H_2F^+ : Herschel observation and laboratory chemical reaction study

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In 2013, the pure rotational lines J_{KaKc} = 2_{12} - 1_{01} and 1_{10} - 1_{01} of H_2F^+ were searched toward W31C, NGC 6334I, GC IRS21, 2Mass J1747 with the Heterodyne Instrument for the Far-Infrared (HIFI) on board the Herschel Space Observatory [1]. The transition frequencies have been measured in laboratory [2,3]. The proton affinity of HF is smaller than that of CO or N_2, so H_2F^+ is expected to be produced in diffuse cloud by proton transfer from H_3^+ to HF. In the two sources W31C and NGC 6334I, HF and H_2Cl^+ have been detected, and other two sources are known to have abundant H_3^+. By data analysis, the abundance of H_2F^+ is found to be less than 1/57 of H_2Cl^+ for NGC 6334I. Since the cosmic abundance of fluorine is one-half of that of chlorine, the small abundance of H_2F^+ may be explained by difference in production and/or destruction mechanism of both ions.

In laboratory, we investigated time-variation of the absorption intensities of H_2F^+ and H_2Cl^+ vibration-rotation lines in the 3 μm region to determine ion-electron recombination reaction rate constants, which have important roles for ion abundances in low density interstellar clouds. We used an optical parametric oscillator (OPO) laser with high resolution for absorption measurements. We employed pulsed discharge and measured time profiles of the absorption lines of H_2F^+ at ν = 3251.99 cm^{-1} (v_3 = 1-0, J_{KaKc} = $3_{13} \leftarrow 4_{14}$), and H_2Cl^+ at ν = 2691.24 cm^{-1} (v_3 = 1-0, J_{KaKc} = $6_{06} \leftarrow 5_{05}$). Figure 1 shows an example of observed time profiles.

Initially, assuming the same densities of electron and positive ion, we attempted 1/*N*(density) plot in the secondary reaction scheme, but it was not possible to fit well. On the other hand, the decay was explained well by an exponential function, so we assumed the decay by the pseudo-first-order reaction between ion and electron. We used the Langmuir probe method for determination of electron density and derive the recombination rate constants, as follows, $k_e(H_2F^+) = 3.8\ (1.6) \times 10^{-8} cm^3 s^{-1}$, and $k_e(H_2Cl^+) = 2.4(1.0) \times 10^{-8} cm^3 s^{-1}$. We did not find major difference between the H_2Cl^+ and H_2F^+ ions for recombination rates. Small abundance of H_2F^+ compared with H_2Cl^+ in interstellar space is thought to be due to the difference in the formation reaction.

In diffuse clouds, the presence of HCl^+ is important for production of H_2Cl^+, where the ion has been detected by Herschel. The ion can produce H_2Cl^+ by a reaction with H_2. On the other hand, HF is not ionized in interstellar radiation field. F^+ reaction with H_2 produces HF^+ [4], but F^+ is not abundant in diffuse clouds.

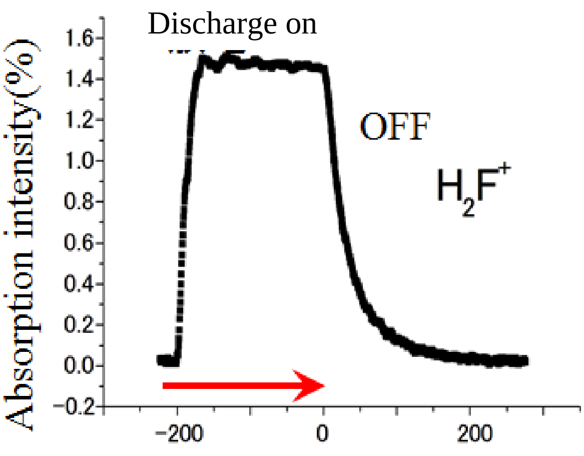

Fig.1 Time profile of the H_2F^+ line for ion-electron recombination study

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[3]T. Amano, F. Matsushima, T. Shiraishi, C. Schnozuka, R. Fujimori, and K. Kawaguchi, *J. Chem. Phys.* **137**, 134308 (2012).
[4] D. A. Neufeld, and M. G. Wolfire, *ApJ*, **706**, 1594 (2009).