ISM-SPP 1573

Column density thresholds and the star formation rate

Paul C. Clark & Simon C.O. Glover

Zentrum für Astronomie der Universität Heidelberg, Institut für Theoretische Astrophysik, Albert-Ueberle-Str. 2, 69120 Heidelberg, Germany

email: p.clark@uni-heidelberg.de glover@uni-heidelberg.de

ZENTRUM FÜR ASTRONOMIE

ARI ITA LSW

Summary

We present a suite of turbulent cloud calculations that span a wide range in mass and radius, and thus sample a range of possible volume and column densities. Our goal is to determine whether there exists a column density threshold below which star formation is suppressed. In addition, we examine how the rate of star formation depends on the conditions in the cloud. The calculations were preformed using a modified version of the publicly available SPH code GADGET2 (Springel '05), which we have modified to include a sink particle implementation to handle regions of star formation. In addition, we have included a time-dependent chemical network, and a treatment of the main heating and cooling processes in the ISM.

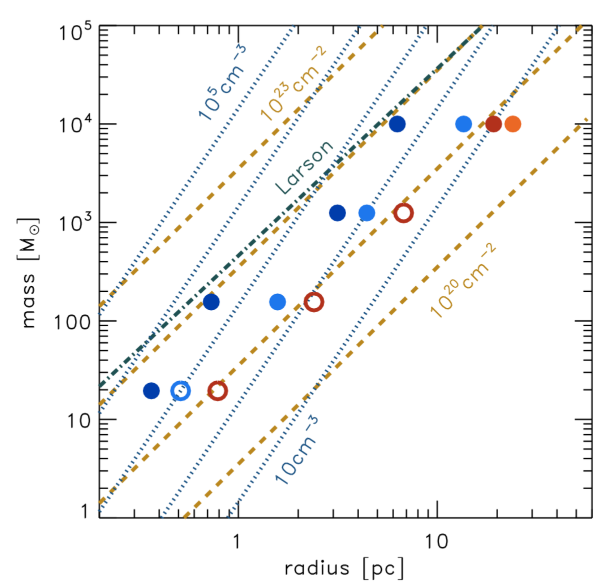


Figure 1:

Points denote the masses and radii of the clouds examined in this study. Clouds that were found to be able to form stars are represented by filled circles, while clouds that were unable to form stars are represented by the open circles. For comparison, we plot both lines of constant column density (dotted) and volume density (dashed). The dot-dashed line shows Larson's mass-radius relation (Larson '81). The numerical simulations are grouped by mass: 20, 156, 1250, and 10,000 M☉.

These simulations show that even very low column clouds are capable of star formation, provided that they are sufficiently massive (~10^4 M☉ and above). For lower mass clouds, there is a rough threshold of around 10^{21} cm^{-2}.

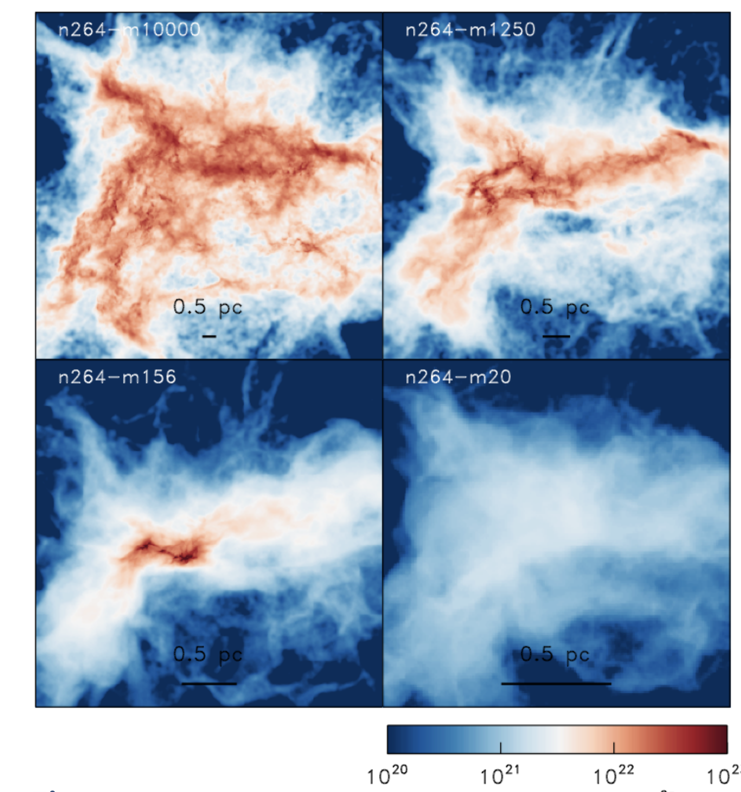


Figure 2:

Column density images from several of our n = 264 cm^{-3} runs. For the starless cloud, the image is at 1 initial free-fall time. The other clouds are shown just before the onset of star formation. In the name-tag, "m" to the mass in M☉.

Figure 3:

Lada et al. ('10) found a tight correlation between the rate of star formation in a cloud, and the mass above A_K = 0.8 threshold (≈116 M☉ pc^{-2}). We construct a similar analysis here (left), using 2 estimates of SFR. The blue diamonds show the total mass of stars formed, divided by the time in which the clouds are active in star formation (we run all simulations until 10% of the mass is in stars). The red triangles show the total mass in stars at the end of the simulation, divided by the total time since the start of the simulation (typically > 1 t_{FF}). Column densities are obtained from the images such as those in Fig. 2.

For the higher mass clouds and the second measure of the SFR, we see that the correlation between the SFR and mass at A_K > 0.8 is within a factor of 2 of the Lada et al. ('10) result. For this measure of the SFR, the clouds have been forming stars over at least 2 Myr -- roughly the assumed YSO age in the observed clusters. The blue points, which reflect the instantaneous SFR in the clouds (a quantity that does not enter the Lada et al. analysis), are not a good fit to the observed relation.

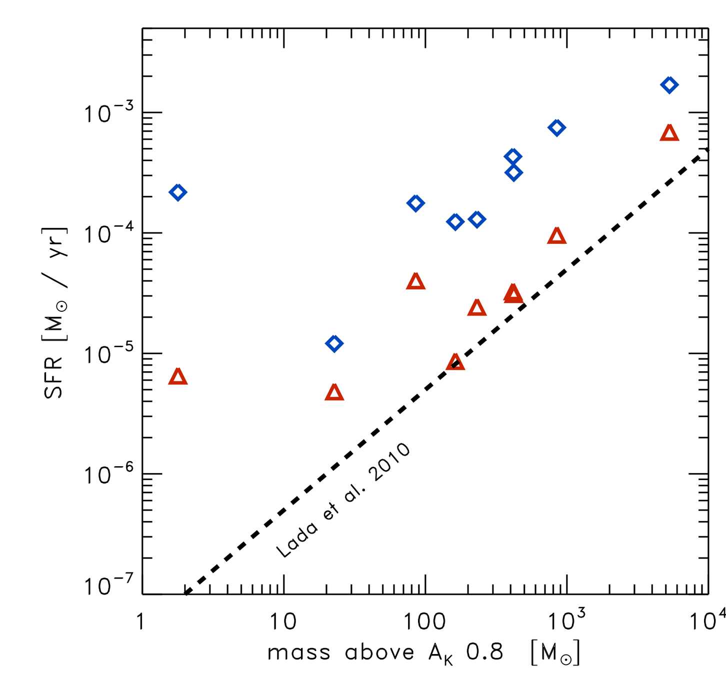
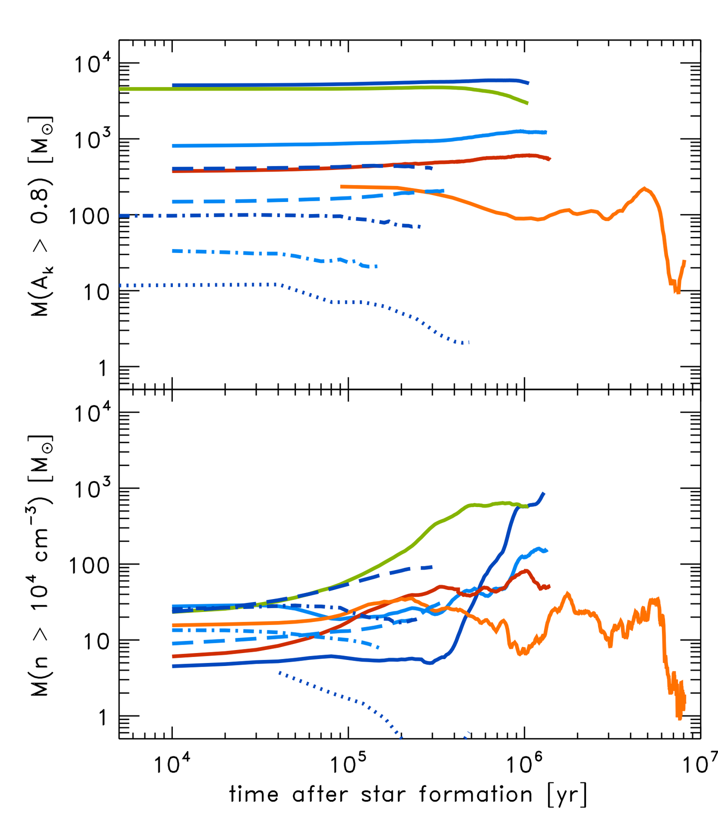


Figure 4:

An interpretation of the A_K > 0.8 threshold is that it corresponds to gas above a number density of 10^4 cm^{-3}. We test this hypothesis in our suite of clouds. On the right, we show the mass above the column threshold (top) and the mass above 104 cm-3 for all our star-forming clouds. The masses are shown for the period of the cloud in which it is forming stars.

The correlation between M(n > 10^4) and M(A_K > 0.8) is very poor for the majority of the star-forming period. This is especially true of the initially high column density clouds. Only at late times (~1 Myr) do the fractions correlate.



Assuming that M(n > 10^4) and M(A_K > 0.8) Lada et al. derive a star formation rate per free-fall time (SFR_{FF}) in the 10^4 cm^{-3} gas of around 0.018. In these models, the assumption that M(n > 10^4) = M(A_K > 0.8) does not hold. As such, our clouds actually have a SFR_{FF} of around unity. However, applying the Lada et al. analysis, we would obtain SFR_{FF} ~ 0.04.

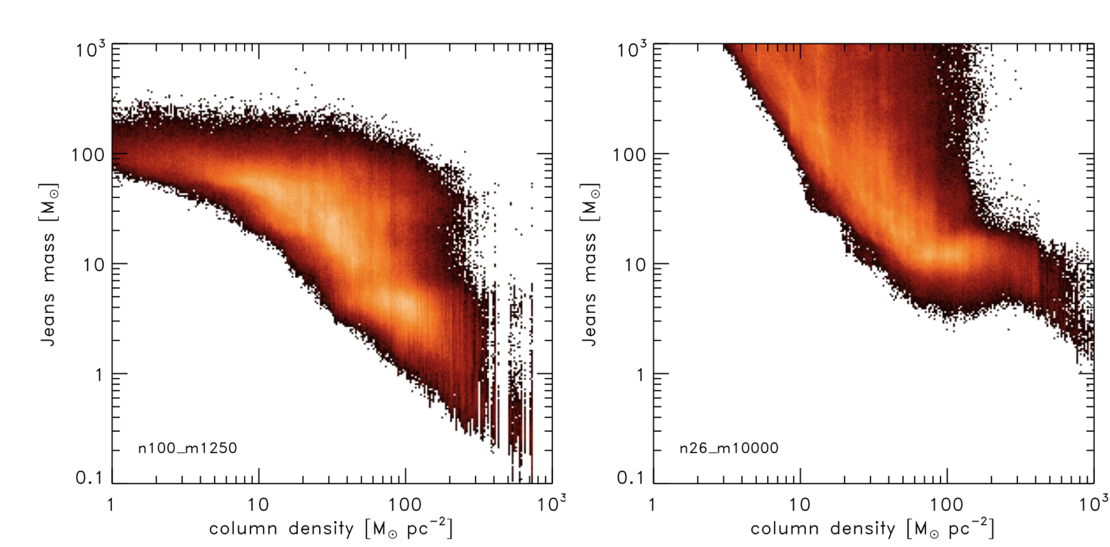


Figure 5:

An alternative explanation of the A_K = 0.8 threshold is that this gas is simply better shielded from the ISRF, and suffers less from photoelectric heating. Above, we show the distribution of Jeans masses of the SPH particles, as a function of their observed column density (from maps such as those in Fig 2.). Note that these two clouds have very different initial conditions.

Above ~100 M☉ pc^{-2}, the scatter in the Jeans mass distribution abruptly falls, and so the mass in gas above this threshold is a good tracer of the number of Jeans masses available to the star formation process.