Letter to the Editor

Abduljalol G. Safarov* and Khursand I. Ibadinov

Conditions for the formation of anomalous tail of comet

https://doi.org/10.1515/astro-2019-0009
Received Feb 02, 2018; accepted Jan 07, 2019

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, 10P/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.

Open Access. © 2019 A. G. Safarov and K. I. Ibadinov, published by De Gruyter. This work is licensed under the Creative Commons Attribution 4.0 License
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’ $\xi$, $\eta$ 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 $u$ of the comet during the observation of the anomalous tail and the ejection of a particle from the nucleus, that is, in magnitude $(u - u_1)$. 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

$$u_1 = u - \Psi + 180^\circ$$

The numerical value of the true anomaly of the comet $u_1$ 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):

$$k\frac{(t_1 - T)}{\sqrt{2q^{3/2}}} = tg\frac{1}{2}u_1 + \frac{1}{3}tg^3\frac{u_1}{2},$$

$T$ - 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, $u$ - is the true anomaly of the nucleus at the time of observation of the anomalous tail, $u_1$ - is the true anomaly of the nucleus at the moment of particle ejection, $\phi = u - u_1$ one. With the known $\xi$ and $\eta$ particles of the tail, the velocity of their ejection from the nucleus is easily determined from the relation (Orlov 1928):

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

where $\tau = 1/k$, $k$ 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 cluster 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 4th 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; Sazonenko 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 $t_1 = 02.12.1844$. 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-
| Comets        | T       | t      | t₁      | V, km/s           | V₄, 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  |
|              |         |        |         | 0.29 (Vsekhsviyatskiyi 1932) | 0.48     | 0.86  |
|              |         |        |         | 0.16 (Babadzanov 1955) | 0.38     | 0.88  |
|              |         |        |         | -                 | 0.98     | 0.91  |
|              |         |        |         | -                 | 0.84     | 0.93  |
|              |         |        |         | -                 | 0.12     | 0.97  |
|              |         |        |         | -                 | 0.53     | 1.22  |
|              |         |        |         | -                 | 0.66     | 1.24  |
|              |         |        |         | -                 | 0.73     | 1.26  |
| C/1851 U1    | 01.29-10.1851 | 22.10.1851 | 24.08.1851 | -                 | 0.14     | 0.73  |
|              |         |        |         | 0.18 (Pokrovskiyi 1915) | 0.92     | 0.40  |
|              |         |        |         | 0.10 (Vsekhsviyatskiyi 1932) | 0.92     | 0.40  |
|              |         |        |         | 0.08 (Pokrovskiyi 1915) | 0.92     | 0.40  |
|              |         |        |         | 0.06 (Orlov 1935) | 0.92     | 0.40  |
|              |         |        |         | 0.56 (Babadzanov 1955) | 0.92     | 0.40  |
|              |         |        |         | 0.67     | 0.43     |       |
|              |         |        |         | 0.73     | 1.26     |       |
| C/1877 G1    | 27.30-04.1877 | 05.04.1877 | 27.03.1877 | -                 | 0.20     | 0.96  |
|              |         |        |         | 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 | 23.01.1883 | 23.01.1883 | -                 | 0.28     | 0.81  |
|              |         |        |         | 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    | 09.93-02.1894 | 27.02.1894 | 08.02.1894 | -                 | 0.05     | 1.22  |
|              |         |        |         | 0.06     | 1.24     |       |
|              |         |        |         | 0.06     | 1.25     |       |

Continued on next page
Table 1. ... continued

| Comets | T          | t           | t₁             | 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  |
|        | 30.01.1910 |             |                | 0.51 (Orlov 1935)       |             |       |
|        | 31.01.1910 |             |                | 0.60 (Pansecchi and Fulle 1990) | 0.44        | 0.51  |
| 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 |             |                |                         |             |       |
| C/1931 P1 | 25.08.1931 | 1710.1931   | 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 | 1749-071961 | 25.021961   | 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  |

Continued on next page
### Table 1. ... continued

| Comets   | T       | \( t \)     | \( t_1 \)     | \( V, \text{ km/s} \) | \( V_A, \text{ km/s} \) | \( r, \text{ AU} \) |
|----------|---------|-------------|-------------|----------------|----------------|---------------|
|          | 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 | 2784-12.1973 | -           | 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 | -             | 0.26          | 1.23          |
|          | 15.08.1980  | -           | -           | 0.26          | 1.24            |               |
|          | 17.08.1980  | -           | -           | 0.44          | 1.29            |               |
|          | 19.08.1980  | -           | -           | 0.81          | 1.31            |               |

Continued on next page
| Comets          | t          | t₁        | V, km/s | Vₐ, 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 |
| 03.01.1998    | -          | 0.17 (Boehnhardt 2003) | 0.21 | 3.95 |
| 26.02.1998    | -          | -         | 0.51    | 4.51     |

C/1999 T2 24.46-11.2000 24.04.1999 24.05.1998 - 0.20 6.08
| 02.04.1998    | -          | -         | 0.05    | 4.86     |
| 25.04.1998    | -          | -         | 0.19    | 5.08     |

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
| 279-07.2000   | -          | -         | 0.003   | 0.76     |

Continued on next page
Table 1. ... continued

| Comets     | T         | t       | t₁       | 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  |
| 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  |
| 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  |
| 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  |
|            | 799-06.1986   | -       | -        | -       | 0.023     | 1.11  |
|            | 25.29-06.1986 | -       | -        | -       | 0.414     | 1.51  |
|            | 26.28-06.1986 | -       | -        | -       | 0.70      | 1.53  |

Continued on next page
### 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 | 23A2-08.1862  | 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 an outburst of brightness with an amplitude of 0.8m - 0.9m, 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/Encke, 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=6.76 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), 6P/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 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 $a$-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, C/1883 D1, C/1932 M1, 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.

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 particles ejection from the nucleus lies within the limits of 0 ≤ V ≤ 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).

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 Cl, 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
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 $\rho$ 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 $\rho$, 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 $15^\circ$ - $20^\circ$ and $60^\circ$ - $75^\circ$. 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  | C/1999 O1     | 0.91395 | 89.42 | 2.93  |
| C/1596 N1    | 0.56716 | 21.49 | 0.64  | C/1999 H1     | 0.70810 | 149.35| 0.92  |
| C/1600 V1    | 0.00622 | 60.67 | 0.64  | C/1999 S4     | 0.76508 | 149.38| 0.76  |
| C/1744 X1    | 0.2222  | 47.14 | 0.73  | C/1999 T2     | 3.03739 | 111.02| 6.08  |
| C/1769 P1    | 0.12275 | 40.73 |       | C/2000 WM1    | 0.555347| 72.55 | 1.55  |
| C/1823 U1    | 0.22674 | 103.81| 1.17  | C/2002 T7     | 0.61518 | 160.57| 0.64  |
| C/1844 U1    | 0.25053 | 45.56 | 0.83  | C/2004 F4     | 0.16826 | 63.16 | 0.49  |
| C/1851 U1    | 0.14205 | 73.98 | 0.64  | C/2004 Q2     | 0.170736| 78.73 | 0.97  |
| C/1877 G1    | 0.94498 | 121.15| 0.96  | C/2006 P1     | 0.170736| 78.73 | 0.97  |
| C/1882 R1    | 0.76006 | 78.06 | 0.81  | C/2010 A1     | 1.558782| 278.61| 0.91  |
| C/1883 D1    | 0.22674 | 103.81| 1.17  | C/2010 X1     | 0.482439| 1.839 | 0.98  |
| C/1885 X2    | 0.57846 | 116.95| 0.76  | C/2011 A1     | 1.558782| 4.473 | 1.76  |
| C/1892 E1    | 1.02683 | 38.70 | 1.05  | C/2011 T2     | 3.03739 | 111.02| 6.08  |
| C/1910 A1    | 0.12897 | 138.78| 0.40  | C/2011 W1     | 0.12677 | 94.50 | 0.68  |
| C/1921 E1    | 1.00845 | 132.18| 1.20  | C/2013 V5     | 0.62558 | 278.61| 0.91  |
| C/1922 U1    | 0.00775 | 142.01| 1.01  | C/2014 A1     | 2.517207| 130.26| 4.36  |
| C/1925 V1    | 0.76356 | 144.59| 0.76  | C/2014 J1     | 1.18290 | 11.72 | 1.32  |
| C/1930 D1    | 1.08711 | 99.88 | 1.26  | C/2015 E1     | 0.74849 | 64.21 | 1.51  |
| C/1931 O1    | 1.04690 | 42.29 | 1.33  | C/2016 T1     | 0.52274 | 49.06 | 1.23  |
| C/1932 M1    | 1.64741 | 78.38 | 2.03  | C/2017 A1     | 0.86895 | 34.08 | 1.08  |
| C/1935 A1    | 0.81114 | 65.42 | 0.81  | C/2018 F1     | 0.99134 | 65.42 | 0.74  |
| C/1939 B1    | 0.71649 | 63.52 | 0.74  | C/2019 O1     | 0.96265 | 113.56| 1.08  |
| C/1948 N1    | 2.517207| 130.26| 4.36  | C/2019 P1     | 0.12677 | 94.50 | 0.68  |
| C/1950 O1    | 0.67764 | 116.15| 1.31  | C/2020 B1     | 0.86895 | 34.08 | 1.08  |
| C/1961 O1    | 0.04099 | 24.21 | 0.39  | C/2020 C1     | 0.99134 | 65.42 | 0.74  |
| C/1962 C1    | 0.03139 | 65.01 | 0.42  | C/2020 D1     | 0.86895 | 34.08 | 1.08  |
| C/1968 H1    | 1.16043 | 143.23| 1.18  | C/2021 E1     | 0.42422 | 13.00 | 1.60  |
| C/1969 T1    | 0.47260 | 75.81 | 0.49  | C/2021 V1     | 0.52274 | 49.06 | 1.23  |
| C/1973 E1    | 0.14242 | 14.30 | 0.55  | C/2022 A1     | 0.99134 | 73.25 | 1.01  |
| C/1975 V2    | 0.21872 | 70.62 | 0.58  | C/2022 B1     | 0.99134 | 73.25 | 1.01  |
| C/1980 O1    | 0.52274 | 49.06 | 1.23  | C/2022 C1     | 0.99134 | 73.25 | 1.01  |
| C/1983 H1    | 0.99134 | 73.25 | 1.01  | C/2022 D1     | 0.99134 | 73.25 | 1.01  |
| C/1984 N1    | 0.29128 | 164.15| 0.55  | C/2022 E1     | 0.99134 | 73.25 | 1.01  |
| C/1987 P1    | 0.86895 | 34.08 | 1.08  | C/2022 F1     | 0.99134 | 73.25 | 1.01  |
| C/1988 P1    | 0.164558| 40.199| 0.74  | C/2022 G1     | 0.99134 | 73.25 | 1.01  |

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 sun-grazing comets is arrived at 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 conclusion

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, 3P/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 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, 19P/1918, C/1921 E1, C/1925 V1, C/1930 D1, C/1975 V2, 2P/Encke, 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.

References

Safarov, A.G. 2018. Dissertation of PhD doctors, specialty 01.03.04-planetary research, Physical-Technical Institute Academy Science of the Republic of Tajikistan, 125 p. http://ptih.tj/shuro_PhD/safarov_a/Safarov_A_diss.pdf (in Russian).
Safarov, A.G. 2017. Ecological Bull. BSEC, 4, 124-134 (in Russian).
Orlov S.V. 1935. Comets. Moscow, ONTI Publ., 280 (in Russian).
Boehnhardt, H. 2005. Earths, Moon, Planets, 89, 91-115.
Weissman, P.R., Asphaug, E., Lowry S.C. 2004. Comets II, Tucson, Univ. of Arizona Press, 337-357.
Moiseev, N.D. 1924. Russian Astronomical Journal, 1-2, 79-86 (in Russian).
Ibadinov, Kh.I. 1981. Reports of the Academy of Sciences of the Republic of Soviet Union Tajikistan, 24, 22-27 (in Russian).
Orlov, S.V. 1928. Publications De L'Institute Astrophysique De Russie, Moscou, III, 74-77.
Jaegermann, R. 1903. Bredichin's Mechanische unter suchungenu-ber Cometen formen. St. Petersburg, 500 p.
Belopolsky, A.A. 1886. Annales de l'Odbservatoire de Moskou, 2, 65-69.
Vsekhsviyatskiyi, S.K. 1932. Russian Astronomical Journal, 9, 166-172 (in Russian).
Babadzanov, P.B. 1955. Transaction Stalinabad Astron., Observatory, Tajikistan, 5, 70 (in Russian).
Pokrovskiyi, K.D. 1915. Structure tail of the comet 1910 I. Yuriev, 63 (in Russian).
Pansecchi, L., Fulle F. 1990. Astronomy and Astrophysics, 239, 369-374.
Richter, K., Keller H.U. 1988. Astronomy and Astrophysics, 206, 136-142.
Kharchuk, S.V., Korsun, P.P., Mikuz, H. 2009. Kinematics and Physics of Celestial Bodies, 25, 268-276.
Boehnhardt, H. 2003. Earth, Moon and Planets, 19-35.
Sergio, F., Rolando, L., Giannanio, M. 2002. La rivista dell’Unione Astrofili Italiani, 1, 7-11.
Pittich, E.P. 1971. Bull. Astron. Inst. Czech., 22, 143-153.
Andrienko, D.A., Vashenko, V.N. 1981. Problems of Space Physics, 16, 3-20 (in Russian).
Ibadinov, Kh.I., Buriev, A.M. 2011. News of the Academy of Sciences of the Republic of Tajikistan, 3 (144), 47-62 (in Russian).
Sekanova, Z., Miller, F. 1976. Icarus, 27, 135-146.
Ryabova, G.O. 2013. Sol. Syst. Res., 47, 236-256.
Sizonenko, Yu. V. 1996. Kinematics and Physics of Celestial Bodies, 12, 35-43.
Andrienko, D.A., Vashenko, V.N. 1981. Comets and corpuscular radiation of the Sun. Moscow, 1981, 164 (in Russian).
Shestaka I.S. 1992. Sol. Syst. Res., 26, 43-51.
Grun E., Pailer N., Fechtig H., Kissel J. 1980. Planet. Space Sci., 28, 333-349.
Jewitt D., Ishiguro M., et al. 2014. The Astronomical Journal, 147, 117 (12).
Marov M. Ya. 1994. Sol. Syst. Res., 28, 5-18.
Ibadinov Kh.I., Safarov A.G. 2015. News of the Academy of Sciences of the Republic of Tajikistan, 4 (161), 47-56 (in Russian).
Marsden, B.G., Williams G.V. 1996. Catalogue of cemetery orbits, 11th ed IAU Minor planet center, Cambridge, USA. 110.
Ibadinov K.I., Buriev A.M., Safarov A.G. 2012. Astronomy and Astrophysical Transacction, 27, 499-502.
Sekanina Z. 2000. Astrophysical Journal, 545: L69-L72. December 10.
Melosh H.J. 1984. Lunar and Planet Sci. Absctr. Pap. 15th Conf. 12-16 March, Houston. Tex., s.a. 15, 538-539.
Ibadinov K.I., Buriev A.M., Safarov A.G., Rahmonov A.A. 2015. Adv. in Space Research, 56, 187-189.
Ibadinov K.I., Safarov A.G. 2017. Bull. of TSU, Series of natural sciences, 1/2, 111-115 (in Russian).