Looking into the heart of a young outbursting star: First AU-scale observations of V1647 Ori with VLTI/MIDI

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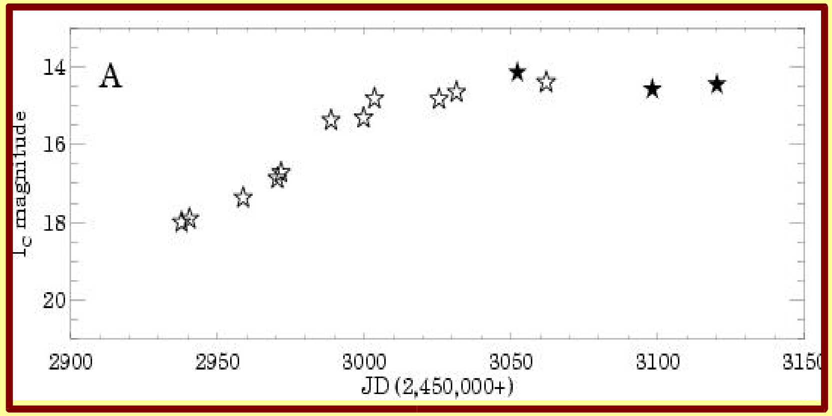
Visions for Infrared Astronomy: A tribute to Pierre Léna, Paris March 21, 2006

The outburst of V1647 Ori

January 23 2004: the appearance of a reflection nebula in L1630 was announced (McNeil et al. 2004) - outburst occured in Nov 2003

Popular target

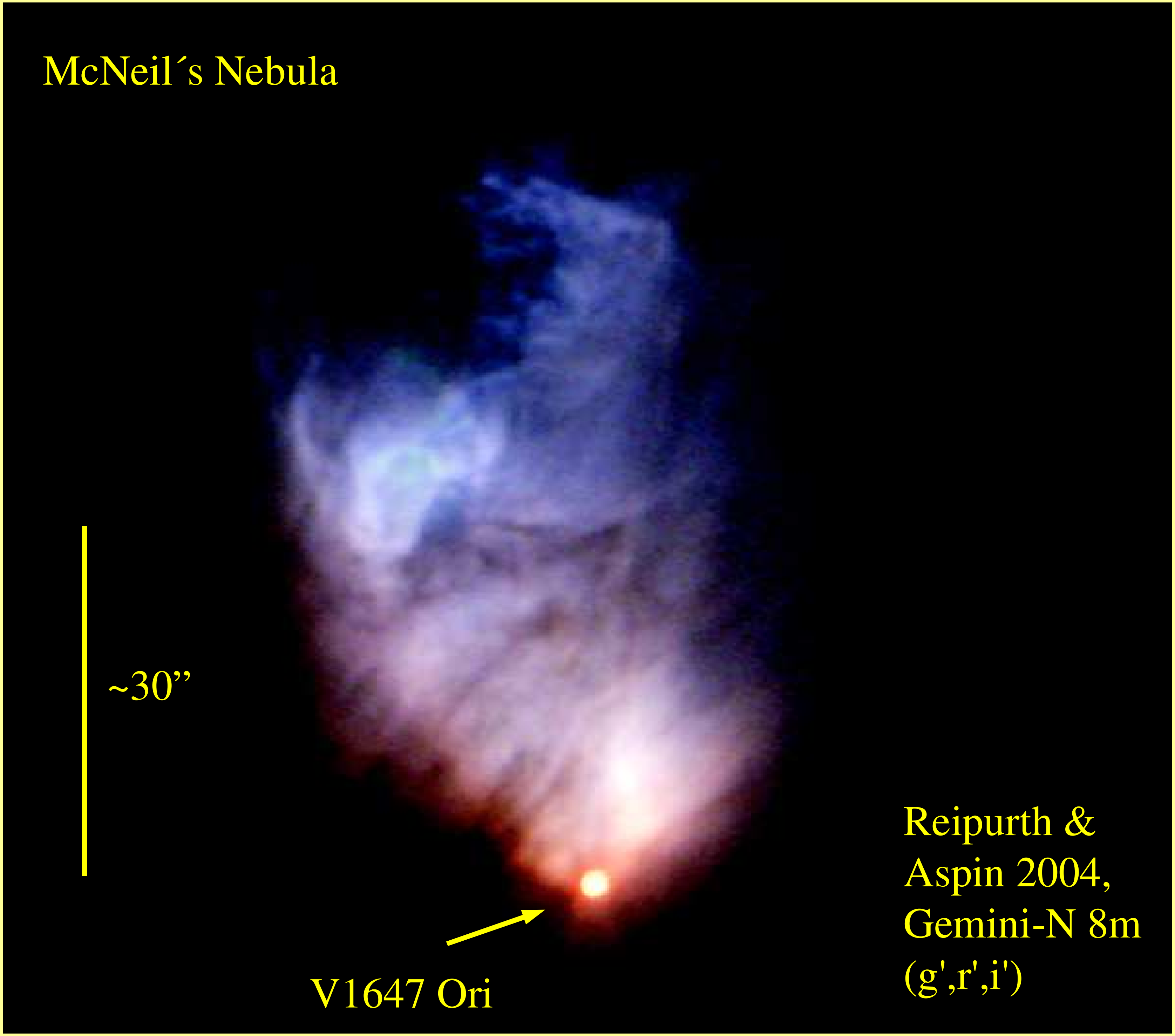
- optical brightening ~ 4 mag
- L ~ 30-90 L_{Sun}, flat SED
- spectrum: accretion, wind
- the source is embedded in an elongated disk-like structure of size ~6000 AU, $i=60^{O}$ (Kun et al. 2004)
- young stellar object (IRAS 05436-0007)



Kun et al. 2004

<u>FUor candidate</u>

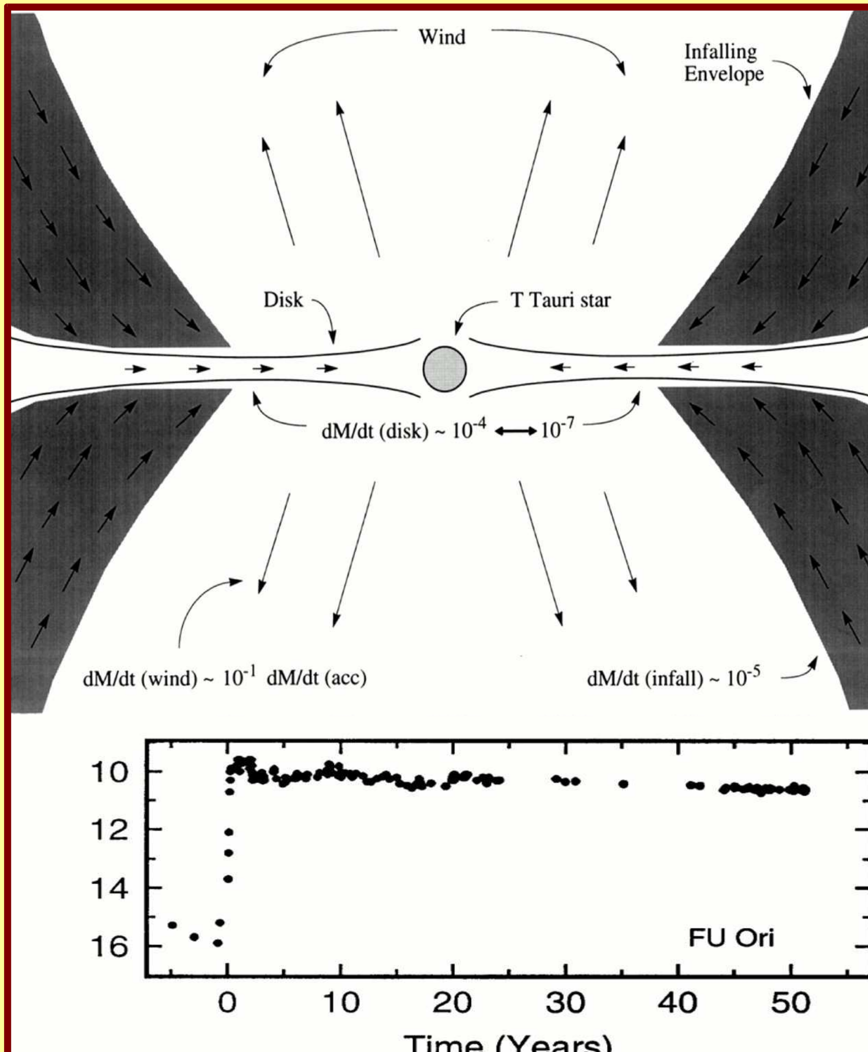
(e.g. Briceno et al. 2004, Abraham et al. 2004, Andrews et al. 2004)


McNeil´s Nebula
~30”
V1647 Ori
Reipurth & Aspin 2004, Gemini-N 8m (g',r',i')

FU Ori type sources (FUors)

- increased accretion ($\sim 10^{-4}\ M_{Sun}$/yr):
  - triggered by the companion (e.g. Reipurth & Aspin 2004)
  - thermal instability (~ 1AU)

    (e.g. Hartmann & Kenyon 1996)
- FUor eruptions are repetitive and recur in T Tau stars after ~ 10000 years (?)
- One class, one model?



FU Ori type sources (FUors)

- increased accretion (~10^{-4} M_{Sun}/yr):
  - triggered by the companion (e.g. Reipurth & Aspin 2004)
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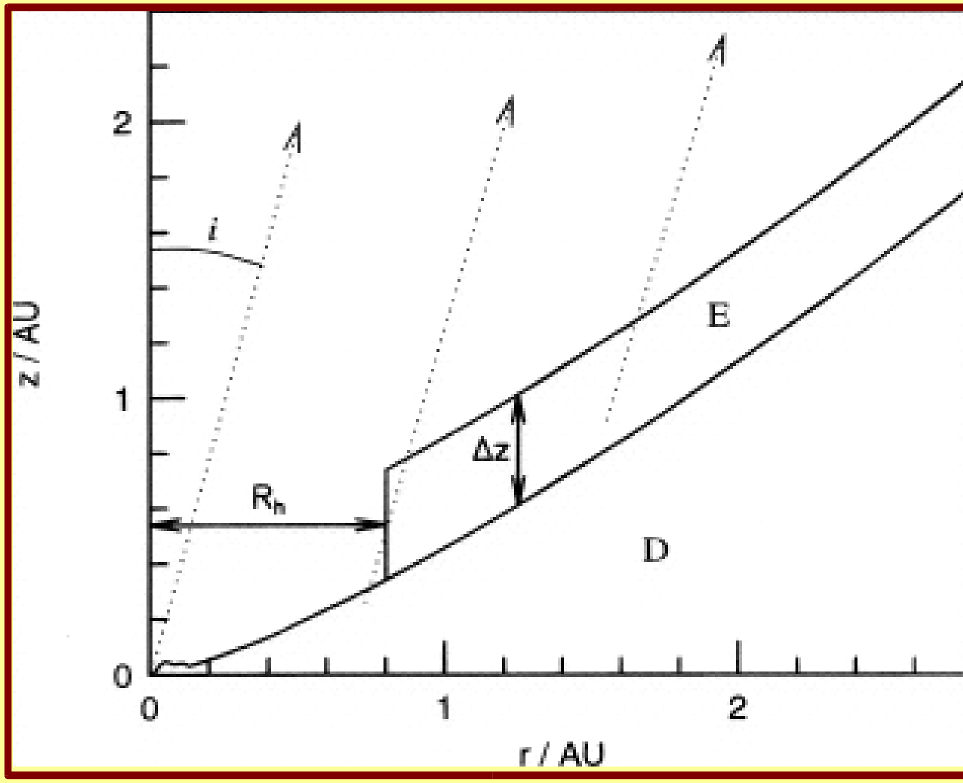
    (e.g. Turner et al. 1997)
- FUor eruptions are repetitive and recur in T Tau stars after ~ 10000 years (?)



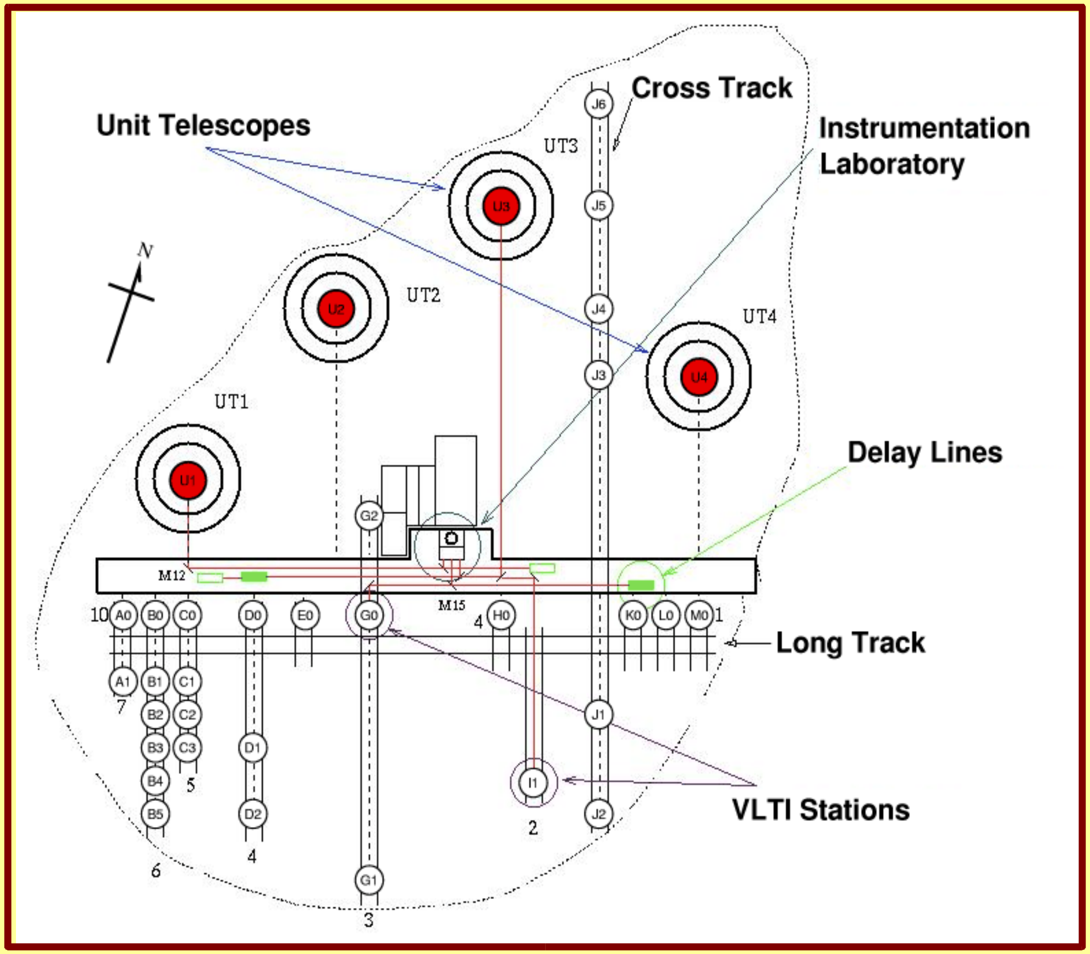
- One class, one model?
- Milli-arcsecond scale observations needed

MIDI observations of V1647 Ori

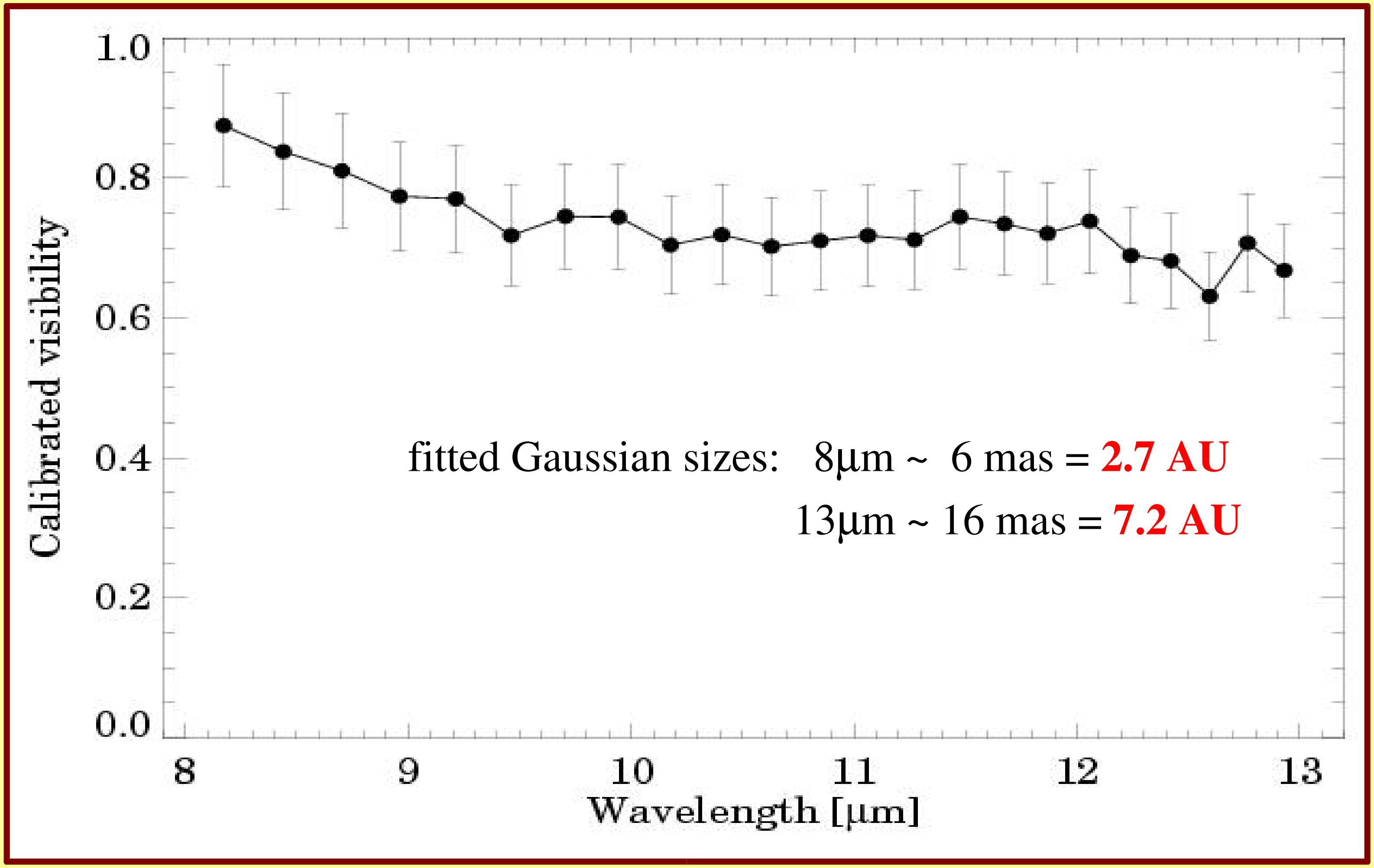
- MID-Infrared interferometric instrument for the VLTI
- Director's Discretionary Time Proposal to ESO (November 2004)
  - investigate the hot inner source structure, compare to models
  - start monitoring the temporal evolution of the inner hot region
  - look for companion (like FU Ori, L1551 IRS5, ...)

MIDI observations of V1647 Ori

- observations from December 2004, successful on March 2, 2005 (UT3-UT4, 56m)
- data reduced with MIA (e.g. Leinert et al. 2004)



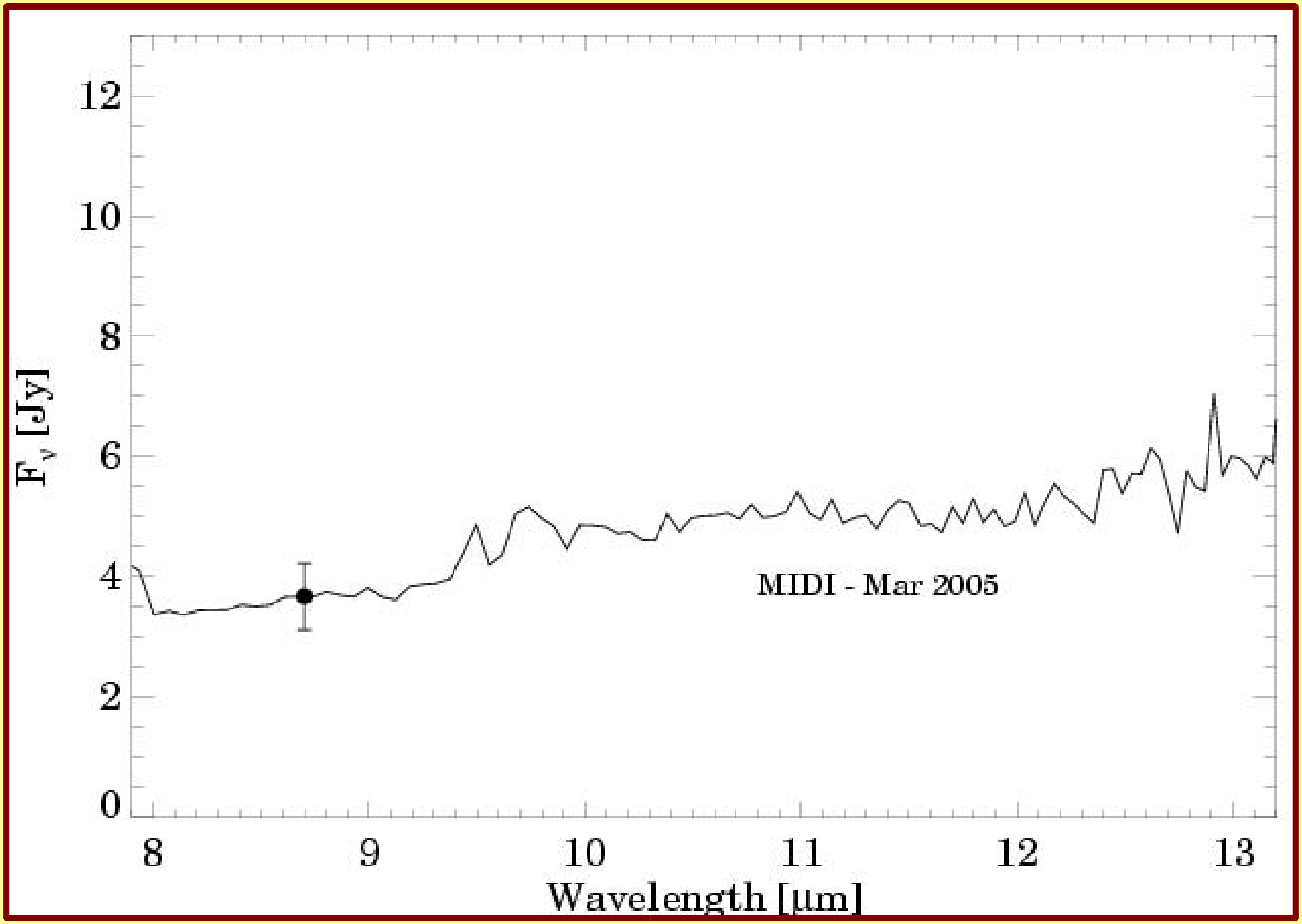
MIDI results I.
Spectrally resolved visibilities



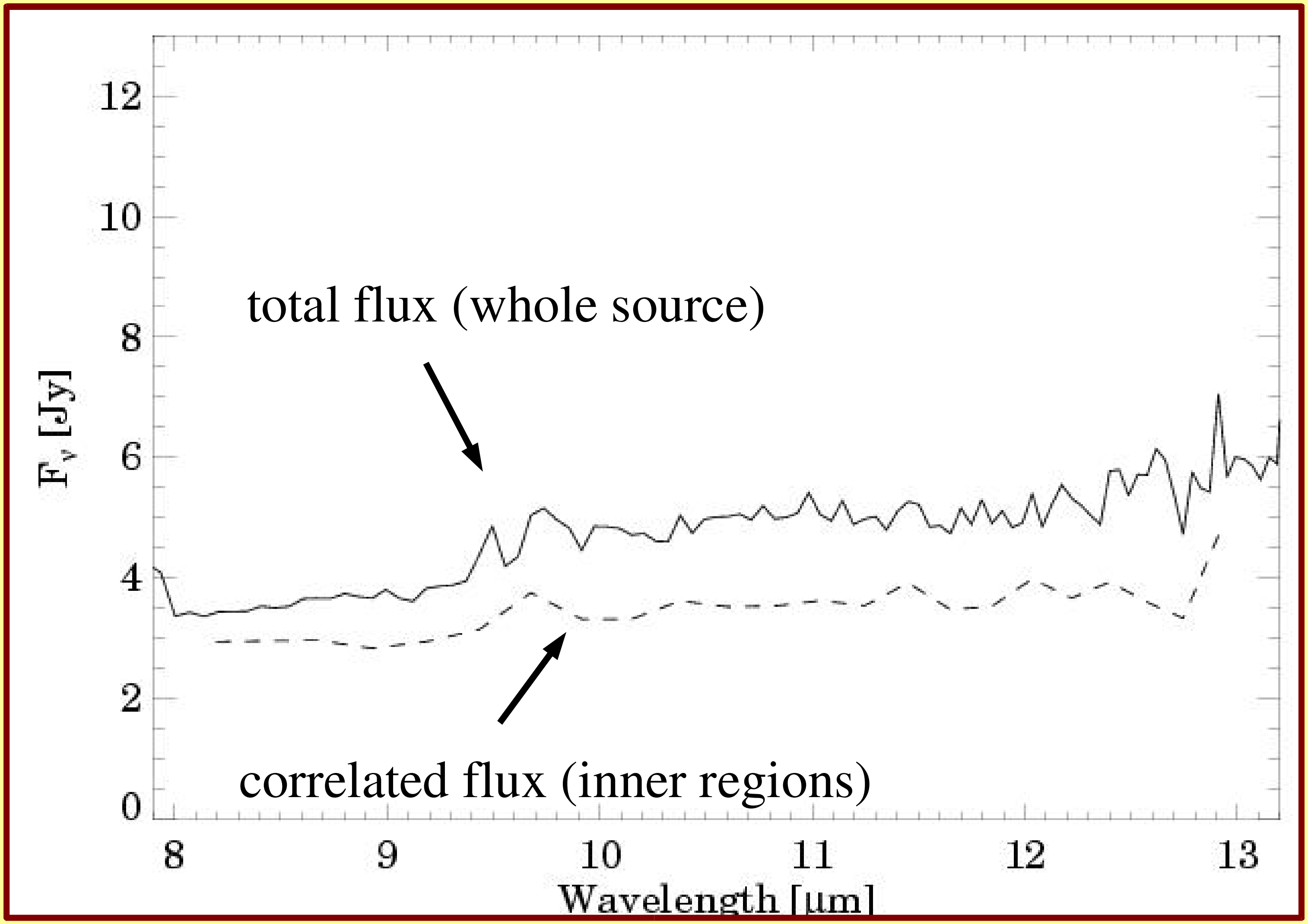
MIDI results II.
Search for companion

- A signature of a companion is the sinusoidal modulation of the spectrally resolved visibilities.
- We determined an upper limit for the brightness of a possible companion, at the measured position angle, with:
  - separation: 50 mas - 200 mas
  - flux ratio: $I_2/I_1 < 0.1$

MIDI results III.
N-band spectrum



MIDI results III.
N-band spectrum



Analysis: model fit

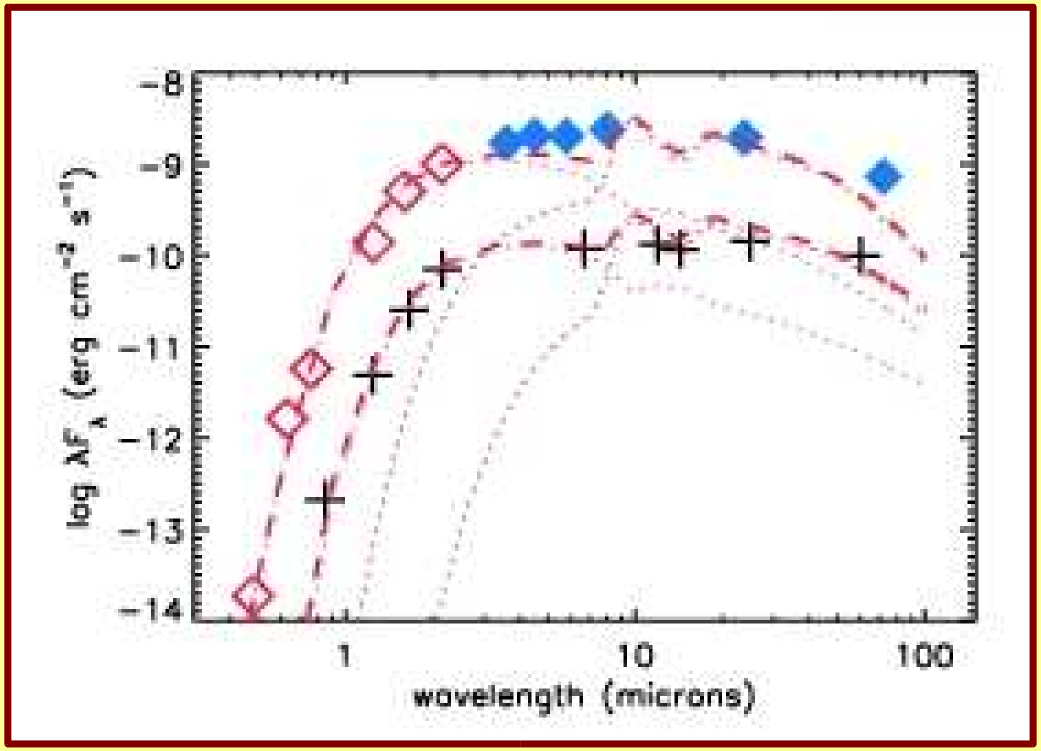
A model of the circumstellar structure (disk, etc.) which fits simultaneously

- the SED,
- the (spectrally resolved) visibilities.

Usually not easy!

Analysis: SED fit

Spitzer: March 2004 (Muzerolle et al. 2004)



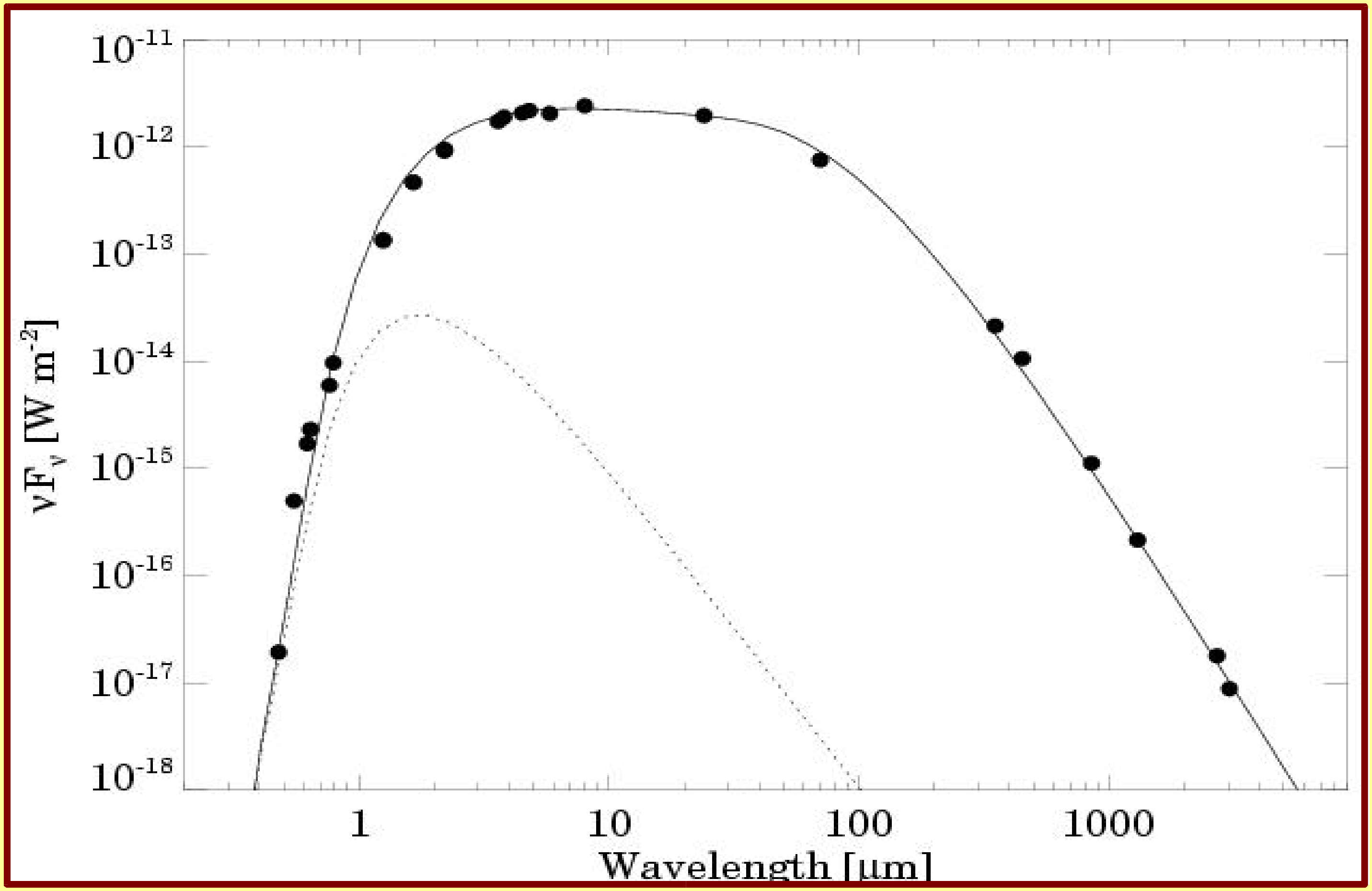
- steady accreation disk, rate ~ $10^{-5}\,M_{Sun}$/yr
- optically thin envelope*, infalling rate ~ $10^{-6}\,M_{Sun}$/yr

* *the featureless N-band spectrum*

* *RT calculations - optically thick*

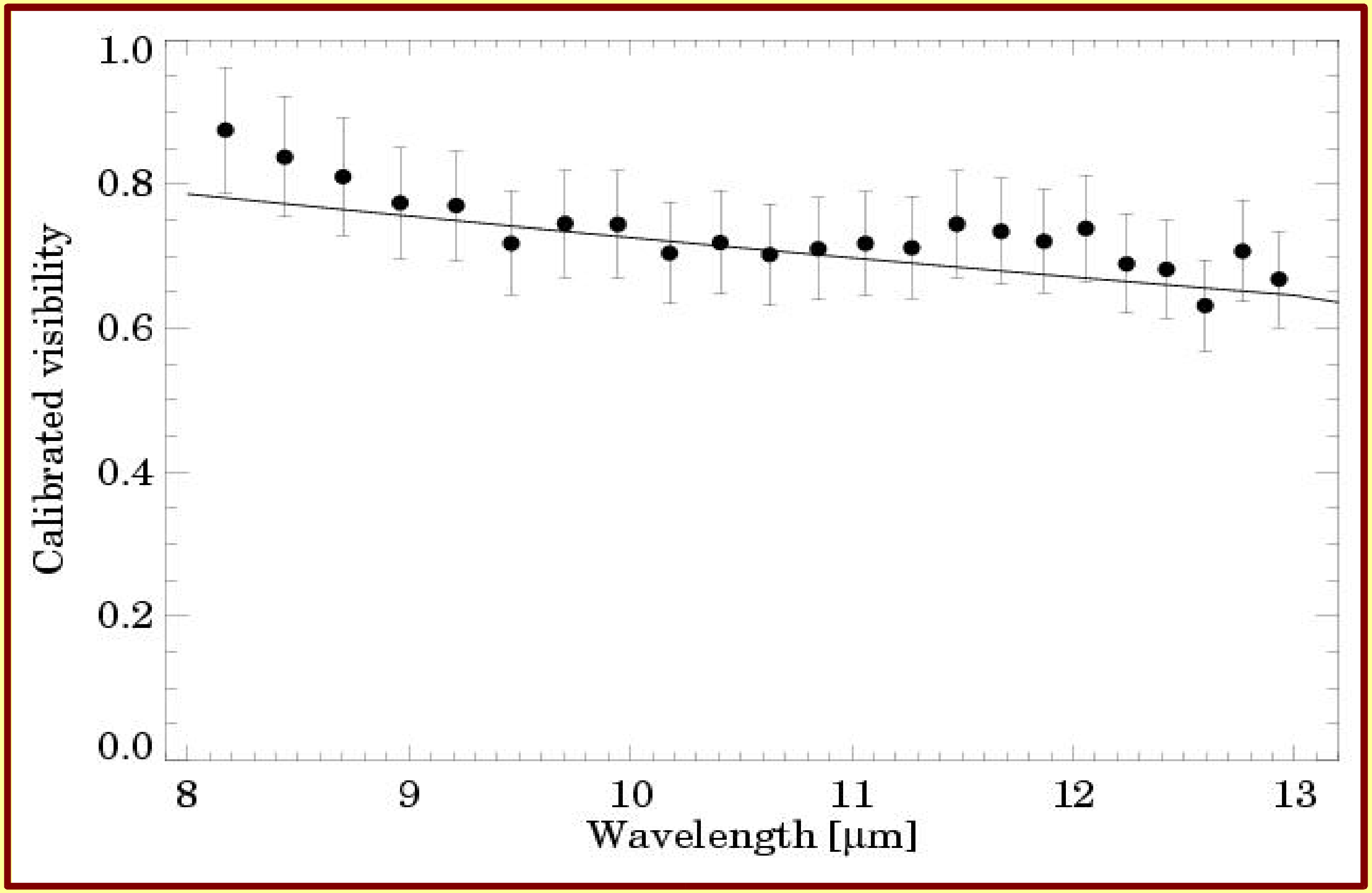
Analysis: SED fit

Alternative: a simple (spatially flat, optically thick) disk model



- R_{in} ~ 5 AU
- T(1AU) = 680 K
- q = -0.53, $T(r) \sim r^q$ (not a simple accretion disk)
- p = -1.5, $\Sigma(r) \sim r^p$
- $M_d = 0.05\ M_{Sun}$
- A_V = 10 mag
- $i = 60^O$

Simultaneous fit of SED and visibilities



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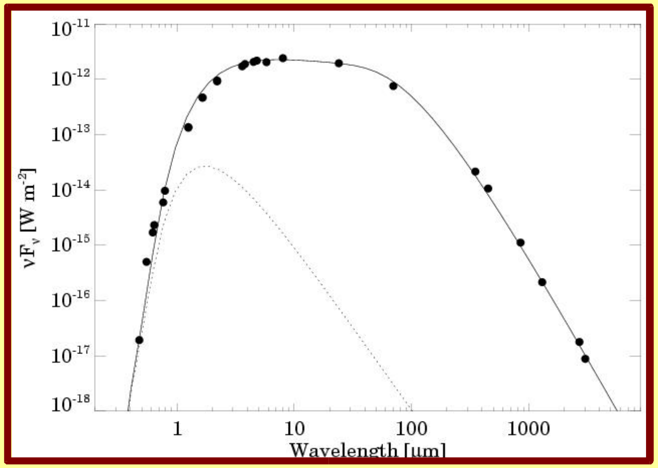
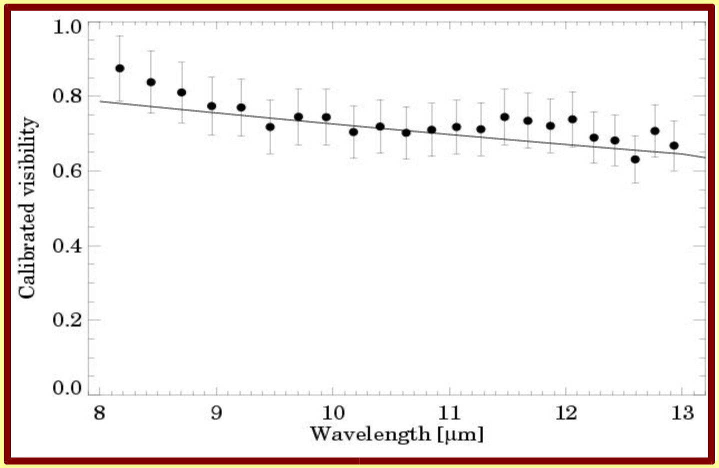
Comparison with FUors





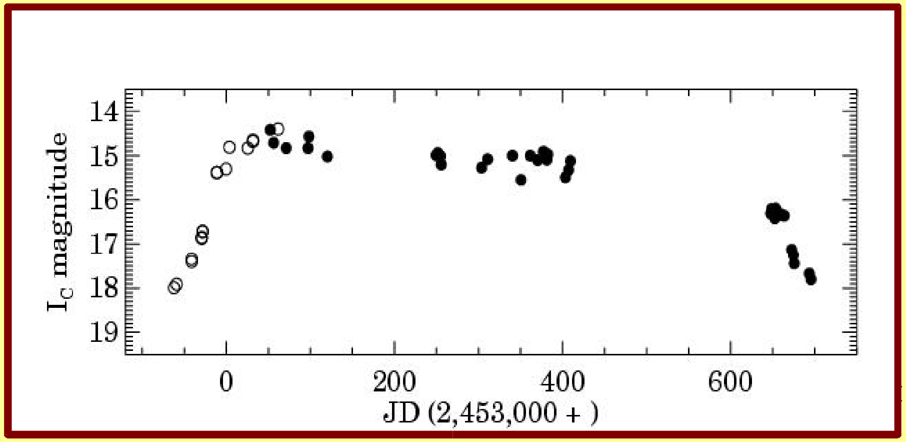
q=-0.53

- FU Ori (Malbet et al. 2005, NIR): q=-0.71
- V1057 Cyg, V1515 Cyg (Millan-Gabet et al. 2006, NIR): q~-0.45
  Z CMa: q=-0.75, ~60% of the flux resolved out
- The inhomogeneous group of young outbursting objects

Monitoring program at Konkoly Observatory

– K-band: LIRIS at William Herschel Telescope (Kun et al., in prep)

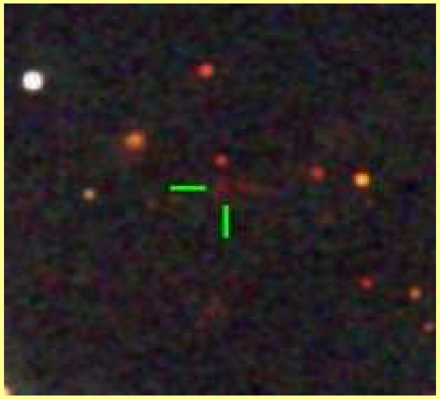
– optical light curve: Feb 2004 - :
    Kóspál et al. (2005) +
    Briceno et al. 2004 (open)



Parsamian 21

Á. Kóspál et al.

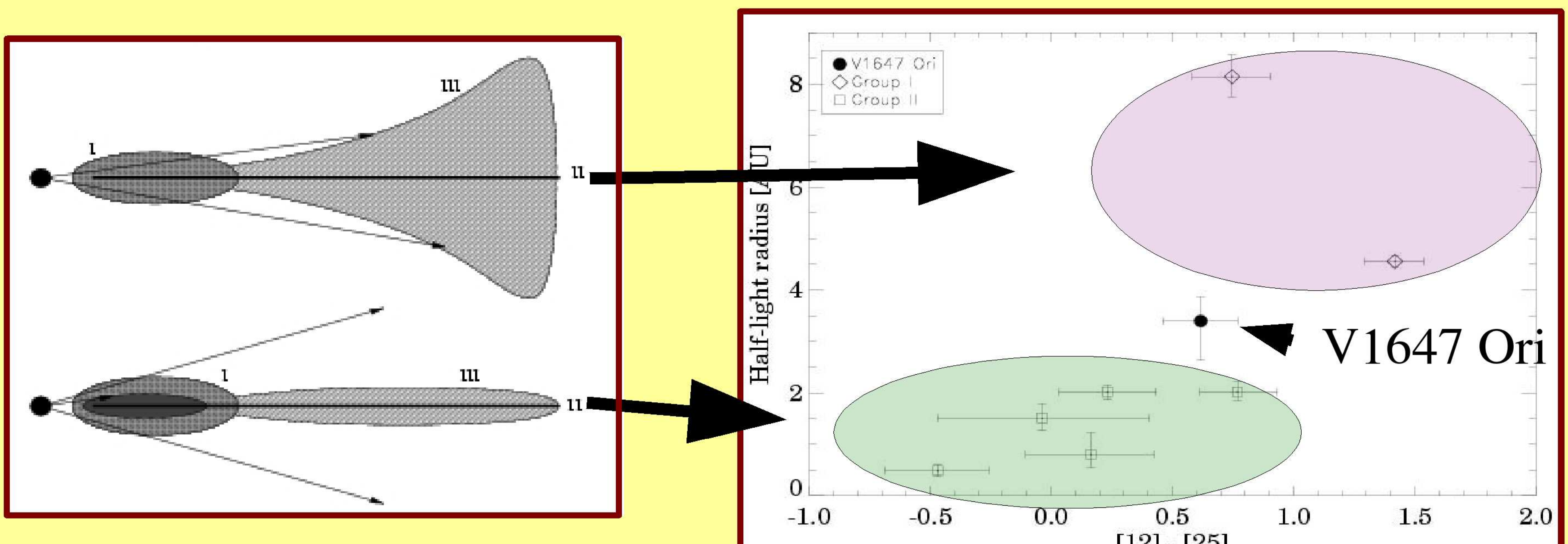
OO Ser



Á. Kóspál et al.

Analysis: geometry

- more refined models (radiative transfer)
- compare to Herbig Ae/Be stars (Leinert et al 2004):
  - visibilities
  - disks



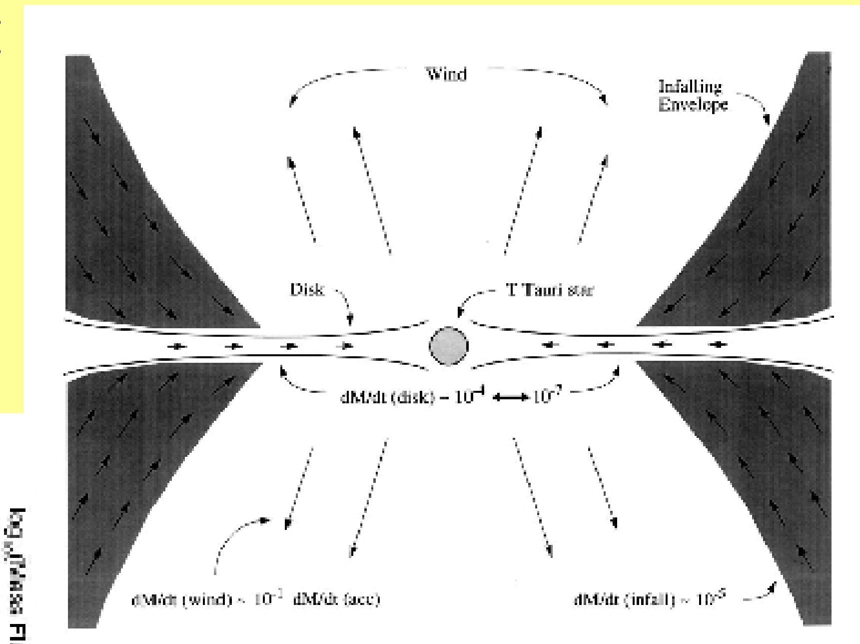
Meeus et al. 2001

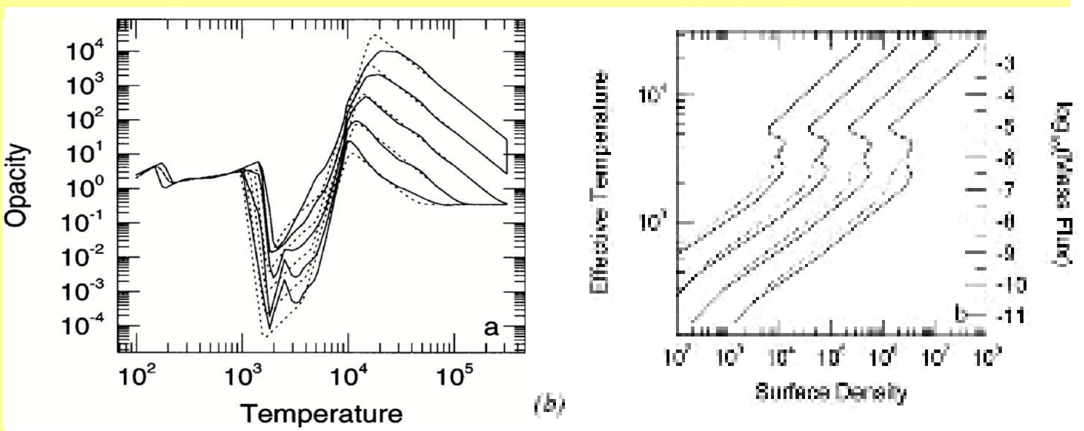
Thank you

Notes

FU Ori type sources - One class? One model?

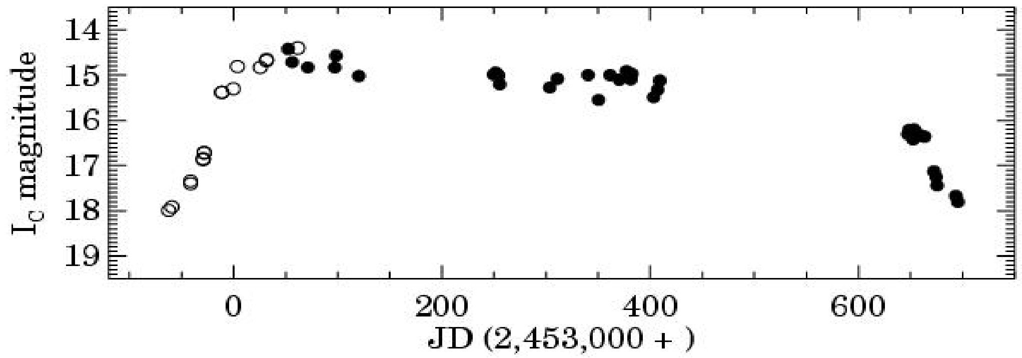
- thermal instability (~ 1AU):
  - Hartmann & Kenyon 1996





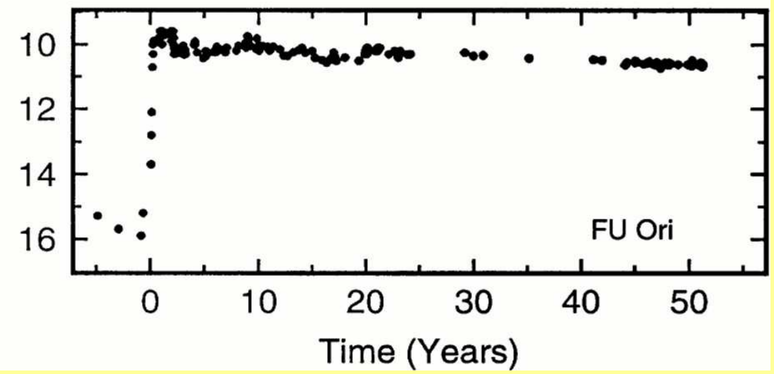
- triggered by the companion (Reipurth & Aspin 2004)
- flare of a rapidly rotating G supergiant with quasi-permanent winds + absorbing shell (optical spectrum, Herbig et al. 2003)

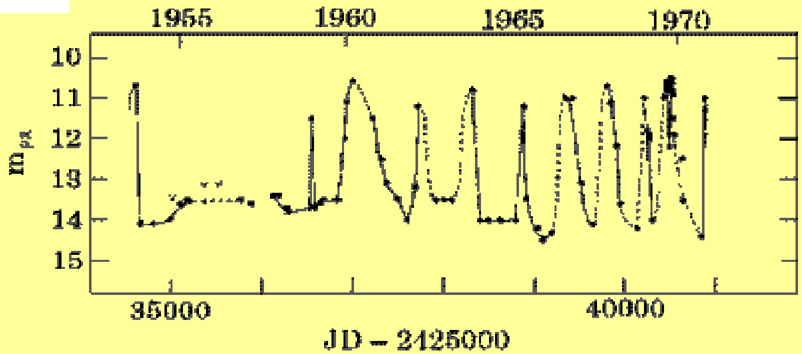
The End?



Kóspál et al. 2005

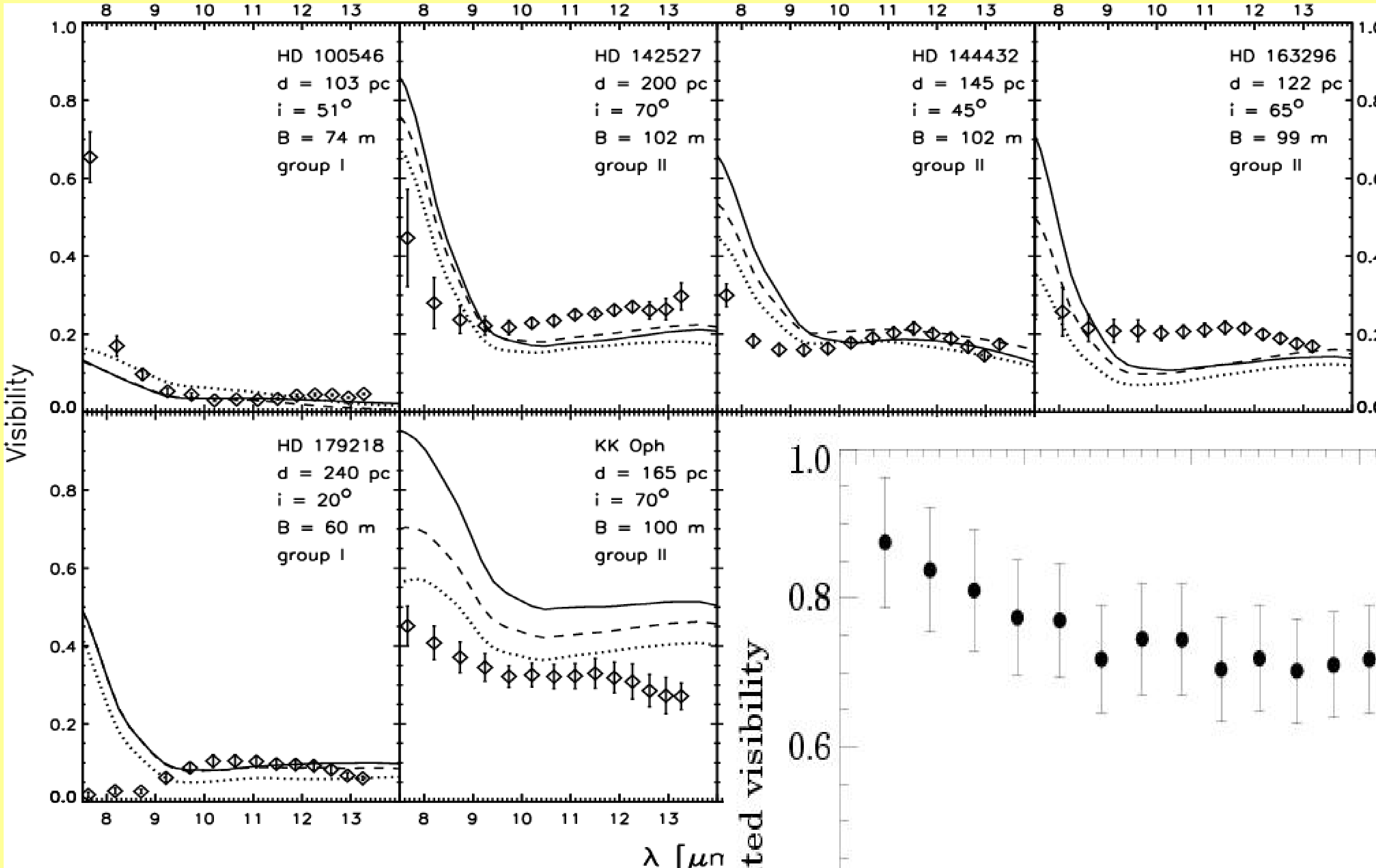
V1647 Ori was detected in 1966 (Messier Album) and 1995 (Eislöffel & Mundt 1997) but not in 1951, 1964, 1979, 1990 (POSS, Konkoly Archive plates): **EX Lupi type?**



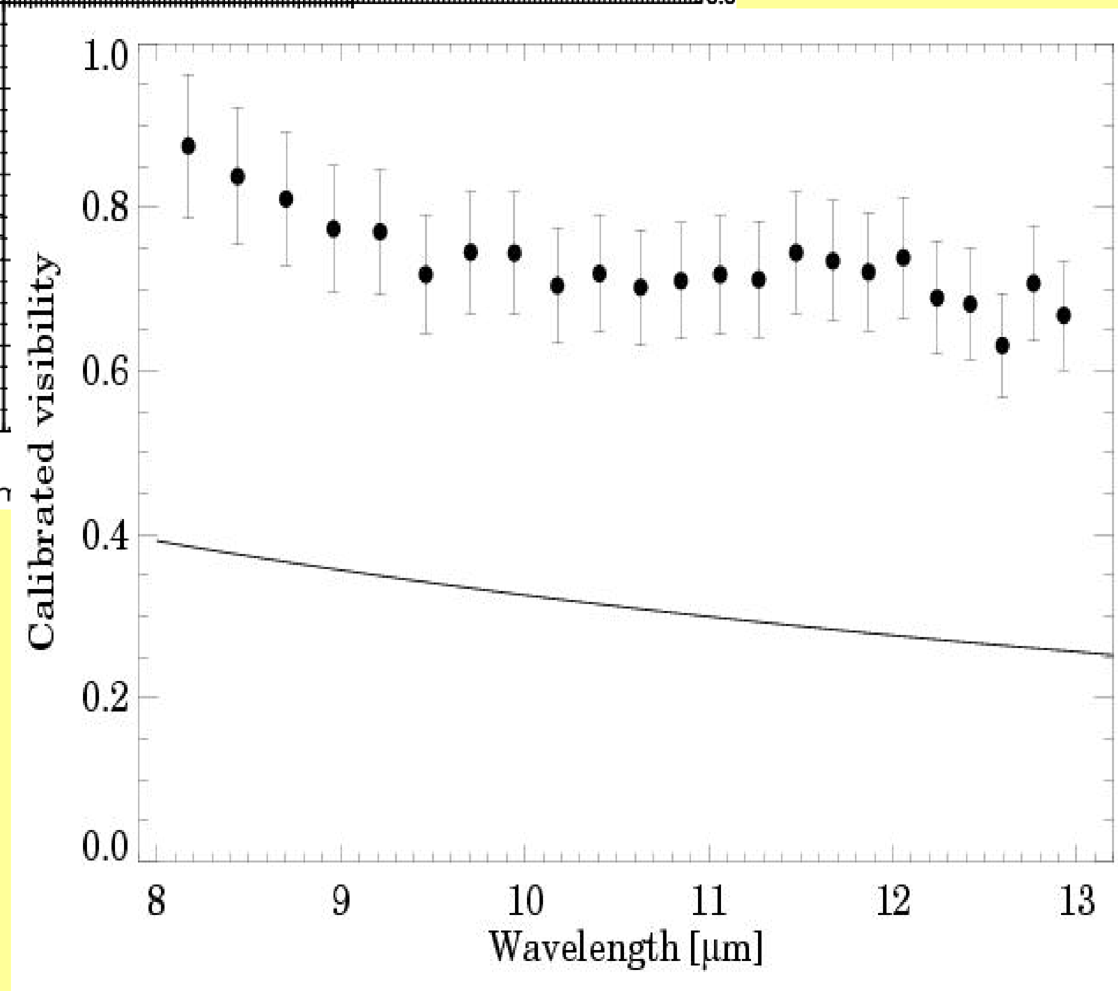


VY Tau (Herbig 1977)

V1647 Ori and OO Ser (Kóspál et al.): a new intermediate class?



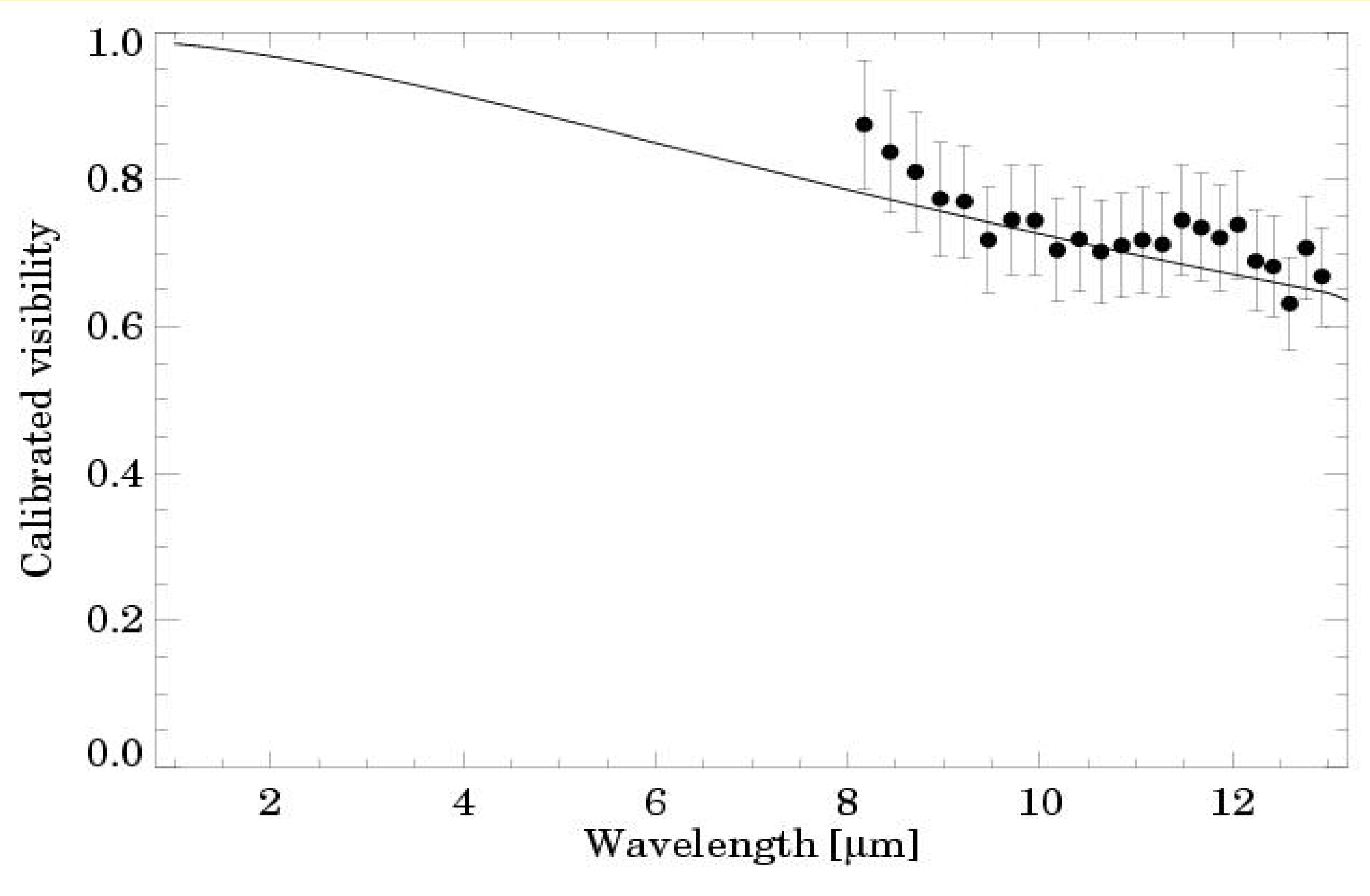
HD 100546
d = 103 pc
i = 51°
B = 74 m
group I
HD 142527
d = 200 pc
i = 70°
B = 102 m
group II
HD 144432
d = 145 pc
i = 45°
B = 102 m
group II
HD 163296
d = 122 pc
i = 65°
B = 99 m
group II
HD 179218
d = 240 pc
i = 20°
B = 60 m
group I
KK Oph
d = 165 pc
i = 70°
B = 100 m
group II
Visibility
λ [μm



Calibrated visibility
Wavelength [μm]

Analysis: SED fit

Alternative: a simple (spatially flat, optically thick) disk model



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Analysis: Model visibilities

- Fourier transformation

$$I(\alpha, \beta) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \nu(u, v) \exp(2\pi i(\alpha u + \beta u)) du dv$$

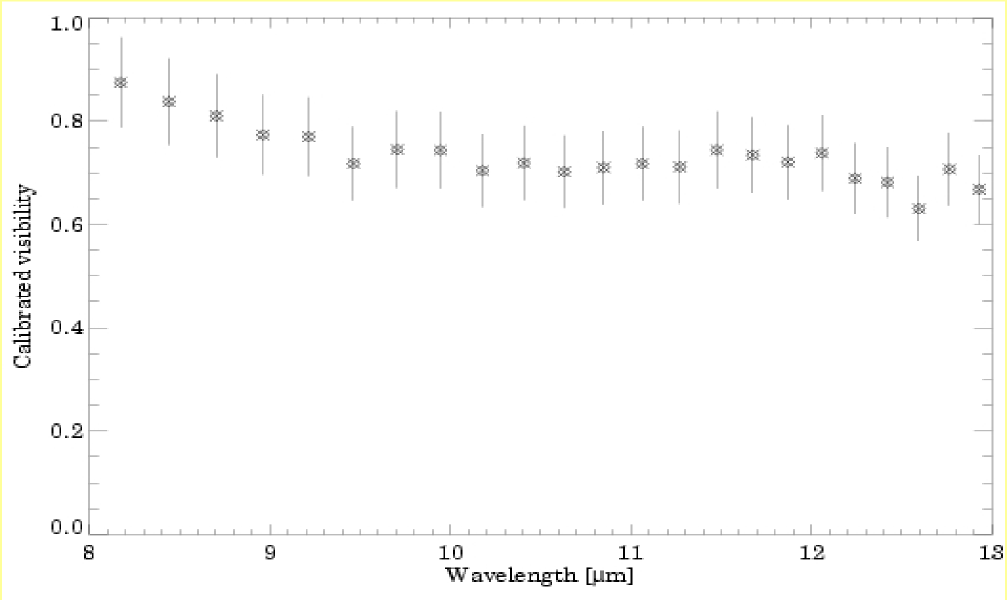
- Hankel transformation: simplified Fourier transformation for circularly symmetric source structure (Berger 2002)

$$\nu(r) = 2\pi \int_{0}^{\infty} I(\rho) J_0(2\pi\rho r) \rho d\rho$$

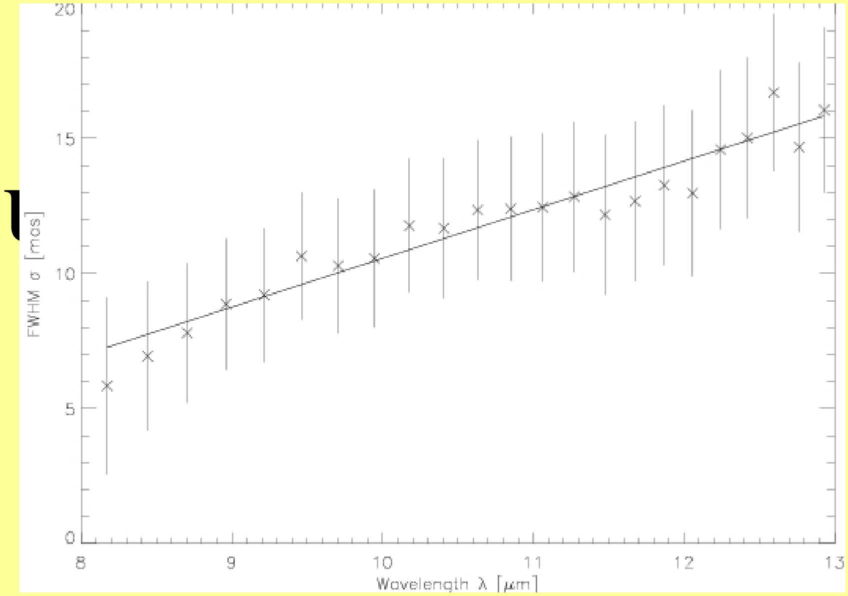
tools soon @ http://www.mpia-hd.mpg.de/MIDISOFT

MIDI results I.

- Spectrally resolved visibilities
  - slightly resolved (similar to other obtained YSO data)
  - errors: on this night all other observations were conducted with MACAO - conservative estimation: 10%

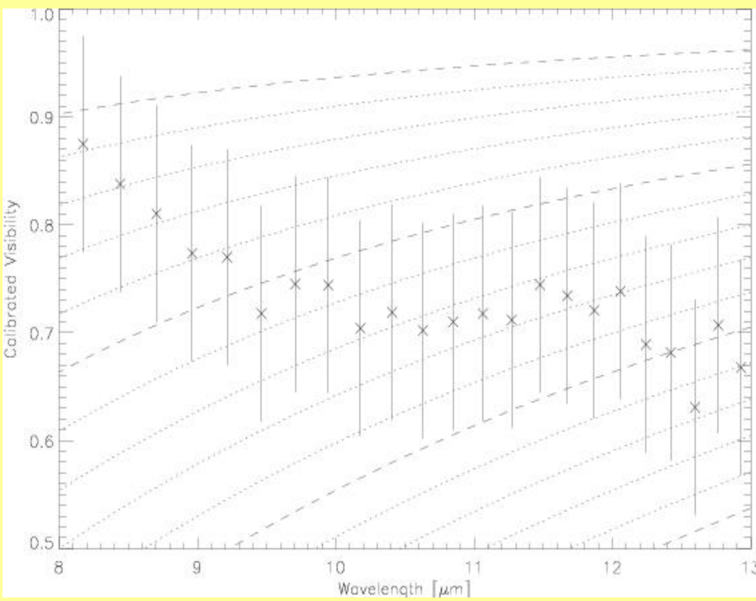


MIDI resu



- Spectrally resolved visibilities
  - slightly resolved
  - fitted Gaussian sizes: 8μm - 7.2 mas = 3.3 AU

    12 μm ~ 12.9 mas = 5.9 AU



all other ob

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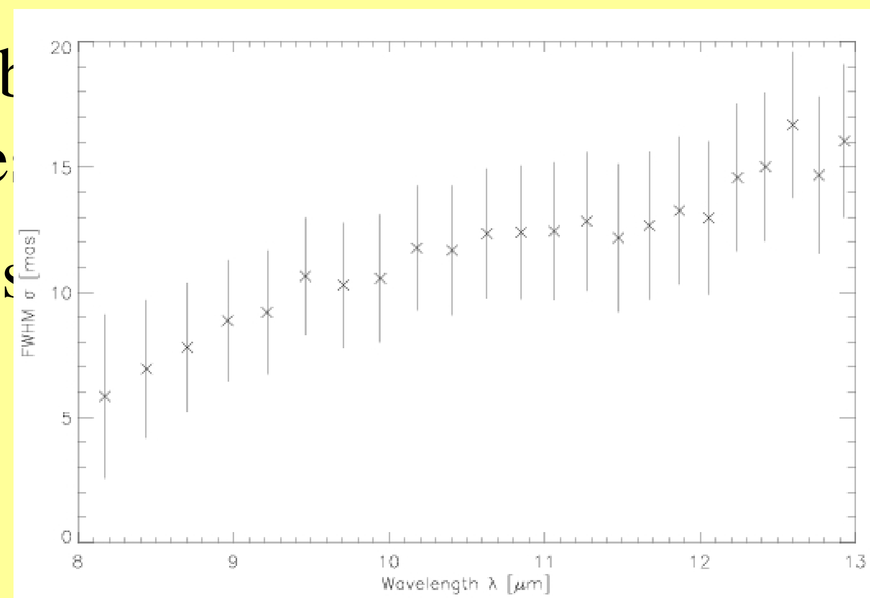


SED 204 vs MIDI 2005

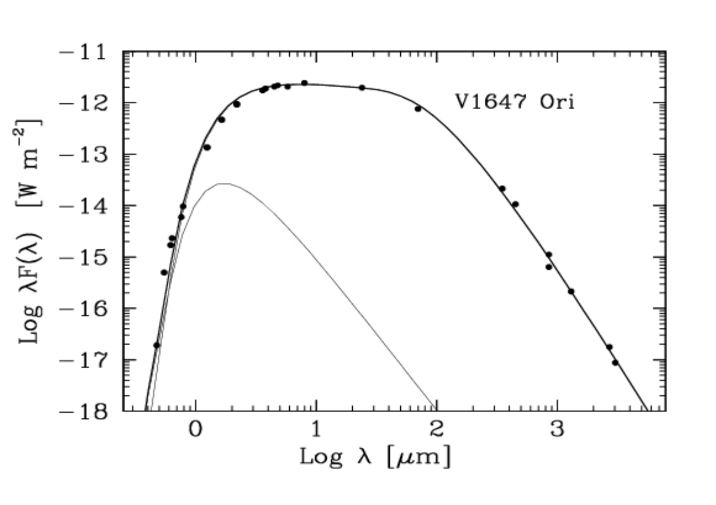
- optical fading till 2005 spring is small (Kóspál et al. 2005)
- MIDI sp. ~ Spitzer IRAC (2004 March, Muzerolle et al. 2005)
- Andrews data not considered in our fit
- no “fading factors” - overinterpretation

Analysis: SED fit

Simple unphysical model (spatially flat, optically thick disk)

.

SED



- optical - NIR: our data and Reipurth & Aspin 20
- 3.6 - 70 μm (Spitzer/IRAC): Muzerolle et al. 20(
- submm: Lis et al. (1999), Mitchell et al. (2001), Andrews et al. (2005) March 10, 2004
- mm: Tsukagoshi et al. 2005, Feb-May 2004, Vacca et al. 2004

SED fit

$q=-3/4$

• spatially flat disk or

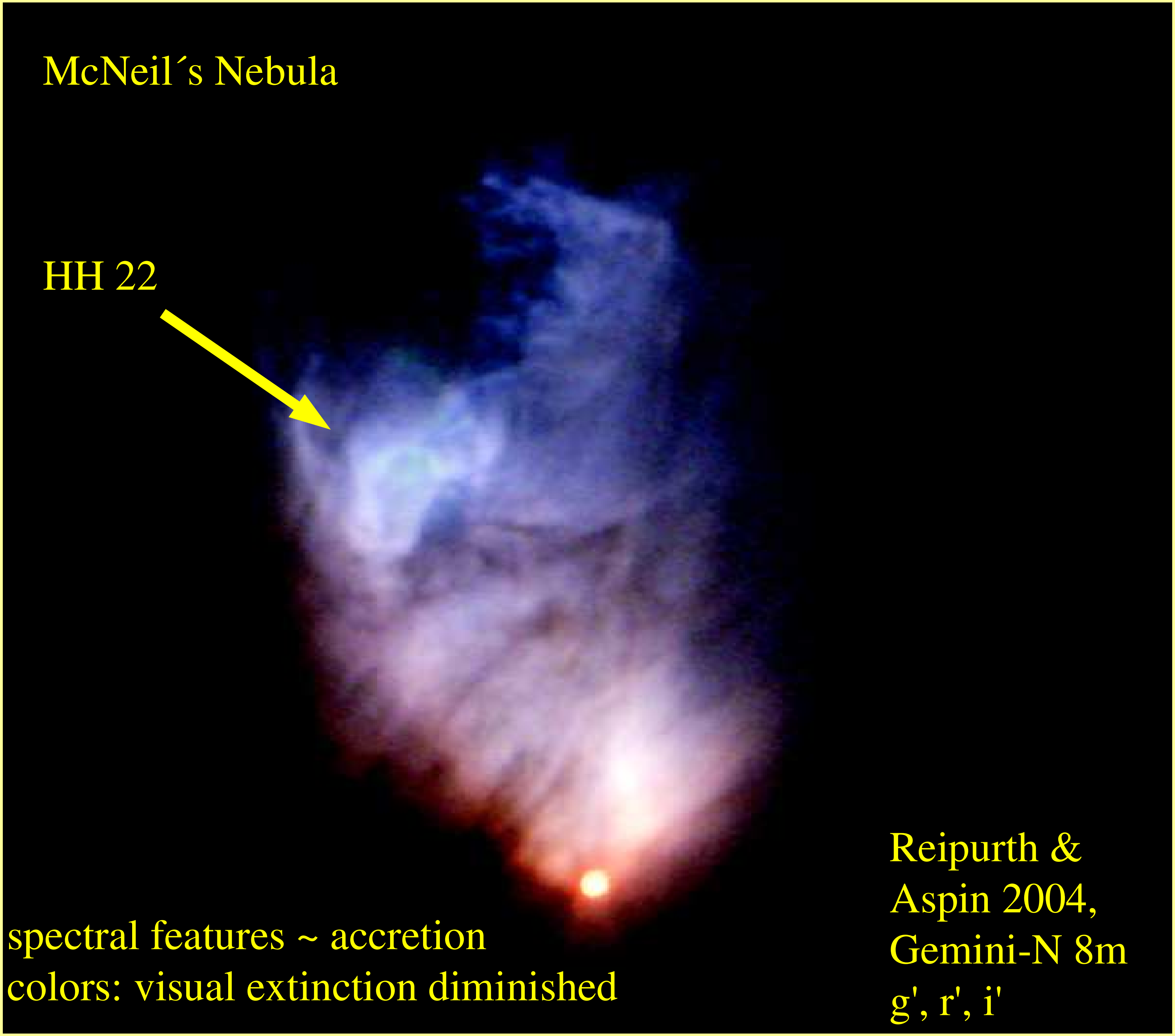
• accretion in the disk with Keplerian velocity

$q=-1/2$

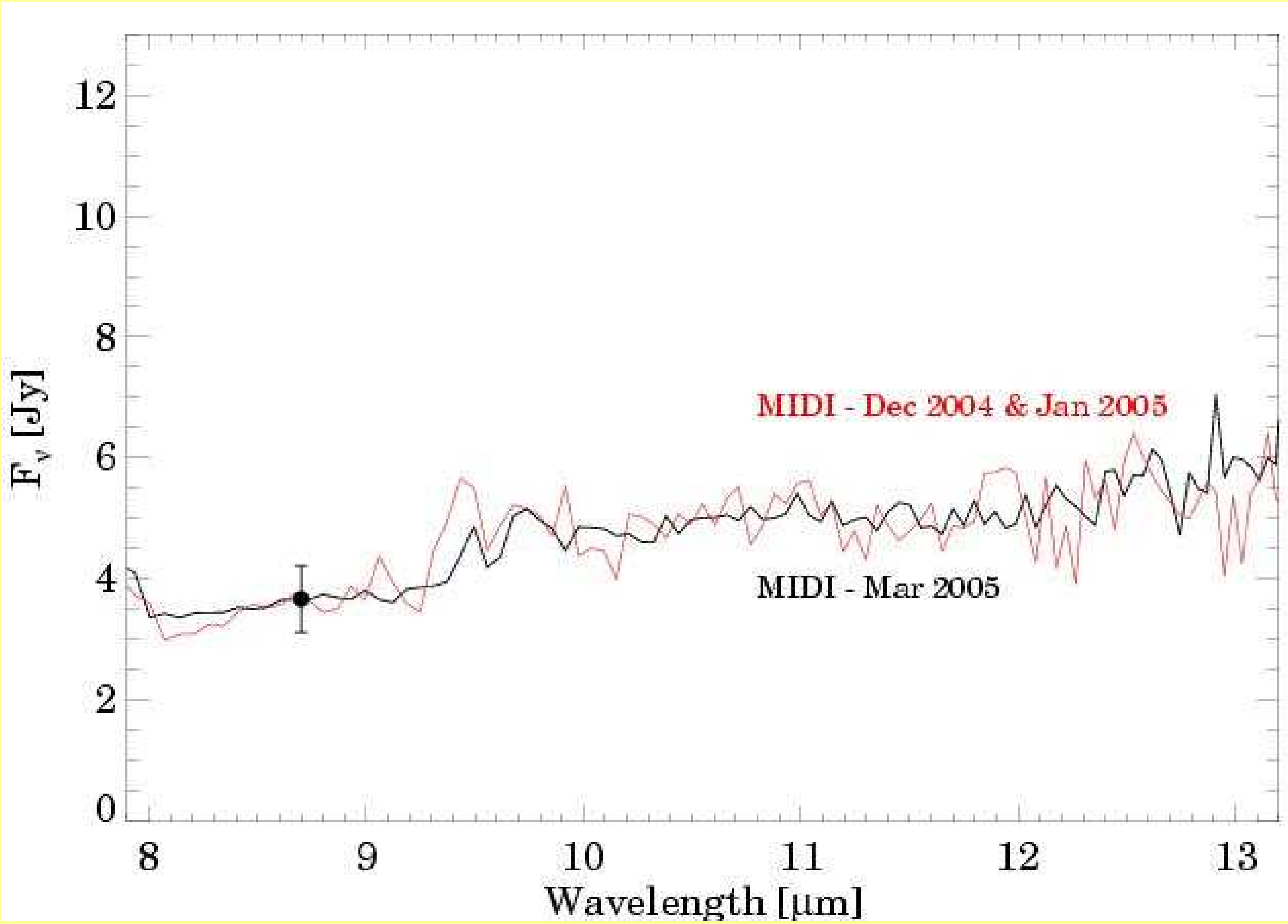
• flared disk or

• accretion in the disk with non-Keplerian velocity or

• Keplerian, but nonviscous: energy transported from inside to outside heating the outer parts and so decreasing the temperature gradient


McNeil´s Nebula
HH 22
spectral features ~ accretion
colors: visual extinction diminished
Reipurth &
Aspin 2004,
Gemini-N 8m
g', r', i'

MIDI results III.
Temporal evolution



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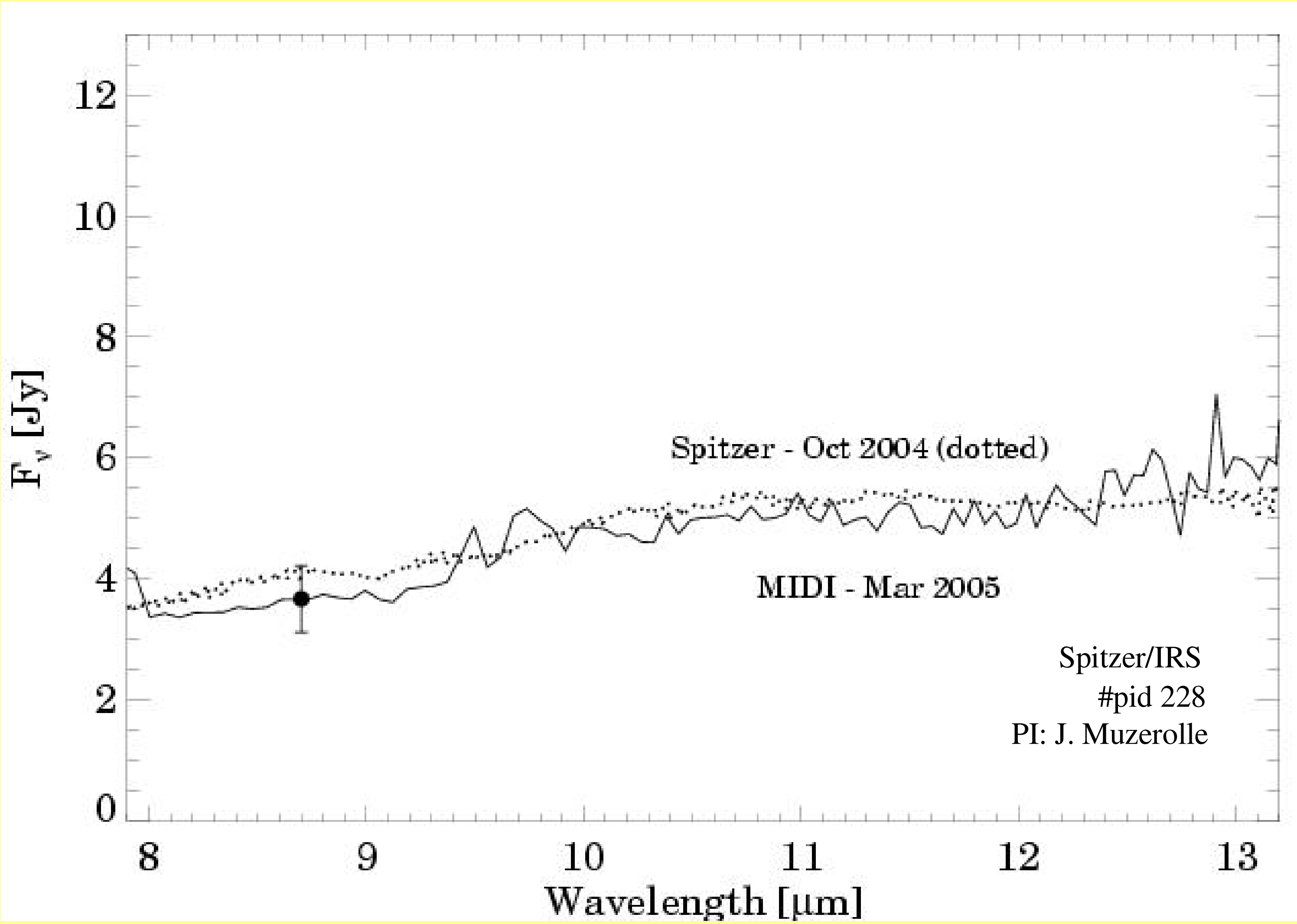

MIDI results III. Temporal evolution