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Multi-Wavelength Studies of Compact Binaries L.E. Rivera Sandoval

Summary

Compact binaries (CBs) are binary star systems in which a white dwarf (WD), a neutron star (NS) or a black hole (BH) accrete from a low mass companion star. The distance between components is small enough that interaction (such as mass transfer) between them occurs. CBs allow to study a wide variety of astrophysical phenomena, such as the end-state of stellar evolution, mass accretion, the equation of state of ultra dense matter and also they allow for testing of general relativity in the strong field regime.

These types of binaries reside in different environments, such as the Galactic field and globular clusters (GCs). However their study is not always easy. Factors like stellar crowding, high interstellar extinction, uncertain distances and intrinsic faintness make difficult their identification and/or study. Thus, observations taken at different wavelengths are crucial for making progress, as well as the combination of different data analysis techniques. In this regard, the development of telescopes with very high resolution and sensitivity, such as the *Hubble Space Telescope* and the *Chandra X-ray Observatory*, have greatly improved our knowledge and understanding of CBs, since for example, only with these telescopes it is possible to identify and study several CBs in crowded environments such as GCs.

In this thesis I focus on the analysis of several types of CBs in which a WD or a NS are the primary objects. More specifically, cataclysmic variables (CVs), ultra compact WD binaries (also known as AM CVns), radio millisecond pulsars (MSPs), transitional MSPs (tMSPs) and NS low mass X-ray binaries (NS LMXBs). These have been studied using observations in ultraviolet (UV), optical and X-rays using the space telescopes *Hubble, Chandra, Swift* and *GALEX*.

In Chapter 2, I present the discovery of two companions to MSPs using near-UV (NUV) images of the GC 47 Tucanae (47 Tuc) taken with *Hubble*. I also show the unambiguous identification of two more of these MSP companions. All the systems identified were classified as He WDs based on their NUV and optical colors. Parameters such as masses and cooling ages were determined in that study. This in turn

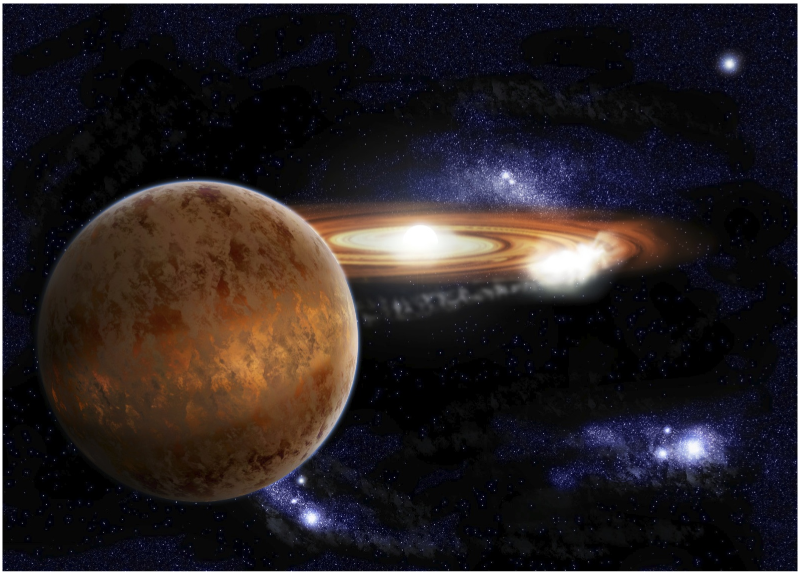

Figure A: Artistic impression of a compact binary. Credit: Stuart Littlefair/Science.

helps to constrain the properties of the NS in the systems. Among the ~ 90 binary radio MSPs that have been found in the GCs of our Galaxy, until recently only for 10 of those the companion was firmly identified at optical wavelengths. This means that the new identifications in 47 Tuc represent an increase of 40% of the total sample of counterparts to MSP companions in GCs.

In Chapter 3, I present a very extensive and detailed photometric study of accreting WDs in the GC 47 Tuc at NUV and optical wavelengths. I used images from the *Hubble telescope* to analyze 238 X-ray sources previously found in the cluster using *Chandra*. This analysis produced the discovery of 22 new CVs and the confirmation of 3 more of these systems. Thus, 47 Tuc is now the GC with most CVs identified so far. Before this study, only few tens of CVs were known to reside in Galactic GCs. With the addition of more than 20 new CVs in GCs, I demonstrate that a NUV guided search, in combination with optical and H_α photometry, as well as X-ray observations of the sources in the cluster is a powerful technique to identify these binaries.

For the first time, I also show a comparison between the properties of the CVs in core collapsed and non-core collapsed GCs. These results shed light on the effects of stellar interactions and the formation and evolution of CVs in crowded stellar environments.

In the same chapter I present the second AM CVn candidate known to reside in a GC to date, as well as four potential MSP companions for which radio pulsations from the NS have not been reported yet.

In Chapter 4 I carried out mid-UV (MUV) studies of the tMSPs XSS J12270–4859 and PSR J1023+0038 during their radio pulsar state with images taken with the space telescopes *Hubble*, *Swift* and *GALEX*. By performing a Markov chain Monte Carlo light curve fitting on optical and MUV data, I show that the presumable intrabinary shock that is formed due to the interaction of the pulsar wind and matter outflowing from the companion, might contribute to the observed MUV and optical radiation of the system. Until recently, the companion was thought to be the responsible from the radiation observed from UV to infrared wavelengths. However, the results of Chapter 4 strongly suggest that it is not the case. The MUV photometric results presented for the tMSP PSR J1023+0038 indicate an asymmetric geometry for the presumable intrabinary shock in that system. This gives new insights about the configuration of that tMSP during the radio MSP state.

Finally in Chapter 5 I show an X-ray analysis of the transient NS LMXB EXO 1745–248 in the GC Terzan 5. Using *Chandra* data I studied the quiescent state of the system. This X-ray binary shows extreme luminosity variations of ~ 3 orders of magnitude (few times 10^{31-34} erg s^{-1}) on time scales from days to years. Unlike many other NS LMXBs at these luminosities, the photon index of the source was found to be always hard ($\Gamma \sim 1.4$). These unusual properties of the system could be related to ongoing accretion in the quiescent state. However, EXO 1745–248 also behaves differently from other NS LMXBs that are thought to accrete during quiescence. The behavior of EXO 1745–248 is thus atypical and has to be investigated more in detail using new observations.