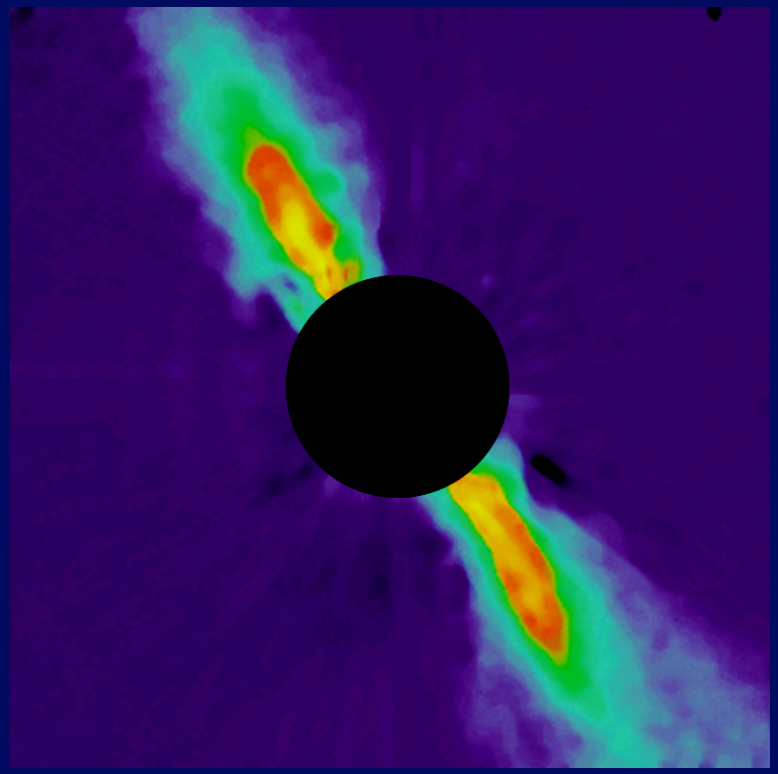
Debris disk census from 5 Myr to 5 Gyr

John Carpenter

Beta Pic

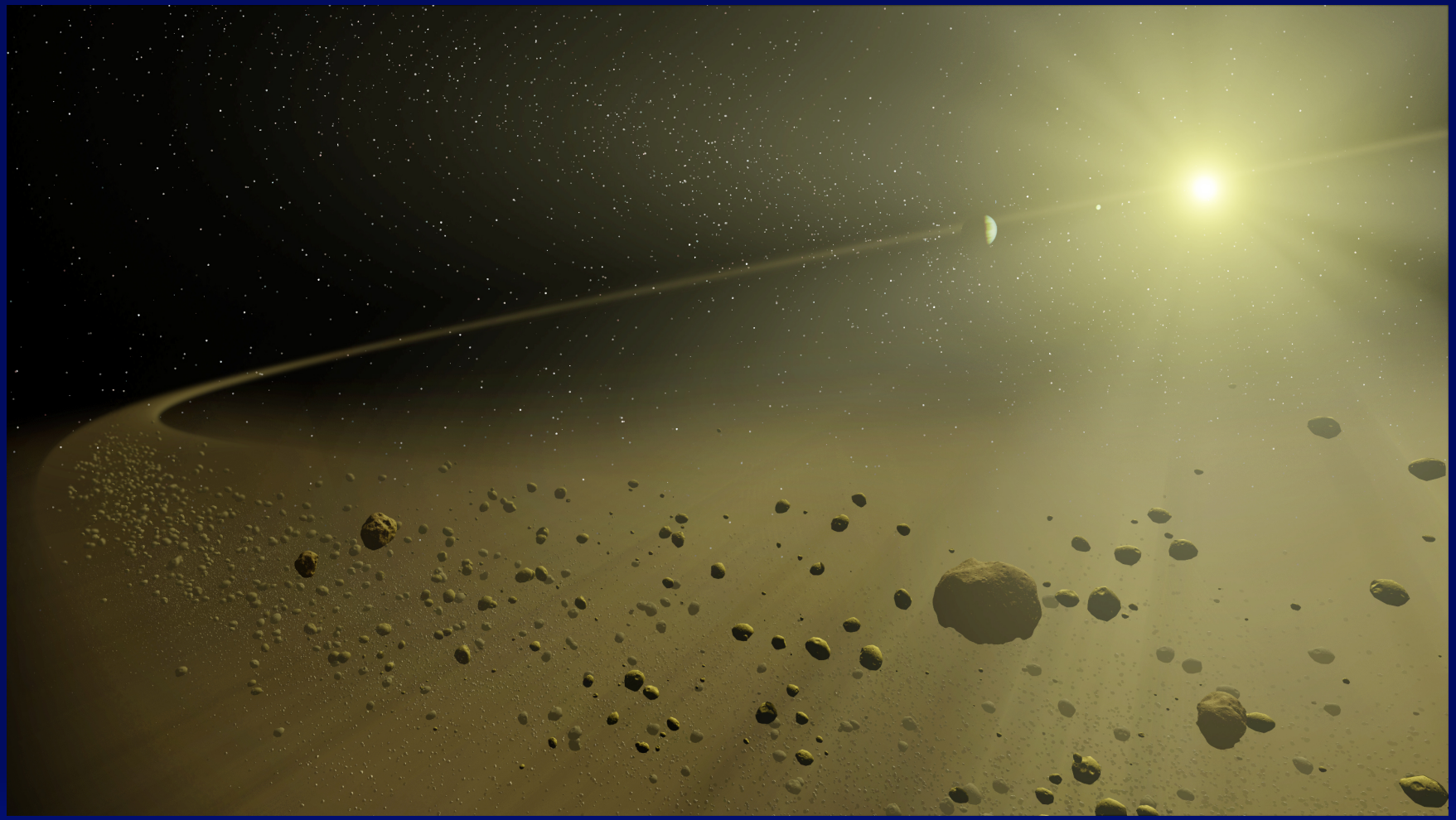


Mouillet et al. (1997)

Solar System

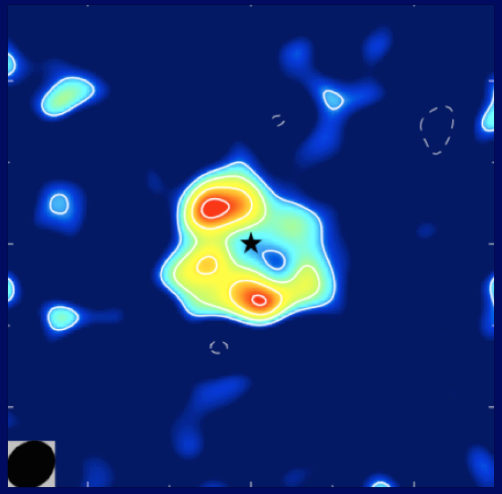
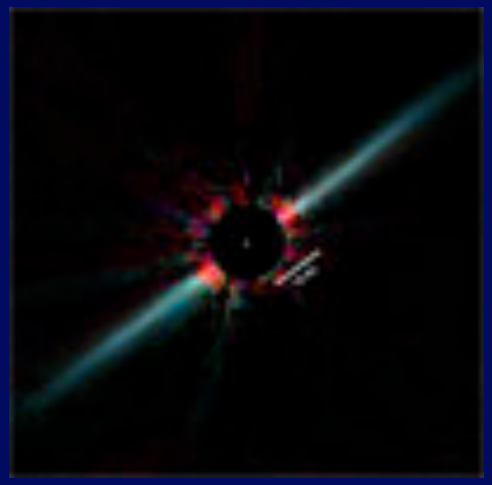
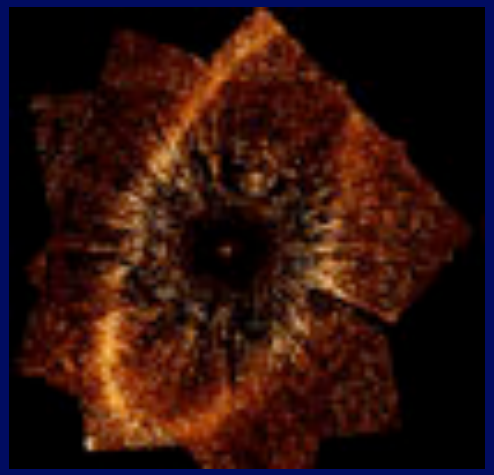
Paul Kalas

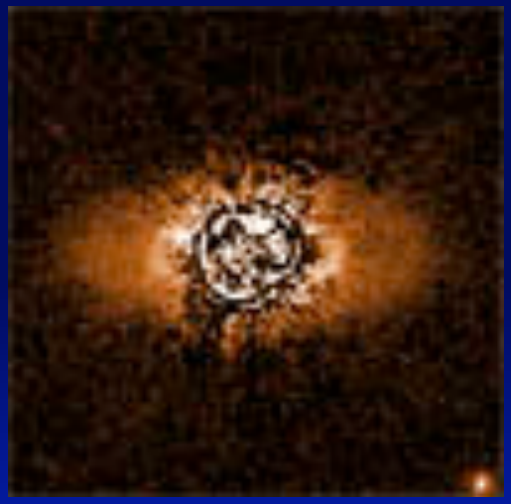
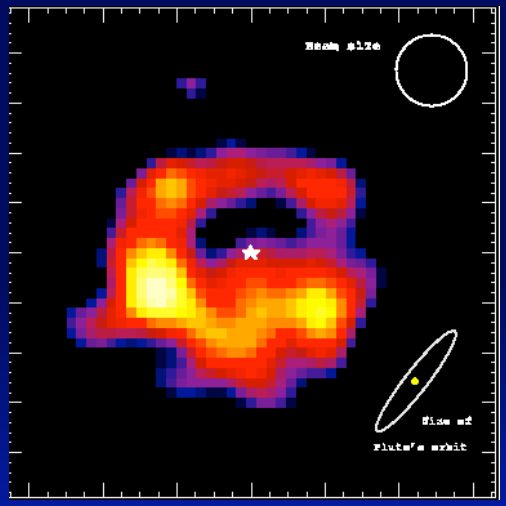
Why study debris disks?



What can we learn from debris disks?

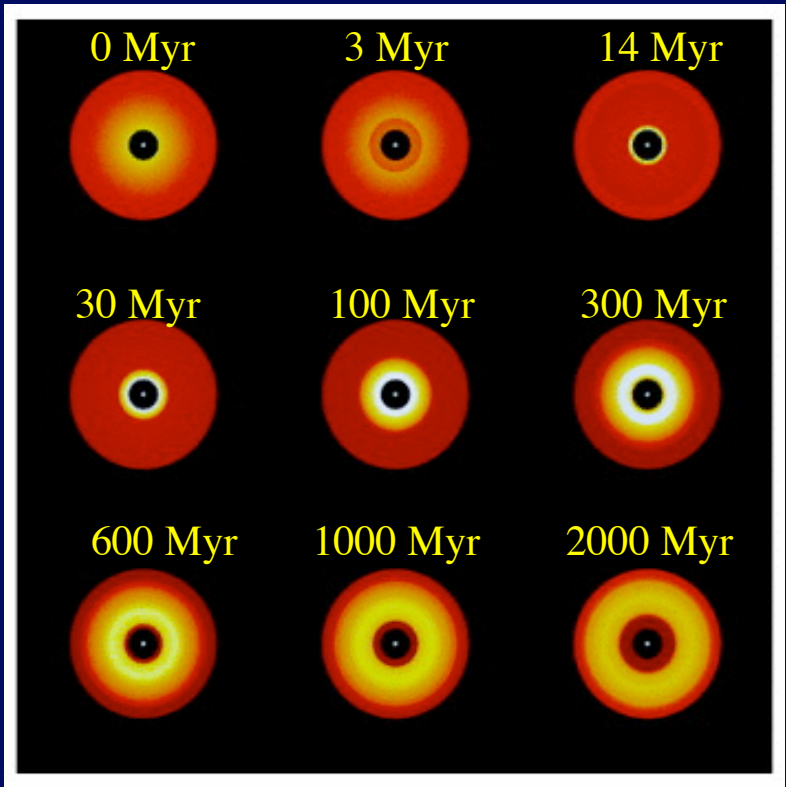
Diversity of planetary systems

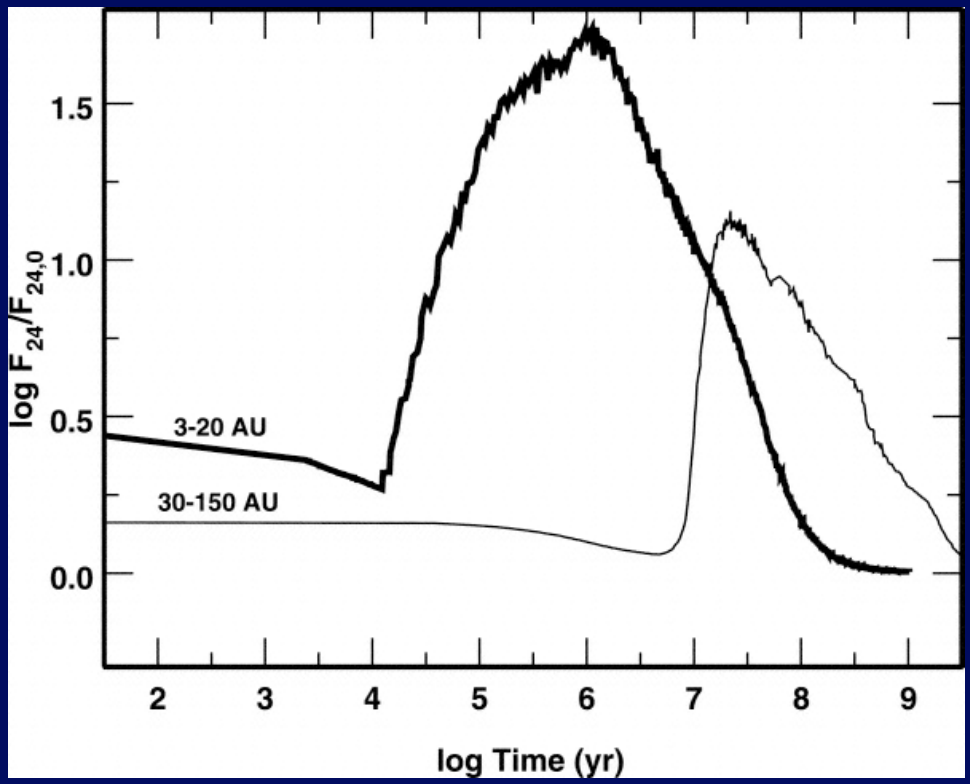



What can we learn from debris disks?

Formation of planetary systems



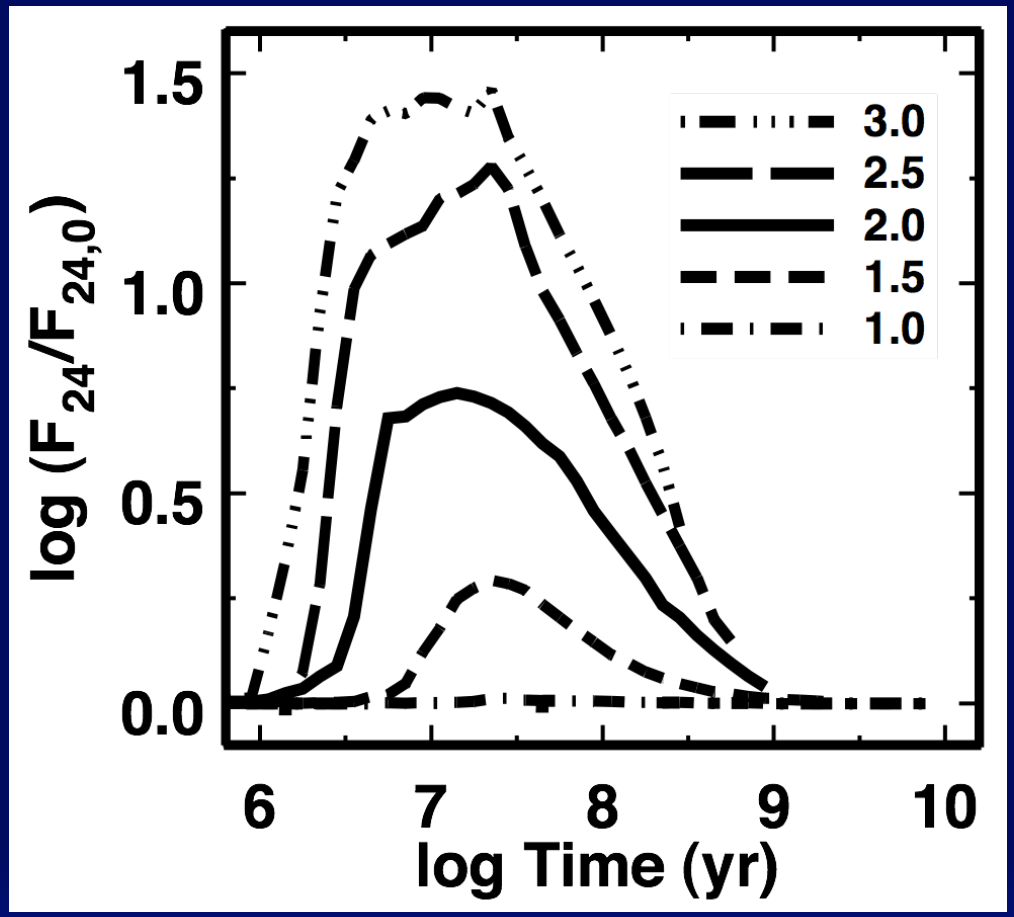
Kenyon & Bromley (2002)



Kenyon & Bromley (2005)

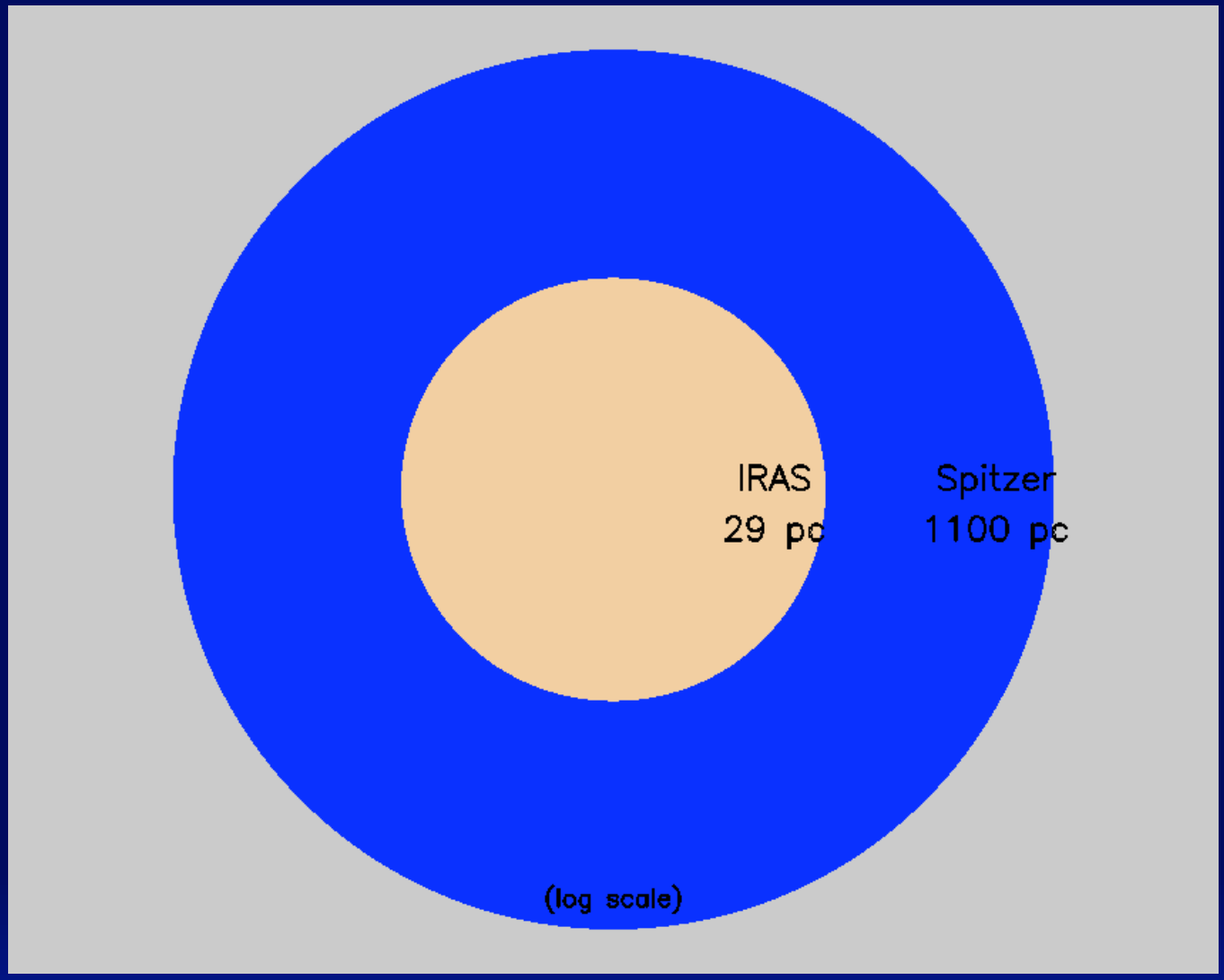
What can we learn from debris disks?

Planet formation across the mass spectrum

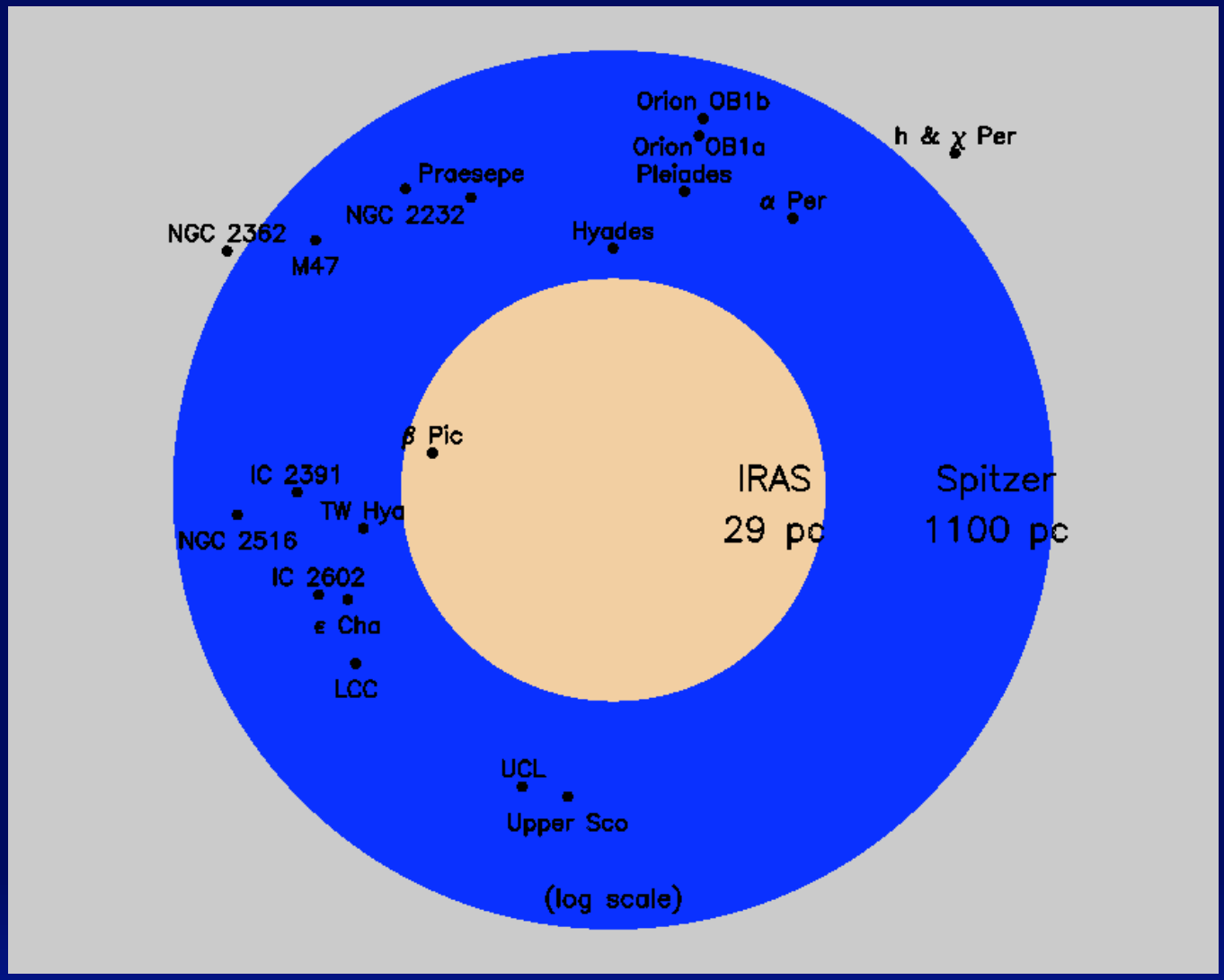


Kenyon & Bromley (2008)

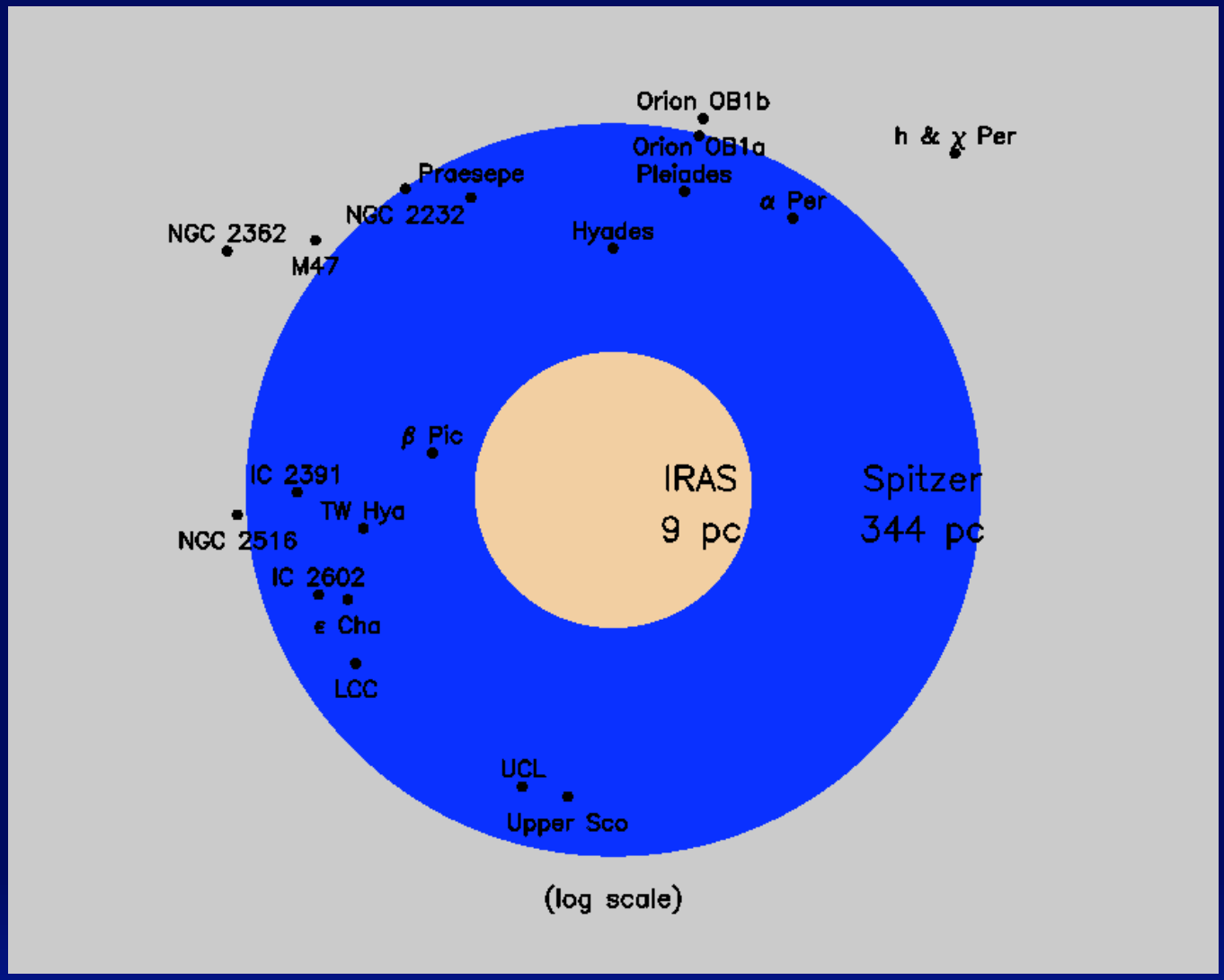
Sensitivity @ 24μm (A0 stars)



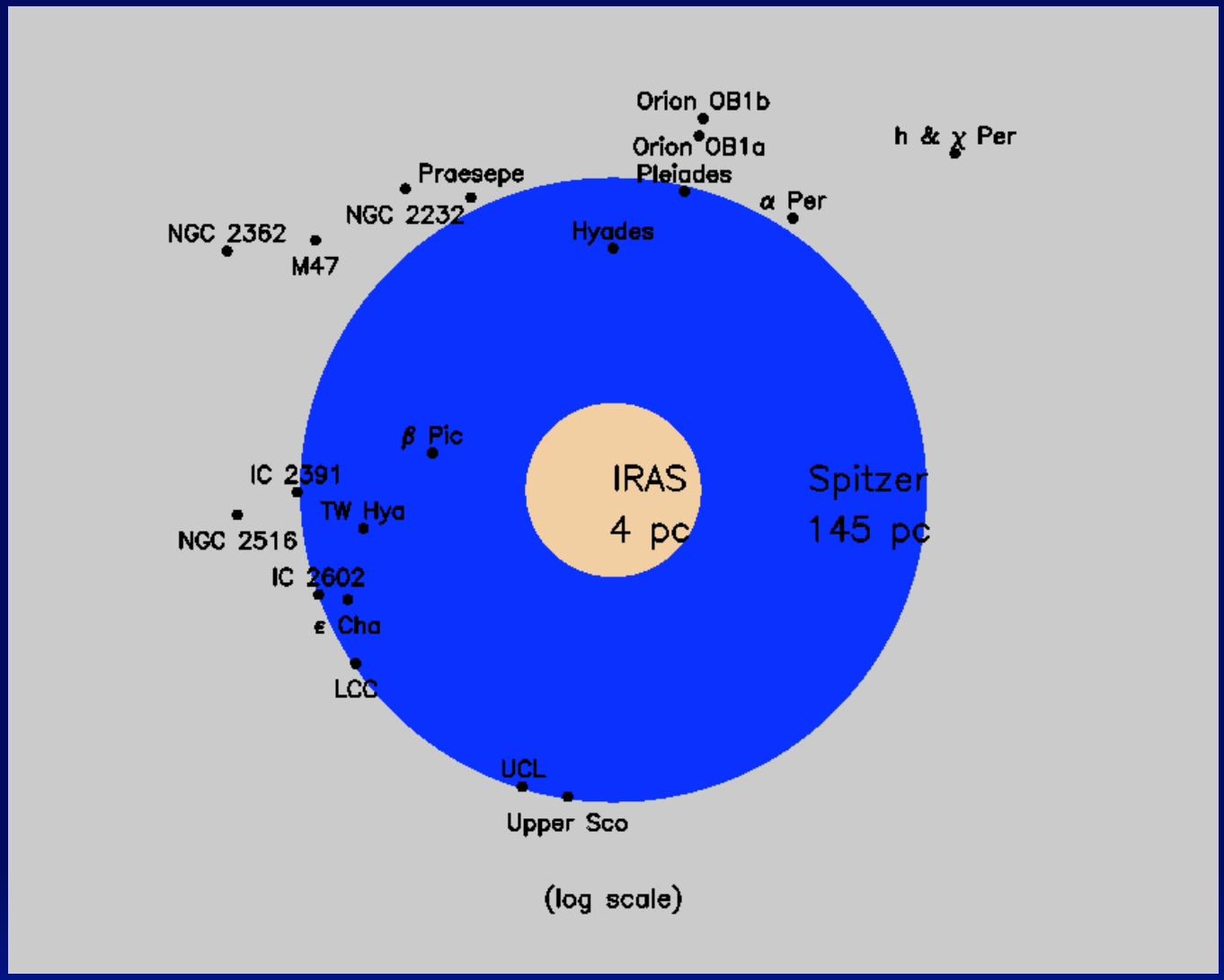
Sensitivity @ 24μm (A0 stars)



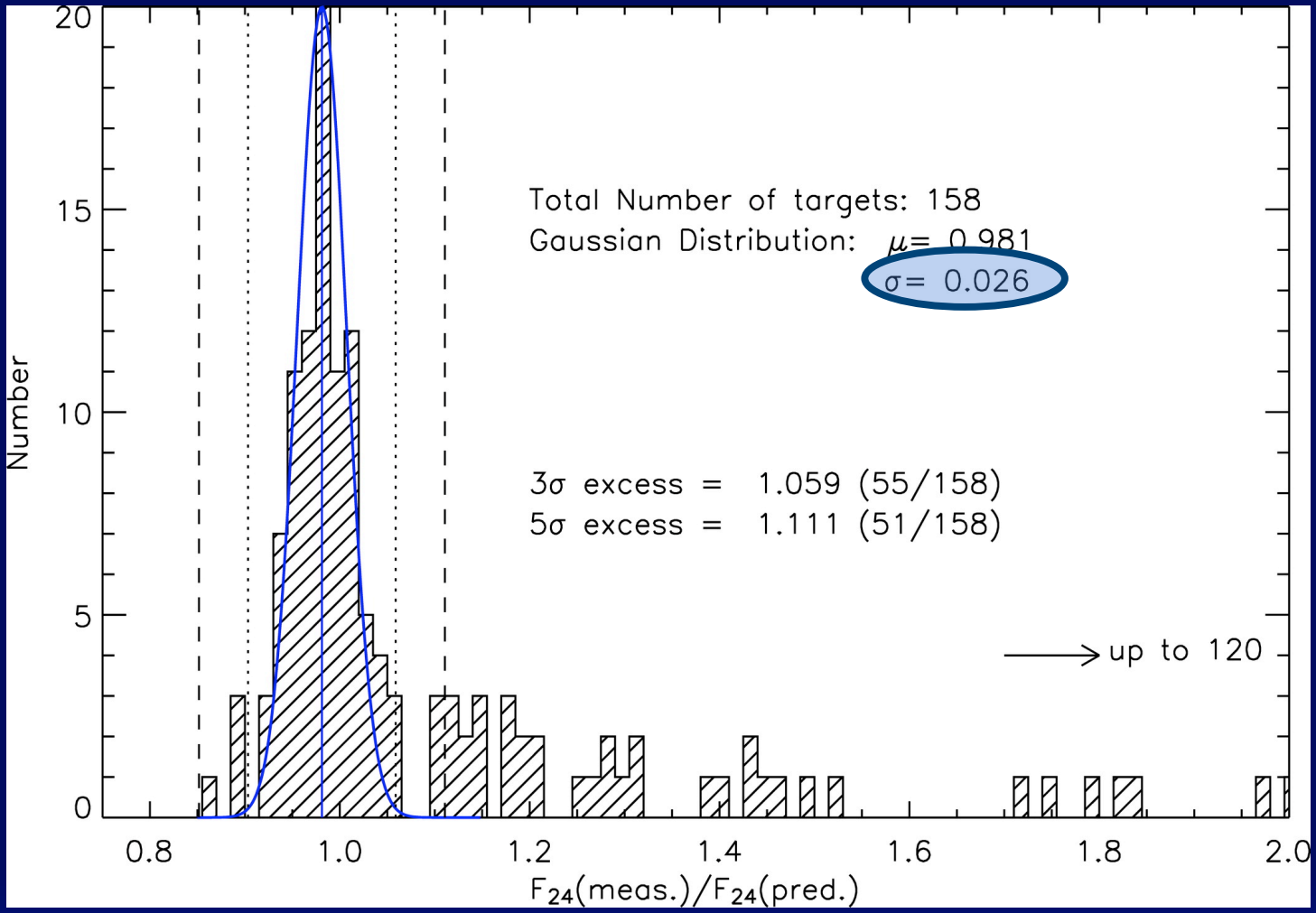
Sensitivity @ 24μm (G0 stars)



Sensitivity @ 24μm (M0 stars)



Photometric Accuracy and Precision



Su et al. (2006)

Goals of this talk …

- Highlight selected topics…
  - Clusters vs. Associations vs. Field stars
  - Binary stars
  - Metallicity
  - Planets
  - Rotation/x-rays
  - Gas
- Debris disk correlations with …
  - Stellar mass (spectral type)
  - Age

What I will not cover …

- Theory of debris disks
  - Talks by Wyatt, Löhne
- Resolved images of debris disks
  - Talks by Staplefeldt, Maness, Su

Debris Disks Observations

- A stars
  - Rieke et al. (2005, ApJ, 620, 1010)
  - Su et al. (2006, ApJ, 653, 675)
  - Trilling et al. (2007, ApJ, 658, 1289)
- FGK stars
  - Beichman, Bryden, & Trilling series
  - FEPS series (P.I. Meyer)
- M stars
  - Gautier et al. (2007, ApJ, 667, 527)
  - Forbrich et al. (2008, in press)
  - Poster #110 by Plavchan

Cluster / Association Surveys

- Cep OB2 (4-10 Myr)
  - Sicilia-Aguilar et al. (2006, ApJ, 638, 897)
- Orion OB1a/b (5-10 Myr)
  - Hernández et al. (2006, ApJ, 652, 472)
  - Hernández et al. (2007, ApJ, 671, 1784)
- Sco-Cen (5-17 Myr)
  - Chen et al. (2005, ApJ, 623, 493)
  - Carpenter et al. (2006, ApJ, 651, L49)

Cluster Surveys

- ϒ Vel (5 Myr)
  - Hernández et al. (2008, ApJ, 686, 1195)
- Eta Cha (8 Myr)
  - Gautier et al. (2008, ApJ, 683, 813)
- TW Hydra (10 Myr)
  - Uchida et al. (2004, ApJS, 154, 439)
  - Low et al. (2005, ApJ, 631, 1170)

Cluster Surveys

- Beta Pic (12 Myr)
  - Rebull et al. (2008, ApJ, 681, 1484)
- h and χ Persei (13 Myr)
  - Currie et al. (2007, ApJ, 659, 599)
  - Currie et al. (2007, ApJ, 663, L105)
  - Currie et al. (2007, ApJ, 672, 558)
- NGC 2232 (25 Myr)
  - Currie et al. (2008, astroph 0807.2056)

Cluster Surveys

- NGC 2547 (30 Myr)
  - Young et al. (2004, ApJS, 154, 428)
  - Gorlova et al. (2007, ApJ, 670, 516)
  - Forbrich et al. (2008, in press)
- IC 2391 (50 Myr)
  - Siegler et al. (2007, ApJ, 654, 580)
- M47 (100 Myr)
  - Gorlova et al. (2004, ApJS, 154, 448)

Cluster Surveys

- Pleiades (125 Myr)
  - Stauffer et al. (2005, AJ, 130, 1834)
  - Gorlova et al. (2006, ApJ, 649, 1028)
- Hyades (625 Myr)
  - Cieza et al. (2008, ApJ, 679, 720)

Clusters / Associations / Field stars

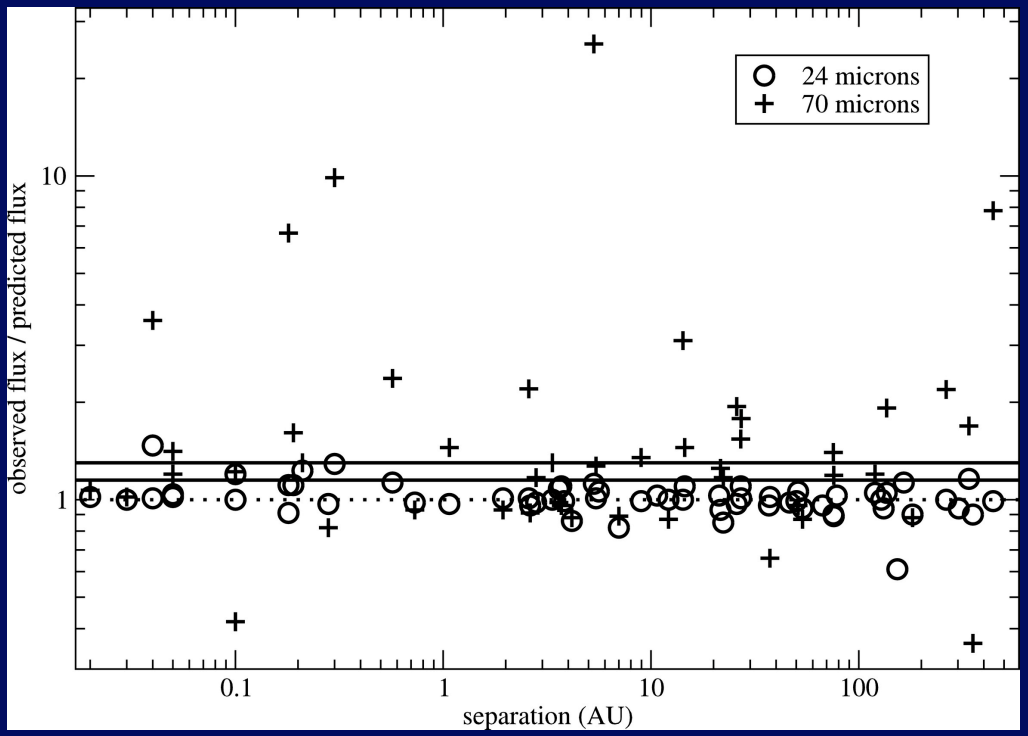
- FEPS
  - 24um excess fraction younger than 300 Myr:

    Clusters : 18% +/- 7%

    Associations : 20% +/- 6%

    Field : 12 % +/- 4%

Binary Stars

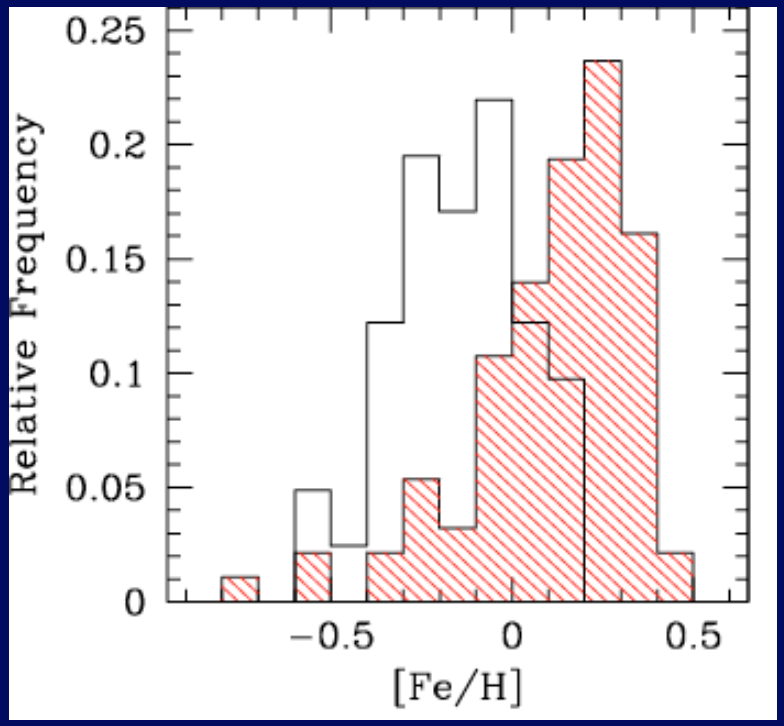


Trilling et al. (2007)

- A-star binaries:
  - 38 ± 8% with 70μm excess for > 600 Myr
- Similar excess fraction for single A-stars
- See poster 111 (Rodriguez)

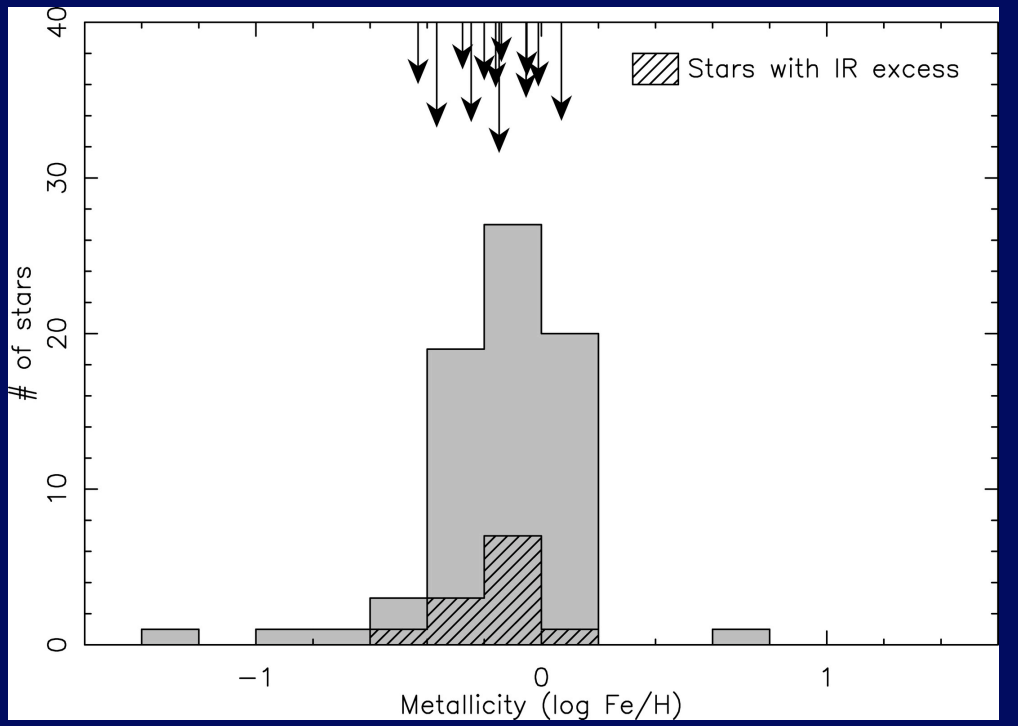
Metallicity

… correlated with giant planets



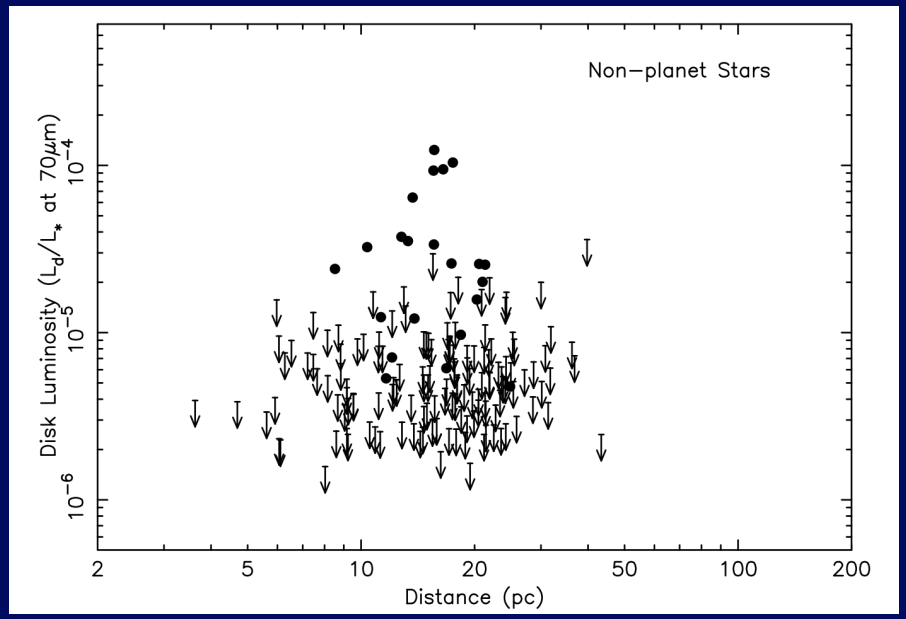
Santos et al. (2004)

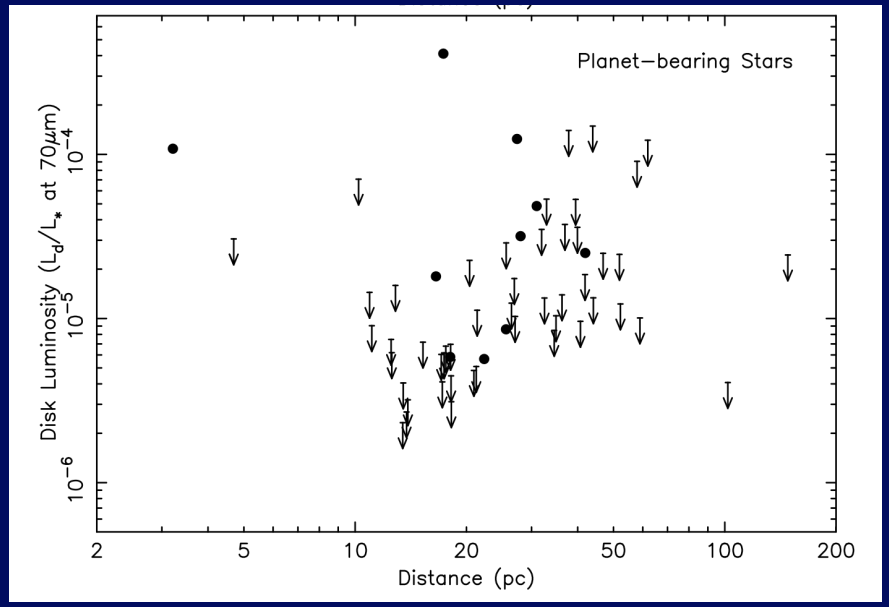
… but not with debris.



Beichman et al. (2006)
(see also Greaves et al. 2006)

Relation to Planets



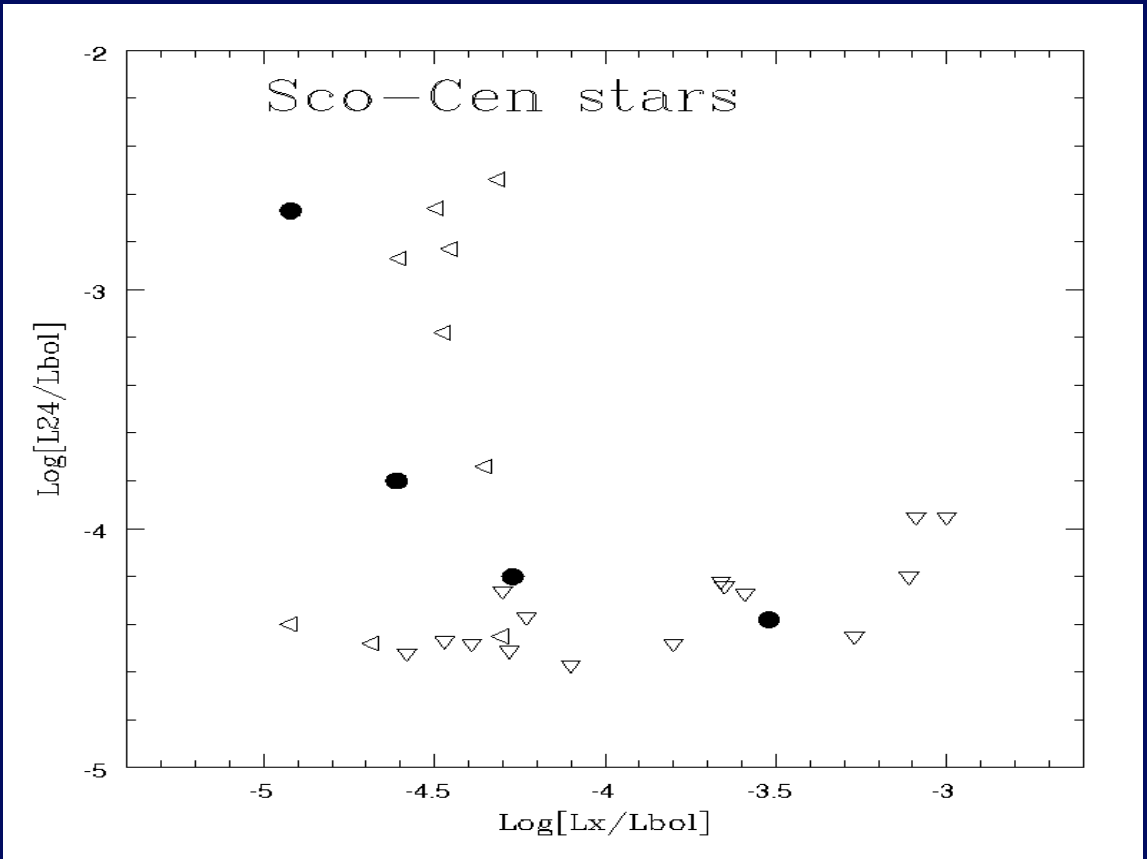


Bryden et al. (2006, 2008)

Moro-Martín et al. (2007a,b)

No strong correlation with (known) planets and excess

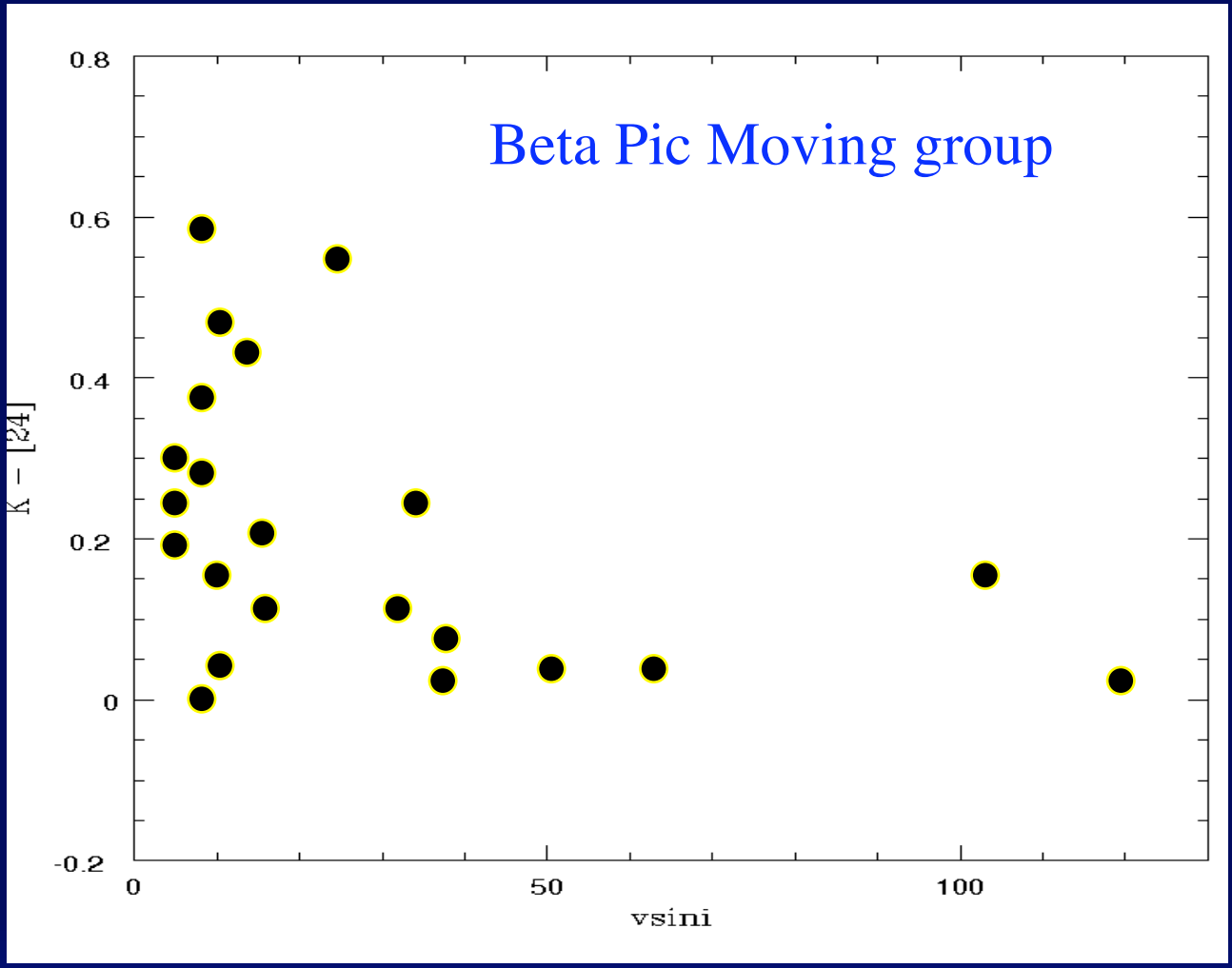
Rotation / X-rays



Infrared excesses around weak X-ray emitters

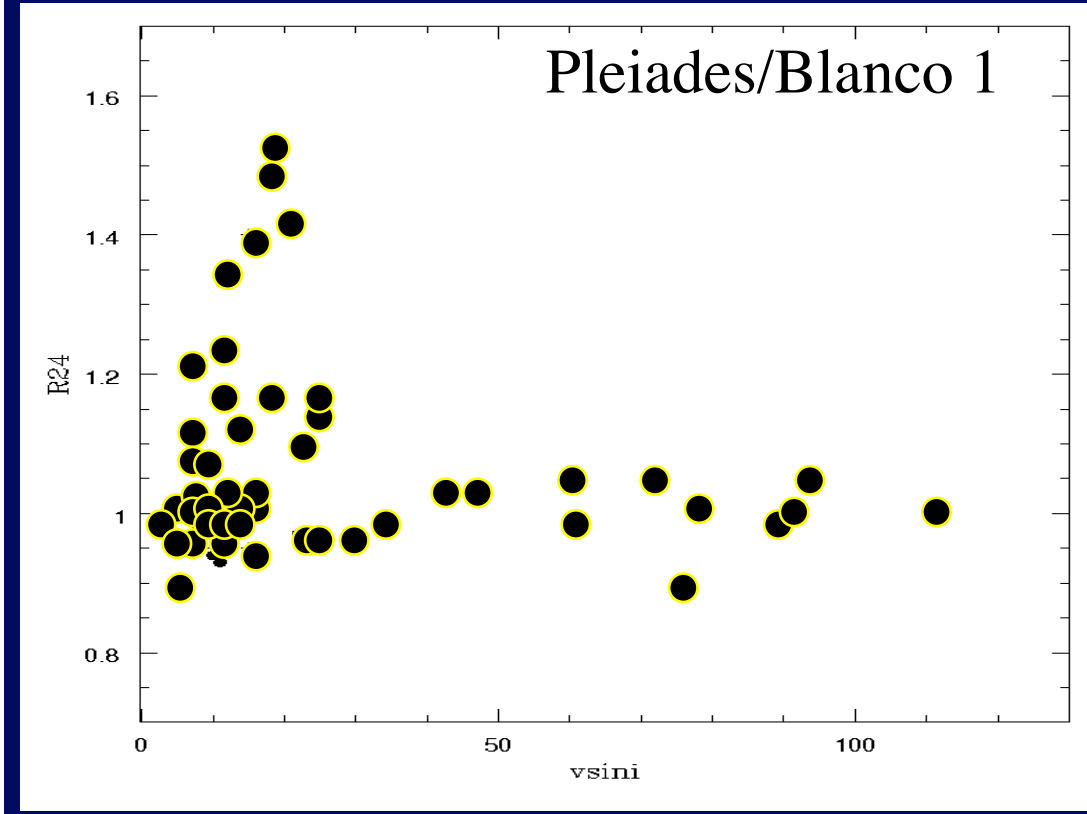
Chen et al. (2005)

Rotation / X-rays



Rebull et al. (2008)

Rotation / X-rays

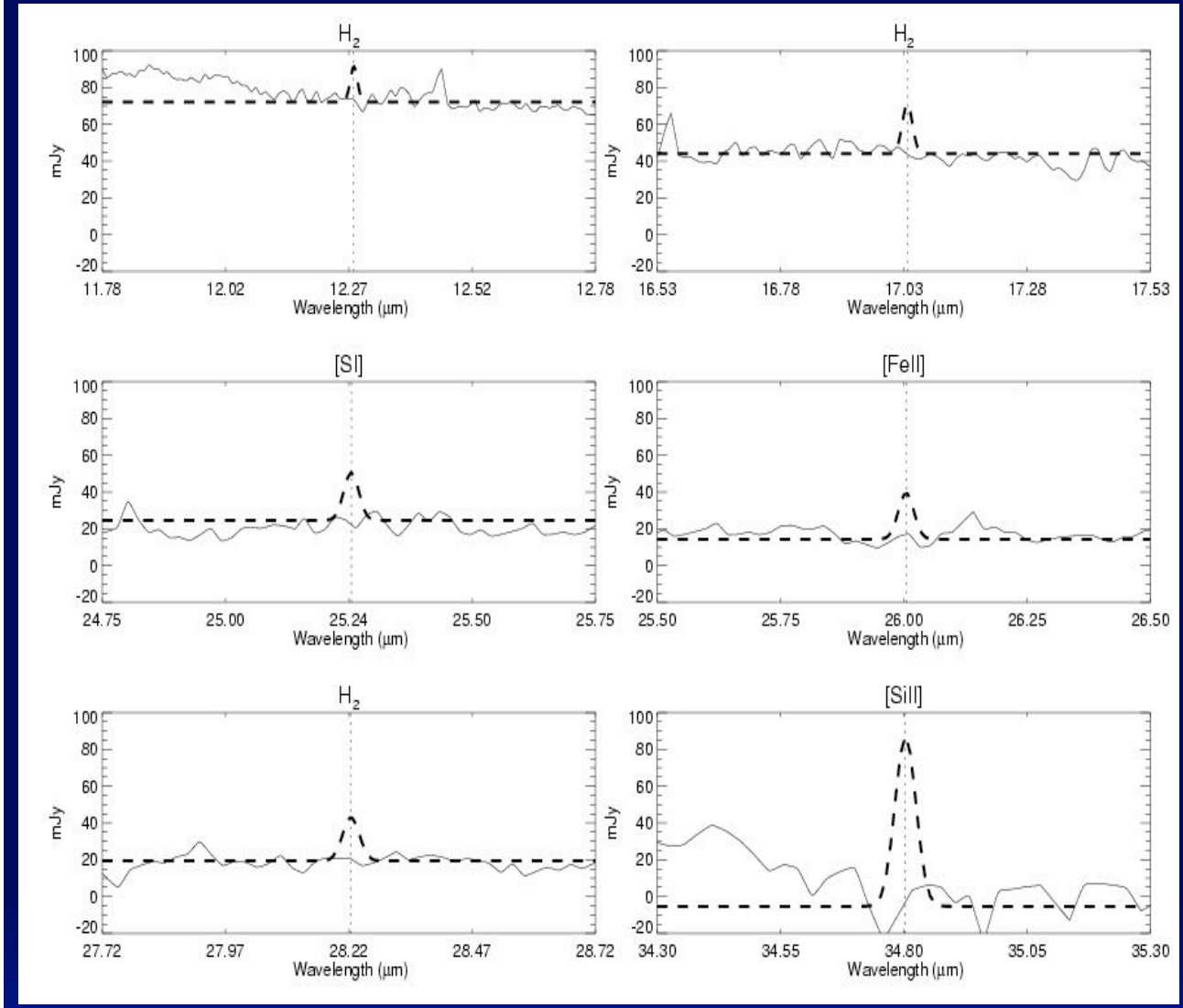


Stauffer et al. (2009)

- winds from rapidly rotating stars remove dust?
- stars with massive disks are slow rotators (disk locking)?

massive disk -> planetesimals

Gas in Debris Disks

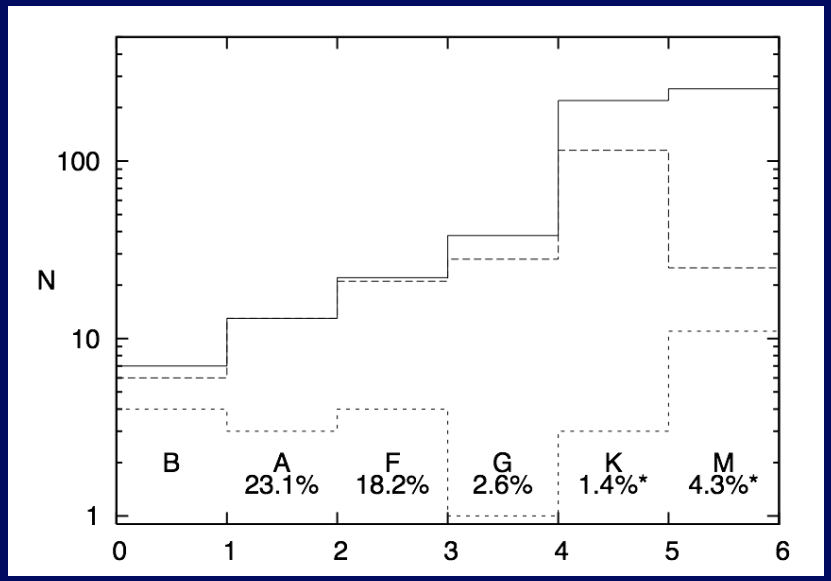


- 16 stars with ages of 5-280 Myr
- < 0.1 Mjup of gas in inner rim

Hollenbach et al. 2005; Pascucci et al. 2006

Debris around M-stars

NGC 2547 (~ 30 Myr)



Forbrich et al. (2008)
See also Gorlova et al. (2007)

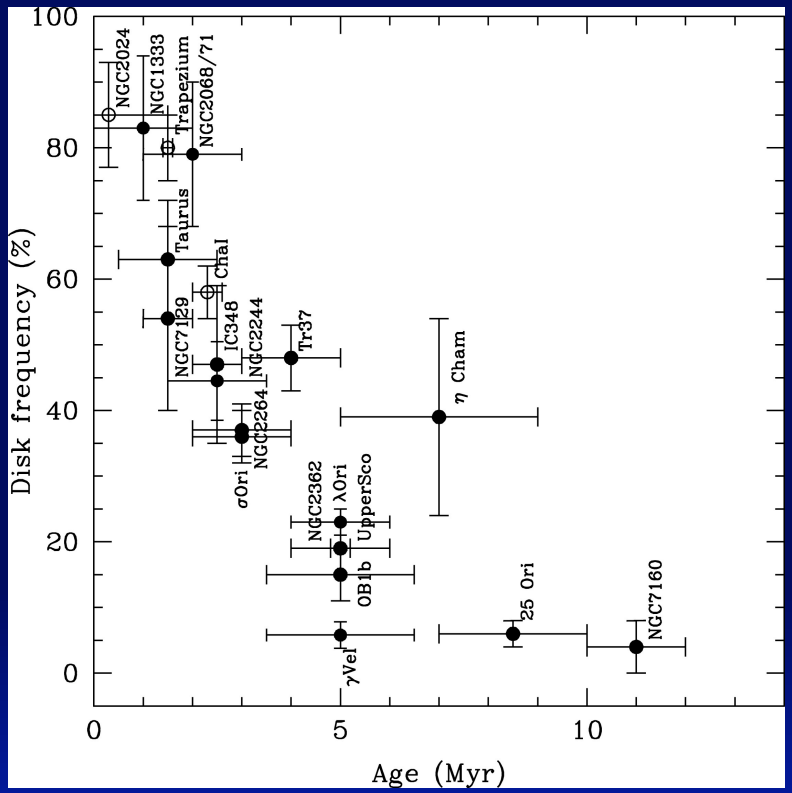
Initial surveys did not detect "old" M-dwarfs (> 1 Gyr) (Gautier et al. 2007)

Increasing sample of debris disks around young M stars

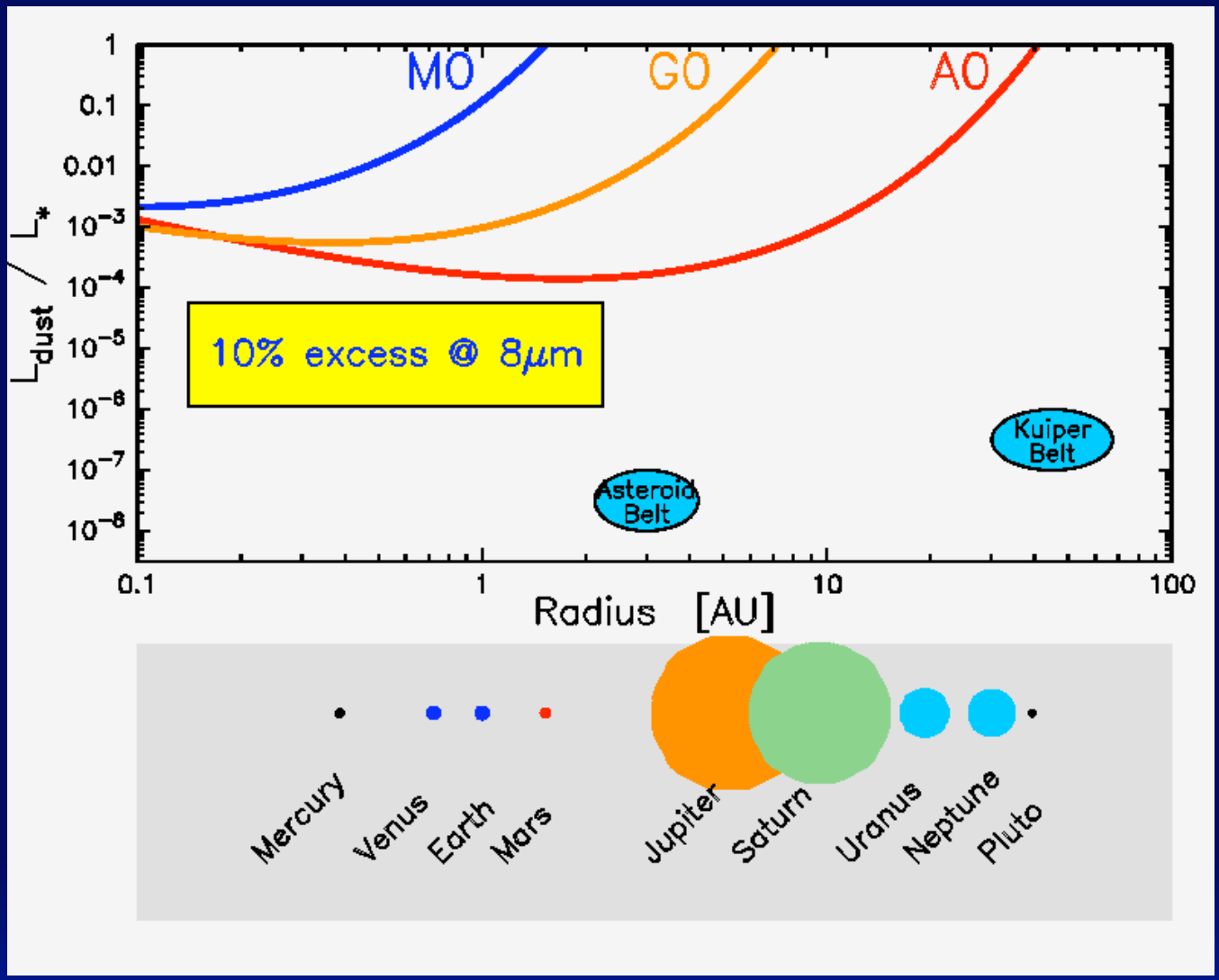
Posters by Plavchan, Forbrich, and Lestrade

Trends with Age and Spectral Type

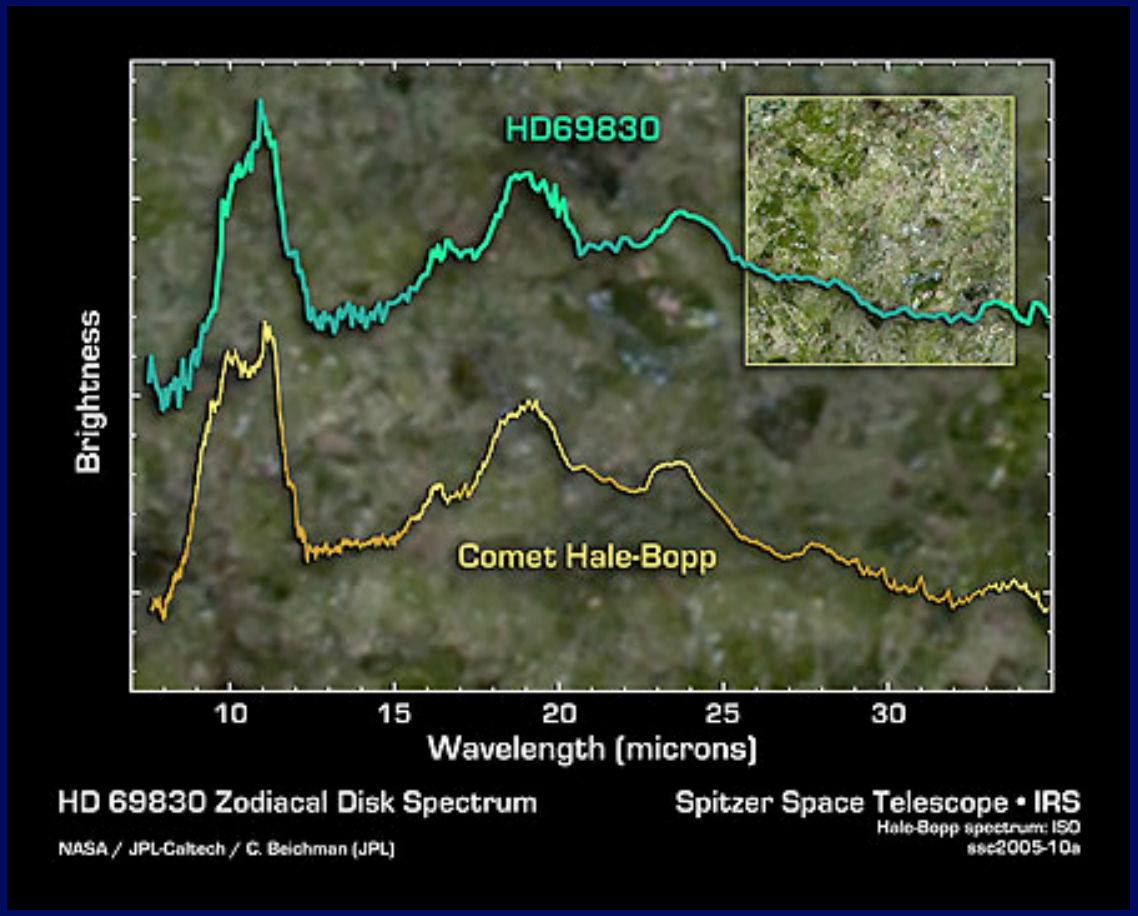
- Sample selection (AFGK stars)
  - Ages > 5 Myr
  - Apply uniform detection threshold
- See also
  - Hernández et al. (2006)
  - Siegler et al. (2007)
  - Rebull et al. (2008)
  - Currie et al. (2008a,b)
  - Spangler et al. (2001)
  - Habing et al. (1999, 2001)
  - Decin & Dominik (2003)



Sensitivity to Debris: IRAC



Warm Debris Disks (~ 300 K)

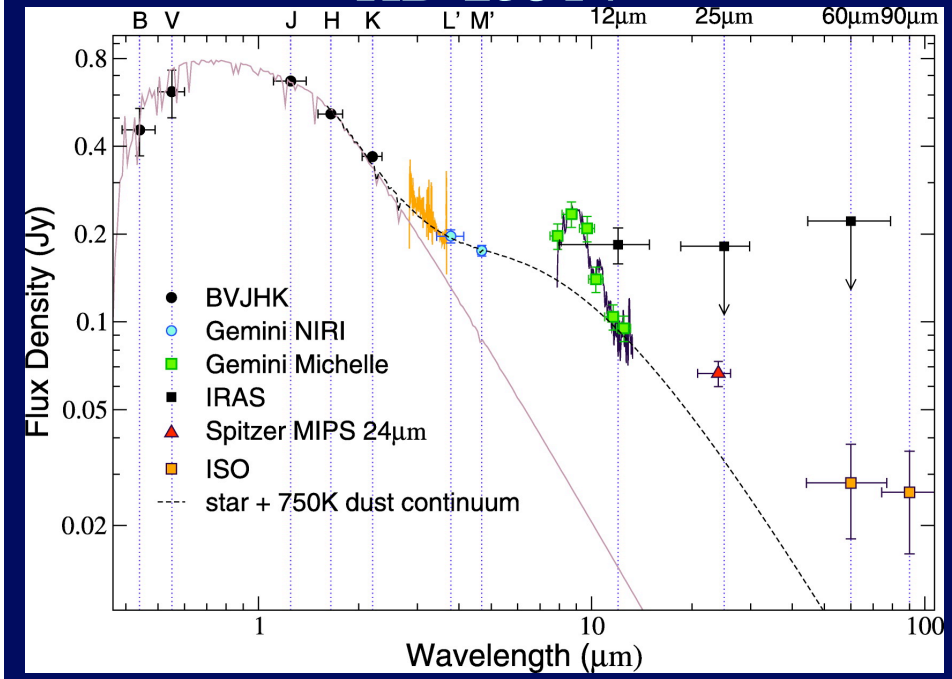


- Emission at ~1 AU
- Composition most similar to asteroids
- Another example in next talk!

Beichman et al. (2005)
(see also Lisse et al. 2007)

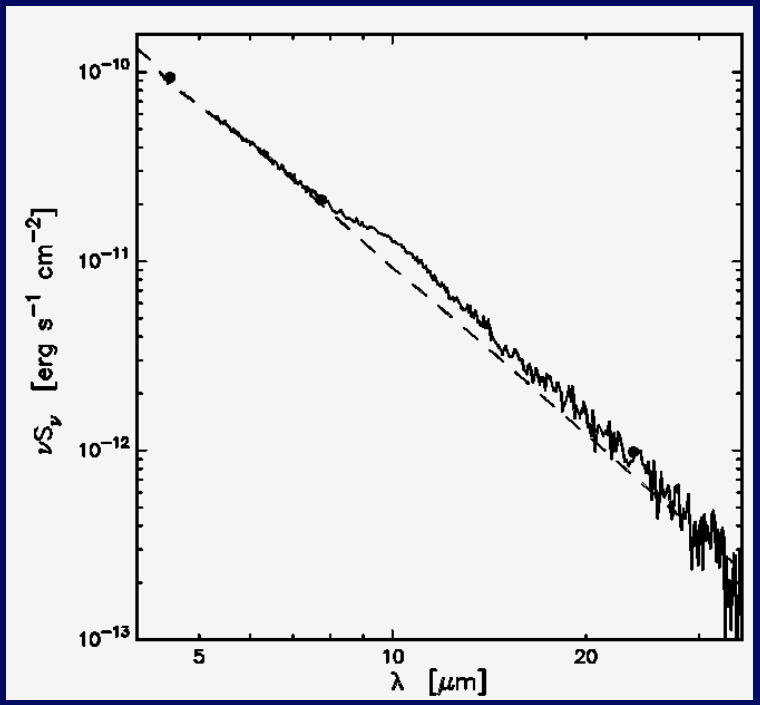
Warm Debris

HD 23514



Rhee et al. (2008)

1RXS J051111.1+281353

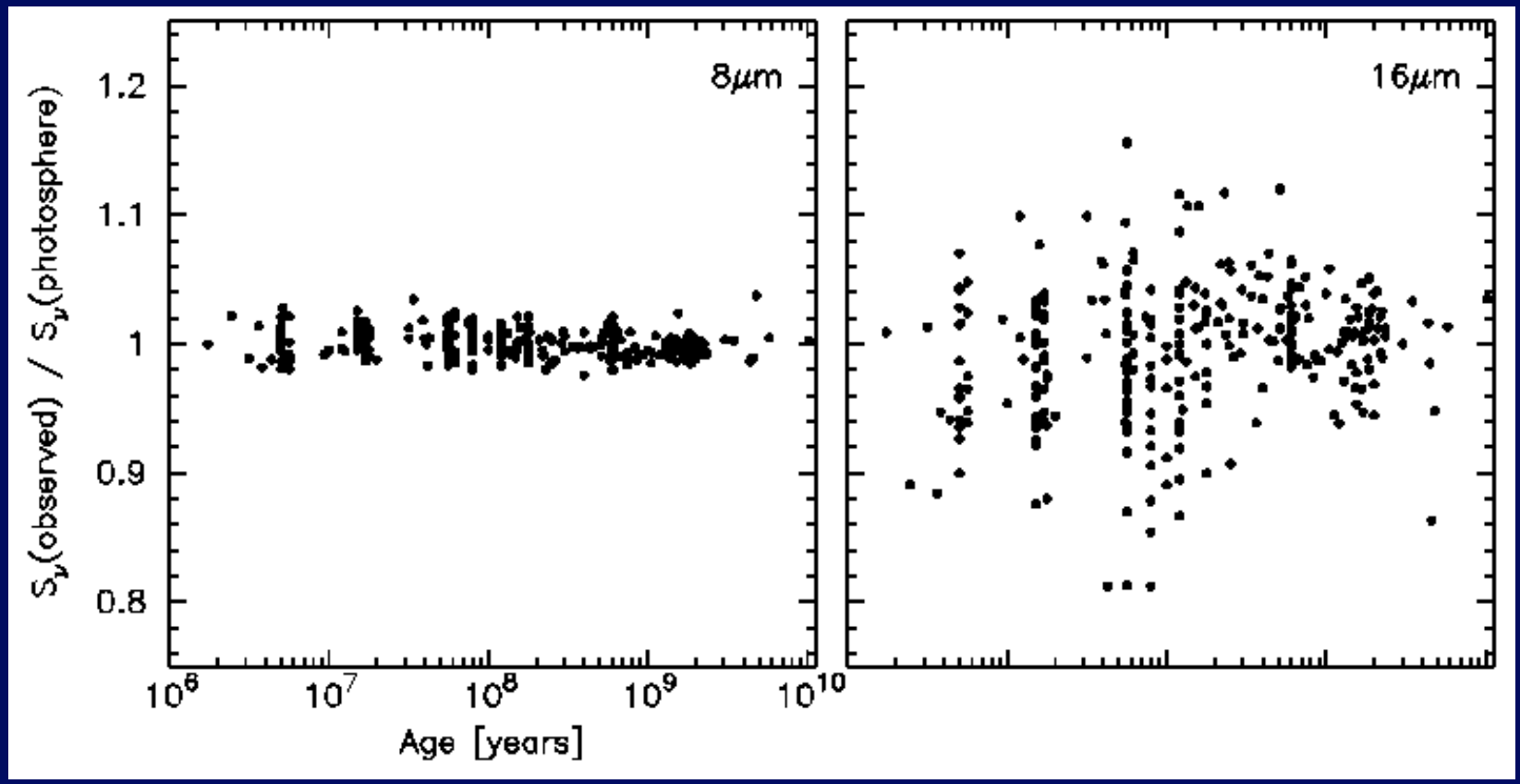


Carpenter et al. (2008)

Warm debris around solar type stars

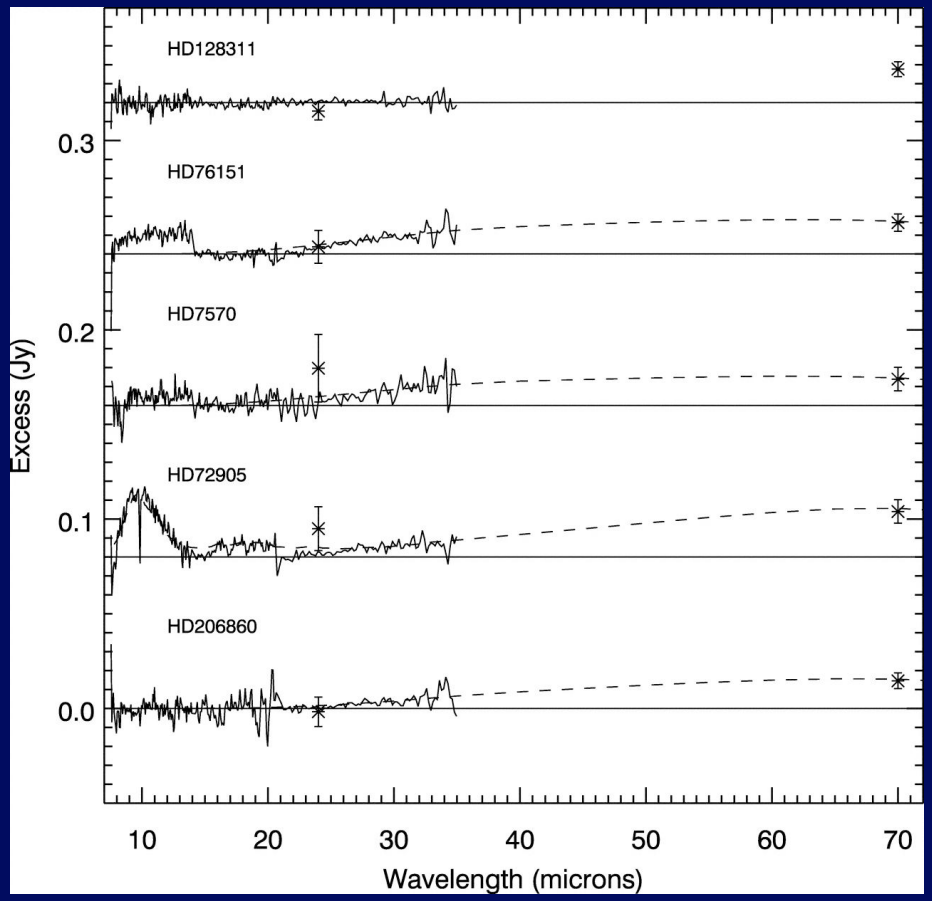
< 3% excess at 8μm

< 15% excess at 16μm



Carpenter et al. (2008)

Surveys for Warm Debris



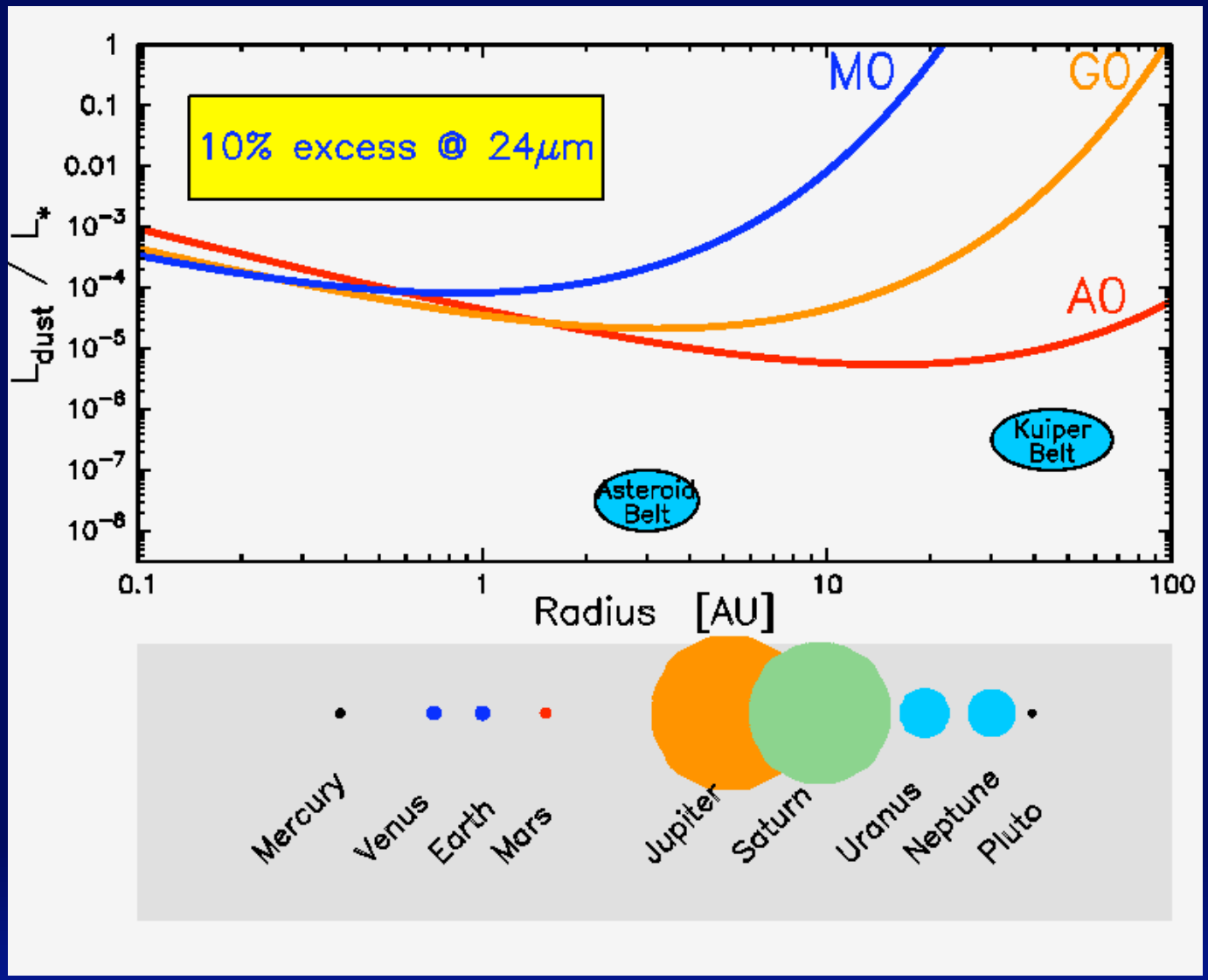
Beichman et al. (2006)

~ 2.5% of > 1 Gyr solar type stars with 300 K dust.

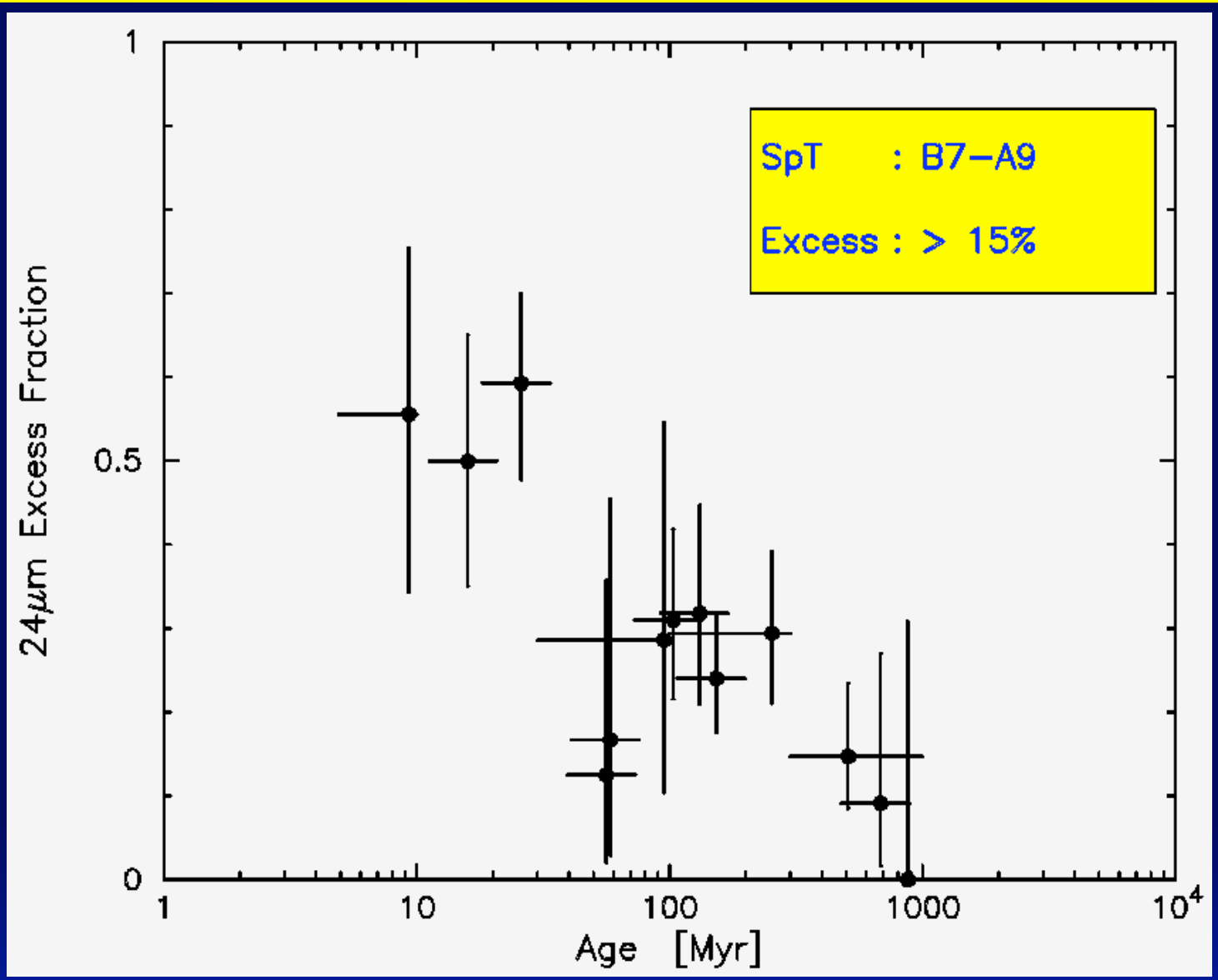
Limits: ~ 1400x zodiacal belt

See also
- Rhee et al. (2007)
- Talk by Thayne Currie

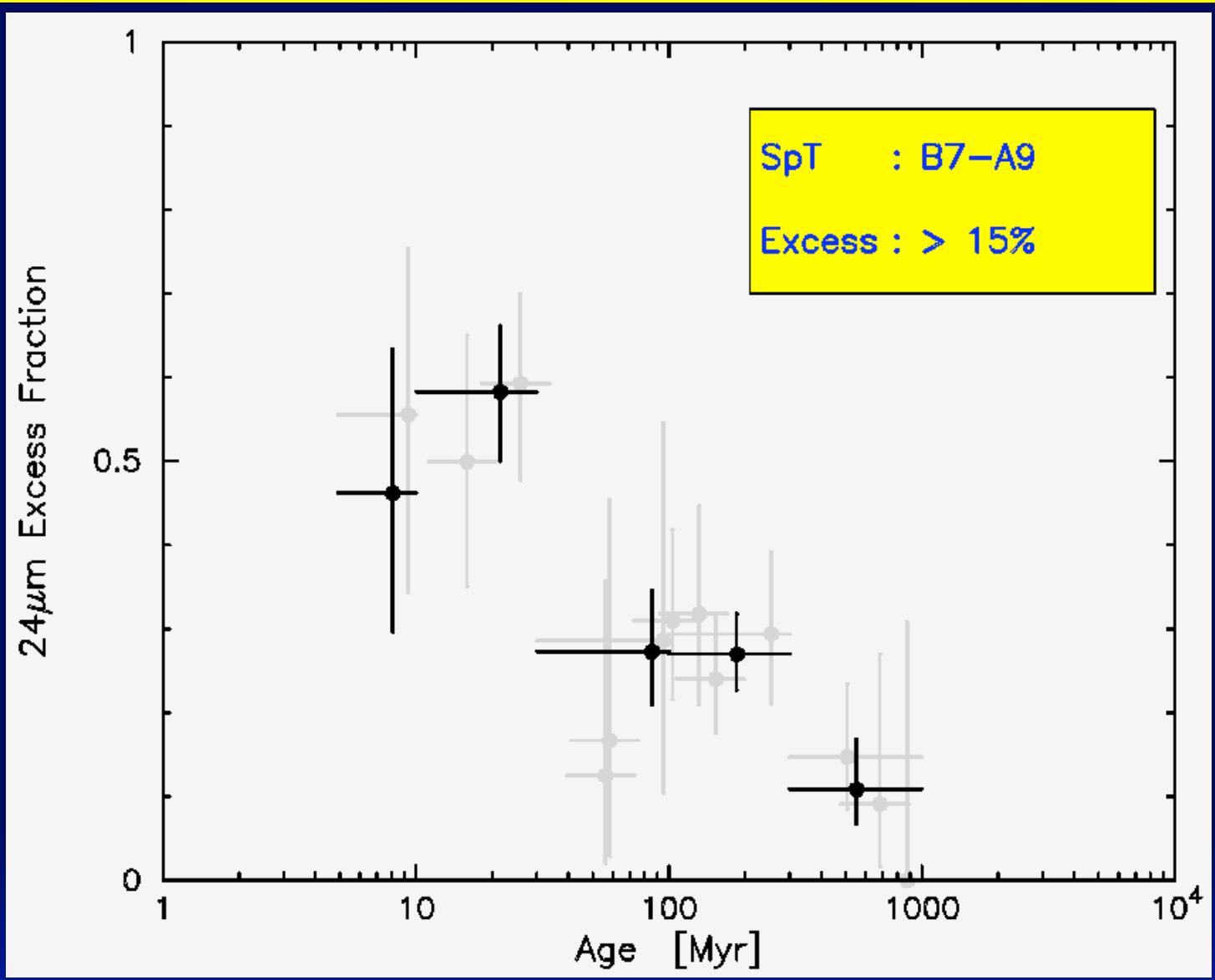
Sensitivity to Debris: MIPS 24 μm



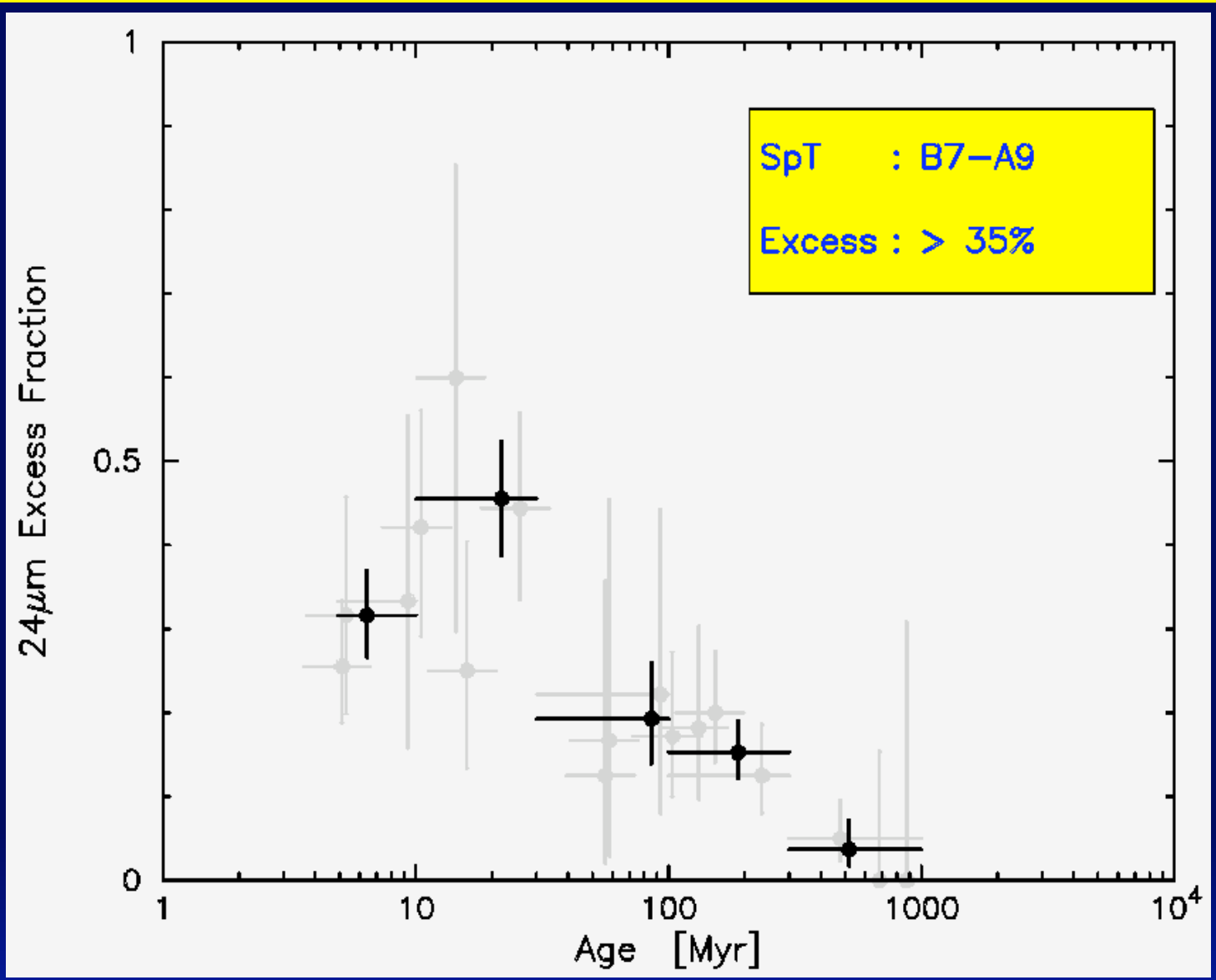
24μm excess fraction: A-stars



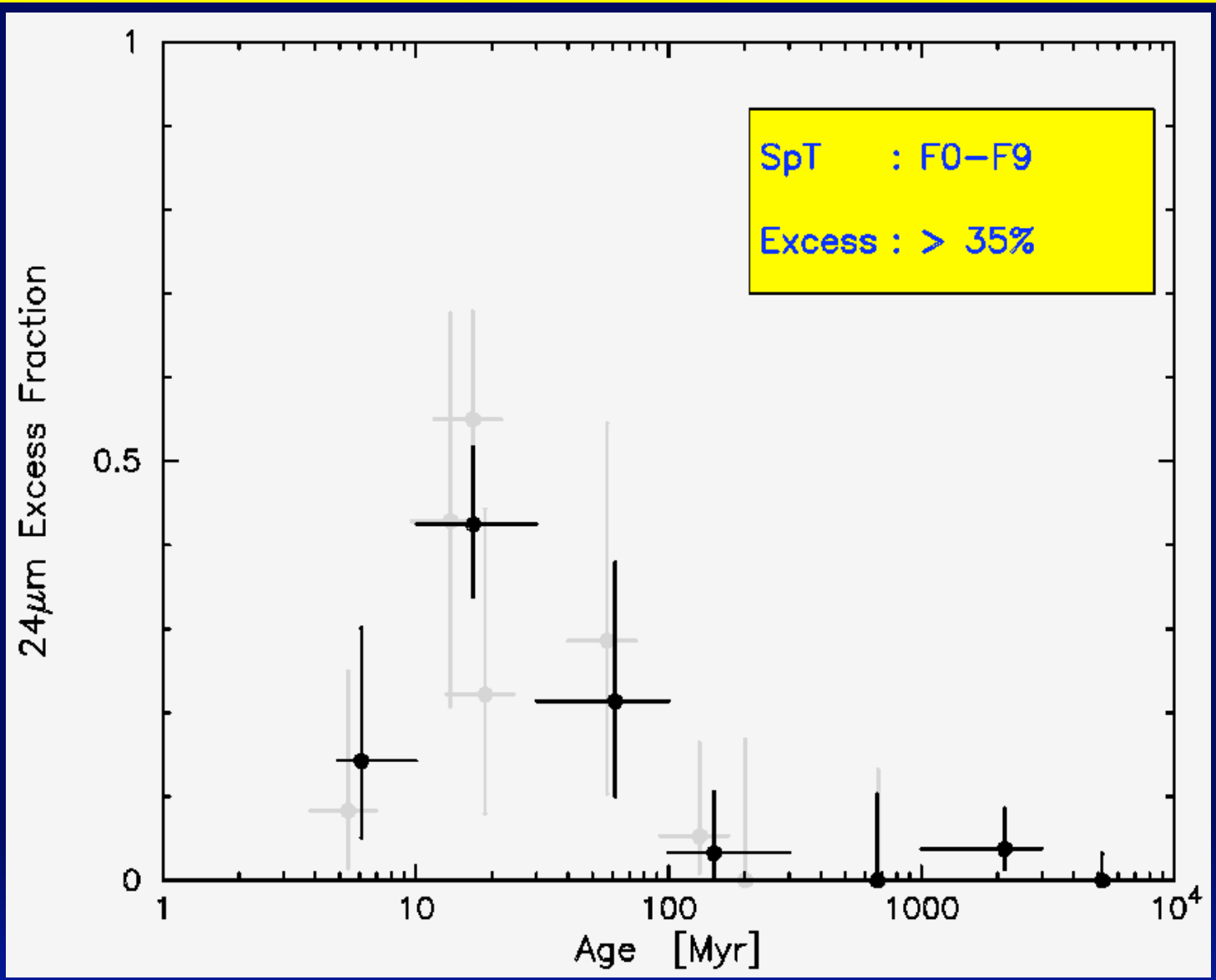
24μm excess fraction: A-stars



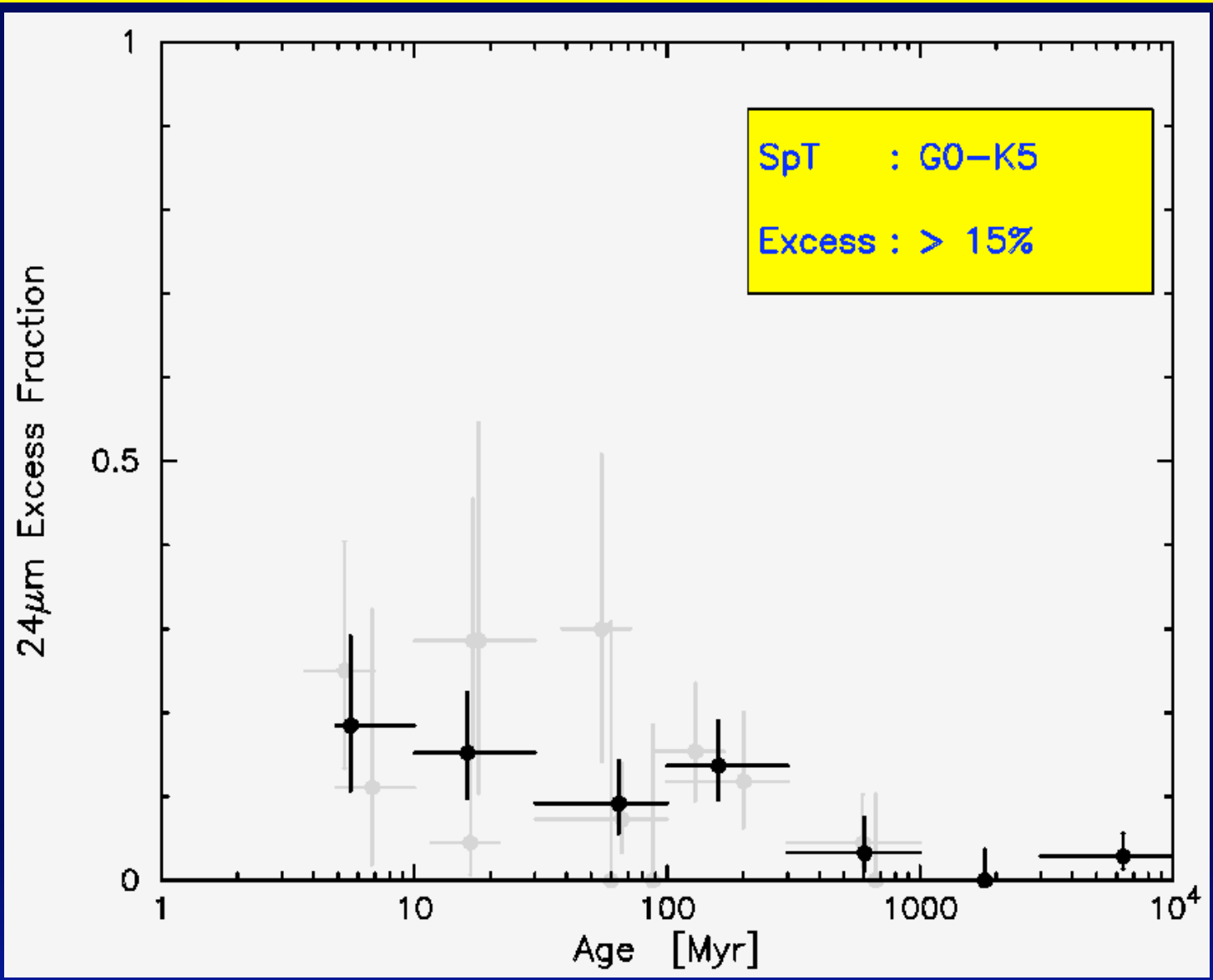
24μm excess fraction: A-stars



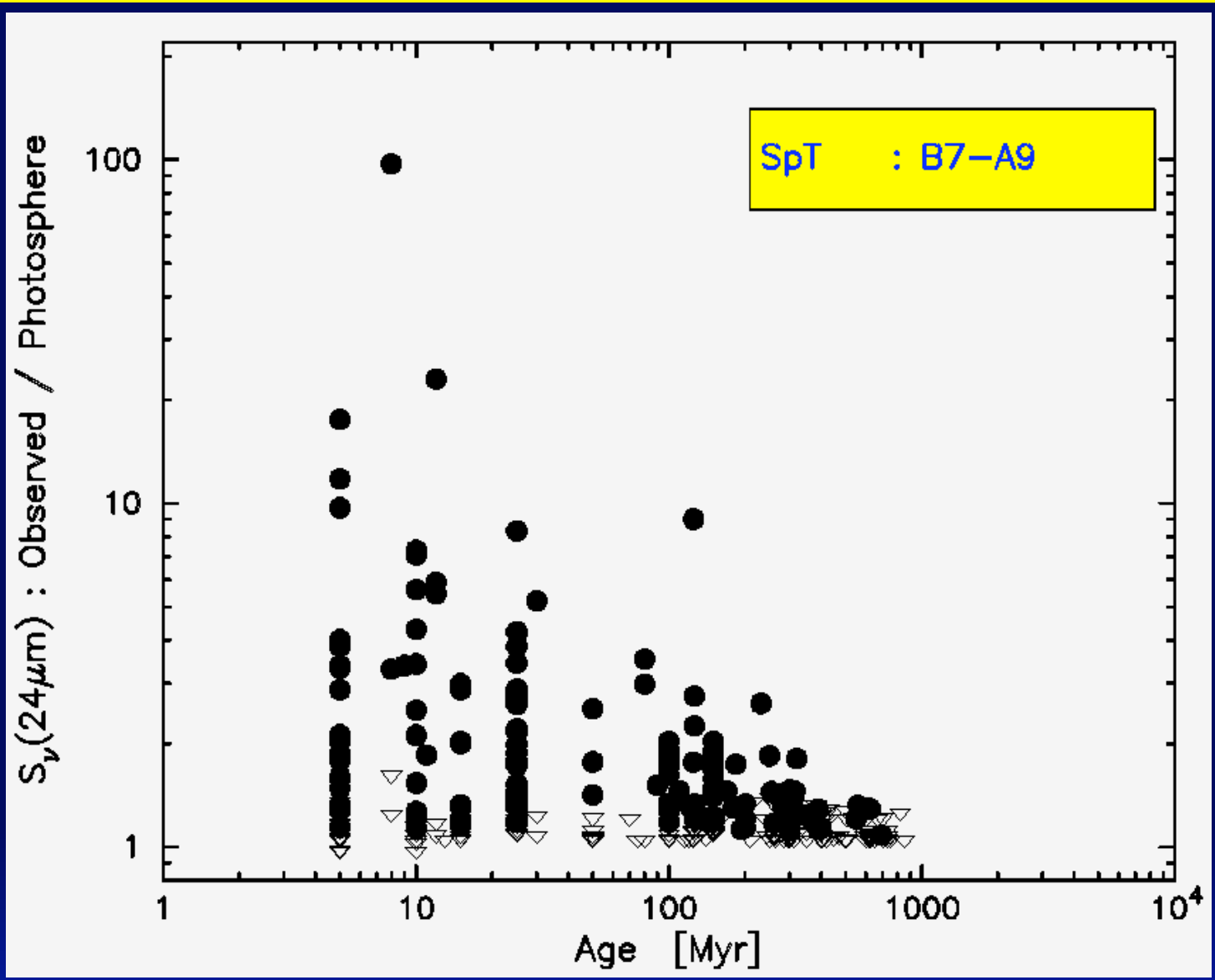
24μm excess fraction: F-stars



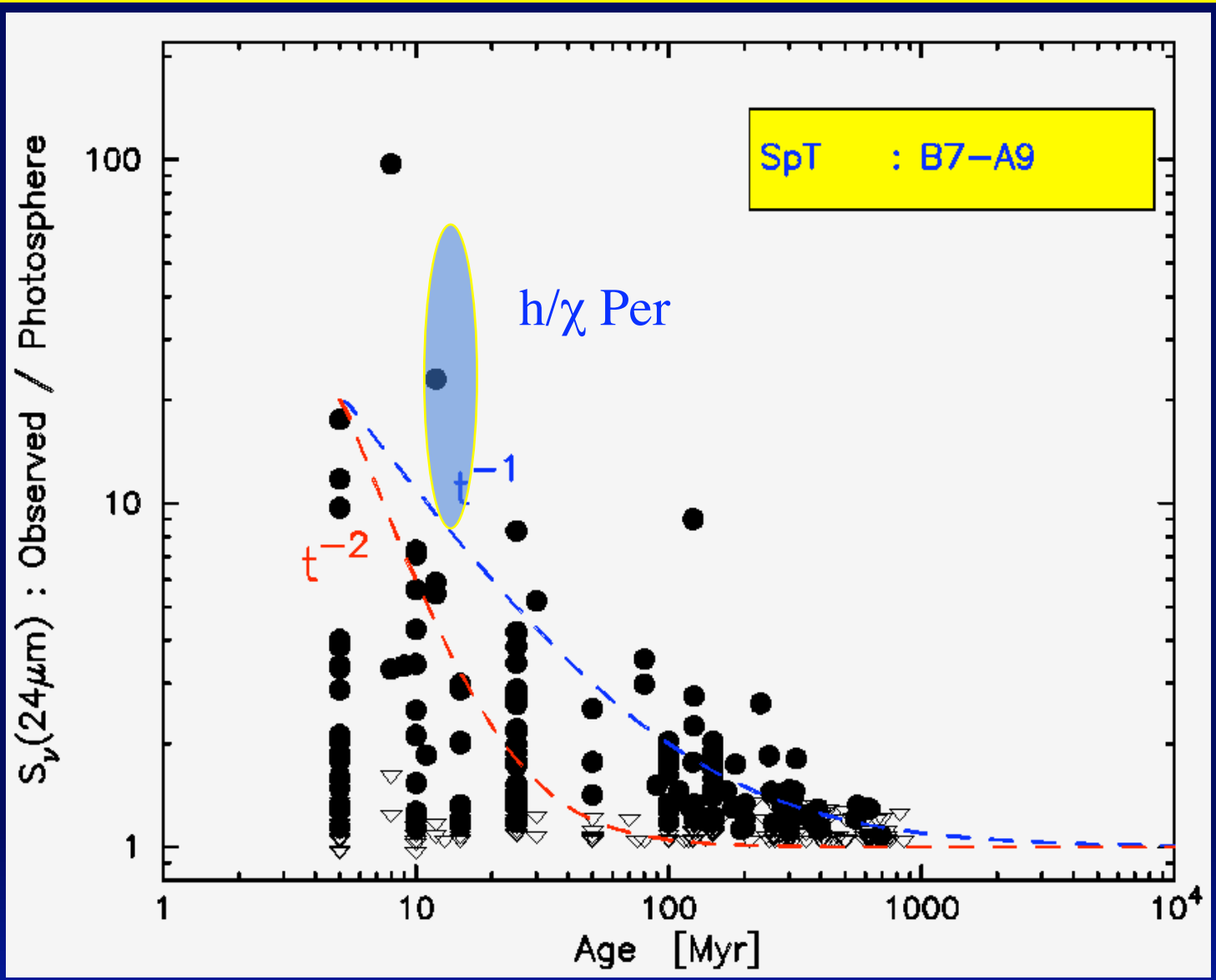
24μm excess fraction: G-K stars



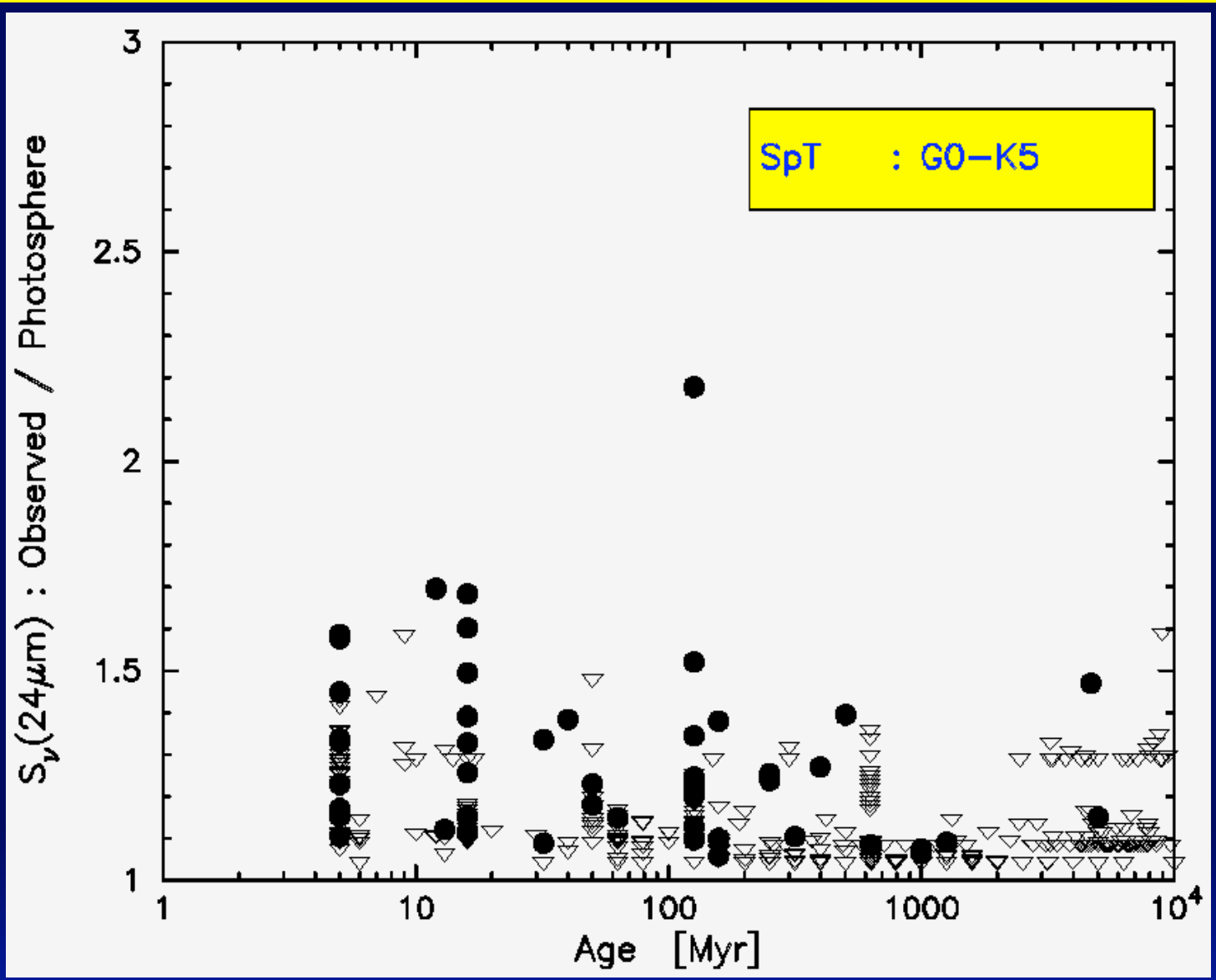
24μm excess vs. age: A-stars



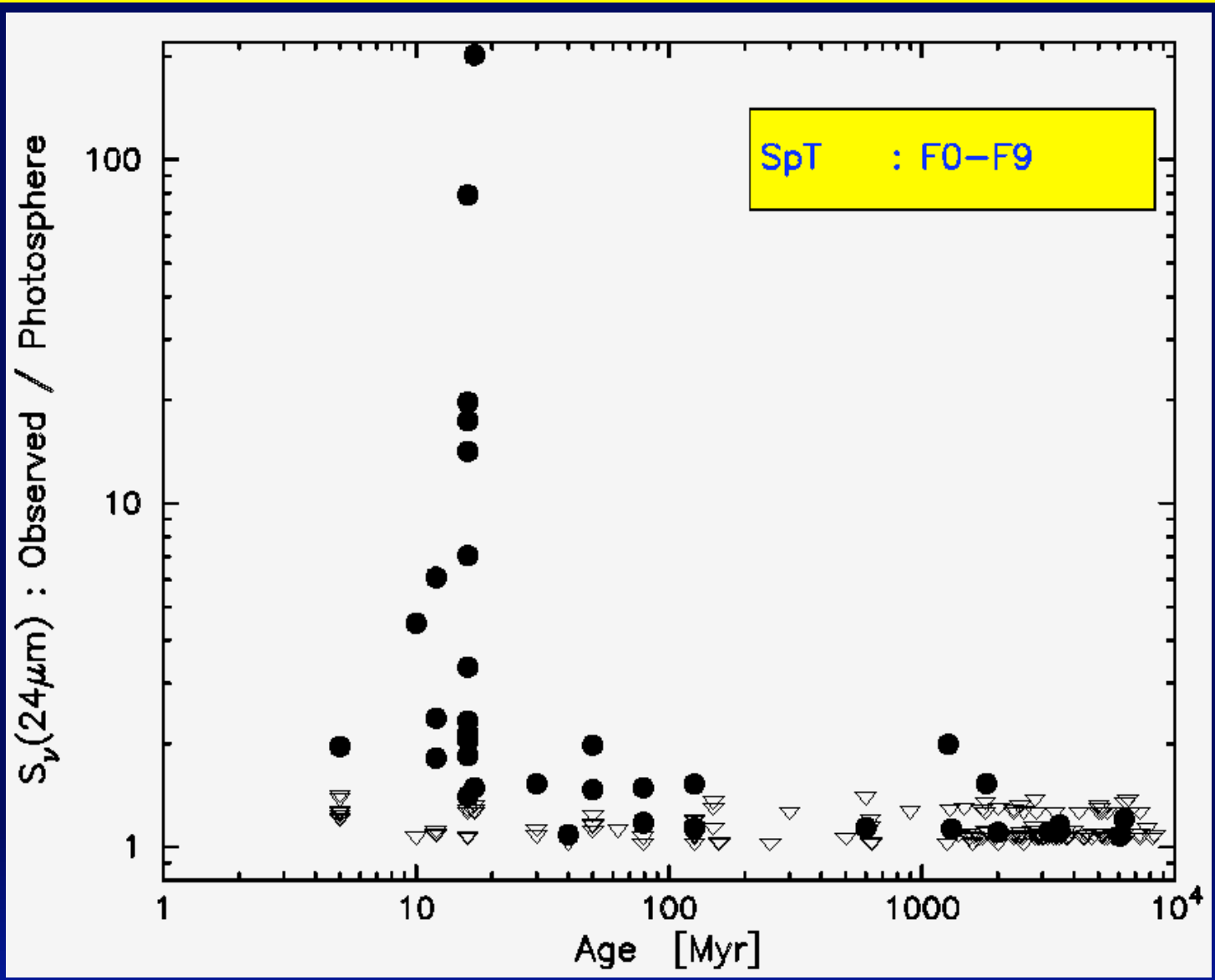
24μm excess vs. age: A-stars



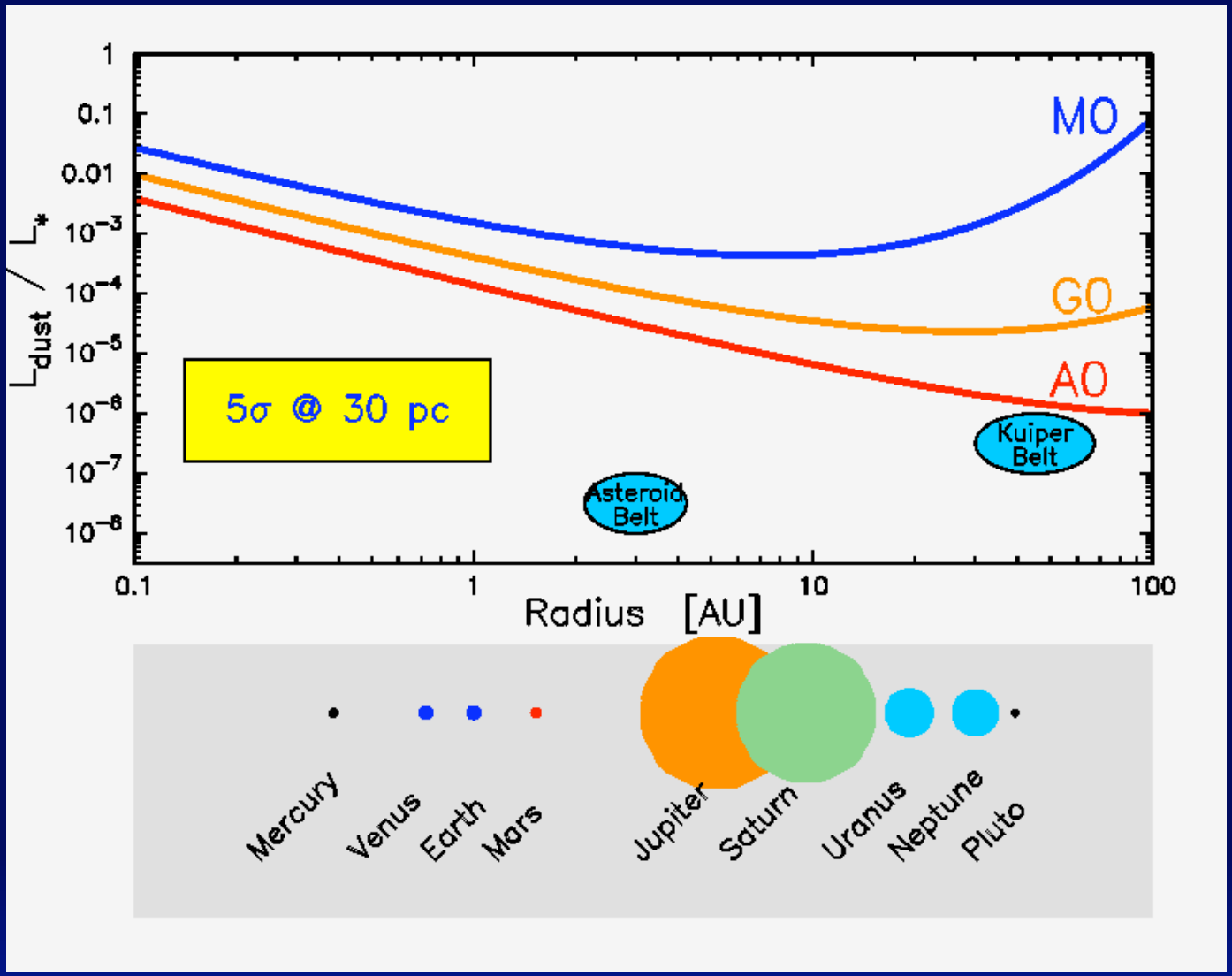
24μm excess vs. age: G-K stars



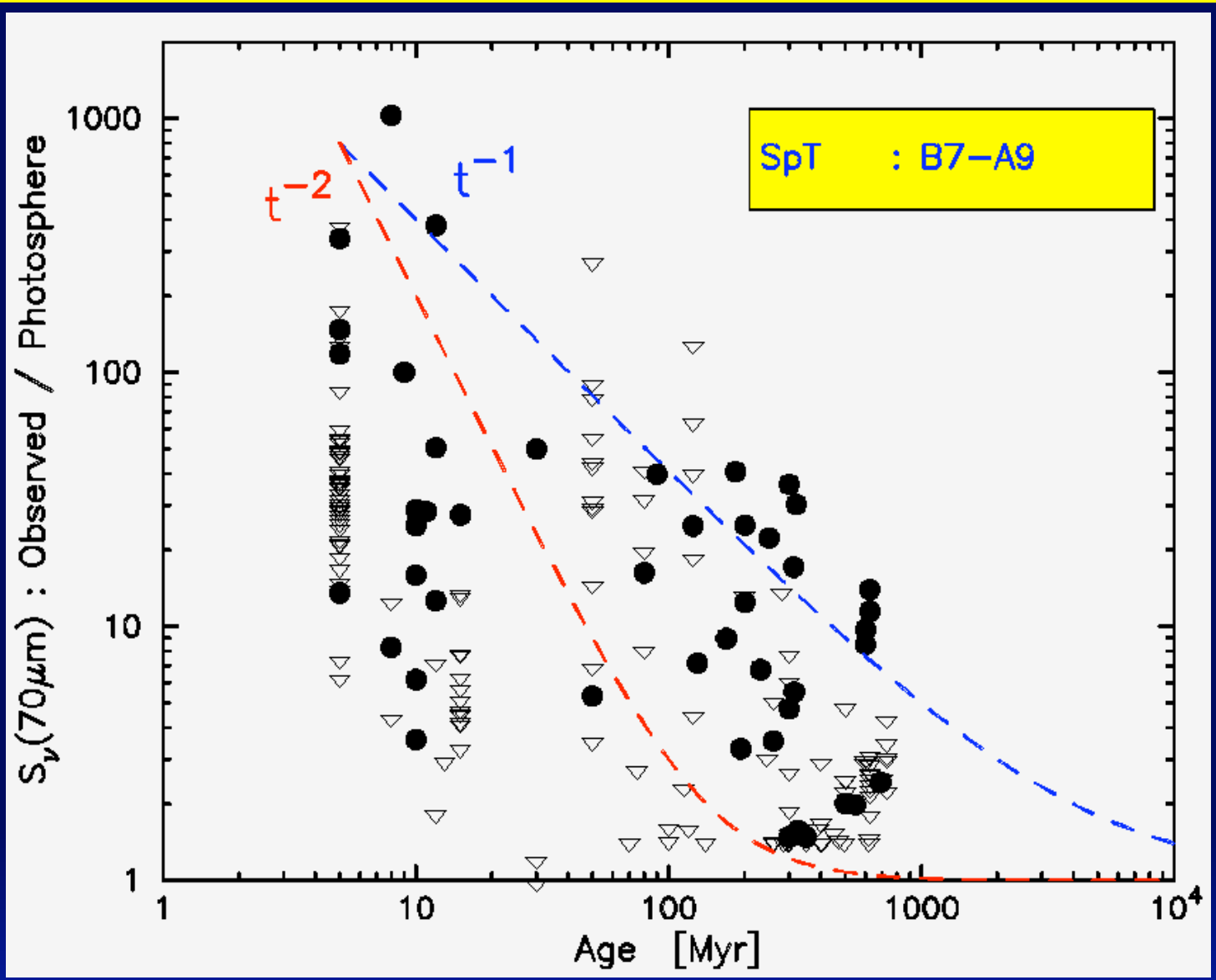
24μm excess vs. age: F-stars



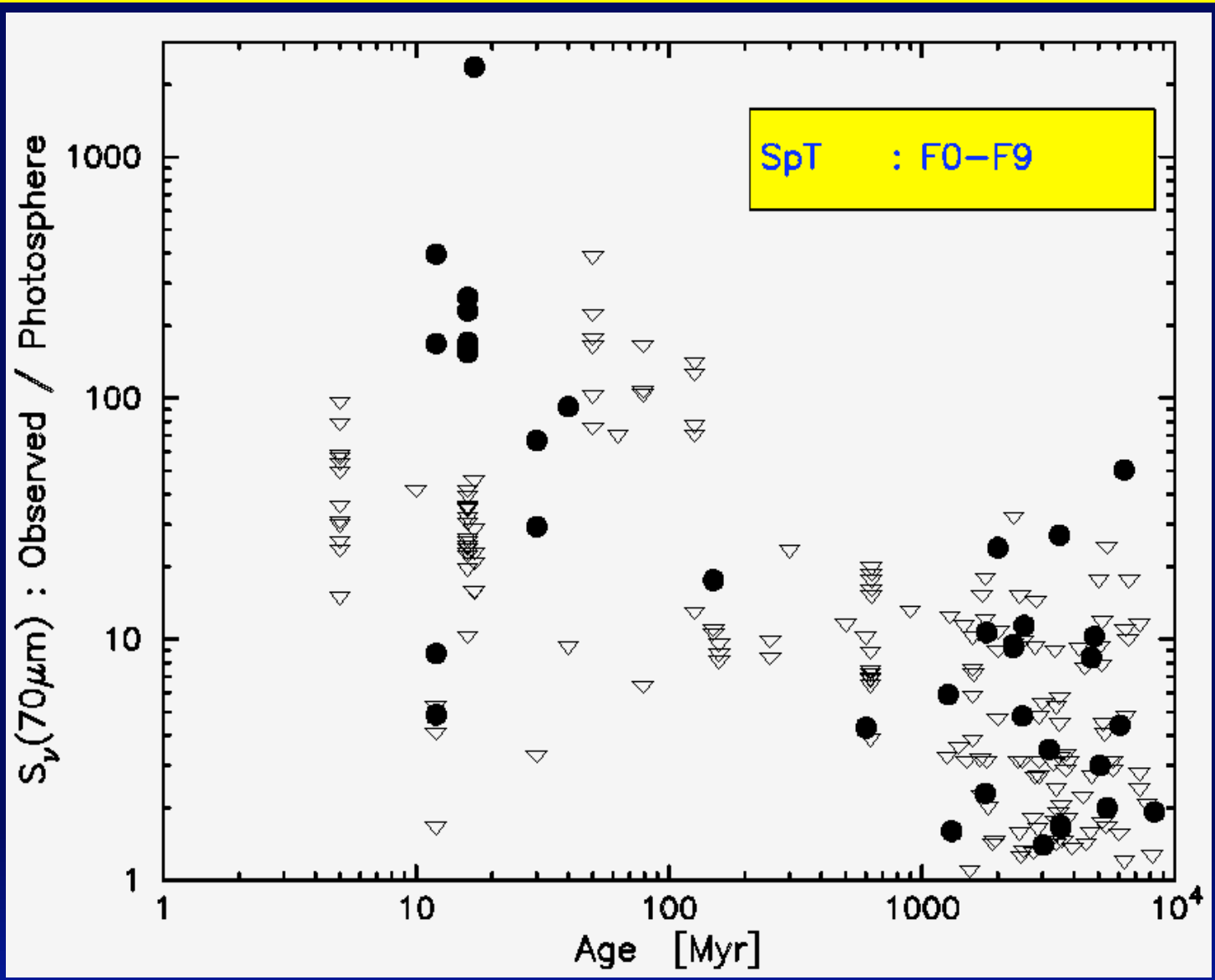
Sensitivity at 70um



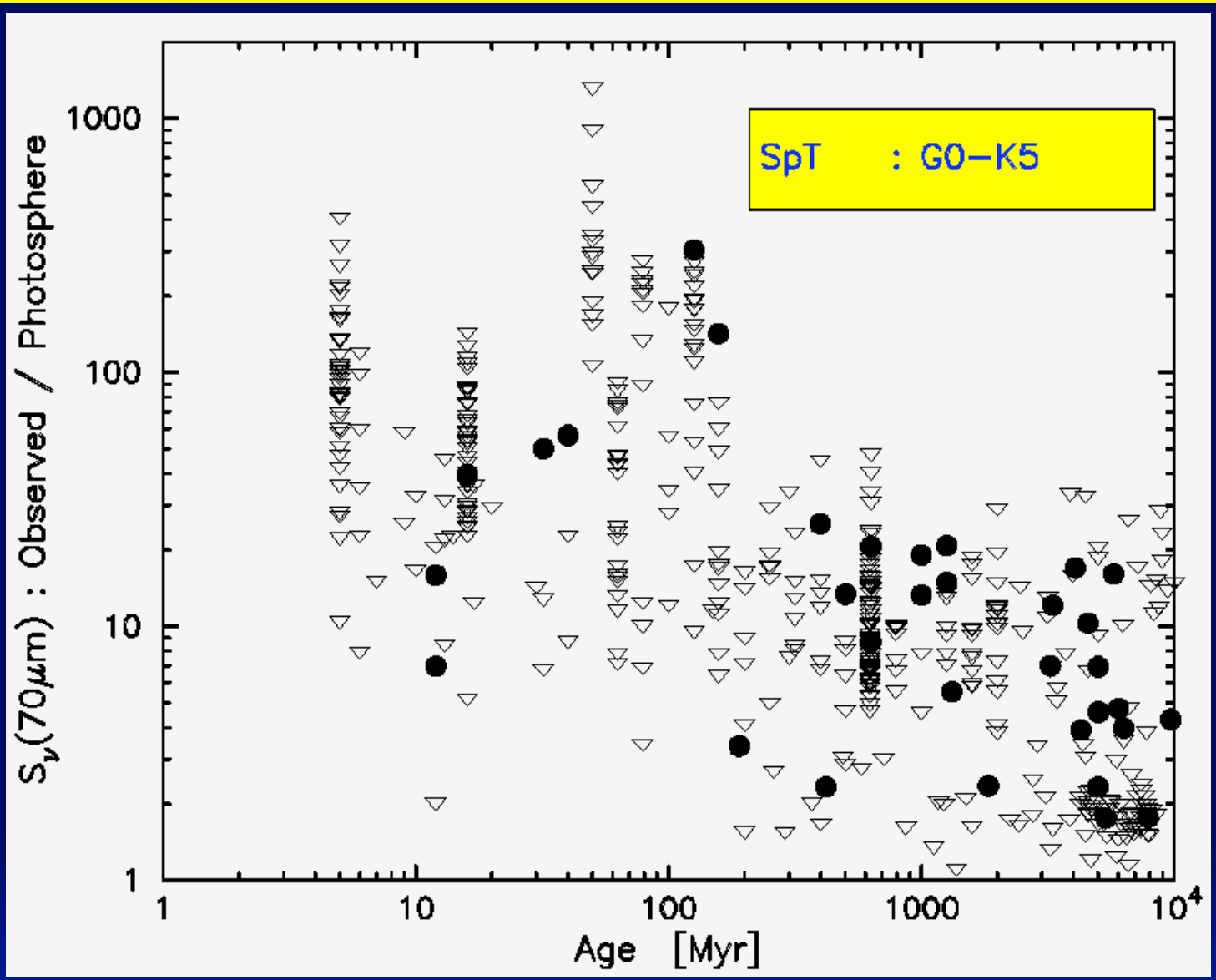
70μm excess vs. age: A-stars



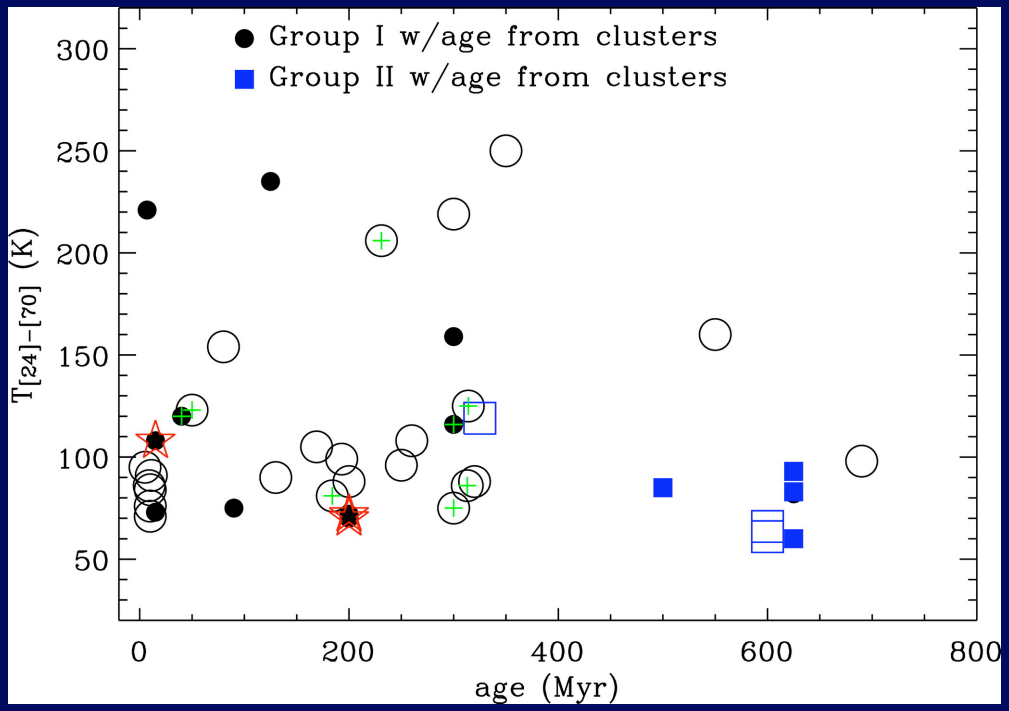
70μm excess vs. age: F-stars



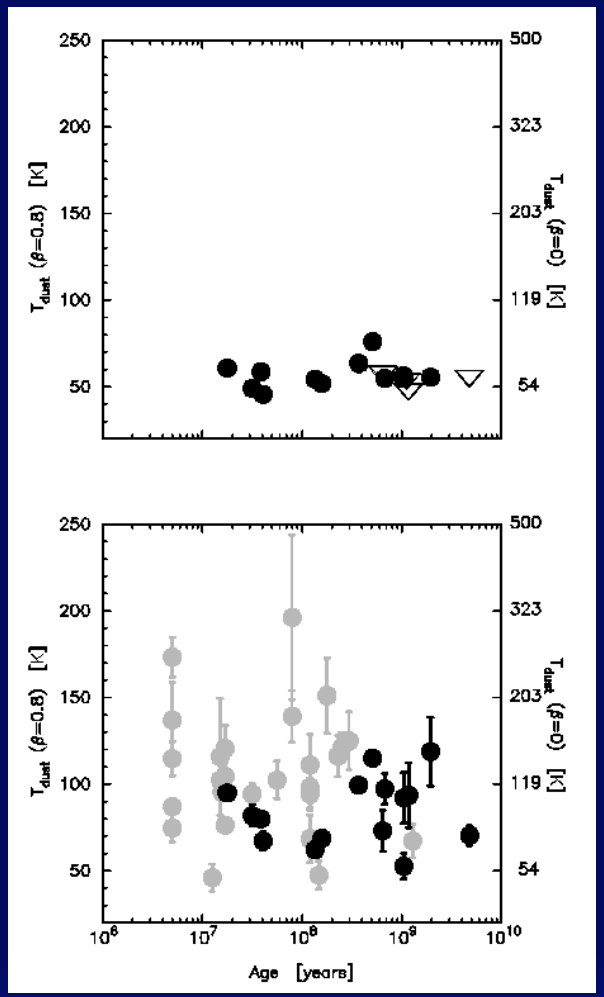
70μm excess vs. age: G-K stars



Dust temperatures

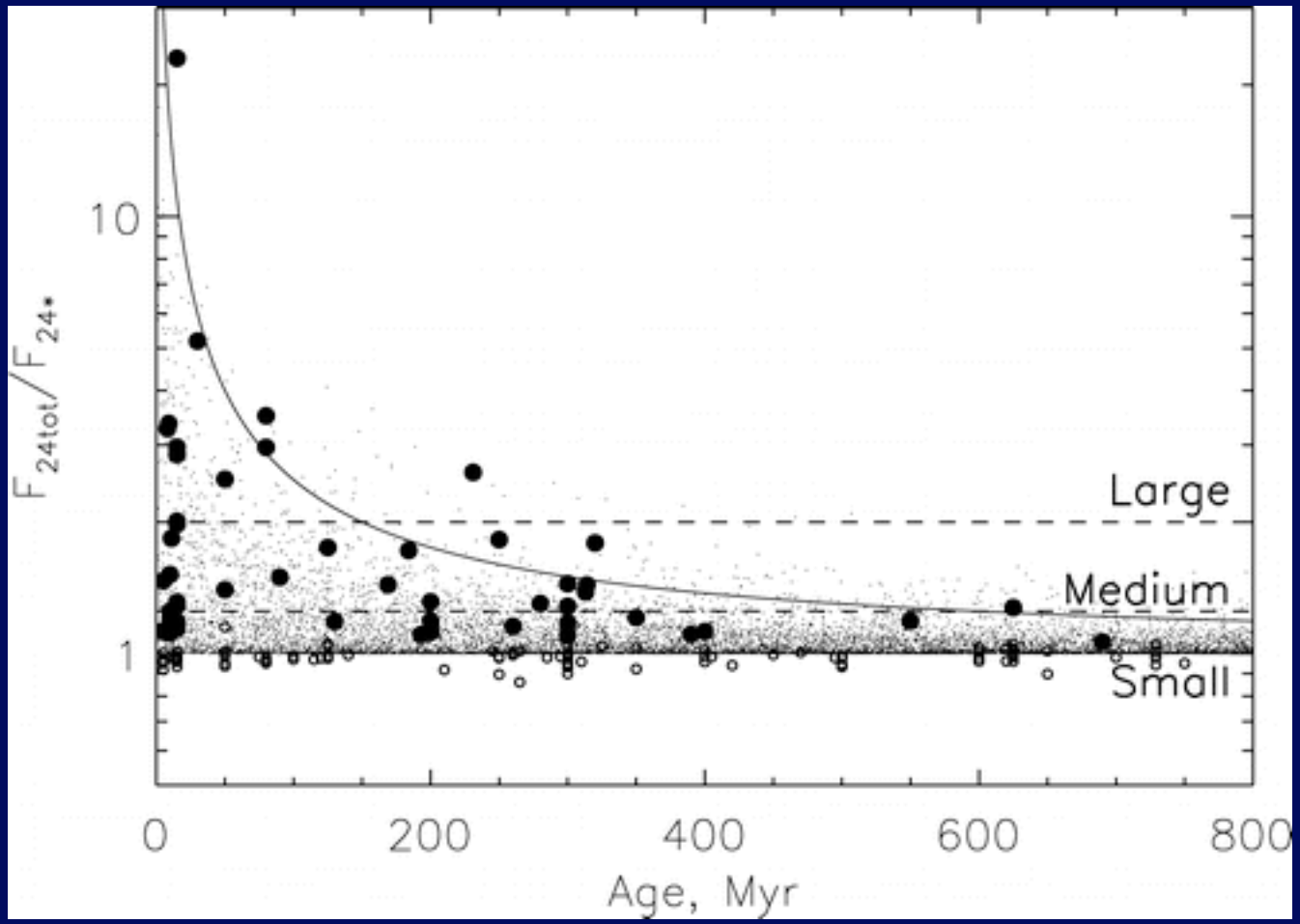


Su et al. (2006)



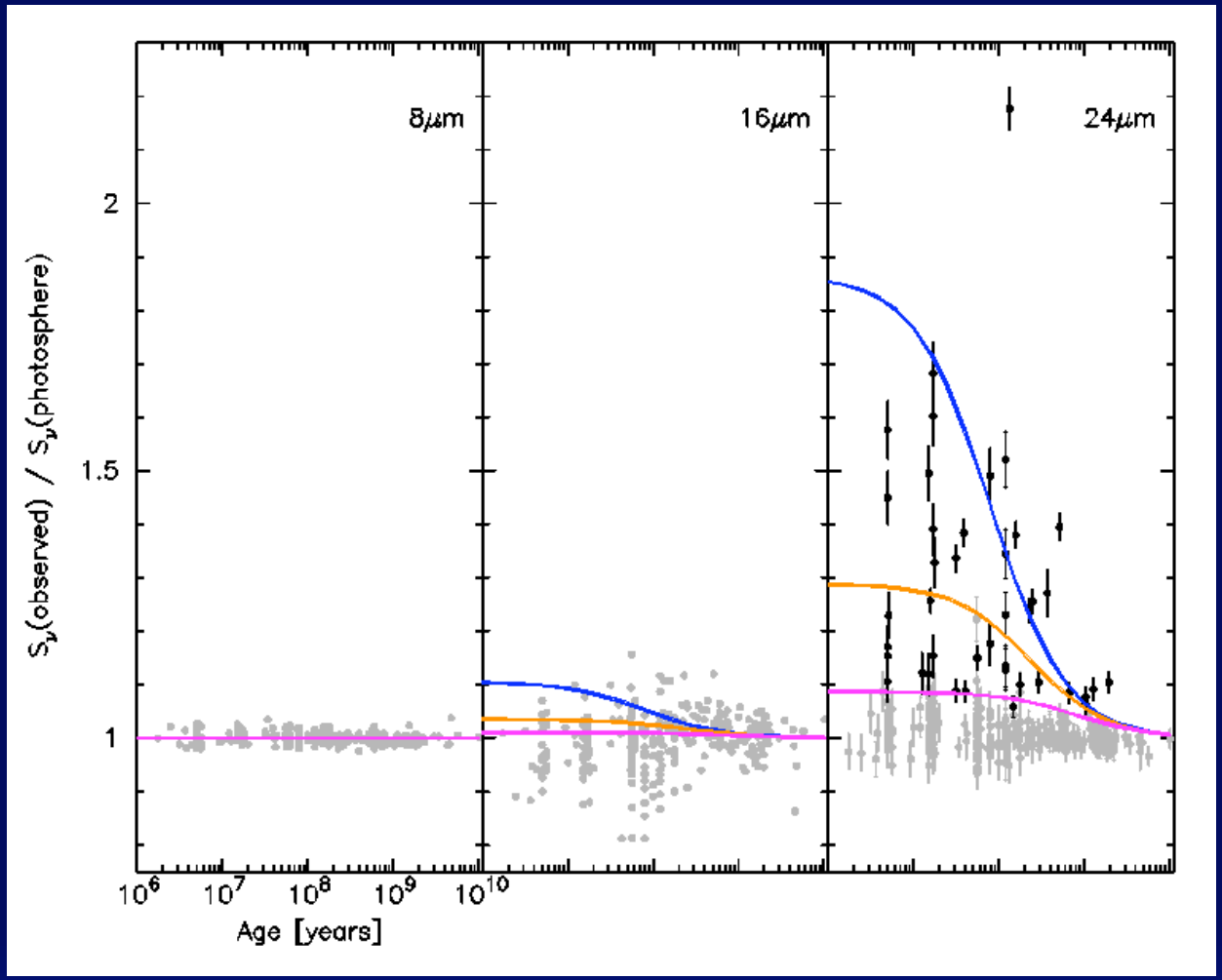
Carpenter et al. (2009)
Hillenbrand et al. (2008)

Steady-state collisional cascade?



Wyatt et al. (2007)

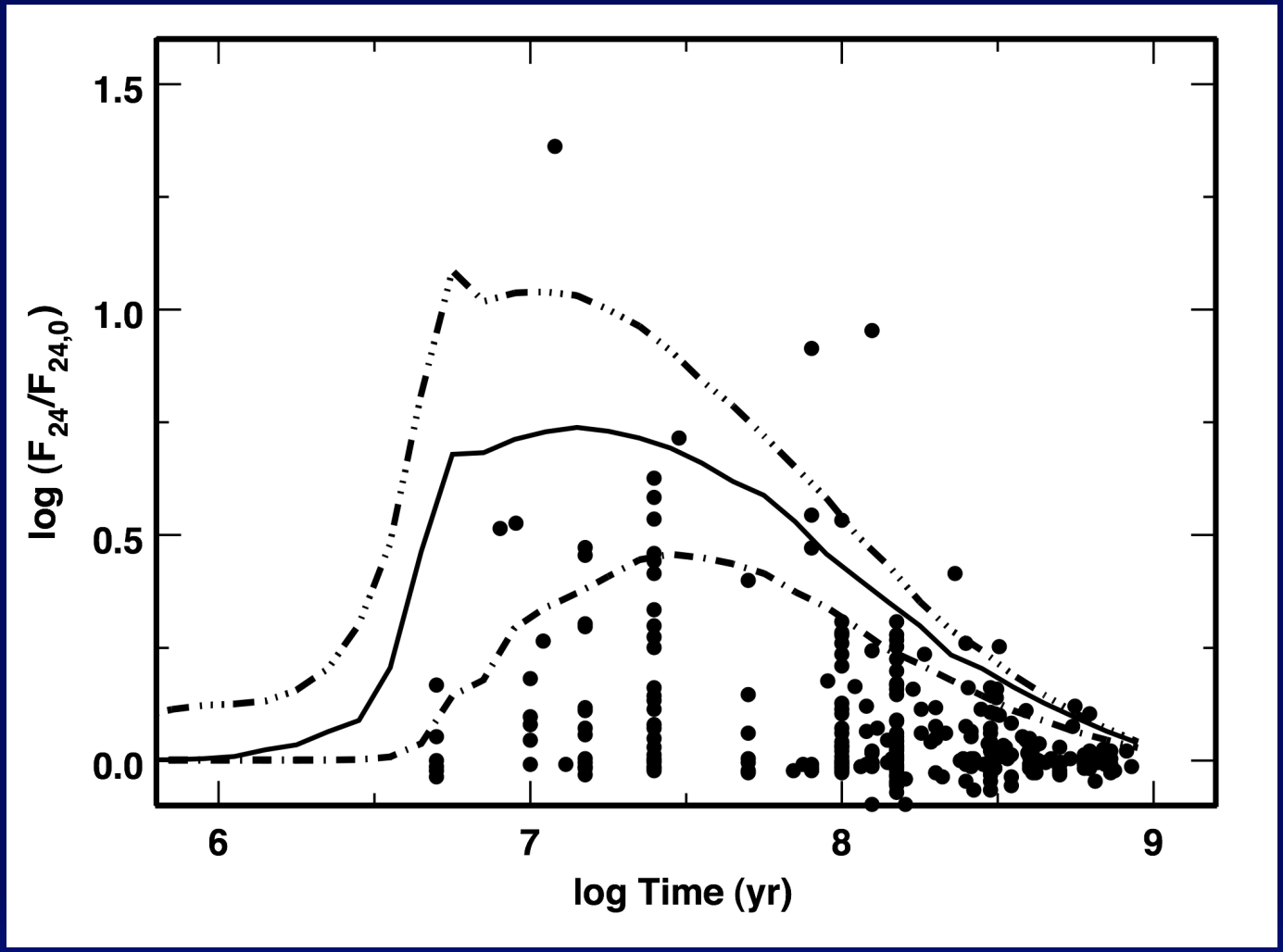
Steady-state collisional cascade?



Inner radius = 10 AU

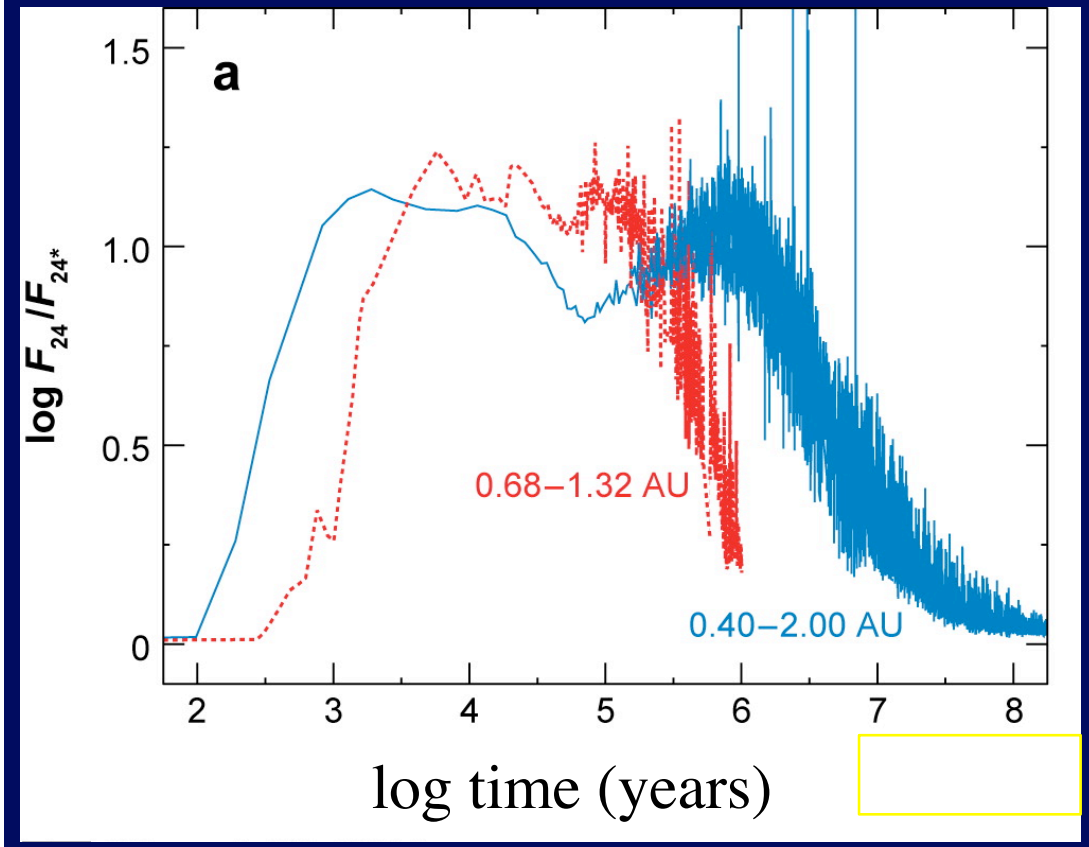
Carpenter et al. (2009)

Formation of icy planets?



Kenyon & Bromley (2008)

But where is the "warm" debris?



- T Tauri disks at ~ 0.3 AU
- Are planetesimal belts truncated?

Kenyon & Bromley (2005)
Adapted from Wyatt (2008)

Spitzer Legacy

- Extensive data set on debris disks
- Probing sophisticated questions on debris evolution