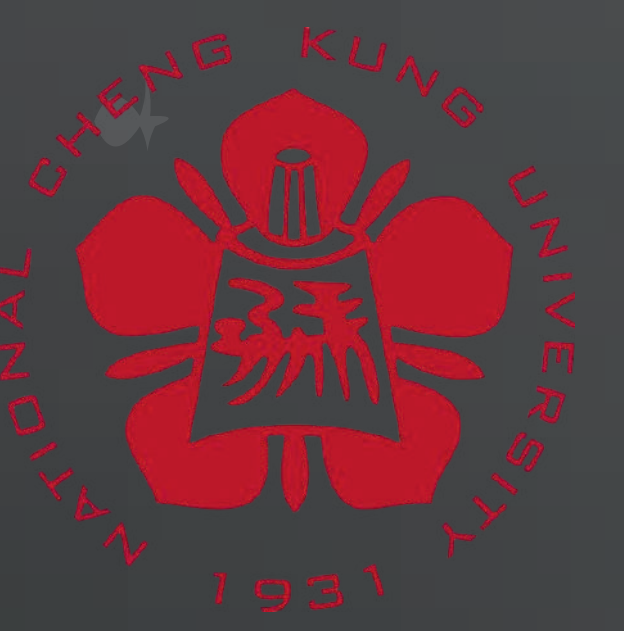


Mapping Molecular Clump Kinematics via Velocity and Intensity Gradients in Panta Rei



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Introduction & Motivation

Star formation is a core astrophysical process, yet what drives cloud collapse and fragmentation remains unclear. The exact contribution between gravity, turbulence, and magnetic fields has been hard to quantify due to small, heterogeneous sample sizes (<20 clumps).

Project Aims

This study aims to use velocity and intensity gradients to map gas kinematics across the Panta Rei sample. By analyzing these gradients from parsec-scale clumps down to sub-parsec cores, we aim to measure the relative roles of gravity, turbulence, and magnetic fields in driving cloud fragmentation and collapse.

Clump Data

To execute such study, I leverage the homogeneous data of 259 clumps provided by the **Panta Rei ALMA Large Program**. Using both the **7m+TP** and the **12m+7m+TP** combination images (shown in Figure 1), this project captures parsec-scale environments of clumps down to individual sub-parsec cores.

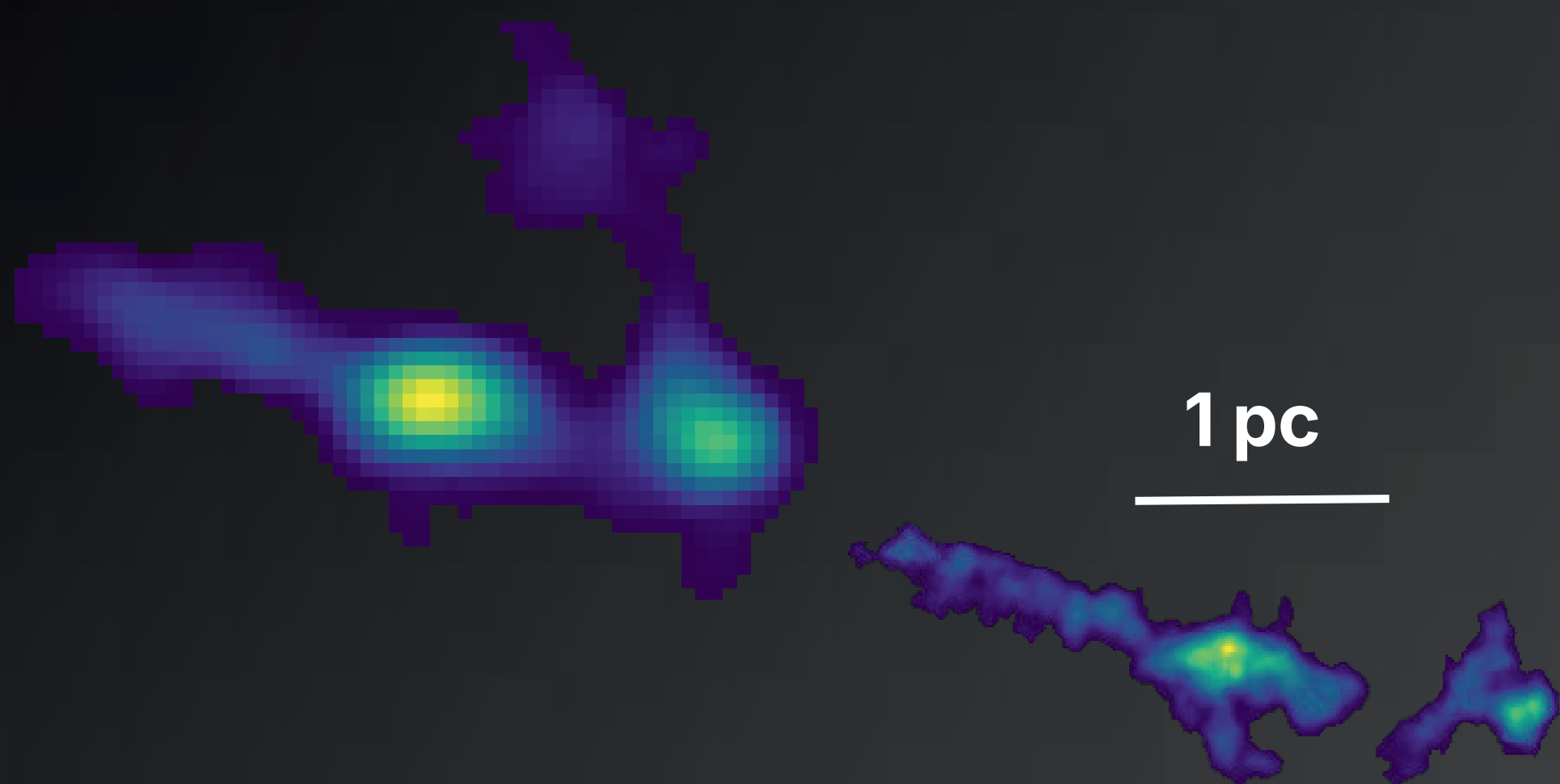


Figure 1: The same clump (AG309.9935-0.228) in the same molecular line (N_2H^+) captured by 7m+TP (Left) and 12m+7m+TP (Right) respectively which shows the two spatial scales accessible to Panta Rei.

Methodology

The velocity gradients (∇v) and intensity gradients (∇I) (shown in Figure 2) are measured via plane-fitting technique (Goodman et al., 1993) that fits a first-order polynomial plane within a localized window. The application of the plane-fitting technique requires a map of the velocity field made by using the moment-masking technique as part of the automated BTS code (Clarke et al., 2018, 2024) which returns a noise-robust moment-1 map, i.e. the intensity-weighted velocity field.

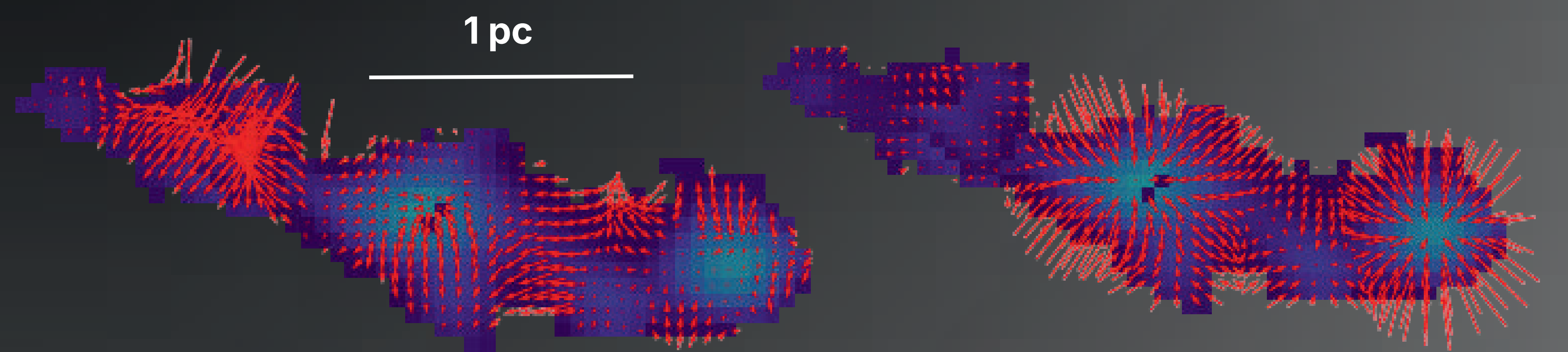
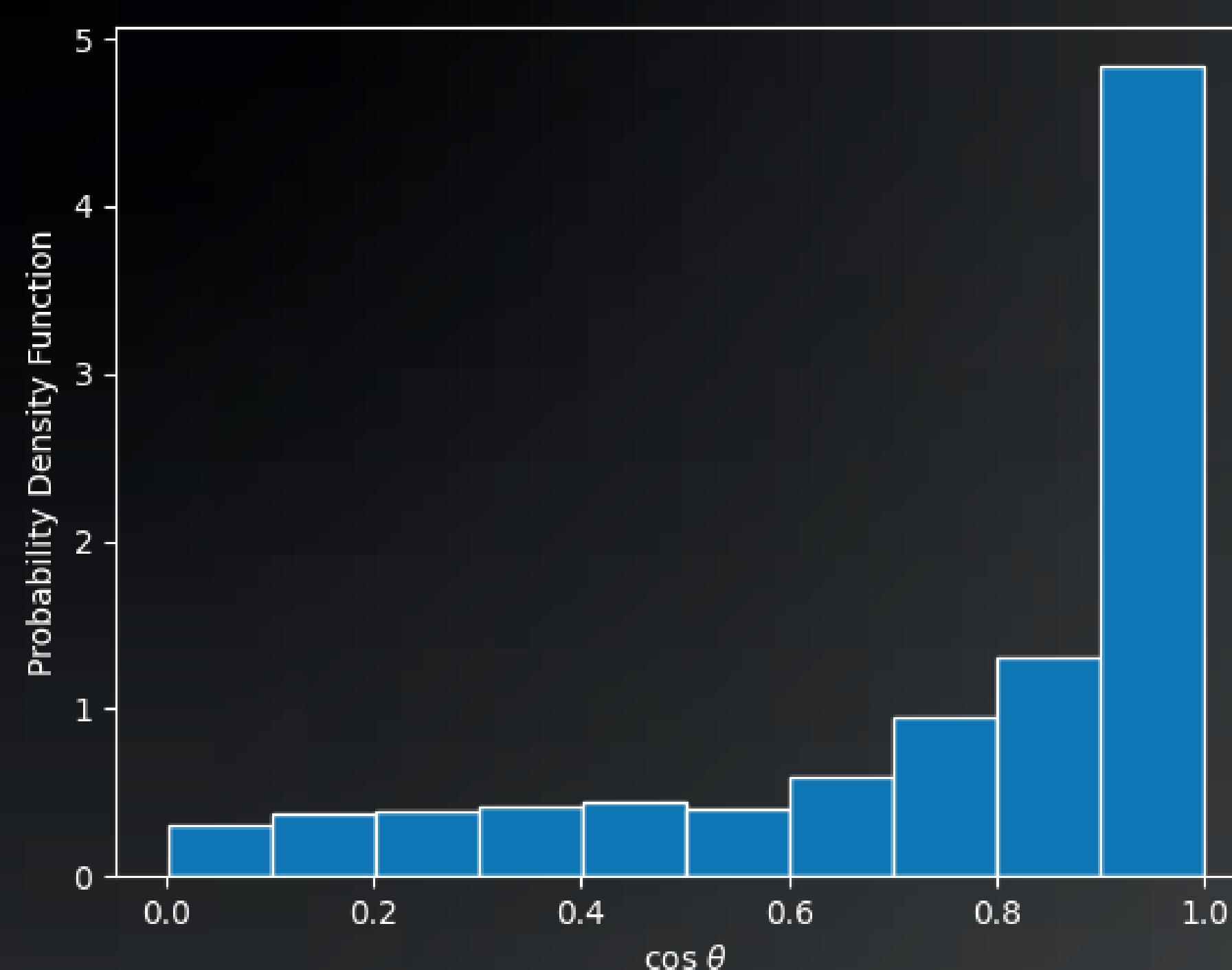


Figure 2: Maps showing the N_2H^+ (1-0) emission of clump AG309.9935-0.228 with the red arrows representing the (left) velocity gradient calculated from the velocity centroid map (right) intensity gradient calculated from the emission map.

Results



The probability density distribution of the angles between ∇v and ∇I ($\cos \theta$) for clump AG309.9935-0.228 shows a **strong peak near 1.0**, revealing a clear parallel alignment between the velocity gradients (∇v) and intensity gradients (∇I).

What does this physically mean?

The parallel alignment indicates that the gas flow is directly aligned with the local gravitational acceleration, which means **the observed velocity field is dominated by gravity**, while other forces like supersonic turbulence and magnetic field have minimal impact on gas motions at these scales.

Future Work & Expectations

1. Expand the gradient analysis technique across the whole Panta Rei sample.
2. Quantify the occurrence rate of the kinematic signature across the entire sample.
3. Relate kinematic behavior to clump properties, such as mass, volume density, and morphology.

References

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