N93-26866

Numerical Modeling of the Interstellar Medium in Galactic Disks

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We have been developing detailed hydrodynamic models of the global interstellar medium in the hope of understanding the mass and volume occupied by various phases, as well as their structure and kinematics. In our model, the gas is modeled by one fluid while representative Pop I stars are modeled by a second fluid. The two fluids are coupled in that the gas forms into stars at a rate given by a Schmidt law while stellar mass loss returns matter into the gas phase (on a time scale of 100 Myr). Also, the stars heat the gas through stellar winds and the gas cools through optically thin radiation. The time behavior of these two fluids is studied in two spatial dimensions with the Eulerian finite difference numerical hydrodynamic code *Zeus*. The two spatial dimensions are along the plane of a disk (x, total length of 2 kpc) and perpendicular to the disk (z, total height of ± 15 kpc) and a galactic gravitational field in the z direction, typical of that at the solar circle, is imposed upon the simulation; self-gravity and rotation are absent. For the boundary conditions, outflow is permitted at the top and bottom of the grid ($z = \pm$ 15 kpc) while periodic boundary conditions are imposed upon left and right sides of the grid. As initial conditions, we assumed a gaseous distribution like that seen for the HI by Dickey and Lockman (1990), although the results are insensitive to the initial conditions.

We have run simulations in which the heating due to stars, parameterized as a stellar wind velocity, a, is varied from low (a = 150 km/s), to intermediate (a = 300 km/s), to high (a = 600 km/s). Since the intermediate case is roughly equivalent to the Galactic energy injection rate from supernovae, this summary will concentrate on results from this simulation. Initially hot gas ($T > 100{,}000$ K) is buoyant and rises up before cooling into neutral material. Eventually, the cold gas ($T < 4000$ K) becomes filamentary and occupies a small volume compared to the warm ($4000 \text{ K} < T < 100{,}000$ K) and hot gas (see figure 1). This filamentary structure of cold gas is elongated parallel to gravitational acceleration. Within a few hundred parsecs of the midplane (within 30–50 zones), the volume filling factors for the cold, warm, and hot gas are 10%, 20% and 70%, respectively. Near a height of 1 kpc (100 zones from the midplane), the warm gas dominates (at 70–80% of the volume) at the expense of the hot gas, and hot gas completely fills the regions at larger z. The scale heights for the cold, warm, and hot gas are 65, 600, and 300 pc, respectively. Note the density vs. height figure shows a second (low-density) component of hot gas above 1 kpc.

This work was completed with the support of NASA Grant NAGW-2135.

Reference

Dickey, J.M., & Lockman, F.J. 1990, ARA&A, 28, 215

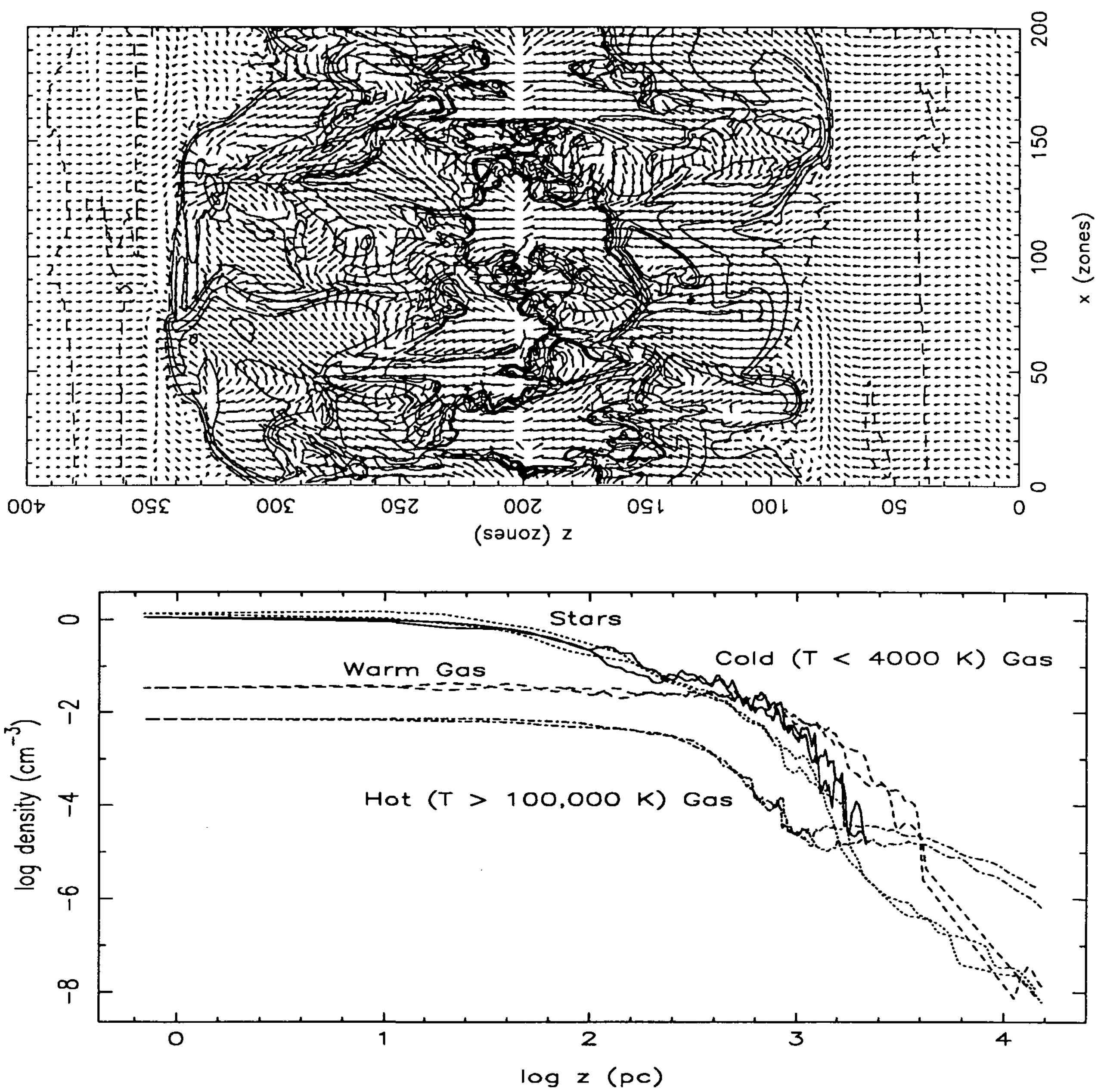

Figure 1. Top plot shows density contours, evenly spaced in log density, and momentum vectors for the intermediate energy injection rate simulation. The middle 200 rows are linearly scaled up to ± 1 kpc, while the outer 200 rows are geometrically scaled from ± 1–15 kpc. On the bottom is an averaged density distribution of the three phases of gas and the stars. The gas distributions are averages at five different times as well as at a particular height.