

# THE CENTRAL 300 pc OF THE GALAXY PROBED BY INFRARED SPECTRA OF $\text{H}_3^+$ AND CO

TAKESHI OKA, *Department of Astronomy and Astrophysics, Chemistry, The University of Chicago, Chicago, IL, USA*; THOMAS R. GEBALLE, , *Gemini Observatory/NSF's NOIRLAB, Hilo, HI, USA*.

Our 15 years' observations of the infrared spectra of  $\text{H}_3^+$  and CO toward 30 young and bright stars with smooth continuum and their analyses have led to the following conclusions.

**I. Predominance of Warm and Diffuse Gas and High  $\text{H}_2$  Ionization Rate<sup>a</sup>:** The CMZ is filled with warm ( $T \sim 200$  K) and diffuse ( $n \sim 50 \text{ cm}^{-3}$ ) hydrogen gas with a volume-filling factor  $f \sim 2/3$  and atomic and molecular hydrogen number densities are comparable. The cosmic ray  $\text{H}_2$  ionization rate,  $\zeta \sim 2 \times 10^{-14} \text{ s}^{-1}$ , is 1000 times higher than in the solar vicinity suggesting stray magnetic field of  $\sim 100 \mu\text{G}$  in the CMZ if equipartition between cosmic rays and magnetic field is assumed. The X-ray-emitting ultra-hot ( $10^8$  K) plasma, which some thought to dominate the CMZ, does not exist.

**II. Expansion and Morphology of the Warm Diffuse Gas<sup>b</sup>:** The wide velocity profiles of  $\text{H}_3^+$  lines have allowed us to draw longitude-velocity diagrams toward 18 stars. They indicated that the diffuse molecular gas is expanding with a front speed of  $\sim 150 \text{ km s}^{-1}$ . This revives the Expanding Molecular Ring proposed by Kaifu et al. and Scoville in 1972 but there are three differences: (1) the expanding gas is diffuse, (2) the expansion is radial, and (3) the gas fills the CMZ. This revives the circular geometry of the CMZ, as viewed face-on. The elliptic structure with high eccentricity is negated.

**III. Locations of Sgr B2 and Star Iota<sup>c</sup>:** The radial motion of the diffuse gas allows us to determine radial location of a star from velocity profiles of  $\text{H}_3^+$  or other molecules. Star  $\iota$ , which has a strong  $\text{H}_3^+$  absorption spectrum and is at galactic longitude  $0^\circ.5476$ , is close to Sgr B2 (at  $0^\circ.6667$ ). Using velocity profiles of  $\text{H}_3^+$  lines toward Star  $\iota$  and of  $\text{H}_2\text{O}^+$ ,  $\text{OH}^+$ , and  $^{13}\text{CH}^+$  spectra toward Sgr B2 observed by HIFI on the Herschel Space Observatory, we find that both Star  $\iota$  and Sgr B2 are  $\sim 90$  pc behind the GC's central black hole, Sgr A\*. This contradicts the previous conclusion based on trigonometric parallax, which placed Sgr B2  $130 \pm 60$  pc in front of Sgr A\*, as well as most models of the CMZ.

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<sup>a</sup>Oka, T., Geballe, T.R., Goto, M., Usuda, T., McCall, B.J., Indriolo, N. 2019, ApJ. 883, 54 (31pp)

<sup>b</sup>Oka, T., Geballe, T.R. 2020, ApJ. 902, 9 (17pp)

<sup>c</sup>Oka, T., Geballe, T.R. 2022, ApJ. 927, 97 (8pp)