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H_2 KINEMATICS OF OUTFLOWS

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The H_2 kinematics of outflows having very different energetics, degrees of collimation, morphologies and ages are studied: OMC-1, Ceph A , DR 21, HH 211, HH 212 and S187IR. By constructing a flux-velocity diagram for each outflow we found a common behavior for all of the outflows: each spectrum is flat at velocities lower than a break point and at higher velocities, it behaves as a power-law $dF/dv \propto v^{\gamma}$ with γ between -1.7 and -3.0.

Observations of the outflows OMC-1, Ceph A, DR 21, HH 211, HH 212 and S187IR, were obtained during 1997 and 1998 with the IR camera/ spectrograph CAMILA (Cruz-González et al. 1994). The kinematics of the 2.12 μm line of H_2 were obtained using a NIR scanning Fabry-Pérot interferometer with R=15000 (Salas et al. 1999). For each outflow we obtain 26 velocity maps at 9.8 km s^{-1} intervals, for an instrumental FWHM of 23$\pm$1 km s^{-1}.

Besides studying H_2 kinematics, our aim is to understand the relationship between molecular outflows traced in CO and H_2.

In order to construct a flux - velocity (FV) diagram, the intensity and velocity for every validated pixel in the images is ordered in bins of velocity $|v_{obs} - v_{rest}|$, with respect to the rest velocity of the region obtained from data in the literature. The fluxes are calculated by adding up all the intensities of pixels within each velocity bin along the extent of the outflow. After adding up binned data, we divide the obtained flux by the width of the velocity bin to obtain dF/dv.

The resulting FV spectra of all the H_2 outflows show a similar behavior. Each spectrum is flat at velocities lower than a break point. For higher velocities, the spectra behave as a power-law $dF/dv \propto v^{\gamma}$, with γ between -1.7 and -3.0. We note that the break point velocity ranges from 4.5 to 13.8 km s^{-1}, i.e. at low velocities. If a single power-law is expected for all H_2 outflows, the obtained value of γ is -2.25, with a mean confidence level of 93%.

Contrary to model predictions depending on the type of shocks involved, we found that the H_2 intensity is not a function of velocity. An important implication of this result, is that the FV relation can then be interpreted as a mass-velocity relation, adding to the similarities with CO outflows.

The power-law behavior is strikingly similar to the well established property of CO outflows, the mass vs. velocity relation, with γ in the range -1.3 to 4 (e.g. Rodríguez et al. 1982; Masson & Chernin 1992; Lada & Fich 1996; Davis et al. 1998; Shepherd et al. 1998). The preferred value of γ=-1.8 for CO outflows, is consistent with numerical simulations of jet and wind driven outflows and entrained turbulent flows. Finally, CO outflows do not show the flat behavior observed in H_2 nor the low-velocity break, which is predicted by recent numerical simulations of Downes & Cabrit (2001).

Our results support a common physical origin for both CO and H_2 emission since they share similar properties, such as mass indexes, bipolar outflow characteristics and low speeds. There is a strong association between the molecular outflows traced in each molecule and they are possibly produced in adjacent regions along the cooling zones behind turbulent shocks within molecular outflows.

This work is discussed more fully in Salas & Cruz-González (2001).

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