Molecular Gas Kinematics in 30 Dor: Analyzing ALMA Data with Scousepy and Acorns

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Why study 30 Doradus?

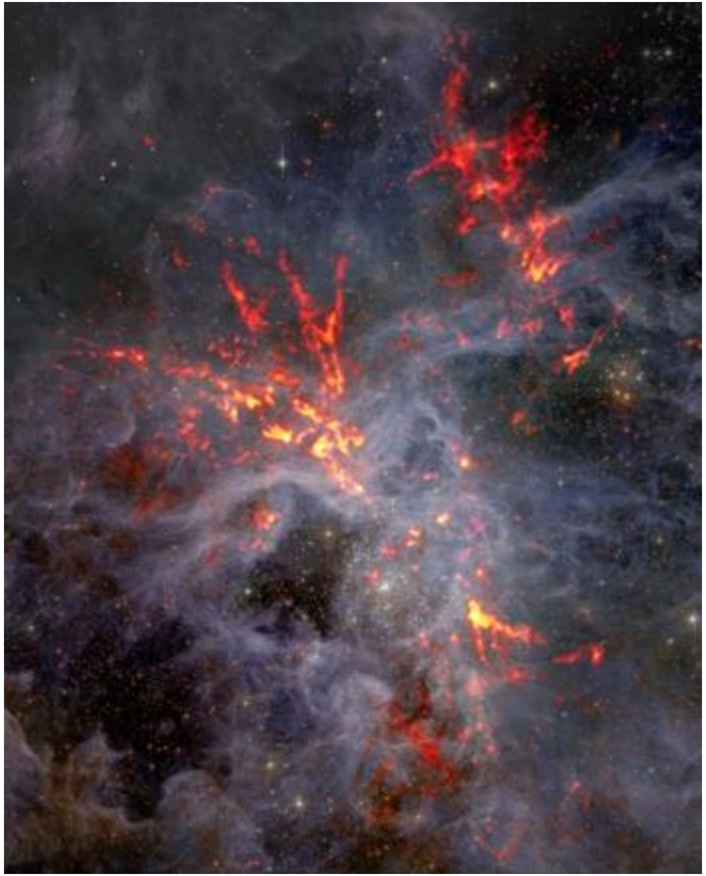
30 Doradus

Most luminous HII region in the Local Group, located within the Large Magellanic Cloud

Its high velocity dispersions in CO molecular gas make it an exceptional site for studying star formation processes.

Challenge

Understanding the complex kinematics of molecular gas in 30 Dor is challenging due to the intricacies of its filamentary structures and velocity variations.



How can we effectively analyze and map the kinematics of molecular gas in such a dynamic environment?

Using Scouse for spectral decomposition and Acorns for hierarchical clustering can provide detailed insights into the kinematic structures of molecular gas in 30 Dor.

What are our research objectives?

Objective of scouse :

- Gaussian fitting solutions for spectral line data

Objective of acorns :

- Hierarchical agglomerative clustering to build and visualize clusters based on spatial and velocity data

Objective of **FilFinder** :

- Extracting 2D filamentary structure in 30 Dor

How do we apply the algorithms?

ALMA Cycle 7 Data

FilFinder

(2D mapping of filamentary structures)

scouse

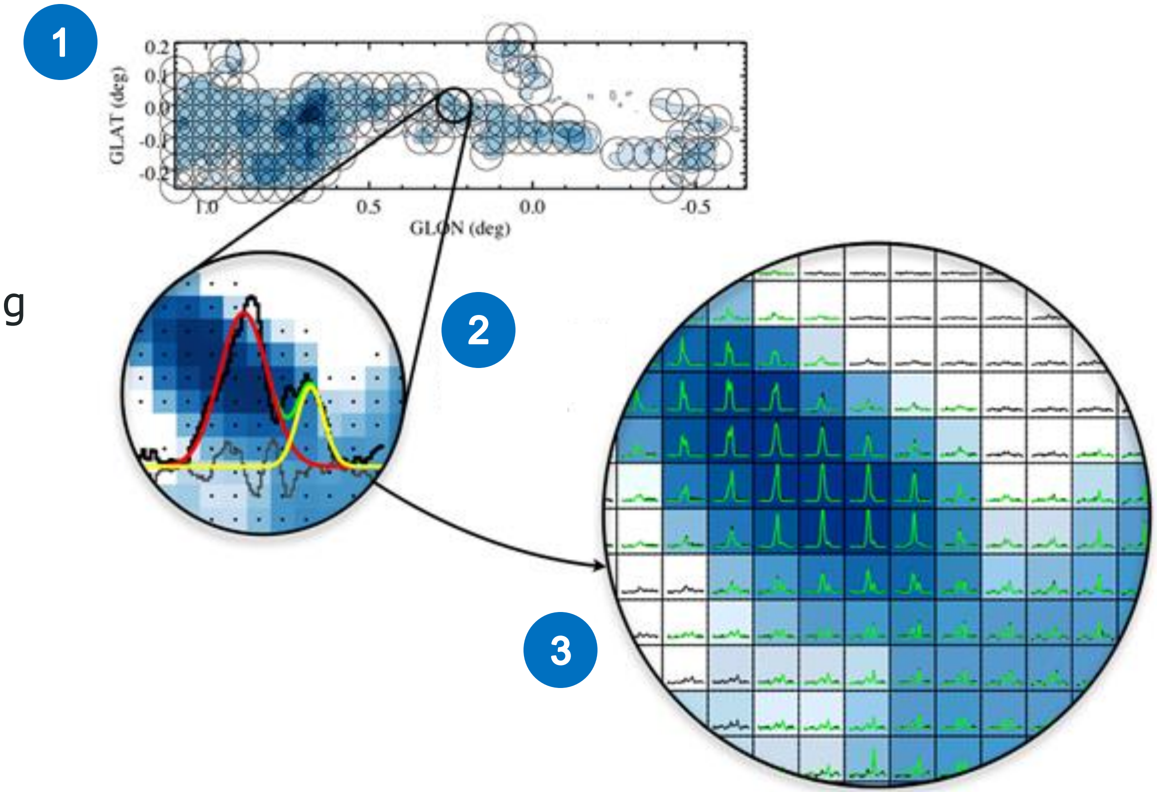
(Spectral decomposition)

acorns

(3D clustering of velocity fits)

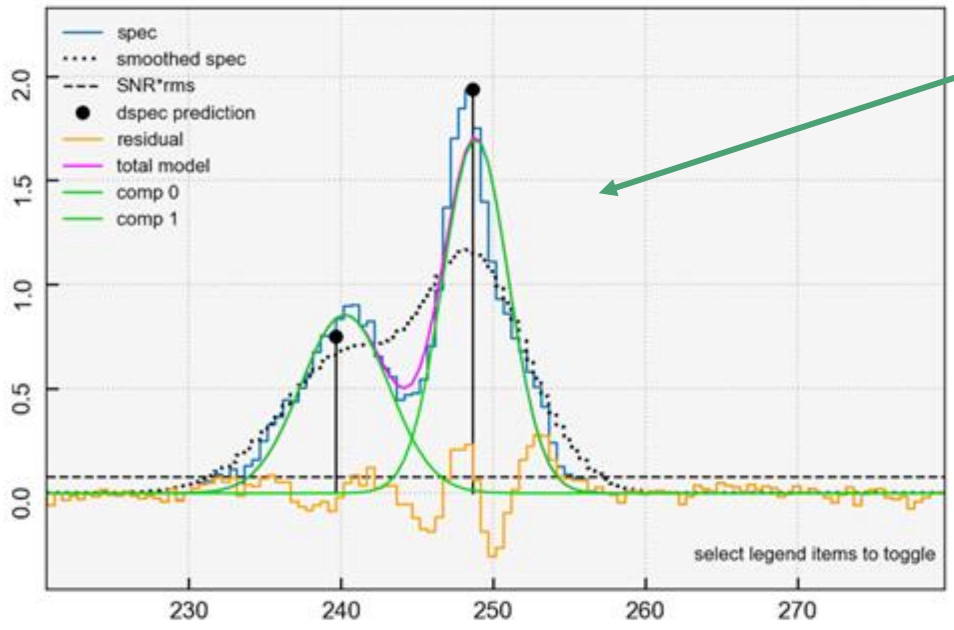
Scousepy operation consists of four stages

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



High-Accuracy Spectral Fitting with SCOUSEPY

Fitting rate : 96%



Each pixel of the cube is fitted with one or more Gaussian components. The example on the right shows spectral line data with two Gaussian components.

Output: a data file containing detailed Gaussian fitting parameters for each pixel

Steps of FilFinder Operations

1. Image Flattening:

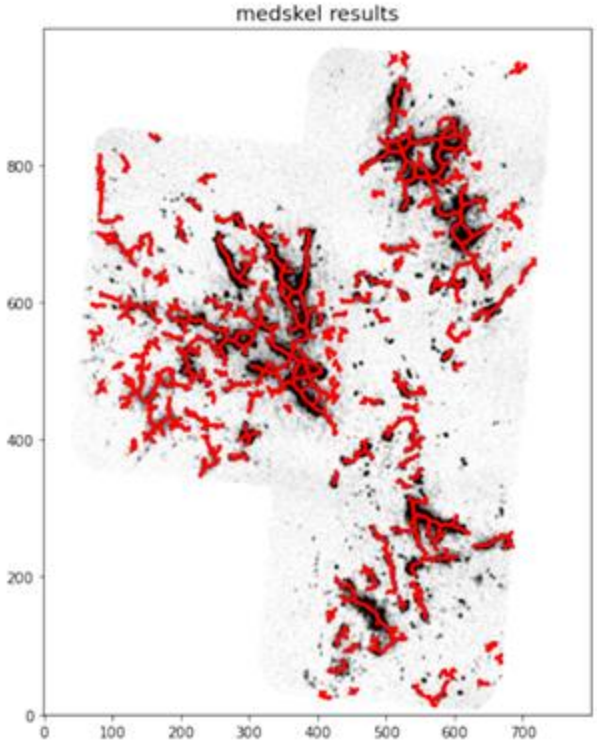
Flattened the multidimensional image to identify structures.

2. Filament Masking:

Identified filamentary structures and created corresponding masks on the flattened image

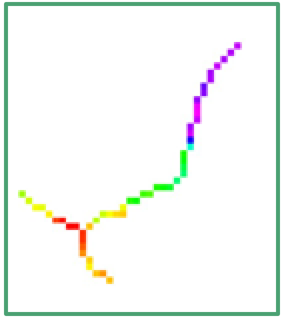
3. Skeletonization:

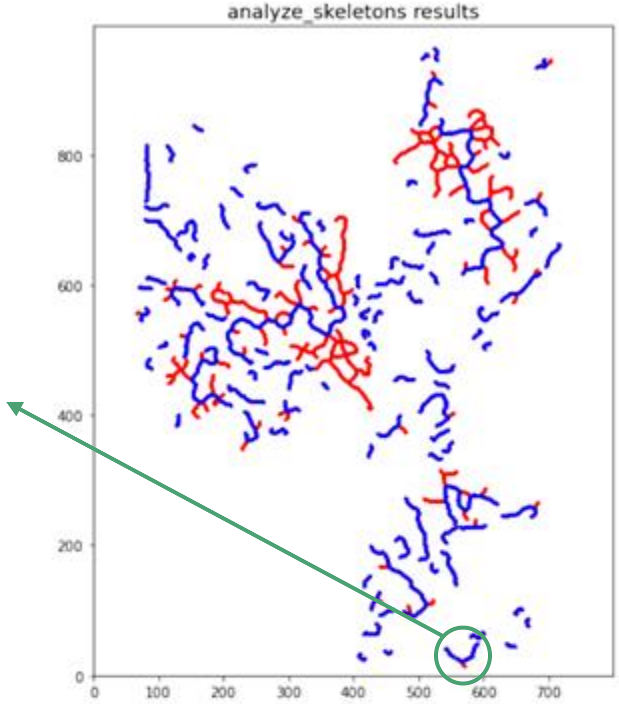
Reduced the masks to single-pixel-width skeletons



FilFinder: Mapping 2D Filamentary Structures from Scousepy Results

We decomposed our velocity fits from Scousepy to map individual filament velocities at these filament locations.



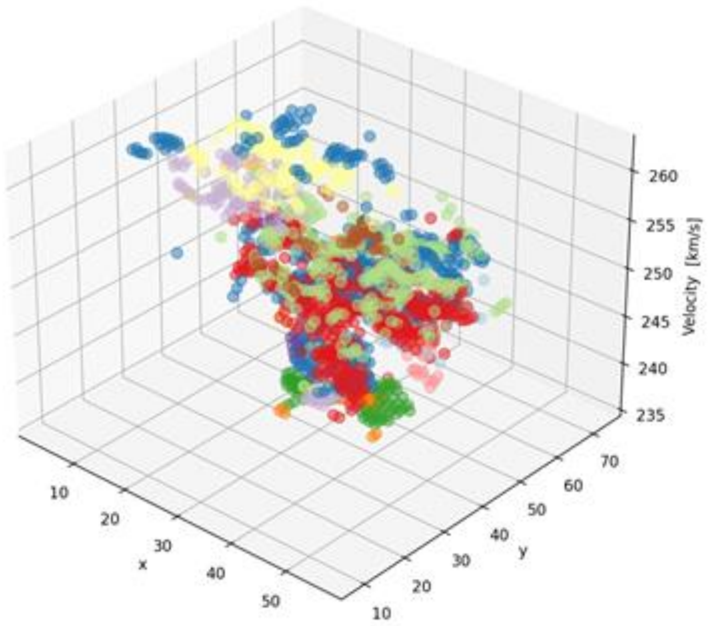


For pixels with multiple components, the velocity of the component with the highest amplitude was selected as the representative velocity.

Overview of ACORNS Clustering

ACORNS utilizes hierarchical agglomerative clustering to build clusters using spatial and velocity data to preserve kinematic structures.

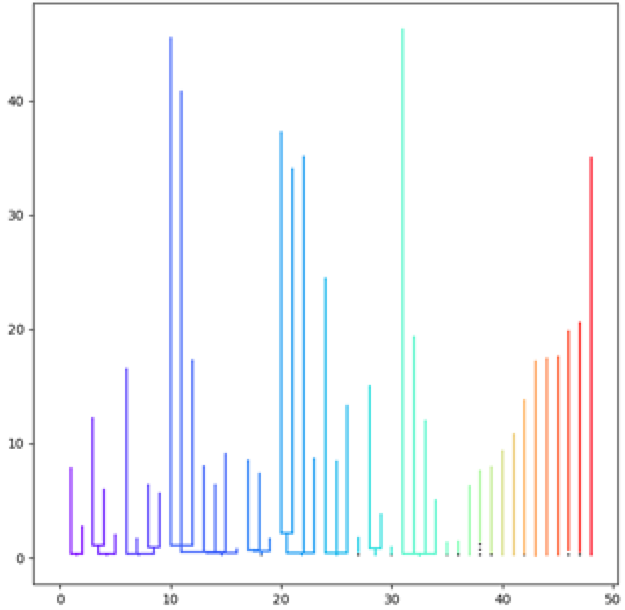
We perform ACORNS clustering on the best fit solutions from Scousepy. It begins by treating each data point as its own cluster and merges them based on specific criteria



ACORNS: Clustering Using SCOUSEPY Results

Output: Graphical dendrograms and data files of each cluster (hierarchical or non-hierarchical)

We found 15 hierarchical out of 45 clusters, and which contain 67% percentage of the data. We created FITS cubes where the pixel values are the cluster labels to investigate the clustering closely.



Compare Acorns clusters with SCIMES

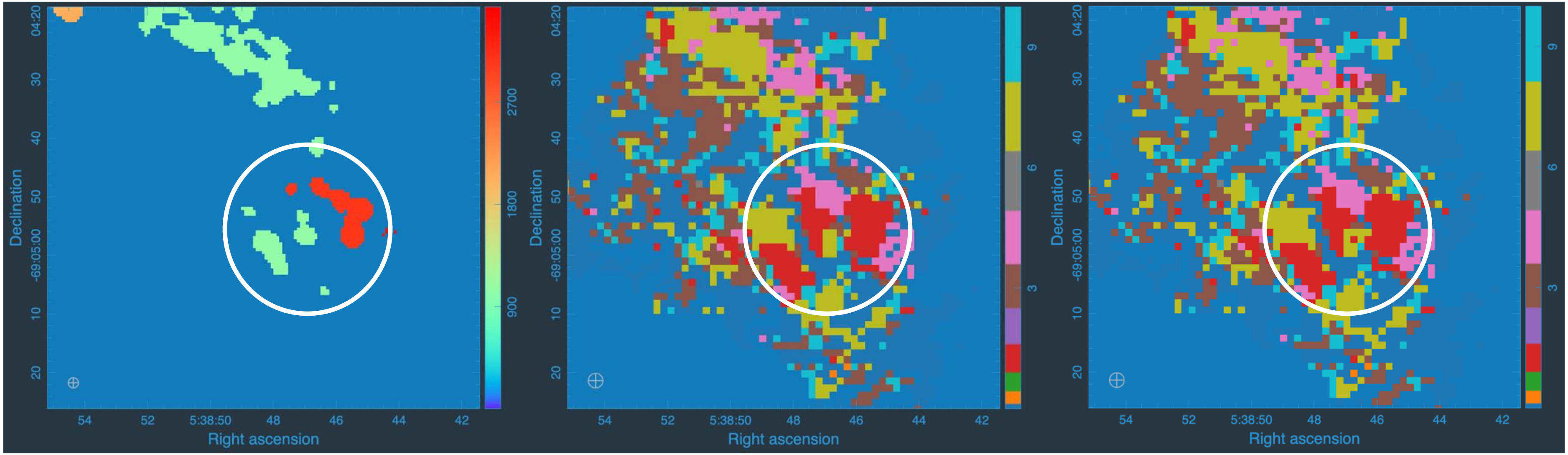


Fig 1. SCIMES Clusters

Fig 2. Acorns Cluster (Proximity Criteria)

Fig 3. Acorns Cluster (Amplitude Criteria)

Future work

We are currently in the process of running several iterations of ACORNS clustering on the entire cube using different clustering parameters. Our goal is to achieve a robust clustering that corresponds to the actual physical clusters in the cube. Once this is achieved, we will be able to visualize and quantify the gas kinematics structure of 30 Dor in detail.

Thank you!

References

1. Henshaw, J. D., Ginsburg, A., Haworth, T. J., Longmore, S. N., Kruijssen, J. M., Mills, E. A., Sokolov, V., Walker, D. L., Barnes, A. T., Contreras, Y., Bally, J., Battersby, C., Beuther, H., Butterfield, N., Dale, J. E., Henning, T., Jackson, J. M., Kauffmann, J., Pillai, T., … Zhang, Q. (2019). ‘the brick’ is not abrick: 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