INFRARED SPECTRUM OF H$_3^+$ NEAR THE GALACTIC CENTER

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The central 150 pc of the Galaxy called the Central Molecular Zone (CMZ) is the hub of astrophysical activities. It has high densities of stars, interstellar matter, supernovae, gravitational and magnetic energies, and emit intense radio and X-rays. A large fraction (~ 10%) of molecules in the Galaxy are concentrated in this region. Nevertheless its extinction is small since molecules are concentrated in dense (≥ 10$^4$ cm$^{-3}$) and massive molecular clouds with a volume filling factor of only ~ 0.01. What kind of gas fills the rest of the CMZ has been a vexed question.

Our observations using infrared spectrum of H$_3^+$ have revealed a vast amount of low density (~ 100 cm$^{-3}$) and high temperature (~ 250 K) gas with a high volume filling factor.$^a$ Crucial to this discovery has been the unique characteristics of H$_3^+$ as a probe based on its simple chemistry and spectroscopy. We use it as a dosimeter, a depth meter, a thermometer, and a densitometer to measure ionization rate $\zeta$, dimensions of the gas $L$, temperature $T$, and density $n$, respectively.$^b$

The H$_3^+$ spectrum in the CMZ first appeared as an enigmatic, intense and broad line toward the brightest star. The line was more than 10 times stronger than any H$_3^+$ line in the Galactic disk indicating a large amount of H$_3^+$ but we did not know how to interpret their intricate velocity profile. Our discovery in 2002 of the spectrum of H$_3^+$ in the $J = K = 3$ metastable rotational level$^c$ provided the key, which we used as the Rosetta stone to decipher the enigmatic spectrum.

Now observations of H$_3^+$ toward more than dozen stars from the center to 30 pc to the East and their analyses based on a model calculation of the thermalization of H$_3^+$, have established existence of a large amount of the warm and diffuse gas. The revelation of this new category of gas drastically changes the previous concept of the gas in the CMZ.$^d$ Its relation with the previously postulated three categories of gas will be discussed.

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