Modeling a unique accretion disk around a high-mass protostar

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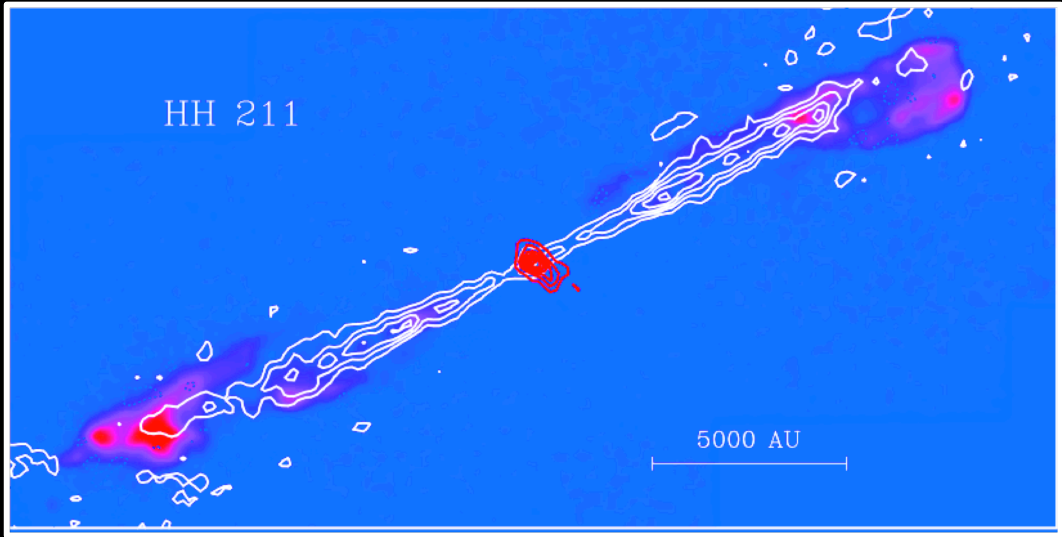
Search for accretion disks in massive protostars

The current paradigm of low-mass star formation predicts the development of a disk-jet system.

Some massive star formation theories also predict the development of similar disk-jet systems in massive protostars.

Search for similar disks in massive protostars has been one of the main topics of research in the last years.

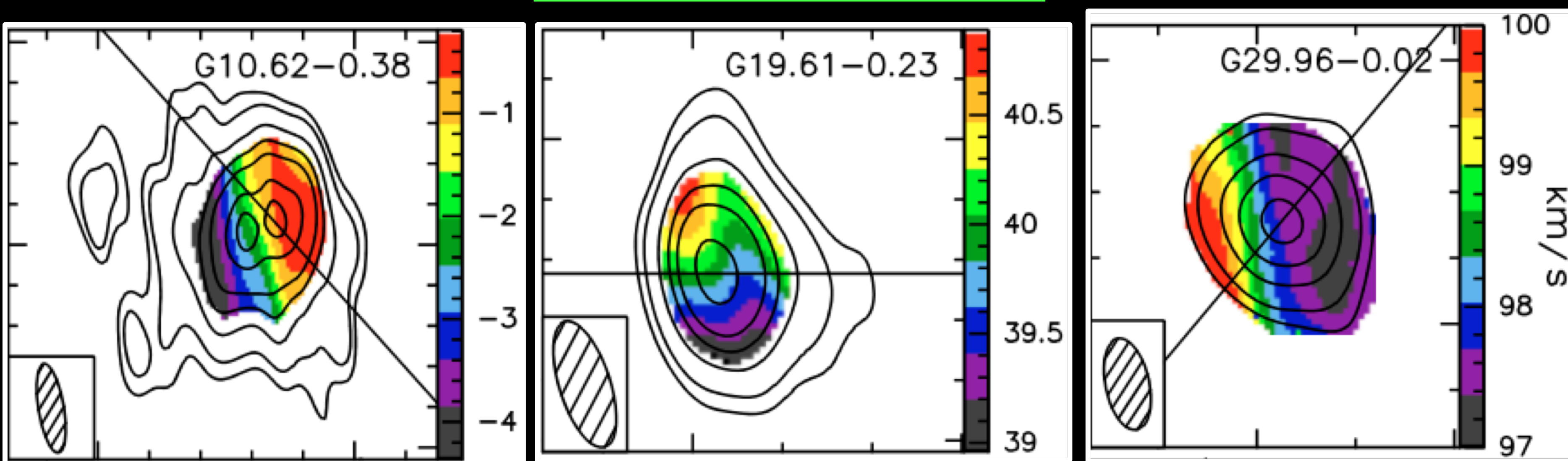


Disk-jet system of the low-mass star HH211 (Gueth & Guilloteau 1999)

Search for accretion disks in massive protostars

Large scale elongated structures have been found around massive protostars. Some of them present velocity gradients that have been interpreted as rotation. However, they do not seem to be true accretion disks since they have sizes of thousands of au and masses considerably larger than that of the central star, therefore being unstable.

ROTATING TOROIDS



R=3300 au
Mass= 80 Msun

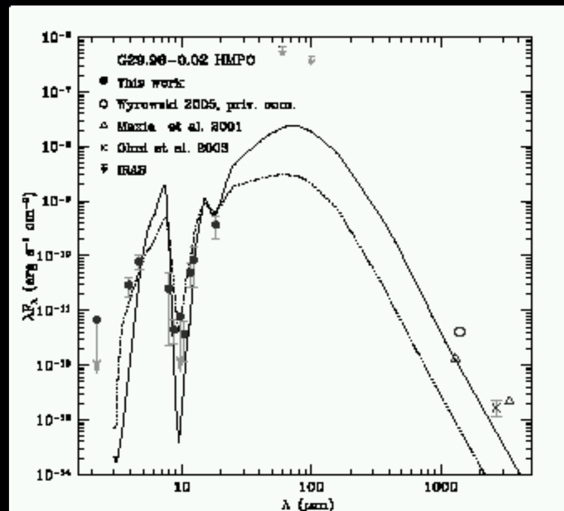
R=6400 au
Mass= 400 Msun

(Beltran et al. 2011)

R=2300 au
Mass= 30 Msun

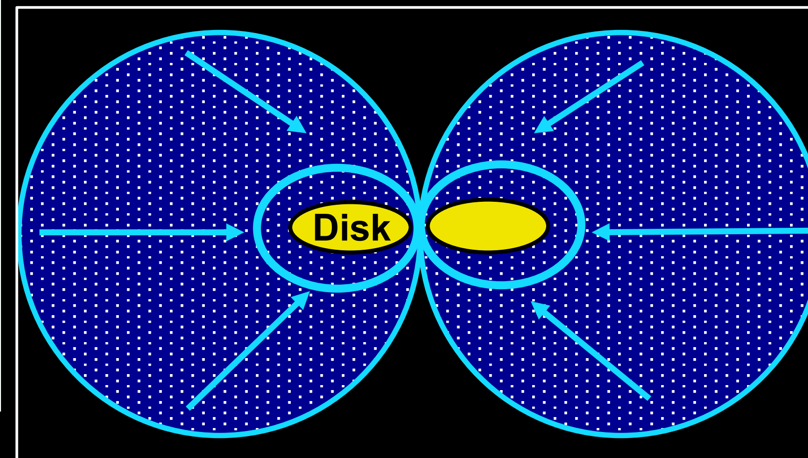
Centrifugal radii in massive protostars

SED modeling of high mass protostars predicts centrifugal radii (i.e. the scale of disk radius) of several hundreds of au.



(De Buizer, Osorio, Calvet 2005)

Infalling and rotating envelope



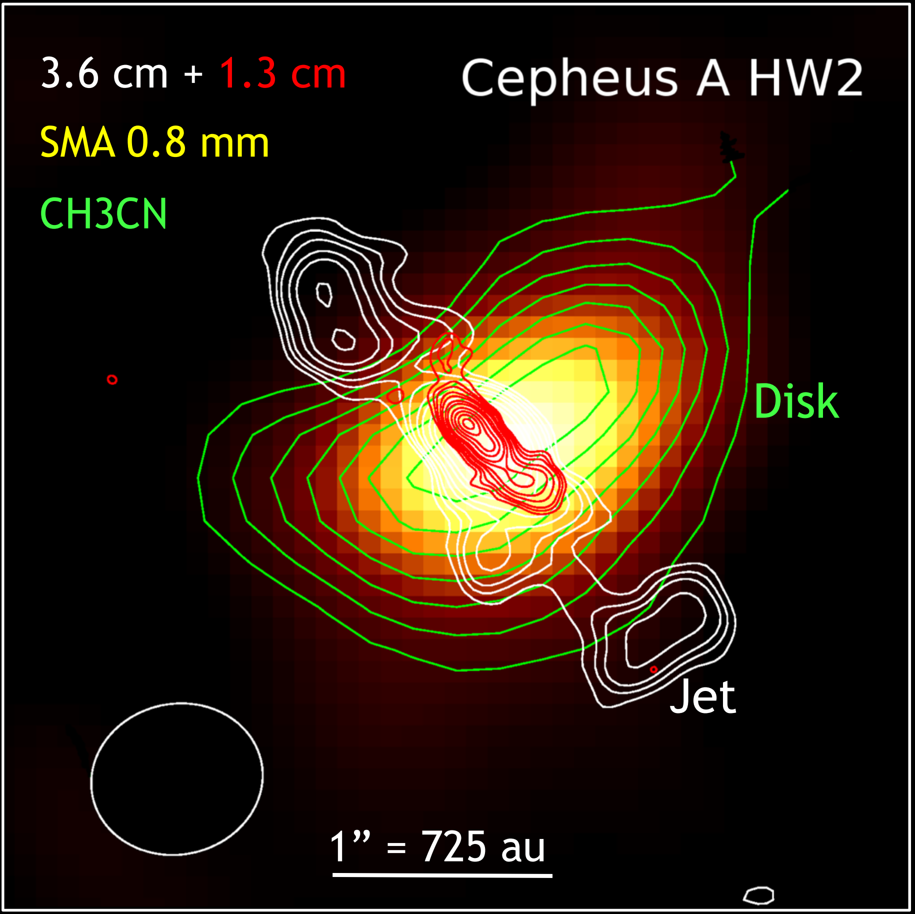
Parameters of the Best-Fit Models

HMPO	η	R_{in} (AU)	R_{out} (AU)	R_c (AU)	L_* ($L_\odot$)	$\rho_{1\ AU}$ (g cm^{-3})	i (deg)
G11.94−0.62..............	2.5	2	5000	30	75	1.5×10^{-13}	53
G29.96−0.02..............	2.5	245	12000	570	18000	3.0×10^{-11}	12
G45.07+0.13	2.5	227	9000	370	25000	5.3×10^{-12}	35

A disk/jet system in the massive protostar Ceph A HW2

One of the best massive disk/jet system is in Cep A HW2 (D=725pc)

- Collimated radio jet (Curiel+2006)
- Compact disk (dust + molecular)
- R_{disk}~330 au
- M_{disk}=1-8 M_{sun}
- M_{*}=15 M_{sun} (B0)

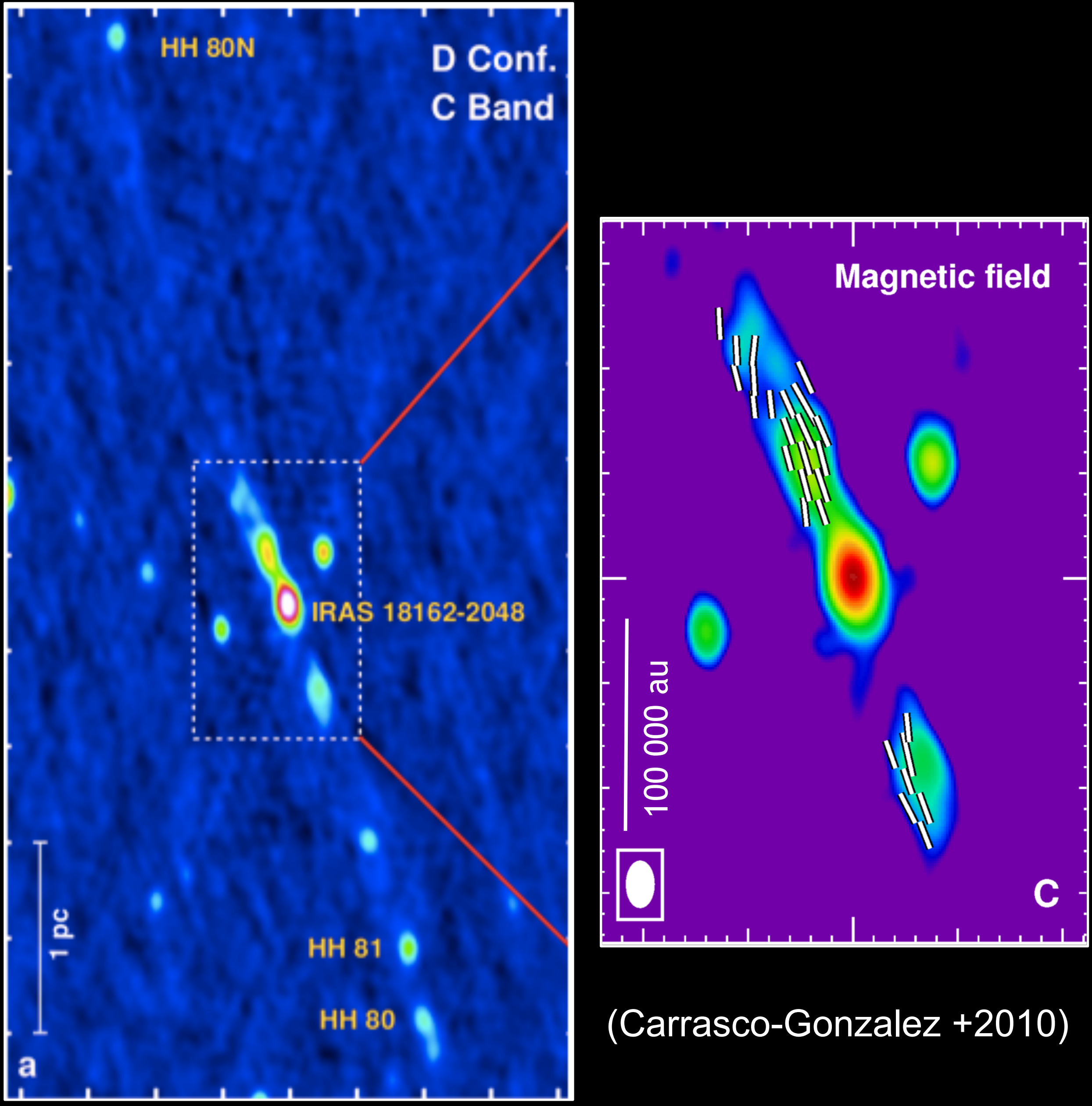


(Patel et al. 2005)

HH 80-81: a collimated jet from a massive protostar

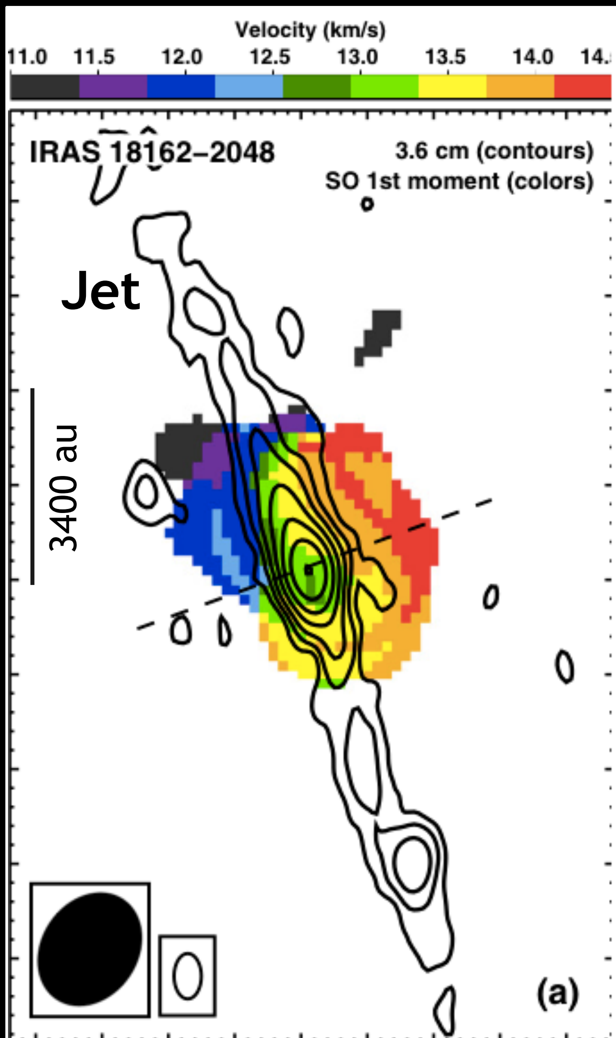
- IRAS 18162-2048(GGD27)
- D = 1.4 kpc (Gaia)
- L_{BOL} ~ 10000 L_{SUN}

- **Large** **(>5.3 pc)** **and highly collimated radio jet** associated with HH80-81
- The magnetic field, B, in this jet has been mapped through polarized synchrotron emission and found to be aligned along the jet direction. So far, this is the only protostellar jet where B has been mapped.

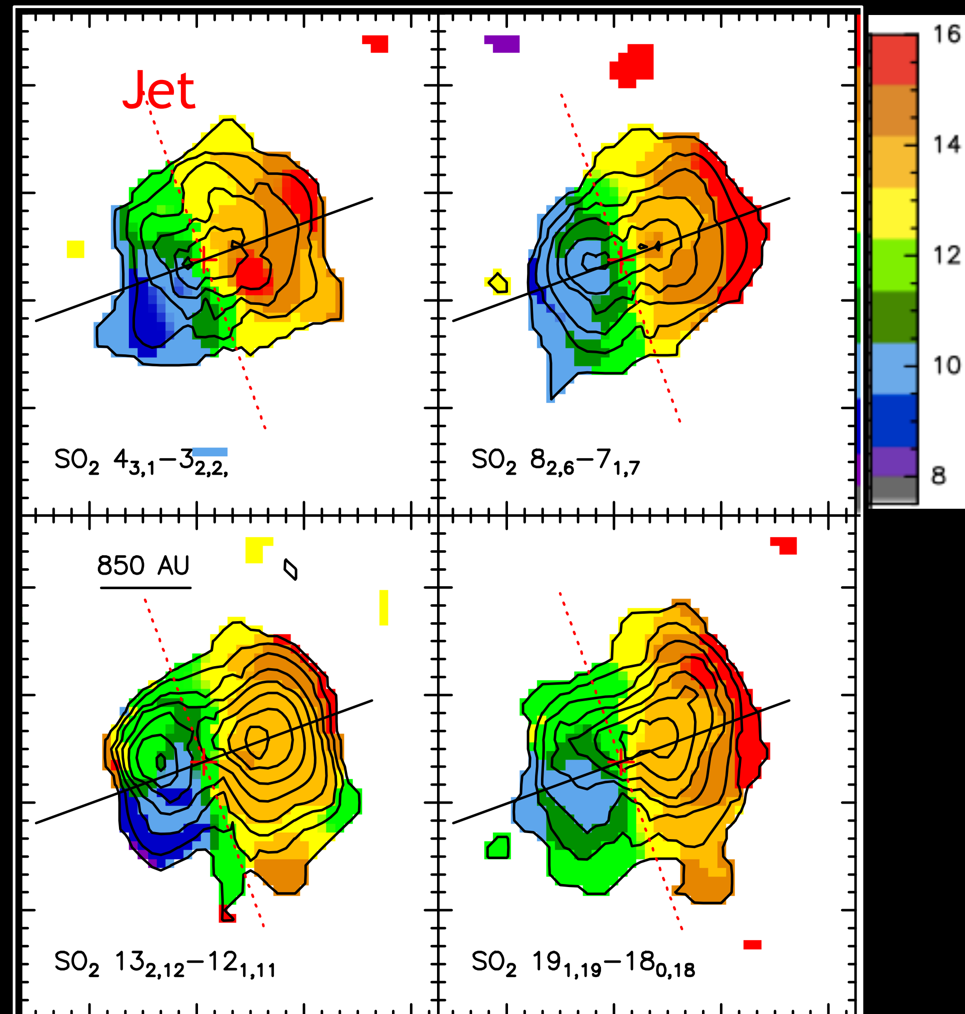


(Carrasco-Gonzalez +2010)

A rotating structure perpendicular to the HH80-81 jet

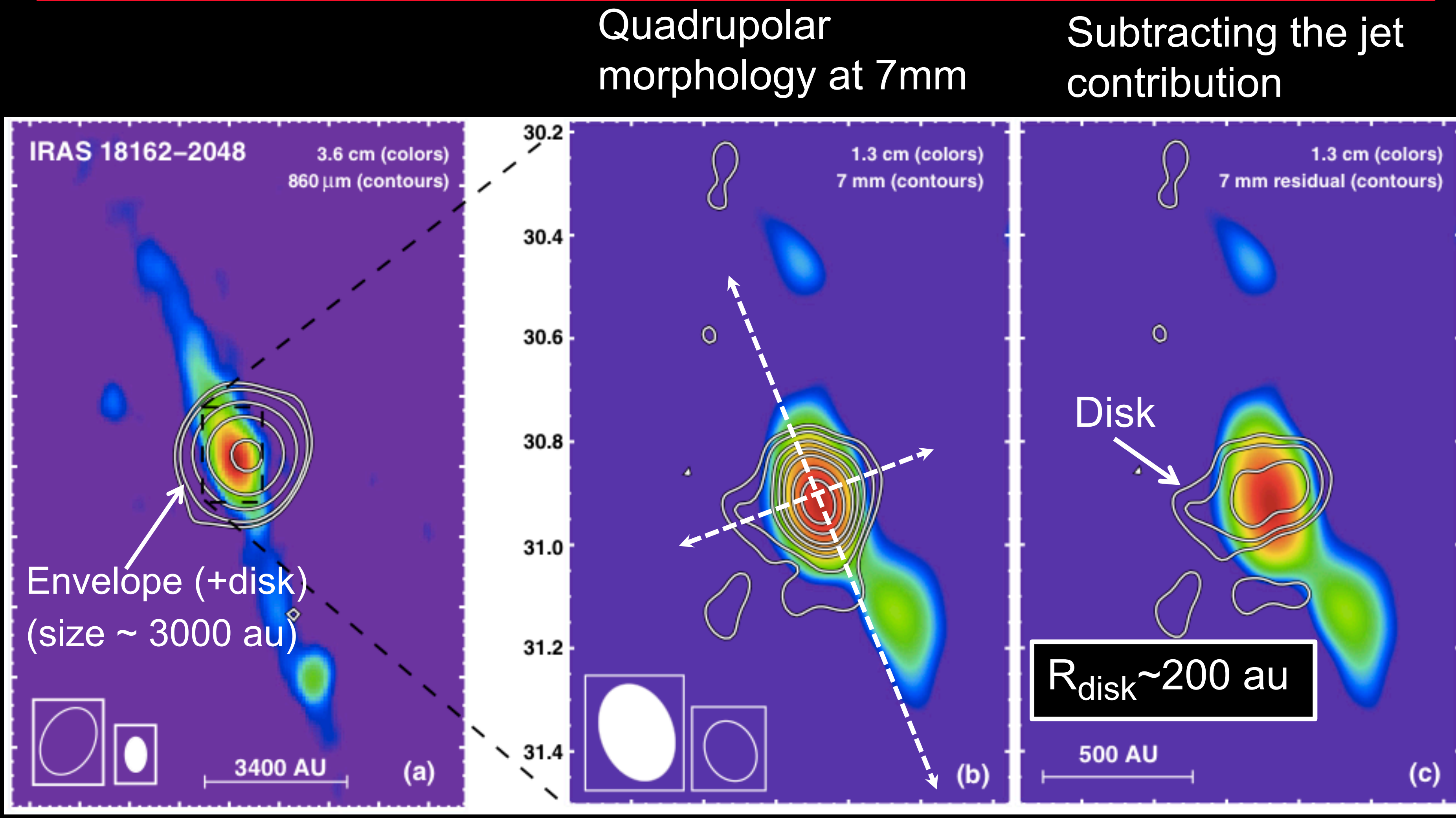


Carrasco-Gonzalez +2012



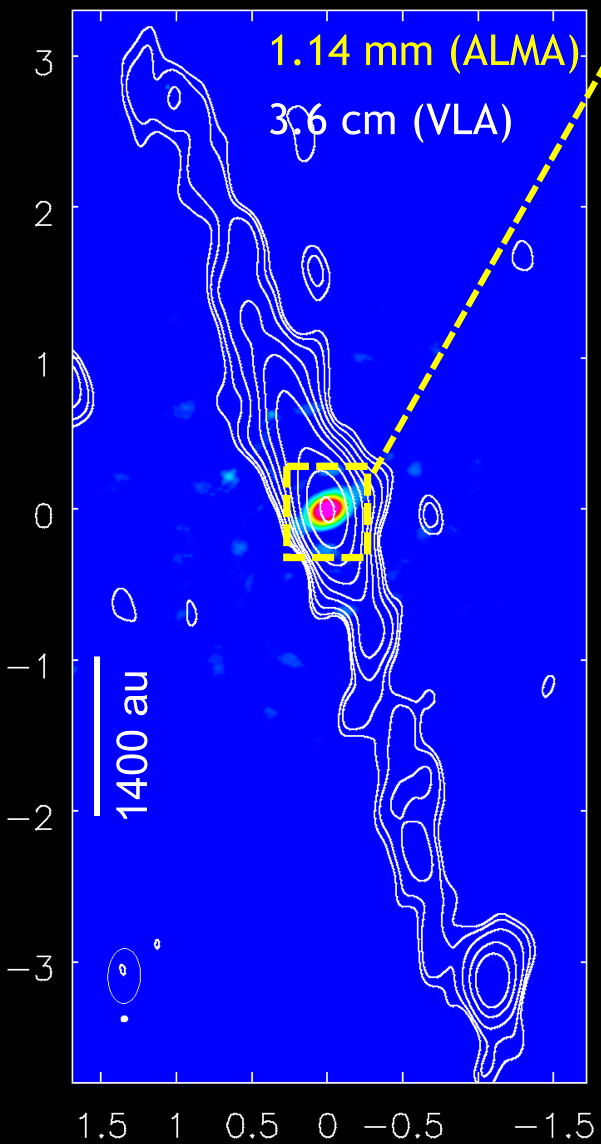
Girart +2017

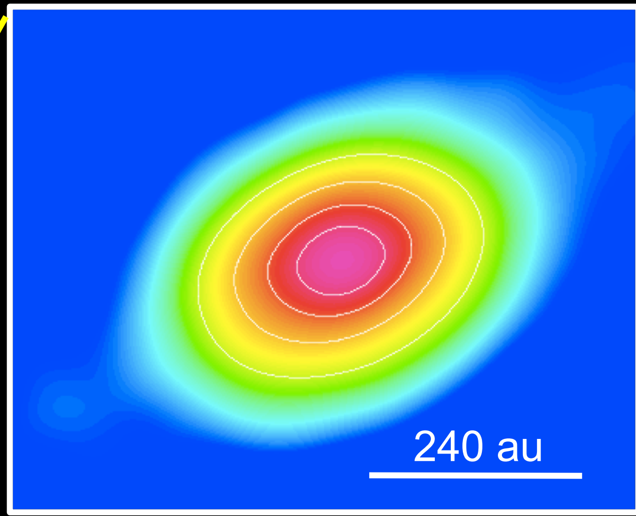
Evidence for a compact (r ~ 200 au) disk perpendicular to the jet at 7 mm



(Carrasco-González et al. 2012)

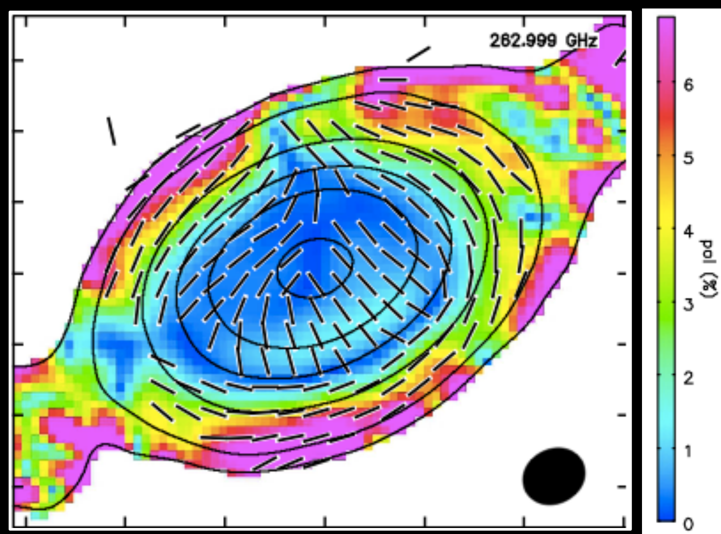
ALMA gives definitive evidence for a true accretion disk in HH80-81 high-mass protostar





Resolved compact disk with R ~200 au perpendicular to the jet

➔ True accretion disk



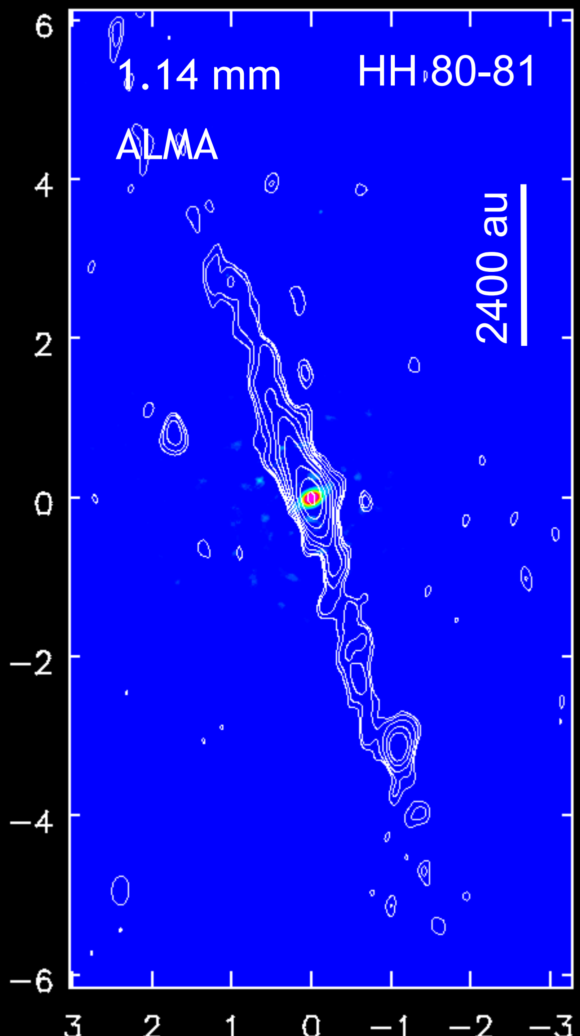
(Girart et al 2018)

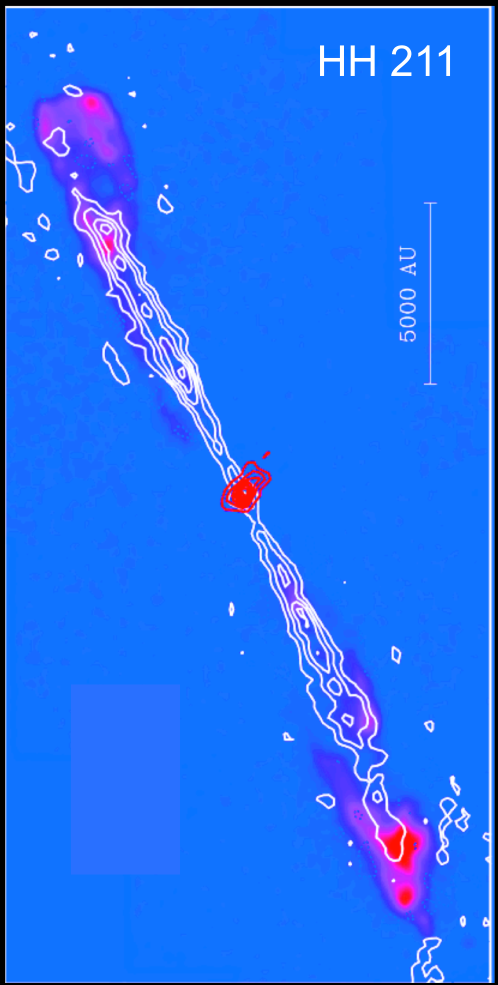
Polarization pattern consistent with self-scattering

*No settling on the disk mid-plane

*Grain sizes: 50-500 um

Disk-jet systems in high-mass protostars are as beautiful as those of low-mass protostars





HH 80-81 shows a disk/jet system analogue to those observed in low-mass protostars.

HH80-81 (Modeling)

We are using irradiated accretion disk models developed by D'Alessio et al, which assume:

♣ The α-prescription (Shakura & Sunyaev 1973):

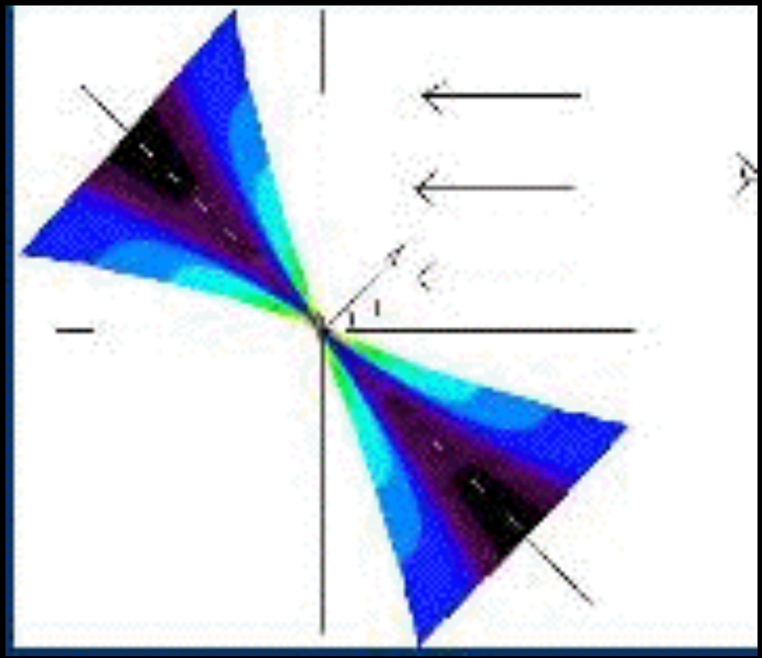
$$M_{acc}=3\pi\Sigma\alpha kT_{mid}/\mu_g\ \Omega$$

α viscosity (standard value=0.1)

♣ The heating mechanisms:

- Viscous dissipation
- Stellar irradiation
- Accretion shock

} L_{tot}



(D'Alessio et al 2006, 2010)

These models yield the vertical structure of the disk in a self-consistent way from the stellar parameters (M_*, R_*, L_*), and M_{acc} without using power-law approximations for the temperature and surface density profiles.

HH 80-81 (Modeling)

Models must fulfil:

- $L_{tot} \sim L_{bol}$ =10000Lsun
  $L_{tot} = L_* + L_{acc}$,
- $M_{acc} >> M_w$ (**$10^{-7}$$M_{sun}$**/yr)
- $M_{disk} << M_{star}$ (stable disk)

To explain the high brightness temperatures (peak = 670K), we have explored:

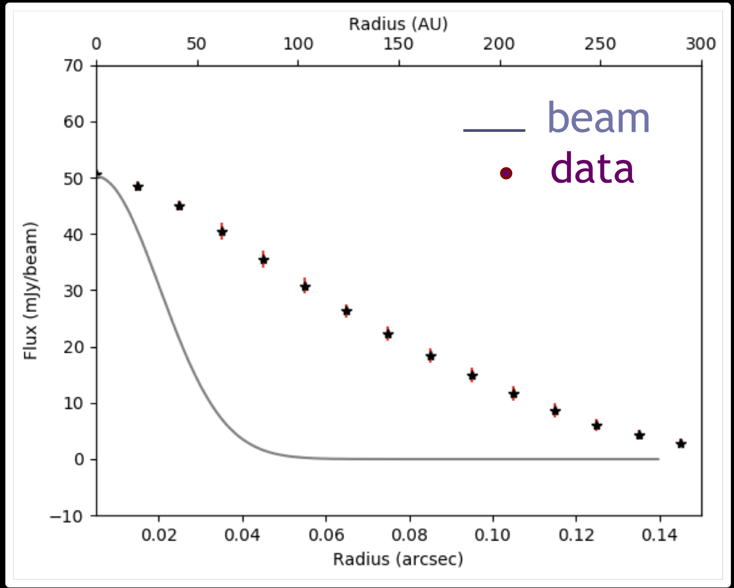
- Luminous stars accreting at high rates.
  We ran > 100 models

$5 \times 10^{-6} < (M_{acc}/M_{sun}/yr) < 3 \times 10^{-4}$

$10 < M_*/M_{sun} < 30$, $6 < R_{star}/R_{sun} < 30$

$10000 < (Teff/K) < 17000$

1.14mm azimuthally averaged intensity profile



The remaining parameters were taken from the observations:

- Inclination~ 49º
- Radius~ 240 au
- A low degree of settling and

amax=50-500um as suggested by the polarization observations.

HH80-81 preliminary disk models

Fitted parameters:

Disk: i= 45-48°

R_{in}=15-20au, R_{disk}=180-200au

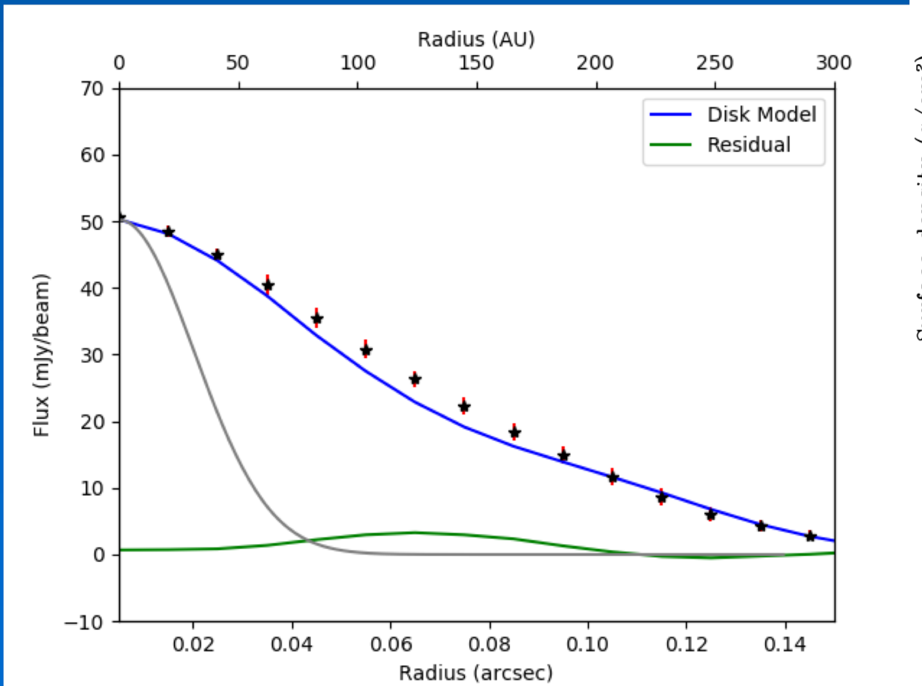
Star: M_{*}=20-30M_{sun}, R_{star}=20-25R_{sun}

M_{acc}=5 x 10^{-5} - 1 x 10^{-4} M_{sun}/yr

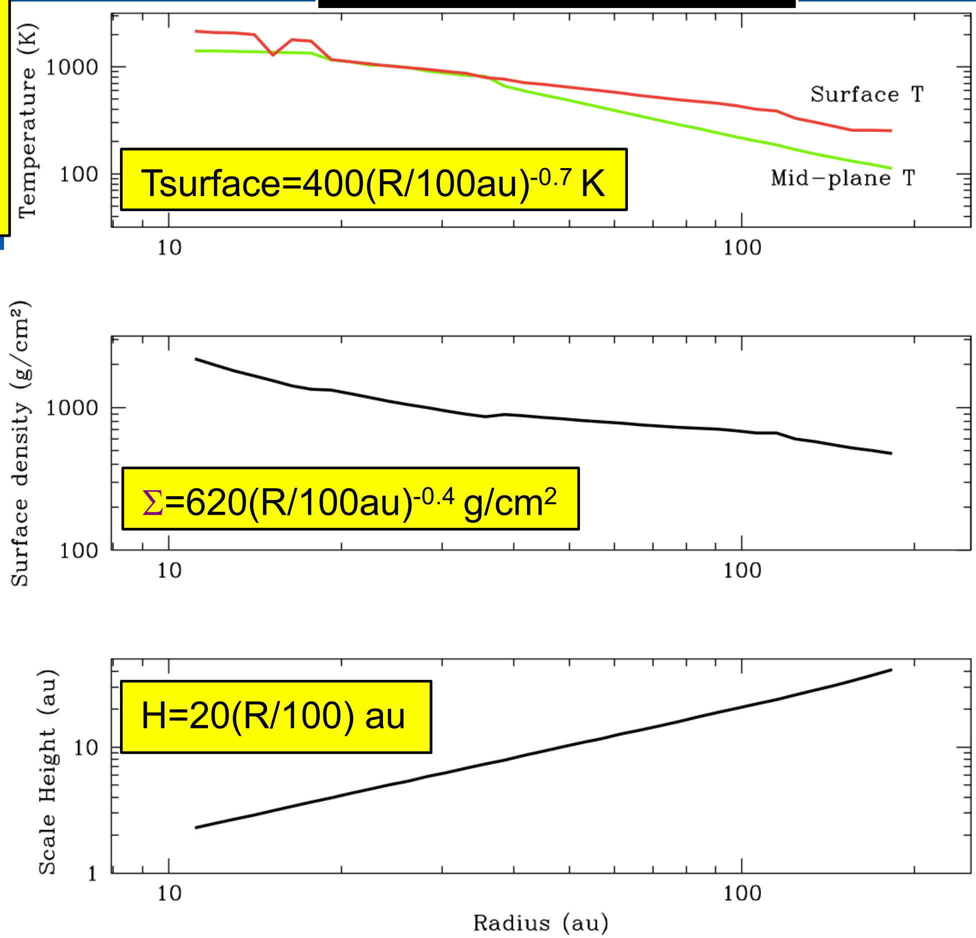
Inferred parameters:

M_{disk}=7-10M_{sun} ,L_{tot}~1-3x$10^{4}$$L_{sun}$

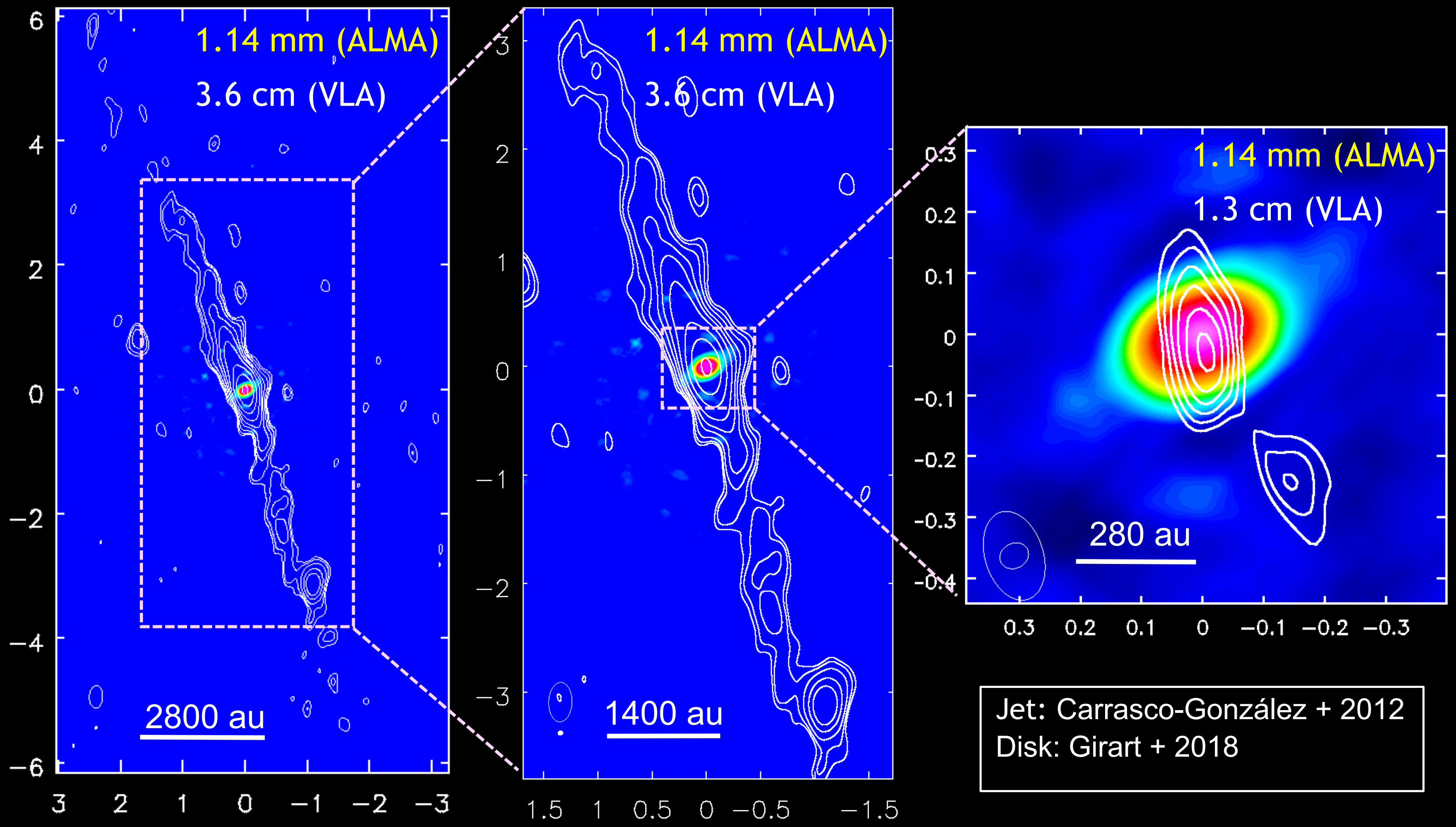
Template for disks around other high mass protostars



Disk physical structure



Disk/jet systems in high mass protostars are beautiful



Jet: Carrasco-González + 2012
Disk: Girart + 2018

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