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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

KINEMATIC AND STATISTICAL PROPERTIES OF PERIODIC COMETS

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Field of science:	Astronomy
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INTRODUCTION

The topicality and research degree of the subject. The problem of comets is one of the actual issues of modern astronomy. Comets are located in the outer regions of the solar system and have an icy nucleus. For this reason, comets were able to preserve the originality of the original matter from which they were formed. By studying comets, we can get an idea about the chemical substances that formed the solar system.

Today, by precisely determining the orbital elements of comets, it is known where they are located and how they pass through the inner regions of the Solar System. As a result of research, the Kuiper belt and the Oort cloud were identified as the main reservoirs of comets. The Kuiper Belt starts from the edge of the orbit of the planet Neptune and extends to a distance of 50 AU from the Sun. Celestial bodies located in this region are also called trans-Neptune objects. The scattered disk gives the donut-shaped classical Kuiper Belt a much wider and thicker extent. In 1950, astronomer Jan Oort proposed that certain comets come from a vast, extremely distant spherical shell of icy bodies surrounding the solar system. This giant swarm of objects, now named the Oort Cloud, occupies space at a distance between 5,000 and 100,000 AU. Comets from the Oort cloud enter the central parts of the solar system from different directions, it can be noted that this region covers the solar system spherically.

In recent decades, the study of comets has become intensive. Several real contact events, such as the Chelyabinsk meteorite, the collision of the Shumaker-Levy 9 comet with Jupiter, and the historical Tunguska event show that the comet threat is real and humanity should not be helpless in solving this problem. For this purpose, the first experiment was carried out by the DART (Double Asteroid Redirection Test) program on September 26, 2022. DART mission is dedicated to investigating and demonstrating one method of asteroid deflection by changing an asteroid’s motion in space through kinetic impact. Launched on 24 November 2021, the DART spacecraft successfully collided with Dimorphos. The collision shortened Dimorphos' orbit by 32 minutes, greatly over the predefined success threshold of 73 seconds. In terms of protecting life on Earth from such threats, the study of comets is always relevant.

Also, by studying comets, it's possible to obtain valuable information about the interplanetary environment, solar activity and the impact of this activity on comets and outer regions of the solar system.

Another topical issue is the use of information obtained from the study of comets in the finding of an unknown planet. Data on comets have long been used in the search for an unknown planet. In the discovery of unknown planets, some authors take into account the concentration of aphelions of comets, and others take into account the effects of gravity. In the research, it is mainly emphasized that the planets formed families of comets in any way and that the aphelions of these comets are concentrated near the orbit of that giant planets. After the discovery of Pluto in 1930, research in this direction was intensified. Astronomers hope that data from the study of comets will play a decisive role in the discovery of the next unknown planet in the solar system. Thus, the topic of the dissertation is relevant and the results obtained from the conducted research are of scientific and practical importance.

The object and subject of the research. The object and subject of the dissertation work is the modern classification of periodic comets, their growth dynamics over the years, and the principles of dividing periodic comets into families. In addition, the conditions of their discovery and the determination of their MOIDs for giant planets, are the topics of the dissertation. One of the topics of the dissertation is the study of their interactions with Jupiter by calculating the Tisserand's parameter for comets of the Jupiter family. The research of twin comets in the system of long-period and sungrazer comets, the study of the influence of 11-year solar activity on various comet groups, and the study of Saturn's comets – are the main topics of the dissertation.

The aim and objectives of the research. The above-mentioned shows that the increase in the number of comets and the accuracy of their parameters, the intensity and optimization of their search, play an important role in solving the comet problem. In this sense, the synthesis of the physical and dynamic parameters of comets, the study of external factors that directly affect their discovery, and the determination and generalization of relevant regularities are extremely important. The dissertation is partially aimed at these issues. The research work is aimed at achieving the following goals:

- Determining the role of the Holecheck visibility conditions in the detection of short-period comets in a real database;
- Study of the possibility of the presence of twin comets among the long-period and sungrazer comet groups;
- Investigate the influence of solar activity on long-period and short-period comets and look for additional arguments for the existence of the Saturn family of comets;
- To investigate the existence of comet families of giant planets with the help of MOID and aphelion distances;
- To analyze the possibilities of application of the Tisserand's parameter as an additional argument in the investigation of the probability of capture of short-period comets;

The scientific innovation of the research:

- The distribution of N(F) 2889 long-period comets for the 11-year phase of solar activity has been studied for the first time based on extensive statistical data. It is established that the maximum amount of comets are found in the intervals of 0.2-0.3 and 0.7-0.8 of the 11-year phase of solar activity;
- The search twin comets among long-period and sungrazer (Kreutz and Meyer group) comets were comprehensively studied and new results were obtained. It was found that the group of Kreutz and Meyer consists of many twin comets;
- For the first time, the response of short-period comets (with the aphelion ($4 < Q < 7$ AU) to the 11-year solar activity was comprehensively studied. It was determined that the maximum number of comets were observed after the period of maximum activity;
- By studying the MOIDs of comets due to giant planets, it was determined that some short-period comets enter the sphere of influence of planets. For the first time it was determined that, 309

comets are included in the sphere of influence of Jupiter, 69 comets of Saturn, and 6 comets of Uranus;

- By studying the Holecheck function, it was found that short-period comets are easier to detect when they are at perihelion, or when they are on the opposite side of the Sun from Earth. For the first time, it was established that long-period comets don't obey the Holecheck visibility condition;

- For the first time, the influence of 11-year solar activity on intermediate comets located between the orbits of Jupiter and Saturn was studied, and the result is similar to Saturn's comet family;

- For the first time, the influence of solar activity on 169 comets belonging to the Saturn comet family was investigated. It has been determined that Saturn's comets are not a continuation of the Jupiter class, but they are an independent group with different physical characteristics;

- The characteristic features of the comets "captured" by the planet Jupiter have been determined according to the Tisserand constant. It was determined that the Tisserand constant of Jupiter's comets varies in the interval $2 < T_p < 3$. As the value of the Tisserand constant approaches 3, it is determined that there is a close interaction between the planet and comets;

The main provisions of the defense:

1. Principles of the division of short-period comets into families according to giant planets, regularities of distribution of their MOIDs, aphelions and Holecheck function;
2. Existence of possible twin comets in the system of sungrazer (Kreutz and Meyer group) and long-period comets;;
3. Distribution of several dynamic parameters of short-period comets on the 11-year solar activity phase;
4. Availability of the 11-year solar activity phase distribution of short and long-period comets by the date of the first detection;
5. Effects of solar activity on the Saturn family of comets, discovery of new argument for the family's existence;

The theoretical and practical significance of the research:

The obtained regularities help in understanding the nature of sungrazer, short and long-period comets as a system, in solving the problem of the origin of both classes, in obtaining additional facts about the existence of comet families of giant planets, in ways of solving the problem of "comet threat", in the search for new comets, as well as may also be useful in considering the possible effects of solar activity.

Reliability of the obtained results:

Special attention was paid to the completeness of the processed material while performing the dissertation work. The author used Internet resources, modern catalogs and sources (NASA's JPL small body database, Marsden's catalog, Seiichi Yoshida's Japanese comet catalog) and other authors' results on the subject.

Publications: 19 scientific works have been published on the subject of the dissertation. 6 of them are scientific articles, and 13 are conference materials.

Approbation and application:
The results of the dissertation work were presented at international and national conferences, scientific seminars of the Department of Physics of Baku Engineering University and the Shamakhi Astrophysical Observatory named after N. Tusi.

The name of the organization where the research work has been carried out: The research was completed at the Department of Physics of Baku Engineering University.

Personal contribution of the author to joint works:

The author was closely involved in the formulation of the issues, collection of materials from various sources, summarization, classification, calculations, statistical analyses, construction of graphs, presentation and discussion of the final results.

The structure of the dissertation:

The dissertation was written according to the requirements set by the Supreme Attestation Commission under the President of the Republic of Azerbaijan. The dissertation consists of an Introduction (28,913 characters), three Chapters (I Chapter 76,403 characters, II Chapter 19,037 characters, III Chapter 39,222 characters), a Conclusion (2,421 characters) and a list of References. The total volume of the dissertation is 165,996 characters. 38 tables, 24 charts, and 5 pictures are included in the dissertation.

MAIN CONTENT OF THE DISSERTATION

The **introduction** substantiates the topicality of the research, the aims and objectives of the research, the research methods, the basic theses for defense, the scientific novelty of the research, the theoretical and practical significance of the research, and the name of the organization where the dissertation was conducted. The name and volume of the dissertation's structural units are indicated separately, and the dissertation's total volume is indicated with a symbol count.

The first chapter of the dissertation is titled **“Modern Classification of short-period Comets”**. In this chapter, a summary of works devoted to the question of the origin of short-period comets is given. Besides these, empirical methods for studying the chemical composition of comets and their physical conditions were analyzed and proposed nuclear models were reviewed. In the first chapter, the modern classification of short-period comets was given, and their growth dynamics over the years were analyzed. In this chapter, the issue of twin comets among long-period, Kreutz and Meyer comets was studied, and the principles of dividing short-period comets into families were analyzed. The first chapter consists of eight paragraphs. **Paragraph 1.1.** summarizes many research studies devoted to the question of the origin of periodic comets, and the formation and evolution of these celestial bodies. After the discovery of telescopes, it was determined that comets aren’t an atmospheric phenomenon. The main research works related to the issue of the origin of comets were carried out in two directions. The first of them is the "capture and multiple changes of orbit" hypothesis put forward by P. S. Laplace[1], and the second is the "eruption mechanism and its types" hypothesis of J. L. Lagrange[2]. Some researchers proposed the idea that comets are formed from asteroids or that there are cometary reservoirs in the zone of motion of giant planets. There are the

[1] P. S. Laplace, Expositi on du systeme, du monde. Paris, 1796. Лаплас П.С. “Изложения системы мира, Л. “Наука” 1982 г. с.373.

[2] J. L. Lagranje, Sur I’origine des comets, Additions a la Connaissance des temps, p. 381–395. Paris, 1812

following main hypotheses that try to explain the question of the origin of comets.

- Capture and orbital change
- Eruptive processes and their types
- The formation of comets from asteroids
- Comet reservoirs near the giant planets

In paragraph 1.2., elements of the empirical basis of the theory of comet's nuclei were reviewed and a summary of the work done in this field was given**.** Important elements of the empirical basis of the theory of comet's nuclei are as follows: photometry of comets, spectroscopy of comets, the presence of comets with meteorite substance and asteroids. Based on observational materials, three different comet nuclei models were proposed by B. A. Voronsov-Velyaminov[3], B. Y. Levin[4] and F. Whipple[5]. These models are respectively the following.

- model of a comet's nuclei as a cloud of particles
- rocky monolith model
- ice nuclei model

It should be noted that the most popular and accepted model by the astronomical scientific community is F. Whipple's icy nuclei model.

In paragraph 1.3., the modern classification of the short-period comet system is given. By early 2024 the number of discovered short-period comets is close to 900. About 15-20 short-period comets are discovered every year. In 2023, 17 short-period comets were discovered and added to comet catalogs. In the dissertation, some of their orbital parameters were analyzed to understand the nature of the short-period comet system. First of all, the dependence of their number on the periods of orbit around the Sun was analyzed.

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[3] Воронцов-Вельяминов Б.А., 1946б - Природа кометных ядер//Публ.КАО. - №1. - С. 209-211.

[4] Levin B. J. Are gases evaporated or desorbed from cometary nuclei?//NOC0. – P. 65-68.

[5] Whipple F. L. A comet model. II. Physics relation for comets and meteors// Ap.J. – V. 113, No. 3. 1951, - P. 464 – 474.

The period of 24 comets is 5 years, and the period of 433 comets is up to 10 years. The period of 638 comets that make up the class is P ≤ 20 years. There are 101 comets with periods in the interval 20 < P < 50 years. There are 58 comets in the interval 50 < P < 100 years, and 39 comets in the interval 100 < P < 200 years. The dependence of the number of periodic comets (N) on the periods of orbit around the Sun (P) is given in Chart 1.3.1.

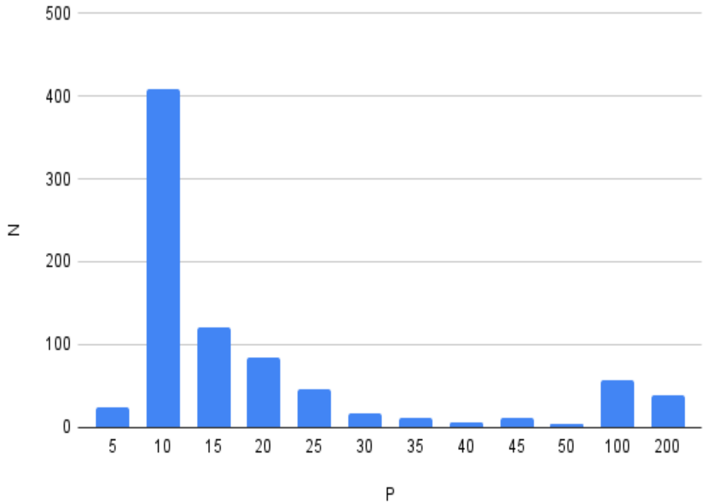

Chart 1.3.1. Dependence of the number of short-period comets (N) on the periods of orbit around the Sun (P)

When studying the distribution of semi-major axes of short-period comets, the semi-major axis of 27 comets was 2-3 AU located in the asteroid belt. These comets are characterized as main-belt comets. The semi-major axis of comet 257 is 3-4 AU, and the semi-major axis of comet 145 is 4-5 AU in the interval. The semi-major axes of the orbits of 402 out of 646 short-period comets are concentrated in the interval 3 < a < 5 AU. Chart 1.3.2 shows the dependence of the number of short-period comets (N) on the semi-major axis (a).

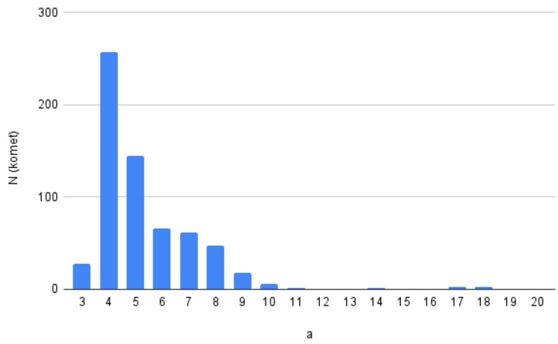

Chart 1.3.2. Dependence of numbers of short-period comets (N) on (a) semi-major axis

The inclination angles of the orbits of short-period comets to the ecliptic plane have been studied. The inclination angle of 259 comets is in the range of 0-10º. The inclination angle of 501 comets, 77% of short-period comets, is in the interval 0º < i < 20º. This means that a large number of short-period comets are concentrated close to the Sun, on the ecliptic plane. 13 comets have an inclination angle greater than 90º, they move in the opposite direction around the Sun. The dependence of the number of short-period comets on the inclination angle is given in Chart 1.3.3.

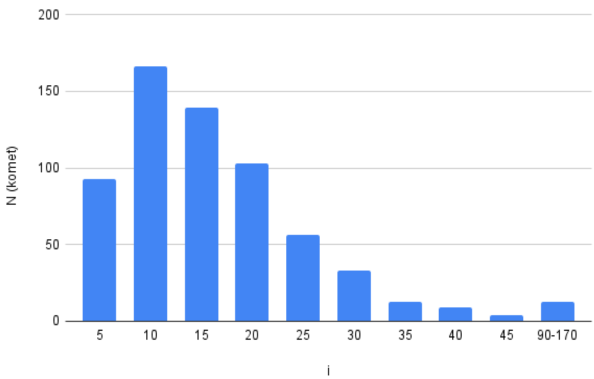

Chart 1.3.3. Dependence of the number of periodic comets (N) on the inclination angle (i)

In paragraph 1.4., the growth dynamics of the periodic comet system over the years have been studied. When analyzing the dynamics of the increase in the number of discovered short-period comets, their number is 135 comets in the catalog published by Marsden in 1989. In the catalog of that author in 2005, the information of 170 periodic comets was listed. Until March 2024, the data of 883 short-period comets were listed in comet catalogs[6]. In recent times, the rapid development of observation devices and the creation of large telescopes equipped with modern technologies have played an important role in the detection of comets. Here, the role of telescope and observation programs such as Pans-STARRS, NEAT, SOHO, and LINEAR should be emphasized. In the last 25 years, the orbital elements of 635 short-period comets have been identified and added to comet catalogs thanks to these telescope and observation programs. Due to their small size and the fact that they are far away from us, it is difficult to count and identify them all. It is estimated that the number of comets is more than 10^{12}. Table 1.4.1 lists the number of short-period comets discovered by centuries.

Table 1.4.1.
The number of short-period comets discovered over the centuries

T_{years}	1700-1800	1801-1900	1901-2000	2001– 2024
N_{comet}	6	42	200	635

In the coming years, the number of short-period comets will seriously compete with long-period comets. The increase in their number casts doubt on the idea that short-period comets are the last stage in the evolution of long-period comets. One of the tasks of this chapter is to detect twin comets in the long-period, Kreutz and Meyer group of comets. The main aim here is to avoid statistical contamination in comet catalogs and to determine their true numbers. Twin comets play an important role in studying the identification, evolution and fragmentation of cometary nuclei observed at different periods. In this way, the

[6] https://ssd.jpl.nasa.gov və www.aerith.net

identification of many short-period comets was carried out, among them, there were two or three names (P/1999 J6 = P/2004 V9 = P/2010 H3).

Paragraph 1.5. is devoted to the issue of the existence of twin comets in the system of long-period comets. In the study, the twin comets were determined by comparing perihelion (q), eccentricity (e), the argument of perihelion (ω), length of the ascending node (Ω), and inclination angle to the ecliptic plane (i) of the orbital elements of 490 long-period comets. Probably, twin comets are formed in two ways. 8 pairs formed from the fragmentation of comet nuclei and 3 pairs obtained from observation of the same comet in different periods have been identified. The result of the study is given in Tables 1.5.1. and 1.5.2.

Table 1.5.1.
Twin comets formed from the disintegration of cometary nuclei

№	Comet	q (AU)	e	ω (deg)	Ω (deg)	*i* (deg)
1.	C/1998 M5	1,742	0,996	101,284	333,376	82,228
	C/2016 T2	1,907	0,981	92,323	339,089	81,302
2.	C/2002 P1	6,530	0,984	347,801	310,672	34,602
	C/2016 P4	5,888	0,982	356,020	320,793	29,903
3.	C/1947 O1	2,827	1,001	9,375	311,796	97,331
	C/2016 K1	2,291	1,000	18,248	325,701	90,843
4.	C/1998 W3	4,914	1,001	6,889	123,918	129,191
	C/2016 A1	5,328	1,001	10,320	128,177	121,183
5.	C/1985 T1	1,317	0,983	53,000	53,012	139,069
	C/2015 WZ	1,376	0,992	66,711	40,046	134,134
6.	C/1988 A1	0,841	0,996	57,387	31,515	73,322
	C/2015 F3	0,834	0,996	57,565	31,641	73,385
7.	C/1987 H1	5,457	1,002	16,996	268,325	132,474
	C/2013 J5	4,904	0,999	19,163	256,764	136,009
8.	C/2003 HT15	2,671	0,419	124,039	81,473	27,670
	C/2013 H1	2,646	0,985	136,576	84,970	27,088

It has been statistically proven that the closeness of the corresponding parameters of such "pairs" indicates that modern comet catalogs contain a large number of comets identified with different names.

Table 1.5.2.

Twin comets formed by observing the same comet at different times

№	Comet	q (AU)	e	ω (deg)	Ω (deg)	*i* (deg)
1.	C/1743 X1	0,222	1,000	151,485	49,296	47,141
	C/2016 U1	0,319	1,000	162,751	61,427	46,433
2.	C/1922 B1	1,629	0,986	183,681	275,599	32,445
	C/2016 T3	2,656	0,976	194,520	271,809	22,661
3.	C/1757 R1	0,337	1,000	268,690	217,677	12,828
	C/2015 TQ209	1,413	0,999	281,499	224,084	11,390

The dynamics of long-period comets are complex, and their orbits can change significantly as they pass through the Solar System. This can be caused by gravitational interactions and a strong sublimation process during comet activation. As a result, it becomes difficult to find the exact of twin comets in the long-period comet population. However, comets that show some degree of similarity can provide valuable insights into the processes that shape the orbits of these celestial bodies.

In paragraph 1.6., was investigated the existence of twin comets among 1670 comets belonging to the Kreutz group. 510 pairs of comets have been identified after a thorough comparison of the orbital elements of comets by the (1.6.1) equation.

$$\Theta_j = \sin^2(\omega - \omega_j) + \sin^2(\Omega - \Omega_j) + \sin^2(i - i_j) \qquad (1.6.1)$$

Here, the condition $\Theta j < 0.0008$ is accepted so that no coincidences are allowed. Among them, two types of pairs are separated. In the first group, the period between the moments of fragments passing through perihelion is less than 3 years. The number of such pairs is 292. Within this group, 75 pairs with perihelion times in the same year were identified. The period between the moments of perihelion of the couples included in the second group is 3 years or more. The number of such pairs is 218. In this group comet pairs are obtained by the disintegration of the same comet. Some pairs are listed in Table 1.6.1.

Table 1.6.1.
Twin comets formed by comet disintegration

№	Comet	ω (deg)	Ω (deg)	q (AU)	*i* (deg)	Θ_j
1.	C/2005 M10	66.05	346.00	0.0051	145.00	0,0002
	C/2005 X9	66.07	344.26	0.0049	144.99	
2.	C/2005 E6	78.80	359.69	0.0048	144.09	0,0002
	C/2005 L7	78.82	358.74	0.0048	144.13	

Some of the pairs obtained as a result of observing the same comet in different years are given in Table 1.6.2.

Table 1.6.2.
Pairs formed as a result of observing the same comet in different years

№	Comet	ω (deg)	Ω (deg)	q (AU)	*i* (deg)	Θ_j
1.	C/1998 G5	78.29	359.89	0.0050	144.40	0,0001
	C/2007 Q9	78.34	359.06	0.0051	144.40	
2.	C/1997 V6	77.78	356.55	0.0054	144.37	0,0002
	C/2006 B3	77.76	358.51	0.0052	144.43	

In paragraph 1.7., the issue of comet pairs in Meyer group comets was studied. The Meyer group of comets is part of the Sungrazers, a family that is next in number to the Kreitz comets. This group was first studied in 2002 by amateur German astronomer Mike Meyer. The family has about 300 members. One interesting fact is that, unlike the Kreitz comets, the Meyer group has only been observed by the SOHO and LASCO.

Calculations were performed as in the Kreutz comet group. 109 comets were used in the study. The orbital elements of each comet belonging to the Meyer group were compared with the orbital elements of other members of the group using the expression (1.6.1). Here, the condition $\Theta j < 0.0008$ was adopted. Then, perihelion distances for possible pairs were compared. After such rigorous selection, two types of comet pairs were identified. In the first group, the period between observations of fragments of each pair is less than three and a half years. For most couples, this period is no more than a year. Some of the 22 pairs formed by disintegration are listed in Table 1.7.1.

Table 1.7.1.

Twin comets formed by disintegration in the Meyer group

№	Comet	ω (deg)	Ω (deg)	*i* (deg)	q (AU)	Θ_j
1.	CK09Y180	57.22	73.33	72.35	0.0353	0.0000
	CK09Y080	57.16	73.43	72.32	0.0353	
2.	C/2008 L11	57.08	73.11	72.45	0.0347	0.0000
	CK10L110	57	73.27	72.65	0.0339	
3.	C/2008 V2	57.43	72.12	71.34	0.0384	0.0001
	C/2008 K7	57.7	71.74	71.21	0.0371	

The difference in the values of the orbital parameters of the corresponding pairs (the value of Θj) is so small that it is possible to ignore them. Due to the variable intervals of the values of the orbital elements, it can be said that randomness is excluded here. Given the numbering of comets associated with perihelion moments, these pairs are likely to be fragments of recent disintegration. Another type of comet pairs was identified during the study. Unlike the previous result, here the time between the fixation of fragments is from 3 to 11 year. The number of such pairs is 12 and some of them are given in Table 1.7.2.

Table 1.7.2.

Pairs obtained from observations of the same comet in different years

№	Comet	ω (deg)	Ω (deg)	*i* (deg)	q (AU)	Θ_j
1.	CK09Y180	57.22	73.33	72.35	0.0353	0.00000
	C/2001K11	57.26	73.28	72.36	0.0339	
2.	C/2001 X8	56.15	74.35	72.28	0.0371	0.00011
	C/2007 X14	56.25	73.79	72.47	0.0345	
3.	C/2007 J1	56.99	73.87	72.59	0.0348	0.00002
	C/2000 J8	56.91	73.65	72.5	0.0367	

Studies show that a significant part of the Meyer group consists of comet pairs. There are two possible reasons for the formation of these pairs: if the period between the dates of observation of the fragments is small, such pairs can be formed by fragmentation relatively recently; if the period between the dates of observation of the fragments is 5 years or more, then the pair can be considered as the appearance of the same comet in different periods. There is no sharp boundary between the two types of couples. In general, there is reason to think that the proto-comet nucleus from which the Meyer group was formed had a relatively short orbital period. Perhaps it was one of the short-period comets belonging to the Jupiter family.

One of the main dynamic features of short-period comets is the concentration of their aphelions near giant planets.

In paragraph 1.8., the non-uniformity of this distribution is statistically justified, and this fact is an indication of the existence of comet families of the giant planets. The distribution of orbital aphelions of 836 short-period comets discovered until April 2023 was studied. There are 27 comets with aphelion distance Q < 4 AU. These are main-belt comets. 422 comets with an aphelion distance of 4 < Q < 7 AU belong to the Jupiter comet family. The aphelion distance of 38 comets is concentrated in the interval 7 < Q < 8 AU. These comets are classified as intermediate comets. The aphelion of 169 comets is concentrated in the interval 8 < Q < 12 AU. These comets can be considered to belong to the Saturn family. 31 comets are observed in the interval 14 < Q < 15 AU, which is called "centaurs". 31 comets belonging to the planet Uranus have been discovered. Their aphelion is concentrated in the interval 18 < Q < 23 AU. Finally, we can see a concentration of 21 comets aphelion near the orbit of the planet Neptune. The result of the study is given in Chart 1.8.1.

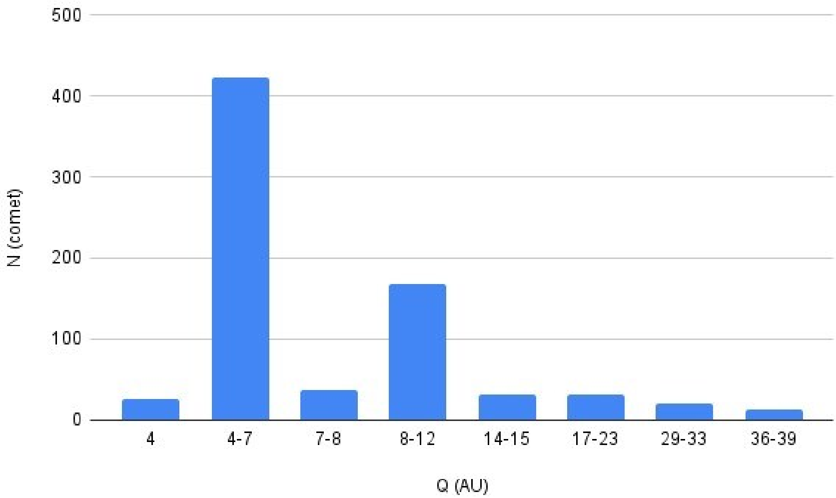

Chart 1.8.1. Dependence of the number of short-period comets (N) on the aphelion (Q)

According to the concentration of the aphelions of short-period comets, it is possible to classify them as the comet family of the planets Jupiter, Saturn, Uranus and Neptune.

Chapter II of the dissertation is named **"Effect of Dynamic and Kinematic Factors on the Short-period Comet System"**. In this chapter, the influence of dynamic and kinematic factors on the short-period comet system is investigated. Here, the main research directions are to verify that short and long-period comets satisfy the Holecheck visibility condition and to study MOIDs of comet families of giant planets. In addition, the Tisserand constant was calculated for the Jupiter family of comets and the "capture" activity of Jupiter was studied. Many factors influence the detection of short-period comets. One of them is solar activity 11-years cycle. When studying the intensity of observations of short-period comets, a sharp increase in the number of comets is observed after a maximum of 11-years of solar activity. Thus, it is known that after each maximum period of solar activity, more short-period comets will become active. To observe comets, it is important to keep the direction of the celestial sphere under control. While some comets can be observed with the naked eye during their active period (comet C/2020 F8 Swan was observed with the naked eye in mid-May 2020), most comets require observation instruments to detect them. **Paragraph 2.1** is devoted to this issue**.** Observing devices should be oriented in predetermined directions of the celestial sphere. Holecheck's visibility condition (function) is used in this research. The Holecheck visibility condition determines the relationship between comet detection periods and perihelion lengths. This function is defined by the equation (2.1.1)

$$\xi = \lambda p - L \pm 180^0 \qquad (2.1.1)$$

where, λp and L are the ecliptic longitude of the comet perihelion and Earth, respectively.

The fulfillment of the Holecheck condition has been studied for short and long-period comets. The angle ξ was calculated for each comet. Data from 591 short-period comets were used in the study. The result of the study is given in Table 2.1.1.

Table 2.1.1.

Distribution of the Holecheck function for short-period comets

ξ_{angle}	30^0	60^0	90^0	120^0	150^0	180^0	210^0	240^0	270^0	300^0	330^0	360^0
N_{comet}	41	41	55	38	42	76	41	45	58	45	56	53

As the value of ξ approaches 180°, the number of observed comets increases.

The Holecheck function was studied separately for long-period comets. The data of 1261 long-period comets discovered from 1750 to April 2020 were used in the research work. Sungrazers and twin comets were not considered in the study. The result of the study is given in Table 2.1.2.

Table 2.1.2.
Distribution of the Holecheck function for long-period comets

ξ_{angle}	30^0	60^0	90^0	120^0	150^0	180^0	210^0	240^0	270^0	300^0	330^0	360^0
N_{comet}	122	109	89	100	99	116	96	105	109	127	94	95

For long-period comets, reliable maxima were not obtained at any value of ξ. The distribution of the Holecheck function for short and long-period comets is given in Charts 2.1.1 and 2.1.2 for comparison.

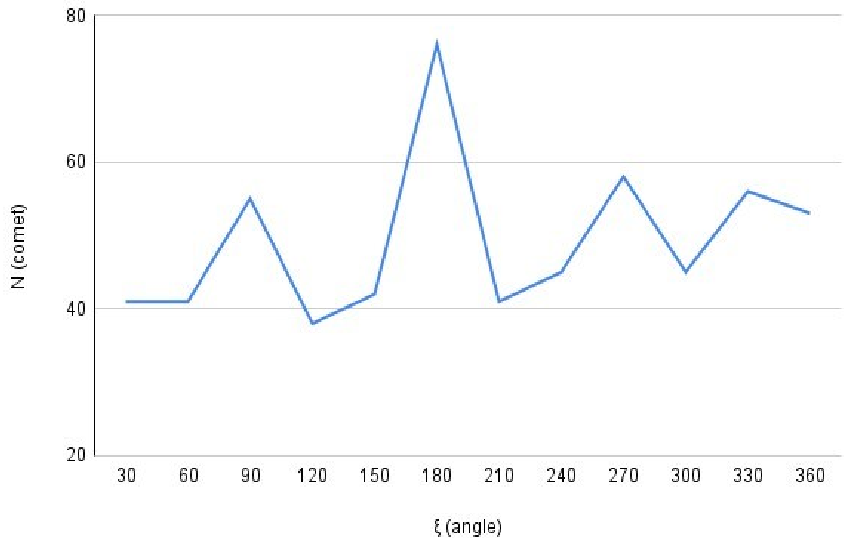

Chart 2.1.1. Holecheck function distribution of short-period comets

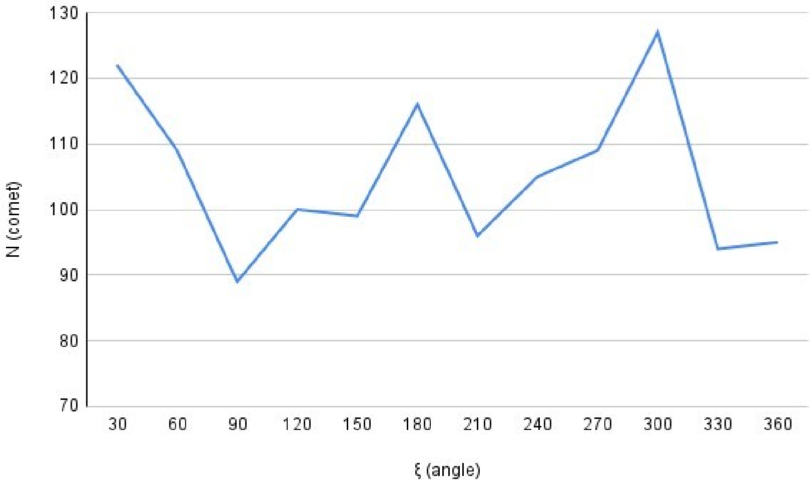

Chart 2.1.2. Distribution of the Holecheck function of long-period comets

Studies have shown that the Holecheck function combines two conditions: comets are easier to detect when they are at perihelion, or when they are on the opposite side of the Sun from Earth. It was determined that the fulfillment of the Holecheck condition is more relevant for short-period comets. Because the inclination angles of their orbital planes to the ecliptic plane are small. Long-period comets don’t obey Holecheck's visibility condition. This can be explained by the fact that long-period comets enter the solar system from any direction of the celestial sphere.

In paragraph 2.2., one of the dynamic factors influencing the change of comet orbits, their MOID (Minimum orbit intersection distance) concerning giant planets were analyzed. MOID is defined as the distance between the closest points of the orbits of two astronomical objects. In astronomy, this measure is used to estimate the potential approaches of celestial bodies and their collision risks. Here, the issue of greatest interest is the collision of celestial bodies with the Earth. Therefore, the MOID values of comets and asteroids concerning Earth are also shown in NASA's Small Object Database (JPL). Those celestial bodies are considered potentially hazardous objects (PHO - a potentially hazardous object) for the planet Earth if their Earth MOIDs are less than 0.05 AU. For giant planets, the MOID values are quite large. For example, the MOID value for Jupiter is 0.322 AU. Although the orbits of planets and small celestial bodies intersect, small MOIDs don't yet mean collisions. For a smaller object to change to another orbit with a different MOID value, it must first arrive at the same point at the same time as the larger object's orbit. In orbital resonance, two celestial bodies bound by gravity can never approach each other.

The results of the study of MOIDs of comets concerning giant planets are an additional argument that the mentioned planets have comet families. In the study, MOID values for four giant planets were calculated for 670 periodic comets with an aphelion of up to 30 AU. When calculating the MOIDs, the Danby program was used, taking into account the radius h of the sphere of influence of the planets. The radius of the sphere of influence for each planet was calculated based on the empirical formula (2.2.1).

$$h = a \left(\frac{M_{pl}}{M_S}\right)^{\frac{2}{5}} \tag{2.2.1}$$

Here, a is the semi-major axis of the planet's orbit, M_{pl} is the mass of the planet, and M_{Sun} is the mass of the sun. The result of the calculations is given in Table 2.2.1.

Table 2.2.1.
Comet families defined by MOID distances

Planet	Jupiter	Saturn	Uranus	Neptune
h, AU	0.322	0.364	0.347	0.58
N	309	69	6	0

According to the results of the calculation, the orbits of 384 out of 670 comets are included in the sphere of influence of giant planets. The existence of comet families can be confirmed based on the MOIDs of short-period comets relative to giant planets. In the worst case, 384 out of 670 comets belong to the three planet's comet family. The effect of selection significantly reduces the true numbers of these families. This fact had the least effect on the family of Jupiter and the most effect on the numbers of the family of Uranus. We can explain the non-existence of Neptunian comets for the same reason. The existence of such groups, which are considered to originate in the Kuiper Belt, is well explained by the generally accepted dynamical evolution of comets.

In paragraph 2.3., the Tisserand constant of 397 comets belonging to the Jupiter comet family (Q < 7 AU) was calculated. The mass of comets is very small compared to the mass of giant planets. Based on the three-body problem, the Tisserand constant is calculated by the following formula (2.3.1), taking into account the semi-major axis of the orbit elements of the object with a small mass, the eccentricity and inclination angle of the orbit, and the semi-major axis of the exciting object.

$$T = \frac{a_p}{a} + 2cosi\sqrt{\frac{a}{a_p}(1 - e^2)} \qquad (2.3.1)$$

Here, a_p - the semimajor axis of the planet, a - the semimajor axis of the comet, e-the eccentricity of the comet, and i - the inclination angle of the comet's orbital plane to the planet's orbital plane. The average value of the Tisserand constant of the Jupiter family of comets was determined at 2.84. The characteristic features of the comets "captured" by the planet Jupiter have been determined according to the Tisserand constant. It was determined that the Tisserand constant of Jupiter's comets varies in the interval $2 < T_P < 3$. As the value of the Tisserand constant approaches 3, it is determined that there is a close interaction between the planet and comets. In the system of long-period comets, the value of the Tisserand constant is less than 2, and in asteroids, it is greater than 3.

Chapter III of the dissertation is named **"The Forms of Influence of Solar Activity on the Short-period Comet System"**. Two main external influences on comets can be noted. The first of these is the complex processes taking place in the Sun, including solar activity. Secondly, the collisions that occur along the orbits of comets, the buoyancy forces that affect the planets during their approach, nuclear fragmentation, etc. processes such as. In this chapter of the dissertation, the form of influence of solar activity on comets will be discussed.

In paragraph 3.1., a summary of the works dedicated to the study of the effects of solar activity on different groups of comets is given. The question of the dependence of comet numbers and their orbital parameters on the phase of solar activity has a long history.

For the first time, such dependence was discussed in the works of Link and Vanisek[7]. Later, Dobrovolski[8], Sekanina[9], Guliyev[10] and other scientists conducted research in this field.

The essence of the matter is related to the spots formed in the solar photosphere. Sunspots are the most characteristic derivatives of the Sun and determine its overall activity. The intensity of the magnetic field in the sunspots is many times greater than the intensity of the total magnetic field of the Sun. According to the observations, it was determined that the process of spot formation on the Sun is repeated periodically with an average cycle of 11 years. 11-year solar activity cycles have been recorded since 1755, and at the end of 2019, the 24th cycle of 11-year solar activity has ended.

The polarity of the magnetic field in the sunspots changes every 11 years. To study the effect of this change on comets, the number of comets detected during odd and even cycles of 11-year solar activity was studied separately. The increase in the number of observations of comets is consistent with the 11-year cycle of solar activity. A huge amount of energy released into space during the period of solar activity causes the activation of comets.

The effect of solar activity on long-period comets is investigated in **paragraph 3.2.** of the dissertation. Data from 2889

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[7] Link and Vanusek, 1947, Influence de l' aktivite solaire sur le nombre des deconvertes de cometes// Compt. Rend. Acad. sci 225, p.1284-1288.
[8] Добровольский О. В., 1966. Кометы. М.: Наука. –288 с.
[9] Sekanina Z. 1962. An analysis of some problems of cometary physics based on photometric data.The c.sc. thesis. Prague. 563P.
[10] Гулиев А.С., 1985. О влиянии солнечной активности на открытие корткопериодических комет. Проблемы косм. физики.1985 –20. – с. 39–43.

long-period comets were used in the research. Comets have been observed from 1755 to December 2019.

By using data from a large number of comets, reliable results can be obtained. The study covers the period of 1-24 solar cycles. It is necessary to remove the asymmetry of the 11-year solar activity curve. For this purpose, the number of comets detected in the intervals of 0.1-0.5 of the phase was multiplied by 1.51. The result of the study is given in the Table 3.2.1.

Table 3.2.1

N(F) dependence of long-period comets

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
N_{comet}	152	199	239	189	234	360	384	426	399	307
N_{norm}	230	301	360	285	353	360	384	426	399	307

The maximum number of long-period comets was observed in two intervals of the 11-year solar activity phase. 360 comets were detected in the interval 0.2-0.3 before the maximum period of the phase and 426 comets in the interval 0.7-0.8 after the maximum period. It can be concluded that the N(F) dependence curve of long-period comets has two maxima and is given in Chart 3.2.1.

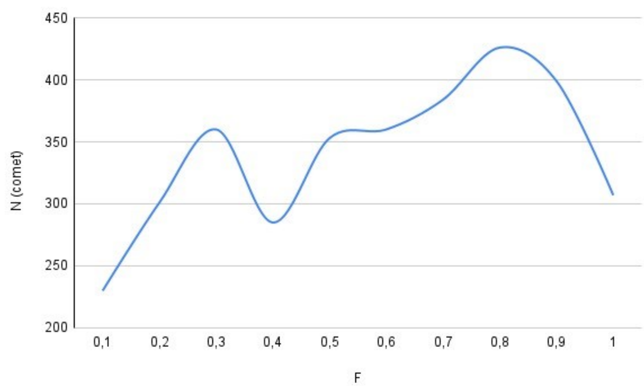

Chart 3.2.1. N(F) dependence of long-period comets. The abscissa axis (F) shows the phase of solar activity, and the ordinate axis shows the number of comets (N)

The number of comets detected on odd cycles is more than twice the number of comets detected on even cycles. The number of long-period comets detected on odd cycles was 1999, and the number of comets detected on even cycles was 890. This result can be explained by the change in the polarity of the magnetic field in sunspots every cycle.

In paragraph 3.3., the dependence of N(F) has been studied for comets with an aphelion less than 7 AU. Data from 403 short-period comets were used in the research. These comets belong to the Jupiter comet family. Such selection aims to study the effect of solar activity on comets, which are considered to be of the Jupiter family. The number of comets detected in the 0.1-0.5 interval was multiplied by 1.51 to coincide with the maximum of the solar activity cycle and the 0.5 interval of the phase. The result of the study is given in the Table 3.3.1.

Table 3.3.1.

Distribution of the number of periodic comets (Q < 7 AU) by phase intervals

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
N_{comet}	13	15	27	28	36	69	66	50	42	57
N_{norm}	20	22	40	42	54	69	66	50	42	57

The maximum number (69) of comets was detected in the phase interval of 0.5-0.6. The number of comets detected before the maximum period (0.5) of the phase was 119, and the number of comets observed after the maximum period was 284. The dependence of N(F) for this group is given in Chart 3.3.1.

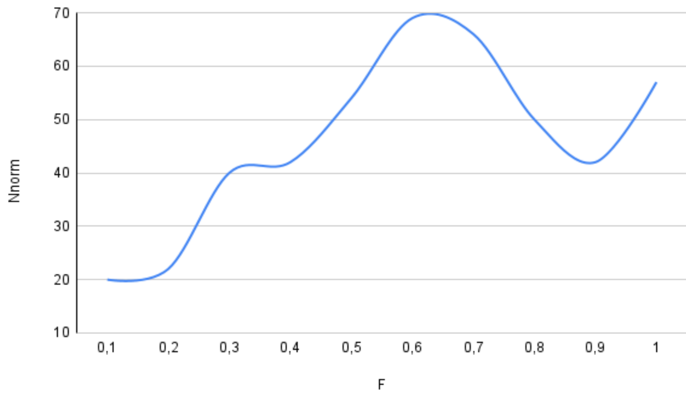

Chart 3.3.1. Distribution of the number of short-period comets (N) over the intervals of the phase (F)

The N(F) dependence of the number of observed short-period comets on the solar activity phase is different from that of long-period comets. Thus, the number of short-period comets detected after the maximum period of the phase reaches its maximum.

At the end of 2019, the 24^{th} cycle ended, and from 1755 to that date, an equal number of odd and even cycles occurred. 306 short-period comets were observed for odd cycles, and 97 short-period comets were observed for even cycles, which is about 3 times more. This suggests that the number of comets detected on odd cycles in both long and short-period comets is many times greater than the number of comets detected in even cycles. The change in polarity of the magnetic field in sunspots correlates with the number of long and short-period comets detected.

In paragraph 3.4., the dependence of several orbital parameters of short-period comets on solar activity has been studied. Here, the distribution of the angle of inclination (i), aphelion (Q) and perihelion (q) on phase intervals has been studied. In the study, the orbital elements of 592 comets observed during cycles 1-24 of solar activity and whose period is less than 20 years were studied. The dependence of the average value of the inclination angles of short-period comets on the solar activity phase shows a distribution with two maxima. The result of the study is given in Table 3.4.1.

Table 3.4.1.
Distribution of inclination angle of comets by solar activity phase intervals

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
i_{aver}	13,51	12,98	15,36	15,92	12,51	14,1	15,3	16,28	17,78	15,32
N_{comet}	38	44	43	47	48	72	74	79	60	87

The first maximum of the inclination angle is in the interval of 0.3-0.4, and the second maximum is in the interval of 0.8-0.9. Comets with a relatively large inclination angle were observed in two intervals of the phase.

One of the elements of a comet's orbit is perihelion. Perihelion is the point at which a celestial body is closest to the Sun in its orbit. When the comets pass through the perihelion, they are exposed to the destructive influence of the Sun's rays and lose a certain part of their mass. Depending on the mass and distance, comets sometimes break up and sometimes they are destroyed.The average value of the perihelions of short-period comets is 2.37 AU. This is one of the characteristics that distinguish short-period comets from long-period comets. Perihelions of long-period comets are usually less than 1 AU. The distribution of the average value of the perihelions of short-period comets ($P \leq 20$ years) on the intervals of the 11-year solar cycle phase is given in Table 3.4.2.

Table 3.4.2.
Distribution of perihelions of comets by 11-year solar activity phase

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
q_{aver}	2,03	2,8	2,34	2,19	2,28	2,35	2,14	2,46	2,28	2,25
N_{comet}	38	44	43	47	48	72	74	79	60	87

The perihelion of comets observed in the phase interval of 0.2 is larger than in other intervals (q_{aver} = 2,8 AU). During this period, comets with relatively large perihelion distances were discovered. The perihelion of such comets lies between the orbits of Mars and Jupiter.

The distribution of the aphelions of 592 comets whose orbital period is less than 20 years over the intervals of the 11-year solar activity phase was studied. The result of the study is given in Table 3.4.3.

Table 3.4.3.

Distribution of short-period comet aphelions by 11-year solar activity phase

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
$Q_{aver.}$	7,01	7,1	6,63	6,68	6,37	6,47	6,26	6,67	6,82	6,3
N_{comet}	38	44	43	47	48	72	74	79	60	87

The average value of the aphelion of a known short-period comet system with a period of less than 20 years is 7,73 AU. Relatively large (7,1 AU) comets with aphelion were detected during the initial periods of 11-year solar activity.

In paragraph 3.5., of the third chapter, the influence of the 11-year solar activity on Saturn's comets has been studied. The distribution of the number of comets belonging to the Saturn family on the intervals of the 11-year solar activity phase according to the dates of their first observation was studied. The data from 169 comets belonging to the Saturn family of comets were used in the study. The aphelion of these comets is located in the interval $8 < Q < 12$ AU. The result of the study is given in Table 3.5.1.

Table 3.5.1.

N(F) dependence of the Saturn family of comets

F	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1
N_{comet}	14	20	22	10	9	19	14	24	17	20
N_{norm}	21	30	33	15	14	19	14	24	17	20

22 comets were observed in the 0.2-0.3 interval of the phase, and 24 comets were observed in the 0.7-0.8 interval. Normalization was performed so that the maximum of solar activity coincides with the maximum of the phase. The N(F) dependence of Saturn's comets is given in Chart 3.5.1.

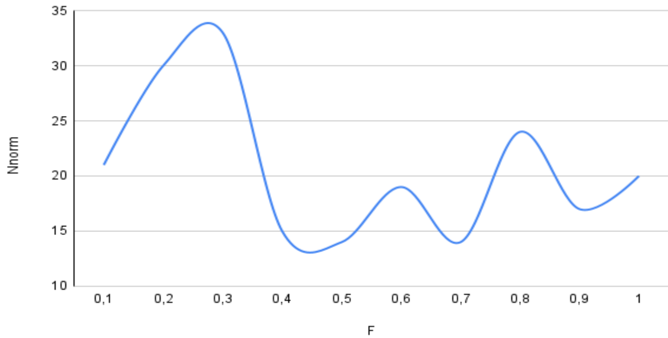

Chart 3.5.1. N(F) dependence of the Saturn family of comets. X- the intervals of the phase, Y- the number of comets

In this group, the N(F) dependence shows a distribution with two maxima. This distribution was expected to be similar to that of Jupiter's comets. Because both groups are included in the short-period comet system. However, the dependence of the numbers of Saturn's comets on the phase of solar activity was obtained as in the case of long-period comets. This can be explained by their cosmogonic origins. It is also revealed that Saturn's comets are not continuations of Jupiter's comet system. The obtained result provides additional arguments for the Saturn family of comets to be an independent group. A small maximum is noticeable in the interval of 0.5-0.6. According to the results of the study, it can be noted that the majority of the Saturn family of comets was formed from long-period comets as a result of the capture of the planet, and some of them were formed from reservoirs near the planet.

MAIN RESULTS

1. Based on the Holecheck visibility condition, it was determined that short-period comets are easier to detect when they are at perihelion and on the opposite side of the Sun from Earth. It is established that long-period comets don’t obey the Holecheck visibility condition.

2. It has been proved that it is correct to classify short-period

comets as comet families of giant planets according to their aphelion. By studying the MOIDs of the giant planets, new arguments were found for the planets to have comet families. The obtained result is an additional argument for giant planets to have comet families, and it strengthens the premises of P. S. Laplace's "capture" hypothesis.

3. The existence of twin-comets in the long-period, Kreitz and Meyer comet groups has been determined. It has been proven that the Kreutz and Meyer group consists of many pairs of comets. Depending on the time between the detection periods, some of the pairs were formed as a result of the breakup of a large cometary nucleus, and some were formed as a result of observing the same comet in different years.

4. It has been proven that the dependence of the periodic comet class on the 11-year solar activity has a maximum. A sharp increase in the number of observed comets was observed in the 0.5-0.6 interval of the phase.

5. It has been determined that the class of long-period comets and the Saturn family of comets have two maxima according to the 11-year solar activity phase. Although the Saturn family of comets belongs to the class of short-period comets, the influence of the 11-year solar activity on these comets is the same as that of long-period comets. It has been shown that Saturn's family of comets is formed from relict comets, as well as from long-period comets as a result of the "capture" activity of the planet. Based on the obtained results, it was concluded that Saturn's comets are not a continuation of Jupiter's comet family. They are an independent group with different physical characteristics.

6. When studying the effect of solar activity on different groups of comets, it was determined that the intensity of detection of comets occurs after the maximum period of solar activity. The maximum number of sunspots can explain this. For all comet groups, the number of comets detected in odd cycles of 11-year solar activity is more than detected in even cycles.

7. It was determined that the Tisserand constant of Jupiter's comets varies in the interval $2 < Tp < 3$. As the value of the Tisserand constant approaches 3, it is confirmed that there is a close interaction

between comets and planets. The small inclination angles of the Jupiter family comets to the ecliptic plane, prove that the group was mainly formed from cometary reservoirs near the planet or as a result of eruptive processes on the planet's icy moons.

The dissertation's main points were published in scientific publications and conference materials as scientific articles and theses.

1. Qasimov H.A. The search of the twin comets among the long-period comets. Journal of Baku Engineering University 2017. Volume 1, Number 1. Pg 96-99.
2. Quliyev A.S., Qasimov H.A., Farhadova T. Distribution of parameters of long-period comets in the phase of the 11- year Solar activity cycle. Journal of Baku Engineering University 2017. Volume 1, Number 2. Pg 181-185.
3. Guliyev A.S., Gasimov H.A. The Influence of Solar Activity on the Discovery of Periodic Comets of the Saturn Family. Journal of Baku Engineering University 2018. Volume 2, Number 1. Pg 82-85.
4. Qasımov H.Ə. Yupiter periodik komet ailəsinin kəşfində Günəş aktivliyinin rolu. Doktorantların və Gənc Tədqiqatçıların XXII Respublika Elmi Konferansı. Azərbaycan Dövlət Pedaqoji Universiteti. 22-23 noyabr 2018. s. 30-32.
5. Quliyev Ə.S., Qasımov H.Ə. Saturn ailəsinə mənsub olan kometlərin ilk dəfə müşahidə olunma vaxtlarının Günəş fəallığının 11-illik dövrünün intervallarına görə paylanması. Bakı Mühəndislik Universiteti. 1-ci Beynəlxalq Elm və Mühəndislik konfransı. 29-30 noyabr 2018. s. 168-170.
6. Gasimov H.A. The influence of solar activity on the discovery of periodic comets of the Jupiter family. Journal of Baku Engineering University 2019. Volume 3, Number 1. Pg 88-92.
7. Quliyev Ə.S., Qasımov H.Ə. Yupiter komet ailəsi üçün Tisseran sabitinin Günəş fəallığından asılılığı. Ümummilli lider H. Əliyevin

anadan olmasının 96-cı il dönümünə həsr olunmuş Gənc Tədqiqatçıların III Beynəlxalq Elmi Konfransı. Azərbaycan. 2019. 29-30 aprel 2019. s. 95-98.
8. Qasımov H.Ə. Dövri kometlərin periheli məsafələrinin Günəş fəallığının 11-illik dövrünün intervallarına görə paylanması. Azərbaycanın innovativ inkişafında mühəndisliyin rolu: hədəflər və perspektivlər elmi-praktiki konfrans. Bakı, Azərbyacan. BMU. 29-30 noyabr 2019. s. 222-224.
9. Qasımov H.Ə. Dövri kometlərin meyl bucağının 11-illik günəş fəallığı fazalarına görə paylanması. Doktorantların və Gənc Tədqiqatçıların XXIII Respublika Elmi Konfransı. Azərbaycan Memarlıq və İnşaat Universiteti. 3-4 dekabr 2019. s. 23-26.
10. Qasımov H.Ə. Dövri Kometlərin Eksentrisitetlərinin Günəş Fəallığının 11-illik dövrünün intervallarına görə paylanması. “Azərbaycan və Türkiyə universitetləri: təhsil, elm, texnologiya" adlı 1-ci Beynelxalq elmi-praktiki konfrans. Azərbaycan Texniki Universiteti. 18-20 dekabr 2019-cu il. s. 52-55.
11. Guliyev A.S., Qasimov H.A. The Influence of Solar Activity on Discoveries of Comets from Different Classes. Kinematics and Physics of Celestial Bodies. Ukraine 03.04.2020. Volume 36. Pg 17-21.
12. Гулиев А.С., Гасымов Г.А. К вопросу о влиянии солнечной активности на открытие комет. Научные труды Института Астрономии Академии Наук России. 14.09.2020. Том 5, выпуск 4. с. 201-206.
13. Guliev A.S., Qasimov H.A. Holechek visibility condition in discoveries the comet family of Jupiter. Ryerson University, ICTEA 2020, Canada. Pg. 3-4.
14. Qasımov H.Ə. Uzun dövrlü kometlərin aşkar olunmasında Holeçekin görünmə şərti. Ümummilli lider H. Əliyevin anadan olmasının 97-ci il dönümünə həsr olunmuş Gənc Tədqiqatçıların IV Beynəlxalq Elmi Konfransı. Azərbaycan. Iyun 2020. s. 42-43.
15. Qasımov H.Ə. 11-illik Günəş fəallığının 23-cü dövründə aşkar olunan periodik kometlərin dövrün fazalarına görə paylanması. Ümummilli lider H. Əliyevin anadan olmasının 98-ci il dönümünə həsr olunmuş Gənc Tədqiqatçıların V Beynəlxalq Elmi Konfransı.

Azərbaycan. Aprel 2021. s. 901-904.

16. Qasımov H.Ə. 11-illik Günəş fəallığının 23-cü və 24-cü dövrlərində aşkar olunan periodik kometlər. 3-cü Türk Dünyası Mühəndislik və Fən bilimləri kongresi. Türkiyə. 23-24 oktyabr 2021. s. 653-656.
17. Qasımov H.Ə. 11-illik Günəş Fəallığının 24-cü dövrü və dövr ərzində aşkar olunan periodik kometlər. Bakı Mühəndislik Universiteti. 2-ci Beynəlxalq Elm və Mühəndislik konfransı. 26-27 noyabr 2021. s. 195-197.
18. Qasımov H.Ə., Məhəmmədov R.E., Məmmədov İ.A. Günəş fəallığının 23-cü dövründə aşkar olunan parabolik kometlər. Ümummilli lider H. Əliyevin anadan olmasının 99-cu il dönümünə həsr olunmuş Gənc Tədqiqatçıların VI Beynəlxalq Elmi Konfransı. Azərbaycan. 29-30 aprel 2022. s. 74-77.
19. Qasımov H.Ə., İmamquliyeva V.İ., Alxanova A.A. Günəş fəallığının 24-cü dövründə aşkar olunan parabolik kometlər. Ümummilli lider H. Əliyevin anadan olmasının 99-cu il dönümünə həsr olunmuş Gənc Tədqiqatçıların VI Beynəlxalq Elmi Konfransı. Azərbaycan. 29-30 aprel 2022. s. 71-74.

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