Modeling meteoroid densities for spacecraft risk assessment

Dr. Steven Ehlert

Qualis Corporation, Jacobs Space Exploration Group, NASA Meteoroid Environment Office, Marshall Space Flight Center, Huntsville, AL 35812 USA

ABSTRACT

A crucial ingredient of any engineering model describing the natural or artificial debris environment is the assumed distribution of impactor bulk densities. The bulk density, which relates the mass of a meteoroid to its size, plays a key role in mapping the debris environment a spacecraft encounters to the hazard it poses. For a meteoroid at a given speed and mass, a higher density allows it to penetrate thicker structures and cause more damage to a spacecraft. While the densities of the artificial orbital debris population are well known, the densities of various meteoroid populations are far more poorly constrained. The newest version of the Meteoroid Engineering Model, Version 3 (MEM 3, to be released in 2019) is the first iteration of MEM to incorporate empirically determined densities rather than a single assumed density for all meteoroids. The new densities are based on the work of Kikwaya Eluo et al. (2009) and Kikwaya Eluo et al. (2011), and model the meteoroid density distribution as two populations based on the orbital parameters from 80 density measurements, shown in the figure below. These two populations correspond to cometary and asteroidal orbits, respectively.

A better characterization of the meteoroid environment will require substantially larger numbers of measured meteoroid densities. To this end, NASA's Meteoroid Environment Office (MEO) has undertaken an effort to greatly expand the sample of Kikwaya Eluo et al. (2011) by modeling the deceleration and optical light curves of meteoroids ablating in the upper atmosphere. In this proceeding we describe the process by which meteoroid densities are calculated using the thermal disruption ablation model, improvements made to the process utilized by Kikwaya Eluo et al. (2011), and preliminary density measurements for both previously modeled and new events.

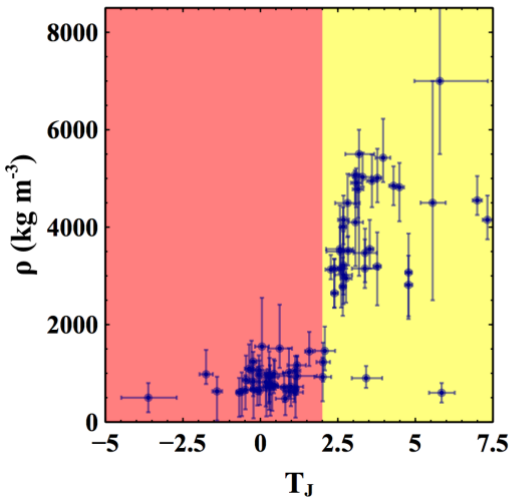

Figure 1: The density of 80 meteoroids as measured by Kikwaya Eluo et al. (2009) and Kikwaya Eluo et al. (2011), as a function of their orbital Tisserand parameter (with respect to Jupiter). The red shaded region corresponds to orbits typical of long-period comets, while the yellow region corresponds to Jupiter-family comet and asteroidal orbits. These are the entirety of meteoroid density measurements used to construct the meteoroid density population in MEM 3.