STAR FORMATION AND FRAGMENTATION IN DENSE CORE IN ORION A

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Introduction

Observations have found that more than half of stars are in binary or multiple systems, which are caused by collapse and fragmentation of dense cores. However, the fragmentation process in dense cores is not well understood observationally. In this project, we measure the physical condition in dense cores in Orion A to find the condition of fragmentation.

Magnetic Field in Molecular Cloud

The magnetic field in molecular cloud is theoretically expected to play an important role in the process of fragmentation. The magnetic field can provide additional support against gravitational collapse and delay or suppress fragmentation in dense cores.

We use Davis-Chandrasekhar-Fermi (DCF) method to estimate the magnetic field strength in these dense cores.

$$B_{\perp} = A\sqrt{4\pi\rho}\,\frac{\Delta v}{\Delta \phi_B}$$

$$P_B = \frac{1}{8}\pi B^2_{total}$$

Jeans Instability in Dense cores

The Jeans instability can cause the collapse and fragmentation of a dense core. In a dense core, if its gravity is larger than pressure, it would tend to collapse. The Jeans length and Jeans Mass are the critical radius and mass of a cloud, and dense cores with sizes and masses larger than these critical scales would bu unstable.

$$\lambda_J \approx \left(\frac{kT}{G\rho m}\right)^{1/2} \qquad M_J = \frac{\pi}{6}\frac{c_s^3}{G^{\frac{3}{2}}\rho^{\frac{1}{2}}}$$

Data & Analysis

To investigate the relation between fragmentation and properties of dense cores, we make use the JCMT 850-um data, JCMT POL-2 data, GBT NH_3. We first identify the dense cores with protostars from the JCMT 850-um continue map of Orion A and find 39 dense cores with single protostar and 19 dense cores with binary or multiple systems.

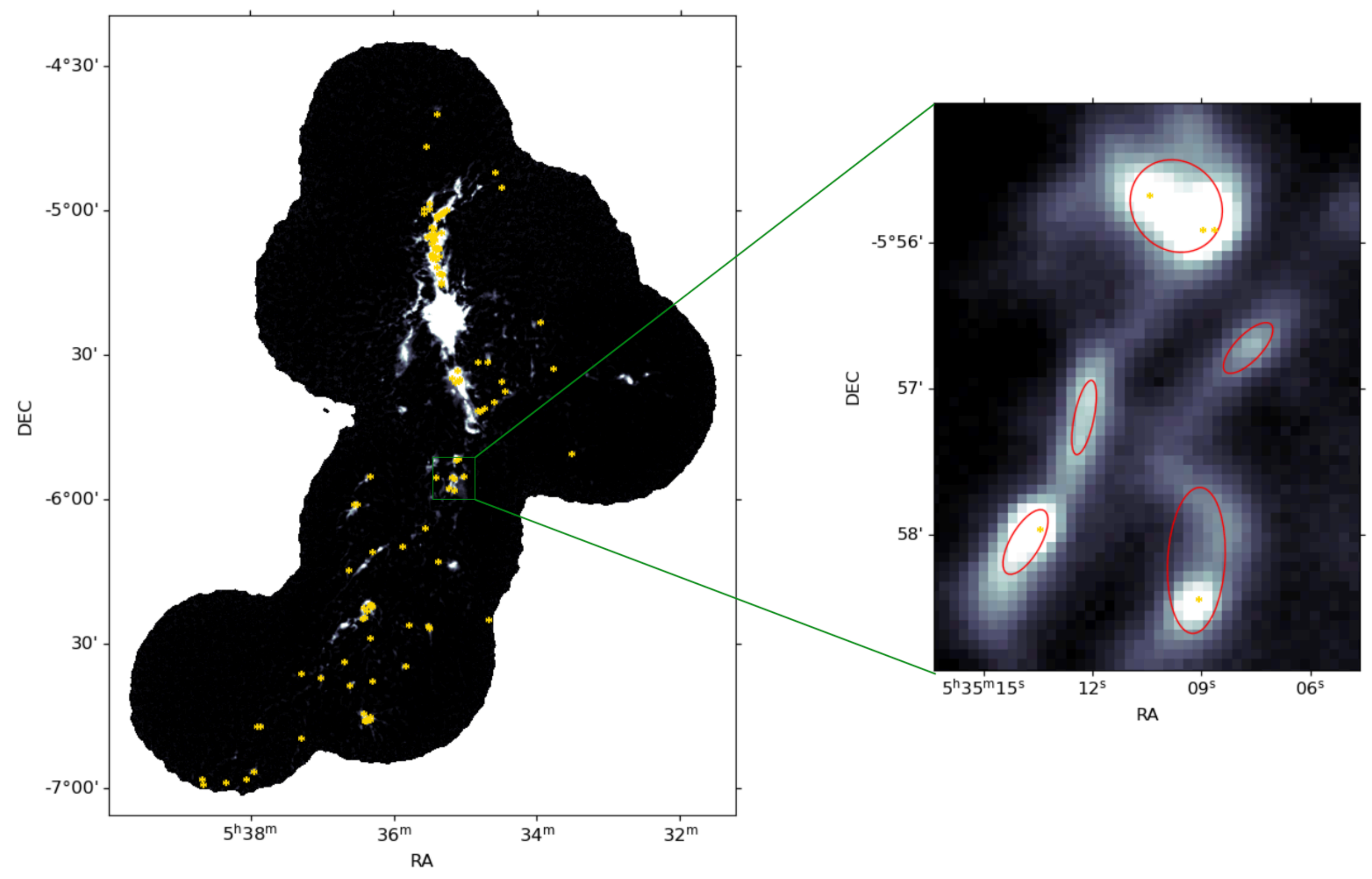

Figure 1: (a) Orion A and positions of protostars
(b) Dense cores with single and multiple system

We apply the Davis-Chandrasekhar-Fermi (DCF) method to estimate the magnetic field strength in these dense cores using the JCMT POL-2 data together with the velocity and temperature from the GBT NH_3 data.

Result

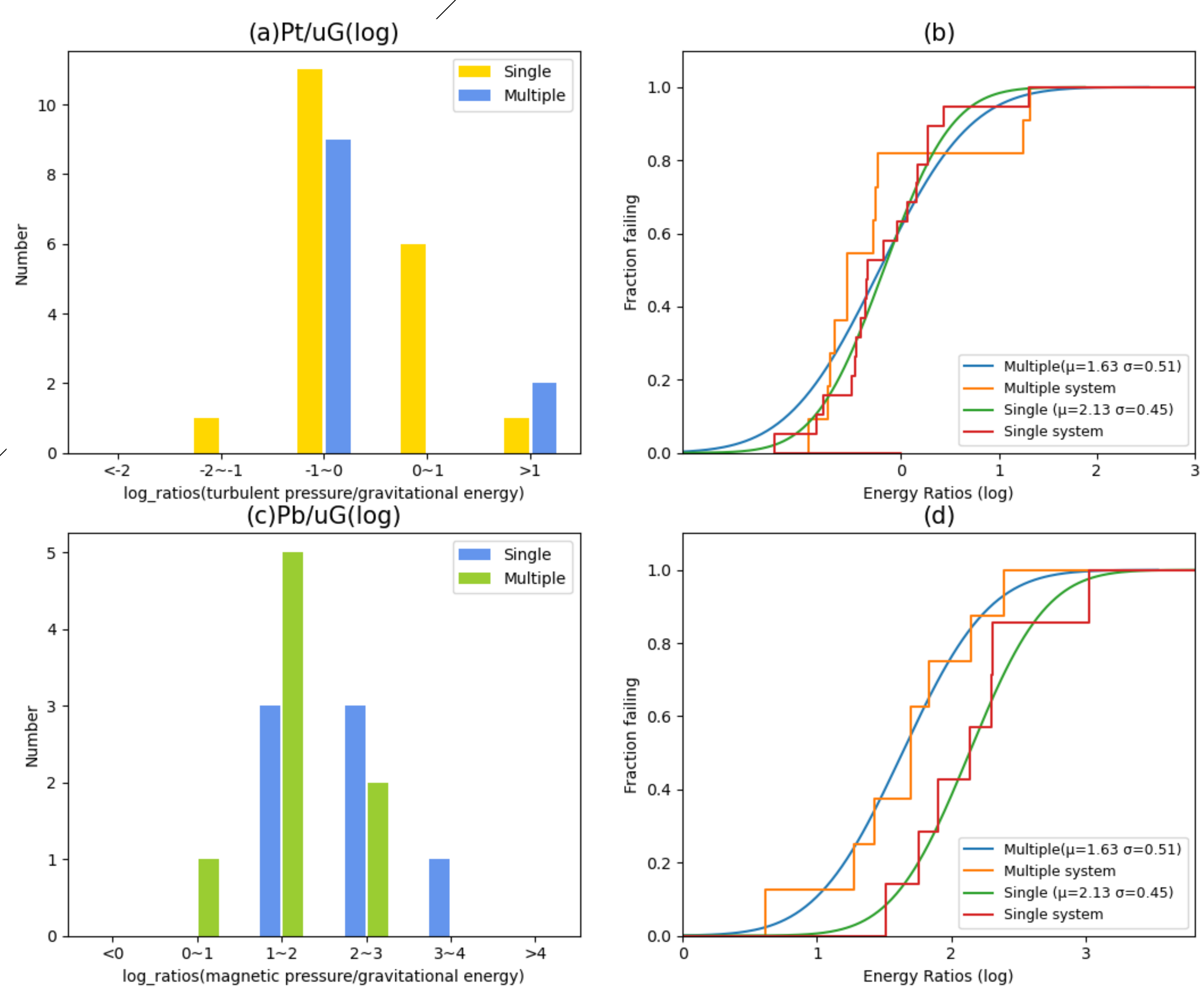

Figure 2: (a) Energy ratio between turbulence pressure and gravitational energy density. The x-axis is the energy ratio. The y-axis is the number of dense cores. (b) The K-S test suggests a D-value of 0.39 and a p-value of 0.16 between two groups. (c) Energy ratio between magnetic pressure and gravitational energy. (d) The K-S test suggests a D-value of 0.5 and a p-value of 0.28 between two groups.

By comparing the energy ratio of the dense cores with single and multiple systems, we find that for the dense cores with larger magnetic field ratios are hard to fragment. The result shows that the magnetic field can suppress the fragmentation of dense cores as theoretical expected.

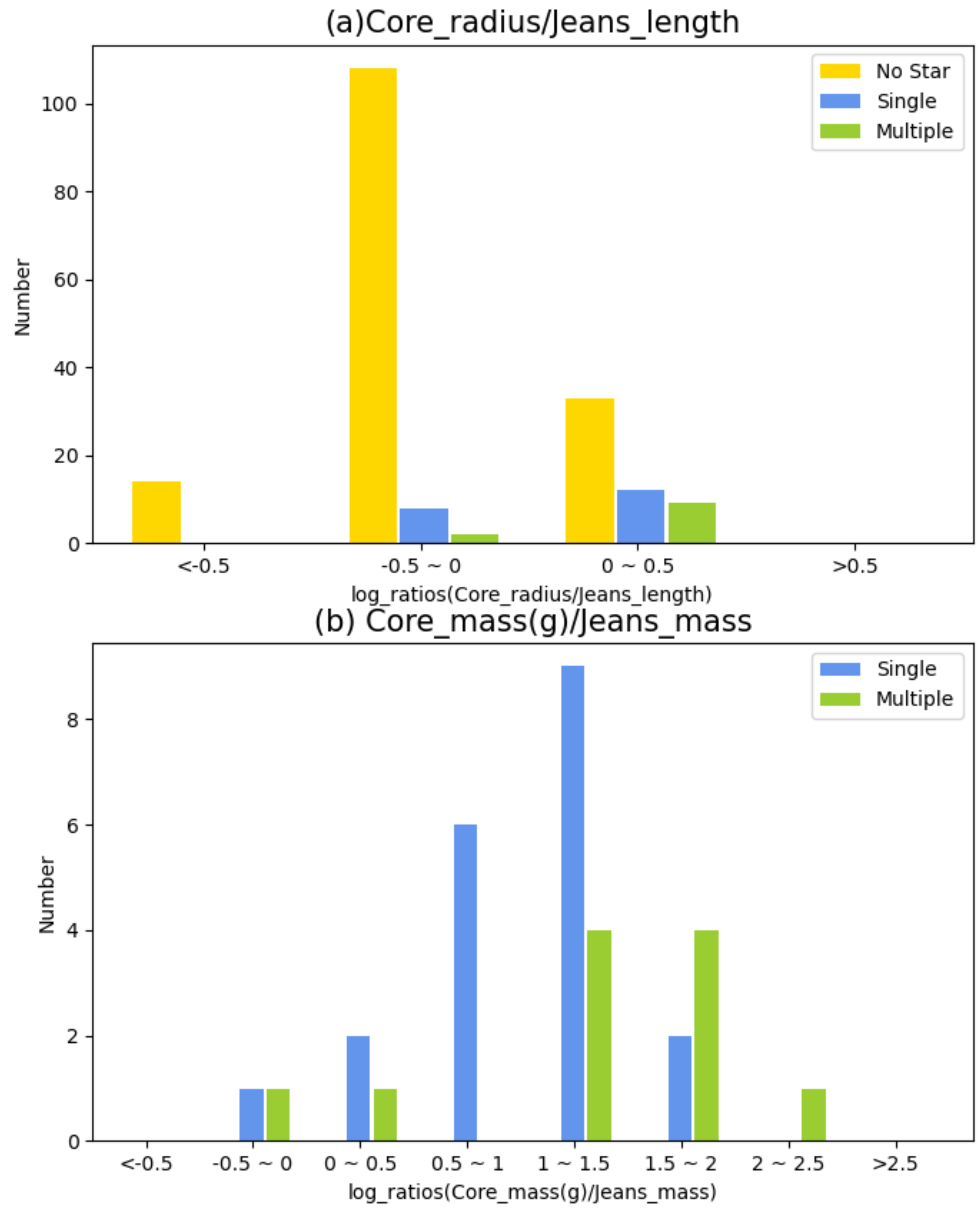

Figure 3: (a) Ratio of core radius and Jeans length of dense cores with single and multiple systems. (b) Ratio of core mass and Jeans mass.

From Figure 1, the core with mass larger than its Jeans mass tends to fragment. For dense cores with a larger ratio of core mass and Jeans mass, they are more unstable.

Next, we will try to consider the turbulence pressure and magnetic pressure in the Jeans instability.

Summary

1. By comparing the energy ratio between magnetic pressure and gravitational energy density of dense cores with single and multiple systems (Figure 1), our results suggest that the magnetic field possibly delay or suppress the fragmentation in dense cores.

2. From the analysis of the Jeans instability, we learn that with the larger ratios of the Jeans length to core radius, the dense cores tend to fragment (Figure 2). For dense cores with core mass twice larger than its Jeans mass, they also tend to fragment.

Reference

Davis 1951, Chandrasekhar & Fermi 1953, McKee & Ostriker 2007, Machida et al. 2008, Tang 2019, Tobin 2022