Molecular Gas Kinematics in 30 Dor: Analyzing ALMA Data with SCOUSEPY and ACORNS

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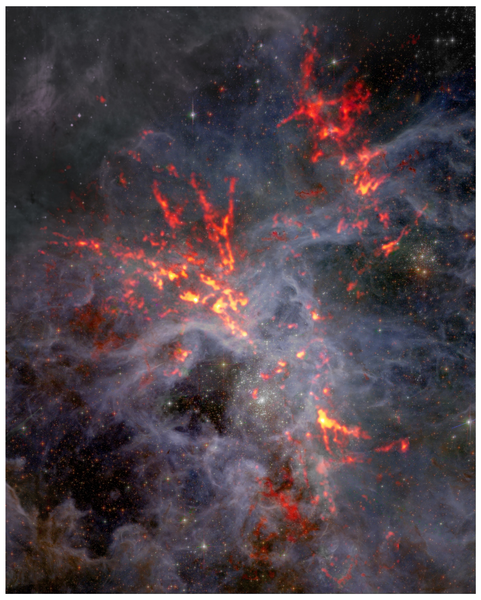
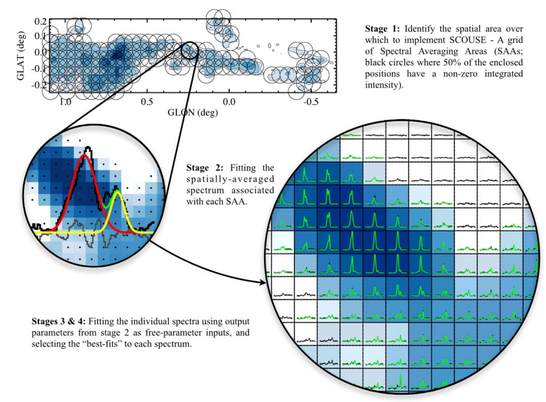
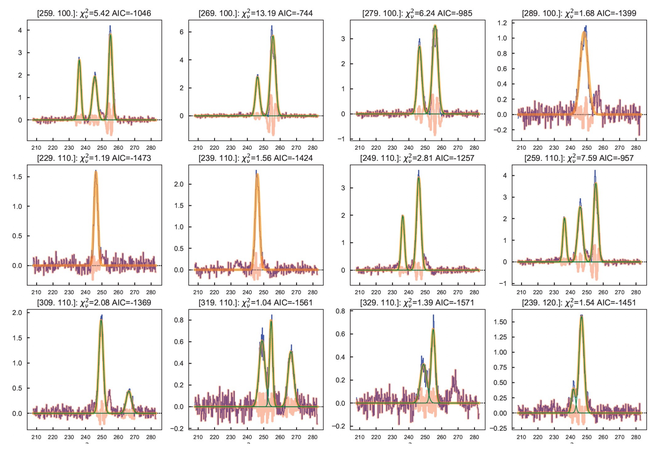
Introduction

30 Doradus (30 Dor), also known as the Tarantula Nebula within the Large Magellanic Cloud, is the most luminous HII region in the Local Group. It is distinguished by its high velocity dispersions observed in CO molecular gas, marking it as an exceptional site for studying star formation. We analyze the ALMA Cycle 7 12CO data using two innovative algorithms developed by Henshaw et al. 2019— SCOUSEPY, which applies a Gaussian fitting method to decompose spectral line data, and ACORNS which utilizes hierarchical agglomerative clustering, offering an alternative to ASTRODENDRO, which primarily focuses on intensity-weighted averages. Complementing these analyses, we have employed FilFinder to map out and assess the kinematics of filamentary structures. This poster outlines our application of these algorithms to the ALMA data to understand molecular gas kinematics.



ScousePy Fitting





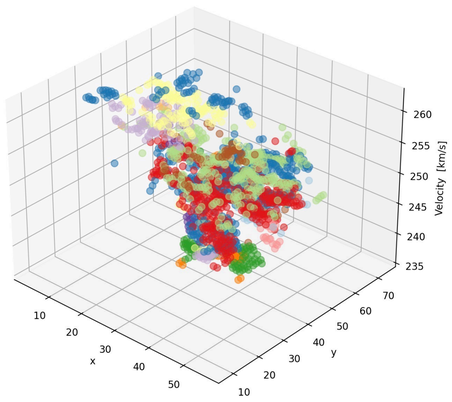
Four Stages of ScousePy Fitting:

1. Defining Coverage
2. Selecting Spectral Averaging Areas (SAAs)
3. Automated Fitting
4. Quality Control

We utilized ScousePy to decompose our data cube through two iterations, achieving a high fitting rate of 96%. The accompanying plot illustrates a sample of our spectral fitting results. Our analysis yields detailed information at each pixel, including the number of components, amplitude, shift, and width.

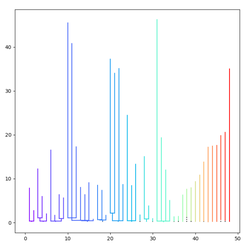
Acorns Clustering

Acorns utilizes hierarchical agglomerative clustering to build clusters using spatial and velocity data to preserve kinematic structures. We perform ACORNS decomposition on the best fit solutions from ScousePy. It begins by treating each data point as its own cluster and merges them based on specific criteria to form a comprehensive hierarchy visualized as a 3D diagram shown below.



Parameters set for clustering:

- **Pixel Size**: Matches the spatial resolution of our data.
- **Minimum Radius**: Set to 4, defining the smallest identifiable structure across 9 pixels.
- **Minimum Height**: Set to three times the mean of our data array's sixth row, ensuring clusters stand out significantly from the background.
- **Velocity Linkage**: Set at 0.14, corresponding to our data's velocity resolution, to link clusters based on their radial velocity.



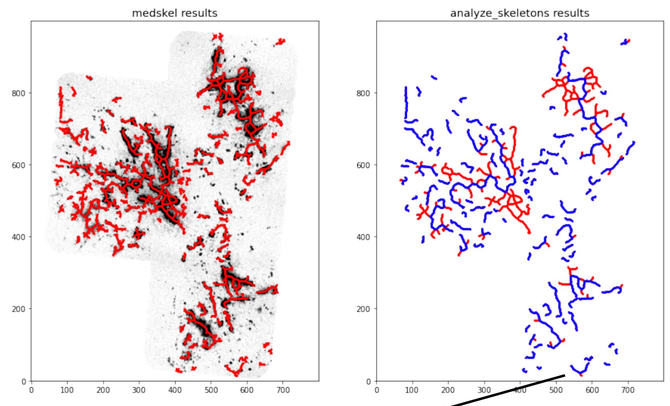
In the left tree diagram, each cluster is assigned a unique color, and the axes represent the clustering structure and the metric used for clustering.

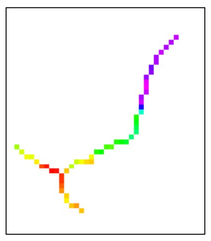
Filament Mapping

To analyze the filamentary structures in the 30 Dor cube, we implemented the following methodological steps using FilFinder:

1. **Image Flattening**: We first flattened the multidimensional image for the identification of structures.
2. **Filament Masking**: On the flattened image, we identified filamentary structures and created corresponding masks.
3. **Skeletonization**: We reduced the masks to single-pixel-width skeletons, which precisely delineate the paths and locations of the filaments.

Following skeletonization, we found 49 filaments in total. Then we assessed the ScousePy spectral line fits at these filament locations. Due to the potential for multiple components at a single pixel in the ScousePy fits, we selected the velocity of the component with the highest amplitude as the representative velocity for pixels with multiple components. We then decomposed our velocity fits to map individual filament velocities according to their skeletal paths.





These are the corresponding velocity fits from ScousePy of this particular filament with index 1. The color bar displays velocity variations along the filament, with purple indicating lower and red indicating higher velocities.

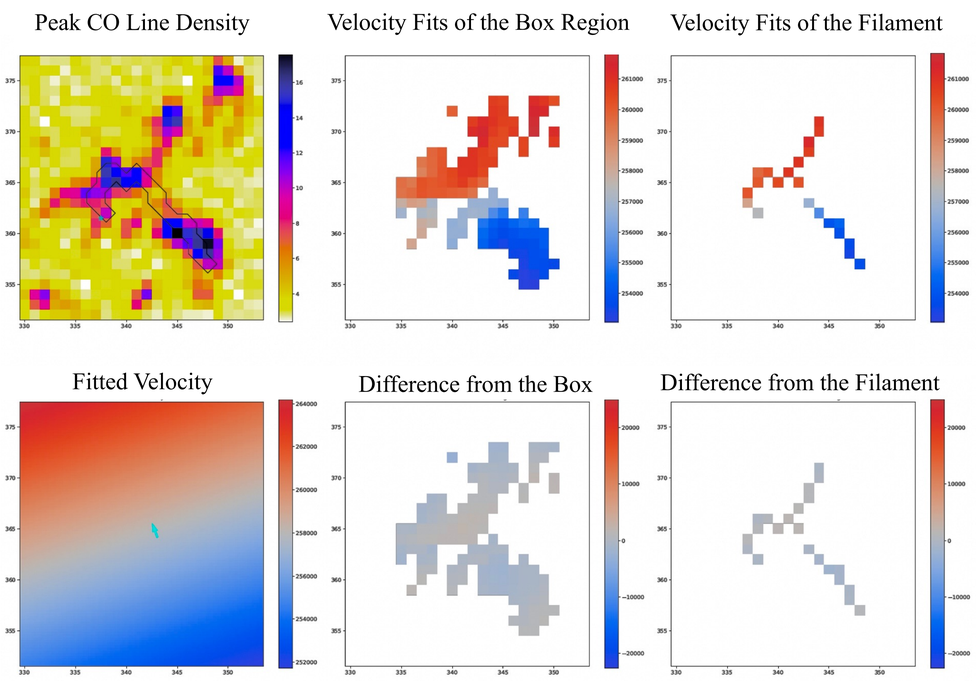
Filament Analysis

Our analysis employs ScousePy to delineate a box region around each filament, extracting velocity fits for detailed examination. We employ the Planar 2D model from Astropy to approximate these velocities, and transform them onto the x-y plane. The vector of maximum gradient directly indicates the steepest velocity increase.

An atlas has been assembled for all 49 filaments we identified, each represented by a set of six images:

•**Top Left**: Peak CO line intensity from the 30 Dor cube.
•**Top Middle**: Box region of ScousePy velocity fits encompassing the filament
•**Top Right**: Specific velocity fits of the individual filament.
•**Bottom Left**: Plane-fitted velocity field with the quiver indicating the direction and magnitude of the steepest velocity gradient.
•**Bottom Middle**: Residual velocities obtained by subtracting the actual fits from the planar model.
•**Bottom Right**: Residual velocities highlighting discrepancies between the actual filament velocities and the modeled values.

This approach provides a clear insight into the movement of filaments in 30 Doradus.



References

1. Colombo, D. et al. (2015). Graph-based interpretation of the molecular interstellar medium segmentation. *Monthly Notices of the Royal Astronomical Society*, *454*(2), 2067–2091. https://doi.org/10.1093/mnras/stv2063
2. Henshaw, J. D. et al. (2019). 'the brick' is not a *brick*: A comprehensive study of the structure and dynamics of the Central Molecular Zone Cloud G0.253+0.016. *Monthly Notices of the Royal Astronomical Society*, *485*(2), 2457–2485. https://doi.org/10.1093/mnras/stz471
3. Henshaw, J. D. et al. . (2016). Molecular gas kinematics within the central 250 PC of the milky way. *Monthly Notices of the Royal Astronomical Society*, *457*(3), 2675–2702. https://doi.org/10.1093/mnras/stw121

Acknowledgments

Eli Sofovich was responsible for the original FilFinder analysis and plotting code.