Evolucija masivnih dvojnih sistema - kako nastaju izvori gravitacionih talasa

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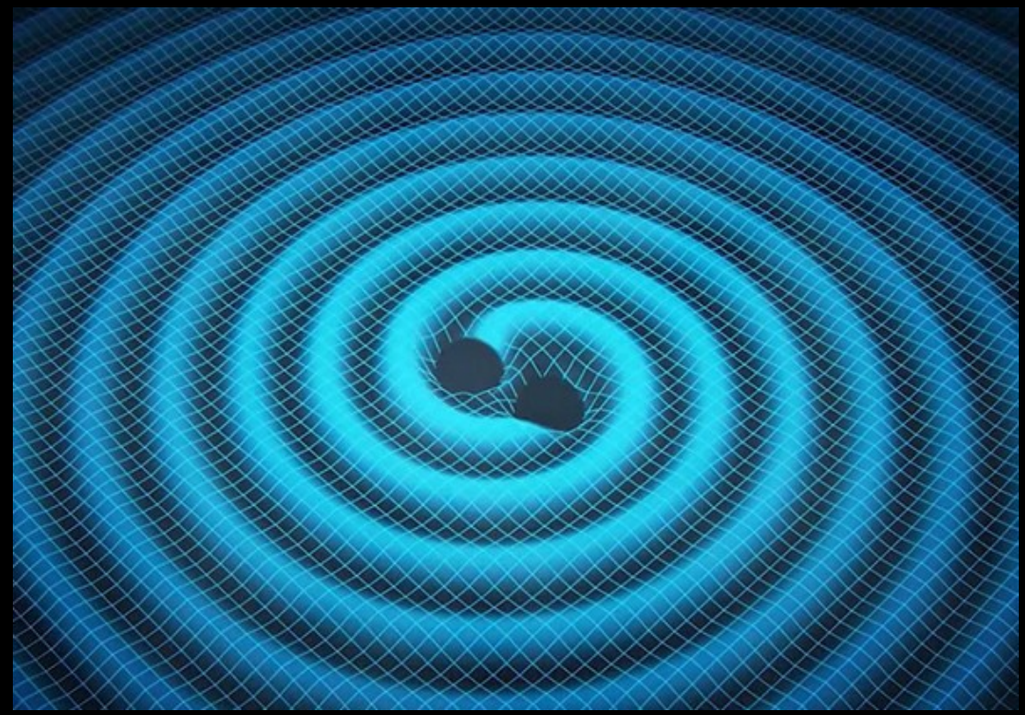
Gravitacioni talasi

- Ajnštajn 1916. godine - predvideo postojanje
- LIGO i Virgo detektori 2015. godine - prvi detektovali talasanja u prostor-vremenu → potvrda postojanja gravitacionih talasa

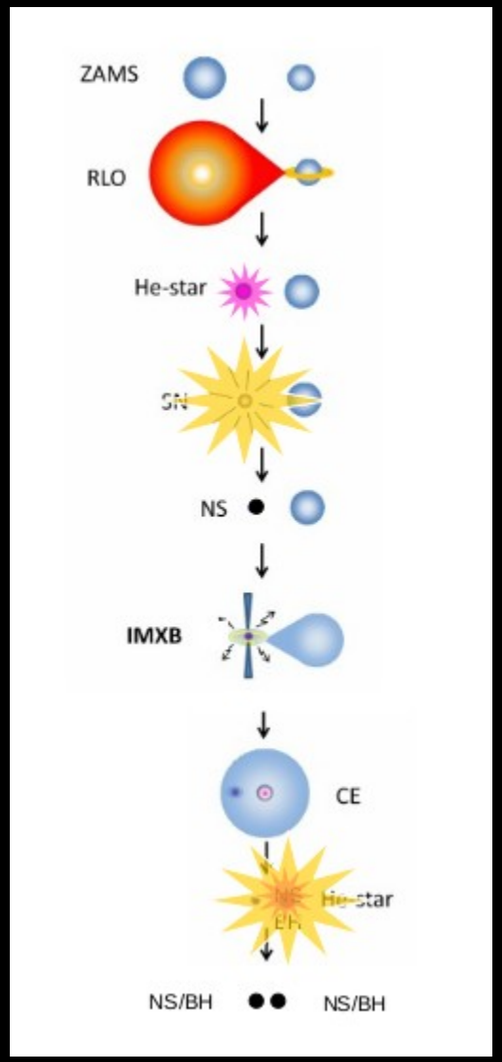


Gravitational Wave events

GW150914	11-02-2016	35.6$M_\odot$	30.6$M_\odot$
GW151012	15-06-2016	23.3	13.6
GW151226	15-06-2016	13.7	7.7
GW170104	01-06-2017	31.0	20.1
GW170608	16-11-2017	10.9	7.6
GW170729	30-11-2018	50.6	34.3
GW170809	30-11-2018	35.2	23.8
GW170814	27-09-2018	30.7$M_\odot$	25.3$M_\odot$
GW170817	16-10-2017	**1.46**	**1.27**
GW170818	30-11-2018	35.5	26.8
GW170823	30-11-2018	39.6	29.4
GW190412	17-04-2020	29.7	8.4
GW190425	06-01-2020	**1.60**	**1.46**
GW190814	23-06-2020	?23.2	?2.59

https://www.ligo.org/detections.php

Evolucija masivnih zvezda u dvojnom sistemu



- Primarna zvezda: ZAMS – RLOF – Wolf-Rayet (He) zvezda (CO jezgro) – SN – NS/BH
- Sekundarna zvezda: ZAMS – tr.mass – MS – RLOF (X-ray binary) - SN
- CE - Common Envelope
- Sistem: NS/BH i helijumska zvezda (He star)
- Sistem postaje kompaktni sistem DCO (NS/BH i NS/BH)

Transfer mase

- Tip A: sagorevanje vodonika u jezgru
- Tip B: počinje sagorevanje vodonika u omotaču
- Tip C: počinje sagorevanje helijuma u omotaču

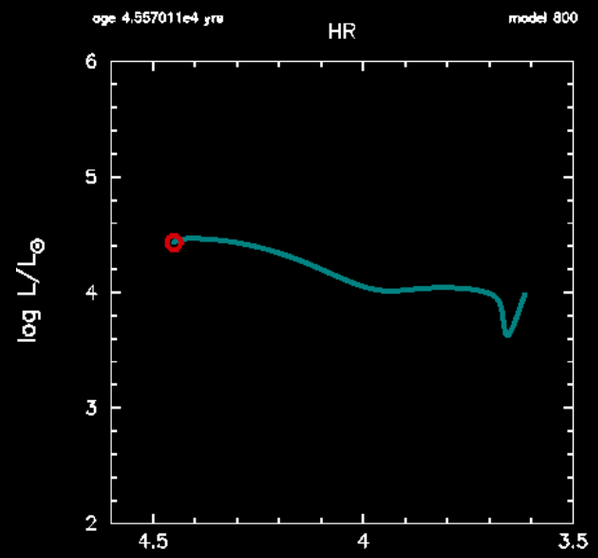
- Konzervativni: sva materija koju je primarna izgubila, sekundarna dobija
- Nekonzervativni: deo materije napušta sistem

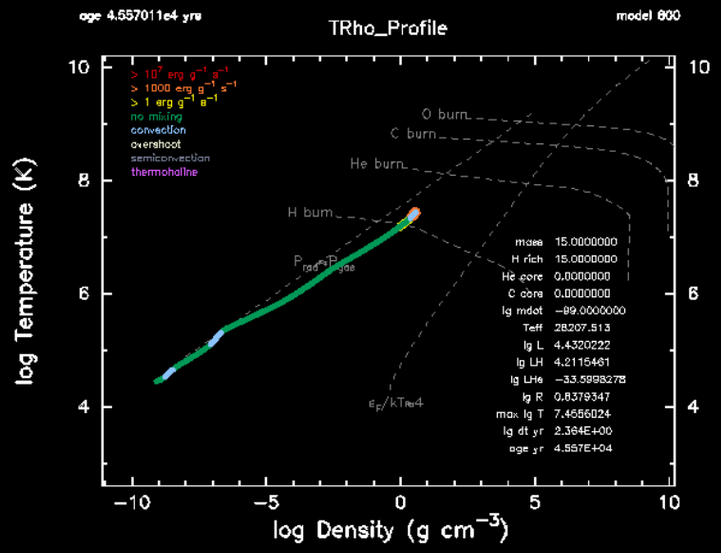
Model

- Masa sistema: 34 + 30.6 $M_{\odot}$ (početni odnos masa: 0.9)
- Orbitalni period: 3 dana
- Metaličnost: 0.02
- Efikasnost akrecije: 10%
- Zvezdani vetar: "Dutch"

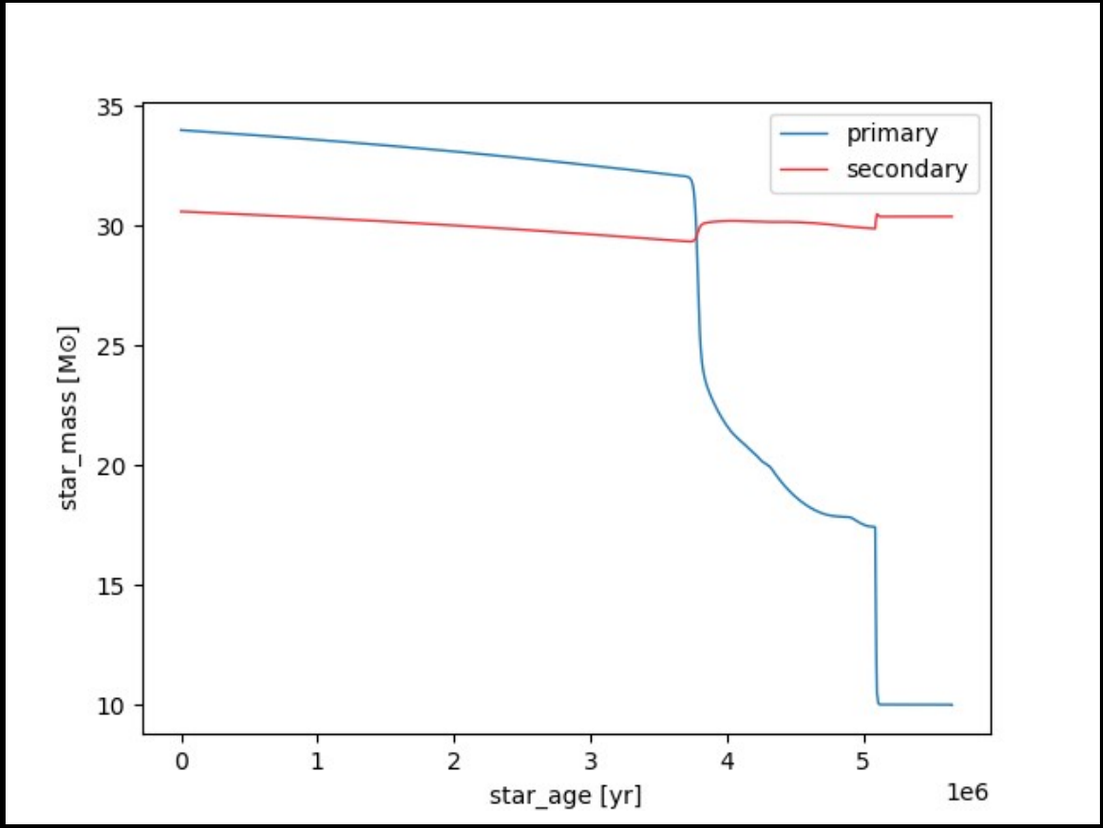
MESA

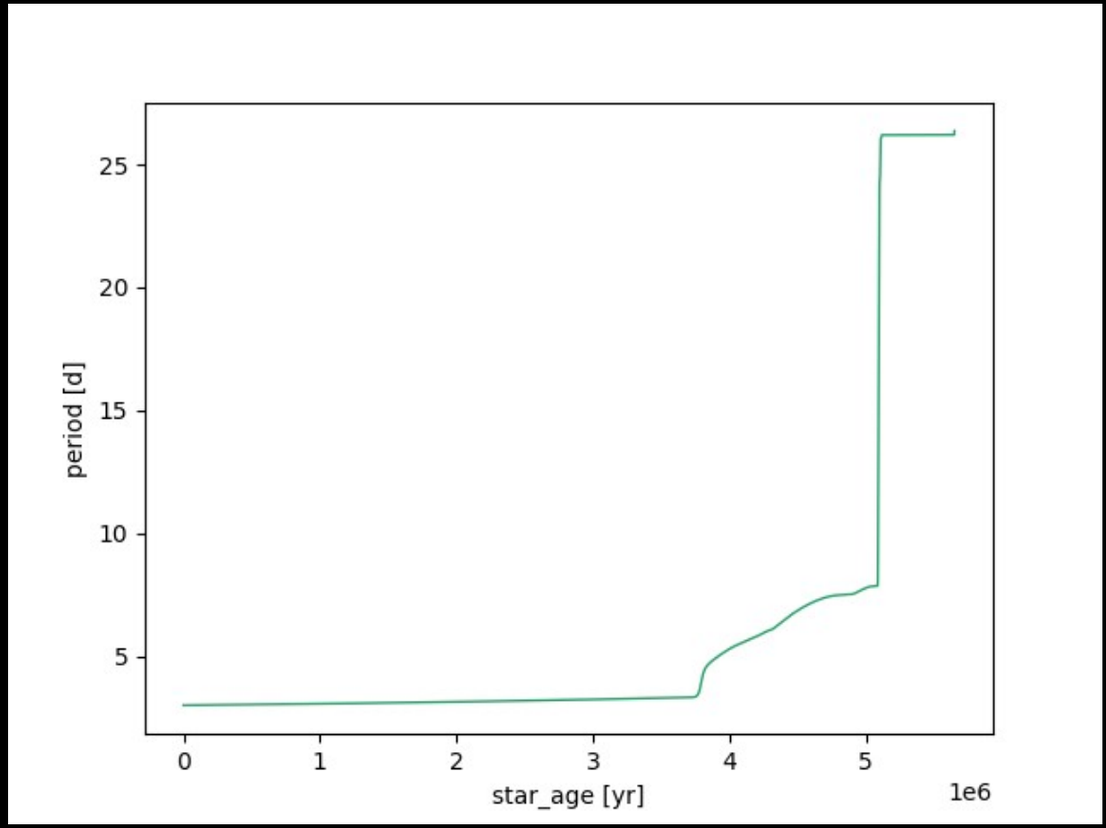
- Modules for Experiments in Stellar Astrophysics (MESA)
- Kod za hidrodinamičku zvezdanu evoluciju (single star, binary system)
- Detaljna evolucija unutrašnje strukture obe zvezdane komponente
- Evolucija orbitalnih parametara



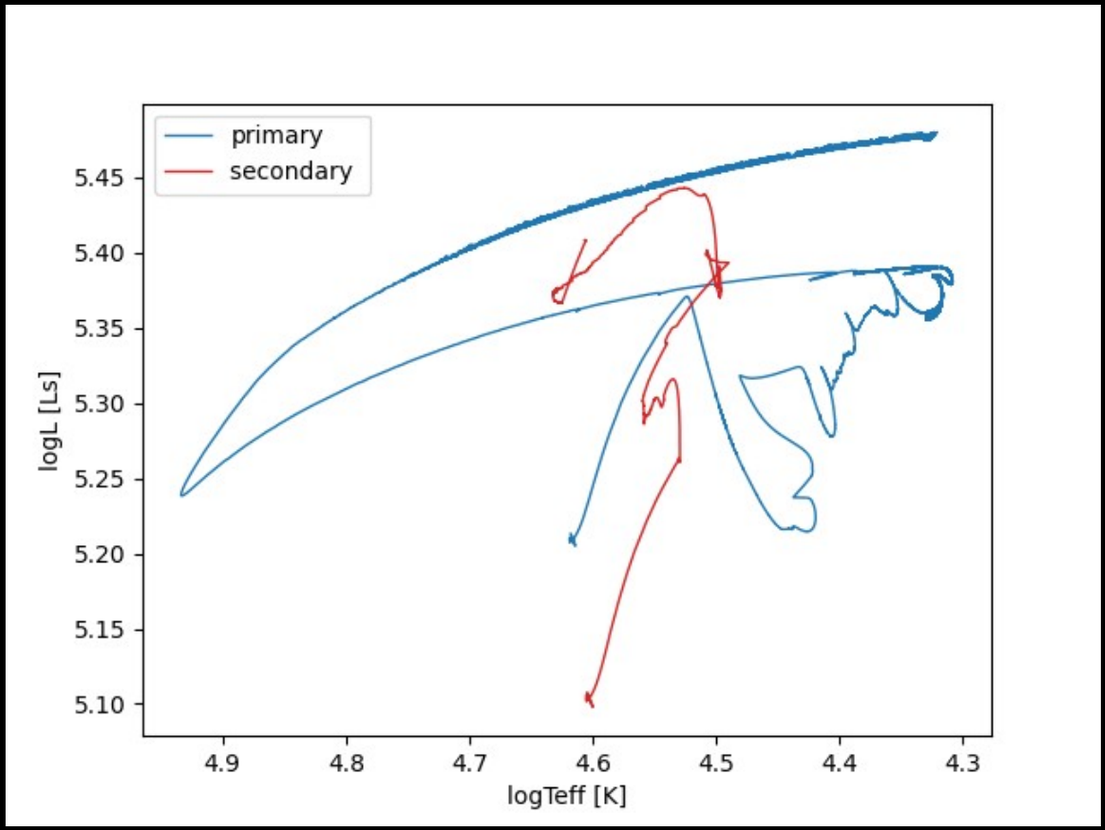


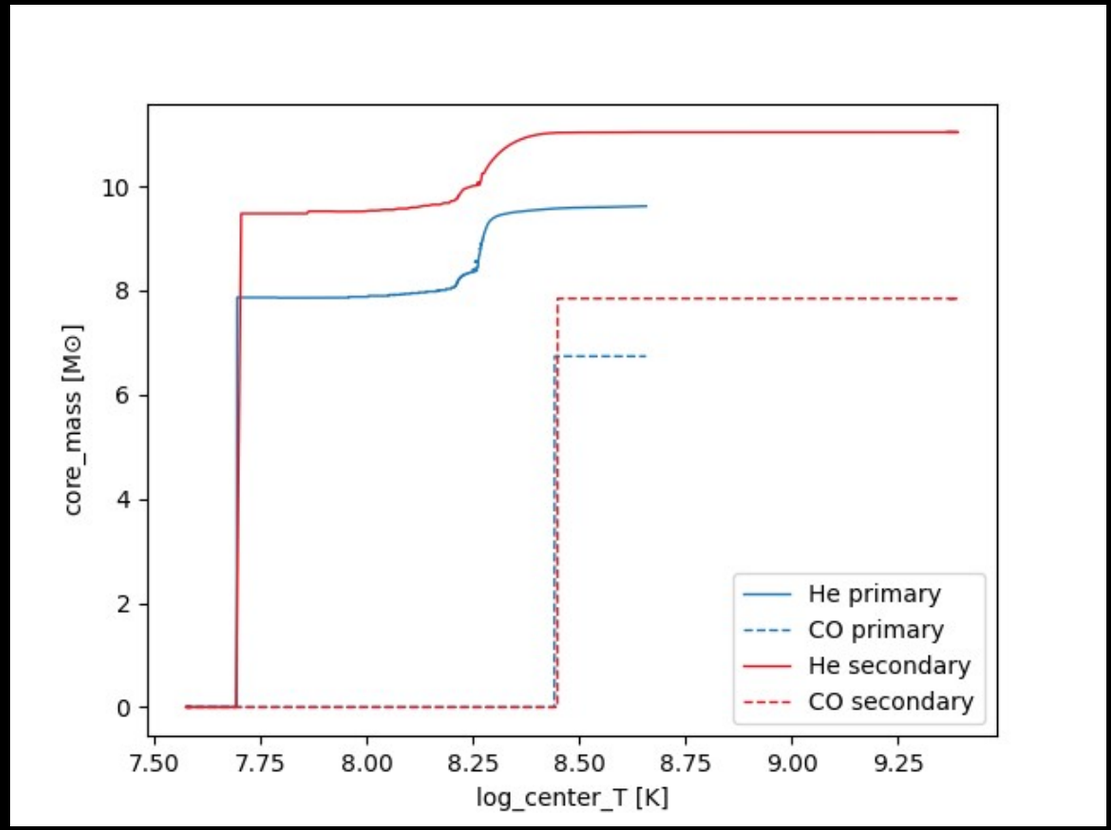
Rezultati


primary
secondary
star_mass [M⊙]
star_age [yr]
1e6
35
30
25
20
15
10
0
1
2
3
4
5

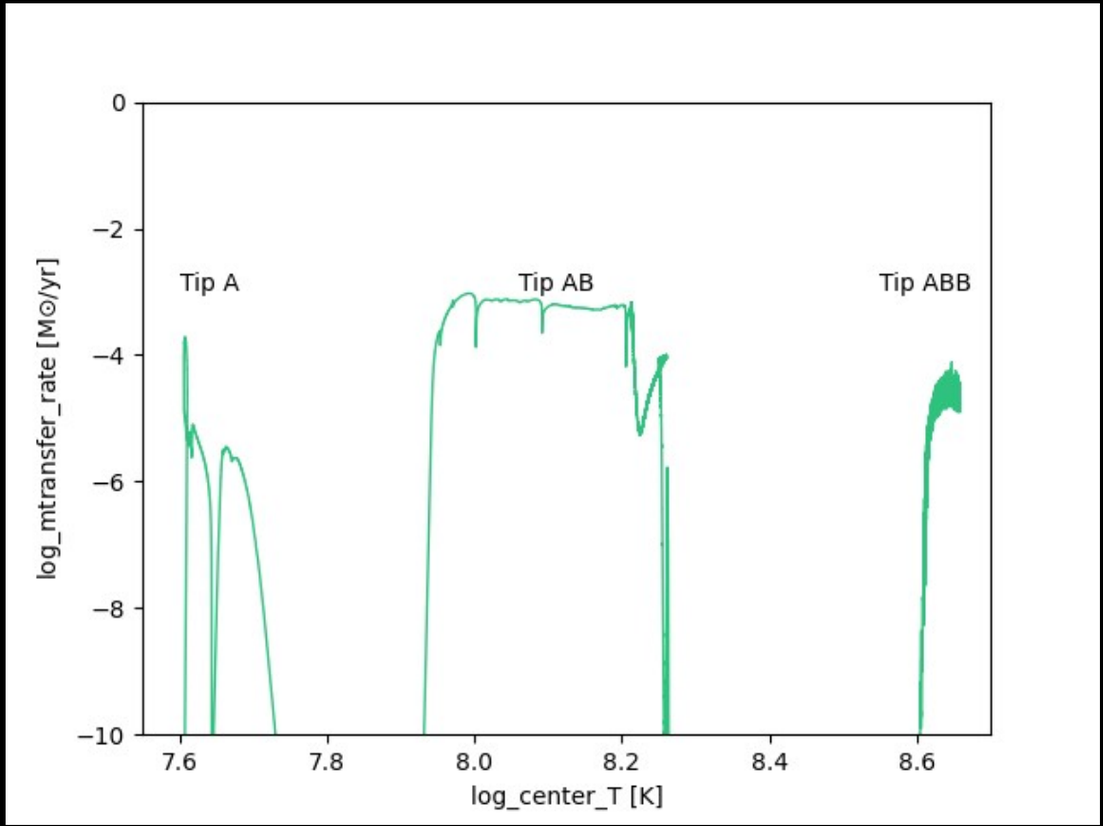

period [d]
star_age [yr]
1e6
25
20
15
10
5
0
1
2
3
4
5

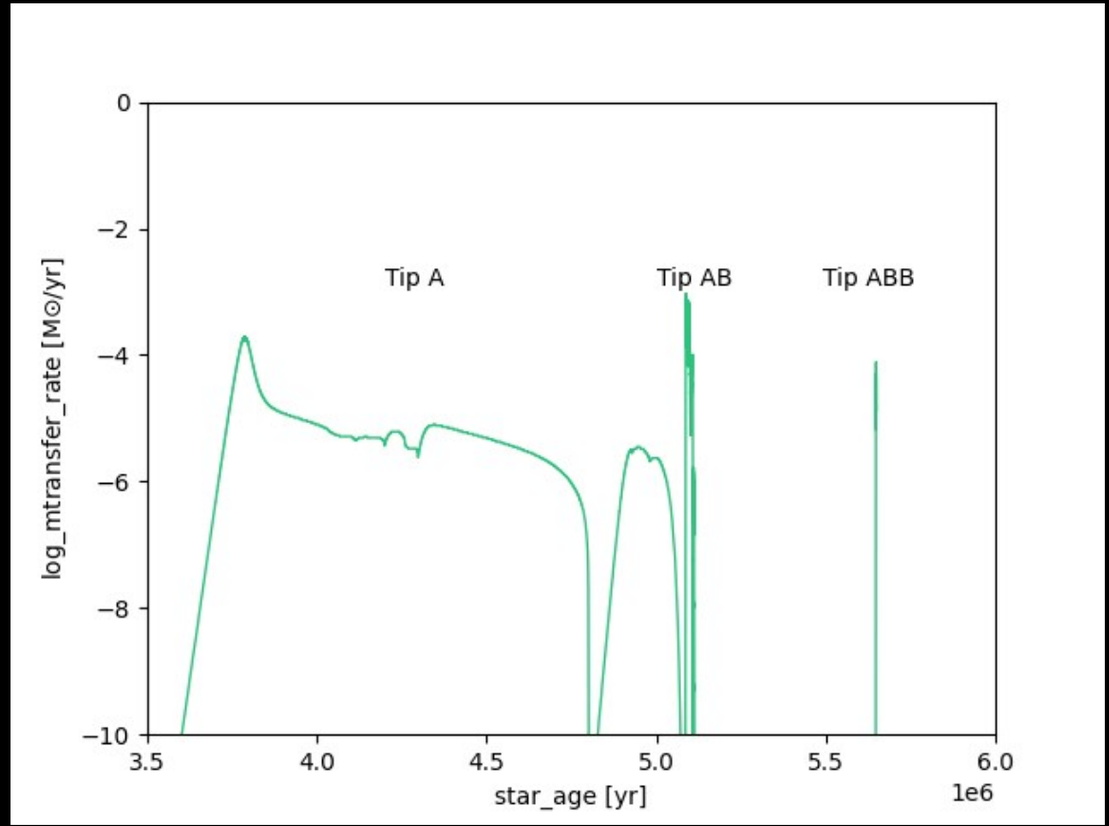
Rezultati


primary
secondary
5.45
5.40
5.35
5.30
5.25
5.20
5.15
5.10
logL [Ls]
4.9
4.8
4.7
4.6
4.5
4.4
4.3
logTeff [K]


10
8
6
4
2
0
core_mass [M⊙]
7.50
7.75
8.00
8.25
8.50
8.75
9.00
9.25
log_center_T [K]
He primary
CO primary
He secondary
CO secondary

Rezultati


Tip A
Tip AB
Tip ABB
log_mtransfer_rate [M⊙/yr]
log_center_T [K]
0
−2
−4
−6
−8
−10
7.6
7.8
8.0
8.2
8.4
8.6


Tip A
Tip AB
Tip ABB
log_mtransfer_rate [M⊙/yr]
star_age [yr]
1e6
0
−2
−4
−6
−8
−10
3.5
4.0
4.5
5.0
5.5
6.0

Zaključak

Inicijalni sistem (ZAMS + ZAMS)

- Masa: 34 + 30.6 $M_\odot$
- Period: 3 dana

Presupernova faza (PSN)

- Masa: 10 + 30.4 $M_\odot$
- Period: 26.4 dana

Primarna:

- He core: 9.63
- CO core: 6.74

Sekundarna:

- He core: 11.04
- CO core: 7.84

→ BH + BH → potencijalni izvor gravitacionih talasa

HVALA NA PAŽNJI!