Statistical analysis of turbulence and fragmentation within stellar nurseries

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Overview

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Introduction

Star formation has challenged theorists for many years due to the complex physical processes that are involved.

These include:

- **fragmentation**
- turbulence
- non-ideal and ideal magnetohydrodynamics (MHD)
- radiative transfer
- dust physics
- tidal torquing
- accretion disk processes

Introduction

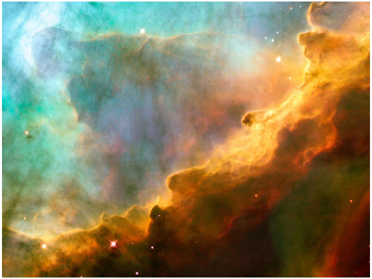
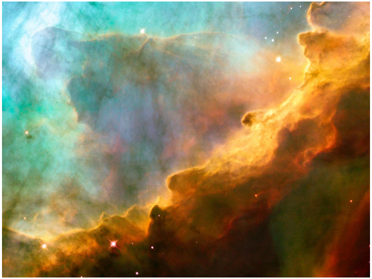


Figure: This is known as M17, the Omega Nebula, some 5,500 light-years away.The green glow corresponds to hydrogen, with trace sulfur and oxygen atoms contributing red and blue. The picture spans about 3 light-years.

1

[1]Image credit: NASA, ESA, J. Hester (ASU)

Introduction



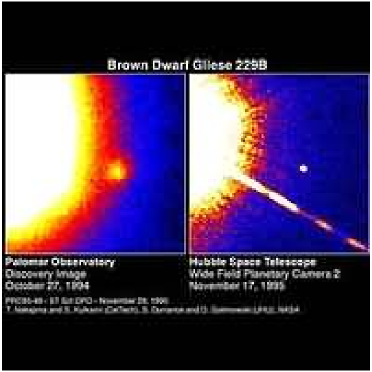
Typical GMC Properties:

- $10^3 - 10^7$ $M_\odot$
- 15 - 600 light-years in diameter
- $10^4 - 10^6$ particles/cm^3
- T $\approx$ 10 - 50 K

Motivation

Nebulae also contain brown dwarfs, or failed stars.

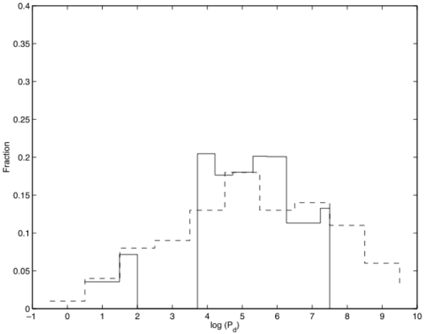
Image credit[2]



[2] Left: T. Nakajima (Caltech), S. Durrance (JHU), Right: S. Kulkarni (Caltech), D.Golimowski (JHU) and NASA

Motivation
Why are we interested?

- It has been shown that turbulence produces a low number of companion stars orbiting within 5 AU of its host star, otherwise known as the *brown dwarf desert*. [3,4]



[3] Shaping the Brown Dwarf Desert: Predicting the Primordial Brown Dwarf Binary Distributions from Turbulent Fragmentation - Peter H. Jumper and Robert T. Fisher

[4] Fisher, R. T. 2004, ApJ, 600, 769

Motivation

Why are we interested?

- Gravitational instability could be "a mechanism for creating disk born companions" [5]

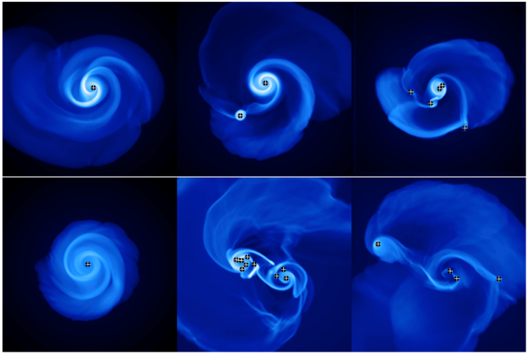


Figure 1. Two examples of single, binary, and multiple systems. The resolution across each panel is 328 × 328 grid cells. The single runs are $\xi = 2.9, \Gamma = 0.018$ (top), $\xi = 1.6, \Gamma = 0.009$ (bottom). The binaries are $\xi = 4.2, \Gamma = 0.014$ (top), $\xi = 23.4, \Gamma = 0.008$, (bottom). The multiples are $\xi = 3.0, \Gamma = 0.016$ (top), $\xi = 2.4, \Gamma = 0.01$ (bottom). Black circles with plus signs indicate the locations of sink particles. These correspond to runs 5, 1, 9, 16, 7, and 4, respectively.

[5] On the Role of Disks in the Formation of Stellar Systems: A Numerical Parameter Study of Rapid Accretion - Kratter, Kaitlin M. and Matzner, Christopher D. and Krumholz, Mark R. and Klein, Richard I.

Goals

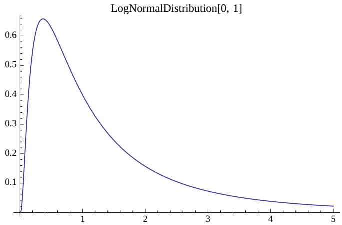
- To understand the fundamental processes of **stellar formation**
- To script program to reproduce the observed values from their statistical distributions
- To refine the original program to account for disk fragmentation

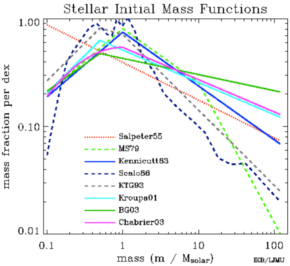
Assumptions

- Core mass and density are independent of each other
- Core is a Bonner-Ebert sphere
- Isolated core fragmentation and disk fragmentation

Methodology

1. Draw edge densities and core masses from two empirical distributions. [6]





[6] http://www.astro.ljmu.ac.uk/ ikb/research/imf-use-in-cosmology.html

Methodology

2. Determine if the mass satisfies the Jeans criterion for collapse to stellar or brown dwarf formation.

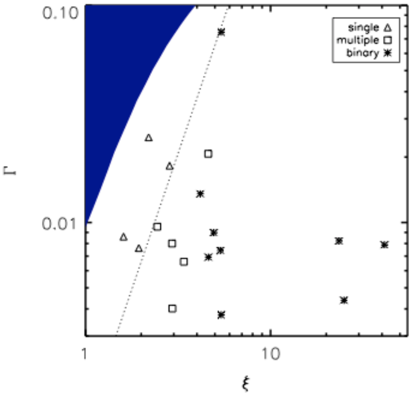
$$M_J = \left(\frac{5kT}{Gm}\right)^{3/2} \left(\frac{3}{4\pi\rho}\right)^{1/2} \quad (1)$$

- If $M_{cloud} > M_J$ the cloud will collapse.
- ρ is the density
- G is the gravitational constant
- m is the mean molecular weight
- T is temperature

Methodology

3. Calculate the GMC core angular momentum induced by turbulence

4. Introduce dimensionless parameters to quantify when disk fragmentation will occur



Progress

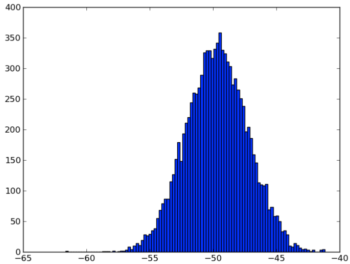
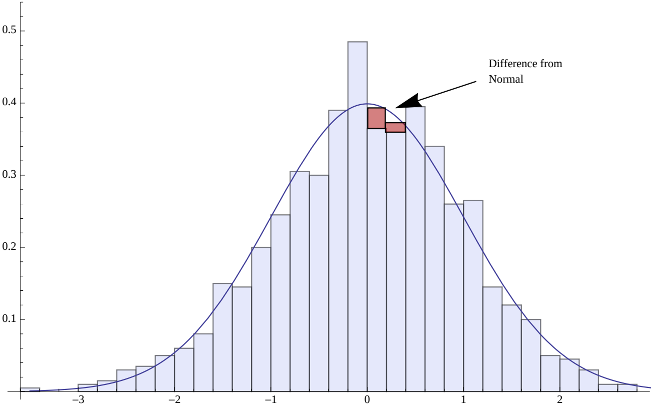


Figure: Here is the distribution of edge pressures for 10,000 GMCs.

Progress

Kolmogorov-Smirnov Test: non-parametric statistical test



Progress

Checked in Mathematica and Python

```
KolmogorovSmirnovTest[newdata2, NormalDistribution[Mean[newdata2], StandardDeviation[newdata2]]]
0.995713
```

```
In [12]: kstest(testing, 'norm')
Out[12]: (0.0039155981334491885, 0.99795030693352127)
```

Future Work

- Use the edge pressure and GMC core in a turbulent flow.
- Impose parameters to simulate disk fragmentation.

Questions

Questions?

Special thanks to Dr. Robert Fisher and our research group for guidance and discussions during this research.