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TITLE: Water vapor emission in ultra-luminous infrared galaxies at $z \sim 2-4$

ABSTRACT BODY:

Abstract Body: *Herschel* observations of local Ultra-Luminous InfraRed Galaxies (ULIRGs) have revealed a rich spectrum of submillimeter H_2O rotational emission lines up to upper level energies of $E_{u/k} = 642$ K. And most local ULIRGs emit such luminous high-excitation H_2O lines. From the analysis of the excitation of these H_2O emission, they are likely probe the local IR radiation field in their dense galactic cores several 100 pc in diameter, but the lower levels ($E_{u/k} \sim 100-150$ K) may also well be excited by collisions and shocks as in Milky Way hot cores. Strong H_2O lines provide therefore a unique diagnostic for a totally different regime than the CO usual lines. We have detected H_2O (five of them have both $J=2$ and $J=3$) in 16 high- z ($z \sim 2-4$) lensed ULIRGs discovered by *H-ATLAS* survey using PdBI. As in local ULIRGs, the intensity of the high- z H_2O lines are about half that of high- J CO lines at similar frequencies. The CO in some of the sources have similar profile compared with H_2O , indicating similar location and thus physical condition, considering differential lensing. The intrinsic H_2O luminosity (corrected for the magnification factor) increases rapidly with the intrinsic IR luminosity (slightly faster than linearly, $L_{\text{H}_2\text{O}} \sim L_{\text{IR}}^{1.2}$). This implies that IR pumping is important for H_2O excitation in these sources. The key role of IR pumping is also confirmed in local ULIRGs such as Mrk 231 and Arp 220 by the strong excitation of $J=3$ and 4 H_2O lines, such as $3_{21}^{-3} 1_2$ or $4_{22}^{-4} 1_3$, with upper level energy $E_{u/k} \sim 300-450$ K. But the ratio of $J=2$ lines ($E_{u/k} \sim 100$ K) to $J=3$ and 4 lines varies in high- z ULIRGs, likely reflecting contributions from different excitation processes. Finally, these $J=2$ H_2O lines may be detected in practically all *Herschel* strong lenses with the PdBI. ALMA should be able to study H_2O in all *Herschel* high- z sources (SMGs) even those that are unlensed. However, high resolution study by the telescope like NOEMA and ALMA is still needed for studying the detail spatial distribution of water vapor.

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