Local Zodiacal Light

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Zodiacal and Exozodiacal Light

• Exozodis can reveal what the solar system might have looked like
• Local zodiacal light observations relevant to these studies as templates
  – empirical (shape, density, variability)
  – Physical (parent bodies, dynamics, resonances)
Asteroidal and Cometary Planetesimals in the Solar Nebula

Solids devolatilized

Icy planetesimals

5 AU
H₂O ice
Collision or perturbation in Kuiper Belt \( \rightarrow \) Centaur \( \rightarrow \) Short Period comet

\[ \tau \sim 10^7 \text{ yr} \]

Passing star, Galactic tide \( \rightarrow \) New comet

Jupiter-Family Comets:
Survive in inner Solar System \( \tau_{JFC} \sim 10^5 \text{ yr} \)
Active when \( q < q_{\text{max}} \sim 4 \text{ AU} \)
Debris can fill orbit \( \tau_{\text{orb}} \sim 10^3 \text{ yr} \)
Truncated at perturbation \( \tau_{\text{pert}} \sim 10^2 \text{ yr} \)

\[ \dot{M} = \frac{M_{\text{trail}}}{\tau_{\text{pert}}} \sim \frac{10^{12} \text{ g}}{50 \text{ yr}} \]
Cometary Material in Present Solar System

Zodiacal cloud
Cometary+asteroidal veneer
Heavy core
Terrestrial planets & asteroids

Accreted nebular gas
Cometary moon
Cometary core
Gas Giants

Ice Giants

Comets
Parent Bodies: Comets or Asteroids?

- Nesvorny et al. 2009
  >90% comets
  Based on latitude profile
- Nesvorny et al. 2003
  Asteroidal contribution
  Dust Bands = debris from young (<few Myr) families
## Recent Asteroid Collisions

<table>
<thead>
<tr>
<th>Age</th>
<th>Source</th>
<th>Feature</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>220±2 kyr</td>
<td>Emilkowalski</td>
<td></td>
<td></td>
</tr>
<tr>
<td>300-800 kyr</td>
<td>Lucasavin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>450 kyr</td>
<td>Datura</td>
<td>trail?</td>
<td>Nesvorny (2006 Sci 312, 1490)</td>
</tr>
<tr>
<td>5.0±0.2 Myr</td>
<td>Karin</td>
<td>2.1°band</td>
<td>Nesvorny (2006 Icarus 183, 296)</td>
</tr>
<tr>
<td>35 Myr (Eocene)</td>
<td>Comet shower</td>
<td>Chesapeake Bay, Popigai crater</td>
<td>Farley (1998 Sci 280, 1250)</td>
</tr>
</tbody>
</table>
Cometary dust production

- Current dust production readily observed in tails ($\beta>10^{-2}$) and trails ($\beta<10^{-3}$)
- Many features commonly called “tails” are trails
- Trail ~ meteor storm
- Mid-infrared survey: >80% comets have trails
- 2 kg/s typical orbit-averaged
- 50 yr typical dynamical lifetime
- Need $\sim10^6$ comets to maintain cloud of $\sim5\times10^{18}$ g (Fixsen & Dwek 2002)
Empirical: Outer Solar System

- Impact detectors *Pioneer 10, Ulysses, Galileo*, *New Horizons* Student Dust Counter (below)
  - Nearly constant density out to 20 AU
  - Significant interstellar contribution
Kuiper Belt Dust Production

- Virtually unknown
- Theoretical: collisions among KBOs
  - Existence of Haumea collisional family
  - Subsequent comminution of fragments
- Need to get beyond 5 AU
- Possibility to join Jupiter/Europa +Ganymede, Saturn/Titan missions
The View from 5 AU: Measuring the Diffuse Sky Brightness from the Outer Solar System
March 25-26th, 2010
6th annual workshop organized and hosted by:
The Center for Cosmology, University of California, Irvine

workshop goals
a) To establish the scientific goals of measuring the diffuse sky brightness from the vantage point of the outer Solar system, pertaining to the cosmic infrared background and interplanetary dust.
(b) To establish astrophysical sciences enabled by simultaneous observations at 1 AU and a small aperture telescope at 5AU.
(c) To establish the practical means for cruise-phase science for a small aperture optical to near-infrared telescope on an outer planets mission.
(d) To establish instrumentation priorities and priorities and specifications.

organizing committee
- Charles Beichman (Caltech)  Jamie Bock (JPL)  Mike Brown (Caltech)
- Rengo Chary (Caltech)  Asantha Cooray (UC Irvine)  Giovanni Fazio (Harvard/CfA)
- Mike Haujjier (STScI)  John Mather (NASA GSFC)  Toshio Matsumoto (JAXA/SAS)
- David Neaves (SWRI)  William Reach (Caltech)  Mark Sykes (PSI)  Mike Werner (JPL)

topics
- Extragalactic Background
- Galaxy Evolution Models
- Reionization
- Oort Cloud, Kuiper Belt and Trans Neptunian Objects
- Zodiacal Light Models
- Microlensing and similar applications
- The Search for Exoplanets
- Instrument Concepts

website:  http://www.physics.uci.edu/5AU
contact:  asantha.cooray, uc irvine : acooray@uci.edu
workshop SPONSORS

NORTHROP GRUMMAN
The Zody Cloud is not static

- Smooth cloud traces mean orbital elements
  - Node randomized by Jupiter in $10^6$ yr so only secular long-time-averaged perturbations survive

- Resonant effects in comoving frame with planet
  - *Spitzer Earth Ring experiment*
  - Frame comoving with Earth
  - Contours of the COBE/DIRBE zodiacal cloud model
  - Trajectory of Spitzer (thick) with crosses every year
  - Able to probe azimuthal structure of zodiacal cloud
Annual Variation of Polar Brightness at 1 AU

days since 2004 Jan 1
Azimuthal asymmetries in Zody Cloud
residuals from sinusoidal fit to Spitzer observations

COBE/DIRBE model

Gaussian fit

No ring

days since 2004 Jan 1

$l_{8a}$ (M Jy sr$^{-1}$)

$l_{24}$ (M Jy sr$^{-1}$)

0 500 1000 1500
Conclusions

- **Parent bodies**
  - Comets dominate meteors and most zodiacal light
  - Recent asteroid collisions make dust bands

- **Dynamics**
  - Radial profile set mostly by PR drag
  - Circumsolar ring of dust in mean motion resonance with Earth

- **Outer Solar System**
  - We need to get out there to see KB collisional dust
  - We need support of exoplanet community for future experiments to observe zodiacal light from the outer solar system