



Collisional Lifetimes of Meteoroids in the Interplanetary Dust Cloud

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Modelling the Meteoroid Hazard

Hypervelocity impacts of meteoroids on spacecraft can cause significant physical and electromagnetic damage.



Impact on to Hubble Space Telescope solar cells (ESA, Drolshagen, 2008)



Introduction

Modelling the Meteoroid Hazard

- ESA Interplanetary Meteoroid Environment Model (IMEM)
 - ▶ Evolutionary, 0.1–5 AU, 10⁻¹⁸–1 g
- NASA Meteoroid Engineering Model (MEM)
 - ▶ Empirical, 0.2–2 AU, 10⁻⁶–10 g





Introduction

Aims of a new meteoroid environment model for ESA

- 1 To include dynamical cometary and asteroidal populations.
- 2 To incorporate the collisional evolution of different orbits.
- 3 To incorporate in-situ, IR data and meteor orbit data.



An Interplanetary Dust Model

Dust Populations

1 Cometary (Nesvorný et al. (2010))

- Jupiter Family Comets
- Halley type and Oort cloud comets
- 2 Asteroidal
 - Asteroid main belt (MPC)
 - Asteroid dust bands (Nesvorný et al. (2006))







Dynamics

- 1 Gravitation (Solar and planetary)
- 2 Radiation forces (PR drag and Radiation pressure)
- 3 Collisions

...and integrate for 200 000 – 500 000 years (planets: J. Laskar IMCCE)



Collisional modelling of meteoroids

• Target particle with mass *m*₁ catastropically disrupted by projectle of mass *m*₂:

 $\textit{m}_1 \leq \Gamma\textit{m}_2$



Collisional modelling of meteoroids

 Target particle with mass m₁ catastropically disrupted by projectle of mass m₂:

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• Where:

$$\Gamma_0 = 9.76 \times 10^2 S_c^{-0.45} (\frac{m_1}{\rho_1})^{0.075} v^2$$



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- Material properties: unconfined compressive strength: $S_c = 3$ kbar
- Particle properties: m_1 , ρ_1 particle parameters
- Impact properties: v the impact speed





Calculating collisional probability along a meteoroid orbit







Calculating collisional probability along a meteoroid orbit







Calculating the Collisional Lifetime





Collisional Lifetime at Earth's orbit



Rachel Soja



Collisional Lifetimes of Meteoroids



Phaethon



Institute of Space Systems



13 / 17

Collisional Lifetimes

Variation of collisional lifetimes for $\sim 1~\text{mm}$ particles



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Collisional Lifetimes on the orbit of 96P



Rachel Soja



Collisional Lifetimes on different orbits



For 100 μ m particles with bulk density 2000 kg m⁻³.



Including collisions in the model

- 1 Assess orbital element dependence as a function of orbital elements.
- $2\,$ Update the lifetime of each particle every $\sim 1000\, {\rm years}.$
- 3 Remove particles once they have reached 100% of their lifetime.



Summary



Summary

- Use of IMEM allows us to extract collisional lifetimes along meteoroid trajectories.
- Collisional lifetimes may be low for some meteoroid orbits.
- Next step: addition of collisions module to the integrator.