MOLECULAR OUTFLOWS AND MASS LOSS IN PRE-MAIN-SEQUENCE STARS

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ABSTRACT. We have conducted a survey for molecular outflows toward 71 pre-main-sequence stars using the J = 2 $\rightarrow$ 1 transition of CO. Outflows were detected and mapped toward 20 of these objects and in an additional six background sources not included in the original survey. The outflow sources range in mass from 0.5 to 30 $M_\odot$, in luminosity from 4 to 1.1 x 10^5 $L_\odot$, and in age from < 10^4 to $\sim 10^6$ years. In the H-R diagram, the outflow sources form a distinct band running across the top of the diagram.

Roughly half of the observed outflows are bipolar at some level; the rest show a rich variety of morphologies. In addition to the CO (J = 2 $\rightarrow$ 1) data, we have obtained CO (J = 1 $\rightarrow$ 0) and ^{13}CO (J = 1 $\rightarrow$ 0) observations that enable us to estimate the excitation temperature and optical depth in each outflow, leading to the derivation of outflow masses. The observed outflows range in mass from 0.01 to 56 $M_\odot$, in size from < 0.07 to $\sim$ 5 pc, and in age from $\sim 10^3$ to 5 x 10^5 years old.

Simple momentum conservation arguments are then used to derive the mass loss rates necessary to produce the observed outflows. The results range from $\sim 10^{-8}$ to $\sim 10^{-3}$ $M_\odot$ yr^{-1}. Correlation of these mass loss rates with other parameters shows that pre-main-sequence mass loss goes as the square root of the bolometric luminosity and as the 1.7 power of the stellar mass. Implications for these findings on the nature of the pre-main-sequence mass loss mechanism, for self-regulated low-mass star formation, and for formation of the terrestrial planets are discussed.

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 79.