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## ***PIRATE – the piCETL Robotic Astronomical Telescope Explorer***

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### **Abstract**

**We have set up PIRATE, a remotely operable 35 cm astronomical telescope in a robotic dome at the Observatori Astronomic de Mallorca, to pilot the real-time use of a telescope by distance-learning students from their home. Remote access software, webpages and course materials for third level Open University students were developed. The experience from the first cohort of students of a 10 week-long project based on PIRATE demonstrates the success of the PIRATE concept for teaching practical science at a distance, and highlights the benefits distance learning students draw from a stimulating framework that facilitates group working.**

## **1 The PIRATE hardware**

In 2007 piCETL made an investment of order £30 k to purchase an off-the-shelf telescope with a robotic mount, guider scope, CCD cameras, auxiliary hardware and control software. The initial aim was to set up a remotely operable facility that allows student access in real-time via the internet. The initial aim of this project was to demonstrate the feasibility and explore the benefits of such a device for the university-level teaching of practical science, in particular in the distance learning context.

Exploiting a long-standing collaboration, the **Physics Innovations CETL Astronomical Telescope Explorer (PIRATE)**, was erected at the Observatori Astronomic de Mallorca (OAM), a teaching observatory in the rural heart of Mallorca. The OAM is the host site of the residential weeks of SXR208 (Observing the Universe), a second level OU residential school course in observational astronomy and planetary science.

PIRATE initially moved into a temporary enclosure with a roll-off roof, constructed by OAM staff, on top of the catering building on the OAM campus. Although successfully used for the first commissioning phase of PIRATE it became clear that the enclosure

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<sup>3</sup> Nuffield-funded summer student 2008

<sup>4</sup> EPSRC-funded OU summer student 2009

was not robust enough to guarantee the fail-safe operation of PIRATE by effectively unsupervised remote student users.

In 2009 further funding became available for a 3.5 m robotic dome in clam-shell design, manufactured by Baader Planetarium (Mammendorf, Germany). The dome could be purchased at a highly discounted price in exchange for dome control software development. In August 2009 PIRATE moved into this new dome, erected on top of the main observatory building at the OAM, and has been in operation ever since.

The main optical component of PIRATE is a 14 inch (35 cm) f/10 Schmidt Cassegrain telescope (a Celestron 14). This is equipped with an SBIG STL 1001E CCD camera with 1024x1024 24 $\mu$ m pixels, resulting in a field of view of 21 arcmin and a pixel scale of 1.21 arcsec per pixel. The CCD camera has an 8 position filter wheel with 5 broadband filters (Clear, and Johnson B, V, R, I) and 3 narrow-band filters ( $H\alpha$ , OIII, SII). The telescope is mounted on a Paramount ME, a robotic German Equatorial Mount, manufactured by Software Bisque. A smaller guiderscope (a refractor with 8 cm aperture and 60 cm focal length, by Celestron) is mounted on top of the Celestron-14 tube. The guiderscope is equipped with its own CCD camera (SBIG ST402 ME, with 765x510 pixels of 9  $\mu$ m, giving a field of view of 40 arc min in the RA direction).

All main electrical components are connected by remote-control power distribution units with built in web servers (by Leunig GmbH).

The Baader Planetarium All-Sky dome is equipped with a rain sensor and uninterrupted power supply (UPS). The dome closes automatically if it detects rain, or if there is a power cut, or if it loses the connection to its control computers. The maintenance of the facility is carried out by the OAM free of charge in exchange for a share in PIRATE observing time.

The internet link to PIRATE was upgraded in 2009 from a standard asymmetric DSL telephone line with correspondingly very slow upload (outgoing) speeds to a symmetric 34Mb/s data link via a transmitter on site into a commercial high-speed network.

## **2 PIRATE software**

The PIRATE control software consists of commercially available and bespoke piCETL-developed applications.

The planetarium software The Sky (Software Bisque) acts as the driver for the mount, while the CCD image processing software MaxImDL (Diffraction Ltd) controls the CCD cameras. The freeware FocusMax operates the focuser. The observatory control program ACP (DC Dreams) is the central hub linking all of these components together, and is also the server for the student web interface.

The two main newly developed applications are the dome driver (the Baader Planetarium all-sky dome is a new product and didn't have an ASCOM-based driver) and the remote switch server. The latter acts as a sort of super-hub that allows users to switch essential hardware components on and off (e.g. the mount, cameras, light in the dome) via phidgets, as well as to open and close the dome, and to launch ACP.

An expert user can log on remotely onto the PIRATE control PC and hence achieve direct, complete control of PIRATE, no different from what a local observer in the control room at the OAM would be able to do. This mode of remote observing is unsuitable for non-expert student users because of the confusing interface and, more

importantly, the security risk in allowing unchecked access to the main control unit of the system.

A more detailed account of the PIRATE software, and of the issues involved in developing the bespoke components, are presented in the companion paper by Lucas & Kolb (this volume).

### **3 Student interface**

The student users have a number of interfaces and tools at their disposal that allow the successful acquisition of photometric data with PIRATE throughout an observing run, without granting security-level access to the system.

#### **3.1 ACP**

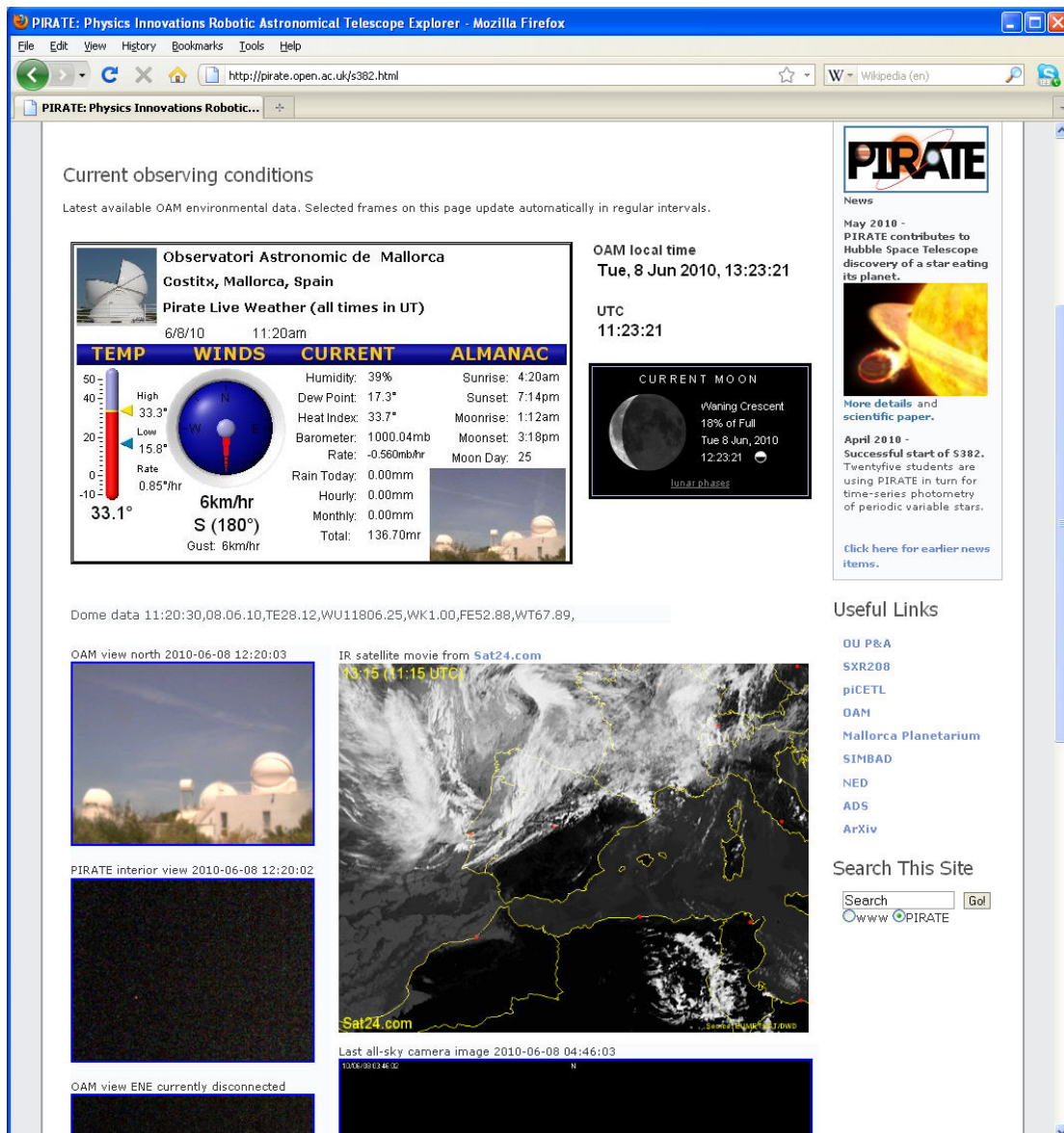
The main observer tool is the web interface of ACP, which chiefly takes care of the telescope slewing and tracking, as well as the actual operation of the main camera to acquire images, both calibration frames and star fields. ACP is a powerful tool that automates the vital tasks of focusing the system, auto-guiding during exposures, and plate-solving (i.e. comparing star patterns on the acquired frame against catalogued star coordinates to determine the actual image centre), and a corresponding pointing update if required, to centre the field on the desired position. ACP provides the user with progress reports on these tasks, but does not normally require user intervention at this stage.

ACP also provides a low-resolution preview of any newly acquired images, and allows the user to browse and download selected full-resolution image files. One image file is about 2Mb in size; typical observing runs deliver between 50 and 500 images. The student users are asked not to bulk download these data throughout the observing run so as not to slow down the data line needed to control the PIRATE system. Instead, an automated FTP process transfers any new data every morning into the central PIRATE data archive hosted at the OU's Walton Hall campus. The archive has a secure, user-friendly front-end which facilitates the download of bulk data by students.

#### **3.2 The observer's area on the PIRATE homepage**

Throughout the observing run the PIRATE user has to monitor the environmental conditions, to establish that it is safe to use the telescope, and to assess the likely impact on the acquired data. PIRATE is equipped with a host of sensors and additional monitors to deliver as complete a picture of the sky conditions as possible. For security reasons direct access to these monitors cannot be granted to a large number of non-expert users. Instead, an automated web feed was developed that provides diagnostic images and sensor readings for an auto-updating web page hosted on the PIRATE homepage (<http://pirate.open.ac.uk>). These data include interior and exterior webcam views of the PIRATE dome, an all-sky 360 degree panorama view (covering altitudes higher than about 40 degrees), an infrared weather satellite animated clip, and weather data such as temperature, humidity and wind speed. A rapidly updating webcam feed gives the impression of a live video stream, allowing students to monitor the opening and closing of the dome, and the slewing of the telescope.

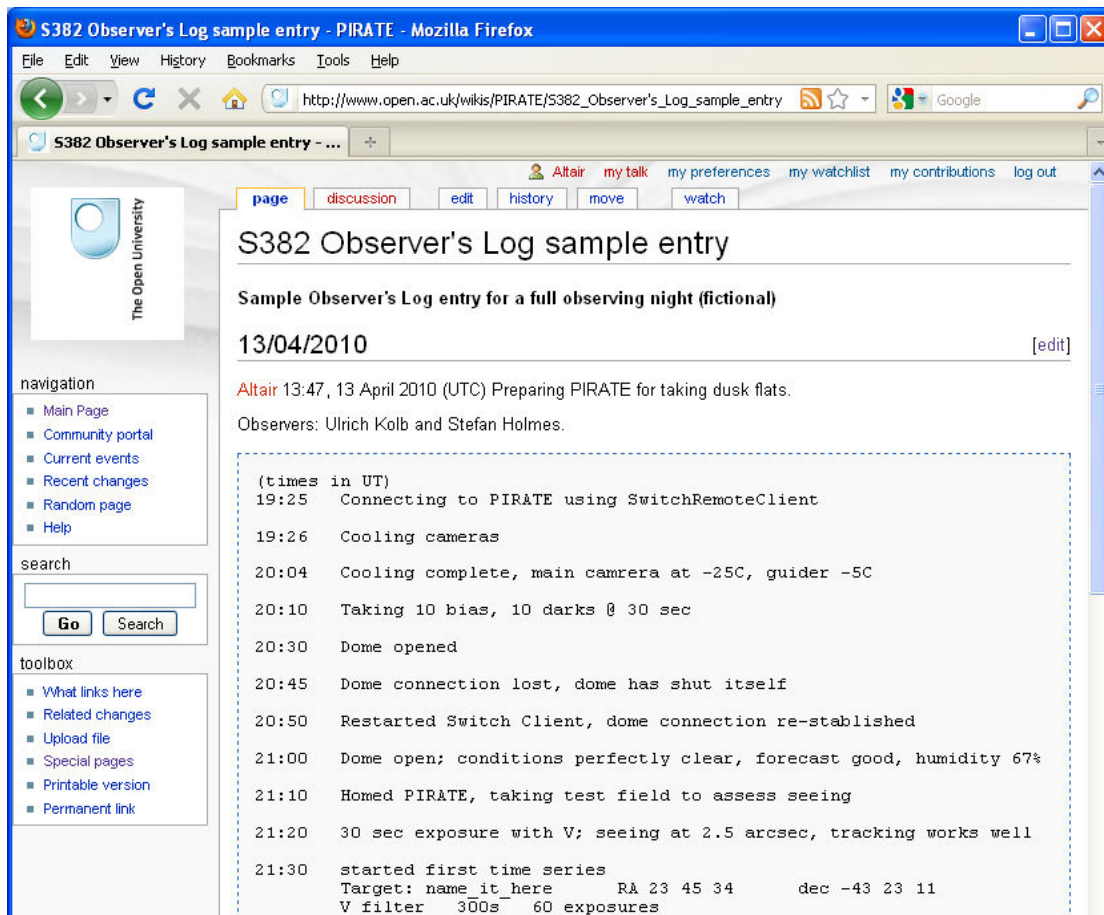
All live primary diagnostic data and images are frequently copied to an OU server, and taken from there to feed the diagnostic webpage. Thus the student-user webpage does not reveal the IP address of any of the diagnostic monitors, and the PIRATE data line is not slowed down by the potential large volume of traffic generated by multiple user access to these devices.



**Figure 3.1** Screenshot of the PIRATE environmental monitor page (S382 tab of the PIRATE homepage).

### 3.3 The Observer's Log wiki

PIRATE observers keep a detailed log of their activities during the observing run. This includes information on the actual target and image data (such as exposure time and filter used), as well as a record of environmental conditions and notes on any unexpected behaviour or problems. This Observer's Log is kept in the form of an OU-hosted wiki ([http://www.open.ac.uk/wikis/PIRATE/Observer%27s\\_Log](http://www.open.ac.uk/wikis/PIRATE/Observer%27s_Log)) which can be edited only by registered users, but read by anybody. Crucially, the log is also used as a communication tool throughout the observing night. Expert PIRATE users (who may or may not be affiliated with the OU) can monitor the work of the student observer and may be able to offer advice on any reported problems by adding comments to the wiki log entries.



**Figure 3.2** Screenshot of a sample Observer's Log entry.

## 4 Student-use and supervision

The way PIRATE is being employed for student-use addresses the desire to give real-time control of PIRATE to a large number of students while still maintaining a manageable hands-on feeling. This latter requirement effectively limits the number of simultaneous users to 2-4 students. Members of such a small observer team can simultaneously log on via ACP and receive real-time status updates. The team members take on different roles throughout the observing night, such as operating PIRATE, keeping the Observer's Log, taking responsibility for monitoring environmental conditions, and inspecting new data for image quality.

In addition, a satisfactory student experience demands that observers obtain and subsequently analyze what they would consider "their own" data. This is made difficult by the unpredictability of the weather. On average, one out two OAM nights is useful for differential photometry, a typical higher-level application of PIRATE, throughout spring and summer.

For the 10 week-long PIRATE project in the third level OU course S382 (Astrophysics) this was resolved by forming a number of project groups of about 10 students each. A project group is responsible for staffing observer teams of 2-4 students for nights allocated to the group. The project group students share all of the data their teams acquire, and collaboratively analyze and interpret these data. Each group was given enough observing nights to ensure that any individual student could contribute in at

least three observing runs as part of an observer team. Taking part in at least one half of an observing night was set as one of the conditions for the successful completion of the project. In this way up to 70 students can be served as part of the S382 PIRATE project. In the 2010 pilot presentation the number of students was limited to 30.

The greatest organisational challenge from a teaching point of view was to deliver an introduction into the safe use of the PIRATE facility to the cohort of S382 distance learning students within a manageable time frame. This was achieved in the form of a series of Elluminate-mediated group evenings which then split into a number of smaller groups of up to 5 participants (including tutor) who communicated via Skype while operating PIRATE. In the Skype session each student is asked to control PIRATE for a few minutes, with the tutor watching and talking the student through procedures. Skype rather than Elluminate was used because of its superior sound quality, and because it is less demanding on student PCs that are already serving a host of PIRATE control applications.

During subsequent observing nights members of the observer team kept in constant audio contact via Skype. They could also contact a nominated night duty astronomer (NDA), an expert PIRATE user, via Skype or an emergency telephone number. The NDA role is important to safeguard a satisfying student experience and the well-being of the hardware. The NDA initially acts as a tutor for the first phase of the first observing night of an observer team, but then takes on a simple trouble-shooting or emergency role.

## 5 Evaluation

Here we can only briefly touch upon the recent experience of using PIRATE with OU students studying the 10-week PIRATE project of S382. The goal of the project is to acquire a long-term light curve in different broadband filters of an as yet unclassified, or little studied, periodic variable star, and constrain the physical nature of this source.

At the time of writing this project is ongoing, and a fuller account of the rich feedback on the teaching and learning experience will be presented elsewhere. It is already clear that the collaborative nature of the PIRATE project was a resounding success, as evidenced by the fact that the 25 active project students, distributed between three project groups, generated more than 1000 VLE forum postings between them in the first 7 weeks of the project. These postings range from simple statements of availability to discussions of results of the data analysis.

At the time of writing the phase of scheduled observing nights for the S382 PIRATE project draws to a close. PIRATE was in use during 38 out of 41 available nights. About 20 nights delivered good-quality long-term light curves, but most of the remaining nights still gave some useful data, albeit with more noise. A non-negligible fraction of observing nights was cut short some time after midnight due to high humidity levels at the OAM, a seasonal characteristic of the site in spring. The dome had to be closed to protect the equipment from condensation on unheated surfaces. The installation of further protective devices that would enable the use of the system at high humidity is being investigated.

Throughout the S382 observing period there were no serious technical glitches. It was necessary to call out OAM staff for night-time assistance only on three occasions. On two of these the UPS unit of the dome developed a fault and prevented the remote use of the dome. This recurring technical problem is being addressed jointly with the dome manufacturer. The other OAM call-out arose after the sudden loss of any communication with the PIRATE system. This turned out to be a planned night-time

internet downtime for upgrade work by the local internet service provider which was not communicated to the OU.

Other minor operational problems could all be easily resolved by the NDA via super-user access to the system. After the initial teething phase of 2-3 weeks with numerous hardware and software problems the routine workload of the NDA settled at a pleasingly low level, with very few occasions where observer teams contacted the NDA because of a problem.

The student-use of PIRATE was much more enthusiastic than anticipated. Observer teams routinely stayed up into the small hours even in largely clouded nights, wrestling with the system to still obtain some useful data. As a result, the alternative "bad weather tasks" were rarely used. This highlighted the fact that PIRATE delivers data that are useful in a teaching context even in rather poor conditions when professional observers would long have given up observing.

The expected failure of automated processes such as the auto-guiding or the focusing in non-ideal weather conditions – what was initially perceived as a threat to the successful use of PIRATE by non-expert student users - turned out to be a valuable feature contributing to meeting the learning objectives. Guider, focus and pointing failures all leave characteristic marks on the acquired images, and the correct reading of these, as well as the discussion and implementation of counter measures, constitutes a vital part of practical scientific investigations. It also gives the experience of being involved in an interactive, real-time experiment, much more so than a faultless system that automatically returns perfect results on the press of a button.

Another extremely beneficial feature is the regular, long audio-contact of students when they work as part of an observer team (normally at least three times during the project, but many students volunteered to take part more often for at least some fraction of additional observing nights). This is a unique chance for sharing and discussing course-related science, data analysis techniques and results, or technical issues. It is obvious that these team meetings provide an enormous additional stimulus for continued active engagement with the project as a whole. The first observing night of a team also always involves the NDA who can provide further reassurance and advice on the project in general, and at times engage in deep and stimulating discussions with students.

The PIRATE project requires students to work throughout the night when they are part of an observer team. There was some initial concern about the sustainability of this mode of study, with the often held view that a remotely operable telescope on the other hemisphere, offering night-sky access during the UK day-time, would be advantageous to a facility at effectively the same longitude as the UK. This concern was probably unwarranted. Due to work commitments a significant fraction of OU distance learning students appears to prefer studying in the evening – and they regard the night-time work as the natural extension of a period when they would study anyway (which is not to say that night-time work isn't demanding!).

## **Conclusions**

The use of the PIRATE facility represents a novel and ambitious approach to teaching practical science at a distance. The technological challenges are significant, and work to improve the current hardware and software setup is ongoing. The third level 10 week-long PIRATE project in S382 was received with great enthusiasm by S382 students, and can be regarded as a resounding success. The presentation of the project did not only prove the feasibility of including a remotely operable observatory in distance teaching, but also very clearly highlights the enormous learning benefits of giving remote students in small groups real-time control of a versatile measuring



device. A future expanded use of this, and similar facilities, should become integral part of the OU science curriculum.

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