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Title: An Investigation of the Cold Interstellar Medium of the Outer Galaxy
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The primary objective of this proposal was to determine the relationship between the molecular gas and dust components of the interstellar medium of the Outer Galaxy. It made use of the High Resolution *IRAS* Galaxy Atlas (Cao *et al.* 1997) and the FCRAO CO Survey of the Outer Galaxy (Heyer *et al.* 1997). These HIRES images greatly augment the spatial dynamic range of the *IRAS* Survey data and the ability to discriminate multiple point sources within a compact region. Additionally, the HIRES far infrared images allow for more direct comparisons with molecular line data observed at 45″ resolution. From funding of this proposal, we have completed two papers for publication in a refereed journal (Heyer *et al.* 1996; Heyer & Terebey 1997).

Heyer & Terebey (1997) analyzed the dust and CO emissions from the W3/4/5 region which is a major star forming region in the outer Galaxy. They identified 886 objects [1] within the longitude range of $140° > l > 130°$ and $-2° < b < 4.8°$ where an object is defined as a closed topological surface within the l-b-V_{LSR} data cube. Background subtracted 60μm and 100μm brightness distributions were integrated over the projected surface of each object to determine fluxes. Using the measured V_{LSR} of the object and assuming kinematic distances, [2] the far infrared luminosities were also tabulated. To account for additional contributions to the measured fluxes from overlapping objects, a contamination factor, η, was derived which is the fraction of the cloud area which contains more than one spectral feature although no corrections to the measured fluxes were applied. Note that for many of the identified objects, the angular extents are quite small ($<2'$) so the HIRES images are essential to accurately tabulate the far infrared properties.

The ratio of far infrared to CO luminosities is frequently used as a measure of the massive star formation efficiency within the molecular interstellar medium (Mooney & Solomon 1988; Scoville & Good 1989). The ratio varies from 1 to 9 for IR quiet clouds and 2 to 100 for regions with ongoing massive star formation and reflects the relative contributions of newborn massive stars and the interstellar radiation field to heating of dust grains. In Figure 1, we show the ratio of far infrared to CO luminosity as a function of V_{LSR} for the W3/4/5 complex partitioned into two groups according to the amount of cloud overlap along the line of sight. "Isolated" objects are those identified features with $\eta <= 0.10$ (crosses) and "shadowed" objects have values of $\eta > 0.10$

[1] We label these "objects" rather than clouds since identified features are often constituent parts of larger clouds or complexes.

[2] Θ_o=220 km s^{-1} , R_o=8.5 kpc

(triangles). We find no statistical difference of L_{FIR}/L_{CO} between the two groups. The mean and standard deviation of the luminosity ratio are 19.3 and 3.2 for isolated objects and 20.0 and 3.4 for the shadowed group. Thus, there is negligible contribution to the measured infrared fluxes from foreground or background material. There are two distinguished cluster of points centered

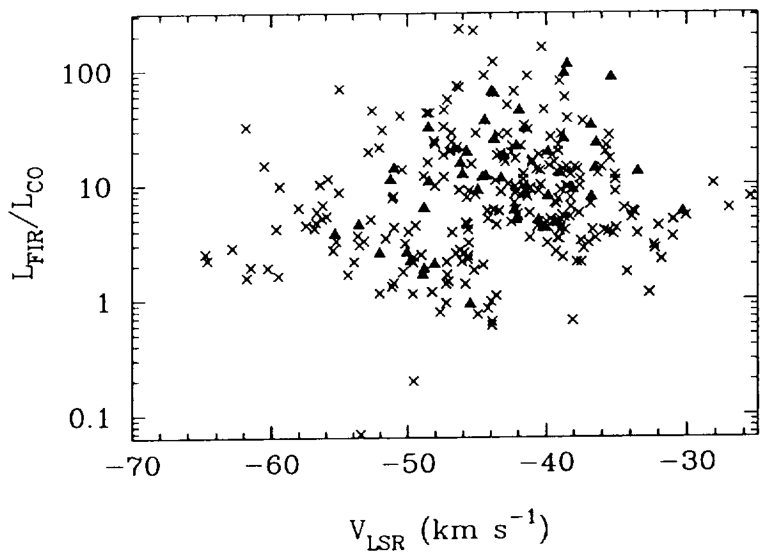

Figure 1: *The ratio of far infrared to CO luminosity for identified objects within the Perseus spiral arm as a function of* V_{LSR} . *Solid triangles are objects with geometric shadowing greater than 10% of the total projected area and crosses are objects with shadowing less than or equal to 10%.*

at (V_{LSR} ,L_{FIR}/L_{CO}) locations -52,2 and -41,10.5. Assuming that the measured V_{LSR} provides a relative location or depth, the observed bifurcation suggest that there are systematic variations of the star formation efficiency across the spiral arm. Locating the exact position within the arm for a given V_{LSR} is not possible without considering streaming motions imparted to the gas by the density wave perturbation. In the Perseus arm of the second quadrant, material is blueshifted with respect to the circular velocity as it enters the galactic shock and is forced along the length of the arm (Roberts 1972). Thus, the material at V_{LSR} =-50 km s^{-1} may be at the inner edge of the Perseus arm and therefore, foreground to the material at V_{LSR} =-40 km s^{-1} .

What chronological sequence do we expect the interstellar gas to follow within a spiral arm? As diffuse material enters the spiral potential, it is compressed along converging streamlines and redirected along the arm (Roberts 1969, Yuan 1969). It is within this galactic shock region where giant molecular clouds are expected to build up from smaller clouds through collisions or condense from a compressed layer of atomic gas (Kwan & Valdes 1987; Roberts & Stewart 1987, Balbus & Cowie 1985). Within a significant reservoir of molecular material, the formation of stars, including many generations of massive stars, can proceed until the gas is either depleted or dispersed. In the outer Galaxy, this star forming capability is exclusively confined to spiral arm regions since very little interarm molecular material is detected (Heyer & Terebey 1997; Digel *et al.* 1996). So the maximum time scale for star formation is the crossing time of the spiral arm or $\sim 50\times 10^{6}$ years.

However, the rate and efficiency of star formation within an interstellar cloud is likely to vary over the course of its transit through the arm as suggested by the two clusters of points in Figure 1. With the onset of massive star formation, the attendant UV radiation fields and stellar winds can significantly modify the local environment. In some cases, the interaction of ionization fronts with ambient cloud material can trigger additional star formation in the hot, compressed interface layers (Elmegreen & Lada 1977). Indeed, the interaction of the W4 ionization front with the ambient W3 molecular cloud is the prototype for such triggered star formation. More generally, these processes likely play a dispersing role in the interstellar medium which would necessarily inhibit subsequent star formation.

While surveys provide general statistical descriptions of the interstellar medium, detailed studies of targeted objects can probe the physics of certain astrophysical processes. Heyer *et al.* (1996) analyzed the far infrared and CO emissions from a unique cloud distinguished by a cometary tail which extends for $\sim 1^\circ$ or a projected distance of 37 pc. IRAS 60 and 100μm data reveal a dust counterpart to the gaseous tail with red colors with respect to the surrounding diffuse IR emission as well as a 1100 $L_\odot$ point source embedded within the cometary head region (Figure 2). The tail points away from the compact cluster of O stars (OCl 352) which are responsible for the W4 HII region and the excavation of a chimney in the HI layer of the Galaxy. This region provides a dramatic demonstration of an externally UV irradiated cloud in the interstellar medium. Due in part to the cool infrared colors, Heyer *et al.* proposed that the long tail is remnant cloud material which lies in the shadow cast by the cometary head region, and thus, has never been directly exposed to the strong, photoionizing radiation field. The availability of the HIRES data was critical to this study since the tail region is extremely narrow and likely unresolved along the minor axis by ISSA images.

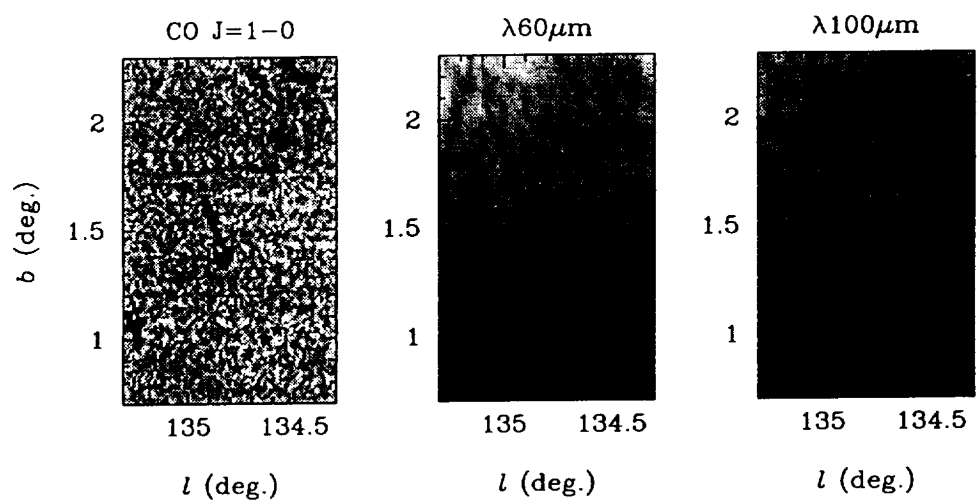

Figure 2: *Images of the gas and dust emission from the IC 1805 cometary cloud identified within the Survey field. The star symbols indicate the positions of members of the OCl 352 cluster of O stars.*