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Helical Magnetic Fields in AGN Jets

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Abstract. We establish a simple model to describe the helical magnetic fields in AGN jets projected on the sky plane and the line-of-sight. This kind of profile has been detected in the polarimetric VLBI observation of many blazar objects, suggesting the existence of helical magnetic fields in these sources.

Key words. Galaxies: jet—magnetic fields—polarization.

1. Introduction

Theoretical model suggests that the magnetic fields in AGN jets are wound up by rotating accretion disk or ergosphere of the central black hole, driving the jet formation, acceleration and collimation (Meier *et al.* 2001). Due to polarization of the synchrotron emission in jets, it is possible to derive the projected magnetic structure on the sky plane, while the line-of-sight component can be constrained through the Faraday rotation RM $\propto \int N(s)B(s) \cdot \mathrm{d}s$, where RM, $N(s)$, $B(s)$ and s are rotation measure, number density, magnetic field and distance along the line-of-sight, respectively (Chen *et al.* 2010). Based on the RM distribution across the jet measured by multi-frequency polarimetric VLBI observations, the magnetic helicity can be tested. In the following, we will construct a coordinate system to investigate how the helical magnetic fields manifest on the sky plane and in the line-of-sight.

2. Simplified helical magnetic model and its application in AGN jets

Assume a source with jet axis (SZ) lies at an angle θ to the line-of-sight (SO) and a helical magnetic field of amplitude B and its axis coincident to the jet axis (the left panel of Fig. 1), the magnetic field components projected on the sky plane B_{sky} (namely the magnetic distribution in VLBI image) and that along the line-of-sight B_{los} at any position across the jet which can be expressed as follows:

$$\begin{aligned} B_{\text{sky}} &= (B\sin\alpha\cos\beta)_{\perp} + (B\sin\alpha\sin\beta\cos\theta + B\cos\alpha\sin\theta)_{\parallel}, \\ B_{\text{los}} &= B(\cos\alpha\cos\theta - \sin\alpha\sin\beta\sin\theta), \end{aligned} \tag{1}$$

where α is the pitch angle, β is the angle between the transverse magnetic component and the normal of the SZ-SO plane. The angle β varies continuously across the

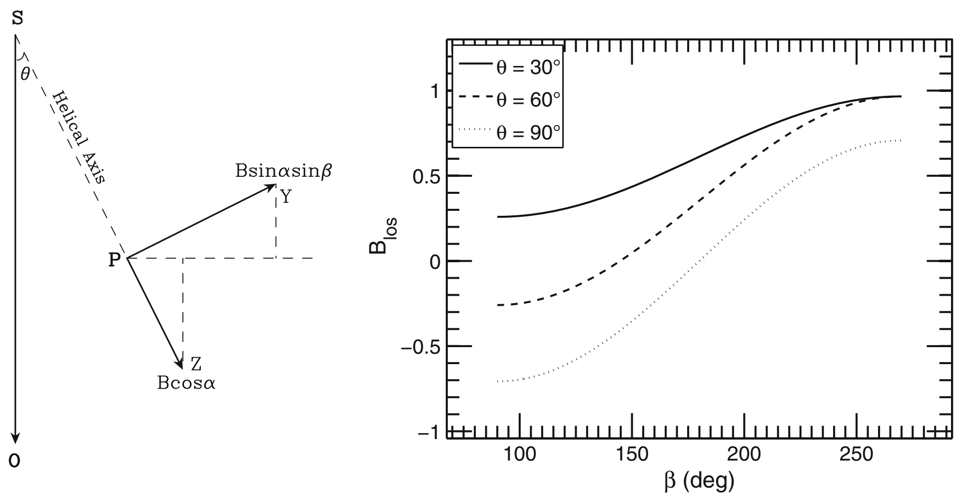

Figure 1. *Left*: A magnetic component sketch in the plane of SO and jet axis; *Right*: $B_{\rm los}$ varies with β with viewing angles taken as 30, 60 and 90°, and a pitch angle of 45°.

jet in the VLBI image, with β at positions of jet axis and jet edges having values of even and odd times of $\pi/2$, and odd number times of $\pi/2$. The $B_{\rm sky}$ may be further subdivided into components parallel (with subscript $\|$) and perpendicular (with subscript $\perp$) to the jet axis, as is expressed in eq. (1).

Based on the above equation, the magnetic field is expected to be parallel to the jet axis at both jet edges, and oblique at jet axis, which is confirmed by polarimetric VLBI observations in many sources such as 0745 + 241, 1418 + 546, etc. (Pushkarev *et al.* 2005). Assume that the Faraday rotation is simply dependent on $B_{\rm los}$, RM gradient is supposed to be present across the jet, which, as an example, is shown in the right panel of Fig. 1. Such transverse RM gradient has been detected in many sources (e.g., 3C273 in Zavala & Taylor 2005), which implies the existence of helical magnetic fields in the jets of these sources.

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