# Circular and linear polarization of comet C/2001 Q4 (NEAT). Why circular polarization in comets is predominantly left-handed?

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**Abstract**

We present the results of new polarimetric observations of comet C/2001 Q4 (NEAT). Measurements of circular and linear polarization were made with the 2.6-m Shain telescope of the Crimean Astrophysical Observatory on May 21–23, 2004. A significant correlation between variations of circular and linear polarization measured along the cuts through the coma and nucleus of the comet was found. It means that single scattering of light on aligned non-spherical dust particles can produce circular as well as linear polarization. We call particular attention to the fact that the measured circular polarization in four comets, 1P/Halley, C/1995 O1 (Hale–Bopp), D/1999 S4 (LINEAR) and C/2001 Q4 (NEAT), was predominately left-handed. This question is discussed in the frame of light scattering by optically active organic particles.

## 1 Introduction

Circular polarization is sensitive to the shape, structure, and composition of the scatterers and thus may provide further proof of a complex structure of cometary grains and put constraints on their shape and composition. However, the measurements of circular polarization in comets are still rare. Attempts to detect circular polarization in comets C/1969 T1 (Tago–Sato–Kosaka), C/1973 E1 (Kohoutek), C/1974 C1 (Bradfield), and C/1975 VI (West) were unsuccessful [1,2]. Notably nonzero circular polarization was measured only for comets 1P/Halley [3], C/1995 O1 (Hale–Bopp) [4,5], and D/1999 S4 (LINEAR) [6]. Therefore it is still unclear if circular polarization is an inherent feature of all comets. In this connection any new attempt to detect of circular polarization in comets is critically important.

## 2 Observations and data reduction

Measurements of circular polarization in comet C/2001 Q4 (NEAT) (hereafter Q4 (NEAT)) were made with a one-channel photoelectric photometer-polarimeter mounted at the 2.6-m Shain telescope of the Crimean Astrophysical Observatory. The photopolarimeter works on the same principle as was described by Shakhovskoj et al. [7]. However, instead of four counters we used eight ones for registration of impulses. It allowed us to measure simultaneously both circular and linear polarization of the comet.

The comet was observed during three nights on May 21–23, 2004. The wide-band R filter and 10 arcsec diaphragm (4350 km at the comet) were used. The phase angle, the heliocentric and geocentric distances of the comet were $\alpha \approx 76°$, $r \approx 0.97$ AU, and $\Delta \approx 0.60$ AU respectively. The comet had the straight gas tail orientated at position angle $PA$=100.5° and the dust jet located approximately orthogonally to the gas tail. This comet was very active. The measurements of the total intensity and parameters determining the circular and linear polarization of the scattered light were made along cuts over the coma. The diaphragm was placed on the northern side of the coma in such a way that each cut passed through the nucleus. The cuts over the coma were determined by proper motion of the comet at position angle $PA = 189.4°$ and passed along the dust jet. The single exposure time was 4 s and each cut consisted of 64 measured points that corresponds to approximately 9000 km at the distance of the comet. To improve the signal-to-noise ratio, we obtained from 15 to 20 cuts during a given observational night which were subsequently summarized. The results in the form of distributions of total intensity *I*, degree of circular $P_c$ and linear $P_l$ polarization, and position angle of the polarization plane $\theta_r$ relative to the scattering plane are presented in Fig. 1. Each data point is result of averaging over the area 2000×4350 km along the cuts.

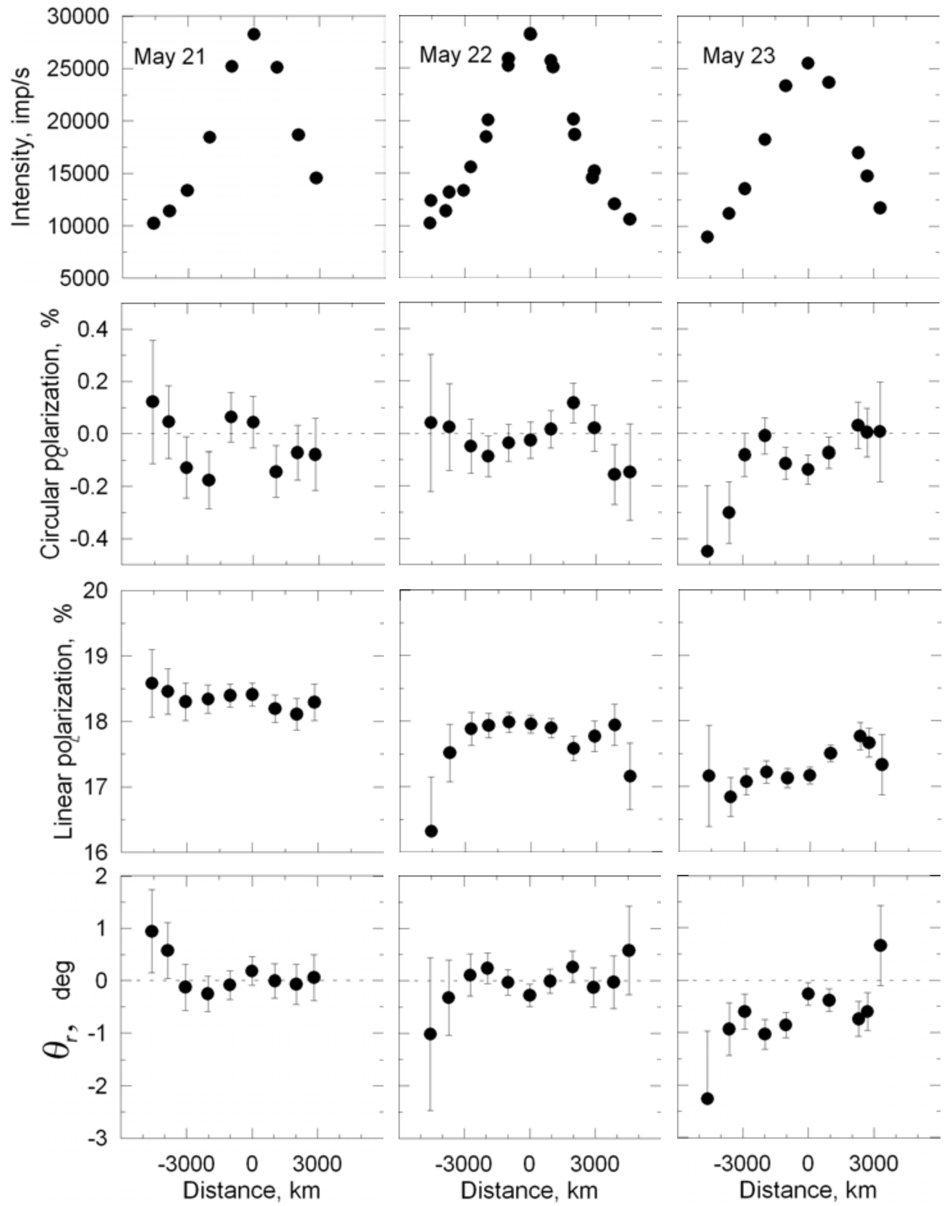


Figure 1: Distribution of intensity I, degree of circular and linear polarization and position angle of the polarization plane relative to the scattering plane $\theta_r$ along the cuts in coma of comet Q4 (NEAT).

## 3 Results and discussion

As Fig. 1 shows, the variations of circular polarization along the cuts correlate with the changes of parameters of linear polarization $P_l$ and $\theta_r$. We have found that the coefficients of correlation between $P_c$ and $P_l$ are 0.740, –0.225, and 0.618 on May 21, 22, and 23 respectively, while the coefficients of correlation between $P_c$ and $\theta_r$ for the same dates are 0.762, –0.405, and 0.705. A significant correlation between these parameters means that there is a common reason which gives rise to changes in circular and linear polarization of the comet. Such reason may be aligned non-spherical particles. It is generally believed that scattering of light on aligned non-spherical particles is most effective mechanism for producing circular polarization in comets. Thus, the same changes of the parameters of linear and circular polarization along the coma testify that there is significant component of polarization that is not related to the scattering plane and can be explained by inhomogeneity or anisotropy of dust medium in which the particles are partly aligned.

The measurements of circular polarization in comet Q4 (NEAT) as well as in three others (Halley, Hale–Bopp, and S4 (LINEAR)) show that the left circularly polarized light was mainly observed over the coma. This effect is well seen in Fig. 2.

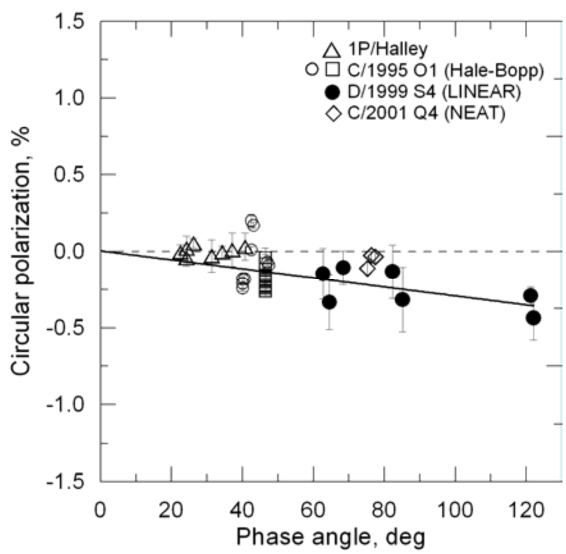


Figure 2: Composite phase-angle dependence of circular polarization for comets Q4 (NEAT), S4 (LINEAR), Hale–Bopp, and Halley. Data for comets Halley and Hale–Bopp are taken from [3, 5].

Circular polarization indicates a violation of symmetry in the medium. However, circular polarization may appear as a result of intrinsic asymmetry of the particles themselves, i.e. scattering of light by particles composed of optically active materials. Optically active substance has different refractive indexes for right- and left-circularly polarized light and therefore light of different handiness has different speed in the medium that leads to separation of left- and right-handed polarized waves and rotation of the plane of linearly-polarized light [8]. These effects are especially strong for organic molecules since they are not only optically active, but also possess circular dichroism, i.e. such substances have different absorption for left- and right-handed circular polarization [9]. It is known that complex organic molecules exist in two forms: L (left-handed) and D (right-handed). For terrestrial biomolecules, there are only L-amino acids and D-sugars. For a long time it was believed that asymmetry in the number of L and D biomolecules, i.e. homochirality, has Earth origin and relates to the birefringence of some Earth minerals. But then L-enantiometric excess was found in amino-acids from the Murchison and Murrey meteorites

[10], suggesting an origin in the pre-solar nebula. This idea was confirmed when the high degree of circular polarization was measured in star-forming regions [11]. The origin of homochirality is explained by illumination of cosmic organics by circularly polarized light in protoplanetary nebulae. In that case chiral organics should be found not only in meteorites but also in other primitive bodies, including comets. Predominantly left-handed circular polarization in comets may testify in favour of L-enantiometric excess in cometary organics.

# 4 Conclusion

We present the results of the measurements of circular and linear polarization in comet Q4 (NEAT). The correlation between the degree of circular polarization and the degree and plane of linear polarization was found. We have also revealed that all comets with a significant value of circular polarization show a common feature, namely predominantly left-handed circularly polarized light. It testifies in favor of L-enantiometric excess in cometary organics.

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