Funding for Ground-Based Observing Data Collection and Analysis

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1. Introduction

Facilities cost money to build and operate, but they also cost money to use. Observers must travel to the telescope, stay on-site for some period of time, reduce their data, and publish their observations. The situations for use of the National Optical Astronomy Observatory (NOAO) and National Radio Astronomy Observatory (NRAO) are somewhat different, but there are mainly similarities in the needs of all ground-based observers.

The 2000 Decadal Survey included a much quoted but little enacted statement that, "To enable observers and theorists to explore and develop the full capabilities of new facilities, the committee recommends budgeting 'facility grants' for research associated with major facilities at about 3 percent of the capital cost per year for the first 5 years. A cost-effective and competitive grants program for moderate facilities requires a somewhat higher percentage, and the committee recommends that facility grants for such facilities be budgeted at about 5 percent per year" (AANM 2000)

None of the major initiatives from the last decadal survey were completed, but it appear that ALMA, which was in the previous survey, is not going to come online with facility grants in place. Two moderate programs from the 2000 survey are in operation, CARMA and South Pole Submm Telescope; neither provides facility grants.

These "facility grants" were envisioned to promote "ground-breaking research – both observational and theoretical –enabled by the new facility..." (AANM 2000). Funding of observations with older facilities was left to the NSF Astronomy and Astrophysics Grants Program (AAG). The Survey wrote, "...past experience shows that it is often the individual investigator grants that are not tied to a specific facility or program - the unrestricted grants - that support the innovative new research that drives the future directions of astronomy.

One question that should be considered for the status of our profession is: **Should grants be distributed with observing time, and if so, should this apply for new facilities or all facilities?**

I've tried to be as objective as possible in the initial sections of this white paper, concentrating on the current funding situation and foreseeable needs. I leave my subjective judgments to the Discussion section.

1.1. Current Funding Situation

At the time of the last decadal survey, NSF provided funding, administered by NOAO, for travel to foreign telescopes (NOAO Newsletter 1999). After that ceased, NOAO continued to provide money for graduate students to go to Kitt Peak National Observatory in Arizona and Cerro Tololo Inter-American Observatory in Chile for thesis research. As of 2009A, NOAO continues this practice and additionally supports two observers' travel for classical Gemini runs (NOAO Response to Users Committee 2008). Some current costs for these are shown in Table 1.

At present, NRAO provides support for one person per run to travel to an NRAO telescope or foreign-owned radio telescope and one person to travel to NRAO for data reduction, up to a maximum of $1000 per trip. NRAO also pays page charges for authors at US institutions for data obtained from NRAO instruments (NRAO Library Website 2009). Most significantly, NRAO provides student support, including stipend and travel, for observing projects. These funds come from NRAO's operating funds. This is a zero-sum exercise within NRAO and such activities compete for funds with, for example, instrument programs. Current NRAO funding for users is summarized in Table 2.

The National Science Foundation (NSF) provides $42M per year for the Astronomy and Astrophysics Grants program as well as some additional money for young investigator awards (CAREER and AAPF). I am not here counting the other components of "Research and Related Activities" account such as instrumentation programs.

Under the current NSF funding and time-allocation system on national facilities, ground-based observing-time and funding proposals are decoupled. Ground-based observers apply for observing time to NRAO or NOAO. Other than for the costs noted above, they must make requests for funding with a separate application to the NSF. Thus, most researchers will face "double jeopardy."

Current over-subscription rates range from 2 - 4 times oversubscribed for telescope time, depending on facility. New capabilities (instruments and/or telescopes) increase demand. For example, the Kitt Peak Mayall 4m had an oversubscription rate of 4.6:1 in 2009A (NOAO Newsletter 2008B). The over-subscription rate for the NSF grants program is currently about 4:1 (24% success rate in FY2007).

Table 1. Current NOAO Expenditures for User Travel

Travel Type	#	Amount
KPNO Student Support	30	$30,000
CTIO Student Support	20	$34,000
Gemini Classical	14	$23,000

Table 2. NRAO Travel and Publication Expenses

Expense Type	Amount from NRAO	Amount not from NRAO
Publication Costs	$190,000	$120,000[a]
Foreign Travel to Telescopes	$10,000	···
Travel to NRAO Telescopes	$10,000	$190,000[b]
Student Support	$330,000	$2,244,000[c]
Total	$540,000	

[a]My estimate based on the 411 refereed papers published in 2008 with NRAO data, assuming half of these come from US investigators, for a cost per paper of $1500.

[b]My estimate.

[c]My estimate based on the 26 US PhDs who did their thesis using NRAO facilities, supported for 3 years each at $33K per year.

2. Needs

2.1. Travel and Publication

Travel expenses are the sine qua non for making ground-based O/IR observations today. Few of the instruments/telescopes offered by NOAO, other than Gemini, offer queue, service or remote observing. The situation for NRAO is different, as the telescopes operate remotely. However, observing trips to Socorro or Green Bank are not uncommon and new facilities will require more travel as observers become familiar with them. For example, first-time observers at the Green Bank Telescope are required to visit GBT for training. So, it is essential that the observatories continue to provide travel support. Even as forms of non-local observing become more common, students will still need to observe in person with experienced mentors in order to themselves become accomplished observers. So, it is unlikely that the next decade sees the disappearance of travel for observing.

NOAO has kindly provided estimated travel and publication costs that would be associated with its telescopes and TSIP time on private telescopes. These numbers are based on 2008 data and are shown in Table 3.

I estimate the needs of NRAO observers based on Table 2. Current total cost for travel is only ∼\$20K and for publication is \$310,000. Of order 100 observers visit each of Socorro and Green Bank each year. I infer that most do not currently charge their travel to NRAO

Table 3. Travel Costs for NOAO (Rounded to \$1K)

Observatory	# Programs	# Nights	Cost
KPNO	103	588	\$121,000
CTIO	112	644	\$225,000
Gemini N	9	18	\$14,000
Gemini S	5	14	\$9,000
Magellan	8	14	\$14,000
Keck	22	29	\$31,000
MMT	13	29	\$10,000
Travel Total	272	1336	\$424,000
Publication	450	···	\$675,000
Total	···	···	\$1,099,000

directly. At $1K per trip, this amounts to $200K. In addition, the amount of travel for NRAO "observing" is likely to increase in the the ALMA era as more investigators travel to NRAO Charlottesville for help from the North American ALMA Science Center on data reduction. Therefore, I estimate the NRAO travel need at 50% more than current or $300K. I also estimate that the number of papers should rise once ALMA and EVLA are operational. I assume 350 papers per year for the NRAO facilities, although I recognize that this is a guess. So, that brings the total for NRAO to $825,000.

So, the grand total for NOAO and NRAO observers to travel as necessary to obtain their data and publish them is nearly $2M.

2.2. Data Analysis

Time spent analyzing data generally exceeds the time spent collecting it. Therefore, the much greater cost associated with astronomical data is its analysis. These costs are paid as support of graduate students, funding of postdoctoral researchers, and providing summer salary for academic faculty.

Programs can be classified as:

- Small: Programs requiring less than or equal to a few nights of time Examples include single targets, single frequency synthesis mapping, and snapshot observations. One target might be suitable for a students' 2nd year project or a single short paper.
- Moderate: Programs requiring up to a week of telescope time. These programs may require summer salary support, hiring of a graduate student and may include research for a PhD thesis. Programs may require follow-up at other facilities for completion. Examples include studies of a class of objects, mosaics of small regions or monitoring of a few objects.
- Large: Programs, surveys, and legacy projects requiring weeks or months of telescope time often over a few years. The effort may require large collaborations and teams of researchers, extensive reduction hardware, special software pipelines, and analysis tool development as well as public data releases. Extensive funding will be required to implement such programs. These include programs with more than 200 hours at an NRAO telescope or NOAO survey programs.

At NOAO's large aperture telescopes, the vast majority of programs receive fewer than 5 nights per semester and about half receive fewer than 3. About 20% of telescope time is devoted to survey programs. The programs on the small telescopes shift toward medium and large sizes and surveys.

3. NASA Analogy

The equivalent of the national observatories in space, NASA's astrophysics missions, have guest observer programs that provide money for data analysis along with time. Table 4 provides approximate numbers for some currently operating space facilities.

Grants from NASA programs support a large community of graduate students, postdoctoral scientists, and faculty summer salaries. There is a general feeling in the community that the availability of this funding contributes to the productivity of the telescopes (publications per year) as well as the demand for telescope time. There is further anecdotal evidence that astronomers put their efforts into designing space telescope projects because they come with funding.

NOAO and NRAO collaborate with NASA to provide investigators with access to ground-based data to complement and enhance their space observations. Generally, NOAO time is available through proposals to the Fermi, HST, Spitzer and Chandra Space Telescopes. NRAO time is available through proposals to Fermi, Spitzer and Chandra.

Table 4. NASA Data Analysis Funding for Select Missions

Mission	GO Funding	GO Time Available
HST	$21M	3000 orbits
Chandra	$11M	16.5 Msec
Spitzer	$22M	6000 hr
GALEX Cycle 5	$2M	1500 ksec
Fermi Cycle 2	$8M	–

4. Discussion

In the regime where observing time and NSF funding are both highly oversubscribed, many researchers will win observing time and not money; others will win money, but not observing time. This is an inefficient way to utilize our resources, both in the time of the investigators to write the proposals and in the allocation of money to the projects most likely to produce good science.

To maximize the scientific return on the nation's investment in ground-based telescopes requires robust funding of their returned data. Funding for data analysis should be thought of as a way of maximizing the scientific output.

I see value in the paradigm where individual investigators can make significant scientific contributions to astronomy. Many have foreseen a dim future where senior researchers spend all of their time writing proposals for observing time and funding while all of the actual investigation is carried out by students and postdocs. It gets even worse, for with permanent jobs scarce, more funding proposals will be written by junior researchers (postdocs), and the personal time available for research will steadily decline or be the province of students. Not only is this an inefficient means of conducting research, but it also will result in senior people who are not well-versed in the newest techniques because they simply don't spend enough time actually looking at data themselves. An alternate bleak reality is that all astronomy becomes survey dominated, with astronomers as data mining experts operating on databases.

Despite the rise in journal pages published over the last decade, it is clear that many astronomers have unpublished observational data sitting in their offices. Many also feel they have not completely exploited the data they have or have only realized some of the many projects that could come from the data.

One might be able to accomplish the goal of increasing productivity by simply increasing the amount of funding NSF provides in its astronomy and astrophysics grants program. If success rates were high (say better than 50%), then "double jeopardy" would not a major impediment. Another advantage to this approach would be that multi-year NSF grants provide stability of funding.

However, there are also reasons to want to tie funding to observing proposals. First, they have a much faster turnaround. Ground-based observatories typically take proposals two or three times per year. A good idea can thus be rapidly approached. The funding cycle for NSF is annual and at least five months elapse between the proposal deadline and the announcement of awards. If money is necessary to the analysis of the data, it would likely be a year before such money became available, from the time the idea was conceived to the time the AAG proposal was submitted to the time the grant was awarded.

Second, it might make ground-based facilities more attractive to users so that effort is not disproportionally put into projects for space telescopes. The report of the 2008 NOAO Users' Committee reiterated the importance of graduate student travel support and noted that "ending the "double jeopardy" of applying for telescope time and data analysis funding separately would be a major improvement in the research climate for ground-based astronomy in the U.S." (NOAO Users Committee Report 2008). NOAO evidently agrees. In its reply to the Users' Committee, it said "We believe support for Users Grants would have a strong, positive impact on our program and telescope subscription rates." (NOAO Response to Users Committee 2008).

Third, it would encourage a new generation of observers. Fourth, it might not be advantageous to make the AAG success rate high just to remove the "double jeopardy" problem, but rather to solve this problem at its root; i.e. explicitly acknowledge that it costs money not only to collect but also to analyze observations.

4.1. Thoughts on User Grant Award Sizes

4.1.1. Small Programs

Small grants are inefficient to award and administer on the observatory side and to manage on the investigator size. Whenever possible, funding should be provided for "meaningful" appointments that reflect the research environment; a minimum of a semester or a summer's support for a student - a year of support for a post-doc, or a reasonable amount of summer salary support for an academic.

These arguments lead to a minimum grant size of ∼\$10k per year. Experience shows the the overhead costs associated with smaller grants become prohibitive in time and money. Grant administration, reporting, overhead charges, and paper-work make smaller grants far less effective.

This presents a problem. Most programs on large apertures fall into the "small" category. It is likely that short focused observing requests will contribute a large fraction of the demand and science return for new facilities as well, as large amounts of time will not immediately be available. It is a mistake to handicap this science at the onset by providing no funding for small programs.

4.1.2. Medium, Large and Survey Programs

If data analysis funding came automatically with moderate and large programs, what then is an appropriate amount of money? A moderate program might take half of a postdoc year to finish or two years of graduate student time. Fully loaded with overhead and benefits, this amounts to about $60K. Based on the number of medium proposals, this would cost $\sim$ $5M to support. A similar amount of money (in fewer proposals) would support large proposal data analysis, for about $10M total for NOAO.

The need for ongoing data analysis funding for NRAO is probably similar at $\sim$5–10M per year. In addition, ALMA, a major new facility is to begin operations at the beginning of the next decade. Following the AANM recommendation of 3% of the capital cost per year would make available $15M per year.

5. Conclusions

It's hard for me to imagine a world in which the NSF AAG program is not oversubscribed by 3 or 4:1. This means that "double jeopardy" will continue to be a problem for observers. We might like to believe that high oversubscription of observing time and funding result in healthy competition that lets the best, most creative science rise to the top. However, high oversubscription rates for both funding and data inevitably lead to inefficient use of resources when people receive one but not the other.

Personally, I am curious whether the statement of the last decadal survey, that unrestricted grants produce the most creative research, is true. If the most creative observational projects require new or archival data from observatories, then I do not see why it advantageous to support them from unrestricted NSF grants rather than from observatory data analysis grants. I suspect a lot of creativity is expended in performing new observations.

Even if substantial new money is identified for user grants programs, I envision the need for AAG to continue funding observers (and of course theorists/computationalists, whose needs are not addressed at all in this white paper). For observers who wish to synthesize data from a diverse set of facilities, do archival research, or use small amounts of data for very detailed studies, I envision the NSF grants program would still be the main source of research funding.

There is also the cost of attending scientific meetings. These serve the important purpose of sharing information between researchers, letting students and young post-docs meet the wider community of astronomers and broaden their intellectual horizons, and facilitating planning for future experiments. While perhaps not absolutely required for producing scientific results, meetings undoubtedly enhance scientific output by stimulating new ideas and cross-fertilization of results. I have not folded these costs into the data analysis numbers above.

I recommend the Astro2010 Survey consider User Grants for ground-based observatories.

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