Searching for Close Binary System in Milky Way Galaxy as Potential Gravitational Wave Sources

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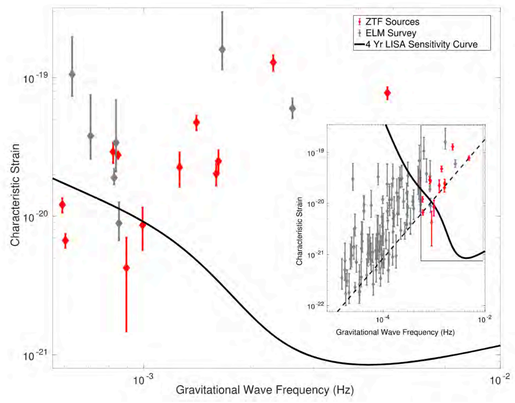
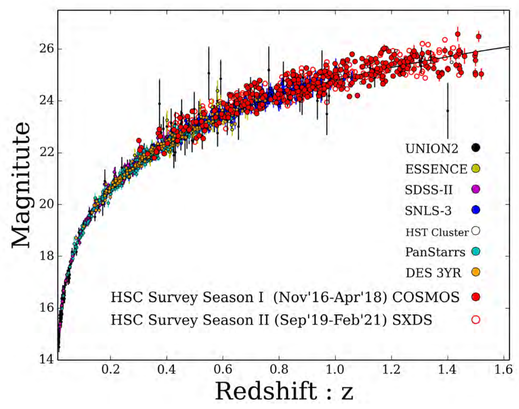
Introduction : Close Binary Systems in Milky Way

Close Binary systems in our Milky Way Galaxy are of our great interest for two major fields of astrophysics studies.

1: Potential Source of the Gravitational Wave
Although the signal per system may be weak, there are numerous binary systems in the Milky Way and the integrated signal can contribute as a background source and it is important for the future planning of the Gravitational Wave to assess its level.

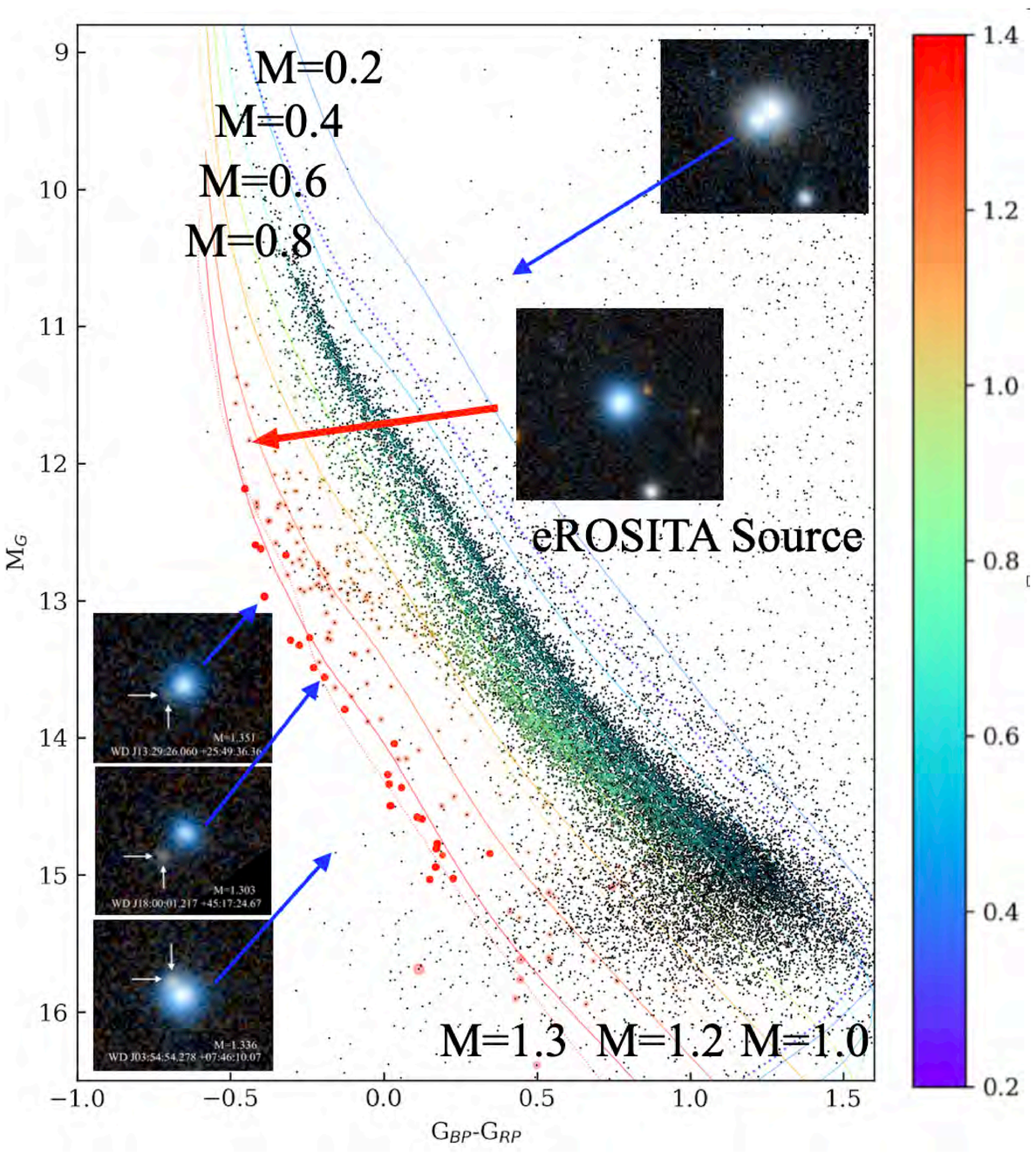
2: Progenitor of Type Ia Supernova
After two decades of the discovery of Type Ia supernova (SNIa), now we have more than 2000 SNeIa on the Hubble Diagram. Hyper-Suprime Cam on Subaru Telescope is finding a few hundred supernovae beyond z > 1.0, and we anticipate that the LSST will discover more than a million SNeIa. However, the progenitor of SNIa has been debated for decades and we still do not know if it is a single degenerate (SD: a pair of white dwarf and main sequence star / red giant) or double degenerate system (DD: white dwarf – white dwarf binary). Binary population in Milky Way can give us a great clue.





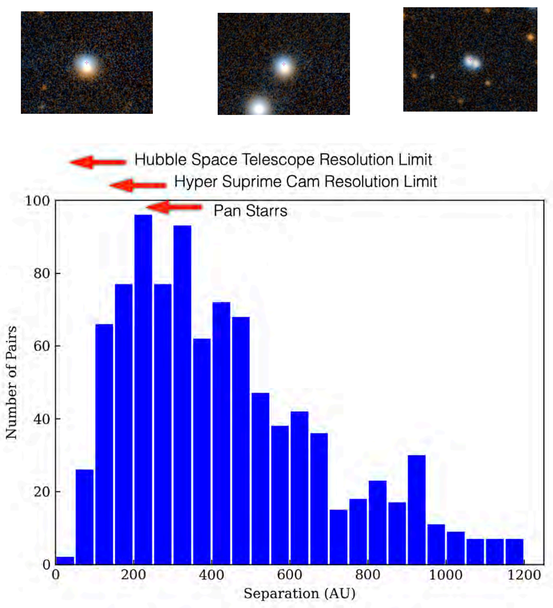
LEFT: Taken from Burdge et al 2020 (Figure 9, ApJ, 905, 32), gray points are from Extremely Low Mass survey. Red points are discoveries from Zwicky Transient Survey. The curve shows the sensitivity of 4 years of LISA data. Some of the nearby close binaries can be observed as a luminous gravitational sources by LISA. RIGHT: The state of art Hubble Diagram from the SNIa cosmology including the latest data from the Hyper-Suprime Cam survey. There exists mysterious host galaxy dependence and one of the explanation is DD vs SD.

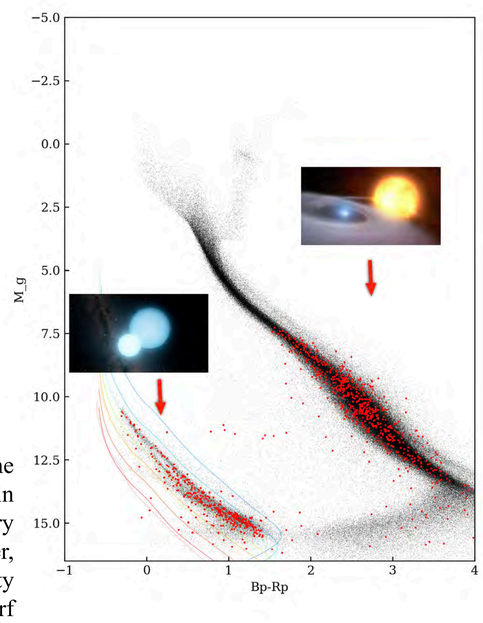
White Dwarf H-R Diagram



HR Diagram of White Dwarfs. The locus is the isomass. The mass increases from right to left and we expect 1.4 solar mass is the limit of white dwarfs. Accurate distance measurement enabled us to resolve subclass of white dwarfs clearly. The average mass of white dwarf is 0.6 solar mass. The ones beyond one solar mass may have a companion. These white dwarfs can gain mass from the mass transfer from the companion star. Indeed, for some cases, we can find companion stars for massive white dwarfs. The most promising one has soft X-ray detection from eROSITA observation and it is the evidence for the mass accretion. The follow-up observation is needed for these systems

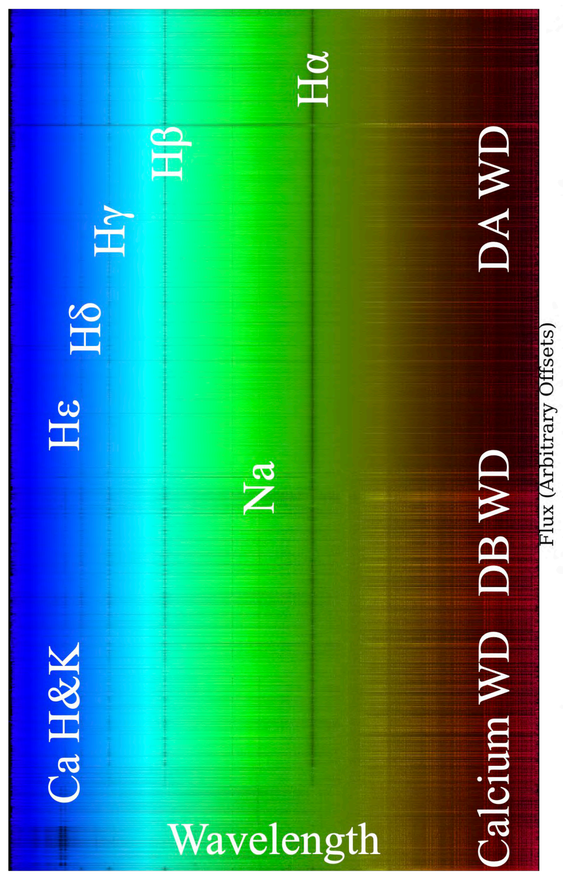
SN Ia Statistics

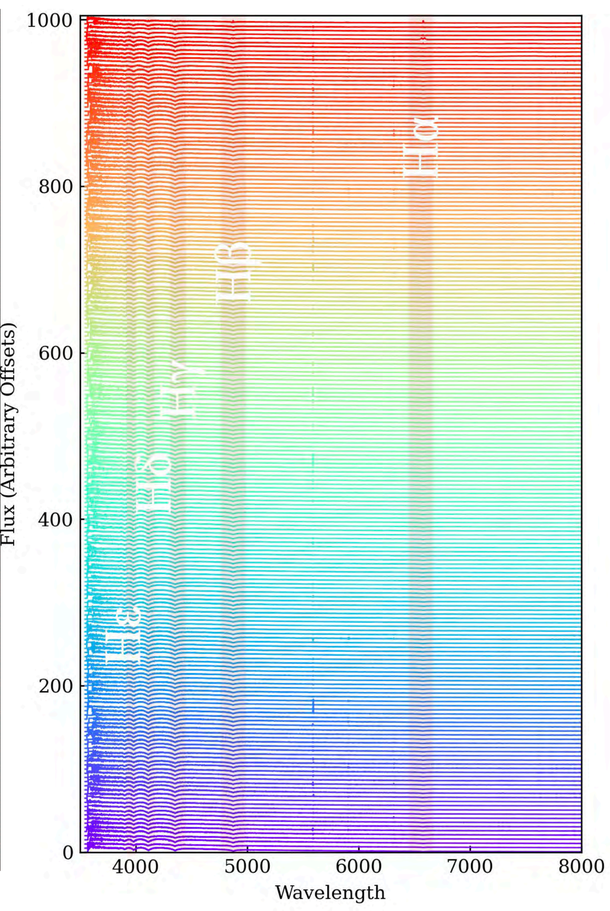




We identified White Dwarf Binaries from GAIA EDR3. LEFT: The ones which has accurate distances, we can measure the separation in terms of AU, and the statistics is shown above. We can resolve binary stars down to 200 AU, but we have to miss closer binaries. However, we can seek closer binaries through light curves and radial velocity shifts from the spectra. RIGHT: What is the companion of white dwarf binary? Both DD and SD combination can be found in our data set.

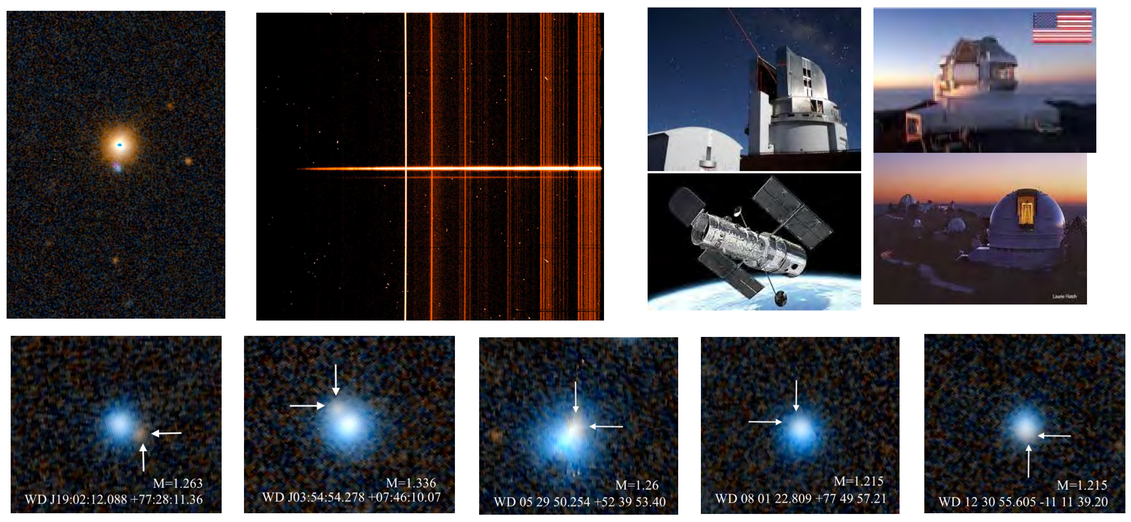
Identifying Close Binaries from SDSS Spectra





We are now in the era of Big Data, and we are taking advantage of the major survey data and seek for close binary systems. LEFT : 30,633 White Dwarf Spectra from 20 years of Sloan Digital Sky Survey. We use "sequencer algorithm which measures the similarity of spectra and order them by Euclidian Distance or entropy based Kullback-Leibler divergence (Baron & Menard 2020). White Dwarfs are automatically classified and binary systems are clustered at the top . The double peaked absorption feature can be found the top spectra, they are the signs of binaries (RIGHT). We aim to refine this technology and plan to apply all of 536,086 SDSS stellar spectra.

Follow-up Observatons and Future Prospectives



We have identified promising close binary candidates and follow-up observations are being planned and executed using Subaru/FOCAS, Gemini, Lick and the Hubble Space Telescope. GAIA satellite releases DR3 in June 2022 which includes catalog of close binary systems. With this large number of statistics, we can get to know the population of close binary system and potentically, this is the way to identify White Dwarf – Blackhole Binaryeis. We anticipate the great discoveries are waiting for us in the near future!

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