URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Current Status and Future Challenges of Newly Developed Imaging Tool for ALMA

Takeshi Nakazato*(1), Shiro Ikeda(2), Takashi Tsukagoshi(3), Akio Taniguchi(4), Masayuki Yamaguchi(5), George Kosugi(1), Mareki Honma(1), Ryohei Kawabe(1), Kazunori Akiyama(6), Toshinobu Takagi(7), Yoshihiro Yamada(7), and Atsushi Miyazaki(7)
(1) National Astronomical Observatory of Japan, Japan; e-mail: takeshi.nakazato@nao.ac.jp
(2) The Institute of Statistical Mathematics, Japan; e-mail: shiro@ism.ac.jp
(3) Ashikaga University, Japan
(4) Nagoya University, Japan
(5) Academia Sinica Institute of Astronomy and Astrophysics, Taiwan
(6) Massachusetts Institute of Technology Haystack Observatory, USA
(7) Japan Space Forum, Japan

Radio interferometer is an instrument to measure the visibility, which is Fourier transform of an intensity distribution of radio emission on the sky (radio image). Reconstruction of the radio image from observed visibility data is difficult task because we only observe part of the spatial frequency components so that the problem is forced to be underdetermined. Traditionally, image reconstruction has been mainly done by the CLEAN method. On the other hand, observation of black hole shadow conducted by the Event Horizon Telescope (EHT) [1] proved that Regularized Maximum Likelihood (RML) method is also a powerful tool to reconstruct radio images. Remarkable feature of the RML method is that it has no algorithmic limitation on the angular resolution so that it has the potential to achieve higher resolution than the restriction imposed by the observation [2], [3].

We have developed an image reconstruction tool dedicated to Atacama Large Millimeter/submillimeter Array (ALMA), so-called Python module for Radio Interferometry Imaging with Sparse Modeling (PRIISM) [4]. PRIISM is an implementation of RML method with specifically chosen regularization terms for ALMA data, and is created on top of Common Astronomy Software Applications (CASA) [5]. Since ALMA is general-purpose telescope, it potentially produces images with diverse characteristics reflecting the physical and/or chemical properties of the target. We incorporated two regularization terms, L1 norm [2] and Total Squared Variations (TSV) [6] into PRIISM to be able to process variety of images. These terms control a sparsity and a smoothness of the resulting image, respectively, and their restrictions are characterized by two hyper-parameters, Λ_1 and $\Lambda_{\rm TSV}$. Resulting image that best describes the observed visibility is determined by optimizing hyper-parameters with k-fold cross-validation. Interface of PRIISM is designed to enable users to produce the best image in a semi-automatic way. Template Python script is provided to help users to easily construct end-to-end processing script for their dataset. With PRIISM, we successfully produced reliable images with sufficient quality for scientific use [3].

In this paper, we report current status of PRIISM and expected challenges toward even larger data produced by future facilities such as upgraded ALMA and SKA. Performance is one of such challenges since the cross-validation is known to be time-consuming. Another challenge is an automation of the imaging process, which aims to produce reliable image from observed visibility data and minimum set of image parameters without human intervention. We will discuss how to overcome those problems.

References

[1] Event Horizon Telescope Collaboration et al., 2019, ApJ, 875, L4, doi: 10.3847/2041-8213/ab0e85

[2] M. Honma, K. Akiyama, M. Uemura, and S. Ikeda, 2014, PASJ, 66, 95, doi: 10.1093/pasj/psu070

[3] M. Yamaguchi, T. Tsukagoshi, T. Muto, H. Nomura, T. Nakazato, S. Ikeda, M. Tamura, and R. Kawabe, 2021, ApJ, 923, 121, doi: 10.3847/1538-4357/ac2bfd

[4] T. Nakazato, S. Ikeda, G. Kosugi, M. Honma, 2020, Proceedings of the SPIE, Volume 11453, id. 114532V 11 pp., doi: 10.1117/12.2560904

[5] CASA Team et al., 2022, PASP, 134, 11451, doi: 10.1088/1538-3873/ac9642

[6] K. Kuramochi, K. Akiyama, S. Ikeda, F. Tazaki, V. L. Fish, H.-Y. Pu, K. Asada, M. Honma, 2018, ApJ, 858, 56, doi: 10.3847/1538-4357/aab6b5