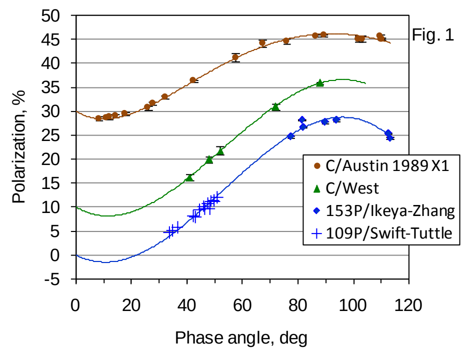
SYSTEMATIZATION OF COMET ACCORDING TO THEIR LINEAR POLARIZATION. D. I. Shestopalov, L. F. Golubeva, Shemakha Astrophysical Observatory, Shemakha AZ-3243 Azerbaijan, (shestopalov_d@mail.ru), (lara_golubeva@mail.ru).

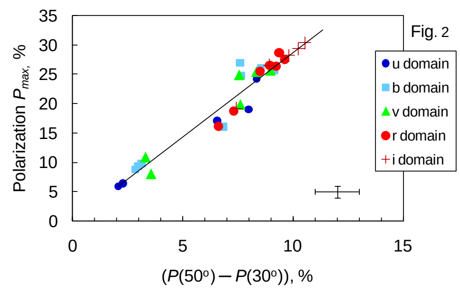
The ground-based observations of comets lead to strong discontinuity of phase-dependent polarization curves and often their termination if a comet leaves a line-of-sight range. To find the best approximation to the phase polarization dependences observed for comets, we apply a simple empiric formula that has already shown good results when operating with asteroid polarimetric curves [1, 2]. Such a procedure allows determining a value of the maximum polarization degree P_{max} (as well as other parameters of polarimetric curve) using a discrete dataset. Figures 1 represents the examples of the fitting of the phase dependences of polarization degree in the red domain (620 – 720 nm) for the high- and low-P_{max} comets. On the plot, the original data taken from the Database of Comet Polarimetry [3] and their fitting curves calculated with the formulae [1] are shifted along y-axis for clarity.



Observations of the majority of comets in [3] turned out to be successful for the phase angles not exceeding 80°. This is a main cause why we were straitened in determining the characteristics of positive polarization branch of such comets. To retrieve more information from initial data [3], we studied a relationship between a slope of almost linear segment of cometary polarimetric curves in the phase angle range from 30° to 50° and the P_{max} values in those cases, where the estimate of P_{max} was possible. A good characteristic of the slope is a difference δP between polarization degree $P(50^o)$ and $P(30^o)$ at the phase angles of 50° and 30°. These values can be easily evaluated with approximating formulae [1] and observation data [3]. Figure 2 demonstrates a close correlation between P_{max} and δP. This regularity is invariant with respect to the spectral range where observations were made, so we have a simple equation for any wavelengths from 400 to 900 nm:

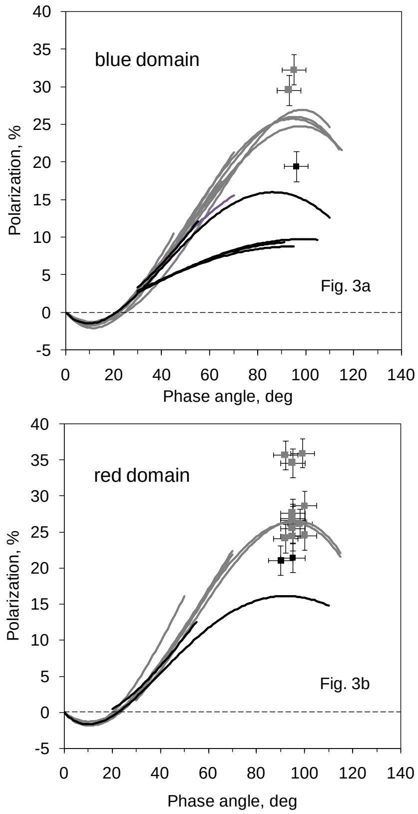
$$P^*_{max} = 2.88\ \delta P,$$

where $\delta P = P(50^o) - P(30^o)$, and correlation coefficient equals 0.95. All quantities in this equation are measured in percentage, and the error in maximum polarization degree estimation is ± 2 %. We use asterisk here to distinguish the values returned by the above equation from the more accurate ones found with approximating formulae [1]. Since the phase angle suitable to P^*_{max} remains unknown, we believe the value can be concentrated in the probable interval of the phase angles of 90° – 100°. The deviations between P^*_{max} and P_{max} lie within 2 – 3 %.



The issue permanently debated by scientific community is the classification of comets by their P_{max} value [e.g. 4, 5 and references therein]. The problem comes to the two following questions. Could observable comets be separated up between two (or more) classes by their P_{max} characteristic? If so, could the differences in the properties of cometary dust and/or the dust-to-gas ratio be responsible for such a separation? Here we study the first question using the P^*_{max} values that have been estimated with the above equation.

On the polarization – phase angle plot (see, for instance, Figs. 22.1 and 22.2 in [5]), the comets show an appreciable data spread in positive polarization, and they may be divided, by-sight at least, into two diffuse groups of comets with predominantly high and low polarization degree. We have constructed Figs. 3ab where the phase polarimetric curves for comets in the blue (425 – 485 nm) and red (620 – 710 nm) spectral domains are shown together with P^*_{max} values (squares) for those comets, whose polarimetric curves were terminated at phase angles < 80°. Examining these plots or similar Figures in other papers (e.g. [5, 6, 7]) we can only build guesses, but it is hard to come to certain conclusion. A statistically valid conclusion about comet systematization according to their polarization has not been still obtained.



We apply a modified Student's t-test to verify a hypothesis of equality of the mean values of maximum polarization degree for two comet populations assuming the unequal variances of the tested parameters [8]. This procedure was performed twice for the P^*_{max} values resulting in the red and blue spectral domains. In both cases, the value of t statistics was substantially larger than theoretical value t_q at a confidence level q equal to 0.95, and consequently the null hypothesis of equality of the means is rejected with the probability of 95%.

So, the realized statistical analysis provides an affirmative answer to the worded question, and we support the opinion [e.g. 4, 5] that there are at least two groups of comets distinguished by the positive polarization degree.

The representatives of the subgroup of comet with low positive polarization are: 109P/Swift-Tuttle, C/1969 T1 (Tago-Sato-Kosaka), C/1973 E1 (Kohoutek), C/1975 N1 (Kobayashi-Berger-Milon), C/1989 X1 (Austin). The representatives of the subgroup of comet with high positive polarization are: 1P/Halley, 153P/Ikeya-Zhang, C/1957 P1 (Mrkos), C/1975 V1 (West), C/1987 P1 (Bradfield), C/1990 K1 (Levy), C/1991 T2 (Shoemaker-Levy), C/1995 O1 (Hale-Bopp), C/1996 B2 (Hyakutake), D/1999 S4 (LINEAR), C/2000 WM1 (LINEAR).

In turn, the authors [9] are of opinion that the comet Hale–Bopp can belong to a third group of comets with extremely high positive polarization.

In the next part of the study, we present evidence that a dust-to-gas ratio contributes to a variation of the positive polarization degree of comets.

References:

[1] Shestopalov D. (2004) *JQSRT 88,* 351–356. [2] Shestopalov D.I. and Golubeva L.F. (2015) *Adv. Space Res. 56,* 2254–2274. [3] Kiselev N. et al. (2006) *NASA PDS*, Database of Comet Polarimetry V1.0. EAR-C-COMPIL-5-DB-COMET-POLARIMETRY-V1.0. [4] Mishchenko M. I. et al. (2010) *Polarimetric remote sensing of Solar System objects.* − Akademperiodyka, Kiev, 291 p. [5] Kiselev N. et al. (2015) *Polarimetry of Stars and Planetary Systems.* – Cambridge University Press, UK, 379–404. [6] Kiselev N. et al. (2005) *Earth, Moon, and Planets 97,* 365–378. [7] Zubko E. et al. (2016) *Planet. Space Sci. 123,* 63–76. [8] Devore J. L. (2015) *Probability and Statistics for Engineering and the Sciences.* 8th ed. Cengage Learning, 769 p. [9]. Levasseur-Regourd A. C. and Hadamcik E. (2003) *JQSRT 79–80*, 903–910.

Acknowledgements: The polarimetric data of comets utilized in this work were taken from database available now at NASA PDS.