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Absorption Line Survey of H_3^+ toward the Galactic Center Sources

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We present high-resolution ($R = 20000$) spectroscopy of H_3^+ absorption toward the luminous Galactic center sources GCS 3-2 and GC IRS 3. With the efficient wavelength coverage afforded by Subaru IRCS, six lines have been detected, three of which are new. In particular the $3.543 \mu\text{m}$ absorption line of the $R(3, 3)^l$ transition arising from the metastable $(J, K) = (3, 3)$ state has been tentatively detected for the first time in the interstellar medium, where previous observations of H_3^+ had been limited to absorption lines from the lowest levels: $(J, K) = (1, 0)$ of ortho- H_3^+ and $(1, 1)$ of para- H_3^+ . The non-detection of spectral lines from other $J > 1$ levels provides observational evidence for the metastability of the $(3, 3)$ level, which is theoretically expected. This suggests that other metastable $J = K$ levels with higher J may also be populated.

The H_3^+ absorption toward the Galactic center takes place in dense and diffuse clouds along the line of sight as well as the molecular complex close to the Galactic nucleus. At least four kinematic components are found in the H_3^+ absorption lines. We suggest identifications of the velocity components with those of HI, CO, and H_2CO previously reported from radio and infrared observations. H_3^+ components with velocities that match those of weak and sharp CO and H_2CO lines are attributed to diffuse clouds. Our observation has revealed a striking difference between the absorption profiles of H_3^+ and CO, demonstrating that the spectroscopy of H_3^+ provides information complementary to that obtained from CO spectroscopy.