Asteroids, Comets, Meteors 1991, pp. 73-76
Lunar and Planetary Institute, Houston, 1992

OBSERVATIONS OF OH IN COMET LEVY WITH THE NANCAY RADIO TELESCOPE

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Abstract. Due to extremely favourable excitation conditions, comet Levy (1990c) exhibited in August-September 1990 the strongest OH 18-cm signal ever recorded in a comet at the Nançay radio telescope. This unique opportunity was used to measure the OH satellite lines at 1612 and 1721 MHz, to perform extensive mapping of the OH radio emission and to make a sensitive evaluation of the cometary magnetic field, of the H_2O outflow velocity and of the OH production rate.

OBSERVATIONS

Comet Levy (1990c) was monitored almost daily, one hour per day, from June 16 to September 30 1990, simultaneously in the1667 and 1665 MHz main lines of the OH ground state Λ–doublet (Fig. 2a), both in right and left circular polarizations. The general observing procedure is detailed in Gérard *et al* (1989). As shown in Fig. 1, the signal was most of the time notably larger than that recorded in comet Halley at Nançay, and exhibited a strong enhancement at the beginning of September. This can be explained from the combination of favourable geometry and excellent excitation conditions (Table 1), in particular the crossing of the galactic plane by the comet on September 5. Indeed, this resulted in the amplification by the OH maser lines of a continuum background notably larger than the 2.7 K cosmic background. We took advantage of the strong signal to measure, on Sept. 3 and 4, the satellite OH lines at 1612 and 1721 MHz. Both satellite lines, which were predicted to be 9 times weaker than the 1667 MHz main line, were detected with a signal-to-noise ratio of about 8 (Fig. 2b, c). To our knowledge, the only reported attempt to observe the satellite lines in a comet was made at Nançay in comet Meier 1978 XXI (Despois *et al* 1979): the lines were detected at a 5-sigma level after nearly one month of observations. From Aug. 21 to Sept. 1 and Sept. 7 to 18, we spent part of the daily integration time with the beam aimed at offset positions with respect to the comet centre. The offsets were ±7, ±10.5 and ±14' in right ascension, corresponding to 2, 3 and 4 beams. The signal was more intense in the anti-Sun side.

Figure 1 : Line area of the 1667 MHz OH line in comet Levy (1990c) as a function of heliocentric distance. Daily values are displayed. The arrow shows the maximum intensity recorded at Nançay for P/Halley.

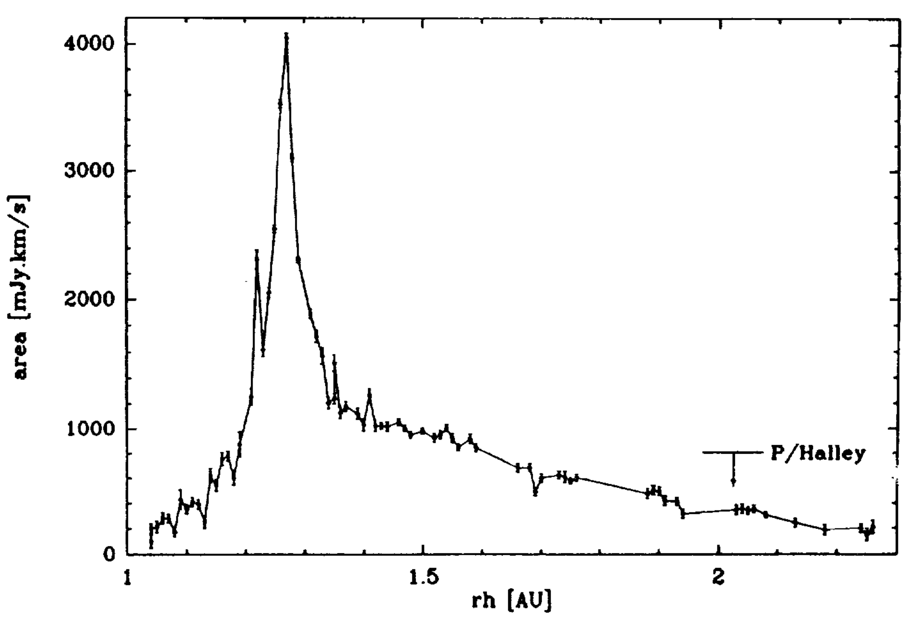


Table 1 : Parameters of the OH spectra of comet Levy (1990c) and inferred OH production rates.

date	Δ AU	r_h AU	V_h[a] km s^{-1}	inv[b]	line area[c] mJy.km s^{-1}	Bs[d] km s^{-1}	Q[OH][e] $10^{28} s^{-1}$	Q[OH][f] $10^{28} s^{-1}$
00616-900627	2.20	2.20	-21.5	0.50	202±11	1.62±0.09	9.5±0.7	12.0±0.9
00701-900705	1.85	2.05	-21.7	0.49	322±08	1.65±0.04	14.0±0.6	16.1±0.7
00712-900717	1.48	1.91	-21.7	0.49	419±11	1.56±0.04	14.5±0.5	16.8±0.5
00726-900729	1.08	1.75	-21.7	0.49	571±13	1.58±0.04	15.4±0.4	16.7±0.4
00731-900803	0.92	1.68	-21.6	0.49	597±12	1.66±0.04	14.7±0.3	15.0±0.3
00809-900814	0.65	1.56	-21.3	0.50	893±13	1.75±0.03	21.2±0.3	16.0±0.2
00815-900819	0.51	1.48	-20.9	0.50	961±12	1.74±0.02	16.1±0.2	13.6±0.1
00820-900824	0.44	1.41	-20.6	0.50	1046±17	1.80±0.04	17.2±0.2	13.1±0.2
00825-900901	0.45	1.34	-19.9	0.50	1355±21	1.77±0.03	21.5±0.3	17.0±0.2
00902-900904	0.51	1.29	-19.3	0.48	2860±38	1.82±0.03		
00905-900909	0.58	1.25	-18.8	0.46	2558±29	1.82±0.03		
00910-900913	0.70	1.19	-17.8	0.42	860±32	2.09±0.09		
00914-900918	0.80	1.15	-16.8	0.38	569±20	1.83±0.08	22.3±0.7	16.6±0.5
00919-900923	0.92	1.10	-15.5	0.32	329±14	1.79±0.09	16.2±0.8	13.5±0.6
00925-900929	1.07	1.05	-13.6	0.22	232±15	2.05±0.14	24.2±1.6	17.5±1.1

a : comet heliocentric velocity ; **b** : OH maser inversion from Despois *et al* (1981) ; **c** and **d** : area and half larger base of the best trapezia ; **e** : OH production rate computed according to Bockelée-Morvan *et al* (1990) (see text) ; **f** : OH production rate computed using the OH density model 1986a, i.e. OH and OH-parent scalelengths of 1.4 10^5 and 6 10^4 km respectively, OH radial velocity of 1.4 km s^{-1}, collisional quenching not being included.

H_2O OUTFLOW VELOCITY

Following Bockelée-Morvan *et al* (1990a), we applied trapezoidal fitting in order to remove the contribution of the OH ejection velocity v_d in the OH line shapes and determine the H_2O outflow velocity v_p. The results of the fits, in particular the half larger base Bs of the best trapezia which should be close to v_p+v_d, are displayed in Table 1. Assuming $v_d = 0.9$ km s^{-1}, the inferred velocities range from 0.6 km s^{-1} to 1.1 km s^{-1} and confirm the global increase of the outflow velocity with decreasing heliocentric distance observed in other comets (Bockelée-Morvan *et al* 1990a, b).

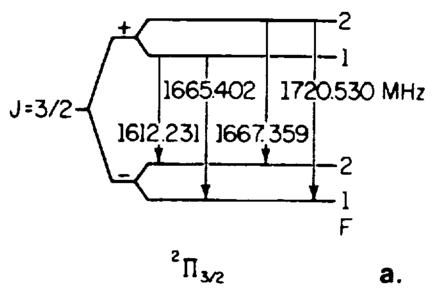
OH PRODUCTION RATES AND TIME VARIABILITY

OH production rates were computed with the model of Bockelée-Morvan *et al* (1990a), which uses the inferred outflow velocities and takes into account the quenching of the maser by collisions. The results obtained for selected average periods are given in Table 1. The evaluation of the production rates during the crossing of the galactic plane requires a careful evaluation of the continuum background brightness temperature at 18-cm wavelength, which is not discussed here. In Fig.1, the OH emission exhibits short term variations, which might be related to the periodicities of 17 and19 hours seen in UV and visible light curves (Feldman *et al* 1991; Schleicher *et al* 1991).

HYPERFINE ANOMALIES

The 1721:1667:1665:1612 line intensities were expected to be in the statistical weight ratios 1:9:5:1 (i.e. 0.111:1:0.555:0.111). Significant departures from these theoretical ratios are present in comet Levy: the 1721 MHz line is weaker ([1721]/[1667] = 0.069 ± 0.012 on Sept. 4); the 1612 MHz line is stronger ([1612]/[1667] = 0.137 ± 0.015 on Sept. 3); the [1665]/[1667] ratio is below the normal value before Sept. 3 (0.506 ±0.01 from July 26 to Aug.16; 0.527 ± 0.008 from Aug. 24 to Sept. 2) and above it after

(0.582 ± 0.008 for Sept. 5-6). [1665]/[1667] anomalous ratios are also present in other comets, with a systematic trend for enhanced ratios at negative inversions of the OH Λ-doublet. UV pumping by the Sun, which is the main excitation mechanism of the OH cometary radio lines, tends to establish normal hyperfine ratios (Despois *et al* 1981). Departures from normal ratios should occur if the optical depths are not negligible. The line intensity is $\propto$ (exp(-τ)-1), the optical depth τ having the opposite sign of the inversion (Despois *et al* 1981). Therefore, for positive inversions, the 1667 MHz line should be enhanced with respect to the 1665 MHz line, and the main lines should be enhanced with respect to the satellite lines. This is in contradiction with what is observed in comet Levy. On the other hand, the relative line intensities are well explained by a net population transfer from F=2 to F=1, occuring within both the upper and lower levels of the Λ-doublet (Fig. 2a). Sub-normal values of the [1665]/[1667] ratio suggest a more efficient transfer inside the lower level than in the upper level, while values above the theoretical value indicate the opposite. A possible explanation for this redistribution of the hyperfine populations might be inelastic collisions.



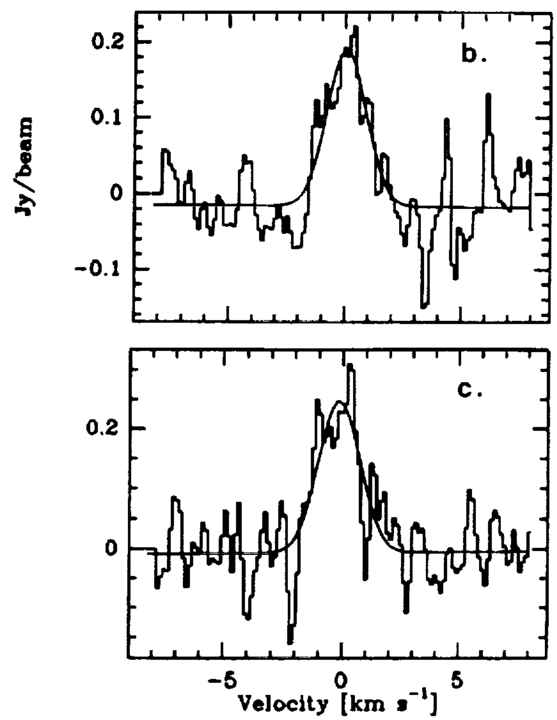


Figure 2 : **a** . The Λ-doublet of the OH ground state. Hyperfine splitting has been exaggerated for clarity; **b.** The 1721 MHz line detected in comet Levy on Sept. 4, 1990; **c.** The 1612 MHz line detected on Sept. 3. The OH Doppler velocities are referred to the nucleus.

ZEEMAN EFFECT AND COMETARY MAGNETIC FIELD

The Zeeman effect (i.e. the frequency difference between the left and right circular polarization components) of the OH 18-cm lines is proportional to the projection of the magnetic field on the line of sight, averaged over the line-of-sight and over the beam. Gérard (1985) measured the Zeeman effect in the OH lines of comet Austin 1982 VI and obtained a tentative detection of the projected magnetic field $<B_p>$ = 50 ± 21 nT for Aug. 6-12, 1982. In P/Halley, outside the magnetic cavity where the field was nil, *Giotto* measured total field values of several 10 nT (Neubauer *et al* 1987). As shown in Fig. 3, the Zeeman effect was clearly detected in comet Levy at the end of August. From Fig. 4, which shows the evolution of $<B_p>$ for individual days, one can see that <Bp> was nearly constant over the period Aug. 31 to Sept. 6, with a mean value of -22 ± 3 nT from Aug. 31 to Sept. 2, the negative sign indicating a magnetic field directed towards the observer. The averages made over several days before August 31 show that $<B_p>$ was, in this period, less intense. It is interesting to note that the viewing conditions were rapidly varying at the end of August.

Figure 3 : Average 1667-1665 MHz spectrum of Levy on Aug. 31 to Sept. 3 in right-handed (thick line) and left-handed (dotted line) circular polarization. The frequency shift from left to right-handed polarization corresponds to a line of sight magnetic field of 22±3 nT towards the observer.

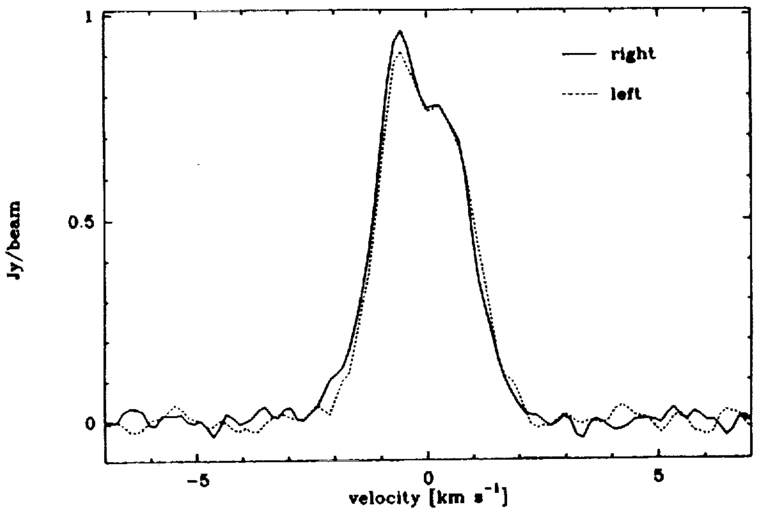
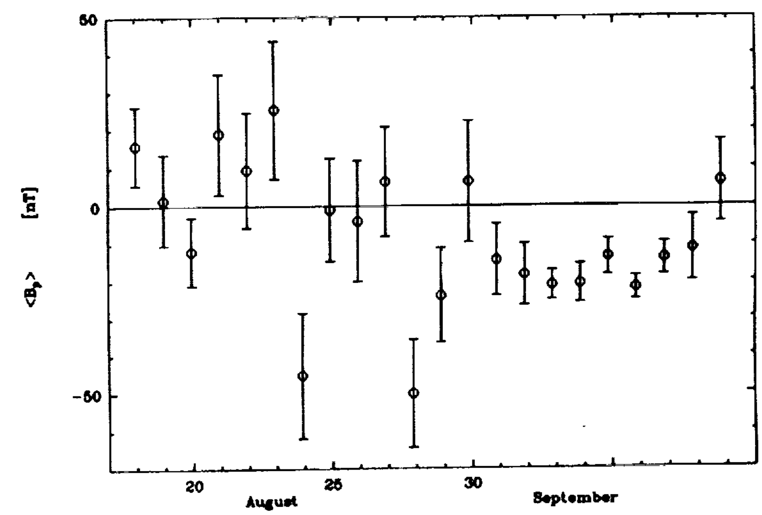


Figure 4 : The line of sight projected magnetic field inferred in comet Levy (1990c) as a function of time.



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