Educational use of the Nordic Optical Telescope

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Abstract.
Telescopes and their instrumentation are the main tools for astronomers and learning their capabilities and how to use them effectively is very important. Here I briefly discuss the role of education at the Nordic Optical Telescope (NOT) and I describe in some more detail what we offer for training courses at NOT. Special emphasis is given to using the NOT remotely as done during the Observational Stellar Astrophysics School at the Molėtai observatory in Lithuania.

Key words: telescopes – instrumentation: miscellaneous

1. The Nordic Optical Telescope

The Nordic Optical Telescope (NOT) is a modern 2.6-m telescope operated at the Observatorio del Roque de los Muchachos on the island of La Palma in the Canaries, Spain. The NOT entered full service in the early 1990s and has established a reputation as a first-class research tool with excellent image quality, optimized instrumentation, and outstanding reliability. As such, NOT provides the only assured access for Nordic optical astronomy to high-quality observations of objects in the northern hemisphere. NOT is operated by the Nordic Optical Telescope Scientific Association (NOTSA), a consortium of the Research Councils of Denmark, Finland, Norway, and Sweden, and the University of Iceland. Observing time is awarded in open competition, based on scientific merit and peer review, and competition from non-Nordic projects is welcomed as a way to maintain scientific excellence. We also offer a "fast track" service program for small observing projects

(max 4 hours) with a short lead time from proposal to execution. Anybody can submit a proposal at any time and successful programs will be executed in queued scheduling service mode.

The NOT core instrument suite of ALFOSC, FIES, NOTCam, MOSCA and StanCam offers imaging, polarimetry and low- and intermediate-resolution spectroscopy in the optical and the infrared, and high-resolution spectroscopic in the optical. Either ALFOSC, NOTCam or MOSCA is mounted at the Cassegrain focus, while both FIES and StanCam are stand-by instruments that are available all the time. Full information on the facilities, staff, and environment at NOT is maintained at the NOT WWW site (http://www.not.iac.es/).

The long-term future of NOT in the light of the development of other European observing facilities has been our focus of attention for the last few years. An international evaluation panel, commissioned by Joint Committee of the Nordic Natural Science Research Councils (NOS-N), concluded in 2006 that NOT is a high-quality telescope, with very satisfactory publication and citations rates and operated in a highly efficient and cost-effective manner. The evaluation panel and a follow-up meeting with all Nordic user groups in the autumn of 2006 (see for complete reports http://www.not.iac.es/news/reports/) agreed that NOT should enhance its role in training the astronomers of the future. This is now part of our strategy for the future of NOT as approved by the Council and is thus official NOT policy which we are implementing.

2. Education at the NOT

To quote the international evaluation panel: "Medium-sized telescopes such as NOT have an important role in the training of the future generation of astronomers. The most efficient use of observing time at large telescopes, and even the ability to write successful proposals for them, requires previous hands-on experience with smaller telescopes. As a real international observatory with a variety of instruments - as opposed to a simple student telescope at a university - NOT provides excellent possibilities for this."

We have expanded the educational role of NOT in several respects. One of our greatest recent successes is the expansion of the NOT Research Student Programme from 1-2 students per year to 4-5, the number our staff can supervise properly. The stu-

dent's work at the telescope includes support duties and service observing, as well as participation in the various developments at the NOT, but 75% of the time should be devoted to their thesis projects. The students now form a real group that interacts extremely well, both professionally and socially, and indications are that ∼80% of them complete their PhDs successfully and go on to productive careers in astronomy or related sciences. Ex-students report that their year with hands-on experience with instrumentation and responsibility for the telescope and visiting astronomers have been great assets in competing for jobs, in astronomy and elsewhere. We receive many applications, roughly half from women; we take the best and find a similar balance in the group.

PhD-level courses in observational astronomy at NOT have been held previously at ∼3-year intervals, both on-site and remotely from the Molėtai Observatory in Lithuania, with support from NorFA/NORDFORSK. Similar courses at NOT are now being offered annually by the new Danish Astrophysics Research School (DARS; see http://www.dars.dk/), with access for other Nordic students, and will form the basis for the optical component of the future joint Nordic optical/submm training programme. For several years, Stockholm Observatory has also organized a hands-on undergraduate course at NOT as the final stage in a regular course in modern instrumentation and data reduction techniques.

A lot of experience in organizing and hosting these courses has been gained, while also the facilities and infrastructure at the observatory have been developed and optimized for educational use. We are currently preparing documents which describe in more detail what we offer to groups that want to use the NOT for an observational course at the observatory or remotely, and what is needed in preparation. Here I give a short overview, where I describe in more detail our specific experience at the 2008 'Observational Stellar Astrophysics School' at the Molėtai Observatory.

2.1. On-site observing courses

The facilities of the NOT at the observatory consistent of the telescope building and a so-called "service" building which is situated ∼50 m away. In the service building the mechanical and electronic workshops are housed, but there is also a common room where an area of ∼3.5m×6m can be converted to a "classroom" setting. In the classroom we can provide 3 or 4 tables which can

comfortably seat 3 persons each, and in front of this we have a large projection screen ($\sim$1.5m$\times$3m). During the night this screen is used to project a live copy of the display of the data acquisition computer being operated in the telescope control room.

Figure 1: The "classroom" in the service building showing the tables and the projection screen

The control room at the telescope can house 4 or 5 people, but only 2 or 3 can reasonably access and operate the observing system. The idea behind our set-up is to provide a way of showing the operations of the telescope and instrument live to many people at the same time. The size of the screen in the classroom is such that everything is well visible for everybody. The sound from the control room is also transmitted and in this way it is possible to provide a reasonable impression of how observing is in practise. The classroom also allows for more detailed or extensive explanations of what is going on without interfering with the observers in the control room. For direct communication with the control room, web-cams and a head-set are provided, which can be used for giving instructions or asking questions.

Our facilities allow a maximum of 12 students plus 2 or 3 teachers, where it is general practise to have the students divided

in groups of 2, or maximum 3 students, that operate the telescope and instrument(s) in shifts. The remaining students can observe what is going on at the telescope from the classroom and/or spend the time analyzing or discussing the (previous) observations. In the daytime the classroom can be used in a normal way, where the same projection equipment can be connected to a regular (laptop) computer and used for presentations. Also wireless Internet connection is available in the classroom

Included in the facilities for courses we provide a full set of 12 laptops for the students. These are offered with a common "standard" software installation on a Linux platform. In principle this includes all basic astronomy reduction and analysis packages, but the specific installation can be adapted for each course.

One of the reasons for providing laptops is the relatively small area available in the classroom, where they occupy very little space. However, we consider providing a common set-up for all students to be the most important advantage, especially in cases where not all students have laptops, or laptops with a similar installation or processing capability. It is our experience that certain applications are not always compatible with different operating systems or other software installations on different (types of) laptops and often significant amounts of time are spent before and during the course on installing software on different laptops, or in searching for alternative solutions.

We can also help with planning travel and arranging for lodging at sea-level and with arranging for lodging and food at the observatory.

2.2. Remote observing courses

There are a number of specific issues to consider when using the NOT for remote observing courses. Our main objective is to as much as possible mimic the "look and feel" of observing at the telescope, but we are depending heavily on the reliability and speed of the Internet connection and we need to take in to account safety issues at the telescope. For this reason we provide a support astronomer at the telescope who monitors what is going on and executes certain tasks (e.g., starting up the telescope) which are considered potentially too dangerous to be executed remotely. The support astronomer can also provide direct advice in case of questions or problems. If there are problems with the Internet connection the support astronomer can also assist with the observations.

There are some specific requirements for the remote set-up
(e.g., for the computer hardware, displays, software installations,
etc) which are relatively straightforward but might be different for
different users and are not detailed here. I do note that the In-
ternet speed of at least 2.5Mbps that was obtained to the Molėtai
observatory throughout the course was sufficient to execute the
remote observations in an acceptable way.

An important issue in general is a proper preparation. This
both applies to the course itself (course program, required tele-
scope and instrument set-up, observing plan, etc), but also to
define and test the set-up for remote observing. Below I describe
the various parts that are involved in the set-up for remote ob-
serving. At the moment the system has been set-up for remote
observations with FIES, but many of the aspects are the same
when using any other instrument, and remote observing can in
principle be offered with any of the core instruments at NOT.

At the end a specific description is given of the remote obser-
vations as they were performed from the Molėtai Observatory.

2.2.1. Remote observing

The starting point is that the observers will login remotely
and as much as possible operate the instrument and telescope by
typing commands directly in to windows which are opened on our
data acquisition computers. Apart from that, there will be a lim-
ited number of (graphical) status display windows. In general the
specific observing system set-up and appearance (partly governed
by the issue of bandwidth) will be different for remote observing
than when doing observation on site, and a specific remote observ-
ing system is provided. A complementary system is set-up at the
telescope to monitor things for safety reasons and also to provide
advise or help in case of problems.

Depending on the precise set-up used there will, apart from
the properties of the Internet connection, also be requirements on
both the hardware (speed and capacity of the computer) and the
software (specific installations which might depend on the oper-
ating system used). In general it is good to limit any load on the
network link as much as possible. Specifically, one should think
about avoiding using the link for anything else during these nights.
It is important to check the link and the software in advance using
as much as possible the same configuration as during the course
to identify any potential problems.

2.2.2. Communication

It is essential to have a good communication link between the remote observing site and the NOT. In general the idea is to set up a Voice-over-Internet connection where we currently use Skype, but any other system would in principle be acceptable as well. The required set-up (software and hardware) is available at the NOT, and should be provided at the remote observing site as well. In case the Internet connection is slow the Skype chat mode can be used. In the worst case regular phone and FAX connections should be available.

2.2.3. Data transfer

A specific issue with any remote observing is the transfer of the data and the associated issue of bandwidth. In principle the data at the NOT is automatically put on our FTP server for retrieval. A system should be set up at the remote observing site to retrieve the data. We can provide a simple programme that transfers the data automatically. The transfer programme can be stopped at any time and will continue at the point it was stopped when restarted. It is also possible to limit the data transfer speed to a certain maximum, e.g., to limit any effect on the bandwidth needed to operate the remote observing system.

2.2.4. Telescope Control System

Pointing the telescope can be done by simply typing commands in the remote window that was opened on the observing system. The guide star selection, centering and starting of the autoguider is done automatically by the Telescope Control System (TCS). In case this fails (e.g., due to the weather conditions) this can be done (semi-)manually by the support staff at the telescope.

To view the status of the telescope and autoguider, a TCS status display can be opened remotely on the data acquisition computer. This display is not essential and in case of a slow Internet connection this can be closed. If there is no connection, instructions can be given by phone. To be safe, all the target information such as coordinates and finding charts should be provided in advance.

The TCS has an automatic safety system which closes the telescope in case of high humidity, rain or very strong winds.

2.2.5. The instrument

As noted, any of the core-instruments can be requested for use in remote observing. Although each instrument is different, the general issues to consider when wanting to use them remotely are similar. It should be defined in advance which mode of observation is to be used as this determines what should be available for remote use. E.g., if one wants to do spectroscopy the means to center an object on the entrance aperture of the spectrograph should be provided. This puts certain requirements on the network connection and/or on the way in which this task is performed. E.g., running a procedure on the data acquisition computer at the telescope which opens a window on a computer at the remote observing site, or transferring the relevant data to the remote site and run a procedure on a local computer.

2.2.6. Data assessment

There is also the general issue of the need to view the observations to assess the data and do some quick analysis (e.g., estimate the signal-to-noise, determine the seeing on imaging data, measure the position of lines in spectroscopic data, etc). Again, this can be procedures that run on the computer at the observatory, or procedures that run on the data that has been transferred to the remote site. We already have some procedures that are used to process all observations that provide estimates that can be used to assess the quality of the observations (e.g., all imaging data are processed using SExtractor and estimates are made of the seeing and background level). There are also procedures that can be used to do a rough analysis of the observations (e.g., for spectroscopic observations extract the target spectrum, do a rough wavelength calibrations and provide a signal-to-noise estimate as a function of wavelength). In principle, all these procedures only present the final result (e.g., a number or a one-dimensional spectrum) which typically puts lower requirements on the bandwidth of the connection. The procedures could also be run on the local computer at the remote observing site, where also more detailed analysis of the data can be made.

3. Remote observing from the Molėtai observatory

3.1. System set-up

Here I describe the specific set-up to observe with the NOT

remotely as provided at the Molėtai observatory for the NORD-FORSK Observational Stellar Astrophysics School, 2008.

The instrument used during the course was the FIbre-fed Echelle Spectrograph (FIES; see http://www.not.iac.es/instruments/fies/ for more information) which is a cross-dispersed high-resolution echelle spectrograph with a maximum spectral resolution of R = 67000. The entire spectral range 370-730 nm is covered without gaps in a single, fixed setting. To isolate it from sources of thermal and mechanical instability, FIES is mounted in a heavily insulated building separate from and adjacent to the NOT dome.

The optical fibers that connect the telescope with the spectrograph are permanently mounted with a movable 45-degree mirror near the focal plane of the telescope. To center an object on the fiber the optical imaging camera StanCam is used. This 'stand-by' camera is permanently mounted at a folded Cassegrain focus and is like FIES always available.

To do observations a general observing system called the 'sequencer' is used. FIES, StanCam and the TCS can be controlled through commands and scripts executed in sequencer windows. Beyond this, there are status displays for the FIES and StanCam detectors, the TCS and for the instrument, and there is a 'Talker' window (a viewer for the log messages produced by the sequencer system). All these windows are started-up by the observers at Molėtai on the data acquisition computer at the telescope.

A special web-page was provided with instructions on how to start-up the remote observing system, with a short summary of the specific steps in the observations and the corresponding commands. A description of all the commands and instructions in their use are provided by the normal instrument web pages.

At Molėtai the computer used to login to the data acquisition computer at the telescope was connected to a projector that showed on a large screen the display with the command windows and status displays that were opened remotely. A second projector was connected to another computer where locally a web-browser was running to look at the NOT web pages for instructions and to check the weather at the observatory, but also to run the FIEStool reduction package for a quick-look reduction of the incoming data. The general objective of this is that beyond the students that are operating the telescope and instrument remotely, a larger audience can see what is going on at all times and get a more thorough understanding of what is being done.
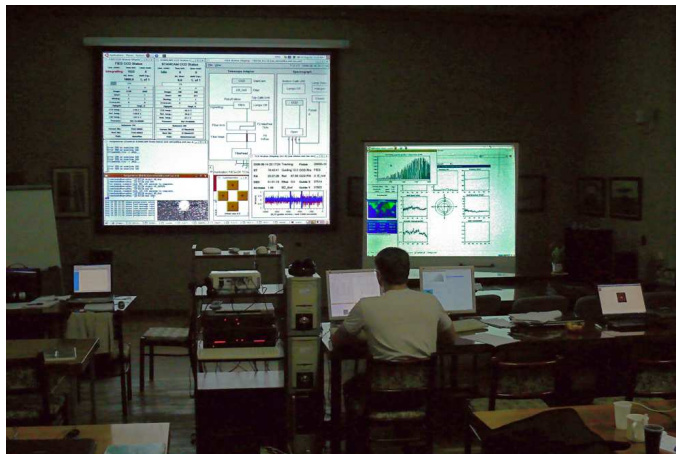
Figure 2: The remote 'control room' showing the projection screens (courtesy G. Barisevicius)

To communicate with the support astronomer at the telescope a Skype connection was used, where the sound was connected to loudspeakers so the audience could also follow any conversation going on between the remote observers and the support staff at the telescope.

3.2. Observing

At Molėtai the observations were supported by the author and Eric Stempels from St. Andrews University in the UK who is the former FIES support scientist and a former employee of NOT. Below I detail the different steps that were made to do the observations.

- **Preparations**

  Before the observations start a general introduction is given to the system. There are also various things that can/should be done in preparation for the observations. For each target the required exposure time can be estimated, the visibility during the night should be checked and finding charts can be prepared. At this time one should also consider what kind of calibration is needed for the data, specifically if apart from day-time calibration, night time calibrations are needed.

With all this information it is now possible to draw up an observing plan, defining the order in which you want to observe your targets with an approximate time-line for the observations. Also the order of priority for the different targets should be defined. Together with the time-line this makes it easier to decide what to do in case the observations do not proceed as fast as expected, if there are problems, or if the weather changes. It also essential to have some back-up targets, e.g., in case some of the main targets can not be observed due to strong wind from the wrong direction, or the observations proceed faster than expected.

- **Logging in**

  From a terminal on the computer at Molėtai the observers login to the data acquisition computer at the telescope under a special account (only possible from computers with a previously registered IP number). The observers are prompted for a password which was supplied by the NOT staff.

- **Starting the control software**

  On the data acquisition computer the remote observing system is started-up. This includes a specific access code for the TCS which changes every day and is obtained from the NOT staff.

  The observing system starts-up a total of 9 windows:

  - 2 'sequencer' terminals (for FIES and StanCam)
  - 2 CCD status windows (for the detectors of FIES and StanCam)
  - the FIES status display 'FIESTA'
  - the TCS status display
  - a window with 4 arrows to control the guide probe
  - a 'Talker' window which provides status, warning and error message for the observing system.
  - a small 'tech-xterm' window in which the low-level communication messages with the instrument can be seen. This window can be 'minimized'.

- **Observing system**

  To operate the observing system, command can be typed in the two sequencer terminals, one for FIES and one for StanCam. The TCS can be operated from either one. To close a sequencer terminal type 'exit' at its prompt. You can always get another sequencer terminal, using the command 'seqterm'. This is possible from any sequencer terminal window as well as any other terminal window logged in on the data acquisition computer.

- **Observing with FIES**

  Target and calibration observation are made with FIES through commands in the FIES sequencer window. Observing with FIES and use of the sequencer system is described in detail on the FIES web pages

  `http://www.not.iac.es/instruments/fies/`

- **Data saving**

  On the data acquisition computer at the telescope a command is issued that sets-up the system to copy the FIES and StanCam images to a special directory where they can be retrieved via anonymous FTP from the NOT FTP site. On the computer at Molètai script a script is run to automatically download the data.

- **Target catalogue**

  To be able to point the telescope to your targets a catalogue with the coordinates needs to be prepared. Instruction and a web form to enter the target coordinates are provided on a specific page at the NOT web site. After generating the catalogue it can be read in to the observing system by issuing a command in any sequencer window.

- **Start of the night**

  Around sunset the staff at the telescope will power-on the telescope, open the hatches and side ports (depending on the weather conditions), load the catalogue (if not already loaded before) for the remote observation in to the TCS, and startup a program that will monitor the instrument during remote observing.

  At this time also the 'Skype' connection is tested.

- **Setting-up the telescope**

  The telescope is set-up for use with FIES typing a single command at the start of the night in any sequencer window and the guide star acquisition is set to fully automatic.

- **Moving the telescope**

  Now the telescope can be sent to a target. For safety reasons, the NOT staff always needs to be contacted before moving the telescope to make sure it is safe to move.

  When the telescope arrives at the target the guide star system automatically selects and centers a guide star.

- **Centering the target on the fiber**

  To center the object on the fiber the light from the telescope is first redirected to StanCam by moving a mirror. The StanCam detector is than set-up and a short exposure taken. The resulting image is downloaded to the local computer at Molėtai. On the local computer the image is loaded into a ds9 image display to measure the X and Y coordinates of the target object. The projected X and Y position of the center of each fiber is defined in advance by the NOT staff. By providing the target X and Y position together with the fiber you want to use in a specific command executed in a sequencer window on the data acquisition computer, the telescope will move such that the target will be approximately centered on the desired fiber.

- **Setting-up the instrument**

  The correct setting of the instrument is prepared by typing a command in the FIES sequencer window defining the specific fiber that is used.

- **Keeping the target in the fiber**

  To redirect the light from the object to the fiber a mirror is moved. The area around the fiber entrance is reflective and is now imaged on StanCam, where the fiber entrance appears as a 'hole' in the ∼middle.

  Although the autoguider will follow the movements of the stars and keep the target in the same place, there is always

some relative movement with time between the guiding system and the fiber entrance (predominantly due to the varying gravity vector as the telescope moves). To check if the object remains in the fiber a continuous 'movie' is taken with StanCam of the fiber head. As transferring this stream of images puts a continuous load on the connection, the files are converted to JPEG format and shown on a dedicated web pages which can be viewed with a regular web-browser. To the images a cross is added that marks the fiber entrance for convenience.

To keep the star on the fiber entrance a 'handset' is provided on the data acquisition computer. This contains 4 buttons with arrows that can be pushed to move the star in small steps (of selectable size) if the object moves away from the fiber entrance.

- **Target observations**

  With the target centered on the fiber, observations can be taken with FIES typing commands in the sequencer window. This typically also includes wavelength calibration observations with a Thorium-Argon lamp. Throughout the observations the 'movie' mode observations are made with StanCam, but do not interfere in any way in the observations with FIES. At the end of the observations, the 'movie' is stopped and the autoguiding is switched-off. A new target can then be selected and the telescope can be moved.

- **At the end**

  At the end of the observations the system can simply be shut down with a single command in any of the terminals which are logged in on the data acquisition computer. After that, just logging out from any windows on that computer closes the connection.

The students were divided in groups of 2, and each of the groups followed the steps outlined above. As there were always 2 groups in each night, the system was closed at the end of the observations by the first group and restarted by the second group. The observations started each night at 20:45 UT, with the handover to the second group at 23:00 UT and the remote observations finishing at 01:15 UT so the students could sleep before the next

day's lectures and the telescope was handed back to the NOT staff at the telescope.

During the remote observations there was one technical problem at the telescope (caused by an electrical problem with a laptop from a visiting astronomer at the telescope) which caused one group to lose nearly all their observing time, and 2 other groups lost most of their observing time due to bad weather.

The observations were very successful and went smoothly without any problems with the remote observing system. On one occasion during a thunderstorm there was a power failure at Molėtai, but simply restarting the system after the power returned reestablished the connection without affecting the observations.

4. Observing courses at the NOT

To obtain time to use the NOT for an observational course the director Dr. Johannes Andersen (email: ja@not.iac.es) should be contacted well in advance ($\sim$1 year) as any such request should be reviewed by the NOT STC and agreed upon by the NOT Council. For more information you can also contact Thomas Augusteijn (tau@not.iac.es) or Raine Karjalainen (rkarjala@not.iac.es) at the NOT.