OBSERVATIONS OF THE OH RADIO LINES OF COMETS WITH THE RECENTLY UPGRADED NANÇAY RADIO TELESCOPE

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ABSTRACT

The 18 cm lines of OH have been observed in more than 70 comets with the Nançay radio telescope since 1974. The observations made from 1982 to 1999 are now organized in a data base (Crovisier et al., *Astron. Astrophys.*, in press; see also http://wwwusr.obspm.fr/~crovisie/basecom/index.html). The Nançay radio telescope has been recently upgraded, and observations since 2000 are made with a sensitivity increased by about a factor of two. Twelve comets were observed at Nançay from 2000 to the first half of 2002. The results are briefly described.

Key words: Comets, OH radical, radio lines.

1. INTRODUCTION

The 18 cm lines of OH have been systematically observed in more than 70 comets with the Nançay radio telescope since 1974. The excitation mechanism of these lines – a weak maser process in the linear regime – is now well known and the object of reliable modelling. This allowed an evaluation of the cometary water production rates and their evolution with time, as well as a study of several physical processes such as the collisional quenching of the OH maser, the expansion of the cometary atmospheres, their anisotropy in relation with non-gravitational forces, and the Zeeman effect in relation with the cometary magnetic field.

These observations were the object of occasional publications. The observations made from 1982 to 1999 are now organized in a comprehensive data base (Crovisier et al. 2002). The detailed data, in the form of figures showing the individual and averaged spectra and tables giving observational characteristics and derived OH production rates, is available electronically from *Astronomy & Astrophysics* and from `http://wwwusr.obspm.fr/~crovisie/basecom/index.html`.

A major upgrade of the Nançay radio telescope started in 1995 and ended in 2000 (van Driel et al. 1996). The Hoghorn feeds at the focus were replaced by a double Gregorian wide-band system with corrugated horns (Fig. 1). The sensitivity increased by about a factor of two, which gives us access to weaker objects, or allows us to follow them at larger heliocentric distances. A new autocorrelator has also been constructed which provides for cometary observations 8 banks of 1024 channels in 195 kHz (corresponding to 0.07 km s^{-1} resolution after Hanning smoothing). As in the past, a frequency-switching mode is used and subsequent folding results in a gain of a factor of 1.4. It is now possible to observe simultaneously the four OH transitions at 1665 and 1667 MHz (main lines) and 1612 and 1721 MHz (satellite lines) in both left- and right-hand circular polarizations, to detect possible Zeeman shifts and departures from the LTE line intensity ratios.

Figure 1. The new focal system and carriage house of the Nançay radio telescope. The tiltable mirror of the telescope is seen in the background.

2. RECENT OBSERVATIONS

Since 2000, twelve comets have been observed with the new system. The observed comets are listed in

Table 1. Comets observed at Nançay since 2000

comet	perihelion yymmdd	q [AU]	date range of observations	N a)	b)
C/1999 S4 (LINEAR)	000726.17	0.765	000706-000803	20	D
C/1999 T1 (McNaught-Hartley)	001213.47	1.172	001115-010130	40	D
C/2000 W1 (Utsunomiya-Jones)	001226.56	0.321	001212-010107	11	D
73P/Schwassmann-Wachmann 3	010127.71	0.937	001201-010310	31	D
45P/Honda-Mrkos-Pajdušáková	010329.89	0.528	010103-010315	27	–
24P/Schaumasse	010502.66	1.205	010310-010630	47	D
C/2001 A2 (LINEAR)	010524.52	0.779	010402-010712	56	D
16P/Brooks 2	010719.82	1.835	010417-010510	18	–
19P/Borrelly	010914.73	1.358	010719-011129	54	D
C/2000 WM_1 (LINEAR)	020122.67	0.555	011004-020420	104	D
C/2002 C1 (Ikeya-Zhang)	020318.98	0.507	020227-020620	78	D
C/2002 F1 (Utsunomiya)	020422.90	0.438	020409-020620	34	D

a) number of observations (one per day);
b) –: no detection; D: clear detection.

Table 1 and are individually commented below.

Some of these observations were coordinated with ground based millimetric and submillimetric observations, with observations of the 557 GHz water line with the *Odin* satellite, or in support of space missions (*Deep Space 1*).

2.1. C/1999 S4 (LINEAR)

This comet passed perihelion at $q = 0.76$ AU on 26 August 2000. Unexpectedly, the nucleus fragmented and underwent complete disruption around perihelion. The comet fizzled out and disappeared in the beginning of August. This disruption was accompanied by an important outburst of gas. This event could be followed by many observations (Bockelée-Morvan et al. 2001, and series of papers in the same issue of *Science*).

Observations were scheduled at Nançay from July 6 to August 3. They could not be undertaken earlier because of upgrading work at the telescope. The observations were offset by $\approx$ 4' in right ascension at the end of July–beginning of August because of the use of an obsolete ephemeris. The OH lines were detected in emission from the 6–9 July average, and marginally in absorption from the 13–19 July average (Bockelée-Morvan et al. 2001).

2.2. C/1999 T1 (McNaught-Hartley)

This comet was observed at Nançay from mid-November 2000 to the end of January 2001 with Q[OH] in the range 3–9 $\times 10^{28}$ s^{-1}. It was also observed at *IRAM*, *CSO*, and with the *SWAS* satellite. A preliminary presentation of the observations was given by Crovisier et al. (2001).

2.3. C/2000 W1 (Utsunomiya-Jones)

This comet was detected just before its perihelion (26 December 2000) with $Q[\mathrm{OH}] \approx 1.5 \times 10^{29}$ s^{-1}. The comet faded post-perihelion and was no longer detectable.

2.4. 73P/Schwassmann-Wachmann 3

This Jupiter-family comet was observed at Nançay at its previous return (Crovisier et al. 1996, 2002), when it underwent nucleus splitting and a major outgassing outburst. It is one of the targets of the *CONTOUR* mission (flyby expected in June 2006). The comet crossed the galactic plane on 12 January 2001 at $l = 7°$. The OH lines were then strong, due to enhanced background, but the spectra suffered from galactic confusion.

2.5. 45P/Honda-Mrkos-Pajdušáková

This Jupiter-family comet was marginally detected at Nançay at its 1995 passage, owing to a close approach to Earth (Crovisier et al. 2002). In 2001 the comet was observed at small solar elongations, which resulted in a degraded system temperature; it was not detected.

2.6. 24P/Schaumasse

This comet was observed at Nançay at its 1993 return (Bockelée-Morvan et al. 1994 and Crovisier et al. 2002). It was detected at the present passage with $Q[\mathrm{OH}] \approx 2 \times 10^{28}$ s^{-1}.

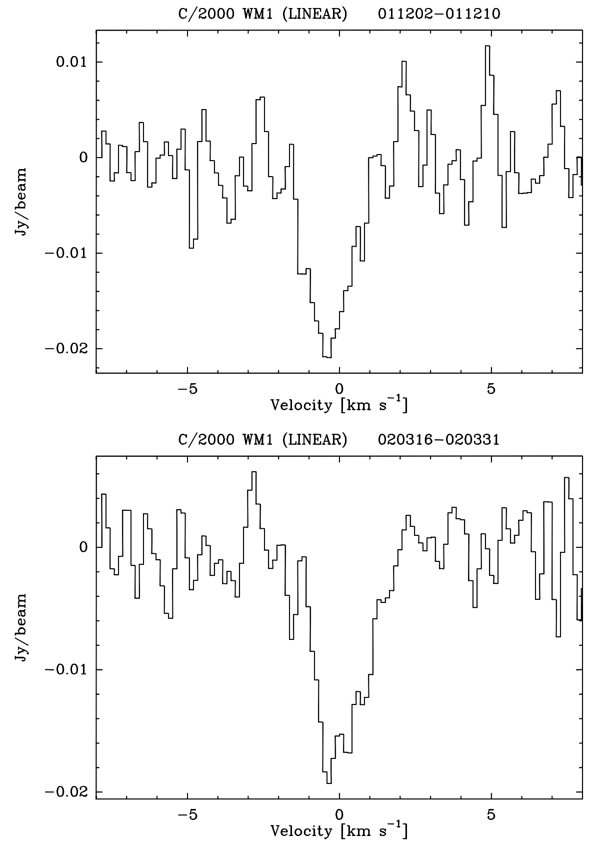

Figure 2. *A sample of representative spectra. The top titles give the names of the comets and the ranges of dates (yymmdd–yymmdd) over which they were observed. All spectra are averages of 1665 and 1667 MHz lines, both circular polarizations, scaled to the 1667 line following statistical weight ratios.*

2.7. C/2001 A2 (LINEAR)

The comet passed at only 0.24 AU from the Earth on 1 July 2001. It showed repeated, erratic outbursts, but did not disappeared at perihelion like C/1999 S4 (LINEAR). It was observed at Nançay from the beginning of April until mi-July 2001. $Q[\mathrm{OH}] \approx 2 \times 10^{29}$ s^{-1} at the beginning of the observing period (just after one of the outbursts of this comet). As the visual brightness of the comet, Q[OH] did not evolved smoothly. It occasionally exceeded 10^{28} s^{-1}. The comet was still detected at the end of the observing period, but a reliable Q[OH] could not be determined, because of the uncertainty on the OH maser inversion at that moment (0.11 or 0.01, according to the models of Despois et al. or Schleicher & A'Hearn, respectively). A preliminary presentation of the observations was given by Crovisier et al. (2001).

This comet was also observed at *IRAM*, *CSO*, *Kitt Peak 12-m*, and with the *Odin* and *SWAS* satellites.

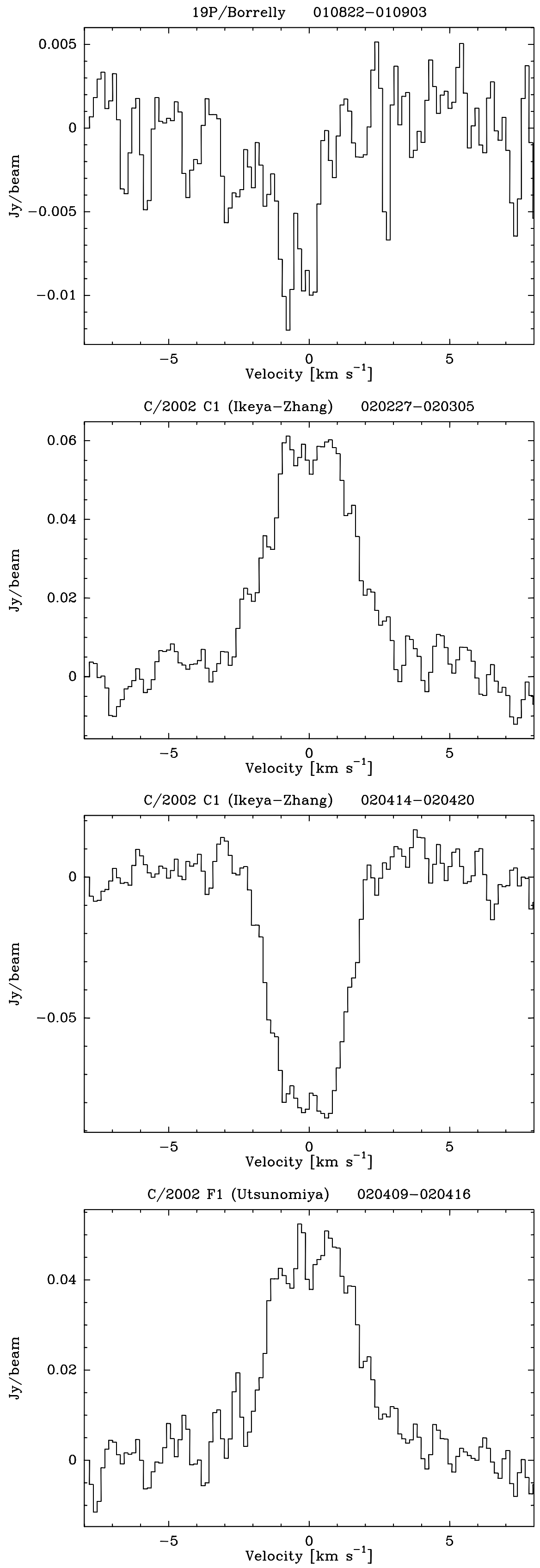

Figure 3. *Another sample of representative spectra.*

2.8. 16P/Brooks 2

No detection could be obtained of this faint Jupiter-family comet.

2.9. 19P/Borrelly

This comet was observed at Nançay at its previous return (Crovisier et al. 2002). This comet was the flyby target of the *Deep Space 1* mission on 22 September 2001. It was also observed at *IRAM* and with the *Odin* satellite. The comet was detected pre-perihelion (19 July– 3 September) under observing conditions less favourable than those of the 1994 passage (Fig. 3). Q[OH] was $\approx 2.5 \times 10^{28}$ s^{-1} at $r \approx 1.4$ AU, similar to what was observed at the preceding return. It could not be detected post-perihelion in November. The observations are presented by Bockelée-Morvan et al. (2002 and *in preparation*).

2.10. C/2000 WM_1 (LINEAR)

This comet made a close approach to Earth (0.32 AU) on 3 December 2001 and was the target of an international campaign of observation. It was observed and detected at Nançay in October–December 2001 (Fig. 2). A conspicuous Greenstein effect was observed in December when the OH maser inversion was close to 0.

The comet was observed again in February–April 2002, after a dramatic outburst of 3.3 magnitudes which occurred on 23 January. On 7 April 2002 the comet crossed the galactic plane at $l = 41.0°$. The spectrum was then dominated by a 1665 MHz maser (listed in Turner 1979). In mid-April, Q[OH] was still $\approx 2 \times 10^{28}$ s^{-1}.

This comet was also observed at *IRAM*, *CSO*, *HHT*, *Kitt Peak 12-m*, and with the *Odin* and *SWAS* satellites.

2.11. C/2002 C1 (Ikeya-Zhang)

This comet is possibly the return of the historical comet C/1661 C1. It was observed as soon as 27 February, with Q[OH] $\approx 2 \times 10^{29}$ s^{-1} (Fig. 3). Q[OH] reached $\approx 5 \times 10^{29}$ s^{-1} around perihelion. The OH satellite lines were also detected.

This comet was also extensively observed at *IRAM*, *CSO*, *JCMT*, *Kitt Peak 12-m*, and with the *Odin* satellite (Bockelée-Morvan et al. and Lecacheux et al., *this conference*).

2.12. C/2002 F1 (Utsunomiya)

This comet was similar to C/2002 C1 (Ikeya-Zhang) with respect to its perihelion distance and Q[OH] ($\approx 5 \times 10^{29}$ s^{-1} in mid-April), but its observing conditions were less favourable, the comet being much farther from the Earth (Fig. 3).

3. CONCLUSION

These two last years granted us with several relatively bright comets (five of them with Q[OH] exceeding 10^{29} s^{-1}) which could be the target of specific studies with the Nançay radio telescope. In addition, weaker comets with Q[OH] $\approx 10^{28}$ s^{-1}, in unfavourable positions, could be detected, demonstrating the capacities of the new focal system.

As for 1982–1999 comets, the detail of these observations will be made available in the future.

ACKNOWLEDGMENTS

The Nançay Radio Observatory is the Unité scientifique de Nançay of the Observatoire de Paris, associated as Unité de service et de recherche (USR) No B704 to the French Centre national de la recherche scientifique (CNRS). Its recent upgrade was financed jointly by the Conseil régional of the Région Centre in France, the CNRS and the Observatoire de Paris.

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August 6, 2002
Asteroids Comets Meteors 2002
ESA SP-500