

SPATIAL DISTRIBUTION OF ALUMINUM MONOXIDE MOLECULES IN A HIGH MASS PROTOSTAR CANDIDATE ORION SOURCE I.

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Introduction: Aluminum monoxide (AlO) is a refractory molecule that can be present as vapor at high temperature. It is a key molecule to form most refractory solids and could thus be a good tracer of kinematics in high-temperature regions around young stellar objects (YSOs). In extended atmospheres of oxygen-rich AGB stars, AlO forms aluminum oxide including corundum (α -Al₂O₃) as the first dust [e.g., 1–3]. The spatial distribution of AlO around an evolved star was observed by ALMA [4]. In circumstellar environments around YSOs, AlO can form refractory minerals within Ca- and Al-rich inclusions (CAIs) in chondrites. The chemistry, mineralogy, and petrology of CAIs strongly suggest their high-temperature origin in the very early stage of disk evolution, but it has been under debate where and how CAIs formed in the early Solar System. The observation of AlO around YSOs should provide a new insight into the formation of refractory components in the early Solar System. There has been no definitive detection of AlO in the star forming regions except for tentative detection of AlO emissions at 229.7 and 344.4 GHz in Orion Source I, a candidate of high-mass YSO in the Orion Kleimann-Low (KL) region [5]. In this study, we analyzed the ALMA observation data for Orion Source I to search for AlO molecules [6].

Data Reduction: The ALMA observation data of Orion Source I obtained in Cycle 1 (2012.1.00123.S) and Cycle 2 projects (2013.1.00048.S) were used in this study. The Band 8 data in the Cycle 2 observation and the Band 9 data in the Cycle 1 observation were used for investigating AlO emissions at 497 and 650 GHz, respectively. The data were reduced following the procedure described in [7]. The reduction was processed with the Common Astronomy Software Applications (CASA) software.

Results: We found broad emission features at 497 and 650 GHz, consistent with AlO ($N=13-12$ and $17-16$) lines with hyperfine structures. The peaks at 497 and 650 GHz can be well reproduced with the line-of-sight velocities of 3.6 ± 0.3 and 4.6 ± 0.1 km s⁻¹ and the velocity widths (FWHM) of 24.1 ± 0.9 and 20.0 ± 0.4 km s⁻¹ for the Gaussian dispersion, respectively. The obtained line-of-sight velocities are consistent with those of other molecules (e.g., SO, SO₂, SiS, SiO, H₂O, and alkali halides) observed for Orion Source I [e.g., 5, 7]. The integrated flux maps of the two emission features show that they are localized in the launching point of outflow from the circumstellar rotating disk of Orion Source I.

Discussion: The upper state energies of AlO lines at 497 and 650 GHz are ~ 167 and ~ 281 K, respectively. Detection of AlO emissions is expected in the wide range of the outflow from the disk if it is in the gas phase. However, the distribution of AlO is limited to the base of the rotating outflow from the disk, which indicates that AlO molecules are not present in the gas phase most likely due to its refractory nature. Aluminum monoxide may thus not be present in the gas phase in the expanding outflow due to recondensation of refractory dust as discussed for alkali halides [5], while SiO molecules sublimated from silicate dust are present in the gas phase in the outflow [7]. The hot nature of the disk around the embedded massive protostar suggests that CAI-like solid objects enriched in refractory elements could form in the disk. Further observations of high-temperature metal-bearing gas molecules in the disk around YSOs could link the high-temperature CAI formation event occurred in the early Solar System to the star formation and subsequent planetary formation processes.

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