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

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Abstract. The “CepHeus-A Star formation and proper Motions” (CHASM) survey is a large project consisting of a combination of astrometric Very Long Baseline Array (VLBA) and Jansky Very Large Array (VLA) observations, to map both the stellar and dense molecular gas components in the star-forming region Cepheus A. With the VLBA, we make use of the CH_3OH and H_2O maser emission in the vicinity of Cepheus A HW2, in order to measure accurate proper motions and parallax distances to both T Tauri stars and massive young stellar objects (YSOs) belonging to the same star-forming region. With the Jansky VLA, we make use of the interstellar thermometer NH_3, in order to image the molecular clump surrounding Cepheus A HW2 and to determine its physical conditions. By combining these informations all together, we can provide, for instance, a direct measurement of the Bondi-Hoyle accretion radius for a massive young star, namely, HW2.

Keywords. surveys, astrometry, ISM: clouds, ISM: kinematics and dynamics, stars: individual (Cepheus A HW2)

Overview

Models of star formation predict that the interplay between the clump gas, and the young stellar objects (YSOs) which form inside the clump, might be fundamental to aid the formation of the most massive objects and to set the stellar initial mass function (e.g., Krumholz *et al.* 2014). With the aim to provide a detailed analysis of how young stars influence their environment (and vice versa), we have initiated the “CepHeus-A Star formation and proper Motions” (CHASM) survey, which makes use of a combination of Jansky Very Large Array (VLA) and astrometric Very Long Baseline Array (VLBA) observations. The target of this study is the massive star-forming region Cepheus A (Figure 1), which, at a trigonometric distance of 700 pc from the Sun (Moscadelli *et al.* 2009; Dzib *et al.* 2011), is the second nearest after Orion. In the following, we highlight the objectives of the VLBA observations.

Astrometric Very Long Baseline Interferometry (VLBI) measurements of both, compact spectral line emission (maser) in the vicinity of massive YSOs, and radio continuum emission from chromospherically active YSOs (low-mass, T Tauri stars), provide us with parallax measurements typically accurate to about $\pm10\,\mu$as, and yield measurements of secular proper motions with accuracies as good as a few $0.1\,\mathrm{km\,s^{-1}}$, for sources within a few kpc (e.g., Reid & Honma 2014; Loinard *et al.* 2011). When applied to stars distributed across the same region, these observations allow us to measure *relative* distances and proper motions of gravitationally bound YSOs, and their 3D distribution and the internal kinematics of the region can be reconstructed.

With this in mind, we are conducting multi-epoch, phase referencing, VLBA observations of three distinct tracers towards Cepheus A: the 6 GHz radio continuum emission from T Tauri stars surrounding HW2 (see below); the 6.7 GHz CH_3OH maser emission

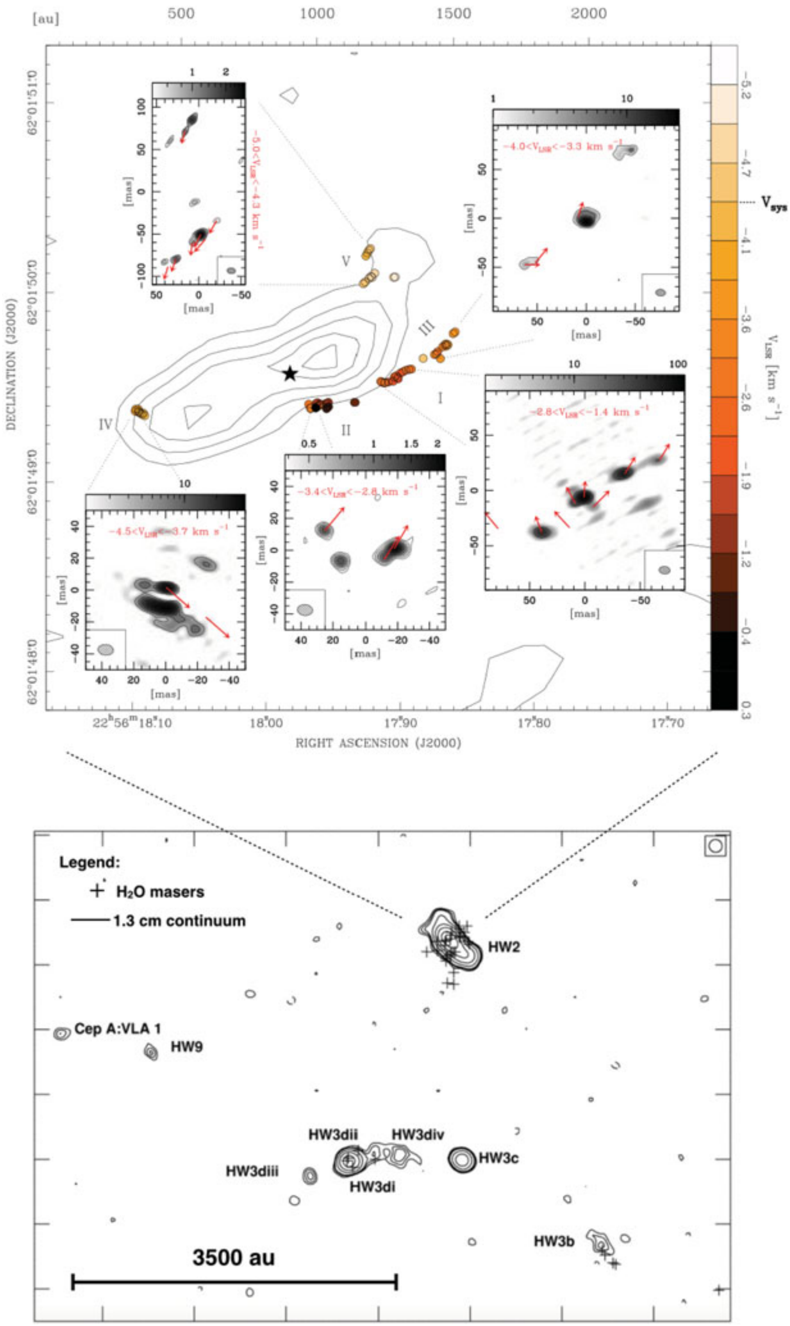

Figure 1. Lower panel: map of the 1.3 cm continuum emission (contours) of the central region of Cepheus A from Torrelles *et al.* (1998). Main sources are labeled according to the literature. Crosses indicate the positions of the 22.2 GHz H_2O masers detected in the region. Liner scale in the bottom left corner **Upper panel:** 6.7 GHz CH_3OH maser distribution (circles) in the vicinity of the HW2 object (star) from Sanna *et al.* (2017). Maser colors give the local LSR velocity according to the right-hand scale (see the on-line version). Linear scale on the upper axis. Individual insets zoom in onto each maser group and show the morphology of the local maser emission. Red arrows trace the proper motions vectors of the maser cloudlets. More details can be found in Figure 2 of Sanna *et al.* (2017).

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within 1000 au of HW2 (Figure 1, upper); the 22.2 GHz H_2O maser emission clustered within 5000 au of HW2 (Figure 1, lower). HW2 is the most massive YSO which contributes half the bolometric luminosity of the region of 2–3 × 10^4 $L_\odot$ (e.g. De Buizer *et al.* 2017).

At C band, we are targeting simultaneously the T Tauri stars and the CH_3OH masers; the former will be searched for blindly, across a large field of radius >0.2 pc centered on HW2, whereas the latest are associated with HW2 solely (e.g., Torstensson *et al.* 2011; Sugiyama *et al.* 2014; Sanna *et al.* 2017). Based on the YSOs population density in a low-mass star-forming region such as Ophiuchus, and taking into account that massive stars grow up in a much more crowded environment, we expect to find more than 40 YSOs spread over an area of $(0.2\,\mathrm{pc})^2$. Note that, Cepheus A is the closest star-forming region showing bright 6.7 GHz CH_3OH maser emission, and this property can be used, in particular, to improve on the detection of faint (< mJy) radio continuum emission coming from young T Tauri stars. On the other hand, H_2O masers are the most suited target to undertake a systematic measurement of distances to high-mass components in Cepheus A. In the literature, tens of maser spots, with intensities as high as several 10 Jy, have been observed to cluster around 5 distinct YSOs (Figure 1, lower): HW2–main, and sub-regions R 4 and R 5 (e.g., Torrelles *et al.* 2001; Torrelles *et al.* 2011), and radio components HW3d (e.g., Chibueze *et al.* 2012) and HW3b (e.g., Torrelles *et al.* 1998).

The immediate goal of the VLBA survey is to measure both accurate proper motions and (absolute and relative to HW2) parallaxes to low- and high-mass YSOs surrounding HW2, as well as to map the young low-mass population in the region. Relative distances allow us to constrain the position of the young stars with respect to HW2 within a few pc (1 pc = 2 μas at 700 pc), in order to prove that these YSOs belong to the same clump (a few pc in size). Having on hand the proper motion measurements of tens of YSOs belonging to Cepheus A, we can study the magnitude and direction of their (3D) velocity vectors with respect to HW2, and vice versa (e.g., Rivera *et al.* 2015). Note that the line-of-sight velocity component will be inferred from complementary observations of the local gas emission (through VLA observations). The full-space motion of HW2 inside the clump, combined with the kinematics of the clump gas, can be used to measure the Bondi-Hoyle accretion radius (r_{BH}) of HW2 directly. The Bondi-Hoyle accretion radius sets the outer radius of the mass reservoir for HW2, and depends on the relative velocity (v_{rel}) of the star with respect to the clump gas ($r_{BH} \propto v_{rel}^{-2}$). Knowing r_{BH} would eventually tell us whether HW2 can accrete mass (mainly) from its immediate surroundings (i.e., the pre-stellar core, $\ll$ 0.1 pc), or its final mass can be clump-fed (i.e., the mass reservoir is supplied outside a radius $\geqslant$ 0.1 pc from the star).

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