NARROWBAND ELECTROPHOTOMETRY OF COMET HALE–BOPP (C/1995 O1) NEAR PERIHELION

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(Received 4 February 1998; Accepted 26 October 1998)

Abstract. We present the results of narrowband photoelectric observations of comet Hale–Bopp near perihelion, which were made with the AZT-14 telescope at the station Lisniki of Kyiv University Astronomical Observatory. The standard set of IHW cometary filters was used. The total number of cometary observations was more than 500 during the interval March 13–April 29, 1997. The comet's nuclear gas production rates Q of C_2 and C_3 were calculated using the stellar calibration for these filters. The calculations used the Haser model for a neutral cometary atmosphere. The value $Af\rho$, which is characteristic of the dust production rate, was determined too. Mean values of the production rates near perihelion are log $Q(C_2) = 28.4$; log $Q(C_3) = 27.2$; $(Af\rho)_{BC} = 6.0$.

Keywords: Comet, narrowband electrophotometry

1. Introduction

One of the most informative methods of comet exploration is photoelectric observation with narrow band filters. Valuable information about absolute fluxes in emission bands and the continuum, gas and dust sublimation rates and their variations as a result of changes in heliocentric distances, nuclear rotation and comet activity, comparative chemical composition, outbursts of brightness, periods of rotation of nuclei and space orientation of rotation axes etc., was obtained at different observatories, as early as 1976 for more than 85 comets (A'Hearn et al., 1995). The Astronomical Observatory of Kyiv University (AO KU) obtained a set of narrow band interference filters from one of the coordinators of the International Halley Watch (IHW) photometric net (A'Hearn and Vanýsek, 1985, 1986) and joined the international cooperative work on creating the observational base of narrow band photoelectric photometry of comets. During 1982–1995 the collaborators of the AO KU participated in narrowband and UBVR photometric and polarimetric observations of 9 comets: Austin (C/1982 M1), Churyumov-Gerasimenko (67P), Halley (1P), Hartley-Good (C/1985 R1), Giacobini-Zinner (21P), Thiele (C/1985 T1), Brorsen-Metcalf (23P), Levy (C/1990 K1) and Hale–Bopp (C/1995 O1) (Churyumov et al., 1990; Churyumov and Rozenbush, 1991). The narrowband photometric and polarimetric data for comets Halley and Giacobini-Zinner were sent to the IHW and are recorded on optical disks in the International Archives of these comets (A'Hearn, 1991) (these two comets were the first to be explored with space probes).

Earth, Moon and Planets **78:** 155–160, 1997.

2. Observations and Processing

Electrophotometric observations of comet Hale–Bopp (C/1995 O1) were made by the authors at the Lisniki observing station of the AO KU with the electrophotometer installed on the AZT-14 reflector, which has a 50-cm diameter of the mirror. During observations the standard narrowband interference filters of the IHW, ecxept the CN-filter (its bandpass shifted noticeably for the last 12 years) were used.

Altogether more than 500 measurements of comet Hale–Bopp were obtained for the period March 13–April 27, 1997. The comet's nuclear gas production rates Q of C_2 and C_3 were calculated on the basis of the stellar calibration of these filters. The calculations utilized the Haser model for neutral cometary atmosphere (Haser, 1957). The value $Af\rho$, which is characteristic of the dust nuclear production rate (A'Hearn et al., 1984), was determined too. In Figure 1 it is seen that comet Hale–Bopp reached maximum of gas (C_2 and C_3 molecules) and dust $(Af\rho)_{BC}$ production close to perihelion. Mean values of the production rates near perihelion are $\log Q(C_2) = 28.4$; $\log Q(C_3) = 27.2$; $(Af\rho)_{BC} = 6.0$.

The Table contains a subset of the data and processed results for comet Hale–Bopp (C/1995 O1) obtained April 1, 1997, when the comet was at perihelion: date and time of observations in UT (column 1–2), narrow band filter (3), magnitudes in the given filter (4) and their errors (5), the radius of the photometer diaphragms r in arcsec (6), the logarithms of the numbers of fluorescing molecules in the column along the line of sight (7) , logarithms of the gas production in emission filters with errors and values of the logarithm of $Af\rho$ for filters in regions of cometary continuum with errors (8). Mean values of the production rates near perihelion are $\log Q(C_2) = 28.4$; $\log Q(C_3) = 27.2$; $\log(Af\rho)_{BC} = 6.0$. These values are close to those obtained by other observers, i.e., Farnham et al. (1997). Differences between $Af\rho$ values for the BC and RC filters show that the cometary continuum is redder than the sun and increases with time according to the law $\log((Af\rho)_{BC}/(Af\rho)_{RC}) = -0.00066 \cdot \Delta t - 0.061$, where Δt = time (in days) from perihelion. This dependence is evidence for the presence of dust in the near nuclear region of the comet that is reder than the Sun. It is possible to describe the similar difference for UC and BC filters as $\log((Af\rho)_{UC}/(Af\rho)) = 0.0045 \cdot \Delta t - 0.0055$.

The dependence in question indicates that near the nucleus cometary dust bluer than the Sun, is also seen. The maximum near perihelion in $\log(Af\rho)$ that is clear in Figure 1 is absent from the curves showing the variation of color. The variation of phase angle ϕ of the comet cannot explain the observed dependences because in the beginning of the observations on 13.03.97 $\phi = 47.2^o$, the maximum of $\phi = 49.1^o$ was on 23.03.97 and in the end of observations on 30.04.97 $\phi = 30.8^o$.

In both cases the sum of mean-square errors is approximately 1.5 times smaller for the temporal law than for a linear dependence with phase. Probably, the observed dependence is explained by changing color characteristics and sizes of the dust particles in the shells constantly being formed in the nuclear region of

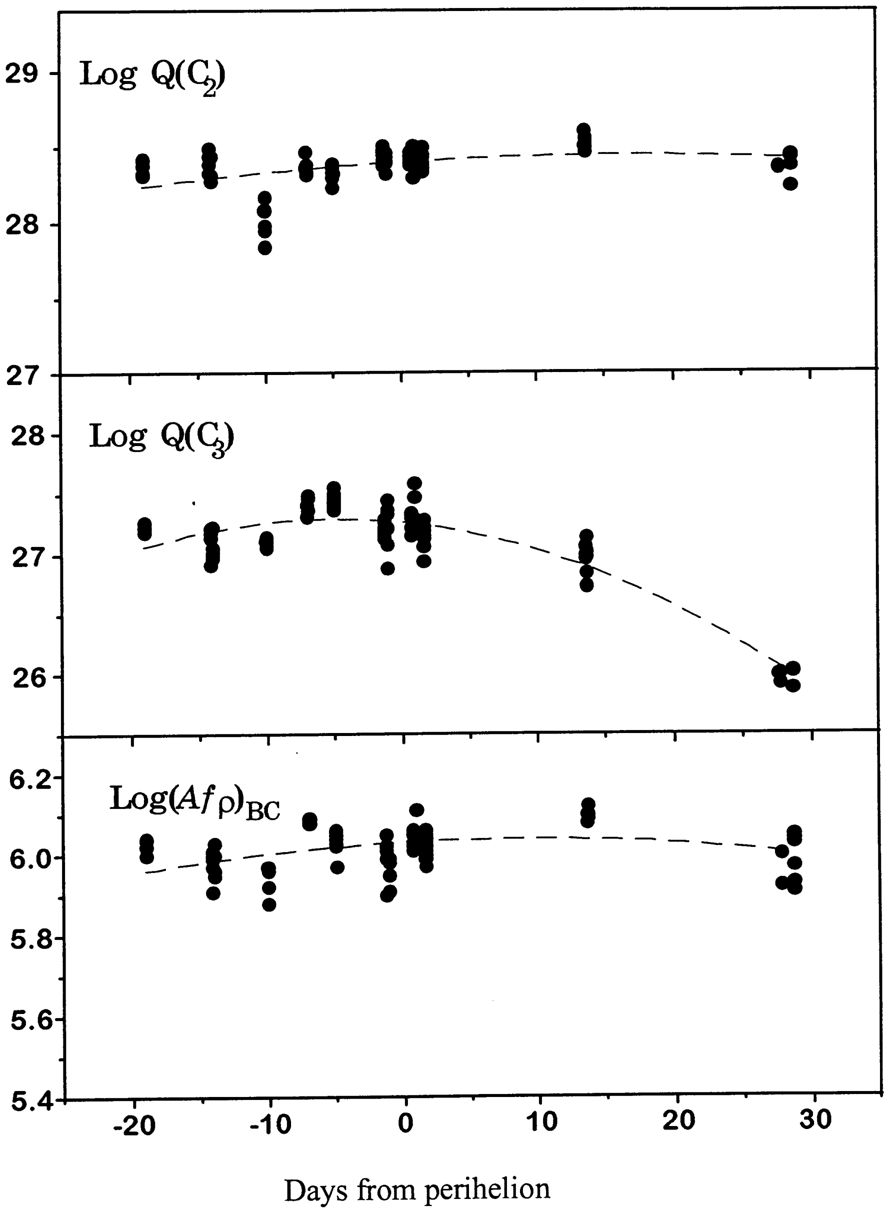

Figure 1. Gas and dust production of comet Hale–Bopp near perihelion.

TABLE I

Results of narrowband photometry of comet Hale–Bopp

Date 1997	Filter	m	Δm	ρ arcsec	log N	log Q mol·sec^{-1}
3 31.070	UC	3.73	0.04	39.2		$5.93^{+0.02}_{-0.02}$
3 31.070	C3	3.10	0.01	39.2	31.94	$27.33^{+0.06}_{-0.08}$
3 31.070	BC	2.46	0.03	39.2		$5.99^{+0.01}_{-0.01}$
3 31.071	C2	1.92	0.02	39.2	32.62	$28.40^{+0.04}_{-0.04}$
3 31.071	RC	1.32	0.02	39.2		$6.07^{+0.01}_{-0.01}$
3 31.071	H_2O^+	1.24	0.01	39.2	30.69	
3 31.073	UC	3.87	0.03	39.2		$5.87^{+0.01}_{-0.01}$
3 31.074	C3	3.08	0.01	39.2	32.06	$27.45^{+0.04}_{-0.04}$
3 31.074	BC	2.46	0.03	39.2		$5.99^{+0.01}_{-0.01}$
3 31.074	C2	1.87	0.02	39.2	32.67	$28.46^{+0.04}_{-0.04}$
3 31.074	RC	1.33	0.01	39.2		$6.07^{+0.00}_{-0.00}$
3 31.074	H_2O^+	1.24	0.01	39.2	30.81	
3 31.085	UC	3.91	0.04	39.2		$5.86^{+0.02}_{-0.02}$
3 31.085	C3	3.22	0.01	39.2	31.97	$27.36^{+0.05}_{-0.06}$
3 31.085	BC	2.66	0.03	39.2		$5.91^{+0.01}_{-0.01}$
3 31.085	C2	2.03	0.02	39.2	32.64	$28.43^{+0.04}_{-0.04}$
3 31.085	RC	1.52	0.01	39.2		$5.99^{+0.01}_{-0.01}$
3 31.086	H_2O^+	1.44	0.02	39.2	30.56	
3 31.089	UC	3.72	0.04	39.2		$5.93^{+0.01}_{-0.01}$
3 31.090	C3	3.24	0.02	39.2	31.69	$27.08^{+0.12}_{-0.17}$
3 31.090	BC	2.57	0.03	39.2		$5.95^{+0.01}_{-0.01}$
3 31.090	C2	2.08	0.01	39.2	32.53	$28.32^{+0.03}_{-0.04}$
3 31.090	RC	1.51	0.02	39.2		$6.00^{+0.01}_{-0.01}$
3 31.090	H_2O^+	1.48	0.01	39.2	30.17	
3 31.099	UC	3.74	0.03	39.2		$5.92^{+0.01}_{-0.01}$
3 31.099	C3	3.17	0.02	39.2	31.82	$27.21^{+0.08}_{-0.11}$
3 31.099	BC	2.48	0.03	39.2		$5.98^{+0.01}_{-0.01}$
3 31.099	C2	1.95	0.02	39.2	32.62	$28.41^{+0.04}_{-0.04}$
3 31.100	RC	1.41	0.01	39.2		$6.04^{+0.01}_{-0.01}$
3 31.100	H_2O^+	1.35	0.02	39.2	30.36	
3 31.101	UC	4.53	0.05	26.6		$5.78^{+0.02}_{-0.02}$
3 31.102	C3	4.14	0.01	26.6	31.35	$26.88^{+0.09}_{-0.11}$
3 31.102	BC	3.68	0.02	26.6		$5.67^{+0.01}_{-0.01}$
3 31.102	C2	3.13	0.02	26.6	32.09	$28.05^{+0.05}_{-0.05}$
3 31.103	RC	2.69	0.01	26.6		$5.69^{+0.00}_{-0.00}$
3 31.103	H_2O^+	2.65	0.01	26.6	29.14	

TABLE I
(continued)

Date 1997	Filter	m	Δm	ρ arcsec	log N	log Q mol·sec^{-1}
4 01.751	H_2O^+	1.24	0.02	39.2	30.74	
4 01.753	UC	3.62	0.03	39.2		$5.98^{+0.01}_{-0.01}$
4 01.753	C3	3.04	0.02	39.2	31.91	$27.30^{+0.08}_{-0.10}$
4 01.753	BC	2.39	0.04	39.2		$6.02^{+0.02}_{-0.02}$
4 01.754	C2	1.86	0.01	39.2	32.65	$28.43^{+0.04}_{-0.05}$
4 01.754	RC	1.32	0.03	39.2		$6.08^{+0.01}_{-0.01}$
4 01.754	H_2O^+	1.24	0.02	39.2	30.76	
4 01.756	UC	3.93	0.02	26.6		$6.02^{+0.01}_{-0.01}$
4 01.757	C3	3.44	0.02	26.6	31.62	$27.15^{+0.11}_{-0.14}$
4 01.757	BC	2.75	0.04	26.6		$6.05^{+0.02}_{-0.02}$
4 01.757	C2	2.27	0.02	26.6	32.44	$28.40^{+0.05}_{-0.06}$
4 01.757	RC	1.68	0.03	26.6		$6.10^{+0.01}_{-0.01}$
4 01.757	H_2O^+	1.63	0.02	26.6	30.04	
4 01.771	UC	3.48	0.03	39.2		$6.03^{+0.01}_{-0.01}$
4 01.772	C3	2.96	0.02	39.2	31.93	$27.32^{+0.08}_{-0.10}$
4 01.772	BC	2.29	0.04	39.2		$6.06^{+0.02}_{-0.02}$
4 01.772	C2	1.80	0.02	39.2	32.66	$28.44^{+0.05}_{-0.06}$
4 01.772	RC	1.23	0.03	39.2		$6.12^{+0.01}_{-0.01}$
4 01.772	H_2O^+	1.15	0.02	39.2	30.78	
4 01.784	UC	3.50	0.03	39.2		$6.03^{+0.01}_{-0.01}$
4 01.785	C3	2.98	0.02	39.2	31.83	$27.22^{+0.11}_{-0.15}$
4 01.785	BC	2.37	0.04	39.2		$6.03^{+0.02}_{-0.02}$
4 01.785	C2	1.81	0.02	39.2	32.69	$28.47^{+0.04}_{-0.05}$
4 01.785	RC	1.23	0.03	39.2		$6.12^{+0.01}_{-0.01}$
4 01.785	H_2O^+	1.14	0.02	39.2	30.83	
4 01.811	UC	3.53	0.03	39.2		$6.01^{+0.01}_{-0.01}$
4 01.812	C3	3.02	0.02	39.2	31.84	$27.22^{+0.10}_{-0.13}$
4 01.812	BC	2.41	0.04	39.2		$6.01^{+0.02}_{-0.02}$
4 01.812	C2	1.88	0.02	39.2	32.63	$28.41^{+0.05}_{-0.06}$
4 01.812	RC	1.23	0.03	39.2		$6.11^{+0.01}_{-0.01}$
4 01.812	H_2O^+	1.12	0.02	39.2	30.98	

the comet. In the shells simultaneously occur both large dark particles, redder than the Sun, and small particles, bluer than the Sun, and this, probably, is seen in the dependences in question.

3. Conclusion

(1) Altogether more than 500 narrowband photoelectric observations of comet Hale–Bopp were obtained at the Lisniki observing station of the AO KU for the period March 13–April 27, 1997.
(2) Mean values of the gas and dust production rates near perihelion are $\log Q(C_2) = 28.4$; $\log Q(C_3) = 27.2$; $(Af\rho)_{BC} = 6.0$.
(3) Comet Hale–Bopp reached its maximum of gas (C_2 and C_3 molecules) and dust $(Af\rho)_{BC}$ production close to perihelion.

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