Principles of queued service observing at CFHT

N. Manset*, T. Burdullis, D. Devost
CFHT 65-1238 Mamalahoa Highway Kamuela HI 96743 USA

ABSTRACT

The Canada-France-Hawaii Telescope started to use Queued Service Observing in 2001, and is now operating in that mode over 95% of the time. Ten years later, the observations are now carried out by Remote Observers who are not present at the telescope. The next phase at CFHT will likely involve assisted or autonomous service observing, which would not be possible without first having a Queued observations system already in place. Some of the advantages and disadvantages of QSO at CFHT are reviewed here. The principles of QSO at CFHT, which allow CFHT to complete 90-100% of the top 30-40% programs and often up to 80% of other accepted programs, are presented, along with the strategic use of overfill programs, the method of agency balance, and the suite of planning, scheduling, analysis and data quality assessment tools available to Queue Coordinators and Remote Observers.

Keywords: Queued scheduling, Service observing, Classical mode, flexibility, efficiency

1. INTRODUCTION

Each observatory has its own mode(s) of operations, which is chosen to meet needs and requirements (coming from Principal Investigators, or scientific programs such as surveys, or the arrangements between various participating agencies), and have to take into account other operational parameters (e.g. the ability or not to switch from one instrument to another within the same night, and the skills of the available staff).

The main concept behind the Queued Service Observing (QSO) mode at CFHT[1,2] is to execute programs only during the sky conditions (seeing, background, clouds, etc.) requested by Principals Investigators (PIs) in order to meet the programs' science goals. Roughly one third of the telescope time is also used for various Large Programs. All programs are grouped in a database and appropriate observations are selected according to a set of constraints, rules and sky conditions. Programs are then carried out by a well-trained local team of observers in a service mode (i.e. investigators are not present at the observatory). The QSO mode is offered with CFHT's 3 main instruments, the visible imager MegaCam, the infrared imager WIRCam, and the spectropolarimeter ESPaDOnS. Each instrument is scheduled sequentially in blocks of time on a semester basis.

One general but key advantage of QSO at CFHT is flexibility. CFHT carries regular and Target-of-Opportunity programs that request as little as a few minutes up to hundreds of hours, and can execute observations prepared only a few hours in advance. The order of the observations can be re-arranged within a night or moved to a different night so that priorities, scientific return, data quality, and agency balance requirements can all be met. Observations of insufficient quality can be attempted again at a later time. Observations can be scheduled at precisely the desired time, to the minute if needed (e.g. an exoplanet transit). The telescope schedule can also be modified if a serious technical issue prevents the use of one instrument.

The Queued Service Observing mode used at CFHT offers many advantages over Classical Observing: higher efficiency on the sky (because Remote Observers are highly trained and observe frequently), high priority given to the most important projects (i.e., those highly ranked), observations carried under constraints specified by PIs (e.g. Image Quality requirement), very short observations possible (e.g. 2 hrs), unexpected and short notice events can be observed (e.g. Gamma Ray Bursts). QSO started in 2001 with CFH12k, and is now used with MegaPrime (2003), WIRCam (2005), and ESPaDOnS (2008).

The QSO Team at CFHT consists of a QSO Manager, a QSO Operations Specialist, a systems programmer, a database specialist, four Remote Observers, and a variable number of Queue Coordinators.

* manset@cfht.hawaii.edu

2. TYPES OF PROGRAMS, GRADES, AND PRIORITIES

2.1 Types of programs

Three types of programs can be carried under QSO at CFHT:

1. Regular programs: default type of program requesting good sky conditions and having known targets.
2. Target-of-Opportunity programs (TOO): programs for which the targets are not known in advance.
   a. Programs submitted at the regular time and as a Regular QSO programs, before the deadline, but for which targets will be identified during the semester (e.g. candidates discovered during a survey on another telescope)

   b. Programs submitted during a semester to observe unpredictable objects (e.g. supernova). The program is submitted through a special Web form (available on the QSO page) and approved according to the CFHT policy. The observations can be carried out the coming night.
3. Snapshot programs: regular programs requesting the worst sky conditions (Image Quality over 1.2", and preferably non-photometric conditions). Snapshot programs have to be simple (e.g. using broad-band filters only, and without time constraints), preferably have short observations, and have to be scientifically useful even if only a small fraction of observations are obtained. Snapshot programs are not charged to the agencies.

2.2 QSO program grades, overfill C programs, and snapshot programs

The proposals accepted by each agency's Time Allocation Committee are split into A and B programs, for MegaPrime, WIRCam, and ESPaDOnS, with a 30/70 to 40/60 ratio of hours. The QSO Team chooses appropriate C programs to overfill the queue. The chosen C programs are usually close to the cut-off line and are suitable as overfill programs (for example, they use an Image Quality which is not requested much, or they have targets in a range of RA not used by accepted A and B programs); C programs only represent a small fraction of the available programs entered in the database (10-20% usually). Snapshot programs, which must request an Image Quality (IQ) greater than 1.2" and have to accept extinction, are usually also accepted. The table below presents the priority given to the QSO grades and the approximate fraction of the telescope time given to A and B programs; since C programs are considered as overfilling the database they are not counted in the last column. Snapshot programs are not accounted for and are not charged to the agencies.

Table 1. Program grades and their corresponding share of telescope time

Grade	Grade name	Global priority	% of telescope time
A	Must do	Highest	30-40
B	Prioritized	Good	70-60
C	Best effort	Medium	N/A
S	Snapshot	Lowest	N/A

Since fewer hours are labeled "Must do" than "Prioritized", it is possible to focus on those A programs first and usually get completion rate of at least 80%, often up to 100%. The completion rate is simply the ratio of the number of hours observed which met the program's requirements and the total number of hours requested. The B programs have a lower priority than the A programs, and therefore usually get a completion rate in the 60-80% range. When bad weather or technical issues impact the success of programs, the A programs, which are the most important scientifically speaking, are less (if at all) affected. On the other hand, if the weather is exceptional, it is not uncommon to complete A and B programs, and provide some C programs with 50-100% of the requested data.

3. PHASE 2 TOOL FOR PI

Each accepted program must be entered in CFHT's database using the Phase 2 Tool (PH2). This web-based tool allows PIs to list their targets and sometimes add finding charts, configure their observations (instrument, filter(s), mode(s), exposure times, etc.), specify acceptable constraints (Image Quality, airmass, background), and schedule observations for specific times or with a monitoring period, if desired. Except for one optional tool, PH2 does not include any Java code. It is entirely developed around JavaScript and the ColdFusion language. Some of the information entered during the proposal phase, Phase 1 (Title, Abstract, contact information, target coordinates) is automatically transferred to PH2.

Observation Groups (OGs) are the entities selected from the database, put in the queues, and executed at the telescope by the Remote (Service) Observer. The entire architecture of PH2 and its database is based on the concept of Observation Blocks (OB); each OB is made of one (and only one) target, one (or many) instrumental configurations, and one (and only one) set of sky constraints. Each target, configuration or constraint is a unique entity and has a unique label. A target, configuration, and set of constraints may be used more than once, to define various OBs and OGs. Since it is easier to schedule short observations at the telescope, there is a limit of 2 hours (7200 seconds) for the total integration time of one individual observation block.

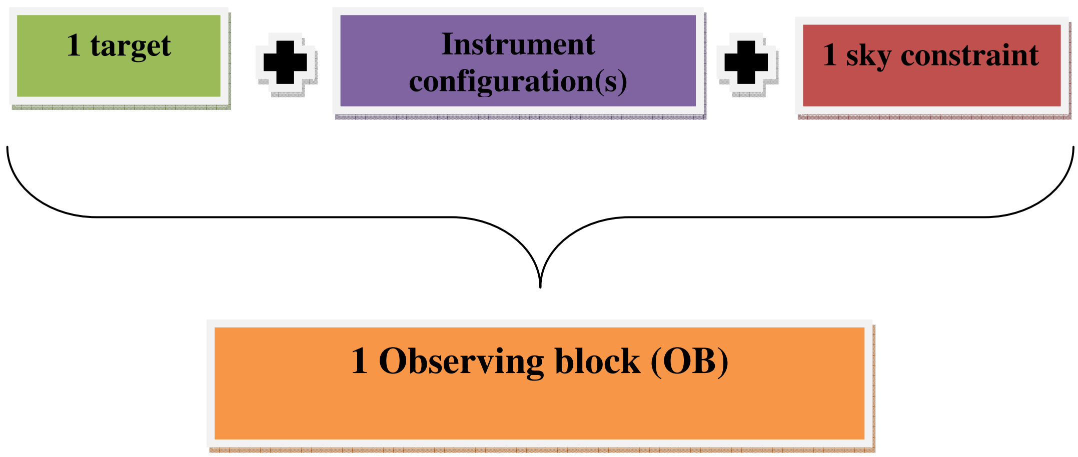

Figure 1. The basic unit of the Observing Block (OB).

Targets can have fixed coordinates, or coordinates defined by ephemeris. For each instrument, tools are available to bring up finding charts and refine the pointing or the identification of the target. An Instrument Configuration (IC) consists of a filter, exposure time, and dithering pattern (for an imager), or an observing mode, exposure time, and Stokes parameter (for ESPaDOnS). An IC can be used in more than one OB and OG, so there is no need to duplicate identical ICs. Constraints concern the desired Image Quality, sky background level, and airmass range. A set of constraints can be used more than once, so there is no need to duplicate identical sets.

To add more flexibility to PH2, the concept of Observation Groups (OG) has been introduced. Three different types of OGs are available: 1OB (simple OG made of one OB, the most common case), SOB (sequence of linked OBs, for example, to use more than one filter, one after the other), MOB (OB with some monitoring parameter).

Several OGs can also be linked together (e.g. "if you observe OG5, observe OG6 30minutes later") or subject to a schedule (for example, to observe during a specific phase of a periodic event).

4. THE ROLES OF CFHT STAFF MEMBERS

Each day during a QSO run, a CFHT astronomer is the designated Queue Coordinator (QC) and prepares various queues suitable for the coming night, based on PI requests for Image Quality and sky conditions, and ranking of the programs. A suite of QSO tools is used to query the database, select OGs, save various queues, and get a graphical representation of each queue. Additional tools such as an almanac, and statistics tables and graphs also provide the QC with information useful to plan the observations. "A" programs are given priority, followed by "B", "C", and Snapshot programs. Queues are also made as much as possible to give each agency its share of the night; if an agency has 30% of the allocated time on a given instrument, it will be found on average in about 30% of each queue.

At night, depending on the sky conditions, the CFHT Remote Observer (RO) selects and executes one or more queues using an Observing Tool. Automatic analysis of images or spectra provide the RO with tools to assess the quality of each image in almost real-time. Each exposure receives a grade indicating the quality of the data (grades 1 and 2 are good for the science proposed), and most exposures also receive comments about sky conditions, technical issues, etc.

The next morning, the QC reviews those grades and comments, which will be made available to the PI, and validates exposures which are good enough for the science goals proposed; only validated exposures are taken out of a PI's allocated time. Exposures which are not validated will be attempted again if possible. The queue efficiency, that is, the ratio between the number of observations carried out and observations validated, is around 90%. This is a measure of how well the RO can adapt to sky conditions.

The majority of QCs are resident astronomers, whose scientific background has proved invaluable in making subtle scheduling decisions based on scientific arguments, and in identifying technical issues that can impact the data quality. However other experienced staff members without a graduate astronomy degree can also act as QC, with or without the supervision of a resident astronomer. The Remote Observers generally do not hold a graduate degree, but are highly trained. Their experience makes them experts at operating the telescope and instruments, at taking calibrations in the most efficient way, and at making the optimum use of the sky conditions.

5. GENERAL QUEUE RULES

Preparation and execution of queues at CFHT follow three steps:

1. Selection: observations stored in the database are selected by the QC according to instrumental constraints, sky constraints, actual sky conditions, completeness level, and the position of the targets.
2. Ordering: selected observations are put by the QC in a prioritized list (the queue) to be sequentially executed according to the grade, rank, target positions, time constraints, user's priorities, etc.
3. Human filtering: the RO may modify the order in a queue according to special constraints like focus sequences, filter change, calibration plan, etc.

Here are a few general rules that the QSO Team follows:

- Images will not be obtained in worse IQ (or sky brightness) conditions than requested. The IQ (sky brightness) measured should not exceed the upper limit of the IQ band (sky brightness) requested by more than 10-15%.
- Images can be obtained in conditions better than requested, if no other observations actually requesting these conditions are available.
- If the IQ>1.2" or the sky is non-photometric, the snapshot programs requesting bad conditions will be executed, unless other possibilities exist among the regular programs.
- The priority of the programs started is automatically increased compared to programs not started.
- When possible, the observations will be tentatively done with airmass smaller than 1.5.
- During selection and ordering of the queues, the priority goes from grade A to B to C, followed by the snapshots. Inside these grades, priority is given according to the Time Allocation Committee rank as much as possible.

- Balancing Agency time has a very high priority and might exceed the other selection and ranking criteria.
- The observations are executed according to the priority index (high, medium, low) given by the PIs during the Phase 2 period.
- A QSO run should never be completed without getting all the necessary calibrations for all the programs fully or partially executed during the run.
- All fields requesting photometry and done during non-photometric conditions will be calibrated with short exposures during photometric periods.
- No programs will be recycled for completion during the next semester.
- When started, a monitoring program receives a higher priority so that the observations to be repeated can be carried out within the specified time frame period.
- The QSO Team will always try to obtain the requested number of observations for a given monitoring program. In case of other constraints, the minimum number of observations specified during Phase 2 is the minimum acceptable.

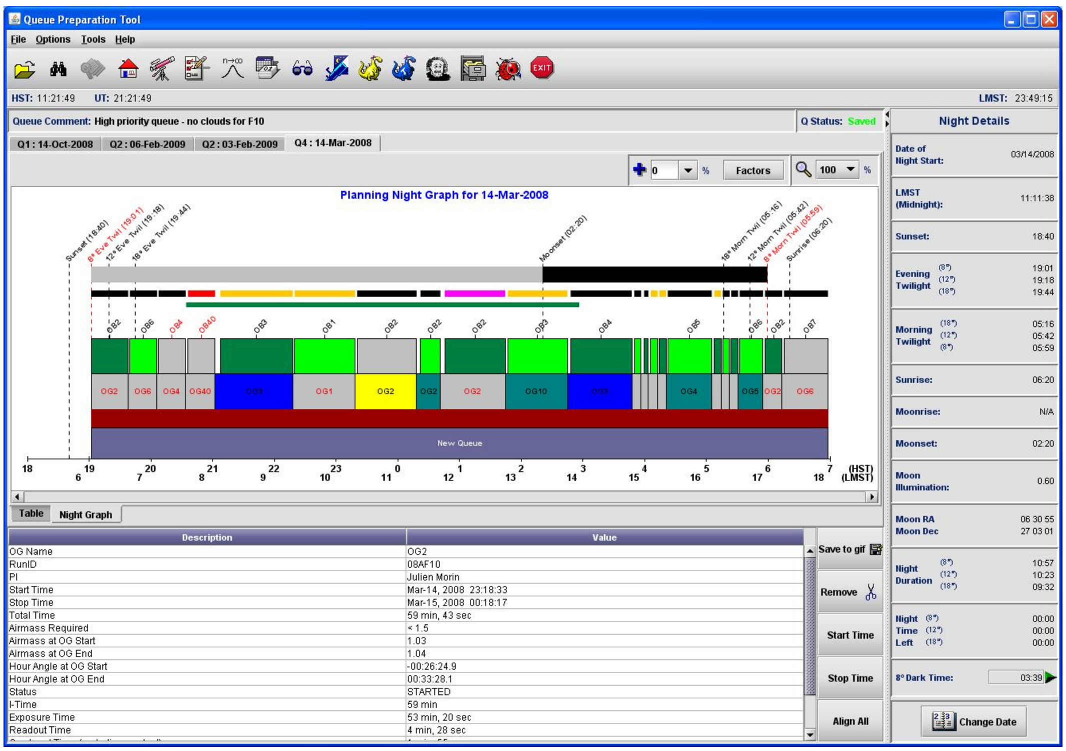

Figure 2. An example of a queue represented in a graphical form.

6. RELATED SERVICES

6.1 Calibrations

For all instruments, appropriate instrumental calibrations are obtained by the QSO Team only (biases, darks, dome and/or twilight flats, lamp exposures, fringe frames). Broad-band photometric standard stars and astrometric standard fields are also taken for the imagers; no spectrophotometric standard is taken with ESPaDOnS. Narrow-band calibrations (for the imagers) must be included by PIs in their proposal and PH2. The calibrations are public and shared among all programs to optimize the quality of the data reduction.

6.2 Night Reports

The QSO schedule is available on the QSO web page and updated whenever there is a change. During a QSO run, Night Reports are available on the web, and provide weather information and a log of validated exposures for each QSO night. PIs are responsible for following the progress of a QSO run and the progress of their program in particular.

6.3 Data reduction and distribution

Data are detrended after each run (MegaPrime and WIRCam) or reduced after each night (ESPaDOnS) by a team of astronomers and software engineers, using custom pipelines developed at CFHT (see Table 2). PIs who request immediate (or quick) access to their data can receive raw data or detrended data as soon as available. When data are ready, PIs receive an email from CFHT with the location of their data; the data (detrended, and raw for some instruments), documentation, instructions, weather information, and metadata are downloadable from a private URL with a unique key sent to PIs.

Table 2. The three main pipelines used at CFHT to detrend or reduce data

Elixir	MegaCam	Bias, flats, photometry, astrometry
I'iwi2	WIRCam	Bias, flats, photometry, astrometry, sky subtraction
Libre-ESpRIT/Upena	ESPaDOnS	Bias, flats, extraction, wavelengths, polarization

7. COMPARISON BETWEEN CLASSICAL AND QSO MODES AT CFHT

Classical mode at CFHT	QSO mode at CFHT
The telescope schedule does not reflect the rank, priority, or importance of programs.	All programs are executed according to their grade and rank.
Night(s) during which a program is scheduled are not always optimal with respect to the coordinates of the target(s).	The observations are carried at the optimum time for each target (minimum airmass, or specific time as requested).
The top tanked programs are not guaranteed to get data.	The top 30-40% programs get 100% completion; the remaining 60-70% of the programs get 60-80% completion.
Highly ranked programs can be impacted by bad weather or technical issues that occur on their scheduled night(s).	Highly ranked programs are executed first and scheduled again if necessary until they are completed.
Programs "under the bar" are not scheduled.	Some programs just under the bar are used to overfill the queue, in case the weather is much better than average.
It is difficult to request very short observations (less than 0.5 night).	It is possible to request observations as short as needed (minutes).
It is difficult to schedule a large program.	It is possible to schedule large programs.
The observer is not necessarily expert with instrument used.	The CFHT Observers are experts with all instruments, and observe on average one month per year on each instrument.
Observers usually do not share calibrations such as twilight flats.	Calibrations such as twilight flats are shared over many nights (over one run). This improves the quality of the data reduction.
The observer has to reduce his own data.	Data are detrended (and even reduced) quickly, distributed to PIs either the next day before noon (ESPaDOnS) or within a few days after a run if requested (MegaCam and WIRCam).
It is very difficult to insert in a target of opportunity program (GRB, asteroid, etc.)	New programs and targets can be added at any time, up to a few hours before a night, and executed that very night.
Due to lack of expertise, the calibrations taken are not always optimum (in number or quality).	The best calibrations taken because CFHT has the expertise, experience, and tools needed.
The agency balance is at the mercy of weather and technical issues.	It is possible to finely balance the fair distribution of successful observations between all agencies, by selecting appropriate programs.

8. THE FUTURE OF QSO AT CFHT

The success, efficiency, and flexibility of QSO have made it the default mode of operation at CFHT. CFHT is planning the construction of new instruments, which will also be remotely operated under the QSO mode. Apart from adding new instruments, QSO is moving towards Assisted Service Observing[3], which will help prevent mistakes (e.g. forgetting an important time constrained observations), speed up and make more uniform the data quality assessment and validation, provide Remote Observers with suggestions of what to observe when conditions change, and speed up the preparation of the queues. In an even more sophisticated Automated Service Observing mode, the concept of queue might even disappear altogether.

REFERENCES

[1] http://www.cfht.hawaii.edu/Instruments/Queue/QSOProjectDoc.html
[2] http://www.cfht.hawaii.edu/en/science/QSO/
[3] Mahoney, W., Thanjavur, K., "Artificial intelligence in autonomous telescopes", these proceedings