Radio Observations of Comet Bradfield (1978c)

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The following story shows the importance of international collaboration in astronomy. The authors, Drs. Despois, Gerard, Crovisier und Kazès of the Département de Radioastronomie de l'Observatoire de Meudon in France, had problems in observing bright Comet Bradfield with their radio telescope, because the comet's position was not known with sufficient accuracy. Fortunately, an optical position could be secured at ESO/La Silla, although under very difficult circumstances, and an improved ephemeris was computed by Dr. B. Marsden in the USA and transmitted to France. The faint radio signal from the comet was detected, just in time to see the change-over from OH emission to absorption.

One of the objectives of cometary research is to measure the gas production of a comet versus heliocentric distance (notwithstanding possible outbursts and changes before and after perihelion) as well as the gas production from comet to comet, referring to a standard heliocentric distance of one astronomical unit. The production rate of the OH molecule is smaller than that of the H atom by only a factor of 2 or 3 and thus the monitoring of the hydroxyl radio line intensities at 1667 and 1665 MHz (the strongest of the 4 hyperfine components of the $^2\Pi_{3/2}$ ground state lambda doublet) is a good indicator of the *total* gas production.

OH in Comets

The advantage of long wavelength radio observations (~18 cm) is that the quality of the spectra is affected neither by atmospheric conditions nor by the proximity of the Sun or the Moon. We had so far studied OH in 4 comets, i.e. Kohoutek (1973 XII), Kobayashi-Berger-Milon

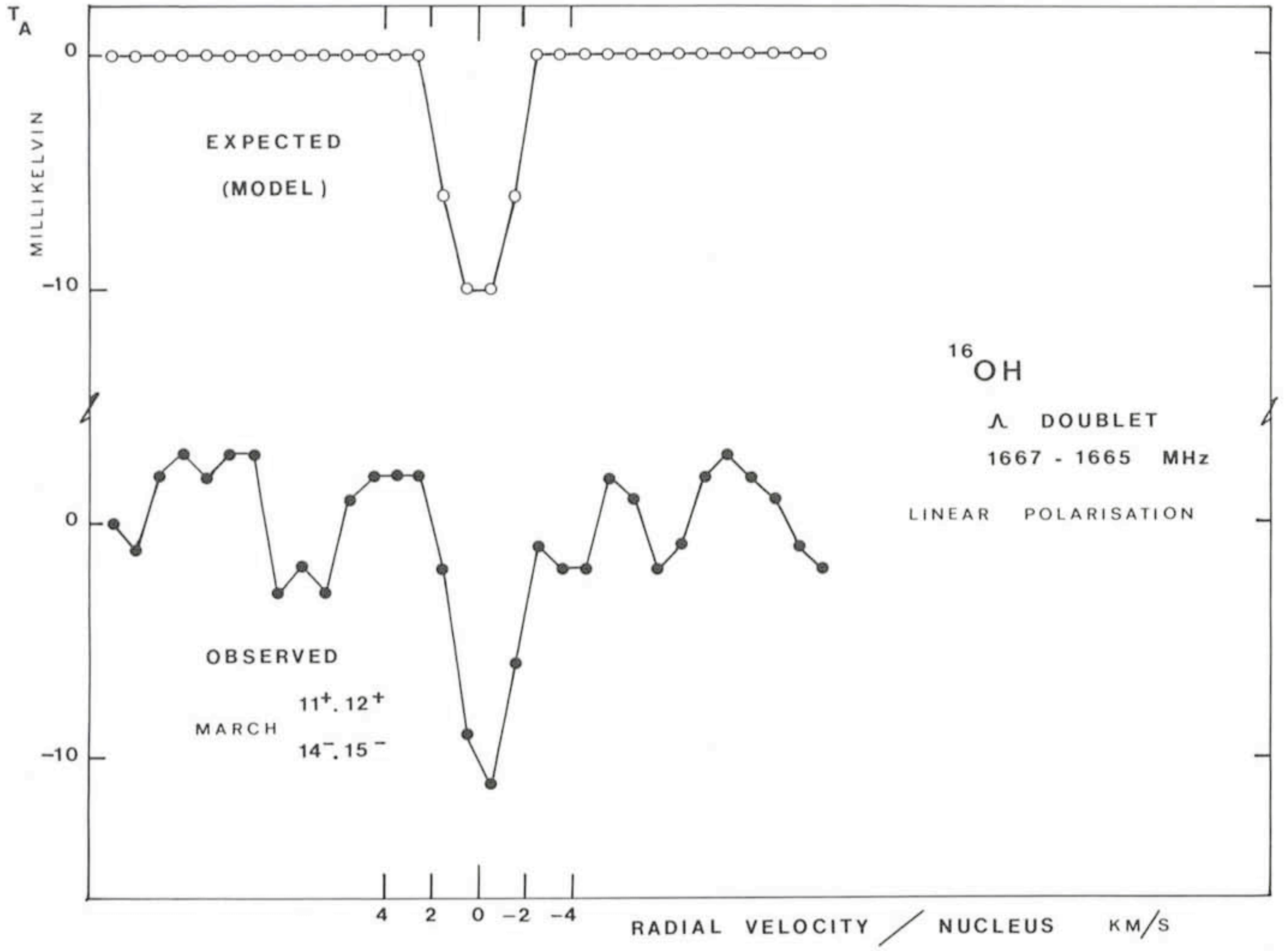
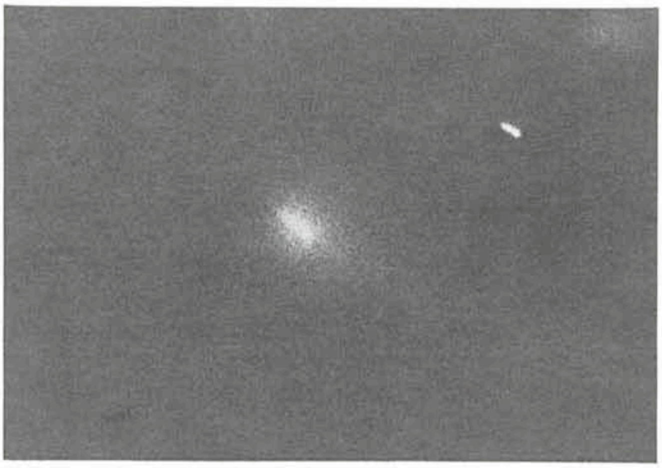


Fig. 1. — *The bottom curve is the OH radio spectrum of Bradfield (1978 c) averaged over March 11, 12, 14 and 15.*
The top curve is the OH line profile expected from a model of the OH coma with a gas production rate about one eight that of Kohoutek (1973 XII).



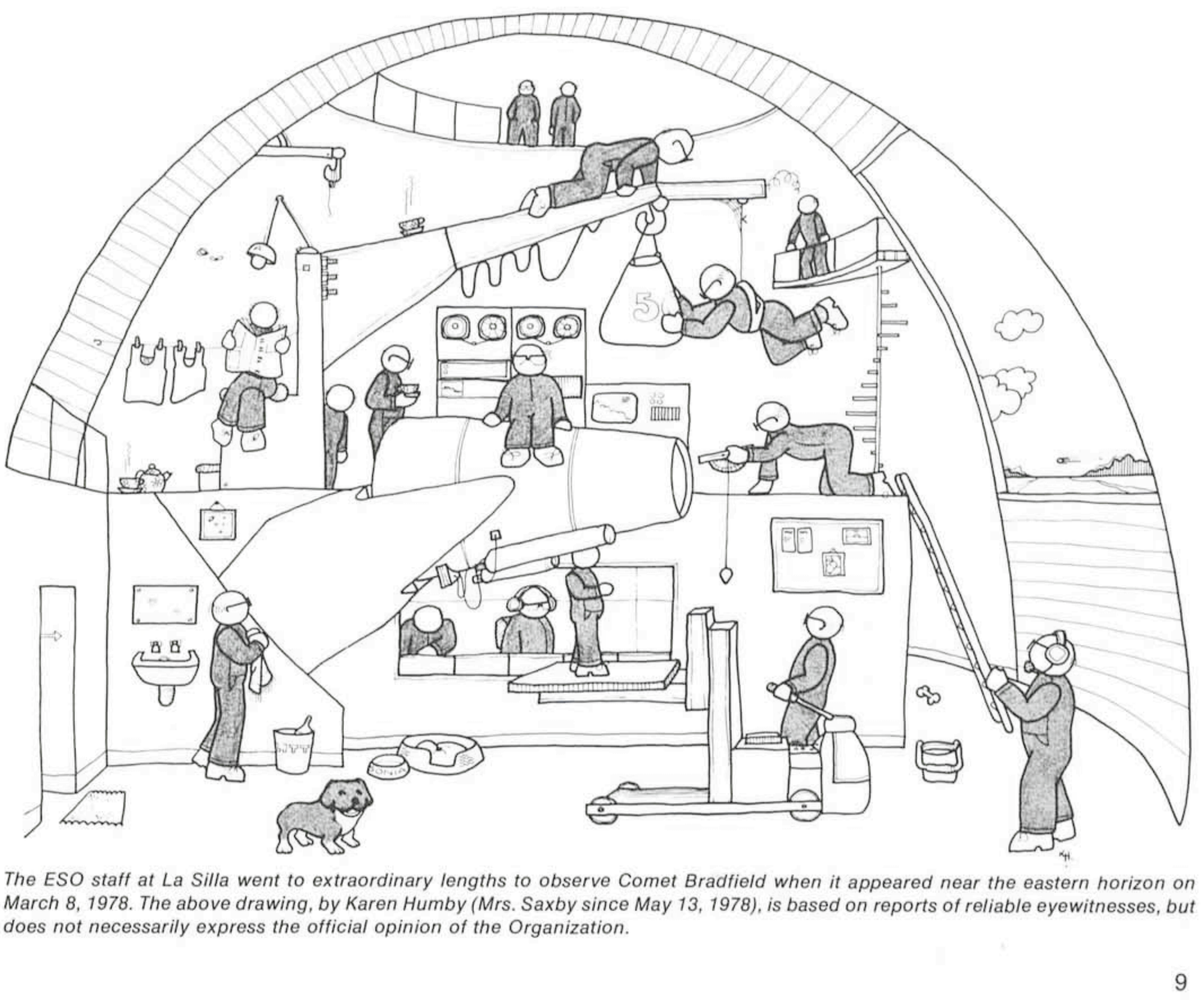
This photo of Comet Bradfield enabled the French radio astronomers to detect radio emission from the OH radical. The comet was observed under extremely difficult conditions with the ESO Schmidt telescope on March 8, 1978. At this date, it was only 25° from the Sun. A three-minute exposure was made, only 12° above the horizon, when the eastern sky was already very bright. The image is severely trailed due to differential refraction. IIa-O + GG 385.

(1975 IX), West (1976 VI) and Kohler (1977 m) with the French Nançay radio telescope, when we learned that a new bright comet, Bradfield (1978 c), was heading North and promised to reach 4th magnitude in March 1978. The major drawback of radio observations of comets is the weakness of the signal, requiring lengthy integration times to obtain a decent signal-to-noise ratio, even for a large radio telescope equipped with a cooled radiometer as we have at Nançay. Furthermore, the beam size is only 3.5 x 19 arcmin., and it is vital to know the apparent coordinates of the comet to better than 1 arcmin.

An Improved Ephemeris

We felt that the best available ephemeris (on IAU Circular No. 3177, by M. P. Candy, based on only eight observations between February 6–13) was not accurate enough when extrapolated to March 4, and preferred to divide the integration in three parts; tracking the nucleus position, 3.5′ East and 3.5′ West (the uncertainty in declination is generally small compared to the 19′ half-power beamwidth). Our upper limit to the antenna temperature on March 4 is 35 millikelvin indicating that Bradfield (1978 c) was intrinsically fainter than Kohoutek (1973 XII), at least by a factor of 3 (~ 1.2 magnitude). For lack of recent, accurate optical positions the observations had to be discontinued.

However, at our request, H.-E. Schuster succeeded in photographing the comet with the ESO Schmidt telescope and we were able to resume the radio observations with the new ephemeris (IAU Circular No. 3196). The comet was detected in emission on March 11 and 12, then in absorption



The ESO staff at La Silla went to extraordinary lengths to observe Comet Bradfield when it appeared near the eastern horizon on March 8, 1978. The above drawing, by Karen Humby (Mrs. Saxby since May 13, 1978), is based on reports of reliable eyewitnesses, but does not necessarily express the official opinion of the Organization.

on March 14 and 15. The signal changed sign on March 13 as expected from our model of the UV-pumping of the OH radical by the Sun (Biraud *et al.*, 1974, *A&A*, **34**, 163): it is a direct consequence of the Swings effect, whereby the population of the ground state lambda doublet critically depends upon the heliocentric radial velocity (Doppler shifted Fraunhofer solar spectrum).

OH Detected

The final spectrum totalizing 5 hours of integration ON source is shown on Fig. 1: it was obtained by inverting the March 11 and 12 spectra and integrating them with the March 14 and 15 spectra. The profile is well centered at the radial velocity of the nucleus and its width is ~3 km/s as expected; the amplitude, however, is only 10 millikelvin. From model calculations the OH production rate is 7 times smaller than what we anticipated from the total visual brightness announced in early February 1978 but is in satisfactory agreement with the visual magnitude observed between March 9 and 17 ($m_0 = 8.6 \pm 0.3$ instead of 6.5). In all likelihood Bradfield (1978 c) was a faint comet from the outset and the predictions were perhaps somewhat optimistic. In fact it is the faintest parabolic comet that we have measured so far at 18 cm wavelength, about 10 times weaker than Kohoutek (1973 XII) in December 1973, and 20 times weaker than West (1976 VI) in March 1976.

Accurate positions and visual magnitudes are of great interest to us. Firstly, the 18 cm OH maser gain is higher for negative heliocentric radial velocities, i.e. *before* perihelion. If we shall be able to measure new comets beyond 2 A.U., it is vital to get an accurate ephemeris *as early as possible.* On March 4, when we first observed Bradfield (1978 c), the right ascension was wrong by 1.'5, and the signal halved on the Centre and West exposures; the detection would have been impossible without the accurate optical position of March 8 made at La Silla. Secondly, the visual magnitude is a good indicator of the outgassing of the nucleus, which helps us to select appropriate candidates for the study of OH gas production all along the cometary orbit.

Catching all the Photons: the CCD

W. Wamsteker

Before you read the figure text on page 11, try to guess which of the photos was made with the ESO 1 m telescope and which with the 3.6 m telescope. The exposure times were 15 and 30 minutes, respectively. If you cannot tell the difference, then you will have been convinced of the efficiency of the new super-detector, the Charge-Coupled Device. ESO astronomer Dr. Willem Wamsteker was privileged to use a CCD on La Silla and tells us about his exciting experience.

In March of this year, ESO was given the opportunity to use at the La Silla Observatory one of the few working CCD (Charge-Coupled Device) detectors for astronomical use. This was made possible through the graciousness of our collegues at the Cerro Tololo Observatory, the generous permission of Jet Propulsion Laboratory (where the detector was developed) and the National Science Foundation which made the funds available for the operation of the detector at various observatories. The director of AURA-CTIO offered to make the JPL-CCD available to ESO for a few nights when no telescopes were available for use at their Observatory. Although the ESO telescopes are always similarly tightly scheduled, three nights could be made free at the 1 m telescope in March. Staff astronomers Drs. Wamsteker, Danks and Bouchet used these nights, assisted by Mr. Cozza (JPL) to evaluate the detector in direct imaging. The reductions were done at the CTIO computing centre in La Serena, using the basic image-processing facilities developed for AURA, in part by Dr. Albrecht (Vienna).

In the future we hope to come back in more detail on these detectors and their usefulness for astronomical observations. However, to illustrate the type of results obtained during the nights in March we show the two photos on page 11. Both pictures show the nuclear region of the nearby peculiar galaxy NGC 5253. The left-hand photograph is a direct plate taken by Dr. Wamsteker in the prime focus of the ESO 3.6 m telescope last year. The right-hand photo is a photographic reproduction (scan-converter) of a CCD frame of the same region. The text below the photographs gives the relevant details of each exposure. To compare the two photographs, it should be pointed out that the light-gathering power of the 3.6 m is about 12 times that of the 1 m, for point-like light sources; also the 3.6 m has a focal ratio about three times faster than the 1 m. Even so the exposure time on the 1 m was only half that of the 3.6 m plate. The actual resolution on both plates is about the same—limited by the mediocre seeing ~ 3 arcsec in both cases. The wavelength region chosen for the CCD exposure is essentially unaccessible to photographic emulsions.

Some of the intensity resolution in the right-hand (CCD) picture is lost in the scan conversion, which has only 16 grey levels. Even then, there exists a striking difference in the brightness distribution between the two prints. The region which dominates the right-hand picture is by far not as dominating in the left-hand photograph. Since the left-hand picture shows essentially the distribution of stellar radiation, the northern condensation is clearly associated with non-stellar radiation. This galaxy contains a strong, unresolved IR source, which is then likely to be associated with the brightest region in the right-hand photograph. The physical conditions in this must be determined on the basis of further study.