TRACING STELLAR ACCRETION HISTORY FROM PROTOSTELLAR JETS.

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Protostellar jets and outflows represent a fundamental process in star formation. According to evolutionary models, mass accretion and ejection rates are expected to be strictly related, because a significant fraction of the infalling material is ejected by the accretion disk (see e. g. [1],[2],[3]). Especially in the early phase of protostars, the study of the jets provides fundamental clues on the formation and the evolution of the inner structure, hidden by the external envelope.

In particular, the mass flux rate derived from protostellar jets (e. g. [4,5,6]) represents an invaluable record of the stellar accretion history, since shocks trace ejecta that are progressively older with increasing distance from the source. The determination of the mass flux rate, however, requires quantitative information on both physical parameters and kinematics of the gas along the flow. In order to determine the absolute flow speed and the inclination of the flow with respect to the plane of the sky, together with spectroscopic radial velocity, also proper motion (PM) measurements of the knots are required.

To address this aim, we have collected a multi-epoch and multi-wavelength (optical and NIR) database of several Herbig Haro (HH) objects and protostellar jets, to be compared with the main driving source properties collected in the catalogue of [7]. Our database includes both imaging and spectroscopy (low and high resolution), mainly covering the optical atomic (Hα, [SII]) and infrared molecular emission (H_2). Here, we present a detailed kinematical and physical study of HH objects in Chameleon II, namely HH 52, 53, and 54. Our analysis allows us to identify the exciting sources, to derive kinematics, gas excitation and mass flux rates along the flows, that are then compared with the physical properties of the driving sources.

Observations - The observations were collected during several runs between 1987 and 2006 with different instruments at the ESO-VLT, ESO-NTT, and ESO-MPG 2.2-m telescopes. Multi-epoch deep ($\geq$1 h) narrow band images (Hα, [SII], and H_2) (7, 6, and, 6 images, respectively) allow us to derive PMs and tangential velocities at different wavelengths. By means of medium ($\mathcal{R}\sim$3000 and $\lambda\sim$6000$\div$8000 Å) and high resolution ($\mathcal{R}\sim$10000 and λ=1.64 μm) spectroscopy, we derive the radial velocities and the physical parameters of the flows.

Morphology & Proper Motions - An overview of the HH 52, 53, and 54 regions is given in Fig. 1, a colour composite of calibrated images (Hα (blue), [SII] (green), and H_2 (red)). A quick inspection shows the presence of at least two flows converging towards (and overlapping on) HH 54 (the brightest region at NE, see Fig. 1). A first outflow is oriented NNE with a position angle of $\sim$22° and a second detected outflow follows a NE direction with a position angle of $\sim$55°, grouping HH 52, 53, and 54. Moreover, our PM analysis reveals the presence of a third outflow, delineated by the three brightest knots of HH 53 and moving in a E-W direction. With few exceptions, the derived PMs have similar values in the three filters, ranging between $\sim$0.01 and $\sim$0.1" yr^{-1}, corresponding to a tangential velocity between 9 and 90 km s^{-1} at a distance of 180 pc. As an example we show [SII] PMs in Fig. 2.

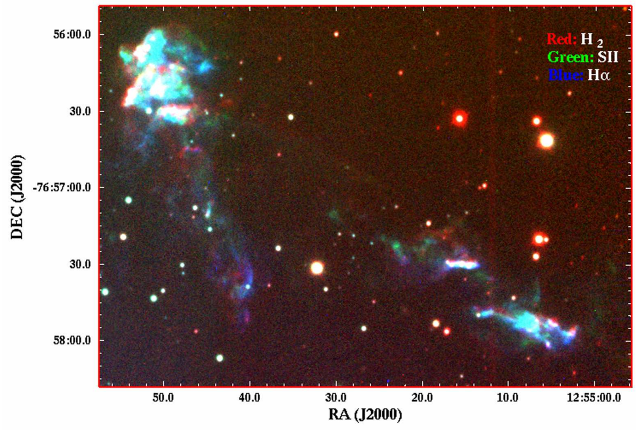

Figure 1: Colour composite of HH 52, HH 53 and HH 54 with Hα image in blue, [SII] image in green and H_2 image in red.

Radial Velocities - Measured radial velocities of the atomic components range between -20 and -120 km s^{-1} with variations similar to the PMs. We derive three different inclinations for the three groups of knots, with values of 58$\pm$2°, 83$\pm$2° and 67$\pm$4°, confirming the proposed scenario of three distinct outflows. Finally, combining radial and tangential velocities, we derive the space velocity of the knots. The inferred values are between 50 and 120 km s^{-1}.

Diagnostic results from spectroscopy & Mass flux - By means of the so called BE technique ([8]), the ratio of the detected lines (namely, [OI], [NII], and [SII]) in the optical spectra provide us with the physical parameters of the shocked gas, as the electron density (n_e), electron temperature (T_e), ionization fraction (x_e), and total density (n_H). In turn, these quantities, together with the kinematical analysis, allow us to evaluate the mass flux rate of the knots ($\dot{M}$) along the flows. We used the following equation to infer $\dot{M}$ (see e. g. [5],[6]):

$$\dot{M}_k = \mu m_H n_H \pi r_k^2 v_k \qquad (1)$$

where μ is the average atomic weight, m_H is the proton mass, n_H the hydrogen density, r_k and v_k are the radius and the velocity of the knots, respectively. Results are reported in Tab. 1. We can estimate $\dot{M}(A)\sim4\times10^{-7}\ M_\odot$ yr^{-1} in HH 52. Similar values are obtained in HH 54 G ($2\times10^{-7}\ M_\odot$ yr^{-1}). Conversely, mass flux in knots A, B, and C of HH 53 is an order of magnitude lower ($\leq10^{-8}$). This could indicate a less

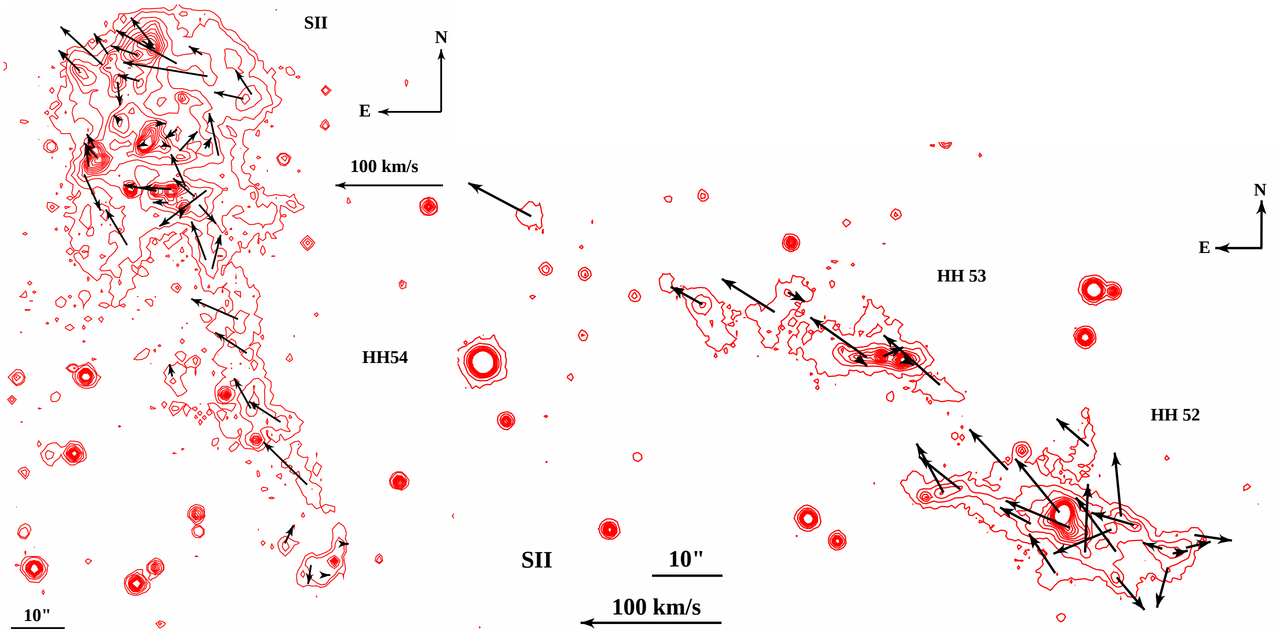

Figure 2: Flow charts of HH 54 (**left**), 52 and 53 (**right**) regions in [SII].

Table 1: Measured mass flux.

knot	r_{knot} "	$\dot{M}$ (A)^a (10^{-8} $M_\odot$ yr^{-1})
HH 52 A	4.1	13±2
HH 52 B	3.3	16±2
HH 52 D2-D3	2.4	7±2
HH 53 A	0.8	1.1±0.2
HH 53 B	0.8	0.7±0.1
HH 53 C	0.6	0.3±0.03
HH 54 C	1.4	0.5±0.05
HH 54 G	1.4	20±0.1
HH 54 X	1.3	0.3±0.08

massive and/or more evolved exciting source.

Exciting Sources & Comparisons - There are five *I*RAS sources in the region with a position angle barely compatible with those derived in the HH flows. We indicate *I*RAS12416-7703, a Class II YSO ([9]), as the driving source of HH 52 flow, and *I*RAS12500-7658, a Class I source with a L$_{bol}$ of 0.5 L$_\odot$ ([9]) as the best candidate for HH 54 streamer. In Spitzer-MIPS images we detect for the first time a MIR source close to HH 53 (named Source 2) well visible at 70 μm and we assume that this is the exciting source of HH 53.

Please refer to the poster for the comparison between flows and sources.

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