Zooming in on Star Formation. T. Haugbølle[1], Å. Nordlund[2] and P. Padoan[3], [1]Centre for Star and Planet Formation, University of Copenhagen (Øster voldgade 5-7, DK-1350 Copenhagen, Denmark; haugboel@nbi.dk), [2]Å. Nordlund, Centre for Star and Planet Formation & Niels Bohr Institute, University of Copenhagen (Juliane Maries-vej 30, DK-2100 Copenhagen, Denmark; aake@nbi.dk), [3]P. Padoan, ICREA & ICC, University of Barcelona (Marti i Franquès 1, E-08028 Barcelona, Spain; ppadoan@icc.ub.edu).

Introduction: Molecular clouds are formed from supersonic magnetized turbulent isothermal gas, with energy cascading from large to small scales generating a roughly self-similar structure until the collapsing scale. The turbulence is driven at the largest scales possibly by spiral arms, supernovae, and stellar winds. Star Formation can be understood as a consequence of turbulent compression and fragmentation, with little influence from self-gravity, and collapse due to gravity of the densest regions, with little influence from turbulence. The star formation rate then depends on the virial number, and on the ratio of kinetic to gravitational energy [1,2]. While much have been understood from turbulence statistics and cloud core distributions using unigrid MHD codes, to follow the collapse of the gas all the way to proto-stellar cores we need adaptive resolution to grasp the dynamic range of the problem.

Results: We study star formation in molecular clouds using very large adaptive mesh MHD simulations with our adapted version of the RAMSES AMR code to zoom in on cloud cores reaching an equivalent resolution of ~$(6 \cdot 10^4)^3$. This allows for the first time to evolve the molecular cloud on parsec scales, modeled with driven supersonic MHD turbulence in a periodic box, while simultaneously resolving the neighborhood of stars with a 10 AU resolution (see figure).

When gas reaches a critical value it is turned into computational sink particles represent stars, and we use them to measure the star formation rate, star formation efficiency and the resulting stellar mass distribution. Historically, simple criteria for the creation of sink particles have led to spurious creation of groups of sinks near massive cores, and a number density of sinks that depends on numerical details, such as resolution and accretion distance of gas around a sink. We use a number of physically motivated criteria, such as potential minima, maximum of density, and convergence of flow that has to be fulfilled for the creation of sink particles [3].

We have evolved the simulations until a point where a significant (typically 30%) fraction of the gas has been turned into stars, and confirmed that we are in agreement with e.g. [1]. For example, for the specific parameters used in the run shown in the figure we find a star formation rate per free-fall time of 20%.

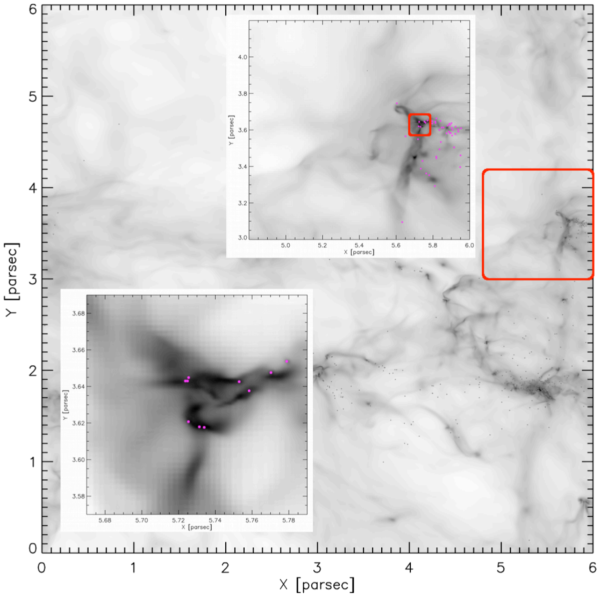

Figure: The logarithm of the column density from an AMR run with a 512^3 base resolution and 6 AMR levels. The run has a Mach number of 10, following the Larson relations for a box of 6 parsec, and $P_{gas}/P_{magnetic}=1/3$. Dots are sink particles, representing stars. The zoom-in illustrates the power of AMR to accurately resolve the neighborhood around single stars in the box.

We find that with the exquisite resolution, we practically resolves the gravitational collapse down to the opacity limit, and the mass accretion from the cloud core to the protostar is realistic. This resolution together with the many consistent checks on creation of sink particles enables us, for the first time, to construct a numerically converged, realistic stellar initial mass function, with the correct Salpeter slope and low mass turnover, in agreement with observations [4] and theory [5,6]. Furthermore, given that the model is practically devoid of any spurious sink particles, we can also study the collapse of single cores and groups of cores to protostars in detail down to the scale of tens of AU.

References: [1] Padoan, P. and Nordlund, Å (2011), ApJ, 730, 40. [2] Krumholz, M. R. and McKee, C. F. (2005), ApJ, 630, 250. [3] Federrath, C. et al (2011), IAU Symposium, 270, 425. [4] Chabrier, G. (2003), PASP, 115, 763 [5] Hennebelle, P., and Chabrier, G. (2008), ApJ, 684, 395. [6] Padoan, P. and Nordlund, Å (2002), ApJ, 576, 870.