Title:	Discovery of cyclotron line in a highly magnetised neutron star X-ray binary: 4U 1901+03
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Abstract:	This thesis deals with the study of high magnetic field (10 12 − 10 13 G) neutron stars also known as Accretion powered X-ray pulsars. In these systems stellar magnetic field plays an important role in channeling of matter onto the surface of a neutron star and the X-ray emission mostly comes from the “hot spots” formed around one or both poles. The misalignment between the rotation axis and the magnetic field causes the observed X-ray flux modulation. A majority of accretion powered X-ray pulsars belong to the class of High Mass X- ray Binaries where the companion star is a Be type star or an OB type supergiant. Be-X-ray binaries are mostly transient systems that go into type I outburst close to the periastron passage, and giant type II outbursts which are rare. Transient X-ray pulsars are excellent candidates to understand the changes in the accretion geometry and corresponding timing and spectral signatures due to magnetically-driven accre- tion. One can understand changes in the accretion processes and characteristics that are intensity dependent. In this thesis, we have studied an X-ray transient source, 4U 1901+03 that has been classified as a Be-X-ray binary. This classification is based only on its X-ray timing properties. Moreover, there have been several debates regarding the plausible value of cyclotron scattering resonance feature (CRSF or cyclotron line) in its X-ray spectrum. During its previous outbursts, 10 keV absorption feature was believed to be its cyclotron line. Observations made with NICER and Insight-HXMT revealed the value of critical luminosity in this source to be 10 37 ergs s −1 . Mushtukov et al. (2015) proposed a relationship between the critical luminosity and the magnetic field which suggests that the CRSF energy in this source to be around 30 keV. In 2019, this source underwent a very bright (with peak X-ray flux of 8 × 10 −9 ergs cm −2 s −1) and long (duration of 6 months) Type-II outburst. During this outbursts several multi-wavelength observations were performed as part of Simultaneous Mul- tiwavelength Astronomy Research in Transients NETwork (SmartNet). During this campaign, 4U 1901+03 was observed four times with Nuclear Spectroscopic Telescope Array (NuSTAR) and several Swift observations were also made. In our work, we have used combined observations with Swift and NuSTAR observations with the primary aim to study its broadband X-ray spectrum. NuSTAR is the first hard X-ray imaging instrument and is an excellent mission to search for CRSFs in the X-ray spectra of X-ray pulsars. Our detailed timing and spectral X-ray study revealed several interesting charac- teristics of this source which provided insights into the evolution of accretion geometry in this system. One of the significant outcome of this thesis is discovery of a cyclotron line around 30 keV. This is for the first time, it has been detected in this source, thanks to the hard X-ray imaging capability of NuSTAR. The measurement of cy- clotron line energy allowed us to estimate the magnetic field of the neutron star. We estimated magnetic field strength of the neutron star in 4U 1901+03 to be 2.9 × 10 12 G . In addition to this very important result, we have also found a strong dependence of pulse profiles on energy and luminosity. The pulse-profiles changed their shape from double-peaked to single-peaked at higher energies and during the decay of out- burst a prominent change in the pulse profiles was observed around 30 keV, indicating that there is drastic change in the accretion or magnetic configuration around these energies. To probe into these variations, we also performed a pulse-phase resolved spectroscopy and found strong dependence of spectral parameters on the pulse phase. A strong pulse-phase dependence of cyclotron line at around 30 keV further confirmed out discovery of a cyclotron line in 4U 1901+03 as cyclotron lines are known to exhibit strong pulse-phase dependence. Thus, our timing and spectral study of 4U 1901+03 revealed several interesting and promising results. We are currently preparing a manuscript to be submitted to the Monthly Notices of Royal Astronomy Journal (MNRAS) for publication.
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