Letter to the Editor

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Conditions for the formation of anomalous tail of comet

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Abstract: The time and velocity of ejection of dust particles of anomalous tails from cometary nuclei are determined. It is revealed that some comets cause the formation of an anomalous tail is the collision of their comet nucleus with other bodies of the Solar System. An investigation of the formation conditions of the anomalous tail shows that the dust ejection velocity from the comet nucleus C/1851 U1, C/1885 X2, C/1921 E1, C/1925 V1, C/1930 D1, C/1975 V2, 2P/1924, 6P/1950 and 1976, 10P/1930, 7P/1933 and 35P/1939 O1 can be explained by the sublimation of the ice of the nucleus and the removal of dust by molecules. It was found that the comets C/1823 Y1, C/1882 R1, C/1883 D1, C/1888 R1, C/1892 E1, D/1894 F1, C/1932 M1, C/1954 O1, C/1968 H1, C/1969 T1, C/1973 E1, C/1995 O1, C/1999 S4, C/2004 Q2, 7P/1869 G1, 10P/1930, 19P/1918, 26P/1927 F1, 67P/1982, 73P/1930 J1, 96P/1986 J1 and 109P/1862 O1, formation of the anomalous tail and splitting of the comet nucleus was observed in one appearance. Nuclear splitting 70% of these comets occurred as a result of a collision of the comet's nucleus with a meteoroid or fragments of their nuclei.

Keywords: Comet, Nuclei, Anomalous tail, Velocity, Ejection of dust particles, Collision

1 Introduction

The anomalous cometary tail is a relatively rare manifestation of the non-stationary activity of the cometary nucleus and, in the framework of the mechanical theory of cometary forms, is explained by the explosive ejection of a cloud of large particles towards the Sun from the cometary nucleus. As a result of the explosion of the comet's nucleus, dust particles are ejected towards the Sun. The particles are quite large (10^{-2} cm or more). The sun's radial pressure cannot produce a noticeable effect on dust particles that have formed the anomalous tail. As a result of the ejection, particles slowly move away from the comet's nucleus to the Sun, forming an anomalous tail. If the ejected particles, from the surface of the cometary nucleus, had the same initial velocity (V), then over time they would have to separate in the form of a faintly luminous cloud from the cometary nucleus. But such formations in the anomalous tails were not observed. From this we can conclude that the initial velocities of the particles during ejection are not the same, but vary from *0* to V. Then the particles with higher velocities move further from the nucleus, with lower velocities - closer to the comet's nuclei (Safarov 2018).

2 Method

According to studies of anomalous tails of comets C/1823 Y1, C/1844 Y1, C/1910 A1, C/1973 E1, 109P/1862 O1, the velocity of ejection of particles of anomalous tails from cometary nuclei were determined (Safarov 2018, 2017). Velocities were more than 1 km/s. Orlov (1935) interpreted such velocities as the result of a collision between the comet's rocky nuclei and meteoroids. It has now become apparent that the comet nuclei consists of a conglomerate of various ices and refractory meteoroid particles (Boehnhardt 2005; Weissman *et al.* 2004), and velocity 1 km/s of ejection coarse dust from the nuclei are much greater than the thermal velocities of molecules during sublimation of nuclei ices dust from the nuclei need other mechanisms.

In most literary sources, an anomalous tail is given information about the observed tail length S in degrees of the arc and its observed positional angle P relative to the north point, *i.e.*, information in the picture plane is given. The truth of the anomalous tail is established only after a perspective design of the observed shape of the tail on the comet's orbit plane. The most acceptable method is Moiseev (1924) and we used it when designing the image of a comet on the plane of its orbit.

The purpose of this work is to ascertain the ejection velocity of the substance of the anomalous tail from the cometary nucleus.

Determination of the velocity of ejection of dust particles of the anomalous tail from the cometary nucleus

To determine the ejection velocity of dust particles of the anomalous tail from the cometary nucleus, data on comets centric coordinates' ξ, η of particles are required during the observation t. Also, data are needed on the time of ejection of particles from the nucleus t_1 and on the elements of the comet's orbit. The most difficult is to determine the time of ejection of particles from the comet's nucleus. Orlov (1935) found the time of ejection of particles from the difference between the true anomalies υ of the comet during the observation of the anomalous tail and the ejection of a particle from the nucleus, that is, in magnitude $(\upsilon - \upsilon_1)$. Due to the fact that the anomalous tail is straight and directed toward the Sun, we have approximately the following equations (Orlov 1935):

$$tg\Psi = \frac{\eta}{\xi},$$

and

$$\upsilon_1 = \upsilon - \Psi + 180^\circ$$

The numerical value of the true anomaly of the comet υ_1 at the moment of particle ejection allows one to determine the ejection time by the known elements of the comet's orbit. For a comet's parabolic orbit, the ejection time is determined by the equation (Ibadinov 1981):

$$\frac{k\,(t_1 - T)}{\sqrt{2}q^{3/2}} = tg\frac{1}{2}\upsilon_1 + \frac{1}{3}tg^3\frac{\upsilon_1}{2}$$

T - is the time of passage of the comet through the perihelion point of the orbit, q - is the perihelion distance of the orbit, t_1 - is the time of formation of the anomalous tail, υ - is the true anomaly of the nucleus at the time of observation of the anomalous tail, υ_1 - is the true anomaly of the nucleus at the moment of particle ejection, $\phi = \upsilon - \upsilon_1$ one. With the known ξ and η particles of the tail, the velocity of their ejection from the nucleus is easily determined from the relation (Orlov 1928):

$$g = \frac{\tau\sqrt{\xi^2 + \eta^2}}{t - t_1},$$

where $\tau \approx 1/k$, k is the Gauss constant. The value of g = 0.1 is 2950 m/s (Jaegermann 1903).

3 Result

The results of determining the ejection velocity of particles of an anomalous tail from the nuclei of 50 comets are presented in the Table 1.

The table shows the designations of comets, the time T of the passage of a comet to the orbit perihelion point, the observation time t of the anomalous tail, the time t_1 of particles ejected from the nucleus, the values of the velocity V of particles ejected from the nucleus obtained by other authors and the velocity V_A of particles ejected from the comet nucleus us.

For some comets, the time of the large outburst of comet luster from Boehnhardt (2005); Pittich (1971); Andrienko and Vashenko (1981) was taken as the moment of the formation of the anomalous tail. They are indicated with an asterisk in the 4^{th} column. For several comets, the time of nuclear splitting according to Boehnhardt (2005); Ibadinov and Buriev (2011) was taken as the moment of formation of the anomalous tail. In the table they are indicated by two asterisks.

4 The mechanism ejection velocity of dust particles of the anomalous tail of comet

The values of the ejection velocity of dust particles of the anomalous tail of comets C/1844 Y1, C/1851 U1, C/1910 A1, C/1962 C1, C/1963 A1, C/1973 E1, C/1980 O1, C/1984 N1, C/1987 P1, C/1995 O1, C/1999 H1, C/1999 S4, C/2002 T7, 96P/1986 J1 limit from 0.04 to 2.74 km/s. The values of velocity of ejection, obtained by other authors for comets C/1844 Y1, C/1910 A1, 73P/1930 J1, 109P/1862 O1 also lie in the limit from 0.08 to 3.6 km/s (Orlov 1935; Jaegermann 1903; Richter and Keller 1988; Sekanina and Miller 1976; Ryabova 2013; Sizonenko 1996). For example, for comet C/1844 Y1, the ejection velocity is V_A = 0.38–0.98 km/s with t_1 = 08.11.1844 and V_A = 0.12–0.73 km/s with t_1 = 02.12.1844. The reason for such a large variation in ejection velocities is that the comet's nucleus is the most active and during the determination of the moment of ejection, we identified two points when the ejection of dust particles from the anomalous comet tail occurred. The comet suffered several outbursts of brightness (Pittich 1971). As we have already noted, such comets are the most active. In comet C/1973 E1, an anomalous tail was observed in three periods. For the first time around the perihelion point of the orbit from December 27 to December 29, 1973, for the second time from January 12 to 26, and for the third time from February 9 to 26, 1974. The comet has several times recorded outbursts of brightness from 2 to 3 stellar magnitudes (Andrienko and Vashenko 1981). With each outburst, dust particles are ejected that will form an anomalous tail. Simultaneously with the ano-

Table 1. Ejection velocity of dust particles of the anomalous comet tail

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
C/1823 Y1	09.93-12.1823	22.01.1824	-	1.36 (Belopolsky 1886)	-	-
			-	1.48 (Vsekhsviyatskiyi 1932)	-	-
C/1844 Y1	14.2-12.1844	11.01.1845	15.23-11.1844	1.50 (Belopolsky 1886)	1.55	0.83
		12.01.1845	08.11.1844	0.29 (Vsekhsviyatskiyi 1932)	0.48	0.86
		13.01.1845		0.16 (Babadzanov 1955)	0.38	0.88
		14.01.1845		-	0.98	0.91
		15.01.1845		-	0.84	0.93
		17.01.1845	02.12.1844	-	0.12	0.97
		29.01.1845		-	0.53	1.22
		30.01.1845		-	0.66	1.24
		31.01.1845		-	0.73	1.26
C/1851 U1	01.29-10.1851	22.10.1851	24.08.1851	-	0.14	0.73
		23.10.1851		-	0.18	0.75
		24.10.1851		-	0.19	0.77
		25.10.1851		-	0.28	0.79
C/1877 G1	27.30-04.1877	05.04.1877	27.03.1877	-	0.20	0.96
		15.05.1877	30.03.1877	-	0.48	1.07
C/1882 R1	17.72-09.1882	16.10.1882	14.29-05.1882	-	1.56	1.01
C/1883 D1	19.4-02.1883	28.02.1883	23.01.1883	-	0.28	0.81
		02.03.1883	19.01.1883	-	4.45	0.84
C/1885 X2	03.78-05.1886	01.05.1886	21.71-04.1886	-	0.02	0.48
C/1888 R1	31.66-05.1889	03.07.1889	26.04.1888	-	2.16	3.61
C/1892 E1	07.15-04.1892	02.04.1892	08.03.1892	-	2.62	1.05
D/1894 F1	09.93-0 2.1894	27.02.1894	08.02.1894	-	0.05	1.22
		28.02.1894		-	0.06	1.24
		29.02.1894		-	0.06	1.25
C/1910 A1	17.58-01.1910	26.01.1910	18.64-01.1910	0.08 (Pokrovskiyi 1915)	0.92	0.40
			18.4-01.1910	0.10 (Vsekhsviyatskiyi 1932)		
			17.88-01.1910	0.11 (Orlov 1935)		
				0.85 (Orlov 1928)		
				0.21 (Orlov 1935)		
			06.58-01.1910	0.56 (Babadzanov 1955)		
		27.01.1910		-	0.67	0.43

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Table 1. ... continued

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
		28.01.1910		0.80 (Pansecchi and Fulle 1990)	0.52	0.45
		29.01.1910		0.70 (Pansecchi and Fulle 1990)	0.44	0.48
				0.51 (Orlov 1935)		
		30.01.1910		0.60 (Pansecchi and Fulle 1990)	0.44	0.51
		31.01.1910		-	0.34	0.54
C/1921 E1	10.45-05.1921	12.05.1921	01.05.1921	-	0.31	1.01
C/1922 U1	26.5-10.1922	06.11.1923	26.12.1921	-	0.90	3.93
C/1925 V1	07.26-12.1925	10.12.1925	20.26-09.1925	-	0.21	0.76
C/1930 D1	15.9-01.1930	24.02.1930	12.5-12.1929	-	0.02	1.26
C/1931 O1	11.06.1931	31.07.1931	15.06.1931*	-	1.10	1.33
		12.08.1931		-	1.10	1.45
C/1931 P1	25.08.1931	17.10.1931	23.08.1931*	-	3.35	1.15
		18.10.1931		-	3.48	1.48
C/1932 M1	24.09.1932	27.06.1932	23.06.1932	-	0.83	2.03
C/1935 A1	26.46-02.1935	19.02.1935	12.02.1935	-	0.69	0.82
C/1939 B1	6.85-02.1939	12.01.1940	28.01.1940	-	0.74	0.74
C/1954 O1	01.93-06.1954	02.08.1954	15.28-04.1954	-	0.21	1.31
		6.9-08.1954		-	0.13	1.37
		7.9-08.1954		-	0.25	1.37
C/1961 O1	17.49-07.1961	25.07.1961	04.51-04.1961*	-	1.72	0.39
		26.07.1961		-	1.75	0.43
C/1962 C1	01.66-04.1962	10.04.1962	10.10.1961*	-	0.32	0.42
		12.04.1962		-	0.81	0.49
		13.04.1962		-	0.88	0.53
		14.04.1962		-	0.43	0.55
		16.04.1962		-	0.25	0.62
		17.04.1962		-	0.23	0.64
		18.04.1962		-	0.21	0.67
		19.04.1962		-	0.21	0.70
		20.04.1962		-	0.23	0.73
		21.04.1962	04.51-04.1961*	-	0.25	0.76
		22.04.1962		-	0.33	0.78
		23.04.1962		-	0.23	0.81

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Table 1. ... continued

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
		24.04.1962		-	0.31	0.84
		25.04.1962		-	0.73	0.87
C/1963 A1	21.47-03.1963	25.02.1963	10.35-01.1963	-	0.04	0.83
		10.05.1963		-	1.00	1.18
		25.05.1963		-	0.64	1.42
		30.05.1963		-	0.74	1.49
		16.07.1963		-	0.23	1.74
		21.07.1963		-	0.24	1.86
		27.07.1963		-	0.16	1.90
C/1968 H1	16.27-05.1968	24.07.1968	03.05.1968	-	0.25	1.18
C/1969 T1	21.26-12.1969	26.12.1969	08.11.1969	-	0.003	0.49
C/1973 E1	28.4-12.1973	27.85-12.1973	27.82-12.1973	0.85 (Richter and Keller 1988)	-	-
		28.99-12.1973	27.84-12.1973	1.0 (Richter and Keller 1988)	-	-
		30.09-12.1973	26.74-12.1973	0.9 (Richter and Keller 1988)	-	-
		30.95-12.1973	25.84-12.1973	1.0 (Richter and Keller 1988)	-	-
		12.01.1974	20.4-11.1973	-	1.75	0.54
		14.01.1974		-	2.74	0.61
		16.01.1974		-	2.45	0.65
		17.01.1974		-	2.56	0.69
		20.01.1974		-	1.88	0.76
		23.01.1974	20.4-11.1973	-	0.67	0.83
		26.01.1974		-	0.53	0.91
		09.02.1974		-	0.53	1.21
		13.02.1974		-	1.31	1.29
		23.02.1974		-	0.59	1.47
		24.02.1974		-	1.93	1.51
		25.02.1974		-	1.67	1.52
C/1973 E1	28.4-12.1973	26.02.1974	20.4-11.1973	-	1.05	1.60
C/1975 V2	21.18-12.1975	03.01.1975	10.12.1975	-	0.02	0.58
C/1980 O1	22.44-06.1980	14.08.1980	06.05.1980	-	0.24	1.23
		15.08.1980		-	0.26	1.24
		17.08.1980		-	0.44	1.29
		19.08.1980		-	0.81	1.31

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Table 1. … continued

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
		29.08.1980	21.8-04.1980	-	2.16	1.47
		03.09.1980		-	2.23	1.57
		04.09.1980		-	1.89	1.59
		06.09.1980		-	1.09	1.61
		07.09.1980		-	1.02	1.63
C/1984 N1	12.13-08-1984	29.08.1984	03.46-07.1984	-	1.04	0.55
		03.51-09.1984		-	1.04	0.68
		09.05-09.1984		-	0.73	0.81
		10.01-09.1984		-	0.27	0.83
		13.11-09.1984		-	0.50	0.90
		20.48-09.1984		-	0.62	1.04
		21.39-09.1984		-	0.36	1.06
		25.32-09.1984		-	0.18	1.14
		27.38-09.1984		-	0.05	1.18
C/1987 P1	7.27-11.1987	08.01.1988	01.16-09.1987	-	1.61	1.38
		09.01.1988		-	1.63	1.39
		10.01.1988		-	1.39	1.41
		17.01.1988		-	1.27	1.49
		18.01.1988		-	1.31	1.51
		19.01.1988		-	1.17	1.52
C/1995 O1	01.04.1997	08.02.1997	15.12.1996 (Kharchuk *et al.* 2009)	0.16-0.7 (Kharchuk *et al.* 2009)	-	-
		18.02.1997	15.12.1996 (Kharchuk *et al.* 2009)	0.14-0.64 (Kharchuk *et al.* 2009)	-	-
		07.03.1997	08.01.1997 (Kharchuk *et al.* 2009)	0.15-0.65 (Kharchuk *et al.* 2009)	-	-
		05.10.1997	01.04.1996 (11.03.1997) (Boehnhardt 2003)	-	0.41	2.93
		03.01.1988		0.17 (Boehnhardt 2003)	0.21	3.95
		26.02.1988		-	0.51	4.51
		22.03.1998	24.06.1996	-	0.04	4.75
		02.04.1998		-	0.05	4.86
		25.04.1998		-	0.19	5.08
C/1999 T2	24.46-11.2000	24.04.1999	24.05.1998	-	0.20	6.08
C/1999 S4	18.28-07.2000	26.9-07.2000	17.75-07.2000*	0.026 (Sergio *et al.* 2002)	0.003	0.76
		27.9-07.2000		-	0.003	0.76

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Table 1. ... continued

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
C/1999 H1	11.17-07.1999	09.08.1999	14.02-06.1999	-	3.23	0.92
		12.08.1999		-	1.64	0.96
		13.08.1999		-	1.66	0.97
		19.08.1999		-	0.80	1.05
		22.08.1999		-	1.94	1.08
C/2002 T7	23.04.2004	25.04.2004	01.04.2004	-	1.55	0.61
		05.05.2004		-	2.14	0.66
		15.05.2004	04.06-04.2004	-	0.43	0.77
		20.05.2004	28.2-03.2004	-	0.50	0.84
C/2004 Q2	24.83-01.2005	13.12.2004	30.09.2004	-	2.09	1.47
		14.12.2004		-	2.26	1.59
		15.12.2004		-	2.30	1.61
C/2004 F4	17.09-04.2004	02.05.2004	01.04.2004	-	0.90	0.55
C/2011 A2	01.6-01.2011	11.54-1.2011	29.06.2009	-	0.016	1.75
2P/1924	31.93-10.1924	05.10.1924	21.07.1924*	-	0.08	0.73
6P/1950	06.37-06.1950	14.07.1950	21.06.1950*	-	0.12	1.44
		18.07.1950		-	0.29	1.46
7P/1869 G1	30.44-06.1869	11.05.1869	25.04.1869**	-	1.22	1.13
7P/1933	18.79-05.1933	23.05.1933	01.05.1933**	-	0.79	1.11
10P/1930	05.78-10.1930	18.11.1930	23.09.1930	-	0.07	1.41
19P/1918	01.49-11.1918	31.08.1918	29.07.1918	-	0.27	1.69
26P/1927	10.24-05.1927	01.06.1927	23.04.1927	-	0.005	0.99
34D/1938 J1	18.48-06.1938	06.05.1938	28.04.1938	-	0.19	1.32
		10.05.1938		-	0.16	1.29
35P/1939	09.46-08.1939	20.10.1939	09.46-08.1939	-	0.025	1.51
67P/1982	12.09-11.1982	24.12.1982	12.6-10.1982**	-	0.15	1.43
73P/1930 J1	14.19-06.1930	24.05.1930	01.05.1930	-	0.08	1.07
		27.05.1930		-	0.51	1.08
96P/1986 J1	23.19-04.1986	13.45-05.1986	30.81-03.1986*	-	0.56	0.68
		26.92-05.1986		-	0.025	0.98
		7.99-06.1986		-	0.023	1.11
		25.29-06.1986		-	0.414	1.51
		26.28-06.1986		-	0.70	1.53

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Table 1. ... continued

Comets	T	t	t_1	V, km/s	V_A, km/s	r, AU
		30.94-06.1986		-	0.50	1.60
		3.93-07.1986		-	0.47	1.65
109P/1862 O1	23.42-08.1862	30.07.1862	-	0.59 (Jaegermann 1903)	-	-
			01.06.1862	3.10 (Belopolsky 1886)	-	-
			11.5-05.1862	1.20 (Vsekhsviyatskiyi 1932)	-	-
			02.07.1862	3.60 (Vsekhsviyatskiyi 1932)	-	-
			11.05.1862	1.80 (Babadzanov 1955)	-	-

Concluded

malous tail, comet C/1963 A1 was observed to synchronize in the dust tail. Comet C/2002 T7 has several fragments around the comet's nucleus. The reason for the velocity variation is the collision of fragments with the comet's nucleus. Comet C/1999 S4 had a outburst of brightness with amplitude of 0.8^m - 0.9^m, after which the brightness began to fall sharply, and the comet disappeared almost in front of the observers. The reason for this disappearance is the complete destruction of the comet C/1999 S4. A number of other comets have a consistent outburst of brightness at certain distances from the Sun. For example, in a short-period comet 2P/Enkce, in several appearances before the passage of the perihelion point of the orbit, the comet's brightness increases and dust comets or a weak anomalous tail, which can be detected with high-aperture telescopes, is observed. Such a phenomenon was observed in comets 6P/d'Arrest in 1950 and 1976, 7P/Pons - Winnecke in 1869, 1921 and 1933, 19P/Borrelly in 1918, 1994, 2001 and 2008, 67P/Churyumov - Gerasimenko in 1982, 2003 and 2008.

The velocity of ejection of dust particles from the nuclei of comets C/1851 U1, C/1877 G1, C/1883 D1, D/1894 F1, C/1921 E1, C/1925 V1, C/1930 D1, C/1954 O1, C/1962 C1, C/1968 H1, C/1969 T1, C/1975 V2, C/1995 O1, C/1999 T2, C/2011 A2, 2P/1924, 6P/1950, 10P/1930, 19P/1918, 26P /1927 F1, 34P/1938 J1, 35P/1939 O1, 67P/1982 and 73P/1930 lie within the limits of 0.003 to 0.4 km/s and such velocities can be explained by the sublimation of nuclei ice and removal. But the release of the substance of the anomalous tail above the comets occurred at large distances from the Sun: D/1894 F1 (q=1.147 AU, r=1.25 AU), C/1921 E1 (q=1.008 AU, r=1.20 AU), C/1930 D1 (q=1.087 AU, r=1.26 AU), C/1954 O1 (q=0.677 AU, r=1.31 AU), C/1968 H1 (q=1.160 AU, r=1.18 AU), C/1995 O1 (q=0.913 AU, r=3.5 AU), C/1999 T2 (q=3.037 AU, r=6.08 AU), C/2011 A2 (q=1.75 AU, r=1.76 AU), 6P/1950 (q=1.377 AU, r=1.44 AU), 10P/1930 (q=1.318 AU, r=1.41 AU), 19P/1918 (q=1.395 AU, r=1.69 AU), 34P/1938 J1 (q=1.182 AU, r=1.32 AU), 35P/1939 O1 (q=3.388 AU, r=6.09 AU), 67P/1982 (q=1.306 AU, r=1.67 AU) and 73P/1930 (q=1.011 AU, r=1.08 AU). At such distances, the inflow of solar energy cannot provide high velocities of large dust particles from the surface of the comet's nuclei, with the exception of comets C/1851 U1, C/1885 X2, C/1921 E1, C/1925 V1, C/1930 D1, C/1975 V2, 2P/1924, 6P/1950 and 1976, 10P/1930, 7P/1933 and 35P/1939 O1. At the same time, in other above-mentioned comets, nuclear splitting was also observed at the same distance. Such a comet experiences a minor fragmentation of the nucleus. This occurs due to the formation of an anomalous tail, gas and dust jets and dust halos. It is known that the comets of the main belt of asteroids as a result of a collision with an asteroid or meteoroid have dust tails and their nucleus is destroyed into several fragments (Belopolsky 1886). In comets C/1888 R1, C/1922 U1, C/1932 M1, C/1995 O1 and C/1999 T2, an anomalous tail was observed in the asteroid belt. This indicates a probable collision of meteoroids with the nuclei of these comets.

When searching for the mechanisms formation of the anomalous tail of comets, it turned out that nuclear splitting was observed in more than 100 comets (Boehnhardt 2005; Ibadinov and Buriev 2011). It was logical to expect that after the comet's nuclear splitting, an anomalous tail should form. However, this is not the case and only for comets C/1823 Y1, C/1882 R1, C/1883 D1, C/1888 R1, C/1892 E1, D/1894 F1, C/1932 M1, C/1935 A1, C/1954 O1, C/1968 H1, C/1969 T1, C/1973 E1, C/1995 O1, C/1999 S4, C/2004 Q2, 2P/1924, 7P/1869 G1, 10P/1930, 19P/1918, 26P/1927 F1, 67P/1982, 73P/1930 J1, 96P/1986 J1 and 109P/1862 O1 in one appearance both an anomalous tail and signs of splitting of the comet's nucleus were observed. One of the reasons for the destruction of the nucleus is that most of the comets that their nucleus underwent decay, they were located close to the Sun (Ibadinov and Buriev 2011). The velocity of expansion of cometary nuclei fragments mainly lie from several meters per second to tens of meters per second (Boehnhardt 2005; Sergio *et al.* 2002; Pittich 1971; Shestaka 1992). This indicates an unlikely collision of the comet's nucleus with other small bodies of the solar system. In addition, the distribution of points of destruction of cometary nuclei does not reveal an increase in the frequency of decay cases in the asteroid belt (Ibadinov 1981). These results have been confirmed (Jaegermann 1903). The list of MAC shows 713 names of meteor showers. Unfortunately, the majority of these flows are not considered confirmed, they are considered hypothetical flows. The average spatial density of interplanetary matter is 10^{-22} g/cm^3. This substance is mainly replenished by active comets. They were found in the space experiments "Pioneer-8", "Pioneer-9", "Helios" and "HEOS-2" and they are called α-meteoroids (Grun *et al.* 1980). With such distributions of matter in the Solar System, a comet collides with meteoroids while moving in its orbit. If the comet's orbit crosses the meteoroid swarm, then the nuclei is bombarded by meteoroids. When a comet's nucleus collides with another cosmic body, there is a simultaneous ejection. Upon impact, numerous particles with different nature are ejected, respectively, the particle size is not all the same and the ejection velocity will be different.

It turned out during the formation of the anomalous tail and the destruction of the nucleus in comets C/1882 R1, C1883 D1, C/1892 E1, D/1894 F1 and C/1999 S4 collisions occurred. Collision in other comets remains a mystery. The comet C/1954 O1 repeatedly outbursts a brightness (Pittich 1971; Andrienko and Vashenko 1981), and comet C/1955 O1 is one of the active.

It is known that a comet of the main belt of asteroids has a dust tail as a result of a collision with an asteroid or meteoroid and their nuclei is destroyed into several fragments, in particular, comet 133P/1996 N2 (Jewitt *et al.* 2014). In comets C/1888 R1, C/1922 U1, C/1932 M1, C/1995 O1 and C/1999 T2, an anomalous tail was observed in the asteroid belt. This may be due to the collision of the nucleus of these comets with the meteoroid.

From the data in Table 1. it follows that the velocity of ejection of the substance of the anomalous tail of most comets corresponds to the conditions of the collision of the nucleus with meteoroids.

From Figure 1 it follows that the most likely heliocentric distance for observing the anomalous comet tail is a distance from 0.5 to 1.6 AU. This may be due to the visibility conditions of comets. The velocity of ejection of dust particles lies in the limit from 0.003 to 4.5 km/s.

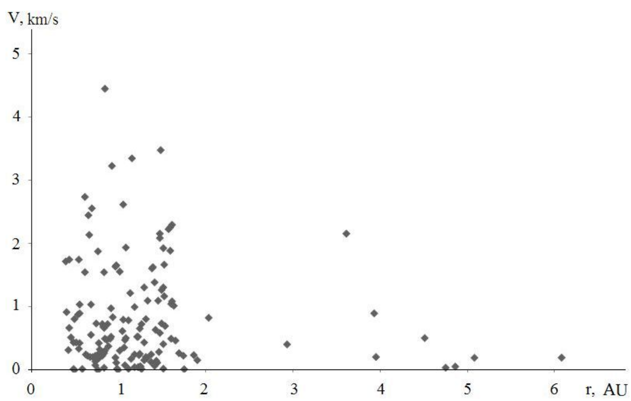

Figure 1. Dependence of the velocity V of the ejection of dust particles of the anomalous tail on the heliocentric r distance.

For comets C/1888 R1, C/1922 U1, C/1932 M1, C/1995 O1, C/1999 T2, the ejection velocity lies in the limit of 0.04-2.16 km/s at heliocentric distances of 2.03-6.08 AU. At such distances from the Sun, the sublimation process will not be able to provide the values of high velocities of dust particles ejection from the comet nucleus. High ejection velocities are associated with the collision of a comet's nucleus with meteoroids.

From Figure 2 that in most comets the velocity of dust ejection from the nucleus lies within the limits of $0 \le V \le 0.4$ km/s. Comets have a very wide of physical characteristics, chemical composition and structure of the nucleus. Such a composition of the cometary nucleus strongly affects their activity. At the perihelion of the orbit, the surface temperature of the nuclei covered with dust reaches 370 K, and if the surface consists of pure ice, then the maximum temperature is 203 K (Weissman *et al.* 2004; Ryabova 2013; Marov 1994). At such temperatures, summing molecules can provide dust ejection velocity of up to 0.4 km/s (Safarov 2018, 2017).

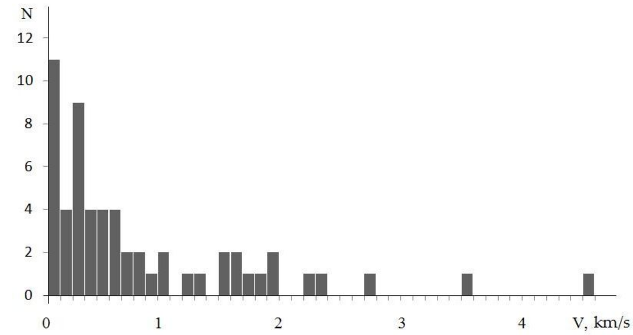

Figure 2. The distribution of the number N of comets in the velocity V of the ejection of particles of the anomalous tail.

For other comets, the release velocity is very high. Such velocities are mainly formed as a result of the collision of the cometary nucleus with the meteoroid.

Most comets, the nucleus of which underwent decay, have a high ejection velocity, and other types of nuclear activity have been observed. Those comets whose velocity of dust particles ejection from the nucleus is high have a connection with meteoroid swarms.

The velocity of ejection of dust particles from the nucleus of comets C/1851 U1, C/1877 G1, C/1883 D1, D/1894 F1, C/1921 E1, C/1925 V1, C/1930 D1, C/1954 O1, C/1962 C1, C/1969 T1, C/1968 H1, C/1975 V2, C/1995 O1, C/1999 T2, 2P/1924, 6P/1950, 10P/1930, 19P/1918, 26P/1927 F1, 34P/1938 J1, 35P/1939 O1, 67P/1982 and 73P/1930 lie within the limits of 0.003 to 0.4 km/s.

The velocity of release of dust particles from the nucleus of comets C/1851 U1, C/1885 X2, C/1921 E1, C/1925 V1, C/1930 D1, C/1975 V2, 2P/1924, 6P/1950 and 1976, 10P/1930, 7P/1933 and 35P/1939 O1 can be explained by the sublimation of ices of the comet's nucleus and the removal of dust by gas molecules. For other comets, this mechanism does not work. The velocity of release from the nucleus of the substance of the anomalous tail of the remaining comets (Table 1) leads to the conclusion that the nucleus of these comets collides with meteoroids.

5 Statistical studies of anomalous tail of comets

We have compiled a catalog of comets from anomalous comet tails (Safarov 2018; Ibadinov and Safarov 2015). The catalog includes 80 comets. In the catalog 47 comets move

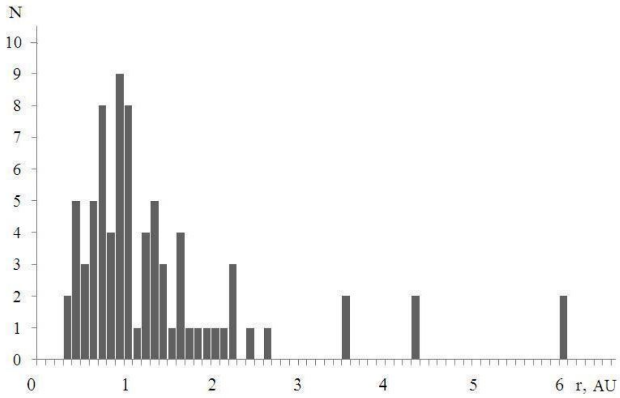

Figure 3. The dependence of the number of comets *N* with an anomalous tail on the heliocentric distance *r*.

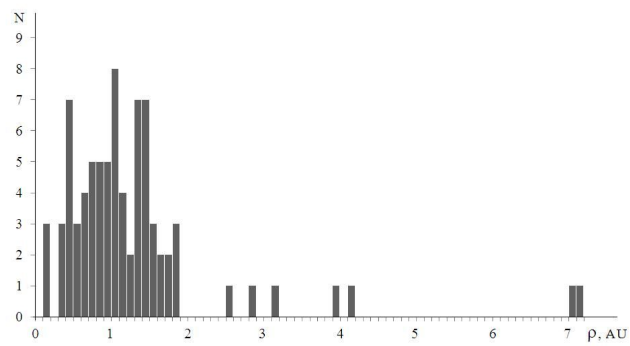

Figure 4. The dependence of the number of comets *N* with an anomalous tail on the geocentric distance *ρ*.

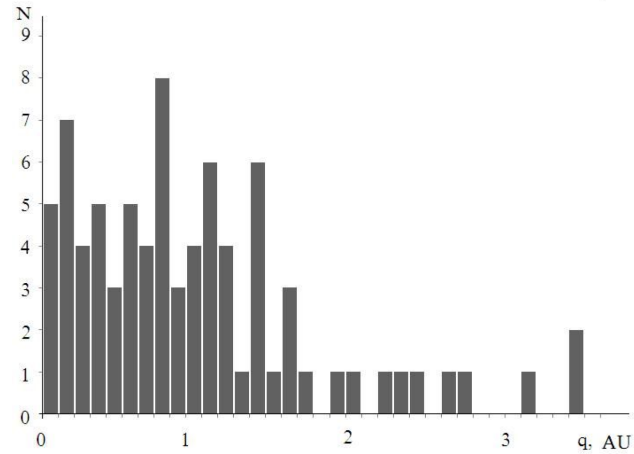

Figure 5. Dependence of the number of comets *N* with an anomalous tail on the perihelion distance of the orbit *q*.

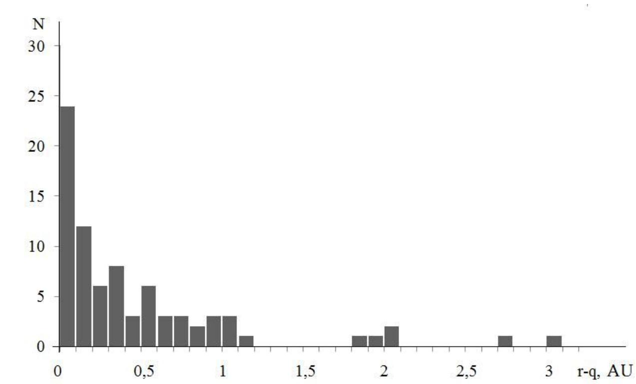

Figure 6. Dependence of the number of comets *N* with an anomalous tail on (*r* - *q*).

around the Sun almost in parabolic orbits, 32 comets are periodic and 1 comet is considered to have disappeared. The ratio of comets with perihelion distances of the orbit q < 1 and q > 1 is 52:28. The perihelion distances of their orbits are in the limit from 0.062 to 3.38 AU. The ratio of orbits with direct and reverse motions is 60:20. The table 2 shows the designations of comets, *q* - perihelion distance orbits, *i* - inclination of the comet orbit to the ecliptic plane according to the Marsden and Williams catalog (Marsden and Williams 1996), heliocentric *r* and geocentric *ρ* distance of the comet during observation of the anomalous tail.

We have studied the dependence of anomalous cometary tails on some parameters of their orbit, in particular, on the heliocentric distance r and on the geocentric distance of comet *ρ*, on the perihelion distance of the orbit q, on the inclination of the comet's orbit plane to the ecliptic plane i and on (*r* - *q*). Some results are presented in Figure 3-6 (Safarov 2018; Ibadinov and Safarov 2015; Ibadinov *et al.* 2012).

The statistical maximum of the number of comets with an anomalous tail is observed in the limit of heliocentric distances of comets 0.7 and from 0.9 to 1.1 AU, geocentric distance 0.5 AU, 0.9-1.1 AU and 1.3-1.5 AU, the perihelion distance of the orbit is 0.2, 0.8, 1.2, 1.5 AU and orbit inclinations up to 15° - 20° and 60° - 75°. In our opinion, this is due to the conditions of observations of comets (proximity to the Earth). Separate peaks are also observed in the orbits of the planets Venus and Mars (see Fig. 3–5). For Comet C/1883 D1, C/1925 V1, C/1935 A1, C/1939 B1, C/1969 T1, C/1999 H1, C/1999 S4, 7P/1869 G1, 35P/1939 O1, the perihelion distance is about the orbit of Venus and comets 37P/1942 L1, 81P/1997 the perihelion distance is located near the orbit of Mars. There is a high probability that the cause of the formation of the anomalous tail of these comets is the tidal effect of the planets Venus and Mars.

For comets C/1922 U1, C/1932 M1, 39P/1943 G1, C/1948 N1, 33P/1950, C/1995 O1, 133P/1996 N2, C/1999 T2, 213P/2009 B3, C/2010 A1, P/2011 P1 anomalous tail was observed on the asteroid belt.

Table 2. The comets with an anomalous tail.

Comets	q, AU	i, deg.	r, AU	ρ, AU	Comets	q, AU	i, deg.	r, AU	ρ, AU
C/1577 V1	0.17750	104.88	0.61	0.12	C/1995 O1	0.91395	89.42	2.93	3.07
C/1596 N1	0.56716	21.49	0.64	1.24	C/1999 H1	0.70810	149.35	0.92	1.45
C/1680 V1	0.00622	60.67			C/1999 S4	0.765089	149.38	0.76	0.41
C/1744 X1	0.2222	47.14			C/1999 T2	3.03739	111.02	6.08	6.99
C/1769 P1	0.12275	40.73			C/2000 WM1	0.555347	72.55	1.55	0.61
C/1823 Y1	0.22674	103.81	1.17	0.49	C/2002 T7	0.61518	160.57	0.64	1.37
C/1844 U1	0.25053	45.56	0.83	1.02	C/2004 Q2	1.20341	38.59	1.95	1.31
C/1851 U1	0.14205	73.98	0.73	0.96	C/2004 F4	0.16826	63.16	0.49	1.06
C/1858 L1	0.57846	116.95			C/2006 P1	0.170736	77.83	0.97	1.37
C/1877 G1	0.94498	121.15	0.96	1.40	C/2010 A1	1.94995	10.334	2.10	1.5
C/1882 R1	0.00775	142.01	1.01	1.42	C/2010 X1	0.482439	1.839	0.98	0.78
C/1883 D1	0.76006	78.06	0.81	1.16	C/2011 A1	1.558782	4.473	1.76	1.44
C/1885 X2	0.47925	84.44	0.48	0.75	C/2013 V5	0.62558	278.61	0.91	0.78
C/1888 R1	1.81491	166.38	0.92	1.36	1P/1982 U1	0.587104	164.24	0.75	0.98
C/1892 E1	1.02683	38.70	1.05	1.08	2P/1924	0.34106	12.53	0.73	0.77
D/1894 F1	1.14700	5.52	1.22	0.48	2P/1937 V1	0.33241	12.55	0.85	0.30
C/1910 A1	0.12897	138.78	0.40	1.17	2P/1941	0.34138	12.35	1.01	1.74
C/1921 E1	1.00845	132.18	1.20	1.21	2P/1947	0.34102	12.35	1.08	0.48
C/1922 U1	2.25877	51.45	2.26	1.88	2P/1951	0.33801	12.38	0.98	1.33
C/1925 V1	0.76356	144.59	0.76	1.02	6P/1950	1.37755	18.04	1.44	1.19
C/1930 D1	1.08711	99.88	1.26	0.39	6P/1976	1.16399	16.68	1.34	0.42
C/1931 O1	1.04690	42.29	1.33	1.84	7P/1869 G1	0.78151	10.79	1.13	0.57
C/1931 P1	0.07492	169.28	0.32	1.18	7P/1933	1.01784	20.11	1.11	0.53
C/1932 M1	1.64741	78.38	2.03	1.30	10P/1930	1.31868	12.75	1.41	1.49
C/1935 A1	0.81114	65.42	0.81	0.87	19P/1918	1.39578	30.49	1.69	1.26
C/1939 B1	0.71649	63.52	0.74	0.60	19P/1994	1.365126	30.27	1.68	0.89
C/1948 N1	2.517207	130.26	4.36	3.90	19P/2001	1.35820	30.32	1.36	1.47
C/1954 O1	0.67746	116.15	1.31	1.69	26P/1927 F1	0.89270	17.48	0.99	0.96
C/1961 O1	0.04099	24.21	0.39	0.88	33P/1950	1.46454	19.70	2.80	3.51
C/1962 C1	0.03139	65.01	0.42	0.99	34P/1938 J1	1.18290	11.72	1.32	0.40
C/1963 A1	0.63213	160.64	0.94	0.33	35/1939 O1	0.74849	64.21	1.51	1.97
C/1968 H1	1.16043	143.23	1.18	1.60	37P/1942 L1	1.54869	4.62	1.62	1.45
C/1969 T1	0.47260	75.81	0.49	1.03	39P/1943 G1	3.38889	3.98	6.09	7.10
C/1973 E1	0.14242	14.30	0.55	0.72	45P/1948	0.5592	13.15	0.69	0.60
C/1975 V2	0.21872	70.62	0.58	1.07	67P/1982	1.30614	7.12	1.67	0.47
C/1980 O1	0.52274	49.06	1.23	1.60	73P/1930 J1	1.01142	17.39	1.08	0.14
C/1983 H1	0.99134	73.25	1.01	0.13	81P/1997	1.58261	3.24	1.61	0.75
C/1984 N1	0.29128	164.15	0.55	1.34	96P/1986 J1	0.12677	94.50	0.68	0.68
C/1987 P1	0.86895	34.08	1.08	0.84	109P/1862 O1	0.96265	113.56	1.08	1.12
C/1988 P1	0.164558	40.199	0.74	1.25	213P/2009 B3	2.12237	10.236	2.24	1.47

It was revealed that the maximum number of anomalous tails of comets falls around the perihelion of the orbit (r - q ≈ 0). This can be explained by the influence of the attraction of the Sun, a large influx of solar radiation energy to the cometary nucleus and a high sublimation velocity of the nuclei ice. Of the comets having anomalous tails, only at C/1680 V1, C/1882 R1, C/1961 O1 and C/1962 C1 the perihelion distance of the orbit is less than q = 0.07 AU. Velocity of the troop landing of dust particles of sungrazing comets is arrived at to V = 0.1 km/s (Sekanina 2000).

The greatest number of anomalous tails of comets is registered near the Sun, in the region of the perihelion of the comets orbit.

At the collision of nuclei of comet with meteoroids velocity of flying away of fragments of nuclei will be considerably anymore and atmosphere of comet large dust particles that will form an anomalous tail must enter. At velocity of hitting an about 10-30 km/s high velocities of the troop landing of meteoroids particles from the nuclei of comet arrive at 0.5-1.5 km/s (Melosh 1984). It ensues from the results of table, that velocity of the troop landing of substance of anomalous tail of 60% comets corresponds to the terms of collision of nuclei with meteoroids. If to suppose that at formation of anomalous tail is generated, even one meteor swarm, then there is probability of formation of the new meteoroids swarms related to the anomalous tails of comets (Ibadinov *et al.* 2015; Ibadinov and Safarov 2017).

6 Discussion and final conculation

The reason for the formation of anomalous tail in comets C/1577 V1, C/1596 N1, C/1680 V1, C/1851 U1, C/1885 X2, C/1921 E1, C/1975 V2, C/2000 WM1, C/2010 X1, C/2013 V5, 2P/Encke (1924, 1937, 1941, 1950), 35P/1939 O1 are the tidal effects of the Sun (planets) and the high velocity of sublimation of the ice of the comet's nucleus. We believe that due to the high velocity of sublimation of nuclei ice in comets C/1796 P1, C/1844 U1, C/1910 A1, C/1925 V1, C/1930 D1, C/1939 B1, C/1961 O1, C/1988 P1, 7P/1933, 37P/1942 L1 formed an anomalous tail.

Comets during the approach to the Sun intersect the asteroid belt and many meteoroid swarms. For this reason, some comets with an anomalous tail have a outburst of brightness. Such a phenomenon was registered during the observation in comets C/1931 O1, C/1931 P1, C/1948 N1, C/1954 O1, C/1980 O1, C/1983 H1, C/1984 N1, 33P/1950, 34P/1938 J1, 39P/1943 G1, C/2011 A1, 19P/1994 and 2001, 67P/1982 and 81P/1997 comets experienced a strong ejection of gas and dust jets.

Formation of anomalous tail in comets C/1922 U1, C/1932 M1, 39P/1943 G1, C/1948 N1, 33P/1950, C/1995 O1, 133P/1996 N2, C/1999 T2, 213P/2009 B3, C/2010 A1, P/2011 P1 occurs at large distances from the Sun, between the orbits of Mars and Jupiter. The reason may be the collision of meteoroids with the nuclei of comets and the destruction of the nucleus of comets.

The time and velocity of ejection of dust particles of anomalous tails from cometary nuclei are determined. It has been revealed that comets C/1883 D1, C/1888 R1, D/1894 F1, C/1922 U1, C/1931 O1, C/1931 P1, C/1932 M2, C/1935 A1, C/1939 B1, C/1954 O1, C/1968 H1, C/1973 E1, C/1987 P1, C/1999 T2, C/1999 H1, C/2002 T7, C/2004 F4, 7P/1869 G1, 19P/1918, 34P/1938 J1, 67P/1982 and 109P/1862 O1 the cause of the formation of an anomalous tail is the collision of their cometary nucleus with other bodies of the solar system.

Investigation of the conditions for the formation of an anomalous tail shows that the velocity of ejection of dust from the cometary nucleus C/1851 U1, C/1885 X2, C/1921 E1, C/1925 V1, C/1930 D1, C/1975 V2, 2P/1924, 6P/1950 and 1976, 10P/1930, 7P/1933 and 35P/1939 O1 can be explained by the sublimation of nuclei ice and the removal of dust by molecules.

It has been found that comets C/1823 Y1, C/1882 R1, C/1883 D1, C/1888 R1, C/1892 E1, D/1894 F1, C/1932 M1, C/1935 A1, C/1954 O1, C/1968 H1, C/1969 T1, C/1973 E1, C/1995 O1, C/1999 S4, C/2004 Q2, 7P/1869 G1, 10P/1930, 19P/1918, 26P/1927 F1, 67P/1982, 73P/1930 J1, 96P/1986 J1 and 109P/1862 O1 in one appearance, the formation of an anomalous tail and splitting of a comet's nucleus was observed. Nuclear splitting 70% of these comets resulted from the collision of a comet's nucleus with a meteoroid or fragments of their nuclei.

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