Evolution of Massive Stars in Blue Compact Dwarf Galaxies:

model tracks, Wolf-Rayet stars and final fates

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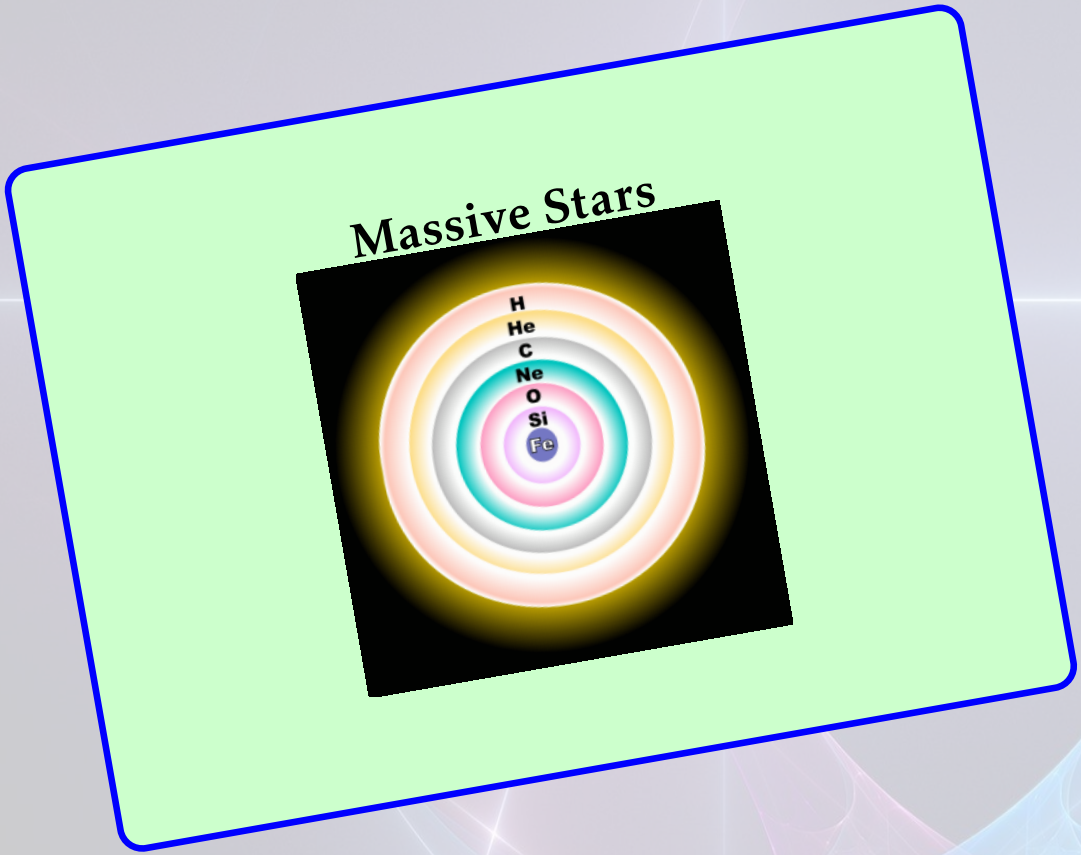
supervisor: Norbert Langer

Argelander-Institut für Astronomie

Group Meeting, Bonn
12th September 2013

Motivations – Overview



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- ~300 model tracks with sub-SMC metallicity
- Wolf-Rayet stars
- Long GRBs...
- ... and Pair Instability SNe
- Synthetic Population of a BCD

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- theory is uncertain
- crucial role in galaxies
- low metallicity:
  - high-z universe, first stars
  - Blue Compact Dwarf Galaxies (BCDs): observable

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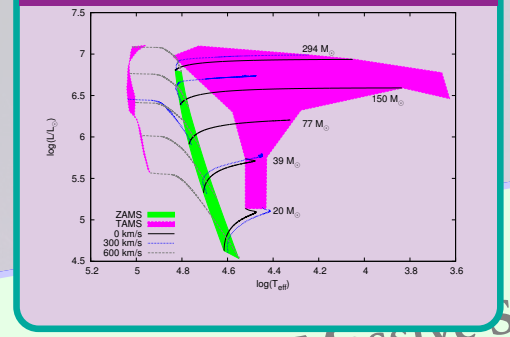

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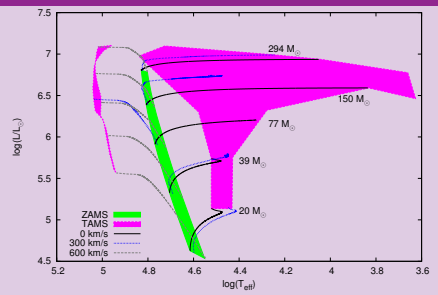

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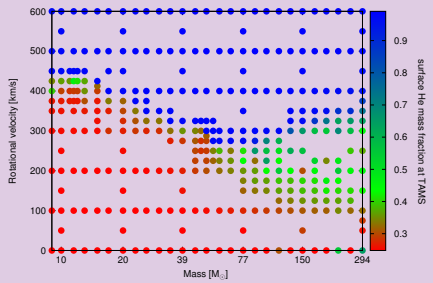

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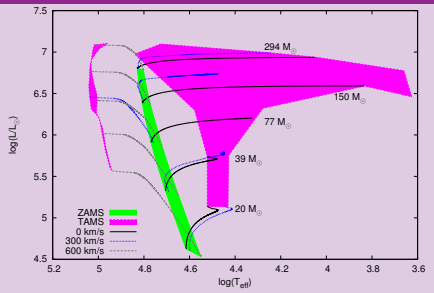

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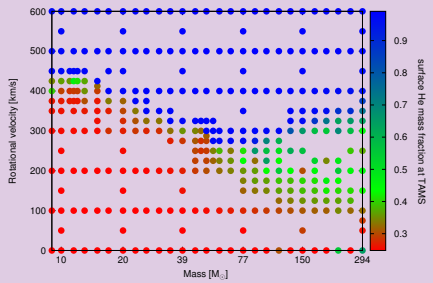

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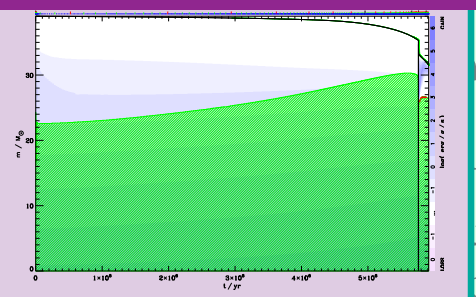

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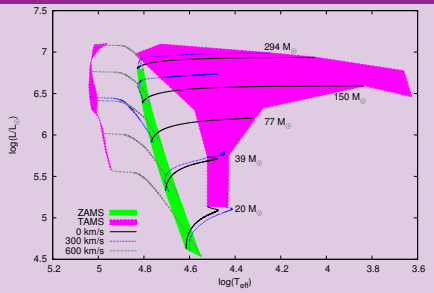

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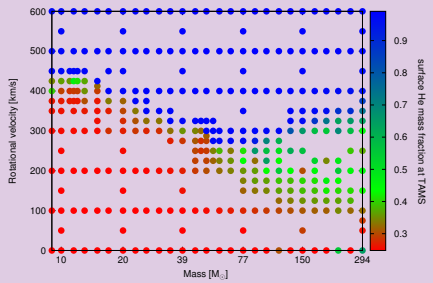

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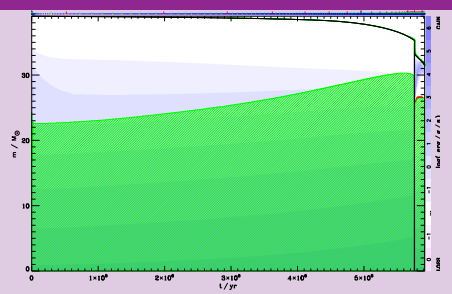

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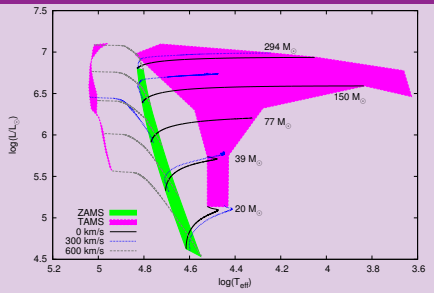

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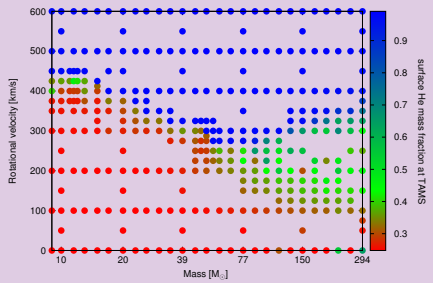

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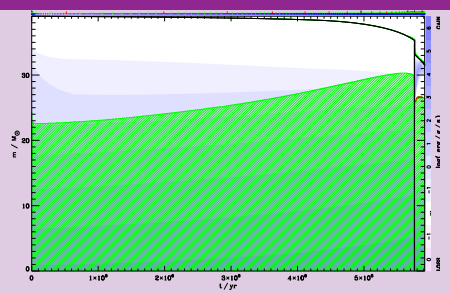

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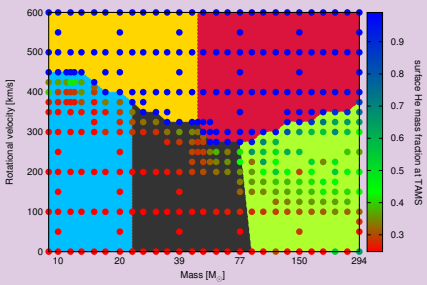
Final fates



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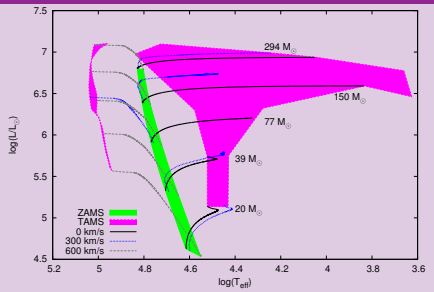

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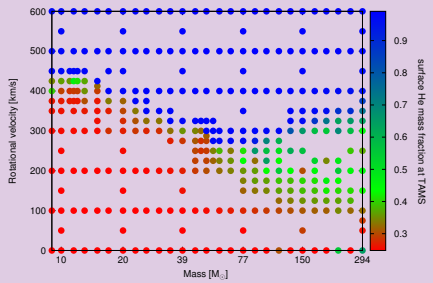

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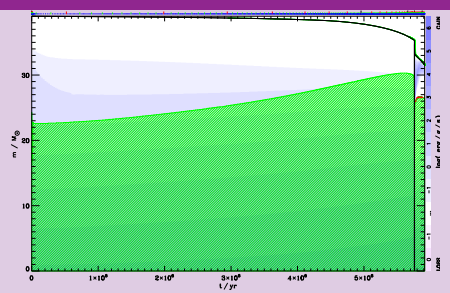

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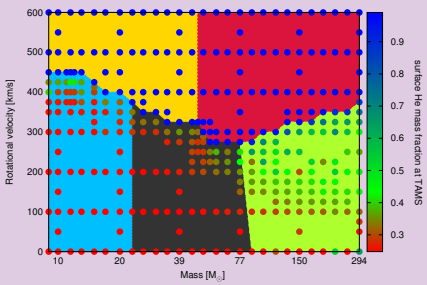
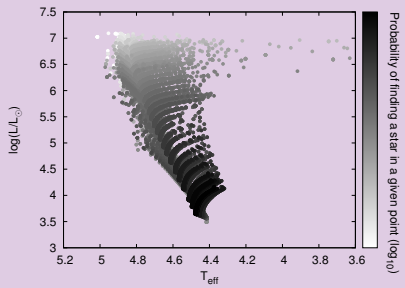


Need more observations!



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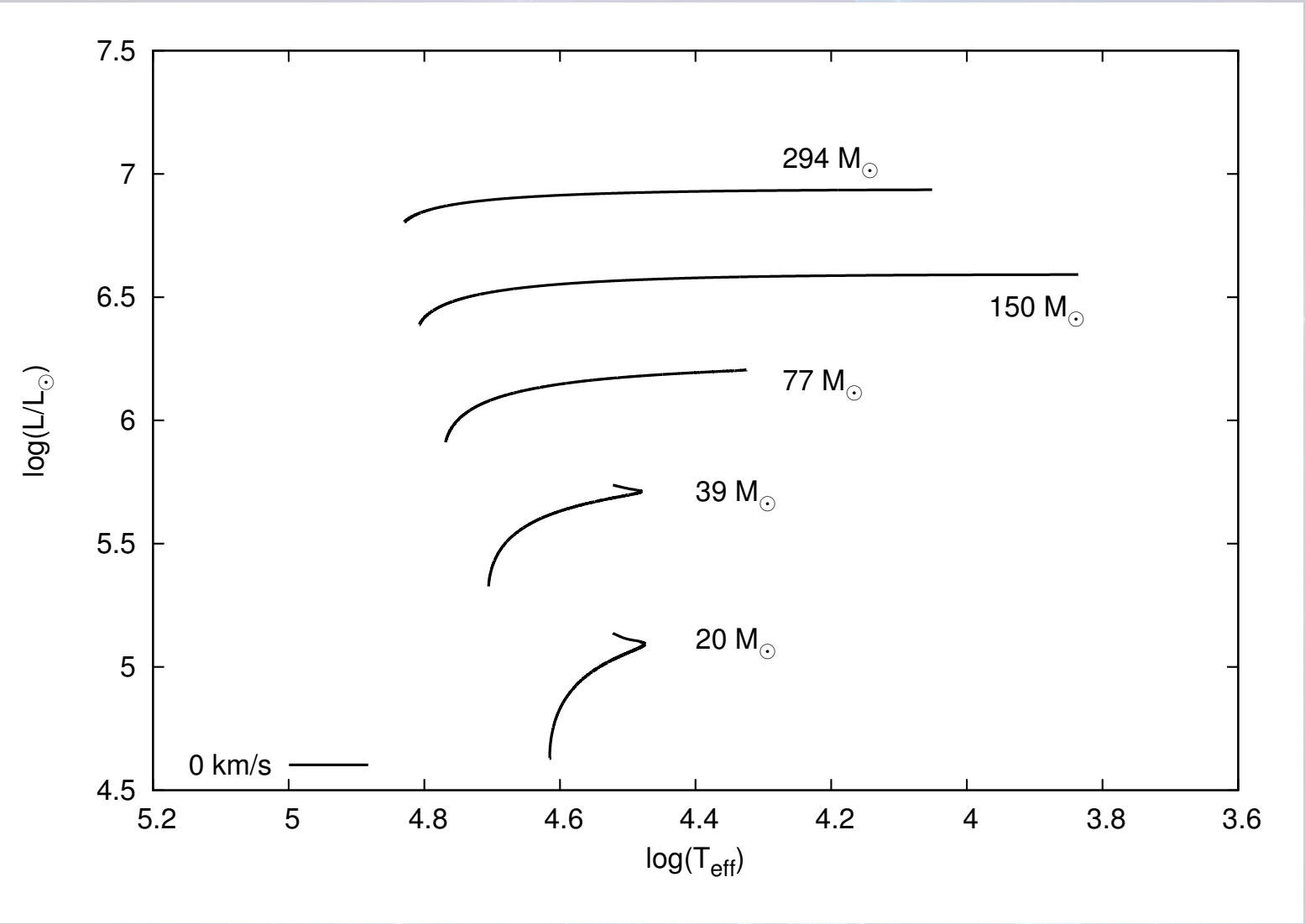

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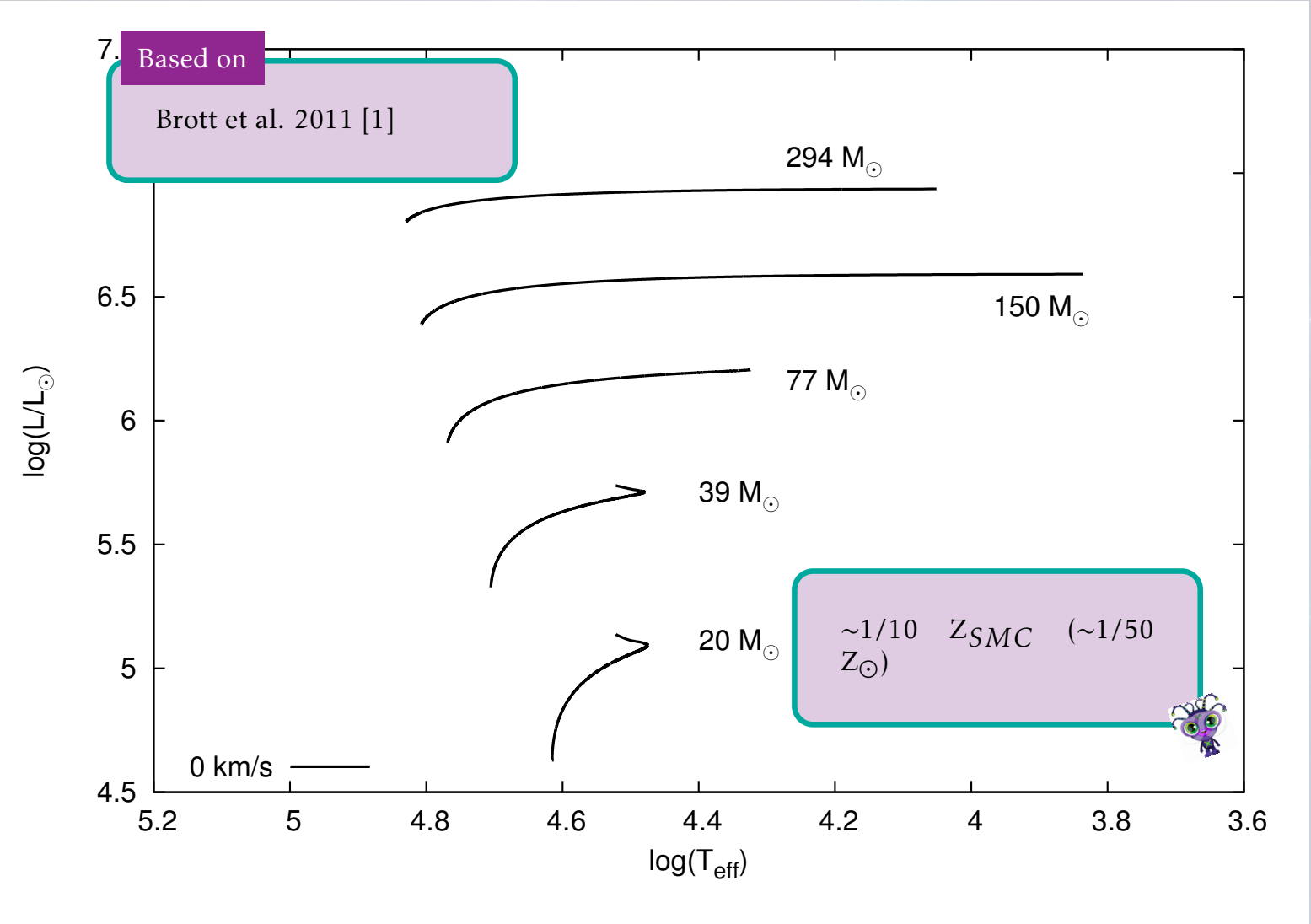

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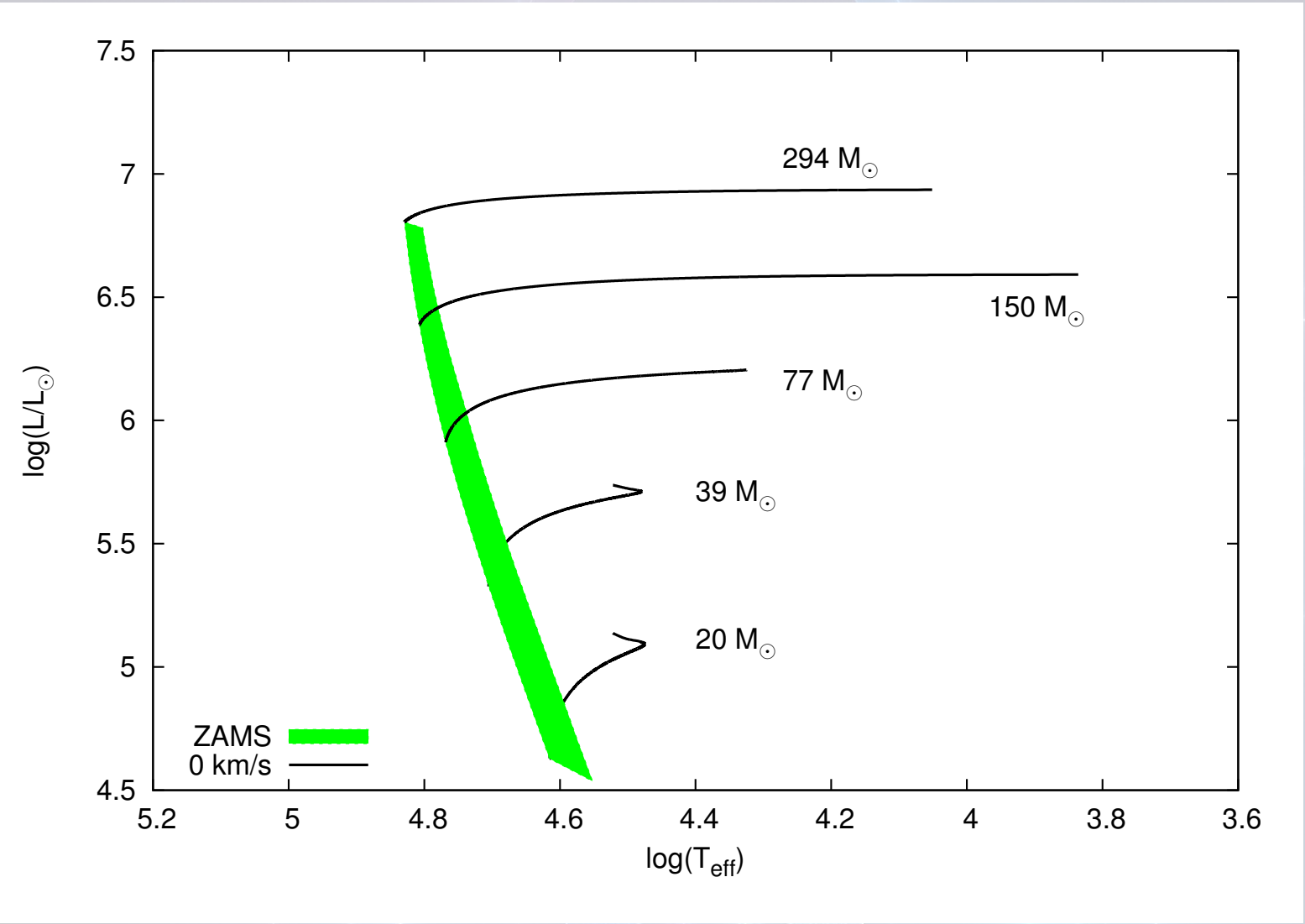

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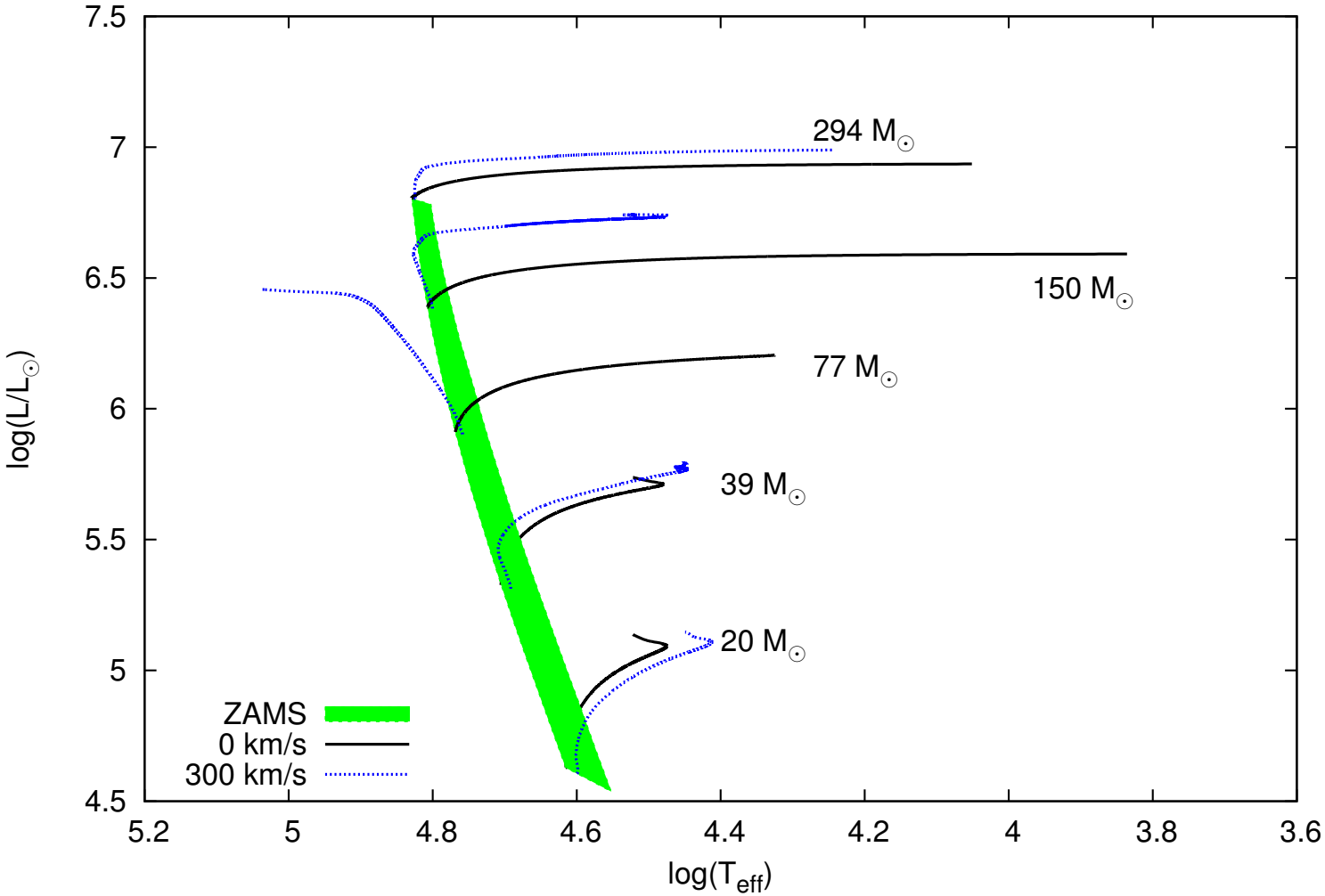

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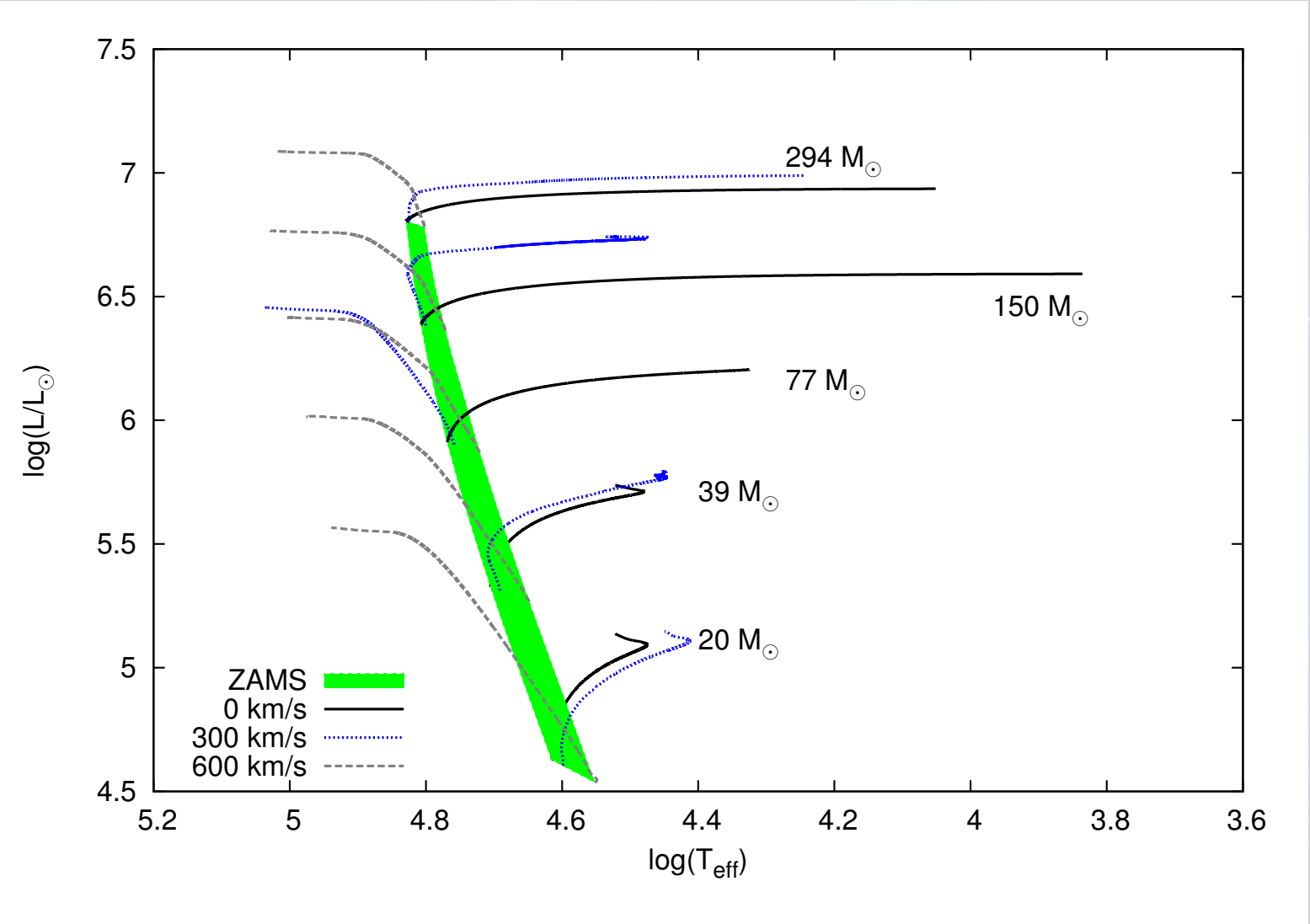

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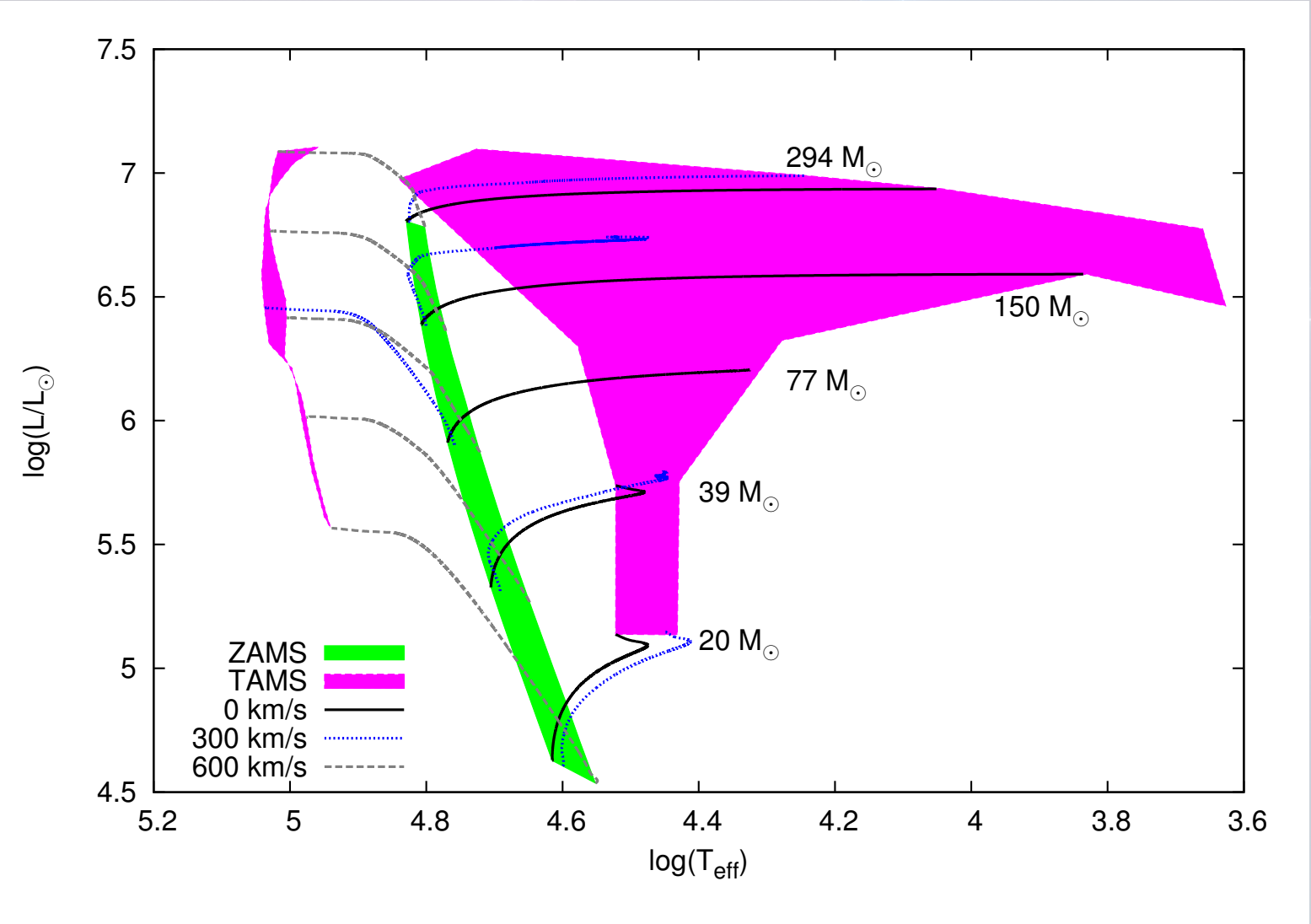

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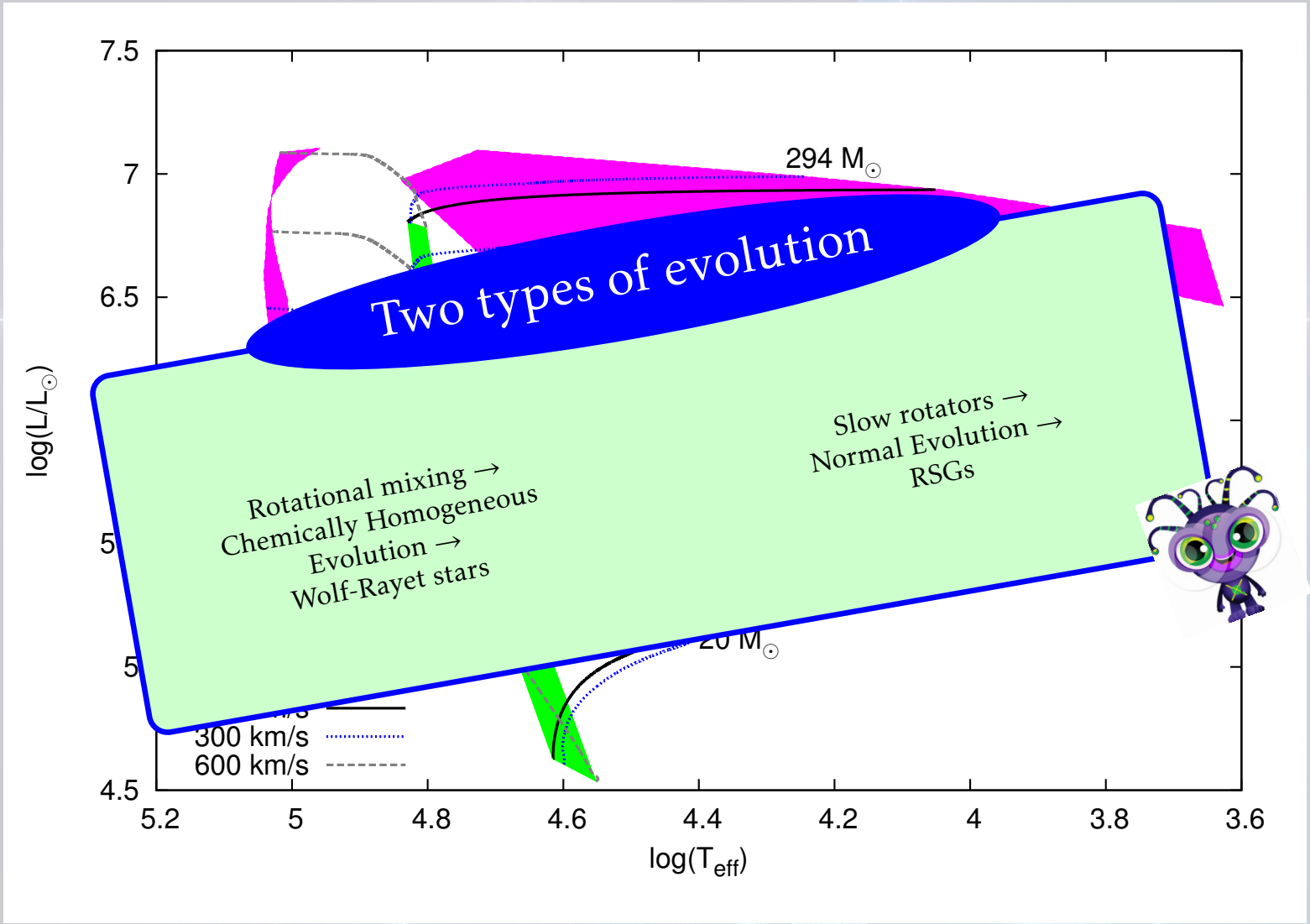

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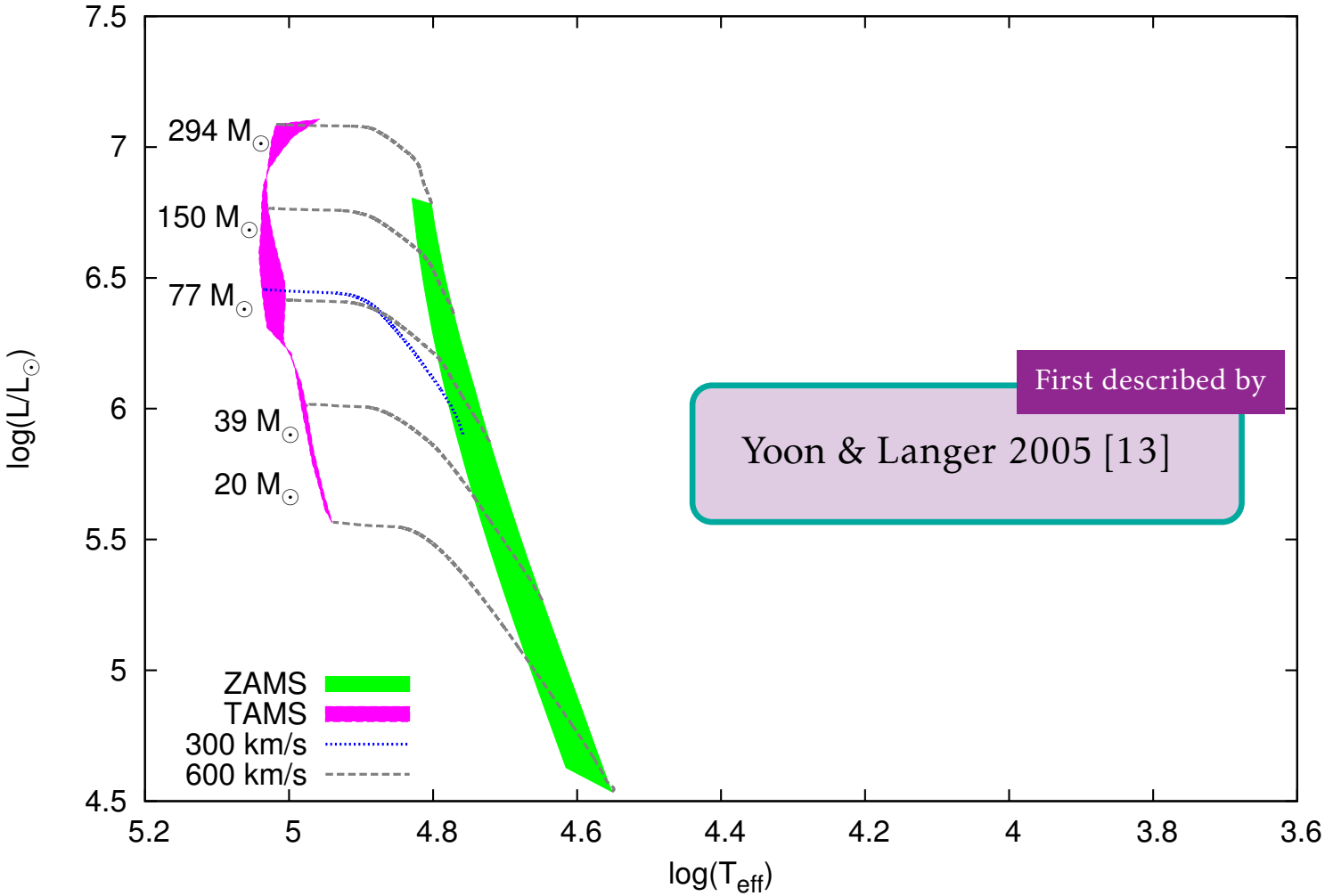

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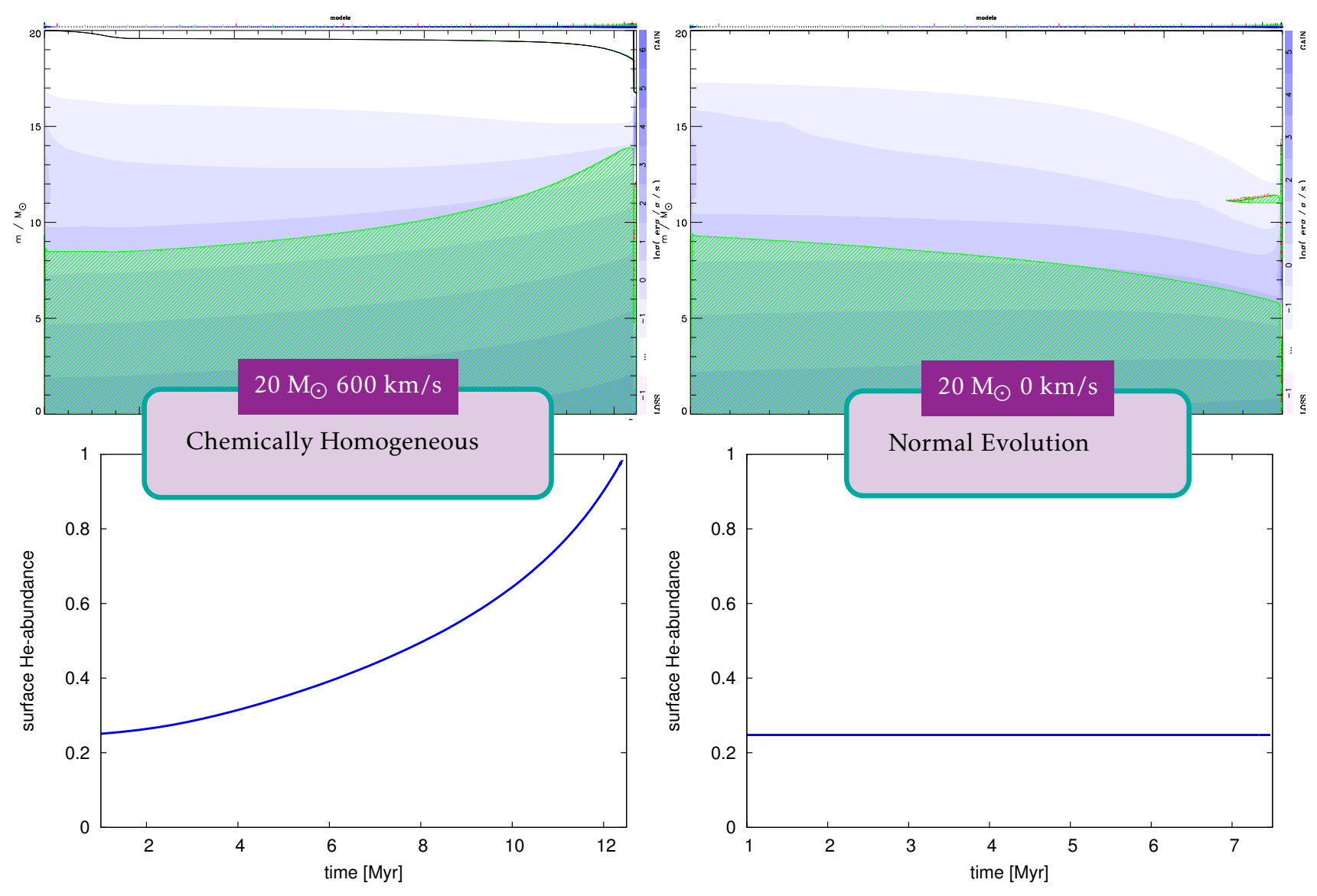

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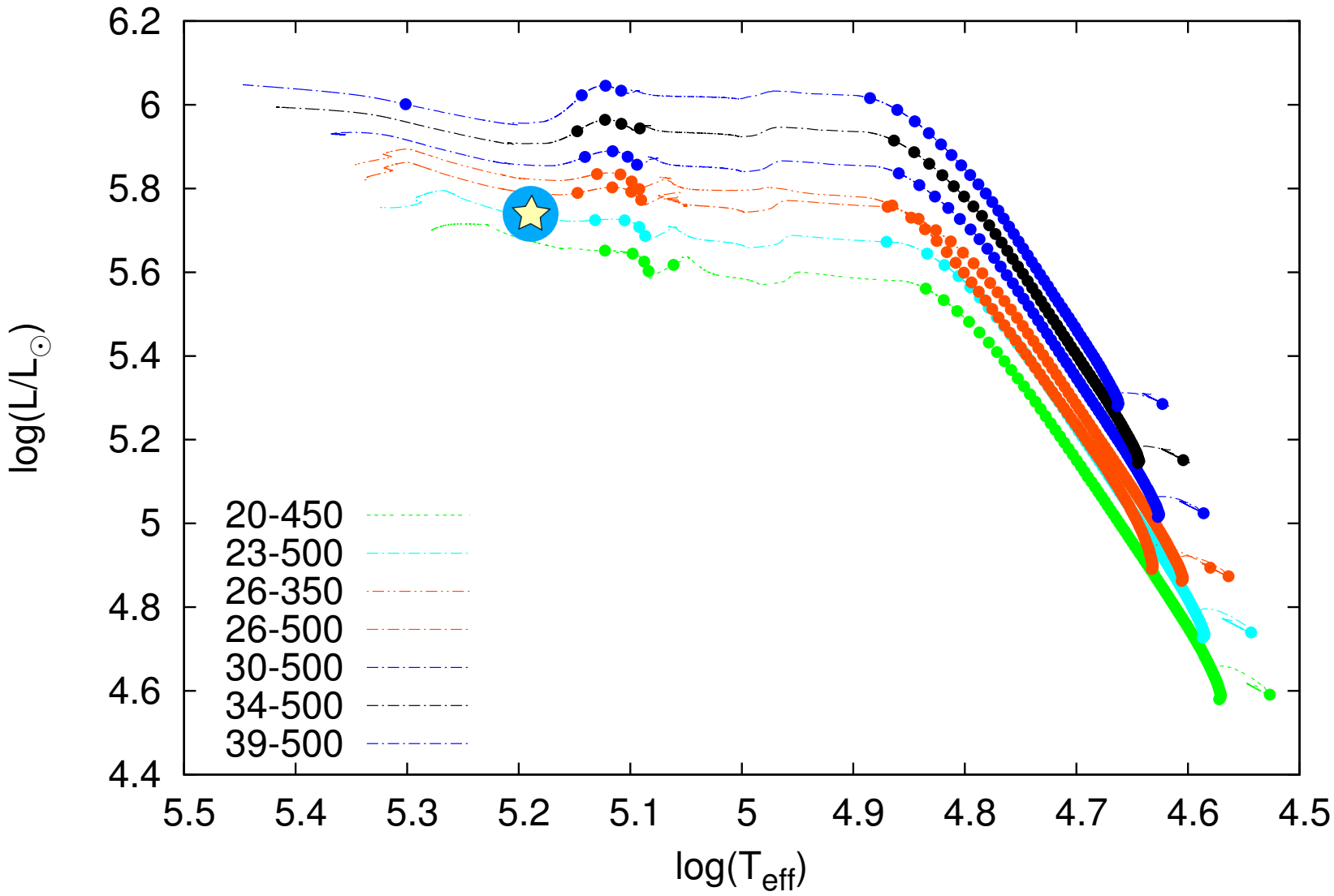

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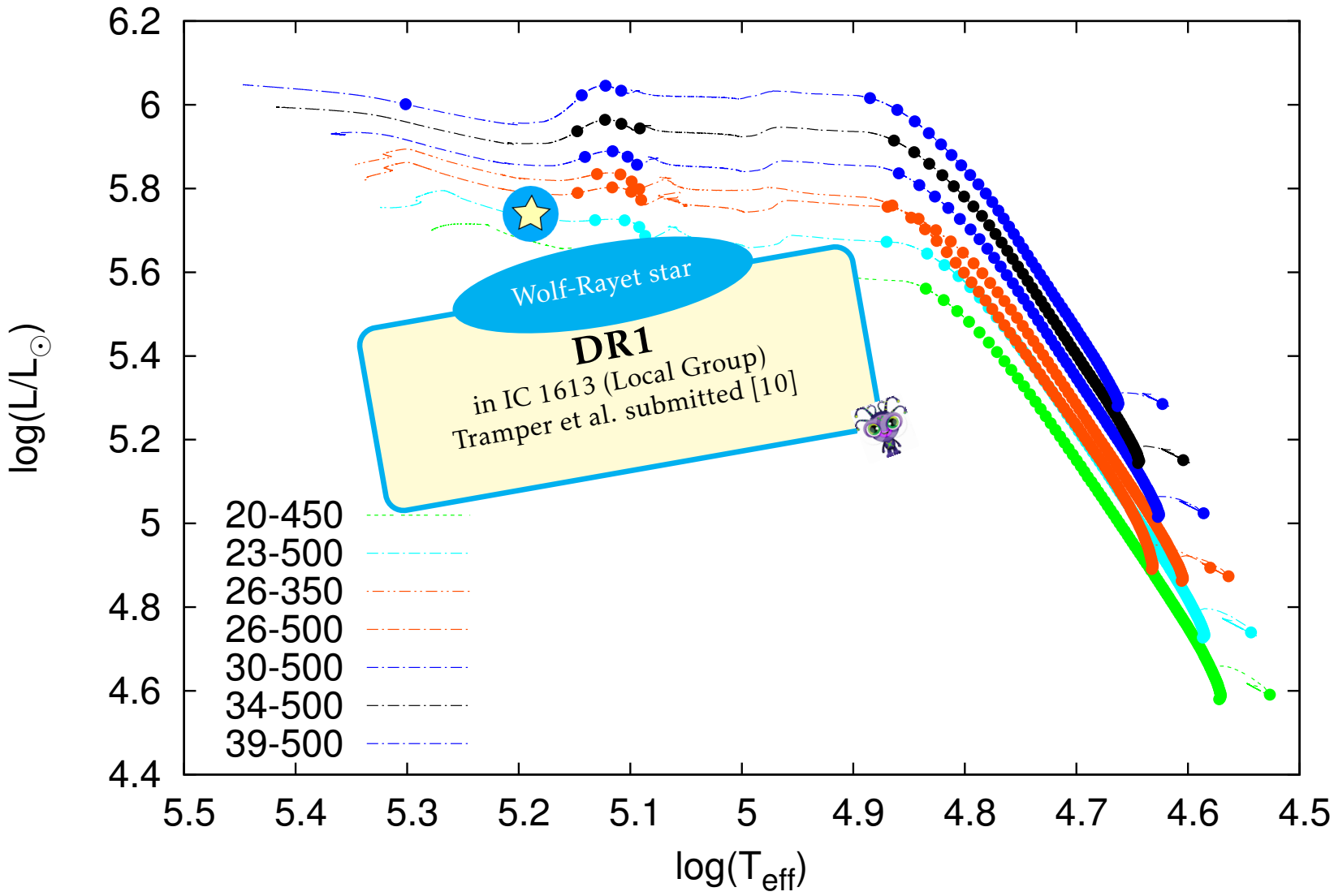

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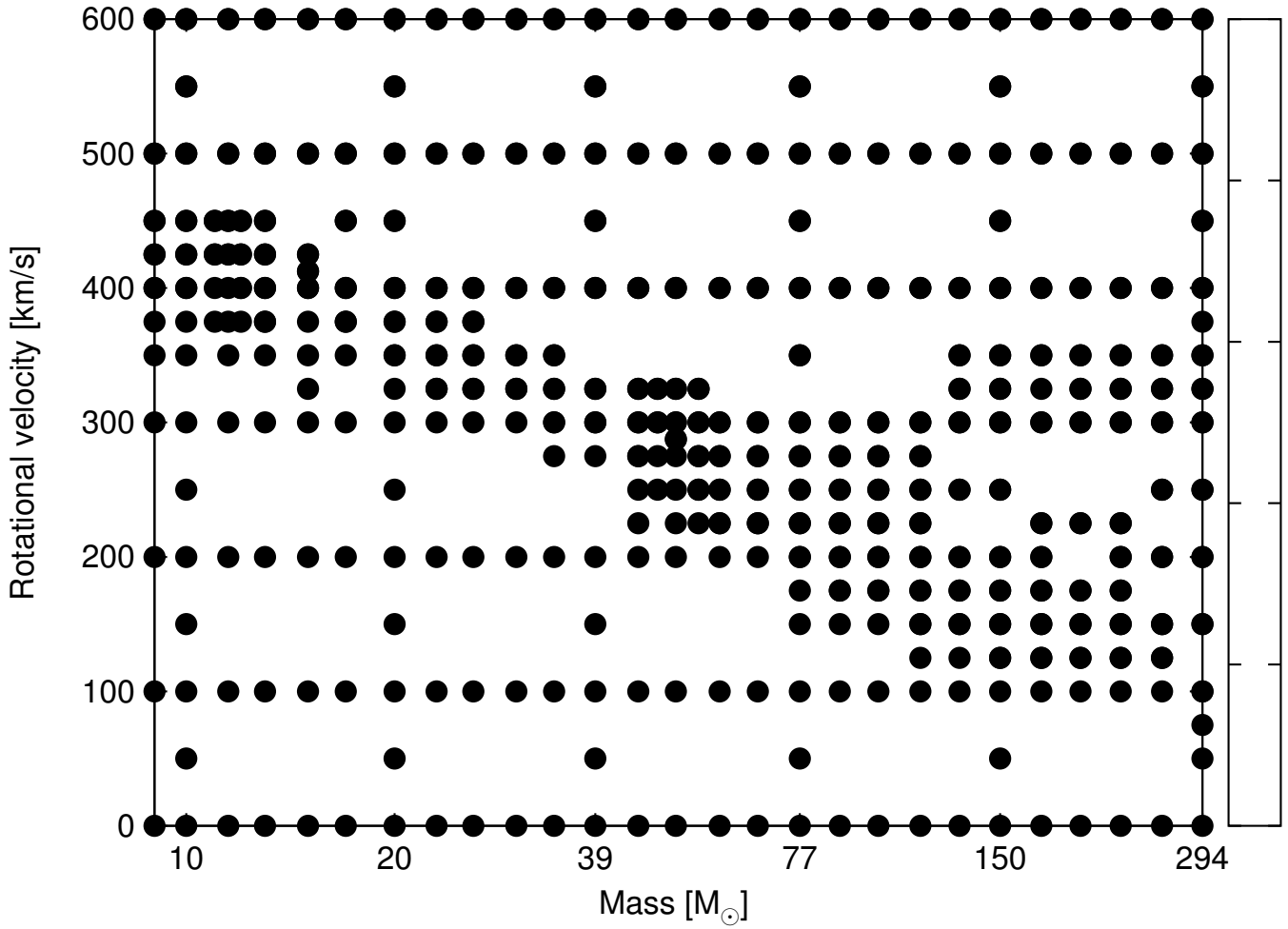

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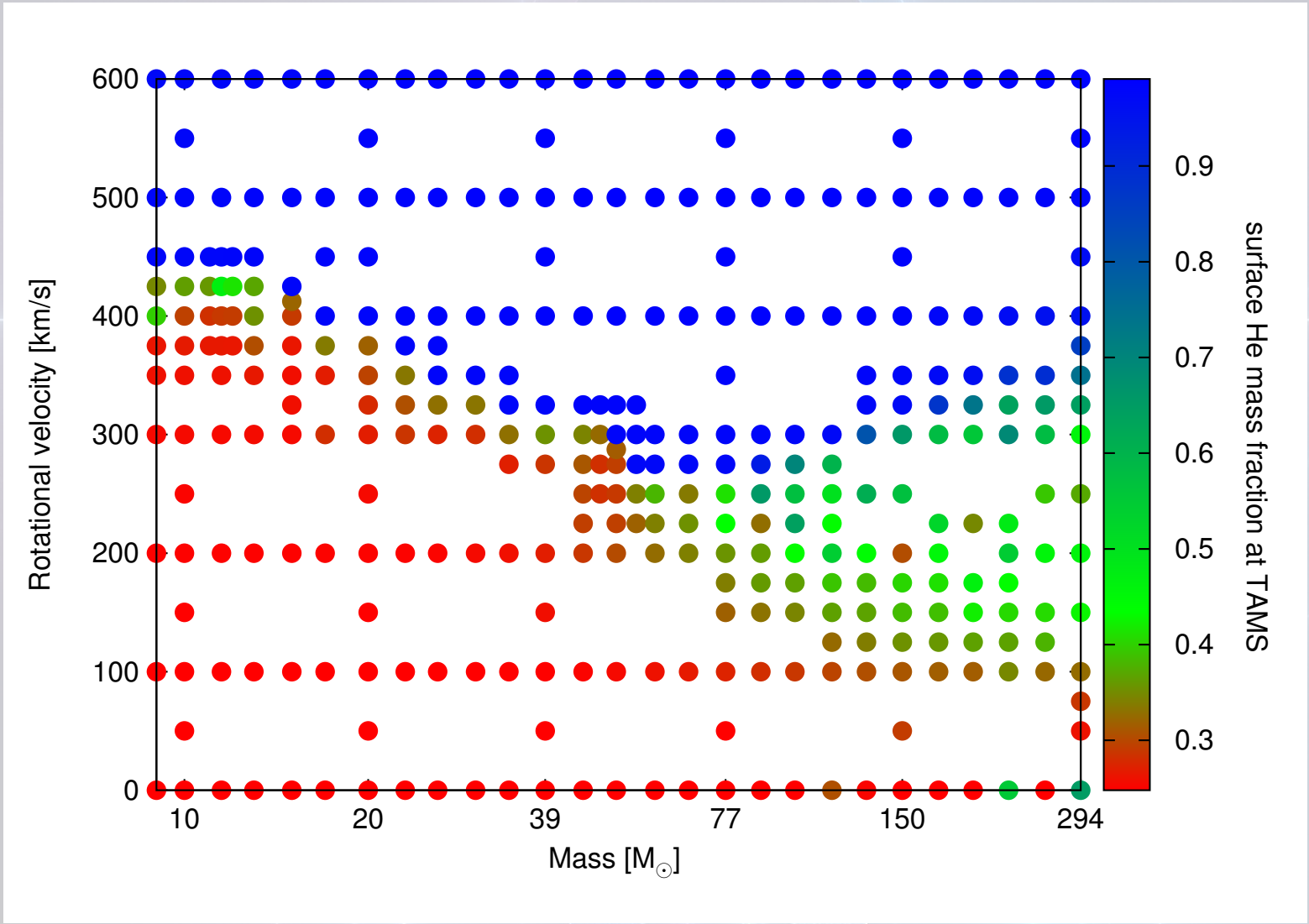

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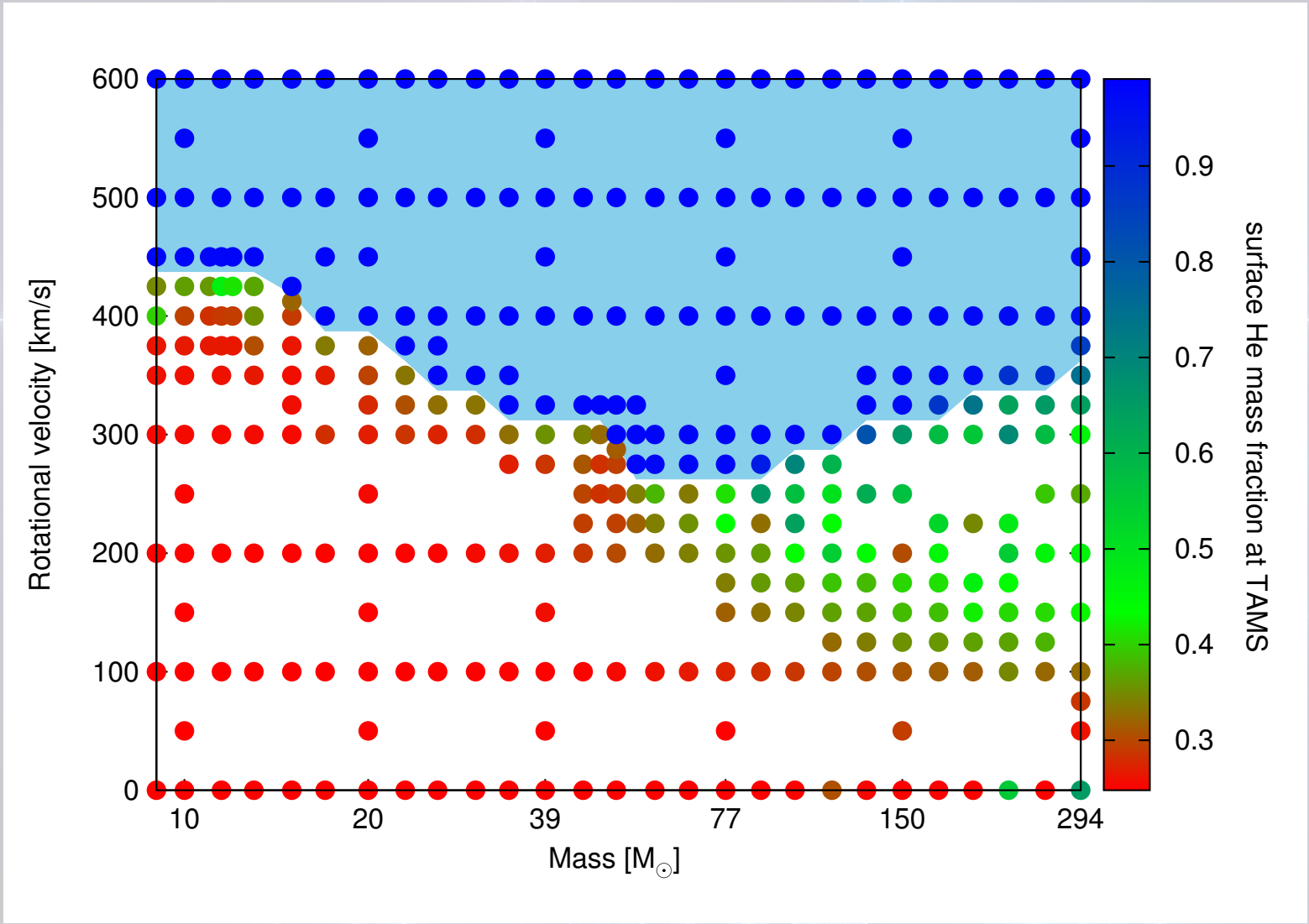

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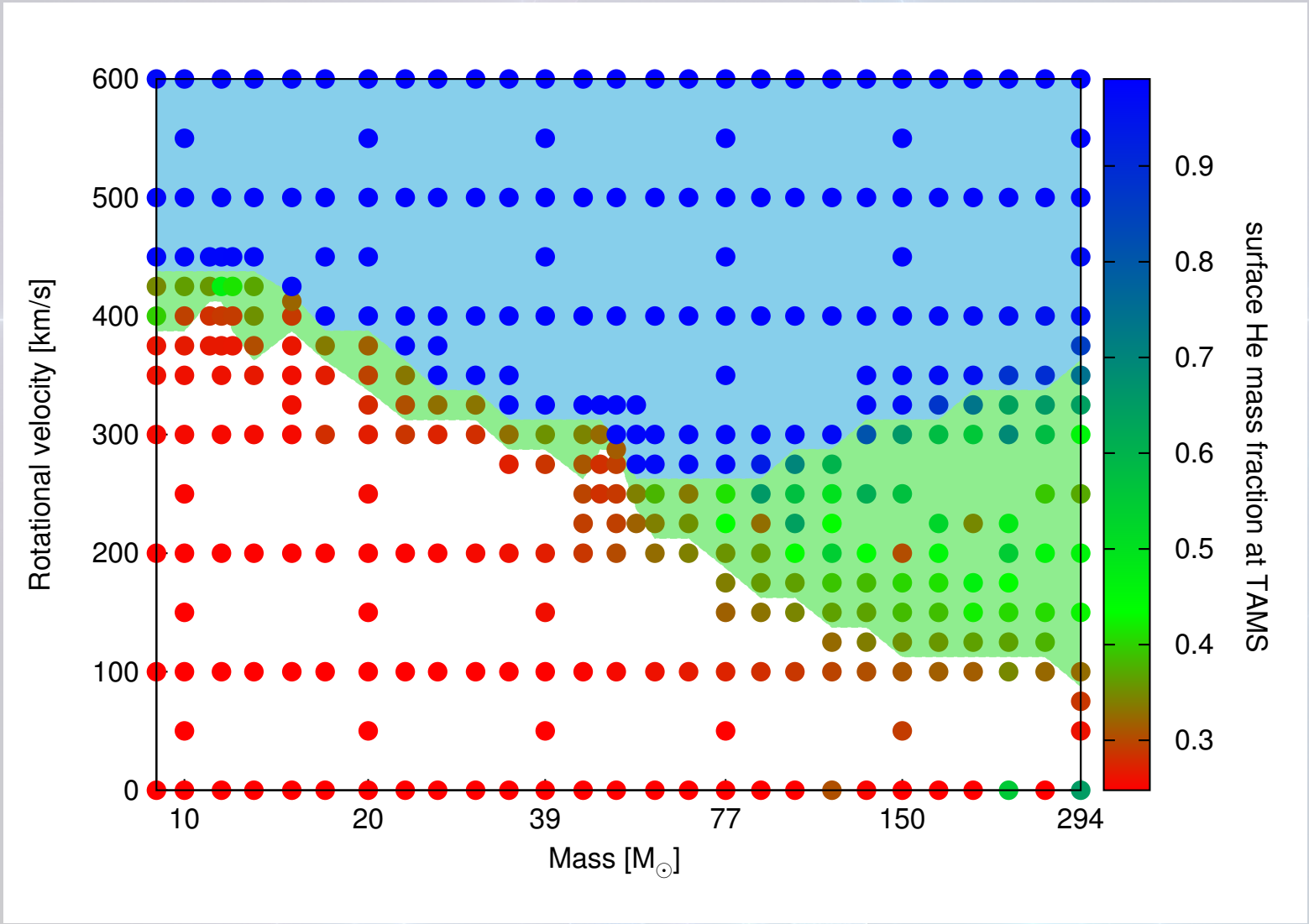

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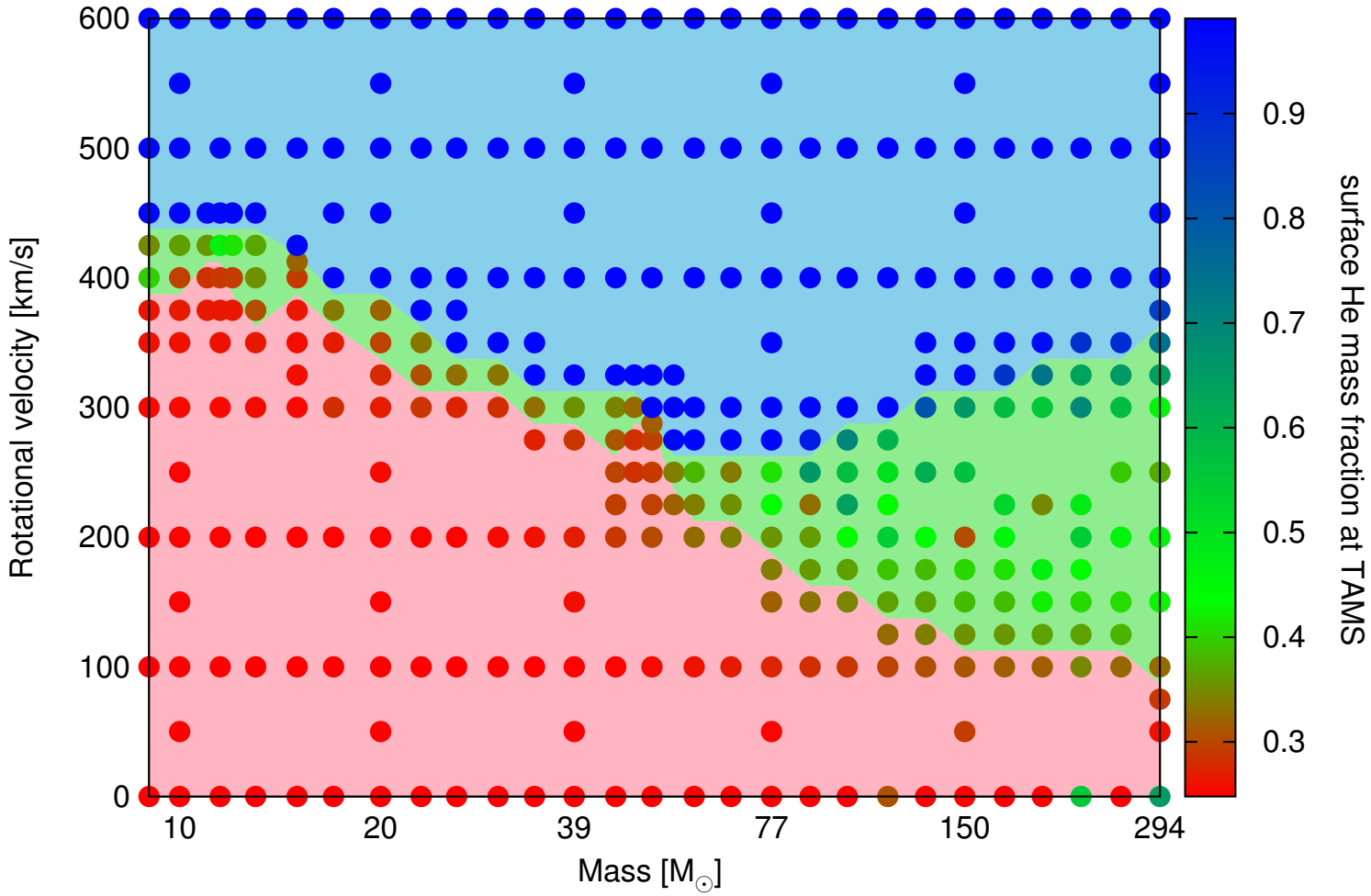

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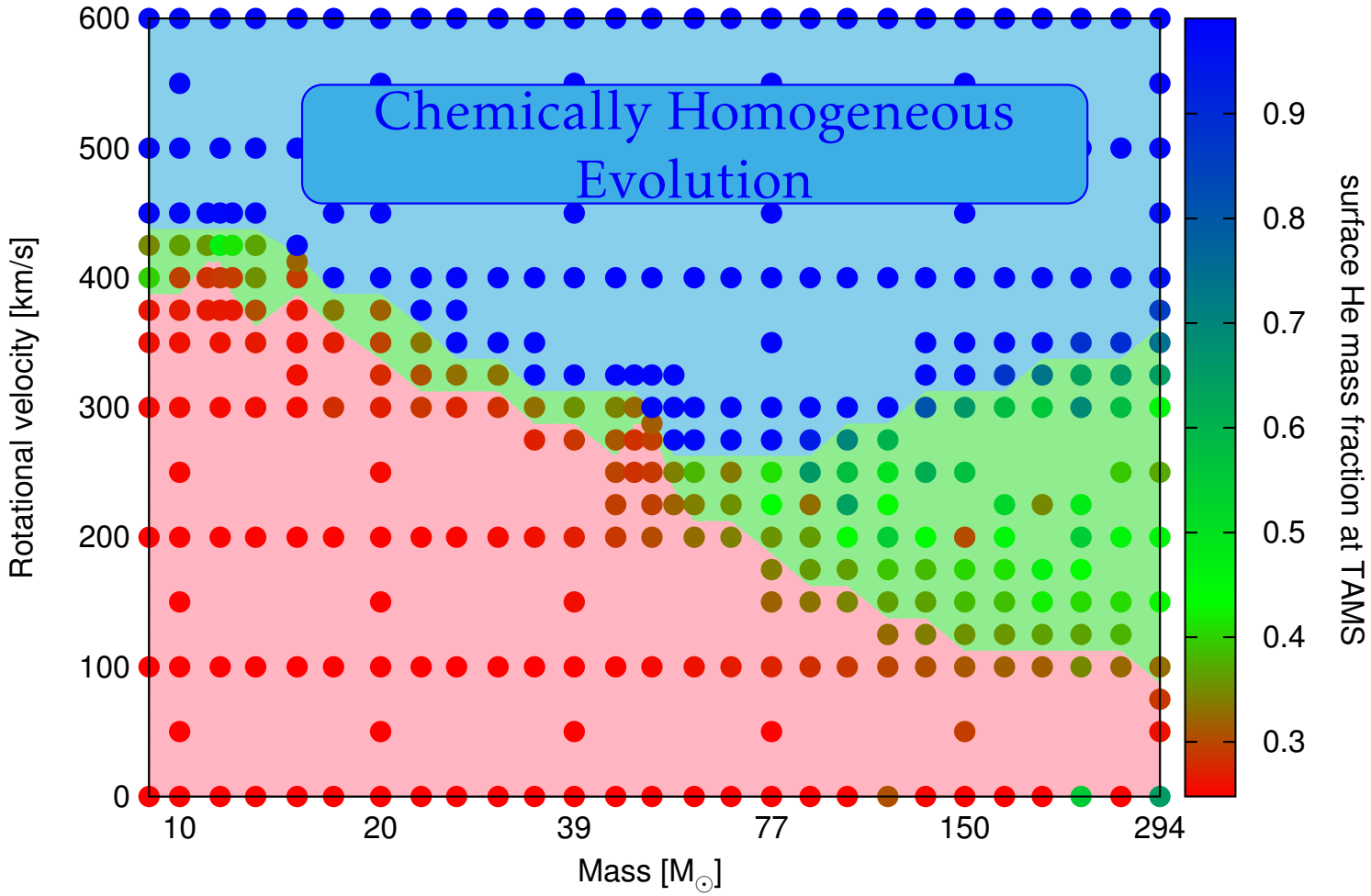
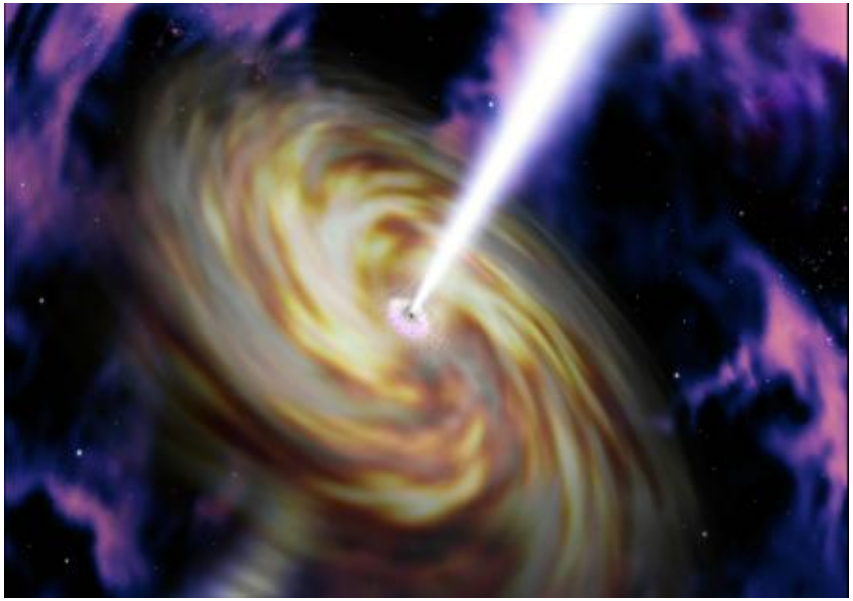


Angular momentum – long GRB



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Collapsar

angular momentum in the core is higher than the critical limit [12] for the formation of an accretion disc around a rotating black hole:

$$j_{Kerr}^{iso}$$

I. Star must form a black hole
II. No hydrogen envelope
III. Rapid rotation [3]

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Collapsar Progenitors

- MS → RSG + strong wind → bare He-core
  - BUT: angular momentum loss ⊗
- Binary interaction ✔
- Chemically homogeneous evolution ✔
  (Yoon & Langer 2005 [13])

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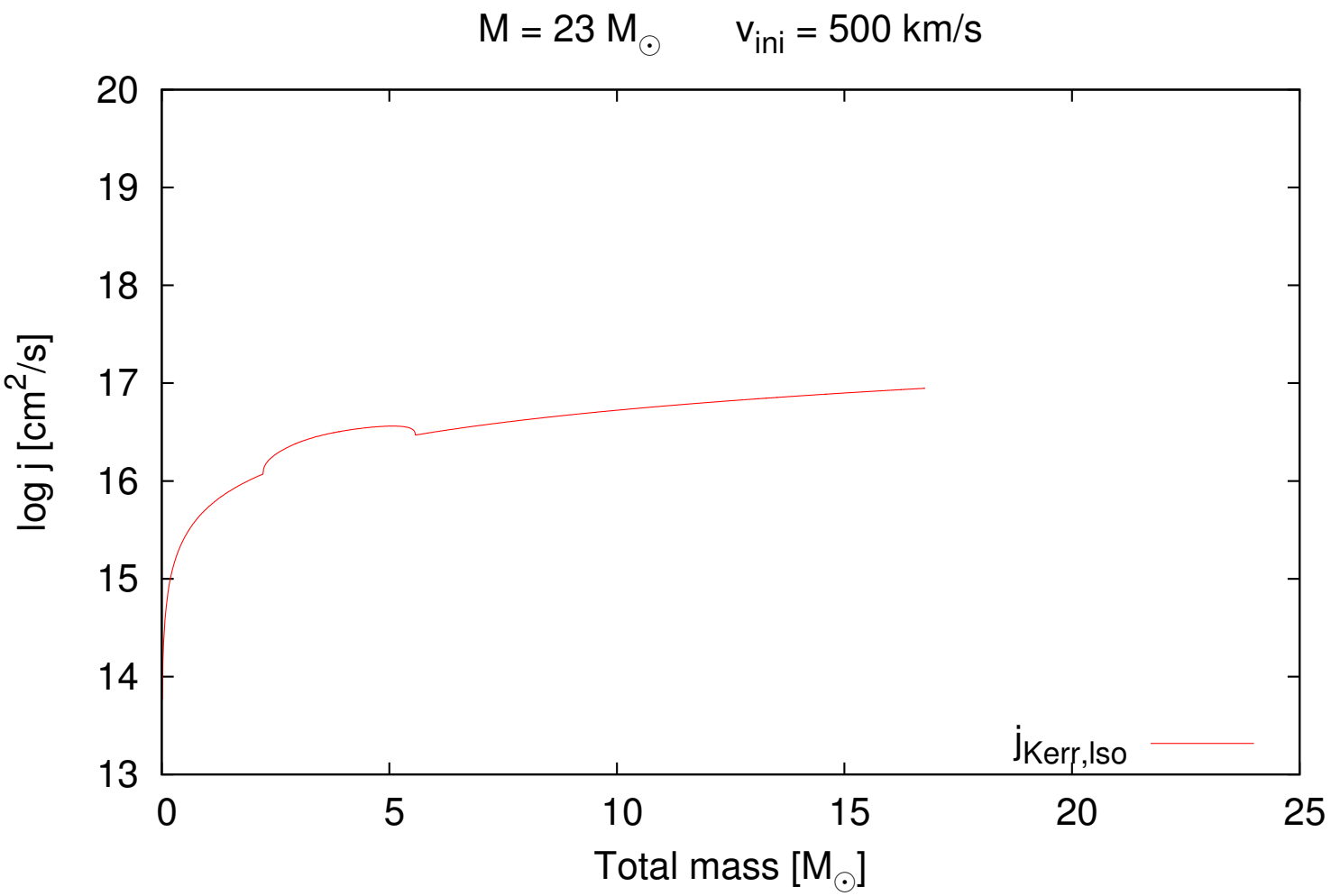

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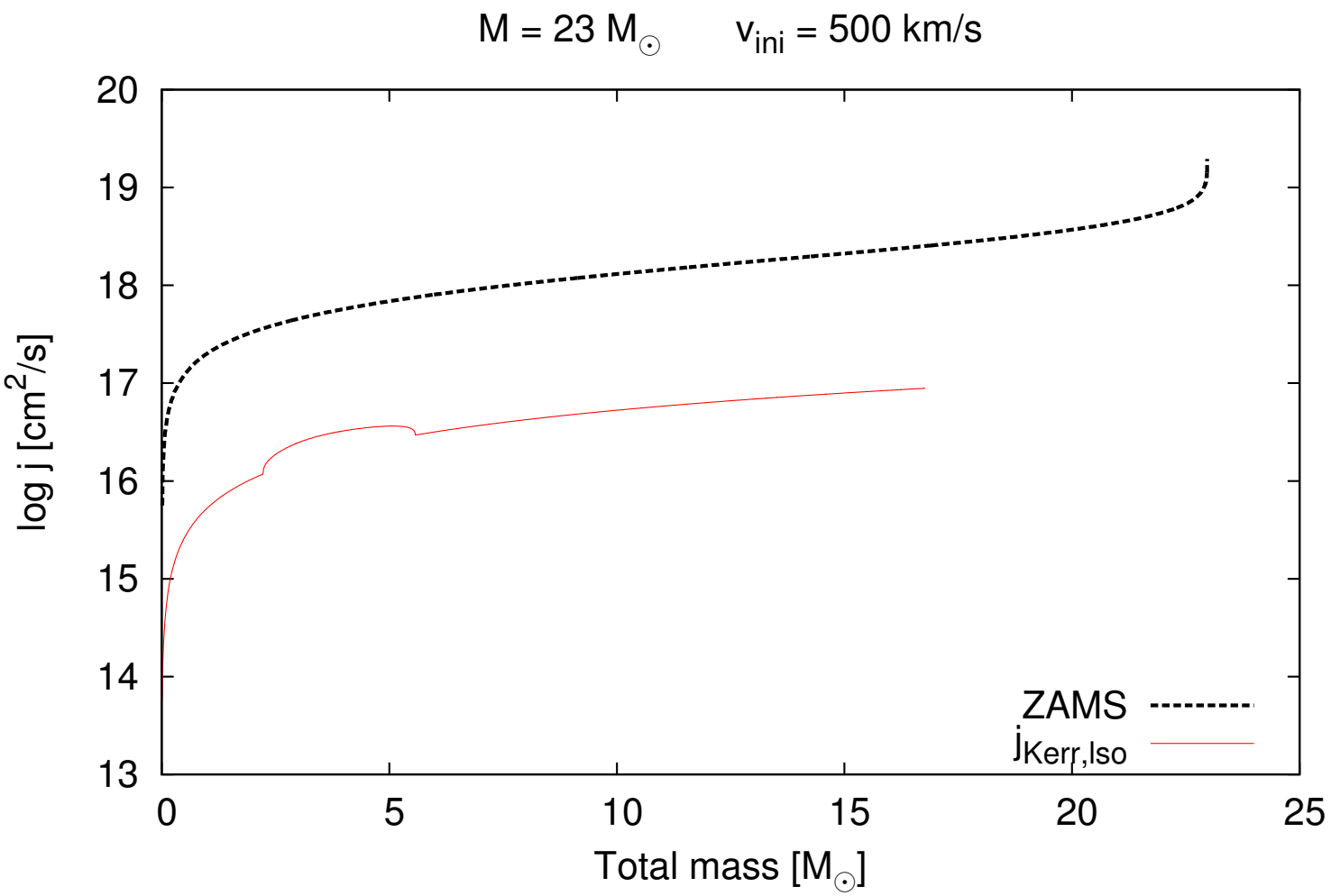

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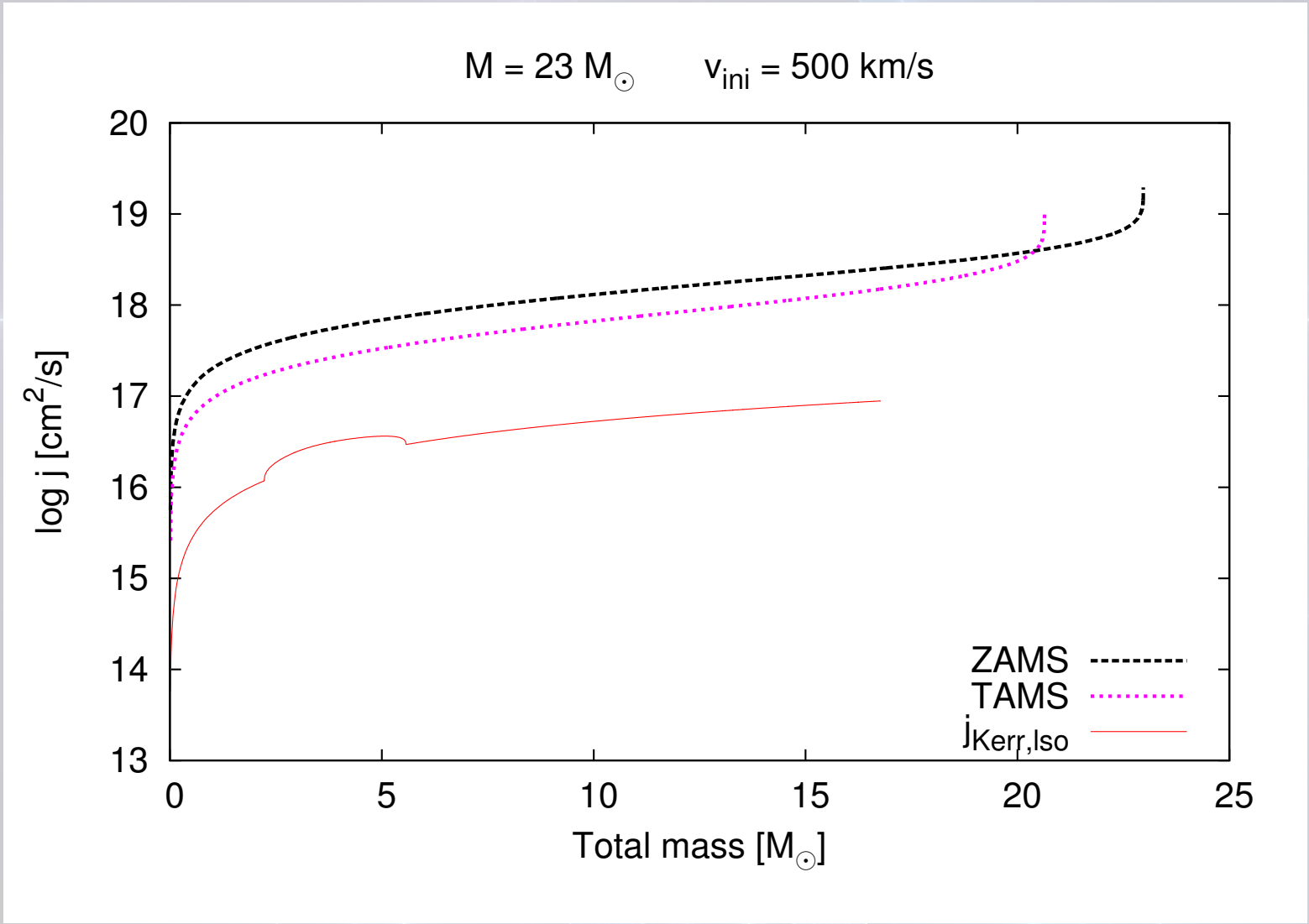

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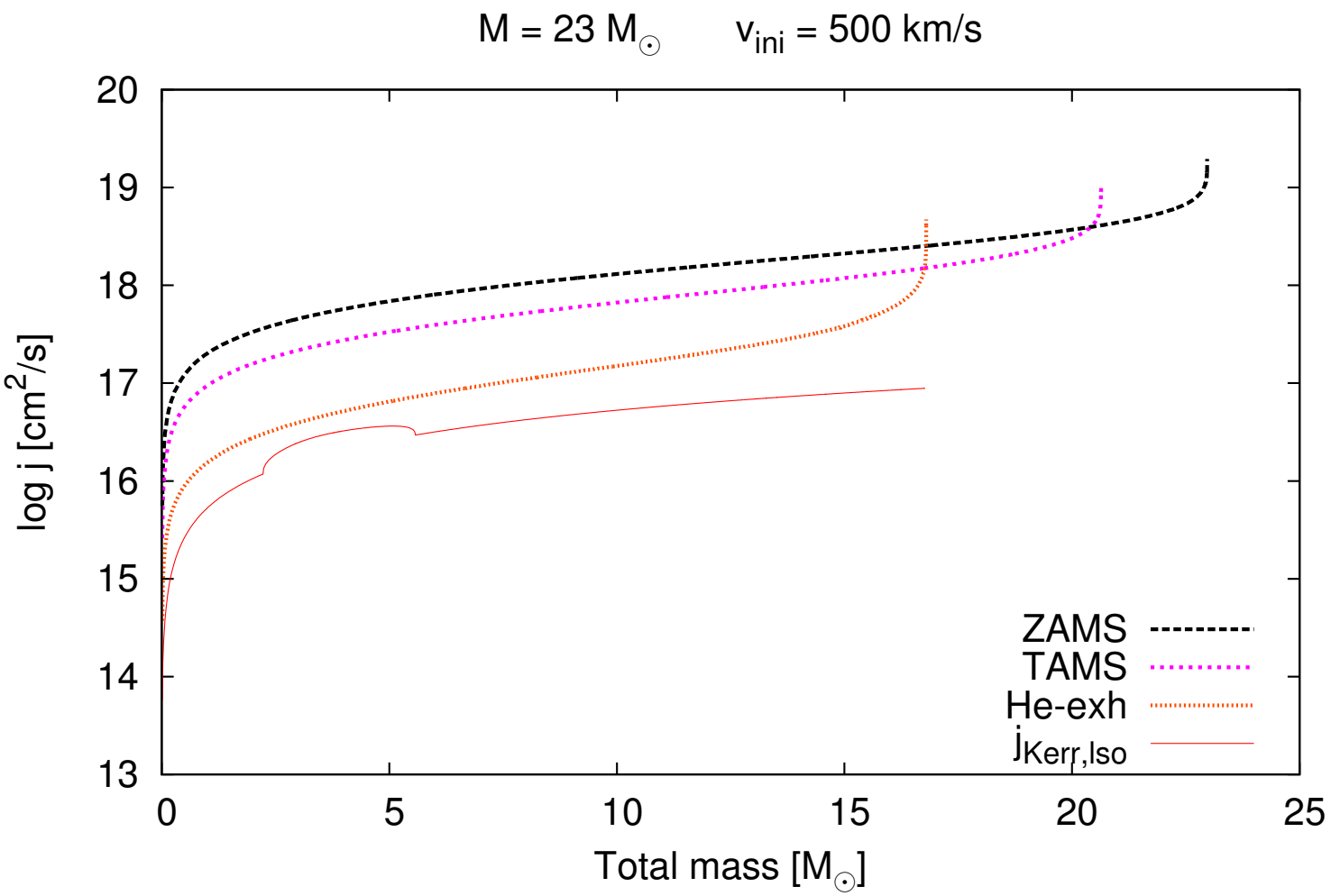
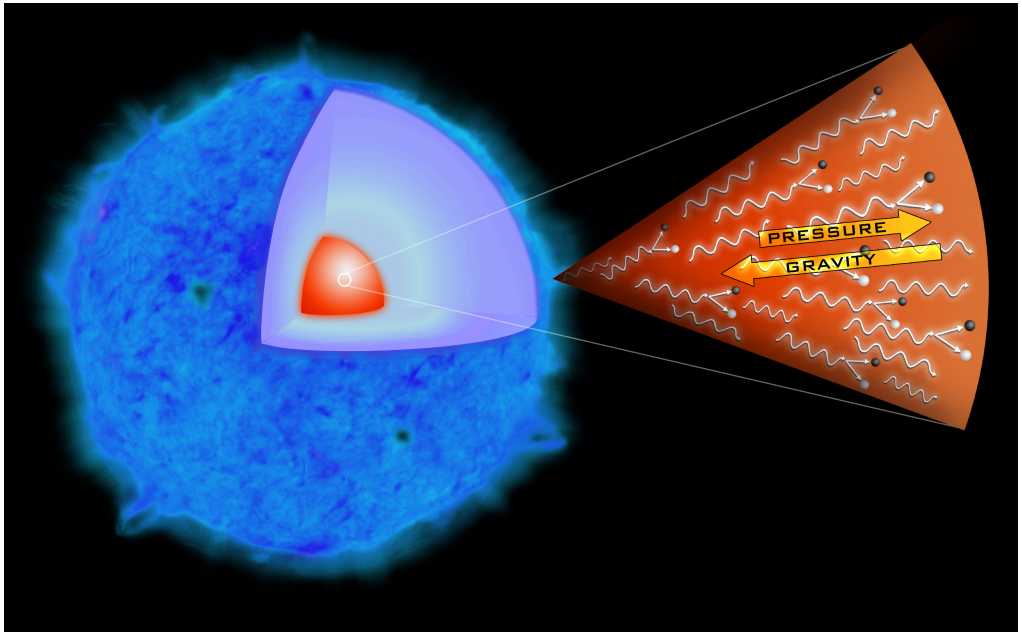


Pair instability supernova



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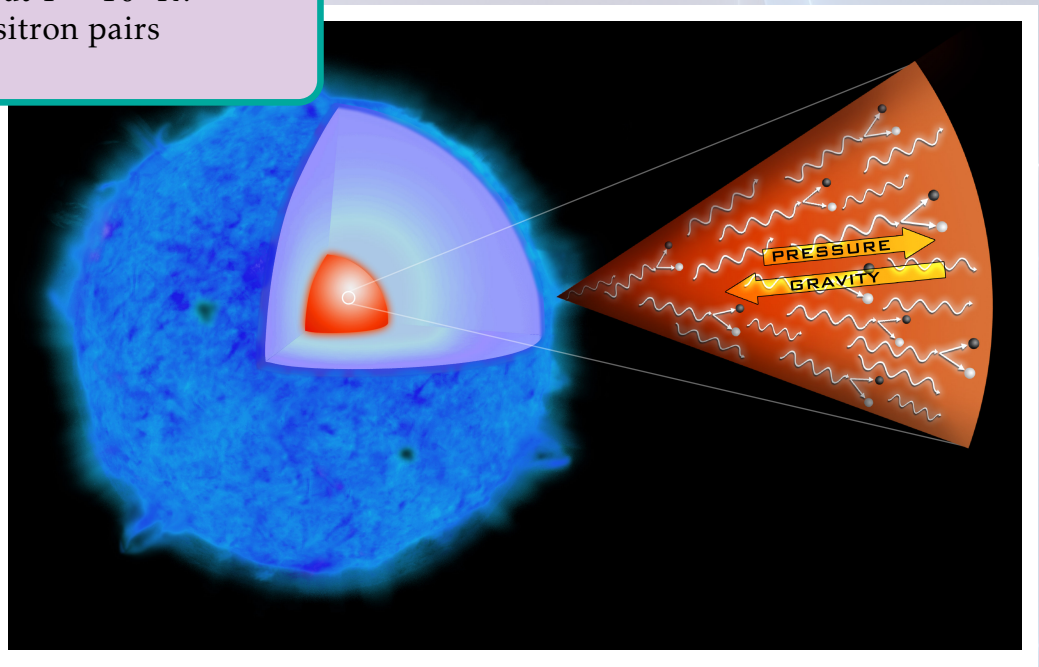
Pair creation

$h\nu > 2m_e c^2$ at $T \sim 10^9 K$:
electron-positron pairs



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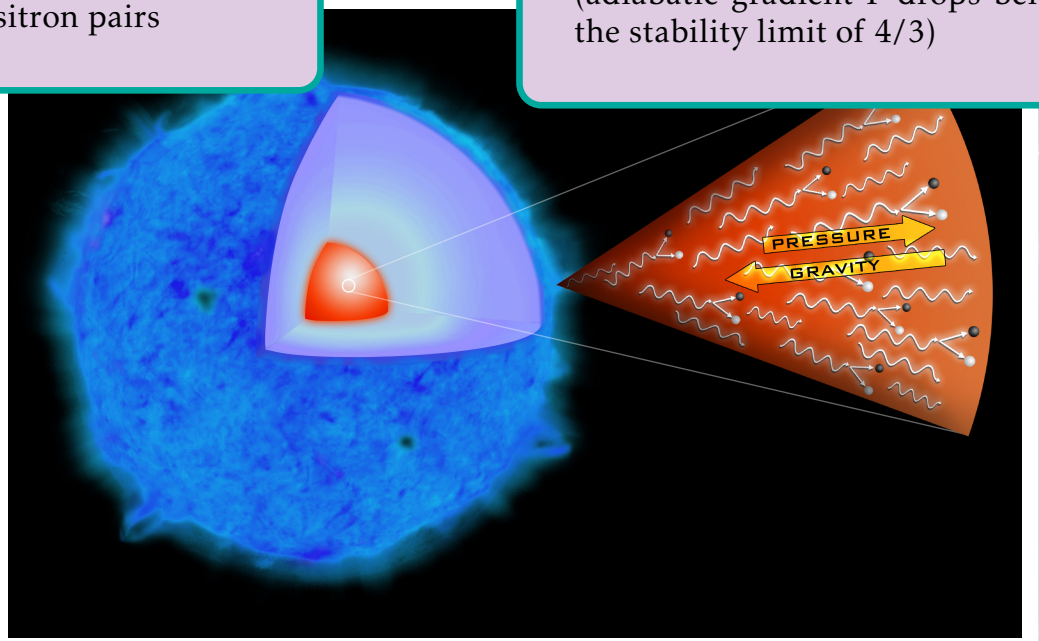

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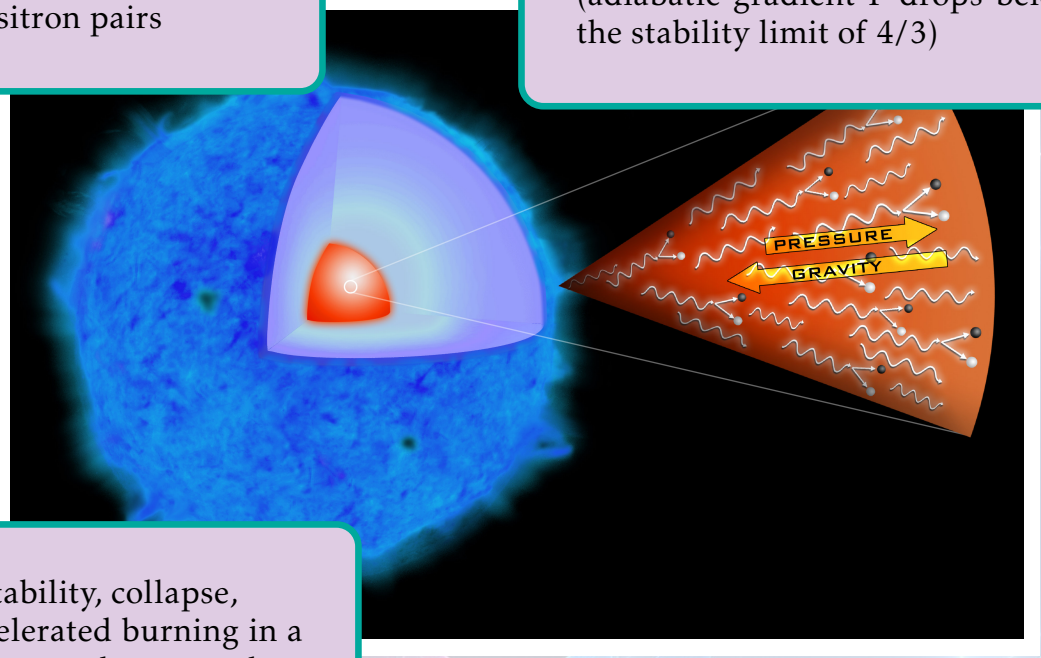

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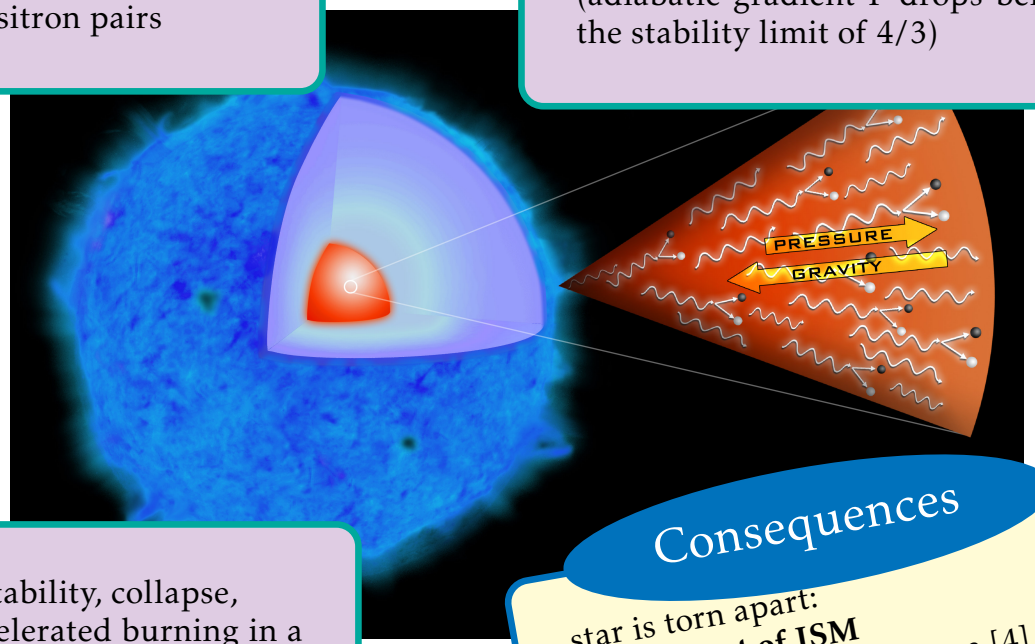

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Consequences

star is torn apart:
enrichment of ISM
Superluminous Supernova [4]
no remnant

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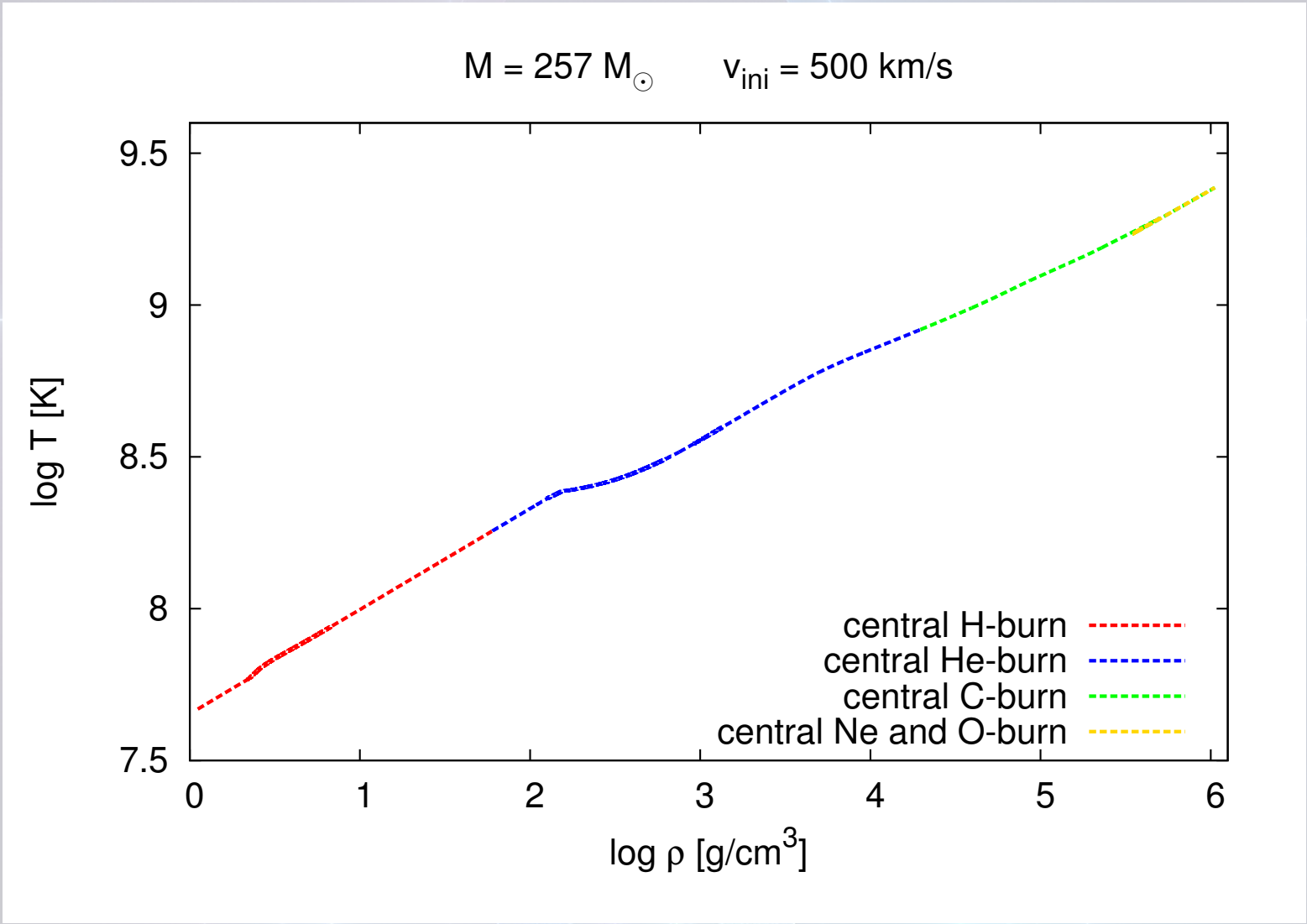

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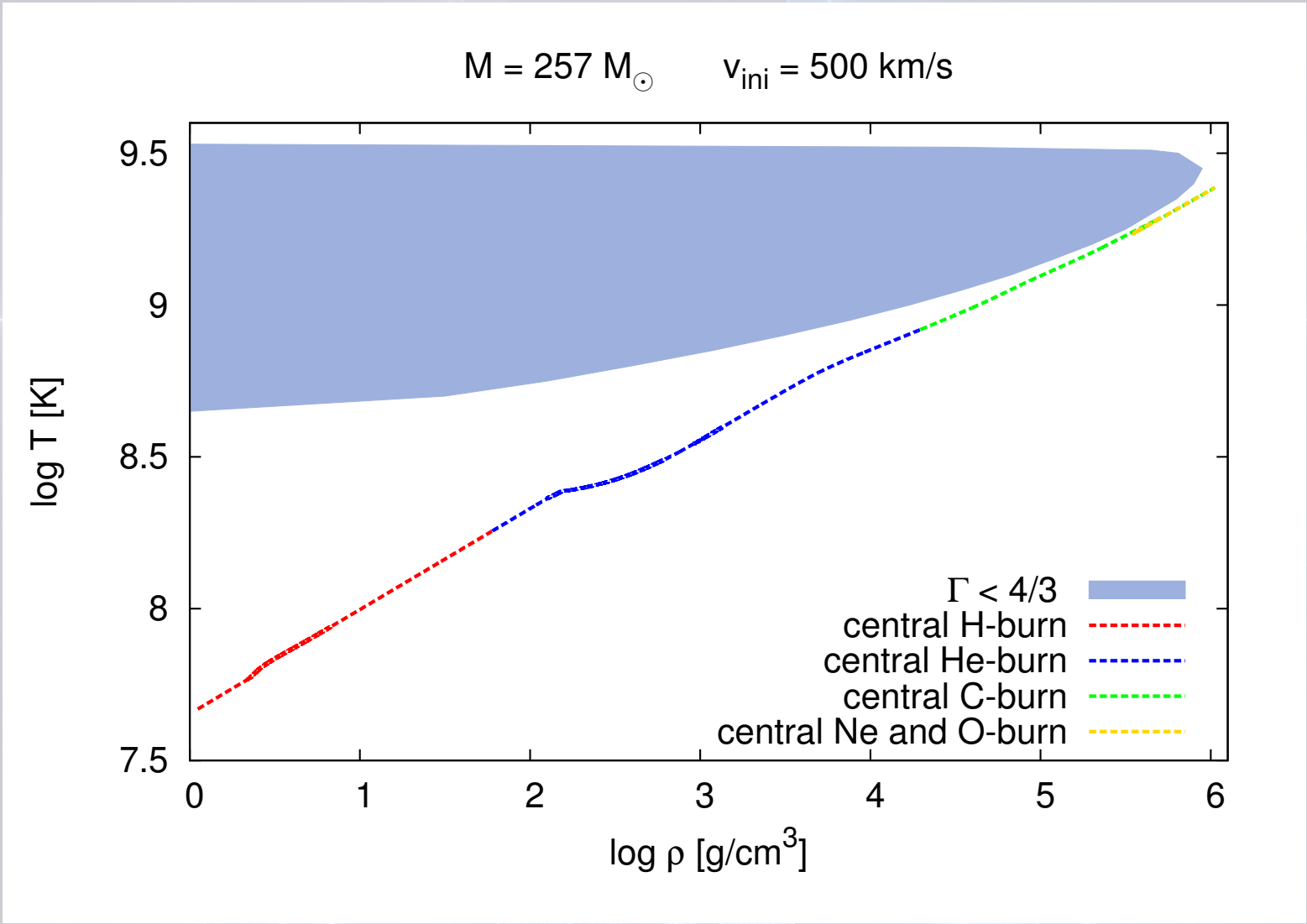

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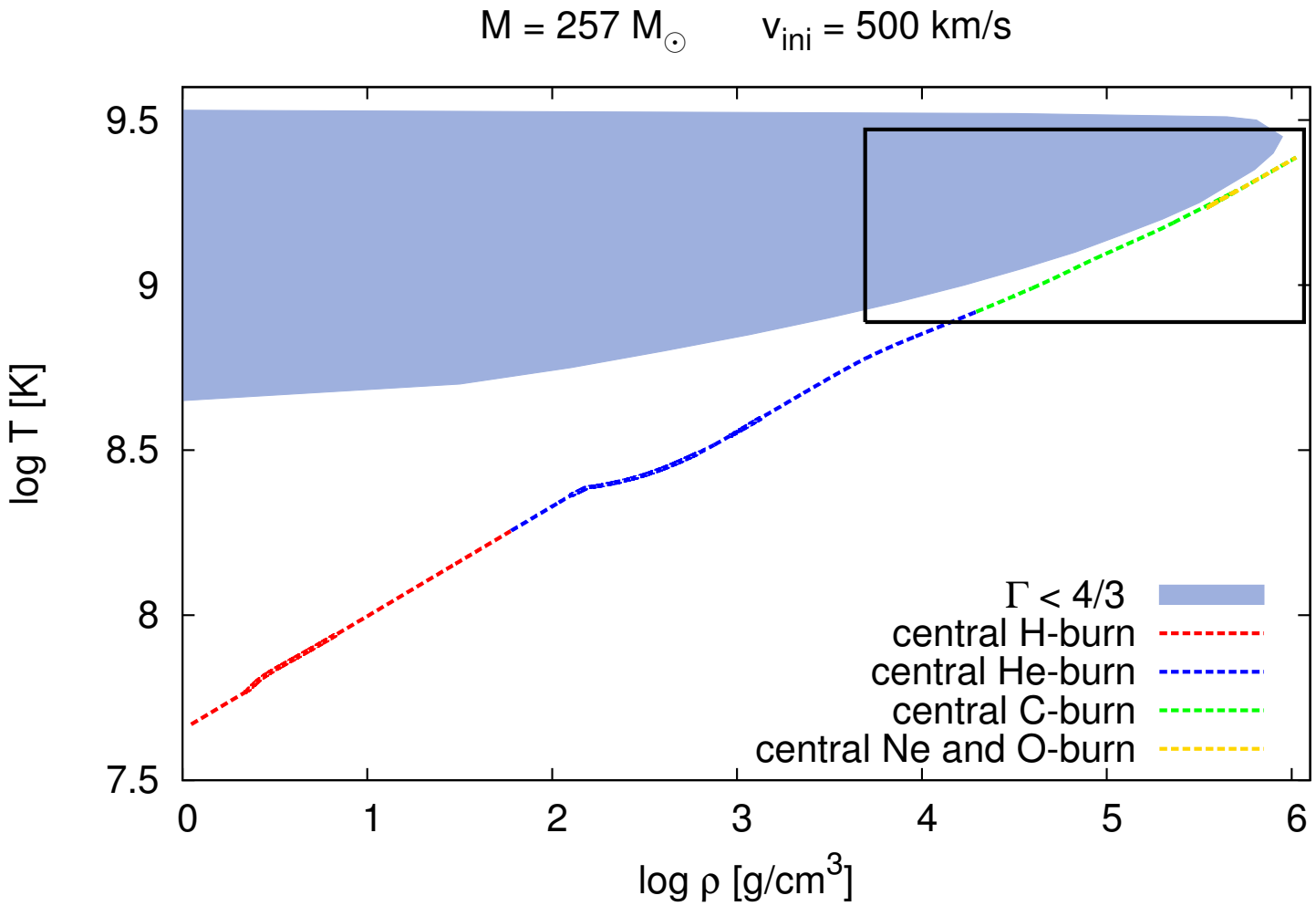

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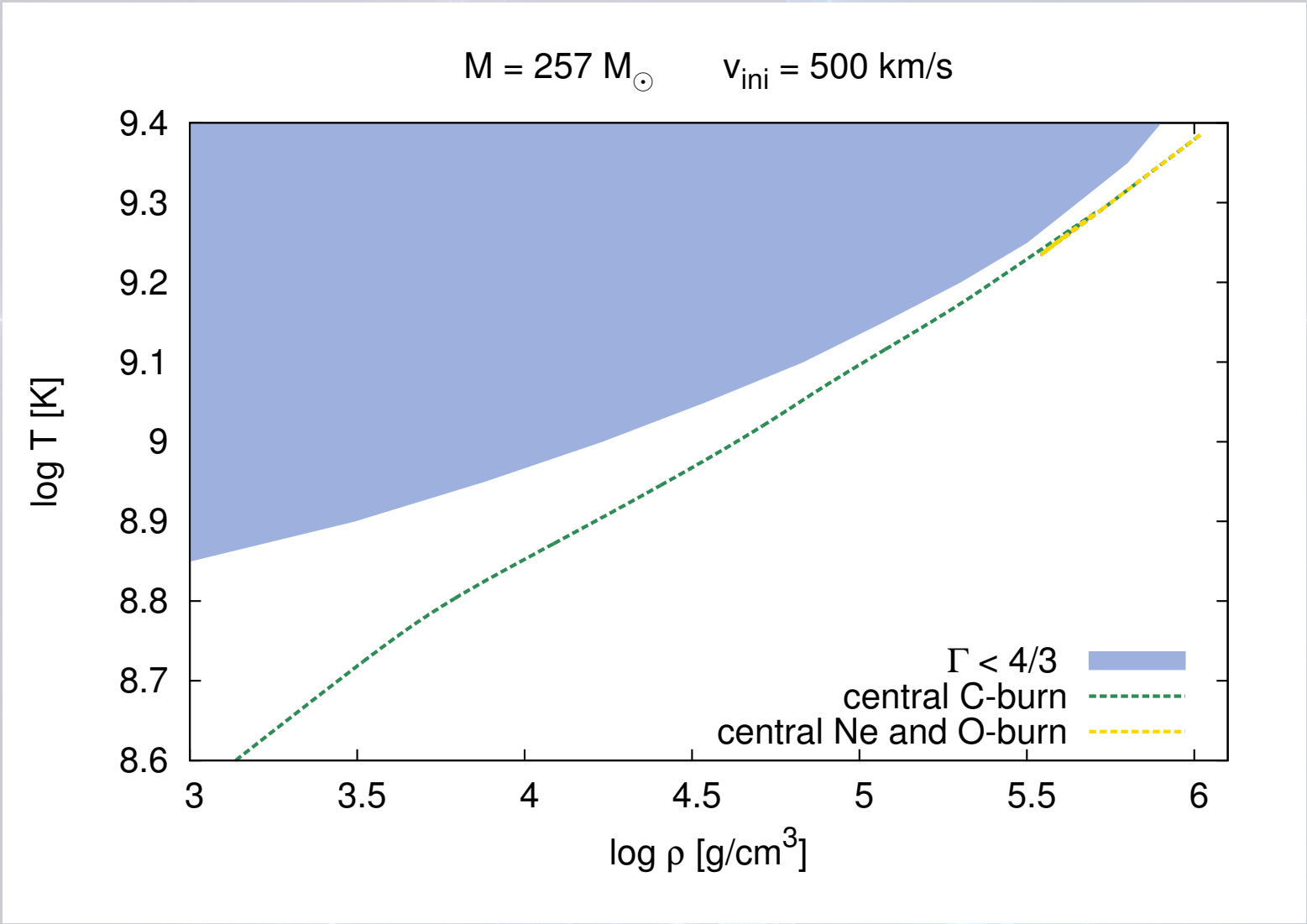
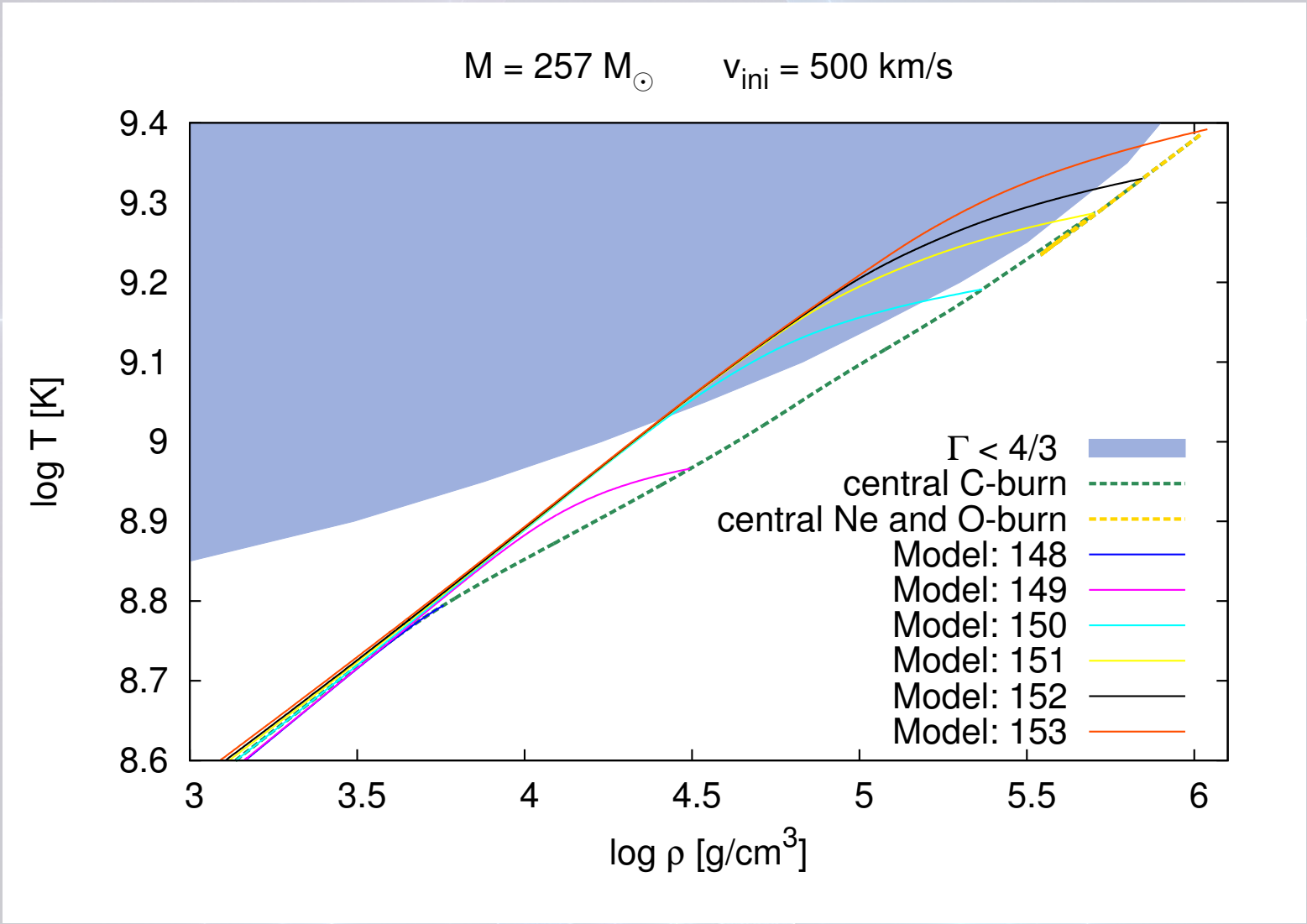
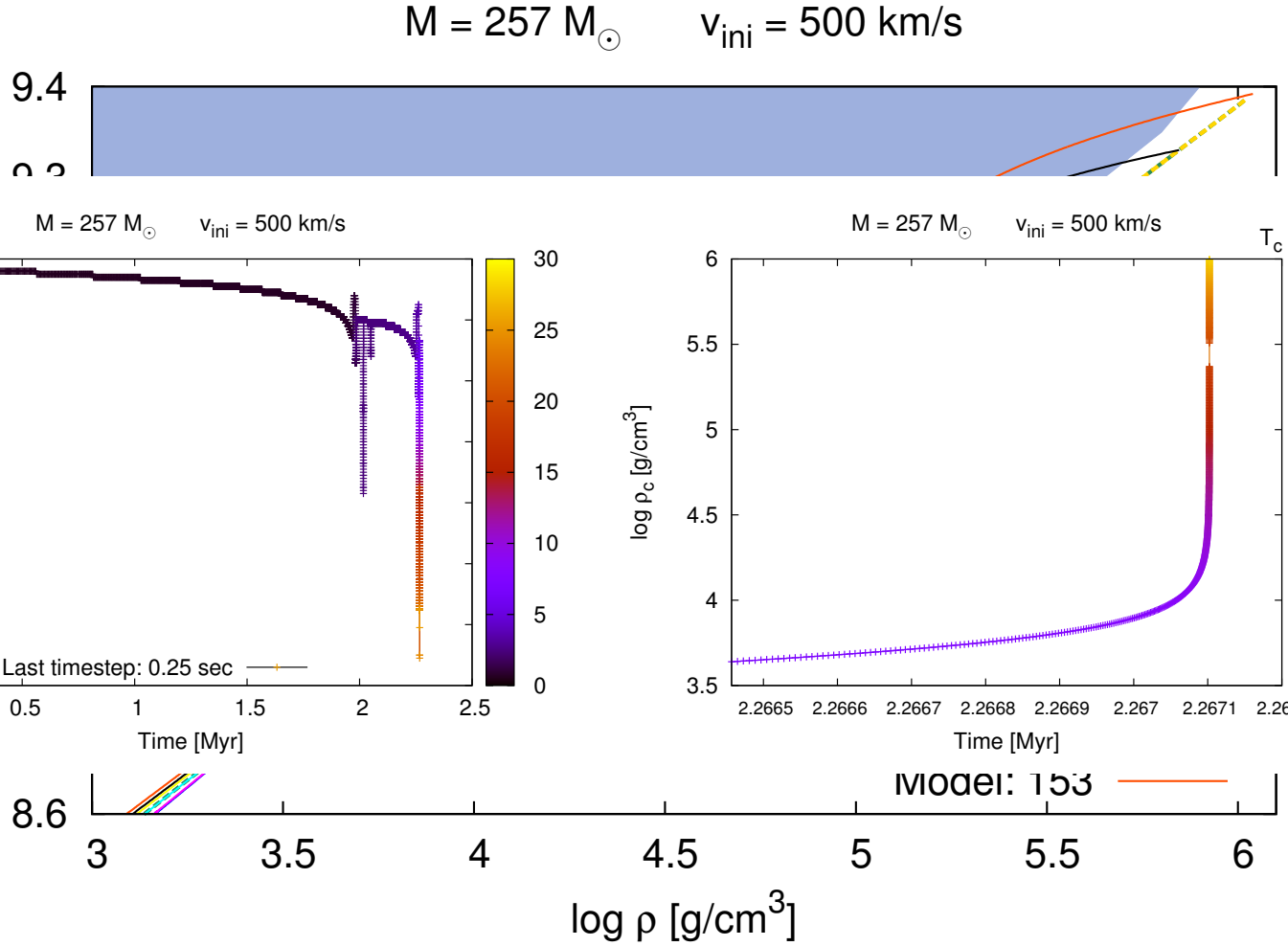


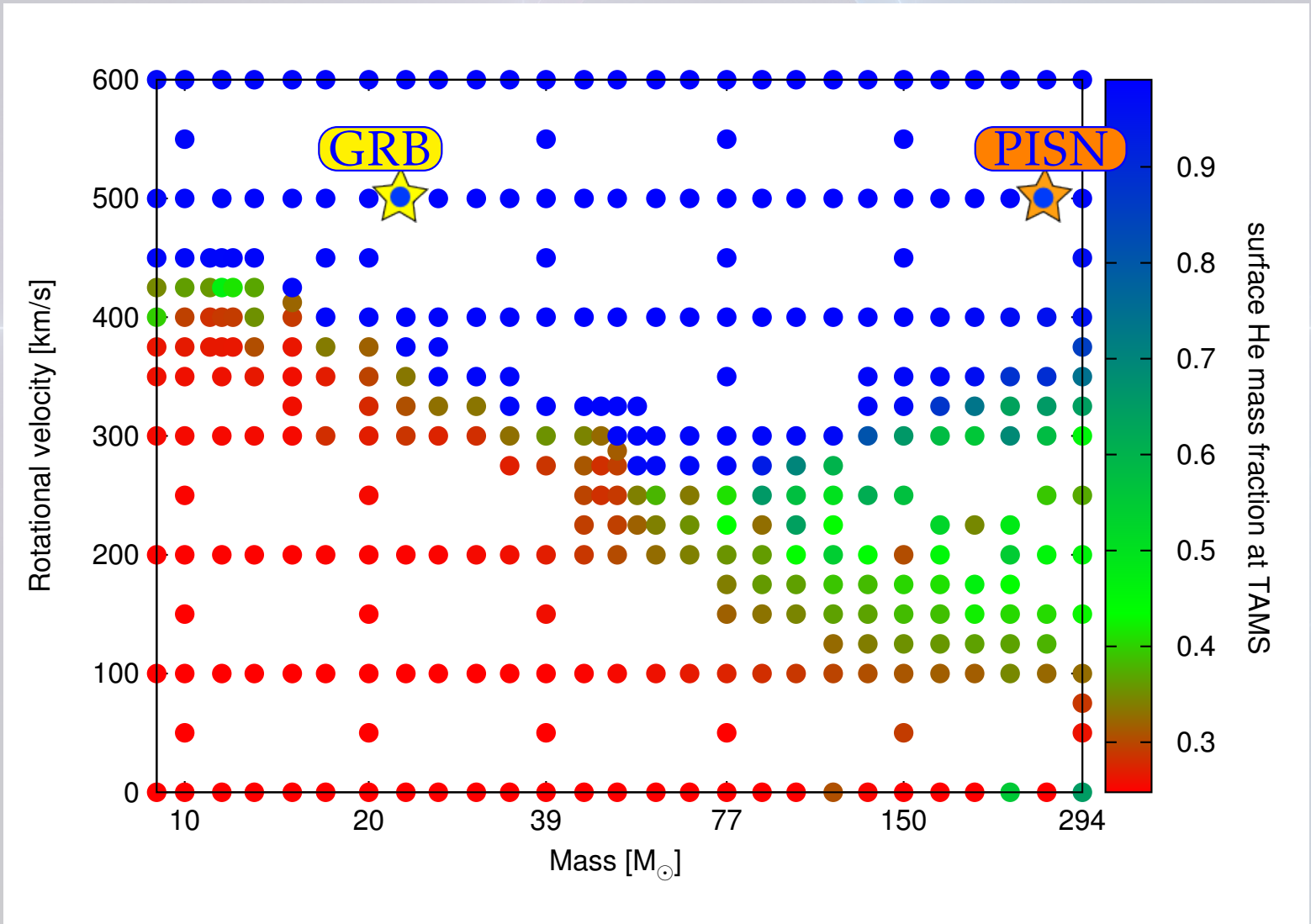
Pair instability supernova



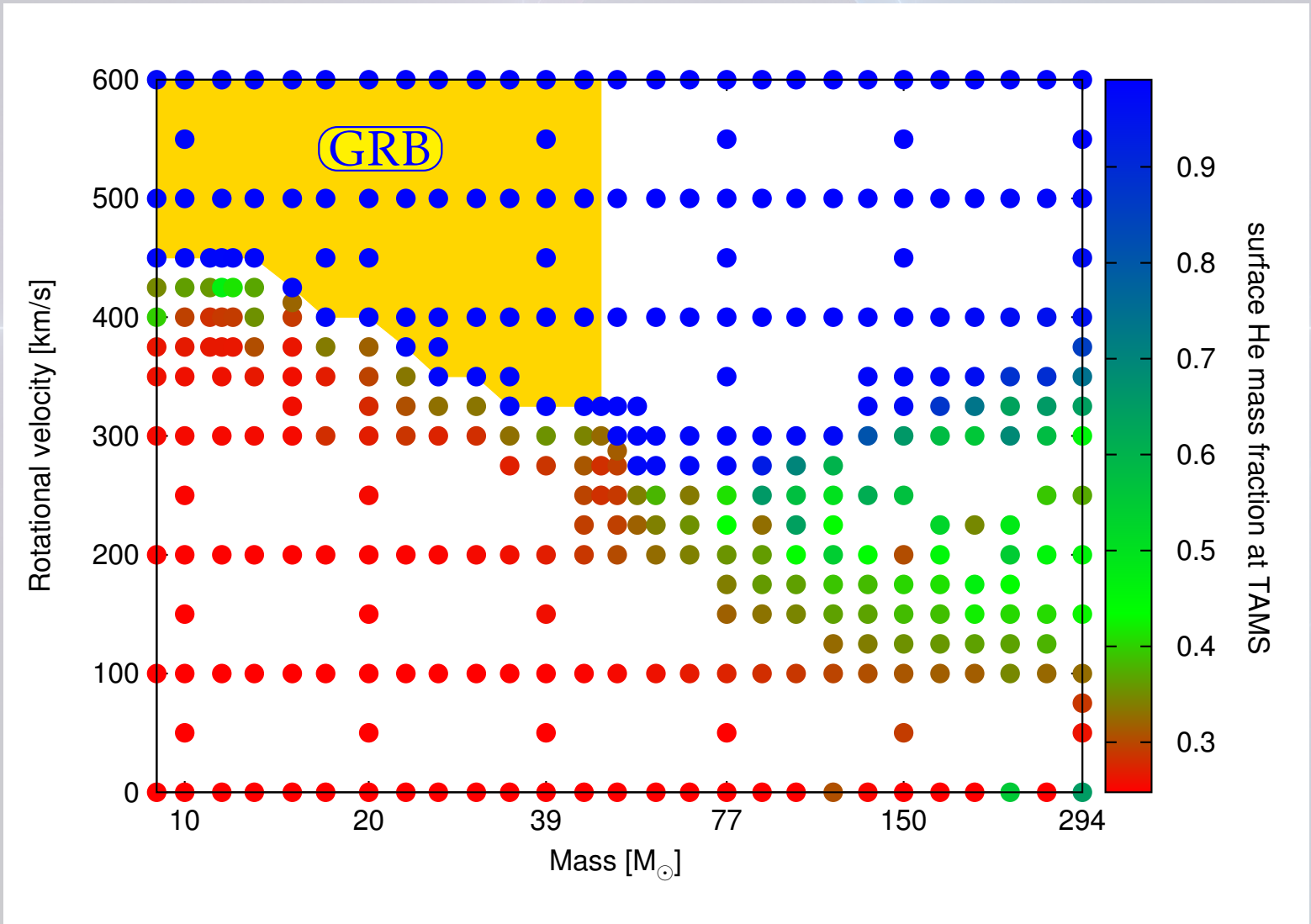
Pair instability supernova



Final fates


GRB
PISN
600
500
400
300
200
100
0
10
20
39
77
150
294
Rotational velocity [km/s]
Mass [M⊙]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
surface He mass fraction at TAMS

Final fates


GRB
600
500
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200
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0
Rotational velocity [km/s]
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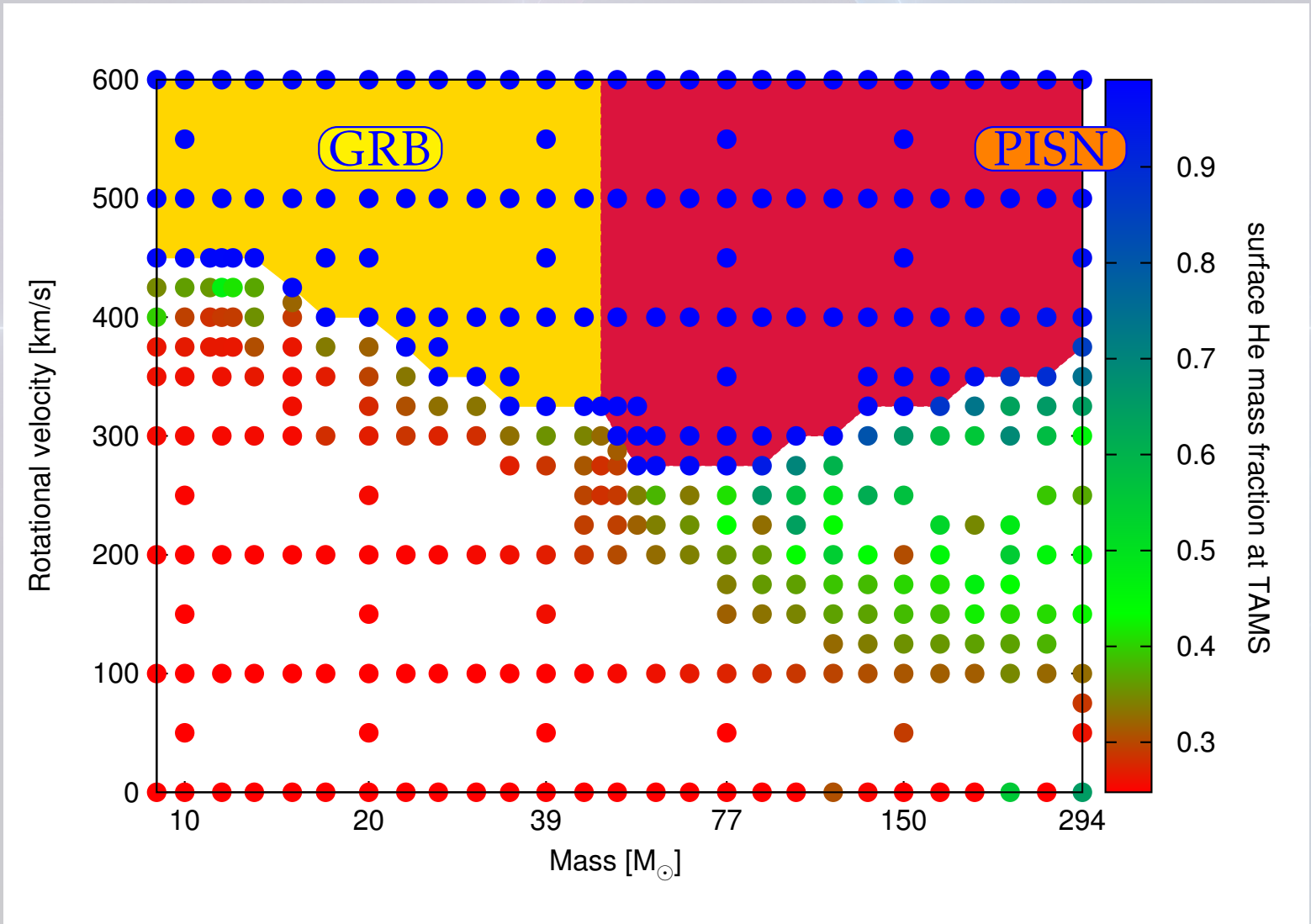
Final fates


GRB
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600
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400
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100
0
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20
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294
Mass [M⊙]
Rotational velocity [km/s]
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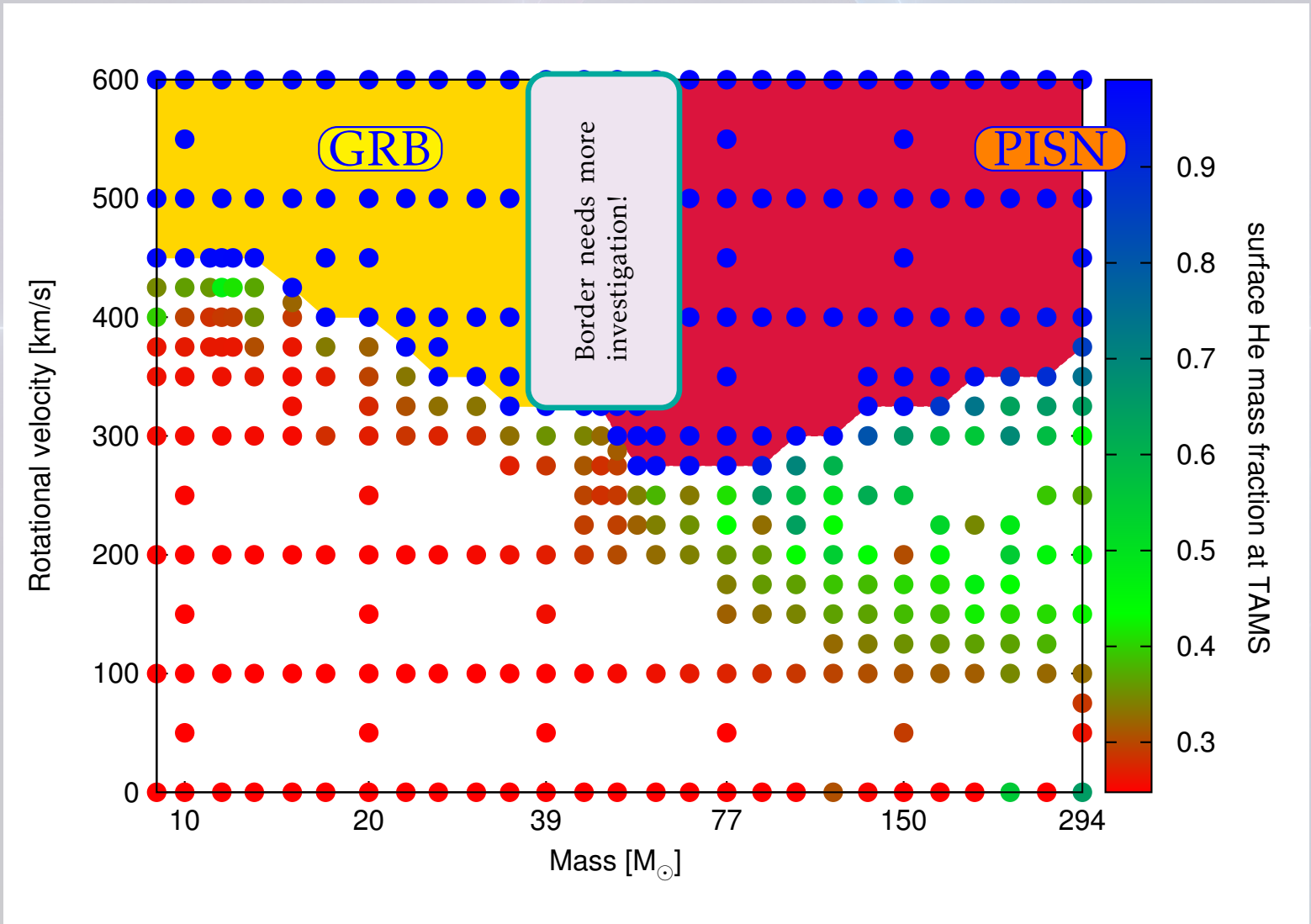
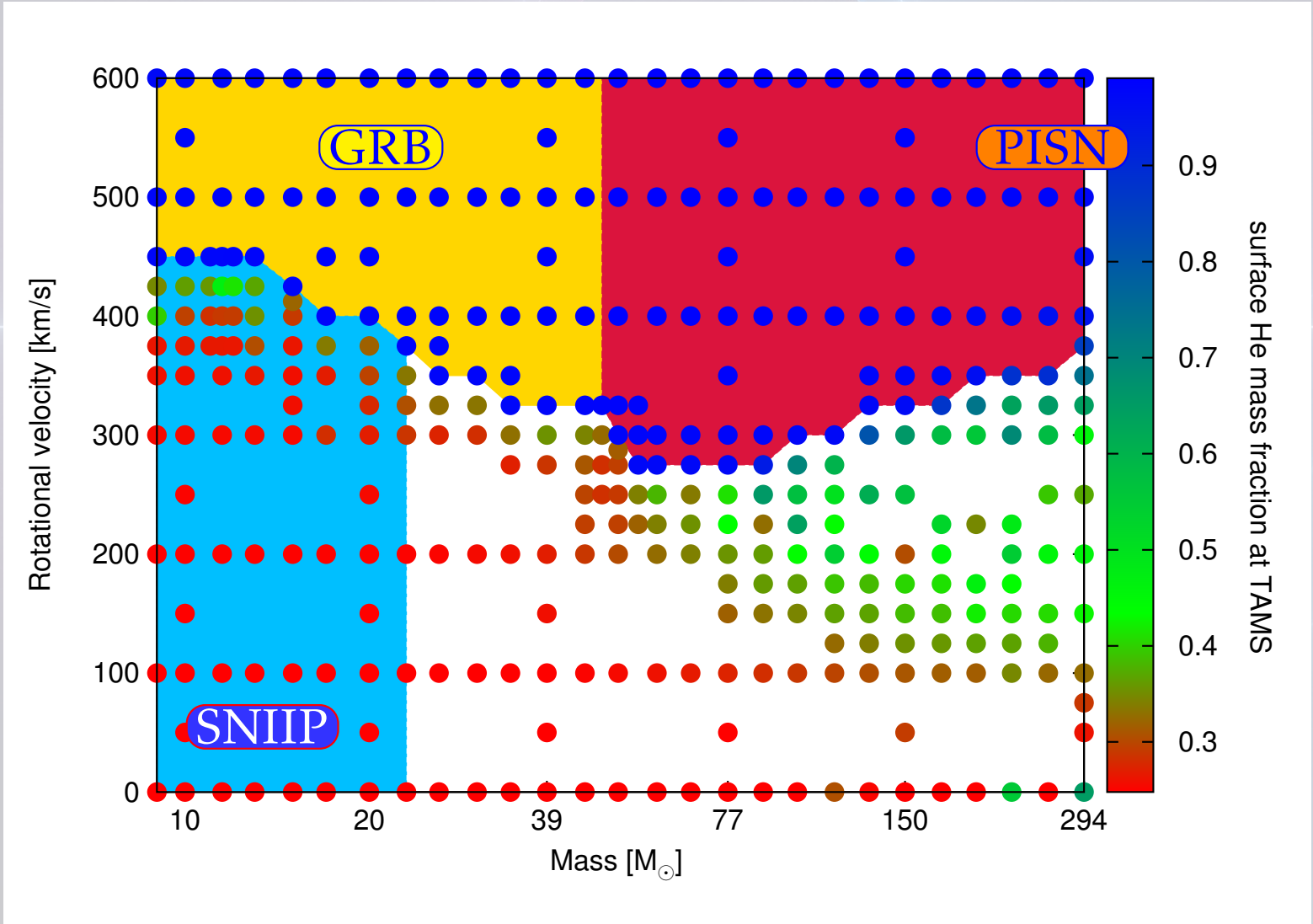
0.8
0.7
0.6
0.5
0.4
0.3
surface He mass fraction at TAMS

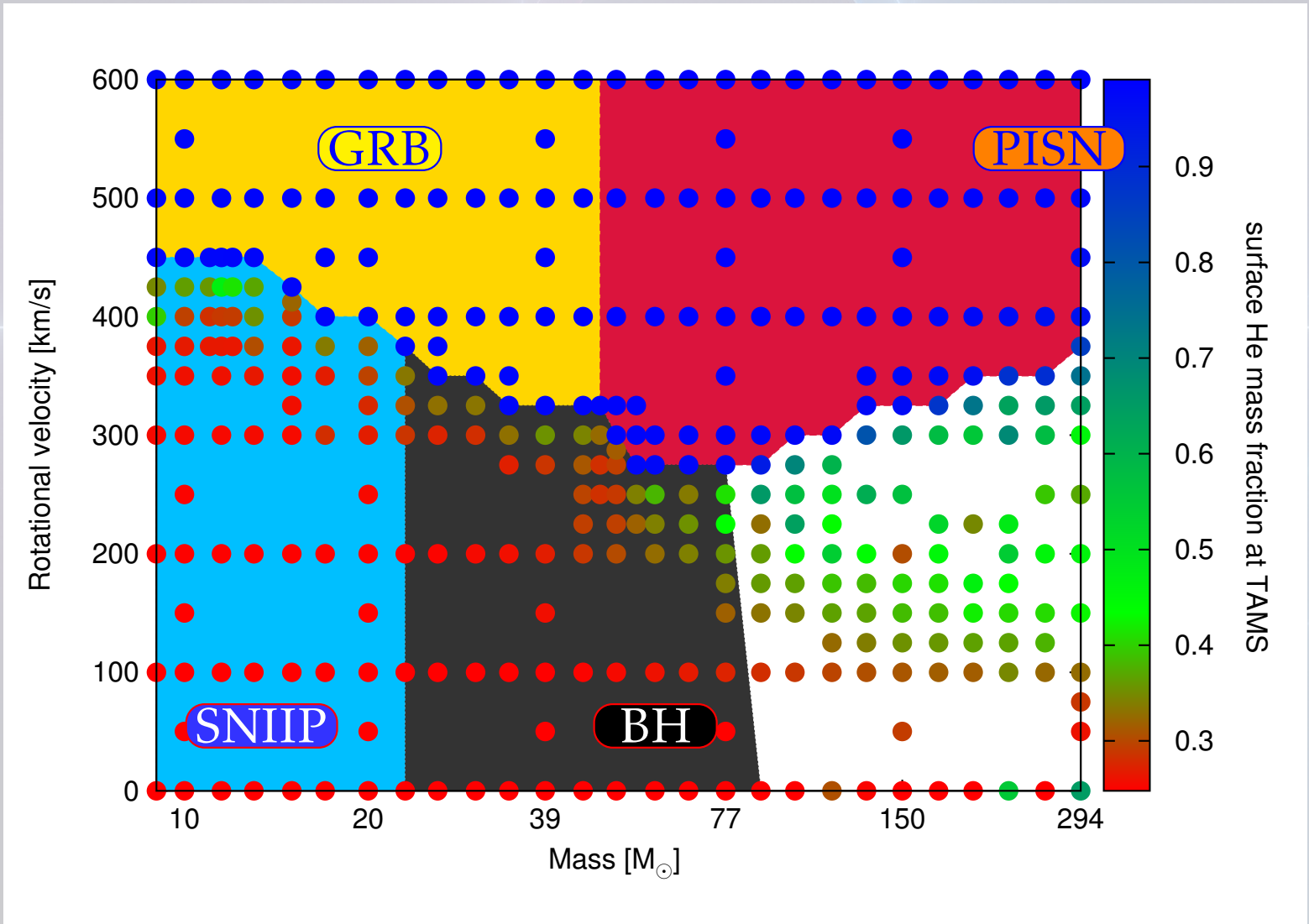
Final fates


GRB
PISN
Border needs more investigation!
Rotational velocity [km/s]
600
500
400
300
200
100
0
10
20
39
77
150
294
Mass [M⊙]
surface He mass fraction at TAMS
0.9
0.8
0.7
0.6
0.5
0.4
0.3

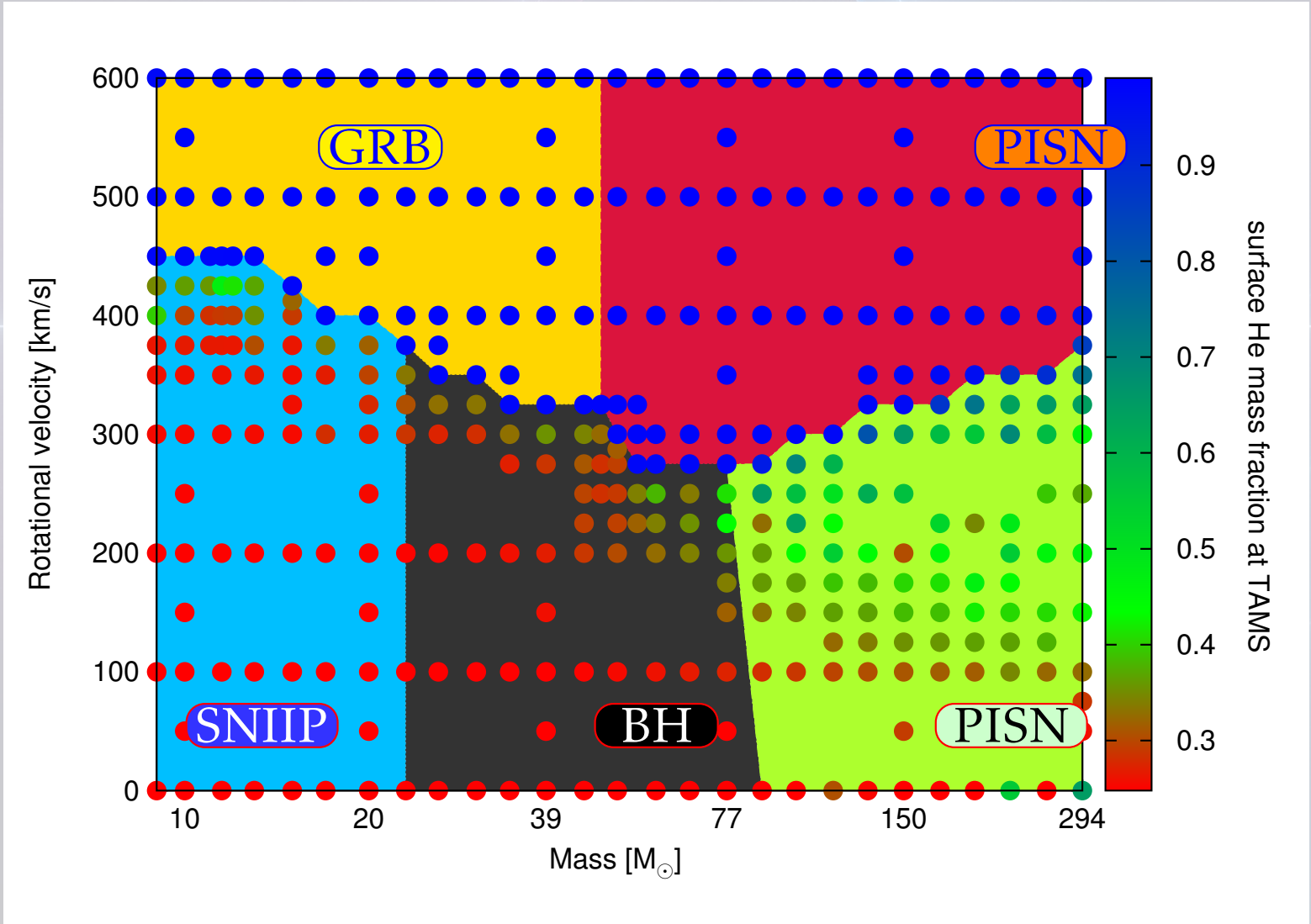
Final fates


GRB
PISN
SNIIP
600
500
400
300
200
100
0
10
20
39
77
150
294
Mass [M⊙]
Rotational velocity [km/s]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
surface He mass fraction at TAMS

Final fates


GRB
PISN
SNIIP
BH
600
500
400
300
200
100
0
10
20
39
77
150
294
Mass [M⊙]
Rotational velocity [km/s]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
surface He mass fraction at TAMS

Final fates


GRB
PISN
SNIIP
BH
PISN
600
500
400
300
200
100
0
Rotational velocity [km/s]
10
20
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Mass [M⊙]
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0.7
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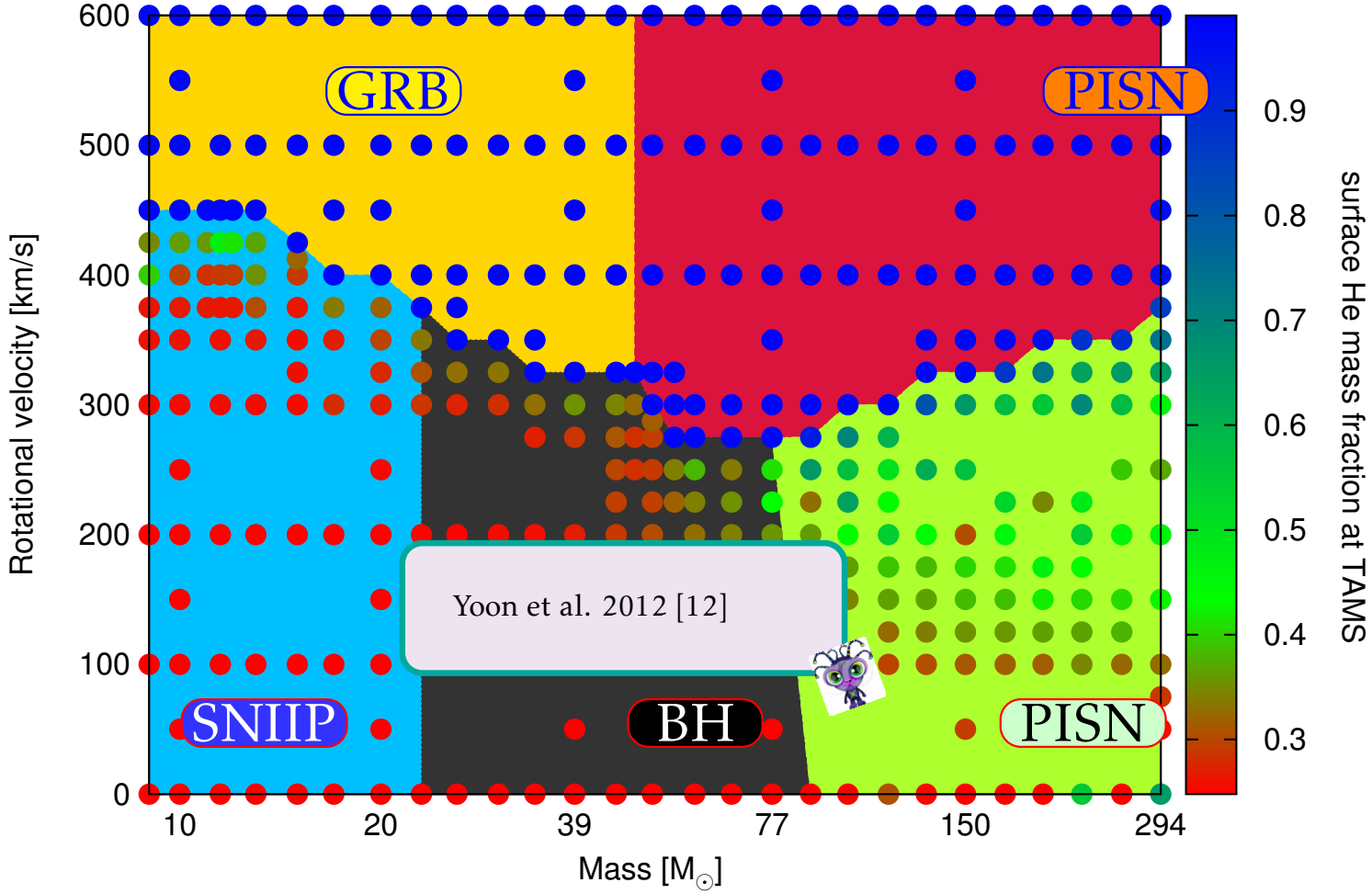
surface He mass fraction at TAMS

Final fates


GRB
PISN
SNIIP
BH
PISN
Yoon et al. 2012 [12]
Rotational velocity [km/s]
600
500
400
300
200
100
0
10
20
39
77
150
294
Mass [M⊙]
surface He mass fraction at TAMS
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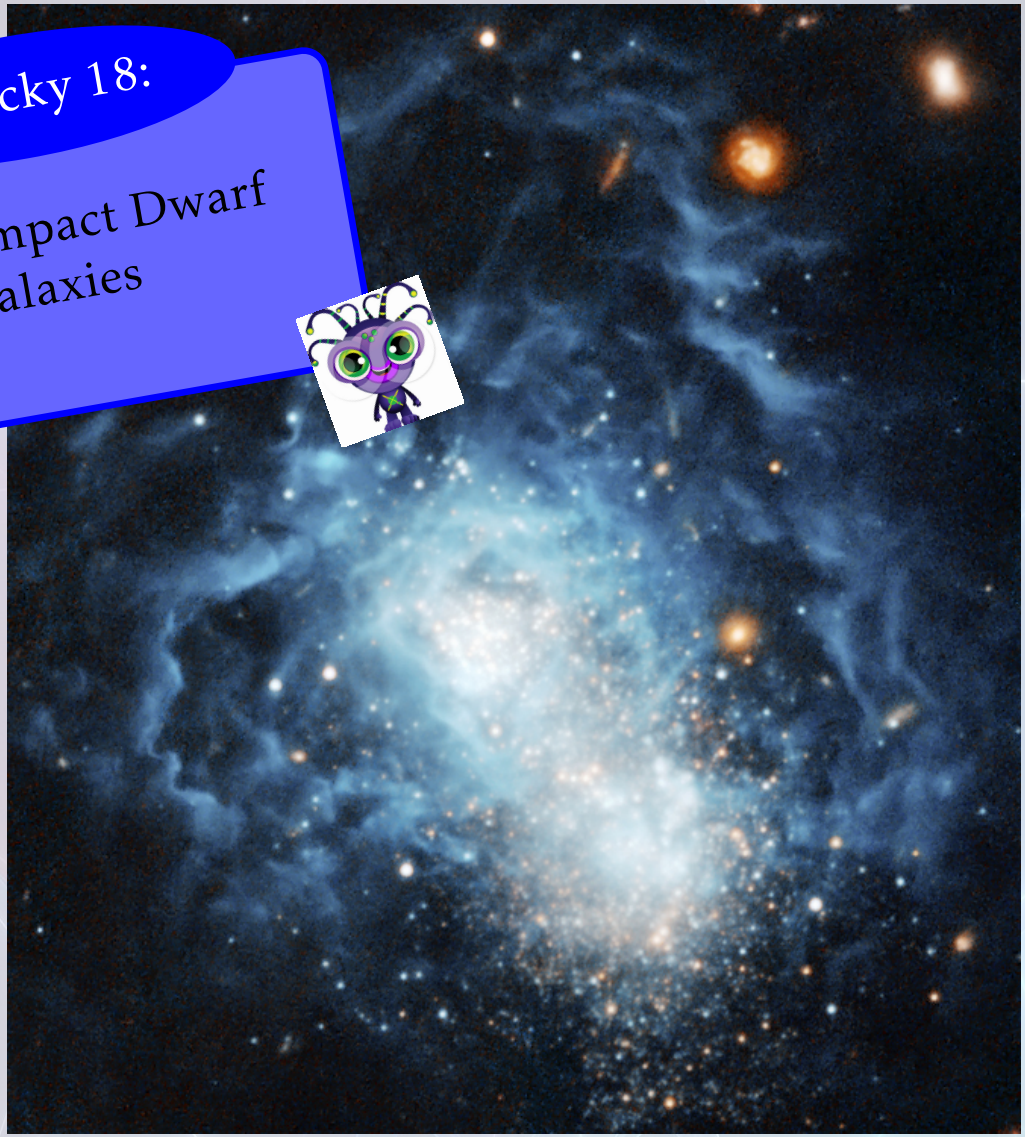
0.8
0.7
0.6
0.5
0.4
0.3

Population synthesis

Population synthesis

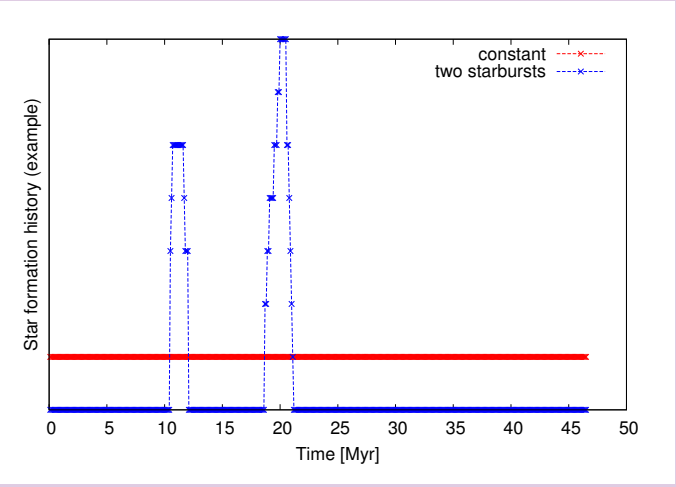
I Zwicky 18:

Blue Compact Dwarf Galaxies



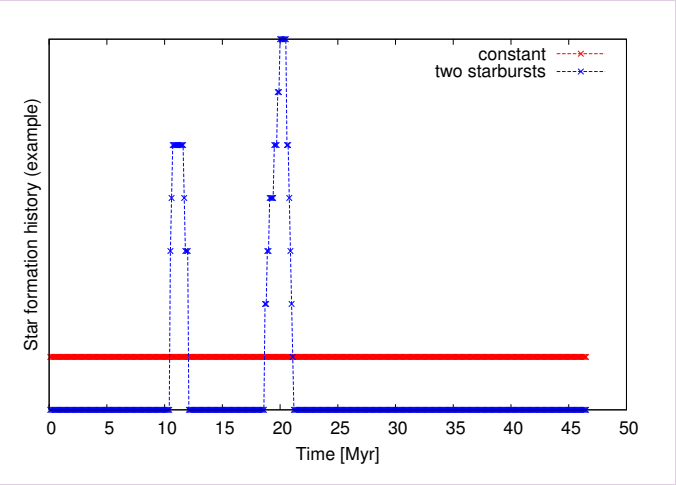
Population synthesis

Star Formation History



Population synthesis

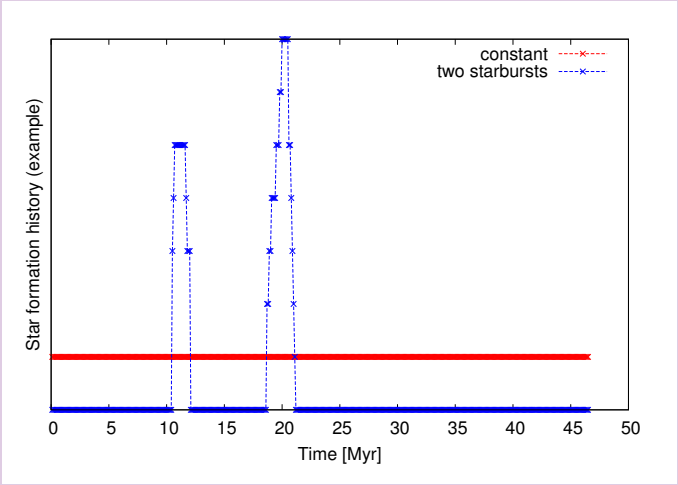
Star Formation History



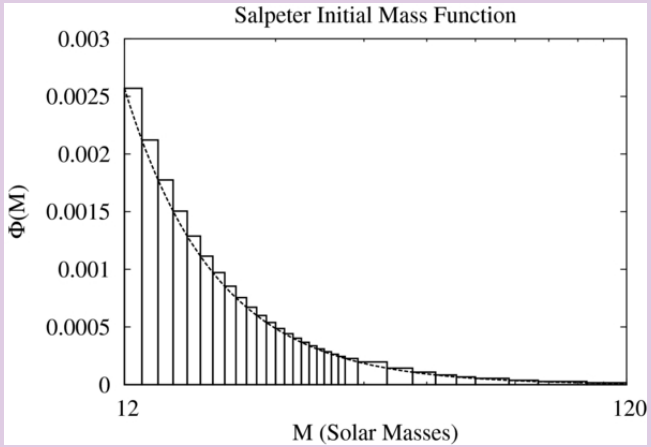
Initial Mass Function [7]

Population synthesis

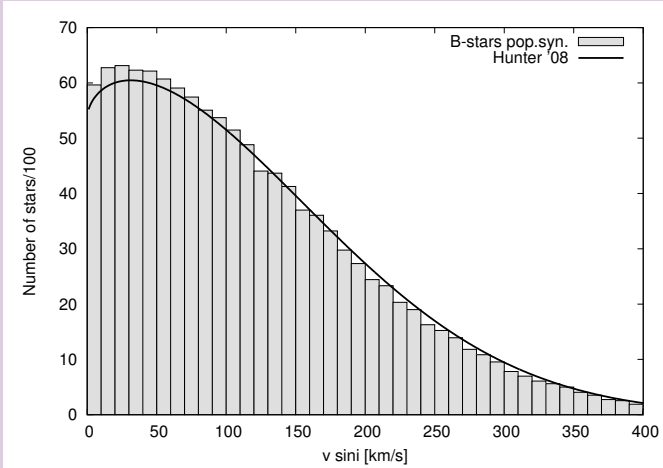
Star Formation History



Initial Mass Function [7]



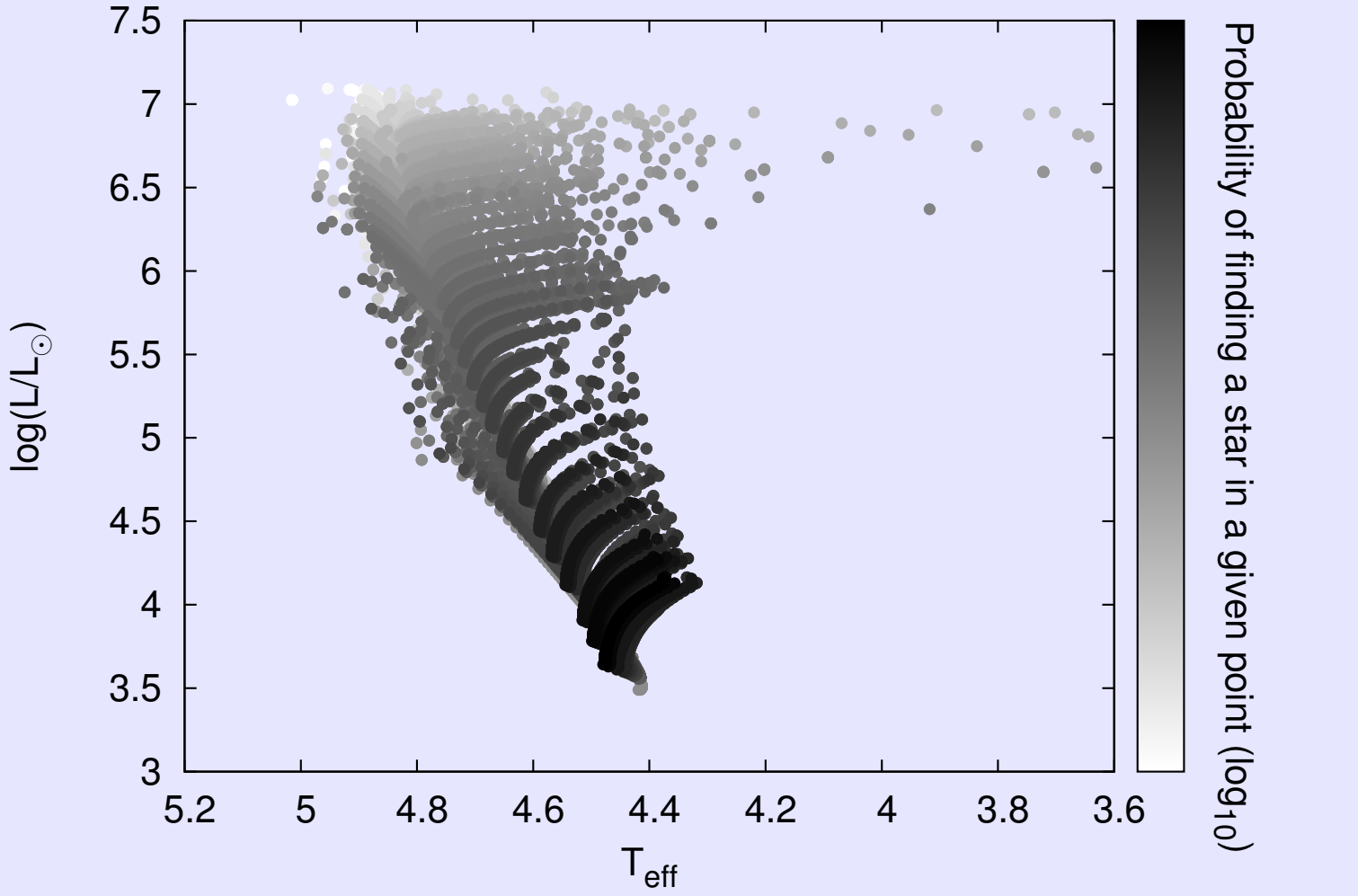
Initial Rotational Velocity Distribution [5] [2]



Population synthesis

Star Formation History

Initial Mass Function [7]

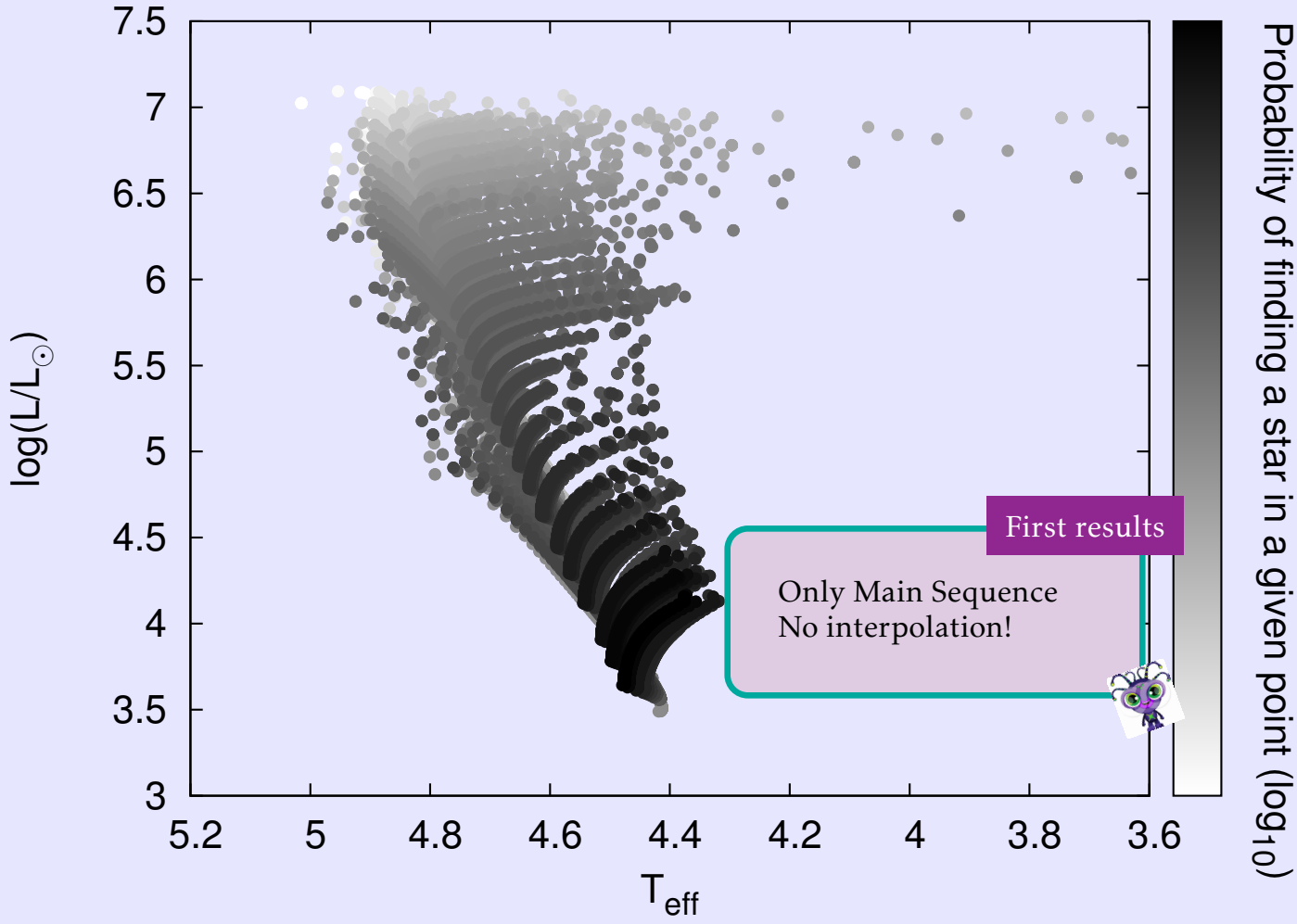


Initial Rotational Velocity Distribution [5] [2]

Population synthesis

Star Formation History

Initial Mass Function [7]

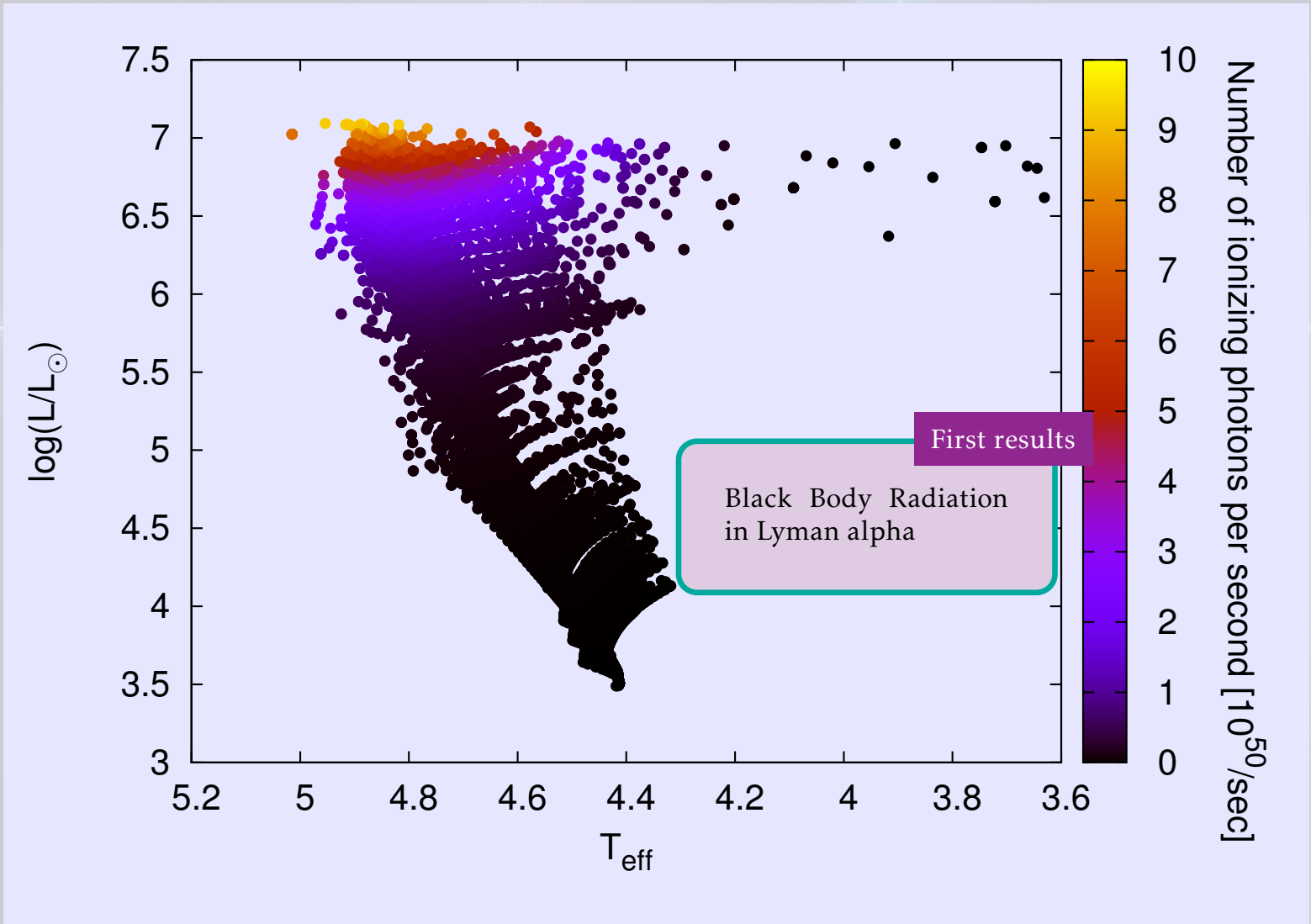


First results

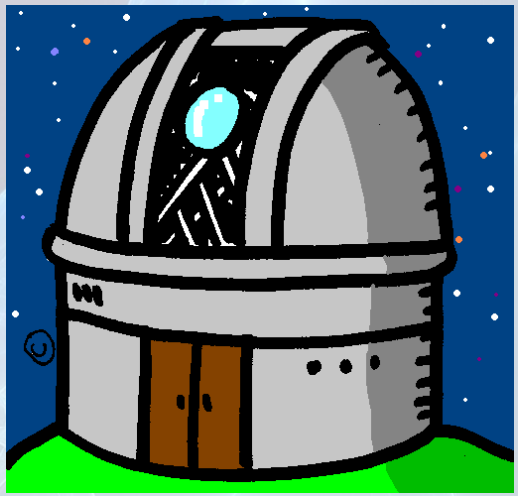
Only Main Sequence
No interpolation!

Initial Rotational Velocity Distribution [5] [2]

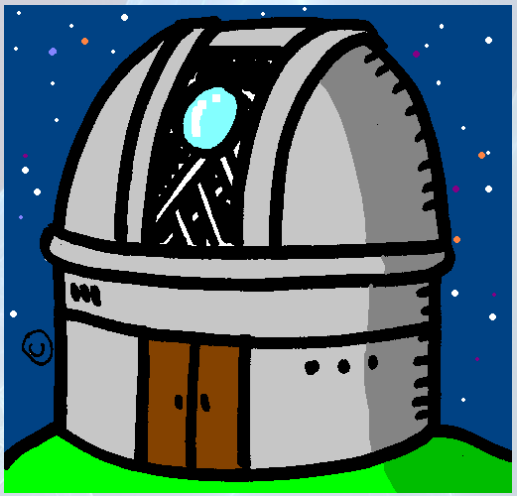
Photoionization fluxes



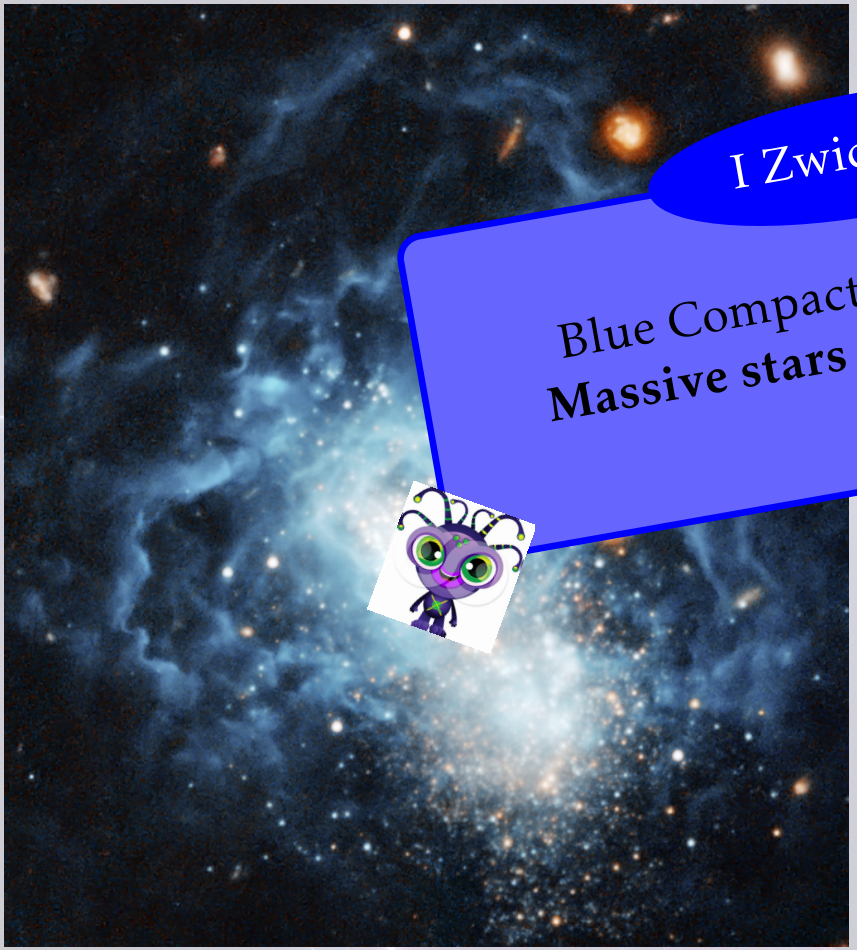
Request for observations!



Request for observations!

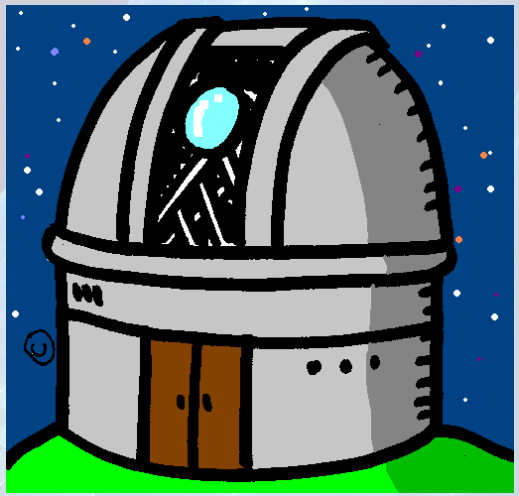


Request for observations!



I Zwicky 18:

Blue Compact Dwarf Galaxies:
Massive stars at low metallicity



Conclusion and Outlook

- Low metallicity [11]:
  - BCD & high-z galaxies
  - lower Z $\rightarrow$ higher M
  - long GRB
- Results presented here [8]:
  - WR stars in BCDs from Chemically homogeneous evolution
  - long GRB, PISN-SLSN
  - very massive stars, ionization
- Future: match result to observations,
  update theory of massive stellar evolution [9]
- Binarity is important
  (PhD project of Nicolás González-Jiménez)

[References]

[1] I. Brott et al. *A&A*, 530:A115, 2011.

[2] I. Brott et al. *A&A*, 530:A116, 2011.

[3] C.L. Fryer. *Stellar Collapse*. Kluwer Academic Publishers., 2004.

[4] A. Gal-Yam. *Science*, 337:927, 2012.

[5] I. Hunter et al. *A&A*, 479:541, 2008.

[6] N. Langer, A. de Koter, et al. *A&A*, 475:L19, 2007.

[7] E.E. Salpeter. *ApJ*, 121:161, 1955.

[8] D. Szecsi, N. Langer, et al. *Conference Poster: 'Massive Stars: From alpha to Omega', Rhodes*, 2013.

[9] D. Szecsi, N. Langer, et al. *A&A*, in preparation, 2013.

[10] F. Tramper et al. *A&A*, submitted, 2013.

[11] S.-C. Yoon et al. *A&A*, 460(199), 2006.

[12] S.-C. Yoon et al. *A&A*, 542(A113), 2012.

[13] S.-C. Yoon and N. Langer. *A&A*, 443:643–648, 2005.

- Low metallicity environments are important for studying massive stellar evolution
- Needed: More observational data of massive stars at low metallicity → BCDs
- Check out the poster!

Thank you for your attention!

D. Szécsi was supported by the Hungarian OTKA-77795 grant.