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CHANGING WORKING HABITS AT OBSERVATORIES: MORE EFFICIENCY FOR BETTER SCIENCE!

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Abstract. Moving away from the widely used model of astronomers going to the telescope to conduct their observations is a trend that is being adopted by an increasing number of facilities. Instead of degrading the data, staff-made observations are actually overall providing better results, as they use the conditions best suited to each program and are done by well-trained observers. The next step is to realize that a PhD is not at all needed to perform these observations: up to some extent, even the night selection of "what to do when" can be left to a well-trained AI-based computer. On the technical side, observing remotely without anybody at the telescope allows for a more relaxed observing environment, leading to better observations. As the telescope is now far from the operator, remote sensing is indispensable and allows for continuous and automatic monitoring, opening the door to automatic alerting when equipment shows signs of problems before they become a real failure. The reliability of the observatory improves and the time lost to failures is dramatically decreased, leading to a much lower level of stress for the technical staff. Using our experience at the Canada-France-Hawaii Telescope, we will explore the practical consequences of this evolution, not only on the performance of the observatory, but also on the changes it entails on the overall redistribution of the work within the observatory, and on the relationship between the staff and the astronomical community, culminating with the notion that an observatory is first and foremost a service provider.

Figure 1. Solar Observatory at Chankillo, Peru. (Courtesy Ivan Ghezzi)

1. The Observing Astronomer

Astronomers/astrologers have for millennia observed the heavens with their naked eyes, discovering in the variation with time of the apparent position of the Sun, the Moon, and the stars some of the fundamental cycles of their motion, from the duration of the various years (sidereal, tropical, ...) to the precession of the equinoxes, of the various lunar months to the Saros cycle. These early observers used natural or man-made features (Fig. 1) in the landscape as alignment aids, later replaced with instruments like gnomons or armillary spheres. Astronomers conducted their own observations, but were also able to tap into the recording of earlier catalogs or observations, thanks to the use of writing systems such as the Sumerian cuneiforms for Western astronomy. This access to earlier observations was key to the study of cycles and time-related phenomena. It is not much different from going back to previous observations or a star catalog when looking for the optical counterpart of a gamma-ray burst or the precursor of a supernova. With naked eye astronomy, only the location of the observer would make a difference in what could be seen of the Heavens: the observable sky depends on the observer's latitude and on the transparency of the atmosphere and darkness of the night.

The advent of the telescope in the early 1600s changed drastically the

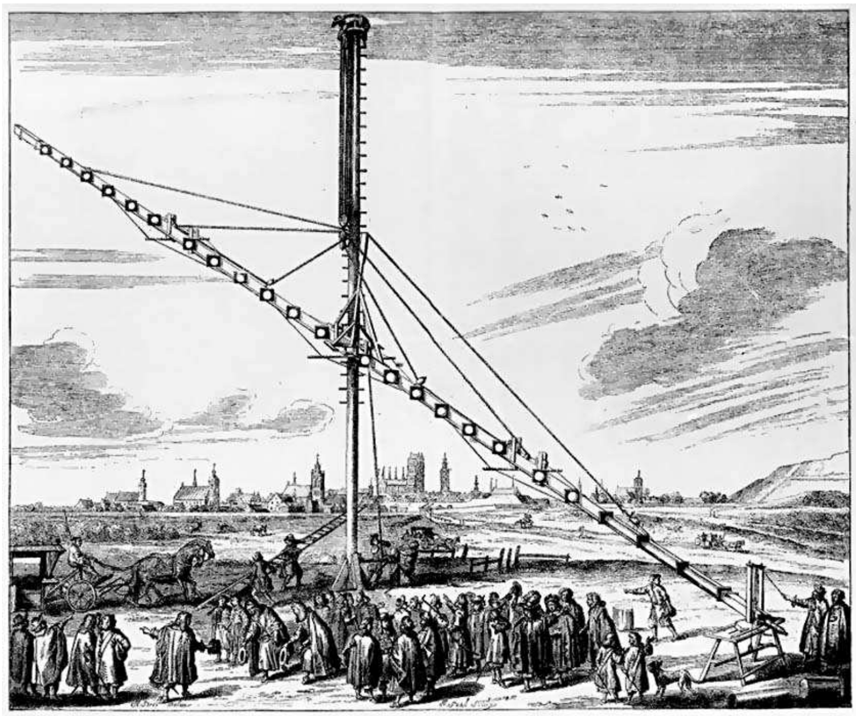

Figure 2. Hevelius' 46m long refractor. (public domain)

situation. If astronomers dealing with observational data wanted to make significant progress, they had to have access to these telescopes, which became quickly more and more sophisticated, therefore expensive and only accessible to a few. Photography would not come to general use before the end of the 19^{th} century. Therefore, for nearly 300 years, these observing astronomers had to rely on their eyes and record their observations as position measurements or as drawings. They spent countless nights at the eyepiece with the help of night assistants when the telescopes were not easily driven single-handed, like in the early days (Fig. 2) or with William Parsons' $72''$ telescope which required well-muscled workers!

For the whole 20^{th} century, from the early days of astronomical photography to the generalized use of CCDs or other modern detectors, astronomers kept observing themselves even though their eyes were no longer needed for the data gathering itself. Most of these astronomers would come from their own institution (an observatory or a university department) to telescopes made available to the scientific community by public or private facilities. As instrumentation evolved from basic imaging in the visible light to more complex instrumentation (spectroscopy, adaptive optics, ...) in new wavelength domains (infrared, sub-millimetric, or radio), astronomers had to learn how to observe with the instrument they intended to use, hopefully reading the user's manual before their observing run and receiving an initial support from staff at the telescope. During the run, the level of support would vary with the facility visited: more often than not, observers would be left by themselves with the assistance of a telescope operator.

In spite of much progress made over the last decade in computer-assisted instrumentation and the amazing growth of the Internet capabilities, the observing astronomer coming to the telescope for an "observing run" is still the main mode of operation at most of the major observatories. However, the availability of fast Internet connections has incited a few observatories to offer "remote" observing: the observing astronomer stays either at his/her own institution, or at a more comfortable location than the telescope itself, while having access in real time to the telescope observing environment in order to act as if at the telescope. This remote observing is more efficient than the traditional "observer at the telescope" mode, as it avoids traveling to the facility, often on long distances, saving time and money while allowing a more rested astronomer to be more efficient in a better environment.

2. Observing for the Astronomer... Why?

If the eyes of an astronomer at the telescope for an observing run are no longer needed to collect the data, what are they needed for?

One of the main arguments given is that the observing astronomer is faced with changing observing conditions, sometimes not suited well to the observing program. There is a need to adapt the observing strategy to these conditions in near real time by looking at the data, sometimes changing targets or moving to a backup" program.

It is true that an observing run can be plagued by poor seeing while a good image quality is required for the success of the program, or by absorption when photometric skies are needed. A full observing run can even be lost to weather! All of this leads to an inefficient use of telescope time, which the presence of the observing astronomer can only mitigate, at the price of much loss when a run is wiped out by weather. The only way to insure that observations are made under the conditions required by the observing program is to schedule them only when those conditions are met. This is done in the Queue observing scheme adopted partially or fully by many observatories: all observations requested by the users are piled up in a pool and, at any time, only those which can use the current conditions are actually executed.

In such a scheme, there is no place for astronomers at the telescope (even remotely) observing only for their own programs, but if they have the telescope full-time for their own use! Data are now always acquired in the requested conditions. The Principal Investigator (PI) of a program, no longer observing, will therefore get what was requested for. After all, space missions work in that mode at the satisfaction of their users! Another advantage is the possibility to share between programs basic information like sky flats or calibrations. A short visitor run will only get flats based on a few images, while, in Queue mode, flats will be taken in all required filters for as long as the instrument is on the sky, leading to a much better set of flats for all the programs observed during a given period.

When observing for the astronomers in queue mode, ground-based observatories are challenged by large changes in observing conditions on short time scales, something space observatories are protected from. However, the burden is on the observatory, not on the PIs.

3. Observing for the astronomer... Who?

We are now looking at an observing model where the observations from all programs which were allocated time are in queue, and where the PIs do not observe for themselves anymore: observations are done in service mode. We will refer to this mode as QSO (Queued Service Observing) (Veillet 2006).

For some observatories, a cheap way to handle QSO is to ask observing astronomers coming to the telescope to run the queue instead of observing for themselves, though they may have a chance to conduct some of their own observations if they pop up in the queue. Unfortunately, the savings are only local: in the great scheme of things, using an astronomer from afar, with the added cost of travels and associated expenses, is not cheap at all! It also only works for a relatively simple instrument which does not require a deep knowledge of its many modes.

An alternative solution is to ask an observatory staff astronomer with a good knowledge of the instrumentation to perform the observations for the users. This time, it is expensive for the observatory: an observatory has to run every night of the run and many astronomers would be required, as one does not want to have them only doing observations for users!

Actually, having an astronomer running the queues at night is not a good idea: it is not the best use of the skills of a scientist. In QSO mode, queues are prepared during the day relatively quickly by a staff astronomer and the work at night is limited to selecting the observations in the prepared queues according to the observing conditions. While this task requires a good knowledge of basic astronomy and observations, it does not require a PhD at all.

At the Canada-France-Hawaii Telescope (CFHT), the Service Observer

(SO) positions created at the onset of QSO only required a BA in astronomy, or physics with a minor in astronomy, ideally with already some knowledge of observation at the telescope, and with a real interest in handling observations for scientifically exciting programs on a large telescope with state-of-the-art instrumentation. All the SO recruitments, made over nearly a decade from a pool of passionate candidates, have been excellent. SOs have played a key role in the success of the observatory, accompanying the progress of the QSO mode initially limited to a single instrument toward the normal operation mode used all year long (but for a few nights with an old instrument used in classical mode).

4. Observing Alone?

When Service Observers started to replace observing astronomers, the observatory still needed an Observing Assistant (OA) to take care of the telescope and the overall facility while the SO was observing. The CFHT telescope is big in spite of its relatively modest mirror size, as it was conceived at the end of the 60s on a Palomar 5-m telescope model (Fig. 3). With more and more computer assistance added to the QSO mode, like an automatic slew of the telescope once an observation is selected, or automatic field acquisition and guiding setting once on a target, the role of the OA became limited to readying the observatory for observing at the beginning of the night and closing and securing it at the end of the night. During the observing itself, the OA's role was mainly to intervene and assist in case of problems. It became clear that one person, with appropriate training, could actually handle both the SO and OA duties. This would reduce the manpower needed for observing, therefore increasing the efficiency of the operations of the observatory. Unfortunately, at sites like Maunakea, safety is an issue as the working conditions are difficult (remoteness of the site and altitude) and having at least two people in the building is mandatory per the so-called "two-person rule". In order to really reduce the manpower needed at night, we had to think about not being at the telescope anymore during observing!

5. Nobody at the Telescope: Moving to Remote Operation

Retrofitting an old facility like CFHT to enable its remote operation is not an easy thing: after all, we are talking about a 250-ton of moving mass telescope, or a 580-ton dome, with their hydraulic drives and high-pressure oil running from the basement to the dome floor, hundreds of meters of hoses carrying glycol running all over the telescope and its instrumentation, ... Is it really feasible to replace all the monitoring carried out by an OA and all the interventions a person could do at night at the facility by

Figure 3. The CFHT telescope. (© CFHT)

remotely-controlled functions accessible on a screen and through the click of a mouse?

Actually, not only it is feasible, but it brings much more than just the possibility of remotely operating of the facility! An example: replacing reading a pressure gauge at the beginning of the night to check that pressure is nominal by a pressure sensor opens the possibility of continuously controlling the pressure through a script reading the value, sending a warning when a significant increase or decrease, or a significant change rate, are detected, therefore preventing a failure before it occurs! Add to the script an automatic notification through text messages on smart phones, write as many scripts for as many sensors as you deem necessary for safe operations, and you end up with technical staff faced with more advance notice of potential failures and consequently much less actual ones: the operations move from fighting fires to well-informed preventive maintenance and preemptive actions. The decrease of the amount of time lost to technical problems is now well below 2% of the clear weather, an excellent reliability for an old facility equipped with complex high-tech instrumentation. The peace of mind given to the technical staff has been a very important outcome of the move to remote operation.

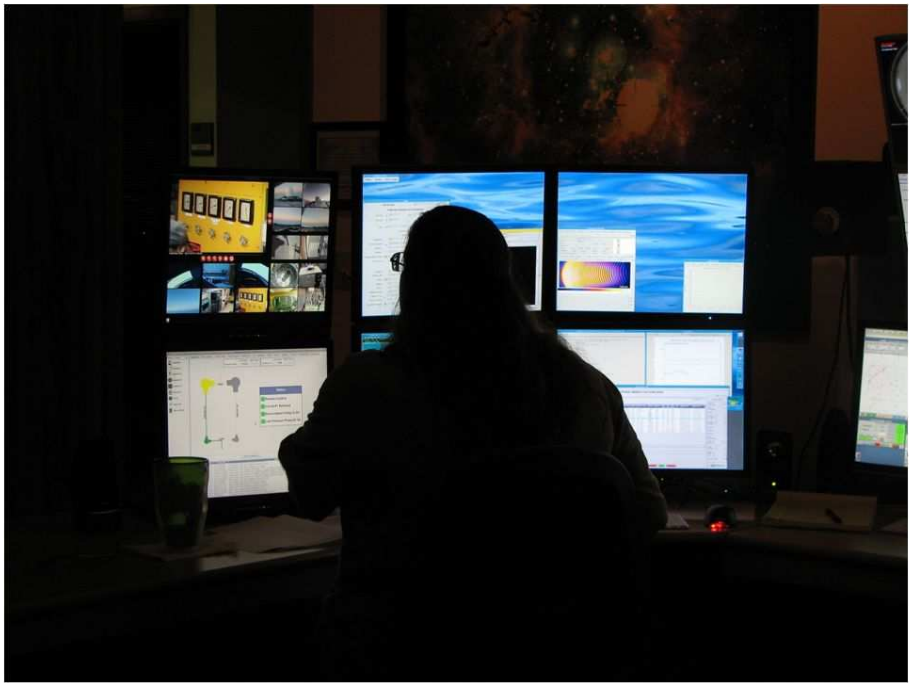

Figure 4. Remote Observer at the helm of CFHT from Waimea. (© CFHT)

6. A Single-Handed Observing Facility

Now that the telescope can be operated remotely, the stage is open for single-handed observation, which requires merging the Service Observer and Observing Assistant positions in a single one, called Remote Observer (RO). The SO contribution is the most demanding as it requires a good knowledge of astronomy. The OA duties are now greatly eased by much computer assisted functions. The training process of the OAs and SOs toward filling the newly created RO positions has been long and at times challenging, but overall very successful. CFHT is now operated at night by a single person running everything (Fig. 4). The observing is done in a much better environment: a normal level of oxygen in the brain facilitates decision-making and the easy drive to the headquarters removes the hazards of driving the summit road to the observatory at 4200m elevation.

Remote observing, especially when the telescope is at a remote site, is highly beneficial, without real technical drawbacks: most of the subsystems of the building, telescope and instrumentation are instrumented to be remotely controlled. Major failures will still happen. However, the presence, or not, of the observer at the telescope does not change the fact that they will always require the appropriate staff to go to the telescope and fix them.

7. A Shift in Duties for the Observatory Astronomers

Among staff astronomers' duties, the support provided to the visiting observing astronomer is critical to the scientific productivity of the observatory. As already mentioned, the degree of preparation of the visitor is highly variable and the support astronomer is often the only way to insure a successful run.

In QSO mode, the role of the staff astronomer becomes even more critical. It starts with the preparation of the so-called Phase 2, in which the PIs who are allocated observing time prepare their observation through a web-based interface, through which they detail the requirements of their scientific program, including those on the environment (image quality, sky transparency and background level, ...). The staff astronomers check the programs once entered in Phase 2. If needed, they request additional information from the PIs or propose them a better strategy. At this point, everything is ready when the time comes for scheduling the observations.

The validation of the data from the previous night and the preparation of the queues for the coming night are handled by the Queue Coordinator (QC), a role generally handled by a staff astronomer, but which can also be performed by a trained Service Observer. Data validation is greatly assisted by the near real-time assessment of the data made by the RO at the time of the observations.

The final involvement of staff astronomers in the observing process is related to data processing. At CFHT, an observatory-run data processing pipeline is mandatory for any instrument to be used in QSO mode. It makes a big difference in the usage of the data by the PIs: as data are ready for scientific analysis, there is a faster turnaround time between the data acquisition and the publication and less time is spent on non-creative work.

During this process, it is very important to maintain a good communication stream between observatory staff and PIs: observing astronomers coming to the telescope allowed a direct connection between the community of users and the observatory. Now that no one is coming anymore, this communication stream is the main link between a facility and its user base.

A last aspect of QSO operations staff astronomers, and observatory management at large, must keep in mind is that the overall queue process has to be flexible, in spite of the desired rigidity inherent to the operation of a complex facility. CFHT's experience is that maintaining flexibility has been indeed paramount to the success of QSO and to the buy-in of its users. In addition to allow for post-Phase 2 changes, as long as they

Figure 5. A florilege of elliptical galaxies observed using LSB (Duc *et al. 2011*. (© CFHT/CNRS/CEA)

are explained and clearly communicated, this flexibility means also to be ready to offer new modes of observing or new strategies which were not necessarily thought off when QSO started. Two striking examples: (1) The "Staring Mode" used on CFHT's Wide-Field Infrared Camera (WIRCam) enabling the observation of secondary transits of exoplanets through sub-millimagnitude precision photometry over several hours (Croll *et al.* 2010). (2) The Low-Surface-Brightness (LSB) mode (Fig. 5), used with the Wide-Field Imager MegaCam to study the extent of the halo of elliptical galaxies showing that they are far from being "dead", as they exhibit clear signs of recent merging activity (Duc *et al.* 2011).

Because these new modes were handled at the observatory level as significant additions to the overall QSO mode, they were made, once tested, readily available to all users instead of only the PI who requested them. They are therefore used for much more than what was initially intended: another way to significantly enhance the scientific potential of the observatory.

8. A Model for Other Facilities?

QSO is particularly well suited to observatories serving a large and diverse community. At a private telescope, there will be some reluctance to move to such a mode as users tend to think that they are entitled to coming to "their" telescope and observe themselves, and often think that they know better than anyone else how to observe for their own program. Actually, their reaction is similar to what was observed with some PIs at CFHT in the early days of QSO. In that respect, it is interesting to see that CFHT and Gemini, both open to many national communities, are observing, at least partly for Gemini, in queue mode, while the W.M. Keck observatory is only used in visitor mode.

In spite of the initial reluctance of some CFHT users, one must recognize that none of them would want the observatory to come back to the old "visitor" mode: PIs don't have to travel and learn the intricacies of the instrumentation; their observations are always taken under the right conditions, including calibrations of good quality; their data are validated and pre-processed by the observatory. For the observatory, operations in queue mode are more efficient and the overall productivity of the telescope is better, as there is better use of telescope time, with observations prioritized according to the importance of the scientific programs (as ranked by the time allocation committees).

Service observing led to the emergence of the new profession of service observer, who handles the scientific operation of the telescope at night. At remotely operated telescopes, another new position was created: remote observer, who handles the overall operation of the observatory single-handed. In the meantime, staff astronomers saw their duties evolve, with more implication in a wide range of ongoing scientific programs. They now actively participate, with much dialogue with PIs, in the preparation of the observations and their validation.

With remote observing, the technical staff has a chance to monitor the observatory with the help of computer-assisted alert systems and watchdogs, allowing more preventive actions instead of "fighting fires". The resulting peace of mind is a real relief for all involved in the operation of the observatory.

As Extremely Large Telescopes (ELTs) are contemplated, we can hope that they will operate in QSO mode: the gain in efficiency will be even larger than for any existing telescope, as the cost of a unit of observing time will be much higher as ELTs will be worth more than one billion dollar in investment only!

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