Pre- and Post-Perihelion Spectrographic and Photometric Observations of Comet Wilson (1986 I)

C. ARPIGNY, F. DOSSIN, J. MANFROID, Institut d'Astrophysique, Université de Liège, Belgium
P. MAGAIN, ESO, and
R. HAEFNER, Universität-Sternwarte München, F.R. Germany

Hardly had Halley's comet left our immediate vicinity when a relatively bright, "new" comet, Wilson (1986 I), was discovered in the summer of 1986. The announcement of this discovery was the more exciting as early predictions gave some hope that the newcomer might become of similar brightness to Halley's in April-May 1987. Just about one year after P/Halley had made its own show, as the comet would be located in the southern sky at that time, and encouraged by our successful Halley runs at ESO, we proposed a programme that would give the opportunity to make a comparison between two comets of quite different dynamical ages observed at similar distances from the sun and with similar instrumentation. Another comparison seemed interesting: to study the behaviour of the comet before and after its passage through perihelion, which occurred on 21 April, 1987. Indeed we were able to carry out observations in April and in May, both spectrographic (2.2-m ESO-MPI telescope, 1.4-m CAT + CES, and 1.5-m telescope) and photometric (0.5-m ESO telescope). Some of the most significant results of these observations will be described briefly here. They refer to spectra in the ultraviolet, blue and red regions, as well as to photometry through narrow-band filters.

Comet Wilson proved to be considerably fainter than had been anticipated on the basis of the optimistic predictions. In early April, it was estimated to be roughly four times weaker than comet Halley had been one year earlier at the same heliocentric distance. However, as far as spectroscopy was concerned, this weakness was, in a sense, compensated by the use of CCD detectors, which had not been available during our observations of P/Halley.

This was indeed a great improvement, for CCD's are particularly suitable for the observations of extended objects: in addition to their high quantum efficiency, linearity and high dynamic range, they offer the crucial advantage of two-dimensional detectors, allowing the determination of the spatial distribution of the spectral emissions over an appreciable region of the object. Furthermore, when they are used at the Cassegrain focus, with as large as the 2.2-m and the 1.5-m telescopes, one avoids the loss of spatial resolution caused by the field rotation inherent to the collimator (where photographic plates were traditionally used in cometary spectroscopy). Knowledge of the radial profiles of the cometary emissions is absolutely necessary to analyse the physical processes responsible for the formation and for the excitation of the various emitting species, to evaluate their production rates, to construct or to test models of the coma and tail. It can also help in the identification of new spectral lines, since the extent of a given emission on each side of the comet centre is related to the nature of the particular atom or molecule involved (neutral or ionized species; short- or long-lived particle).

Ultraviolet – Blue Region

Particular emphasis was laid upon the ultraviolet sensitivity. The importance of the UV-blue region stems also from the fact that it contains emissions of OH, CO, CO+, hence information related to the abundance ratios of the major constituents of the cometary material, water and the carbon oxides.

As an example, a spectrum obtained at moderate resolution is shown in Figure 1. The heliocentric distance (r) of the comet was 1.21 A.U. pre-perihelion and its geocentric distance (F) was 0.95 A.U. The upper tracing corresponds to a strip 10 arcsec or 7,000 km wide, approximately centred on the nucleus, extracted from the CCD. The flux unit is arbitrary in this and the two other plots. No correction has been applied to take out the atmospheric extinction and the instrument + detector response, in order to illustrate the tremendous attenuation produced by these effects. For instance, the difference in overall flux reduction between 387 nm and 308.5 nm amounts to about 4 magnitudes in this case: the OH (O-O) band is, in fact, appreciably stronger than the CN (O-O) band, outside the earth's atmosphere. The middle and bottom panels compare, at a magnified scale, extractions of the same width as above, but offset by about 40,000 km on each side of the
nucleus. While the emissions from the neutral radicals are nearly symmetrical, the ionic emissions on the contrary are present only on the side opposite to the sun, at this distance from the centre of the comet. To bring out the latter emissions, their contributions have been indicated qualitatively in black on the tailward spectrum.

A striking difference with P/Halley's spectrum in this wavelength range concerns the strength of the CO$_2^+$ emissions as compared to the OH$^+$ band, which was predominant in P/Halley near 1 A.U. from the sun after perihelion (C. Arpigny et al., 1986). This was not caused by a difference in the fluorescent excitation of the emissions and since the relative ionization efficiencies involved were probably similar as well, it appears that the proportion of released carbon dioxide relative to water was higher in comet Wilson than in comet Halley at their respective heliocentric distances. As for the CO$^+/CO_2^+$ ratio, it is comparable in the two comets and we reach the conclusion that the relative abundance of carbon monoxide too was larger in Wilson.

We note that the emission near 413 nm has been assigned to CO$_2^+$ on the basis of a higher resolution spectrum where we measured the same features at 410.9, 412.3, 414.6, and 416.2 nm that we had discovered in P/Halley (ibidem). The identification of these emissions was possible thanks to the kind help of S. Leach, who is currently analysing further the CO$_2^+$ spectrum in this region. Looking back at some older spectrograms, we found that this 413 nm feature was present in comets showing CO$^+$ and CO$_2^+$, like Bester, Humason, Bennett, West. At lower resolution it tends to be mistaken for the (4-1) CO$^+$ band, which has but a very small contribution in the case of Wilson.

In view of the importance of the carbon compounds, especially those containing the C-H band, as revealed by Halley's comet, the analysis of the CH emission seemed attractive. Thus, we took a spectrum of the R and Q branches of the A-X (0-0) band of this radical (Figure 2). The high resolution used (50,000, or about 0.01 nm) allows the separation of the satellite lines such as O$_{21}$ or R$_{12}$ from their companion principal lines. This yields useful additional information since these lines are issued from different upper energy levels. Another unusual characteristic of this spectrum is the weakness of the R$_1$ (2) line. Comparing with the CH spectrum of P/Halley, for example, we see that the excitation rate of this line was indeed roughly twice as low in comet Wilson. It should be pointed out that although the

Figure 1: Spectrum of comet Wilson (1986 r) in the near UV-violet region (12 April 1987, r = 1.21 A.U., $\Delta = 0.95$ A.U.; 2.2-m telescope + Boller and Chivens spectrograph with coated GEC CCD, resolution ~ 0.5 nm; exposure 45 min). Extractions corresponding to three different locations in the comet are shown on an arbitrary flux scale (see text).
Besides the $C_2$ Swan band sequences, whose interpretation still meets with difficulties, we selected another interesting wavelength interval, comprising the 9-0, 8-0, and 7-0 bands due to NH$_2$, the red forbidden lines of oxygen, as well as the 8-0 and 7-0 bands of the H$_2$O$^+$ ion. These emissions were monitored both before and following perihelion, the main difference between these periods being the fading of the comet after perihelion and the increase in night sky contamination in May as compared to April. The 590-670 nm region recorded after perihelion is illustrated in Figures 3 and 4, where we see that the contribution of the night sky (n.s.) is indeed quite substantial. Even the weak (9-3) and (6-1) bands of the Meinel system of the hydroxyl radical show up clearly, near 630 and 655 nm, respectively (see Kvifte, 1959, for line identifications); the red [O I] doublet is dominated by the telluric emission; at 656.3 nm the situation is rather complex, with three contributors coming in: nightglow Ha, cometary Ha, and a line of the H$_2$O$^+$ 7-0 band (which, incidentally, is quite weak compared with the 8-0 band in this spectrum).

The ionic emissions extend to distances of ∼30,000 km on our different spectra, which is comparable to what we saw in P/Halley post-perihelion. This may at first appear contrary to expectation, in view of the lower gas production rate of comet Wilson. However, the solar wind conditions may have been different themselves, the relative "softness" of the cometary obstacle being, so to speak, balanced by a weaker incoming breeze in the latter case.

As far as the neutral species are concerned, the predominance of NH$_2$ in this spectral range is a common characteristic among comets near 1 A.U. from the sun or a little beyond. So is the weakness of the C$_2$ Swan $\Delta v = -2$ sequence. The $\Delta v = -3$ sequence of the same system, which should be about three times weaker still, does not appear on our spectra, although its presence on spectra for the same period has been reported by Jockers and Geyer (1987). This detection seems rather surprising, especially at a distance of 5 arcmin or 140,000 km away from the nucleus!

In April 1987 we were able to repeat on Wilson the same high-resolution observations of the [OI] + NH$_2$ blend we had made on P/Halley (Arpigny et al., 1987a). The relative intensities of the various lines turned out to be similar in these two objects, although Wilson was appreciably fainter.

Visual Region

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Photometry

Comet Wilson was observed photometrically in March, April and May 1987. The special filters defined by the IAU were used in the standard one-channel photometer of the ESO 50-cm telescope. These filters have narrow band-passes and isolate essential information concerning several molecular emission features (OH, CN, C2, CO, H2O+) and the continuum (ultraviolet, blue, and red). Because of the faintness of the object, only the central part of the coma could be measured. On the contrary, in the case of P/Halley (C. Arpigny et al., 1986) it had been possible to map a wide area (over about 5 arcmin).

The main characteristic of comet 1986f was its stability. While comet Halley varied by as much as a factor of 3 or 4 within one day, comet Wilson proved remarkably steady. Between March 30 and April 10, for instance, the apparent brightness increased by little more than 0.2 magnitude, although the comet was nearing both the earth and the sun. Actually, a more significant quantity can be derived by removing the effect upon the apparent brightness of the varying geocentric distance. Besides the purely geometrical dilution effect, proportional to 1/Δ², we have to take account of the fact that the fraction of the coma seen by the photometer also varies as Δ changes. The latter part of the correction can be estimated approximately by adopting a model representing the brightness distribution within the cometary disk (e.g. Haser’s model, corresponding to the outflow of “parent molecules” decaying into the observed radicals, which are themselves destroyed by photodissociation). When applying the Δ-correction in this way, we find that the intrinsic brightness in the various filters remained very nearly constant as the comet approached its perihelion. There was even a tendency for the scattered continuum to weaken slightly.

When we observed the comet again, in May 1987 (4 nights), it was at about the same geocentric distance as in the beginning of April, so that the corresponding data are directly comparable. Unfortunately, the weather was very bad in May and did not allow many measurements. It seems that comet Wilson was somewhat more variable after perihelion. Comparing the fluxes in various filters, it also appears that it was intrinsically fainter by a factor of 1.5 to 2.0 postperihelion, except perhaps in the light of OH, which seemed to stay at about the same level. It should be noted that this last result is rather uncertain because the atmospheric extinction is not easily evaluated at 309 nm.

This is to be compared with P/Halley. Photometric measurements were made at approximately the same comet-sun distance (~ 1.25 A.U.), both before and after perihelion (Haute-Provence Observatory Chiran, New Zealand Mount John, ESO). The geocentric distances differed appreciably in these cases; fortunately, however, a whole series of diaphragms were used at the Chiran and in New Zealand. By interpolating between the results from the different diaphragms it was possible to derive the flux received from a given volume equi-
The Iluxes are given in ergs cm$^{-2}$s$^{-1}$ and the numbers between parentheses indicate the power of ten by which the entry is to be multiplied.

This point was obtained during a minimum of activity. P/Halley was as much as 3 times brighter at other phases of its lightcurve.

We regret that due to a last minute mistake at the printer, the colour photo showing the Supernova 1987 A and the 30 Doradus nebula has been reproduced upside down. The error was discovered when this issue of the MESSENGER was delivered to ESO.

We trust that the readers will understand that under the circumstances it was not reasonable to repeat the entire printing run.

The editors