Astro2020 APC White Paper

Ground Based Optical Astronomy – Keeping the Innovation Window Open

State of the Profession: Research opportunities

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Abstract:

The deployment of more and larger ground-based observing facilities complement the trend toward dramatically fewer opportunities for peer-reviewed community access to a wide variety of telescopes and instruments.

The evolution of ground based optical astronomy toward highly multiplexed surveys offers unprecedented science throughput. The massive cost of these programs requires large, highly structured teams working on decade time-scales to generate the community support necessary to ensure development and operation. Science by broad consensus enables construction of facilities and associated resources for large-scale programs. However, this approach has over time subtracted from the resources needed for the continuous turbulent innovation that arises naturally with regular competed PI access to a broad range of telescopes and attendant capabilities. While the trend in astronomy shows an increase in large-team science, a larger fraction of publications still show authorship by small teams.

This white paper makes the case for providing where practical a component of community access to private and consortium observatories. We recommend ensuring that even our very large survey-driven facilities, such as DESI, LSST and their successors, should be organized, funded and operated to provide a fractional component of traditional, competed access in an open marketplace of ideas. We also recommend that the balance between large, medium and small funding opportunities should be modulated by thoughtful decisions based on evidence and the for the best interests of the science and the profession.

The basis for these recommendations is the record of innovation in science, experience with telescope access, record of publications in astronomy, and quest for equity of opportunity in our exploration of the universe.

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Key Issue – Supporting Individual Initiative in an Era of Major Surveys

Just a few decades ago, ground-based astronomy supported a large number of independent research teams pursuing their research on dozens of telescopes with hundreds of instruments – metaphorically, "let a thousand flowers bloom". In recent decades, ground-based astronomy in the U.S. has undergone a dramatic turn to large survey programs. As these surveys get larger and more fiscally dominant, the metaphor risks approaching "all the eggs in one basket".

The decision process for large programs is different, involving longer lead times and broader consensus. The strengths of this approach are clear: the breadth and depth of a large team bring to bear enormous intellectual and fiscal resources for addressing the frontier problems of the day.

But there is an attendant weakness: reduced agility and responsiveness to new opportunities; reduced sympathy for the unexpected, and a higher potential barrier for challenges to the paradigm.

Here, we will review the trends in facilities and data, the evidence for the value of small science teams, and the challenges of consensus-based and key project surveys, we conclude with recommendations that suggest new paths toward seeking a balance in our way of doing science.

The trend is toward reduced access to observing facilities, and increased access to data.

The main point of community access to ground-based optical observing facilities is through the NOAO Telescope Allocation Committee (TAC). This access has been evolving, and its changes over time bear witness to developing trends in our science. Figure 1 shows decadal snapshots of the allocation rate over the past 26 years, first in telescope-nights, and then in telescope-meter nights (multiplying the number of nights by the diameter of the aperture)

The number of telescope nights decreases monotonically, as it follows the trend to reduce open community access to small aperture, and then medium aperture, telescopes. In order to represent the shift of investment from smaller to larger apertures, the data is also represented as meter-nights. This number initially decreases, then rises as a several of 4-8m telescopes are activated. This bump also reflects the temporary augmentation in community access provided by private facilities through negotiated arrangements, especially those enabled by the NSF TSIP program. Then the meter-nights also bends down as TSIP ends, and as the NOAO 4m and 2.1m telescopes are removed from the available pool.

Figure 1 shows that open community access to observing facilities is undergoing a significant, downward trend. In an ideal world, the balance between types of facilities and projects should follow from head-to-head science-based competitions and reviews. However, review of large, compelling programs, largely against one another, effectively undervalues the multiplicity of other opportunities. As a result, the community is losing at all scales the diversity of opportunity that is essential to healthy advancement of science. We believe that the plummeting trend in Figure 1 should at least flatten, and better, recover.

The trend toward less telescope access has its complement in the increased access to open datasets. This is illustrated by two snapshots. Figure 2a shows the explosive growth in the use of the SDSS[2] survey data sets, illustrated by the number of hits per year to the server website. A similar trend is occurring with publicly-accessible telescopes. Figure 2b shows the growth of the NOAO Science Archive[3]. The rapid growth is due to the increasing deployment of wide field-of-view imaging cameras, both in the north and south. The NOAO dataset is now so large that it constitutes a crowd-sourced survey of the entire sky (Nidever et al, 2018).

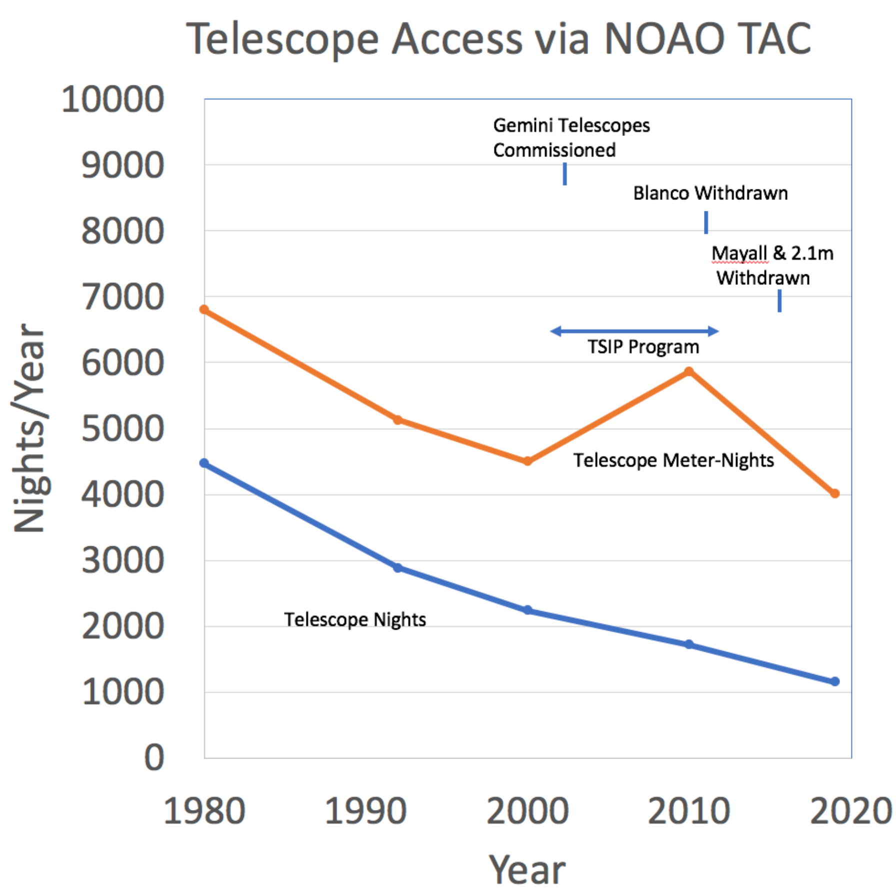

Figure 1. Historical record of telescope allocations by the NOAO TAC, illustrated with decadal samples, shown as the number of allocated telescope nights, and of meter-nights (nights multiplied by telescope diameter). The initial trend downward resulted from funding agency pressure to stop supporting smaller apertures

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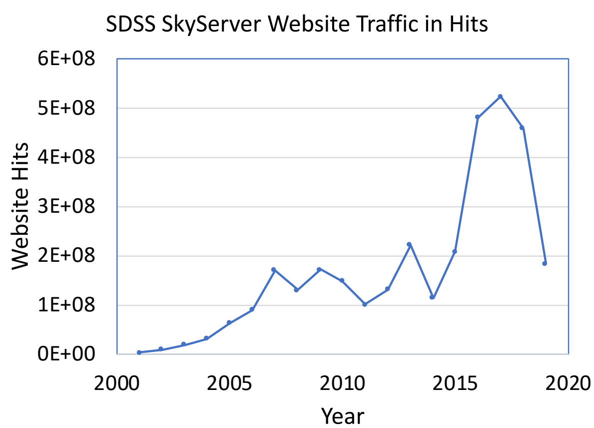
[2] SDSS, the Sloan Digital Sky Survey, is a private observatory program dedicated to surveys with public release and supported access.

[3] All data recorded at NOAO telescopes eventually becomes open access.

Deeper and more robust catalogs represent one essential path forward. The dramatic increase in publications from archives suggests that many aspects of our science are well served by the evolution toward consortium programs. Surveys themselves provide excellent vehicles for discovery, a venture into the unknown, where even basic parameters may be unclear.



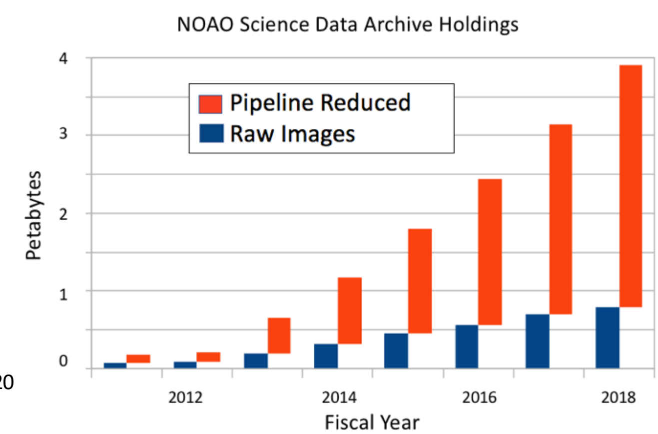


Figure 2. (a) Left, the data access activity for the SDSS sky survey archive, as tracked by the number of hits per year at the SkyServer website.(b) Right, the growth in the NOAO Science Archive, as measured in archived data volume. As this is written, the size is well past 4 PB and growing.

The new way of doing astronomy

The pathfinder and new benchmark for ground-based optical astronomy is the Large Synoptic Survey Telescope (LSST). This $\$10^9$ project is necessarily founded on planning by consensus at the large scale, integrated over hundreds of researchers, dozens of institutions and multiple decades. Such a focus is essential to provide the astonishing wide-fast-deep LSST imaging power for research., LSST will have the capability to execute literally in minutes programs that would simply not be possible with earlier generation facilities.

Inevitably with the protracted developmental time scale, observing plans for such a mega-project are built on science cases that were freshest many years ago, and may or may not correspond perfectly were the program developed today *ab initio*. This contrasts remarkably with the methodology of astronomy through the 20th century. Until the beginning of this century, investment has been aimed primarily at optimizing the opportunities and resources available to the individual investigator or small team, and enabling rapid turn-around from idea, to scheduling, to measurement, to interpretation and discovery. Scheduling by semester traditionally has allowed discovery, follow-up and in-depth studies with feedback on a 6-12 month cadence. Working from a large survey is a different way of doing science.

The trend to large teams – and the vitality of the small team

It is obvious to a reader of astronomy journals that large teams appear more frequently today than in the past. The rate of publication for teams of 9 and more members is rising year over year. It is less well known that the number of single -author papers in astronomy has been dropping steadily. But in between, the publication numbers by small teams are rising rapidly. Figure 3 (adapted from Smith, 2016) shows that 53% of ApJ papers in this decade have 1-4 authors. We believe that this trend is consistent with the entrepreneurial spirit that has driven astronomy in the past.

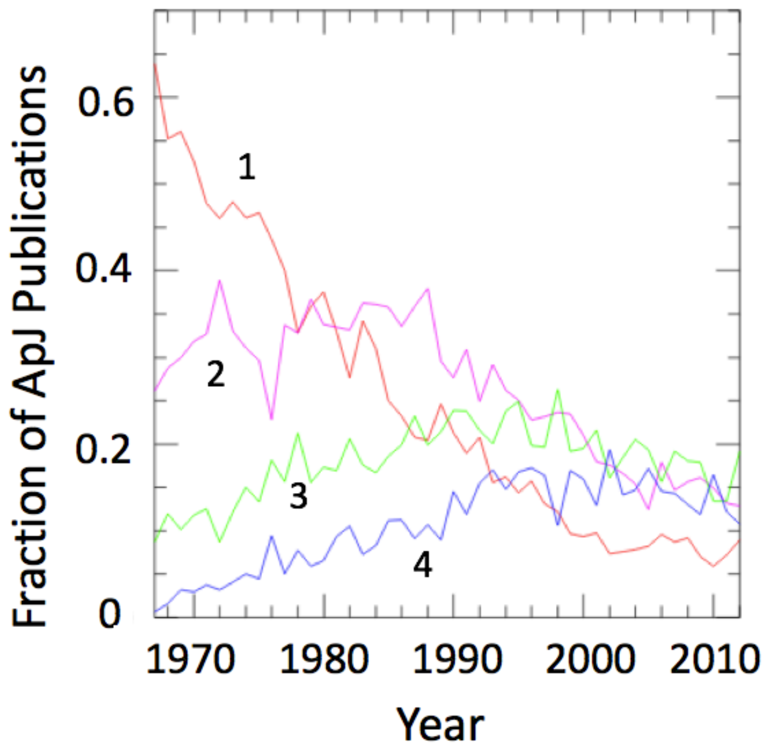


Figure 3. The fraction of papers in ApJ with 1, 2, 3 or 4 authors (Smith, 2016). Note that over this time span (1970 – 2010), the annual number of ApJ papers increased by approximately 4X, thus in publication count, all the curves except single-author are rising sharply.

The vital role of the small team in research has been a subject of considerable study and commentary in recent years. Publishing in Nature, Wu, Wang and Evans (2019) analyzed 65 million publications over 1954-2014, and found strong evidence that smaller teams contribute vital innovation and essential disruption to science. Describing their work in an interview, Evans said, “Big teams take the current frontier and exploit it. They wring the towel. They get that last ounce of possibility out of yesterday’s ideas, faster than anyone else. But small teams fuel the future, generating ideas that, if they succeed, will be the source of big-team development." (Evans, 2019).

To "fuel the future", it is important to nurture the individual investigator and the small team with support, encouragement, and even privileged access. Providing competed facility access to small teams taps the research spirit at its most basic level – ownership of ideas, reward for creativity and drive, credit for products, respect of peers, unambiguous roles in publication. Elements of the entrepreneurial spirit, posting innovatively in the marketplace of ideas, leads to discovery and breakthroughs, and it allows young researchers to exhibit their abilities and leadership early in their careers. Such opportunity is essential for community standing, promotion and tenure decisions, and enabling of competitive access to other observatory platforms (radio, space).

These concerns may be more concrete with specific examples. LSST is the most developed of the massively multiplexed public projects. It is quickly realized that one cadence cannot serve all desired goals. In fact, it can be very difficult to simultaneously optimize a general survey even for just two somewhat different purposes. The LSST Science Book highlights 100 science objectives (45 in the time domain) that are well matched to the facility. We don't know if the actual survey depths and cadences can satisfy 50% or 95% of these, but there is reason to believe that it cannot satisfy 100%.

In the case of a multiplexed spectroscopy survey, the situation becomes very clear, as observing parameters and target selection are entirely science objective-driven. A choice must be made - a key objective can be prioritized more highly, or a compromise can serve several objectives, but *one size does not fit all*, and not all science ideally matched to the facility will be enabled by the survey as executed. Such a concern applies to DESI, in development. Whole classes of science well-matched to the facility will not be included in the key projects – nor is PI access planned at present. Other facilities in formulation (MSE, 4MOST) are also favoring consensus survey science with no plans for PI access. Similar concerns will apply for any costly community facility, including ELTs, where use strategies and time allocation models are still in formulation.

Of course we understand that with even the largest and most focused surveys, at least some science may be done by small teams. But fully accessing the drive and creativity of individual scientists may require direct participation in the design of focused, purpose-built observing programs, quite orthogonal to the philosophy of the uniform and homogeneous survey.

The potential value of PI observing opportunity is magnified by the extraordinary throughput of modern facilities. Actually, given the community tradition of independent research, it is almost ironic that the orders of magnitude increase in research power of a major new facility might not be available for significant blocks of individual investigator or small team research pushing the frontier beyond key survey objectives.

However, for some of the most powerful planned facilities, providing this resource to the community is not a priority, or is even anathema to operations models. Science will be done from surveys (even "mini surveys" will be massive) planned by committee. The years of program development, community participation, and prestigious review panels ensures that these major programs have been carefully developed and prioritized. But the agility of the discipline will suffer significantly if there is little opportunity for short turn-around small programs providing rapid feedback to the research and to the community.

Small innovative PI programs do not just serve the team members. A team may record different targets, with new patterns - exercise new analysis - with the potential to advance knowledge of the product, detect unrecognized discrepancies, or eliminate additional systematics. These may or may not be convenient for the on-going major programs, but they could be priceless in long-term reformulations of the facility mission.

The large investment in new datasets should be balanced with continuing access to measurement (observing) opportunities and other research support

Out thesis is that training young scientists, innovation in experimental methods, perfection of technique, and timely iteration of investigations will at times require access to the full gamut of scientific tools. We focus here on an endangered species: access to the measurement facilities of ground-based astronomy. In the Strategic Plan, below, we recommend several target objectives that will reverse the decline of facility access, and lead to a soft landing at a healthy and thoughtfully designed level. Specifically, we recommend programs that provide long term community access to select private facilities, and to the powerful new survey facilities that are coming on-line now and in the future. We endorse a broad spectrum of funding options, flexible in amount, duration and qualifications required of applicants. Particularly, a small number of large funding disbursements should be balanced by a large number of small ones. Modest funding options directly linked to successful granting of competitive access to ground-based facilities should be encouraged, in analogy with HST, alleviating thereby the double jeopardy problem of observing access/research support.

Equity of opportunity

Finally, it is essential to consider the role of open access in providing equity of opportunity in our profession. Of course a very large program is developed with broad input from across the community. But it would be naive to suppose that opportunity for input is equally accessible to all community members. Many factors of privilege, recognized and unrecognized, enter into the influence that individual researchers can exercise in the key fora scattered over many years of process. Once a project is underway, decision making is largely internal, for natural and correct reasons. It is understandably difficult for even senior scientists to find their way into a mature team. For young scientists the on-ramp may be virtually invisible without a personal guide. This is not a fault of a large project – it is in its nature - a large body of participants has accumulated many years of oral history, assumptions and hands-on experience. Even a nominally open door can have a formidable threshold. On the other hand, open and competed access to a facility not only gives the broad community an opportunity for innovative work. Merit-based access serves as a potential entry point for those who were not well placed (or foresightful enough or free enough or connected enough or old enough) to participate in the development stages.

Strategic Plan – Peer Review and Open Access

The Decadal 2020 commission should recognize the historically validated model of open access. The commission can endorse the value of supporting and funding access for competitively reviewed programs of varying scope, including PI and small team programs. This opportunity should be endorsed for all ground-based observing facilities. In particular:

Continue traditional observatory access offered by public observatory user facilities.

In recent years, NOAO has turned its telescopes of many aperture size increasingly to closed private or public programs. The community should have an opportunity to compete for access to a fraction of the tools, some very expensive and powerful, that are deployed in these telescopes.

Open access to private user facilities.

Experience has shown that public open access as an adjunct to public funding works effectively, as demonstrated by the success of the NSF TSIP program especially, and in the MSIP opportunities to some extent. These programs have provided access to for example Keck, Las Companas, the Las Cumbres network, and the CHARA Array. Similar mechanisms could be used where appropriate for access to private survey facilities such as SDSS and ZTF.

Open access to multi-agency research facilities.

Facilities that serve several agency and scientific communities (such as DECam, NEID and DESI) could include opportunity for open access as a natural and strengthening element of an already strong program.

Plan now for open access to major public/private collaborations

Whatever the funding model, ELT's are going to require significant public resources for operation and perhaps instrumentation, and open access is a natural companion to public funding.

Open access to public survey facilities.

In the case of large-scale public survey facilities such as LSST, competed access is in our opinion necessary if the community and the science is to fully benefit from their unique capabilities.

How to do it

We are not recommending that a specific fraction of time be reserved for peer reviewed access. There are several reasons for this. First, each facility/instrument is a special case, and the need for and value of direct access will be a strong function of the particulars. In the case of access via *quid pro quo*, public access will trade naturally against the value of the resource and the public contribution.

Instead, in the case of large and expensive facilities, we propose that PI access be allocated competitively, not only against other PI proposals, but against the key programs for which the facility was constructed. This competition should fully recognize the essential contributions and priority access earned by the key science teams advising a facility, and the need for some neutrality and independence of a proper peer review.

There are ample examples. NASA missions of all sizes often split operation between mission science team and "guest investigators", with the mission team granted significant time early in the mission lifetime, with increasing "guest investigator" time granted as the mission matures. Observatory instrumentation projects commonly divide access between the instrument team and the other telescope users, often with rules that privilege the developers over some period of months or years. The increasing use of queue scheduling tends to place ground-based observatories more nearly on a par with space missions, offering users of differing background the opportunity to have their programs interleaved with mission-specific measurements. The more facilities move toward queue scheduling, the easier it will be to include exploratory, rapid turn-around programs. Queue operation also can be turned efficiently to support event-driven follow-up opportunities that flow from time domain surveys.

It is possible to compete a small program of minutes or hours with a key science program requiring years. Proper management of a Telescope Allocation process can populate a TAC with the required expertise – this is what TACs are designed to do.

Our recommendation, therefore, is not necessarily that a specific fractional allocation of PI time should be provided, but that a guaranteed opportunity should be offered, at regular frequent intervals. Notionally, a key-science dedicated facility could shift from initially 100% commissioning and key science, evolving towards a more balanced program of follow-up key science with increasing community access on a competitive basis.

Organization, Partnerships, Current Status

Ground-based optical astronomy already has deep experience in operating user facilities, in organizing and managing peer review, and supporting observing programs. These existing processes can be extended to other facilities, propagated as is, or revised as appropriate.

NOAO's Community Science Data Center (CSDC) operates a Telescope Allocation Committee (TAC). Initially used for national facilities operated by NOAO, the function of this TAC has been extended to manage proposal review for other public facilities (Gemini North and South). In 1997 NOAO began offering *one stop shopping*, offering access to a wide mix of public and private facilities in a single proposal review. At various times, the NOAO TAC has allocated resources available through the TSIP program, including Keck, LBT, and Magellan. The NOAO TAC currently allocates community access to AAO and Subaru through time exchanges. It allocates to the NOAO-NASA collaborative spectrograph NEID at the private-public WIYN telescope. It allocates time to the private LCO telescopes, and to the private CHARA optical interferometry array, both available in connection with NSF MSIP funding opportunities. This breadth of experience qualifies CSDC for managing TAC reviews of additional ground-based observatories. (Note that the CSDC division of NOAO will propagate intact to the reorganized observatory provisionally known as NCOA.)

Schedule and Cost Estimates

Our schedule is "immediate". We do not request new funds, but appropriate modulation of existing funding paths.

An endorsement of this white paper by the decadal committee will have the immediate impact of assigning a consensus value to open access. With an endorsement of the value of continuing/increased PI open access to ground-based facilities, funding agencies, dispensing grant and project funds during the decade, will have the incentive and flexibility to include open access as an element in their calls for proposals and a factor in their evaluations.

We recommend a funding model that ensures a balanced distribution of grant numbers and size. We could do worse than a logarithmic model, which for example describes well the relative sizes of user data downloads from large public astronomy databases: a small number of large grants to support large, 'legacy science' teams; a large number of small grants to support exploratory science; and intermediate-scale funding and numbers for deep analysis of developing fields.

Acknowledgement

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