DOI: 10.32703/2415-7422-2019-9-1(14)-77-88

UDC 52.008:378.4(477.74–21)

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Development of meteor astronomy at the Odessa University during the period of Ukraine's independence

Abstract. *The article using the methods of bibliographic and source study analysis and systems approach highlights the state and main trends in the development of meteor astronomy in Odessa during the time of independent Ukraine. At the beginning of the 21st century, continuous meteor patrol was restored at the Odessa Astronomical Observatory, which was intensively conducted at the Observatory during Soviet times. It was based on the use of the television and telescopic method, which was used in the CIS for the first time. The advantages of using the television telescopic method in comparison with the photographic and radar methods for solving the fundamental problems of meteor astronomy are noted. The text gives valuable information on the features of continuous meteor patrols at the observation station Kryzhanovka and the work of the expeditionary automatic meteor patrol on Snake Island (Odessa region, Ukraine). The methods of conducting telescopic television observations and processing observational material developed by Odessa researchers are considered. The main directions of meteoric studies conducted in the Odessa Astronomical Observatory using television meteor patrol materials were determined. Studying the physics of meteoric phenomena, obtaining exact coordinates of individual meteor radiant, spectral observations of meteors, studying double and multiple meteors, studying the structure and density of meteoric dust particles, solving interaction problems meteor showers with the Earth's atmosphere, statistics of meteor phenomena in the Earth's atmosphere are the main directions of meteoric studies of Odessa Astronomical Observatory. The scientific potential of Yu. M. Gorbanev in the field of meteor astronomy of, the leader of the meteoric group, O. V. Holubaieva, the head of the meteor's television patrol at the Kryzhanovka observation station in 2003-2011, as well as participation in the meteor research S. H. Kimakovskyi, I. I. Kimakovskyi, S. V. Podlesniak, I. A. Stognieieva, L. A. Saresta, A. F. Prinzykov, V. A. Shestopalov, etc are noted. Conclusions are drawn about the importance of conducting meteoric research for the development of fundamental and applied science.*

Keywords: *Odessa Astronomical Observatory; meteor patrol; television telescopic method; Kryzhanovka, Snake Island*

Introduction

Today the research of meteors is a current task, which is important not only for fundamental science. As a result of numerous theoretical and experimental work carried out by scientists all over the world, the great practical importance of meteor research, the possibility of using meteor phenomena to solve a number of practical problems, in particular, forecasting meteoric danger for spacecraft, developing near-Earth dust cloud models, became apparent (Ovezhel'diev, Kashcheev & Nechitajlenko, 1986). The study of the physics of meteors gives an idea of the nature of the interaction of particles of macroscopic size with velocities unattainable in laboratory conditions (~ 11-73 km/s) with the atmospheres of the planets. The results of this kind of research may be used and are used to solve the problem of overheating of the skin of spacecraft when they enter the dense atmosphere of the Earth and other planets or their satellites (Kozak, 2006, p. 1). Studies of the drift of meteor trails contributed to the formation of modern concepts of atmospheric circulation at an altitude of 80-110 km, tides and internal atmospheric gravitational waves, and the effect of circulation processes in the upper atmosphere on weather and climate (Ovezhel'diev et al, 1986, p. 84). The study of the distribution and evolution of meteoric orbits in the solar system contributes to cosmogony, in particular, makes it possible to establish a genetic connection with the bodies that generate them (Kozak, 2006, p. 1).

The meteoric research at the Odessa Astronomical Observatory (OAO) started in the nineteenth century, but it received the greatest scope in the middle of the twentieth century. Scientific interest in the study of meteoric phenomena was caused primarily by the study of near-Earth space and the development of astronautics. The participation of the Odessa Astronomical Observatory in the research program of the International Geophysical Year was of great importance for the development of meteor astronomy at Odessa University. The performance of the functions of the Head Office for the “Meteor Astronomy” problem contributed to the strengthening of the international authority of OAO (Hrushytska, 2017). In the following years and until today, OAO is one of the leading scientific institutions of Ukraine in the field of meteoric astronomy. However, in the history of domestic science and technology, this issue has not been studied sufficiently.

Several works by Ukrainian researchers are devoted to the history of Odessa meteor astronomy of the Soviet period (Kramer, 1996; Kramer, 1997; Hrushytska, 2017). As for the history of the development of Odessa meteor astronomy in independent Ukraine, it has not been studied and is represented mainly by short use information in a number of scientific publications (Koval, (Eds.), 2015; Smyntyna et al., 2008).

The purpose of this study is to determine the state and main trends in the development of meteor astronomy in Odessa during the time of the independence of Ukraine using the methods of bibliographic and source study analysis.

Research methods

The methodological basis of the study consists of the basic principles of modern historical science – the principles of historicism and objectivity. The principle of objectivity implies consideration of the studied historical events in their interrelation and development, the principle of objectivity is focused on a comprehensive analysis and reliable assessment of historical facts. The use of methods of bibliographic and source study analysis contributed to the search and systematization of primary information, and the use of the system method allowed to investigate comprehensively the state and development prospects of Odessa meteoric astronomy in the period of independence of Ukraine.

Results and discussion

A systematic study of meteor phenomena in Odessa was carried out from 1953 till 1993, and in the regime of continuous patrol since 1956. The meteor patrol is that the panoramic equipment is constantly ready to receive a signal from a certain area of the celestial sphere to fix the meteor. At the same time, the main features of meteors are their short duration (observed for about seconds and less) and the unpredictability of the place of flight in the sky (Holubaiev, 2017, p. 26). During this time, more than 600 images of basic meteors were obtained, that is, meteor phenomena recorded simultaneously on two or more optical instruments (cameras) spaced at a sufficient distance. Such observations in meteor astronomy are called basic and they allow determining the basic kinematic parameters of meteoric phenomena – the altitude, speed, and coordinates of an individual meteor radiant (Smyntyna et al., 2008, p. 138). In addition, several thousand non-basic meteors were obtained, which could not be used for a full-scale investigation (Kramer, 1997).

But over time, the meteor patrol technique grew old and needed significant modernization, which required significant material investments. This coincided with the economic crisis in the country after the collapse of the USSR and gaining independence, as well as the crisis of panoramic radiation receivers. That is, the photo faded into the background, and large new receivers did not exist (Gorbanev, 2013). It took almost a decade to search for new methods and since 2003 (although attempts to use new television methods by Odessa researchers began since 2000), meteor studies in Odessa have been restored. They are based on the use of the television telescopic method, which allows solving the fundamental problems of meteor astronomy and was used in the CIS for the first time (Koval, 2015, p. 926). By this time, the modernization of the observation equipment was completed and a meteor TV patrol was created. A monochrome camera «WATEC LCL 902» was used as a panoramic radiation receiver. The camera allows you to record meteor phenomena with a temporal resolution of 0.02 seconds (Gorbanev et al., 2006). A

wide range of observational equipment was used: from the Schmidt system telescope (F = 540 mm, F/D = 2.25, the field of view FOV = 0.68º × 0.51º, the limiting magnitude SLM = 13.5 mag, the astrometric accuracy - 1-2 ") to Fisheye lenses (F = 8 mm, F/D = 3.5, FOV = 36º × 49º, SLM = 7 mag) (Holubaiev, 2015).

This method of research compared to traditional methods being used in the twentieth century - photographic and radar, allows us to observe rather weak meteors up to + 10^m. But the existing photographic observation technique (from high-aperture short-focus cameras to super-Schmidt) does not allow meteor phenomena to be observed, weaker than + 4^m (Smyntyna et al., 2008, p. 138). Although the radar method allows observing a large number of meteors from + 7^m to + 15^m around the clock and regardless of weather conditions, however in this case, the ionized trace is fixed, rather than the optical image of the meteor (Holubaiev, 2017, p. 31). Combining the optical capabilities of the telescope (long-focus aperture lenses) and the technical characteristics of a CMOS sensor (CCTV cameras) made it possible to shift the threshold for recording meteors in the optical range to + $5^m \div + 10^m$. Such a range of meteoric bodies was previously the least studied, as well as there were no high-precision catalogues with their orbital elements, kinematic and physical characteristics. Over time, the technique of telescopic television observations and processing of observational material was developed and a catalogue with meteors kinematic parameters up to + 10^m was created (Holubaiev, 2017, p. 35; Gorbanev, 2017).

Since June 2003 to this day, meteor patrols are regularly conducted at the observation station Kryzhanovka of OAO (Holubaiev, 2017, p. 37).

In addition to stationary installations, which conduct regular patrol observations at the observation station Kryzhanovka, there is an expeditionary automatic meteor patrol. It is used during astronomical expeditions to Snake Island (Odessa region, Ukraine), as a rule, during the action of the Perseid meteor shower in August, the maximum of which falls on August 11-12 (Koval, 2015, p. 926). In 2003, the first expedition was conducted to study and select the location of the meteor patrol, in 2004 the first photographic meteor observations were conducted (Smyntyna et al., 2008, p.139). In 2005, the meteor patrol was tested on the island, consisting of one station and a non-manned unit. In 2006, in order to conduct basic meteor patrols, two observation stations were deployed on the island were deployed. The base stations of meteor patrol showed high tactical and technical capabilities of the observation complex. In 2007, similar observations were made on Snake Island using an upgraded installation to study July meteor showers (Holubaiev, 2017, p. 38).

A database has been created for each instrument, being continuously updated during the initial processing of new observations. The database contains information on meteors that were recorded from 2003 to 2017 with continuous meteor patrols (Holubaiev, 2017, p. 38; Gorbanev, 2017).

The database structure includes observational material (video films) and video processing data (single images and combined images of the meteoric phenomenon, summed images of star fields, background values files, etc.). For the formation of

statistics of television observations of telescopic meteors, a technique was developed and software was created that allows for the rapid analysis of the entire volume of observational material. After a night of meteor patrols, observational material is promptly entered into the database and is automatically processed by the developed software. Since the situation with meteoric activity is constantly changing, this approach allows for a comparative analysis of incoming observations with data from previous years. This is very important for planning future observations and increasing the productivity of patrols (Gorbanev, 2008, p. 245).

A technique has been developed and a processing software package has been created that allows carrying out positional and photometric measurements of observational material. The technique was tested on observational material 2003-2007. The program complex included the following main components (Kimakovskyi, Gorbanev, Knyazkova, Shestopalov & Holubaiev, 2008, p. 247):

1. AVICutter – a program for working with television films of observations and pre-processing of star and meteor images.
2. Combo – a program for creating with N frames a combined image consisting of fragments with images of a meteor in a single coordinate system.
3. PSF - a program for quick search and identification of observed parts of the starry sky.
4. PicScan – a program for measuring television images of meteors.
5. Meteor Pole – a program for calculating the poles of large circles of meteor trajectories.
6. FROSA – a program for obtaining the coordinates of a meteor radiant by the Stanukovych method using non-basic observations.

The processing procedure includes working with television films of observations and pre-processing of star and meteor images. At the next stage, an on-line search and identification of the observed parts of the starry sky, and then measurements of star and meteor images are carried out. The final stage of processing is to obtain high-precision coordinates of points of meteor trajectories, the poles of their large circles, coordinates of radiant, light curves of meteor phenomena, etc. (Gorbanev, 2008, p. 245).

The main directions of meteor studies at the Odessa Astronomical Observatory on television meteor patrols include the following questions (Gorbanev, 2008, p. 246):

1. Statistics of meteor phenomena in the earth’s atmosphere;
2. The study of radiation areas of meteor showers;
3. The obtaining exact coordinates of individual meteoric radiant;
4. The study of the physics of meteor phenomena;
5. The outbreak nature of the birth of meteoric phenomena;
6. Meteoric “tails” (wake);
7. The nature of meteor’s persistence;
8. The study of the structure and density of meteoric dust parts.

Meteor studies are conducted under the guidance of a graduate of the Odessa University in 1985, Yurii Mykhailovych Gorbanev, who graduated from the graduate school at the department of astronomy under the guidance of a well-known specialist in the field of meteoric astronomy in the USSR, doctor of physical and mathematical sciences, Professor Yuhym Naumovych Kramer. In 1997, Yurii Gorbanev defended his thesis for the degree of candidate of Physics and Mathematics on the topic: "Drift, accretion and transformation of the orbits of interplanetary dust particles." In 2000, he got a position of senior researcher. Currently working in the department of small bodies of the Solar system of the Scientific Research Institute "Astronomical Observatory" of ONU named after I. I. Mechnikov. Kimakovskyi Serhii Reymundovych, Kimakovska Iryna Iliivna, Podlesniak Serhii Vasyliovych, Stohnieieva Iryna Aleksandrivna, Sarest Leonid Aleksandrovich, Kniazkova Olena Fedorivna, Shestopalov Vasylii Oleksandrovych, Holubaiev Oleksander Vladymyrovych and others took part in the meteor studies (group members).

In 2017, O. V. Holubaiev defended his thesis for the degree of candidate of Physics and Mathematics on the specialty 07/05/12 – Remote aerospace research on the topic: "Kinematic and physical characteristics of meteoroids with radiants near the Sun according to ground-based television observations" under the direction of Yu. M. Gorbanev. During 2003-2011 O. V. Holubaiev was the head of the television meteor patrol at the Kryzhanovka observation station. The defence took place on June 27, 2017 in the specialized academic council K 26.062.13 at the National Aviation University. In the thesis of O. V. Holubaieva solved a set of scientific problems of meteoric astronomy related to the improvement of observational methods, processing observational material and analyzing the results obtained to study the kinematic and physical properties of meteoroids, which, when collided with the Earth, have radiants near the Sun on the celestial sphere. This study is of practical importance for assessing the degree of threat on such collisions, because such objects are the most dangerous due to the lack of modern capabilities of ground or space technology to fix them in advance even on approaching the Earth from heliocentric distances of less than one astronomical unit from the Sun (Holubaiev, 2017).

One of the important tasks of meteor astronomy is to determine the global influx of interplanetary dust matter into the Earth’s atmosphere. To solve this problem, various observational methods (visual, photographic, television, radar) and theoretical methods are involved. To solve the problem of interaction of the meteor shower with the Earth’s atmosphere, determine the height of occurrence, disappearance and maximum brightness of a single meteor, Odessa researchers created a computer model of a meteor phenomenon. It allows, by setting the basic parameters of a meteor phenomenon and using the basic equations of meteor physics, as well as the empirical model of the Earth’s standard atmosphere CIRA-86, to simulate a meteor phenomenon and obtain a standard light curve of meteor brightness by given speed, meteor inlet angle, particle mass and density. (Gorbanev & Ivanova, 2004, p. 135). In addition, using the statistical test method, this model allows generating elements of N orbits by given distributions for the meteoroid swarm, and then, based on the model

of the Earth's motion and the meteoroid, select model particles of the meteor shower. A model was tested using observational material from the World Geminid Meteoric Data Centre. According to the results of the calculations, the following results were obtained: after the meeting with the Earth and the formation of the meteor shower, the initially independent elements of the meteoroid swarm became dependent on only the geometric factor of selection. This primarily concerns such elements as the semi-major axis of the orbit, eccentricity and longitude of the ascending node. The inclination of the orbit of a meteoric particle of the Geminid meteor shower is the least vulnerable orbital parameter for geometric selection (Gorbanev & Kimakovskij, 2004, p. 141)

New technical observational capabilities of the television method allowed to record and study in detail the double and multiple meteors, which are 0,62% of all recorded meteors at Kryzhanovka station. Their study is relevant because of the difficulty of observing these objects. Processing was carried out using the software Odessa Meteor, which was supplemented by programs designed and created to work with double and multiple meteors. Computer processing of television images of double meteors showed the reliability of such a meteoric phenomenon. The classification of images of double and multiple meteors was carried out and the cases of crushing of meteoric particles were described. The detected increase in the angular distance between the components during the flight of a double meteor serves as evidence of their atmospheric origin (Kimakovska, Gorbanev & Kimakovskyi, 2017). Also at the observation station Kryzhanovka A085 in Odessa, spectral television observations of meteors were conducted (Gorbanev, Mozgovaya & Kimakovskaya, 2015).

At present, the monitoring of near-Earth space by the telescopes of the observatory in search of small bodies and comets is being continued in Odessa, (Konovalova, Gorbanev & Davruqov, 2018). Observation results are promptly sent to international electronic circulars (Koval, (Eds.), 2015, p. 926). The effect of major meteor showers on total ozone in the Earth's atmosphere is being investigated (Gorbanev et al., 2017).

Conclusions

So, the high international status of OAO in the field of meteor astronomy, which it received in Soviet times, was not lost in the years of independence. The meteor team work under the leadership of Yu. M. Gorbanev ensured the continuity of generations, the restoration of basic meteor observations and continuous meteor patrols by telescopic television, the creation of new equipment, the development of new methods for processing observations and corresponding software. This allowed conducting researches, which have important theoretical and practical significance for both fundamental science and applied science. In view of this the study of the modern history on the astronomy development at Odessa University seems to be a promising research area.

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Розвиток метеорної астрономії в Одеському університеті у період незалежності України

Анотація. *У статті з використанням методів бібліографічного й джерелознавчого аналізу та системного підходу висвітлено стан і основні тенденції розвитку метеорної астрономії в Одесі у часи незалежної України. Показано, що на початку XXI століття в Одеській астрономічній обсерваторії було відновлено безперервне метеорне патрулювання, яке інтенсивно проводилося в обсерваторії у радянські часи. Базувалося воно на застосуванні телевізійно-телескопічного методу, що був використаний на території СНД вперше. Відзначено переваги застосування телевізійного телескопічного методу у порівнянні з фотографічним та радіолокаційним методами для вирішення фундаментальних задач метеорної астрономії. Подано інформацію про особливості проведення безперервного метеорного патрулювання на спостережній станції Крижанівка та про роботу*

експедиційного автоматичного метеорного патруля на острові Зміїний (Одеська обл., Україна). Розглянуто розроблену одеськими дослідниками методику проведення телескопічних телевізійних спостережень і обробки спостережного матеріалу. Визначено основні напрями метеорних досліджень, що проводяться в Одеській астрономічній обсерваторії за матеріалами телевізійного метеорного патрулювання: вивчення фізики метеорних явищ, отримання точних координат індивідуальних радіантів метеорів, спектральні спостереження метеорів, вивчення подвійних і кратних метеорів, вивчення структури і щільності метеорних пилових частинок, розв'язання завдань взаємодії метеорних потоків з атмосферою Землі, статистика метеорних явищ у земній атмосфері. Відзначено науковий доробок у галузі метеорної астрономії Ю. М. Горбаньова – керівника метеорної групи, О. В. Голубаєва – завідувача телевізійного метеорного патруля на спостережній станції «Крижанівка» у 2003-2011 роках, а також участь у проведенні метеорних досліджень С. Р. Кімаковського, І. І. Кімаковської, С. В. Подлесняк, І.О. Стогнєєвої, Л. О. Сареста, О.Ф. Князькової, В. О. Шестопалова та ін. Зроблено висновок про важливість проведення метеорних досліджень для розвитку фундаментальної та прикладної науки.

Ключові слова: *Одесская астрономическая обсерватория; метеорне патрулювання; телевізійний телескопічний метод; Крижанівка; о. Зміїний*

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Развитие метеорной астрономии в Одесском университете в период независимости Украины

Аннотация. *В статье с использованием методов библиографического и источнико-ведческого анализа и системного подхода освещено состояние и основные тенденции развития метеорной астрономии в Одессе во времена независимой Украины. Показано, что в начале XXI века в Одесской астрономической обсерватории было восстановлено непрерывное метеорное патрулирование, которое интенсивно проводилось в обсерватории в советские времена. Базировалось оно на применении телевизионно-телескопического метода, который был использован на территории СНГ впервые. Отметим лишь преимущества применения телевизионного телескопеческого метода по сравнению с фотографическим и радиолокационным методами для решения фундаментов ментальных задач метеорной астрономии. Представлена информация об особенностях непрерывного метеорного патрулирования на наблюдательной станции Крыжановка и о работе экспедиционного автоматического метеорного патруля на острове Змеиный (Одесская обл., Украина). Рассмотрена разработанная одесскими исследователями методика*

проведения телескопических телевизионных наблюдений и обработки наблюдательного материала. Определены основные направления метеорных исследований, проводимых в Одесской астрономичний обсерватории по материалам телевизионного метеорного патрулирования: изучение физики метеорных явлений, получение точных координат индивидуальных радиантов метеоров, спектральные наблюдения метеоров, изучение двойных и кратных метеоров, изучение структуры и плотности метеорных пылевых частиц, решение задач взаимодействия метеорных потоков с атмосферой Земли, статистика метеорных явлений в земной атмосфере. Отмечено научный потенциал в области метеорной астрономии Ю.М. Горбанева - руководителя метеорной группы, А.В. Голубаева – заведующего телевизионного метеорного патруля на наблюдательной станции «Крыжановка» в 2003-2011 годах, а также участие в проведении метеорных исследований С.Р. Кимаковского, И. И. Кимаковской, С. В. Подлесняка, И. А. Стогнеевой, Л. А. Сареста, А. Ф. Князькова, В. А. Шестопалова и др. Сделан вывод о важности проведения метеорных исследований для развития фундаментальной и прикладной науки.

Ключевые слова: *Одесская астрономическая обсерватория, метеорное патрулирование; телевизионный телескопический метод; Крыжановка; о. Змеиный*

Received 07.02.2019
Received in revised form 19.05.2019
Accepted 27.05.2019