平成30年度国立天文台滞在型共同研究報告書
Activity Report for NAOJ Visiting Joint Research in FY 2018

2018／10／30

申請者 Applicant	氏　名 Name	Hajime Sotani
	所属・職 Division・position	Division of Theoretical Astronomy Project Assistant Professor
研究課題名 Research Title	Semi-analytic pulse profile modeling	
研究場所 Place	Mitaka Campus.	
共同研究者 氏名・所属・職名 Joint researcher's Name・Institution・Position/ Graduate Student year	Hector Okada da Silva Montana State University Postdoctoral researcher	

１．研究概要（Summary of research）

Neutron stars are unique objects in the Universe. The high-density within their core (a few time above the nuclear saturation density) and their high compactness creates large gravitational fields (requiring General Relativity to their description), makes neutron stars ideal laboratories to study fundamental physics. Some neutron stars posses hot spots, small regions on their surface emitting X-rays, caused, for instance, by accretion of matter by a companion object (such as low-mass X-ray binaries) or due its magnetic field configuration (such as in millisecond pulsars). This radiation is observed as a roughly sinusoidal flux. Since the radiation travels through the strong gravitational field of the rotating neutron star, examining the pulse profile offers an exciting possibility of measuring a number of physical parameters related with the star. For instance, gravitational light bending strongly affects the pulse profile — the magnitude of this effect being mostly dictated by the compactness of the star. If the neutron star spins sufficiently fast (~600 Hz), it develops a nonzero quadrupole deformation, which also impacts the shape of the pulse profile. The ongoing NICER (Neutron Star Interior Composition Explorer) mission by NASA, launched in June 2017, is currently on observing mode, collecting data (i.e. pulse profiles) from a number of targets. To fully explore the outstanding scientific potential of this mission it is of utmost importance to develop techniques (either numerical or analytical) to describe and calculate the pulse profile of neutron stars. In this context, we propose to develop an accurate, easy to implement, semi-analytic pulse profile model, exploiting the Hartle-Thorne formalism to model rotating neutron stars in General Relativity. Current pulse profile models are either (i) fully numerical and require expensive numerical work (in the form of ray-tracing) to generate the pulse profile; or (ii) are analytical and easy to implement, however do not apply to neutron stars rotating at high-frequencies. Our proposal targets to fill the gap between these two extrema, developing a complete toolkit that can be used to model neutron stars, which rotate with moderate spin frequencies (to the point of being deformed by centrifugal forces) in the context of General Relativity.

２.研究成果(Research achievements)

We were able to do important progress on our project. Namely: (i) we decided that it would be important to investigate the effects of finite sized hotspot on neutron star surfaces in pulse profiles. In the literature, infinitesimal hotspots are often considered. In reality, as shown by numerical relativity calculations, these hotspots are of finite extent. (ii) We studied the previous works on finite size hotpots and were able to develop two, independently written numerical codes, which reproduces (and agree with one another), recent results. (iii) In the spirit of the original proposal of developing semi-analytic methods to study pulse profile. We know plan to: (iii-a) extend our code to include approximate, analytical, formulae and test their validity using our newly developed numerical codes as comparison. (iii-b) to examine different hotspot shapes and their effect on pulse profiles. We have already developed a method to do so, with its numerical implementation pending. We have also started to sketch a draft as for this work and planned the steps for the coming months.

During my stay, I also gave a talk in the Division of Theoretical Astronomy's colloquium, entitled "Illuminating the strong-field regime of gravity" were I presented some of the work I am doing at my home institution.

３．本制度に対する意見、要望など【申請者記載欄】
(Any comments on this program【For applicant】)

This time, the joint researcher needs to get visa for visiting Japan. In such a case, I think that this NAOJ program should also cover the fee for getting visa.

４.本制度に対する意見、要望など【本事業で来訪した共同研究者記載欄】
(Any comments on this program【For joint researcher】)

My stay at NAOJ was a very productive and pleasant one. During my visit, I had extensive discussions with Dr. Hajime Sotani and Dr. George Pappas, and the group member and staff of the Division of Theoretical Astronomy were very welcoming. I think the program is an excellent one.

５.共同研究者の滞在日程(Joint research period)

氏名・所属 （Name・Institution）	Hector Okada da Silva Montana State University	
滞在日程（Period of stay）		日数(days)
2018/09/21 ～ 2018/10/21		31 days
年 月 日 ～ 年 月 日 YYYY/MM/DD ～ YYYY/MM/DD		日間(days)
合 計 (Total)		31 days