Assessing Hierarchical Cloud-Cloud Collisions Using Dendrogram Analysis

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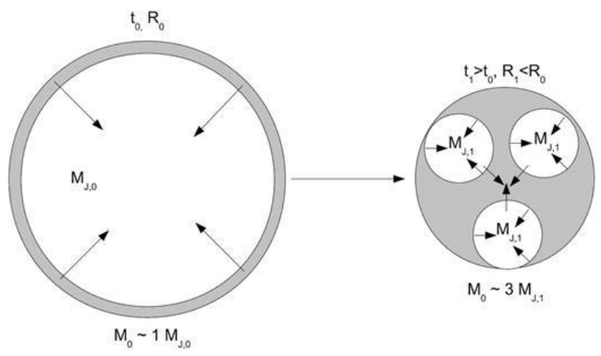
1. INTRODUCTION

Context

High-mass stars have been observed to form exclusively as clusters within giant molecular clouds (GMCs), but **the process by which star clusters emerge from GMCs is not yet fully understood.**

Previous research has suggested that **hierarchical gravitational collapse is a likely scenario[1] (Fig 1)**:

1. Giant molecular clouds contract globally
2. High-density regions form hierarchically within them
3. Internal structures frequently collide with each other



(Fig 1) Schematic diagram of hierarchical CCC[1]

→ This could explain the observational phenomena specific to high-mass star formation, such as the formation of massive stars only in giant molecular clouds and molecular cloud collisions.

Aims

Analyze molecular emission line data to clarify whether and how hierarchical cloud cloud collisions (CCCs) occur.

2. METHOD

Data

The position-position-radial velocity data of 17 star-forming regions obtained from FUGIN[2] were analyzed.

Analysis Method

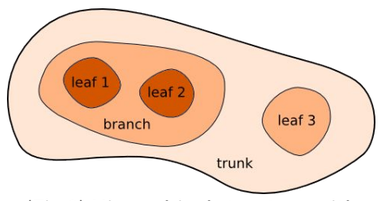
Dendrogram[3] is used for analysis.

・Minimal structure without internal structure: leaf

・Structure containing internal structure: branch

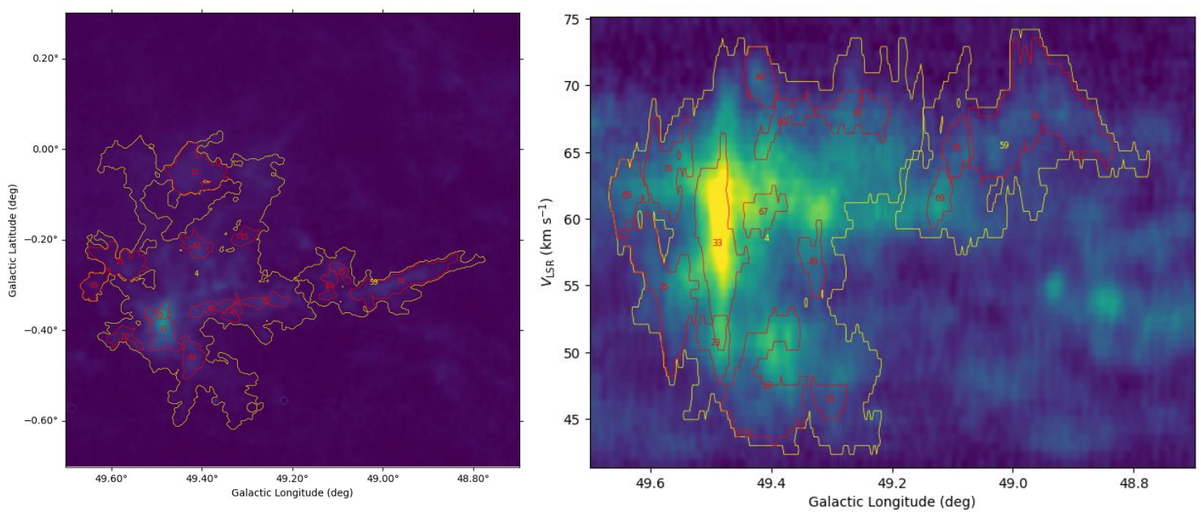
・Outermost structure: trunk

Find and discuss the size, mass, etc. of the structure.

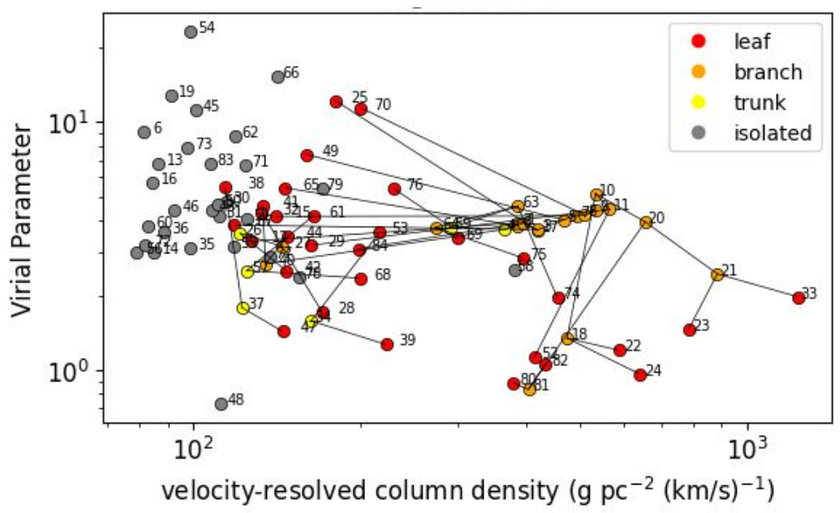


(Fig 2) Hierarchical structure with dendrograms[4]

3. RESULT



(Fig 3) Part of the hierarchical structure identified in the star-forming region W51



(Fig 4) Graph of density vs virial parameters for all structures of W51

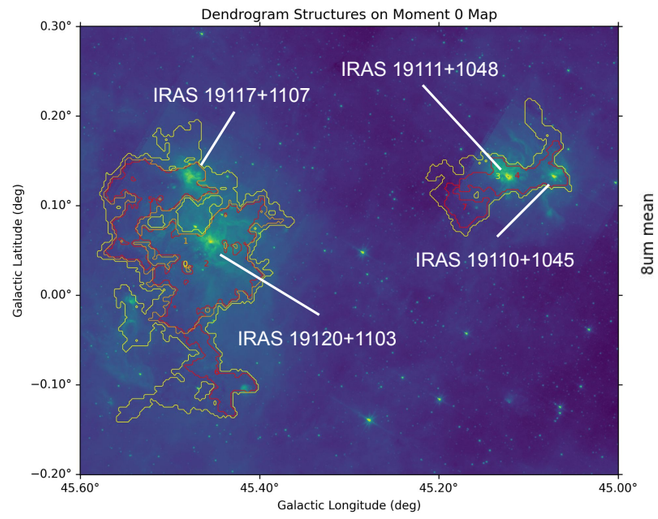
Hierarchical structure was observed in all star-forming regions (Fig 3 left).

The PV diagram shows that **there are leaves on top of multiple velocity structures, and branches and trunks exist across the velocity range, covering them (Fig 3 right).**

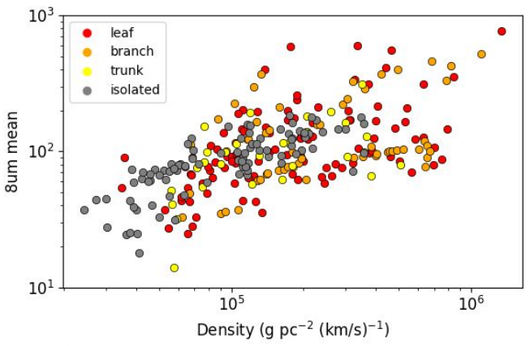
The hierarchical structure has higher density and smaller virial parameters, i.e., it has a strong tendency to gravitationally contraction (Fig 4).

4. DISCUSSION

Compare with Spitzer/8μm



(Fig 5) Comparison of the structure of the star-forming region G45 with Spitzer/8μm

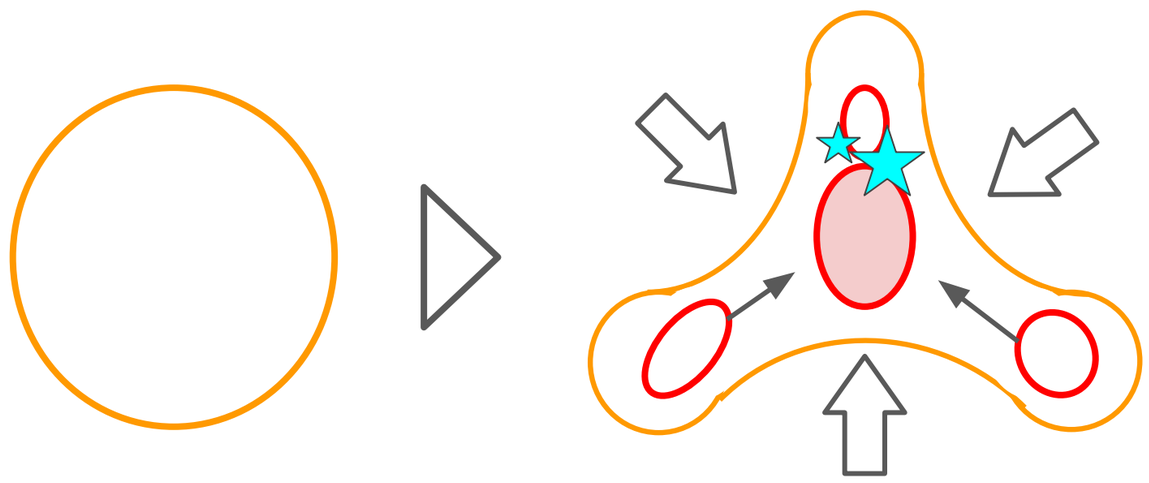


(Fig 6) Graph of density vs. 8μm intensity for all structures of all regions

The region with high density of gas and bright 8μm, that is, the region with active star formation overlaps (Fig 5).

The hierarchical structure is more dense and has a higher intensity of 8 μm, meaning that star formation activity is more active (Fig 6).

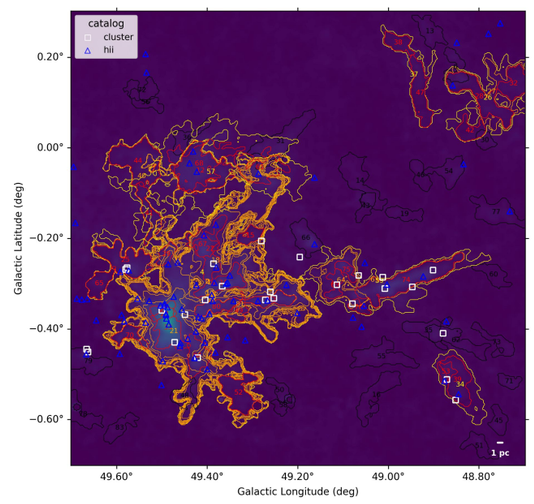
Possible Hierarchical CCC Scenarios



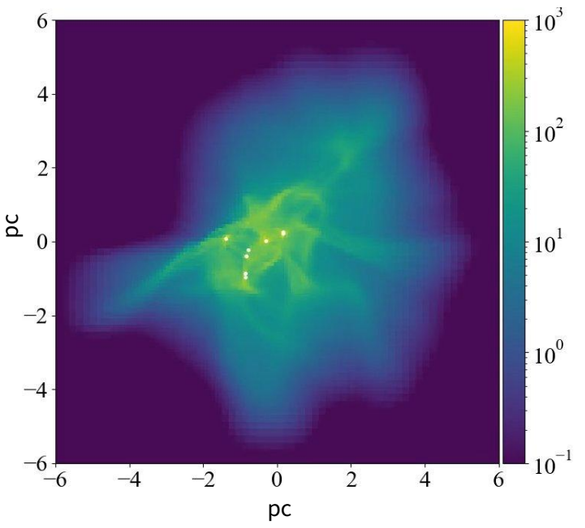
(Fig 7) Conceptual diagram of a possible hierarchical CCC

It is possible that **the hierarchical gravitational contraction of a uniform molecular cloud results in the creation of a high-density internal structure, and that the accretion of a low-density internal structure onto this structure leads to collision and merging, leading to the formation of a large mass.**

5. FUTURE WORK



(Fig 8) Comparison of HII regions and clusters with the structure in W51



(Fig 9) Density map of a fluid sphere simulation

We will test the above scenario by the following approaches:

1. Comparing the distributions of H II regions and clusters to investigate the progress of star formation within molecular clouds (Fig 8).
2. We perform fluid simulations assuming GMC on the Miyabi supercomputer using the GPU-enabled SFUMATO[5] (Fig 9).

REFERENCES

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[5] Matsumoto T., 2007, PASJ, 59, 905