The structure of the thermally bistable, turbulent and magnetized atomic gas: Hydrodynamical to MHD simulations

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SUMMARY AND CONCLUSION

We performed a parametric study on hydrodynamical simulations to determine the initial conditions that lead to the formation of 40% of CNM with a Mach number close to 1. We conclude that the ISM turbulence cascade on its own cannot induce a transition from WNM into CNM at the average density of the WNM. The production of 40% of CNM with a Mach number close to 1 is likely to be due to turbulent motions of moderate amplitude associated to a compressive event of the WNM.

The structure of the neutral atomic medium (HI) in the Milky Way is composed of a warm diffuse phase (Warm Neutral Medium - WNM) with n~0.5 cm⁻³, T~8000 K, and a colder phase (Cold Neutral Medium - CNM) with n~100 cm⁻³ and T~200 K. About 40% of the HI mass is in the cold phase due to an increase of the volume. The HI has the properties of a turbulent flow. The WNM turbulent velocity dispersion has the following scaling: v_turb(WNM) = 0.9 L(pc) where L is the distance to the observer (Schmidt et al., 2009). Even when averaged over the whole disk height (300 pc at the solar radius), the WNM turbulent velocity dispersion (5.9 km/s) is significantly lower than the thermal motions (8.3 km/s); the WNM is thus expected to have the properties of a subsonic turbulent flow.

Questions: Do the subsonic turbulent motions of the WNM lead to the formation of the cold structures in the ISM? What is the impact of the magnetic field on the formation of CNM?

Method: To study the phase transition and the formation of the cold clouds from purely hydrodynamical numerical simulations of ISM, we performed a hydro- and MHD simulations (Gonzalez et al., 2007). Our simulations include the main heating and cooling processes described by Wolfire et al. (2003), with turbulence driving applied at large scales in Fourier space (Schmidt et al., 2009) at each time step. The 3D simulations have a cell size of 0.3 pc with 128³ to 1024³ cells leading to resolutions from 0.3 to 0.04 pc. The gas is initially static and uniform, at a temperature of 8000 K, consistent with WNM.

Hydrodynamical study vs initial conditions that statistically reproduce well the observations:

- A biperfect medium
- Volume filling factor of the CNM ~ 1% (purely sinusoidal) to 1 (purely compressive)
- A sub-sonic or transonic turbulence (Mach~1)

WHAT WE WANT TO REPRODUCE

- A high density medium
- Massive fraction of cold gas (0–4)
- Volume filling factor of the CNM ~ 1%
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VARYING PARAMETERS

- Initial density (n_0): from 0.3 to 10 cm⁻³
- Large scale amplitude (v_turb) at 20 pc: from 5 to 20 km/s
- Spectral weight (Q): from 0 (purely compressive) to 1 (purely sinusoidal)

RESULTS

- No transition in 5 simulations
- Transition less efficient in 30 simulations
- Transition more efficient in 90 simulations

DUST POLARIZATION

Angular dispersion (Hildebrand, 2009): where φ is the polarization angle

\[ \sigma(\phi) = \sum_{l=0}^{\infty} S l \left( 1 \right) \]

\[ P = \frac{I_{\text{pol}}}{I} \]

Planck data: All sky map of the dispersion of the polarization angle => anti-correlation of the angular dispersion. \(\sigma(\phi)\) and the polarization fraction \(P\).

SYNTHETIC OBSERVATIONS OF DUST POLARIZATION:

Stokes parameters computation

\[ I = \int \rho \, dV \]

\[ Q = \int \rho \cos(\phi) \, dV \]

\[ U = \int \rho \sin(\phi) \, dV \]

\[ P = \frac{Q^2 + U^2}{I} \]

\[ \phi = 0.2 \phi_0 \]

\(\phi_0\) is the intrinsic dust polarization angle.

SYNTHETIC OBSERVATIONS OF DUST POLARIZATION:

Heatbox projected Planck noise addition and smoothed