2nd Asia-Pacific Conference on Plasma Physics, 12-17,11.2018, Kanazawa, Japan

Modelling star formation from first principles: Magnetic fields and the birth of the Sun

Daniel J. Price[1], James Wurster[2], Matthew R. Bate[2]
[1] School of Physics & Astronomy, Monash University
[2] School of Physics, University of Exeter
daniel.price@monash.edu

Stars like the Sun form in a turbulent, magnetised plasma. But what roles do turbulence and magnetic fields play in the birth of stars? And could the magnetic fields in the Sun be a fossil leftover from its birth?

I will discuss recent attempts to model the birth of stars from first principles in turbulent, magnetized clouds [1-4]. We employ the smoothed particle magnetohydrodynamics technique in order to adapt the numerical resolution to the huge range of length and timescales involved [6,7].

The plasma regime is out-of-this-world: Typical motions are both supersonic and super-Alfvenic, and the plasma is weakly ionized. Recent work [1-5] has revealed how plasma effects including Ohmic resistivity, ion-neutral drift and Hall drift can solve the `magnetic braking catastrophe' where swirling discs of gas – from which planets are born – failed to form in models. We have recently been able to simulate for the first time the entire dynamic range in the gravitational collapse, over 17 orders of magnitude in density, to understand the magnetic field implanted in stars at birth [1,2].

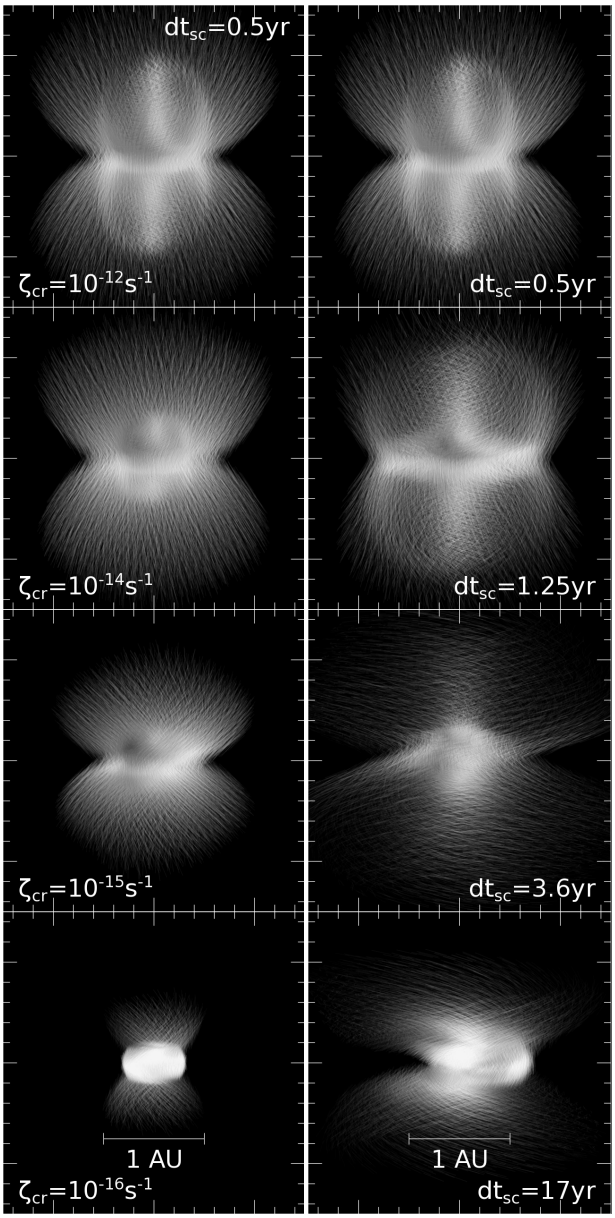

Figure: Magnetic field geometries during the formation of a protostar, showing the field structure just after birth (left) compared to the later evolution (right), and for different assumed cosmic-ray ionization rates (top to bottom, from most to least ionized), showing the effect of partially ionized plasmas on the launching of jets and winds from the newborn star. Reproduced from [2].

References

[1] Wurster, Bate & Price (2018), 'On the origin of magnetic fields in stars', submitted to MNRAS
[2] Wurster, Bate & Price (2018), 'The collapse of a molecular cloud core to stellar densities using radiation non-ideal magnetohydrodynamics', MNRAS 475, 1859
[3] Wurster, Price & Bate (2017), 'The impact of non-ideal MHD on binary star formation', MNRAS 466, 1788
[4] Wurster, Price & Bate (2016), 'Can non-ideal magnetohydrodynamics solve the magnetic braking catastrophe?' MNRAS 457, 1037
[5] Tsukamoto et al. (2015), 'Bimodality of Circumstellar Disk Evolution Induced by Hall Current', ApJL 810, L26
[6] Price (2012), 'Smoothed Particle Hydrodynamics and Magnetohydrodynamics', J. Comp. Phys. 231, 759
[7] Tricco, Price & Bate (2016), 'Constrained hyperbolic divergence cleaning in smoothed particle magnetohydrodynamics', J. Comp. Phys. 322, 326