dust density has remained virtually unchanged in the meantime. There is a broad, fan-shaped area of excess luminosity towards East; i.e. in the direction opposite to the comet's motion. This apparently represents the projected image of a normal dust tail, seen almost head-on. There is also a rather narrow fan that extends towards North, possibly a result of an earlier dust ejection event.

Some technical information: Johnson-V filter; stars, galaxies and cosmics cleaned from individual frames before addition; smoothed by 3 × 3 gaussian filter; outermost isophote corresponds to ~28 mag/arcsec^2; 1 pixel = 0.464 arcsec; frame size: 201 × 201 pix = 93 × 93 arcsec; seeing 1.2–1.5 arcsec; North is up and East is to the left.

R. M. WEST, ESO

Some Highlights from Comet Tempel 2 Observations at ESO

K. BEISSER, H. BOEHNHARDT, V. VANYSEK, Dr.-Remeis-Observatory, Bamberg, F. R. Germany
K. REINSCH, TU Berlin, F. R. Germany
E. GRÜN, MPI für Kernphysik, Heidelberg, F. R. Germany
L. MASSONNE, ESOC, Darmstadt, F. R. Germany

1. Introduction

During its 1988 perihelion passage, periodic comet P/Tempel 2 (orbital period of 5.3 years) was an object of intense ground-based observations, because it was one of the possible targets for the NASA Comet Rendezvouz and Asteroid Flyby mission (CRAF) in 1993. Although due to funding problems the CRAF project has been postponed to at least 1995, thereby automatically rejecting P/Tempel 2 from the mission target list, the ground-based study of this comet continues.

ESO has granted observing time for P/Tempel 2 to several groups of observers. Here we present preliminary results from our direct imaging and spectroscopic observations of comet P/Tempel 2. The data were collected at ESO La Silla between early May and early November 1988 with the 2.2 m, the 1.5 m Danish, the 1.5 m ESO and the GPO telescopes. Table 1 summarizes the geometrical aspects of the Sun-Earth-Comet constellation during the observation intervals.

2. Direct Imaging of P/Tempel 2

On May 4, 1988, comet P/Tempel 2 was observed with the 2.2 m telescope + CCD through a Johnson V filter. Two short exposures of 30 seconds and 3 minutes were taken. The nucleus of the comet appears star-like in the images, no coma can be detected around the comet (see Fig. 1). The small brightness extension to the west of the nucleus arises from a faint background star close by the cometary position. From the CCD images a nucleus brightness of 16.45 ± 0.05 mag is derived. From that one can estimate the effective nucleus radius R of comet P/Tempel 2 by (Spinrad et al., 1979)

$$R^2 \, A \, \Phi(\alpha) = r^2 \, 10^{0.4\,(M_\odot - (m - 5 \log \Delta))}$$

$M_\odot$ and m are the filter brightnesses of the Sun and the comet, respectively, r (in km) and Δ (in AU) the solar and Earth distances of the comet, A the albedo and $\Phi(\alpha)$ the phase function of the nucleus for the phase angle α. Using the albedo A = 0.024, derived by A'Hearn et al. (1988) for P/Tempel 2 from simultaneous optical and infrared observations, the effective nuclear radius R of the comet is about 6.1 km, when using the phase function of the Moon and about 5.1 km when using the phase function of Spinrad et al. (1979). A'Hearn et al. (1988) found an effective nuclear radius R = 5.6 km for comet P/Tempel 2, the data published by Spinrad et al. (1979) lead to R = 4.1 km when scaled to the much lower albedo A = 0.024 measured recently. Sekanina (1988) suggested nucleus dimensions of 18 × 11 × 7 km for P/Tempel 2 based on observations of Luu and Jewitt (1988a, b) in 1987 and 1988. Photometric obser-

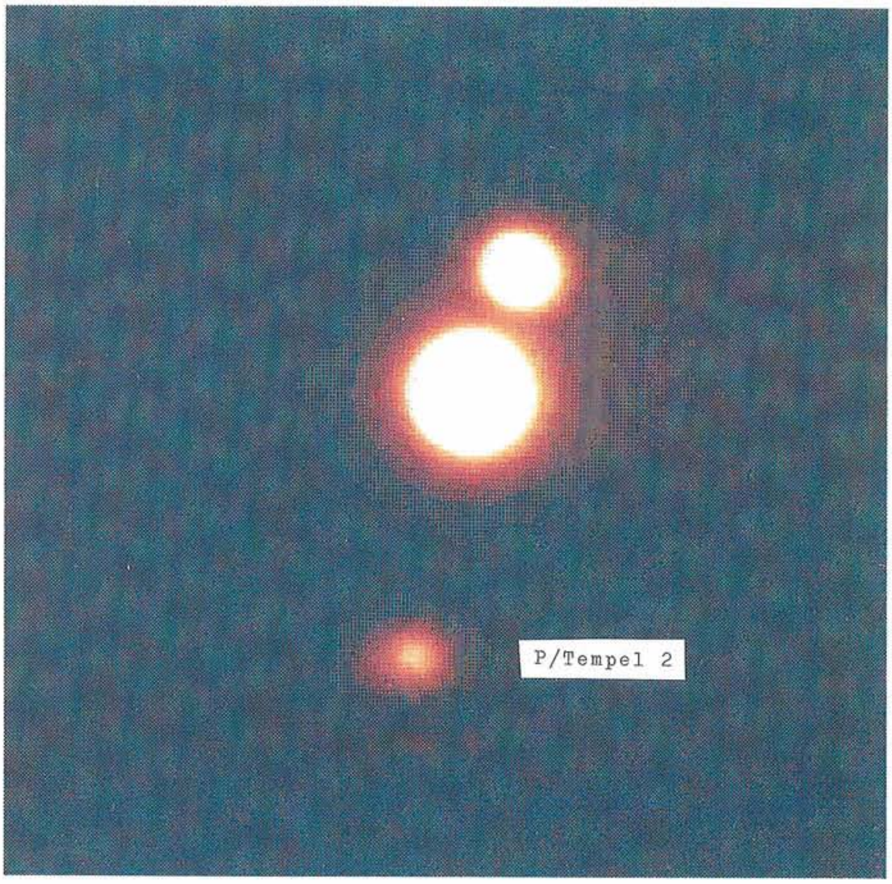

Figure 1: *3-min V exposure of comet P/Tempel 2, obtained with the 2.2 m telescope at ESO La Silla on May 4, 1988. North is up, east is to the right, the field of view is 1 × 1 arcmin. The small image extension of P/Tempel 2 to the west arises from a faint background star.*

vations of the comet also indicate that P/Tempel 2 may have an aspherical nucleus of 2 : 1 axes ratio, rotating with a period of about 9 hours (Jewitt and Luu, 1988; Wisniewski, 1988; A'Hearn et al., 1988). Hence the different effective radii of P/Tempel 2 derived from data obtained at different observation dates may be due to the unknown and changing attitude of the nucleus with respect to the Sun and the observers.

It is interesting to note that on May 4, 1988, i.e. at solar distance 1.95 AU pre-perihelion, the nucleus of P/Tempel 2 has not yet started significant gas and dust production like many other comets do even further away from the Sun. On May 16, 1988, West (1988a, b) already found a well developed coma around P/Tempel 2, while from April 9 to 15, 1988, Jewitt and Luu (1988) obtained star-like CCD images of the comet. Therefore we conclude that the nucleus activity started between 135 to 124 days before perihelion passage. This may provide an additional constraint in the nucleus modelling for the illumination of active regions on the cometary surface.

From July 18 to 24, 1988, comet P/Tempel 2 was observed at ESO La Silla with the Danish 1.5 m telescope. During that period the Earth passed through the orbital plane of the comet. Several broad-band B, V, R and a few IAU cometary filter CCD images of the comet were obtained. In the broad-band images, a rather asymmetric coma extension in the solar direction is visible (see Fig. 2), while the tail in the anti-solar direction (position angle γ = 110°) is hardly detectable. The main axis of the sunward coma expansion points to position angle of about 300°, slightly deviating from the direction to the Sun. Sekanina (1987) studied the fan-like coma asymmetries of comet P/Tempel 2 during the past apparitions and derived a quantitative spin-vector model for the rotation of the nucleus. From that he predicted (1988) a position angle of the fan axis of about 325° for the observation interval in the second half of July 1988, which is rather close to what we actually found from the CCD images.

IIa-O plates of comet P/Tempel 2, obtained in early November 1988 with the GPO telescope at ESO La Silla, also show a coma asymmetry with an axis pointing to approximately 340 to 350°. Again, this is close to Sekanina's prediction for this observation interval. Furthermore, the cone angle of the coma asymmetry in November 1988 was definitely broader than in July 1988, which is in agreement with the spin-vector model of the nucleus.

From the preliminary results we therefore expect that a detailed analysis of the imaging data of P/Tempel 2 may help to improve significantly the nucleus model for this particular comet.

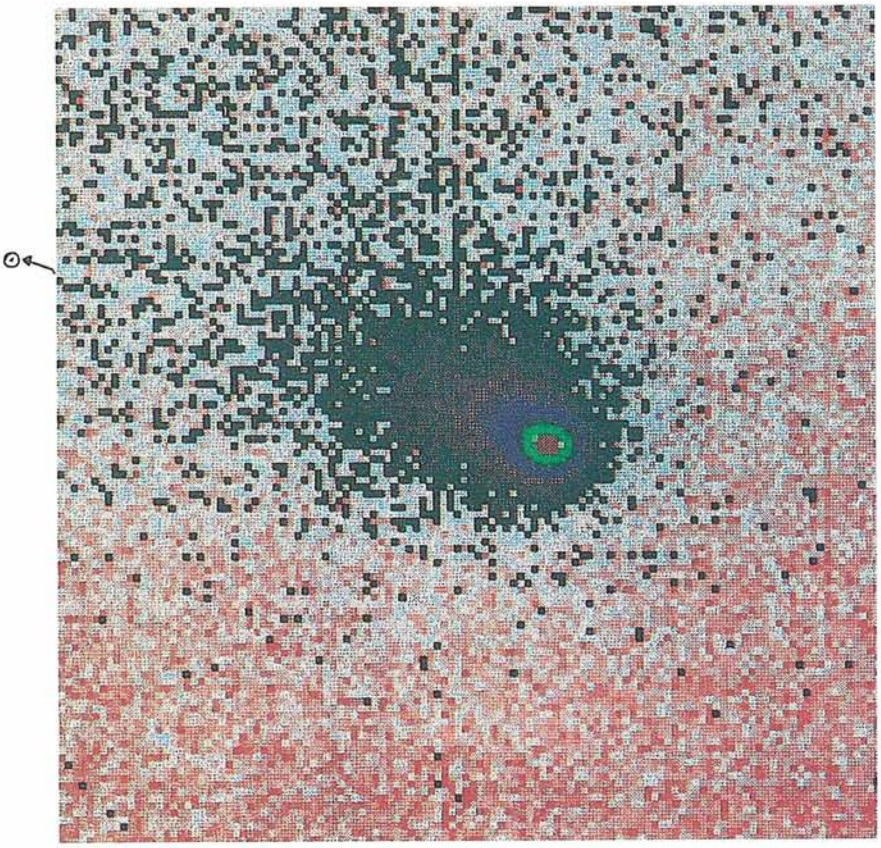

Figure 2: *1-min R exposure of comet P/Tempel 2, obtained with the 1.5 m Danish telescope at ESO La Silla on July 24, 1988. North is up, east is to the right, the field of view is 29 × 29 arcsec corresponding to 16,700 × 16,700 km at the distance of the comet. The direction of the Sun is indicated by the ⊙ symbol.*

3. Spectroscopy of P/Tempel 2

From October 29 to November 2, 1988, comet P/Tempel 2 was observed spectroscopically with the ESO 1.5 m telescope at La Silla. A Boller and Chivens long-slit spectrograph (3 arcmin slit) with CCD was mounted to the Cassegrain focus. The coma was monitored in two slit orientations (in and perpendicular to the projected radius vector) in the wavelength region 3700 to 5400 Å with 114 Å/mm spectral resolution. Beside the production of the molecules (CN, C_2, C_3 and some minor abundant species), the flux ratio of the vibrational sequence in the C_2 Swan band was studied in this observing programme (see Fig. 3).

Since the strongest band sequence of C_2 falls in the visible spectral region, this molecule is one of the best candidates for a test of various hypothesis concerning the dissociation and radiation processes in comets. Like other daughter molecules, C_2 is freed from the parents near the nucleus and radiates until further decomposition or ionization. The flux distribution of the band sequences of the resonance fluorescence spectra reflects the vibrational population distribution in the lowest electronic triplet state of C_2. If this distribution is determined by the statistical equilibrium, the corresponding vibrational temperature T_{vib} would be about the same as the colour temperature T_b of the Sun in the

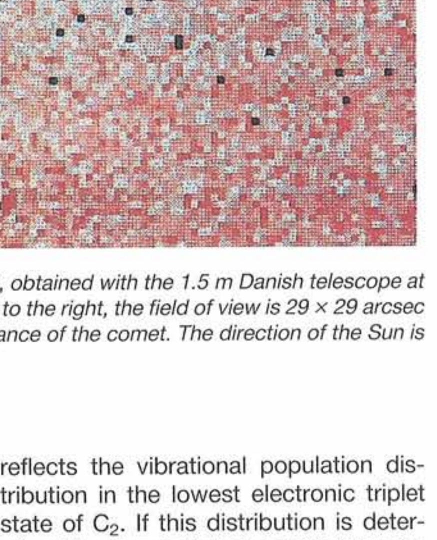

Figure 3: *The C_2 Swan sequence in the spectrum of P/Tempel 2, obtained with the ESO 1.5 m telescope on October 30, 1988. The wavelengths are given in Angstrom, the intensity in arbitrary units.*

TABLE 1: *Sun-Earth-Comet constellation during the observing periods of comet P/Tempel 2 at ESO La Silla*

Date	r (AU)	Δ (AU)	ϑ (o)	α (o)	γ (o)	ESO telescope
4.5.1988	1.94	0.99	152	14	48	2.2 m
18. – 24.7.1988	1.53 – 1.50	0.79	115 – 111	37 – 39	291 – 288	1.5 m Danish
30.10. – 2.11.1988	1.46 – 1.47	1.22 – 1.24	81	42	258	1.5 m ESO
3. – 10.11.1988	1.47 – 1.50	1.24 – 1.31	81 – 80	41 – 40	258 – 256	GPO

r = solar distance of the comet; Δ = Earth distance of the comet; ϑ = Sun-Earth-Comet angle; α = Sun-Comet-Earth angle or phase angle; γ = position angle of the Sun (measured east of north).

spectral range of the Swan bands. However, this would be fulfilled only if there is no exchange of populations between the lowest vibrational levels. Such transitions are indeed forbidden, because the C_2 is homonuclear and one can expect that the ratio of the integrated band fluxes and consequently also the vibrational temperature would be constant and independent on the heliocentric distance. But the observational results obtained for many comets indicate that T_{vib} is systematically lower than T_b. This effect can be explained by a sophisticated model developed by Krishna Swamy and O'Dell in the past decades (1987). They propose a mechanism which allows transitions between triplet state and adjacent lowest singlet state via a cascade-like radiation process.

Due to this process low values of T_{vib} should be derived from the observed flux ratios of the Swan bands. Since the probability of the downward spontaneous transitions is independent of the radiation density, while the upward induced transitions are proportional to the photon flux, the effect of the downward transitions into singlet states becomes more dominant if the radiation field decreases. Thus the apparent T_{vib} decreases with increasing heliocentric distance. Because the relative strength of the (Δv = +1) band increases with T_{vib}, the flux ratio of (Δv = +1)/(Δv = 0) is a function of the heliocentric distance.

Ratios of the integrated fluxes of these bands are primarily determined by the rate at which transitions occur between the lowest electronic triplet state forming the Swan bands and the lowest singlet level.

The transition probability between these two states (denoted for simplicity as a-X) is unknown, but can be assumed as a free parameter. In Figure 4, the full lines represent the dependence of the integrated flux ratio of (Δv = +1)/(Δv = 0) Swan bands on the heliocentric distance, theoretically predicted by Krishna Swamy and O'Dell (1987) for various values of the transition moment $(Re)^2$ expressed in atomic units. The filled circles indicate the most precise values of the flux ratios obtained by O'Dell et al. (1988) for comet P/Halley. Symbols V indicate data obtained from comet P/Halley with high spatial resolution onboard the spacecraft VEGA 2 (Vanysek et al., 1988). V_o stands for the impact parameter (i.e. minimal distance of the line of sight from the nucleus) < 1000 km and V the same for 2500 km.

Our preliminary result for the (Δv = +1)/(Δv = 0) flux ratio of C_2 in comet P/Tempel 2, marked by symbol T in Figure 4, falls between data for comet P/Halley. Hence the most probable value of the transition moment seems to be about 2.5 10^{-6} and the corresponding Einstein coefficient for the downward spontaneous transition to be about 7 10^{-3} s^{-1}.

Since the C_2 molecules can be formed either in the singlet and/or in the triplet state, the time required for establishing the triplet/singlet equilibrium would be several hundred seconds and the vibrational temperature would be time-dependent. Immediately after the C_2 formation which occurs in the innermost part of the coma, the vibrational temperature should be high and close to the colour temperature of the Sun, but during the expansion of the C_2 molecules into space, the populations in the lower states become redistributed and T_{vib} as well as the relative flux of the (Δv = +1) band decreases. This effect seems to be confirmed by VEGA 2 data obtained for comet P/Halley.

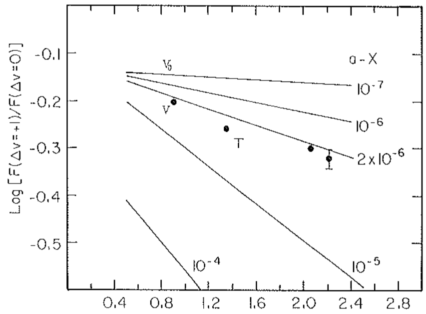

Figure 4: *The dependence of flux ratio C_2 (Δv = +1)/(Δv = 0) on the heliocentric distance. Full lines represent theoretical model calculations for various values of the electronic moment, derived by Krishna Swamy and O'Dell. Full circles are measurements of comet Halley, symbol T for comet P/Tempel 2. V_o and V represent the average value obtained from Vega 2 spectrograms of P/Halley (for details, see text).*

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Spectral Analysis of A-F Giant Stars

S. BERTHET and B. HAUCK, Institut d'Astronomie de l'Université de Lausanne, Switzerland

1. Introduction

A very large variety of stars of spectral type A-F display abundance anomalies: metallic-line stars, magnetic stars, λ Bootis, . . .

These stars are best distinguished from normal stars by means of photometry. Two photometric systems are especially well adapted to this effect: the uvbyβ and Geneva systems. A description of the latter has been given in