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ON THE BOWSHOCKS ASSOCIATED WITH THE ORION PROPLYDS

F. García-Arredondo

Instituto de Física y Matemáticas, Universidad Michoacana de San Nicolás de Hidalgo, México

S. J. Arthur and W. J. Henney

Instituto de Astronomía, Universidad Nacional Autónoma de México

RESUMEN

Presentamos simulaciones numéricas hidrodinámicas de la interacción entre el flujo fotoevaporado de un disco circunestelar externamente irradiado y el viento estelar de una estrella caliente. Los resultados fueron comparados con observaciones de arcos de emisión de alta ionización encontrados en frente de algunos proplyds de la nebulosa de Orión.

ABSTRACT

We present hydrodynamic simulations of the interaction between the photoevaporating flow from an externally irradiated circumstellar disk and a stellar wind from a hot star. The results are compared with observations of the high-ionization emission arcs found in front of proplyds in the Orion nebula.

Key Words: **HYDRODYNAMICS — ISM: INDIVIDUAL(ORION NEBULA) — ISM: JETS AND OUTFLOWS**

Faint high-ionization arcs of emission are found to be associated with some of the photoevaporating circumstellar disks (proplyds) in the Orion nebula (Bally et al. 1998). These arcs are typically offset by 1–4 arcsec from the proplyds, in the direction of the ionizing star (θ^1 C Ori) and have commonly been interpreted as bowshocks, resulting from the collision between the transonic photoevaporating flow from the proplyd and the highly supersonic ($1000\,\mathrm{km\,s^{-1}}$) stellar wind from θ^1 C Ori.

In Figure 1, we compare the ram pressure of the proplyd photoevaporating flow at the bowshock, $P_{\mathrm{ram}}^{\mathrm{prop}}$, with the ram pressure of the fast wind from θ^1 C Ori, $P_{\mathrm{ram}}^{\mathrm{wind}}$. From the observed parameters of the proplyds (Table 1, data from Henney & Arthur 1998) we calculate

$$P_{\mathrm{ram}}^{\mathrm{prop}} = 1.6 \times 10^{-6} M_{\mathrm{shock}} \left(\frac{R_{\mathrm{if}}}{R_{\mathrm{shock}}}\right)^2 \left(\frac{n_{\mathrm{if}}}{10^6\,\mathrm{cm^{-3}}}\right) \left(\frac{c_0}{10\,\mathrm{km\,s^{-1}}}\right)^2 \ \mathrm{dyne}\ ,$$

where M_{shock} is the Mach number of the shock, while $P_{\mathrm{ram}}^{\mathrm{wind}}$ is given by

$$P_{\mathrm{ram}}^{\mathrm{wind}} = 2 \times 10^{-6} \left(\frac{\dot{M}_{\mathrm{wind}}}{4 \times 10^{-7} M_{\odot}\mathrm{yr^{-1}}}\right) \left(\frac{u_{\mathrm{wind}}}{1000\,\mathrm{km\,s^{-1}}}\right) \left(\frac{D}{10^{16}\,\mathrm{cm}}\right)^{-2} \ \mathrm{dyne}\ .$$

In most cases the bowshocks are consistent with ram pressure balance but for some proplyds (180–331, 177–341), the ram pressure of the proplyd flow at the bowshock is significantly higher than the fast wind ram pressure expected at their position. This could be due to the fast wind passing through a global shock at a radius of 0.03–0.05 parsecs before reaching the two proplyds, in which case they would lie in the approximately isobaric hot subsonic wind bubble.

However, hydrodynamic simulations of the proplyd interaction with a subsonic wind (Fig. 2) produce a thick shell all around the proplyd, contrary to what is observed. Further modeling is necessary to determine if this shell can subsequently be eroded by the subsonic flow. Some proplyd bowshocks show strong deviations from spherical symmetry, which in some cases may be because they lie outside the wind-swept shell and inside the flow from the principal ionization front of the nebula. In the case of 168–326, the asymmetry appears to be the result of an interaction with a binary companion. Three-dimensional modeling is required in these cases.

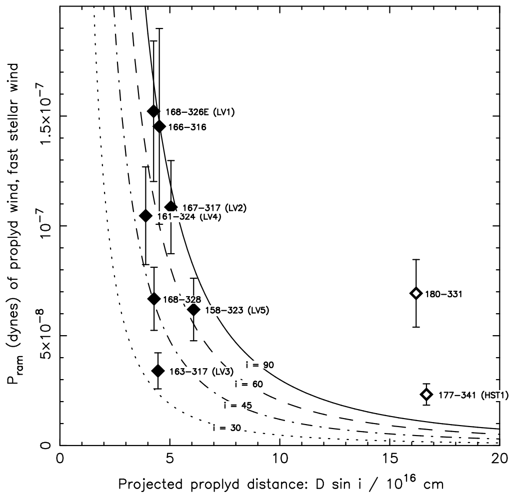

Fig. 1. The ram pressure of the proplyd photo-evaporating flow at bowshock (diamonds) compared with the ram pressure of the fast wind from θ^1 C Ori (lines) versus projected proplyd distance for various assumed inclinations, i.

TABLE 1

OBSERVED PROPERTIES OF PROPLYD SAMPLE

Proplyd	D sin $i^{(a)}$	$R_{\rm shock}{}^{(b)}$	$R_{\rm if}{}^{(b)}$	$n_{\rm if}{}^{(c)}$
161–324	3.90	66.0	3.5 ± 0.3	6.2 ± 0.34
168–326E	4.26	74.0	6.3 ± 0.6	3.5 ± 0.06
168–328	4.28	65.0	2.8 ± 0.3	6.0 ± 0.02
163–317	4.46	144.0	5.0 ± 0.6	4.7 ± 0.44
166–316	4.52	40.0	2.5 ± 0.6	6.2 ± 0.25
167–317	5.05	116.0	7.9 ± 0.3	3.9 ± 0.17
158–323	6.08	116.0	6.3 ± 0.6	3.5 ± 0.33
180–331	16.20	97.0	12.2 ± 1.2	0.73 ± 0.05
177–341	16.67	258.0	20.4 ± 1.6	0.62 ± 0.03

Units: (a) 10^{16} cm (b) 10^{14} cm (c) $10^{6}\,{\rm cm}^{-3}$

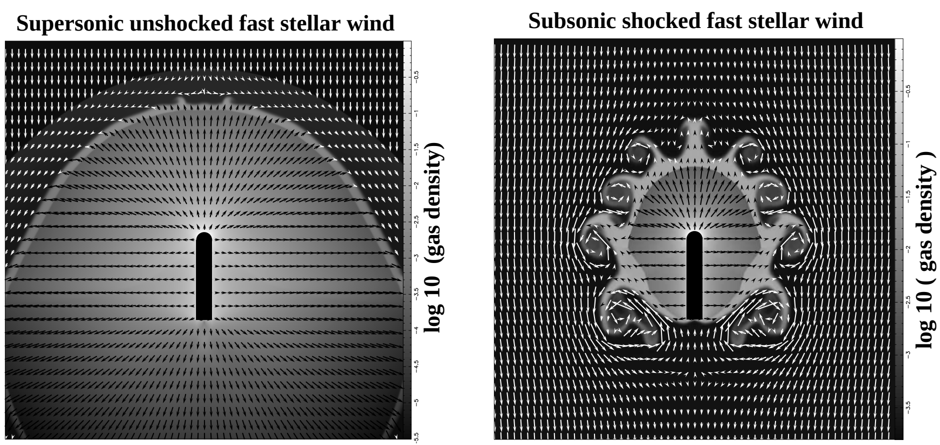

Fig. 2. Hydrodynamic simulations of the interaction between the ionized flow from a proplyd and a supersonic (left panel) or subsonic (right panel) stellar wind. Proplyd parameters match those of 167–317 (left) and 177–341 (right).The equation of state is assumed to be adiabatic ($\gamma = 5/3$) for the fast wind and quasi-isothermal ($\gamma = 1.01$) for the proplyd flow. The fast wind parameters are $\dot{M}_{\rm wind} = 10^{-7} M_{\odot} {\rm yr}^{-1}$ and $u_{\rm wind} = 1000\,{\rm km\,s}^{-1}$.

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F. García-Arredondo: IFM-UMSNH, Morelia, Michoacán, México (gaful@astrosmo.unam.mx).
S. J. Arthur and W. J. Henney: Instituto de Astronomía, UNAM, Campus Morelia, Apartado Postal 3-72, 58089 Xangari, Morelia, Michoacán, México (jane, will@astrosmo.unam.mx).

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