MID-INFRARED IMAGING OF THE TRANSITIONAL DISK OF HD 169142: MEASURING THE SIZE OF THE GAP

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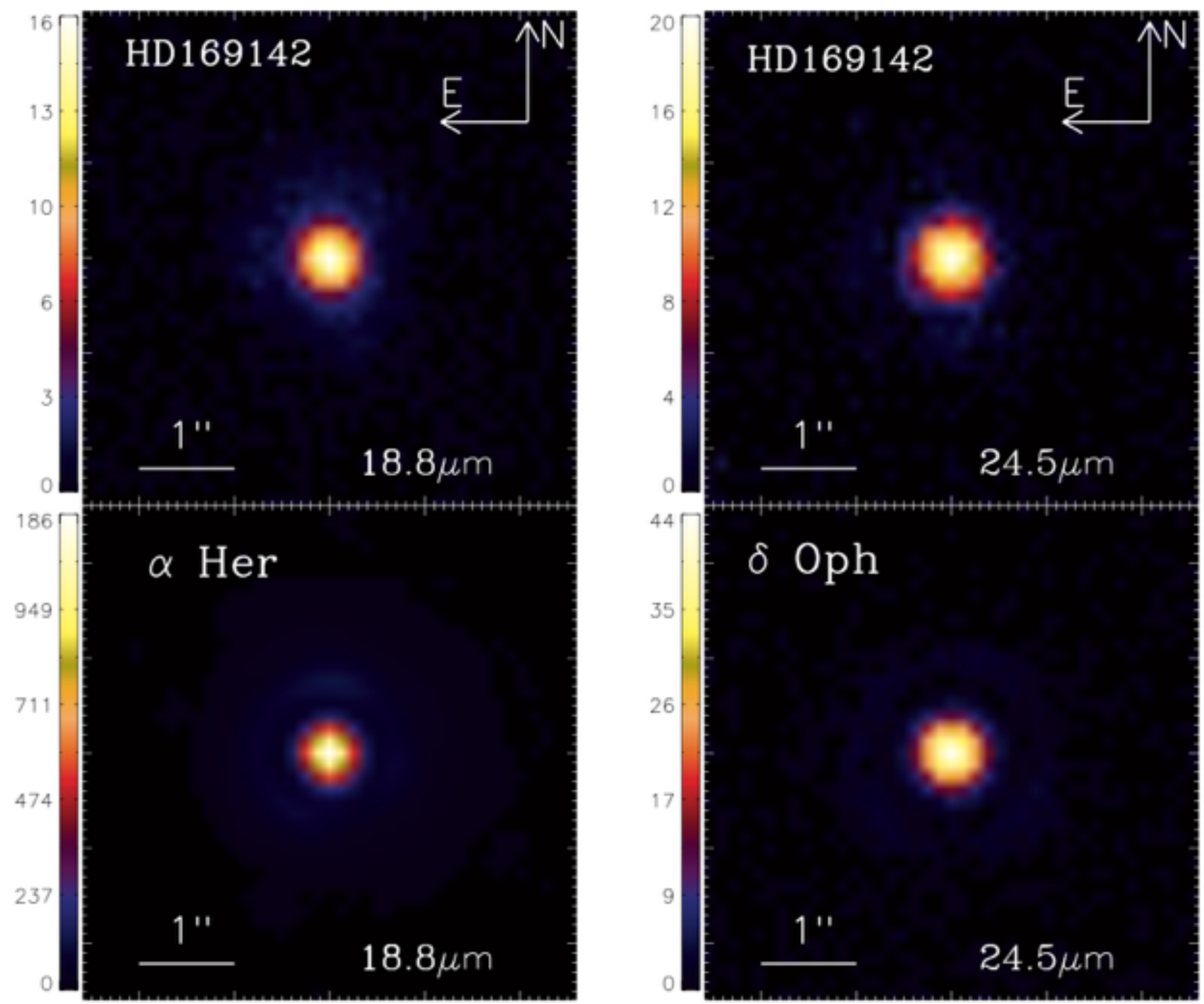
The Astrophysical Journal, 752:143 (7pp), 2012 June 20

Ábrahám Péter

2016. december 13.

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

Subaru/COMICS
18.8um, 24.5um

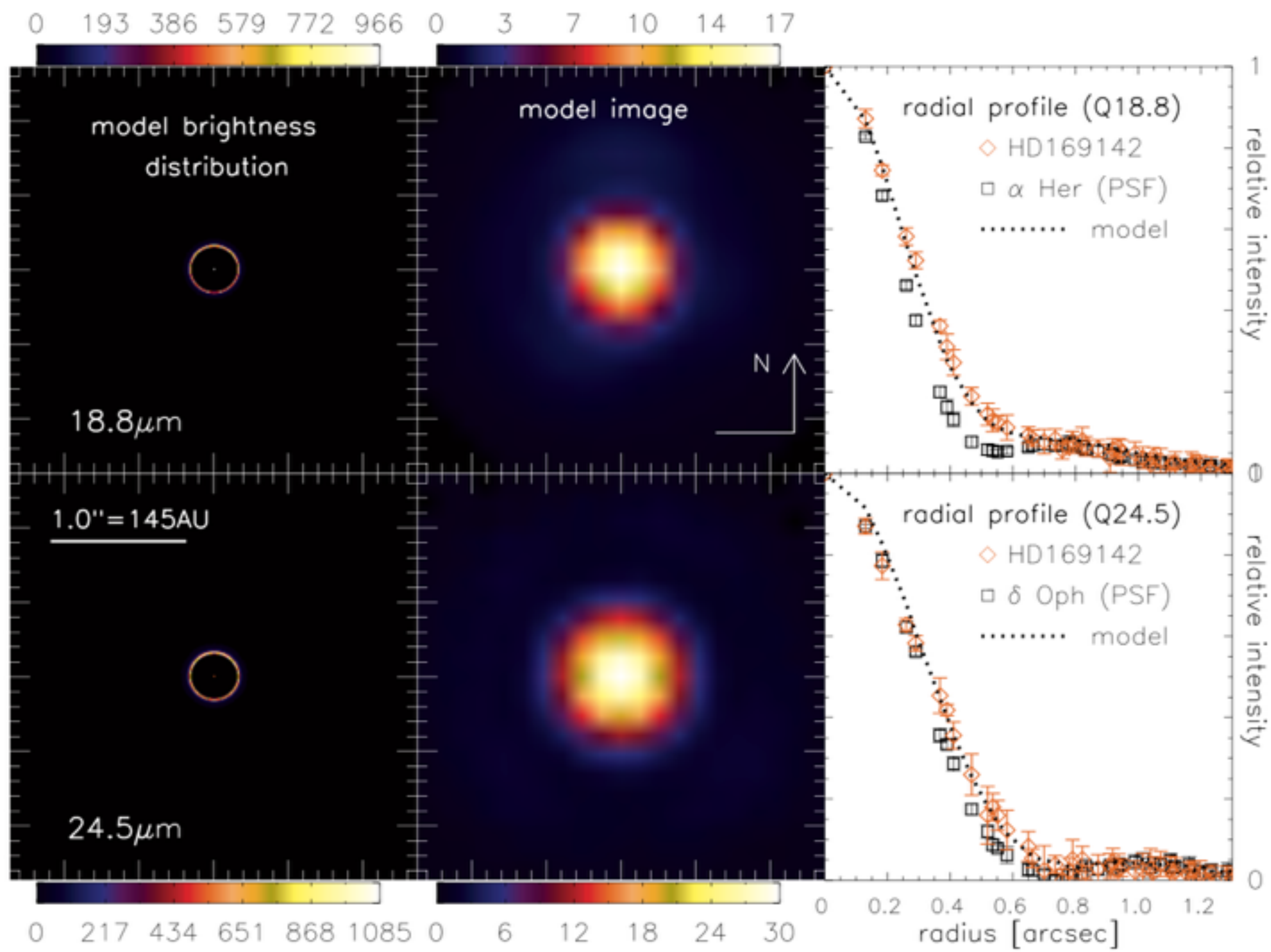


Mid-IR imaging of the disk of HD169142: Measuring the size of the gap

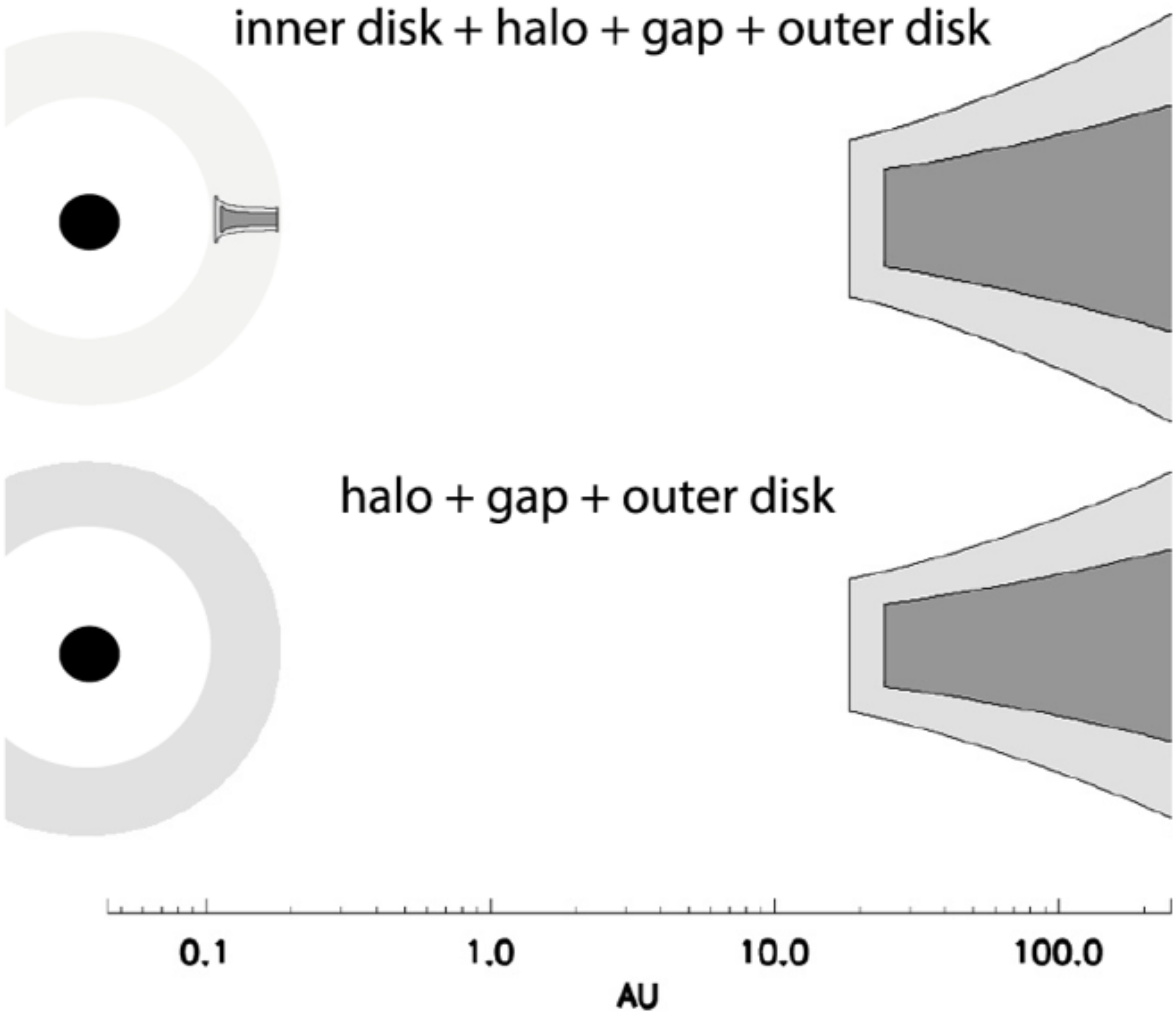
@18.8um:
0.604”+/-0.017”

@24.5um:
0.680”+/-0.034”

Size is similar, which is not consistent with a continuous flaring disk model!



Disk geometry

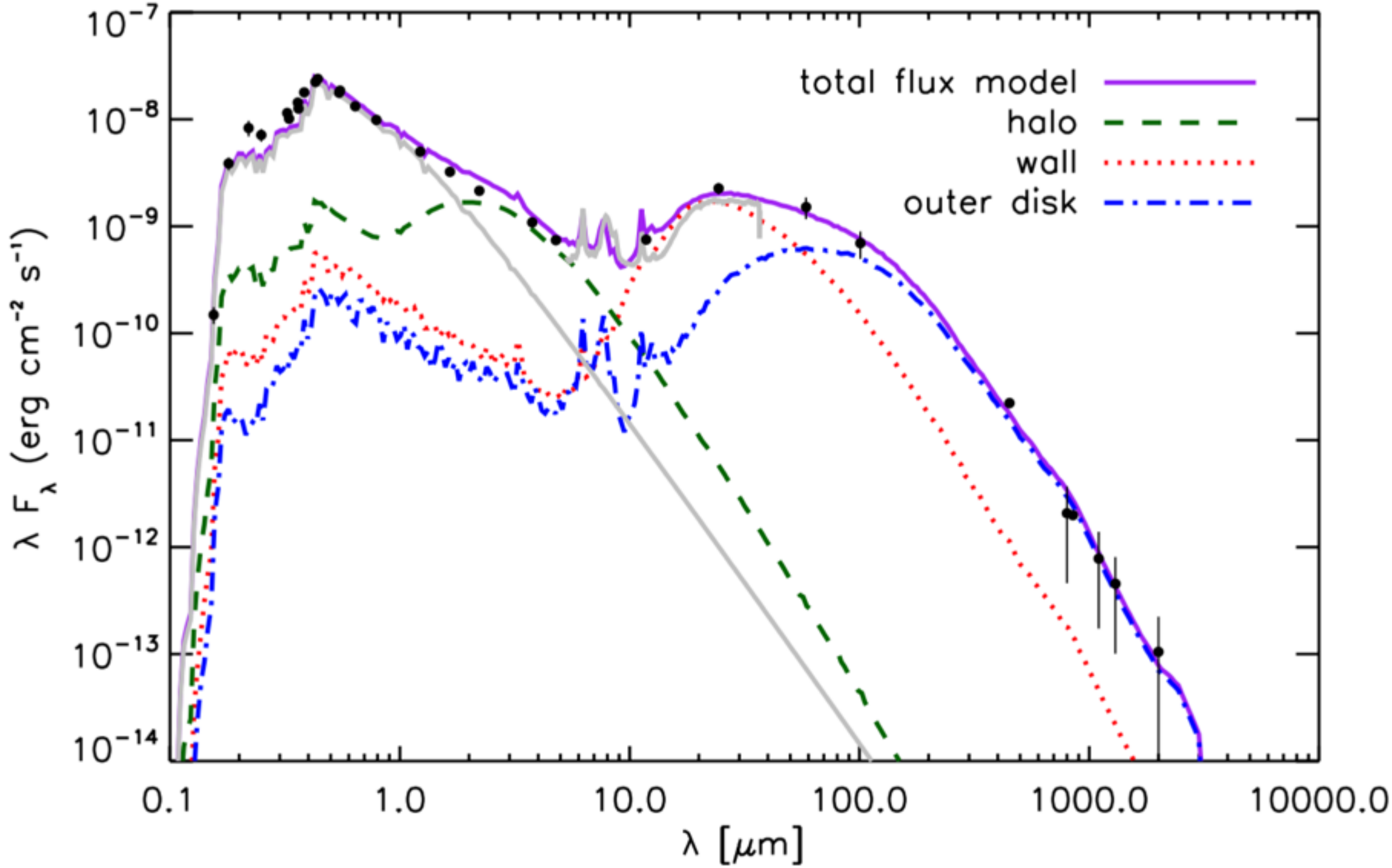


SED fitting

Parameters of HD 169142 System Used in our Best-fit Model

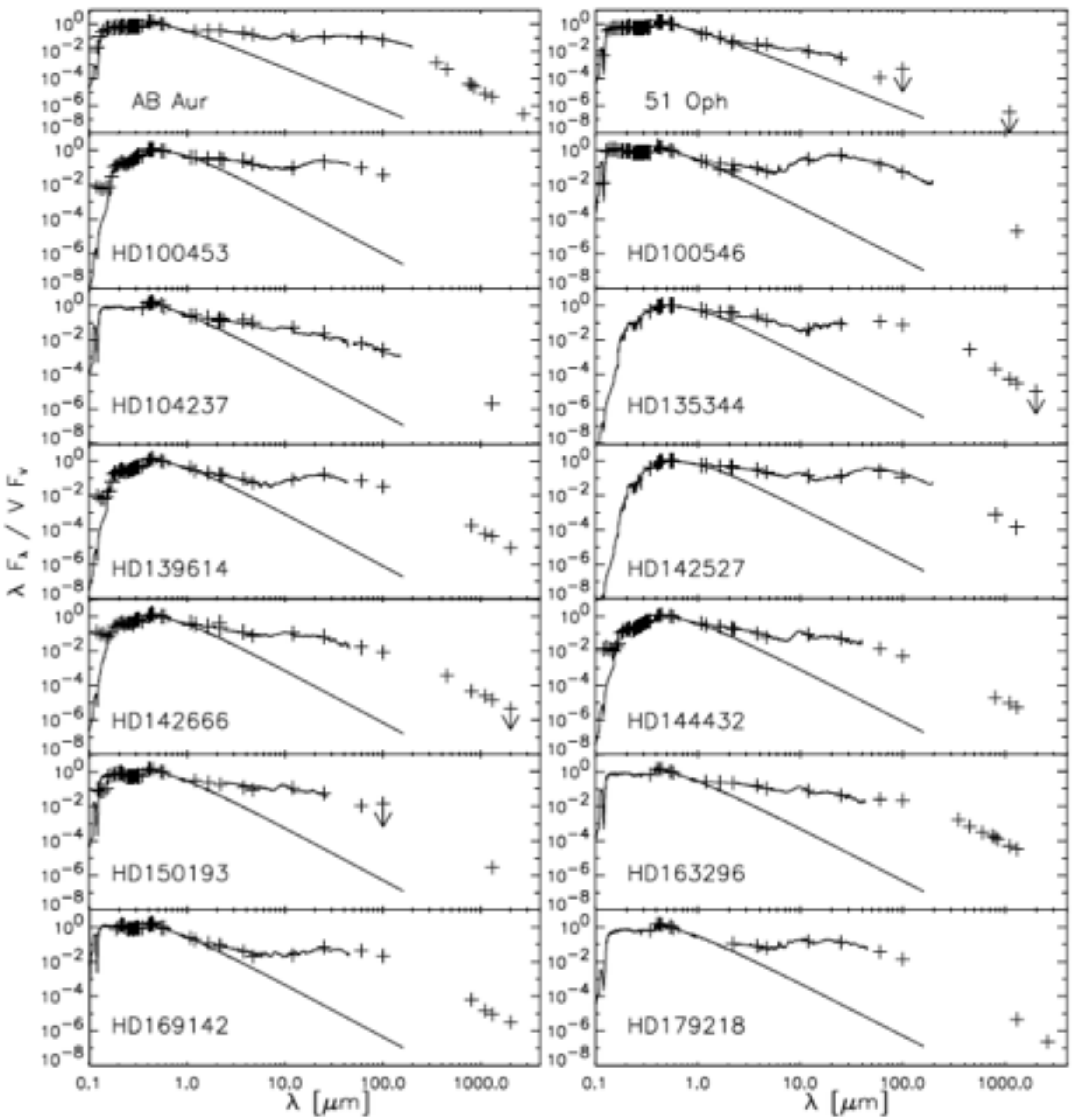
Parameter	Value	Remarks
Spectral type	A5Ve	Dunkin et al. (1997)
Extinction A_V	0.46 ± 0.05	van den Ancker (1999)
log g	4.22	van den Ancker (1999)
Temperature	8200 K	Dunkin et al. (1997)
Distance	145 ± 15 pc	de Zeeuw et al. (1999)
Age	6^{+6}_{-3} Myr	Grady et al. (2007)
Stellar luminosity	$15.33 \pm 2.17\ L_\odot$	van den Ancker (1999)
Stellar mass	$2.28 \pm 0.23\ M_\odot$	van den Ancker (1999)
Stellar radius	$1.94 \pm 0.14\ R_\odot$	van den Ancker (1999)
Gas disk mass	$(0.16\text{–}3.0) \times 10^{-2}\ M_\odot$	Panić et al. (2008)
Dust disk mass	$4 \times 10^{-4}\ M_\odot$	Fit to the submillimeter photometry
Inclination	13°	Raman et al. (2006); Dent et al. (2005)
Accretion rate	$\leqslant 10^{-9}\ M_\odot\ \mathrm{yr}^{-1}$	Grady et al. (2007)
$R_{\rm halo}$	0.1–0.2 AU	Geometrically high, optically thin component to fit the NIR
$R_{\rm in}$	23^{+3}_{-5} AU	Fit to RBP of Subaru/COMICS data
$R_{\rm out}$	235 AU	Panić et al. (2008)
Surface density exponent	-1.0	Hydrostatic equilibrium
Particle size	$a = \{0.03\ \mu\mathrm{m}, 1\ \mathrm{cm}\}$	Power-law distribution of -3.5
Silicates	70%	Similar to Mulders et al. (2011)
Amorphous carbon	30%	Zubko et al. (1996)
$M_{\rm PAH}$	$0.45 \times 10^{-7}\ M_\odot$	Uniform PAH distribution
$M_{\rm halo}$	$0.28 \times 10^{-10}\ M_\odot$	Only carbon
$M_{\rm disk}$	$0.3 \times 10^{-3}\ M_\odot$	Mass of grains $a = \{0.03\ \mu\mathrm{m}, 1\ \mathrm{cm}\}$ in the disk

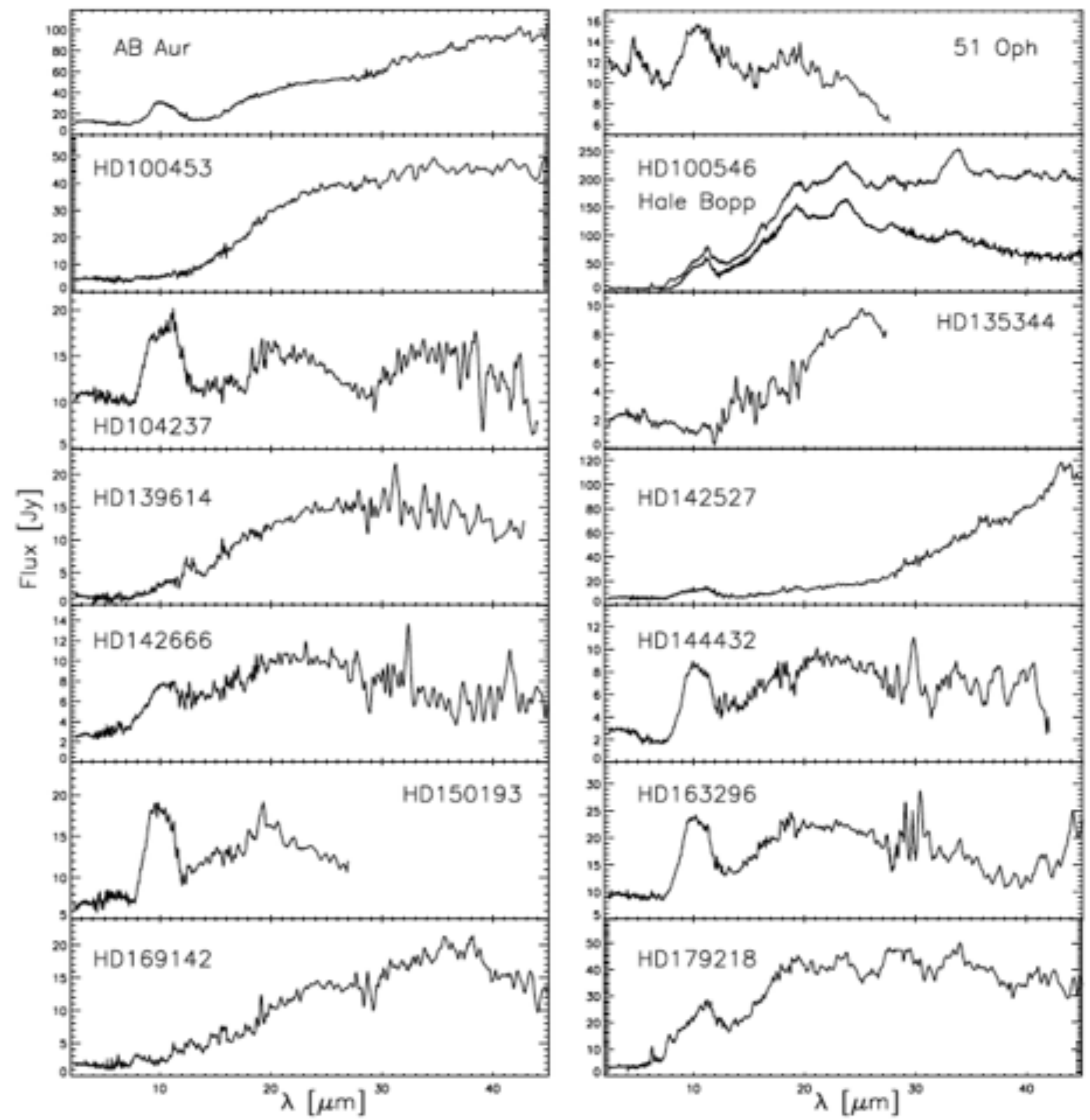
SED fitting



total flux model
halo
wall
outer disk
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
λF_λ (erg cm^{-2} s^{-1})
0.1
1.0
10.0
100.0
1000.0
10000.0
λ [μm]

Meeus classification of Herbig Ae/Be stars

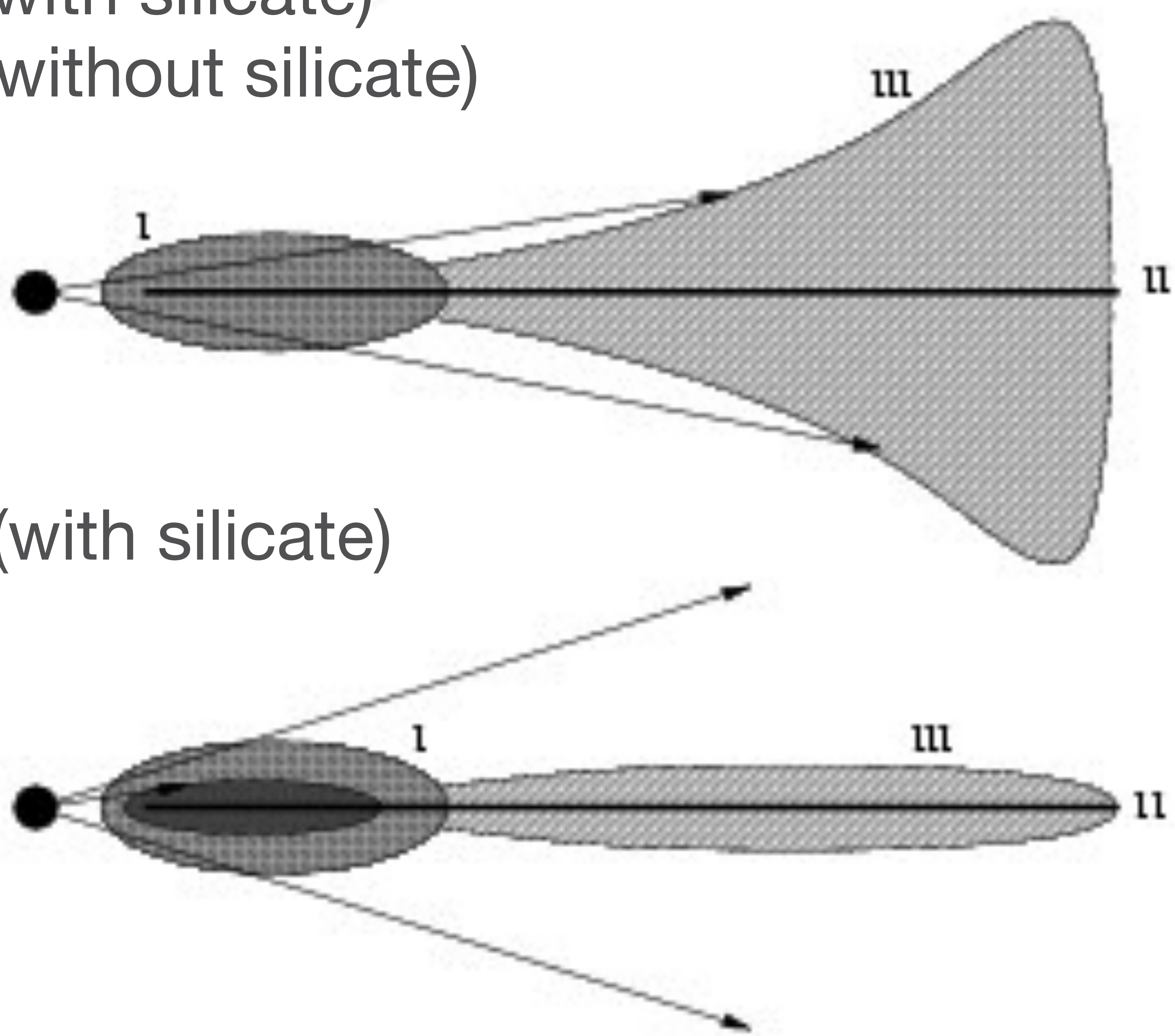




Meeus classification of Herbig Ae/Be stars

Group Ia (with silicate)
Group Ib (without silicate)

Group IIa (with silicate)

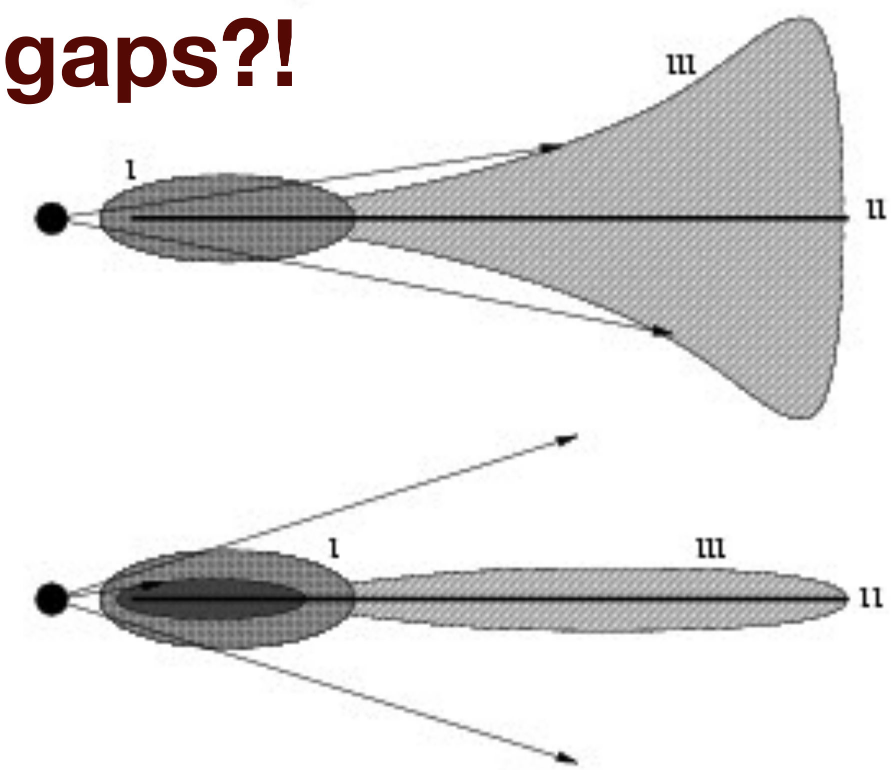


Meeus classification of Herbig Ae/Be stars

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?!



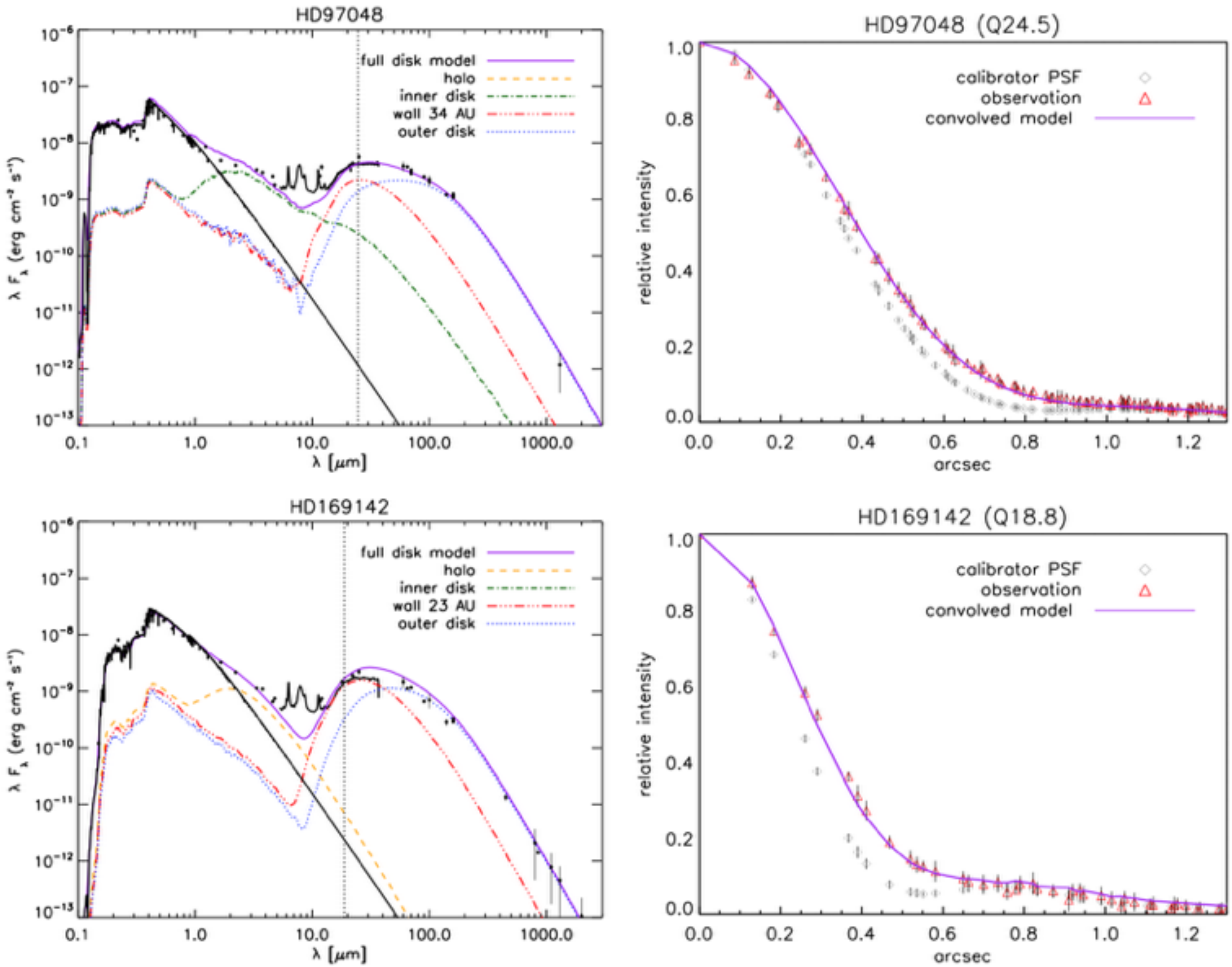
Identifying gaps in flaring Herbig Ae/Be disks using spatially resolved mid-infrared imaging

Are all group I disks transitional?

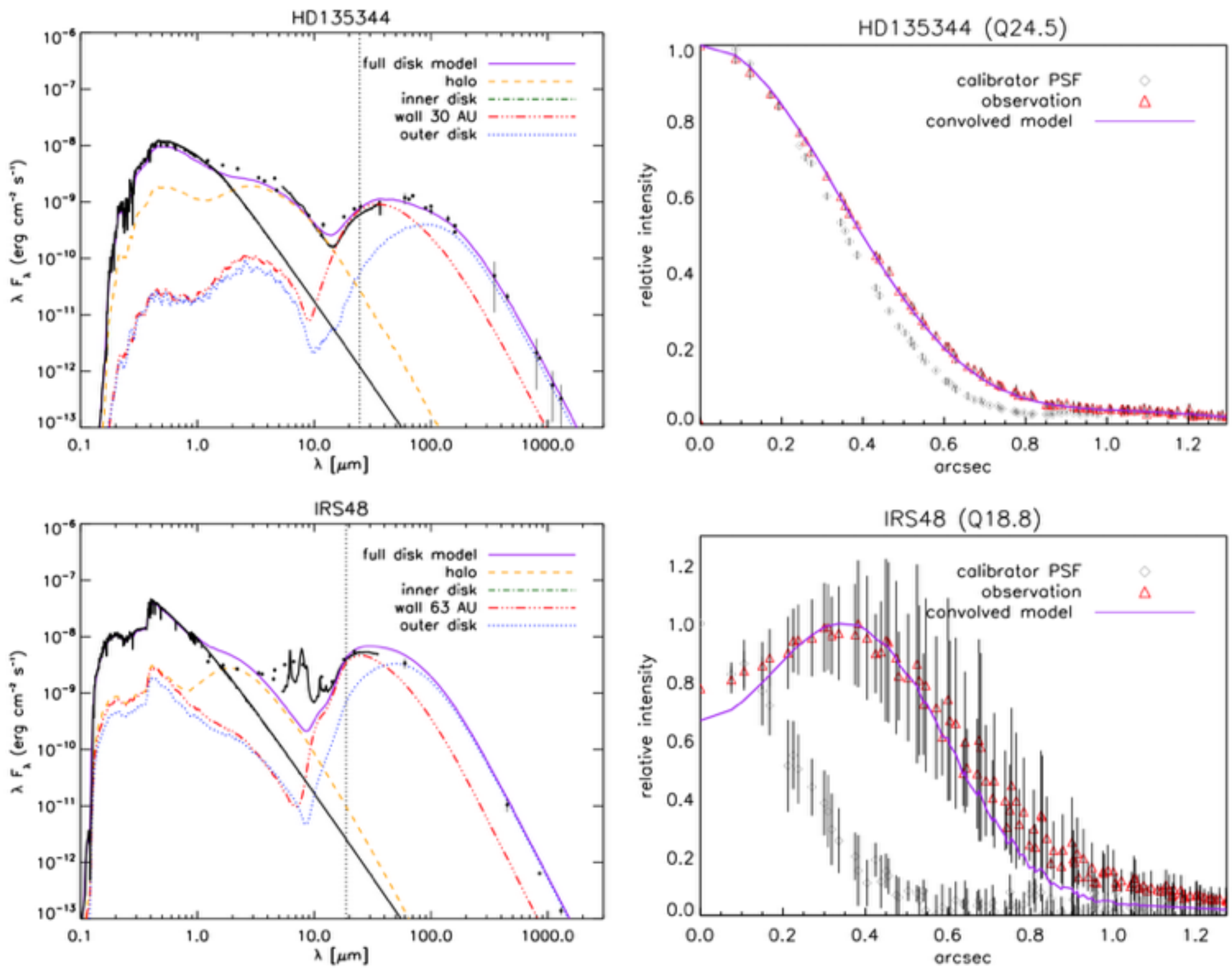
K. M. Maaskant, M. Honda, L. B. F. M. Waters, A. G. G. M. Tielens, C. Dominik,
M. Min, A. Verhoeff, G. Meeus, and M. E. van den Ancker

Astronomy & Astrophysics, Volume 555, A64 (2013)

Observations of other Herbig stars



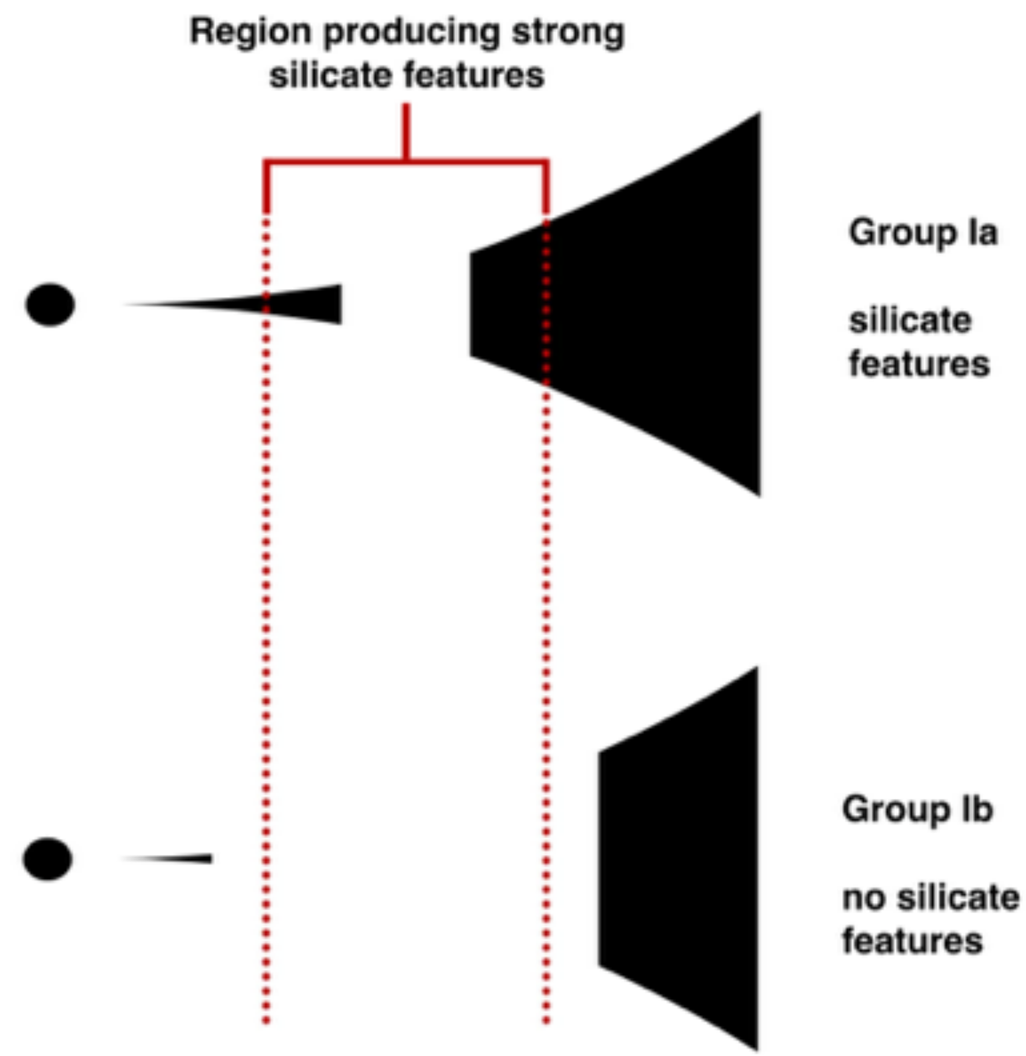
Observations of other Herbig stars



Gaps in Group I sources

Object	M_{dust} $[M_\odot]$	M_{halo} $[M_\odot]$	$R_{\mathrm{innerdisk/halo}}$ [AU]	R_{wall} [AU]	R_{out} [AU]	a $[a_{\mathrm{min}}, a_{\mathrm{max}}]$	p
HD 97048	6.0×10^{-4}	…	0.3–2.5	34^{+4}_{-4}	500	{0.5 μm, 1mm}	–3.5
HD 169142	0.8×10^{-4}	0.31×10^{-12}	0.1–0.2	23^{+4}_{-4}	235	{0.5 μm, 1mm}	–3.5
HD 135344 B	1.0×10^{-4}	0.47×10^{-12}	0.1–0.3	30^{+4}_{-3}	200	{1.0 μm, 1mm}	–4.0
Oph IRS 48	3.0×10^{-5}	0.50×10^{-12}	0.1–0.3	63^{+4}_{-4}	235	{0.1 μm, 1mm}	–4.0

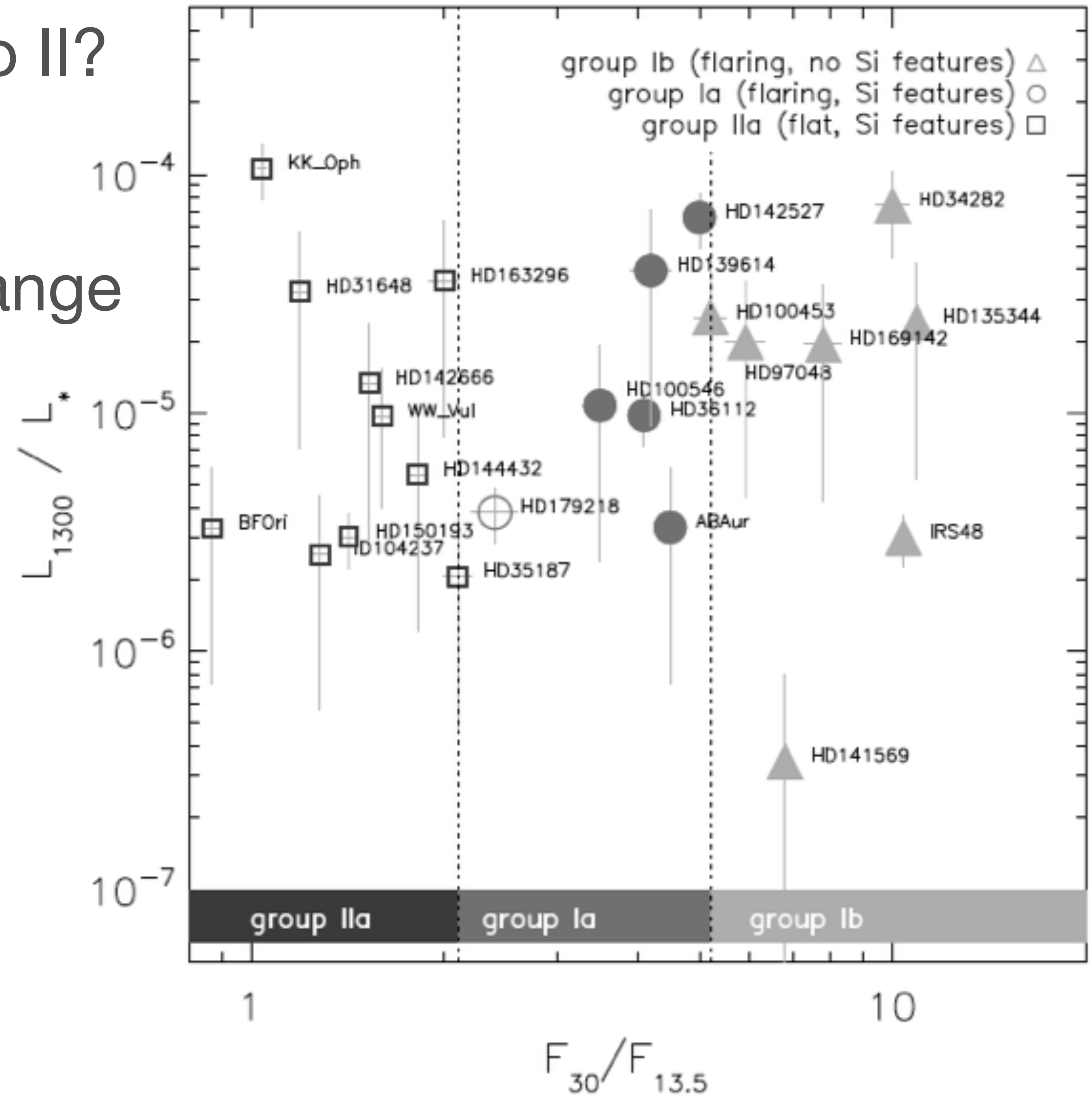
Explanation for the Group I a/b difference (yes/no silicate feature):



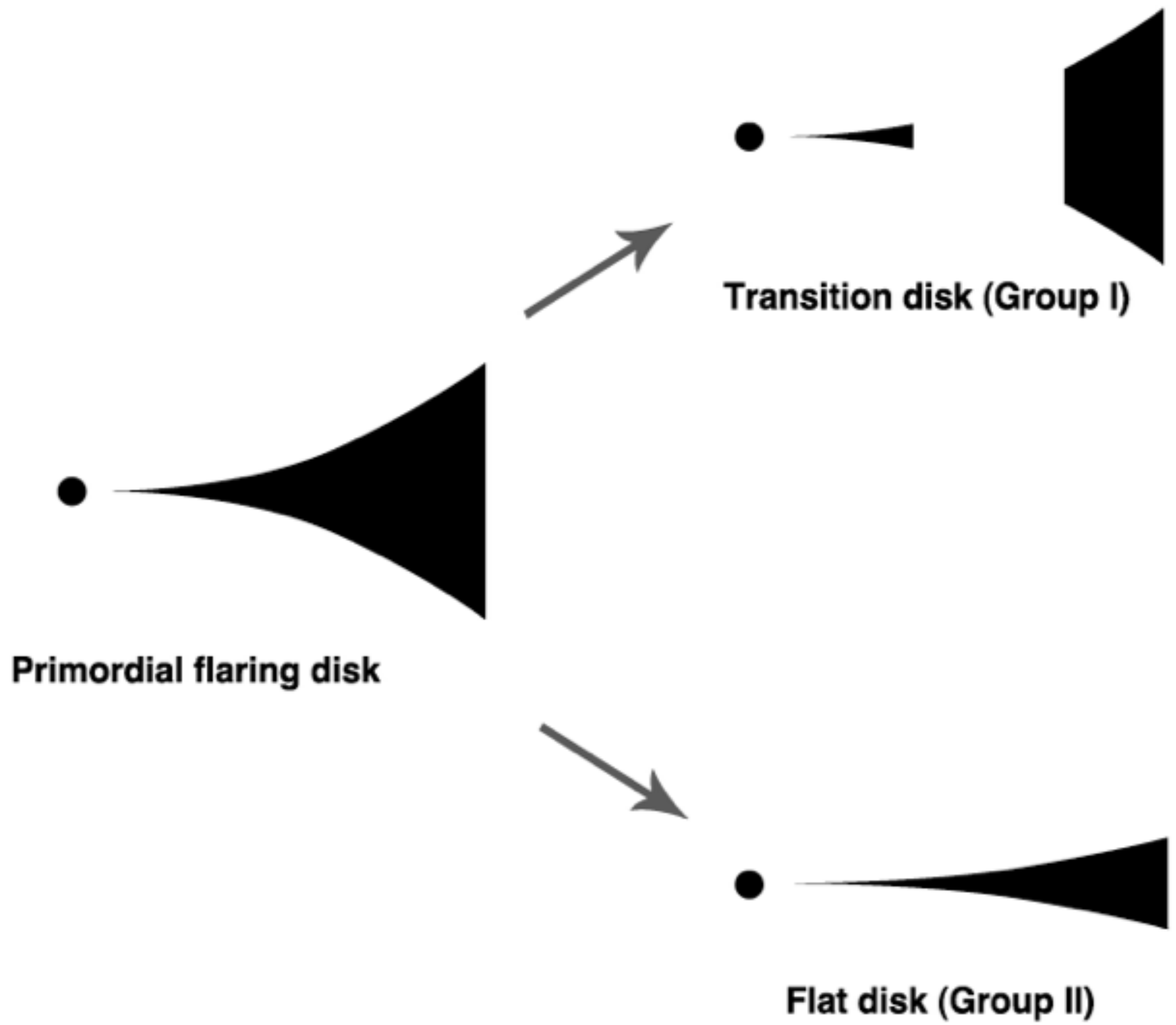
Gaps in Herbig disks

Evolution from Group I to II?
Not obvious…

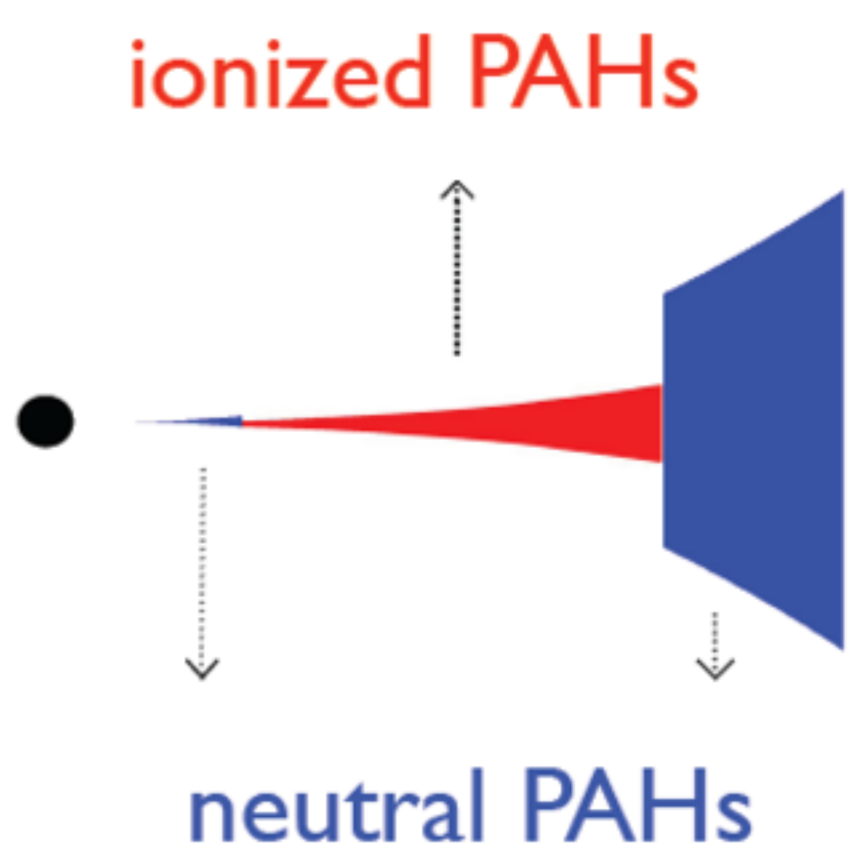
Group Ia -> Ib -> IIa strange



Disk evolution in Herbig stars?



PAH ionization as a tracer of gas flows through disk gaps

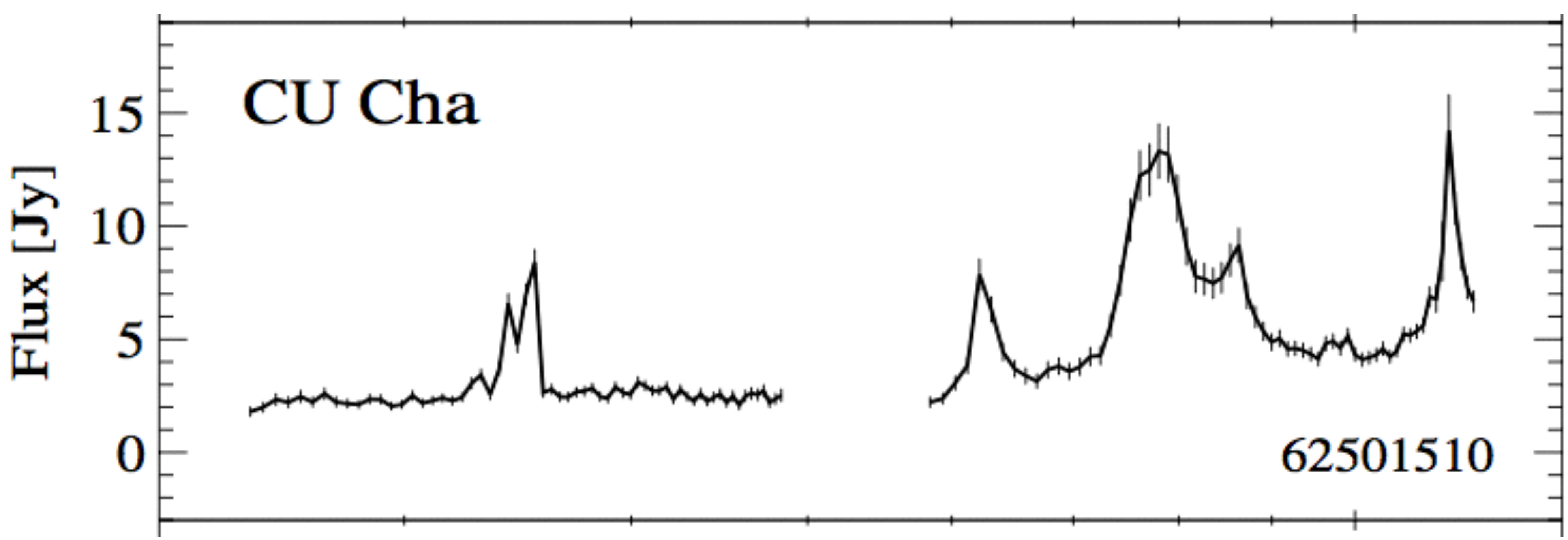


Koen Maaskant
(PhD student Leiden Observatory)

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

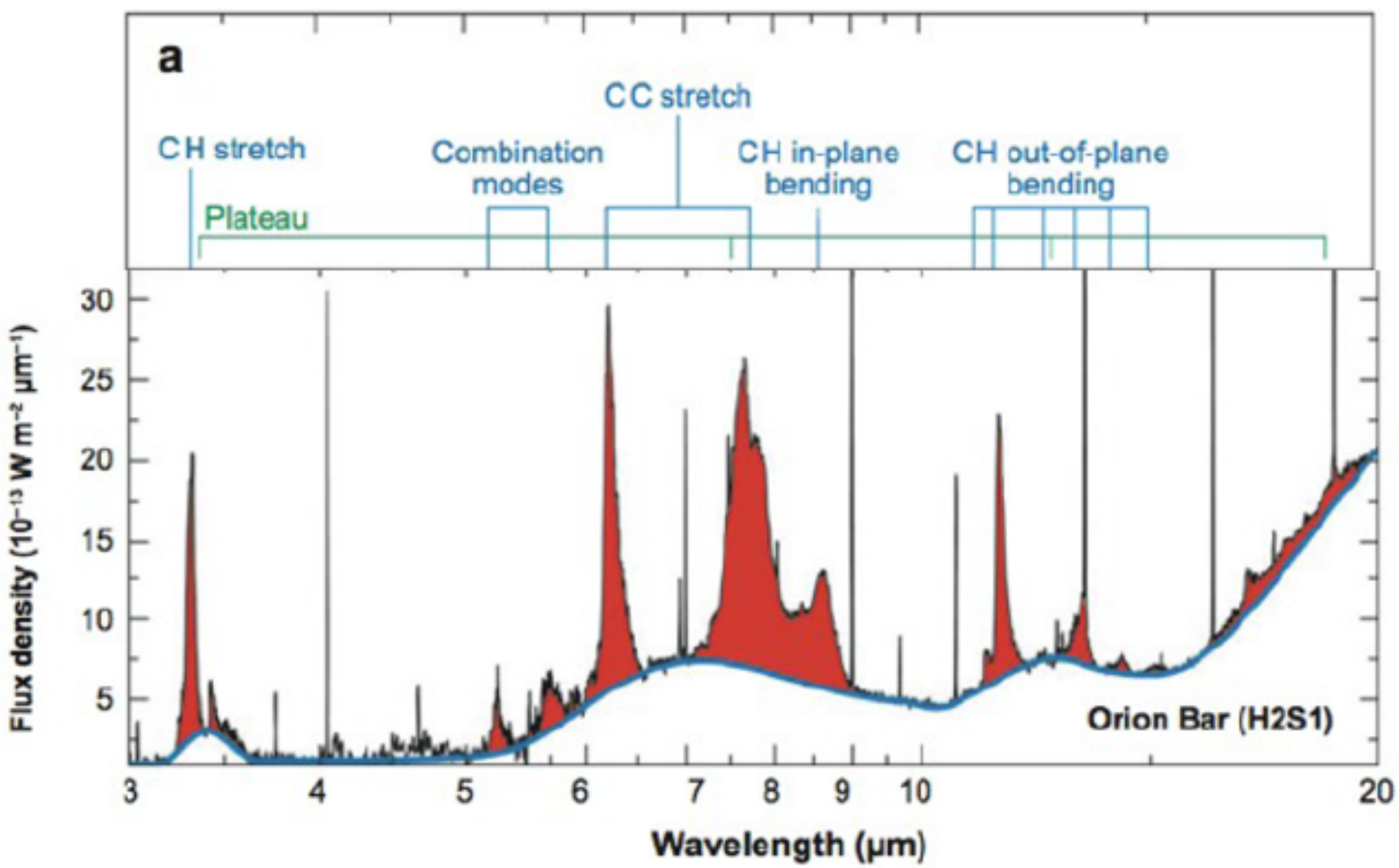
Introduction to PAHs

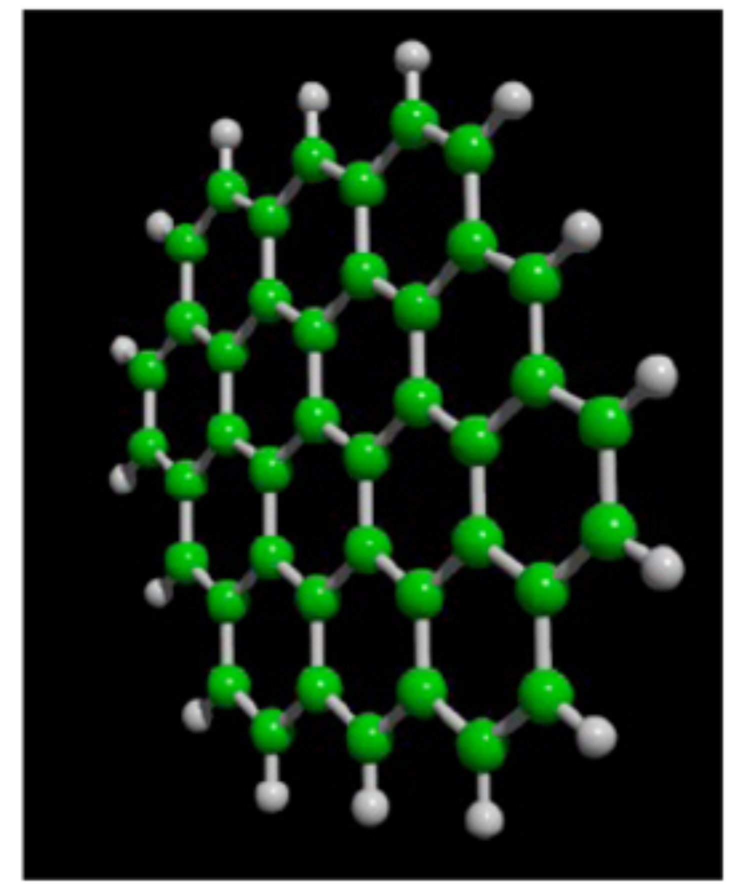
Polycyclic aromatic hydrocarbons (PAHs) can be observed in the infrared spectra of protoplanetary disks of Herbig Ae/Be stars, and - with a lower frequency - T Tauri stars The strength of the features decreases with stellar effective temperature. They can be used as tracers of the outer disk



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).

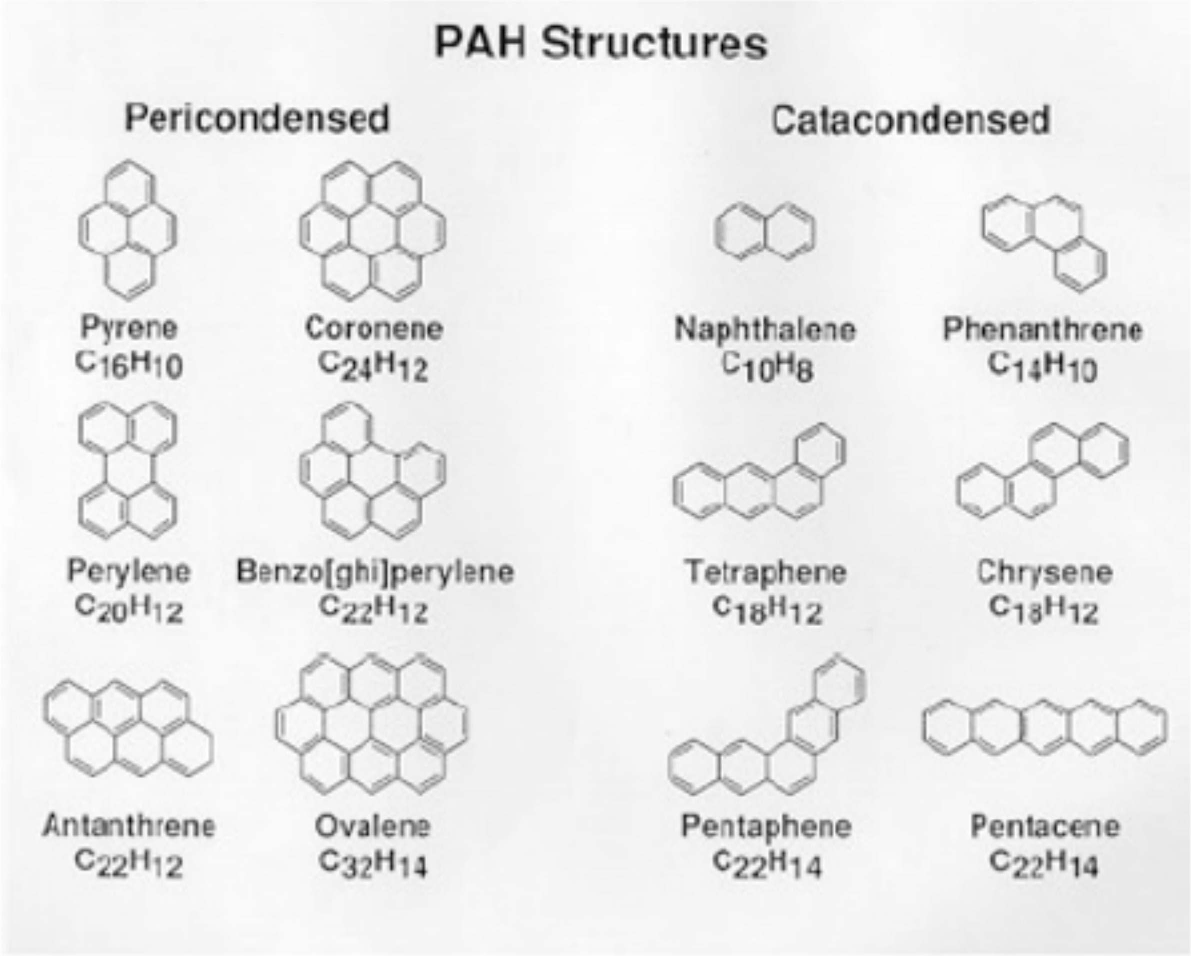


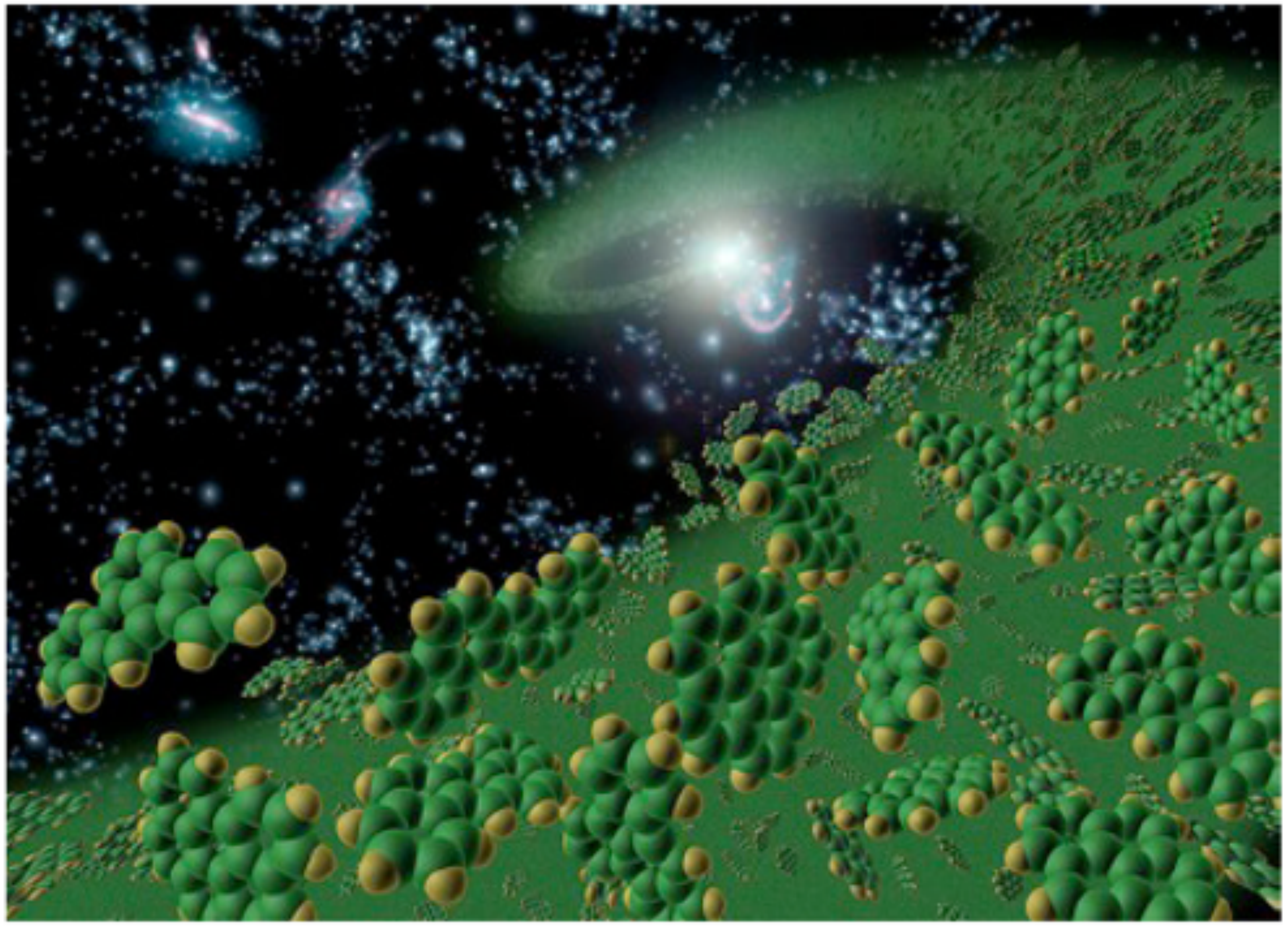


Peeters et al. 2002

PAHs

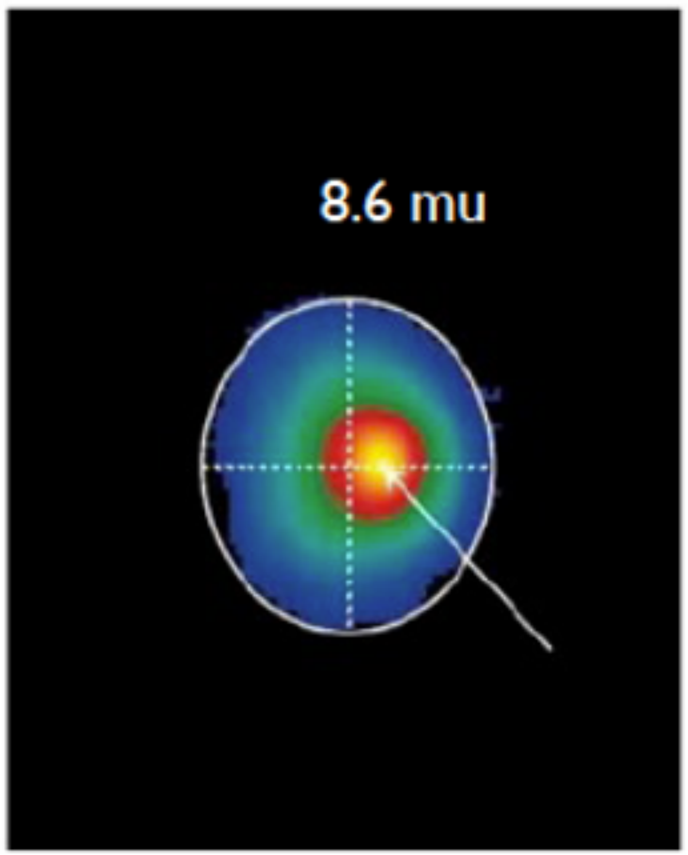
Electronically excited by UV photons (quantum heating)
Cooling by CH- and CC- stretching and bending modes

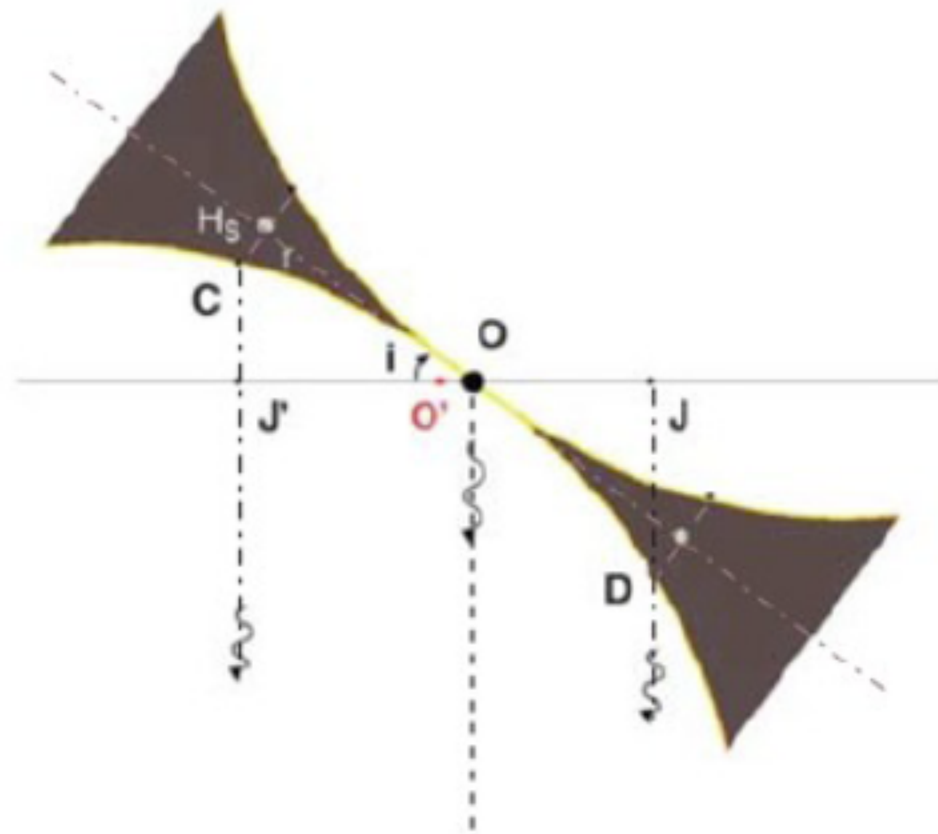




PAHs and the disk structure

Tracing the flaring disk structure

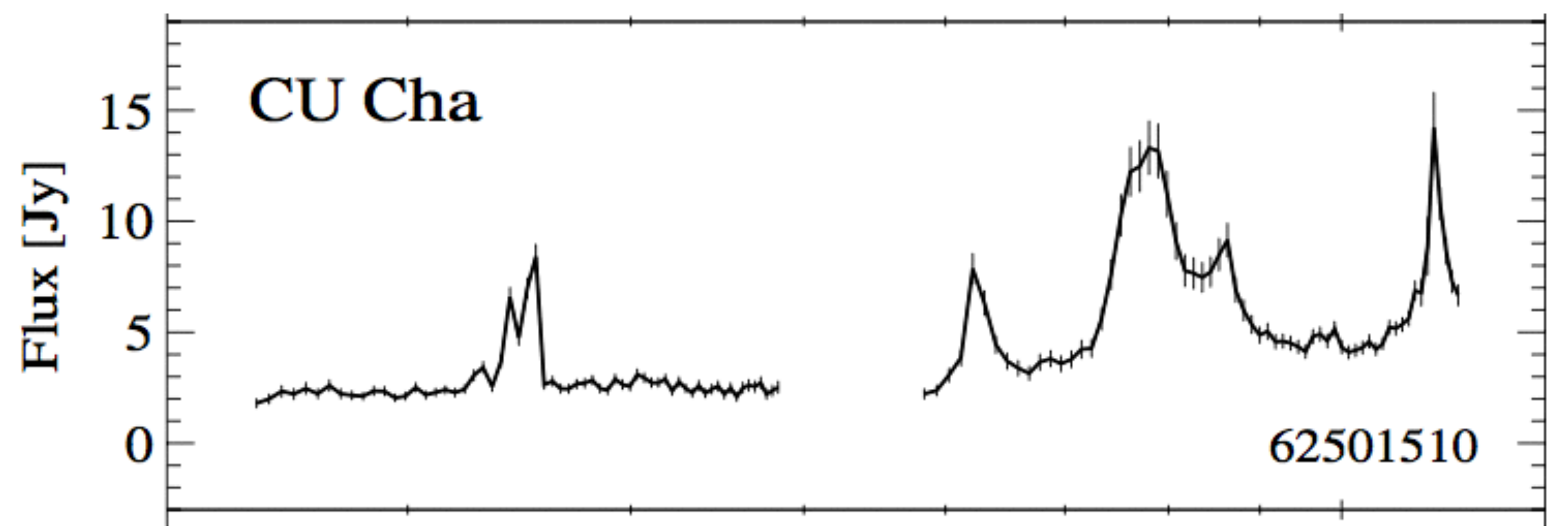




HD97048, Lagage et al 2006, Doucet et al 2006

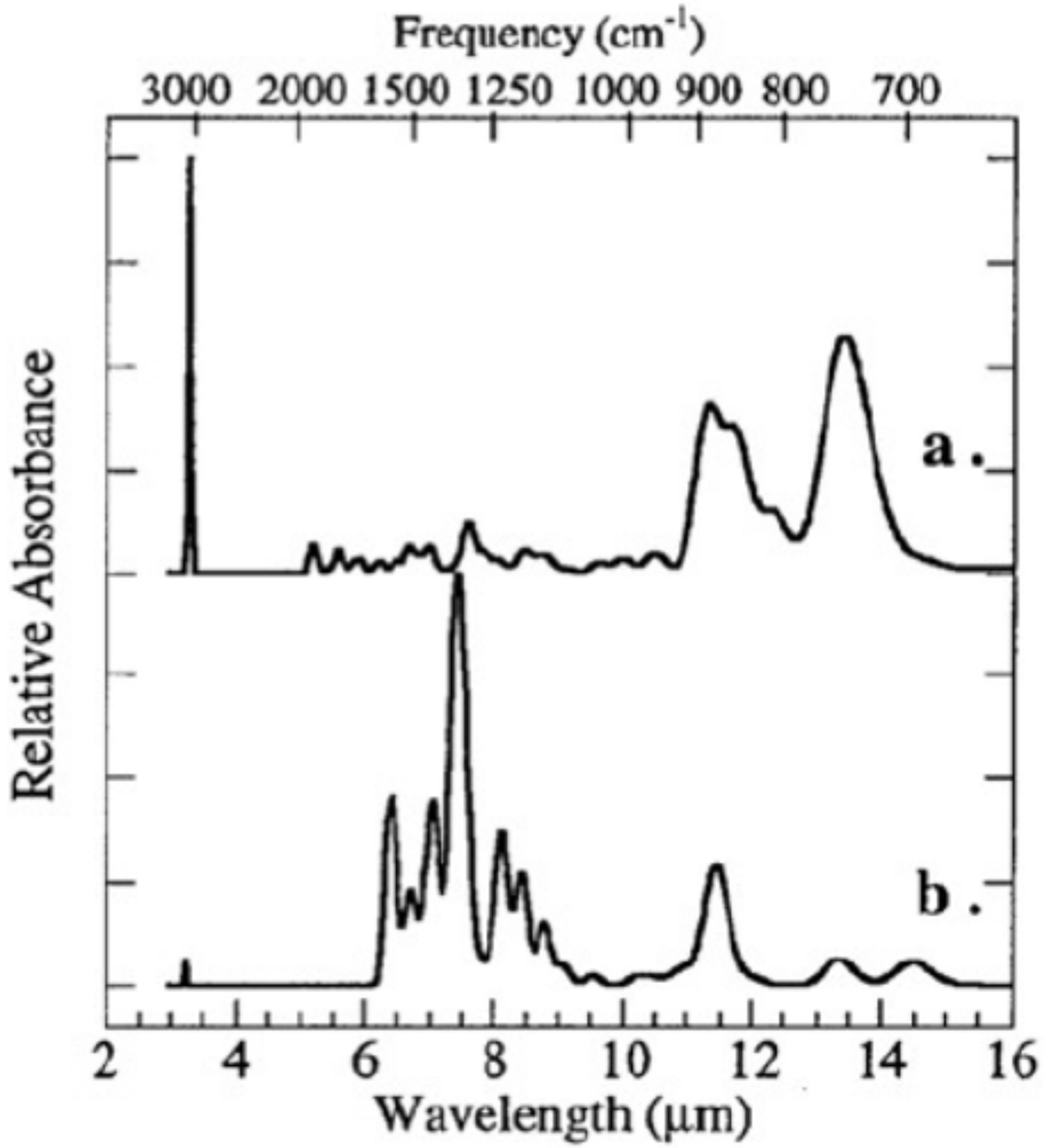
PAHs

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:

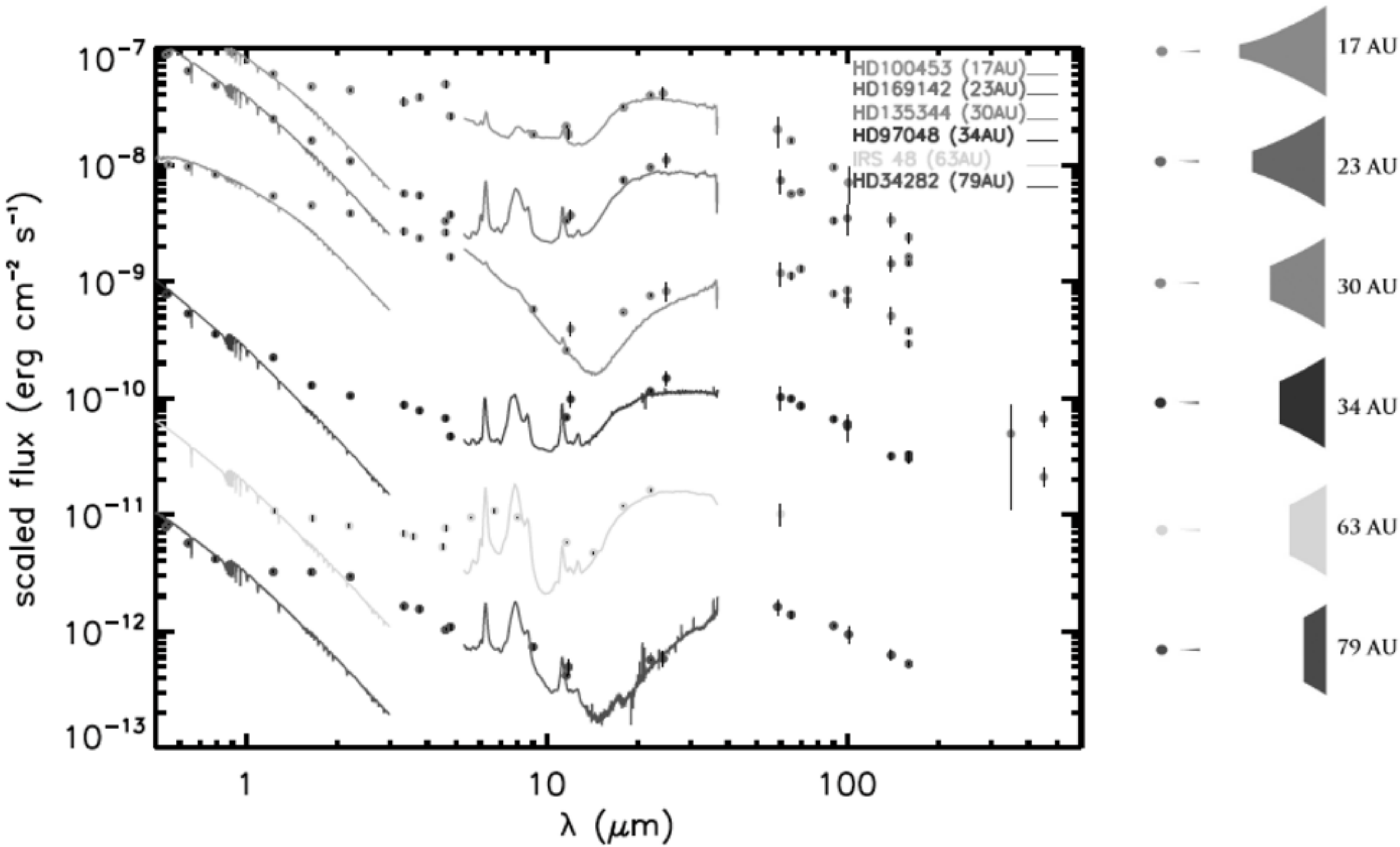


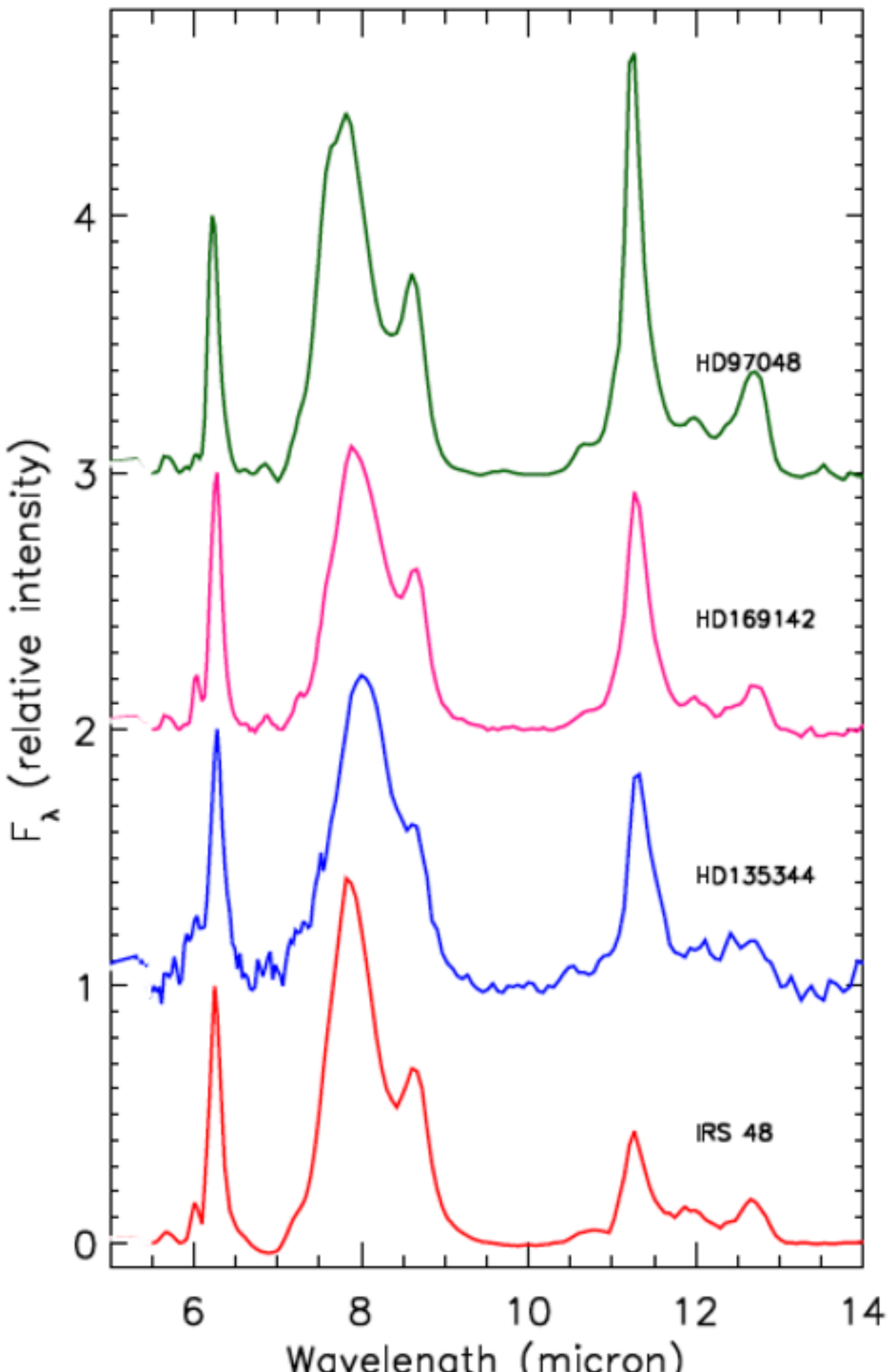
Neutral

ionized

Allamandola et al 1999

Our sample with gaps





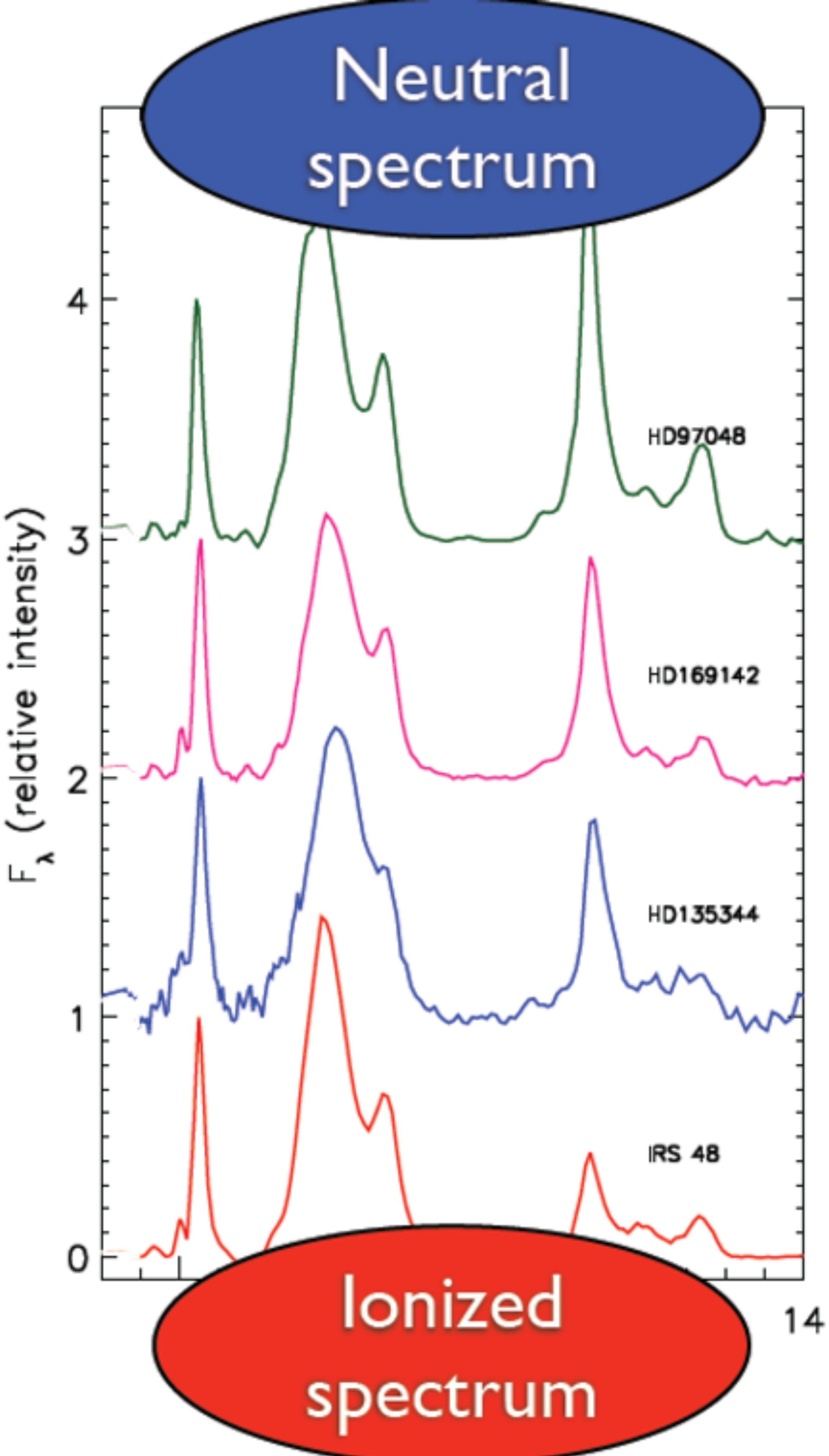
HD97048

HD169142

HD135344B

Oph IRS 48

Maaskant et al 2013, 2014

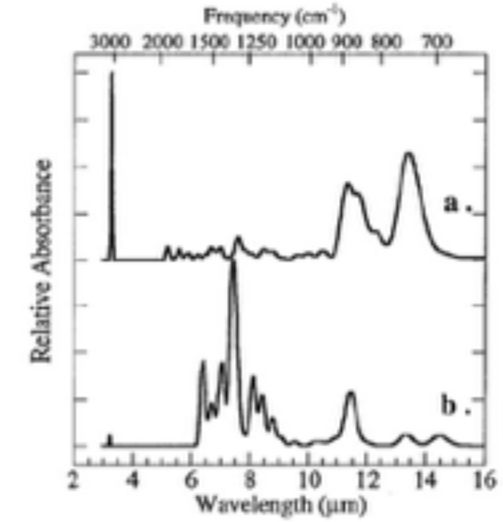


HD97048

HD169142

HD135344B

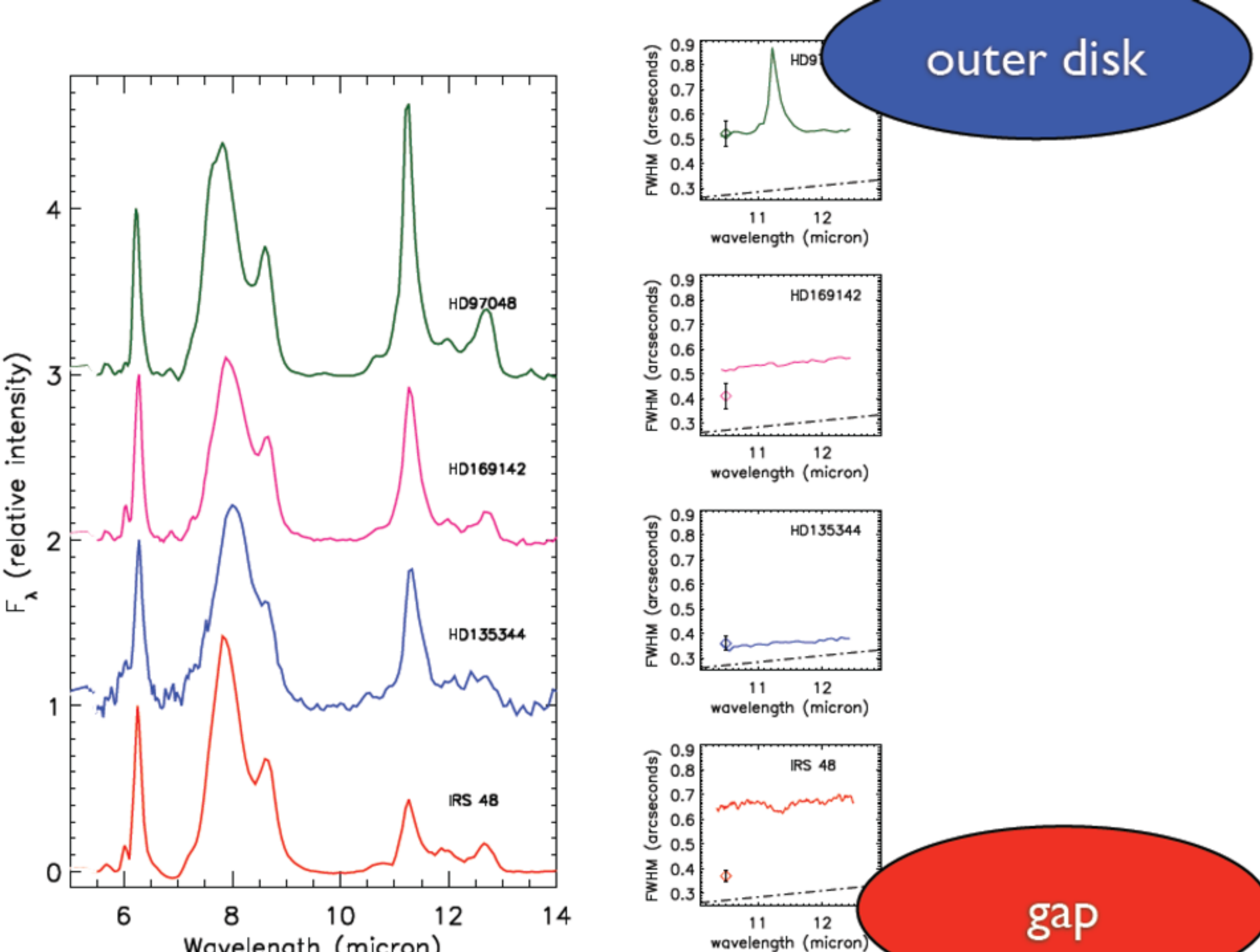
Oph IRS 48



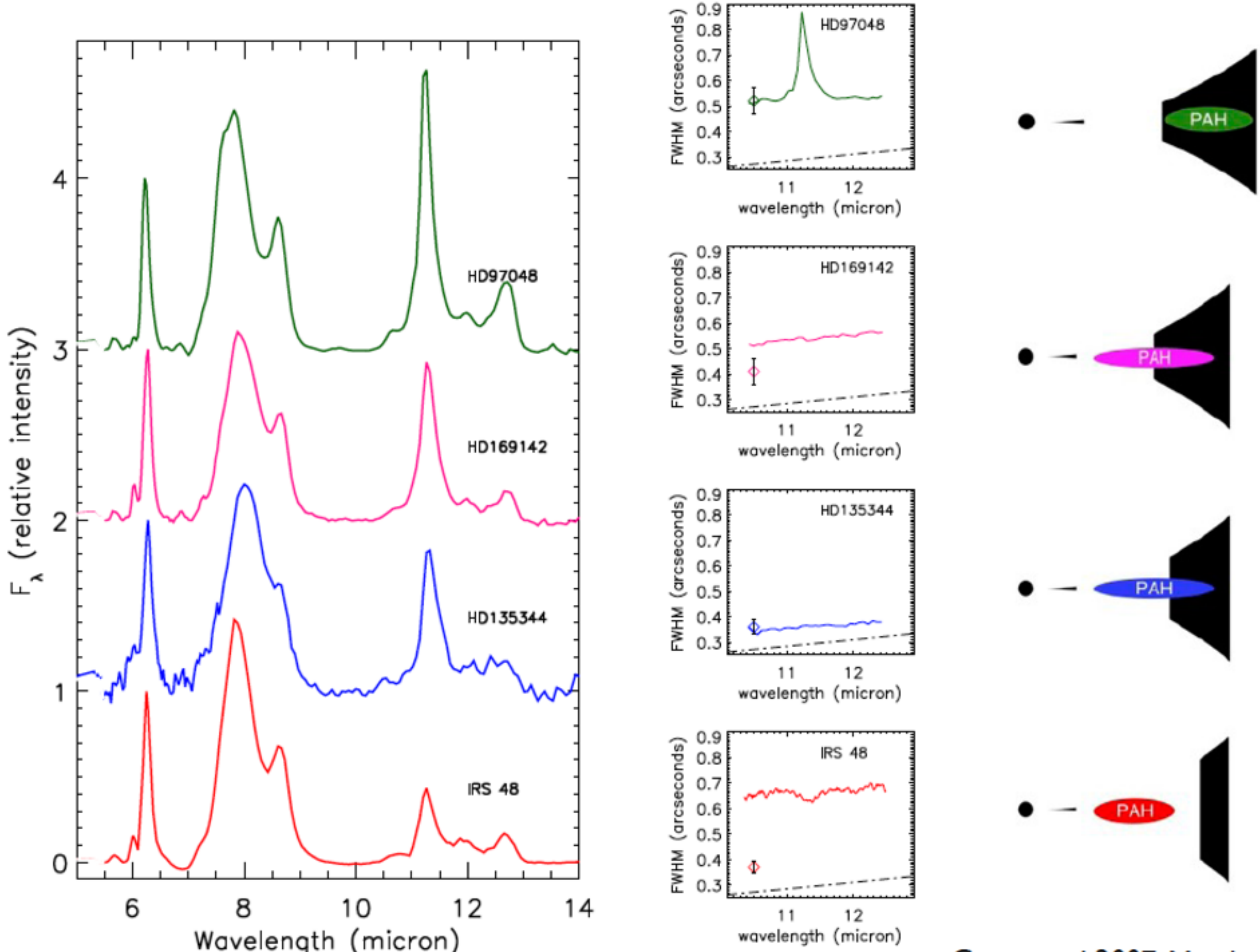
Neutral

ionized

Maaskant et al 2013, 2014

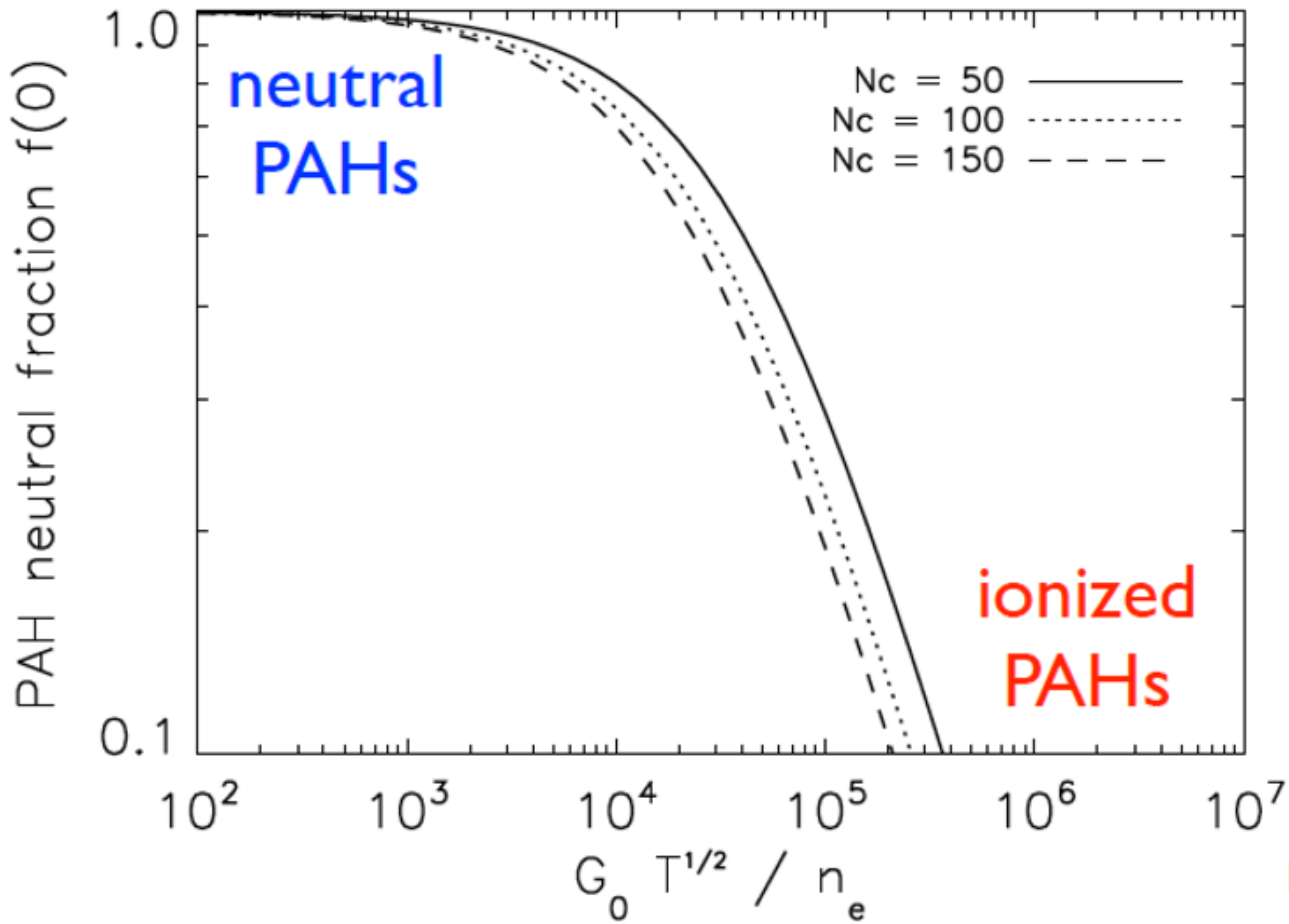


kant et
al 2013, 2014



Geers et al 2007, Maaskant et al 2013, 2014

PAH model in RT code MCMax (Min et al 2009)

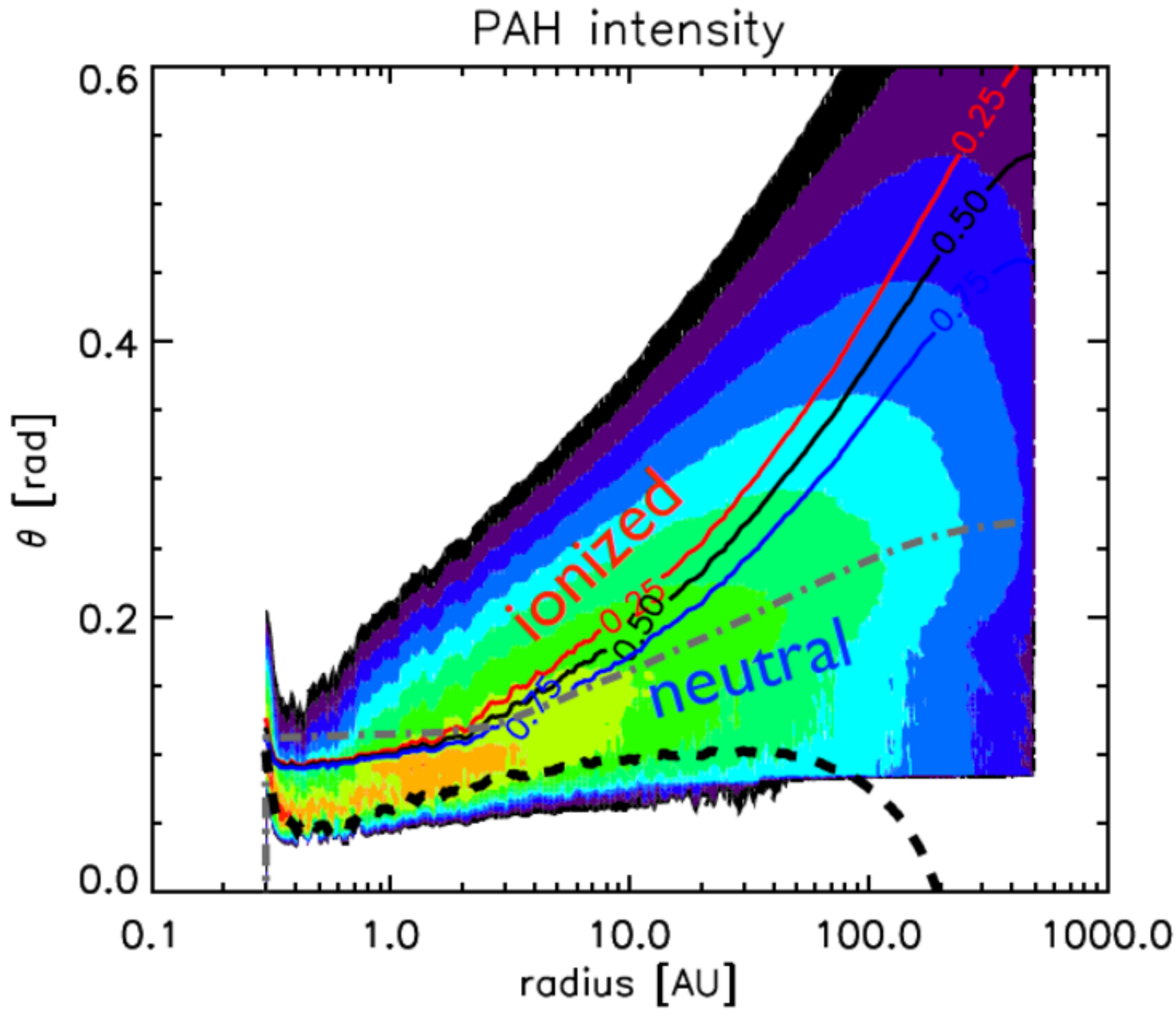


ionization parameter

Bakes & Tielens 1994
Tielens 2005
Galliano 2008

Benchmark model

~90 %
neutral
at all radii

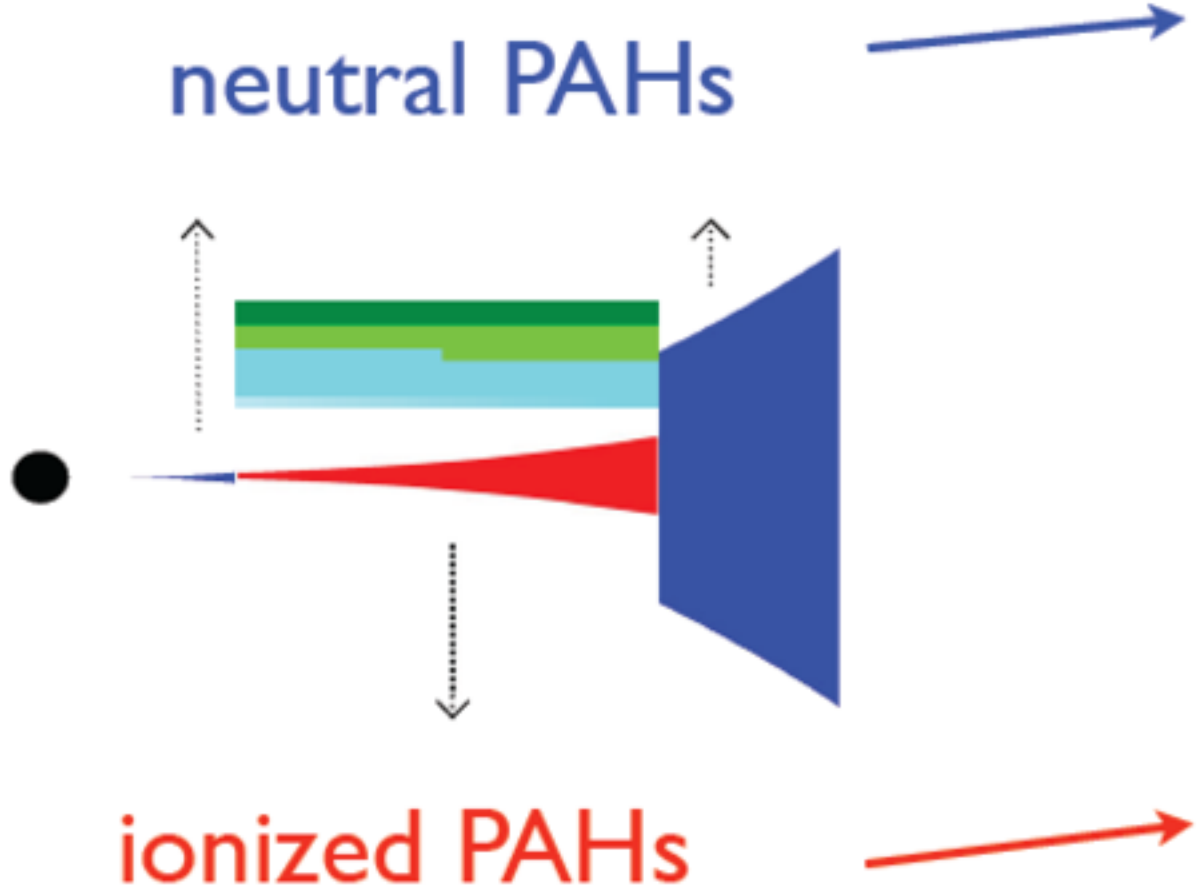


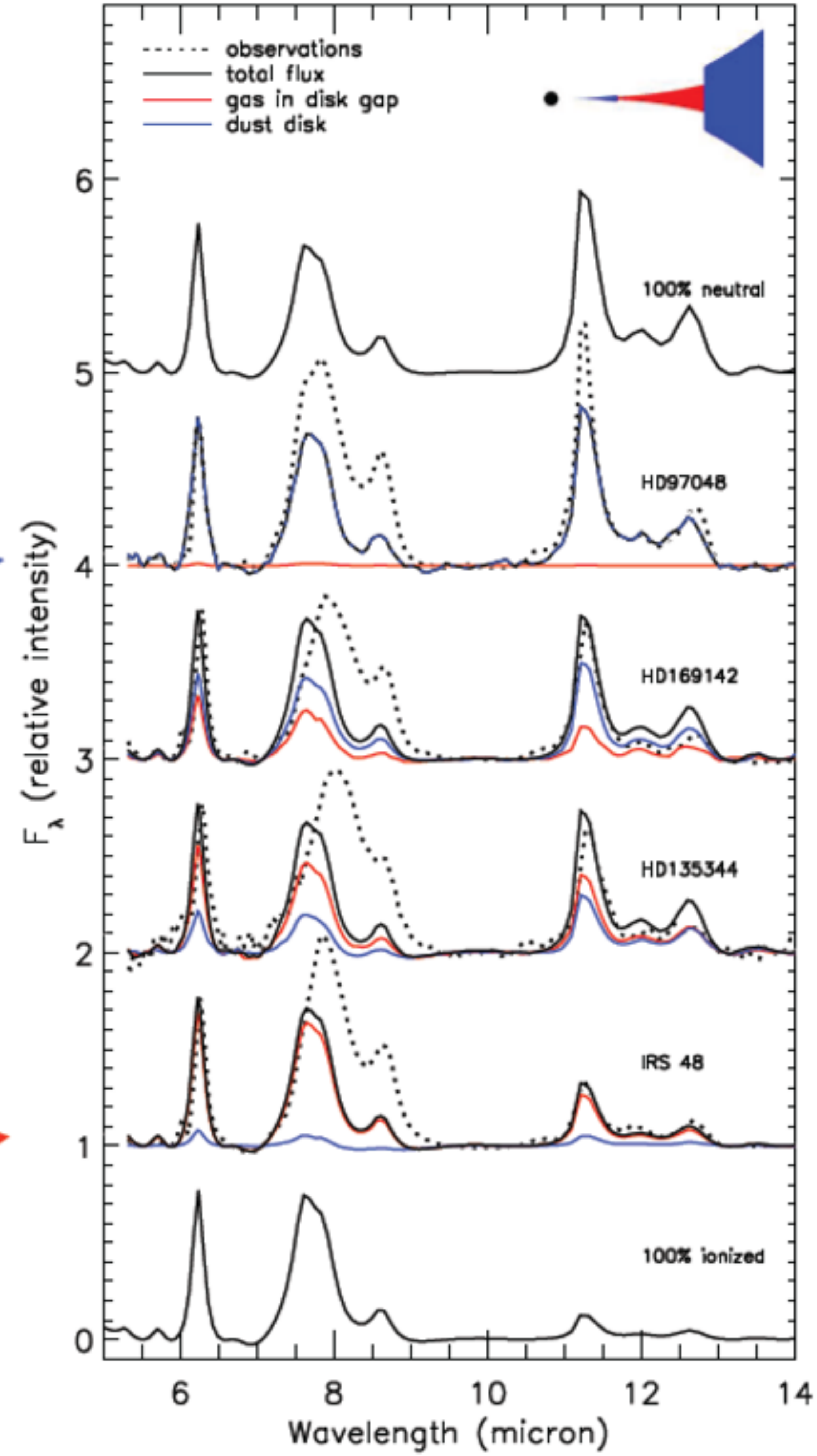
How to get ionized PAHs in disks?

↓

Optically thin gaps!

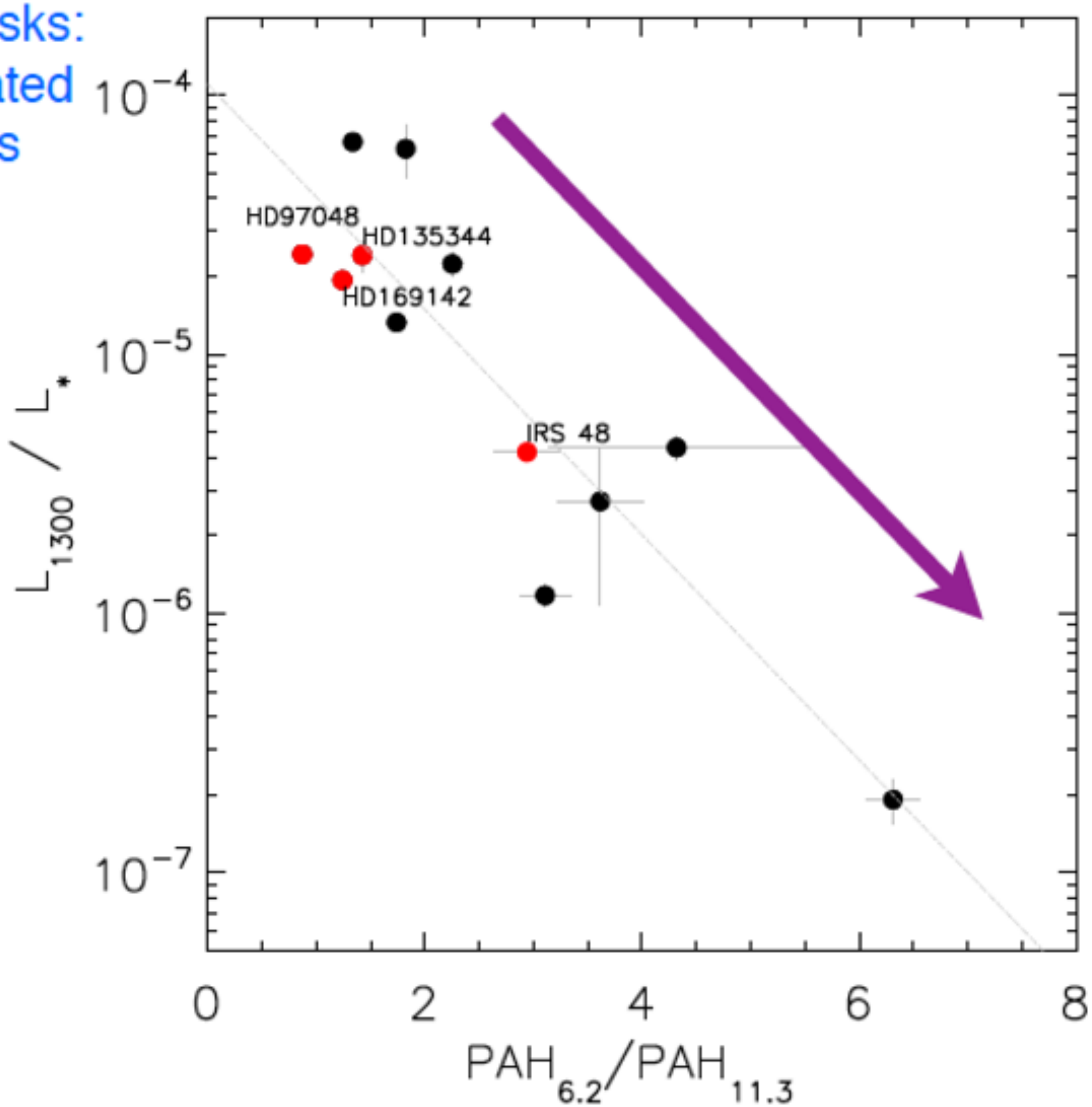
Demonstration: RT models of four transitional disks





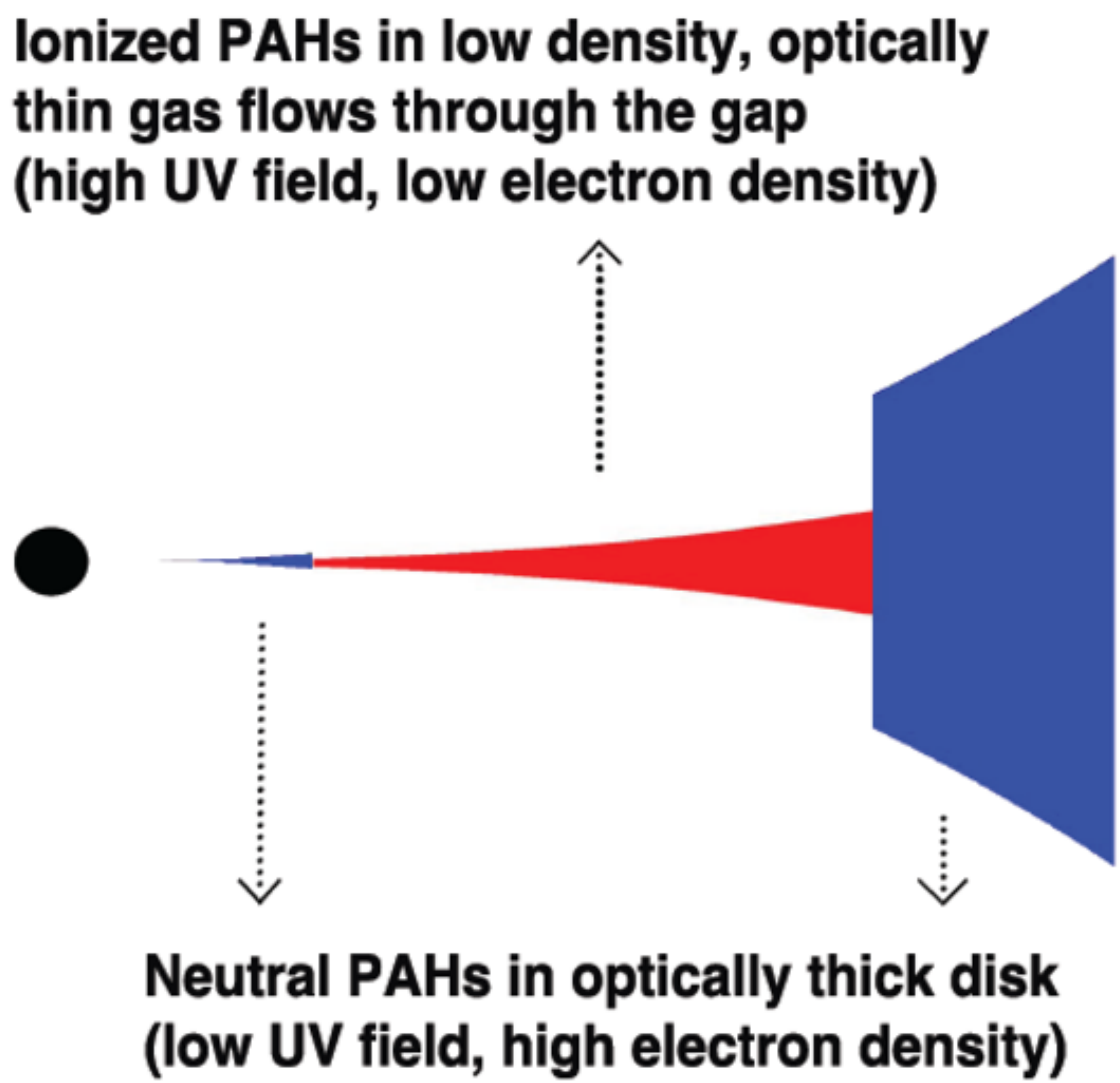
Trend:
mm luminosity (disk mass) vs PAH ionization

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)