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A Compact Density Condensation Around L1551-IRS 5 - 2.7 mm Continuum Observations with 4" Resolution

Jocelyn Keene and Colin Masson
Downs Laboratory of Physics
Caltech
Pasadena CA 91125

The dark cloud L1551 contains the (arguably) best known example of bipolar molecular outflow (Snell, Loren and Plambeck 1980, *Ap. J.* (*Lett.*), **239**, L17.) Such outflows are assumed to be driven by winds from young stars embedded in a cloud but the mechanism for collimation of the outflows is still in doubt, though it has been much debated. Among the possibilities put forth to date are intrinsically anisotropic stellar winds, isotropic stellar winds collimated by interstellar toroidal shaped clouds on the order of 10^{17} cm in size, or circumstellar disks of order 10^{15} cm in size. Because the outflow in L1551 as revealed by VLA cm continuum observations is collimated even at the arc second level (Bieging, Cohen and Schwartz 1984, *Ap. J.*, **282**, 699) it seems as though the stellar wind powering the outflow must either be initially anisotropic or be collimated by something very close to the star, such as a circumstellar disk.

We have observed L1551 in the continuum at 2.7 mm with the OVRO millimeter-wave interferometer in the winter of 1983-4 and again, more extensively, in 1985-6. The resulting map (Fig. 1) shows for the first time direct evidence for a density condensation capable of collimating an initially isotropic flow from IRS 5. This map was made from data taken in 1985-6 with projected baselines up to 100 m in length (37 kλ). It has been CLEANed and reconstructed with a 4" gaussian beam. It shows a nearly unresolved source with a suggestion of extension at the 3" level (assuming a gaussian source shape). The integrated flux density in this map is 170 mJy, in excellent agreement with lower resolution maps made during 1983-4. There is no suggestion that we are missing any flux in the interferometer maps; the source looks like a point source at all except the very longest baselines.

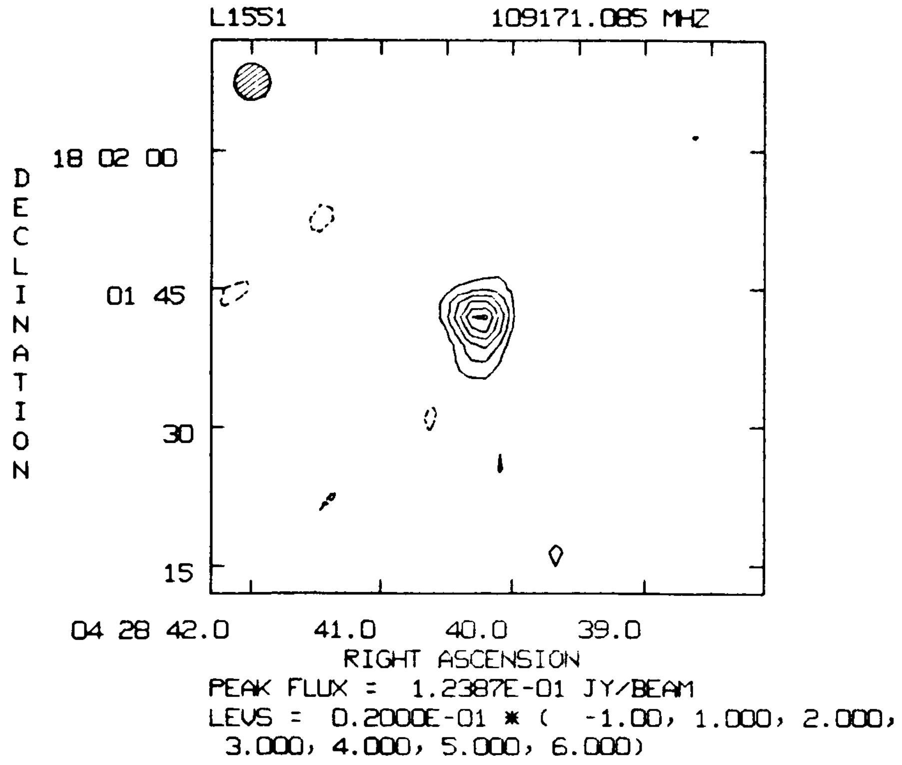

Figure 2 shows a composite spectrum of L1551 (taken from many sources). Through the points we have drawn a curve of the form $(1 - e^{-\tau}) B(\nu,T)$ where τ is a function of the form ν^{α}. For $\lambda < 250\ \mu m$ $\alpha_1 = 1$, while for $\lambda > 250\ \mu m$ α_2 was allowed to range from 1 to 2. It is obvious from this spectrum that the flux at 2.7 mm is due to the thermal radiation from dust that is also seen at shorter wavelengths. Very little of it can be due to the continuation of the nearly flat cm wavelength spectrum which is assumed to be from thermal bremsstrahlung radiation. The map in Figure 1 and spectrum in Figure 2 provide strong constraints on the size, $\Theta(FWHM) \lesssim 3''$, temperature, and optical depth of the density condensation surrounding IRS 5. Given the size constraint of Figure 1, the product of the temperature, T, and optical depth, τ, at 2.7 mm must $\gtrsim 3$. The far-infrared spectral points put a strong constraint on T. Reasonable fits to this region of the spectrum were obtained for $55 < T < 70$ K and $2'' < \Theta \lesssim 3''$ with $1.7 \lesssim \alpha_2 \lesssim 2$. The implied opacity at 250 μm ranges from 3 to 12 for this range of parameters; thus this is an extremely optically thick source.

From our fit to the spectrum we deduce a mass of $\sim 0.8\ M_{\odot}$ for the circumstellar gas in agreement with Davidson and Jaffe (1984, *Ap. J.* (*Lett.*), **277**, L13). For a diameter of 3'', the average gas density is $n_{H_2} \gtrsim 10^9\ cm^{-3}$ and the gravitational force on such an amount of material is more than sufficient to balance the pressure in the outflowing wind. The circumstellar material thus is capable of collimating the outflow from L1551 IRS 5.

The simple function shown in Figure 2 cannot reproduce the entire spectrum of L1551-IRS 5. Because of the bipolarity of the molecular flow it is obvious that any density condensation around IRS 5 must not be spherical. Although the opacity of the source is extremely high in some directions there must be a direction in which short wavelength radiation from an even smaller and hotter region can escape (along with the stellar wind).