Line profiles of water for the non-uniform density distribution in a cometary coma

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Observations and modeling of the molecular lines provide powerful diagnostics of the physical conditions in a cometary coma such as the density and the velocity structure. The pure rotational transitions of ortho- and para-water for several comets has been recently successfully provided by the Herschel space telescope. The rotational lines of water are optically thick. The water line shapes and the OTF maps taken with the high-resolution instrument Herschel/HIFI allowed to localize an active region on the nucleus of comet 10P/Tempel 2, close to its pole [1]. The evidence of anisotropic outgassing of comets may be interpreted with models of non-uniform distribution of activity.

A numerical model for the simulation of water line emission in cometary coma is presented. The model is based on a non-uniform density distribution and the escape probability method for treating radiative transfer. The excitation model includes collisions with water and electrons, and infrared pumping. The equations of statistical equilibrium are solved in all cells of the coma with constant properties like density, temperature, and expansion velocity. The gas density profile in the regions of enhanced activity is described by a density function for emission into the cone. The density within the cone can be constant or vary as a function of the angle with respect to the outgassing axis. The outgassing pattern model assumes also the isotropic emission or uniform emission outside the cone where the temperature, the density and the expansion velocity can differ from those within the cone. Two different parts of the coma (material inside the cone and outside it) are radiatively coupled, thus the integrated mean intensity depends also on the non-local contributions to the radiation field. Synthetic line profiles of water (ground-level rotational transition) as seen with different telescope beams (e.g., Herschel, or MIRO - the Microwave Instrument for the Rosetta Orbiter) are computed at various off-set positions. It is shown that the gas density distribution influences the line shape and absorption and emission signal in the line profile. For the non-uniform density distribution, the emission peak is shifted with respect to the nucleus-observer direction. Effects of the physical parameters (density distribution, expansion velocity, and temperature) on the line profile and the line intensity at the off-set positions are discussed.

Acknowledgements: This work was partially supported by the Polish Ministry of Education and Science funds (181/N-HSO/2008/0).

References: [1] Szutowicz, S.; Biver, N.; Bockelée-Morvan, D.; Crovisier, J.; de Val-Borro, M.; Moreno, R.; Hartogh, P.; Rengel, M.; Lis, D. C.; Küppers, M.; HssO Team, 2012, ACM2012, LPI Contribution No. 1667, id.6190.