EVIDENCE FOR HELICAL VELOCITY FIELD IN MOLECULAR BIPOLAR FLOWS -- SUPPORT FOR MAGNETODYNAMIC MODEL

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ABSTRACT: A search for the helical velocity field that had been predicted in a magnetodynamic theory of Uchida and Shibata was made in the bipolar flows L1551 by using ^{12}CO 115 GHz line, and evidence was obtained for it in the low velocity maps as the skew inter-invasion of the root part of the blue- and red shifted lobes into different sides of the opposite lobes. Theoretical implications of this and other findings are discussed, and the advantage of models with magnetic field is stressed.

Summary of the Poster Paper Presented

The model for the bipolar flows proposed by Uchida and Shibata (1985a, b, Shibata and Uchida 1986) is based on a global picture of the star-formation in which the *magnetized* cloud condenses into a star-disk system. The angular momentum component perpendicular to the large scale magnetic field may damp in the early phase of contraction of the cloud due to the excitation of Alfven waves. In the later part of evolution, the disk thus has a tendency to rotate perpendicularly to the magnetic field, twisting up the part of the field lines brought into the rotating disk in the process of contraction. It is shown by the 2.5-dimensional simulation by Uchida and Shibata that the magnetic twist relaxes out along the large scale field as a nonlinear torsional wave, driving the mass by the $j \times B$ force, and causes a hollow cylindrical jet having a helical velocity field in it. Angular momentum loss due to the production of the spinning jet as well as to the emission of the torsional Alfven waves allows the continued accretion of the disk to the star.

A series of observations was made in order to check whether such a velocity field actually exists in the bipolar flows. The bipolar flows L1551 were taken as a typical case and observations were made in ^{12}CO J = 1 → 0 115 GHz line at the Nobeyama Radio Observatory in 1985 and 1986 (Uchida *et al.* 1987). The results are presented at the Symposium in the form of the detailed maps at various velocity offsets and the position-velocity diagrams for various base-lines. Among several other points of interest (see Uchida *et al.* 1987 for the details), special attention is attracted to the maps with small velocity offsets (+1.5 km/s and -1.5 km/s from the LSR velocity, 7.6 km/s) which show skew inter-invasion of a part of the blue- and redshifted contours into different sides of the opposite lobes.

These features, together with others, are shown to be well

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reproduced by the following simple model synthesized from the observed characteristics: outflows are assumed to stream on a hollow cone $z = ar^{\gamma}$ ($a \sim 1, \gamma \sim 3$, r and z in the cylindrical coordinates with the z-axis taken along the axis of the lobes) with a long range acceleration up to a point corresponding to 0.15 pc and a gradual deceleration thereafter. The longitudinal velocity reaches $\sim$ 50 km/s in the model, and a small spinning velocity around the axis is assumed to have $\sim$ 1.5km/s in the same direction as the rotation of the disk-like object found by Kaifu *et al.* (1984). It is shown that the iso-velocity contours and PV-diagrams computed from the simple model reproduce (i) the inter-invasion of the part of the blue- and redshifted lobes into different sides of the opposite lobes for the inclination of the axis of the flows, $10^{\circ} \sim 15^{\circ}$, (ii) the receding ridges in the intensity in the maps for larger velocity offsets, (iii) the seemingly linear feature in the PV-diagram taken along the axis, and (iv) the semi-elliptic feature having a void in the PV-diagram taken along the strips across the lobes.

Another point of interest in the observed results is the velocity field around the blobs found in the flow. It is seen that the main body of the blob is visible at lowest velocities, and the contours at higher velocities appear to shift downflow. This suggests that the main part of the blob is initially at rest, and the mass at the surface of it is being peeled off by being given momenta of the flow. This is reproduced in the simulation, and the result is shown in the poster (Shibata and Uchida 1986, in preparation). If this is the case, the estimate of the mass of the molecular flows may go down by a considerable factor to ease the requirement for the theories.

It is pointed out that the characteristics described above, especially those related to the spinning of the lobes and the long-ranged acceleration of the flows, favor Uchida-Shibata model, or those models (Blandford and Payne 1982, Pudritz and Norman 1983 with centrifugal effect due to magnetic lever arms) which take into account of the magnetic field which transfers angular momentum to the lobes from a large enough reservoir, the rotating accretion disk rather than the central star (see details in Uchida *et al.* 1987, submitted to PASJ).

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