Transient dust in warm debris disks

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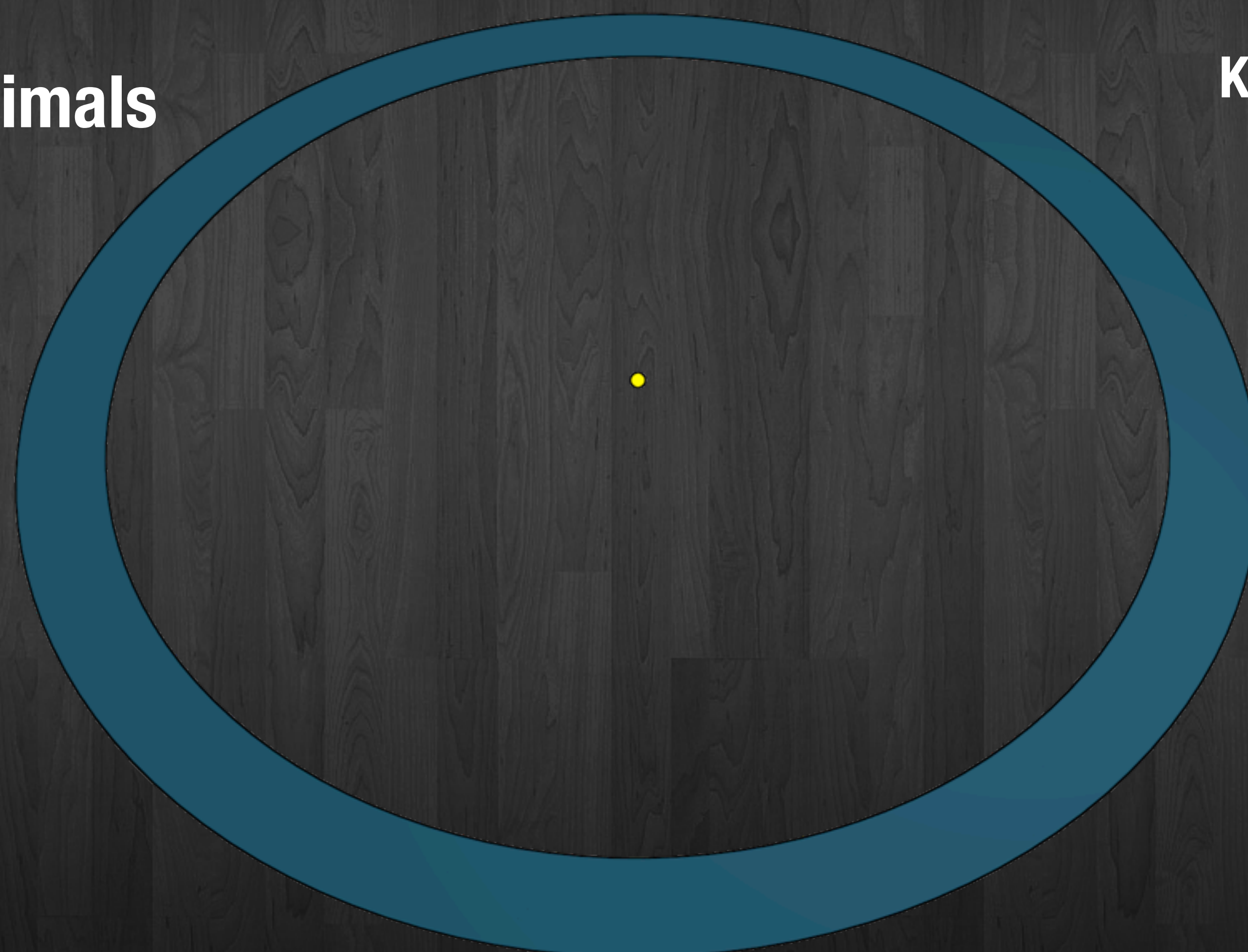
Debris disk

Final product of star formation

Reservoir of planetesimals

Kuiper-belt like



Cold dust (T~50K)

100s of known objects

Optically thin

Mid-, far-IR excess

Typical ages > 10-20 Myr

Warm debris disk

Final product of star formation

Warm inner belt

~~Kuiper belt like~~

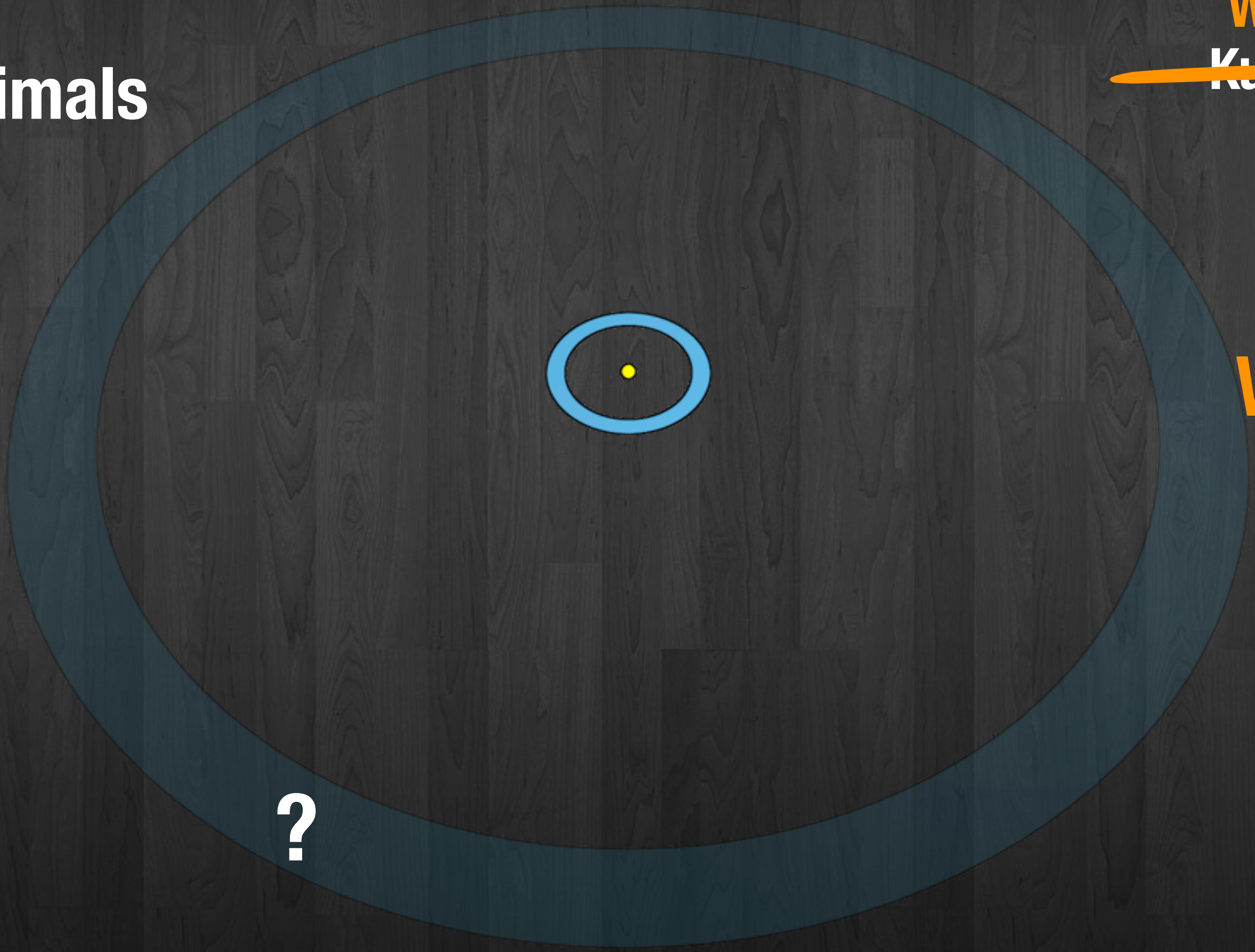
Reservoir of planetesimals

~~Cold dust (T~50K)~~

Warm dust (T~500K)

~~100s of known objects~~

Rare objects



Optically thin

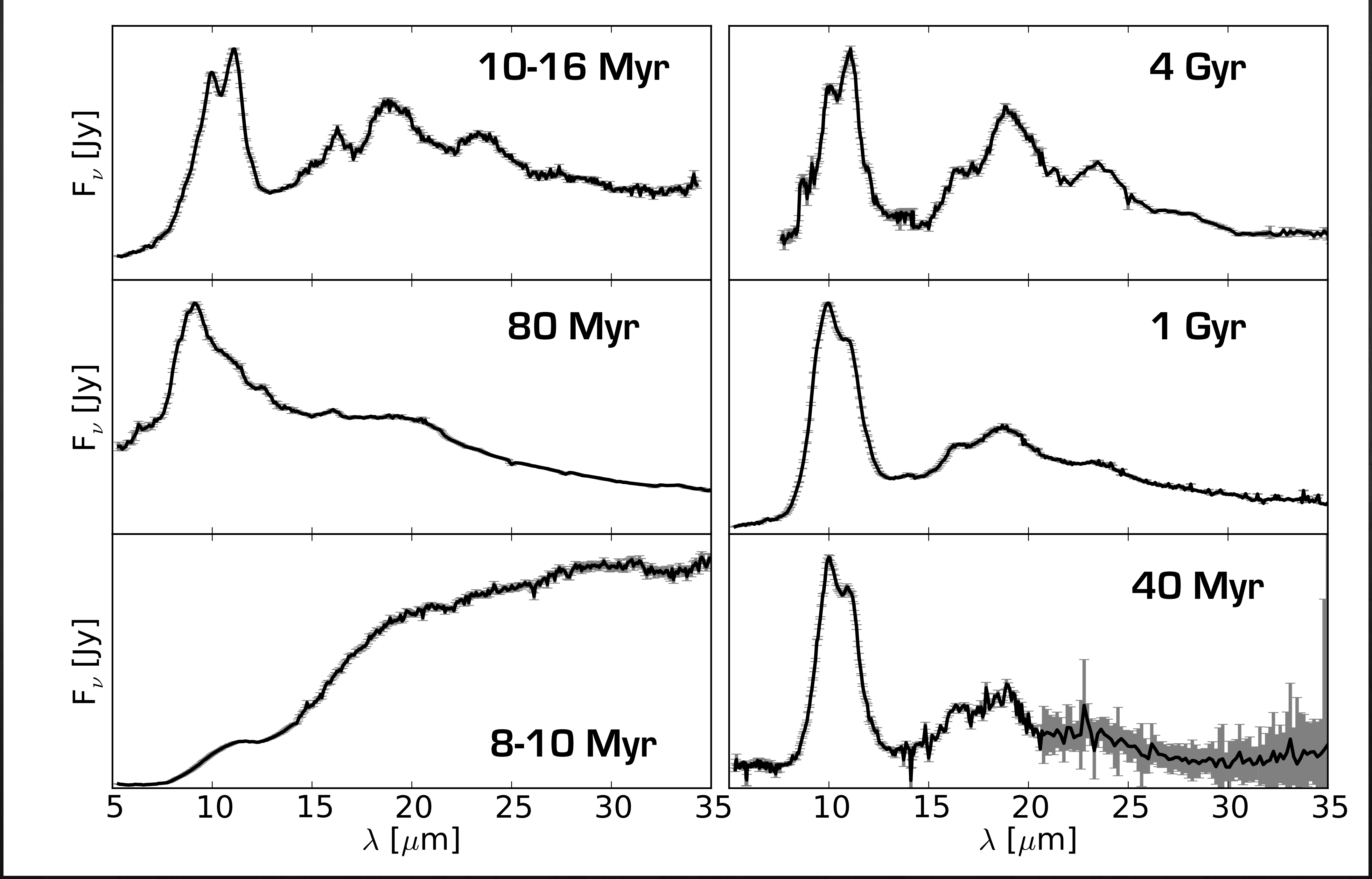
~~Mid-, far-IR excess~~

Near-IR excess

Typical ages > 10-20 Myr

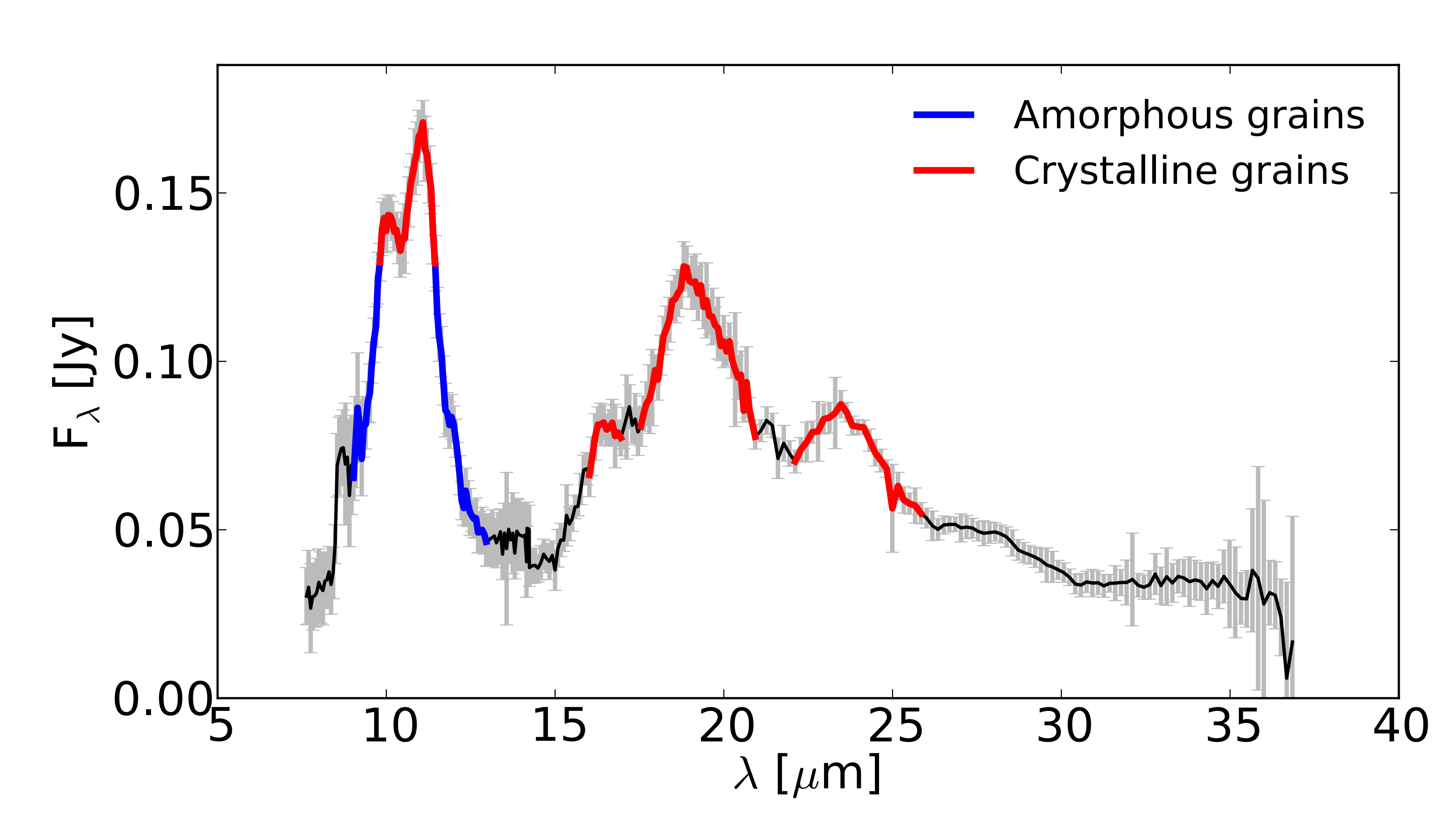
Warm debris disk

- Olofsson et al. (2012): sample of 7 debris disks (rare objects !)
- Emission features !



Emission featu... what?

- Optical properties of dust grains: Henning (2010)
- Peak positions and shape of the features:
  - Grain sizes (0.1 < s < 5 - 10μm)
  - State: amorphous or crystalline
  - Chemical composition



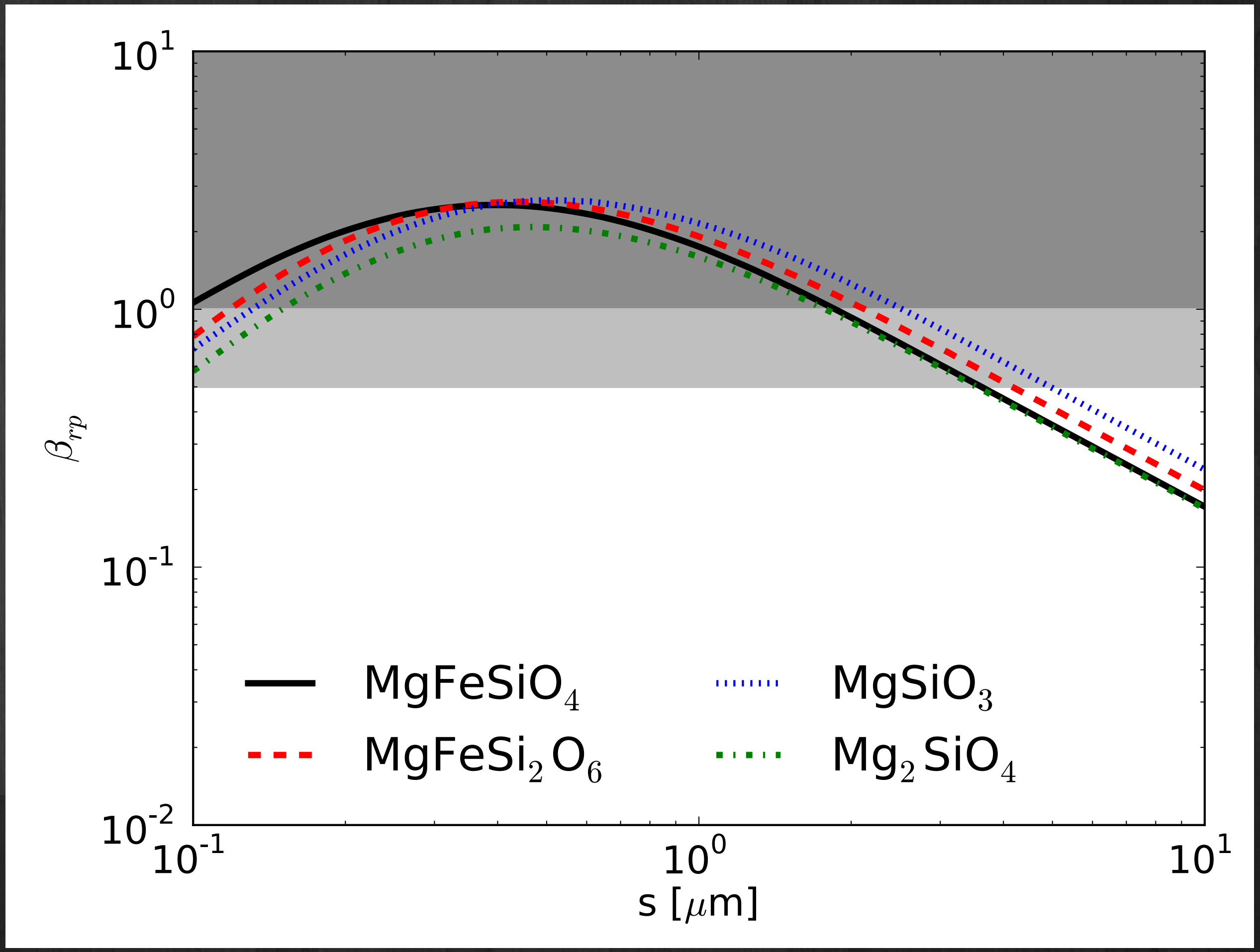
Why are they rare?

- Dust removal: radiation pressure vs. gravitational force (ratio = β)

  “Acts as an apparent reduction of stellar mass” - Someone

- Emission features = μm-sized grains

- Transient dust grains: they should have been evacuated from the system

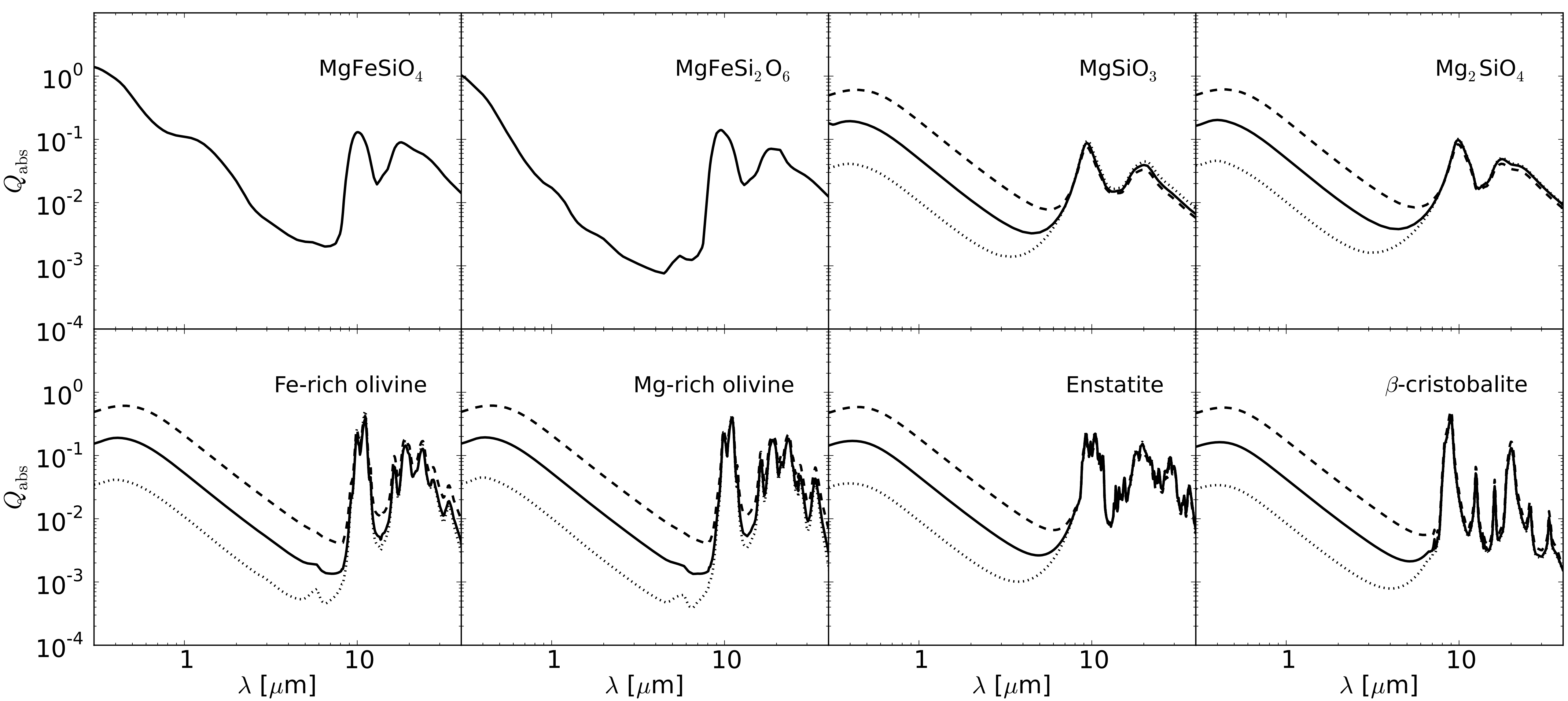


- Possibility #1: collision between planetesimals
- Possibility #2: Kuiper-belt feeding the innermost regions (Late Heavy Bombardment ?)

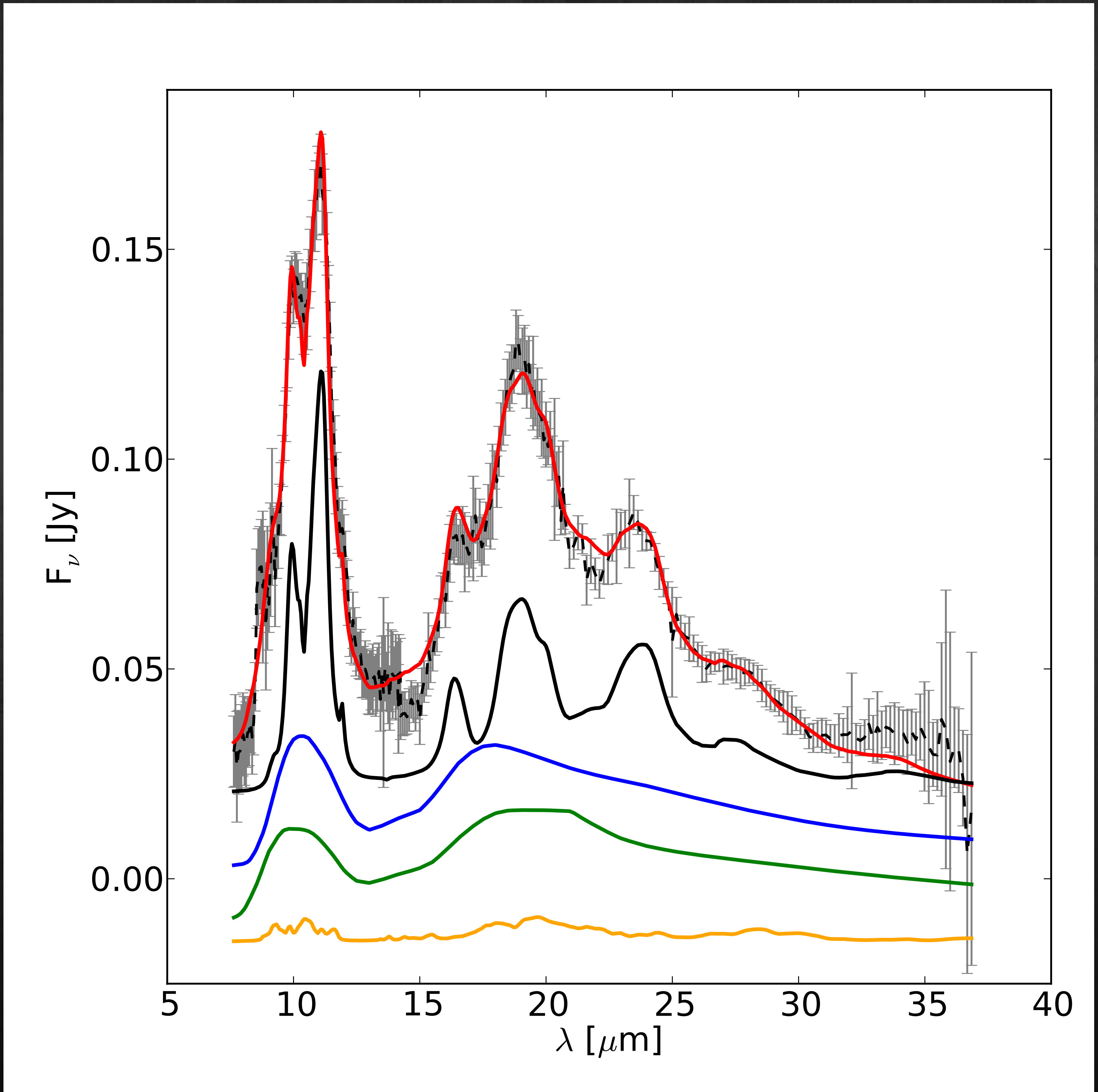
Question: can the dust mineralogy help us ?

Spectral decomposition

- Amorphous & crystalline grains
- 9 dust compositions: olivine & pyroxene group + β-cristobalite silica + carbon
- Optically thin, no gas: each dust grain has its own temperature T(r, composition)



Spectral decomposition

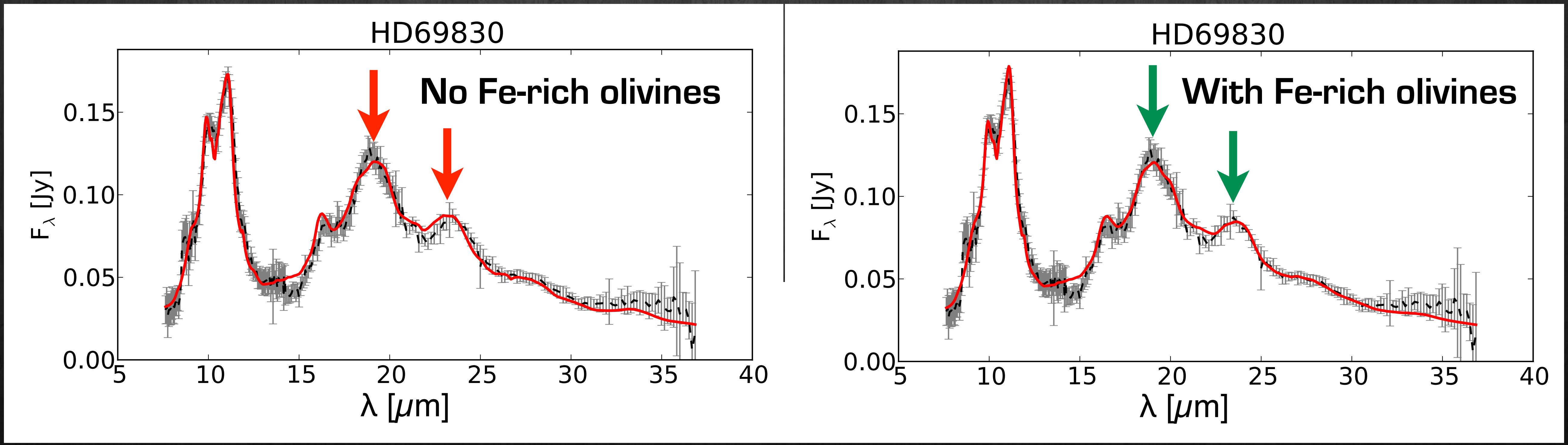


The iron content in crystalline olivine grains

- Crystalline olivine grains: $(Mg_xFe_{(1-x)})_2SiO_4$
- "Mg-rich" olivine grains: Fe / [Mg + Fe] = 7.5%
- "Fe-rich" olivine grains: Fe / [Mg + Fe] = 20%

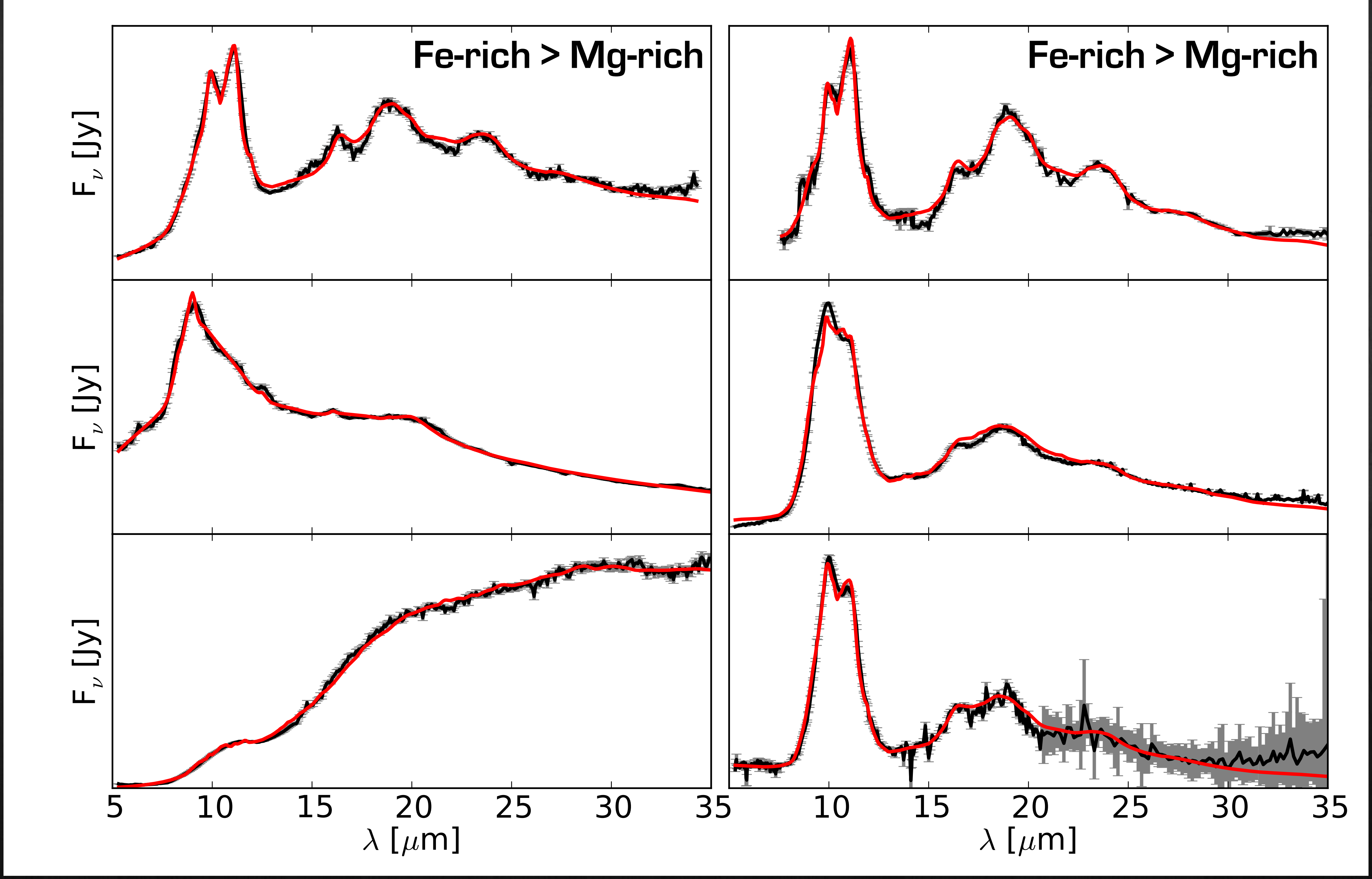
Tamanai & Mutschke (2010)
Aerosol measurements

- Mandatory to match emission features at about 19 & 24μm



Results

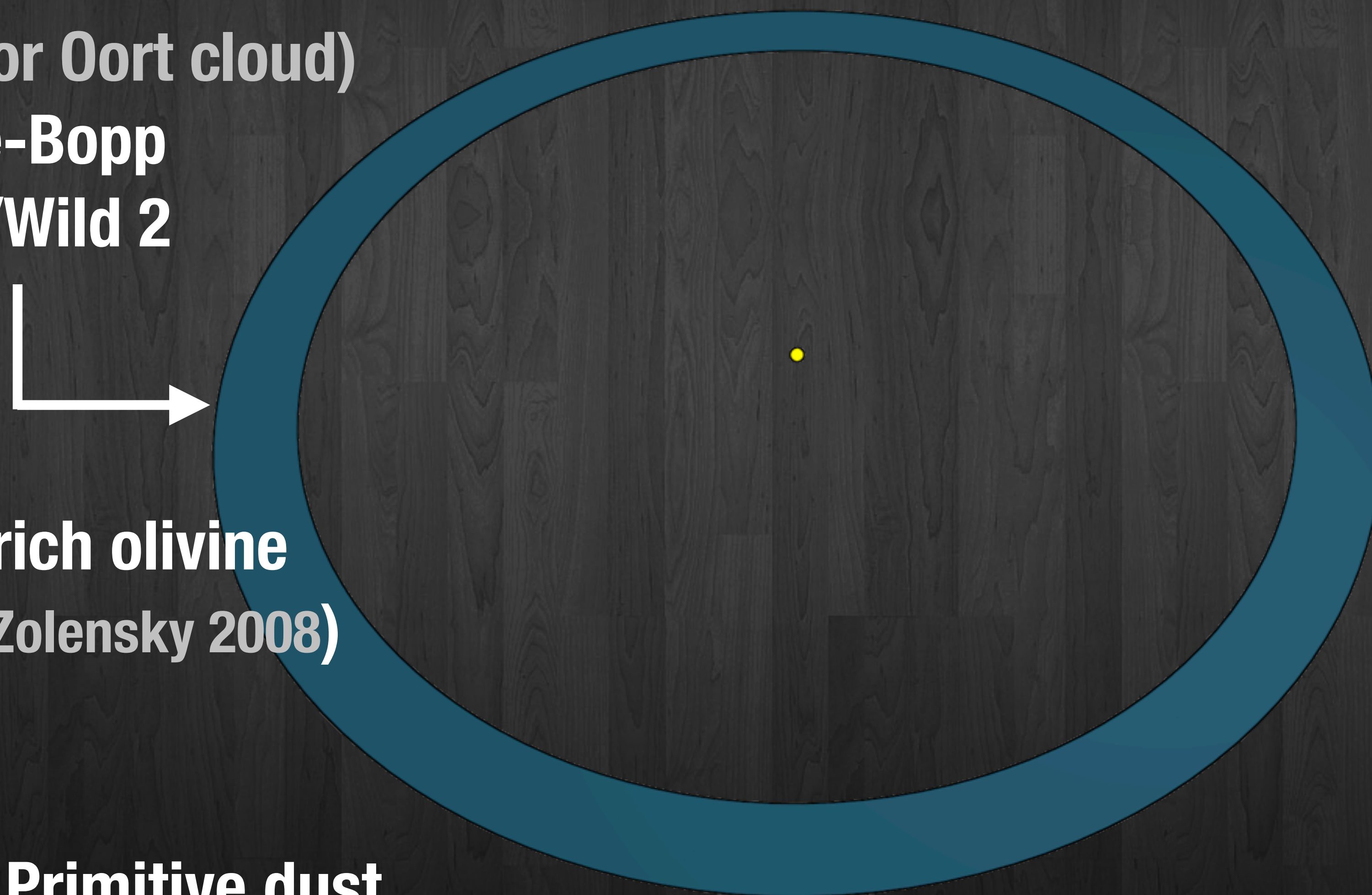
- Dust located close to the star (1 AU)
- Detection of Fe-rich crystalline olivine grains around HD 113766 A & HD 69830



Comparison to the solar system

A “classical” debris disk,
Kuiper-belt analog

Comets:
(Kuiper-belt or Oort cloud)
- Hale-Bopp
- P81/Wild 2



Mostly Mg-rich olivine
(Wooden 1999, Zolensky 2008)

Primitive dust
Inherited from the primordial disk

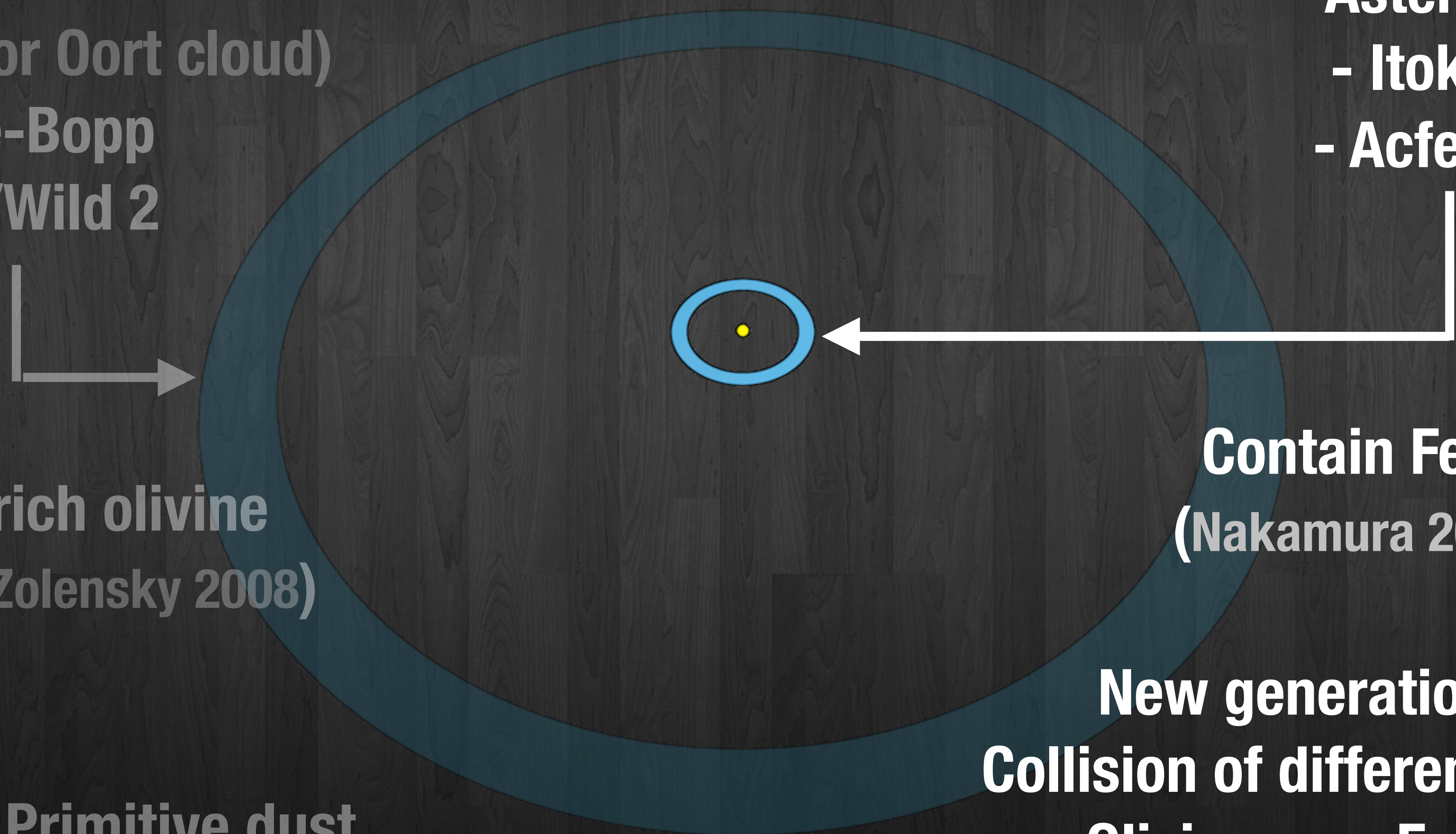
Comparable to β-Pictoris
(de Vries et al. submitted)

Comparison to the solar system

A "warm" debris disk,
asteroid-belt analog

Comets:
(Kuiper-belt or Oort cloud)
- Hale-Bopp
- P81/Wild 2

Asteroids:
- Itokawa
- Acfer 094



Contain Fe-rich olivine
(Nakamura 2011, Bose 2010)

Mostly Mg-rich olivine
(Wooden 1999, Zolensky 2008)

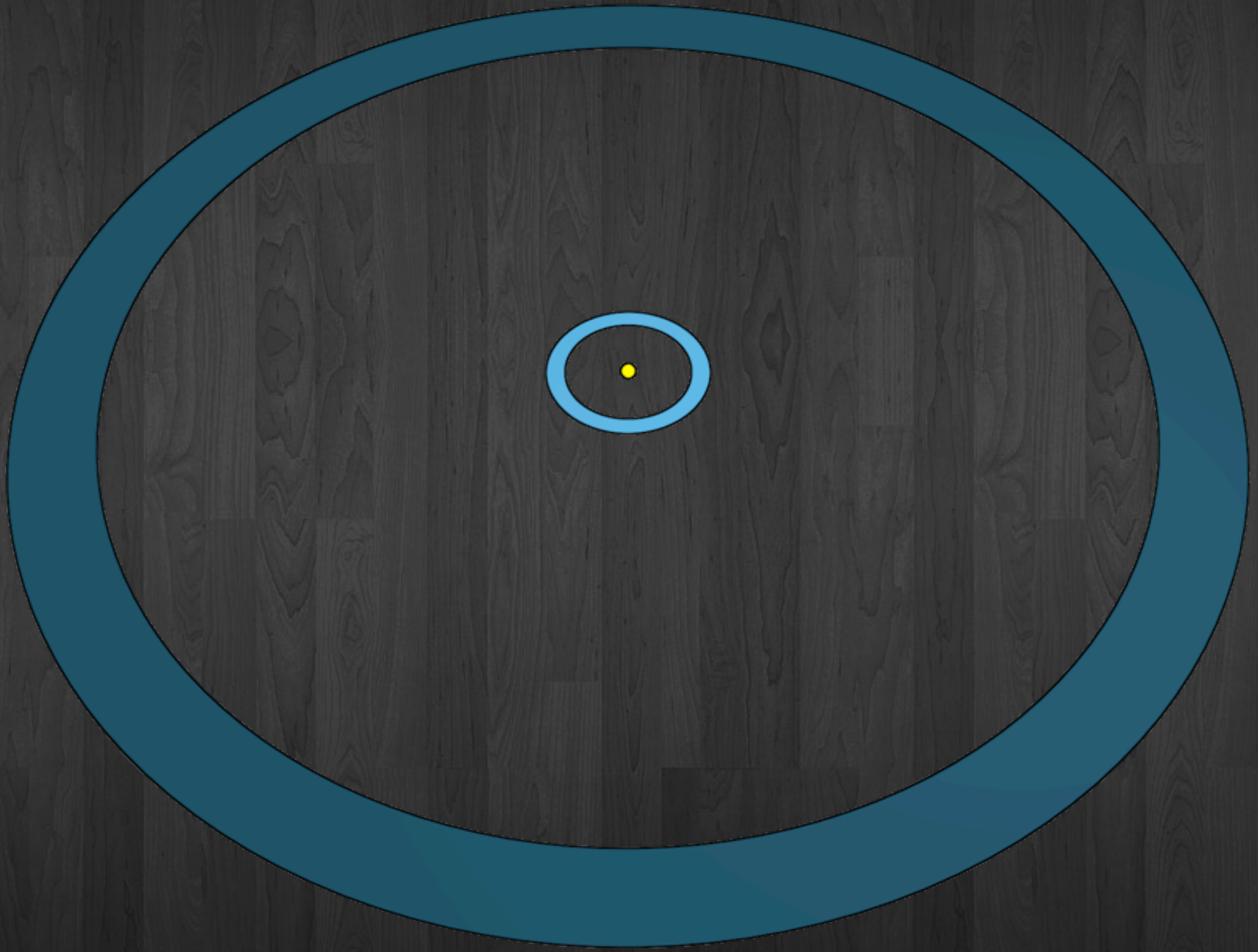
New generation of dust
Collision of differentiated bodies
Olivines are Fe-enriched

Primitive dust
Inherited from the primordial disk

Comparable to β-Pictoris
(de Vries et al. submitted)

Comparison to the solar system

A “warm” debris disk,
with an outer belt ?



Beat degeneracies of SED modeling:

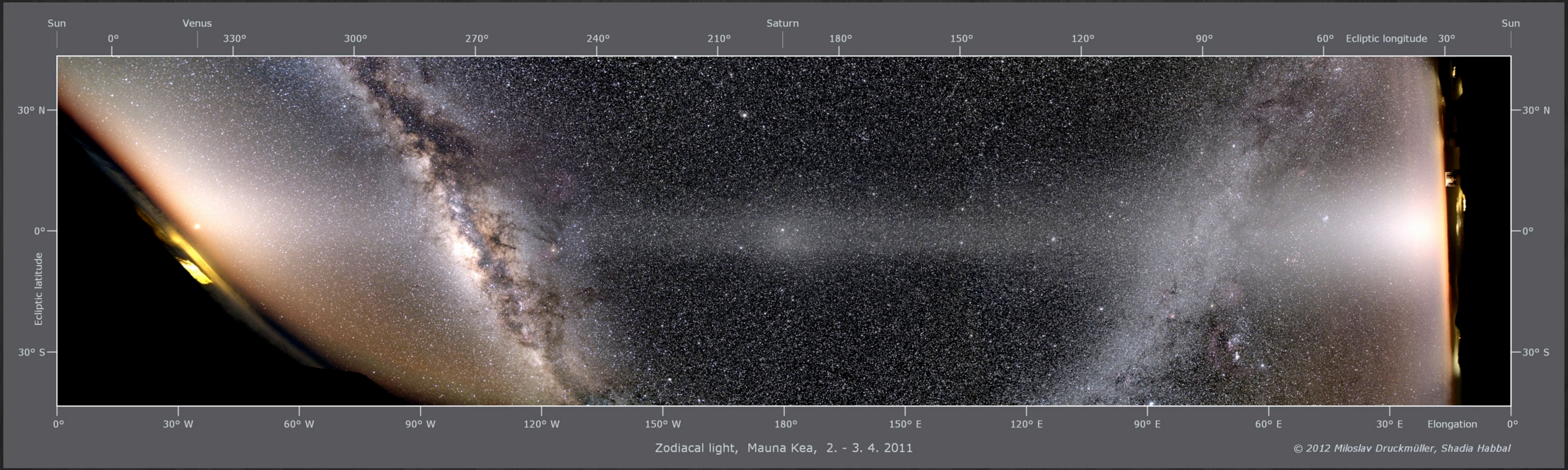
- better SED coverage (Herschel)
- complementary observations (MIDI / VISIR)

Olofsson et al. (in prep)

Conclusions

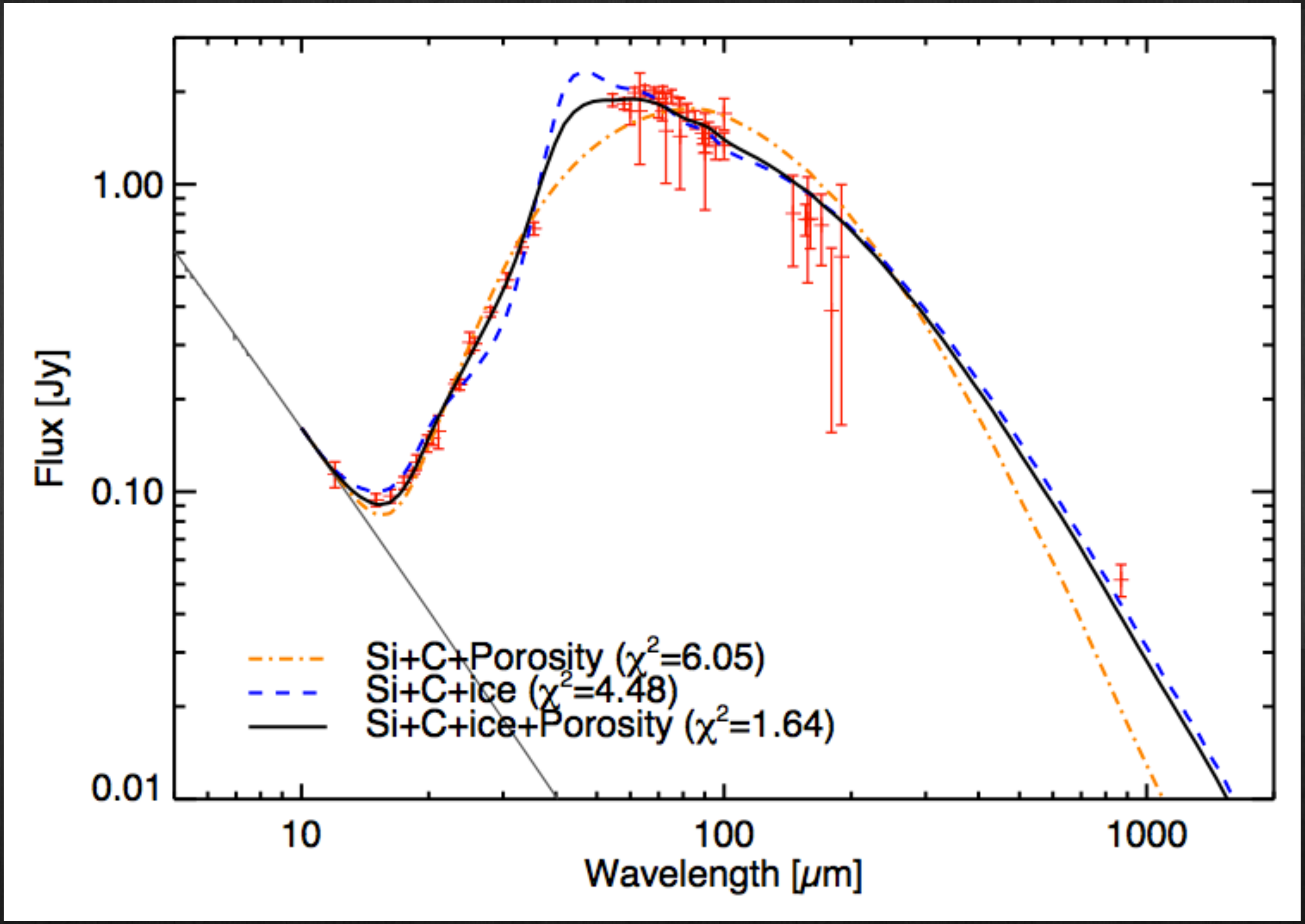
- Quality of the fits intimately connected to laboratory experiments !
- Detection of crystalline olivine grains enriched in iron
  - Disruptive collisions of differentiated planetesimals
  - Formation of terrestrial planets: highly unstable period (Kenyon & Bromley 2005)
- An outer dust belt: hunting for planets (Herschel, ALMA)
- Observed dust in warm debris disks is transient: time variability? Which timescale ?
  - Follow-up spectroscopic observations (e.g., VLT/Visir, JWST/Miri)

Zodiacal light in the solar system



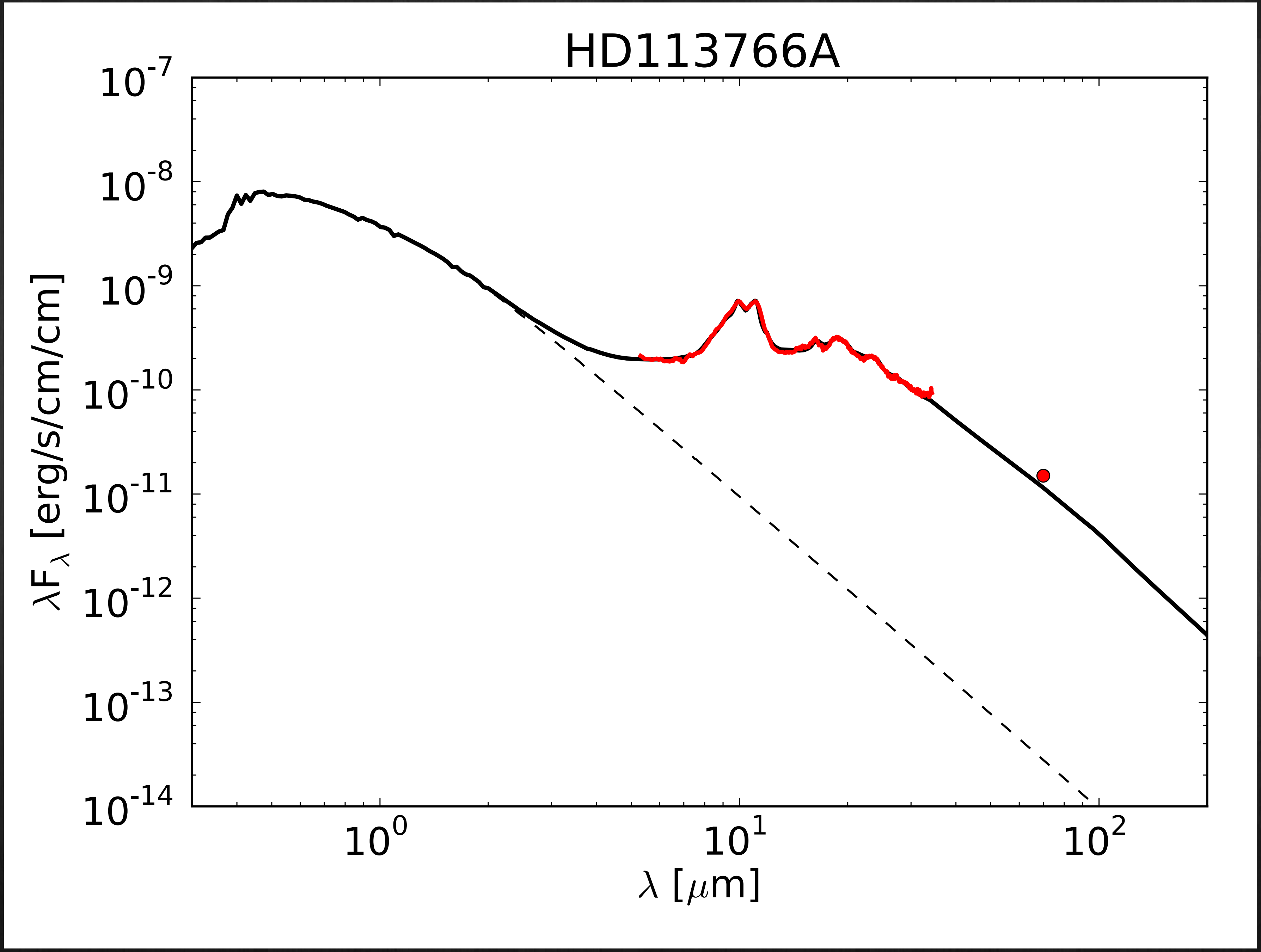
Credits : M. Druckmuller & S. Habbal

Debris disk



Lebreton et al. (2011)

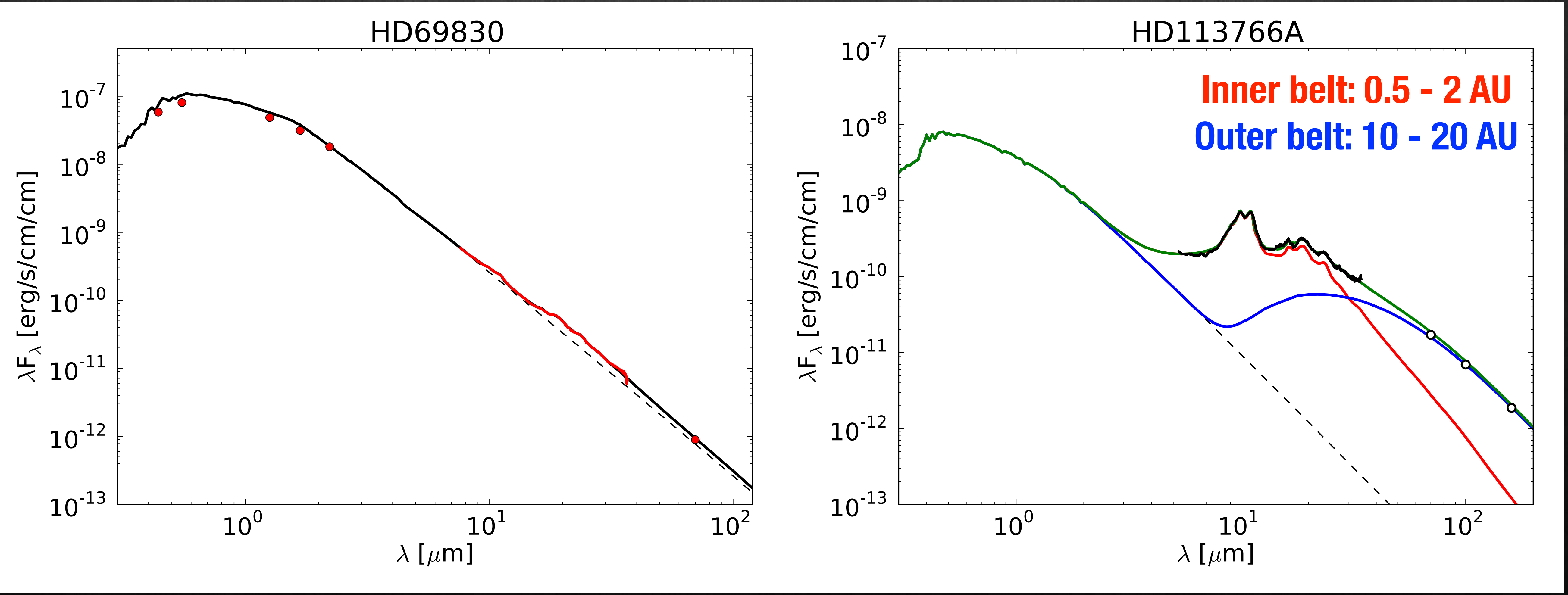
Warm debris disk

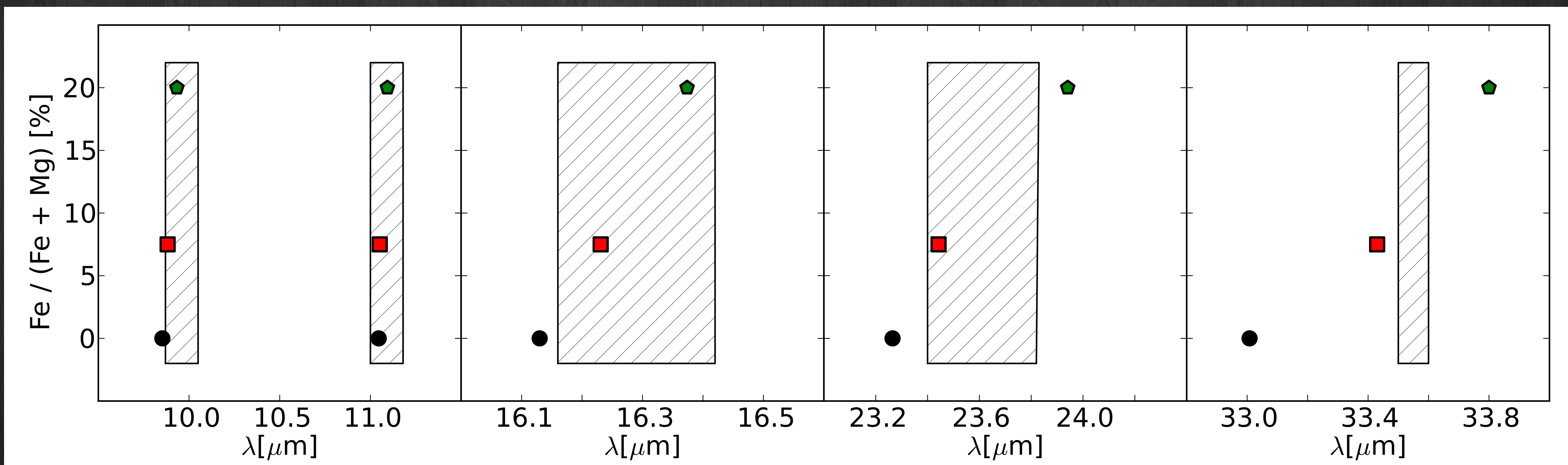


Olofsson et al. (2012)

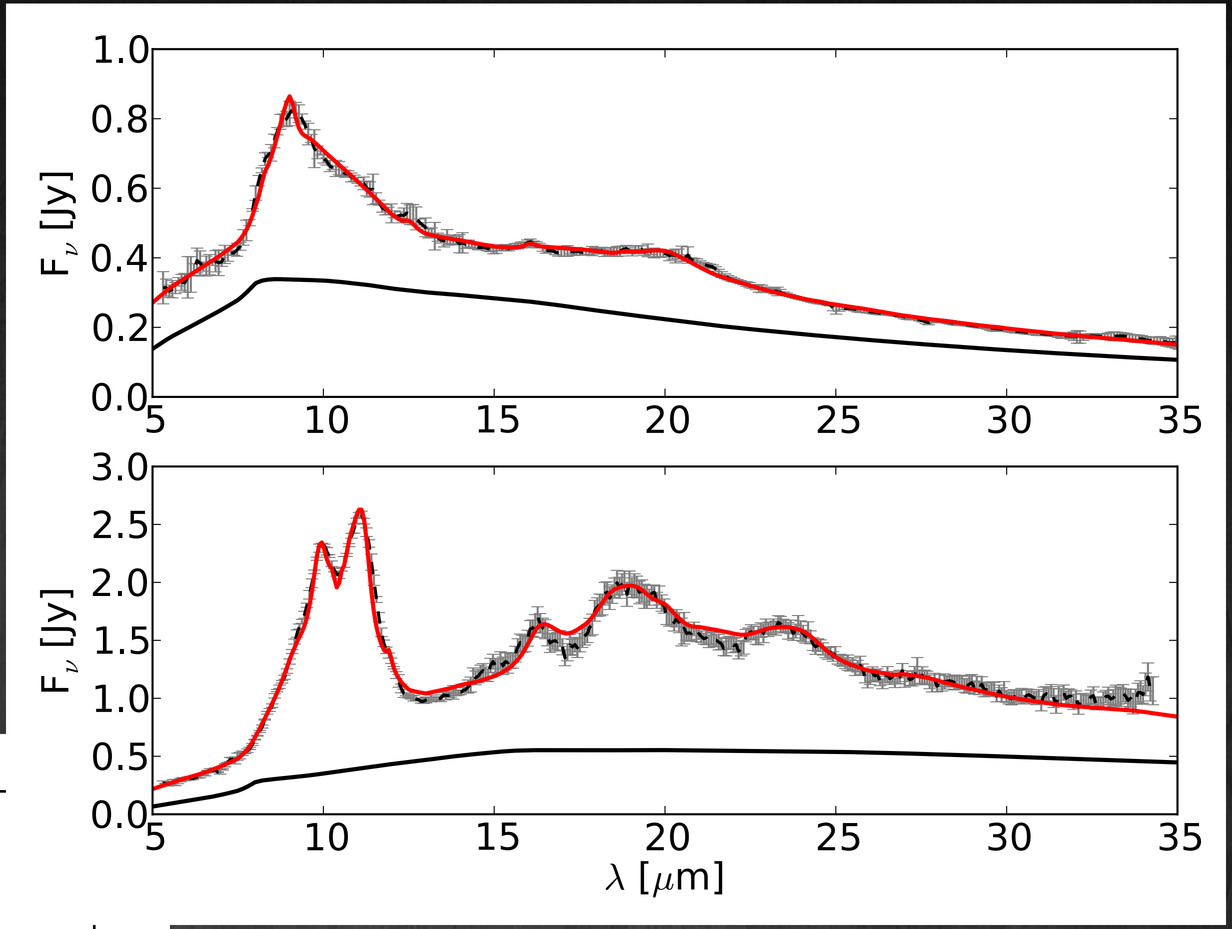
An outer dust belt?

- Far-IR observations are required:
  - Spitzer/MIPS 70 µm
  - Herschel/PACS 70, 100,160 µm
- HD69830: no measurable excess - no outer belt
- HD113766A: excess at all 3 PACS wavelengths (Olofsson et al. in prep)
  - Need for spatially resolved observations

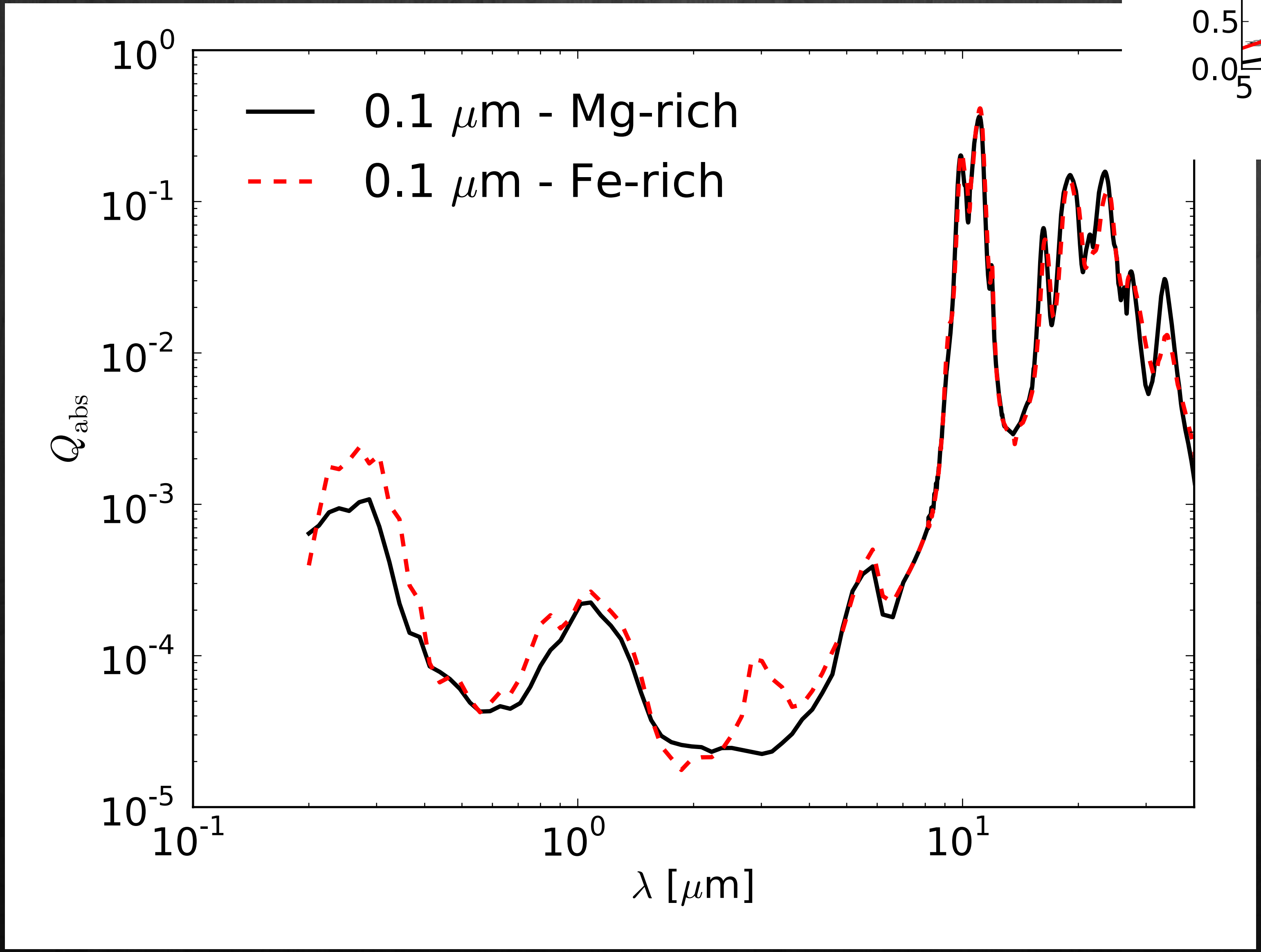




Fe / (Fe + Mg) [%]
0
5
10
15
20
10.0
10.5
11.0
λ[μm]
16.1
16.3
16.5
λ[μm]
23.2
23.6
24.0
λ[μm]
33.0
33.4
33.8
λ[μm]

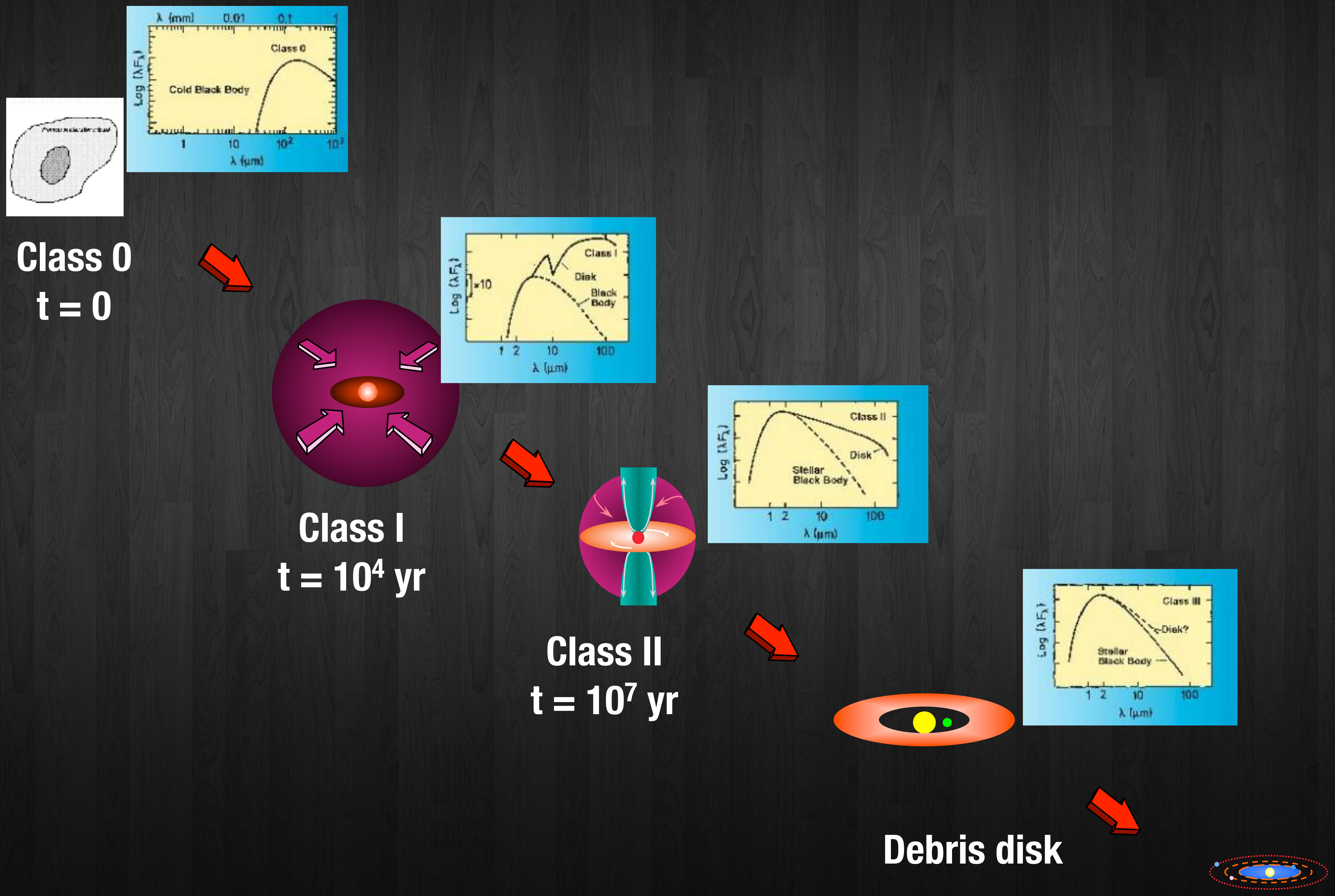


1.0
0.8
0.6
0.4
0.2
0.0
F_ν [Jy]
5
10
15
20
25
30
35
3.0
2.5
2.0
1.5
1.0
0.5
0.0
F_ν [Jy]
λ [μm]



0.1 μm - Mg-rich
0.1 μm - Fe-rich
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$Q_{\rm abs}$
10^{-1}
10^0
10^1
λ [μm]

Stellar formation



Credits : S. Beckwith