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New peculiarities of cometary outburst activity

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Abstract

The results of investigations of visual light curves, brightness outburst activity and photometrical evolution of some comets are presented. The peculiarities of brightness outbursts distribution on heliocentric distance, of temporal variations of outburst activity, outbursts correlation with sudden changes of power law coefficient and outbursts relation with precision positions of comets are discussed.

The new phenomena found by authors must be taken into account when a mechanism of the cometary outburst activity is developed.

Keywords: Comet; Light curve; Outburst; CCD astrometry

1. Introduction

The cometary brightness outburst activity was studied for more than 150 years, but the physical mechanism of outbursts is not known until now. More than 10 different physical mechanisms of brightness outbursts were proposed. But none of these mechanisms can fully explain all phenomena which are observed during brightness outbursts. Therefore the investigations of peculiarities of cometary brightness outburst activity are important hitherto.

As a result of their long-term study of the photometrical behavior and outburst activity of comets, authors revealed the new observational peculiarities of brightness outbursts, which are presented in this paper.

2. Peculiarity of the outbursts distribution on heliocentric distances

The short-period comets give a unique opportunity to study the evolution of their brightness during several appearances. Authors constructed and studied the light curves of one of such comets – a comet 10P/Tempel 2 during its three different appearances: 1967, 1983 and 1988 (Fig. 1). As a result of the analysis of photometrical evolution of this comet, it has been found that its brightness outbursts were occurring at the same heliocentric distances during the several appearances of the comet (Churyumov and Filonenko, 1992a,b). Later on Kidger (1993) found a similar peculiarity of the outburst activity of comet P/Metcalf–Brewington.

Is this phenomenon typical only for these comets or for comets on the whole? To answer this question, the authors studied 180 brightness outbursts of 129 comets observed during 1847–1975. The distribution of these outbursts on heliocentric distance is shown in Fig. 2. The general appearance of this distribution reflects a well known fact (Hughes, 1975, 1990): most of the outbursts occur at 1.0–1.5 A.U. from the Sun. This is a result of observational selection. For heliocentric distances $r < 1$ A.U. the decrease in the number of outbursts is a result of the restriction of comets visibility by the dawn cone. For $r > 2.5$ A.U. the number of outbursts is decreasing as a consequence of the increase in heliocentric distance [$r = 2.5$–3.0 A.U. is an upper limit of visual visibility of comets (Vodopianova, 1935)]. On the distances $r > 3$ A.U. only the outbursts of comet P/Schwassmann–Wachmann 1 (which orbit has a small eccentricity) are observed routinely. Also only single powerful outbursts of some comets (e.g. 1P/Halley,

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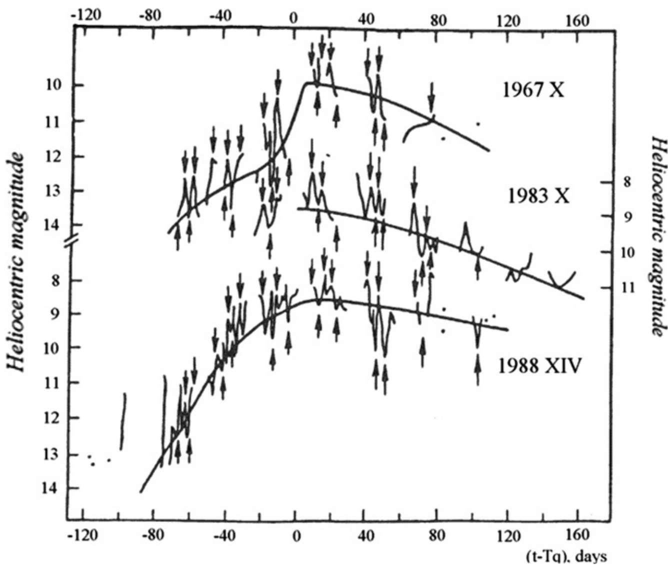

Fig. 1. Light curves of comet 10P/Tempel 2 for three different appearances. The vertical arrows indicate the light curve maxima and minima occurring at the same comet heliocentric distances.

Table 1
Heliocentric distances r_0 where brightness outbursts of most of comets have observed (under Fig. 2)

r_0 (A.U.)	α
0.275	0.30
0.375	0.40
0.525	0.35
0.650	0.55
0.775	0.13
0.925	0.008
1.025	0.015
1.175	0.07
1.325	0.25
1.625	0.27
1.825	0.21
1.925	0.28
2.025	0.03
2.125	0.24
2.400	0.02
2.625	0.015
2.875	0.001

Notes: α-probability of randomness of this outbursts maximum in Fig. 2 (calculated with χ^2-criterion).

Hale–Bopp) were observed at such large distances. Therefore only the region $r < 3$ A.U. was studied.

As it turns out (Fig. 2) the outbursts distribution displays thinner structures: narrow large maxima of the number of outbursts at certain heliocentric distances are separated by narrow minima. The three statistical criterions (Pirson's, Kolmogorov's and von Mises's) have been used for all distribution as a whole and locally for each maximum. It has been shown that the detected distribution structure is statistically significant with a probability higher than 0.97 (Churyumov and Filonenko, 1997). Thus it has been shown that brightness outbursts of comets occur with higher probability at certain heliocentric distances. The values of these distances are given in Table 1.

3. Quasi-periodicity of cometary brightness outburst activity

On the basis of visual estimations of the cometary integrated brightness, the authors constructed the light curves of 27 comets; these brightnesses were retrieved from the

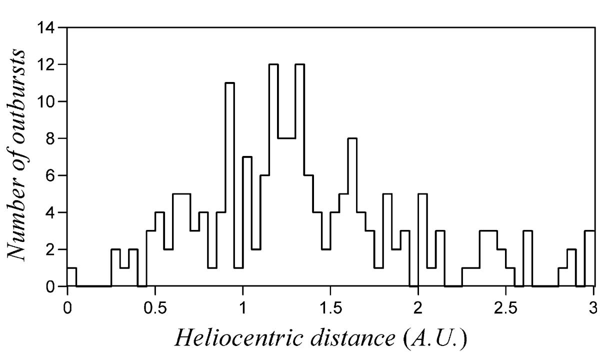

Fig. 2. Distribution of 180 brightness outbursts as a function of the heliocentric distance.

International Comet Quarterly archive, archive of Comet Section of British Astronomical Association and from other Internet sources. About 280 brightness outbursts of these comets have been revealed as a result of the study of these light curves.

A frequency of brightness outbursts was calculated for each comet

$$v = \frac{N}{\tau}, \tag{1}$$

where N is the number of observed outbursts, τ is the time of uninterrupted observations of comet. The mean value of this frequency for 27 comets is $v = 1.03 \pm 0.09$ outbursts per week.

This mean frequency corresponds to the mean period $T = 6.8^d \pm 0.6^d$ that, probably, conforms to the most steady four-sector structure of the interplanetary magnetic field (Filonenko and Churyumov, 1997). Lukianyk and Filonenko (1998) and Lukianyk (2000) analyzed our catalogue of cometary brightness outbursts, which contains the information on 389 outbursts of 75 comets observed between 1927 and 1989. It has been shown that 27% of the outbursts from this catalogue occurred on the sector boundaries of the interplanetary magnetic field. Sixty-five percent of outbursts were beginning before the comet intersected the sector boundaries. Possibly, the brightness fluctuations of comets which occurred before reaching sector boundary developed into an outburst during the comet intersection of the sector boundary. Eighteen percent of brightness outbursts occurred when comets crossed the high-speed stream of the solar wind.

Thus the detected quasi-periodicity of outburst activity is a new evidence of the correlation between brightness outbursts of comets and recurring corpuscular streams and sector structure of the interplanetary magnetic field.