Placing Our Solar System in Context with the Spitzer Space Telescope

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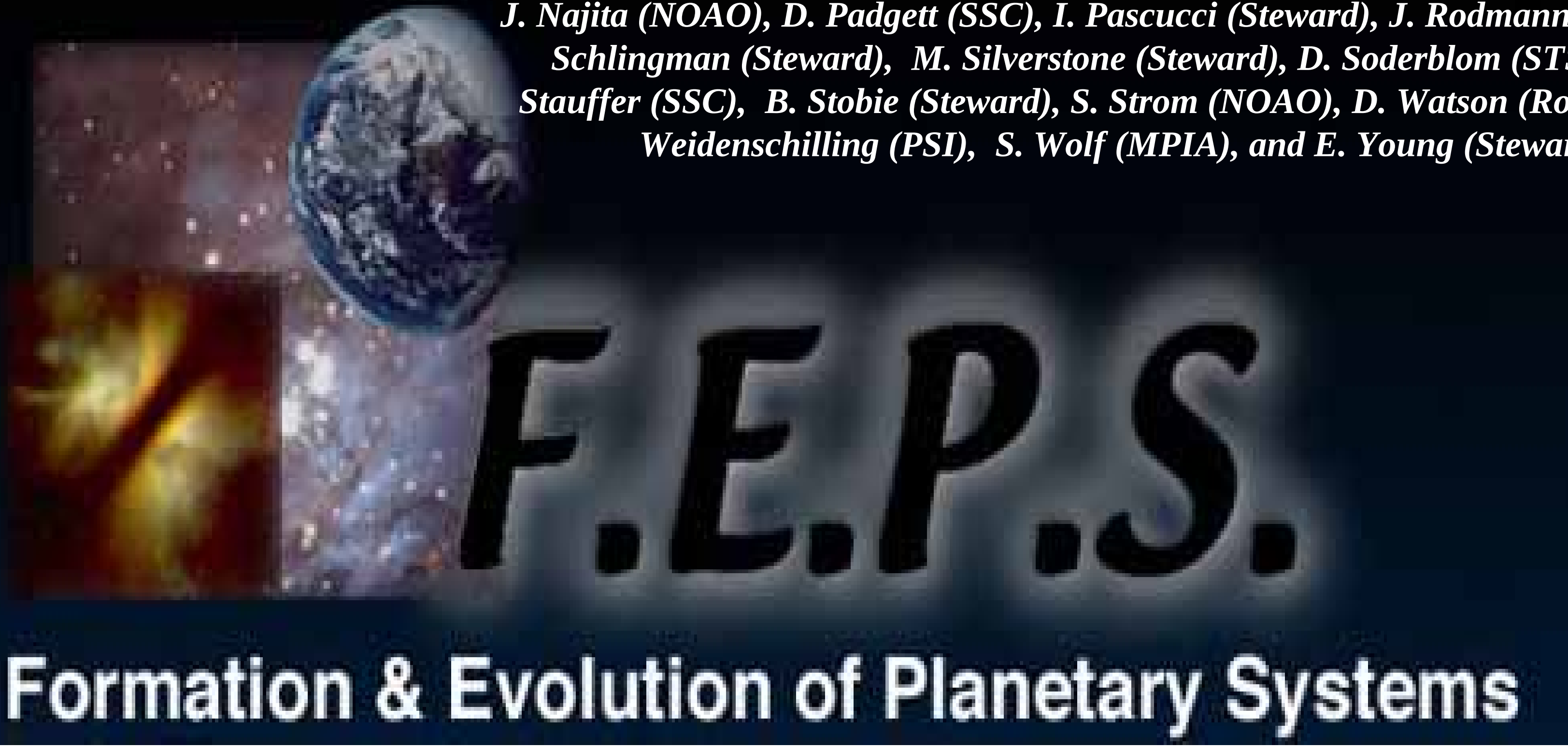
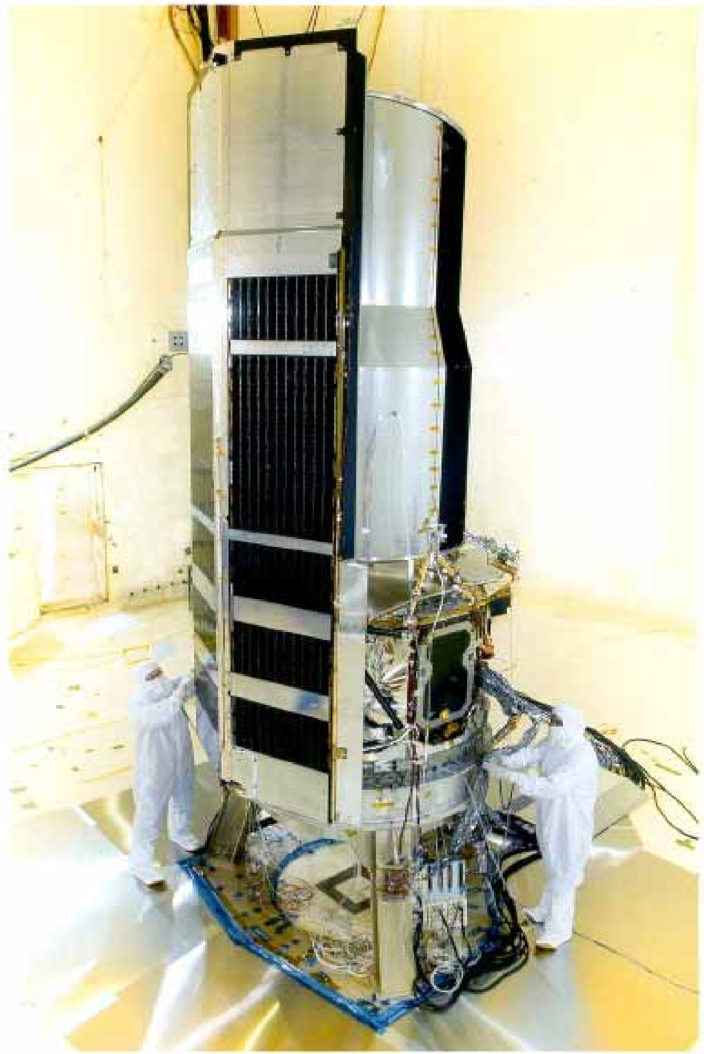


The Spitzer Space Telescope

- Instrumental capabilities
  - Imaging, 3.6-160 μm
  - Spectroscopy, 5.3-40 μm
  - SED, 50-100 μm
- Image size 1.5'' at 6.5 μm
- Pointing stability <0.1''
- Pointing accuracy <1.0''
- Field of view ~5'x5' (imaging)



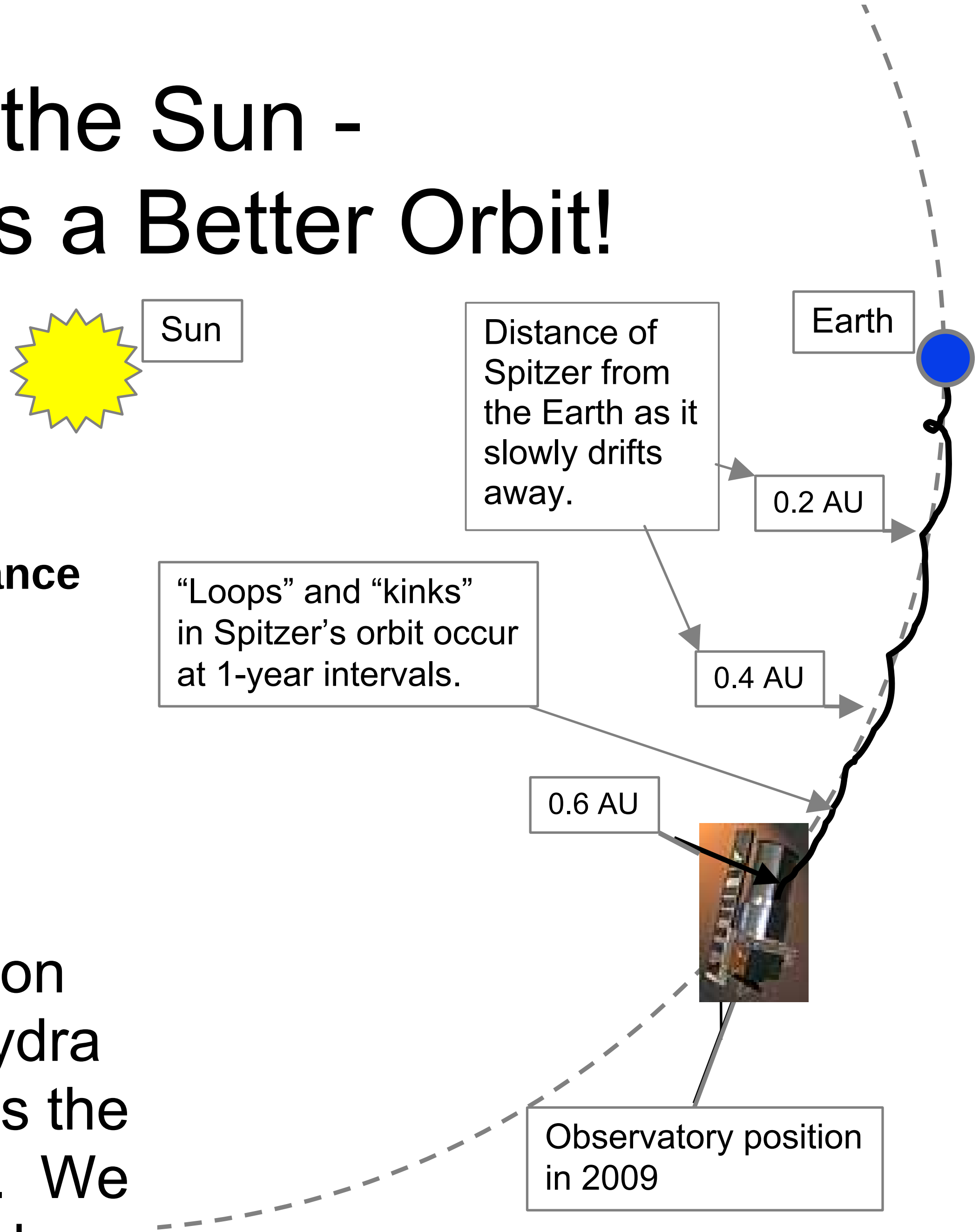
And away we go!

Early morning EDT, 25 August 2003

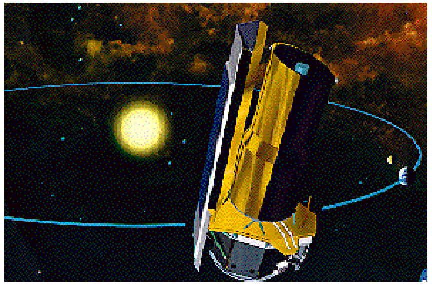
Spitzer Orbits the Sun - A Solar Orbit is a Better Orbit!

Why a Better Choice?

- **Better Thermal Environment (allows passive cooling)**
- **No Need for Earth-Moon Avoidance (Maximizes observing time)**
- **No Earth Radiation Belt (no damage to detectors or electronics)**



Spitzer is now >5 million miles away, towards Hydra (just south of Leo). It lags the Earth by about 7.5 days. We use ~1 ounce of L(He)/day.



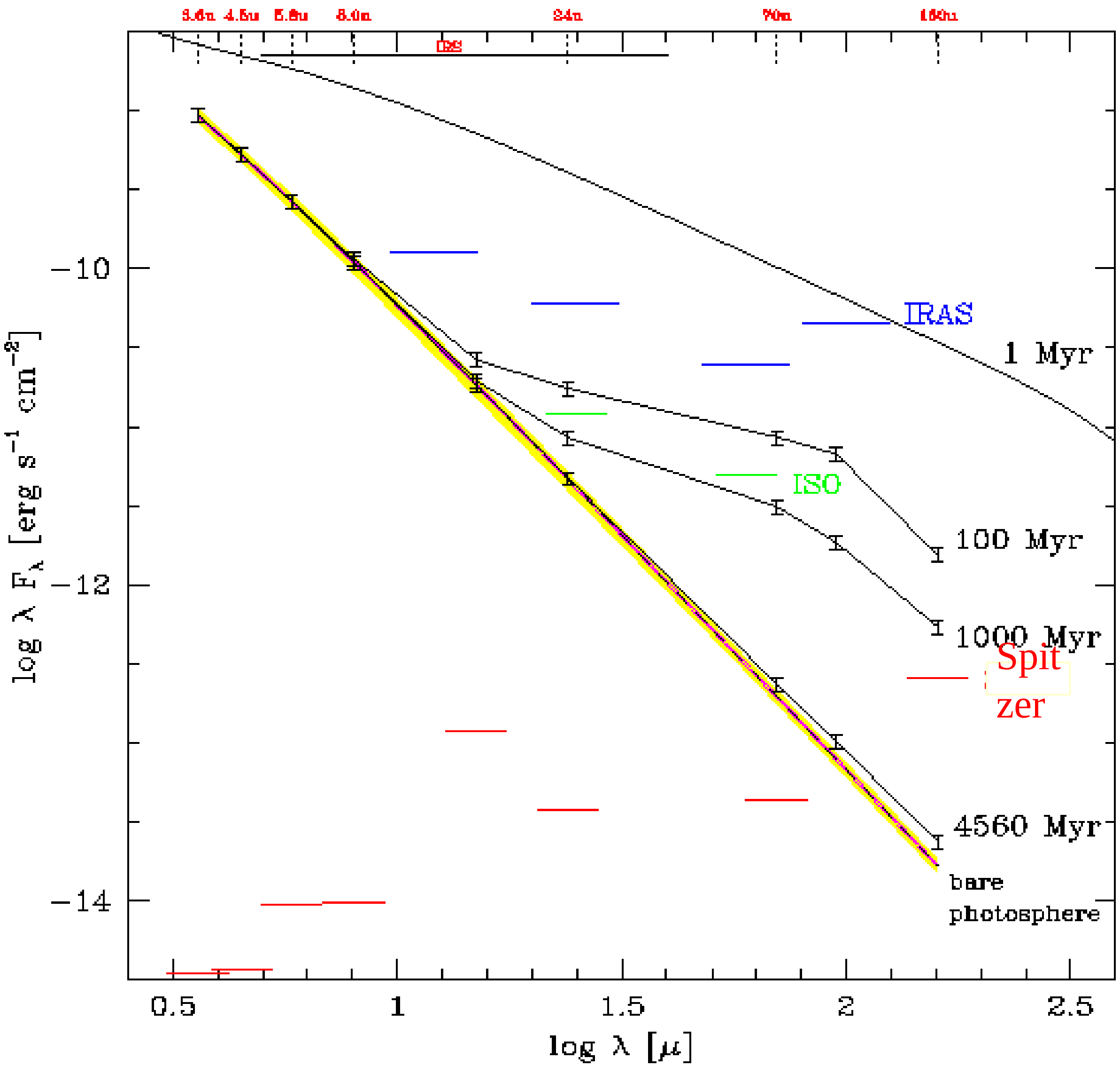
Spitzer Legacy Science: The Formation and Evolution of Planetary Systems

- Formation of Planetary Embryos:
  - » Characterize transition from primordial to debris disks.
- Growth of Gas Giant Planets:
  - » Constrain timescale of gas disk dissipation.
- Mature Solar System Evolution:
  - » examine the diversity of planetary systems.

Our program builds on the heritage of IRAS and ISO.

Characterizing Planetary Systems: Our Dust Disk in Time

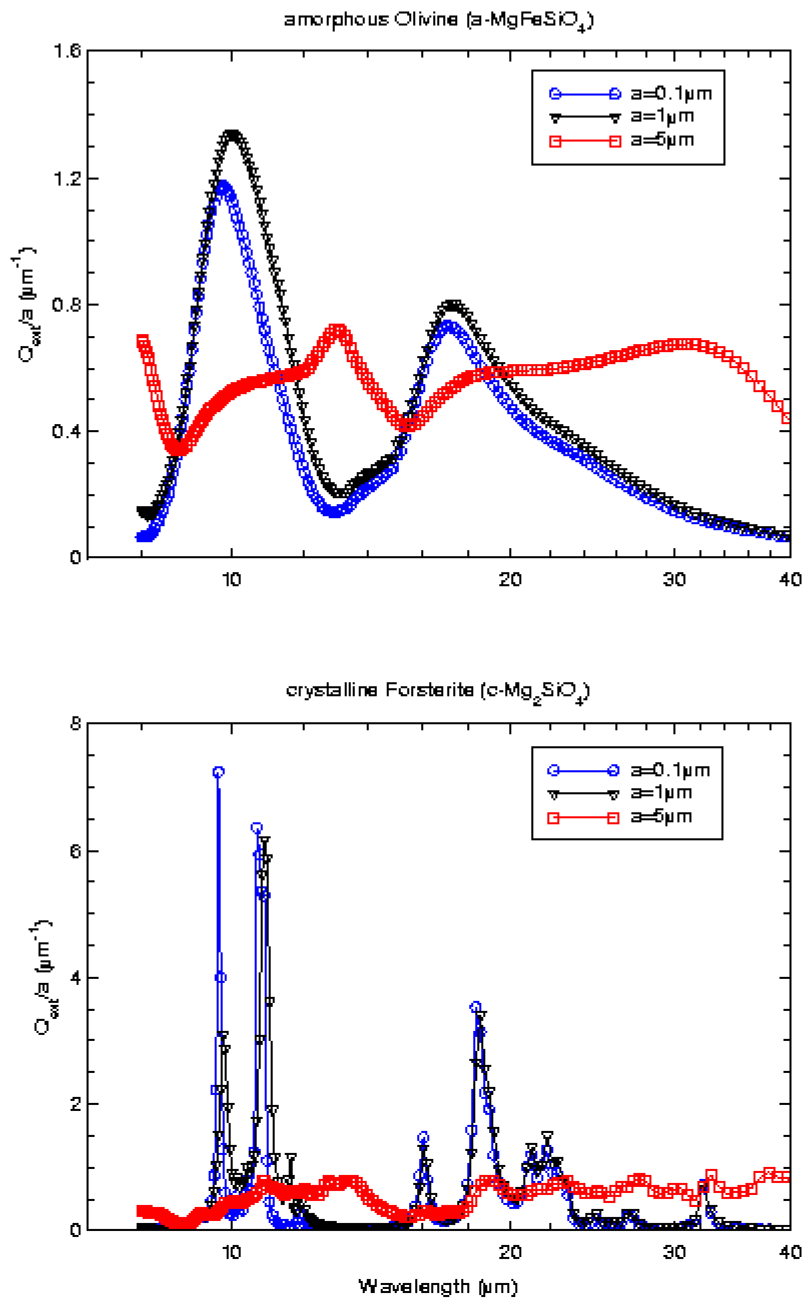
N/M/F-IR



Sample of 336 stars:

- 0.8-1.2 Msun
- 3 Myr to 3 Gyr
- 15 < d < 150 pc

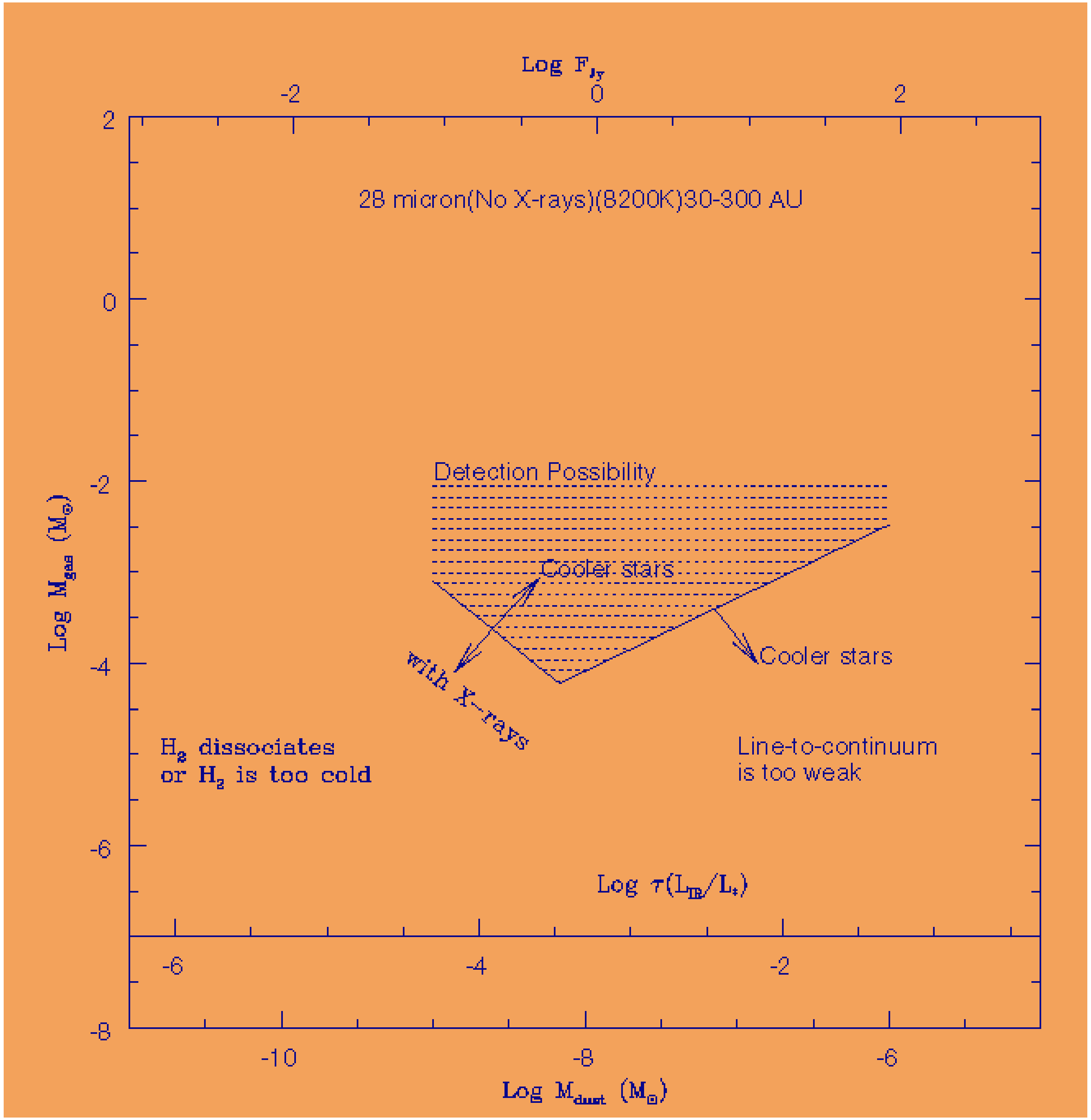
Dust Opacity: Effects of Size and Composition shown at R=100 (Henning et al. 2000)



MIR

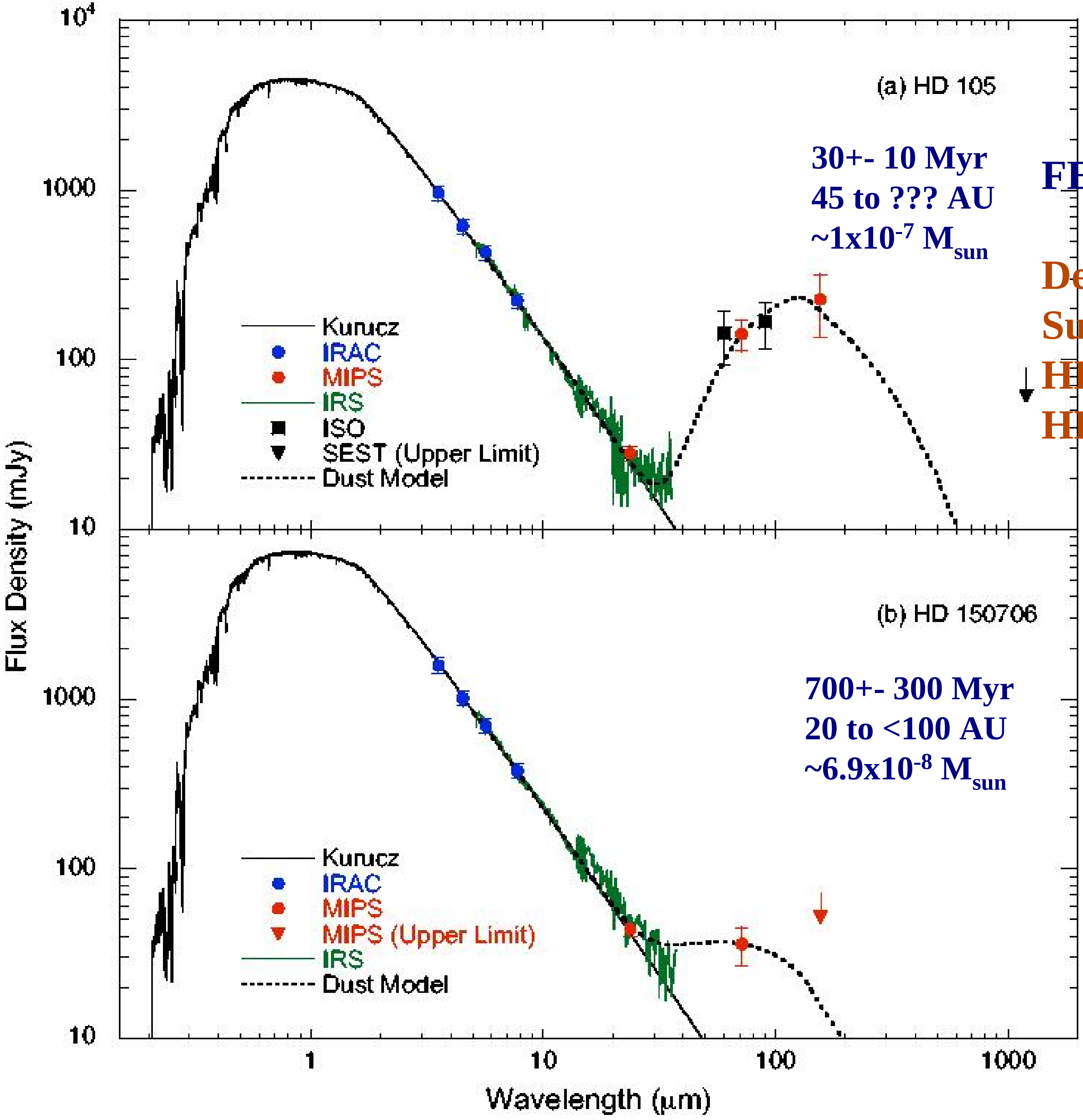
GAS

Detecting Gas in Disks



Placing limits on lifetimes of gas disks that form giant planets.

Gorti & Hollenbach ApJ (2004)



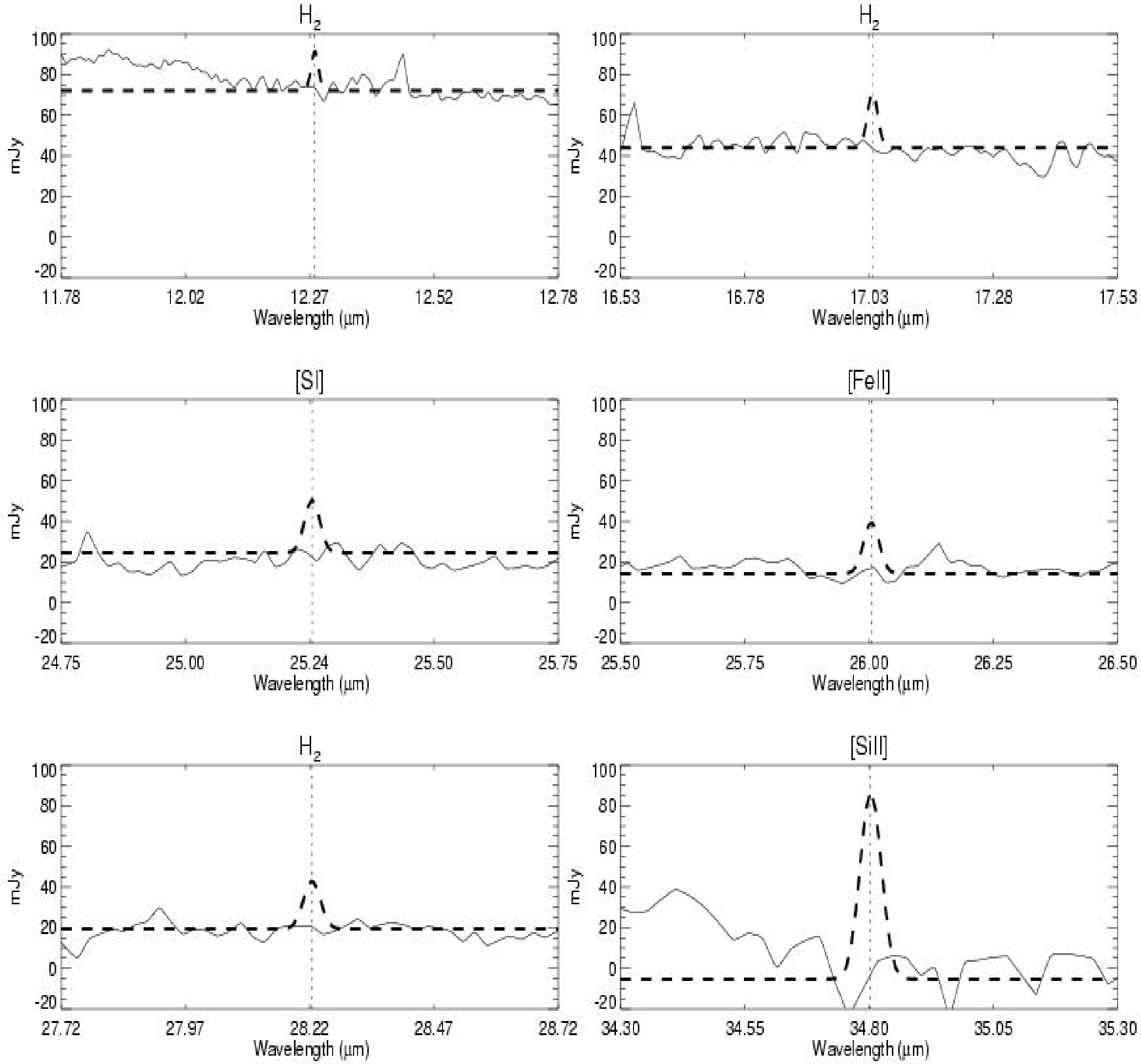
FIR

FEPS First Results!

Debris Disks Surrounding HD 105 and HD 150706

Meyer et al. (2004) ApJS Special Issue.

GAS

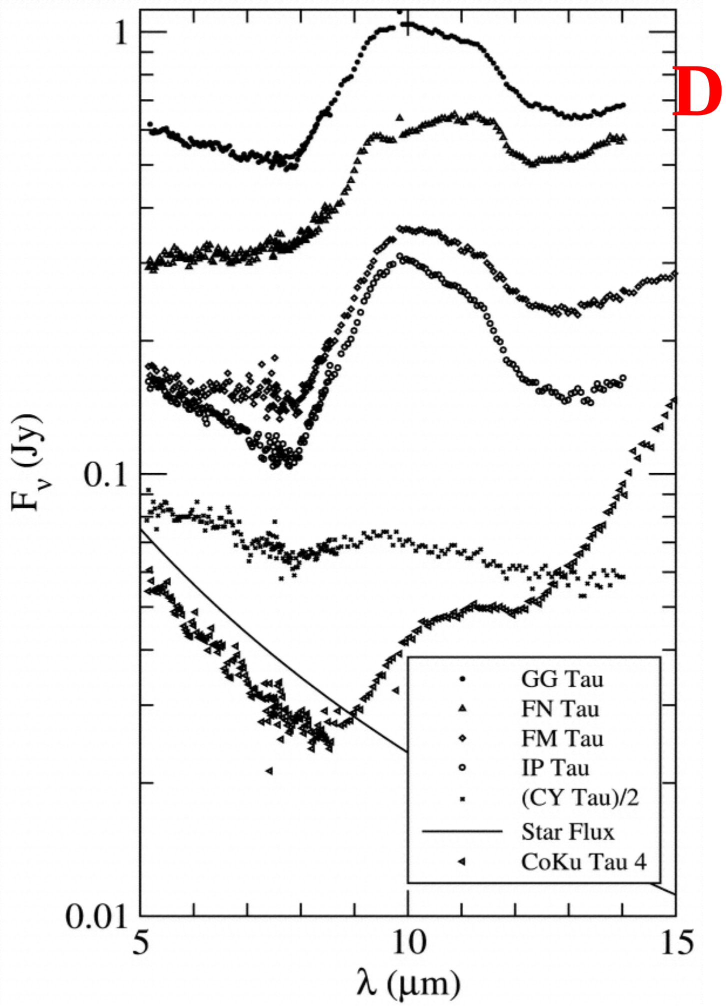


Limits on Gas Mass in 30 Myr Old Disks

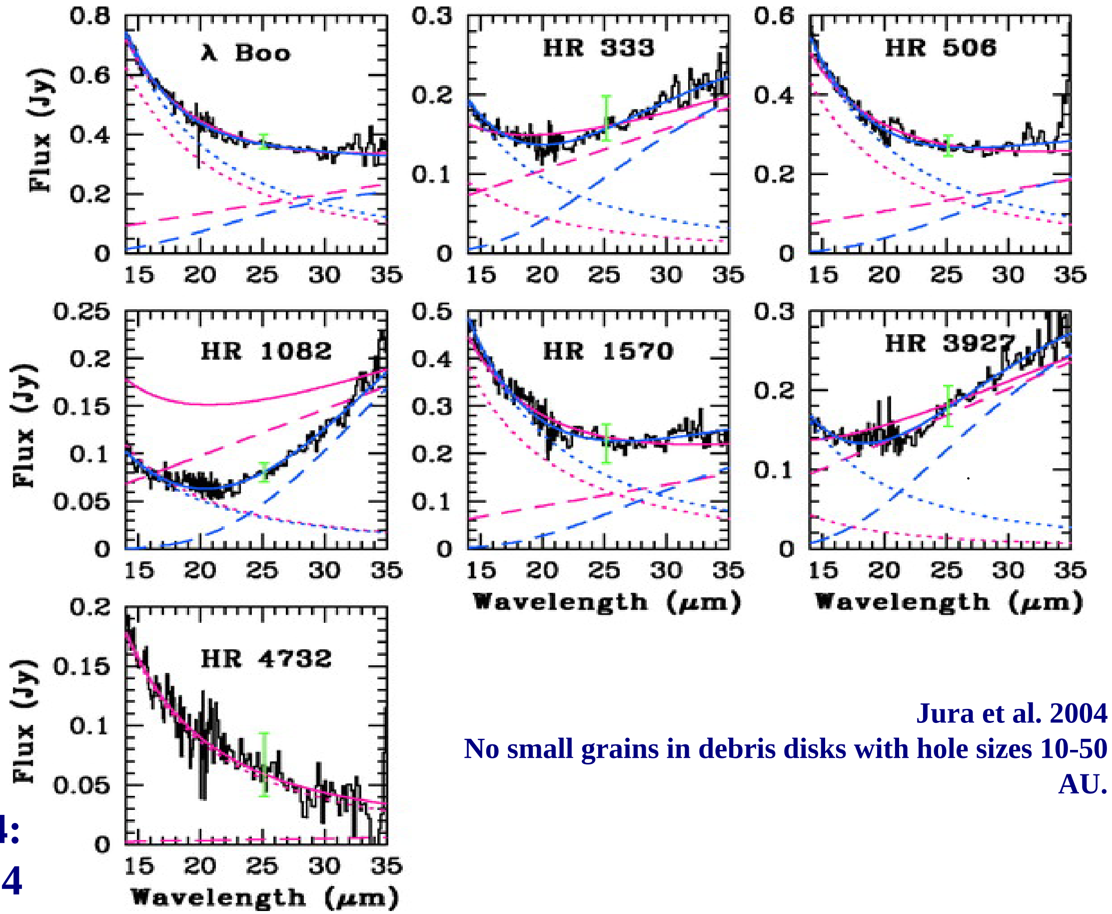
No lines detected for HD 105 Mass in H_2 $< \sim 0.1\ M_{jup.}$

Hollenbach et al. (ApJ, in press)

Do holes in disks indicate planets?



Forrest et al. 2004:
Inner hole in disk of CoKu Tau 4



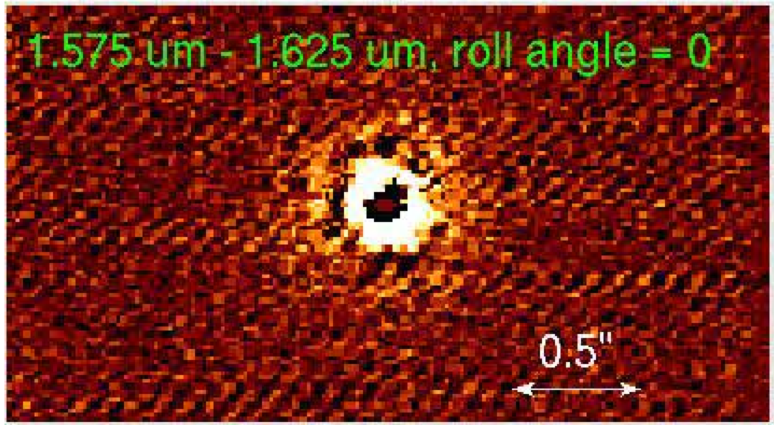
Jura et al. 2004
No small grains in debris disks with hole sizes 10-50 AU.

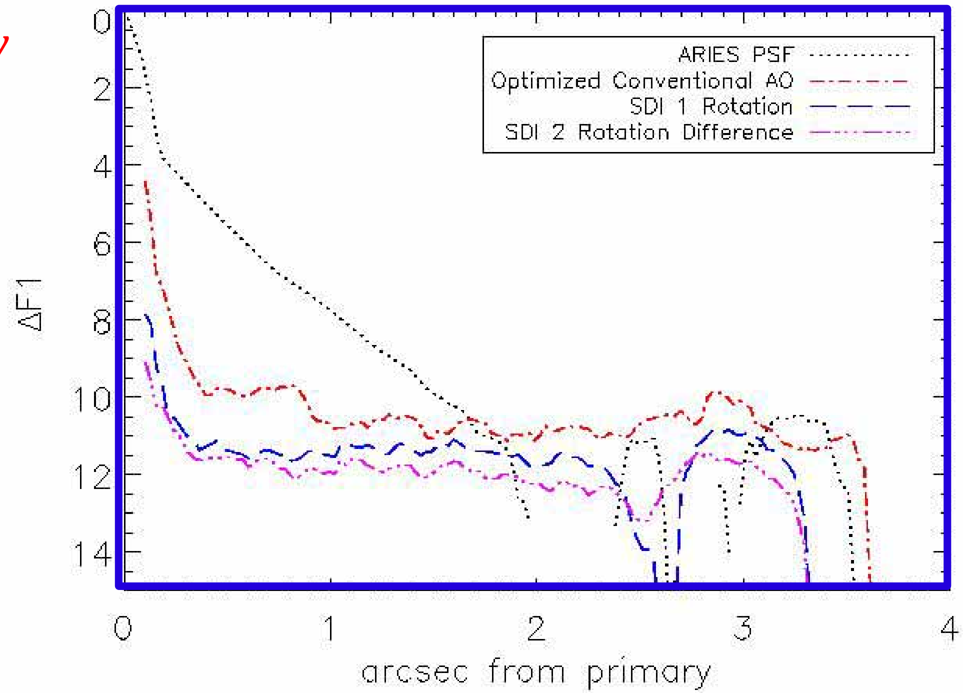
Spitzer Points the Way: High Contrast Imaging MMT-AO SDI Observations of HD 134319

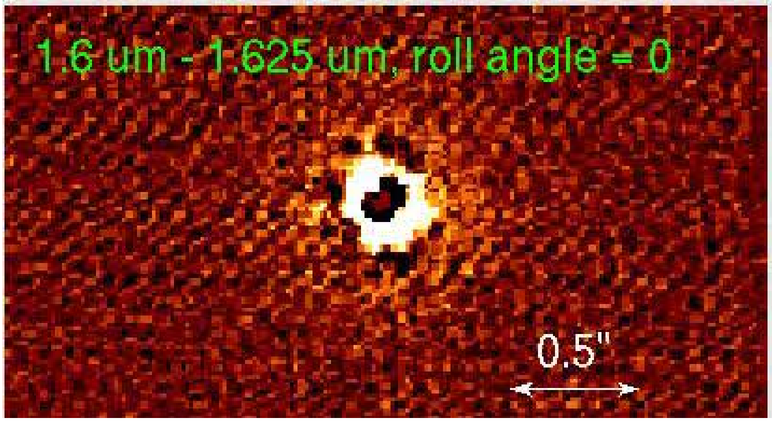
EGP

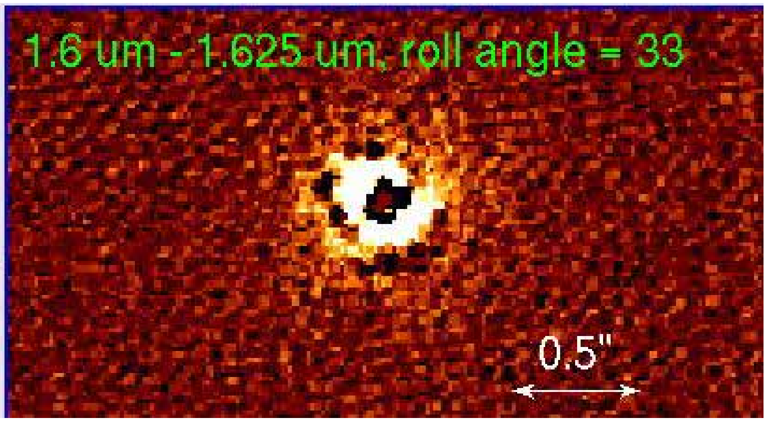
Either a large (> 1 Mjup) planetary body is responsible for the inner hole or we need to find another explanation!

Apai et al. (in preparation).



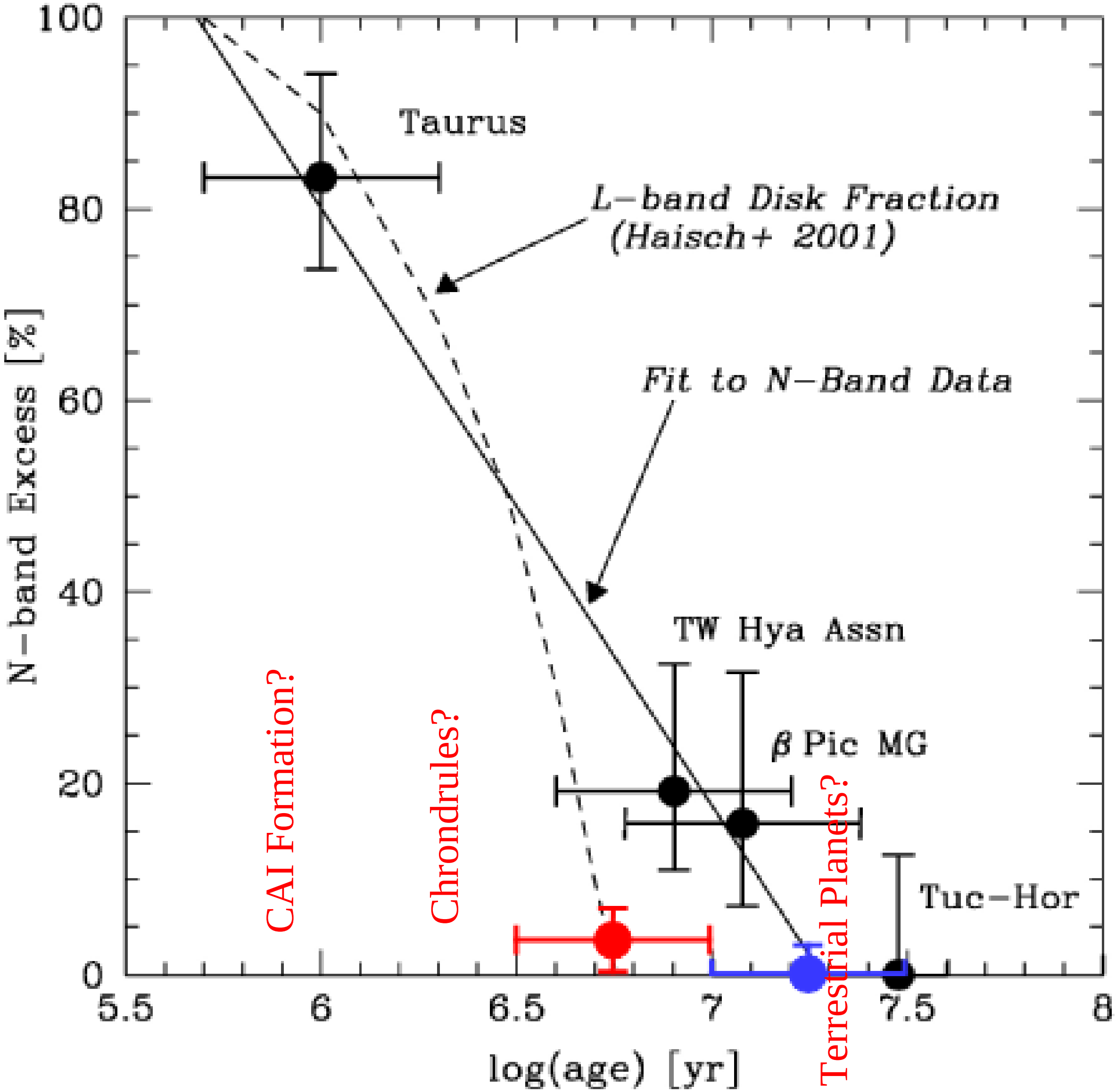






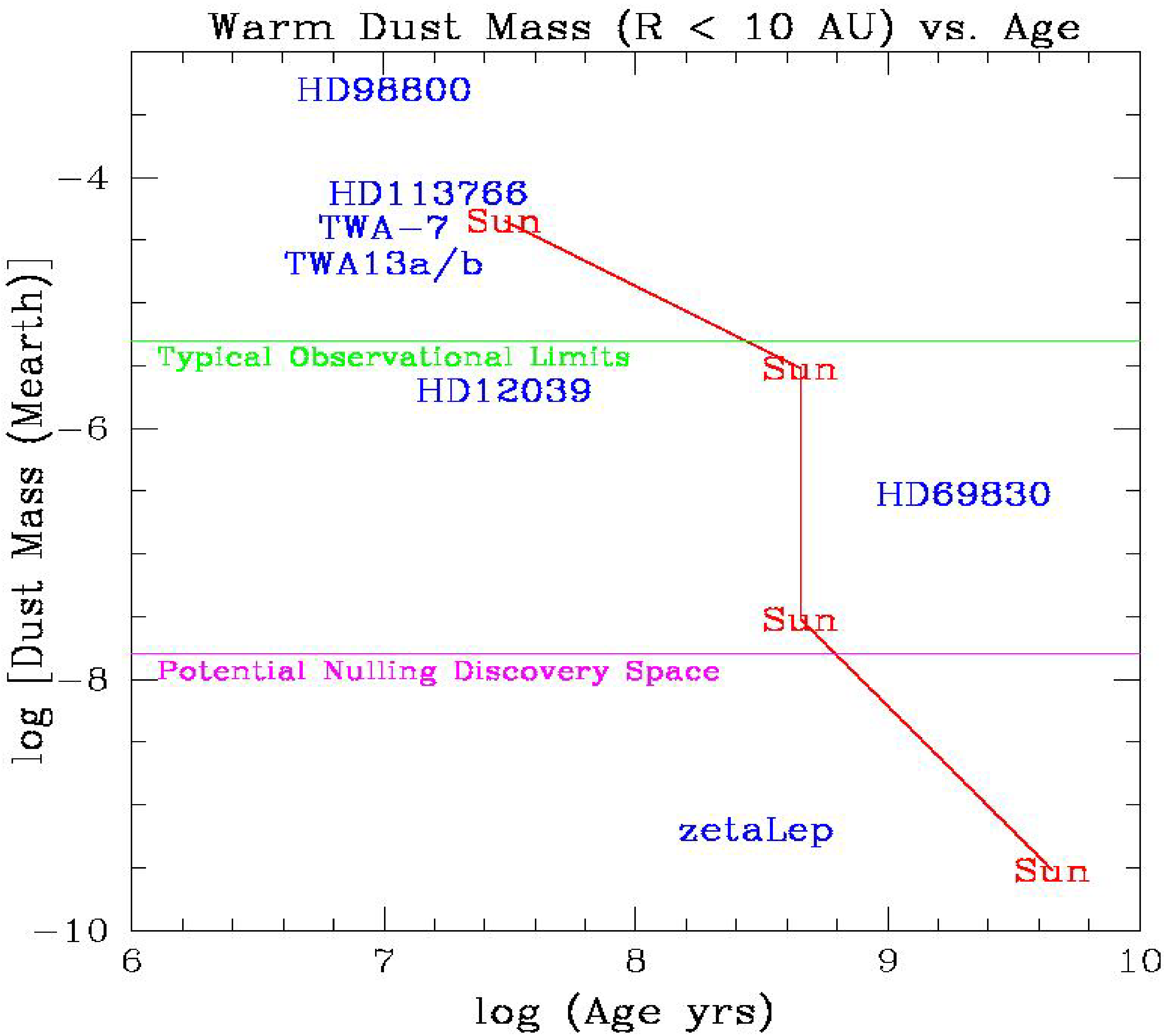
See also Biller et al. (2004); Masciardi et al. (2005); Close et al. (2004); Lenzen et al. (2004).

MIR Excess Fraction (0.3-1.0 AU) vs. Cluster Age



Silverstone et al.
(ApJ, Submitted)

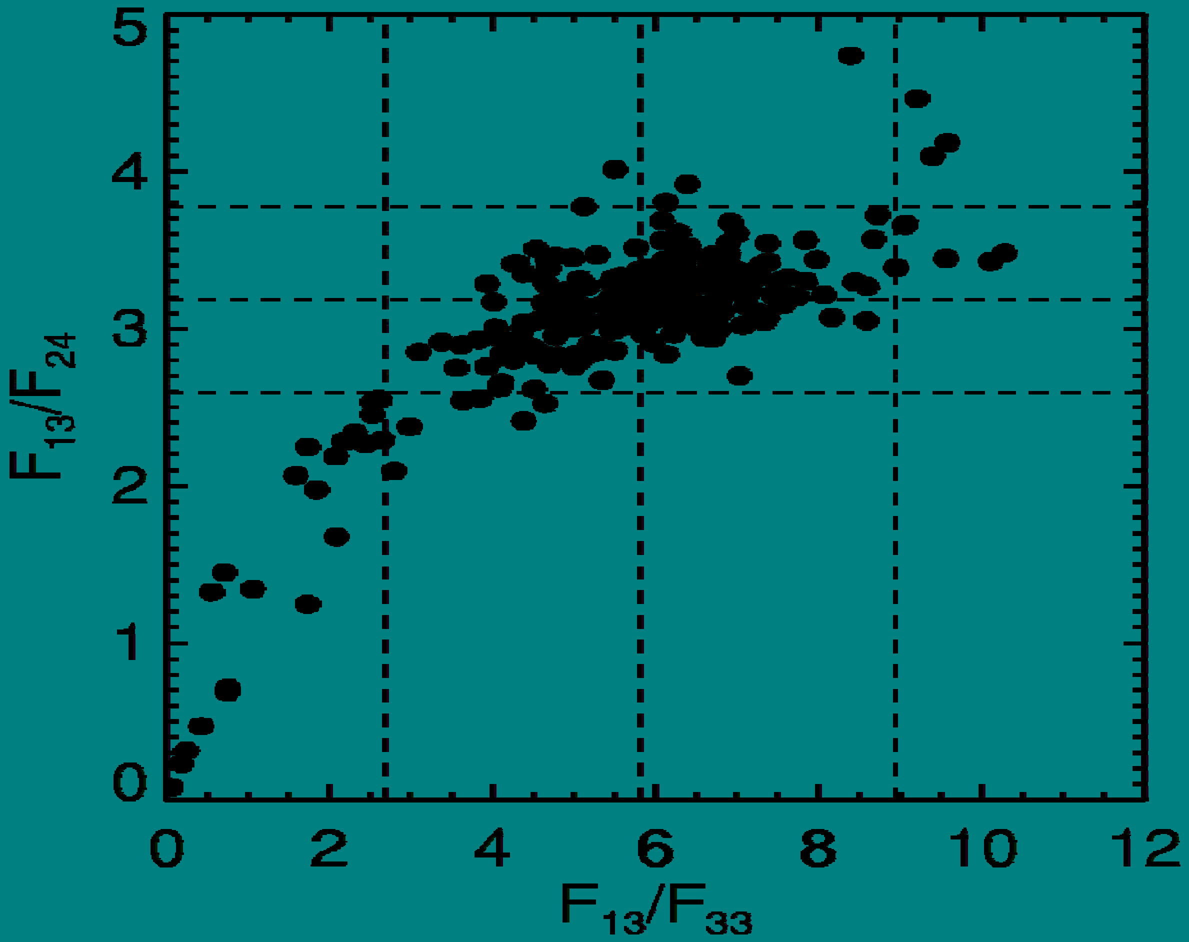
3-10 Myr old IRAC.
10-30 Myr old IRAC.


Warm Dust Mass (R < 10 AU) vs. Age
HD98800
HD113766
TWA−7
TWA13a/b
Sun
Typical Observational Limits
HD12039
Sun
HD69830
Sun
Potential Nulling Discovery Space
zetaLep
Sun
−4
−6
−8
−10
6
7
8
9
10
log [Dust Mass (Mearth)]
log (Age yrs)

MIR

Searching for **Warm Debris** Disks

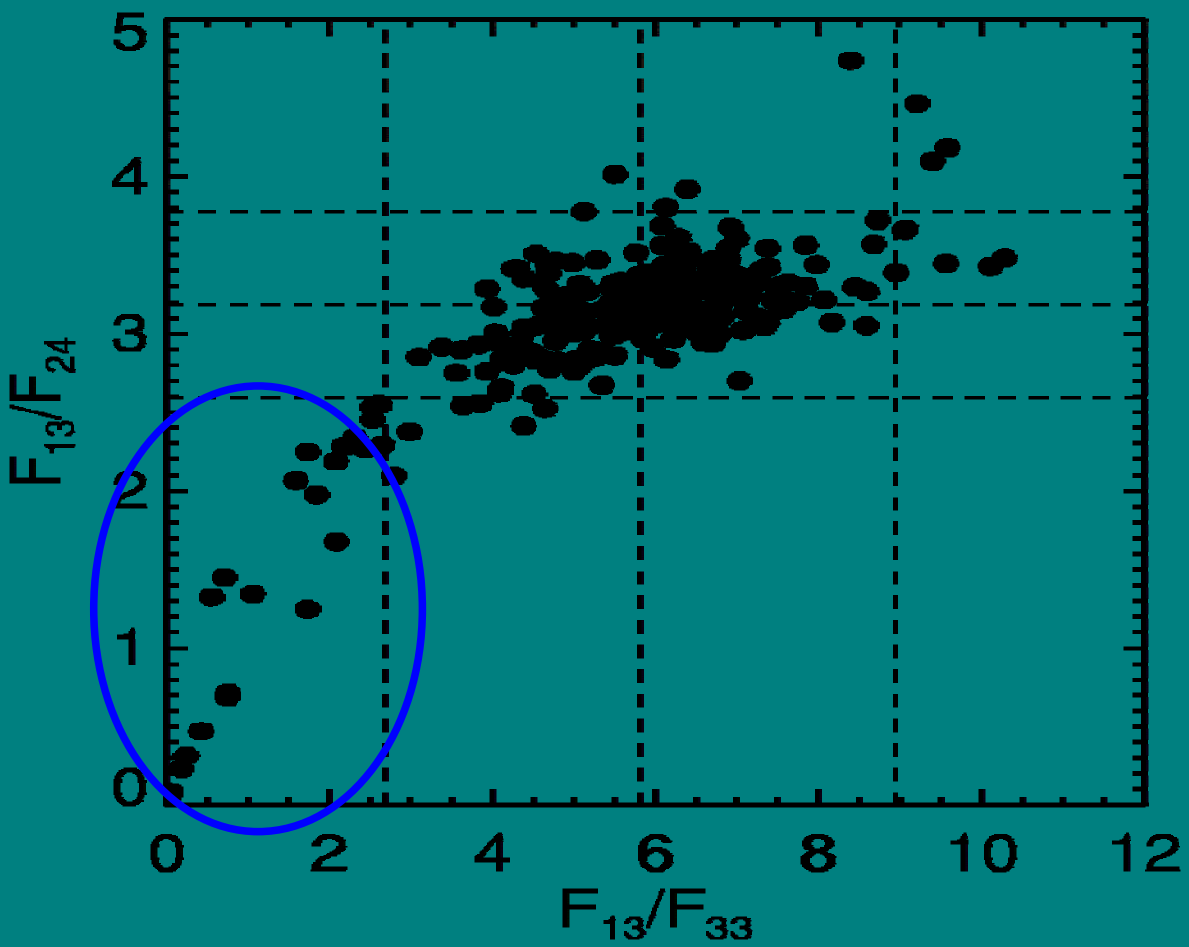
MIR



Bouwman et al. (in preparation); see also Chen et al. (2005).

Searching for **Warm Debris** Disks

MIR

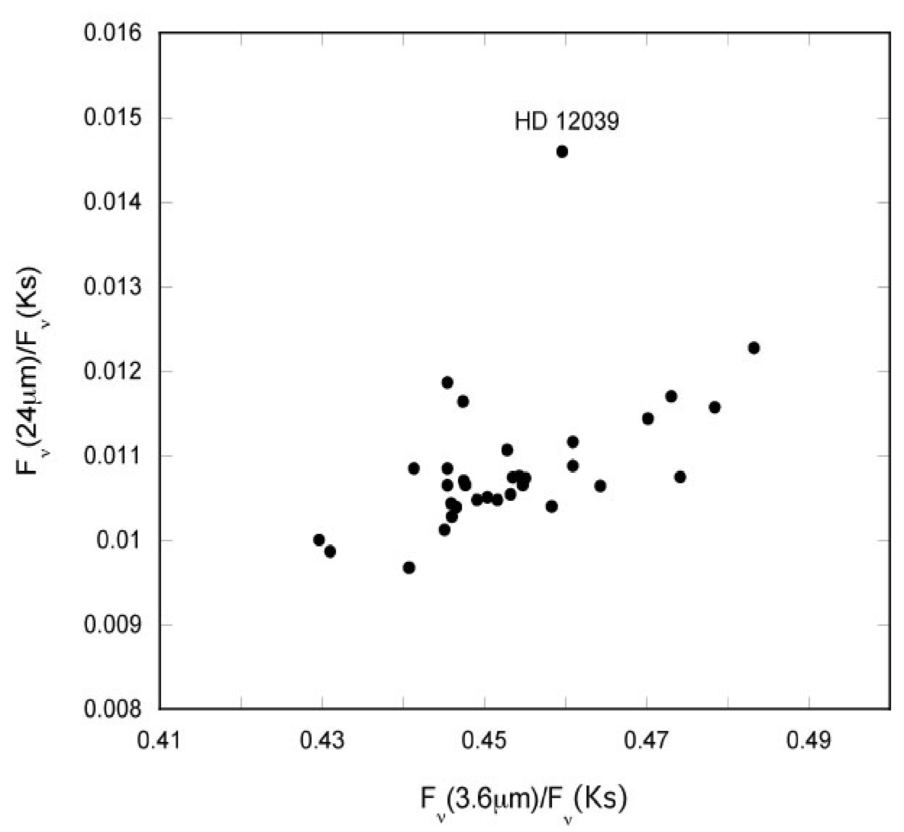


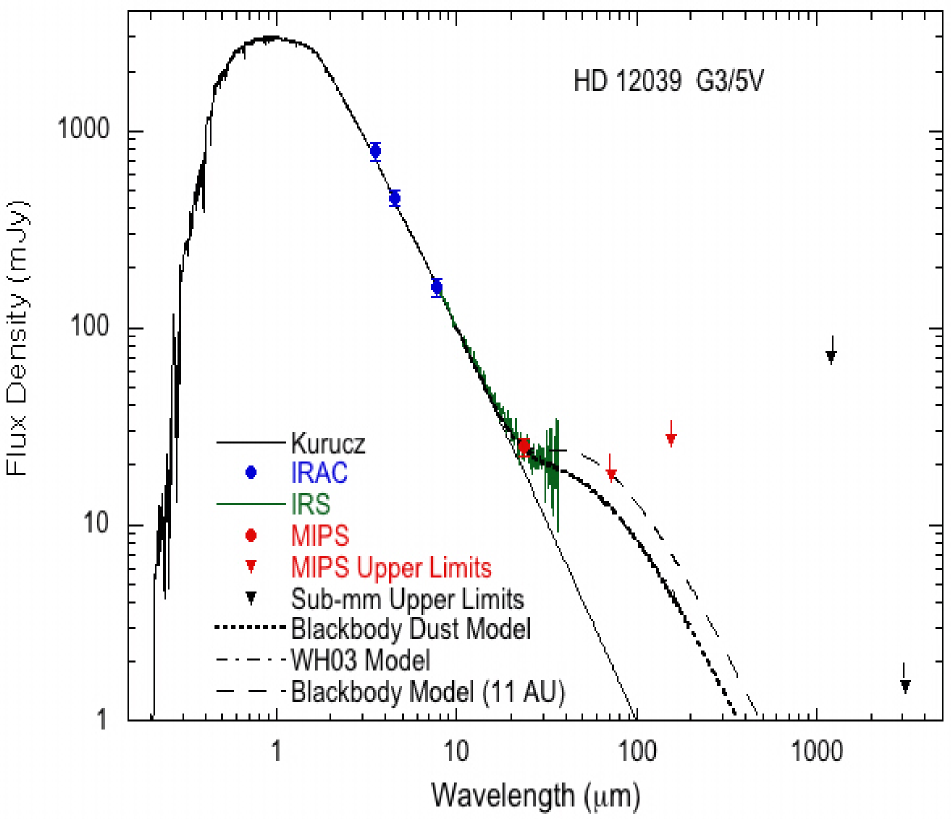
MIR excess sources mostly 10-100 Myr old!

Carpenter et al. (in preparation); see also Chen et al. (2005).

MIR

Spitzer IRS Reveals ``Needle'' in FEPS Haystack

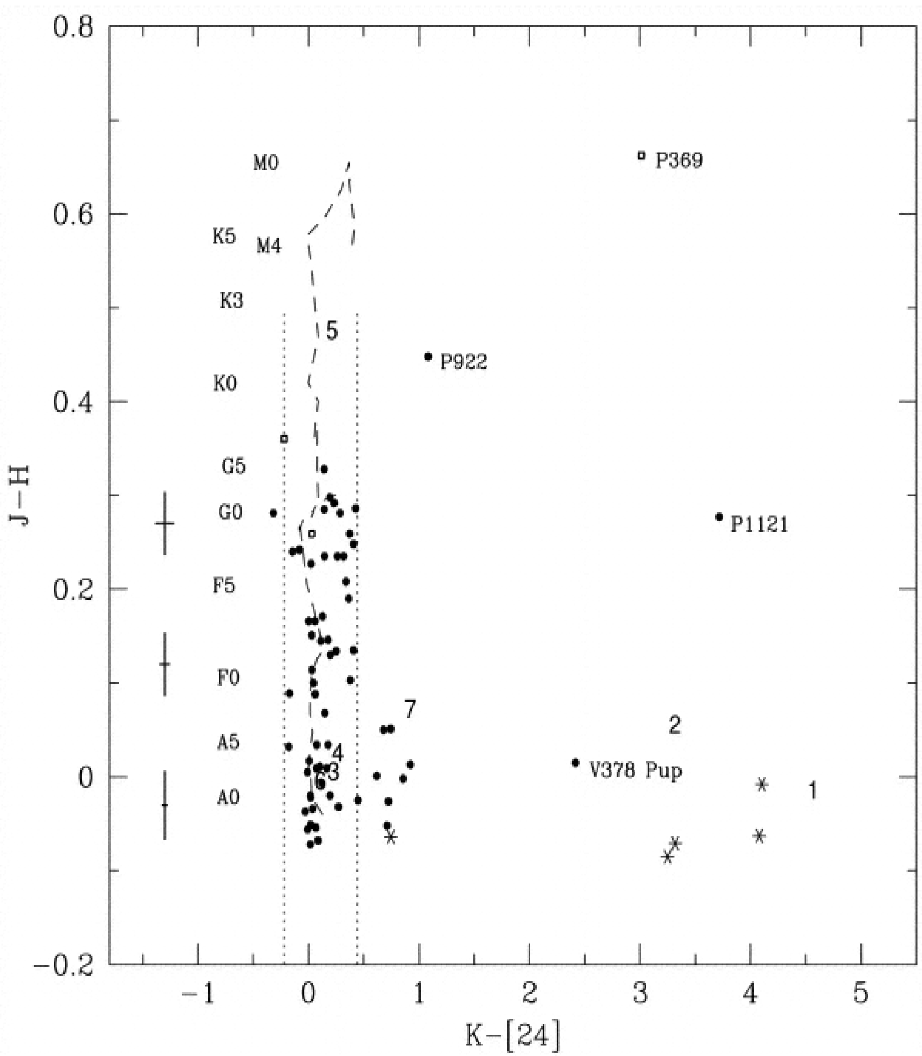




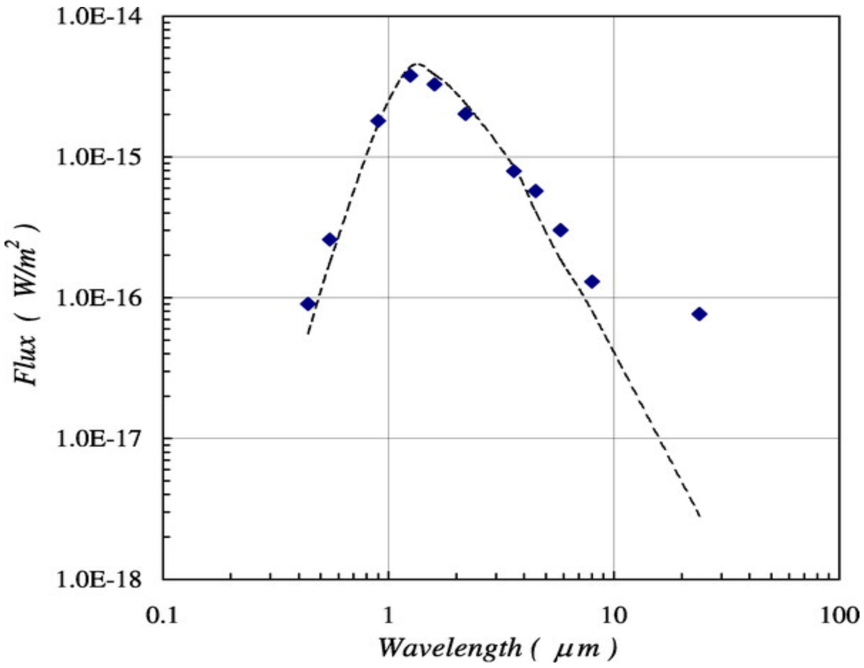
Warm debris belt 4-6 AU around 30 Myr old sun-like star!

Hines et al. (ApJ, submitted)

ow stochastic is disk volution from 10-100 Myr?

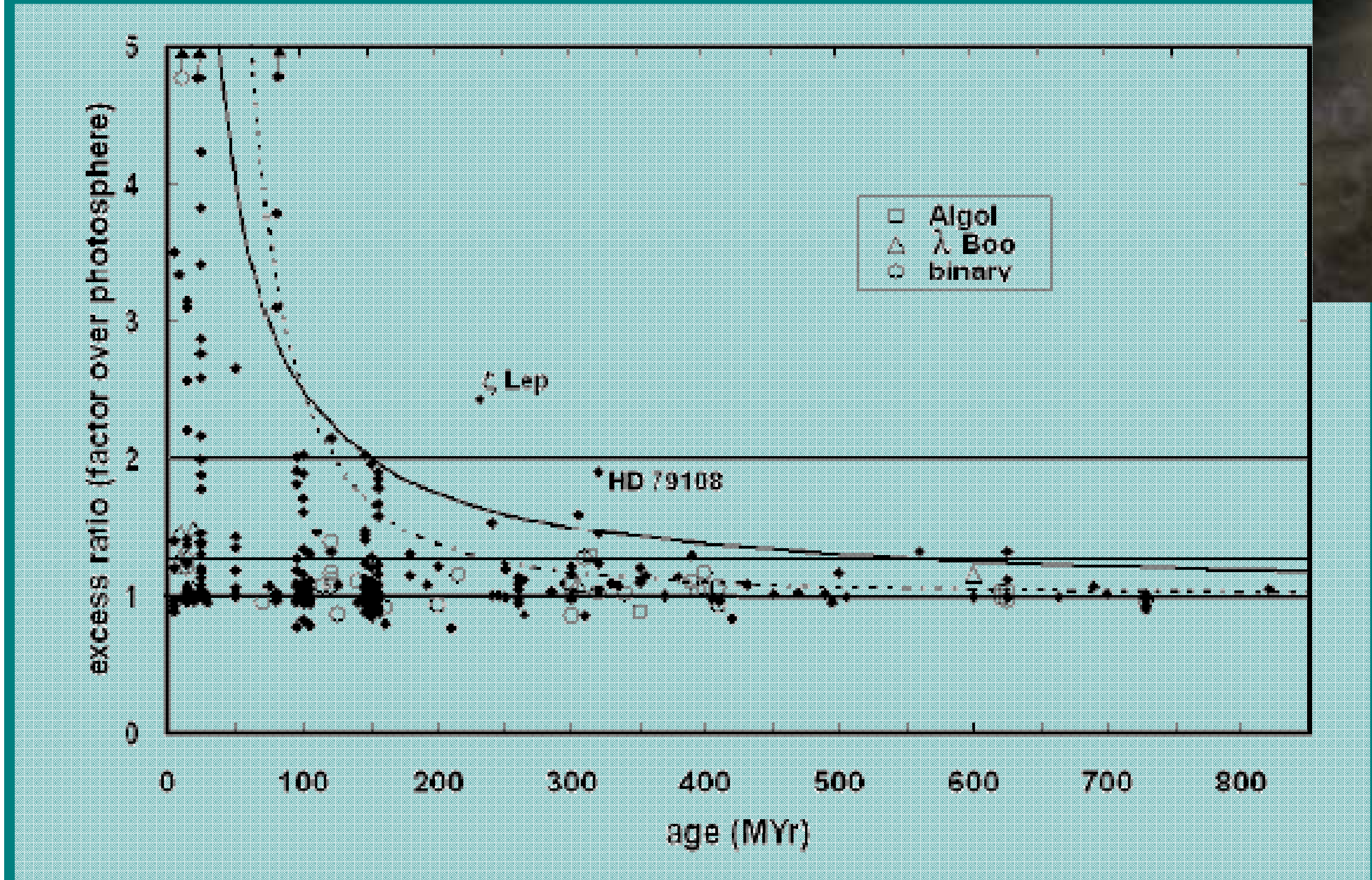


Gorlova et al. 2004 Transient, massive disks around 100 Myr old sun-like stars?



Young et al. 2004 Outer disks around late-type stars 25 Myr old

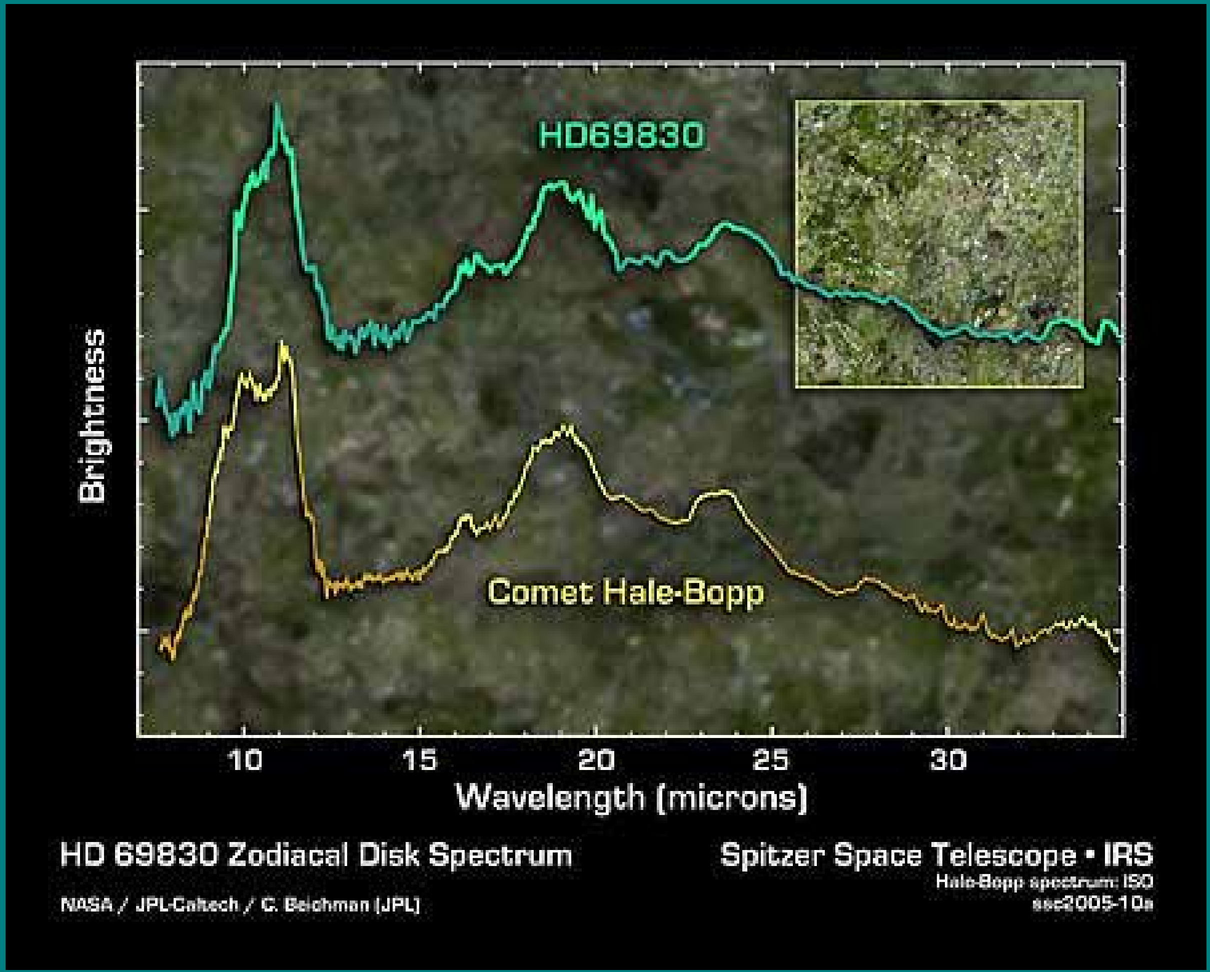
MIR



Rieke et al. (ApJ, 2005)

Spitzer IRS

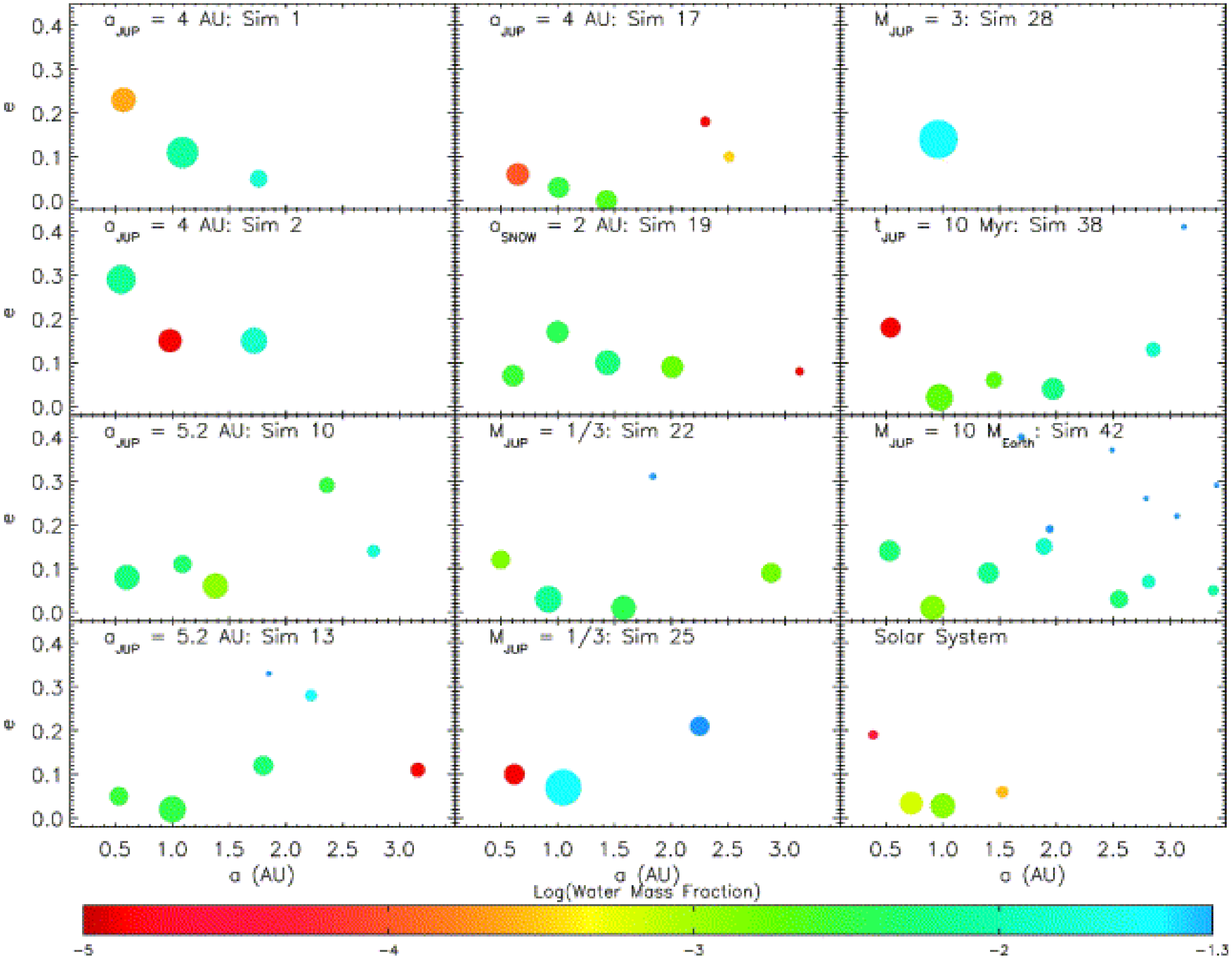
MIR



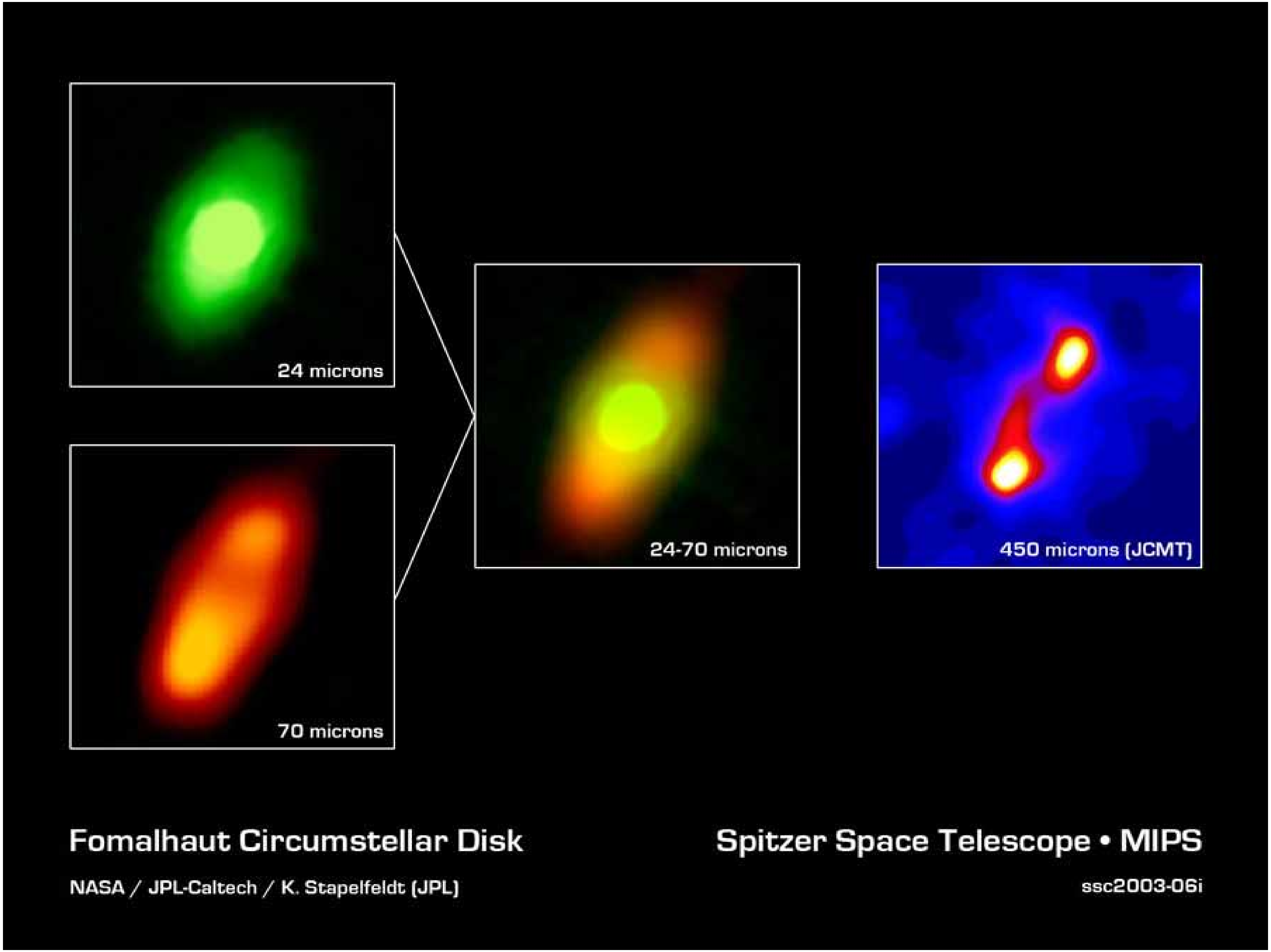
Beichman et al. (ApJ, 2005).

Planetesimals Dynamics: Water Worlds

MIR

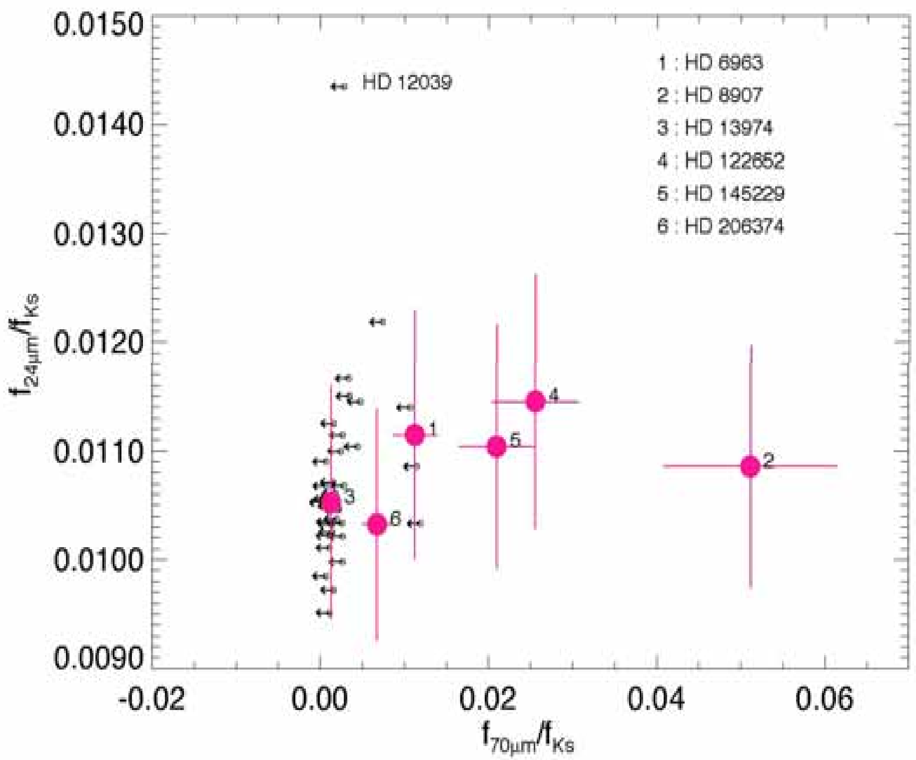


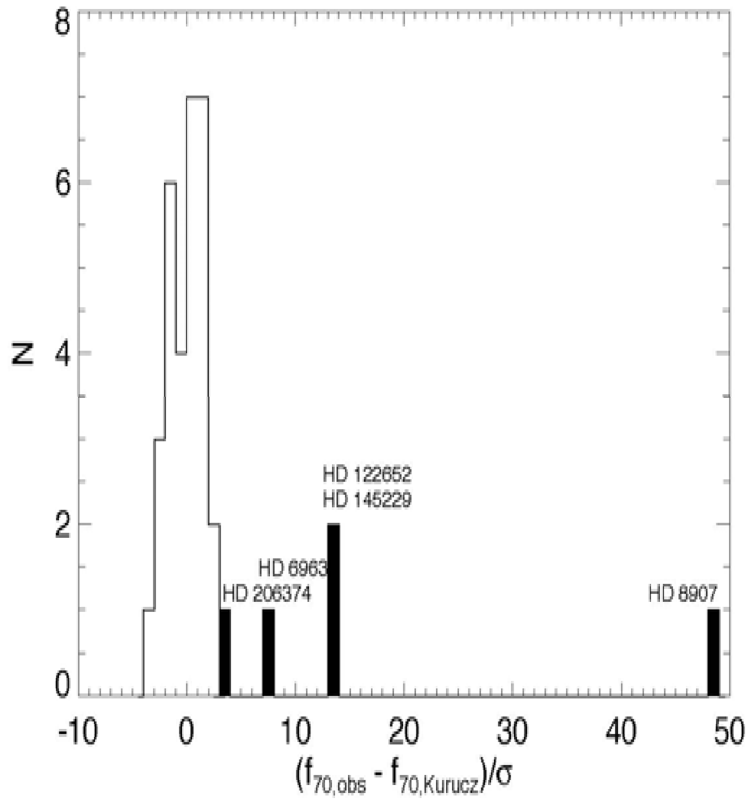
Raymond et al. (2004); See also Kenyon and Bromley (2005)


24 microns
70 microns
24-70 microns
450 microns (JCMT)
Fomalhaut Circumstellar Disk
Spitzer Space Telescope • MIPS
NASA / JPL-Caltech / K. Stapelfeldt (JPL)
ssc2003-06i

Searching for Old **Cold Debris** Disks

FIR

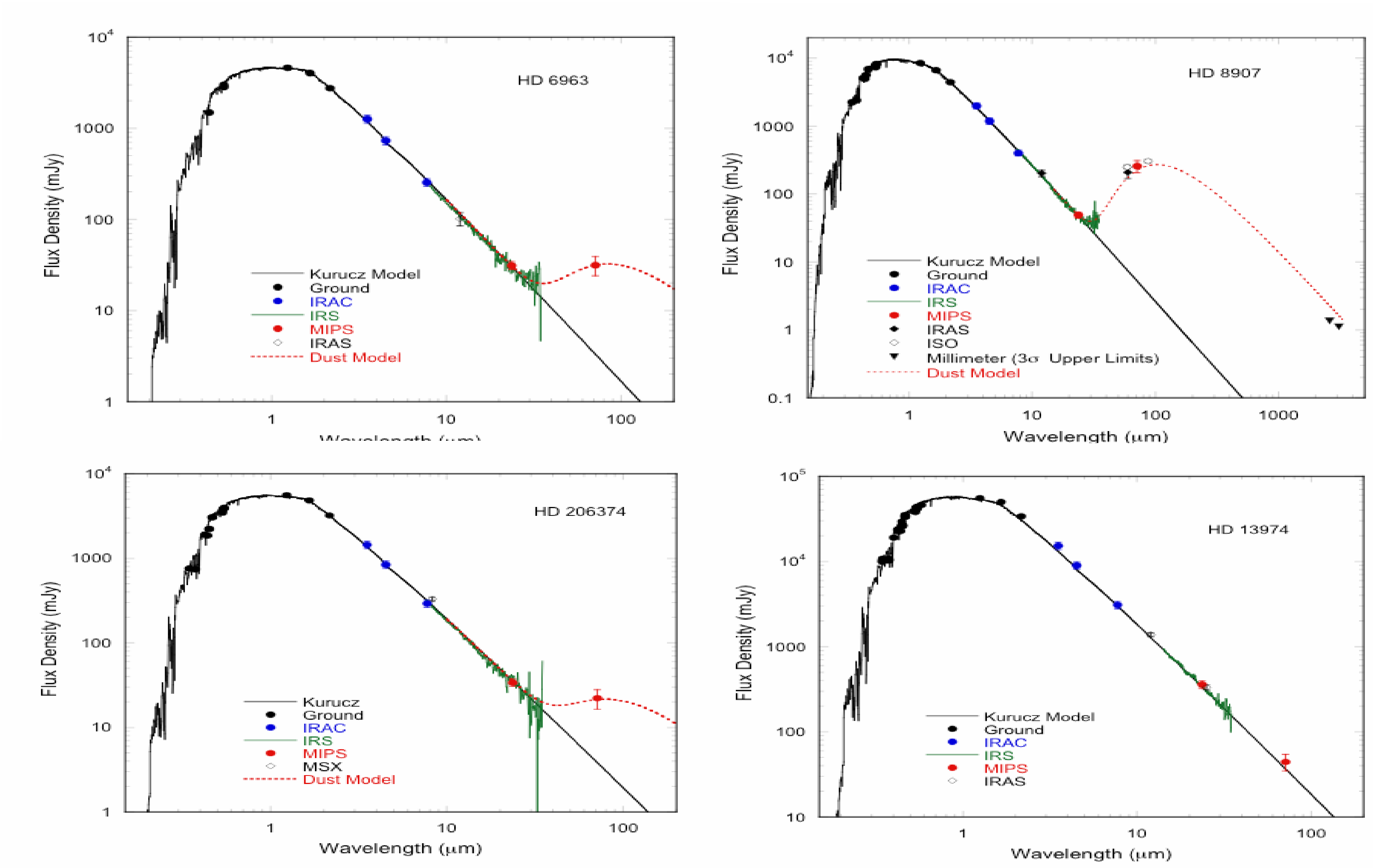




J.S. Kim et al. (ApJ, in press)

Searching for Old **Cold Debris** Disks

FIR

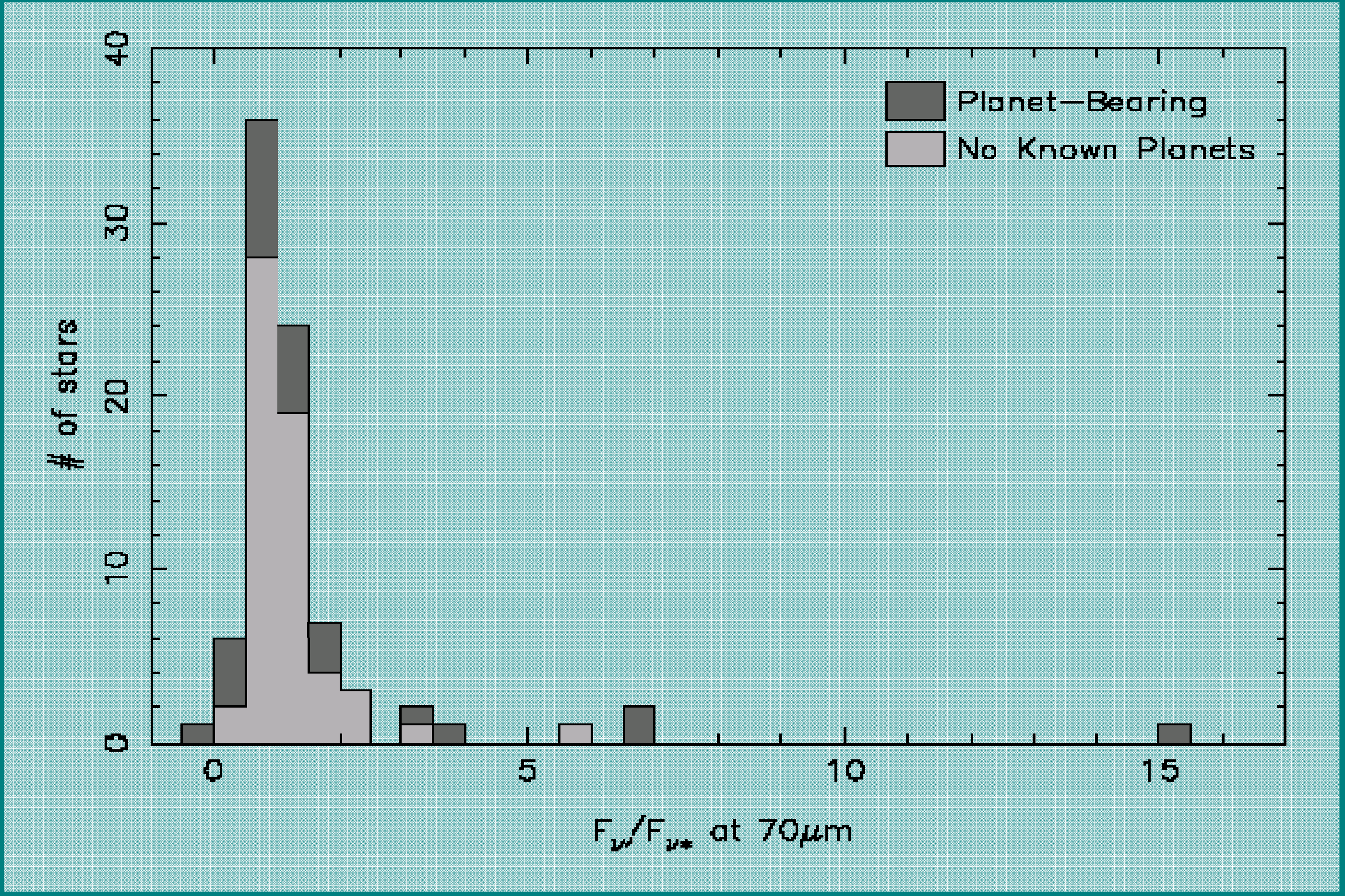


J.S. Kim et al. (ApJ, in press)

Kuiper

FIR

Disks

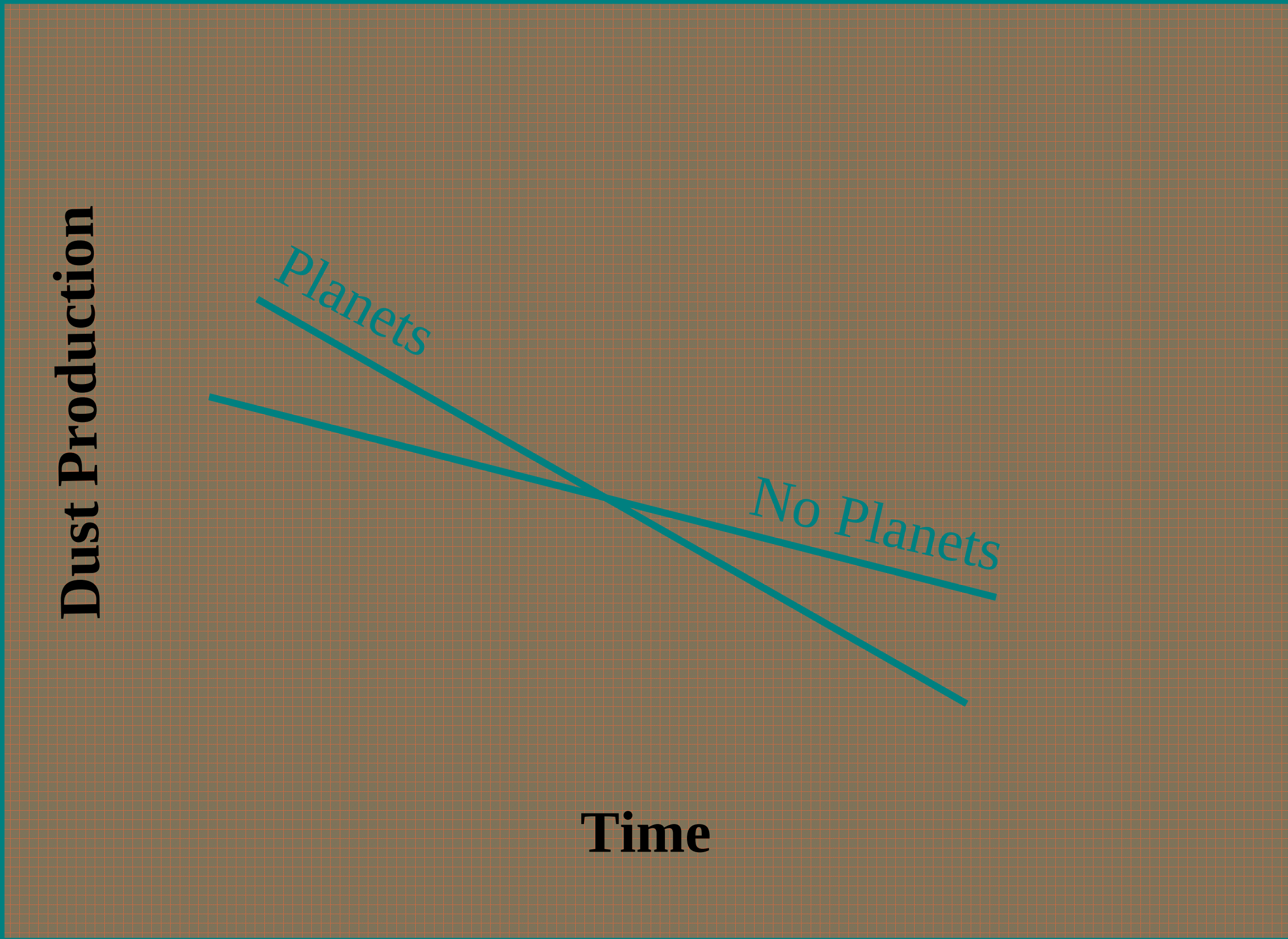


Beichman et al. (2005)

Kuiper

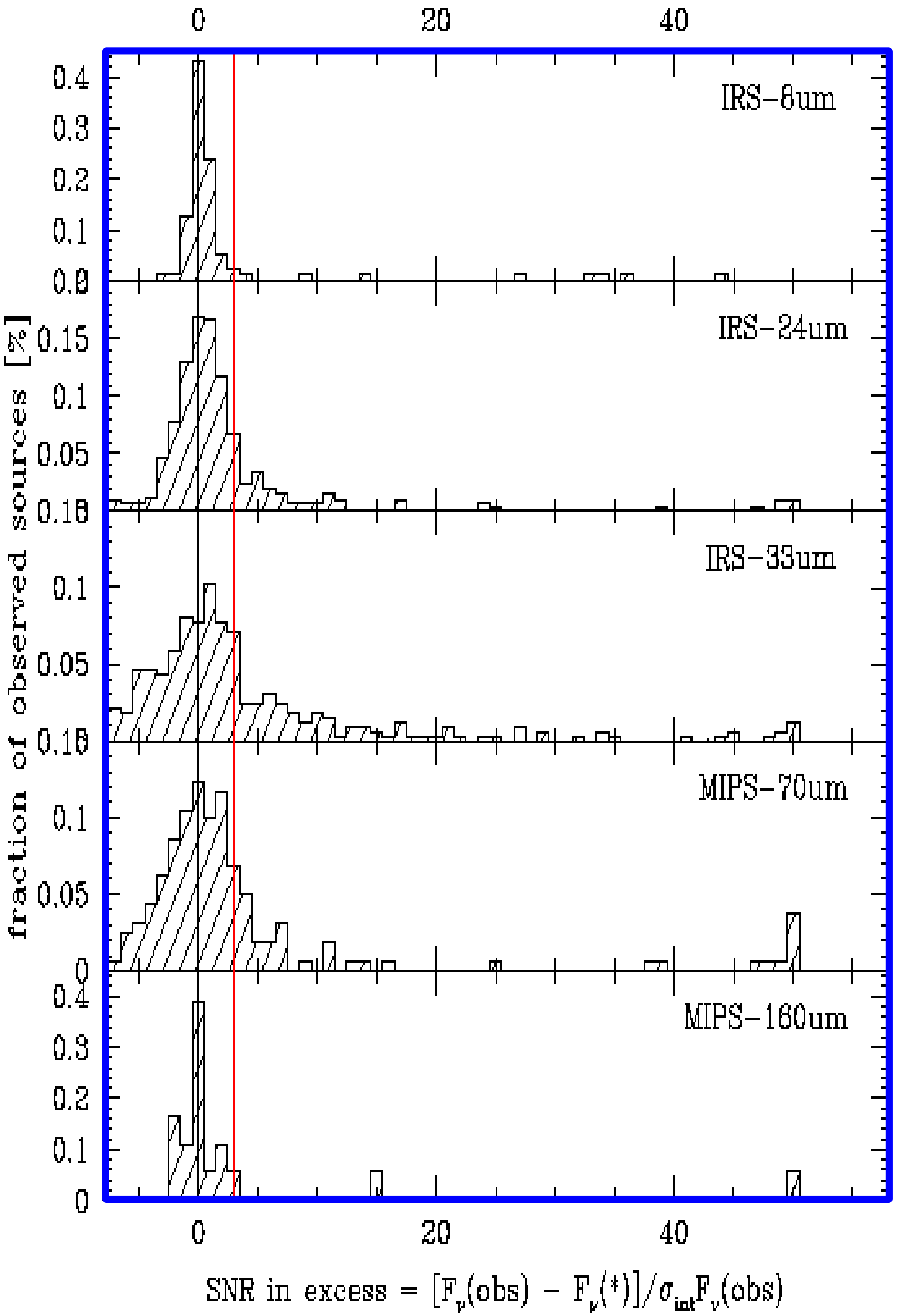
FIR

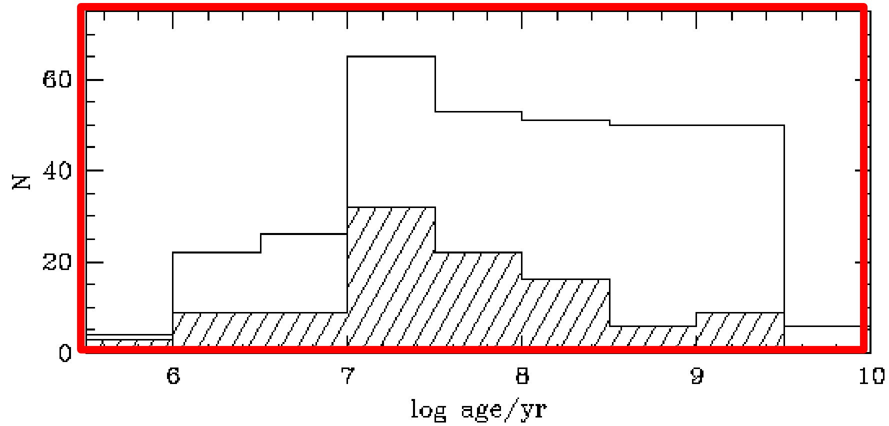
Disks

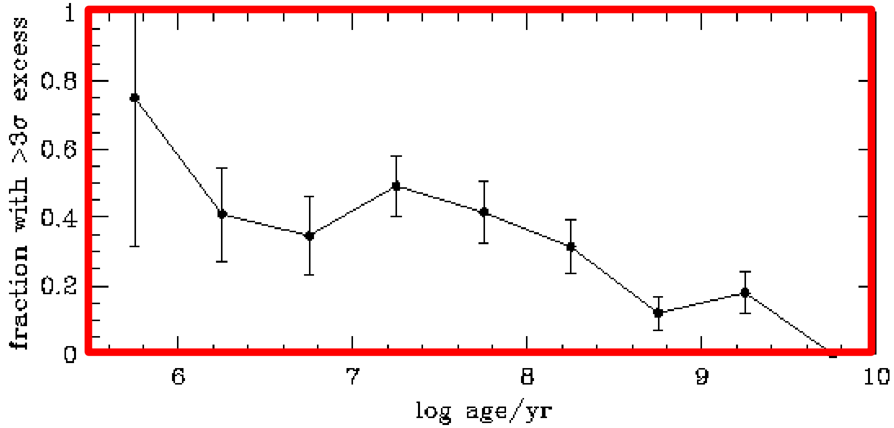


N/M/F-IR

Statistics of FEPS Detections



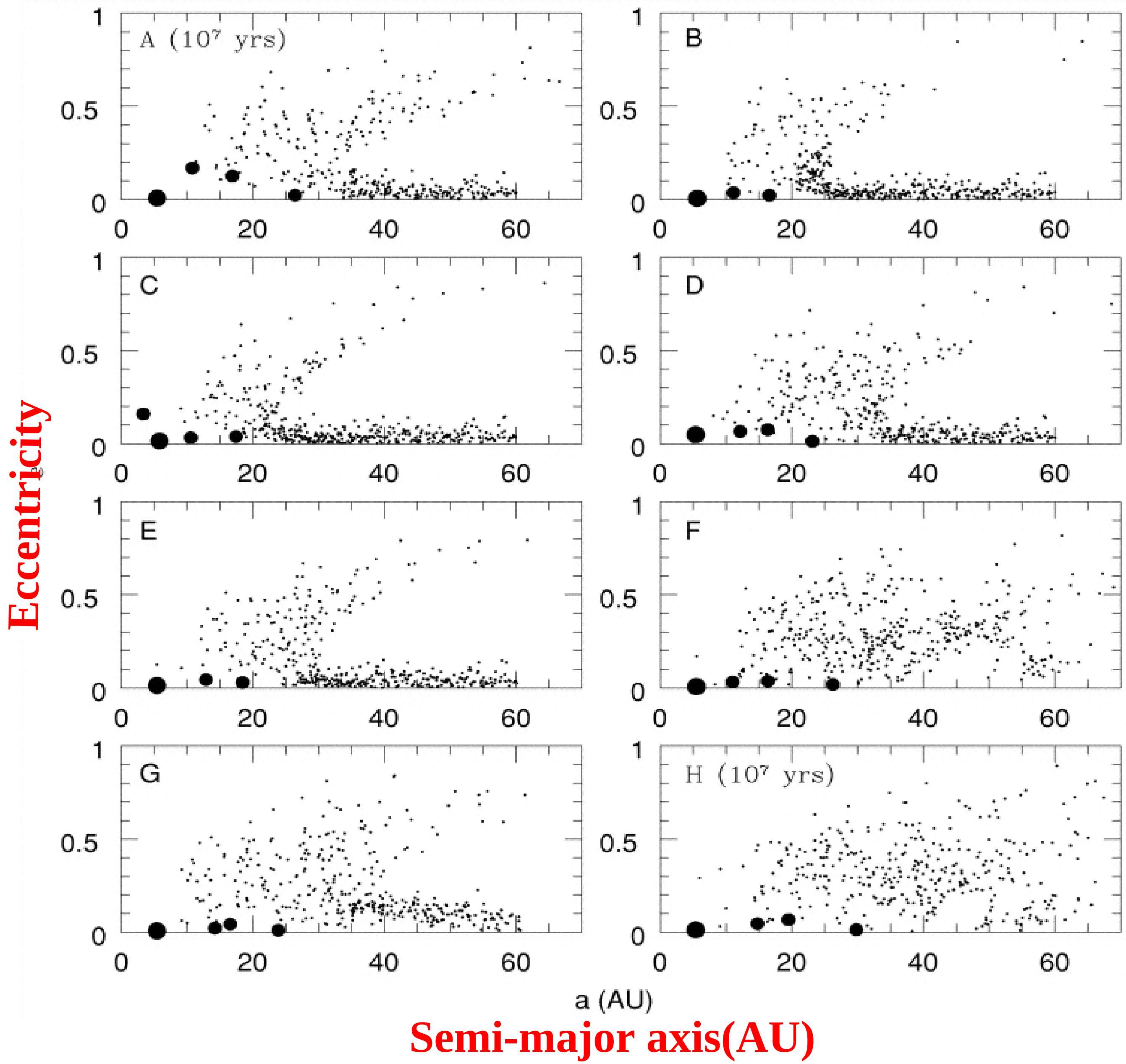




Courtesy of Lynne Hillenbrand

An OLD Fairy Tale: Uranus & Neptune

FIR



Thommes et al. (2002)

New Fairy Tales...

Nature: May, 2005

Morbidelli et al. (2005)

Gomes et al. (2005)

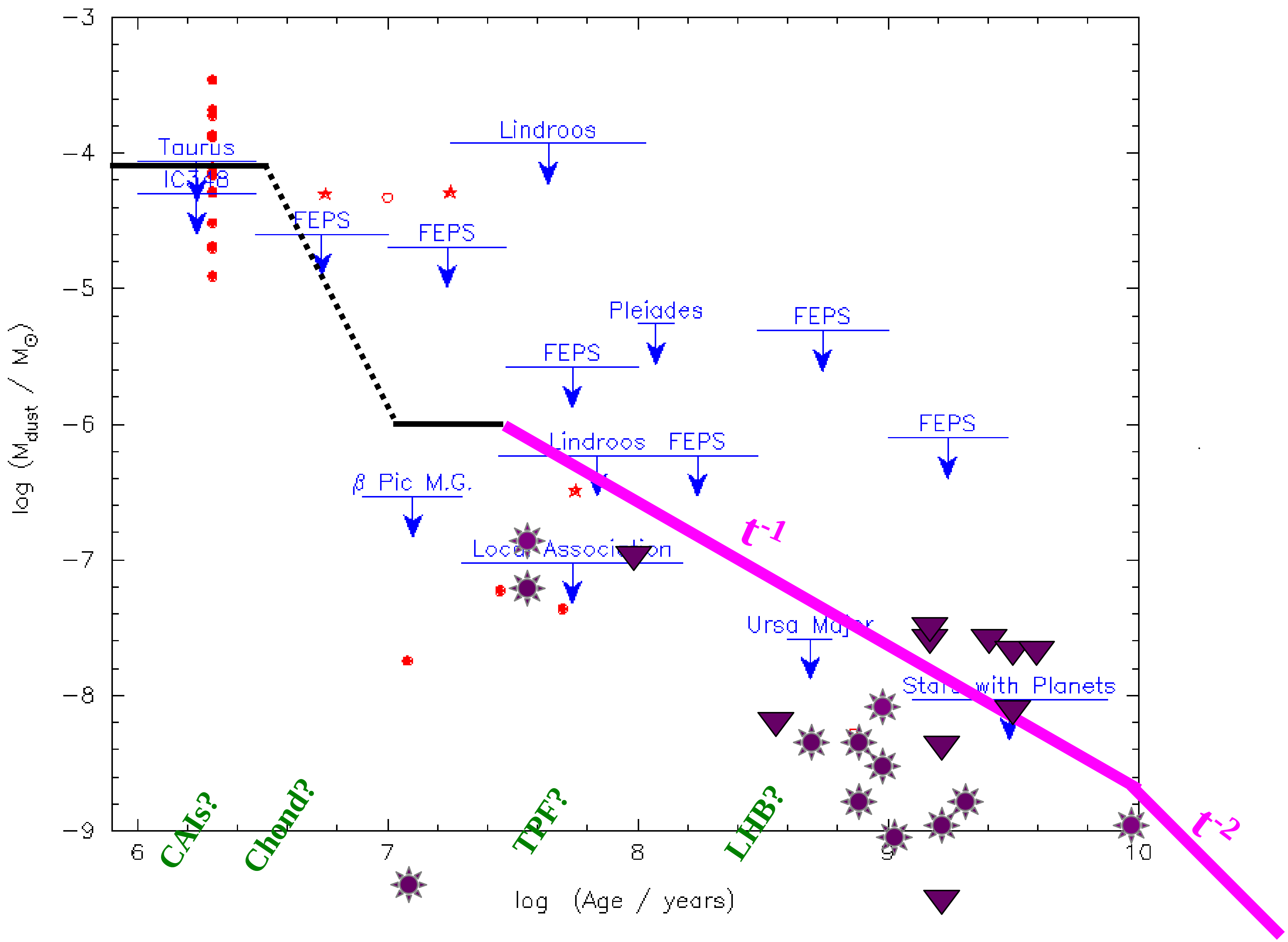
Tsiganis et al. (2005)

Science: 2005

Strom et al. (submitted).

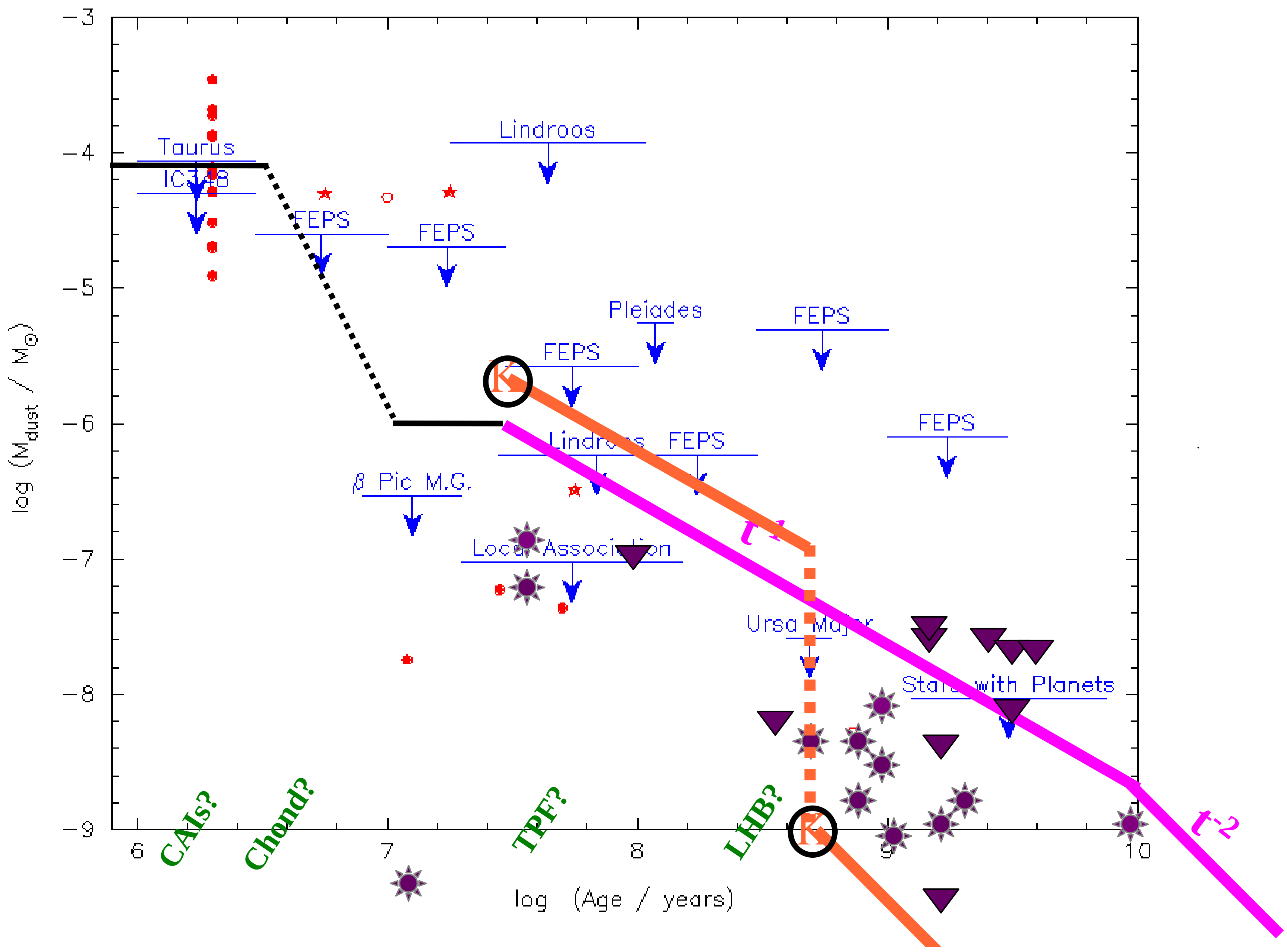
Is Our Solar System Common or Rare?

FIR/SMM

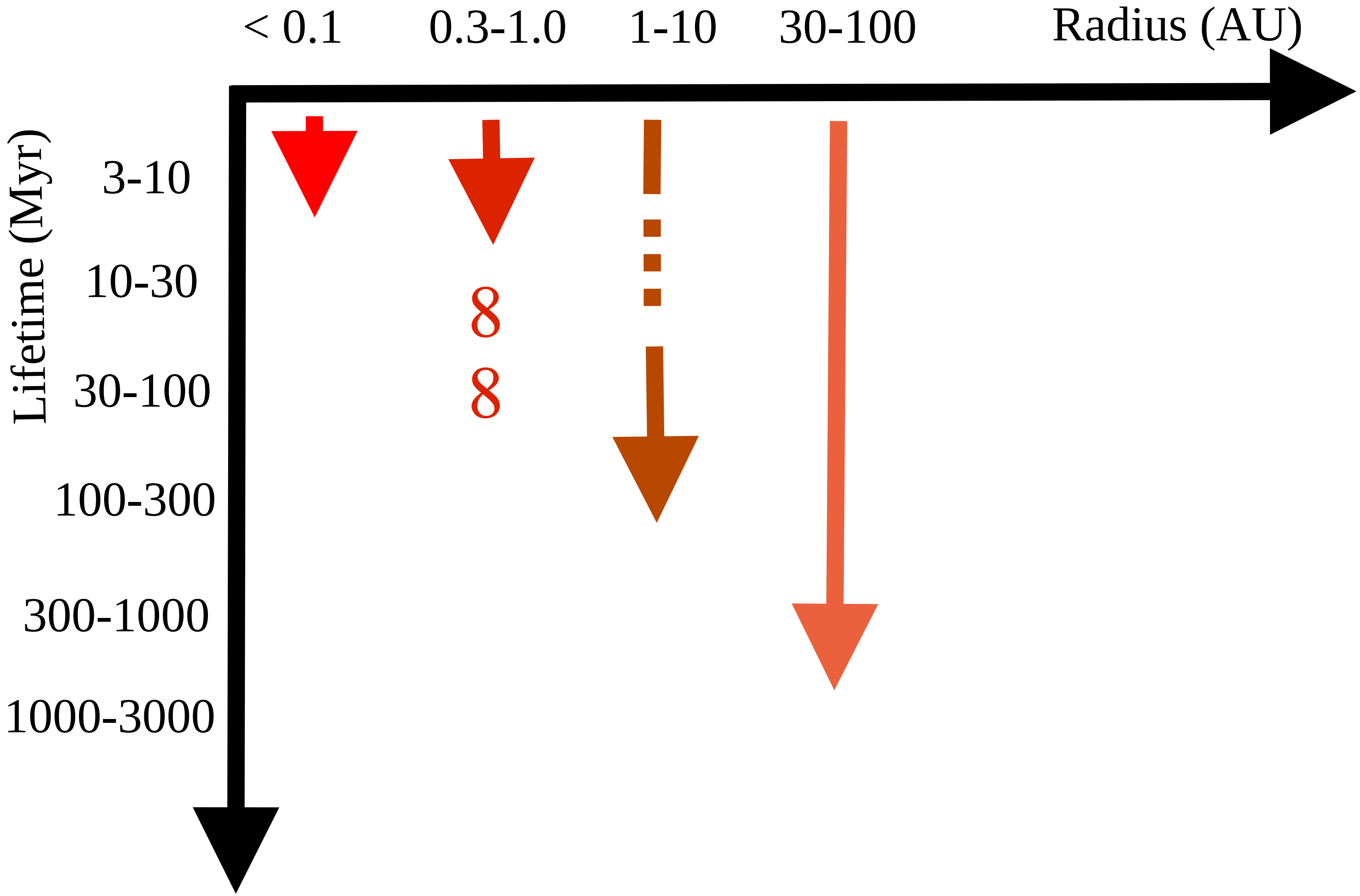


Is **Our Solar System** Common or Rare?

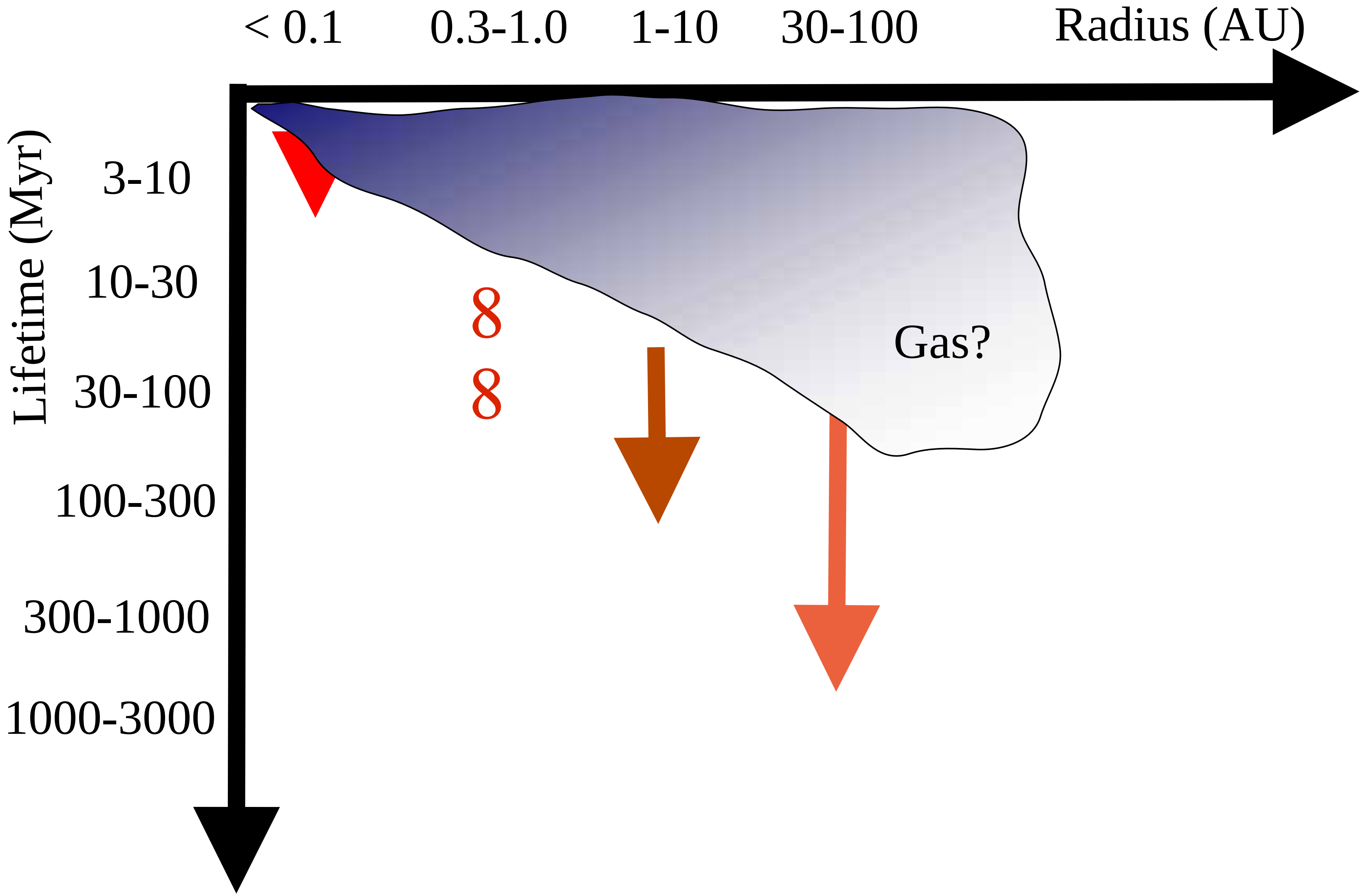
FIR/SMM



FEPS *Preliminary* Results: Debris Disk Lifetimes



FEPS *Preliminary* Results: Does Gas Persist?



FEPS Initial Results: Executive Summary

- Gas disk lifetimes still uncertain (< 30 Myr?).
- ***``Asteroid Belts''*** are rare (but more common 10-100 Myr).
- **Warm debris** disks seen around ~ 10 % (all < 300 Myr old).
- **Kuiper Disk analogues** are common: ~ 10-30 % over all ages.

Problem #5: More questions to ponder...

•For more information => http://feps.as.arizona.edu