158μm [CII] Mapping of the Galactic Center Molecular Clouds

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ABSTRACT. We have made 55" resolution maps of the 158 μm [CII] emission line in the region of the curved, thermal filaments and the +20 / +50 kms^{-1} molecular clouds in Sgr A. The [CII] emission is spatially well correlated with the radio continuum in the filaments. The large intensity of the [CII] radiation excludes shocks as the origin of the ionization and we conclude that the curved filaments are most likely photo-ionized HII regions at the surface of dense molecular clouds. Our [CII] maps of the +20 / +50 kms^{-1} clouds indicate that the +50 kms^{-1} cloud is close to (<10pc) Sgr A west while the more massive +20 kms^{-1} cloud is at a greater distance from the center (>30pc).

1. Observations

We observed the 158 μm [CII] line at 65 kms^{-1} resolution using the three channel UCB tandem Fabry-Perot spectrometer (Stacey et al. 1988, Lugten 1987). The observations were made on June 16, 1988 from NASA's Kuiper Airborne Observatory. The diffraction limited beam size was 55" and the maps were fully sampled with step size 30". The region mapped is shown in Fig. 1, superposed on the Yusef-Zadeh, Morris and Chance (1984) 20 cm VLA radio image of the Sgr A region.

2. Results and Discussion

2.1. RADIO ARC REGION

The curved, thermal filaments of the Arc show bright far-infrared [CII] emission (peak: 10^{-3} erg s^{-1} cm^{-2} sr^{-1}, Fig. 2). The fine structure line emission is spatially well correlated with the individual filaments and peaks of the radio continuum emission, and is strongest where the ionized gas is close to the dense molecular clumps observed by Serabyn and Güsten (1987) and Bally et al. (1987). The partially ionized gas also has about the same velocities (v_{LSR} = -30 kms^{-1}) as the ionized and molecular gas.

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The peak C^+ column densities are 10^{18} cm^{-2}, resulting in hydrogen masses of at least a few hundred $M_\odot$ per beam, and 10^4 $M_\odot$ or more integrated over the arc region ($C^+/H < 3 \cdot 10^{-4}$). Hence, the amount of partially ionized gas exceeds that of the ionized gas (2000 $M_\odot$), and is about 10% of the molecular mass (>10^5 $M_\odot$).

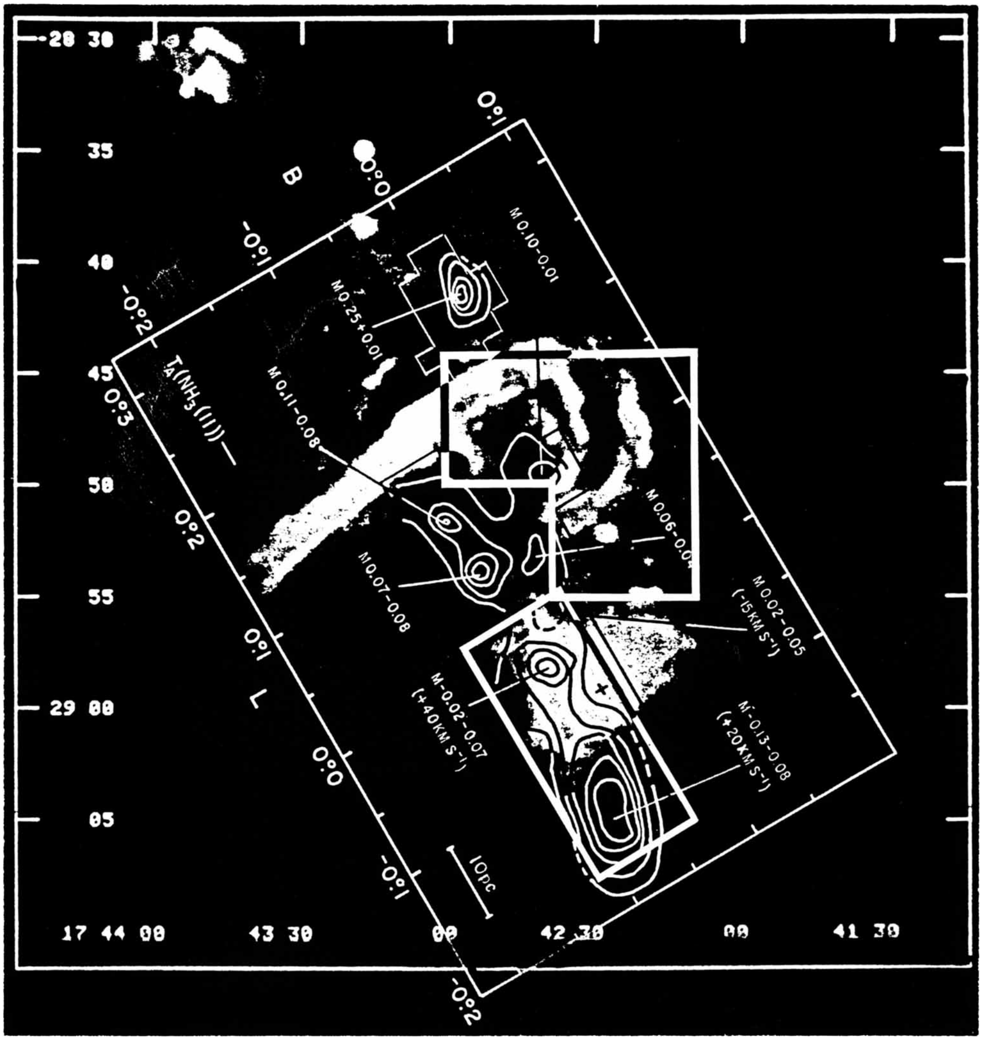

Fig. 1 The two regions mapped in the 158 μm [CII] fine structure line are shown superposed on the 20 cm radiograph of Yusef-Zadeh, Morris and Chance (1984) and the contours of NH_3 distribution (Güsten et al., 1981).

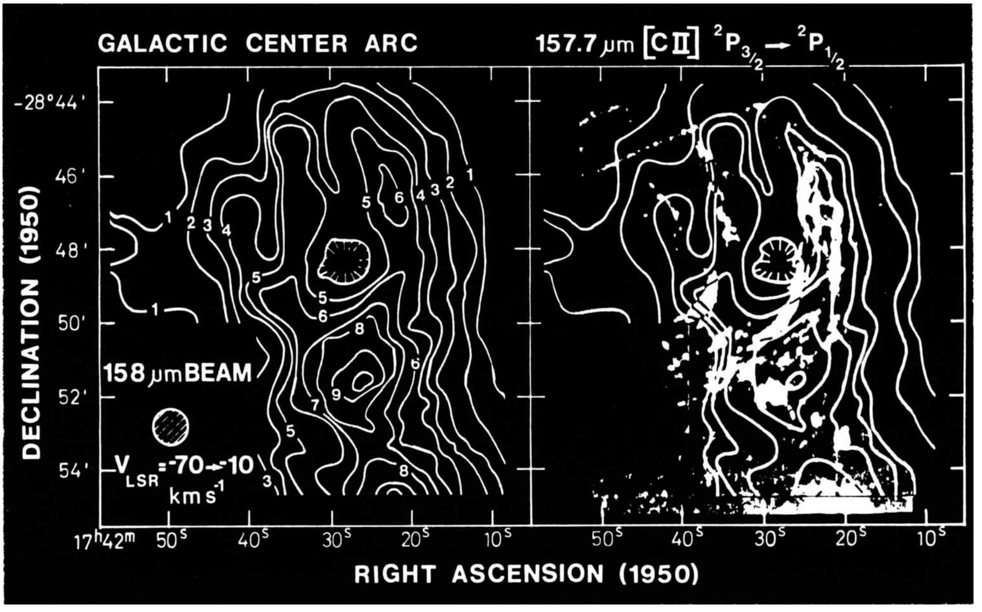

Fig. 2 [CII] map of the arc region between V_{LSR} = -70 and -10 kms^{-1} (left, contour unit 1.2 · 10^{-4} erg s^{-1} cm^{-2} sr^{-1}) and superposed on the thermal radio continuum emission (right, Morris and Yusef-Zadeh 1985).

Hollenbach and McKee (1988) have calculated the expected infrared line emission from fast shocks in interstellar clouds. Their calculations show the maximum [CII] line intensity emergent from a 40-50 kms^{-1} J-shock is 30 times weaker than the observed intensity. Thus, the high intensity of the [CII] emission excludes shocks as the origin of the ionization.

The [CII] line intensity is, however, consistent with emission from the warm, dense photodissociated gas found at the interface between molecular and fully ionized gas as in normal OB star forming regions. We conclude that the curved filaments are most likely photo-ionized HII regions at the surface of dense molecular clouds, as proposed by Serabyn and Güsten (1987). The line intensities of the several far-infrared lines detected by Erickson et al. (1988) from the curved filaments are in support of this conclusion.

Our new spectroscopic observations, together with the far-infrared continuum measurements of Gatley et al. (1977) and Dent et al. (1982) are best explained by recent OB star formation within about 30 pc of the galactic center.

2.2. THE +20/+50 kms^{-1} CLOUDS

The spatial distribution of [CII] emission between v_{LSR} = +10 and +70 kms^{-1} in the area of the Sgr A molecular clouds M -0.13 -0.08 (the +20 kms^{-1} cloud) and M-0.02-0.07 (the +40→50 kms^{-1} cloud) is shown in Fig. 3, together with the distribution of 1 mm dust emission (Mezger et al., 1988).

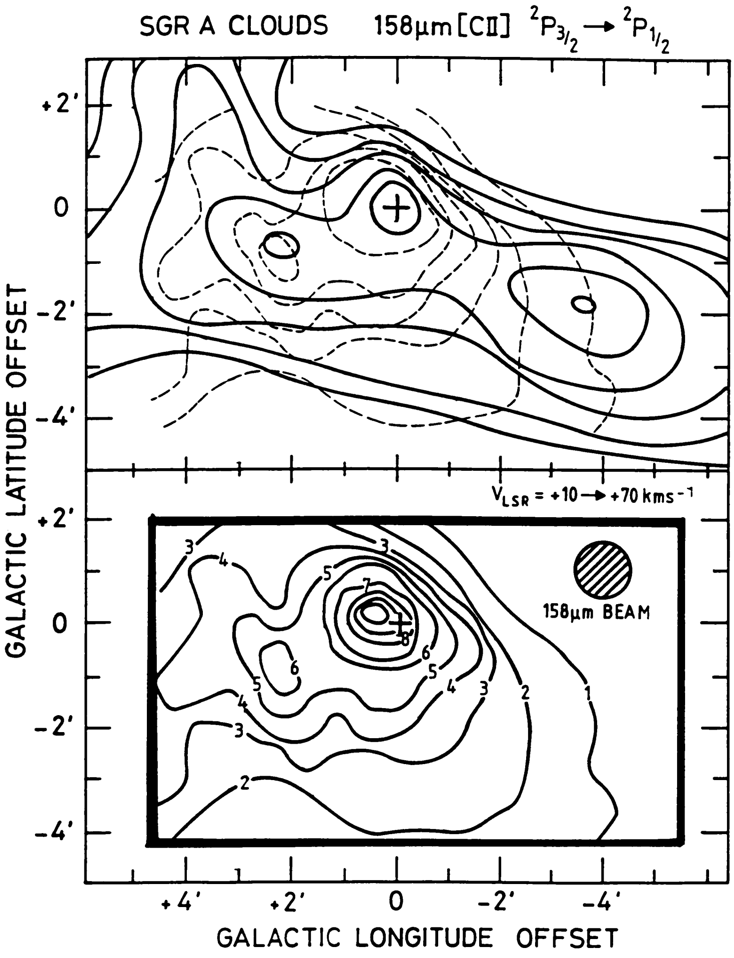

Fig. 3 [CII] map of the +20/+50 kms^{-1} molecular clouds between v_{LSR} = +10 and +70 kms^{-1} (bottom, contour unit 1.4 · 10^{-4} erg s^{-1} cm^{-2} sr^{-1}) and superposed on the clouds' 1 mm continuum emission from cool dust (top, Mezger et al. 1988).

The strongest [CII] emission at these velocities originates in a compact source about 40" (2pc) north of Sgr A*. This is the northern, redshifted lobe of the circum-nuclear disk or ring, and has been previously discussed by Lugten et al. (1986). Somewhat weaker, extended

[CII] line emission originates from the +50 kms^{-1} cloud. No detectable, or much weaker [CII] emission comes from the region of the +20 kms^{-1} cloud.

We interpret the measurements as follows. The far-infrared line emission probably cannot be accounted for by UV radiation coming from sources within the Sgr A molecular clouds, given their low far-infrared luminosity and dust temperature (cf. Dent et al. 1982, Mezger et al. 1988). The [CII] brightness can be explained by external UV radiation from the galactic center itself, if the +50 kms^{-1} cloud is close to Sgr A WEST, while the more massive +20 kms^{-1} cloud is at a greater distance from the center (> 30pc).

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