Effects on polarization properties of radio galaxies by magnetized AGN jets

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Abstract

Radio galaxies are a subtype of active galactic nuclei (AGN) generated by supermassive black hole jets. Polarization measurements of the radio lobes could potentially probe the magnetic field geometry and initial magnetization of the jets. Previous polarization observations have found magnetic field aligned with the jet axis; however, the connection between the magnetization of the jets and the observed polarized emission remains poorly understood. In this research, we use 3D magnetohydrodynamic code GAMER-2 to simulate magnetized AGN jets with a toroidal field geometry within an isolated cluster. We perform simulations with different jet magnetization, and study their difference in the evolution of field geometry within the lobes, and polarization and rotation measure maps.

Introduction - Polarization in FR II Galaxies

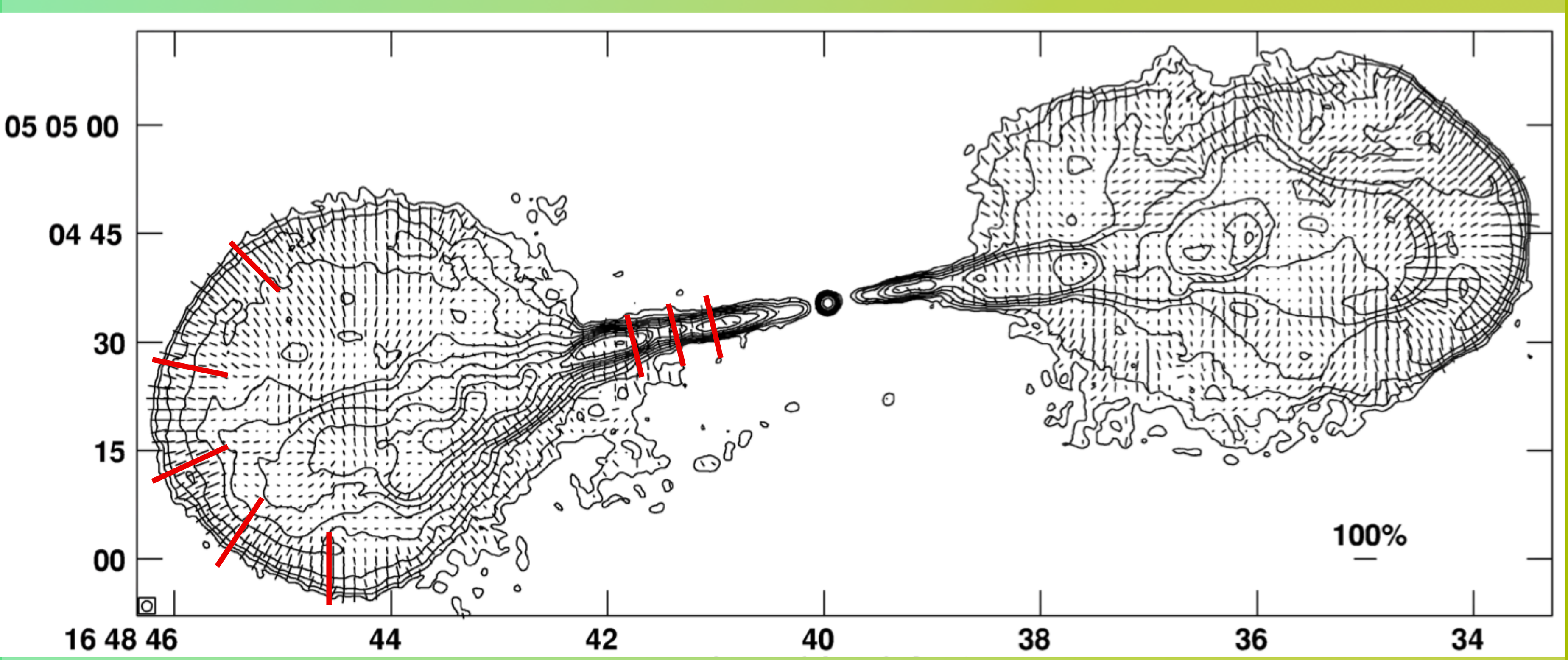

Figure 1: The 8440 MHz radio map of Her A (Gizani and Leahy 2003). The E-vectors suggest the magnetic field parallel to the edge around the lobe, while parallel to the jets axis near the origin.

- Simulations show that magnetic field in AGN jet material can convert into thermal / kinetic energy
- Polarization measurement on radio galaxies implies the magnetic field aligned the AGN jet axis
- The relation between magnetic field in jet material and polarization signal is still not clear

Result - Magnetic Field Magnitude

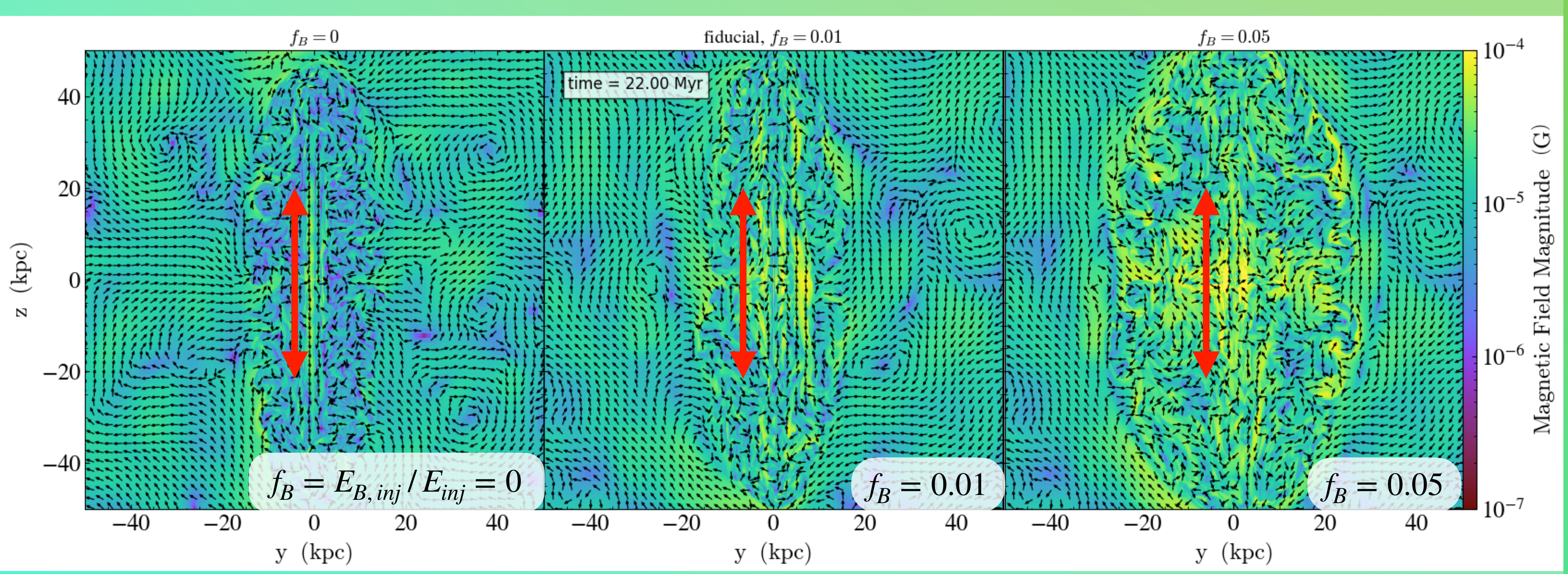

Figure 4: The magnetic field magnitude over-plotted with the direction vector.

- The amplification appears even without the injection of magnetic field
- The direction of magnetic field around central region is aligned with the jet axis; weak alignment is found at the lobe edge

The Jet Injection Model

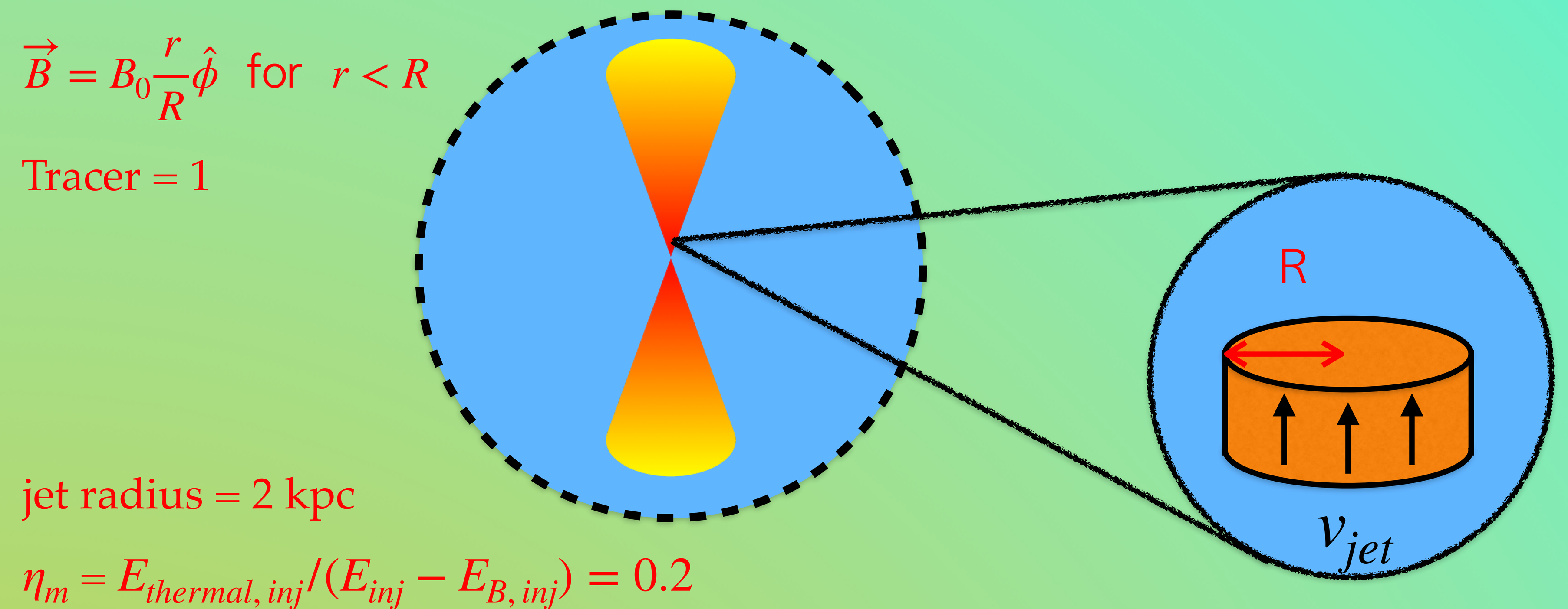

Figure 2: The picture of the injected magnetic field. Inside the radius A, the magnetic field magnitude is proportional to the radius; between radius A and R, it is proportional to inverse radius.

- We utilized the MHD code GAMER-2
- The jets are injected in an isolated Perseus-like galaxy cluster
- $P_{jet} = 5 \times 10^{45}\, erg\, s^{-1}$, continuous injection
- Toroidal jet magnetic field, $f_B = E_{B,inj}/E_{inj} = 0, 0.01, or\ 0.05$
- Tracer fluid = 1 in injection region, tracer $\geq 10^{-4}$ as jet material
- Initial ambient B-field is tangled with $\beta = 100$

Result - Projected Faraday Rotation

$$RM\,(rad\,m^{-2}) = 0.812 \int_{source}^{telescope} \frac{n_e}{cm^{-3}} \frac{B_{LOS}}{\mu G} \frac{dl}{pc}$$

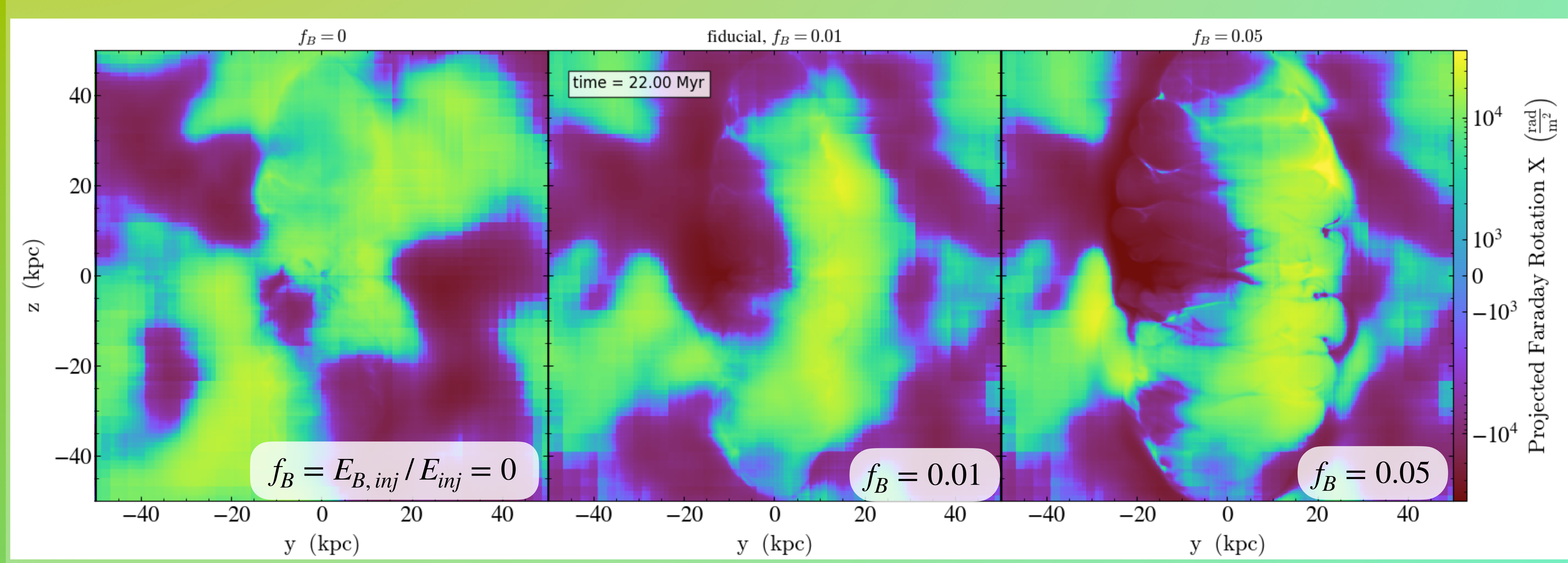

Figure 3: Faraday rotation projected through the x-axis.

- Weakly magnetized jets don't make much difference on the projected Faraday rotation map
- More magnetized jets make rotation measure (RM) amplification at the edge of the lobe region on the map

Future Works

- Generate synthetic polarization maps using polarized radiative transfer code by Chan et al. 2019
- Study the effect of jet magnetization and ambient B-field

References

- Nectaria A. B. Gizani & J. P. Leahy, 2003, MNRAS, 342, 399
- Jennifer Y. H. Chan, et al., 2019, MNRAS, 490, 1697