OBSERVATIONS OF JETS FROM YOUNG STARS

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ABSTRACT. Optical jets, and collimated outflows, are now recognized as a common phenomena associated with young stars (Mundt 1985, Strom et al. 1986). Presented here are the results of new CCD imaging and spatially resolved spectroscopy for ten such objects. Using these and previously published data on twenty known jets, we compiled a set of observational criteria describing the phenomena. From this compilation we addressed several physical questions pertaining to the nature of collimated outflows associated with young stars.

1 INTRODUCTION

Morphologically, optical collimated flows are seen as radially projected single or bipolar elongations with an observed length to width ratio of ≈10:1. The radiated flux is dominated by the strong shock induced emission lines seen in HH objects, (e.g. [OI], [NII], [SII] and Hα). There is no optical continuum observed, and it is via the line emissions that jets are detected. Surface brightnesses are in general not uniform, but instead present a patchy or knotty structure. Regions of very weak or no emission along the outflow direction are common.

Spectroscopic data indicate that collimated flows have mean radial velocities of ≈ 100 – 400 km/s. Both blue and redshifted jets are observed, indicative of their bipolar nature. Four outflows show evidence of radial velocity variations along the jet. The electron densities, from [SII] 6717/6731, range from 400-2000 cm^{-3}. There are cases (DG Tau, HH33/40) in which Ne decreases significantly along the jet.

To summarize, a jet from a young stellar object can be described by the following characteristics: bipolar optical morphology emanating from approxiamtely < 100 au from the driving source; lengths about 3×10^{17} cm; width $< 2 \times 10^{16}$ cm; radial velocity ≈100 km/s; velocity dispersion 80 km/s; Ne about 1000 cm−3; source luminosity 5-10 $L_{\odot}$; jet

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 177–178.

https://doi.org/10.1017/S0074180900156323 Published online by Cambridge University Press

and source system associated with a bipolar molecular outflow and/or a cometary reflection nebula.

2 DISCUSSION

This list of observed properties constitutes a useful definition or set of criteria for recognizing the phenomena of jets emanating from young stars. Analysis of these properties has lead us to the following general physical description and interpretation of these objects.

1. The emission line spectrum is created by shocks of $\approx 40 - 100$ km/s.
2. Bright knots probably represent the working surface of shocks.
3. The gaps of weak or no emission are probably regions of a freely expanding jet.
4. The surface brightness irregularities or knotty structures are due to internal shocks.
5. These outflows are efficient means of transporting kinetic energy over large distances, as the energy dissipation in the internal shocks is shown to be extremely small.
6. Physical parameters for a typical jet:

   v_{jet} = 200 - 400 km/s
   Mach number = 10 - 40
   N_{jet} = 20-100 hydrogen atoms cm^{-3}
   $\rho_{jet}/\rho_{ambient} = 1 - 2$
   $\dot{M}_{jet} = 0.05 - 2 \times 10^{-8} M_{\odot}/yr$
   $(L_{kin})_{jet} = .01 - 0.2 L_{\odot}$
   $2\dot{M}_{jet}/\dot{M}_{radio} = 0.1$

7. Time scales:

   statistical duration of outflow visibility: 2×10^4 years
   dynamical age of outflows : 200 - 3000 years
   age of driving sources : 10^5 years
   age of optical flow $\approx$ to the age of molecular flow.

A full report of this work will appear in the Astrophysical Journal.

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