

[초 IM-01] H₃⁺, the New Astrophysical Probe

Takeshi Oka

*Department of Astronomy and Astrophysics and Department of Chemistry,
The Enrico Fermi Institute, the University of Chicago, Chicago, Illinois, U. S. A.*

After atomic hydrogen, H, and molecular hydrogen, H₂, the protonated molecular hydrogen, H₃⁺, is the third hydrogenic astrophysical probe which has been introduced recently. The infrared spectrum needed for its detection was discovered in the laboratory¹ in 1980. The spectrum was discovered in Jupiter^{2,3} in 1989 and in interstellar space⁴ in 1996. The interstellar H₃⁺ was first detected in dense molecular clouds⁴ where it had been predicted, but soon detected also in diffuse clouds⁵ where detectable H₃⁺ was unexpected. Surprisingly, observations have established that the H₃⁺ to H₂ ratio is 10 times *higher* in diffuse clouds than in dense clouds⁶. Quite unexpectedly, H₃⁺ has emerged as a powerful probe to study the diffuse interstellar medium.

H₃⁺ provides four kinds of astrophysical information: the temperature, T , the density n , the (cosmic ray) ionization rate ζ , and the radial length of clouds L . The surprising abundance of H₃⁺ in diffuse clouds has revealed that the soft cosmic ray flux is 10 times higher in diffuse clouds than in dense clouds.⁷

H₃⁺ is particularly abundant and ubiquitous in the Central Molecular Zone (CMZ), a region of radius ~ 200 pc near the Galactic center. Observations has led to the discovery of a vast amount of warm ($T \sim 250$ K) and diffuse ($n \sim 100$ cm⁻³) gas in the CMZ^{8,9}. H₃⁺ has also been detected in an ultra-luminous infrared galaxy IRAS 08572+3915 NW¹⁰. The recent results will be discussed.

¹ T. Oka, Phys. Rev. Lett. 45, 531 (1980)² P. Drossart et al. Nature, 340, 539 (1989)³ T. Oka, Rev. Mod. Phys., 64, 1141 (1992)⁴ T. R. Geballe and T. Oka, Nature, 384, 334 (1996)⁵ B. J. McCall, T. R. Geballe, K. H. Hinkle, and T. Oka, Science, 279, 1910 (1998)⁶ T. Oka, Proc. Natl. Acad. Sci. USA, 103, 12235 (2006)⁷ N. Indriolo, T. R. Geballe, T. Oka, and B. J. McCall, ApJ, 671, 1736 (2007)⁸ T. Oka, T. R. Geballe, M. Goto, T. Usuda, and B. J. McCall, ApJ, 632, 882 (2005)⁹ M. Goto, et al. ApJ, 688, 306 (2008)¹⁰ T. R. Geballe, M. Goto, T. Usuda, T. Oka, and B. J. McCall, ApJ 644, 907 (2006)