Infrared view of (candidate) accretion disks around massive young stars.

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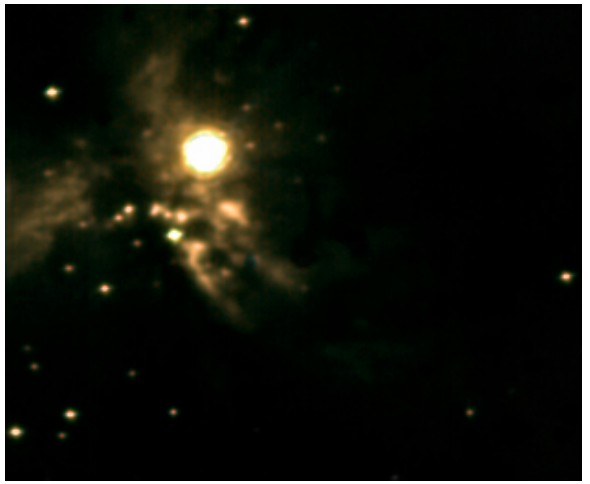
What is a massive Young Stellar Object?

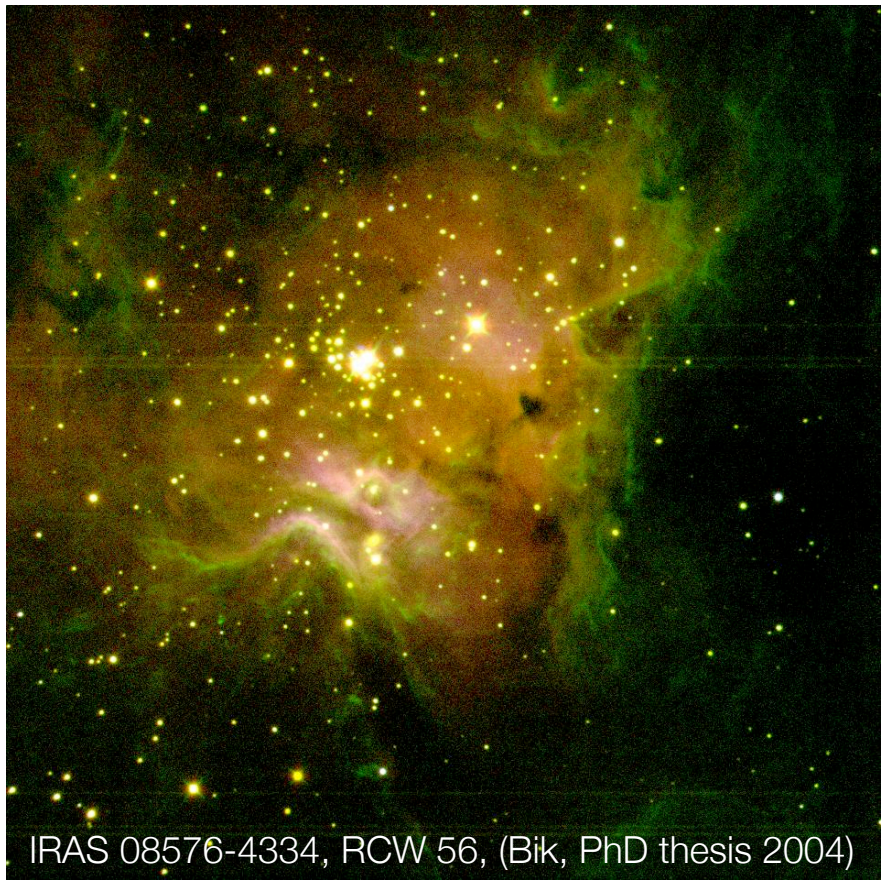
- A star with a mass more then ~10 solar masses, surrounded by a (remnant) accretion disk.



- massive YSOs detected in the near-infrared are more evolved then those detected in the (sub) mm.

Observational Characteristics

- Located in high-mass star-forming regions, subject of high extinction (Av 10 - 40).
- Have an infrared excess, central star is difficult to observe.
- Have an emission line spectrum with lines from ionized and neutral species.



IRAS 08576-4334, RCW 56, (Bik, PhD thesis 2004)

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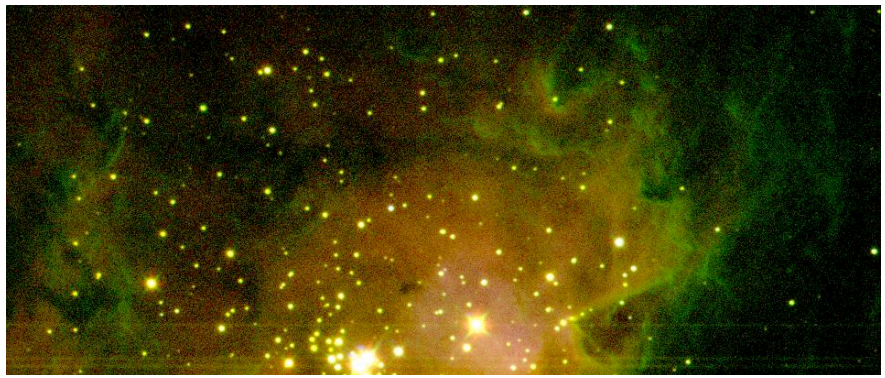
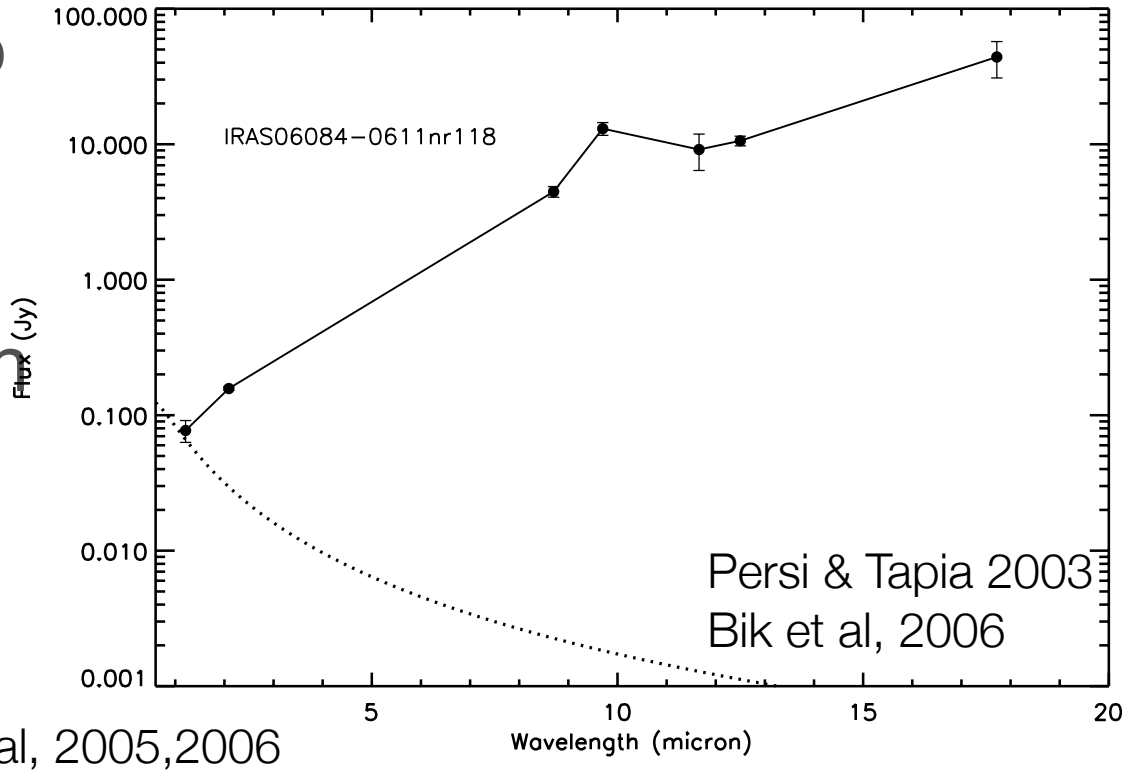
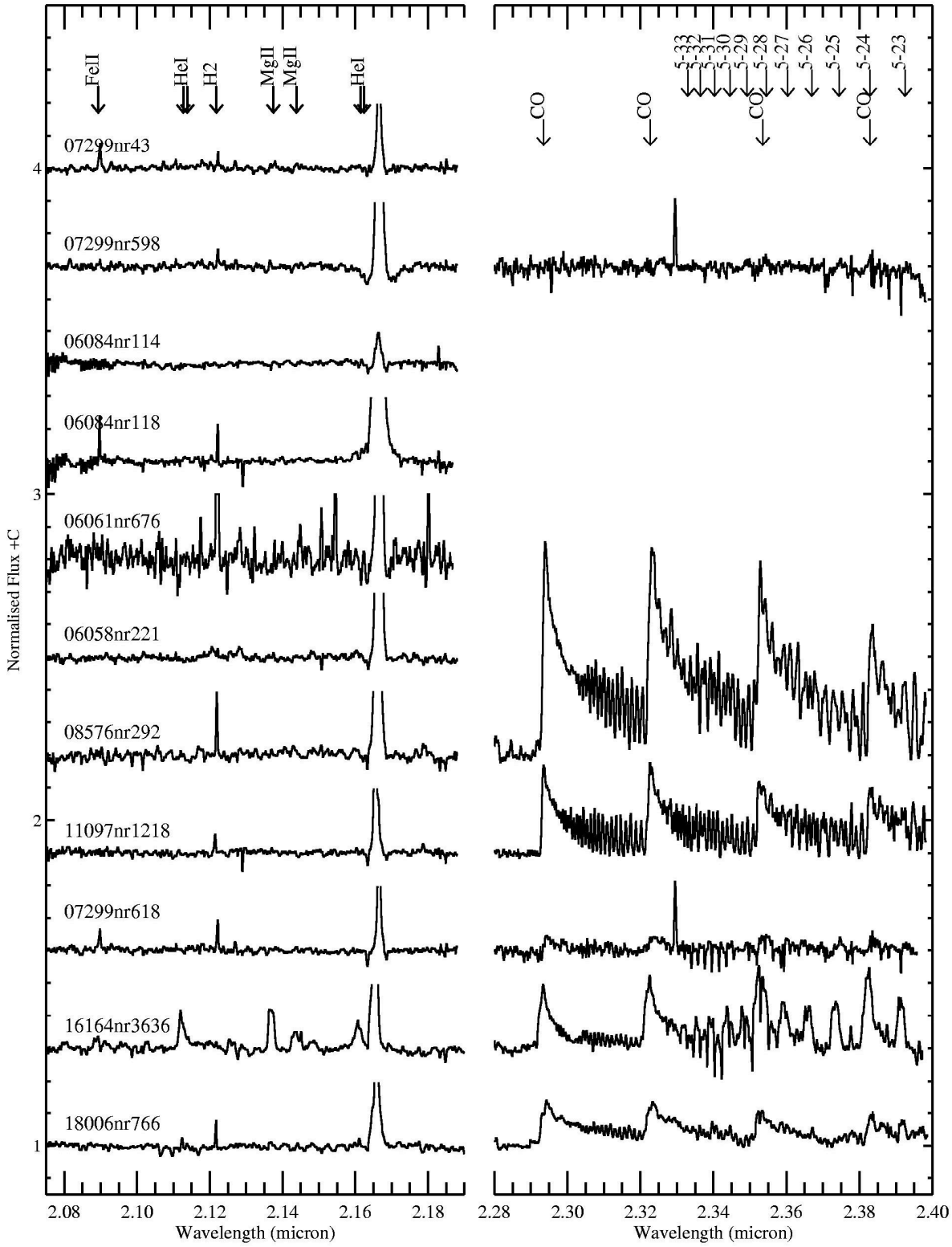




Bik et al, 2005,2006


FeII
HeI
H2
MgII
MgII
HeI
CO
CO
5-33
5-32
5-31
5-30
5-29
CO
5-28
5-27
5-26
5-25
CO
5-24
5-23
07299nr43
07299nr598
06084nr114
06084nr118
06061nr676
06058nr221
08576nr292
11097nr1218
07299nr618
16164nr3636
18006nr766
Normalised Flux +C
4
3
2
1
2.08
2.10
2.12
2.14
2.16
2.18
Wavelength (micron)
2.28
2.30
2.32
2.34
2.36
2.38
2.40
Wavelength (micron)

Infrared diagnostics

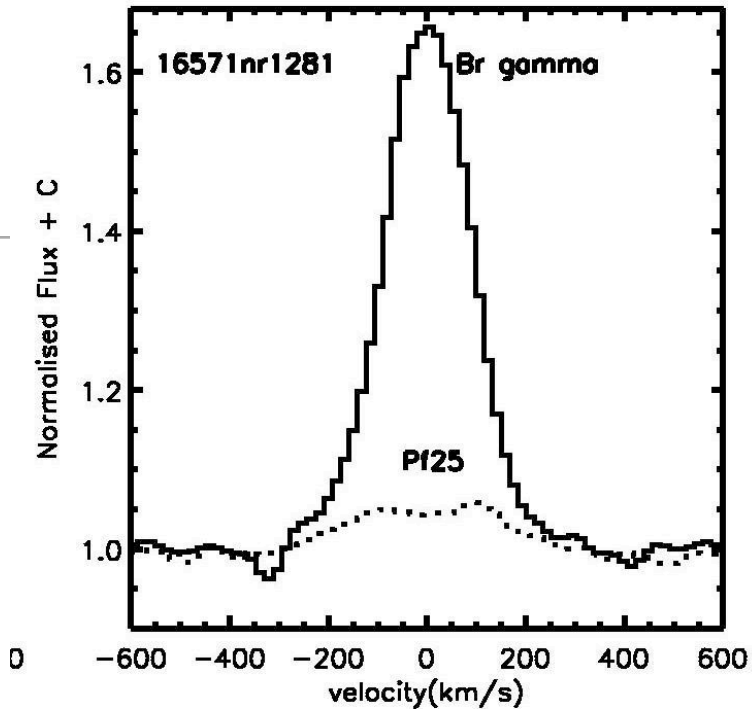
- Emission lines of ionized Hydrogen and Helium.
- Emission lines from neutral species (CO molecule)
- near- and mid Infrared Spectral Energy Distributions
- Molecular absorption spectroscopy.

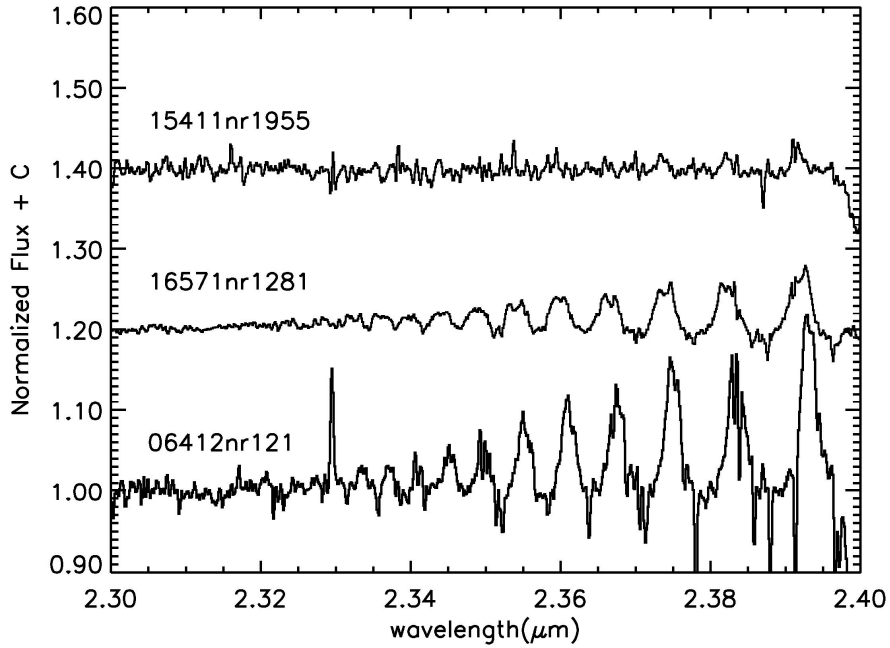
NOTE: the Near- and Mid-Infrared are “only” sensitive to material warmer than 200 - 300 K.

Few exceptions: Absorption against bright background sources (e.g. Chini et al 2004, Nuernberger et al, 2007)

Ionized emission (Hydrogen, HeI)

- Hydrogen lines spectrally resolved (FWHM = 100 - 200 km/s) or even double peaked (Bik et al 2006, Blum et al 2004,Kendall et al 2003)
- Where does the hydrogen emission come from?
  - Ionized surface layer of the disk?
  - Stellar/disk wind?





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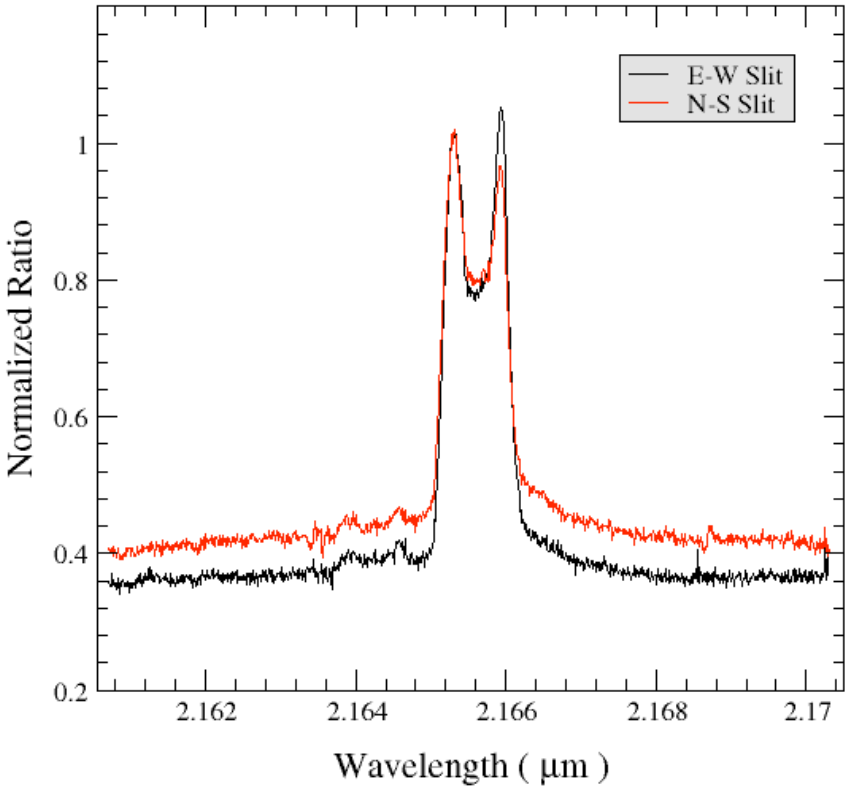
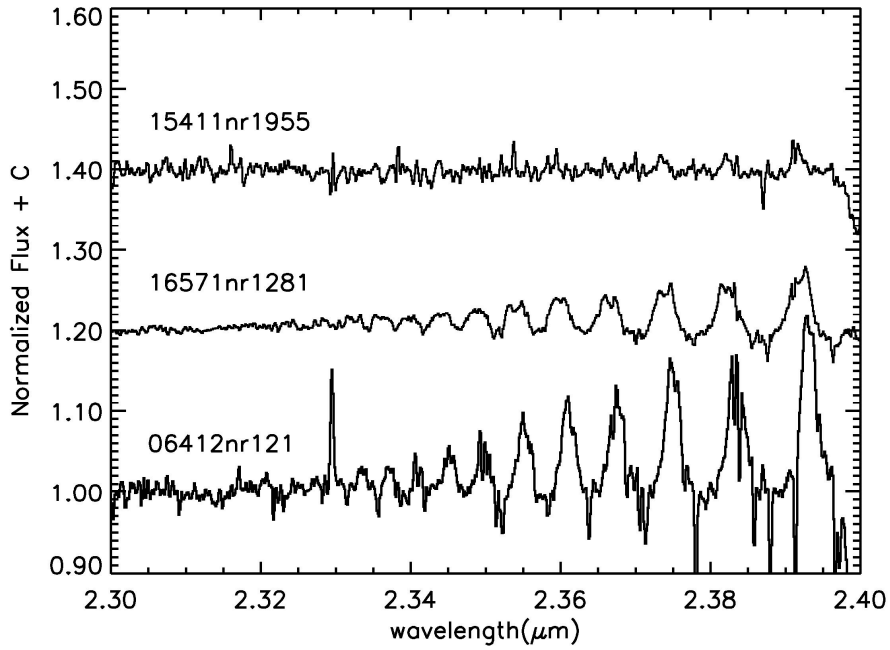
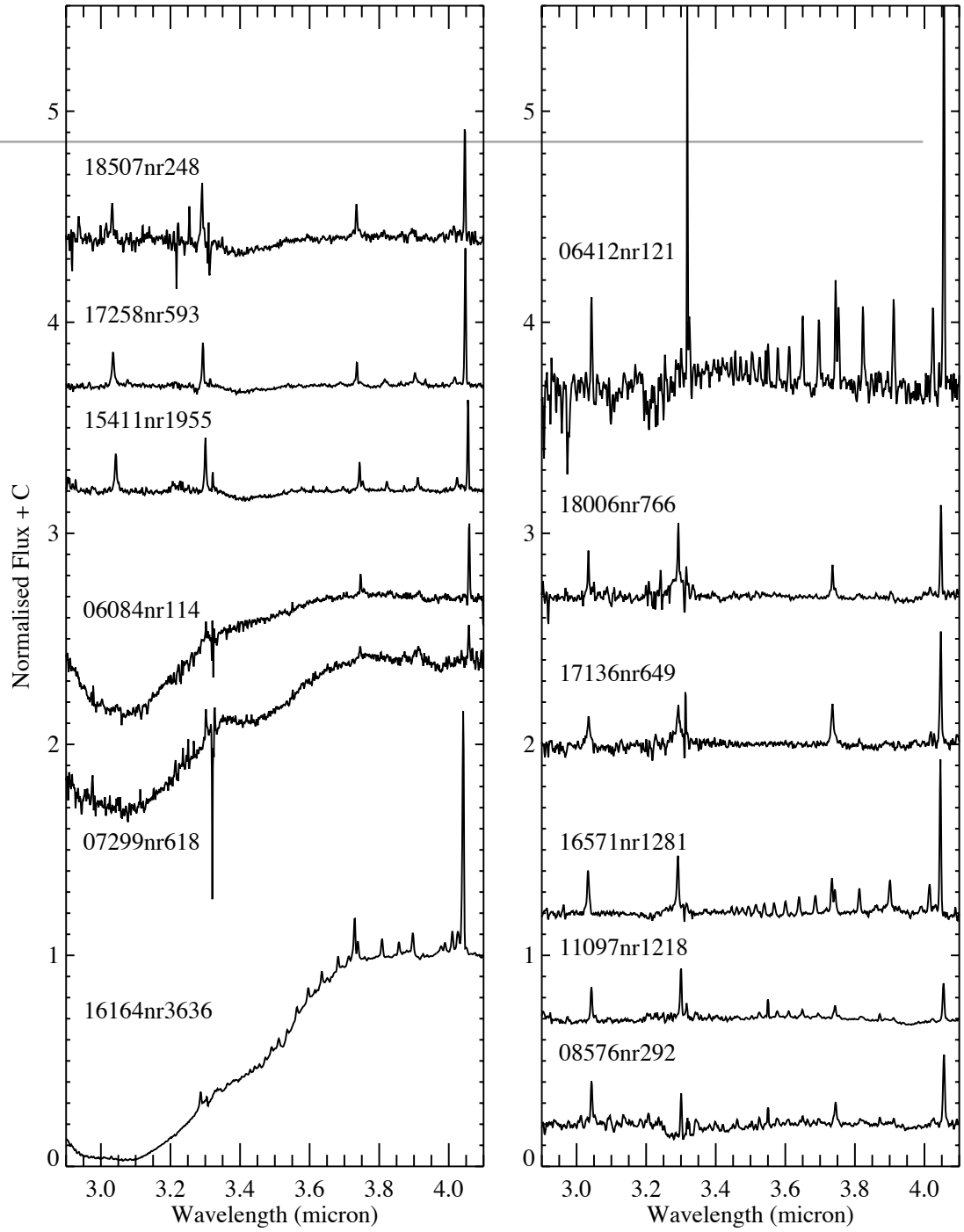




L-band Hydrogen lines

- Line ratio of hydrogen lines in massive YSOs show deviations from Case-B ratios.
- Their ratio can be used to trace the geometry of the ionized material.
- Line ratio massive stars with known circumstellar geometry: LBVs, B[e] and Be stars (Lenorzer et al, 2002)
- The Hydrogen in some massive YSOs seems to be fully coming from a disk surface, while others have a more optically thin contribution (disk-wind!).



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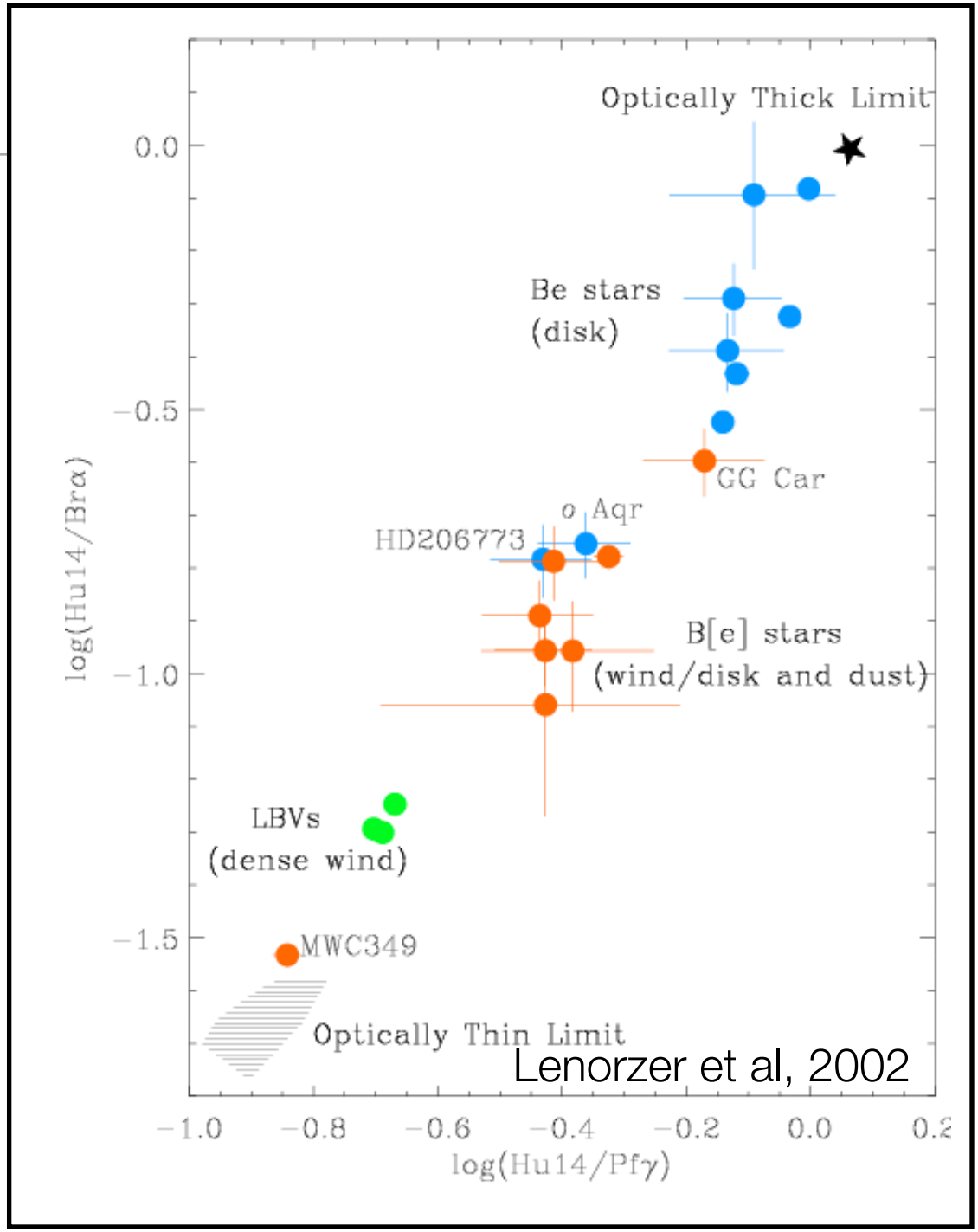

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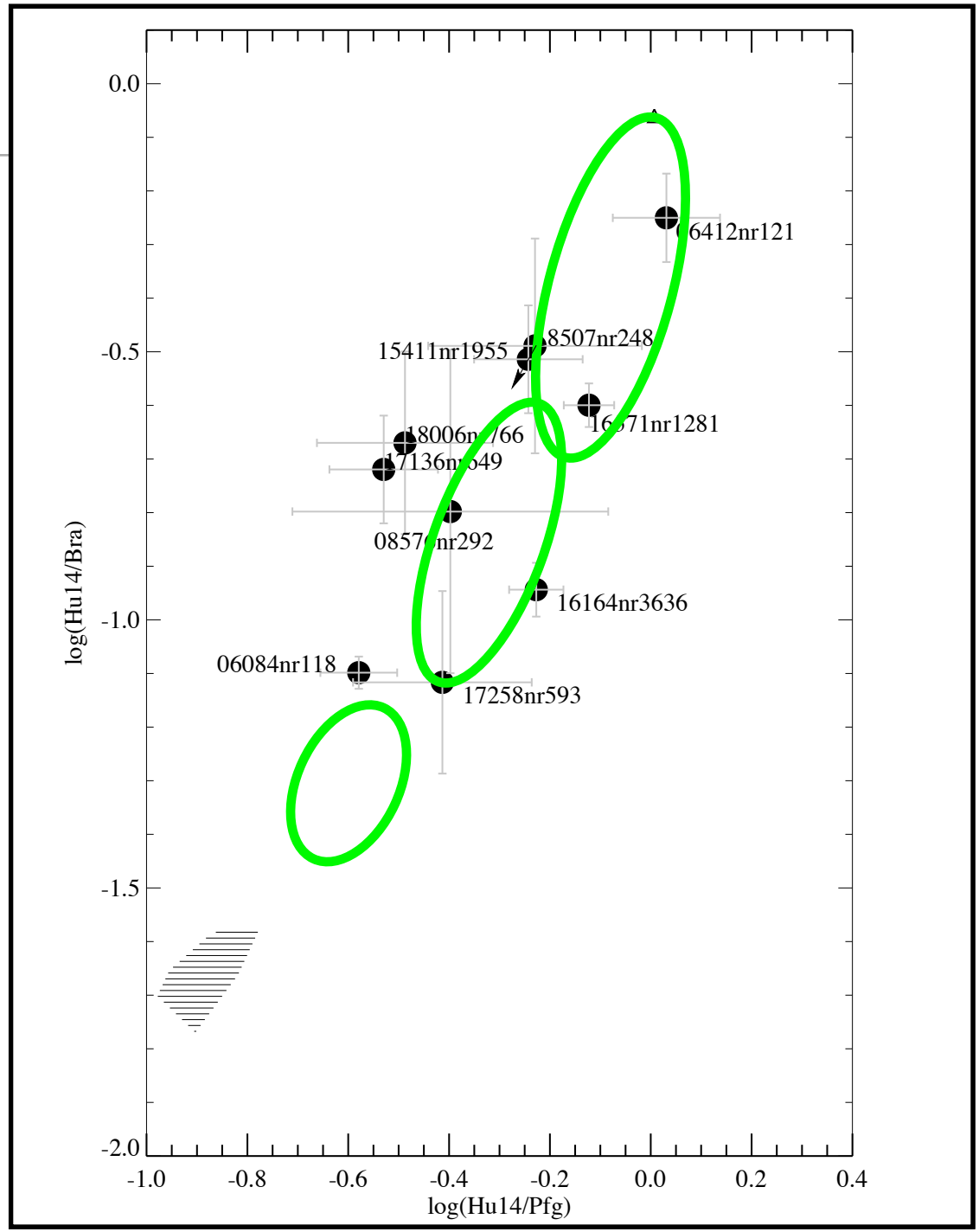
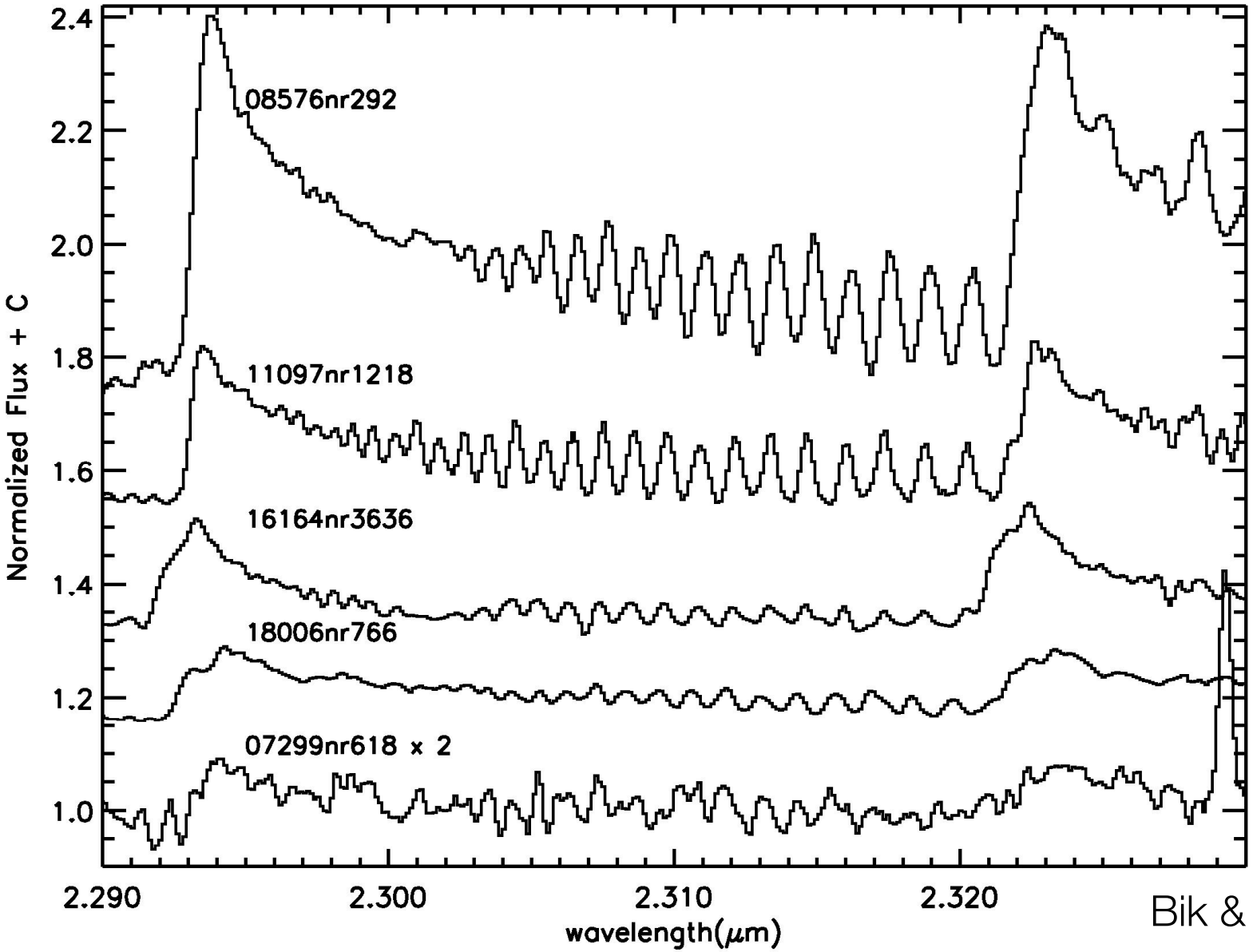


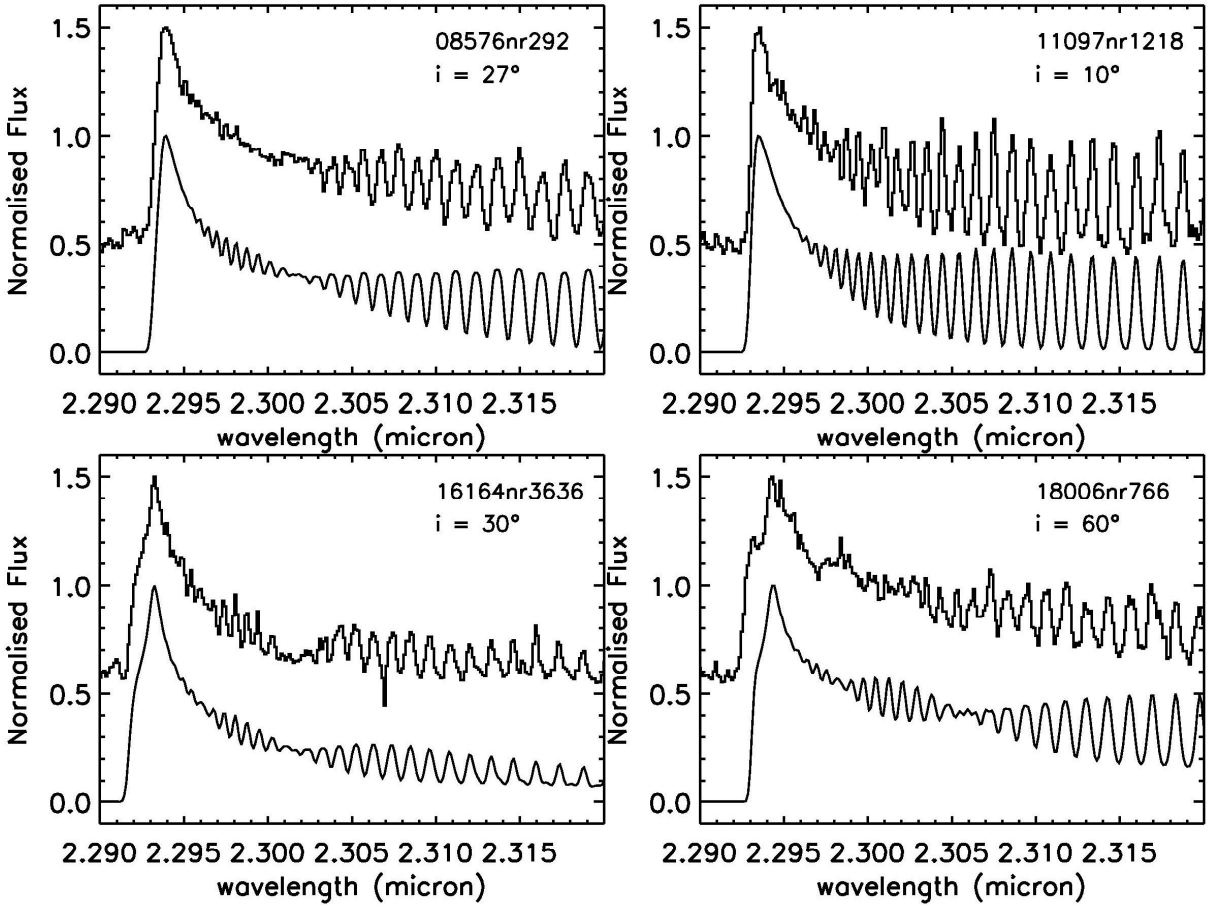
Emission lines from neutral species (CO)



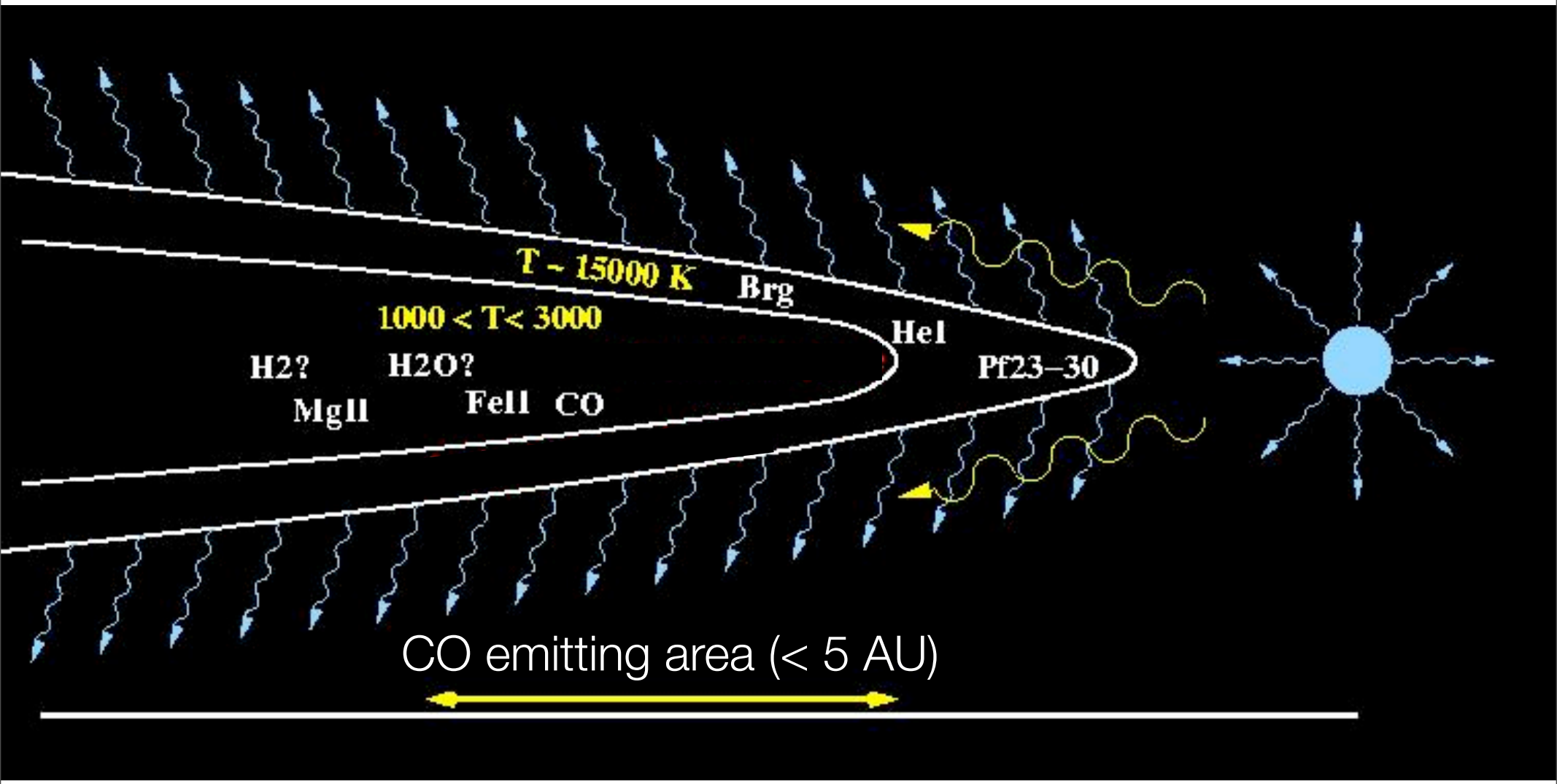
Bik & Thi, 2004

CO first-overtone emission

- CO first-overtone emission traces: dense neutral gas:
- n_H > 10^10 cm-3
- T_ex = 2000 - 5000 K
- Velocity information due to the bandhead.
- Keplerian disk:
  - CO is emitted in inner 5-10 AU of the central star.



Some order in the mess: where is which line emitted?



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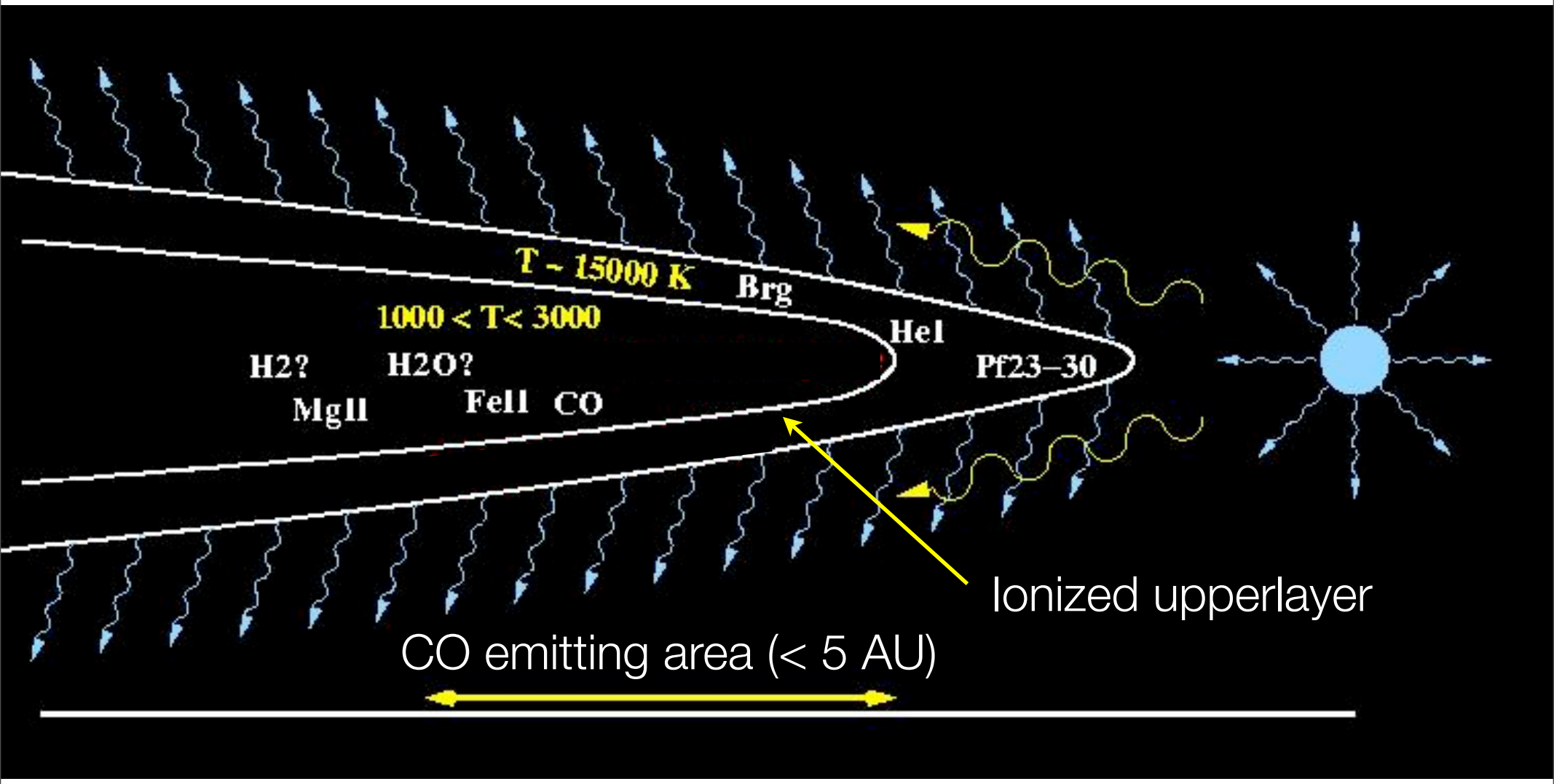

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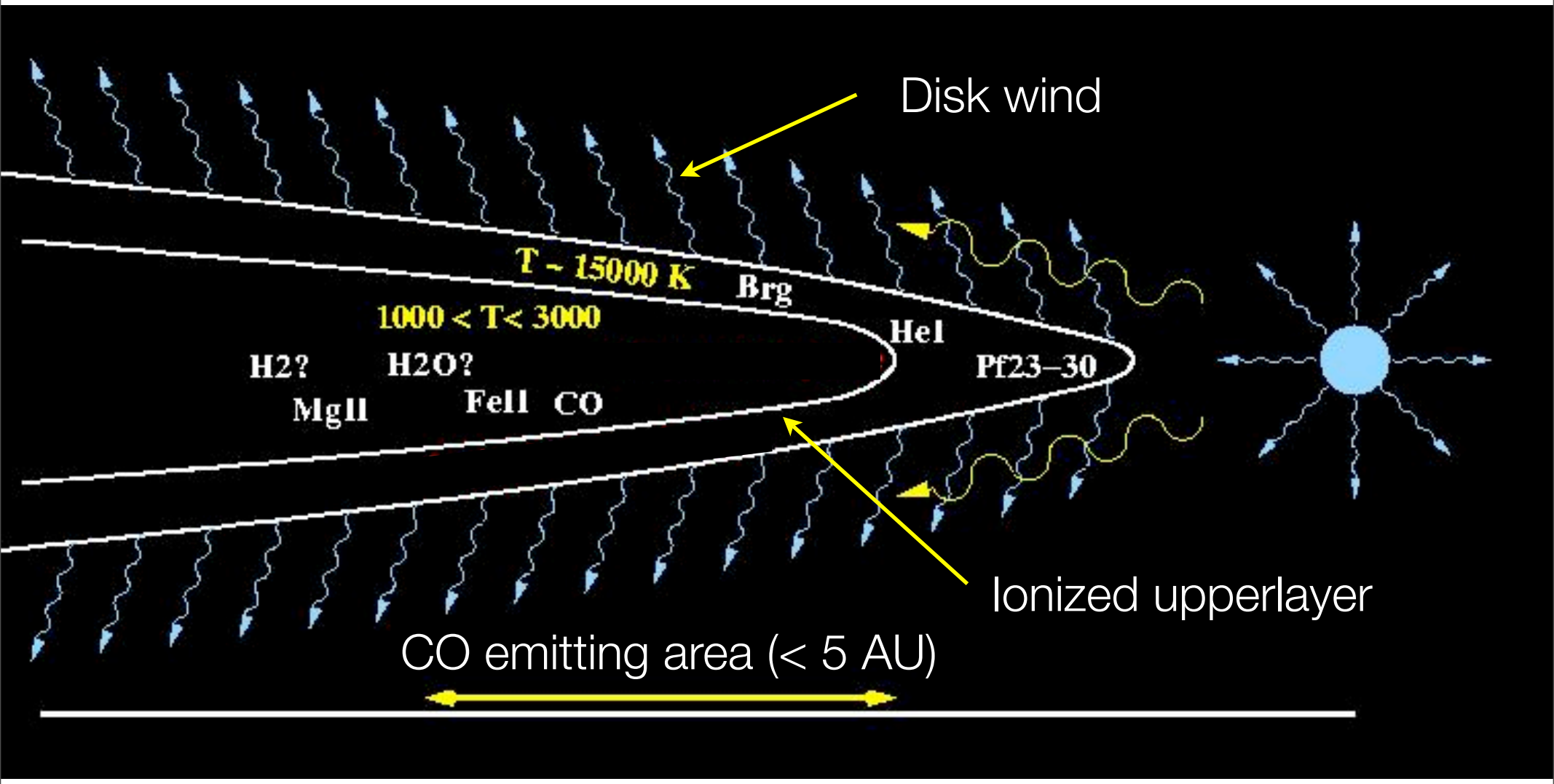

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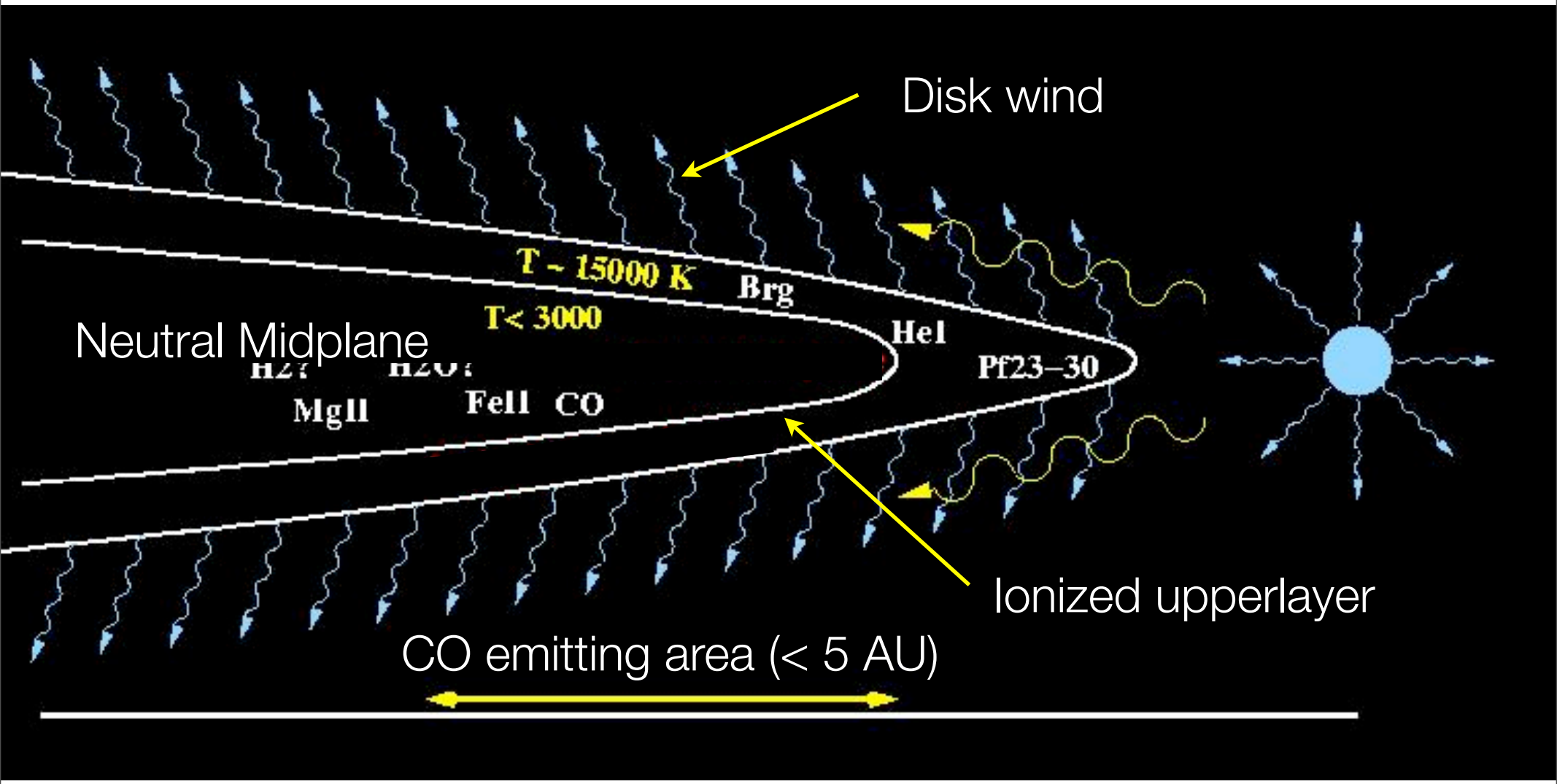
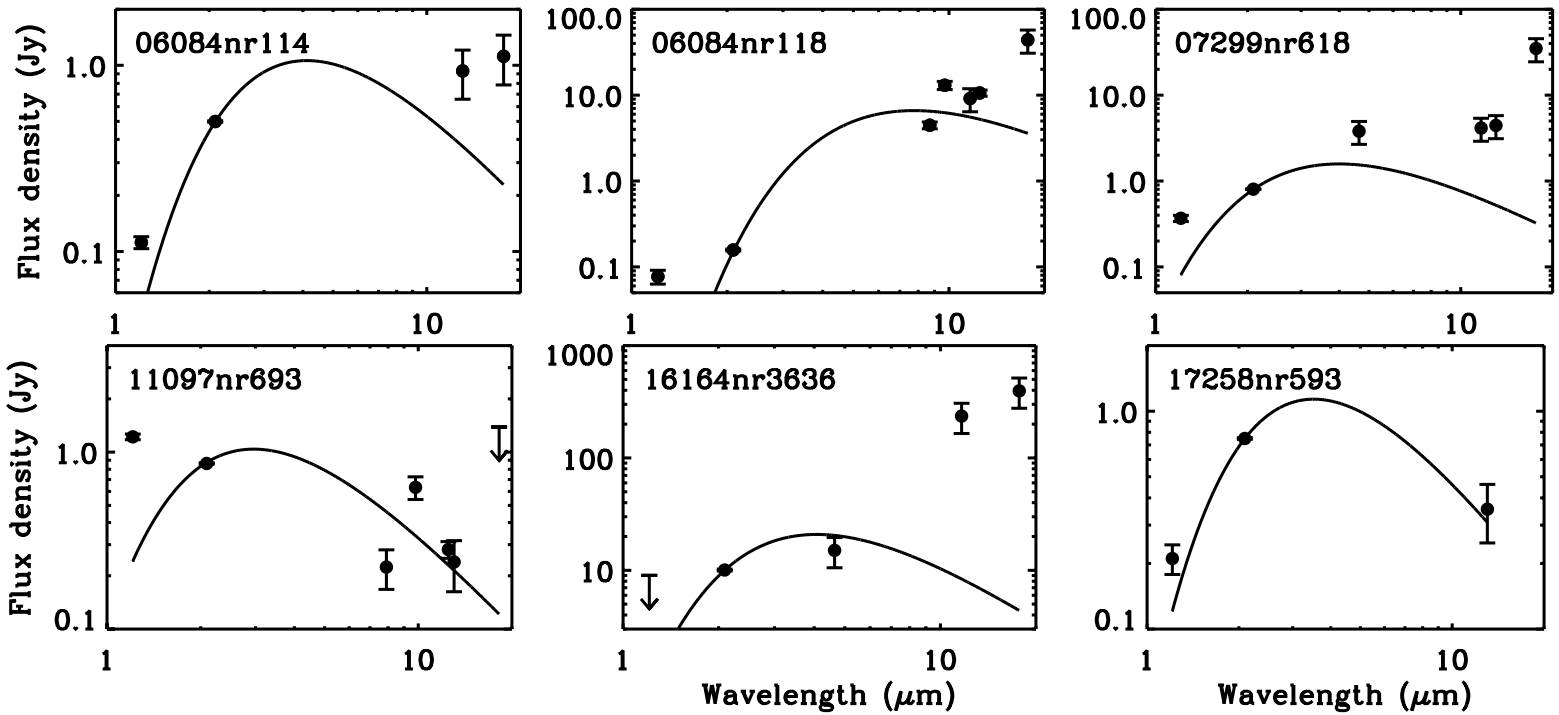


Spectral Energy Distributions

1 - 20 micron photometry from SOFI(NTT), TIMMI2(3.6m) and VISIR(VLT).

- Traces material further away from the central stars: Hot and warm (~200K) dust.
- Some sources show evidence for a second cold component in their SED (envelope?)
- Some objects are resolved at MIR wavelength; cold material is located further away from the central star.



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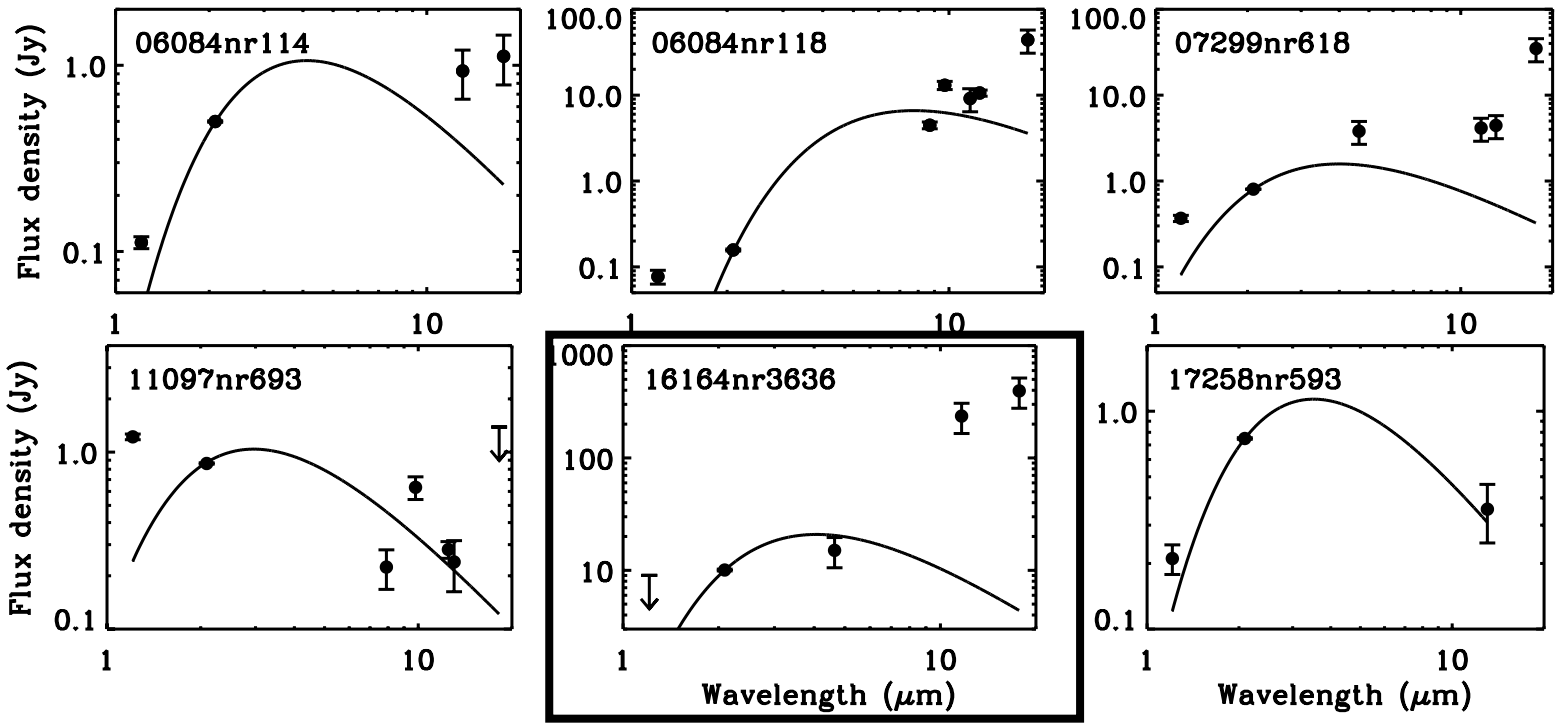
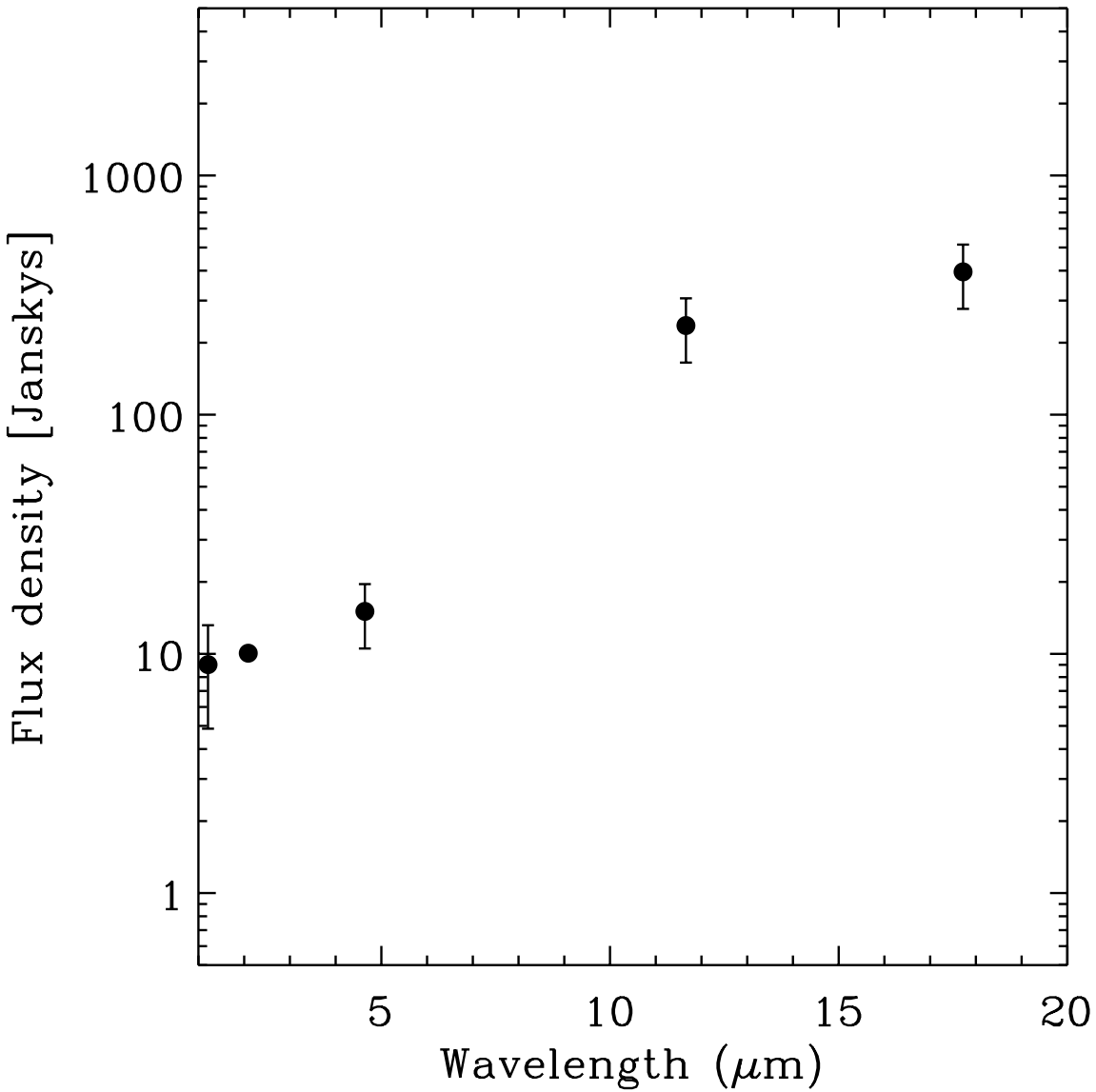


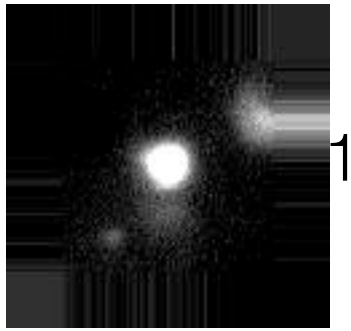
IRAS 16164-5046



2.1 micron

4.5 micron

11.9 micron



17.7 micron

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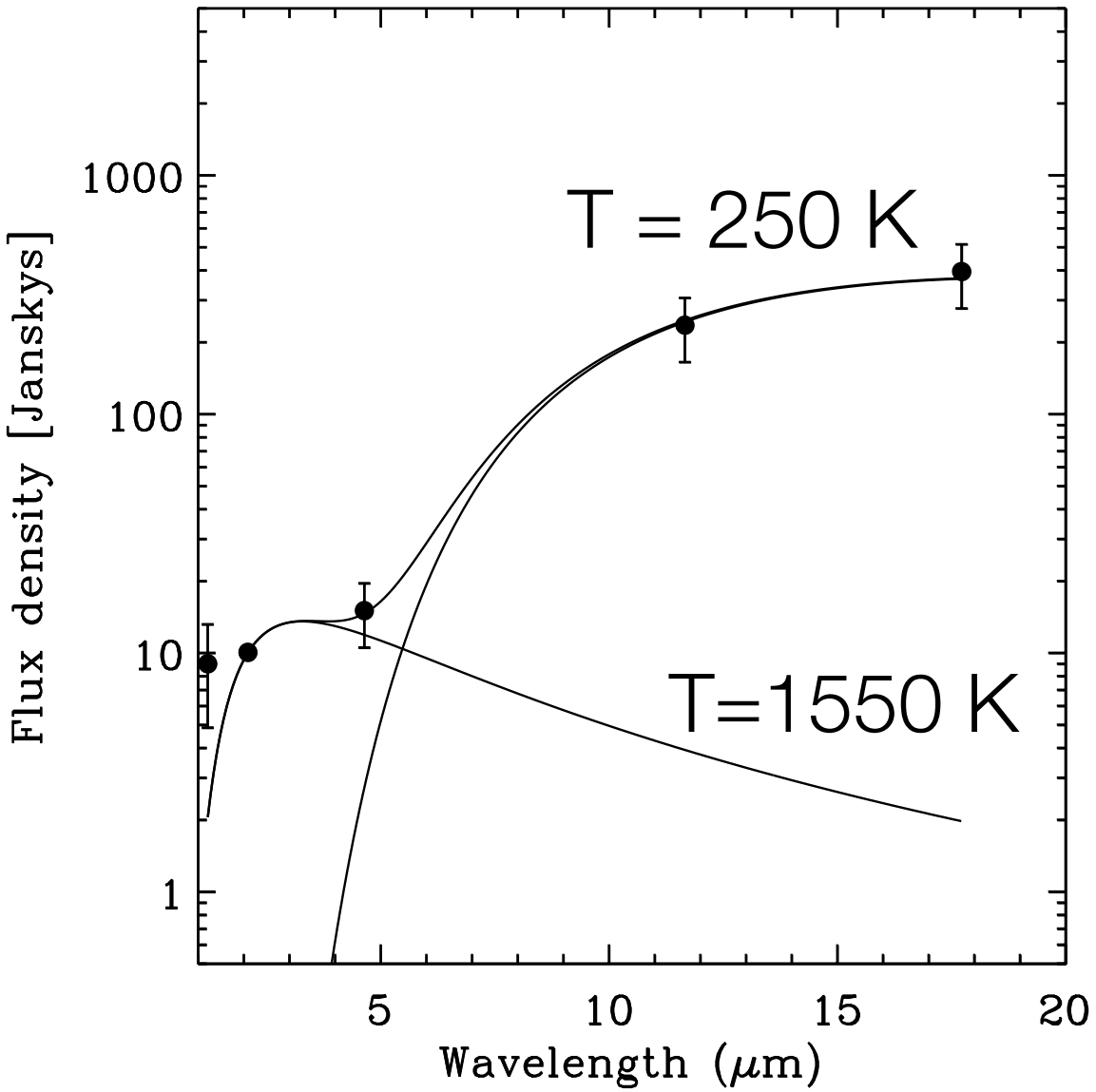

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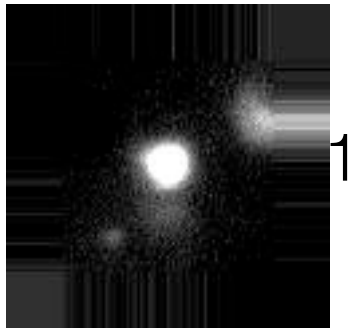

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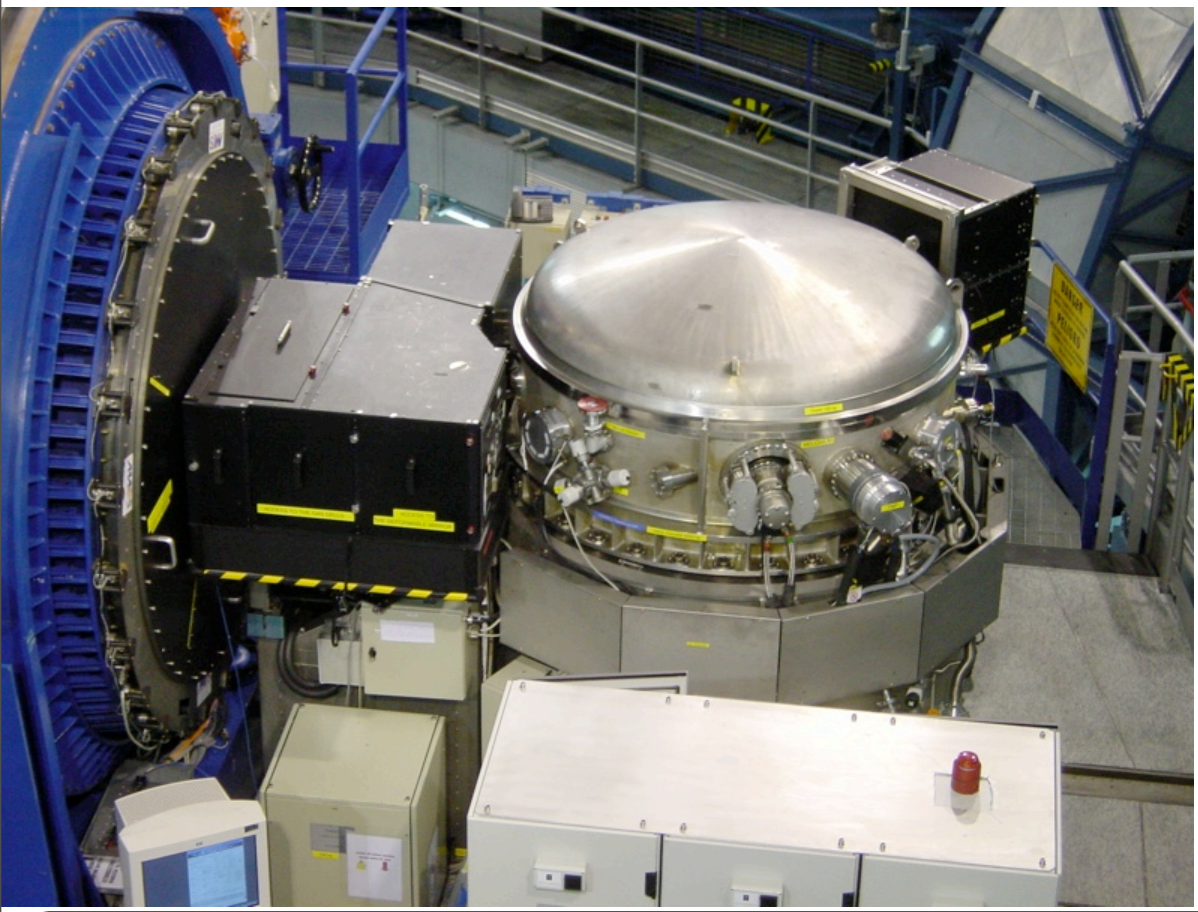
CO absorption spectroscopy with CRIRES



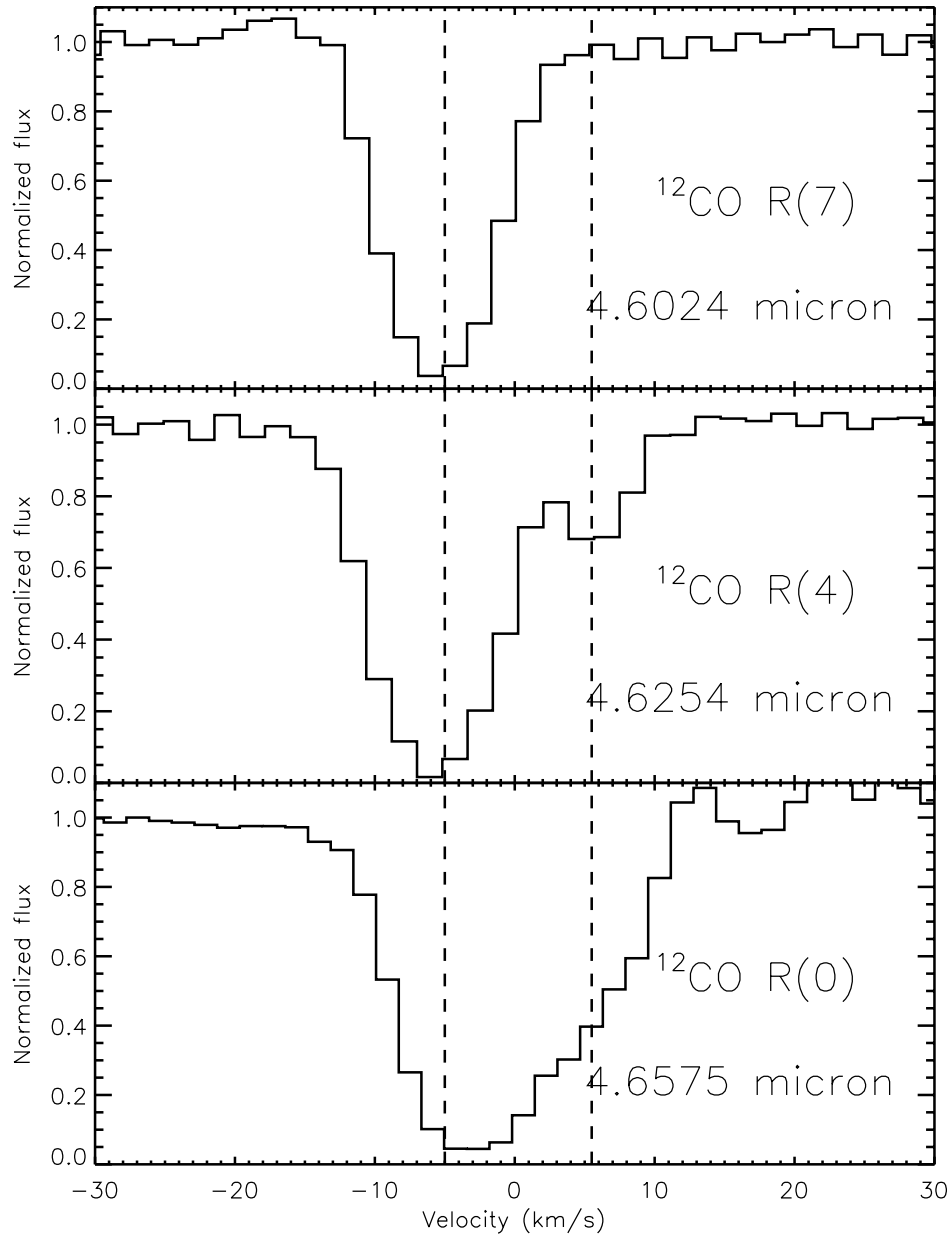
- CRIRES: AO fed infrared high-resolution long-slit spectrograph at the VLT
- JHKLM band
- resolving power up to 100,000 (3 km/s)
- Our data taken during Science Verification 3 with R=50,000 (6 km/s) in the M-band

ESO CRIRES Science verification team: J. Melnick, H.-U. Kaeufl, R. Siebenmorgen, A. Smette, M. Sterzik , F. Primas, H. Sana, A. Bik, A. Seifahrt, S. Uttenthaler and thanks to F. Kerber

Picture: Stefan Uttenthaler

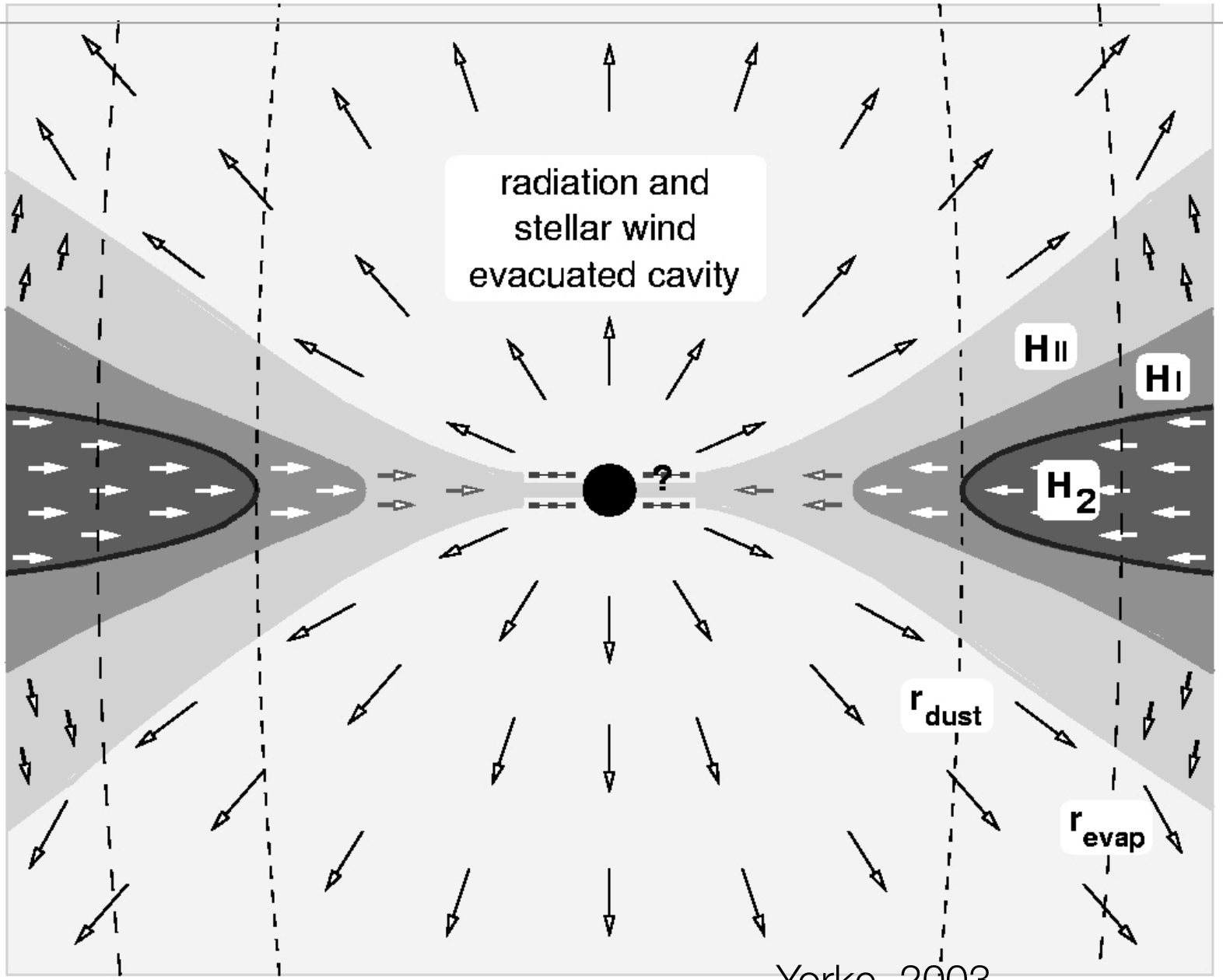
CO absorption spectroscopy with CRIRES of IRAS16164-5046

- Probes the outer cold envelopes around the massive Young Stellar Objects.
- Strong sub-mm source (Karnik et al, 2001).
- Two components detected in CO absorption
  - 1 Saturated component
  - 1 Very cold component.

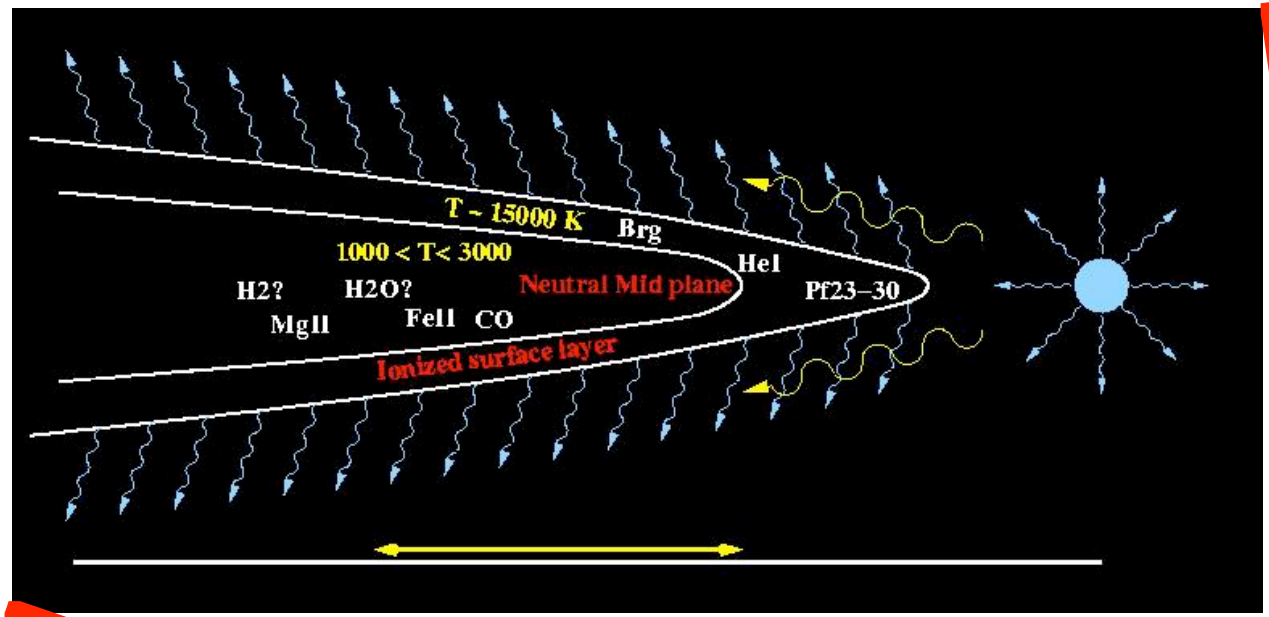


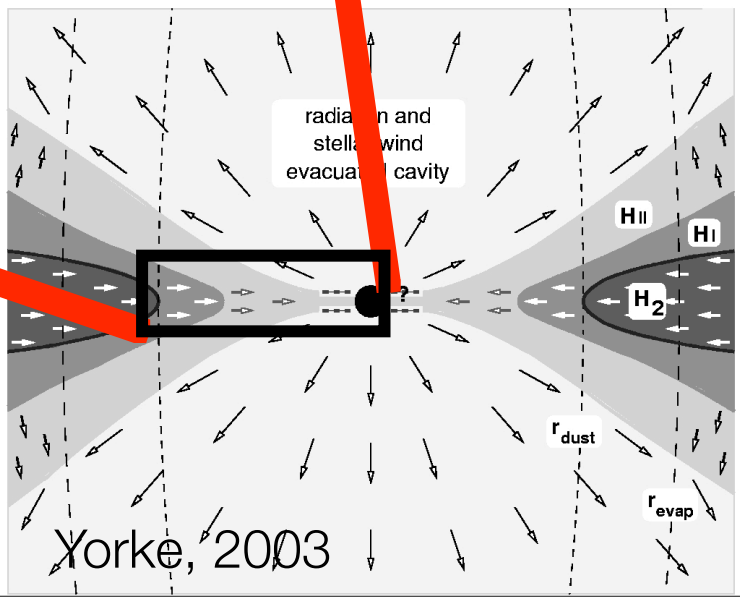
Evolutionary status

- Objects are characterized by a near- and mid-Infrared excess.
- Some of them show evidence for a hot circumstellar disk
- A few objects show evidence for a warm/cold component further away from the star.
- Apart from a few they do NOT have a (sub) mm counter part; the outer layers of the disk is photo-evaporated. (Hollenbach 1994)
- We are looking at the massive stars just after they have formed and did not manage jet to clear their circumstellar environment.


radiation and
stellar wind
evacuated cavity
HII
HI
H2
?
rdust
revap

Yorke, 2003


T ~ 15000 K
Brg
1000 < T< 3000
HeI
H2?
H2O?
Neutral Mid plane
Pf23–30
MgII
FeII
CO
Ionized surface layer


radiation and
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HII
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Yorke, 2003

The most massive YSO?

- O5.5V spectral type with a very thin disk.

- See also P57 by Annique Lenorzer

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