FRAGMENTATION OF ISOTHERMAL GAS CLOUDS

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An analysis of the collapse and fission of the isothermal gas cloud examined by Boss and Bodenheimer (BB, 1979) has been made using SPH (Lucy 1977, Gingold and Monaghan 1977, 1978). While SPH is not as effective as finite difference methods for problems with spherical symmetry, it has the advantage in fragmentation problems that the description of the fragments is independent of their position and orientation. Furthermore, the SPH algorithm has been tested by applying it to non axisymmetric problems for which accurate solutions are known as well as spherically and axially symmetric problems.

The initially non-axisymmetric rotating cloud is found to undergo a fission as in the BB calculation. Up until $t \sim 2.4 \times 10^4$ years, the central and maximum densities of the two calculations are in good agreement. From $t \sim 2.4 \times 10^4$ years until $\sim 2.8 \times 10^4$ years, when the BB calculation was discontinued because of its poor azimuthal resolution, the two calculations differ considerably. At the end of this time the SPH fragments are rotating with a $\beta \sim 30$ times the BB value. Furthermore, the SPH fragments have become elongated whereas the BB fragments are roughly spherical. The rapid rise in the BB maximum density is not found in the SPH calculation, possibly because of the abovementioned differences. Because the SPH calculation has a better resolution of the fragments it can be continued for a much longer time. We find the fragments become subject to strong tidal forces and eventually coalesce to form a bar surrounded by a halo. The conclusion of BB that the final state is a binary must therefore be doubted. The difference between the BB and SPH calculations may be due to the fact that initially the mass which forms each fragment in the BB calculation only occupies about 4 cells in azimuth, and at the time the two results begin to diverge from each other, the fragments in the BB calculation occupy $\sim$ 2 cells in azimuth. The BB calculation therefore has an initially low and continually degraded azimuthal resolution. In contrast the SPH resolution increases by a factor of 3 during the collapse.

References

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DISCUSSION

Bodenheimer: Could numerical diffusion of angular momentum play a role in the calculation, and is it a possible cause of the discrepancy between your results and ours?

Gingold: Since the SPH code is a Lagrangian formulation, it does not suffer from the angular momentum problem that arises in Eulerian codes. If the system is axisymmetric, then we conserve local angular momentum exactly. Tests on polytropes with moderate rotation show that the small deviations from axisymmetry that arise from the use of a finite number of paticles do not significantly change the distribution of local angular momentum. The total angular momentum is always conserved exactly.

Sørensen: You mentioned the resolution problems facing the hydrodynamic calculations. The smoothing of your particles will, however, also limit your resolution. Could you give a value for this limit?

Gingold: The resolution is of the order of half the smoothing length $\underline{h}$ shown in the diagrams (which will be published elsewhere). At the stage when the fragments first clearly form ($t \sim 2.4 \times 10^4$ yr), the fragments subtend about 6×3 smoothing lengths. At this stage, our fragments would subtend only one azimuthal cell in the finite difference schemes.

Sørensen: Bodenheimer increased his resolution by doubling the number of grid points. Have you tried to reduce your resolution too see whether or not your result approaches Bodenheimers?

Gingold: We have also used only 400 particles and a resolution twice as coarse as the present resolution. The results were similar. However, this resolution may still be better than that achieved by the finite difference codes. To degrade the SPH resolution further may cause the initial density distribution to differ significantly from that used by Boss and Bodenheimer. Also, various ways of generating the initial density distribution have been tried and all behave similarly.

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