The Queued Service Observing Project at CFHT

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ABSTRACT

In order to maximize the scientific productivity of the CFH12K mosaic wide-field imager (and soon MegaCam), the Queued Service Observing (QSO) mode was implemented at the Canada-France-Hawaii Telescope at the beginning of 2001. The QSO system consists of an ensemble of software components allowing for the submission of programs, the preparation of queues, and finally the execution and evaluation of observations. The QSO project is part of a broader system known as the New Observing Process (NOP). This system includes data acquisition, data reduction and analysis through a pipeline named Elixir, and a data archiving and distribution component (DADS). In this paper, we review several technical and operational aspects of the QSO project. In particular, we present our strategy, technical architecture, program submission system, and the tools developed for the preparation and execution of the queues. Our successful experience of over 150 nights of QSO operations is also discussed along with the future plans for queue observing with MegaCam and other instruments at CFHT.

Keywords: queue observing, service observing, mosaic camera, queue software

1. INTRODUCTION

1.1 Queued Service Observing as a Concept

Since the introduction of wide-field mosaic cameras at the Canada-France-Hawaii Telescope (UH8K followed by the CFH12K, 8192 x 12288 pixels, mosaic camera), the demand for these instruments has become exceedingly high. About 35% of the total telescope time at CFHT is currently used by CFH12K and this fraction will increase by a factor of 2 in 2003 with MegaCam becoming fully operational (section 6.1). Most investigators propose programs which make strong demands on the capabilities of the instrument or the site. In particular, the best seeing available at CFHT is often required to meet the science goals. Some programs also include time constraints for regular monitoring of astronomical targets. Clearly, these constraints cannot always been met in a classical mode scheme, in which programs are granted fixed allotments of time becoming then vulnerable to poor weather, technical problems, and the inflexibility of a pre-defined schedule. Moreover, in such a mode, highly ranked proposals may suffer as a result of poor weather conditions whereas lower ranked ones may be completed. This can strongly impact the science productivity of the observatory and goes against the scientific priorities set by the Time Allocation Committees (TAC)

To address these issues, CFHT undertook the development of the New Observing Process (NOP) in 2000, which includes the Queued Service Observing (QSO) mode. The QSO mode was intended to replace the classical mode with CFH12K. The QSO mission statement is *to obtain astronomical data during the optimum sky conditions as requested by the investigators of a given science program.* While the primary objective of the QSO mode is to increase the science productivity of the telescope, another goal is to complete as many highly ranked programs as possible.

The objective of gathering *high quality* data in the framework of the best observing efficiency possible necessitated the development of several software components as well as new observing procedures. In this paper, we describe the technical development of the QSO Project and relate to our experience with this mode of operation during 150 nights since January 2001.

1.2 The New Observing Process

The QSO Project is a complex component of a broader observing system, the New Observing Process, developed at CFHT. The major components of the NOP and a simplified data flow are identified in Figure 1.

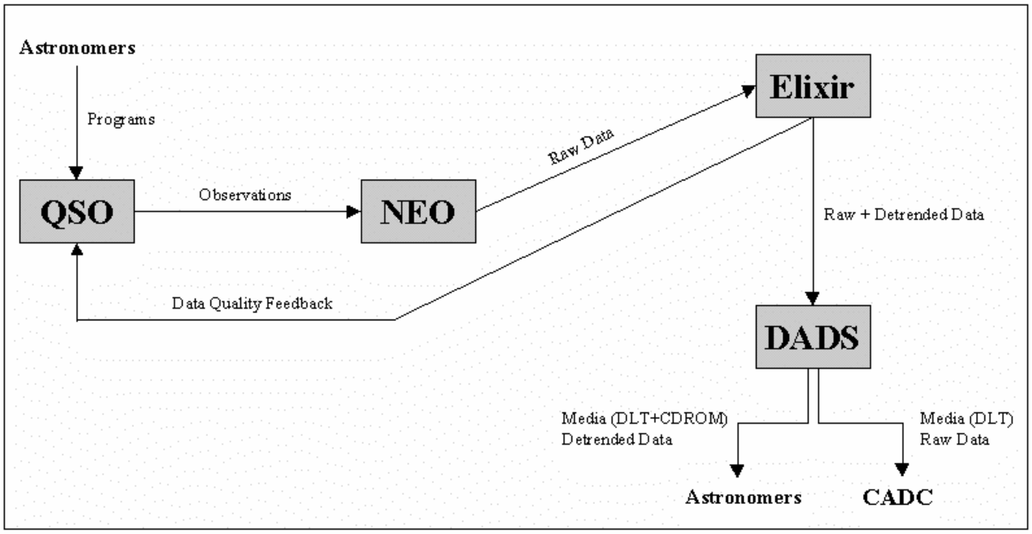

Figure 1. Components of the CFHT New Observing Process and Data Flow.

Each component of the NOP was developed as an independent project but with the common goal of acquiring data of the highest quality possible, then process and distribute them in a timely manner.

?? QSO: The purpose of the **Q**ueued **S**ervice **O**bserving project is to create lists ("queues") of science observations, which are prioritized and scheduled with telescope and scientific efficiency in mind. These observations are performed under the conditions specified by Principal Investigators (PI).

?? NEO: The **N**ew **E**nvironment for **O**bserving component provides the necessary functions to control the instrument and the telescope following a user command language. NEO is the central component within the observing process at the telescope. It has a simple command line interface to accept input and produces FITS files as output.

?? Elixir: This module produces "detrended" data (e.g. bias subtracted and flat-fielded) as well as photometric and astrometric solutions for the data. Elixir provides real-time image quality and sky background analysis during observations. Another Elixir pipeline provides sky transparency from a CCD camera mounted on the telescope.

?? DADS: The **D**ata **A**rchiving and **D**istribution **S**ystem ensures archiving and distribution of the raw and detrended data to the astronomers and the Canadian Archiving Data Center (CADC). Data are sent on DLT tapes and each PI receives a CD-ROM with ancillary information (e.g. data and weather logs) used for interpreting their science data.

2. THE QSO MODE: OVERVIEW

The QSO software components were developed around several key steps which lead to the acquisition of the data within the specifications requested by the investigators. The steps involved in the QSO mode are as follows:

1. *Proposal Submission:* The proposal submission is done in two different tiers. The *Phase 1* is done twice a year through the CADC web interface Poopsy. This tool populates a relational database and produces a printable Latex version of the proposals for evaluation of their science merit by the Time Allocation Committee. After this evaluation process, each accepted program for a given Agency (C,F,H, Korea) receives a priority *grade* (A, B, or C, the latter being considered for overfilling the queue database). A special "snapshot" (S) category also exists for programs requesting mediocre sky conditions. Within each grade for a given Agency, each program also receives a *rank*. Finally, each program receives a certain amount of "*integration time*" (I-time, in hours) which includes only the overhead for the mosaic readout time. Relevant information (e.g. Investigators, Abstract, Target list, etc.) is then transferred from the CADC database to the QSO database in preparation for the second submission phase. During *Phase 2,* PIs precisely define the observations to be performed using an online submission tool named PH2. This tool directly populates our database and is accessible on the CFHT web site as well as on the CFHT mirror site in

France (hosted by CDS). An overview of PH2 is provided in the next section. The Phase 2 period spans about 5 weeks and is usually completed several weeks before the beginning of a semester.

2. *Queue Preparation:* Several tools have been developed for preparing the observing queues. An overview of the QSO Tools suite is described in section 4. The tools are first used to prepare and display queries of the Phase 2 database using parameters such as image quality, sky background, target position, or time constrained observations. The query results are sorted and scheduled into about 6-8 queues covering a variety of conditions for a given night. Photometric calibration fields (Landolt standard stars) can be included as well. The queues are prepared with the assistance of a graphical tool for visualizing a night and other tools such as a sky almanac, a target map, a statistics calculator, and a program viewer for examining individual scientific programs. These queues are then saved in the database and ready to be observed during the night.

3. *Observations and Evaluation:* During the night, the Service Observer (SO) uses two other main components of the QSO system: the Observing Tool and the Electronic Logbook. Through the Observing Tool, the SO loads a prepared queue and has the ability to select a subset of observations to be performed. A secondary pending queue can be prepared while a primary queue is being observed for quick adaptation to changing conditions. The crux of the Observing Tool is a procedure ("breaker"; see section 4) which translates the information from the database into a list of commands which are sent to the NEO command line interface for controlling the camera and the telescope. When an exposure is completed, it is automatically inserted in the Electronic Logbook. Measured image quality and sky background can be inserted into the Electronic Logbook by Elixir when this information is available. The observer can then assign a quality grade and add comments for each exposure. The final evaluation of the data is done on the next day by the Queue Coordinator, a CFHT astronomer in charge of the process during a queue run.

4. *Night reports:* An essential aspect of all queue systems is to keep the investigators informed of the progress of their programs. Automatically generated night reports, including weather conditions and program statistics, are published on the CFHT web site as soon as the data are validated (see section 5 for details on the validation process).

3. THE QSO PHASE 2: DATABASE AND SUBMISSION TOOL

3.1 The QSO relational database

The QSO relational database is the backbone of queue observations. The software architecture of the QSO system revolves around this database, developed in-house specifically for queue observing. The database stores all the necessary information for the observations and contains logic to manipulate this information. It is where PIs store all the elements defining their programs. From this information, it is how the QSO Team filters and sorts the programs to plan the queues. Stored procedures in the database "break" the queues into a command set for communicating with the instrument and telescope. Resulting exposures are logged in the database, and data distributions are planned and tracked using this information. The vast amount of data that must be collected from the PIs about their programs, sorted and scheduled, while constantly monitoring what has and has not been observed makes a relational database management system (RDBMS) a necessity for effective queue observing.

The database is actually a collection of several independent databases, which can communicate with each others, all running on mirrored Sybase servers. The database where PIs define their programs is named PH2 after the web based application used to populate the database. This database is replicated on three Sybase servers, one at CFHT Headquarters in Waimea, one at CDS in France, and one at the summit of Mauna Kea. The database where queues are saved, exposures are logged and weather is logged is named OP which is short for 'operational' database. This database is replicated on the Waimea and Summit servers. Finally a database named DIS keeps track of exposures which need to be distributed and those which have been distributed. The reason for replicating the PH2 database in France is to improve the performance of the PH2 application for users in France. All three databases are replicated in Waimea and at the Summit so that the crash of one server will not halt observations.

The entire observing strategy of the QSO mode is developed around the concepts of Observation Blocks (OB) and Observation Groups (OG) (see section 3.2). A block is formed of one target, one or several instrumental configurations

(IC) (e.g. filter, dithering pattern, exposure time), and one constraint (e.g. image quality, sky background, airmass). One of the critical uses of the database is for tracking what has been observed. We use the concept of validation to accomplish this. Most data objects in the database have a status associated with them. For instance, when the requisite number of exposures for an IC is validated, a database trigger changes the IC status to “validated”. When the requisite number of ICs within a block is validated a database trigger changes the OB status to “validated”. Finally when the requisite number of OBs for an group are validated, the OG becomes “validated”. Lastly, when a program has 100% validated OGs it acquires a status of validated. With this automated validation cascade, it is easy to track what has been observed and what remains to be done.

The database also maintains a special program with automatically generated OGs for photometric calibration of science OGs observed in non-photometric conditions. OGs including all the filters requested by the science observation but with 1/10 of the science exposure time are created and carried out during photometric conditions, if necessary.

3.2 PH2: A Brief Description

PH2 is a web application written in ColdFusion and JavaScript used by PIs to populate our database. Since this is where the investigators define how (and sometimes when) their observations should be performed, *PH2 is considered the key of the entire QSO system*. After much deliberation, it was decided for the QSO Project that a web based application was superior to a standalone application which should be distributed to users, because it reduces the amount of time needed for supporting users across multiple platforms and for distributing upgrades. It is also much easier to provide support during the Phase 2 periods with a on-line tool since it is possible to follow the progress done on the different programs in real time. The tool has been developed to be compatible with major browsers (version 3 and higher) running under different platforms. The PH2 database and web application are replicated at CDS in France. This architecture provides a very robust system in case of interruption on one of the sites and improves performance for the French community.

As explained above, PH2 is developed around the concept of *Observation Blocks* (OB) and *Observation Groups* (OG). The tool mainly consists in a series of tables which users build to define their observations. For instance, they build a table of targets, instrument configurations, and constraints. These elements can then be combined in different configurations to create the blocks and the groups. Time constraints and monitoring parameters can also be specified. In QSO mode, an OG is the smallest unit that is scheduled and observed un-interrupted. An automated algorithm calculates the I-time requested by all the groups defined and compares it to the I-time allocated. Fields in the table are checked for mistakes during entry and the save procedure. The target form allows the possibility to upload and download a XML file and populate the table, and includes also tools (e.g. CDS’ Aladin) to view the field and redefine the target coordinates. An exposure time simulator is also available. PIs can also add information necessary for the data distribution, and write comments or special instructions unique to their program. An example of a form in PH2 is illustrated in Figure 2.

The user can define any number of OGs as long as they do not exceed their maximum allocated integration time. An OG is an arrangement of OBs and can consist of a) a single OB, b) multiple OBs to be observed in succession, or c) a single OB to observe n–iterations at some interval of hours or days (monitoring). The *maximum length allowed for an individual OG is 2 hours of integration time*. This limit is essential to keep the queue scheduling concept manageable; with longer OGs queue building would become very difficult in the restricted amount of time available during one observing night. PIs can assign a priority of High, Medium or Low to their OGs which the QSO Team will use for scheduling observations when there are multiple possibilities.

When the PI has completed his/her program, PH2 generates a summary (HTML) which is emailed to any number of recipients specified by the PI. We have also implemented a web-based Helpdesk system, available within PH2, for communication between the PIs and the QSO Team. The Helpdesk has private forums for each program visible only to that PI and CFHT staff as well as a public forum for general PH2 questions.

So far, the implementation of a web-based Phase 2 submission tool has been very successful and our users sent us very positive feedback about it. The advantage of being able to monitor progress of the programs in real-time during the Phase 2 cannot be overstated. Suggestions for the observing strategy and corrections can then be proposed to the users, saving them time and improving the chance of success for their program.

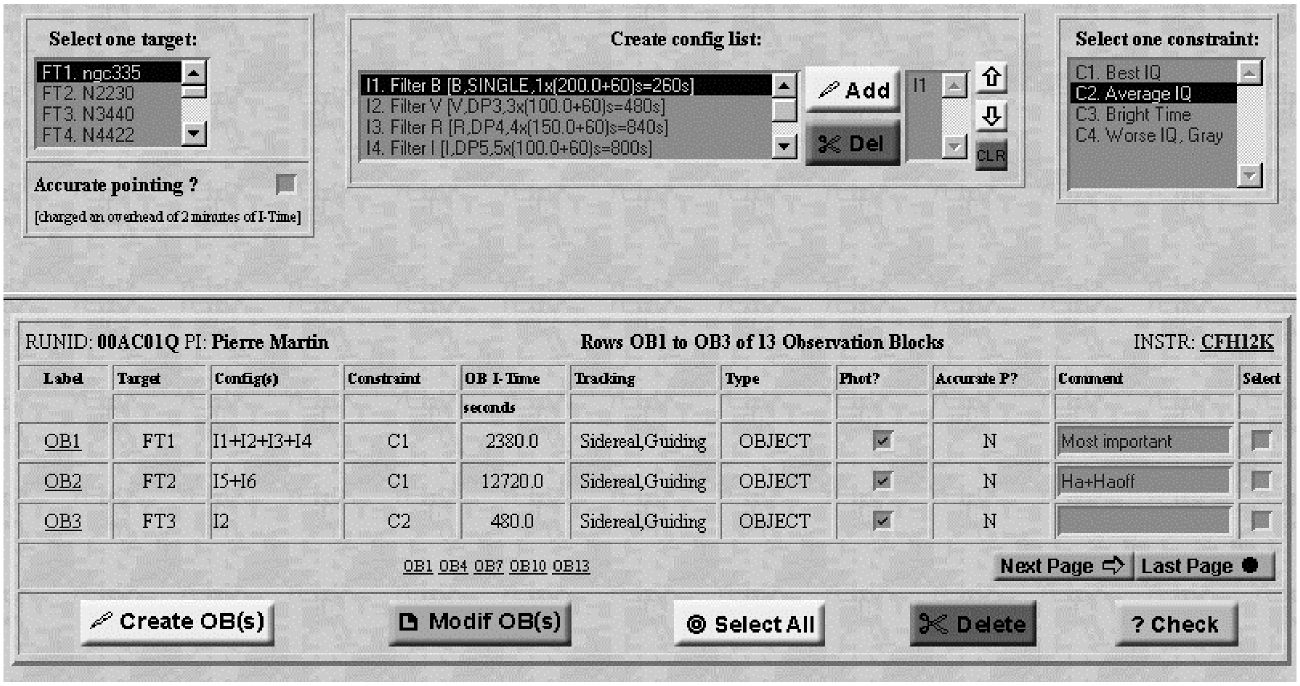

Figure 2. The Phase 2 Tool: the Observation Block form. At the top of the form, the lists of the targets, instrument configurations and constraints, defined on the previous forms, are displayed. The user can then combine these entities to define a block (table row) by selecting the desired elements and clicking on "Create OB(s)". PH2 is very easy to use; an experienced user can define a complex program spending several hours of telescope time within 15 minutes.

4. QSO TOOLS SUITE

The QSO Tools are designed to easily query and display the contents of the Phase 2 database, act as an interface for sending commands to the scientific instrument, and finally as a tool to record information back in the operational database which contains all logs. The tools were written entirely in Java because of its portability and its well developed database API. Supporting multiple platforms was also a concern which Java successfully resolved, because CFHT staff use both Linux and Windows operating systems for QSO related tasks. There are three main tools within the suite for planning, executing and logging observations.

4.1 Queue Preparation Tool

The Queue Preparation Tool (QPT; see Figure 3) is the component used to prepare queues for a night of observing. To prepare a queue, the user opens a query wizard and specifies parameters to search for such as: Date, Agency, Program Id, Grade, Program Status, Target Position, Filters, Image quality requested, Sky Brightness, Program completeness, etc. Database stored procedures apply the search criterion and return a result set of OGs. The Queue Coordinator chooses a subset of OGs to observe from the list returned by the database. The Night Graph (Figure 4), a graphical representation of the queue, is primarily used to sort the OGs into the most efficient order for observing. The Night Graph displays night duration and twilight times, Moon information, target airmass during an OG, sky brightness and slew time estimates between targets. An overhead can be applied to the queue in the Night Graph to approximate actual observing times and assist in scheduling. The night graph is also used while observing to adapt queues and plan which OGs to execute in the remaining night time.

Figure 3. The Queue Preparation Tool is used to query the database and build queues. Observation Groups are displayed here in a table with descriptive and status information. Rows can be manipulated to change the order of the observing sequences to improve efficiency. Each queue has an associated Night Graph as in figure 4.

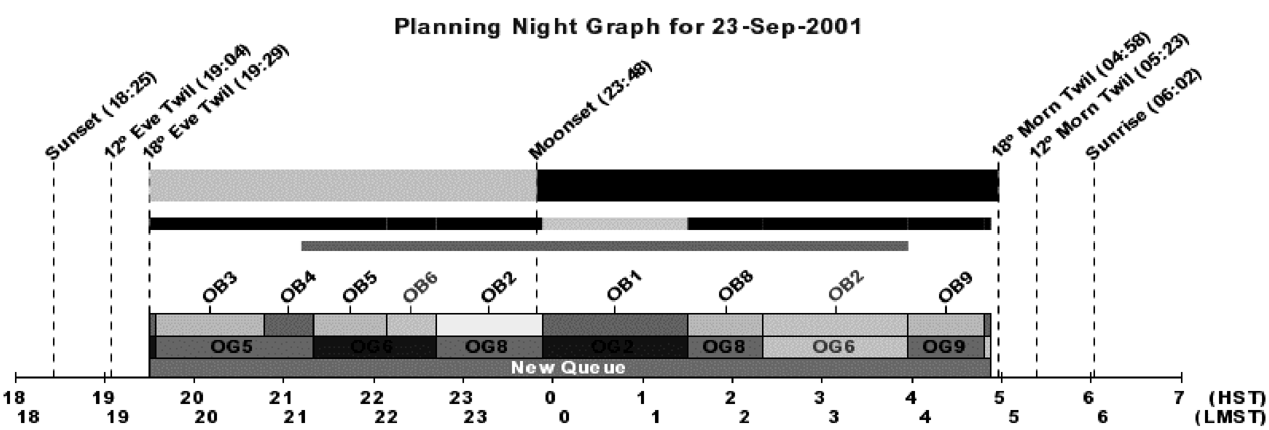

Figure 4. The Night Graph is a graphical display of a queue with important rise and set times. Critical airmass values for an OG are graphically displayed and color coded when it is clicked. Blocks can be moved around to find the best solution for the observing sequence covering the entire night.

4.2 Observing Tool

The observer uses the Observing Tool (OT) during the night to load and execute the prepared queues at the telescope. When a queue is loaded it is displayed on the left hand panel as a tree and on the right hand panel as a table of commands to be sent to the instrument control software (Figure 5). To reduce the probability for error, all manipulations to the queue are performed on the tree. Instrument control commands can be edited directly in the command table, but it is a practice reserved for test or emergency situations in order to prevent possible mistakes in either FITS Headers or actual instrument commands. The most common operations performed are to enable or disable OGs and insert or remove focus and pointing check exposures. Any OG or part of an OG can be enabled or disabled in the tree. Only enabled tree nodes can be selected and sent to the telescope when the “Send Selected” button is clicked. A pending queue tab in the OT allows the observer to load a backup queue and select OGs for observation. When it is time to switch queues, the observer clicks a button and can immediately begin sending commands. The OT also has a night graph that tracks the progress of the night as it unfolds. The OT can be cloned so that several persons can follow the progress of the observations.

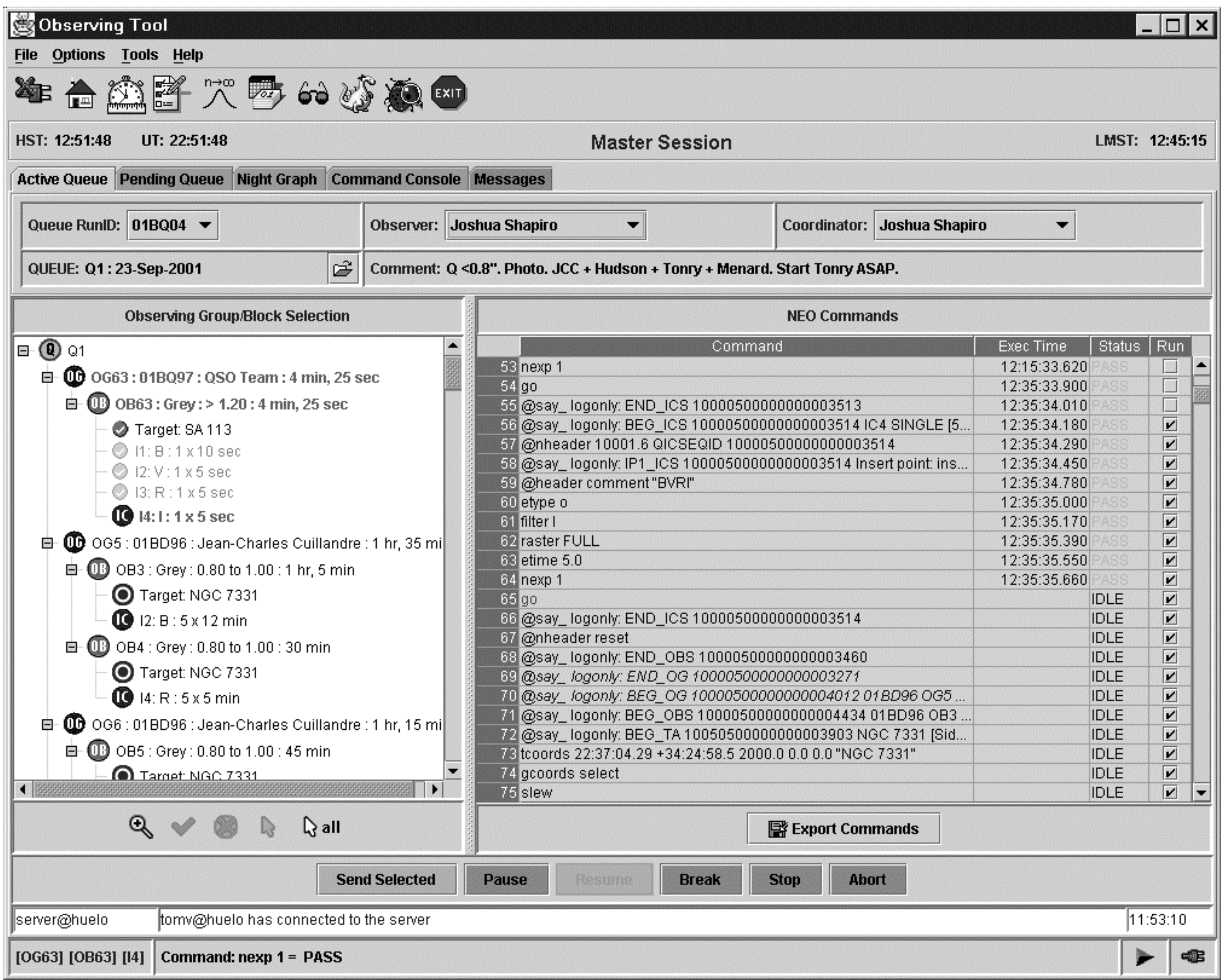

Figure 5. The Observing Tool is used to load queues, add focus sequences, and select OGs to send to the camera and telescope. The left panel displays the queue as a tree of OGs, OBs and ICs; the right panel displays the queue as a list of instrument and telescope control commands.

4.3 Electronic Logbook

When an exposure is completed and the FITS file is saved, a script is called which notifies the database of a completed exposure. The database ingests the FITS Header for that file to fill in fields for later reference. A real time component of Elixir is also notified of the exposure and produces a measurement of image quality and sky background levels. When these measurements are complete, they are also pushed into the database. Any discrepancies between requested exposure properties and actual exposure properties are automatically noticed and colored red by the logbook. The observers can then choose an evaluation grade (section 5.3), add specific comments and update the exposure in the database. Any computer with a secure connection to the database and a distribution of the QSO Tools is able to immediately use the electronic log to see what has been observed.

4.4 Auxiliary Tools

There are a few auxiliary tools that are useful for planning the queues and monitoring the progress of the semester. The Sky Almanac displays useful sky information such as rise and set times for any date. The Statistics tool displays statistics about observed and completed observations categorized by either program or agency. This is especially useful for ensuring a good agency balance. The Target Distribution Tool plots all the targets on a map of the sky along with solar system objects and the local horizon for any time. It can be used to identify potentially unobservable targets as well as quantify the amount of time requested for different filters for any region of the sky. One of the most useful auxiliary tools is the Program Viewer, which displays a summary of a selected program the way it was entered in PH2. The Program Viewer color codes validated objects so it is easy to tell at a glance what remains to be observed in a program, or to gather global statistics information on a semester.

5. QUEUE OBSERVING AT CFHT

5.1 Principles and Rules

When QSO was in its infancy at CFHT, three "Golden Rules of QSO" were specified:

1. The observations should ***never*** be performed under worse sky conditions than the ones requested by the investigators during the Phase 2 submission tier.
2. The queue planning process should optimize the total observing efficiency of the camera and telescope.
3. A high level of completion for as many programs as possible is preferable to lower completeness for a larger number of programs.

In addition to these three rules for QSO, CFHT maintains an additional rule specific to our observatory:

4. Agency Balancing **-** The relative fraction of time spent observing for a given agency (e.g. C, F, H, K) must be equal to the relative fraction of time that Agency requested in the queue mode.

The above maxims were originally specified as rules but it is perhaps more appropriate to categorize them as goals. We approach queue observing with the above goals in mind and do what we can to achieve them. However we have discovered that no rules exist that apply to all observing conditions and programs. This is primarily the reason that no dynamical algorithm for planning and scheduling queues has been developed as of yet.

As each semester comes to a close, some of the above goals take a higher precedence over others. The rule stating that observations should never be performed under worse sky conditions than the ones requested will sometimes be "stretched" (after consultation with the PI) in an effort to achieve a high level of completion for high ranked programs. However, we never compromise our efforts to achieve higher observing efficiency, or abandon the goal to balance observing time between our respective agencies.

Our experience also benefits the PIs for understanding scheduling problems so that they can tailor their observations and improve their chances of getting data. From a QSO perspective:

a. It is easier to schedule shorter Observation Groups than longer ones.
b. Scheduling for instruments with filter limitations, such as CFH12K, is easiest with fewer filters in an OG. If it is not necessary to observe a target in several filters in succession, it is better to create OGs that use fewer filters.
c. Lower ranked programs are more likely to receive data if they are more willing to accept marginal conditions, such as brighter skies or poorer image quality.
d. Time constraints are very restrictive so use them only when necessary.

5.2 The importance of the Time Allocation Committee

The Time Allocation Committee (TAC) is critical to the success of QSO operations. Remembering the goal to strive for the highest camera and telescope efficiency, queue scheduling is most effective if the queue is overfilled with *observations well dispersed over the sky and which require a range of conditions*. It is the TACs responsibility to choose programs and to rank their importance. The QSO Team depends on the grade and ranks of the TAC to decide which programs to focus on for 100% completion (A programs) and which ones to use to fill the queue during less than ideal conditions (C programs and "snapshots"). Since Agency Time balancing is important, it is essential to distribute the total time of the A and B programs according to the relative fraction of time allocated for a given agency before the Phase 2. For instance, if only A programs are completed at the end of the semester due to bad weather, at least the time between the agencies will be distributed as requested. Below are some guidelines the CFHT TAC attempts to follow.

?? Low ranked programs should not have strict time constraints.
?? Programs using uncommon filters should be given a high priority if they are expecting to receive data.
?? The queue benefits from a well distributed set of targets and programs requested diverse sky conditions. In particular, "snapshots" programs requesting mediocre conditions are very important to avoid waste of telescope time.

The problem with time constraints is that they automatically receive a high precedence when the date of observation requested arrives, even if the conditions or scheduling is not optimal for the remainder of the queue programs. The limited set of filters that can be installed in the camera gives importance to the second guideline above. Because QSO strives for high quality flat field frames, we do not switch filters during the night, and generally keep filters in the camera long enough to attain sufficient twilight flat fields, at least two days. This practice restricts when and how many filters can be used during a semester. If a low ranked program requests an uncommon filter, it is almost guaranteed that the program will not be observed, counteracting the desire to overfill the queue with a variety of OGs. As obvious as the concept of a well distributed set of targets sounds, it happens that similar projects will be proposed by multiple PI s and accepted, especially when there is insufficient communication between agency TACs. When multiple programs request observations of a single area of sky, such as the Virgo cluster, and other areas of sky are neglected the queue suffers. Allocating time for programs all requesting similar conditions is also very bad and will result in a large fraction of data taken during conditions worse than requested. Careful planning can satisfy many programs in this situation, but a few stretches of bad weather can disrupt the planning and result in incomplete programs.

5.3 Operations: Planning, Observations, Evaluation

During any given day of a queue run, there are two people responsible for the planning, execution, and evaluation of queue observations. The Queue Coordinator works during the day preceding each queue night using the QSO Tools to prepare a set of queues for the coming night tailored for various conditions. The Service Observer spends the night at the telescope where they choose the queue most appropriate for the conditions and execute it, all the while maintaining the various night logs. The following morning, the Queue Coordinator is also responsible for examining the logs and the data. The final validation of all exposures which are judged to meet the science requirements of the program is also under his/her responsibility.

Planning the queues is one of the most involved and important tasks of the night. While there are no specific rules for how to prepare queues, CFHT staff has converged on a method that works well with our system. Each night, about six queues are prepared, each containing enough observations to last the entire night. Each queue differs in the requested image quality, sky background, priorities, and/or photometric constraints. An example list of queues would be:

?? Q1 **-** <0.65” Seeing, Must Be Photometric, Priority: Martin, Savalle.
?? Q2 – 0.65”< 0.80” Seeing, Must Be Photometric, Priority: Shapiro, Vermeulen.
?? Q3 – 0.65”< 0.80” Seeing , Thin Cirrus Acceptable
?? Q4 – 0.80”< 1.0” Seeing, Must Be Photometric, Priority: Manset, Veillet.
?? Q5 – 0.80”< 1.0” Seeing , Cirrus Acceptable
?? Q6 **-** Snapshot queue, Seeing higher than 1.2”, absorption.

Some queues will contain the same Observation Groups. A high ranked program will often be observed under conditions better than requested so that the program can be completed sooner. We try to observe all OGs at an airmass lower than 1.5, if possible. If sky opacity increases considerably, a queue is chosen for worse seeing conditions than actually exist at the time in an effort to achieve the same depth.

An observer’s main responsibilities are to make sure that the instrument shutter is open as much as possible, the instrument is in focus, the pointing is good, and that the data will be scientifically useful. Conditions on any night can be very stable or highly variable, and sometimes both. The observer always has a pending queue or a plan for what OGs will fill the remaining night with no dead time. The queues are often too long for the night, by design, and the observer chooses the best OGs to fill the remaining time. Principal Investigators often have special requests as to the ordering or real constraints of their program that they express in a text comment field in the database. The SO is responsible for knowing all the special conditions and nuances of a program so that data is acquired appropriately. The observer is ultimately responsible for deciding if cirrus absorption is too high; he/she must try and anticipate whether the seeing will get worse or improve and make a choice for what to observe accordingly.

Much thought and planning goes into developing a collection of queues before an observing night begins so that these goals can be achieved as much as possible. It still happens, however, that unforeseen conditions or circumstance make all of the given queues un-observable. At this point, the observer attempts to acquire as much useful data as possible in the remaining time available. In the case of conditions un-suitable for most other programs, the observer has the option to switch to a low ranked or a snapshot program or start a program that has not been started yet. This can be dangerous because of the goal to strive for high program completion. Once a program has been started it enters a state where its relative priority is increased with respect to other programs. Scheduling becomes much more difficult as many uncompleted programs compete for the same time. Snapshot programs are essential for bad time because data can be obtained in time generally deemed unsuitable for other programs. Time spent observing snapshot programs is *not* charged to any agency, so agency balance and completion considerations are not upset.

As the data comes off the telescope, a real-time component of the Elixir pipeline produces a seeing measurement and a sky brightness measurement for each exposure. These values become automatically available in the QSO Electronic Logbook along with a subset of values taken from the FITS header. The observer correlates these measurements with the requested values and assigns the exposure an evaluation grade of:

1. Excellent **-** Image within constraints or < 10% out of specified constraints.
2. Good – One parameter might be 10–20% out of specified constraints.
3. Poor – One or more parameters 20-30% out of specified constraints.
4. Useless – Image probably not scientifically useful (bad conditions, technical problem)

In addition the SO looks at the image and notes any abnormalities and the measured absorption due to clouds, if any, in a ‘comments’ field. The next morning, the Queue Coordinator examines the logs, checks suspicious or poor quality exposures, revises the grade or comment if necessary, and finally ‘validates’ exposures judged to meet the scientific needs of the program. The meta-data (FITS header fields, measured image parameters and QSO comments) become publicly available via the Night Reports as soon as an exposure has been validated, usually the next morning.

5.4 Results: Facts and Fiction of Queue Observing

The experience of about 150 nights of queued service observing with CFH12K has been quite successful. Although the first semester was a bit difficult due to the lack of experience and technical glitches (although we were gathering queue data in the first hour of the first NOP night!), high quality data have been gathered in an efficient manner. So far, about 13 000 exposures (science, calibrations, detrend) have been obtained in the QSO/NOP system (about 3 Terabytes of data), this with a higher fraction of time lost to bad weather than first expected. The technical downtime due to the NOP system is basically negligible. Here are some of our conclusions and results, based on the three semesters:

?? *The QSO mode is very appropriate for highly ranked programs*. We aim to achieve 100% completeness for as many high ranked programs as possible. The completeness level of A programs reaches 90% and more in the QSO system. Most B programs are completed at a level of 60-75%. Some C programs (overfill) can reach a decent fraction of completeness (50%) if conditions requested are moderate. Clearly, the completeness level is very dependent on the global weather statistics: lower ranked programs might never be started if the weather is worse than expected through a semester. This is particularly the case with lower ranked B programs requesting good conditions.

?? The validation rate reaches about 85%, that is, *85% of the data taken are judged scientifically useful by meeting the requirements specified by the investigators*. We aim for 90% for future semesters because we did not have snapshot programs until the 3rd semester, forcing us to observe regular programs in less than appropriate conditions.

?? By carefully preparing queues, for instance by limiting the number of long slews and filter changes, the overheads can be minimized so that *the observing efficiency can reach 80-85%.* Some nights can reach 90%. Efficiency can be somewhat lower than this during variable conditions, when “queue switching” is more frequent.

?? *Queue observing is very well-suited for time constrained programs* (e.g. supernovae monitoring). However, as mentioned above, the number of programs with time constraints must be limited and ranked highly because their impact is very strong on the completeness level of other regular programs (especially if weather is bad).

?? *On a semester basis, appropriate balance of the Agency Time is possible.* We have been able to achieve a balance at a 2% level or so (meaning more or less half a night of observing time) although this leads sometimes to difficult compromises between completeness level and Agency time accounting. Balancing of the Agency time is meaningless on a shorter time basis.

?? *More programs get completed in a queue mode.* Although we still do not reach the level expected (because weather has not been very cooperative), among 60% of programs during our best semester were completed. It is interesting to note that despite 42% of the QSO time lost to weather during the first semester of 2002, “grade A” programs were completed at a 92% level! This suggests a clear increase in the science productivity of the telescope in a queue mode compared to a classical mode when the weather is globally degraded.

?? *By calibrating all the data requesting photometry, scientific value of the data is increased.* So far, 100% of the data requesting photometry have been calibrated. For archiving purposes, this adds a tremendous value to the data. Calibrating the data taken during non-photometric conditions with short exposures during photometric nights is not too time consuming (< 1 night).

?? *The science data quality is improved in QSO mode by the availability of very high quality instrumental detrend files.* The long scheduled runs of QSO mean that high quality biases, darks, and especially flats can be taken. The flattening, or detrending, of data performed at CFHT is equal to or better than any possible by a PI with a short observing run at CFHT.

?? *Interaction with the investigators during a semester is important.* It is frequent that the QSO Team communicates with the PI to request more information on their observations, in particular programs with time constraints. The communication is done between the Queue Coordinator and the PI, never directly with the Service Observer.

?? *The phase 2 is quite critical for a queue system*. It is particularly important to interact with the investigators during the phase 2: strategy of observations, technical details, etc., should be resolved before starting the observations. The tool provided must be able to check for mistakes and be robust and simple to use.

6. QSO AT CFHT: FUTURE PLANS

6.1 MegaCam

Starting at the end of 2002, the main instrument at CFHT for dark/grey time period will be MegaCam. It is a 1 degree squared field-of-view camera (40 CCDs) installed at the CFHT prime focus. MegaCam will be entirely operated in the QSO mode, that is, for about 90-100 nights per semester. Runs will take place every month and last 16-18 consecutive nights. It is expected than about 100-150 Gigabytes of data will be produced every night with this instrument. A major component of all of the observations performed with MegaCam will be for the Canada-France-Hawaii Legacy Survey which has been allocated 500 nights for the next 5 years. The remaining 40% or so of MegaPrime telescope time available will be for regular PI programs. Except for some changes on the high-level applications, there are not many modifications necessary to adapt the QSO system from CFH12K to MegaCam because it was originally designed for this purpose. The main challenge will be allocation of human resources during these frequent operation periods.

6.2 WIRCAM/ESPaDOnS

Two other major instruments will join MegaPrime at CFHT in a few years from now: WIRCAM and ESPaDOnS. WIRCAM is a wide-field infrared imager to be installed at the telescope prime focus. The camera will have a field of view of about 20 arcminutes and should become operational in 2004. It is expected than most of the observations with WIRCAM will also be performed in the QSO mode. The other instrument, ESPaDONs, is an echelle spectropolarimeter spectrograph installed in the Coude chamber. The instrument is fiber-fed from a module installed at the Cassegrain focus. Commissioning is planned for mid-2003. In the long-term, an optical fiber link could be installed in the MegaPrime focus cage environment. This will allow queue observations with ESPaDONs during MegaCam runs, for instance, when the seeing becomes mediocre.

6.3 Dynamical Algorithm

A major challenge in operating in a queue mode is the decision making process during an observing night. As described earlier, several queues covering diverse conditions for the entire night time are prepared for a given night in the QSO system. However, when conditions are changing rapidly, queue matching becomes an issue. For instance, switching from one queue to another requires a complete re-evaluation of the remaining time available during the night so that the ensemble of observations available in the pre-defined queues represents the best option to fit in this time window. The QSO tools and query algorithm are detailed enough that a decision can me made rapidly. However, this decision would be made easier if the observer was assisted by a *dynamical algorithm*. This algorithm would provide in real time a list of the most plausible observations to be performed in the context of the sky conditions, time constraint requirements, priorities, program requirements and, current night observing time available. This is challenging software to develop because the number of parameters can become very large and there are some “soft” parameters that are somewhat difficult to implement as entries in the relational database. The QSO team has started to design such an algorithm and hopefully, it will be tested and developed in a near future.

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