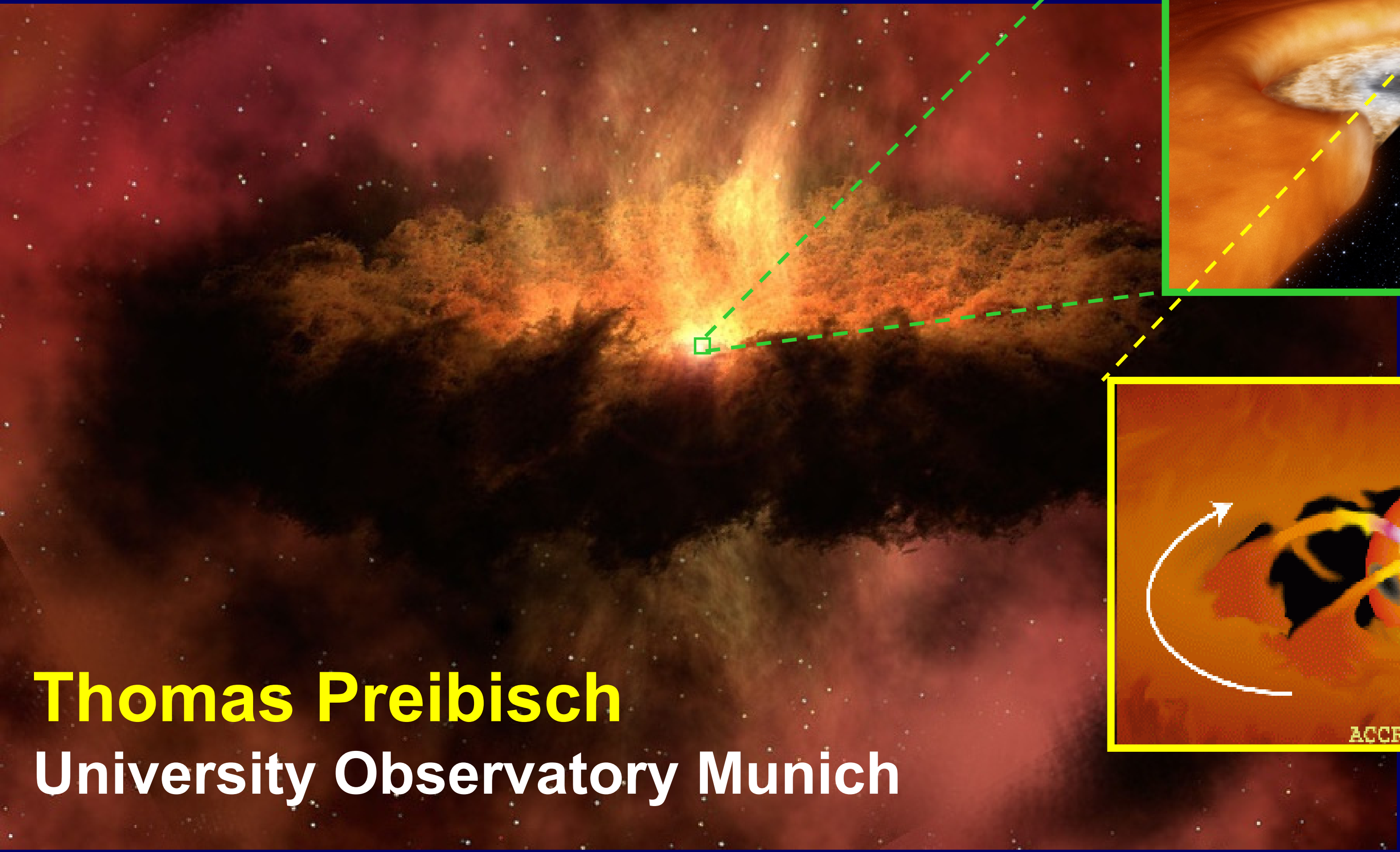
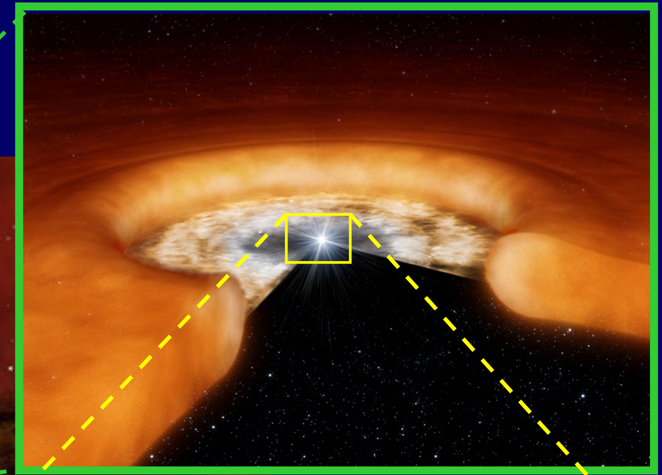
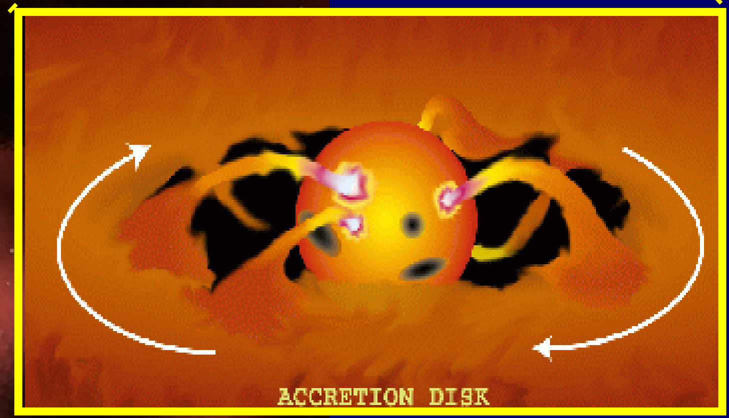
Infrared Interferometric Studies of Protoplanetary Accretion Disks







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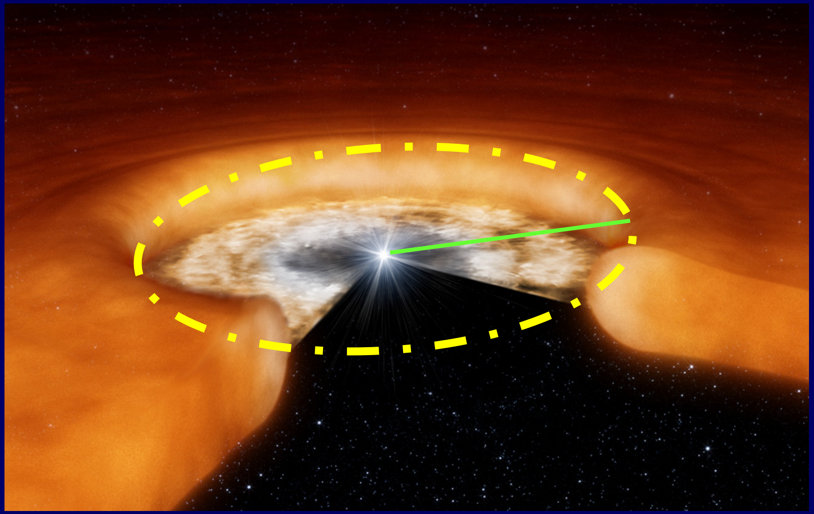
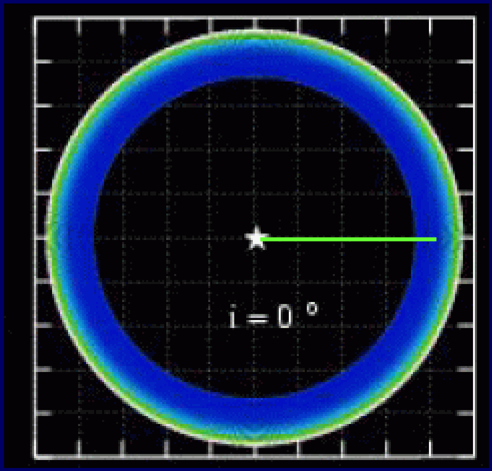
University Observatory Munich

Near-infrared emission from young stellar objects is usually assumed to be dominated by emission from hot dust at the dust sublimation radius

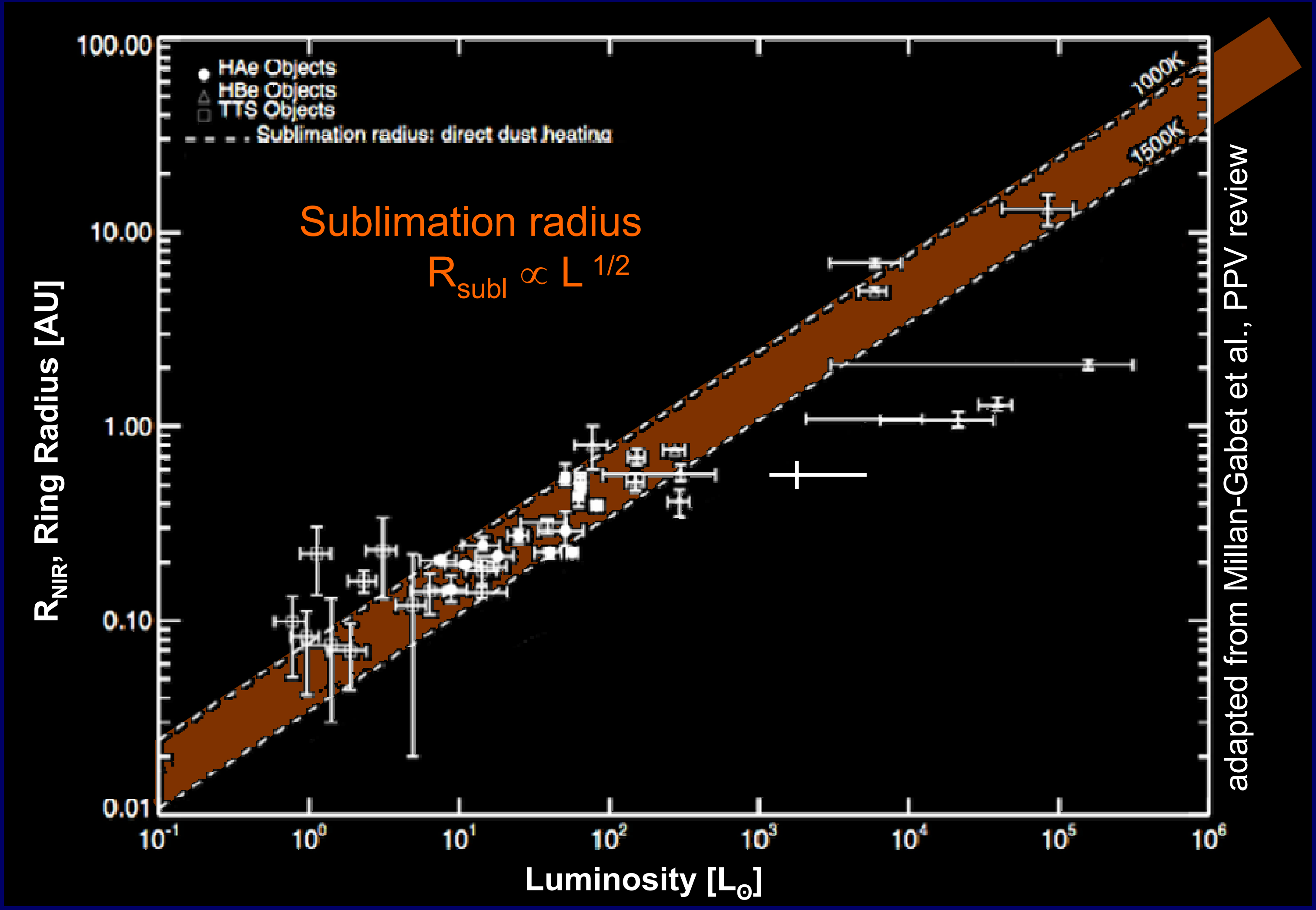


Model view from above

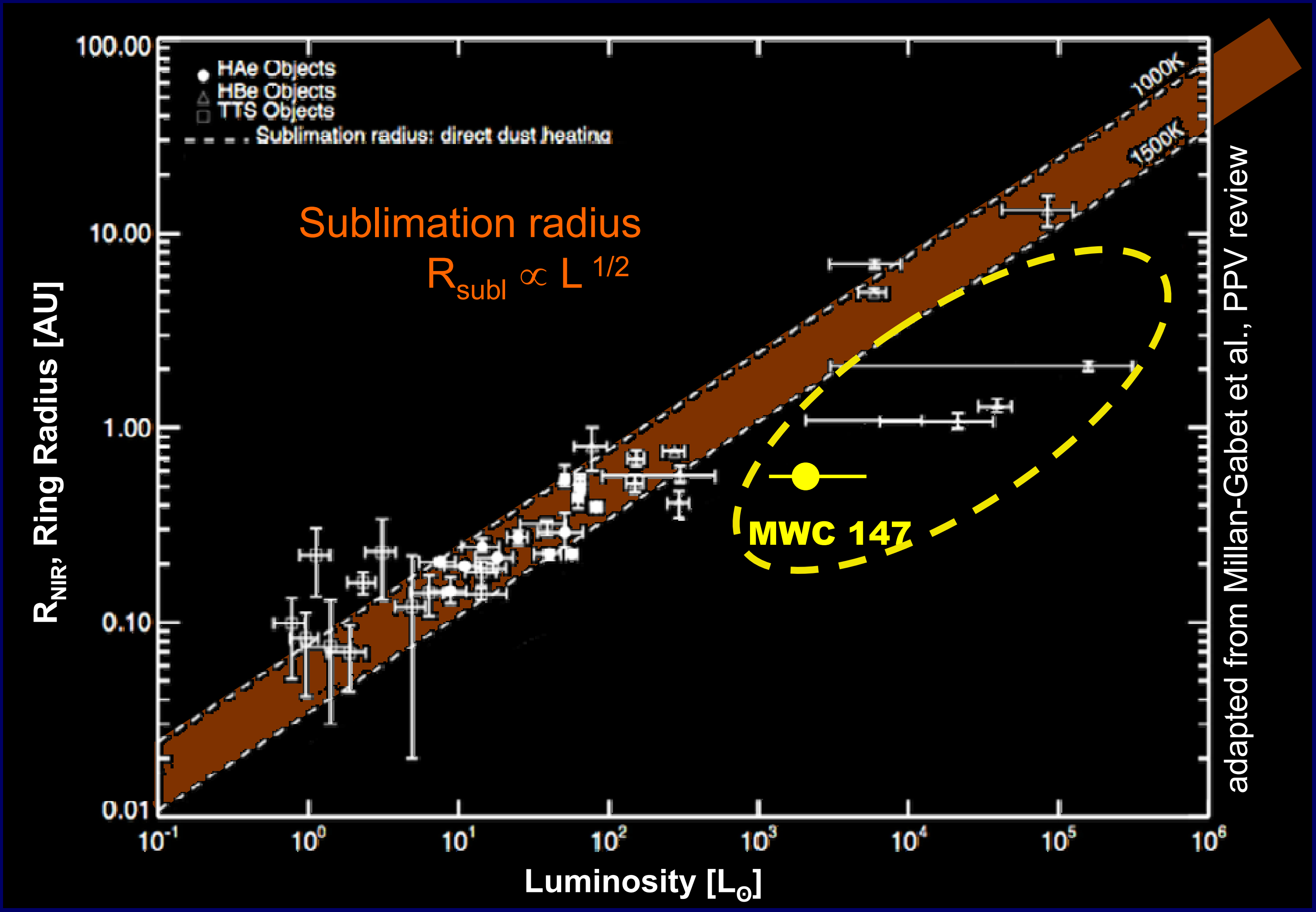


→ looks like a simple ring

Simple geometric ring-model fits to (single) visibility measurements → ring radii



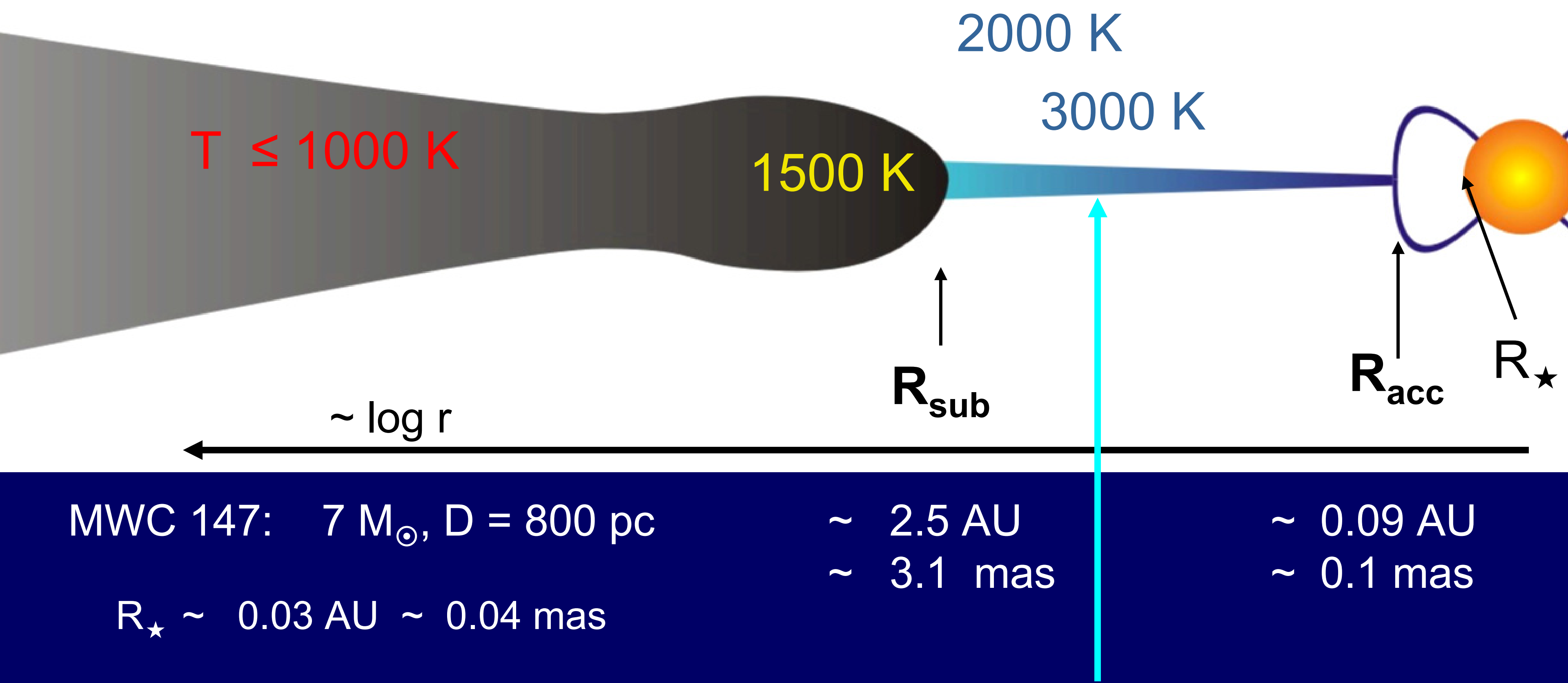
In most objects, the ring model radii agree well with the expected dust sublimation radii



Some intermediate / high - mass objects deviate from the relation

A closer look at the inner disk regions

Fraction of accretion energy released: 2% | 32% | 66%



MWC 147: 7 $M_\odot$, D = 800 pc

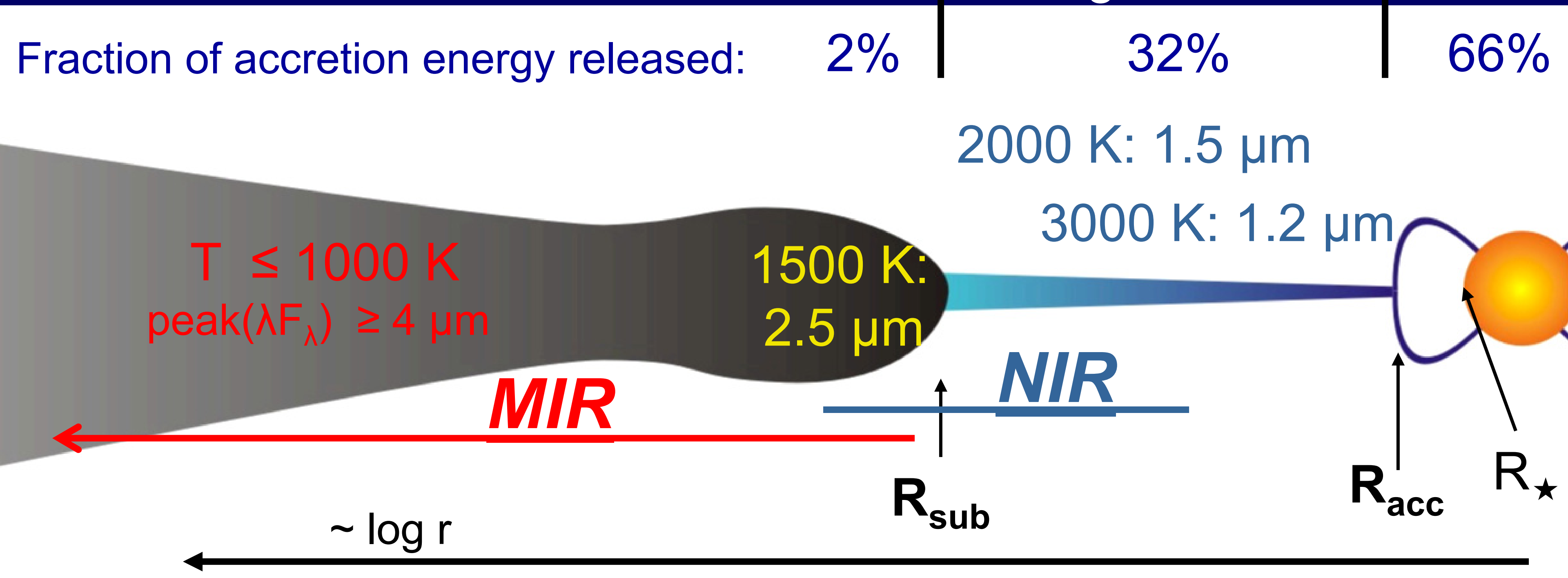
~ 2.5 AU
~ 3.1 mas

~ 0.09 AU
~ 0.1 mas

$R_\star$ ~ 0.03 AU ~ 0.04 mas

Gas disk produces near-infrared emission

A closer look at the inner disk regions



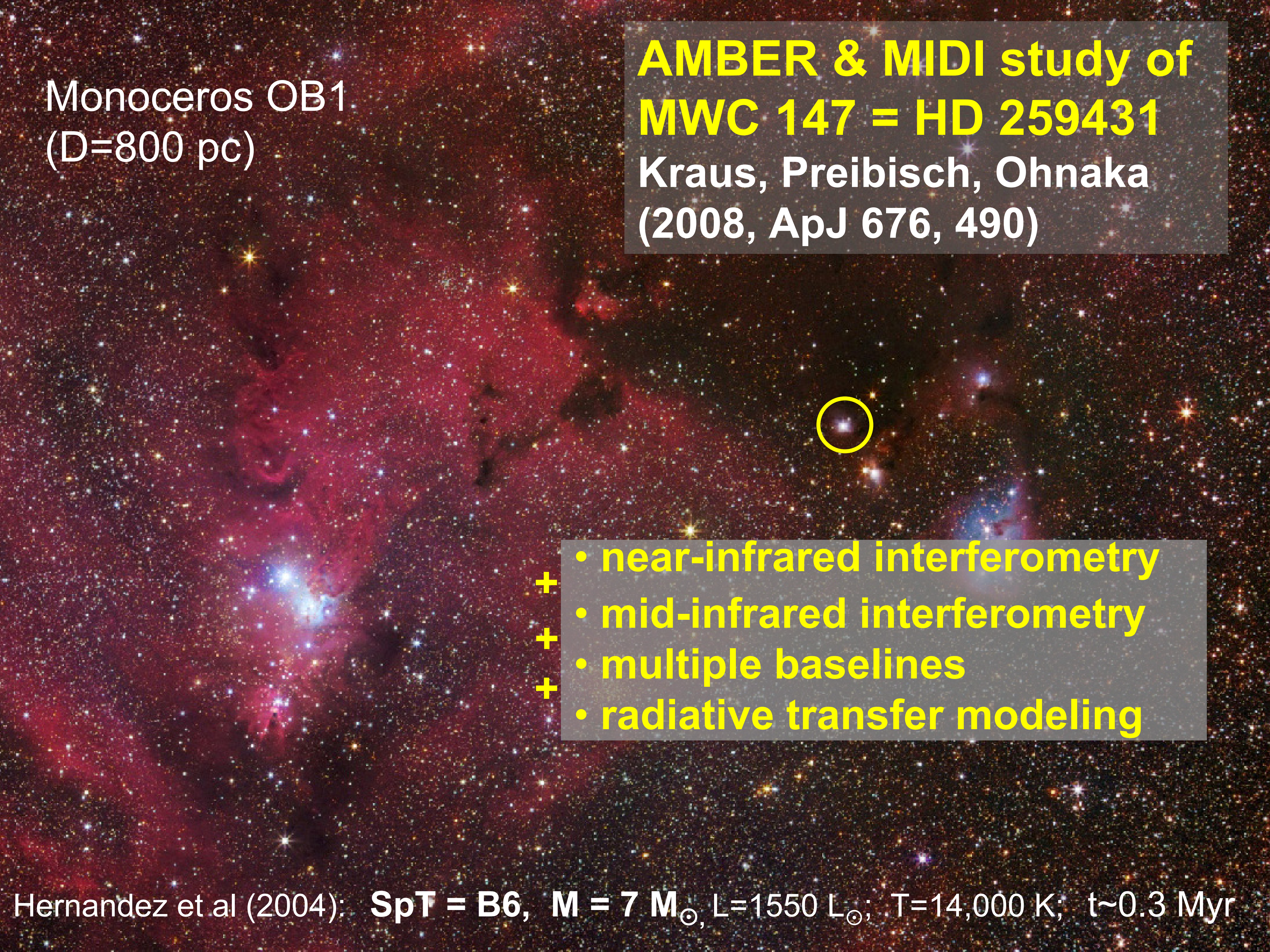
Emission from dust disk predominantly at $\lambda \geq 2.5$ µm

→ **Combination** **of** **near- + mid-infrared** **data** is important for the determination of physical conditions in the inner disk,

e.g. radial temperature profile

AMBER & MIDI study of MWC 147 = HD 259431

Kraus, Preibisch, Ohnaka (2008, ApJ 676, 490)

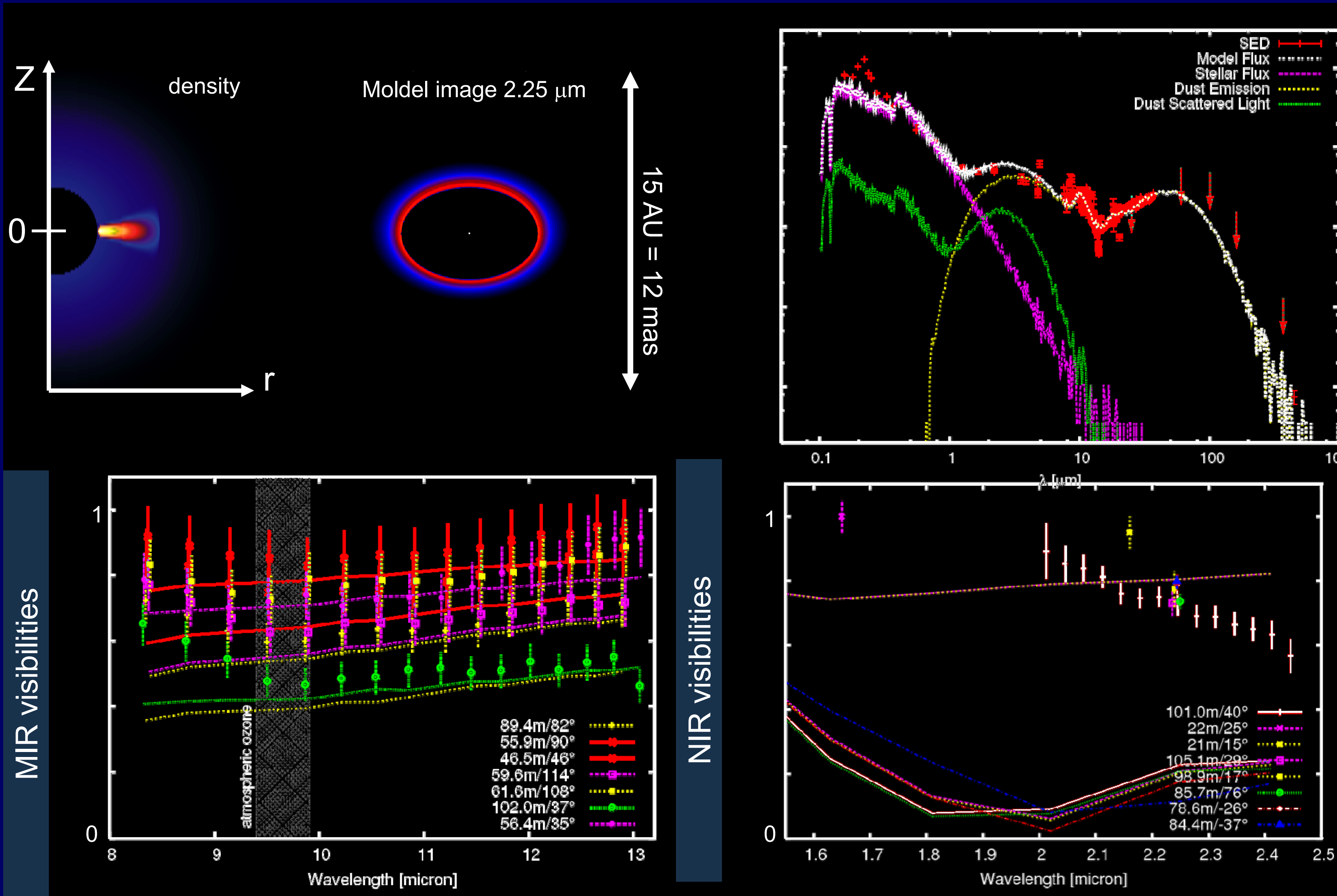


- **near-infrared interferometry**
- \+ **mid-infrared interferometry**
- \+ **multiple baselines**
- \+ **radiative transfer modeling**

Hernandez et al (2004): **SpT = B6, M = 7 $M_\odot$**, L=1550 $L_\odot$; T=14,000 K; t~0.3 Myr

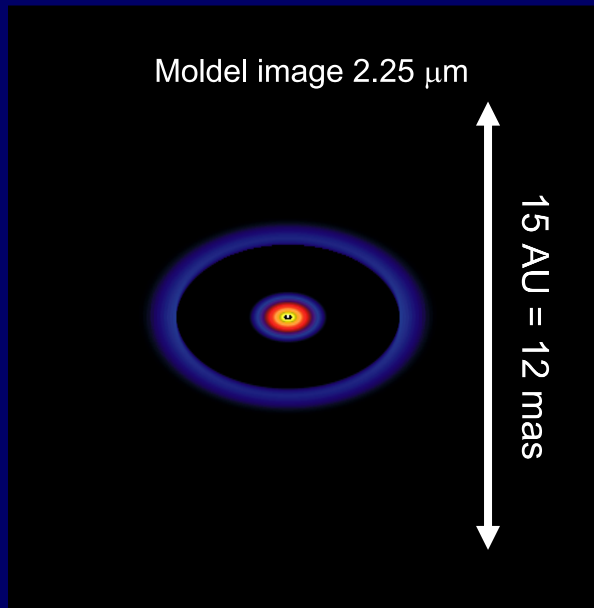
Dusty circumstellar disk model

$\chi_r^2 = 42$

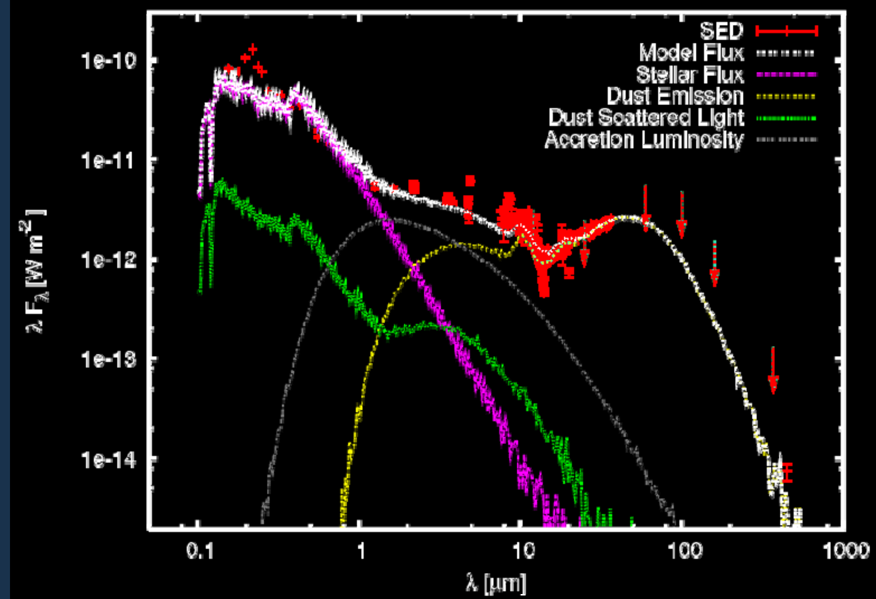


Dusty disk + inner gas disk: $\chi_r^2 = 1.28$

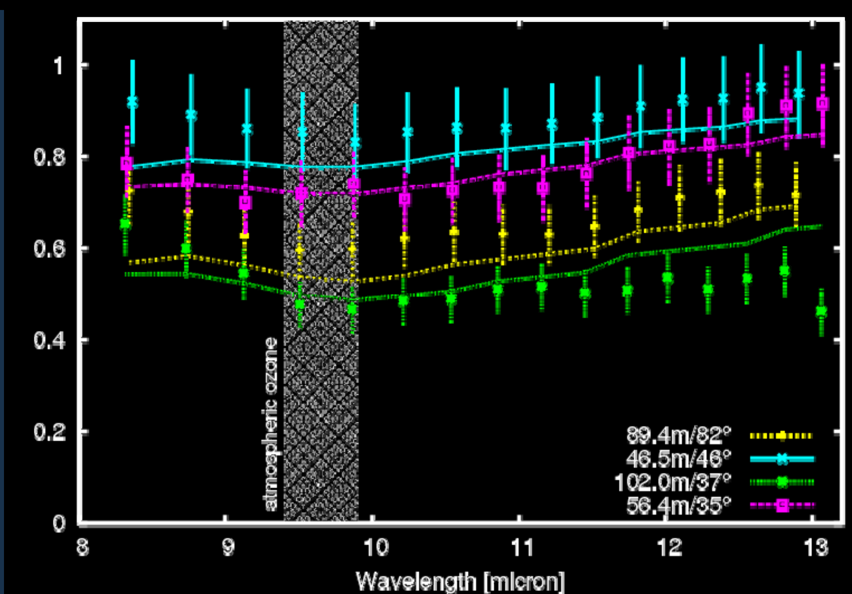
Inclination: 60°, $\dot{M}_{acc} = 9\times10^{-6}\ M_\odot/yr$



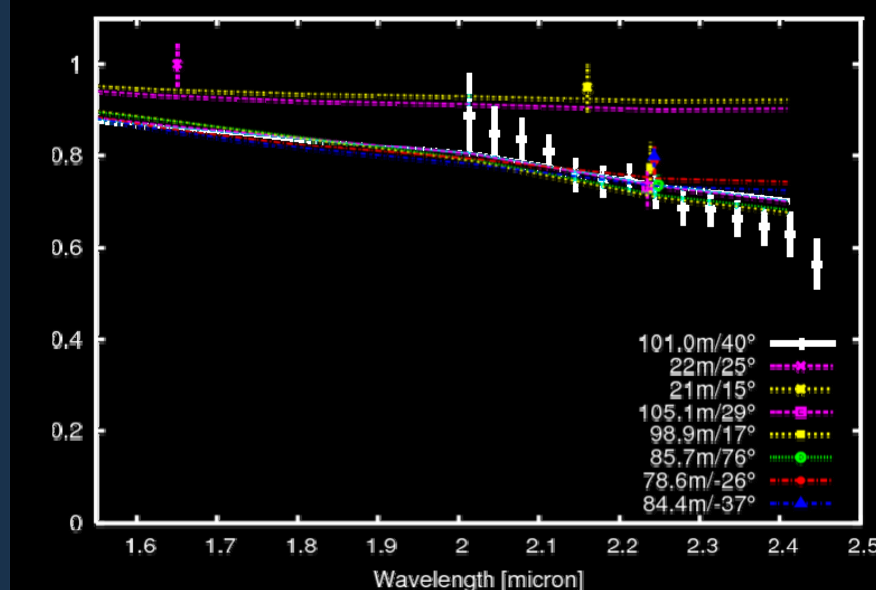
SED



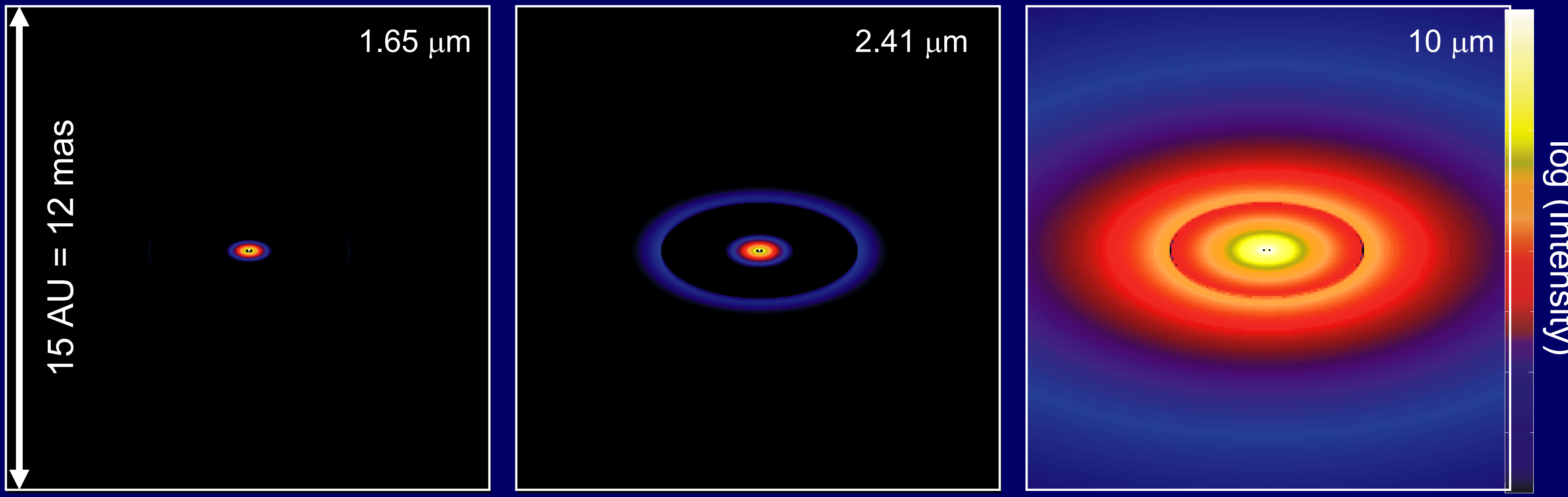
MIR visibilities



NIR visibilities



Best-fit radiative transfer model images



NIR emission mainly from hot inner gas disk

MIR emission also from warm dust disk

Applications 1: gas luminosity $\propto$ accretion rate

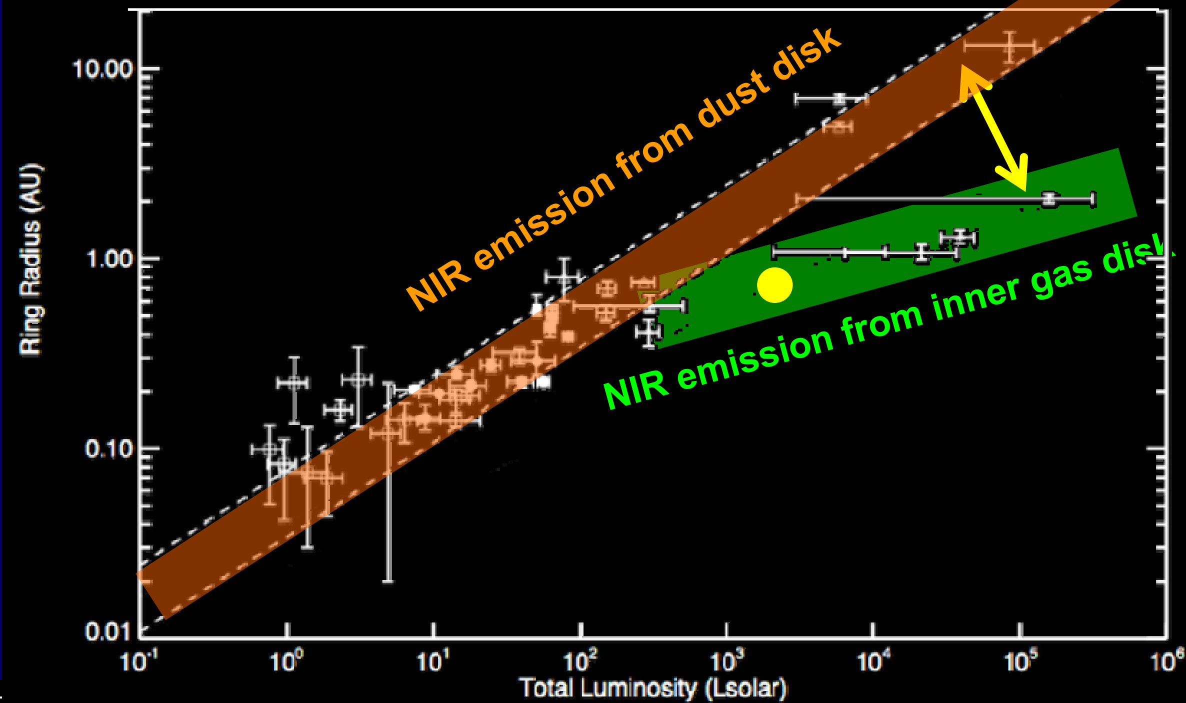
$\rightarrow$ $dM/dt = 6 \cdot 10^{-6}\ M_{\odot}/yr$

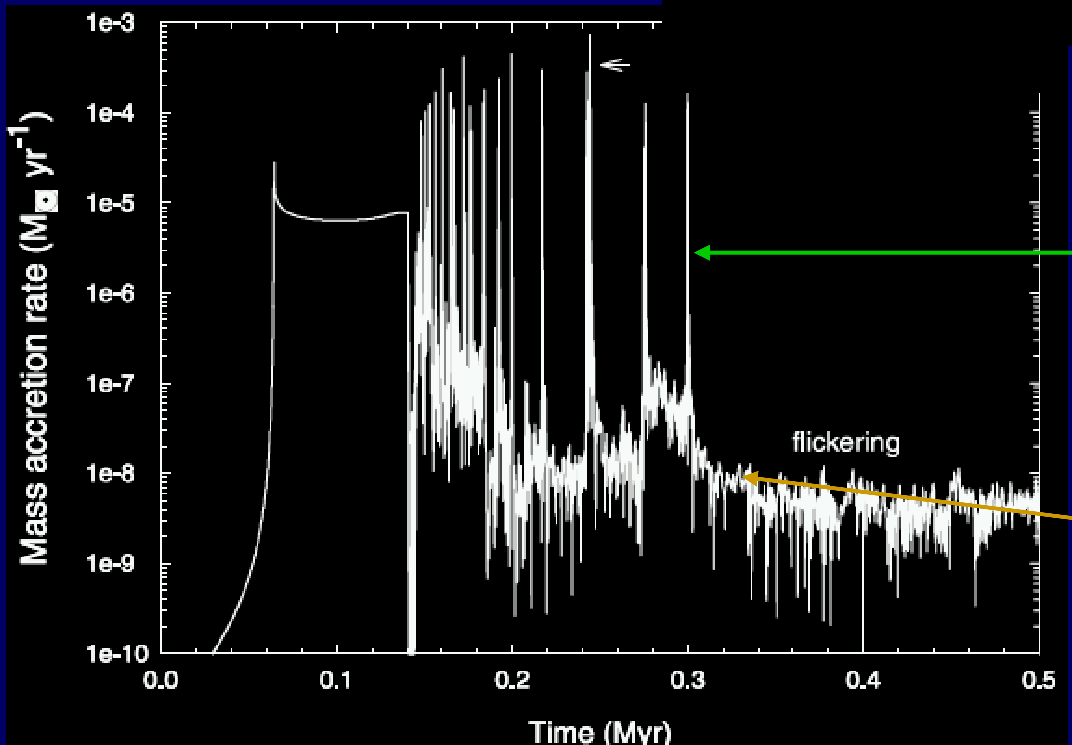
Applications 2:

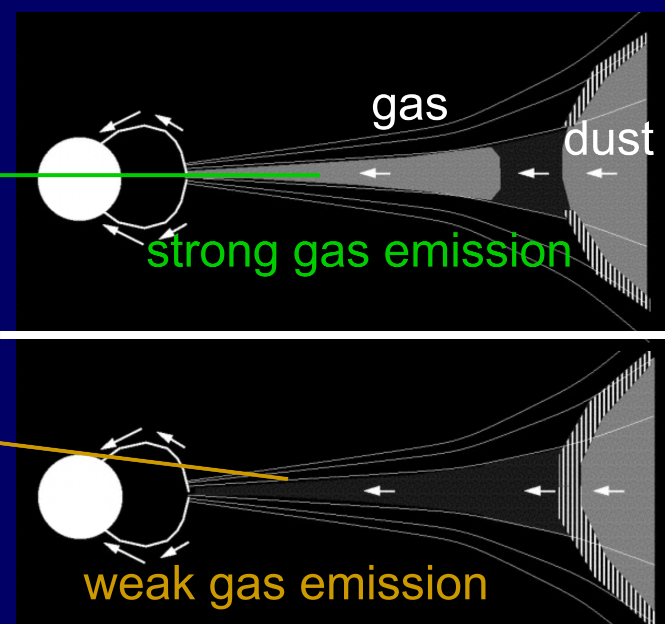
Variations in accretion rate

→ variations in strength of gas emission

→ variations in sizes measured by infrared interferometry



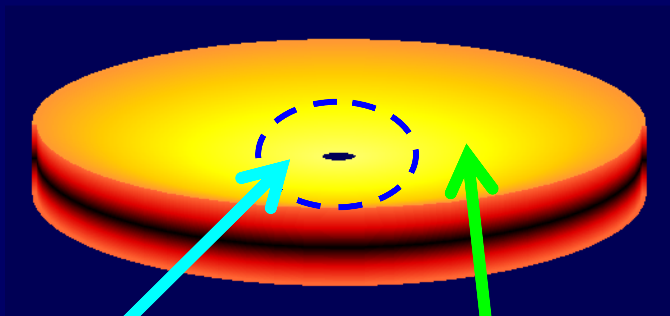




Muzerolle et al. 2004

Applications 3:

Spatially resolved spectroscopy of gas accretion disks



inner part
φ < λ/B
unresolved

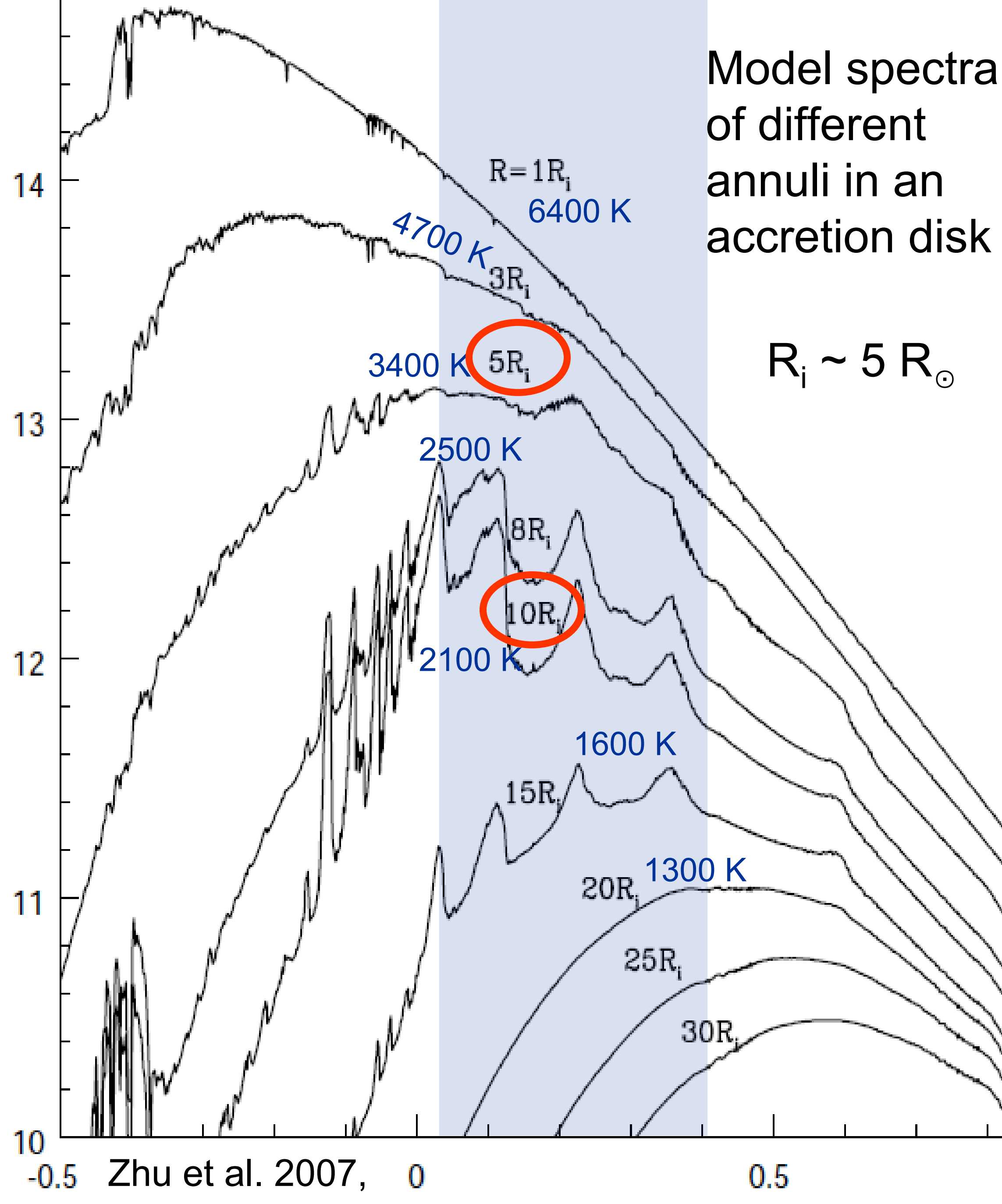
outer part
φ > λ/B
resolved

$F_\lambda(\text{in}) \sim F_\lambda(\text{tot}) \times V_\lambda$

$F_\lambda(\text{out}) = F_\lambda(\text{tot}) - F_\lambda(\text{in})$

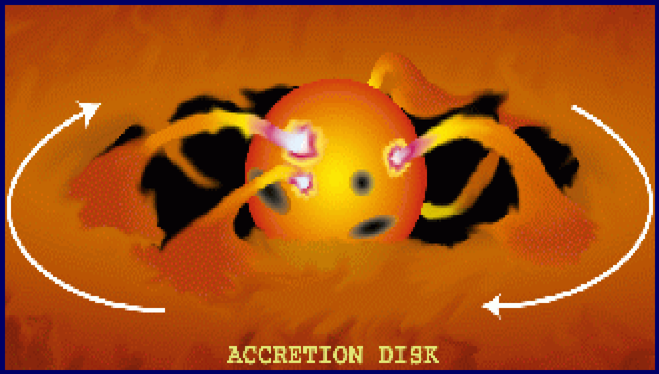
φ = 1 mas ~ 4 R_i at 140 pc

φ = 1 mas ~ 12 R_i at 500 pc



Zhu et al. 2007, ApJ 669, 487

Is Brγ emission a good accretion tracer ?



$R_{acc} \sim 3\, R_\star \;\leq 0.2$ mas

for D ≥ 500 pc

For low / intermediate mass stars ($\leq 4\, M_\odot$), Brγ emission is often assumed to originate from accretion funnels: → $L_{acc} \propto L_{Br\gamma}^{0.9}$

If true, Brγ emission should be *unresolved* .

Spectro-Interferometry with R > 1000
→ measure size of line emission regions

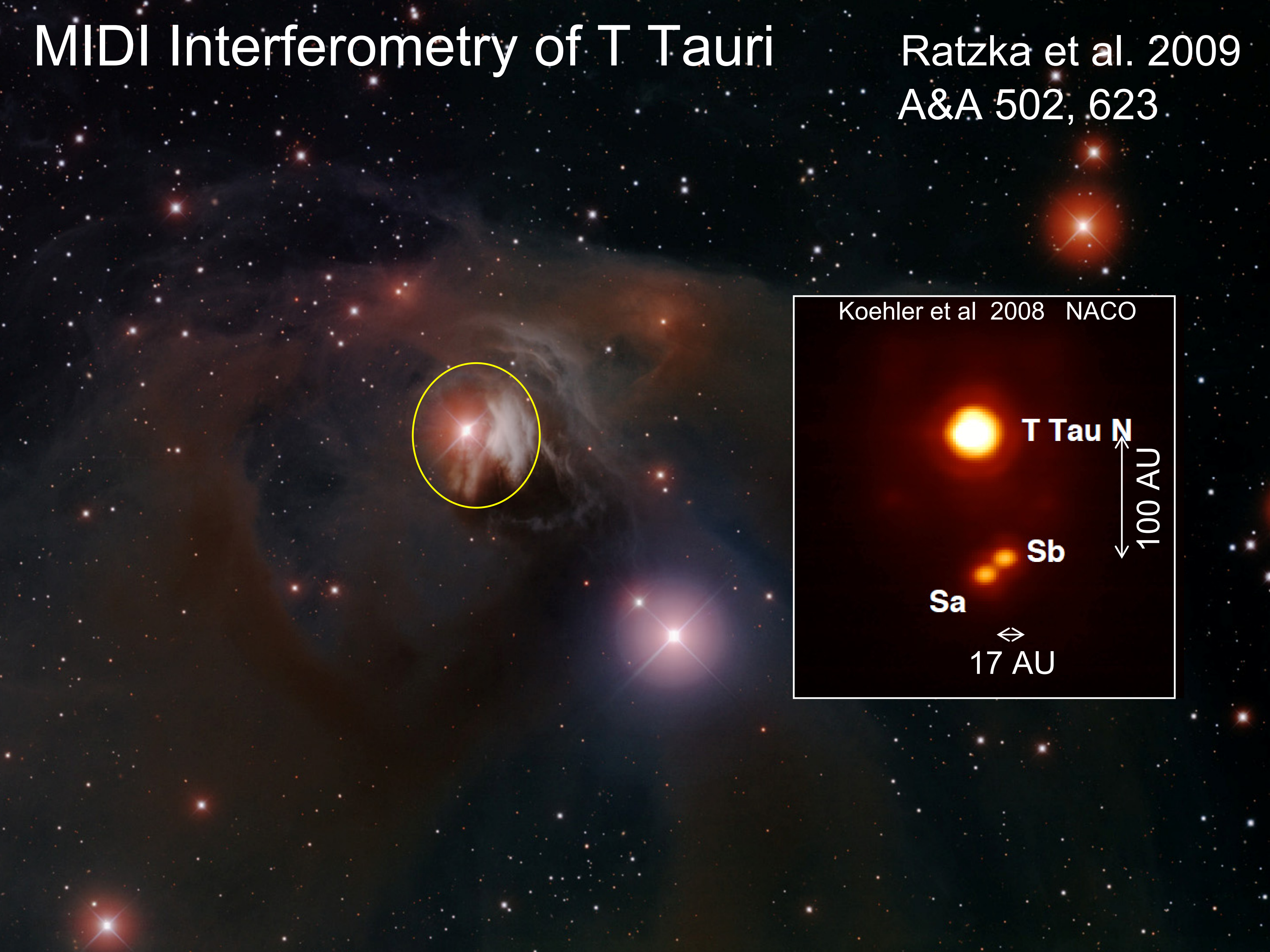
See Talk by Stefan Kraus on Thursday

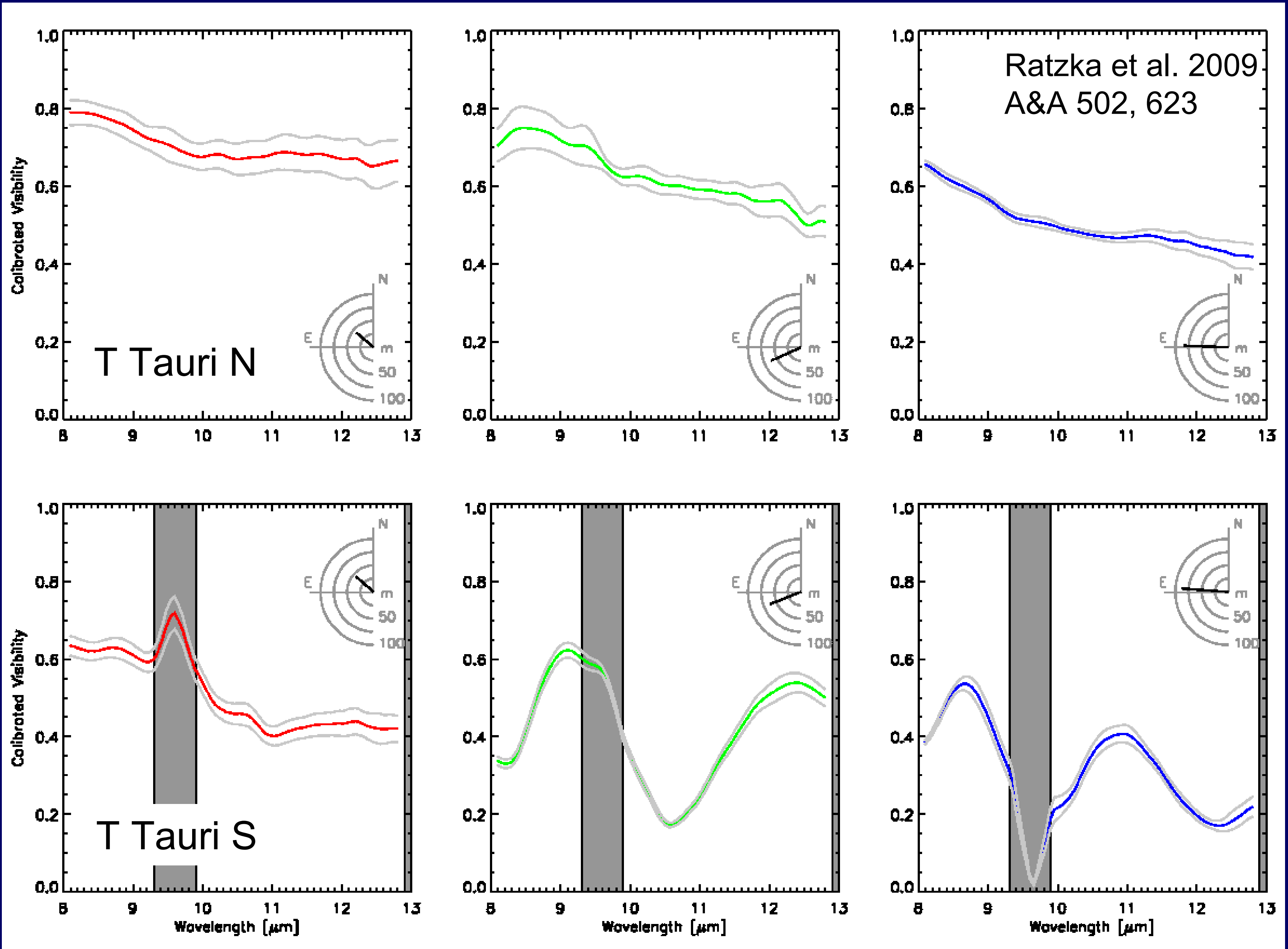
Result: In only two out of 5 objects the Brγ emission zone is compact enough to be related to accretion funnels.

Kraus et al., 2008, A&A 489, 1157

MIDI Interferometry of T Tauri

Ratzka et al. 2009
A&A 502, 623

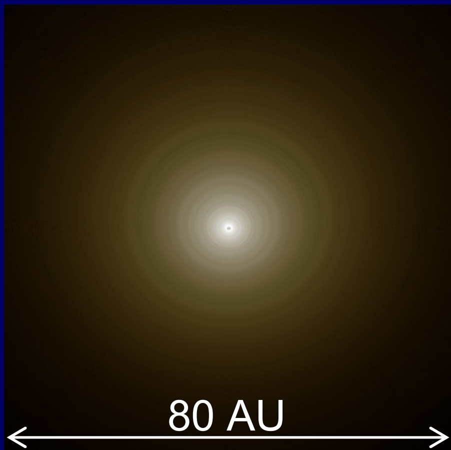




Binary Sa-Sb: r, PA = 125.9 ± 2.9 mas, 301.4 ± 4.5°

T Tau N

G5



$M_* = 2.1\ M_\odot$

$M_d = 0.04\ M_\odot$

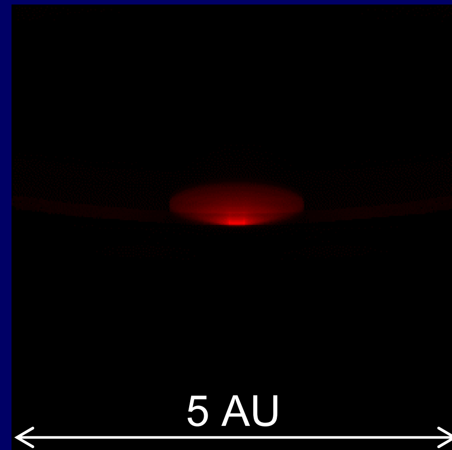
$r_d = 80$ AU

$i < 30^o$

$dM/dt = 3 \cdot 10^{-8}\ M_\odot/yr$

T Tau Sa

A3e



$M_* = 2.4\ M_\odot$

$M_d = 0.003\ M_\odot$

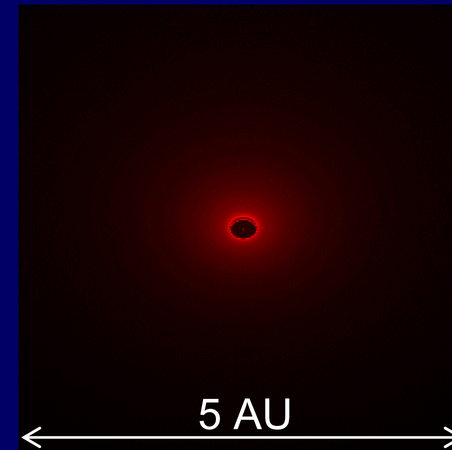
$r_d = 5$ AU

$i \sim 72^o$ τ_v(l.o.s) ~ 15

$dM/dt = 1 \cdot 10^{-8}\ M_\odot/yr$

T Tau Sb

M1



$M_* = 0.4\ M_\odot$

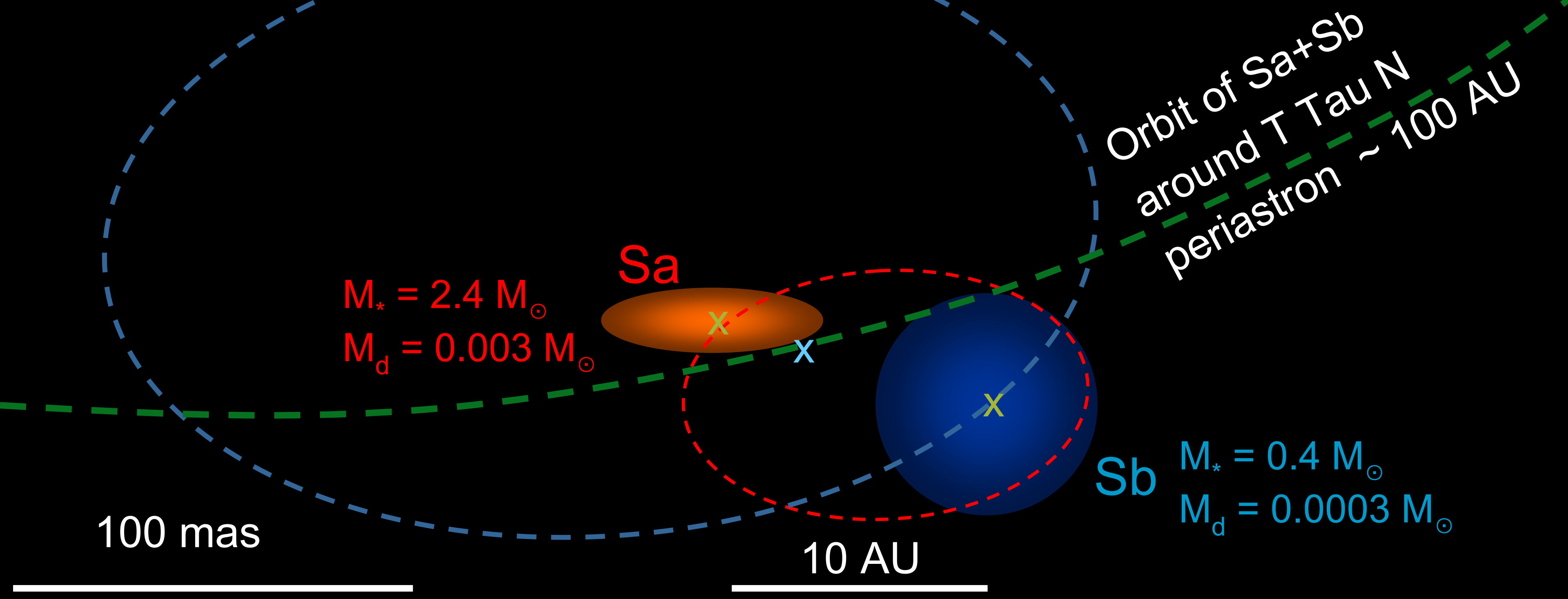
$M_d = 0.0003\ M_\odot$

$r_d = 5$ AU

$i < 60^o$

$dM/dt = 1 \cdot 10^{-7}\ M_\odot/yr$

Ratzka et al. 2009, A&A 502, 623



- Orbit Sa – Sb: **periastron distance ~ 10 AU, disk radii ~ 5 AU**:

  → **strong tidal interactions**

- **Disk planes of Sa and Sb are tilted by > 45 degrees**

- Warning: for D > 1 kpc, Sa-Sb would remain unresolved

THE END