Observations of Comet P/Crommelin at ESO in the Near Infrared Range

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Near infrared photometry has been used for a long time for cometary observations (Ney, 1982). The 1-3 μ spectral range is adequate for observing the solar light scattered by the particles, since there is no strong gaseous signature expected in this region (except in some cases a weak possible contribution from a CN band at 1.1 μ). It has been shown that photometric measurements in the J, H and K filters are useful for deriving constraints upon the nature and the distribution of the cometary dust (Campins and Hanner, 1982).

In order to prepare as well as possible the campaign of Comet Halley's ground-based observations, the International Halley Watch (IHW) has initiated a "trial run" on comet P/Crommelin. This periodic comet, which comes back every 27.7 years, arrived at perihelion on February 20, 1984, with a heliocentric distance of 0.73 AU, and presented for ground-based observers the same overall configuration as expected for the 1986 apparition of Comet P/Halley. Apart from its trajectory and expected visual magnitude, little was known on P/Crommelin itself, and nothing about its dust composition and distribution, before its 1984 apparition.

An observing campaign was organized at ESO for infrared observations of P/Crommelin, from January to March 1984, involving Dr. Drechsel (Dr.-Remeis-Sternwarte, Bamberg), Dr. Engels (Universitäts-Sternwarte, Bonn) and Dr. Krautter (ESO, Garching). The equipment used were the ESO InSb infrared photometers at the 1 m telescope and the 3.6 m telescope.

The first attempts to observe the comet in January 1984 were unsuccessful due to the low brightness of the comet.

Comet P/Crommelin was observed on March 19, 1984 at the 1 m telescope. The diaphragm was 30 arcsec, with a throw of 60 arcsec in east-west direction. Calibration was achieved with the standard star HR 1136 ($J = 1.98$; $H = 1.53$; $K = 1.44$). The air mass ranged between 1.6 and 1.9 for both the comet and the star. Results for P/Crommelin are $J = 11.4$, $H = 11.0$, $K = 11.0$ with an uncertainty of 0.1 for each filter. P/Crommelin was also observed in the J filter at the 3.6 m telescope on March 20, with a 7.5 arcsec diaphragm and a throw of 15 arcsec in east-west direction. A magnitude of 13.4 was measured, possibly overestimated.

Fig. 1 shows the quantities J-H and H-K plotted as functions of the scattering angle θ. The curves shown in Fig. 1 are theoretical curves computed by Veeder and Hanner (1981) and Campins and Hanner (1982), from Mie scattering theory, for various types of grains, assuming the Sekanina-Miller distribution (Sekanina and Miller, 1973). Among the types of grains considered are dirty ice grains, silicate grains and magnetite, a typical absorbing material present in meteorites. Our result tends to eliminate the presence of absorbing grains, as shown by the magnetite curve which corresponds to a colour redder than our result.

Icy grain models seem also incompatible with our measurement, in particular because they would lead to a (J-H) colour bluer than observed. This result is not surprising, since our diaphragm was large (30 arcsec, which corresponds to 18,000 km in the coma at the time of observation); moreover, the comet's heliocentric distance was 0.9 AU at that time, and icy grains could not survive long enough to make a significant contribution to the cometary flux. In conclusion, our measurement tends to support a silicate composition of micron-sized particles, from both the (J-H) and (H-K) colours. P/Crommelin would thus have a dust composition different from P/Meier, P/Tuttle and P/Stefan-Oterma, for which a mixture of absorbing particles and irregular silicate grains has been suggested (Veeder and Hanner, 1981; Campins and Hanner, 1982). However, it has to be mentioned that our conclusion is not unambiguous, because different kinds of grains could eventually lead to the same (J-H) and (H-K) colours, so that the solution is not unique.

Other measurements of Comet P/Crommelin were achieved in the same filters at the UKIRT telescope on March 27 (Eaton and Zarnecki, 1984) with a 6″.2 aperture and at the IRTF telescope (Hanner and Knacke, 1984) on March 31, with a 7″.1 aperture. The corresponding (J-H) and (H-K) values are also plotted in Fig. 1.

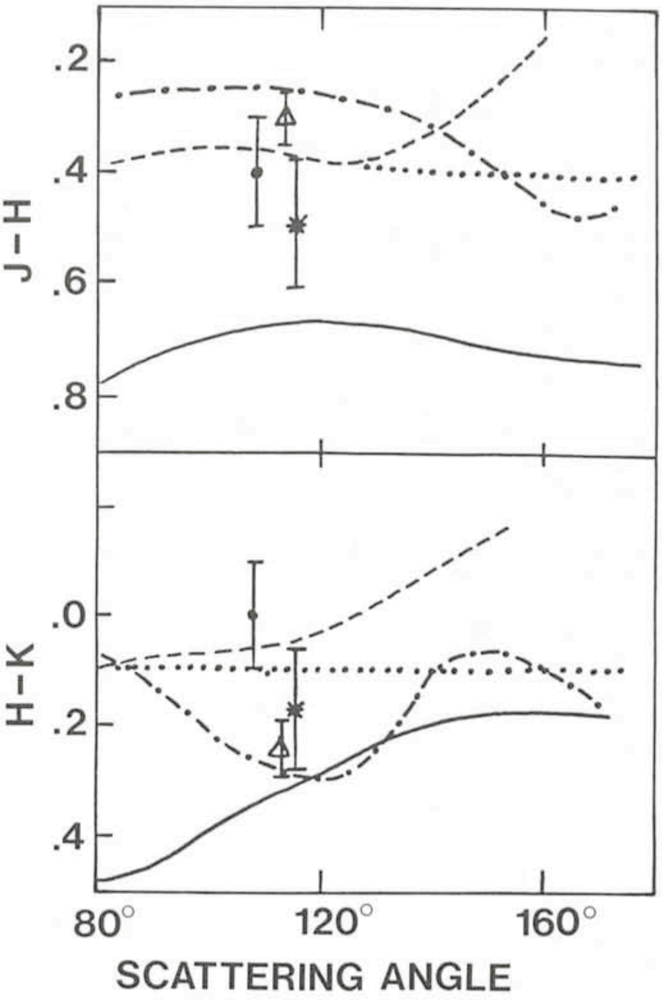

Fig. 1: *(J-H) and (H-K) diagrams as functions of the scattering angle. The curves have been calculated by Veeder and Hanner (1981) and Campins and Hanner (1982). Solid curves: magnetite grains (absorbing material); dashed curves: silicate grains; dotted curves: irregular silicate grains; dash-dot curves: 20 μ slightly dirty ice grains, n″ = 0.002 (Campins and Hanner, 1982). The observations are from this paper (black point), Eaton and Zarnecki (triangle) and Hanner and Knacke (star).*

Assuming the dust composition did not change between March 19 and March 31, and assuming the dust composition to be homogeneous within the 30 arcsec diaphragm, we can compare our (J-H) and (H-K) values to the values derived from the two other sets of observations. The agreement with Hanner and Knacke's data is reasonably good; in the case of Eaton and Zarnecki's measurement, there is some discrepancy for the (H-K) value. A possible explanation could be that Eaton and Zarnecki's results, obtained in a smaller diaphragm (6.2 arcsec) imply a contribution due to dirty ice grains; however, we would expect in this case the same behaviour in Hanner and Knacke's results, which do not appear for (J-H); moreover, the presence of a significant ice contribution in a sphere of about 3,500 km is not expected at a heliocentric distance smaller than 1 AU (Campins and Hanner, 1982). The final conclusion which can be derived from the three sets of measurements is that there is no evidence for absorbing particles in the dust composition of P/Crommelin.

Another information which could be derived from the data comparison concerns the spatial distribution of dust, using the fact that observations were performed in different diaphragms. If the dust is assumed to be ejected radially, isotropically, with a constant velocity, then the dust density at a given distance r from the nucleus varies as r^{-2}, and the number of particles inside a diaphragm of radius δ increases linearly with δ. The observed flux, either in the scattered component or in the thermal component (since the medium is optically thin) is proportional to the number of particles and thus proportional to δ. This linearity has been checked by Becklin and Westphal (1966) on Comet Ikeya-Seki for diaphragms ranging from 20 to 80 arcsec. For smaller apertures, the linear law might be altered by collisional effects or anisotropic dust ejection. However, in our case, this study requires that we are able to monitor accurately the intrinsic variations of the comet's magnitude between March 19 and March 31. The geocentric distance of P/Crommelin remained constant within 2% between these dates; in contrast, the visual magnitude changed rapidly, not only because of the heliocentric distance, but also because of intrinsic cometary activity. Information upon the M_V curve is available from Marsden (1984) but a more complete analysis, involving more data, would be useful.

In conclusion, the preliminary results reported here show the potential interest of near IR photometry for studying cometary dust, especially for future observations of Comet P/Halley. Extension towards higher wavelengths will be necessary to obtain more constraints upon the nature and size of the dust particles. A systematic study with different size diaphragms should allow a good determination of the dust density distribution.

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Line Profile Shapes in Optical H II Regions

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Some of the most spectacular astronomical photographs and favourite subjects for popular astronomical slide shows are colour pictures of H II regions. Probably every astronomer, both amateur and professional, is familiar with the nebula in Orion, M 42. Shaped like an opened fan, this well-known H II region ("H II" is the technical term for ionized hydrogen) appears to be yellow in its bright core and fades out to red and then a faint bluish hue towards the outer perimeter. Of course, the exact colours and size of the Orion Nebula, M 42, is dependent on the type of colour film used and the amount of light gathered. Longer exposure times tend to make the nebula appear larger, expanding outward in the direction of the fan's perimeter. Short exposures of the nebula (or using the eye instead of film) reveal the presence of four bright stars in its core, the "Trapezium", so named because of their relative geometrical positions. These stars cannot be seen on long-exposure pictures, because the light from the nebular core saturates the film.

H II Regions – the Strömgren Theory

On the theoretical side, much has been learned about the nature of H II regions such as the Orion Nebula. An important theoretical breakthrough came when Strömgren, in 1939, published his paper on "The Physical State of Interstellar Hydrogen" (1). Strömgren recognized that ionized hydrogen at typical interstellar densities is transparent to the extreme ultraviolet radiation from hot O and B stars, such as the Trapezium stars in the Orion Nebula. Neutral atomic hydrogen on the other hand should be very opaque to this radiation at wavelengths shorter than $\lambda = 912$ Å. This critical wavelength corresponds to the ultraviolet photon energy necessary to ionize the hydrogen atom, expelling its single electron. The process of absorbing ultraviolet photons and ionizing hydrogen changes the material originally opaque to ultraviolet light to material transparent to subsequent ultraviolet photons. If it were not for the fact that the electrons and protons in an ionized gas occasionally recombine to form atomic hydrogen, all the material in the Milky Way Galaxy could be converted into ionized gas by fewer than 10^4 O5 stars. The process of occasional recombination in an ionized gas makes this gas only partially transparent to the hydrogen-ionizing ultraviolet photons. Thus, an H II region, which is produced whenever a hot O or B star is embedded in a cloud of neutral material, has only a finite extent.

The equilibrium size of the ionized region can be calculated in an approximate way by equating the total number of recombinations per second in a fully ionized gas with the total