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Editorial

Editorial to the Special Issue "Advances in the Physics of Stars—In Memory of Prof. Yuri N. Gnedin"

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This Special Issue collects articles devoted to various aspects of astrophysics which can be understood as a science investigating stars, galaxies, their types and properties, stages of their evolution, distribution in the Universe and the interstellar and intergalactic media. It is devoted to the memory of outstanding astrophysicist Prof. Dr. Yuri N. Gnedin whose scientific interests and expertise were extraordinarily wide by including the theoretical investigation of the polarized radiation transfer, generation of high-energy radiation in close binary star systems and galactic nuclei, and cyclotron lines in spectra of accreting neutron stars. Prof. Dr. Yuri N. Gnedin developed the pioneer method for the determination of magnetic fields of cosmic sources from polarimetric observations, contributed a great deal to physics of intermediate-mass and supermassive black holes and magnetic white dwarfs, supernovae, exoplanets and dark satellites of stars, cosmic gamma-ray bursts, dark matter and dark energy.

Yuri Gnedin was born on 13 August 1935 at the Russian city of Tula. After graduation from the Physico-Mechanical Department of Leningrad Polytechnic Institute (presently Peter the Great Saint Petersburg Polytechnic University) in 1959, he was employed by the famous A. F. Ioffe Physico-Technical Institute of the Russian Academy of Sciences, where he worked during 25 years in the field of theoretical physics and astrophysics. In 1966, Yu. N. Gnedin obtained his PhD and in 1979, after defending the Doctorate dissertation entitled "Propagation of polarized radiation in cosmic conditions", obtained the degree of Doctor of Physical and Mathematical Sciences (which is the second scientific degree in Russia similar to Habilitation in Germany which is significantly higher than PhD). In parallel with research activity at A. F. Ioffe Physico-Technical Institute, Yu. N. Gnedin delivered lectures in astrophysics for students of Leningrad Polytechnic Institute. In 1981, he obtained the academic status of Full Professor.

In 1984, Prof. Dr. Yu. Gnedin was invited to create the Department of Astrophysics and to lead the research work at Central Astronomical Observatory at Pulkovo of the Russian Academy of Sciences in the positions of the Head of Department and the Deputy Director of the Observatory on Science. It should be noted that Pulkovo Observatory was created in 1839. It is one of the oldest Institutions in Russia intended especially for scientific research. It is well known all over the world by many outstanding scientific results in the field of observational astronomy. However, by the end of 20th century, due to the great discoveries made in astrophysics and cosmology, astronomy already could not be further developed separately based mostly on the methods of mathematics. It should be mentioned, however, that in Russia astronomy was traditionally teached at the mathematical Departments of Universities and the most of members of the Pulkovo Observatory scientific staff graduated from the Department of Mathematics of Saint Petersburg (Leningrad) State University.

Because of this, the mission suggested to Prof. Gnedin was extremely complicated. He ought to become the part of old, well established and famous Institution, to create the new part of it consisting of researchers with quite a different background in physics and astrophysics, to organize the research activity in new scientific directions, and to convince everybody that the observational astronomy and astrophysics are not the hostile competitors but useful complements and assistants in obtaining new knowledge about our Universe. In order to cope with this task, one must be not only a brilliant scientist, but also an outstanding organizer. Prof. Dr. Gnedin accepted the offer and successfully solved all emerging scientific and organizational problems over the next more than 30 years.

Before reviewing the content of the present Special Issue, we briefly mention the research fields where important contributions by Prof. Dr. Yu. N. Gnedin are well known and recognized by the scientific community (in Figure 1 he is working in his office at Pulkovo Observatory [1]). These are the theory of radiation transfer, investigation of the polarized radiation emitted by various cosmic objects, X-rays and gamma-rays astronomy, physics of neutron stars and black holes. Specifically, Prof. Yu. N. Gnedin elaborated a new method for investigation of supermassive black holes based on polarimetric observations of active galactic nuclei. In collaboration with Prof. R. A. Sunyaev, Prof. Yu. N. Gnedin predicted an existence of cyclotron lines in the radiation of neutron stars. This discovery was used to develop the reliable method for measuring magnetic fields of neutron stars. Furthermore, Prof. Yu. N. Gnedin developed new method for measuring the magnetic fields of hot stars. This method is based on the phenomenon of Faraday rotation of the polarization plane of electromagnetic radiation scattered in their atmospheres. Prof. Yu. N. Gnedin initiated important investigations of several unusual cosmic phenomena using RT-32 radio telescopes. These include cosmic gamma-ray bursts, compact astrophysical objects, and active galactic nuclei. He also contributed a lot to constraining the parameters of axions and arions as possible constituents of dark matter by means of measuring different polarimetric effects in astrophysical processes. Prof. Yu. N. Gnedin is the author of 330 scientific papers and three books [2–4].

Figure 1. Prof. Dr. Yuri N. Gnedin (13 August 1935–27 March 2018) is working in his office at Pulkovo Observatory of the Russian Academy of Sciences.

An important part of Prof. Yu. N. Gnedin scientific life was his work as an outstanding organizer. He took part in many International research projects, was the member of International Astronomical Union, led the Program Committee of the 6-meter telescope of Special Astrophysical Observatory of the Russian Academy of Sciences, was the member of Bureau of the Scientific Council on Astronomy of the Russian Academy of Sciences. Prof. Yu. N. Gnedin was one of the main organizers and active participants of Alexander Friedmann International Seminars on Gravitation and Cosmology during the years 1993–2016. In honor of Prof. Yu. N. Gnedin, the small planet N 5084 is named "Gnedin".

Prof. Yu. N. Gnedin was a talented teacher whose lectures always created great interest among students. For several decades, he elaborated and delivered for students of the Peter the Great Saint Petersburg Polytechnic University the original lecture courses on modern problems of astrophysics, relativistic astrophysics, and general relativity theory, was the superwiser for many master's degree and PhD students.

Research articles and reviews published in this Special Issue, devoted to memory of Prof. Yu. N. Gnedin, touch many subjects of his wide scientific interests. Thus, article [5] outlines contributions of Prof. Gnedin to understanding polarization of radiation from neutron stars and presents new simulations of observations to be performed by NASA's Imaging X-ray Polarimetry Explorer (IXPE) launched in December 2021. These observations will provide the opportunity to test some models proposed by Prof. Gnedin and his collaborators.

Article [6] investigates unusual microwave and X-ray radiation from the ultracool dwarf TVLM 513-46546. According to the proposed model, the microwave radiation of this source comes from hundreds of magnetic loops quasi-uniformly distributed over its surface. This model suggests that the second population of magnetic loops is at the same time a source of X-ray emission.

Article [7] considers a new class of energetic transient sources called fast blue optical transients which possess moderately relativistic outflows in between the nonrelativistic and relativistic supernovae-related events. The kinetic particle-in-cell and Monte Carlo simulations are performed which allow to explain the observed broad band character of the radiation from these sources. Specifically, it is demonstrated that synchrotron radiation of accelerated relativistic electrons in the shock downstream may fit the observed radio fluxes. The suggested nonlinear Monte Carlo model predicts that protons and nuclei can be accelerated to petaelectronvolt energies and, therefore, the fast blue optical transients can be considered as one of the sources for galactic high energy cosmic rays.

In the article [8], the multi-component numerical model of hot Jupiter envelopes is suggested. By implementing the completed magnetohydrodynamic model of stellar wind, it becomes possible to calculate the structure of an extended envelope of hot Jupiter in both the super-Alfvén and sub-Alfvén regimes of the stellar wind flow as well in the trans-Alfvén regime. Using this approach, computations of changes in the chemical composition of hydrogen-helium envelopes of hot Jupiters are performed in different regimes. In particular, in the super-Alfvén flow regime, all the previously discovered types of extended gas-dynamic envelopes are reproduced. The dependence of the extended envelope on the magnitude of the wind magnetic field is investigated.

A new, interesting view on dark matter, dark energy and their relationship is suggested in the article [9]. According to this view, at the present epoch, the dark energy may have two components. The first of them is the standard one. It is determined by the cosmological constant in Einstein equations. Meanwhile, the second one, which is smaller in magnitude, is determined by remnants of the inflaton field which gives rise to the presently existing matter. In doing so, the second component of the dark energy becomes closely connected with the usual matter. Based on possible existence of the second component of dark energy, the so-called Hubble tension problem is discussed and its solution is suggested.

Thermal radiation spectra from a magnetized neutron star are further studied in [10] using the well known model assuming that the star is internally isothermal and possesses a dipole magnetic field in its outer layer. It is shown that the blackbody radiation emitted by any local surface element is nearly independent of the chemical composition of an envelope. The obtained theoretical results are found to be consistent with observations for certain neutron stars.

Constraints on the parameters of hypothetical interactions predicted by different extensions of the Standard Model following from the recent experiment on measuring the Casimir force at separations of a few micrometers are obtained in [11]. Specifically, the Yukawa-type corrections to Newton's law of gravitation and interactions of axions with nucleons are considered. As was mentioned above, both massive and massless axions (i.e., arions) were in the scope of scientific interests of Prof. Yu. N. Gnedin as the possible constituents of dark matter. It is shown that the obtained constraints are stronger than those following from other measurements of the Casimir interaction and gravitational experiments over certain interaction regions but weaker than the constraints obtained from the Casimir-less experiments where the Casimir force was completely nullified. The prospects of obtaining stronger constraints from experiments of different kinds are discussed.

The article [12] is devoted to estimations of the values of magnetic field at the event horizon of the supermassive black hole and the exponents of the power-law dependence of this magnetic field on the black hole radius. These estimations are obtained by using the polarimetric data of 33 Seyfert type 1 galaxies observed with the 6-meter telescope of Special Astrophysical Observatory of the Russian Academy of Sciences and the model of optically thick but geometrically thin Shakura-Sunyaev accretion disk. The obtained results are compared with those found by other methods.

A review on the progress in understanding of the first microquasar discovered in the Galaxy (SS433) is given in [13]. The stress is made on the results obtained by means of spectral and photometric observations at the Caucasian Mountain Observatory of the Sternberg Astronomical Institute of M. V. Lomonosov Moscow State University. According to common views, this mictoquasar is a massive eclipsing X-ray binary. The observations made at the Caucasian Mountain Observatory gave the possibility to determine the ellipticity of the microquasar orbit and to discover an increase in the orbital period of this system consisting of the relativistic object (black hole) and the optical star. Furthermore, a more precise constraint for the mass ratio of these objects was obtained.

The detection of magnetospheric accretion among Herbig Ae/Be stars of different kinds with accretion disks is reviewed in [14]. Specifically, the Herbig Ae star HD 101412 with a comparatively strong magnetic field, the early-type Herbig B6e star HD 259431 whose magnetosphere was recognized only recently, young binary system HD 104237 which includes a Herbig Ae star and a T Tauri star, and the Herbig Ae/Be star HD 37806. For the young binary system HD 104237, using the discovered periodic variations of equivalent widths of atmospheric lines in the spectrum of the primary, it is concluded that the star surface is spotted. The origin and nature of these spots are discussed.

A review of the most important results in investigation of magnetic fields of chemically peculiar stars obtained in the Special Astrophysical Observatory of the Russian Academy of Sciences using the 6-meter telescope is contained in the review [15]. Altogether more than 200 stars of this kind (i.e., more than 30% of their total number discovered elsewhere) were found at the Special Astrophysical Observatory. Objects with strong magnetic fields have been detected among stars with small rotation periods of years and decades. It was shown that for young chemically peculiar stars in Orion the probability of occurrence and strength of magnetic fields decreases sharply with age. An effective method of searching for magnetic stars was suggested.

The review [16] is devoted to the scattered radiation of circumstellar protoplanetary disks. In the majority of cases, this contribution to the total optical radiation of young stars is rather small. There are, however, two classes of stars in which the scattered radiation of circumstellar disks plays an important role. These are irregular variable stars with UX Ori as a typical example and highly embedded stars as well as stars with edge-on disks. The mechanism of variability of UX Ori and similar astrophysical objects was investigated using synchronous observations of linear polarization and brightness of their radiation. The highly embedded stars and stars with edge-on disks where examined by means of observations in the polarized light using the largest telescopes and a coronographic technique.

Although the articles included in this Special Issue cover a rather wide range of topics in modern astrophysics, they are incapable of embracing all the scope of scientific interests of Prof. Yu. N. Gnedin, whose breakthrough results and organizational and teaching activities were so important for the progress of this field of science.

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