Numerical stellar clusters: A data rich environment

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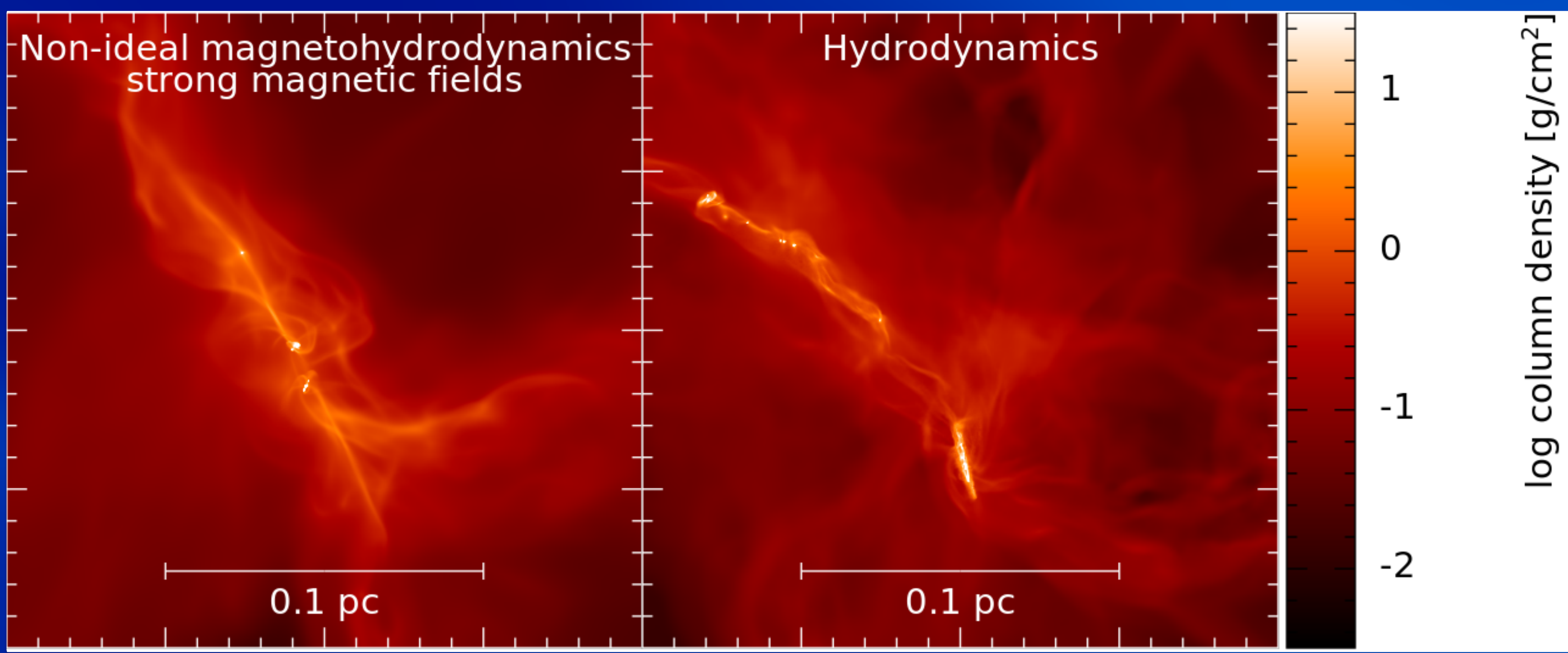
Overview:

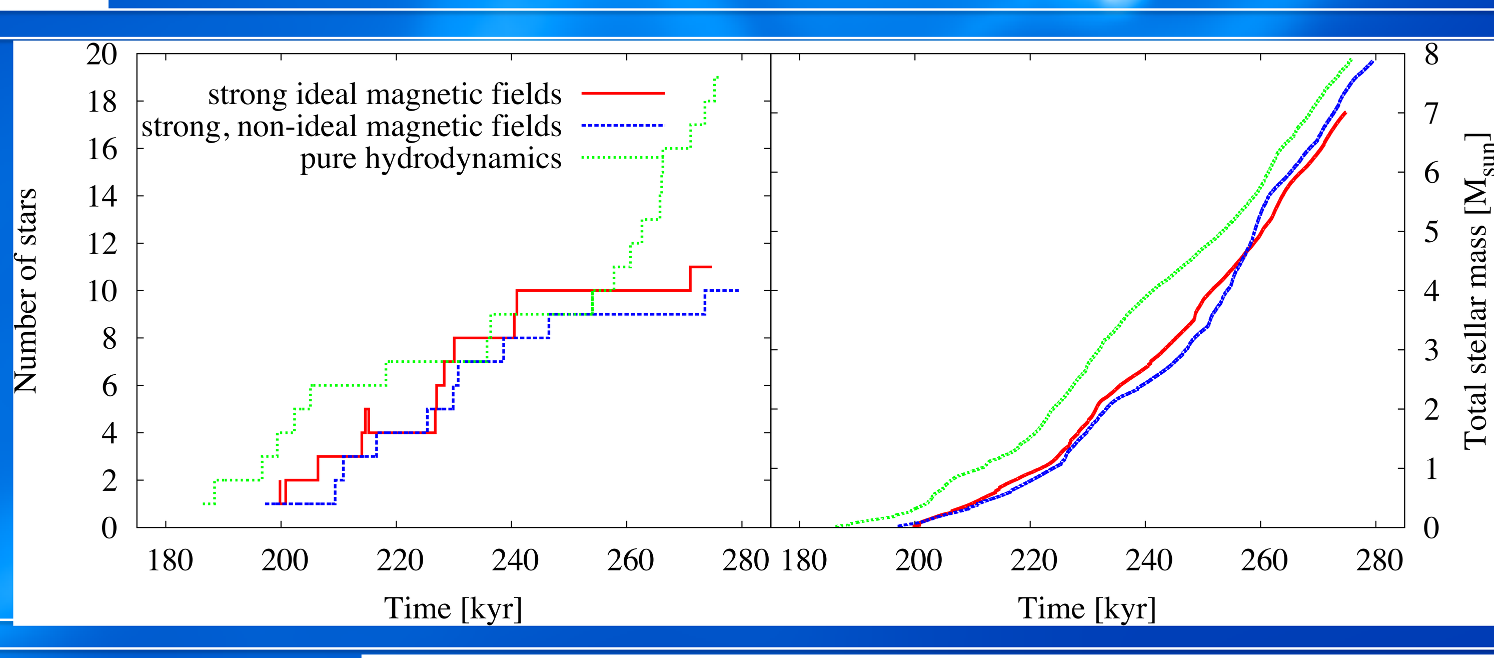
STARS form in chaotic environments that are home to many physical processes. Although star-forming environments and young stars are being observed with state-of-the-art telescopes, advanced high-resolution simulations are required to help interpret the observational data for a better understanding of star formation.

WE simulate the formation and early evolution of a stellar cluster using the smoothed particle radiation non-ideal magnetohydrodynamics code, sphNG. Our simulations resolve the Jeans mass, meaning that we can model the formation of individual stars; the stars are subsequently modelled using sink particles rather than 100-1000s of gas particles. Our simulations are initialised with 50 solar masses of turbulent gas in a magnetised medium. To investigate the effect of magnetic field strength and non-ideal magnetohydrodynamics (MHD), we ran nine simulations. These simulations are computationally expensive thus require resources such as DiRAC. However, much information can be extracted:

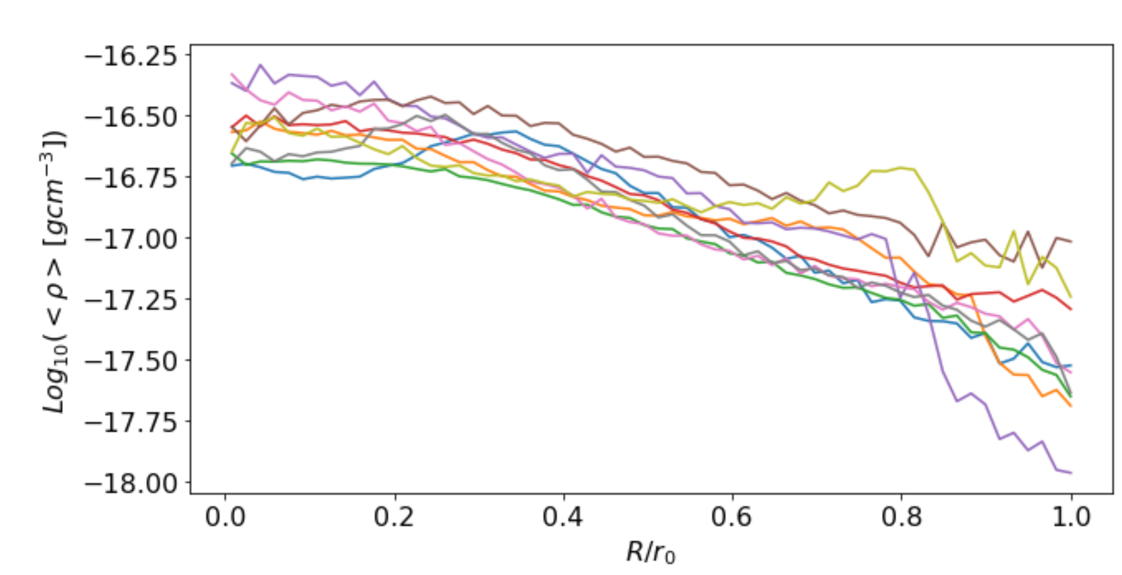


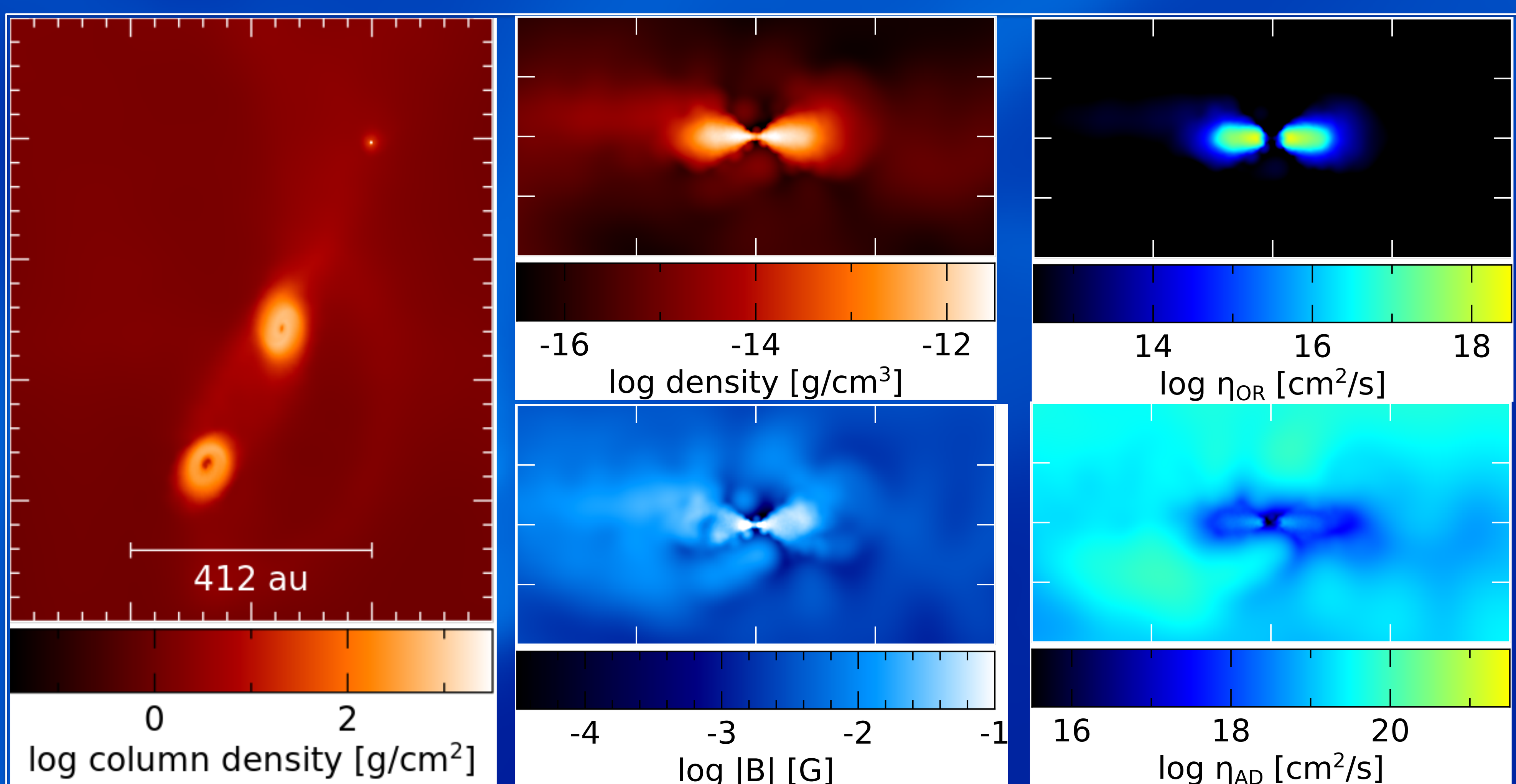
GAS structure of two star forming regions after 275kyr. The gas motion is more restricted in the magnetised model (left), thus there are fewer star-forming hubs. The single filament is somewhat aligned with the initial magnetic field, while there is no preferential direction of the filaments in the purely hydrodynamics model (right).
The initial magnetic field strength affects the evolution of the filaments and the number and location of star-forming hubs.

MAGNETIC fields hinder star formation. Fewer stars form in the magnetised models (left), and less gas is converted into stars (right); the stars that do form are slightly more massive. The inclusion of non-ideal MHD does not have a significant affect on the total stellar mass when considering the entire cluster.



STAR-FORMING cores represent the initial conditions for the formation of an individual star. Realistic star-forming cores are not the smooth, idealised spheres typically used in numerical simulations. For each star that forms, we can analyse earlier epochs and extract the properties of the gas from which the star will be born to obtain realistic profiles of the various properties (density, temperature, velocity, magnetic field, etc). The figure shows the density profile of several star-forming cores in these simulations well before this gas is converted into a star (Rowan, MPhys thesis).





DISCS form around many of the stars, and these discs are dynamically evolving and interacting (far left panel). We can extract statistics about the discs (e.g. the hierarchy of discs and the number of stars they surround; see also Bate 2018) and analyse the properties of individual discs (e.g. remaining four panels that show gas density, and magnetic field $\boldsymbol{B}$, Ohmic resistivity η_{OR} & ambipolar diffusion η_{AD} strengths in a vertical slice through the disc; Wurster, submitted). Thus we have many realistic discs that can be analysed at multiple epochs for a complete understanding of their formation and early evolution.

Thus, HPC is an essential and invaluable resource in trying to better understand star formation.
Primary Reference: Wurster, Bate & Price. MNRAS, 489:1719-1741, Oct 2019.