An Estimate of the Flux of Apophis-Particle Meteors at Earth

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Near-Earth asteroid (99942) Apophis is predicted to make a close encounter with Earth on April 13, 2029. This close encounter will bring Apophis within 6 Earth radii from our geocenter providing an excellent opportunity to study and observe the asteroid and any subsequent effects of the interaction. Here, we bring to your attention the possibility that the passage of Apophis will not be the only event worth observing. We predict a rain of Apophis meteors that may be detectable to Earth's meteor monitoring systems.

NASA's OSIRIS-REx mission has recently shown that near-Earth asteroid (101955) Bennu has been continuously producing cm-sized ejecta at rates of ~10^4 grams per orbit [1]. The production mechanisms of Bennu's activity may be common to all asteroids in near-Earth space [2]. Apophis experiences a dynamical environment which is very similar to Bennu. Assuming Bennu-like activity rates are also happening on Apophis, we have developed a complex simulated environment which accounts for the most potent perturbing gravitational bodies and solar radiation forces that are applicable to the evolution of the motion of centimeter-size material [3]. We are using REBOUND, an orbital integration API developed by Hanno, Rien and Tamayo [4], augmented with REBOUNDx, developed by Tamayo et al. [5], to include solar radiation pressure and Poynting-Robertson drag. The meteoroid stream is propagated between 1900 - 2029 using an Apophis ephemeris that places the asteroid at its most likely position for the 2029 encounter. Unlike most meteoroid stream evolution studies, our simulations release particles from Apophis at a regular (~weekly) rate around its entire orbit, consistent with the Bennu observations.

Assuming similar particle production mechanisms at Apophis as observed at Bennu, Apophis could be producing on order of 10^4 grams of material continuously throughout its orbit. Of that material, we assume 30% will escape on hyperbolic trajectories [6]. This results in roughly 3500 grams of new material entering the Apophis meteoroid stream annually. We model this production at rates of 150 particles per simulated week.

Initial simulations produced over 2 million particles within the 129 year time range of our simulation (1900-2029). This is representative of double the mass loss expected for this time range. These preliminary simulations show that meteor activity from Apophis can be expected during the 2029 close approach. From the 2 million particles produced, ~3500 particles were found within 5 Earth radii at the time of close approach. These particles are found to follow a size distribution that is distinctly larger than the average (**Figure 1)**. This is an interesting initial result, as it

provides a way to compute the magnitude of the meteors as these particles enter the Earth's atmosphere.

We calculate a peak flux density of $5*10^{-6}$ $km^{-2}hr^{-1}$ at 9:40 pm UTC April 13 2029 lasting for ~90 minutes. To an observer this would appear as a Zenith Hourly Rate of ~0.2 meteors per hour.

This initial flux estimate is on the order of the smallest observable meteor showers [3]. However, observations are feasible and they promise to be closely correlated to the timing of Apophis' close approach.

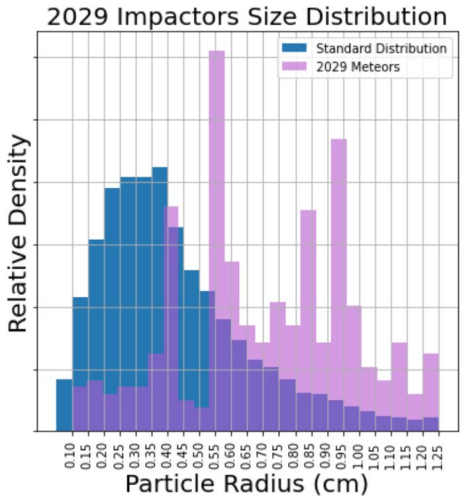

Figure 1: Particles produced in our simulation follow the size distribution shown in blue. The particles predicted to contribute to the meteor flux in 2029 are overlaid in purple.

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References:

[1] Hergenrother et al. (2020) Journal of Geophysical Review: Planets 125, 9 https://doi.org/10.1029/2020JE006381
[2] D.S. Lauretta and C.W. Hergenrother et al. (2019) Science 366, 1217-1227.
[3] P. Jenniskens et al. (2011) Icarus 216, 40-61, & cams.seti.org
[4] H. Rien and S.F. Liu (2012) Astronomy & Astrophysics 537, A128.
[5] Tamayo, Daniel, et al. (2020) Monthly Notices of the Royal Astronomical Society 491.2
[6] S.R. Chesley et al. (2019) Journal of Geophysical Review: Planets 125, 9 https://doi.org/10.1029/2019JE006363