The role of metallicity in Compact binary merger Formation

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Aim

Recent analysis of the evolution of stars have indicated that the metallicity significantly impacts the features of compact objects. We investigate how the metallicity of a compact object influnces the characteristics of a galactic binary merger.

Introduction

The most favourable sources of gravitational waves (GWs) for terrestrial detectors are the coalescence of two neutron stars, two black holes, or a neutron star and a black hole [1, 2, 3] due to the enormous amount of energy released in the final stage of their inspiraling trajectory, the merger, and the ringdown. Uncertainty surrounds the number of the still constricted system after two supernova explosions (or an immediate core collapse). The intrinsic parameters, which include masses, spins, and eccentricity, depend on an intricate evolution scenario through a common envelope and mass transfer. The metallicity of the star population has a significant impact on the features of compact object binaries [4, 5]. Both observations of binaries containing a large BH accreting from a Wolf-Rayet star and binary population synthesis show that the formation rate of binaries containing black holes significantly increases with decreasing metallicity. However, it has been demonstrated that the usual mass of a black hole grows at low metallicity.

Background Formalism

- Two stars, bound through their mutual gravity.
- The separation of the stars $r = a(1-e^2)/(1+e\cos\theta)$.
- The specific angular momentum of the system $h = r^2\theta$.
- The semilatus rectum $l = a(1-e^2)$.
- Chirp mass $\mathcal{M} = \frac{(m_1 m_2)^{3/5}}{(m_1+m_2)^{1/5}}$.

Results from Simulation

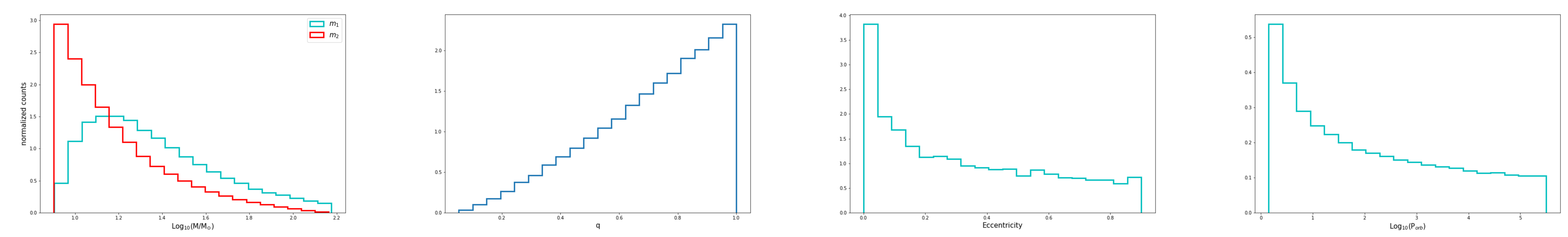

Figure 1: Discrete probability distributions for a range of primary and secondary masses, mass ratio (m_2/m_1), eccentricity and orbital periods in normalized form.

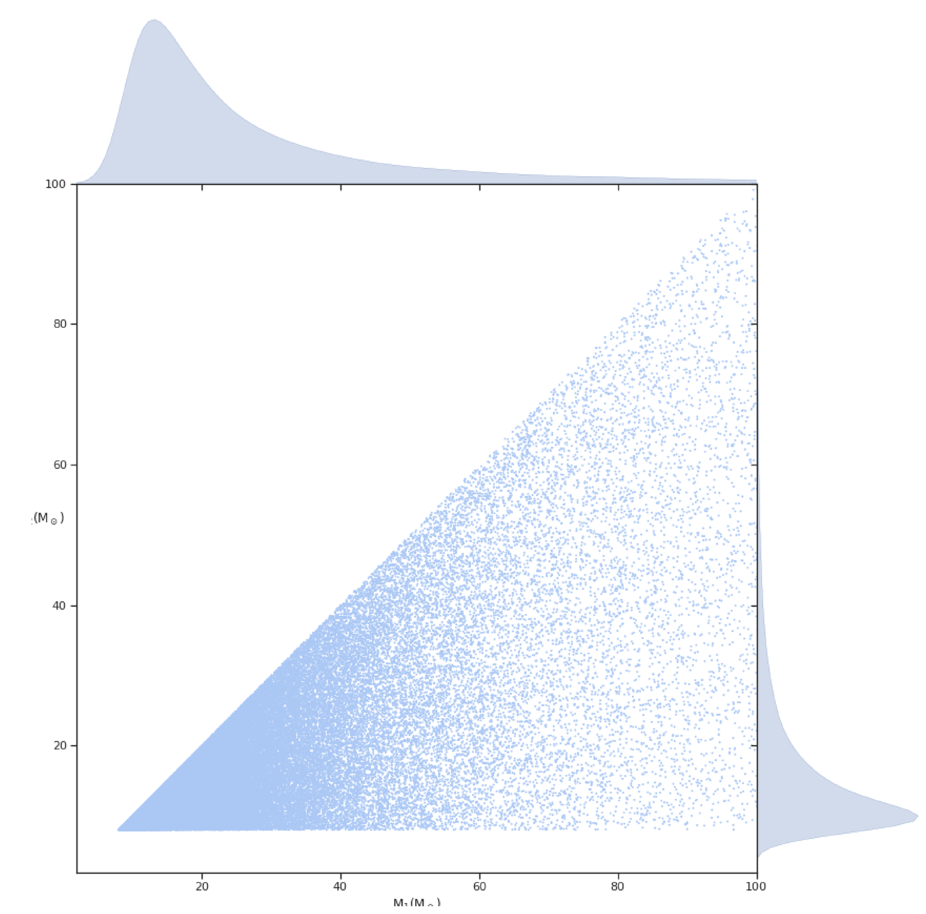

Figure 2: Density distribution of primary mass with secondary mass.

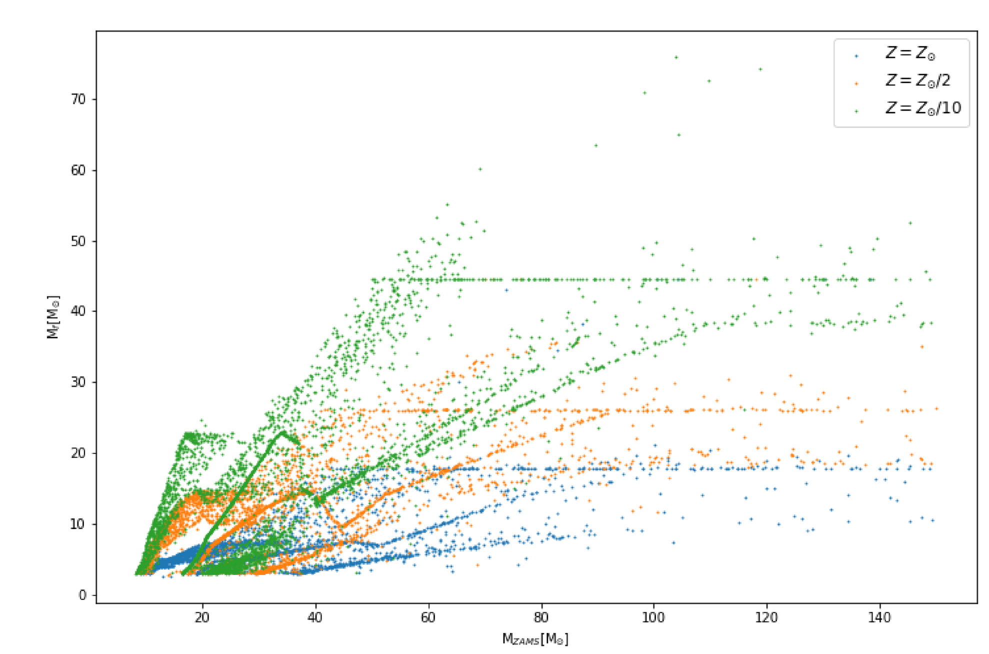

Figure 3: Variation of final mass (y-axis) with initial mass (x-axis) based on metallicity.

Binary Evolution

For a single binary evolution, the information regarding mass loss and formation of a common envelop (CE) formation encoded within the parameters specified.

During stable Roche-lobe overflow (RLO), [6]:

- Wind mass loss, $\alpha_{RLO}(\approxeq 1.0)$.
- Minimum mass ejection by accretor, $\beta_{min}(\approxeq -1.0)$.
- Circumbinary torus mass transfer, $\delta_{RLO}(\approxeq 0.5)$.
- Circumbinary torus size, γ $(\approxeq -2.0)$.

During CE:

- CE efficiency parameter, $\alpha_{CE}(\approxeq 0.2)$.
- Fraction of internal energy, $\alpha_{th}(\approxeq 0.5)$.
- Critical mass ratio for mass transfer stability, $q_{limit}(\approxeq 1.0)$.

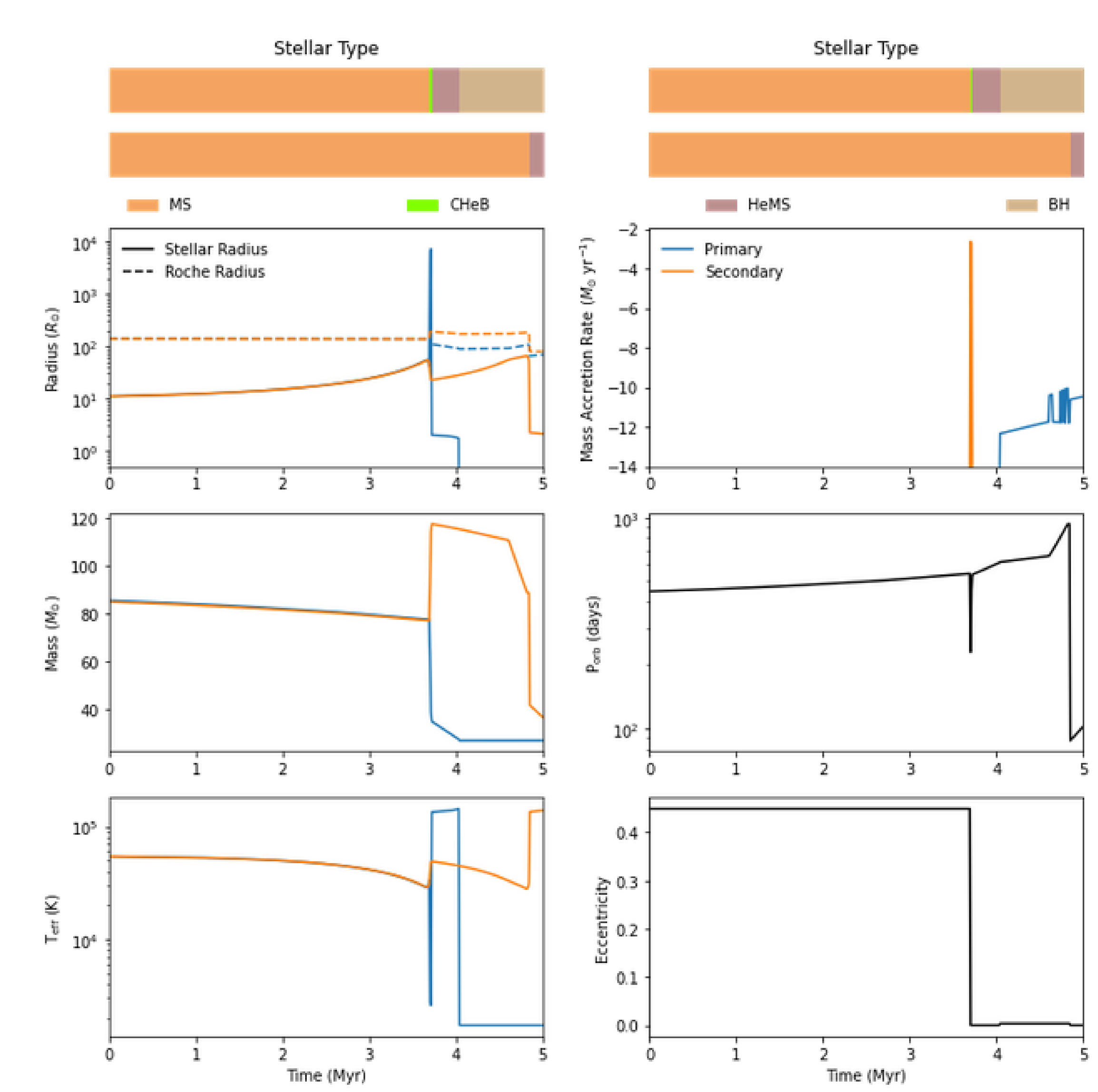

Figure 4: Simulation results for the evolution of a binary system.

Method

- We simulate a binary population of N = 10,0000 binaries with of primary mass drawn from Saltpeter(1995).
- Using COSMIC we evolve the characteristics of single binaries to determine the final stellar mass.
- We fix the metallicity to be $Z = 0.02Z_\odot$.

Conclusions and Outlook

- We model the galactic population of compact binaries with the "Binary Population Synthesis" method using COSMIC and GW signals.
- The population's ultimate fate has been predicted based on metallicity.
- The formation characteristics depend on (i) the initial mass, and (ii) the metallicity.
- Critical points (sharp discontinuity) are strongly correlated to the metallicity of the system.
- Distriution is maximized around primary BH of mass $22.34M_\odot$, and for the secondary BH mass $14.23M_\odot$.
- The effective concentration for the chirp mass is around $16.95M_\odot$.

References

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Acknowledgements

The work of S.R.C. was supported by Southern Federal University (SFedU) (grant no. P-VnGr/21-05-IF). This research was supported in part by the ICTS Summer School on Gravitational-Wave Astronomy (code: ICTS/GWS-2022/5). The research by M.K. was financially supported by Southern Federal University, 2020 Project VnGr/2020-03-IF.