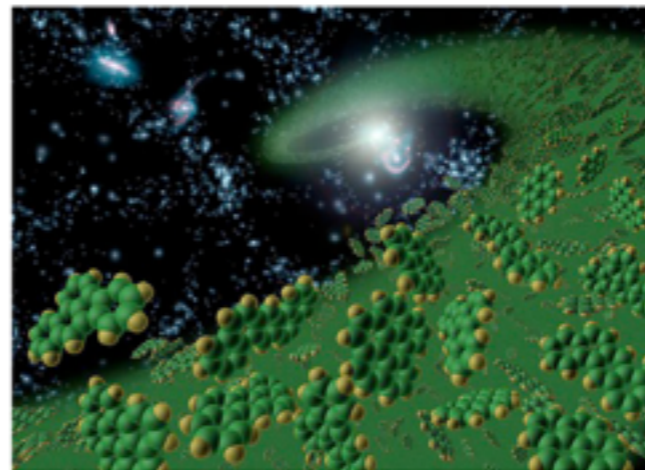
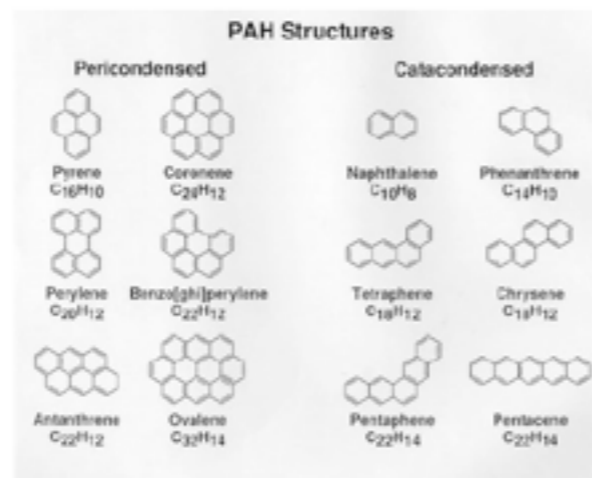


Polycyclic aromatic hydrocarbon ionization as a tracer of gas flows through protoplanetary disk gaps

K. M. Maaskant, M. Min, L.B.F.M. Waters, and A.G.G.M. Tielens
Astronomy & Astrophysics, Volume 563 (2014)



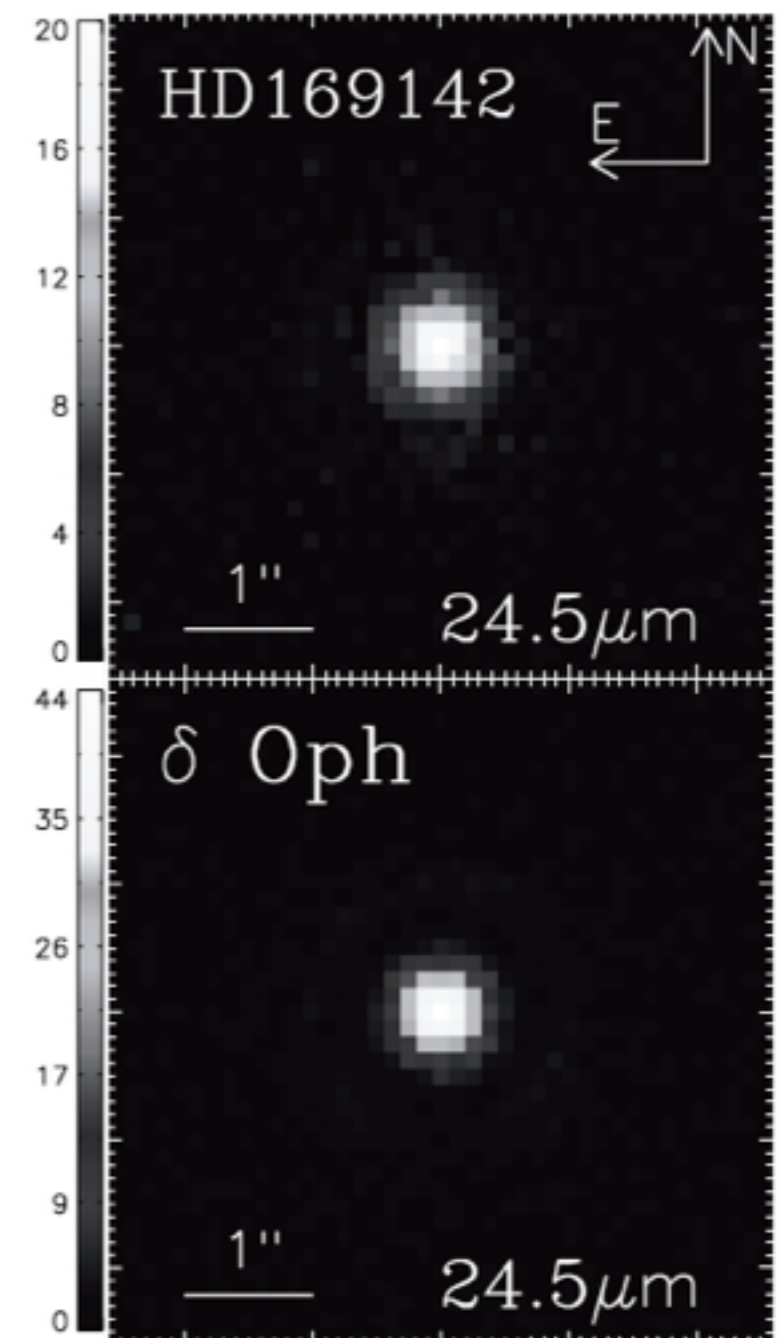
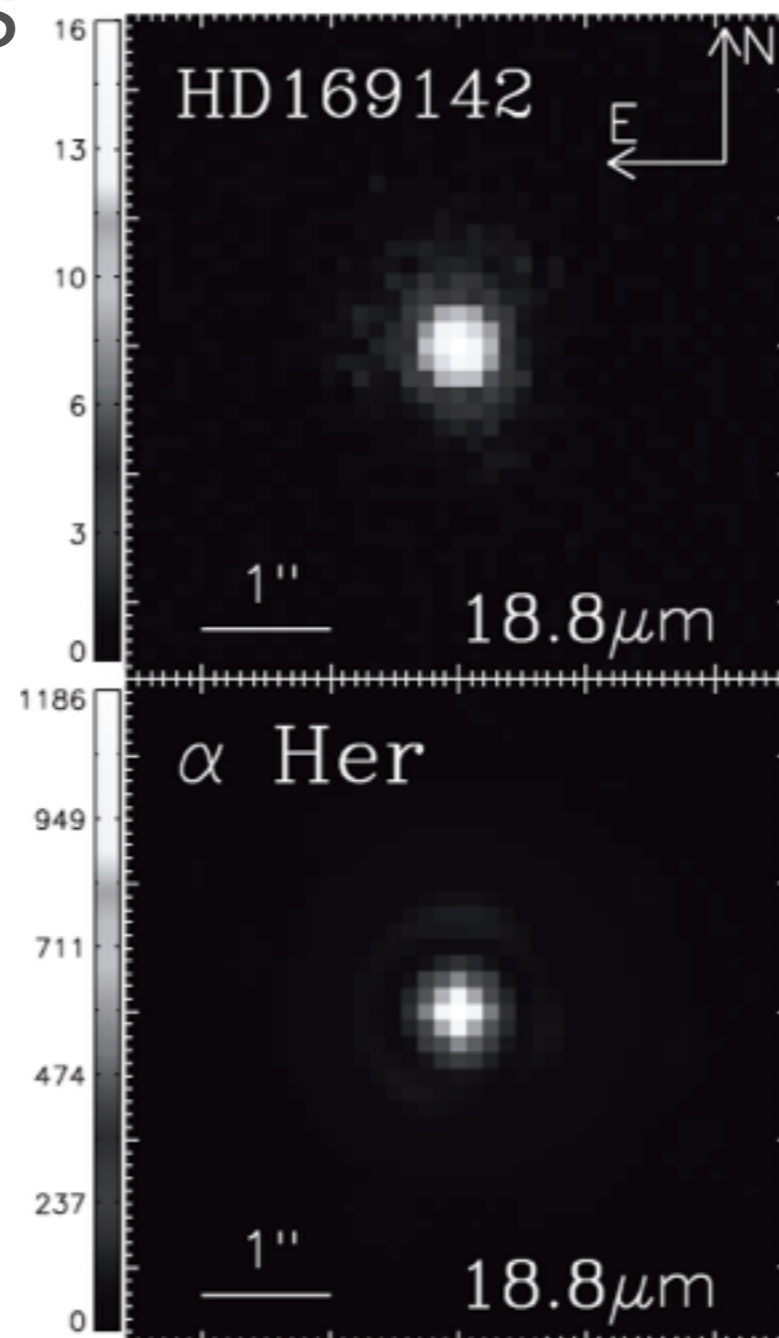
Ábrahám Péter

Accretion processes, 2014. október 15.

Mid-IR imaging of the disk of HD169142: Measuring the size of the gap

Honda et al. (ApJ. 752, 2012)

Subaru/COMICS
18.8 μ m, 24.5 μ m

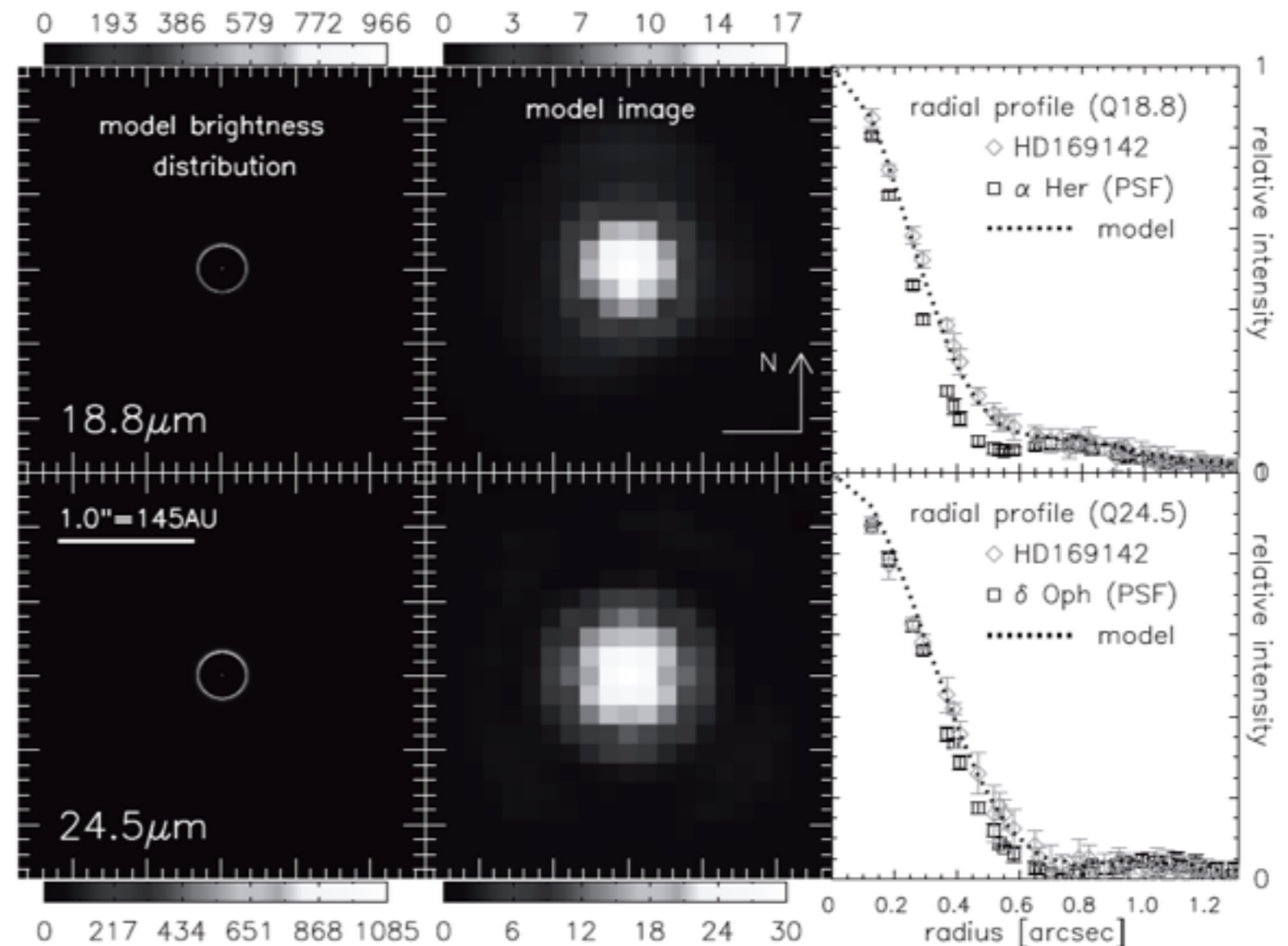


Mid-IR imaging of the disk of HD169142: Measuring the size of the gap

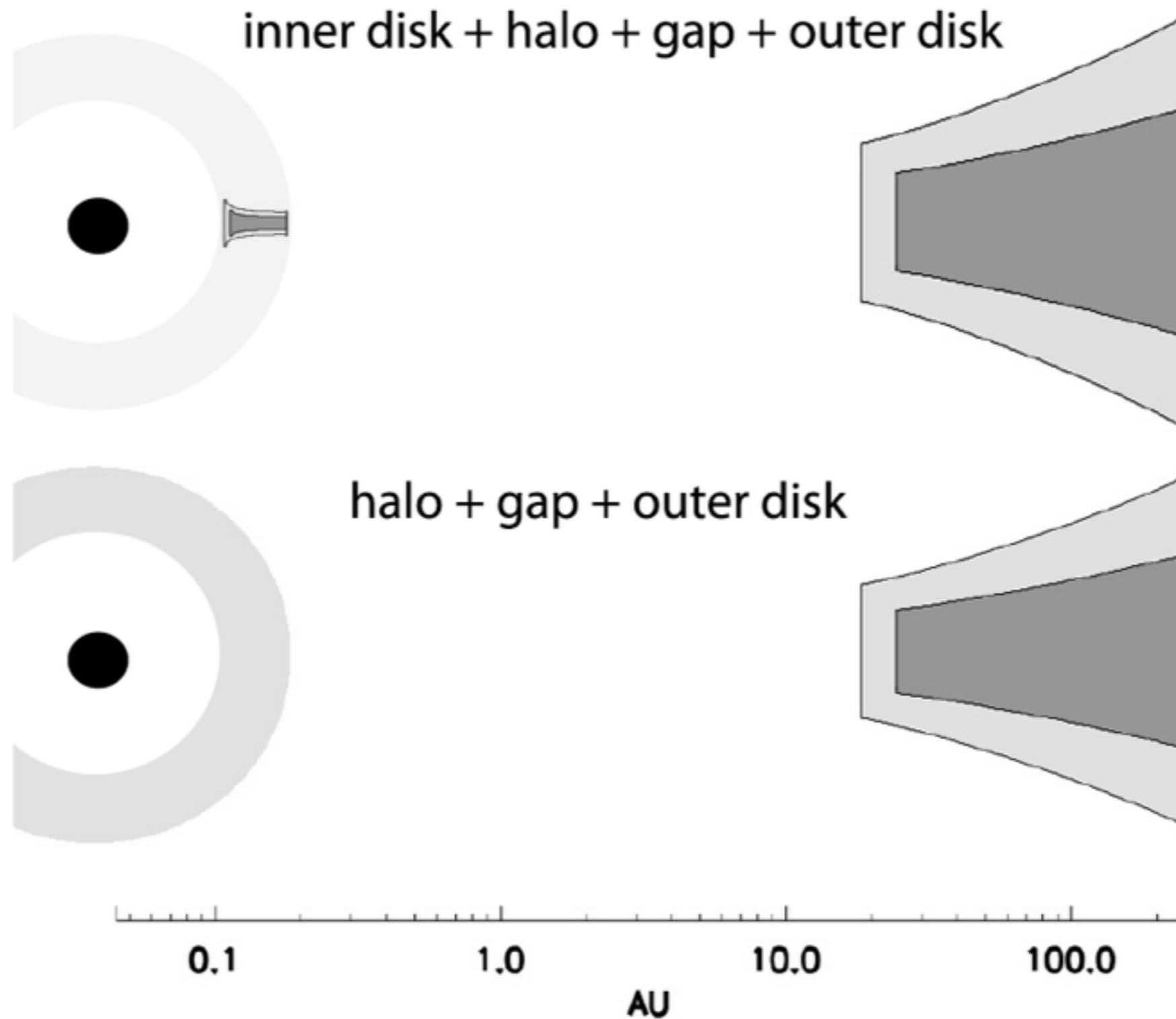
@18.8 μm : $0.604'' \pm 0.017''$

@24.5 μm : $0.680'' \pm 0.034''$

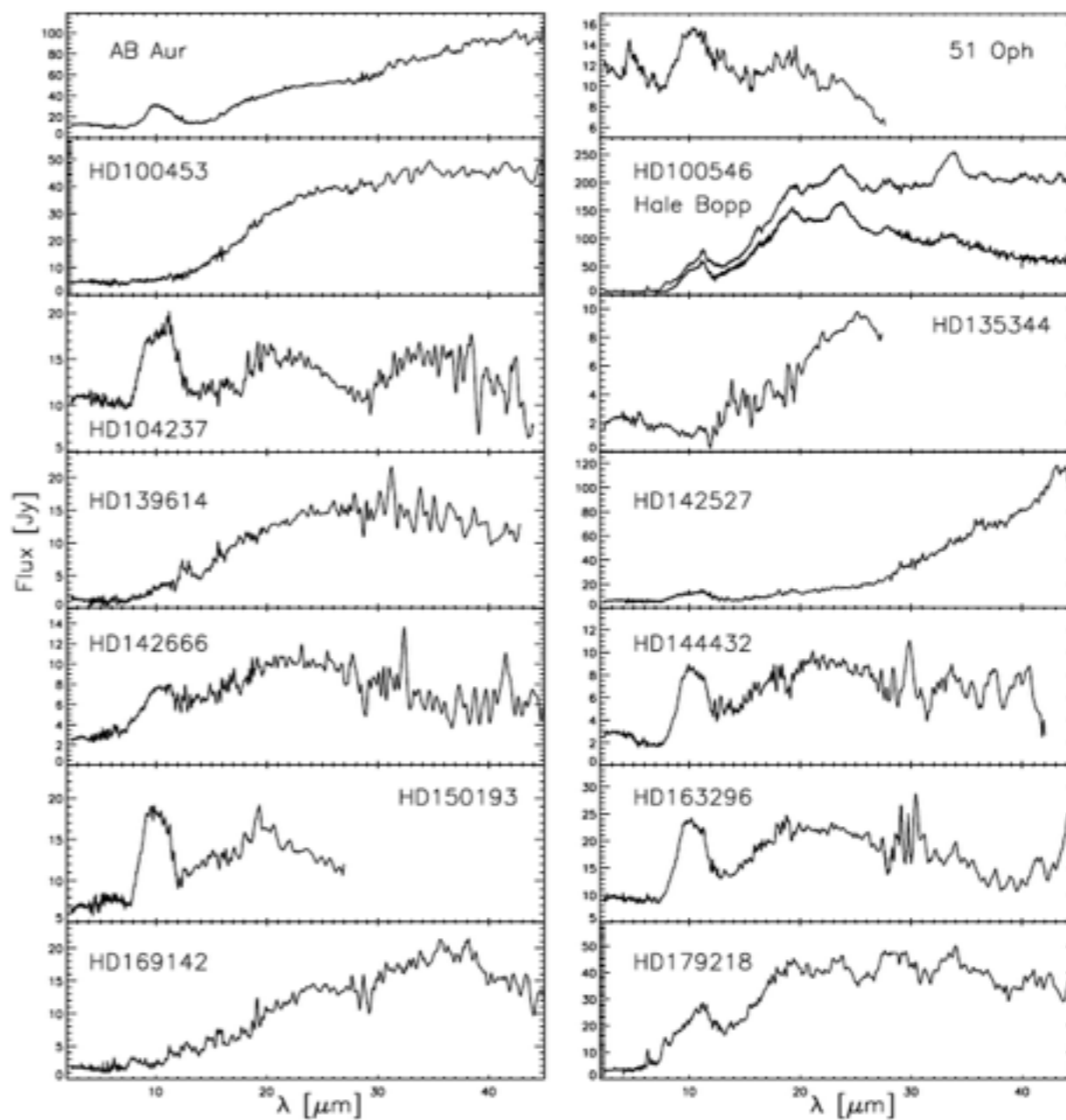
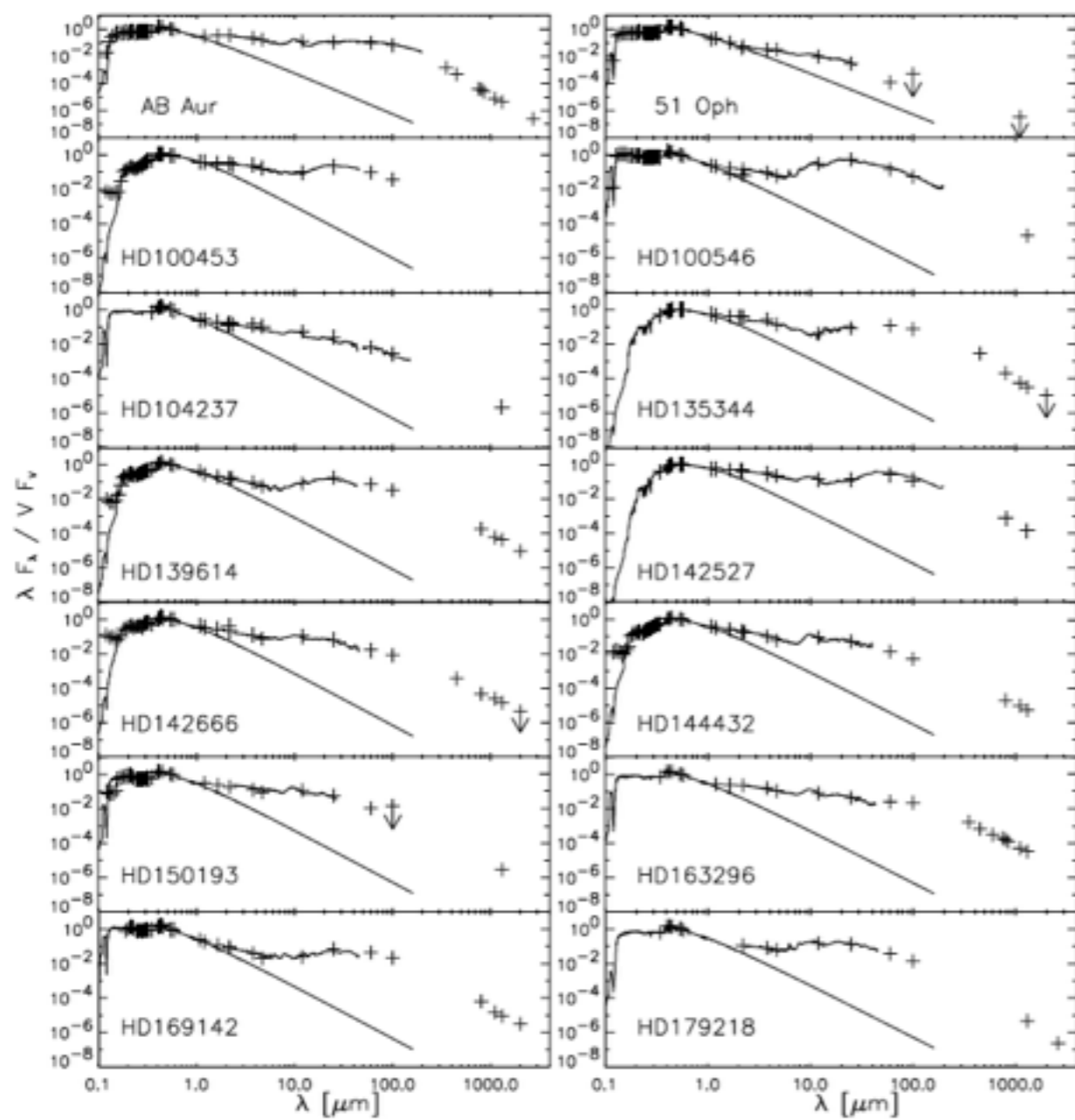
size is similar



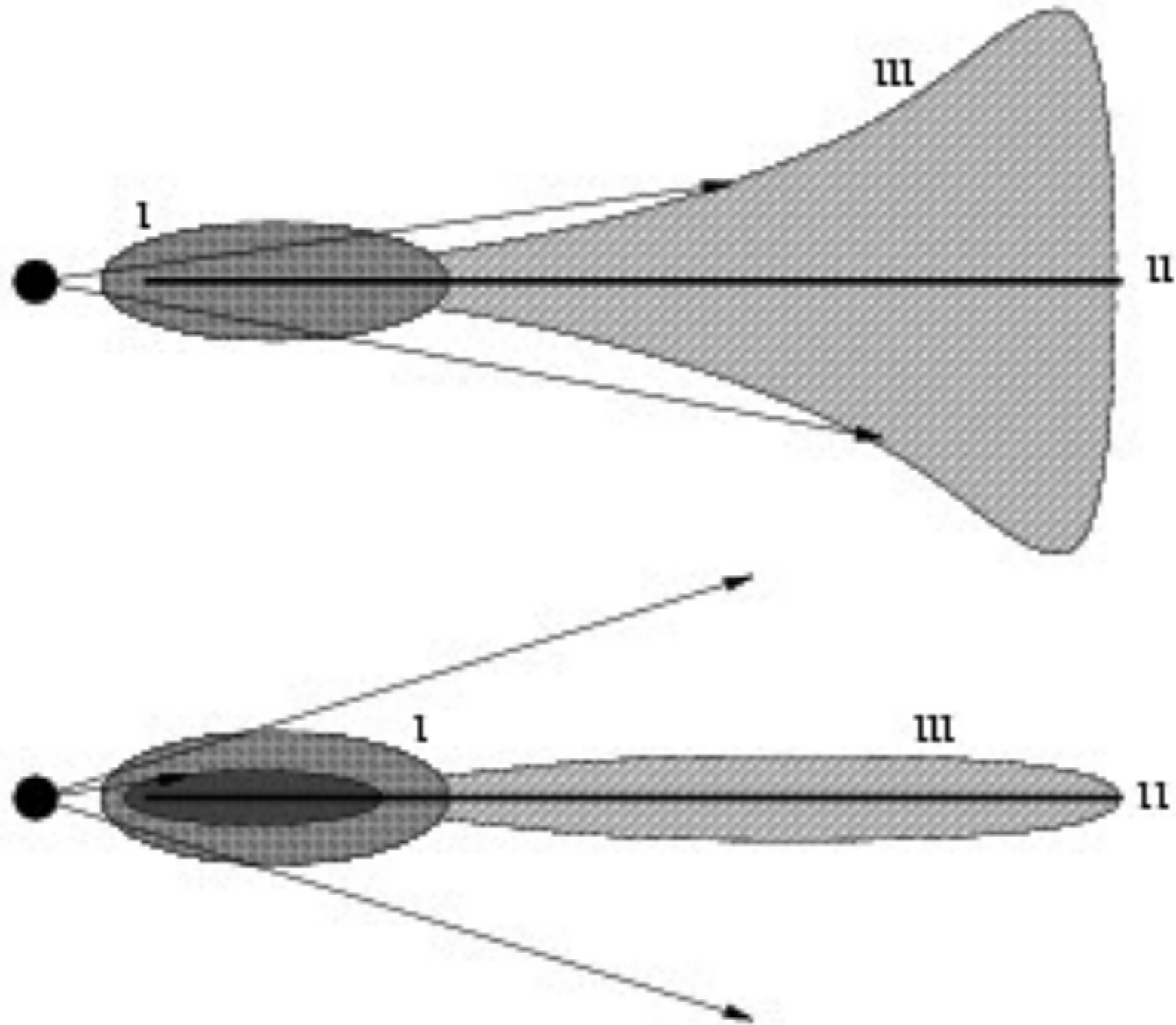
Disk geometry



Meeus classification of Herbig Ae/Be stars



Meeus classification of Herbig Ae/Be stars

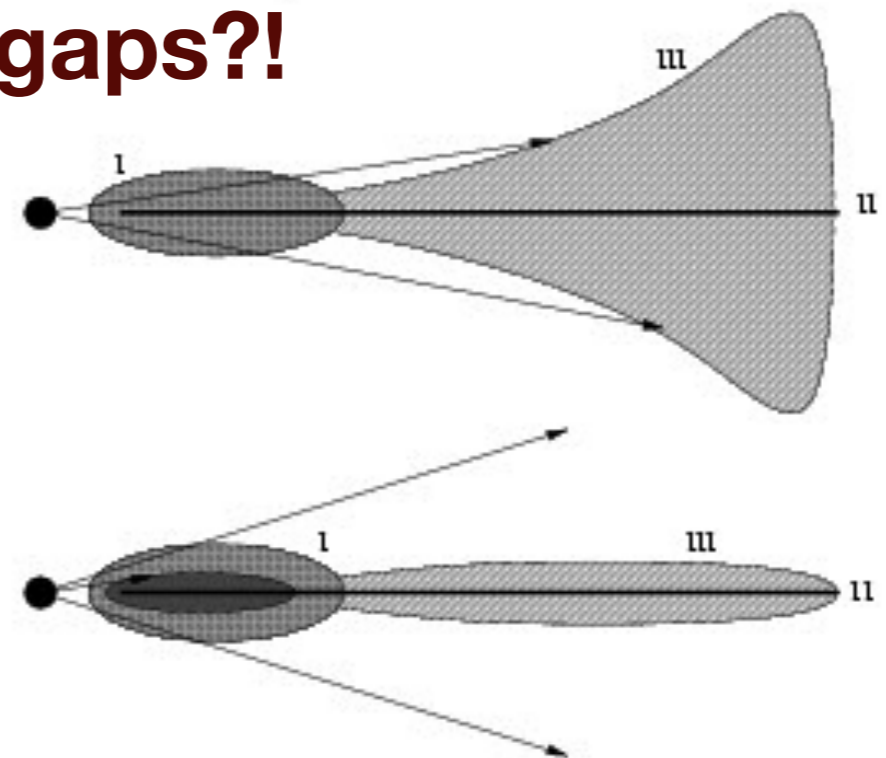


Meeus classification of Herbig Ae/Be stars

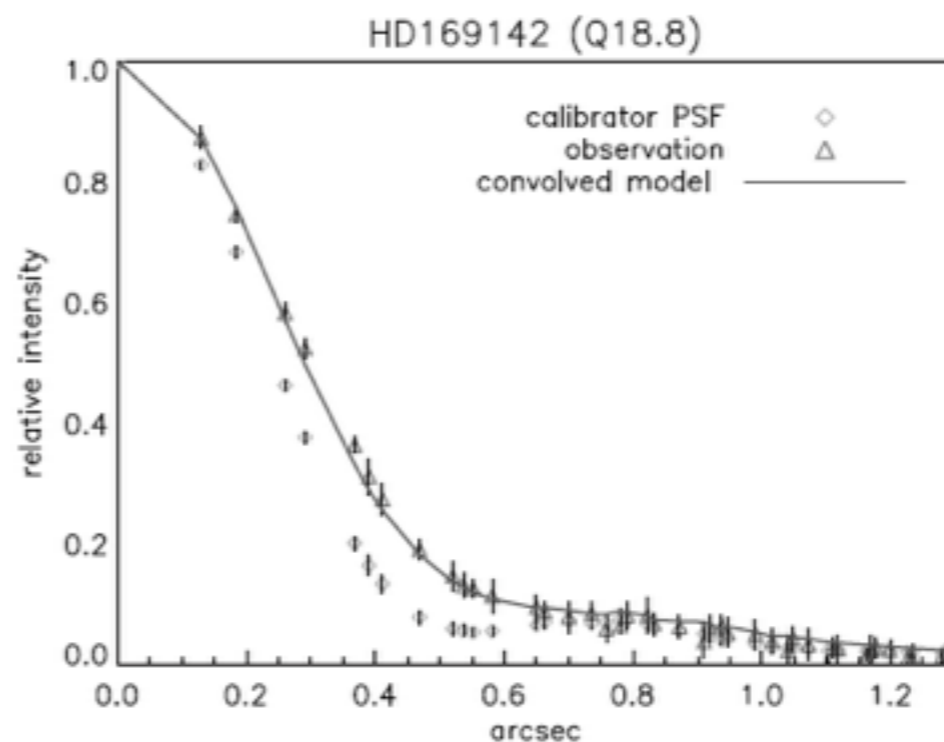
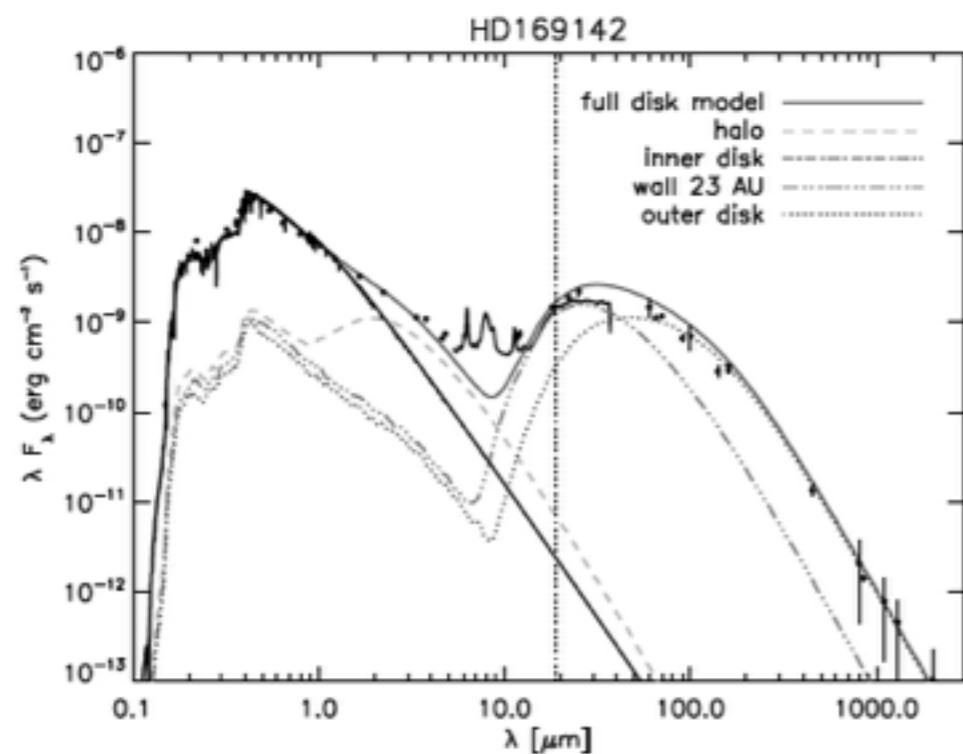
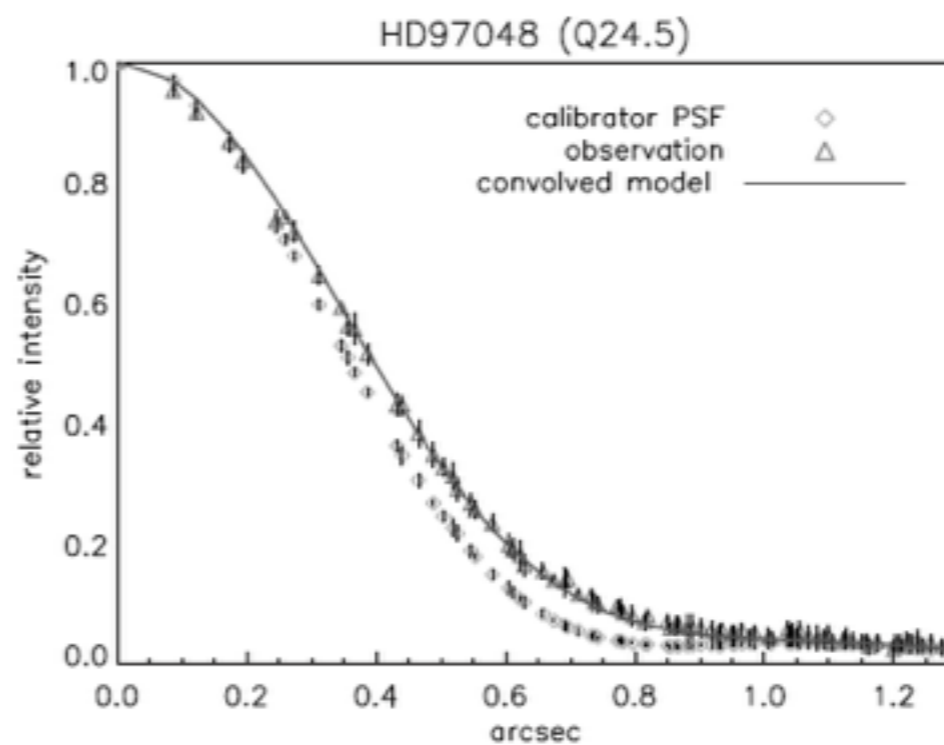
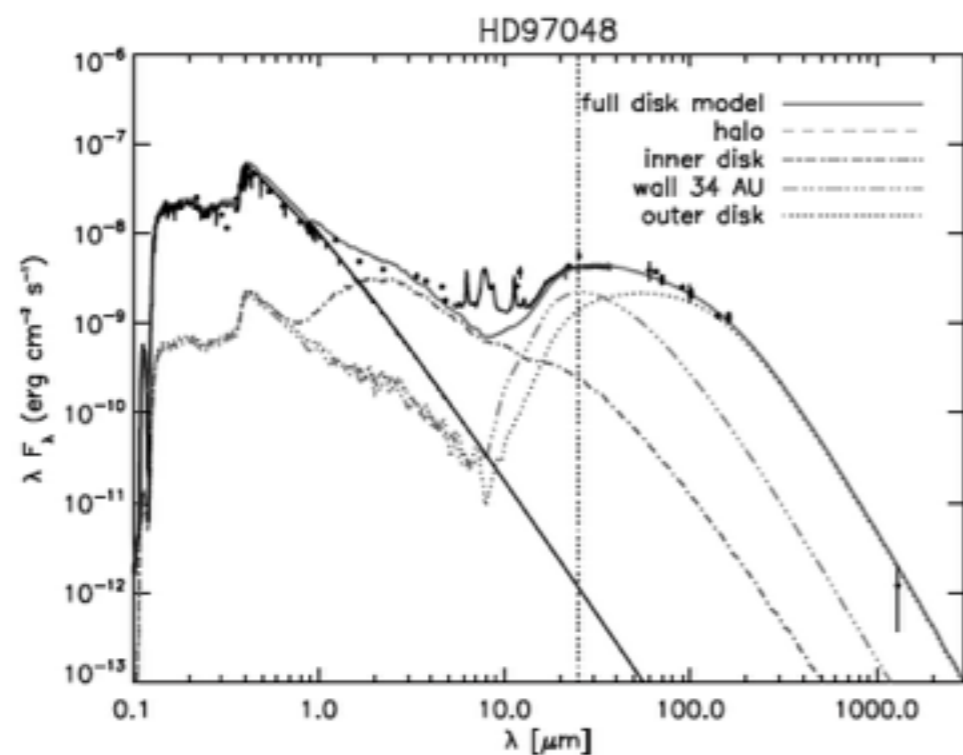
HD169142 is a Meeus Ib disk, and it has a gap

Other Group I sources also have gaps: AB Aur (Honda et al., 2010), HD 142527 (Fukagawa et al., 2006, Fujiwara et al., 2006, Verhoeff et al., 2011), HD 135344 (Brown et al., 2009), HD 36112 (Isella et al., 2010), HD100546 (Bouwman et al., 2003, Benisty et al., 2010, Mulders et al., 2011)

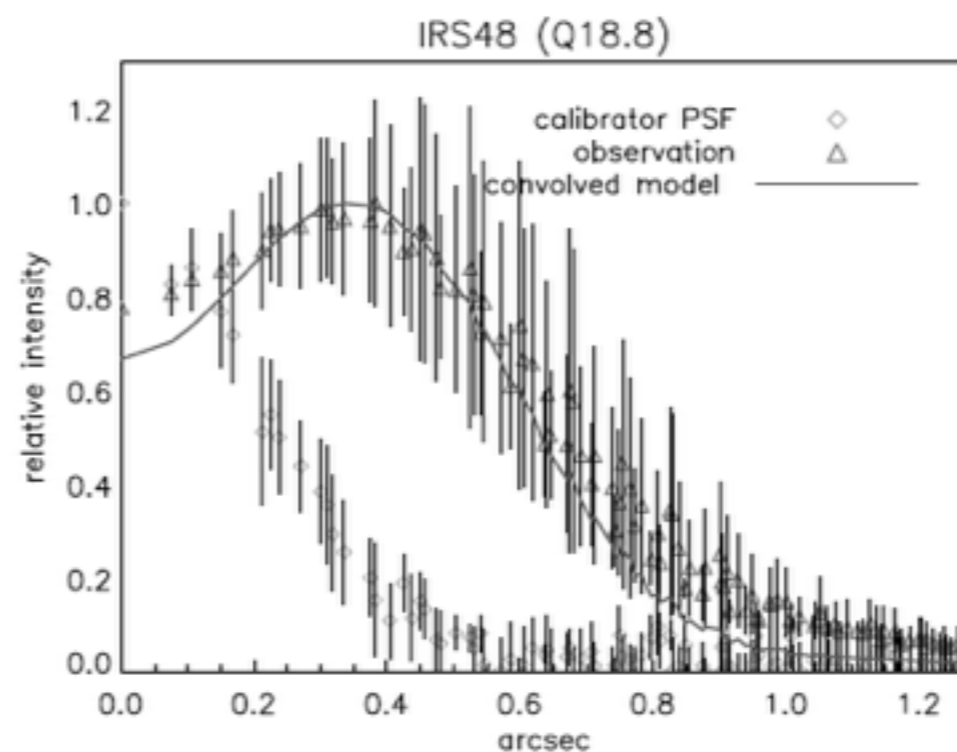
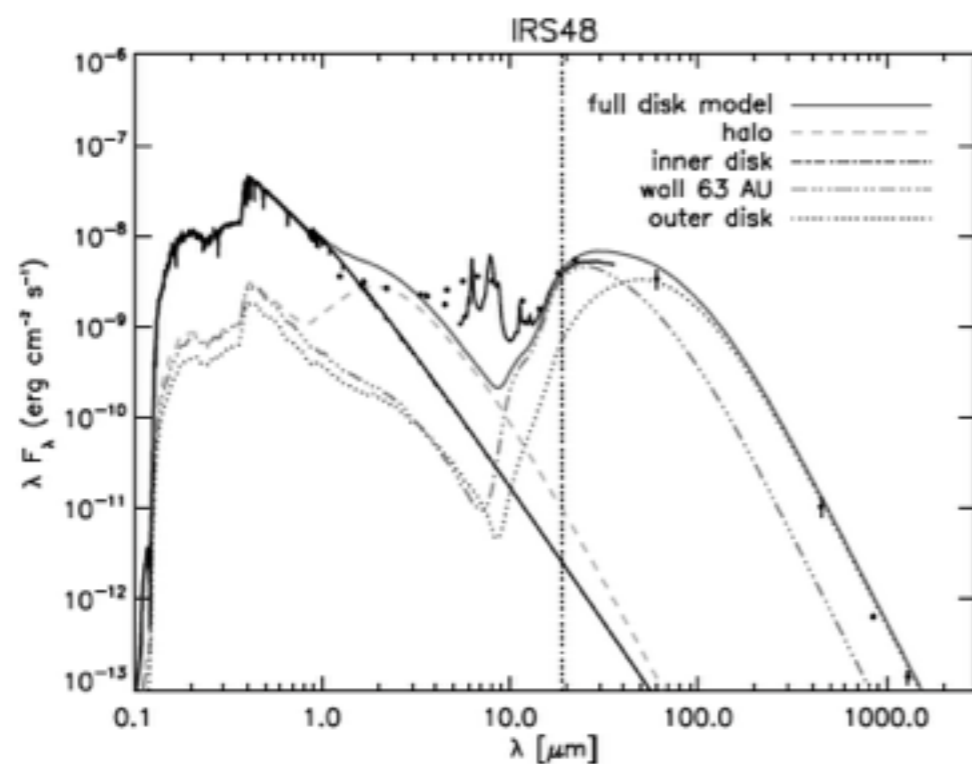
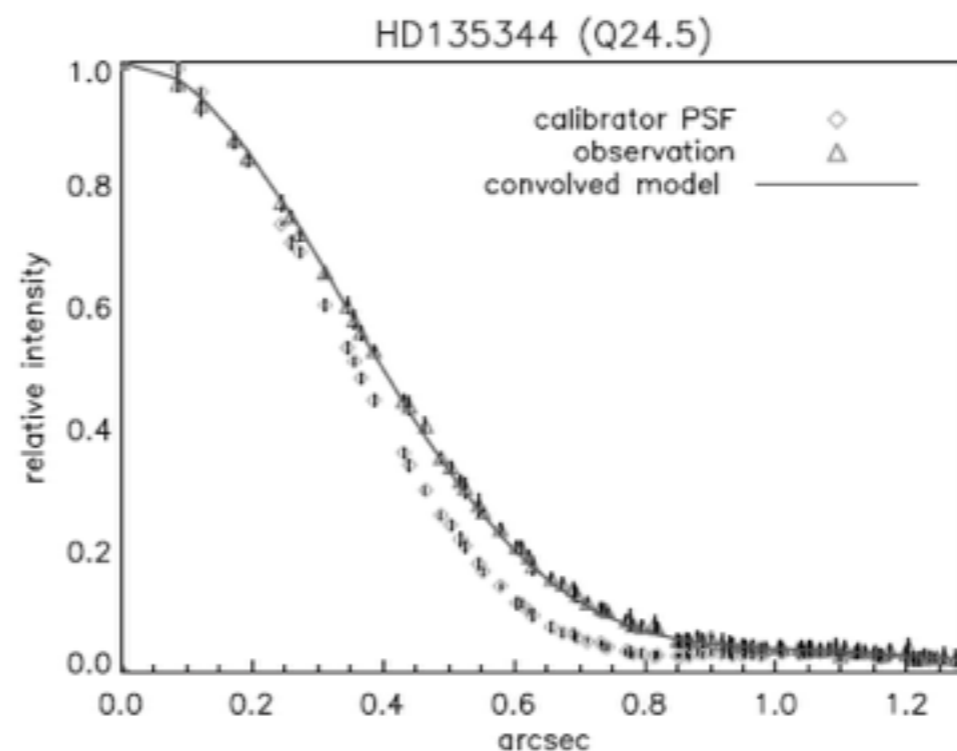
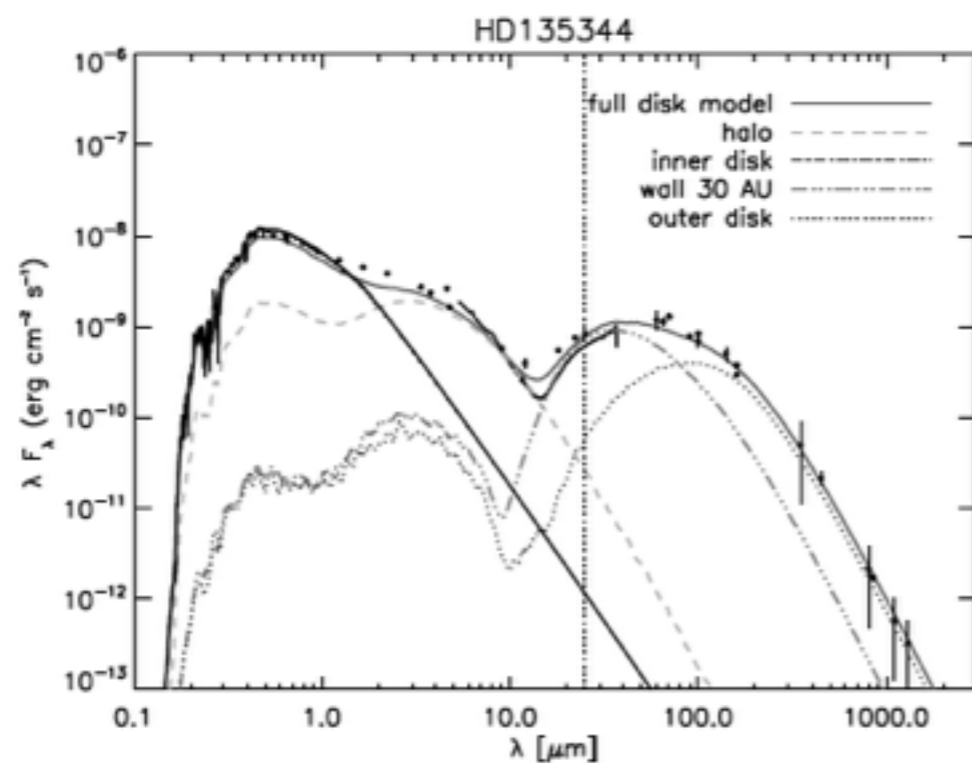
Maybe all Group I sources have gaps?!



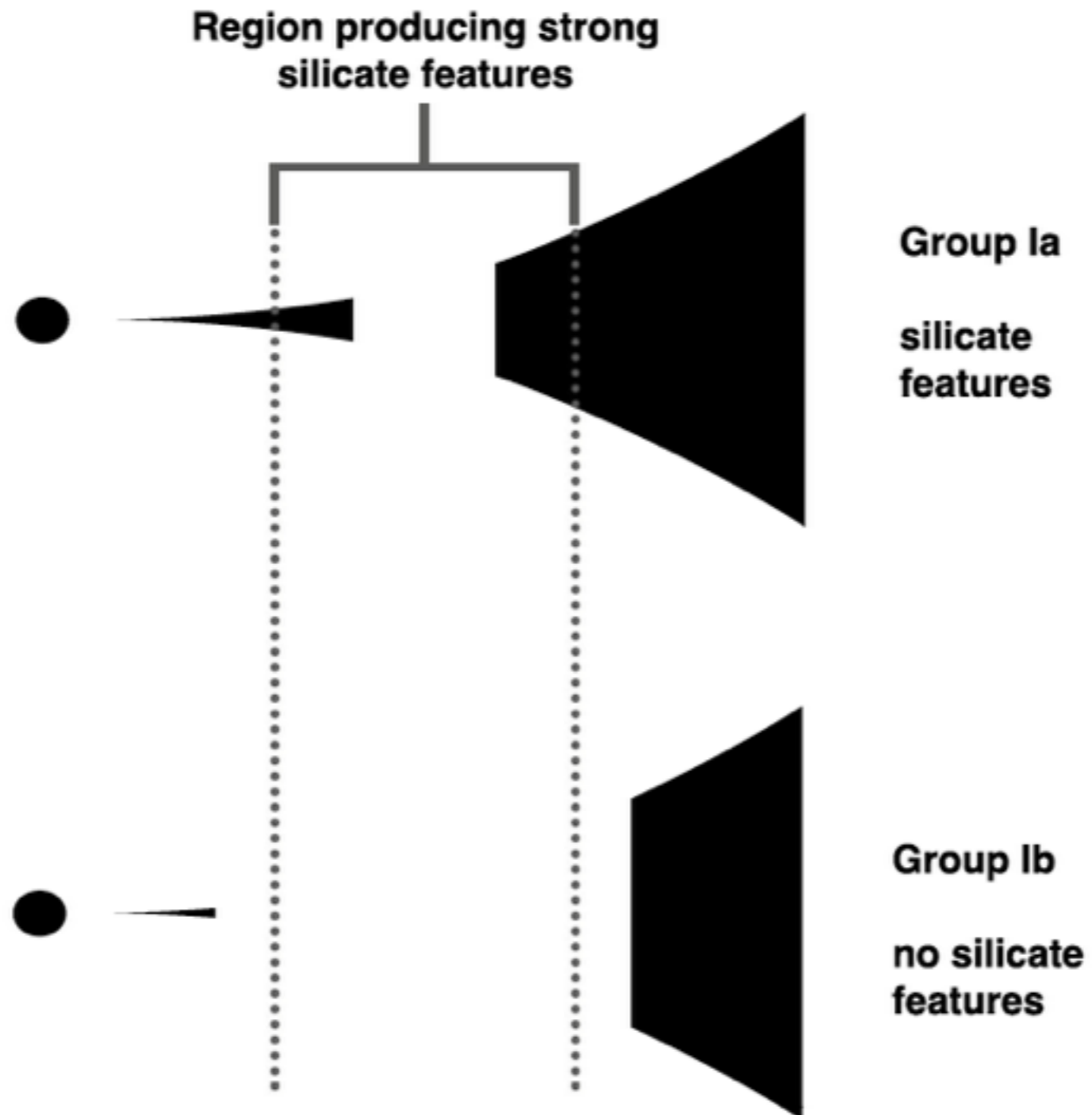
Observations of other Herbig stars



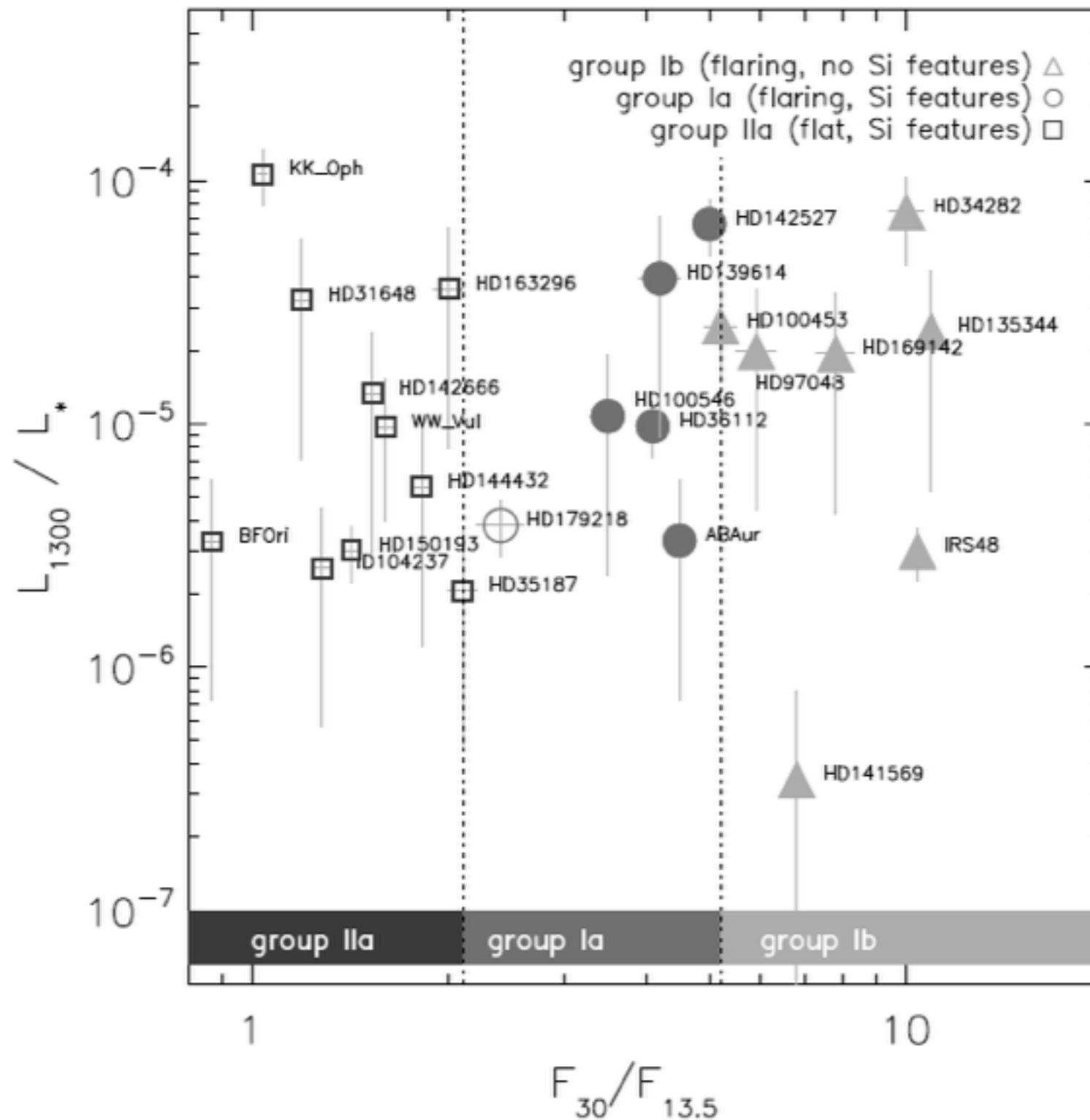
Observations of other Herbig stars



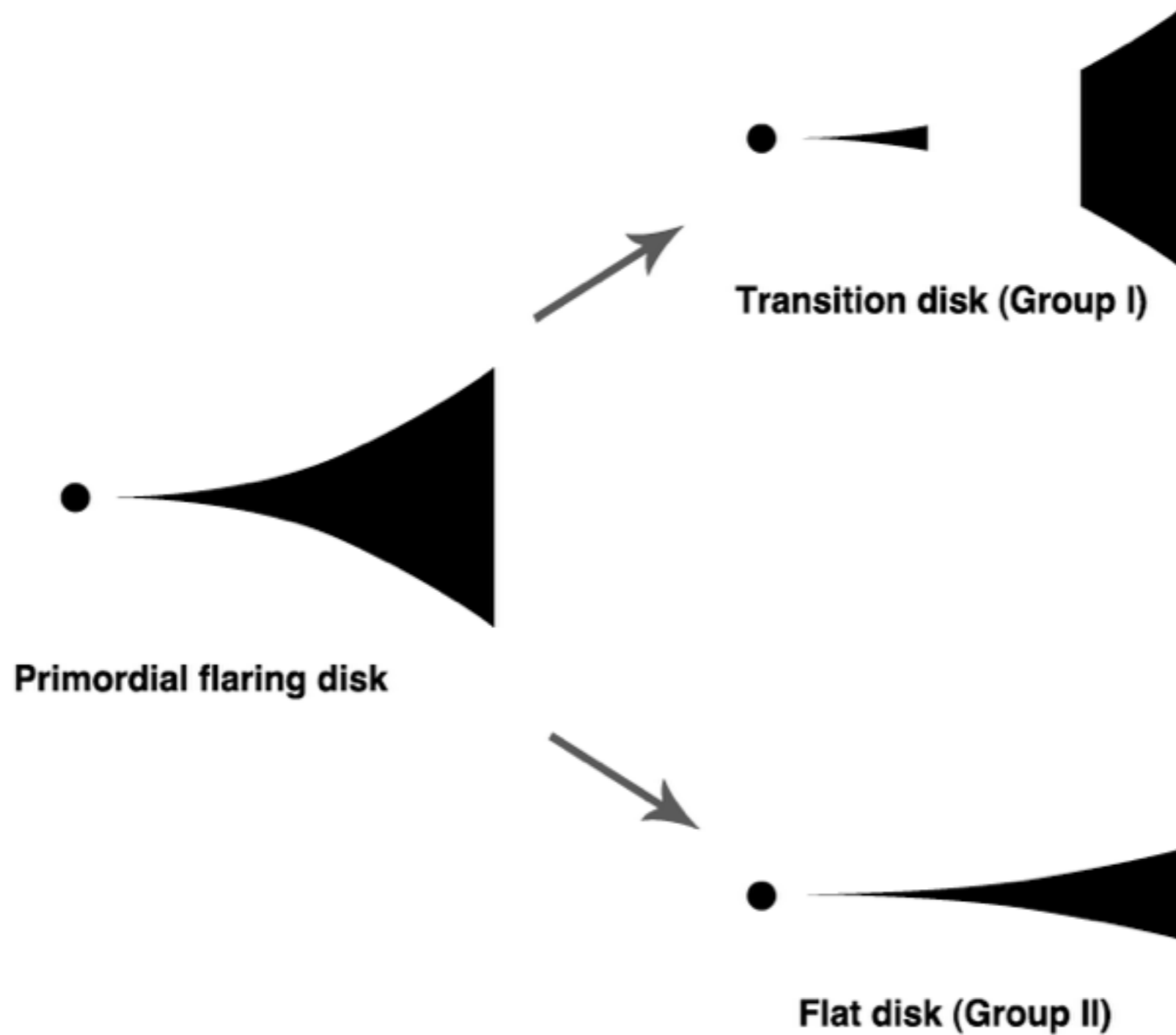
Gaps in Group I sources



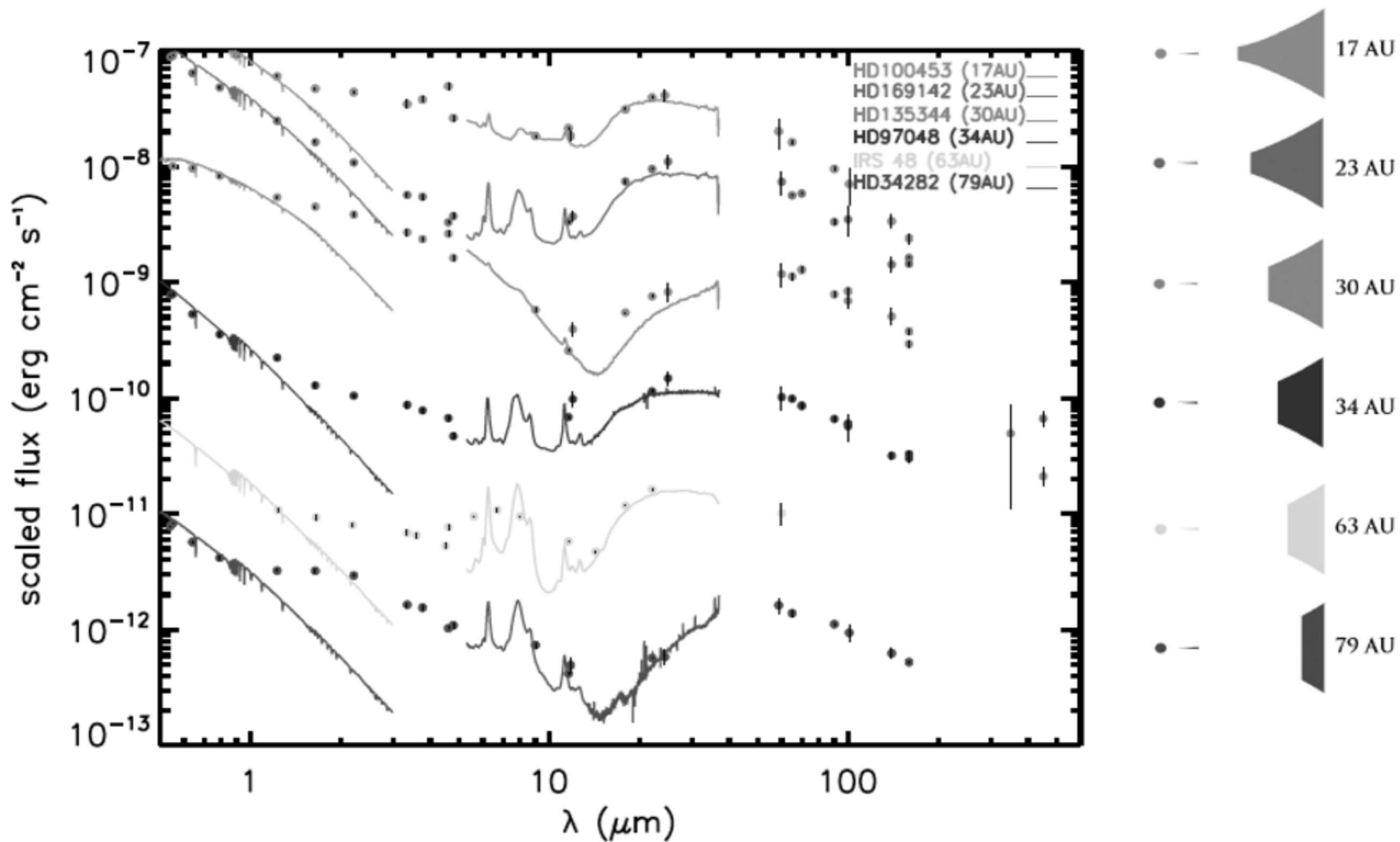
Gaps in Herbig disks



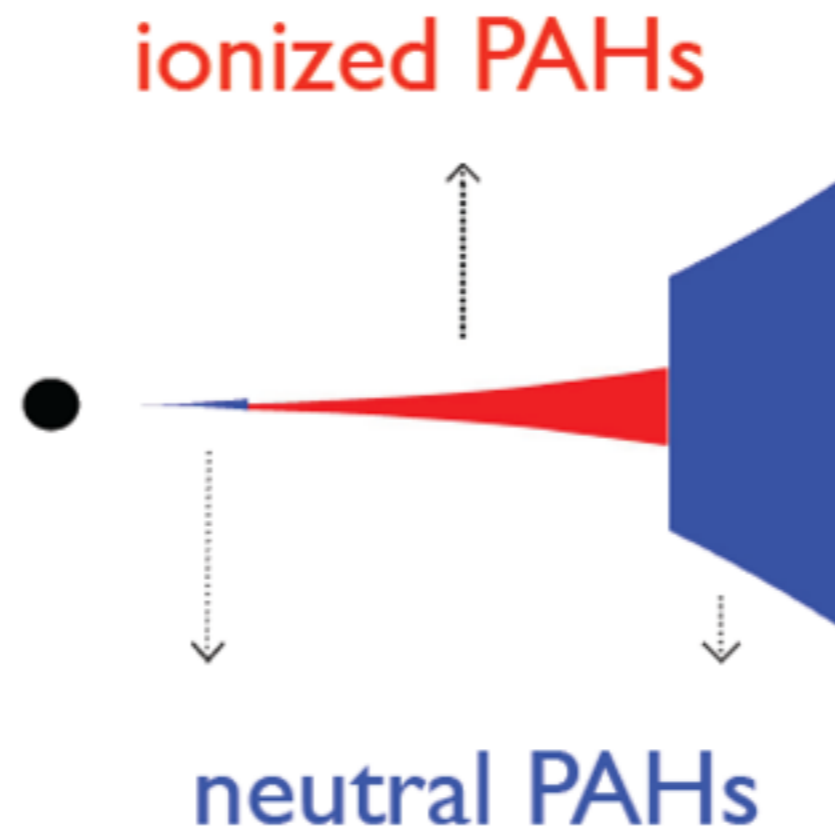
Disk evolution in Herbig stars?



Our sample with gaps



PAH ionization as a tracer of gas flows through disk gaps



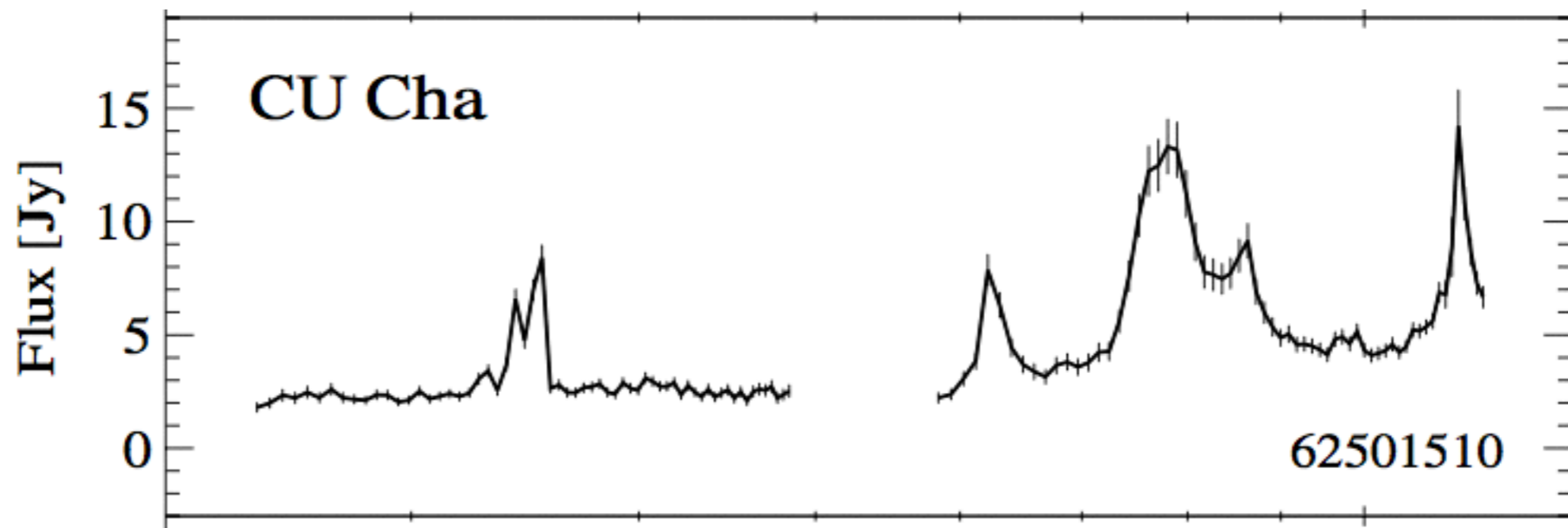
Koen Maaskant

(PhD student Leiden Observatory)

Collaborators: *Xander Tielens, Rens Waters, Michiel Min, Carsten Dominik*

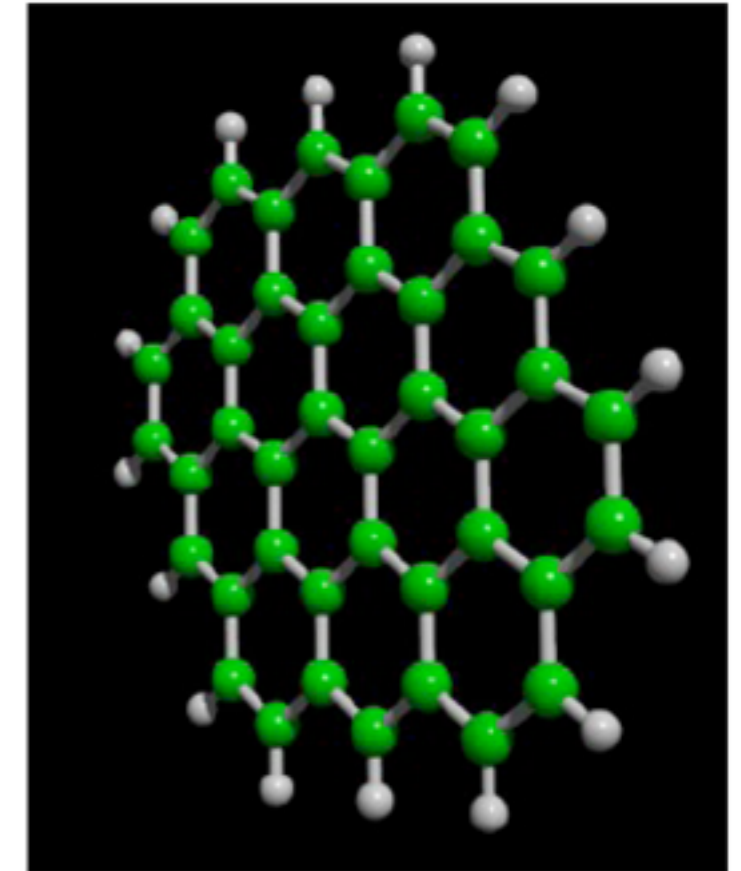
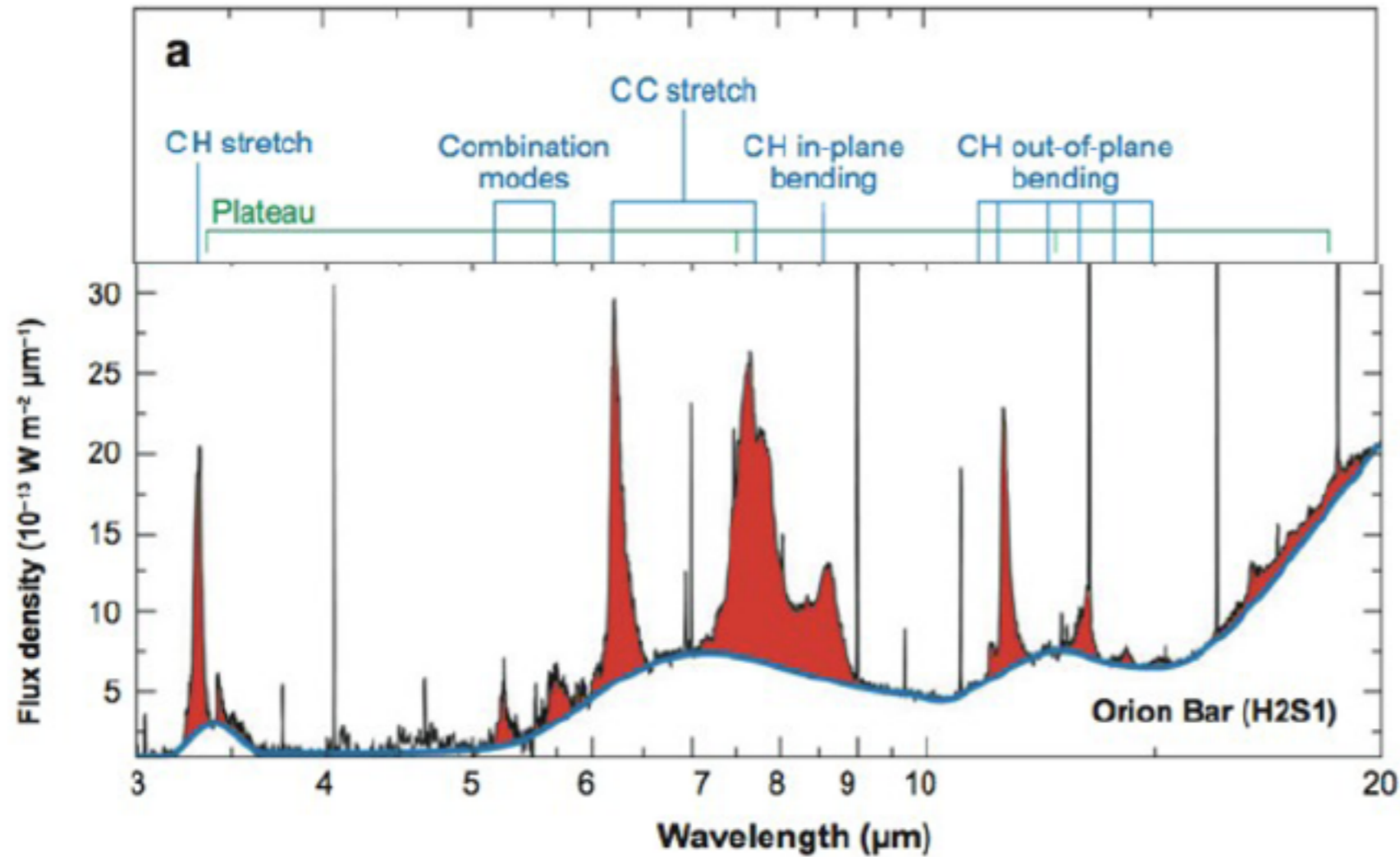
Introduction to PAHs

Polycyclic aromatic hydrocarbons (PAHs) can be observed in the infrared spectra of protoplanetary disks of Herbig Ae/Be stars, and - with a lower frequency - T Tauri stars. The strength of the features decreases with stellar effective temperature. They can be used as tracers of the outer disk.



Kóspál et al. (2012)

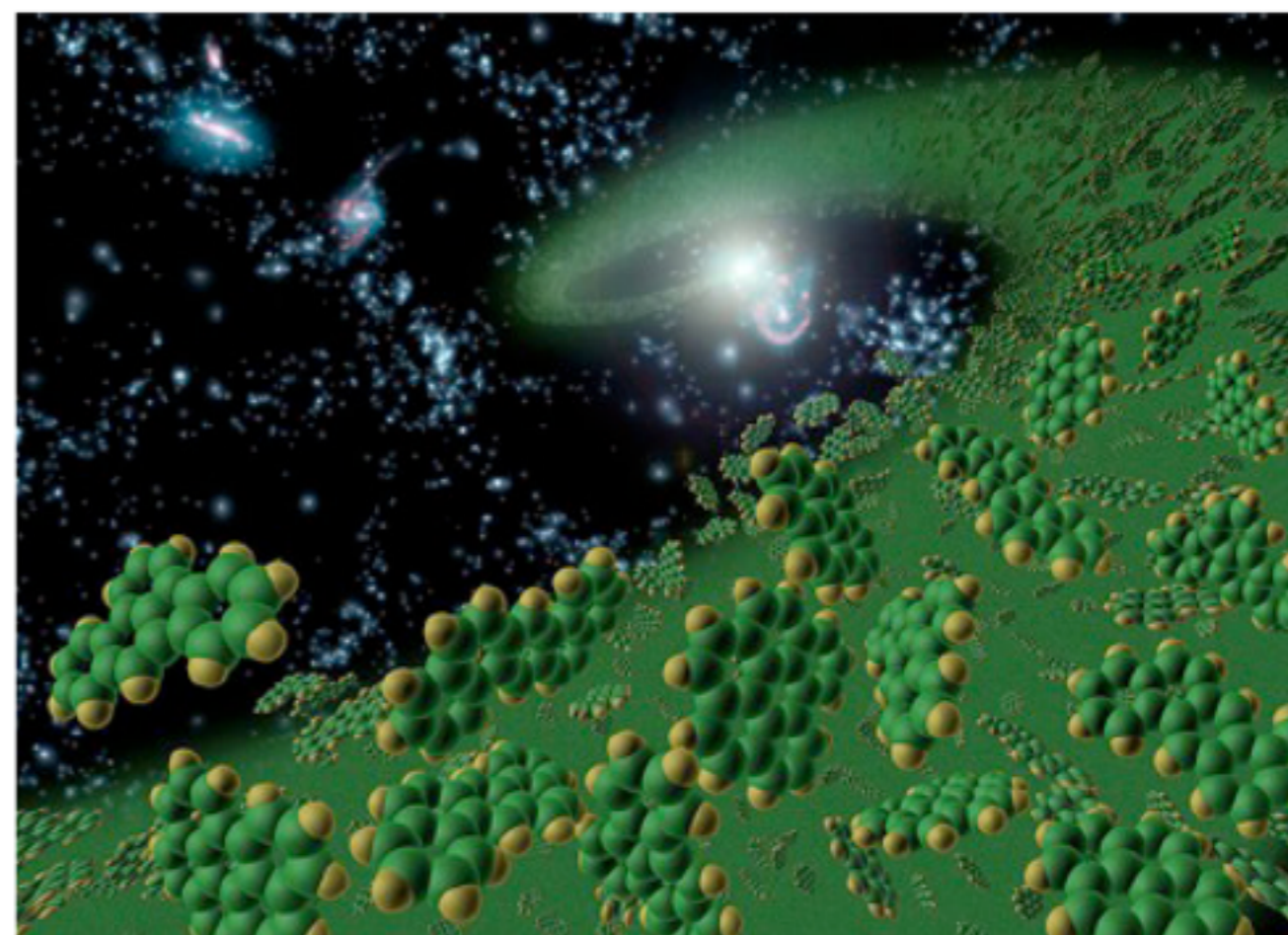
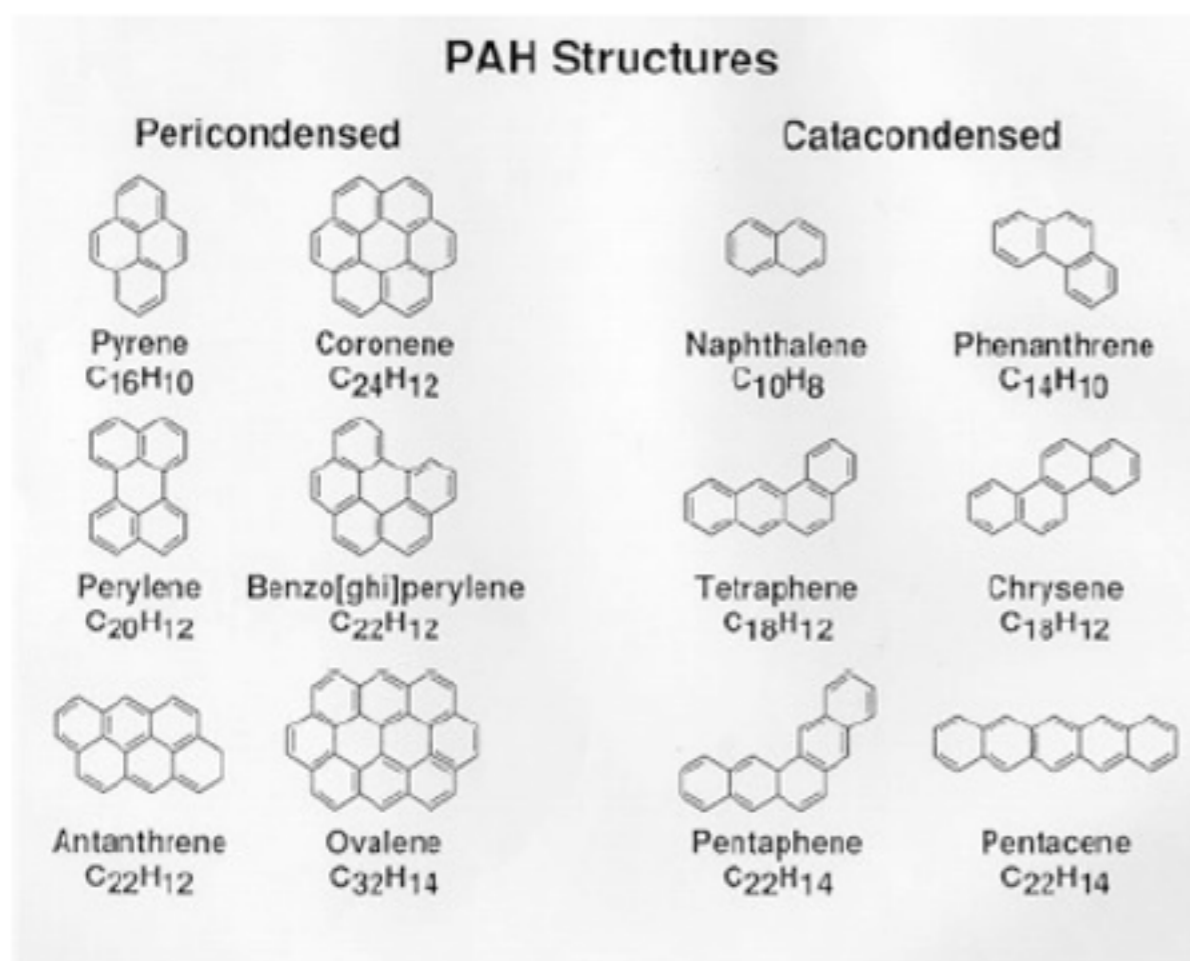
PAHs probe the physical conditions of a region (density, temperature, radiation field)
(e.g.: *Hudgins & Allamandola 1999, Allamandola et al. 1999, Galliano 2008, Tielens 2008, Bauschlicher et al 2009, Ricca et al 2012*).



Peeters et al. 2002

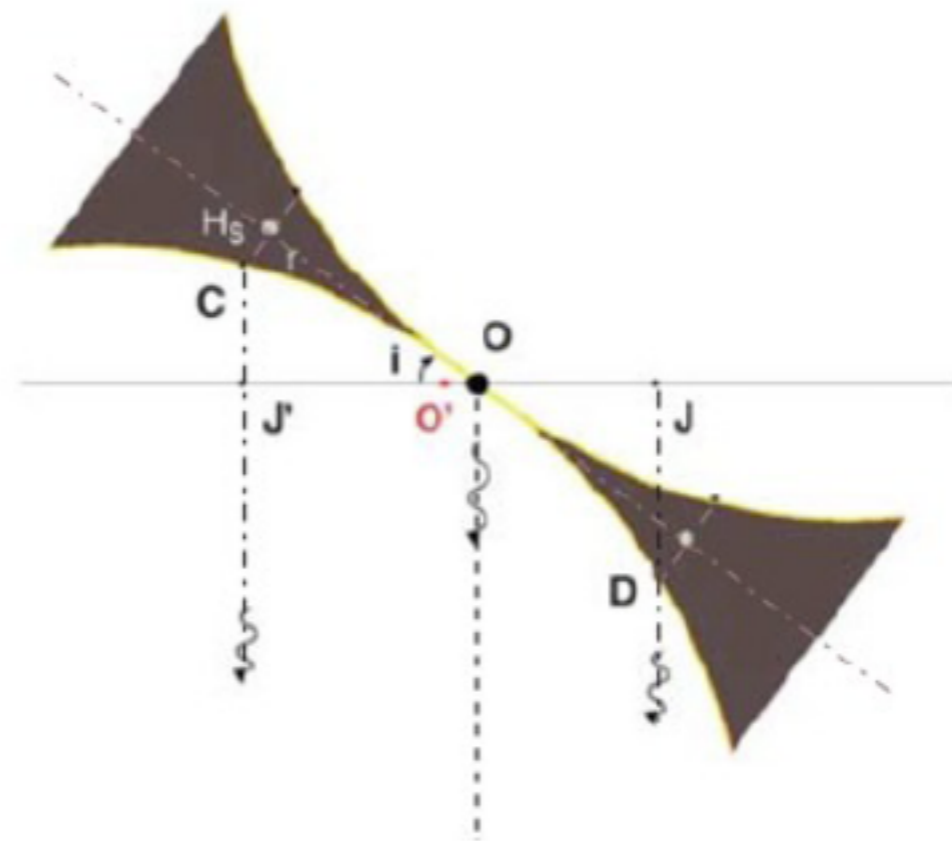
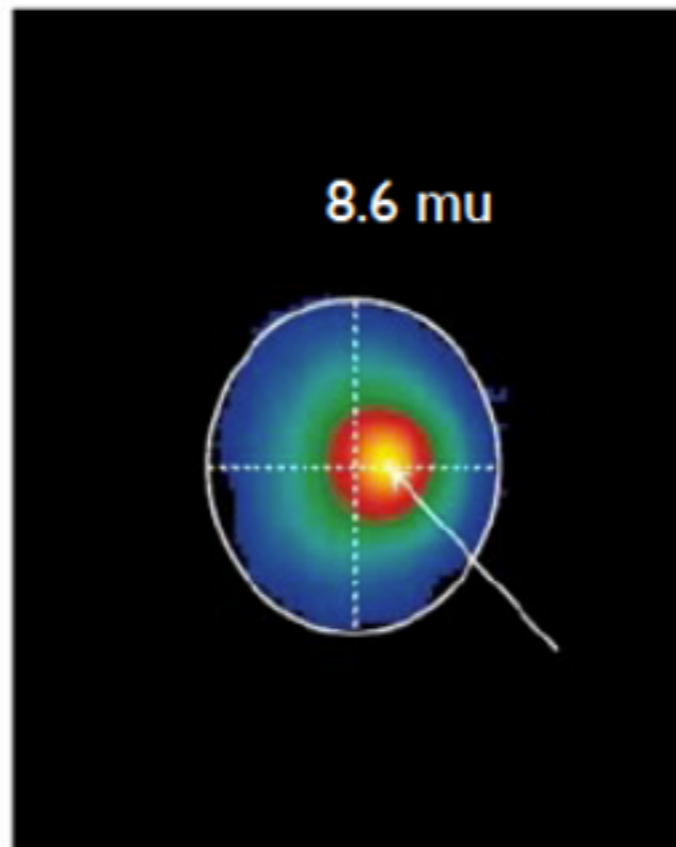
PAHs

Electronically excited by UV photons (quantum heating)
Cooling by CH- and CC- stretching and bending modes



PAHs and the disk structure

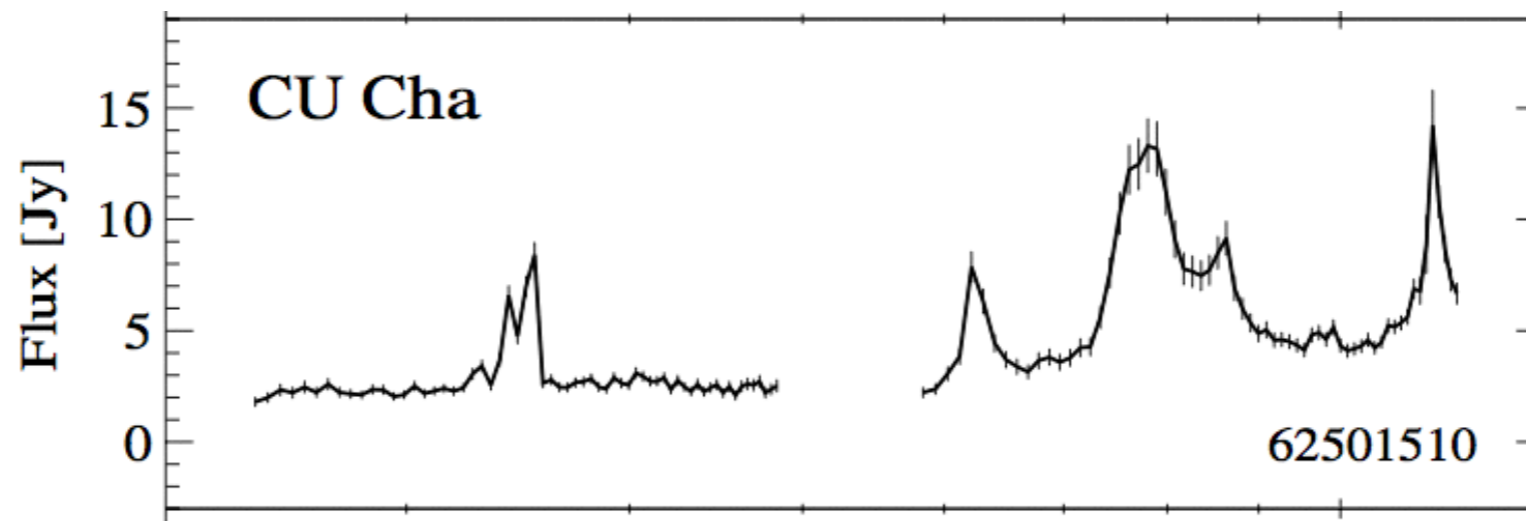
Tracing the flaring disk structure



PAHs

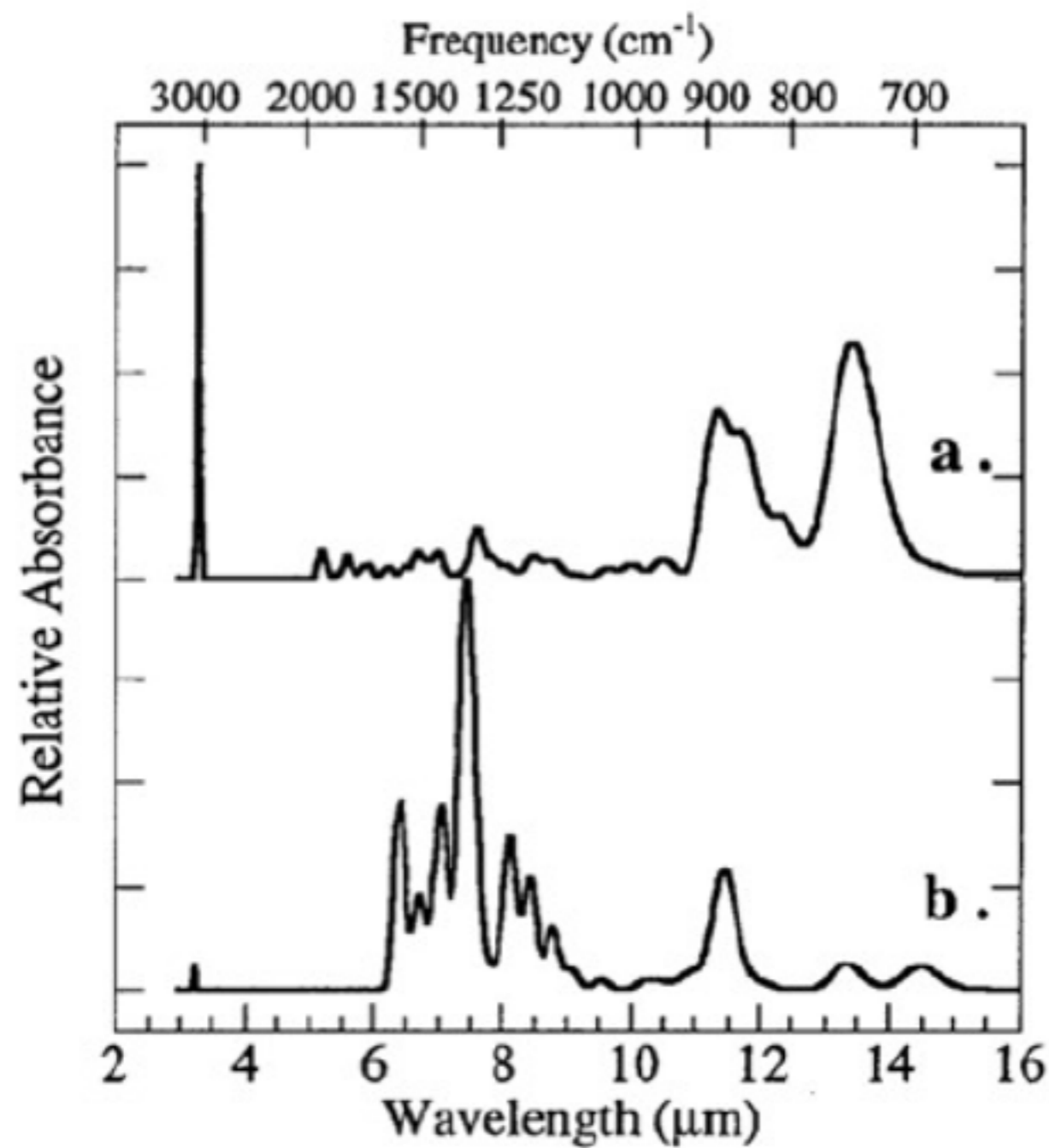
An important parameter that influences the relative feature strength of the CH and CC modes is the effect of ionization
CC modes being carried predominantly by ions and CH modes by neutrals

6.2/11.2 ratio measures ionization



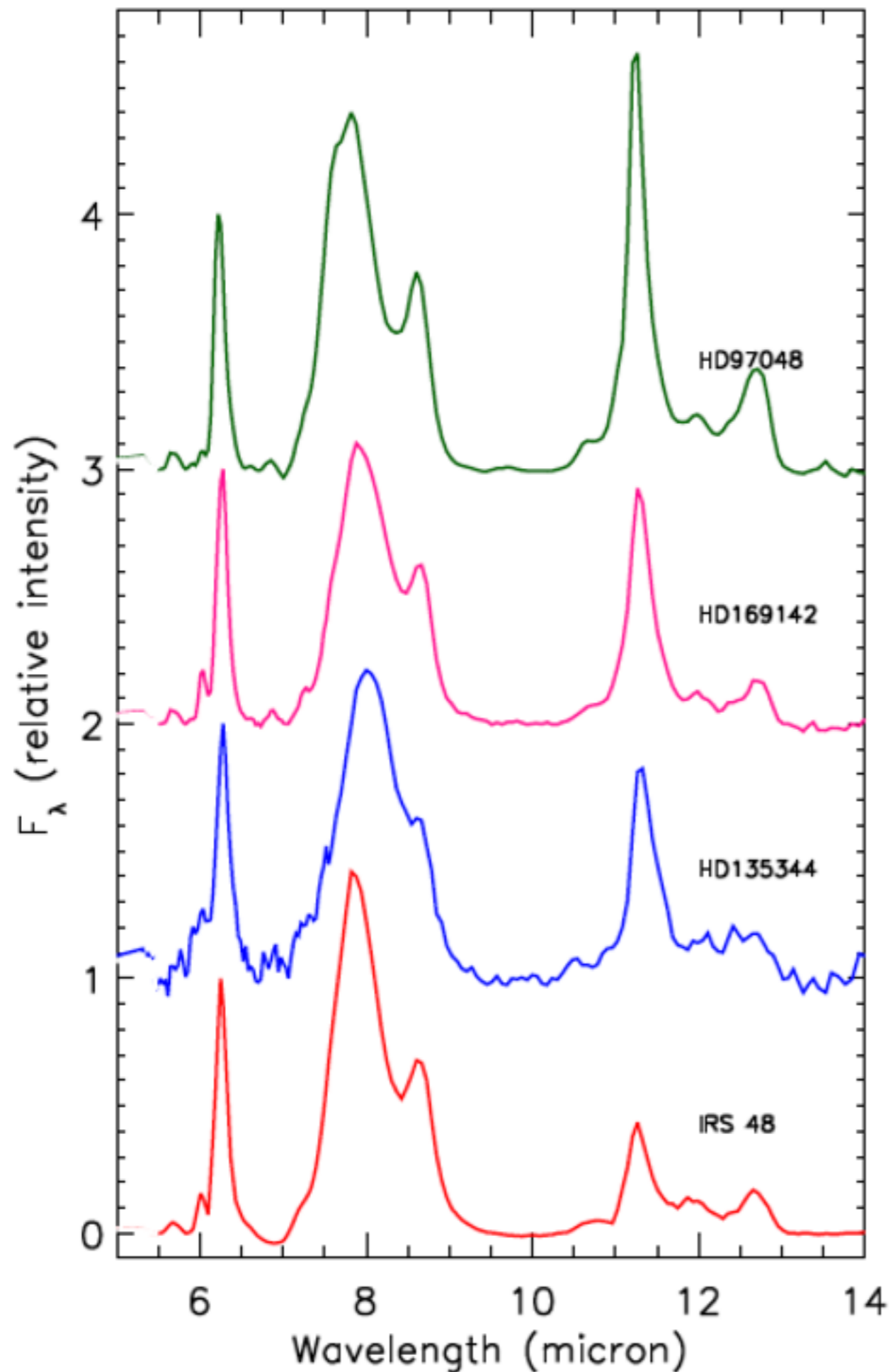
- ❖ can we use the ionization balance of PAHs as a tracer of processes in protoplanetary disks?

neutral and ionized PAH spectra:



Neutral

ionized

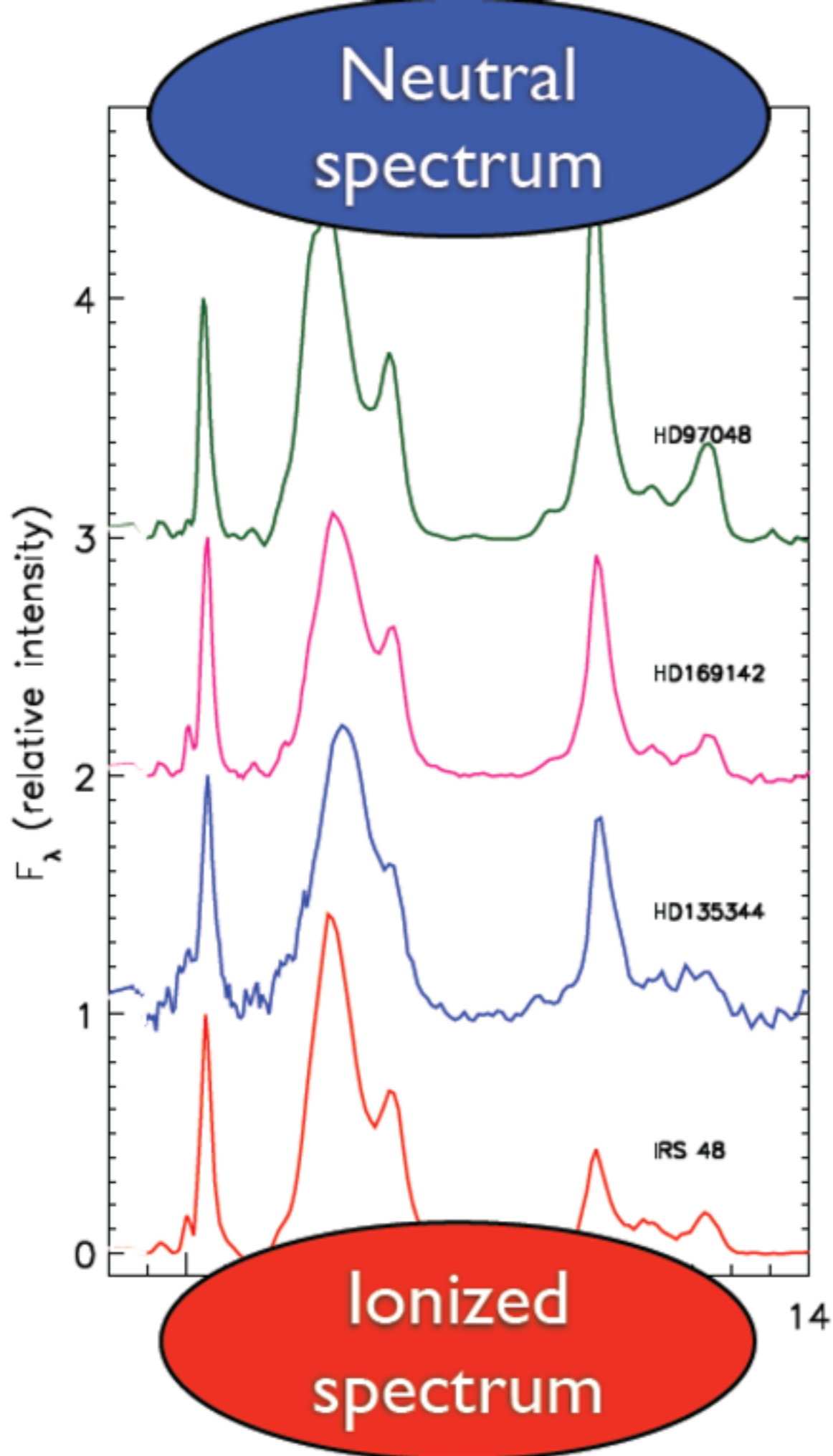


HD97048

HD169142

HD135344B

Oph IRS 48

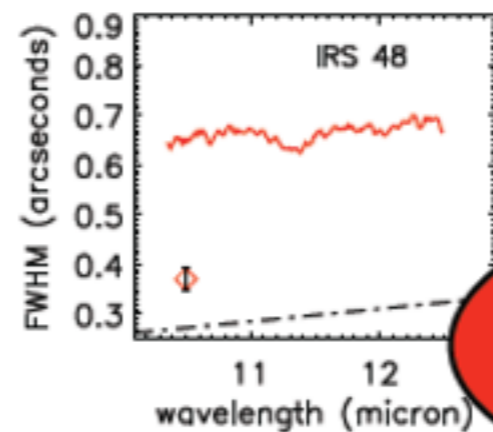
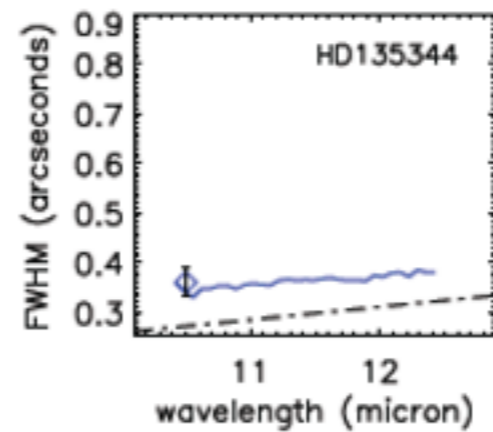
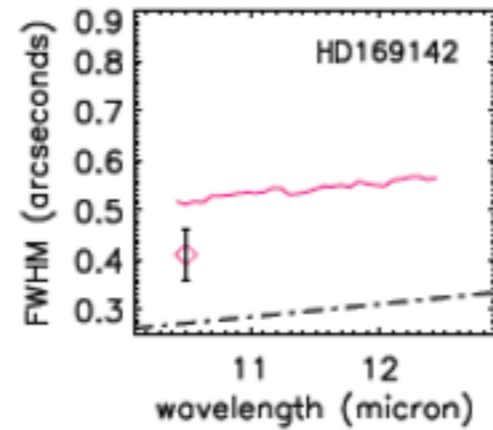
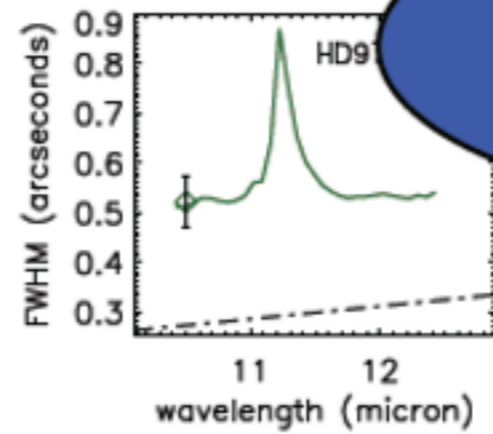
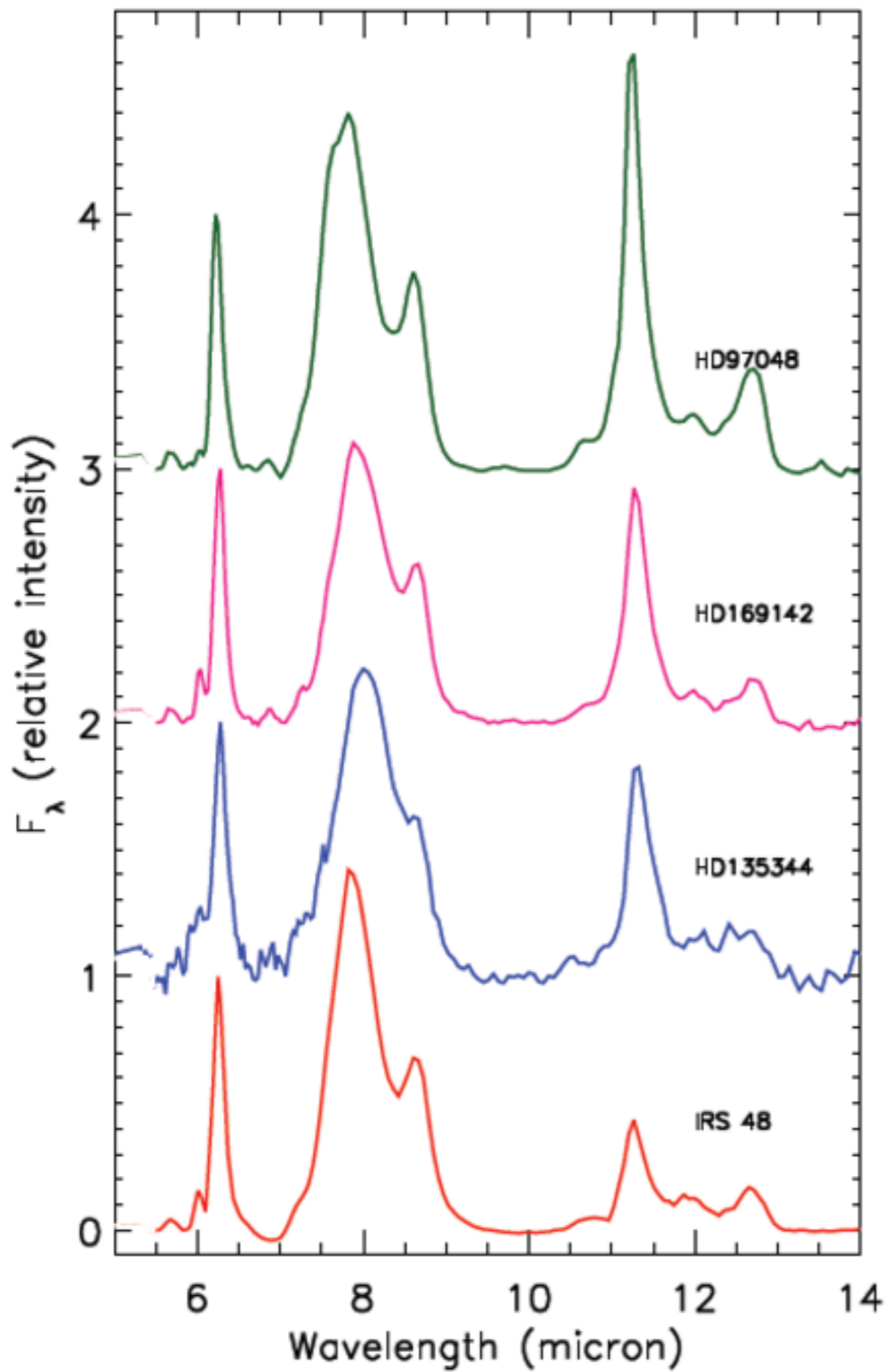


HD97048

HD169142

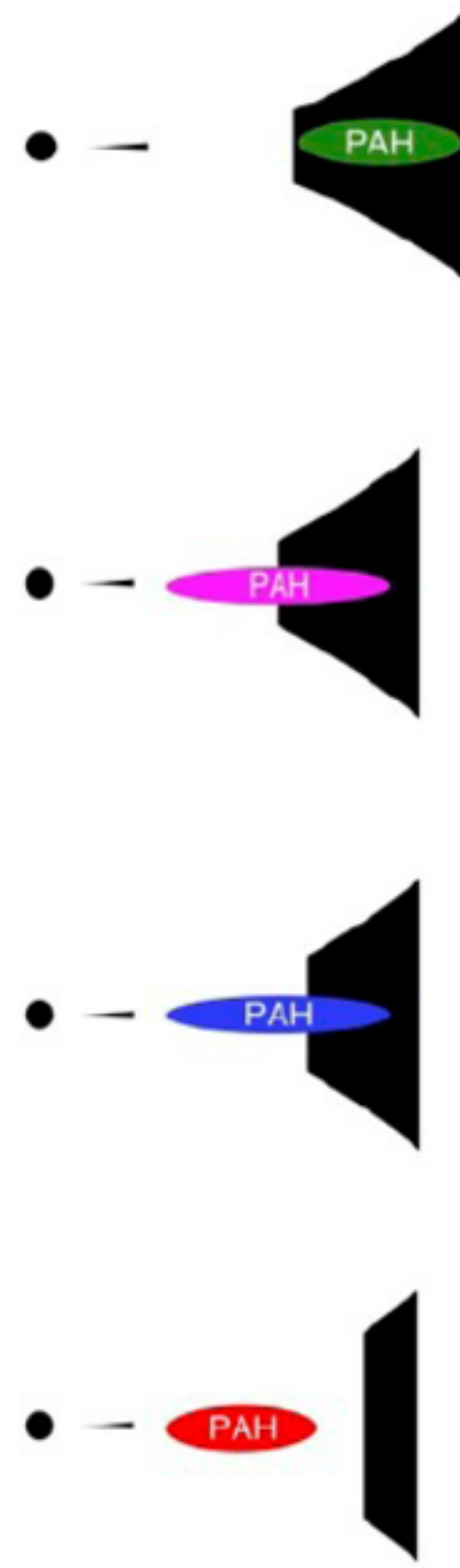
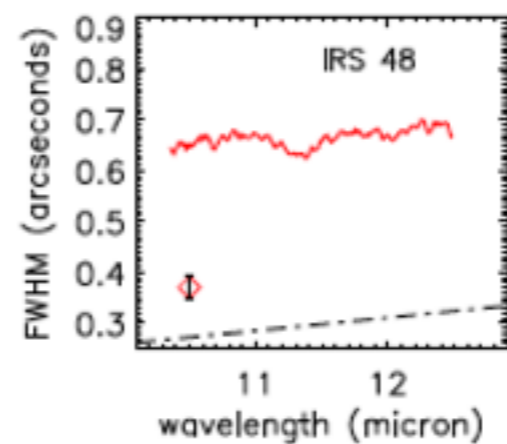
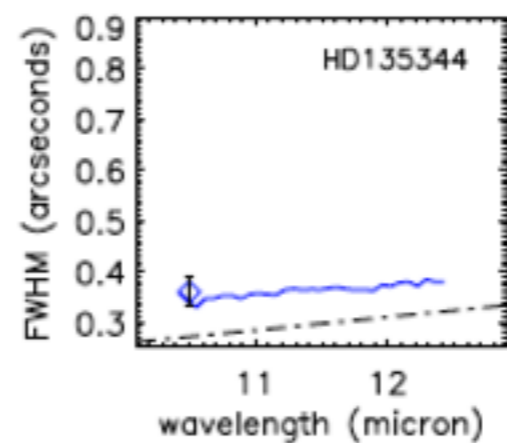
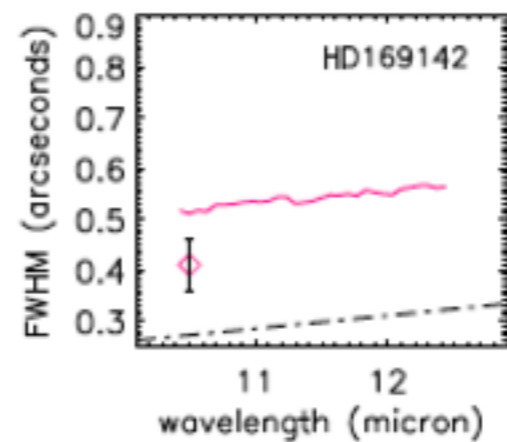
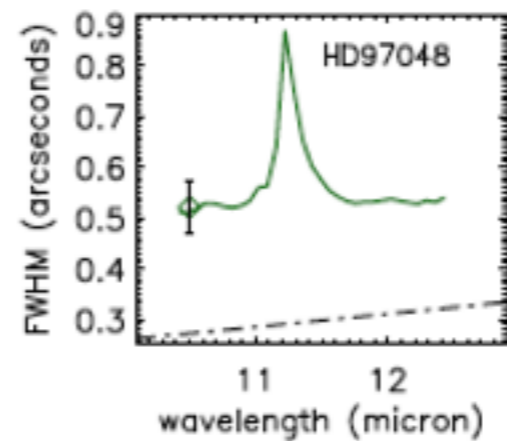
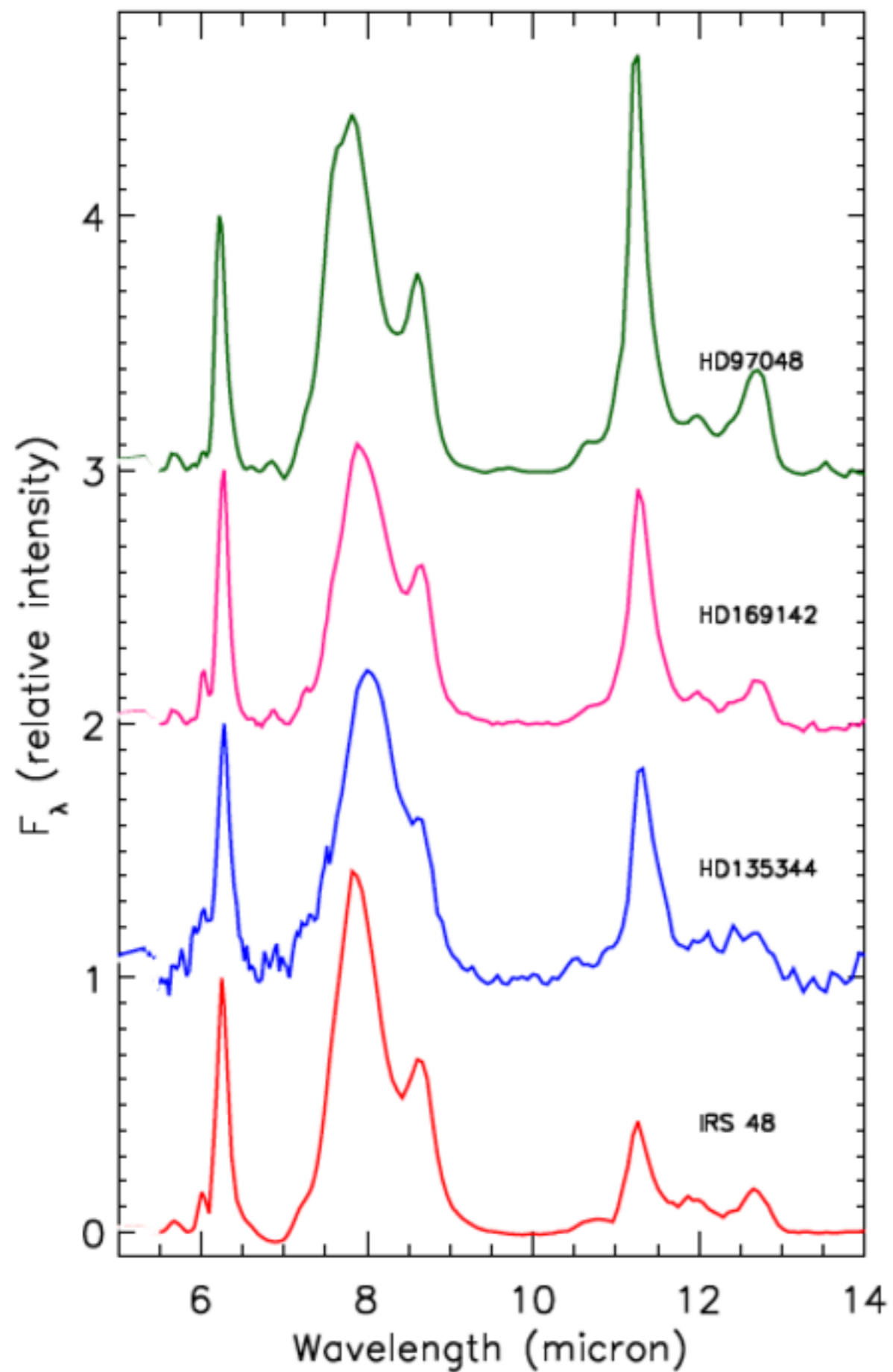
HD135344B

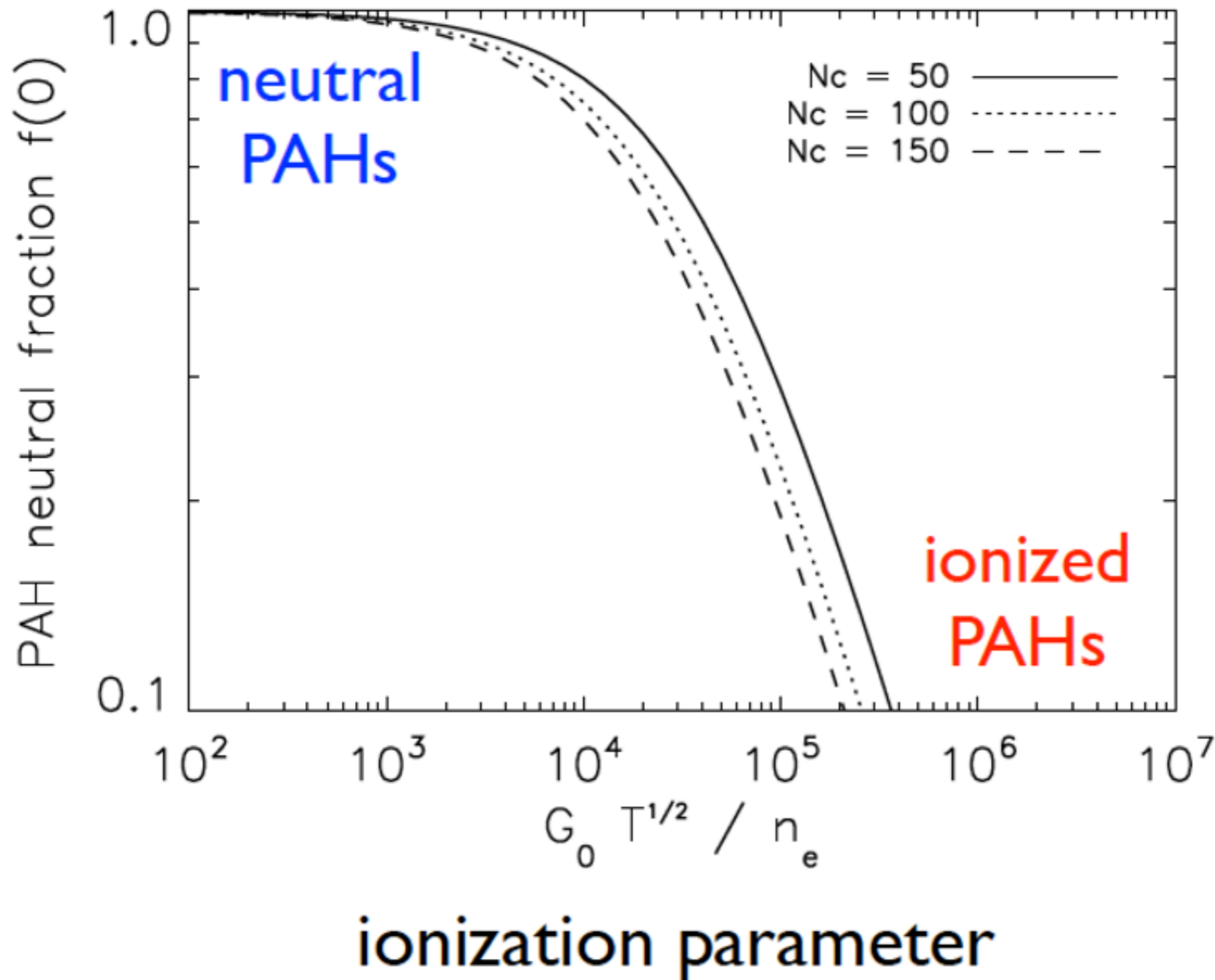
Oph IRS 48



outer disk

gap





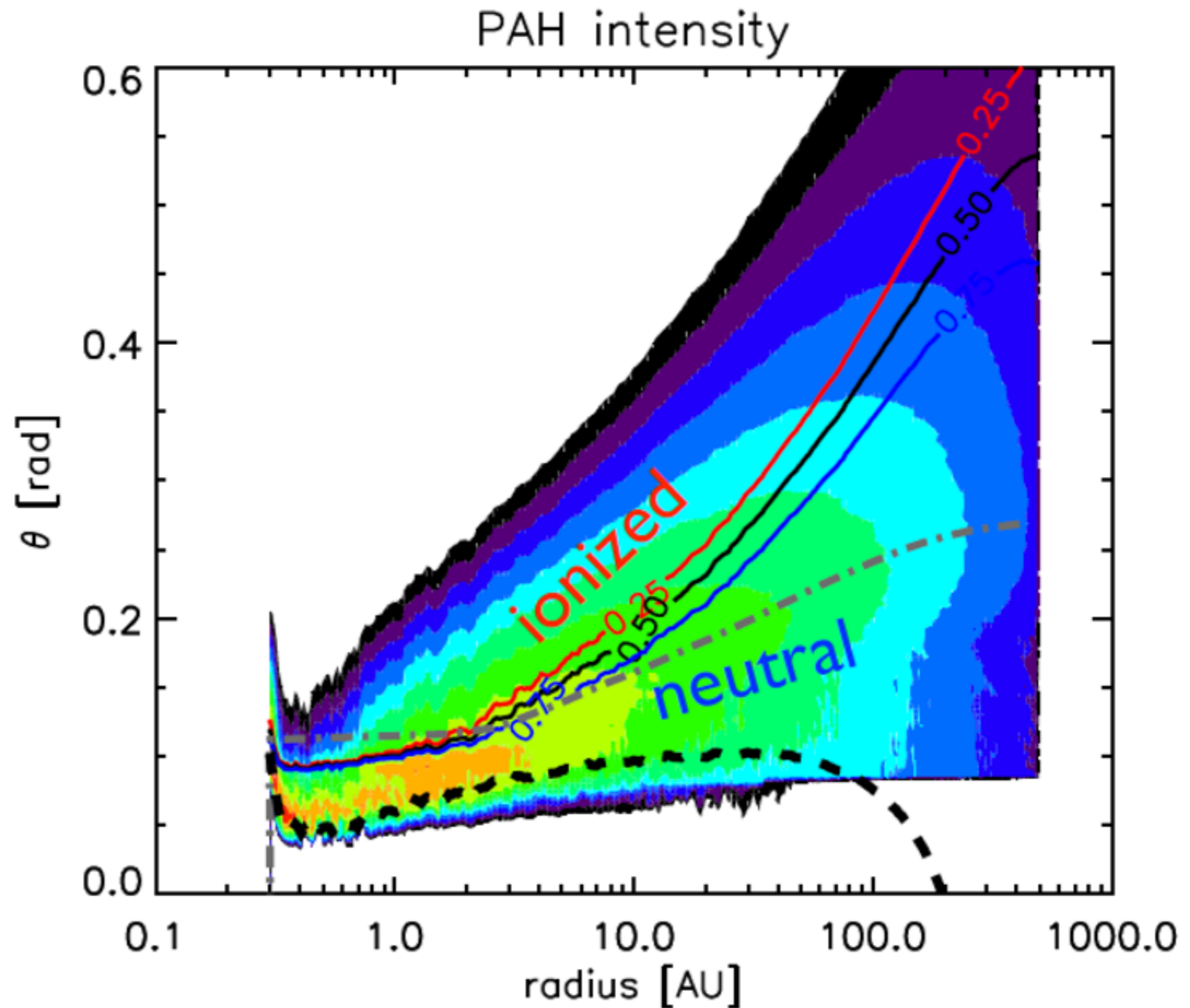
Bakes & Tielens 1994

Tielens 2005

Galliano 2008

Benchmark model

~90 %
neutral
at all radii

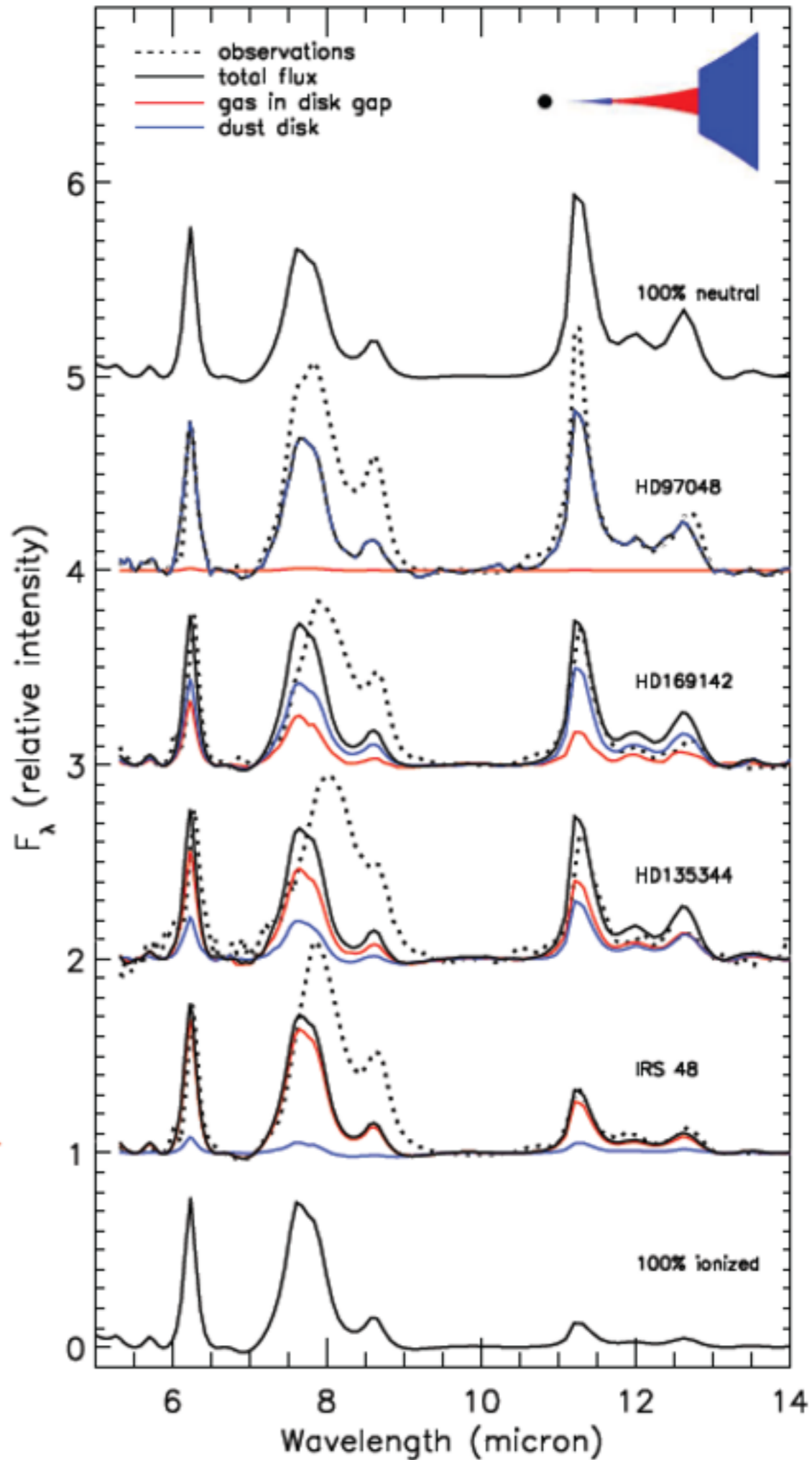
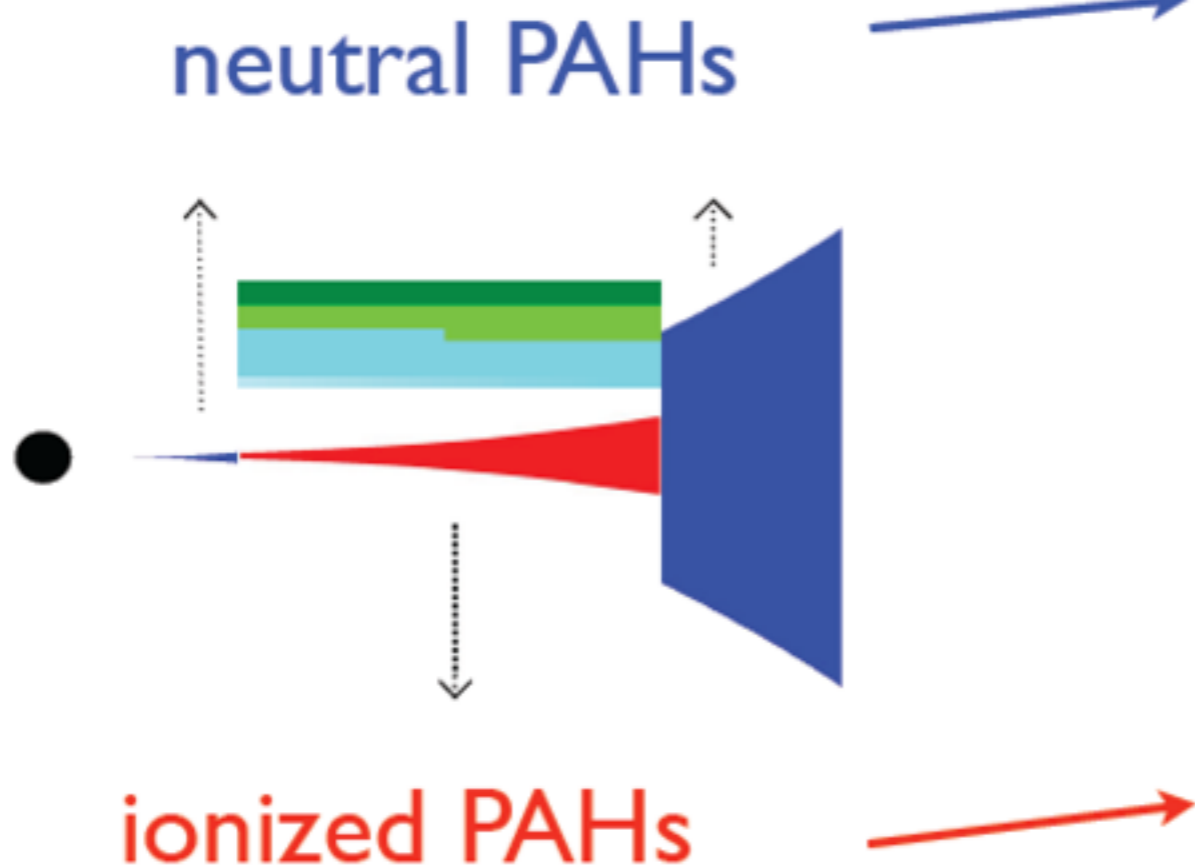


How to get ionized PAHs in disks?



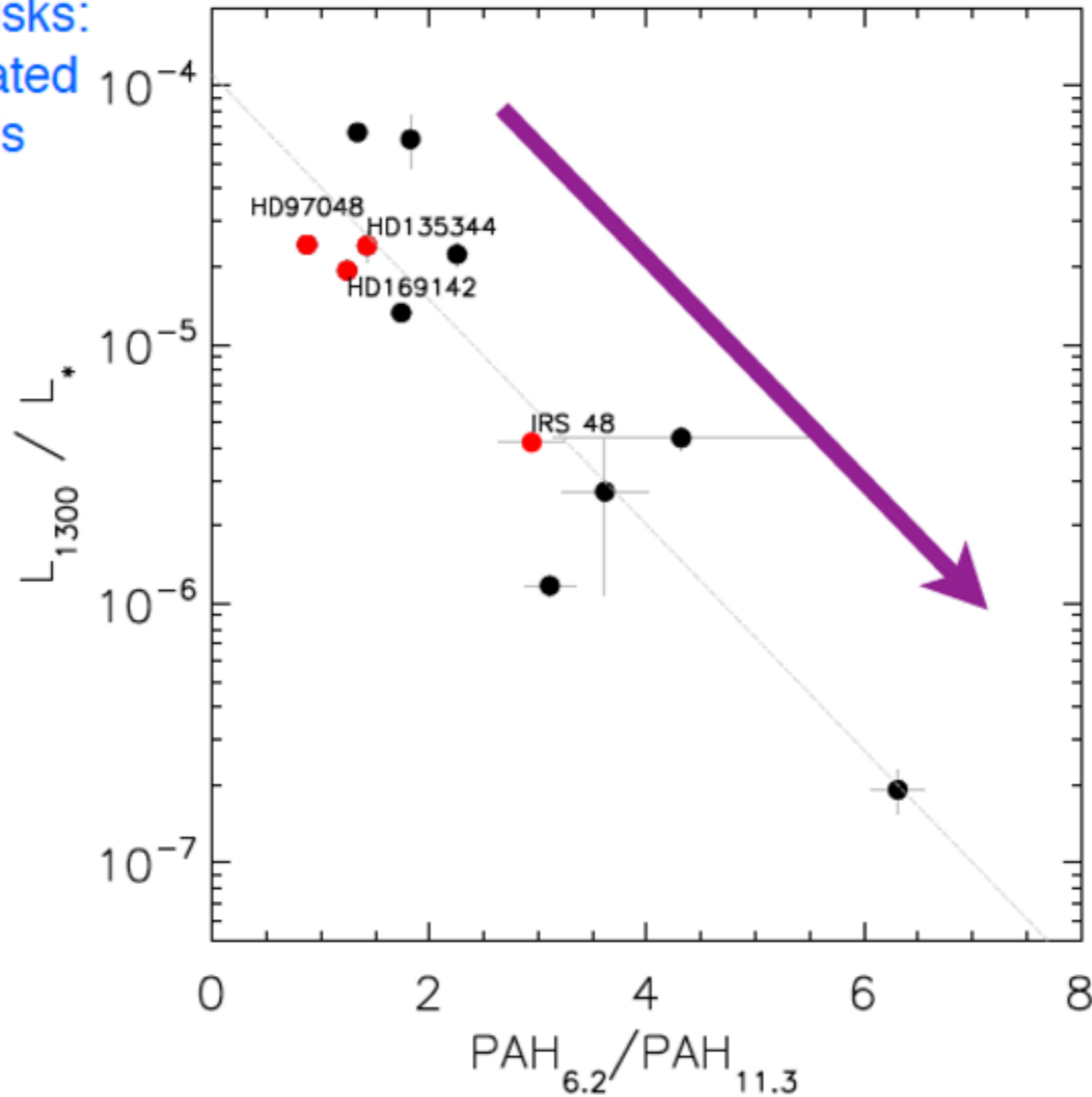
Optically thin gaps!

Demonstration: RT models of four transitional disks



Trend: mm luminosity (disk mass) vs PAH ionization

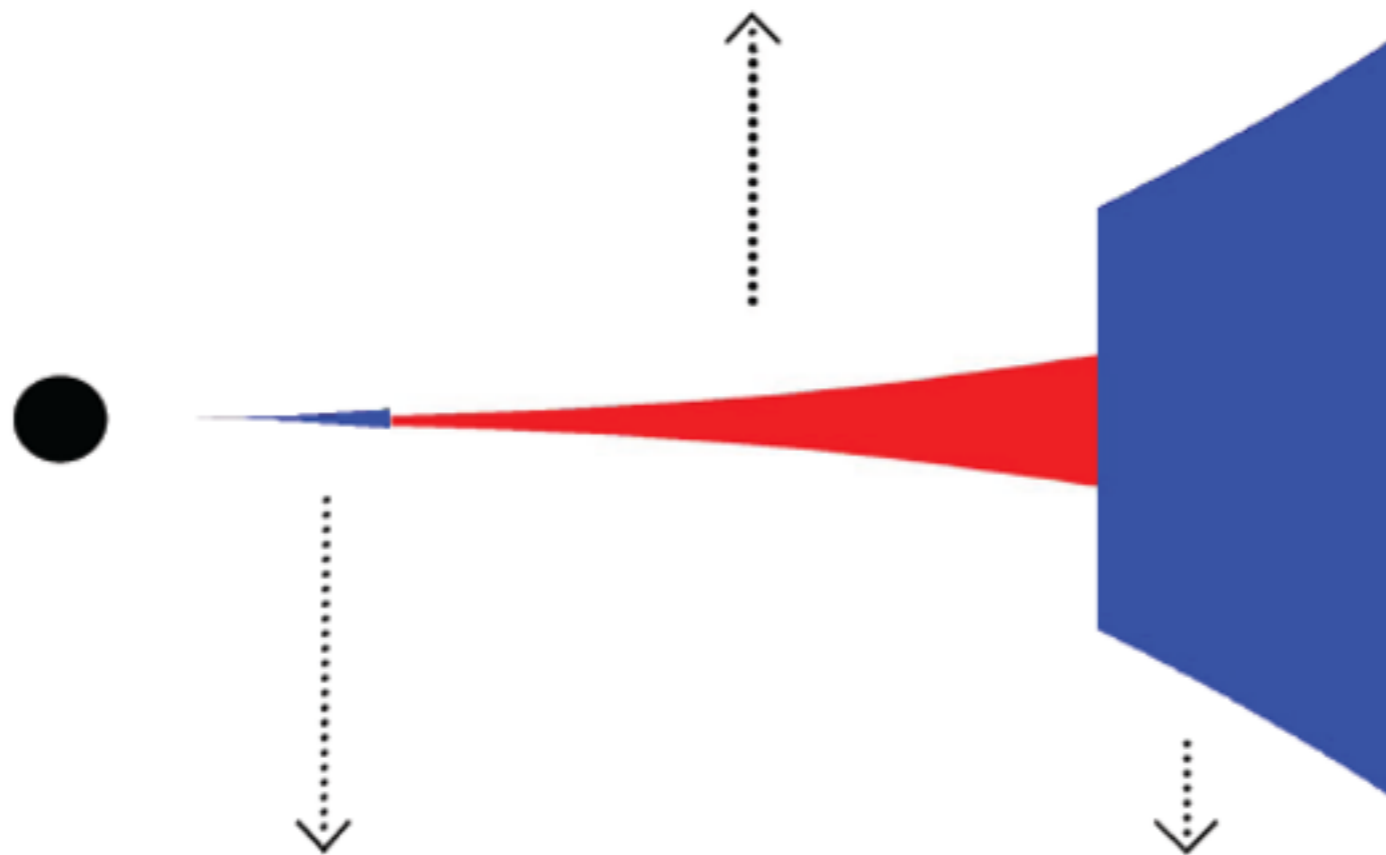
Higher mass disks:
spectra dominated
by neutral PAHs



Lower mass disks:
spectra dominated by
ionized PAHs in gaps

Conclusion

**Ionized PAHs in low density, optically thin gas flows through the gap
(high UV field, low electron density)**



**Neutral PAHs in optically thick disk
(low UV field, high electron density)**