

Experimental Molecular Emission Spectroscopy of Ethylene Oxide in ALMA Band 6

A. Tamanai,¹ Y. Watanabe,² T. Sakai,³ R. Nakatani,¹ S. Zeng,¹ S. Yamamoto,⁴ and N. Sakai¹

¹ Cluster for Pioneering Research, RIKEN, Japan

²Material Science and Engineering, Shibaura Institute of Technology, Japan

³Department of Engineering Science, The University of Electro-Communications, Japan

⁴Department of physics, The University of Tokyo, Japan

New discoveries related to astrochemistry in mm and sub-mm frequency ranges have provided us fruitful information on valuable chemical properties of organic compounds. Thanks to the highly sensitive ALMA telescope, it has become possible to detect very complex interstellar organic molecules than ever before [1-4]. Emission and absorption lines from each molecule obtained from observations give us a clue to understand the chemical pathways from simple molecules to complex molecules including the essential molecules of life.

Either or both of theoretically calculated and experimentally measured emission spectra are applied for interpretation of observed molecular lines in general. One of major problems concerning molecular survey is that an insufficient supply of experimentally measured data sets for both organic and inorganic compounds in millimeter and submillimeter frequency ranges. To solve this problem, we have set up the emission type molecular spectroscopy for astronomically relevant materials in the frequency range between 216 GHz and 264 GHz (ALMA Band 6). Superconductor-Insulator-Superconductor (SIS) mixer for ~230 GHz band mounted on the ALMA-type cartridge receiver as a heterodyne apparatus (SUMIRE) is applied in this measurement (details in [3]).

In here, we introduce our experimental broadband and high-resolution spectroscopic apparatus as well as a measured ethylene oxide (C₂H₄O) which has been detected in high-mass star forming regions such as the galactic center source Sgr B2 (N) [5], hot molecular clouds DR21 (OH), NGC7538 [6] and low-mass protostar IRAS 16293-2422 [7]. In consequence, 677 peaks due to rotational transitions have been detected. Molecular parameters including predicted transition frequencies, rotational constants, and centrifugal distortion constants were derived by making use of a least-squares analysis and self-developed SUMIRE data analysis code, Aqualious for both C₂H₄O and ¹³C₂H₄O. 256 peaks and 108 peaks were assigned as contributions from C₂H₄O and ¹³C₂H₄O rotational transitions, respectively. In addition, we compared our experimental outcomes with the data sets in Cologne Database for Molecular Spectroscopy (CDMS) [8] and previous works [9-10]. Thereby our results are in good agreement with previously obtained data. This also demonstrates the reliability of our experimental results.

References

- [1] Y. Oya & S. Yamamoto, 2020, ApJ 904, 185.
- [2] B.A. McGuire, C.L. Brogan, T.R. Hunter, A.J. Remijan, G.A. Blake et al., 2018, ApJ 863, L35.
- [3] Y. Watanabe, N. Sakai, A. López-Sepulcre, T. Sakai, T. Hirota et al., 2017, ApJ 847, 108.
- [4] N. Sakai, T. Sakai, T., Hirota, Y. Watanabe, C. Ceccarelli et al., 2014, Nature 507, 78.
- [5] J.E. Dickens, W.M. Irvine, M. Ohishi, M. Ikeda, S. Ishikawa, 1997, ApJ 489, 753.
- [6] M. Ikeda, M. Ohishi, A. Nummelin, J.E. Dickens, P. Bergman et al., 2001, ApJ 560, 792.
- [7] J.M. Lykke, A. Coutens, J.K. Jørgensen, M.H.D. van der Wiel, R.T. Garrod et al., 2017, A&A 597, A53.
- [8] C.P. Endres, S. Schlemmer, P. Schilke, J. Stutzki, H.S.P. Müller, 2016, J. Mol. Spectrosc. 327, 95.
- [9] R.A. Creswell & R.H. Schwendeman, 1974, Chem Phys L 27, 521.
- [10] C. Hirose, 1974, B Chem Soc Jpn 47, 1311.