Post-Flyby Observations of *Apophis* from the *Moon*

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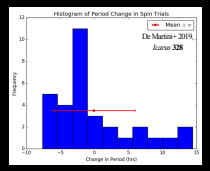
Models suggest that following the 2029 near-Earth flyby, Apophis will experience strains from the Earth's tidal forces that will cause Apophis' rotation period of $30.56\,h$ to be altered by a few up to ~5 h, spinning up or down (e.g. De Martini+ 2019, Scheeres+ 2005).

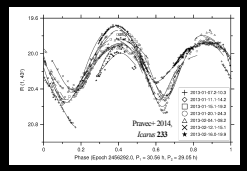
Apophis has a complex non-principal axis rotation period consists of a rotation and a precession cycles that combine to a period of $30.56 \pm 0.01\,h$ (Pravec+ 2014). In order to measure the change in both components of this period, a data arc of longer than $30.56\,h$ is required.

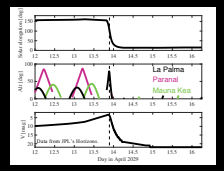
While Apophis will be an easy target before the flyby, just after it Apophis will proceed in the direction of the Sun, making it unavailable for optical ground-based telescopes, such as those on Mauna Kea, Paranal and La Palma.

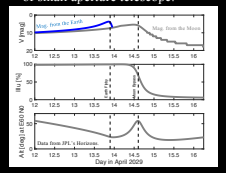
However, the Moon will be ideally located for photometric observations of Apophis.

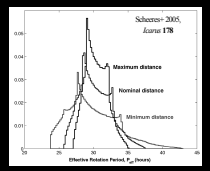
- New moon, no direct sunlight.
- Apophis at sufficiently high elevation (>15°) of the Lunar horizon for 56 h after Earth flyby.
- Surface Illumination: >90%
- V-mag: 5.4 to 18, allowing the use of small aperture telescope.

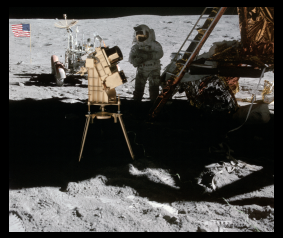


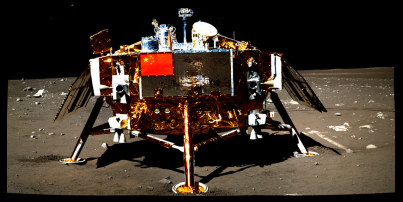




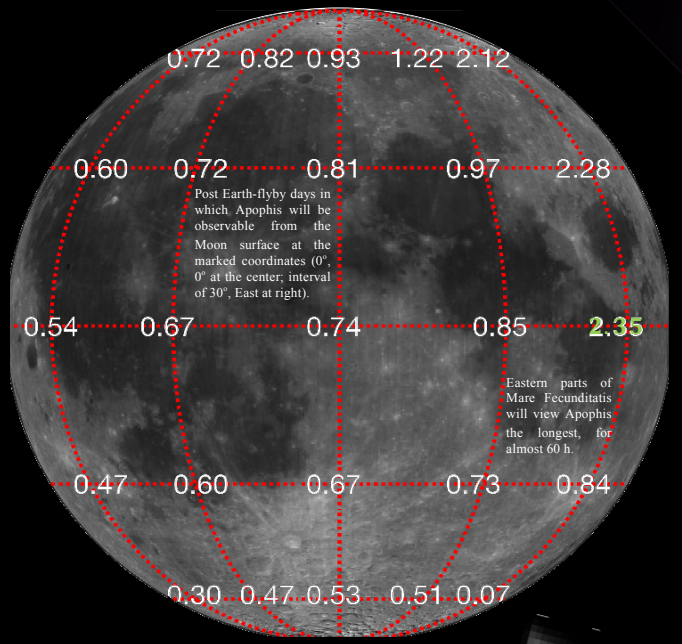








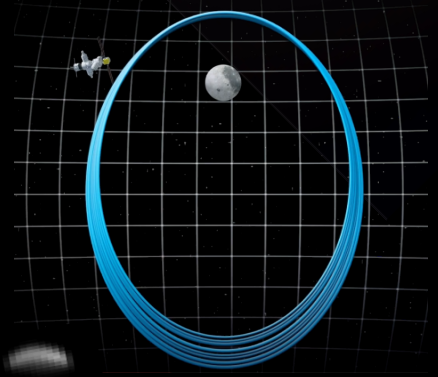
Telescopes were already used on the Moon: *Apollo 16* astronauts operated the Far Ultraviolet Camera / Spectrograph mounted on a 75 mm telescope and returned 178 frames of multiple targets. Recently, China's *Chang'e 3* was equipped with a robotic 150 mm Lunar Ultraviolet Telescope (LUT) that had stable photometric performance up to at least 18 months after the landing (Wang+ 2015).



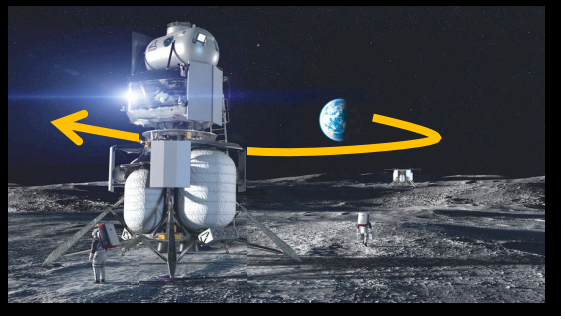
Post Earth-flyby days in which Apophis will be observable from the Moon surface at the marked coordinates (0°, 0° at the center; interval of 30°, East at right).

Eastern parts of Mare Fecunditatis will view Apophis the longest, for almost 60 h.

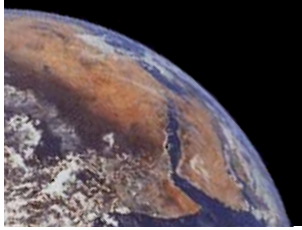
The *Lunar Gateway* is a space station concept planned as a communication hub for astronauts, instruments and scientific experiments in orbit around the Moon. The space station id planned to be operational starting from 2024 continuously until the end of the Artemis project.
The *Lunar Gateway* is planned to circle the Moon in a *Near-Rectilinear Halo Orbit* (NRHO), that uses Lagrange points to keep the space station stable. The eccentric orbit is approximately perpendicular to the moon orbital plan, and has a periapsis of 3k km, apoapsis of 70k km, and a period of ~7 days. Therefore, bringing the *Lunar Gateway* to the eastern side of the Moon during the Earth flyby time, will allow it to measure Apophis for additional ~2.5 days, slightly better than from the eastern parts of the lunar surface. NASA searches for scientific experiments to be held on board, including telescopes, thus an Apophis observing campaign will give additional incentive for choosing such scientific component.



Artist's impression of *Artemis* astronauts with their lander. Apophis' orbit after the Earth flyby is marked, as observed from the Eastern side of the Moon.



Reaching the Moon requires partners that wish to go there anyhow. For them, the Apophis Lunar telescope will be a unique scientific incentive giving additional rational for their high expenses. NASA's *Artemis* project is the most reasonable partner, aiming to land astronauts on the Moon as early as 2024. Specifically, Artemis VIII is planned to land on 2029.
However, private companies such as *Blue Origins* are also developing lunar landers allowing additional opportunities. A client of this service can be one of the large telescope manufacturing companies (such as *Celestron* or *Orion*) using the Apophis telescope as an advertising tool for a future Lunar observatory service, for professional and amateur astronomers alike.



Brozovic+ 2018, *Icarus* **300**