NEW CONCEPT OF SPECTROGRAPH FOR NEAR-EARTH ASTEROIDS OBSERVATIONS

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Abstract. The article presents the concept of a new spectrograph designed to observe asteroids. The main objective of this instrument is the coverage in one shot of the wavelengths interval of the visible and near-infrared, between 0.5 and 1.6 μm. The spectrograph is designed to observe in low resolution and to characterize the minerals at the surface of asteroids.

Key words: asteroids – instrumentation – spectrograph.

1. INTRODUCTION

Spectroscopy is becoming a used technique in astronomy once the telescope apertures as well as the sensitivity of detectors increased. For the Solar System objects it is now in common use for the groundbased observations of major planets (Vernazza *et al.*, 2010; Marcq *et al.*, 2015), satellites (Emery *et al.*, 2005), or small bodies.

The modern science of asteroids uses spectroscopy in several modes: i) as a standalone method of investigation, which imply either new statistics (commonly named new taxonomic system, *i.e.* (Birlan, Barucci, and Fulchignoni, 1996; DeMeo *et al.*, 2009); ii) a complete spectroscopic investigation of one asteroid (one group or a family) which will be then modeled using the comparative planetology methods on which the result will be the mineralogy and physical properties of the surface of objects (Birlan and Nedelcu, 2010; Vernazza *et al.*, 2015).

Taxonomy is the classification of objects into categories defined by some characterizing parameters. Bus-DeMeo taxonomy underlines the importance of both vis-

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ible and near-infrared data in the characterization of asteroids by statistical procedures. The principal objective of a taxonomic system is to identify groups of asteroids that share similar surface composition and thus similar thermal history.

More recently, the spectroscopy is part of a *set of techniques of observing asteroids* on which observations of objects (and the scientific results) are combined with dynamical modeling of their evolution (Nedelcu *et al.*, 2014; Binzel *et al.*, 2010; Nesvorný *et al.*, 2010).

The spectroscopic technique applied to asteroids (and more generally to atmosphereless bodies) could be classified into:

- reflectance spectroscopy, when the spectrum is dominated by the reflected electromagnetic spectrum of the Sun on the asteroid surface
- emission spectroscopy, when the spectrum of an asteroid is dominated by its emission.

Indeed, for a spectral interval of the visible and near-infrared up to about 3μm (the exact value is dependent of surface properties, albedo, and the distance to the Sun) the spectrum of asteroid is composed from the reflected electromagnetic waves. The spectrum after 3 μm will be also contaminated with the asteroid proper emission of energy due to the heating of its surface. Thus, between 10 and 30 μm the spectrum is characterized by a radiation envelope of a blackbody on which the signatures of emission of minerals could be present.

The characterization of asteroids physical properties and mineralogy from the ground is possible due to spectroscopy in both visible and infrared spectral regions (*i.e.* reflectance spectroscopy). Diagnostic features in reflectance spectra that come from electronic and vibrational transitions within minerals or molecules are detectable in the 0.35–2.50μm spectral range.

Telescopes from the ground could observe just the spectral windows on which the atmosphere is transparent (in this case the visible and the near-infrared spectral intervals). Indeed, over this spectral interval we could observe spectroscopically using astronomical medium and large facilities, while asteroids are quite faint objects. Spectral analysis of reflectance spectra of asteroids demonstrate that minerals of silicium presented on the surface, plagioclase or sulphur compounds present broad band absorption features in the visible and near-infrared. The most representative signatures are centered around 1 and 2 μm.

The paper describe the concept of new spectrograph which will be installed on Pic du Midi Observatory 1meter telescope (T1M). The set of requirements is presented in the next section of the article, followed by the section describing the chosen design. A section of technical issues and the on-site tests marks the ongoing project. Finally, the section of conclusions ends this article.

2. DEFINING THE SPECTROGRAPH SET OF REQUIREMENTS

SOVAG is the acronym of French sequence **S***pectrographe pour l'***O***bservations dans le* **V***isible et infrarouge proche d'***A***stéroïdes* **G***éocroiseurs* for the spectrograph. This is the initiative for developing a new instrument for spectroscopy, specific to asteroid investigations. T1M from Pic du Midi-France is used for observing asteroids and comets, for astrometry and photometry in the visual range (Colas *et al.*, 2015). Remarkably planetary imaging runs are also scheduled.

The objective of SOVAG is to extend the capacity of available instruments of T1M (*i.e.* spectroscopy) toward the spectral interval covering the visible and the near- infrared up to 1.6µm.

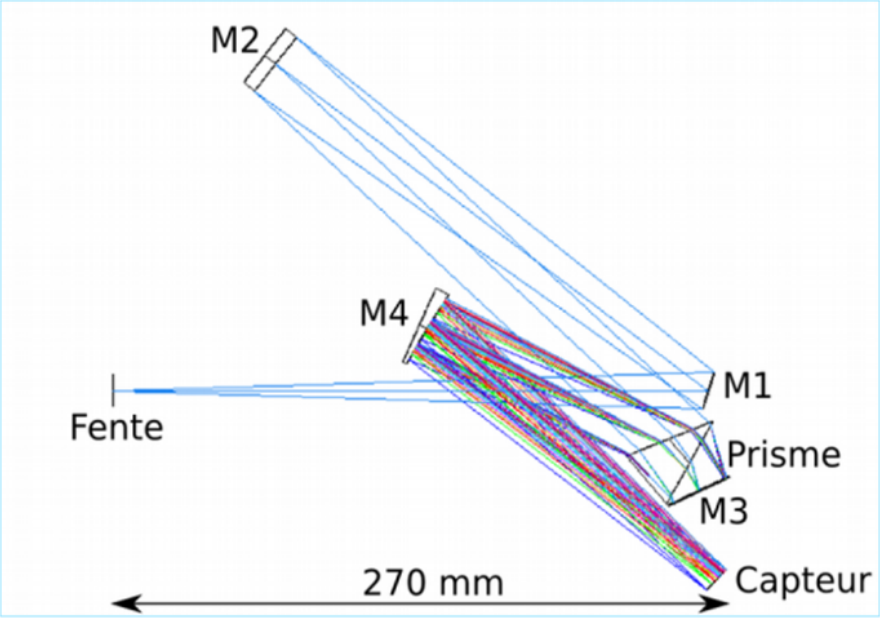

Fig. 1 – Optical path of SOVAG.

While the scientific objective is mainly the spectroscopy of *Near-Earth Asteroids* (NEA), the instrument will cover into one exposure the whole spectral interval between 0.5 and 1.6 µm. Indeed, the favorable geometry of observations for a NEA is be very tight, between one and 12 days, when the object graze the Earth (Birlan *et al.*, 2015). Such kind of favorable window may occur just few times per century[*]. It is fundamental for the scientists to not miss such an event and consequently to have access to observing time and dedicated instruments of observations. SOVAG belongs

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[*] the apparent magnitude is lower during the graze of NEA than during its opposition

to a dedicated instrumentation to observe NEAs when grazing the Earth.

Among the requirements we make an option for the as simplest as possible optical path of the spectrograph in order to avoid as much as possible the photon loss through the reflective and dispersive elements. This is an important requirement while the NEAs are faint and the integration time for one observation of one hour should be accounted.

The required spectral resolution should not be lower than R=100. While the 1µm spectral band is a complex of individual spectral bands, this resolution is optimal for distinguish between mineralogical components. In fact, this need to be in agreement with the available technical specifications of the detectors available on the market (pitch, size of matrix, quantum efficiency, etc).

A new requirement in the design of the spectrograph is to integrate indispensable modules for guiding and calibration of spectra.

Finally, the miniaturization effort was emphasized into the list of requirements. This item was introduced mainly in the perspective of a future use of SOVAG as invited instrument for another telescope.

3. DESIGN OF SPECTROGRAPH

Several technical and radiometric studies were done in order to find the best compromise between costs and performances with a high value output science. The option of one optical path slit spectrograph was selected. The design contains one dispersive element, three flat and one off-axis mirrors (Figure 1).

A prism was used as dispersive element, while the spectral resolution is low enough to be achieved by this solution. Table 1 presents the spectral resolution over the spectral interval 0.5-1.6 µm. A single order spectrum can be achieved using this configuration.

The detector based on the InGaAs technology with the extension of sensitivity toward 0.5 micron was also chosen. The evolution of technologies in terms of sensitivity and the miniaturization of devices allows new performances for the detectors which must be adapted also to astronomy. For accomplish the spectral resolution requirements, a 640 x 512 matrix or bigger, having a pitch around 20 µm is necessary.

For this purpose a prospection of the market for using detectors on the shelf was performed. Our template of camera was close to the Xenix Bobcat-640 SWIR low noise CL/GIGE detector, sensitive for the spectral interval 0.5–1.6 micron. This template must be declined in terms of performances, knowing that this model has no references for astronomy until now.

SOVAG design is presented in Figure 2.

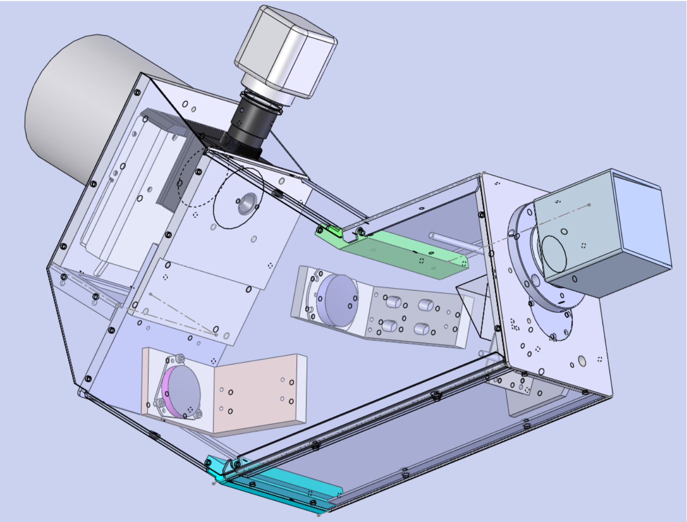

Fig. 2 – Design of SOVAG. This figure presents the spectrograph together with the detector and the auxiliary elements for tracking and calibration.

Table 1

Spectral resolution of SOVAG
for the whole spectral interval 0.5–1.6 μm.

Wavelength (μm)	Spectral Resolution
0.5	268
0.6	215
0.7	162
0.8	132
0.9	116
1.0	107
1.1	104
1.2	104
1.3	108
1.4	114
1.5	122
1.6	132

4. TECHNICAL ISSUES AND ON-SITE TESTS

In Spring 2017 the integration of instrument occurred and the laboratory tests have started. Calibration runs in the laboratory were performed during January and March 2017 for several objectives namely: check of optical path and alignment of optical components, coverage of the spectral interval, use of the new camera and its interface, check of possible annoying reflexion inside the spectrograph, check for parasite light, etc (Figure 3). Some of these items were presented into the Asteroids, Comets, Meteors 2017 which was held in Montevideo-Uruguay (Birlan *et al.*, 2017).

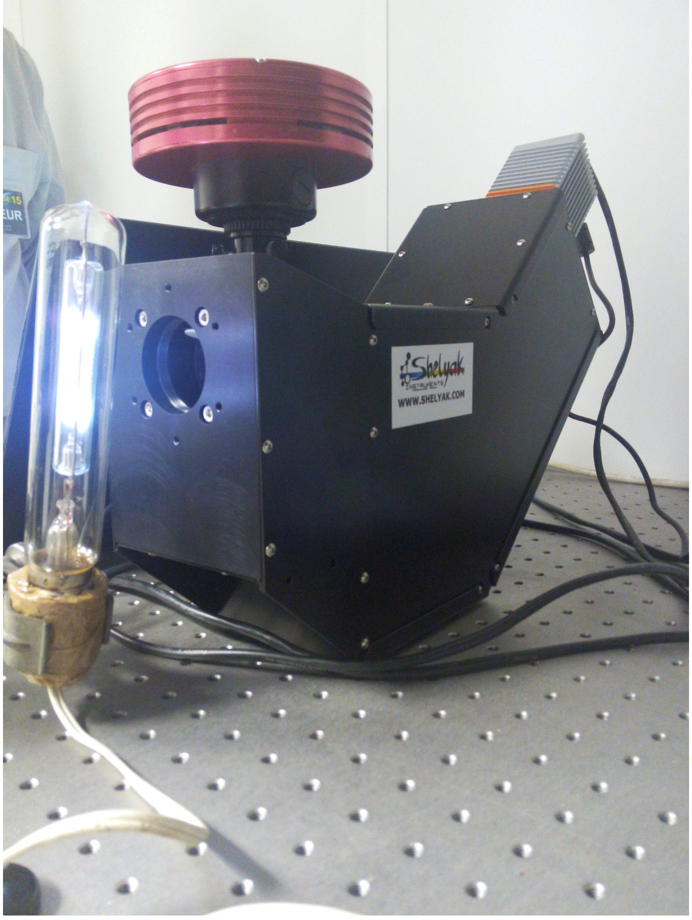

Fig. 3 – Breadboard for testing SOVAG inside Paris Observatory. The picture shows one calibration source and the integrated spectrograph.

These laboratory tests were continued in June 2017 by the technical run on T1M in Pic du Midi observatory. This on site run allows us to fix the technical issues related to the installation of SOVAG in the focus of the telescope, pointing over the guiding camera, acquisition of spectra. This run was also essential for determining the limiting magnitude using the camera still unexploited for astronomy and to find issues of improving the interface and the performances of the spectrograph. While the objective of this article is to present the concept, the scientific data will be presented in future articles.

5. CONCLUSIONS

The article presents the concept of the spectrograph SOVAG designed to observe Near Earth Asteroids. SOVAG will acquire spectra of asteroids in low resolution and will characterize the minerals having a spectral bands centered around 1 μm. The spectrograph will be installed on the T1M in Pic du Midi observatory (IAU code 586).

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