# Comparison of Meteoroid Environment Models

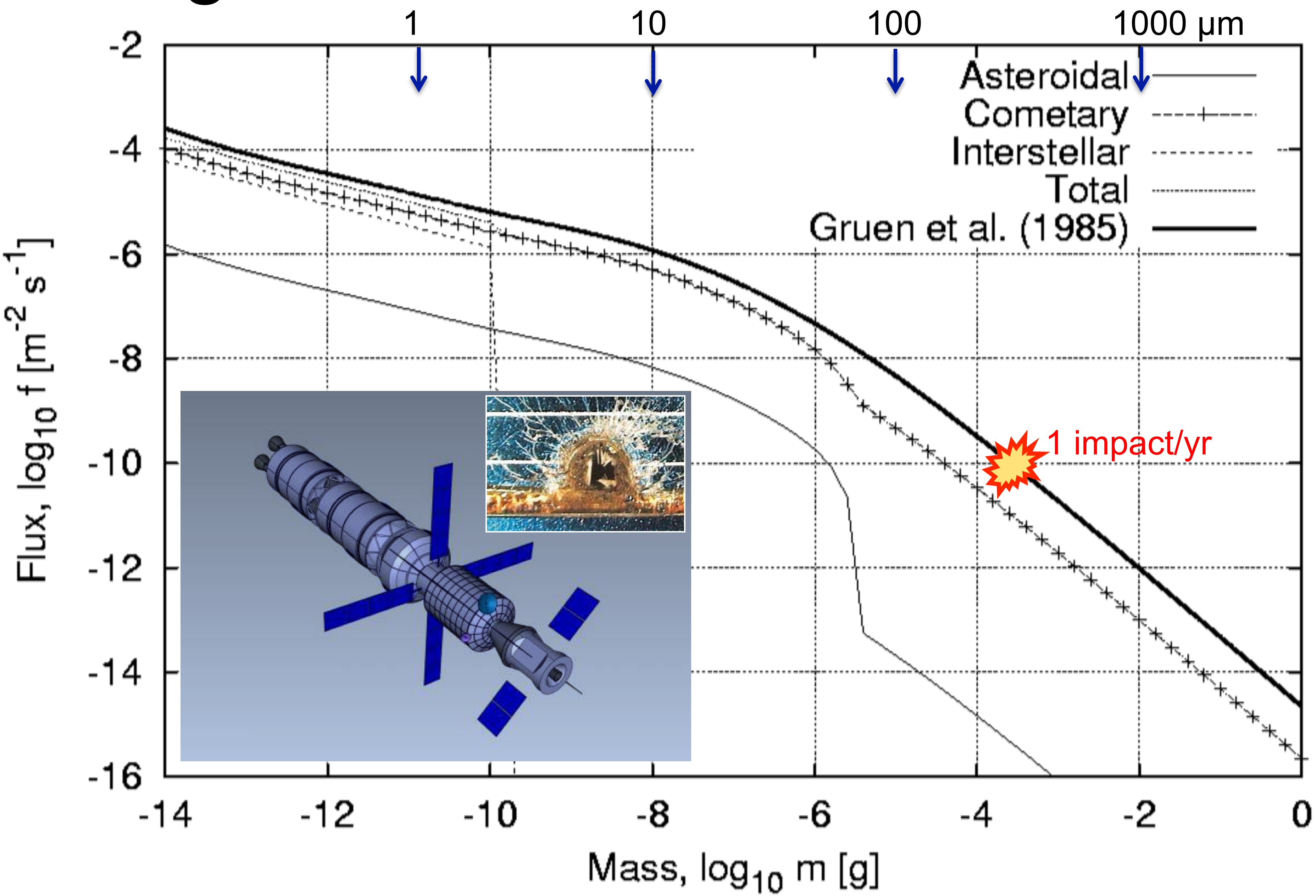
Meteoroid Engineering Model, **MEM 2.1**

- Mass the range: $10^{-6} < m < 10$ g
- Distance range: 0.2 to 2 AU (near ecliptic plane

Interplanetary Meteoroid Engineering Model, **IMEM 1.1**

- Mass range: $10^{-18} < m < 1$ g
- Distance range: 0.1 to 5 AU

# Background Meteoroid Flux at 1 AU



Inter-Agency Space Debris Coordination Committee Report (IADC-09-03, 2009) Comparison of Meteoroid Models states:

*‘It might be surprising to many, but the meteoroid population appears to be one of the most uncertain space environment components.’*

Our analysis of current Meteoroid Models confirms the IADC statement

# NASA's Meteoroid Engineering Model, MEM

Developed by Jones (2004)

- Orbital elements: Sporadic meteor observations from the Canadian Meteor Orbit Radar CMOR (axial symmetry); atmospheric sample -> pre-atmospheric sample -> space sample; luminous/ionization efficiency ~ $v^4$

- Radial distribution from zodiacal light observations from Helios: $n \sim r^{-1.3}$ (Leinert et al., 1983); PR evolution & local source; no longitudinal variation.

- Mass distribution in the range from $10^{-6}$ to 10 g

- Applicable range: 0.2 to 2.0 AU from Mercury to Mars, only near ecliptic plane

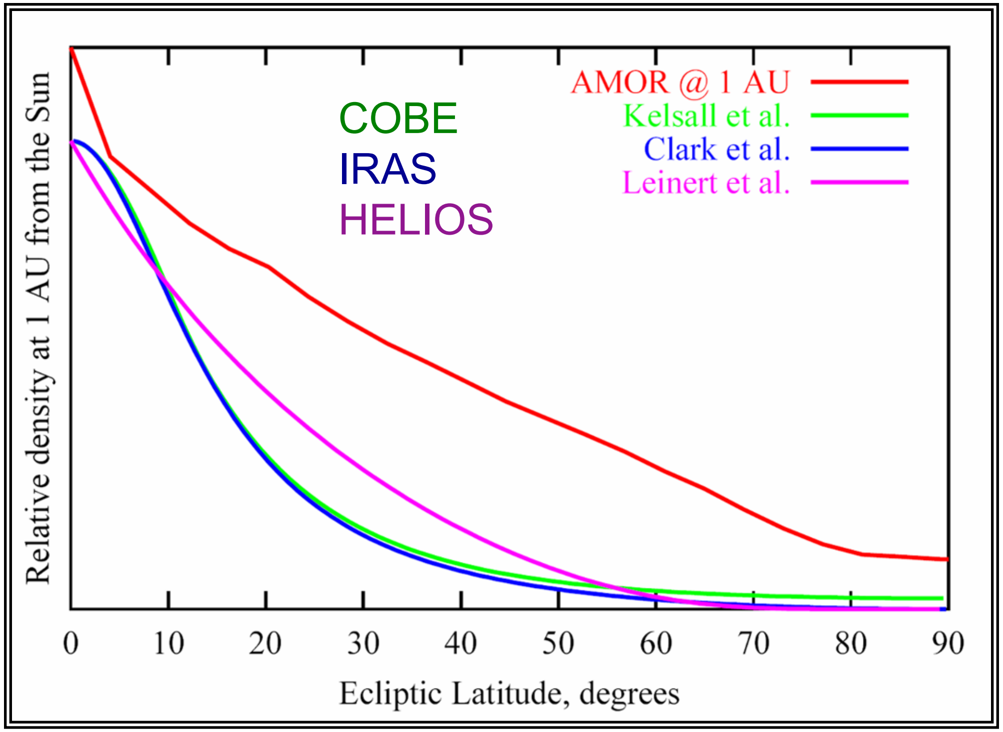
# ESA ‘s Interplanetary Meteoroid Engineering Model, IMEM

Developed by Dikarev et al. 2005

- Orbital elements: Known sources of interplanetary dust: Jupiter Family comets and asteroids & In-situ measurements (axial symmetry)
- Spatial distribution: Thermal radiation measurements by the COBE DIRBE & In-situ data from Galileo and Ulysses dust instruments
- Mass Distribution: Lunar micro-crater distributions; small particles: source distribution & PR evolution (Gorkavyi et al., 1997); big particles: only source distribution
- Mass distribution in the range from $10^{-18}$ g < m < 1 g
- Applicable range: 0.1 to 5.0 (10) AU from Mercury to Jupiter and beyond

# Comparison of Radio Meteors with Zodiacal Cloud Observations

- Orbital distributions derived from the AMOR survey could not fit to COBE IR maps
- AMOR reduced meteor orbital distributions contain probably too few particles on low inclination prograde orbits




(Dikarev et al., 2005)

# Input Data of Meteoroid Models

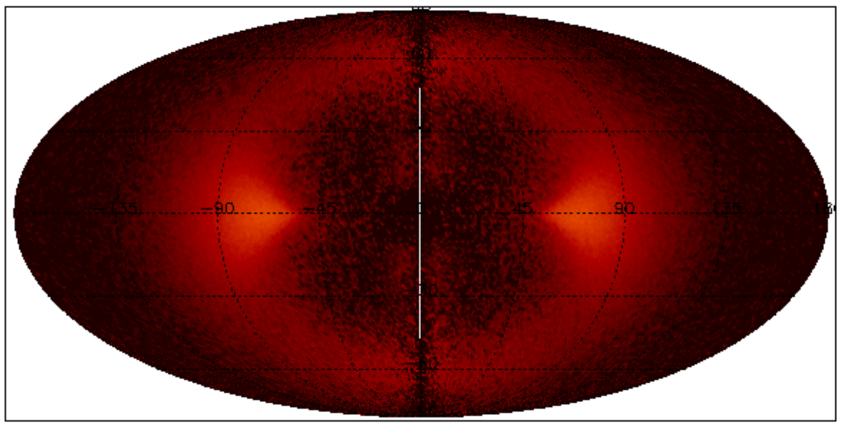
| **Meteoroid Models** | **NASA MEM** | **ESA IMEM** |
|---|---|---|
| Lunar microcrater distribution | + | + |
| Meteor observations | + | - |
| In-situ measurements | - | + |
| Thermal IR observations | - | + |

# Discrepancies Between Models

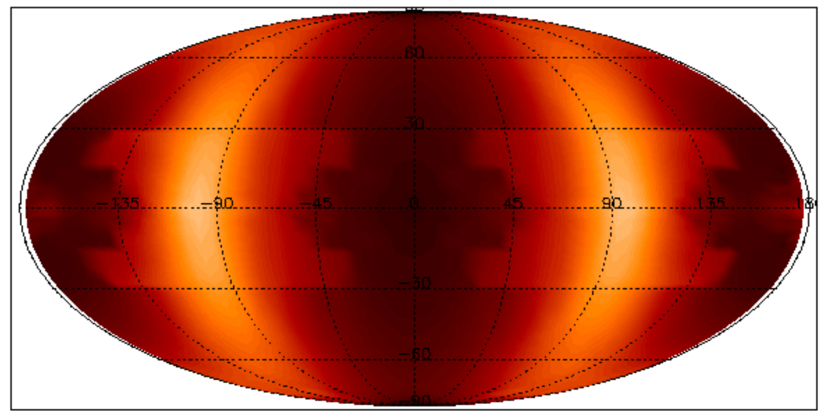
- Directional distribution (Sky Map)
- Mass/size distribution
- Impact speed distribution
- Radial distribution

# Meteoroid Flux Sky Maps at 1 AU

MEM > $10^{-6}$ g

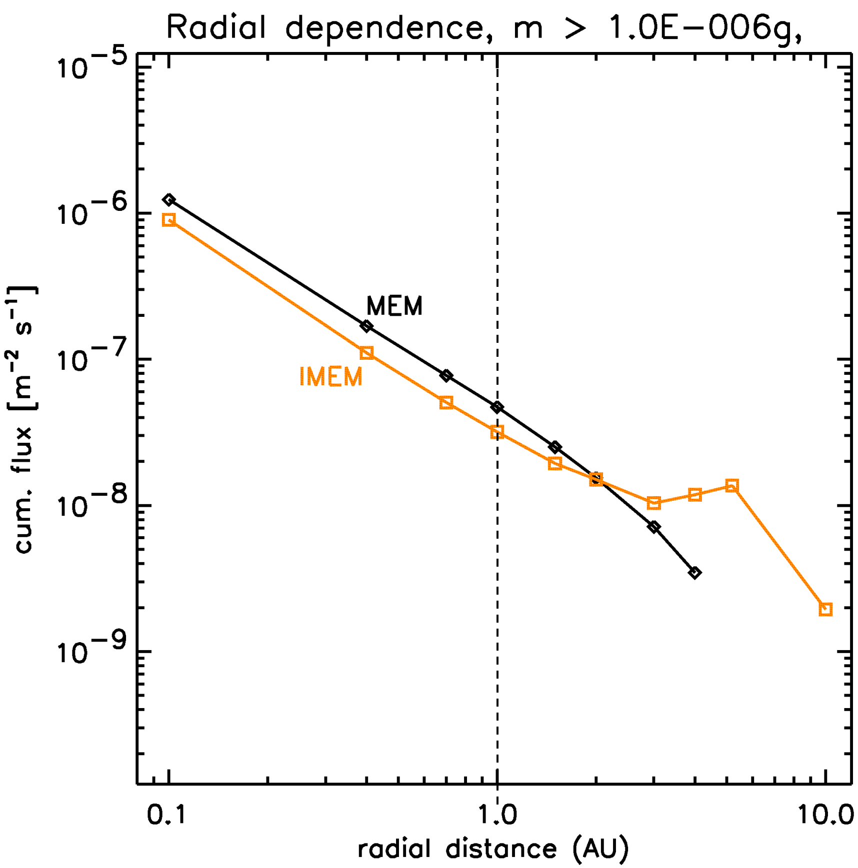


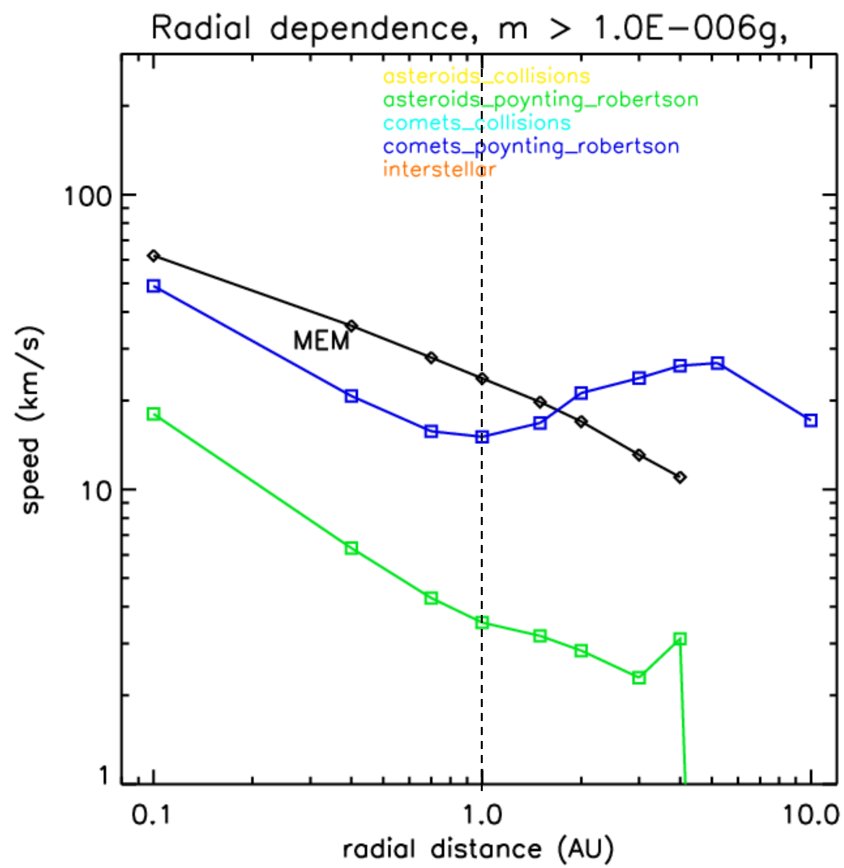

IMEM > $10^{-6}$ g



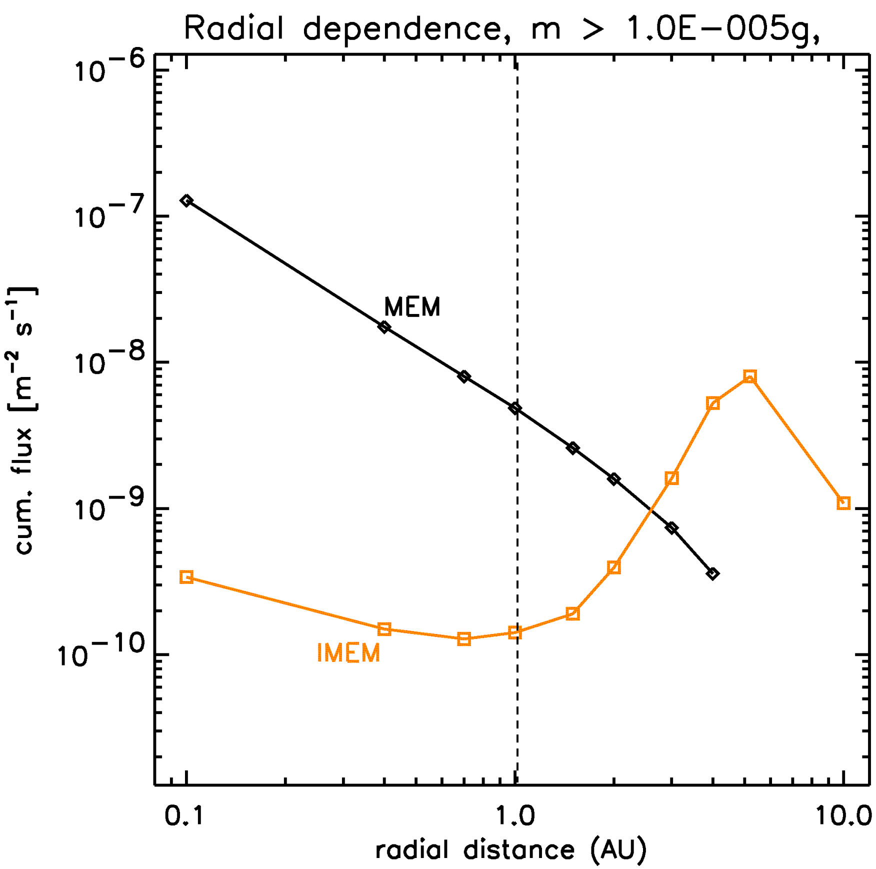

Compatible with CMOR data

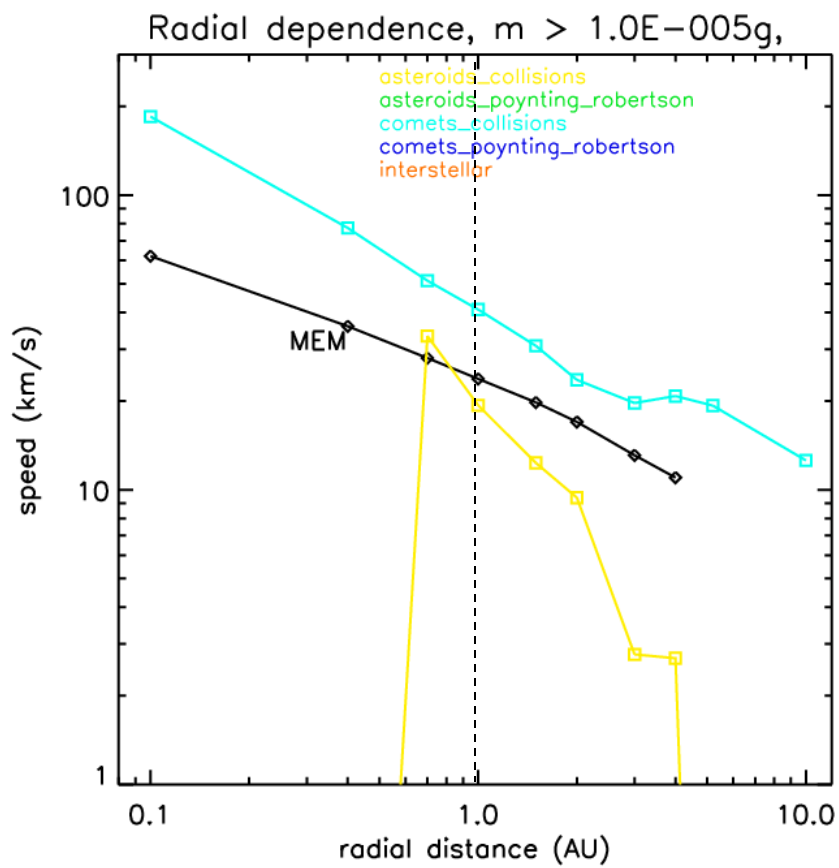
# Comparison of MEM and IMEM Small Particles (> 50 μm)



# Comparison of MEM and IMEM Big Particles (> 100 µm)



# MEM caveats

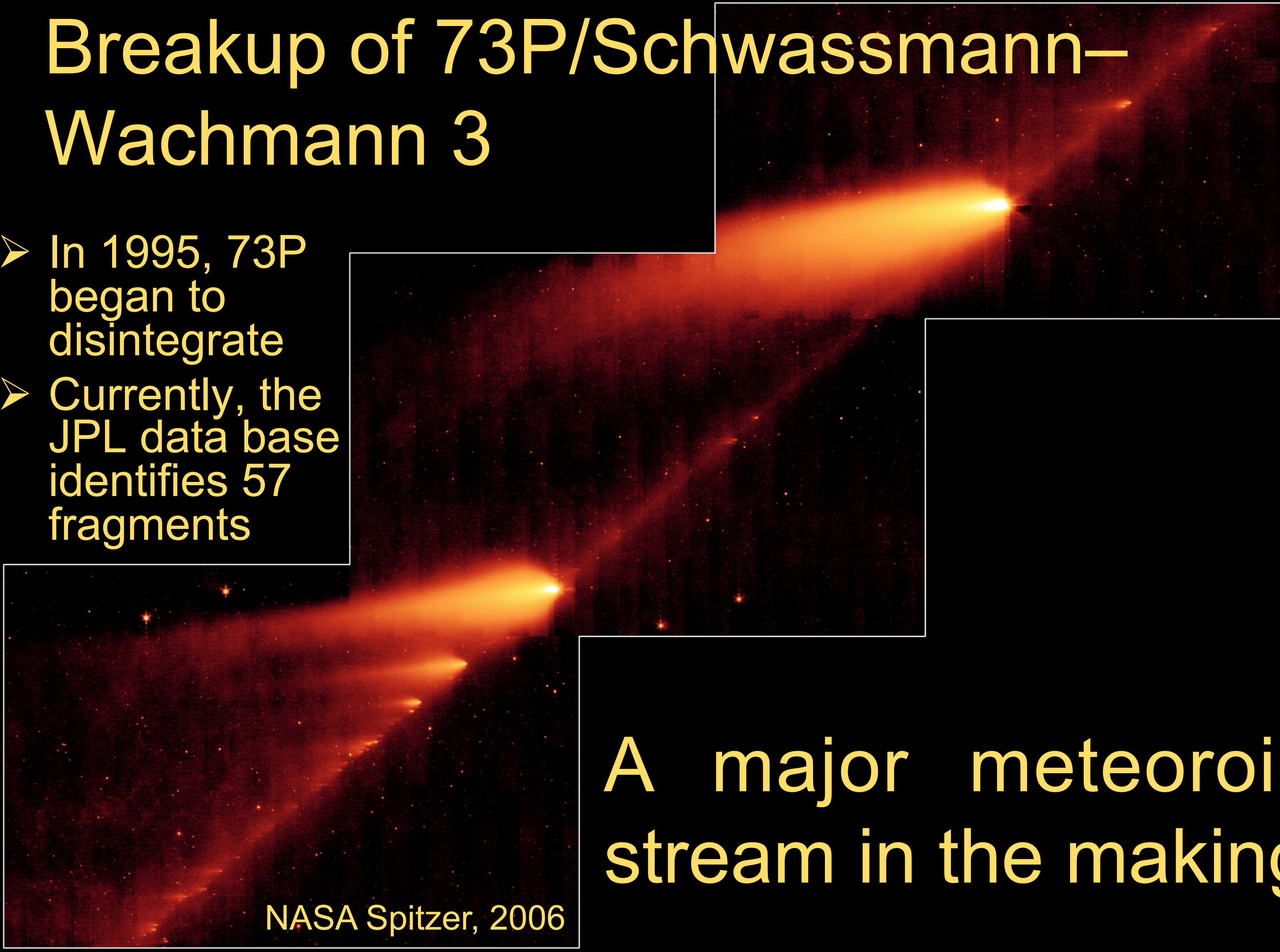
- Zodiacal light brightness corresponds mostly to particles of ~3 $10^{-7}$ g where the cross-sectional distribution peaks. This mass is below the mass represented by CMOR observations (m > $10^{-6}$ g).
- Significant changes of mass distributions at different heliocentric distances expected (Ishimoto, 2000)
- MEM reproduces satisfactorily the speed-separated populations of CMOR meteor radar data but their relative contributions and the importance of slow (< 20 km/s) meteoroids remains obscure.
- MEM assumes rotational symmetry about ecliptic pole. But even the sporadic meteor flux displays about a factor two variations during the course of a year.
- No consideration of thermal IR observations of Zodiacal Cloud
- No time variability considered

# IMEM caveats

- Due to the different treatment of orbital distributions (no orbital evolution of big particles) there is a major discrepancy between fluxes of $m < 10^{-6}$ g and $m > 10^{-5}$ g meteoroids.
- Only JFC source. Other sources (e.g. Halley type, long-period comets, Kuiper belt objects) not included
- No consideration of meteor observations
- IMEM assumes rotational symmetry about ecliptic pole. But even sporadic meteor flux displays about a factor two variations during the course of a year.
- No time variability considered

# Breakup of 73P/Schwassmann–Wachmann 3

- In 1995, 73P began to disintegrate
- Currently, the JPL data base identifies 57 fragments



NASA Spitzer, 2006

A major meteoroid stream in the making

## Possible improvements:

- Inclusion of all observations of meteoroid complex: meteor observations, lunar micro-craters, infrared thermal emission, and in-situ measurements
- Better characterization of luminous/ionization efficiencies for inclusion of meteor data in meteoroid models
- New measurements of meteoroid dynamics by Dust Telescopes/Dust Trajectory Sensors
- Improved orbital evolution of big meteoroids $m > 10^{-6}$ g (combination of orbital and collisional evolution; inclusion of planetary resonances; time variations)

# Conclusions

- Interplanetary human space missions are more vulnerable than robotic missions
- The flux of big meteoroids on large structures (>100 $m^2$) in interplanetary space can be orders of magnitudes higher than the average flux at that distance from the sun

➲ The interplanetary meteoroid flux poses a major strategic knowledge gap.