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RADIO OBSERVATIONS OF COMET 9P/TEMPEL 1 BEFORE AND AFTER DEEP IMPACT

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Abstract. We summarize the results of our coordinated observations of comet 9P/Tempel 1 with the Nançay, IRAM 30-m and CSO radio telescopes and with the Odin satellite, in support to the *Deep Impact* space mission.

1 Context and observations

The key objective of the *Deep Impact* mission (A'Hearn et al. 2005; Biver 2006) was to excavate material from the inner nucleus of comet 9P/Tempel 1 in order to observe the release of possibly more pristine matter. As a support to this mission, a worldwide Earth-based campaign was advocated (Meech et al. 2005). We present here, as our participation to this campaign, coordinated radio observations of comet 9P/Tempel 1. They were organized in two steps in order to characterize the chemical composition of comet 9P/Tempel 1 and the effect of the impactor released by the *Deep Impact* spacecraft onto the comet on 4 July 2005.

Pre-perihelion, the water outgassing of the comet was monitored through observations of the OH radical lines at 18 cm with the Nançay radio telescope (Crovisier et al., 2005) from March to May. They were followed by Odin observations of the H_2O line at 557 GHz in June; molecular lines were also observed at the IRAM 30-m telescope on 4–9 May 2005 (Biver et al. 2005).

The second step was the observations at or near impact time. Lines of OH (with the Nançay radio telescope), H_2O (with the Odin satellite), HCN, CH_3OH, H_2S, CO and CS (with the IRAM 30-m and CSO 10-m telescopes) were monitored: 1) to characterize the amount of volatiles released following impact and obtain information on the gas velocity and spatial distribution; 2) to look for variations in molecular abundances ratio in order to investigate whether pristine material with different molecular composition has been released from deeper layers in the comet.

2 Results and conclusion

The evolution of the water production rate, from Nançay and Odin observations, is shown in Fig. 1. HCN, CH_3OH and H_2S were detected at IRAM in May–June, whereas upper limits were obtained for other species

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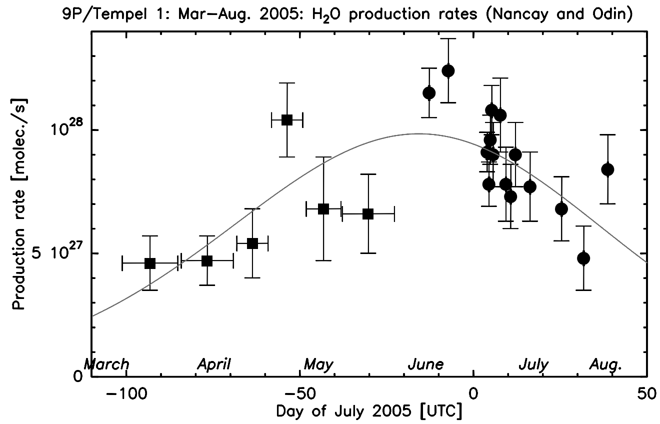

Fig. 1. Water production rates based either on Nançay observations of the OH radical (squares) or Odin observations of the H_2O line at 557 GHz (circles). The full line is a model fit to the observations, as explained in Biver et al. (2006).

(CO, CS). The evolution of HCN and CH_3OH around the time of impact could be monitored at IRAM and (marginally) at CSO.

Comet 9P/Tempel 1 is certainly one of the weakest comets extensively studied at radio wavelengths, with a peak outgassing rate around 10^{28} molec. s^{-1}. This investigation campaign put into evidence several characteristics of the comet:

- The relative molecular abundances are "classical", of the order of (H_2O:CO:CH_3OH:H_2CO:H_2S:HCN:CS) = (100 : < 10 : 2.7 : < 1.5 : 0.5 : 0.12 : <0.13). This is comparable to mean values observed in many comets.
- A strong regular variation of the outgassing rate is clearly observed in HCN data obtained in May 2005. Its amplitude is a factor of 3 from minimum to maximum and its periodicity ($T_p = 1.73 \pm 0.10$ days) is likely related to the rotation period of the nucleus. Outgassing anisotropy is also evident. This suggests that one side of the nucleus was more active than the other when illuminated.
- The periodic variation of the outgassing of the comet must be carefully taken into account when analyzing the effects of the Deep Impact collision. It is not excluded that "natural" outgassing was still varying by ±40% in early July and that it was in a rising phase at the time of the impact.
- As regards to *Deep Impact* consequences, the total amount of water released is estimated to $5 \pm 2 \times 10^6$ kg, corresponding to the cumulated production of 0.2 day of normal activity. This water was most likely released from icy grains that took several hours to sublimate (around 4 h according to our simulations). It was not possible to assess precisely the composition of the ejecta, except for a possible increase in the abundance of CH_3OH. No large excess of HCN was seen.
- The comet also underwent significant natural outbursts of outgassing, possibly of larger amplitude than the burst related to *Deep Impact*. One took place on 22–23 June and may have released as much water as 1.4 day of normal activity.

Although the signal was rather weak to make a detailed compositional study of the impact ejecta, this observing campaign allowed us to observe in detail the behaviour of a Jupiter-family comet, and to put into evidence outbursts and periodic variations of outgassing poorly observed in any comet before.

A full account of these observations is to be published in *Icarus* (Biver et al. 2006).

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