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Oxygen chemistry in the circumstellar envelope of the carbon-rich star IRC+10216

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Abstract. IRC+10216 is a low mass AGB star losing mass at a rate of 2-4$\times10^{-5}$ $M_\odot$ yr^{-1} in the form of a wind that produces an extended circumstellar envelope (CSE). The processes of dredge-up during this thermal pulsating evolutionary phase has enhanced the C/O ratio above 1. Local thermodynamic equilibrium (LTE) calculations, valid in the high temperature and density region (T$\sim$2500 K and $\rho\sim10^{14}$ cm^{-3}) near the photosphere, show that in such a C-rich environment the CO molecule locks almost all the oxygen, due to its high stability, and allow for the carbon in excess to form C-bearing molecules, which dominate the circumstellar chemistry. However, recently some O-bearing molecules have been detected towards IRC+10216 with moderate abundances, H_2O (Melnick et al. 2001; Nature, 412, 160), OH (Ford et al. 2003; ApJ, 589, 430) and H_2CO (Ford et al. 2004; ApJ, 614, 990). The presence of water, not expected in this source, was interpreted by these authors as the evaporation of cometary ices from a Kuiper belt-analog.

Can the presence of water in a C-rich CSE be univoquely assigned to a cometary origin?. We have studied the possible chemical routes leading to the formation of H_2O as well as other O-bearing molecules in the conditions of the C-rich expanding envelope of IRC+10216.

We distinguish two zones of the CSE: inner and outer envelope, with well differentiated properties. The former extends from the photosphere up to some few stellar radii, in which phenomena such as pulsational driven shocks and dust condensation make the gas to expands. LTE calculations predict that H_2O become very abundant when temperature decreases below $\sim$ 700 K but gas phase chemical reactions are not rapid enough for transforming CO into H_2O in the dynamical timescales of the expanding envelope. Only processes on grain surfaces acting as a catalyst would be able of such transformation, as have been proposed by Willay 2004; ApJ, 600, L87. In the expanding outer envelope some O-bearing species increase its abundances when CO photodissociates due to the interstellar standard UV field. Neutral-neutral reactions without activation energy and radiative associations are competitive in producing O-bearing species until they are also photodissociated. At this moment we just have some preliminary results: H_2CO abundance predicted by these routes reach a peak values of 4×10^{-9}, somewhat lower than the observational estimation of 1.3×10^{-8}. Predictions for H_2O and OH abundances are some orders of magnitude lower than the ones derived from line observations, but these depends on the assumptions for the size of the emitting region. The higher the size, the lower the abundance needed for explaining a given line intensity. HCO^+ is also predicted with an abundance that ranges from 1×10^{-10} to 6×10^{-10} depending on the H_2 ionization rate by cosmic rays. Using these values in a non-local radiative transfer modelling, the 1-0 line of HCO^+, which has an intensity of $\sim$ 20 mK, can be well reproduced.

Future observations of submillimeter lines of H_2O with the HIFI instrument on board the Herschel satellite together with detailed radiative transfer modelling of the lines will help to constraint the water abundance, the location from where it comes as well as the chemical origin, i.e. cometary ices, grain surface processes or chemistry in the outer envelope.

Keywords. stars: AGB, carbon, circumstellar matter, stars: individual (IRC+10216)

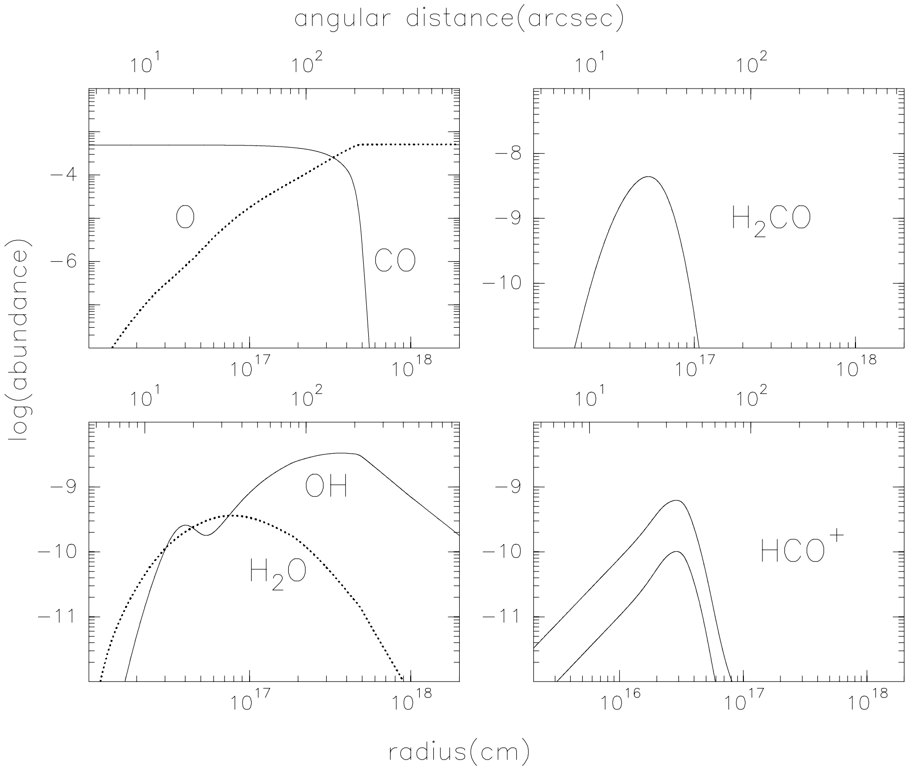

Figure 1. Abundances for some O-bearing molecules in the outer envelope of IRC+10216 as predicted by chemical modelling.