

Assessing the Future Landscape of Scholarly Communication: An Exploration of Faculty Values and Needs in Seven Disciplines

CHAPTER 3: ASTROPHYSICS CASE STUDY

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CHAPTER 3: ASTROPHYSICS CASE STUDY

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INTRODUCTION AND OVERVIEW OF THE FIELD

Astrophysics, the study of the physics of the universe, provides a fascinating case because of its dependence on large data sets, the importance of complex visual data, the ubiquitous use of a preprint repository, the convergence of collaborating scholars around large and expensive telescopes, and its popular appeal stimulating significant amateur participation. Astrophysics has two primary branches: observational astrophysics (representing applied research, such as infrared, optical, radio, and gamma ray astronomy) and theoretical astrophysics (the study of physical cosmology, including galactic structure and the dynamics of stellar systems). Department organization varies by institution, although most departments encompass both branches. Astrophysicists can also hold positions in academic units including observatories, laboratories (such as the [Space Sciences Laboratory](#)), or can perform civil service roles at NASA.

Astrophysics is a relatively small, high-paradigm, fast-moving field in which the refereed journal article is the primary means of final publication. Journals are typically society-owned, are few in number, have page charges, and display high acceptance rates. The field has a strong pre-publication tradition that functions in parallel with formal publication. Well-developed papers are generally disseminated through the open access preprint server, [astro-ph](#) (the astrophysics section of the [arXiv](#)), in conjunction with journal submission. In addition, early work is shared informally with a trusted network of colleagues to elicit feedback before being presented at professional conferences for further refinement and to stake a claim. Because early sharing of well-developed research is prevalent, there does not appear to be a need for online and open access journals.

Although astrophysics is a well-funded field in the US, astrophysicists who conduct research using data from NASA's flagship space missions were noted as being better funded than those engaged in theoretical astrophysics.¹ The application process for telescope time can be variable and highly dependent on a scholar's home institution. New technologies enable the possibility of remote observing, although a preference was expressed for doing such work on site, particularly since stable Internet connectivity can be a problem. Complex large collaborations at national facilities are commonplace, many of which are multi-institutional and intergenerational, and result in the publication of multi-authored papers, sometimes running into the dozens of authors. Although astrophysicists use several methods to collaborate, including video-conferencing and Internet calls, most work is facilitated through wiki use and email networks. Face-to-face interaction remains an essential part of the collaborative process.

There is an array of digital data types in astrophysics and reliance on bibliographic and observational repositories is widespread; the [Astrophysics Data System](#) (ADS), a NASA-funded bibliographic database, and the arXiv are used heavily to keep up-to-date with the field. Since data are unique to their observed point in time and data capturing techniques are becoming increasingly sophisticated, data growth has been exponential. Public-access data archives, such as those associated with whole-sky surveys and NASA's space-born observatories (including, among others, the [Hubble Space Telescope](#), the [Chandra X-Ray Observatory](#), and the Spitzer Space Telescope) are fast becoming the bedrock of observational astronomy.² The field may be witnessing a move toward virtual astronomy where individual scholars, and even the public, can mine data archives and access free software that is increasingly available online. While the "lone" researcher is well

¹ Astrophysics receives significant support from [NSF](#), [NASA](#), private foundations (including the [W.M. Keck Foundation](#), the [Alfred P. Sloan Foundation](#) and the [Gordon and Betty Moore Foundation](#)), and universities. Funding is awarded across institutions and national facilities.

² These data become publicly available after a twelve-month embargo period.

positioned to make a scientific discovery—by taking advantage of the mass of available resources—complete independence from a project team may impede a full understanding.

Data sharing among scholars is widespread, though demand for more comprehensive and mandatory guidelines is prevalent. The [International Virtual Observatory Alliance](#) is working toward providing access to global astrophysical data by developing consistent data standards. Refined or raw data can be posted on journal websites as supplementary or supporting online material, on personal or project websites, or made available upon request.

Astrophysicists have limited engagement with Web 2.0 technologies; Facebook, LinkedIn, YouTube, and other such platforms are not frequently utilized for scholarly purposes. As a rule, blogs are rarely consulted, though a few renowned academics write them; listservs, the arXiv, and “telegrams” are more widely used. Scholars utilize a variety of avenues to engage significant public interest—these include the popular press, observatory talks, and school outreach. Astrophysics as a field has high rates of amateur participation and boasts a growing role for the citizen scientist, particularly as online sites, such as [SETI@home](#) and [Galaxy Zoo](#), encourage involvement by the general population in processing data. Google Sky and Microsoft’s WorldWide Telescope enable exploration of the cosmos by turning the home computer into a virtual telescope.

In sum, astrophysics is a small field with little to no commercial potential, and the publication system is well-adapted to the discipline’s needs. The astro-ph preprint repository and other scholarly communication vehicles serve a variety of functions to get ideas, announcements, and well-developed papers into the public domain quickly. There are only a few journals (which are society owned, but often outsourced to commercial publishers) and acceptance rates are relatively high. Correspondingly, there appears to be little discussion about the need for open access publication outlets among astrophysicists, despite the fact that scholars in physics—a close disciplinary neighbor—are participating in the [Sponsoring Consortium for Open Access Publishing in High Energy Physics](#) (SCOAP3), an open access publishing initiative. Demand for an improved computing infrastructure is widespread. A major challenge facing the field is managing, moving, and preserving the ever-increasing volume of data generated. As data collection becomes more complex, training astrophysicists in computer science and the use of new technologies and tools likely will be widespread.

1. REQUIREMENTS FOR TENURE AND PROMOTION: WHAT ARE THE QUALITIES OF A SUCCESSFUL SCHOLAR?

Making important scientific discoveries and assuming leadership in the field are prerequisites for earning tenure and promotion in astrophysics. Scholars at top-tier universities typically publish in flagship society journals, which, in tandem with citation indices, inform the tenure and promotion decisions made by review advancement committees. Increased reliance on citation indices, as a substitute for reading actual articles, has been met with criticism and resistance by many in the field.

In addition to a record of significant publications, securing extramural funding is essential for success as a scholar. Presenting research at conferences is important for making a name, but appears to count little toward achieving tenure. Developing astronomical instrumentation and software, posting announcements in the form of listserv-based circulars and telegrams, and database creation are considered “support” roles and are usually ascribed a lower value than publication in advancement decisions. Furthermore, it

is acknowledged that judging scholarly activities falling outside the traditional realm of publication can complicate evaluation for tenure and promotion committees. At elite research universities, teaching and service constitute part of a tenure package but count for less than one's publication record. Young scholars are generally advised to avoid spending too much time on non-publication activities at the expense of their research.

Ap1.1 A Suite of Achievements Anchored by High-Impact Publication

Many criteria are used to judge scholarship holistically. They include scientific discoveries that advance the field, high-impact peer-reviewed journal articles, securing research grants, invitations to present at conferences as a keynote speaker, and attracting graduate and postdoctoral students to study at one's home institution. These, in addition to other intangible criteria such as research dynamism, are "difficult to quantify."

This research institution is a very special place; it does have this aggressive atmosphere where people are trying to always be the leaders in their field. So this creates an atmosphere where just putting out the requisite number of papers per year isn't enough. People are looking for discoveries, attention, articles in magazines, press releases, keynote talks in conferences...I think the main qualities of a good scholar are research dynamism, ability to do big projects, bring in grant money, leadership of projects in astronomy, and the ability to build a group of postgraduate students and postdoctoral workers. And then teaching—I would say is somewhere on that list—but not very high. So visibility in America is a very big thing; visibility of research record and press releases. We have individuals here who are somewhat frowned upon because they're trotting along and putting papers out, but it's not spectacular enough.

If you're in a top-notch research school, people don't count papers. They look at: have you done transformative advances? Have you discovered something really important? Have you made a homerun or two, or three? We aim to hire the very best people in the field, period...So the essence is really about scientific achievements, and I suspect that, as you go down the ladder of prominence in research, people go more into counting-the-papers mode. People always count papers at some level, but what I know is—in my mind and in the minds of my colleagues—when we look at these cases, we never count how many papers this person has written. But rather, we ask, "Do I actually think that they might make a major discovery?"

I suspect as you go up and down from the top of the scientific pyramid, people simply have to rely on some kind of statistics—citation counts, paper counts, and so on—which is not good...personally I never bother with citation rates. I can imagine a place where you have 5,000 professors. You may naturally be tempted to go for...some bibliometric measures. I am suspicious of such things. I am suspicious, especially in terms of funding, because, in some sense, it represents both intellectual laziness and unnecessary bureaucratization...I don't think that the richness of intellectual achievements in science or any other field...can be reduced to any scale or value, or even to two or three of them...We're dealing with very complex, multidimensional, often very difficult-to-quantify phenomena. And they're simply not reducible to some small set of numbers or one number...So the essence is scientific achievements.

Nothing's ever written down in the sense that it's one of these things people will know—if you've been successful—when they see it.

Although at top research institutions the emphasis is on the "quality" of publication rather than "quantity" *per se*, a substantial publication record is still important in this highly competitive field. For example, reliance on bibliometric measures, including quantity of

publications or citation counts, to judge the quality of scholarship and gauge its impact on the field is not uncommon.

I think at the end of the day you get this large list of papers that were written...and you just don't pay that much attention. It's the number of citations that are important. If, in a poor journal, a scholar got 1,000 citations, I don't care where they are published...I wouldn't say that we have any other obvious way of gauging the impact of a paper...This has been a big change in the last five years. It used to be it was very difficult to get citation numbers. You publish papers, other people write papers, and they refer to your work. And we probably put too much weight on that citation index—how many cites do your papers get as an evaluation of their importance. We follow it really closely...It's often part of the letter and part of our discussion when we look at advancement or hiring...It's probably the number one discussion for hiring. And once it's the last round...it's a bar...I know this will vary from person to person in a big way, but in my mind it's a bar at which below that bar I'm not going to even consider those candidates, and above that bar maybe it's less of a gray area. They're all in one boat together. That's often how I treat the situation...At a research-level institution, it's certainly publication...not just the number of publications...but also the impact in the field. So there's some balance between the size of the body of work...as well as the number of citations that are garnered by that body of work. And there's no tried-and-true recipe. Someone can have one or two very influential papers that are plenty sufficient for a tenure case, or alternatively one could maybe be more broad and have fewer high-impact papers but just more papers overall.

Ten years ago all we knew was people published papers—and they published a lot of papers or they published few papers. Then we started to have easy access through the astrophysical data service and it actually listed citations. It kept track of all that stuff, so anybody could find out how many citations their paper had at any time. So all of a sudden citations became very highly weighted.

It's very nice if you want to learn about somebody. You know, "Oh, here's someone. What have they done?" So you can just see what their most popular or influential papers have been. And I find that this doesn't exist in other fields. For example, I'm involved in nominating people for prizes in a certain field right now. It's imperatively much harder to find out what these people have done. So citation indices are a marvelous tool. We're totally spoiled.

Observational and theoretical astrophysicists are acutely aware that sustained high-impact article publication is necessary both to advance the field and their own careers. They typically publish in flagship society-owned journals including the *Astrophysical Journal*, *Monthly Notices of the Royal Astronomical Society*, and the *Astronomical Journal*. These publications "remain the gold standard for scholarly communication and academic advancement" and undergo stringent peer review.

Visibility in the field

Making a name in the field requires more than a sustained record of publication. A highly productive career trajectory cements external reputation and serves to inform external letters of reference; as in other fields, external letters of reference are a key piece of a tenure and promotion dossier. Being invited to national and international conferences and meetings as a keynote speaker contributes to establishing one's reputation as a leader in the field.

Sometimes, scholars are so young that it may be too early to tell if they might make a major scientific discovery. So I wouldn't necessarily know whether some

young string theorist has done something fantastic. But I judge from people who know.

Letters are sent out to external referees and they essentially have to come back uniformly good. Maybe you can have one three-sigma letter. But they all have to say that you're a leader in your field. It's not good enough to have done a good job. You have to come back with some kind of superlatives...we might like one of our colleagues within a department a lot, but there are several other hurdles that are there to maintain the overall quality of the institution...so that's why what we think doesn't matter all that much. What matters is what the outside world thinks. And I think there is more than one way to come back with good letters like that. One is to write very good papers and another is to travel a lot and have your face out there all the time...In this department we have zero so-called "deadwood" on the faculty. We have several faculty that are nominally beyond retirement age who are still getting as much done as anybody else in the department. So the expectations about being productive are very high—and even if you've already received tenure, you're expected to continue along that road.

I write letters for advancements of other faculty. One of the considerations is international visibility and recognition. If they've gone to conferences where they are the invited speaker or prime speaker, or a reviewer, I think that is worth something. So it's not quite true that conferences are worth zero...I'm saying that conferences have value.

The writing time for giving papers and conference proceedings competes with journal time...The invitation itself is a sign that you are held to be an expert in the field. If you are invited to present at many meetings, you are clearly a leader, and if they're international meetings, you're an international leader.

The coin of the realm is journal articles, but presenting work at conferences successfully and publicizing them is worth more and more.

While presenting work is a mechanism to publicize one's work and gain recognition, it was noted that final archival publication takes precedence.

Conferences get classified with abstracts of talks you gave at meetings, which have very low weight compared to a peer-reviewed journal publication, traditionally.

The importance of extramural funding and postdoctoral fellowships

The ability to secure extramural funding in astrophysics is an important indicator of successful scholarship and is often critical in the hiring and advancement process, particularly for pre-tenure scholars.

You need to start bringing in grant money to the university, at least in my field. So you need to start thinking about big projects and getting funded from outside sources. The more outside funding you can get, the easier it's going to be to get tenure.

Astrophysics is mainly funded by federal grants and private foundations (including the [W.M. Keck Foundation](#), the [Gordon and Betty Moore Foundation](#), and the [Alfred P. Sloan Foundation](#).) The types of research supported by NASA and NSF differ significantly, with a substantial proportion of financial support from NASA awarded to research associated with space missions. Consequently, we were told that there are some subfields lagging behind in their ability to win funding, particularly theoretical astrophysics.

As a theorist, it is very much the case that funding is difficult to secure. It seems very difficult to apply for funding to study some idea without already having done the study to show that it actually works and, therefore, that it's worth funding. It seems like you're stuck in a circle. Occasionally that circle is broken, but that does seem to be the case.

Postdoctoral fellowships, in particular, are highly competitive and perceived as a boon to one's resume, according to a director of a research center.

The graduate students are, of course, primarily working for a professor. But then we have two categories of "postdoctorate," which are very different. There's what I would call a grant-funded postdoctorate, which is: you're working in a group with a pre-assigned task. There's some flexibility depending on the professor. But then there are these prize postdoctoral fellowships, which are highly sought after, terribly competitive, which give you freedom for three years with a reasonable travel budget. So, these prize fellows have all the time in the world and, of course, they're in their late 20s, early 30s, so they're full of beans and energy. So they are the ones who are whizzing around to all these conferences, listening to everything and it's a great time in their lives. And people desperately want this freedom because they know that this is their chance to get tenure if they go through one of these three-year positions. It's having a negative effect because there are only maybe 20 of these in the US, and every year, we're churning out many more Ph.D.'s than can possibly get these positions. So there's now this air of despondency that if you don't get one of these prize fellowships, your chances for tenure are doomed. I mean these are 26- and 27-year-olds thinking that they're at the end of their career because they didn't get one of these prize fellowships. I try to dispel this and give examples of people who never got these fellowships—but then became successful faculty. These are national space telescope fellowships—Hubble fellowships, Spitzer fellowships, Chandra fellowships. Then each university has a few others—like the Miller at Berkeley. Unfortunately the demographics are exactly as the young people fear. If you are a prize fellow, departments tend to look very favorably on you as a possible tenure-track hire. It looks good on your C.V. and it's an early distinction in your career.

Because securing funds can be too onerous a task, some young scholars turn to alternative careers.

The best graduate student I've ever had—could have basically written his/her own ticket to a faculty position anywhere—decided to leave the field because s/he just didn't want to be nicked and dined the rest of his/her life...it's quite fun being a graduate student and a postdoc. But then, as a professor, you actually can only spend 15 percent of your time doing the things that you thought you were going into the field to do...We try to compete with institutions and organizations that have much more in the way of people resources, but maybe not the same level of financial and infrastructure resources. And, I've found it to be a satisfying but extremely stressful environment, in that sense.

Ap1.2 Evaluating Other Scholarly Genres

Additional forms of scholarly contributions include announcements, astronomical instrumentation, software development, and the creation of data archives and virtual organizations. Many scholars engaged with these types of activities are drawn from observatories, institutes, and NASA research centers, as well as university departments of astronomy and astrophysics. Yet, since the rubric in science is being "creative," scholarship beyond traditional publication counts little and can be a challenge for tenure and promotion committees to evaluate.

Announcement posts

Announcement posts (listserv distributions of circulars and telegrams), are playing an increasingly important role in the field by alerting scholars instantaneously to exciting new events and phenomena. These types of scholarship can be a challenge for advancement committees to evaluate, despite their value to the academic community as a whole.

There are mechanisms to notify astronomers very quickly that something interesting is happening—a gamma-ray burst, a supernova, a comet, or something or other—and there are forms of telegrams or circulars. And those words are inherited from the bygone era when people were actually sending telegrams or mailing little cards and things like that. Now it's all electronic and they come instantly. There are the Astronomer's Telegram, IAU circulars (Central Bureau of Astronomical Telegrams), gamma-ray burst notices...there are the virtual observatory event messages...None of this is refereed, of course. How can we? You have to react to them in seconds or minutes. They're all saved somewhere and they contain extremely useful information, but they do not fit in any rubric of anything else that we ever had...they just don't fit in traditional formats at all. And then how do you value that output, say, in a young astronomer who's really good at doing this kind of stuff? That person may have produced 200 of these little electronic circulars and telegrams—and created new exploding things in the sky—versus one or two papers in the *Astrophysical Journal* that have gone through the traditional path. It's all valuable. How do you weigh things? So we just don't know how to do this.

It's a question of new kinds of expertise...people who spend the time and effort doing it, how do they get credit? Because these are not the astrophysical journals; this is, say, the Sloan server. And that's something that the community is trying to understand. Or how about numerical simulations? You can write a paper describing a final outcome and interpretation, but who reviews algorithms or the code? Or, do you preserve the output of the whole performance simulation, which is, again, terabytes and petabytes worth of stuff? Or do you just save a few steps and show those? With this exponential growth of data on the experimental side, not only do you have instrument builders versus users or observers in astronomy, but now you have to have database experts and data miners, and all kinds of stuff like that. There are all of these new groups and branches that grow, that respond to technological growth, and that simply didn't exist before. And because academia is such a closed club, they tend not to be validated very well.

From the standpoint of tenure and promotion committees, non-refereed papers are a much lower coin in the realm. They're much less valued. So that is a problem.

Astronomical instrumentation and software development

Within astrophysics, scholars engaged in building instruments have historically been relegated to a secondary status compared to their "academic" counterparts, despite their crucial role in the overall productivity of the field. Their publications can be the product itself, in the form of an instrument, or can be published as conference proceedings that do not undergo peer review in the traditional sense. Astronomy instrumentation may be suffering as a result of its ascribed lower status since young scholars are simply not attracted to the endeavor.

There's another culture, the instrument builders...the observatory people build things; their publications are often instruments. The society associated with photo-electronic instrumentation has enormous meetings twice a year, with

sessions devoted to astronomy instrumentation and published proceedings in hard copy and on CD. That's where all their papers are published, and none of them are refereed...These people are not traditional, their publication is the thing they built, not words. The test is how original, advanced, and creative their things are. Someone here developed instruments from scratch. I may have to get letters saying, "These allow us to do things that nobody else could, they are ingenious, etc." The publication is a square inch of silicon, but it's as valid as a paper, because it required creativity.

Here, we've always had a problem—a lack of good, young instrument builders—because the astronomical community didn't value that skill very highly. It does now. But, it takes time to grow a new generation of good, young instrument builders.

Even within the realm of instrument building, there is a distinction between developing an instrument based on an original concept, as opposed to building one already conceived.

Building an instrument counts for absolutely nothing...You don't get intellectual credit for doing it...you can get intellectual credit for developing heterodyne submillimeter spectrometers and things like that...The instrument that we're building is state-of-the-art, but the *concept*—people have known for a long time how to build one—and at some level, it's an engineering project. And we could never hire a faculty member here to do primarily instrumentation...Some institutions have many people where this is what they do, this is why they were hired. We can't do that here, because it doesn't seem like science to the people who are passing judgment on it.

According to one professor, tenured scholars may be less constrained and free to pursue their non-academic interests, such as instrument building.

I build instruments out of a sense of obligation to the observatory, knowing that if I didn't work on this, it wouldn't happen...And I feel like I'm at the point in my career where I can...I like learning new things and this is an opportunity. I started getting involved in instrumentation years ago and I quite enjoy working with engineers. But I don't expect any pats on the back from my faculty colleagues. They'll go and use it when it's done. But that always made me feel uncomfortable—going and using equipment that was conceived and built by other people. And I felt like I needed to contribute.

Similar to bioinformatics specialists in biology, scholars in so-called "support" roles, such as computer science staff and software developers, tend not to receive equal credit for their efforts when compared with traditional researchers.

The astronomical community still doesn't value anything to do with computers and software. And that's going to come and bite us in the long run...You have to reward people for making all of this possible, who make sure that bytes go from the raw instrument into something that scientists can use. And we do not value those people very well now at all. So this is a real problem. Academia is a hostile environment to any truly interdisciplinary effort... I'm seeing some great young people, who are trying to bridge gaps, get squished because they're neither this nor that. I had a great postdoc who was one of those computational astronomers, who was good in computer science and good in astronomy, but wasn't great in either one. It took a long time to get this student a decent job. And it's people like that who should be extremely valued.

Blogs

Although writing a blog is a discouraged activity, especially at the pre-tenure stage, some scholars suggested including a metric for measuring its impact as part of a tenure dossier.

My position here...is an interesting position. It's basically like being at a national lab. It's a research position. I am a faculty member. I get all the stuff that faculty members get. I get to go to faculty meetings, I supervise graduate students, I teach if I want to, and I don't teach if I don't want to. And I get paid like a professor, which is very nice. The only major downside is that I don't have tenure. So they can fire me. So I would like to have tenure for various reasons, but right now I'm very much enjoying this position that I have and am taking advantage of it...There's certainly more than one senior faculty member who has said out loud that they would never vote for tenure for someone who has a blog...when research-level, top-10 universities come to give people tenure, the only thing they care about it is the quality and amount of research output. And you can have the best teaching evaluations of anyone in your department but it is completely irrelevant.

So if a well-renowned blogger worked for me, and I was writing up his merit increase, I'd have his blog in there for sure. I'm sure there are some statistics stating that 20,000 people a week read this—and I would absolutely try to make that case.

I know some people in our department would put in their resume, "I was referred to as having the most important paper, or most cited paper, or whatever." And those types of things will happen if you open the tenure process up. It has not yet happened. This is dangerous...I can claim to be anybody I want, of course.

How do you preserve blog and wiki content that's not appropriate to publish in any traditional sense? So it's low-grade, useful, process information that should get credit in some sense. It's just daily life, but it's useful information.

Ap1.3 Teaching and Service

Several scholars noted that although publication, teaching, and service are all considered in advancement, publication is deemed most important.

Teaching and textbooks

There's no question. It's publication first as far as tenure cases go. And I say this without having sat through a tenure case. I'm only recently tenured, so I guess I don't know this for a dead fact, but I'm pretty sure that's the expectation. Teaching quality isn't that highly regarded. It's certainly a bar you've got to get above, but I don't think it largely informs the case—unless the performance is very poor.

In astronomy, research record is dominant. If you are absolutely hopeless at teaching, it will hurt, but it's surprising how much tolerance there is to poor teaching in the US. In the promotion and hiring at Oxford, an exam question is given to the candidate. So we're talking about an interview where somebody has to actually do and explain how they would teach an undergraduate a particular project. I haven't seen that in the US at all.

In astronomy and astrophysics, at least in research-based universities, of course, research is what counts. We all pay lip service to teaching, and some people

actually care about it, but, in reality, it's the scientific achievements that really count.

To earn tenure and promotion, a scholar must demonstrate significant research productivity, adequate teaching skills at the undergraduate and graduate level, and some degree of usefulness to the specific institution and the outside world—although this can be moderate at that stage of the career.

Textbooks play a negligible role in the advancement process and, as in other disciplines, may work against a scholar coming up for tenure.

Many of my senior colleagues wrote textbooks, and it's okay to write textbooks when you're long past getting tenure—but the hiring committee decides, if you do it before you get tenure, it's not considered a good sign.

Service

Young scholars may be overburdened by professional and campus service. Too many service obligations can be particularly problematic for postdoctoral scholars trying to increase their publication productivity. In addition, with the pressure to achieve gender equity, women may be called upon even more than their male colleagues.

Most institutions will pretend to try to protect you while you're still on the tenure track from things like service. But, in reality, it's not the universities that are the problem...A graduate student of mine was offered three faculty positions within about six months of starting her first postdoctoral position, which was way too early and unfair, I thought, for the universities to be putting that pressure on her. She didn't get to enjoy the postdoctoral time in the way that you should—where you don't have to think about all these other things. I think that's a significant problem and I don't know what to do about that...And it's particularly problematic for women faculty in this field, and probably physics, because everyone wants gender balance on every task or committee or panel. And women constitute only 15 or 20 percent of the field, so they get asked three times more than anyone else does. I've had two very successful women graduate students and I was trying to put myself in their shoes—you have to be so good at saying no, or else you're just going to get completely reduced to nothing.

I think it's great to change the world, but not until you hit tenure, right? One of the things being talked about a lot on our blogs is the issue of women and minorities in science. We think it's really important. I would tell a young woman looking for tenure not to spend her time agitating about the position of women in science, because it will be counted against you. You're not doing research when you're doing that. And there's no protection for that kind of thing. Therefore I don't necessarily think it's going to change because I think that most people still have their eyes on the prize—they want to get a tenure job, and those jobs are very few and far between—and just like any scenario where resources are scarce, if there's a reason to exclude you, it will be taken. All else being equal—someone who spends time as an activist in some way, is going to be looked at with suspicion. The incentive structure, in other words, does not encourage young people to branch out in these ways. And I don't see how to change it, actually, as much as I would like to.

Ap1.4 The Pressures of Academic Life

Many scholars feel oversubscribed in their academic obligations and commitments, in part because academic job parameters are so vague.

I think it's a particular problem of academia that one is always uncertain about how far one's responsibilities actually go. And so you're never finished. You don't have a job description, really. I find that I spend 40 percent of my time doing things for other people who ask me—proposal reviews, sitting on committees, all that kind of stuff—at least that much, maybe 50 percent. Even if you say no to 80 percent of those things, on the grounds that you're too over-subscribed, you're still too over-subscribed.

I look at our students and...everyone's rushing around trying to do the latest, greatest thing, publish, get on top of astro-ph, whatever, and are lacking the care that's needed really to be scholars in many ways. It's a blanket statement that is, of course, not true of everybody. But, as a general sentiment, there's less understanding and more rushing. And if you're out to make money that's fine, because there's a goal, that's well-defined...All these companies, everyone's goal is to make the most money and have the highest stock price, and whatever. The currency is known. But the academic currency is much more diffuse...But, we're caught up in this rat race and I don't know what we're chasing.

2. CHALLENGES AND OPPORTUNITIES FOR DISSEMINATING RESEARCH: WHAT ARE YOUR CRITERIA FOR CHOOSING A MEDIUM?

Observational and theoretical astrophysicists choose to publish in the most selective peer-reviewed journals appropriate to the desired audience. Given the small size of the field, astrophysics has relatively few refereed journals. Most of the journals are published by professional societies and, compared to other fields, have high acceptance rates. Similar to economics, a strong pre-publication culture enables scholars to get well-developed articles into the public domain. The arXiv, an online preprint server developed by Paul Ginsparg in 1991, serves a number of fields, including physics and astrophysics (“astro-ph” is the astrophysics section of the arXiv). The arXiv runs in parallel to traditional journal publication, though the journal article still remains the formal, peer-reviewed version of record.

The scholars we interviewed did not identify a crisis in scholarly communication in astrophysics. The preprint system precludes the slow dissemination of work and turnaround time by journals is relatively fast in the US. There were some concerns that the formal editorial and peer review process is overburdened. Preliminary peer review by the academic community can be elicited on papers posted to the arXiv. Publication of data sets and high-quality graphics is common practice, often produced in supplementary online material. The launch of a few online-only journals has had little impact on the field, probably because astrophysicists do not appear to face difficulties publishing through traditional means. Open access has long been integral to dissemination practices, so concern about open access as a final publication model is deemed irrelevant.

Ap2.1 Criteria for Choosing a Publication Outlet: Prestige, Peer Review, Audience, Speed

Prestige

Astrophysicists choose to publish in the most high-impact prestigious journals. The more select a journal, the more stringent the peer review is perceived to be. The flagship society-owned journals have a high level of integrity, according the scholars we interviewed. There is substantial agreement regarding the ranking of top-tier journals,

which include: the *Astrophysical Journal*, the *Astronomical Journal*, *Monthly Notices of the Royal Astronomical Society*, the *Astronomical Society of the Pacific*, and *Astronomy & Astrophysics*.

Astronomy is unusual in having so few journals...there has been a definite pecking order internally about where you publish to establish your place in the field. And globally the place to publish has always been the *Astrophysical Journal* published by the University of Chicago Press...approaching the same distinguished level is *Monthly Notices of the Royal Astronomical Society* in England...The *Astrophysical Journal* is considered the top level...there's very strict peer reviewing, and a paper published there is considered to have gone through the gauntlet. The second journal in the country is the *Astronomical Journal* published by the American Astronomical Society, and it's not quite at the same status, and then there's the *Astronomical Society of the Pacific*...And they have a journal, and that's definitely the third rank, and that's it...There's some little journals that are not of much significance. In Europe, there's a journal called *Astronomy & Astrophysics*, and again, that's next tier. Then there are some regional national journals, for national prestige or whatever—the *Japanese Astrophysical Journal* and one in Australia. Mexico has a journal.

Astronomy is blessed by the fact that it has very few active journals. There are about five of them and then you add planetary sciences and that adds a few more. There's not exactly a big choice...there are two journals that have a little bit more stature than the others, but they're all respectable. In the United States, if you have a major piece of work, you publish it in the *Astrophysical Journal*. That's our premier journal here. And if you are working abroad, you might choose either the *Monthly Notices of the Royal Astronomical Society* or *Astronomy & Astrophysics*, which is a European journal. Then there's the *Astronomical Journal*, and finally a distant fifth is *Publications of the Astronomical Society of the Pacific*, which is for shorter, less consequential things.

The journals in astronomy...they're pretty well known for research and, for whatever reason, have a label of high integrity...So there's definitely a hierarchy of journal quality within, say, astronomy-specific journals and I think *APJ* would be at the top. *AJ* is second and...somewhere in there are a couple European journals, and that's about it. Astronomy is not a big field...it does not have a big list of refereed publications.

Even though there are only a handful of journals, I think there are definite, perceived levels of quality. I think that I tend to go for what are perceived as the upper level of top-tier journals.

I'm sure there was a premier journal for these guys [looks around the room at his established colleagues]...There's certainly a historic and continuing perception towards different journals of quality...There's the *Astrophysical Journal*, which has the letters and a main journal, and a supplements version, but they're all under the one umbrella. And then the *Astronomical Journal*, which I guess just has one standard format. And a third one that I've published in a little bit is called *Publications of the Astronomical Society of the Pacific*.

I think that astrophysical journals have become the stamp of approval that this paper has become kosher—that it's passed peer review, and it's introduced into the official archive.

One young scholar privileges quantity of publications over publication venue, which may be because of the selectivity of most journals.

I probably would be more concerned about the number of publications I was producing. I don't think I worry as much about where they're being published.

Audience

Ensuring that the content of an article is a good fit with the mission of a specific journal is deemed crucial and often the country/continent in which a scholar is located feeds into journal choice.

There sometimes tends to be a small difference between the US astronomers and the European astronomers—in terms of which journals they publish in. If your team is very Eurocentric or US-centric, or if you have huge supplemental tables, then it goes to the supplement series or otherwise the main journal. If it is a paper related to techniques, you tend to publish in something like the *PASP*, which is the *Publications of the Astronomical Society of the Pacific*.

I do a lot more astrophysical kind of things so I tend to publish in the *Astrophysical Journal* without giving it a whole lot of thought, to be honest. If I have a much more astronomy-related project, maybe I'll put it in the *Astronomical Journal*. If it is a student project, sometimes I'll put it in the *PASP*.

Occasionally, a paper will appear in *Nature* or *Science* when a scholar wishes to reach a wider, more general audience. Although publication in these prestigious outlets is ranked highly by some scholars, the small publishable unit can be a constraint for developing a detailed argument.

I didn't mention *Nature* and *Science*. Once in a while there's an astronomy paper in those journals, but not very often.

In the United States, there's a bias among scholars for the few United States periodicals...I'm writing a paper at the moment that we'll probably submit to *Nature*. People reach a more general platform publishing there.

The size of your paper is a big limitation for us. If you want to get something into *Nature*, you really have to boil it down to one or two pages. A lot of the time in my research, I find that you need at least ten pages to explain what is going on.

Speed and acceptance rates

Similar to the biological sciences, competition and the fast pace of research in astrophysics (especially given the speed at which astronomical events occur) make speed to publication important. Long lag times are not a problem due to the coexistence of interim and final publication platforms. There are very high acceptance rates of papers in astrophysics compared to some disciplines.

In other fields, it can take years to get a paper out. They are one percent, sometimes, to acceptance. I think astronomy has 95 percent acceptance, even in our most prestigious journals. We do not have difficulty publishing. Usually, it's just going through the rounds.

The acceptance rate is very, very high, which is completely different from other fields where it really can be a few percent.

The publication process—from manuscript submission to actual publication—moves relatively quickly in the US. Journal editors have made efforts to decrease lengthy review

processes by placing pressures on scholars to conduct timely reviews. Also, as a result of increasing speed to publication, scholars are reluctant to publish conference papers.

There's a very fast turnaround time compared to other fields, is my understanding. Well, much faster than it used to be.

Journal editors are really concerned about the world changing—and they're not changing at the journal—so that's partly why they've pushed so hard to speed up the publication cycle. They realized that very slow turnover was hurting them. People simply publish things in astro-ph.

Now you submit your paper and usually within a month you have a referee report back. If you respond to it in a couple of days and everything works, you're out there within two months, often. The process used to take a year...You get pressured a lot more upfront, "Do you agree to referee this by this date?" And then they start pestering you pretty hard. So our culture has just slightly shifted. I used to hang on to papers forever.

The rate at which people are publishing genuine papers in refereed journals is so fast in astronomy that nobody can be bothered to write conference talks anymore. The feeling is nobody reads them. People go to the conference, they listen to what you have to say, but they don't read anything that you write down afterward.

In addition, the field has witnessed a move by one flagship journal toward more frequent publication.

The *Astrophysical Journal*, though, finally is now coming out every two weeks. It became a very big and fat journal, hard to keep up with, and about four years ago, it had to finally issue a second version, "Part 2," which is letters for faster publication. "Letters" means a nine- or eight-month turnaround. The main journal is a year. So this led to enormous preprint circulations, which, for many years, was by regular mail...But, now, of course, all of that is done through the Web circulation of preprints.

Nonetheless, according to a graduate student we interviewed, lag time is slower when submitting to the larger, more prestigious journals.

There are a couple of famous journals—*Astrophysical Journal*, *Astronomical Journal*, and there are also some smaller ones, like the journal of the Pacific Astronomical Society. So those are the big ones and the small ones. There are pros and cons for submitting to the big ones and small ones, depending on how fast you want to get it through the review process. The big journals usually take longer...Time turnaround is a big issue.

Ap2.2 Perceptions of the Publishing Environment

Peer review

Archival publications remain the version of record because they have undergone stringent peer review. As in other disciplines, the peer review process can function as a filtering mechanism for selecting what to read. Peer review often begins with a posting on the arXiv, but final formal peer review is still seen as essential by most.

Fraud never happens in our field. What would be the percentage of my publishing the wrong number? "People are going to find that out. I will be exposed quickly." Even if the result is boring, in which case I don't profit, or it's a very exciting

result, in which case it is quickly checked. There's no win. But, in these other fields, I think you can stir up controversy...I think there is still a need for the refereeing process. It keeps us honest. It's like the policeman on the road. If we took all policemen away maybe somebody like me would be a less good driver. I hate to admit it. So we do need the occasional kick, to keep us on track, but we don't need constant monitoring, which other people in other fields seem to need.

Established scholars often make their own judgments about new scholarship without relying on the prestige of a journal, citation indices, or the like. The small size of the field facilitates this process. Finding a balance, however, between filtering scientific research findings without quashing new talent is important.

It just makes no difference whether papers appear on the arXiv or are published anywhere else, and whether they are refereed, because I use my own internal refereeing process to decide what's good and what's not good, because I'm an expert. I know who's who. I know this guy's a crackpot and this guy's great, and so I judge for myself what to believe and what should I read.

In a sense refereeing goes on now at the individual level. As far as progress in the field, you read a paper and you referee it yourself in a way. If you're working and doing research in the field, you look at it. If you think, "There's something wrong here," then you write a letter or send an email to the author and say, "I don't understand why you said this. What's going on here?" So papers are sort of instantly refereed by maybe 50 people who are working in the field, who will say, "What's going on here?"

You somehow need to distill down publications. On the other hand, there is this potential of missing important new things from somebody unknown—an obscure person from an obscure place. On the one hand, we say, "Isn't this great? Technology is flattening the world. So then smart students in Bangalore and North Dakota and wherever do just as well as students at Caltech or Harvard or Berkeley." But, on the other hand, how are we going to know? They can submit their preprint to arXiv server, but we'll say, "Who is this person?" And that may be a new Einstein. This is where the old boys and girls club of peer review will fail...So somehow we need to allow for the penetration of genuine new ideas—because technology and data explosion are flattening the playing field. The talent is spread much more widely than money. Somehow, we need to do something about it...Suppose there is a brilliant young fellow somewhere in China, who is just writing first-rate papers, and I've never heard of this person, and, consequently, I won't read it. We need some new way of validating quality or interesting publications that would actually work.

An overburdened peer review system

The numbers of scholars and papers have inflated in recent years, adding more pressure to an already over-stretched review system. As a result, scholars often lack the time to perform refereeing duties and the referring process itself can be slow and uneven with some poorly written reviews. Despite criticisms, peer review is seen as "value added" in most cases. Younger scholars may be more dissatisfied with peer review than their more established colleagues, however.

Peer review, by all accounts, has been declining in quality and utility for many years now. And I would say a large part of that has been the inflation of the number of scientists— and papers per scientist that they have to write. Then there are the usual problems: Some people are sloppy and others are a little too nitpicky. And editors, of course, have to suffer through all this. So there are all these problems with peer review. But once there is an effective communication venue that everybody looks at, like an arXiv, who needs peer review? Now, this

is, of course, not true, right? Peer review should be scholarly quality control. But the way it's been conceived does not scale to the production levels that we see in sciences today. People are just too damned busy to do it right, and this is a real problem. Now, I can judge what's interesting and what's not in my field, or what I should trust and what I shouldn't trust. But a young graduate student doesn't have that experience and doesn't know who to trust. That's one problem.

Peer review is intense. Everything is peer reviewed. All of these journals have referees and we've all been referees. And sometimes they're good and sometimes they're infuriating.

A lot of my generation is not happy with peer review. I'm more of a tough guy. I prefer it, I'd say, more than most of my generation. They are not happy because of the absence of quality refereeing...For me it's that...not even by 50 percent do I get value added. I get more value by posting on astro-ph ahead of time and distributing it by email. When I submit it now I definitely take the advantage to submit it to the top ten pundits in the area and say, "If you want to comment, feel free." I think my level of griping over peer review is not that different from anyone my age or older. I think most of us now are used to seeing just a range of referee reports and acknowledge it's an imperfect system.

Peer review has deteriorated over recent years due in part, according to some, to a lack of editorial involvement by some editors. Similar to the biological sciences and economics, rejected papers can be submitted to different journals until accepted. High acceptance rates in astrophysics, however, makes this process rare compared to some other fields.

Peer review is stochastic. It's entirely unpredictable. I've got over 100 papers written and published. I can't predict when I submit a paper how it's going to be judged, and that's because of just how random the refereeing process is to some degree. Sometimes you get very positive, helpful comments on a paper that I thought was very controversial. Sometimes a very benign paper is seen as stepping off the deep end. It's not really disillusion, but it's stochastic and random enough that there's no guarantee that going through the process is going to improve the paper. And I think on average you have some improvement, but there are plenty of times where you've got to struggle with it—what is probably an un-expert referee—and it's just not that fun. It's also tough for the editor; a lot of papers are written, a lot of people have to serve as referees, sometimes not in their primary field, and they don't always get the right match. I think maybe what's lacking to some degree these days is a more powerful editor system. The editors of these journals are pretty knowledgeable astronomers. They don't make as much of an effort to impose themselves as they could—and as I think they used to in the referee process. They're more apt to rely on the expertise of the referee and whatever he or she says, they accept that at face value. I don't know what has set that policy for the past decade or two, but it would certainly help the system if the editor took a stronger role in the process.

In my own experience, most reviews are mildly useful but contain many red herrings as well. A strong journal editor with good scientific judgment can make a huge difference in how painful the refereeing process is for both the referee and the author. The worst case is when the editor just lets the referees and the author slug it out over multiple reviewing cycles, without intervening.

Sometimes the scientific editors play a big role in determining a publication venue and their experience with the refereeing process.

It's hard to make the peer review process faster when you only have a certain amount of experts in the field.

Peer review is basically an endurance test, at least in my field, where if you are willing to resubmit your paper enough times, it will get published no matter what. If you wear out referees enough times or wear out the editor, anything will get published. The publication rate to the fraction of submitted papers must be very high. The only papers that don't get published are just authors who decide it's not worth pushing it anymore.

Ap2.3 Alternative Filtering Mechanisms/Pre-Publication Peer Review/The arXiv

The premium placed on speed in the field has enabled the arXiv (which includes [astro-ph](#), the astrophysics section of the arXiv) to robustly support informal communication practices; it enables scholars to circulate current findings online for comment and keep up to date with the most recent scholarship.

The reason why people go to the arXiv preprint server, and don't wait for the review in the real journal, is that the preprint is available now. The printed version will be available a year from now, and who cares? And time is of the essence. So you have this extra hurdle that, if you're going to have real peer review that's actually useful and meaningful, it has to operate in real time. And, if somebody were to call me or to email me and say, "Hey, can you please referee this one today?" I would say, "Sorry, I'm too busy. I'd love to help. Maybe next month." That won't work.

The majority of people working in astronomy find new publications from looking at the preprint arXiv instead of from published physical journals anyway. So, for probably 95 percent of the papers that I read, I have no idea what journal they've either been published in or submitted to, because that's not the way I find them.

The advent of an online preprint server has resulted in a democratization effect on the field; hard copy preprints that were traditionally mailed to a select "few" have now been replaced by wide dissemination.

So the arXiv has really made communication a lot easier, especially because before there was a preprint system where you mailed preprints to people, you had to be on the list. And there was an in-crowd that got the preprints, and now everybody who has an Internet connection can get them. Even when I want to look up one of my own papers, it's much easier for me to get it from the arXiv than to find it in one of these stacks of papers. So that's made things tremendously easier.

The arXiv has really transformed scholarly communication as far as published papers in physical sciences. There are obvious things—like access—so that people in a small school in India can easily go and see what's going on, that kind of thing. The world really is much flatter because of all these technologies.

Pre-publication peer review

One benefit to sharing work on the arXiv is the early ongoing review conducted by the community. This can act as an intermediate step in the peer review process before papers undergo "expert" peer review provided at the journal level.

The arXiv is seen as the answer to how we might move scholarly communications forward...arXiv was an addition to peer review. It's more the preprint stage than the journal article stage. While those two things—the journal article and the preprint in most cases—are the same, the people who publish in general think of them as two different items. Publishers now have started—and this has been going on for some time—accepting preprints via the arXiv as submissions into the

peer review process. It's not a replacement for peer review, is really just another step in the process.

Preliminary review is not a complicated process; the author of an arXiv paper can solicit public review by the academic community by providing an email address. There were differing opinions about the degree to which feedback by the community is helpful in the revision process. The introduction of a commenting function on the arXiv could be a step toward more public vetting.

You just send me an email...there is not the public vetting...so somebody can't comment on the comment. You don't get Joe Schmoe, who is in some completely differently field, sending an email saying, "I think you need to include my latest theory of cosmology" or something. You get people who are in the field sending you emails and that's usually useful.

What's nice about astro-ph is, to some degree, if you post your paper at an early stage—while it's being refereed, say—all the experts in that community can read the manuscript and offer, not anonymous, admittedly, but comments directed to you, and those often prove to be as valuable as the anonymous referee comments.

I always submit my article as a preprint to the arXiv as I submit it to a regular journal, because usually I get more interesting feedback from other interested people who are reading it, than from the referee who is actually assigned to referee the paper. I guess that's the way I proceed.

I put something on the arXiv and within a couple days I get interesting comments from people. Some of them just want to be cited but others actually find something interesting to say.

Usually there are a few emails that are mildly helpful. I haven't had any a-ha moments because of the emails, but they've been helpful.

High levels of accuracy in publications

In this high-paradigm field, the vast majority of material posted on the arXiv is considered accurate. The quality of the preprint papers can be equivalent to those published in archival journals, though peer review improves the paper somewhat. Although papers posted on the arXiv go through a minimal review process, questionable content can still be posted.

Ninety-nine-point-nine percent of the stuff on the preprint server in astro-ph is correct. So it's nice to have a refereeing service to catch things and improve papers, but the field would not fall apart through people publishing wrong stuff. The biologists didn't think that was true; they thought there was a significant fraction of wrong results, and therefore their hierarchy of journals is important. Our journals are flat, because everything is correct. Their hierarchy of journals represents the most reliable researchers and results at the top. I think there are huge differences between the biological scientists and the physical scientists.

This sort of self-policing of the preprint arXiv and server has worked in my field. There are very few junk papers...You occasionally get some crackpot posting his paper there, but I really don't think there's a significant difference between the quality of things that get posted on the preprint server and what ultimately ends up in peer-reviewed journals.

There are some people who think the arXiv is ridiculous, and just incites competition, and refuse to post their papers there. So a lot of this culture...is the

younger people who are slaves to it. I don't read it every day. As I said, if I have time somewhere, I'll sit and look at what I've missed, once a week barely. I think that's pretty good, but, I have my own science and my own things to do; I can't be so caught up in what everybody else is doing all the time, whereas I think you see that culture, particularly in our graduate students—there's so much crap on it.

A recently tenured scholar posed the possibility of forgoing the traditional route of formal publication in favor of the arXiv postings. But such a strategy would only be possible for scholars unconstrained by tenure requirements.

The decision that we haven't talked about yet is...like physics we have an abstract server, run through the Internet, where people post their paper at various stages of the publication process. They might publish it there before they even submit it. They might publish it when they submit it. They might publish it after they get their first refereed report. They may wait until it's been accepted. And some people have started to say, "I'm not going to even bother ever publishing in a journal again. I'll just post it to astro-ph and let that be."

The role of endorsement and voluntary moderators

In order to post a paper on the arXiv, authors have to be endorsed by a member of their community to prove they are a legitimate scientist. Voluntary moderators, representing various subject communities, then perform a review of posted material. This is not peer review *per se*, but a first filter and a check that a paper is not pseudo-science.

The endorsement is part of that system as well. Essentially arXiv represents the community of scientists that are involved in those subject areas. So in that sense it's kind of like a bulletin board in that it's a community affair. The endorsement system involves people who are answering essentially to the community. We ask that if they have not submitted in the past, that they get an endorsement from someone who is a member of the community. In this case, the endorsement has to do with, "Is this person a legitimate scientist?"

First you have to register in order to submit a paper, so you can't just be any old person, writing obscenities or anything. And they will block papers. There are instances where you could write a paper that aggressively challenges an earlier paper and I don't know the details, but apparently such papers are filtered out. So there is some control, but it's remarkably loose. If it's a scientifically valid paper that's not been refereed it will appear there. But that's the only thing that goes there.

There are moderators, which is not a well-known fact. People don't know about the moderation process that takes place. Volunteers from the various subject communities take a quick look at the material that's submitted to arXiv to ensure that it really is good enough science. They're not doing peer reviews, they're not saying this is good, this is excellent, or this should be published, but they are checking to ensure that this actually is science, and not pseudoscience. The material is submitted through the arXiv software, and then—this maybe is changing—there are several people in each subject area who take a look...so for example, at the author or the title, something like that, some parts of the submission to ensure that it is an appropriate scientist and the subject matter is appropriate to their area. A number of people who submit, who think that they should have all their material accepted, have not had material accepted.

Now, submitters can choose whether they want to post a paper as soon as they submit it to a journal or wait for the referee's report first—or whatever. Of course, some people can try to put out papers on UFOs or whatever, but they filter who

can submit. If you come from a .edu, you're probably okay. And sometimes crackpots do post things, but, by and large, the system seems to work okay.

The utility of a preprint repository and a glut of information

Some form of peer review is necessary to cope with the abundance of literature, which is exacerbated by a growing preprint culture.

The arXiv has just revolutionized how we communicate, because it takes months or a year to publish a paper in a journal. You can literally go to the library these days, to the associated physics department, and you can see that the journals changed color around 1992 because before 1992 they were heavily thumbed through. No one reads them anymore. It's nice, and it's good for tenure and promotion to get accepted by peer review, but everything is done through the arXiv online. The downside is there are too many papers. Now I have over 50 abstracts to read every day, because I'm interdisciplinary, so there are too many things to do.

By far the most effective means to get your work out there in my field is the preprint server arXiv. Ultimately, that's where you publish things. No one ever breaks out the *Astrophysical Journal* anymore, or if they do, it's only because it's a sort of archive of the final version of the paper. Everything that is current you read from the preprint server...I think it's nerve-wracking, actually; you read these 50 abstracts that get to sent to you every evening and it's just a constant feeling that there are all these things happening and you don't have time...In your ears, "Oh, I have to finish this project before it becomes past its time, and all that." And so I think the improvement in communications and dissemination of results, it probably leads to progress in the field, but...I find it nerve-wracking, compared to when I was a graduate student, where if you got preprints, you would get them by mail or you'd read them leisurely in the library. I have not gone to the library for years because there's no reason to go there anymore. Every journal in this field is available online going all the way back as far as you would ever need to go...I have weeks—a week or two—where I don't look at preprints at all; and then I try to say to myself, "Well, I'll go back and look at them." But I've felt like I'm increasingly at sea and just drowning in things to do.

Astro-ph comes out every day, and it's tough to maintain even reading the 40 new papers, looking them over quickly every day. So I don't even necessarily keep up with that.

The literature in astrophysics is not distilled yet. It probably needs to be. Roughly 35 papers are posted per day on astro-ph. I endeavor and always succeed to read the title of every posting and the abstracts of those that I find interesting. I never go to *APJ* and look at their listings. I never go to any journal and look at its listing of new papers. I never take advantage of that—the fact that papers have been peer reviewed—and what is published is therefore distilled.

Like just about every active research astronomer, I look at the arXiv postings every morning. I actually get an email that gives me the titles and abstracts, but I never look at that email. I go to the website, which is linked to my page right away on the new stuff. I scroll down the page, I maybe look at 10 abstracts out of the order of a hundred or something like that, 10 percent of the total. I maybe print one or two of the papers. Then, since I printed them, I feel good about it. I might actually read them, but I might not. But that's how I get informed of what's going on...And that is market-driven. You choose what it is that you want to read...But that requires your expert judgment. That might work in a relatively small-sized community like a physical science, but in the field of biomedical

science, where there are literally millions of papers published per year, that doesn't work.

The future of peer review

One scholar suggested that sophisticated online platforms for community-based peer review could be the future, regardless of the arXiv.

I can also imagine that in the future things would change. There are now things called wikis where you can put information and can contribute—whether it's Wikipedia or whatever—where you put the paper in and people can comment...They don't have it yet...but, in the future, you could put the comments in and say, "Hey, this is wrong or this is right," and someone can debate that issue. And you can imagine just a very different flow, so it's almost got this internal refereeing...of its value, by community. For us, we've always thought that papers should pass at least one threshold.

Ap2.4 Capabilities and Affordances of Publication Models

As a data-rich field, data publication is *de rigueur* in astrophysics. The ability to access data is crucial and can take place a number of ways. Online technologies enable existing publication models to provide data sets and high-quality graphics as supplementary or supporting online material, which can be particularly attractive to scholars not wanting to pay page costs. For instance, the *Astrophysical Journal Supplement Series* is published in conjunction with the *Astrophysical Journal*, supplementing the latter and serving as a data archive.

The main journals have online data. *Science* calls it "supplementary online material" or "supporting online material," the *Astrophysical Journal* calls it something else. It can be basic data or, increasingly, it's fancy color graphics that you didn't want to pay the page charges to print.

Theorists have vast amounts of data that they want to publish from computations, and anybody observing has vast amounts of data. The *Astrophysical Journal* has yet another journal called the *Supplement Series*. They publish a 100-page paper and it's published occasionally. The length of the paper, and the fact that it includes a lot of data that may not be what you might call all individually analyzed, can serve as a database. So, it is in the form of an archive, but there's always analysis and discussion.

Online supplementary data have undergone various levels of refinement and sometimes peer review, and are available to readers in a reduced form.

Normally not entire data sets are published, but only the results. But the project that we are working on, soon we are going to publish the database...and so that will be sitting on computers most likely...there'll be Web servers so people can look at it, so that is what we'll be publishing and that'll be processed.

Usually I post data both on a personal website, but also to the journal accepting the paper...I haven't really looked at the way that's disseminated...whether they disseminate it as a table or as an actual file, I'm not sure, But they have managed to ingest, not the raw data, but the top-level end product, and so this other site is connected to the journal itself.

The data set is peer reviewed at some level. I don't think the referee actually downloads the data and looks at it in any serious and set fashion. I produced

tables and figures that summarize the data sets, but that was the degree of review that they received.

In addition, scholars posting on the arXiv are not constrained by word limits and can post papers in their entirety.

A big change that has happened since I started in this field is...I don't know what the percentage is...50 to 80 percent of papers appear on the arXiv, which is a completely open abstract server. And I will treat most of my papers that way...Well, the whole paper is published...and that's how I access most papers these days. So even if scholars publish in *New Astronomy* there's a good chance they're going to post it on this other server in the whole form, and you can still access it and read it and cite it.

Ap2.5 The Problem of Cost/Page Charges

In the US, flagship journals tend to be society-owned and have page charges, which can act as a deterrent for some scholars. In contrast, the UK-based *Monthly Notices of the Royal Astronomical Society* and some other European journals do not require the author to pay charges. These latter options can be especially attractive to scholars without funding.

I probably budget \$6,000 a year for myself and my students. They're all coauthors. People publish color things in the journals. *Monthly Notices of the Royal Astronomical Society* still doesn't have any page charges so sometimes people go there. If you're really impoverished, you can ask the mainline University of Chicago Press journals to waive your page charges. I don't know how many people do that.

The American Astronomical Society, which is the professional organization under which most US astronomers are aggregated, set rates that are consistent and, more or less, other, more minor journals follow that simply to be competitive. And so it's certainly an issue for smaller journals where the overheads are the same. They have a hard time charging less, but there's a market rate. So there is not a huge disparity, but the foreign journals and *Monthly Notices*—it's still free.

Another factor is just page charges—how much they want to charge for publishing your paper—because for a lot of papers that gets to be pretty significant. There are some that are completely free ranging to whatever it is for *APJ*—\$120 a page or something.

For us page charges are probably \$5,000, \$10,000 a year. \$125 a page. It's pretty pricey. And it's no longer clear what the benefit is, I have to admit. I still do it because I do have the money for it but probably only that reason. A colleague published in *Monthly Notices* because it didn't cost anything.

Most scholars use grant monies to pay for page charges. For under-funded scholars— theorists in particular—this can be a problem. Academic departments cover the cost in some cases.

The *Astrophysical Journal* has very high page charges. It's over \$100 a page. *Monthly Notices* has no page charges. So some people opt for it for just for that reason. But an additional problem is, if you were in the US, and you wanted to help your status or recognition in the field, you have to publish in the *Astrophysical Journal*—but you have to have the money. A lot of the partners can't afford to pay for, say, 100 or 200 pages of *Astrophysical Journal* publication per year, because they don't have that money in their department fund. If you don't have a grant you've got a real problem. The *Astrophysical Journal* or the

University of Chicago Press, they are very hard-nosed. So they would say, "If you plead you can't afford it, okay." But they put you through the wringer.

It's just the way the system has been set up. The NSF, for example, could say, "We will subsidize X number of journals." But astronomers basically publish through the referee process and that's it. NSF gives us money and assets, as well for publications. If they didn't, that would totally change everything instantly. If they were to say, "We will henceforth not pay anybody to publish papers in scientific journals that are refereed," overnight it would change.

You often see theorists in the US publish papers in *Monthly Notices* because of the lack of grant support to pay page charges.

There's one established journal—*Monthly Notices of the Royal Astronomical Society*—that has no page charges. If you don't have any money for a particular project, you publish there. It hasn't hurt its reputation any. It's still a very well-respected journal.

Americans like to publish in the *APJ*. But *Monthly Notices* has no page charges. If you can't pay the page charges, which are on the magnitude of \$100 a page, then you might opt for *Monthly Notices*, although probably you will have a longer wait. I think they have a bit more of a backlog, but they're a good-quality journal.

In my experience, the cost is always covered by the department and it goes by page count. And then you have to pay extra for color figures and stuff like that.

Page charges are ploughed back into financial support for various scholarly society activities, such as raising the public profile of the field and supporting conference meetings. Publishing in online-only journals or posting on the arXiv exclusively would only serve to undermine the good work done by the society, according to some.

In astronomy, there are no for-profit journals. There's Springer, in Europe, but their journals publish more review, specialty, and interdisciplinary articles and not so much mainstream astrophysical research by US authors... The page charges that the main journals collect are used to support the activities of the profession and the society. So they help with meetings, and presence of the AAS in Washington, and various activities supporting astronomy in the public eye. So that's good for all of us. By paying our page charges to publish our papers we're contributing to the public presence, the public face of astronomy. So if everything is done through the arXiv, and if a lot of these little start-up journals take off because people don't want to pay page charges, it can be net bad for the organization of astronomy. Change the business model and you destroy the good things. It's not somebody collecting money because they want to charge you; that money actually goes to the benefit of the profession.

I forget exactly how scholarly societies interact with the journals. I don't know if they help fund them, but I bet they do. What other roles? Societies advocate autonomous astronomy policy on Capitol Hill. That's probably their main role. They organize mass national meetings, grants, prizes, and a few things like that.

Part of me says why not publish in the online-only journal *New Astronomy*? There are probably no page charges. A big burden in astronomy is we have to pay to get our research published...we have to pay a lot of money...The main impediment, I'd say, to the traditional journals are page charges. It costs money to publish, whereas this other journal is free, I believe. The page charge monies aren't super cheap. They're \$2,000—or maybe not that much for a paper. And people have just gotten accustomed to writing that into their grants and having those funds available. There are a few others, a couple of European journals, *Astronomy & Astrophysics*. Those are free as well. And so American astronomers

who are not willing to pay the page charges do submit to those journals...I think the turnaround time is not often much longer.

Ownership of copyright

Some journals are more stringent about copyright than others, which can be particularly problematic for a field with a strong preprint culture. Scholars' perceptions vary as to whether top-flight journals condone simultaneous online posting of a paper.

Science and *Nature*, which are in some sense the prestige quick publication journals, will have a fit if you post anything online ever because once it's published, it's copyrighted. They want you to pay to get it...They're at the extreme. The University of Chicago Press, which does several of our journals—I don't know what their official policy is—but people usually won't post a paper until they've actually submitted it. You don't post preliminary copies.

Well, *Nature* is the only one anti-authors-posting on astro-ph and they even have acquiesced at this time...There's some press rule—but aside from that, scholars are allowed to post to the abstract server...Copyright hasn't been an issue for me. Who knows? I could be violating copyright control on occasion, so I don't know those rules very well. It probably would pay to have some knowledge here, but I don't think there are copyright issues in astronomy at least. There's no money to be made in most cases.

For astronomy, copyright is not an issue because our data are commercially worthless. But you can imagine in some biomedical research, or engineering, patents are a huge, big mess.

In years gone past, there was a long-term editor of the *Astrophysical Journal* who actually elevated the status of the journal. He won the Nobel Prize. And for long-standing tradition, until it was accepted for publication, you could make no announcement of it, and, in fact, you couldn't even issue a press release until the day of publication. The editors were very fanatical. That's all gone by the wayside now because people aren't going to wait a year.

So I think that the physicists, the hard-core particle physicists, may use arXiv differently from the way we do, because some of the astronomy journals won't let you post until it's actually published, some won't let you post until it's accepted, and some don't care.

The arXiv has run into a couple of journals, publishers who are not happy...If something has been published and then the author wants to post it on arXiv after publication, and its in PDF form, the arXiv is very careful to check what the publishers' requirements are. There have been several publishers who have suggested that things be taken down. I'm sure there are publishers who would not permit scholars to put anything on arXiv until after it was published. It tries to be very careful about copyright.

Ap2.6 New and Emerging Publications Models

Online-only journals

Publishing in astrophysics seems angst-free when compared to other fields. There are very few online-only journals in astrophysics, and those have not met with great success. Elsevier's digitally borne *New Astronomy*, for instance, has failed to attract the top scholars in the field, despite boasting an impressive editorial committee. This lack of interest could be attributed to an associated newness of the journal (which equates to a

lack of prestige), the small size of the field, and/or an already high acceptance rate by traditional archival print journals.

I think somebody was trying to found an electronic journal but I obviously don't use it. It's so easy to get stuff into the regular journals that there's not that much motivation to switch.

I guess there's *New Astronomy*, which is a purely online journal. There's a new set of online-only journals and *New Astronomy* is one of them...they did everything right to gain immediate prestige equivalent to the older journals, but somehow it hasn't happened.

So we're more small-time compared to a lot of other fields. But there are lots of start-up online-only journals. I don't think many of them have gone very far. There's *New Astronomy*, which is still around...Astronomy is a small field relative to many others and there are only a few major journals; a couple in this country and a few others in select countries.

New Astronomy is not high-level. The editors are prestigious. The people involved in the refereeing or the managing the journal are prestigious...there are some online-only journals. I haven't tried those myself, but they do exist, and they're just not that popular...I think it's driven a lot by the editors. I know one of the editors has a strong background—he does computational math and physics—and I think he's had a few people in his community use that journal. So there are quite a few papers in computational astrophysics. I think he's been successful at getting some people to go along, but it's not caught on. It's been around for several years now, maybe five.

Open access

Open access publishing is not perceived as revolutionary. In fact, astrophysicists appeared somewhat blasé about the concept.

I wish there was a culture change where physicists appreciated being followers of the Internet more than they do. There's a huge irony because physicists like to think they're responsible for the Internet. The World Wide Web was put together at [CERN](http://cern.ch). And, of course, the arXiv was started by physicists. Physicists look a little puzzled when people start talking about open access publishing, like "I've been doing this for years, what is the big deal, just do it, quit talking about it."

Astrophysics is not like engineering or biology or chemistry or medicine where there are hundreds of journals, open access stuff, and it's just about getting the word out. There are a few respected places to publish and that's mostly where it happens. That's not to say there aren't other venues, but there's a gold standard that's set, and there's no real bucking of that trend just yet...So I don't think we're in danger. There's certainly a threat of open access. I know it's huge in other fields. We're sort of immune to it now. But I must have gotten four emails last week about this or that journal, asking would I be on the board of editors of some new journal, and there's a lot of this going around. They're trying to get into the astronomy market and I don't think anybody is biting yet.

3. HOW DO YOU SHARE YOUR WORK WITH OTHER SCHOLARS AND KEEP UP TO DATE IN A FIELD?

Astrophysicists frequently share early-stage ideas and data, and sharing work occurs incrementally prior to formal publication. Scholars initially discuss preliminary work informally with colleagues and students, and circulate drafts to a trusted circle of scholars, often by email. Typically, scholars present polished work formally at colloquia or conferences. As work becomes more refined, the formal mechanism used by scholars to publicly share their work is the arXiv preprint server, often in conjunction with journal submission. The network of peers that flags papers of interest and attends conferences to discuss research is often composed of the same individuals. Data sharing is common practice in the field; data are published on personal, project, and journal websites or made available on request. Data can also be accessed through observatory archives, which typically become publicly available after a twelve-month proprietary period. Although listservs are widely used by scholars for both sharing information and keeping up to date, there is little indication that blogs or social networking sites are being adopted for scholarly practice.

Ap3.1 The Importance of Informal Networks

Before early ideas are spun into a well-developed preprint or journal article, they are shared informally with a network of subfield experts through either face-to-face meetings or email. Hallway conversations enable scholars to bounce ideas around with colleagues, and further exchanges can occur during sabbatical visits and colloquia. Since collaboration is common practice in observational astrophysics, collaborators, including (former) advisors and advisees, constitute the core of a scholar's informal network.

It's a fairly even mixture between having people right here...having my students across the hall or my other colleagues right down the hallway, or email.

I have a network of people often competing with me whom I trust. Obviously, I have friends, I have people who I'm a little worried about, who are competing with me. Generally I will send my papers to them for comments via email. I usually would submit it for publication first, but occasionally, if I feel a little insecure that I'm moving into an area where I'm not an expert, then I will get their comments first. They do the same; they send me papers and say, "Will you be interested in this?" We have sabbaticals. I go to give colloquia. If I go to a university to give a colloquium, I will do the rounds of the professors in that department. I will give them copies of my work and I'll listen to what they're doing. Traveling is an important way of communicating, emailing preprints to one another. Very rarely would I pick up the phone and discuss something with somebody, unless it's a proposal. So I think we're using email as the communication medium, and travel.

Most of the things that I publish in a journal are published long after I have discussed them in meetings and acquainted the people who would be most concerned with the results of it.

Limited time can be an impediment to discussing current research with colleagues.

I'm not saying I have a problem with my colleagues. It's just that no one has any time. You go to other places and people will sit around for an hour in the morning in the coffee room and talk about things. It's extremely rare, at least outside of the theorists, to do that because no one has time. I think part of it is just the improved communications at every level, which have made it impossible to ignore

the pile of things that you're supposed to be doing at any given moment. And I find myself always playing catch up. I never feel like I have a free moment to do anything at all. So, part of that is that it takes a good solid two hours to answer email on a daily basis. And, one of the things I tell younger faculty when they first arrive is the most important skill to learn is how to do a barely passable job on 80 percent of the things that you're asked to do, so that you can do a good job on the other 20 percent. Most people are trained to try to do a good job on everything and you just kill yourself these days if you try to do that.

Some established astrophysicists consider junior scholars valued resources for keeping them abreast of the field. In addition, "journal clubs" provide a forum for scholars to get together to discuss topical papers. Both face-to-face and email communication is essential for such interchanges.

I rely on colleagues to send me a quick email about papers that have come out. I rely on students, as much as they can, to keep me abreast of the literature.

Most of my collaborators are either current or former graduate students. We stay quite close in that sense. I have one collaborator in the UK and, of course, we exchange things all the time.

One thing that I did this morning, because it's freshest to remember, I saw that there were five new papers today in a field in which I'm not an expert. But I'm interested in that, and I have a colleague who works on that, so I immediately sent him an email, "There are five new papers, I don't think I'm going to get to them but very likely you are, so maybe you should tell me if there is something really outstanding." So that kind of communication also happens.

So the way I keep up to date is twofold. One, I talk to my colleagues and my students. So we regularly meet and review what's happening. Once somebody goes to a conference, we gather to make a report—especially if I'm paying. And then we read the preprint server. I read it every day, so I print it out, here it is. Here's today's, and all of these are the articles that appeared this morning. I highlight the ones that are of interest and then I file them and then when I go to a conference I digest everything that's happened in the last, say, three months. Technology has changed this. I can do all this in my office. I can download these papers off my laptop on the plane. I can browse them before I go to the conference. I still regard the conference as my opportunity to catch up and I know that if I'm going to give a review talk, everybody expects me to be up to date. I'm going to give a review talk next Friday and I haven't written it yet. What I'm going to do is swallow what's happened in this area, with this preprint server, download those relevant papers, and even use figures in those papers—which I can extract from the papers—in my talk, to present as if I'm completely on top of the literature.

I think most of us look at the arXiv preprints at least once a week, if not every day, and it's kind of changed the sociology. We used to have various things that we tried to get our graduate students to do over coffee in the morning with the faculty, and one of the things that's clicked all over the country is having a morning coffee periodically, whether it's once a week or once a day, which discusses three hot arXiv papers. So that has really made quite a difference in the culture, as well as the more routine things of how you actually proceed when you're trying to do research on a specific narrow topic.

Right now I would read almost nothing, because I'm too busy. I'm relying a lot on our graduate students and postdocs. I attended a journal club here today. There were three papers that were discussed, one of which I already knew about, but I actually learned a lot more today. We have coffee here every morning, four days

out of the week we're discussing papers, and I try to come to those as much as I possibly can.

I really wish graduate students did distill information. I find that it would be really nice to depend on students to be on the lookout for important things that one ought to know about, but they don't seem to...well, most of them are so busy with whatever it is they're doing that they've become very narrow, I would say. I think that it's hard to say how efficient people are now with too many possible distractions—and I include the students and myself—because you're sitting there and you decide you need to go find some piece of information. And in the meantime, you go and read the *New York Times* webpage or whatever. And, it's hard to say actually how effective one's time is given that. But there's certainly been a change. I mean, we find that a lot of our students don't go to colloquia when they're not in the general area that they're working on.

Ap3.2 Widening the Circle: Conferences, Seminars, Meetings

Annual conferences hosted by scholarly societies help scholars establish a reputation, stake claim on a research idea, and meet potential collaborators in a public forum. Conferences provide young scholars with an opportunity to establish and grow informal networks, and enable scholars across the board to discuss their research more intimately. Some scholars noted that conferences have turned into “job fairs” for young people in the field and suggested the need for more scholarly exchange.

As you get older and have more teaching and you're sitting on telescope boards, you can't possibly go to all of these meetings. And so we have to be very selective. Conferences are key in astronomy, they really are. They're the place where people establish collaborations, they're the place where young people make their reputations, and even old people go to them and try to take them seriously...Astronomy has a phenomenal number of conferences. In my area alone there's something every month and you just have to be selective, but the younger people are finding that this is becoming the way that they get recognized, especially straight after the Ph.D. Get on the conference circuit. So people take conferences very seriously and the young people put a lot of effort into their talks. The older people like me tend to just recycle the old stuff and turn up and grunt and continue. But the younger people are really driving the conference progress.

When you're young, there's no question you've got to go out and meet people of your own age and learn what's going on in the field, to meet the higher-ups who are going to review your case, so you can come up with new ideas. There are a lot of reasons to go when you're younger. If you're moving into a new field, you want to advertise it. A lot of times the older folk are just giving review talks and they're well established and they're invited to give more of a broader perspective on some area of research that they're obviously experts in. There's not a ton of value. At my age, in my career, it's diminishing returns at this point, maybe. I'm tenured.

Going to talks does serve that purpose of keeping up to date quite efficiently for me. To hear 40 presentations in a few days, that gives you a pretty quick view of what's going on, usually in a pretty select area, but still that's valuable...So there are a lot of meetings, maybe too many in astronomy right now—special meetings. You could easily spend twice a month just attending meetings throughout the year, and people do...Well, not each month, but, last year, it was a busy year for me attending meetings...I had four separate trips to Europe and a couple of those were multiple meetings. I don't know, not 10, but more than five.

The twice-a-year meetings of the American Astronomical Society have lost most of their usefulness. There are too many parallel sessions, the talks are too short (talks are only five minutes), and the poster sessions are uneven. Sometimes I think that the main people who attend are those seeking jobs, those wanting to hire people through the AAS job postings, and the few invited speakers themselves. Instead, most people prefer to go to topical conferences and workshops where they can talk with researchers in their own fields on a more intensive basis.

I find at conferences now that only some small fraction of the talks is actually telling me something new because so much has already appeared on the arXiv. But I certainly feel like I have to get to a couple conferences a year just to stay informed and for the networking. We keep in touch with people and start new collaborations. But also you still find out new things, because you actually get to talk to people and ask them questions and get more than is in the published work—find out what directions they're going in next.

It used to be that you would find out what people were doing by going to conferences. But now, when you go to a conference, you've already heard about all the things that people are talking about from the arXiv.

Teleconferences

Despite a growth in real-time teleconferences, face-to-face networking affords a level of interpersonal interaction that teleconferences simply do not.

A lot of people are proposing that with Internet video communication we won't need to go around giving seminars, we won't need to go to conferences, and things like that. And I suspect that's completely not true. I very much enjoy going to conferences to talk to people, to go to coffee breaks—and that's just not something that's going to happen online.

I've attended a conference virtually a couple times and many talks do tend to be done in real time these days. It's not very convenient because sometimes you don't get heard and so on.

The norm now is webcasting the talk and putting the PowerPoint on the Web, and that's becoming the standard medium for people who can't go to the conference. It works really well. I can sit here and effectively attend a conference in Baltimore just by looking on the Web. I can even ask a question. The space telescopes have been doing this for about two years now. It needs to be well managed to be effective, but I have seen it work.

Conference proceedings

Increasingly, in the US, conference proceedings appear online as a PDF file, especially since online dissemination is inexpensive and timely. Invited papers, in particular, are often published as a book or special issue journal. Although these tend not to undergo formal peer review, a low level of review does occur.

Historically, at least, it was expected to get proceedings written along with the oral contribution paper after the meeting. That's becoming less the case...conference proceedings don't offer you much in terms of tenure or even advertisement...they're for getting your ideas out there. They're somewhat dismissed as they're generally not refereed and they're often a very short synopsis of the talk. So the written contributions are actually pretty weak. What's happening more is the talks are being placed online and some people are

checking out what happened at the meeting by looking at the slide presentations on the Internet. I think the European folks still probably require it for funding...the European Astronomical Consortium, I have a feeling their funding agencies require them to request proceedings. And I've got a black mark on my name because I never do it.

Until quite recently, most topical conferences published non-peer-reviewed conference proceedings, which researchers and libraries endeavored to purchase. There is now somewhat of a backlash against published conference proceedings since (a) you have to publish a peer-reviewed paper anyway, (b) they are expensive, and (c) they appear well after everyone has forgotten the conference in the first place. Some conferences and workshops are deciding to post PDF files of all the talks on the Web, rather than going through the trouble of publishing proceedings.

If you have an outstanding faculty, they're invited to all kinds of meetings to give invited papers. Those papers are written up and usually appear in a book or some kind of a special issue of a journal and they're not refereed. These take a lot of time, and it's time where they present their original results...More recently, the conference proceedings and a lot of meetings in astronomy are actually published as a book, because the invited papers are felt to be like plenary session papers, distinguished addresses, and worth having as a permanent record.

We actually read all the papers and do, maybe not the most critical peer review, but we do review them for obvious conceptual errors or things that don't make sense and have the papers revised.

Ap3.3 Open Public Sharing on the arXiv

As noted previously, the arXiv enables scholars to disseminate their work in preprint form to the academic community and stay abreast of the most current scholarship. As such, early sharing is highly centralized in astrophysics, but is not in lieu of a formal publication.

Timing a posting to the arXiv

Posting on the arXiv is typically not done in lieu of submission to a journal and can take place at a number of points in the scholarly life cycle of a paper. Often papers are posted to the arXiv simultaneously with journal submission and/or revisions (depending on journal policy).

Everybody, without question, is now publishing on arXiv. The actual appearance of the article in a journal is almost a formality.

Personally, I don't feel like I need to be protected from bad work by the peer review system. I would say that most people who do experimental or observational things never post on the preprint server until the paper's been accepted by the peer-reviewed journal, whereas theorists like to get feedback right away. If they have mistakes in it, they want people to point them out. But, generally speaking, there have been maybe only one or two exceptions in my whole career. Since we've been using this, I only post accepted papers. The reason to use it at all is that that's where people look. It takes six months or something like that for the thing to come out in a journal after it's been accepted.

You send your paper into the journal, you get a referee's report, the referee says, "It's a wonderful paper except for the following 289 changes I want you to make." And so you make the changes and then you post that revision. In some parts of

physics, people post the equivalent of astro-ph, arXiv stuff, way before it's ready for publication, and then get comments. That has not been my experience in astronomy or astrophysics, partly because of journal policies, I suspect, but partly just because it's not in the culture. I don't put a paper up on astro-ph until I've submitted it to the journal, so the revision process is mostly a response to the journal's referees, plus whoever has sent me emails in the interim.

Some people refuse to put their papers on until they've been refereed and accepted. Others think—especially theorists—they often just put a paper on and say, "Comments welcomed." So the standards of peer review are being gradually eroded with this webpage. But we all read it.

I think a lot of people submit their article to arXiv as they submit it to a refereed journal, so it appears there right away. I think some people wait until their article has actually been refereed and accepted.

When a paper gets accepted in the journal, then I go ahead and post it to astro-ph and there it's accessible to everyone. Some people, in fact, post things to astro-ph when they haven't been accepted to a journal, so it's a little more of a wild and woolly landscape.

I do put things on the preprint server, but not until they've been passed by the referee and accepted by the journal and that may be something that differs from place to place.

Strategic posting on the arXiv

Strategic posting on the arXiv is rife among scholars. Research indicates that articles appearing close to the top of the astro-ph list tend to receive twice as many citations on average as those articles appearing lower on the mailings.³ Some scholars we interviewed noted that papers posted at strategic times could ensure placement at the top of the list.

The cutoff, I think, is at 1 p.m. If you submit it just before 1 p.m. then you are going to be toward the end. If you do it after 1 p.m. and everything goes through fine, then the next day you'll be at the top.

Posting on the arXiv depends on the order that it was submitted.

The arXiv is like advertising; it's people trying to advertise their work, otherwise why is it there? And so there's all this scheming of who can be at the top of the listing. People were shocked when I told them that the way I search the arXiv or look at the arXiv, the article that they worked so hard to get at the top, was actually at the bottom. I mean, there are two ways of looking at it. There's a time, and you can go ask any graduate student here and they'll know what time to submit your paper to get it at the top of the list. It depends on whether you get the version with the abstracts or just the titles, in which case the listing is totally reversed.

³ See, for example, Dietrich, J. P. 2008. The Importance of Being First: Position Dependent Citation Rates on arXiv:astro-ph. *Publications of the Astronomical Society of the Pacific* 120, no. 864: 224-228. See also: Haque, Asif-ul, and Paul Ginsparg. 2009. Positional Effects on Citation and Readership in arXiv. *Journal of the American Society for Information Science and Technology* 60, no. 11 (July 27): 2201-2218.

Posting on arXiv can stake a claim to an idea, especially since posted papers are date-stamped.

This introduces a number of puzzles. In astronomy, things are very competitive, especially discoveries. If somebody finds the most distant object or the lowest mass planet around a star, you know that there are three or four groups around the world trying to do this kind of work. And, often, an object will even be studied by more than one group, so certain satellites will trigger an explosion, like a supernova or a gamma ray burst, and everybody will be racing to get the first paper out from that intriguing object. So this archival server becomes the medium for unrefereed papers—that the idea is simply to put it on the Web as soon as possible, to establish your stake; it's like the old gold pioneers, just grab your stake, "I've got this." There's tremendous competitiveness. But what it does mean is that there's no standard on this archival server.

Some of it has to do with the date stamping that is done. Much as data lab notebooks are indicators—or were—of whether a patent would be granted...for arXiv probably it's very important to some people because it's their idea, that they want it out, first.

Versioning concerns

Multiple versions of a paper can be posted, though only the most recent version of a paper appears on the arXiv. Authors are responsible for stipulating, via a statement, any changes or status updates (i.e., if it has been accepted to a journal).

Once a paper posted on arXiv gets published in a journal, it's pretty unambiguous at that point, that that's the final version. That's up to the person to indicate on arXiv that it's been published in a journal. So, if you submitted it before it was actually accepted to the journal, then you probably have written into astro-ph that this is the submitted version, and whether you go back and put in the final version on astro-ph, or whether you say "no, it's been accepted," that's up to the submitter. I haven't been keeping up with that myself. I have papers that are submitted that are now fully in the journal and are accepted. So I do have multiple versions of papers out there in the online literature...I look at whether a paper posted on arXiv has been submitted to, or accepted by, a journal. So, yes, I absolutely take that into account.

Basically astro-ph is just a repository of papers where the most recent ones are presumably submitted for publication or haven't been published yet. But people leave their papers on there endlessly, so most of the papers in previous years have appeared officially in journals. And there's a little notice there that says, "appeared," "was published" or something.

Papers just stay on arXiv post-journal submission. Almost never is anything removed. And then usually the author indicates where it has been published. There are ways to tag that entry that says there's a new version of this.

If there are any changes that are going to happen, then you need to resubmit and update your submission, and typically the resubmitted version appears towards the end, which I think not many people read—so you tend to read the fresh ones, and so if there are substantial changes to your paper after you've first submitted it, maybe they'll be lost on many readers.

Ap3.4 Data Sharing

Sharing data in astrophysics typically occurs post-publication. Derived (and sometimes raw) data are shared in multiple ways, including personal, project, or journal websites, or are made available upon request. The absence of mandatory data sharing guidelines, in addition to institutions being allotted varying observation times, means that data sharing practices are often dependent on personality and department; certain factions of the field are notorious for sitting on data.

I have not made my back-end data available. It's an interesting set of issues. We are doing a project now and we are making the data available on a website—both the raw data and the reduced data. So that's me sticking my toe in the water. But I wouldn't do it, and I haven't done it, for studies of individual objects. What happens is, I write to somebody, or somebody writes to me, and we say, "You know, gee, I really like your paper on blah, blah, blah. I've got these new observations with whatever, some completely different instrument, and I'd love to compare your data with mine and register them, and blah, blah, blah." So we exchange the data files informally, just one-on-one, and that happens a lot. And then you acknowledge the person in the paper.

Even after we've published the paper, we will make that data available in its reduced form, which means in its processed form, so that other people can instantly access it on a webpage. And that webpage then becomes highly sought after as a record of what we've done, that others use...Of course, it's up to each individual whether you want to make this data available.

It depends where I publish data. If it's a little table, it goes in a journal, and if it's a bigger table, it goes on a website. If it's a huge data set, it's in an arXiv server, and then maybe we'll write a paper saying, "This is the first data release of our digital sky survey. This is what we've done, here are the tests, and here is the URL where you can actually get the data."

The group at that university is very, very averse to making anything public because their whole history has been that they have gobs and gobs of telescope time, and they take the data and leave it in their desk drawer for decades and they don't want anybody knowing about it.

So the point is that in the presence of these data-sharing tools, a lot of moral suasion has come to the fore. Astronomers used to be big offenders. They would observe over a lifetime, and the data would be in the desk drawer and they would never share...I think that if you build an observatory and you are sure that you will never need any federal money, for any purpose—to build an instrument, operate your observatory, or get research grants to facilitate the work of the individual scientist—then fine, don't disseminate your data. That's a recipe for making the world mad at you, especially if you have one of the world's largest telescopes.

Ten years ago, maybe 15, at the time there was one big telescope. It's a private facility, so there were a select few astronomers who could use it and those people held their data quite tightly and some of them still do.

Data preservation

In recent years, the methods for saving and storing astronomical data have changed significantly. The field has evolved from photographic plates to digital storage; for instance, data collected at an observatory tend to be written to CD. Migration to new

technology formats is necessary, before data become unreadable and rendered obsolete. Overall, data management practices are largely idiosyncratic.

Basically all my data are on spinning disks, and...I have to admit that they're not terribly well-organized. There's no thought or professionalism put into it. We protect the data by having redundant copies of things on multiple spinning disks. And, we use DVDs. We always write DVDs of the raw data at the observatory, but normally we never have to look at those because it's so easy to transport all the data over the network at the end of a night of observing, so you never actually have to deal with these external media.

The formats change, the programs change, the media change, but the information should persist. I think we are moving past the old conundrum of obsolete media, especially magnetic media. Somebody once said that digital information will last forever, or five years, whichever comes first. But now, spinning disks are cheaper than paper, and it's a matter of hooking an Internet cable from your old computer to your new computer, so it's much easier than having someone move tapes, which can become demagnetized. I think, in terms of the persistence of media, that problem is going to go away. And storage is becoming infinitely cheap. But then there is the whole different preservation issue of formats and standards.

Raw data will be saved on discs or maybe they will be put on tapes, but they will normally not be exposed to the world. Besides the data in image form, catalogs from which you can derive some processed data are most useful...and in general we will save as much data as possible but it's difficult. A few decades ago, many photographic plates were taken. We hope to convert them into digital format, but there are so many of them and they're expensive to convert, so that has not happened yet. They are available somewhere, in dungeons, and in principle, accessible, but not available in practice.

Stakeholders in data sharing

Data archives in astrophysics are typically open access. Data associated with national facilities (such as the Hubble and Spitzer space telescopes) become publicly available after a twelve-month embargo period, which provides scholars a window to work on the data first. In contrast, some data are released sooner, such as those associated with the Lick observatory, which is owned and operated by the University of California.

The sociology of our field is changing so that data are becoming public more quickly. Projects like the Large Synoptic Survey Telescope (LSST) and others are providing lots of data. I think there will be more of that in the future. The public institutions and the federal governments encourage that type of release.

Data in astronomy are made public usually one or two years after they're taken. The national facilities, like the Hubble Space Telescope and the Spitzer Space Telescope, provide and fund archives that enable anybody in the world to download their data. These archives are now incredibly useful, because they integrate of all the observing that's been done by that facility over 10 years or more. That provides a huge data set for people to study. And you can even get money to analyze that data—you can write a proposal, not for observing time, but just for resources to analyze the archive.

Public-access data archives, frequently international in scope, are becoming the bedrock of observational astronomy. Some examples, initiated by NASA, include all data from the Hubble Space Telescope, Chandra X-Ray Observatory, etc., which become public 12 months after they are taken. The data are stored in a public archive...The Hubble Space Telescope's archive was the first big archive in

astronomy that showed how it could be done. I don't think they're wonderfully organized, but nevertheless, it's a huge step forward. After one year all data are public...So now people are used to using the archive, and even if you don't get the money, it's sort of in our blood already. And they're doing the same kind of thing with all the new NASA space observatories. It's a completely public archive and access does not depend on funding...I think that all of our telescope data ought to be archived publicly, with a grace period of maybe a year...The Sloan Digital Sky Survey was a private consortium funded by the Sloan Foundation, initially, and they've also gotten some government money. And so they have a two-level archive. They have an archive that's private and then every once in a while they do a big data release where they are happy that everything is in good enough shape that someone from the outside like me can come in and not use it incorrectly...Increasingly astronomers are participating in very large surveys for which the data are eventually released in public archives.

I'm using the [Sloan data archives](#) and the big public database. They have made their data products publicly available, not the raw data but processed data, and many scientists are doing first-class science just by downloading their data sets, and I'm one of them...There's still a high premium on being there first and you won't be first if you're not physically there first...and some data sets are truly public where everybody does get immediate access...quite a few projects are run that way these days. There's the Lick telescope itself—a gamma ray burst satellite. It transmits all the data to the whole world immediately as soon as it gets it. It truly comes as fast as you are observing. Sloan is not quite that way. There is a year-long lag on their release. Some of the product being designed in the large LSST is supposed to be public immediately. In practice, however, I think there will be some kind of a lag.

NASA satellites have got the one-year proprietary period. Scientists want to get a chance for a first crack on the data...that's the principle...For each of the space facilities that goes up, NASA sets up a very expensive and very well done archive with access, calibration, all that kind of stuff.

The most heavily used of all the astronomy archives is probably the Space Telescope Science Institute at the Johns Hopkins University. They have a very elaborate archive and they dedicate millions of dollars to it every year.

One project is developing a really fancy website for multi-wavelength participation, so it's one-stop shopping...There are instructions there that tell you what the data files look like. You press a button, and the data are all available in tabular form. If you want to download all the images—every picture ever taken—you can get it. Every spectrum is fully reduced. You can do whatever you want with it and it's public.

The reuse of data sets is widespread practice in astrophysics, though dependent on corresponding developments in software. Programming is often done by graduate students.

There's a lot of sharing. Everyone freely shares software, with no guarantees, of course. So the software tools are becoming very useful.

Data curation

Astrophysics has a fairly long-term perspective on data collection and curation; telescopes are expensive to build and astronomical events may take place only once or may extend over several decades. Data are decentralized and distributed across numerous archives, described by one scholar as an "archive archipelago." The [International Virtual Observatory Alliance](#) (IVOA), funded partly by the NSF, is an effort

to coordinate astrophysical archival data. As a virtual large-scale collaborative partnership, the IVOA involves a number of member organizations drawn from various countries around the world. While it is perceived as a potentially useful resource, its success is questionable since funding is said to be “piecemeal.” Although the IVOA is addressing data interoperability through the development of consistent and common standards for both data description and analysis, data interoperability remains a challenge.

The Virtual Observatory is an example of this new kind of scientific, virtual organization. Virtual organizations are discipline based, like astronomy, or biology, or earthquakes, etc., and they provide a research framework for science with massive and complex data sets, measurements, or theories. And they’re internally distributed. In the case of astronomy, you have data centers for each NASA mission, for each observatory, for each major sky survey. And so we have what I call an archive archipelago. So you go to one place to get this piece of data or you go to another place to get that piece...It can’t be centralized because data should be where the experts are, where the producers are, and so the archipelago grows exponentially. What can be done, and what was done, is to connect these different archives. And so that middle-ware or connective tissue was what the Virtual Observatory was all about. And they have done fairly well with it. They’ve established a data grid.

There’s a whole mechanism now called the Virtual Observatory. It’s funded partly by the NSF and by other agencies, and it’s supposed to be a big repository of astronomical data. Google is getting involved. They’re starting to archive very top-level astronomical observations.

I think the National Virtual Observatory could be enormously important. It would be great to be able to go to any point of the sky and see, at a given moment, who’s observed it, and how you get the catalogs...My feeling as an outside observer is that the project is stalled, or it’s slow in being realized. But I’m not an expert.

In principle, you should be able to bring together these diverse data sets in a way that actually allows you to make use of them together in a useful way. The idea is to have theoretical models or calculations alongside data so that, in principle, if you’re interested in some particular set of objects in the sky, you can gather the data on them from all these different sources, but then also simultaneously look at what theoretical models would predict as well, and you can compare these different threads and look for inconsistencies. If that could be made to work, it should be incredibly powerful.

On the global scene, there’s been talk for years now of a National Virtual Observatory that would incorporate all the different data from different observatories into one single interface with ways to cross correlate data. And I don’t know why that’s taken so long to get someplace...it’s been a little piecemeal...The project involves a combination of astronomers with computer scientists, so they really get concerned about standards, and they can argue over a four-day meeting about how to spell keywords. I think it’s going to get there but it hasn’t quite yet. It would be nice if in fact we just had some nationally organized, well funded facility that took care of all of this.

Especially in the Virtual Observatory context, a lot of effort was spent trying to devise standards of communication, metadata, and it’s working fine.

The astronomical community worldwide is aiming for a future where the archived data from many different places are linked through some common language, so

that you can, for example, search for an object and find out where that piece of data is, and access that data from wherever it is located in the world.

The International Virtual Observatory is the archive to end all archives. The idea is for computer scientists to come up with a way for all the archives to talk to each other, on one website. You type in some keywords and get a list of everything on earth that's ever been done on that subject...we have a National Virtual Observatory that's part of the International Virtual Observatory. They have a website that's up and running but I have never used it. At conferences when I've talked with people who are working on the National Virtual Observatory, they talk to me in computer science language. And my response is confusion, since I'm not a computer scientist. The idea is that eventually astronomers and astrophysicists will use it. But right now the computer scientists are trying to figure how to make it work.

Ap3.5 New Technologies for Sharing

Email largely sustains informal networks. In addition, listserv use is widespread, changing scholarly communication patterns, particularly among younger scholars. While there is limited reading of blogs and uptake of social networking tools for sharing information, both are perceived as generational. They are not generally used by scholars for early sharing of work.

Listservs

Scholars stay abreast of the field by following subfield-specific listservs and alerts in the form of electronic telegrams, circulars, and e-newsletters. These belong to various scholarly venues including scholarly societies, such as the American Astronomical Society, journals, and the arXiv. Specifically, electronic telegrams or circulars notify scholars "instantly" by email of interesting events taking place. These include, though are not exclusive to: the astronomer's telegram, IAU circulars, gamma ray burst notices, and virtual observatory event messages. The astronomer's telegram, in particular, is a self-regulated forum in which scholars can post announcements and share ideas that are not written up as papers.

For example, gamma ray burst satellites detect gamma ray bursts. Stuff goes to the ground control station. Within literally seconds, an email is generated and gets exploded to subscribers. Some of those are actually formatted for humans to look at, saying "swift satellite found such-and-such." Others are written in XML and they're intended to be consumed, not by humans, but by robotic telescopes that receive an email from satellite via the ground control station, intended to interrupt their program, and instruct them to go take a picture. And then the telescopes can send their own email. So there is this real-time communication story that is never on paper. It's all electronic, which involves four players: human producers, human consumers, robotic producers, and robotic consumers. And they all communicate with each other.

We use the astronomer's telegram a lot, actually...this is something that I read very regularly. It comes by email to my mailbox and I make sure I read that.

Most people on the astronomer's telegram are people who do high-energy astrophysics. So it's organized by the sort of people studying supernovas, novas, X-ray binary, cosmic gamma ray bursts, and so on and so forth...all those people will be registered on the astronomer's telegram by now...There's one other service, which is specifically for cosmic gamma ray bursts...and, again, that's similar but it's specifically just for people doing cosmic gamma ray bursts.

The astronomer's telegram is extremely important to me...It started about seven or eight years ago as a competitor to the IAU circulars telegrams, which have existed for 100 years when they used actual telegrams...It's something that has been used for rapid communication of things that are popping off in the sky. You discover a new asteroid, a supernova goes off, an X-ray binary goes into transient outburst, whatever it is, you would publish a telegram. So now you have a new result, you go to the astronomer's telegram...You don't pay anything...You just go to the webpage, you just write it, you submit it, you click "go." If it's something that's so time-urgent that you want people to put their telescopes onto your new object within hours, you click the box that says, "instant email," and it sends it immediately to all the subscribers. There's another use for it...if you've discovered something that's kind of neat but isn't worth the paper, sometimes you'll just put it on the astronomer's telegram as soon as you've discovered it. It's supposed to be timely, but it's not always timely what people put on there...But what is remarkable is that the quality has been very high. The only screening is when you register. The editor-in-chief checks to make sure you're a real astrophysicist, but, from that point on, it's entirely self-policed as to what you put up there. And, to me, the quality of it has been extremely high. People haven't been abusing it grossly...The population of people who use it has been growing...my community, in particular, has moved over to the astronomer's telegram.

Unlike other disciplines we have examined, scholars in astrophysics use listservs as a mechanism for communication, and they have replaced traditional patterns of keeping up to date, particularly among pre-tenure scholars.

A listserv has changed the way most of the younger generation receives and vets papers. It is through the listserv. Nobody gets papers in a journal and nobody goes to the library. That's a given. I don't even know that many people who go to the website of the journal when they release their new papers. It really is primarily from the listserv. Astro-ph does send out its own email to those who want it. I'm a member of very few listservs. I get the astro-ph one, and then just a few ones local to our department. I guess there's an AAS one for announcements for the American astronomical community.

The arXiv preprint server also serves as a platform for dissemination of different kinds of information not intended for journal publication. This can range from announcements of database releases to newsletters and tutorials.

Astro-ph serves a broader purpose. You can publish things where the intention was never to put it in the journal. So you can announce, for example, the release of a database to the whole astronomy community without having to go through a regular journal process, or some other announcement.

We've used it occasionally for essentially announcing data releases...telling people that we have put up a bunch of publicly available data on some website and giving a brief description of it. The first time we did this, we actually contacted whoever was administrating the arXiv and asked if this was acceptable content and they actually said, "Yeah, this is one of the reasons we set this up in the first place—to allow this kind of communication."

There are newsletters. There are email exploders where we're all kept up to speed. I can give you a good example. Right now we're all writing Hubble proposals and there's a document that tells you how to apply for time and it contains all kinds of information about the efficiency of the Hubble space telescope. That was produced last October. It has mistakes in it so the entire community gets email updates, not entire documents, but just saying, "We've subsequently found that this has changed or we've got an improved version of

this." And the webpages are constantly being updated with addendums and so on. So, they're living documents.

There are some articles that get published only on the arXiv that are like tutorials, for instance, which are unlikely to go into an actual journal...because scholars have accumulated some knowledge, which they would like to get to others but it's not something new worth publishing.

Blogs

Few scholars consult blogs to stay abreast of recent developments in the field and many consider them a time drain. For those astrophysicists who read blogs, they can serve as a filtering mechanism, much like a sophisticated subject listserv.

I don't have time. I would look at other things before I'd look at that. I don't have time.

No. I don't read blogs. I'm actually quite vigilant about trying to avoid things that I feel would be wasting my time, because if I weren't, then I would get nothing done at all.

No, I'm not looking at blogs...I don't have time for this.

I don't have time for reading blogs.

I'm not familiar with blogs.

I don't find blogs very useful myself, but project-based wikis are a much better structure for that kind of thing. To me, blogs are a chattering thing. But wikis are okay.

When something comes up in the news, the first thing I do is go check the blog of this particular scholar, who's very smart. I have absolute confidence in this scientist's assessment of new results. And sometimes this author will say, "This is silly for these reasons," or sometimes, "This is important." That's an absolutely new way to sort through the quality of papers that come up...I know a lot of people refer to this scholar's view of things...everybody reads it...S/he'll write a piece and pretty soon everybody in the field will have their views and it's very interesting and handy to read. There are some real heavyweights who weigh in with opinions...It takes a lot of time to maintain a blog...This author updates it often, and thoughtfully; it's very well written.

The blog is a new kind of reviewer.

So a blogger, who is particularly interested in what is on arXiv, would comment in his or her blog. Blogs are certainly more common than 10 years ago...I think it's maybe a young person's game, or at least limited to people who like to blog, but I don't think it's become the default means of communication.

That medium hasn't really grabbed onto me. I do read a political blog, so I can't even say it's a failing of the medium altogether. It's some kind of thing that I still enjoy, but for astronomy, no. Maybe it's too distilled at that point. It becomes like a press release. They're nice, but I'd prefer a more technical look at the paper myself, to get the results myself.

Among the astrophysicists that we interviewed, there was the perception that blogging activities are generational.

I'm sure students are reading blogs. They tend to look at them more than we do.

I think that the specific reluctance to use the Internet is a generational thing. Among the people who have blogs and are using them in energetic ways, it's certainly the younger crowd that is leading the way. That is true. Nevertheless, I think that the general feeling—that the serious people sit at their desks and write equations at their blackboards and they don't bother talking to the outside world—is not going away. That's not generational.

To an extent, I read blogs. I think the main information does come from the more standard ways, but yes, blogs are interesting. There's one I look at every now and then, not every day.

Writing blogs

Astrophysicists generally consider blogs outside the realm of scholarly production and there is a certain degree of academic stigma and frivolity associated with writing blogs. One scholar, who actively maintained a blog, could envision it as a venue for sharing undeveloped research ideas.

I'm now in a position where my job is only doing research. Blogging is purely a spare time activity, which is fine...My institution doesn't mind it, but I think that mostly they just don't care one way or the other. It's neither a plus nor a minus...If you have an idea and you put it out there on a blog without getting a paper out of it, someone else will take it and write it up. One of the reasons why we did not choose to use our blog mostly as a technical tool to talk among researchers, is that at some point you have enough communication between people. And I think that the arXiv works really, really well with that. You write a paper that is at the same level as a scholarly paper and everyone sees it the next morning. And the blog is very, very informal in the way that we've done it...Within physics or mathematics, there's a huge downside to that. Namely, that you have an idea and you put it out there without getting a paper out of it, then someone else will take it and write it up. We have a system right now where you get credit for the papers that you write, the official scholarly papers...Nothing I write on my blog ever appears on my C.V. as a scholarly contribution. Right now we have this threshold that until you write something that's worthy of being published as a paper, it's not a contribution. I'm not saying it's a bad fact—it may be perfectly reasonable—but because of that fact, it's harder to have a forum for discussing things that you think are interesting ideas that are not quite publishable as a paper. I don't quite know how that would work. Either I have an idea that's not very interesting and "Who cares?," or I have a good idea, in which case I'm going to write a paper about it. So I think that's the current system. Maybe in other fields it works differently. If you were in economics or political science, you might think about, "How does this electoral college feature interact with this campaign feature?" Maybe it's an interesting thing to say, but not quite something you want to do your research on. So there's more room for that in-between kind of research.

Social networking/Web 2.0

There is little indication that astrophysicists use social networking tools for sharing at this time, though some scholars envision a future in which these venues might provide such opportunities.

There are new, different things that people are experimenting with that will change and make these cyber environments compatible with research. A lot of that has to do with Web 2.0 technologies and the semantic Web that's coming. It's to be decided. It's a marketplace of ideas. We'll see what works and what

doesn't. Right now, we're essentially reacting to commercial or silly things. For example, one discussion I keep having with people is about Facebook and LinkedIn, or YouTube. So Facebook was essentially created by undergraduate students to find dates and LinkedIn is intended for business people to get business contacts. So scientists go on those and try to establish their own groups. And you know what? It's just not working...because it's not made for that. We're just using this stuff because it's there. What about virtual reality? There are people now experimenting—having lectures in Second Life—which is probably just a baby version of what's coming.

One thing that has been discussed is something like Facebook for astronomy, and the typical name being used for that is "Spacebook." Unfortunately, that term has already been taken by two other groups...So, that is one thing that many people seem to find interesting...in the future, something like Facebook is going to be very important.

There is the perception that the younger generation may use social networking technologies for sharing information. The European Space Agency uses YouTube to reach a younger audience and prospective Ph.D. candidates utilize MySpace. Similar to history, the astrophysics job rumor mill is accessed by scholars to find job-related information online.

I'm thinking about having a presence in Second Life. It would be the first observatory. And it looks to me like we can take a bunch of the stuff on our website...the history of the observatory, the modern instrumentation, all our press releases, somehow it looks like there's a way to get all of that stuff easily into a Second Life location...We just have to buy some land...it's not very expensive. I think for a thousand bucks we can have a pretty real presence.

The European space agency has a young guy...and he talks to the younger generation about astronomy. I think it's YouTube. That is their communication forum.

I think there's a fair amount on MySpace that goes on by kids younger than me...it's not my generation, but I think...I remember being told when students were deciding what department they were going to go to for a Ph.D., other students knew via the MySpace universe.

The astrophysics job rumor mill is actually based at Berkeley now. The astronomy job rumor mill was started about 12 years ago, as a way of publishing rumors about jobs in astronomy—so faculty jobs, postdoctorate jobs, analyst jobs, whatever. And it's basically who was on short lists for jobs, who had been interviewed, which jobs had already been offered and accepted. It's not scholarly communication, that's a little outside the purview. It's community input. Right now it's a wiki in the Berkeley astronomy department...it's self-correcting and it's kind of interesting.

4. HOW DO YOU COLLABORATE WITH OTHER SCHOLARS? AT WHAT STAGE OF RESEARCH?

Collaboration takes many forms in astrophysics, many of which transcend disciplinary, institutional, and national boundaries.⁴ Collaborations frequently center around costly

⁴ Birnholtz, Jeremy. 2008. When Authorship Isn't Enough: Lessons from CERN on the Implications of Formal and Informal Credit Attribution Mechanisms in Collaborative Research. *The Journal of Electronic*

national facilities and are often driven by funds awarded across multiple institutions. Some astrophysicists collaborate with technical experts involved in the construction and maintenance of a facility's hardware and software. Evaluating individual contributions in team-based research is a growing challenge for the field. The use of wiki-based technologies by scholars is prevalent, particularly for project coordination and management, and coauthorship of papers.

Ap4.1 The Nature of Collaboration

Collaboration in observational astrophysics is the norm, although its scale can vary. Traditionally, scholars have analyzed observations of individual targets over a few nights. Increasingly complex and ambitious research projects can, however, require observations over hundreds of nights by teams of scholars drawn from multiple institutions. The allocation of highly competitive and expensive telescope time for observation drives collaboration for some scholars. The emergence of survey astronomy has magnified the size of collaborations in the field, which are often motivated by data sharing and analysis requirements.⁵

For thirty, forty years of modern astronomy, individuals have been going to a telescope for a couple nights. There are some projects you can't do that way. You need 400 nights on a facility dedicated to a single project. To put together that kind of a facility requires bringing in lots of people who have contributed from the beginning to the end.

Telescope time, either in space or on the ground, is sufficiently hard to get that people are very motivated to collaborate with other people so they'll be more likely to get telescope time...In some cases the teams are so big that they're quite unwieldy...it can be anything from half-a-dozen people to 100 or 200 people. The Sloan Digital Sky survey is the archetype of billions of people...Before these big surveys came along, people were collaborating in small groups, frequently on multi-institutional projects. Then there were a few inspired people...I could probably name less than half-a-dozen individuals, who came up with the idea for these big surveys, and who stuck with it long after everybody else said, "Forget it, you're way over budget, you're way overscheduled, don't even think about it, you're doing a terrible job." And it turned out great. All of those negative things were true, but in the end the project turned out great. And it really changed the way people think about doing research on the early universe and the evolution of galaxies, and even things like looking at the halo of the Andromeda Galaxy, which is our nearest decent-sized galaxy...So that's relatively nearby, but it's all done in this big survey mode...So if you want to find out the shape of the universe, you look at a million or even a thousand galaxies and get good statistics on what these galaxies are doing. And anything that big is a collaboration between a bunch of people. Those surveys have made a real change in how people do extragalactic astrophysics, anything beyond our galaxy. They're encouraged by the various time allocation committees.

We deal with experimental facilities, accelerators, for example. They're so expensive that you have to have teams of hundreds of people. And now, in astronomy, people get into these enormous surveys that can have a hundred members. It's like the accelerator physics mode of work. Because an accelerator costs \$10 billion or Keck Telescopes cost \$100 million apiece, and time goes for one dollar per second, whether the sky is clear or cloudy. You can't screw around.

Publishing 11, no. 1.

http://quod.lib.umich.edu/cgi/t/text/text-idx?c=jep:view=text:rqn=main:idno=3336451_0011_105

⁵ The Sloan Digital Sky Survey (SDSS), for example, comprises a collaboration of about 150 scientists drawn from participating and non-participating institutions and external collaborators. The members of the SDSS coalesce around a 2.5-meter telescope at Apache Point Observatory in New Mexico.

And so you need the political might to corner the resources. That means that you need to have big teams and so on. These things are sometimes inevitable in order to actually get the data flowing.

Certainly bigger and bigger collaborations seem to be the rule. Many people resist them, but I don't think you will be able to resist them because they're so powerful. The ones I know about are largely American with a few international members. So, for example, one collaboration I'm involved in...has some people in it from England and Canada, as well as the United States. But the bulk of our people are in the US. So there's still a barrier there. As much as anything, the time zones are a barrier.

Collaboration for theoretical astrophysicists is often one-on-one and internationally based, largely because their research has historically been more solitary in nature.

I think there's collaboration but maybe only one-on-one rather than in big groups. It's hard to spin off the parts of a theory the same way that you would spin off parts of an instrument. There's a lot of international collaboration in theory, maybe even more than in observation. So people flit around the world to work together; somebody will go someplace for a week, Munich or somewhere, and somebody from Europe will come here for a week.

Inter- and multidisciplinary collaboration

As data collection and analysis become more large-scale and complex, research teams require technical expertise and skills, often provided by visualization experts, statisticians, and computer scientists who manipulate and process data. Since observations are made across the electromagnetic spectrum, astrophysicists can team up with colleagues working at other wavelengths, such as x-ray and gamma ray experts. Astrophysicists may also collaborate with scholars who specialize in astronomical instrumentation, including physicists and engineers.

Our group does have a database expert, a computer science expert who works on neural networks and things like that, and then a couple of other people who function between astronomers and computer programmers...The survey I work on is a slightly bigger project. We handle much more data. But it is difficult when there are more people to coordinate things in a coherent manner.

You call upon an expert in visualization. In the early days there were probably only one or two people who knew what they were doing in that area and had the wherewithal to make the tools, and either you had to call them up and beg them for help. There are experts in building this software and it's essential to doing research.

I guess we don't have any people who are employed as experts in a particular area. We don't have a database expert. I guess we've all become experts in small areas as we've needed to, so within the collaboration, we all know who to go to with a particular problem, because they handled that before.

It started out as a survey...that was the core of this bigger collaboration. We measured spectra with a Keck telescope...As we were part way through that, we focused on one region of the sky and proceeded to team with other people working at different wavelengths with x-ray satellites, gamma ray satellites, with ground-based radio telescopes, etc. So a team that started out with about twenty people has grown to more than 100 by the time we added all these other wavelengths.

There are now so many services that are out there that once you find something interesting, you want to know, "How does it look in x-ray?" You can just go to

your computer and get that data and then do more things. But then if you need an x-ray expert, that starts another collaboration, you start with someone, then add a third one, so it spreads just like that.

In high energy physics, you can have up to 1000 physicists and engineers designing instruments and machines. With greater technology, broader expertise is required, which increases the number of people involved in collaborations. Space missions are huge collaborative endeavors.

Ap4.2 How Do Collaborations Arise and How Are They Sustained?

In astrophysics, collaborations are frequently developed through informal networks, ranging from departmental contacts to meeting like-minded scholars at conferences. Some scholars collaborate because they need certain data and because collaborative research gives them a competitive edge and is more time efficient.

There might be a shared set of expertise. If I have an idea and I understand some aspect of it, but there's something else I don't, if I'm thinking about cosmology, which is my thing, but I want to relate it to quantum information theory, I'll go across and knock on my colleague's door, because s/he knows that stuff...Well, there are also other factors. One is it just might be more fun. You have friends, you know they're interested in this thing, so you say, 'Hey, do you want to work on this?' Or you might come up with the idea in the course of a conversation with somebody at a conference or under informal circumstances.

Astrophysicists working together would be able to accomplish the task in two or three years. It would take ten years just by yourself. The field has totally changed in that time. So the pace has moved so fast that, if you do not collaborate, I think, you will not be competitive.

Our facilities are not in our universities, so research suddenly becomes open for inter-university collaborations. A theorist in Princeton meets an observer in Chicago and they decide that this would be a good thing to work on together. That happens in conferences, it's not going to happen over email, it's primarily going to happen at conferences.

I sent an email to someone in Australia to tell them I had an idea and they had some of the data that I was interested in using, and we struck up a collaboration that way. But it doesn't necessarily have to be international.

Collaboration between senior scholars and their younger counterparts, including postdoctoral researchers and graduate students, is common in astrophysics and can contribute to department collegiality. Collaboration among senior faculty within an astrophysics/astronomy department, however, is rarer because faculty members are busy running their own research groups, labs, or centers.

One of the things that we deal with here—that isn't as true at other institutions—in astrophysics at least, is that everyone is expected to have a sort of self-sustaining and independent program where it's actually almost discouraged from collaborating with faculty colleagues. Everyone works with younger people, like post-docs and graduate students. I think with that comes with quite a bit of stress, particularly for younger faculty who don't have a group...Departmental collaboration can contribute to the collegiality and feel of a department. I think once you get down one level, it's good among the post-docs and graduate students...It's just that everyone is so busy running their show that there isn't any time left to collaborate.

Funding

Funding often drives collaboration in astrophysics. Grants are frequently awarded across multiple institutions, as evidenced in the case of the [Sloan Digital Sky Survey](#) (SDSS). Grant proposal writing in astrophysics is highly nuanced as scholars tailor their collaborations to secure funding and to negotiate the ‘politics of international collaboration.’ An element of competition and collaboration between countries and continents is prevalent.

Money is a big question. Sloan would not have gone to a single institution. They needed a combination of institutions, including private ones that were wealthy enough to bring in a few millions apiece to put together a package that is big enough. For our case, we have collaborations because individually, I can't get sixty or fifty collaborators in two or three years. So I collaborate with other institutions...I think NASA has really changed some of that. In the last fifteen to twenty years, the type of projects that they've supported, and each of their efforts, are huge teams of people. They gave the Nobel Prize to two scholars out of a big, big team.

For the Gemini Observatory, you often need your international partners to make sure that your project is really accepted. So the politics definitely dictate collaborations. So when you write proposals you take into consideration, for example, the Hubble Space Telescope. If it's going to be a US project, you're going to ask for hundreds of orbits. Over half the members are Europeans and in evaluating the proposal they won't look on it as kindly as the ones of their colleagues in their own institutions from their countries.

There are obviously funding streams that have very different facilities...there's a north-south hemisphere divide almost between the United States and most of its observatories...if I want to observe something that's south, there's only a couple of US-based ones, and if they want to observe something in the north there's only a couple. There was nothing European-based. So there's an interest to come together across the hemispheres, if nothing else. And in the end people are doing similar science on both continents. We compete and we collaborate.

Ap4.3 Judging Multiple Authorship

Multiple authorship is not new in astrophysics, but an increase in the size of collaborations has resulted in more scholars attributed in the final research paper. Typically, the key contributor is listed as first author. Credit is assigned to those engaged with intellectual heavy lifting and to ‘builders,’ who are associated with data produced by a facility (which can include telescope instrumentation, optics, technical infrastructure, spectrography, software archiving, and data reduction.)⁶ Multiple authorship is a particular concern for younger scholars because it dilutes their individual contribution.

There's usually a whole group of people associated with the instrument. So all of a sudden if you propose to collect some data for a project, all of the collaborators become coauthors. But there are pros and cons with that as well. Sometimes it dilutes your own contribution if there are 20 or 30 collaborators on your paper.

⁶ For instance, under author inclusion, the [SDSS Scientific and Technical Publication Policy](#) states that, “At the very least, any scientific paper will include in its author list any individual who has contributed to the scientific analyses presented, along with all builders who have requested authorship.” Authorship is based on a “two-group” system. The analysis group consists of scholars who contributed to specific analyses outlined in a scientific paper (including research described in the paper and the writing of the paper). The second group consists of all other authors on the paper and assignment of these names is alphabetical.

There's just this proliferation of involvement and, therefore, entitlement to results. I may want to publish a specific data point and I can't do it because it's a specialized piece of data that involves a team of 40 people and you don't necessarily want all those people on your paper. I personally try to shy away from big projects; I've been involved in one in my entire life, and it's not that I regret it, but it was a painful way to do science. So I'm not necessarily in a position to comment. Anything done in a group takes longer, it's more expensive, but the result is probably a bit better because you have many more eyes with different areas of expertise on a problem.

There's a lot of politics that goes into the ordering of author names and we are still in the process of working that out because these huge collaborations are a fairly recent thing with in the field. When we were a smaller team, we sat down and we wrote down policies about collaboration and publication...our database is so rich that you could probably write 400 papers with it so there's plenty of stuff to go around. So the way this has worked is that somebody gets an idea for a paper and writes what we call a paper proposal, which has a title, an abstract, known authors, possible authors, but the authorship list is still open within the collaboration, and a list of data that is going to be used...And so we approve these proposals, and once they're approved they're filed away and that's your protected turf. The order of authors is not specified in that first paper proposal. There are two groups of authors—there are people who actually did the work on that particular thing, with the leader of the paper called the first author being first in the list. In astronomy, the custom is that the most important person goes first...And then people appear in order of their importance. And we leave it up to the first authors to decide with very little argument over what the ordering of people should be. Then because we're part of a huge survey, and somebody's measured red shifts, which went into this particular project, even though they didn't do anything more than that, so we've been in a mode where we're very generous and we have long author lists and that part is alphabetical...We're entering a new mode where the author lists are going to get shorter and be confined to people who actually did something important on the particular project. We're in transition.

So usually you have a little battle or rather you have a discussion between one and four contributors. And at some point you can look in the list, and if there are thirty authors, all of a sudden it becomes alphabetical and that's where you know those people all made some contribution but it wasn't the major one.

I find working in a collaboration of six quite easy...it's usually clear who should be the first author on a paper because there's almost always one person who did 90 percent of the work, and then our approach is that everybody else has the option to be a coauthor, if they want. That ordering is sort of negotiable.

Evaluating multiple authorship

Since citation counts are often skewed in favor of a "baseline team" or "builders," tenure and promotion committees often rely on other indicators, including external letters of reference, to inform their decisions on multiple authorship publications. In addition, a scholar coming up for review may need to specify personal contribution to a given paper.

Our efforts now are becoming increasingly large scale, where we have the thirty-meter telescope, we have the big project called Sloan, and there are others that are very large. They're much more team oriented, and I believe they've grown by large factors in the last twenty years. In the old days we used to publish by ourselves. Now, there are teams of 3, 50, 100 people. And so you get publications now with, say, 100 people and they're understood to always be on every paper so they produce 100 papers. There are people who have done no

writing and they get 5,000 citations now because they're part of the Sloan baseline team. How do we judge their contribution? How are we going to judge citations is this way? In our university here, for example, we're supposed to write our specific role for each publication. So evaluating total citations, one could ask us, "How many projects have you led? Can you verify that you were the main originator of the ideas? Are you the person who came up with the discovery?" I think some of these questions will have to come into play. Yet we have to find that kernel of the citation that's relevant to what we would judge.

The problem that I face is how to deal with a multiple author paper. It can have 20 authors so how do I apportion credit? I would ask for every faculty member coming up for review to write a self-evaluation and a description of each of their papers and their known contributions. At some level, what they say is about all you have to go on, unless you actually go out and investigate. If it's a promotion then you get outside letters and you can use that. Otherwise, you go on what they say. But generally I found that was enough to build on for something like that. But it still doesn't get to the real heart of the matter of what's central to the university. What is the real scholarly level of this person? At what level are they a scholar advancing the field? And in multiple author cases you often don't really know. And there's nothing much you can do about that.

Intergenerational coauthorship

Intergenerational coauthorship can give younger scholars a leg up in their pre-tenure years. Some senior scholars assign graduate students first authorship on a paper or coauthor with their graduate students to provide them with much-needed writing experience.

More often the case is that the coauthors are graduate students, and often the faculty members will put their graduate student first, just so that the student's name gets out there and they feel they can get a job.

If I have a good idea, even if I could write it up myself, it might be more useful for me to hand it to a graduate student and have them play with it, so many of these collaborative papers are an advisor and a graduate student.

Ap4.4 Mechanisms for Collaboration

Many astrophysicists have adopted new technologies for scholarly communication and project management. Collaborative research, in particular, harnesses multiple technologies in the research process because scholars need to be in touch with colleagues located around the world.

Data analysis and discussion

Although sophisticated communication technologies can facilitate collaboration—some international collaborators may never meet in person—they do not replace face-to-face interaction for some scholars. Meeting fellow collaborators at ground-based telescopes provides a more intimate and creative exchange than afforded by other means. That said, use of communication technology is widespread. In particular, telephone, email, Internet telephony, instant messaging, webcams, video-conferencing, and wikis are most commonly used.

Astronomy is really nice because the teams are still generally up to ten people, often four or five. And so, we can all keep in touch with one another, even across the Atlantic, by telephone. We have teleconferences, we have video conferences,

and the observatory is often the focal point. We meet at the telescope....People like to travel to the telescope because it gets them out of the office. It's like moving into your laboratory. You have your administrative office, but then you have the lab where all the students are and that's where everything's happening, it's where the social interaction is. Our lab is the telescope, and so when I go observing, I regard it as research. It's like a mini sabbatical. I'm going for a week or four days or five days, and I get out of the office and I deliberately try not to take teaching work with me. People will fly in and meet there, and that's where we really communicate in the spirit of research. So the observatory is the focal point for a lot of activity. Now for some people, there is of course the capability to operate the telescope remotely, and some people do this, but I think it's quite unpopular because you don't get this feeling of getting out of the administrative duties. Of course the younger people don't feel this quite so much as the senior people...There are two reasons why even lousy weather is still a productive trip. One is you're physically with your collaborators, and so, if there's no observing then you can get on with something else, like writing that paper that you found difficult to do when you were all in different places.

Well, technology certainly makes it easier. So one of the things I've noticed is in the past I might have collaborated with a faculty member, and now they say, "Well, do you mind if my student sits in on the iChat?" And then we see each other face to face and there's a little bit of ice broken. There's a human relations aspect to all of this, too. It's easier to start sharing hypotheses and ill-formed ideas if you've actually seen the person and chatted with them for a while about the weather. When you're trying to actually collaborate, there's a lot done by email, there's a lot done by video teleconference, which is getting more common because of iChat and iSight and Skype. They all have video now...So we used to collaborate by mailing things back and forth and talking on the phone. Now, we collaborate by posting things on personal websites or twikis and wikis, and getting on iChat, iSight. If it's in a group it's more likely to be a video cam. That's becoming more and more common. So that's sort of in the fluid stage of research, when you still don't quite know what you're doing and you're trying to get your ducks lined up.

I don't use wikis. I know other people who have set up wikis for their research groups and I've thought about that. But again, there's this cost benefit analysis. There are only two or three people working on a paper. I think it would be different if I had a large experimental collaboration, then it would make all the sense in the world to share common information. But basically we're dealing with ideas that are pretty abstract and we can just talk about them back and forth. And we do have group meetings where we talk about what we're doing, but I haven't seen an obvious need for that yet.

Telecoms...It's real time discussion of various issues. A conversation, and it's often about the strategy, how to do something, wrapping up a paper, and comments and discussion of issues. So I think it's not really replaceable by other means. It's certainly better than having everybody in some common electronic chat room or something. It's discussion, so I think it's reasonably effective.

We use iChat a lot now, and I'd like to do it even more. I'm just in the process of upgrading the number of pixels I have. We're going to put up a big screen...If you're going to have a meeting with your collaborator, it turns out better than email, better than phone calls, and now often we use the built-in cameras on our laptops.

We have videoconferences once a week with the whole engineering and sciences team. So this is going very well and it's the first time we've actually done this. We do videoconferencing and the whole team meets face-to-face once a month.

Altogether, it's about 20 people, I would say. Mostly engineers and a few other faculty involved, but it's mostly engineers.

It's now reasonable to have full-on collaborations with people you've never met face-to-face, and may never meet face-to-face, simply through Internet interaction. So it ranges from something as simple as email to chatting tech type programs between Mac software and Skype software that people do for both immediate communication as well as file transfers.

Although virtual gathering places may be beneficial to the field, especially as a means of bringing a project team together, collaborative efforts can be hampered by everyday practicalities, such as low bandwidth.

I envision in the future we will have more of these distributed institutes and centers without walls...Really we need wall sized TVs showing common areas in all the places, to create an electronic virtual gathering place; that would be wonderful. People have tried to do this but can't. Maybe it's bandwidth? Sound turns out to be a worse problem than pictures. I'd like to see us make progress on that. We need really effective multi-node coordination communication so that people don't have to travel so much.

I don't like videoconferencing. If you only have a couple of people, a telephone is much better. I'm not too impressed with videoconferencing technology, because in most of the systems, the bandwidth is too small, and so people can't talk over each other. You end up spending a lot of time thinking someone else is about to say something or talking over and just eliminating each other through destructive interference. So I don't find that works very well.

Project coordination and organization

Wiki-based technologies, including wikis and twikis, were noted as particularly useful for project coordination and organization, enabling scholars to hold discussions, and share and manage information (such as documents, tools, software, data, and results). Team collaborators are more likely to respond to questions posted on a wiki rather than those sent by email because the public nature of a wiki elicits feedback and messages do not get lost in an email inbox. Concern over security is noted, even though access to a wiki is password protected.

We have a wiki going that is mostly internal. The purpose is to stay coordinated, and also to let people know what tools are available, because, with 100 people we're writing software all the time and somebody might have written a tool that you could use. It's just a sharable set of instructions for using tools and data.

We have a center here, there's one at another institution and there's one out at Waimea at Keck headquarters. Those guys do all their communication through a wiki they set up here. So as new results come in they get posted on it. When questions come up they get posted on the wiki. Everybody can read them and respond, and it's proved to be amazingly effective at keeping those collaborations close. And it's clearly the way things are going to work in the future. I think it's because people spend so much time in front of their computers now. Communication flows very freely, and you don't get this business where you send an email and there's no response and you forget about it in two days. I think that is because it's public. So if we need someone to answer this question, it's there for anybody who feels compelled to answer it. It's really helped our research.

I work with a collaboration of five or six people spread around the world. We actually use a wiki mostly for managing software development. So the particular bit of software that we work on in this collaboration, we have a wiki, which is

really a list of tasks to be done and ideas, what jobs different people are supposed to be doing. We've been doing that for a little over two years, maybe three years now. It's incredibly useful for keeping track of what everybody's doing, because before we would send each other emails but then information would just get lost.

We have a wiki for our group. It's a place where group members can list the latest topics that require attention, and then depending on whether you have time, or whether it relates to your particular field, you can tackle those challenges.

A wiki can serve as a preservation mechanism since drafts of scientific papers and research processes are archived and can be retrieved with relative ease.

The way we're using wikis is very fluid...it's a format where you edit webpages very, very simply, so you can go in and add your own page...And you could just put down musings, you can upload files that somebody can easily download, and you can do it in literally 30 seconds. It's very, very fast. So while we used to be able to do this using FTP sites and webpages, this is much less hassle. So, in principle, this was all available before, but it's much more efficient now...A wiki also is archival in a different sense. The whole history of whatever you're working on is there, all the drafts and something that somebody said last February are still there. So since research involves a lot of backtracking, and side tracking, you can pick it up and...Whereas I used to do research using a notebook, and by the time I would pick it up...an idea would be four notebooks back and I couldn't find it anyway...I think if we didn't have a wiki, the project wouldn't have been organized the way it has been.

I'd say that many large groups and projects now have wikis where they put all of their information...it's preserving all of the information...my post-doctorate will do some test and say, "Here I have done this and that, and it's on this page and look at those plots and here is the manual, how you do this particular part of the project and so on." So all of that stuff can and should be made in digital form. Then you have to decide which stuff is for my group only and which stuff the whole world can see. And then you don't know what's actually important and suppose that some group's work someday is great, fantastic research. Nobel prize. Scientific revolution. Then historians would want to know, "How exactly did they do this?" And there is no equivalent of Einstein letters or Milliken's logbook.

Age

Intergenerational models can serve as building blocks for technology innovation in astrophysics as technically proficient younger scholars assist their senior counterparts. Graduate students often set up wikis for their research groups.

I'm older than these guys and have never used a wiki, though our engineering group here and at other places uses it extensively.

People are using wikis quite a bit. I haven't started, although I want to. So when a student starts a project they might start a wiki based on that, and then log what they're doing as they go and put in figures. And they can point collaborators to the website and within a wiki format that person can ask a question or two, as opposed to email communication.

A wiki is more like a chat room, right. I'm not following that trend because...frankly, I'm cruising along at a very high level. This is...what grad students use, and I'm not doing that.

The way I've learned these things is largely from my graduate students, with the exception of the twiki...they've grown up with computer programming to an extent that we didn't. So I think I was probably in the first generation of scientists that did computer programming at all...I'm not as fluent in some of the nitty-gritty stuff as the students are.

Coauthoring papers

Astrophysicists author and edit research articles by passing documents back and forth among themselves using email and FTP. While wikis are predominantly used for project management, a few scholars use wiki-based technologies and CBS software for coauthorship of scientific papers, particularly when documents are too large to send as attachments.

We collaborate using email to transfer files. Or, everyone knows how to set up FTP sites and all that kind of thing, too. So if the files are too big to email, you know how to deal with that. We've also started using wikis.

I've written papers with people I've never met just by emailing back and forth. I've also worked with people whom I have known from something else but, in academia, we move apart but we still talk. We end up writing papers together through email, so it's very easy to do.

We usually have a telecom, so we have a telephone call, and we usually agree to a structure for the paper, and then we agree who's writing each section. Then we set their lines and then usually the student collates the paper if he or she's the first author. That's all by email. We don't use a wiki...We are terribly old fashioned.

I do a lot of paper building or writing in collaboration using a four-year-old software tool called CBS, which people use to build software, mainly, but then I build papers that way. It's an archiving system that allows you to have different people to work on the paper at the same time and kind of manage that. But we have a big firewall here and it's tough for me to share that with my collaborators as a result.

5. WHAT DO YOU NEED TO CONDUCT YOUR RESEARCH?

The research process in astrophysics is data-intensive. For observational astrophysicists, primary research data are generated and collected from optical, infrared, gamma-ray, and X-ray telescopes. Observations are made from orbiting observatories, such as the [Hubble Space Telescope](#) (HST), or from ground-based telescopes at locations worldwide. Although traditionally, scholars apply to telescope allocation committees for telescope time, increased access to archival data is changing the research process and "democratizing" the field. Theoretical astrophysicists produce data from computational analysis of observational data sets.⁷ As new technologies enable larger and more complex means of data collection and distribution, astrophysicists require better tools for storing and processing data, as well as extensive technical support and training.

⁷ Research Information Network. 2008. *To Share or not to Share: Publication and Quality Assurance of Research Data Outputs*. Report commissioned by the Research Information Network. <http://www.rin.ac.uk/our-work/data-management-and-curation/share-or-not-share-research-data-outputs>

Ap5.1 What Do Scholars Do in Their Research? How Is What They Do Changing or Not?

Data collection

Conventionally, scholars collect data by applying for telescope time and specifying what they want to observe. More recently, publicly accessible data archives—many initiated by NASA—have become the ‘bedrock’ of observational astronomy. Some scholars rely on extant data such as sky surveys, which involve large-scale data collection across wide areas of the sky.

Standard versus remote observing

Traditionally, the research process in astrophysics involves the collection of data by an individual researcher through telescope time allocated by the observatory. While a handful of universities own and operate observatories, such as the Lick observatory on Mount Hamilton, astrophysicists from institutions without access to their own telescope can submit proposals for observation time on NASA’s space-borne observatories and other telescopes. New data capturing technologies enable remote observing, where astrophysicists provide the facility in question with their observation specifications and data are subsequently transferred, via the Internet, to their home institution. Although remote observing cuts down on research cost and time, and is attractive to scholars who experience high altitude sickness⁸, low bandwidth can hamper such efforts, particularly between the US mainland and the [Mauna Kea observatories](#) on the Island of Hawaii. Some scholars note that a physical trip to the observatory remains an important part of the research process.

The availability of space resources...means that anybody can apply for telescope time...I think certainly many more institutions are very active participants in the field...anybody from an institution that doesn’t own big glass can apply for time at the National Observatory, which has two major telescopes and a lot of really good minor ones. And then also there are all these spacecraft that anybody can apply for time on. So, that seems like a *de facto* leveling of the field.

I only do remote observing when I’m unable to travel...I use it quite rarely. And it actually makes a big difference to go out there in person, not so much in terms of what you get out of the telescope, but just because that’s the way that you find out all the things that are happening at the observatory and what the new changes are, etc....You can now do remote observing at the Keck observatory. I was just doing it the other night, sitting there working with someone out in Hawaii and they have this VNC viewer where you can see the exact console that they’re using to operate things. And, in fact, you get your own cursor and you can make things happen on the console that override or supplement whatever is happening on the other end. That’s certainly useful.

As far as the observing goes, often being on location gives you a much clearer understanding of whether it’s hopeless or whether it’s worth persevering compared to when you observe remotely. Generally, I would say 80 percent of astronomers want to go to the telescope as they feel that they have more influence if they are physically there.

⁸ For more information, see: Cohen, Judy, Patrick Shopbell, and Larry Bergman. 1998. Remote Observing with the Keck Telescope Using the ACTS Satellite. <http://www.astro.caltech.edu/~pls/papers/acts-report/node2.html>.

Public access to data archives

Widespread access to online astronomical data is changing the research process in the field. For some scholars, downloading data is preferable to waiting for telescope access because it is more cost effective and, “the online data detail and quality is likely to rival that generated by the typical telescopes” (Szalay and Gray, 2000).⁹ Increased access to data enables the lone researcher (or small teams) to make discoveries and write research papers without physical use of telescopes. As such, the field is evolving from the “ownership of data and resources” to the “ownership of expertise and creativity.” Scholars may run into problems, however, if they lack a full understanding of the data in question. “Plucking” data off the Web is simply no substitute for understanding the research process in its entirety, such as knowing the origin of the data stream.

You can either sit at your desk the way I do, informally, and just go hunting around the archive, which doesn't get me any money, or you can make a proposal to the Space Telescope Science Institute to do a larger project with archival data, and they'll send you the data and the money. These options have been very productive.

There's been at least one superb result on a pulsar that wasn't even a solar emission. It went off near the sun and this junior scholar just pounced on the data, wrote one email asking the head researcher a very simple question, and then analyzed the data and found some incredible star quake oscillations on the neutron star in the data from this mission. It was a very nice result that probably made this scholar's career. So it can happen, even when the instrument is a messy one. Someone can step in and do good work. They could also step in and do terrible work and mistake instrumental effects for real physics, so practically speaking it's always best to team up with someone who knows what they're doing...The data go straight to an archive, and the only edge that the instrument team has is that they're very adept at the data analysis. The team is supposed to make a good faith effort to also post their best data analysis software, as well as the raw data. So it's a different paradigm. It still turns out, in this particular case, that the instrument is so complicated, and has so many instrumental effects, that people in general would do well to consult a member of the instrument team before they start analysis.

One thing that is maybe more true of astronomy than many other fields is that young people, and students in particular, can make a huge impact, essentially all by themselves. You can go to a telescope or do some calculations. And students in astrophysics are capable of doing top-tier science from the start, which is just not true in biology or chemistry or a lot of other fields where it's a big team effort and there's a pyramid with someone driving everything at the top and the people at the bottom doing the tinkering. And so there's a bit of a big head culture that gets established very early...so junior people *think* that they can do great things, and they certainly have the potential, but it causes problems in some areas...Downloading data from a catalog is not as good as understanding the data stream from the start to the catalog. So what you see is people just plucking information off webpages or out of catalogs and publishing it without a true understanding of the errors or the systematics.

In general, public data sets are the growing wave of the future. We're in a time where...a large number of scientists on the planet is taking advantage of the data flow...It's kind of a free for all at the moment, in terms of becoming creative and finding new ways of doing astronomy...I'm sure there are going to be people

⁹ Szalay, Alexander and Gray, Jim. 2000. Designing and Mining Multi-Terabyte Astronomy Archives: The Sloan Digital Sky Survey. See: http://research.microsoft.com/en-us/um/people/gray/papers/ms_tr_99_30_sloan_digital_sky_survey.pdf

misusing the data, usually not intentionally, but making bad conclusions out of data...It's a by-product of the way that things are shaping up...You need to have a knowledge of astronomy to take full advantage of the data, and that doesn't necessarily require a large team but it does require some expertise or teaching along the way.

A discovery can be made by a team of two hundred people or it can be made by one person, or two or three people working together. And if you put all of the data and tools up on the Web in an open way—although somebody may have paid a hundred-million dollars for some experiment and there are two thousand people involved—in the end, some smart person in Bangalore can make the discovery and write a paper without help. This is a very interesting and strange situation. The focus is changing from the ownership of resources and data to the ownership of expertise and creativity, which is, of course, priceless. I don't think the scientific community has *quite* gotten that message.

Whole-sky surveys

The advent of survey astronomy has revolutionized the field. These projects involve whole-sky surveys covering multiple wavelengths, such as the [Sloan Digital Sky Survey](#) (SDSS) and the [Two Micron All Sky Survey](#) (2MASS). Large-scale and complex data collection efforts—requiring 'real-time' automated processing of the data stream—have been transformative for the field, enabling scholars to rapidly harvest and mine large volumes of data to better understand the universe.

In the area of imaging, technology has really changed or enabled a whole range of science in the last ten years. We're just dealing with pictures of the sky, nothing more complicated than that. And with modern telescopes, you can take a tremendous number of pictures of the sky. Having the computing resources to process that data, look for changes in the sky, and count objects and cross-correlate their colors is a huge advantage. We now have the computer resources to do that on large data sets that were unfathomable ten years ago. You would previously have to rely on humans to count the objects themselves or do things that would have taken hours of time, but these tasks are now achievable with modern software. There are whole new experiments being devised that you just couldn't imagine doing observationally without the advances of computer speed and data storage.

It's going to be crazy in the next few years when the next generation of really big observatories comes online, because they will take snapshot images, at several gigabytes per image, and with each image at only a 10 second exposure. And they will do this throughout the night. So we will have millions of megabytes of data constantly streaming in. There's going to have to be some kind of archival system. All of the data needs to be processed immediately because you have to make decisions, based on the observations, whether you want to continue the observation or move on...so it's definitely changing the field.

There's a project called the [Large Synoptic Survey Telescope](#), at a telescope in Chile, which will scan the sky and generate 20 or so terabytes of data every night. That is a lot of data by any account. All of that will be somehow stored and saved...Now, in these 20 terabytes of data, they expect to see...somewhere on the order of 10 to the 5th power of things...go bang in the night, per night. And from what I can estimate from our experiences, we may also see between a million and 10 million asteroids, most of which will be uncatalogued. All of that has to be communicated, sorted for follow-up, and reacted to right away. And that means that there are no humans in the loop. It all has to be done automatically. The data volume is getting serious...And so it's a very different story. The mode of operation is different. Traditionally, you obtain some measurements, you analyze

the measurements and say, "Oh, gosh, this is interesting. I need some more data." And then you write a proposal to get some more data. A year later, you get more data. So it's a cyclical process...This is typically how astronomy works...But now everybody's got exponential data growth. In astronomy, we have the number of bits doubling every year-and-a-half, like [Moore's Law](#). And what this means is that, in the next year-and-a-half, we'll generate as much data as in all of the previous history of astronomy...and everybody's in that position.

I write computer programs to basically mine through large amounts of data, from...a robotic telescope that takes snapshot images. Every 10 seconds it takes a snapshot and then moves to a different galaxy and takes another snapshot. And we find supernovae by comparing an archival image to the new image, and you subtract the two images because it's all digital, and if anything is left over, any bright point, any new pixel, it's probably a supernova...For us, you would traditionally go to the observatory and look through the telescope, but that doesn't happen as much anymore. It all goes straight to the computer, because it's all taken with a really big digital camera, so you don't even look through the eyepiece anymore. You just give it the coordinates and it zooms in on it.

There's a whole new area of astrophysics called time domain astrophysics. So there are a couple of telescopes being built on the ground, which will take pictures of the entire sky once every few days with great depth and sensitivity. And they're going to find things varying all over the place, and we'll want to know what they are. So if there's a big splash, or we see something dramatic, we're going to need to cut across all these different modalities to find out what it was. You're going to need to find someplace that looked at that place in the sky before the thing blew up or whatever happened, and then people to follow it as it's dying down, if it's dying down slowly enough. And then you're going to ask, "Has anybody ever seen anything like this before someplace else, in any wavelength, ranging from gamma rays to millimeter waves?" And that's the kind of thing that the National Virtual Observatory ought to be able to do...And then the other set of things they'll do, in addition to individual dramatic spectacular things, is find things that are just varying day to day or month to month or year to year...I think that's going to demand being able to reach into all the existing data sets in ways that we haven't done before...to go in and make time specific queries and cross-correlations among different wavelength bands.

There's a lot of data out there and people have more ideas and the science builds upon itself. I could have a whole career where I should just stop everything I'm doing and turn off all the telescopes and go sit and work on the ideas I already have. But science moves at such a pace that, again, there's a cost-benefit analysis of, "Okay, I have this old data, which is really interesting, but I have access to new information that's even better."

Visualization and simulations

Theoretical astrophysicists produce data on a scale that rivals the generation of observational data. In particular, specialized visualization and modeling software is used to produce simulations of the universe. Increasingly, informatics-driven research is blurring the boundary between the observational and theoretical arms of the field. Some scholars rely on visualization technologies to make sense of the large amount of data produced.

People who rely on advancements in visualization tend to be more theoretically oriented; they're doing models on computers, and they're visualizing their models, as opposed to those of us who take data. They're a synthesis of imaging and spectra that requires new visualization tools. I don't have much data dealing with that technology.

One of the biggest developments is in simulations. When we observe the universe, we don't change it ourselves, we're not experimenting with it, we're really just observing it passively, which is a big problem in astronomy...So people have now created simulations of the universe that allow us to compare a whole family of realizations of the universe with the data that we see, or if you like, with the one universe that we have. And I think the boundary between the people who simulate the universe and the people who observe the universe is blurring. It used to be that we would meet at conferences and the observers would say, "Well, here are my data," and the simulators just felt triumphant if they could come anywhere near reality. And the two sides would jeer at each other and not get on very well. But now we realize that the tools of modeling the universe are an integral part of understanding our data to the extent that the simulators can account for the characteristics of the observatory and the telescope. These tools have taken a while; it's taken about 15 years for the observational astronomers to grow accustomed to the idea of working with theoretical simulators. But even the old diehards are now doing it. So this has been a gradual transformation in the subject.

A thousand-fold increase in data...is not just data from the sky, but it's also data from the theorists. The theorists are creating huge simulations that are just as intensive as the observations...there is a huge data flow and...we need to be timely. Our advances in technology are happening so fast that we can't even imagine what the science will be five years from now. We have some idea, but I would say it's very difficult to say in detail even ten years downstream. So for us, the technological rapidity and the handling of huge amounts of data, the ability to reach across the world, in the public as well as private domain, with security, observing all these things, characterize our field.

New technologies for data analysis

As observational data grow in volume, astrophysicists rely on statistical methods, such as principle component analysis, to find patterns in large data sets. Some scholars advocate the use of more complex algorithms for advanced statistical analysis in the field.

A technique that's very useful with large statistical data sets finds patterns in the data that you wouldn't be able to spot by yourself. The data sets are getting so big that you often can't plot them out. In the old days, if you didn't know what you were looking for, you'd think, "Well, here's a unique set of data and I know there's some trend here, but I don't know what it is," and you could plot everything against everything until you saw some trend. Now there are clever codes, which allow you to take a huge set of data and filter it directly, and it will tell you the most significant trend or component in the data that allows you to shortcut the process if you don't know what you're looking for. This is called [principle component analysis](#), where you just throw the whole thing in a box and out comes a whole set of parameters that tells you the most significant correlations in your data. When this idea was first presented to astronomers, people thought it was terrible, "We should approach our data with a rational viewpoint and some hypotheses." But it's amazing how people are now growing accustomed to statistical tools in looking at big data sets.

We need to be able to apply statistical techniques to large data sets. In my field we find many variables and transients, and individually we tend to know what they are. But...statistically we would like to be able to predict using just a small number of observations. That is not possible, so personally I would like to better combine statistics with astronomy...A study a few years back found that about 50% of all astrophysics publications use some sort of statistical tool, and 60% of those techniques are older than the first World War. There are so many advances in statistics that we should use.

Computer-aided design

Computer-aided design (CAD) enables scholars to test instruments virtually, which is considered a boon for engineers working on astronomical instrumentation.

The 3D CAD programs are so much better than they were ten years ago that I find it almost mind-boggling what the engineers can do with these programs to avoid making costly mistakes because...in a big mechanical system you might not notice that a bolt went a 16th of an inch too far. And you can check all that before it ever gets built. The way it used to be done is you would design something and then you'd build it to see if it worked. And now you can basically tell if it's going to work before you ever touch a piece of metal. That's certainly been a big thing.

Search and discovery of secondary literature

Journal articles are typically accessed through online bibliographical databases. Scholars rely heavily on the [Astrophysics Data System](#) (ADS), a NASA-funded bibliographical database, and the arXiv preprint server, though the former is preferable for accessing *final* archival publications. Using ADS, scholars can download PDFs and data, search by keyword, and retrieve citation information. Citation metrics in both ADS and arXiv can inform selection of frequently cited papers. Although there is limited use of Google Scholar, astrophysicists may rely on search engines for literature searches outside of their immediate field of expertise. Because of these online resources, there has been a consequent decline in individual journal subscriptions.

We have the astronomical data service...and they have put everything in physics and astronomy online, and they keep adding to it over time. So supposing you were interested in what I have published, there's an interactive webpage, where you type in my name, you can limit the dates or you can look at all dates, and all my papers will come up. You can sort them according to your preference, backwards in time, forwards in time...It's a marvelous tool. We're totally spoiled...I can download a PDF of the paper; I can look up all the citations to that paper. I can get a version that has great figures, to snare a figure for a talk I want to give. And data sets are tabulated there, so more people are not spending the money to publish long tables. They'll publish the first 10 lines to show how the table format works and then the rest of the table is available electronically. You can download huge tables that way and it's very efficient.

ADS is essentially *the* electronic library of astronomy, supplemented with the arXiv preprint server for all physical sciences, which is now expanding to other fields. I essentially start 99% of my literature searches with these two resources. I find that I very rarely go to electronic journals' sites. I would go there largely to get a better formatted version of the paper that I have discovered on one of these two sites, to get them nicely printed, as opposed to LaTeXed. Every six months or so, I go to an electronic journal site—and there are only two, three, four in our field that really matter—to see if there is something that I missed.

If I'm trying to find some reference, I pretty much always go through ADS just because it'll take you to the actual, final published version. That way you don't run into the problem where you're not sure if you've got the latest version of something or if they didn't update it...and, of course, it goes the whole way back to the beginning of time, essentially.

People are not so interested in papers in detail, but they look for papers that are repeatedly cited, in other words, papers that have matured over time to become important and influence present papers. I always look for papers that reappear or are cited often. That alerts me to important papers that have appeared in the

past. Some people never look at papers that are never cited. Of course, that's dangerous too.

Because the physics community worked that system out pretty early, I think that we have not paid attention to things like Google Scholar that work for all of academia. But now, in my research, I've become more interested in areas that are slightly outside what I'm used to doing, and Google Scholar turns out to be very useful for looking at wider ranging sources...ArXiv works very well, in part because it works very closely with something called [SPIRES at Stanford](#) [a high-energy physics literature database], which has been around even longer than the arXiv and has been keeping track of what papers are cited. So, for better or worse, I can go online right now and tell you every paper that's cited each paper I've ever written. It's a tremendously useful scholarly tool because if I read someone else's paper and I think it's interesting, and I'm going to use it in a paper that I write, I need to know who else has found that paper interesting, what else have they said, and what are the chances that they said the same thing I'm trying to say?

Annual reviews

Traditionally, scholars moving into new research areas rely on annual reviews or review papers to bring them up to speed. These could be replaced by online-only review journals, such as [Living Reviews](#), which enable scholars to contribute and update articles electronically.

There's something called *Living Reviews*. Review articles are excellent ideas for young researchers or anybody really. If you're moving into a new field, how do you find a state-of-the-art article that summarizes everything that's been achieved? Now, up until recently we've written these articles called annual reviews, and there's a book called [Annual Reviews of Astronomy and Astrophysics](#), produced in California. You get an article on some topic in astronomy, but it's out-of-date within two years...and this is really a chore. But now to write an article on the Web that's constantly updated...it's not too difficult to imagine this could become like Wikipedia. At the moment there's still a person who is charged to update it. But it's only a small step from that to an editable Wikipedia version.

The publications of the Astronomical Society of the Pacific invite review papers on a subject from an authority. They might invite one from somebody on the discovery of planets, and then they will send that out to be refereed. Even though it's an invited review paper, they feel their journal's integrity is at stake.

The role of the library

Although astronomy/physics libraries are widespread, the role of the library is declining in the field. Libraries tend to hold conference proceedings, annual review volumes, and monographs.

There was a big argument when we moved into a new building about whether we were going to have a library or not. And I thought it was probably a waste of space if no one's going to use it...It's just a whole bunch of books that no one looks at...I think the whole concept of a library has changed, at least in this field. I know there are still fields where they haven't quite caught up in terms of electronic publication.

People do not visit the library much anymore. We have a library, but I rarely set foot in it.

Astronomy libraries, which are large reading rooms embedded within astronomy departments, are focusing more on keeping up to date with proceedings volumes, annual reviews volumes, and monographs, with the presumption that the main archival journals will be accessed electronically.

Ap5.2 What Do Scholars Need? How Are These Needs Being Met or Not?

As astrophysicists become increasingly sophisticated in their data generation and analysis, the need for better technologies for streamlining the data collection process has become more urgent. Scholars look to their institutions to provide technical support and training in the use of new tools and technologies.

Bandwidth

There is demand for an infrastructure to support remote sensing and archival research among the scholars we interviewed. In particular, scholars complained about low bandwidth, which can hamper data-intensive research. Many scholars complained that their institutions do not have high-speed Internet, which is required to access, download, or manipulate large amounts of data remotely.

It would be good to have a higher bandwidth link to any big telescope for remote observing. I always go to Hawaii to observe at Keck, because there's a time delay at the remote observing room here. Their spectrograph has the world's largest spectroscopic detector; every picture is 100MB. To get that from Hawaii to my home institution takes 20-30 seconds. I don't want to wait for that. You have to feel more in touch.

There's a lot of discussion going on at this campus about high bandwidth...I'd say it's being driven more by simulation, because simulations are producing more data than actual observations. We only have one universe but we could simulate a million of them...and the simulations are just churning out data. We have a mini supercomputer on campus and they can't get data from there into their offices. Once they've got it in their offices, they can't analyze it because it's so copious; they don't have the sophisticated visualization hardware that we now need. So it's on our list to raise resources for. We're thinking about starting an astrophysics visualization center, with a combination of software, hardware, and people. But the first step is to have a high-speed channel. We have to upgrade the wiring in these buildings to get at least one gigabyte onto the office desktop. So that's more money.

Our institution is in a special position of not having high-speed Internet, the next generation technology. If there's some way we can get it, that is what we need in astronomy and I think probably in other disciplines too.

The thing to keep in mind is that our volume of data will increase enormously, if not by factors of a hundred, probably a thousand in less than ten years. Therefore, if this university does not have high-speed Internet...we will be out of the running for quick access to large amounts of data. It is important to keep that basic communication channel. Then we can use whatever technologies are developed commercially or otherwise. There is remote observing, but we would like to be able to pipe the data from whatever observatory to our home institution, to work on.

What we can't do is get huge data sets back and forth. So we can look at the guider, we can point the telescope. It's a little harder to evaluate because we don't have the pipes to get the data through all the instruments. So that's the state of things, and that's the way the future is going to look.

The scale of data is becoming so large that some scholars conduct their computational analyses at the site of the data set, instead of downloading the data locally.

I work in a large collaboration, which does very large simulations of structure in the universe, and generates *huge* data sets, tens of terabytes of data, so it's just not practical for everybody who wants to use them to drag a copy across to their machine. So we have switched to a system where you take your analysis software and move it to where the data are and do it all remotely. It's all in Munich at the moment, so...I have access to the computer and I just log into that, and then run my analysis on their machines. So practically, it makes very little difference. I still sit at my computer in my office and do the work, but having that infrastructure allows you to connect in this way.

Technical support and training in the use of new tools/technologies

Scholars rely on their institutions to provide technical support, particularly for developing and maintaining data archives, which are often made available through project websites. Technically proficient individuals, which can include graduate students, postdoctoral researchers, and librarians, often provide this support.

Data management is no longer something that a computer savvy faculty member can do simply. The average faculty member can't make their data easily available. It requires some professional software and specialized equipment. The data sets are getting big enough that you need to spend some real resources on it, which is a change from the past.

When you get Hubble time, you're offered enough money that you can hire a grad student to actually reduce your data, which is good. It's made the research process much more productive.

I'm hiring somebody next year whose full-time job will be to help organize the data sets we have and make them it easily accessible. We have the luxury of hiring people to do that here because we serve a lot of people.

The amount of data, and just the organization of it, is either something we're not very good at or don't want to do. We have it on our hard drive, we use it on a daily basis, but we aren't able to conveniently get it to the community, and having a professional working on this...would be a huge advantage.

We have a very, very good but extremely overworked system administrator for the computing here. I am told that our new librarian is willing to help with those kinds of things...managing data archives and things like that. So there's a lot of expertise in these areas, but if you don't have money to pay for it, it's hard to make use of it.

At our research institution, the information technology was in such a mess that they completely redid it...One of the guys who was on the team to revamp the whole thing was an ex-system manager for the physicists...It's interesting. This is all one human being's idea...if they hadn't found him and put him on the team, it never would have happened. They just needed somebody to see it was an issue.

Our biggest problem is getting webpages designed and written. Maybe that hasn't been fully absorbed into the culture yet. It's extra overhead to manage this new publication medium, and our manpower allocations are so far not fully successful in riding both horses. I would like technical support, perhaps somebody to design a webpage for me. I could write the content and they would make it look reasonable...Every unit here in astronomy solves this problem in a different way and to a different degree of success....Our webpage actually is slick, and that's

because we got a grad student who happened to love this...that's very hit or miss. Without that person we would have not solved the problem.

Developing a website is left up to the individual. I would say on a scale of one to ten, I'm a number three; there are quite a few people who are not very tech-savvy at all and worse than me...It's a headache...I could probably find somebody here whom I could pay to develop a website, pay a couple hundred dollars to just set it up, but I have no time...If I look at my own career, the old days of being able to do the calculations of the brightness of a star just using a hand calculator are gone. The instruments that we use now are extremely complicated. We need to process data rapidly and to deal with new technology. We now need graduate students who are incredibly talented at dealing with the complexities of computer systems and data sets that are often spread over many different databases and need to be brought together...How do we keep up? The answer is we need students and postdoctorates. As we get older, it gets harder and harder to keep track of all the complexities involved in technology.

Astrophysicists receive limited training in computational technology. While there exists the perception that astrophysicists, and in particular young scholars, are "innovative" in their use of new technologies, they frequently simply inherit tools and techniques from their more established counterparts and the world at large.

The problem with the technology is that almost all these tools that are available to us have so many different options and modes, there's no really efficient way to learn how to use them. Most of them never get used because no one knows how to use them. I've learned everything just by needing to do something and having someone down the hall show me how it's done.

I don't think that younger scholars are more innovative. I don't know why that's not the case. To some degree, I've seen in the field that we basically pass down the techniques of the trade, and students get handed a tool whether you want to or not. And then there's the opportunity to innovate from there, but you're already at a point where there is an accepted way of doing things that restricts your options to begin with. I don't see the younger generation doing things in such a radically different way than the previous.

We do not innovate. We just use what the world gives us. It would be nice if we could innovate in some way...I find myself frustrated that the academic community, by and large, is not really leading the charge...The way most academics use these new tools and technologies is no more sophisticated than what their secretaries do: there is an off-the-shelf product and we use it because it's there.

6. TO WHAT DEGREE DO YOU OR YOUR COLLEAGUES ENGAGE WITH THE PUBLIC? HOW? WHY OR WHY NOT?

Astrophysics as a field enjoys widespread public interest and has broad public participation: professional societies enroll a substantial volume of amateur members, the Smithsonian's [National Air and Space Museum](#) continues to have a significant influx of visitors every year,¹⁰ and members of the public frequent observatory visitor programs. Scholars engage with the public in multiple ways, including in schools and community programs, and in a variety of media outlets. Citizen scientists are playing a growing role

¹⁰ See: Friedlander, Amy. 2008. "The Triple Helix: Cyberinfrastructure, Scholarly Communication, and Trust." *The Journal of Electronic Publishing* 11, no. 1. <http://quod.lib.umich.edu/cgi/t/text/text-index?c=jep:view=text;rgn=main:idno=3336451.0011.109>

in the field by helping scholars to process and analyze large amounts of data in crowdsourcing initiatives like [SETI@home](#) and [Galaxy Zoo](#).

Ap6.1 Why Do You Engage with the Public?

As in biology, many scholars in astrophysics feel a sense of obligation to give something back to the public, especially since public agencies are the primary funding sources in the field. Funding bodies, such as the NSF, increasingly require public engagement as a condition for rewards.

I'm a fairly senior person, and I've been giving public talks since day one. I think many astronomers feel an obligation. I'm paid by the taxpayers and we ought to give something back. Communication with public audiences is my attempt to share some of this interesting knowledge. We provide inspiration and entertainment, and it doesn't do any good if it doesn't reach its destination.

Initially, we paid no attention to public outreach. Then we paid lip service to it and now you have to take it very seriously. You need a real plan and you need to report on those activities as well. It has become part of the proposal and part of your reporting structure, so you can't ignore that anymore.

We need to communicate to the public. There's a lot more pressure by the NSF and the federal government for us to be out there, doing outreach and education.

Many postdoctorate and graduate fellowships stipulate public outreach as a specific component that you have to address through public engagement.

The NSF and NIH tried to include a K-12 component to grant applications, but I don't think it's working terribly well. It worked well right after Sputnik was launched. At that time, I went out to high schools and we did summer institutes for teachers. It was a lively period. Public engagement is most valuable when it creates a sense of professional community with a much broader range than just the professional university and college scientific community.

Writing and lecturing for a public audience can also "fire up" a scholar, especially since the process requires them to take a step back from the intricacies of research.

I give public lectures, if the opportunity arises. I actually enjoy it. I usually find that giving a lecture gets me more interested in what I'm doing, just because in your daily research you can get into a state where you're worrying about your own problems in detail, often about simple mechanical things. So public engagement forces you to step back and look at the big picture and then communicate it in an interesting way. And that usually is a very therapeutic thing to do. And so I like to do it. Although perhaps I don't actively seek out opportunities to do that as much as I could or should.

Why not?

Even if scholars are enthusiastic about their outreach responsibilities, some feel restricted by a lack of time and resources. Public interest in astrophysics depends on subfield; "pretty" images are said to resonate with the public more than overly "technical" work, because there is a greater grasp and appreciation of pictures of the sky.

We have open days at the observatory. Outreach is time consuming and the resources we get to help us do it are lacking and very competitive. So I'm trying to get other resources to help improve my outreach.

I used to do more public engagement when I was a postdoc but it's too much responsibility and I barely see my own kids. I'd rather see my kids than somebody else's Girl Scout troop.

Some amateurs say, "I have a theory of the universe and I would like you to critique it." I don't take those questions seriously, but a lot of times interested people who saw some astronomical DVDs may have a reasonable question that I'll try to answer. So that takes some extra time.

I engage with the public mainly through public lectures. My own science is mainly spectroscopy-based, which is tough to make very flashy and accessible to the public, not that I couldn't try harder. But I'm not taking pictures of the sky where you have immediate gratification, and make a general person say, "That is really cool."

The contested nature of the "public intellectual"

While young scholars are advised to steer clear of excessive public service—such as writing a blog—it is encouraged among scholars who can "make a splash" through a new research discovery.

The campus increasingly wants their people to be prominent. Everybody is scrambling for a spot on the front page, including astronomers. When we have a good story, we try to put it out there.

People in the social sciences and humanities have taken to using the Internet in a much more active, energetic way partially because, I'm guessing, what they do relates more directly to the things people on the street are interested in...But for a physicist, it's just not respectable to do that. [Stephen Hawking](#) gets a tremendous amount of grief for writing popular books, and he's one of the leading physicists of the last 30 years. You can be a really good, productive physicist without ever leaving your office or talking with anyone other than your colleagues while you can't be a very good political scientist or economist without doing that. So talking to a wider audience is perceived as unserious and with suspicion. Even as people will blatantly tell you otherwise, saying that public outreach is very important, secretly, you're considered less serious if you spend time doing that.

There are NSF awards for young faculty called [NSF Career Awards](#) where I find that there's a distressing expectation now for us to be all things to all people. You're supposed to be doing heroic, world-changing research and running some huge enterprise for public outreach at the same time. I think it's important for people doing the research to take opportunities to communicate to the public when they arise, but really both responsibilities are full-time jobs. I think that the people with the right skills to do each job well are not necessarily the same people, and they don't have the same training. So it seems unfair to expect, particularly for young people trying to establish themselves in their research program, to be doing planetarium nights and setting up outreach programs where none existed.

Ap6.2 How Do Scholars Engage with the Public?

Public engagement can take a variety of forms, including school and community outreach, observatory and university-based public lectures (some of which are made available to the public in DVD form), observatory visitor programs, websites, and blogs. There is also the online "ask an astronomer" service, maintained by graduate student volunteers at Cornell University, which enables members of the public to ask astronomy-related questions based on personal hobbies and as a supplement to K-12 teaching. In

addition, some societies (such as the Astronomical Society of the Pacific) have a large amateur member population alongside its professional constituency.

For the past couple of years, I've given a public lecture at our observatory in the summer.

We have a summer visitor program where an astronomer gives a talk each night, and then the observatory is open to the public to look through the telescope and to hear a science lecture...the Keck Observatory is doing even more of this all the time. They have general public lectures and then "invitation only" events. You have to be really rich or a major donor to get one of those.

I have a blog that I use most obviously for outreach to the general public. We don't post a lot of equations or complicated jargon. We're trying to talk to a wider audience...We're not getting paid for this, we're not hired by a magazine, we're not doing a service, it's what we want to do. And, so we get thousands of readers every day, which is more people than I would ever get in giving a talk.

The graduate students support the "ask an astronomer" Internet service, so you could ask a question and some grad student will then read it and pass it onto the appropriate person or they'll answer it themselves...And I think we need to do more public outreach. The other way we do public engagement is when we get calls, from say, the Rotary Club. And I either do those or I ask a colleague to do those public talks. We've gotten pretty good with those requests. We're now at about 100% participation in any request we get, and we get about three a month...I actually try to lean on faculty, rather than graduate students, to show up at events, but different events require different people.

The Astronomical Society of the Pacific was created by the Lick Observatory in the 19th century as a way of inviting wealthy armchair astronomers to events and soliciting them for funds. It survives as a professional society to this day.

Astronomers are fairly strategic in disclosing their research results to the public. Press releases are issued by press offices, often with input from the scholar in question. Press conferences held at society meetings can also act as a source of information for journalists and the public. Also, science writers act as "mediators" between scholars and the public by fostering public understanding of the field.

There was an American Astronomical Society meeting where the authors presenting a paper held a press conference associated with the meeting. Apparently they had all these planets saved up that they presented at once, so they made a big splash.

If you have a really good research result that you think is interesting, you issue a press release and you may also organize yourself into a larger cluster of scholars so that you can release a larger body of results in a more major concentrated way, which will get a lot of attention. So you try to create these packets of critical mass.

We have a press office, where someone specializes in the sciences...and it's up to us to say, "We have a press release with AAS, or we have a *Nature* article, etc." And he's very good at responding to those things.

Serious public outreach requires a dedicated staff position in the department. We have a public relations person at our Observatory, but they're just swamped. It's amazing how, if you just do a little work in that direction, the response completely overwhelms you...I worry that if I started to spend all my time getting the public to help me look for distant galaxies, I would just be *completely*

inundated with emails and phone calls, and with people wanting to come and talk to me. So if we were to do that seriously, and it sounds like a great idea, we would need a lot more manpower here, with non-faculty people running it.

Citizen science

Astrophysics has a large citizen-scientist component and various scholar-driven campaigns aimed at soliciting help from the public. Examples include [SETI@home](#) and [Galaxy Zoo](#), which enable individuals to contribute their home computing power to help sift through the data involved in the process of galaxy classification. These initiatives are hosted and run by individual universities or by multiple institutions.

It could be very lucrative and helpful to get the public involved, and it would raise the field's visibility...The only example that I can think of is [Chris Lintott](#) at Oxford, who's running a galaxy classification project. He has got a huge amount of attention from the BBC. The idea was that there are all these galaxies that need categorizing. There's a webpage where you can learn how to help, and he's had something like 20 times more inquiries than he imagined. It was just over the top.

Another issue is classification of galaxies. Galaxies come in various sizes and shapes, and in the old days we used to look at them by eye, classify them, and see, for example, how they're distributed. A round galaxy is more common in certain areas of sky than spiral galaxies. We now, through Hubble, have observed millions of galaxies with different sizes and shapes, and so the process of classifying galaxies has become standardized. In fact, the public is now doing it. There's a webpage that's a little bit like the search for extraterrestrial intelligence. Your idle computer analyzes signals that are coming from radio telescopes, to look for signatures of life in the universe. And lots of people have signed up for this. If you have a PC, you get a software package and you can dial up and use the data. People are now doing this for galaxy classification, too.

There's also the VSNET (Variable Star Network), which is a project between amateur astronomers and professionals. Because of the sheer volume of asteroid-related activities, professionals cannot do all the work. So amateur astronomers are very interested in following up on leads. There are other communities like VSNET where the public can do a lot of work.

Computer programs, such as [Google Sky](#) and Microsoft's [WorldWide Telescope](#) (WWT), further feed the public's interest in astronomy by turning home computers into a simulated telescope capable of exploring the virtual universe. Data and time for these projects are donated from a variety of sources. The withdrawal of funding is a concern for some, particularly if these types of programs provide training or spark interest in future generations of astrophysicists.

Google Sky uses some of our data and Microsoft is going to release their own competitor, called WorldWide Telescope. Google Sky has different layers, so some data come from the Sloan Digital Sky Survey, and also from others, and then they also have smaller areas, which come from specific smaller surveys and larger telescopes. And Microsoft is doing the same thing. And you can add your own data. Google Sky has what they call a "mash up" where new view events are immediately seen there on Google Sky. So astronomers who are following up on events, even through Google Sky, can find out the new sources.

Google has a project...where they keep attaching new data sets to the library, which they think of as layers. For instance, here's the sewage system, here's the ethnic makeup of that point, etc. That way of thinking about things fits well with the celestial sphere, because you could think of various ways of observing a piece

of sky as being layers. So they have an automatic way of accessing, browsing, and keeping track of observations. This is what virtual observatories are supposed to do, so I'm not sure who's going to win or how things are going forward.

I saw a huge display of Google Sky at the [American Astronomical Society](#) meeting. I've seen students playing with it, and it seems great that a company that has funds is actually doing this, rather than trying to scrape together federal funding to do it. But then, that makes one concerned about relying on a for-profit company to do this kind of thing; it seems, ultimately, like a bad idea, because they can change their minds at any time and withdraw funding.

SELECT RELEVANT LITERATURE AND LINKS

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