

C2PU: AN ORIGINAL MIX OF RESEARCH AND PEDAGOGY AT OBSERVATOIRE DE LA CÔTE D'AZUR

P. Bendjoya¹, L. Abe¹, J.-P. Rivet¹, O. Suárez¹, D. Vernet² and D. Mékarnia¹

Abstract. C2PU stands for “Centre Pédagogique Planète et Univers” and consists in an experimental and observational facility located at 50 km from Nice (France), at the Calern Plateau. It is dedicated to the pedagogy in Earth and Universe sciences by and through research projects.

Keywords: Methods: observational, Techniques: photometric, Techniques: polarimetric, Techniques: interferometric

1 Introduction

C2PU offers an infrastructure devoted to the immersion of students in the experimental environment in astrophysics and geophysics (<http://c2pu.oca.eu/>). C2PU stands in French for “*Centre Pédagogique Planète et Univers*”, that is: “Center for Pedagogy in Planet and Universe sciences”. It is a project both for pedagogic and research purposes. Concerning the astrophysical part, it relies on the renewal of two 1-meter diameter telescopes. These two telescopes are located in southern France, 50 km away from the city of Nice, on the so-called “Calern Plateau”. The coordinates are 6° 55' 22" East in longitude, 43° 45' 14" North in latitude and 1260 m in elevation. The average number of clear nights per year is around 200 and the sky background level ranges from 20.7 to 21 magnitudes per square arc-seconds. One of the telescopes is planned to be operated by remote access in order to offer undergraduate classes the possibility to participate to sky observations after several sessions of teacher training in the framework of the EduCosmos project, the astronomical counterpart of the French educational outreach project “*Sismo à l'École*” (<http://educosmos.oca.eu/>). This remote access capability will also be offered to national and international universities in partnership with C2PU.

The center offers a capacity of 28 sleeping arrangements, a restaurant, a visio-conference facility and a computer room with high speed internet connection which allows a complete immersion of the students during their stay at the observatory. Groups can be driven to the center with a van owned by the Observatoire de la Côte d'Azur (OCA).

The Calern Plateau and its surrounding display several geophysical and geological structures of interest,. They can be used both for experimental and practical lectures. Several unique geological sites are easily reachable from the Observatory. Both astrophysical and geophysical practical trainings can be combined within a common infrastructure.

The project is supported by the *Observatoire de la Côte d'Azur*, the University of Nice Sophia-Antipolis (UNS), the *Collège de France* (CdF), the *Conseil Général des Alpes Maritimes* and the *Conseil Régional Provence Alpes Côte d'Azur*.

2 Astrophysics

2.1 Instruments

The two telescopes that C2PU will offer, were earlier coupled as part of an interferometric instrument called SOIRDETE (for “*Synthèse d'Ouverture en Infra Rouge avec DEux Télescopes*”), described in Rabbia et al.

¹ Laboratoire Lagrange UMR 7293, Université de Nice Sophia-Antipolis, Observatoire de la Côte d'Azur, CNRS

² Laboratoire d'Interférométrie Stellaire et Exoplanétaire, Collège de France

(1990). These two instruments are planned to be renewed in two phases. The first one which began in September 2010 involves the shaping and polishing of a 1-meter primary mirror for the West-telescope (W-Tel), out of a Zerodur blank provided by OCA. This phase ended late 2011. During this polishing operation by D. Vernet from CdF, the refurbishing of the mechanical structure of the telescope is undertaken. In parallel, the C2PU team has designed and implemented the hardware and software for the remote control of W-Tel through Internet. The W-Tel is presently in beta-testing phase, and is not yet remote-operable. Its Cassegrain $F/12.5$ focus is in a temporary configuration for characterization tests. The second phase will begin in 2013 and will concern the second 1-meter telescope, the East-telescope (E-Tel).

The W-Tel is planned to have two different focus configurations: an $F/3.24$ primary focus for wide field imaging, and a Cassegrain $F/12.5$ focus. Switching from one configuration to the other will only consist in plugging or unplugging an opto-mechanical module. The whole mechanics have been designed and manufactured by the department of mechanics at OCA. The telescope will be driven by a control computer, accessible through an internet interface, to allow for remote observations.

The $F/3.24$ focus will be equipped with a 4096×4096 SBIG STX-16803 CCD camera with a set of filters. This will lead to a pixel scale of $0.6''/\text{pix}$ and a $40' \times 40'$ field of view. The 20th magnitude is expected to be reachable at 5σ with a 1 minute exposure. This configuration will be dedicated to wide field imagery and transit photometric surveys.

The $F/12.5$ focus will receive a SBIG ST8XME CCD camera. This will provide for a $3.8' \times 2.5'$ field of view, with a pixel scale of $0.15''/\text{pix}$. Magnitude 17 is expected to be reachable at 5σ with a 1 minute exposure. This configuration will be used for polarimetry and photometry.

The E-Tel will have an $F/12.5$ focus, quite similarly to W-Tel, plus an $F/35$ “coudé” focus and should be available early 2014. The $F/12.5$ focus of E-Tel will be either a Cassegrain or Gregory combination. It should be dedicated to spectroscopy. Concerning the “coudé” focus, the focal image will be delivered on a very stable optical bench, at a fixed point, regardless of the position of the astronomical target. On this optical bench, all kind of focal instrumentation will be welcomed, such as a deformable mirror and a wave front sensor for a low-order adaptive optics system. With a SBIG ST8XME CCD camera, this configuration would lead to a $1.3' \times 1'$ field of view, with a pixel scale of $0.05''/\text{pix}$. Magnitude 15 should be reachable at 5σ with 1 minute exposure.

2.2 Research Projects

C2PU will offer a list of conventional observational practical lessons to undergraduate and graduate students in order to acquire the fundamental techniques for performing observations and processing data: imagery, photometry, spectroscopy, polarimetry. For this purpose, smaller telescopes (two 14 inches commercial telescopes), both equipped by SBIG ST402 CCD cameras, will be available. But the original purpose of C2PU is to make students participate to research observations in order to feed professional data bases and/or characterize transient events. With this philosophy, C2PU offers a list of research programs for which observations will be performed essentially by supervised master students, but in case of alerts during a non pedagogic period, dedicated staff will be available for an in situ observation and/or remote session assistance.

- **CAPS: Calern Asteroid Polarimetric Survey.** The W-Tel Cassegrain $F/12.5$ focus will be equipped by a CCD polarimeter build at Torino Observatory which will be dedicated to asteroid polarimetry. The CAPS project consists in a survey of asteroids, down to magnitude 18, to study the linear degree of polarization as a function of the phase angle (angle between asteroid-solar axis and asteroid-earth axis). From this analysis, both albedo and diameter of asteroids can be estimated, leading to the determination of crucial lacking physical parameters. CAPS is possible thanks to a collaboration with Torino Observatory, which builds the polarimeter and furnishes the dedicated CCD camera. Near Earth asteroids and space mission targets are under the scope of this survey but systematic studies of main belt and possibly Kuiper belt asteroids will benefit from the data bases of small body physical parameters that will be accessible via the Virtual Observatory.
- **GAIA-FUN: GAIA Follow-Up Network** (<https://www.imcce.fr/gaia-fun-sso/>) is a worldwide network of ground based telescopes that is coordinated by the *Institut de Mécanique Céleste et de Calcul des Ephémérides* (IMCCE) of the *Observatoire de Paris*, whose aim is to follow the alerts of the GAIA probe concerning transient events. GAIA is a space mission of the European Space Agency (ESA) that will be launched in 2013 with the main goal of obtaining micro arcsec precision astrometry of 1 billion stars

in our galaxy. GAIA will also provide a huge amount of “secondary results” in several fields of astronomy. Among them, transient events will be detected but will not be followed by the satellite itself: novae, exoplanetary transits, fast near earth asteroids, comets, collisions... Alerts will be sent to the IMCCE node that will relay the informations over the GAIA-FUN. C2PU belongs to this network and will be well adapted for asteroid recovery and astrometry computation, photometry light curves and spectroscopic characterizations (asteroids, exoplanets, novae and collisions). Depending on the thresholds chosen for the alerts the number of relayed information could reach 600 per day.

- **PISCO : Pupil Interferometry Speckle COronagraph**
(http://userpages.irap.omp.eu/~jprieur/Pisco_e.html) is a speckle camera that has been designed and built at *Observatoire Midi-Pyrénées* (Prieur et al. 1998). After several years of operation on the 2-meter telescope “Bernard Lyot” at the *Observatoire du Pic du Midi*, PISCO has been transferred at the *Osservatorio Astronomico di Brera*, in Merate (Italy) (Scardia et al. 2004). It has yield eleven articles on astrometric measurement of visual binaries and orbit determinations. PISCO will be mounted on the E-Tel within the framework of an agreement between *Osservatorio Astronomico di Brera* and OCA. This project has been approved and encouraged by the IAU Commission 26 (Double Stars) and will be used not only in the pedagogic framework to introduce speckle interferometry but also for double star studies.
- **TEP2C : Transient Event Photometric Characterization at Calern.** Independently of photometric GAIA alerts, C2PU will be involved in the characterization of photometric events novae photometric follow-up, asteroid occultations, search for optical counterparts of gamma ray bursts, variable stars.
- **EXOTIME : EXOplanet search with the TIming MEthod**
(<http://www.na.astro.it/~silvotti/exotime/>) is a long time photometric monitoring of pulsating stars for the detection of exoplanets. Following the example of V391 Peg b (Silvotti et al. 2007), the main goal of this project is to detect planets orbiting evolved pulsating stars such as sub-dwarf B (sdB) stars or white dwarfs (WDs) through the timing method, using the stellar pulsation as a clock. The EXOTIME collaboration is based on a network of ground-based one to four meters class telescopes.
- **QS2C : Quasar Spectroscopic Characterization at Calern.** By the means of a collaboration with University of Liège in Belgium, C2PU will participate to the spectral characterization of the quasars detected by gravitational lensing on the International Liquid Mirror Telescope (*ILMT*: <http://www.aeos.ulg.ac.be/LMT/instruments.php>). It is a 4 meter class telescope project, in which several institutions from different countries are actively involved (Belgium, Canada, Poland, India). The primary mirror of the telescope is a rotating container with highly-reflecting liquid in it (mercury). The surface of the spinning liquid takes the shape of a paraboloid. It will be installed at Devasthal (India) where it will monitor a strip of sky of 0.5 degree of declination down to a limiting magnitude of about 23 in the I band in a single integration. This survey will last for about five years (Poels et al. 2012).
- **Instrumental development.** The “coudé” focus of the E-Tel will deliver the sky light onto a very stable optical bench, regardless of the position of the astronomical target. This configuration is ideal to develop and test a wide range of focal instrumentation (adaptive optics, stellar coronagraphy, aperture interferometry). This telescope can also be seen as a R&D tool both for pedagogic and research purposes.

All these research projects are addressable with a 1 meter class telescope and will provide the students with the opportunity to be in touch with the astrophysics issues underlying the observations and also to participate to the data acquisition and processing. Results will be either immediately exploited or will feed data bases depending on the nature of the observation. The list of research projects is not exhaustive and will be adapted to the forthcoming scientific proposals.

2.3 Test and first lights

The first light of the W-Tel occurred on August the 10th, 2012, with temporary, not optimized equipment (color SBIG ST-4000XCM and B&W SBIG ST-10XME cameras). Figures 1 and 2 show samples of the processed astronomical images obtained this night. The commercial field corrector was a Type 2 Parracor providing an F/3.31 ratio. This configuration was not optimal since a SBIG-STX camera (4096×4096 pixels) with a customly designed 3-lenses Wynne corrector will soon be fabricated and installed as mentioned before. The custom Wynne corrector, under construction at OCA, will provide for a 3 times larger field of view (40' × 40'), with a better

and more uniform wide band coma correction. It is to be reminded that the color CCD used for the images in Figures 1 and 2 lowers the potential resolution due to its built-in Bayer's matrix. Moreover, these images have been obtained without any auto-guiding system (to be implemented soon). These sample images (more images at <https://c2pu.oca.eu/>) show both that the Plateau de Calern site is optically and that the telescope promises high performances.

Figure 1 is an image of the well-known Hercules globular cluster M13 taken with the C2PU. The upper-right frame is a zoom on the central part of the main image, and the lower-right frame is the same field from the Hubble Space Telescope.

To assess the photometric quality of this new observation facility, we have followed the transit of exoplanet HAT-P-5b across its $V=12$ host star, on August 17th, 2012, with the same optical configuration (C2PU E-Tel ; primary focus at F/3.31; commercial type 2 Parracor field corrector, B&W camera SBIG ST-10XME). Each individual frame was obtained with 8 seconds exposure time, on defocused images (FWHM between 2" and 3"). The achieved photometric accuracy is 3 millimagnitude on un-binned data, which appears to be highly promising for the future photometric and polarimetric research projects.



Fig. 1. The globular cluster M13 from the C2PU W-Tel. Upper-right frame: a magnified crop of the center of the cluster. Lower-right frame: the same zone extracted from a HST image.

3 Geophysics

Specific characteristics of Plateau de Caussols make this site an ideal location for the study of some geophysical aspects:

- The Plateau de Caussols is one of the biggest slopes of gravitational deformation of the Alps with three collapses
- these collapses affect the whole slope in front of Caussols and involve 160 million m^3 of rocky materials.
- Important perturbations in the morphology are present in the landscape : typical gravitational morpho-structures (steep slopes, inverted steep slopes, rift valleys,...)

The morpho-geological cartography can be coupled to deep geophysical surveys (electrical resistivity tomography) in order to point out correlations between morpho-structures and resistivity anomalies. The "Risk Team" of Laboratory GeoAzur at OCA uses on the Plateau a specific instrumentation that allows long term survey for



Fig. 2. The NGC7331 galaxy from the C2PU W-tel.

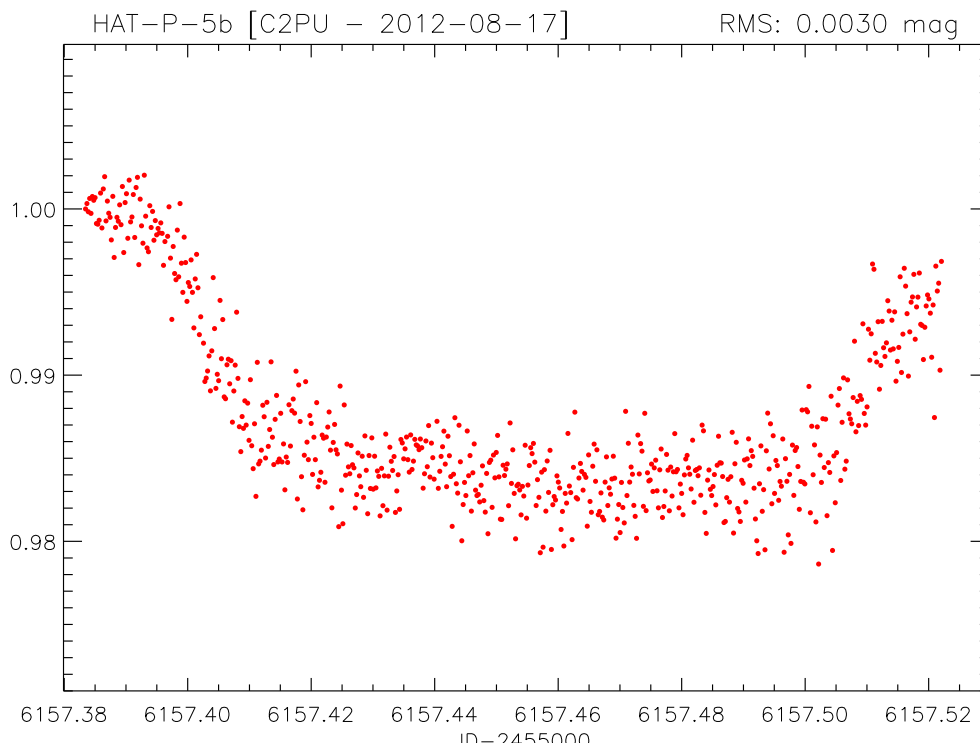


Fig. 3. The light curve of the transiting exoplanet HAT-P-5b, with C2PU W-Tel (August 17th, 2012).

the observations of collapses and long term evolution of electric resistivity

In the framework of a collaboration OCA/IPGS (Institut de Physique du Globe de Strasbourg), a seismological short period instrumentation was installed by the Réseau National de Surveillance Sismique (RENASS)

in 1980 at the Plateau de Calern, as an element of the real-time seismological watching of the Nice region. This site was closed after loyal services in 2011.

In 1994, one of the most ancient broad band seismological stations of from the RLBP (Réseau Large Bande Permanent) was installed at the Plateau de Calern. This station is the premise of the large metropolitan seismological antenna RESIF (REseau Sismologique Français). From the beginning of 2000, it has been integrated to the VEBSN (Virtual European Broad Band Seismological Network), coordinated by ORFEUS (Observatoires and Research Facilities for European Sismology), whose data is distributed in real time to the scientists for the quick interpretation of the major world-wide seisms and for several studies about terrestrial structures.

From June 2011, this station has been equipped by the CEA (Commissariat à l'Energie Atomique et aux énergies alternatives) with a satellite data transmission to contribute to the French tsunami detection system (<http://www.info-tsunami.fr/>).

A station belonging to the Réseau Accélérométrique Permanent français (RAP) has been associated in 1997 and is mainly devoted to the recording of large magnitude seisms.

Real-time data contribute, within the different French groups concerned, to the detection and quick characterization of the regional seismicity (<http://www.geoazur.net/sismoazur/>) and eventually worldwide.

After a manual verification of the signal, data contributes to the elaboration of the official seismic catalogue of the French territory, that is distributed by the Bureau Central de Sismologie Français (BCSF). These data also contribute to the studies of the seismicity, the seismic risks and also of the deep terrestrial structure.

Data recorded during the last week can be consulted on the site <http://www.geoazur.net/sismoazur/helicorders.php>.

4 Conclusions

C2PU offers professional class telescopes and a site with many geological interests with an infrastructure that allows complete immersion of students in astrophysical and geophysical experimental works. It offers the possibility to train graduate and undergraduate students to astronomical observation techniques and make them participate to research programs. The remote access of C2PU will open this facilities to many other audiences that will have the opportunity to be introduced to actual research subjects covering a vast field of modern astronomy. Astrophysics and geophysics theoretical lectures, practical data analysis, signal processing, practical and experimental optics lectures will be in situ or remotely given thanks to this original tool proposed to the community.

Authors are grateful to the *Observatoire de la Côte d'Azur* (OCA), the University of Nice Sophia-Antipolis (UNS), the *Collège de France* (CdF), the *Conseil Général des Alpes Maritimes* and the *Conseil Régional Provence Alpes Côte d'Azur*, for their support to the C2PU project. C2PU team want also to thank Anne Deschamps from GéoAzur Laboratory for her fruitful inputs on the geophysics section.

References

- Poels, J., Borra, E., Hickson, P., et al. 2012, in IAU Symposium, Vol. 285, IAU Symposium, ed. R. E. M. Griffin, R. J. Hanisch, & R. Seaman, 394–396
- Prieur, J.-L., Koechlin, L., André, C., Gallou, G., & Lucuix, C. 1998, *Experimental Astronomy*, 8, 297
- Rabbia, Y., Mekarnia, D., & Gay, J. 1990, in Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, Vol. 1341, Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, ed. I. J. Spiro, 172–182
- Scardia, M., Prieur, J. L., Koechlin, L., et al. 2004, *IAU Commission on Double Stars*, 153, 2
- Silvotti, R., Schuh, S., Janulis, R., et al. 2007, *Nature*, 449, 189