Five Years of Keeping It Cool

The Contribution by Gemini Mid-Infrared Instrumentation to the Understanding of Massive Star Formation

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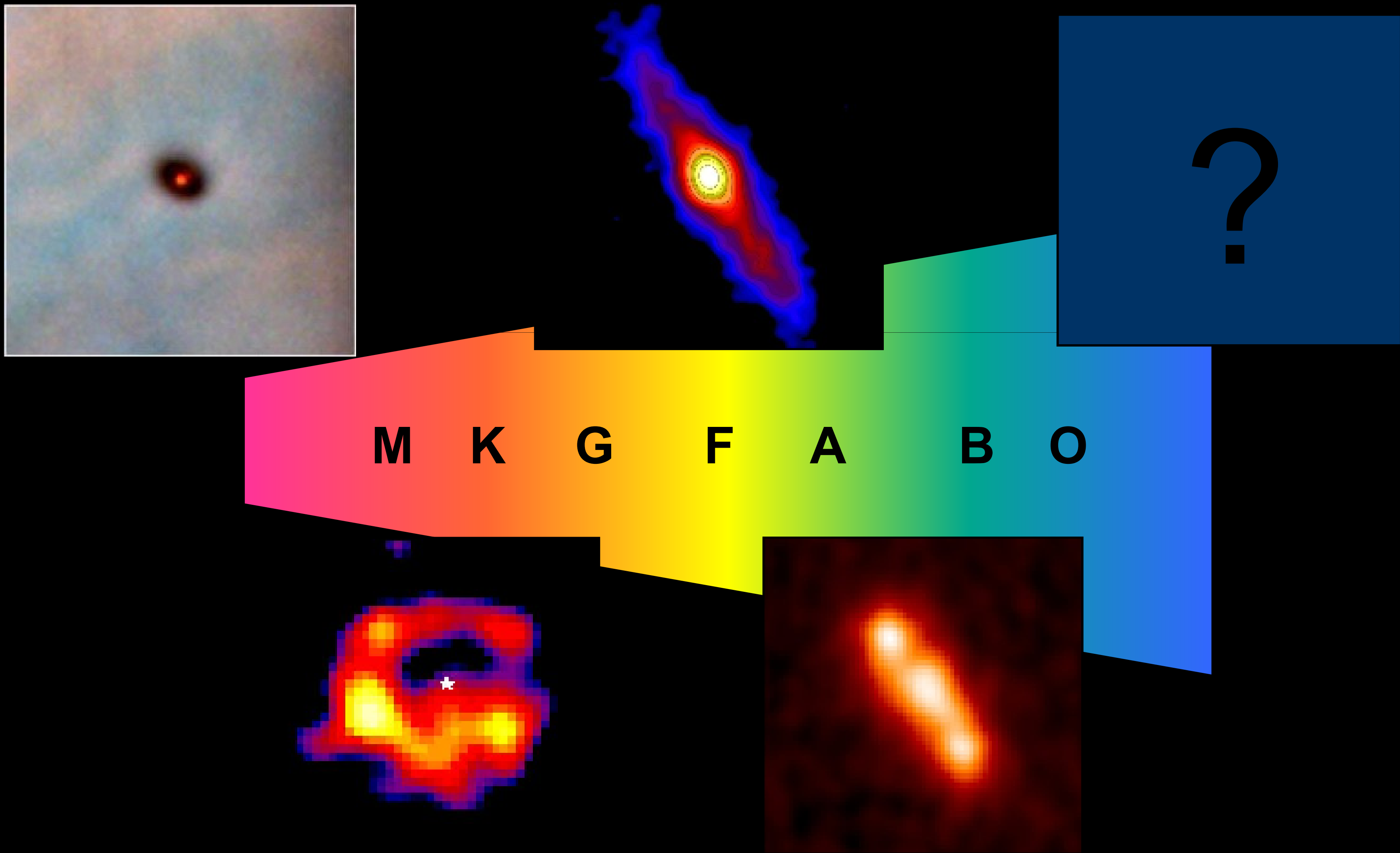
Circumstellar dust emission is traditionally believed to trace disks

- For example, Lada et al. (2000) find 80% of Trapesium cluster stars have “IR excess” independent of stellar mass
- Conclude that disk fraction is high

But can we be sure that MIR emission traces the same thing in massive as low mass stars?

There are *no* confirmed *directly* detected massive stars with circumstellar disks

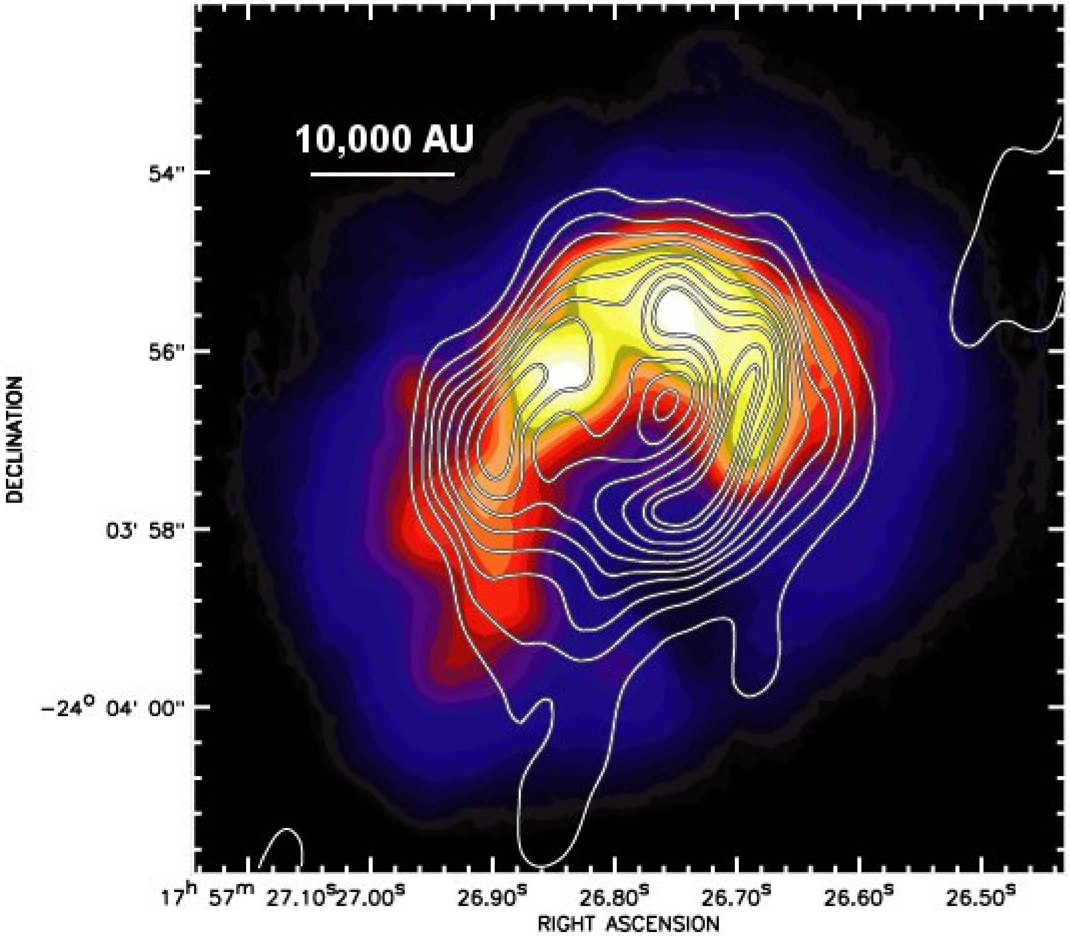


Very young massive stars and their disks are hard to observe in the MIR

- Generally FAR away (few kpc, rather than few pc)
- Extinction towards massive star forming regions is extremely high, even at MIR wavelengths (+ self embedded)
- Early stages of massive stellar evolution with a disk proceed *very* rapidly ($<10^5$ yr) and then the disk dissipates

Massive stars evolve quickly into compact HII region phase, where extended emission from ionized bubble can be seen readily in MIR

G5.89-0.39



Circumstellar disk has been disrupted at this point!

HMPO phase is heavily obscured, but Gemini successfully observed the in the MIR

"High Mass Protostellar Objects" are compact and massive young stellar sources:

✓ *Undergoing disk/envelope accretion*

✓ Display molecular line emission and dust emission (MIR to mm)

✓ Lack free-free emission from ionized gas (i.e. a ultracompact HII region has not yet formed),

✓ Usually associated with maser emission

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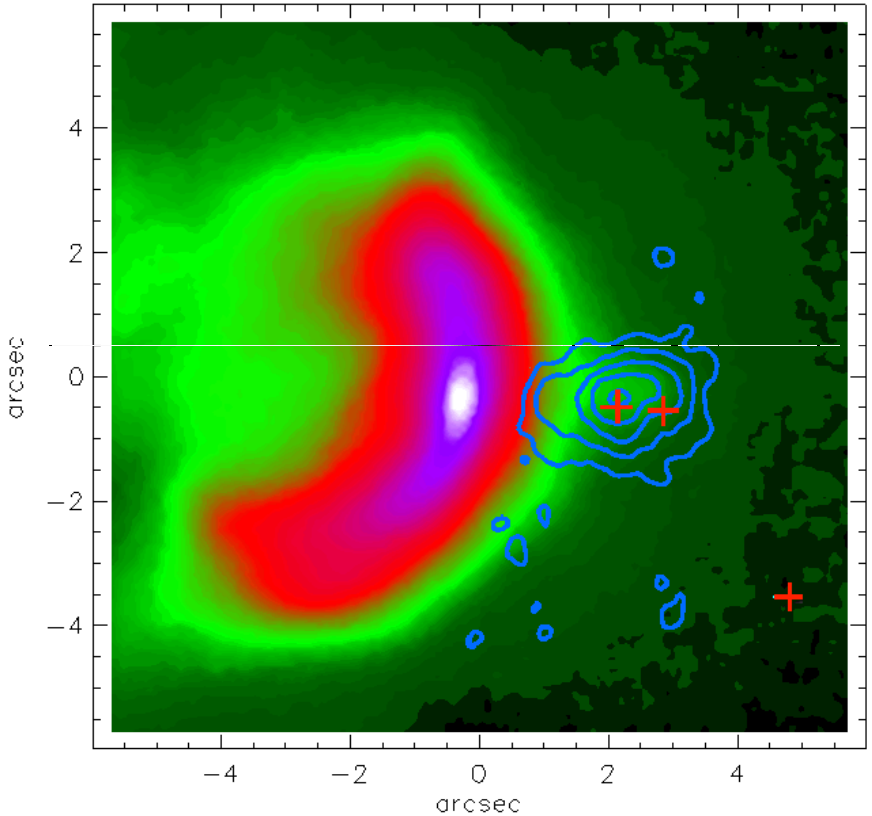
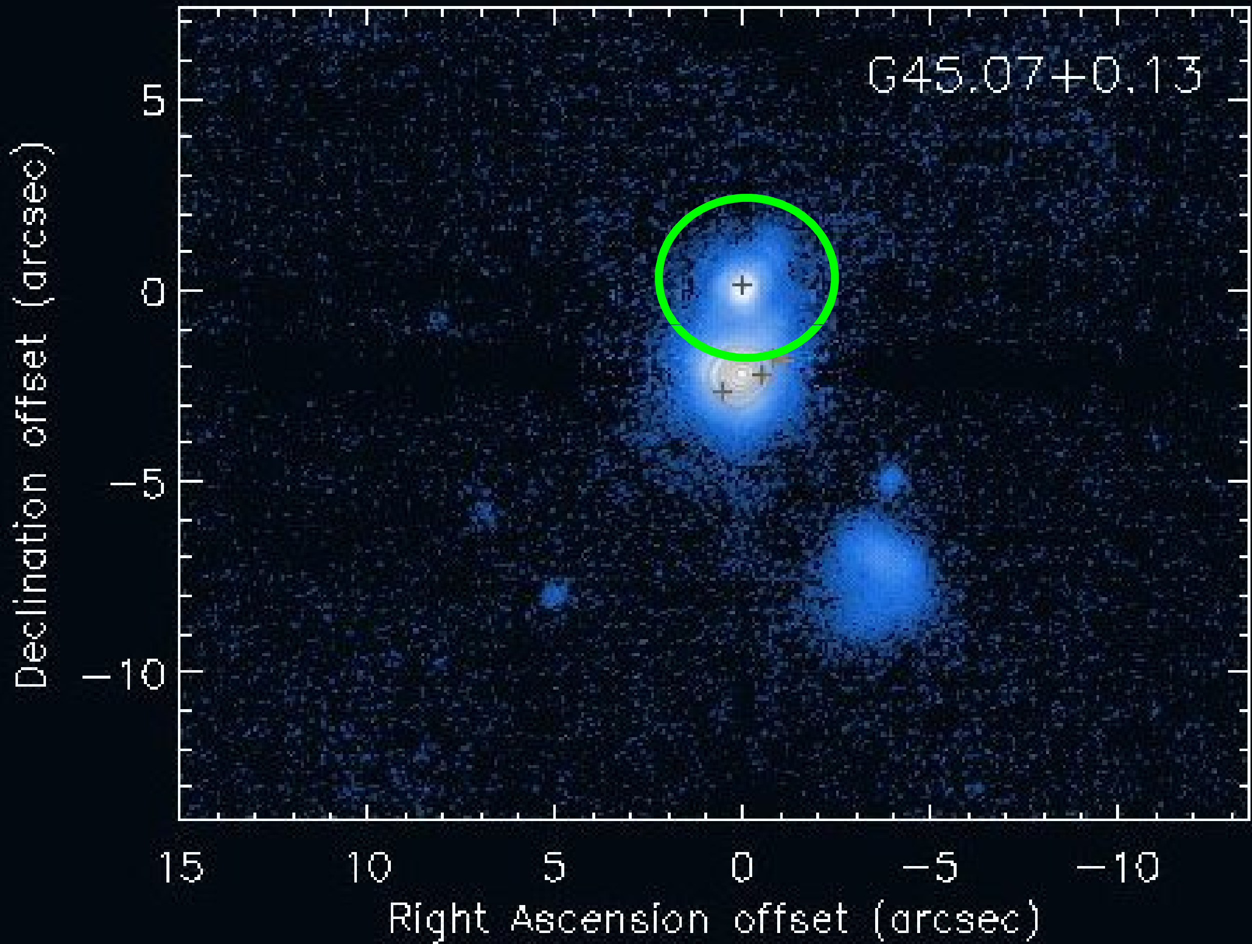


Radio continuum and ammonia line emission from Cesaroni et al. (1994)
MIR continuum emission (Gemini North/OSCIR) from De Buizer et al. (2002)

More HMPOs were found by Gemini, and SED models showed that the MIR ***may*** constrain disk parameters



T-ReCS Data - De Buizer, Osorio, & Calvet (2005)

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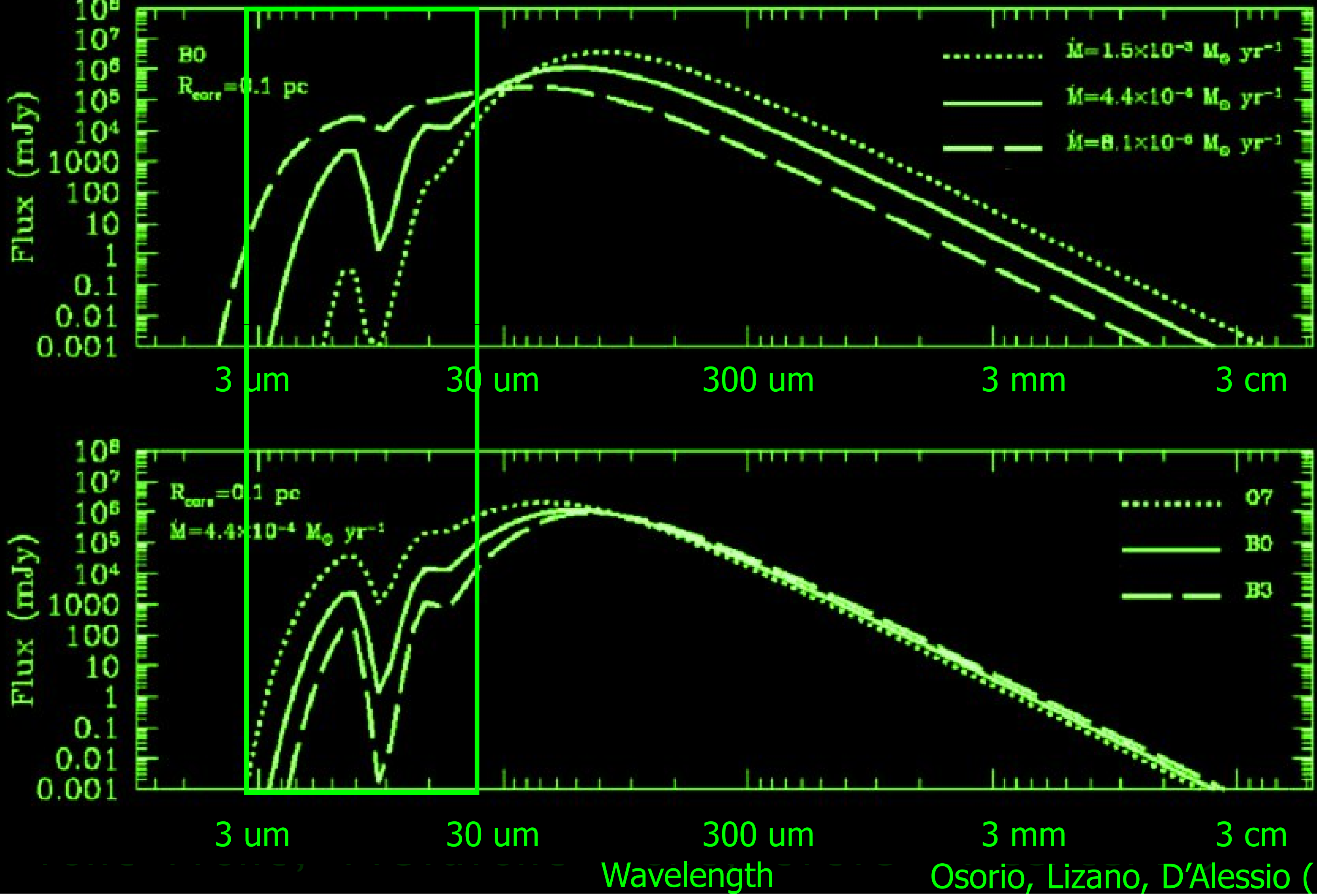
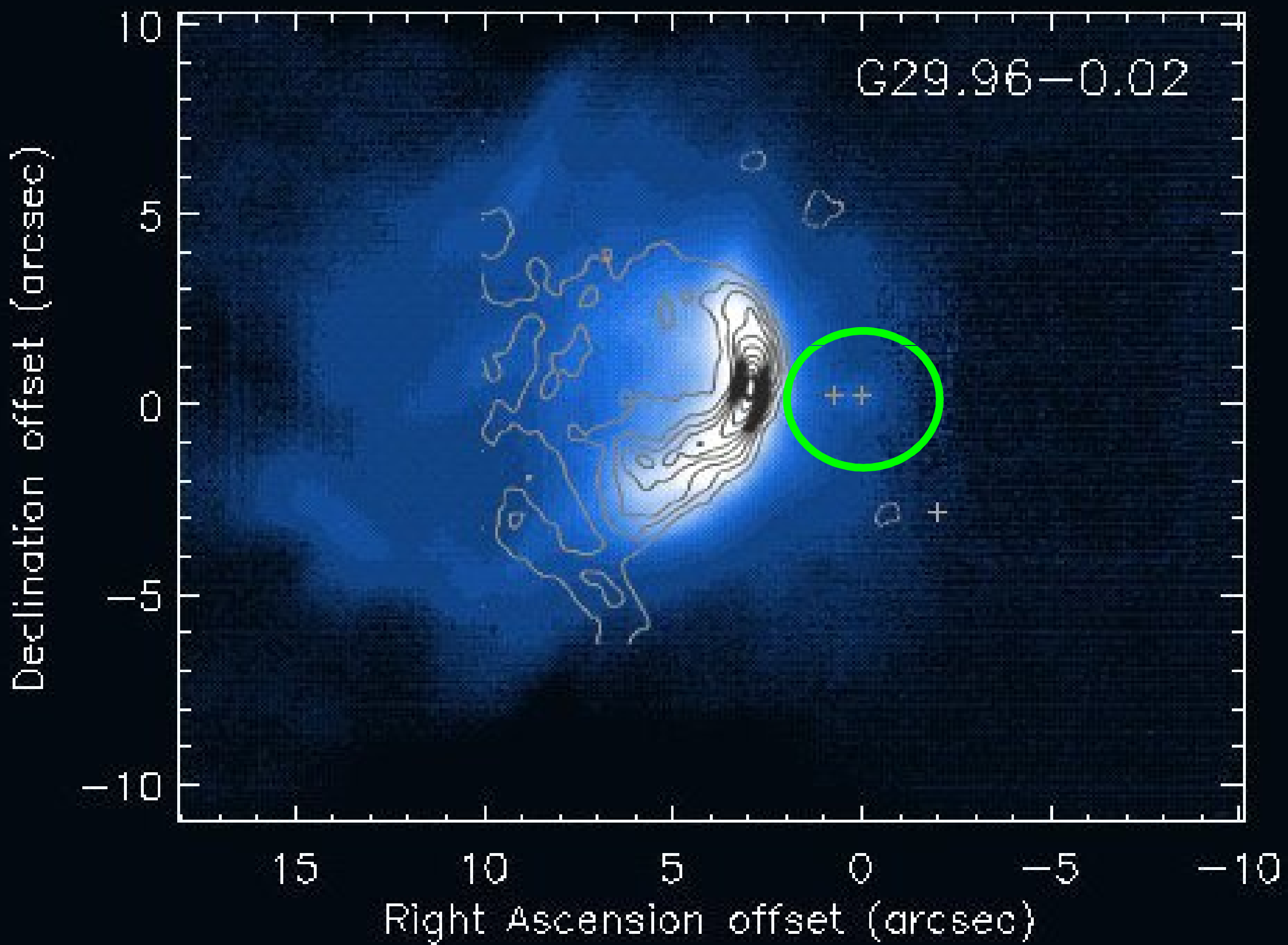


Osorio, Lizano, D'Alessio (1999)

We do not directly detect the disk, but ***may*** deduce disk properties with the help from MIR fluxes



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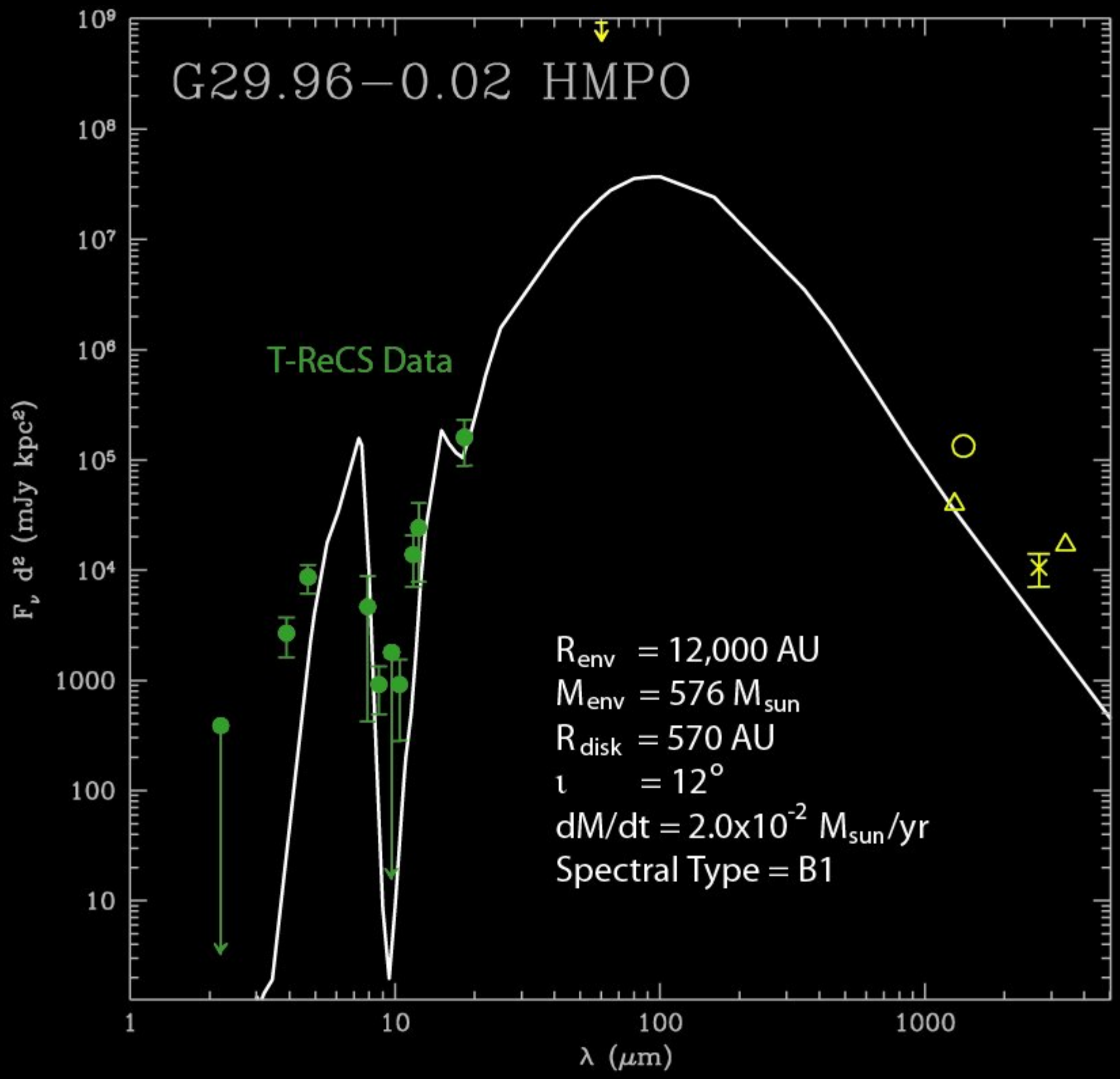
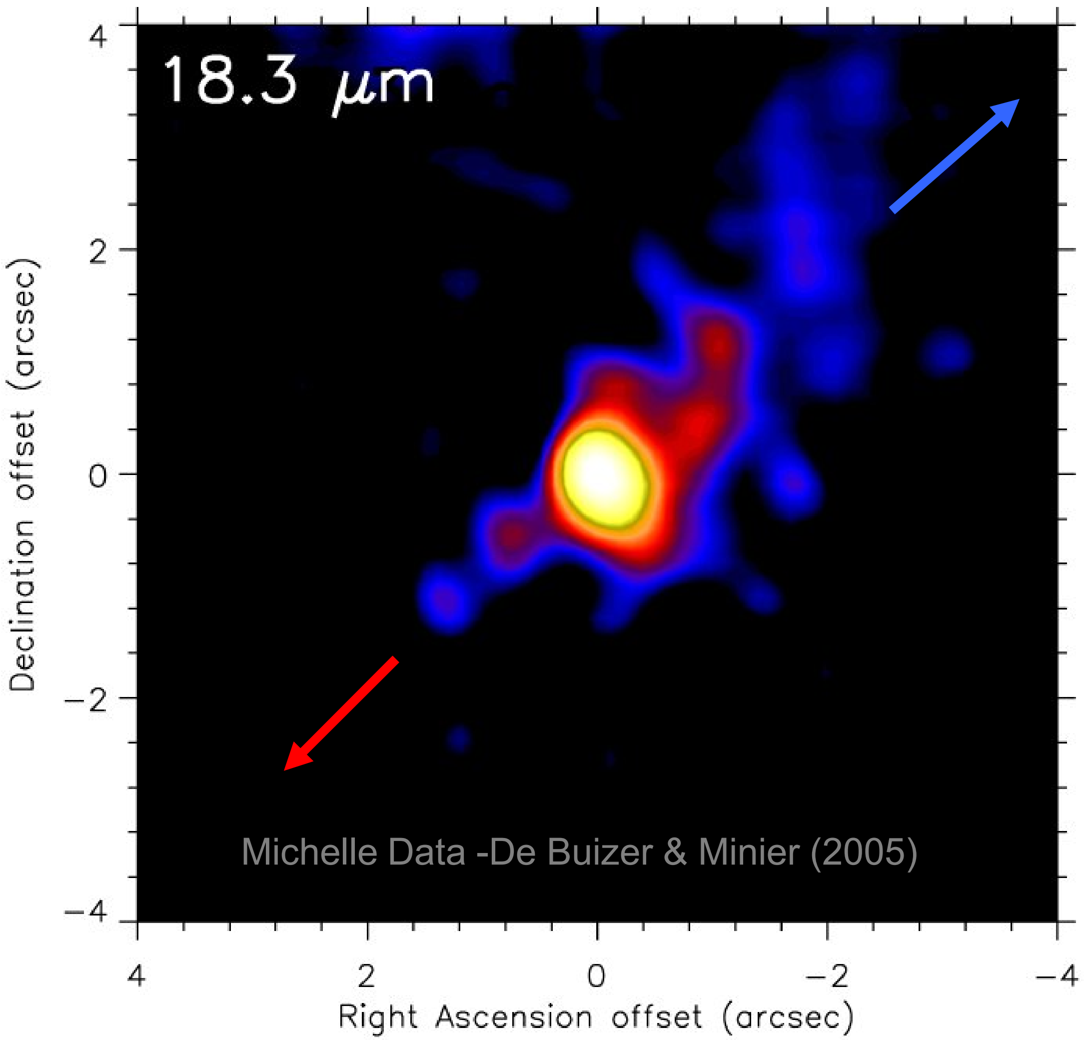
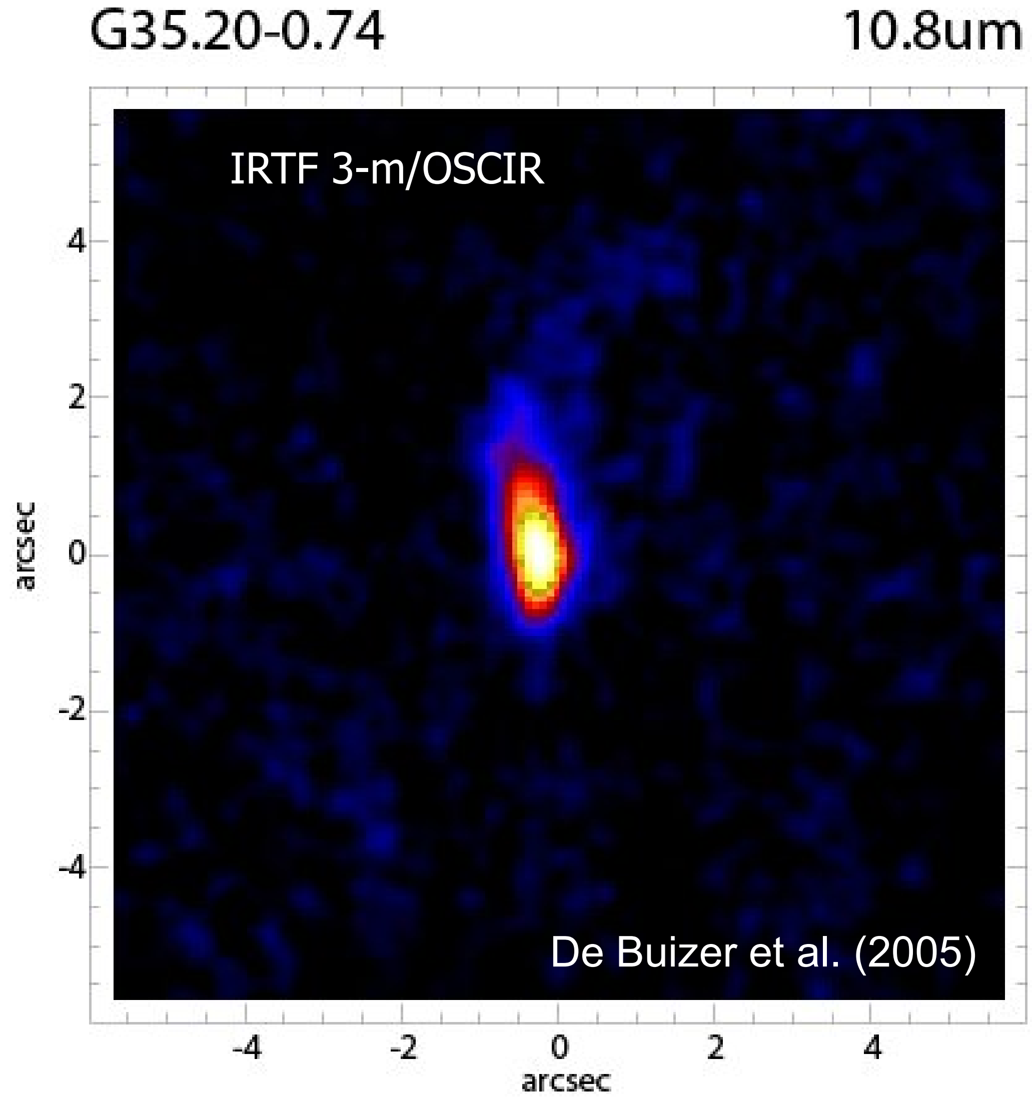


T-ReCS Data - De Buizer, Osorio, & Calvet (2005)

High-res images of NGC 7538 IRS1 show MIR emission can come from an outflow!



G35.20-0.74 is a even more conclusive example of MIR emission from an *outflow*, not a disk!



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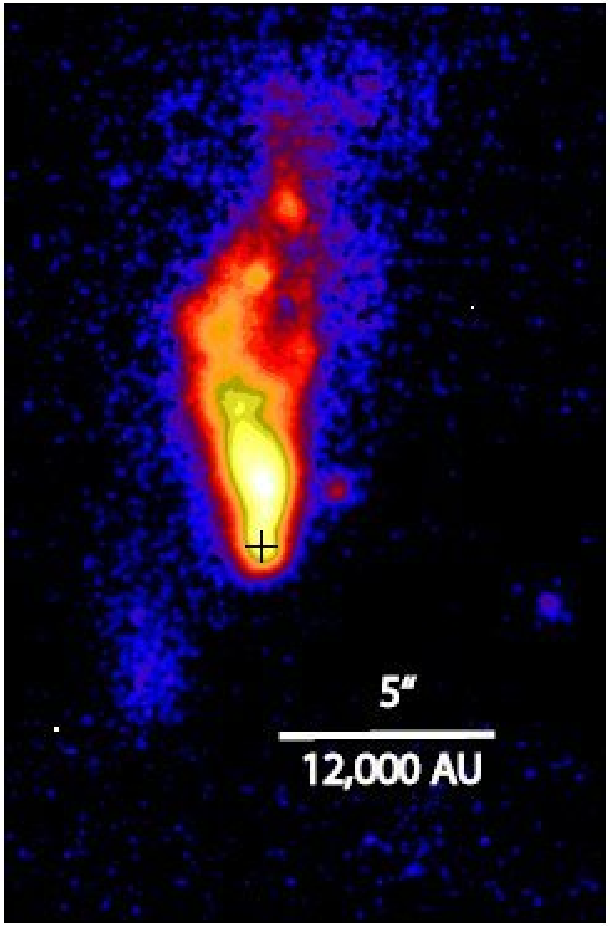
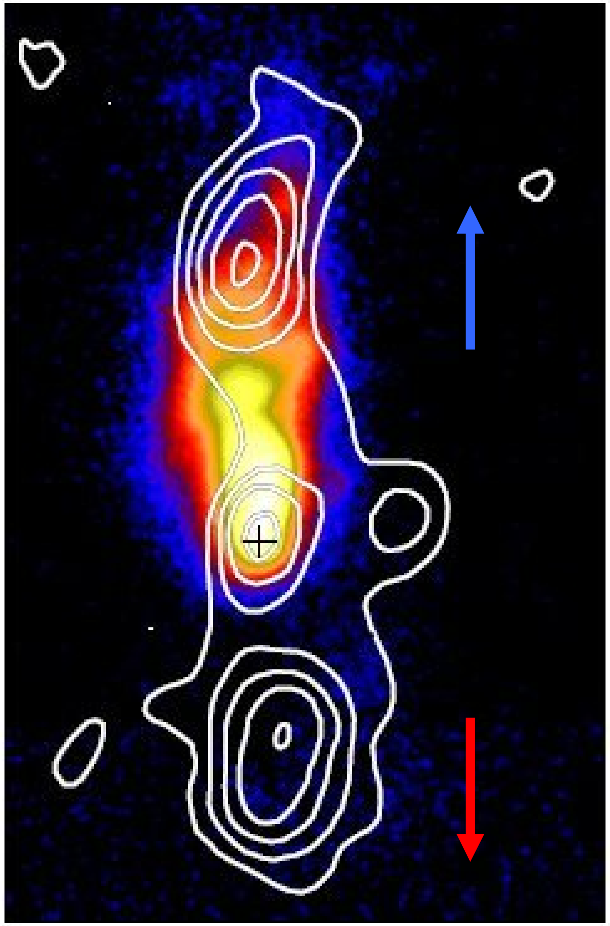
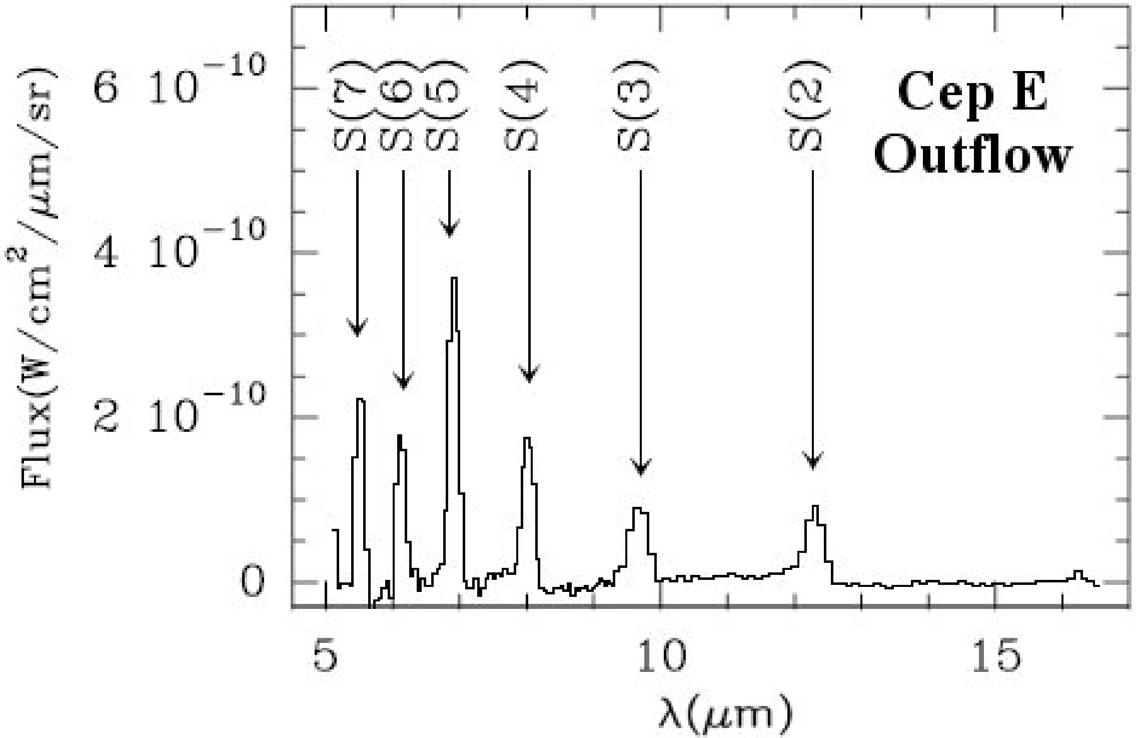




- Dust continuum from outflow dominates the MIR emission from this source

T-ReCS Data - De Buizer 2006

Spectra confirm outflow emission is continuum MIR, and not shock lines of outflow emission



- MIR emission from outflows and HH objects has been seen before, but was dominated by shock-excited H_2 lines

ISO Data – Noriega-Crespo 2002

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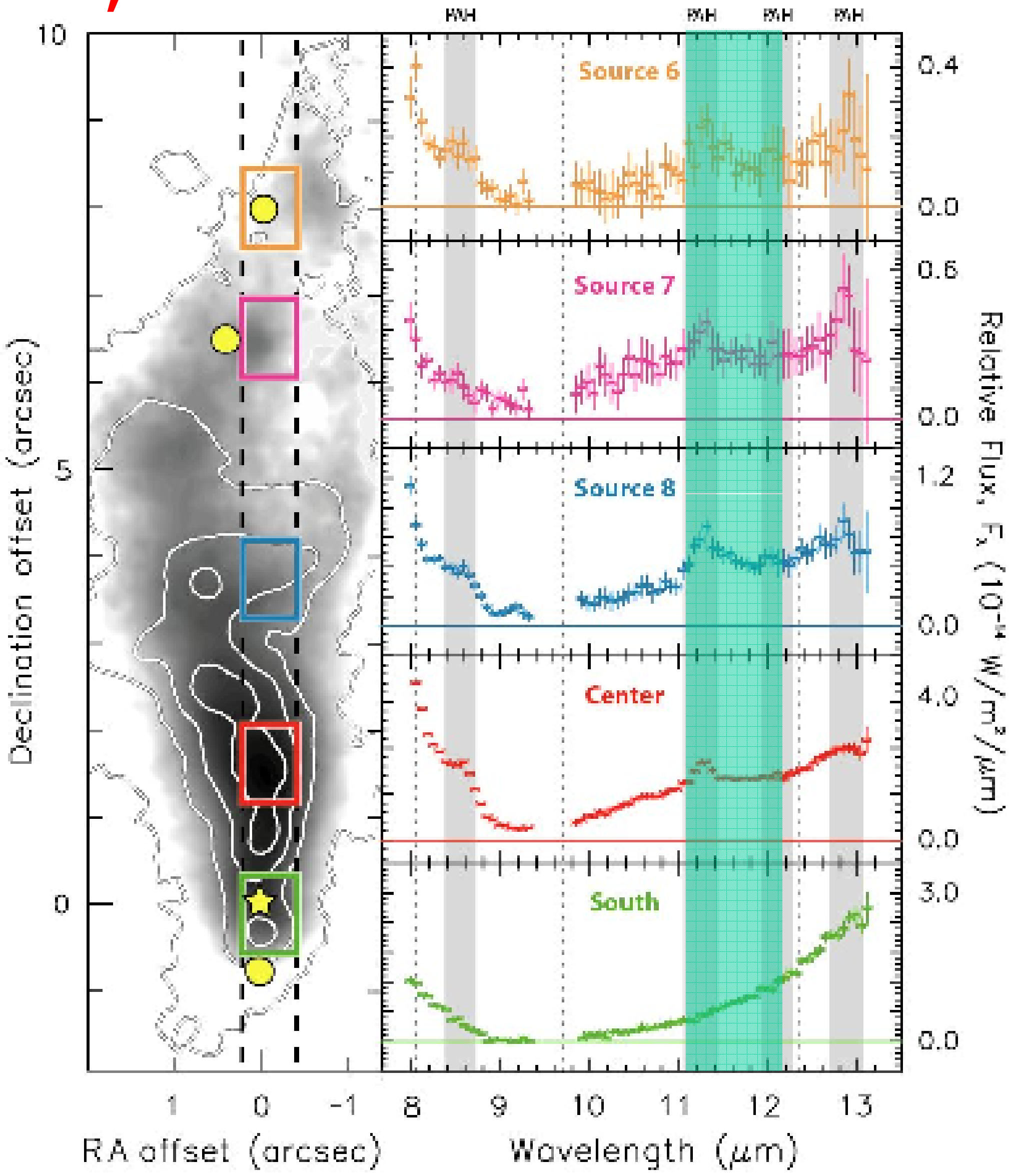
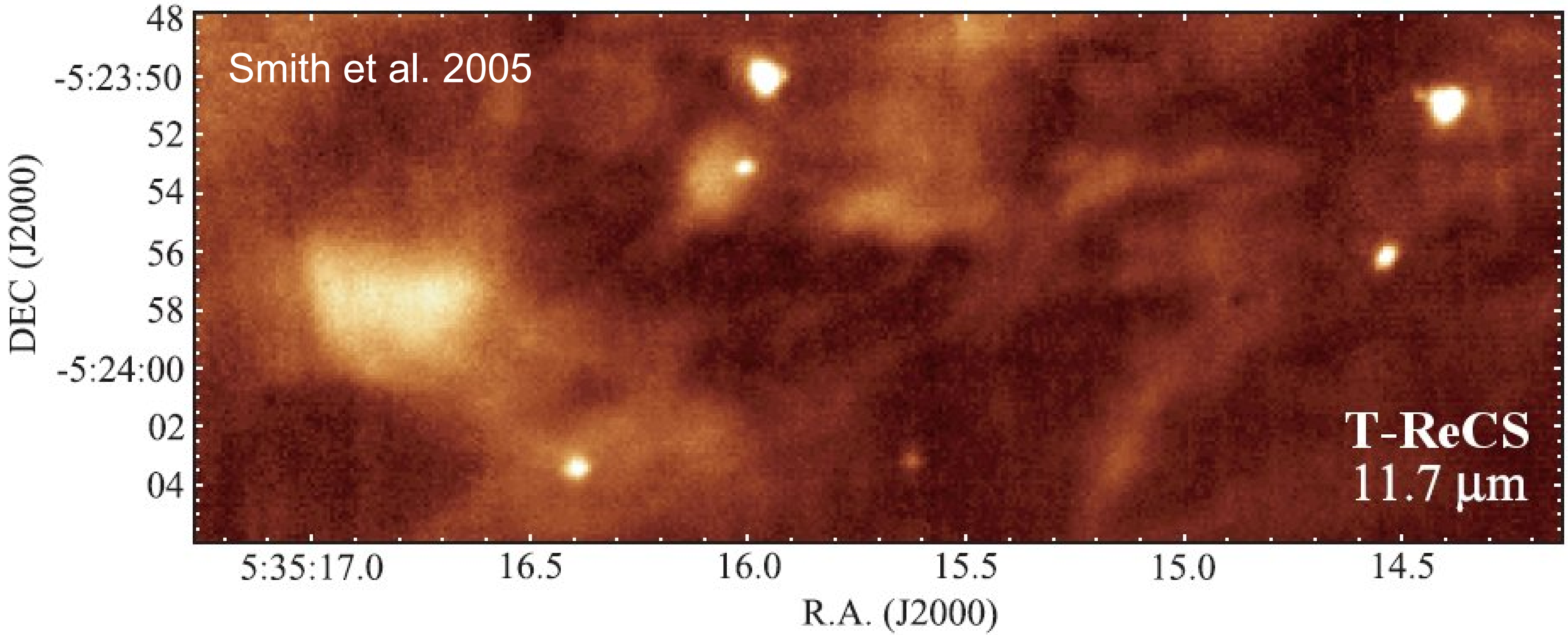


- T-ReCS spectra prove that the H_2 lines are not contributing to the MIR emission
- There is some PAH emission, but the outflow seems dominated by dust continuum
- Actually the Si-5 filter does not include any H_2 lines anyway
- Outflow spectra look like disk spectra!

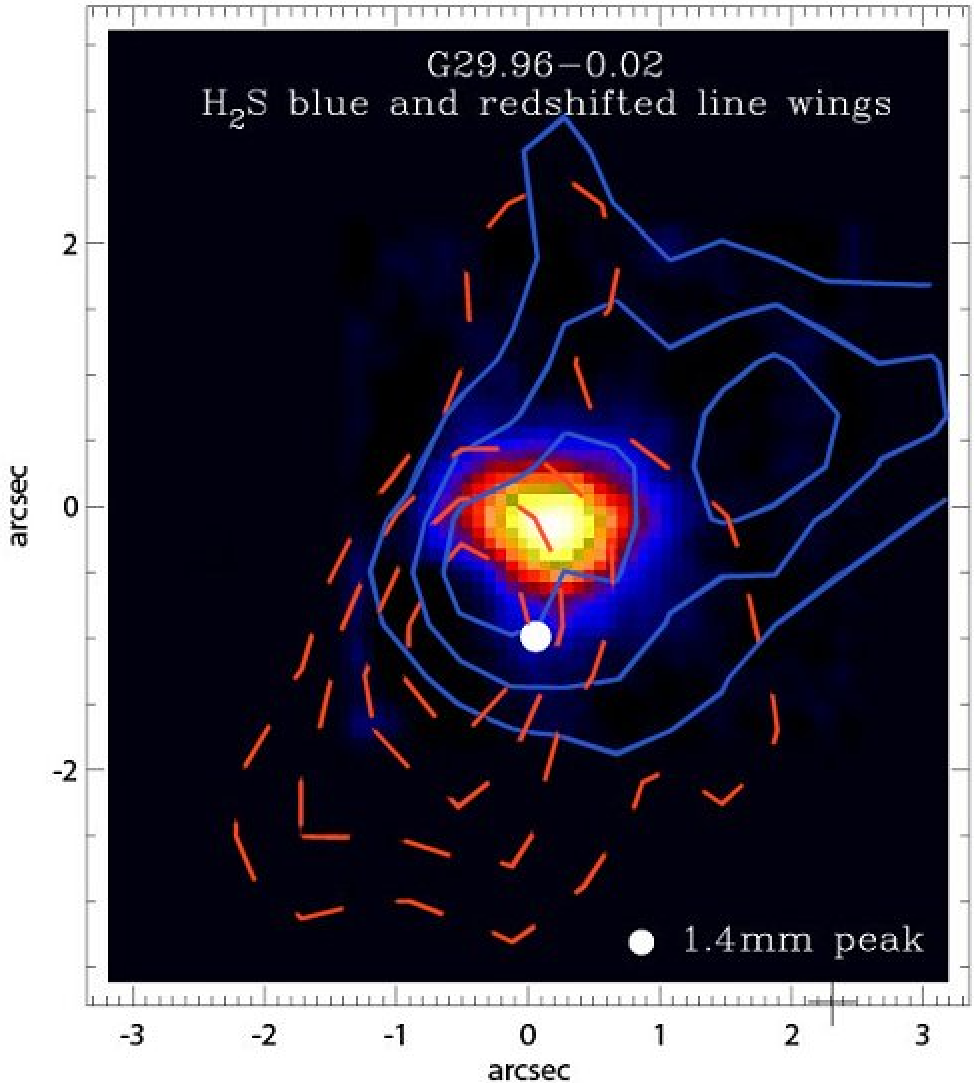
T-ReCS Data - De Buizer, in prep

Observations of Orion show MIR emission in outflows & HH objects from LOW mass stars too



- Dust may be entrained in outflow, or form in dense cooling zone behind a reverse shock or bow shock

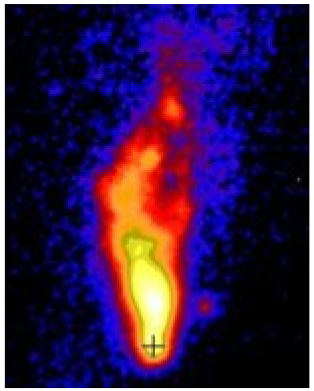
New observations of the G29 HMPO show the MIR emission detected is from outflow as well!



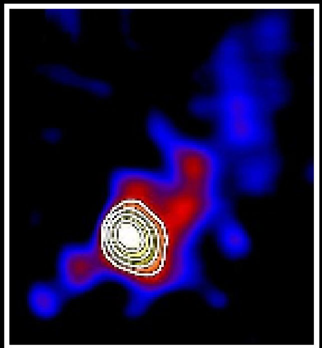
Contours from Gibb et al. 2004

Figure from De Buizer, in prep

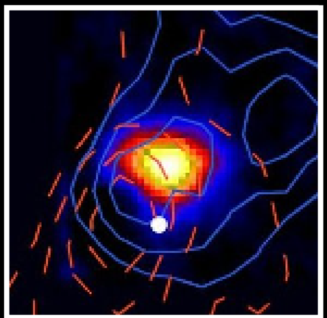
Important Results from Gemini MIR Observations of Massive Star Formation



• An observational paradigm shift: MIR ***continuum*** emission, traditionally thought to trace disks, is being found to commonly come from outflows in massive stars (and even low-mass stars)



• These MIR outflows can look similar to disks, have spectral properties like disks, and even their fluxes can be fit with disk parameters in SED models



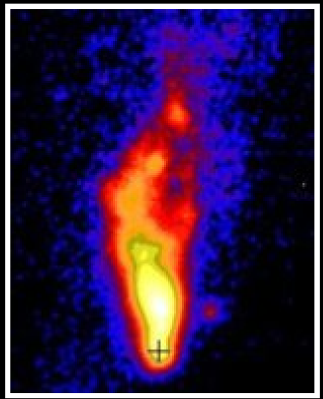
• Perhaps MIR from the heavily embedded HMPO phase may often be detected only if there is an outflow pointed toward us

COME FLY WITH US!

SOFIA Science Flights Winter 2010

(There will be peanuts and our in-flight movie will be "Beverly Hills Chihuahua")

Important Results from Gemini MIR Observations of Massive Star Formation



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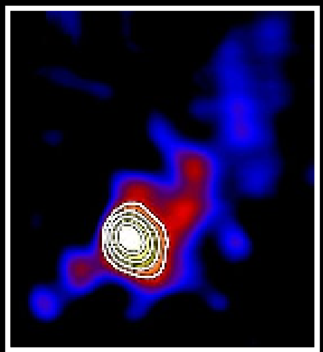

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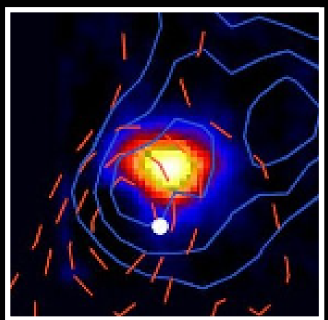

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