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X-ray induced chemistry for water and related molecules in low-mass protostar envelopes

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Water has been used to study dynamical properties of star-forming regions, and it is also one of key molecules in chemical evolutions. Recent water line observations toward several low-mass protostars suggested low water abundances in the inner warm envelopes. Water destruction by strong X-ray fluxes may influence in these regions, but detailed processes, including molecules holding oxygen instead, have not yet understood.

In our study, we calculated the chemical evolutions of low-mass Class 0 protostar envelopes using the detailed gas-grain chemical reaction network including X-ray induced chemical reactions, and investigated the dependences of water and related molecule’ s abundances on X-ray radiation fields.

If the central protostars have higher X-ray luminosities ($L_X>10^{30}$ erg s^{-1}), water gas abundances become higher (up tp $x(H_2O)\tilde{}10^{-8}$–10^{-7}) just outside the water snowline (T<100 K), compared with the values ($x(H_2O)\tilde{}10^{-10}$) in the cases of lower X-ray luminosities ($L_X<10^{30}$ erg s^{-1}). Inside the water snowline (T>100 K), in the cases of lower X-ray luminosities, water gas molecules maintain the high abundances of 10^{-4}, and they are considered to be the dominant oxygen carrier with CO. On the other hand, in the cases of higher X-ray luminosities, water gas abundances become much smaller just inside the water snowline (T˜ 100–250 K, below to $x(H_2O)\tilde{}10^{-8}$–10^{-7}) and in the innermost hot regions (T˜250 K, $x(H_2O)\tilde{}10^{-6}$). In these cases, molecular and atomic oxygen abundances reach around 10^{-4} within the water snowline. In addition, some other water related molecules, such as HCO^+ and CH_3OH, are also affected by X-ray radiation fields. These X-ray effects are larger in the envelope models with lower number densities. Current and future molecular line observations for protostars (e.g., ALMA) will access the regions where such X-ray induced chemistry is important.

Keywords: astrochemistry, molecules, protostars, snowline, water, X-ray

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