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ORIGINAL ARTICLE

# The early phase of multiple proto-stellar system emerging from collapse of molecular cloud under various initial thermal states

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**Abstract** An attempt is made here to revisit structure formation in a proto-stellar cloud during the early phase of evolution. A molecular cloud subject to a set of various initial conditions in terms of initial temperature and amplitude of azimuthal density perturbation is investigated numerically. Special emphasis is on the analysis of ring- and spiral-type instabilities that have shown dependence on certain initial conditions chosen for a rotating solar mass cloud of molecular hydrogen. Generally, a star-forming hydrogen gas is considered to be initially at 10 K. We have found that a possible oscillation around this typical value can affect the fate of a collapsing cloud in terms of its evolving structural properties leading to proto-star formation. We explored the initial temperature range of the cloud between 8 K to 12 K and compared the physical properties of each within the first phase of proto-star formation. We suggest that the spiral structures are more likely to form in strongly perturbed molecular cores that initiate their phase of collapse from temperatures below 10 K, whereas cores with initial temperatures above 10 K develop, instead of a spiral structure, a ring-type structure which subsequently experiences fragmentation. A transition from a spiral to ring instability can be observed at a typical initial temperature of 10 K.

**Keywords** Interstellar medium · Smoothed particle hydrodynamics · Stellar dynamics · Binaries · Low-mass brown dwarfs

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## 1 Introduction

Molecular clouds host the formation of a variety of proto-stars, among which low-mass proto-stellar systems have always remained as a class that requires special attention. This is mainly due to their unavailability for any astronomical observation as these systems during their initial phases of evolution hardly radiate and they grow inside a thick envelop of gas and dust that keep their secrets. However, for the last two decades, these star-forming regions have been analyzed in some detail through indirect indicators such as CO and $NH_3$ emission line observations (Maddalena et al. 1986; Bally et al. 1987). The CO emission line from dark clouds in the Orion (Bally et al. 1987) and Taurus (Ungerechts and Thaddeus 1987) have given indications of filamentary and clumpy structures in the interstellar gas clouds. Similarly, elongated shapes resembling prolate ellipsoids are found in most of the molecular cloud cores (Myers et al. 1991). This has revealed the structure along with other fundamental properties of these dark regions of the interstellar medium.