The View from 5 AU

Beckman Center, UC Irvine, 25-26 March 2010

Introduction
&
Objectives

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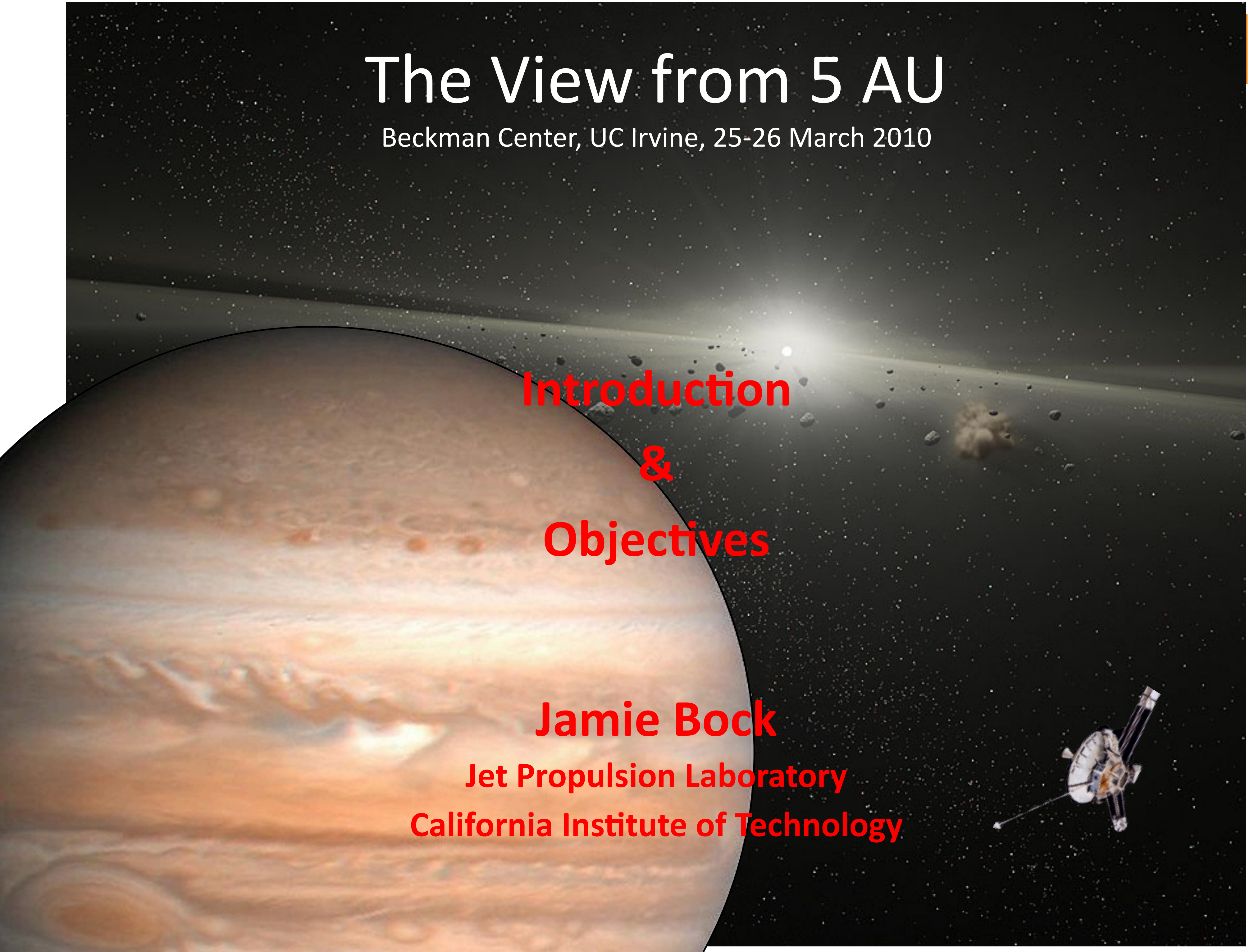
Jet Propulsion Laboratory

California Institute of Technology



Memorial for Andrew Lange

7/23/1957 – 1/22/2010

May 7 afternoon: Public memorial at Beckman auditorium, Caltech.

May 8: *The Future of Observational Cosmology: A Symposium for Andrew Lange*. The symposium will have invited speakers and guests, and open registration as space allows.

www.astro.caltech.edu/lange-memorial (currently under construction)

If you wish to attend and have *not* received the initial email announcement, please contact me and I will see that you are added to the announcements list.

Also visit the Facebook page In Memory of Andrew Lange

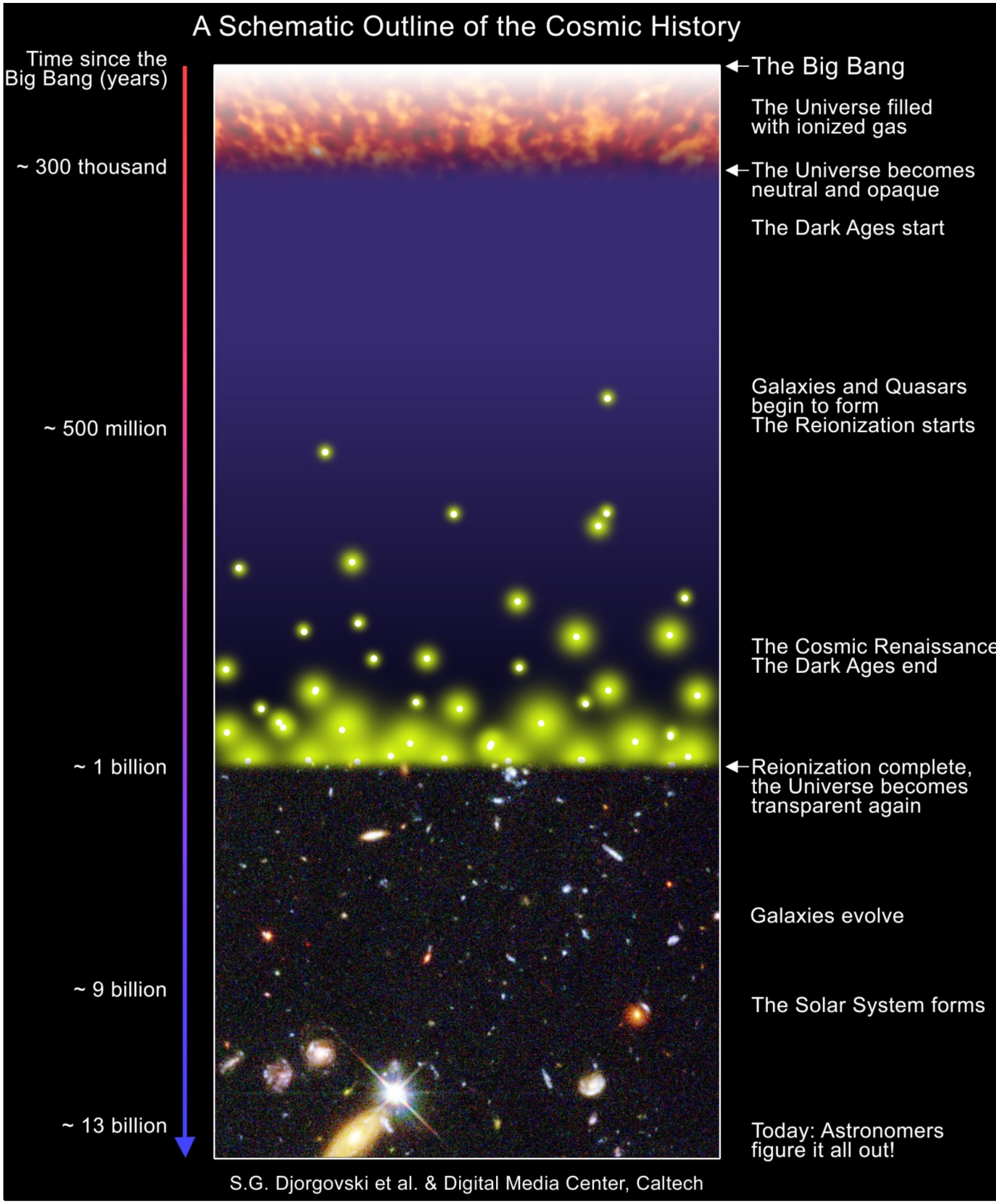
This is Not Your Usual Workshop

- We have a very specific focus: a small optical/IR piggyback instrument on an outer planets mission

- We want your help!
  - What is the science case for interplanetary dust?
  - What is the science case for extragalactic backgrounds?
  - What other science can you do with this?
  - How do we optimize the instrument design?
  - What are the synergies with coming mission opportunities?

  Speakers should address key questions rather than give their usual science talk

- Diverse experts invited: extragalactic backgrounds, interplanetary dust and solar system science, instrumentation, and missions



The Extragalactic Background Light

The sum of light from all galaxies since the Big Bang, a quantity of fundamental interest in cosmology

What do we learn from the EBL?

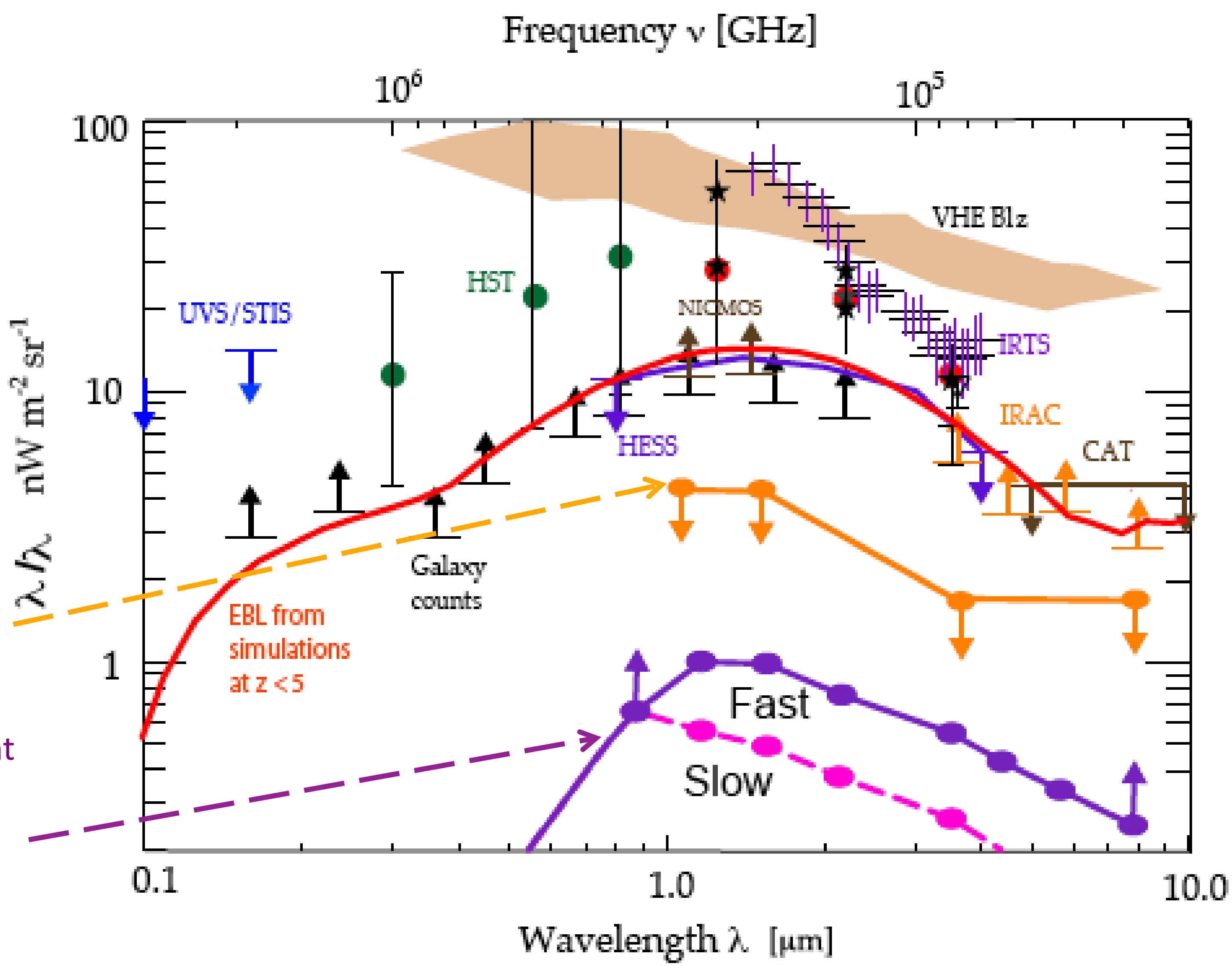
- Amplitude and spectrum constrain galaxy formation over cosmic time
- The background may contain hidden galaxy populations
- Near-infrared EBL needed to interpret spectra of gamma-ray sources
- Exotic physics could produce a uniform background
- Reionization EBL amplitude and spectrum give information on history and luminosity, and must be present at some level

Reionization Epoch

- Very little direct experimental data exists, so we are largely ignorant about this time!
- Inter-galactic medium becomes 'reionized' by UV radiation from first-generation stars and their remnants (e.g. black hole disks)
- First generation stars have primordial metalicity, predicted to be massive, luminous and short-lived
- IGM is reionized to most distant quasars $z \sim 6$
- CMB data constrains total column of electrons e.g. $z = 11 \pm 1.4$ if stepwise
- Many different histories possible

State of NIR/Optical Extragalactic Background Measurements

Asantha Cooray *et al.*
A New Era in Extragalactic Background Light Measurements: The Cosmic History of Accretion, Nucleosynthesis and Reionization
Astro 2010

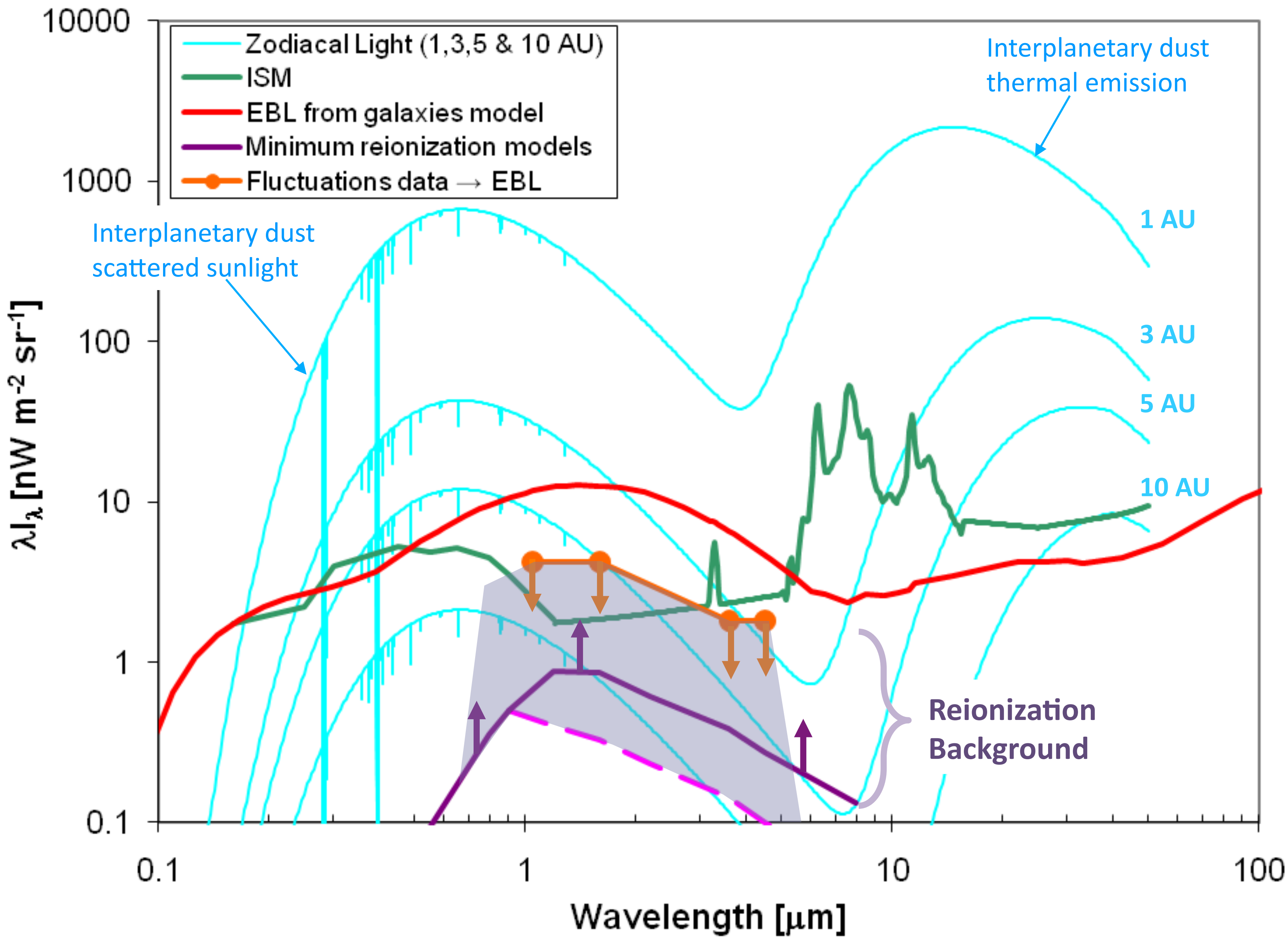


Upper limits from *HST* and *Spitzer* fluctuations – (EBL is somewhat model dependent)

Conservative first light models. Just enough photons to ionize the IGM – two different histories shown

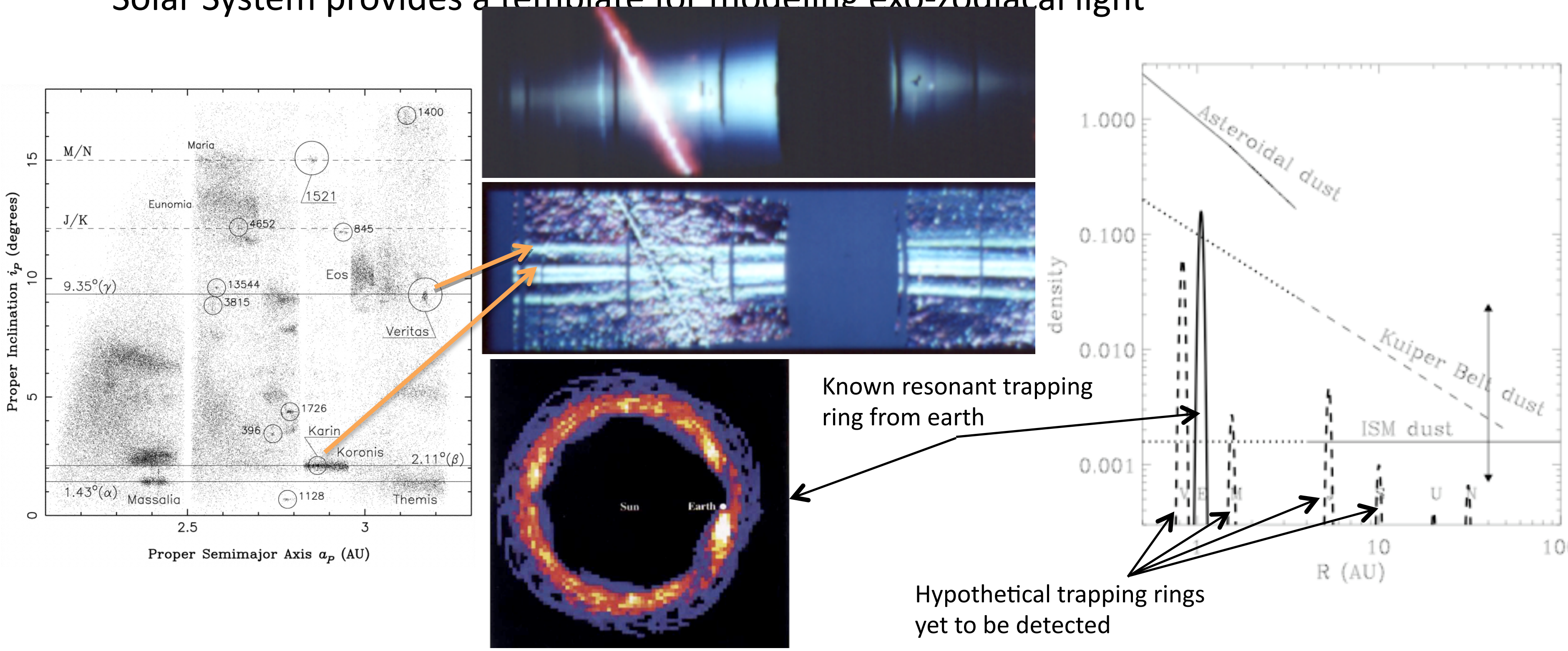
Absolute measurements completely limited by Zodiacal foreground removal

A Unique Opportunity at 5 (or 10) AU



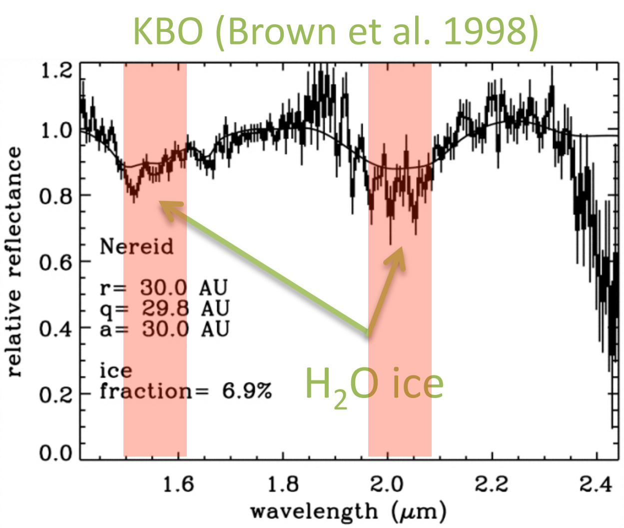
The Outer Solar System Zodiacal Light

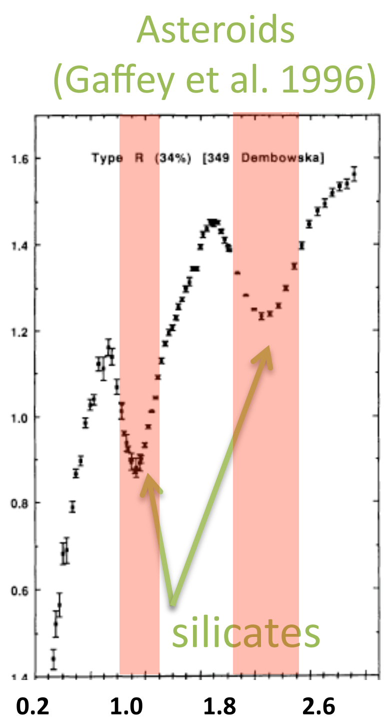
- Collisions among Kuiper Belt objects will generate a dust cloud analogous to the one generated by asteroids and Jupiter family comets. Such a cloud has not yet been seen due to the bright foreground from the inner solar system.
- The amount of KB dust and its distribution reveal the amount and location of collisions
- A collisional family was recently discovered in Kuiper Belt (Brown et al. 2007, Nature 446, 294)
- The view from 1 AU has revealed structures in the zodiacal cloud due to recent collisions in the asteroid belt, cometary meteoroids, and resonant trapping by Earth
- Dust at Kuiper Belt distance is common around nearby stars; a radial profile of the Solar System provides a template for modeling exo-zodiacal light

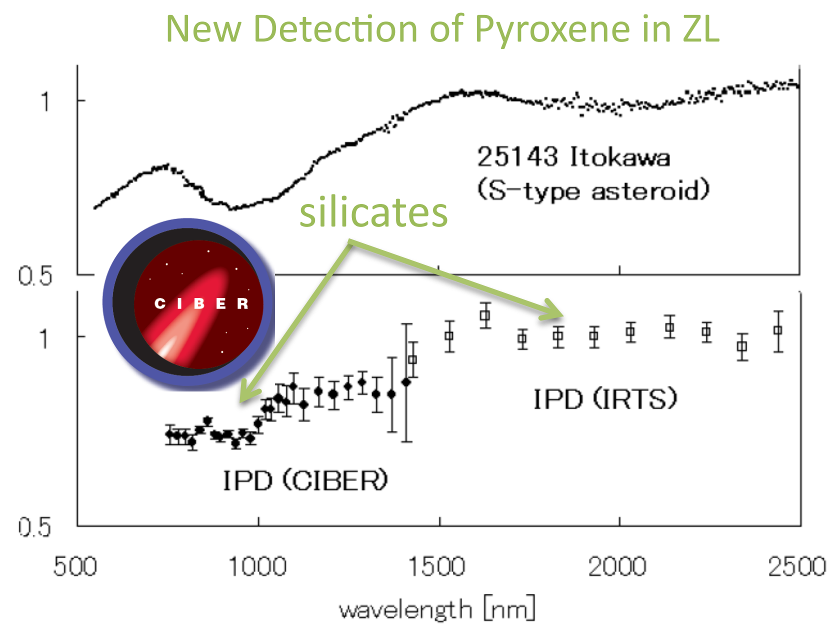


Composition of Interplanetary Dust

- Are KBOs mostly ice or rock? How are asteroidal and icy material distributed transitioning from the inner to the outer solar system?
- The outer solar system zodiacal light will trace the composition of disrupted KBOs
- Reflectance spectra discriminate the type of parent body by the placement of NIR absorption bands from silicates and ices

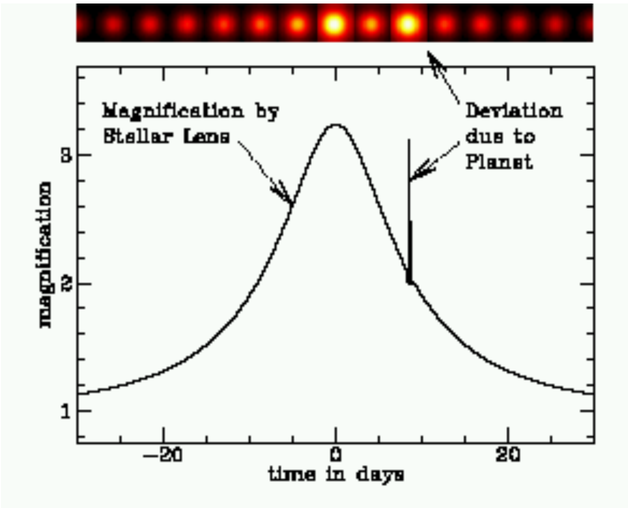




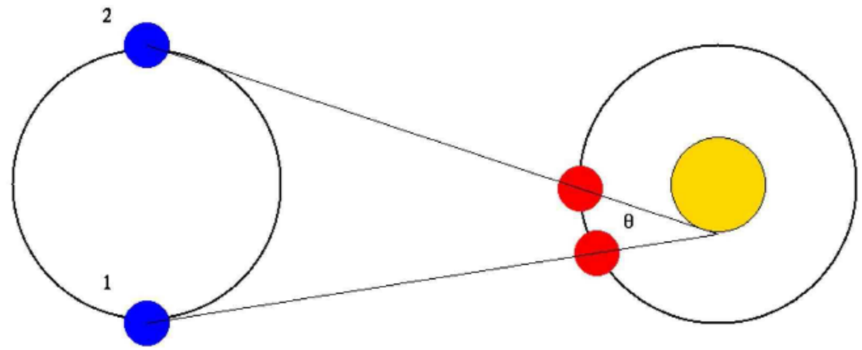


A. Espy & A. Graps et al. *Interplanetary Dust*
(Planetary decadal white paper)

Additional Opportunities and Synergies

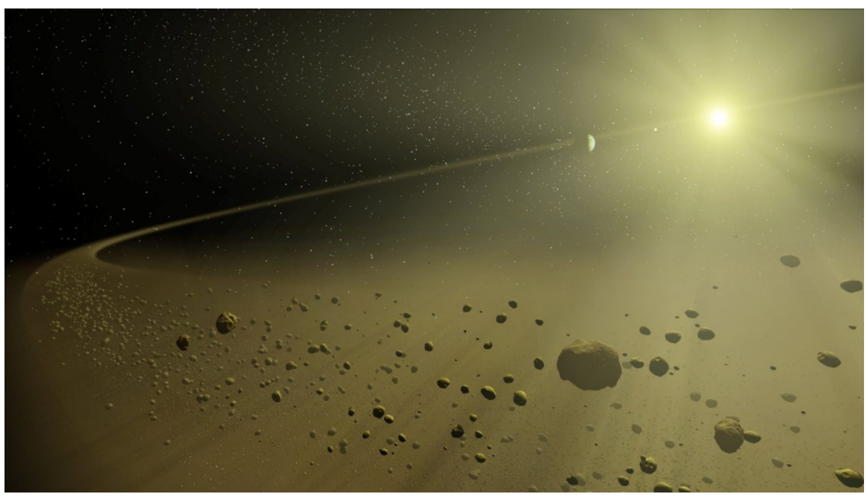


Parallax effect in microlensing



Parallax effect in transits

Need to bear in mind instrumental and operational considerations


Implications for exo-planet searches

A Programmatic Synopsis of the Field

- IRAS (1983) maps Zodiacal dust structure in inner solar system
- COBE/DIRBE (1989) dedicated to IR background measurements
- IRTS (1995) higher spatial and spectral resolution in NIR
- HST, Spitzer and Akari
  - Not designed for absolute measurements, but have some capability
  - Background fluctuations measurements
- Track record for dedicated background measurements poor

  EGBIRT, LZM, DESIRE - All unsuccessful 1990's MIDEX proposals

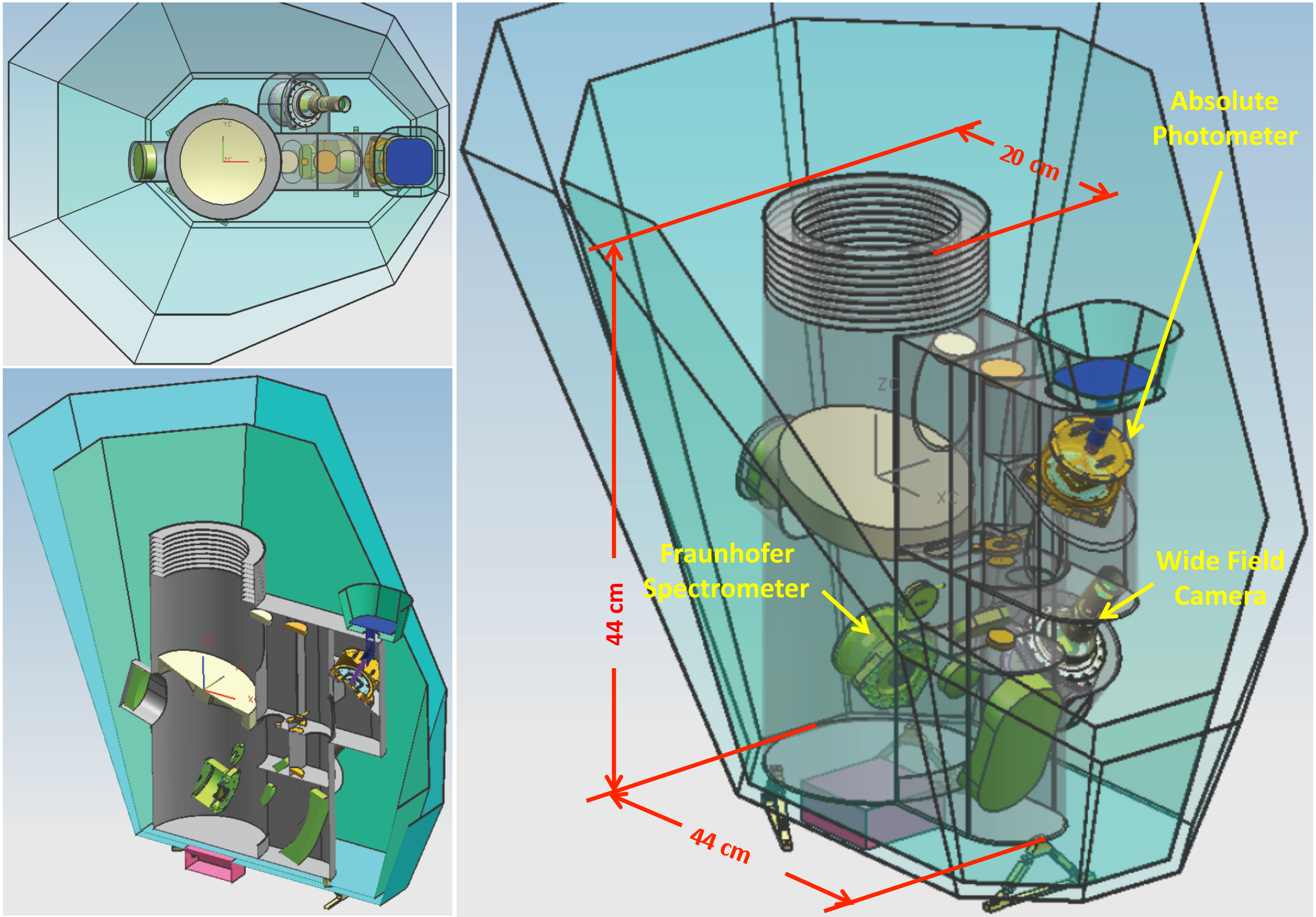
  Many planetary instruments with not enough sensitivity

  Last planetary instruments designed to measure diffuse light: Voyager

  "Mixed planetary/astro science" a common criticism for non-selection
- Coming missions: WISE, JWST, and JDEM

  Anything developed at this workshop must be complementary

ZEBRA: Zodiacal dust, Extragalactic Background, & Reionization Apparatus



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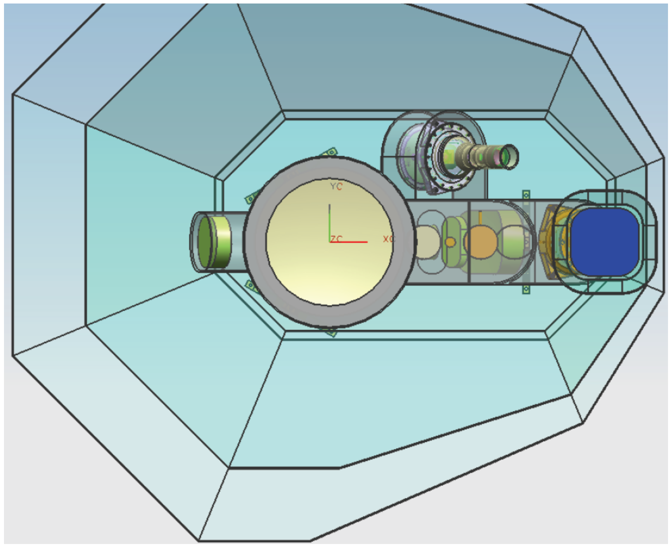
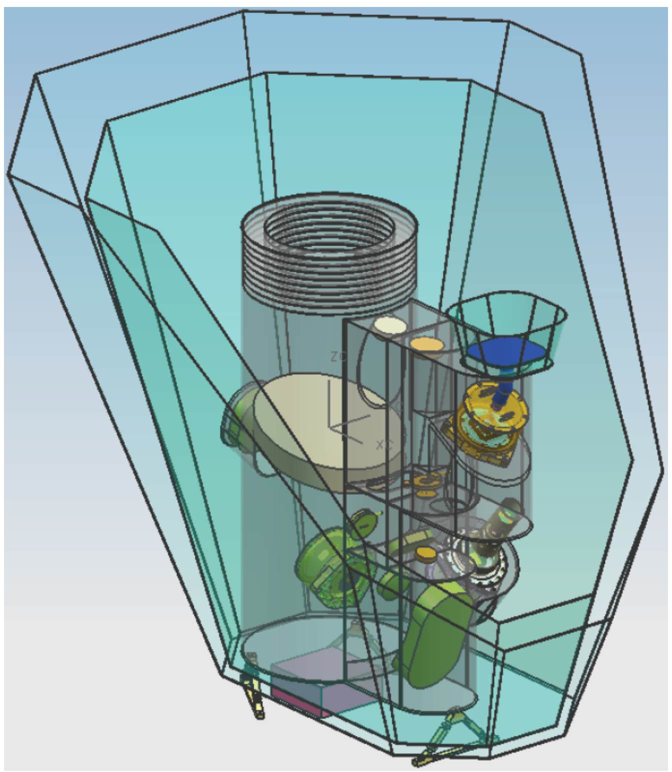
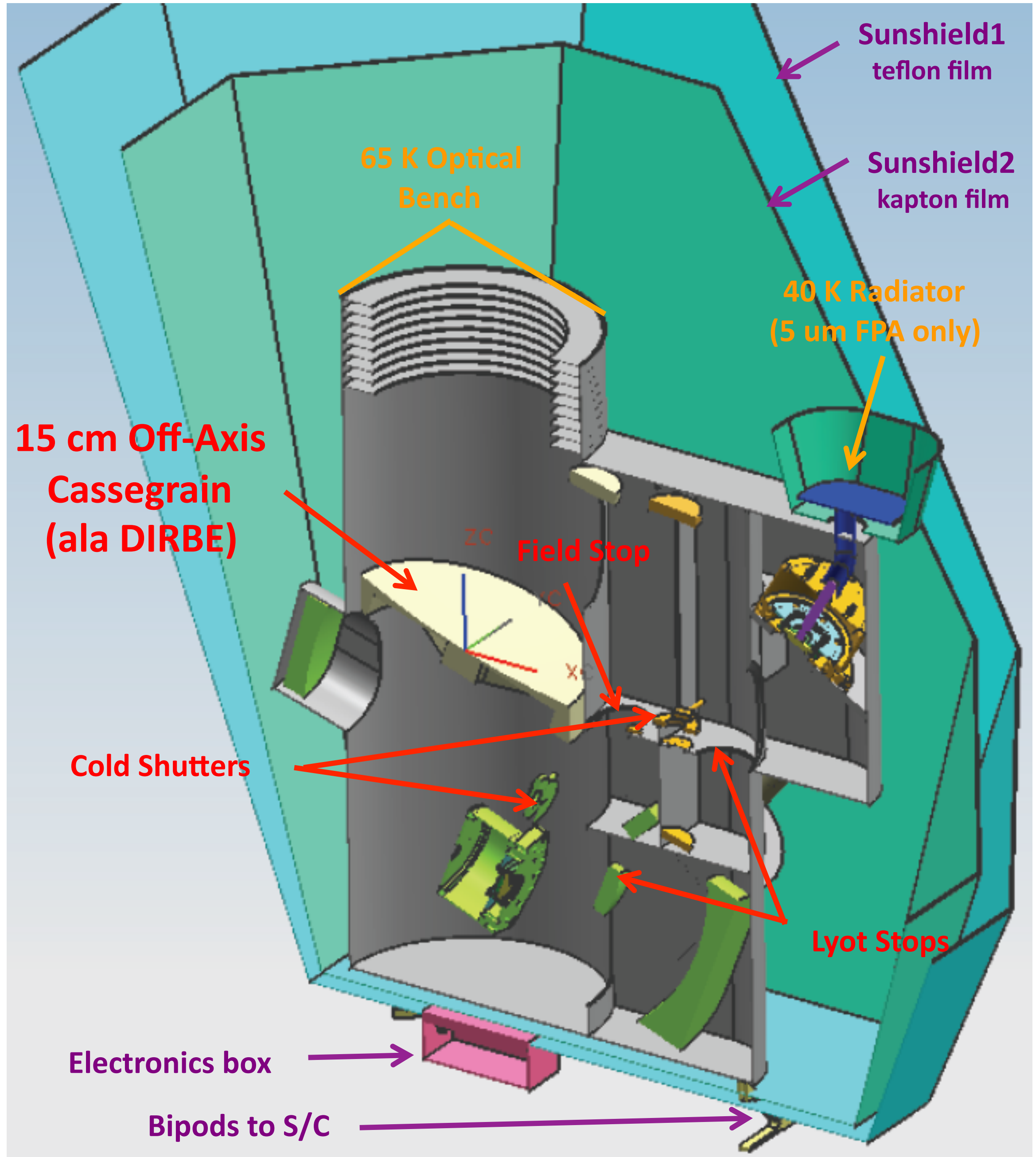
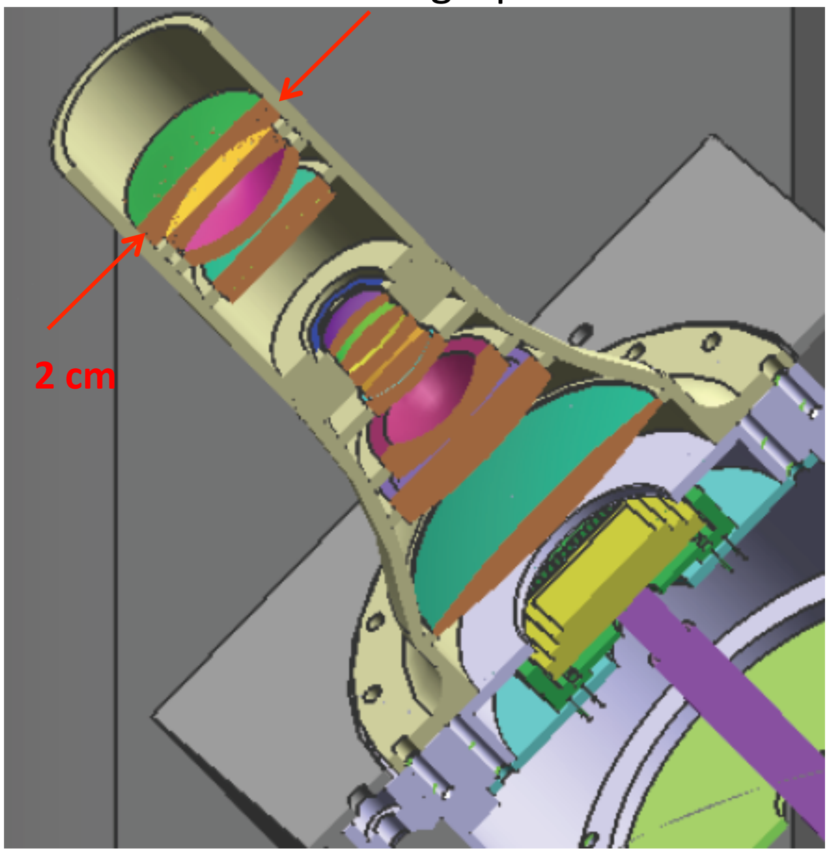


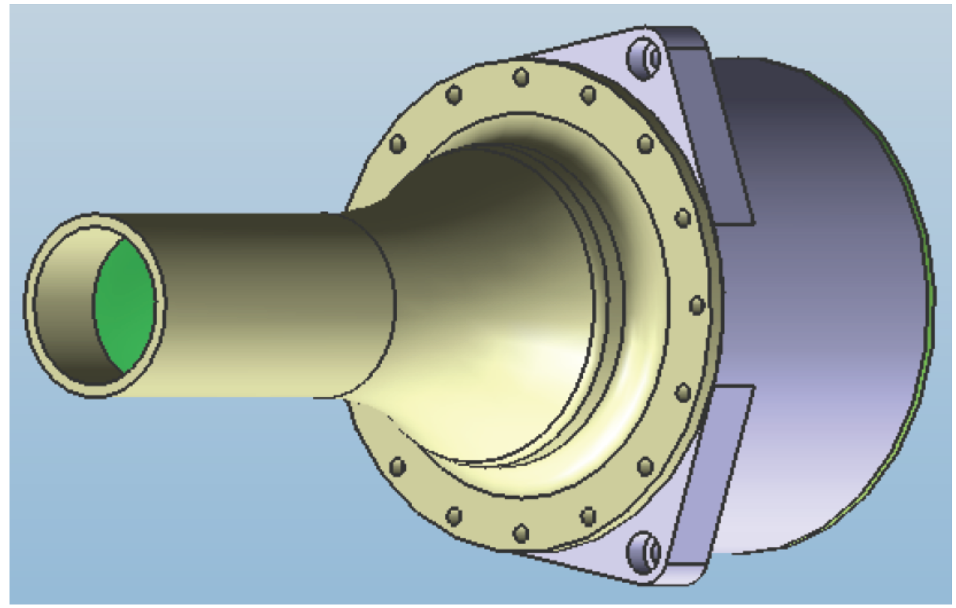




Wide-Field Camera

Refracting Optics





Specifications

Spatial resolution: 5' x 5' pixels

Field of view: 85º x 85°

Focal plane: 1024^2 HAWAII 1.7 um HgCdTe or HiViSi

Wavelength band: 800 nm

Sensitivity: < 0.1 nW/m^2 sr per pixel

Science

- Kuiper belt cloud structure
- Interplanetary dust cloud structure

A High Readiness Instrument

Absolute Photometer

15 cm aperture (shared)
2”x2” pixels, 0.6° FOV
15 bands b/w 0.4 – 5.5 um

- IPD composition
- Extragalactic background
- Search for reionization

Wide-Field Optical Camera

2 cm aperture
5’ x 5’ pixels, 85° FOV
Single band at 800 nm

- Imaging Kuiper-belt structure
- 3D mapping of Zodiacal cloud during cruise-phase

Fraunhofer Spectrometer

15 cm aperture (shared)
30” x 30” pixels, 2.1° FOV
$\lambda/\Delta\lambda$ = 300 resolution
380 – 880 nm

- Separation of ZL, starlight

Main challenge is absolute measure of low light levels

Technologies

15 cm telescope

- low-scatter off-axis optics
- multi-band fixed filter
- shutters only moving part
- Optical design adapted from DIRBE
- Shutter adapted from ISO, IRTS, MIPS

Passive cooling

- no active cooler required
- 65 K optics, 40 K for 5 um array
- Flown on Planck and Spitzer

3 Arrays

- Hawaii-1RG 1024^2 5.5 um HgCdTe
- Hawaii-1RG 1024^2 1.7 um HgCdTe (or Si)
- PICNIC 256^2 1.7 um HgCdTe
- Hawaii-1RGs flown on HST and WISE

Resources

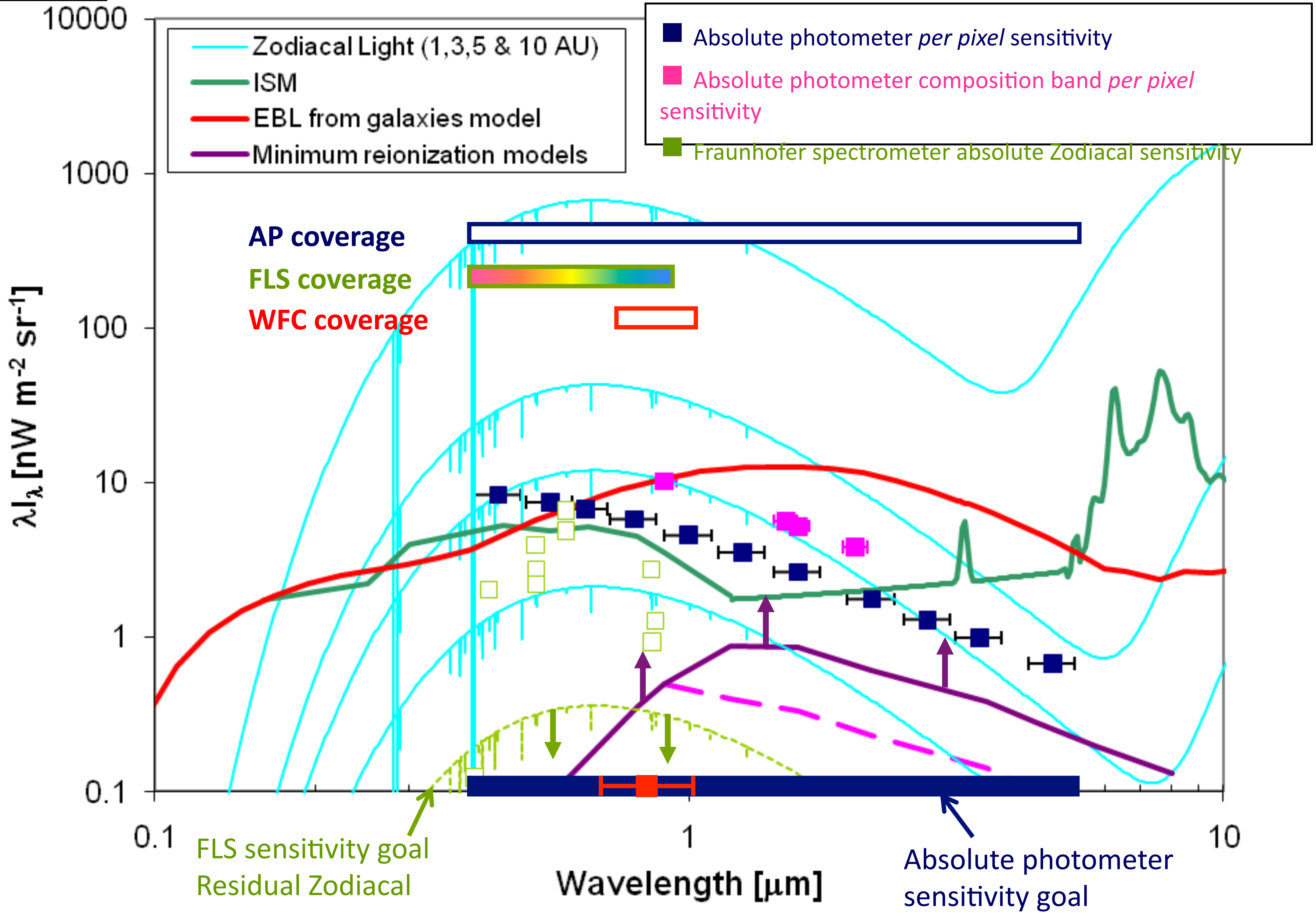
Observations

- Only during cruise-phase
- 2” pointing during ~500 s integrations
- Observations obtained at periodic and intermittent intervals during cruise

Instrument

M < 20 kg
P < 30 W
100 kbps (input rate during observations before compression)

Instrument Bands and Sensitivities at 5 AU



Key Questions to Address

Astrophysics

1. Can galaxy formation and evolution models be constrained with a precise measurement of the EBL spectrum?
2. What is the fractional EBL spectrum from sources and cosmologically important diffuse forms of radiation present during reionization?
3. Does the science case rely on the reionization search, or is galactic EBL sufficient?
4. With source counts from deep fields with JWST and other large aperture telescopes, can we resolve the EBL from all sources below a certain redshift?
5. Is it appropriate to deemphasize fluctuations, assuming this will be done from 1 AU?
6. What are the other astrophysical applications of a small instrument at 5AU (microlensing, transients)?

Planetary Science

1. What is the origin of interplanetary dust in the inner and outer solar system?
2. How does interplanetary dust interact with the outer planets?
3. What is the composition of inner and outer solar system material?
4. How does the solar system dust cloud relate to exoplanetary systems?
5. Can a zodi-mapping instrument stand on its own planetary science merits for a contribution to a planetary mission?

Instrument Design Drivers

1. What instrument parameters are needed to remove foregrounds? e.g. spatial resolution (aperture), Fraunhofer line spectrometer
2. What are the instrument parameters most useful for planetary science, e.g. how much spectral information for composition studies, spatial resolution, wide-field, thermal infrared imaging?
3. What cadence of observations during cruise is needed for understanding the dust cloud?
4. What is the potential of a planetary instrument making these measurements?

Speakers are to address relevant questions in their talks

Programmatic Questions to for Final Discussion

1. **What is the desired long term objective we are working towards?**

2. **How can we build support and interest in the astronomy and planetary communities to help achieve that objective?**

3. **Should we pursue a dedicated mission to achieve both the astronomy and planetary science goals? Or is the piggyback approach best?**

4. **Are there programmatic, scientific, or technical currents within the "new" NASA which we ought to catch on to?**

	Moderators
Astro	John Mather
Planetary	Bill Reach
Instrumentation	Jamie Bock
Programmatic	Chas Beichman

→ *Summarize responses to questions from sessions in 2-3 viewgraphs*

Final Discussion

Mike Hauser

Mike Werner