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Teaching the basics of data science on astronomical data and catalogs

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Abstract. Today it is difficult to imagine research in the field of astronomy and astrophysics without qualitative and quantitative analysis of data obtained using modern astronomical instruments, the quantity and quality of which has grown significantly over the past quarter century. However, until now, this topic has not been studied in school astronomical education and pre-university training, which significantly hinders the inclusion of applicants and elementary students in scientific and research work. Therefore, our report will describe the methods of teaching astronomical data analysis and working with astronomical catalogs of famous space projects. The results of testing these techniques when working with students of the HSE (Higher School of Economics) Lyceum and the Center for Pedagogical Excellence will also be discussed.

Keywords: astronomical databases: catalogs, reviews

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1 Introduction

Due to the large number of modern ground-based and space observatories, the improvement of the quality of information receivers and the increase in the operating time of telescopes in the mode of surveys of the celestial sphere, a significant increase in observational data is observed in modern astrophysics. In this regard, today there is a serious problem of the methodology of teaching modern astronomy in the field of working with astronomical data (Korolev et al. 2021). Therefore, studying only the classical astronomy course does not give an idea of the modern work of astronomers and trends in the development of science (Drobchik & Nevzorov 2018), (Tihomirova et al. 2020). The most important, in our opinion, is the introduction into the astronomy training program of methods of working with astronomical data and numerous astronomical data catalogs that have appeared in recent decades, teaching modern schoolchildren and students methods of mathematical processing of observational data, as well as the ability to identify and find dependencies and correlations in these data. These methods will help students to connect more effectively and productively to research in astronomy at the modern level.

2 Working with astronomical observational data

2.1 Messier catalog

As a starting example when working with catalogs, it is logical to choose one of the first catalogs that appeared in astronomy, namely the Messier catalog. It is studied within the framework of basic astronomy and there are enough objects for visual demonstration.

As the first task when working with this catalog, you can display all the catalog objects in equatorial coordinates in a stereographic projection or in a Mollweide projection (Fig.1).

Also, using this catalog, we can consider the problem of finding the coordinates of the center of the Galaxy, studying the subsystem of globular clusters, finding their average position.

2.2 FITS-files

Most astronomical data files are stored in a special Flexible Image Transport System (FITS) format. This format differs from classic graphic formats in that, in addition to the main image, it stores additional metadata about that image. Therefore, the first step is to teach students how to work with this format, for example, based on the analysis of images from the Hubble telescope. Interesting and accessible tasks

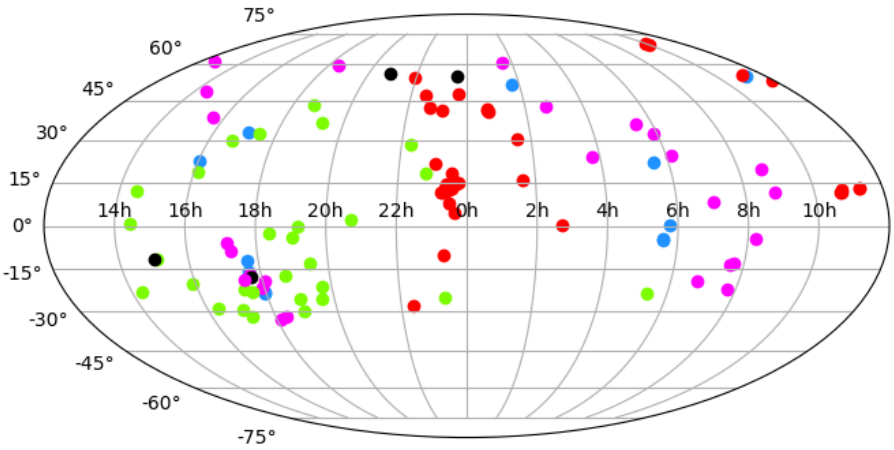

Fig. 1. Messier objects on the map in the Mollweide projection. Galaxies — red, open star clusters — pink, globular star clusters — green, nebulae — blue, others — black.

for schoolchildren here are: determining the background of the sky, counting the number of elements in a photo (stars, galaxies) and analyzing objects, for example, determining the size of the halo and the nucleus of the galaxy.

2.3 Hershel catalog

As an example of a modern catalog, we can consider the catalog of galaxies obtained by the Herschel Space Observatory, which is the predecessor of the James Webb Space Observatory, with the catalog of which it will be possible to work similarly in the future. And the first task when working with this catalog is a simple task — visualization of the catalog, i.e. displaying its objects — galaxies in a given area of the sky in equatorial coordinates.

Further analysis and search for correlations by parameters are already research work and depend on the level of further training of students. For example, one can study the correlation between the redshift of galaxies and their number in the region of the celestial sphere, limited by a certain radius.

2.4 The Hipparcos and Gaia catalog

Next, we propose to investigate the properties of variable stars according to the astronomical catalog created based on the results of the Hipparcos and Gaia space observatories.

Based on these catalogs, it is possible to study the spatial distribution of variable stars in our Galaxy in galactic coordinates and make sure that the stars gravitate

to a planar distribution, which means that our Galaxy has the appearance of a flat disk.

The next task is to independently obtain the "period-luminosity" dependence for classical cepheids according to the Hipparcos and Gaia catalog. This dependence is a very important stage in constructing the distance scale in the Universe — it allowed E.Hubble to determine the distances to other galaxies and build a Hubble diagram, which led to the discovery of the expansion of the Universe. And now schoolchildren and students can independently repeat this work using the catalogues of cepheids of modern space observatories and reproduce this dependence on their own.

3 Results and conclusions

According to the listed range of tasks, lessons were conducted for students of the Center for Pedagogical Excellence and the Lyceum of the Higher School of Economics. The teaching staff was highly appreciated and the significant usefulness of such classes was noted, since they:

1. introduce students to the latest achievements in the field of astronomical research;
2. teach scientific research skills;
3. cover several subject areas at once and establish interdisciplinary connections;
4. allow the use of interdisciplinary competencies to solve scientific problems.

In the course of this work, several final qualification papers have been completed and a textbook with a detailed analysis of each of the tasks is being prepared for publication.

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