CARMA Large Area Star formation Survey: First Look at Serpens Main

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BACKGROUND

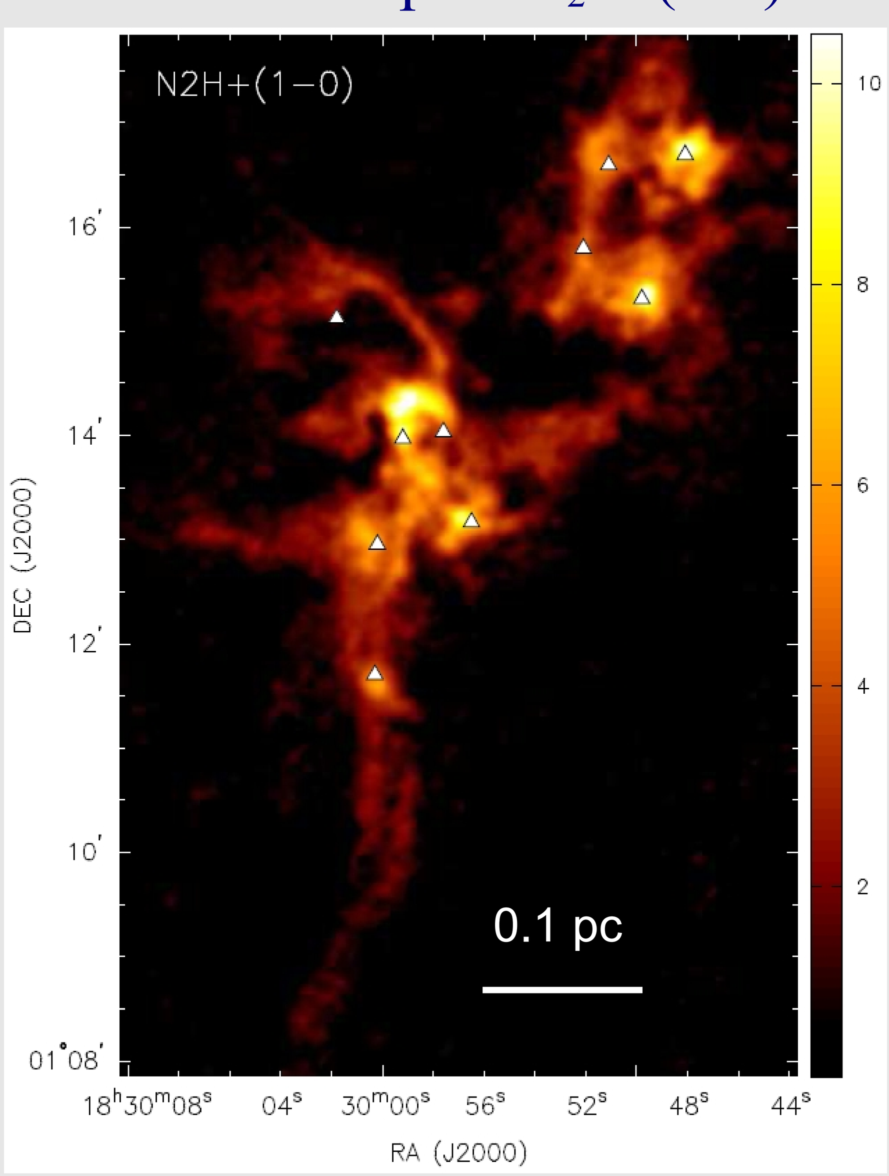
We present the Serpens Main results from the CARMA Large Area Star-formation Survey (CLASSy). The main goals of this collaborative project are to study the star formation process from large to small scales. By combining the cross-correlation and auto-correlation data from all CARMA 23 antennas, the observations are able to reconstruct the emission at a wide range of spatial scales with the angular resolution of 7 arcsecs. As one of the five observing targets, Serpens Main is a nearby region (230 pc) of active low-mass to intermediate-mass clustered star formation. Our observations cover an area of 12' by 17' with the total observing time of 100 hours, including two major regions of warm dust and gas in the northwest and southeast. Also, the observing region contains about 40 young stellar objects identified by previous studies. We present an overview of density structure and kinematics probed by the three gas tracers in Serpens Main. Based on these results, detailed studies toward specific goals are being conducted. We also show the comparison between our results, the Herschel Space Observatory and the Spitzer Space Telescope. The combination of these data provides unprecedented insight to the star formation activities in this region.

TAKE AWAY POINTS

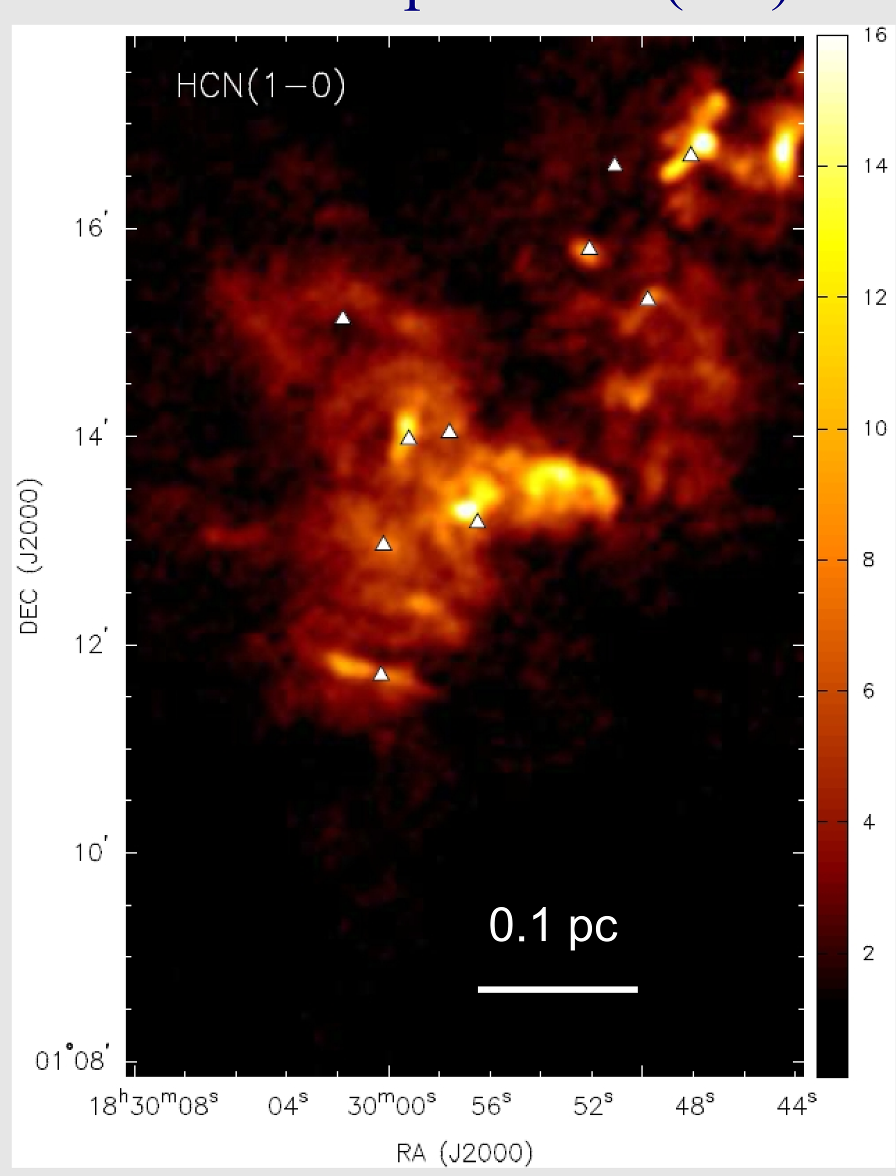
- Dense gas morphologies and kinematics traced by N_2H^+(1-0), HCN(1-0), and HCO^+(1-0) are revealed in Serpens Main with high resolution for the first time.
- N_2H^+(1-0) gas well coincides with submillimeter dust cores and Herschel results.
- N_2H^+(1-0) shows two resolved filamentary structures in the south for the first time.
- Global velocity structures suggest a shift from the NW to SE cluster; the complex velocity field suggests collision between shells powered by nearby stars.

Large-Scale, High-Resolution View of Dense Gas

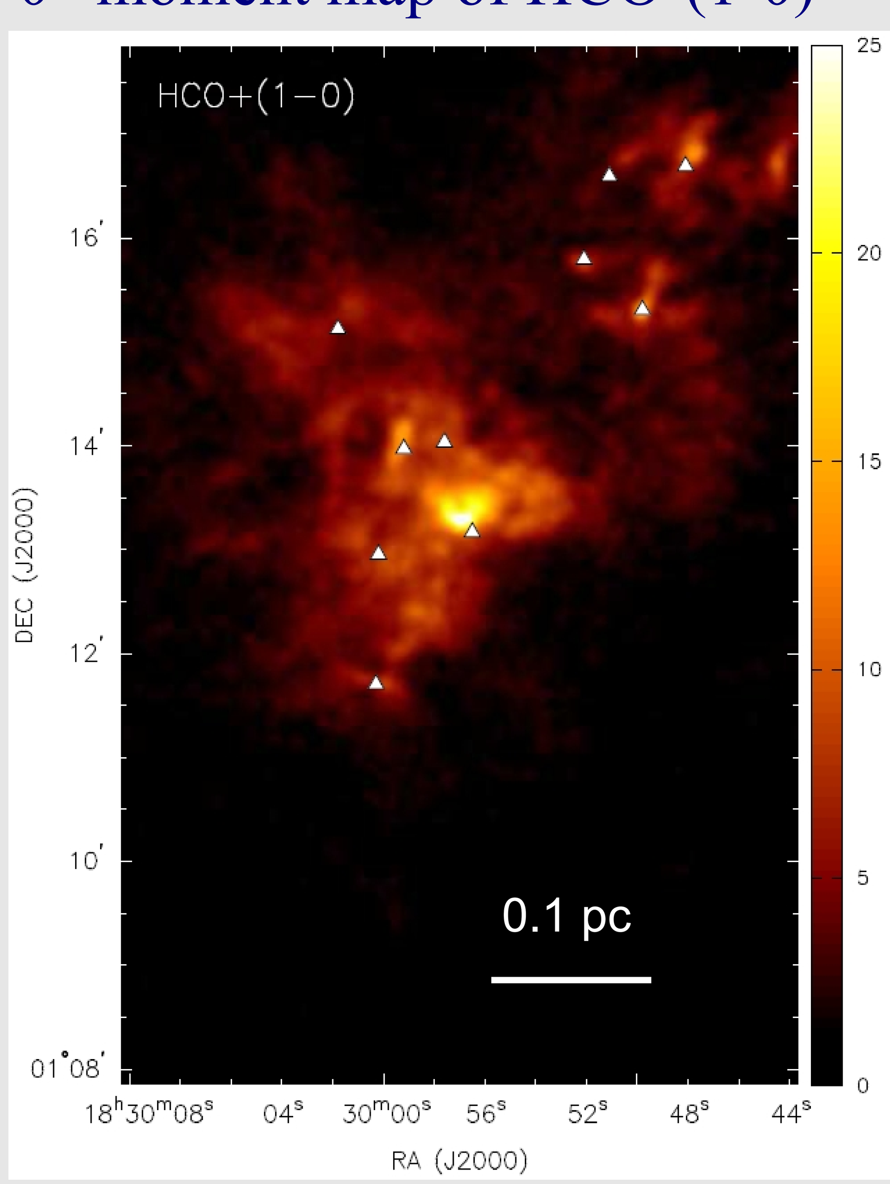
0th moment map of N_2H^+(1-0)



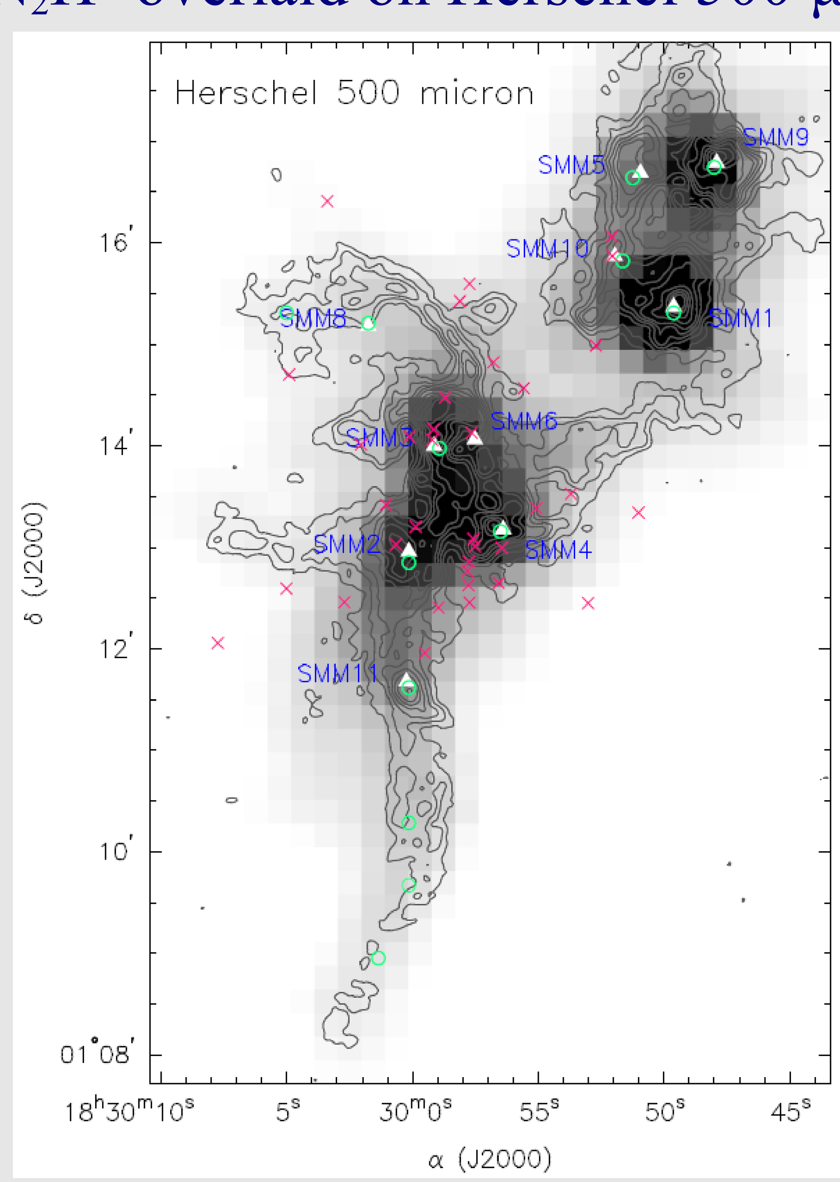
0th moment map of HCN(1-0)



0th moment map of HCO^+(1-0)



N_2H^+ overlaid on Herschel 500 μm



N_2H^+(1-0) shows prominent filamentary structures in the entire region. The two filaments in the south are resolved for the first time. HCN(1-0) and HCO^+(1-0) trace different morphologies from N_2H^+(1-0). All three molecules are in agreement with most of the SMM cores from SCUBA 850 μm (white triangles; Davis et al. 1999). Green circles: SCUBA 850 μm cores (Di Francesco et al. 2008). Red crosses: c2d Spitzer YSOs candidates (Evans et al. 2009).

References: [1] Arce et al. 2011, 742, 105 • [2] Davis et al. 1999, MNRAS, 309, 141 • [3] Di Francesco et. al 2008, ApJS, 175, 277 • [4] Evans et al. 2009, ApJS, 181, 321 • [5] Graves et al. 2010, MNRAS, 409, 1412 • [6] Padoan et al. 2001, ApJ, 553, 227

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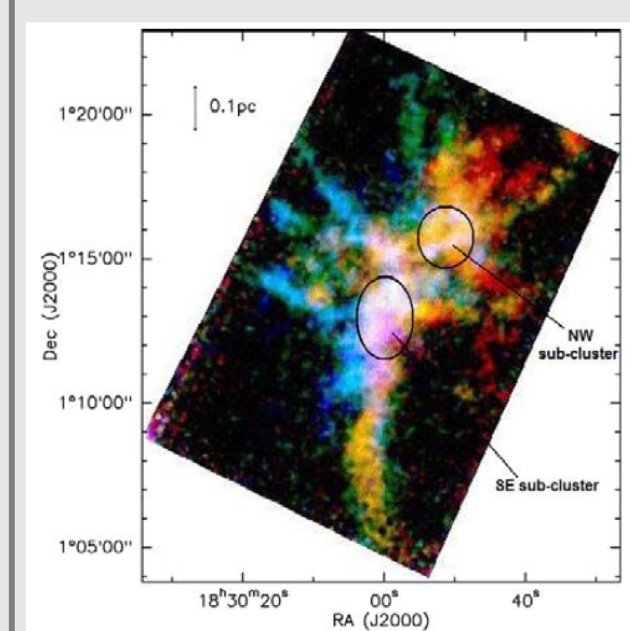
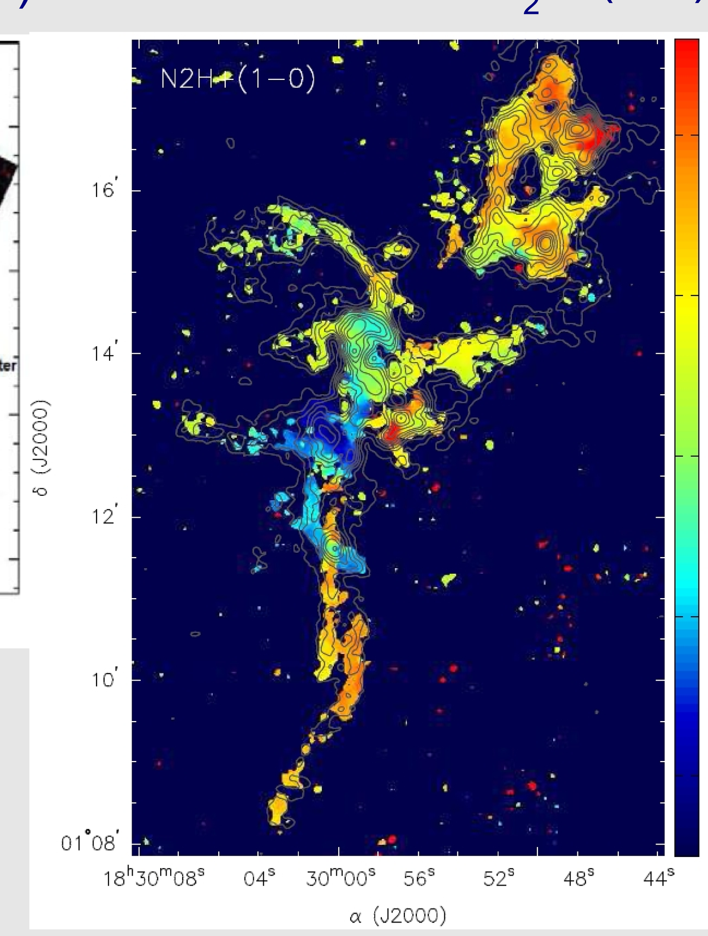
Global Velocity and Linewidth Structure

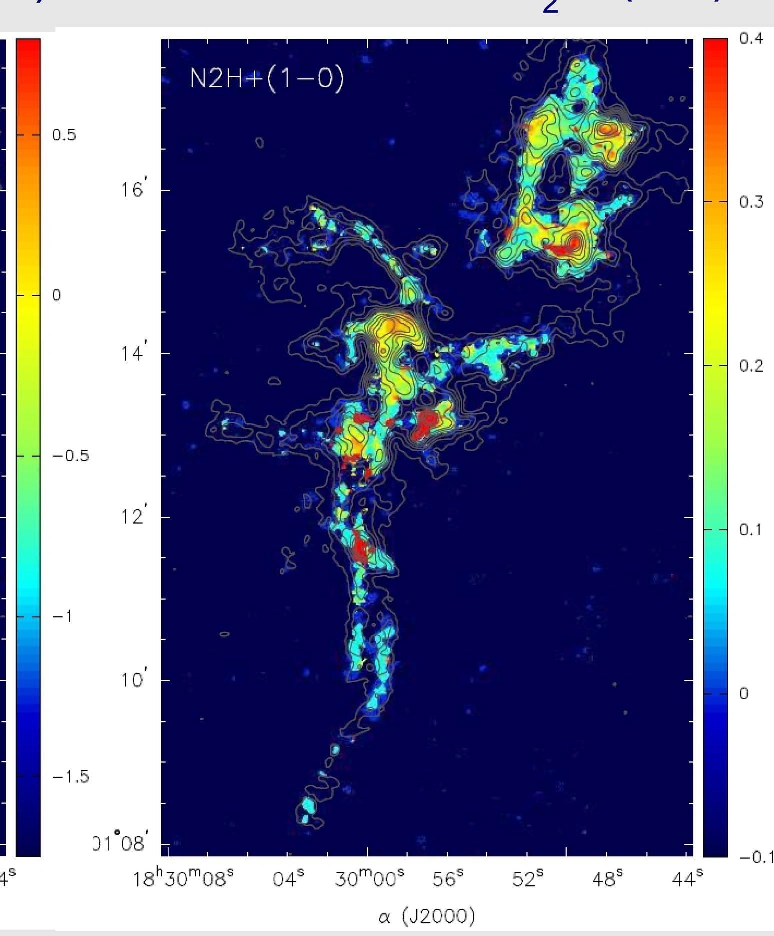
1st moment of $C^{18}O$(3-2)



1st moment of N_2H^+(1-0)



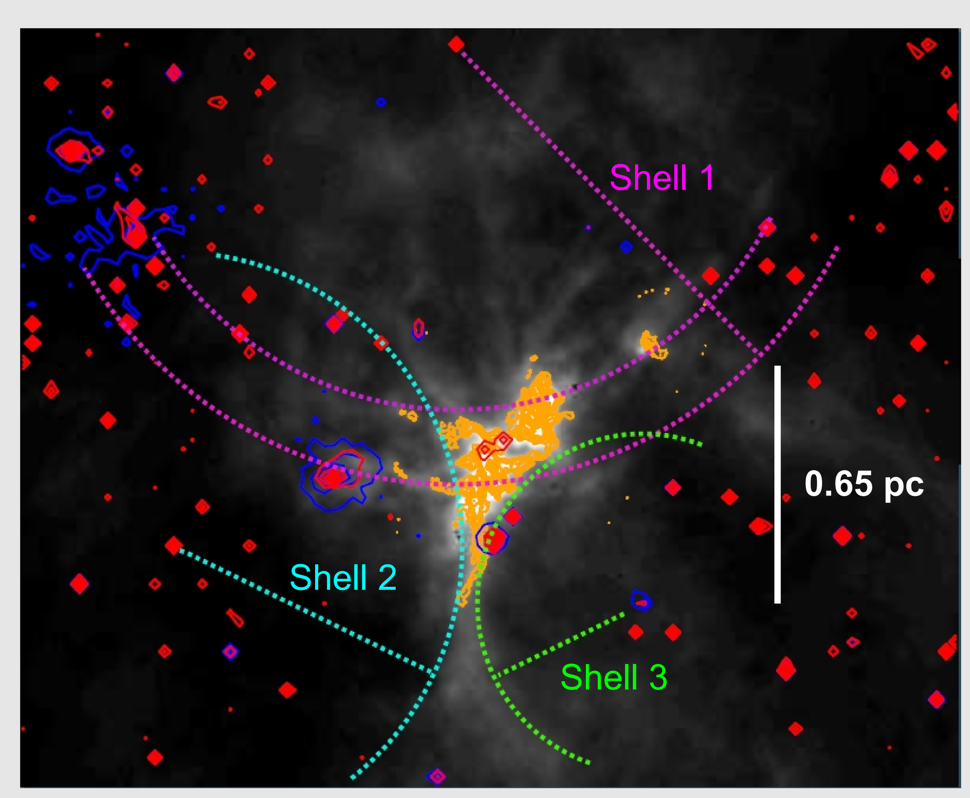
2nd moment of N_2H^+(1-0)



Left: Velocity coded 3 color plot from Graves et al. (2010). The blue color indicates lower velocities and the red color shows higher velocities. Central: 0th moment map of N_2H^+ overlaid on the 1st moment map (velocity). Right: 0th moment map of N_2H^+ overlaid on the 2nd moment map (linewidth).

- N_2H^+(1-0) global velocity: higher velocity (NW cluster) → lower velocity (SE cluster) → higher velocity (south filaments). The NW cluster shows uniform velocity field in large scales. The SE cluster shows more complex velocity fields than NW cluster and is associated with large-scale velocity gradients.
- Global velocity structures traced by $C^{18}O$(3-2) and N_2H^+(1-0) are consistent in general.
- Sharp change in velocity from SE cluster to the two southern filaments which show similar velocities.
- Both NW and SE clusters mostly present thermal linewidths (0.2 km/s assuming 10 K); the southern filaments are sub-thermal.
- Several cores are associated with large linewidths (supersonic), suggesting star formation mechanisms other than the flow-driven scenario which predicts decreasing linewidths with increasing gas densities (e.g., Padoan et al. 2001).

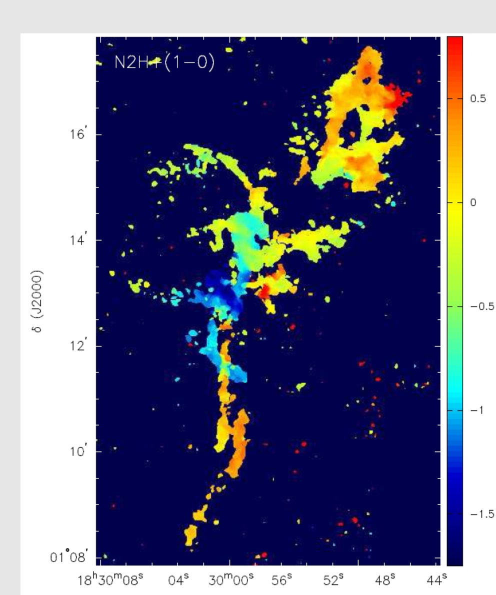
Models for Structures and Kinematics



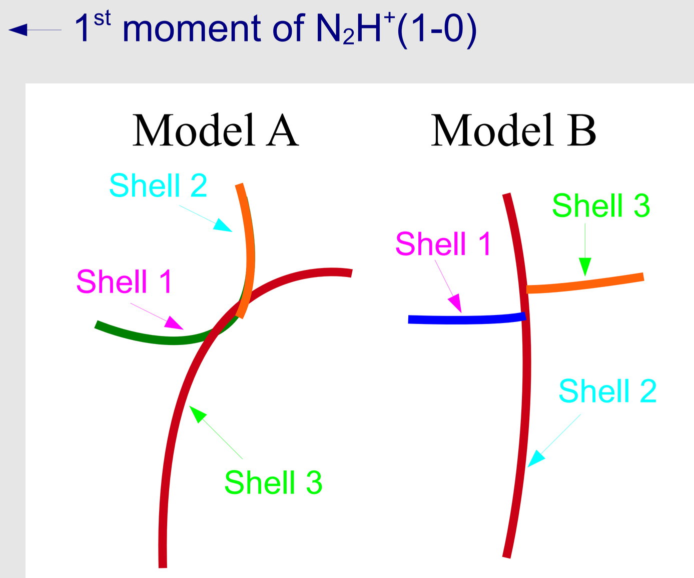
Collision Between Shells

Image description: The N_2H^+ emission (orange contours) superimposed on the Herschel 250 μm image (grey-scale). The blue and red diamonds indicate the blue and red stars identified from the Digital Sky Survey.

Structural Model: We identified three main arc-like shell structures (purple, cyan, and green dashed circles) in the Herschel 250 μm image. The Herschel image shows consistent morphology with the N_2H^+ emission in the intersection of the shells, implying that the collision of the shells are possibly the cause of the observed filamentary structures in Serpens Main. The shells may be powered by nearby low- to intermediate-mass stars (centers of the dashed circles), which are observed to power similar shells in other regions such as Perseus (Arce et al. 2011).



← 1st moment of N_2H^+(1-0)



Kinematics in the SE Cluster

The morphology and velocity structures of the filament-shaped shells in the SE cluster are consistent with the large-scale model of three-shells collision presented above. Two main models are suggested based on the combination of the colliding shells.