THE EXTENDED INFRARED RADIATION FROM THE L1551 BIPOLAR FLOW, L > 19 $L_\odot$

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ABSTRACT. The infrared bolometric luminosity of the extended infrared emission from the L1551 flow is estimated as 19 (-4 +10) $L_\odot$. Ultraviolet radiation from the shock associated with the flow appears to heat the surrounding dust. The extended infrared emission raises the total energy requirement for the flow over a 10^4 year lifetime to 10^46-47 ergs. If gravitational in origin, this energy likely originates from a region <10^13 cm. Infrared radiation offers a new probe for interstellar shocks by sampling the ultraviolet halo surrounding the shock.

1.1. INFRARED LUMINOSITY OF THE L1551 FLOW

Bipolar flows from very young stars have heretofore been detected primarily by means of broad wings on spectral lines. We analyze the energetics of the infrared emission detected from the bipolar flow in L1551 (Clark and Laureijs 1986), and show that infrared emission from dust surrounding bipolar flows is an effective tool for studying such flows. To estimate the extended flux and dust temperature, IRAS data were analyzed and background levels determined over a 16.5° by 33° field. We have estimated the total extended flux by assuming a constant flux from the inner region near IRS5 as 90 Jy (-13 +12) at 60 μm and 870 Jy (-170 +440) at 100 μm. The extended flux above represents an observed infrared luminosity of 10 (-2 +4) $L_\odot$. Correcting for that portion of the Planck curve not seen by IRAS, we estimate the infrared bolometric luminosity as 19 (-4 +10) $L_\odot$. This estimate of the infrared luminosity is some 50% of the bolometric luminosity of the central star.

The conversion of mechanical energy in the shock to infrared radiation is unlikely to be 100% efficient. We estimated the mechanical luminosity of the shock by modeling the ultraviolet heating of the dust to the observed spatially resolved dust temperature using the numerical coefficients from Hollenbach and McKee, resulting in estimates of the mechanical luminosity of 40-140 $L_\odot$, corresponding to a range of infrared dust emissivities which vary with wavelength^(-1 to -1.5).

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1.2. THE DUST HEATING MECHANISM

The dust exhibits a nearly constant temperature in the outer parts of the flow of 22-26 K. We exclude large scale radiative heating from IRS5 as the dust temperature is so uniform. We have made calculations of collisional and ultraviolet heating from the shock and find ultraviolet heating generally more efficient. The path length of ultraviolet photons from the shock which heat of the dust offers a simple explanation of the infrared morphology which is twice the CO length and width.

1.4. WHAT DRIVES THE L1551 FLOW?

Emerson et al. (1984) estimate the bolometric luminosity of IRS5 as 38 L_o, which indicates that the observed infrared luminosity is some 50% of the bolometric luminosity of IRS5, and IRS5 may not be energetically capable of driving the L1551 flow with radiation pressure (Draine 1983). A luminosity range of 19 L_o over a flow lifetime of 10^4 years implies an energy of ~10^46 ergs. If IRS5 is estimated as 2 M_o, then the gravitational potential energy from ~ 10^13 cm away from IRS5 is ~10^47 ergs, and could provide the necessary energy with 10% conversion efficiency. Several times 10^48 ergs are released in the collapse of a solar type star to the main sequence. The model of Draine (1983) provides energies of this order and is consistent with the shock parameters derived here.

1.5. SUMMARY

Infrared emission offers a new technique for probing bipolar flows. The infrared luminosity of the L1551 flow is estimated as 19 (-4 +10) L_o, 50% of the estimated bolometric luminosity of IRS5. The dust appears to be heated by ultraviolet radiation from the shock; the excess infrared size being well modeled by the surface of UV opacity one around the shock. Over a 10^4 year lifetime 19 L_o requires an energy of 10^46, two orders of magnitude larger than previous estimates of the energy in the flow based on CO measurements (Snell and Schloerb 1985). The energetic requirements suggest that the phenomenon driving the flow, if gravitational in origin, likely originates from a region of order 10^13 cm. Draine's magnetic bubble model for the bipolar flow is capable of supplying energies of this magnitude. We acknowledge stimulating discussions with E.E. Becklin and F. Shu.

1.6. References

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