THE 2021 APOPHIS CLOSE APPROACH OBSERVATIONAL CAMPAIGN AT THE CANARY ISLANDS OBSERVATORIES. J. Licandro[1], J. de León[1], D. Morate[1], M. Popescu[2], H. Medeiros[1], M. Serra-Ricart[1], M. Rodriguez-Alarcón[1], and H. Tatsumi[1,3] , [1]Instituto de Astrofísica de Canarias, C. Vía Láctea, s/n, 38205 San Cristóbal de La Laguna, Santa Cruz de Tenerife (Spain) – jlicandr@iac.es, [2]Astronomical Institute of the Romanian Academy, Bucharest, (Romania), [3]Department of Earth and Planetary Science, The University of Tokyo, Bunkyo, Tokyo (Japan).

Introduction: Potentially hazardous asteroid (PHA) 99942 Apophis, with a diameter 380-393m [1], came to its 2021 close approach on March 6, 2021, at 01:06 UT. It approached at 0.1126 au from Earth, providing an excellent opportunity to obtain good data to do a detailed study of its physical properties.

The Solar System Group of the Instituto de Astrofísica de Canarias (IAC) participated in the International Asteroid Warning Network (IAWN) Observing campaign, an observational effort to better characterize Apophis. We did photometric, spectrophotometric and spectroscopic observations using several state-of-the-art telescopes in the Canary Islands observatories including the world largest optical telescope, the 10.4m Gran Telescopio Canarias (GTC). Observations started mid-January and will end mid-April, 2021.

In this work we present the observing program, some preliminary results and the observational possibilities at the Canary Island observatories during the next 2029 Apophis close approach.

Observations: Starting on Jan. 18 we contributed with 3 different kind of physical observations:

Spectroscopy: low resolution spectroscopy in the visible and near-infrared were done in 5 different runs using the world largest optical telescope, the 10.4m GTC and the 2.5 INT telescopes at the “El Roque de los Muchachos” Observatory (ORM) to study the surface composition of the asteroid

Spectrophotometry: simultaneous *g,r,i,z* photometry was obtained in three different nights using the MUSCAT-2 instrumet attached to the 1.5m TCS telescope at Teide Observatory (TO) to study surface composition, surface homogeneity, and rotational properties

Light-curve photometry: time-series photometry was obtained in 2 nights with the 1.0m JKT at ORM, 10 nights with the 0.82cm IAC-80, 18 nights with the 46cm TAR2 and 7 nights with the 40cm TAR4 telescopes at TO with the aim of refining the knowledge of its rotational properties.

Results and contribution to the Apophis Planetary Defense Campaign: All the obtained data was shared with the IAWN campaign members and the complete analysis of the wole database is going to be presented in Reddy et al. (in preparation). In this section we present the IAC contribution.

Spectroscopy: Low-resolution visible reflectance spectra were obtained in 4 different nights (see Fig. 1). Measured spectral slopes in the 500-750 nm spectral region were 12.6, 12.9, 11.2, and 12.0 %/100nm (with an uncertainty of 0.5 %/100nm).

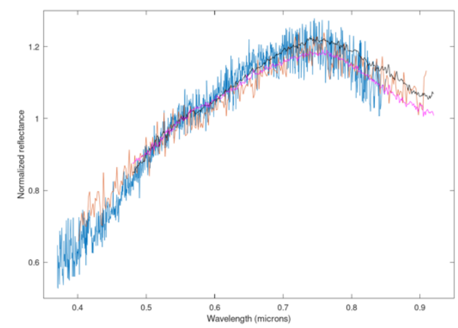

Figure 1. Reflectance spectra of Apophis obtained on Feb. 11 (INT), Feb. 12 (GTC), Mar. 19 (GTC), Apr. 04, 2021 (INT).

A Near-infrared spectrum was obtained on Jan. 29, 2021 with the GTC. Our VISNIR spectrum (see Fig. 2) is similar to the previously reported ones ([2],[3]) supporting their conclusion that the Apophis spectrum shows that best meteorite analog is an LL ordinary chondrite.

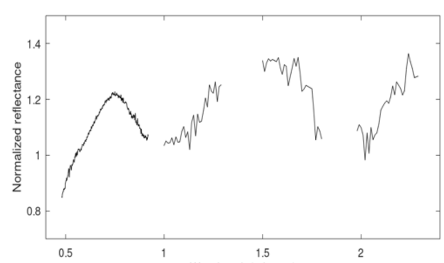

Fig. 2- composite VISNIR Apophis spectrum using the Apr. 4 visible and the Jan. 29 near-infrared spectra obtained with GTC.

Spectrophotometry: Apophis was observed On Feb. 18, March 09 and 16, 2021 during about 5hr each night with the 1.5m TCS using MUSCAT-2 instrument. MUSCAT-2 use 4 CCDs that image the field simultaneously allowing to do accurate color determinations

Data is reduced and calibrated using Photometry Pipeline [4]. In Fig. 3 we show the light-curve obtained on Feb. 18 in the four filters. The mean measured colors are *(g-r)* = 0.66, *(r-i)* = 0.17 and *(i-z)* = -0.05. The obtained colors are compatible with the observed spectra. No indication of rotational color variations are shown, indicative of a rather homogeneous surface.

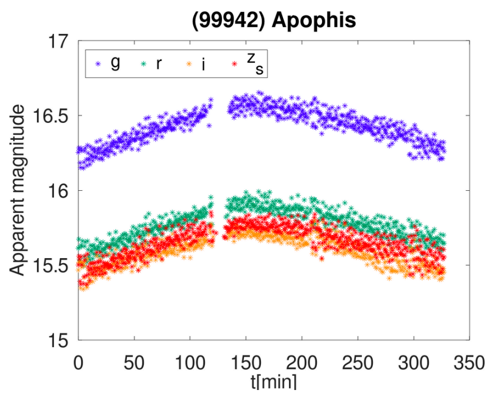

Figure 3: Apophis light-curve obtained on Feb. 18 with the TCS simultaneously in the 4 filters Sloan g,r,i,z filters.

Light-curve photometry: Apophis was observed in 24 different nights. The data presented in Fig. 4 is reduced & calibrated using Photometry Pipeline [4]

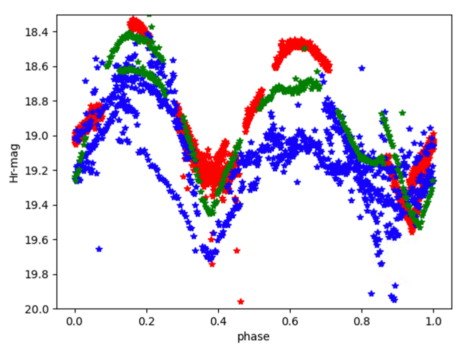

Figure 4: All the photometric data obtained during this campaign phased to a period of 30.56hr. Data from each telescope in different colors (IAC80 in red, TAR2 in blue, TAR4 in green). H mag is the absolute magnitude corrected by distance and phase angle. Ligh-time correction is also applied

Our data is compatible with previous observations [5]. They report Apophis is in a non-principal axis rotation state with precession and rotation periods of 27.38 hours and 263 hours respectively, with the strongest observed lightcurve amplitude for single axis mode with a 30.56 hours period. The analysis of the whole IAWN campaign will improve Pravec et al. results.

The 2029 close approach observing campaign: Apophis will be observable using the large set of state of the art telescopes installed in the Canary Island observatories from January 2029 to it close approach the night of Apr. 13, 2029. Mid Septemper it will be observable again until the beginning of 2030 with magnitudes between 17 and 20. We will be prepared to study possible variations of it physical properties induced by the very close approach to our planet.

Conclusions: IAC participation in the IAWN coordinated observational Apophis produced relevant results that analyzed together with the data reported by other groups within the IAWN observational campaign will allow to largely improve the knowledge of Apophis physical properties, help to prepare the observations during its 2029 close approach and help in the space missions that are in consideration by the space agencies to study this object this year.

References:

[1] Licandro, J. et al. 2016, A&A 585, 10L, [2] Binzel, R. et al. 2009, Icarus, 200, 480, [3] Reddy et al. 2018, AJ 155, 140, [4] Mommert, M. 2017, Astron. & Computing, 18, 47, [5] Pravec, P. et al. 2014, Icarus, 233, 48

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