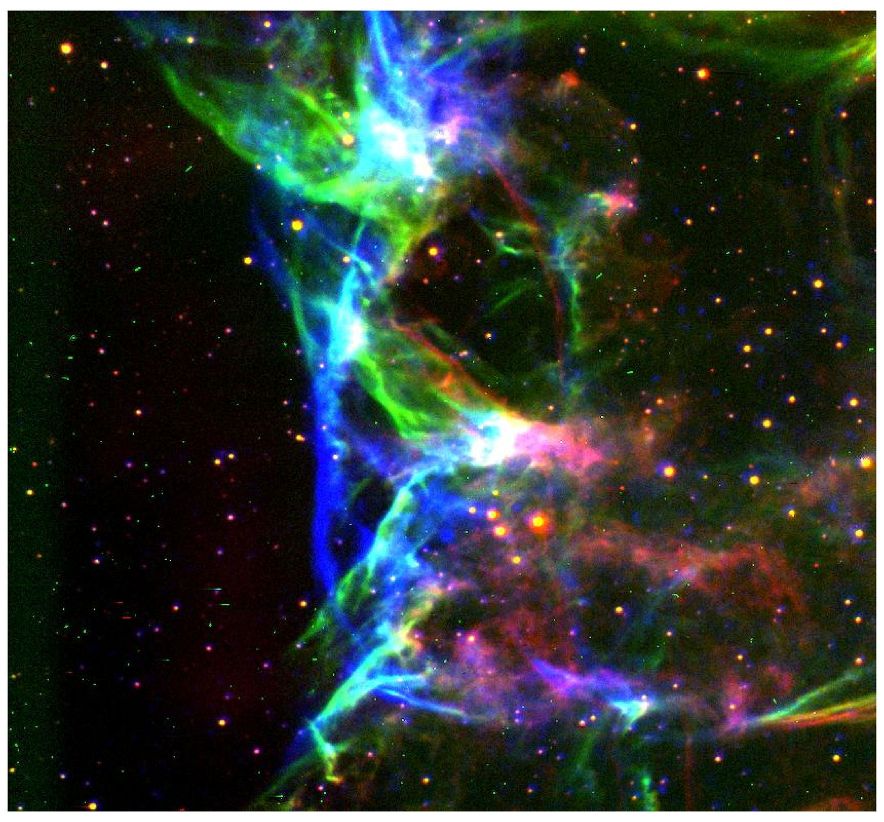
Simulating Shock Triggered Star Formation with AstroBEAR2.0

Shule Li[†], Adam Frank and Eric Blackman. Department of Physics and Astronomy, University of Rochester, Rochester NY. [†]shuleli@pas.rochester.edu

UNIVERSITY of ROCHESTER

Introduction

Star formation can be triggered by the compression from shocks running over stable clouds. Triggered star formation is a favored explanation for the traces of SLRIś in our solar system. We use AstroBEAR2.0 code to simulate the collapse and subsequent evolution of a stable Bonnor-Ebert cloud by an incoming shock. Through our simulations, we show that interesting physics happens when the newly formed star interacts with the cloud residue and the post-shock flow. We identify these interactions as controlled by the initial conditions of the triggering and study the flow pattern as well as the evolution of important physics quantities such as accretion rate and angular momentum. We also demonstrate that when rotation is added to the initial cloud, the triggered star formation leads to disks.

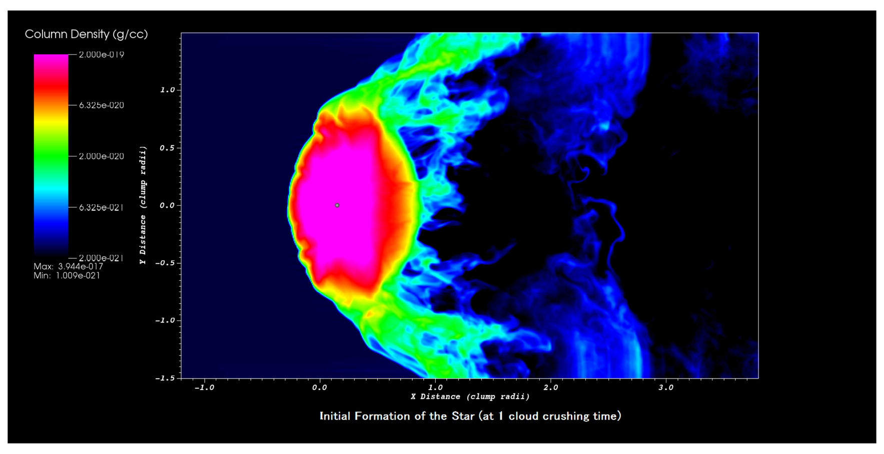


We explore:

- Star formation and subsequent behavior from shocking a cloud with an otherwise stable stable Bonnor-Ebert profile.
- Influence of the initial cloud rotation as well as disk formation.
- Important physics quantities such as mass of the star and mixing ratio of wind material onto the star.

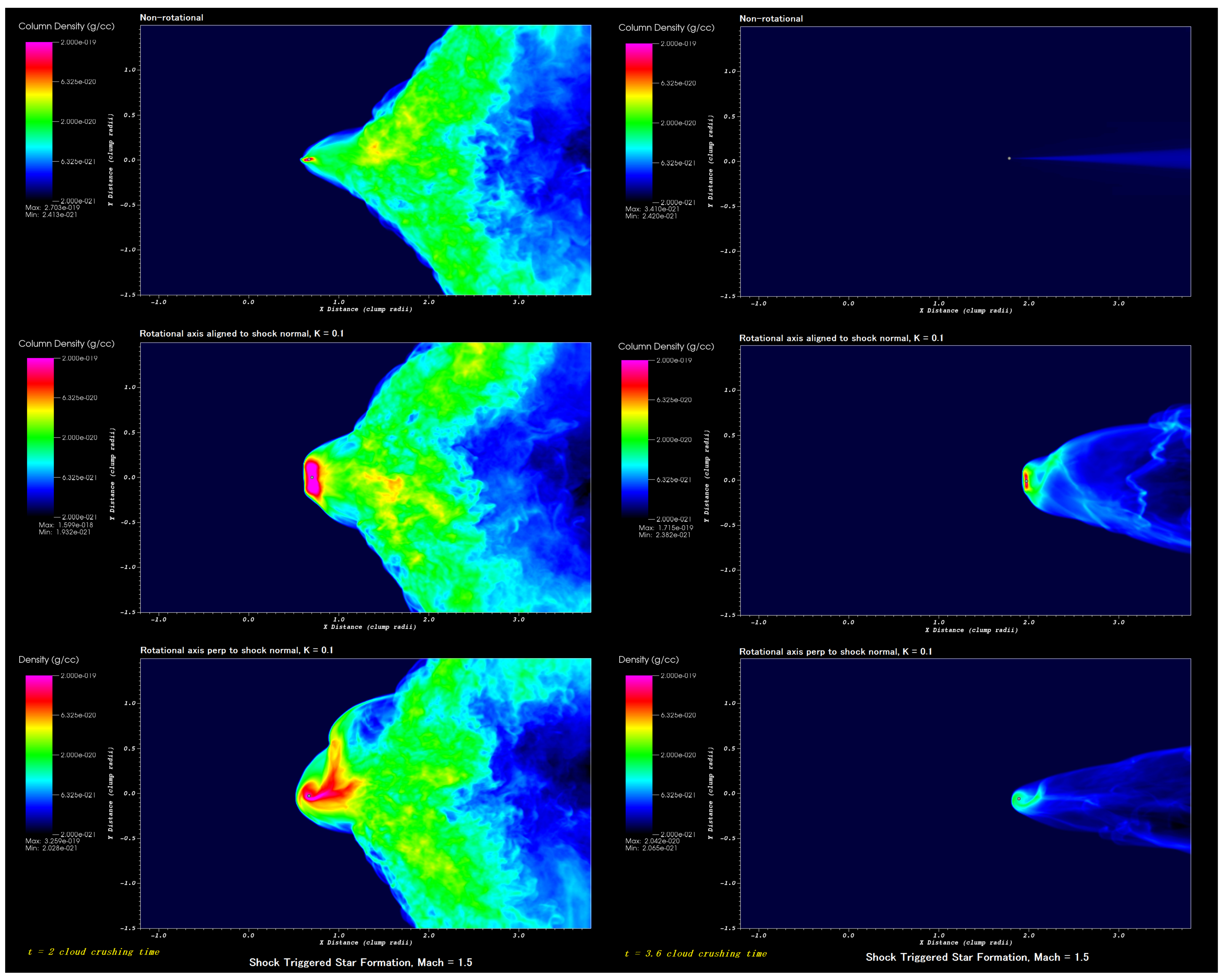
Initial Formation of the Star

$t \leq t_{cc}$ is the time frame when the transmitted shock is traversing through the cloud. This period can be identified as the cloud compression phase. With self-gravity, the compressed cloud can hold together due to gravitational pull of the compressed core and reach a point where Jean's criterion is violated. As material continuously fall onto the compressed core, a star will eventually form and pull in even more material.



For all the cases presented in our study, almost all cases forms a star at the center of the cloud around $t \approx t_{cc}$. Depending on the rotational property of the initial cloud, the post-star-forming evolution can be drastically different.

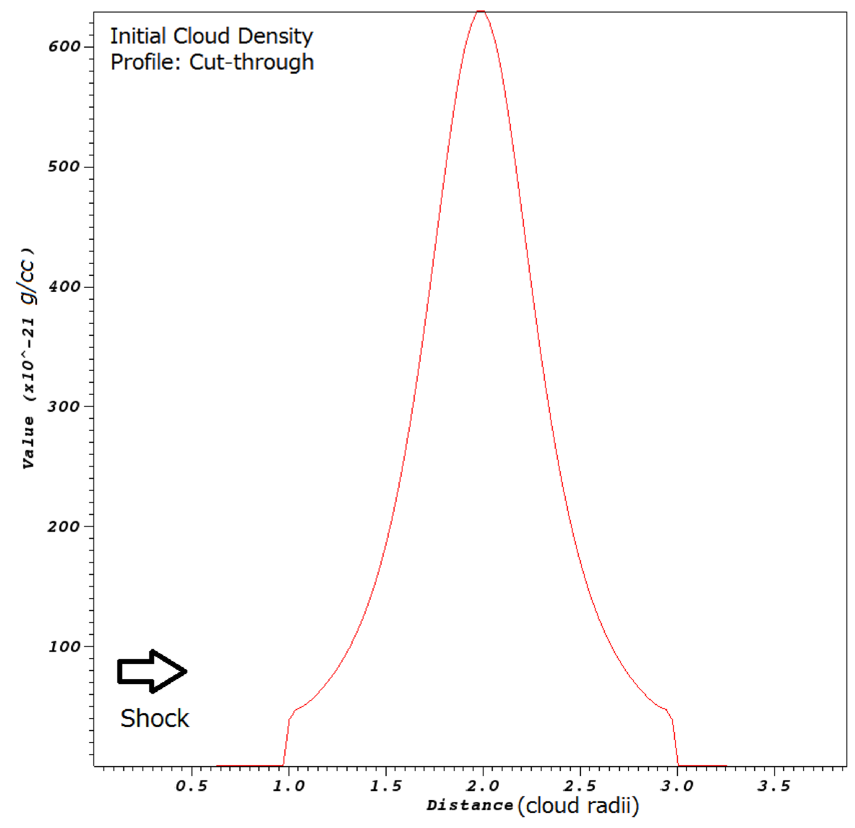
Subsequent Star Evolution



Star evolution and disk formation for the post-shock star for different rotational cases under $M = 1.5, K = 0.1$. Disk is formed only when there is an initial rotation.

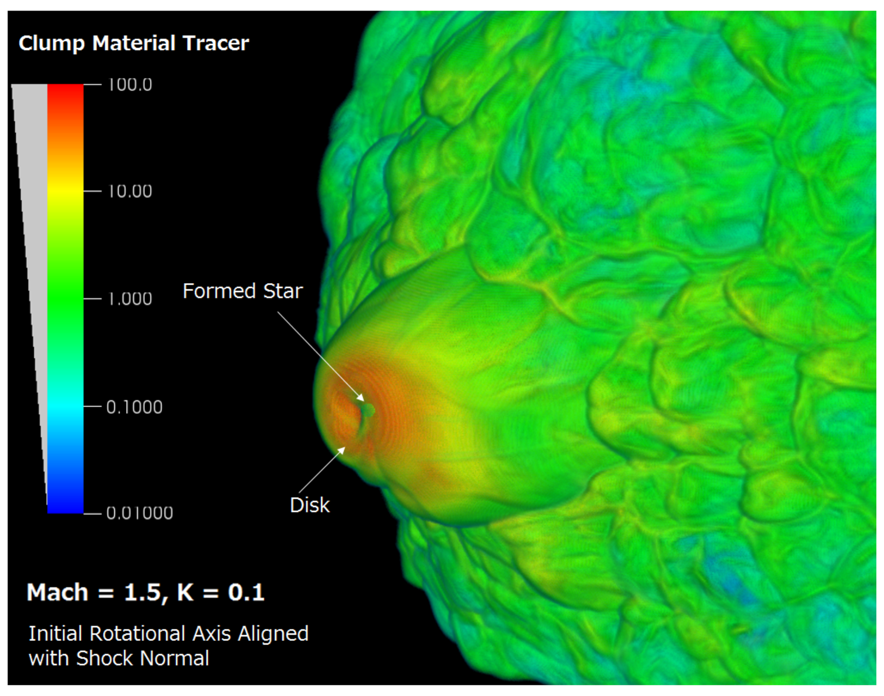
Initial Setup

We assume isothermal $\gamma = 1.0$, and an initial marginally stable (tested to be stable within several sound crossing time) Bonnor-Ebert profile of the cloud. The cloud (about 1 $M_\odot$) has a radius of $0.058pc$, central density $6.3 \times 10^{-19} g/cc$ and edge density of $3.6 \times 10^{-20} g/cc$, with temperature $10K$ inside. The ambient medium satisfies pressure balancing at the cloud edge, with density $3.6 \times 10^{-22} g/cc$ and temperature of $1000K$. The incoming shock has a Mach number of either 1.5 or 3.16. The cloud crushing time by the shock is $t_{cc} \approx 276kyrs$. The free-fall time of the cloud is $t_{ff} \approx 84kyrs$. We simulate the shock-cloud interaction through $4t_{cc}$ time.



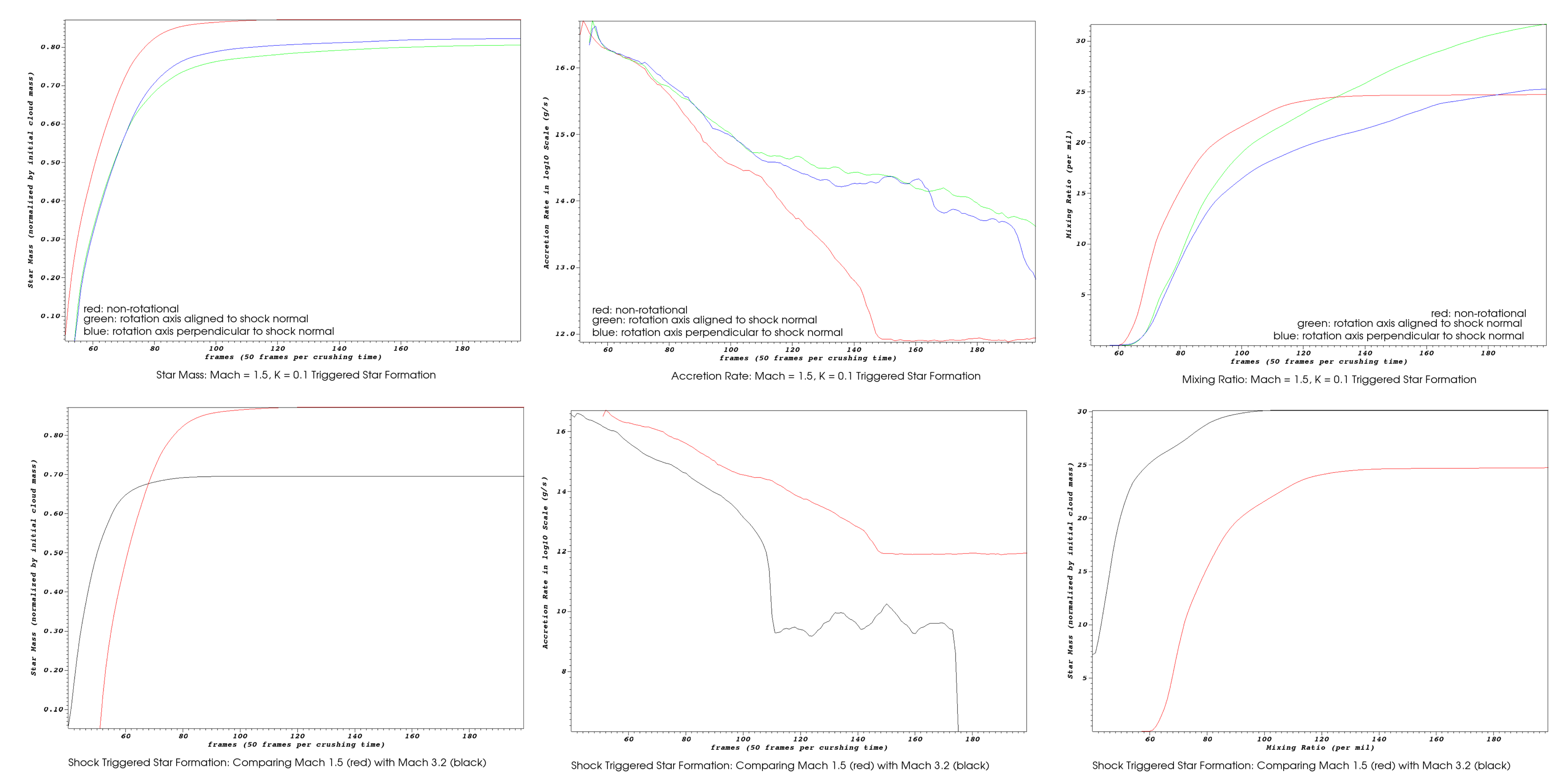
With initial rotation added to the cloud, we identify $K = \Omega \times t_{ff}$ as a parameter characterizing the importance of the rotational energy: $K = 0.1$ for the rotational cases presented here.

A Closer look at Disk Formation



The 3D rendering of the RA case with $Mach = 1.5$ and $K = 0.1$ at $2t_{cc}$. The pancake shaped material rotating around the star (marked in the image) forms a disk that spirals onto the star while gets shredded by the incoming wind and becomes thinner.

Star Mass, Accretion Rate, Mixing Ratio



Conclusions

- The lower the shock speed, the later the formation and the greater the mass of the formed star. With $M = 1.5$, 90% of the initial cloud mass
- Initial cloud rotation can result in the formation of disk surrounding the formed star.
- The accretion rate drops as the star drifts into the incoming wind. It can be amplified by the presence of a disk.
- The mixing ratio of wind material onto the star is about 20 30 per mil in the studied simulations, which can be enhanced by an initial rotation.

References

[1] A.P. Boss, 2010, ApJ, 708, 1268 [2] A.P. Boss, S.A. Keiser, 2010, ApJ, 717, 1 [3] A.P. Boss, S.A. Keiser, 2012, ApJ, 756, 9 [4] M.R. Krumholz, C.F.Mckee, 2006, ApJ, 638, 369 [5] C. Federrath, R. Banerjee, P.C. Clark, R.S. Klessen, 2010, ApJ, 713, 269 [6] Cunningham A. J. et al., 2009, ApJS, 182, 519 (https://clover.pas.rochester.edu/trac/astrobear/wiki/WikiStart);