Brown dwarf disks

What did we learn
from Spitzer?

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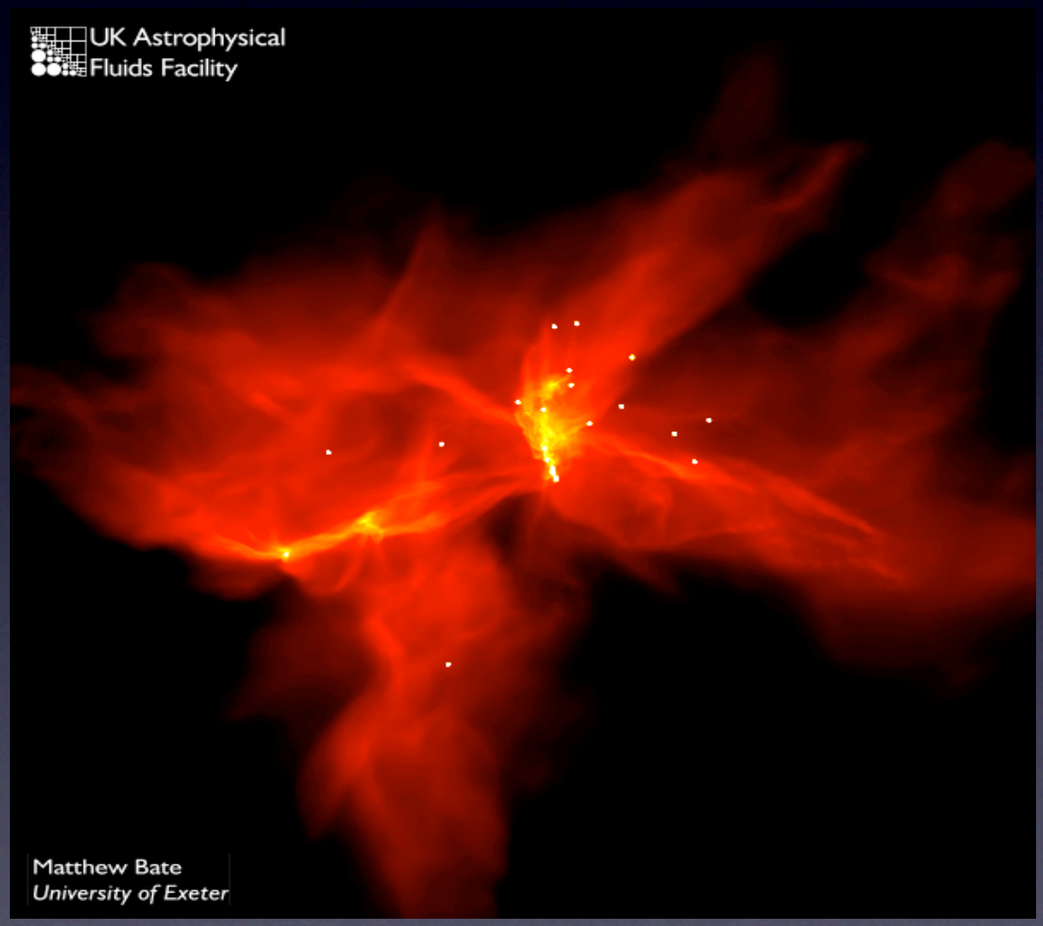
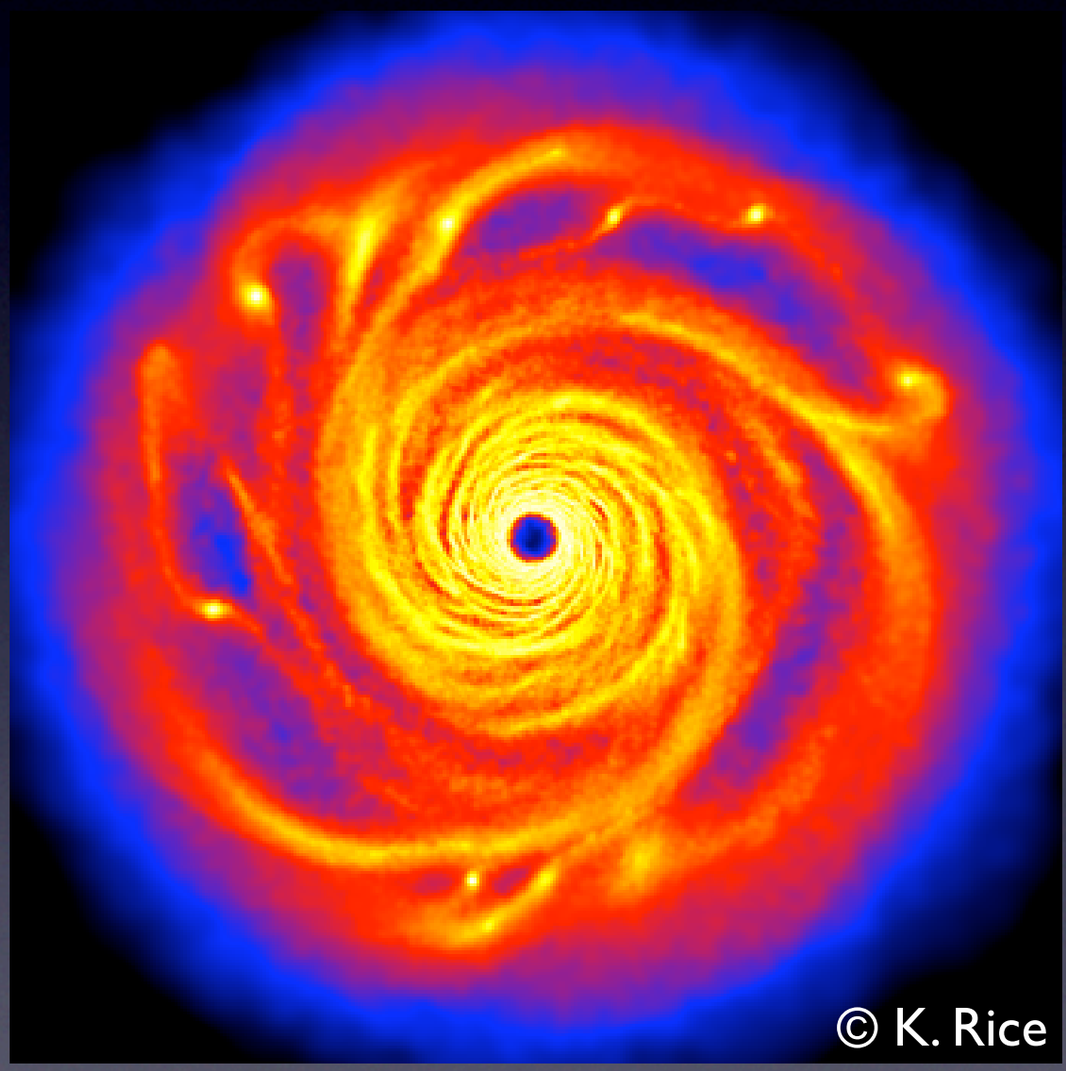
1) Testing star formation

- Which processes mainly affect the low-mass end of the IMF?
- How relevant are dynamical interactions, fragmenting disks, photoevaporation, tidal interactions?
- Where is the opacity limit of fragmentation?



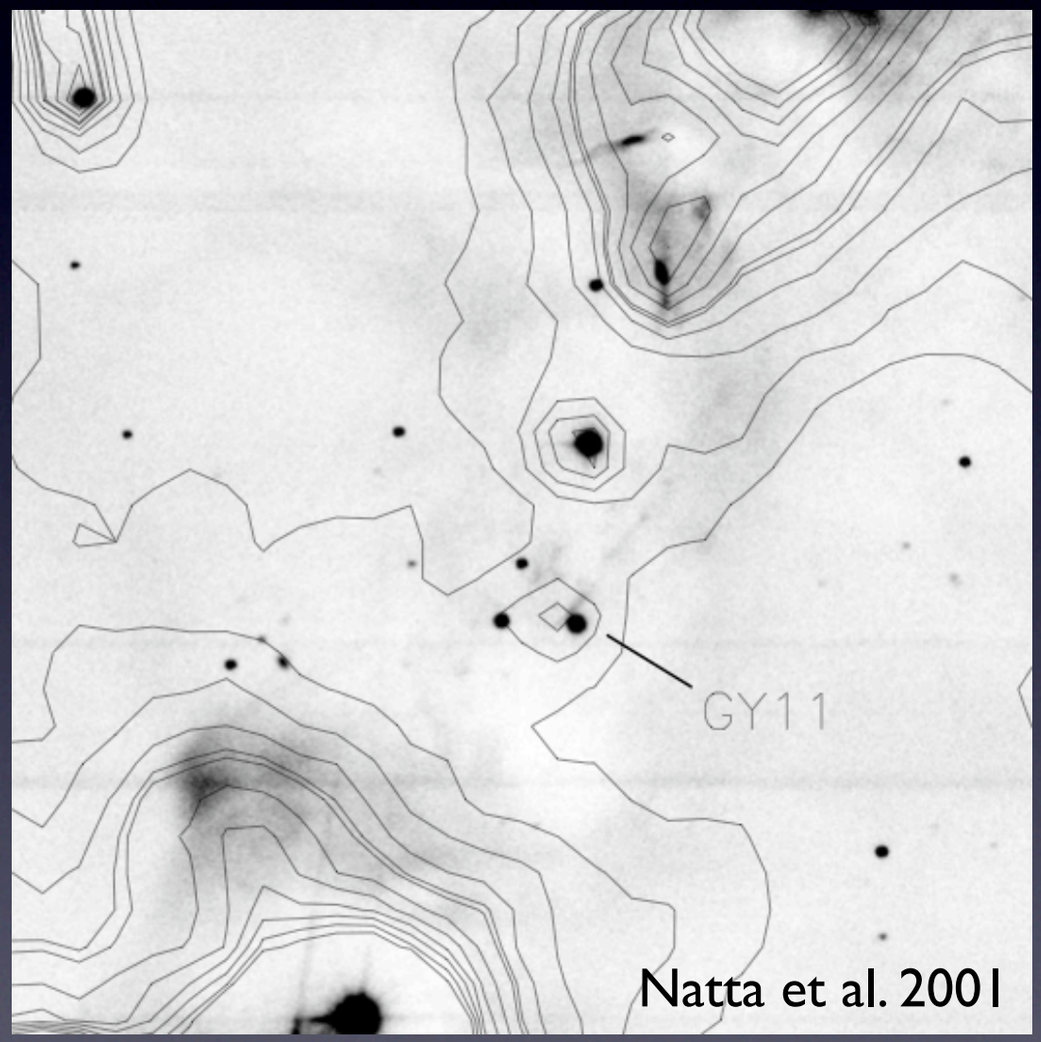
2) Testing planet formation

- How does the disk evolution and dispersal change with mass?
- Are BD disk properties compatible with core-accretion or gravitational instability?
- Do BD disks show signs of ongoing planet formation?



Looking back: pre Spitzer

- NIR surveys, few objects with MIR detection
- BDs have scaled down T Tauri disks, lifetimes not vastly different from stars, disks detected down to ~10 Mjup
- evidence for flaring, dust settling, grain growth, Silicate feature



Natta et al. 2001

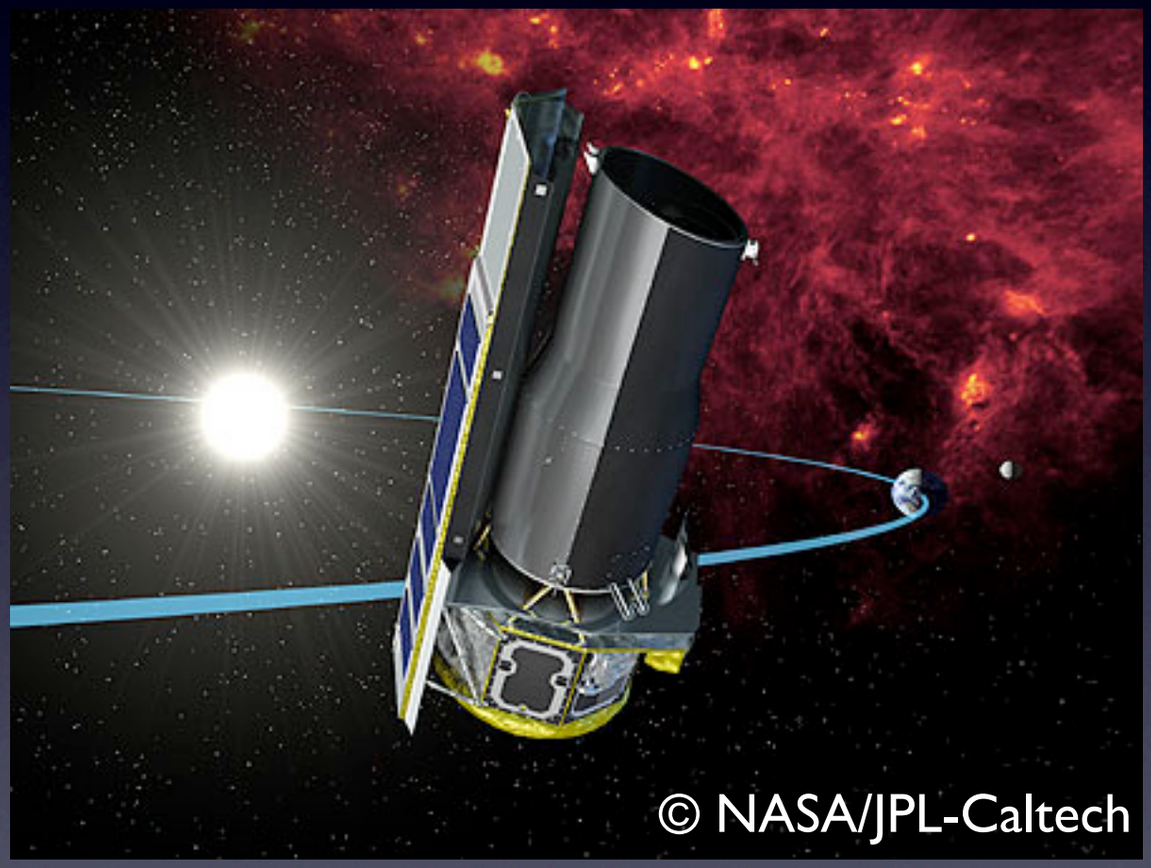
Comeron et al. 1998, Natta et al. 2001, 2002, Muench et al. 2001, Testi et al. 2002, Apai et al. 2002, 2004, Pascucci et al. 2003, Jayawardhana et al. 2003, Liu et al. 2003, Sterzik et al. 2004, Mohanty et al. 2004, et al.

Enter Spitzer

- numbers: improving the statistics for disk fractions and properties

- sensitivity: μJy accuracy at 3-8μm, 0.1mJy at 24μm

- SED coverage: dense sampling from 3 to 24μm with IRAC, IRS, MIPS

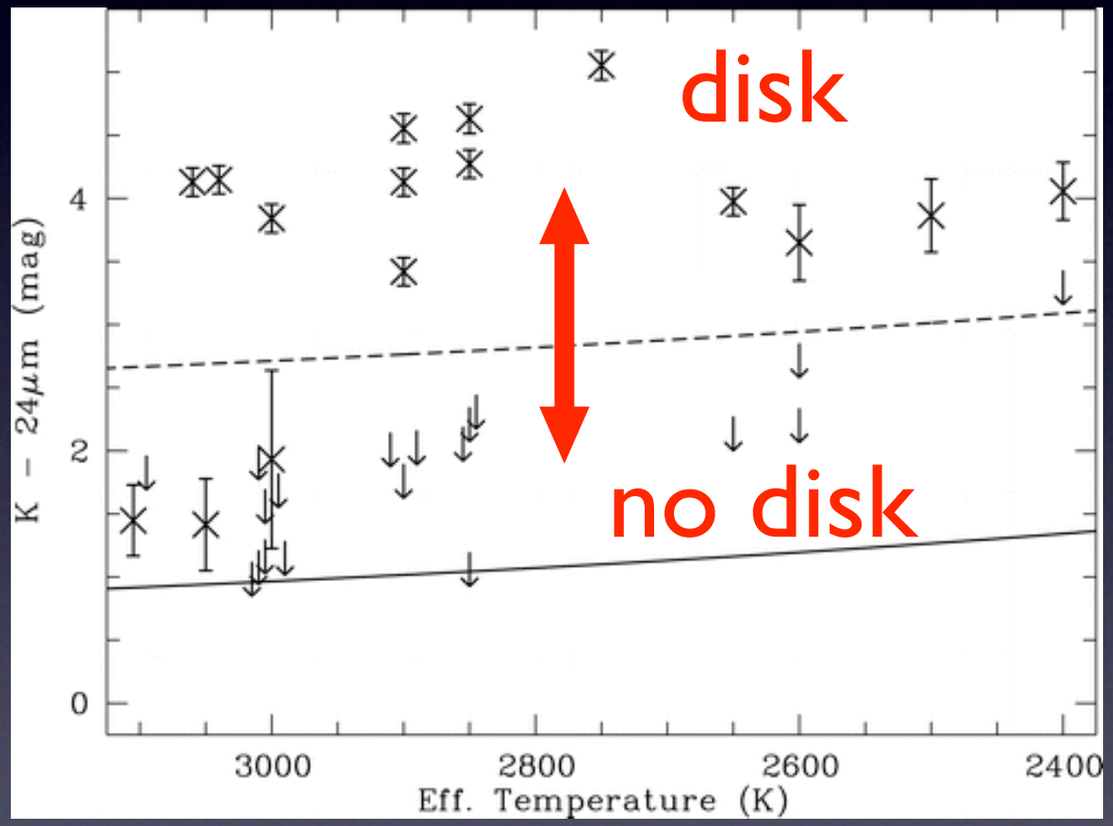


Disk lifetimes

- about 100 BDs with disks are published, ages from 1-10 Myr

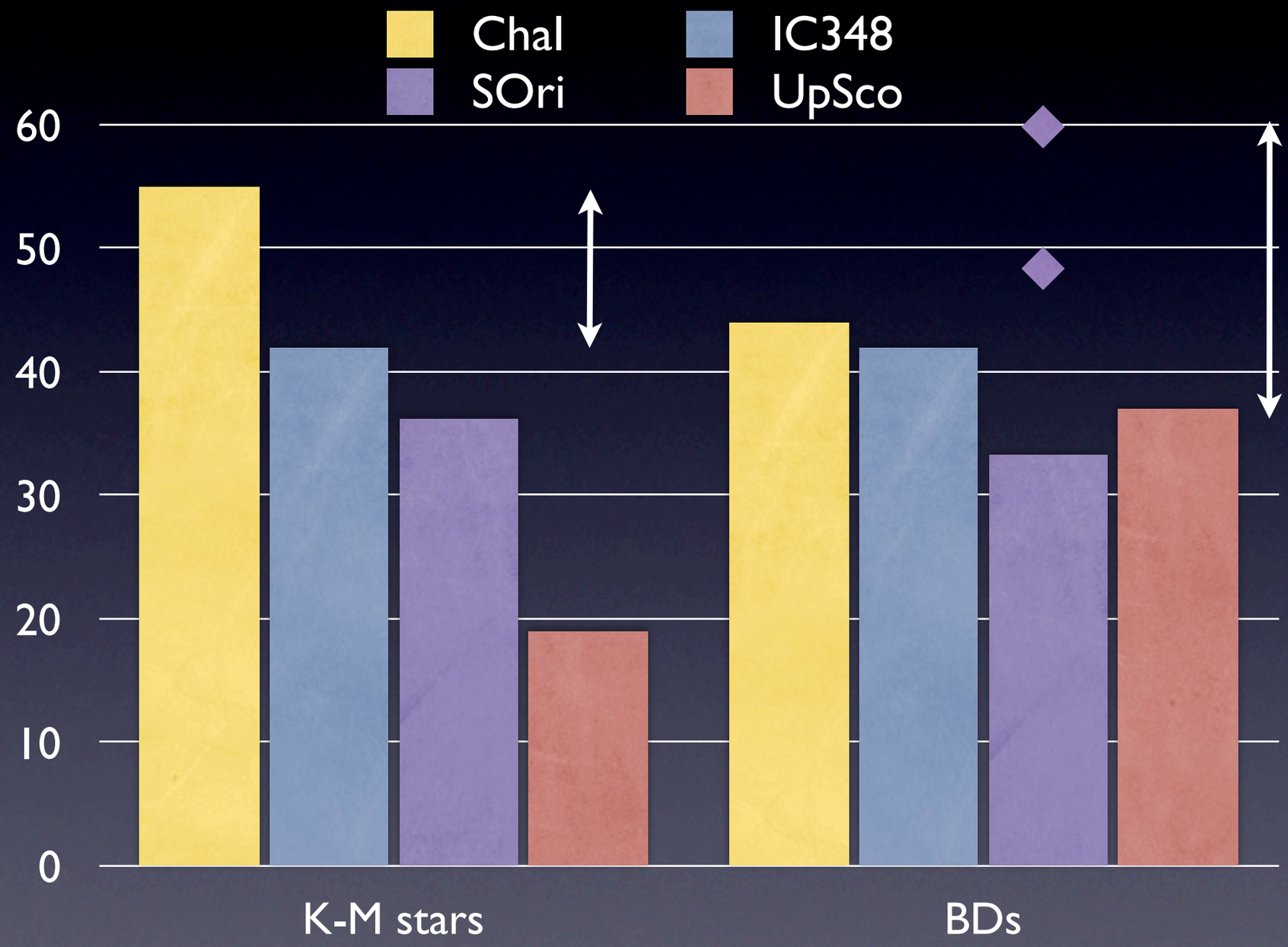
- testcase UpSco (5 Myr): 13/35 (37%) BDs have excess at 24μm - more than K-M stars

- rapid clearing of the inner disk (~10^5 yr)



Scholz et al. 2007

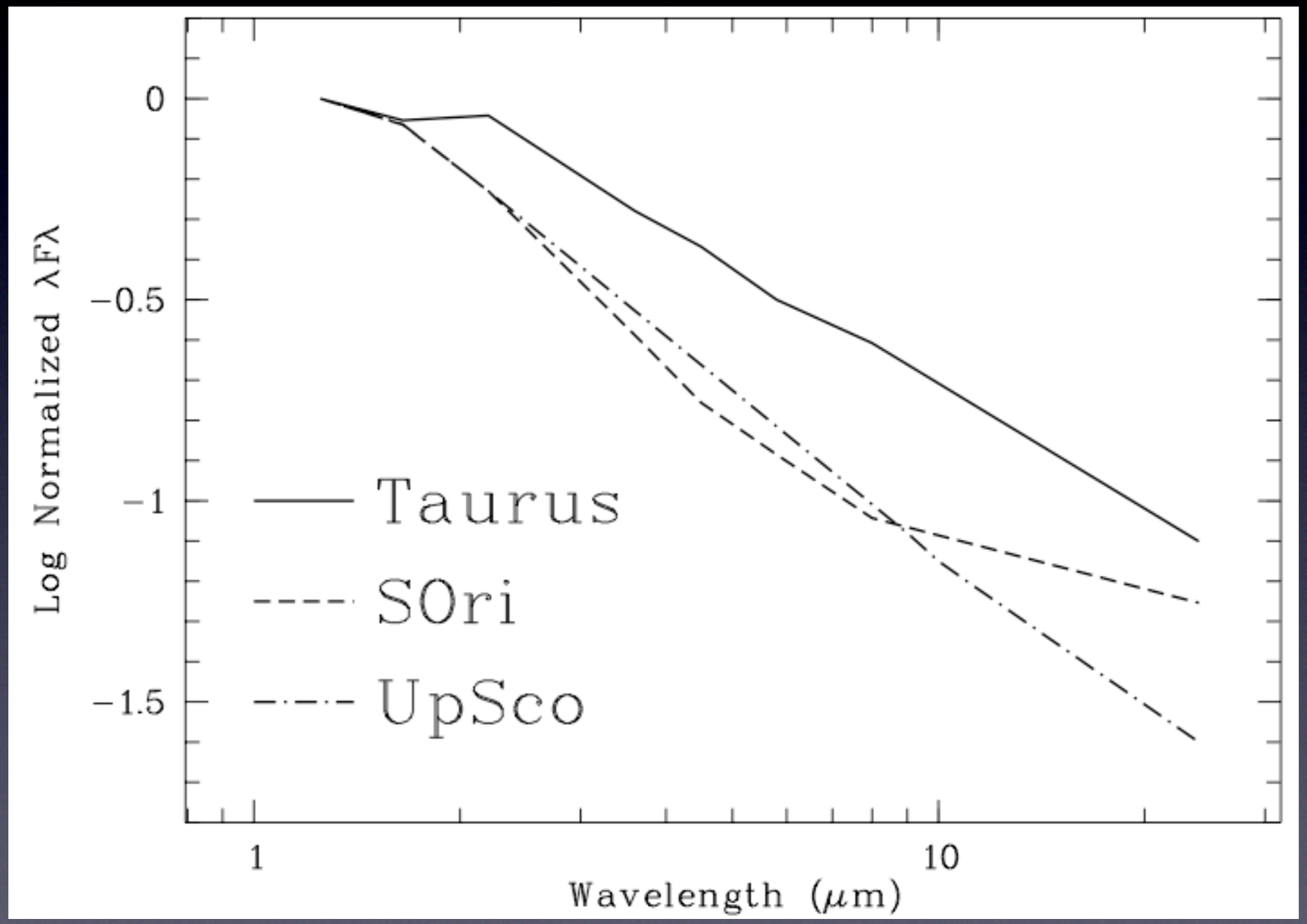
Disk fraction vs. age



Chal: Damjanov et al. 2007, Luhman et al.
IC348: Luhman et al. 2005, Lada et al 2006

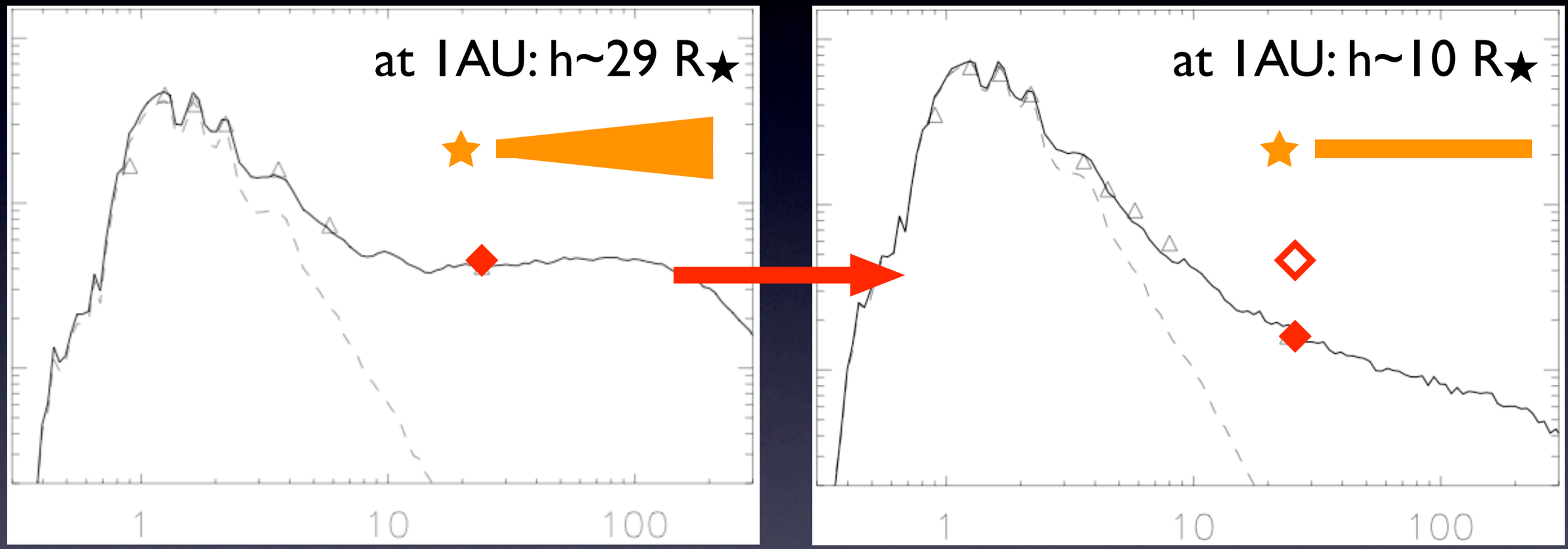
SOri: Hernandez et al. 2006, Caballero et al. 2007
UpSco: Carpenter et al. 2006, Scholz et al. 2007

Disk SEDs vs. age



Scholz et al. 2008, including data from Guieu et al. 2007, Hernandez et al. 2006

Dust settling



Scholz et al. 2008

flaring power or conversely the degree of dust settling can account for a) most of the SED diversity at any given age and b) the SED evolution

Grain growth

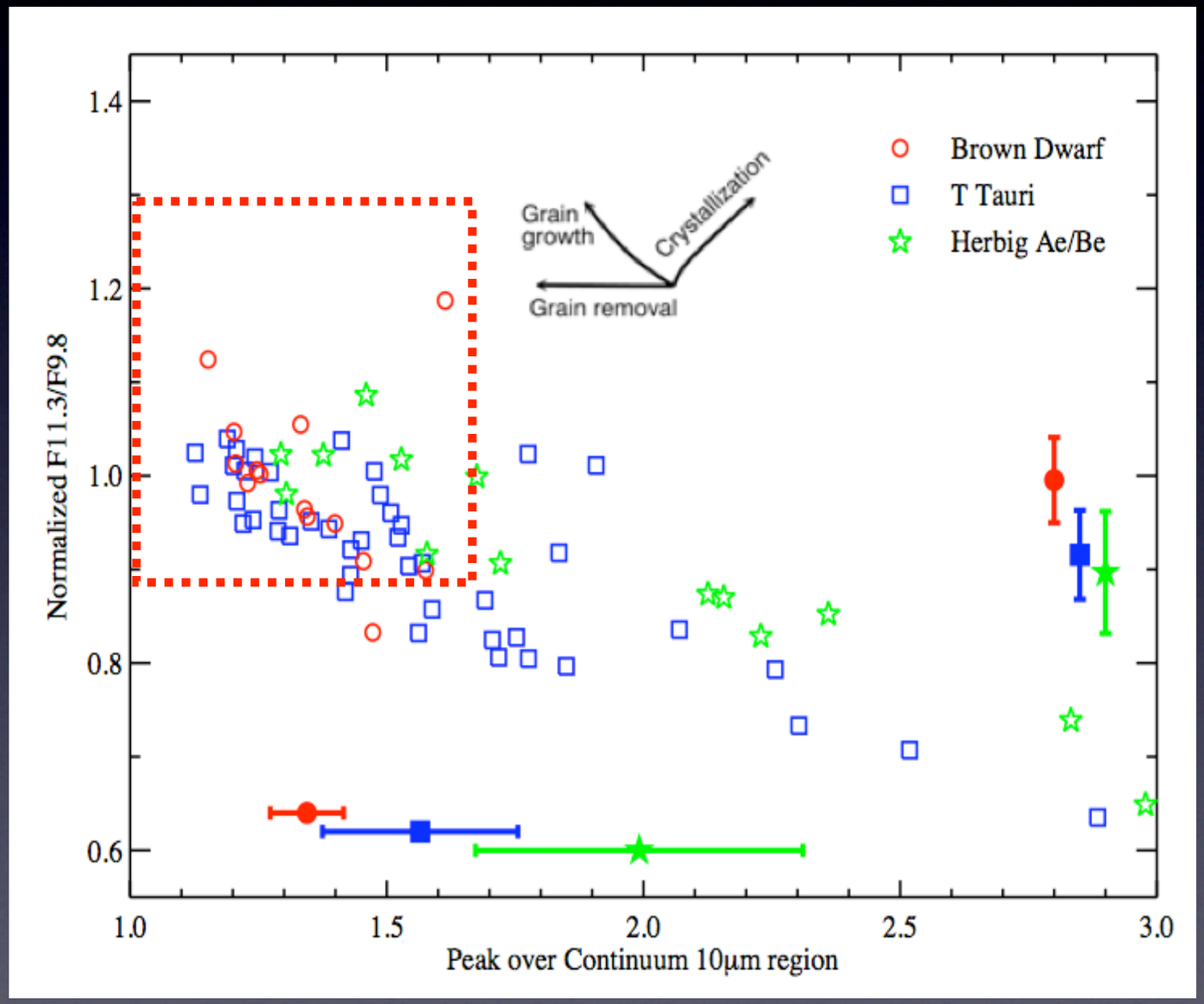
- grain growth indirectly seen with dust settling and the absence of the Silicate feature

- Silicate peaks weaker than in stars → processed grains

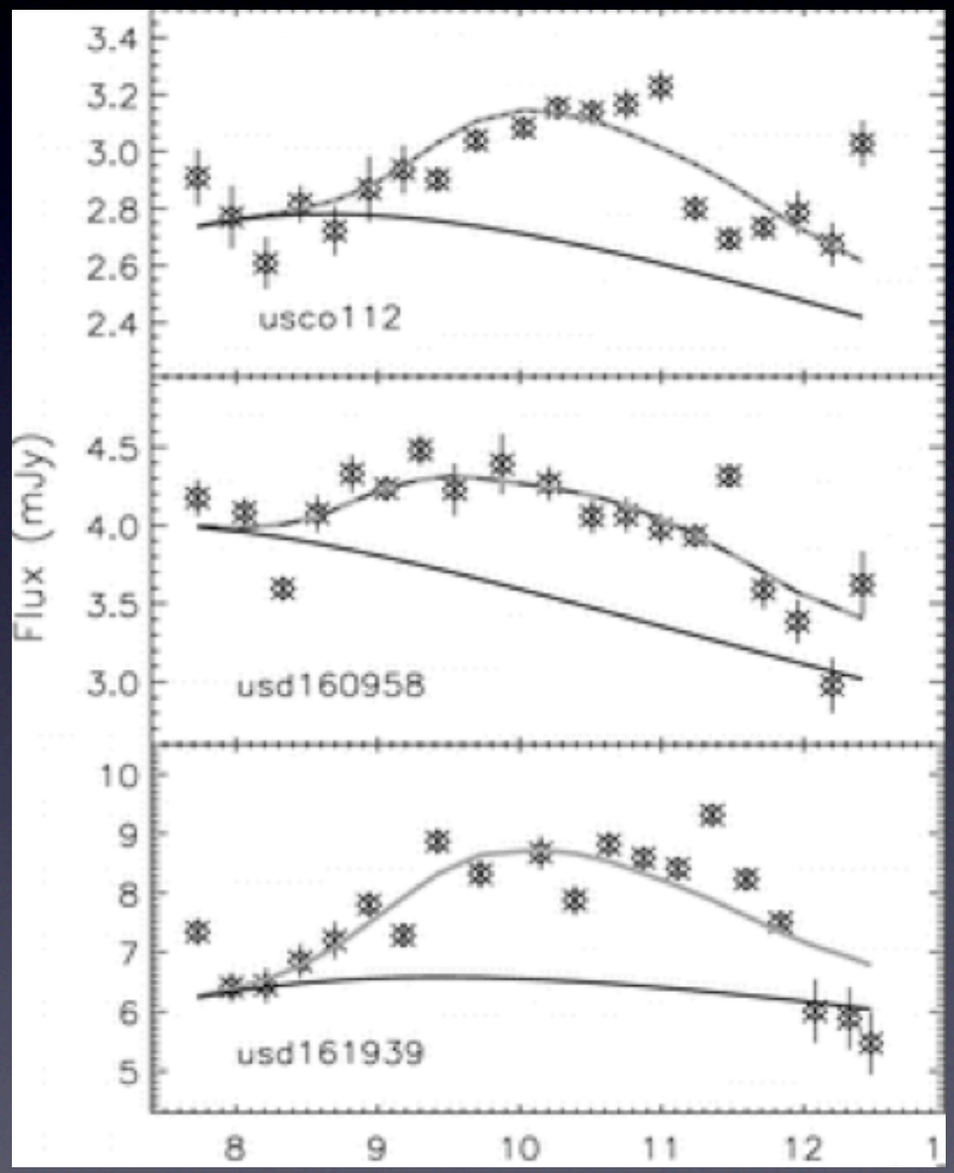
- how representative is the disk atmosphere?

dust settling: Lada et al. 2006, Riaz et al. 2006, 2007, Morrow et al. 2008, Scholz et al. 2006, 2007, 2008
Silicate feature: Apai et al. 2005, Siciliar Aguilar et al. 2007, Kessler-Silacci et al. 2007, Bouy et al. 2008

Silicate feature



Chal, Pascucci et al. 2008



UpSco, Scholz et al. 2007

Disk clearing

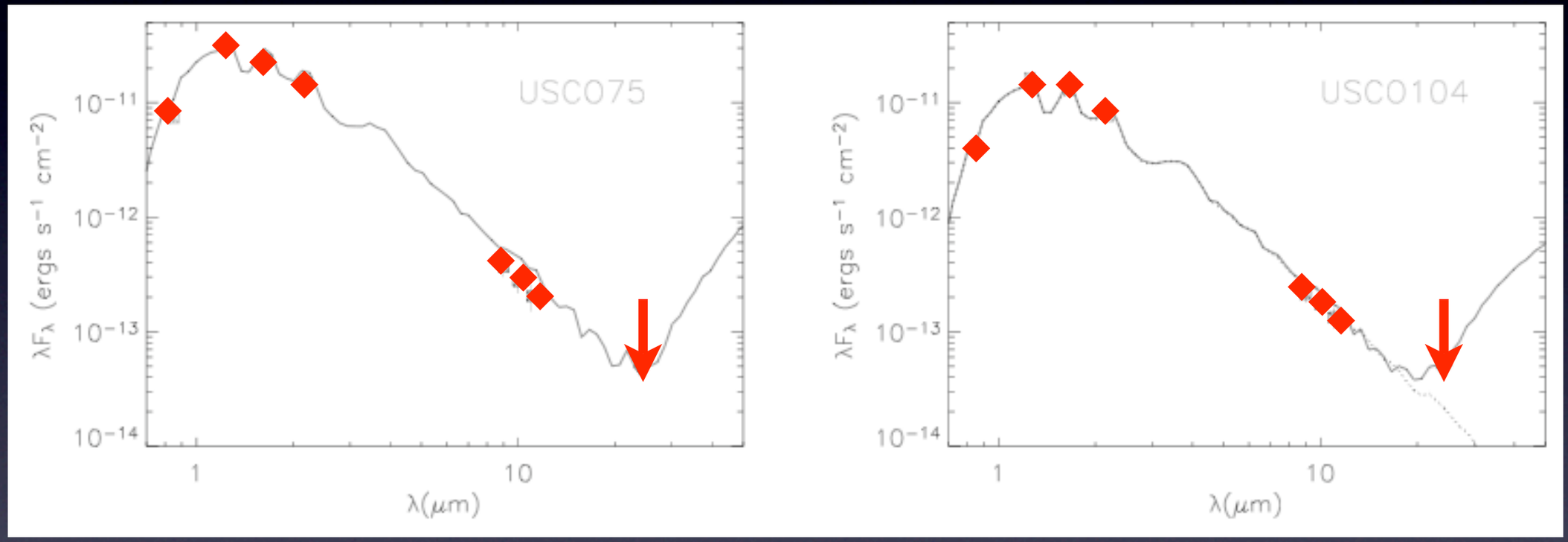
- BDs with inner opacity holes with radii 0.1-1AU, i.e. at 2-5μm

- fraction might be as large as 50%? but low contrast makes detection problematic

- mass dependence? age dependence? binarity or transition objects?

Muzerolle et al. 2006, Luhman et al. 2007, Sicilia Aguilar et al. 2008

Large inner holes?



Scholz et al. 2007

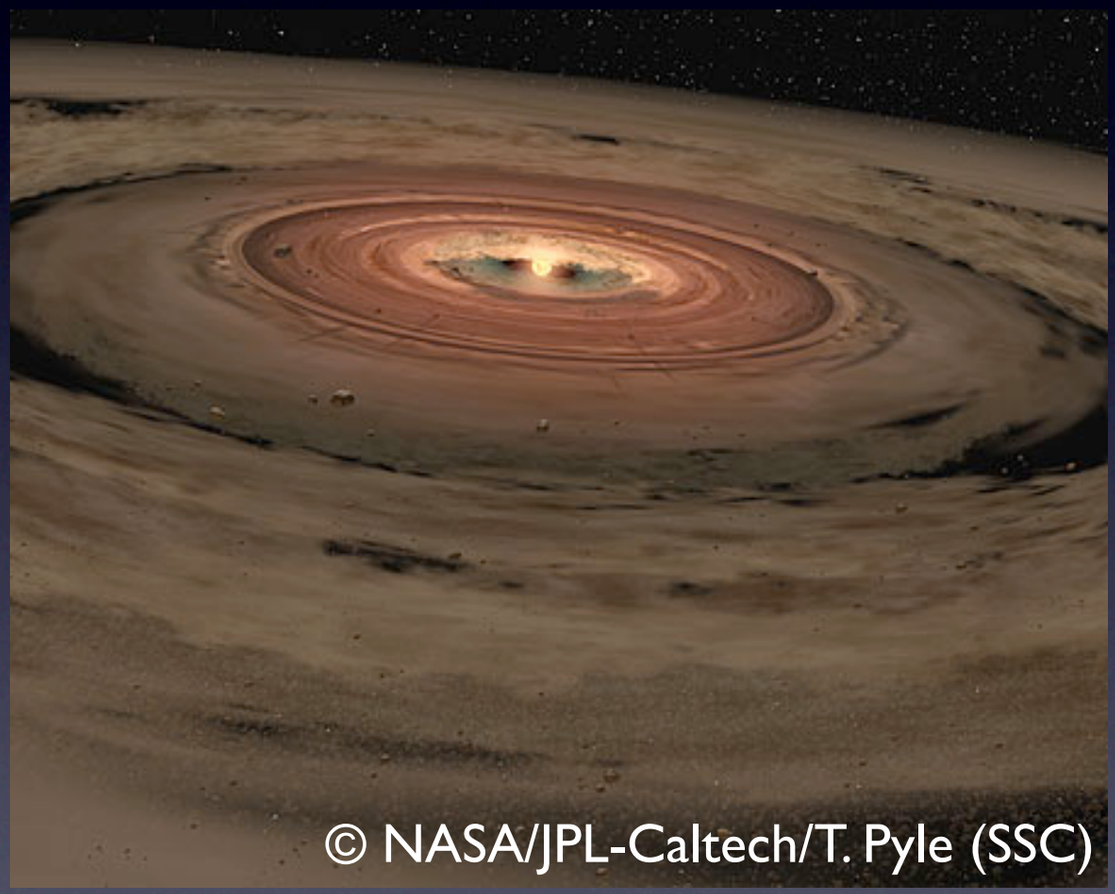
UpSco: ~60% BDs are either diskless or have disks with 5-10AU holes

→ a substellar 'GM Aur' is hard to find with Spitzer

→ BD disk fractions might in fact be underestimated

The lowest mass CTTS

- probing for the 'bottom of the IMF': disks around 'planemos'
- disk excesses at 3-8μm detected for objects down to ~8 Mjup



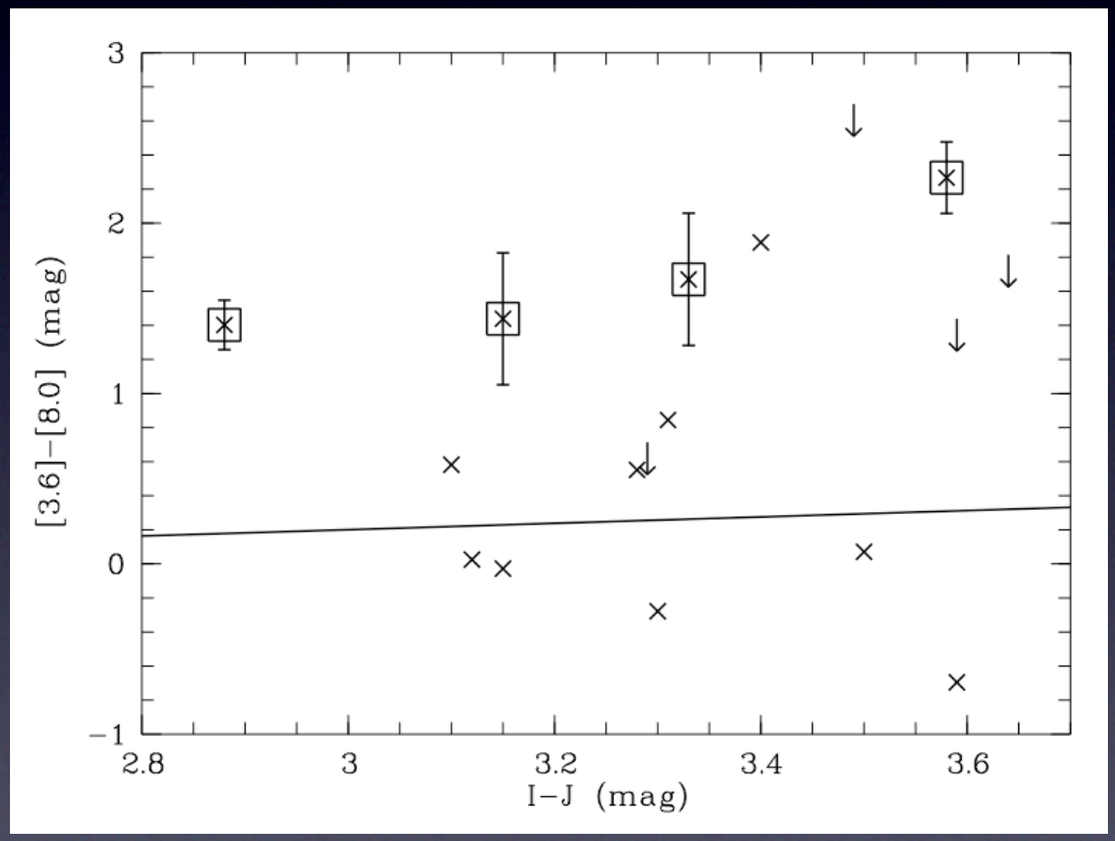
Luhman et al 2005a,b, 2008, Allers et al. 2006

The bottom of the IMF

- disk fraction at 8-20 Mjup: 29 ±15%, indistinguishable from the values for stars/BDs

- common formation scenario for objects from 0.008 to 2 Msol

- but ejection allows for small disks, needs longer wavelength data



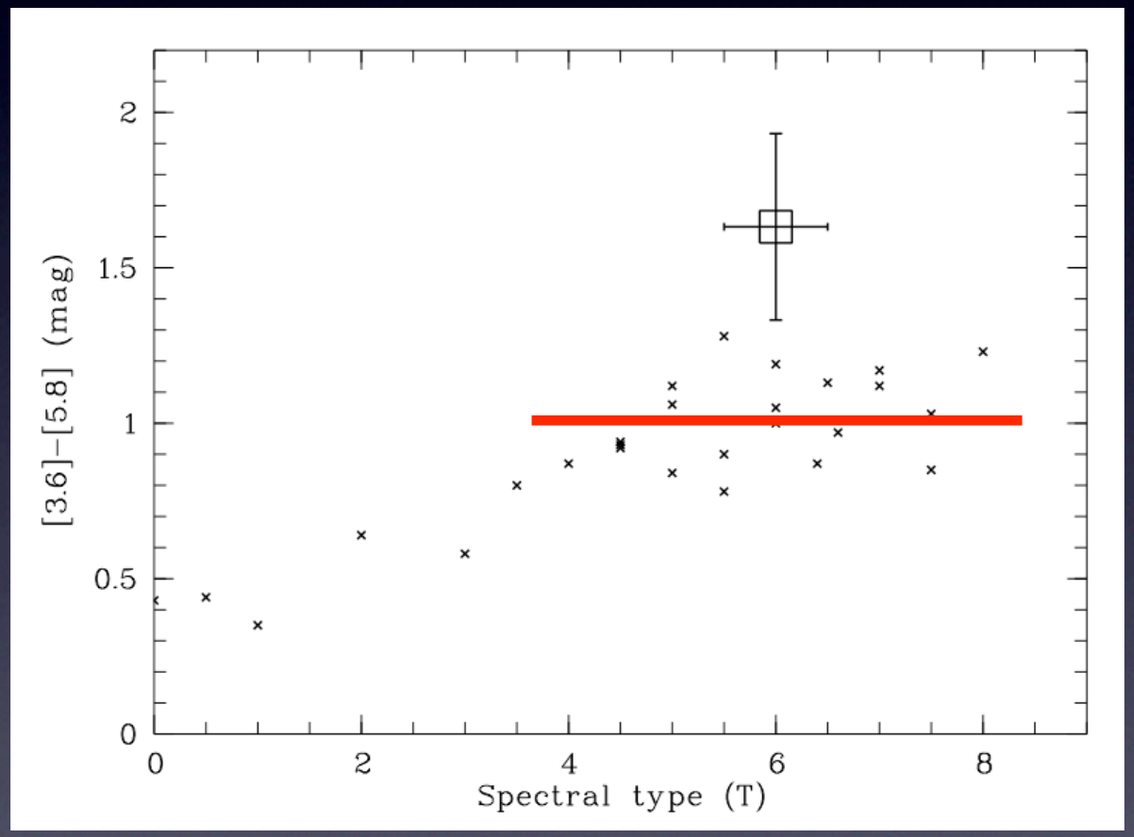
Scholz & Jayawardhana 2008

Beyond Spitzer: SOri 70

- SOri 70: debated young 3Mjup mass T dwarf, disk or not?

- IR colours ‘appear discrepant’ from field objects (ZO08), ‘2σ excess’ (SJ08), ‘redder, but low s/n’ (L08)

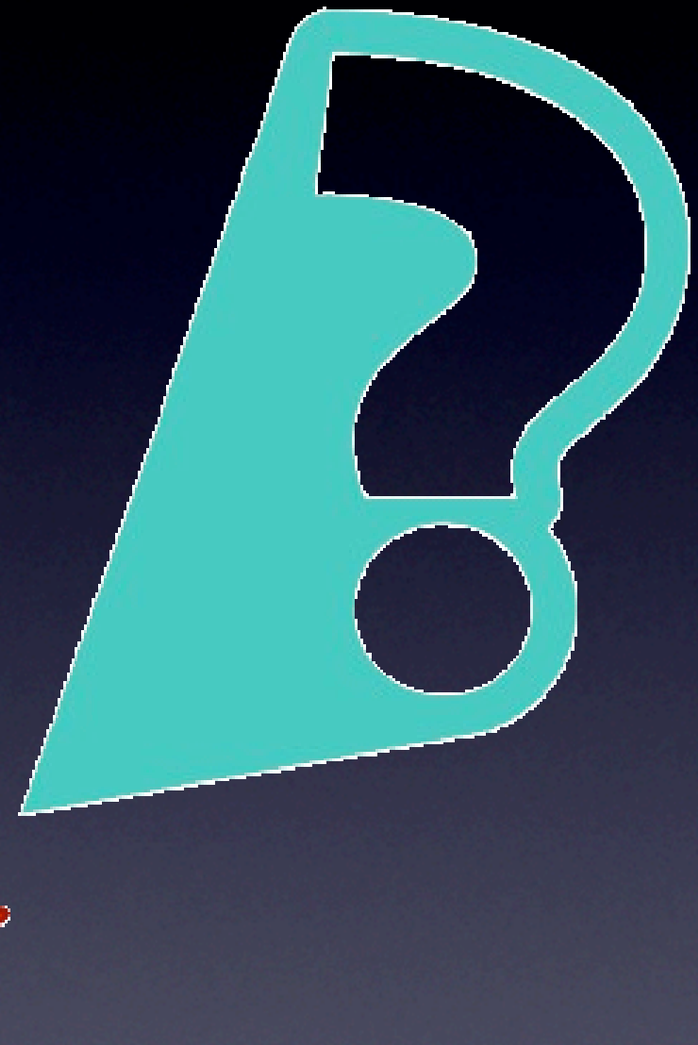
- unresolved issue, a task for JWST



Scholz & Jayawardhana 2008, Zapatero Osorio et al. 2008, Luhman et al. 2008

What did we learn?

- BD disk lifetimes longer than in stars
- disk evolution: BD follow the T Tauri ‘blueprint’, efficient grain processing
- planemo disks are as common as BD disks
- new brown dwarfs with disks detected



The implications

- formation process continuous over >2 orders of magnitude in object mass

- planemos are (probably) brown dwarfs

- BD disks are compatible with planet formation