The Importance of Telescope Training in Data Interpretation

Thematic Areas: ☐ Ground Based Project ☐ Space Based Project
☐ Infrastructure Activity ☐ Technological Development Activity
☒ State of the Profession Consideration

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Overview

Remote observing and the use of data obtained from mid- to large-scale astronomical surveys now accounts for a sizable portion of the data used for research in astronomy. This shift has enabled novel research activities and has democratized them to the extent of making large datasets available to anyone with an internet connection. As a side effect, fewer astronomers are being trained on the basics of telescope operation. The dangers associated with this reduced training include the risk that professional astronomers lose the ability to discern instrumental from astrophysical signals in their data. Additionally, there is a real risk that technical skills that were once associated with professional practitioners will be relegated to the realm of support staff and amateurs. This may result in the average population of professional astronomers possessing inferior technical skills in observing, and therefore less creativity and fewer insights in the pursuit of their research.

In this State of the Profession Consideration, we will discuss the state of hands-on observing within the profession, including: information about professional observing trends; student telescope training, beginning at the undergraduate and graduate levels, as a key to ensuring a base level of technical understanding among astronomers; the role that amateurs can take moving forward; the impact of telescope training on using survey data effectively; and the need for modest investments in new, standard instrumentation at mid-size aperture telescope facilities to ensure their usefulness for the next decade.

Recommendations:

- Professional observing facilities allocate funds to support travel for observers who wish to observe on-site, with favor shown to junior researchers (including students and early post-doctoral fellows)
- We encourage both university and national stakeholders (e.g., the National Science Foundation) to support the development of new campus observing facilities and the upgrade and maintenance of existing facilities
- Mid-size (2- to 5-meter class) national, state, and consortium facilities operating as traditional observatories be provided with funds to upgrade their standard instrumentation suite, to ensure their usefulness for the next decade

1 Modern Observational Astronomy

Large-area surveys of the sky and observing queues for space- and ground-based observatories are innovations made possible by computing power and the internet. Since the Infrared Astronomical Satellite (IRAS) came out with a full-sky map and fluxes for every detected source, we have increasingly depended upon such surveys, and now the great majority of astronomers use results from surveys as part of their normal practice.

Surveys have allowed astronomers to study very large samples at once. This has been revolutionary, when one considers how difficult it was to obtain data before the advent of electronic detectors; in the mid- to late-twentieth century sample sizes of hundreds of objects were considered quite large, whereas thousands to hundreds of thousands of data points are more common today. The statistical results from these new, large surveys have greatly increased our understanding of things such as the mass-metallicity relation for galaxies (e.g., Tremonti et al. 2004), Baryon Acoustic Oscillations (e.g., Tojeiro et al. 2014) and stellar population studies (e.g., Gouliermis et al. 2006). They have become so common that we accept as common language discussions concerning statistical likelihood of model fits to our large samples. And the growing use of Artifical Intelligence in the search for data-driven solutions that are of a statistical nature, are regularly used to conduct research.

The ready availability of big data means that trips to traditional telescopes to collect what are now considered small samples of data are becoming increasingly rare. Some facilities have shut their doors; others have been threatened with closure[1]; still others have transitioned from traditional observing mode to survey[2]. And psychologically, this only seems to re-enforce the greater value of survey data, or the quick follow-up that is possible with queue observing, over traditional observing runs. And yet much important work in astronomy is being conducted traditionally, including: calculations of the primordial Helium abundance (e.g., Izotov et al. 2014), hunting for young solar analogs (Gray et al. 2015), and follow-up observations of transient events (e.g., emission-line B-type stars; Labadie-Bartz et al. 2018, and exoplanets; Huber et al. 2019).

A close look at the big data trend suggests that the astronomical community is at risk of losing something vital, however. Without visting telescopes to collect data, astronomers are one step removed from considering fundamental issues such as focus and image quality, signs of optical aberrations and how to mitigate their effects, the quality of the acquired flatfield images and whether superflats will need to be constructed, or the shape of the instrument profile in spectroscopy and whether it can reasonably be removed. Allowing computers to handle so many of the mundane aspects of practical observing such as those listed here sets the dangerous precedent of de-valuing the base knowledge that may not be in itself publishable.

Do we de-value the most fundamental knowledge about observing? It would seem not: staff astronomers at observing facilities are generally tasked with ensuring that the data product, beginning in the raw form and processed by whatever automatic data reduction and extraction pipeline has been created, is of the highest possible quality. For surveys, studies are performed to assess data quality and derive uncertainties in quoted results. These studies are done to provide the astronomical community with necessary information about the limits of the dataset and any appropriate caveats. It is up to members of the community who wish to use these data to read the appropriate

[1] e.g., at Kitt Peak www.mira.org/newsletr/NL_spring14web.pdf

[2] the Dark Energy Spectroscopic Instrument (DESI) will be the sole instrument on the Mayall 4-meter telescope on Kitt Peak: https://www.desi.lbl.gov/telescope/

documentation in order to educate themselves about these limitations.

But what about observers using survey and queue data products? How can we offer opportunities for them to gain the lower, more fundamental knowledge necessary to interpret their data? Out of respect for the scientific method, is it possible to question the validity of the automatic pipeline reduction without offending the staff astronomers who have worked diligently to create the data products we wish to use? The problem is that automatic pipelines risk serving as black boxes, about which little is known and no questions may be asked. And this level of trust *is* unscientific; since the people responsible for making the automatic pipelines are fallible, not every mistake can be caught by them. And since mistakes may lurk in the reduced data product, then it is possible (and has in fact happened) that observers could treat an instrumental signature for an astronomical one, or else, by doing the opposite and ignoring small details as spurious, lose valuable insight that is available to them, if only they knew how to look.

2 The Continued Need for Hands-on Observing Training

As described above, mere exposure to pipeline-reduced data products or data secured by queue observing does not suffice to teach observers about the importance of the lower-level fundamentals of their trade. We contend that the only real method available to deepen understanding about telescopes and telescope data is active participation in data collection, including trouble-shooting problems on-sky, and reducing one's own data according to the accepted methods. This presents a difficulty, in that trips to observing facilities are expensive, and funding is not always available as it once was to enable them. There is the additional consideration of how to be conscious about our carbon footprint. But we are here discussing the need for training, not that queue and remote observing should be done away with; in fact, queue and remote observing modes are excellent tools that allow us to be more environmentally conscientious.

Our first recommendation to foster telescope training is that **observing facilities be allowed to allocate funds to support travel for observers who wish to observe on-site**. This type of support is particularly important for junior researchers (from students to early post-doctoral fellows), who may be doing on-site training for the first time, or have a vested interest in securing data for their future careers.

Travel may be prohibitive for a number of reasons, and we therefore **urge members of the community at colleges and universities to investigate avenues by which to support their own campus observatories**. Studies have shown (Benn & Sánchez 2001,2005; Trimble et al. 2005) that telescopes in the 1-meter class routinely produce cutting-edge data products, outperforming expectations based on studies comparing publication and citation rates *vs.* aperture size. This is clearly indicative of the great number of unsolved questions lurking among the bright and nearby in the sky. Campus observatories also have two practical advantages over larger, national facilities for the purposes of training, in that they are close to the students, and, by virtue of being relatively small, offer observers the opportunity to learn about their telescope, instruments, and environment in great detail. Put simply, campus observatories offer the single best way to teach future astronomers the fundamental observing practices, by providing ample time on sky, and room for making mistakes without using time at high-cost professional observatories.

We believe so strongly in the use of college and university observatories to train observers that we additionally recommend that **national funds, perhaps through the National Science Foun-**

dation, be made available for the creation of new campus facilities and the refurbishment of existing, out-of-date ones. Something like a *Minor* Research Instrumentation Program would be a low-cost opportunity with the singular goals of increasing accessibility to observing facilities for students: it is possible to make an entire facility for something on the order to $250,000 or less (including telescope, mount, instrumentation, and software), and for purchases related to refurbishment (CCD cameras and commercial spectrographs) to total less than $25,000.

It is reasonable to question whether college and university observatories will, before or after being funded, be used in the absence of a willing professional astronomer to oversee it. We have learned from personal experience that interested members of a faculty with limited prior experience with telescopes can easily be trained starting at an amateur level, largely because of the amount of material available to amateur astronomers on the internet. When these resources are found wanting, as they will if interest continues, one often has colleagues elsewhere to call upon for assistance.

Furthermore, there are a number of projects already in existence that are perfect for college observatories to partake in, particularly when starting a new facility means that there is pressure to demonstrate its scientific usefulness. For exoplanets, the Kilo-Degree Extremely Little Telescope (KELT; Pepper et al. 2007) has developed the KELT Follow-Up Network, whereby small observatories can contribute to follow-up observations, to discern real exoplanet transits from eclipsing binaries or other phenomena. The Transiting Exoplanet Survey Satellite (TESS) has a similar program[3]. Studies of classical emission-line B-type stars have the Be Star Spectra (BeSS) Database[4] to contribute to, studies of cataclysmic variables have the Center for Backyard Astrophysics[5], and a variety of other projects exist through the American Association of Variable Star Observers[6]. A local amateur community may also be a well of enthusiasm and practical expertise.

For mid-size (2- to 5-meter class) professional observatories, there is generally an issue that instrumentation is aging[7]. Funds may not be available to make replacements, or there may be a lack of interest in doing so, or else there may be a lack of vision in how this is to be done. We believe that professional observatories deserve to be furnished with a suite of up-to-date instrumentation, and recommend at least the following:

- a large-format CCD camera and associated suite of astronomical filters for photometry;
- a low- to mid-resolution spectrograph, in the optical and/or near-infrared; and
- a high-resolution spectrograph, at similar wavelengths.

We strongly recommend that **mid-size (2- to 5-meter class) national, state, and consortium facilities operating as traditional observatories be provided with funds (federal, state, or private respectively) to update every facility to this minimum standard**. This instrumentation is the most common for follow-up observations of transient events, and their standardized availability will not only make these telescopes useful for the next decade, but provide ample opportunity for

[3]TESS-FOP: https://tess.mit.edu/wp-content/uploads/TFOPcharterDWLv10.pdf

[4]http://basebe.obspm.fr/basebe/

[5]https://cbastro.org

[6]AAVSO: https://www.aavso.org/observing-main

[7]See APC White Paper: "The Importance of 4m Class Observatories to Astrophysics in the 2020s"(Chanover et al.)

collaboration between observers from different sites[8]. We realize that, with funding as tight as it is these days, it may seem redundant to produce the same suite of instruments at every mid-size observatory; when this is seen as impractical, it might be beneficial to **promote time trades between facilities with different and complementary instruments**. For telescope facilities with other specialities at their disposal besides those listed above, such as a Coudé feed, additional funding should be made available to update the appropriate instrumentation, if there is a demonstrable need for it from within the community.

3 In Conclusion

The prevalence of large surveys of data within the astronomical community risks conditioning us to rely too heavily on data products created by a small percentage of people within our community. This situation has endangered our ability to understand the true limitations of the datasets that we work with – a situation that can only be corrected by actively seeking opportunities to take part in the data collection process. To that end, we have made several recommendations:

1. Funds be made available to support travel to telescopes, especially in aid of junior-level research;

2. Funds be made available to support the refurbishment or creation of campus observatories to train students and create research opportunities; and

3. Mid-size facilities take steps to modernize their instrumentation in a standard way, and/or promote time trades to increase their user base

We additionally support ongoing efforts by members of faculties at colleges and universities to create local opportunities for their students.

Understanding that skills require upkeep, the ability of observational astronomers today to analyze their data requires that they be properly trained in the fundamentals of observing. This is what principally allows us as a community to continue to make progress in unveiling the secrets of the Universe.

4 Cost Estimates

4.1 Travel to Professional Observing Facilities

Supporting travel to observing facilities will vary greatly depending on how many observers are expected and how difficult (expensive) it is to reach the observatory site. If we roundly say that travel costs (flight, rental vehicle, fuel) are $2,000 per person, and if an observatory expects to fully support ten observers, then their budget should be $40,000. This is, in round figures, a reasonable number: considering that 186 PhDs in astronomy were awarded in 2016/17[9] and that maybe 50 of

[8]These items are complimentary with the motivations and recommendations described in the APC White Paper "2020 Vision: Towards a Sustainable OIR System" (Oey et al.)

[9]https://www.aip.org/statistics/reports/roster-astronomy-2017

these required travel support in a year, then supporting ten trips *per observatory* seems about right (or even a little high). If all 50 or so people in need of travel funds are supported every year, the total cost shared by all observatories will be about $100,000.

Our recommendation is not that these funds come from federal sources necessarily, but that each observatory strive to make these funds available from their own operating budgets, or by applying for grants.

4.2 Campus Facility Support

We have recommended that campus facilities be provided with federal support. We estimate that small equipment purchases will typically come in under $25,000 and funds to make an entire observatory will typically cost less than $250,000; these numbers are justified below.

Commercial CCD cameras are available from a wide array of manufacturers, and can cost upward from ~$3,000 to more than $15,000. Commercial astronomical spectrographs are also becoming common, thanks in large part to Shelyak Instruments[10]. The cost of a long-slit spectrograph can begin at about $3,500, whereas a fiber-fed echelette is upwards of $15,000 (FY 2019). Hence, small equipment upgrades will typically come in at less than $ 25,000.

Telescopes, mounts, and observatory buildings are also commercially available, thanks in large part to the interest of amateur astronomers. While it is apparently possible to build an entire facility for as little as $20,000[11], costs may need to run higher if a warm room is required, or additional computers, or a substantial amount of concrete needs to be poured. Construction costs will vary across the country.

For our estimate of $250,000 or less to fund a new observatory, we have considered the following, rounded to the nearest thousand dollars (FY 2019):

- CDK600 24-inch Ritchey-Chrétien telescope from Planewave ($86,000)[12]
- constructed building, including electricity ($50,000)
- dome ($20,000)[13]
- computers ($10,000)
- software licenses ($1,000)[14]
- CCD camera for imaging ($7,000)[15]
- astronomical filters ($5,000)[16]
- spectrograph and camera ($23,000)[17]

[10] https://www.shelyak.com/?lang=en

[11] https://www.geek.com/geek-cetera/man-builds-20000-space-observatory-in-back-yard-1512879/

[12] https://planewave.com/products-page/cdk700/cdk600-6-meter-telescope-system/.XSYzyxBReho

[13] e.g., https://www.observatorysolutions.com/obs/home-dome-10.php

[14] e.g., http://diffractionlimited.com/product/maxim-dl/

[15] e.g. http://diffractionlimited.com/product/aluma-3200/

[16] https://www.omegafilters.com/optical-filters/bandpass

[17] e.g. spectrograph camera: https://optcorp.com/products/fli-microline-e2v-42-10-1-319back-illum-enh-bdband-43mm-shut; and long-slit spectrograph: https://www.shelyak.com/produit/lhires-iii/?lang=en

- miscellaneous accoutrements ($1,000)

The total cost, as quoted here, would be $203,000.

4.3 Instrumentation Upgrade

Our recommendation does not stipulate federal funds for state and consortium facilities beyond what is currently available to the astronomical community.

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