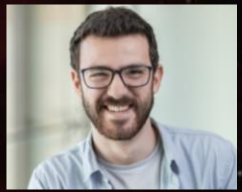
The Impact of Magnetic Fields in Cloud Formation and Evolution

Cameron R J Bogue, Rowan J Smith

Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

The University of Manchester



1. Abstract

Using the moving-mesh code Arepo (Springel 2010), we have run **two** categories of **magnetohydrodynamic (MHD)** galaxy simulation thus far in this project, testing the **feasibility of including magnetic fields** in galaxy size simulations. Early results are presented for both the **Isolated Flocculent M51** simulations and for the **Milky Way** style simulations which feature **an embedded high resolution box**. We are keen to follow up with future work these results have led the way for, and look forward to collaborations in the next year. **We aim to contribute to the growing body of knowledge on the effects of magnetic fields in the ISM**, which will hopefully lead to new insights into the process of star formation.

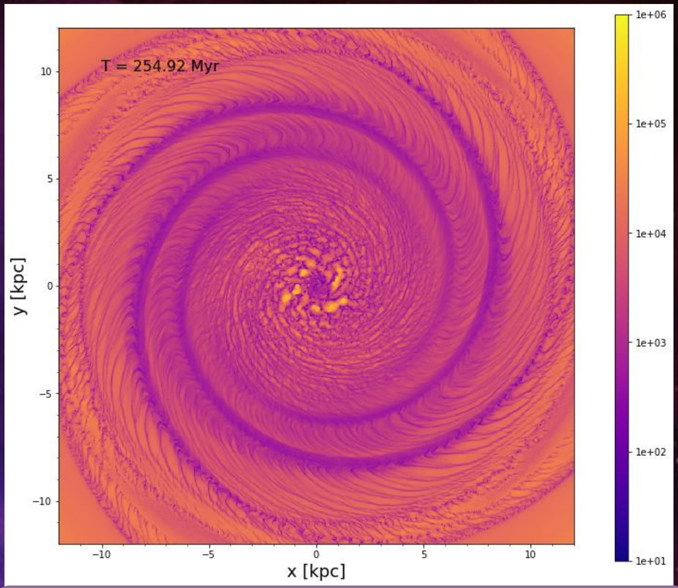


Fig 1. Gas temperature (K) from the 'HIBOX' simulations.

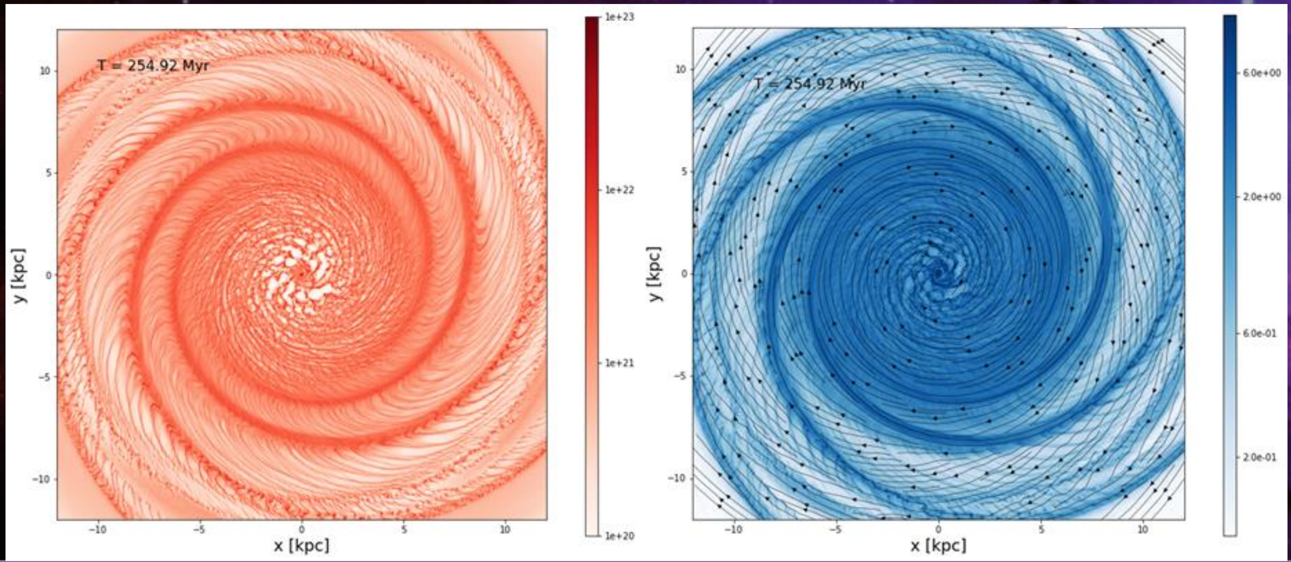


Fig 2. Surface density and magnetic field projections of the entire Milky type galaxy from the 'HIBOX' simulations.

2. Methods

These simulations take advantage of physics beyond the base implementation of Arepo, including **magnetic fields** (Pakmor & Springel 2013), **chemistry networks** (Glover & Clark 2012), and **sink particles** (Federrath et al. 2010, Clark et al. 2019, Tress et al. 2020).

The University of Manchester

The Impact of Magnetic Fields in Cloud Formation and Evolution

Cameron R J Bogue, Rowan J Smith
Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

3. Early Results – HIBOX

The HIBOX simulations continue on from previous simulations run by the group of a Milky Way style galaxy (following the set-up of Smith et al 2014) that ran for 200Myr. At this stage, **I added a 1kpc×1kpc×1kpc high resolution box** at a resolution of 100$M_{\odot}$, which ran for 50Myr. The resolution of the box was then increased to 10$M_{\odot}$, and ran for approximately a further 20Myr.

We see sharp vertical features in the density and in the magnetic field of the gas perpendicular to the spiral arm. Given the toroidal field direction, field lines are expected to be horizontal on these images; this would mean the gas can flow along the field lines onto these filaments from a perpendicular angle. Horizontally flowing gas on these paths would not obstructed by the field.

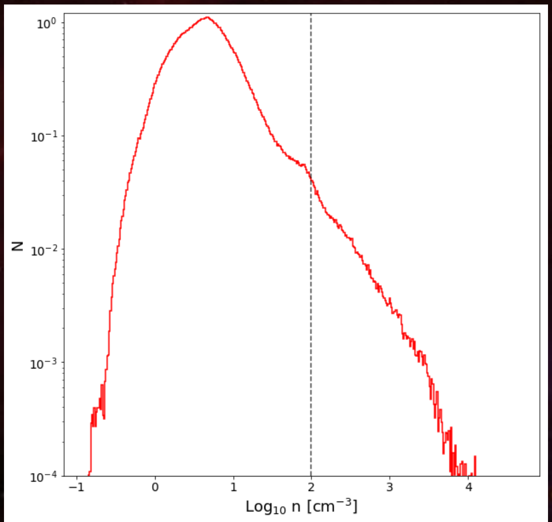


Fig 3. Number densities of the simulated gas.

3. Early Results – HIBOX

We also find in these high resolution box simulations that the composition of the gas is highly atomic (over 90%). The lack of molecular gas however is not attributed to the addition of magnetic fields, but rather to the creation density of the sink particles. Gas that would be molecular is being put into sink particles instead. The dashed black line in figure 3 shows the number density at which sinks are formed.

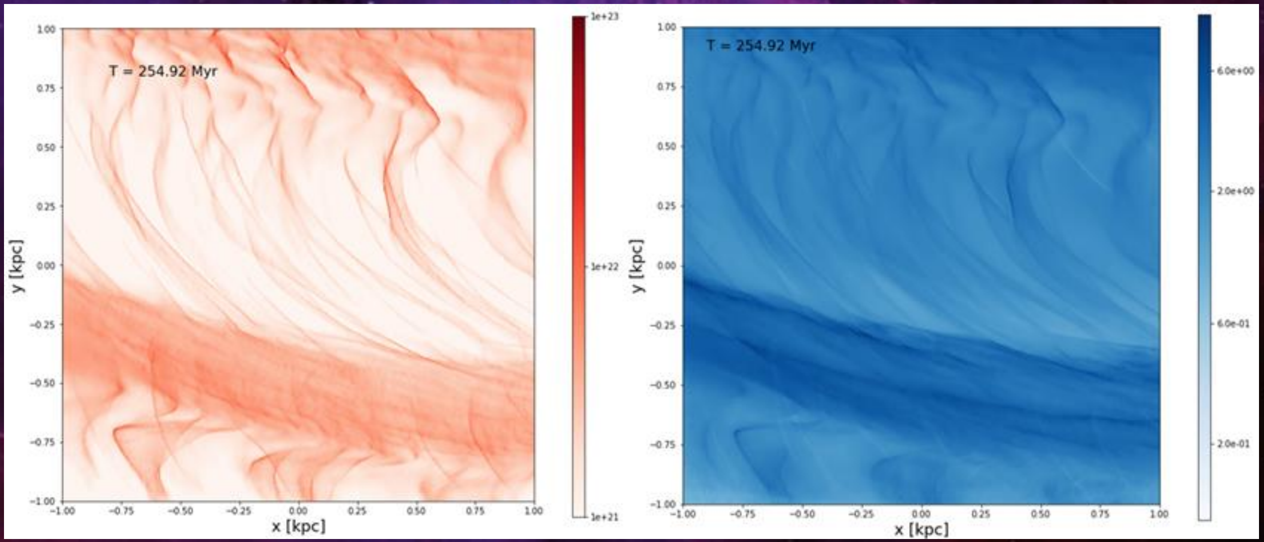


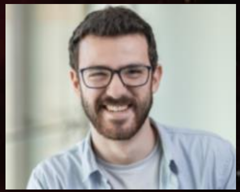
Fig 4. Surface density and magnetic field projection of the extracted high resolution box.

The Impact of Magnetic Fields in Cloud Formation and Evolution

The University of Manchester

Cameron R J Bogue, Rowan J Smith

Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK



4. Early Results – M51

The Isolated M51 Flocculent runs simulate a galaxy modelled after M51, as discussed in detail in Tress et al. (2020), and were run for a physical time of roughly 300Myr. The 2 x 3 grid below show the surface density and magnetic field strength projections of the galaxy from 60Myr to 180Myr in approximately 60Myr intervals. The blue points on the surface density plots denote the location of sink particles. The plot on the right shows the field amplification.

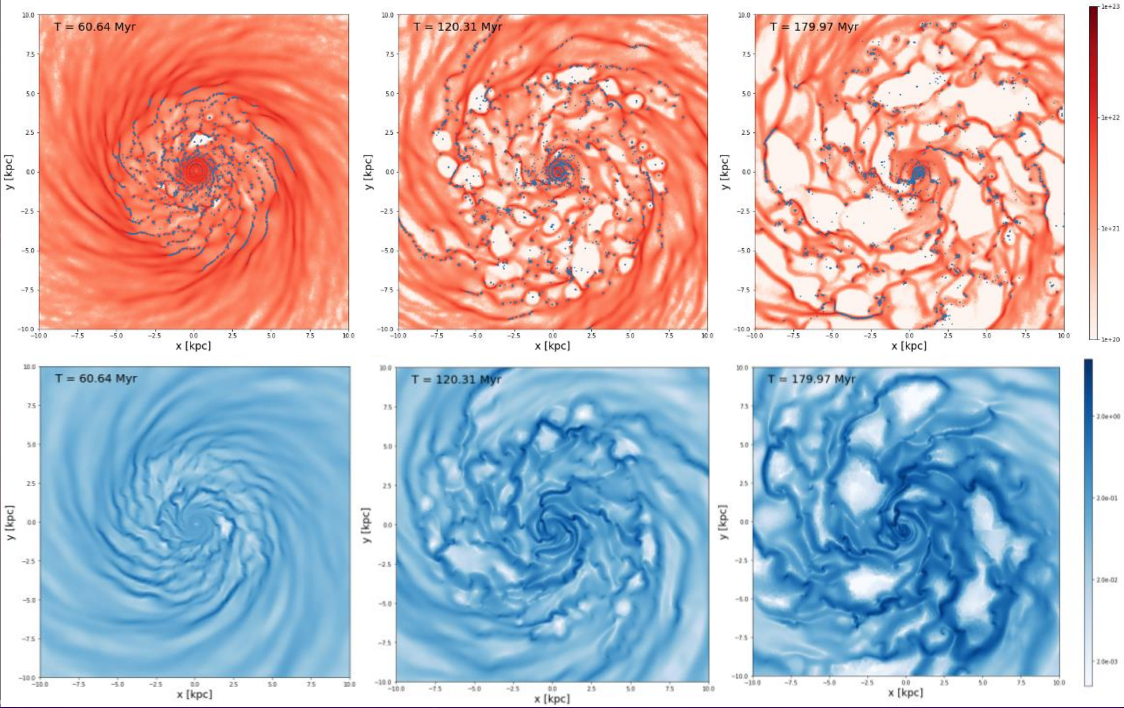
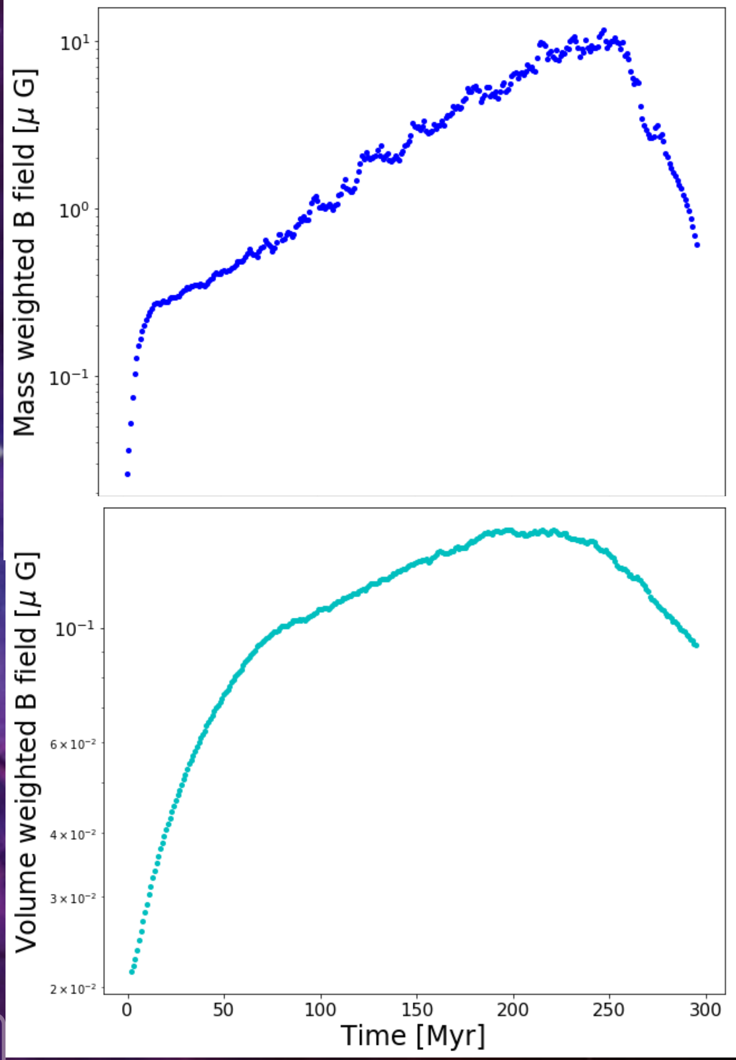


Fig 6. Surface density and magnetic field projections from the Isolated Flocculent M51 type galaxy simulations.

Fig 5. Mass and volume weighted magnetic field amplification.



MANCHESTER 1824

The University of Manchester

The Impact of Magnetic Fields in Cloud Formation and Evolution

Cameron R J Bogue, Rowan J Smith

Jodrell Bank Centre for Astrophysics, Department of Physics and Astronomy, University of Manchester, Oxford Road, Manchester M13 9PL, UK

References

Springel, V. (2010), 'E pur si muove: Galilean-invariant cosmological hydrodynamical simulations on a moving mesh', *Monthly Notices of the Royal Astronomical Society*

Pakmor, R. & Springel, V. (2013), 'Simulations of magnetic fields in isolated disc galaxies', *Monthly Notices of the Royal Astronomical Society* **432**(1).

Glover, S. C. & Clark, P. C. (2012), 'Approximations for modelling CO chemistry in giant molecular clouds:A comparison of approaches',*Monthly Notices of the Royal Astronomical Society* **421**(1)

Federrath, C., Banerjee, R., Clark, P. C. & Klessen, R. S. (2010), 'Modeling collapse and accretion inturbulent gas clouds: Implementation and comparison of sink particles in AMR and SPH', *Astrophysical Journal*

Clark, P. C., Glover, S. C., Ragan, S. E. & Duarte-Cabral, A. (2019), 'Tracing the formation of molecularclouds via [CII], [C I], and CO emission', *Monthly Notices of the Royal Astronomical Society* **486**(4),

Tress, R. G., Smith, R. J., Sormani, M. C., Glover, S. C., Klessen, R. S., Low, M. M. M. & Clark, P. C. (2020), 'Simulations of the star-forming molecular gas in an interacting M51-like galaxy', *Monthly Notices of the Royal Astronomical Society*

Smith, R. J., Glover, S. C., Clark, P. C., Klessen, R. S. & Springel, V. (2014), 'CO-dark gas and molecular filaments in milky way-type galaxies', *Monthly Notices of the Royal Astronomical Society*