Queue observing at the Observatoire du Mont-Mégantic 1.6-m telescope

Étienne Artigau[a], Robert Lamontagne[a], René Doyon[a] & Lison Malo[a]

[a]Département de Physique and Observatoire du Mont-Mégantic, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, QC, H3C 3J7, Canada

ABSTRACT

Queue planning of observation and service observing are generally seen as specific to large, world-class, astronomical observatories that draw proposal from a large community. One of the common grievance, justified or not, against queue planning and service observing is the fear of training a generation of astronomers without hands-on observing experience. At the Observatoire du Mont-Mégantic (OMM) 1.6-m telescope, we are developing a student-run service observing program. Queue planning and service observing are used as training tools to expose students to a variety of scientific project and instruments beyond what they would normally use for their own research project. The queue mode at the OMM specifically targets relatively shallow observations that can be completed in less than a few hours and are too short to justify a multi-night classical observing run.

Keywords: Observatory management, student training, queue observing, small telescopes

1. INTRODUCTION

The OMM 1.6 m telescope[1] is located in south-eastern Quebec and is managed by Université de Montréal and Université Laval, both located ~ 250 km from the facility. The observatory is mostly used by graduate students from both institutions with a few visiting astronomers per year from other institutions, both national and international. Ever since its first light in 1978, the observatory has been run in classical mode by visiting students and astronomers. The observatory has an active instrumentation development program with the current instrumentation including a wide-field optical imager (PANORAMIX-II[2]), a optical spectrograph, a wide-field near-infrared imager (CPAPIR[3]), a near-infrared spectrograph and polarimeter (SIMON), a Fourier-transform imaging spectrograph (SPIOMM[4]) and an optical polarimeter (La Belle & la Bête). The observatory also regularly serves as a testbed for instrumentation used in larger facilities; instrument such as TRIDENT[5] and MONICA[6] (both used at CFHT) and the near-infrared tunable filter for use with Gemini South Flamingos II instrument[7] were first tested at the OMM. The SPIOMM FTS also serves as a demonstrator for the proposed SITELLE instrument for CFHT.

Graduate student formation has always been central in the use of OMM. A queue-observing program was introduced in Fall 2009 to give graduate students from both universities, and eventually from other institutions, an observational astronomy experience beyond what they would normally get through the observations required to complete their thesis project. During the first year of this program, the only instrument used in queue mode was the CPAPIR wide-field imager*, but we plan to expand this program to other instruments in the upcoming year. The idea behind the OMM queue is freely inspired by the Gemini queue in which one of us (ÉA) took part during the 2006-2009 period. The queue observing at the OMM is unique as it does not only increase the obsevatory's efficiency but also provides a training opportunity for graduates students. Queue observing currently represents $\sim 30\%$ of telescope time at the OMM.

Queue observing is normally seen as belonging to world class astronomical observatories where the observations are complex and cannot be run efficiently by visiting observers. This obviously applies to space observatories, but also to a growing number of 4 to 8-m telescopes where optimal operation of the facility implies that the

Further author information: (Send correspondence to É. A.)
E-mail: artigau@astro.umontreal.ca, Telephone: 1 514 343 6834

*Please visit the CPAPIR queue observing page http://www.astro.umontreal.ca/cpapir/index_en.html nightly plan must be adapted to the changing weather conditions, something that cannot be done with classical observations. While this approach is arguably optimal in term of telescope operations, it is often perceived as having a negative impact on the formation of graduate students in astronomy. With many major facilities largely run in queue mode (GEMINI, CFHT), a graduate student in 'observational' astronomy can easily gather all its dissertation dataset without ever spending a night at a telescope.

In parallel, small (i.e. $< 2\,\mathrm{m}$) telescopes strive to survive and need innovative approaches to remain relevant among the large players. It is interesting to note that for an institution not located immediately next to a small research telescope, obtaining queue data from a 4 to 8-m telescope is less expensive than sending a graduate student to a small telescope for a week-long observing run and, once the program has been approved for queue, it is less likely to suffer from weather loss.

We have undertaken a queue observing program at the Mont-Mégantic 1.6-m telescope where graduate student are responsible for the observations. This program has several benefits, both in terms of training and efficiency. This paper details the motivations, both scientific and formation-wise, for this program and its practical implementation. Representative science programs currently in the OMM-queue are described. Finally, we give a few lessons learned from the first 8 months of this program and suggestions for other observatories.

2. SCIENCE MOTIVATIONS BEHIND QUEUE SCHEDULING OBSERVATIONS AT THE OMM

2.1 Getting the best out of a sub-optimal observing site

The site of the OMM, at an altitude of 1111 m, near the Appalachian mountains has a median seeing of $1.5-2.0''$ and more than $\sim 50\%$ of nights are lost to weather while $\sim 25\%$ of nights partially lost to clouds. This make some observing programs that require uninterrupted observing for most of the night challenging (e.g. brown dwarf photometric monitoring). Attempting these programs in classical runs would be inefficient as short periods of clear sky would not provide scientifically useful lightcurves. At the same time, many programs do not require photometric conditions and can readily be interrupted, especially in the near-infrared where exposure times rarely exceed 1 minute. Our data reduction pipeline relies on the 2MASS point source catalog[8, 9] to normalize images in the photometric data and optimally weighs the observations getting the best out of non-photometric conditions but of course this can only be done if there is no need for time-resolution. We argue that queue scheduling is *more* important in a site with relatively poor conditions than it is in the best sites in world-class locations. One really needs to get the most out of the best conditions the site offers as they only occur a handful times a month. Also, poor but usable conditions are relatively common and one needs to take advantage of these nights to complete programs that do not require the best conditions the site may offer.

2.2 Getting the best out of Canadian winters

Wintertime temperatures at the OMM regularly drop below $-20°$C, making it a remarkably good observing site for observations in the K_s band. Between $-30°$C and room temperature, the intensity of the black body spectrum at $2.15\,\mu$m is reduced by a factor of two for every 8°C in temperature drop. One would therefore expect excellent observing conditions under typical wintertime conditions at the OMM, to be significantly better than what is seen at temperate sites. Figure 1 gives the mean monthly nighttime temperatures for clear nights at the OMM and measured K_s-band background. In January, the K_s-band background gets to $\sim 14\,\mathrm{mag/arcsec^2}$ while in early-fall and late-spring, backgrounds between 12 and $13\,\mathrm{mag/arcsec^2}$ are more typical with a significant night-to-night scatter. This important reduction in background leads to a $4-6$-fold gain in efficiency. In practice, as can be seen in the gap in background measurements during summer months in Figure 1, we avoid K_s observations during summer.

An important point that may not be readily seen is that despite the fact that prime winter conditions are only seen for about 3 months per year, most of the sky can be accessed during winter (see Figure 2). The OMM is at a moderately northern location (latitude 45°27′) and 76% of the sky at $\delta > -15°$ can be observed on December 21 at an airmass below 2 for at least 2 continuous hours assuming that observations can be performed during the civil twilight (Sun more than 12° below horizon, reasonable for K-band observation). This fraction falls to 62% on March 21. Remarkably, a total of 90% of the sky can be observed for more than two continuous hours

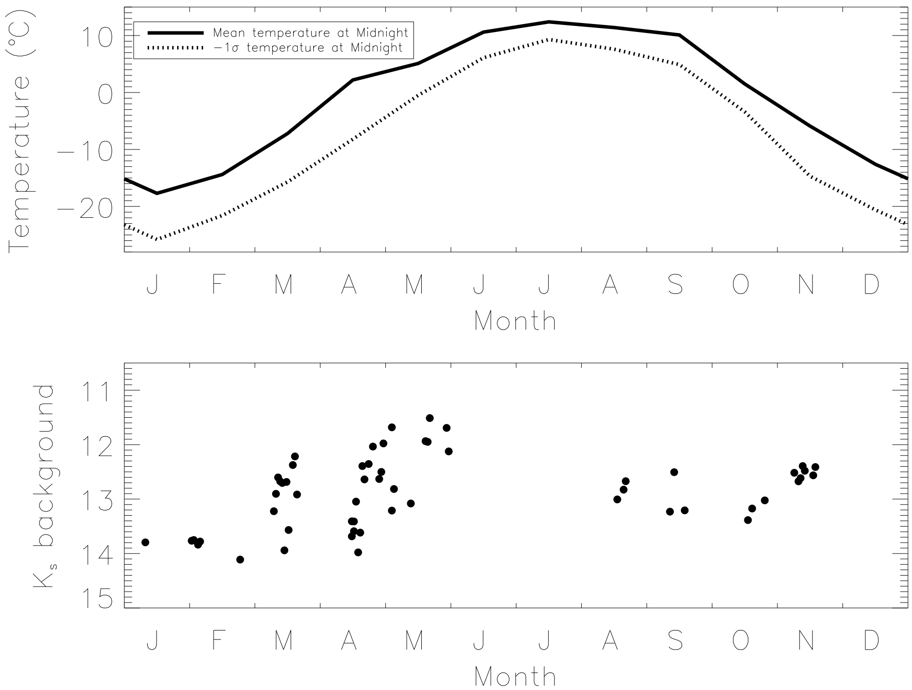

Figure 1. Upper panel : Mean monthly temperature at midnight on clear nights at the OMM. The dashed line gives the -1σ deviation, typical of especially good nights where K_s observing should be prioritized. In practice, temperatures below -10° are the norm from early-December to mid-March and regularly occur from early-November through mid-April. Lower panel : Measured K_s background in mag/$''$ as a function of time of year.

between these two dates. In practice, the vast majority of targets at $\delta > -15^\circ$ will therefore be accessible from the OMM under the best K_s background conditions, but to take advantage of this fact, one needs to carefully plan the observations and take advantage of targets that are visible only for a fraction of the night.

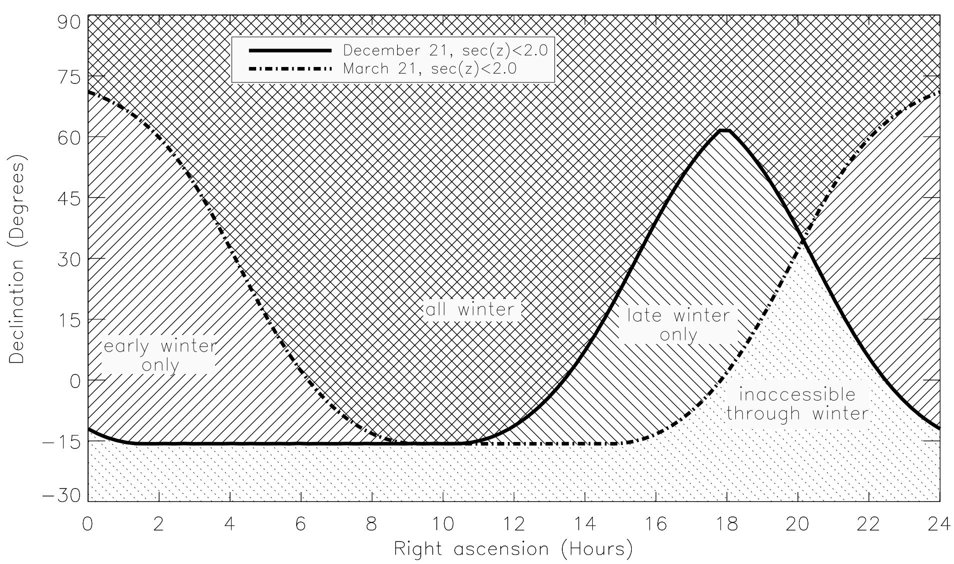

Figure 2. Sky area accessible for at least two hours at an airmass smaller than 2 during winter months at the OMM. The long winter nights allow one to observe objects over 90% of the sky above $\delta > -15^\circ$. The only inaccessible region during the prime time of the year for K_s observing is a relatively small triangular region centered at RA = 20h.

2.3 Filling the near-infrared sensitivity gap

For most of the sky, the only available near-infrared imaging data is from 2MASS and DENIS (southern sky) imagery and reaches depths of $J \sim 16.5$ and $K_s \sim 14.0$. While these surveys brought a revolution in near-infrared astronomy, these observations remain very shallow compared to archival data available in the optical domain; the depth of the 2MASS imaging can be reached in ~ 8 s on a 1.6 m telescope such as the OMM. While all major facilities have near-infrared cameras, there remains a sensitivity gap between what can realistically be requested in terms of shallow observations at a 4-8 m telescope and all-sky near-infrared surveys. There is no facility where one can readily obtain an observation, say, 2 magnitudes deeper than 2MASS. Such an observation would be too short (i.e. tens of seconds) on a 4-8 m class telescope and can hardly justify a proposal in itself. Even on smaller telescopes, such an observation takes only tens of minutes and cannot justify a multi-night classical run. One of the goals of queue scheduling at the OMM is to bridge this gap and allow relatively shallow observations to be performed. This can be crucial for teams making proof-of-concept observations to justify observing time in larger facilities.

2.4 Time-variability over timescales of months

Variability on timescales of weeks to months of bright targets cannot readily be studied through classical runs and would not make an efficient use of telescope time in major facilities. Queue blocks at the OMM are typically 2 weeks long and spaced by ~ 6 weeks, making the sampling on these intermediate timescales feasible.

3. PRACTICAL IMPLEMENTATION

3.1 Rapid quality assessment, automated reduction and feedback

One positive aspect that cannot readily be quantified from classical observing runs is the sense of ownership of the data, especially for graduate students on a first-time observing run at a major observatory. This sense is less present when data is distributed via electronic means. Similarly student observers gathering data for others may take observing guidelines more loosely knowing that its not their thesis' data that is at stake. We have found that rapid feedback to observers about the previous night mistakes is critical to formation. Feedback should be given while the student is still at the telescope, ideally before the following night.

In that sense, having an automated data reduction pipeline proved to be crucial. Our team developed a set of IDL tools for this purpose. A first set of tools parses raw data, standardizes headers, adds a world coordinate system on science data and produces normalized flats. Once the dataset is parsed, it is automatically reduced and a set of standardized outputs are automatically uploaded to an internal webpage. This requires little human interaction and is handled by the queue coordinator. The standardized outputs include a PSF map to visualize image quality across the filed of view, a plot of full-width-at-half-maximum (FWHM) and background as a function of time and *jpeg* renditions of the flat field to ensure that there was no dew on the camera's window or vignetting.

All automated diagnostic outputs and reduced data for all fields are accessible on an internal webpage and can be viewed by the observer to diagnose possible problems or mistakes.

3.2 Nightplans

A night plan is prepared by the queue coordinator and uploaded on a password protected webpage that also includes a target list, finding charts as well as links to the PIs proposals and to the instrument manual. The old night plans and logs sent by previous observers are compiled and accessible to the observer for reference. The clear-sky-clock[†] has been found to be very reliable for very short (i.e. tens of hours) term predictions and a single plan is prepared using this forecast. There are no true observing constraints defined in the OMM proposals, but some programs do require relatively long, uninterrupted, sequences (brown dwarf variability) and others can readily be done under non-photometric conditions (astrometry).

[†]http://cleardarksky.com/c/Observatoires_du_Mont_Megantickey.html

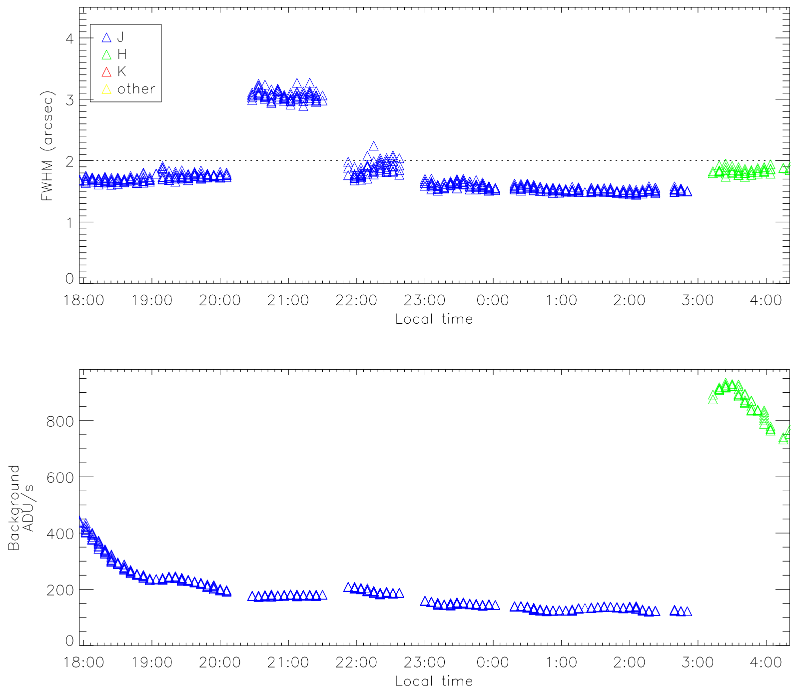

Figure 3. Example of automated output to assess data quality. The observer made an error during a focus sequence and observed for about 1h significantly out-of-focus. The night was mostly spent observing in J-band; the decrease of J-band background seen during the first hours of the night is observed on most nights.

4. CURRENT OMM QUEUE PROGRAMS

The OMM queue hosted 14 programs for the April-July semester. The programs listed below illustrate the scientific opportunities opened by queue observing on a small telescope.

- Variability of AGB stars in Leo I (Université de Montréal); this ongoing programs is a J and K_s-band search for long-period (100-1000 days) variable in the nearby dwarf Leo I. The timescales involve are prohibitive for classical runs and the typical brightnesses ($J = 15 - 17$) could not justify the use of a larger telescope.

- Brown dwarf variability (University of Toronto, Université de Montréal); one of the most spectacular science result obtained with CPAPIR is the discovery of a quasi-periodic modulation in the flux of an early-T dwarf[10] with a period of ~ 2.5h and a modulation of the period over timescales of days. This has been attributed to the presence of evolving clouds on the surface and rotation-induced modulation. The result has motivated further search for photometric variability in T dwarfs. These observations require at least 4 hours of continuous monitoring under near-photometric conditions; these conditions are not always present at a continental site like that of the OMM and a classical observing would lead to a large number of less-than-optimal 1-2 hours lightcurves that put little constraint on variability and lead to an effective loss of a sizeable fraction of the clear time. These observations are only attempted on nights that are predicted to be entirely cloud-free.

- K_s surface luminosity of spiral galaxies (Université de Montréal); this program aims at obtaining accurate measurement of the stellar content of relatively large ($> 2'$) galaxies in the SINGS[‡] sample. The program requires relatively short observations (< 1 hour) in wintertime conditions.

- Photometry of heavily obscured stars in dark clouds (University of Minnesota, Université de Montréal); this program aims at obtaining accurate photometry of heavily obscured stars in a sample of dark clouds

[‡]http://sings.stsci.edu/

for observation in polarimetry at IRTF and JCMT to determine interstellar dust properties. This program and the one below exemplify the need for relatively shallow near-infrared observations that take a few hours at the OMM and cannot readily be obtained on an 4-8 m telescope.

- Deep multiband photometry of two galactic open clusters (St-Mary's University); this project aims at accurate JHK photometry extending the 2MASS sensitivities by $\sim$ 1.5 mag and requires only tens of minutes per filter.
- Astrometric follow-up of young low-mass star candidates (Université de Montréal); a program consisting of J-band snapshot imaging of relatively bright targets ($J < 13$) that have activity (Hα, X-ray) and colors indicative of youth and require astrometric follow-up to refine proper motion measurements and constrain young association membership. This programs serves as a filler on non-photometric nights.

5. FUTURE PROSPECTS

The first 8 months of queue observing at the OMM have been largely successful, with 52 nights in the first half of 2010 shared by 9 observers. Up to now, queue observations were only performed with the CPAPIR wide-field imager, but we plan to extend this program to the wide-field optical imager in Fall 2010. Considering that the pool of observers is, by definition, in training, instruments requiring complex observing procedures will probably always be offered in classical mode. Also, as instrument changes can only be done during daytime, one needs a large enough pool of programs observable during a given night with an instrument to justify queue scheduling and adjust to varying conditions possible. On the long term, we expect to add optical and near-infrared spectrographs, currently used at the observatory in classical mode only, to the pool of queue instruments.

5.1 Acknowledgments

The authors thank all graduates students that participated in the queue observations at the OMM; Anne Archibald, Sandie Bouchard, Yacouba Djabo, Jonathan Gagné, François Girardin, Patrick Ingraham, Sié Zacharie Kam, Lison Malo & Julien Vandeportal. This work would have been impossible without the patience and dedication of our telescope operators; Pierre-Luc Lévesque, Bernard Malenfant, Guillaume Provencher, Ghislain Turcotte & Philippe Vallée. The Observatoire du Mont-Mégantic is funded by the Université de Montréal, Université Laval, the Natural Sciences and Engineering Research Council of Canada (NSERC), the Fond Québécois de la Recherche sur la Nature et les Technologies (FQRNT) and the Canada Economic Development program.

ACKNOWLEDGMENTS

REFERENCES

[1] Racine, R., "The Mont Megantic astronomical observatory - a new major observatory for Canada," *JRASC* **72**, 324–334 (1978).

[2] S. Thibault, M. Doucet, L. Drissen, "Optical design of PANORAMIX-II, the OMM wide-field VIS-NIR camera," in [*Ground-based Instrumentation for Astronomy*], Moorwood, A. F. M. and Iye, M., eds., *Proc. SPIE* **5492**, 293–302 (2004).

[3] E. Artigau, R. Doyon, P. Vallee, M. Riopel, D. Nadeau, D., "CPAPIR: a wide-field infrared camera for the observatoire du mont megantic," in [*Ground-based Instrumentation for Astronomy*], Moorwood, A. F. M. and Iye, M., eds., *Proc. SPIE* **5492**, 1479–1486 (2004).

[4] A.-P. Bernier, et al., "First results and current development of SPIOMM: an imaging fourier transform spectrometer for astronomy," in [*Ground-based and Airborne Instrumentation for Astronomy II*], Moorwood, A. F. M. and Iye, M., eds., *Proc. SPIE* **6269** 135–143 (2006).

[5] C. Marois, et al.., "TRIDENT: An infrared differential imaging camera optimized for the detection of methanated substellar companions," *PASP* **117**, 745–756 (2005).

[6] D. Nadeau, D. C. Murphy, R. Doyon, N. Rowlands, "The Montreal near-infrared camera," *PASP* **106**, 909–914 (1994).

[7] E. Mentuch, A. Scott, R. Abraham, E. Barton, M. Bershady, J. Bland-Hawthorn, D. Crampton, R. Doyon, S. Eikenberry, M. Gladders, K. Glazebrook, J. Jenson, J. Julian, R. Julian, R. J.-P. Kneib, D. Loop, N. Raines, N. Rowlands, J. D. Smith, "Optical-mechanical operation of the F2T2 filter: a tunable filter designed to search for First Light" in [*Ground-based and Airborne Instrumentation for Astronomy II*], Moorwood, A. F. M. and Iye, M., eds., *Proc. SPIE* **7014**, 1479–1486 (2008).

[8] R. M. Cutri, M. F. Skrutskie, S. van Dyk, C. A. Beichman, J. M. Carpenter, T. Chester, L. Cambresy, T. Evans, J. Fowler, J. Gizis, E. Howard, J. Huchra, T. Jarrett, E. L. Kopan, J. D. Kirkpatrick, R. M. Light, K. A. Marsh, H. McCallon, S. Schneider, R. Stiening, M. Sykes, M. Weinberg, W. A. Wheaton, S. Wheelock, N. Zacarias", "2MASS All Sky Catalog of point sources," *The IRSA 2MASS All-Sky Point Source Catalog, NASA/IPAC Infrared Science Archive. http://irsa.ipac.caltech.edu/applications/Gator/* (2003)

[9] M. F Skrutskie, R. M. Cutri, R. Stiening, M. D. Weinberg, S. Schneider, J. M. Carpenter, C. Beichman, R. Capps, T. Chester, J. Elias, J. Huchra, J. Liebert, C. Lonsdale, D. G. Monet, S. Price, P. Seitzer, T. Jarrett, J. D. Kirkpatrick, J. E. Gizis, E. Howard, T. Evans, J. Fowler, L. Fullmer, R. Hurt, R. Light, E. L. Kopan, K. A. Marsh, H. L. McCallon, R. Tam, S. Van Dyk, S. Wheelock, "The Two Micron All Sky Survey (2MASS)," *AJ* **131**, 1163–1183, (2006).

[10] Artigau, E., Bouchard, S., Doyon, R., and Lafrenière, D., "Photometric variability of the T2.5 brown dwarf SIMP J013656.5+093347: Evidence for evolving weather patterns," *ApJ* **701**, 1534–1539 (2009).