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THE CCD PHOTOMETRIC OBSERVATIONS OF COMET C/1995 O1 (HALE-BOPP)

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I. INTRODUCTION

Long-periodic comet C/1995 O1 (Hale-Bopp) (hereafter comet Hale-Bopp) was discovered by Alan Hale and Thomas Bopp on July 23, 1995 (Hale, Stevens and Bopp, 1995). The initial reports and subsequent orbital detemination show:

(1) The visual magnitude of comet Hale-Bopp $\approx$ 10.6 while it placed at a heliocentric distance of $R_h \approx 7.1$ AU. It is predicted that it will reach perihelion on early 1997 at a distance of 0.91 AU when it may reach a visual magnitude of -1 to -2 (Fitzsimmons A. and Cartwright I. M., 1996).

(2) Astronomers have been wondering if the large amount of coma activity (and corresponding total brightness) might mean a larger nucleus than usual comet nuclei for this comet, but recent calculations suggest that the current activity does not require a nucleu larger than 10 $\sim$ 15 km in size (Sekanina, 1995).

In this paper, the results of CCD photometric observations of the comet Hale-Bopp are presented, and the estimations of the mass and size of cometary nucleus are derived.

II. OBSERVATION AND REDUCTION

The CCD imaging observation of comet Hale-Bopp was carried out at Sheshan Station of Shanghai Observatory of China on March 11, April 22 and May 22, 1996. We monitored comet Hale-Bopp by use of the 1.56m telescope with series 200 CCD camera system at Sheshan Station. The focal ratio of 1.56m telescope is 1:10, the viewing field of CCD camera is $4'16'' \times 4'16''$, the image size is 1024 $\times$ 1024, 1pixel=$0.''25$. The observation data are given in Table 1.

The data reduction was made by an image processing software, IRAF. The bias substraction, flat field correction and dark correction were applied with relevant data corresponding to observation date, respectively.

III. THE APERTURE PHOTOMETRY

We carried out aperture photometry of cometary nucleus and obtained the instrument magnitude (afterhere mag.) in I, V, R bands for different date. For analysis and study, we processed in detail the images of May 22, 1996. We derived the V-mag. and R-mag., by different apertures, m(3), m(5), m(7.5), m(10), m(20) and m(30), where the number in the parentheses indicates the radius of the applied aperture in the unit of pixel. As indicated above, 1pixel =$0.''25$, obviously, m(3), m(5), m(7.5), m(10), m(20) and m(30) should be equivalent to the magnitude with aperture of diameter $1.''5$, $2.''5$, $3.''75$, $5.''0$, $10.''0$ and $15.''0$, respectively. The results of aperture photometry on May 22, 1996 are presented in Table 2.

IV. ESTIMATION OF MASS AND SIZE OF NUCLEUS

Let a_1, a_2 be the radius of the applied aperture in the unit of pixel, $m(a_1)$ and $m(a_2)$ be R-mag (or V-mag.). corresponding to two different apertures a_1 and a_2, where a_1, a_2 indicate any one of 3, 5, 7.5, 10, 20 and 30.

Jewitt (1990) suggests that the each magnitude contains scattering light from the nucleus. Therefore the R-mag (or V-mag.). within an annular region can be given by

$$m(a_1 - a_2) = m(a_1) - 2.5\log(10^{0.4\Delta m} - 1).$$

where $\Delta m = m(a_1) - m(a_2)$.

The magnitude $m(a_1 - a_2)$ can be regarded as being the light scattered from only the pure dust coma, of which the geometrical cross section C is estimated to be

$$C = 2.25 \times 10^{22}\pi\Delta^2 r^2 10^{0.4(m_s - m(a_1-a_2))}/(\Psi(\alpha)P_r).$$

Where m_s is the absolute R-magnitude of the Sun ($m_s = -27.26$), Δ is the heliocenter distance, r is the geocenter distance, P_r is the albedo of the dust particles, usually $P_r = 0.04$, and phase function $\Psi(\alpha)$ is taken to be unit (Jewitt and Luu, 1989).

This cross secttion is related to the total mass of ice and dust particles, M, as

$$M = \psi\rho C.$$

where ψ is conversion factor, which depends on the size distribution of dust particles (see Jewitt and Luu, 1989). In this paper, we employ different values of ψ for comparison, $\psi = 2.9 \times 10^{-6}, 1.0 \times 10^{-6}, 0.4 \times 10^{-6}$.

We assume that the nucleus is a sphere. So, the approximate radius of nucleus, $R = (3M/4\pi\rho)^{1/3}$, can be easiely derived as long as the mass M can be obtained. Combining eq.(3) and eq.(2) and taking $\rho = 1000kgm^{-3}$, $P_r = 0.04$, we can calculate the lower limits of the mass and radius of comet Hale-Bopp for different values of a_1, a_2 and ψ. The results are listed partly in Table 3.

Table 1. The Observation Data

Observation date (1996, UT)	Number of Obs.	Filter	α (2000.0) (h:m:s)	δ (2000.0) ($^{\circ}$:$'$:$''$)	r (AU)	Δ (AU)
Mar. 10 21:07:33 -Mar. 10 21:32:45	3	I	19:35:00	-21:01:40	4.945	5.267
Apr. 21 19:34:05 -Apr. 21 20:22:50	11	None	19:45:32	-18:04:29	4.211	4.710
May 21 18:30:39 -May 21 18:44:46	3	None	19:35:54	-15:38:28	3.657	4.384
May 21 19:40:37 -May 21 19:54:57	3	V				
May 21 20:03:56 -May 21 20:22:34	3	R				

Table 2. The Results of Aperture Photometry on 1996 May 22

Beginning of Exp. 1996 May 21 (UT)	Exp. (sec.)	Filter	m(3) (mag.)	m(5) (mag.)	m(7.5) (mag.)	m(10) (mag.)	m(20) (mag.)	m(30) (mag.)
19:40:37	300	V	24.702	23.715	23.061	22.684	22.002	21.737
19:47:08	300		24.472	23.569	22.993	22.653	21.995	21.735
19:54:57	400		24.958	23.909	23.198	22.772	21.951	21.568
20:03:56	300	R	22.457	21.487	20.825	20.428	19.681	19.365
20:10:07	300		22.392	21.412	20.744	20.346	19.605	19.287
20:16:07	300		22.387	21.387	20.711	20.288	19.519	19.217

Table 3. The Estimative Values of Mass and Radius on 1996 May 22

$m(a_1 - a_2)$	$\psi = 2.9 \times 10^{-6}$		$\psi = 1.0 \times 10^{-6}$		$\psi = 0.4\times$	10^{-6}
V-band	M($\times 10^{13}$)(kg)	R(km)	M($\times 10^{13}$)(kg)	R(km)	M($\times 10^{13}$)(kg)	R(km)
m(3-5)	2.224247	4533.399	0.997076	3469.544	0.306793	2342.312
m(3-7.5)	2.183535	4505.569	0.978826	3448.245	0.301177	2327.932
m(3-10)	2.165326	4491.765	0.969856	3437.680	0.298417	2320.800
m(3-20)	2.130219	4468.595	0.954926	3419.948	0.293823	2308.828
m(3-30)	2.117869	4459.943	0.949390	3413.326	0.292120	2304.358
R-band	M($\times 10^{13}$)(kg)	R(km)	M($\times 10^{13}$)(kg)	R(km)	M($\times 10^{13}$)(kg)	R(km)
m(3-5)	2.128588	4467.455	0.954195	3419.075	0.293598	2308.239
m(3-7.5)	2.087139	4438.267	0.935614	3396.737	0.287881	2293.157
m(3-10)	2.066069	4423.282	0.926169	3385.268	0.284975	2285.416
m(3-20)	2.029758	4397.215	0.909891	3365.318	0.279967	2271.948
m(3-30)	2.015135	4386.630	0.903336	3357.217	0.277950	2266.479

The above results show that:

(1) We present the mass and size of the nucleus of comet Hale-Bopp, which may be $2 \times 10^{12} \sim 3 \times 10^{13}$ kg in mass and $5 \sim 10$ km in diameter for several parameters. These results are based on the assumption: the density of nucleus $\rho = 1000 kgm^{-3}$, the albedo $P_r = 0.04$, and the shape of nucleus is spherical. The values of mass and radius are only lower limit values because of the uncertainty in the nucleus density, in the active-area fraction and in the dust and gas production rate. But, the values show that comet Hale-Bopp doesn't have an unusual large nucleus.

(2) Table 3 show that the absolute values of mass and size have not obvious difference for different apertures and wave bands. However, the mass and radius are strongly dependent on the conversion factor ψ, i.e. the particular size distrubution of dust particles.

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REFERENCES

Fitzsimmons A. and Cartwright I.M., 1996, MNRAS, 278, L37-L40

Hale A., Stevens J. and Bopp T., 1995, IAU Circ. 6187

Jewitt D., 1990, ApJ, 351, 277

Jewitt D., Luu J., 1989, AJ, 97, 1766

Sekanina Z., 1995, IAU Circ. 6234