AMBER observations of circumstellar disks around Herbig AeBe stars

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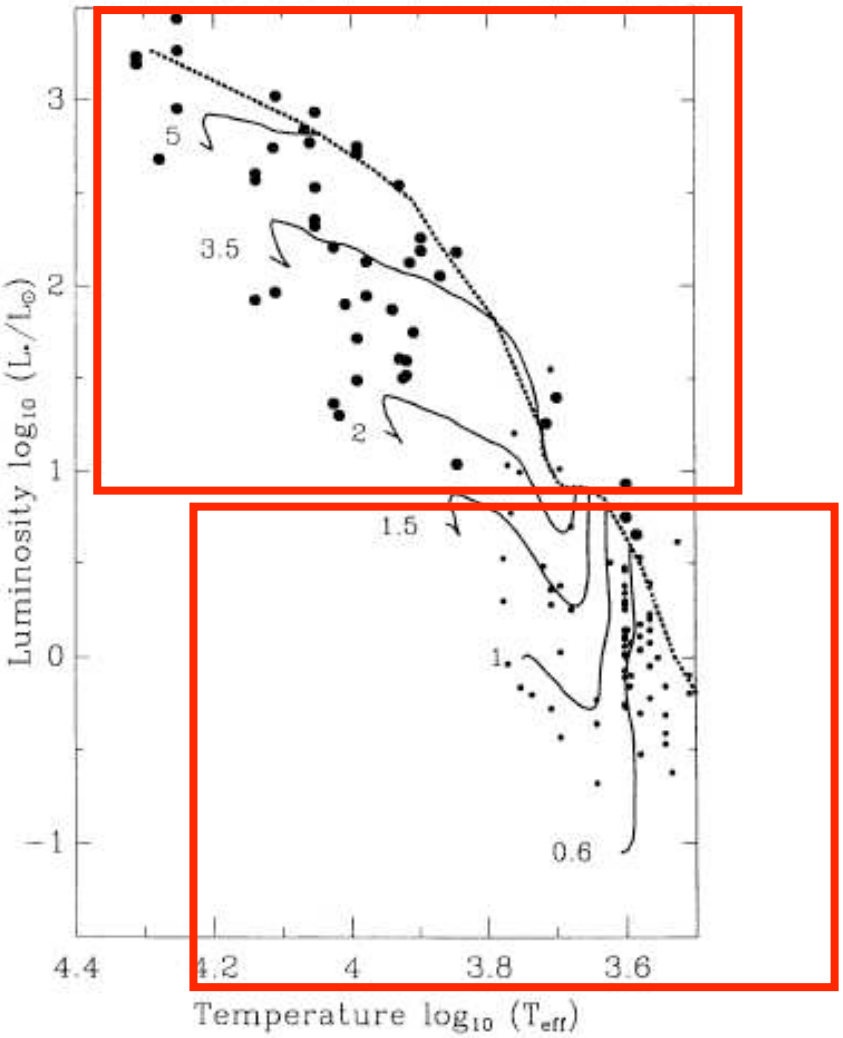
The Herbig AeBe stars

Pre-main sequence stars of intermediate mass (2-10 $M_\odot$)

Herbig AeBe stars



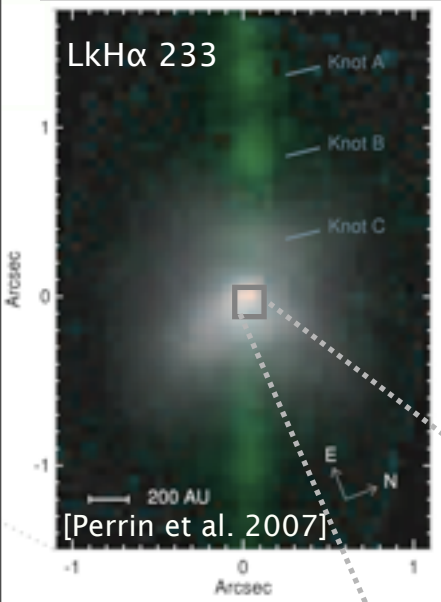
(Palla & Stahler 1993)

- Emission lines in their spectra (Ha...)
- Lying in obscured regions
- Spectral types B-A
- Illuminating close-by reflection nebulae

T Tauri stars

No pms phase for more massive stars in a standard accretion scenario

The close environment

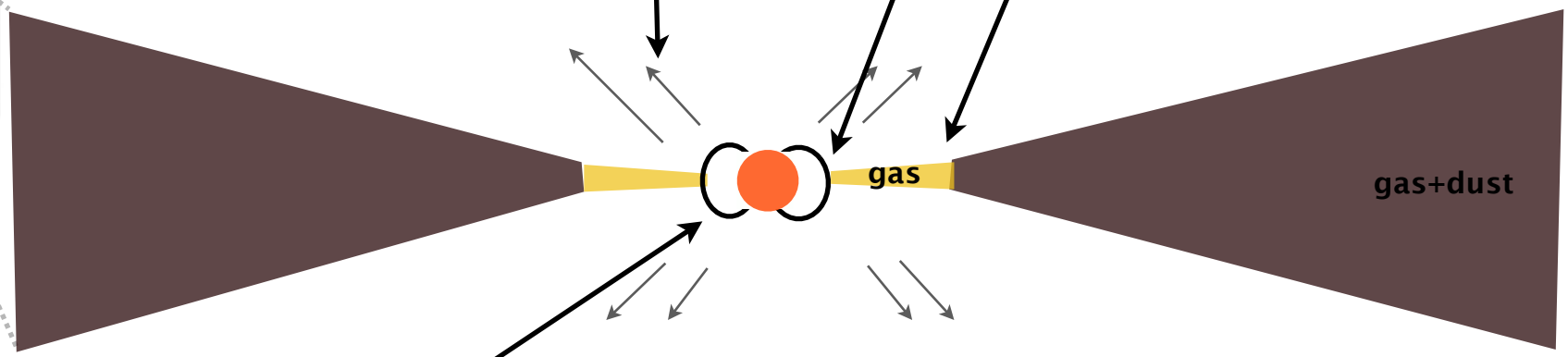


In search for *spatially resolved* constraints on:

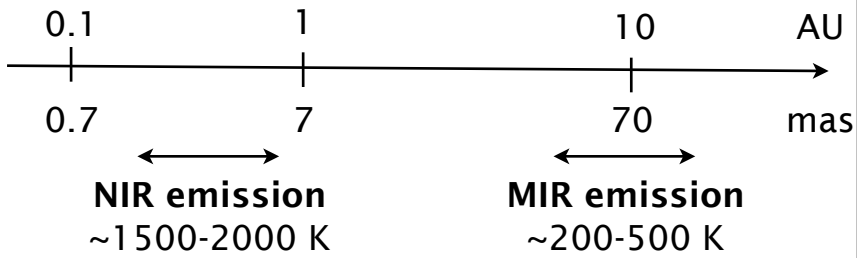
the star-disk interactions

the jet launching and collimation zone

the structure of the innermost disk



the mass accretion process



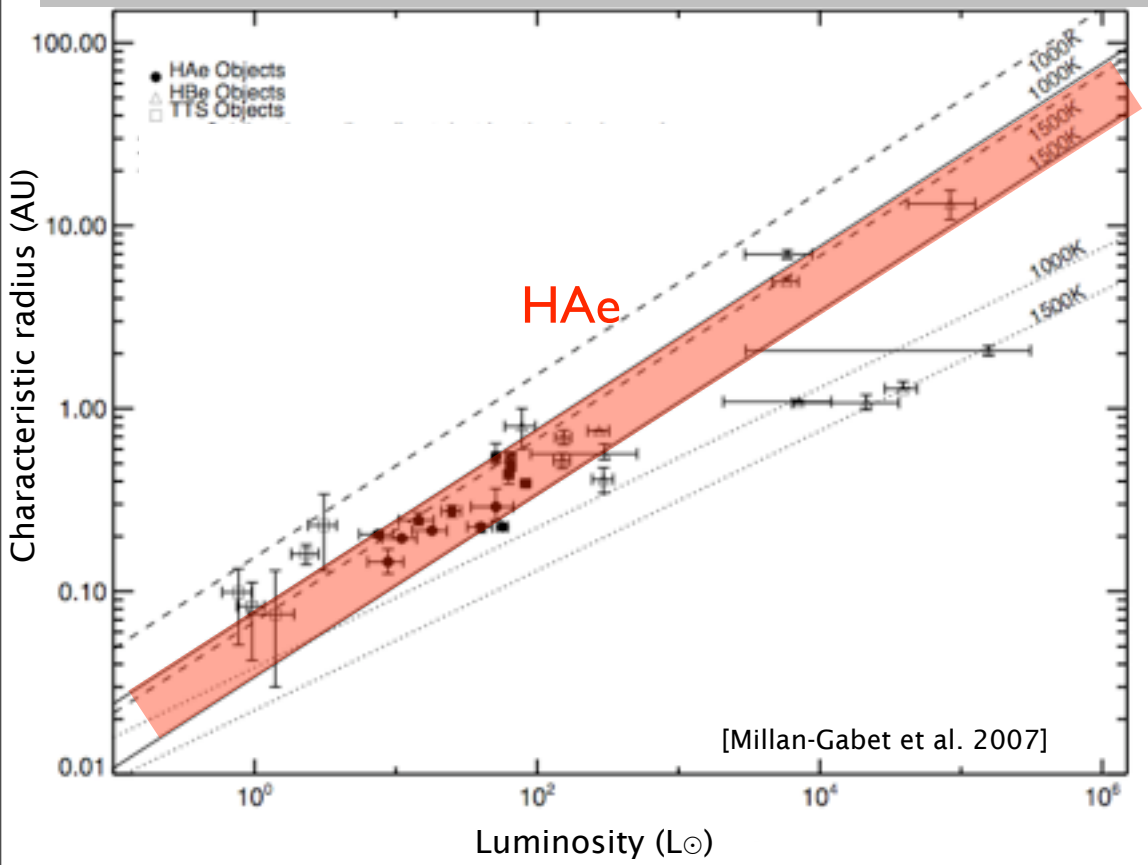
… and planet formation!

Sub-AU scale studies (mas resolution) require **near-infrared interferometry**

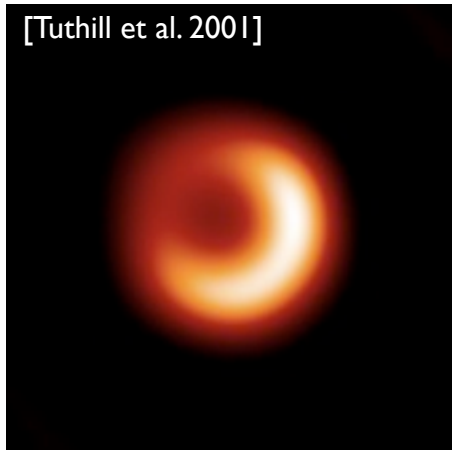
$V^2 \Leftrightarrow$ characteristic size

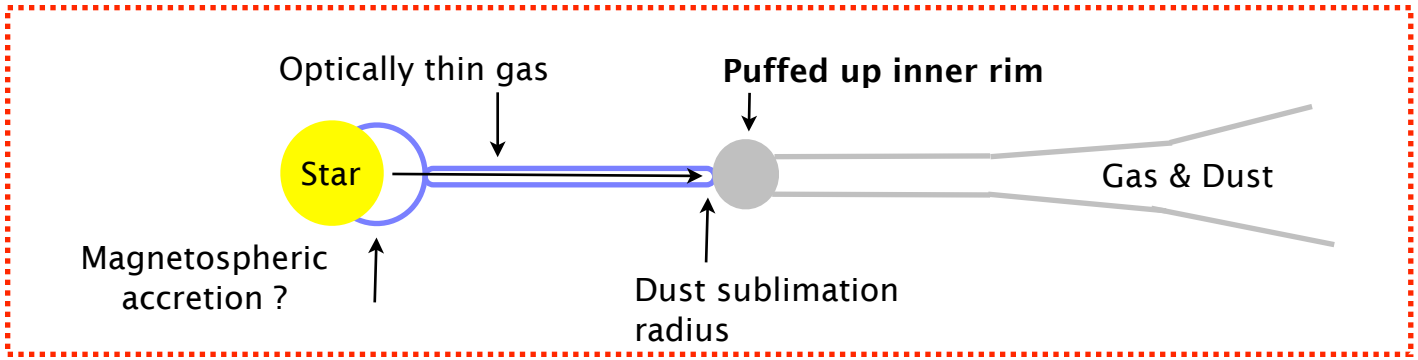
CP$\Leftrightarrow$ asymmetry

NIR size-luminosity relation



$R_{NIR} \propto L_*^{1/2} \propto R_{sub}$





The NIR flux is due to direct thermal emission from hot dust located at the edge of the disk.

[Natta et al. 2001, Dullemond et al. 2001, Isella & Natta 2005, Tannirkulam et al. 2005]

Physical conditions?

↓

Spectro-interferometry
HD163296 & HD100546

INTERFEROMETRY IN A NUTSHELL

Visibility: a measure of source size

V=1 source unresolved ($\lambda/B >> \theta$)

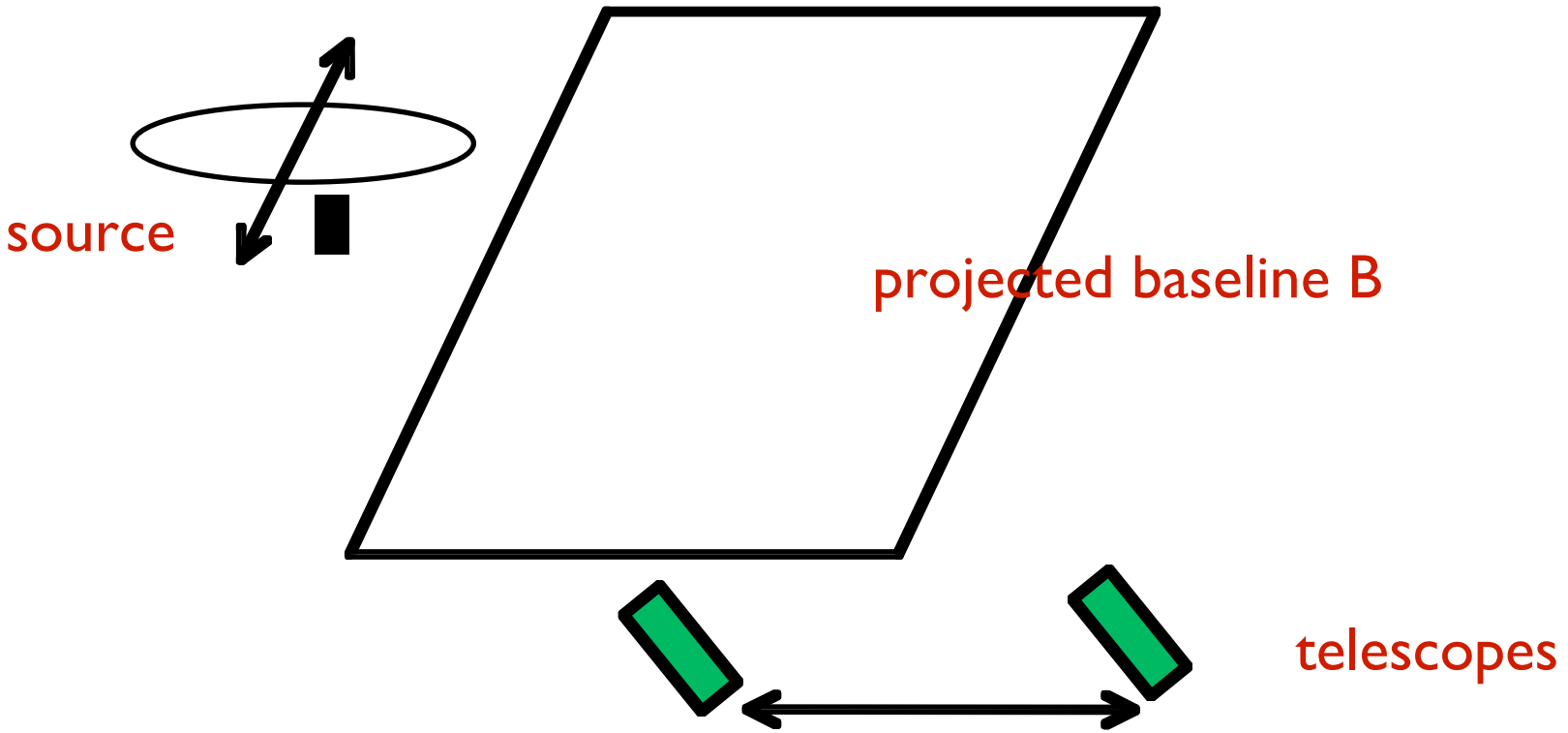
V=0 source resolved out ($\lambda/B << \theta$)

Phase: a measure of source position

(unfortunately not measured by AMBER, but)

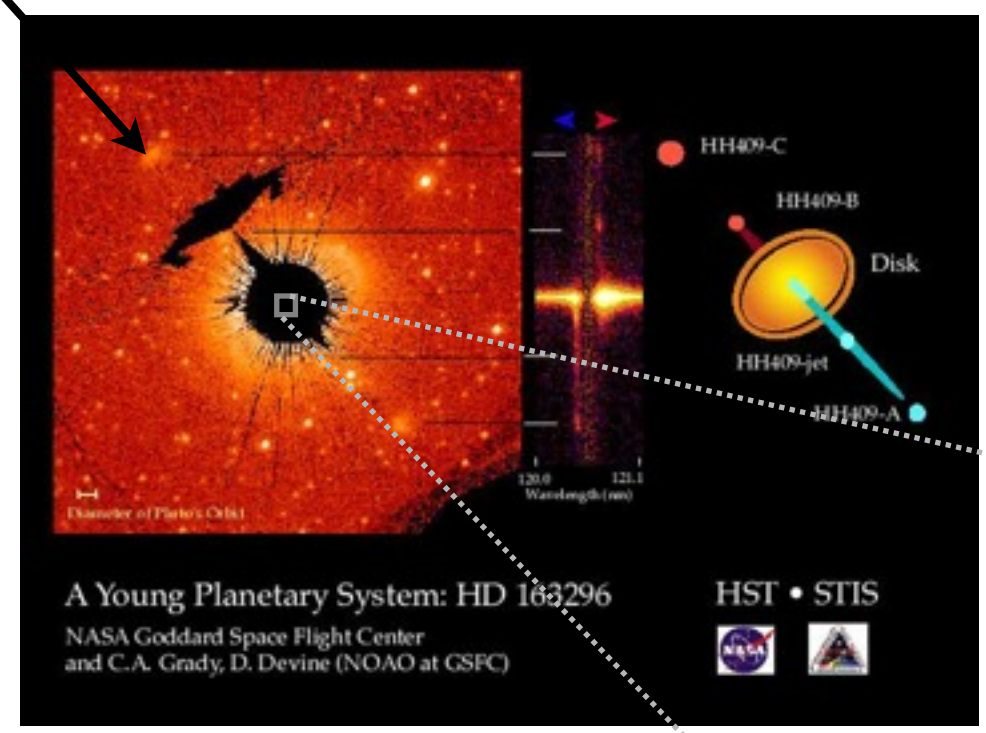
Closure phase: a measure of source symmetry

CP=0 deg source is symmetric



What is the origin of the NIR excess in HD163296 ?

jet

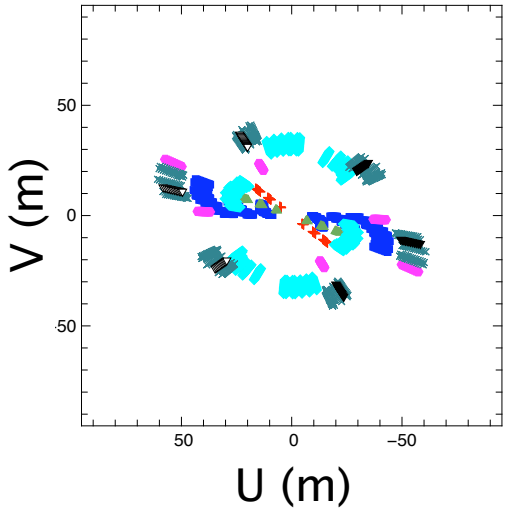


[Grady et al. 2005]

Herbig Ae star A1V, 2-4 M_{yrs}
T_{eff}~9250K, 2.3$M_\odot$
with a large scale keplerian disk and a jet
Accretion rate (Brγ): 8.10^{-8} $M_\odot$/yr

[Grady et al. 2000,2005; Devine et al. 2000; Isella et al. 2007]

Spectro-interferometry with AMBER/VLTI



5 VLTI configurations
H & K bands R~35
~1500 V^2 and 450 CP

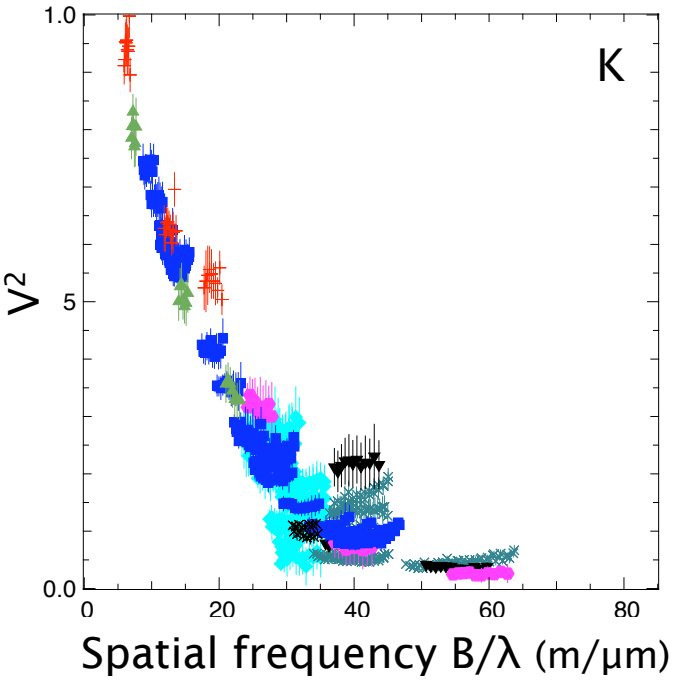
The NIR interferometric observations

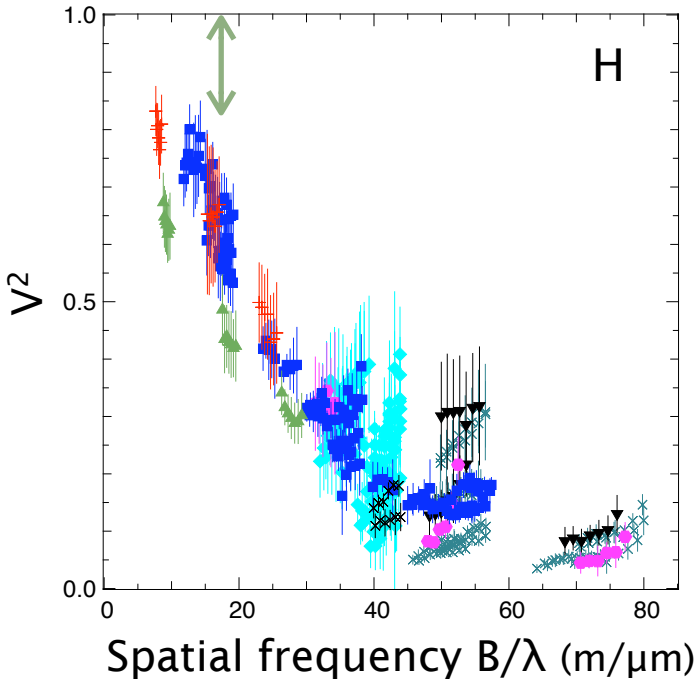
The *entire* circumstellar matter emitting in the NIR is resolved at resolutions of 3 to 12 mas.

Characteristic sizes increase with wavelength and change with baseline orientation.

Smooth V^2 -variation with spatial frequency.

Drop of V^2 and CP=0 at small spatial frequencies.



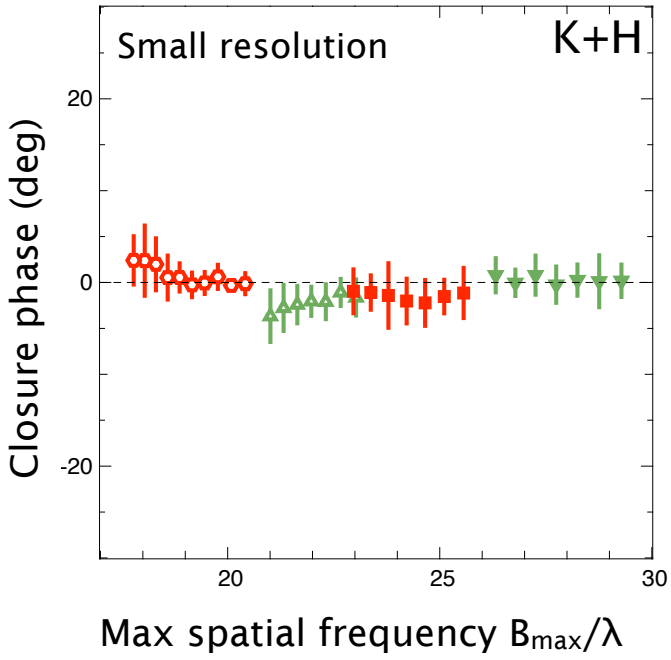


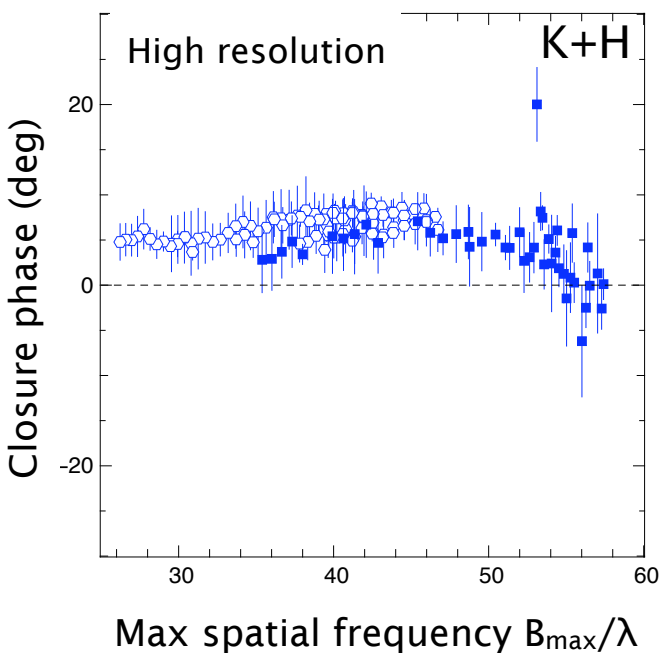
i~48° & PA~135° consistent with outer disk observations.

Is there an extended halo?

No strong discontinuity in the brightness distribution.

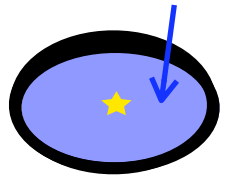
Rim alone





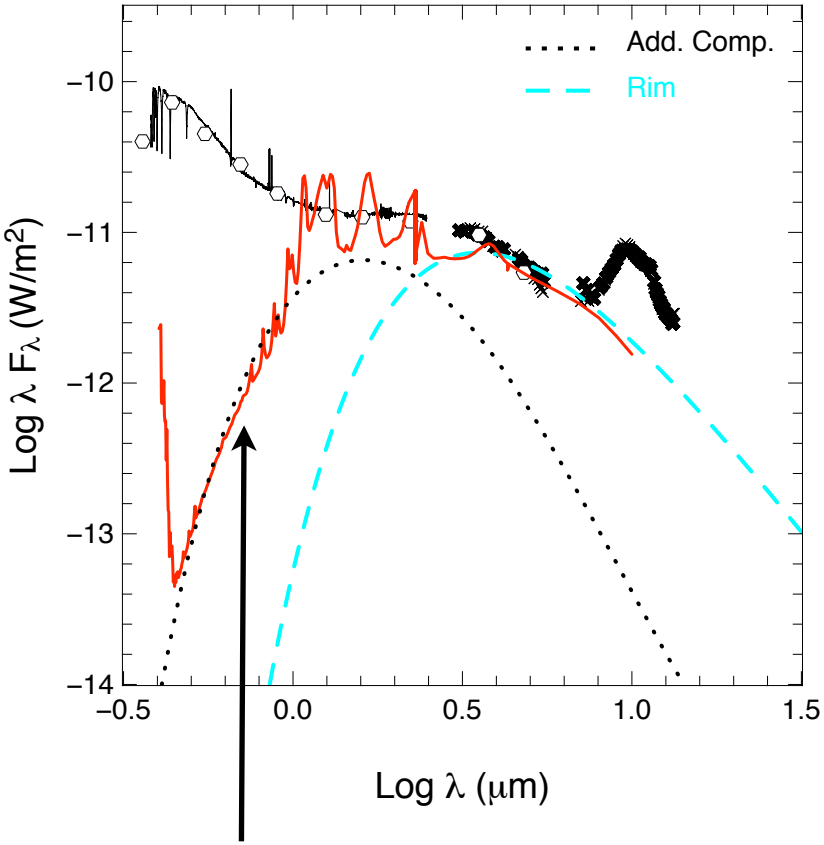
A gaseous inner disk?

Model: the star + a rim at the silicate sublimation radius [Isella & Natta 2005] + **an additional component**



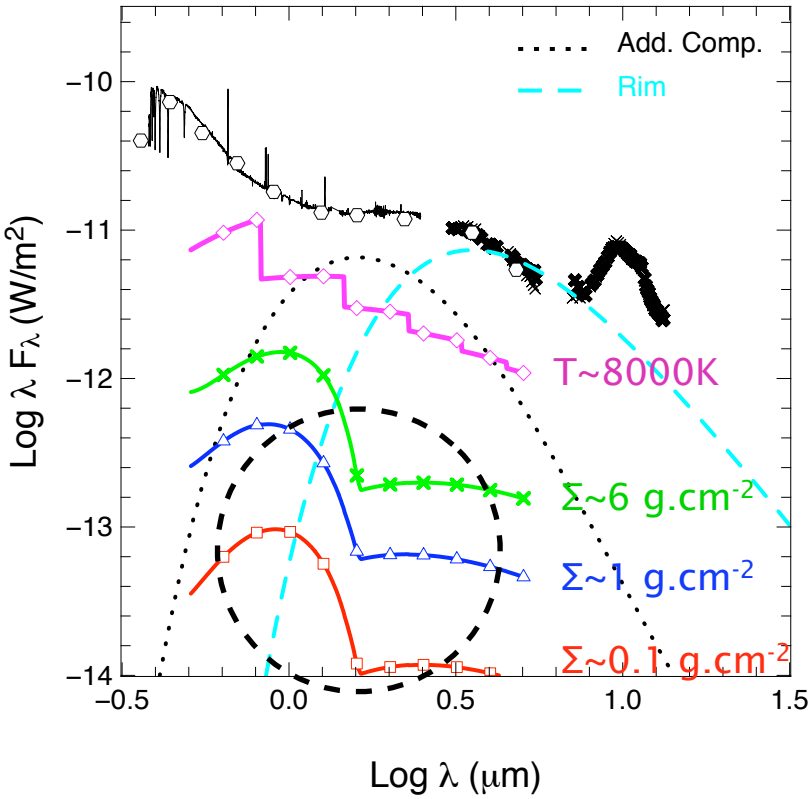
Gas ?

[Tannirkulam et al. 2008;
Eisner et al. 2007; Isella et al. 2007]



LTE gas in accretion disk: no molecular lines!

[Sitko et al. 2008; Muzerolle et al. 2004]



Thin atomic or ionized non-LTE gas
(disk upper layers)

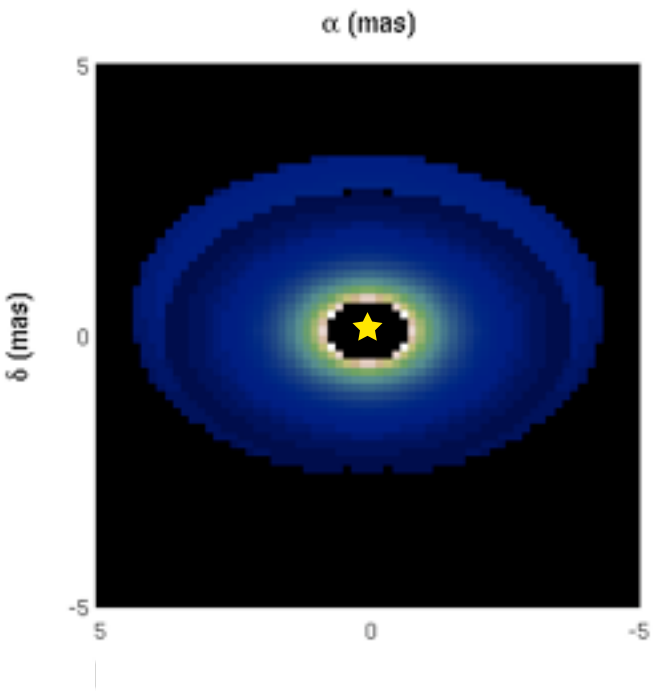
[Ferland et al. 1998; CLOUDY]

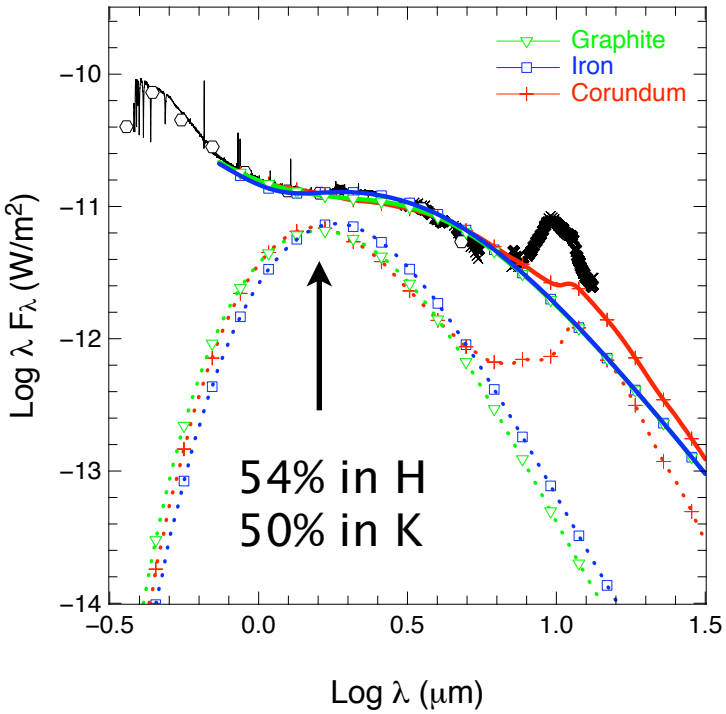
unlikely to produce a strong NIR continuum...

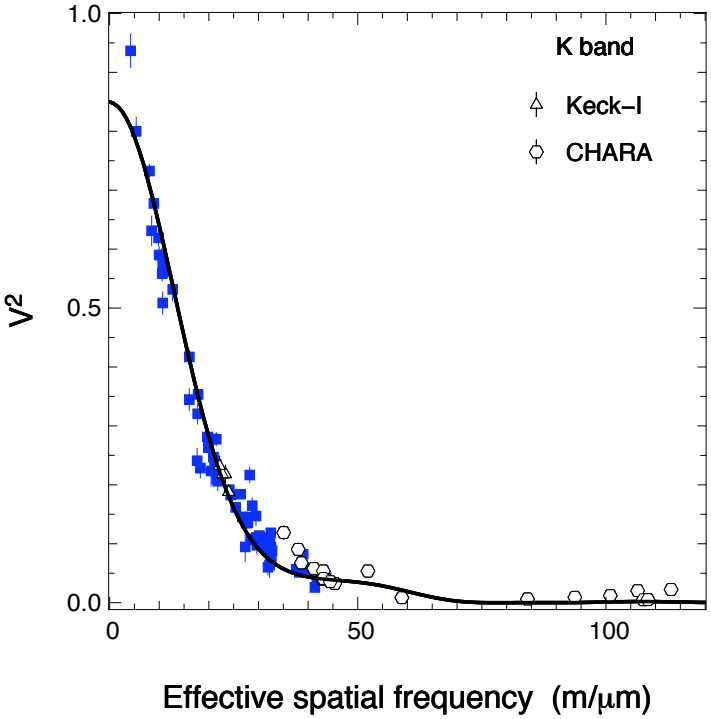
A dusty inner disk?

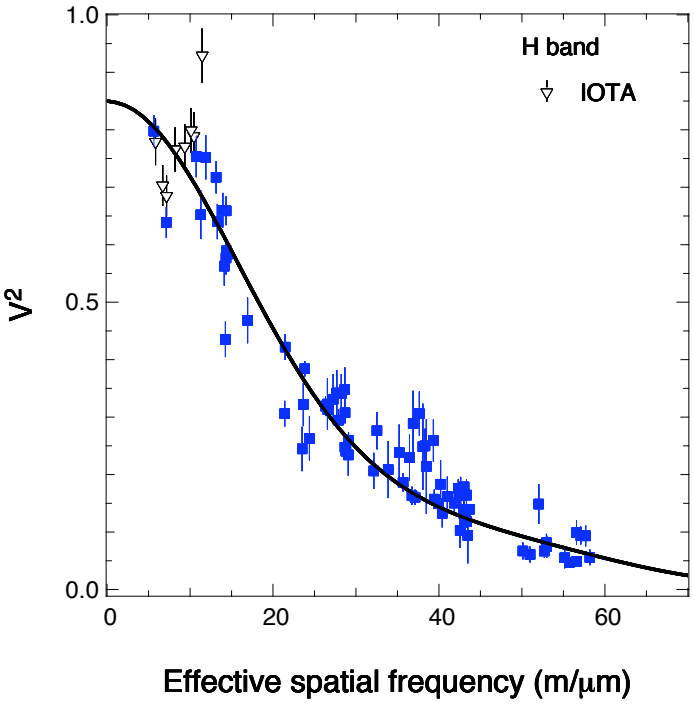
Refractory grains in a low density region inside the rim?

Iron, corundum, graphite dust grains in an **optically thin** inner disk ($\tau_{K,0.1AU}$~0.2) from **0.1 to ~0.45 AU** - where a partially shielded silicate rim forms.







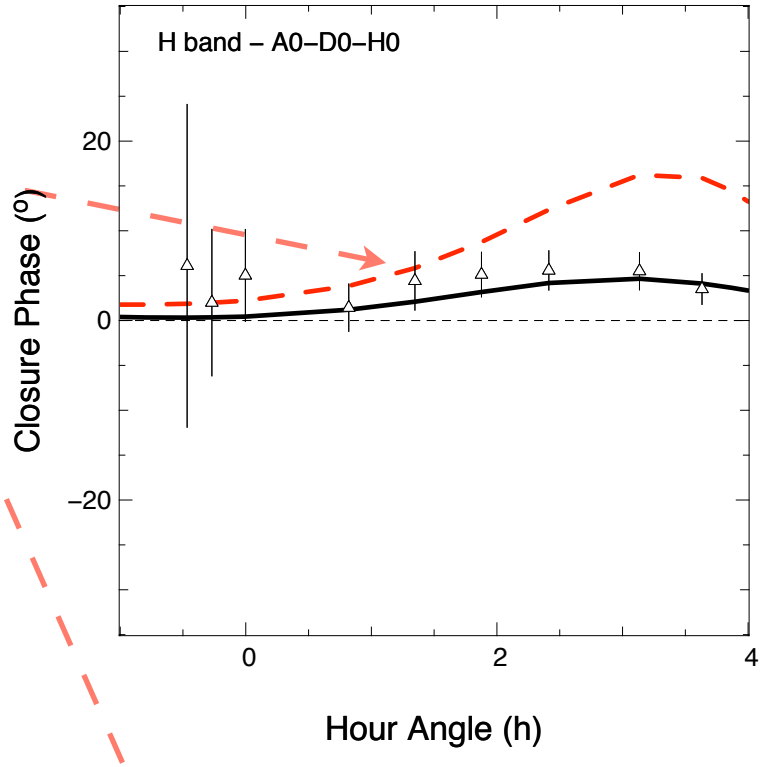


[Pollack et al. 1994; Koike et al. 1995; Begemann et al. 1997; Laor&Draine 1993]

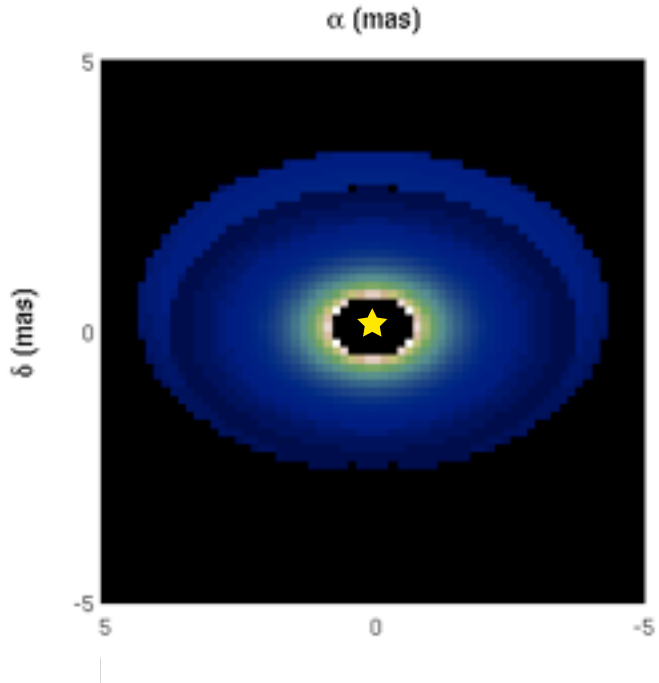
A dusty inner disk?

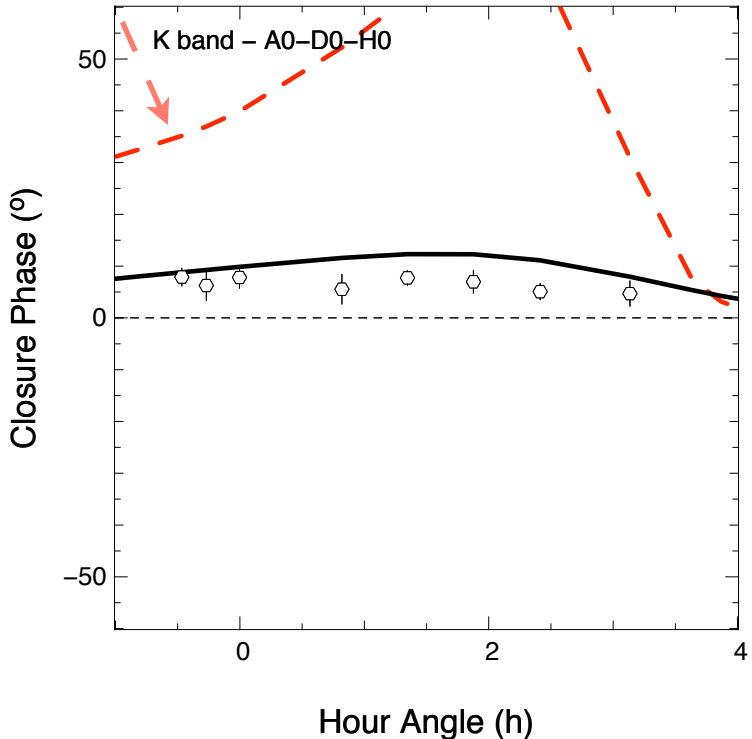
Refractory grains in a low density region inside the rim?

rim alone



The star+rim+refractory grains model successfully reproduces the level of asymmetry





Conclusions

Spectro-interferometry is a powerful tool that provides unique constraints on the disk morphology and physical conditions at play.

SED, NIR visibilities and closure phases are well reproduced using a model of a star, a silicate rim, and a low density region dominated by **refractory grains inside the rim.**

A puffed-up inner rim **alone** is not sufficient to reproduce the observations... and models should be refined.

The inner zone is tenuous ($M_{iron} \sim 10^{-5}\ M_{\oplus}$), partially cleared inner region in a massive disk: common in HAe? Evidence for disk evolution?

The nature of these grains is uncertain: they must survive to very high temperatures (2100 K @ 0.1 AU).

Strong need for self-consistent models of gaseous and dusty inner disks!

Is it common in Herbig AeBe stars?
Needs spectro-interferometry **and** very long baselines...

[Tannirkulam et al. 2008;
Isella et al. 2008;
Kraus et al. 2008, 2009;
Eisner et al. 2009]

Benisty, Natta, Isella, Berger, Massi et al. 2009, A&A, in press