Molecular Gas Conditions in a Quasar at Redshift 6 Probed by High-J CO and H_2O^+ Observations

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Quasars at redshift 6, which are located at the end of the Epoch of Reionization, are believed to play a key role in the evolution of massive galaxies. Studying the interstellar medium in their host galaxies allows us to gain more insight as to how they affect the surrounding molecular gas as well as star formation. Numerous studies have been conducted into building the CO SLEDs of quasars, but more observations of high-J transitions are necessary in order to unveil whether there are any high temperature or high density components. We made observations of the quasar, J2054-0005, at redshift z = 6.04 during ALMA's 11th cycle and detected three new high-J CO emission lines, as well as two H_2O^+ absorption lines: CO (J = 14-13), (J = 15-14) and (J = 19-18), H_2O^+ ($6_{2,4}$-$5_{3,3}$) and ($6_{3,3}$-$6_{2,4}$). H_2O^+ ($6_{3,3}$-$6_{2,4}$) and CO (J = 19-18) are both tentative detections. In order to deduce the physical conditions from the CO emission lines, we used a non-LTE radiative transfer code to model the observed integrated flux values, which could be fit with two components. The physical conditions we obtained for component 1 were T_{kin} ~ 300 K and $\log(n(H_2/cm^{-3}))$ ~ 6 and for component 2 they were T_{kin} ~ 400 K and $\log(n(H_2/cm^{-3}))$ ~ 3. H_2O^+ traces molecular gas, and is ionised due to cosmic rays and X-rays, which could be induced by the quasar. Moreover, there is one H_2O^+ line, which is blueshifted by ~200 km/s with respect to the systemic velocity of the quasar, thereby indicating that the H_2O^+ molecules could exist in the quasar's outflow, which has been previously detected in OH 119 µm.