WIDE-LINE MOLECULAR CLOUDS AND THE GAMMA-RAY DEFICIT TOWARD THE GALACTIC CENTER

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ABSTRACT. The discrepancy between observed and predicted γ-ray emission toward the Galactic Center is attributed to a unique population of wide-line molecular clouds. The most prominent objects of this class show evidence of rotation and a significant stellar population. The observed ^{12}CO emission traces the gravitational field produced primarily by *stars*, not molecular gas.

1. Introduction

The correlation between diffuse, Galactic, high-energy γ-ray emission and gas tracers of the interstellar medium (*e.g.*, CO and HI) is well-established (Hartman *et al.* 1979, Strong *et al.* 1988). The one region of notable exception is the Galactic Center, where an order of magnitude discrepancy between observed and predicted γ-ray flux has been reported (*e.g.*, Blitz *et al.* 1985). We have undertaken a reanalysis of this question using a more fully-sampled, wide-latitude CO survey of the Center region (Bitran 1987), and the COS-B γ-ray data base (Mayer-Hasselwander 1985).

2. Wide-line Molecular Clouds

One of the most striking features of the Galactic Center CO survey is the presence of a unique population of wide-line molecular clouds (=WLC's, $<v_{rms}>\sim$20–60 km s^{-1}, Bitran *et al.* 1988). We have identified the overestimate in predicted γ-ray emission with the WLC's, the eight most prominent of which contribute approximately 58% of the total integrated CO intensity, W_{CO}, in the vicinity of the Galactic Center (Stacy *et al.* 1987). In order to investigate those cloud properties which may affect the molecular mass estimates of these objects, we have selected as archetypes the 3° (="Clump 2") and 5° WLC's, which are the most prominent and well-defined objects of their class.

We find evidence for rotation in both the 3° and 5° WLC's, based on maps of emission-weighted mean velocity (see Figure 1). Model fits to the data yield velocity gradients of 0.6 to 0.8 km s^{-1} pc^{-1}, with projected rotation axes inclined by $\sim$40–50° with respect to the Galactic plane. These values indicate rotational line widths of $\sim$60 km s^{-1}, implying that about half the observed line width is due to ordered, rotational motion.

We also find that the 3° and 5° WLC's contain a significant population of old stars, deduced from large-scale surveys of 2.4 μm emission toward the Galactic Center (*e.g.*, Melnick *et al.* 1987). The total NIR brightness of the 3° and 5° clouds is estimated to be

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at the level of ~1–2% that observed for the nuclear disk itself, implying stellar masses of $\sim 10^8\ M_\odot$ (assuming $M/L_{2.4\mu m} \sim 1$–$3\ M_\odot/L_\odot$).

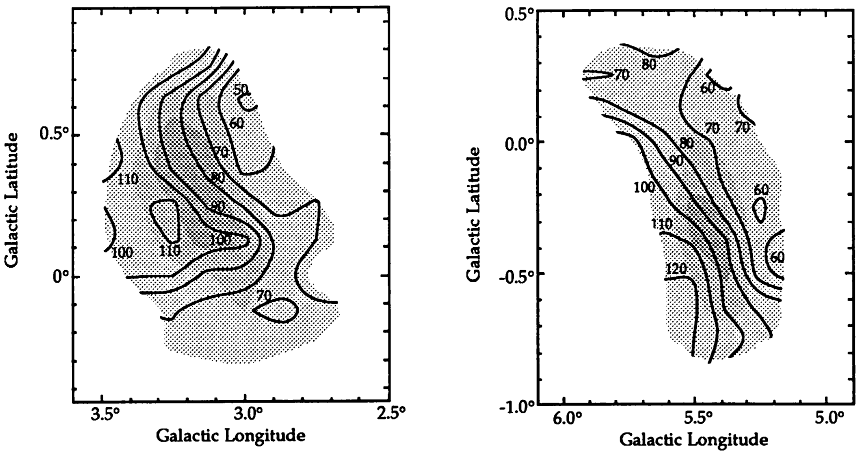

Figure 1. Emission-weighted mean velocity contours (in km s^{-1}) superposed on grey scale maps of integrated ^{12}CO antenna temperature for the 3° (left) and 5° (right) molecular clouds (grey scale levels: 175,375,575 K km s^{-1} and 50,150,250 K km s^{-1} for the 3° and 5° clouds, respectively).

3. Implications for γ-ray Emission

We conclude that the observed ^{12}CO gas traces the gravitational field produced primarily by *stars*, not molecular gas. The combination of optically-thin ^{12}CO emission (implied by the large velocity gradients) and possible enhanced metallicity effects (due to evolved stars) argues for a lower mass conversion ratio, N_{H_2}/W_{CO}, for these objects, which may be sufficient to reduce the *molecular* mass of these clouds to the extent that the γ-ray emission per nucleon is comparable to that in the outer Galaxy, *i.e.*, effectively removing the γ-ray deficiency. Observations with the next generation of γ-ray satellite experiments (*e.g.*, the Gamma Ray Observatory) should be capable of confirming the wide-line cloud origin of the γ-ray deficit.

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