# Increasing mass-to-flux ratio from the dense core to the protostellar envelope around the Class 0 protostar HH211

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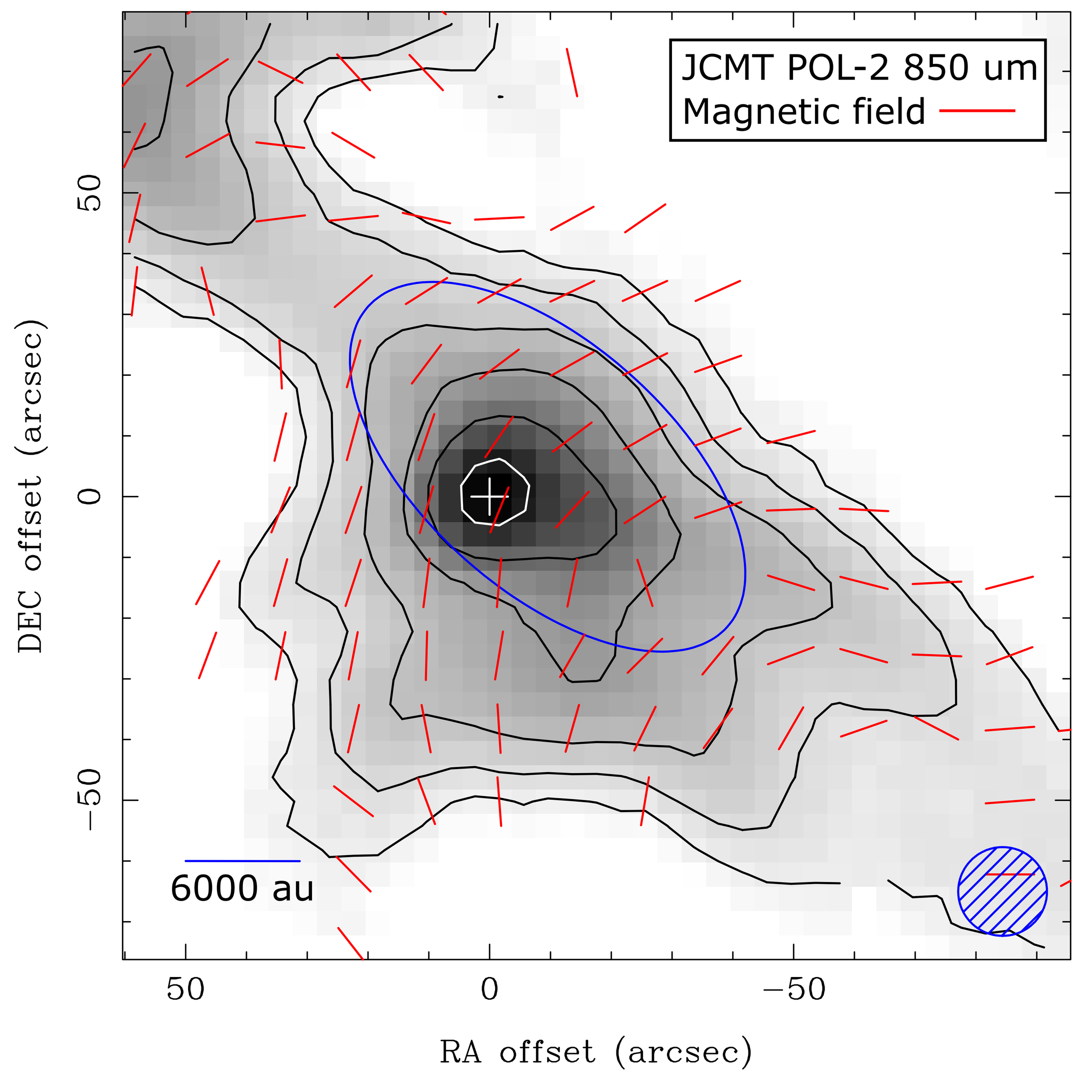
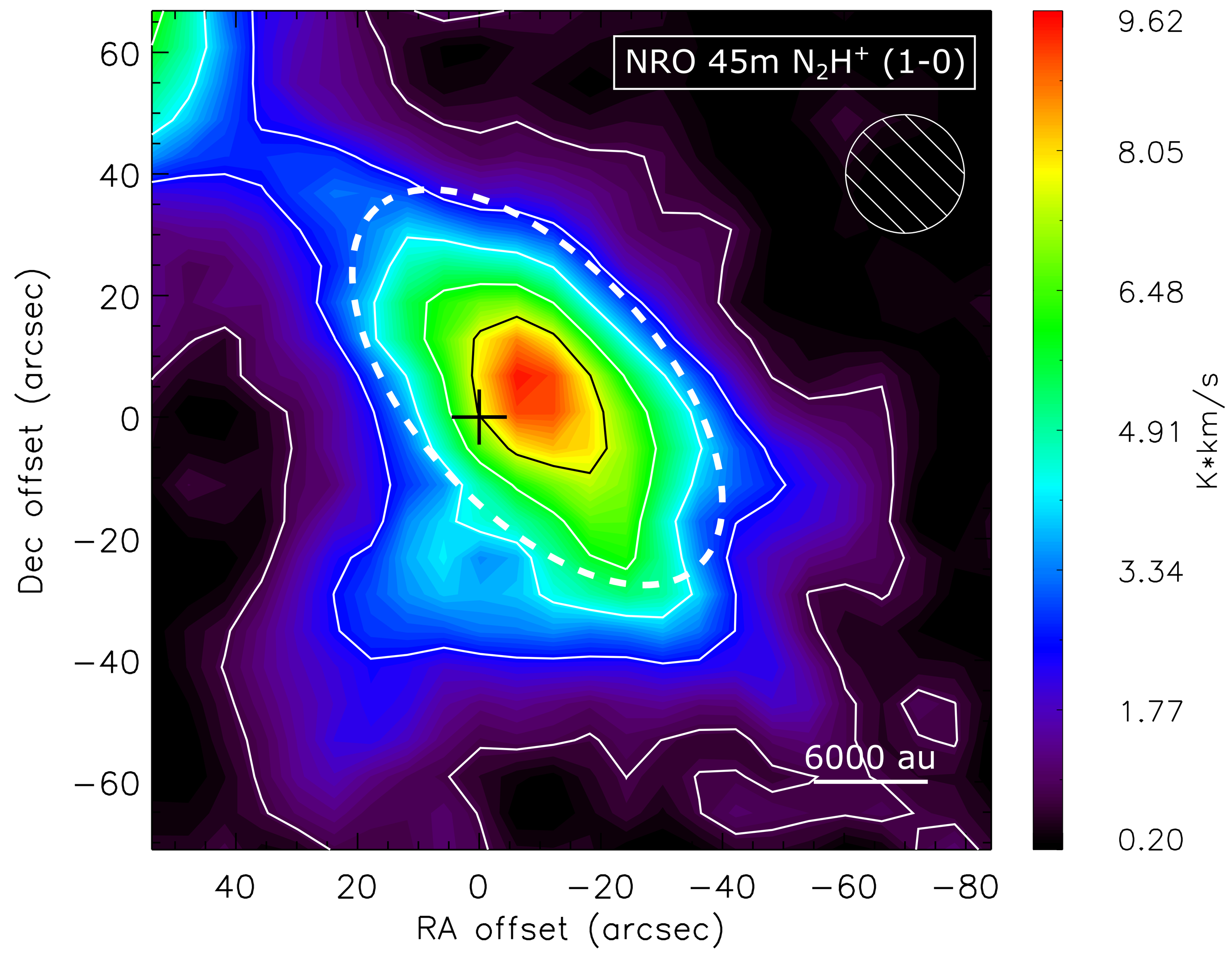
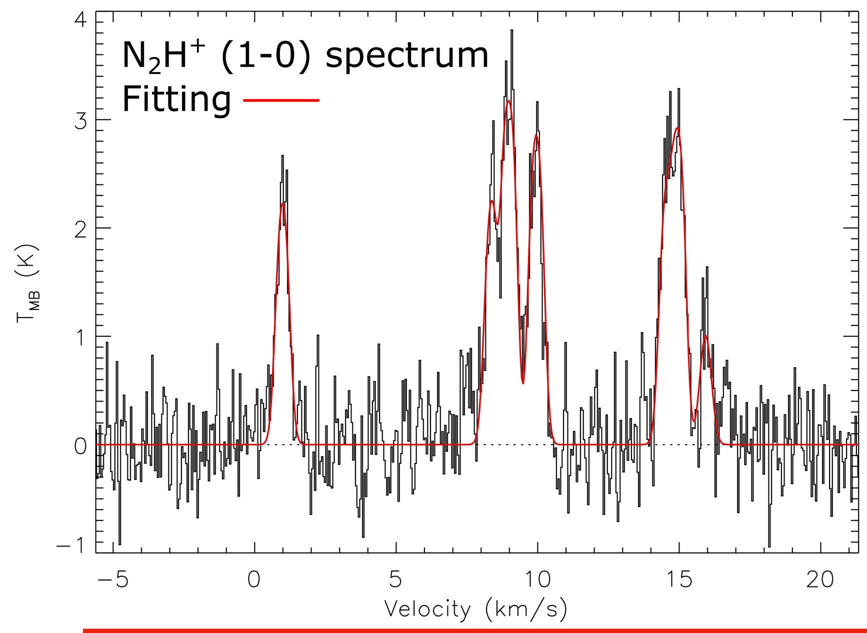
**Abstract.** To study the transportation of magnetic flux from large to small scales in protostellar sources, we estimate the magnetic field strengths in the dense core on a 0.1 pc scale and in the protostellar envelope on a 600 au scale around the Class 0 protostar HH211 with the single-dish and ALMA observations. Our result suggests that from 0.1 pc to 600 au scales, the magnetic field strength and mass-to-flux ratio increase by at least a factor of three. This hints at efficient ambipolar diffusion in the infalling protostellar envelope in HH211, enabling the magnetic fields to decouple from the matter.

## Magnetic field strength in the dense core on a 0.1 pc scale

We measure the temperature using the Herschel GBS data[1], the line width using the NRO 45m $N_2H^+$ (1-0) data, the density using the JCMT 850 um data, and the angular dispersion of the magnetic fields using the JCMT POL-2 data. Then the magnetic field strength ($B_{pos}$) and mass-to-flux ratio ($\lambda$) are estimated with the the Davis–Chandrasekhar–Fermi method[2,3].



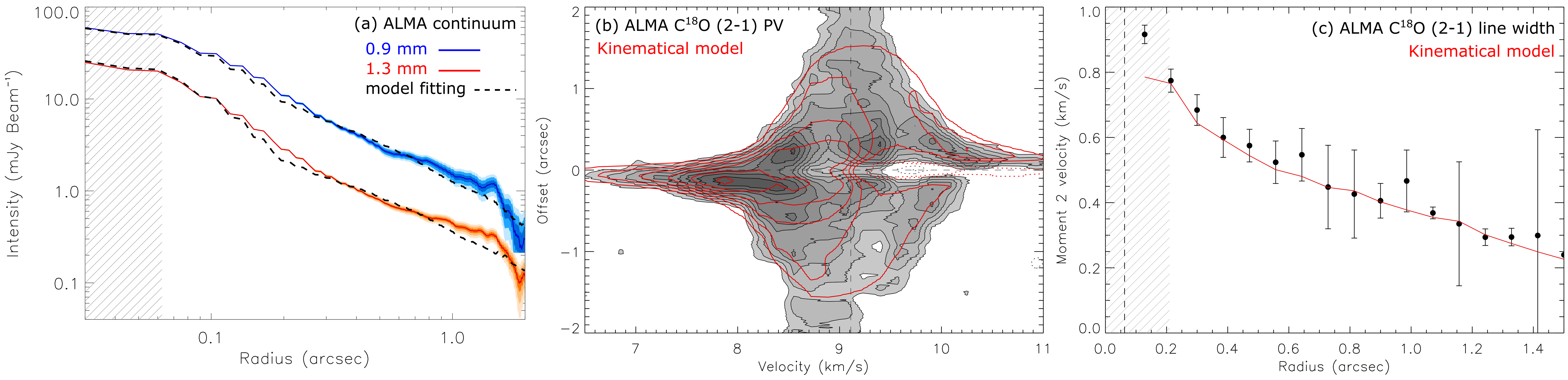




$$B_{pos} = \xi \sqrt{4\pi\rho}\frac{\delta V_{nt}}{\delta \theta_B} \sim 40\text{–}107 \text{ uG}$$

$$\lambda = 2\pi\sqrt{G}\frac{\Sigma}{B_{pos}} \sim 1.2\text{—}3.7$$

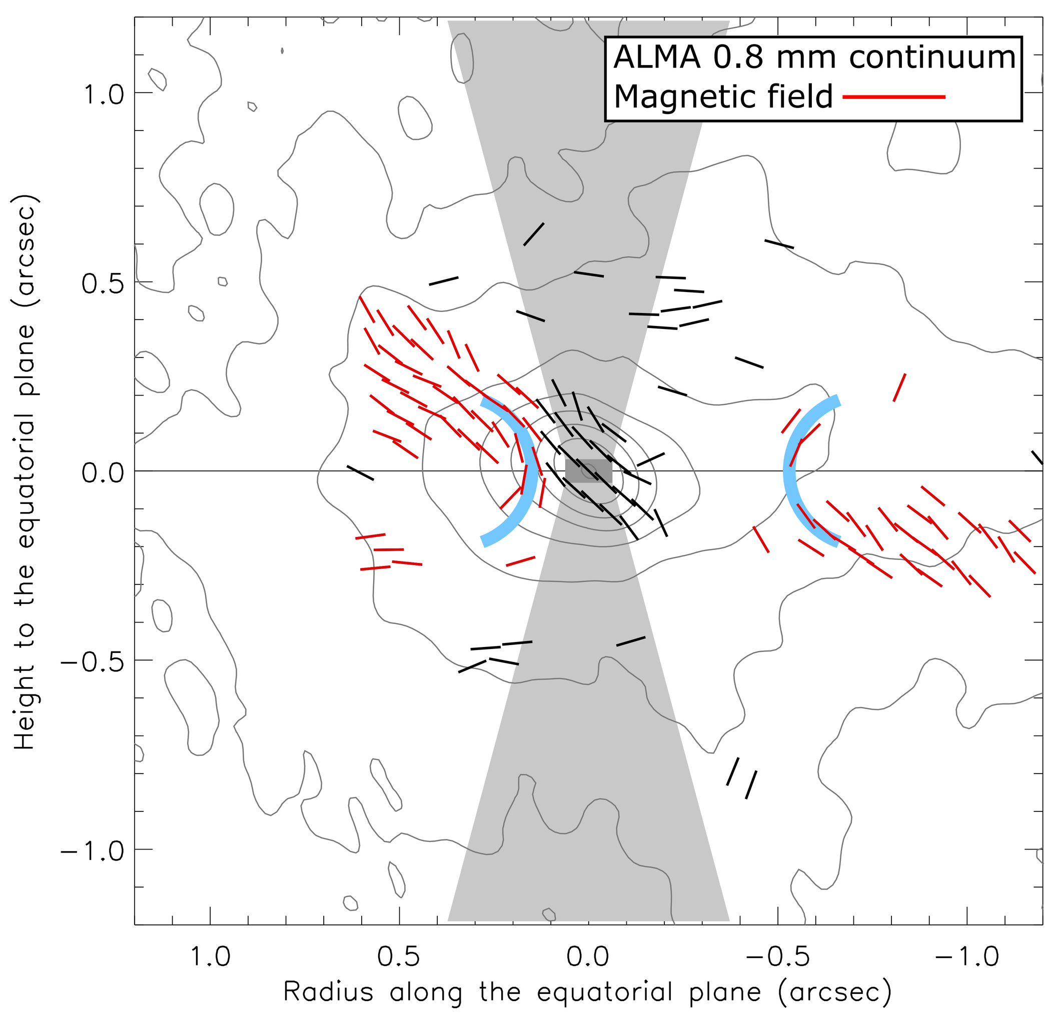
## Physical conditions and kinematics in the protostellar envelope on a 600 pc scale

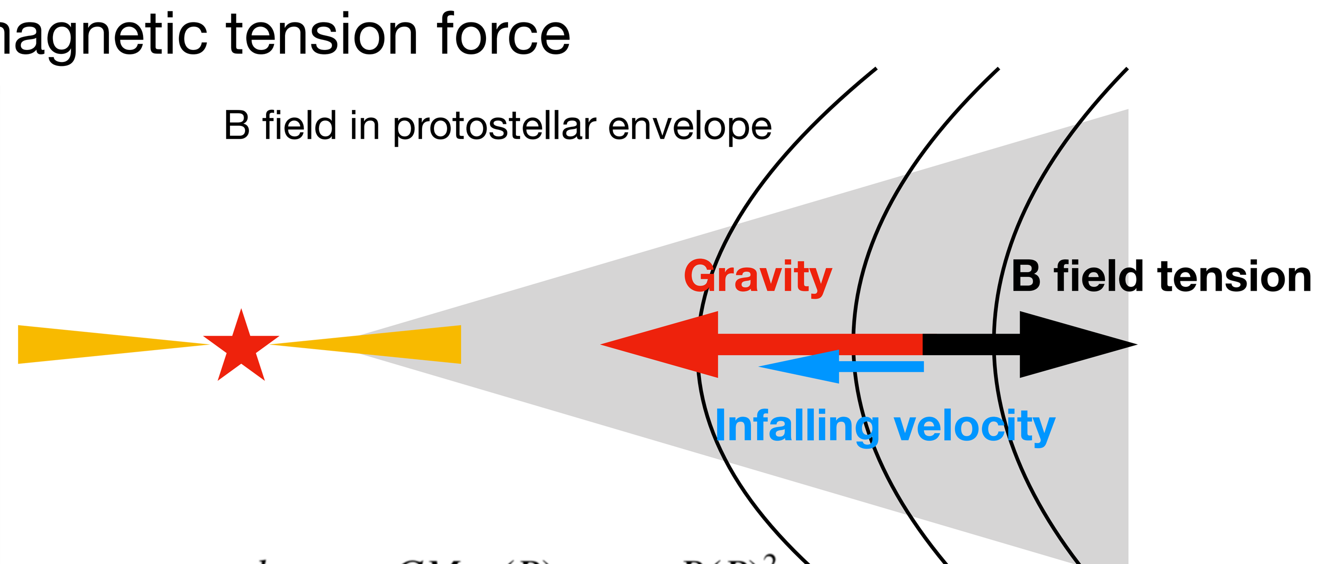
We measure the radial profiles of density, temperature, and infalling and rotational velocities of the protostellar envelope by fitting the ALMA 0.9 and 1.3 mm continuum and $C^{18}O$ (2-1) data in the visibility domain with a disk+envelope model and radiative transfer calculations. The comparisons between the model and observed data (radial profiles along the major axis) are shown below.




## Magnetic field strength in the protostellar envelope

We measure the curvature of the magnetic fields in the protostellar envelope using the ALMA polarization data at 1.3 mm. Together with the density and infalling velocity profiles measured above and the central stellar mass of 0.08 $M_{sun}$ measured from the disk rotation[4], we estimate the magnetic field strength from the balance between the gravity and magnetic tension force



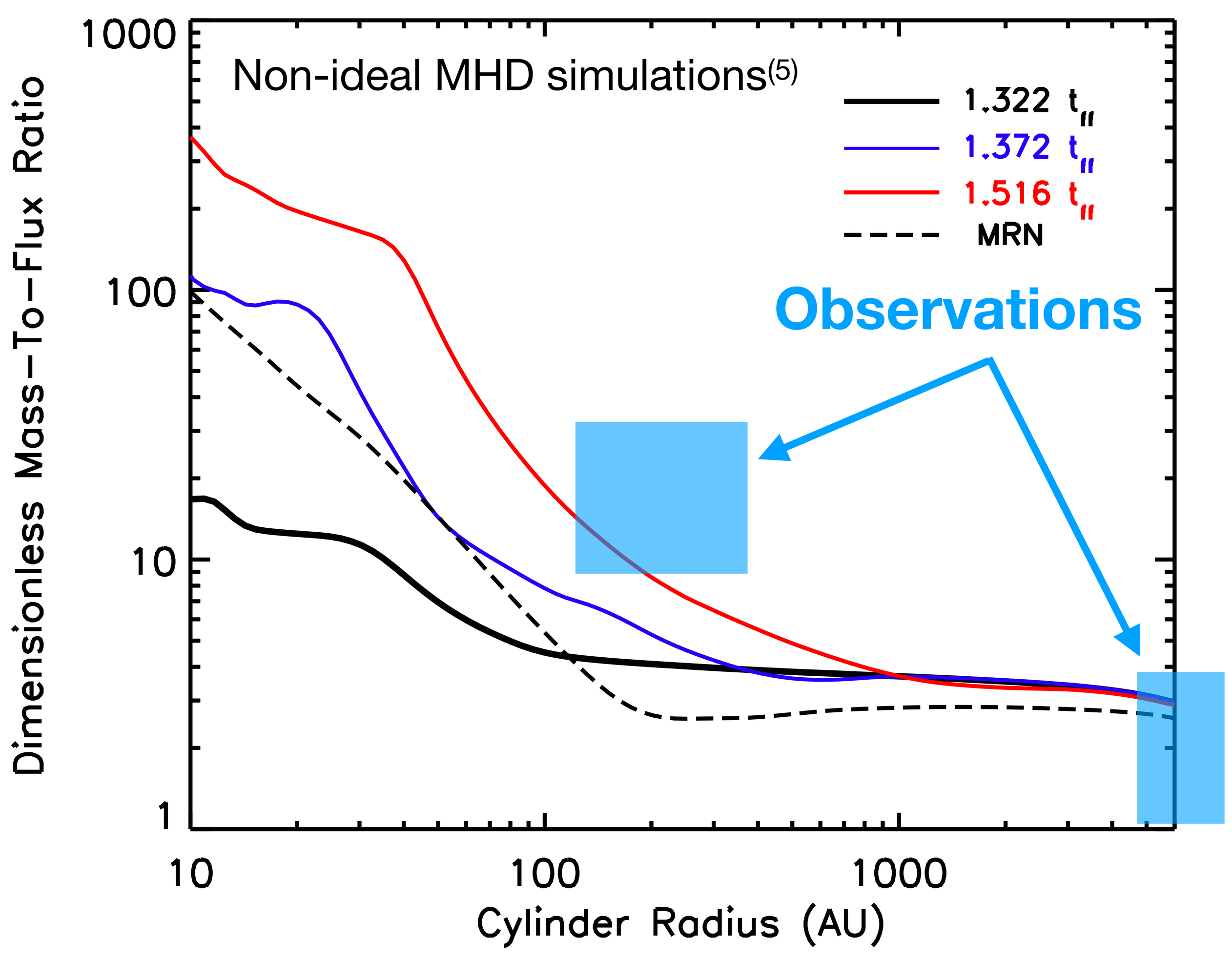

$$\rho(R)v_r(R)\frac{dv_r}{dR} = -\frac{GM_*\rho(R)}{R^2} + \frac{B(R)^2}{\mu_0 R_{curv}(R)}$$

Infalling velocity — Gravity — B field tension

$$B \sim 0.3\text{—}1.2 \text{ mG}$$
$$\lambda \sim 9.1\text{—}32.3$$

## Conclusion

Our results of the increasing mass-to-flux ratio are consistent with the expectation from the non-ideal MHD simulation with efficient ambipolar diffusion[5], where the magnetic field is partially decoupled from the matter in the infalling protostellar envelope (solid lines).




**Reference.** [1]Zari et al. 2016, A&A, 587, A106; [2]Davis 1951, Physical Review, 81, 890; [3]Chandrasekhar & Fermi 1953, ApJ, 118, 113; [4]Lee et al. 2018, ApJ, 863, 94; [5]Zhao et al. 2018, MNRAS, 473, 4868