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HERBIG-HARO OBJECTS FROM ORBITING SOURCES

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The wiggles detected in HH outflows can be related, in a few cases, to the orbital motion of a binary stellar system. For these outflows it is possible to calculate the mass of the jet source and the orbital parameters using observational measurements (i.e., the opening angle of the wiggling jet pattern, the separation between successive wiggles, the jet velocity and the orientation of the jet with respect to the plane of the sky). An application to a few real cases will be presented.

The precession and the orbital motion are related physical phenomena. The existence of a precession implicitly indicates the existence of an interaction between at least two bodies orbiting around a baricenter. In the case of stellar outflows the wiggles observed in some of the outflows from YSOs were interpreted by a few authors as originated by the precession motion (Raga et al. 2001; Raga et al. 2000a; Lim 2001; de Gouveia Dal Pino & Benz 1993).

In this scenario, one has to suppose that the sources of the jets are binary or multiple systems and that the tidal forces of such systems induce the precession of a circumstellar disk that is not parallel to the orbit plane. In this case, the temporal scales of the wiggles are of the same order of magnitude as the precession period $\tau_{\rm p}$.

Here, we study the problem of a jet ejected in a time-independent direction from a source that is in an orbit around a binary companion with the idea of investigating the conditions in which the wiggles can be produced by the orbital motion and not by the precession. This study is based on the fundamental idea that the wiggles generated by the precession and the orbital motion coexist but that the temporal scale of the observed wiggles are sometimes of the same order of magnitude as the period $\tau_{\rm o}$ of an orbital motion ($\tau_{\rm o} \sim 9$ to $100\,{\rm yr}$) and not of the period $\tau_{\rm p}$ of a precession motion ($\tau_{\rm p} \sim 90$ to $1000\,{\rm yr}$). The precession period $\tau_{\rm p}$ is generally (Terquem et al. 1999) an order of magnitude larger than $\tau_{\rm o}$.

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We calculate the analytical trajectories of a ballistic jet ejected by a source moving along a circular orbit and verify that there is good agreement between analytical solutions and numerical simulations. The latter were obtained using the 3-D hydrodynamic adaptive grid code yguazu-á (Raga et al. 2000b). Moreover, we calculate an analytical expression that relates the mass M of the star ejecting the outflow with the observational parameters of the wiggles:

$$M = 3.79\times10^{-3}\left(\frac{v_{\rm j}}{100\,{\rm km\,s^{-1}}}\right)^2\left(\frac{\alpha}{1^\circ}\right)^3 \times\left(\frac{\Delta z_{\rm p}}{100\,{\rm AU}}\right)(\cos\phi)^2 M_\odot, \quad (1)$$

where ϕ is the angle between the axis of the jet and the plane of the sky, α is the half-opening angle of the wiggling jet structure (measured on the plane of the sky), $v_{\rm j}$ is the velocity with which the source ejects the outflow and $\Delta z_{\rm p}$ is the distance between two successive maxima or minima of the locus of the jet beam projected on the sky plane (see Figure 3 in Masciadri & Raga 2002).

Applying equation (1) to the real cases DG Tauri, Serpens, and HH 46 we find that the observed wiggles are consistent with an orbital motion of a binary central source with masses and orbital parameters that appear reasonable for YSOs. For the case of a multiple (rather than binary) outflow source, it would be difficult to recover the mass of the source from the observed wiggling jet structure.

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