



First observations of the Fabra-ROA telescope at the Montsec Astronomical observatory

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Abstract. The Baker-Nunn Cameras (BNCs) were produced by the Smithsonian Institution during the late 50's as an optical tracking system for artificial satellites. One of those telescopes was installed at the Real Instituto Observatorio de la Armada (ROA) in San Fernando (Spain) and managed jointly between these two institutions until 1979, when the Smithsonian transferred the instrument to the ROA.

In 2000, due to its excellent mechanical and optical original design, the Observatori Fabra of the Reial Acadèmia de Ciències Arts de Barcelona (RACAB) and the ROA agreed to refurbish the BNC and to install this new facility in a new observatory at 1570 m altitude founded in Catalonia, in the NE of Spain. After the refurbishment period and first test at the ROA the now called Telescope Fabra-ROA Montsec (TFRM) was moved to the Observatori Astronòmic del Montsec (OAdM) on 2010 September. Since then, it is in commissioning period to test both observing modes: remote and robotic.

In this presentation we shall show the results of some observational campaigns carried out with the TFRM while it was in commissioning. Mainly the instrument has participated, as an informal partner, in the CO-VI Satellite Tracking Campaign of the ESA's Space Situational Awareness (SSA). These campaigns are experimental observations of Earth orbit objects using existing European telescopes and radars to determine how accurately they can work together. Also some transiting observations of known exoplanets have been conducted.

More information in <http://www.am.ub.es/bnc/>

Keywords : wide field astrometry – photometry – exoplanets – NEOs – space debris

1. Introduction

In 2000 a major refurbishment for the old Baker Nunn camera of the ROA was started, as part of a cooperation agreement between this Institution, the RACAB and the Departament d'Astronomia i Meteorologia (DAM) of the Facultat de Física of the Universitat de Barcelona.

The Baker Nunn camera is a Schmidt telescope of 50-cm of aperture and a focal ratio of 1:1. The original mechanical design of the Baker Nunn camera has been changed from altazimuthal to equatorial mount and the motions in right ascension and declination were upgraded with new servo-motors and absolute encoders able to move the tube 180 degrees in less than 2 minutes (Carter et. al. 1992). The old photographic film system has been changed by a modern CCD camera housed in a new spider vane with motorized focusing. The optics was redesigned adding a meniscus lens and a field flattener lens to achieve a totally flat field of view (FoV) of 4.4 x 4.4 degrees, an angular area which covers the whole CCD camera.

The telescope's motion axes, the focusing and command of the CCD camera, the opening and closing of the building roof, the monitoring of meteorological data and, in general, a plethora of different devices belonging to the automated observatory is controlled by an INDI-based software supplied by Clear Sky Institute, Inc (Downey 2008). This software was specifically tailored for the TFRM.

The modifications of the telescope finished early 2010 and after a short period of test observations at the ROA on July the telescope was moved to the OAdM at 1570 m of altitude in the NE of Spain. In September 2010, the telescope was installed in its new observing site and since then it has been operative in commissioning period (Fors, et al. 2010; Fors et al. 2010). After the refurbishment, the telescope has been named as Telescopio Fabra-ROA en el Montsec (TFRM).

2. Specifications

At present the TFRM is an equatorial mount telescope whose optical and CCD camera specifications are shown in Tables 1 and 2.

3. Automation system

The telescope is fully automated and is able to work in both remote and robotic modes. There are several subsystems collecting meteorological data, managing the

Table 1. Specifications of the telescope.

Aperture	494.08 mm
Focal ratio	1/ 0.96
FoV	4.4 x 4.4 deg
Spot size (80% of encircled energy)	20 microns

Table 2. Specifications of the CCD camera.

CCD chip	Kodak KAF-16803
No. of pixels	4096 x 4096
Size of pixels	9 microns
Scale	3.9 arcsec per pixel
Peak Q.E.	0.69%
Cooling	Peltier with refrigerated glycol recirculation

telescope's motion, CCD camera commanding and focusing, glycol cooling system for the camera, roof opening-closing etc.

The meteorological data monitoring is carried out by a Vaisala MAWS100 weather station with a WXT510 multisensor installed in a meteorological mast that records temperature, pressure, humidity, rainfall and wind speed and direction. A Vaisala DRD11A precipitation detector is also placed in the mast to get a redundant and faster rain and snow detector systems. Also several temperature and humidity probes are placed inside the dome and near the CCD camera inside the telescope to control the environment conditions in those places.

The time synchronization is directly performed from the GPS satellites network through a Time Server Meinberg of the type LANTIME M200/GPS whose timebase accuracy assures the time of our local network to be below 0.2 ms.

All these subsystems are controlled by two PCs running an INDI-based software supplied by the company Clear Sky Institute specifically tailored for the TFRM. Such control software can be distributed running in several PCs on the observatory LAN, all serving to several simultaneous clients, running different operative systems such as Linux, Windows, Mac-OS, etc.

The observations may be carried out following the sky diurnal motion or tracking an artificial satellite orbit. The CCD camera shutter is able to be closed and opened at will during one single exposure. In this way, when tracking satellites (Montejo et al. 2011), the gaps in the star's trailed images supply timing information to get the coordinates of the stars present in the field of view.

4. First observations and results

In the framework of the CO-VI Study within the ESA Space Situational Awareness Preparatory Program (SSA-PP), optical tracking campaigns with European assets are necessary. The Astronomical Institute of the University of Bern (AIUB) is in charge of the planning of these tracking campaigns and the processing of the resulting data. This program is designed to gather information about the current European observational assets, and to guarantee the security of spatial navigation. Due to the fact that space objects orbiting the Earth increase dangerously, programs like this help insure the safety of the satellites at different orbits, and their lifetime in space.



Figure 1. TFRM robotic observation of the LEO Delta1 R/B, encircled in green. Orbit 304, distance 1608 km, inclination 89.1 degrees. The image was taken on Feb 7th 2011, with an exposure time of 0.3 second.

In the first days of January 2011, and despite being still under the commissioning period, the TFRM was invited by the ESA SSA Office to participate as an informal partner in an observational campaign of seven days, during the first week of February

2011. That campaign was the last one of the three runs which formed the CO-VI Satellite Tracking Campaign of the ESA SSA-PP.

Since Jan 30th to Feb 7th 2011, astronomers of the Observatori Fabra and the Real Instituto y Observatorio de la Armada (ROA) have conducted systematic observations of artificial satellites and got 1137 images of different Low Earth Orbit (LEO), GPS and Geostationary satellites. Although under in-situ human supervision, those were the first official robotic mode observations of the TFRM.

Telescopes and radars from UK, Sweden, Switzerland, Cyprus and Spain have participated in the campaign. Three observing stations in Spain (including the TFRM) were involved in the observations. 1137 accurate satellite positions were determined and submitted to the coordinating office in Switzerland. At present the TFRM has already been integrated in the ESA SST program. The Fig.1 shows an image taken with the TFRM of the LEO Delta1 R/ B. The telescope was tracking the satellite so the stars are trailing images.

In order to test our data quality, Orbit Determination (OD) from the angular measurements was carried out using the Orbit Determination Tool Kit (ODTK) software (Hujak et al. 2007), from Analytical Graphics, Inc. (AGI). This licensed software is used by ROA in collaboration with the Instituto Nacional de Técnica Aeroespacial (INTA). As an example, in Fig.2 we show the 2-sigma (95%) uncertainties obtained over the MSG2 satellite, with 175 angular measurements along 4 nights in which the satellite was not maneuvered. The mean uncertainties in the classical elements; semi-axis, eccentricity and inclination, are of the order of 12m, $1.8E-6$ and $1.5E-6$ degrees respectively. Although these results are quite preliminary, they reveal the usefulness of TFRM in tracking objects in the GEO region.

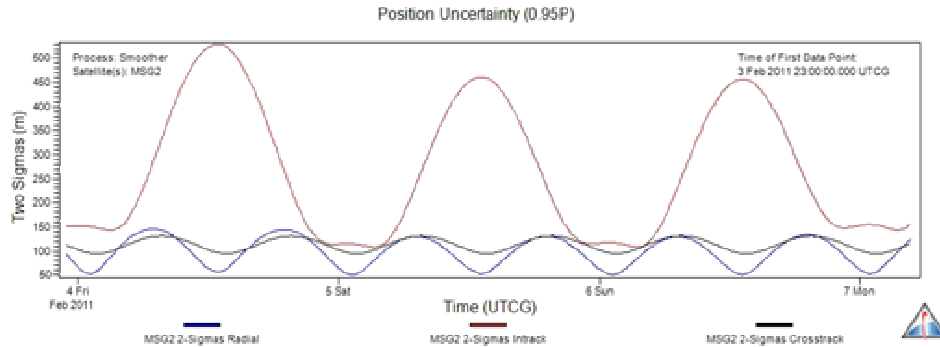


Figure 2. Uncertainties in the position of the MSG2 satellite, at 2 sigmas (95%) and in RIC coordinates.

In addition, as a part of the current commissioning period and in order to check the reliability and performances of the TFRM, a second key observational program was initiated. With its huge 4.4×4.4 degrees FoV and its moderately large aperture

the TFRM can achieve mmag precision differential photometry when observing stars in the magnitude range of $12.5 < V < 15$ mag. Therefore a new program to detect new super-Earth transits around M-type dwarfs stars has been started on the basis of a targeted-field strategy. Just as a matter of example of what TFRM can deliver in one single-night of observation, on Apr 8th 2011 the telescope was scheduled to observe the WASP-37b exoplanet transit (Street et al. 2003) in a completely unsupervised robotic mode. The complete transit spanned about 4.5 hours. The results of the observation have been surprisingly outstanding for a first attempt and for a preliminary analysis: a differential photometric precision of 4.3 mmag for WASP-37b transit was found. Fig.3 shows the light curve of WASP-37b transit.

In addition, as a by-product of those 4.5 hours of photometric measures, several dozen of similar magnitude stars present in the field were detected as variable stars of different types with a differential photometric precision of 3 mmag with V up to 14 mag.

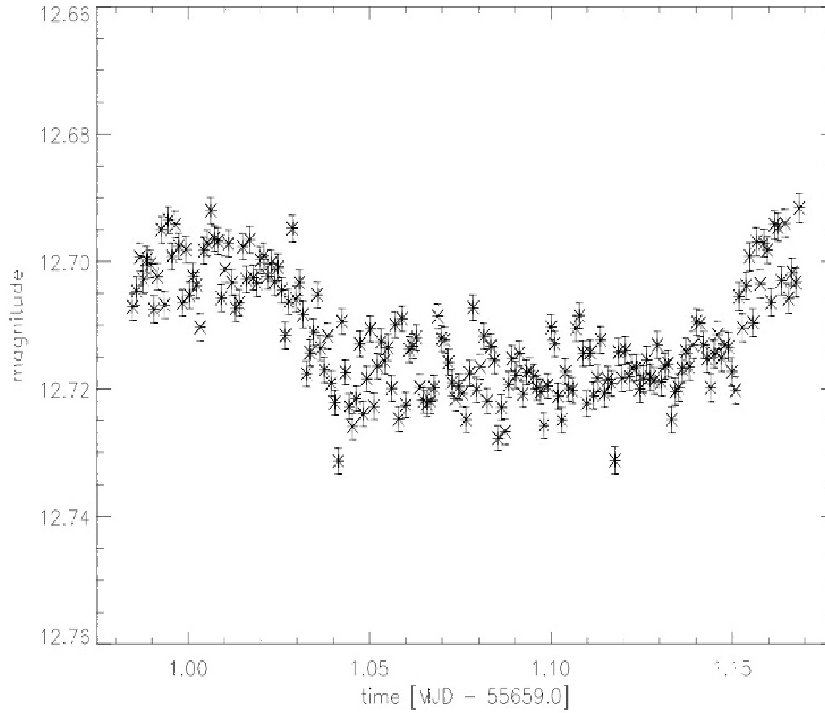


Figure 3. WASP-37b transit light curve observed by TFRM on April 8th 2011.

5. Conclusions

The TFRM, due to its extraordinary large FoV, and photometric precision can undertake a wide variety of observational programs such as: detection and follow up of NEOS, PHAS or space debris and by differential photometry detection of exoplanets, novae or supernovae.

Although positions derived from astrometric TFRM observations are not very accurate (~ 0.25 arcsec, assuming an interpolation to 1/15 of pixel in the compute of the centroid position), this level of positioning is far enough to point other facilities with much smaller FoV and more better astrometric accuracy.

When fully operative, the instrument will be able to observe all the sky visible from its emplacement in only four or five days, so doing surveys periodically will be possible to detect NEOS, PHAs or space debris by their change in position and exoplanets, novae and supernovae by their change in its photometry.

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