Conference materials
UDC 521
DOI: https://doi.org/10.18721/JPM.161.281

Analysis of comet C/1969 Y1 parameters using isophote structural modeling

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Abstract. This work is devoted to the construction of a brightness structural model of the long-period comet Bennett C/1969 Y1. This comet belongs to the comets of the Jupiter family (JF) and has a Tisserand's parameter T > 2. Determining the brightness characteristics of the comet has been one of the most important goals of cometary observations over the past century. The complexity of such studies lies in the fact that we are dealing with extended sources moving relative to background stars. The problem of obtaining reliable estimates of the distribution of brightness parameters (BPs) for long-period comets also remains especially important, because for many of them observations were made back in the days when high-precision methods, such as CCD-matrices and other technical tools, were not available. At the same time, most of the determined stellar magnitudes of long-period comets were related to the gaseous coma surrounding the comet's nucleus, and not to the comet's nucleus itself. At the same time, cosmic ultraviolet observations of comets in the Lyman-alpha hydrogen lines made it possible to obtain very important data for estimating the emission of H_2O by the cometary nucleus, as well as other types of molecules (e.g. C2, C3, CN, OH). In the presence of dependencies between the productivity of the H_2O cometary nucleus and its brightness characteristics, the determination of BPs of cometary nuclei has acquired a new meaning. However, the dependence of the size of the nucleus on its BPs is not linear, since there is a correlation with the albedo of the surface of the nucleus. In this work, BPs and albedo for comet Bennett C/1969 Y1 are studied. Taking into account the data obtained and the solution of the described problems, we applied the author's isophote method to analyze the structure of the brightness characteristics of Bennett C/1969 Y1.

Keywords: comets, planetary science, isophote analysis

Funding: This work was supported by Russian Science Foundation, grant 22-72-10059.

Citation: Churkin K.O., Andreev A.O., Nefedyev Yu.A., Kolosov Yu.A., Korchagina E.P., Demina N.Yu., Borovskih V.S., Analysis of comet C/1969 Y1 parameters using isophote structural modeling, St. Petersburg State Polytechnical University Journal. Physics and Mathematics. 16 (1.2) (2023) 530–535. DOI: https://doi.org/10.18721/JPM.161.281

Материалы конференции
УДК 521
DOI: https://doi.org/10.18721/JPM.161.281

Анализ параметров кометы C/1969 Y1 с использованием метода изофотного структурного моделирования

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Аннотация. Настоящая работа посвящена построению структурной модели долгопериодической кометы Bennett C/1969 Y1. Эта комета принадлежит к кометам семейства Юпитера (СЮ) и имеет параметр Тиссерана T > 2. Определение яркостных характеристик кометы было одной из важнейших целей кометных наблюдений в последнее столетие. Сложность таких исследований заключается в том, что мы имеем дело с протяженными источниками, движущимися относительно фоновых звезд. С учетом полученных данных и решения описанных задач мы применили авторский метод изофот для анализа структуры яркостных характеристик Bennett C/1969 Y1.

Ключевые слова: кометы, планетология, изофотный анализ

Финансирование: Работа поддержана Российским научным фондом, грант №. 22-72-10059.

Ссылка при цитировании: Чуркин К.О., Андреев А.О., Нефедьев Ю.А., Колосов Ю.А., Корчагина Е.П., Демина Н.Ю., Боровских В.С. Анализ параметров кометы C/1969 Y1 с использованием метода изофотного структурного моделирования // Научно-технические ведомости СПбГПУ. Физико-математические науки. 2023. Т. 16. № 1.2. С. 530–535. DOI: https://doi.org/10.18721/JPM.161.281

Introduction

Comets were seen in ancient times and were considered random incoming objects in the celestial sphere. Comets can be of different types, have different brightness of the nucleus, its size and chemical composition. Comet tails also have differences in their length, width and number of rays. The motion of comets obeys Kepler's laws and they move along orbits with different parameters [1, 2]. Comets also differ in color: they are blue, green, pale orange and yellow. The orbits of comets, unlike the planets, are strongly elongated ellipses; in addition, the planes of the comets' orbits do not coincide with the plane of the planets' orbits [3, 4]. There are short-period (P) comets with a period of less than 300 years and long-period (C) ones [5]. In the names, after indicating the periodicity of the comet, the year is usually indicated, and then a letter characterizing the quarter of the month in which it was discovered is written, then the first discoverers of the comet are indicated in brackets [6, 7].

It is more convenient for astronomers to observe and study large comets, however there is no exact definition of "large comet". It can be said that the approximate brightness of such comets near the perihelion is in absolute terms greater than $6^m - 7^m$ [8]. Their perigee distance is about 0.6 AU, and the distance when passing near the Earth does not exceed 15 million km. Examples of large comets with the longest Earth passing distances are C/1961 T1 (Seki) and C/1996 B2 (Hyakutake), and one of the shortest is D/1770 L1 (Lexell) (2.26 million km) [8].

Издатель: Санкт-Петербургский политехнический университет Петра Великого.

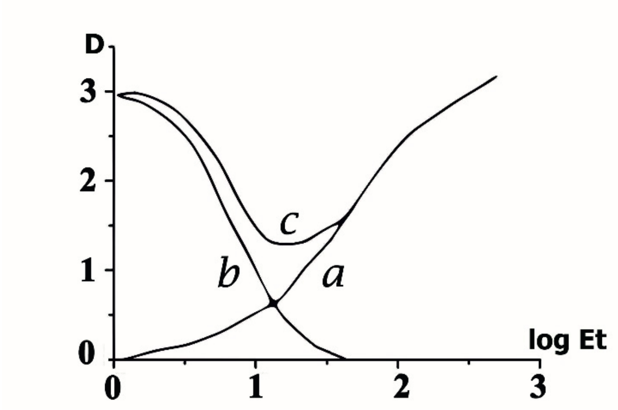

Fig. 1. Curve of the change in the light density of the image (D) on the logarithm of the brightness strength (*Et* is the brightness *E* multiplied by *t*): gradient curve for negative comet image (*a*); gradient curve for positive comet image (b); integrated darkening of the image with the determination of isophotes with the same light density (*c*)

Materials and Methods

Isophotes are areas that have the same brightness density. The boundaries of isophotes are determined on the basis of the pseudo-solarization law and, in doing so the developed author's automated software package is used. The method is shown in Fig. 1. First, we get a negative image of the comet. After this stage, using the software package, a positive image is created from the negative image of the comet. The method of creating the isophote system consists in the modern interpretation of the method described in [9, 10], and is as follows: To construct isophote regions with specified parameters, the approach of simulating the change in brightness was used (Fig. 1).

Results and Discussion

Comet Bennett C/1969 Y1 is one of the brightest small celestial bodies. C/1969 Y1 at perihelion was quite close to the Sun (0.54 AU) and its brightness was greater than 0^m. The comet had a complex tail structure. Around the head of C/1969 Y1 there was a large cloud of hydrogen with a size of more than 12 million km [11]. Parallel to the elongated structure of the comet's head was the comet's tail. The light force at the center of the comet could be as high as 0^m.

Fig. 2 shows an isophote model of comet Bennett (C/1969 Y1). The first isophote represents the brightest region of the C/1969 Y1 head. The second isophote has a circular structure. Next, come the isophotes that are distorted towards dust emission from the Bennett nucleus. The structural center of the C/1969 Y1 image has an irregular shape. The isophotes are quite close to each other, and the difference in light density between the isophotes is 0.07^m. The differentiated change in the light density of the first isophote to the ninth is 3.50^m.

The C/1969 Y1 isophote model proves that the structural elements are sufficiently self-similar. When the comet passed perihelion, the radiation from C/1969 Y1 was quite significant, but the cloud of particles ejected by the comet did not change. One of the hypotheses to explain this effect is that large-scale formations in the structure of comets are a consequence of the radiation of the cometary nucleus under the influence of its rotation. Since comet C/1969 Y1 does not have such cometary material radiation elements, this means that Comet Bennett does not have separate outgassing regions, and the radiation is uniform throughout the cometary nucleus or the radiation sources did not pass through the terminator.

It has been established previously [12] that the emission of dust particles occurs mainly from the side of the comet that is turned towards the Sun, so the next conclusion is that the surface of the cometary nucleus was cleaned at the moment of crossing the perihelion and a large number of emitted particles were formed. At the same time, C/1969 Y1 does not have a pronounced cometary tail, although the emission by cometary head should have captured many dust particles.

Conclusion

In this work, an isophote model with a clearer structure, compared to previous works, was built. This made it possible to evaluate BPs with higher accuracy and reliability. In addition, we also determined the brightness characteristics of the nucleus, coma, and tail of Comet Bennett (C/1969 Y1). At the same time, there are works in which it was found that large-scale structures in cometary coma lead to significant radiation from nuclei caused by the rotation of the nucleus [12]. In addition, according to the approach described in [13], it can be concluded that H_2O emission from the cometary nucleus is limited.

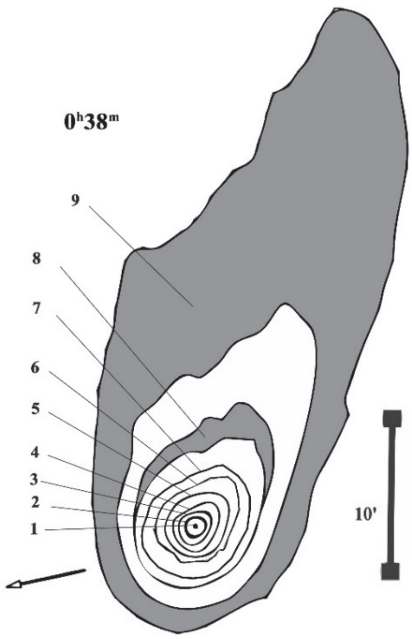

Fig. 2. C/1969 Y1 isophote model

At present, the study of comets has moved to a higher level [14–16]. Space missions are used to observe small bodies of the Solar System [17–22]. The means of processing observations are also being improved [23–24].

It should also be noted that over time, the orbits of comets undergo changes and evolve, as the comet is subjected to various gravitational effects from the planets. This is especially evident when comets pass near giant planets and other celestial bodies, as well as under the influence of non-gravitational effects associated with the fact that comets emit dust and gas. M. Krylikowska (2004) [25] presents the results of an analysis of the influence of non-gravitational effects (NGEs) on the motion of 60 long-period comets, including Bennet (C/1969 Y1). The analysis took into account that water evaporation reaches its maximum a few days before or after the comet passes perihelion [26]. The parameters of NGE were obtained for the model of forced precession with the standard function g(r) for Comet Bennett. All parameters of NGE were determined for 19 comets, of which, for 14, the axes of rotation of the comet nuclei were also determined. For the first time, non-gravitational effect was discovered in the motion of the following comets: /1999 H1 Lee, C/1991 T2 Shoemaker-Levy, C/1999 J3 Linear, C/1975 T1 Mori-Sato-Fujikawa, C/1987W2 Furuyama, C/1991 B1 Shoemaker-Levy [26]. It was also found that the average value of the non-gravitational effect for long-period comets is 10 times greater than the average value of non-gravitational effect determined for short-period ones.

Determining the size of the nucleus is a difficult task, since the size also depends on the surface albedo of the nucleus. Delsemme & Rud (1973) [27] made the first attempt to determine the radius of the nucleus and albedo for comets C/1969 Y1 (Bennett), C/1969 T1 (Tago-Sato-Kosaka) and 2P/Encke using the dependence between the emission velocity of comet H2O near perihelion and the magnitude of the comet's nucleus [28]. Gonzalo Tancredi and a group of researchers analyzed the observed nuclear magnitudes of comets and compiled a catalog for comets of the Jupiter family [14]. The Comet Light Curve Catalog (CLICC) were used, and the research team's own observations were used [14]. The catalog contains comets with a nucleus up to 12.8^m (39P/Oterma) and no weaker than 19.3^m (45P/Honda-Mrkos-Pajdusakova) [29].

The EAO Digital Library has 2145 digital images of comets and small celestial bodies. The study of these celestial bodies with a new approach will make it possible to build new three-dimensional models and determine the physical parameters of these bodies.

Acknowledgments

This work was supported by Russian Science Foundation, grant 22-72-10059.

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Received 01.11.2022. Approved after reviewing 14.11.2022. Accepted 16.11.2022.