Optical Spectroscopy of the Coma of Comet Halley at ESO

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The present observing programme performed at La Silla is part of a more comprehensive coordinated project for the study of the coma of comet Halley, a joint collaboration between the Arcetri Astrophysical Observatory, the Astronomy Institute of the University of Florence and the Physics Department of the University of Naples.

The main scientific objectives of the coordinated project can be summarized as follows:

(a) determination of the coma radiance at various heliographic distances and over the widest spectral range, to improve the knowledge of the main mechanisms for the coma formation and evolution, to study the cometary activity and to check the existence (and the possible causes) of highly variable phenomena (bursts, jets, etc.);

(b) the detailed analysis of the dynamic equilibrium conditions of the most abundant gaseous chemical elements within the coma and also their spatial distribution (from the inner coma region, partially influenced by the collision, to the outer coma, collisionless and optically thin);

(c) the study of the physical conditions of the dust and gas components within the coma together with the determination of their ratio along various lines-of-sight within the coma, for a better understanding of the physical mechanisms of their production and evolution.

To reach the above-mentioned objectives it was necessary to perform contemporary measurements over wide spectral ranges, with sufficient spectral resolution, together with the highest possible spatial resolution. Moreover, the whole observing programme had to be repeated during the pre- and post-perihelion phase to study the strong irradiation effects induced by the Sun.

Visible range spectroscopy supplies important information especially on the points (b) and (c), by measuring the diffusion of solar radiation by the coma dust and the molecular and atomic resonant scattering, of some of the main gaseous "daughter" components. Spatial resolution could be obtained by putting a long spectrographic slit on various parts of the coma image.

For the pre-perihelion phase we obtained the optical spectra (3550–6800 Å) of the Halley coma with the 1.5-m telescope of the Astronomy Department of the University of Bologna in Loiano (Italy), equipped with a Boller and Chivens spectrograph and an EMI 9914 image tube.

For the post-perihelion phase we used the 1.52-m ESO telescope equipped with the Boller and Chivens spectrograph. As detectors, we used the EMI 9914 image tube for 4 nights and the Reticon for the remaining 1 night. The best compromise between spectral resolution, luminosity and spectral range, with the EMI tube, has been obtained by using the 1,200 l/mm diffraction grating (ESO # 26) with the entrance spectrograph slit of 150 μm width × 25 mm decker height. With the image linear scale of 19.4 arcsec/mm and reciprocal dispersion of ~59 Å/mm, given by the telescope and spectrograph, we then could have a spectral resolution of ~3 Å and a sky coverage of 8.09 arcminutes with a linear resolution along the slit of ~3 arcseconds (roughly corresponding to an extension of 2.8×10^5 km and the resolution of 1,700 km on the Halley coma for the days of observation). The whole optical range has been covered with only two spectra (3500–5400 Å; 5400–7300 Å).

A total of 25 spectra were obtained during the nights of March 19–22, 1986, with different exposure times, wavelength range, slit positions and orientations (parallel and perpendicular to the sunward direction). The exposure times ranged from 1 minute up to 60 minutes in order to correctly expose the most intense features (e.g., the CN 3883 band) near the photometric nucleus as well as the weakest features in the outer coma regions. Two examples of the obtained spectra are given in Figures 1 and 2. At a first glance the quality of the spectra seems to be very good. This photographic material has been digitized by means of a PDS microdensitometer and is presently being elaborated. We would like to remark here the great extension of the scattered solar radiation (see, e.g. the strength of H_β, H and K lines along the slit direction) that roughly implies a very extended dust component.

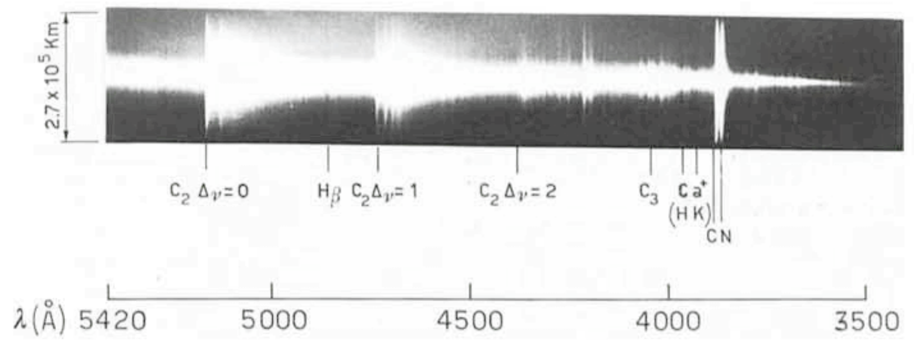

Figure 1: *Example of a spectrum in the 3500–5400 Å range taken on March 21 at $8^h\,01^m$ UT. The slit was perpendicular to the sunward direction and the exposure time was 10 minutes. Identification of some lines are reported.*

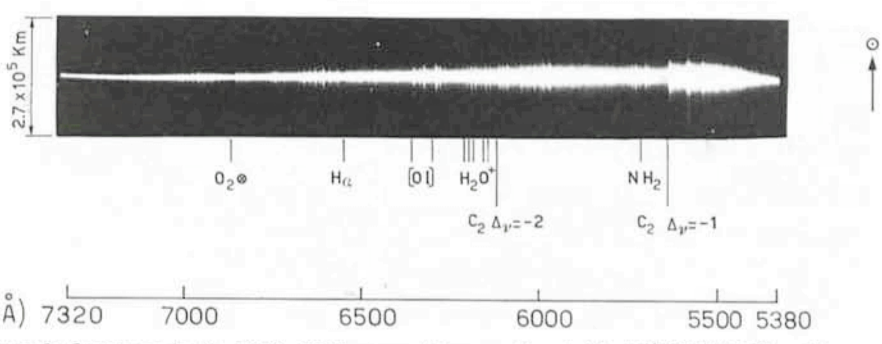

Figure 2: *Spectrum in the 5400–7300 range taken on March 20 at $8^h\,06^m$ UT. The slit was parallel to the sunward direction. Exposure time was 8 minutes. Identification of some lines are reported.*

The Reticon has been used for 1 night in the spectral range 8500–10000 Å to study the CI atoms in the metastable level $2p^2\ ^1D_2$. The atoms in this level can give emission, by resonant scattering of solar radiation, at 1931 Å, and by spontaneous decay to the $2p^2\ ^3P_{1,2}$ ground state, at 9823 and 9850 Å. Measurements of the 1931 Å line with IUE, for other comets, have shown a very fast decreasing of $^1D_2$ population with heliocentric distance, indicating the possible presence of collisional sources (Feldman, 1983). It would then have been important to measure the two near infrared lines in various parts of the coma to map the CI atoms in this metastable level. Unfortunately, also in the spectrum taken with the longest exposure on the photometric nucleus, there was no presence of these lines. These spectra are still under study in order to evaluate upper limits to be compared with ultraviolet measurements.

References

Feldman, P.D.: 1983, *Science,* **219,** 347.

Halley Through the Polaroids

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According to ancient tales a comet brings severe misfortune to people. This was again confirmed by the appearance of Comet Halley (see photo on page 18). We had in mind to perform linear and circular narrow band polarimetric measurements of this comet using the new ESO polarimeter. However, mostly due to a damage of the polarization optics which happened last year on transport from Europe to La Silla, this instrument was not available for the scheduled observations in March 1986.

To get the best out of it, we decided to convert the one-channel photometer at the ESO 50-cm telescope into an auxiliary polarimeter. Since during our observing time the comet could be measured only for about 30 minutes to 100 minutes in the very last part of the night, this had to be done without affecting preceding photometric investigations of other objects. Inserting sets of specially prepared Polaroid sheets into the filter wheel of the photometer provided an uncomplicated and economic solution. There were different reasons to restrict ourselves to circular polarimetric measurements: Whereas a large amount of linear polarimetric observations has been performed during the past years, only very few circular measurements exist up to now. To determine linear polarization, at least three sets of Polaroids are necessary whereas two sets are sufficient to derive the circular polarization. Since the different sets can be used only sequentially, the time to complete one measurement is much longer and therefore the required tracking accuracy must be much higher for linear polarimetric observations. Furthermore, measuring linear polarization requires a very precise alignment of the Polaroid sets relatively to each other, whereas the circular polarization can be determined without specially fixed positions of the two sets. Moreover, long-lasting calibration measurements of polarized standard stars are necessary in order to determine the coordinate system of the instrument for the linear polarimetry. Finally, the linear polarization is much more affected by the sky background polarization, especially shortly before and during dawn.

We prepared two sets of Polaroid sheets fabricated by E. Käsemann Ltd., each containing one Polarex polarizer and two quarter wave foils (retarders). The first quarter wave foils were placed in front of the polarizers and aligned with the fast axes at +45° respectively −45° versus the polarization axes of the polarizers. So, within the limits imposed by the effective wavelength (approx. V band, given by the spectral response of the Polaroids and the photomultiplier as well as the spectral distribution of the comet), these sets exhibit maximum transparency for + circular respectively − circular polarization. The remaining retarders were each placed behind the polarizers in such a way that the linear polarized light leaving the polarizers was again transformed into circular polarized light, thus avoiding the instrumental problems arising from the recording of linear polarized light. A consecutive measurement through these two sets (A and B) allows then the determination of the circular polarization.

What is the accuracy of such an arrangement? The one-channel version does not allow for a seeing compensation and causes together with the absorption of the Polaroids a light-loss of about 70%. To shorter and longer wavelengths the retarders deviate gradually from the quarter wave characteristics, thus producing a depolarization. The same holds for the cometary emission lines, especially the C_2 λ 5165 complex. Based on tests in the laboratory and on previous experiences with such Polaroids, we estimate the error of a single polarization determination to be of the order of 0.5%. This means that the circular polarization of Halley to be detected by this device must be of the order of a few per cent.

Indeed, theory predicts circular polarization in comets up to 4% (Dolginov, A.Z., and Mitrofanov, I.G., 1975, *Russ. Astron. J.* **52,** 1268). However, no hint for circular effects was found in either Comet Kohoutek or Bradfield or West (Michalsky, J.J., 1981, *Icarus* **47,** 388) or Tago-Sato-Kosaka (Wolf, G.W., 1972, *Astron. J.* **77,** 576). The reason for this could be that the measurements were made using too large apertures (up to 42″) centred on the core of the comet, thus averaging over too large areas. Indeed, the dusty Comet Bennet showed up to 5% and even once 18% circular polarization when measured through a 14″ aperture placed on different areas within the coma (Metz, K., 1970, Thesis University Munich).

After some test runs in situ, five successful observing runs between March 16 and 20, 1986, could be obtained. Halley showed a pronounced condensation of a few seconds of arc around the nucleus as seen through the view finder. This allowed an accurate positioning of selected areas to be measured using its cross wire and concentric rings. These areas are shown in Figure 1. The tracking speed of the telescope has been adjusted to the actual motion of the comet. However, due to differential refraction (high air mass at start time), there remained a very small uncompensated motion which could influence the subsequent measurements. To overcome this, the sequence ABBA was taken for one polarization measurement. Normally the smallest aperture (10″) was used since obviously the measured degree of polarization decreases with increasing diameter of the diaphragm. This is well known for linear polarization and suspected to hold also for the circular one. An integration time of 20 seconds per Polaroid set proved to be appropriate. Several unpolarized standard stars of solar type were measured every night at the beginning and the end of the Halley run in order to derive the instrumental effects. There was no moon and perfect meteorologi-