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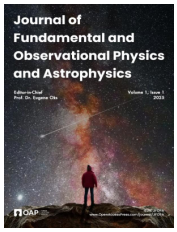

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Discovery of Red Flare Dwarf Stars

Gershberg R.E. [1, *]

[1] Crimean Astrophysical Observatory of the Russian Academy of Sciences
Nauchny, Russia 298409

*** Correspondence: gershberg@craocrimea.ru**

Abstract The paper presents the chronology of the discovery of red flare dwarf stars and their subsequent studies. The most important part of the discovery and the studies is the physical identity of the flare activity of red dwarfs and the activity of the Sun.

Keywords red flare dwarf stars; solar flares

Danish astronomer Ejnar Hertzsprung was born on October 8, 1873 in Frederiksborg near Copenhagen. He studied at the Copenhagen Polytechnic Institute, where he received a degree in chemical engineering. After graduating in 1898, he worked in St. Petersburg for three years. Returning to his homeland, he began to study astronomy, simultaneously conducting photographic observations at the Copenhagen Observatory, then in Potsdam and Leiden, where he became director in 1935.

Hertzsprung's main scientific works relate to astrophysics and stellar astronomy. In 1905-1907 he discovered the existence of giant stars and dwarf stars, showing that stars with the same temperature can have significantly different luminosities. He determined the proper motions of many stars in the Pleiades cluster in order to isolate members of the cluster. He was the first to note differences in the stellar population of the Pleiades, Hyades, and Praesepe clusters, which were later explained by the difference in the ages of these clusters. He performed a huge number of measurements of binary and variable stars from their photographs. He calibrated the relationship between the brightness and period obtained by H.S. Leavitt for variable stars in the Small Magellanic Cloud, showing that these variables are Cepheids; he determined the distance to the Small Magellanic Cloud using this relationship. He established the relationship between the period of Cepheids and the shape of their light curves. In 1911 he showed that Polaris is a Cepheid star. Hertzsprung was the first to construct a diagram of the dependence of apparent stellar magnitude on the color index for stars in the Pleiades and Hyades clusters; later, when G. N. Russell constructed a similar diagram for all stars with then known distances, it was called the Hertzsprung-Russell diagram. This diagram became the cornerstone of studies of stellar evolution.

While observing the Eta Carinae region with a 10-inch telescope in Johannesburg, Ejnar Hertzsprung discovered on the plate on January 29, 1924: on the third of five half-hour photographs obtained that night, it was brighter by 1m.8 than on the first two, on the fourth by 1m.1, and on the fifth by 0m.75. On all 37 plates obtained over 19 nights, the star had a low brightness. Hertzsprung noted that the discovered nature of the variability did not allow the star to be identified either as an RR Lyrae variable or as a nova, and associated its outburst with the fall of a minor planet onto the star. As it turned out later, this is how flaring red dwarfs were discovered, and Hertzsprung's variable received the standard designation DH Car. For a hundred years, no other manifestations of activity were detected on this M4 dwarf.

In the following quarter of a century, several more such variable stars were discovered, but the difficulties of observation

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due to their weak brightness did not arouse much interest. With the progress in observation techniques and new methods of processing the data obtained in the middle of the last century, the situation changed significantly. When electrophotometry prevailed in stellar photometry, it replaced visual observations with objectivity and photographic studies with high accuracy, sensitivity and time resolution. As a result, hundreds of flaring red dwarf stars were discovered, the first catalogs of such variables were compiled, the non-periodicity of their flares was established, the power-law nature of the energy spectrum of flares was discovered, and the cyclicity of the activity of such stars was discovered based on photometric series over tens of years. With the installation of spectrographs with sensitive detectors on large telescopes, flare spectra with high time resolution were obtained, the nature of changes in various spectral lines of flares at different phases of their development was discovered, the parameters of stellar chromospheres in quiet and flare states, temperatures, densities and speeds of motion of the substance of flares were determined. These optical results made it possible to establish changes in various spectral lines of flares at different phases of their development, to determine the parameters of stellar chromospheres in quiescent and flare states, temperature, density and velocity of the flare matter. Ultimately, this led to the discovery of the physical identity of the flare activity of red dwarfs and the activity of the Sun.

High-resolution spectra and spectropolarimetric methods led to the discovery of stellar magnetic fields. With the advent of large radio telescopes, stellar coronas were discovered, their thermal radiation in the quiescent state of stars and non-thermal radiation of flares were measured.

With the launch of astronomical devices into space, ultraviolet and X-ray radiation of flare stars became available, their registered line spectra made it possible to estimate the parameters of the upper atmospheres of these stars. To analyze this rich experimental data, the necessary theoretical studies were simultaneously carried out. The theory of the Balmer decrement for the conditions of the atmospheres of such stars was developed, various methods for estimating the parameters of cold star spots were proposed, and a theory of the generation of magnetic fields on stars was developed, which made it possible to estimate the structures and intensities of these fields.

A major step in the experimental study of stars with solar-type activity is the launch of telescopes into space for panoramic photometry of star fields. They provide the opportunity for simultaneous observations of thousands of objects over a long period of time and with high temporal resolution. As a result, very rare stellar flares were discovered, 2-3 orders of magnitude higher in energy than the most powerful solar flares, catalogs of such stars were created, the largest of which contain hundreds of thousands of objects.

Recently, our large monograph [1] was published. The book is available in the Astrophysical Data Abstract Service and is also available at: https://ui.adsabs.harvard.edu/abs/2024arXiv241111898G. It describes in some detail the history of the study of these objects from the discovery of Hertzsprung to the writing of this book. The list of references in it contains about 2800 titles. This is the creative legacy of Ejnar Hertzsprung's discovery of flare dwarf stars.

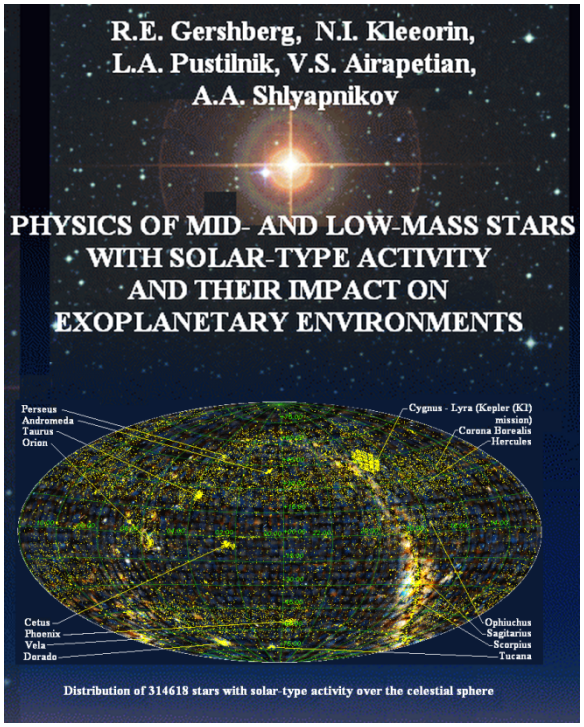

Figure 1. Book cover

In February 2024, a two-day conference dedicated to the centenary of Hertzsprung's discovery was held at the Crimean

Astrophysical Observatory of the Russian Academy of Sciences. The author's introductory paper at this conference [2] was published the same year.

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[2] R.E. Gershberg, *Stars with solar-type activity: studies in resent years*, Acta Astrophysica Taurica **6** (2025) 1-23.