

## HIGH-VELOCITY HERBIG-HARO OBJECTS. THE JET INTERPRETATION

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A growing number of oppositely-directed, high-velocity Herbig-Haro objects are currently being discovered in association with young stellar objects. The high degree of collinearity manifested by the velocity vectors in some of these objects provides strong support for the interpretation of bipolar outflows in molecular clouds in terms of highly collimated, supersonic jets. Such jets might form as a result of an anisotropic pressure distribution in the cloud, which could lead to the establishment of transonic de Laval nozzles (see *Ap. J.*, 261, 115). The jets, in turn, provide a natural framework in which such issues as the energy budget for HH-objects and their location relative to (CO) emission and (optical) reflection lobes can be resolved. In this picture, the HH-objects are interpreted as dense clumps of matter which have been entrained in the jet and accelerated by the flow. The large spread in velocities often found within HH-objects which are observed with a sufficiently high resolution could be attributed to the fragmentation (and subsequent differential acceleration) of clumps which have only recently encountered the flow (or which have recently left the jet and are starting to decelerate). Alternatively, this spread in velocities could correspond to a range of velocities acquired by the clumps near the origin of the jet. In the latter interpretation, the clumps move in pressure equilibrium with the flow, and become visible only when they pass through high-pressure region in the jet, where they are compressed by shocks. The high-pressure regions could correspond to quasi-periodic oscillations in the jet radius which are included by surface instabilities. This interpretation may explain the apparent absence of gradients in the measured proper motions of high-velocity HH-objects, as well as the quasi-periodic distribution of some of these objects. Finally, it is noted that the short travel times ( $\sim 10^2$  yr) which are inferred for the outflows associated with these objects imply that the high-velocity outflows are effectively continuous on the time scale ( $\sim 10^4$  yr) of the separating CO lobes within which the HH-objects are found.

## DISCUSSION

*Bok:* 1) What fixes the direction in which the jet (or collimation) goes? Is it rotation of the protostar or its magnetic field? 2) Do you expect the embedded protostar to be rotating?

*Königl:* 1) It could probably be either of the above mechanisms, which in fact may not be unrelated. I would like to note in this connection that in a number of bipolar sources there is evidence (from polarization measurements) that the background magnetic field in the cloud is aligned roughly in the direction of the bipolar axis. 2) The specific collimation mechanism which I have described does not depend on whether the star rotates or not. I expect that in some cases the embedded protostar may still be rapidly rotating, as evidenced by observations of certain T Tauri stars.

*Peimbert:* Can you make a theoretical prediction as to the separation in seconds of arc between the [O I], [S II] emission and the X-ray or UV emission? Is it possible to observe it with present equipment?

*Königl:* As I noted, if the observed HH-objects correspond to high-pressure regions in the jet, then the shocks (Mach disks) which could accompany the compression of the jet material might give rise to X-ray emission from roughly the same region as the optical line emission (which presumably is associated with the clump shocks). This may explain, for example, the X-ray emission already reported for HH 1. In this picture, the X-ray, UV, and optical emission arise from the same general location. The same conclusion would apply if the X-rays arise from the bow shock attached to an accelerating or decelerating clump.

*Tenorio-Tagle:* HH 1 and 2 and 7-11 are moving in the plane of the sky and both spatially coincide with the maximum in CO and/or formaldehyde emission (see *Loren et al.* 1979, *Ap. J.*, 234, 932; *Evans* 1976). Could you comment on how could these possible fit in your interpretation if a decreasing density gradient is required to form the nozzle? 2) The numerical simulations of *Norman et al.*