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Machine Learning-Driven Determination of 3D Structures of Molecular Clouds in High-Resolution mm Images

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The analysis of dust scattering halos (DSH), caused by the intense radiation from Galactic black hole transients (GBHTs), provides observational insights to understand the composition and structure of molecular clouds in the line of sight to the source and determine the distance to the source. Observations of DSH of 4U 1630−47, a GBHT, identified a significant molecular cloud (MC −79) that shapes the observed DSH as well as the additional clouds in the line of sight, as evidenced by Chandra and Swift data. The structural analysis of the halo provided a kinematic distance estimate, yet the 'near-far' distance ambiguity for most clouds persists, necessitating future multi-wavelength observations (Kalemci et al. 2018).

Unraveling the near-far distance ambiguity for molecular clouds present in the DSH of 4U 1630−47 requires the determination of the detailed 3D morphology of molecular clouds in the line of sight by utilizing high-resolution 12CO J = 1 − 0 maps and spectral data acquired from the APEX.

We have developed a novel methodology with an application of a machine learning algorithm for clustering for identifying the three-dimensional structures of molecular clouds from sub-mm wave images. Our method consists of four core stages: finding local peaks through Gaussian decomposition, dividing the data into segments, applying OTSU thresholding to identify cloud-occupied regions, and clustering the data into clouds with a modified version of the Mean-Shift (MS) clustering algorithm. The development of this novel methodology was driven by the necessity of analyzing data with a narrow field of view coupled with the complexity of cloud overlaps within the observational data. Overlapping clouds in the data require an approach to assigning one pixel to more than one cloud by applying a pixel division strategy. This strategy is achieved by the modification of the MS algorithm which allows the creation of soft clustering assignments and division of the pixels with the soft assignment results for the overlapping areas.

Through our approach, we have identified the 3D structures of 15 molecular clouds along the line of sight of the source object, providing pivotal data to resolve the distance ambiguity associated with these clouds. This innovative approach holds potential for broader applications in analyzing various DSHs and molecular clouds within the interstellar medium.

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