Photometry of the Near Nucleus Dust Distribution in Comet C/1999 S4 (LINEAR)

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Abstract

The bright new comets offer an opportunity for tracing the evolution of their dust production along a large heliocentric distance intervals. We started observations of comet C/1999 S4 (LINEAR) in November, 1999 when its heliocentric distance, **r** was 3.8 AU. At this time we obtained images of the comet in 5 narrow-band spectral ranges. We derived the cometary flux in these images by synthetic aperture photometry around the nucleus. The fluxes show small reddening of the cometary dust, about 0.2 mag in the spectral range from 387 nm to 663 nm. Reddening of the dust is seen in the images obtained in February 2000 (r=2.8 AU), and in March 2000 (r=2.4 AU), also, but this effect is disturbed by increased contribution of gas emissions in some of the observed spectral intervals. We present images of the comet calibrated in terms of $\mathbf{Af}\rho$ and a map of the dust colour derived from the two clean continuum windows at 443 nm and 684 nm.

1 Instrumentation

The optical data were obtained with Focal Reducer Rozhen (*FoReRo*) attached to 2m RCC telescope of the National Astronomical Observatory, Rozhen ($\lambda = -24^\circ\!.7$, $\varphi = 41^\circ\!.7$, h= 1759 m) and six narrow-band filters (CN – 3870 Å, C_3 – 4060 Å, C_2–5125 Å, HN_2–6630 Åand two clean continuum windows at 4430 Åand 6840 Å) were used. The detector is CCD camera Photometrics CE2000, comprising 1024 px×1024 px, 24 μm. The reduced focus is 7200 mm and the field of view is $11'\!.7 \times 11'\!.7$.

2 Observations

We present observations from November 1999 to the end of July 2000. The geometrical conditions during the observations are shown in Table 1.

Table 1: Geometrical conditions during the observations

Date	Δ, AU	r, AU	Phase
1999 11 12	2.904	3.832	5.9
1999 11 13	2.888	3.821	5.7
2000 02 07	2.893	2.814	19.8
2000 02 08	2.900	2.801	19.8
2000 03 07	3.028	2.447	17.0
2000 03 08	3.030	2.435	16.8
2000 05 30	2.030	1.310	25.3
2000 07 02	0.956	0.897	66.5
2000 07 03	0.919	0.887	68.5
2000 07 24	0.376	0.766	121.7
2000 07 25	0.385	0.765	120.3
2000 07 26	0.398	0.765	118.1
2000 07 27	0.416	0.765	115.4
2000 07 28	0.437	0.766	112.2
2000 07 29	0.461	0.767	108.9

3 Data reduction

– Bias substraction using right an left overscans of the CCD camera;
– Flat fielding with master flat field made with median filtering of several flats for each filter;
– Cosmic rays removing;
– Sky substraction using Daophot sky.

Calibration to:

– Fluxes – using spectrophotometric standard star;
– Mean solar disk intensity (MSDI) – using solar spectrum from IHW CD-ROM Vol. 21 (Kurucz 1984);
– Af – Albedo, filling factor;
– Afρ – Albedo, filling factor and linear radius of the field of view of comet.

For estimating the dust production we use the quantity **Af**ρ (A'Hearn et al. 1984), where **A** is Bond albedo, **f** is filling factor of the grains in the field of view, and ρ is the radius of the aperture. **Af**ρ was calculated by aperture photometry of images calibrated to fluxes using the following equation:

$$Af\rho = \frac{F_{com}}{F_{\odot}} \rho \left(\frac{2\Delta r}{\rho} \right)^2 ,$$

where $\mathbf{F}_{com}$ is the cometary flux in the aperture with radius ρ, $\mathbf{F}_{\odot}$ – the mean solar flux at 1 AU, ρ – radius of aperture, Δ – geocentric distance and **r** – heliocentric distance.

4 Results

Fig. 1 shows the change of **Af**ρ with heliocentric distance. Triangles are the values at 443 nm and squares at 684 nm. Asterisks denote **Af**ρ – measurements reported by D. Schleicher, C. Eberhardy and L. Woodney (IAUC, 1999, 2000, 2000db) The overplotted lines have a slope of -2. A remarkable deviation from the $\mathbf{r}^{-2}$ law is seen at smaller heliocentric distances which is most probably caused by the disintegration of the comet close to its perihelion on July 26, 2000. Table 2 contains the calculated **Af**ρ values.

Figure 1: Evolution of Afρ with r

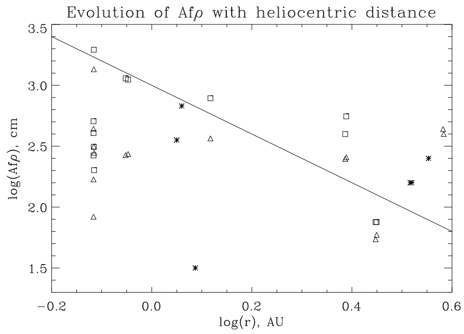

Table 2: Evolution of Afρ with r

Date	r, AU	Afρ, cm	
		IF4430	IF6840
1999 11 12	3.832	398.55	
1999 11 13	3.821	436.57	
2000 02 07	2.814	59.20	75.34
2000 02 08	2.801	54.38	75.34
2000 03 07	2.447	256.77	555.76
2000 03 08	2.435	248.67	397.42
2000 05 30	1.310	366.46	783.18
2000 07 02	0.897	272.55	1114.41
2000 07 03	0.887	267.43	1139.99
2000 07 24	0.766	1353.67	1959.57
2000 07 25	0.765	439.85	405.34
2000 07 26	0.765	83.46	506.98
2000 07 27	0.765	168.94	265.55
2000 07 28	0.766	314.98	312.30
2000 07 29	0.767	279.29	201.07

For larger heliocentric distance **Af**ρ was calculated for other spectral regions, too. The results shown in Fig. 2 suggest that there were no significant gas emissions at this time. The corresponding **Af**ρ values are present in Table 3.

A color map of the dust on July 24, 2000 is shown in Fig. 3.

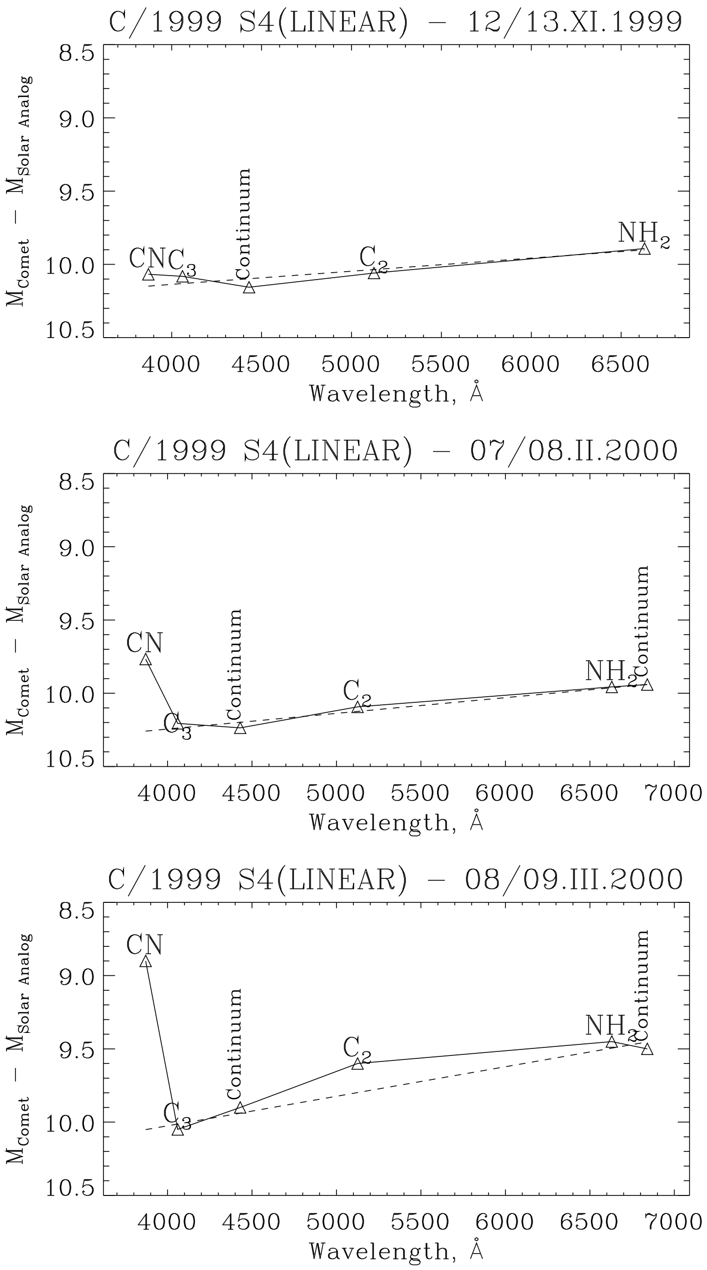

Figure 2: Comet bearing at larger heliocentric distances

The outermost contour in the left panel has a value equal to 1 which corresponds to neutral color, i.e. color of the Sun. Close to the nucleus the dust is redder, reddening decrease outwards and the color approaches unity at approximately 30.103 km tailwards. The tendency of outward decrease of the reddening

Table 3: Afρ in other spectral regions

Date	r, AU	Afρ, cm			
		IF3870	IF4060	IF5120	IF6630
1999 11 12	3.832	364.12	420.66	467.63	585.26
1999 11 13	3.821	391.12	501.89	510.74	615.02
2000 02 07	2.814		62.77	84.24	76.14
2000 02 08	2.801		51.33	78.05	65.16
2000 03 07	2.447		408.22		460.35
2000 03 08	2.435		221.91		381.09

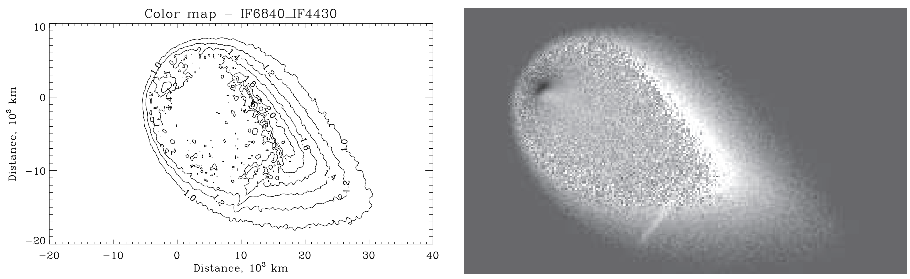

Figure 3: Color maps – 24 July 2000

is disturbed by a remarkable local increase in the upper part of the color map, the white elongated area in the right panel of Fig. 3.

Two dimensional observations allow the description of the dust distribution in terms of intensities. The corresponding quantity is $\mathbf{p}\Phi(\theta)\mathbf{f}_l\rho$ (Jockers et al. 1998).

$$p\Phi(\theta)f_l\rho = \frac{i_{com}r^2}{i_\odot R_\odot^2},$$

Where, $\mathbf{p}$ is geometric albedo, $\Phi(\theta)$ – the phase function, $\mathbf{f}_l$ – the local filling factor at a projected distance ρ from the nucleus, $\mathbf{R}_\odot$ – solar radius and $\mathbf{i}_{com}/\mathbf{i}_\odot$ – dust intensity measured in units of the MSDI. This parameter is eight times smaller than $\mathbf{Af}\rho$ (Jockers & Bonev 1997). Intensity profiles of our images are presented in Fig 4.

Conclusion

– The comet shows a dust production similar to P/Halley at comparable heliocentric distances;

– The spatial distribution of the color suggests that larger particles dominated the inner dust coma;

– Before perihelion the dust production follows approximately the r^{-2} law;

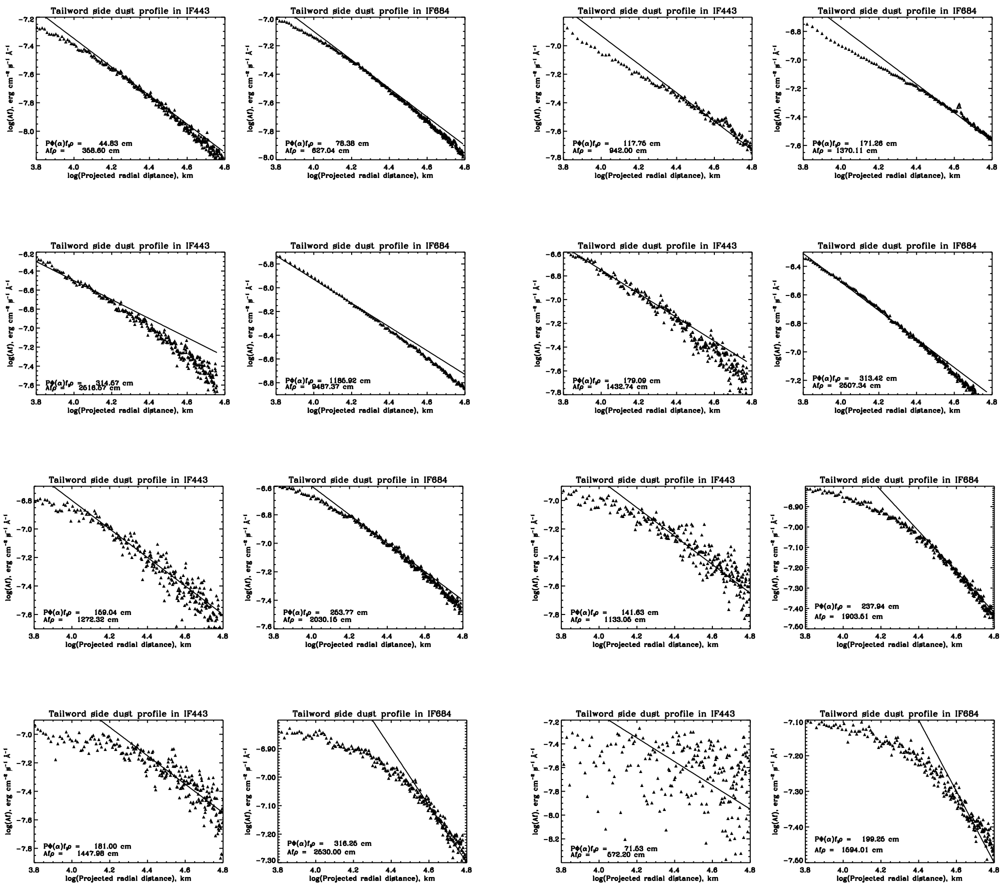

Figure 4: Intensity profiles

– After 24 - 26 July the dust production decreases rapidly, a consequence of the disintegration of the comet.

References

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