Properties of compact remnants are substantially impacted by uncertainties in stellar evolution models.

Impact of stellar evolution on the interaction of stars in binary systems and the formation of gravitational wave progenitors.

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Background :
Stars more massive than 9 $M_{\odot}$ are important both for the chemical enrichment of their surroundings and for the formation of compact objects: neutron stars (NSs) and black holes (BHs). Mergers of compact objects result in the emission of gravitational waves observable by LIGO/Virgo. Stars are modelled using stellar structure and evolution codes. However, as massive stars are rare in nature, their evolution parameters are not very well constrained. As a consequence, stellar evolution codes make certain assumptions about the interior and physics of these stars, such as the mass-loss rate and location of convective regions. In this work, we present our new stellar population synthesis code METISSE (Method of Interpolation for Single Star Evolution) and study the impact of the above uncertainties on the evolution of massive stars and their remnants.

Results

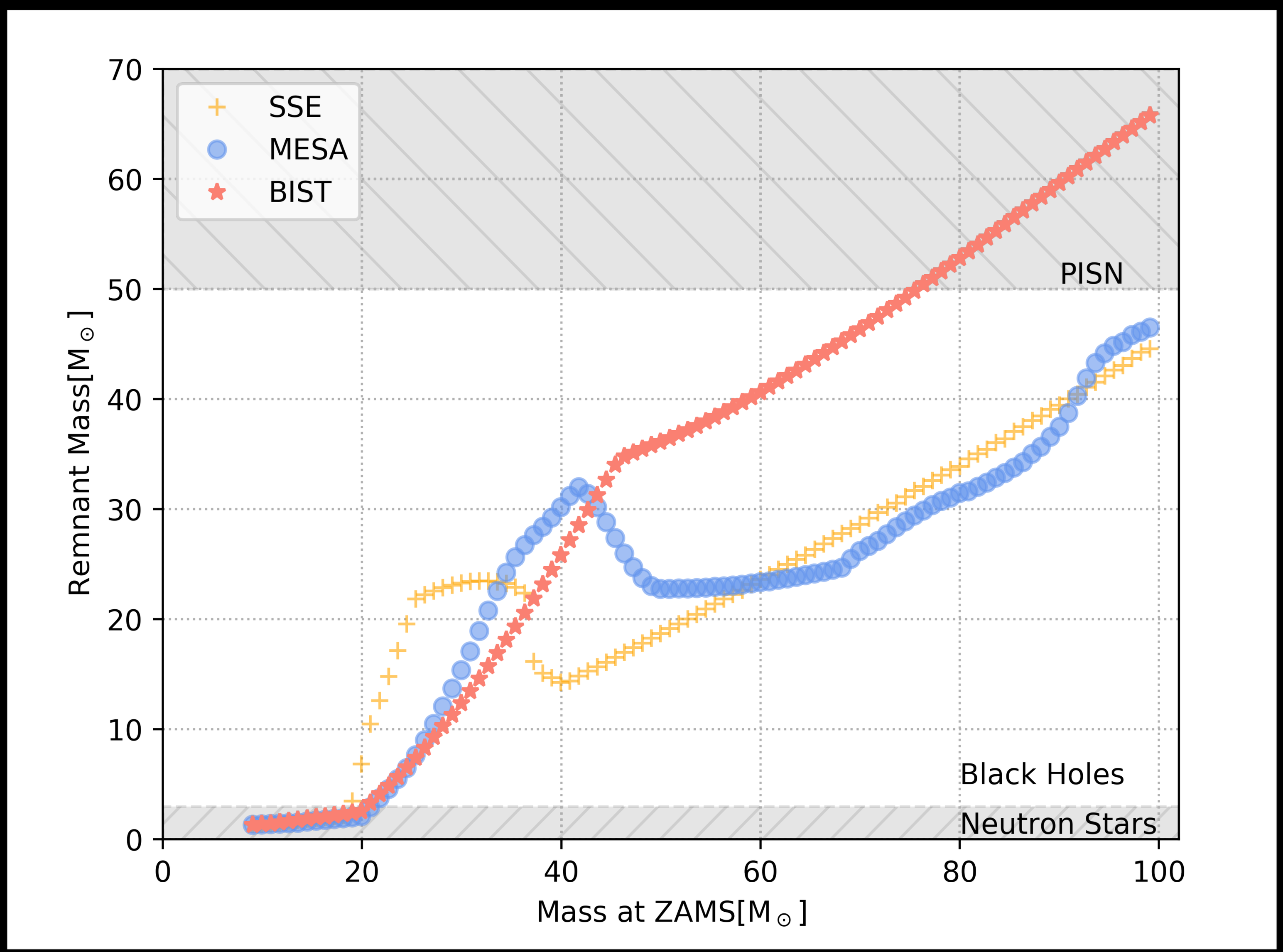

Fig 1: Mass of stellar remnants against mass of their progenitors calculated using SSE (gold plus symbols), METISSE with MESA tracks (blue circles) and METISSE with BIST (red stars). The grey area above 50 $M_{\odot}$ shows the region where stars may explode as Pair Instability Supernova (PISN) leaving behind no remnant. **The mass of the remnant is clearly influenced by the choice of stellar evolution code.**

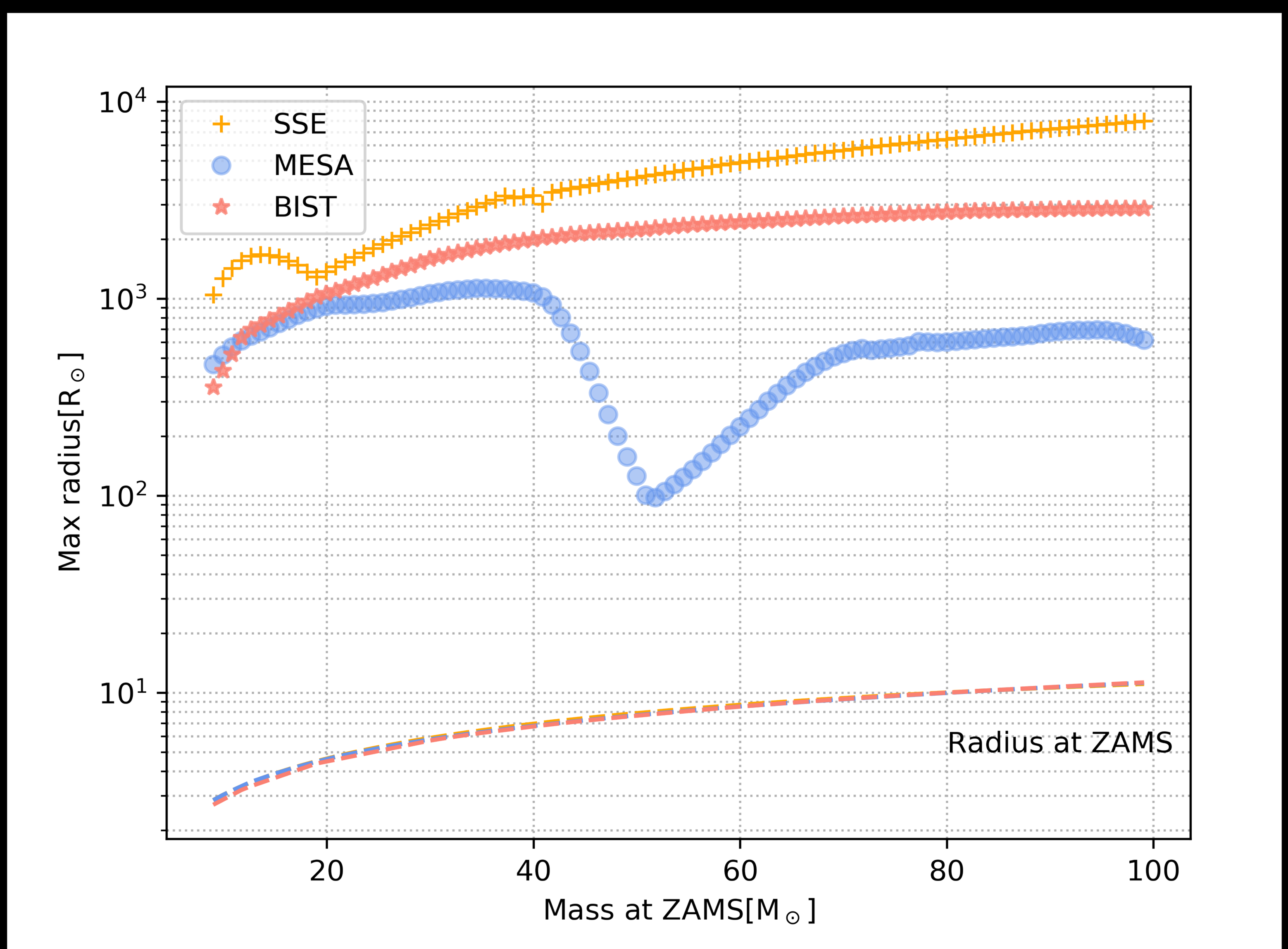

Fig 2: Maximum radius obtained by stars as a function of their initial mass, symbols mean same as in Fig 1. The dashed lines below show the radius at ZAMS. **The lower radii predicted by the new models will have impact on the outcome of close binary interaction.**

Method

- METISSE[1] interpolates between a grid of precalculated evolutionary tracks to approximate the properties of an isolated star of given mass and metallicity at any instant.
- Evolution parameters are calculated starting from Zero Age Main Sequence (ZAMS) until the star becomes a remnant.
- An alternative to Single Star Evolution (SSE[2]) in the globular cluster modelling code *NBODY6*[3] and the binary population synthesis code COMPAS[4].
- We test METISSE with two grids of stellar tracks evolved using:
  - Modules for Experiments in Stellar Astrophysics (MESA[5])
  - Bonn Evolutionary Code/Bonn Interpolated Stellar Tracks (BIST[6])
- Fig 1 and Fig 2 show the remnant masses and maximal radii of 100 stars uniformly distributed in mass between 9 - 100 $M_{\odot}$ at 0.1 $Z_{\odot}$ calculated using the MESA and the BIST grids in METISSE.

Discussion

- There is a significant variation between the models themselves in addition to SSE.
- These differences are a direct consequence of the different approximations used while evolving these stars with MESA and the Bonn Code, particularly in modelling the radiation dominated envelopes of massive stars.
- Even for the same stellar evolution code, values of uncertain parameters governing the processes inside these stars can lead to different evolutionary outcomes.
- It can change the behaviour of stars in a binary and in a globular cluster system and is important for predicting the properties of compact binary remnants.

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