THE APOPHIS 2029 FLYBY: A UNIQUE SCIENCE CASE FOR SPACE PLASMA PHYSICS. S. Barabash[1], Y. Futaana[1], M. Holmström[1], N. Krupp[2], M. Fränz[2], E. Roussos[2], T. Kleine[2]
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Introduction: The scientific importance of the asteroid (99942) Apophis's Earth close approach on April 13, 2029 for various disciplines, planetary defense, physics and dynamics of asteroids, is comprehensively assessed. In particular, such science questions as how Apophis is affected by tidal forces during the approach and its interior are emphasized [1]. However, the unique science that this fly-by provides for space plasma physics has not been assessed at all. We demonstrate in this report that the Apophis fly-by of the Earth in 2029 opens unique opportunities for space plasma physics not only to address fundamental problems of the interaction of small airless bodies with plasma but also to contribute to better understanding of the Apophis environment needed for planetary defense aspects.

Apophis and its flyby: The Apophis size is around 340-360 m. Very likely it has similar composition to LL chondrites and thus a low conductivity of $2\cdot10^{-7}$ S/m [2]. Apophis will approach to the Earth at ~31600 (~6R_E) km altitude with the velocity 5 – 7 km/s and will thus travel through all principal plasma domains and boundaries of the magnetosphere, bow shock, magnetosheath, magnetotail lobes, outer electron radiation belt, ring current, maybe even the plasmasphere depending on geomagnetic conditions at the day of the flyby.

The interaction with the environment: The magnetic field will vary along the trajectory and will reach ~300 nT at the closest approach. The asteroid size is much smaller than the electron gyro-radius even for electrons in the solar wind but at closest approach it becomes comparable with the gyro-radius of electrons below 1 keV, i.e, some signatures in plasma observations could be expected.

Due to low conductivity the inductive currents caused by the variation of the magnetic field along the trajectory are unlikely but this problem requires more detailed studies. Also, magnetic field strongly affects dynamics of lofting and levitating dust that may be released by the tidal forces during the fly-by as was shown for the lunar conditions [3].

Apophis will reach the outer edge of the radiation belt. In this region the typical omnidirectional integrated (> 1MeV) electron fluxes are up to 10^6 $cm^{-2}s^{-1}$, >100 keV proton fluxes up to $5\cdot10^6$ $cm^{-2}s^{-1}$, and >1 MeV proton fluxes $5\cdot10^2$ $cm^{-2}s^{-1}$, i.e, the asteroid will experience significant radiation exposure from particles with high sputtering yields.

Particular interesting and unique to investigate how Apophis and, in general, airless body interact with the ring current ions, protons, helium, oxygen. The ions in the ring current energy range from keV to 10s-few 100 keV are very effective sputters. One would thus expect significant

Microphysics of the particle – surface interaction at airless bodies, the Moon, Mercury, Phobos, and asteroids is very complex and rich. The interaction of the solar wind protons results in sputtering and backscattering of both negative and positive ions, and neutrals. These processes have been studied at the Moon, Phobos, and a comet but never at an asteroid and, in particular, traveling though such variable and high-flux plasma environment.

One of the fundamental problems related to the interaction with the environment is understanding the surface charging and how variable plasma environment affects the levitation of dust [1]. That even has important implication for defining technical specifications for future missions to Apophis, if they will be required in the frame of planetary defense.

Science case for space plasma physics: The Apophis fly-by through the magnetosphere provides the unique opportunity to address the following science questions:

(1) *How does Apophis interact with the magnetosphere?* This question is related to the moon – magnetosphere interactions at the outer planets, the solar wind – asteroid interactions, and the interaction of the Moon with the environment.

(2) *How does plasma interact with the Apophis surface?* This question is related to the general problem of the microphysics of particle – regolith, particle – solid surface interactions.

(3) *What is the plasma environment at Apophis as it travels though the magnetosphere?* These supporting measurements are required to study such related problems as dust levitation and asteroid surface changing.

Missions to Apophis and plasma measurements: Currently none of the approved or planned missions to Apophis carry instruments for plasma or magnetic field measurements. We thus propose to consider a small package including a plasma detector measuring ions and electrons over an energy range few eV – few 10s keV and a magnetometer for Apophis mission proposals. Normally, plasma instruments are compact, have high TRL, and readily adoptable for mission requirements. Spare units from other missions can be easily re-used.

References:

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