Zodiscout: A Small Satellite to Explore the Origins of the Interplanetary Dust in our Solar System

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What we know about dust in our solar system

- In 1683, Giovanni Domenico Cassini gave one of the first scientific explanations for the zodiacal light as sunlight scattered off dust particles in the solar system.

Zodiacal light seen over Cerro Paranal in Chile

What we know about dust in our solar system

- Since then the zodiacal light's extent, shape, composition, and the total amount of dust have continued to be debated.

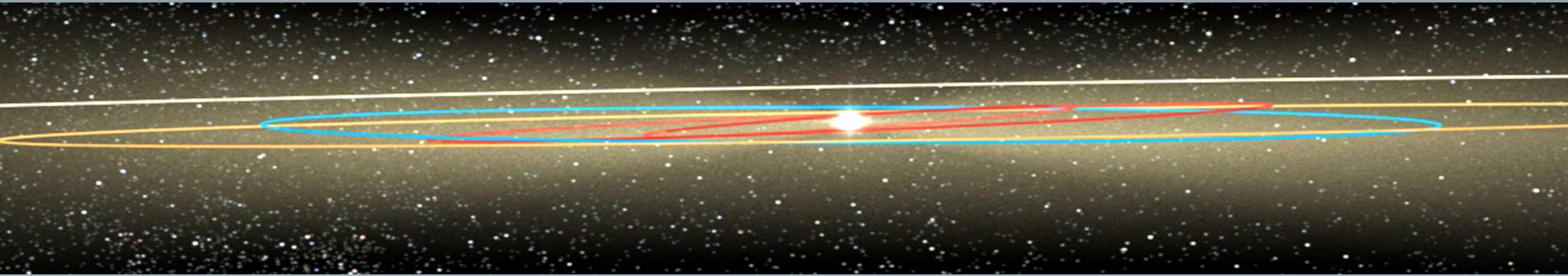
Zodiacal light seen over Cerro Paranal in Chile

What we know about dust in our solar system

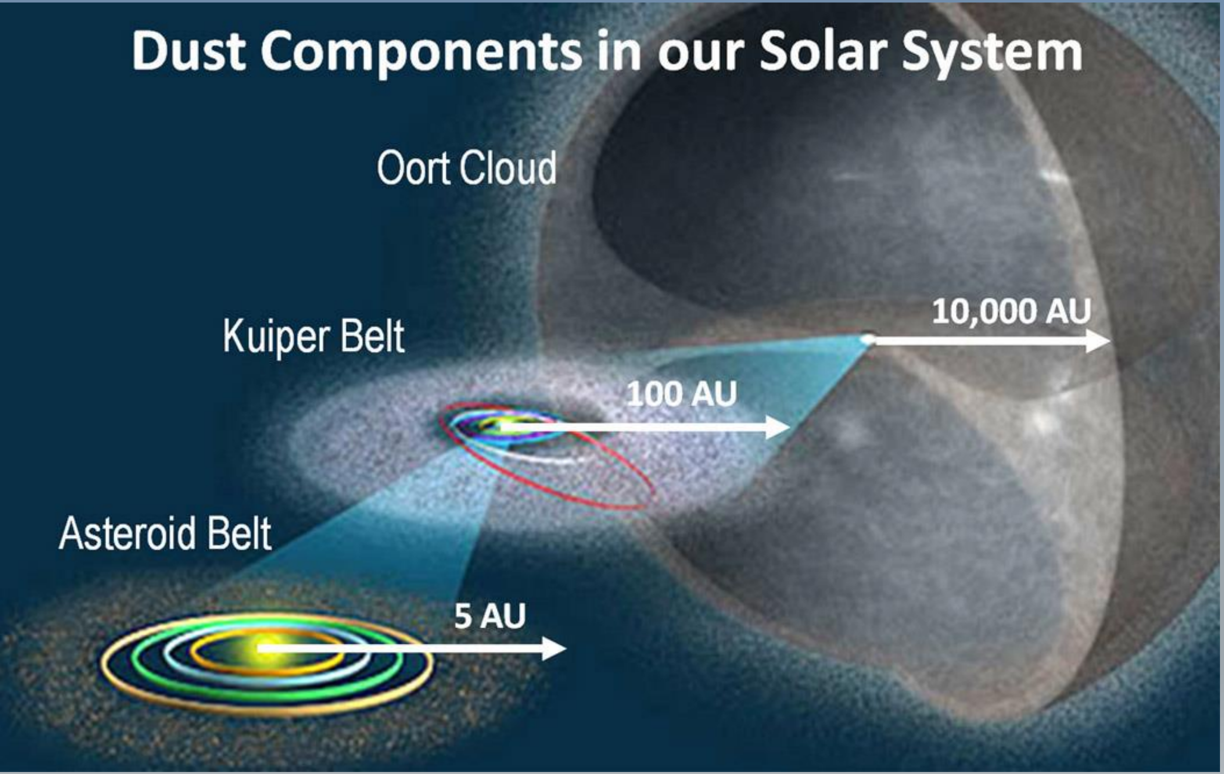
- It is one of the **largest** structures in our solar system, yet one of the least understood.
- The difficulty in studying it comes from being embedded within its diffuse extended structure

What we know about dust in our solar system

- The cloud is made up of dust released by asteroids and comets, spiraling in towards the Sun under Poynting-Robertson (PR) drag.



What we know about dust in our solar system



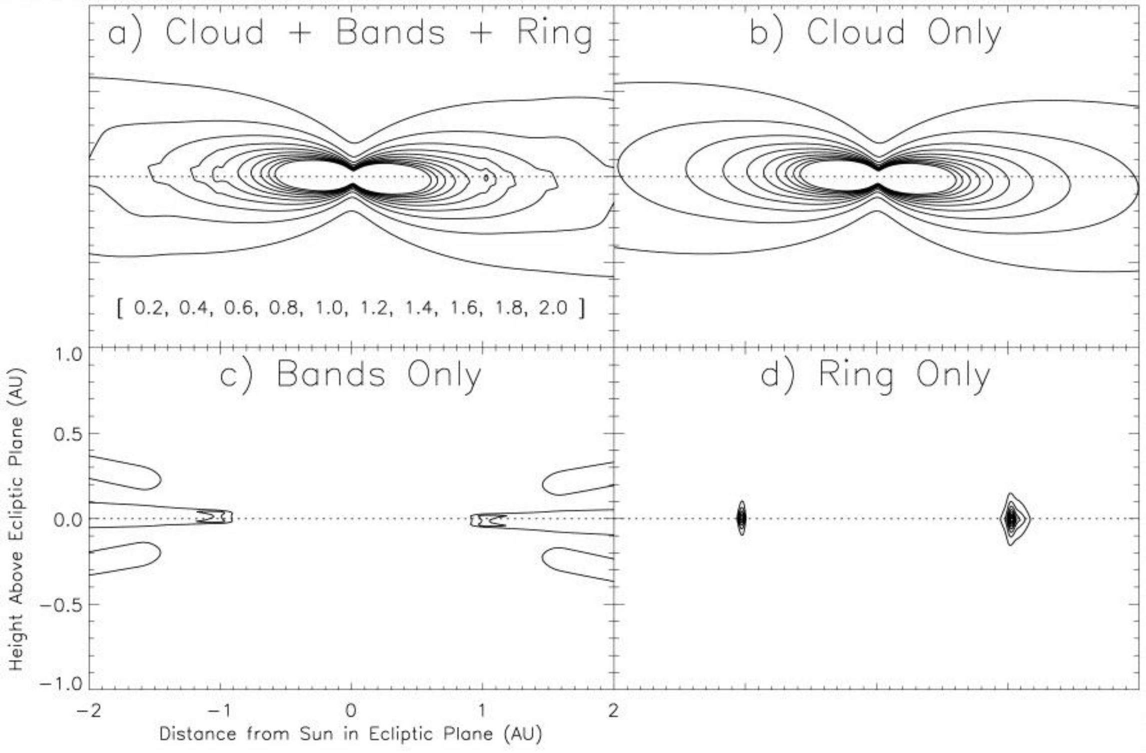
A pictorial breakdown of the dust producing bodies in our Solar system and the scales they occupy. Note in particular that studying the dust brought by comets from the Oort Cloud allows us to study a structure that is over 10,000 AU away from the Sun. (Bock et al. 2012)

Previous Observations

- All outer planets missions have measured some aspect of the dust on their way out of the inner solar system
- The Earth orbiting Cosmic Background Explorer Satellite had the Diffuse Infrared Background Experiment (DIRBE) which gave one of the best images of the dust from 1 AU

Previous Observations

DIRBE results



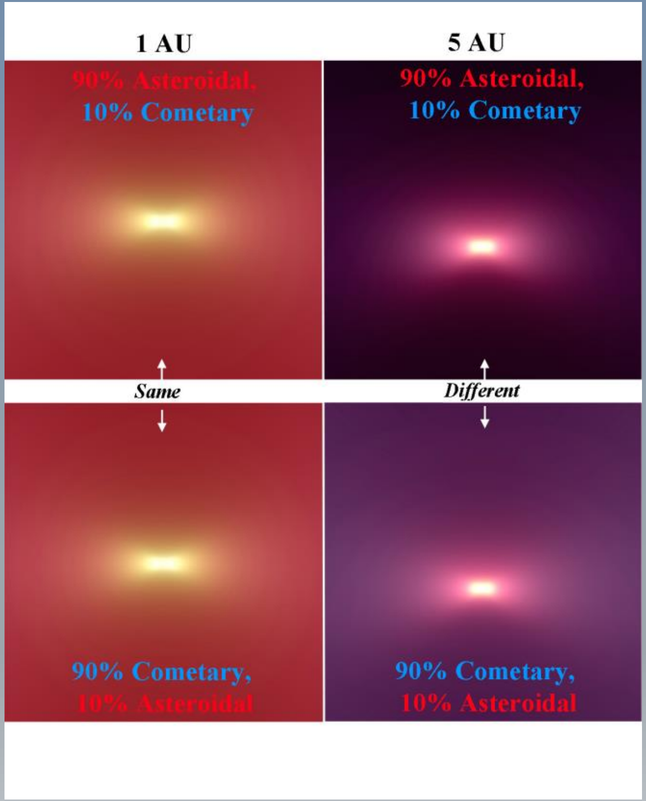
Isodensity contours of the IDP model components, shown for a cross-sectional slice perpendicular to the ecliptic plane looking towards the Sun at the center of each panel. The density contour levels used in (a) and (b) are listed in brackets at the bottom of (a), in units of 10^{-7} AU^{-1}. Contour levels used for (c) and (d) are a factor of 8 smaller. Kelsall et al (1998)

How to characterize the Zodiacal Dust

- Since the asteroid belt is a significant source of the dust, taking measurements inside and outside of the asteroid belt will constrain the asteroid belt's contribution
- Going outside of the plane of the solar system will significantly reduce the contribution of the asteroid belt and the Kuiper belt.

How to characterize the Zodiacal Dust

Leaving the ecliptic plane



A model by co-I Turner of the zodiacal dust viewed towards the Sun from 1 AU (left column) and from 5 AU and above the ecliptic (right column). From 1 AU the view is almost the same whether Kuiper belt or asteroidal dust dominates (top left vs. bottom left). From 5 AU there are striking differences, with the Kuiper belt dust still surrounding the spacecraft, while the asteroidal dust now lies only in the sunward direction. The sun is saturated since the color scale is chosen to show the much fainter zodiacal cloud. Color channels: blue = 1 μm, green = 2 μm, red = 5 μm.

What kind of measurements are required?

- Small grains in the zodiacal dust are strongly forward scattering in the optical and hence to trace them we need optical monitoring

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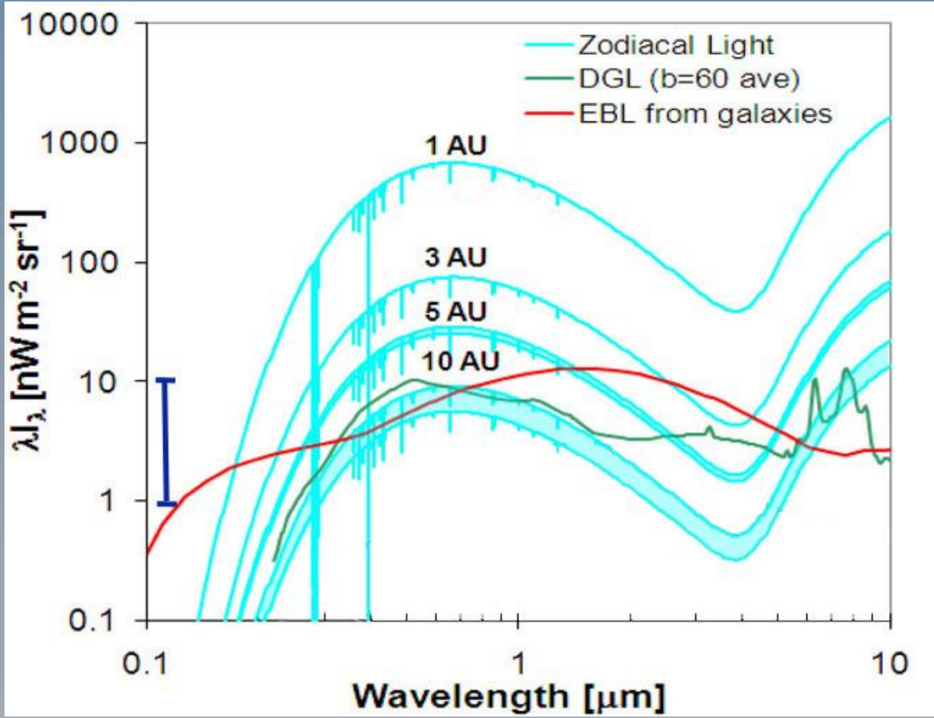

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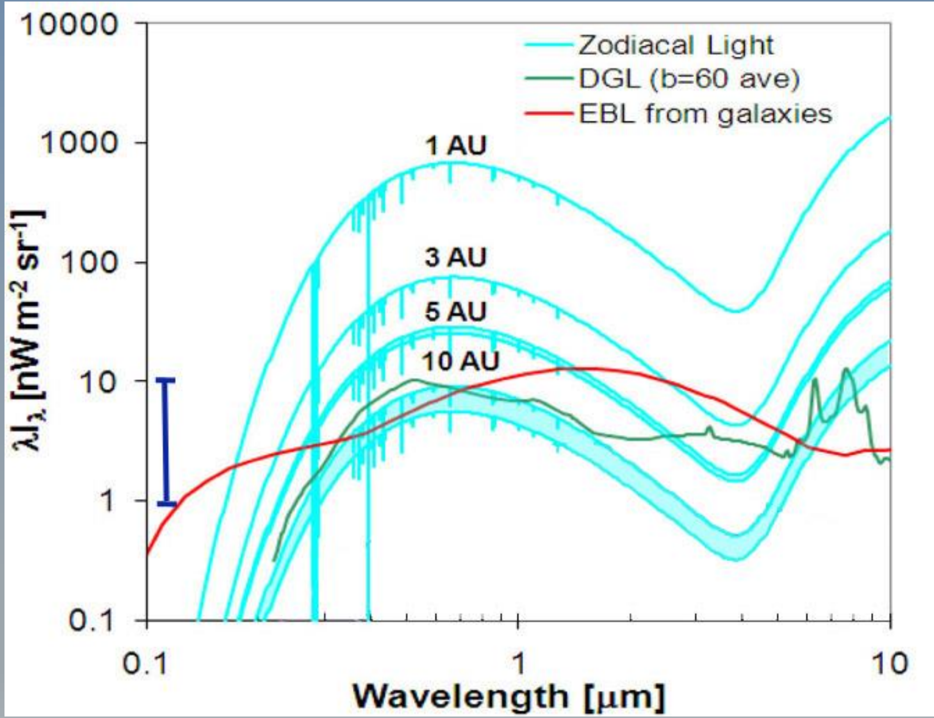
- Small grains in the zodiacal dust are strongly forward scattering the optical and hence to trace them we need optical monitoring
- Larger grains emit strongly in the infrared and so need infrared monitoring

What kind of measurements are required?



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- Two telescopes
  - 10 cm apertures
  - 6^ox6^o FOV
  - Low resolution spectra (R~100) covering 0.5-2 μm 2-5 μm

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- A high resolution spectrograph (R~3000) to monitor scattering of solar Fraunhofer lines to distinguish Zodiacal light from redshifted Extragalactic Background Light

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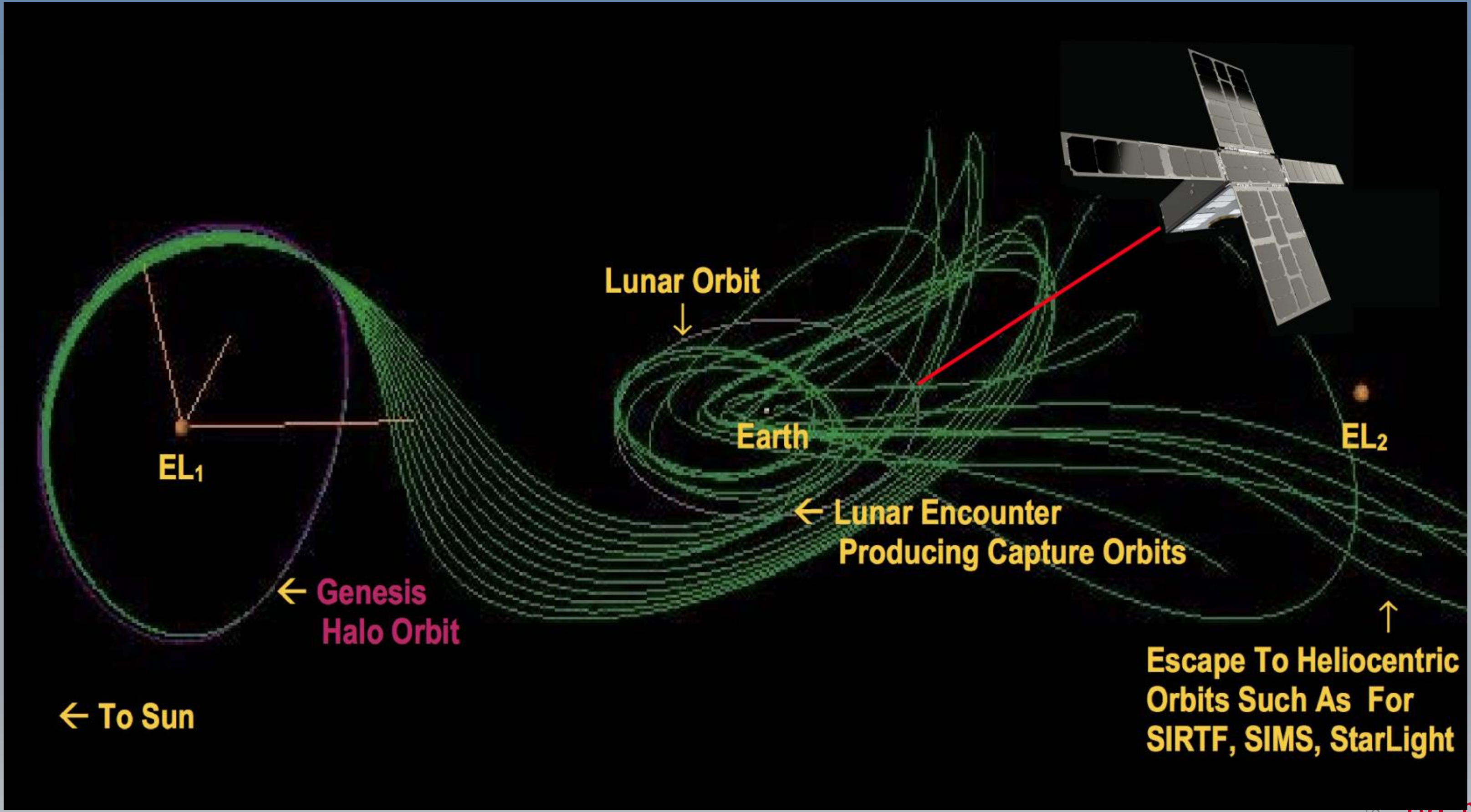
How to get to the outer solar system

- Launch with an outer planets mission. Once the mission has achieved a velocity sufficient to reach an outer planet like Jupiter, the cubesat will detach and fly independently
- Launch with a mission going to the moon and use the interplanetary superhighway with some additional propulsion

The Interplanetary Superhighway (ISP)



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How to leave the ecliptic plane

- Use a gravity assist from Jupiter to leave the ecliptic plane

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Anticipated Results

- How are interplanetary dust particles generated, how do they evolve dynamically?
- What are the relative contributions of dust particles from each source to the zodiacal cloud as a whole and what limits can it set on the source population?
- What is the global structure of the cloud and how does it compare to exo-zodiacal clouds?

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Challenges

- Telecommunications
  - Data rates are low as it takes a long time to get a high signal to noise image

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Challenges

- Thermal
  - We need cooled detectors for reaching the longer IR wavelengths but these can be achieved by passive cooling

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Challenges

- Power
  - The spectrographs are low power instruments and only the telecom will need significant power but that is mitigated by a low data rate

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Challenges

- Longevity
  - Cubesats/smallsats are not currently designed or built with long lifetimes in mind
  - This mission will require a ~5 year primary mission

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Thus a small mission with the right vantage point will have a large impact on our understanding of the zodiacal cloud