INVESTIGATIONS OF THE COMETS IN SHAMAKHY ASTROPHYSICAL OBSERVATORY

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Period 1952-2013

The works performed in this direction can be classified as follows: theory of motion of the satellites of planets, comets and asteroids; the origin of asteroids and comets; physics of comets and asteroids; physics of the planets. The study of small bodies of the solar system (satellites of planets, comets and asteroids) is one of the main scientific directions of the Shamakhy Astrophysical Observatory. For a long time, the department "Dynamics and Physics of the Solar System Bodies", headed by academicians G.F. Sultanov, functioned at the observatory. Currently, the department is called "Planets and small celestial bodies." For more than fifty years, both theoretical and observational studies have been carried out in this direction. The ultimate goal of theoretical work was mainly reduced to cosmogonic constructions. Observational work covered mainly planets - giants and their satellites, and asteroids. To conduct these studies, all the main telescopes of the observatory were used, including at 2-m telescope.

Theoretical work was mainly based on observational data. The pioneering work in the field of asteroid research in the ShAO belongs to G.F. Sultanov [1]. He performed a statistical analysis of the distribution of asteroids over some invariant elements and revealed several stable family groups. Further, the author considered the theoretical aspects of the Olber's hypothesis about the origin of asteroids by the collapse of a large planet that once moved in the Mars-Jupiter zone. At first, he managed to prove that the mentioned hypothesis in its original form is not able to explain the division of minor planets into separate families. Further, the author took the position of a more promising version of the hypothesis and considered the version of repeated decay. Approaching the problem completely unbiased, the author derived the basic formulas for the elements of the orbits of the decay fragments under various initial conditions. By varying them, certain distributions of asteroids over individual invariant parameters were obtained.

Comparing a number of characteristics that occur in the statistical distributions of asteroids, the orbits of primary large bodies and their positions in space were first determined. Next, various tasks were examined to study the decay mechanism of primary large bodies, taking into account the variability of the laws of distribution of the magnitudes and directions of the relative velocity vectors of their fragments. The magnitudes and directions of the relative velocity vectors are taken as arbitrary. Under this assumption, the functions of the joint distribution of the semimajor axis and eccentricity of the orbits of the fragments of primary large bodies, as well as the longitude of the ascending node and the inclination of the plane of the orbits of the fragments to the ecliptic, are determined. It turned out that the obtained functions are generalizations of the results of previous works of the author. In a similar way, the possibilities of the origin of various groups of comets were also studied. It turned out that it has a certain similarity.

In the 1960-70s, a series of works [2] were conducted in the ShAO, dedicated to the search for the characteristics of hypothetical comets that begin to move from the surface of Jupiter and its satellites. The motion of the same hypothetical comets was investigated under the gravitational influence of Jupiter until then, when it can be neglected. Further, a comparison was made between model and real families of periodic comets. It turned out that basically, many periodic comets, judging by the main characteristics, are very similar to real ones. Thus, had been studied the classical Lagrange hypothesis about the origin of comets by an explosion on the surface of giant planets. In our century, the hypothesis was developed by the Soviet astronomer S.K. Vsekhsvyatsky. The result of the work was that the characteristics of periodic comets fit into the framework of this hypothesis, and the characteristics of long-period comets, on the contrary, contradict it. The dynamic characteristics of the motion of long-period hypothetical comets with semi-major axes (~ 10,000 AU) were studied on a computer under the assumption that, as a result of their multiple passage through the solar system, they ultimately come closer to Jupiter and find themselves in its sphere of action. Losing mechanical energy, they are transformed into short-period comets. Of the 300,000 hypothetical studied - initially almost parabolic comets - about 2,000 cases of capture occur. Of these captured comets, after leaving Jupiter, 301 turned out to be hyperbolic. The rest switch to elliptical (1600) and even meet 80 cases when their circulation periods are less than 80 years. Thus, in fact, it was once again unlikely that the capture of comets into short-period orbits was proved. But on the other hand, a comparison of the main characteristics of the two categories (real and hypothetical) comets revealed a certain similarity. Consequently, the orbital features of periodic comets do not give an unambiguous answer to the question of their origin. These studies have once again shown that to solve the problem of the origin of comets, celestial-mechanical premises alone are clearly not enough. Other criteria are required, which are most likely related to the astrophysical parameters of comets. Along with hypothetical comets, objects of research of ShAO employees also became real comets of their classification.

The analysis of individual comet families was carried out, their structural features and interactions were studied. Research was conducted through the prism of cometary cosmogony. Clarity has been clarified on the discussion of the division of periodic comets into separate families. The question of the possibility of forming comet families of large planets was considered in detail [3]. Particular attention was paid to the criterion for the classification of periodic comets by individual families.

The question of the possibility of forming comet families of large planets is examined in detail. Particular attention is paid to the Uranus family [4,5]. On the other hand, it has been proven that the “Neptune family” does not actually exist. In the cosmogonic context, the question of the secular decrease in the brightness of comets is considered and it is established that the age of active residence of periodic comets does not exceed 1000 years.

For the first time, data on the spectral characteristics of comets were used in cosmogonic analysis [6].

The duality of the structure of the cometary family of Jupiter has been established [7]. According to the advanced version, one of the groups consists of “home-born” comets, their absolute majority in the family, and the second contains “newcomer” comets, which are captured from long-period comets associated with giant planets.

For the first time, the spectrum of values of the constant Tisserand for periodic comets was examined in detail and the methodology for their use in cosmogonic arguments was determined [8]. A qualitatively new interpretation of the irregularity of the perihelion of long-period comets in the celestial sphere is given [9].

New ways of using cometary data in solving the problem of unknown planets and their prediction have been revealed [10]. In total, in these works more than fifty laws were established, both for the entire system of comets and for their individual groups.

In addition, a number of works have been analyzed related to existing cosmogonic theories and hypotheses [11, etc.].

One of the directions in the study of small bodies of the solar system is the problem of the origin of short-perihelion comets. Often they are called comets that scratch the Sun or as sungrazers. Such comets are clearly concentrated in separate groups bearing the names of scientists who identified the corresponding groups (Kreutz, Meyer, Marsden, Kracht). According to 2011 data, their number exceeds 2000. There are several hypotheses in the scientific literature explaining the origin of such cometary groups, but they are not always able to explain the nature and number of the mentioned groups. Since 2010, the ShAO has been developing a qualitatively new theory [12], according to which these cometary groups are formed as a result of the collision of proto-comet bodies with meteor showers. In the cited source, the distances and planes where the alleged collisions occur are calculated. In addition, it was possible to identify another group of sungrazers [13] and a number of twin comets. In general, the developed theory is free from internal contradictions and is promising.

A new approach to the so-called "hyperbolic" comets has been developed and is being developed in the ShAO [14, 15]. There are 37 known cases when the initial 1/a turns out to be negative, i.e. the corresponding comets are hyperbolic (hereinafter HC). The analysis shows that the proportion of HC in the total set of comets is gradually growing. Initially, 4 versions of the existence of HC were considered: 1. a hyperbolic excess of the heliocentric velocity of the comet's nucleus arises as a result of the physical processes occurring on it; 2. hyperbolic excesses of eccentricities are the result of errors either in the determination of orbits, or in the determination of “initial” orbits; 3. HCs are of interstellar origin; 4. hyperbolic excesses of eccentricities is the result of unknown and unaccounted factors. The absence of a concentration of HC perihelion near the apex of the peculiar motion of the Sun, as well as regularities in the 1/a distribution, exclude the version of interstellar origin of the HC. The chaotic nature of the 1/a time distribution contradicts the second version. It was found that the HCs practically do not differ from other long-period comets in the parameters L, q, i. The absence of a difference in the HC from the total population with respect to the parameter q creates difficulties for the version about the non-gravitational nature of the hyperbolic excess of the velocity of HC, since in this case the latter should have extremely small q. By “unaccounted for” factors, we can mean the influence of dwarf and unknown planets. Indeed, the orbits of some HCs are located so that in the recent past they could receive some gravitational acceleration from dwarf planets. The author of this work in his earlier works assumed the existence of 4 unknown planets and, based on some calculations, gave the planes of their motion and average distances. A large role in this sense could be played by a large trans-Neptune body moving in a plane with parameters $\Omega = 273^0$; $I = 86^0$ and at a distance of 250-400 AU. Indeed, a noticeable concentration of HA is observed near the indicated plane with respect to parameters B and i. Further, a series of new evidence was found in favor of the assumption of the role of TNO in the formation of hyperbolic cometary orbits [16]. In particular, some aspects of the hypothesis about the connection of hyperbolic comets with large Kuiper bodies with a diameter of more than 200 km, as well as with unknown planets, the existence of which is assumed in the trans-Neptune zone, were considered.

For 37 hyperbolic comets and 91 trans-Neptune planetary bodies, the MOID values are calculated. Hyperbolic comets have been shown to be very close to TNO compared to others. The same problem has been solved with respect to hyperbolic comets and unknown planets. The calculation results show that hyperbolic comets can play a significant role in the search for such planets.

The observatory pays much attention to the search and detailed study of many cometary groups. In particular, the possibility of the presence of periodic and long-period comets dynamically or evolutionarily associated with Pluto was considered in [17, 20]. As a result of the analysis of the distant nodes of the orbits of long-period comets relative to the plane of motion of Pluto, a group of 51 comets was distinguished (currently this number has doubled). A comparison with other planes showed a redundancy in the number of such comets. It is especially noticeable in comets with $e<1$ and in comets discovered after 1950. The results obtained show that the assumption of the presence of a cometary family of the planet is quite realistic. It was also found that comets in this category have a number of distinctive properties. In particular, «plutonic» comets are relatively weak compared to others [21].

From a similar point of view, the question of the relationship of cometary groups with other TNOs, in particular with Eris [22], as well as unknown planets [23], the existence of which is supposed by the observatory staff, was studied.

The search for twin comets among the known long-period comets has also become an object of study in the ShAO [24]. In the cited source, the closeness of the following parameters was considered as the selection of comet pairs: perihelion distance; perihelion argument; the longitude of the ascending node and the inclination of the orbit. In total, 33 conditional cometary “pairs” were distinguished. They were classified into 3 categories: “pairs” - probable fragments of decaying cometary nuclei; “Pairs” are the possible occurrences of the same comet in different eras; “Pairs” are of interest for identifying cometary appearances. It was statistically proved that the proximity of the parameters of the corresponding “pairs” is practically not explainable by permissible fluctuations in the distribution of cometary parameters.

As is known, many comet experts recognize only the existence of a family of periodic comets of Jupiter. As a result of multivariate analysis, it was established in [25, 26] that the families of Saturn and Uranus also exist, and in percentage terms they grow faster than the families of Jupiter.

During the analysis of the system of long-period comets, ShAO employees found a number of patterns. Among them, the detected concentration of aphelion near the plane perpendicular to the ecliptic and the local maximum in the distribution of nodal distances in the range from 250 to 400AU. It is very important that a similar maximum exists in the distribution of aphelion distances of long-period comets. The combination of these two patterns, according to the authors of [27], indicates the presence of a very large trans-Neptune body on the periphery of the solar system.

In general, according to calculations of ShAO employees [28] in the solar system at distances of 35, 53, 80, 110, and 165AU large Kuiper bodies move, being the sources of a significant part of the observed comets.

The problem of the origin of comets is a priority in the activities of ShAO. The results obtained in this direction can be classified as follows:

- the dual structure of the family of periodic comets of Jupiter;
- patterns in the distribution of perihelion of comets of the family of Saturn and Uranus;
- patterns indicating the connection of a certain part of comets with trans-Neptune bodies;
- patterns in the secular fall of the brightness of comets; assessment of their age;
- Patterns in the distribution of the values of the Tisserand constant for periodic comets
- critical analysis of the Oort hypothesis
- critical analysis of the interstellar concept of comets
- Analysis of the spectral characteristics of long-period comets
- modified version of the eruptive concept of the origin of comets

In the ShAO, the light curve of the famous Halley's comets (1P) was studied in detail before and after the comet passed through the perihelion in 1986, taking into account factors such as phase angles, elongation, solar activity level, etc. [28,29,30] In the analysis of about 4400 comet brightness estimates, a number of periodicities were established coinciding with the periods on the Sun.

The light curve of the famous Schwassman-Wachmann comet (29P) was studied in a similar manner. Recall that such an analysis is possible only if the observation of the comet covers an extended interval of distances (several AU) and a large period of time (several years). In addition, the number of observations should be in the hundreds and thousands.

The observatory constructed and studied in detail the light curves of 120 periodic comets (a total of 502 occurrences), taking into account the elongation of perihelion [31]. As a result, the fact of the secular loss of brightness of periodic comets was confirmed, and it was also proved that comet families of giant planets also differ in the characteristics of the parameters of light curves.

From a similar point of view, the light curves of about 150 long-period comets were studied [32,33]. As a result of this analysis, 40 previously unknown outbursts of brightness were identified. Later it was proved that meteor showers play a significant role in the flare activity of comets [32,33,34]. When comets pass through meteor showers, the received impacts not only lead to the decay of comets, but also provoke a short-term increase in brightness due to exposure of part of the surface of cometary nuclei. A number of consequences follow from this hypothesis regarding the dynamic parameters of “flashing” comets, in particular, the ascending and descending nodes of their orbits. An analysis of the available material on the outbursts of the comet’s brightness and a comparison with the data on meteor showers show that these consequences receive real confirmation. From a similar point of view, the phenomenon of the disintegration of cometary nuclei was also studied [35,36,37]. Calculations showed that often comets that pass through meteor showers are often exposed to decay.

As we have already noted, among the works carried out in the ShAO on comet physics, there is a series of articles devoted to the influence of solar activity on the distribution of cometary parameters. In these works, it was established that long-period and short-period comets react differently to changes in solar activity. The brightness of the former increases during the ups and downs of activity, while the latter are more active during the period of maximum and post-maximum era. If the bimodal distribution of long-period comets was known even earlier, then the single-vertex distribution inherent in short-period comets was established for the first time. The idea that this difference can be used in comet cosmogony has been grounded on [38]

As you know, comet-asteroid hazard is one of the urgent problems that humanity can face. This topic is also the subject of a number of works [39,40] by the observatory specialists. In particular, the calculations performed by our astronomers show that the frequency of collisions of comets with the Earth is about 960 years. The book [37], co-authored with Ukrainian astronomers, details various aspects of this problem.

In the period 1999-2013 on 2m telescope obtained the echelle spectra of two bright comets - C/1999 S4 (LINEAR) and C/2004 Q2 (Machholz). In this case, the second was observed precisely at the moment of disintegration. As a result of the analysis of these spectrograms, many known and unknown molecular lines [41, 42] in the atmosphere of two comets were identified.

The photometric features of comet West (1975), one of the brightest comets of the 20th century [43], were also studied. Some physical parameters, the expansion rate of individual fragments of the nucleus, the instantaneous mass of the atmosphere, etc., are determined.

Among the works on the physics of comets, the new statistical approach to the study of their brightness drop should also be noted [44]. This approach, in addition to the time factor, also takes into account the change in the elongation of periodic comets from appearance to appearance.

Period 2014-2019

1. A hypothesis was created about a large planet that exists at a distance of 250-400AU and transfers observable comets. The hypothesis is based on the regularities of the motion of comets from distant regions of the solar system. It has been proved that there is a plane around which comet perihelion are concentrated. Its parameters: $Ip = 86^0.2$; $\Omega p = 272^0.7$ This plane might be the result of the influence of a planet that exists at a distance of 339AU As a result of the analysis of comets, the elements of the planet's orbit were estimated as follows: $a = 339AU$; $e = 0.16$; $\omega = 57^0$; $\Omega = 272^0.7$; $I = 86^0$. It is assumed that its mass is around 1-10 Earth masses [62,63,67,69].
2. The effect of 11 years of solar activity on the detection of different classes of comets has been studied on the basis of new data. It has been confirmed that the comet family Jupiter and long-period comets show different views in this sense. In the first group, two-maximum distributions were obtained in one-maximum and long-period comets. The extremes of these distributions do not overlap. It is shown that this difference is not rooted in external factors (comet visibility, differences in orbits, etc.). The study of this factor has provided additional indirect evidence for the existence of the Saturn comet family.
3. On the occasion of the 650th anniversary of Nasimi, in accordance with the relevant decree of the President of the Republic of Azerbaijan, we submitted a request to the International Astronomical Union to name a small planet after the poet. The catalogue number of the asteroid Nasimi is 32939, and the zone of motion is the asteroid belt between the planets Mars and Jupiter. The planet was discovered by Czech astronomers at the Klet Observatory on October 24, 1995 and has long been known as 1995 UN2.
4. The parameters of the luminosity curves of 319 comets belonging to different classes were calculated, and their absolute stellar dimensions were determined. Several articles have been published in this direction [60.65 et al.]

5. The dependence of the physical properties of Trans-Neptune Objects on their orbital parameters is studied. The fact of the matter is that TNOs exhibit dual features at very small inclination angles. Thus, when their inclination $i>5^0$ is large, the color properties shift to the blue region, and when $i<5^0$ is small, they shift to the red region. That is, the price of 5^0 for the trend plays the role of a "red" line. In the initial approximation, it was found that the inclination parameters of all classes of TNOs form a very strong correlation with the blue-red (B-R) color differences of their spectra. The reliability coefficients of these correlations are also quite high. The existence of such a connection suggests that many of the TNOs settled in the Neptune zone as a result of the collision. Studies have shown that the angle of inclination shifts to blue. To prove that the collision hypothesis is true, it is necessary to study the dynamic dependence of color difference on other parameters. No such significant dependence was found on the established modelling. Instead, a new theory has been put forward to explain this. Thus, the reason for the color shift is not the mechanism of the collision, but the scattering of sunlight from dust particles, as in the Earth's atmosphere. The size of these dust particles should be in such a range that relay scattering occurs in that range. Our calculations assume that this region is in the order of $10nm<d<400nm$. Light from the sun is scattered when it reaches the surface of the Trans Neptune Object, so those with a relatively large angle of inclination (i>50) are blue and those with a low angle of inclination (i <50) are red. In other words, the idea of a strip of dust or micro-particles in the Trans-Neptune zone is put forward, and it should be noted that this is the first time such a provision has been submitted to the scientific arena. Thus, our final conclusion is that all this colour difference is observed by the scattering of the sun's rays both on the surfaces of the TNO and on the gas-dust particles surrounding it. This is easily explained by the popular relay scattering. The reason why TNOs show different properties is not only due to their surface composition, but also due to the optical refraction of the sun's rays [53].
6. The calculation of the Tisseran constant for about 1,200 long-period comets relatively to large-mass transneptune bodies (their number is 159) has been completed. A statistical relationship was found between the constants in the 2.5-3 range and the parameter a of the TNOs, and other types of relationships were identified [52,57,59,66].
7. Long-term studies have shown that meteor showers play a special role in the formation of hyperbolic comets [72]. Statistical analysis of the dynamic parameters of these two groups of celestial bodies: 300 long-period comets and 112 meteor showers gives us reason to say that there is a strong enough dynamic connection between these objects. As a result of the collision of long-period comets with these meteor showers, the parameters of comets, especially the price of eccentrics, approach the unit, and thus comets with parabolic orbits begin to move along the hyperbola.
8. The study of the effect of large meteorites that may exist in known meteor showers on the fragmentation and increase of brightness of comets, the formation of hyperbolic comet orbits was continued [46,49,50,51,54,58,68,72,73]. The distribution of fractions at a certain distance from the orbit of meteor showers (0.001, 0.005, 0.01, 0.05, 0.1AU) was considered. The parameters of 114 fragmented comets and up to 120 confirmed meteor showers were used to solve the problem. It has been confirmed that the number of comet faults has increased in some floods. The distribution of the angles of collision is currently being studied. Such a distribution is likely to be dominated by head-to-head collisions. Spectral study of one of the fragmented comets (C/1999 S4 (LINEAR)) was performed [64].
9. For the first time, with the help of modern integrators, a close convergence between several comets and large-mass TNOs was discovered [55,56,71]. This new fact proves once again that TNOs play a role in the transfer of comets from the Kuiper belt. The dynamic evolution of newly discovered small objects - damacloids has been studied [47,48].

10. For the first time, meteor bodies with hyperbolic orbits were studied on a new basis [45]. It has been shown that the hyperbolic increase in their eccentricities cannot be explained only by errors in measurements and the gravitational influence of giant planets. It has been proven that distant planetary bodies, especially Kuiper bodies, play a role in their formation.
11. The 5,000-year orbital evolution of the 55P periodic comet has been studied. It has been shown that during that period, the comet was not occupied by either the Kuiper belt or the long-period comet class. [74].

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