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 \( \mu \text{m} \)
  - Spectroscopy, 5.3-40 \( \mu \text{m} \)
  - SED, 50-100 \( \mu \text{m} \)
- Image size 1.5'' at 6.5 \( \mu \text{m} \)
- 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

Sample of 336 stars:
- 0.8-1.2 M$_{\text{Sun}}$
- 3 Myr to 3 Gyr
- 15 < d < 150 pc
Dust Opacity: Effects of Size and Composition shown at R=100 (Henning et al. 2000)
Detecting Gas in Disks

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

Gorti & Hollenbach
FEPS First Results!

Debris Disks Surrounding HD 105 and HD 150706

Meyer et al. (2004)
ApJS Special Issue.
Limits on Gas Mass in 30 Myr Old Disks

No lines detected for HD 105 Mass in $\text{H}_2 < \sim 0.1 \text{ M}_{\text{jup}}$.

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

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.
Searching for **Warm Debris Disks**

Bouwman et al. (in preparation); see also Chen et al. (2005).
Searching for **Warm Debris Disks**

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

MIR excess sources mostly 10-100 Myr old!
Spitzer IRS Reveals "Needle" in FEPS Haystack

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

How stochastic is disk evolution 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
Spitzer Results for Debris Disks Surrounding Intermediate Mass Stars

Spitzer IRS

Planetesimals Dynamics: Water Worlds

Raymond et al. (2004); See also Kenyon and Bromley (2005)
Spitzer Early Release Observations

Fomalhaut Circumstellar Disk
Spitzer Space Telescope • MIPS
NASA / JPL-Caltech / K. Stapelfeldt (JPL)

24 microns
24-70 microns
450 microns (JCMT)
70 microns
Searching for Old Cold Debris Disks

Searching for Old Cold Debris Disks

Do Stars with Planets Also Have Kuiper Disks?

Beichman et al. (2005)
Do Stars with Planets Also Have Kuiper Disks?
Statistics of FEPS Detections

SNR in excess = \[ \frac{F(x_{\text{obs}}) - F(x^*)}{\sigma_{x} \times F(x_{\text{obs}})} \]

Courtesy of Lynne Hillenbrand
An OLD Fairy Tale: Uranus & Neptune

Thommess 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?

- CAIs?
- Chond?
- TPF?
- LHB?

\[ \log (M_{\text{dust}} / M_\odot) \]

\[ \log (\text{Age} / \text{years}) \]

- Taurus
- IC348
- FEPS
- Lindroos
- Pleiades
- Ursa Major
- Stars with Planets

\[ t^{-1} \]

\[ t^{-2} \]
Is Our Solar System Common or Rare?
FEPS Preliminary Results: Debris Disk Lifetimes
FEPS Preliminary Results: Does Gas Persist?

<table>
<thead>
<tr>
<th>Radius (AU)</th>
<th>Lifetime (Myr)</th>
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<tbody>
<tr>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
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<tr>
<td>0.3-1.0</td>
<td>0.3-1.0</td>
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<td>1000-3000</td>
<td>1000-3000</td>
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</tbody>
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Gas?
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