Advanced tools, multiple missions, flexible organizations, and education

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ABSTRACT

In this new era of modern astronomy, observations across multiple wavelengths are often required. This implies understanding many different costly and complex observatories. Yet, the process for translating ideas into proposals is very similar for all of these observatories. If we had a new generation of uniform, common tools, writing proposals for the various observatories would be simpler for the observer because the learning curve would not be as steep. As observatory staffs struggle to meet the demands for higher scientific productivity with fewer resources, it is important to remember that another benefit of having such universal tools is that they enable much greater flexibility within an organization. The shifting manpower needs of multiple-instrument support or multiple-mission operations may be more readily met since the expertise is built into the tools. The flexibility of an organization is critical to its ability to change, to plan ahead, and respond to various new opportunities and operating conditions on shorter time scales, and to achieve the goal of maximizing scientific returns. In this paper we will discuss the role of a new generation of tools with relation to multiple missions and observatories. We will also discuss some of the impact of how uniform, consistently familiar software tools can enhance the individual's expertise and the organization's flexibility. Finally, we will discuss the relevance of advanced tools to higher education.

Keywords: Common User Tools, Multiple Mission Tools, Observatory Operations Philosophy

1. INTRODUCTION

We are living in a modern golden age of astronomy, yet, to paraphrase the words of Charles Dickens, it is the best of times, and it is the worst of times. We need to find better ways to manage the revolution in our user support tools, our ways of doing astronomy, and the ways in which we manage the process, but we need to do it with less pain and anguish than that in Dickens' story. New telescopes and instruments are giving us unprecedented views of the universe, yet the means of using these new tools is sometimes fraught with uncertainty, anxiety, and stress. For the observer trying to attack a problem using multiple telescopes and instruments in different and sometimes less familiar wavelength regimes, the differences in the technology, terminology, and concepts may sometimes prove an unnecessary impediment to asking questions and finding answers fundamental to the underlying science. This need not be the case if a new generation of tools which leverage on the advances in information technology are developed with efficient user support at the core of their developmental philosophy. The nature of many of these advances and the rationale for the adoption of a new generation of software tools is spelled out in greater detail in a number of previous publications. [1.] With the advent of NGST development and the even more immediate reality of the trading of Chandra and HST time for multi-wavelength observing, the upcoming launch of SIRTF, and the inauguration of a powerful new generation of ground-based observatories, an era is now upon us in which it will be advantageous to have ready access to a new generation of tools that are easy to use, uniform, extensible, and provide expert assistance.

1.1. Motivation for Uniform Common Tools

Let us next turn our attention to the observer's life as a practicing professional astronomer, for it is the professional astronomer for whom the new tools of modern astronomy are being built and the investment of funds is being made. In order to truly understand astronomical objects and the astrophysical phenomena associated with them, modern astronomy is of necessity becoming more and more a multi-wavelength enterprise. The latter half of the twentieth century has witnessed a flowering of study in radio, infrared, and x-ray astronomy, among others, for example. Yet

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each of these sub-fields of astronomy has grown up with its own culture and its own terminology, its own technology, and its own way of addressing the problems in the field. Researchers have tended to make their careers in developing the exploration of these hitherto unexplored parts of the spectrum, and the time and effort required to do this has often meant that an astronomer could often be categorized by the wavelength in which he or she predominantly worked, e.g. radio astronomer, infrared astronomer, x-ray astronomer. As the need for a multi-wavelength approach has increased and been recognized, investigating teams have tended to grow larger in size, in contrast to the old optical astronomy paradigm of the lone astronomer working perhaps with one or two assistants over a long span of time on eternally-proprietary data. Many of the reasons for collaborations are the same as they always were - the recognition of common interests and of individual expertise and effort in some area which contributes something beneficial to the group. However the pace of astronomy has accelerated with the advent of public archives and non-proprietary data. The pressure on individual researchers and their teams to be more productive on shorter time scales has likewise increased. This, combined with the greater need for a multiwavelength approach has placed a higher premium on astronomers being more facile and conversant with the concepts, language, and tools of a variety of wavelength regimes. Uniformity of tools both across functions or kinds of work and across multiple observatories is a key factor in providing effective support to the users.

A new generation of tools with integrated modular capabilities to work across multiple observatories can help to translate unfamiliar terms or terms which are used differently (e.g. integration time means something different in radio astronomy than it does in optical astronomy, and the HST concept of a "visit", and the concept of an AOT or "Astronomical Observing Template" used by ISO and SIRTF each have their own mission-specific definitions), can automatically help ease the transformation. Observers unfamiliar with working in a given spectral range can better understand the capabilities of telescopes working in that regime, thus making them more competent as proposers and therefore generating higher-quality proposals from a wider range of proposers. In other words, the use of well-designed common or uniform tools for multi-wavelength observing can give observers of all backgrounds greater expertise at working back and forth across spectral bands with the telescopes and instruments most suited to their science. This can be extremely valuable not only in cases such as unexpected or unplanned for targets of opportunity, when understanding has to be gained quickly and decisions have to be made on short time scales, but also in terms of considering both general multi-wavelength observations (not coordinated in time), as well as the more demanding simultaneous coordinated multi-wavelength observing.

1.2. A Glimpse of the New Tools

The tools that currently exist for proposal preparation, while far better than those which were originally used for queue/remote observing, are still very basic tools in terms of providing expert assistance to the user community. Much has to be gleaned from reading instrument handbooks and Proposal Instructions, and then information about the observer's choices has to be manually incorporated into the final observing program. To truly go beyond the current generation of tools, more innovation is required.

Salient features of such advanced tools and their importance to both the user and observatory operations staff include (1) accomodation of both the novice and expert user (not requiring the expert user to follow a process which merely leads to already known information, while also not overwhelming the novice user), (2) ease and logical, well-documented nature of navigation of the tool, and (3) non-intrusive capture of essential information required to plan the observations.

One possible glimpse of the future is provided by usage of expert rules in uniform modular extensible observing tools such as the Scientist's Expert Assistant (SEA) which is a prototype designed to test some concepts, and to generate feedback among observers as to which kinds of features are most valuable and preferred by astronomers. This is discussed further in an article by Jones et al. [2] Wolf et al. report on the use of expert systems in capturing information from users. [3] Koratkar et al. report on results of the SEA evaluation which was recently conducted. [4]

By making it easier for the proposer to do a better, more thorough and comprehensive analysis of the proposed observations, it is possible to obtain both better proposals and more useful information which can be transferred to the observatory staff if needed, at lower cost to the user than ever before. Better, more comprehensive information allows the observatory to quickly adapt to changing observing requirements without extra workload and in a timely manner. The observatory can then act in a proactive manner and thus enhance the user experience. The user and observatory staff should share the tools and a common environment so that both can see the same kinds of information in a quick, easy, and consistent manner when planning or implementing observations and solving problems. It is also clear that the general navigability of advanced tools is very important. Just as one who is driving in an unfamiliar city needs to see maps of an appropriate level of detail at different stages of the trip, first more general and then more specific, users need to see that they can access roadmaps or tools for assistance of different types and at different levels of detail when needed at different stages in the process without the immediate informational content being either overwhelming or filled with information of an inappropriate level. Such tools help bridge the gaps in users' expertise across the electromagnetic spectrum and across various telescopes and instruments.

2. NEW TOOLS AND MULTIPLE MISSIONS

The phrase "multiple missions" may apply to the same organization managing multiple telescopes or spacecraft as well as different organizations managing different telescopes or spacecraft. These may be instruments and telescopes all operating in roughly the same wavelength, or they may be operating in different spectral regimes across widely separated parts of the spectrum. When considering multiple missions and observatories, many factors may vary. There may be different fields of view, different types of detectors, different modes of operation and means of interacting with or commanding instruments and telescopes, and different operating restrictions. For these reasons, a variety of problems may present themselves, and a number of useful tools may help to solve them.

2.1. An Example of a Possible Simple New Tool

Even in perhaps the simplest and most familiar case to most astronomers, one in which more than one optical telescope is being used, there is advantage to be gained from the incorporation of easy-to-use software tools which can quickly help a user to transform the world coordinate system of an image from one telescope to that of another, especially when time is of the essence. A good example of this might be a discovery image made at one telescope followed by spectroscopy with another, with a short turn-around time between the imaging and spectroscopy. Tools which readily help the user to transfer reference frames to the world coordinate systems of the telescope being used and which also help match any field of view at one telescope with that of any other will be useful to observers in many places. There is already software existent for transferring world coordinate systems and reference frames from image to image. Incorporation of such software into an easy to use interface would help to make this a simpler, more universally useful task for the user at any telescope, whether ground-based or in space, and would enable quicker and more reliably accurate transformation of coordinates especially when speed is of the essence.

Multi-wavelength observing implies the use of different telescopes and perhaps different types of detectors with their own characteristics, their own set of commanding and operating restrictions, and their own fields of view and their own reference frame which may or may not be used in common with some other telescopes or observatories. It usually implies at least another level of complexity for the user who is working in more than one wavelength since in addition to the factors mentioned above, even the physical appearance of objects may not be the same in different wavelengths, and tying the reference frame from one image to another may well be even more critical in this instance. In addition to that most basic of points are the details of easing the use of what may be less familiar technology, less familiar terms and concepts, and less familiar telescope-specific or instrument-specific operational requirements. Well designed, modular, uniform, extensible tools can be applied to all of these problems.

2.2. A Special Challenge: Coordinated Multi-wavelength Observing

Coordinated multi-wavelength observing can present the greatest challenge to observers, because the user not only has to contend with the usual multi-wavelength observing problems but also all the operational restrictions of all the various telescopes. Therefore, common environments and the ability to mesh the scheduling of such programs is essential. Various constraints such as day/night transitions, sky background level requirements in multiple wavelengths, the relative nature of the orbits of spacecraft (low earth orbit, geosynchronous orbit, other orbits beyond the earth), the evolution of those orbits over time, and the South Atlantic Anomaly need to be considered while scheduling coordinated observations. Thus, we see that while tools for the observer can be very beneficial in normal observing, in coordinated multi-wavelength observing, they are essential. It is of paramount importance to be able to take the scientific requirements and find a time or times when all of the participating observatories can schedule the coordinated observations. This scenario can be even more complicated if the observations are of a target of opportunity with a short turn-around time. While it will be important for observers to be able to see and be aware of the impacts of all the constraints when planning their science, it will be even more critical for observatory staff to see this information and to be able to meet the observer's requirements on fairly short notice. A prototype tool (VOLT) under development at Goddard Space Flight Center may be a promising direction for the future. [5.] See the paper by

Peterson et al. for a much more detailed look at issues and developments related to coordinated multi-wavelength observing. [6]

2.3. Need for Collaboration

Just as observers are under more stress today, so are observatories and the people who manage and staff them. With the demand for more new and greater facilities comes more cost accountability and a certain sense of obligation that limited (and in many cases, public) funds should not be spent merely reinventing the wheel from scratch at each separate observatory. Although reasons for the specificity of tools at various observatories are certainly valid and the ability to have local variations for local use is critical, a more universal set of user tools for observatory operations and control, plus associated tools for proposers and observers, could have the benefit of both saving money and providing a more common standard with which software tools could be built at many major observatories. For example, UKIRT staff have adapted Gemini software tools for their own use, and Spike tools from STScI which are used for planning HST observations have now been adapted for use by a number of observatories including FUSE, SIRTF, and ESO's VLT. Such standardization, combined with the ability to plug in other tools from other telescopes, will also have the additional benefit of enabling observatory staff members at individual observatories to more readily transfer their knowledge, skills, and abilities so as to more readily develop the expertise required with a new observatory. The new expert software tools can thus make the learning curve less steep for them, and allow them to be more fully integrated and valuable employees on a shorter time scale.

Shared software, of a modular nature readily allowing for modification and expansion of capabilities, with common interfaces and environments for proposers, observers, and observatory staff, built to be useful in ways which both enlighten and empower the user can have the powerful effect of enhancing the breadth and depth and consistency of expertise of all of its users. And, if truly well-designed, it can provide cost-savings by allowing different modular pieces of software to be built in different places by different groups with whom the expertise resides. The tools which proposers, observers, and observatory staff use can be consistent in both form and function across multiple observatories and multiple wavelengths. They can also be consistent across the range of functions, such as visualization tools for assessing scientific and technical feasibility of an observation, and data reduction and analysis. Such suites of tools would require excellent multi-observatory cooperation, communication, and coordination of effort, but they should be well worth it over the long term since they will also have the capability to make organizations and their staffs more flexible and more capable of supporting multiple missions.

3. MULTIPLE MISSIONS AND FLEXIBLE ORGANIZATIONS

One of the biggest challenges for any organization is to be organized so as to optimize its effectiveness in fulfilling the reason for its existence, to meet or exceed the expectations of its customers, and to meet or exceed its own institutional goals. Observatories are no different - their role is to facilitate the asking of relevant scientific questions and to facilitate the acquisition of astronomical data and the diffusion of that knowledge. Though software is still a relatively new phenomenon when considered against the backdrop of the rise of astronomy over the course of the 20th century, it has had a tremendous effect in improving the efficiency of observatories both on the ground and in space. However, due to the increased complexity and greater specialization in functional roles of observatory staff, there has also sometimes developed an unnatural rift, somewhat segregating staff in various parts of the observing support process, both due to the complexity of the job and the inadequacy of the software to expertly assist the staff member in developing and maintaining expertise in areas other than one's own specialty.

3.1. Traditional Observatory Models

The traditional ground-based observatory model developed over the 20th century was and is fairly simple, with some variation. A machine and optical shop and staff combined with the staff of professional astronomers and later, telescope operators or night assistants and electronics technicians to comprise the scientific and technical staff of an observatory. In some instances such as the Harvard College Observatory in its early days, people (in this case women) were employed as human computers, making a myriad of calculations in support of the staff astronomers, and generally acting as data aides. Most major observatories were private, and to use them, anyone not affiliated with the observatory had to collaborate with the staff scientist(s) who had similar interests. All in all, such operations were pretty self-contained.

The advent of public observatories such as the current NOAO began the tradition of public service in modern astronomy. A local staff on the mountain and usually in a nearby town supported observers from near and far whose proposals were accepted by the Telescope or Time Allocation Committee, a group who themselves were potential users of the same telescope and those who often had some experience with the observatory. In general, the same kinds of technical and scientific staff were present as at private observatories, however they now were also charged with the support of external users who might not be familiar with the telescopes and instruments in use on the mountain. A similar organizational structure was later generally applied to IUE, a space-based UV telescope in geosynchronous orbit which could be pointed at different targets in real time much as a traditional ground-based observatory. Even later, though more complicated operationally since it is in low earth orbit, the same basic kind of model was applied to HST support. In this traditional model, more telescopes and more missions means larger staff and more operating costs.

The opportunity to manage a multiple telescope, multi-wavelength, or multiple mission observatory poses new and different challenges in addition to those of the traditional model. Excellence must be maintained in each part of the operation, both by function (e.g. peer review support, planning and scheduling, calibration and data analysis support) and by telescope or mission. There are, of course, pluses and minuses to any method of organizing. Independent of the organizational structure, operating multiple telescopes and observatories implies a certain flexibility of the staff to handle various processes within the organization. This is crucial in an era of declining budgets.

3.2. New Technologies: The Expert and the Flexible Organization

Advanced software tools using new technologies will help address the needs of the organization by building expertise into the tools rather than having it merely reside with individuals who may be sick, change jobs, leave, or be otherwise unavailable when needed. If designed so as to treat all phases of an observing program as merely different facets of the same process, in unified fashion, advanced software tools may help to mitigate and even minimize the effects of cultural differences across the various functional roles within an observatory's organization (e.g. "front-end" development, implementation, and planning and scheduling and "back-end" calibration and data reduction and analysis, for example.) It may also help unify the processes between observer and TAC and observatory staff by providing a common, mutual environment in which all parties are using the same software, and can clarify issues regarding feasibility, schedulability, calibration and data quality, and analysis. Though nothing will take the place of creative use of scientific experience and judgement, which is after all the true basis of the individual ideas for science proposals, building in the combined expertise of a number of experts could have the unifying and elevating effect of giving all scientific and technical staff better insight into all phases of the operation. Simultaneously, each individual's level of competence in all phases of the operation can be enhanced. This would also have the effect of making an organization much more flexible, and thus more ready to meet new challenges and opportunities on shorter time scales, providing a competitive edge in the quest for new business.

Software which can "learn" could indeed have a culturally and intellectually unifying and simplifying effect. It would make it easier for astronomers to participate in multi-wavelength observing, and easier for observatories to accomodate and serve them. Furthermore, if done on a cooperative basis between major observatories, limited funds could be applied more effectively to modular facets of the tools which can be incorporated or modified in various places and situations as needed, thus eliminating the tendency to keep re-inventing the wheel at great expense, and putting limited funds to better use. In fact, such software can even go beyond the merely operational and provide great benefits in the realm of education, as well, as we shall discuss in the next section.

4. ADVANCED TOOLS AND EDUCATION

Advanced tools are not merely tools for assisting proposers, observers, and observatory staff to create better, more feasible proposals and manage the observing program of an observatory more effectively, although those are prime benefits. In a very real sense, they are educational tools for professional astronomers and observatory staff, and as such, they easily have much wider application as educational tools for students at all secondary levels - high school, university undergraduate, and graduate students as well as post-doctoral students who are, in fact, professional astronomers in training. Good modular design can enable a wide variety of instructional applications such as teaching students about k-correction effects when observing high-redshift galaxies (just to name a quick and easy example) while also serving as a quick reference for the professional astronomer who might otherwise be doing a quick mental or back-of-the-envelope calculation. Such add-on modules need not be complex. They only need illustrate the way that such calculations are made, even if simple, and on what basis and in what circumstance, e.g. the quick why, how, and what of the question and answer.

Traditional sources of funding for the development of today's observatory tools have tended to be from within the operational budgets of those observatories, but educational applications of these tools can widen the scope and the basis for funding. While funding from private and public corporations for some observatories may help with the development of software tools for observatory operations, there may be other channels of funding from those same funding agencies which have earmarks for educational projects. Given the educational nature and great possibilities for the expansion of educational applications within advanced tools, such alternative funding possibilities should be fully explored. Especially if a coordinated, community-wide effort is presented to potential funding agencies to make such tools applicable and available all across the spectrum, the prospects of success would seem to be much greater since it would represent organizations rising above their own most immediate concerns to present a comprehensive, far-reaching vision for the future.

5. SUMMARY

We have discussed how some possible future developments in a new generation of tools may be used effectively in a multi-mission environment, particularly with respect to the issue of organizational flexibility. Well-designed, modular software tools of consistent look, feel, and operation, developed in a cooperative manner across multiple observatories, and across multiple functional aspects or facets of observatory operations, can be used by proposers, observers, and observatory staff, and will have a unifying effect for all concerned. They can also help save money on operations, and make funding for software development go further and have wider applications more readily. Plans for such tools may be especially effective when organizations present a united, coordinated front to funding agencies. Finally, we have briefly explored the educational application of a new generation of tools, and the concomitant increase in funding opportunities and sources which that may provide. We believe that such tools offer great promise for the future if the current opportunities are handled wisely and with a generosity and commonality of spirit, with good coordination within, among, and between observatories and the astronomy community in general. This rare opportunity in the new golden age of astronomy should not be squandered.

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