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ARE BIPOLAR JETS PRECESSING?

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No one has drawn attention as to whether bipolar jets precess or not. We examine here the possibility of precession of bipolar jets from a theoretical point of view (Fukue and Yokoo 1986).

We first characterize various models proposed for bipolar jets in the light of precession. That is, can they admit precession? If they can, how long is a precessional period P?

(a) Beam (twin-exhaust) model (Blandford and Rees 1974, Königl 1982): difficult to precess since the scale of a confining ellipsoidal cloud is too large.

(b) Interaction between a stellar wind and a high density disk (Sakashita *et al.* 1985, Okuda and Ikeuchi 1986): difficult to suppose precession because of their nonsteady nature.

(c) Hydrodynamical wind-type jets from an accretion torus (Fukue 1982,1983, Calvani and Nobili 1983, Ferrari *et al.*1984). Precession is possible in two ways: (i) the forced precession of the torus around a proto star of mass M by a companion of mass m is given by

$$P = -4.23\ 10^{2}\ \mathrm{yr}\ M_{10}^{\frac{1}{2}}\ m_{10}^{-1}(1+m/M)\, a_{10\,\mathrm{AU}}^{\ 3}\, r_{\mathrm{AU}}^{-3/2}\ (\cos\alpha)^{-1},$$

where the unit of mass is ten solar masses, a(separation) and r(torus' radius) are respectively measured in units of 10AU and 1AU, and α is an angle between the torus' equatorial plane and the binary orbital plane; this period lies typically within 10-10^4 yr. (ii) The orbital precession of the torus around the proto star is given by

$$P = -2.45\ 10^{4}\ \mathrm{yr}\ M_{10}^{-\frac{1}{2}}\ R_{10}^{-2}\, r_{\mathrm{AU}}^{7/2}\ (\varepsilon\cos\beta/0.01)^{-1},$$

where R is the radius of the proto star in units of 10 $R_\odot$, ε roughly means its ellipticity, β is an angle between the star's equatorial plane and the torus plane,and P = 1 ∿ 10^4 yr (r = 0.1AU ∿ 1AU).

(d) A magnetic field anchored on the star (Draine 1983). Precession is possible in two ways: (i) the free precession, which yields a rather short period, of the proto star is given by

$$P = -1.38\ \mathrm{yr}\ R_{10}\, V_{100}^{\ -1}(\varepsilon\cos\gamma/0.01)^{-1}\ ,$$

where V is the star's rotation speed in units of 100 km/s, and γ is an angle between the rotational axis and the figure axis. (ii) The forced precession of the central star by the companion is given by

$$P = -4.84\ 10^5\ \mathrm{yr}\ m_{10}{}^{-1}(1+m/M)R_{10}{}^{-1}V_{100}\, a_{10\,\mathrm{AU}}^3\ (\varepsilon \cos \delta/0.01)^{-1},$$

where δ is an angle between the star's equatorial plane and the binary orbital plane. This gives a rather long period.

(e) A magnetic field anchored on the disk (Blandford and Payne 1982, Pudritz and Norman 1983, Uchida and Shibata 1985) gives essentially the same results as (c) on precession.

TABLE I. Observational Appearance of Precession for Various Models*

		P >> T†	P ∿ T	P << T
Expected Properties		Undetectable	S(Z)-Shape, Wiggle, Corkscrew-pattern	Periodicity of P, Collimation Angle ∿ Precession Angle, Hollow Cylinder
Model	(a)	/	/	/
	(b)	/	/	/
	(c)-i	Δ	O	O
	(c)-ii	O	O	O
	(d)-i	x	x	O
	(d)-ii	O	Δ	x
	(e)-i	Δ	O	O
	(e)-ii	O	O	O

* / Not predicted, x not expected, Δ unknown, O expected.
† T: a typical age of bipolar jets $\sim 10^4$ yr.

We finally note the case of L723 (Goldsmith *et al.* 1984, Hayashi *et al.* in this volume). We can easily see the Z-shape structure in the map of L723. If this means precession, then P ∿ T. Thus precession of the torus/disk surrounding the proto star will be responsible for it, and models (c) or (e) might apply. Further observations are desired to confirm precession -the clue of astrophysical jets- in bipolar jets.

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A HELICAL MAGNETIC FIELD MODEL OF THE JETS

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ABSTRACT. A hydromagnetic model is presented for the bipolar flow of molecular gas from newborn stars and for the radio jet emerging out of active galactic nuclei. We assume a tightly-twisted helical magnetic field in the jet, which can collimate and accelerate the gas along the jet axis. The Lorentz force is also shown to rotate the gas around it.

1. ACCELERATION AND COLLIMATION

When the magnetic field in the jet is tightly-twisted and the gas moves mostly along it, we have

$$|B_\phi| \gg |B_r|, |B_\theta|, \qquad (1)$$

$$|u| \gg |v|, |w| \quad . \qquad (2)$$

Assuming a steady and axisymmetric structure, we can derive the following equations from the cold MHD equations by using the extreme-inequality conditions (1) and (2)

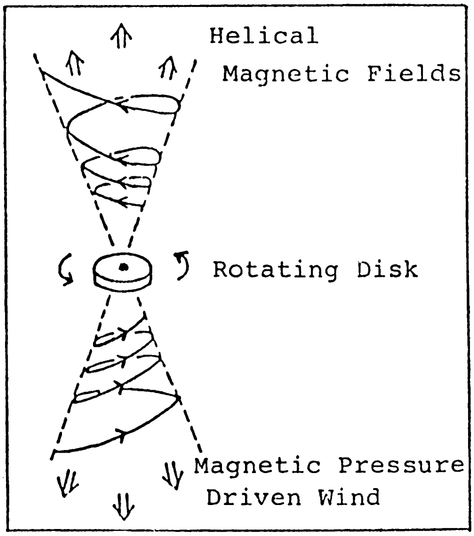

Fig. 1