Max-Planck-Institut für Radioastronomie

MAX-PLANCK-GESELLSCHAFT

Gas dynamics driven by a massive YSO – from 0.1pc down to 100AU –

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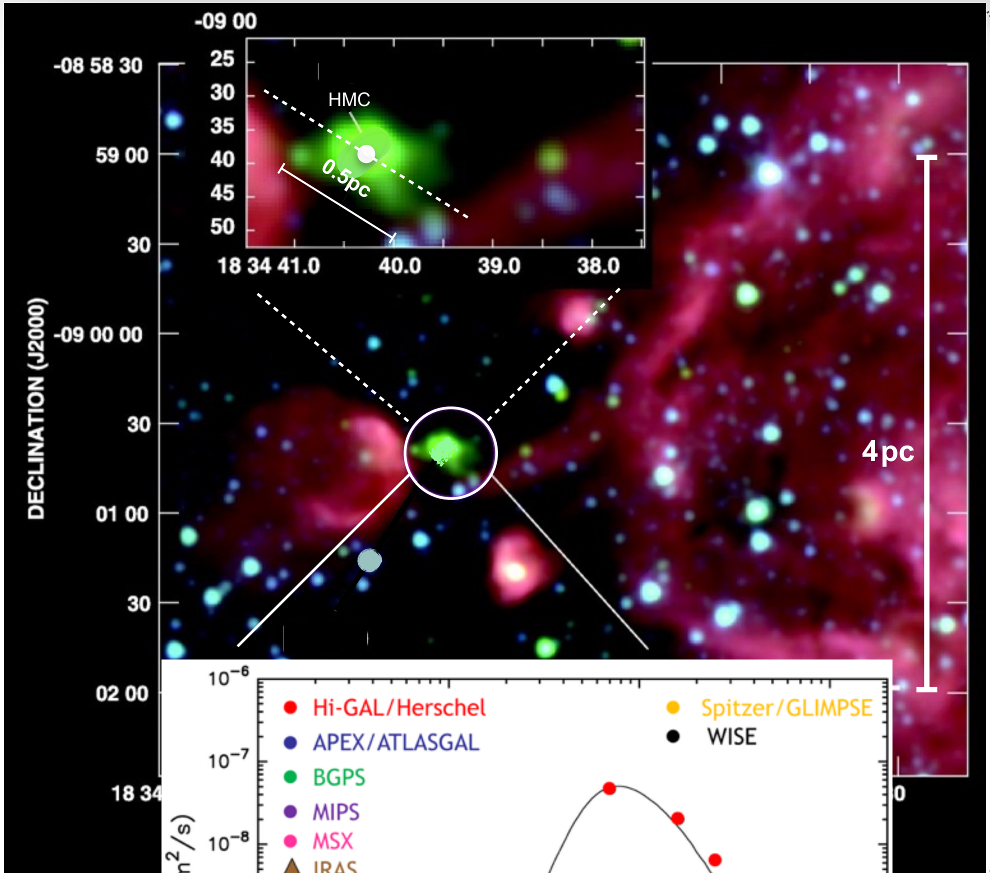
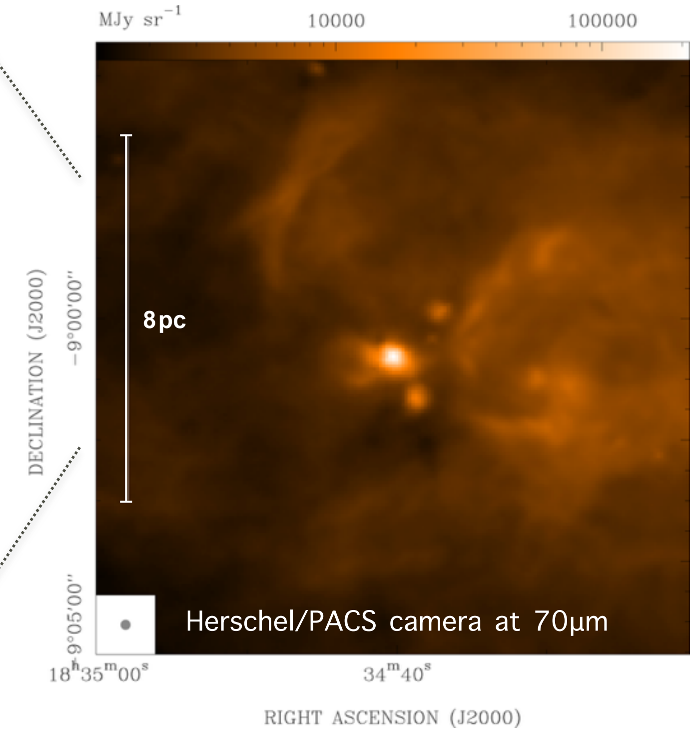
DFG Priority Program 1573 ISM-SPP Interstellar Medium

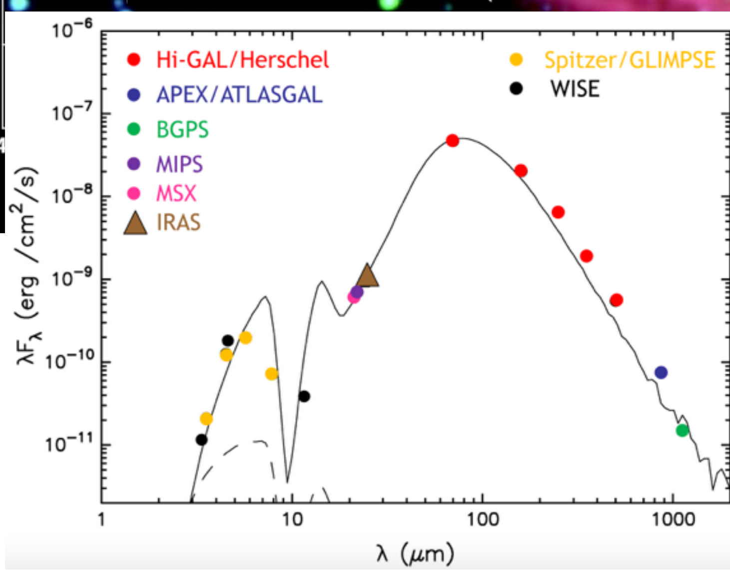
ESTEC, Noordwijk (NL) — October, 27th-29th

Spitzer IRAC GLIMPSE. – 3.6 (blue), 4.5 (green), 8.0 μm (red)



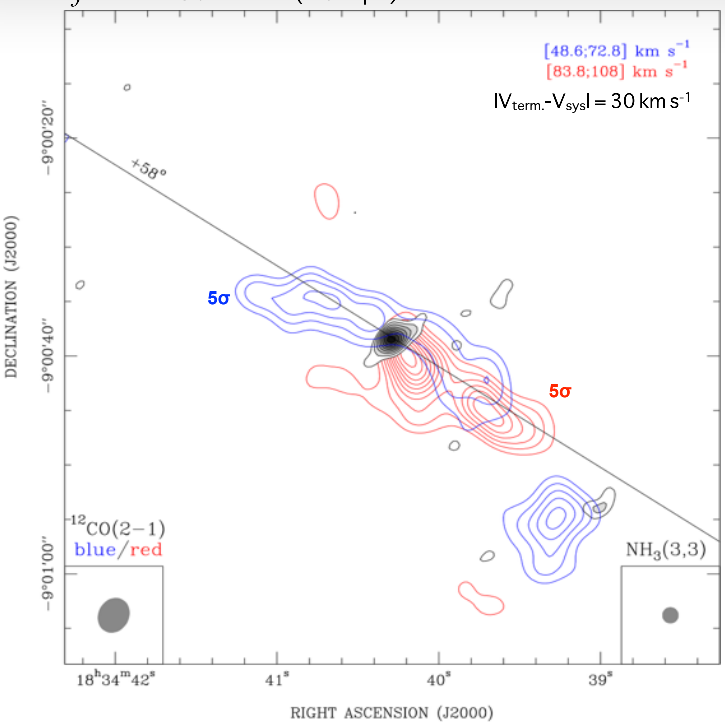
Heliocentric distance (Brunthaler et al. 2009):
D = 4.59 ± 0.38 kpc (± 8%)





SED between 3.4μm and 1.1mm
(Sanna et al. 2014)

f.o.v. = ±30 arcsec (±0.7 pc)

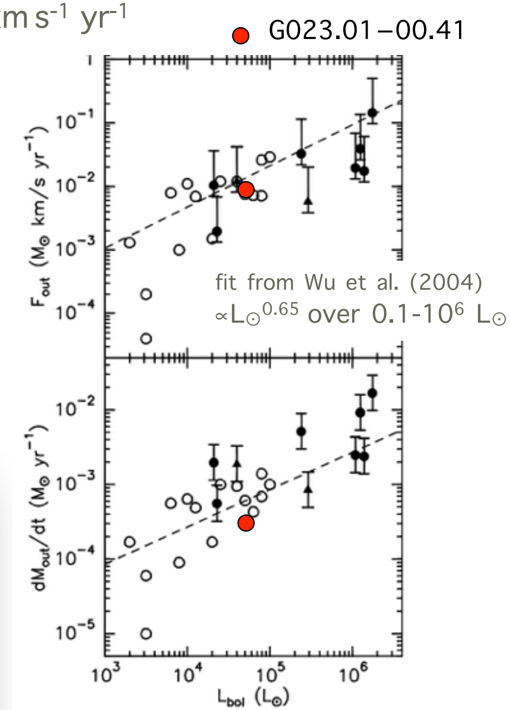


Bipolar Outflow Properties:

- symmetric outflow lobes, each extending for ~0.5 pc
- width-to-length ratio of each lobe of ~0.3
- outflow lobes partly crossing the plane of the sky

⇒ outflow axis almost ⊥ to the l.o.s.

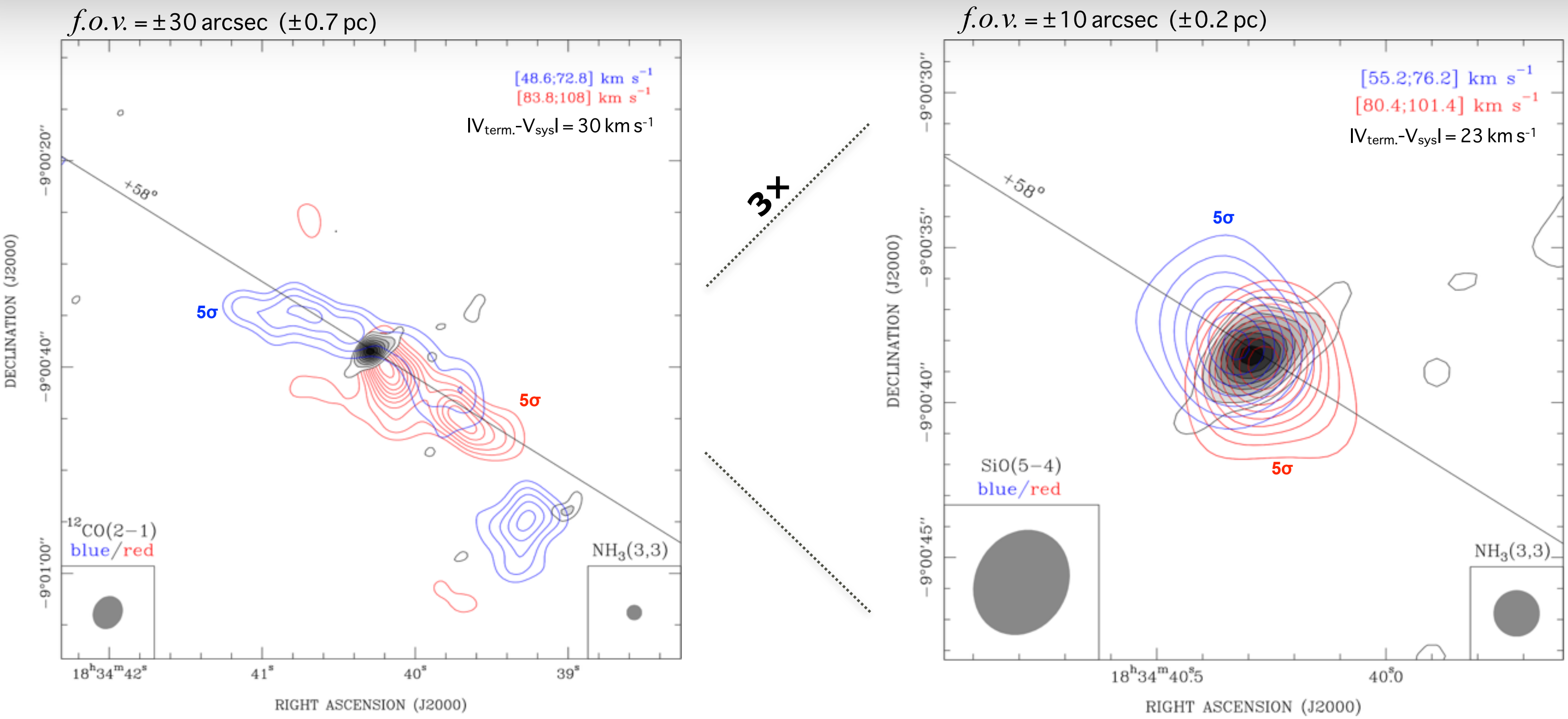
- mass-loss rate: 2×10^{-4} M$_\odot$yr^{-1}
- mechanical force: 6×10^{-3} M$_\odot$ km s^{-1} yr^{-1}



- Massive outflows energetics from López-Sepulcre et al. (2009)

Table 5. – Sanna et al. (2014), A&A, 565, A34

Tracer	Lobe	R (pc)	t_{dyn} (yr)	M_{out} ($M_\odot$)	$\dot{M}_{out}$ ($M_\odot$ yr^{-1})	p ($M_\odot$ km s^{-1})	$\dot{p}$ ($M_\odot$ km s^{-1} yr^{-1})	E_{mec} (10^{46} erg)	L_{mec} ($L_\odot$)
^{12}CO	Red–A	0.51	3.4×10^4	2.5	0.8×10^{-4}	37.5	1.1×10^{-3}	0.6	1.4
	Blue–A	0.44	2.9×10^4	1.4	0.5×10^{-4}	20.5	0.7×10^{-3}	0.3	0.9
		$R\times\frac{1}{\cos 30°}$	$t_{dyn}\times\tan 30°$	M_{out}	$\dot{M}_{out}\times\cot 30°$	$p\times\frac{1}{\sin 30°}$	$\dot{p}\times\frac{\cos 30°}{\sin^2 30°}$	$E_{mec}\times\frac{1}{\sin^2 30°}$	$L_{mec}\times\frac{\cot 30°}{\sin^2 30°}$
^{12}CO		0.55	1.8×10^4	4.0	2.2×10^{-4}	116	6.2×10^{-3}	3.6	16



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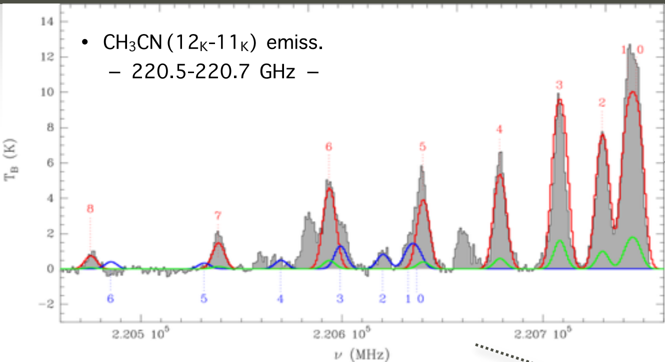
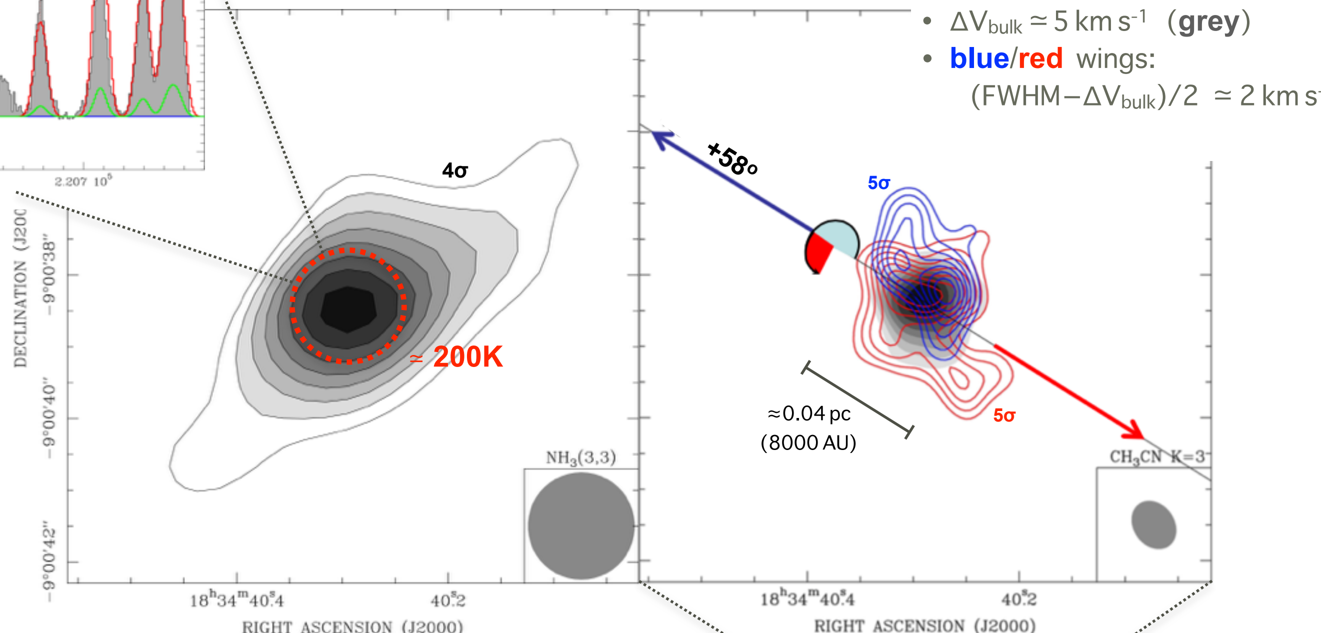
SiO	Red–A	0.13	5.5×10^3	1.0	1.8×10^{-4}	23.1	4.2×10^{-3}	0.5	7.9
	Blue–A	0.12	5.1×10^3	0.6	1.3×10^{-4}	14.9	2.9×10^{-3}	0.3	5.5
		$R \times \frac{1}{\cos 30°}$	$t_{dyn} \times \tan 30°$	M_{out}	$\dot{M}_{out} \times \cot 30°$	$p \times \frac{1}{\sin 30°}$	$\dot{p} \times \frac{\cos 30°}{\sin^2 30°}$	$E_{mec} \times \frac{1}{\sin^2 30°}$	$L_{mec} \times \frac{\cot 30°}{\sin^2 30°}$
^{12}CO		0.55	1.8×10^4	4.0	2.2×10^{-4}	116	6.2×10^{-3}	3.6	16
SiO		0.14	3.1×10^3	1.6	5.4×10^{-4}	76	2.4×10^{-2}	3.2	92



f.o.v. = ± 4 arcsec (± 0.09 pc)



Results of the CH_3CN (12_K-11_K) spectra analysis.

K-component	V_{LSR} (km s^{-1})	Δv (km s^{-1})	$\int T_B dv$ (K km s^{-1})
K = 0	78.34 ± 0.04	9.43 ± 0.05	62 ± 1
K = 1			63 ± 1
K = 2			66.4 ± 0.8
K = 3			69.2 ± 0.8
K = 4			45.7 ± 0.8

XLCASS synthetic spectrum:
Source size (diameter): 1.2 arcsec ≃ **5500AU**
Rotational Temp.: 195 K
Column density: 5.1×10^{16} cm^{-2}

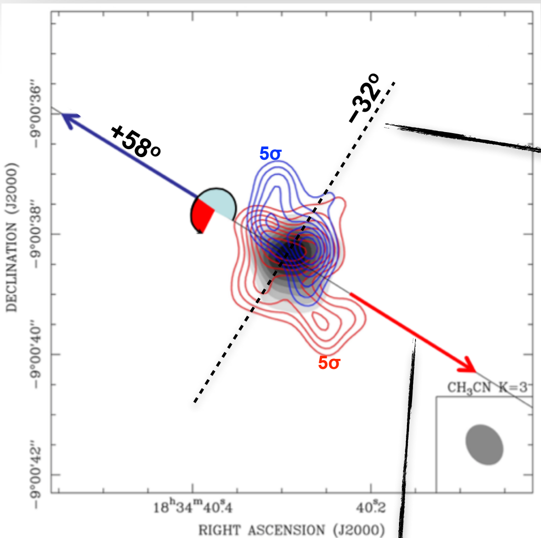
CH_3CN (12_3-11_3) integrated velocity maps

Velocity field.– 2 ⊥ velocity gradients:

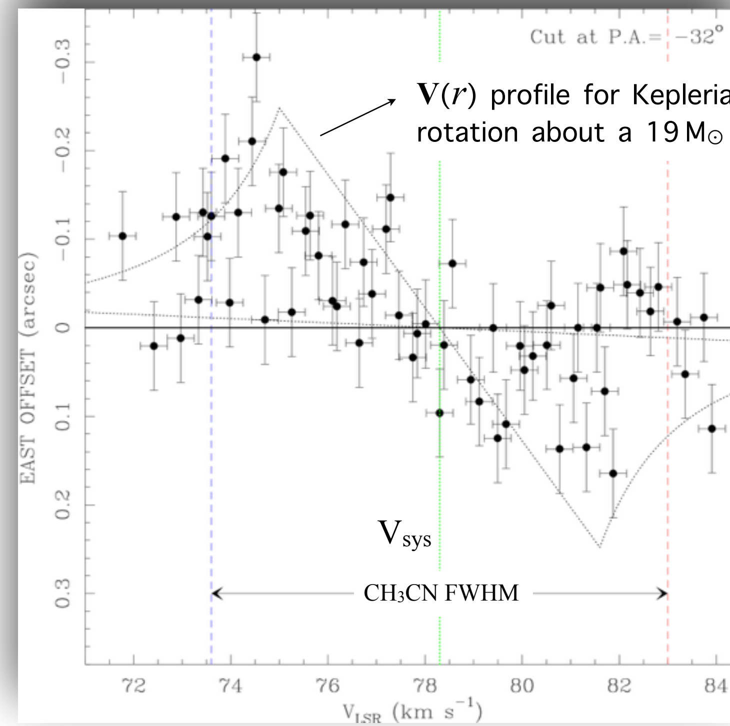
(I) NE-SW direction – outflow direction
(II) NW-SE direction – HMC elongation

Sanna et al. (2014), A&A, 565, A34

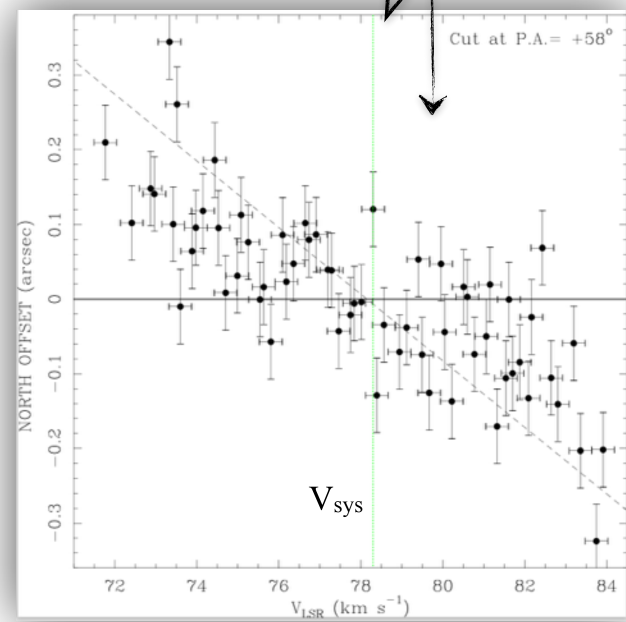
f.o.v. = ± 4 arcsec (± 0.09 pc)



p-v distribution of the peaks (dots) of the CH_3CN (12_K-11_K) emission at different LSR velocities (for K=1−4)



1100 AU

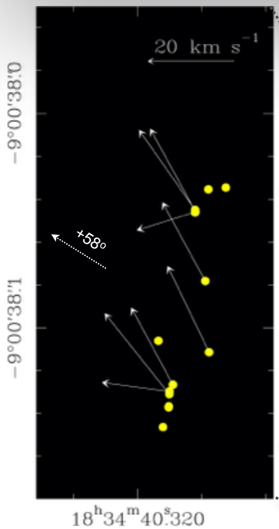


- Linear fit (r = 0.8):
  $\partial v/\partial x = -22.4 \pm 2.4$ km s^{-1} arcsec^{-1}
- Hubble-law:
  $\partial v/\partial r \simeq 5$ km s^{-1} (1000 AU)$^{-1}$

Sanna et al. (2014), A&A, 565, A34

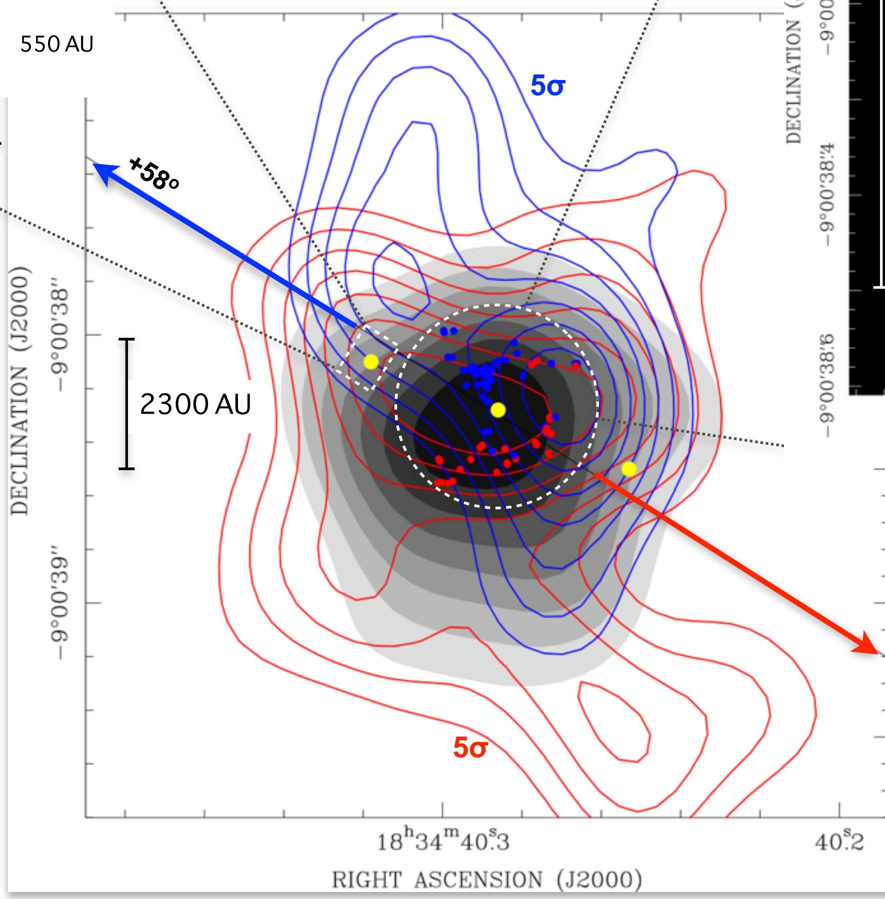
DOWN TO *1mas* RESOLUTION

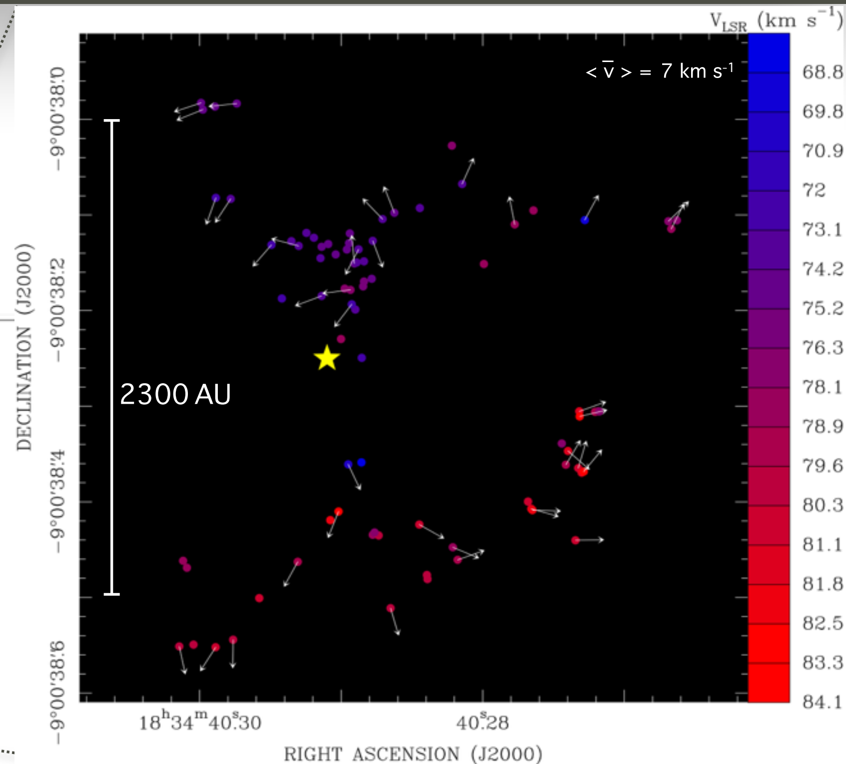
VLBI vs. SMA view



550 AU

SYMBOLS —
- 22.2 GHz H_2O MASER CLOUDLETS
- 6.7 GHz CH_3OH MASER CLOUDLETS (BLUE AND RED-SHIFTED)
- HMC CENTER





- H_2O masers:
  ⇒ shock tracer
- Morphology:
  ⇒ jet-like component

- Class II CH_3OH masers:
  ⇒ IR excited/nearby source
- Morphology:
  ⇒ funnel-like structure/base of the outflow cavity (or surface of a flared disk)

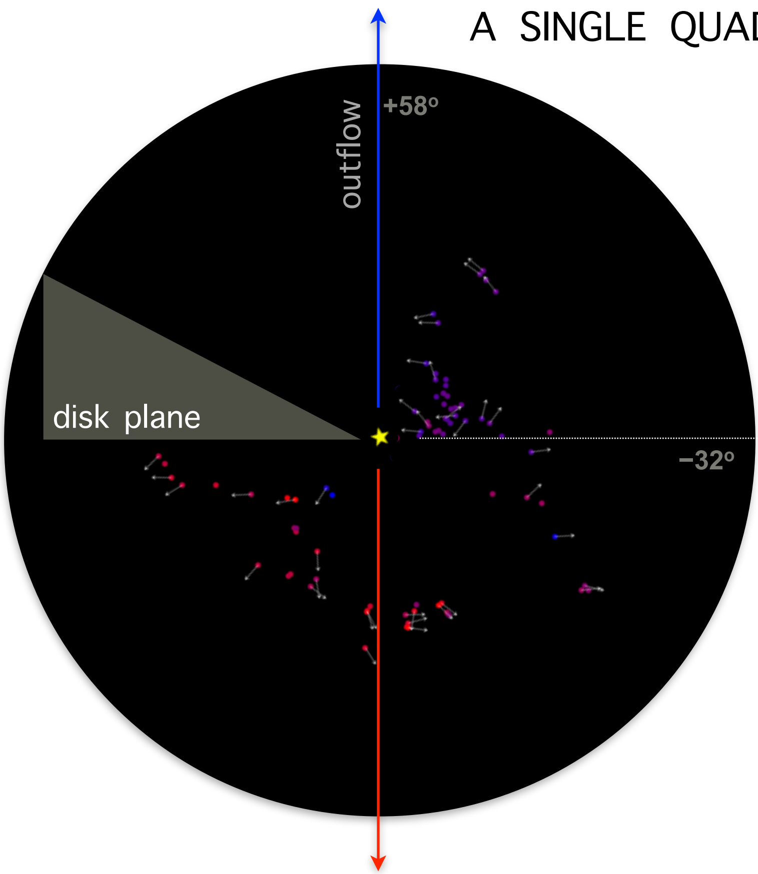
Sanna et al. (2010), A&A, 517, 78

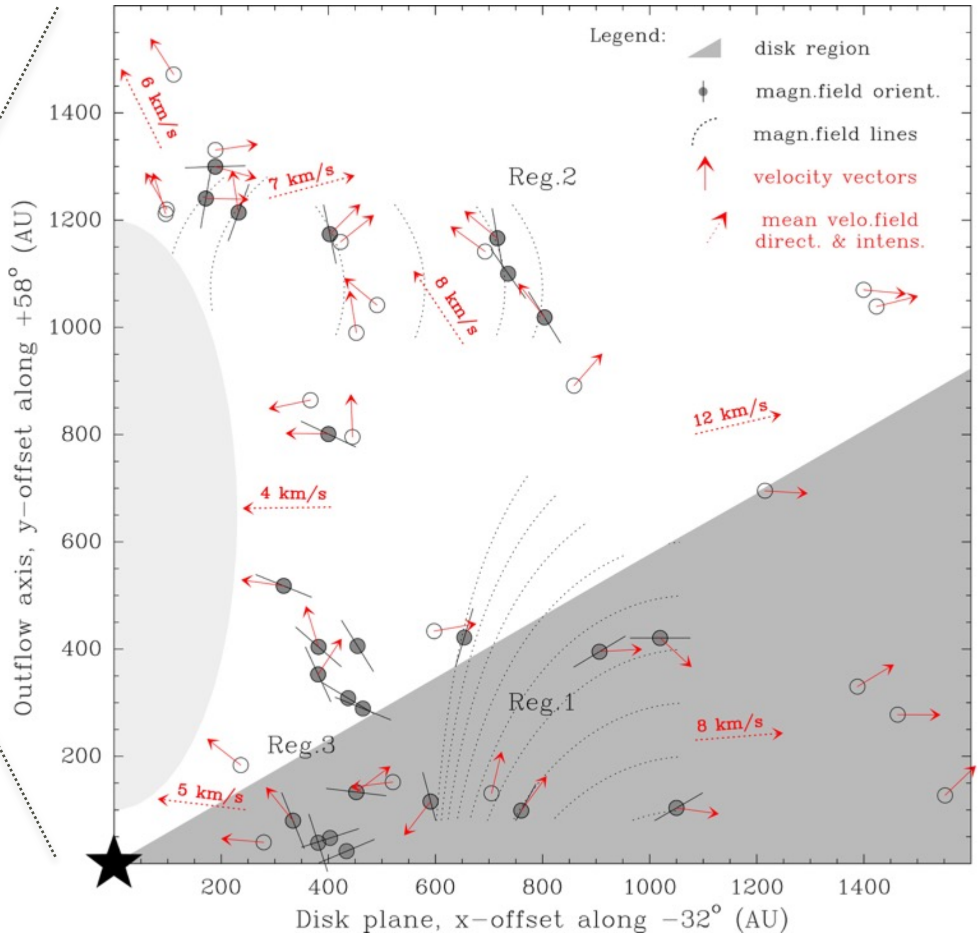
VLBI view 1. — r ≲ 2000 AU

SYMBOLS —
6.7 GHz CH_3OH MASER CLOUDLETS:

- ● with linearly polarized emission
- ○ without linearly polarized emission

MIRROR IMAGE OVER A SINGLE QUADRANT





Sanna et al. 2015, arXiv:1509.05428

SYMBOLS ——

6.7 GHz CH_3OH MASER CLOUDLETS:

- ● with linearly polarized emission
- ○ without linearly polarized emission

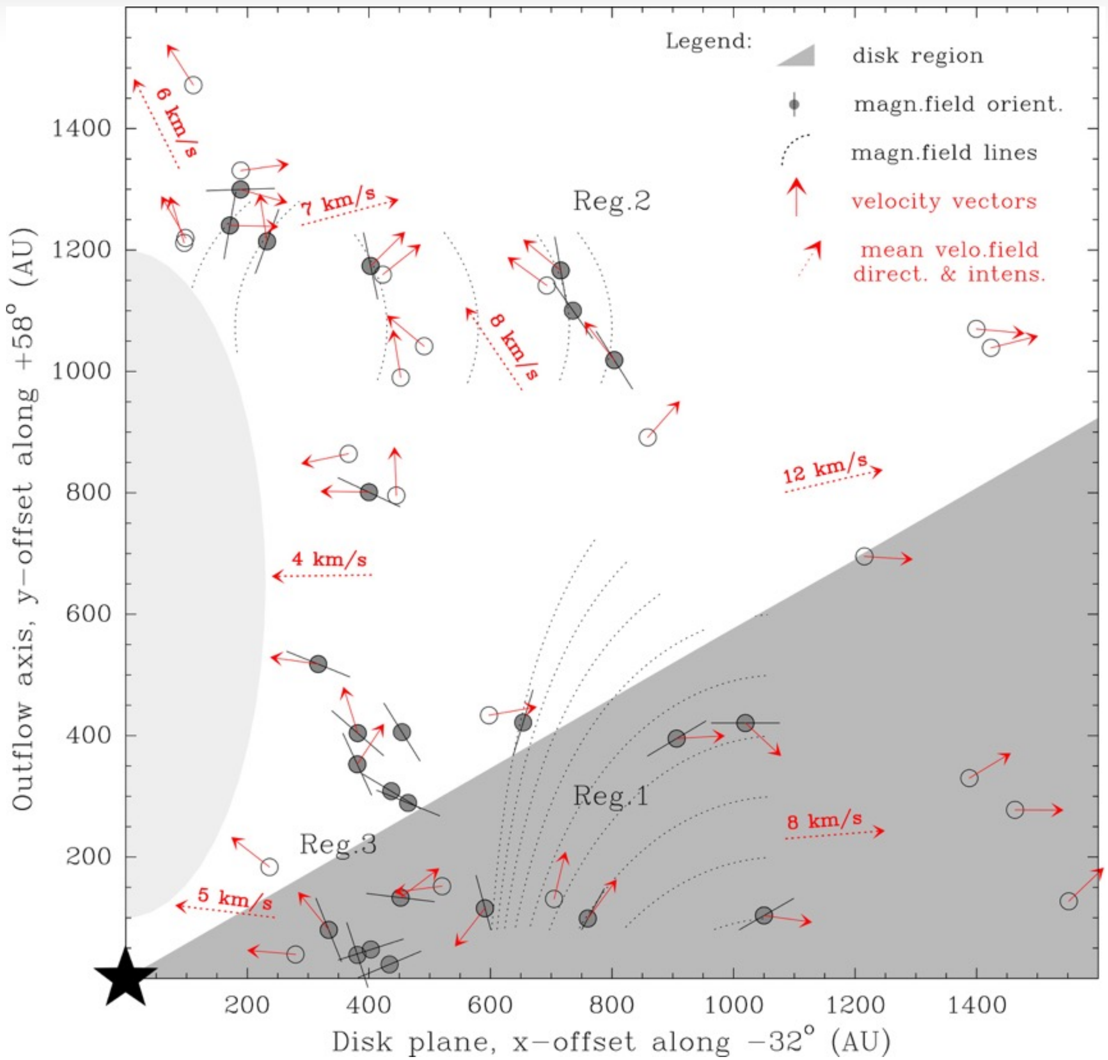
I. Average speed 7 km s^{-1}

II. Gas flow collimation at 1000 AU from the disk plane (Reg.2)

III. Outward stream along the disk plane for R > 500-600 AU (Reg.1)

IV. Inward stream along the disk plane R < 500-600 AU (Reg.3) with:

$$\dot{M}_{in} = 2 \times 10^{-4}\, M_{\odot}\, yr^{-1}$$



Sanna et al. 2015, arXiv:1509.05428

SYMBOLS —

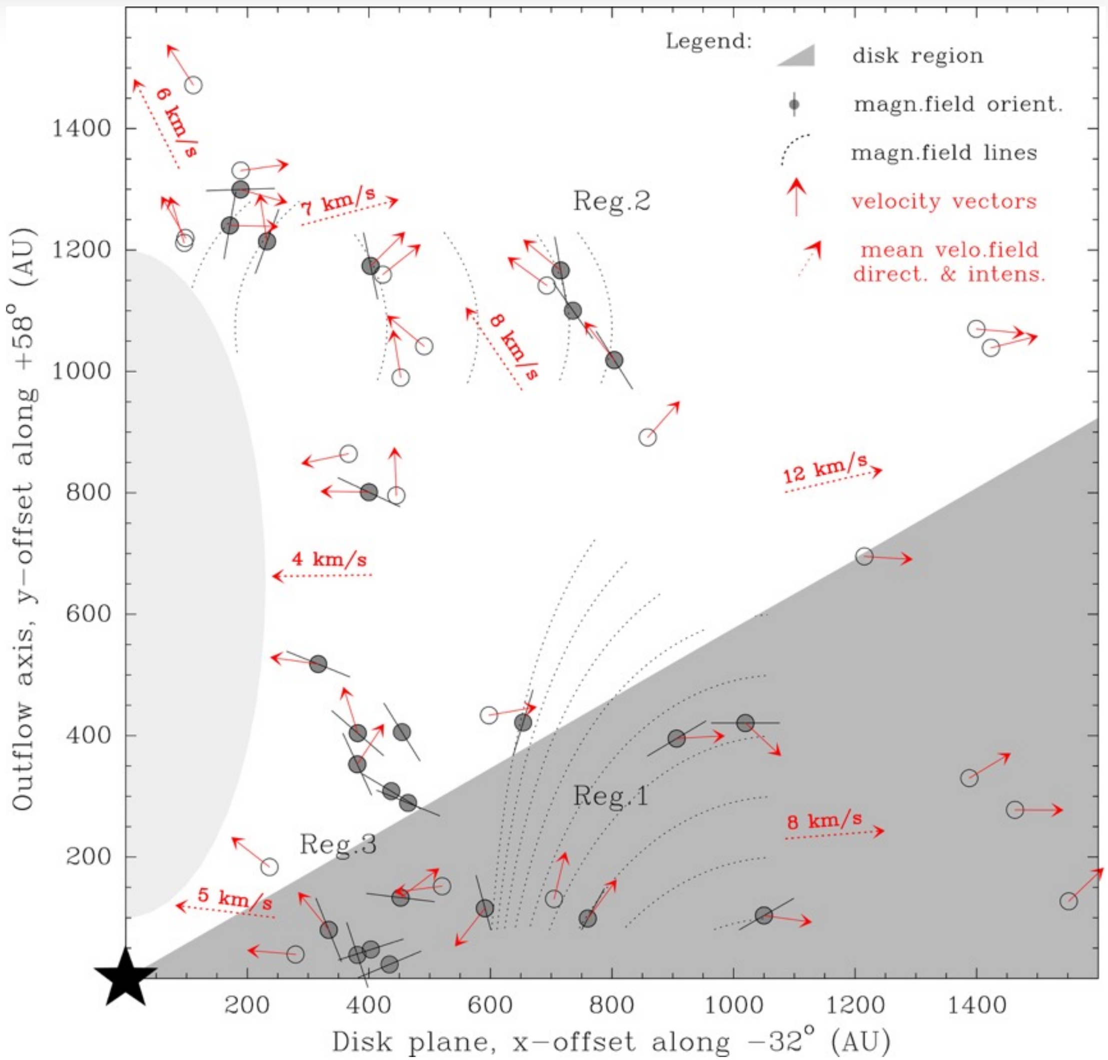
6.7 GHz CH_3OH MASER CLOUDLETS:

- ● with linearly polarized emission
- ○ without linearly polarized emission

V. Smooth **B** change of 0.2° AU^{-1} in Reg.1 and 2

VI. Average tilt between $\vec{V}(r)$ and $\vec{B}(r)$ of 30°

VII. Turbulent velocity field of 3.5 $km\,s^{-1}$?

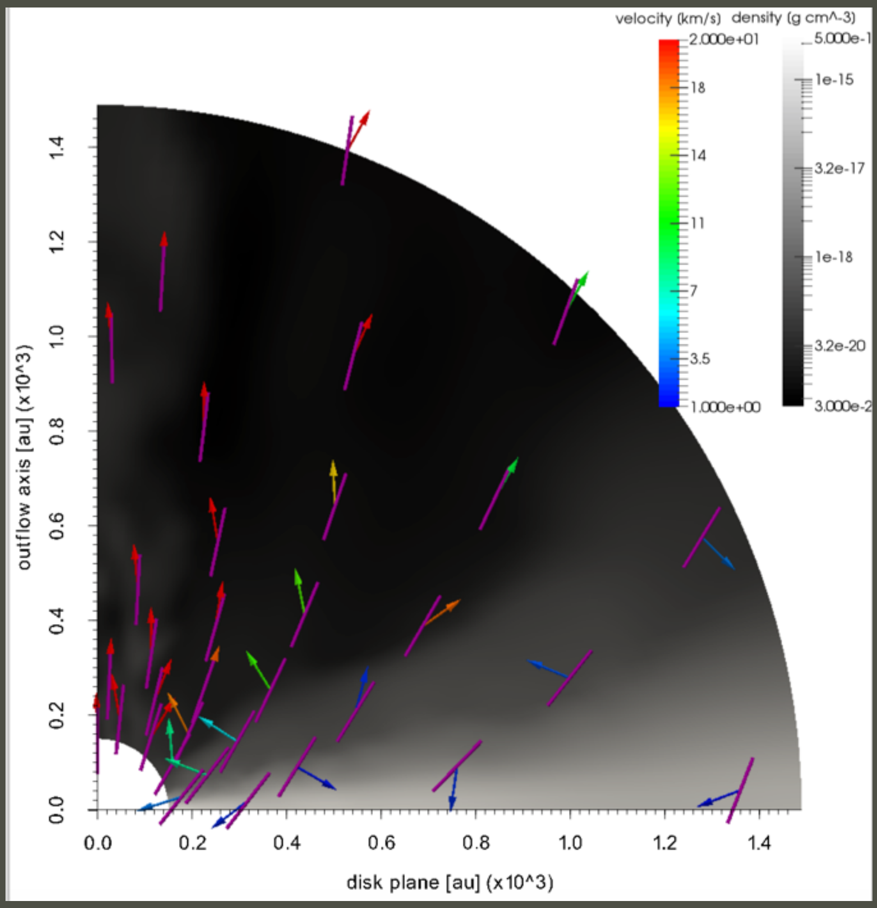


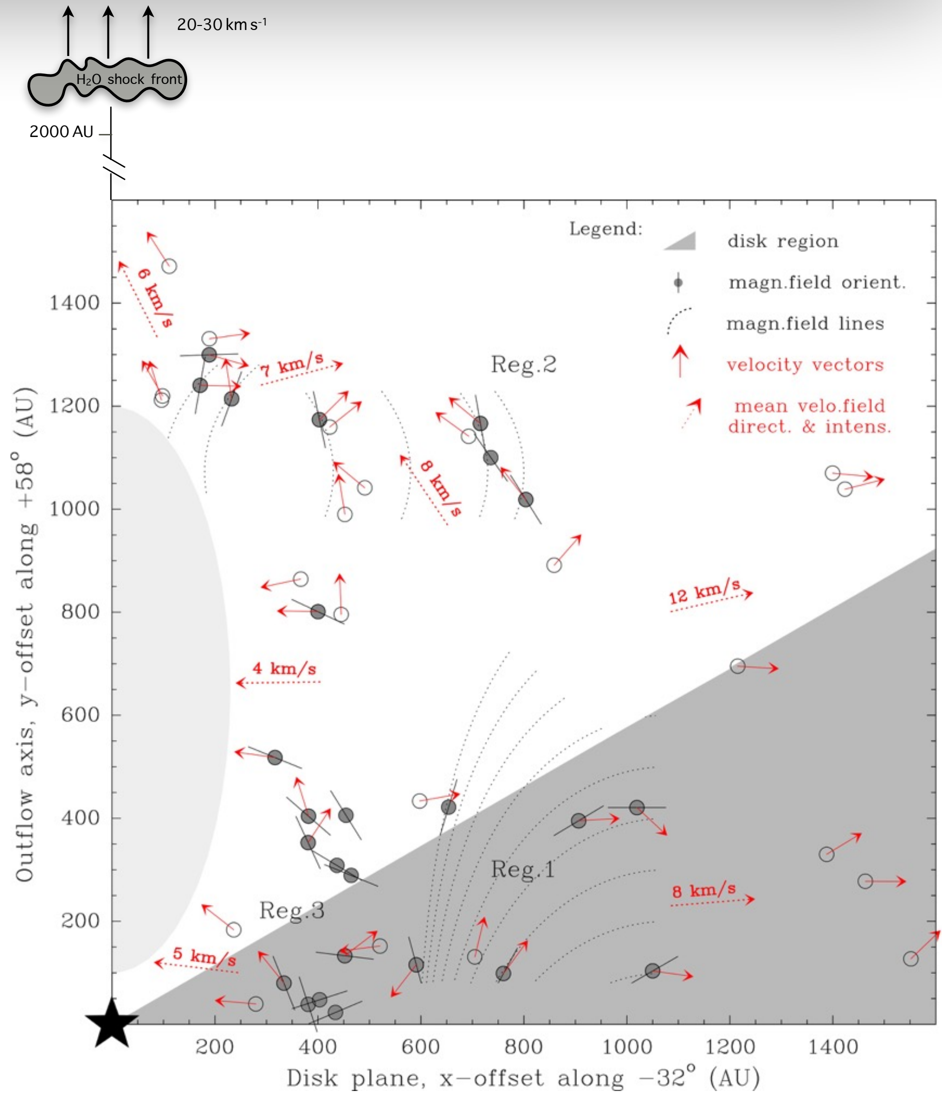
Sanna et al. 2015, arXiv:1509.05428

VLBI view 4. — $r \lesssim 2000$ AU

$B_{t_0} \approx$ mG
time (t_1): 10^5 yr
$M_{\star,t_1} = 48\ M_\odot$
$\dot{M}_{in,t_1} = 1 \times 10^{-4}\ M_\odot\ yr^{-1}$

LEGEND —
velocity vectors
magnetic field vectors





see poster by Anders Kölligan (Kölligan, Kuiper et al. in prep.)