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OBSERVATIONS OF COMET 73P/SCHWASSMANN-WACHMANN 3 WITH THE NANÇAY RADIO TELESCOPE

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Abstract. 73P/Schwassmann-Wachmann 3 is a Jupiter-family comet which showed recently spectacular multiple fragmentations. This comet was observed with the Nançay radio telescope at its last three passages. In spring 2006, observing conditions were exceptional with a close approach to the Earth at 0.08 AU in mid-May. The Nançay radio telescope monitored the outgassing of the two main fragments of the comet, fragments B and C. OH production rates variations were observed, and are related to the fragmentation events observed in optical images.

1 Introduction

The cometary program at the Nançay radio telescope (NRT) has now observed the 18-cm lines of OH in almost 100 cometary returns since 1973 (Crovisier et al. 2002a, 2002b). One of its goals is to monitor the water production rate to determine its evolution with heliocentric distance and to cover unexpected outbursts of activity.

Split comets (see Boehnhardt 2005 for a review) offer us the opportunity to observe the outgassing of freshly exposed nucleus material in a quite natural way (in contrast with costly space experiments such as *Deep Impact*). In this respect, 73P/Schwassmann-Wachmann 3 (hereafter 73P/SW3), a Jupiter-family comet with an orbital period of 5.4 years, is particular. It was discovered in 1930, with a prograde low inclination orbit. The following apparitions were missed, due to the intrinsic faintness and orbital uncertainties. It was seen again in 1979.

Its fist signs of splitting were observed in 1995 and successive fragmentations apparently occurred all the time since that date. Among the host of fragments which were detected and cataloged, fragment C appears to be the main fragment, representing the remnant of the initial nucleus, with a rather stable activity. Fragment B is considered as secondary, but it showed erratic variations of activity, occasionally exceeding the outgassing of fragment C. The other fragments were much weaker (see Sekanina 2005 for a review of the fragmentation process at the two preceding passages of this comet). In spring 2006, the close approach to the Earth of this comet, at only 0.08 AU in mid-May just before perihelion on 6 June, provided an unprecedented observing opportunity.

73P/SW3 was observed with the NRT at its last three passages. The goal was to establish the water production rate of the comet from the observation of the 18-cm OH lines, and to monitor the outgassing activity. In spring 2006, observing conditions were exceptional with a close approach to the Earth at 0.08 AU. The NRT monitored the outgassing of the two main fragments of the comet, fragments B and C.

2 The Nançay observations and activity monitoring

We present here the 1995, 2000-2001 and 2006 passages of comet 73P/SW3 as observed with the NRT. As it is an meridian instrument allowing $\sim$ 1 hour transit observations, medium-term and long-term monitoring programs are favored (as well as surveys).

The line area of the transitions of OH in comets at 1667 and 1665 MHz are used for OH (a substitute for water) production rates derivations, through modeling of the coma expansion and of the OH excitation (Despois et al. 1981; Bockelée-Morvan et al. 1990; Crovisier et al. 2002; Colom et al. 2004).

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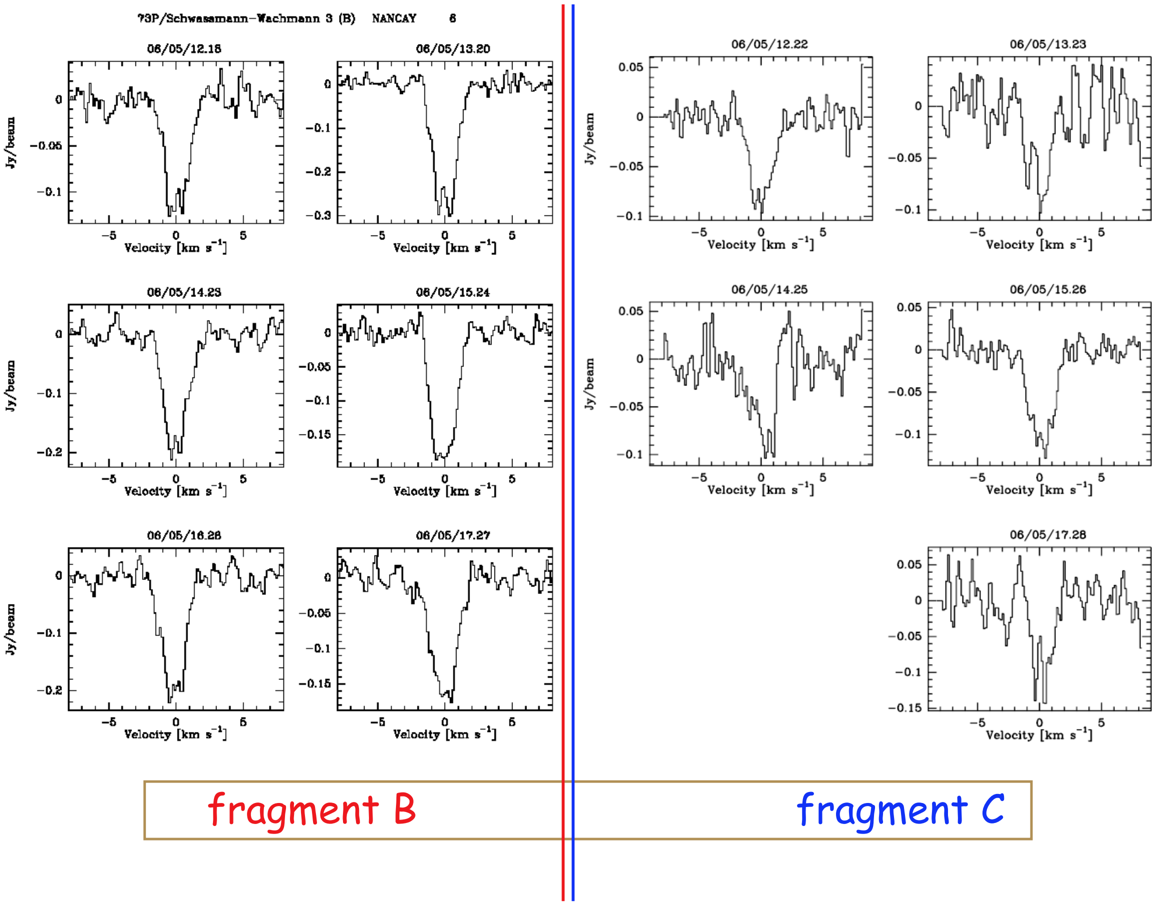

Fig. 1. A set of 18-cm wavelength spectra of OH measured at comet 73P/Schwassmann-Wachman 3 with the NRT in May 2006. Fragments B and C are displayed, from May 12 to 17.

2.1 1995

Comet 73P/SW3 was monitored at Nançay from 30 August to 1st November 1995. Q[OH] was $< 3 \times 10^{28}$ molecules s^{-1} at the beginning of September. It suddenly began to increase around 10 September, reaching $\approx 2 \times 10^{29}$ molecules s^{-1} in mid-September (Crovisier et al. 1995, 1996). Then, Q[OH] decreased to $\approx 10^{29}$ in October.

Amateur observers noticed an enhancement of the comet brightness as traced by the visual magnitudes, with a peak delayed by more than one month with respect to the radio one (Sekanina 2005). This delay is accounted for by the time needed for filling the coma with the newly ejected dust. This major outburst of 5 magnitudes amplitude, was followed by a second one of ≈ 1.5 magnitudes, one month later.

Optical observations afterward showed that the comet had just fragmented in four parts (Bohnhardt & Käufl 1995). With the help of his fragmentation model, Sekanina (2005) has shown that the B and C fragments should have broken apart at a time close to the major outburst onset, given by the OH production rate surge. However, the observational arcs were not long enough to determine the time of separation with an uncertainty better than 1 or 2 weeks. Therefore, the issue about the cause of 73P/SW3 fragmentation is still an open question: the increase of activity might have preceded the breakup, or alternatively was subsequent to the nucleus split.

2.2 2000–2001

In 2000–2001 (perihelion on 27 January 2001), observing conditions were poor with the comet on the other side of the Sun ($\Delta \approx 2$ AU). The observations were done from 1st December 2000 to 10 March 2001 (with gaps) with the newly upgraded Nançay radio telescope. The comet (main fragment C) was only barely detected in December 2000 with a production rate Q[OH]$= 2.7 \pm 0.7 \times 10^{28}$ molecules s^{-1}. The comet crossed the galactic plane on January 12. At that time, strong OH lines were observed, due to enhanced continuum background amplified by the cometary OH maser, but confusion due to galactic sources was also present, complicating the interpretation of the observation.

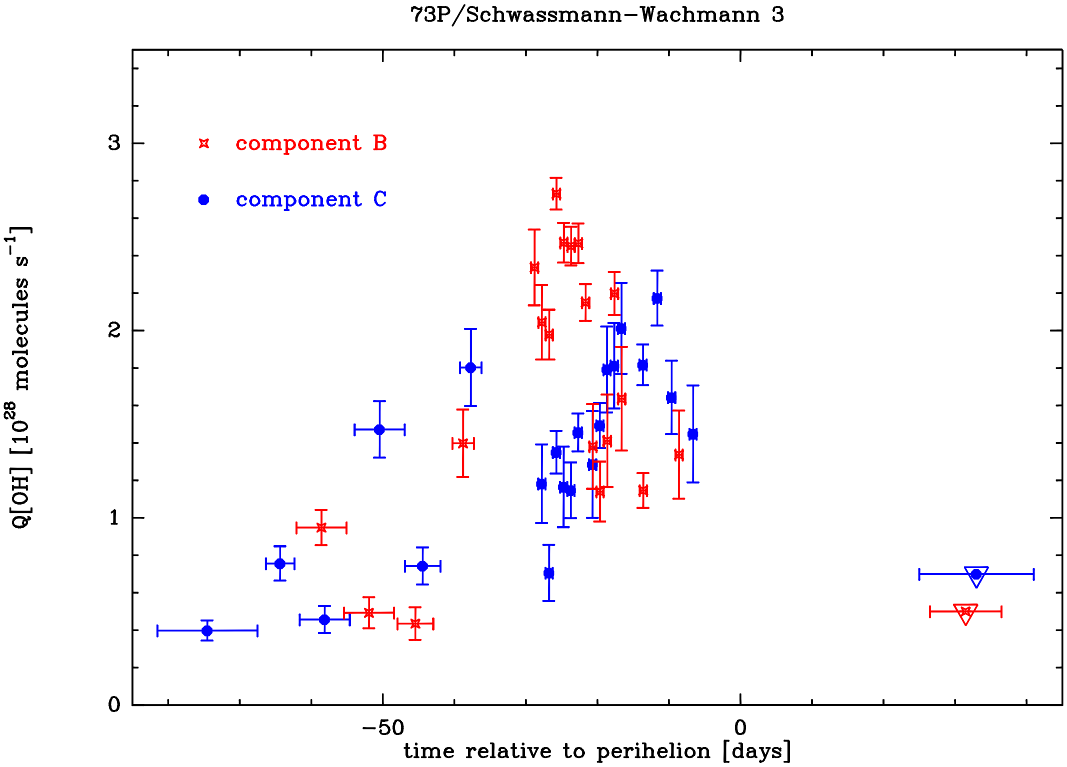

Fig. 2. OH production rate evolution of fragments B and C in 2006. The time origin is the perihelion date for component B (6.9 June 2006). Triangles indicate 3–σ upper limits. Vertical bars are ±1–σ errors. Horizontal bars are integration time spans.

2.3 2006

In 2006, taking advantage of the close approach to the Earth at 0.08 AU in mid-May, the NRT monitored the outgassing of the two main fragments of the comet, fragment B since the beginning of April and fragment C since the beginning of March. Both fragments were detected after several days of integration soon after their observations began. When the comet was closest to the Earth, the fragments were detected on individual days with a good signal-to-noise ratio. A sample of the OH spectra obtained during May 2006 is shown in Figure 1. The observations were carried on until 20 July, but the comet could no longer be detected after the end of May, due to the weakness of the OH maser inversion in June, and the increasing distance of the comet in July.

The evolution of the OH production rates is shown in Fig 2. Q[OH] was $\approx 0.4 \times 10^{28}$ molecules s^{-1} when the fragments were first detected at Nançay. It fell down to an upper limit of the same value in our post-perihelion observations of July. Both fragments experienced outbursts in May, with typical increases by factors 2 or 3 (Fig. 2), which are smaller than the major outburst of 1995. Fragment C reached Q[OH] $\approx 2 \times 10^{28}$ molecules s^{-1} by the end of May. Fragment B exceeded this value ($\approx 3 \times 10^{28}$) on 13 May, at the time outbursts were observed in the visible. A compilation made by S. Yoshida (2006) clearly shows an optical outburst of the B fragment, with maximum brightness (m1 $\sim$ 5) around 13 May 2006 and of 3–4 days duration. A second peak in Q[OH], less prominent, could be noticed on 21 May.

From the OH line shapes, we retrieve and expansion velocity $V_p = 0.8$ km s^{-1} for the OH-parent molecules when the comet was close to the Earth, which is in line with the velocities obtained for other comets of similar water production rates and heliocentric distances (Tseng et al. 2006).

3 Conclusion

Coordinated spectroscopic observations of molecules were made in the millimeter and submillimeter range using the CSO 10-m, IRAM 30-m and APEX 12-m telescopes. In addition, the water outgassing rate was measured through the observation of the H_2O 1_{10}–1_{01} line at 557 GHz with the Odin satellite (Biver et al. 2006; Crovisier et al. 2006). Large time variations of the observed lines were observed. These observations are presently under analysis to investigate whether fragments B and C have similar chemical compositions. The simultaneous observations made at Nançay are precious for following the gas production rate of the comet and for the intercomparison of the observations made with the different instruments.

These observations make this comet one of the best studied Jupiter-family comet from remote sensing.

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