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# Wide-field observations at Dome Concordia

R.F. Viotti[1], M. Badiali[1], A. Boattini[1], A. Carusi[1], R.U. Claudi[2] A.M. Di Lellis[3], C.D. La Padula[1], M. Frutti[1], G.R. Lemaitre[4] P. Montiel[4], D. Nanni[6], G. Piotto[5], G.B. Valsecchi[1] and A. Vignato[6]

[1] Istituto di Astrofisica Spaziale e Fisica Cosmica, CNR, Via Fosso del Cavaliere 100, 00133 Roma, Italy e-mail: uvspace@rm.iasf.cnr.it
[2] INAF–Osservatorio Astronomico, Vic. Osservatorio 5, 35122 Padova, Italy
[3] AMDL s.r.l., Via G. Angelini 33, 00149 Roma, Italy
[4] Observatoire Astronomique de Marseille Provence, 13248 Marseille, France
[5] Astronomical Dept., Padova University, Vic. Osservatorio 5, 35122 Padova, Italy
[6] INAF–Osservatorio Astronomico di Roma, 00040 Monte Porzio (Roma), Italy

**Abstract.** Within our project for wide–field telescopes, we discuss the researchs that would particularly benefit of observations at the Concordia Station: discovery and follow up of potentially hazardous near–Earth asteroids, search for extrasolar planet transits, and stellar oscillations. For this purpose we are developing projects for compact wide–field two–mirror, three reflection telescopes, and have realised two 45 cm active optics prototypes and a new 30 cm prototype.

**Key words.** NEA – Extrasolar Planets – Sky Survey – Telescopes – Detectors

## 1. Introduction

In the last years wide–field Astronomy has attracted more than ever the attention of researchers, basically for studies, such as those discussed below, where the sizeble population of astrophysical objects is a basic need. Such researches require very high photometric accuracy and, for many variability studies, high time stability and extensive long term continued observations, which can be achieved by *ad hoc* space experiments (e.g. EDDINGTON) or on the best terrestrial sites, such as Dome Concordia.

*Send offprint requests to*: R.F. Viotti
*Correspondence to*: R. Viotti, IASF, Roma

## 2. The project

Many aspects of our project have been presented in previous articles (Lemaitre 1996, Viotti et al. 1996, 2001, 2002, Nanni et al. 2002, La Padula et al. 2003). Our aim is to realise within 3 years a small, compact and fully automatised telescope in the Concordia Station for wide FOV (2–3$^o$) astronomical observations from the near–UV to the near–IR. The optics is based on the Amoretti's design of an F/3 two–mirror, three–reflection telescope, where the primary mirror acts both as first and third reflecting surface (Amoretti et al. 1989). This design, in particular, provides a large corrected and unvignetted FOV, a flat focal plane which allows the easy placing of the large area detector, an easy baffling of straylight, a minimum encumbrance (width/length ratio up to unity), and an instrument easy to handle. The last two points are both critical issues for an astronomical instrument at Dome C.

An F/3 30–cm 2MTRT first prototype has been realised using traditional polishing systems, and tested with a 2k×2k CCD camera, partly funded by PNRA (Viotti et al. 2001). To have a cost effective telescope we have investigated different systems. For this purpose a new 30 cm prototype was realised, within the collaboration with the CRATI University of Cosenza Consortium, where the inner and outer parts of the primary were polished on two separate substrates, then glued together (Nanni et al. 2002). Our project also includes a large area detector and a high quality CCD controller in view of Antarctica observations.

An alternative interesting solution was proposed by Lemaitre (1996) based on his elastic relaxation methods. In 2002 two 45 cm prototypes were realised with the Lemaitre's active optics techniques (MINITRUST 1 and 2). The primary (and tertiary) mirrors M1,3 were obtained from double–vase form substrates with a thickness distribution slowly increasing from the centre to the edge; the mirror's borders are semi–clamped into an axially thicker cylinders. The mirror substrate was polished spherically at rest, and leaned on the optically rectified border of the mirror support, thus creating a vacuum cell. The required mirror asphericity is obtained by the in situ stressing of the surface by applying back to the mirror a 0.8 atm air depressure. The secondary mirrors were realised with a tulip form distribution with a thickness larger around its central hole, and decreasing outward. The active optics hyperbolisation was carried out by a full size lap and a stress polishing of the mirror at 0.9 atm air depressure applied under the tulip form distribution. The focal plane is sited back of M2, where there is much space for the photon detector. MINITRUST-2 was assembled in Tor Vergata in March 2003, and optical tests were started at the IASF observation station. A first light image obtained with MINITRUST–2 at the Tor Vergata observing station is shown in Fig. 1.

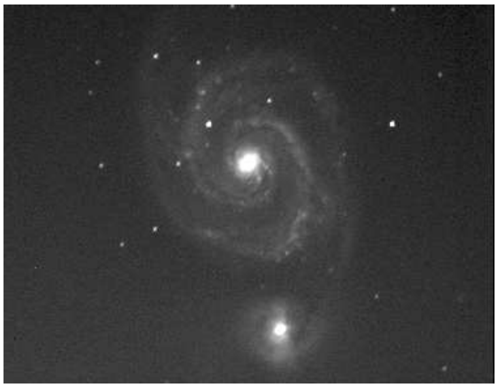

**Fig. 1.** One first light MINITRUST-2 image of the sky region centred on M51. Only the 13'×10' central part of the telescope FOV is reproduced ($V_{lim}$ ≃19.5).

## 3. Wide-Field Science at Dome C

### *3.1. Potentially hazardous NEAs*

In recent times, the study of the minor bodies of the Solar System has been enriched by the discovery of many categories of objects, among which the Near Earth Aasteroids (NEA) and comets are of particular interest having orbits approaching or even crossing that of the Earth. NEAs can be divided in different groups based on their osculating orbital elements: Amors, Apollos, Atens and IEOs. The Apollos and Atens are different from the Amors because they interesect the orbit of the Earth: the Apollos have a larger orbit than that of the Earth, while the Atens, whose orbit is smaller than that of our planet, are even more interesting for showing the highest frequency of Earth close encounters. Therefore, they represent a potential danger for our life, as catastrophic collision events occurred in the past. In this framework an international organisation – the Spaceguard Foundation – has been created with the project of cataloguing all the potentially hazardous NEA and deriving their physical parameters (see Carusi et al. 1998).

To address better the discovery of the Atens and to obtain a first inventory of objects that are always inside the orbit of the Earth (IEOs), it becomes of particular importance surveying sky regions at small solar elongation, where there is a much higher discovery probability (e.g., Boattini & Carusi 1998). Such observations are difficult from the ground because of the sky luminosity near sunset or sunrise, and the high atmospheric turbulence close to the horizon. But, even from the best terrestrial sites searches are limited in various ways: in particular, such efforts can be conducted for a modest amount of time in the evening sky after sunset and in the morning sky before dawn. Though minor planets are concentrated on the ecliptic plane, NEOs can found for geometrical reasons at tens of degrees from the ecliptic in spite of their small orbital inclination (Fig. 2). For this reason observations at high altitude in dry sites such as Dome C offer unique conditions for a non–spatial station, and shall give fundamental contribution to our knowledge of the NEO population. The first advantage is that observations can be conducted for many hours consecutively during the 24 h–cycle and under very stable atmospheric conditions. The search for minor planets is made by taking a sequence of fields (a scan) which are repeated four times at 10–20 min interval between two consecutive images of the same field. Moving objects are detected automatically through a blinking procedure. A second advantage of Dome C is that the automatic detection procedure is more efficient as the result of the fact that the area of the sky we are scanning will be at similar air mass during the four passes of the search process.

The minimum telescope size for this search is of the order of 0.8–1.0 m (effective aperture of at least 0.6/0.7 m), with a FOV of $\geq$2–3 deg$^2$. Larger facilities (1.5–2. m range) could be very competitive for much longer time even with smaller FOVs. They require a level of organization and

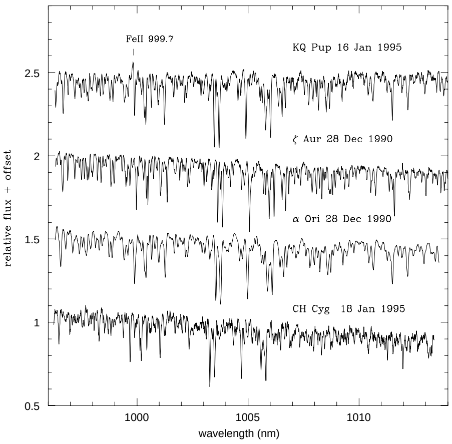


**Fig. 2.** Simulation of the visibility condition of NEA–Atens from the Earth in geocentric ecliptic coordinates. Occurrence at different magnitudes are indicated (large dots: V<16, small dots: V=18–20).

funding much more relevant but the scientific return would be extremely valuable. Observations at small solar elongations are also difficult because NEOs located inside the orbit of the Earth will have high phase angles. In this regard, the search will most effectively achieved with IR observations at thermal wavelengths where NEOs emission is at maximum, and the confusion with background stellar sources is minimum. A $\sim$1 m IR telescope with FOVs of $\geq$30'$\times$30' will be competitive enough for this purpose, and a useful complementary of the optical observations. Both telescopes will concentrate efforts at solar elongations from $40^o$ to $70^o$ all the night at various ecliptic latitudes.

### *3.2. Extrasolar giant planet transits*

From radial velocity surveys, the occurrence of close-in giant planets (P<3.5d) around the main sequence stars is about 0.7% (Butler et al. 2001). For a giant planet the geometric probability of a transit event is about 10%, so that we expect an upper limit of 0.07% for the possible transit

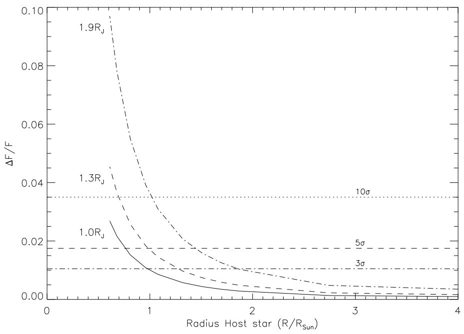


**Fig. 3.** Predicted extrasolar giant planet's detection for different parent stars for a 0.4 m aperture telescope at Dome C.

frequency. This frequency means that it is possible to find one transiting system every 1500 stars. A more realistic estimate, considering close binary stars and early type stars and giants, is of one transiting system every 5000 stars. Using a 0.4 m aperture telescope with a field of view of $3^o$ centred on the Galactic Plane it will be possible to collect time series for 10 000 stars with V<16. We have computed the predicted photometric error as function of the exposure time for different values of star's magnitude. The transit diming depends on the planet and star sizes, and is about 1–3% for a GOV star. The lower limit for the exposure time is imposed by the pixel full well saturation (100 000 $e^-$/pixel for a 2k×2k CCD KAF-4202 Series and pixel size 9 $\mu$m). We consider a sky magnitude of 22 mag/arcsec$^2$ and white light. It is possible to see that a photometric error of ~0.35% is achievable for a star of magnitude 16 with an exposure time of 350 s. The telescope efficiency is sufficient to detect mature (1.3 $R_J$, 8 Gyr aged) and young (1.9 $R_J$, 1 Gyr aged) Jupiter–like close–in planets orbiting stars later than G0 at a $10\sigma$ level, and later than F5 at $5\sigma$ (Fig. 3).

Finally, we recall that a wide FOV, small–size telescope taking an uniterrupted sequence of high photometric quality images of the same sky region for a few days to a few months is ideal for a deep investigation of all kinds of variability (e.g. long term pulsation, stellar rotation and binary motion, flares) of some $10^4$ stars, simultaneously, hence with an unprecedented very high statistical value, and is an ideal complement of the EDDINGTON mission.

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