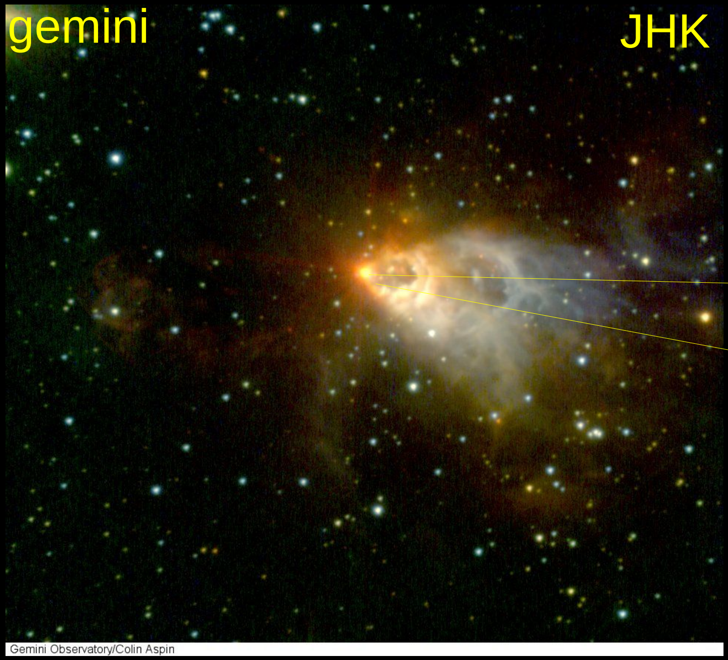
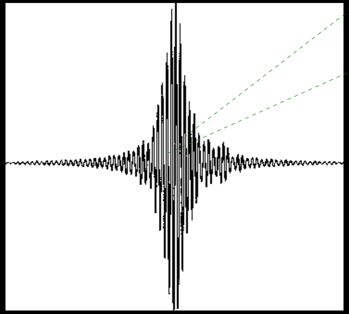
MIDI's view on Massive Young Stellar Objects





Willem-Jan de Wit (ESO)
Melvin Hoare (Leeds)
Izaskun Jimenez-Serra (CfA)
Dieter Nuernberger (ESO)
Rene Oudmaijer (Leeds)
Hugh Wheelwright (MPIfR)

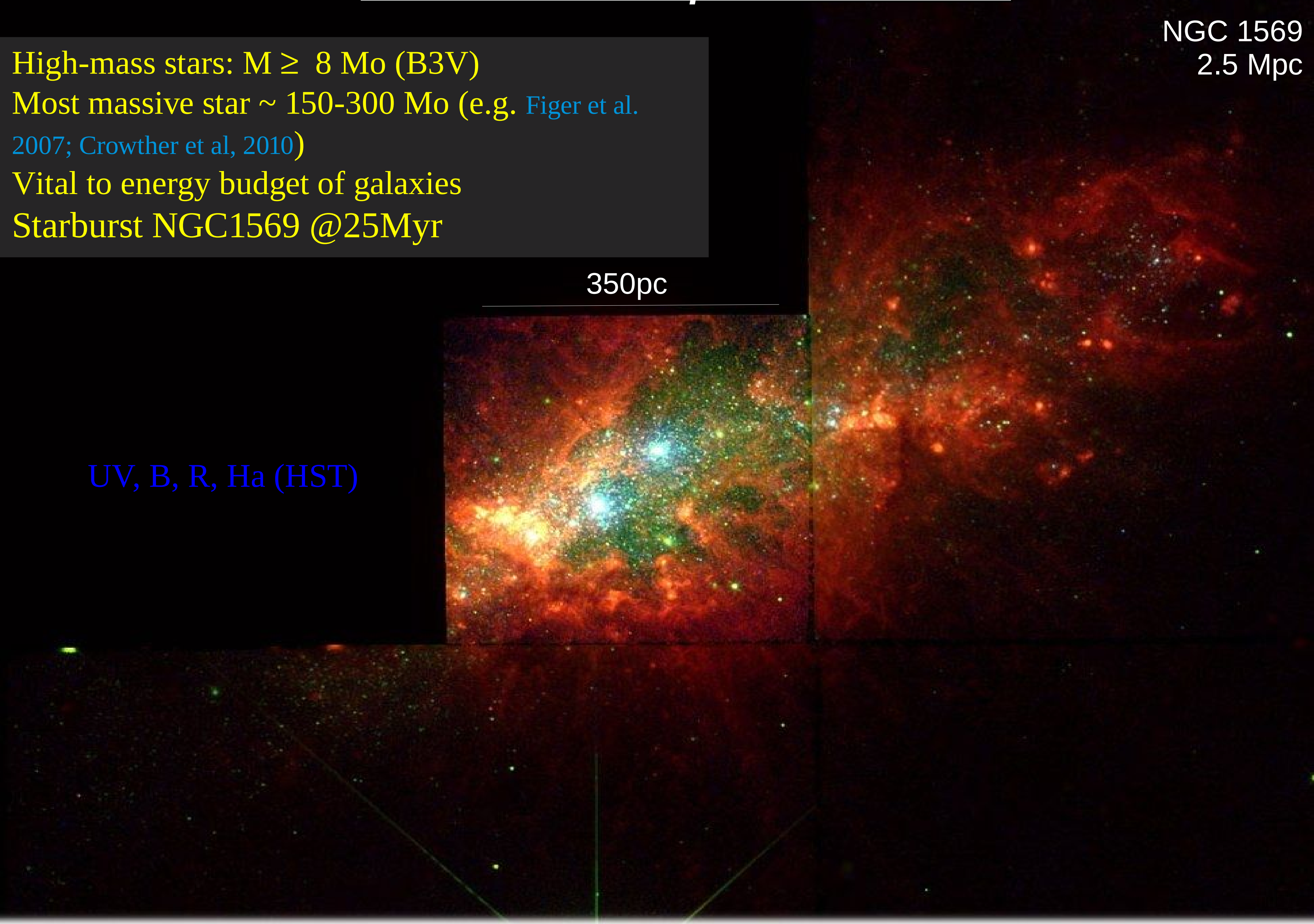
Extra-Galactic Super star clusters

High-mass stars: M ≥ 8 Mo (B3V)

Most massive star ~ 150-300 Mo (e.g. Figer et al. 2007; Crowther et al, 2010)

Vital to energy budget of galaxies

Starburst NGC1569 @25Myr

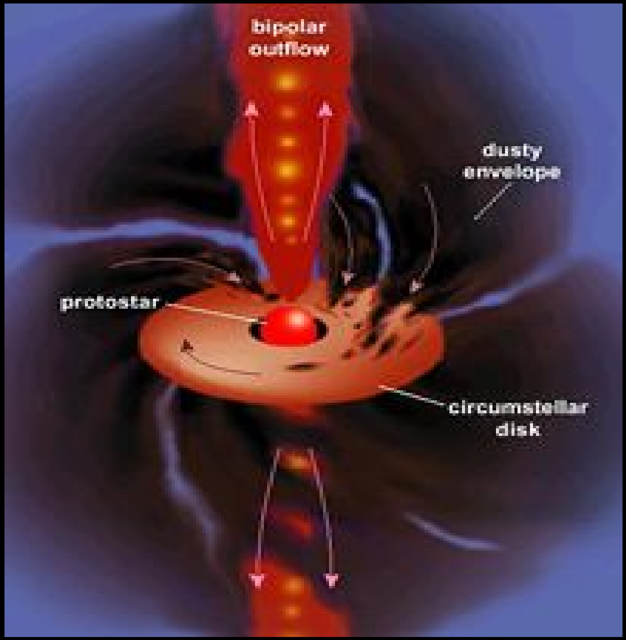


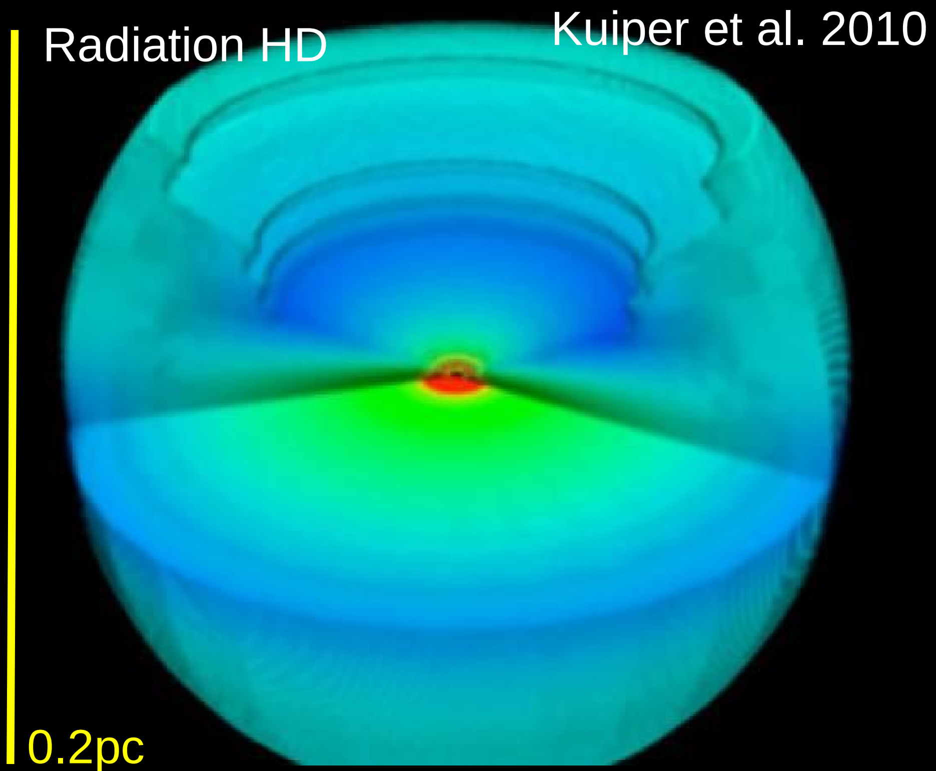
Envelopes, disks, and outflows in MYSOs

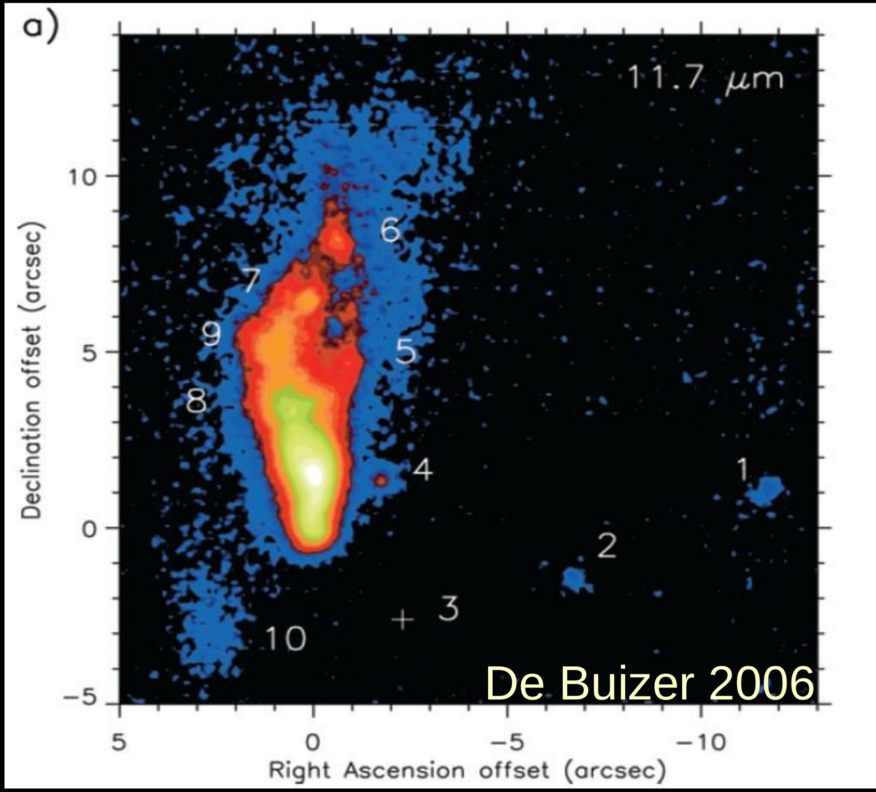
Banerjee & Pudritz (2007):
- 3D magnatized collapse of BEs
- "outflow cavities are carved out of the collapsing cloud very early"
- Outflows reduce P_{rad} (see also Krumholz et al. 2005)

Kuiper et al. (2010):
- $480 M_{O}$ core => $137 M_{O}$ star
- $M_{acc} = 10^{-2}\ M_{O}$/yr (peak)

Beuther et al. (2002); Lopez-Sepulcre et al. (2009):
- Outflows are common in high-mass SF regions

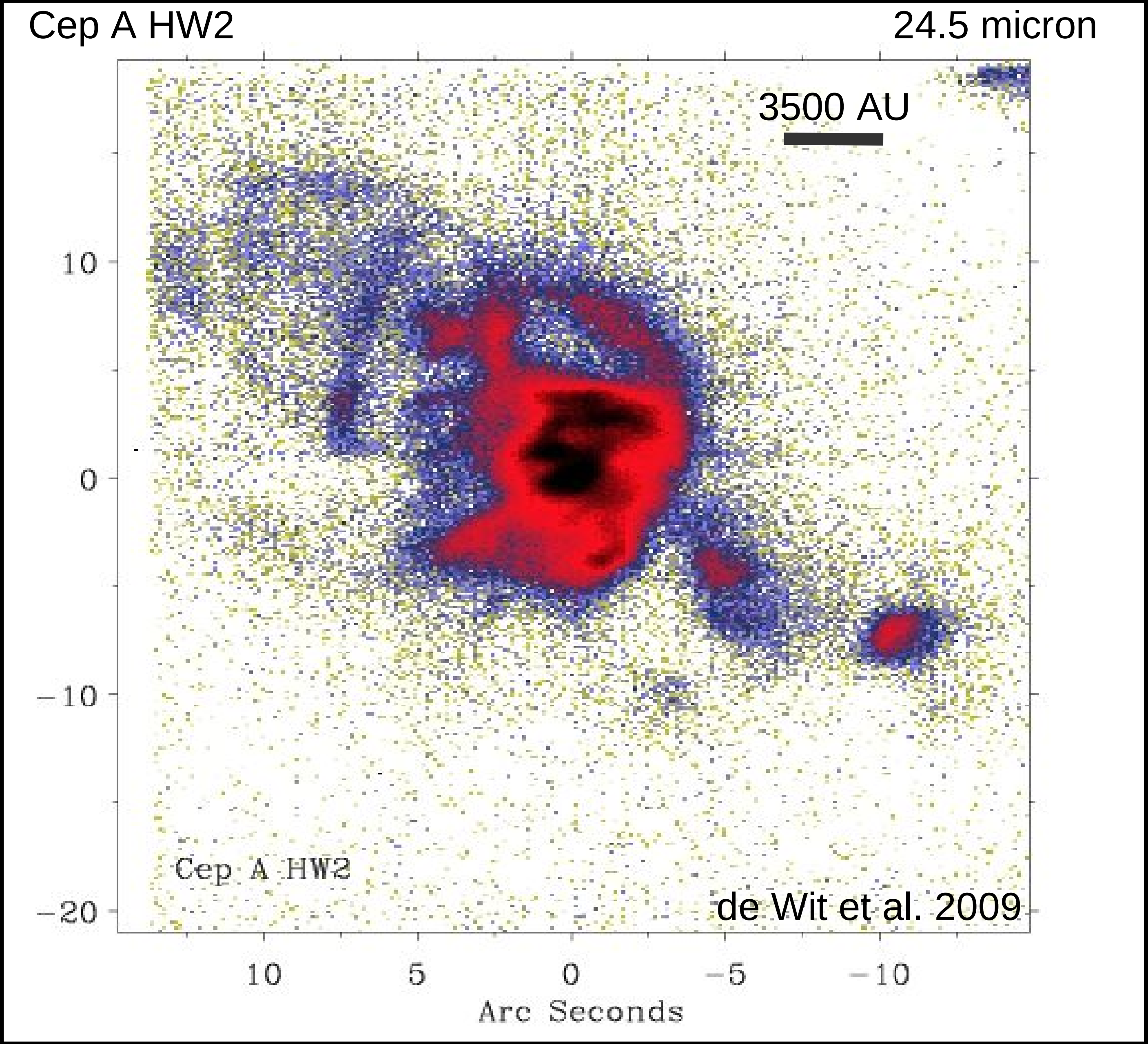






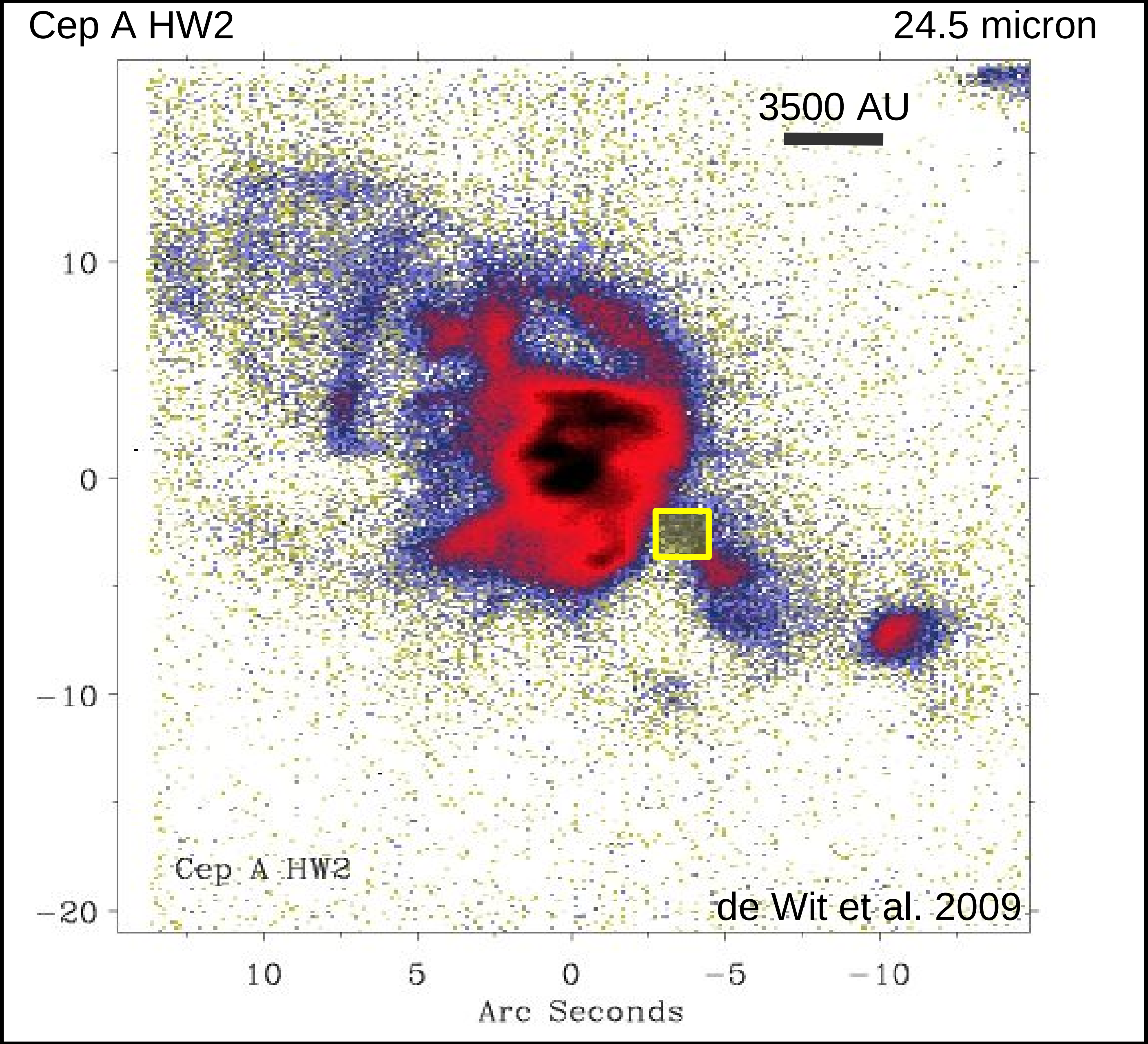
Outflow cavities in MYSOs

MID-IR



Outflow cavities in MYSOs

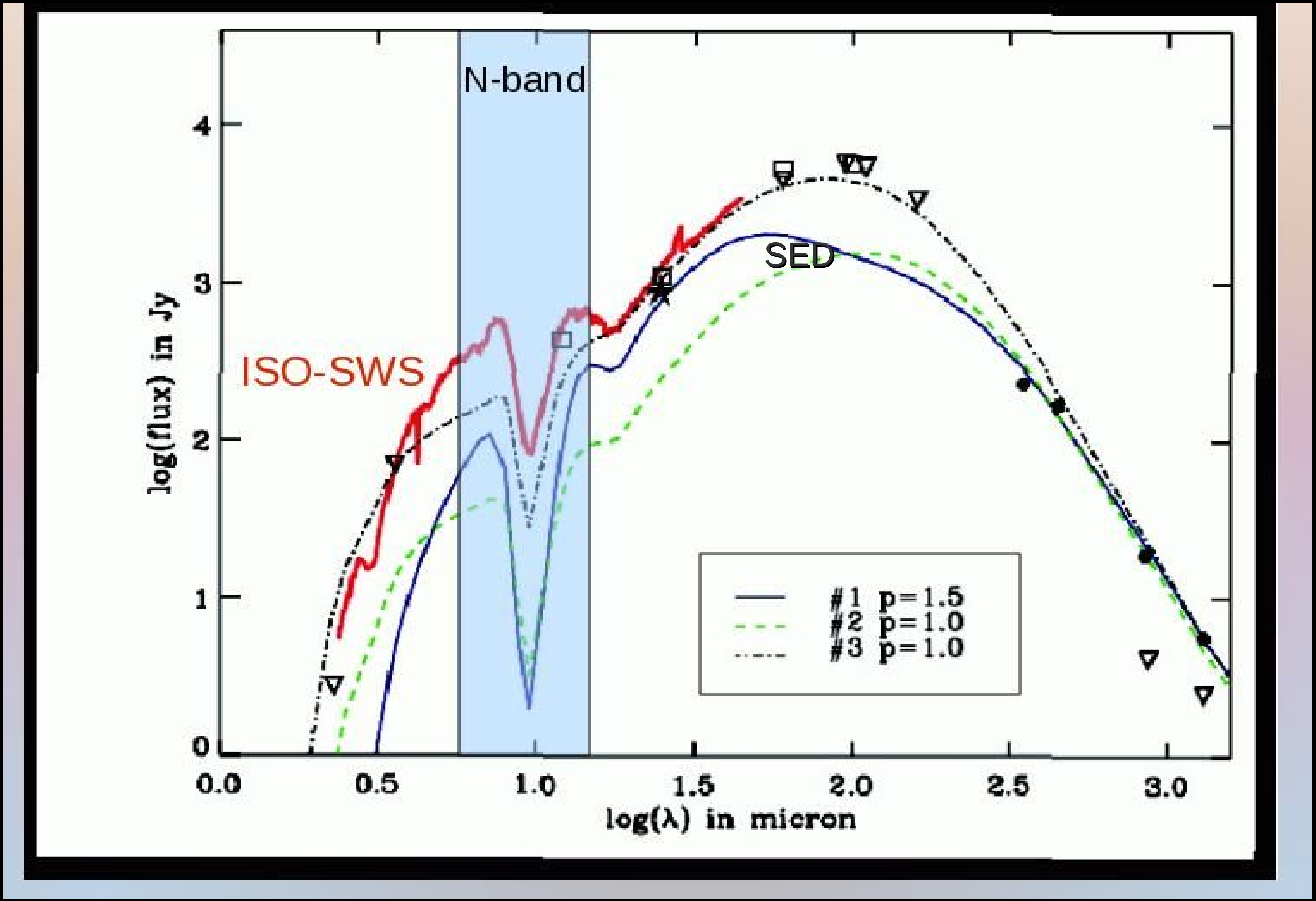
MID-IR



Observational properties of MYSOs

MYSO: luminous (L>10^4 L$_0$), embedded IR source which shows signs of ongoing mass accretion (i.e. molecular outflows, lack of HII region: Walmsley 1995; Dale & Bonnell 2011)

10 micron: generally spatially unresolved (e.g. Mottram et al. 2007)



2D-axisymmetric dust RT code for YSOs

by Whitney et al. 03 [see also Robitaille et al. 06]

input | output

- Proto-stellar envelope
  - TSC (rotating and collapsing)
  - Outflow cavities (paraboloidal)
- Dust disk
  - includes alpha-type accretion
  - flared structure

- Spectral Energy Distribution
  - for 10 inclinations
  - per "geometrical" element
- Images
  - for given inclination
  - for any wavelength/filter

geometry example

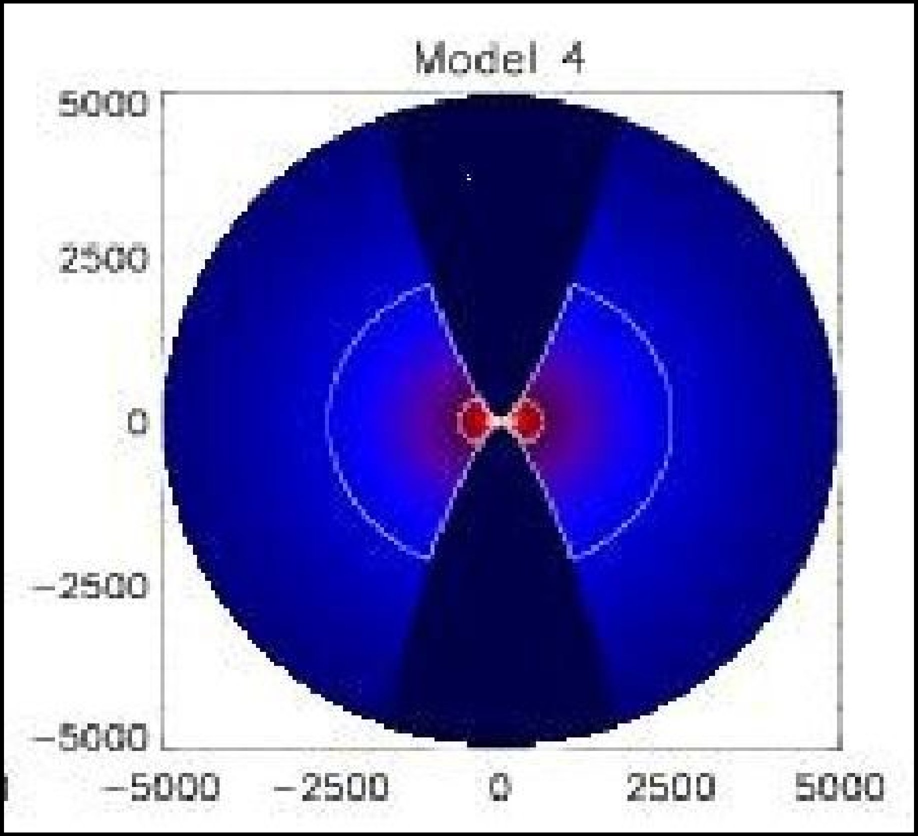
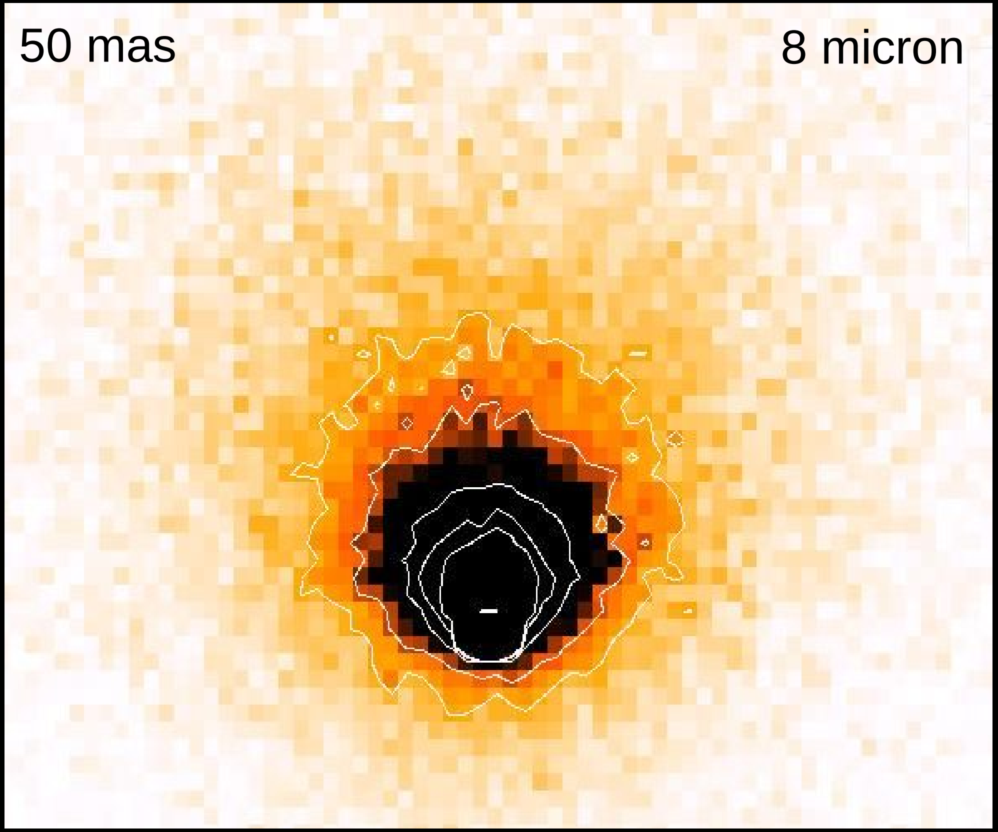


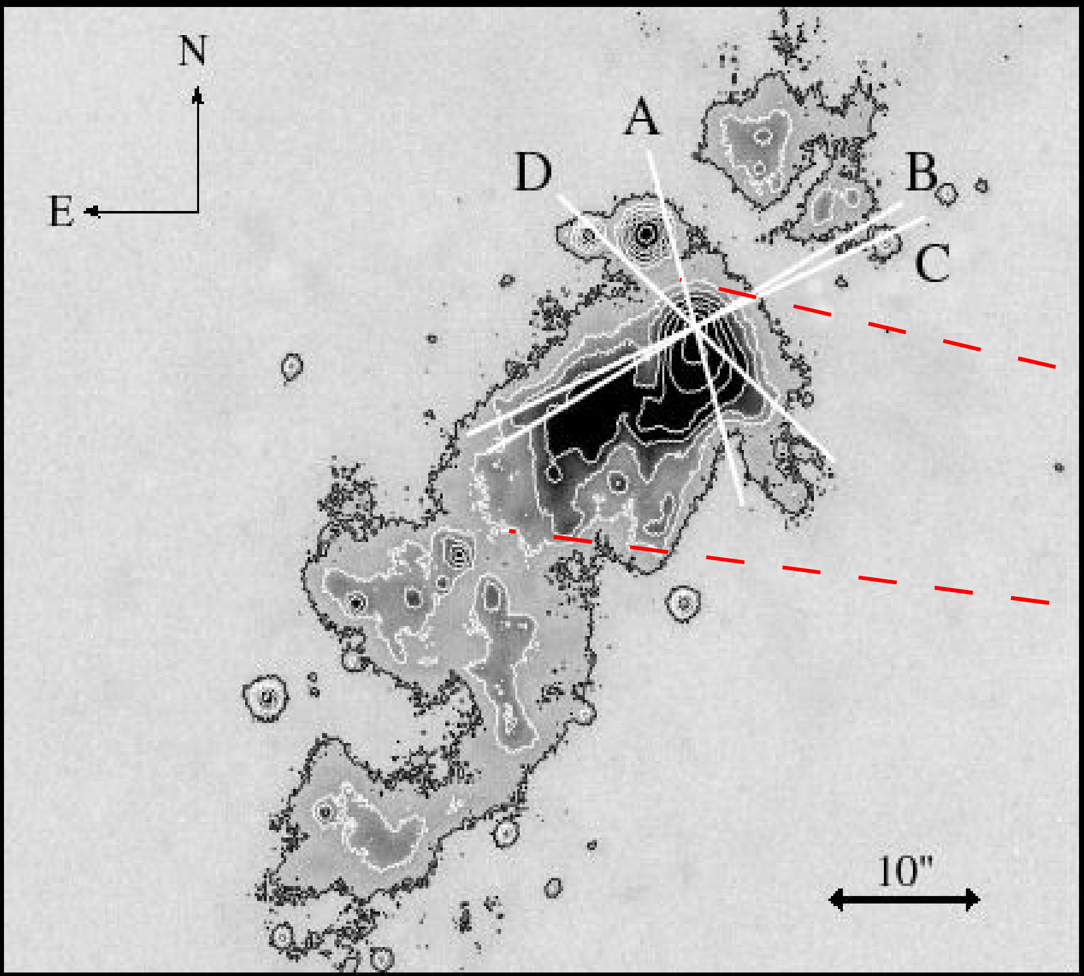
image example

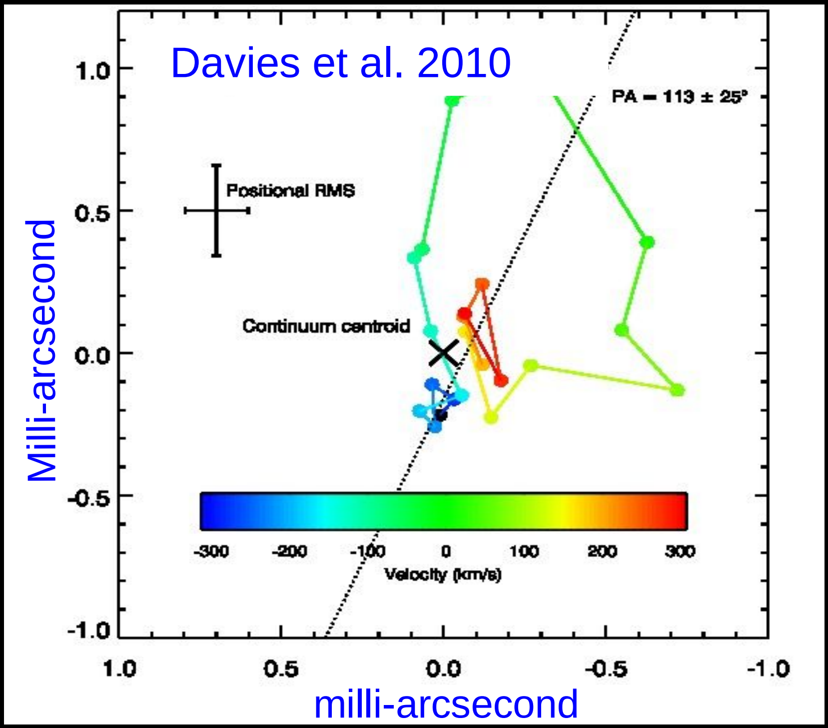


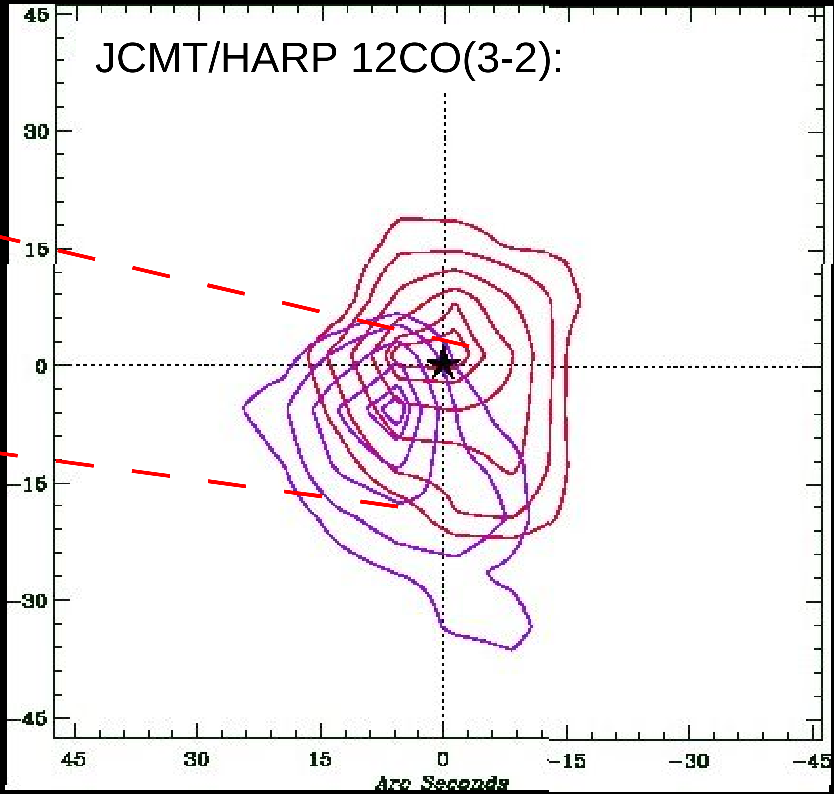
CASE: W33A -- jets and outflows

- $L = 10^5 L_o$
- D_{kin} = 3.8 kpc
- Weak, compact 2cm emission (Rengarajan & Ho 1996)
- Broad single peaked HI emission (Bunn et al. 1995)
- Fast bipolar jet (Br γ) (Davies et al. 2010)

K-band (UKIDSS), VLTI baselines:

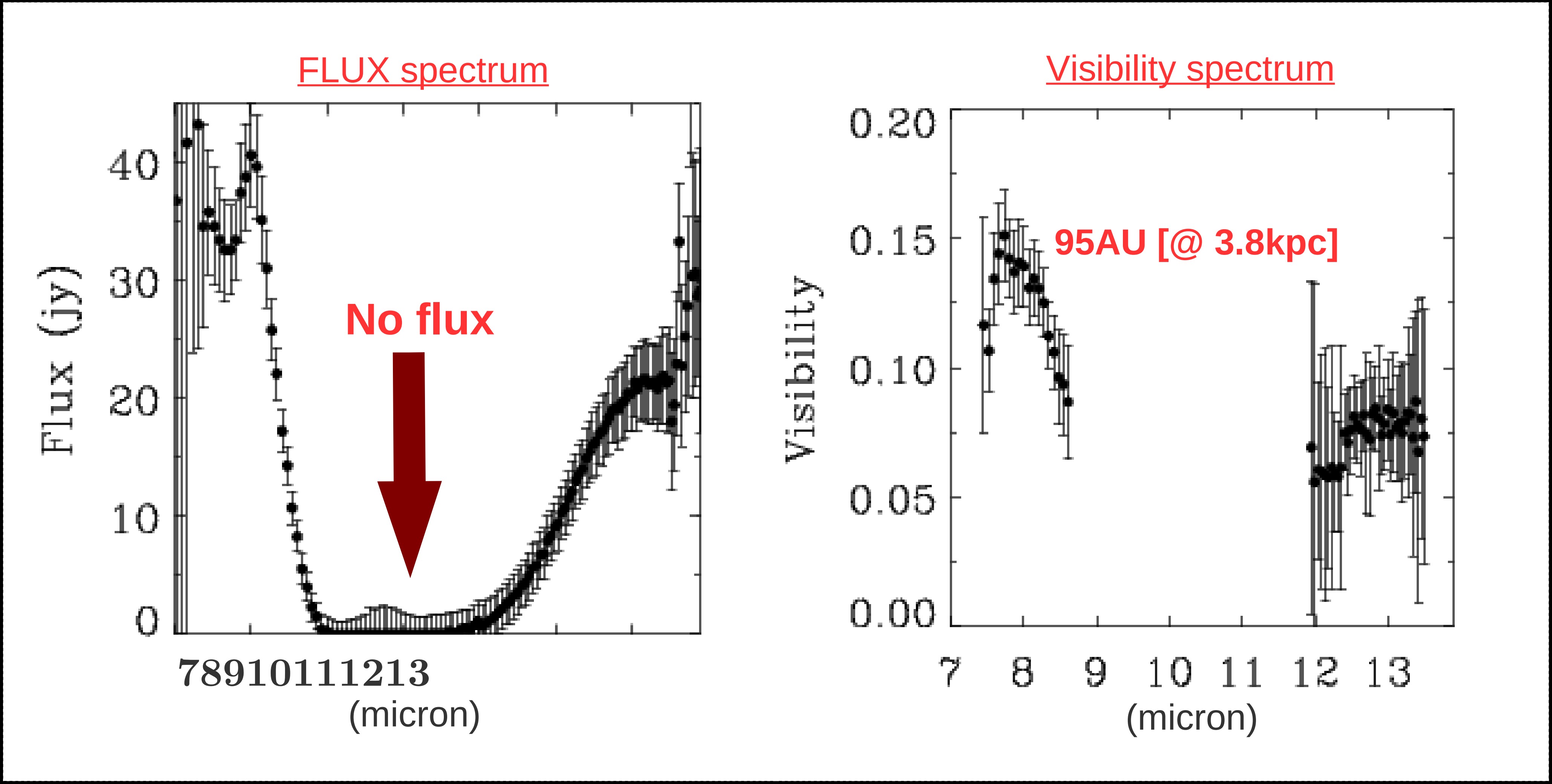




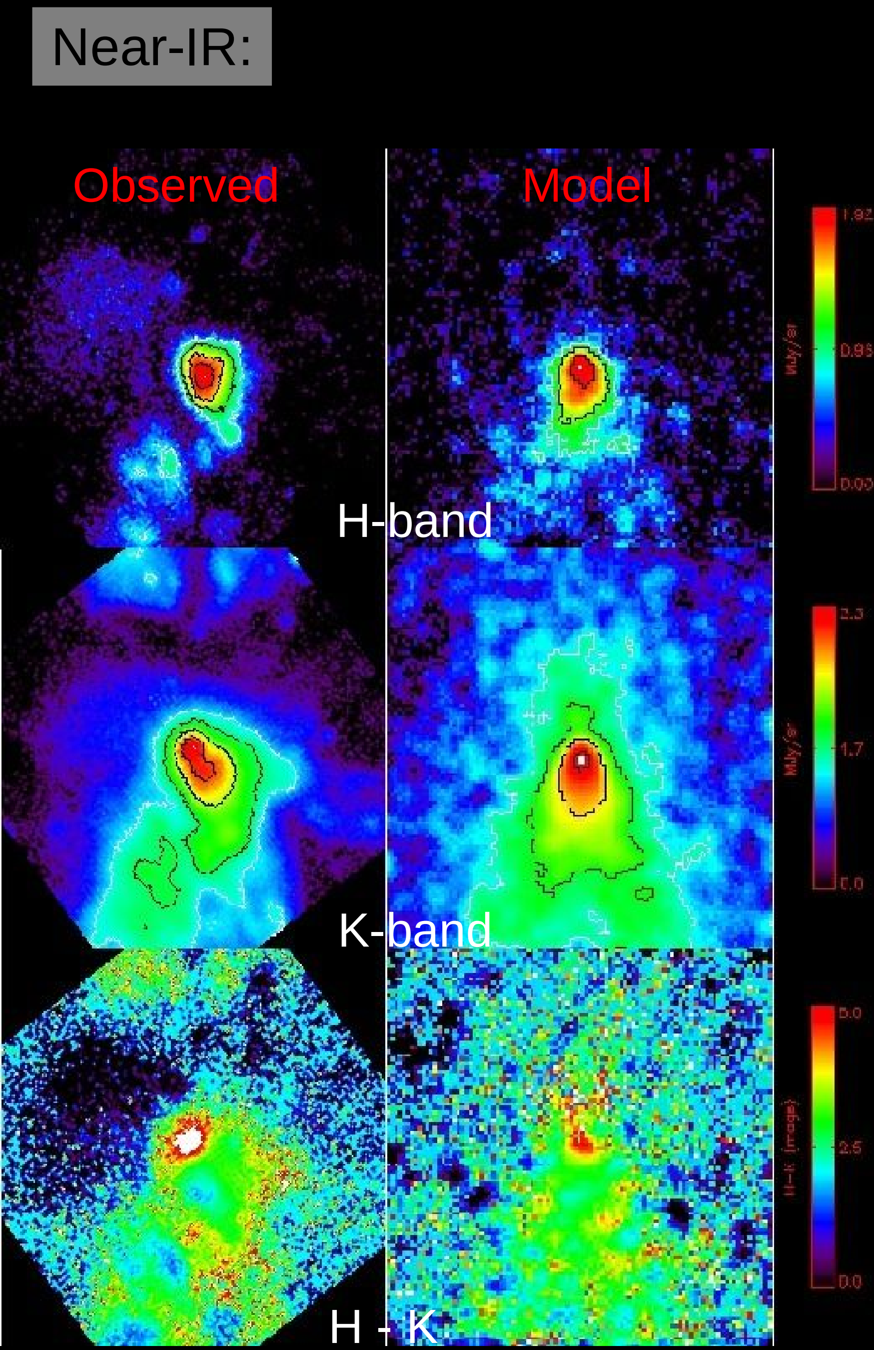


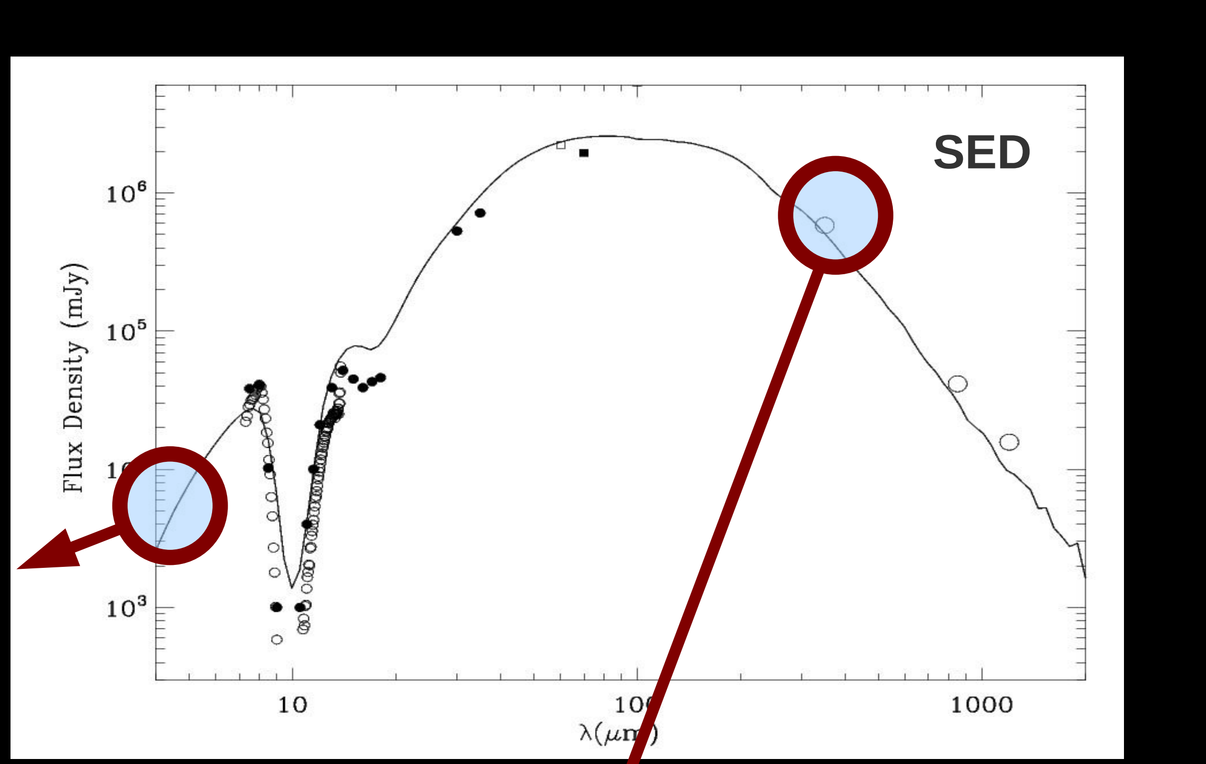
W33A MIDI observables

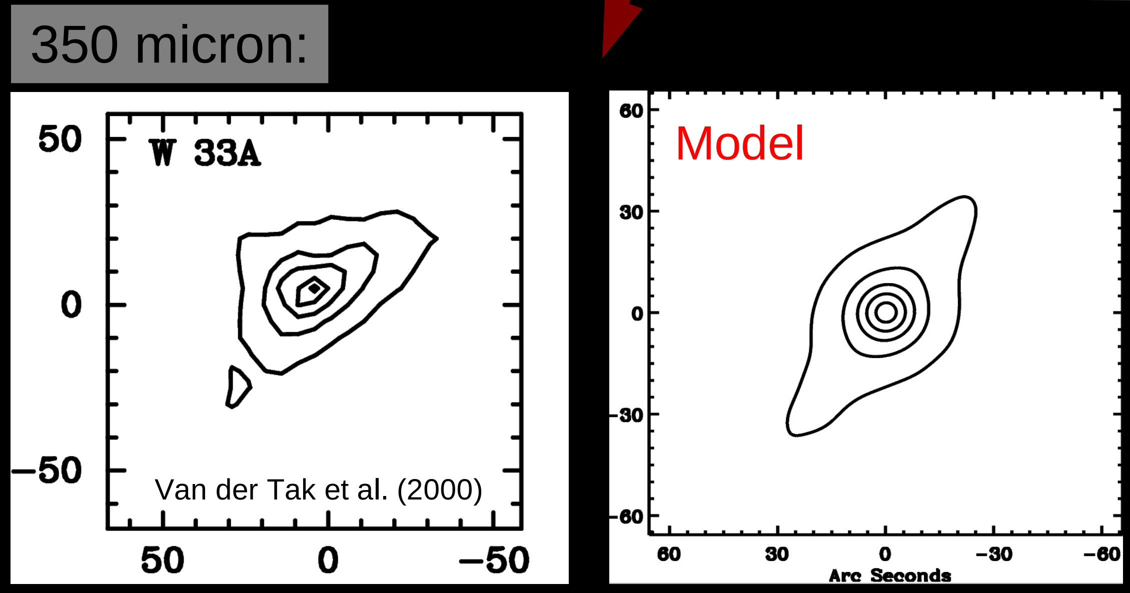
- 4 baselines
- Near-perpendicular PAs
- Baselines stretching between 40 and 60 meters
- Equivalent Gaussian FWHM sizes between 95 and 115AU



W33A model fit



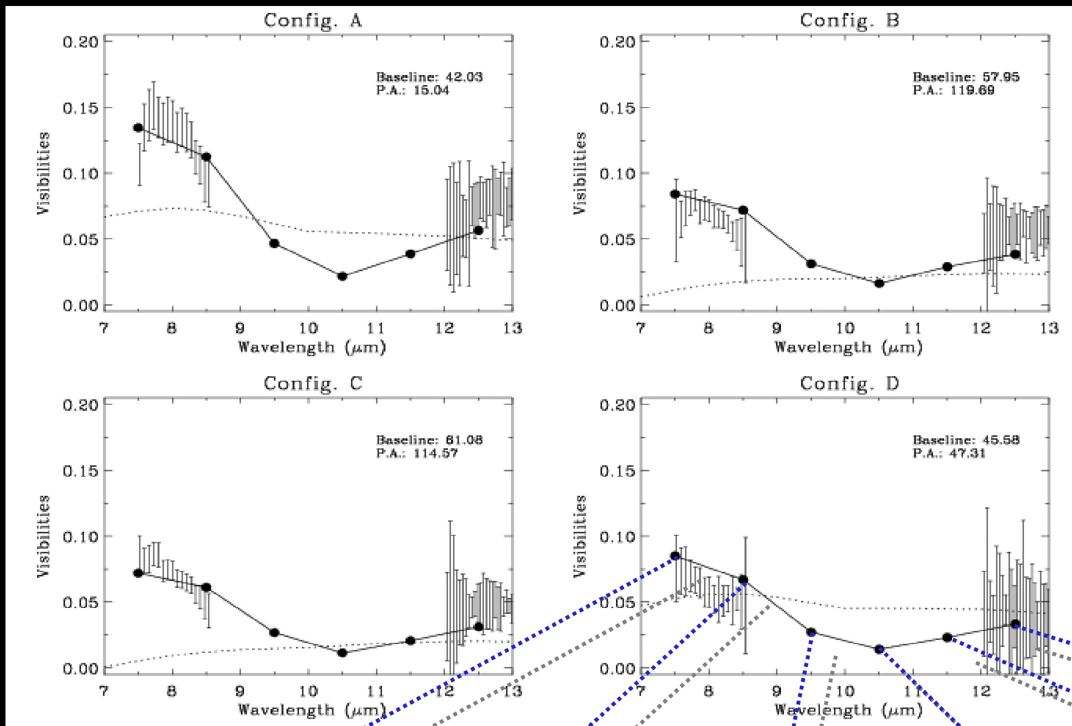




On the sky …

de Wit et al. 2010

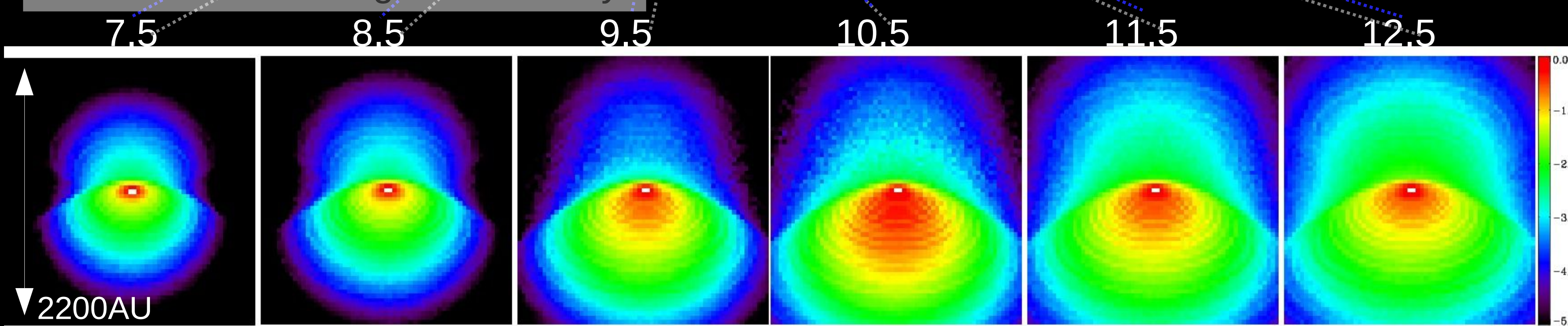
MIDI Visibilities:



Dust model parameters:

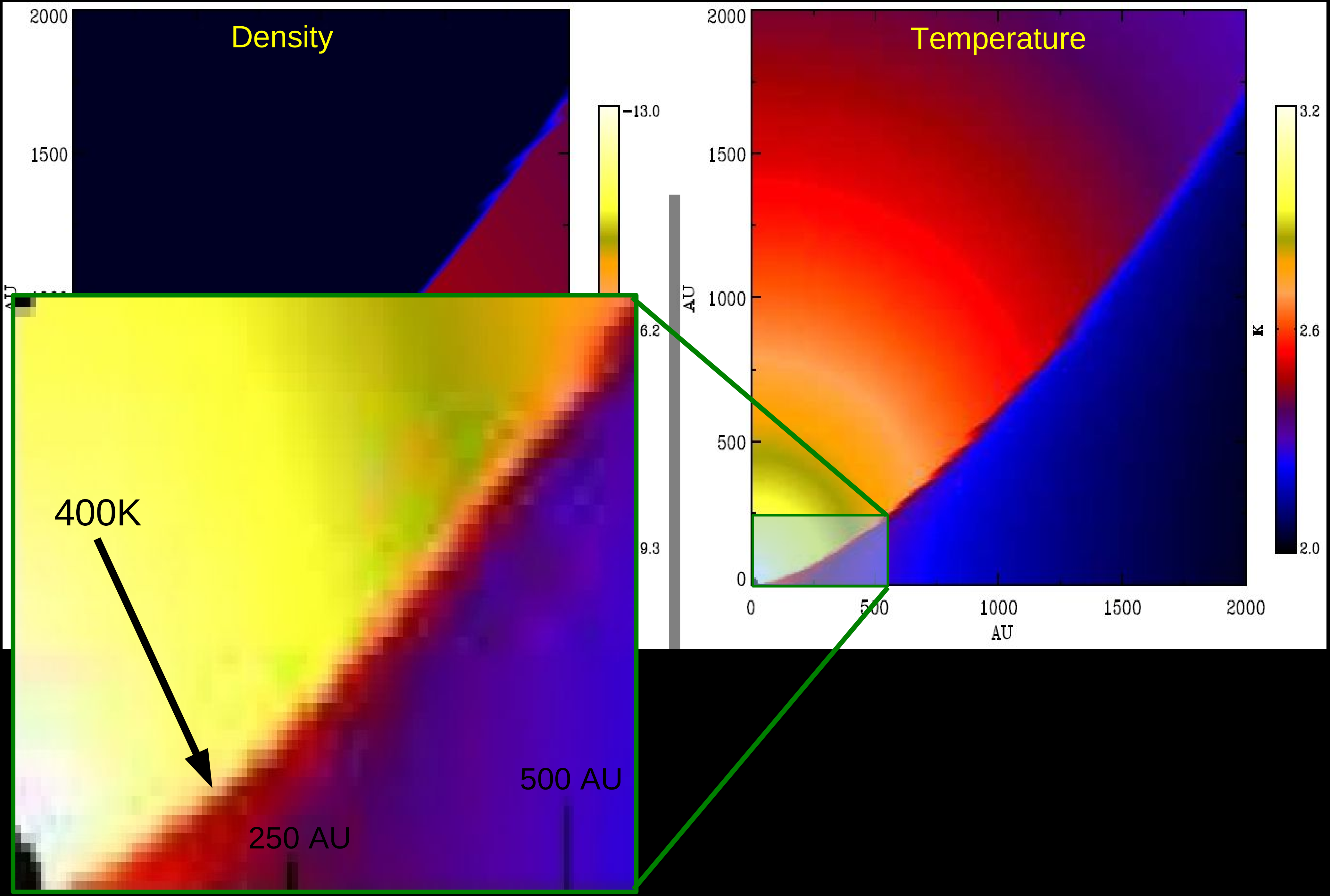
- No disk, only envelope (cavities)
- M_{infall} = 7 10^{-4} M_o/yr
- R_{sub} = 25 AU (nominal)
- A_v = 230
- T_{eff}= 35000 K
- R_* = 8.5 R_o
- M_* = 25 M_o
- 2*θ = 20° (opening angle)

Monochromatic images on the sky:



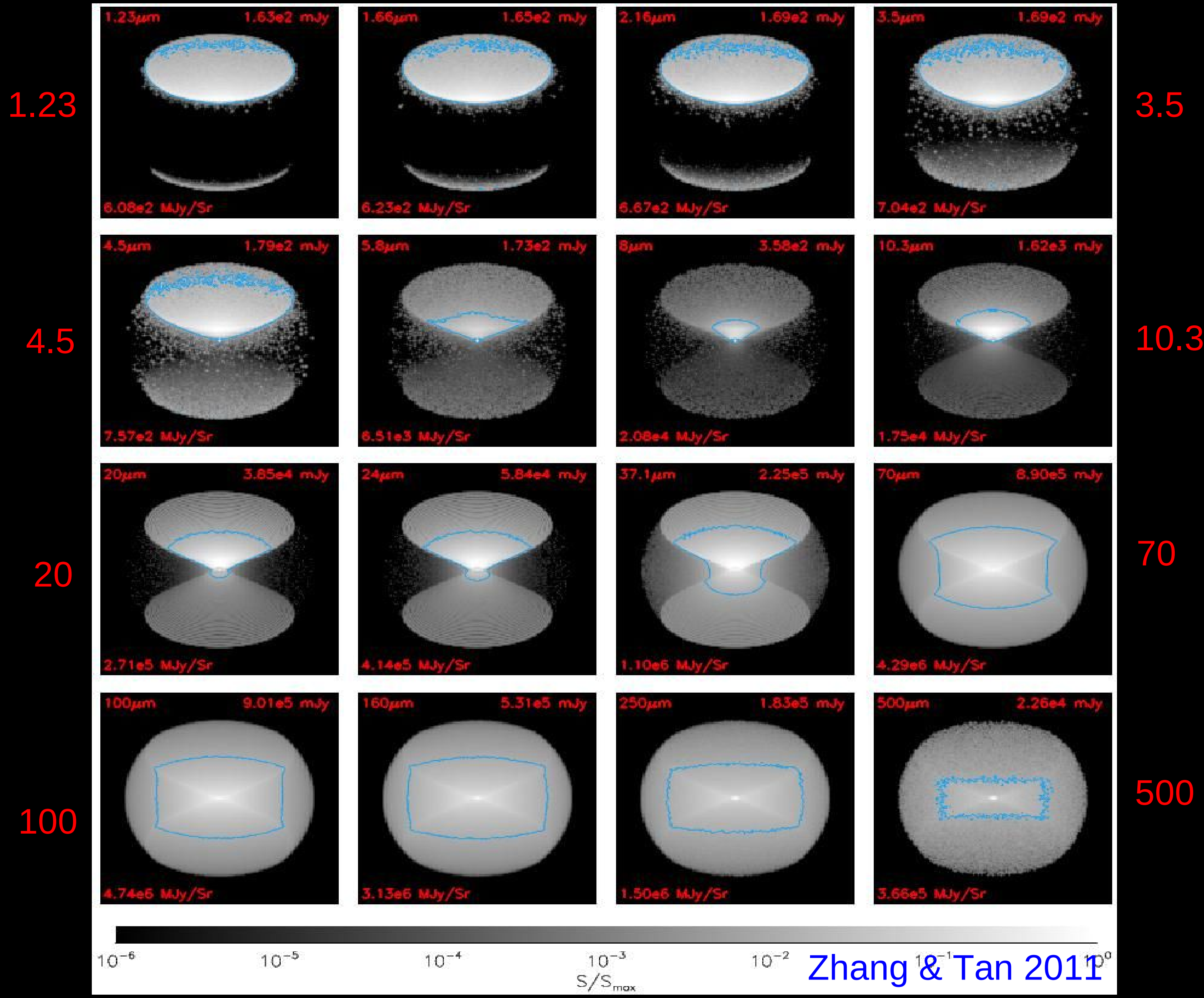
Cavity wall emission

Cut through geometry



Disk-ussion (I)

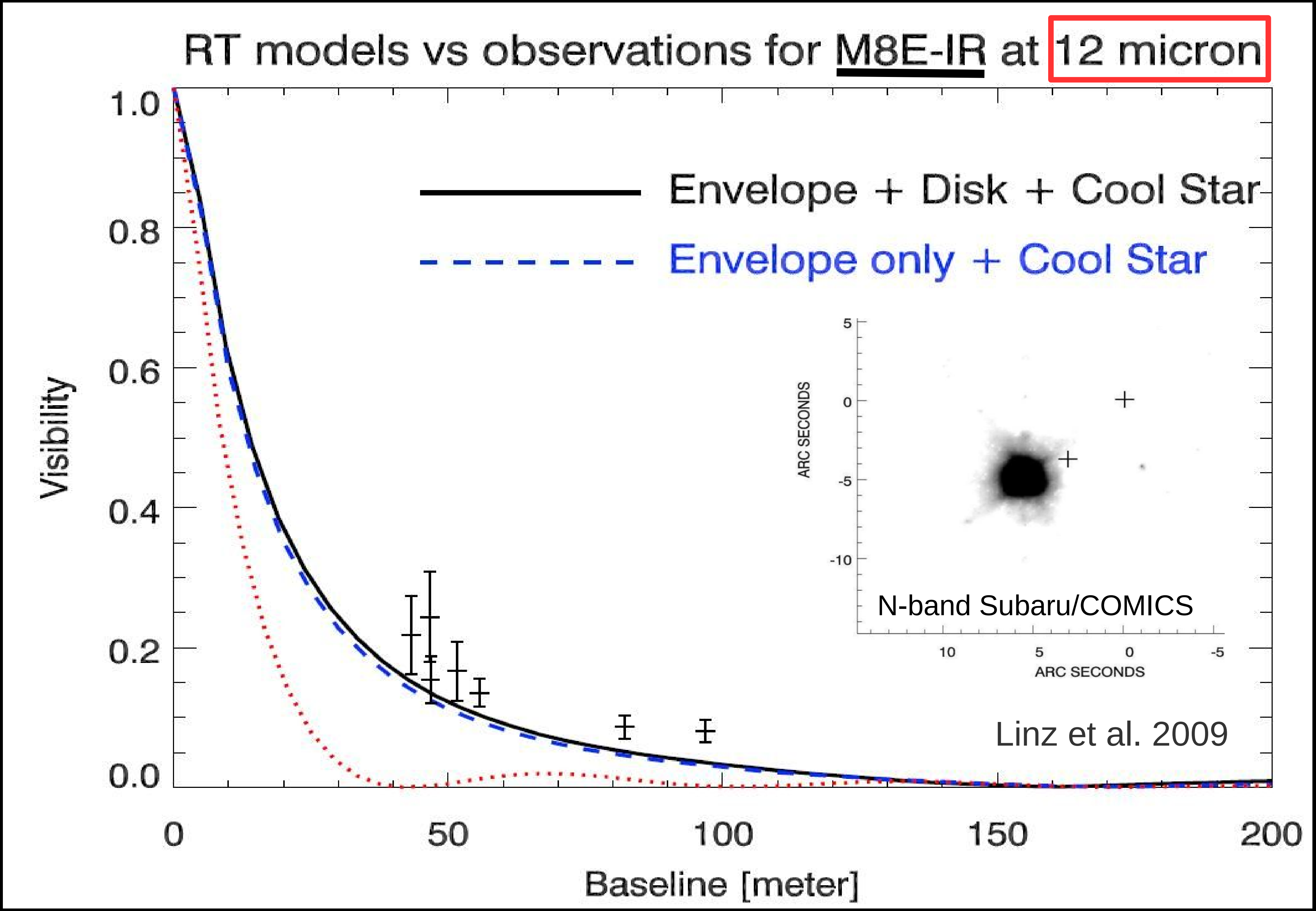
Is it just cavity wall emission MIDI sees?



Zhang & Tan 2011

Disk-ussion (I)

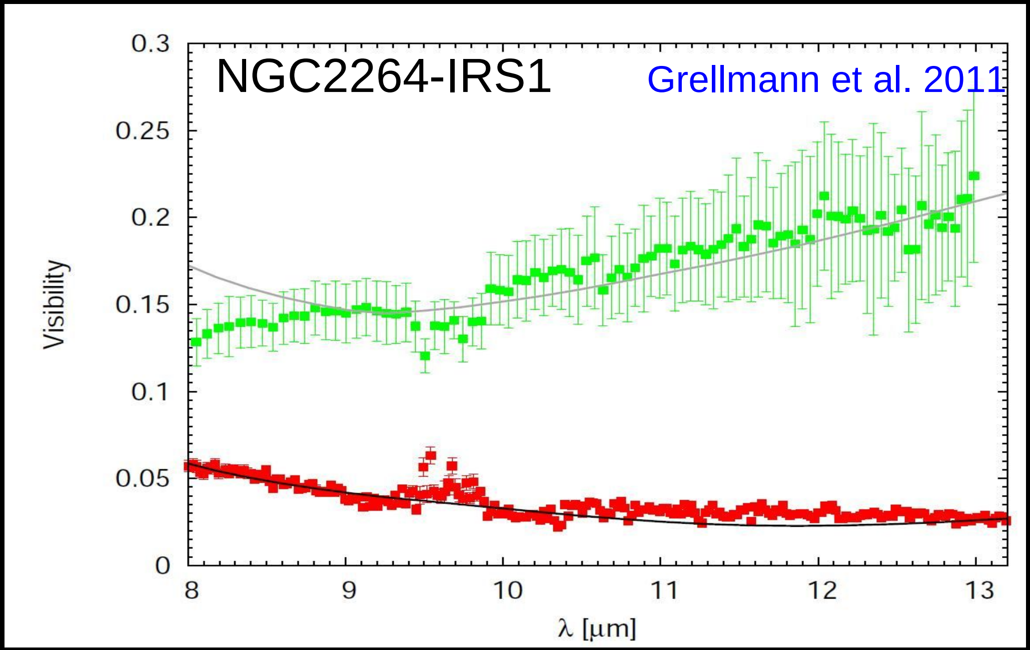
Is it just cavity wall emission MIDI sees?

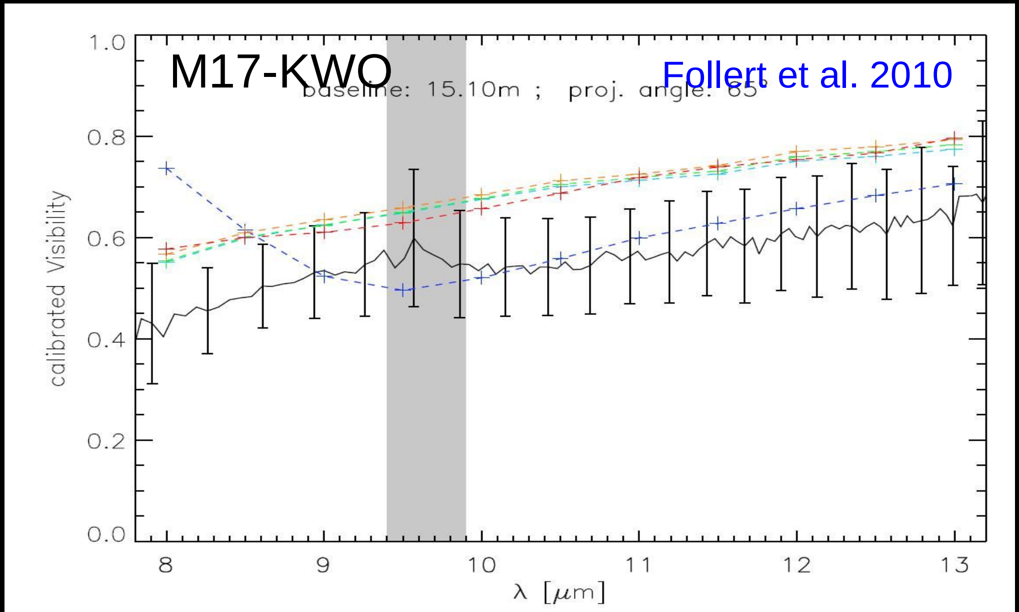


Disk-ussion (II)

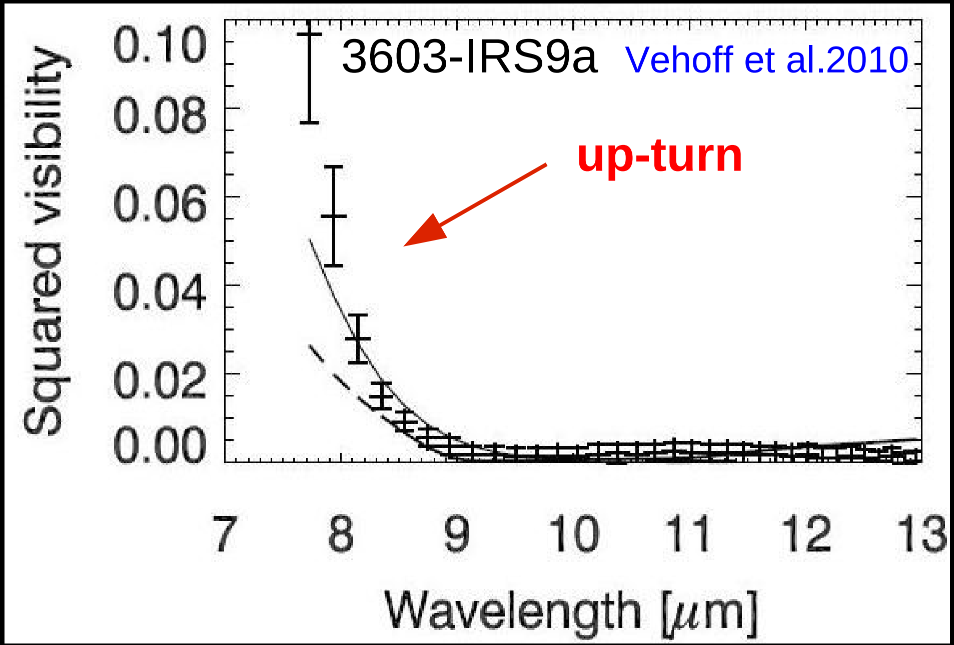
Is it just cavity wall emission MIDI sees?

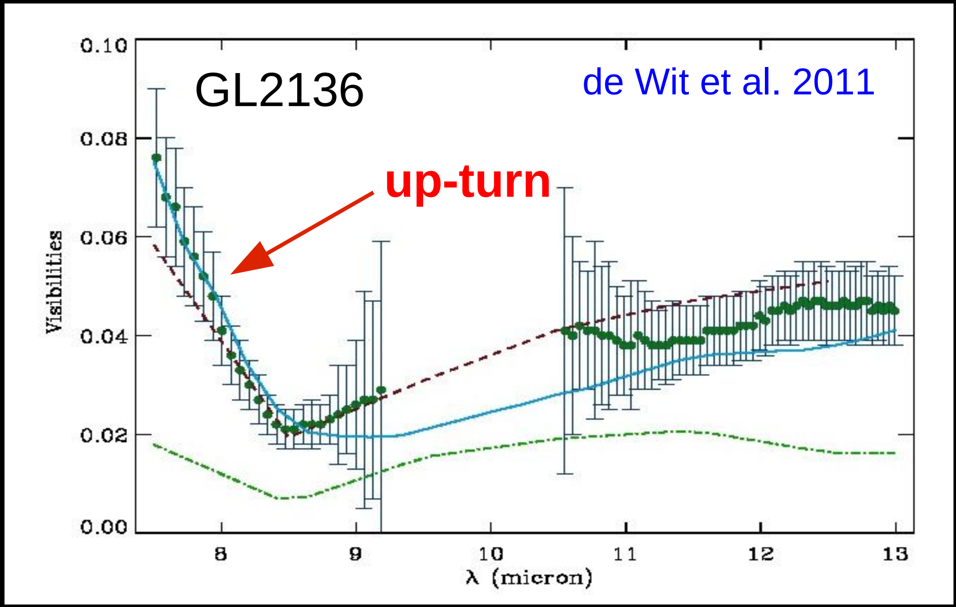
DISK ONLY SYSTEMS?





DISK+envelope SYSTEMS?

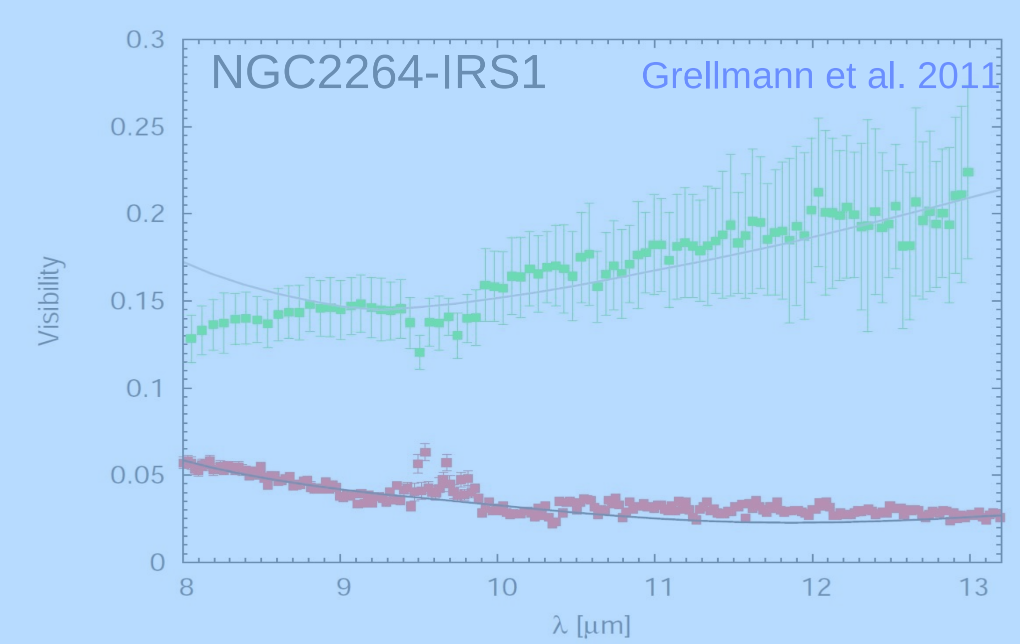


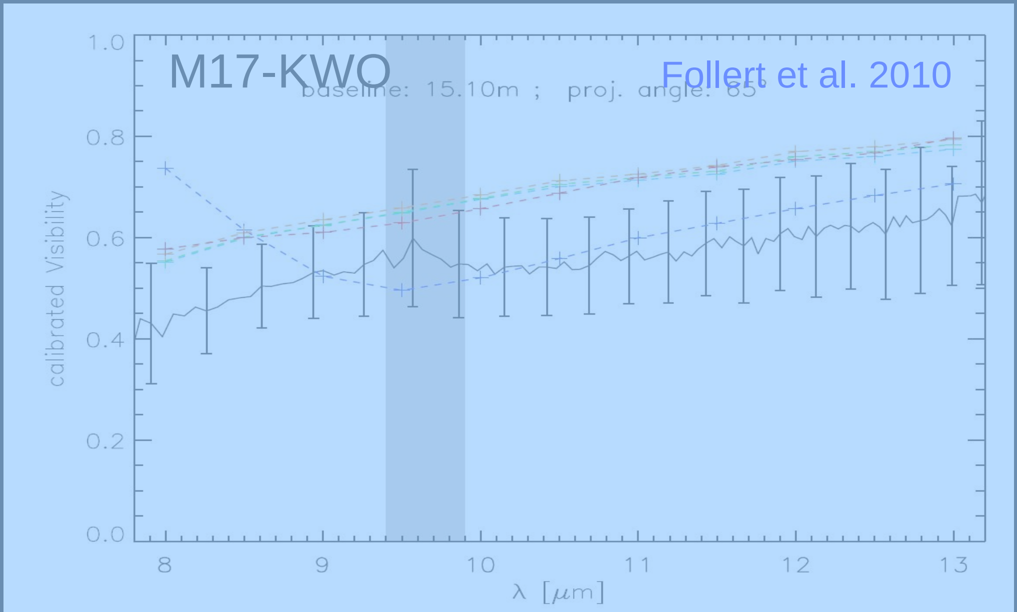


Disk-ussion (II)

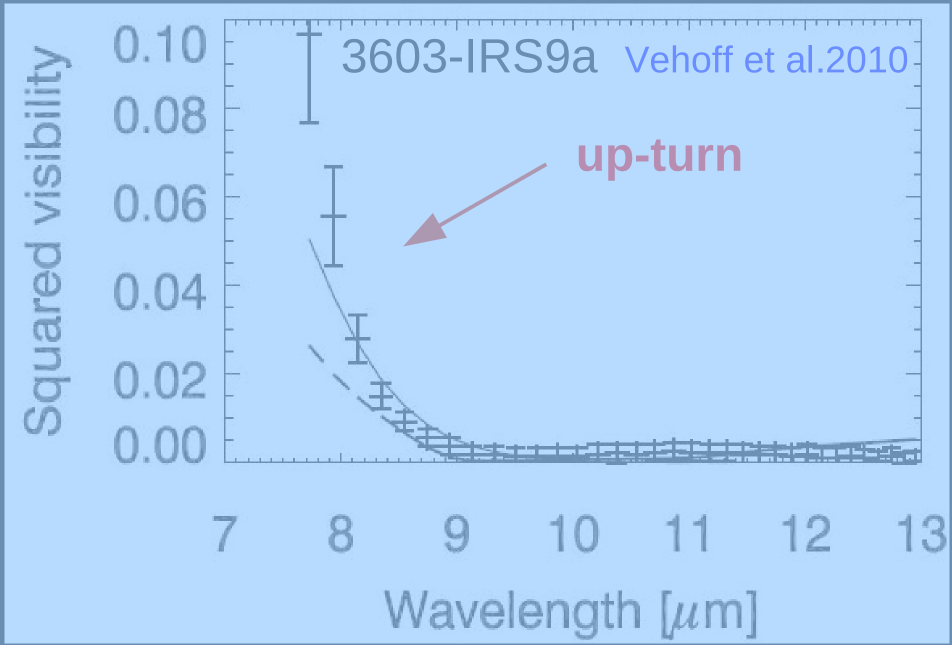
Is it just cavity wall emission MIDI sees?

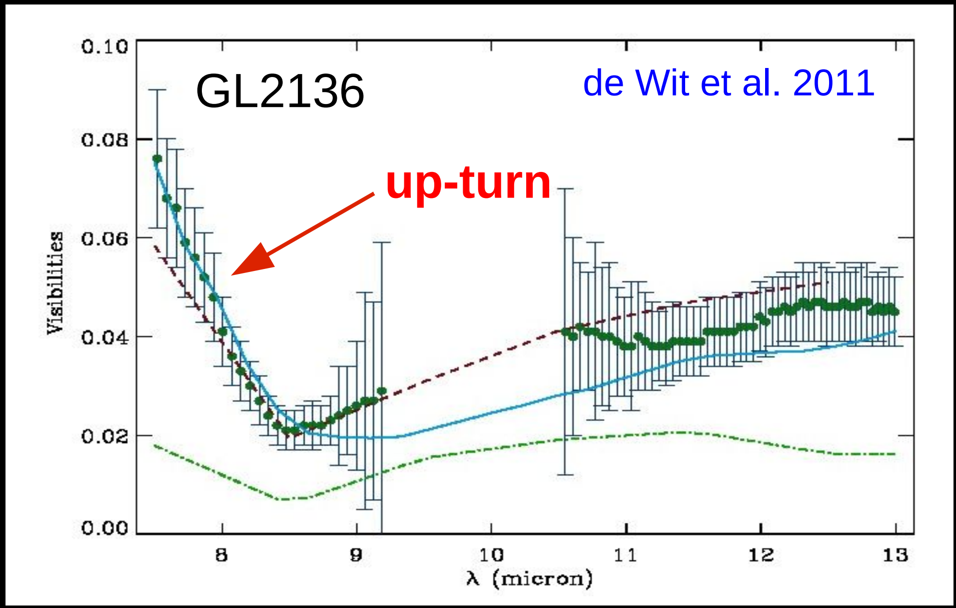
DISK ONLY SYSTEMS?





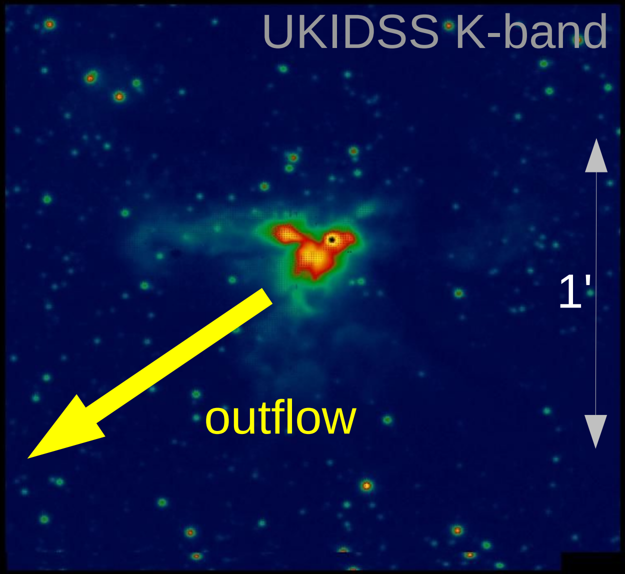
DISK+envelope SYSTEMS?





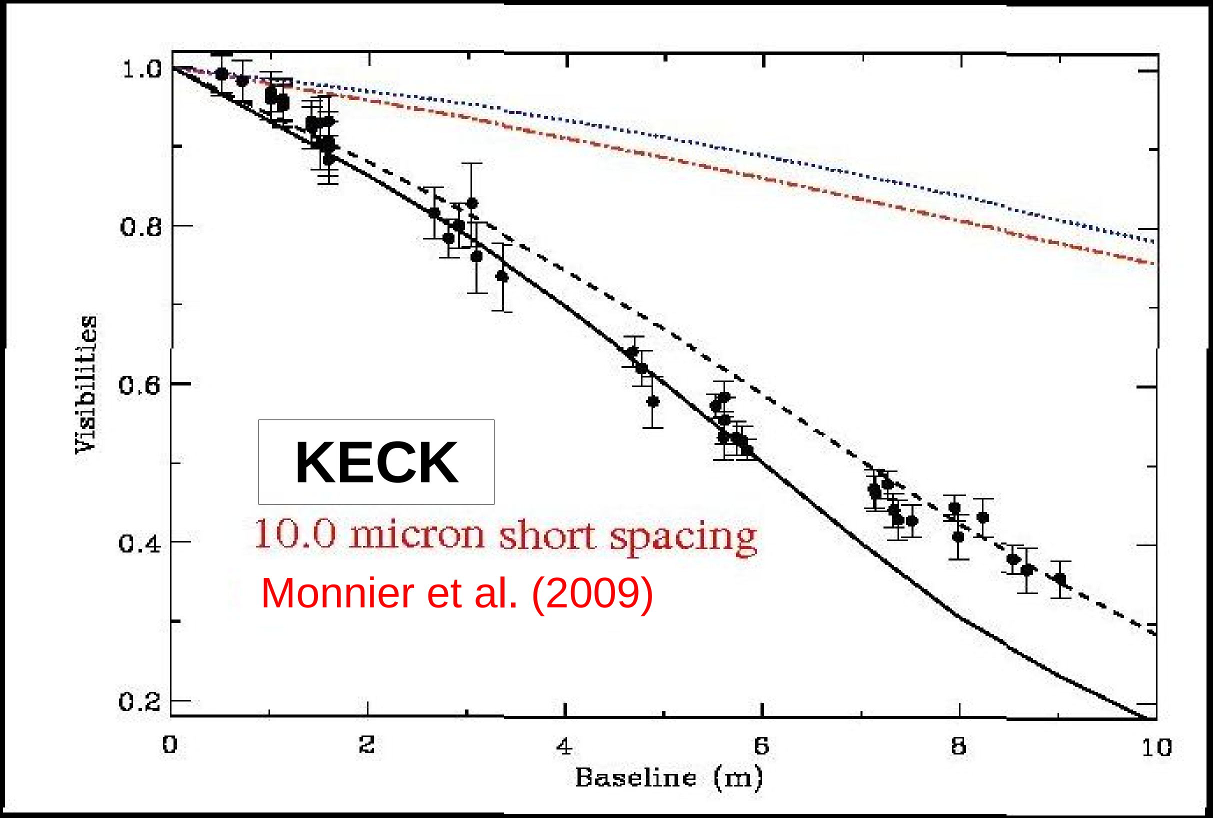
N-band disk signature in AFGL 2136 ?

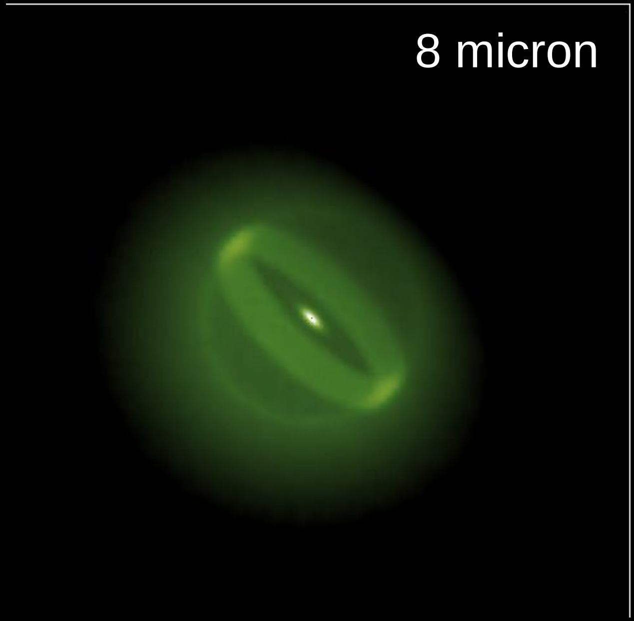
- L= 7e4 Lo
- D= 2.0 Kpc
- Polarization disk (Murakawa et al. 2008)
- Arcmin bipolar CO outflow (Kastner et al. 1995)
- Compact, 70 AU radio emission (Menten & Van der Tak 2004)



Modelling results:

- Short spacing + SED : 120 AU dust radius
- M_{acc} : 3 10^{-3} M_O/yr



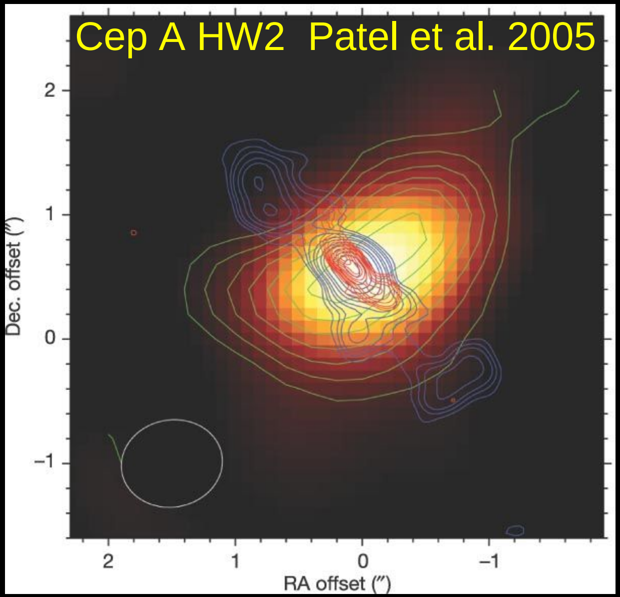


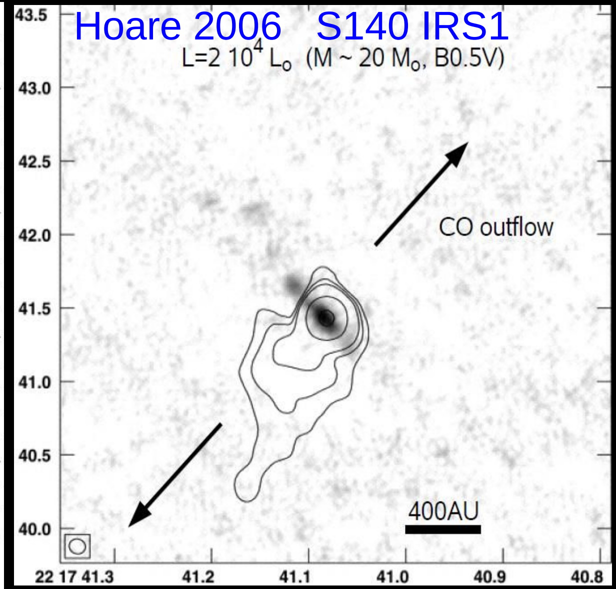
Summary

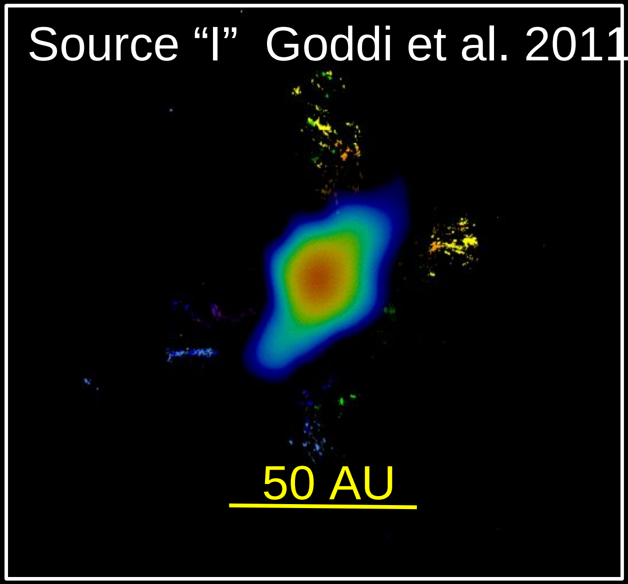
- N-band emission is dominated by “cavity wall” emission on scales of a few 100 AU in W33A.
- N-band emission is dominated by “cavity wall” emission on scales of a few 100 AU in AFGL 2136 longward of 9.0mu.
- Dust disks (beyond dust sublimation radius) are excluded from any significant contribution (W33A).
- Gas disk are relatively compact and would dominate visibilities at long baselines and at shorter wavelength.
- .. still physical disk models fail to reproduce MWC 297 (~10M_o, 250pc see Acke et al. 2008)

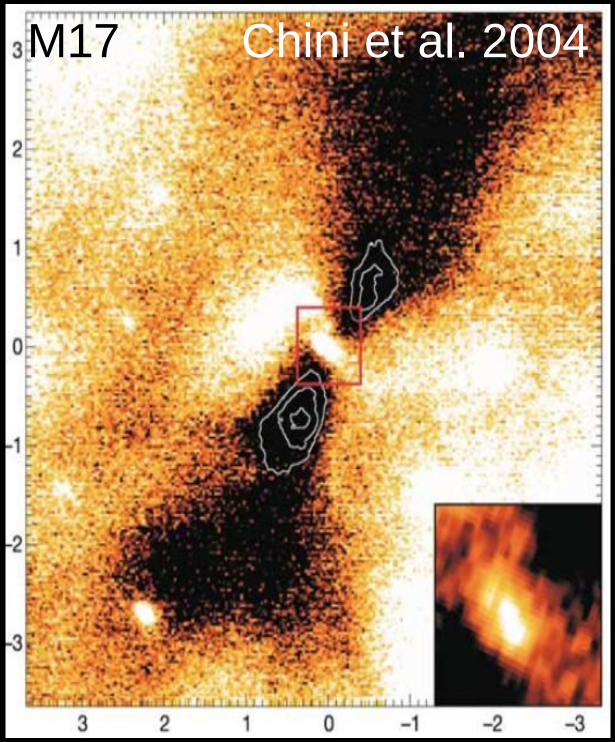
Thank you

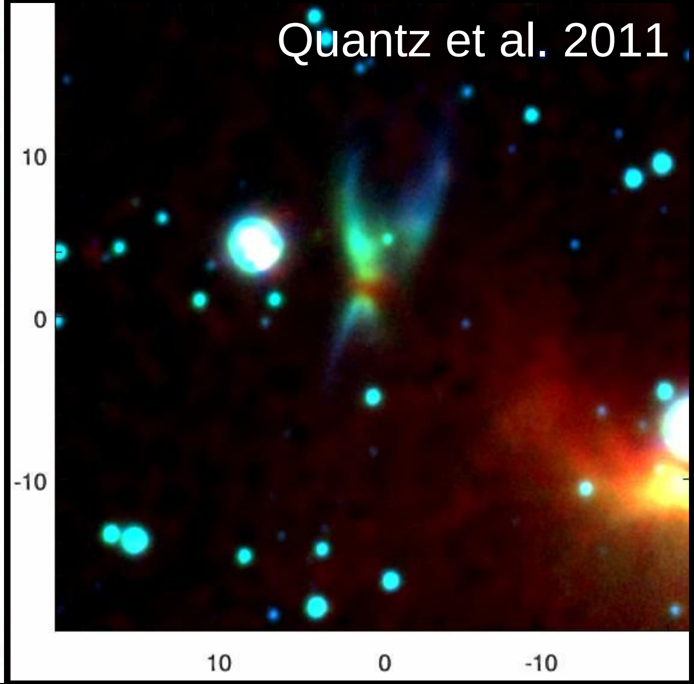
Accretion disks in HMSF?











24.5 micron imaging of MYSO envelopes

Longest mid-IR amenable to ground-based imaging

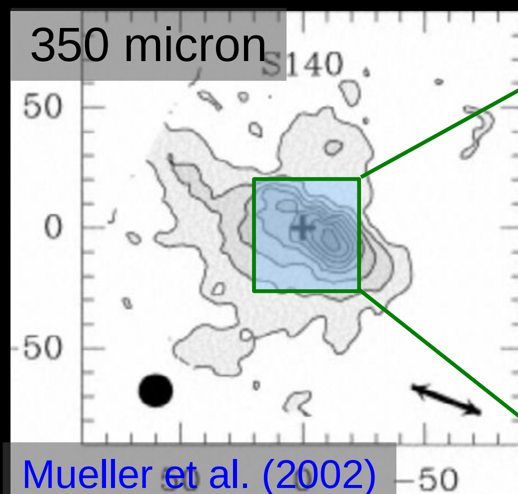
$\rho = \rho_0 \, (r/r_0)^{-p}$

- p=1.0 : Logatropic (McLaughlin & Pudritz '96)
- p=1.5 : Collapsing (Larson '69)
- p=2.0 : Thermally supported (Shu et al. '77)

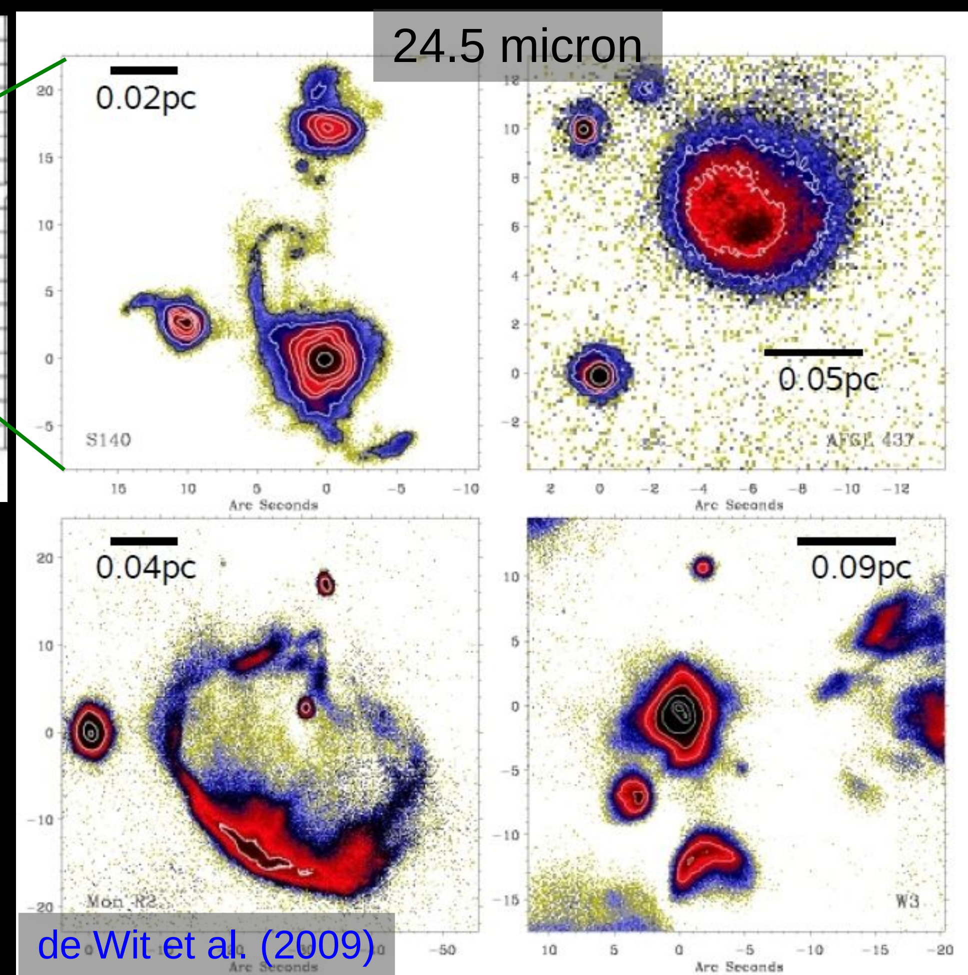
- 14 target MYSOs
- 0.6" spatial resolution (1000 AU)
- 24.5 micron imaging (SUBARU/COMICS)
- DUSTY (1D RT) modelling

Able to fit:

- 24.5 mu intensity profile
- 24.5 mu flux
- 9.7 mu silicate absorption
- submm emission

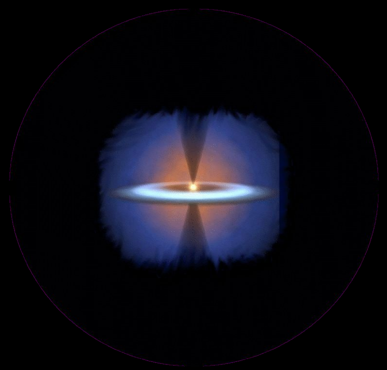


Mueller et al. (2002)



de Wit et al. (2009)

=> Preferred p=1.0, shallower than longer wavelength => rotational support?




JHK
Gemini Observatory/Colin Aspin
dust + gas
8 micron
de Wit et al., 2011
300 AU
VLTI/AMBER image
2.2 μm
Kraus et al., 2010
Beam
c
0.006"
20 AU

The environment of a massive YSO

Jets and outflows (mass loss, Beuther et al. 2002)

Cep A HW2 in H_2 (725 pc)