

Max-Planck-Institut für Radioastronomie



The CepHeus-A Star formation and proper Motions (CHASM) Survey

– Where is the mass reservoir of high-mass YSOs? –

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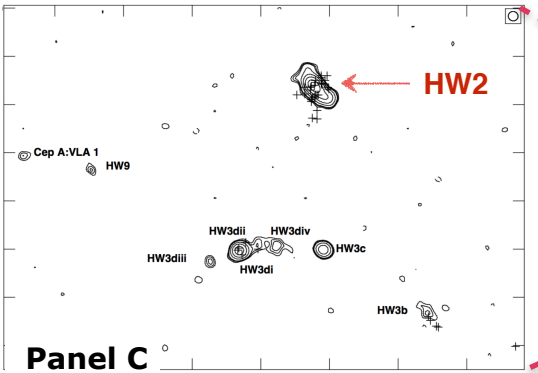
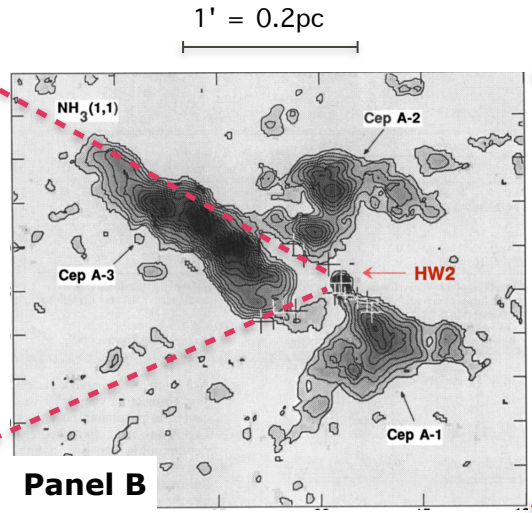
Target: The Star Forming Region - Cepheus A

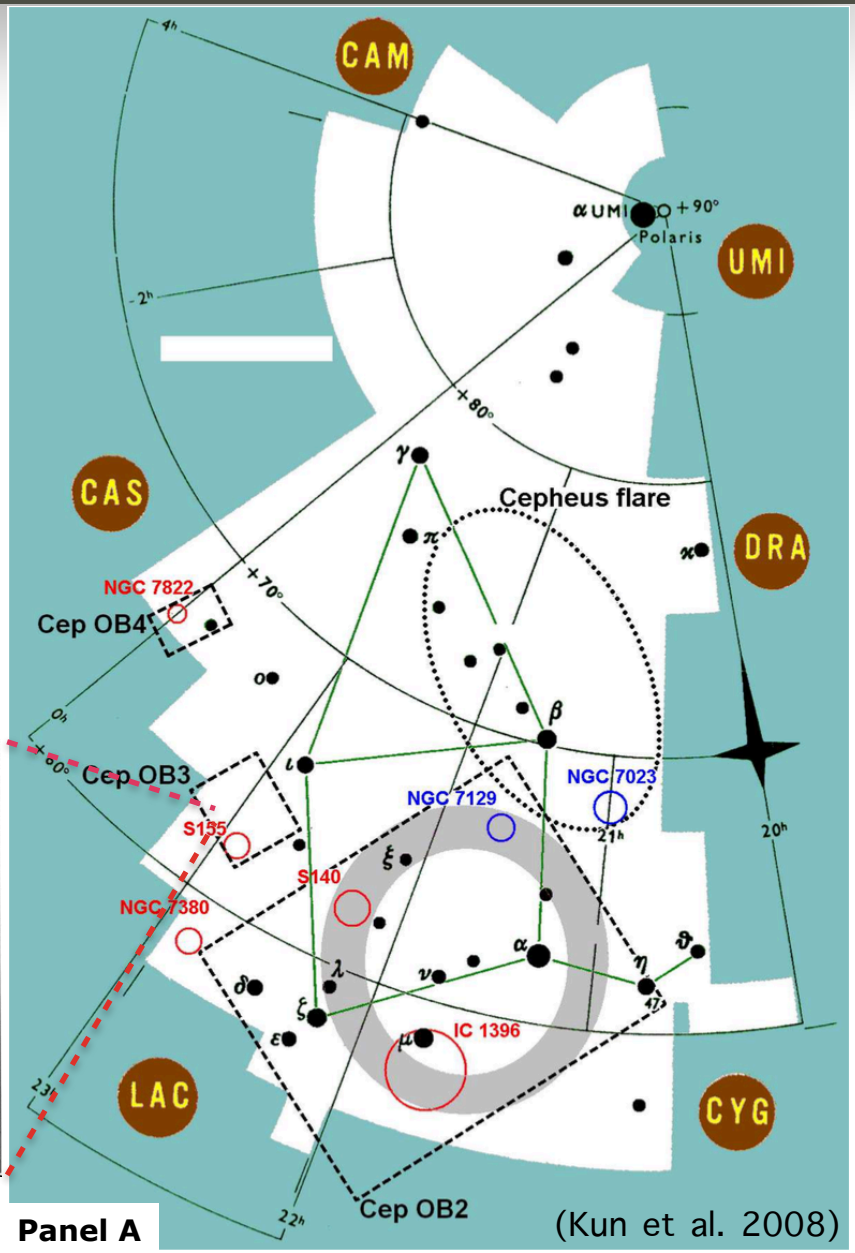
- densest condensation (**Panel B**) within the cloud complex Cepheus OB3 (**Panel A**);
- second nearest high-mass star-forming region (L_{bol}=2.5× 10^4 $L_\odot$) at a trigonometric distance of 700 ± 30pc (Moscadelli et al. 2009; Dzib et al. 2011);
- tight cluster (**Panel C**) of radio continuum and maser (OH, H_2O, CH_3OH) sources;
- nearest 6.7GHz CH_3OH maser source (**HW2**)



VLA-A 22GHz cont.
(Torrelles et al. 1998)



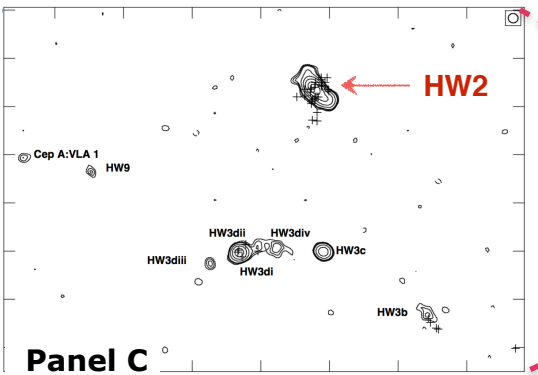
VLA-D 23.7GHz line
(Torrelles et al. 1993)



(Kun et al. 2008)

Target: The Star Forming Region - Cepheus A

✓ The high YSO multiplicity, and the close distance to the region, make this site a preferred target for a study of the YSO cluster properties



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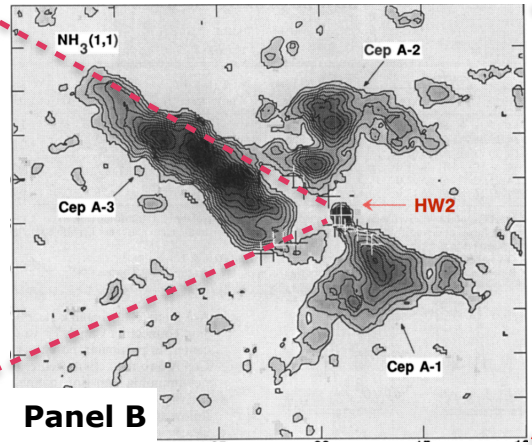

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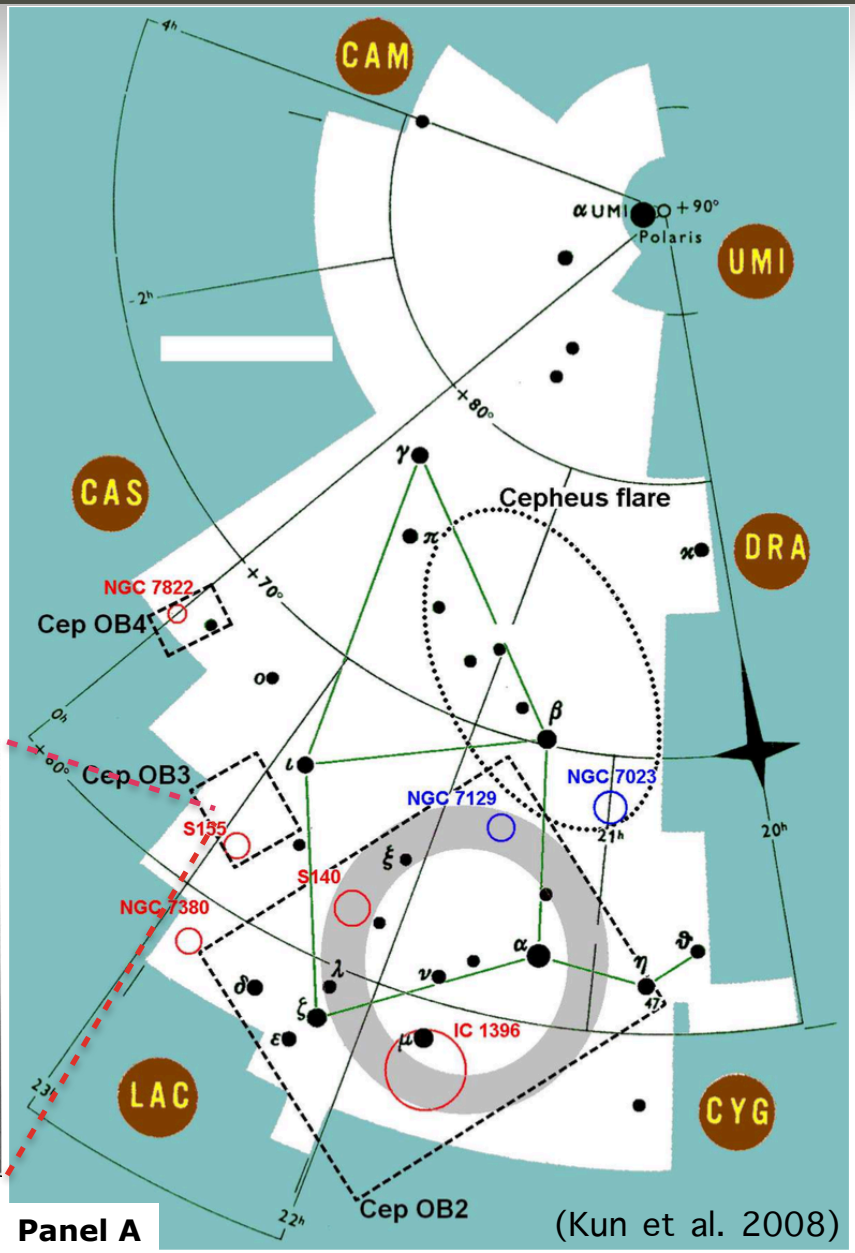
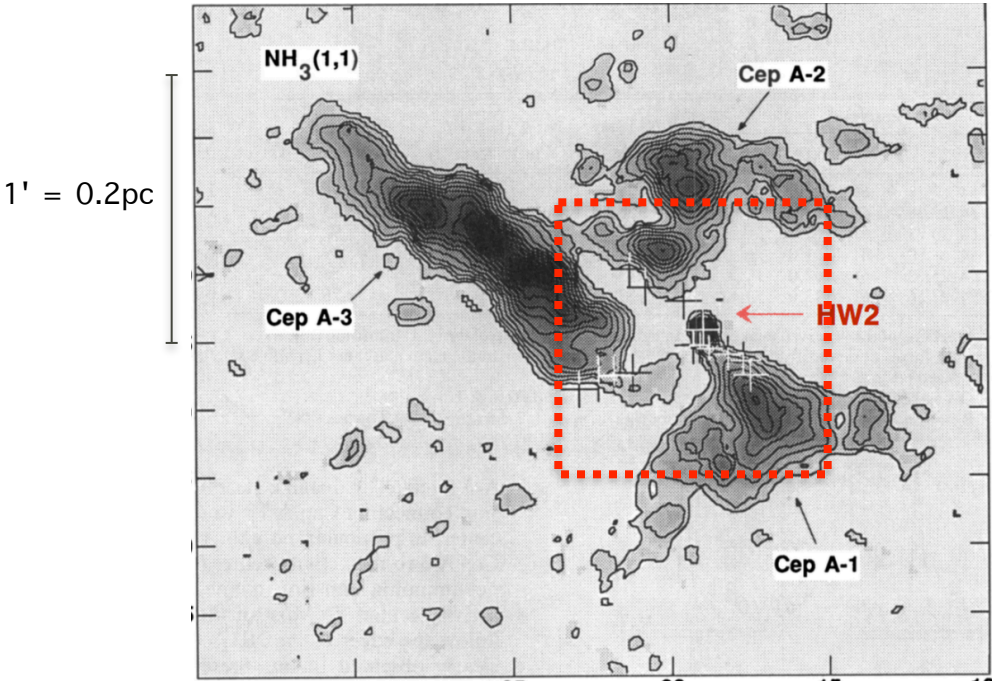


(Kun et al. 2008)

Tracers. — 1. **H_2O masers at 22.2 GHz**
2. **CH_3OH masers at 6.7 GHz**
3. **Radio cont. at 6 GHz from T Tauri stars**
4. **NH_3 (1,1) and (2,2) emiss. from the clump**



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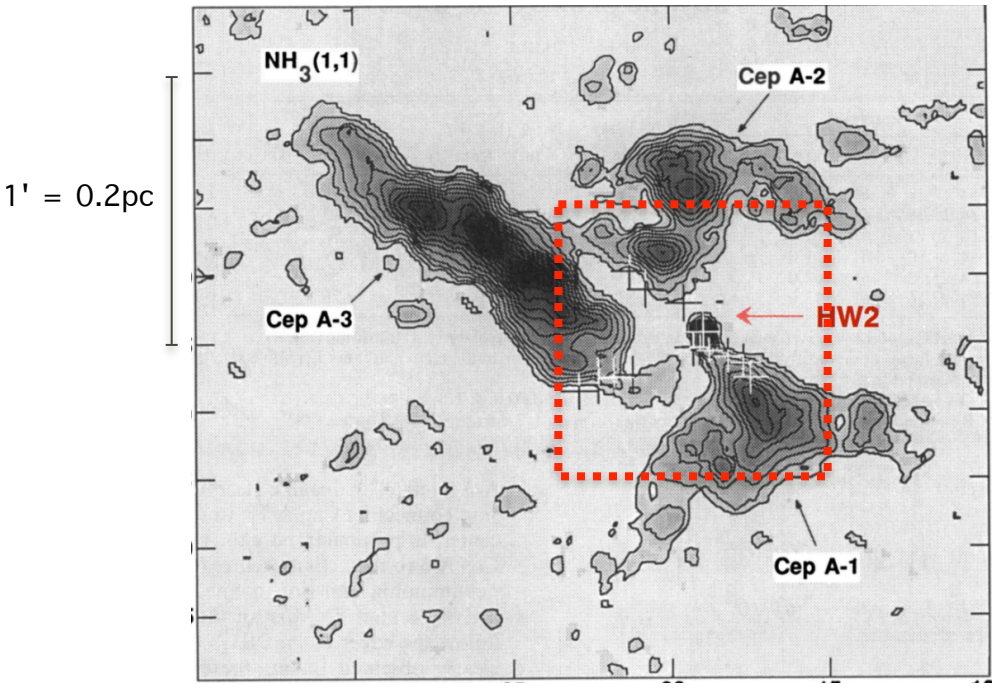
Observations. —

1) Astrometric **VLBA** observations at C (6 GHz) and K (22 GHz) bands around Cepheus A, for a total of **150 hr between 2016-2018 (18 epochs)**:

- **C-band: 103 distinct correlated fields** to trace uniformly the inner 1'x1' area around Cepheus A HW2 (r ~0.1 pc; **red box in Panel A**) + trace a few additional fields further away from HW2 (up to r ~0.4 pc);
- **K-band: 3 distinct correlated fields** within a radius of ~0.05 pc from Cepheus A HW2.

2) **JVLA spectral line observations** at K (22 GHz) band to image the NH3(1,1) and (2,2) line emission (**10 hr**).



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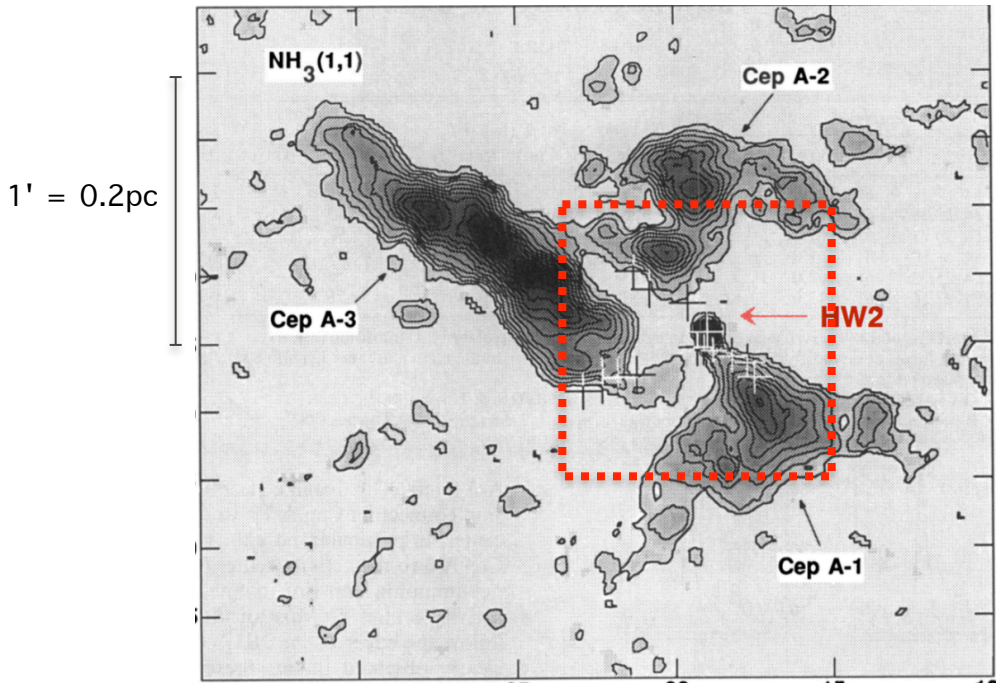

VLBA targets. —

- **5 massive YSOs** associated with H_2O masers;
- >**40 T Tauri stars** clustered within a radius of 0.4 pc from HW2 (their emission will be calibrated thanks to the 6.7 GHz masers).

Immediate Goals. —

- **VLBA**: to measure accurate **trigonometric parallaxes** (uncertainty <1%) and **proper motions** (uncertainty ca. ±0.1 km s^{-1}) of a young cluster of high-mass YSOs (through H_2O and CH_3OH masers) and low-mass YSOs (through VLBI radio cont.)

- **JVLA**: to measure the physical conditions, **ρ** and **T**, of the clump gas and the **local gas V_{LSR}** (uncertainty ca. ±0.1 km s^{-1})

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Final Goals. —

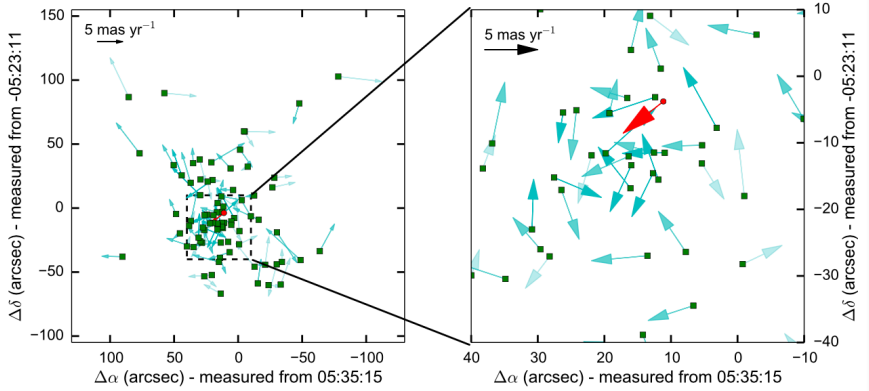
1) To measure the Bondi-Hoyle accretion radius of HW2:
— sets the outer radius of the mass reservoir of HW2 —

$$r_{BH} \propto \frac{1}{(V_{rel}^2 + C_s^2)}$$

$(V_x ; V_y ; V_{LSR})$ — VLBA, JVLA

T_{NH_3}

Example of T Tauri (2D) proper motions in the ONC from Dzib et al. (2017):



2) To measure the Bondi-Hoyle mass accretion rate of HW2:

$$\dot{M}_{BH} \propto \rho_{cl} \times r_{BH}^2$$

from NH_3

Planar Infall of CH_3OH gas around Cepheus A HW2

– Small-scale accretion vs. Large-scale –

A. Sanna, L. Moscadelli, G. Surcis. H.J. van Langevelde, K.J.E. Torstensson, and A.M. Sobolev 2017, A&A, 603, A94

The 6.7 GHz maser distribution around HW2

Observations —

- Western EVN array (8 antennas)
- 3 epochs between 2013-2015
- C band (5 cm)
- HPBW of 4.5 mas (or 3 au)
- RMS of 4-6 mJy/beam

Symbols —

Main Panel:

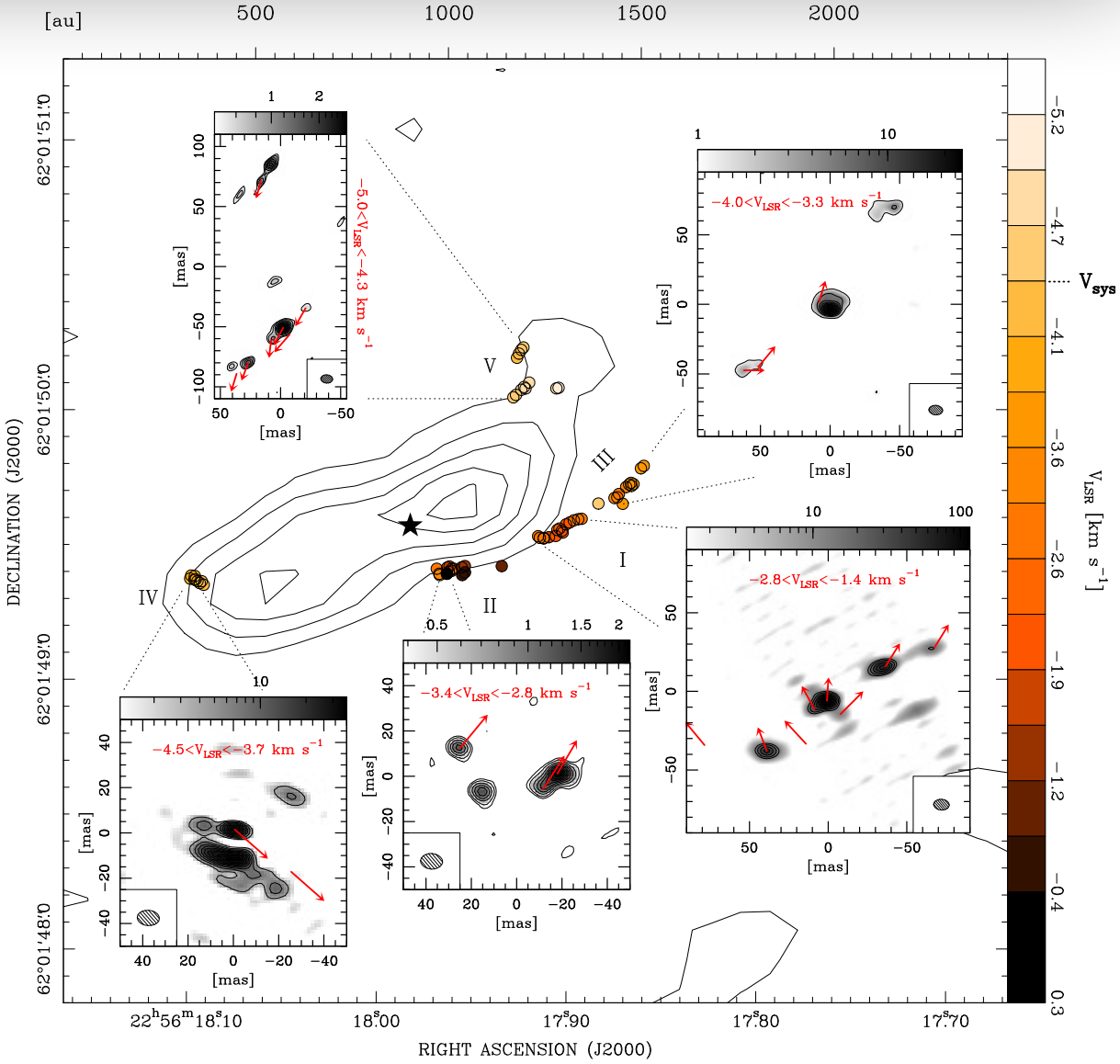
★ HW2 position from 43GHz VLA data (center of the radio jet)

● 6.7 GHz CH_3OH maser cloudlets
Colors: LSR velocities

— Contours - HC_3N emission between 7-3 km/s (Jiménez-Serra et al. 2009)

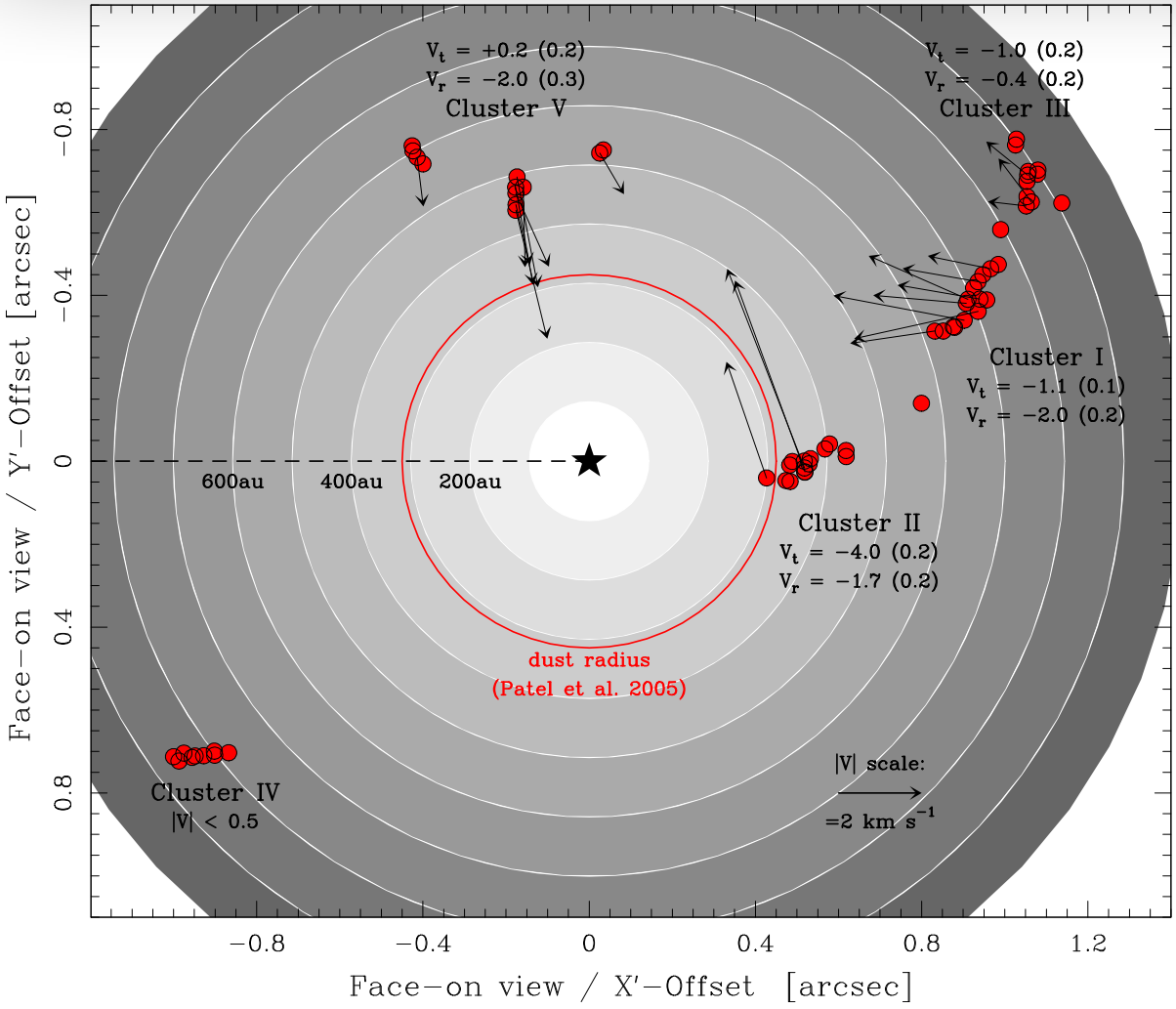
Insets - Maser Integrated velocity maps

↗ CH_3OH cloudlets Proper motions



Sanna et al. (2017)

HW2: Face-on View of the "Disk" plane



Sanna et al. (2017)

Symbols —

- ★ HW2 position from 43GHz VLA data (center of the radio jet)
- ● 6.7 GHz CH_3OH maser cloudlets
- → CH_3OH cloudlets motions
- V_T/V_R Tangential/Radial Group velocities w.r.t. HW2

I. Inward flow (V_R) between 300-800au with average speed of ~2 km s^{-1}

II. Rotational component (V_T) at ca. 300au of 4 km s^{-1}

III. $\dot{M}_{in}$(disk) ~3×10^{-5} $M_\odot$ yr^{-1}

The Chasm Survey: Outlook

Ongoing Projects —

VLBA large astrometric survey at C (6 GHz) and K (22 GHz) bands:
to map distances and accurate proper motions of ca. 40 among low- and high mass YSOs within a radius of ~0.4pc from Cepheus A HW2.

JVLA D-array observations at K band:
to measure the distribution, kinematics, local density, and temperature of the clump gas surrounding HW2.

Foreseen Results —

- to provide a unique dataset of accurate parallaxes and proper motions of both T Tauri and high-mass YSOs in the same YSO complex —> study relative proper motions & Bondi-Hoyle accretion radius

- to study whether or not a correlation between the number of young stars and the minimum fragment mass of the clump exists —> does radiative heating from low-mass YSOs suppress fragmentation?