H$_3^+$ Line Survey Towards the Galactic Center

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1 H$_3^+$ Survey Towards the Galactic Center

The H$_3^+$ in the interstellar medium is a unique probe of physical and chemical environments in dense and diffuse clouds. As the observational study in many lines of sight is becoming matured, we have as many problems newly found. The overabundance of H$_3^+$ in diffuse clouds is one of them [3, 4]. We undertook the absorption line survey of H$_3^+$ toward the Galactic center sources to shed light on it [1].

The Galactic center sources are ideal line of sight to start the survey since they suffer heavy visual extinction of $A_V = 25–40$, the highest in the Galaxy among those obscured by diffuse clouds. The intervening clouds have different radial velocities, and the nature of them have been studied in previous spectroscopic observations from near-infrared to radio wavelengths. We observed two infrared sources, GCS 3-2 in the Quintuplet cluster and GC IRS 3 near Sgr A*. Both have intrinsically featureless spectra, and sufficiently luminous to provide good continuum fluxes in the $3 \mu$m region.

The observations were made in June 2001 using the Infrared Camera and Spectrograph (IRCS; Tokunaga et al. 1998; Kobayashi et al. 2000) at the 8.2 m Subaru Telescope. Subaru IRCS is equipped with an echelle and a cross-dispersing gratings. The high resolution ($R=20,000$) spectroscopy with wide wavelength coverage is unique characteristic of the instrument. It allows us to record one third of 3.2–4.0 $\mu$m with a single exposure. This makes the system very suitable for any line-survey projects, in particular for H$_3^+$ vibrational transition lines that scatter all over the $3 \mu$m region.

2 Result and Discussion

2.1 Velocity Components

All transitions within our spectral coverage starting from the ground states $(J, K)=(1, 0)$ and $(1, 1)$ are successfully detected (Figure 1). At least four velocity components are resolved in both GCS 3-2 and GC IRS 3 (Figure 2).

The bluest component of GC IRS 3 at $-140$ km s$^{-1}$ is attributed to the expanding molecular ring [7]. The expanding molecular ring is a chain of the
molecular clouds that rotates around the nucleus at 200 pc away from the Galactic center, slowly receding from it. The same component appears at $-110$ km s$^{-1}$ in the line of sight toward GCS 3-2.

The two absorption minima at $-60$ km s$^{-1}$ and $0$ km s$^{-1}$ toward GC IRS 3 closely match with those of H$_2$CO in the same line of sight. The HI spectrum toward Sgr A shows self-absorption at the same velocities. It indicates that those H$_3^+$ absorption to GC IRS 3 are originated from diffuse interstellar clouds. We attributed the $-60$ km s$^{-1}$ component to the clouds in the 3 kpc arm because the radial velocity is consistent. The signature of the 3 kpc arm also appears at similar velocity in absorption in GCS 3-2.

The $0$ km s$^{-1}$ components are usually attributed to the local clouds within a few kps from the solar system. However, in contrast to the absorption features at $0$ km s$^{-1}$ ubiquitously seen in the HI 21 cm spectroscopy, the H$_3^+$ absorption at $0$ km s$^{-1}$ with this intensity has not been observed in many