Revista Mexicana de Astronomía y Astrofísica, **28**, 3-6 (1994)

PHOTOELECTRIC PHOTOMETRY OF PERIODIC COMET FAYE

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Received 1992 December 1

RESUMEN

Se presentan resultados de observaciones del cometa P/Faye realizadas desde la Estación Astronómica "Dr. Carlos U. Cesco" del Observatorio Félix Aguilar, San Juan, Argentina, en noviembre y diciembre de 1991 utilizando los filtros estándar del International Halley Watch (IHW). Las tasas de producción de CN, C_2 y C_3 se obtuvieron utilizando el modelo de Haser, y las del $O(^1D)$ y H_2O se derivan de las relaciones dadas por Cochran (1990b) y Newburn & Spinrad (1985, 1989). Se da finalmente un valor estimado del radio y fracción de superficie activa del núcleo.

ABSTRACT

We present the results of narrow-band filter photometry of Periodic Comet Faye obtained from Estación Astronómica "Dr. Carlos U. Cesco" of Félix Aguilar Observatory, San Juan, Argentina, in November and December 1991 using the International Halley Watch (IHW) standard filters. The production rates of CN, C_2 and C_3 are derived from the Haser model, and that of $O(^1D)$ and H_2O are derived from the relations provided by Cochran (1990b) and Newburn & Spinrad (1985, 1989). Estimated values for the radius and fraction of nuclear active surface are given.

Key words: **COMETS – INDIVIDUAL (FAYE)**

1. INTRODUCTION

Cometary nuclei appear to have formed in the outer regions of the solar nebula, or possibly even farther in the presolar cloud. Thus they offer invaluable samples of the population of minor bodies which accreted out of primordial grains under cold enough circumstances for this material to remain essentially unaltered. Even though later thermal modifications are by no means excluded (Rickman 1991), their apparently low density, porous structure (Rickman 1989) testifies to their relative pristine nature. By studying their properties one may reach a wealth of otherwise inaccessible information on the origin of the Solar System.

From this point of view, surprisingly little is known about cometary nuclei. The first resolved images of a cometary nucleus were provided by the *Vega 1* and *Vega 2* spacecrafts (Sagdeev et al. 1986) and by the *Giotto* spacecraft (Keller 1986) during encounters with comet P/Halley, probably quite atypical in terms of its dynamical history (Rickman & Froeschlé 1988). Extant data allowing to separate nuclear mean radius and albedo are mostly concentrated on comets which are exceptional by their low level of activity.

To gain insight in our knowledge about cometary nuclei, and to learn about the processes taking place in the coma, it is very important to study the rate of gas production of the molecular species and correlate them with the H_2O production (Cochran 1990b). This rate, as the water is the most important nuclear component, is similar to the total gaseous rate (Q_{total}). The knowledge of Q_{total} together with the nongravitational forces, may provide information about the mass and density of the comet nucleus (Rickman 1986), aging and progressive deactivation (Rickman et al. 1991), and percentual surface area in active sublimation, which tell some-

TABLE 1

FILTER CHARACTERISTICS

	CN	C_3	C_2	*UC*	*BC*	*RC*
λ_0 (A)	3870	4060	5140	3650	4845	6840
FWHM (A)	50	70	90	80	65	90

thing about the existence of a thick mantle over the nuclear surface and about dormant comets among the Aten-Apollo-Amor asteroids.

We present here narrow-band photometry of comet P/Faye during its 1991 apparition. The observations were planned as part of our extensive program on periodic comets, but equipment problems and weather ultimately limited it to the two nights of data reported here.

2. OBSERVATIONS

During the nights of November 12 and December 4, 1991, we have made photoelectric photometry observations of comet P/Faye using the IHW cometary filters and a photon counting photometer equipped with a cooled RCA 31034A photomultiplier tube attached to the 76-cm telescope of the Estación Astronómica "Dr. Carlos U. Cesco" of Félix Aguilar Observatory (San Juan, Argentina), and using 33″ and 63″ diaphragms. The characteristics of the filters are summarized in Table 1.

The observed magnitudes were standardized to the system chosen by the IHW using the standard stars HD 3379 and HD 26912 and the solar analog HD 218697 obtained from the list of Osborn et al. (1990). Two stars near the comet were observed frequently and used as local standards to monitor extinction and check for any instrumental variations. None of the local standards showed intrinsic

TABLE 3

EXTINCTION COEFFICIENTS OBTAINED FOR EACH NIGHT

Date	3650 (A)	3871 (A)	4060 (A)	4845 (A)	5140 (A)	6840 (A)
Nov 12, 91	0.554	0.448	0.405	0.225	0.202	0.12[illegible]
Dec 4, 91	0.567	0.476	0.427	0.238	0.230	0.14[illegible]

variability. In Table 2 we present the observationa[illegible] data as mean night values for each diaphragm use[illegible] with the fluxes expressed in units of (erg cm^{-2} s^{-}[illegible] A^{-1}) for the continuum and (erg cm^{-2} s^{-1}) fo[illegible] the bands and in Table 3 the extinction coefficien[illegible] obtained each night.

3. COLUMN DENSITIES AND PRODUCTION RATES

The total number of molecules $M(\rho)$ of each spe[illegible]cies radiating within a column of radius ρ defined b[illegible] the aperture used and extending through the com[illegible]et, was computed using the standard relation,

$$\log M(\rho) = \log F(\rho) + 27.449 + \\ + 2 \log (r\Delta) - \log g \quad , \qquad (1$$

where r is the heliocentric distance, Δ is the geo[illegible]centric distance and g is the fluorescence efficienc[illegible] factor at 1 AU (in units of erg s^{-1} molecule^{-1}). g i[illegible] a constant for the molecules C_3 and C_2, whereas fo[illegible] the molecule CN, it is a function of the heliocentri[illegible] distance and radial velocity of the comet (A'Hear[illegible] 1982). The g values adopted by us for determinin[illegible] the column densities of the three gas species are $g(C_2) = -12.347$ (A'Hearn et al. 1985); $g(C_3) = -1$[illegible]

TABLE 2

OBSERVATIONAL DATA OF COMET P/FAYE[a]

Date (1991)	Nov 12	Dec 4	Dec 4
r (AU)	1.594	1.604	1.604
Δ (AU)	0.636	0.734	0.734
Diaph. (arcsec)	33	33	63
Temp. (C)	7	8	8
C_2 $F(10^{-12})$	3.65 ± 0.29	1.27 ± 0.27	1.68 ± 0.31
C_3 $F(10^{-12})$	1.30 ± 0.49	3.46 ± 0.54	0.57 ± 0.59
CN $F(10^{-12})$	1.71 ± 0.57	1.73 ± 0.70	3.69 ± 0.84
3650 A $F_{con}(10^{-14})$	3.03 ± 0.38	2.81 ± 0.59	3.50 ± 5.76
4845 A $F_{con}(10^{-14})$	9.59 ± 0.58	4.73 ± 0.34	7.17 ± 0.45
6840 A $F_{con}(10^{-14})$	8.98 ± 0.16	4.23 ± 0.10	6.73 ± 0.13

[a] The columns are self-explanatory.

TABLE 4

COLUMN DENSITIES AND PRODUCTION RATES[a]

Date (1991)	ρ (km)	C_2	C_3	CN	C_2	C_3	CN	log Q^b_{dust}
		log M(mol cm^{-2})			log $Q(s^{-1})$			
Nov 11	7606	28.370	27.573	28.281	24.931	23.453	24.614	13.373
Dec 4	8778	28.042	27.139	28.345	24.505	22.921	24.586	12.134
Dec 4	16758	28.164	27.347	28.675	24.154	22.763	24.442	12.034

[a] The column labels have the usual meaning
[b] In arbitrary units.

lillis et al. 1982); g(CN) = −12.536 on November ! and g(CN) = −12.467 on December 4 (Tatum & illespie 1977). The derived $M(\rho)$ values are given Table 4.

The molecule number, M, can be compared th theoretical calculations using the Haser mod- (Haser 1957; O'Dell & Osterbrock 1962) to es- nate the molecule production rates Q of the metary nuclei. Although several criticisms have :en put forward about the non-physical nature this model (see for example Festou 1981), is widely used, computationally quite simple, id provides a reasonably good approximation of e column density distribution of the cometary mae (at least if no short term fluctuations are esented) that offers excellent empirical fits to e gas distribution in comets (Millis, A'Hearn, & hompson 1982; A'Hearn, Millis, & Thompson)83). The production rate Q is determined from e following equation given by A'Hearn & Cowan 975)

$$M(\rho) = Qv^{-1}\rho\mu(\mu-1)^{-1}\left[\int_x^{\mu x} K_0(y)dy + \right.$$
$$\left. + 1/x(1-1/\mu) + K_1(\mu x) - K_1(x)\right] \quad , \qquad (2)$$

here μ = ratio between daughter and parent olecule scale length, v = velocity of the released ecies; x = ratio between ρ and daughter molecule ale length; K_0 and K_1 are the modified Bessel inctions of the second kind of order 0 and 1. We sume $v = 0.58\sqrt{r}$ (Delsemme 1982; Cochran 985, 1987), the parent and daughter scale length e taken from Cochran (1985).

The production rates in s^{-1} are given in Table 4.

From the dust continuum filter fluxes F_{dust} one in estimate the relative production rate Q_{dust} of ie dust component in the comae of comets as

$$Q_{dust} = const\ Lr^2/\rho \quad , \qquad (3)$$

here L is the luminosity of the comet (calculated : λ = 4845 A) and, as usual, we put the $const$ = 1. This equation implies that the dust outflow is spherically symmetric leading to a spatial dust density distribution proportional to ρ^{-2}. Radiation pressure effects on the dust distribution in the coma are neglected in this model.

4. CONSIDERATION ABOUT THE CONTINUUM

In Figure 1 the flux density ratios between the comet and the solar analog versus wavelength is presented. The solid line is a linear least-squares fit through the three continuum filters. It becomes immediately obvious that the light reflected in the grains is redder than the solar flux, but we cannot decide whether the difference is due to scattering geometry or to the particle size and/or composition.

5. DISCUSSION

Cochran (1987, 1990a) has published an analysis of abundance correlation among comets, showing that there is a strong correlation of the production rates of C_2 and C_3 with CN. We apply the same correction to our observations to obtain production

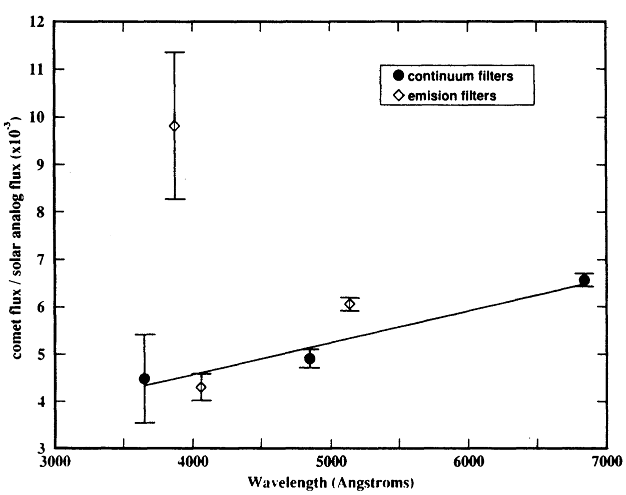

Fig. 1. Ratio between the comet flux and solar analog flux for the IHW filters. The line is a least squares solution for the three continuum values.

rates at 1 AU using a r^{-2} law and the estimated production rates of CN, C_2 and C_3 in comet P/Faye closely match Cochran's results. The ratios $Q(C_2)/Q(CN) = 0.96$ and $Q(C_3)/Q(CN) = 0.03$ are in good agreement with the ratios published by Cochran. We therefore conclude that P/Faye is a "normal" object concerning its gas emission.

As the sublimation of all the species of the nucleus is controlled by water sublimation due to the structure of the ices being a hydrate-clathrate (Delsemme & Miller 1970) then there ought to be a correlation between the production of the minor, more volatile species (CN, C_2, and C_3) and the production of the H_2O vapor. Cochran (1987, 1990a) showed that there is a strong correlation between the production rates of C_2 and C_3 and the production rate of CN, and Cochran (1990b) showed the existence of a correlation between production rates of CN and $O(^1D)$, so from the CN production rate, the water production rate could be derived. From Cochran's relation (shown graphically) we obtain $\log Q[O(^1D)] = 26.6$ and 26.5 for the diaphragms of 33 and 63 arcseconds respectively. The values obtained using another relation due to Newburn & Spinrad (1989) give us a slightly smaller value: $\log Q[O(^1D)] = 26.3$ and 26.1, respectively.

The water production rate was obtained using the relation $H_2O/O(^1D) = 12.5$ (Newburn & Spinrad 1985), that gives $\log Q(H_2O) = 27.7$ and 27.6 using the values obtained with the Cochran's relation, and $\log Q(H_2O) = 27.4$ and 27.2 using the other one.

We can compute the radius and fraction of nuclear active surface for the comet using the water production rates obtained and a model proposed by Delsemme & Rud (1973) corrected by a factor that takes into account the fraction of the absorbed solar energy which goes into thermal re-radiation and heat conduction, and considering that only a fraction f of the nuclear surface is active (Fernández 1992). With a nuclear apparent magnitude of 20.5 obtained by Gibson (1983) when the comet was at 3.17 AU from the Sun, and an absolute visual magnitude of 14.7 (Fernández, Rickman, & Kamél 1992) we obtain for a geometric albedo $\leq$ 0.05, a radius $r = 4.7 \pm 1.1$ km and a fraction of active nuclear surface $f = 0.03 \pm 0.02$. Also we consider the possibility of coma contamination of the observed nuclear magnitude, but using a value of 21.5 instead of 20.5 we obtain similar results.

The authors express their gratitude to M. A'Hea for providing the IHW filters and reduction meth od, to J. A. Fernández for his comments, and t the personnel of the Félix Aguilar Observator The second author has a partial support from th PEDECIBA and CONICYT.

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