Dear Prof. **RNDr. Jan Rybak, CSc**

I am applying for the PhD position in "**Solar activity and the cosmic rays – magnetic fields in the solar atmosphere and their effect on the cosmic rays level**" at the Astronomical Institute of the Slovak Academy of Sciences. The project aims to analyze how the Sun's magnetic field influences the cosmic rays reaching Earth, with a focus on how this effect varies across different solar cycles. As the strength of the Sun's magnetic field changes with each cycle, it significantly affects the intensity of cosmic rays that penetrate the Earth's atmosphere. The objective of the project is to identify the causes of cosmic ray variability based on the spatial distribution, structure, and duration of large-scale magnetic fields in the solar atmosphere, an area I find particularly fascinating. To achieve these outcomes, key tools such as spectroscopy and telescopes will be essential for better understanding the relevant parameters.

I have successfully completed my master's degree in Physics from the University of Madras, India, where I achieved a CGPA of 8.5/10 and cleared a Graduate Aptitude Test in Engineering (GATE) with rank 2879 out of 19375 and Joint Entrance Screening Test (JEST) with percentile 89.07. I have completed my Bachelor's degree in physics from the University of Madras, India, with a CGPA of 8.6/10. Throughout my studies, I have focused on a wide range of physics disciplines, including Astrophysics, Quantum Mechanics, Relativity, Electromagnetic Theory, and Classical Mechanics, providing me with a strong foundational understanding of the key areas necessary for the PhD position.

During my master's program, I conducted thesis research on "**Quantization of Constrained Systems - Particles on an N-Dimensional Sphere**" for 9 months. The objective of this project was to determine the eigenvalues of a constrained system. Specifically, I investigated the case of particles constrained to move on an N-dimensional sphere. One of the primary challenges in analyzing such systems lay in the use of the Lagrangian formulation, which required working with positions and velocities - a process that could become quite complex. To overcome this, I adopted the Hamiltonian formulation, which described the system in terms of positions and momenta and a concept of **Principle of Least action**. This approach simplified the analysis and allowed for the determination of the time evolution of dynamical quantities using a technique known as **Poisson brackets**. However, in the case of constrained systems, the Hamiltonian was not uniquely defined due to the presence of constraints. This led to what is known as the **canonical Hamiltonian**. To handle such situations, I applied a powerful method developed by Paul Dirac, specifically designed for systems with constraints. In this method, the first step was to identify all the constraints present in the system and ensure that they were preserved under time evolution. Once the full set of constraints was established, **Dirac brackets** were constructed using the Poisson brackets along with the identified constraints. These Dirac brackets replaced the Poisson brackets in constrained systems and formed the foundation for consistent quantization in quantum field theory. Applying this methodology to the problem of a particle on a sphere, I first derived the Lagrangian of the constrained system. From there, I transitioned to the Hamiltonian framework, incorporating the system's constraints. I then systematically identified all the constraints by analyzing the time evolution of the primary constraints with the canonical Hamiltonian using Poisson brackets. Finally, I constructed the Dirac brackets between the dynamical variables, which led to the formulation of the correct Hamiltonian for the system. This final Hamiltonian was then used to determine the eigenvalues of the constrained system.

I am currently engaged in studying two fundamental areas of theoretical physics: "**The Special and General Theories of Relativity" and "Lie groups & Lie Algebras"**. The objective of this project was primarily to test Einstein's field equations by applying them to the Schwarzschild solution for a static, spherically symmetric mass. To undertake this, the first step I took was to derive Einstein's field equations using **contraction techniques**, and the concepts of **Christoffel symbols**. This entire framework is grounded in the **Equivalence Principle**, which reveals the profound similarity between free fall and experiencing a uniform gravitational field. Another crucial technique I employed in deriving the field equations was **tensor analysis**, a powerful and indispensable tool in the formulation of General Relativity. By applying tensor operations and performing successive contractions, I constructed the **Riemann curvature tensor** which then led to the **Ricci tensor** and the **Ricci scalar**. Through a series of rigorous mathematical steps, I derived **Einstein's field equations**. By applying Einstein's field equations to a system consisting of a static, uncharged, non-rotating, spherically symmetric mass with no external sources of matter or energy, I obtained the **vacuum field equations**, which form the basis for determining the metric tensor of such a system. Through the application of contraction techniques to the Ricci tensor, and by incorporating the boundary conditions appropriate for spherical symmetry, I successfully derived the **Schwarzschild metric**. This metric also introduces the concept of the **Schwarzschild radius**, a critical quantity associated with the event horizon of a black hole. I have also begun exploring the concepts of **Lie groups** and **Lie algebras**, which are powerful tools for understanding the continuous symmetries of physical systems, as well as the behavior of particles and their interactions.

During my internship, I explored the fascinating topic of "**Cosmic Rays"** which are high-energy charged particles originating from outer space, including their types (solar, galactic, and ultra-high energy cosmic rays), their sources, and how magnetic fields influence their paths before reaching Earth's atmosphere. In this project, I focused particularly on **muons**, as they serve as an excellent example to demonstrate Einstein's **Special Theory of Relativity**. To begin with, I noted that muons have a half-life of approximately **2.2 microseconds**. Given this extremely short half-life, muons produced high in the atmosphere should decay long before reaching the Earth's surface. However, experimental observations have consistently shown that muons are detectable at ground level. I investigated this apparent contradiction and determined that it can be fully explained by the relativistic effects of **time dilation** and **length contraction**. From the perspective of an observer on Earth, the muon's internal clock runs slower due to its high velocity, effectively extending its lifetime. Simultaneously, from the muon's frame of reference, the distance to the Earth's surface is contracted. These two effects together allow muons to reach the ground before decaying, thus providing compelling evidence for the predictions of Special Relativity.

During my literature review, I came across several relevant papers, including "**Monitoring the Daily Variation of Sun–Earth Magnetic Fields Using Galactic Cosmic Rays**." This study aims to predict solar storms and solar winds by monitoring the Interplanetary Magnetic Field (IMF) between the Sun and Earth. The "cosmic ray Sun shadow," created as cosmic rays are blocked or deflected by the Sun, is used to study IMF variations. The authors measured the IMF daily using a cosmic-ray observatory during the sunspot minimum and were able to estimate IMF components approximately 3.31 days ahead of spacecraft data - contributing to better forecasting of solar activity. Another valuable paper I reviewed, "**Disentangling the Sun's Impact on Cosmic Rays,**" investigated how Galactic Cosmic Rays (GCRs) interact with the Sun's heliosphere, reducing their flux and energy. The study used the Alpha Magnetic Spectrometer (AMS) and Neutron Monitors to track solar modulation of GCRs, which changes with the solar cycle. The AMS was integrated with the International Space Station (ISS) by placing a detector to measure the daily fluxes of GCR electrons and protons between 2011 and 2021. These changes in flux were analyzed in the context of solar activity and the magnetic polarity cycle. Accurate prediction of GCR flux is crucial for safeguarding human space exploration from harmful solar activity - an aspect I found particularly fascinating.

Throughout my academic journey, I have been a motivated and curious student, driven by a deep desire to understand the nature of the Universe. This passion for research led me to pursue several projects even after my Master's degree, further strengthening my skills in observational methods, data collection, theoretical physics, and mathematical problem-solving. Engaging discussions with my professors have often sparked fresh ideas and new perspectives. My strong interest in Astrophysics and Theoretical Physics has inspired me to commit to research and contribute meaningfully to the field. I have developed a solid foundation in mathematical modeling using "**Mathematica"** and scientific writing with "**LaTeX"**. I believe my skills and research experience make me a strong candidate for a rigorous PhD program at a leading institution for astronomical research, the Institute of the Slovak Academy of Sciences. I am particularly drawn to Europe for its excellent education system, diverse culture, and opportunities for international collaboration and growth.

Thank you for considering my application.

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