Dust Levitation on Asteroids

University of Wisconsin Eau Claire Physics and Astronomy Department

Student Researcher: James Truchinski **Faculty Mentor:** Dr. Paul Thomas

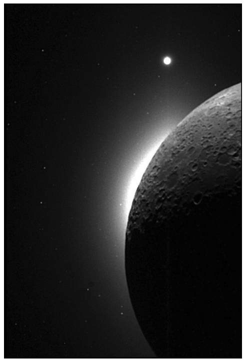
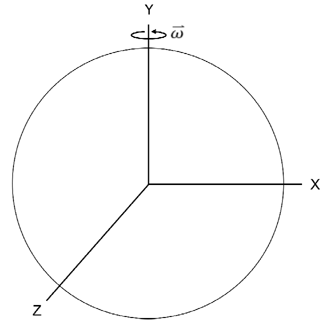


Photo of the moon as taken by the Clementine spacecraft shows the this glow around the entire edge of its body.

Introduction

On asteroids and other celestial bodies that lack atmosphere, a strange phenomena can be observed: a glowing about the surface of the bodies right off the horizon. The cause of this glowing was found to be micron sized particles floating off the object's surface. These particles are photoionized by nearby stars and repelled from the surface of the asteroid. If this occurred off the surface of an inertial sphere, these levitating photoionized particles would just settle back to the asteroid with relatively little change. However, because asteroids are non-spherical with non-inertial forces at work, the dust being emitted might tend towards particular regions of the asteroid. This research investigates whether these particles accumulate on the surface of asteroids in a significant enough way such that they affect the asteroid's shape over the course of millions or billions of years.

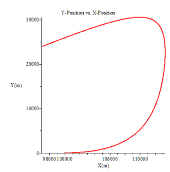


Coordinate representation of a spherical non-inertial body

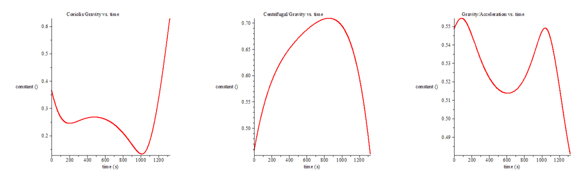
Digital reconstruction of Eros based on high resolution measurements made by NEAR's Laser Rangefinder.

Color-exaggerated photo of Gaspra as taken by the Galileo spacecraft.

These photoemissions occur when an electron orbiting an atom on the surface of any body lacking atmosphere absorbs a photon of just the right wavelength to unbind the electron from the nucleus causing the atom to become ionized. This newly ionized particle repels from the surface and thus becomes temporarily levitated.



Graphing the location of the particle on a spherical asteroid already shows behavior unexpected by normal gravity without non-inertial forces.

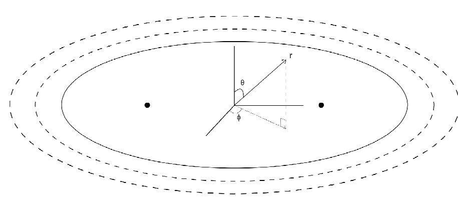


These graphs show the relative force on the particle as supplied by each non-inertial force compared to the force supplied by spherical gravity.

Spherical Gravity

$$F_g = -\frac{GM}{r^2}$$

Ellipsoidal Gravity



Depiction of equipotential shells expanding from the surface of an elliptical body, including the spherical coordinate system for the ellipsoidal body.

$$F_g = -\frac{GM}{r^2} + \frac{GMa^4}{8r^4}J_2(3cos^2\theta + 24sin\theta cos\theta - 1) + \omega^2 r sin\theta(sin\theta - \frac{1}{2}cos\theta)$$

Normal component — Flattening — More Centrifugal components

Non-Inertial Forces

$$\vec{F}' = \vec{F} - 2m\vec{\omega}\times\vec{v} - m\vec{\omega}\times(\vec{\omega}\times\vec{r})$$

Observed — Physical — Coriolis — Centrifugal

The primed Force notes the direction the force that would seem to act on an emitted dust particle as seen by an observer at the center of a spherical asteroid. The unprimed Force notes the actual forces (in this case, gravity) acting on the object. It is worth noting that one can also define a transverse non-inertial force that depends on $\vec{r}$ as well as the change in rotational speed, $\dot{\vec{\omega}}$, but this model assumes constant rotation speed, so that term has been ignored.

Conclusion:

From the information found via particle emission modeling, the non-inertial components of the acceleration are definitely non-trivial for most asteroids approximated thus far. Whether this will lead to the particles tending to a single location is as of yet unclear.

Future work:

Continuing to work with ellipsoidal gravity to see what behaviors unfold under varied eccentricities will give insight as the project evolves to account for non-homogeneous distributions of mass as well as asteroids lacking symmetry. Eventually the project will move to account for variations in ejection velocity based on relative incidence to a star light source and may begin to model the travels and accumulation of dust on actual asteroids based on records of the asteroid's shape, mass, and location relative to stars.

References:

Asteroid and moon Images were taken from NASA's online image database.

Articles referenced:

Colwell, J. E., et al. (2009). Lunar dust levitation. Doi: 10.1061/(ASCE)0893-1321(2009)22:1(2)

Hartzel, C. M.,, Scheers, D.J. (2011). Dynamics of levitating dust near equilibria on asteroids. Colorado: EPSC.

Li, X., Goetze, H.J. (May, 2001). Ellipsoid, geoid, gravity, geodesy, and geophysics. Geophysics Online, (vol. 66).