Observational Verification of Hierarchical Evolution Models in Galactic Molecular Clouds

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High-mass star formation plays a crucial role in galaxy evolution, yet its detailed physical mechanisms remain under debate. Recently, the "global hierarchical collapse" model, which proposes the global contraction of molecular clouds accompanied by the formation of internal high-density structures, has been proposed[1]. However, observational evidence supporting this scenario is still limited. This study aims to systematically clarify the relationship between hierarchical structures and star formation activity in Galactic molecular clouds to verify this model.

We utilize ^{13}CO (J=1-0) emission line data from the FUGIN project obtained with the Nobeyama 45-m Radio Telescope[2]. The analysis targeted 12 active star-forming regions. We applied astrodendro[3] to the 3-D data cubes to extract hierarchical structures (classified as leaves nested within branches and trunks) and compared them with star formation activities traced by Spitzer mid-infrared images and WISE-based HII region catalogs.

Our results indicate that hierarchical structures exhibit higher volume densities and lower virial parameters compared to isolated structures, suggesting they are more strongly gravitationally bound. Position-velocity diagrams reveal that large-scale trunks encompass multiple velocity components, implying that internal structures with different velocities are confined and interacting within the large-scale cloud. Furthermore, while the probability of containing HII regions is similar between hierarchical and isolated structures, hierarchical leaves contain a significantly larger number of HII regions (up to 8) compared to isolated structures (maximum of ~3) for similar effective radii. These findings support the hierarchical evolution model, where the contraction of large-scale clouds confines internal structures, preventing gas dissipation due to feedback and sustaining collective star formation.

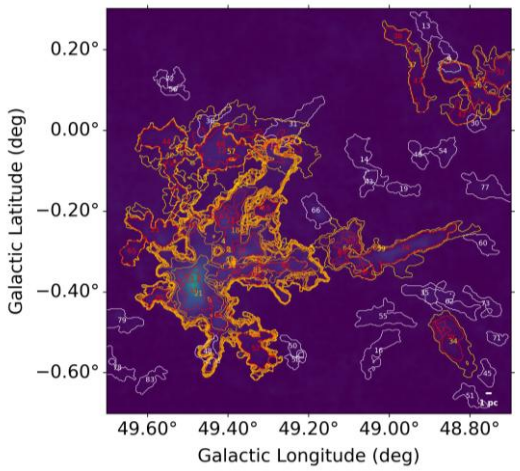

Figure 1. Extracted structures in the W51A region.

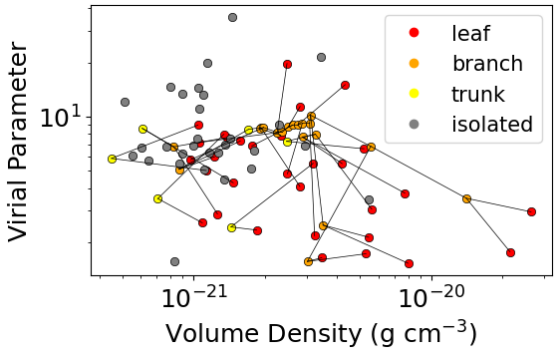

Figure 2. Density–virial parameter plot for structures in the W51A. Hierarchical structures provide better environments for star formation due to their higher densities and lower virial parameters.

References

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