The View from 5 AU

Beckman Center, UC Irvine, 25-26 March 2010

Summary of Workshop

and

Future Plans

Jamie Bock, Asantha Cooray, Ranga Chary, and Bill Reach

Workshop Attendance

Focus: science potential of observations with a small optical/near-infrared telescope from outer solar system

IR Backgrounds and First Galaxies

Tom Able, Stanford
Rick Arendt, GSFC
Rebecca Bernstein, UCO/Lick
Jamie Bock, JPL
Ranga Chary, IPAC
Asantha Cooray, UC Irvine
Giovanni Fazio, CfA
Harry Furguson, STScI
Varoujan Gorjian, JPL
Mike Hauser, GSFC
Richard Henry, Johns Hopkins
Alexander Kutyrev, GSFC
Louis Levenson, Caltech
Charles Lillie, Northrup
John Mather, GSFC
Toshio Matsumoto, ISAS/JAXA
Shuji Matsuura, ISAS/JAXA
Jayant Murthy, Johns Hopkins
Joel Primack, UC Santa Cruz
Louis Stringari, Stanford
Kohji Tsumura, ISAS/JAXA
Mike Werner, JPL
Rogier Windhorst, ASU

Planet Finding and Disks

Chas Beichman, IPAC
Dan Coulter, JPL
Nick Cowan, U. Washington
Andy Gould, Ohio State
Jane Greaves, St. Andrews
Mark Wyatt, Cambridge

Planetary / Zodiacal

Pat Beauchamp, JPL
Mike Brown, Caltech
Stan Dermott, U. Florida
David Nesvorny, SWRI
Kevin Hand, JPL
Mihaly Horanyi, U Colorado
Krishan Khurana, UCLA
Casey Lisse, Johns Hopkins
Scott Messenger, JSC
Ruth Murray Clay, CfA
Bill Reach, IPAC

http://www.physics.uci.edu/5AU/

Summary of the Workshop

- Specific questions addressed in each session
  - What is the science case for interplanetary dust?
  - What is the science case for extragalactic backgrounds?
  - What is the science case for exoplanets?
  - What other science can you do with this?
  - How do we optimize the instrument design?
  - What are the synergies with coming mission opportunities?

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

- Diverse institutional representation: US universities, NASA/JPL, NASA/GSFC, international (Japan, UK)

- Presentations and discussion available on conference website http://www.physics.uci.edu/5AU/

- Written summary report in preparation

Science Themes

Astrophysics/Cosmology

- Extragalactic background light
- Signature of reionization from first stars in extragalactic background light

Astrophysics/Exoplanets

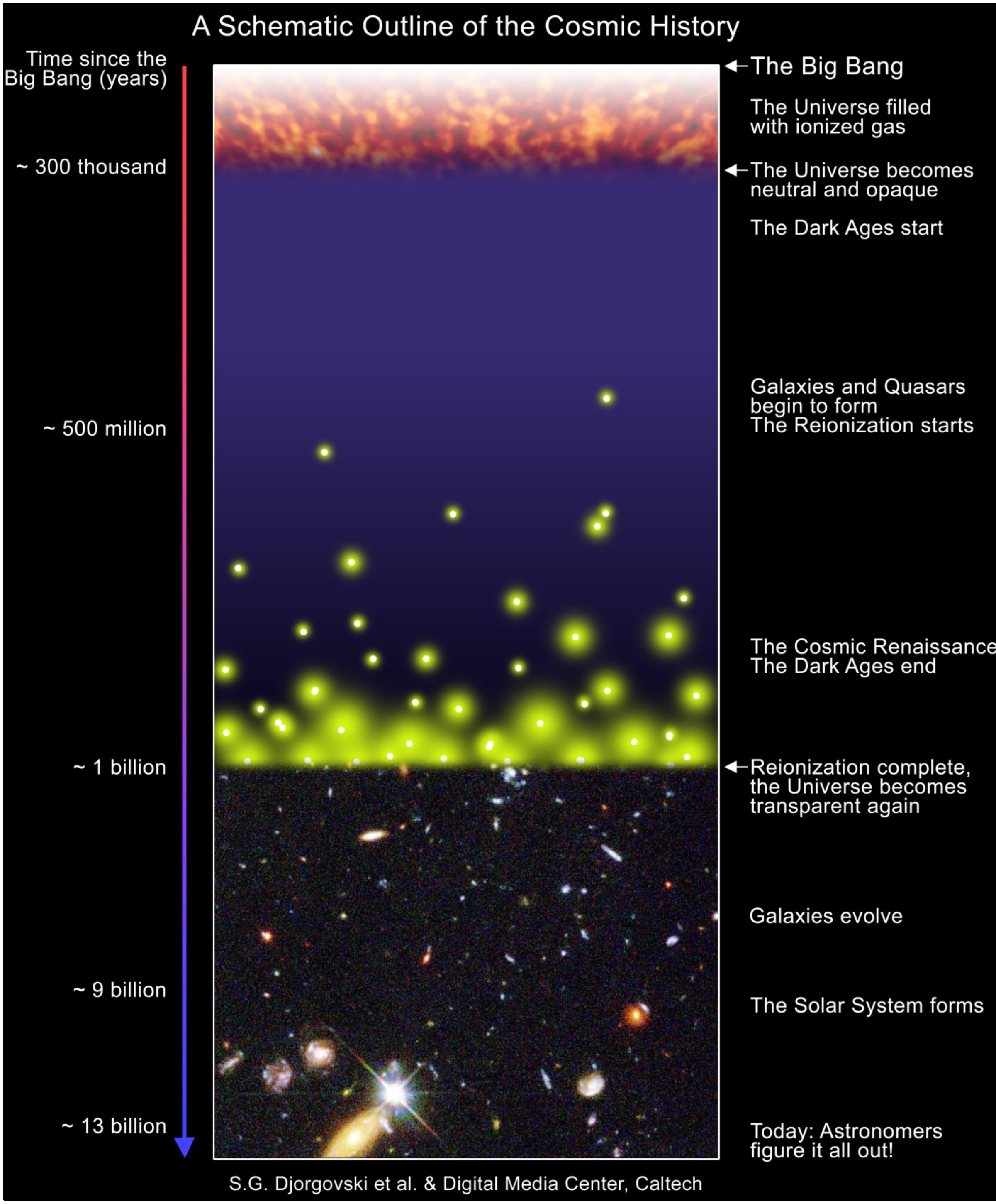
- Distribution of Kuiper-belt dust in our solar system
  - Formation history (e.g. ‘Nice model’ based on KBO orbits)
  - Comparison with exo-Zodiacal systems
  - ‘Site Survey’ for future exo-planet observations from outer solar system
- Microlensing measurements, parallax with Earth-based observatories
- Transit measurements

Planetary/Small Bodies

- Nature/distribution/origin of dust in Solar System
- Comet debris vs. asteroid debris f(R); Size and Composition of dust f(R)
- Influence of planets on distribution of dust (Jupiter resonances)
- Structures left from collisional families of asteroids and KBOs

Planetary/Large Bodies

- Imaging and spectroscopy for e.g. moons of Saturn and Jupiter
- Low surface-brightness rings, plumes



The Extragalactic Background Light

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

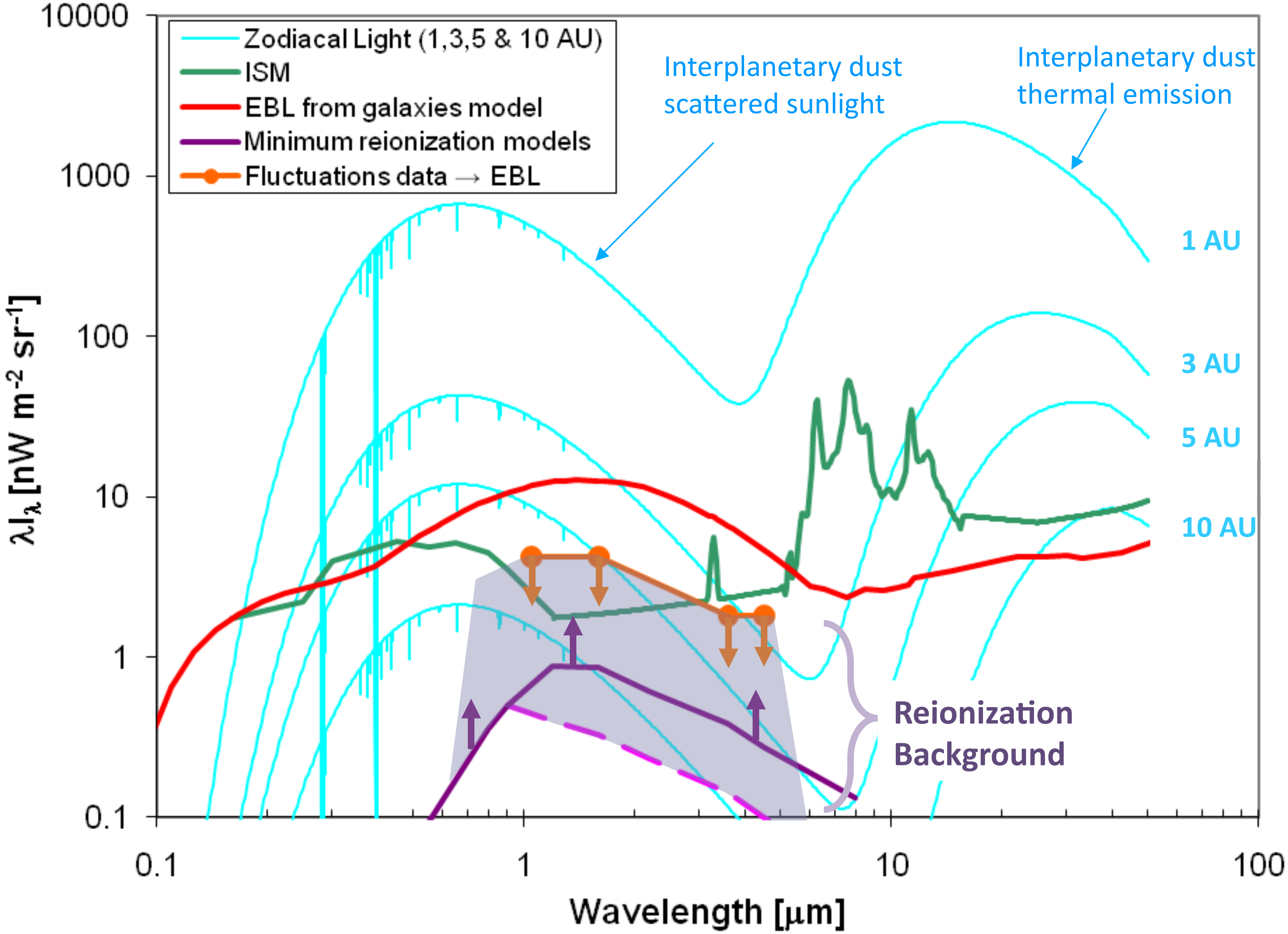
What do we learn from the EBL?

- 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

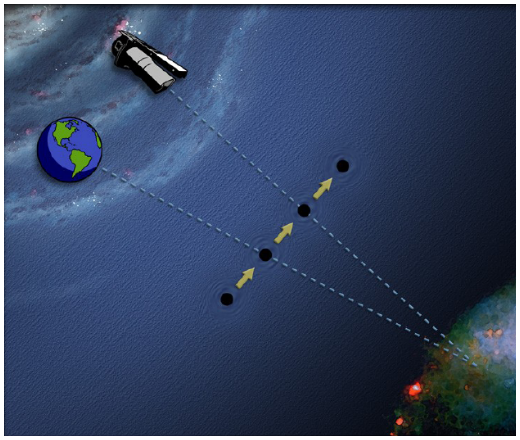
- Very little direct experimental data exists, so we are largely ignorant about this time!
- Inter-galactic medium becomes ‘reionized’ by UV radiation from first-generation stars and their remnants (e.g. black hole disks)
- First generation stars have primordial metalicity, predicted to be massive, luminous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

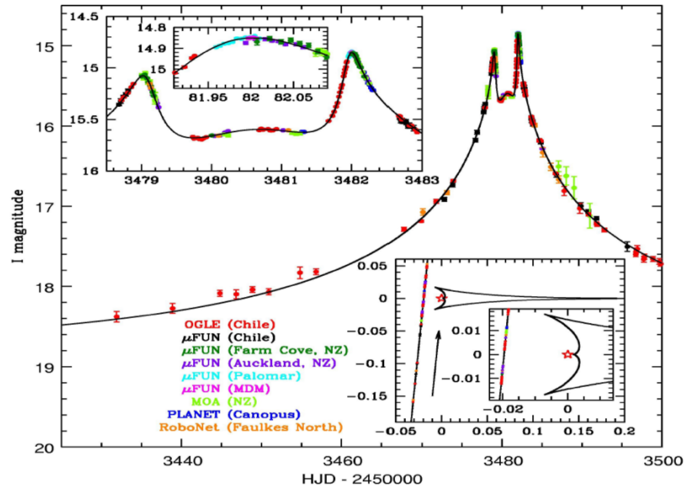
A Unique Opportunity at 5 (or 10) AU

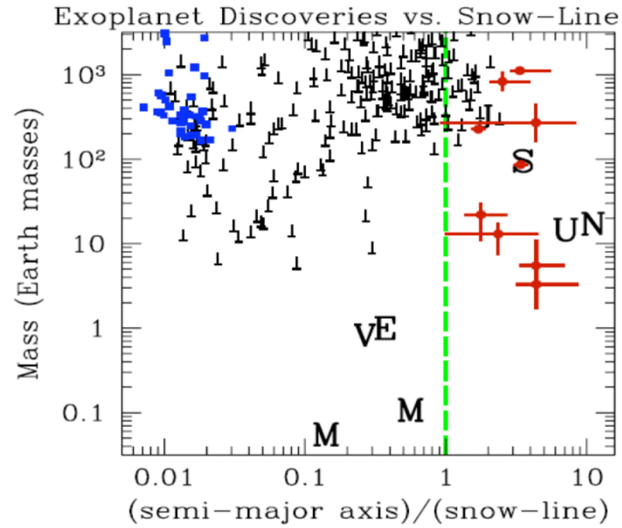


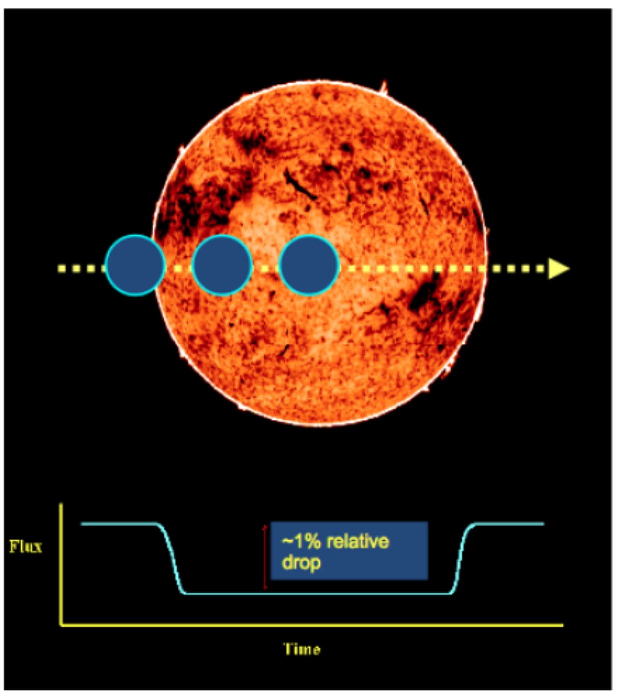
- Protogalaxies responsible for reionization thought to be fainter than JWST sensitivity level
- JWST may detect bright protogalaxies but not majority population

Microlensing and Planetary Transists







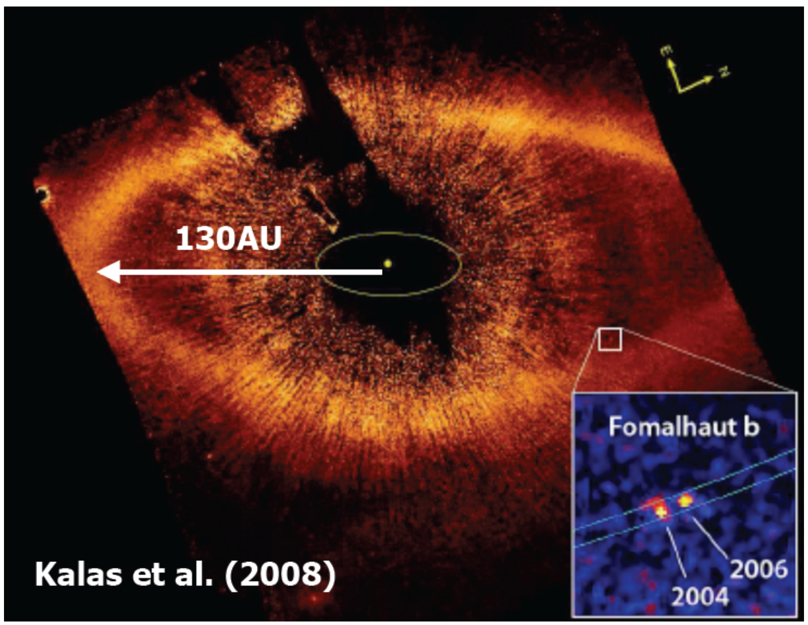


5AU parallax observations necessary to break degeneracies of bulge microlens events involving extra-solar planets. Expected to contain most planets (Gould)

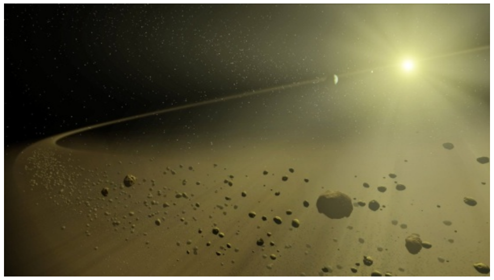
What role for extra-solar planetary transits from an instrument at 5AU? (Bright stars skipped by Kepler)

Understanding Kuiper-Belt Dust

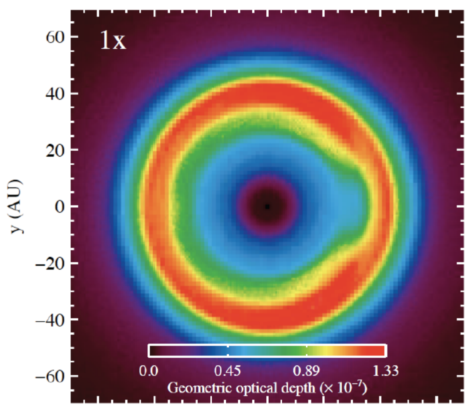
- Dust at Kuiper Belt distance is common around nearby stars; a radial profile of the Solar System provides a template for modeling exo-zodiacal light
- Test the Nice model for Solar system and analogue effects in extra-solar disks. In the Solar system scattering within an initial large debris disk by Neptune and Uranus and capture of resonant KBOs and the evolution of the dust population with Neptune migration explain the current known dynamical properties and missing mass problem (Levison et al.2008)
- Constrain how well we can use KBOs as collisional test particles (a break in the size distribution may lead to different resonant populations of large and small bodies).
- Assess the Kuiper-belt foreground for future exo-planet observations from Jupiter's orbit.



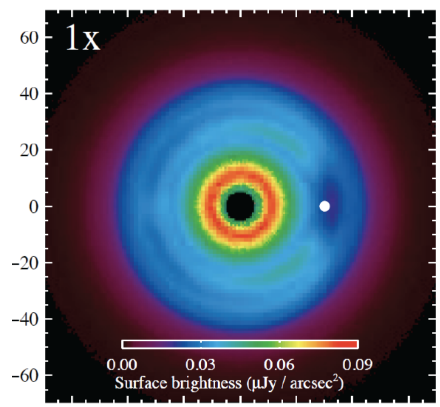
Fomalhaut: debris disk interaction has been used to constrain the mass of a wide separation planet



Kuchner 2010



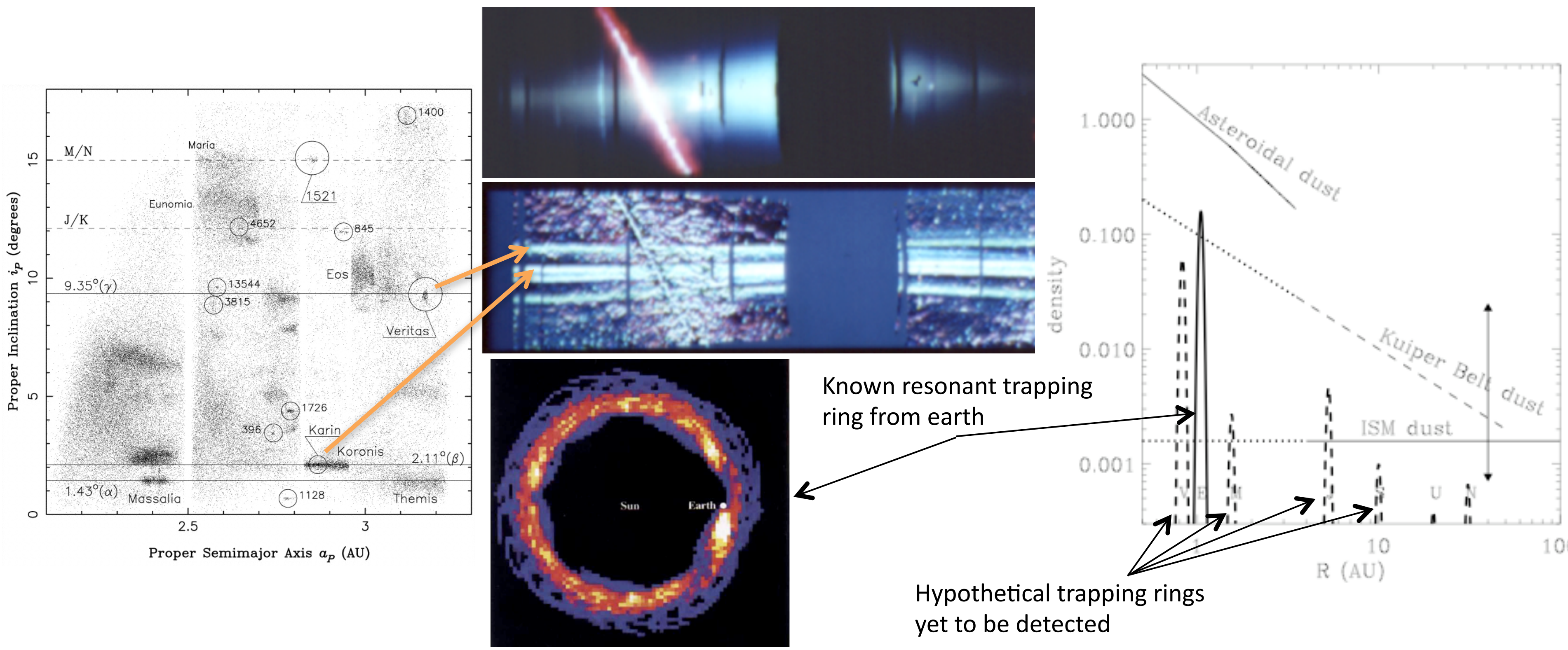
Azimuthal distribution of dust



Optical emission

The Outer Solar System Zodiacal Light

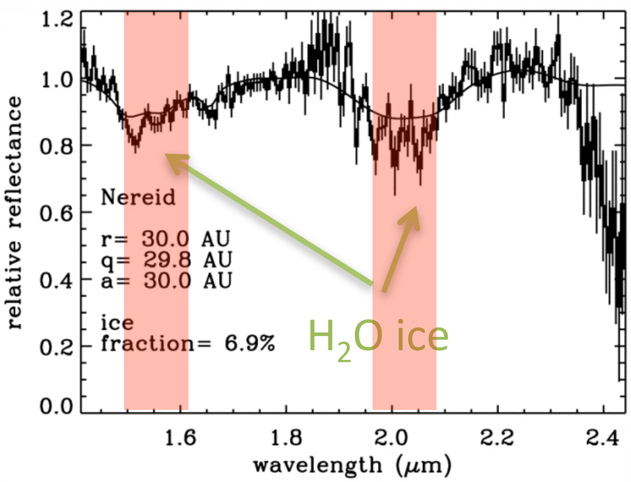
- Collisions among Kuiper Belt objects generates a dust cloud analogous to the one generated by asteroids and Jupiter family comets. Such a cloud has not yet been seen due to the bright foreground from the inner solar system.
- The amount of KB dust and its distribution reveal the amount and location of collisions (e.g., Brown et al. 2007, Nature 446, 294)
- Constrain theories of Kuiper Belt formation by looking at variations in dust properties with inclination
- 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



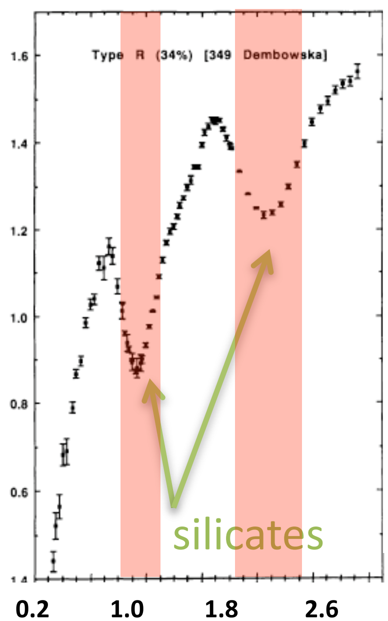
Composition of Interplanetary Dust

- 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

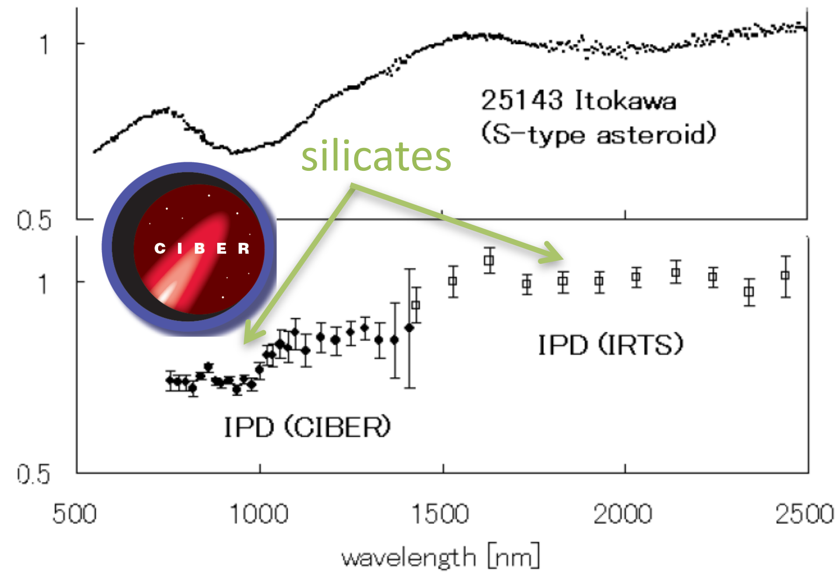
KBO (Brown et al. 1998)



Asteroids (Gaffey et al. 1996)



New Detection of Pyroxene in ZL



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

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

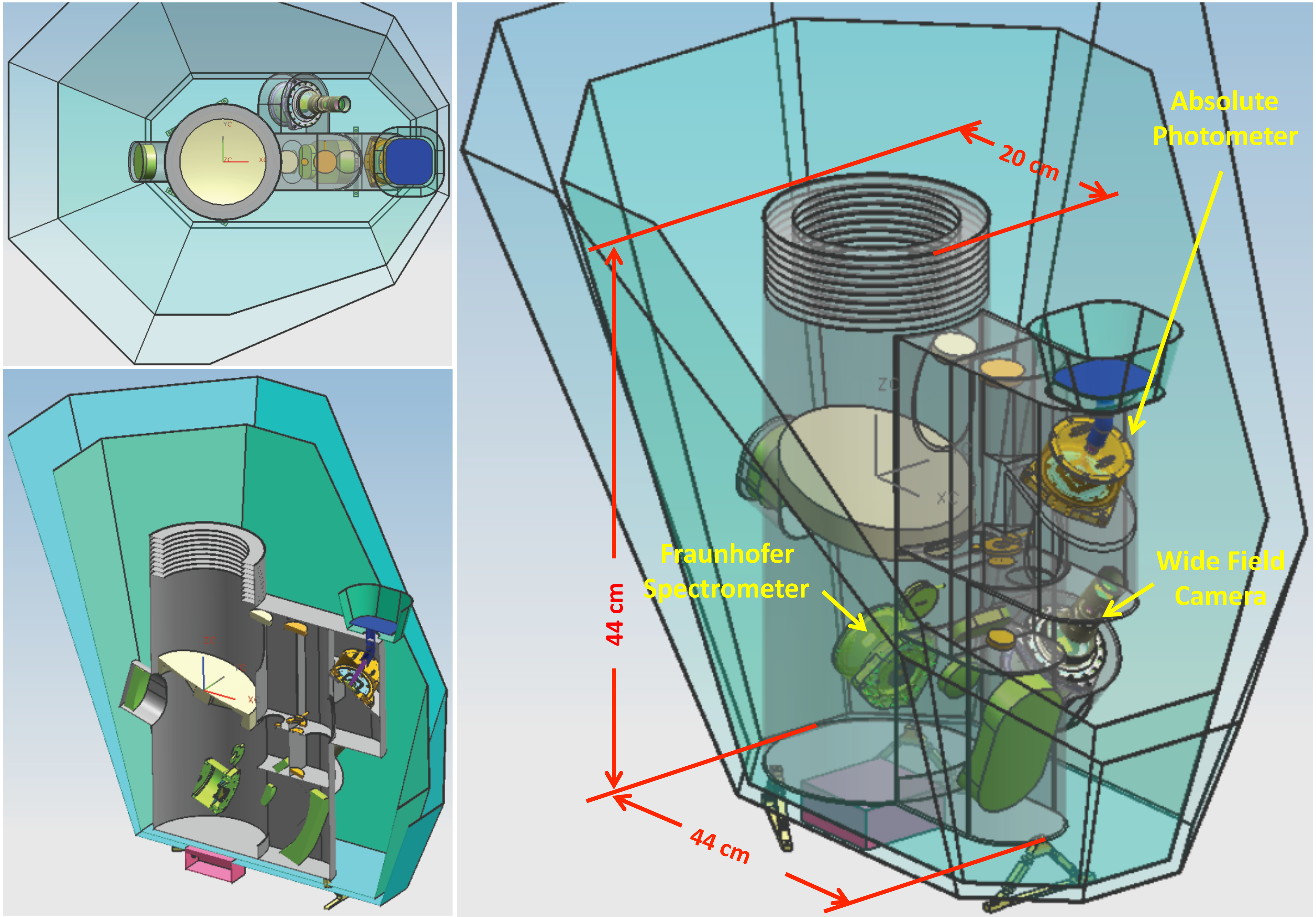
3 Arrays
- Hawaii-1RG 1024^2 5.5 um HgCdTe
- Hawaii-1RG 1024^2 1.7 um HgCdTe (or Si)
- PICNIC 256^2 1.7 um HgCdTe
- Hawaii-1RGs flown on HST and WISE

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)

ZEBRA: Zodiacal dust, Extragalactic Background, & Reionization Apparatus



ZEBRA: Zodiacal dust, Extragalactic Background, & Reionization Apparatus