Spectral Portrait of Apophis: Groundwork for the 2029 Earth Flyby

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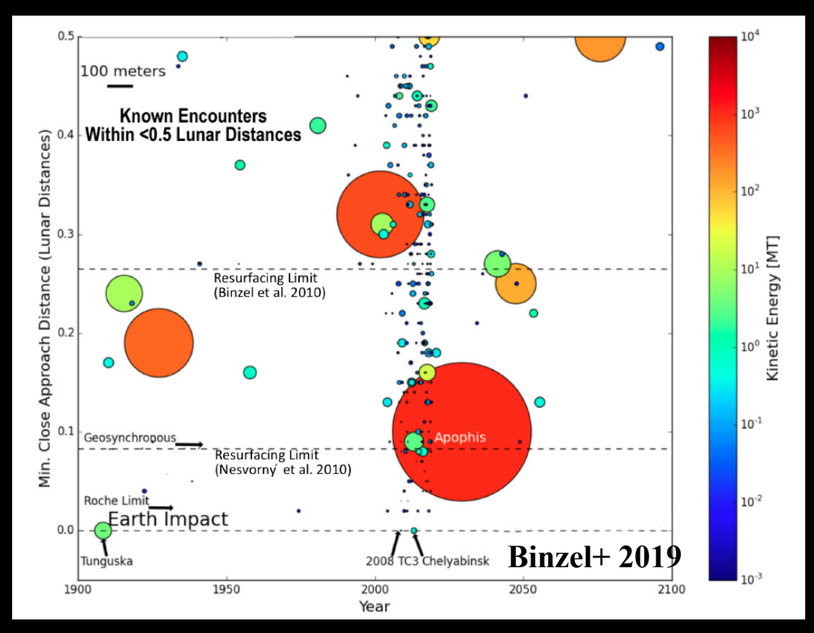
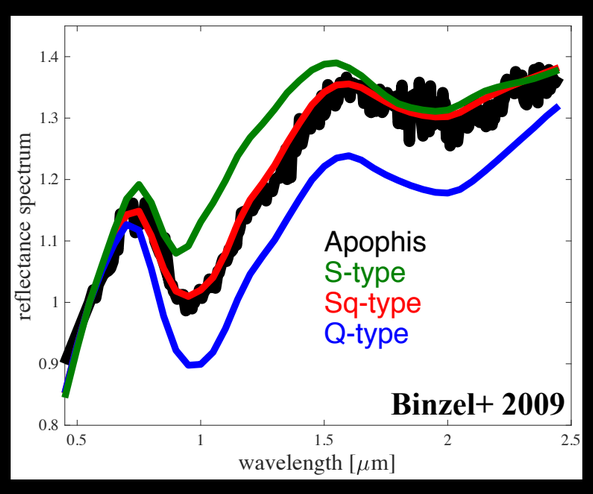
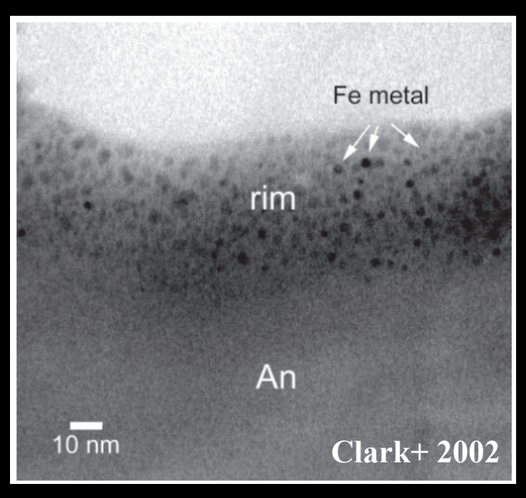
Motivation

The April 2029 near-Earth encounter by the asteroid Apophis is a **once-in-a-lifetime event** where a relatively large asteroid will approach Earth to within a distance of ~31K km. Estimates are that a 300m asteroid approaches this close about once-per-thousand years. During Apophis' approach Earth's tidal forces will modify Apophis' spin state, possibly alter its shape, and might generate seismic waves in its interior.

This makes the Apophis' 2029 flyby **a unique opportunity to study surface altering effects** on asteroids, and if instrumented, the first direct measures of an asteroid's interior. Apophis has a 'weathered' surface (Sq-type spectrum), that may reveal its true 'fresh' character (Q-type spectrum) due to quakes imposed by Earth's tidal forces. Therefore, since surface 'refreshing' due to planetary encounters could cause global spectral changes or local spectral changes, any current, pre-flyby variability is extremely important to establish with precise Apophis pre-encounter spectral characteristics.





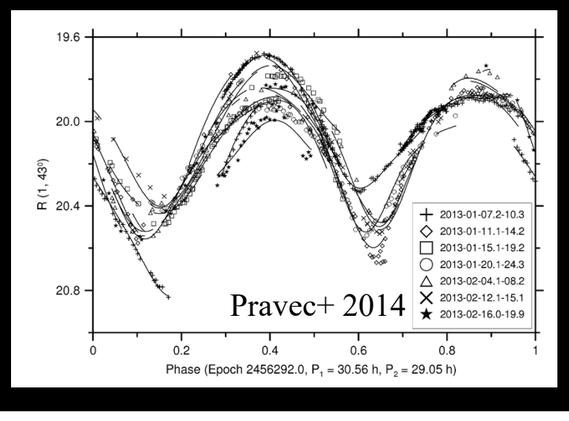


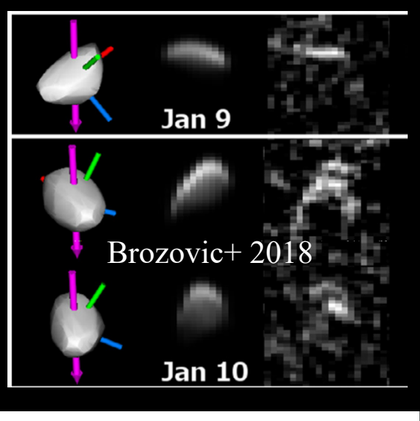
Space Weathering

This mechanism, triggered by solar particles and cosmic rays, cause evaporation and immediate condensation of nano-size iron spheres on the top surface layer of an atmospheres-less body. This cause it to display a 'weathered' reflectance spectrum, characterized with higher (redder) spectral slope and shallower 1μm absorption band (Clark et al. 2002). Excess of asteroids with non-weathered, 'fresh' spectrum were found among those Near-Earth Asteroids that had a dynamical history of close encounters with the terrestrial planets (Binzel et al. 2010, DeMeo et al. 2014). A minimal estimation of the timescale of space weathering is ~10^5 years (Nesvorny et al. 2010).

Apophis Tumbling Rotation

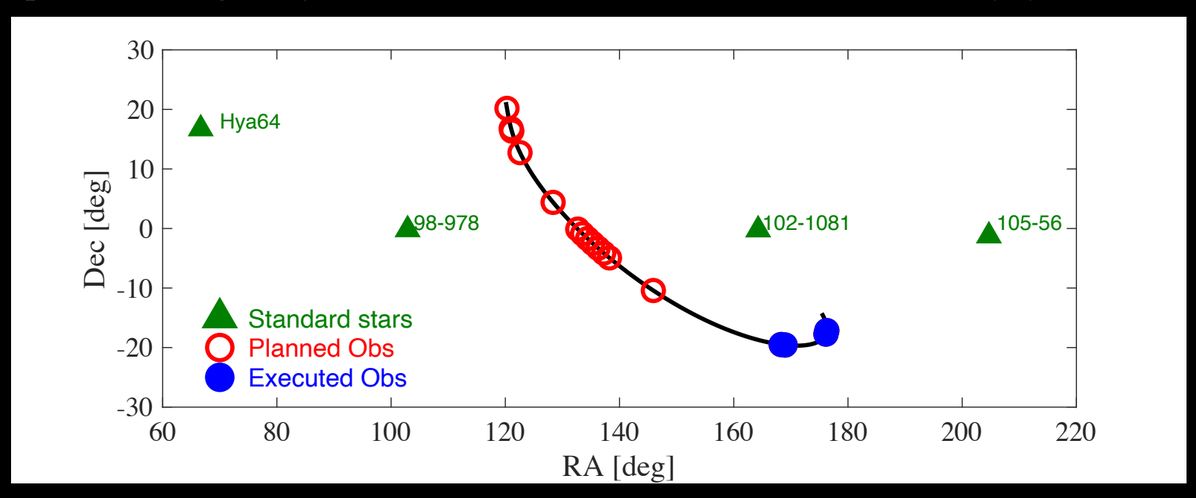
Apophis has a complex non-principal axis rotation period (*i.e.* tumbling) consists of a rotation and a precession cycles that combine to a period of $30.56 \pm 0.01\ h$ (see lightcurve, Pravec+ 2014). Planetary encounters can deliver an additional torque to an asteroid, suggesting this is not the first time Apophis passed near a terrestrial planet. Thus, in order to know the rotation phase, a data arc longer than $30.56\ h$ is required. Many stations around the world are collecting photometry of Apophis this apparition, including our contributed data from the C28 telescope at the Wise Observatory in Israel.



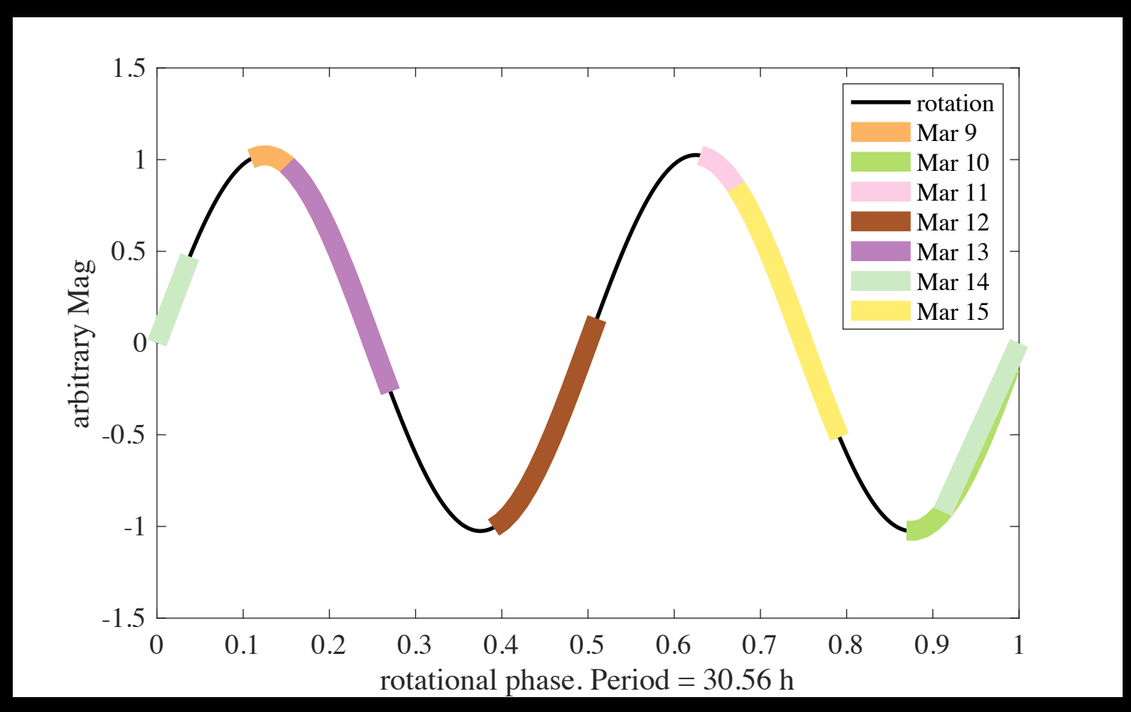


Observing Program

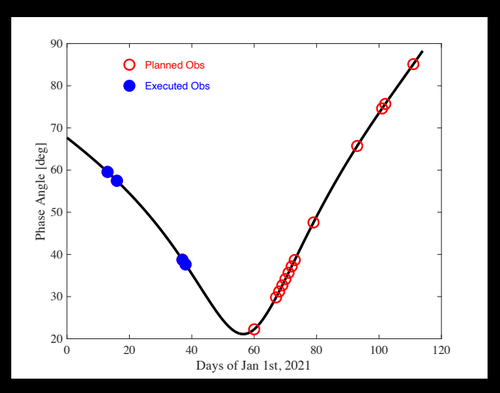
Early 2021 presents the **only opportunity** to closely scrutinize Apophis ahead of the 2029 flyby, when Apophis will be at a distance of 0.11 AU and Vmag of 15.4. We proposed to conduct **an extensive observational campaign on NASA's 3m InfraRed Telescope Facility (IRTF)**, using SpeX's low resolution mode at near-IR, and obtained 38 hours spreading during 12 nights on March-April. The campaign will allow us to conduct a full spectrally rotational coverage of Apophis surface along its rotation period of ~30.5 h and to determine if spectral homogeneity exist on the entire surface ahead of the 2029 flyby.

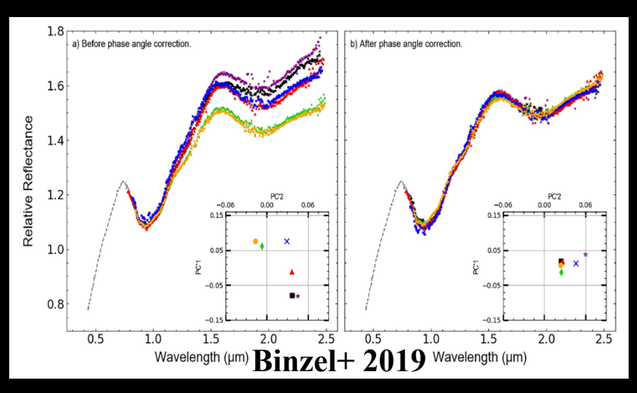


Apophis motion on the night sky (black line) with circles marking observing times granted on the IRTF. Nearby standard stars, used for calibration are marked in green triangle.



Dispersion of the rotational phases at which observing time was granted, during seven consecutive nights. Note that the reference for zero rotational phase of the model is arbitrary; the time gaps between sessions are correct.





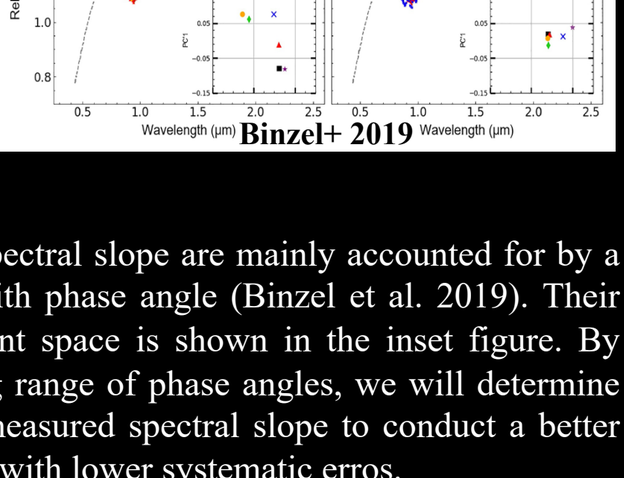
Phase angle effect

Systematic errors of asteroids' spectral slope are mainly accounted for by a spectral reddening correlation with phase angle (Binzel et al. 2019). Their dispersion in principal component space is shown in the inset figure. By observing Apophis during a long range of phase angles, we will determine the correlation and correct the measured spectral slope to conduct a better rotationally resolved comparison with lower systematic erros.

IRTF Telescope

Located on Mauna Kea, HI, NASA's IRTF is a leading power for asteroids IR spectroscopy. Our MIT-based team, gained experience of hundreds of observing hours, reducing and analyzing asteroids' spectra.

On the right, the Israeli remote observing post, located at the Weizmann Institute, while operating the IRTF's instruments to observe near-Earth asteroids.



Future plans

Looking forward to 2029, various plans are suggested to conduct remote observations and *in situ* measurements of Apophis using spacecrafts, orbiters and landers during the flyby. We are looking for partners to contribute engineering, theoretical, and experimental contributions, and to join in to this once-in-a-lifetime astronomical event.

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