Density, temperature and kinematics of the MYSO AFGL 2591

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C. Aspin et al., NIRI, Gemini Obs., NSF

How massive stars form?

Can they form like low mass stars?

What physical processes dominate their formation?

Is there a single model that can explain MYSOs observations?

MYSO:

Deeply embedded YSOs with $L>10^4\ L_\odot$

Have not started to ionise their circumstellar matter

AFGL 2591 proto-cluster

VLA 3: Proto-typical MYSO with jet

Distance†: 3.3±0.1 kpc

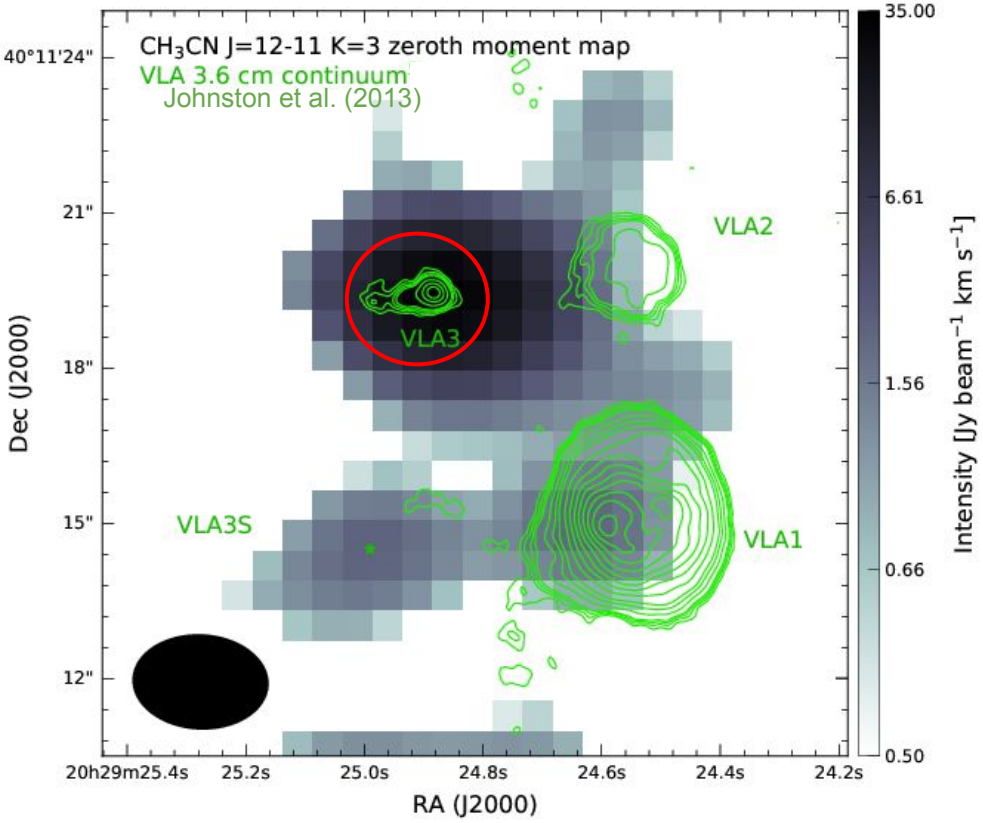
Luminosity*: 2×10^5 $L_\odot$

Stellar mass*: 20-40 $M_\odot$

→ Good candidate to be resolved by Herschel (Olguin et al. 2015)

HII regions:

VLA1 & VLA2 (Trinidad et al. 2003)



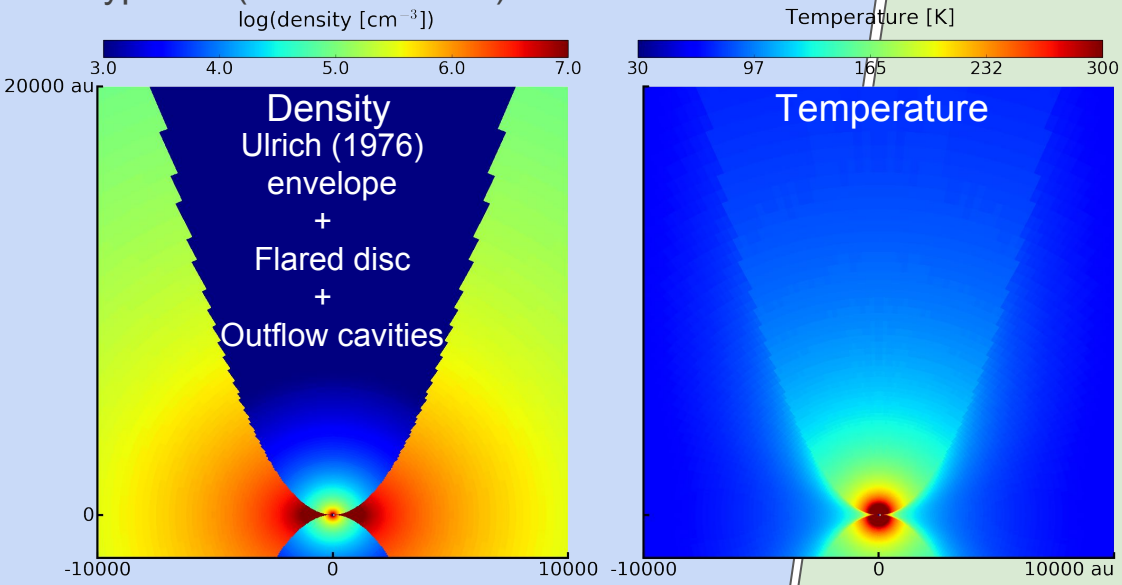
†Rygl et al. (2012)

*Sanna et al. (2012)

1. Dust continuum

$L_\star = 1.6\times10^5\ L_\odot$
$\dot{M}_{env} = 1.4\times10^{-3}\ M_\odot\ yr^{-1}$ for a luminosity $M_\star = 40\ M_\odot$
$R_{env} = 2.0\times10^5$ au
$M_d = 1\ M_\odot$, $R_d = 440$ au
Opening angle = 57°

RT: Hyperion (Robitaille 2011)



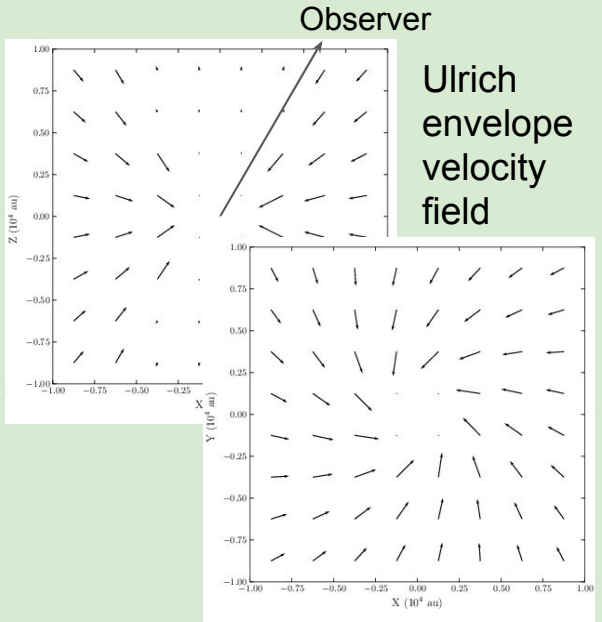
2. CH_3CN Line emission

Kinematic $M_\star = 7\ M_\odot$

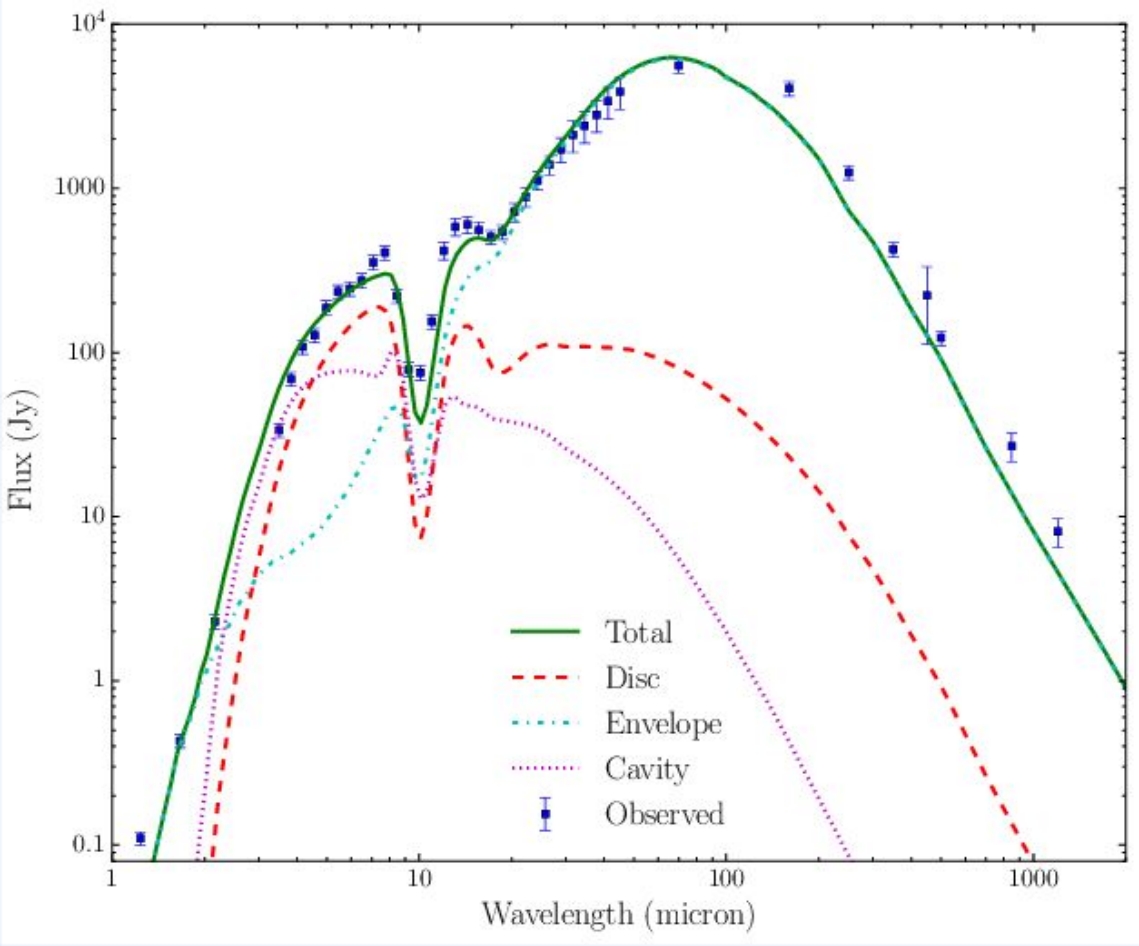
Abundance = 3×10^{-8} for gas at T>100K

Line width = 1 km/s

RT: Mollie (Keto & Rybicki 2010)



SED



Dust:

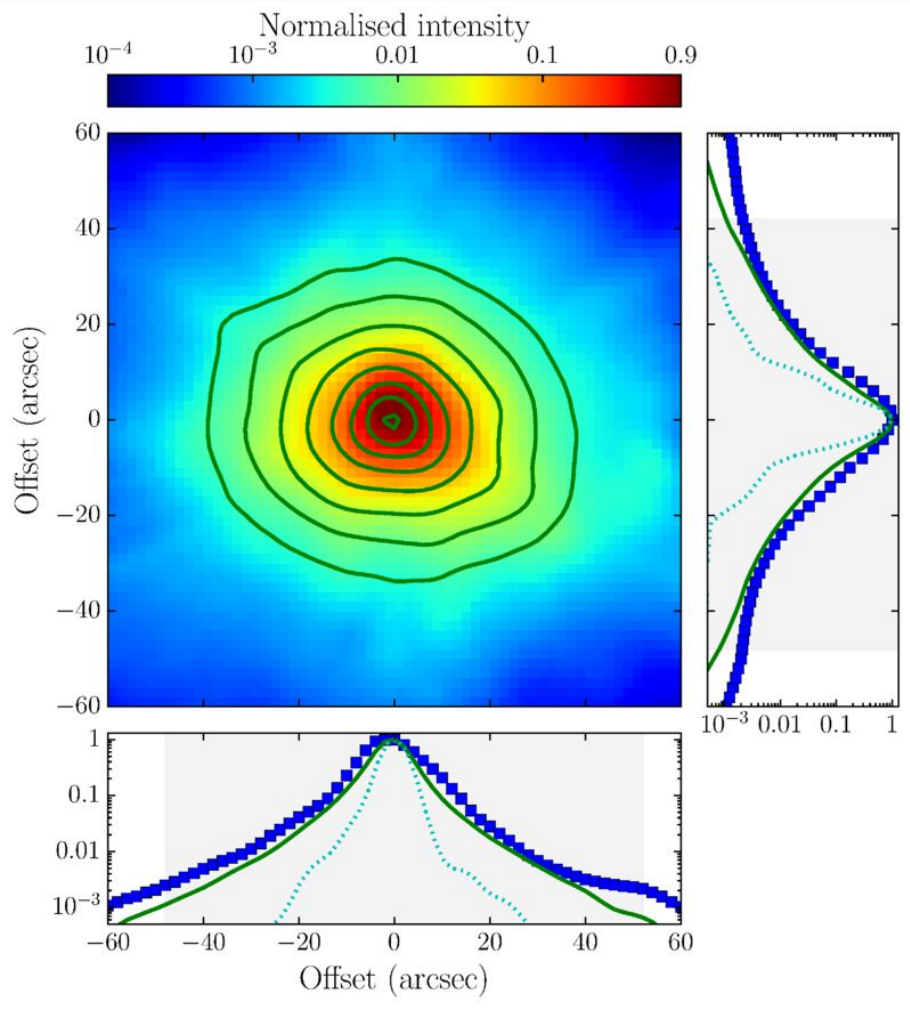
Envelope & Disk:
(de Wit et al. 2010)
warm silicates (Ossenkopf et al. 1992) + MRN amorphous carbon

Cavities:
Kim et al. (1994)

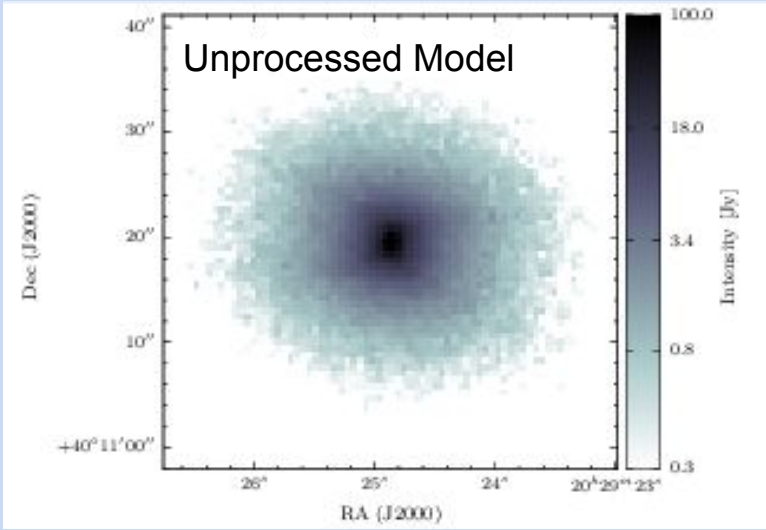
Herschel/HOBYS 70 micron

(Motte et al. 2010, Schneider et al. 2016)

Resolution ~6 arcsec



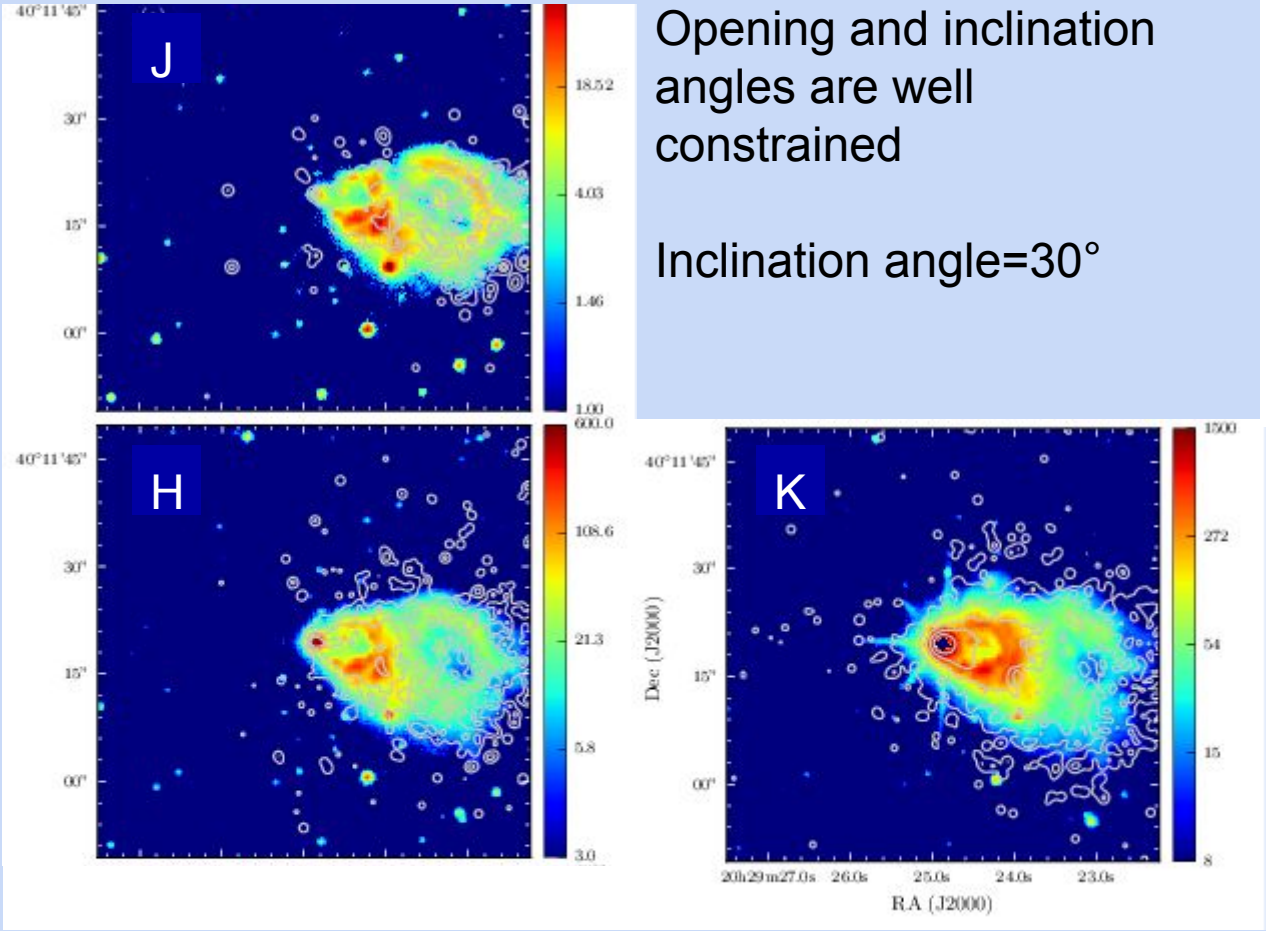
Extended along outflow cavity direction



Near-IR

UKIDSS/UKIRT

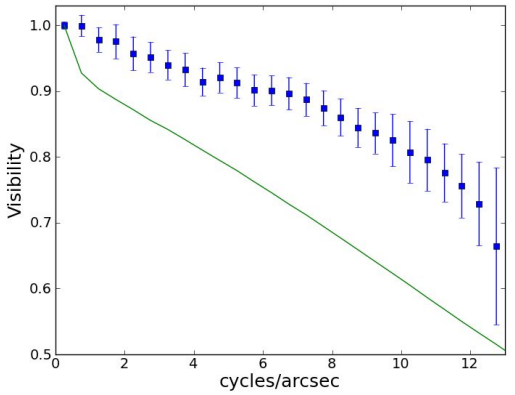
Resolution ~1 arcsec



Opening and inclination angles are well constrained

Inclination angle=30°

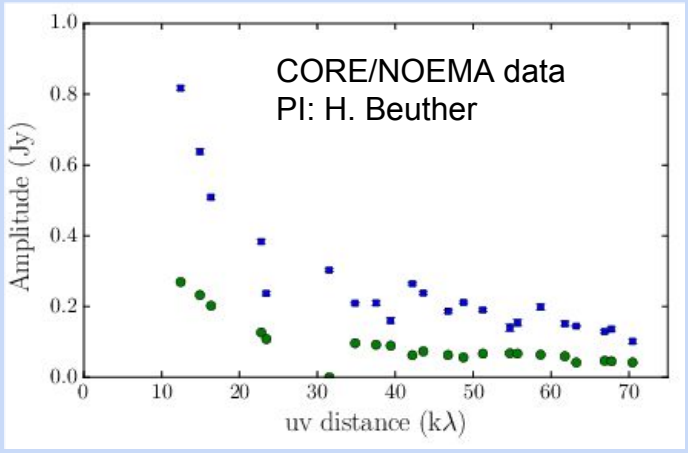
K-band Speckle interferometry (Preibisch et al. 2003)
Resolution: 170 mas



Partially resolved inner region not well fit

1.3 mm interferometry

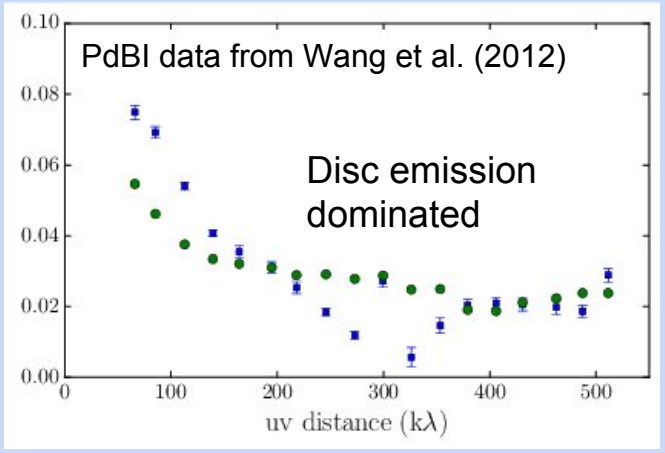
Emission from ~5000-10000 au scales

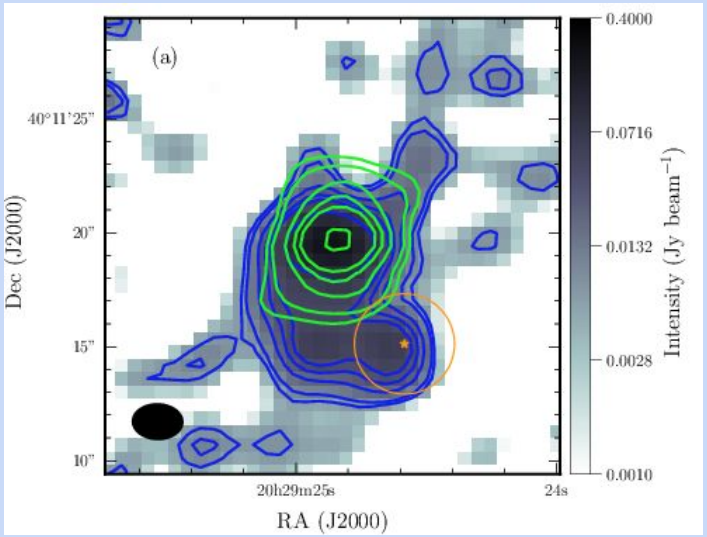


Disc mass 1 $M_\odot$ and 400 au radius

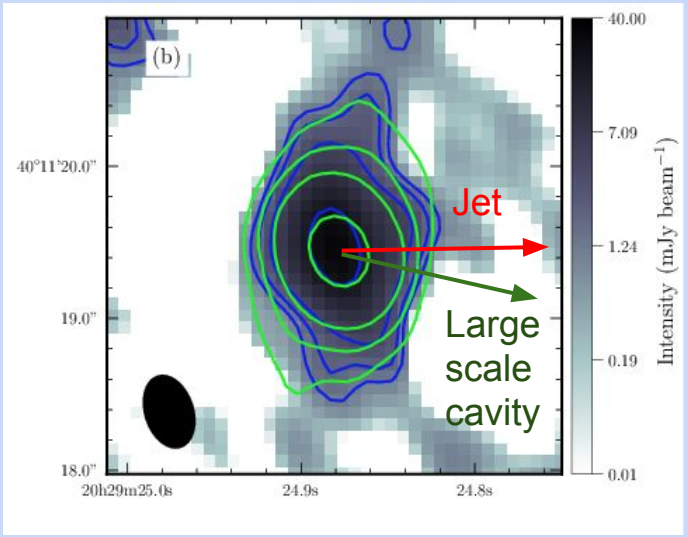
Short baselines not well fitted by models

Emission from <1000 au scales





Disc precession?



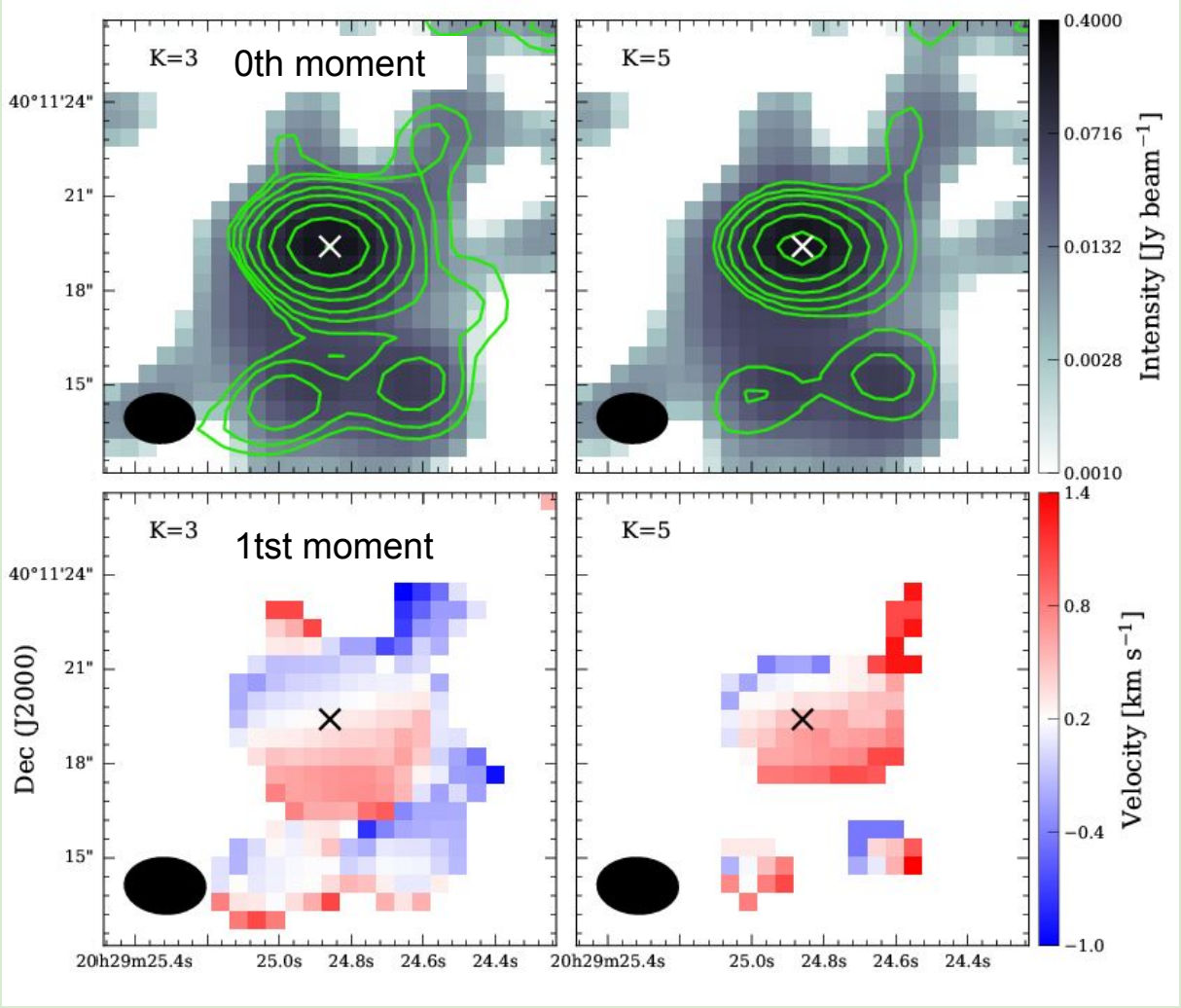
CORE/NOEMA CH_3CN J=12-11

Partially resolved source

Line emission observed towards southern sources

1st moment shows hints of rotation

Line emission not contaminated by outflow

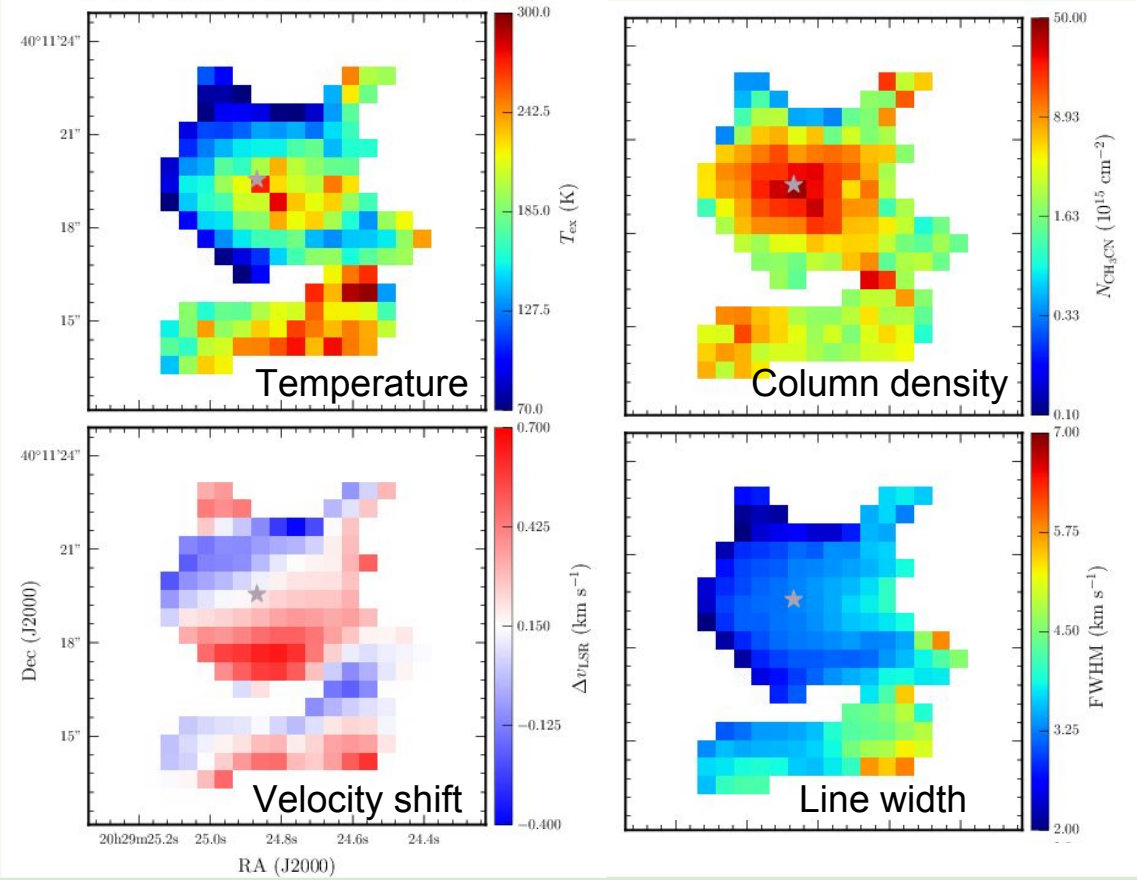


LTE modelling

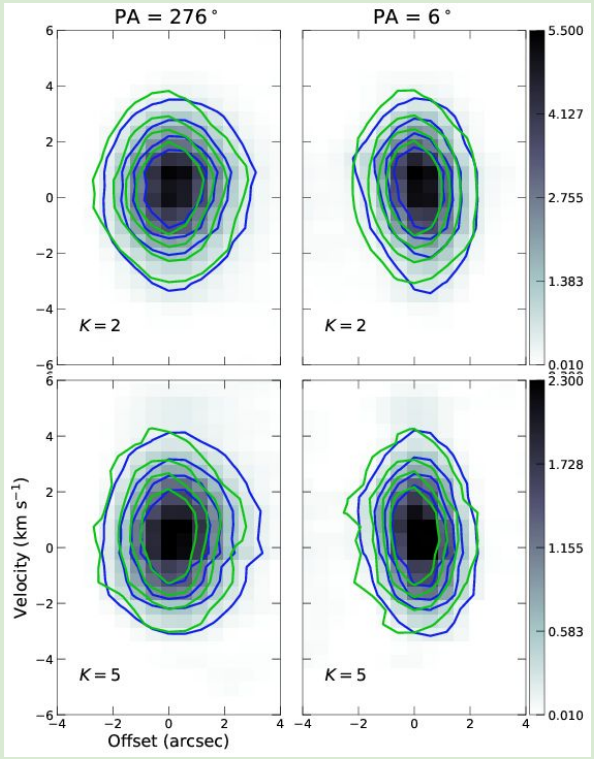
Temperature and column density peak at the source position

Line widths are larger along the cavity direction

All sources seem to be rotating in the same direction



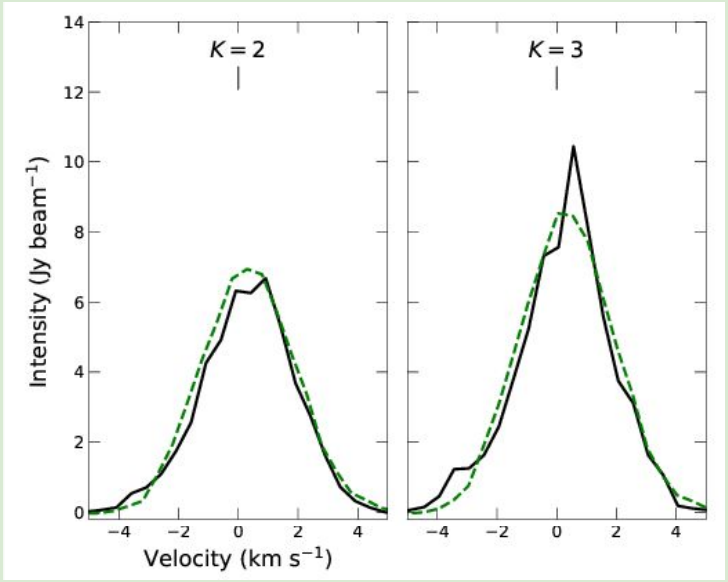
3-D LTE Modelling

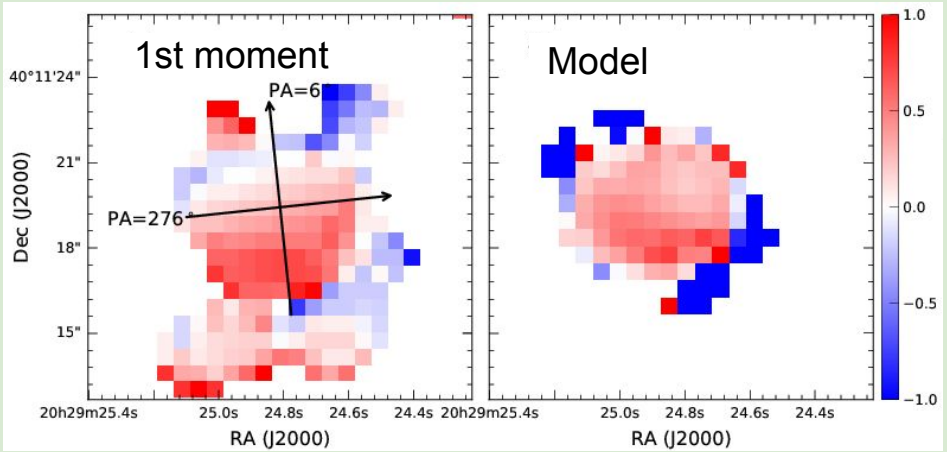


We model pv-maps along and orthogonal to the rotation axis

Emission from the envelope dominates the line emission

Peak spectrum





Summary

We performed a detailed modelling of the MYSO AFGL 2591 and found:

Herschel 70 micron emission is extended along the cavity

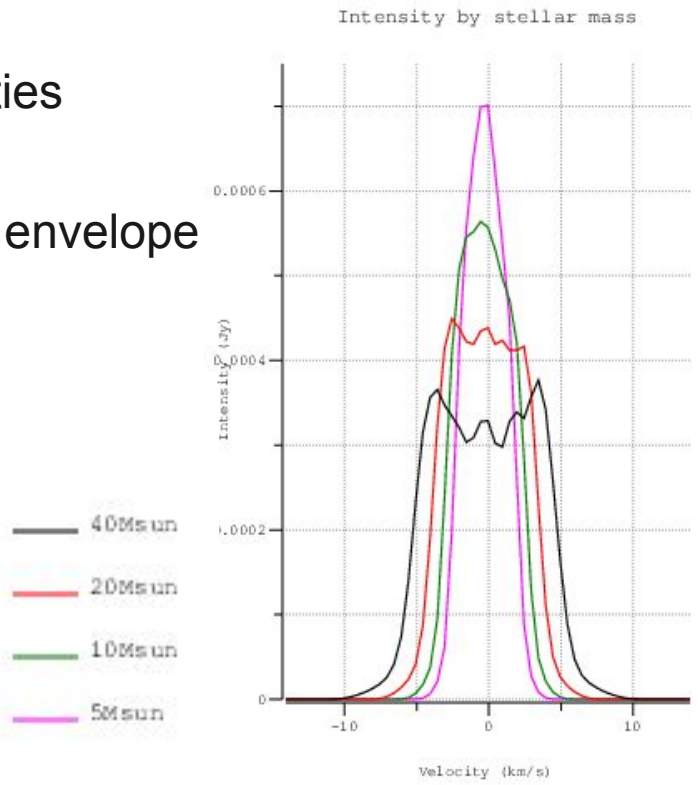
- The cavity walls are being heated by radiation escaping through the cavity

Models require a disc (1 $M_{\odot}$) for fitting the mm visibilities

Line emission shows evidence of rotation of the inner envelope

Velocity gradient is not well matched

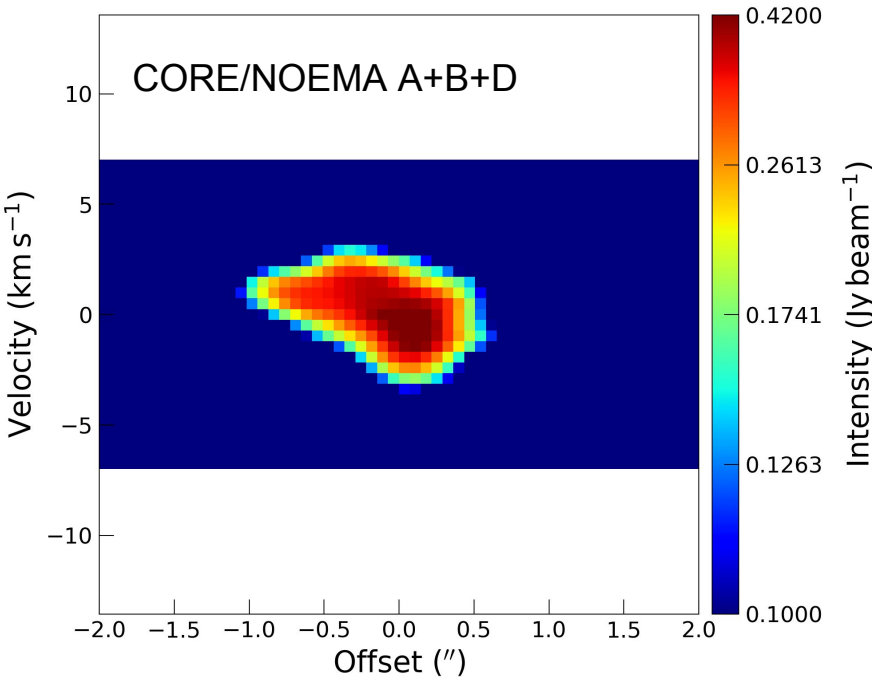
- Kinematic stellar mass not consistent with the luminosity one

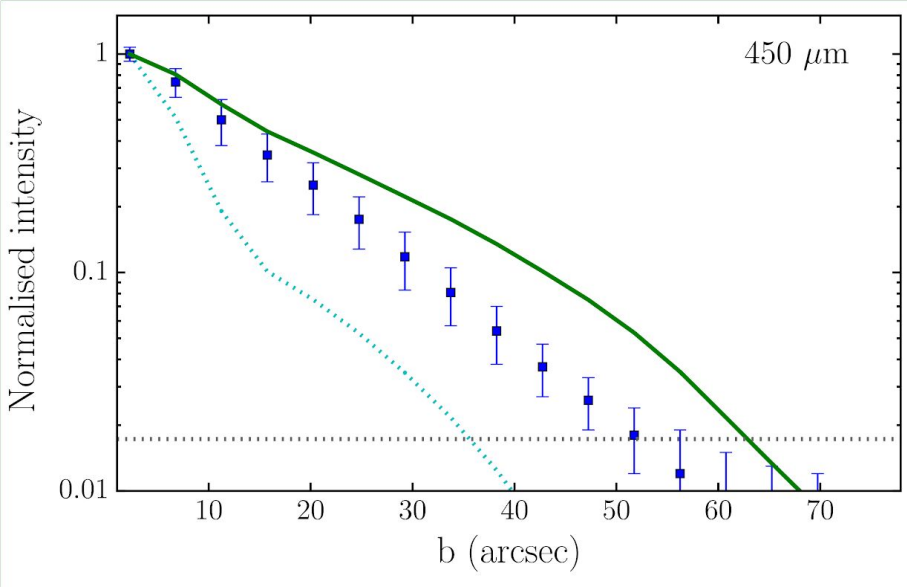


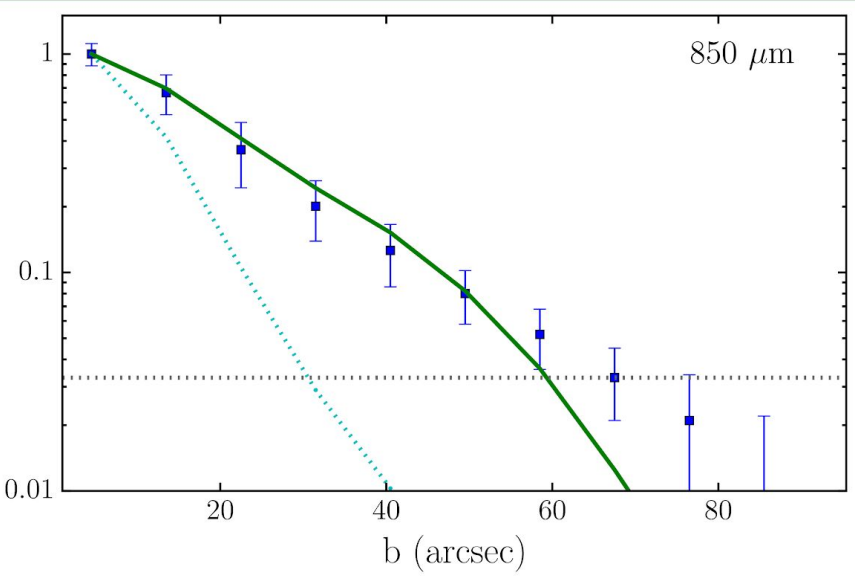
Future work

Extend study to more sources:
using high(er)-resolution observations

Test other physical models:
e.g. models that allow removing angular momentum

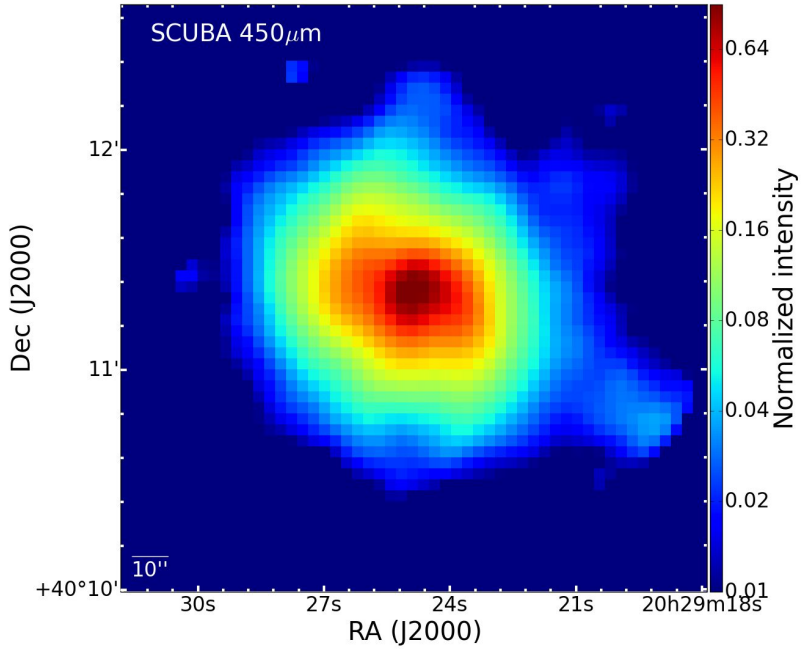






Emission overestimated at 450 microns

Model emission is not extended as the observed one



Sub-mm

Caveats

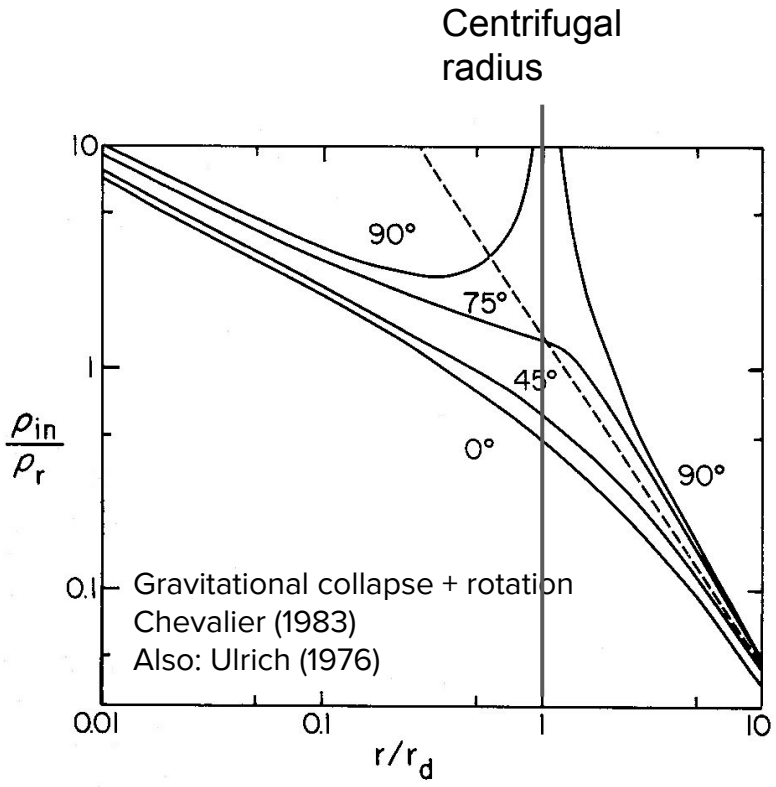
Gravitational collapse is not symmetric as in the Ulrich model

The model reproduce most of the observations but submm observations require a different density slope

The density distribution is not smooth

The stellar mass is inconsistent with the source luminosity

The model singularity at the centrifugal radius has a high effect in the model velocity



Solutions?

Fix the velocity and density distribution from models

Test numerical simulations