COMET 10P/TEMPEL 2 OUTGASSING OBSERVED WITH HERSCHEL SPACE OBSERVATORY.

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Introduction: Comet 10P/Tempel 2 was observed with the *Herschel Space Observatory* using its three instruments (HIFI, PACS and SPIRE), in the framework of the *Herschel* guaranteed time key project "Water and related chemistry in the Solar System" [1]. One of the main goals of the project is studying water emission and excitation processes in cometary comae. The observations of Comet 10P covered the period from June 15 to July 29, 2010 when the comet was at a distance ~1.43 AU from the Sun and ~ 0.85 - 0.68 AU from *Herschel*. Here we present long and short-term monitoring of the water lines performed with the *Herschel/HIFI*: several ortho- and para-water transitions: 1_{10}–1_{01} (557 GHz), 2_{12}–1_{01} (1669 GHz) and 2_{02}-1_{11} (987 GHz), 1_{11}–0_{00} (1113 GHz), as well as on-the-fly (OTF) maps – three of water lines at 557 GHz and one at 987 GHz. The (1-0) ammonia transition was detected for the first time in a Jupiter-Family comet [2].

Comet 10P/Tempel 2 is a well-known member of the Jupiter-family comets. It passed its last perihelion on July 4.9 UT, 2010 at heliocentric distance of 1.42 AU.

Model: The transfer of line radiation of ortho- and para-water in a cometary coma is calculated using an escape probability approximation. The excitation model includes collisions with water and electrons in the inner coma. Model calculations are performed with parameters established by [2]: the gas temperature T= 25 K and the density scaling factor for electrons xne=0.15. The outgassing pattern model assumes contribution from localized active regions, f_{jet}, and some isotropic emission, f_{iso} with expansion velocities, v_{exp}, of 0.9 and 0.5 km/s, respectively. The gas density profile in the jet (active region) is described by a density function for emission into the cone $\rho(\theta) \sim \cos^n\theta \cdot r^{-2}$, where r is cometocentric distance and θ is the angle between emission direction and the surface normal to the jet. The orientation of the rotation axis of the nucleus is taken from [3]: RA = 150°, Dec = 55°. Then the spin axis is directed to the North-East towards *Herschel*. The rotation period of the comet is P = 8.95 h. Free model parameters are the locations of the active regions (colatitude,β, and longitude, λ), the contributions of the isotropic and anisotropic part, f_{iso} and f_{jet} and the width of the emission cone.

Results: Different locations of the active regions are studied to reach agreement of the simulated water line profiles and the modeled maps of the cometary coma with the detected water transitions and OTF maps provided by *Herschel*. In all accepted cases the gas emission is directed towards the observer over large intervals of the rotational period. In consequence the lines (optically thin) are strongly blueshifted and maps show anisotropic emission in the north-east direction. However, the self-absorption effects change the optically thick line profiles substantially to suppress blueshifted emission (see Fig.1). Satisfactory solutions are found for the active region located at the northern hemisphere of the nucleus close to the pole with contribution of f_{jet} = 0.7 to the total outgassing. The water production rate based on Herschel/HIFI observations is ~$2.5 \cdot 10^{28}$ s^{-1}. The temporal variation of the production of water is in good agreement with the light curve that exhibits a strong asymmetry with respect to perihelion. The outgassing peaks about 10 – 20 days after perihelion.

Conclusions: The line shapes and the OTF maps taken with the high-resolution instrument Herschel/HIFI suggest anisotropic outgassing. Such anisotropic emission indicates a nonuniform distribution of active regions over the nucleus surface, with gas emission preferentially directed to North-East towards the observer in the time interval covered by our observations. Additional evidence for localized activity of Comet Tempel 2 comes from the strong asymmetry of the production rate with respect to perihelion.

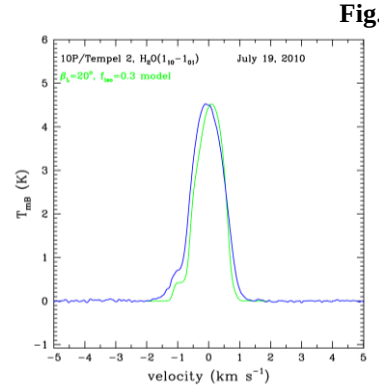

Fig. 1. (blue) - the H_2O (1_{10}–1_{01}) line observed in the comet with *Herschel* using the HRS on 19 July 2010. (green)- simulated line profile for emission at colatitude 20° and f_{jet} = 0.7.

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

References:

[1] Hartogh, P. et al. (2009) PSS 57, 1596–1606. [2] Biver, N. et al. (2012) A&A in press. [3] Sekanina, Z., (1991) AJ 102, 350-389.