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Progenitors of LGRBs: Are single stars enough?

Rafia Sarwar

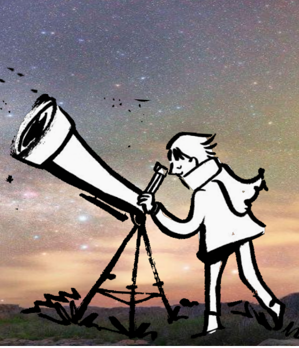

Figure Credit: NASA

Institute of Astronomy | Faculty of Physics, Astronomy and Informatics,
Nicolaus Copernicus University, Toruń, Poland.

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Do stars change with time…

Figure Credit: NASA

Rafia Sarwar
06 February 2023

Do these stars change with time...

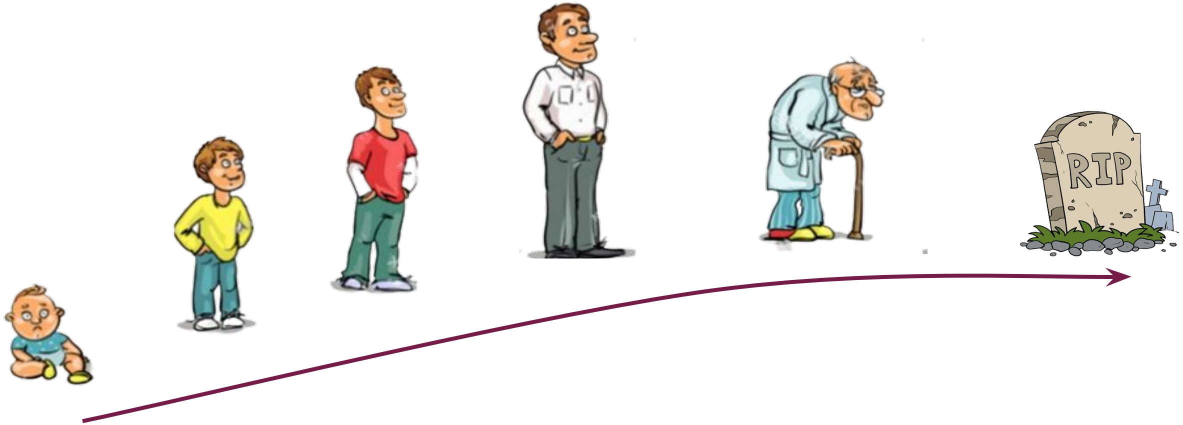


Figure Credit: NASA

Stars live and die just like humans...

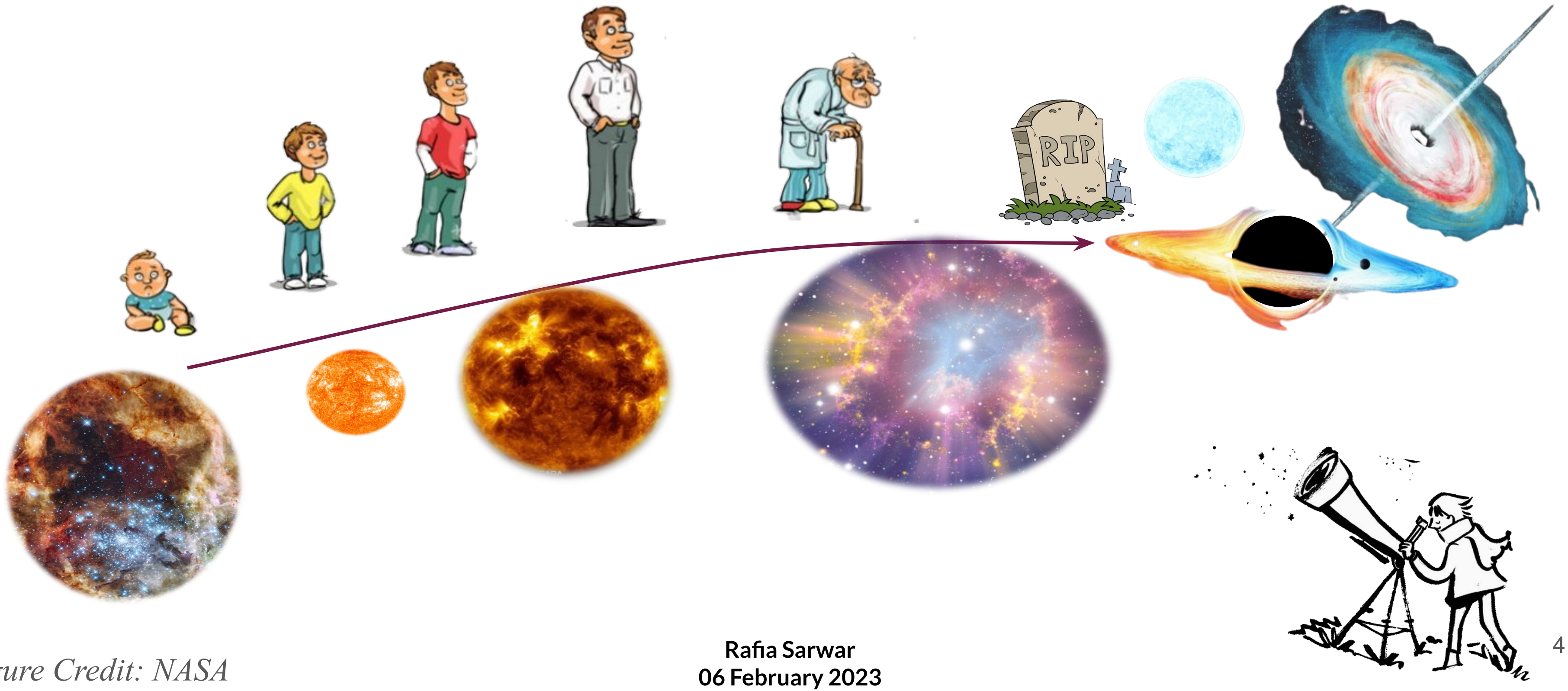
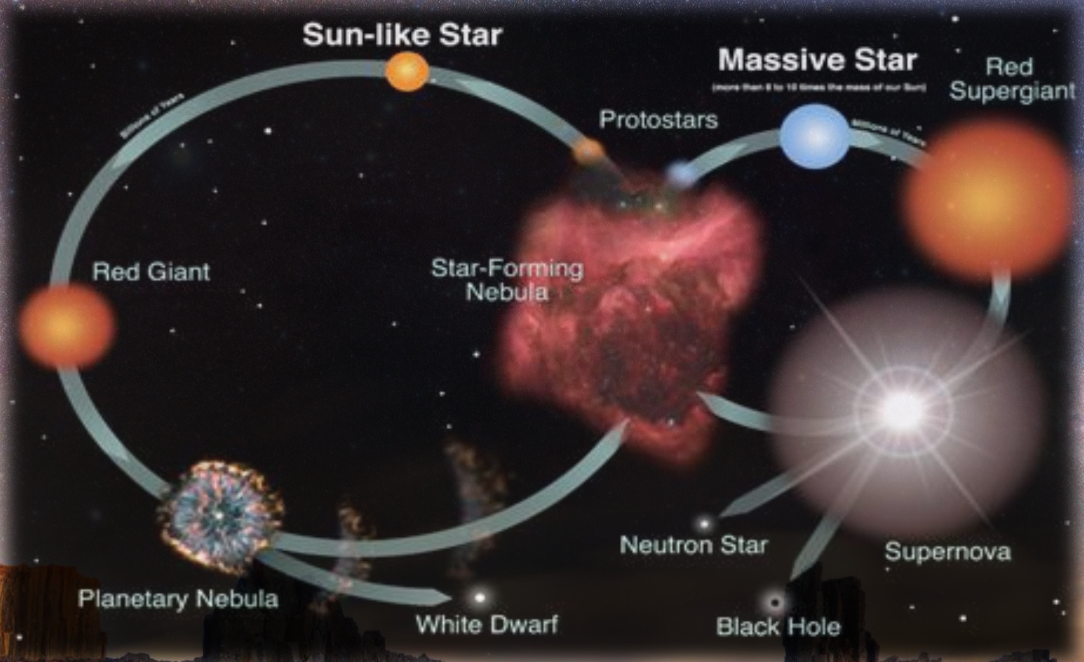


Figure Credit: NASA

Life cycle of stars

$(0.1 - 8)\ M_\odot$



$(8 - 300)\ M_\odot$

Figure Credit: NASA

Massive stars

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Massive stars

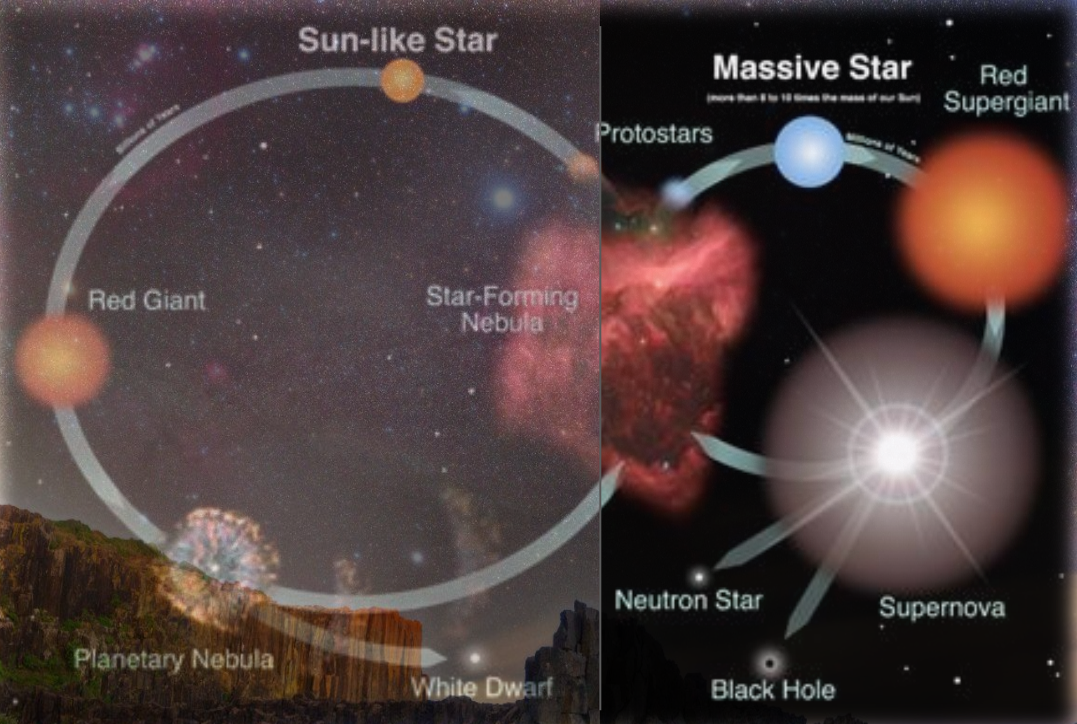


Figure Credit: NASA

Massive stars

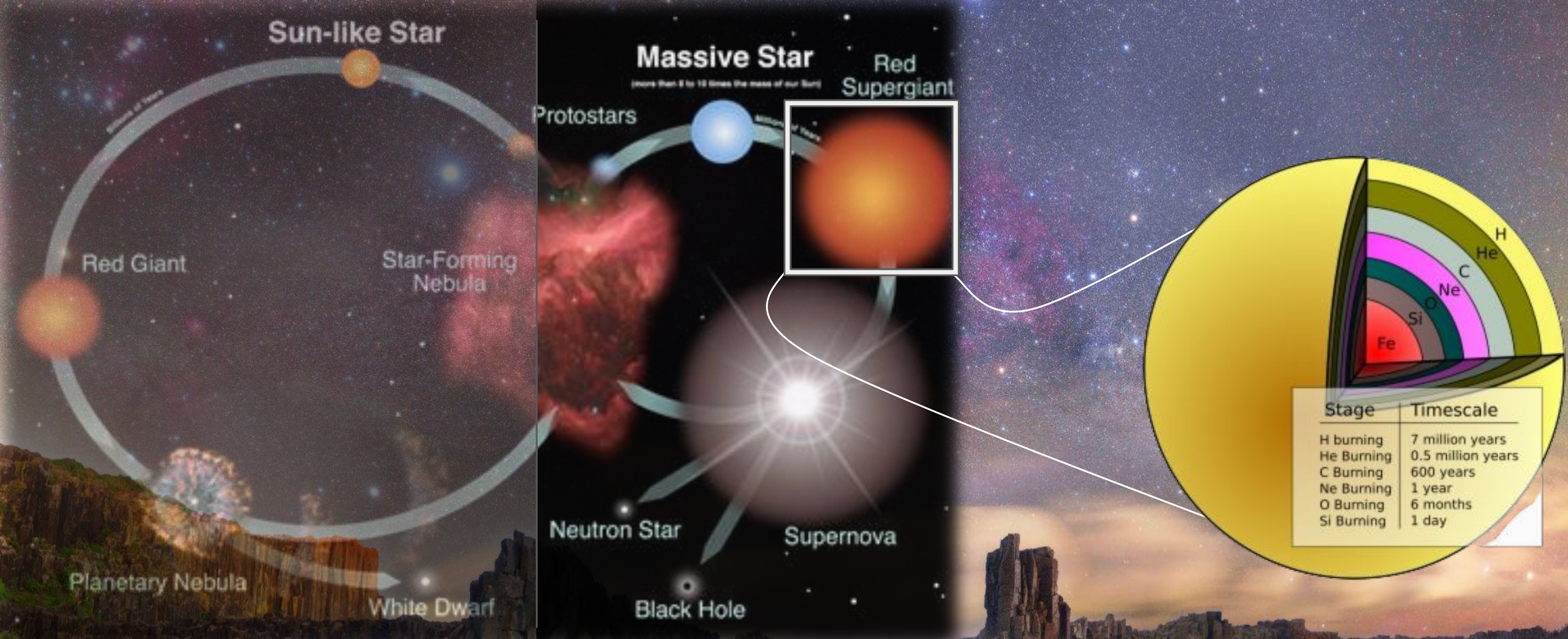
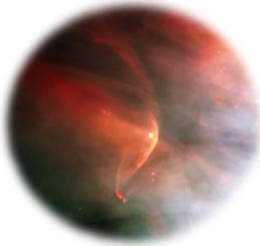


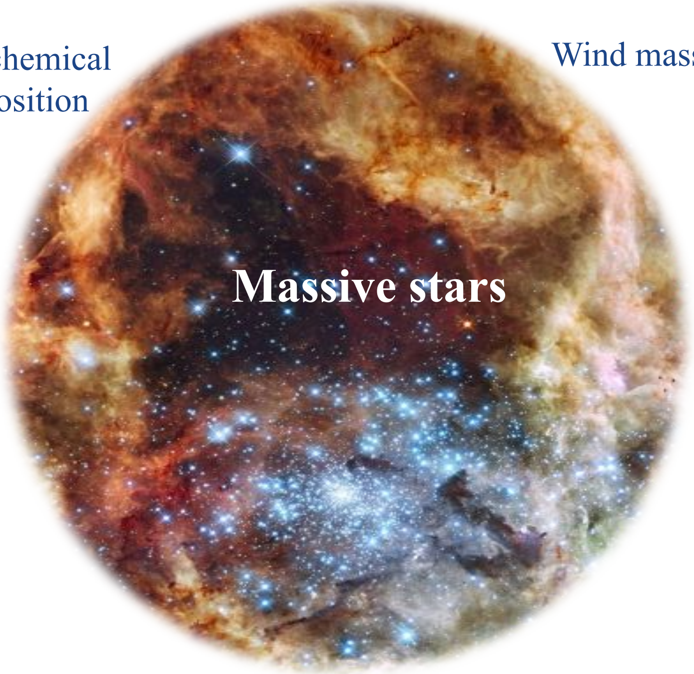
Figure Credit: NASA

Factors impacting massive stars

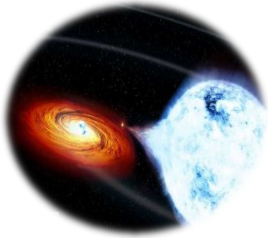
Initial chemical composition

Wind mass loss

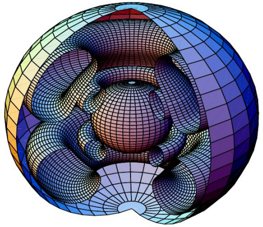




Binary interaction



Rotational mixing



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Bifurcation of massive star evolution

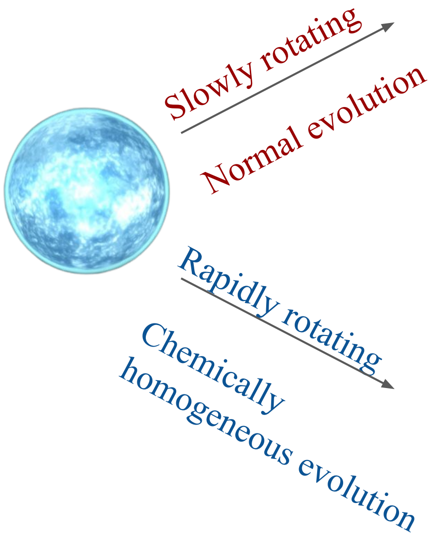

Figure Credit: De Mink et al. (2008)

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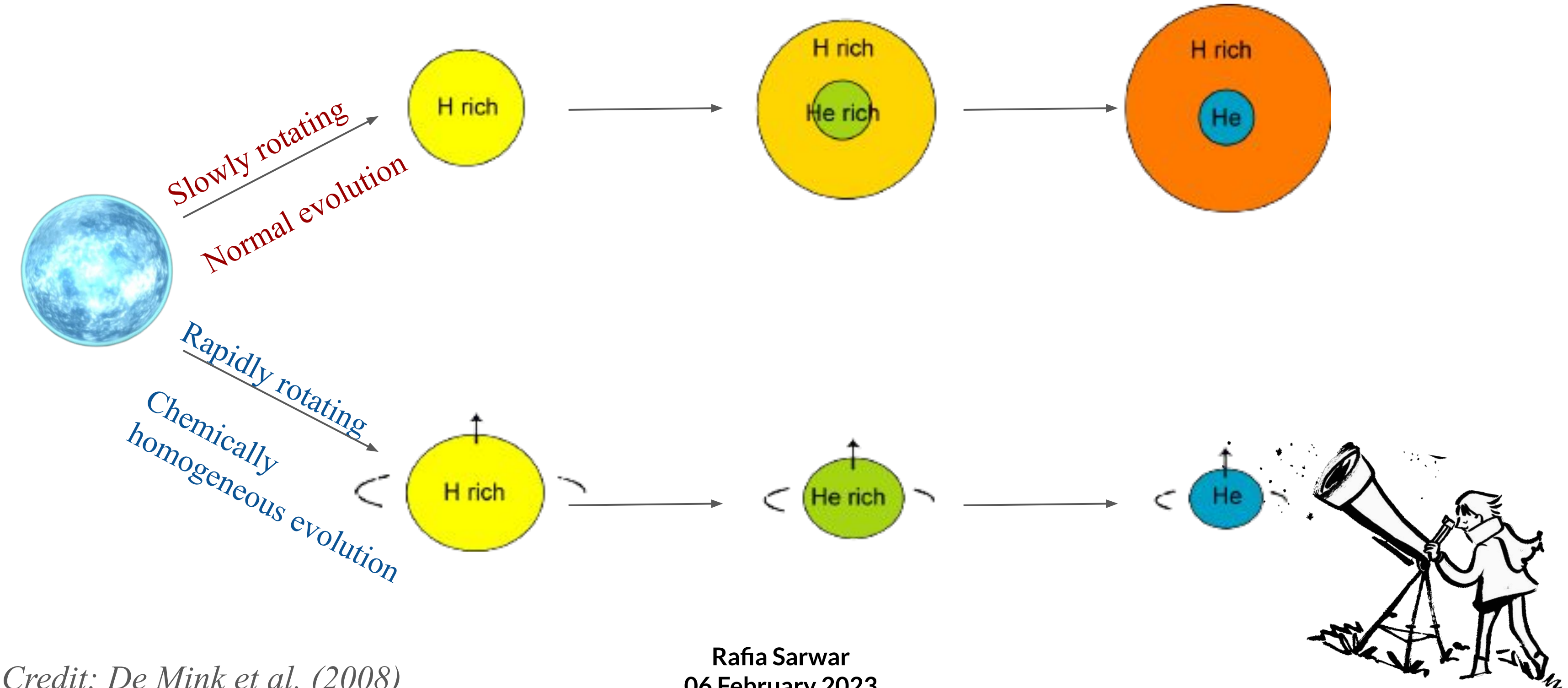

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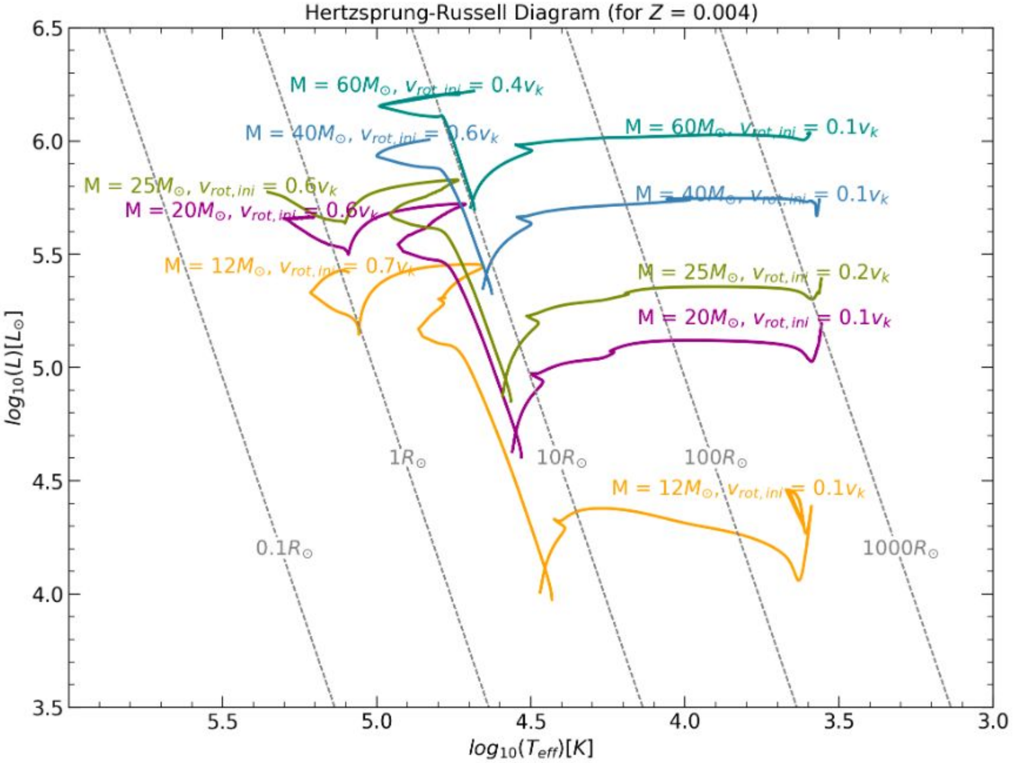
Stellar evolution codes

- MESA
- Bonn
- Geneva

Evolution of massive stars



S.-C. Yoon et al. (2006)

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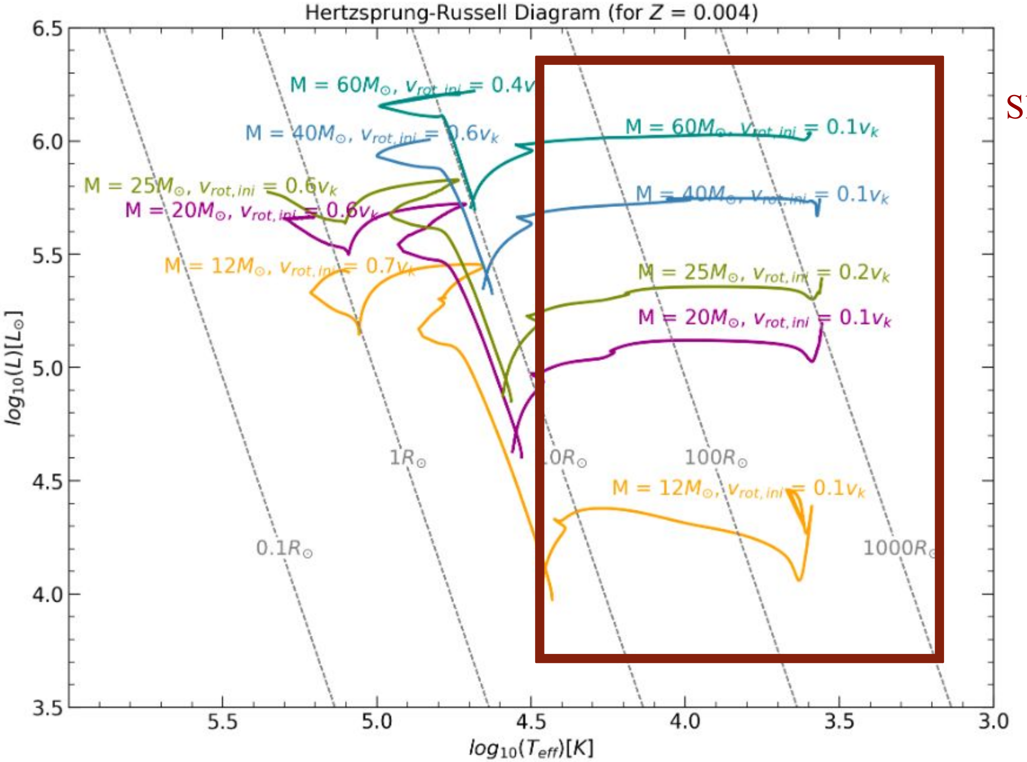
Evolution of massive stars

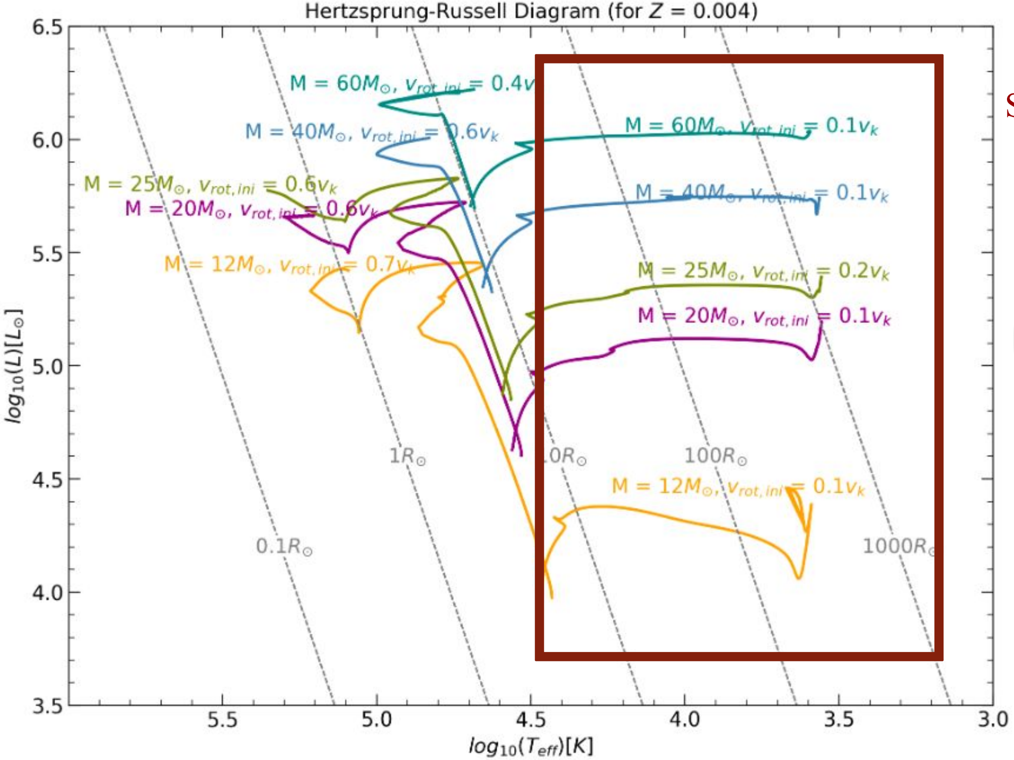


Slowly rotating:

- classical core-envelope
- red-supergiant

S.-C. Yoon et al., (2006)

Evolution of massive stars



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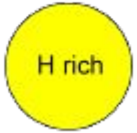

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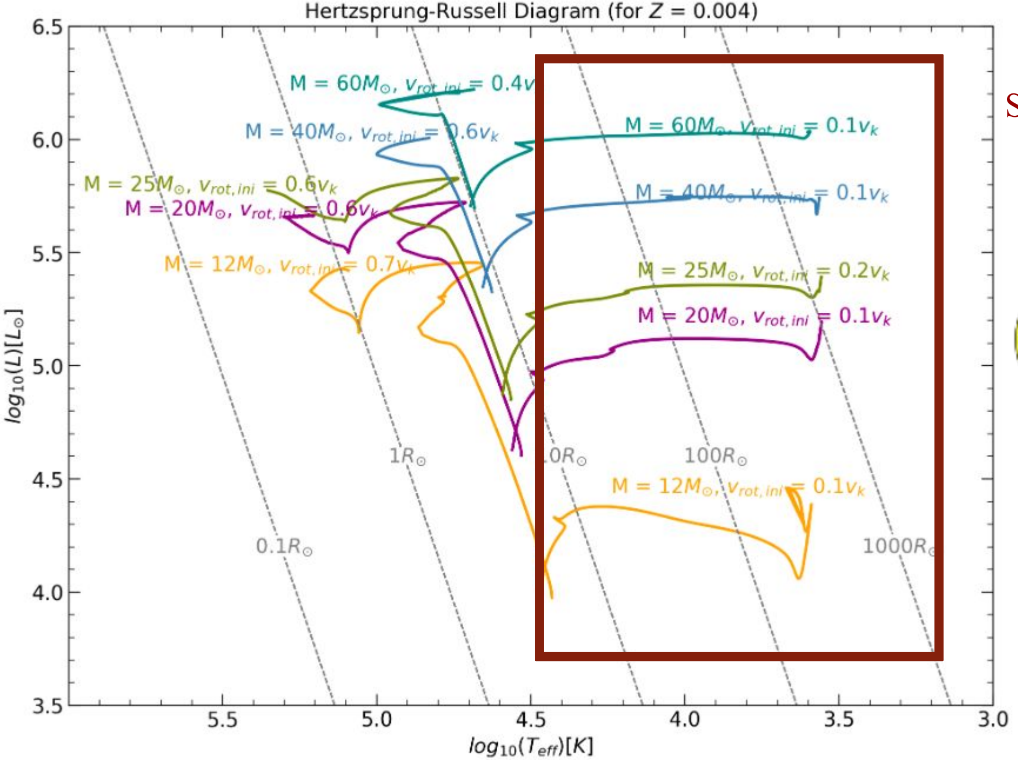

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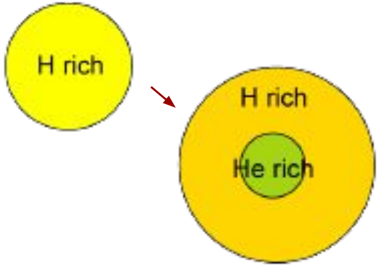

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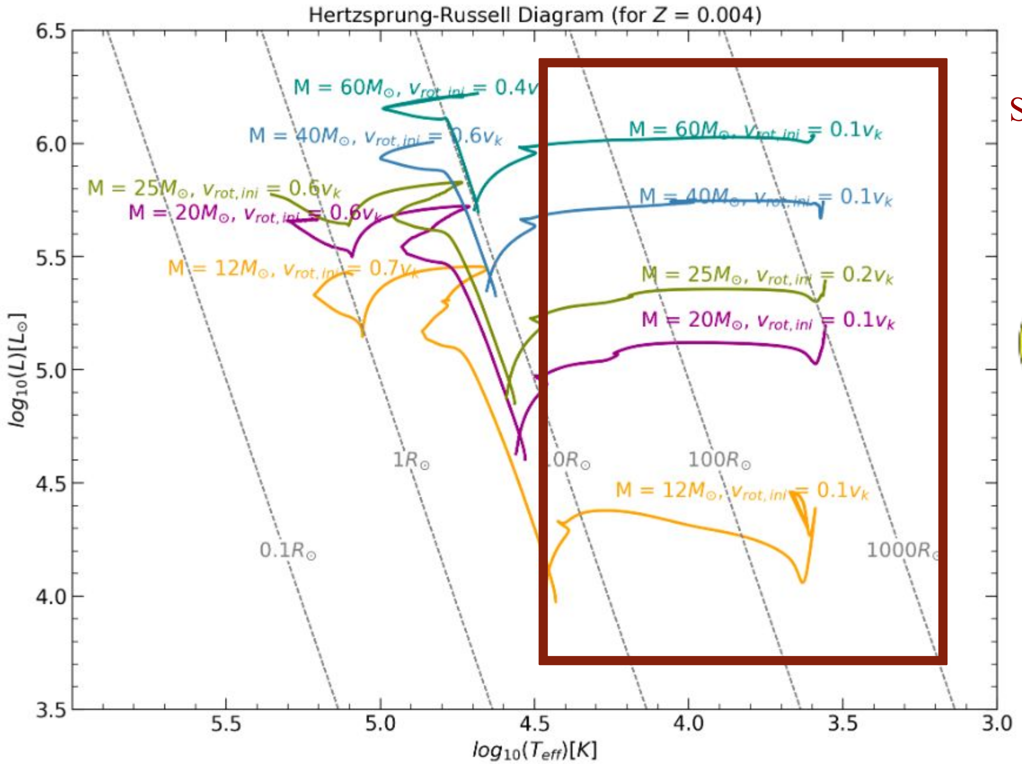

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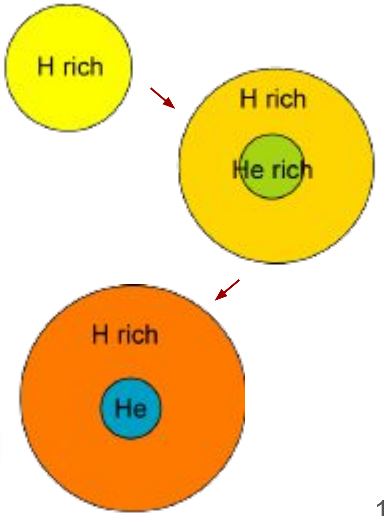


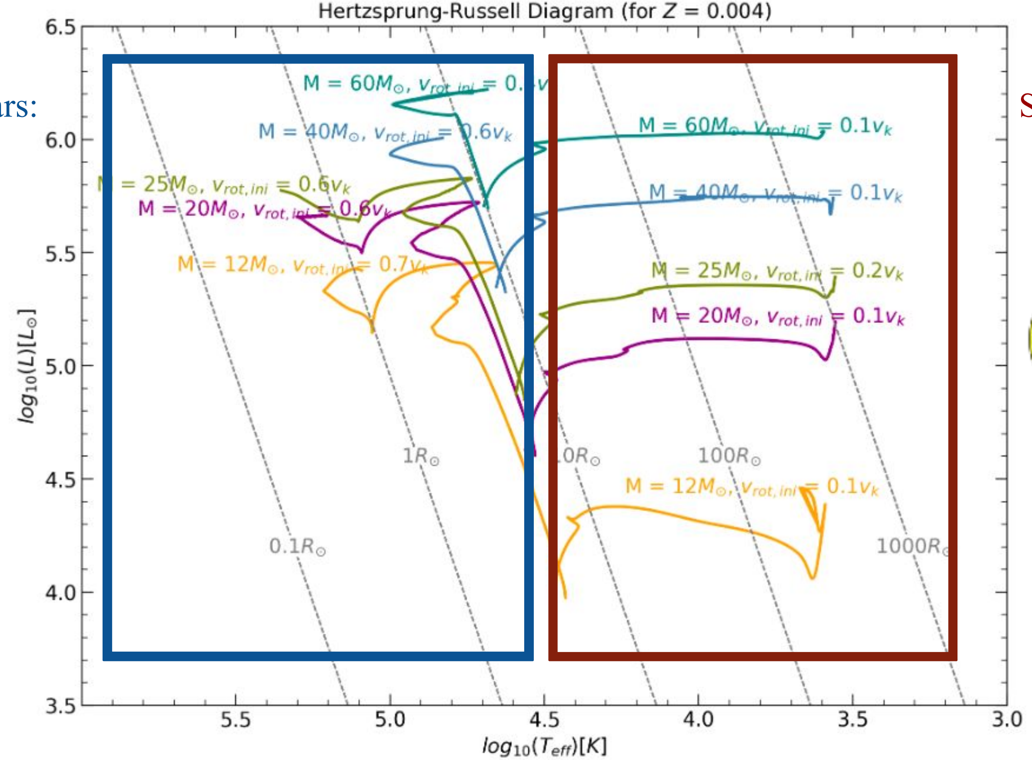
S.-C. Yoon et al., (2006)

Rafia Sarwar
06 February 2023

Evolution of massive stars

Rapidly rotating massive stars:

- rapid rotationally-induced chemical mixing
- quasi-chemical homogeneity



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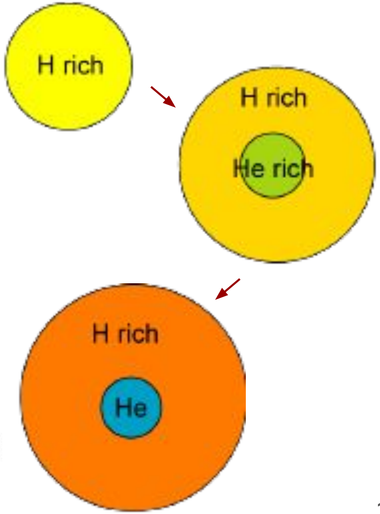

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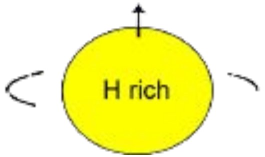

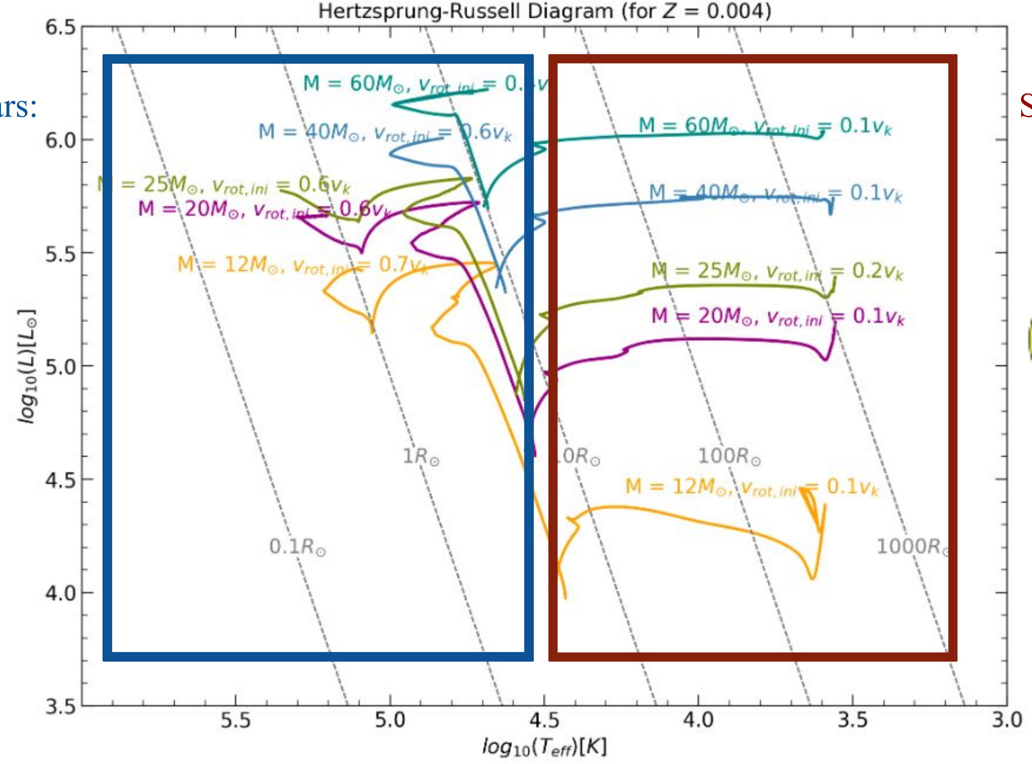

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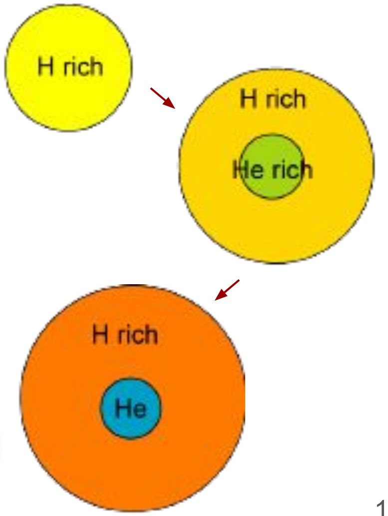

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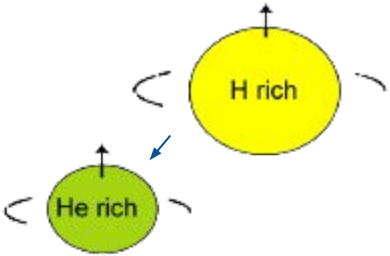

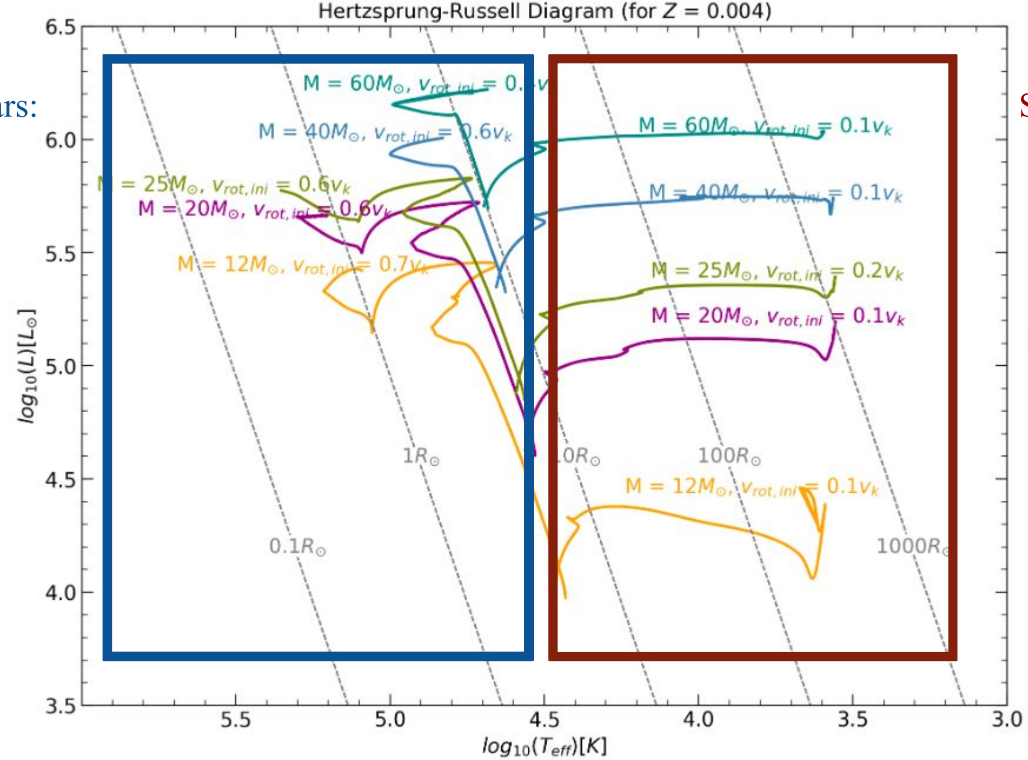

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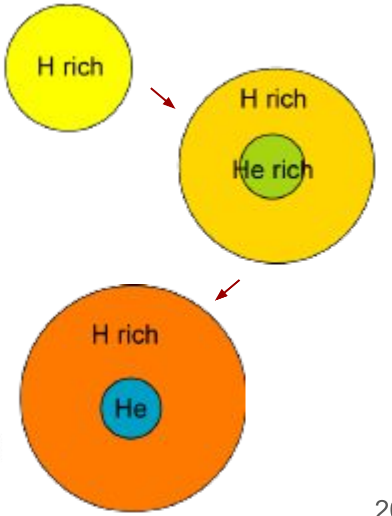

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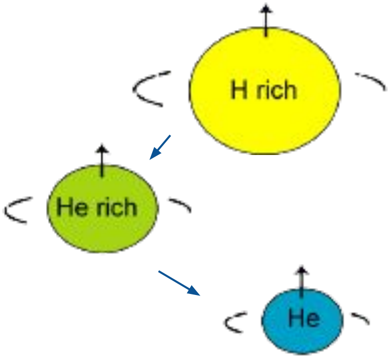

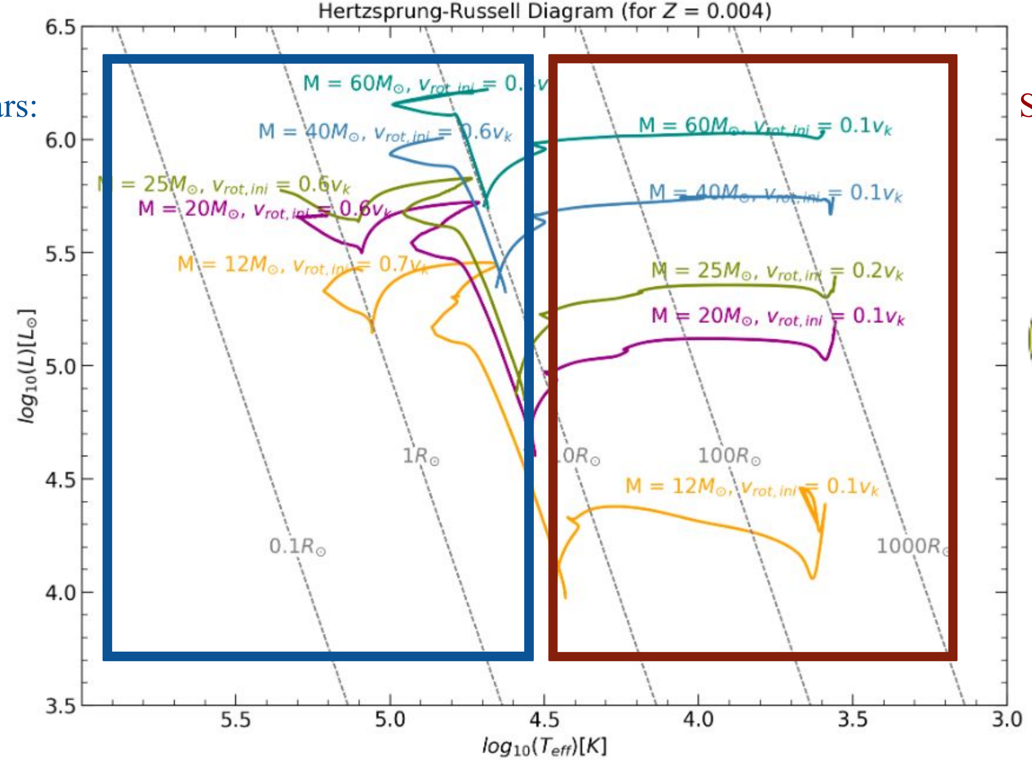

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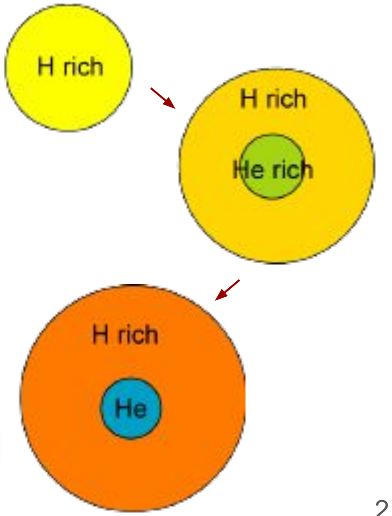

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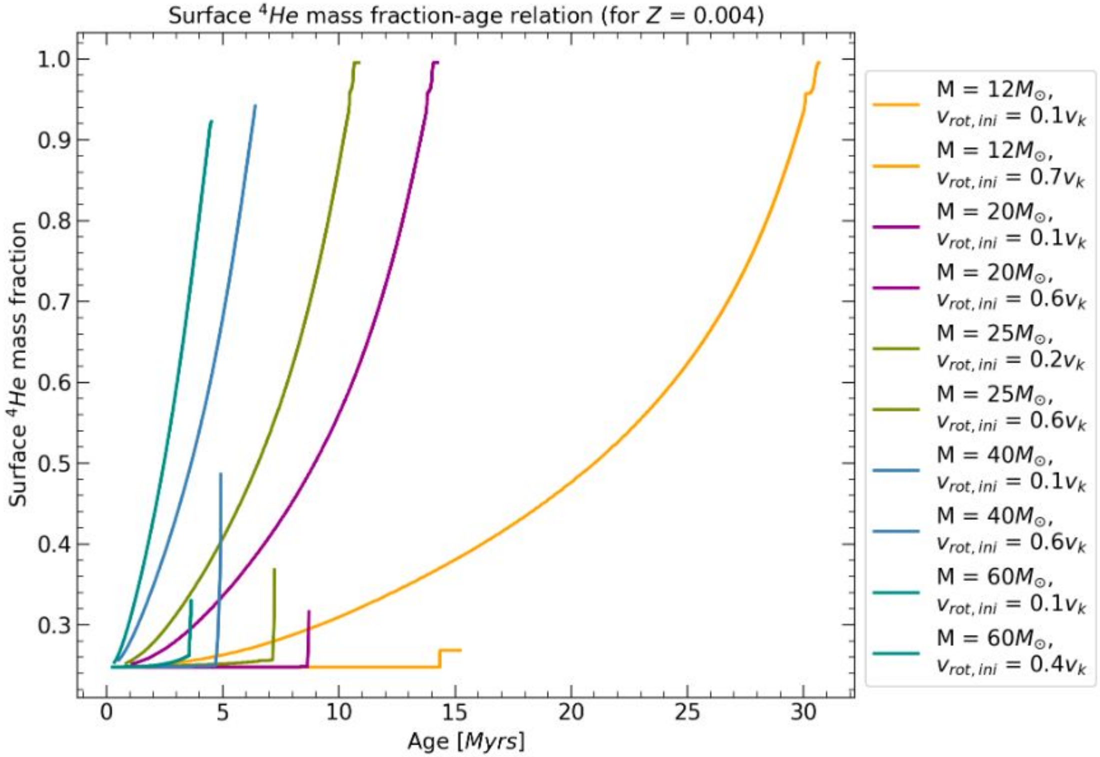

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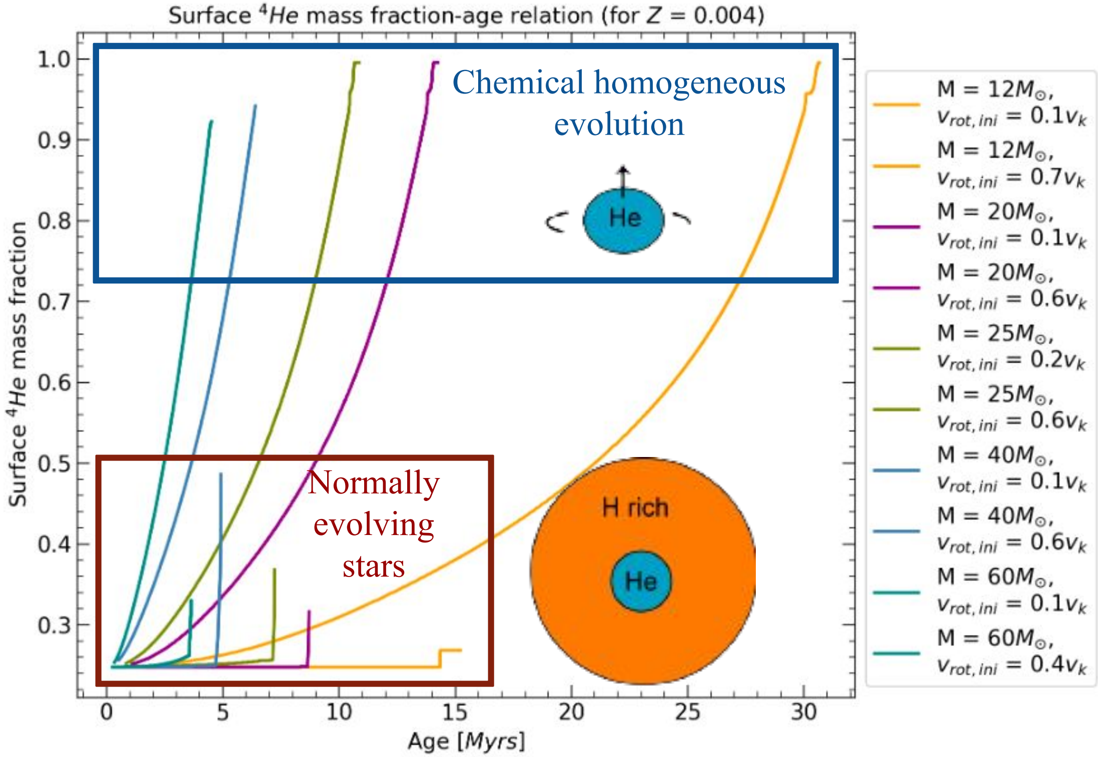

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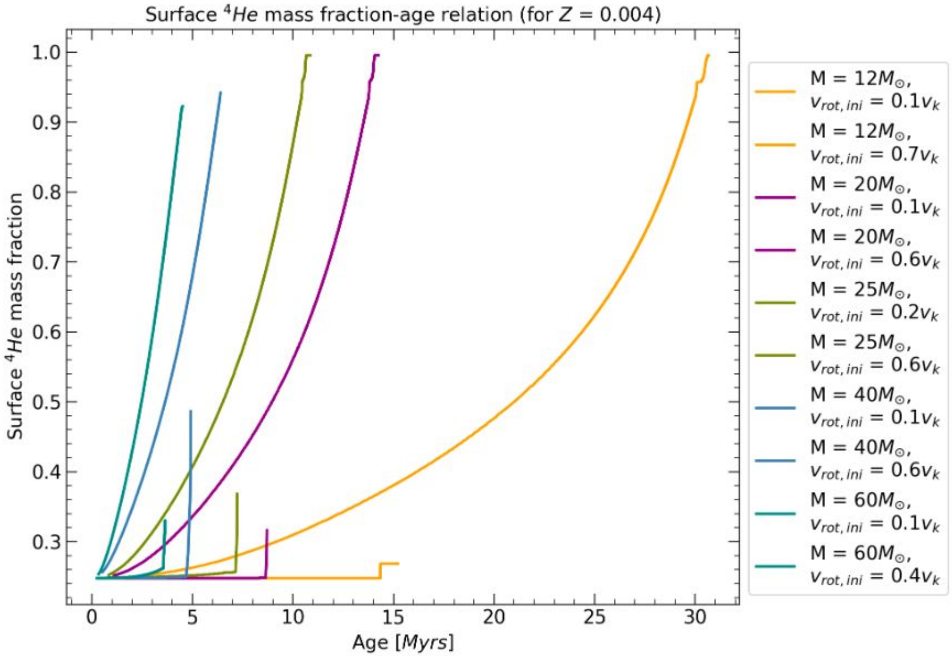

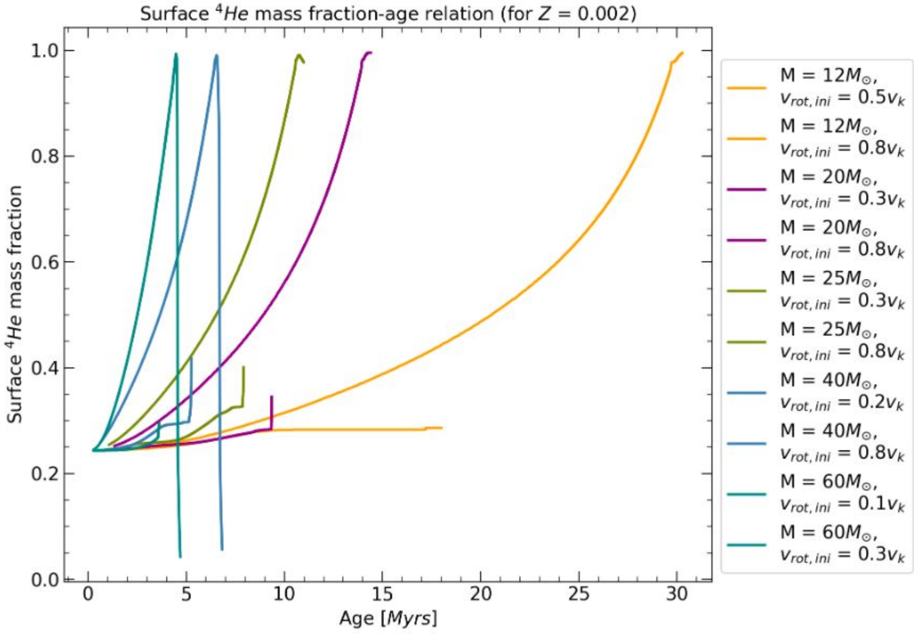

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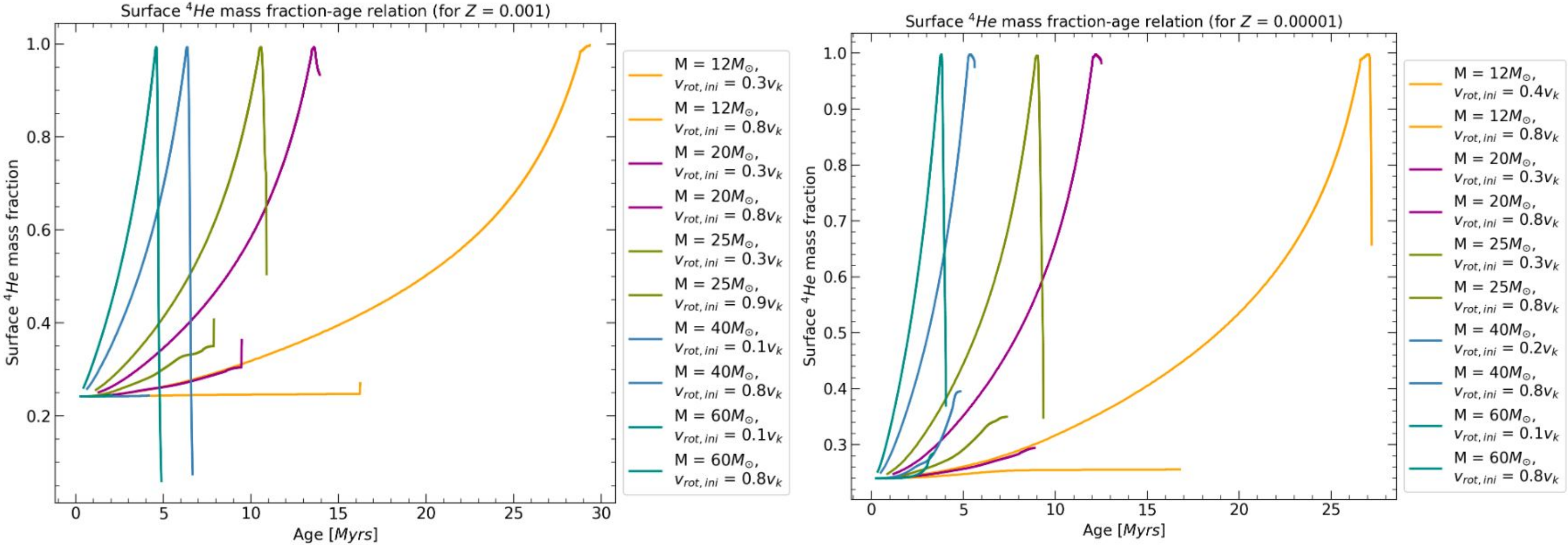

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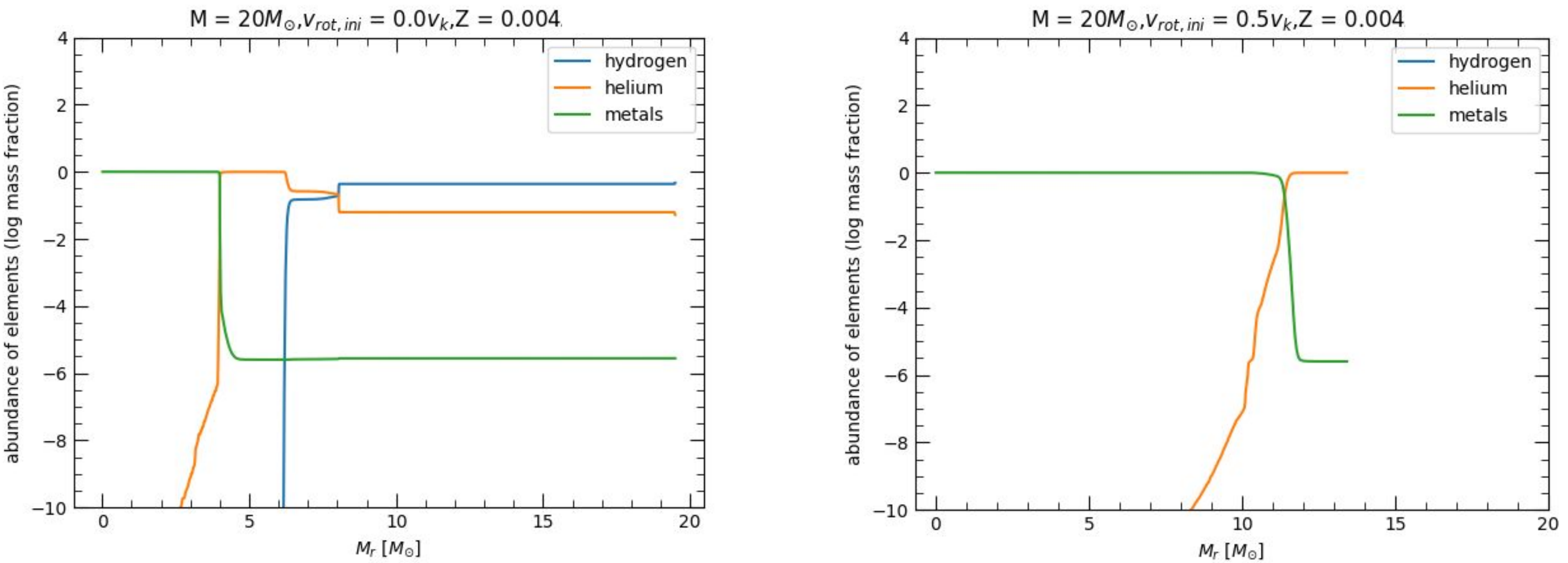
Internal composition of massive stars



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Any questions so far…

Figure Credit: NASA

Cosmic impact of massive stars

Figure Credit: NASA

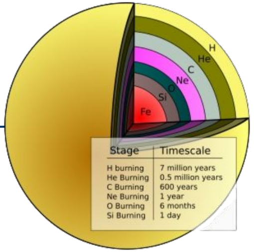
Cosmic impact of massive stars

Cosmological impact by the feedback processes

Figure Credit: NASA

Cosmic impact of massive stars

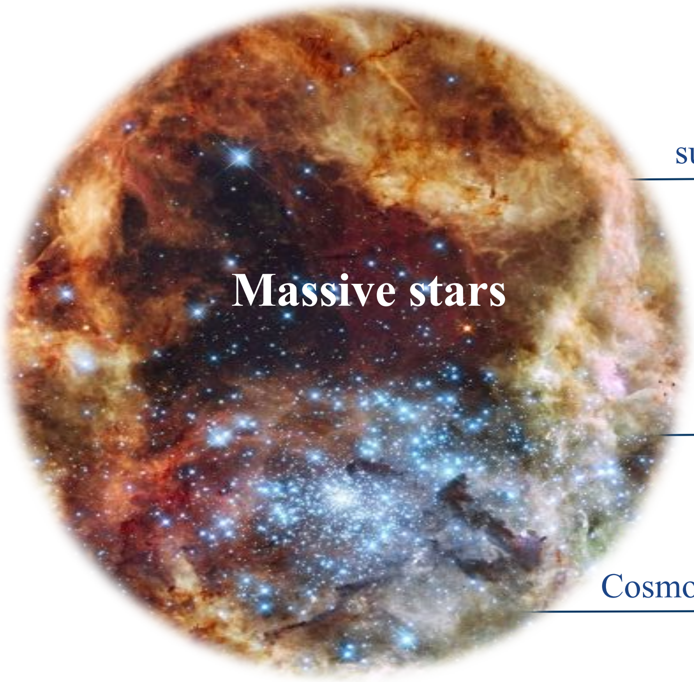
Nuclear processes



Cosmological impact by the feedback processes

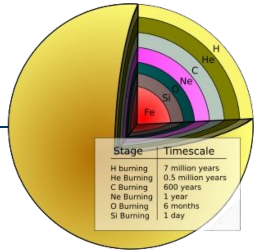
Figure Credit: NASA

Cosmic impact of massive stars



Progenitors of supernova & gamma ray bursts

Nuclear processes

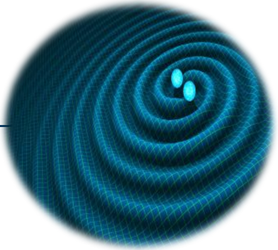


Cosmological impact by the feedback processes

Figure Credit: NASA

Cosmic impact of massive stars

Binary stars as progenitors of gravitational waves



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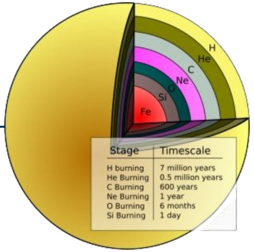

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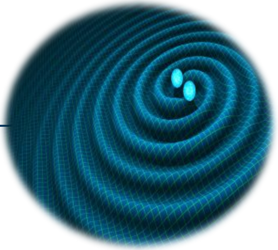

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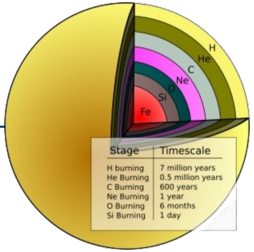
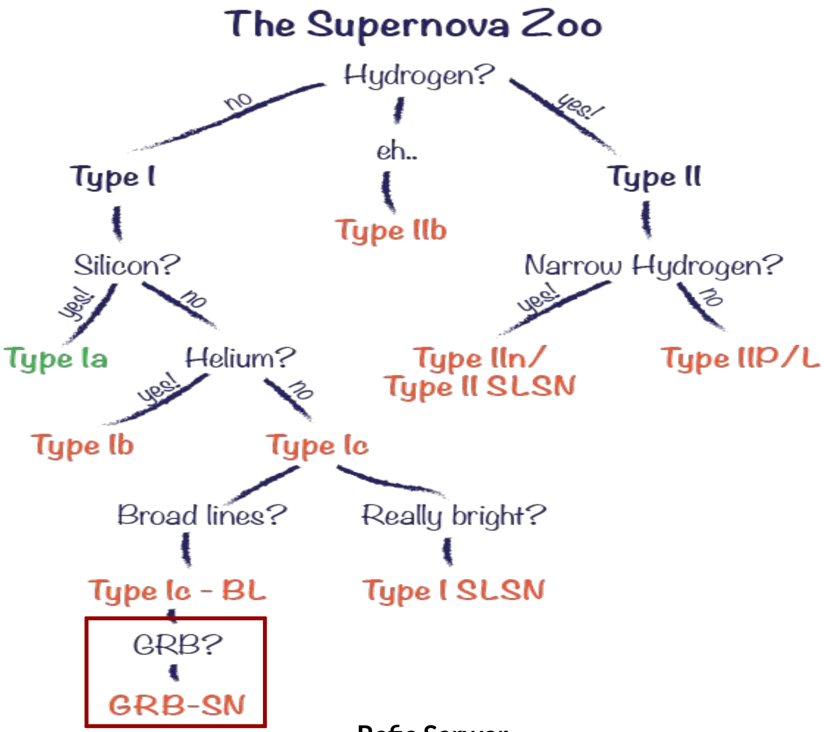


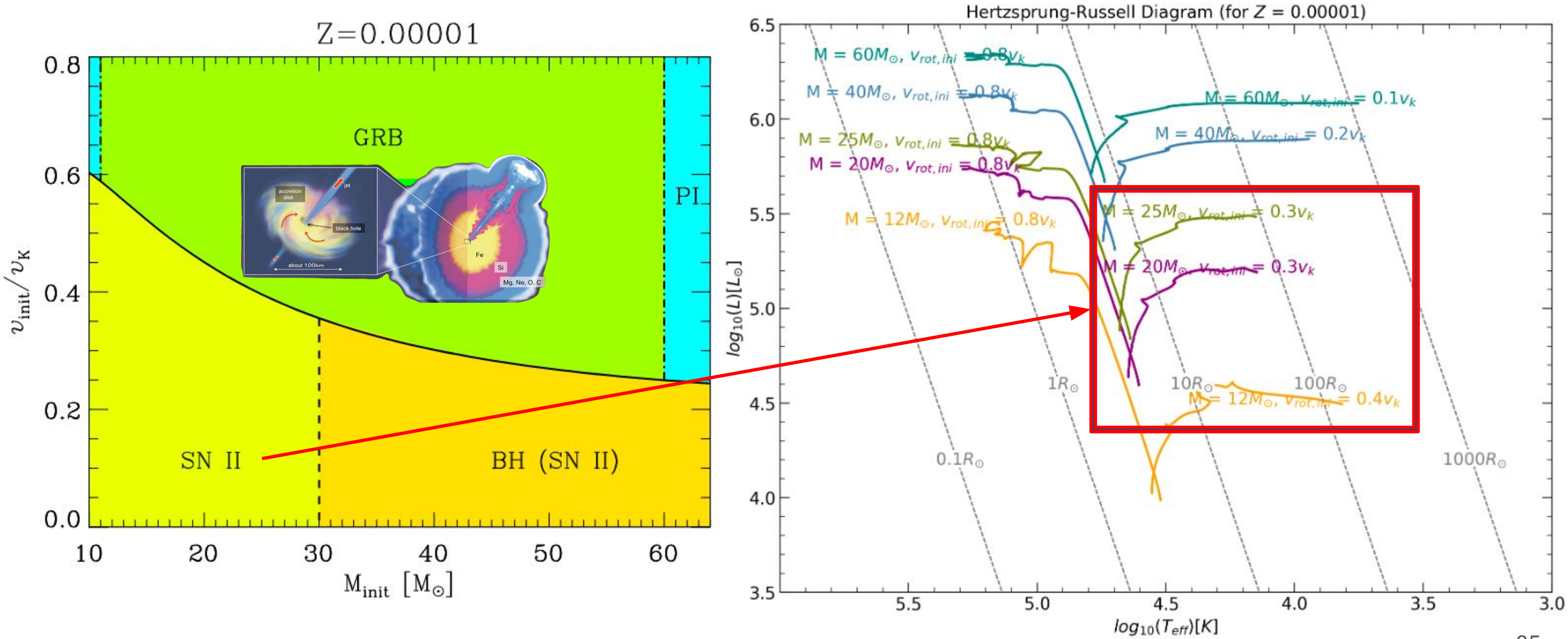
Cosmological impact by the feedback processes

Figure Credit: NASA

Supernova taxonomy



Fate of massive stars



S.-C. Yoon et al. (2006)

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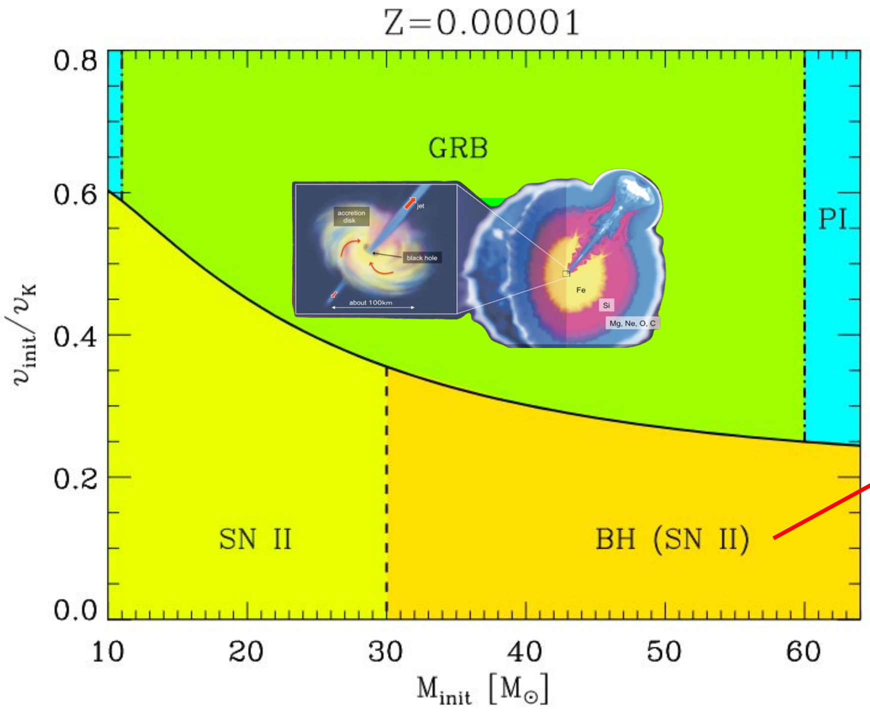

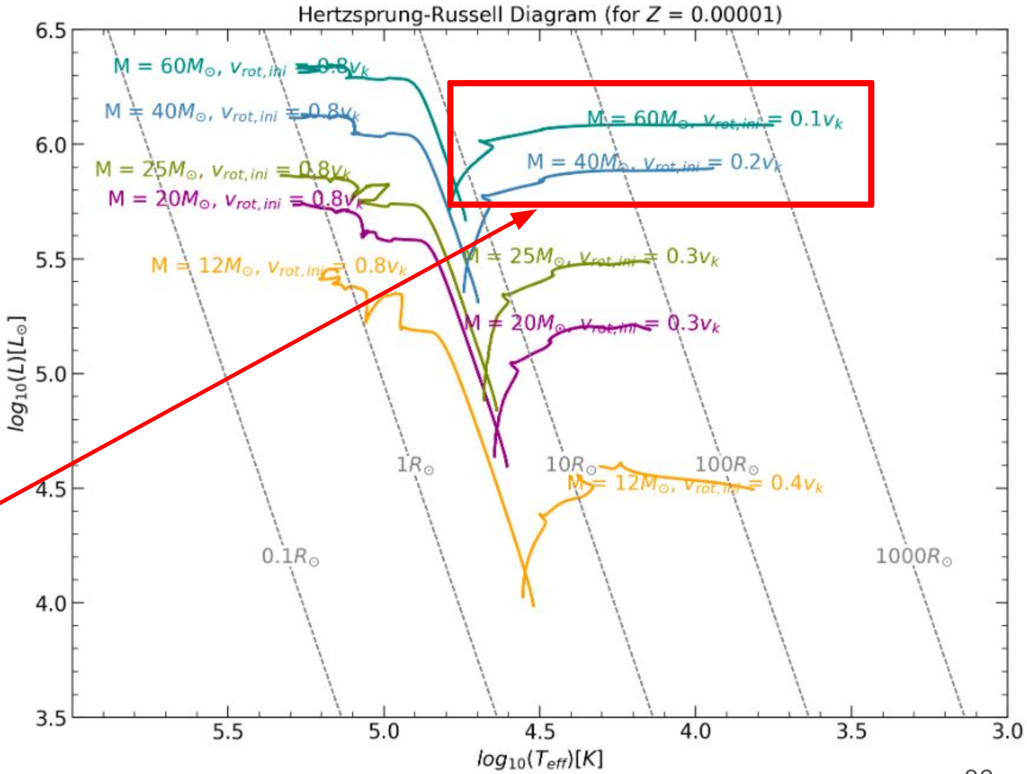

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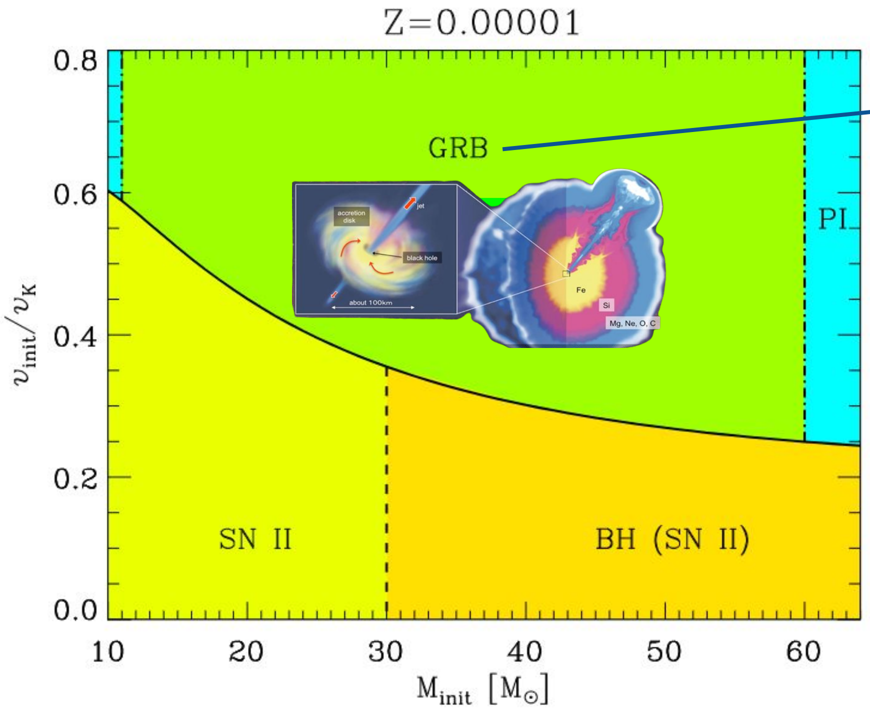

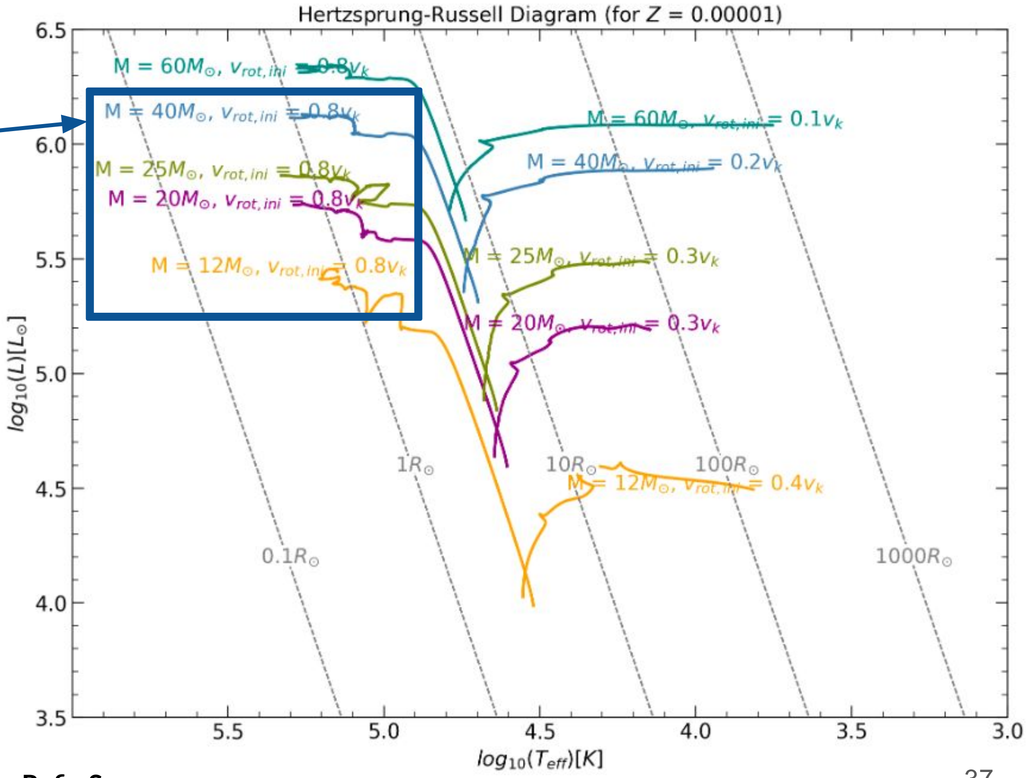

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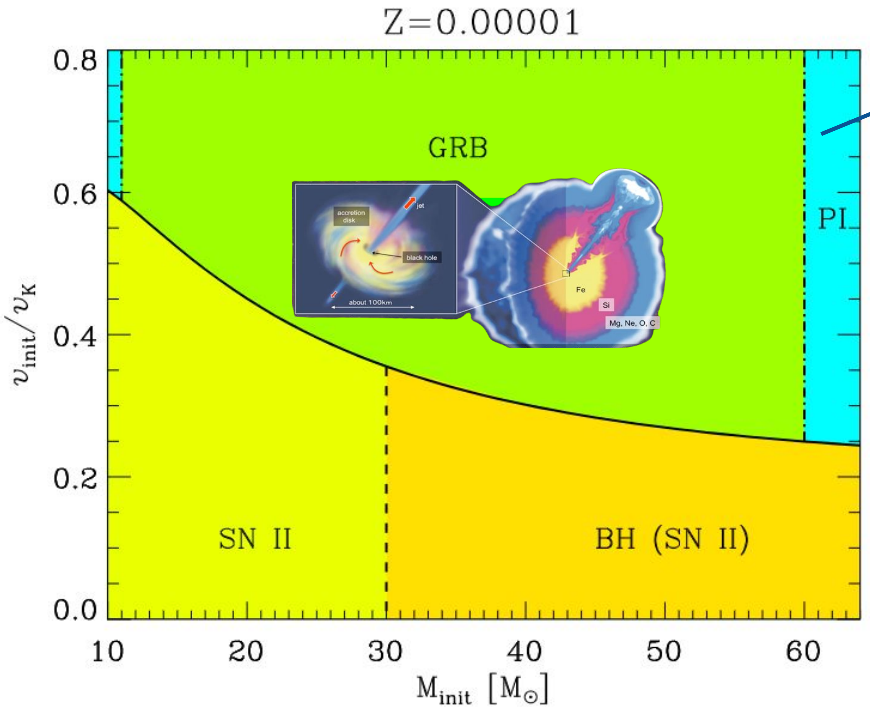
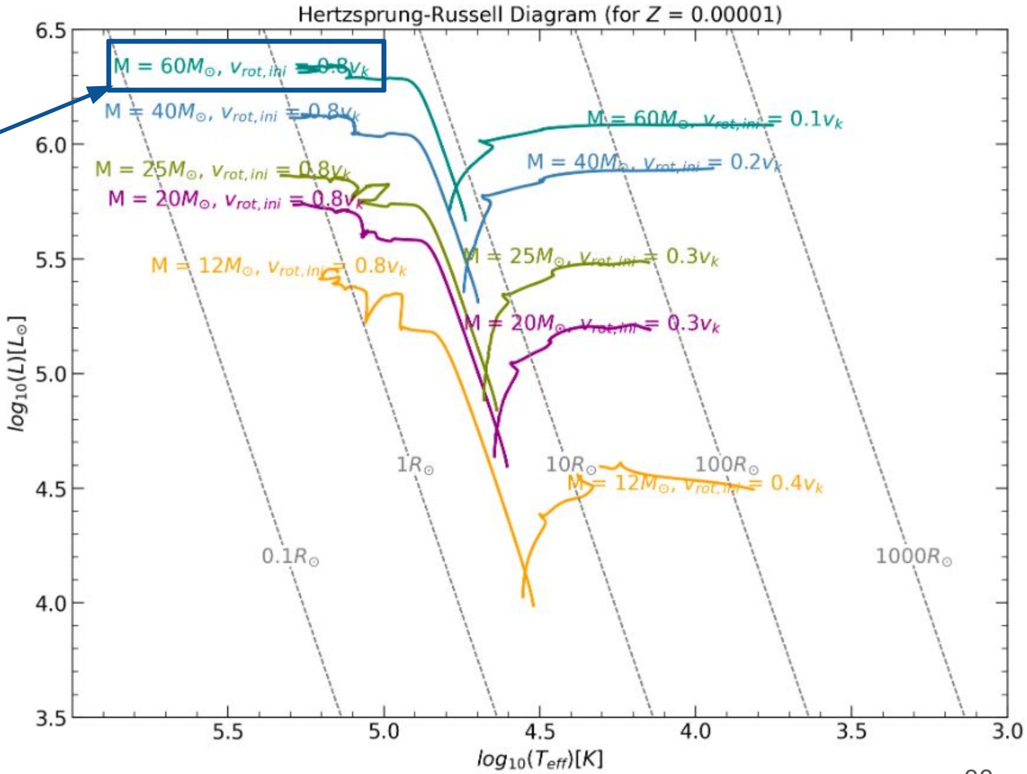
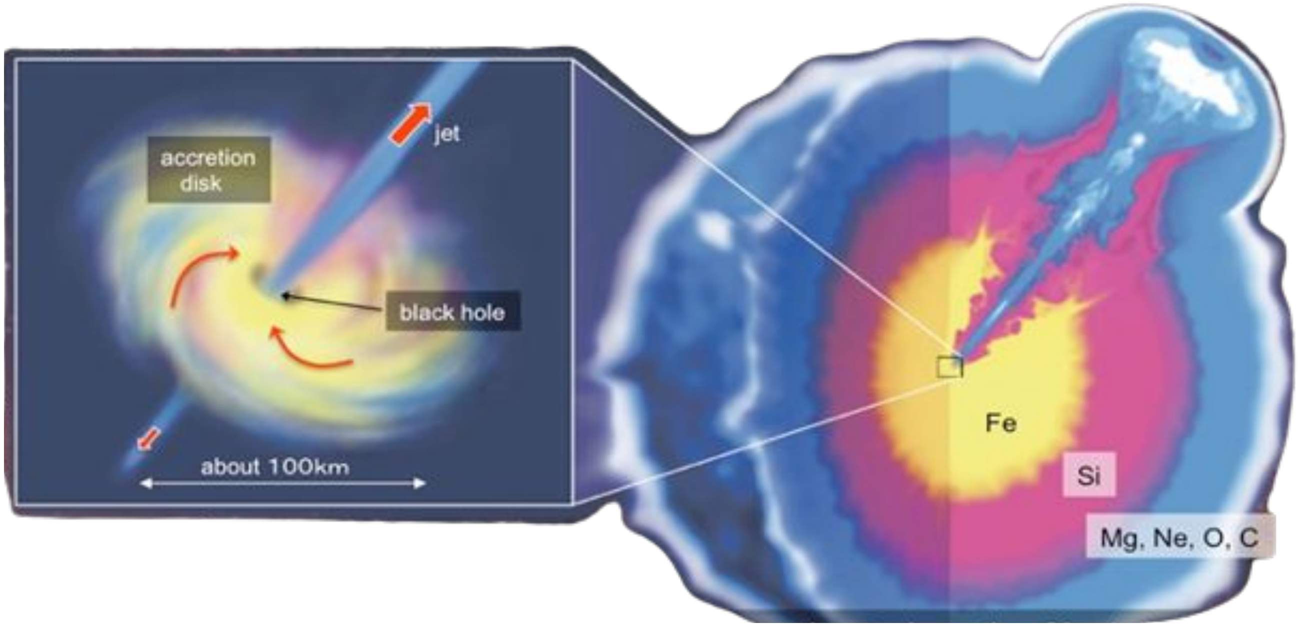




S.-C. Yoon et al. (2006)

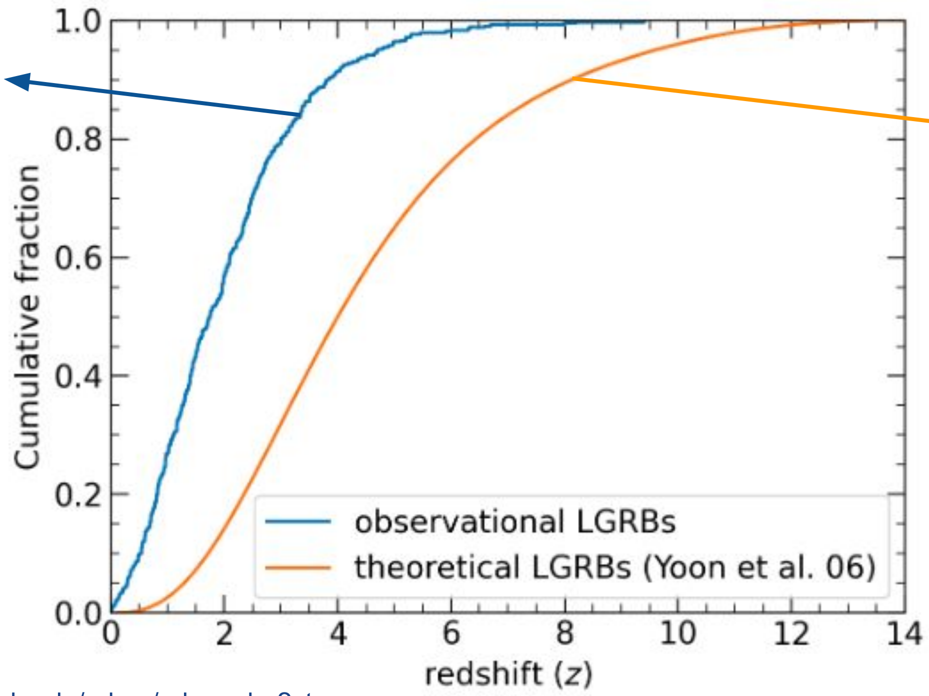
Collapsar model



Single star models vs observation

Observational LGRBs Data:

475 GRBs
447 LGRBs
28 SGRBs

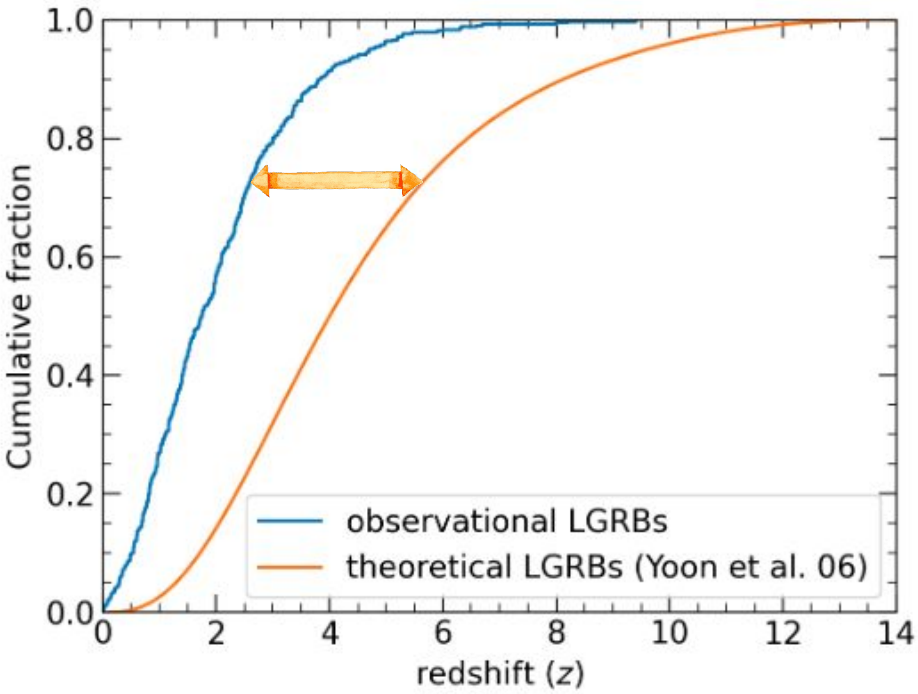


LGRBs based on theoretical single star population from S.-C. Yoon et al. (2006)

https://sites.astro.caltech.edu/grbox/grbox.php?starttime=700101&endtime=181231

I Horvath et al., (2020)

Single star models vs observation



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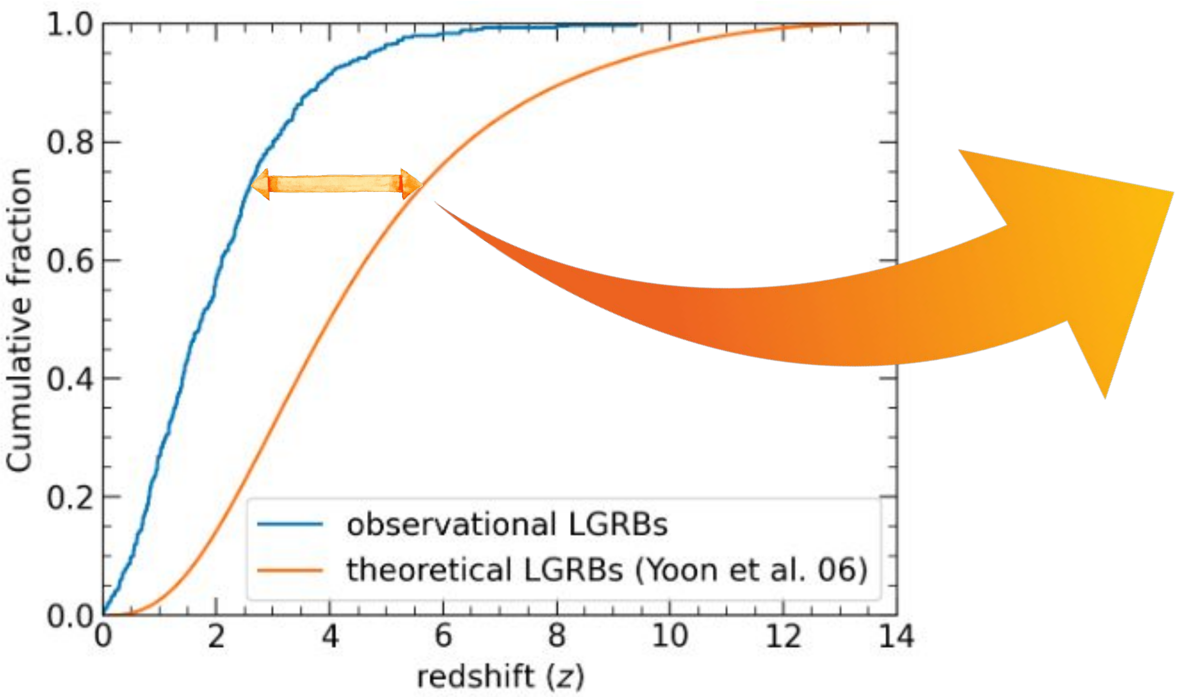

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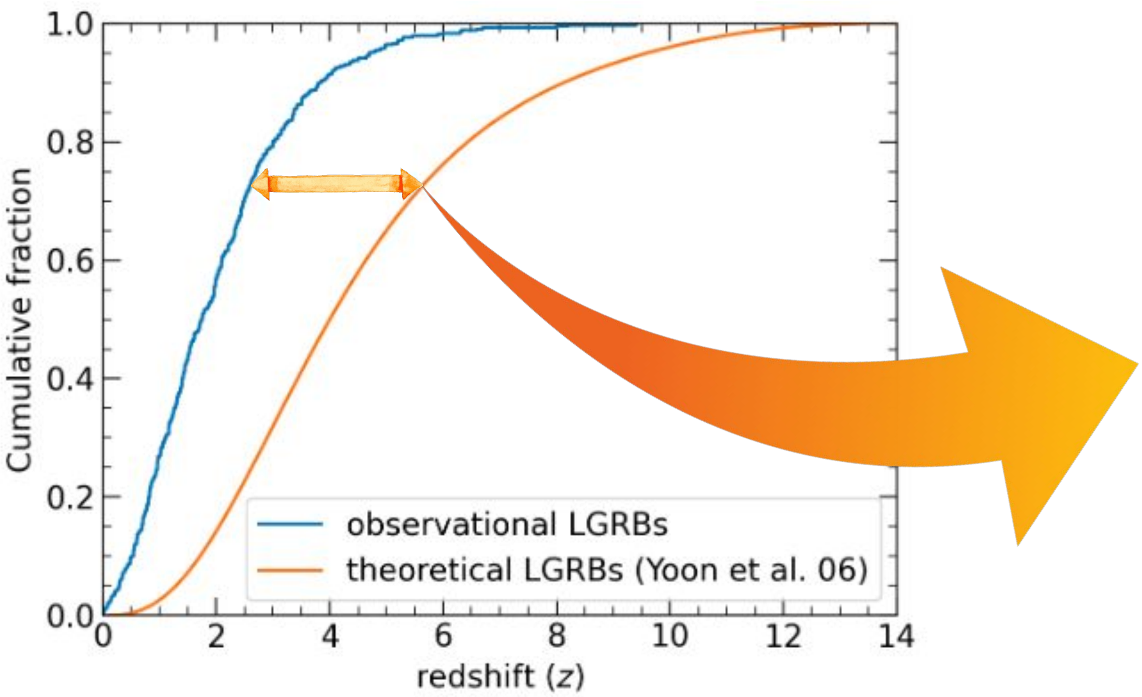
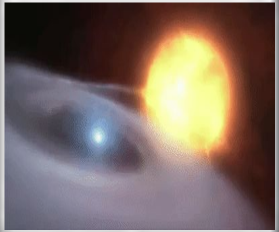


Binary stars



Binary System

=

a system of two objects in space (usually stars), which are so close that their gravitational interaction causes them to orbit around their common center of mass.

According to this definition, almost all stars are binaries (or multiples). The Sun is one of the exceptions.

Rafia Sarwar
06 February 2023

Chemically homogeneous evolution of massive binary stars

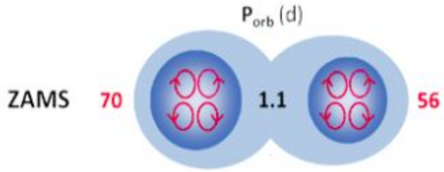


Figure Credit: Pablo Marchant et al. (2016)

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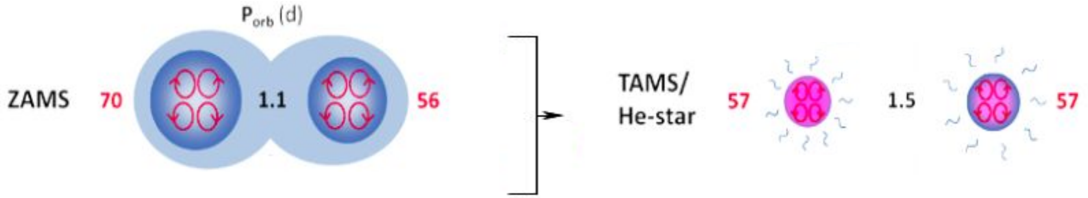

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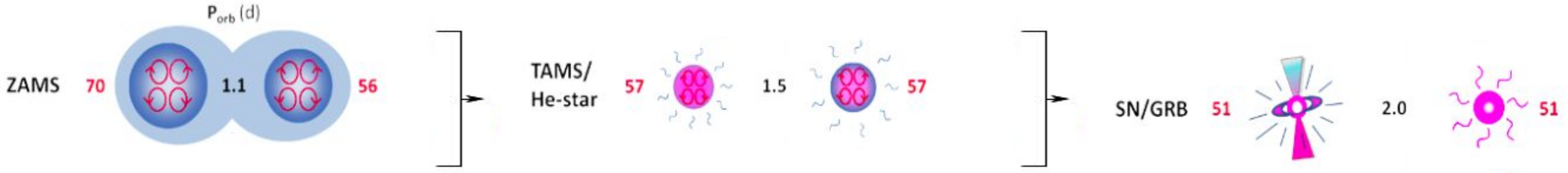


Figure Credit: Pablo Marchant et al. (2016)

Chemically homogeneous evolution of massive binary stars

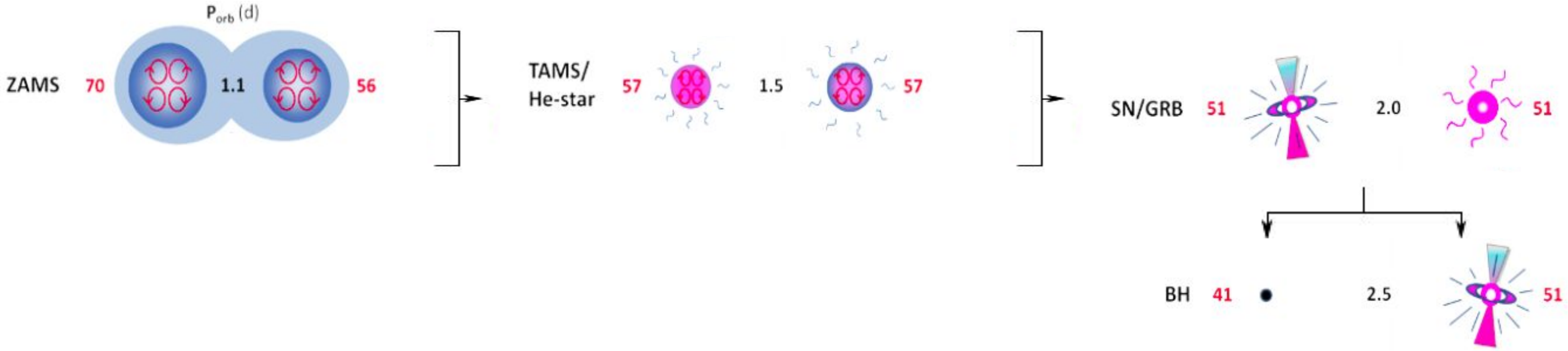


Figure Credit: Pablo Marchant et al. (2016)

Chemically homogeneous evolution of massive binary stars

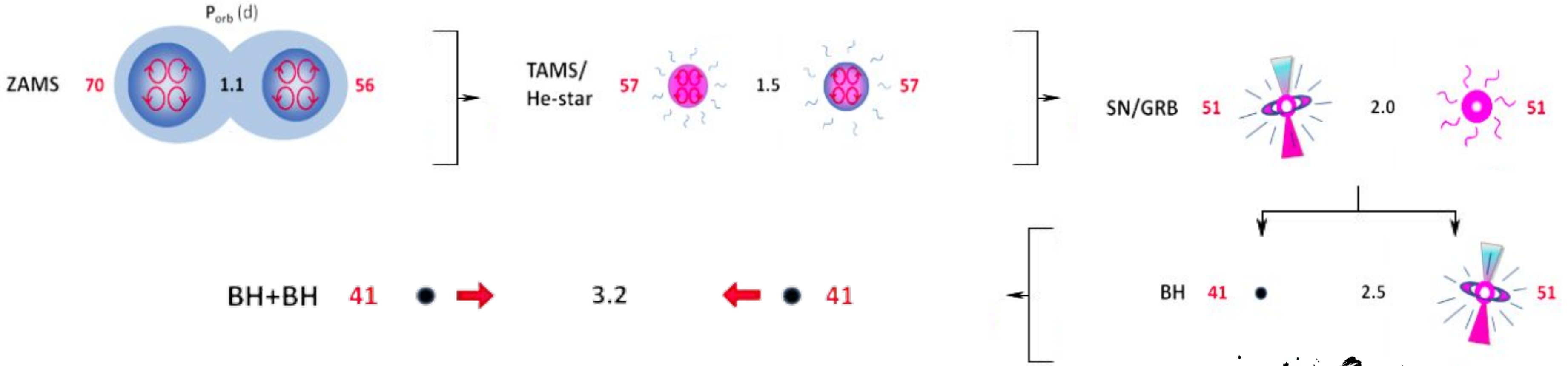


Figure Credit: Pablo Marchant et al. (2016)

Chemically homogeneous evolution of massive binary stars

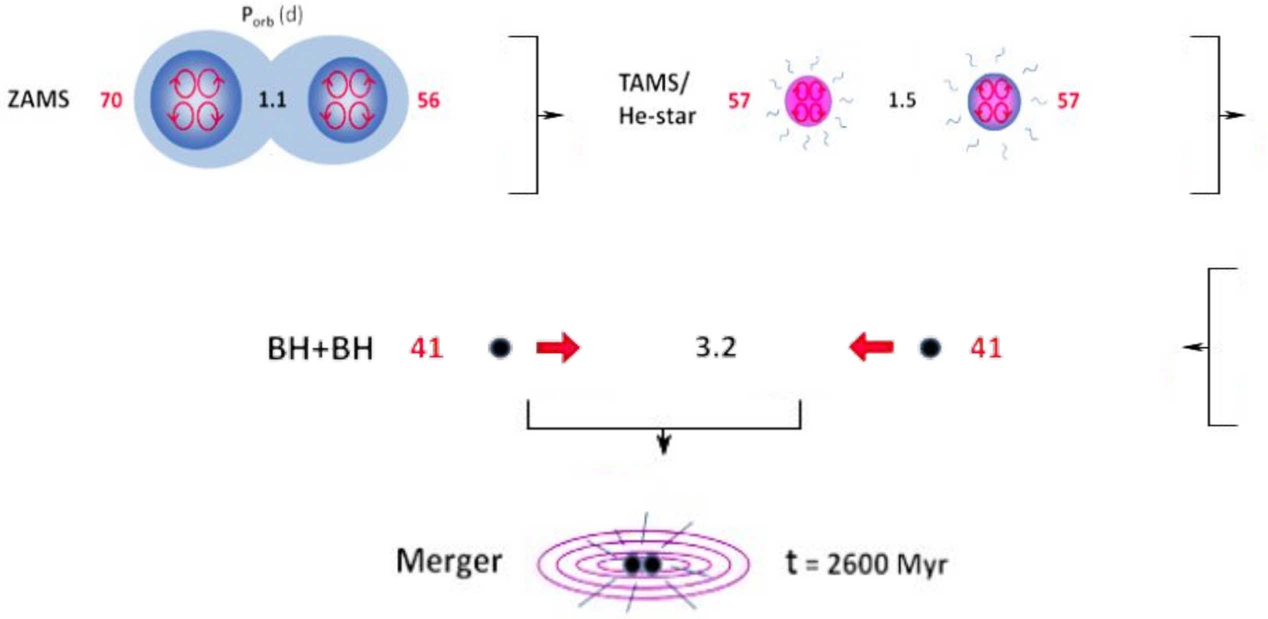


Figure Credit: Pablo Marchant et al. (2016)

The Gravitational-Wave Transient Catalogue 3 (GWTC-3)

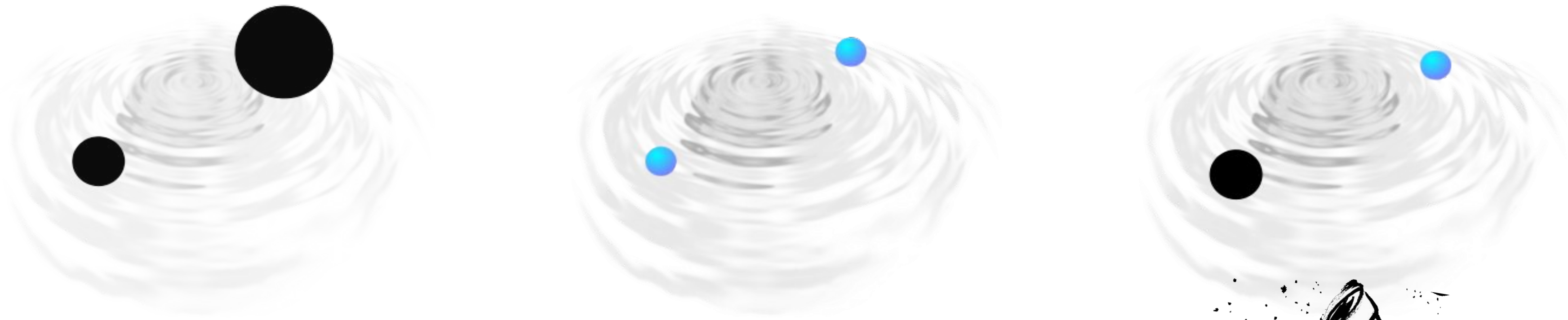
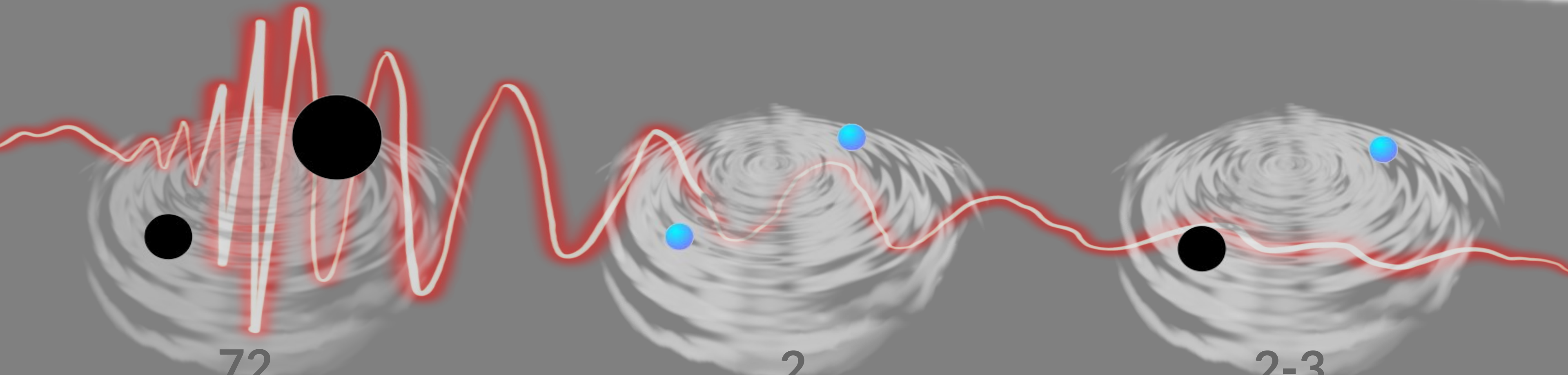


Figure Credit: Tassos Fragos

The Gravitational-Wave Transient Catalogue 3 (GWTC-3)



72
Binary black holes

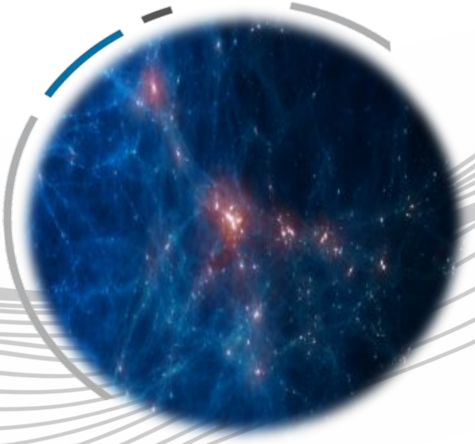
2
Binary neutron star

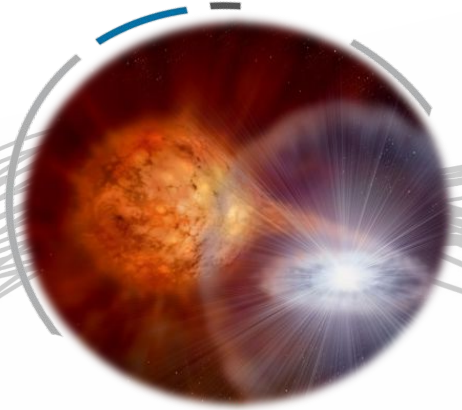
2-3
Black hole-neutron star

Abbot et al. arXiv:2111.03606 (2021)

Take home message

Theoretical understanding of the evolution of massive stars requires binary population synthesis studies to match the observations.

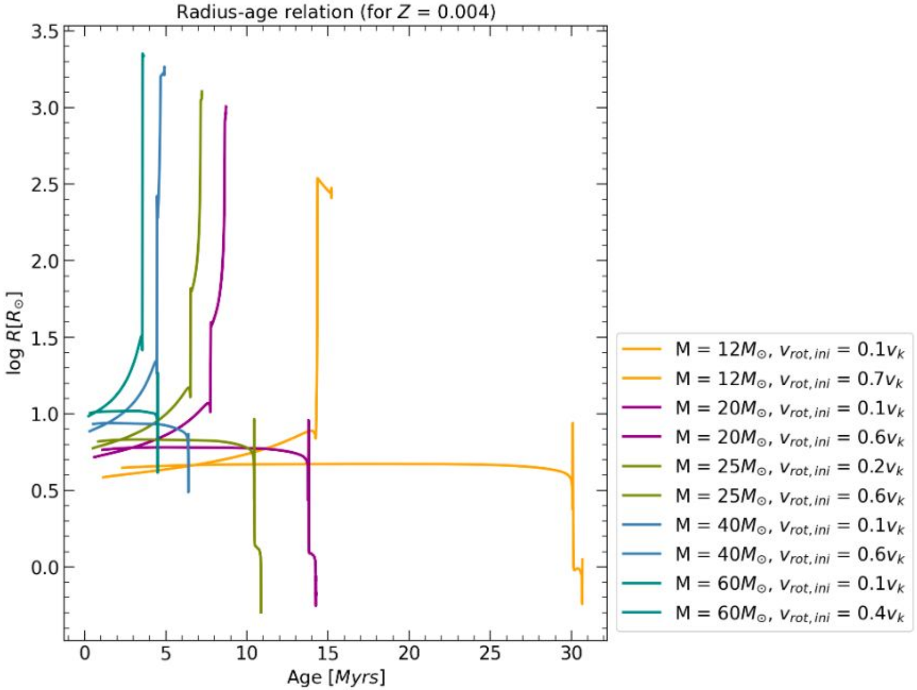


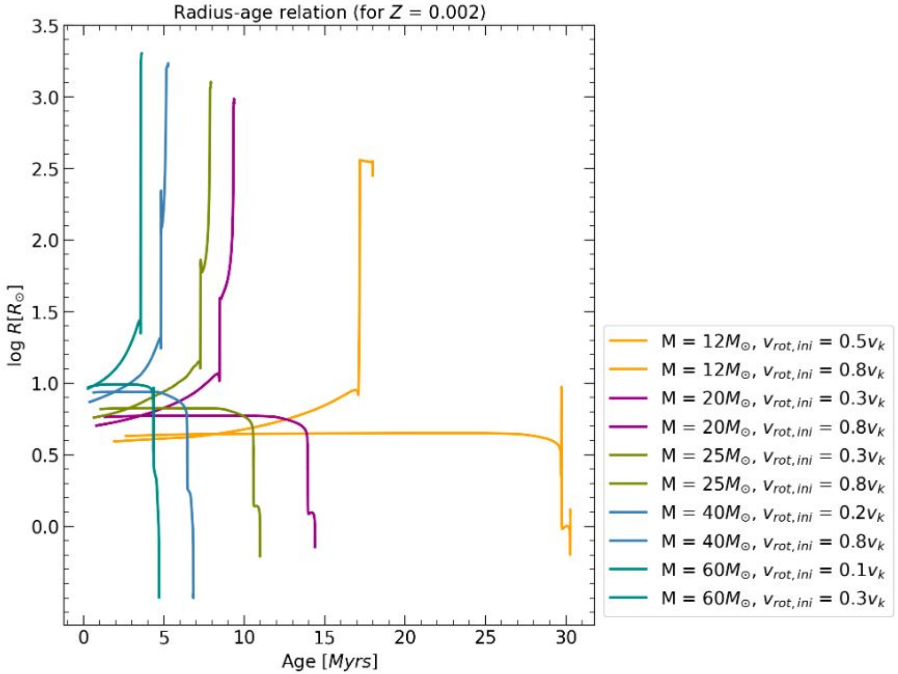


Thank you...

Figure Credit: NASA

Evolution of massive stars





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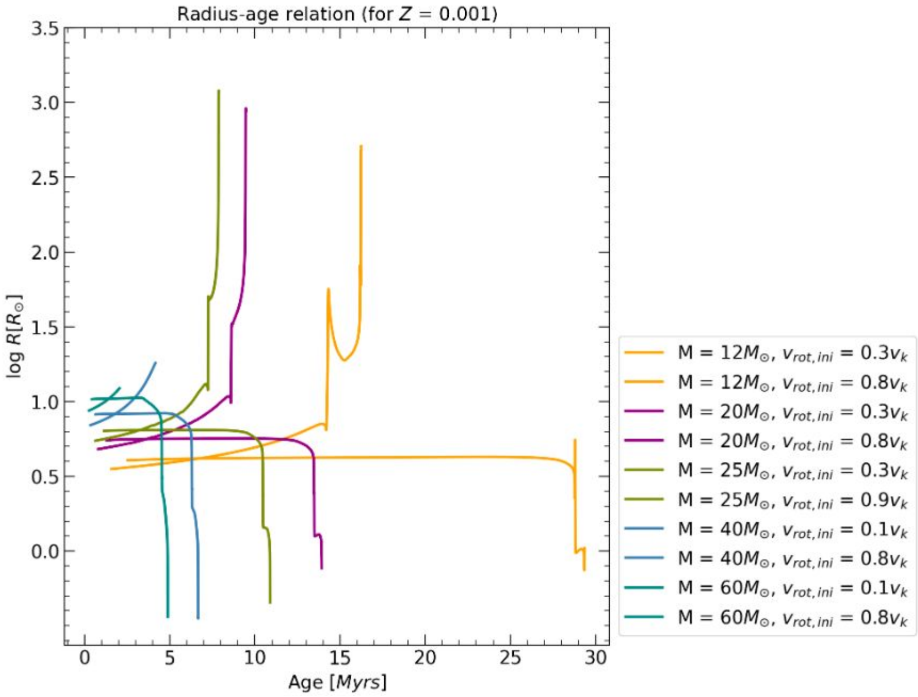
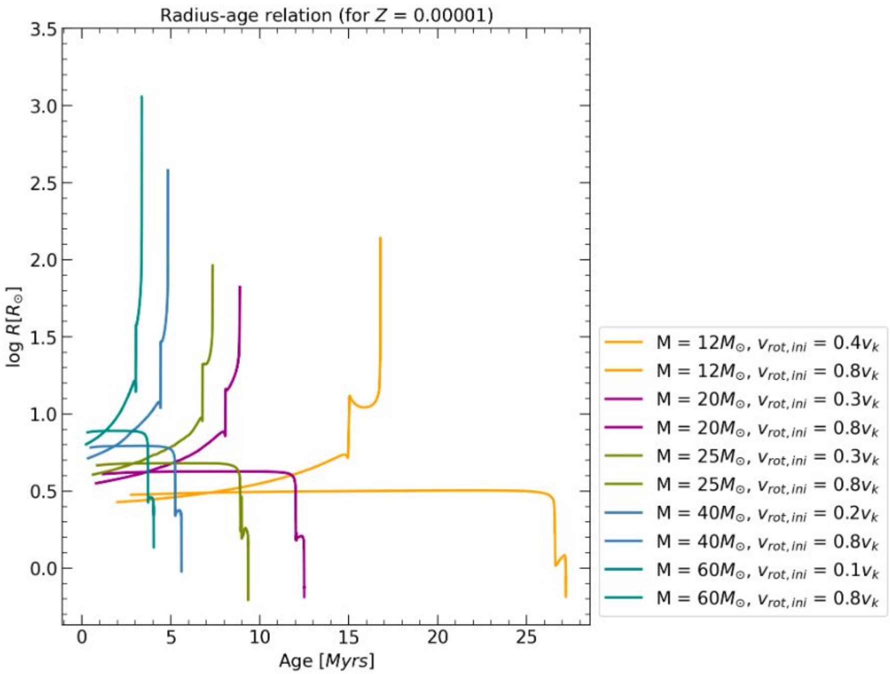
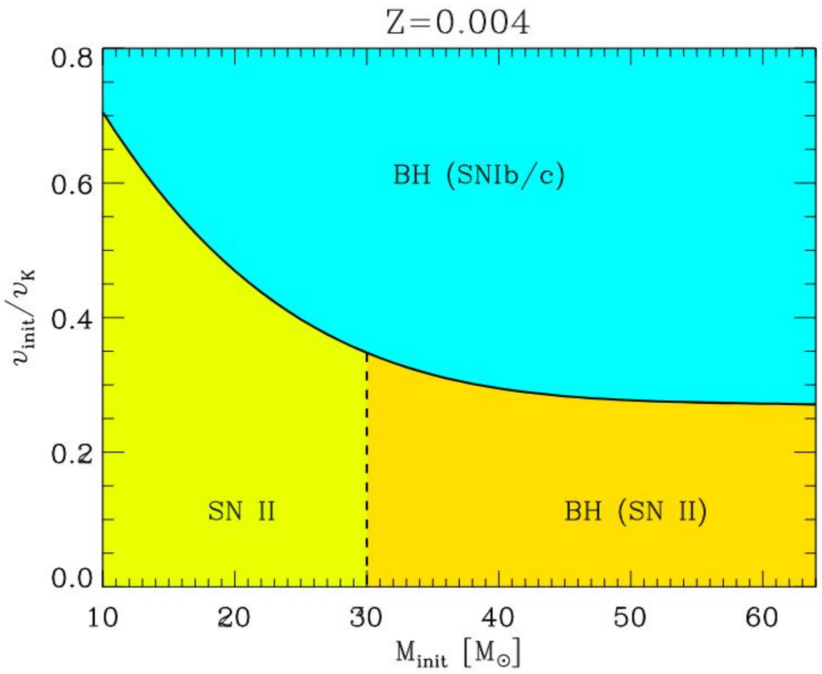
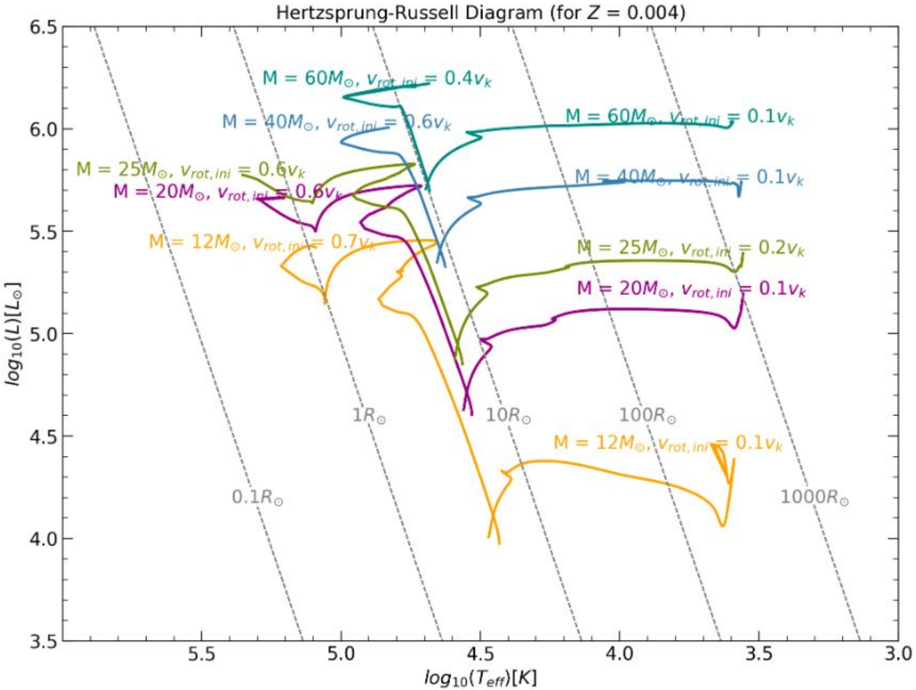
Evolution of massive stars



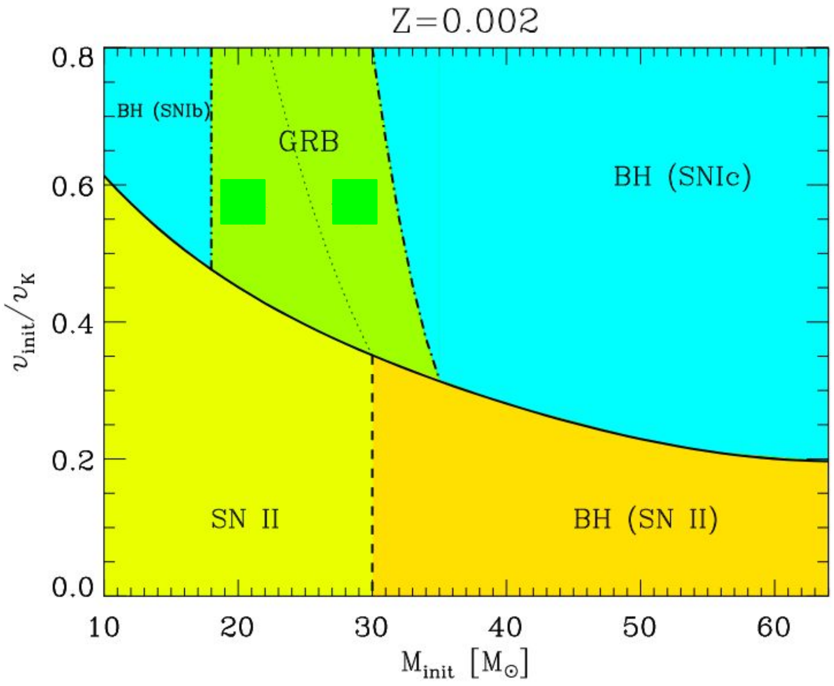


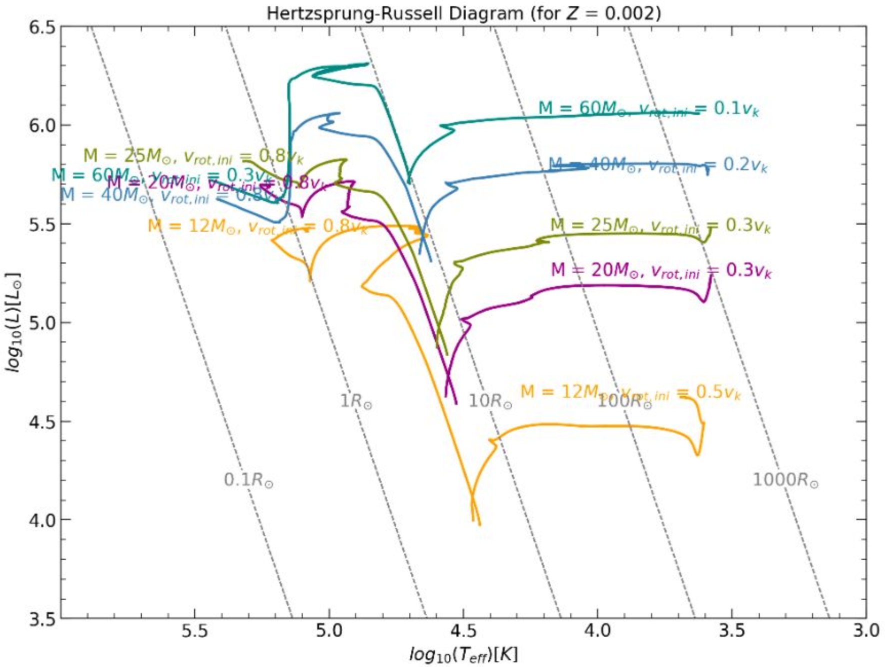
Fate of massive stars





Fate of massive stars





Fate of massive stars