# Declaration

I, **Binay Rai**, certify that the work embodied in this thesis is my own bonafide work and carried out by me under the supervision of **Prof. (Dr.) Bikash Chandra Paul** from January 2016 to July 2021 at the **Department of Physics**, University of North Bengal (NBU), Darjeeling, Siliguri. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma. I declare that I have faithfully acknowledged and given credits to the research workers whenever and wherever their works have been cited in my thesis. I further declare that I have not willfully copied any others' work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports dissertations, theses, etc., or available at websites and have not included them in this thesis and have not cited as my own work.

Date 02/07/2021

Place Darjeeling

*Signature*

Binay Rai

(Binay Rai)

Registration no. - Ph.D/Phy.(1256)/427/R-2019

# University of North Bengal

Accredited by NAAC with Grade "A"

*Dr. B. C. Paul*
*Professor*
Department of Physics
www.nbu.ac.in

समानो मन्त्रः समितिः समानी

P.O.NORTH BENGAL UNIVERSITY
Darjeeling, West Bengal
India, PIN 734013
Email: bcpaul@nbu.ac.in

## CERTIFICATE OF SUPERVISOR

It is certified that the work contained in the thesis titled "An X-ray view of Compact Objects" by Mr. Binay Rai, has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

01.07-2021

**Signature of Supervisor (s)**

**Name (s) : Dr. Bikash Chandra Paul**
***Professor***
**Department of Physics**
**North Bengal University**

**July 2021**

Department of Physics University of North Bengal

Professor
Department of Physics
University of North Bengal

Curiginal

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Binay Rai
02/07/2021

02/7/2021



Professor
Department of Physics
University of North Bengal

DEPARTMENT OF PHYSICS
UNIVERSITY OF NORTH BENGAL
P.O. North Bengal University, Siliguri, Dist. Darjeeling, West Bengal, Pin - 734013, India

Website:www.nbu.ac.in

ENLIGHTENMENT TO PERFECTION

Phone: +91-(0) 353-2776338, Fax: +91-(0) 353-2699001

# DRC CERTIFICATE

It is certified that the work contained in the thesis titled "An X-Ray View of Compact Objects" by Mr. Binay Rai, have been carried out following University guidelines and have been approved by the Departmental Research Committee for processing by the Board of Research Studies.

Approved | Date

Committee Members:

1. B. C. PAUL 28-06-2021
(Name and Signature of the DRC Member)

2. PROVASH MALI 28/06/2021
(Name and Signature of the DRC Member)

3. Malay Kumar Das M. K. Das 28.6.21
(Name and Signature of the DRC Member)

SUMAN CHATTERJEE

4. Suman Chatterjee 28/06/2021.
(Name and Signature of the DRC Member)

Head
Department of Physics
University of North Bengal

Department of Physics

University of North Bengal

Department of Physics ★ University of North Bengal ★

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*Dedicated to my loving parents . . .*

# Preface

The emission of the X-rays from a compact objects is due to very complex processes which occurs in the magnetosphere or in the accretion disk near the compact object. For the neutron star the X-rays are mostly originated from the accretion column formed at the magnetic poles of the neutron star. The compact object considered in this thesis is neutron star, which are in a binary system (X-ray binaries) and sources of X-rays. It is known that X-rays generated from a neutron star in a binary system appears as a pulses of X-rays. The brief outline of the thesis is as follows -

- **Chapter 1** - In this chapter we have given a brief discussion about the history of X-ray astronomy, different types of X-ray binaries, different ways of accretion of matter onto the neutron star. We have mentioned shortly about different mechanism by which X-rays are generated in this chapter. Also we have briefly described about the pulse profile, theoretical study of spectrum of a X-ray pulsar and origin of cyclotron line.

- **Chapter 2** - In this chapter the brief description of the instruments onboard different space observatories from which the observed data were taken up for the study are presented. We have also given a list of the sources used in this thesis and discussed briefly about the discoveries and studies done by others before our study. Finally at the end of this chapter we have given the description of different models used in our study with concluding remarks.

- **Chapter 3** - In this chapter the analysis of NS HMXB SMC X-1 is presented. The RXTE PCA data for the high mass X-ray binary source SMC X-1 between 2003-10 and 2003-12 when the source was in high states are analyzed. The source is found to be frequently bursting which is seen as flares in the light curves, on an average of one in every 800 s and an average of 4-5 X-ray burst per hour. Typically a burst was short lasting, for few tens of seconds, in addition to that few long bursts of more than hundred seconds were also observed. The flares apparently occupied 2.5% of the total time of observation of 225.5 $ks$. A total of 272 flares with mean FWHM of the flare $\sim$ 21 s are noted. The r.m.s. variability and the aperiodic variability are found to be independent of flares. As observed the pulse profiles of the lightcurves do not change its shape implying that there is no change in the geometry of accretion disk due to burst. The hardness ratio and the r.m.s. variability of light curves show no correlation with the flares. The flare fraction shows a positive correlation with the peak-to-peak ratio of the primary and secondary peaks of the pulse profile. The observed hardening or the softening of the spectrum cannot be correlated with the flaring rate but may be due to the interstellar absorption of X-rays as evident from the change in the hydrogen column density (nH). It is found that the luminosity of the source increases with the flaring rate. Considering the viscous timescale equal to mean recurrence time of flares the viscosity parameter is estimated $\alpha \sim 0.16$ for consistency.

- **Chapter 4** - In this chapter timing and spectral the analysis of Accreting Millisecond X-ray Pulsar (AMXP) Swift J1756.9-2508 during 2018 is presented. We have used the data of *Swift* and *NuSTAR* observations. The simultaneous fitting of the Swift and *NuSTAR* spectra indicates that the source was in the hard state with a cut-off energy of about 74.58 keV. The pulse profiles of the AMXP and its dependence on energy are also probed. The colour-colour diagram of the source is plotted for investigating how hard colours are distributed with respect to soft colours. The pulse-phase, orbital-phase and time resolved spectral analysis using *NuSTAR* data are carried out. Pulse phase-resolved spectra were fitted with a power-law model and significant changes in the spectral parameters with pulse phase are observed. The column density and photon index obtained from the orbital phase spectral analysis were found to have some anti-correlation with the flux. Through the time-resolved spectral analysis, we observed that the spectral parameters show positive correlation with each other and also with the flux. We do not observe a softening of the spectrum with time here. No emission lines or Compton hump were observed in the spectrum of the AMXP.

- **Chapter 5** - In this chapter a detail study of pulse profiles and spectra of the source 4U 1901+03 during 2019 outburst is presented. The timing and the spectral properties of the BeXB 4U 1901+03 during 2019 outburst is studied using *NuSTAR*, *Swift* and *NICER* observations. Flares are observed in all the observations which are of tens to hundreds seconds duration. It is observed that the pulse profiles changed significantly with time. It is evident that the single peak of the pulse evolved into double peak having one main peak thereafter to a single peak once again. An increase in the height of the peak of the pulse profiles with energy is observed. The pulse fraction increases with energy and at the end of the outburst. The variation of the pulse profile with time indicates transition from one accretion regime of the pulsar to the other. The absorption like feature at 10 keV found here is connected with positive correlation with the luminosity and along with other spectral parameters. However due to uncertainties in the estimated distance to the source we cannot confirm this feature to be CSRF. Another absorption like feature about 30 keV is observed in the spectra of the last two *NuSTAR* observations in which line energy about 30.51$\pm$0.42 and 30.41$\pm$0.54 keV respectively. The softening of spectrum along with the increase in pulse fraction at the end of the outburst and absence of pulsation after 58665.09 MJD indicates that the pulsar entered propeller phase, which is also supported by Swift-XRT observations

- **Chapter 6** - In this chapter we have summarize the results obtained from the analysis of the observed data for the pulsars. The analysis carried out here will be extended for other pulsars using the data from *ASTROSAT* and other observatories in future.

# List of figures

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