The first AU of protoplanetary disks as seen by PIONIER/VLTI

Myriam Benisty

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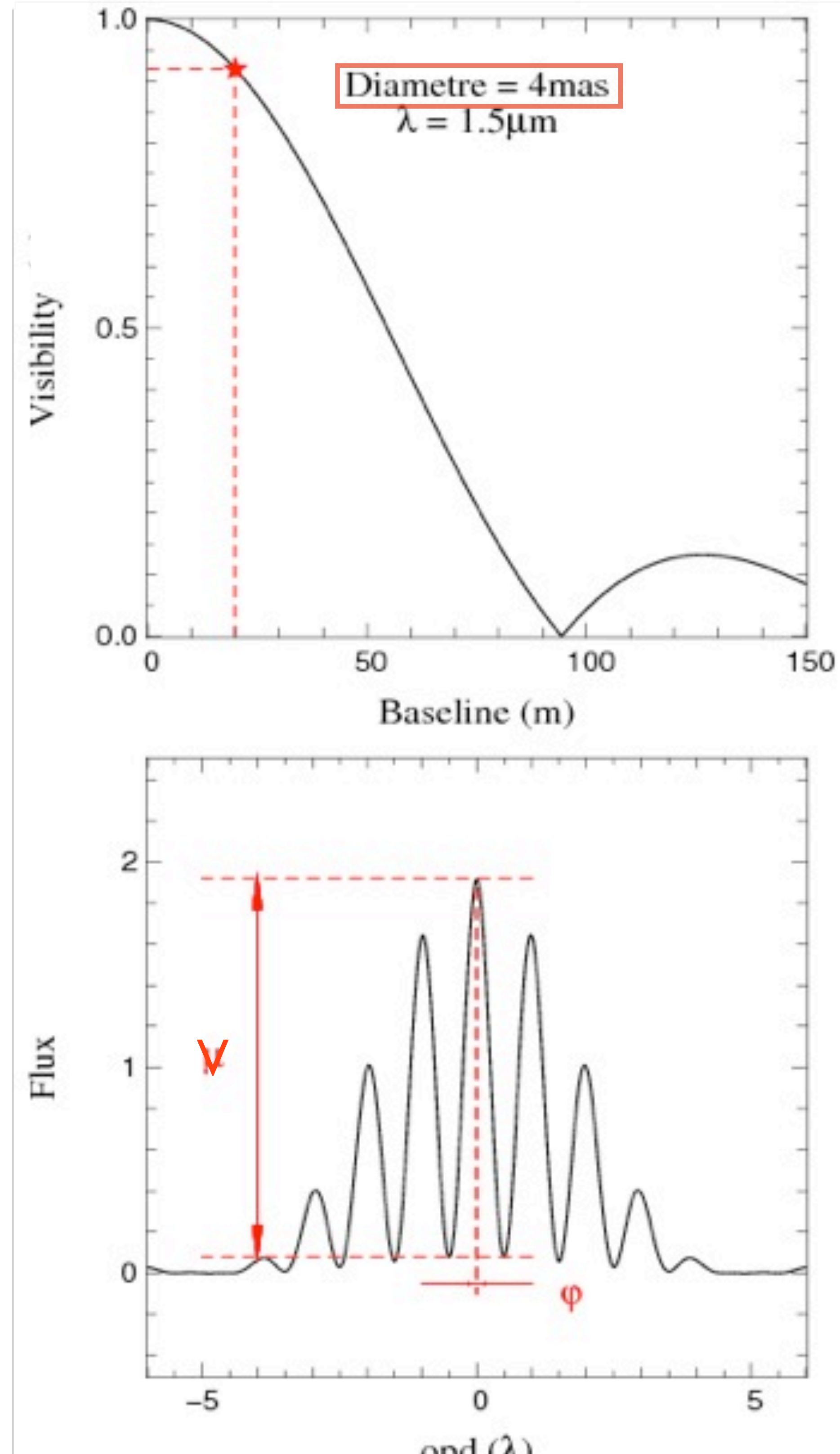
(IPAG/ESO/MPIA/Caltech)

Why interferometry ?

$\lambda/2B$ ~1.5-10 mas i.e., ~0.2-1 AU

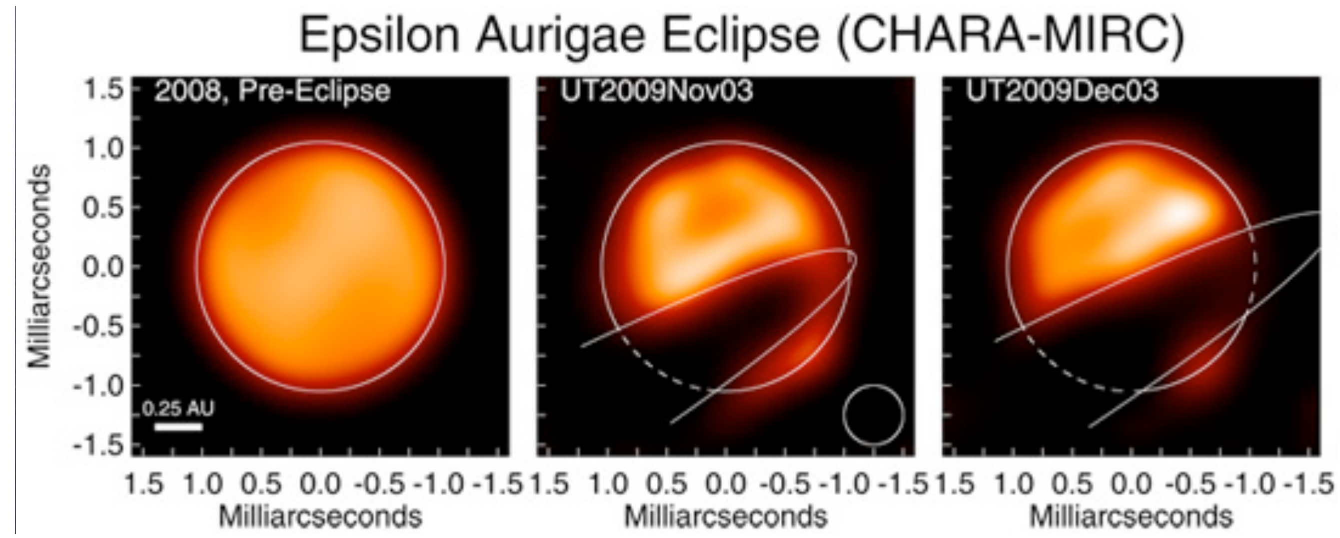
$$V\, e^{i\phi} = FT\{\text{ Object }\}_{(B/\lambda)}$$

- visibility V : spatial extent
- closure phase $\sum\phi$: asymmetry



PIONIER

Context in 2009: imaging era at the mas scale (e.g. MIRC/CHARA: 6T in the NIR).



Kloppenborg et al. 2010 Nature

Building PIONIER:

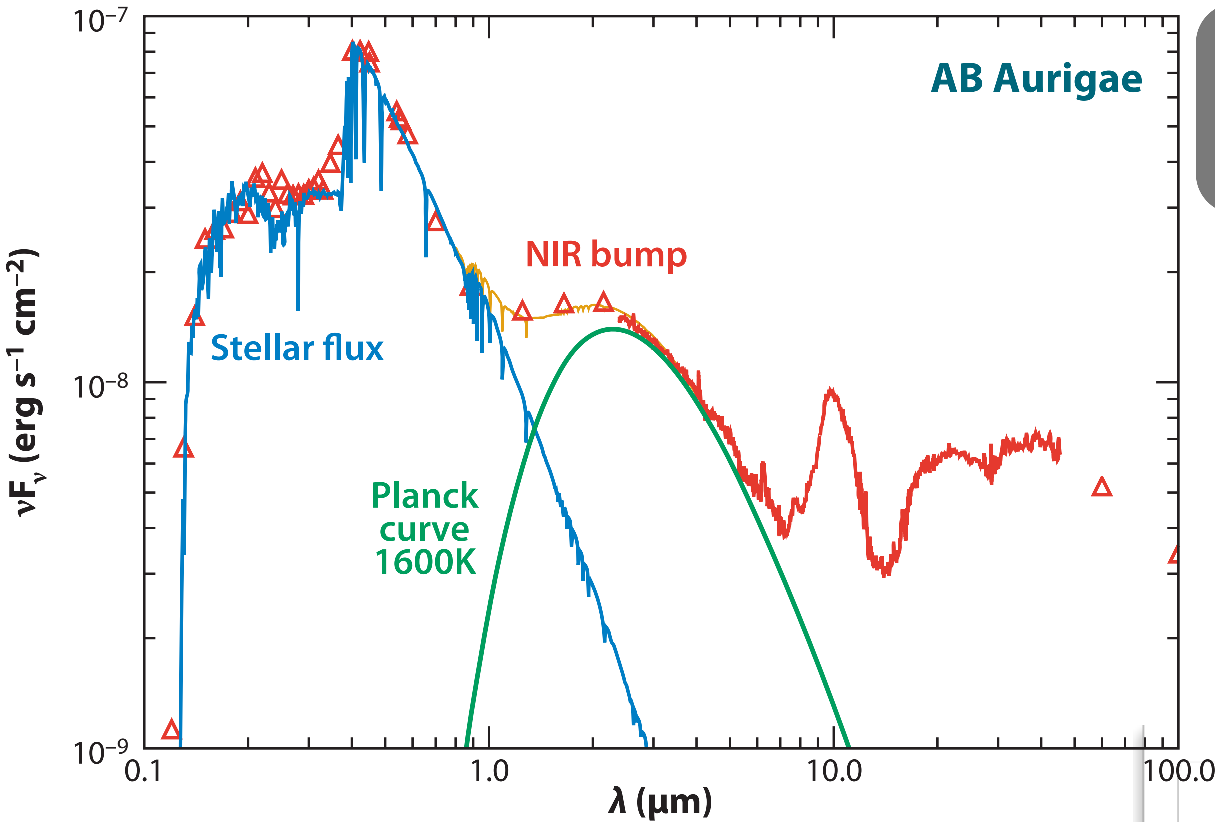
- OK from ESO: End of 2009
- Integration: Jan.–Sep. 2010
- First Light: Oct. 2010
- PI : JB LeBouquin / JP Berger

Science goals : YSO + Debris disks

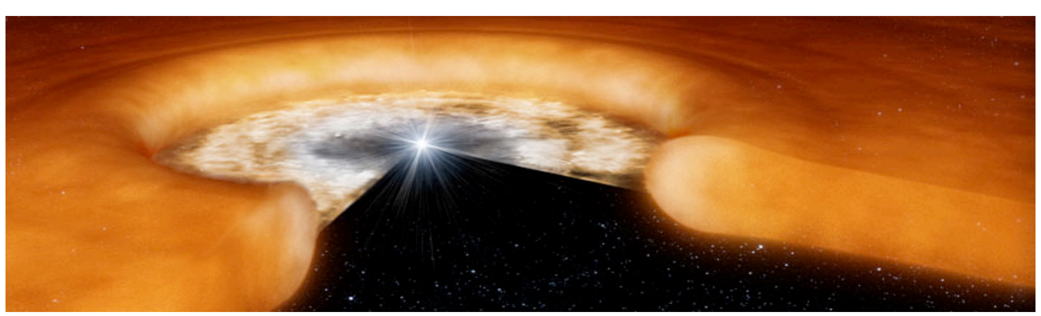
- sensitive
- accurate
- providing multi-baselines simultaneously

- Statistics of disk properties
- Study time-variable objects
- Image well-resolved disks

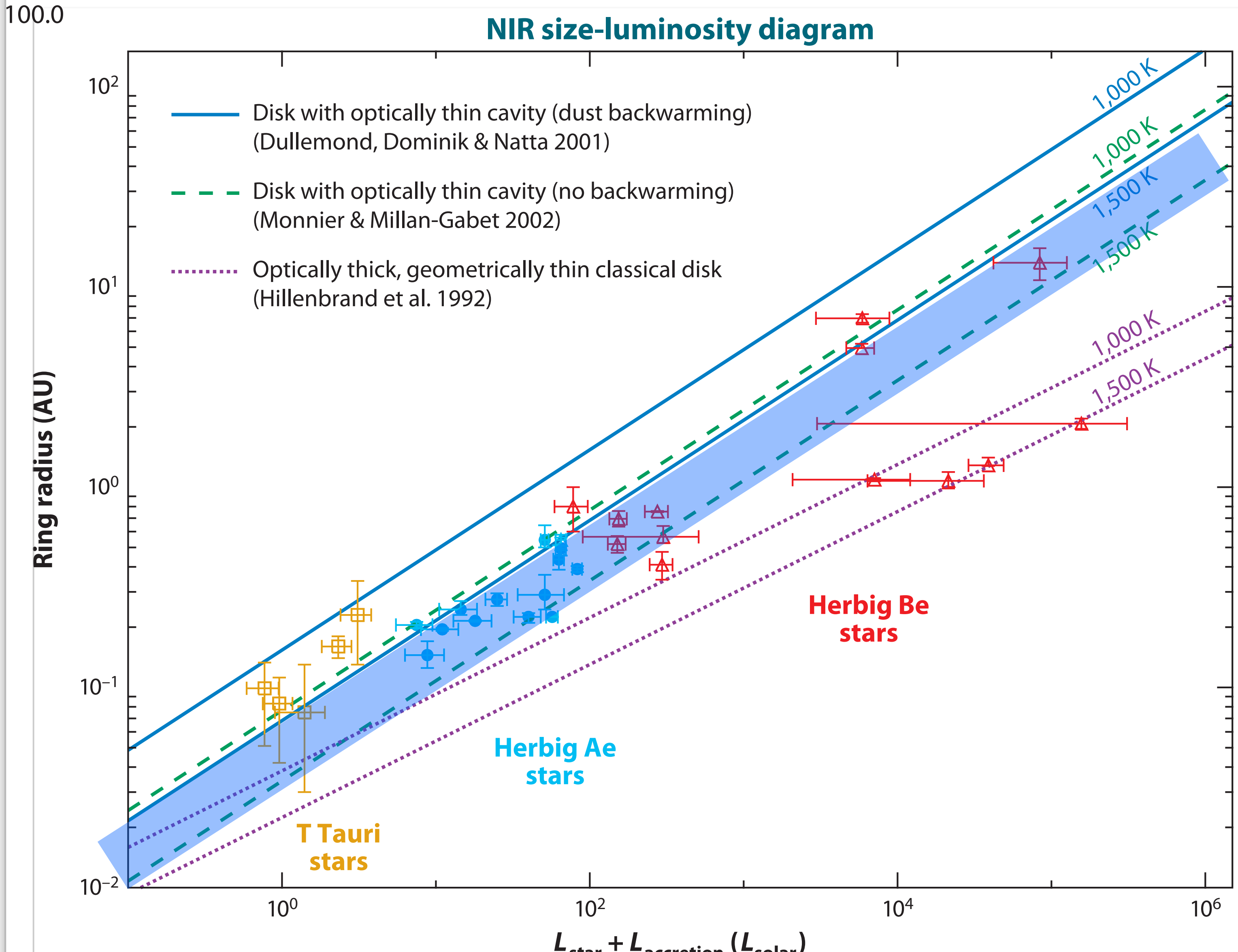
Near IR excess



Natta et al. (2001)
Dullemond, Dominik & Natta (2001)

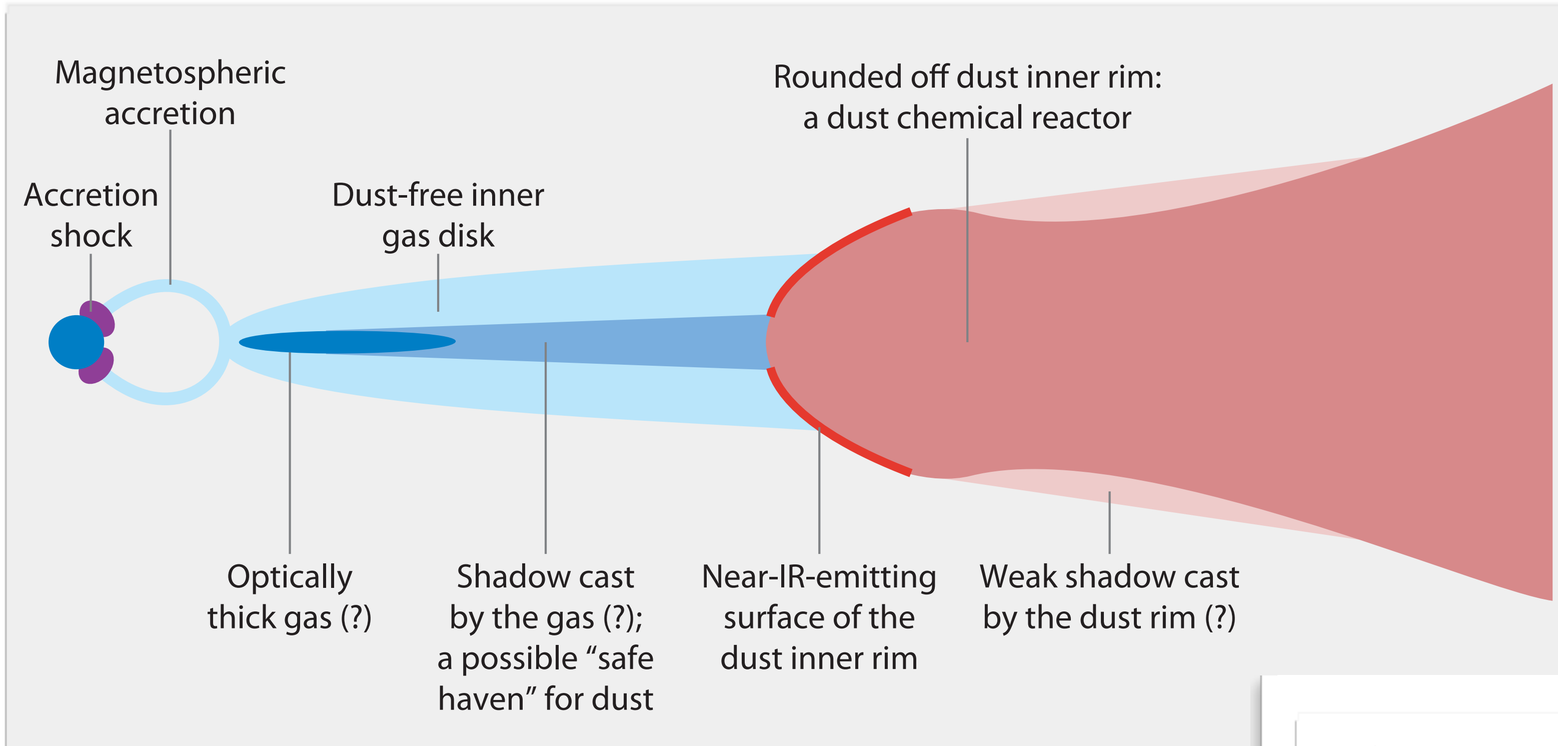


Ring diameters

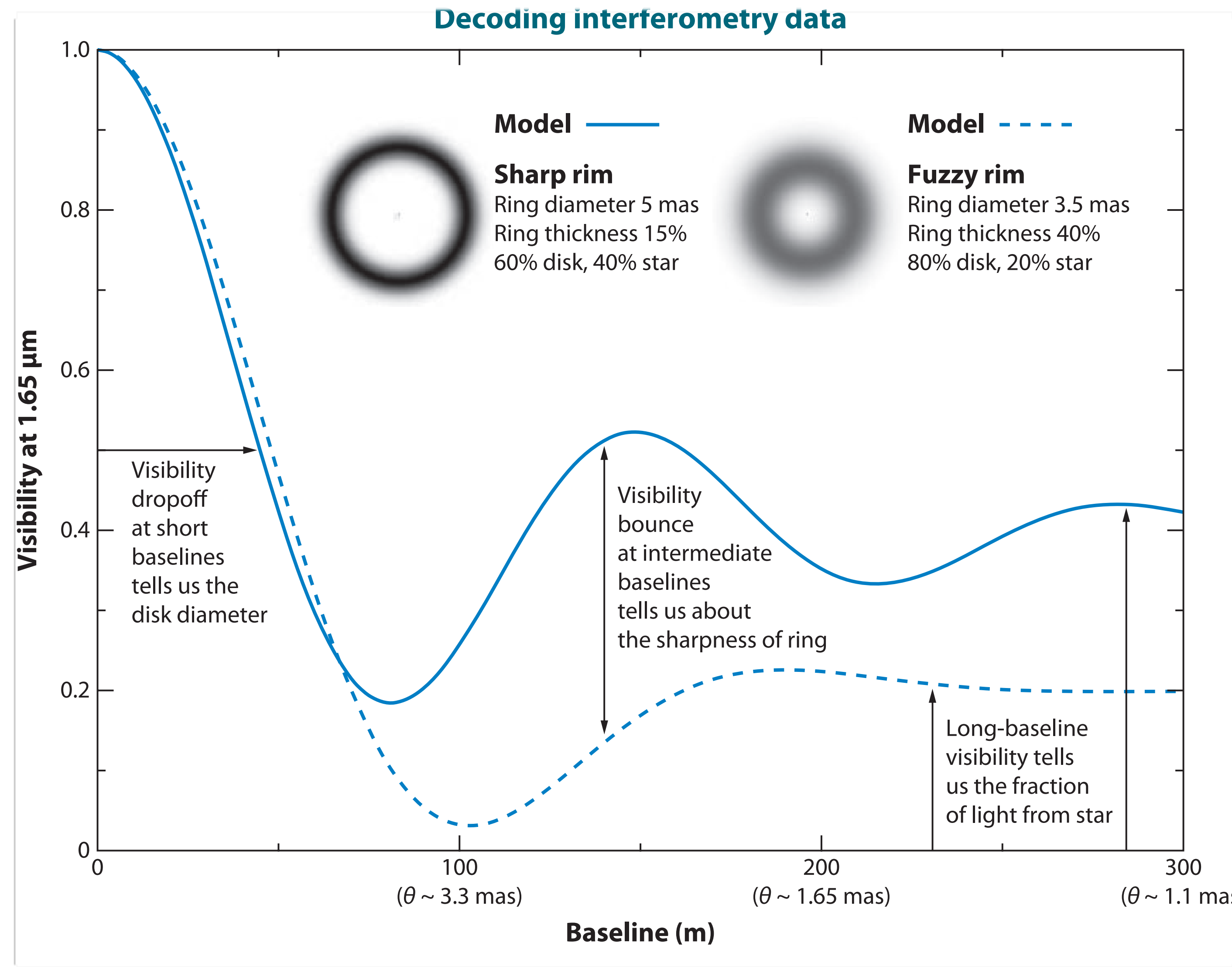


Dullemond & Monnier 2010

The inner disk



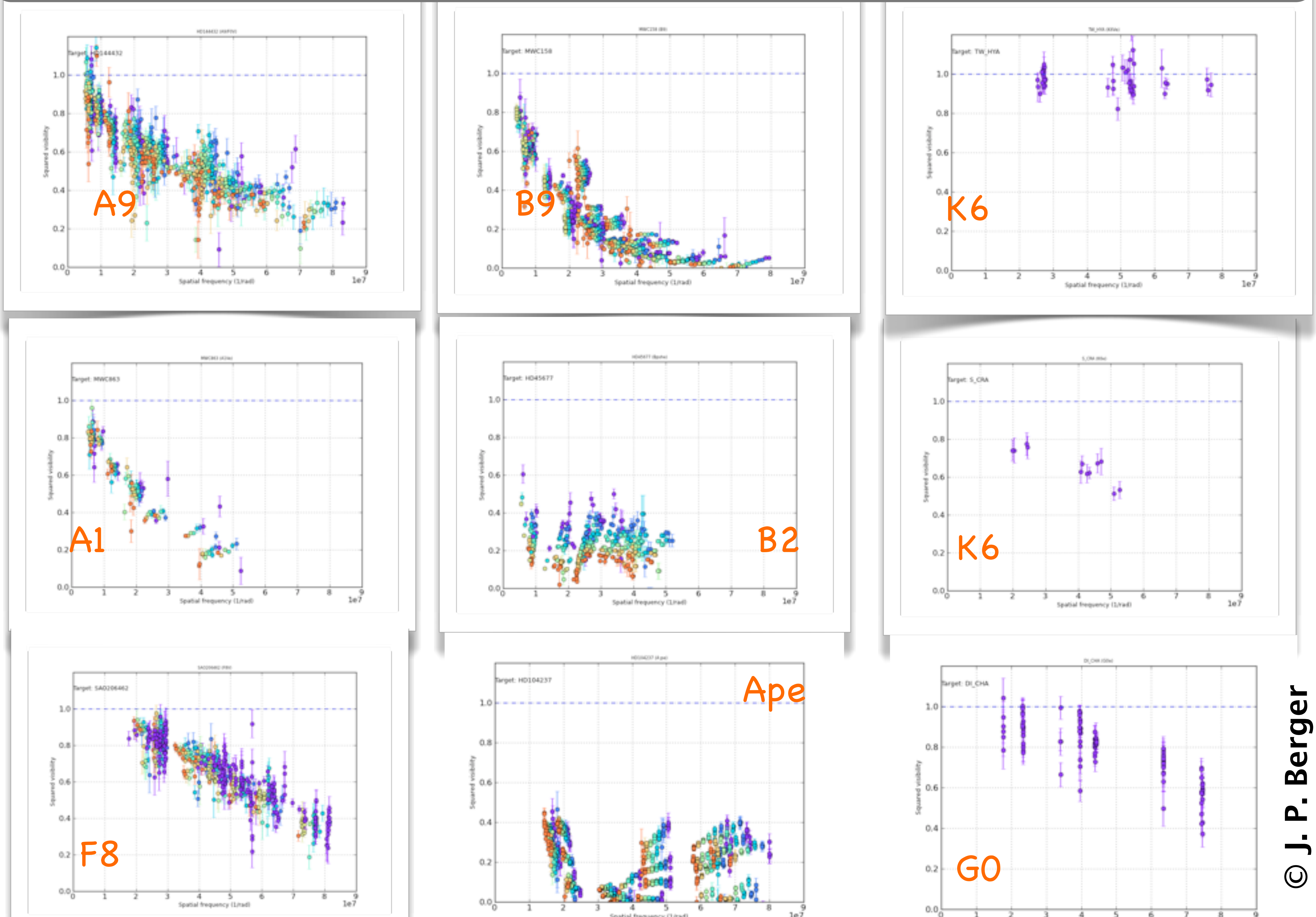
Dullemond & Monnier 2010



(early) YSO program on PIONIER:

~70 TTS, HAeBe, TD.

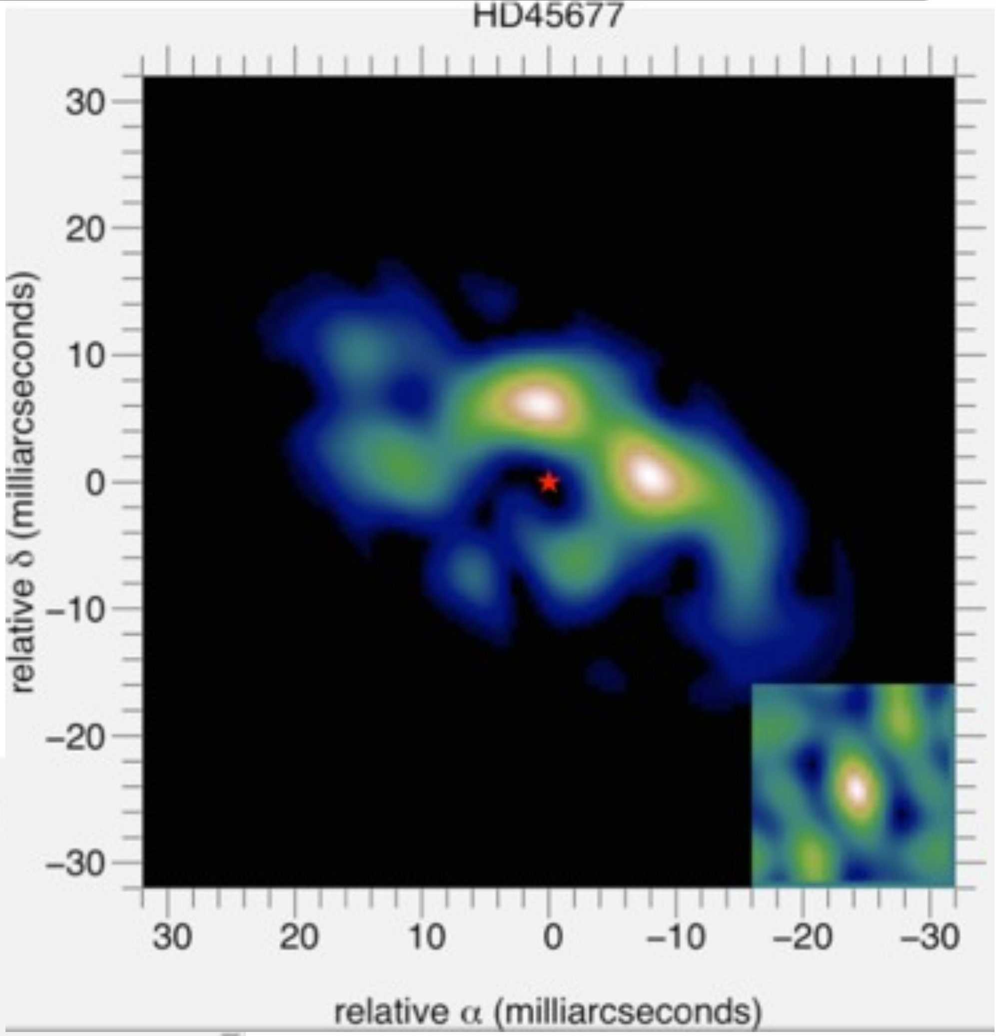
Family portrait

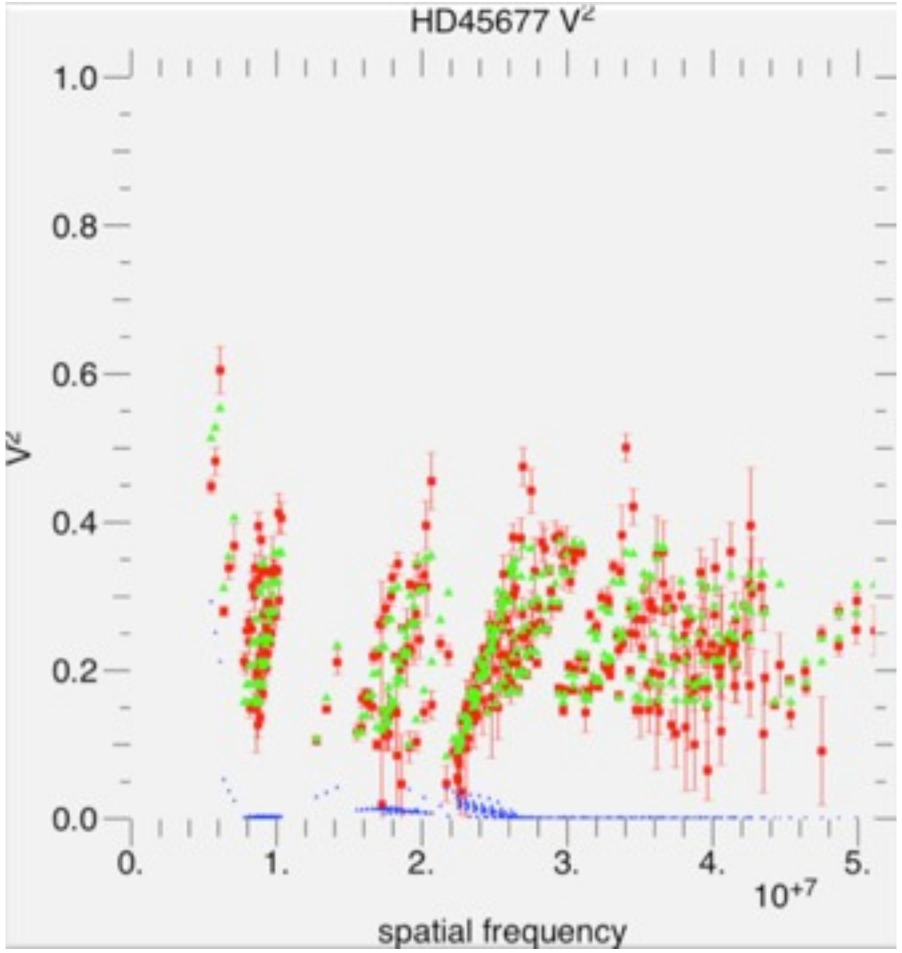


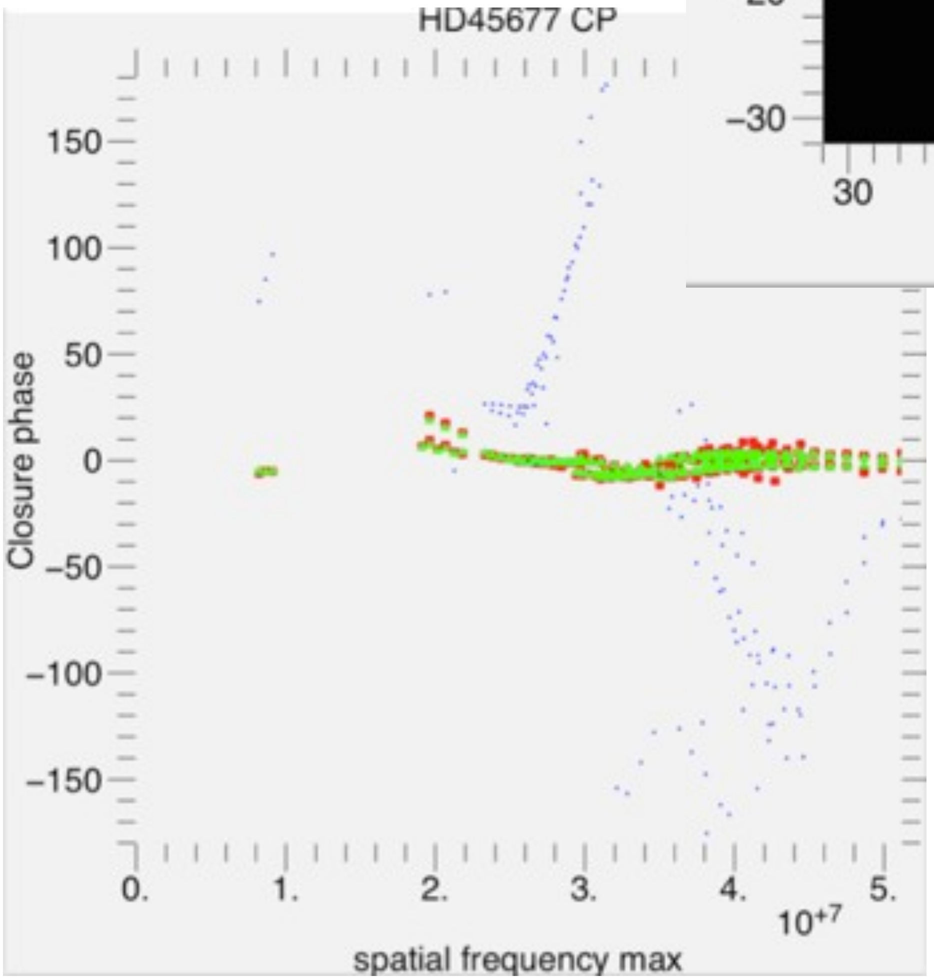
Reconstructed images

$$V e^{i\phi} = \text{F.T.}\{\text{Object}\}(B/\lambda)$$

Image reconstruction algorithm (e.g. MIRA)







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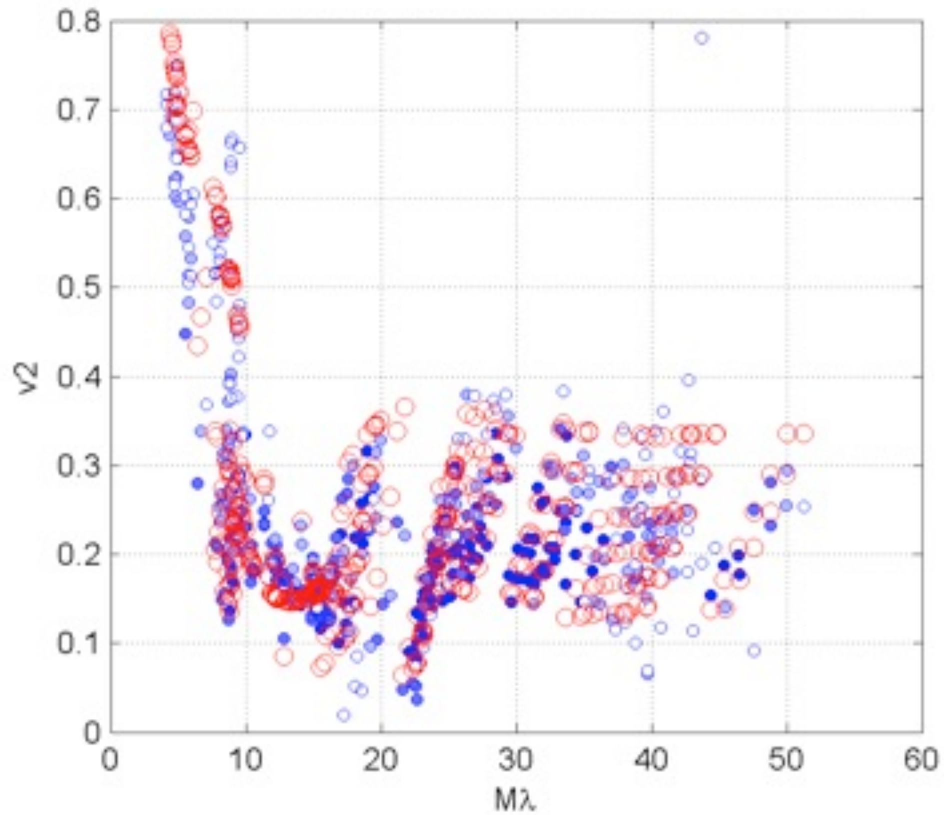
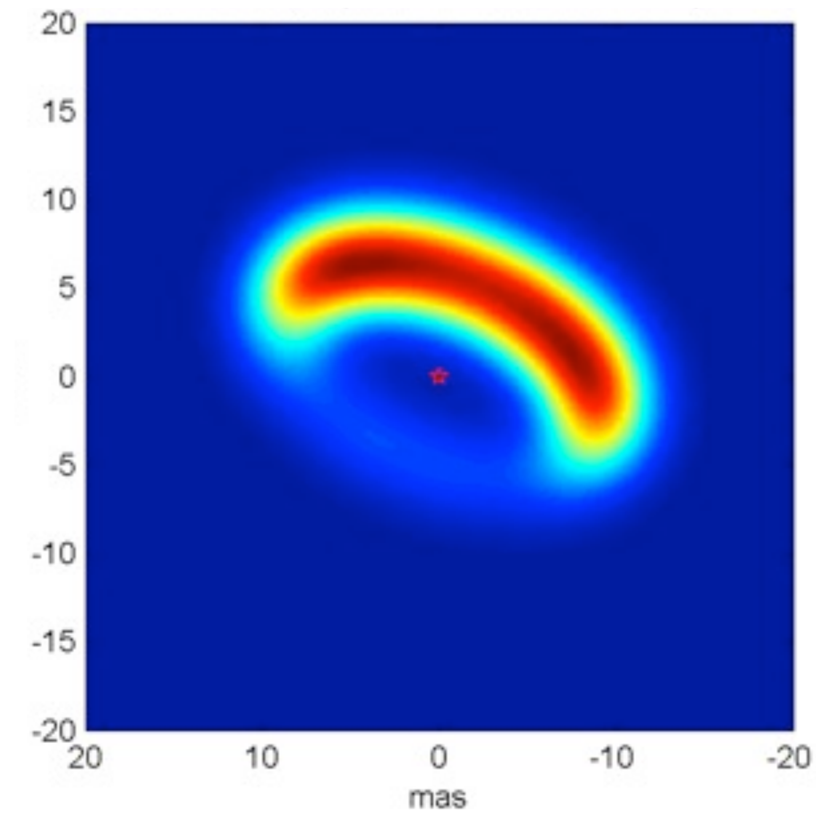
Inner disk modeling

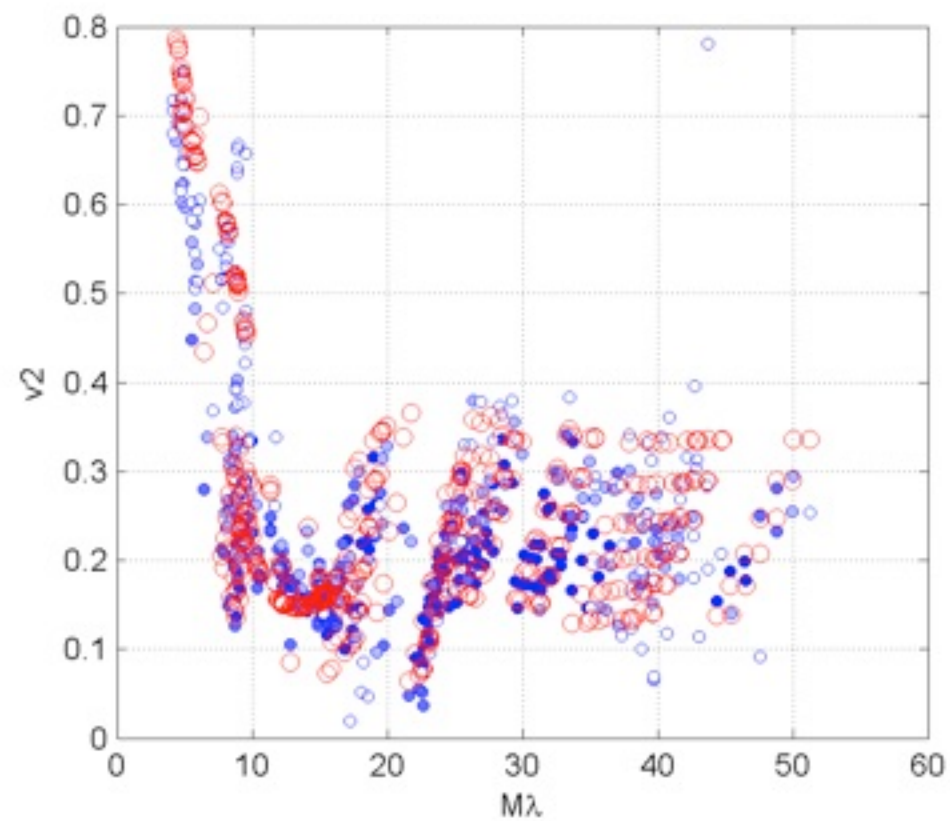
Parametric modeling: provides R_{in}, surface brightness, asymmetries

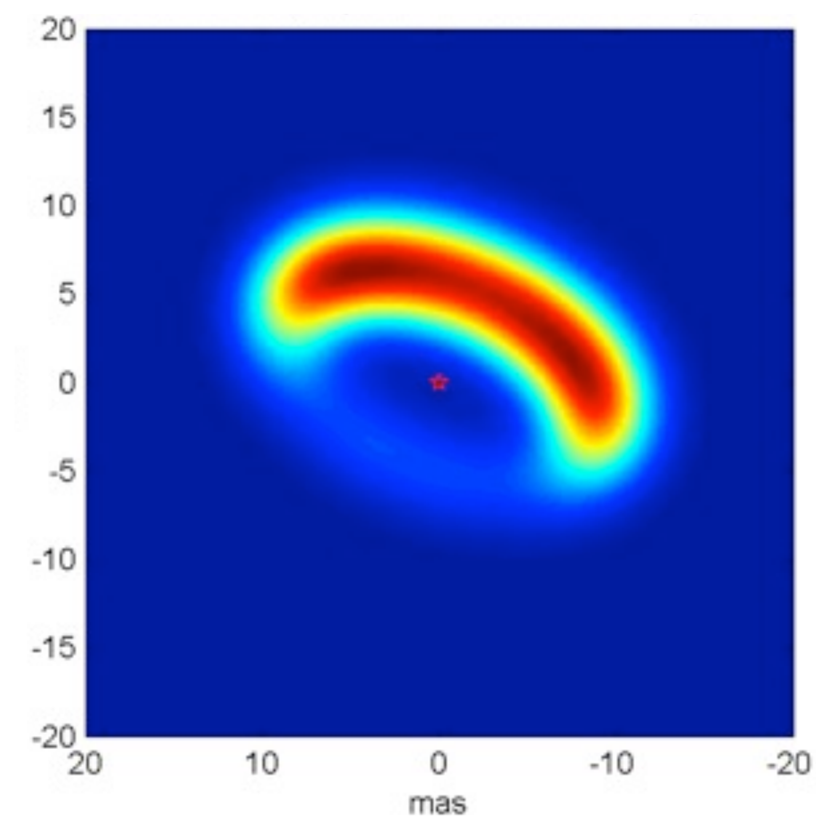




Inner disk modeling

Parametric modeling: provides R_{in}, surface brightness, asymmetries





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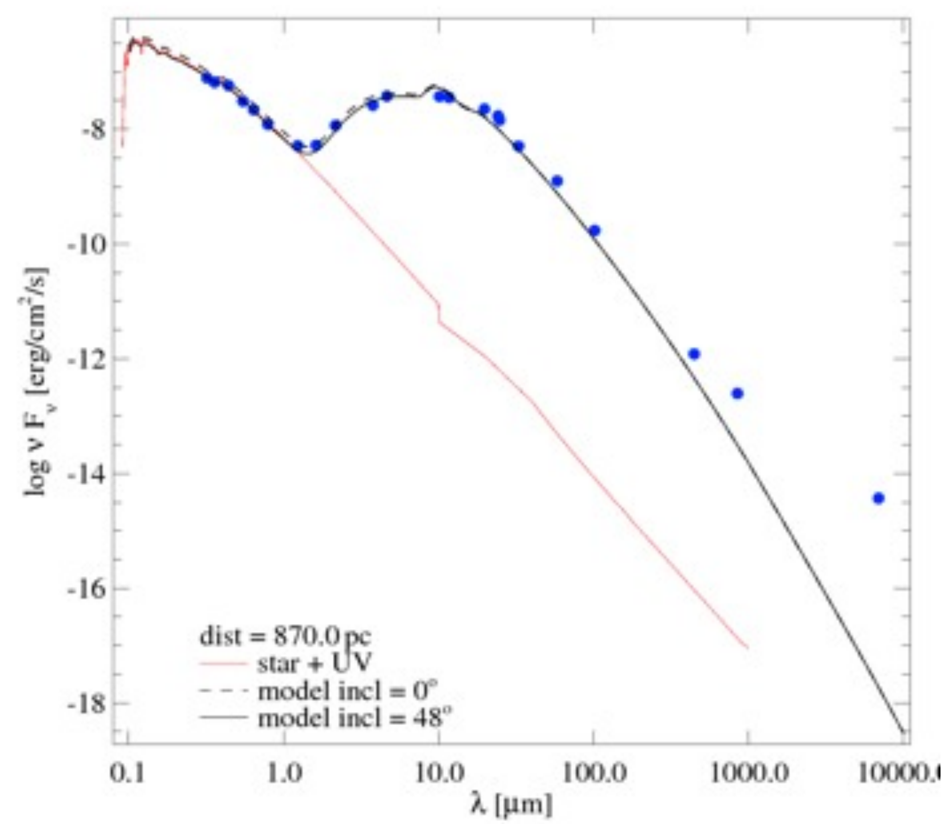
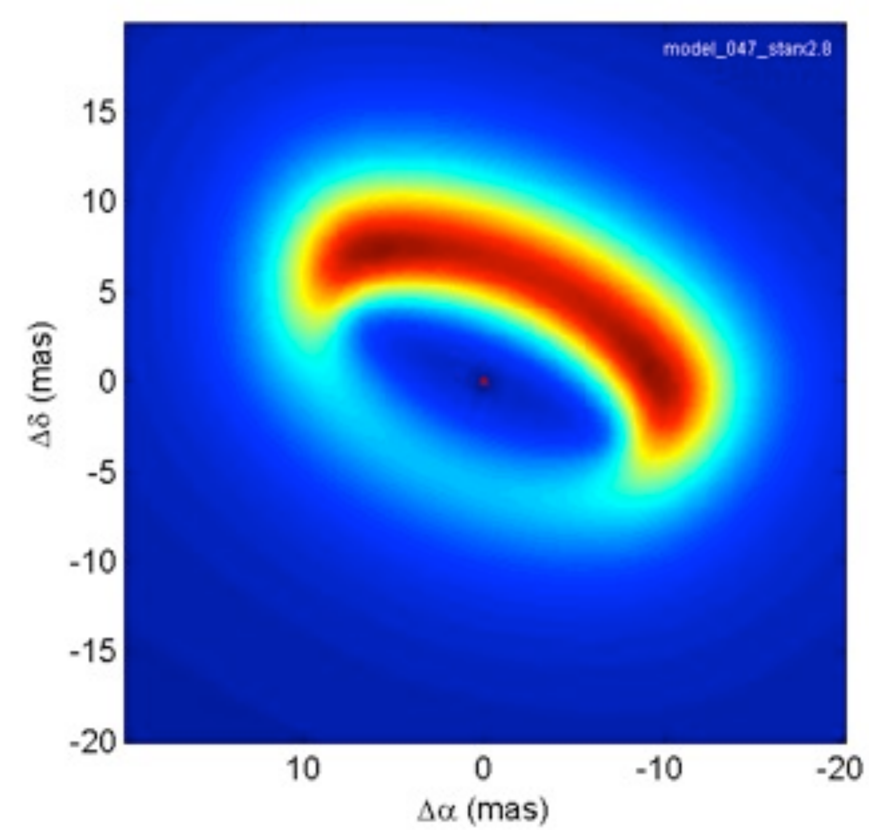
Refine with ProDiMo e.g. sedimentation, physical conditions

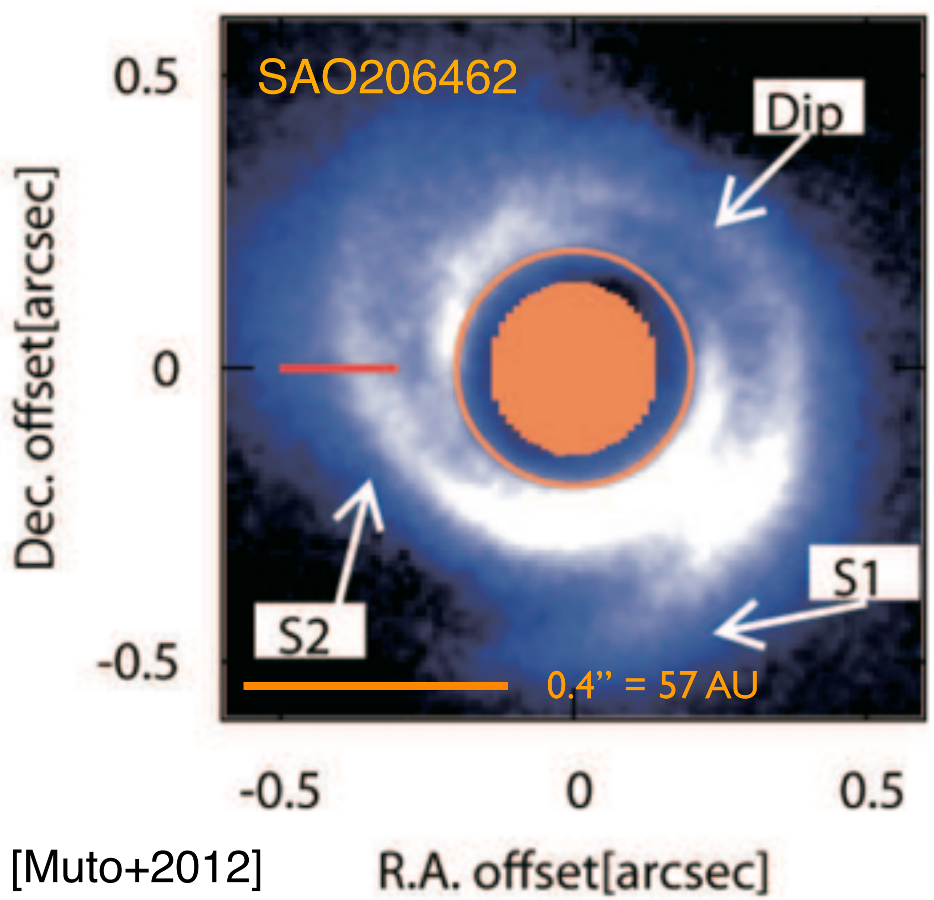
"Tdust, Tgas from thermal balance, and full vertical hydrostatic"





Transition disks

T Cha	(G8)	**Gap** < 12 AU	[Cieza+2011]
SAO206462	(F4)	< 45 AU	[Andrews+2011]
HD142527	(F6)	< 130 AU	[Verhoeff+2009]
...			



[Muto+2012]

Complex disk structures
[Fukagawa+2011,Muto+2012]

Companion candidates in the gap
[Huelamo+2011,Biller+2012]

Massive (resolved) outer disks
[Andrews+2012]

Benisty et al. in prep

Close companions & asymmetries

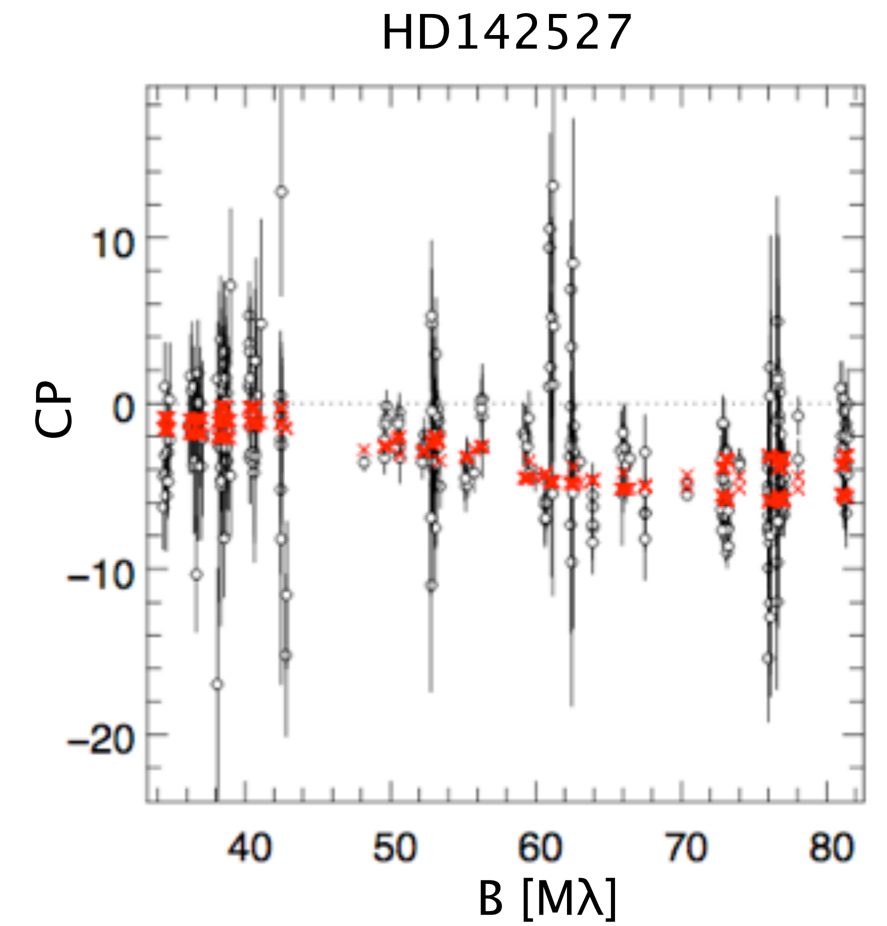
Search for companions at separations 3-50 mas (~0.5-7 AU)

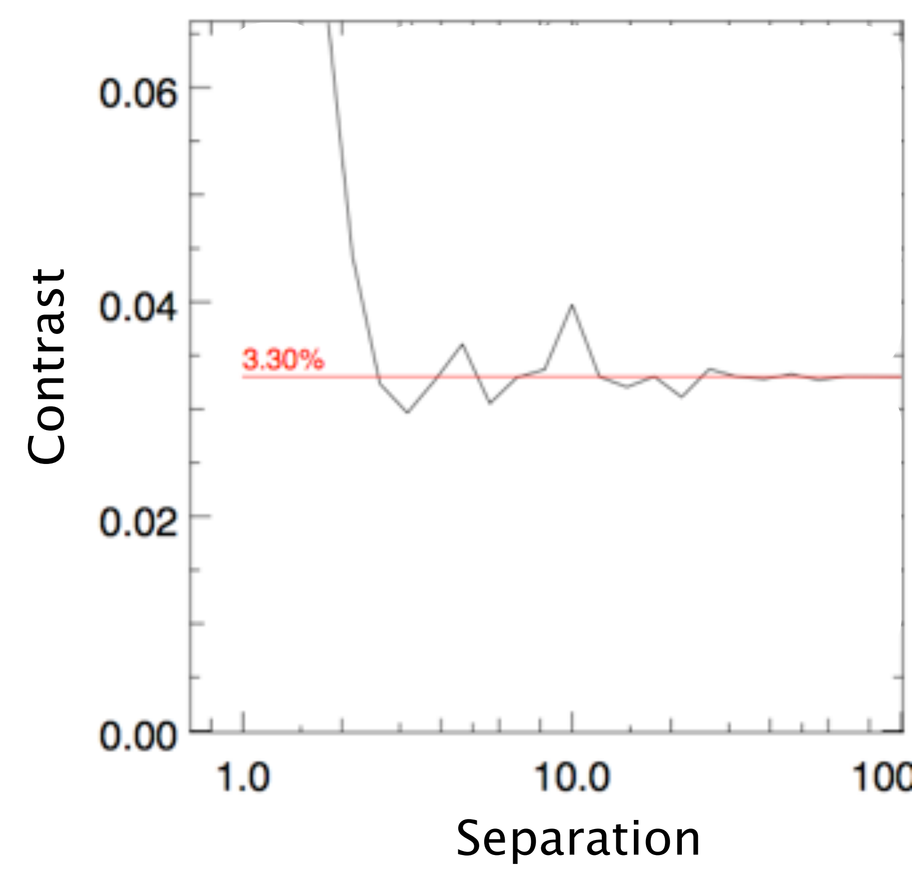
* SAO 206462 & T Cha: no companion (contrast>1.2%)
* HD142527: point source at ~1.5 mas (3% contrast)?
  Or inner disk rim ?

No detection of bright companions [Pott+2010]

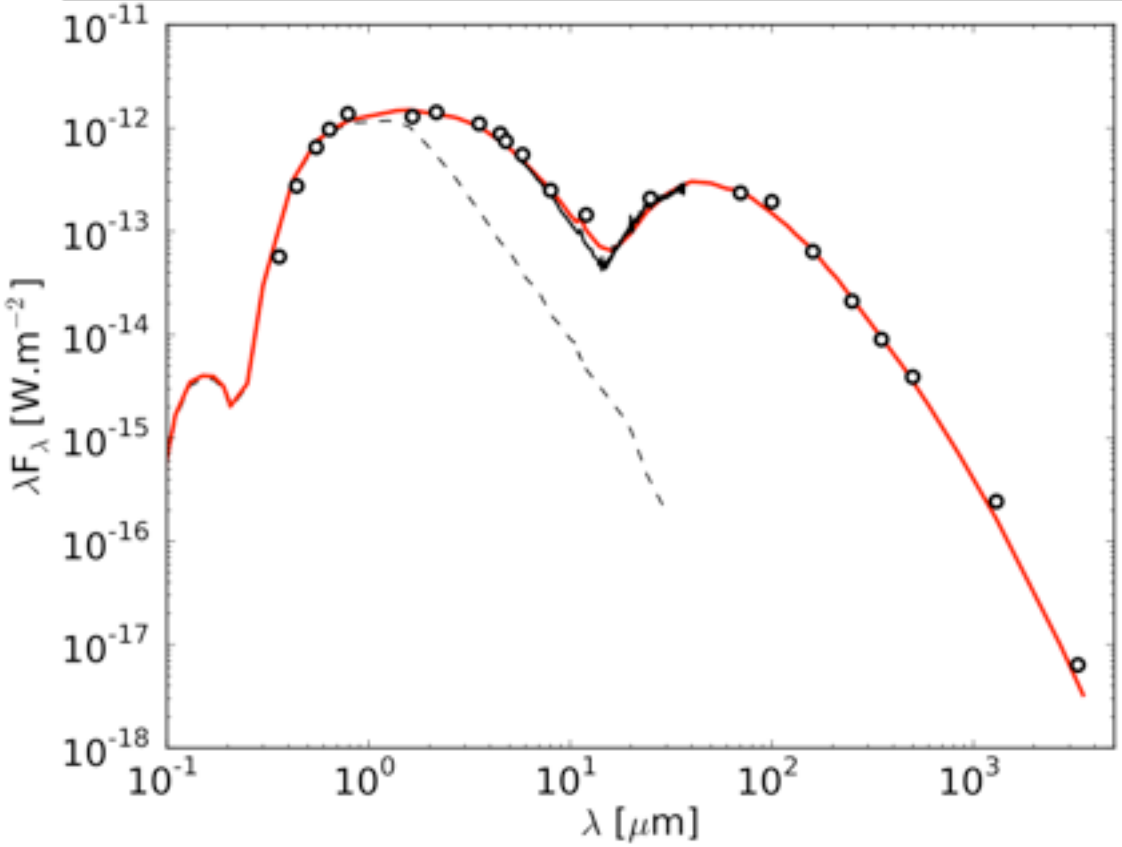
Low asymmetry – no sharp rim

Explained with anisotropic scattering

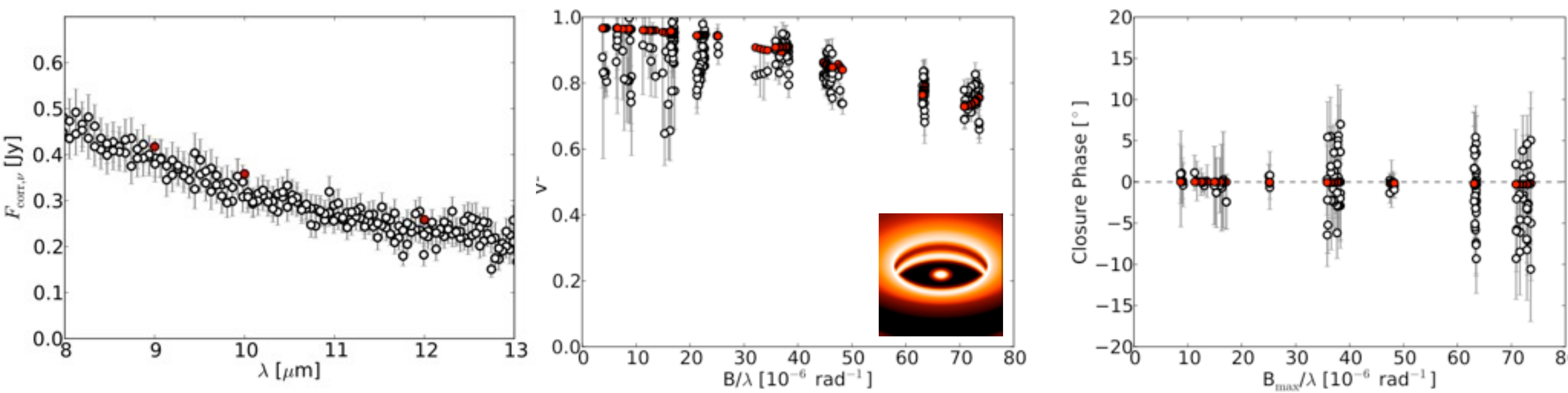




T Cha

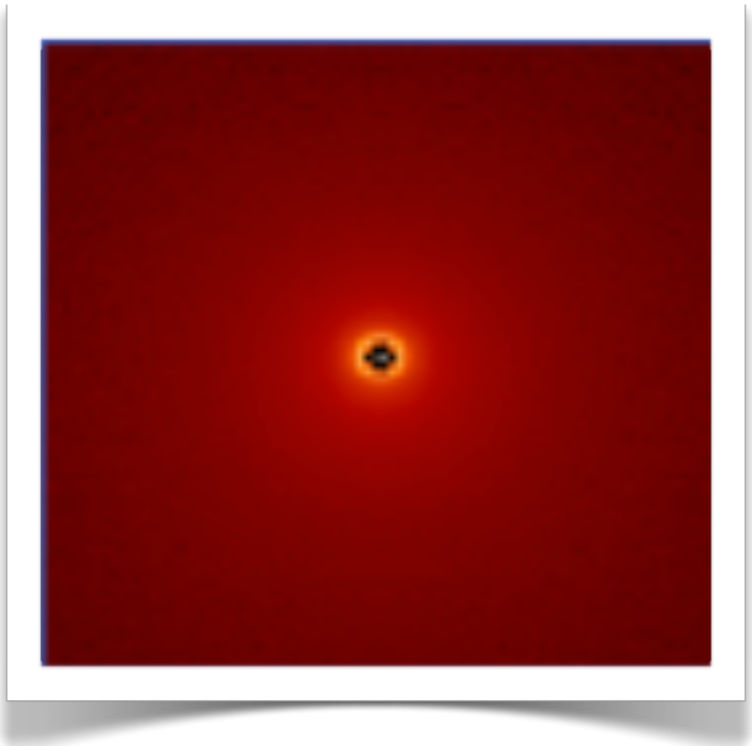


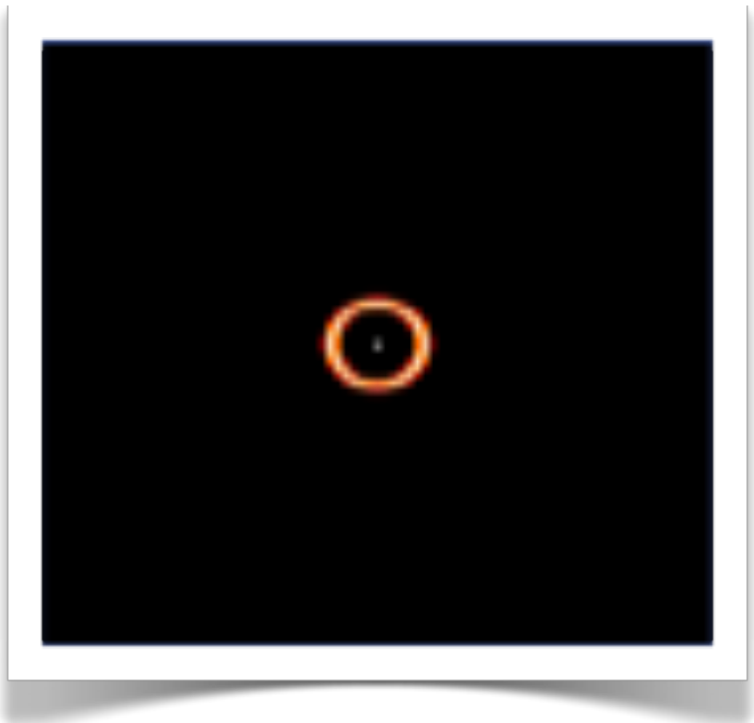
- ✳ Candidate companion @ 6.7 AU ? [Huelamo+2011]
- ✳ Single temperature black body ~ 1500 K
- ✳ Tiny inner disk : 0.07-0.13 AU
- ✳ M = 3 10^{-11} $M_\odot$ of carbon
- ✳ H=0.2 AU @ 1 AU sets outer disk radius



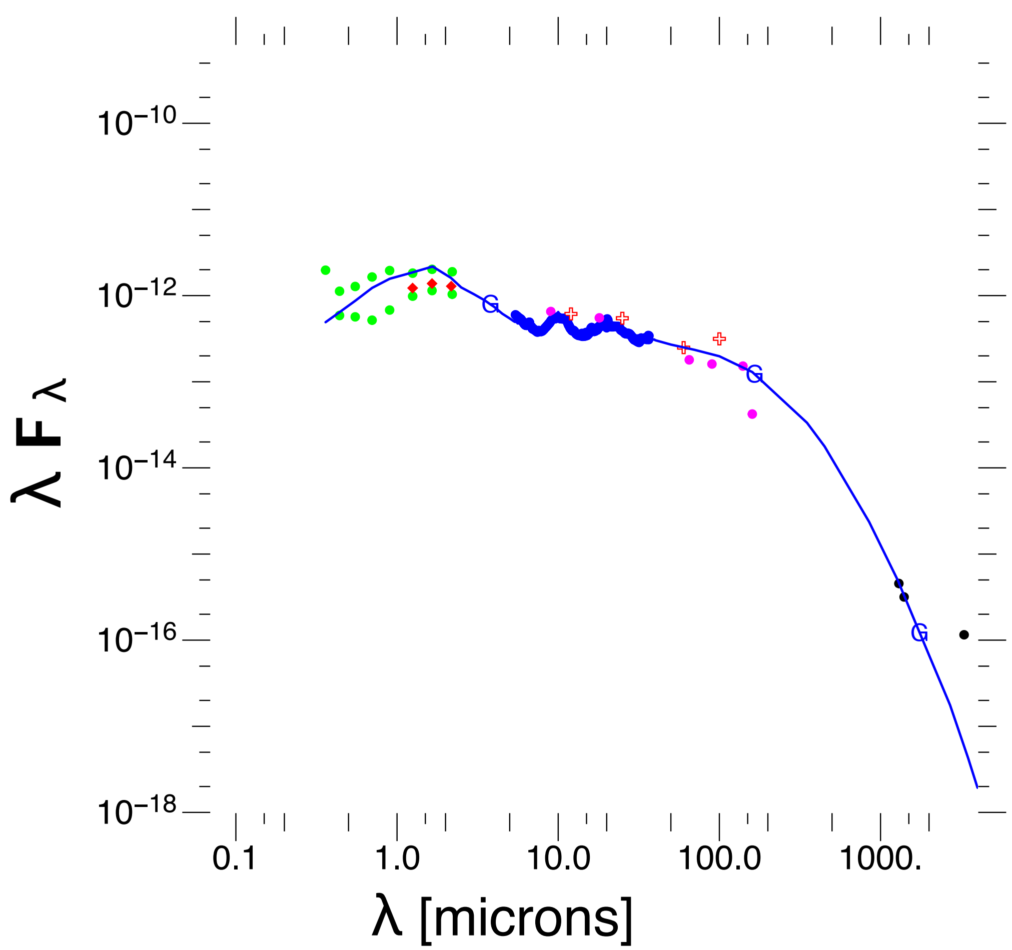
Olofsson et al. in prep

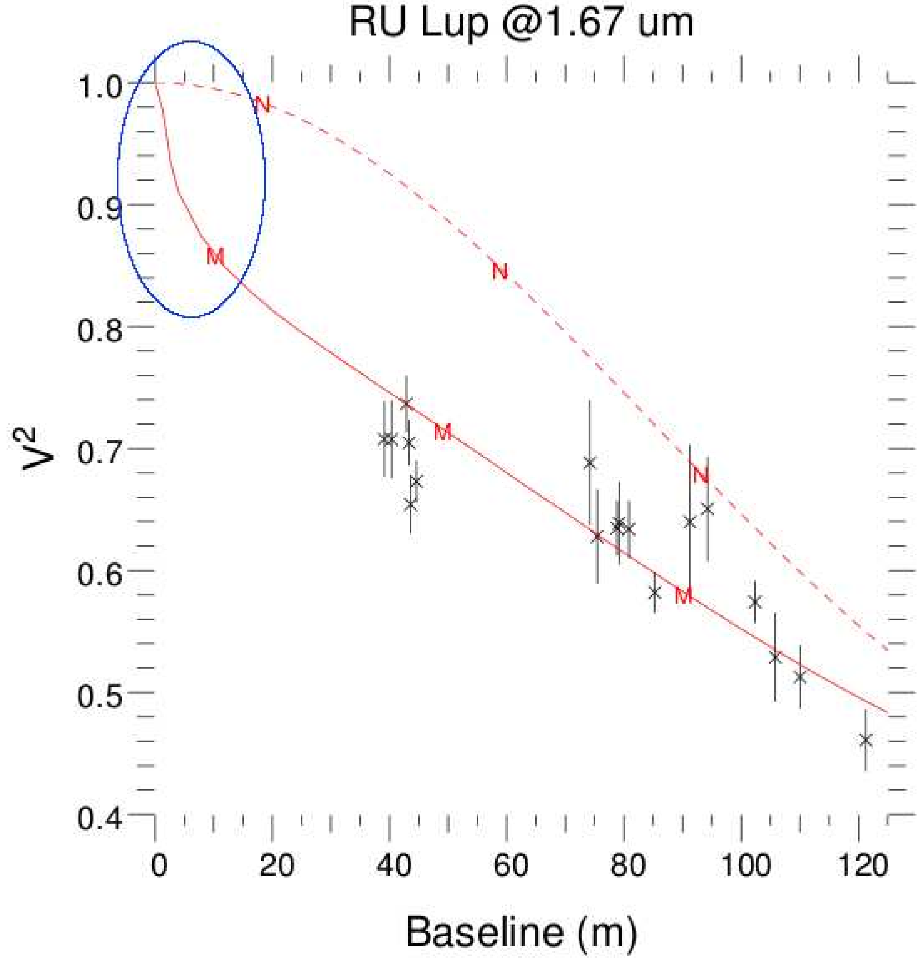
T Tauri stars



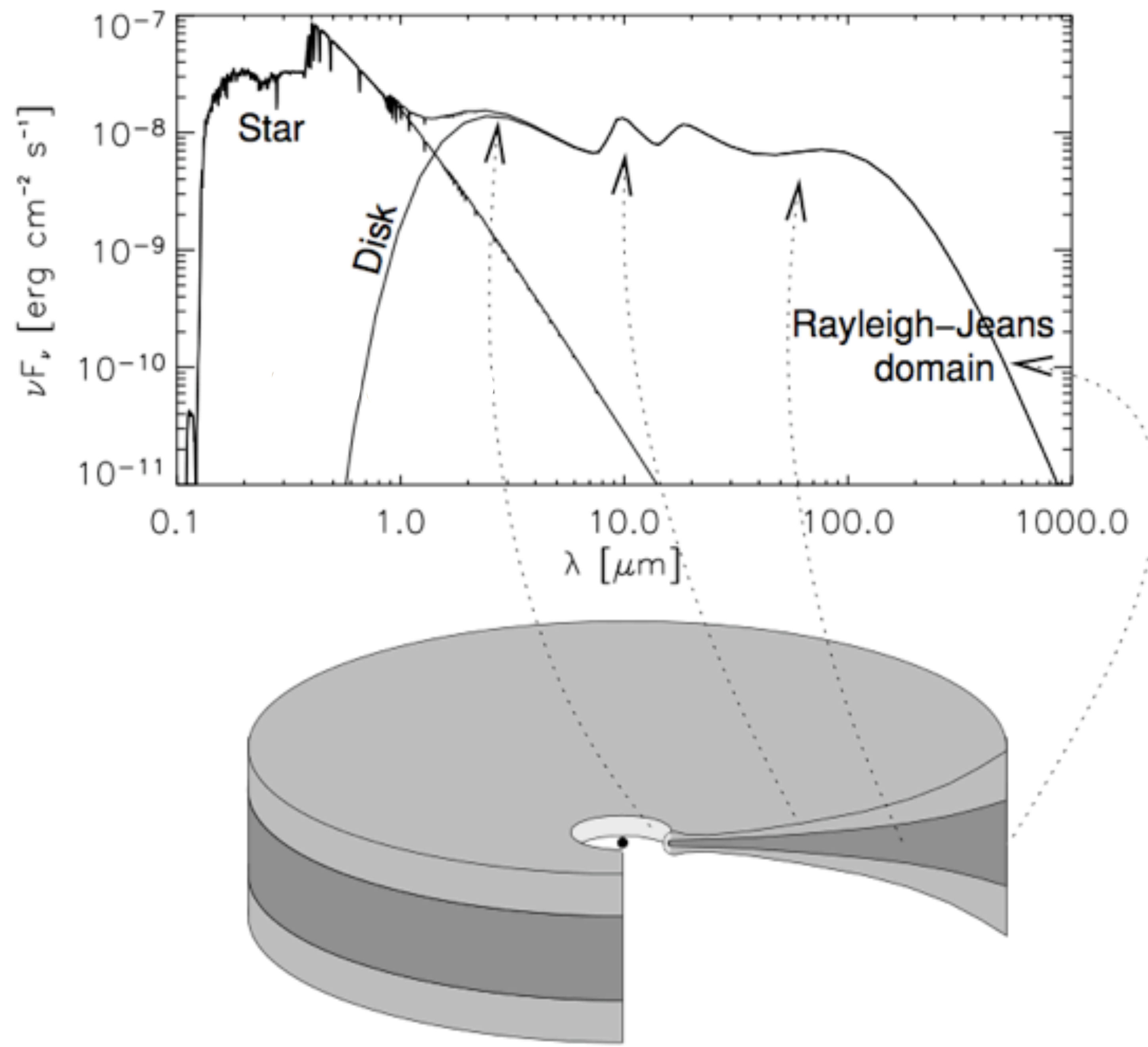


[Pinte+2008]





Perspectives

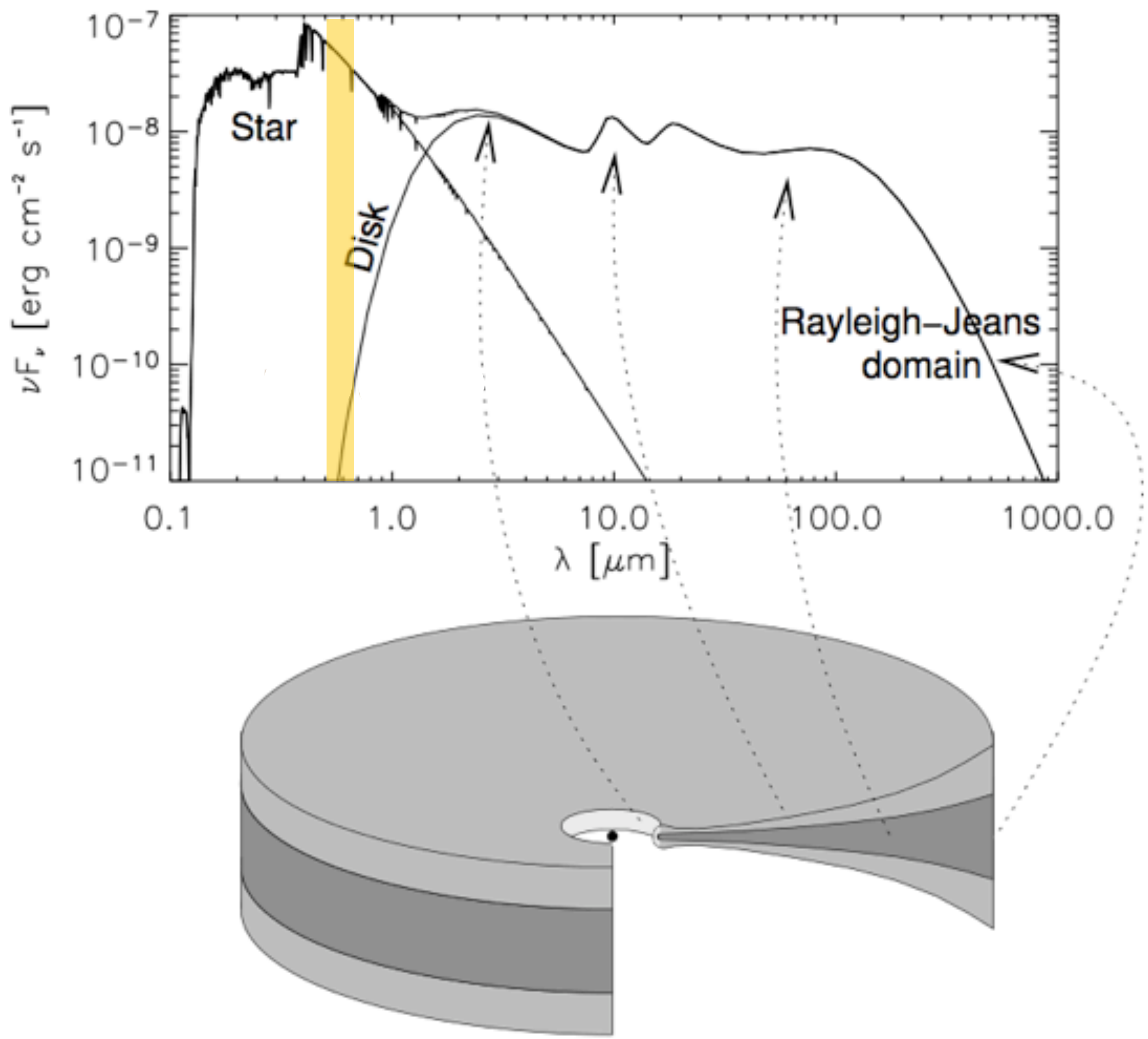


Planet forming region

Jet launching

Perspectives

VEGA-
CHARA (V)
0.4-4 mas



Planet forming region

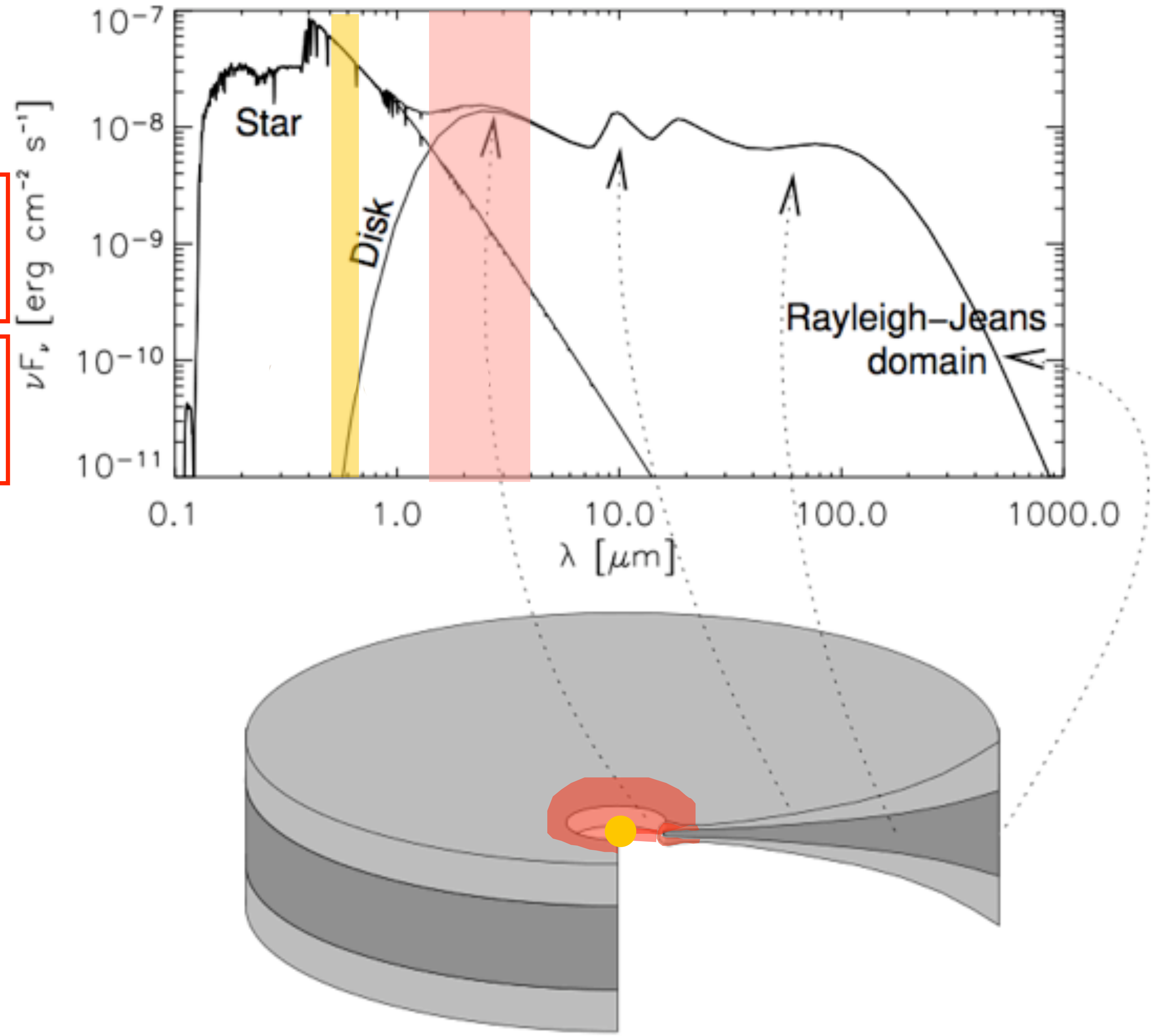
Jet launching

Perspectives

VEGA-CHARA (V)
0.4–4 mas

PIONIER/VLTI (H)
2–5 mas (LP)

GRAVITY/VLTI (K)
2–5 mas



Planet forming region

Jet launching

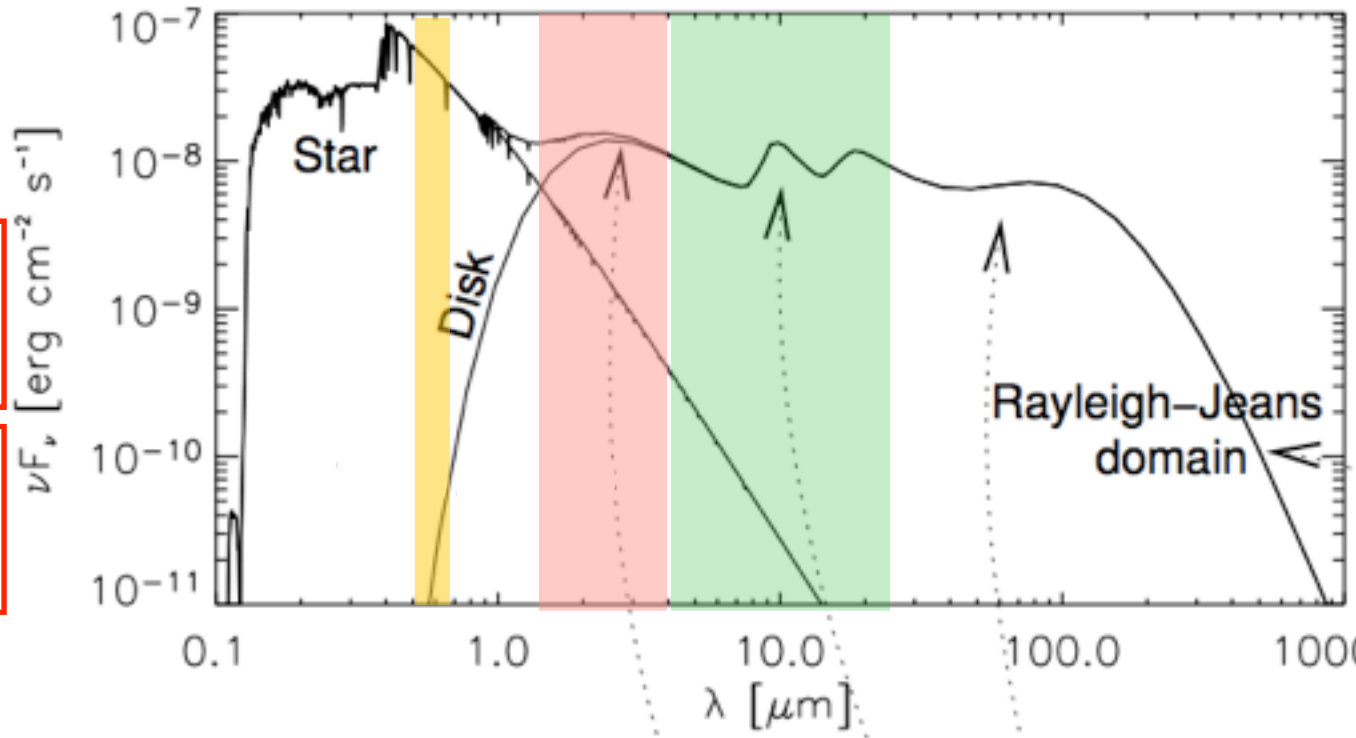
Perspectives

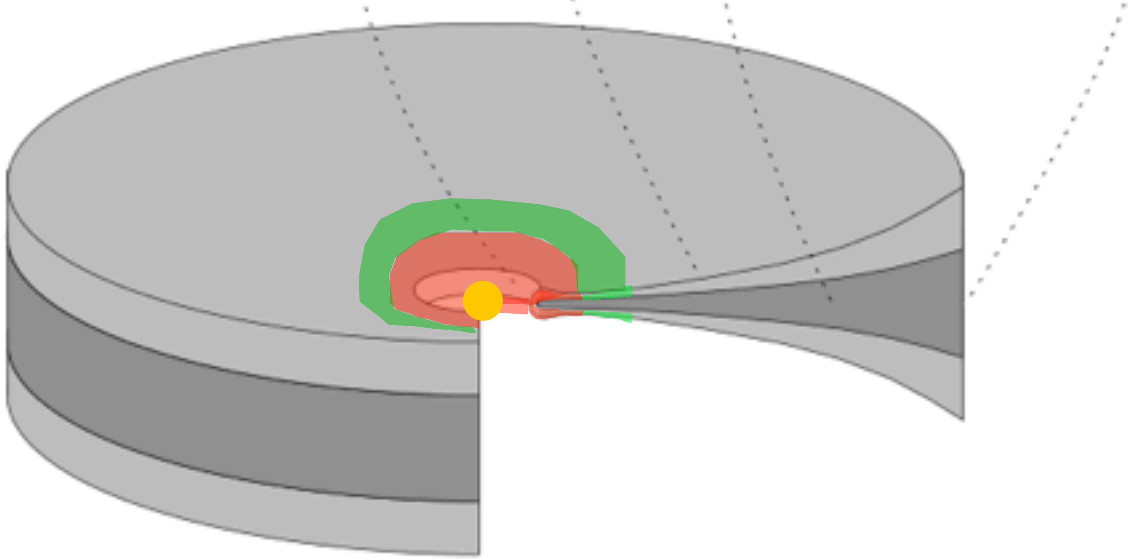
VEGA-CHARA (V)
0.4-4 mas

MATISSE/VLTI (L,M,N,Q)
5-20 mas

PIONIER/VLTI (H)
2-5 mas (LP)

GRAVITY/VLTI (K)
2-5 mas





Planet forming region

Jet launching

Perspectives

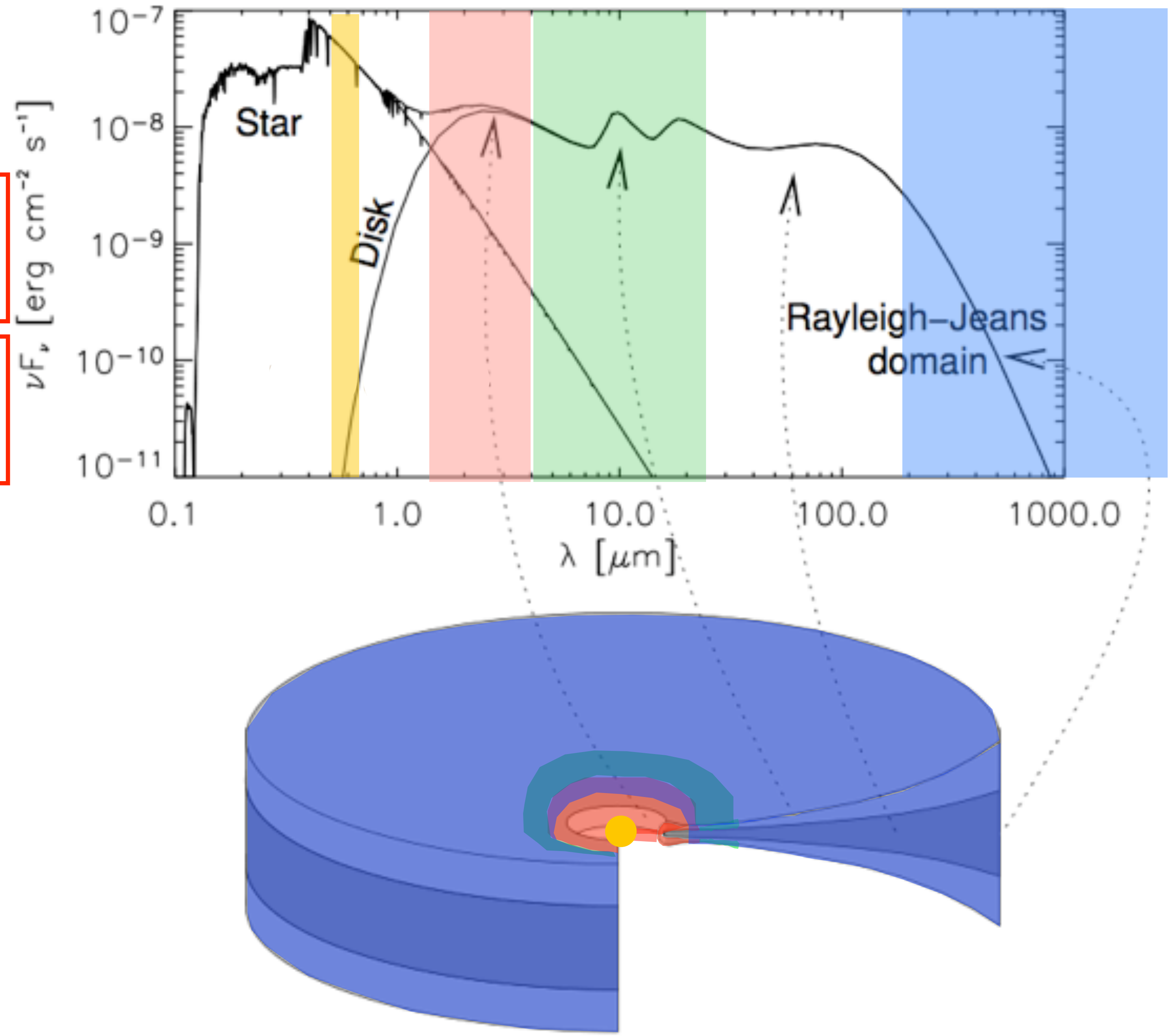
VEGA-CHARA (V)
0.4–4 mas

MATISSE/VLTI (L,M,N,Q)
5–20 mas

ALMA (mm)
$5–100^{+}$ mas

PIONIER/VLTI (H)
2–5 mas (LP)

GRAVITY/VLTI (K)
2–5 mas



Planet forming region

Jet launching

Reconstructed images

$$V\, e^{i\phi} = \text{T.F.}\{\text{Object}\}\,(\mathbf{B}/\boldsymbol{\lambda})$$

Image reconstruction algorithm (e.g. MIRA)