DISKS AND TOROIDS AROUND YOUNG STARS

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ABSTRACT. We review the observational evidence for interstellar and circumstellar size gaseous structures that appear to be collimating the bipolar outflows observed in regions of star formation. In particular, there is growing evidence for circumstellar disk-like objects that may be related to a protoplanetary cloud like the one that once surrounded the Sun. There are similarities between these disks around young stars and that found around the main sequence star β Pictoris. Both flattened structures around L1551 IRS5 and β Pictoris appear to have an inner "hole" with radius of a few tens of AU. On the other hand, there is observational support for focusing and collimation processes acting on the same source from tens of AU (circumstellar dimensions) to tenths of pc (interstellar dimensions).

I. INTRODUCTION

Since the detection of the phenomenon now known as a bipolar outflow (Snell, Loren and Plambeck 1980; Rodríguez, Ho and Moran 1980), a major topic of research has been determining the nature of its focusing mechanism. Why are most molecular outflows bipolar and not isotropic, as one would expect to first approximation? A variety of explanations has been advanced in the literature. A family of models involves a more or less "classic" stellar wind that is being collimated either at or very close to the stellar surface (Hartmann and MacGregor 1982; Jones and Herbig 1982), or by an external gaseous structure of circumstellar (Snell, Loren and Plambeck 1980; Strom et al. 1985b) or interstellar size (Cantó et al. 1981; Torrelles et al. 1983). More recently, an alternative set of models has been developed around the concept of a hydromagnetic wind (Pudritz and Norman 1983; Pudritz 1985; Uchida and Shibata 1985). In this type of models the rotational energy of a magnetized, rotating molecular disk is released continuously in the form of a bipolar outflow.

In this paper we review the growing evidence for the presence of flattened gaseous structures around the exciting central objects of the bipolar outflows, while an overall review of the bipolar

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outflow phenomenon has been given recently by Lada (1985). These gaseous structures are required both by the models with an external disk or toroid that collimates an isotropic wind and by the hydromagnetic wind models. Our knowledge of the physical parameters (size, geometry, density, mass, chemical composition, angular momentum, magnetic field, etc.) of these gaseous structures are still primitive. However, with further research it should be possible to determine these parameters better and to favor one of the available models. The exciting possibility that some of these disks and toroids could be related to a protoplanetary cloud like the one that surrounded the Sun during the formation of the planetary system is also being considered (Beckwith et al. 1984; Grasdalen et al. 1984; Rodríguez et al. 1986).

2. INTERSTELLAR TOROIDS AND BIPOLAR OUTFLOWS

Cantó et al. (1981) studied the young star R Mon and its surroundings with the $J=1\rightarrow0$ rotational transition of CO. They found a bipolar outflow of modest velocity aligned approximately in the N-S direction. They also detected a toroid-shaped molecular cloud of interstellar dimensions (tenths of pc) whose major axis lies nearly perpendicular to the outflow axis. As a result of this relative orientation, Cantó et al. (1981) proposed that an originally isotropic wind was being focused into a bipolar outflow by this interstellar toroid. A similar relative orientation was found in NGC2071 by Bally (1982). In this case the CO bipolar outflow is approximately perpendicular to a dense gaseous structure detected by him in CS. A systematic search for these dense ($n \gtrsim 10^3$ cm^{-3}) structures was carried out in the (1,1) inversion transition of ammonia by Torrelles et al. (1983), who found that for nine sources where clear orientations could be assigned to both the major axis of the condensation and the direction of the outflow, seven gave nearly perpendicular relative orientations. In all these cases there are compact radio, IR or visible sources at the center of the dense clouds. Presumably, these compact sources mark the position of the star or stars energizing the outflow. Torrelles and collaborators proposed that an interstellar toroid was the collimating agent of the bipolar outflows, based on the models of Barral and Cantó (1981) and Königl (1982).

Since the study of Torrelles et al. (1983) more interstellar toroids perpendicular to bipolar outflows have been reported. Kaifu et al. (1984) observed with the Nobeyama radiotelescope a CS structure aligned perpendicular to the L1551 outflow. Although the recent results of Bartla and Menten (1985) suggest that the CS structure is not rotating as was originally proposed by Kaifu et al. (1984), its geometry is consistent with a focusing toroid. Other cases of dense clouds aligned perpendicular to bipolar outflows have been recently reported in B335 (Menten et al. 1984), HH1-2 (Torrelles et al. 1985), G35.2-0.74 (Little et al. 1985) and GL490 (Kawabe et al. 1984). The case of HH1-2 is quite interesting. These two prominent Herbig-Haro objects are separated by ∿3' and the outstanding proper motion studies of Herbig and Jones (1981) showed that they are moving away from each other at velocities of hundreds of km s^{-1}. These motions occur in a direction nearly perpendicular to the line of sight and, consequently the radial velocity component (that is, along the line of sight) is small. This orientation with respect to the line of sight explains the lack of a clearly detectable bipolar molecular outflow (Snell and Edwards 1982). In any case, it was obvious from the geometry of the outflow that the powering source should be located somewhere along the line connecting HH1 and 2. For several years it was believed that the exciting object was a visible T Tauri-like star located about 30" to the southeast of HH1 (Cohen and Schwartz 1979). However, the VLA observations of Pravdo *et al.* (1985) revealed the presence of a radio continuum source located midway between HH1 and 2. These authors proposed that this heavily obscured object, and not the visible star, was the exciting source. To elucidate the situation, Torrelles *et al.* (1985) mapped the region in ammonia, detecting an elongated structure aligned perpendicular to the outflow axis and centered on the Pravdo *et al.* (1985) radio source. The main features of the region are shown in Figure 1. This geometry, similar to that found by Torrelles *et al.* (1983) in other sources, strongly supported the Pravdo *et al.* (1985) VLA radio object as the exciting agent of the HH1-2 system. Since then, a large body of optical, IR and radio results (Bohigas *et al.* 1985; Strom *et al.* 1985a; Rodríguez, Roth and Tapia 1985; Harvey *et al.* 1985; Torrelles and Rodríguez 1986) have corroborated the interpretation of Pravdo *et al.* (1985), but it is relevant to emphasize that the first supporting evidence came from the coincidence of the radio source with the center of an interstellar toroid.

One should point out that the interpretation of the data related to the interstellar toroid is not straightforward in some cases. In particular, molecules that are good tracers of high density gas ($n \gtrsim 10^3$ cm^{-3}), such as NH_3 and CS, can give contradictory evidence. For example, in L1551 the CS structure mapped by Kaifu *et al.* (1984) suggests a toroidal cloud around IRS5, the exciting star of the bipolar molecular outflow. However, the NH_3 structure observed by Torrelles *et al.* (1983) and Menten and Walmsley (1985) is elongated along the direction of the outflow and does not resemble at all the CS structure. We are thus facing poorly-understood excitation and/or abundance effects in this and other sources such as AFGL490 (Torrelles *et al.* 1986).

In Table 1 we give the best studied cases of bipolar outflows where an elongated structure has been found perpendicular to the outflow axis. The typical radius of these gaseous structures is of the order of a tenth of a pc with the exception of Orion KL and L1551 where the structures mapped are an order of magnitude smaller.

3. EVIDENCE FOR COLLIMATION AT A SMALLER SCALE

Even when the interstellar toroids appear to be playing an important role in the large-scale focusing of the bipolar outflows, in the last few years several observational results point, at least in some sources,

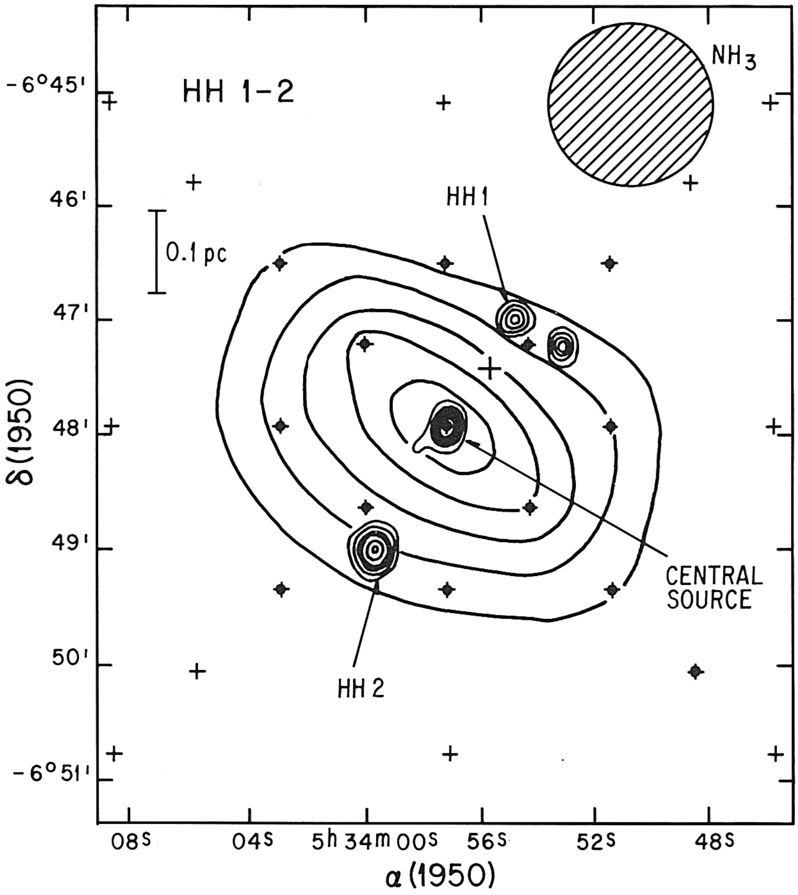

Figure 1. Contour map of the integrated main line of ammonia (thick line; Torrelles et al. 1985) superposed on the 6cm VLA continuum map (thin line; Pravdo et al. 1985). The small crosses denote the positions observed in ammonia, and the dots denote the positions where this molecule was detected. The large cross marks the position of the Cohen and Schwartz (1979) star, previously believed to be the exciting source of the HH1-2 system. The ammonia structure has its major axis perpendicular to the HH1-2 bipolar outflow. The central 6cm continuum source lies at the center of this structure, supporting the proposition of Pravdo et al. that this object powers the HH1-2 system.

TABLE 1

INTERSTELLAR TOROIDS ALIGNED APPROXIMATELY PERPENDICULAR TO BIPOLAR OUTFLOWS

Source	Radius of Toroid (pc)	References
R Mon	0.2	1
NGC 2071	0.1	2
HH26 IR	0.2	3
Mon R2	0.5	3
S106	0.05	4
Orion KL	0.02	5
L1551	0.01	6
B335	0.05	7
HH1-2	0.3	8
G35.2-0.74	0.2	9
GL490	0.2	10

1.- Cantó et al. (1981), 2.- Bally (1982), 3.- Torrelles et al. (1983), 4.- Bieging (1984), 5.- Plambeck et al. (1982), 6.- Kaifu et al. (1984), 7.- Menten et al. (1984), 8.- Torrelles et al. (1985), 9.- Little et al. (1985), 10.- Kawabe et al. (1984).

to the existence of very small ($\sim 10^2$-10^3 AU) gaseous structures of flattened geometry around young stars. These structures may be collimating the outflows very close to the exciting star. We will now discuss these evidences for circumstellar structures in what we consider to be an increasing order of reliability.

3.1 The Low Momentum in the Interstellar Toroids

Takano et al. (1984), Kawabe et al. (1984) and Davidson and Jaffe (1984) have found that for some sources the momentum in the bipolar outflow is larger than the momentum in the associated interstellar toroid. They argue that if the toroid is focusing the outflow then it should have momentum (in the form of expansion) comparable to that observed in the outflow. These authors conclude that the observed interstellar toroids can not be responsible for the collimation, and that the process must be taking place at smaller scales. Torrelles et al. (1985) do not consider these arguments as compelling. First, there is considerable uncertainty in the mass determination of both the toroids and the outflows. Second, the real orientation of the system with respect to the line of sight is poorly known and we are only measuring the radial components of the velocity. For example, in the case of HH1-2 the outflow is nearly perpendicular to the line of sight and the radial momentum from CO data is less than 1 $M_\odot$ km s^{-1} (Snell and Edwards 1982). The ammonia toroid observed by Torrelles et al. (1985) is expanding with momentum of about 20 $M_\odot$ km s^{-1}. Consequently, for this source one derives the opposite conclusion than that derived for the cases studied by Takano et al. (1984), Kawabe et al. (1984) and Davidson and Jaffe (1984). Finally, Torrelles et al. (1985) note that the interstellar toroids are probably embedded in more extended clouds that could absorb a considerable fraction of the momentum.

3.2 Infrared Polarimetry

Most of the central stars of bipolar outflows are heavily obscured by dust and it has been most profitable to observe them in the infrared. In a thorough study, Sato et al. (1985) showed that it is usual for the infrared sources associated with bipolar outflows to have linear polarizations perpendicular to the direction of the outflow. These linear polarizations can be explained if the infrared radiation is scattered off a disk-shaped cloud around the star (Heckert and Zeilik 1985). Since the infrared observations refer to dust relatively close to the star (∿30" or ∿0.1 pc at a distance of 500 pc), it is implied that the disk-shaped or toroid-shaped gaseous structures are already present at these somewhat smaller scales. However, the regions sampled by the Sato et al. study are still not truly circumstellar. Infrared polarization observations with higher angular resolution should be carried out to define the spatial distribution of the scattering dust closer to the exciting star.

3.3 Optical Jets from Young Stars

Recent optical observations have revealed the presence of elongated emission filaments associated with young stars (Mundt and Fried 1983; Strom, Strom and Stocke 1983; Graham and Elias 1983; Reipurth et al. 1985; Krautter 1985). An excellent review of the topic has been given by Mundt (1986). In brief, these optical jets have spectra similar to that of HH objects (indicating a shock-excitation nature), velocities of a few hundred km s^{-1}, hydrogen number densities of 10-100 cm^{-3}, and mass fluxes of 10^{-10}-10^{-7} $M_{\odot}$ yr^{-1}. These filamentary structures have been usually interpreted as well-collimated jets that emanate from the associated young stars. Since the widths of the structures are in the arc sec range (10^2 to 10^3 AU for typical source distances), it has been proposed that the jets are being collimated by structures of circumstellar size. Cantó, Sarmiento and Rodríguez (1986) have suggested that at least in some sources the "jets" may be simply a projection effect. As a result of the stellar wind interaction with the surrounding medium, cavities are expected to be common in star forming regions. The walls of these cavities can be illuminated (if they are photo or shock-ionized or if they reflect radiation from a nearby star). In projection, these luminous walls will appear as elongated structures. Although this mechanism may explain curved "jets" that do not appear to emanate from a star (see, for example, the HL Tau images of Mundt and Fried 1983), it is hard to understand how it could account for the spectacular jet-like structures observed, for example, by Reipurth et al. (1985) in association with HH34.

The relation between the optical jets and the bipolar molecular outflows is poorly understood. Many of the optical jet sources do not have a detectable molecular outflow associated. In the cases where there is an optical jet associated with an outflow, the momentum in the jet appears to be one or two orders of magnitude smaller than that in the bipolar outflow (Mundt 1986). On the other hand, there must be a relationship since in the better-studied cases, notably L1551, the optical jet and the outflow axis are nearly coincident (Mundt and Fried 1983). It is conceivable that we may be dealing with two different but related collimation processes, one responsible for the low momentum, highly collimated optical jets and another for the high momentum, poorly collimated bipolar outflows.

In summary, the optical jets provide indirect evidence for collimating structures of circumstellar size around young stars.

3.4 Millimeter Interferometry of Molecular Gas

The recent development of radio interferometers for the mm range is starting to allow observers to map the distribution of molecular gas around young stars with arc sec resolution. Sargent et al. (1987) observed several outflow sources finding that the bipolar structure is present within 10" of the exciting sources. They conclude that the flows are collimated on scales of less than 10^{17} cm. Beckwith et al. (1986) have detected circumstellar CO within a few hundred AU of the stars HL Tau and R Mon. Although their observations still lack the angular resolution to provide information on the geometry of these circumstellar structures, Beckwith et al. (1986) proposed that they could be disk-shaped since both HL Tau and R Mon are associated with molecular outflows (Calvet, Cantó and Rodríguez 1983; Cantó et al. 1981).

3.5 Images of Circumstellar Disks

We finally come to what is obviously the strongest evidence in favor of circumstellar disks: images and maps of high angular resolution that reveal the existence of small flattened structures around some young stars.

From near-infrared interferometric observations of HL Tau, Beckwith et al. (1984) inferred the presence of a flattened dust halo of dimensions 320x200 AU around the star. Grasdalen et al. (1984) independently observed this possible disk in the near-infrared using maximum entropy image reconstructions. Based on indirect evidence, Cohen (1983) had previously proposed the existence of a circumstellar disk around HL Tau.

In Orion KL, Lester et al. (1985) found from diffraction-limited scans in the middle-infrared that IRC2 is elongated, with a major semiaxis of ~400 AU. The shape and orientation of this small structure is similar to that seen on a larger scale in the molecule SO (Plambeck et al. 1982), as it is shown in Figure 2.

Another case of a small toroid inside a larger toroid occurs in association with L1551 IRS5. Strom et al. (1985b), using maximum entropy imaging methods, found that this source is surrounded by

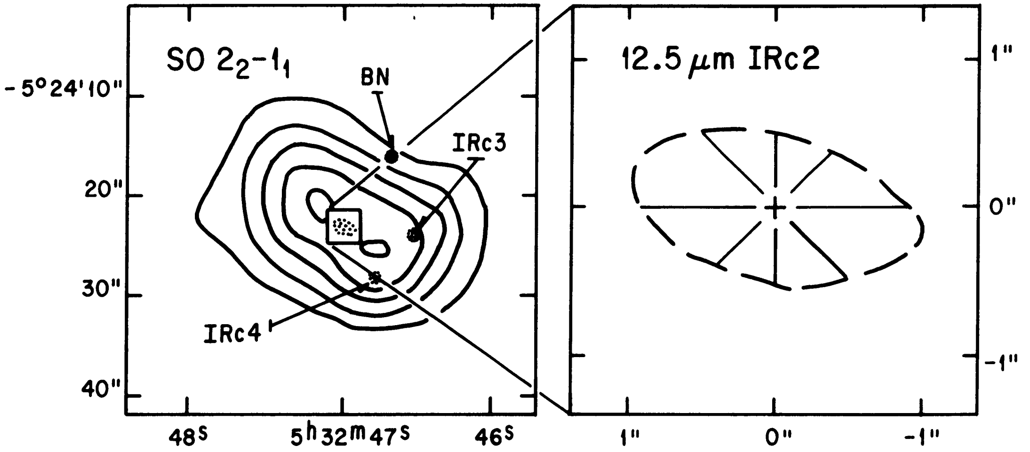

Figure 2. The left hand side of the figure is excerpted from the SO map of Plambeck *et al.*(1982). This structure has its major axis perpendicular to the bipolar outflow associated with Orion KL IRc2. The right hand side gives the geometry of the inner infrared structure observed by Lester *et al.* (1985). Note the similar shape and orientation of both structures.

what appears to be a thick dust disk with radius of about 500 AU. This thick disk has its polar axis along the observed direction of the bipolar outflow. It would thus seem that the Strom *et al.*(1985b) infrared structure is the core of the more extended toroid seen by Kaifu *et al.* (1984). Furthermore, Rodríguez *et al.* (1986) have proposed that the double radio continuum source observed with the VLA by them and previously by Bieging and Cohen (1985) may be the ionized inner part of a confining toroid seen nearly edge-on and not two stars as was previously surmised (see Figure 3). If this suggestion is correct, the inner radius of this toroid has 25 AU in radius. Assuming that this torus is capable of confining the wind from L1551 IRS5, Rodríguez *et al.* (1985) estimate the density of the inner walls to be $\sim 10^{10}$ cm^{-3}, and note that this value is similar to that expected in protoplanetary clouds at positions tens of AU from the central star (Opik 1973). Persson (1986) estimates from optical data that the density near the base of the outflow in young stellar objects is also about 10^{10} cm^{-3}.

It is yet unclear what relation exists between the disk- or toroid-shaped structures around the young stars HL Tau, Orion KL IRC2, and L1551 IRS5, and the circumstellar dust disks found surrounding the main sequence star β Pictoris (Smith and Terrile 1985), and possibly other main sequence stars with far-infrared excesses discovered by IRAS (Aumann 1985). While the circumstellar structures around the young stars appear to be "fat" disks (Strom *et al.* 1985b; Beckwith *et al.* 1984; Rodríguez *et al.* 1986), the structure around β Pictoris is thin

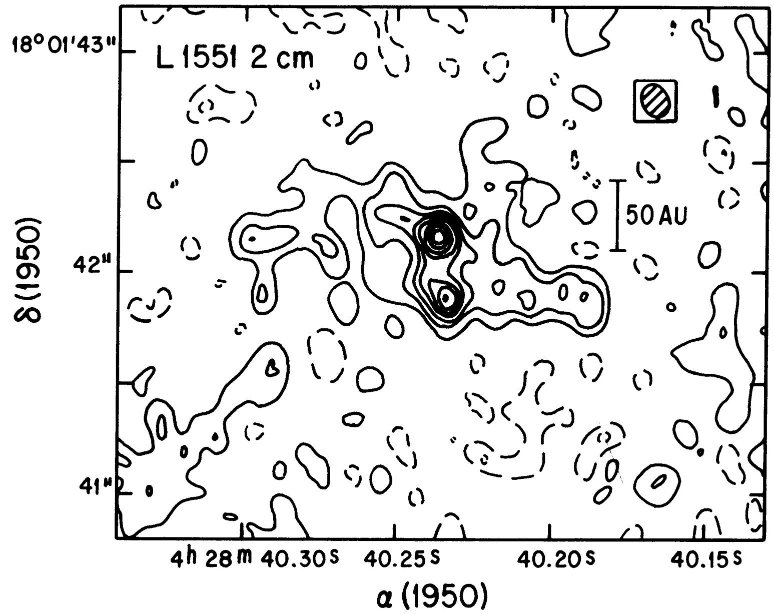

Figure 3. The double radio source observed at the core of L1551 is interpreted by Rodríguez et al. (1986) to be an ionized torus seen nearly edge-on. This torus is proposed to be the inner part of the dust disk observed in the IR by Strom et al. (1985b).

and can properly be called a disk. One is tempted to speculate that with evolution the disks become progressively thinner. A provoking similarity is that both the disks around L1551 IRS5 and β Pictoris have central "holes" of comparable size. Rodríguez et al.(1986) propose that the stellar wind of L1551 IRS5 has cleared a region with a radius of 25 AU at the center of the toroid. From the modeling of their optical data, Smith and Terrile (1984) suggest that the disk around β Pictoris extends inwards only to about 30 AU and that the region within 30 AU is relatively clear. We can draw the conclusion that L1551 IRS5 and β Pictoris are surrounded by circumstellar structures of very similar outer and inner radii, 500 and 25 AU for L1551 IRS5 and 400 and 30 AU for β Pictoris. It may prove to be relevant that the size of the inner holes around these stars is similar to the extent of our planetary system. In table 2 we list the cases of observed circumstellar disks and their dimensions.

TABLE 2

OBSERVED CIRCUMSTELLAR DISKS

Source	Radius of Disk (AU)	References
HL Tau	150	1,2
Orion KL IRc2	400	3
L1551 IRS 5	500, 25*	4,5
β Pictoris	400, 30*	6

1.- Beckwith et al. (1984), 2.- Grasdalen et al. (1984), 3.- Lester et al. (1985), 4.- Strom et al. 1985b, 5.- Rodríguez et al. (1986), 6.- Smith and Terrile (1985).

* The two values refer respectively to the outer and inner radii of the circumstellar disk.

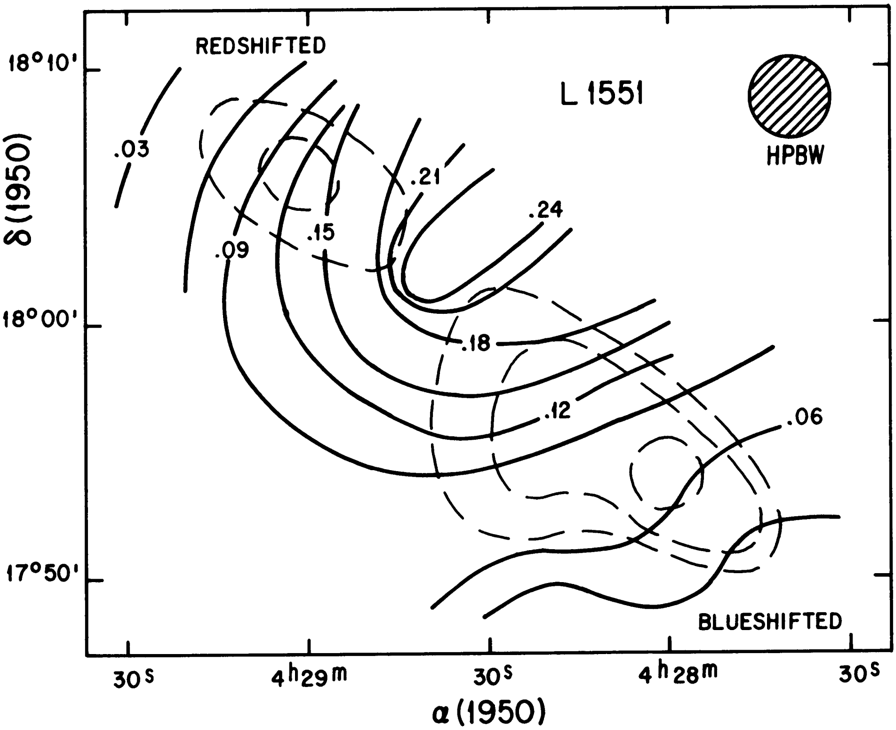

Figure 4. The solid contours mark the peak OH emission from the ambient cloud L1551 (Mirabel et al. 1986). The dashed contours mark the integrated high-velocity OH absorption (Mirabel et al. 1985). Note that the lobes are elongated in the direction of the steepest gradients of the ambient cloud, suggesting that these gradients play an important role in the large scale collimation of the outflow.

4. COLLIMATION AT DIFFERENT SIZE SCALES IN THE SAME SOURCE: THE CASE OF L1551.

It would appear from our previous discussion that if circumstellar disks are found to collimate the bipolar outflows near to the exciting star, larger size structures would not be required. However, the observations suggest that the situation is more complex, as we will see from the integration of the vast amounts of data related to L1551. In the smallest angular scale ($\sim 0\overset{\prime\prime}{.}1$) the ionized torus proposed by Rodríguez *et al*. (1986) would imply a nearly E-W collimation of the outflow, while the larger scale CO lobes (Snell *et al.* 1980) are aligned along a NE-SW axis. This can be explained with a bending of the disk plane as we go from the inner parts to the outside since the isocontours of the dust disk mapped by Strom *et al*.(1985b) appear to rotate from having its minor axis almost E-W to a NE-SW alignment. The larger scale CS toroid observed by Kaifu *et al*.(1984) has its minor axis well aligned with the outflow lobes, as defined by the CO (Snell *et al*. 1980) and OH data (Mirabel *et al*. 1985). However, the outflow lobes do not extend straight away from IRS5 but have a small bend to the SE. Mirabel *et al*. (1986) have proposed that this bending is due to the large scale density structure of the ambient molecular cloud since the outflow lobes are elongated in the direction of the cloud's steepest density gradient (see Figure 4). This focusing is occurring on an angular scale of tens of arc min, dimensions that are factors of tens larger than the collimation produced by the CS toroid (Kaifu *et al*. 1984) and thousands larger than the size of the ionized torus proposed by Rodríguez *et al*. (1986).

In summary, for L1551 we have evidence of focusing and collimation processes acting on size scales from tens of AU (circumstellar dimensions) to tenths of pc (interstellar dimensions).

5. CONCLUSIONS

The mechanism responsible for the collimation of the bipolar outflows is an issue far from settled. In this review we have presented evidence of the relevance that interstellar size toroids and even the density structure of the ambient cloud have in collimating bipolar outflows. An exciting recent development of the last few years has been the presence of circumstellar disk-like structures that appear to be focusing the outflow already within a few hundred AU from the central star. These disks may be related to a protoplanetary cloud like the one that surrounded the protosun during the formation of our Solar System. In some sources there is evidence of collimating and focusing processes acting from the circumstellar to the interstellar scales, a situation we depict qualitatively in Figure 5.

Many unanswered questions assure that this topic will continue receiving intensive attention from observers and theoreticians alike. Have the circumstellar structures formed or are forming planets? Are we dealing in some sources with two different but related types of flows, one of low momentum but highly collimated (the optical jets) and another of high momentum and low collimation (the molecular lobes)?

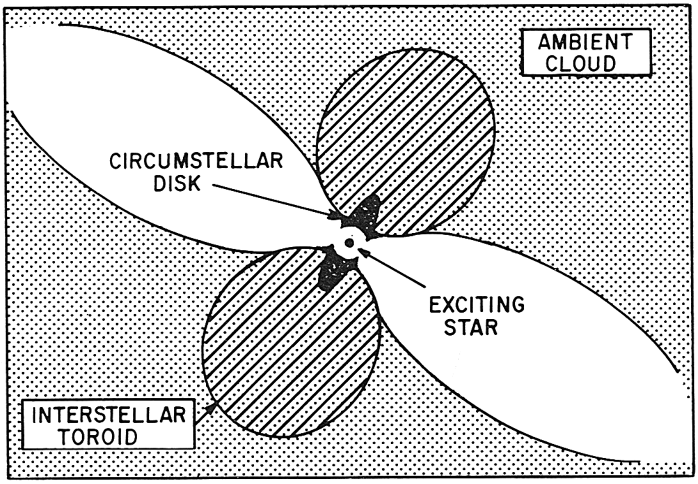

Figure 5. A schematic description (not to scale) of the collimation processes that may be influencing the bipolar outflows. A circumstellar disk of a few tens of AU of inner radius and a few hundred AU of outer radius produces collimation close to the exciting star. At larger scales (tenths of pc) the collimation is caused by interstellar toroids and possibly even the large scale density gradient of the ambient cloud.

Is focusing already present in some way at the stellar surface? Are hydromagnetic models the correct mechanism, solving the focusing and angular momentum problems simultaneously?

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FUKUI: The evidence you presented for disk collimation of the bipolar flow is more or less concerning lower-luminosity sources. In them, I suspect that pre-existing momentum in the central core is relatively large compared to the outflow momentum, making it difficult to discern the effect by the outflow. Therefore, it seems better to use very energetic outflows like NGC 2071 and GL490 in order to investigate the importance of the disks in collimation. We have been arguing against the capability of collimation due to interstellar disks based on observations of these two sources (e.g. Takano *et al.* 1984, Astrophys. J. 282, L69).

RODRIGUEZ: Comparing the momentum in the outflow with the momentum in the molecular toroids is a difficult matter. First, the mass determination of outflow and toroid has large uncertainties. Second, there is a projection angle needed to find the total velocity which is not known. For example, if I apply your reasoning to the HH1-2 case, I will get that the momentum in the toroid is larger than that in the outflow, opposite to what you get in NGC 2071 and GL490. Finally, the molecular toroids are embedded in a more diffuse medium that is also absorbing momentum. This momentum absorbed by the diffuse medium is very hard to detec.

WILSON: The higher resolution NH_3 data of Monteri and Walmsley (MPIFR, Bonn) show that the toroid reported by Torrelles *et al.* breaks up into a series of structures which do not form a symmetric toroid.

RODRIGUEZ: We believe that in this source the ammonia traces a low velocity counterpart of the CO outflow. The confining structure in L1551 is better traced by the CS data.

FORSTER: We have observed L1551 at the VLA with 10" resolution in the formaldehyde line at 6-cm. We see H_2CO in *emission* near IRS5. Since this requires densities around 10^6 cm^{-3} or greater, we may be seeing emission from the inner collimating disk you described. Moreover, we see H_2CO absorption on the scale of the larger toroids seen in NH_3 and in CS by Kaifu *et al.* A perplexing thing about these observations is that the velocities of the absorption on opposite sides of IRS5 are the same within 0.2 km/s implying little or no rotation rotation. Can you explain this?

RODIGUEZ: Your results are very exciting. The lack of rotation is somewhat perplexing. However, other support mechanisms are perfectly viable. In particular magnetic support is very probable, specially when one considers the evidence for alignments between the toroids axes and the magnetic field.

SMITH: We have observed several low-luminosity BPF's in Brackett α and BR γ emission, including L1551/IRS5. All show line strengths consistent with outflow models, but in L1551/IRS5 the line is too weak by a factor of $\gtrsim 10$. We have investigated predictions of shocked-gas models, such as you suggest here, but these also predict lines much stronger than we see. It is possible that high local extinction could block the line, but to keep the mass of such a clump reasonable the region should probably be much smaller than the shocked bows you see in L1551/IRS5. On winds, and also shock mechanisms as described by Cox, the IR lines are very strong as compared to the radio continuum, perhaps 10^3 stronger than in the H II region case. They are a very sensitive probe of inner ionized flows, and in L1551/IRS5 the limits indicate some more unusual phase than seen in other BPF's.

RODRIGUEZ: The density of the confining torus, as deduced from the VLA observations, is very large, $n(H_2) \cong 10^{10}$ cm^{-3}. So, for L1551 the extinction in the near IR could be considerable.