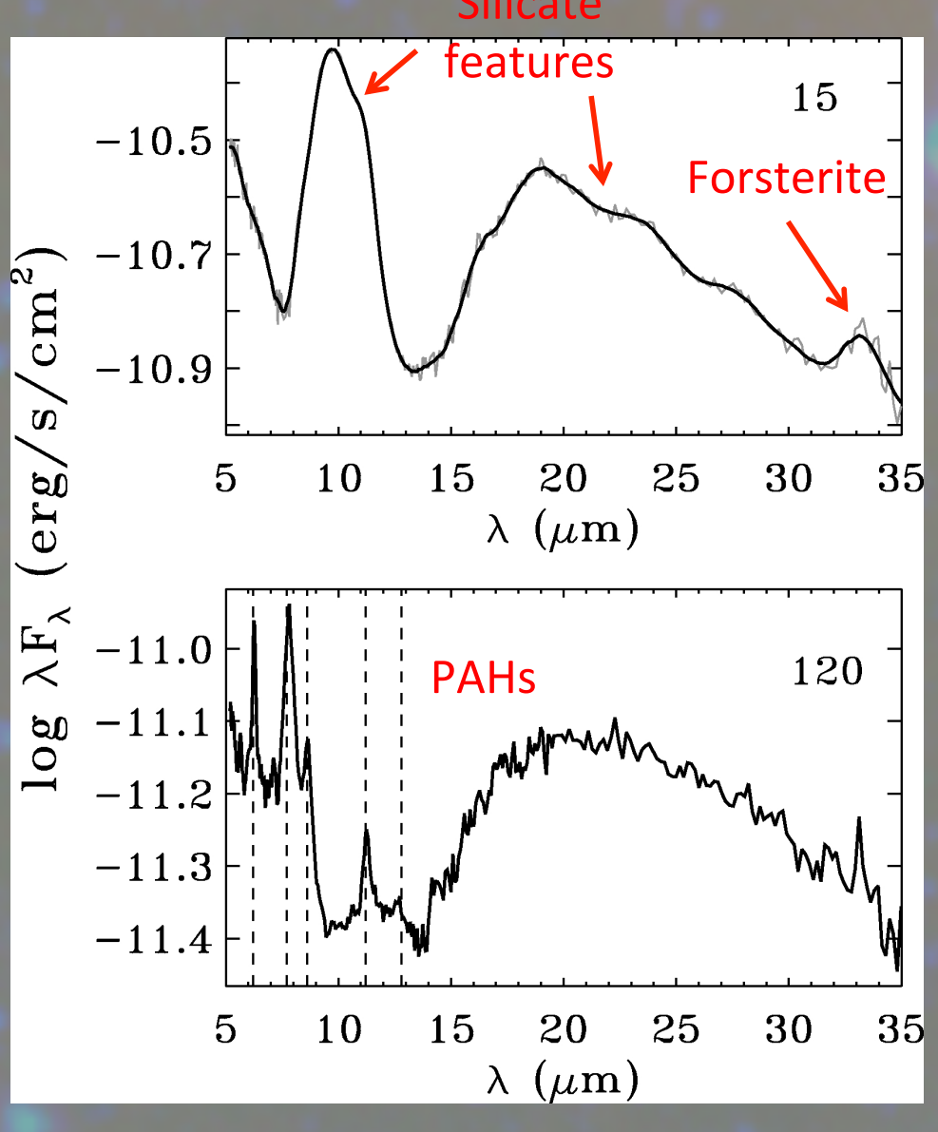
Evolution of Dust Mineralogy in Protoplanetary Disks*

Isa Oliveira[1], Johan Olofsson[2], Klaus Pontoppidan[3], Ewine van Dishoeck[4,5], Jean-Charles Augereau[6], Bruno Merín[7]
[1]UT Austin, [2]MPIA, [3]STScI, [4]Sterrewacht Leiden, [5]MPE, [6]Grenoble, [7]ESAC

Context

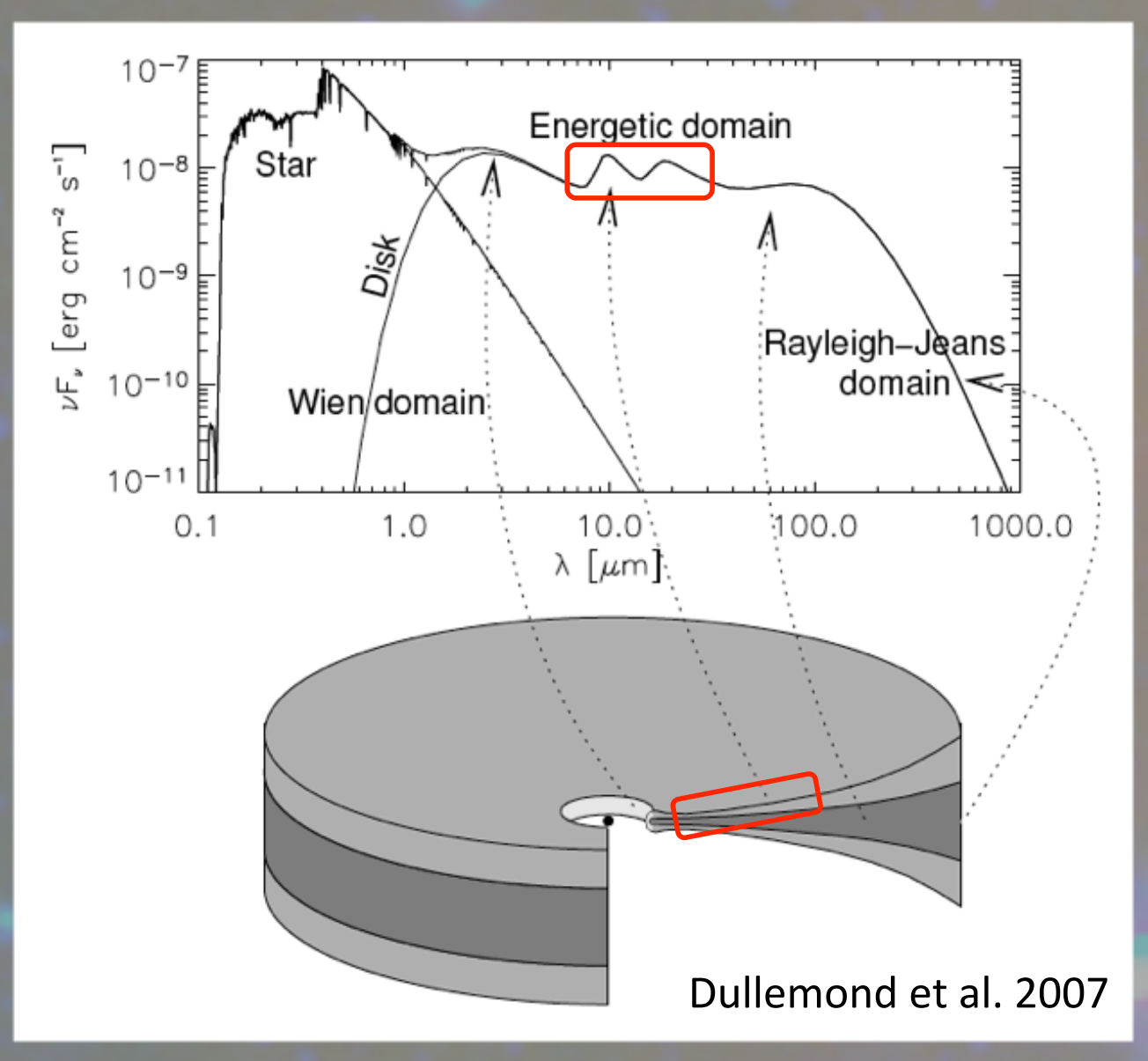
Mineralogical studies of silicate features emitted by dust grains in protoplanetary disks and solar system bodies can shed light on the progress of planet formation. The significant fraction of crystalline material in comets, chondritic meteorites, and interplanetary dust particles indicates a modification of the almost completely amorphous interstellar medium dust from which they formed. The production of crystalline silicates, thus, must happen in protoplanetary disks, where dust evolves to build planets and planetesimals. Different scenarios have been proposed, but it is still unclear how and when this happens. We present dust grain mineralogy (composition, crystallinity, and grain size distribution) of disks belonging to clusters with different ages, using the same analysis technique for all samples. This comparison allows an investigation of the grain mineralogy evolution with time.

Spitzer/IRS Spectra



- Constraints on disk structure
  - Flared vs. Flat, Disks with inner holes
- Dust features as probes of physical and chemical processes
  - Silicate features -> grain sizes
  - Crystalline features -> heating and mixing
  - PAHs -> UV radiation

IR excess connects to disk geometry



Dullemond et al. 2007

Regions Studied

Young bin of disk evolution:

Serpens (2-3 Myr)

Taurus (1-2 Myr)

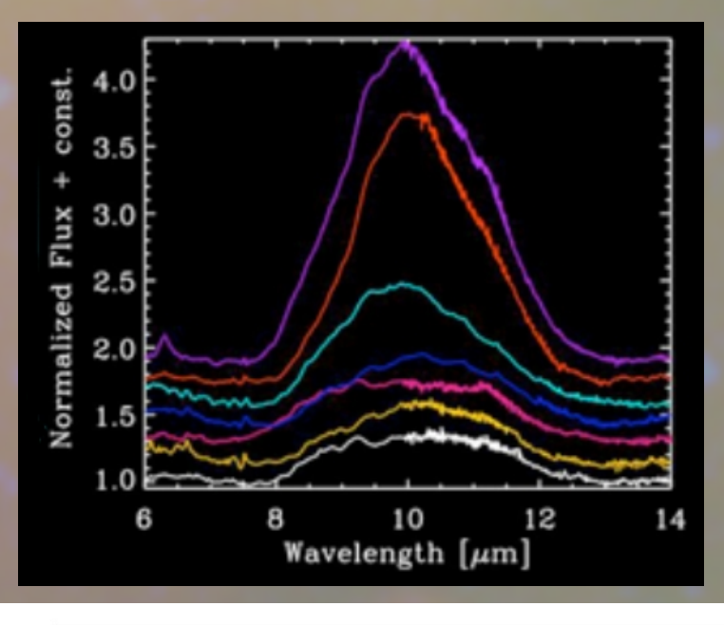
Old bin of disk evolution:

Upper Scorpius (5-6 Myr)

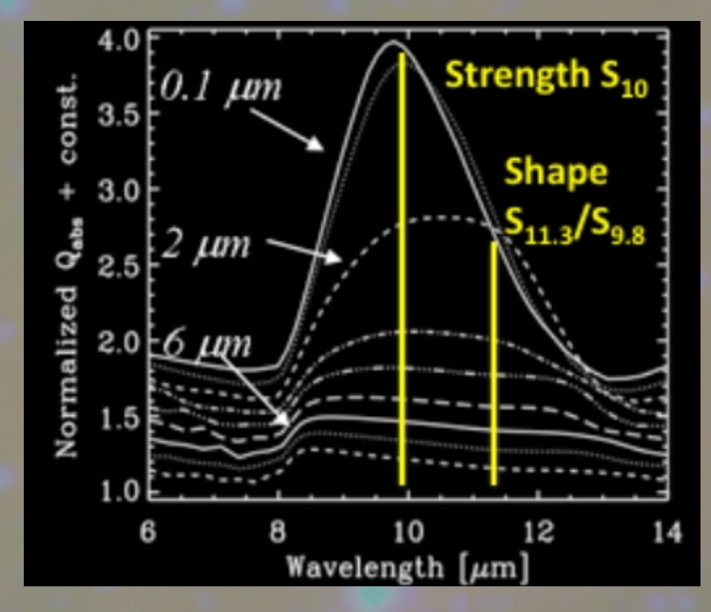
η Chamaeleontis (6-7 Myr)

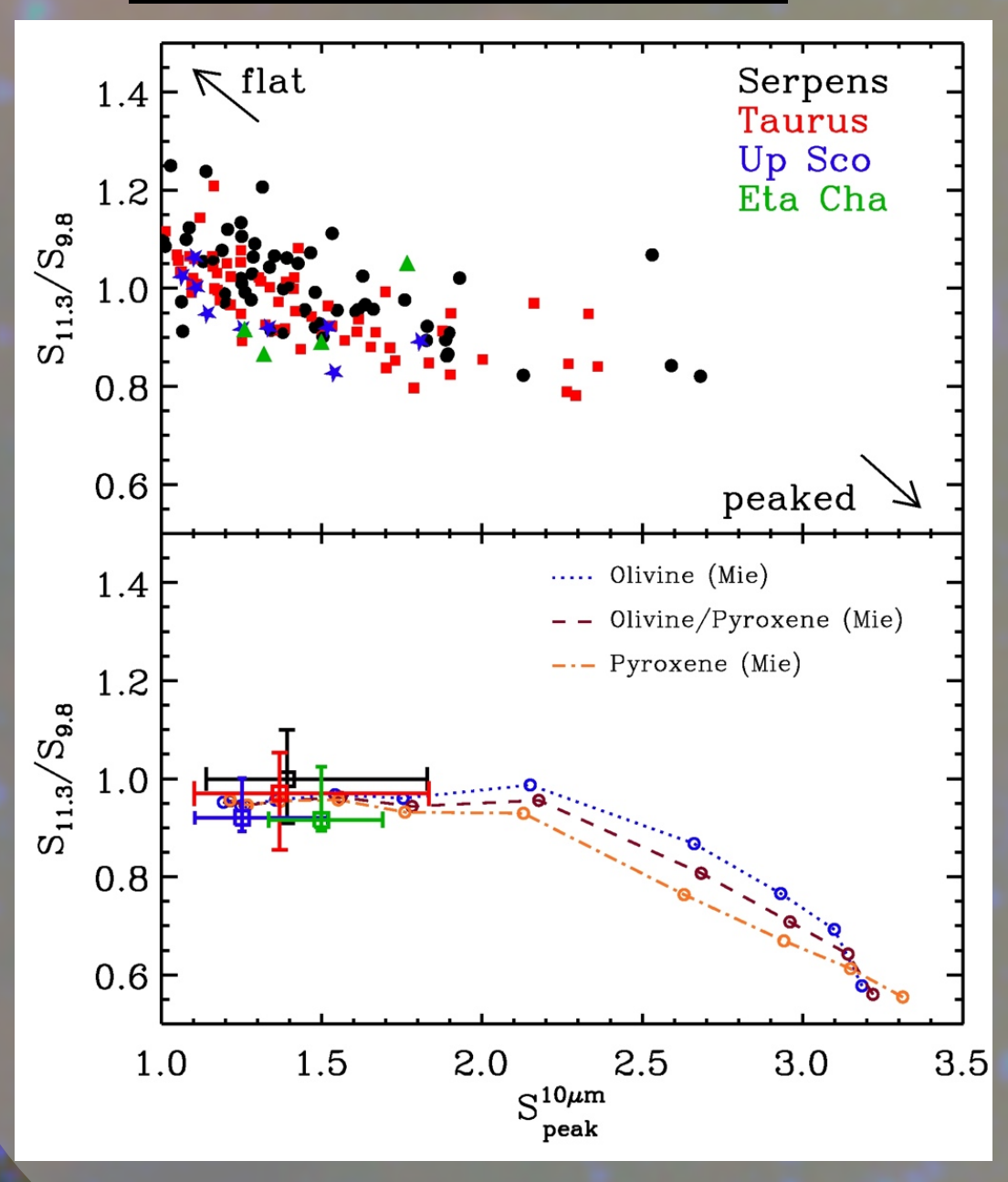
10 μm Silicate Feature

Observations



Models



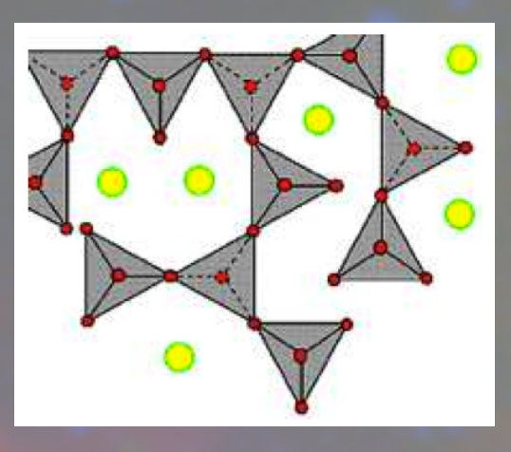


Difference in mean ages not reflected in difference in average surface dust sizes

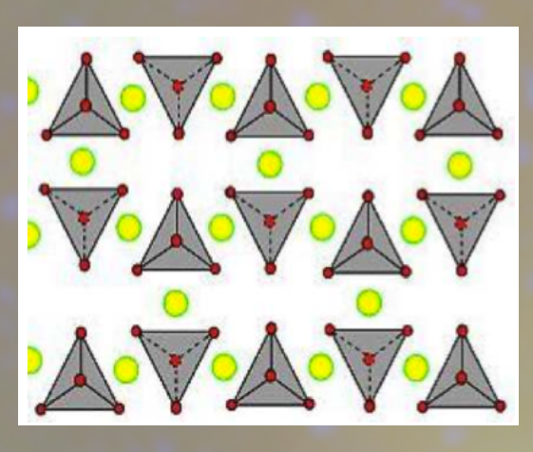
Equilibrium of growth and destruction processes necessary to maintain small dust population on disk surface

Dust Composition

Amorphous silicates:
Olivine (Mg, Fe)$_2$ SiO$_4$
Pyroxene (Mg, Fe)$_2$ Si$_2$O$_6$
Silica SiO$_2$



Crystalline silicates:
Enstatite (Olivine group)
Forsterite (Pyroxene group)



ISM grains almost completely amorphous

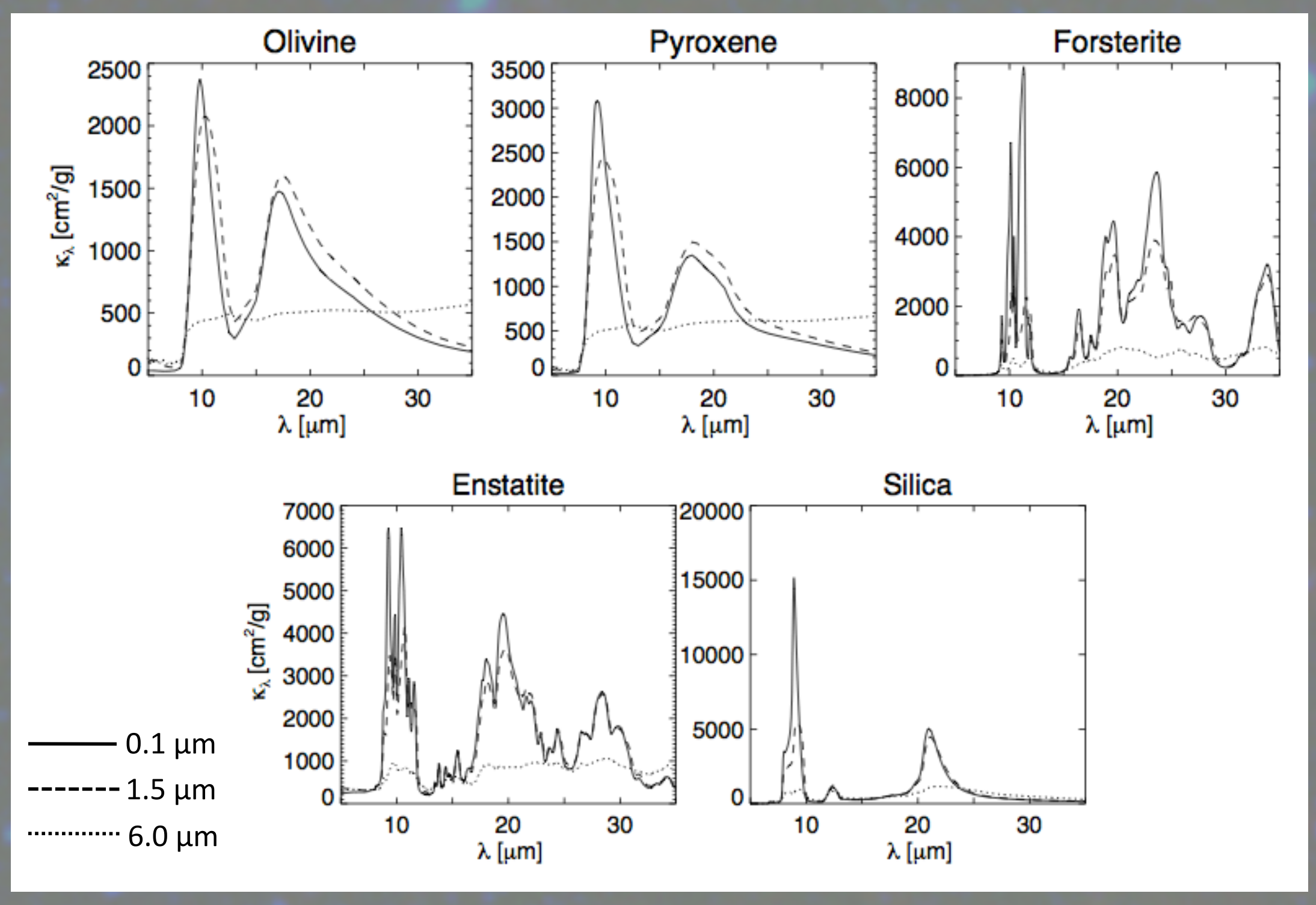
Crystallization of amorphous grains a thermal process (≥ 1000K)

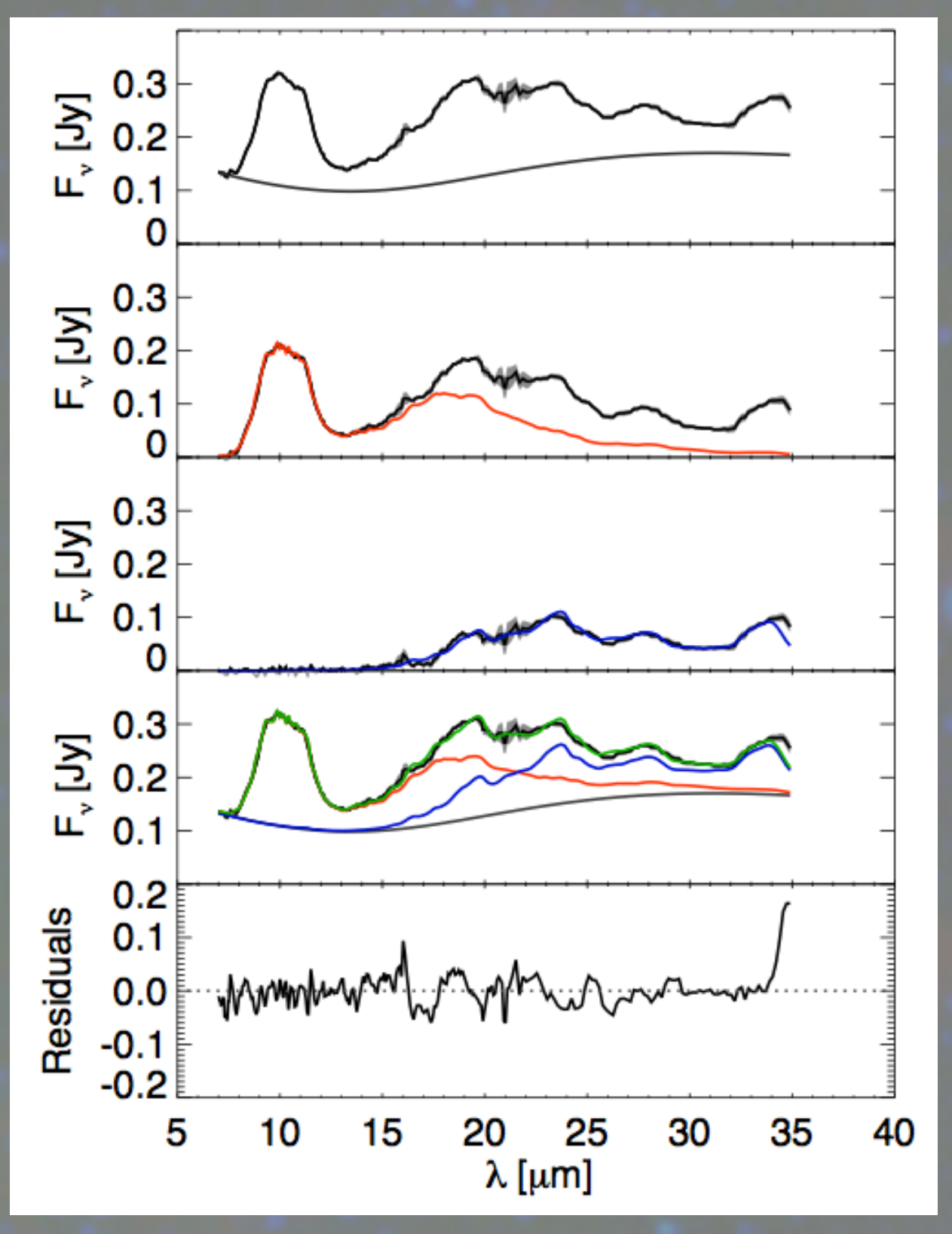
Such temperatures only reached in the inner disk

Spectral Decomposition

Goal is to infer composition and dominant grain size of emitting grains

Two temperatures (components), each composed of 3 amorphous (0.1, 1.5 and 6 μm) and 2 crystalline (0.1 and 1.5 μm) species





Procedure:

1st step: continuum subtraction

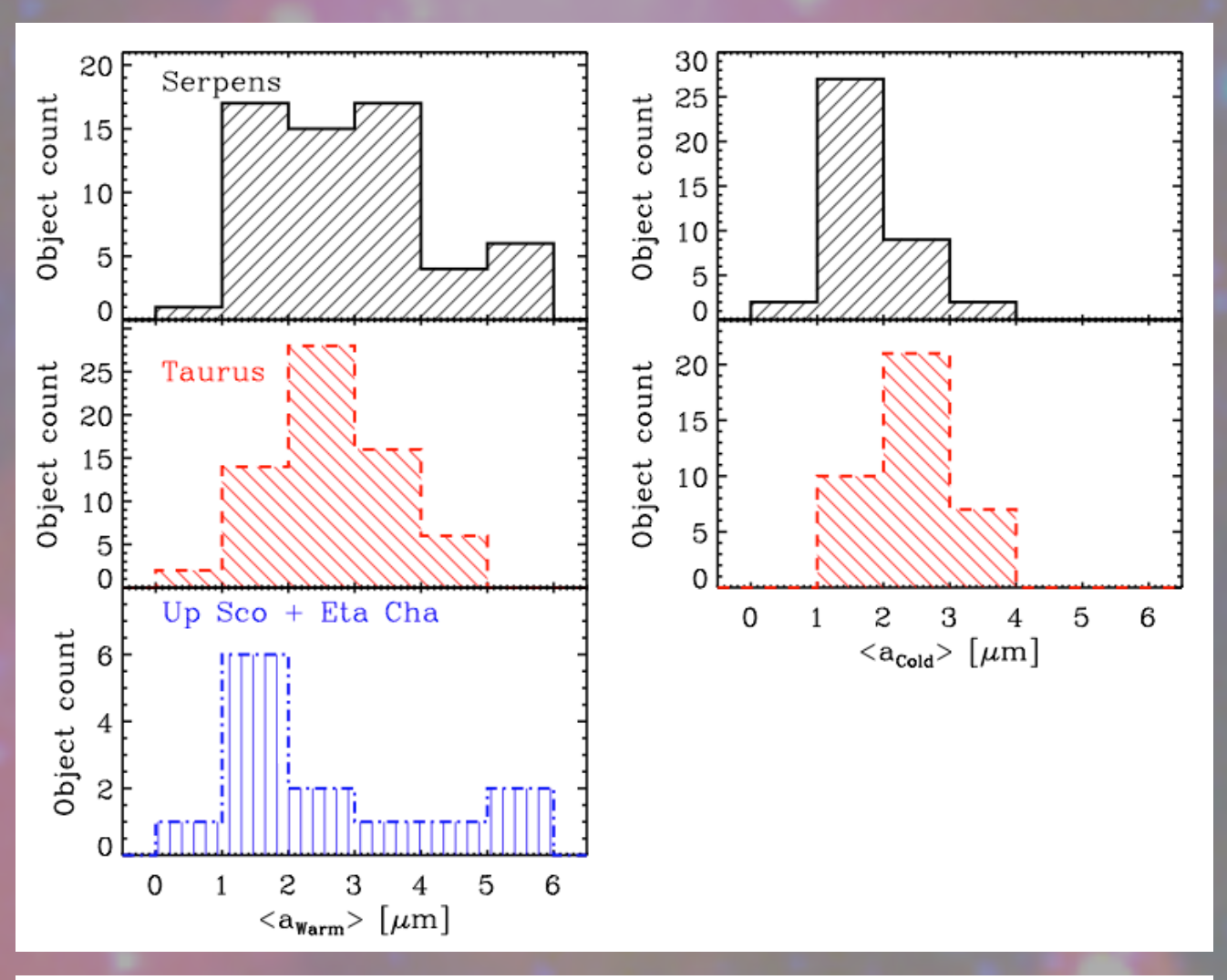
2nd step: fit warm component to reproduce 10 μm feature (red line)

3rd step: fit cold component to residuals (blue line)

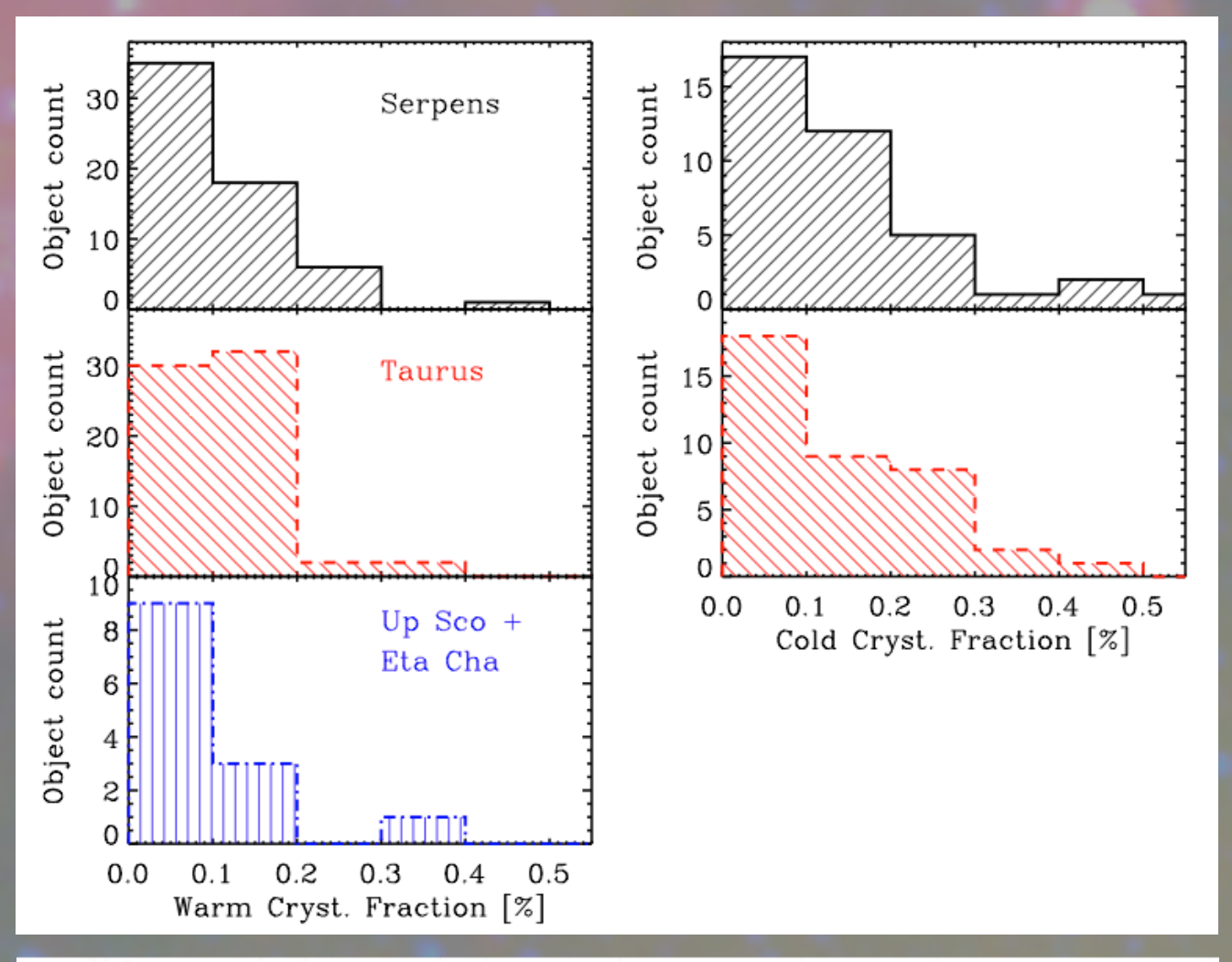
Final fit (green line) reproduces very well entire spectrum

Olofsson et al. 2010, A&A, 520, 39

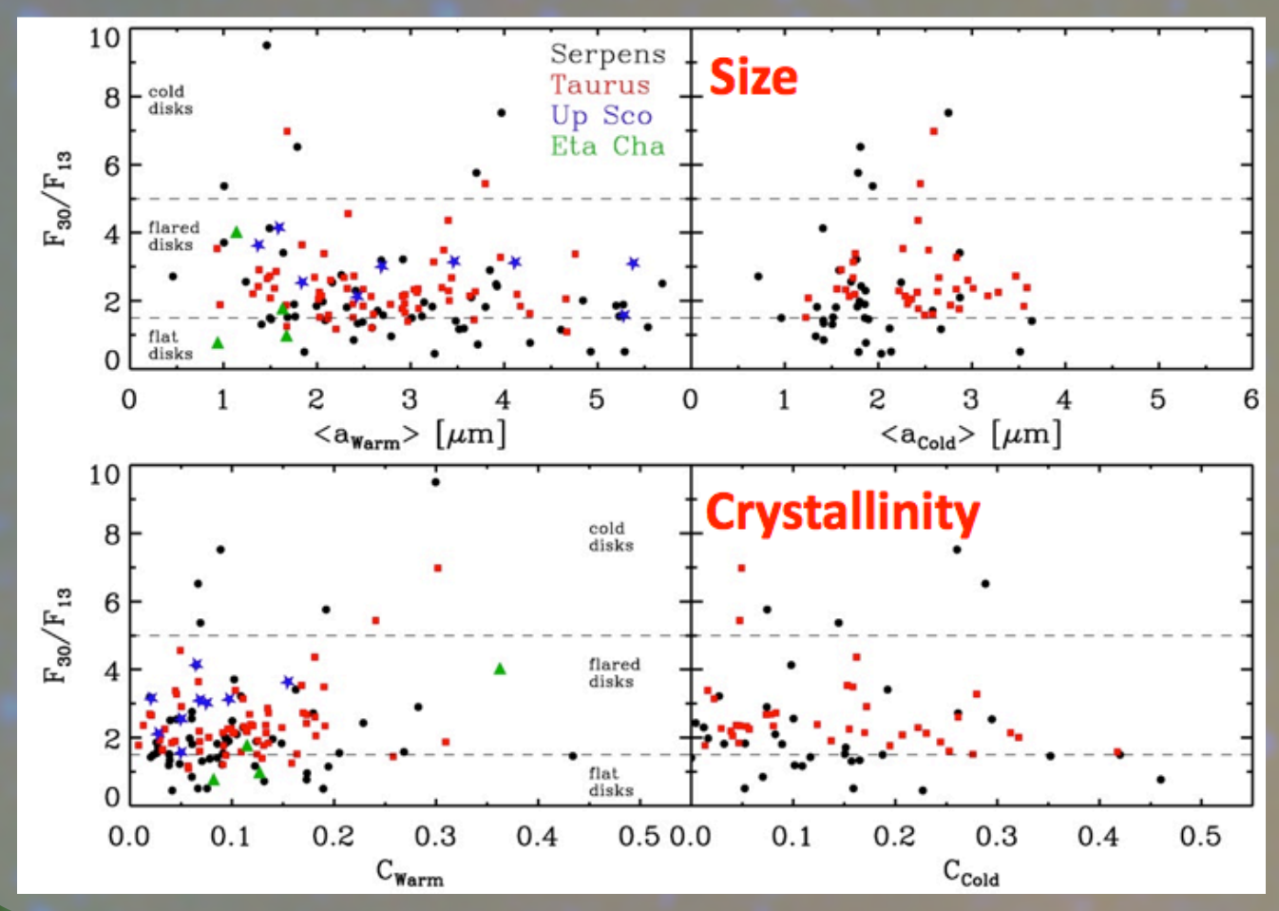
Results



Different ranges for warm and cold components, but same spread for different regions

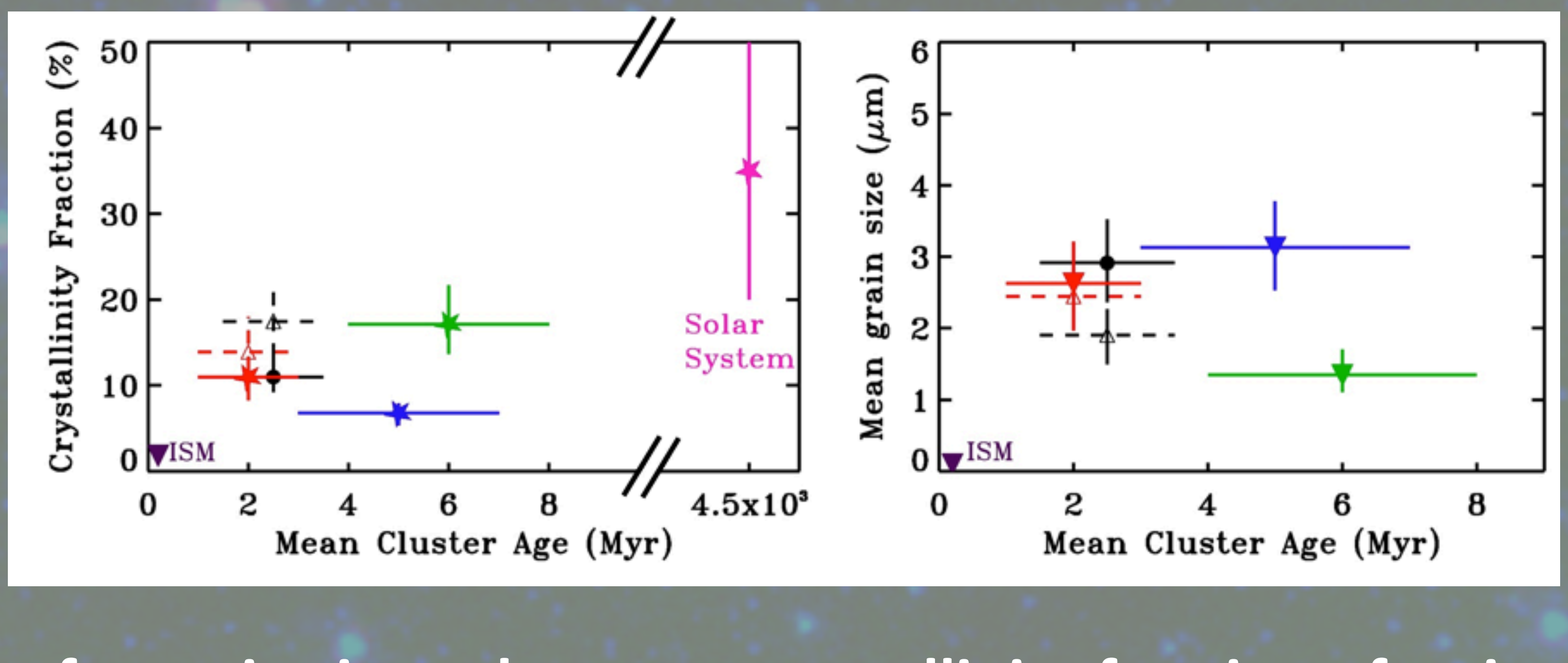


No correlations found for either mean grain size or crystallinity fraction of warm and cold components



No preferential grain size or crystallinity fraction for a given disk geometry

EVOLUTION



As for grain sizes, the mean crystallinity fraction of a given star-forming region does not statistically change with time

-> An equilibrium is reached very quickly (≤ 1 Myr), lasting until until disks dissipate

If planets are forming in disk mid-plane, no such equilibrium can take place there

-> Dust at surface and midplane evolving differently?

(even though the populations are connected through vertical mixing)

* Oliveira et al. 2011, ApJ 734, 51