HYDRODYNAMICAL SIMULATION OF BIPOLAR FLOWS

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High velocity bipolar gas flows are observed very frequently towards regions of star formation, and it has been conjectured that almost every star of mass larger than 1 $M_{\odot}$ could undergo a phase of mass ejection during its formation (see e.g. Lada 1985). To explain the collimation of gas flows at interstellar scale, models have been proposed based on a stellar wind or violent isotropic ejection of matter by the protostar, that is pressure collimated by the molecular cloud in which it is embedded (Cantõ 1980, Königl 1982). In some cases, a molecular disk is observed perpendicular to the direction of the flow, but it is not quite sufficient to collimate it, see for example the high resolution CS observations of Takano *et al.* (1984) and Kawabe *et al.* (1984). Also, collimation occurs at a distance smaller than 3×10^{13} m, according to the optical emission line observations of Mundt and Fried (1983).

In another class of models, the ejection of matter is anisotropic near the surface of the protostar, and the energy is taken out of the rotation of an accretion disk. This is the case for hydromagnetic models (cf.Pudritz and Norman 1983, Ushida and Shibata 1987), but also for purely hydrodynamic mechanisms (cf. Torbett 1984): the accreted gas spirals in towards the star, with a rotation velocity nearly Keplerian, but near the surface, it must be drastically braked. The energy dissipated by viscosity heats up a thin boundary layer, which behaves adiabatically, due to the large density and high optical depth.The vertical pressure force due to the high temperature gradient accelerates the gas, which in some circumstances can reach the escape velocity, before getting out of the layer and then loose all its energy in radiation.

We have indeed found evidence for such an ejection of gas with hydrodynamical simulations using a Lagrangian description of the fluid of the accretion disk (finite size particle methods without grid, as described by Gingold and Monaghan 1982). This enables us to determine the critical values of the protostar mass and rate of mass accretion for the ejection to occur in the boundary layer.

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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

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