Email To the Professor, the italics were hyperlinks.

Subject line : Request to be part of you Research group as a visiting student; to apply for the ThinkSwiss Research Fellowship

Dear Prof. Dr. Falanga

This email is a very kind request for the opportunity to work as a visiting student in any of your current research groups working on Data Analysis and Interpretations of Neutron Stars or Pulsars Observations.

I am Piyush Marmat, an Undergraduate member of the *Indian Pulsar Timing array* and final year student of Integrated Masters of Science in Physics at *Indian Institute of Technology Roorkee, India.*

Some of my relevant experiences include:

1. My Master thesis work is titled: "Equation of State based on phenomenological relativistic mean-field theory for single and double fluid Neutron Stars"
which will be completed before the summer of 2022 under the kind supervision of Prof. Arumugam (faculty at IITR and also an InPTA member). With this thesis, I learned computational astrophysics using Python and also quantum hadrodynamics (effective QFT model).

2. Project leader for developing a 5m Aperture single-dish radio telescope facility at Indian Institute of Technology Roorkee (funded by the Dean of sponsored research and consultancy). Our initial design and performance calculations will be presented at the upcoming 40th meeting of the Astronomical Society of India in March 2022. I am leading a team of 20 UG students with a faculty advisory committee of 5 members from the electronics and mechanical engineering department at IIT Roorkee.
This project taught me proposal writing, team management, and logistics, also I learned and eventually developed a lot of interest in Radio Telescope Instrumentation.

3. My Project on Pulsar Scintillation: Before being an InPTA member, with the kind guidance of Prof. Bhal Chandra Joshi, I got the fortunate opportunity to develop a PSRCHIVE and Python-based pipeline to generate scintillation spectra of ORT and GMRT pulsar observations. The results obtained using ORT data will be presented in the upcoming ASI meeting. With this project, I learned data reduction and analysis using the python interface of PSRCHIVE. These experiences helped me to contribute to the PSR J1713+0747 mode-changing paper (J. Singha et. al. 2021)

4. Former Head secretary and Joint secretary of the Physics and Astronomy Club-IIT Roorkee. I learned scientific outreach and seminar organization being a part of this student club and also learned and eventually taught amateur astronomy with optical telescopes

I am attaching my latest CV for your reference for more details on my ongoing thesis and all other research works.

I can catch up to new topics fast and have the dedication to learn any extra software and

languages as per the need of the projects.

The motivation is the *ThinkSwiss-Asia-Pacific Research Fellowship*. If you find me deserving then I can apply for this fellowship and work without any financial support from your side. I came to know about you from one of my senior fellows that are working on Neutron Star's Glitch observations and modeling. My major aim is to find a topic for my aspiring Ph.D. thesis, hence I am seeking opportunities in the field of Neutron Star and Pulsars that can provide me valuable experiences to pinpoint a thesis topic as well as potential advisors.

Thanking you in anticipation.
My apologies again for the inconvenience caused.
My ResearchGate Profile: https://www.researchgate.net/profile/Piyush_Marmat
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Piyush Marmat,
Final year master's student,
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Research Project

Piyush Marmat

Pulsar profile morphology during a neutron star - black hole merger

Research Experience as a Master's student

I am an undergraduate member of the Indian Pulsar Timing array (InPTA) and a final year master's student of Integrated Masters of Science in Physics at the Indian Institute of Technology Roorkee (IITR). My Master's thesis work is titled: *"Equation of State based on phenomenological relativistic mean-field theory for single and double fluid Neutron Stars,"* which will be completed before May 2022 under the supervision of Prof. Arumugam (faculty at IITR and also an InPTA member). I developed complex numerical codes to generate Equation of States with density-dependent coupling constants for single and double fluid neutron stars following the formalism of Quantum Hadrodynamics. Before finishing my Master's thesis, I have also been deeply involved in two papers that have been published in peer-reviewed high-impact astronomical journals. In these two papers, I contributed to the pulsar observations and data reductions, and analysis. I already have a solid background in theoretical astrophysics (Pulsars) and skills in pulsar radio data reductions and analysis. At the University of Bern in Switzerland, I will work with Prof. Dr. Maurizio Falanga to continue and extend my experience in theoretical and observational studies of pulsar astrophysics.

Motivation and Scientific Background

One of the most important results of modern astronomy was the discovery of gravitational waves from merging compact objects in binary systems (neutron star - neutron star (NS-NS) or neutron star - black hole (NS-BH) or BH-BH). Neutron stars are fast rotating very dense compact objects, also called pulsars. Pulsars are also found in binary systems accompanying another compact object which can be a neutron star, a white dwarf, or even a black hole. They emit radio beams like a lighthouse between a few milliseconds to a few seconds. Given the high matter density of around 1.4 solar masses confined in a 10 km radius, general-relativity has to be applied to describe the space-time around the pulsar or to model the observed pulsed beam (pulse profile), including the arrival time as a function of time. The characteristics property of pulsars is their remarkably stable period of pulse-profiles, but as a binary pulsar system evolves and approaches the merger, the morphology of this profile will also evolve and therefore can be a very crucial probe to test general relativity. Now, since the discovery in 2015 of the merging BH-BH mergers (by gravitational waves), in our study case, the scientific question is, how does the evolving space-time modify the NS pulse profile during an NS-BH merging process? Please note gravitational waves are emitted by accelerating binary compact objects during the merger process and are observed as ripples in the geometry of spacetime. What are the observables of NS pulse profile evolution or the time of arrival signatures in the radio data?

Milestones

The first milestone is to study the literature on this specific topic. This should be done prior to visiting Prof. Falanga. He will assist me remotely during this process. The second milestone is to write a general relativistic code (or adapt an already existing numerical code) to produce NS pulse profiles for different metrics. The next step is to study the NS pulse profile variation and time of arrival affected during an NS-BH space-time disturbance. Ultimately, we are interested if, in radio data archives, we can find such a signature (radio data taking close to a gamma-ray burst emission, i.e., during a merger event). This is a very ambitious project that needs deep dedication and knowledge of general relativity, as well as a solid base in numerical relativity.

Expected Findings and their implications

NS-BH binary close to the merger can be modeled as a general relativistic decaying orbit, hence one expected parameter, among others, is the orbital decay time. A gamma-ray burst will manifest itself in the profile morphology and it implies variation in peak and mean flux densities of pulse profiles over a range of observation frequencies. The NS period will also change as the merger approaches and therefore its rate can also be modeled. Based on this information and known sensitivities of the Square Kilometer Array (SKA) and other radio telescopes (e.g., in India), we may also be able to predict which merger condition would be detectable by which telescope. This research field has been emerging since the discovery in 2015 of gravitational waves and has a high impact in modern astrophysics to further test general relativity.

The Scientific Outlook

This project, in particular, can help me earn more experience with several aspects of compact object astrophysics. This project should lead me to a Ph.D. in the field of compact objects and hence this project plays an instrumental part in gaining the skills and knowledge relevant to it. Scientifically this is a major step forward in understanding and testing general relativity. This project should lead not only to a Ph.D. but if possible to a first original publication in a peer-reviewed high-impact factor scientific journal.

Letter of motivation

Piyush Marmat

Application Think-Swiss Research Scholarship 2022

It is my great pleasure to apply for the Think-Swiss Research Scholarship 2022 in the field of Astronomy and Astrophysics.

Why you should be awarded the ThinkSwiss Research Scholarship

I am currently pursuing my master's in Physics having already published, as co-author, two peer-reviewed publications in pulsar astronomy, and two more papers (a second other paper on modeling Dispersion Measure of pulsars considering Interstellar medium effects and a first-author paper on the software package to simulate variable pulse-broadening effects) are in preparation. I aspire to advance my research career in astronomy and astrophysics much further by engaging in research projects that can help me earn a competitive mindset and the skills needed to conduct independent research. A Ph.D. in Astronomy just after the master's is the best for the above purposes. Therefore, in that direction, it is necessary to understand the ongoing research in the fields that interest me the most, which are theoretical and observational studies of compact objects. We plan to not just “make the student learn research” but also to carry out a fruitful science project that has the potential to be published. Also, Prof. Falanga aims to foster a spirit of cooperation and synergy among the research groups at Bern and IIT Roorkee, India. Getting a chance to work with Prof. Falanga will help me diversify my research interests and strengthen me to participate in international research collaborations.

Why would you make an excellent “student ambassador” in the future?

I have served as the joint and the head-secretary for the Physics and Astronomy Club of the Indian Institute of Technology Roorkee, India. This club is a student organization funded by my current university, that works to promote research in Physics and astronomy on the campus and the nation. We have successfully organized several colloquia by eminent physicists and astrophysicists all over the globe, several night-sky observation sessions using optical telescopes for the local public and students, and won a couple of national-level inter-university competitions to represent the institute—organizing competitions and several outreach activities like Journal Clubs, Workshops, and screening of science documentaries. Our student members have worked as a team on all these. As an instrumental part of this Club, I learned the power of science popularization using social media and engaging events. I recently became part of the Education and Public Outreach group of the International Pulsar Timing Array Collaboration based on my experiences (promotional, web design, and graphic designing skills). This project has all the potential that I could apply all the outreach skills

I have learned so far to promote the words of Swissnex through my scientific results and stay at the University of Bern.

Why are you choosing Switzerland?

This research proposal is directly related to one Swiss and Indian priority subject in the fields of space science and technology. It is in particular related to the science goal of the Square Kilometer Array (SKA) project, the world's largest radio telescope located in the Karoo desert in South Africa (in the construction process). Switzerland had for several years an observer position in the SKA project and in 2021, the Swiss Federal Council decided to join the SKA organization as a full member. India's National Centre for Radio Astrophysics has been a full SKA Organisation member since 2014. My research interests are highly aligned with the aim of SKA and specifically with the expertise of Prof. Falanga. In addition, Switzerland is known for its world-class education system. Therefore, collaborating with Prof Falanga at the University of Bern will also tighten the synergy between my institute in India and Switzerland.

If my application to the ThinkSwiss Research Scholarship is approved, we agreed with Prof. Falanga that I would spend my three months at the University of Bern starting from September to the end of November 2022.

Yours sincerely

Piyush Marmat

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