Ambipolar Diffusion in the Formation of Prestellar Cores

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Abstract

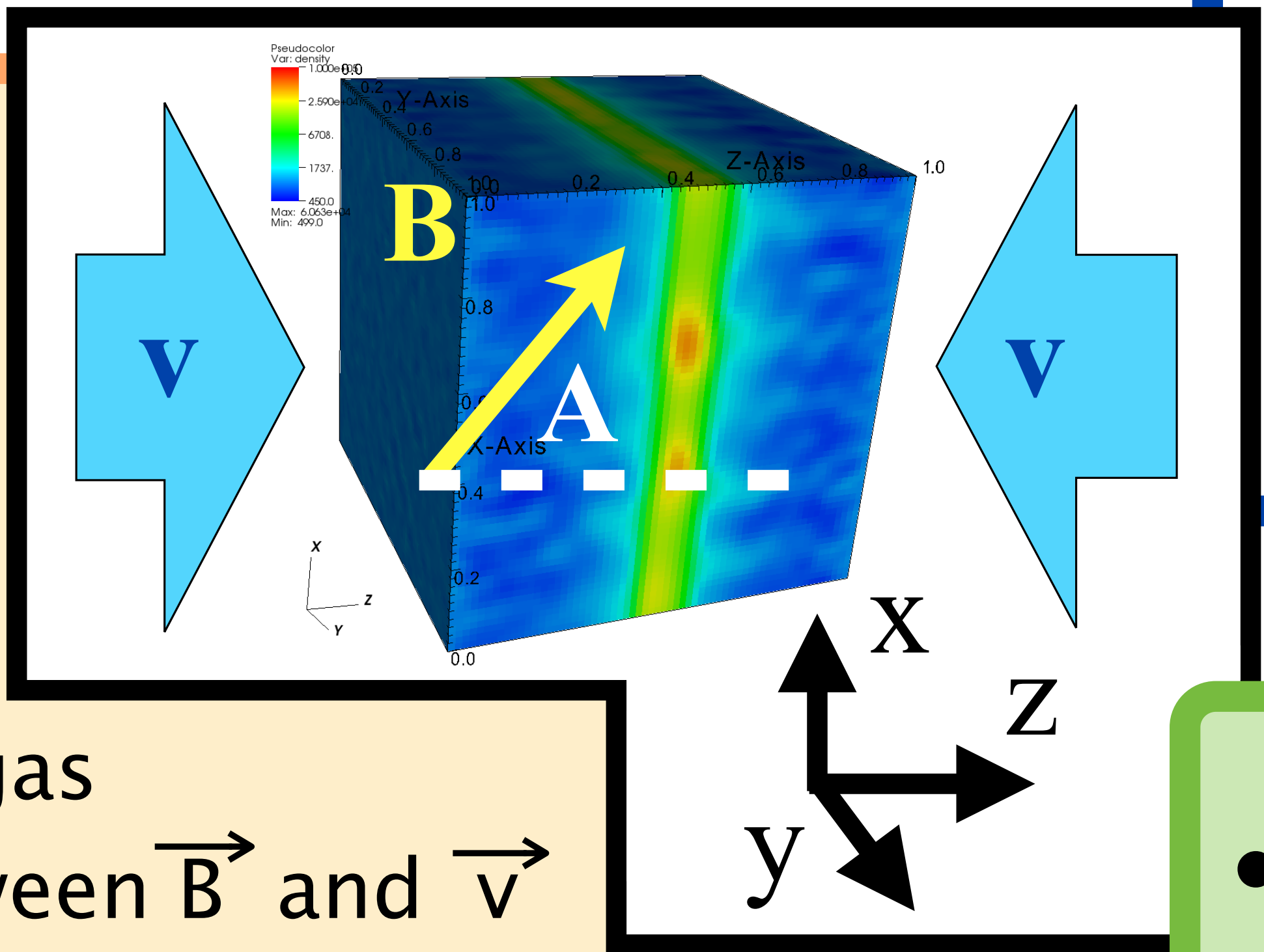
We present preliminary results of a numerical survey of core formation in turbulent, magnetized clouds with ambipolar diffusion (AD). We find that cores with high mass-to-flux ratios can only be formed with a strong AD (low ionization fraction n_i/n_n). However, core masses and sizes are similar regardless of the presence or absence of magnetic fields, and the level of ionization. This indicates that anisotropic concentration is important during core formation in strongly magnetized environments.

Introduction

In GMCs, shocks in the turbulent flow create high-density regions, in which filaments grow and then fragment gravitationally into prestellar cores. This process is influenced by magnetic fields, but magnetic effects on the mostly-neutral gas are limited by the coupling through ion-neutral collisions. The resulting ambipolar diffusion (AD) modifies the core formation process. In previous work, we discovered a transient stage of AD during compression of magnetized gas by supersonic turbulence, creating post-shock regions with relatively high mass-to-flux ratio. Cores that develop in these regions will be magnetically supercritical and able to collapse gravitationally.

Here, we use three dimensional MHD simulations of shocked converging flows, including self-gravity, turbulence, and varying levels of ionization, to investigate how the process and outcome of core formation is affected by AD.

Methods & Parameters



- MHD code: *Athena*; L_{box}=1 pc
- Cloud density: 1000 cm^{-3}
  Convergent inflow v = 2 km/s
  Cloud magnetic field B = 10 μG
- Include turbulence in inflowing gas
- Oblique shock with angle A between $\vec{B}$ and $\vec{v}$
- Structures grow from self-gravity in shocked layer
- Varying upstream magnetic field parallel to shock front $B_x = B \sin(A)$: A = 5°, 20°, 45°
- Varying ionization fraction coefficient (X): $n_i = X\, 10^{-6}\, n_n^{1/2}$ with X = 0 (hydro = "HD"), X = 3, X = 10; ideal MHD = "ID"

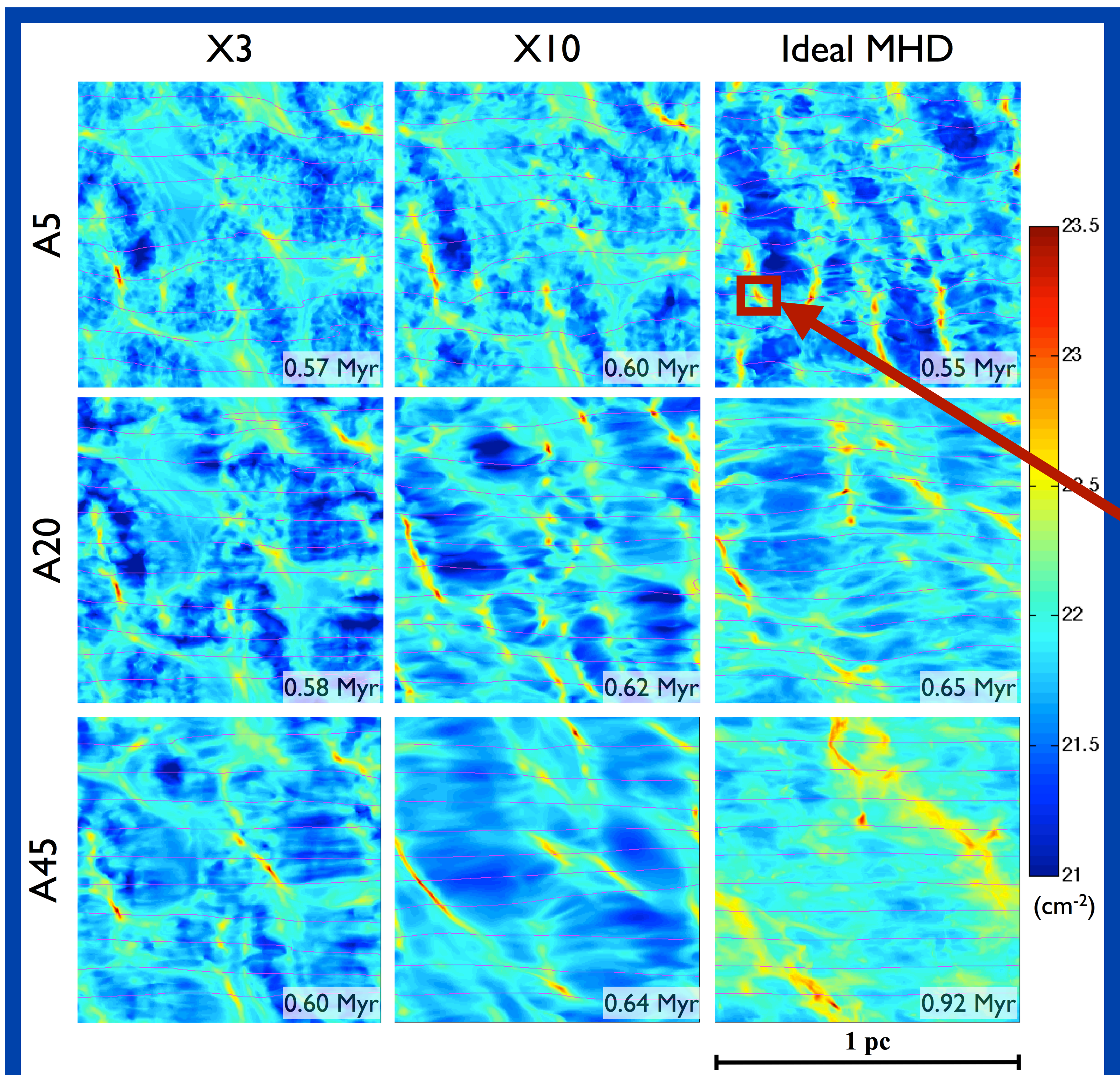
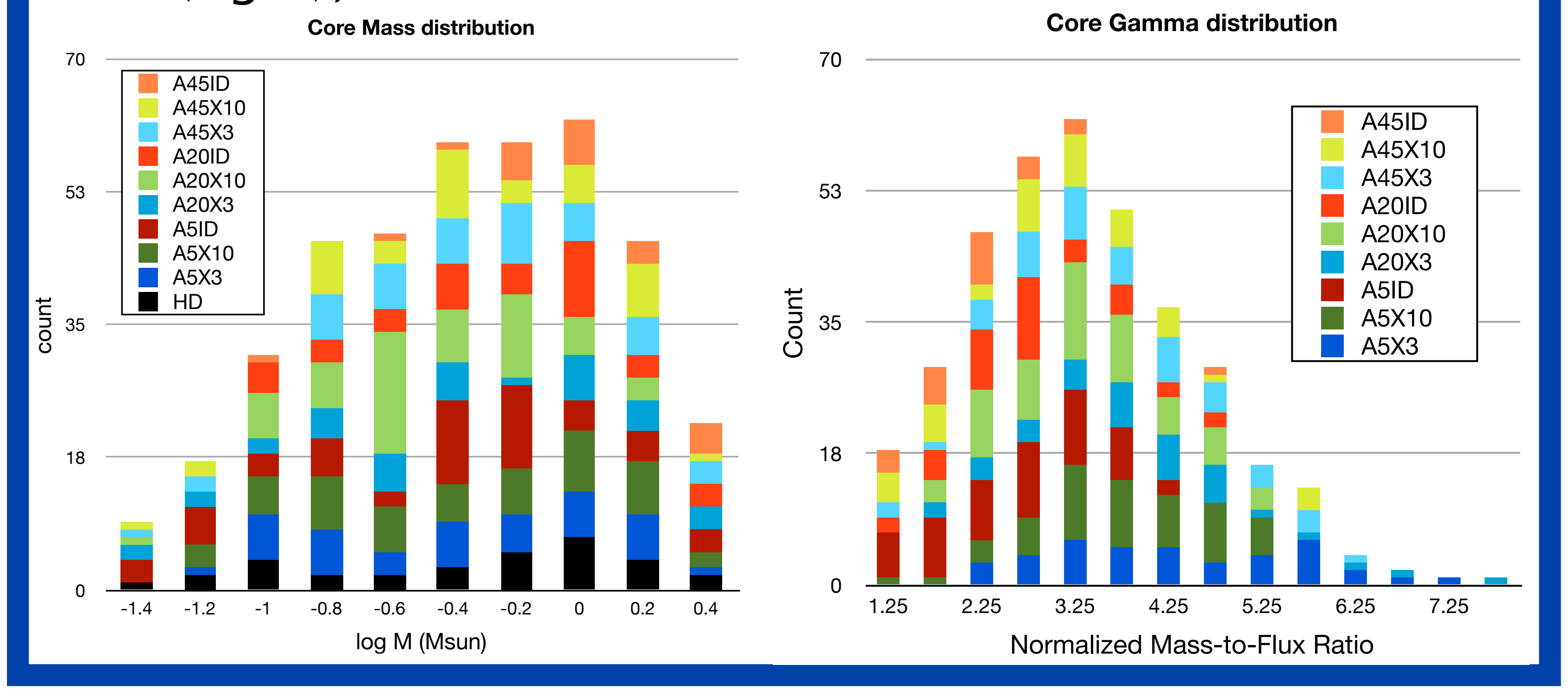


Fig 1: The "spectrum" of column density (color map) and magnetic field (pink lines) structure in the shocked gas layer for varying magnetization and ionization, at the time that maximum density reached 10^7 cm^{-3}.

Fig 2: Distributions of core mass (left) and mass-to-flux ratio (right), from all models combined.



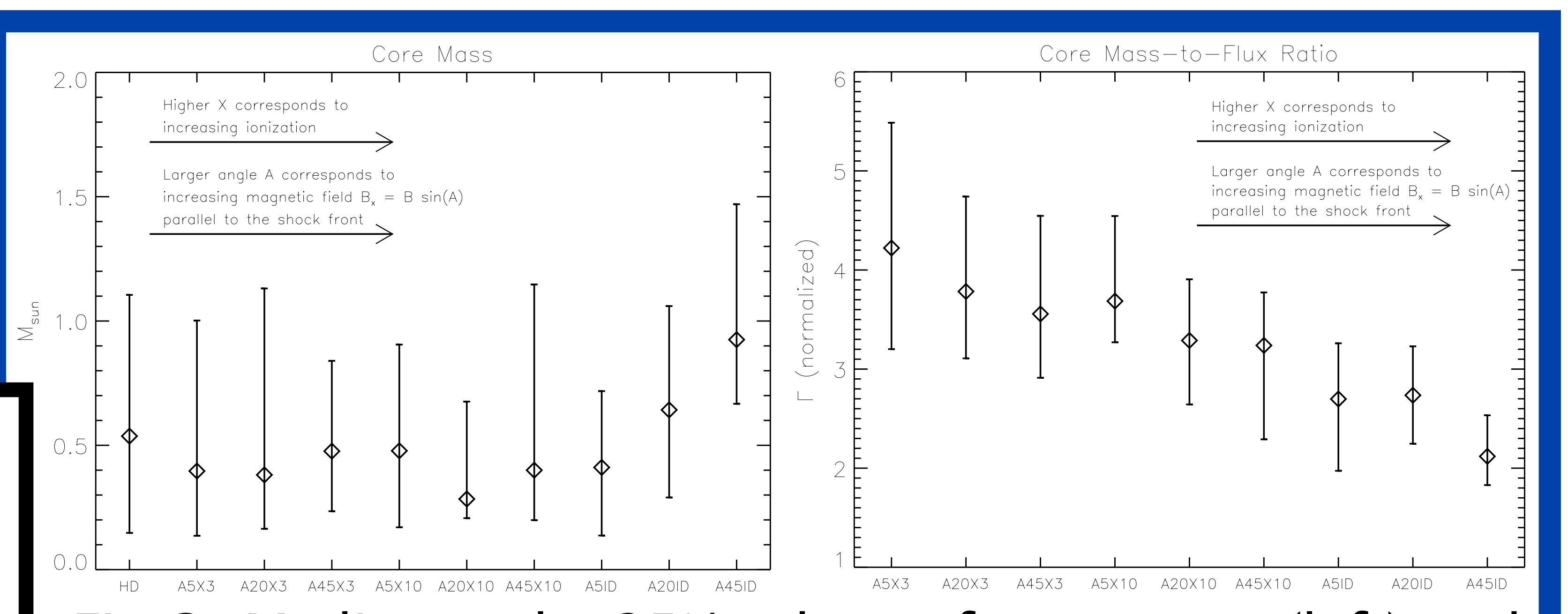


Fig 3: Median and ±25% values of core mass (left) and mass-to-flux ratio (right) of different models.

Results

- Cores form in models with converging velocity either nearly aligned with the magnetic field (small angle A) or highly oblique (large A), and for all levels of AD (Fig 1)
- Cores have masses and normalized mass-to-magnetic flux ratios $\Gamma = (M/\Phi)(2\pi\sqrt{G})$ similar to observed values (Fig 2)
- Core masses are similar, independent of the angle between converging flow and magnetic field, and the level of ionization (Fig 3a)
- Mass-to-flux ratios relative to the critical value are $\Gamma > 2$ for all simulations (Fig 3b), including large obliquity and perfect ionization (A45ID) models. Γ secularly increases for low ionization, reaching ~ 4 for X = 3.

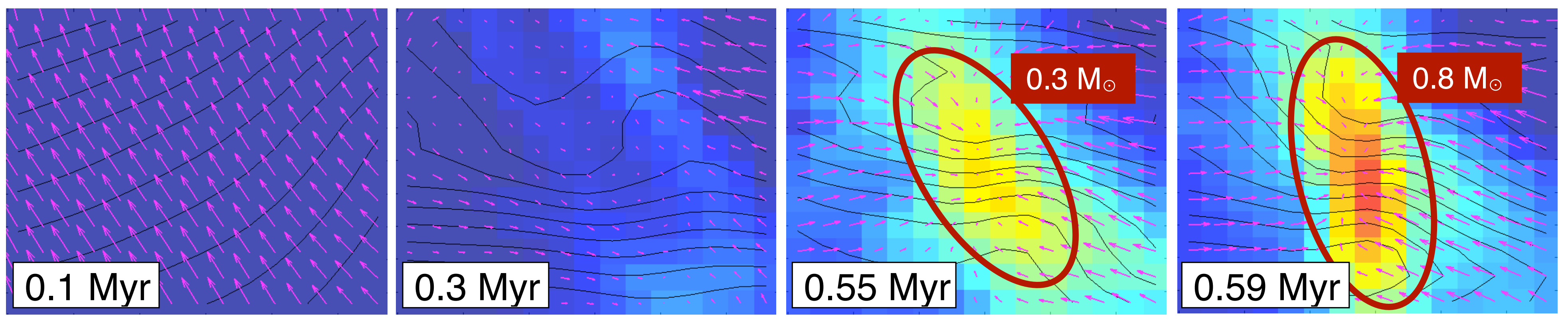


Fig 4: Magnetic field (black lines) and gas velocity (pink arrows) over column density (color map) around a core at different time.

Core Formation

- Shocks created by converging flows amplify the magnetic field and tend to align it parallel to the shock front
- In strongly magnetized post-shock regions, dense cores form anisotropically. Flows that are primarily along the magnetic field concentrate the gas, until it becomes self-gravitating (Fig 1 & 4)