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Star and Planet Formation
Homework #4

Paper title: Cosmological SPH simulations: A hybrid multi-phase model for star formation
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In this paper, the authors detail a model of star formation and supernovae feedback that is designed for cosmological simulations. While a powerful predictive tool of galaxy formation and evolution, cosmological hydrodynamic simulations do not have the resolving power to model 'small scale' processes such as star formation. There is also little understanding how to best consider and implement supernovae feedback – too little and you result in an overcooling problem at high redshift and an overproduction of stars. There have been multiple attempts on treating this problem in numerical and semi-analytic simulations, each coming with their own set of caveats and lessons learned. Using this breadth of knowledge, the authors attempt to produce a star formation model that describes self-regulated star formation and physically motivated feedback in smoothed particle hydrodynamic (SPH) cosmological simulations. This model utilizes a statistical formulation to better globally model the dynamic behavior of the interstellar medium (ISM).

The model consists of the following. Each SPH element represents a region of the ISM that consists of two phases – cold, condensed clouds in pressure equilibrium with the ambient environmental hot gas. The partition of hot gas in the cell is subject to hydrodynamics while the cold gas partition is subject to gravity and inertia changes. Three processes between the two phases are considered: i) star formation, ii) supernovae-driven cloud evaporation, and iii) cooling-driven cloud growth. Star formation consumes the cold gas contained in the clouds, and when stars go supernova, their feedback energy directly heats the ambient partition, which in turn evaporates a population of the cold clouds. A mass exchange is possible between the two phases, which drives cold cloud growth. A consequence of this model is that it leads to self-regulated star formation where cold clouds are formed, consumed, and evaporated. The development of this model also led to a formal treatment of galactic winds for energy and enrichment transport in the galaxy.

The authors conduct a variety of tests to verify their model. First conducted is a test of star formation histories in disk simulations that live in different halo masses, followed by a time evolution analysis of gas inflows and outflows. Projected surface densities are also studied, as well as the volume normalized star formation rate density as a function of time. The authors find as part of their results that the key to metal transport and enrichment of the IGM and star formation suppression lies with the winds. If you have winds that are too energetic, they suppress star formation in the disk. They also find that observations match quite well, and that the inclusion of winds can help address metal yield signatures in Lyman-alpha forests. The authors note that the minimum temperature for the gas in this model is 10^4 K and in reality, the cold cores formed would be much, much cooler. They also do not model starburst, however there is potential for run-away star formation in the model.