

USING THE SAO IMAGE DS9 PROGRAM IN FORMING SCIENTIFIC ANALYTICAL COMPETENCE IN FUTURE PHYSICS AND ASTRONOMY TEACHERS

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Abstract

This article discusses the experience of using the modern astronomical data visualization and analysis program - SAOImage DS9 - in the process of forming scientific analysis competence in future physics and astronomy teachers. The possibilities of strengthening theoretical knowledge and developing practical scientific analysis skills through the study of real astronomical observation data using the DS9 program are shown. As an example, as part of an independent research project, gravitationally lensed quasar images obtained in the optical range with the AZT-22 telescope of the Maidanak Observatory were analyzed in the DS9 program. The article presents and discusses the methodology of this project, the results obtained - in particular, the photometry of quasar images, light curves and analysis of the lensing effect. The results show that such a practical assignment using the DS9 program is effective in forming scientific analysis competence in teacher training, and increases students' skills in the practical application of theoretical knowledge, working with digital data and drawing scientific conclusions.

Keywords: Scientific analysis competency, astronomy education, SAOImage DS9, gravitational lensing, quasar, photometry, Maidanak Observatory, observational data.

Introduction

Today, one of the pressing issues in the training of teachers who have deeply mastered physical and astronomical knowledge is the development of their scientific and analytical competence. Scientific analytical competence is understood as a set of skills such as posing a problem from a scientific point of

view, collecting and analyzing data, applying theoretical knowledge in practical situations, and drawing conclusions. As part of the latest reforms in the education system of Uzbekistan, special attention is paid to the formation of such competencies in students and students by introducing modern information technologies and methods of working with real data into the educational process. In particular, in the training of future teachers in the field of astronomy and physics, it is advisable not to be limited only to textbook theory, but also to involve them in independent work on the analysis of real scientific observation data [1].

The large amount of observational data collected in astronomy and open scientific archives can serve as a rich source for strengthening students' theoretical knowledge and developing their research skills. In this regard, the training and use of special software tools used by professional astronomers is of great importance. In this sense, the SAOImage DS9 program is a very convenient tool. DS9 is a software application designed for visualizing astronomical images and data, which provides such capabilities as opening FITS format images and tables, viewing multiple frames at once, working with regions, applying various scaling algorithms and color maps. Although DS9 was originally created for professional astrophysicists, its functionality allows it to be used for educational purposes as well.

The use of DS9 in the educational process is also observed in foreign experience. For example, in educational programs of the Chandra X-ray Observatory, teachers and students are invited to analyze real X-ray data using DS9 - in which students perform the data processing process typical of astronomers with their own hands. This approach, while increasing students' interest in science, develops their scientific thinking and analytical skills [2].

The article presents the results of an independent scientific and practical work organized using the DS9 program in order to form the scientific analytical competence of future astronomy teachers. For this work, one of the interesting phenomena in astronomy - the phenomenon of gravitational lensing - was selected. Gravitational lensing is a phenomenon predicted by Einstein's theory of general relativity, in which the gravitational field of a massive object (for example, a galaxy) bends the direction of light coming from a distant bright source (for example, a quasar), splitting it into several images. In gravitationally lensed quasars (GLQ), two or more separate images of the same quasar (for



example, a distant active galactic nucleus) are visible when observed, due to the fact that the light from the same quasar (for example, a distant active galactic nucleus) comes to us from several directions. Such a lensing phenomenon has important practical significance in astrophysics and cosmology: the study of multiple images formed by lensing serves as an important tool in solving unsolved problems such as determining cosmological parameters, including the Hubble constant, and studying the distribution and nature of matter in a lensing galaxy. For this reason, gravitationally lensed quasars have become a constant object of study in the scientific literature [3].

In the last decade, the number of gravitationally lensed quasars has increased significantly with the help of astronomical observation programs (SDSS, GLASS, GAIA, etc.) - for example, in the early 2000s, only about 80 such objects were known, while today their number has exceeded 200, most of which are two-image (two-component) lens systems. Nevertheless, to date, the delay time between two images has been measured for relatively few lensed quasars. Determining the delay time is extremely important, since, as mentioned above, it becomes possible to calculate the expansion rate of the Universe [4]. In this regard, regular observation of gravitationally lensed quasars and analysis of their luminosity changes remains an urgent task for the scientific community. Such observations should be carried out using powerful telescopes at mountain observatories with high-quality atmospheric conditions. The data obtained from the observations require processing using modern digital methods. As you know, the Maidanak Observatory in Uzbekistan is an international observatory known for its high-quality astroclimatology, which houses the 1.5-meter AZT-22 telescope. The Maidanak Observatory has been participating in a number of international lensing observation programs.

This article describes the process and results of working on real images of the lensed quasar obtained at the Maidanak Observatory using the DS9 program. The goal is not only to reach astronomical conclusions, but above all to develop the scientific analysis skills of future teachers through this process. Below is a more detailed analysis of the research methodology, the results obtained and their discussion, as well as the educational significance of such practical independent work [6].

Methodology

Seven 3rd-year students of the Faculty of Exact Sciences of Chirchik State Pedagogical University, studying in the "Physics and Astronomy" department, were involved in the independent work. These students were selected as future teachers of physics and astronomy. They previously had theoretical knowledge as part of a general astronomy course and did not have experience working with the DS9 program and astronomical data in the FITS format. Initially, a short seminar training was held with the participants on the theory of gravitational lensing and the scientific significance of lensed quasars. During the seminar, the basic concepts of gravitational lensing were explained using the example of the system. They were also shown the main functions of the SOAImage-DS9 program and given brief instructions on how to use the program.

The astronomical data necessary for independent work were obtained from the open observation database stored in the Data Archive of the Ulugbek Institute of Astronomy. In particular, digital images of the gravitationally lensed quasars obtained with the AZT-22 ($D = 1.5$ m) telescope at the Maidanak Observatory during 2017–2021 were selected [4]. The observations were carried out with I, R, and V optical photometric filters, with consecutive observations being made for several months each year. In total, dozens of images were collected for each filter over 5 years, which allows us to see changes in the brightness of the quasar images over time. The images were stored in FITS format and contain the galaxy lensing the quasar and two images of the quasar (conditional A and B components).

Stages of working with the DS9 program: Students each installed the DS9 program on a separate computer. Each participant was given a set of observational images from 2017–2021 for the system. Their independent work process was divided into the following stages:

1. Loading and viewing images: Students loaded FITS files provided in DS9 one by one and viewed the images. They were taught to see objects in the image more clearly by adjusting the scaling and contrast parameters of DS9. In particular, the zoom and pan tools of DS9 were used to separate the lensed images of the quasar, since they were close together. In the initial stage, students visually identified the two components of the object and marked them in the image.
2. Calibration and relative photometry: For each image, regions (circular in shape) were set in the DS9 environment, and the A and B images of the quasar

were selected with the appropriate radius around the center. Similar regions were also defined for several nearby stars (for comparison) in the image field. The total luminous flux values (according to numerical calculations) were obtained for each region using the “Counts” function of DS9. It is worth noting that the direct photometric calibration function (for example, outputting star magnitudes) in the DS9 program is limited, so we used only the relative photometry method. That is, the brightness of the quasar images was evaluated by comparing them with each other and with stars of constant brightness in the field. Initially, the best quality (no clouds in the sky, good seeing) image from one night was selected for each filter and set as the main image. In this image, the flux values of the quasar A and B components were taken as F_A and F_B , respectively. In all subsequent images, the same regions were set, the fluxes for A and B were taken, and their relative brightness relative to this main image was calculated as $\mu_A = \frac{F_A}{F_{A_0}}$ and $\mu_B = \frac{F_B}{F_{B_0}}$ (or in the form of the difference in star magnitude). In order to reduce the differences in the observational conditions to a certain extent, the brightness of the field stars was also controlled - if it changed significantly, the data from this image were rejected.

3. Brightness curve construction: Each participant entered the relative brightnesses of quasar components A and B measured over 7 years using the filter attached to them into Excel spreadsheets as a function of time. Based on this data, light curves were constructed - that is, graphs of the change in the brightness of quasar images over time. A separate curve was drawn for component A and a separate curve for component B. When constructing the graphs, the time axis was taken as Julian days (JD) or, more simply, calendar months, and the relative brightness was placed along the vertical axis.

4. Visual analysis of images using DS9: In addition to photometric data analysis, an attempt was made to determine the coordinates of quasar images and measure their angular distance using the visual tools of DS9. The DS9 program contains special WCS (World Coordinate System) data, which allows converting image pixel coordinates to precise angular coordinates in the sky. The mutual distance between objects A and B was checked using the coordinates (R.A. and Dec.) shown on the image dial. Also, an attempt was made to see the trace of a lensing galaxy by distinguishing the excess light (i.e., the quasar image) and viewing its

profile against the background around the object using the “Marker” and “Pixel Table” functions of DS9.

The students' independent work was carried out for about 3 weeks. During the first week, they learned to work in the DS9 environment, the second week was spent collecting data - photometry, and the third week was devoted to analyzing the resulting light curves and providing scientific explanations. Throughout the entire process, the teacher, as an observer, provided advice from the author (writer), but the students worked independently as much as possible [7].

Although the independent work conducted does not directly claim to be a scientific discovery, this process had a significant positive effect on the development of the scientific and analytical competence of future teachers. The following pedagogical results were noted:

1. **Strengthening of theoretical knowledge:** Students deepened their theoretical knowledge on topics such as gravitational lensing, quasars, and photometry during practical work. It can be said that they saw the phenomenon of "gravitational bending of light" that they had studied in theory in real data and felt the confirmation of Einstein's theory for themselves. This made the theoretical knowledge much more meaningful and memorable.
2. **Digital literacy and working with instruments:** While working with the DS9 program, students were introduced to professional instruments in astronomy. They learned about issues they had not encountered before in practice, such as the concept of the FITS format, pixel data, coordinate systems, and photometric calibration. They realized that behind the initially simple-looking images lies a large amount of digital data. This experience gave them confidence in using computer programs in future laboratory work or scientific projects.
3. **Problem-solving skills:** During independent work, students encountered a number of problems and tried to solve them independently. For example, when using the function of comparing several images in the “blink” mode (i.e., detecting changes in successively alternating images) in the DS9 program, the program gave an error, as a result of which they found an alternative method - comparing the images one by one manually. Or, during the photometry process, they initially drew the wrong conclusion because the image of the stars in some images turned out to be blurry; then, looking at the observation notebook, they determined that the seeing that night was bad and suggested that such ambiguous

information be disregarded. Such situations encouraged students to think independently and analyze the problem.

4. Teamwork and scientific communication: Since the students worked in small groups, they exchanged information and ideas with each other. Although everyone analyzed the observations in their own filter, in the end they were required to compile all the results in one place. This helped them to acquire the skills of scientific communication, checking and supplementing each other's work, and discussing the results together. As a result, they were able to feel like a scientific team, albeit small.

5. Scientific thinking and drawing conclusions: Most importantly, the DS9 program and the process of working with real data would not be an exaggeration to say that the students sowed the seeds of scientific thinking. They began to ask questions to explain the observed phenomena: “Why is there an additional fluctuation in image B, and not in image A?” “Why is the brightness change large in some years, and small in others?” They discussed them with questions such as. In the process of finding scientific answers to these questions, they turned to theoretical concepts (for example, microlensing, internal activity of quasars, etc.) and thus put their analytical thinking into practice. At the end of the independent work, each student presented their conclusions in writing - this took the form of a small scientific report, in which they analyzed their level of understanding and results. Analysis of these reports showed that most students had a deep understanding of the topic, were able to correctly interpret the results, and even expressed ideas about what direction research could take in the future.

The above pedagogical results show that an independent work process organized with the involvement of real scientific information and tools is very effective in forming students' scientific and research competence. Now, based on these findings, we will dwell in detail in the discussion section.

Discussion

The results and process analysis confirm several important points. First, working with real scientific information helped students “revive” the theoretical knowledge they had acquired during the learning process. For example, the topic of “gravitational lensing” in theory became a real process for students by separating quasar images in the DS9 program and calculating their delay. This not only explained the phenomenon better to them, but also aroused interest in

science. They felt like they had made a small discovery. This, we believe, will also be reflected in their future pedagogical work - it can be a source of inspiration for teaching their students natural sciences in an interesting way.

Secondly, the use of the DS9 program increased the digital culture of future teachers. Nowadays, digital competence is also considered very important in education. In subjects such as physics and astronomy, working with various simulations, databases, and programs is becoming commonplace. Our experience has shown that students were able to master the DS9 program in a short time and use it for creative purposes. In the future, when they work at school, they can also offer students small project work with open data and programs - for example, taking ready-made astronomical data from the Internet and performing simple analysis, thereby increasing student interest. The DS9 program can be useful not only in astronomy, but also in visual analysis of satellite images or for other purposes, because it is distinguished by its universality.

Thirdly, working in the format of independent research work encouraged students to be active. Usually, during university lessons, more ready-made knowledge is given, and students are in the role of passive listeners. In this project, they became active participants, made their own decisions, made their own mistakes and had to correct them. As a result, self-learning skills were developed. This skill is doubly important for a future teacher - because he will not only have to continue learning throughout his life, but also teach his students to learn independently.

Conclusion

In conclusion, the scientific and pedagogical results achieved within the framework of this work are summarized as follows:

1. Experience has shown that the SAOImage DS9 program can be a very effective tool not only for professional astronomers, but also for pedagogical purposes. Using the program, students mastered real scientific information, applied theoretical knowledge in practice, and developed their scientific and analytical competencies. The convenient graphic interface and functional capabilities of DS9 were understandable to students, allowing them to master it in a short time and create a basis for creative work.
2. This work, organized as an independent project, formed a number of important competencies in future physics and astronomy teachers: setting and solving problems on a scientific basis, digital processing of data, working in a team,

interpreting scientific results and drawing conclusions from them. Students gained their own experience, having passed the path from theoretical knowledge to practical results. Observations show that such experience has a positive impact on their future development as scientifically and creatively thinking educators.

3. Using real scientific data in the education of natural sciences such as physics and astronomy, giving students small scientific research assignments increases their interest in science and leads to a deeper understanding. Therefore, it is recommended that higher education institutions integrate open programs such as DS9 and work with astronomical data archives into their curricula in physics and astronomy. In particular, it is effective to focus independent work or coursework topics on real data analysis rather than theoretical solutions, and for this, professors and teachers should provide the necessary resources and guidance in advance.

In conclusion, the presented data and analysis confirm that by introducing even small elements of scientific research into the educational process, not only the level of knowledge of students increases, but also their scientific outlook, ability to conduct independent research, and interest in science. This is an important step in the formation of a modern competent teacher. In the coming periods, it is planned to expand the scope of experiments in this direction and apply them to other topics.

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