Snow White had 7 Dwarfs !

UNIVERSITY OF WARSAW

Astronomical Observatory
of the University of Warsaw
Founded in 1825

White Dwarf Binaries as Gravitational Wave sources

64th Cracow School of Theoretical Physics

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Motivation

We focus on modelling the Gravitational wave background from White Dwarf Binaries in the LISA sensitivity range and building a model of their population in the Milky Way.

Why White Dwarfs ??

White dwarfs are the remnants of Sun like stars, making up a significant portion of our galaxy. Studying their binaries allows us to better understand how stars evolve and interact throughout their lifetimes.

The Promise of Gravitational Waves!!

These waves, detectable by instruments like LISA, offer a unique opportunity to study white dwarf binaries. Unlike electromagnetic signals, gravitational waves pass through cosmic dust and gas unhindered, revealing insights into the unseen universe.

Further astrophysical significance :

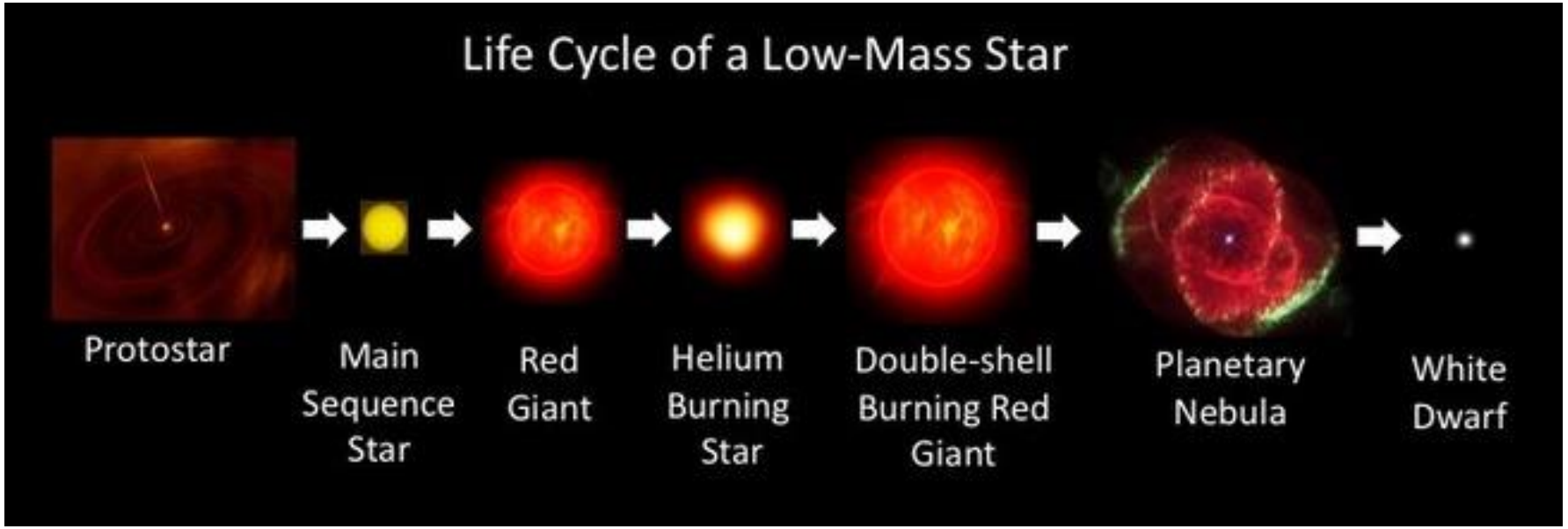
Probing stellar evolution, galactic dynamics and evolution, understanding cosmology, testing theories of gravity

Overview

- White Dwarfs
- Binary stellar evolution : Evolution of isolated White Dwarf Binary
- Globular clusters
- COMPAS
- Gravitational Waves and LISA
- Population modelling of White Dwarf Binaries
- Gravitational Waves from White Dwarf Binaries
- Summary

White Dwarfs

White Dwarfs are stellar remnants of Sun like stars of mass ranging from 0.08 to 8 Msun



nate-thegreat.weebly.com

White Dwarfs

Mass ~ **0.17 to 1.4 Msun**

Radius ~ **7000 km**

Surface Temp.~ **8000 to 40000 K**

Gravity is supported by **electron degeneracy pressure**

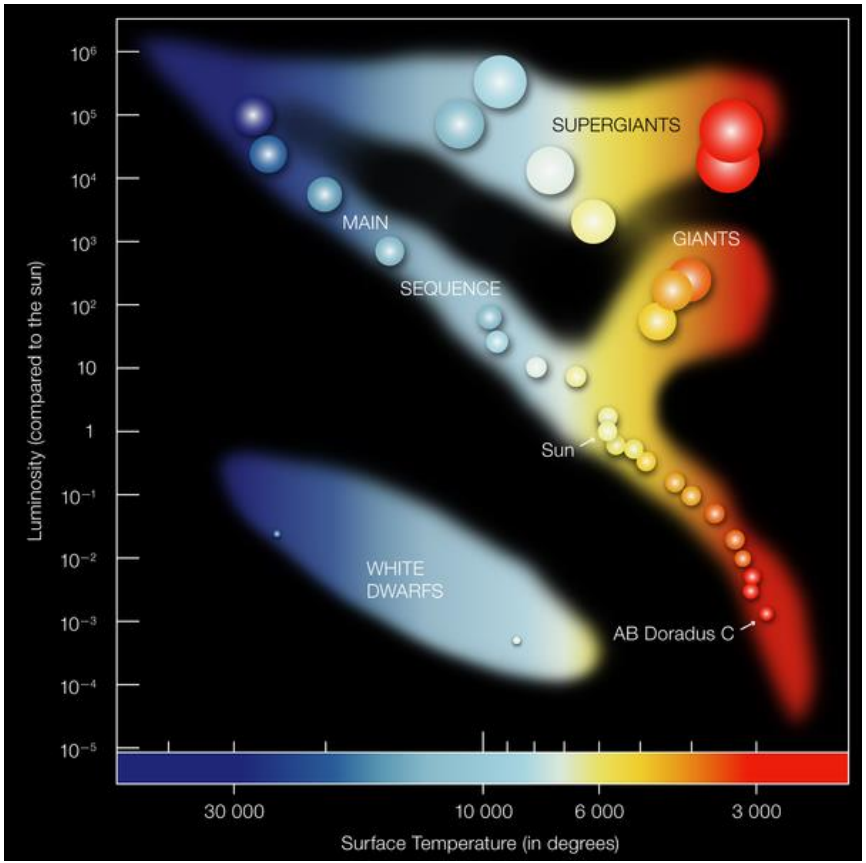
Low luminosity because of smaller radius according to

Stefan-Boltzmann law : $L = 4\pi R^2 \sigma T^4$

White Dwarfs follow the mass-radius relationship

$R \sim M^{-1/3}$

Imagine a star of the size of Earth and Mass of Sun !!!!



[Chandra X-Ray Observatory]

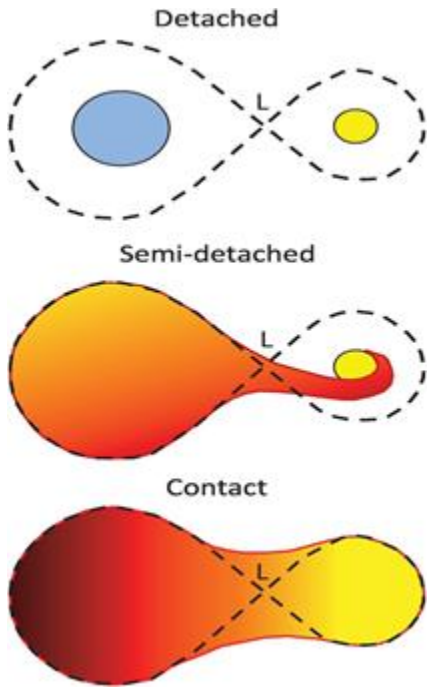
Binary Stellar Evolution

Binary stellar evolution primarily depends on the mass transfer between the two stars.

The type of mass transfer depends on the configuration of the binary system.

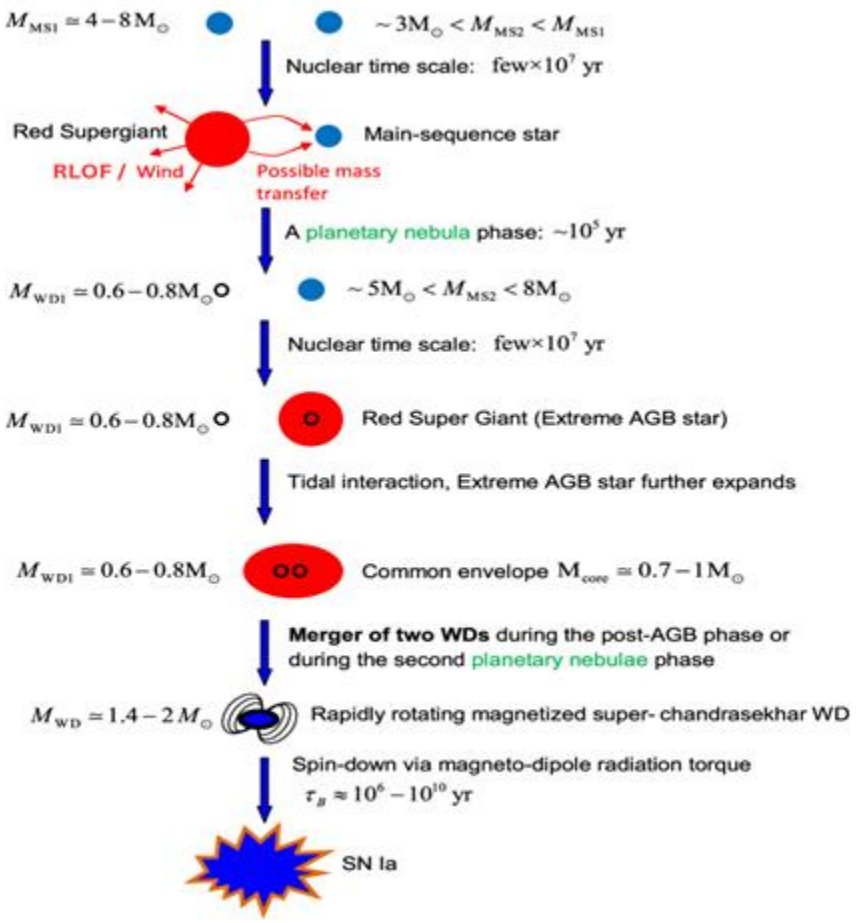
Three types of binary configurations are detached, semi-detached and contact binary.

The corresponding mass-transfer channels are stellar winds, Roche-Lobe overflow and common envelope mass transfer.



[Richard Walker, Spectral Atlas for Amateur Astronomers, 2017]

Evolution of White Dwarf Binaries



[10.48550/arXiv.1109.4652]

Globular Clusters

Globular clusters are dense, spherical collections of very old stars spread across 10-300 ly with mass ranging from 10^3-10^6 solar mass.

Their high stellar density enhances the formation of various types of binary star systems like WD binaries.

Close encounters within clusters lead to dynamical interactions, influencing the evolution of binary systems.

The dense stellar environment and dynamical interactions foster conditions that can give rise to detectable gravitational wave signals.

Messier 2

[Wikipedia]

COMPAS : Binary Synthesis Simulator

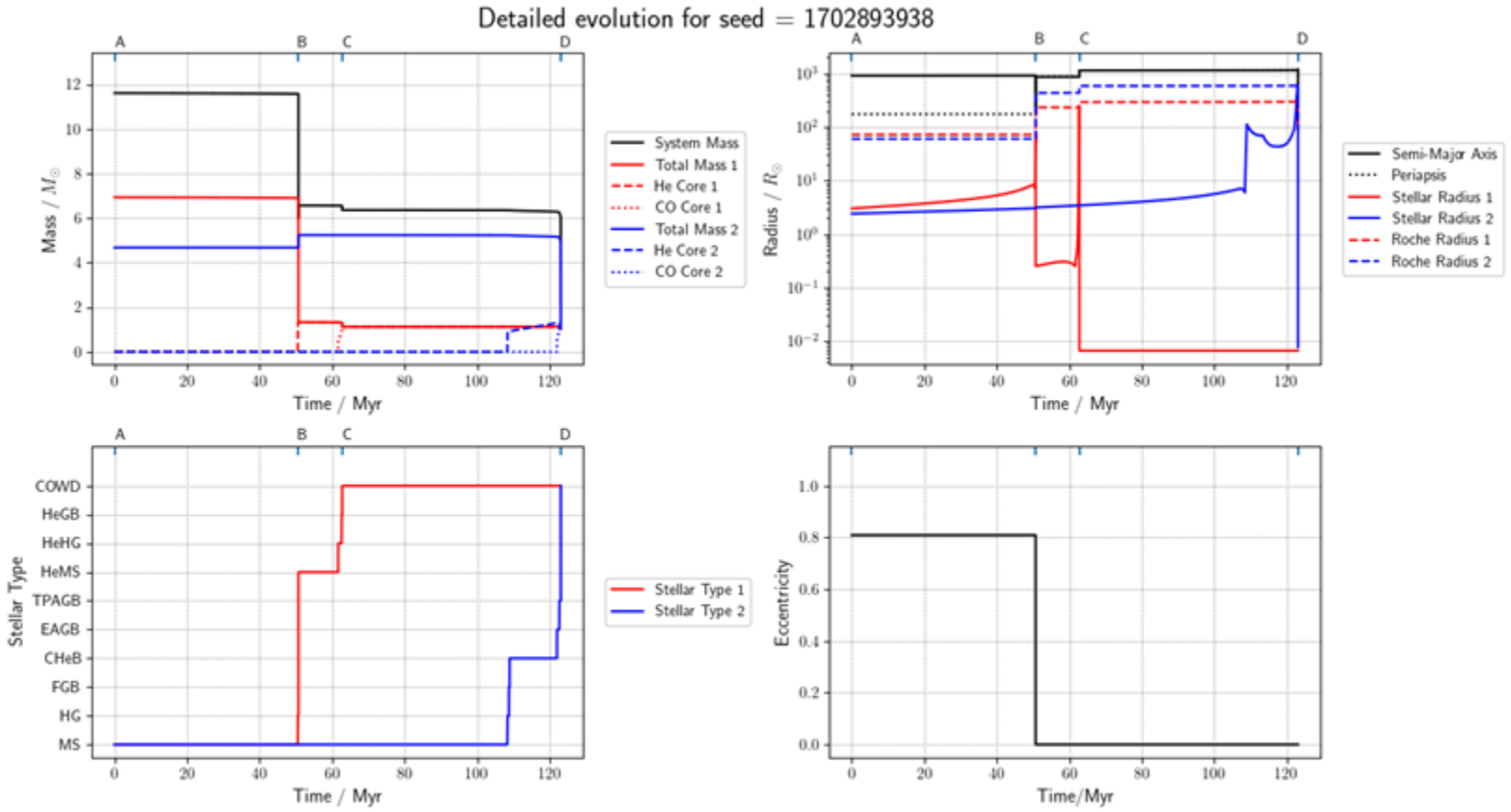
COMPAS is a publicly available rapid binary population synthesis code https://compas.science/.

Draws binary system properties from initial distributions, evolving from zero-age main sequence to compact remnants.

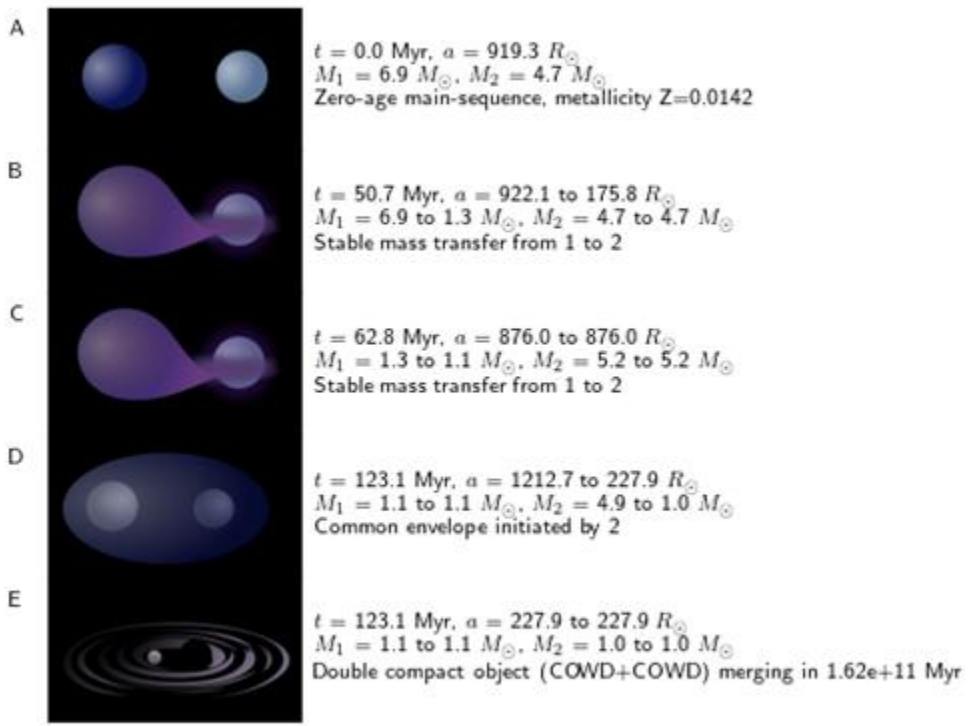
Easily adjustable evolution prescriptions and model parameters.

Enhances gravitational wave analyses by predicting diverse binary population properties, enhancing precision and insights.

COMPAS : Binary Synthesis Simulator



COMPAS : Binary Synthesis Simulator



Gravitational Waves

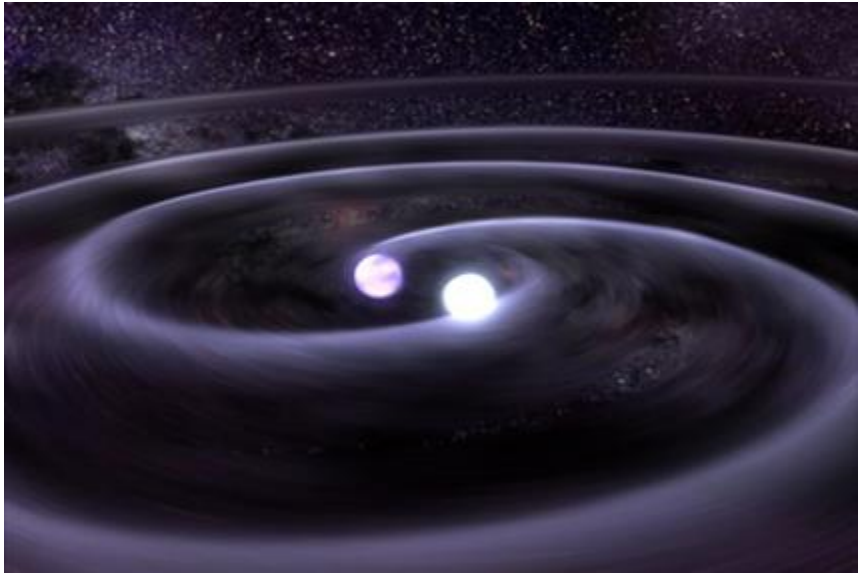
According to general relativity, two masses orbiting each other will emit energy in the form of gravitational waves (ripples in space-time fabric).

Frequency of gravitational waves depend on binary orbital frequency, which in turn depends on the binary masses and compactness.

$$2f_{orb} = f_{gw}$$

White Dwarf binaries are a reliable source of gravitational waves due to their abundance and could help us map the structure of our own galaxy.

Diverse characteristics of White Dwarf binaries offer a broad spectrum of gravitational wave frequencies, enriching our understanding of compact binary evolution.



Harvard-Smithsonian Center for Astrophysics

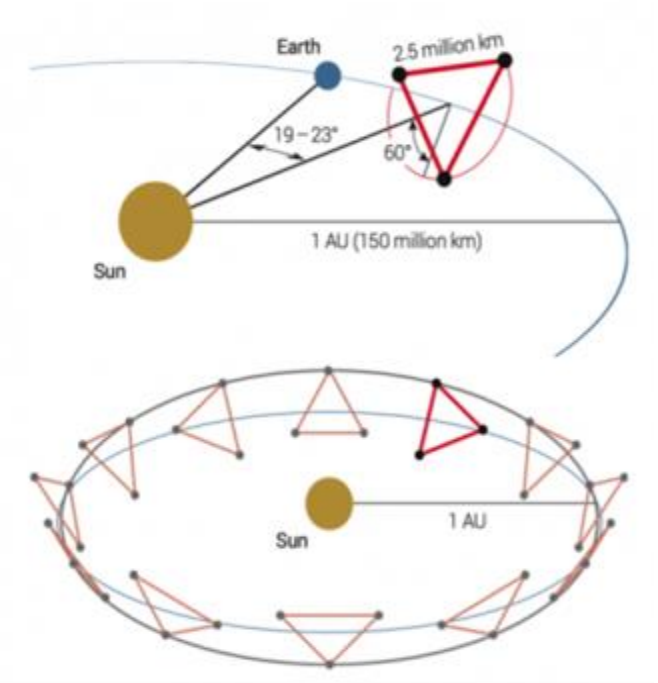
Gravitational Waves and LISA

Gravitational wave frequencies from White Dwarf binaries lie in the range of to 0.1 mHz to 0.1 Hz which falls in the range of LISA.

LISA's sensitivity detects thousands of individual White Dwarf binaries and captures gravitational waves from millions more, forming an unresolved background concentrated in the Milky Way's disk.

LISA's yearly cycle of orientation change creates a characteristic modulation which helps to distinguish between the background noise produced by White Dwarf binaries and other types of noise, facilitating accurate gravitational wave analysis.

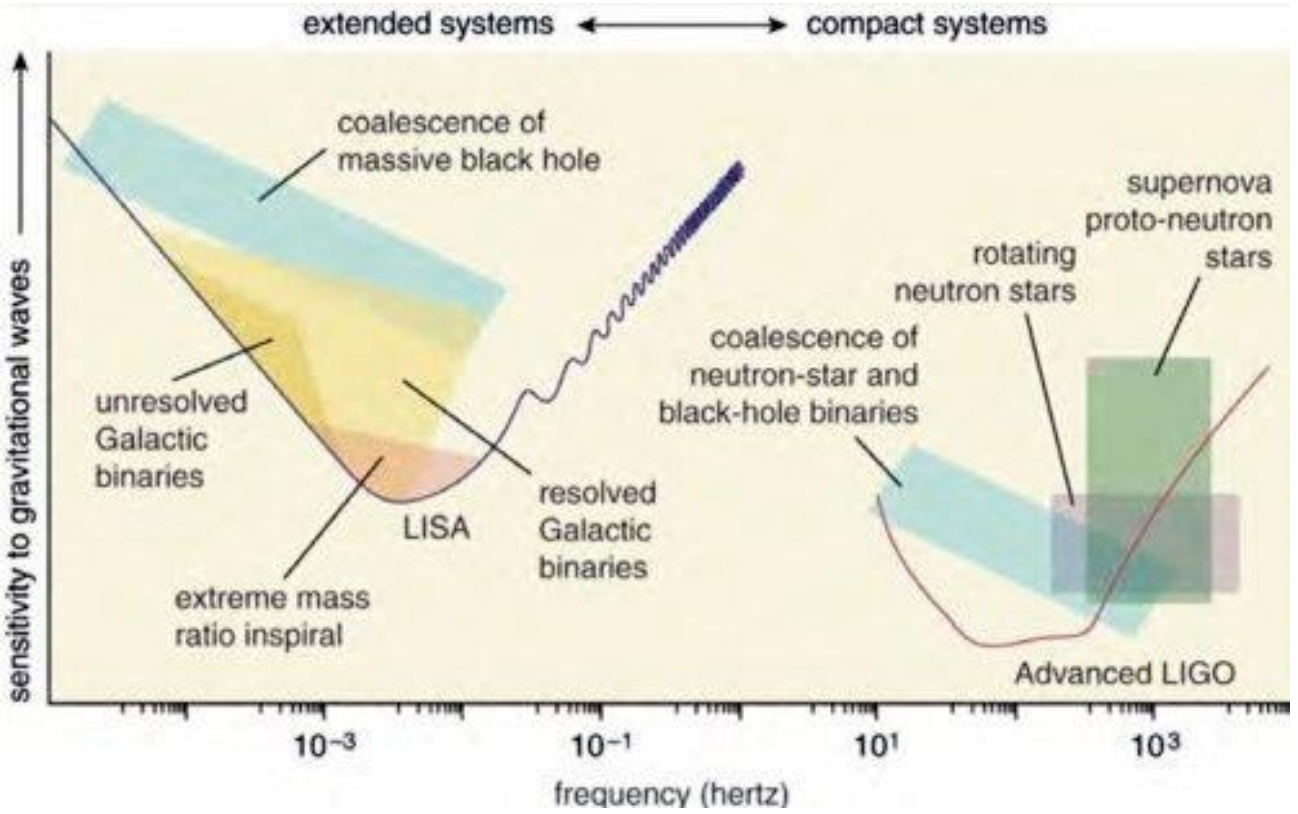
It is worth mentioning that the Astronomical Observatory, University of Warsaw is a member of the LISA consortium.



LISA

[ICE-CSIC]

Gravitational Waves and LISA



Key, Joey. (2010). Characterizing astrophysical sources of gravitational waves

Population Modelling using COMPAS

COMPAS is used to generate a population of White Dwarf Binaries with initial parameters :

Initial Mass range : 0.5 – 15 Msun

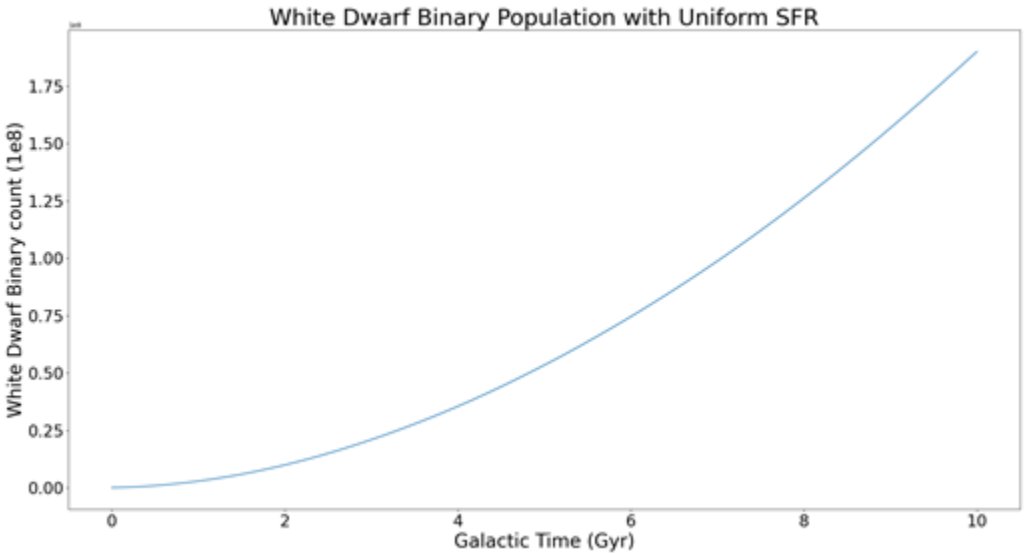
Initial Mass Function : Salpeter

Initial Mass-Ratio Distribution : Flat

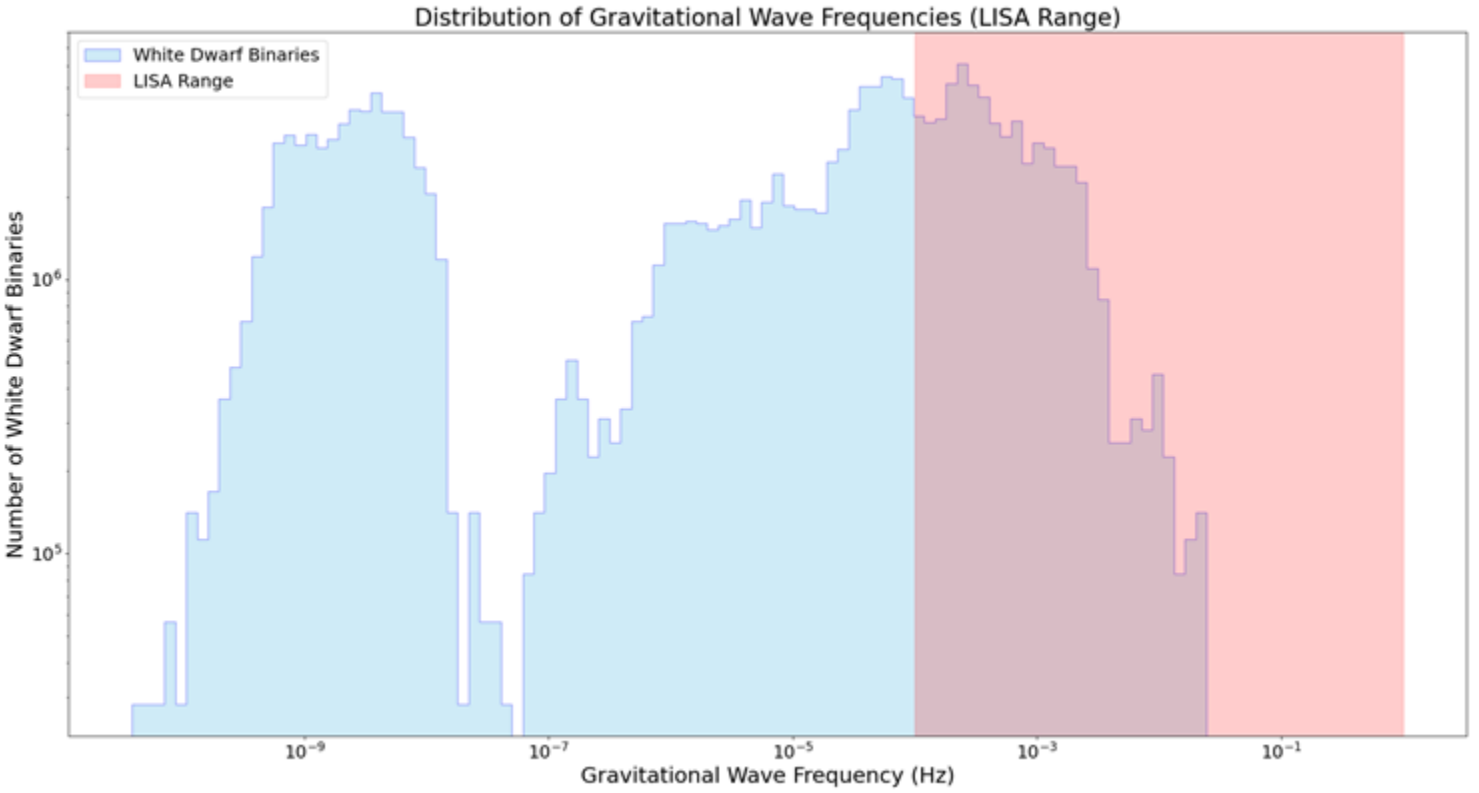
Initial Semi-major Axis range : 0.01 – 10 AU

Initial Semi-major Axis Distribution : Flat in Log

Eccentricity Distribution : Thermal

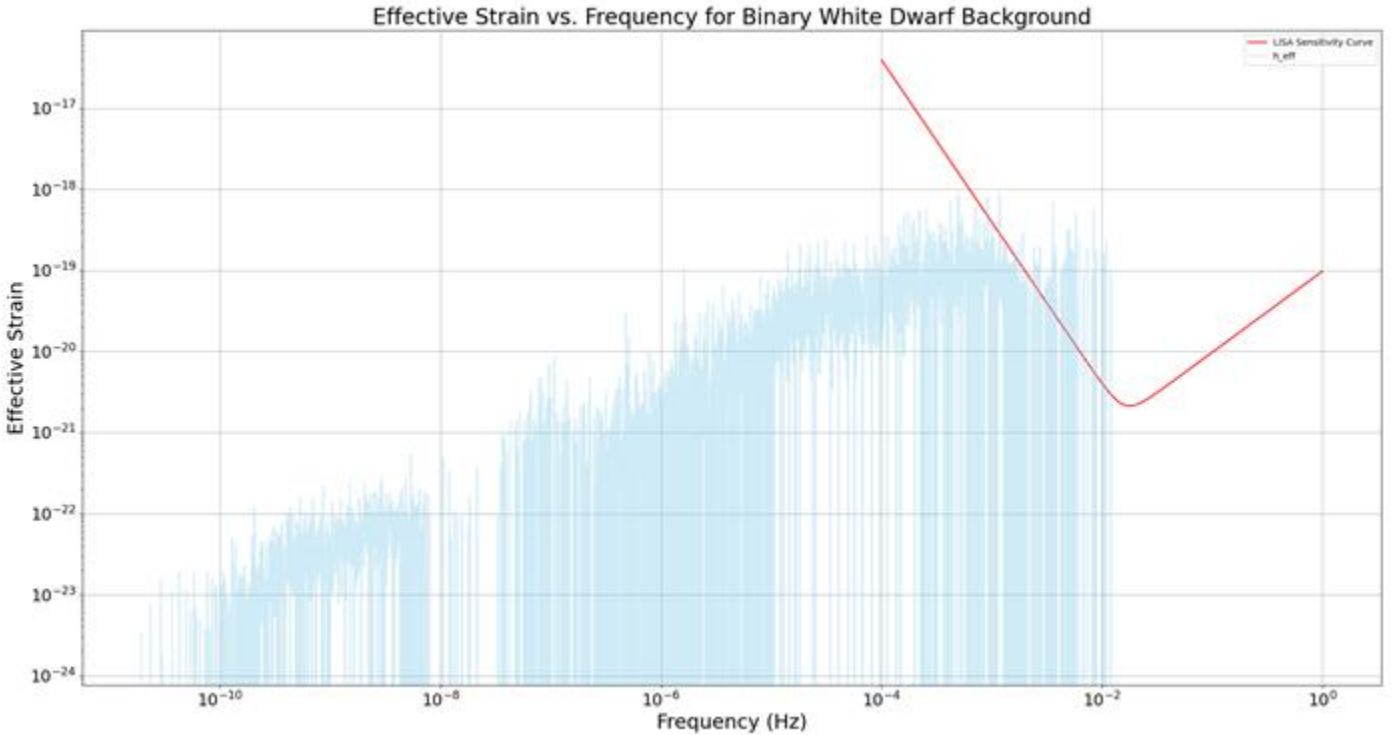


Gravitational Waves from White Dwarf Binaries



Gravitational Waves from White Dwarf Binaries

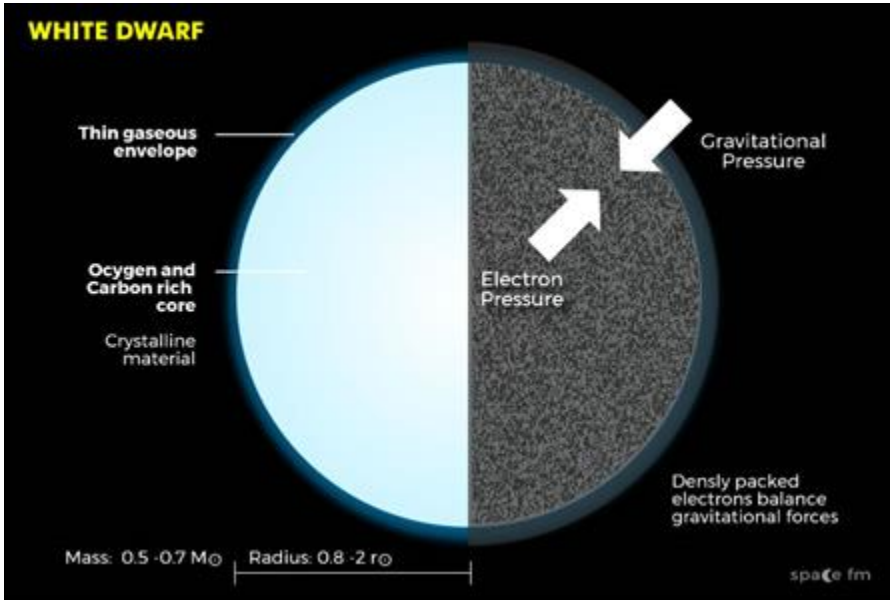
$$h \approx \frac{4(G\mathcal{M})^{5/3}(\pi f)^{2/3}}{c^4 D}$$



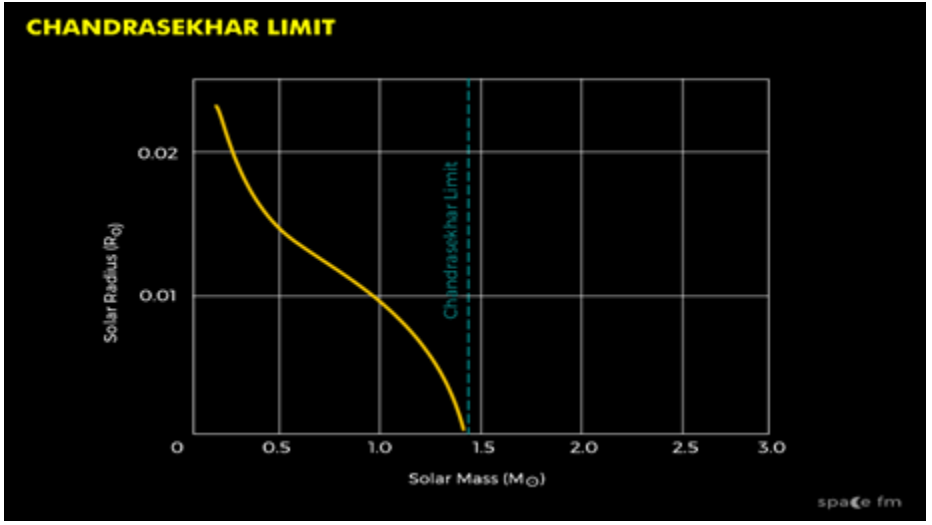
Summary

- Most stars in the universe end their life as White Dwarfs.
- Binary White Dwarfs both from Galaxies and Globular Clusters are important sources of Gravitational Waves for the upcoming LISA.
- Probing Gravitational Waves from Binary White Dwarfs can help map the structure of our own Milky Way.
- COMPAS is an useful tool for population synthesis of compact objects.
- Galactic White Dwarf Binaries contribute to the Gravitational Wave background in LISA sensitivity range.
- Studying Gravitational Waves originating from White Dwarf Binaries in Globular Clusters will help to shed light on dynamic stellar evolution.

White Dwarfs



White Dwarf structure



Mass-Radius relation for White Dwarf