NEAR-EARTH ASTEROIDS: OBSERVATIONS *VIA* REMOTE OBSERVING TECHNIQUES

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Abstract. Telescopic observations using remote observing techniques are now used either by professional or amateur astronomers. This technique allows the comfort and ergonomicity while the observers do not need to travel for several time-zones. Thus an observing night could become an ordinary working day while the distance between the telescope and the remote control room are separated of 10-12h of time-zones. This article presents the principles and organization of CODAM and ROC observing centers. Some of the scientific results obtained for the spectroscopy of Near-Earth Asteroids (8567) 1996 HW1 and (269690) 1996 RG3 are used as examples of science produced via remote observing centers.

Key words: Near-Earth Asteroids, spectroscopy, photometry, astrometry , remote observing.

1. INTRODUCTION

Remote observation is a useful and modern observing method for ground-based astronomy. This concept was proposed in the 70's (Whelan and Mitton , 1977), and the ground-based radio astronomy was the first field that benefit of this method (Zijlstra *et al.*, 1997). However, optical astronomy was conducted to find alternatives to ordinary observing run missions by installing concepts such as remote observing and observing service mode.

The concept of remote control in astronomy is appropriate to the space observatories and spacecrafts. The instruments conceived to work in the extra-atmospheric space require special designs and developments to be remotely operated. This is a simple necessity which requires greater capital investment in both spacecraft instrumentation and the reception station from Earth.

Astronomical observations from space are not influenced by the additional disadvantages brought by the presence of the terrestrial atmosphere (the case of the ground-based observations). Through this perspective, the observing modes of the instruments could be considered less complex than those of instruments conceived to be used by ground-based telescopes. Also, the maneuver, maintenance and exploitations of the spacecraft requires specific tasks (telemetry, data transfer modules, very precise stability and orientation of spacecraft, etc) which must be designed, scheduled, and implemented long time before the launching of spacecraft. As feed-back for the ground based observatories, this experience gained with space missions is valuable in identifying the necessities of remote operations for the ground telescopes.

Between 1975 and 1990 several pioneering programs have been imaged for different ground-based telescopes in order to implement the remote observing technique (Longair, Stewart, and Williams , 1986; Raffi and Ziebell , 1986; Raffi and Tarenghi , 1984). We must emphasize that the remote observing programs were developed also for the medium and large sized telescopes (4-16m of diameter for primary mirror). These observatories are located at high altitude and at good quality atmospheric places all over the World.

Basically, the major part of the programs converged to a relocation of the telescope control office and telescope tasks, from the neighborhood of this one, to the bottom of the mountain. This remote office was located at altitudes easy to attend for any researcher who proposes the scientific program ”in the traditional method” (mission of observations of proposers). In technical terms, the relocation of the telescope control office means, at least, the relocation of parts of both telescope and instrument control, with the possibility of reception of data and sending queries between the remote control office and the telescope. It became clear that remote observing successful operations are possible if both the telescope and the instrument design could provide this capabilities.

In parallel, the concepts characterizing the observing methods in astronomy have been crystallized. Thus, we distinguish now several methods of observations:

- the traditional method of mission of observations, when the astronomer travels to the telescope and observes ”on-site”

- the remote observing method, when the distant astronomer controlled at least parts of the telescope and instrument set-up and received at least part of the data immediately

- service method (or queuing method), when the observations are performed by the observatory staff (on-duty astronomer) at the request of a distant astronomer without interaction on his part with the observing process.

Related to the remote observing method, we can distinguish between:

- the passive remote observing, when the distant astronomer is in contact with the observer only by phone or e-mail, or a talk procedure, and the interaction is very limited;
- the active remote observing, when the distant astronomer operates autonomously the instrument (CCD* camera, spectrograph, etc) and partially or totally the telescope.

As a particular case we can mention here robotic telescopes. In this case, the telescope and the detector are working without human intervention. This category includes also the telescopes which are initiated by human intervention at the beginning of the night and turned off at the end of the night. Several subsystems are included into this concept such as: the subsystem of pointing capability of the telescope, the one of the dome control, the one of operating of detector autonomously, weather condition control, etc.

If the distant astronomer operates from his/her office, we will use the concept of distributed remote observing, and when a dedicated site allows the distant astronomer to operate with the instrument and telescope we define the remote observing centre (Davies , 1993).

2. CODAM - PARIS OBSERVATORY

CODAM is the acronym of *Centre d'Observation Distance en Astronomie* Meudon (Figure 1). The principal aim of CODAM is to use the same technical infrastructure for implementing several telescopes and instruments. The informatics and the logistic of the centre are able to quickly switch between different types of astronomical observations (Bus *et al.*, 2002; Birlan, Barucci, and Thuillot , 2004).

CODAM operates since January 2002 in Meudon Observatory, France. Most of our observations were performed using the IRTF, a 3 m telescope located in Mauna Kea, more than 12,000 km away from Meudon. We used SpeX and CSHELL spectrographs in both image and spectroscopic modes. In parallel, after 2004, remote observing tests have been started in interferometry, with CHARA system, located on Mount Wilson, in California.

The location of the remote observing center was chosen in order to simulate the telescope control room usually located nearby the telescope. CODAM location is far from the traffic inherent to an academic institution, in order to avoid unwillingly perturbations of observers, and to permit maximum concentration during the critical moments of a run.

The observations are realized through internet network link, without the service

*acronym of Charge Coupled Device

quality warranty. Thus, the pass-band for our link is variable, as function of the traffic between the remote instrument and Meudon Observatory. When using IRTF the observing hours occurred mainly during relatively normal working daylight hours for France, which offer a versatile program for observers. However, IRTF daylight observing programs are already made from CODAM. CODAM night observations (Hawaii daily observations) concern the planet Venus and were performed mainly as ground based support of Venus Express mission and as long-terms evolution of dynamics of molecular tracers of its atmosphere.

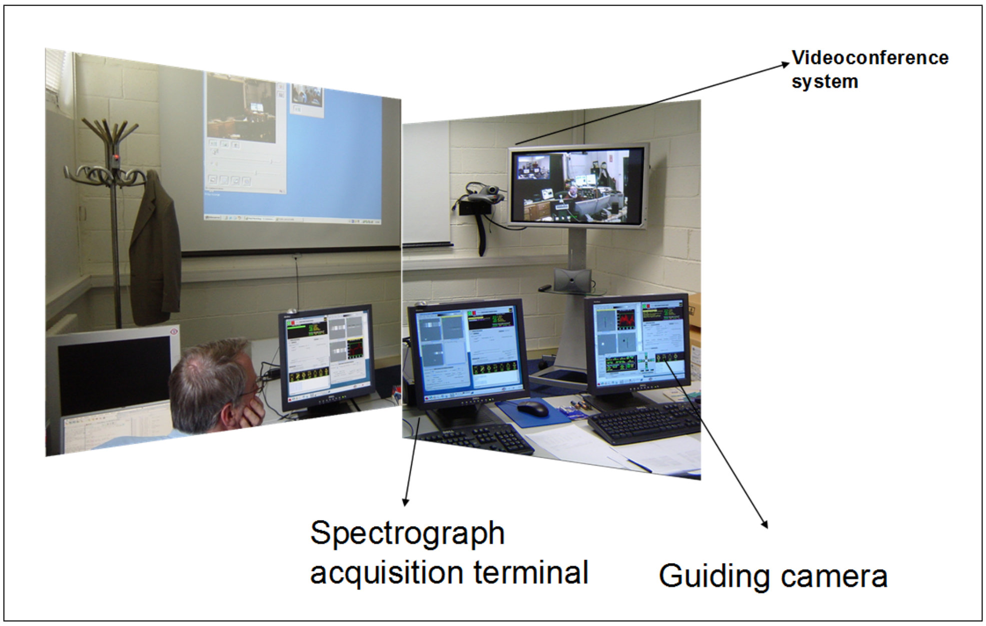

Fig. 1 – This figure presents the composite image of CODAM. Image showing the main component of the remote centre: the displays of the guiding camera software interface as well as the spectra acquisition interface together with some tools of a preliminary analysis of the data are presented.

Since 2002, more than 56 observing runs were conducted from Meudon, summing 149 nights of observations. The percentage of successful nights is around 81%, the missing nights were associated mainly to poor weather conditions.

Each run was granted by the Time Allocation Committee after competitions with other scientific proposals. The major part of our runs concerns the solar system exploration; among them some projects were devoted as a ground based support for space missions and proposals of space missions (ex: Venus Express, Rosetta, Dawn, Marco Polo-R).

3. ROC - BUCHAREST OBSERVATORY

Remote Observation Center in Planetary Sciences (ROC) is located in Bucharest in the Astronomical Institute of the Romanian Academy. It was conceived and installed in 2011 (Figure 2).

ROC includes a Polycom ODX6000 video-conference system (visio.astro.ro). A dual head video card workstation manages the VPN/SSH tunnels for export to the remote center the GUIs for operating the telescope guiding and the spectrograph.

Currently eight observing runs summing more than 30 hours of observations were performed from ROC using IRTF/SpeX and Moris instruments. The time-zone interval between Bucharest and IRTF-Hawaii is 11hours (12hours during the Summer), ideally for observations during daily regular program in Bucharest.

The major part of these observations were devoted to NEAs parent bodies of Taurid meteor shower, the low-deltaV NEAs and to asteroid associated to *howardite-eucrite-diogenite* (HED) meteorites.

Fig. 2 – Screen capture of ROC Bucharest which presents the image of the remote control room of IRTF (left side) and the remote observers in Bucharest-Romania (left side).

4. SPECTROSCOPY OF NEAS

Small bodies of the Solar System which approach or intersect Earth's orbit are called *Near-Earth Asteroids* (NEA). NEAs define dynamically those objects for which the perihelion distance is less than 1.3 AU and the aphelion distance is greater or equal to 0.983 AU. The catalogue of NEAs contains 10,663 objects†. Among this population there is a sub-class of Potentially Hazardous Asteroids (PHA) represented by objects with an absolute magnitude $H < 22$ (corresponding to a diameter of 1 km or larger) having a *Minimum Orbit Intersection Distance* (MOID) of 0.05 A.U. or less.

There is an increasing interest in the last two decades for the completeness of catalogue of these objects at a given threshold in diameter (diameter greater than 100 meters), thus surveys for their discovery and their physical characterisation are now under run all over the World.

A major scientific objective in studying NEA population is the global characterization of their physical parameters such as: diameter, spin period and spin axis, albedo, density, polarization factor, texture of surface, porosity, mineralogical composition, and degree of weathering of surfaces.

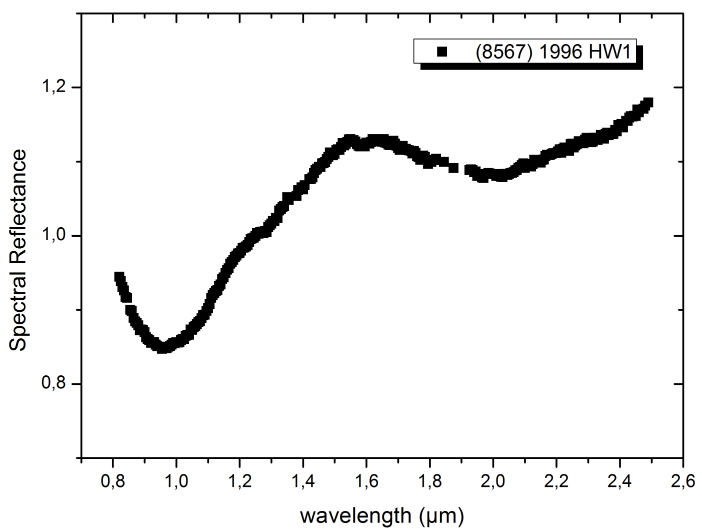

Fig. 3 – NIR spectrum of asteroid (8567) 1996 HW1 obtained in 27 August 2008 using SpeX/IRTF and CODAM facilities. This hight S/N spectrum shows the absorption bands around 1 and 2 μm specific to olivine and pyroxene composition of regoliths.

Spectroscopy of NEAs represents an important method of investigation of physical properties of their surfaces, the nature of minerals and mineralogical composition of regoliths. Visible and near-infrared (VNIR) spectroscopy could be obtained

†Number of NEAs in March 6, 2014.

via ground based telescopes equipped by spectrographs due to atmospheric transparency. VNIR spectroscopy is in fact the reflectance spectroscopy for atmosphereless bodies. Indeed, at these wavelength intervals (0.38-0.95 μm and 0.9-2.5 μm) the flux received from a NEA is the reflected solar radiation. The features in spectra are mainly due to the interaction of solar radiation with the regoliths on the surface of NEAs. The result of observations is given by the values of spectral reflectance of an object relative to a solar analog over a wavelength interval.

Several scientific programs of physical properties developed for NEAs are driven by different scientific ideas: exploration ”in situ” of puzzling objects, study of non-gravitational effects such as the Yarkovsky one, developing of procedures for mitigation, long term dynamics of NEAs, research of primitive objects among NEAs, relationships between NEAs and meteor showers.

Two of our observed objects are presented into this article as examples of spectral characterization of NEAs observed for two different scientific objectives.

Asteroid (8567) 1996 HW1 was observed in 27 August 2008 using SpeX spectrograph installed on IRTF telescope. The observations were performed from CODAM. NIR spectrum was obtained using the ”nodding” procedure (Birlan *et al.*, 2006) for a total time of 26 minutes (Popescu *et al.*, 2011). This object is a low-deltaV object, thus interesting for ground-based investigations as target of futures space missions. The solar analog HD217577 was used for the calibration of final spectrum. This spectrum is presented in Figure 3.

Spectral analysis of (8567) 1996 HW1 was performed using M4AST on-line tool (Popescu, Birlan, and Nedelcu , 2012). Thus, 1996 HW1 belongs to the S-type taxonomic complex in the Sq subclass, which is an indicator of spectrally fresh silicate surface. Its comparison with meteorites spectra from Relab database shows a good fit with ordinary chondrite meteorites with low iron content. One of the best fit is obtained using a sample of meteorite Hamlet, an ordinary chondrite of petrologic class LL4 (Popescu et al, 2011).

The asteroid (269690) 1996 RG3 is a PHA of about 1km in diameter. This object was investigated spectroscopically using SpeX/IRTF and ROC-Bucharest facilities. The asteroid was tracked using Moris system. The observational program was devoted to several NEAs and their possible association with the complex of Taurid meteor shower. Indeed, the comet P/Encke is considered at the origin of this meteor shower. However, the low production rate of dust and volatiles of comet Encke imply that other objects with similar orbits could contribute to meteoroid delivery of Taurid shower. Based on a metric of orbital elements, 1996RG3 was also identified into the so-called Taurid Complex of objects. (269690) 1996 RG3 was observed on 21 of September 2013 when the geometry of observations was favorable and the object apparent magnitude (V=17.8) was low enough to obtain spectra using 3-m telescope class. Indeed, the next favorable geometry for observing spectroscopically this object

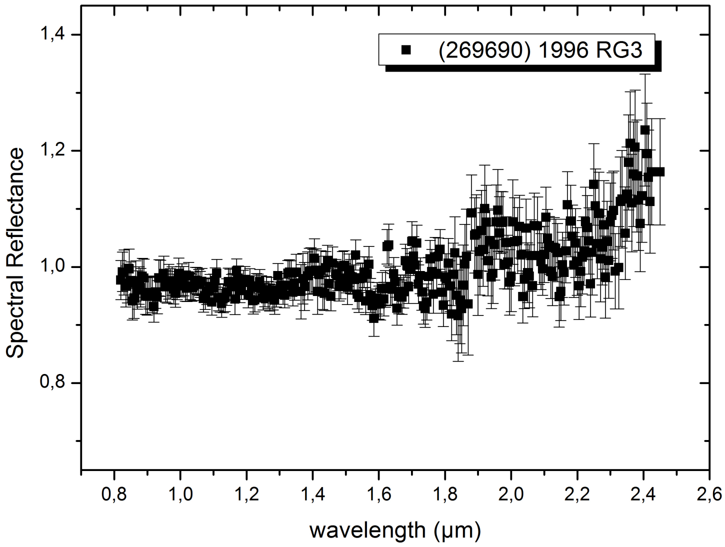

Fig. 4 – NIR spectrum of (269690) 1996 RG3 obtained on 21 September 2013 using SpeX/IRTF and Moris from ROC Bucharest.

will occur only in 2030. Thus, these data are very important for its characterization.

The spectrum is one with no features implying neutral components covering its surface. The spectral reflectance toward 2.3 μm show values in excess from a monotonic positive trend of spectrum and this feature can be associated to a thermal excess produced by the heating of a low albedo surface.

This hypothesis is sustained by its taxonomic classification. M4AST calculi (Popescu *et al.*, 2014) classify this object in the C-complex (Cg, Ch taxonomic classes).

The comparison with spectra of meteorites shows an affinity to carbonaceous chondrite meteorites, mainly CM2 and CI ones (Popescu *et al.*, 2014). These classes of meteorites are mainly characterized by high content of carbon and volatile which imply a primitive structure of chondrules. This composition of regoliths at the surface of 1996 RG3 is also consistent to primitive structures of comets.

5. CONCLUSIONS

While several programs of observations could be done in queuing mode, in the frame of robotic telescopes concept, the remote observing remains an important option in handling in real time the data acquisition.

Our main goal will be the extension of remote observing experiences to telescopes and instruments other than IRTF, and to various scientific objectives.

Another aspect concerns the establishment of a strategy (or strategies) for observations with networks of telescopes especially for dedicated programs. In this case, observations of the same target in different wavelength intervals, using various techniques (photometry, spectroscopy, polarimetry) will be very useful in global characterization of physical parameters of one object during only one observational campaign.

Finally, the remote observing is useful for the students in astronomy. They will be able to observe and these observations will stimulate their initiative in astronomy science. The "live" observation perception will be different than a classical training exercise of astronomy in a classroom. This kind of observations is more suggestive for students. With a small budget, the student will become able to complete the whole teaching sequence in practical astronomy, from doing their own observations, learning about the data-reduction technique, and obtaining the final scientific products.

The remote observing scientific outcome was underlined in this article by spectral analysis of two NEAs: (8567) 1996 HW1 and (269690) 1996 RG3. Our analysis allows to characterize the spectral behavior of regoliths on the asteroids' surface and to impose constraints on other physical parameters such are thermal albedo, diameter, and density.

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