Evolution of Massive Stars in Blue Compact Dwarf Galaxies:

model tracks, Wolf-Rayet stars and final fates

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Galaxies meet GRBs at Cabo de Gata, Spain
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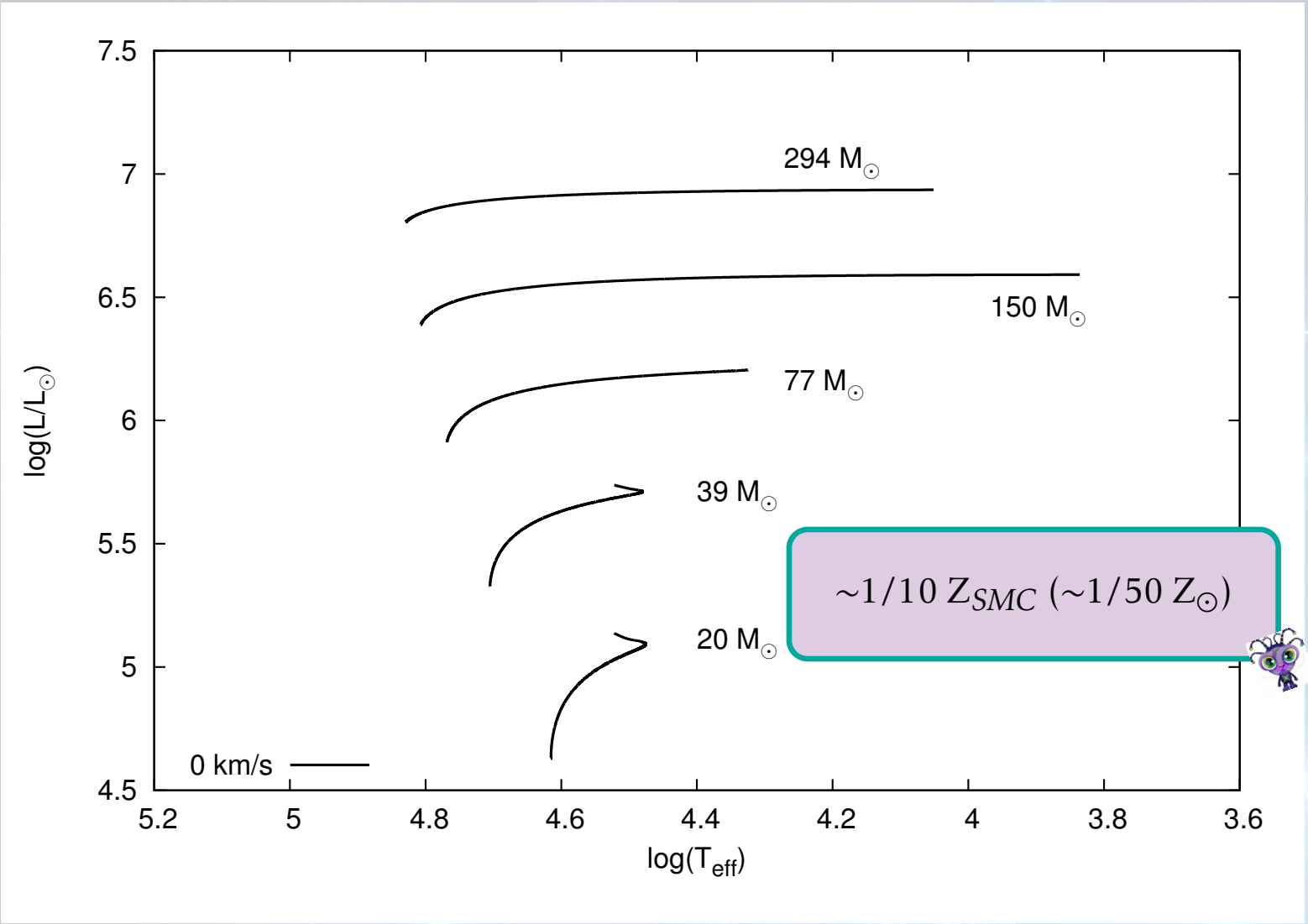
Motivations

- **Massive Stars**
  - mixing & mass loss = ?
  - Milky Way, LMC, SMC [Brott et al. 2011]
- **Low metallicity**
  - massive stars evolve differently [Yoon et al. 2006]
  - → lGRBs, Pair Instability SNe
- **$Z = 0.1 \times Z_{SMC}$**
  - lowest Z to observe stars: **B**lue **C**ompact **D**warf galaxies
  - $\simeq Z_{GC}$ & high-z galaxies

Hertzsprung–Russell diagram



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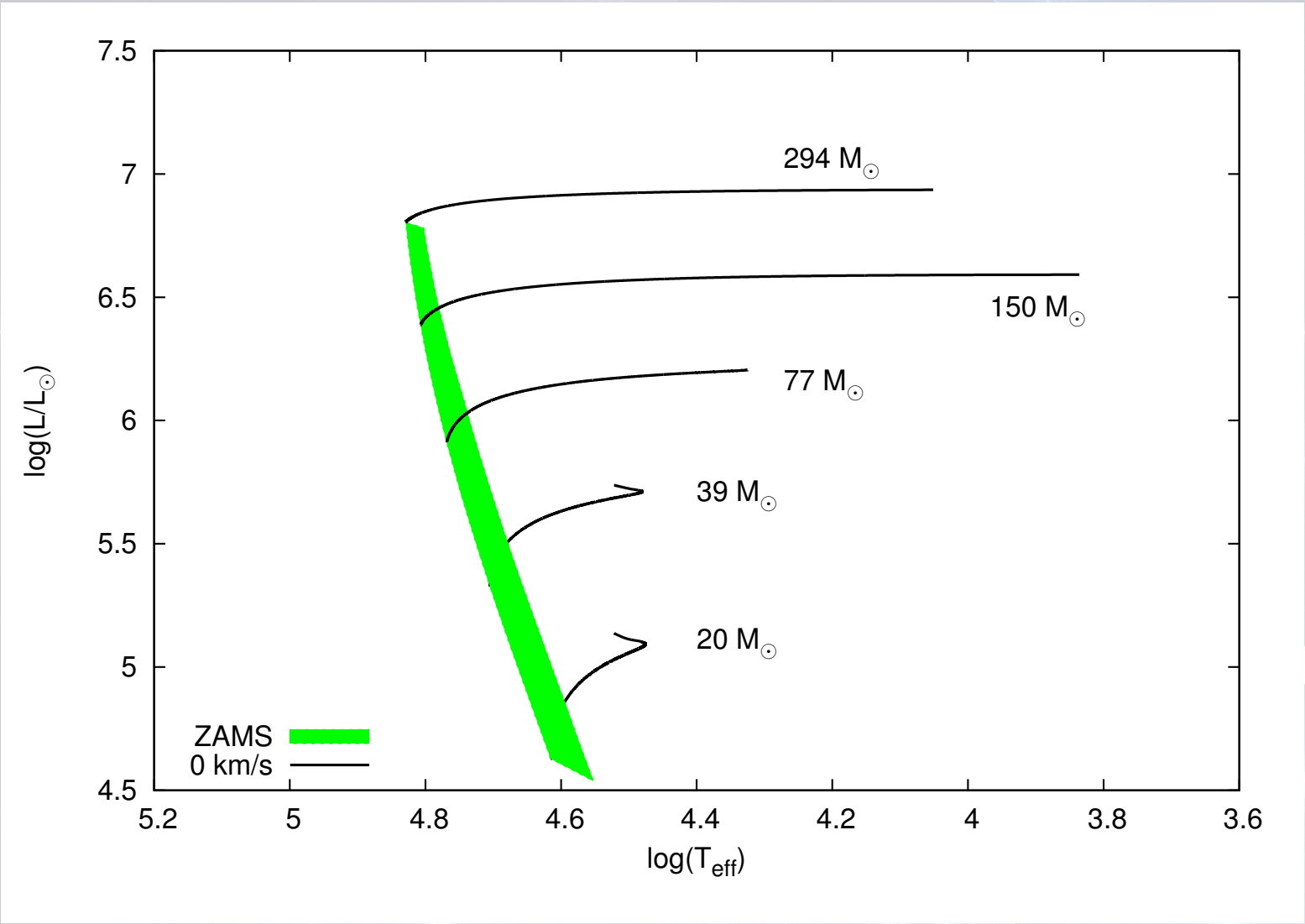

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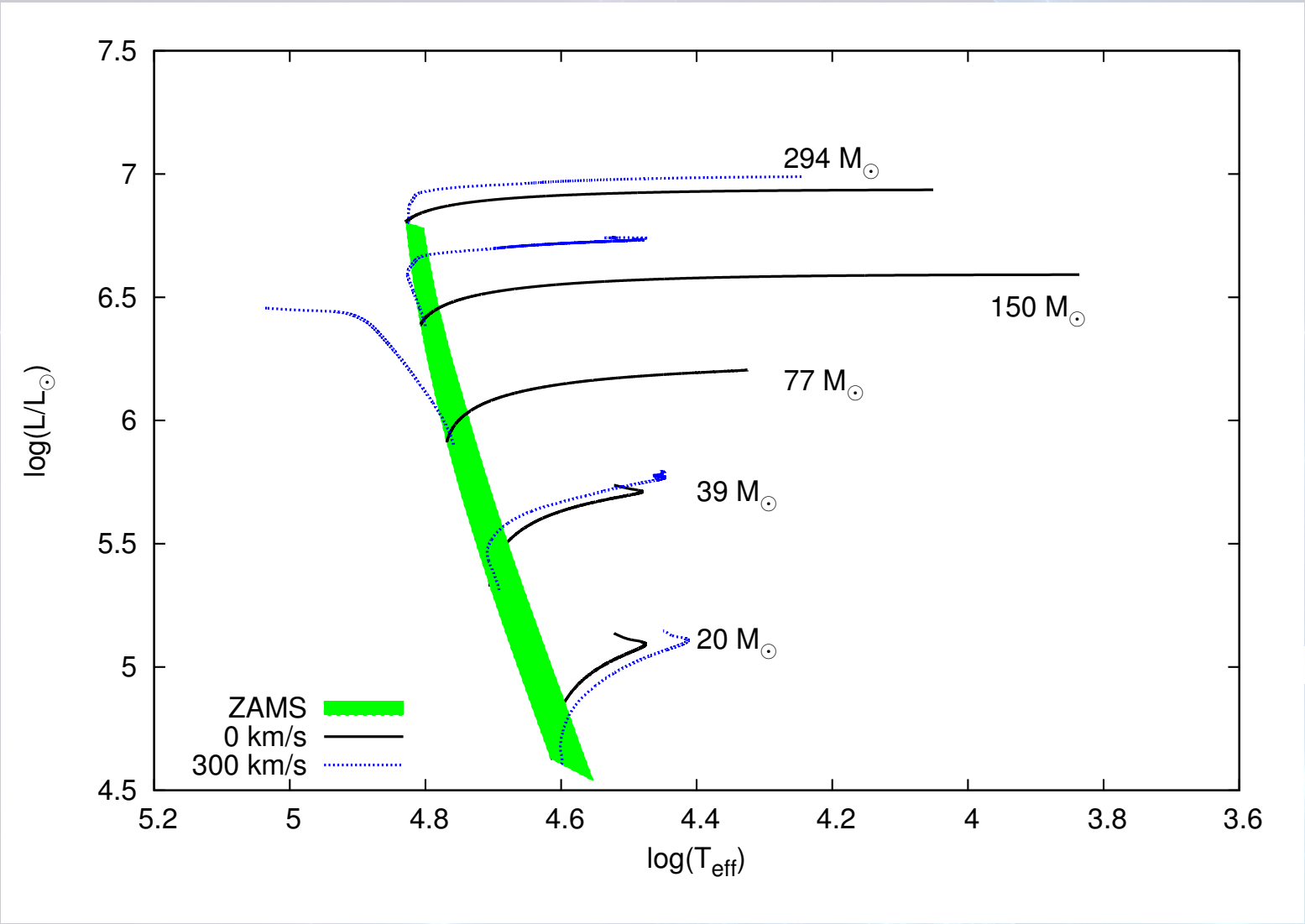

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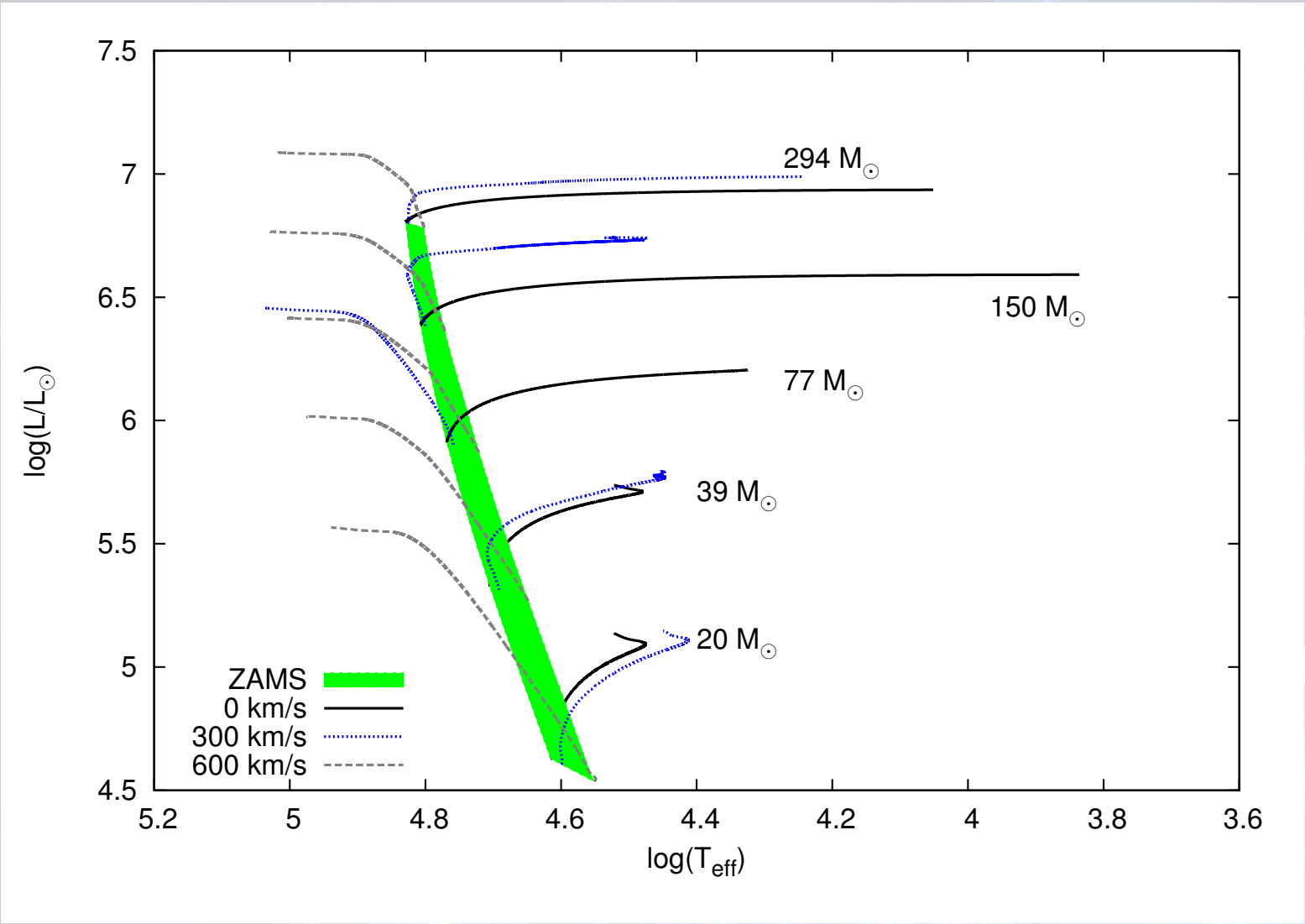

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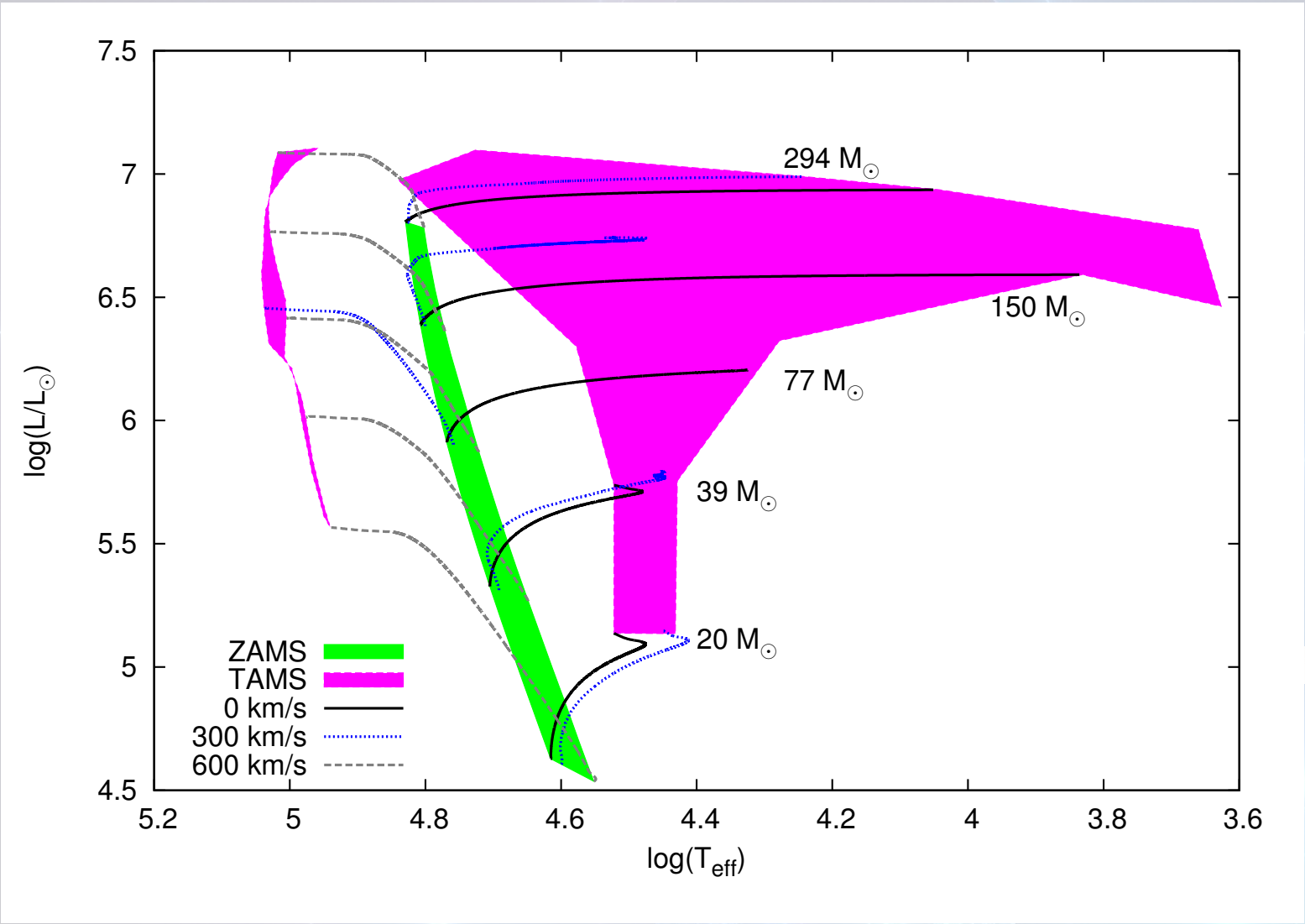

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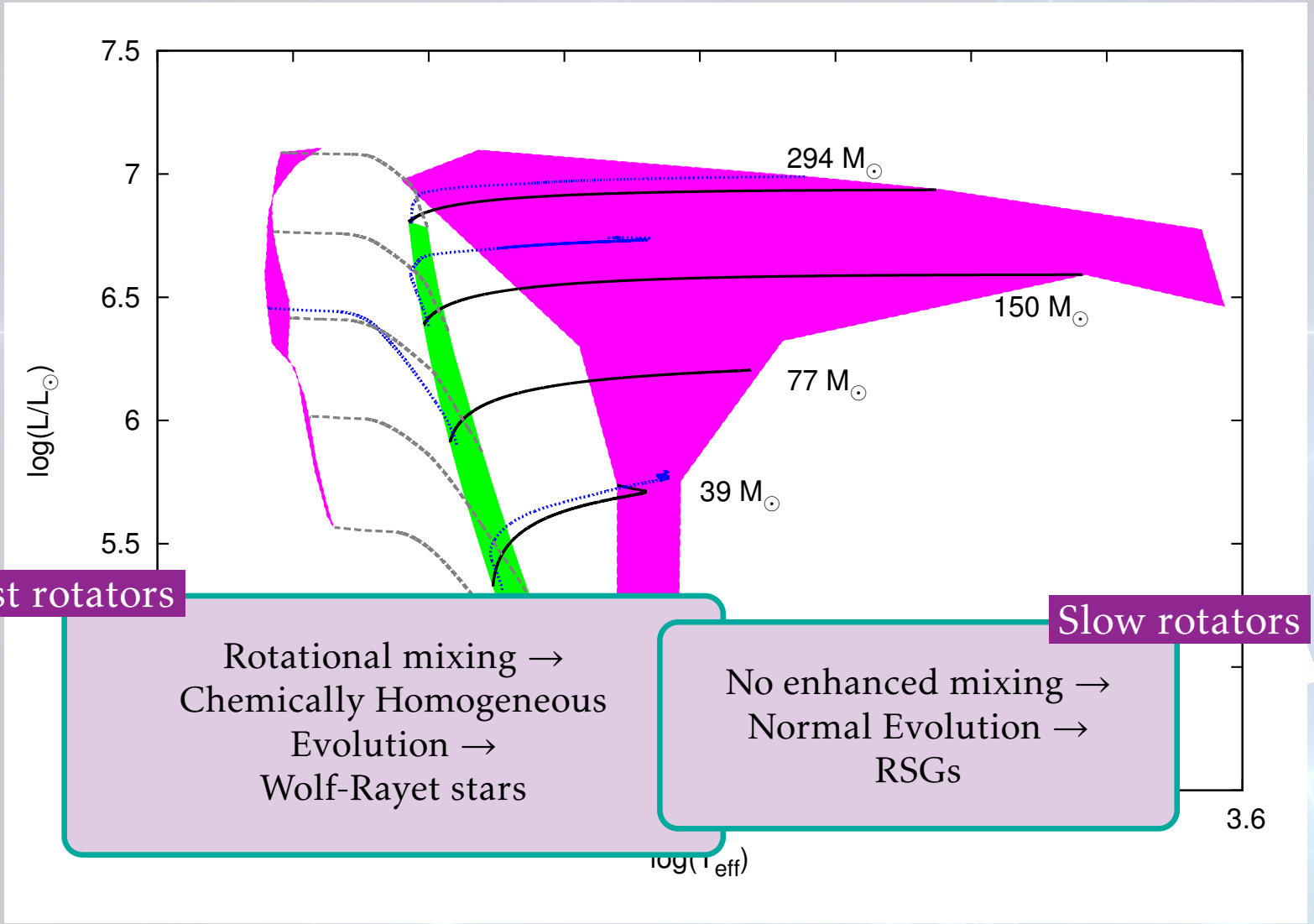


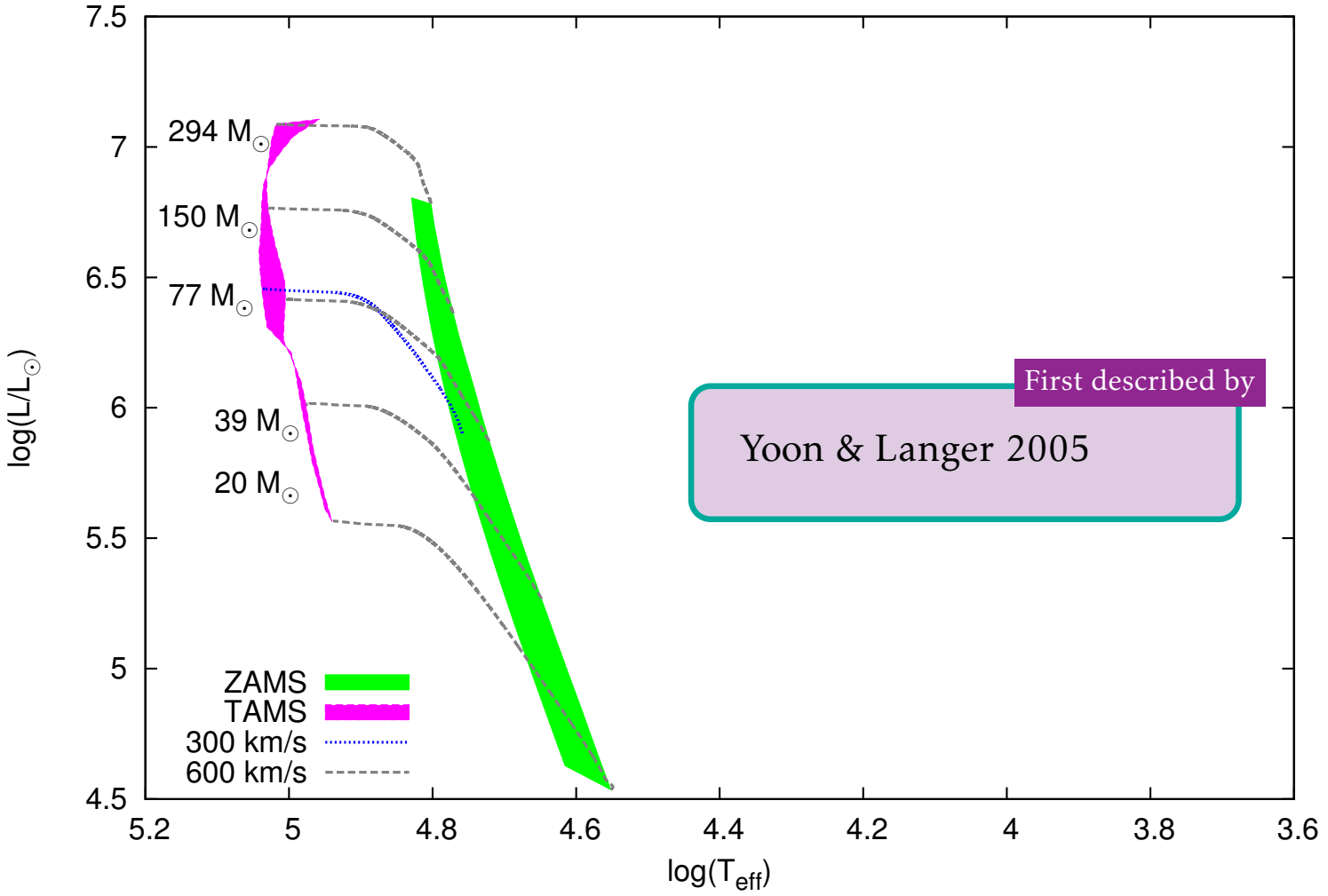
Fast rotators

Rotational mixing → Chemically Homogeneous Evolution → Wolf-Rayet stars

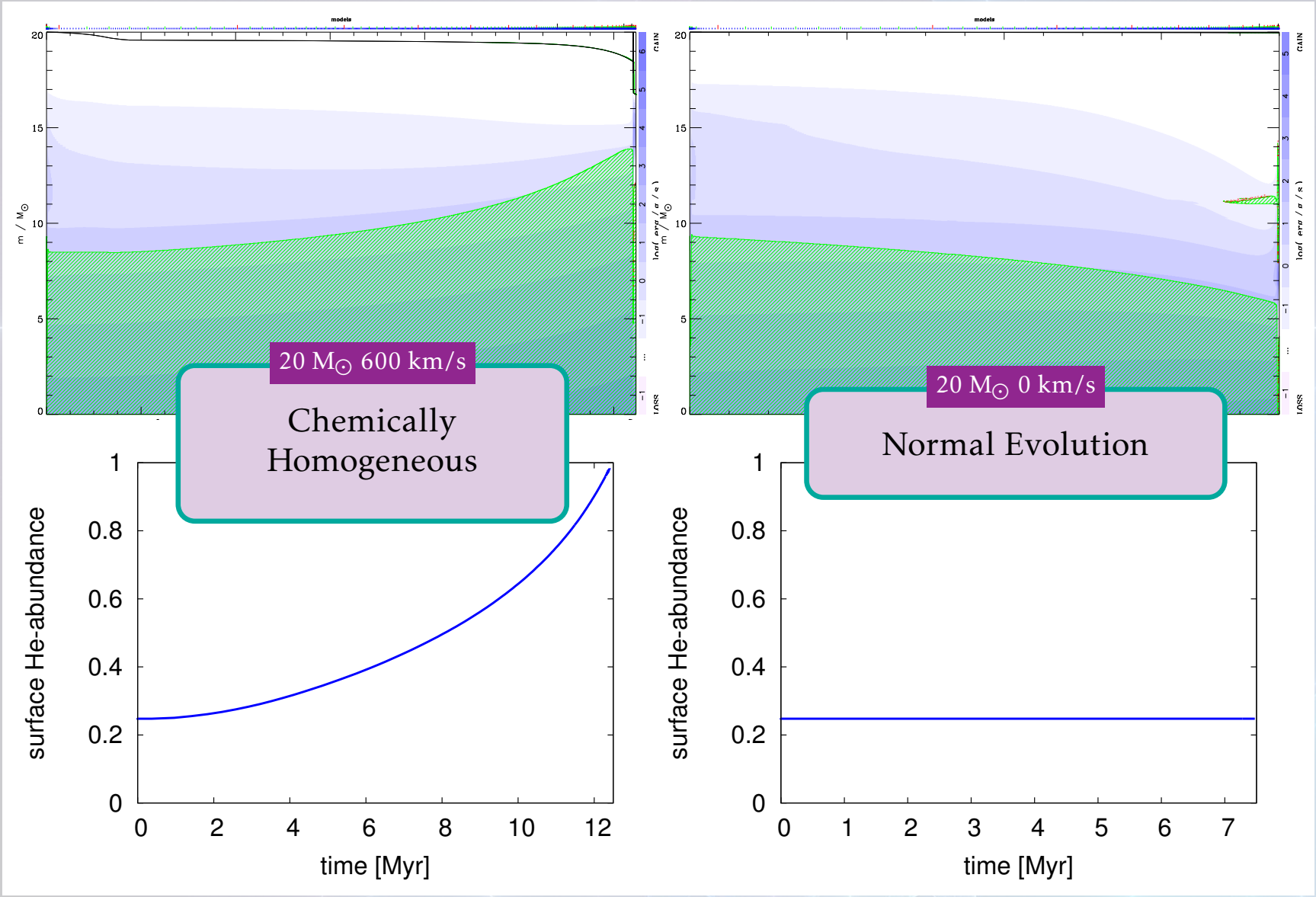
Slow rotators

No enhanced mixing → Normal Evolution → RSGs

Chemically homogeneous evolution + Wolf-Rayet stars



Chemically homogeneous evolution + Wolf-Rayet stars



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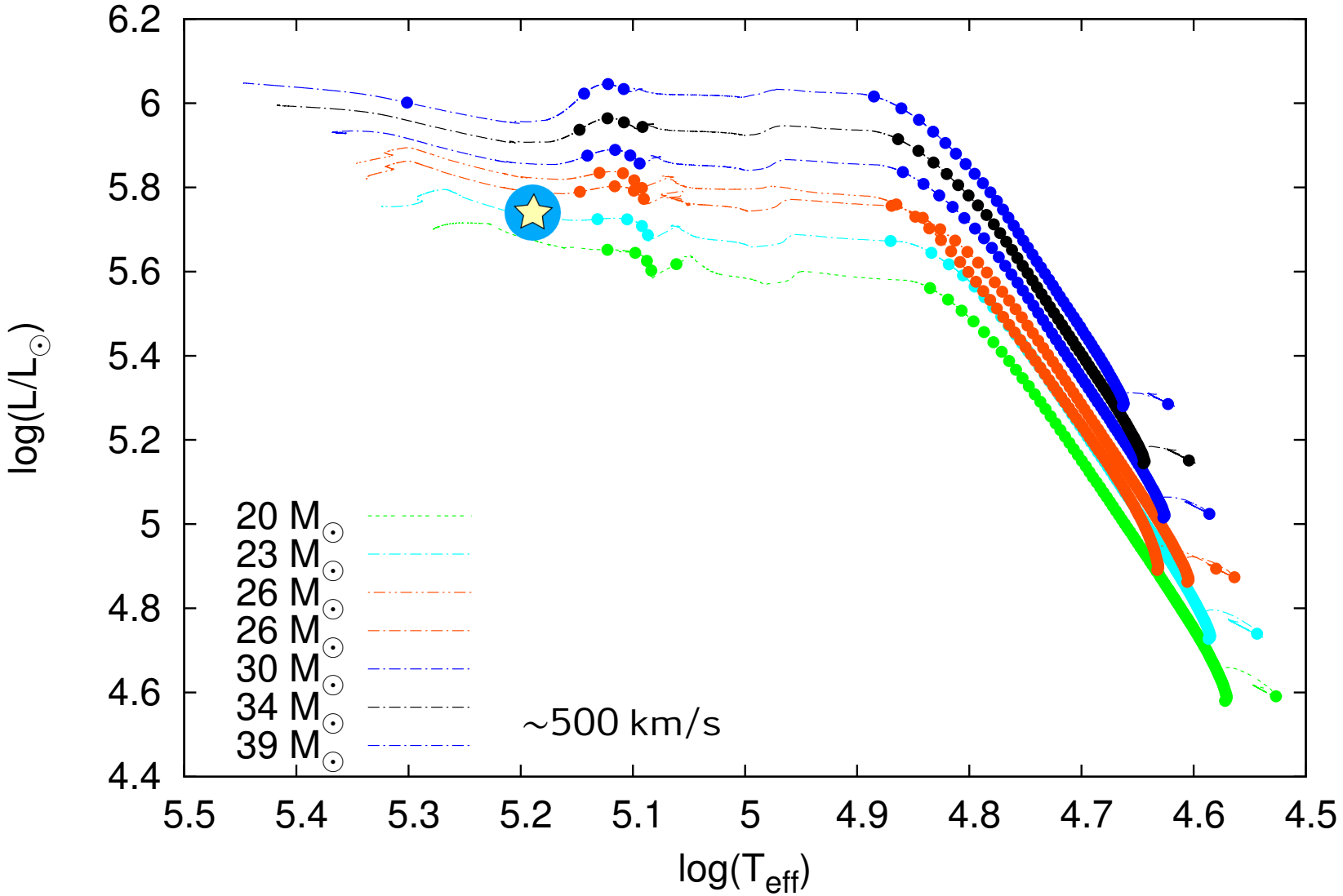

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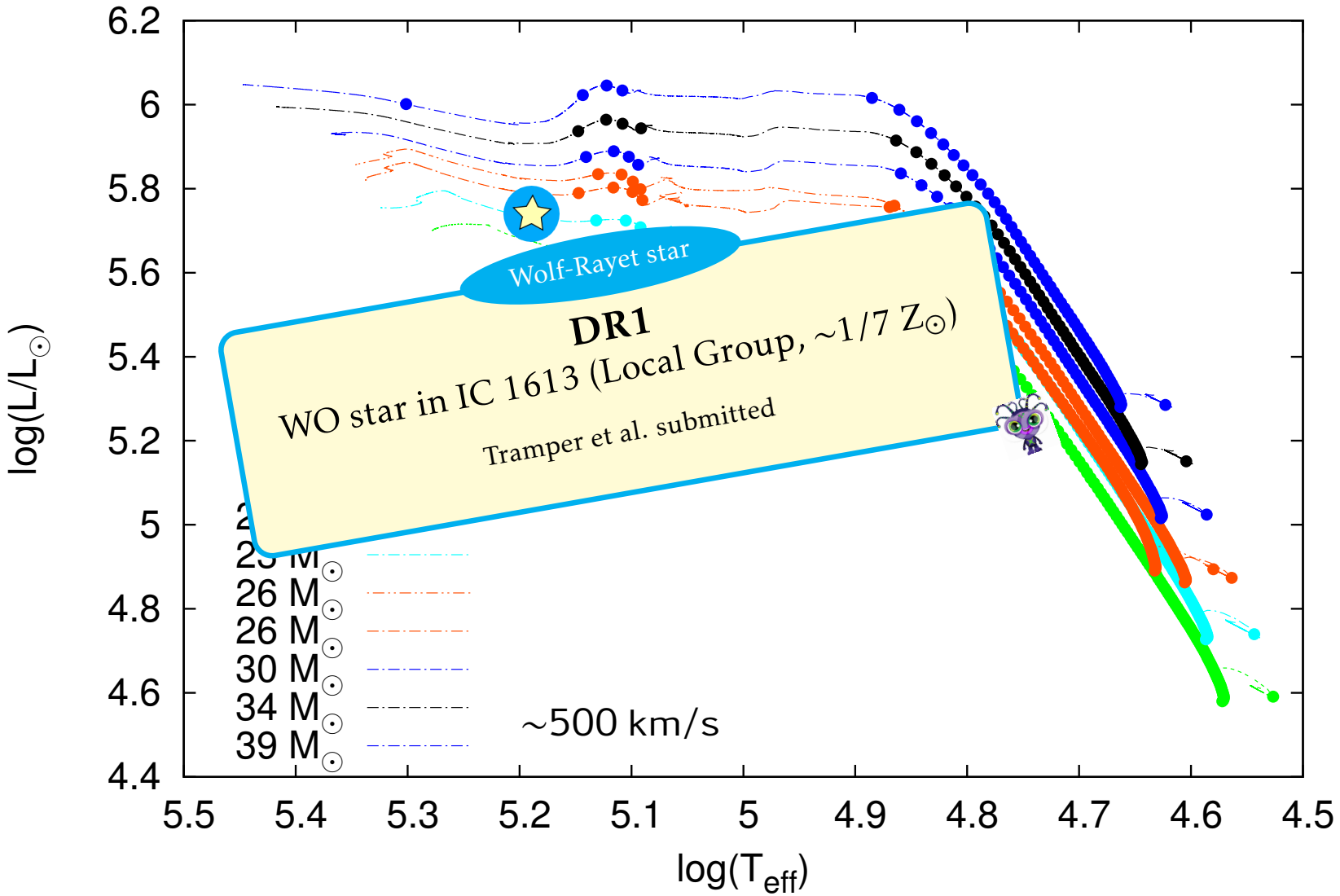
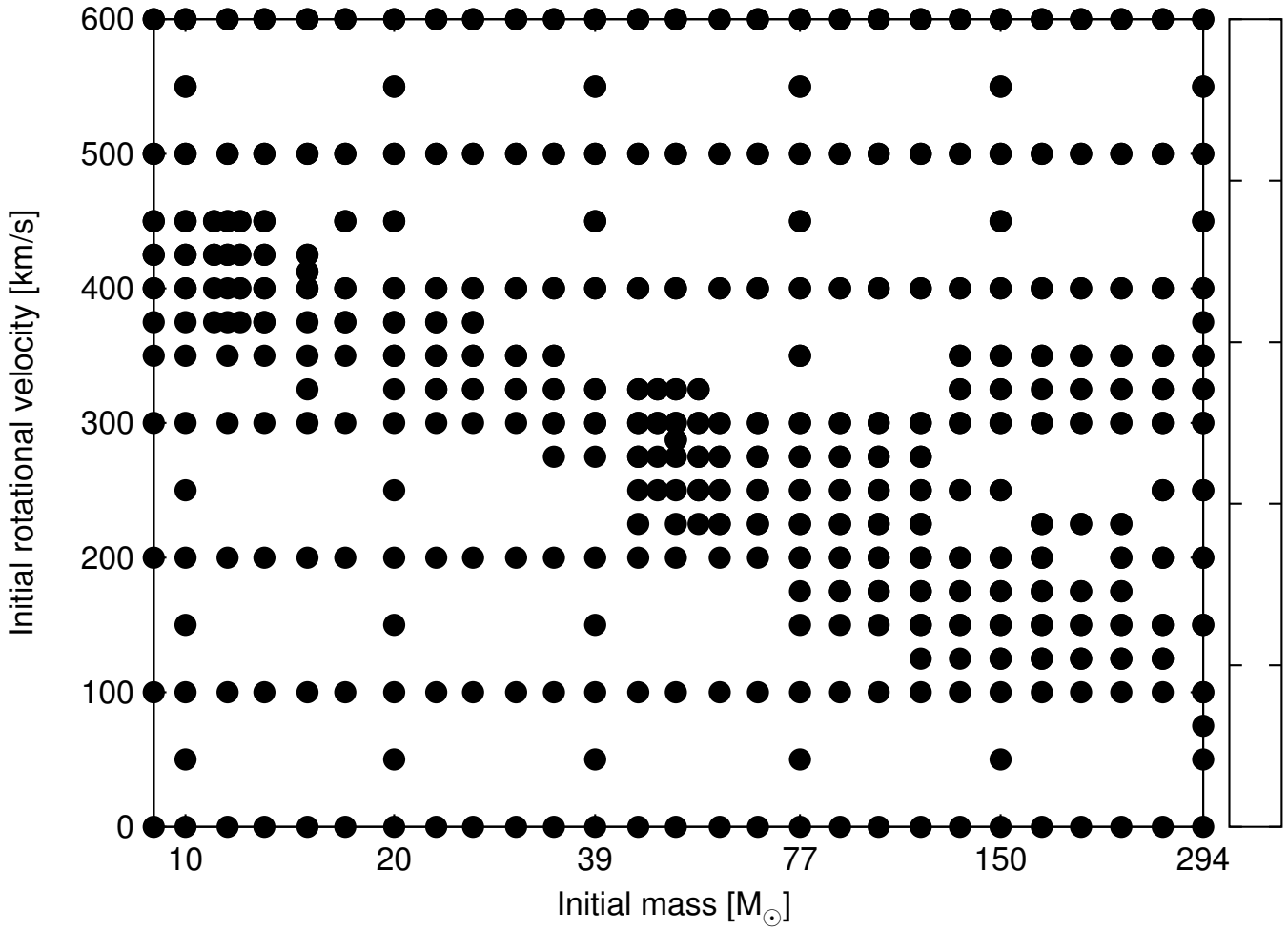


The grid of stellar models



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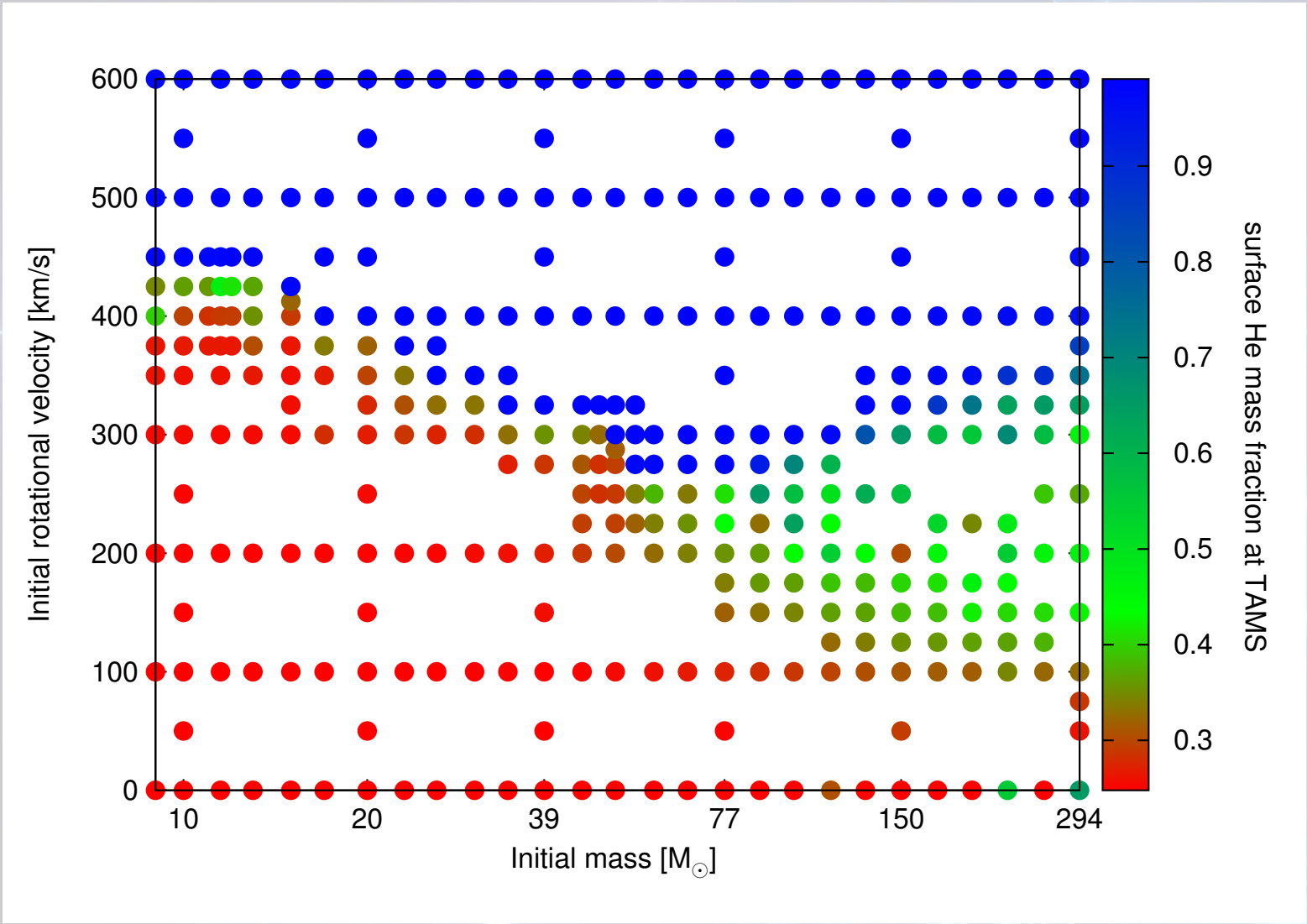

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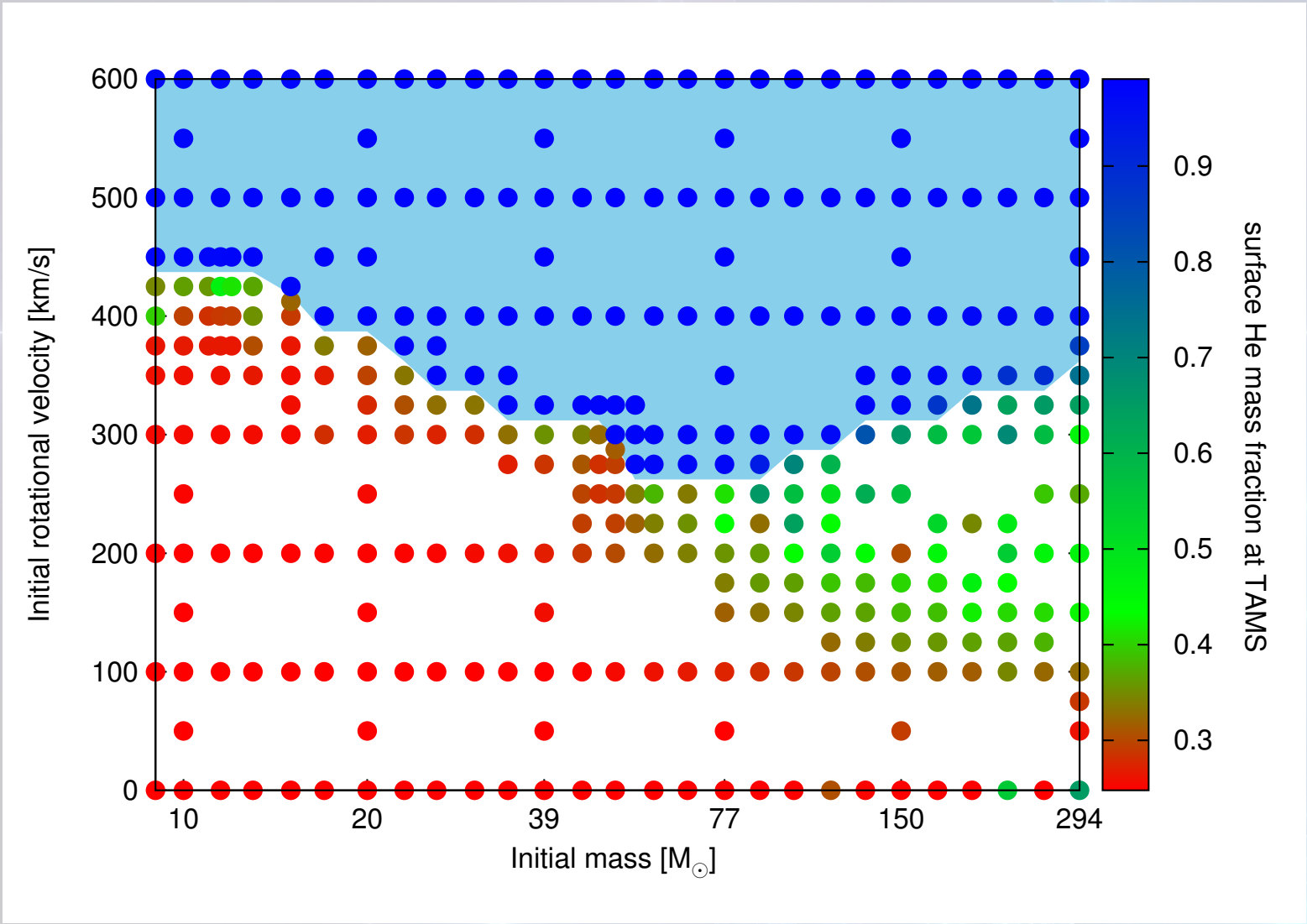

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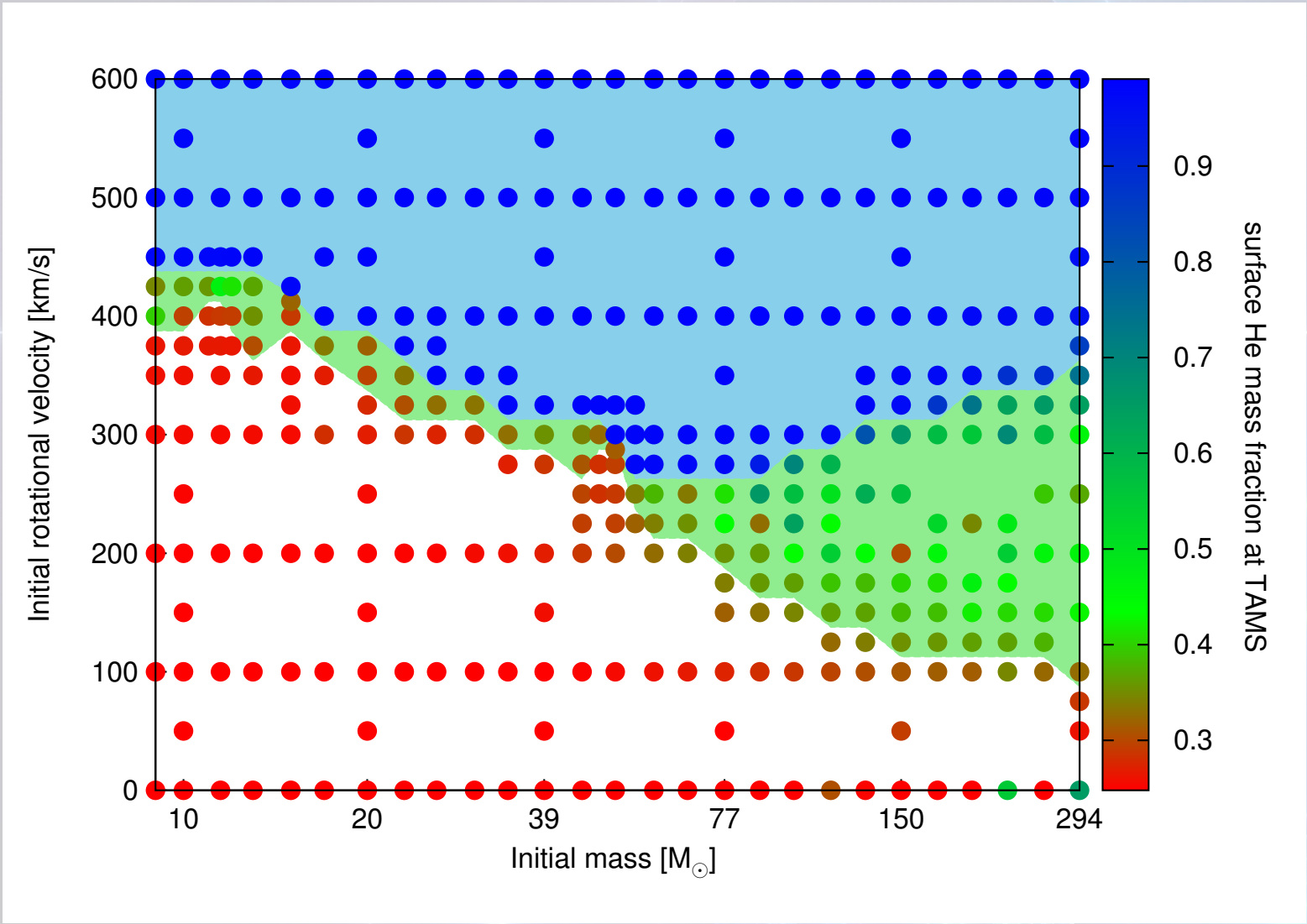

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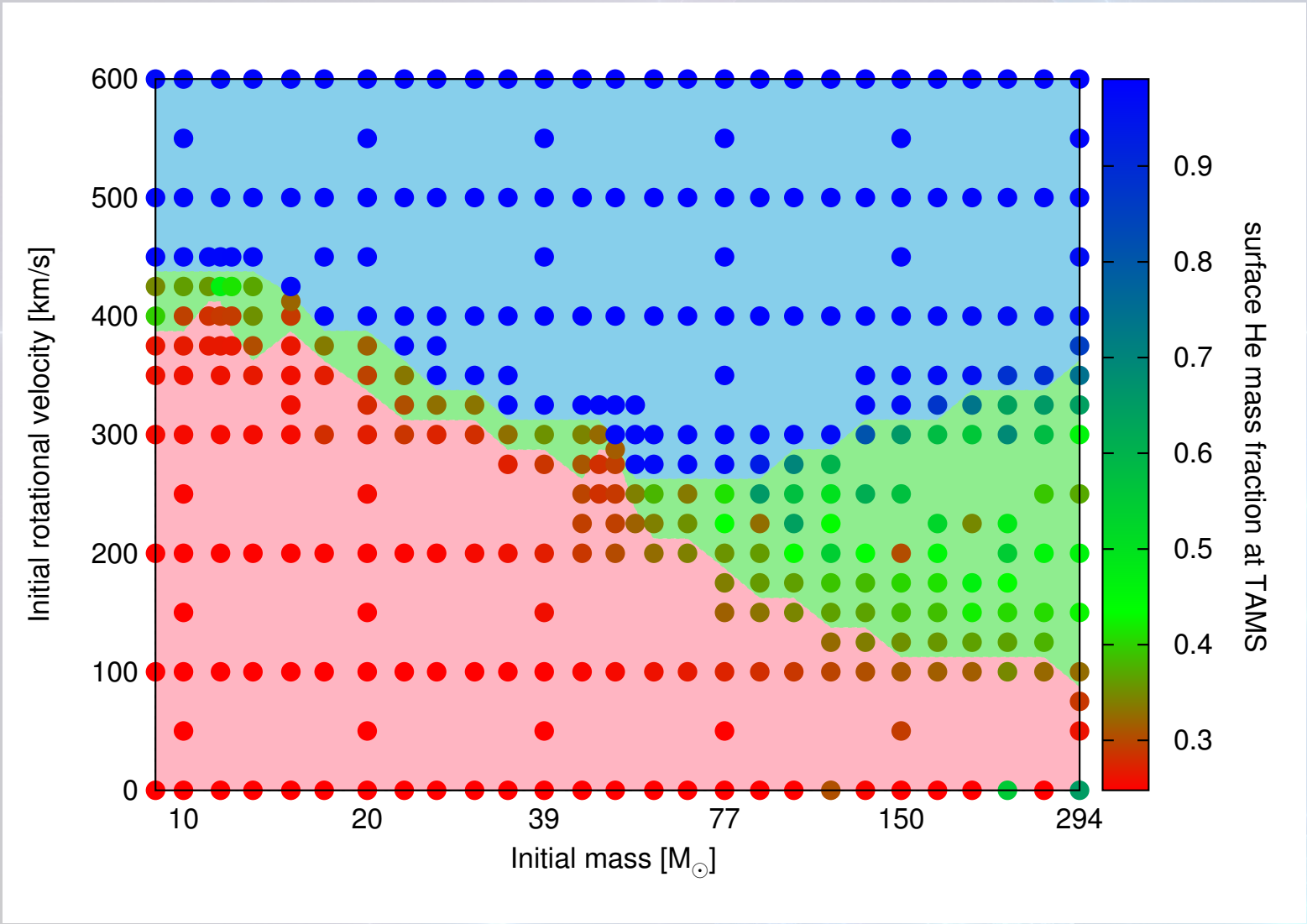

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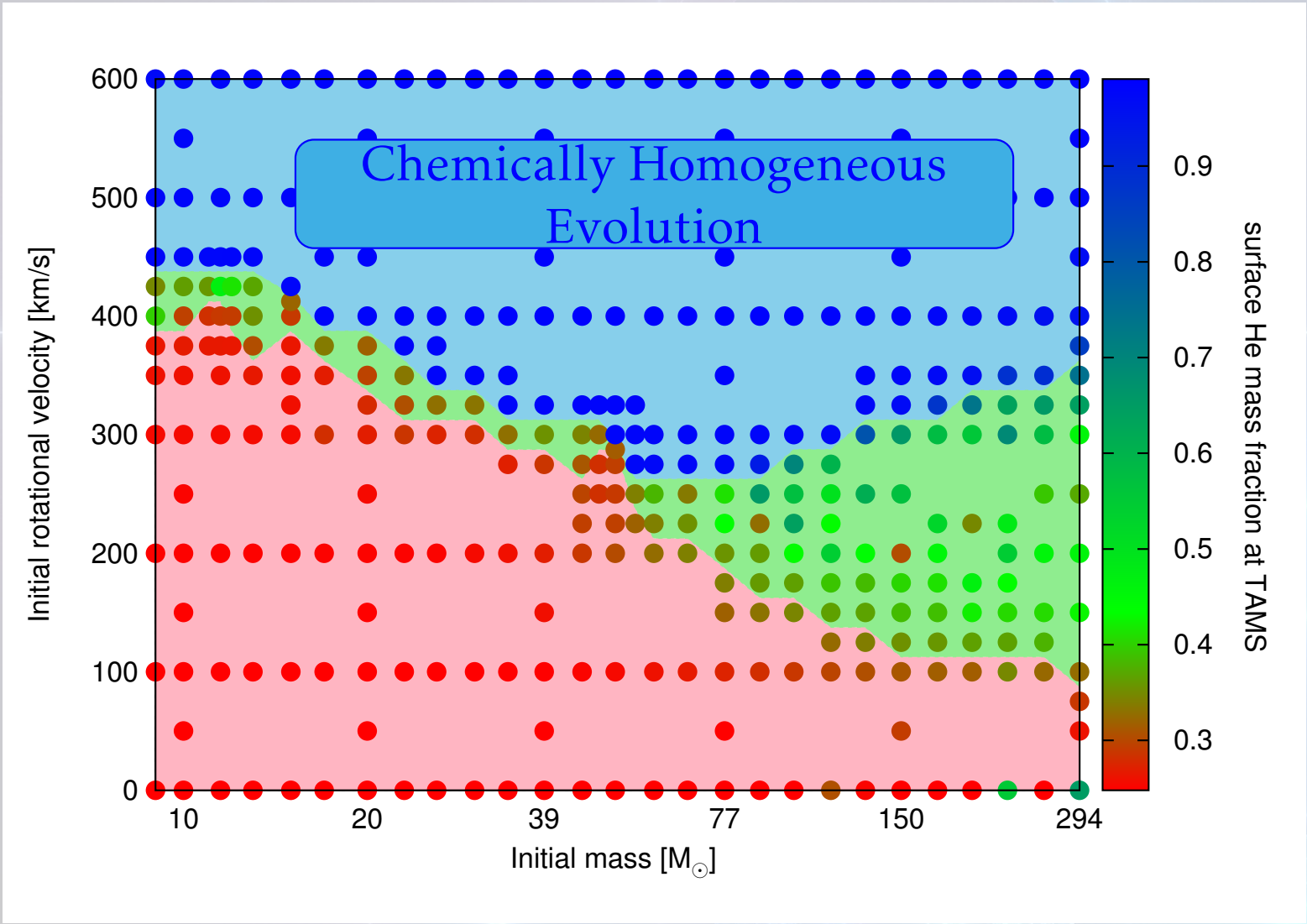
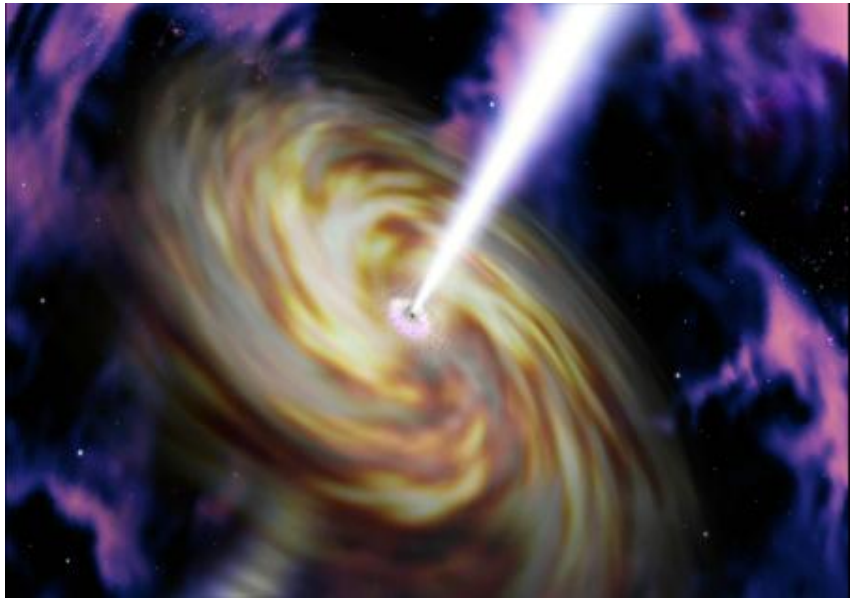


Angular momentum – long duration GRB



Angular momentum – long duration GRB

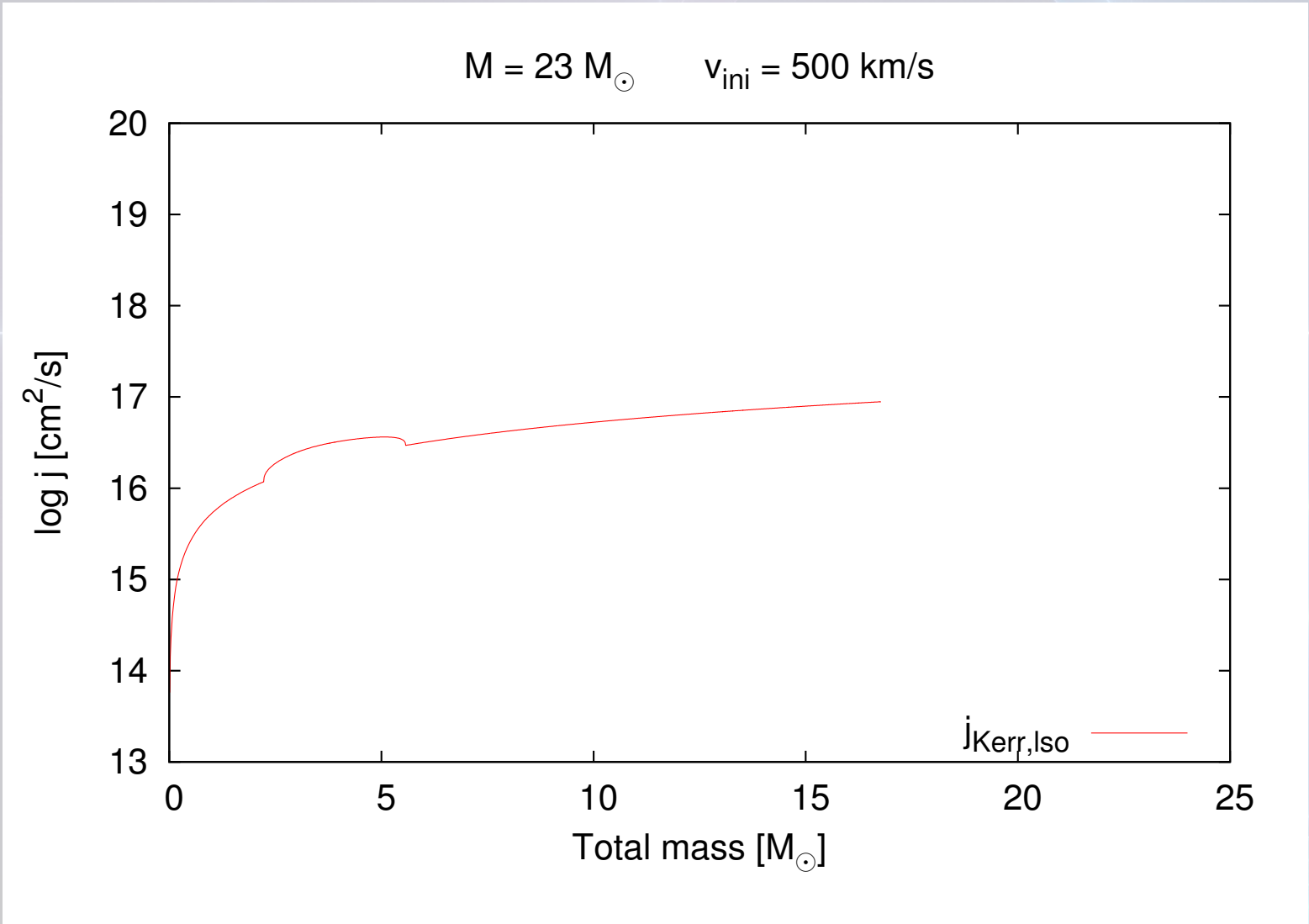
Collapsar

angular momentum in the core is higher than the critical limit for the formation of an accretion disc around a rotating black hole: j_{Kerr}^{iso}

Collapsar Progenitors

I. Star must form a black hole
II. No thick hydrogen envelope
III. Rapid rotation [Fryer 2004]

Angular momentum – long duration GRB



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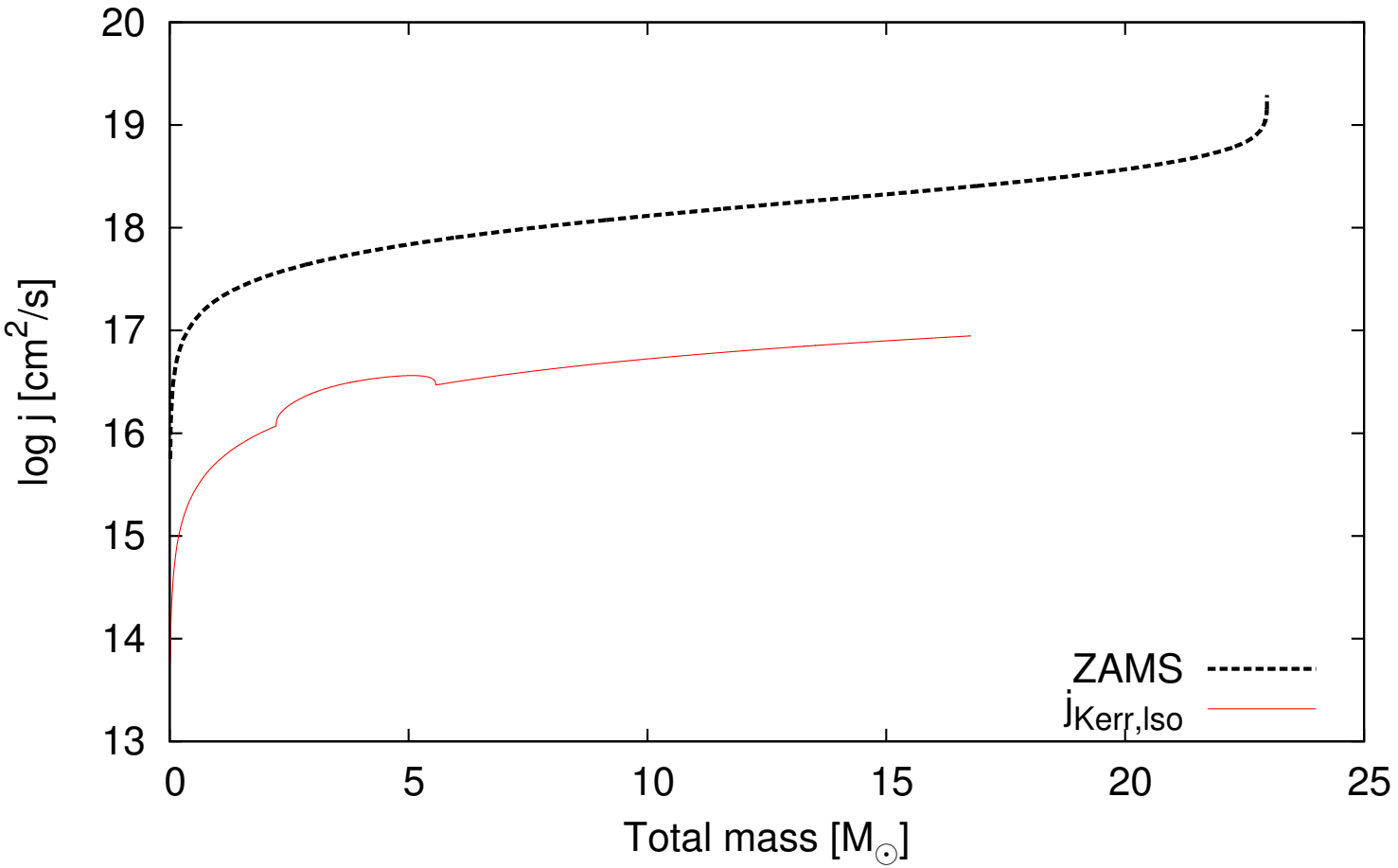

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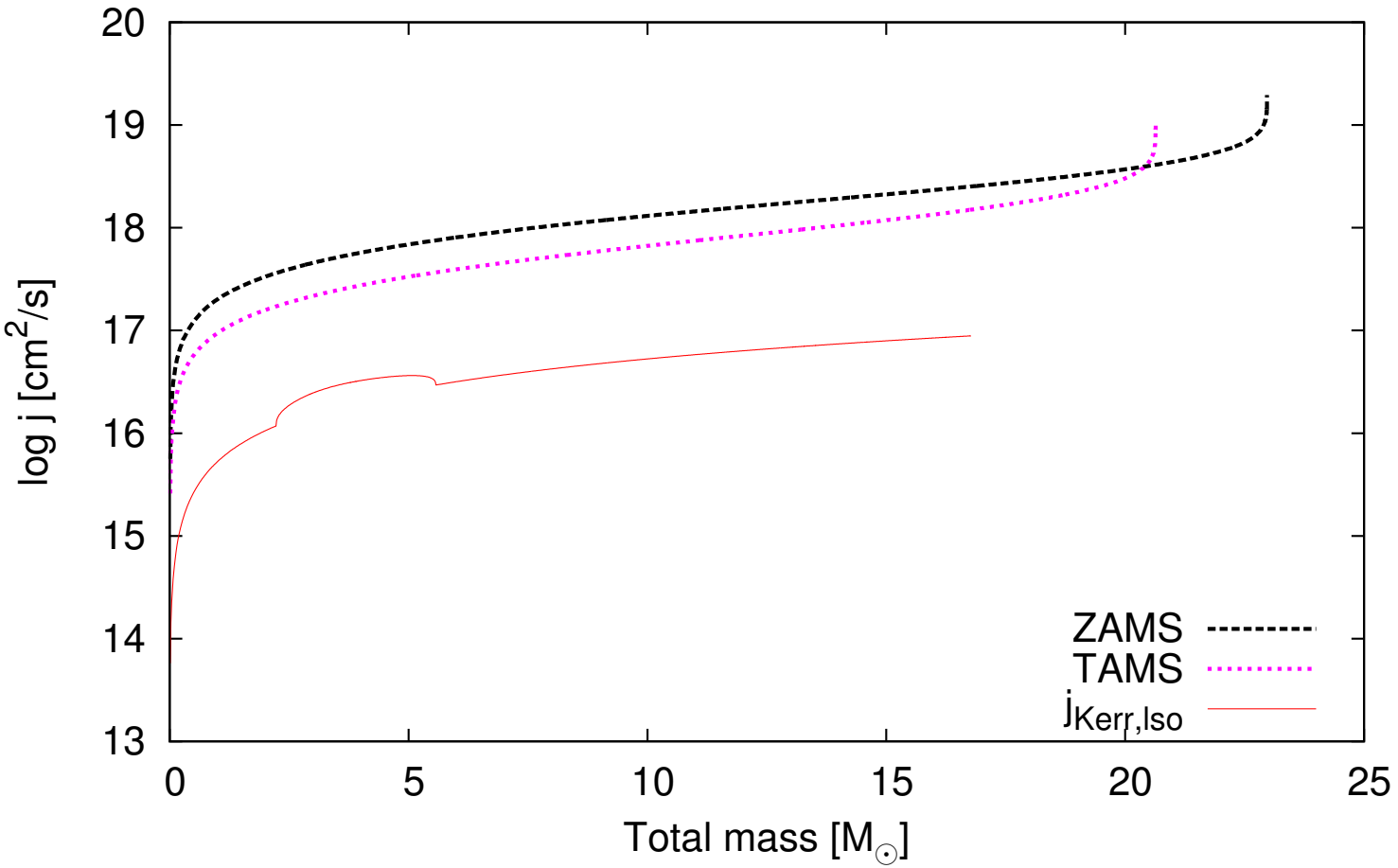

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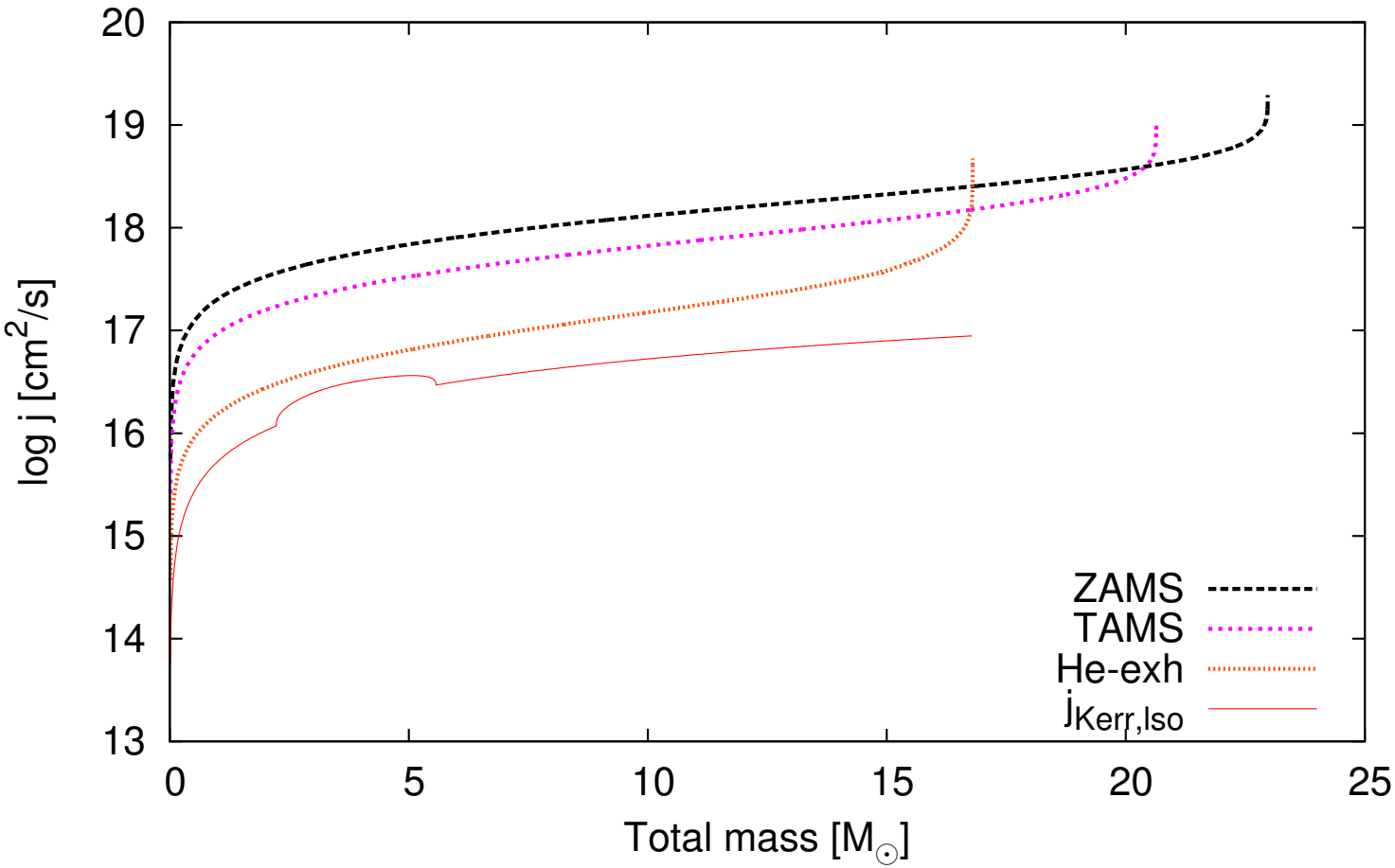

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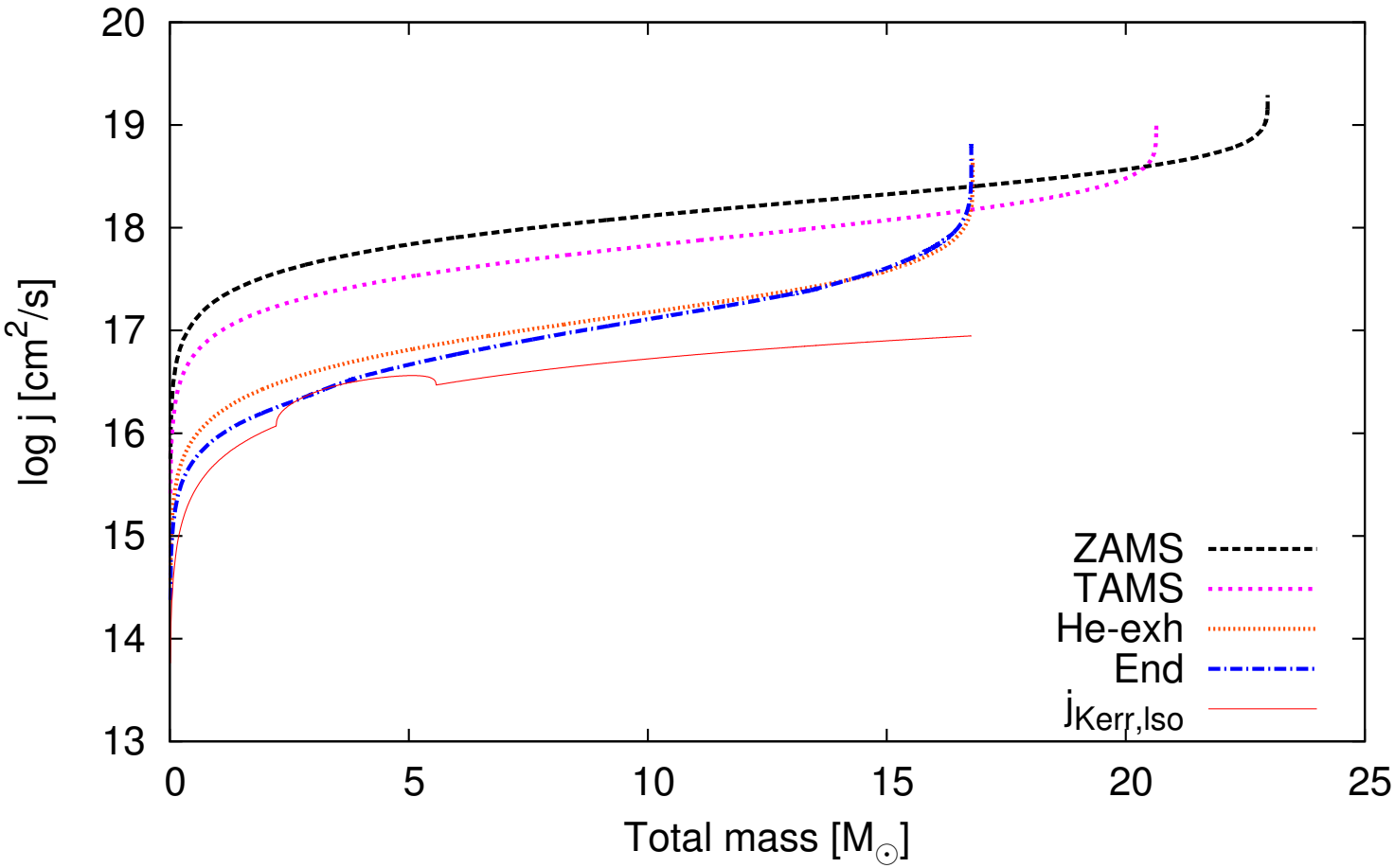

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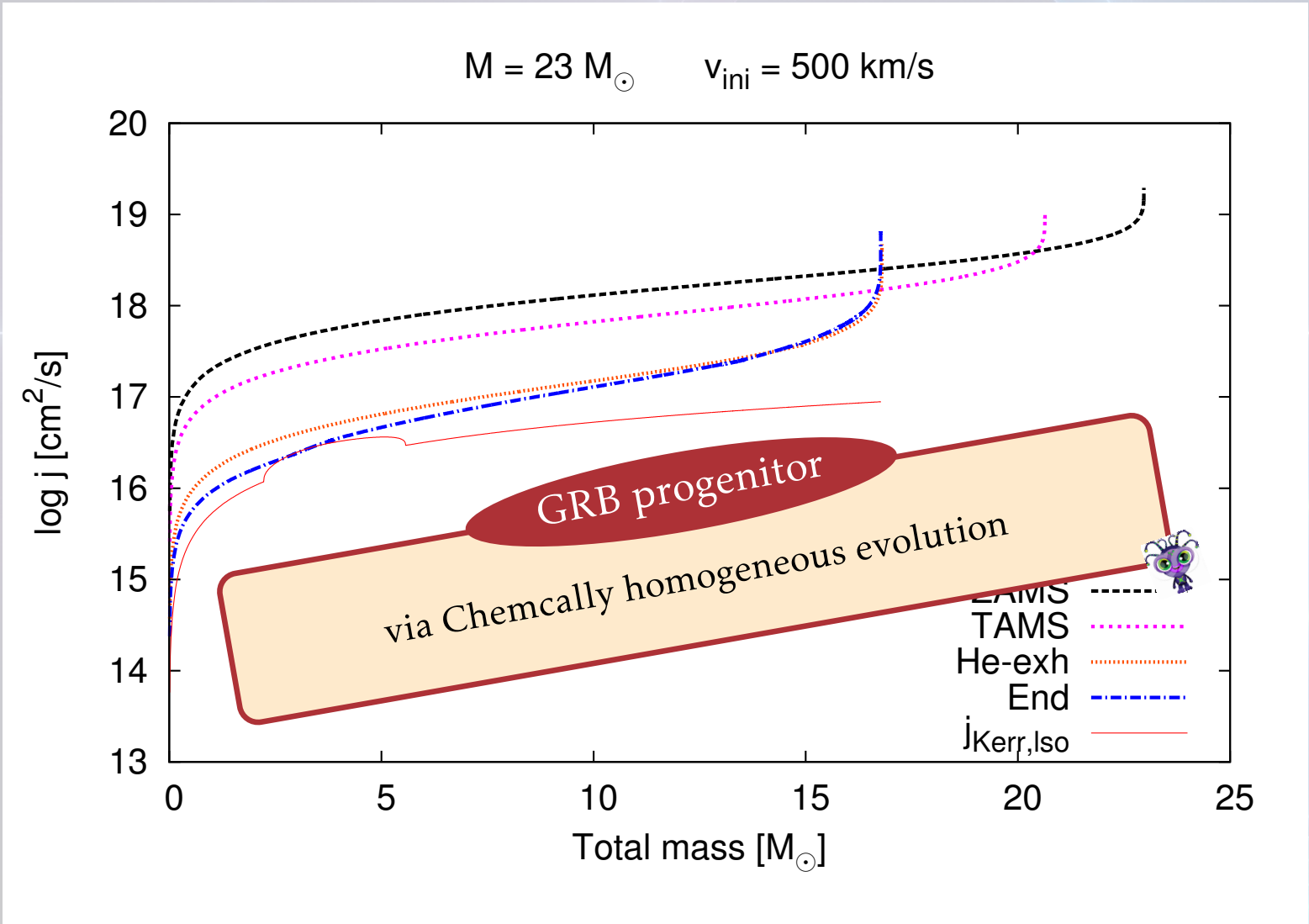

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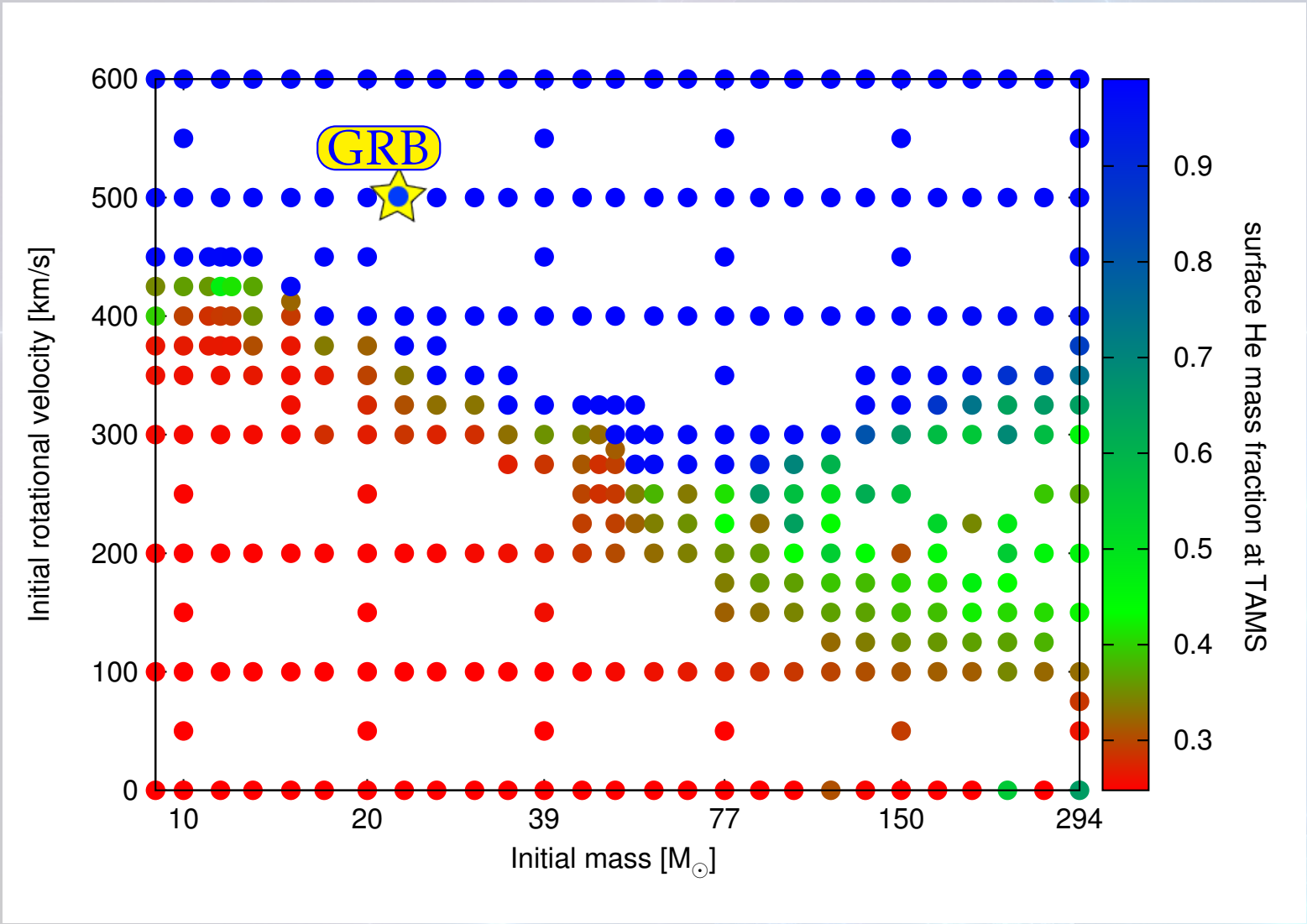

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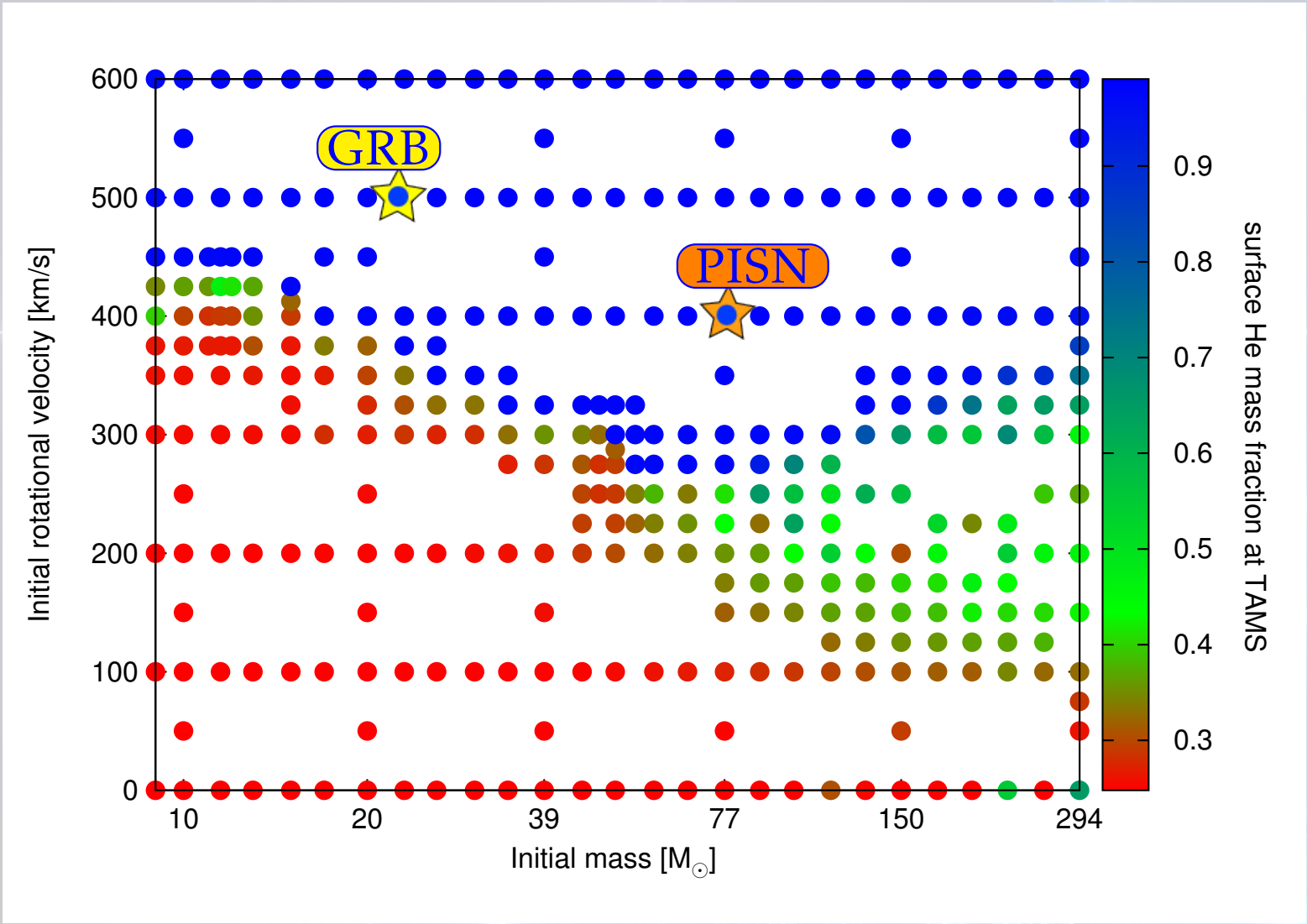
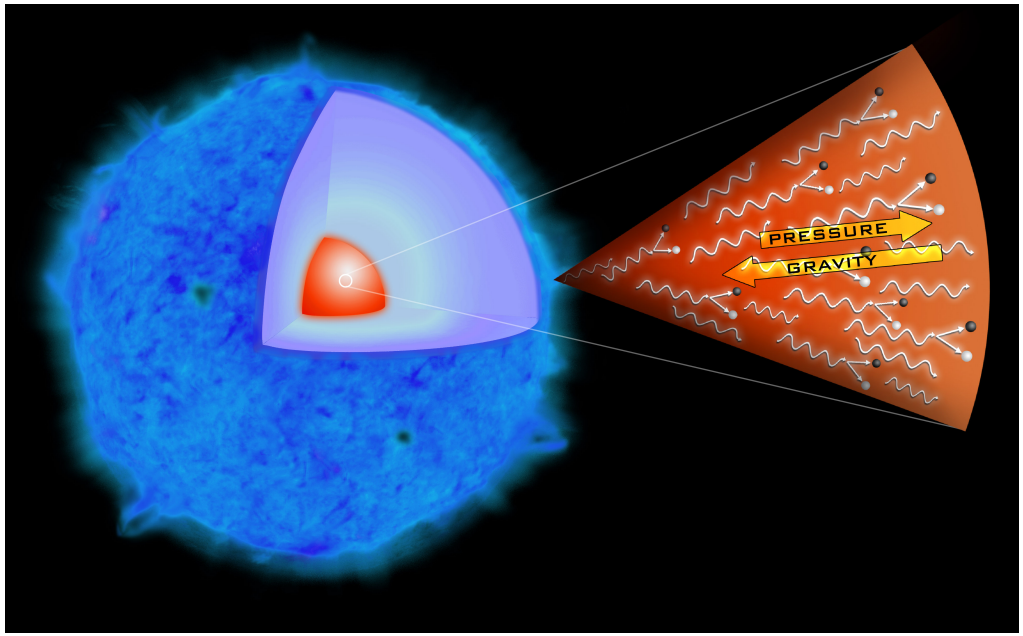


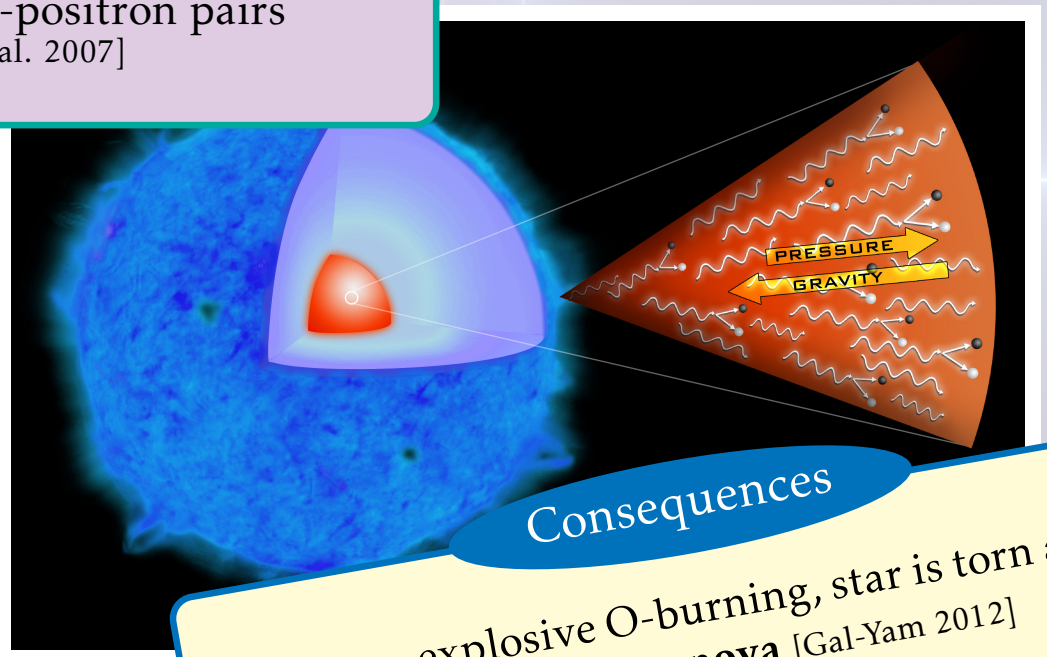
Pair instability supernova



Pair instability supernova

Pair creation

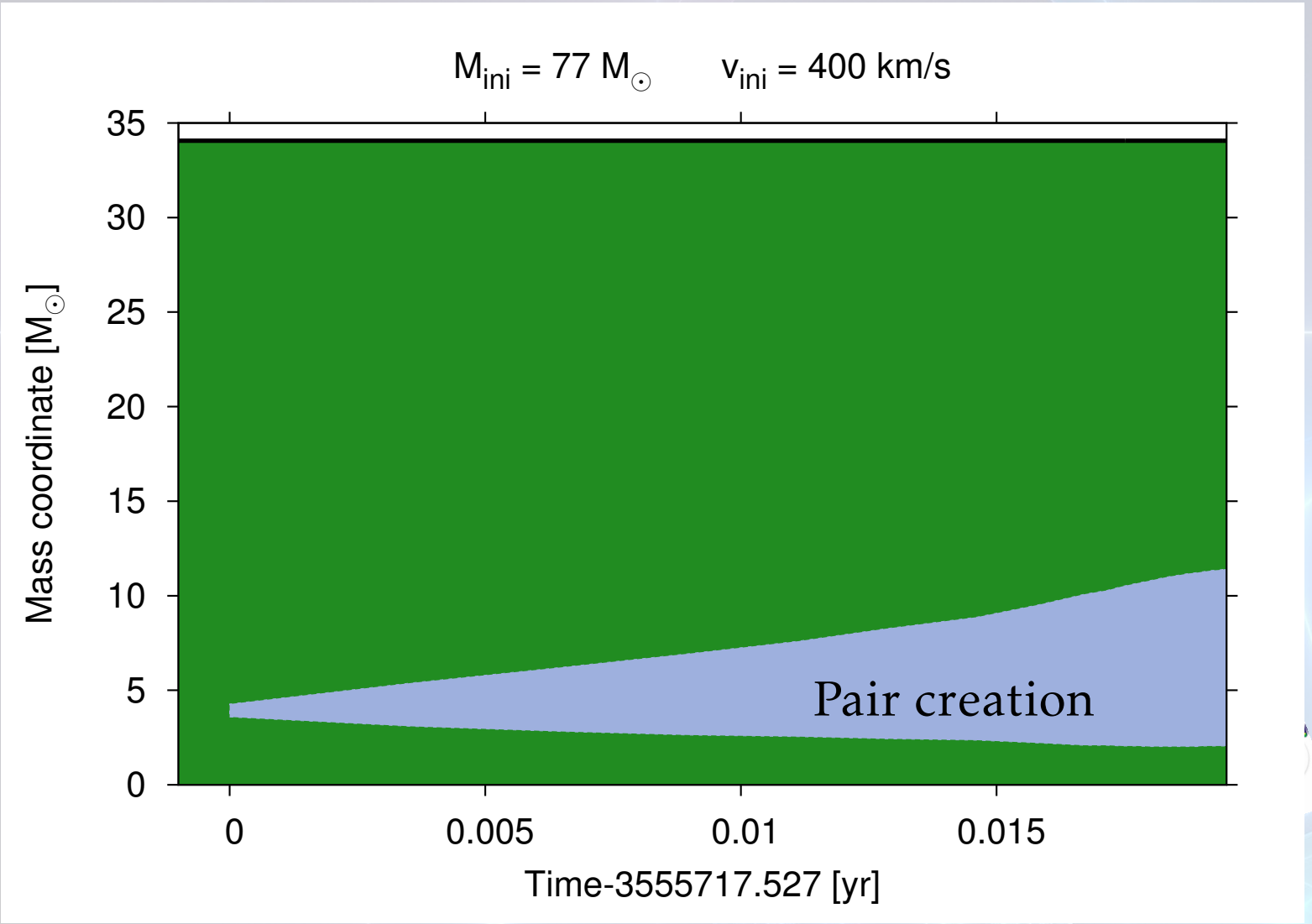
T~ 10^9K:
electron-positron pairs
[Langer et al. 2007]



Consequences

collapse, explosive O-burning, star is torn apart:
Superluminous Supernova [Gal-Yam 2012]
enrichment of ISM, no remnant

Pair instability supernova



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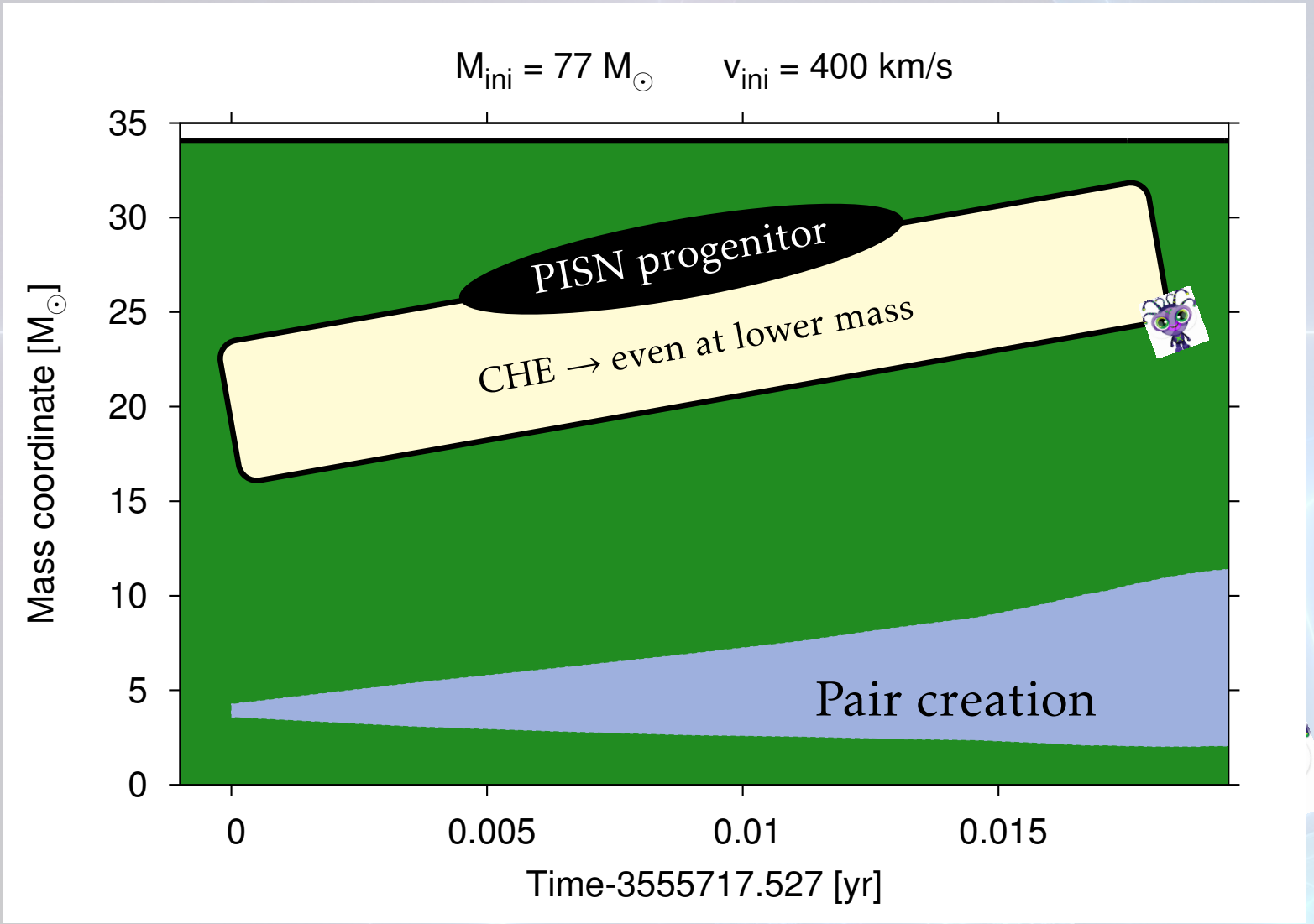
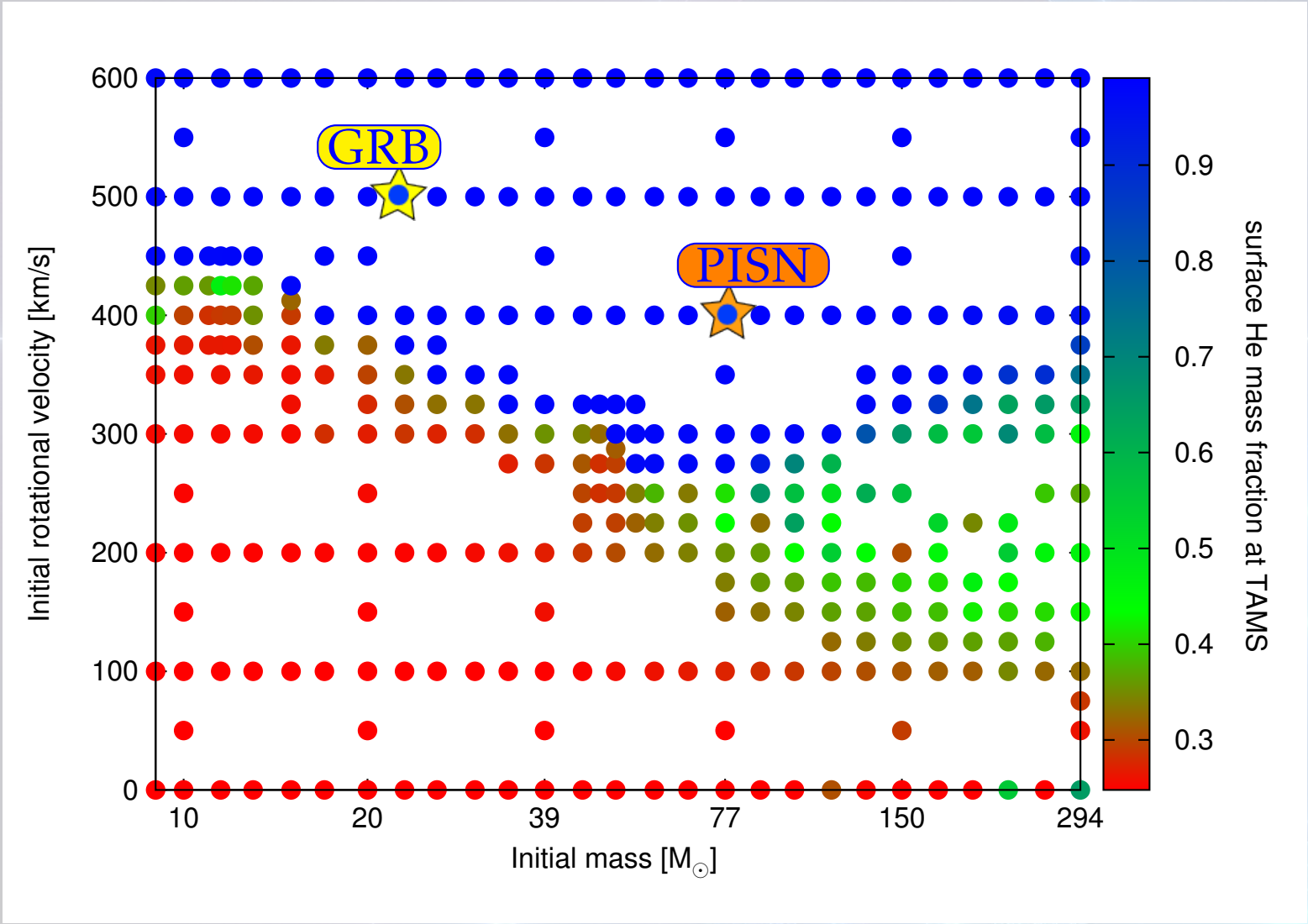


Final fates


GRB
PISN
600
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294
Initial rotational velocity [km/s]
Initial mass [M⊙]
0.9
0.8
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0.6
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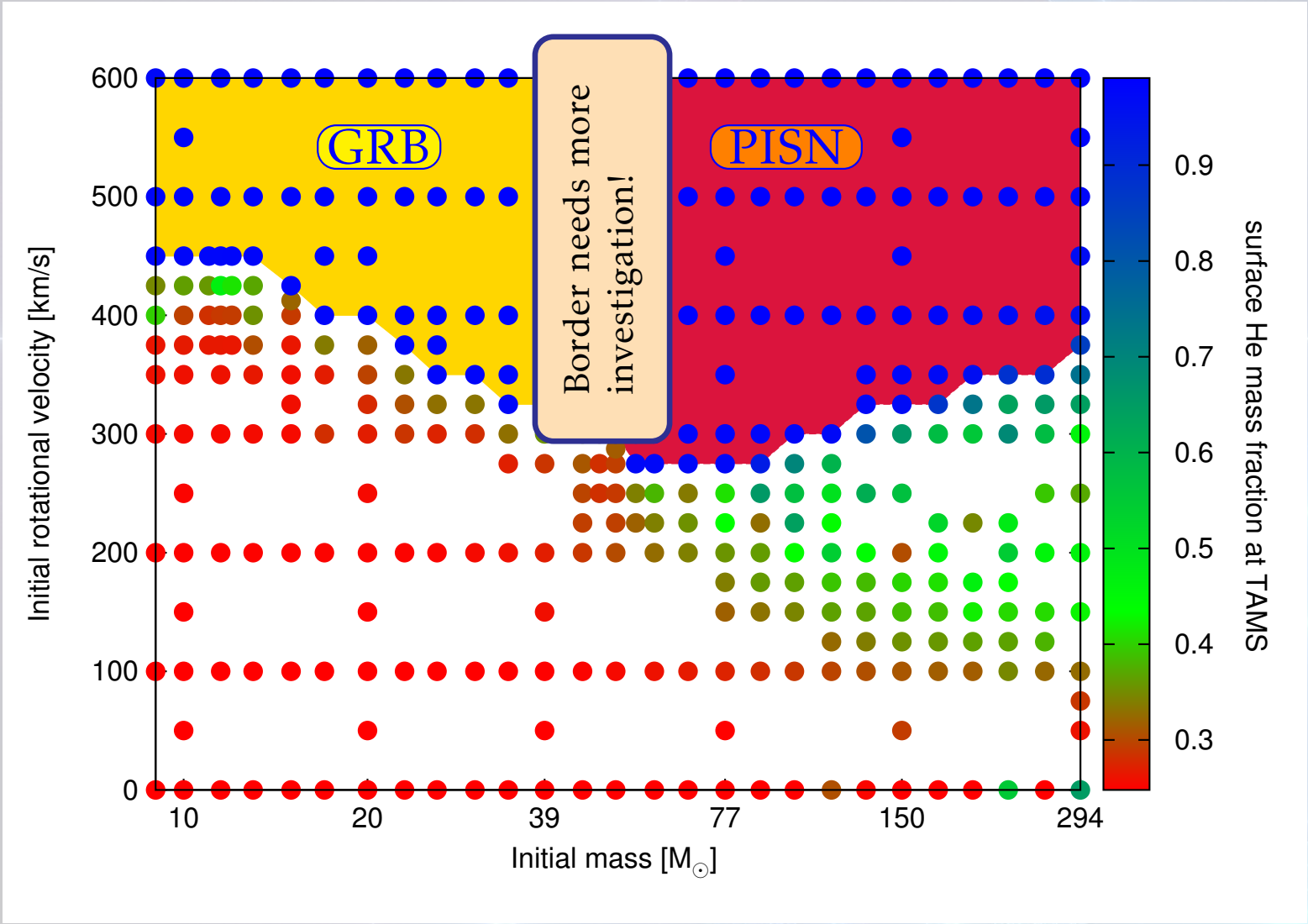
0.4
0.3
surface He mass fraction at TAMS

Final fates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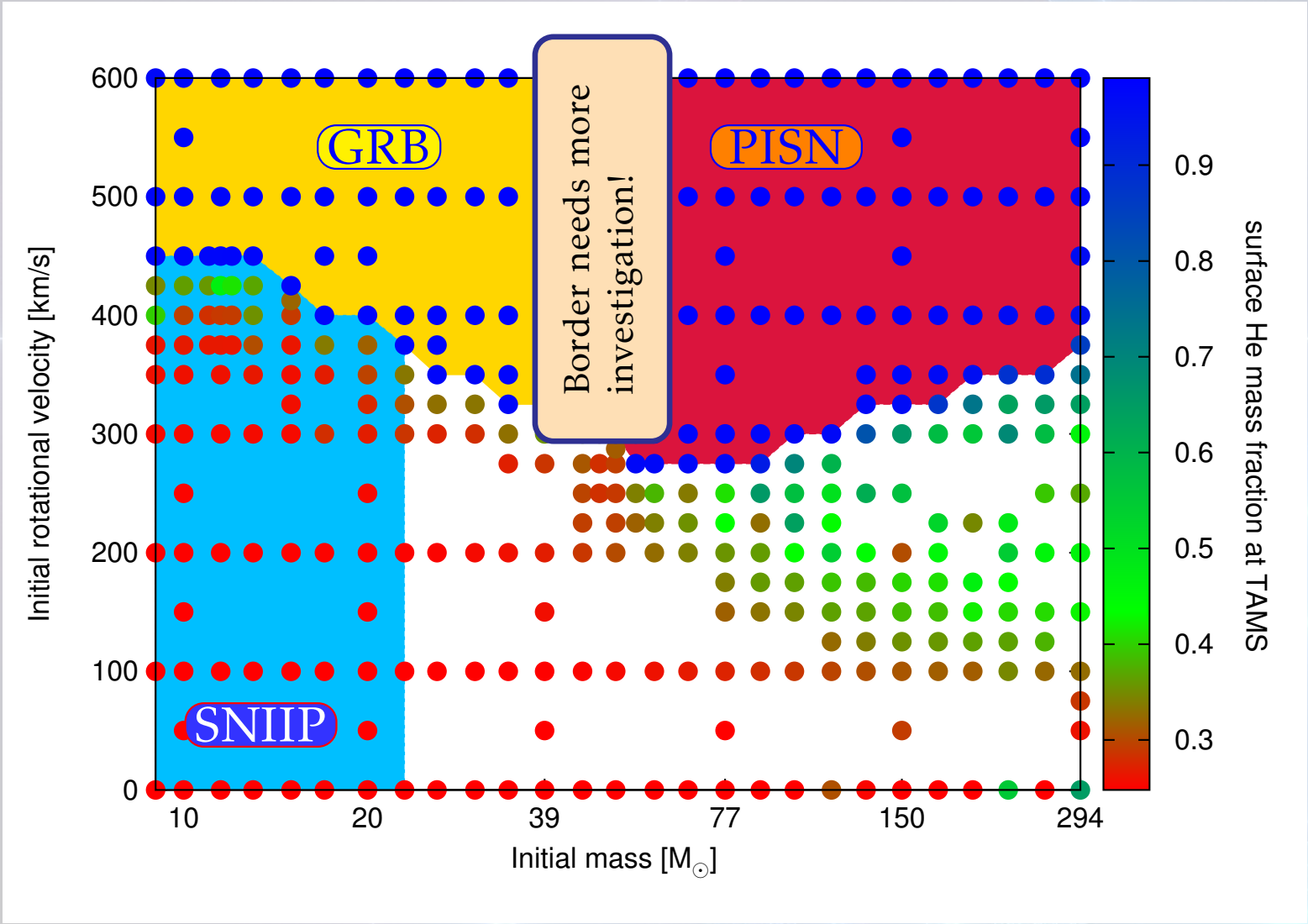
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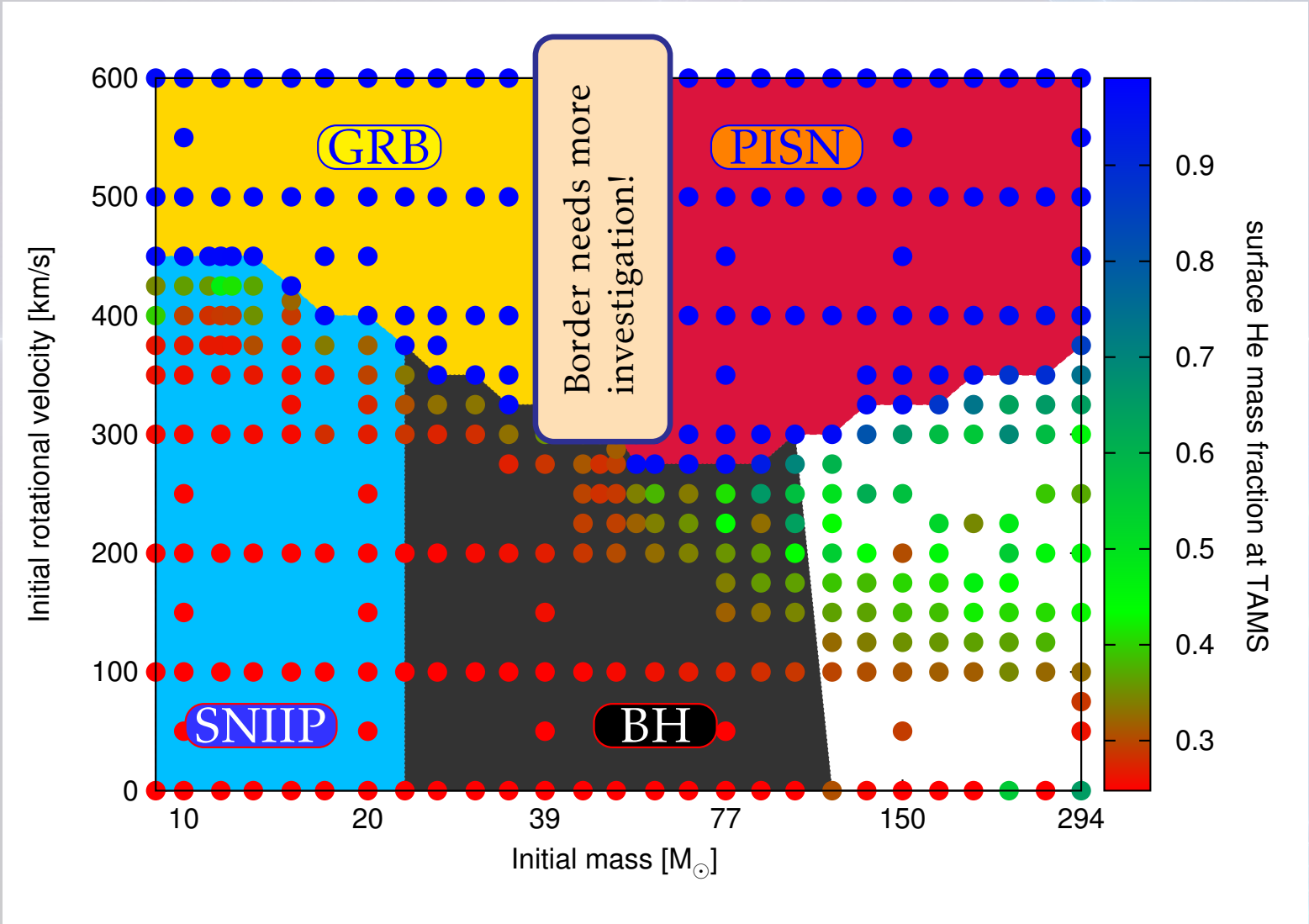
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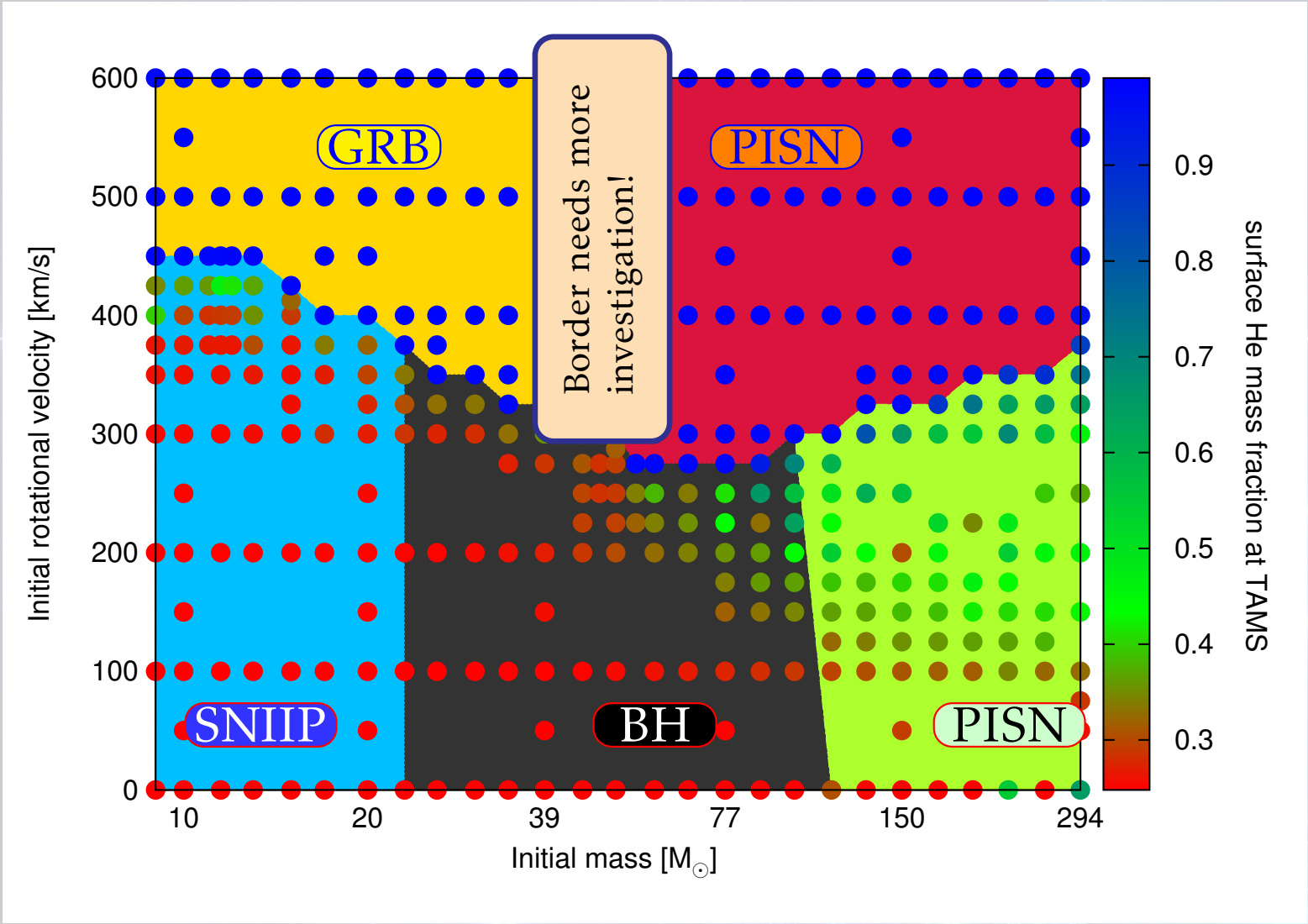
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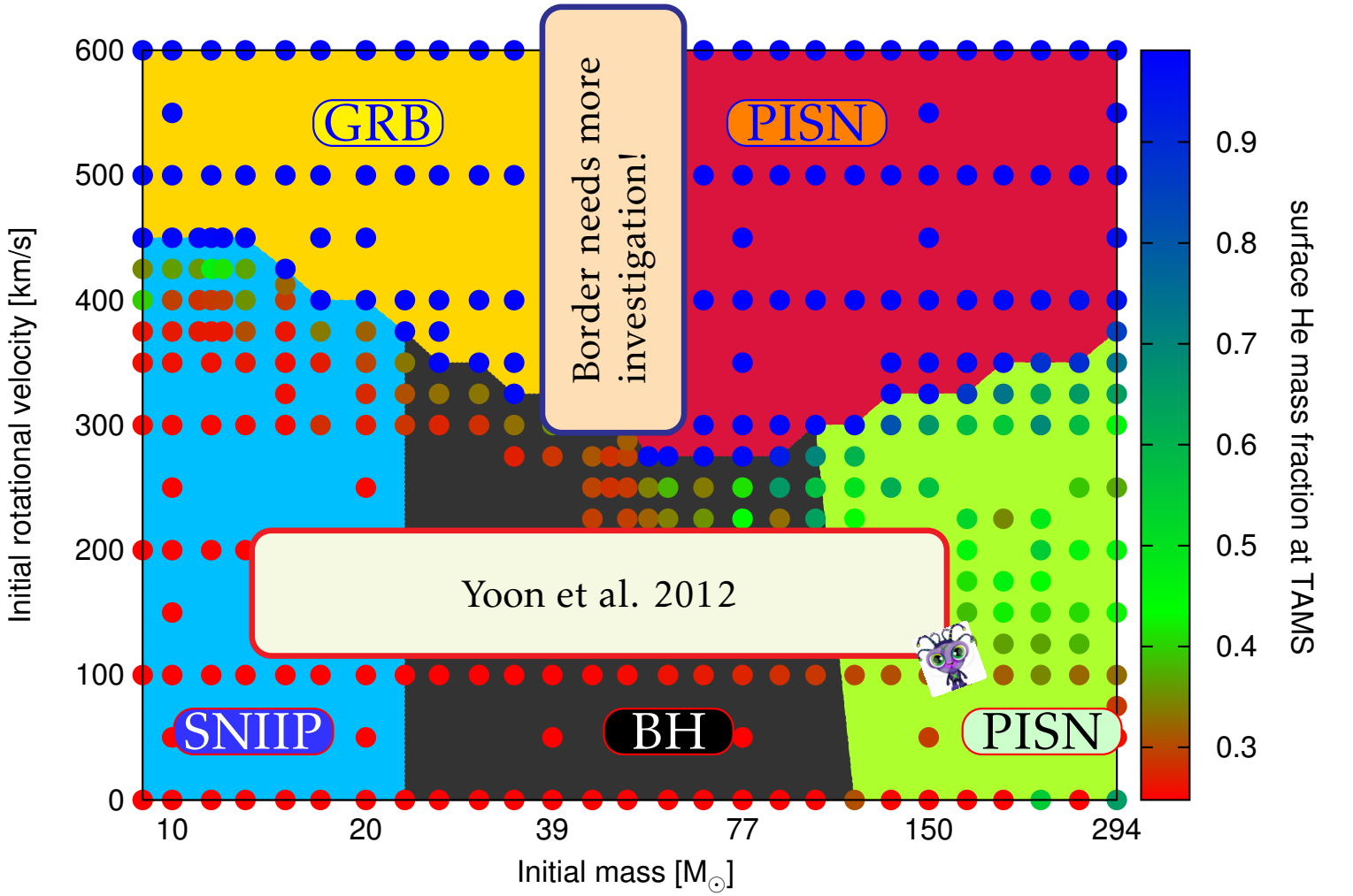
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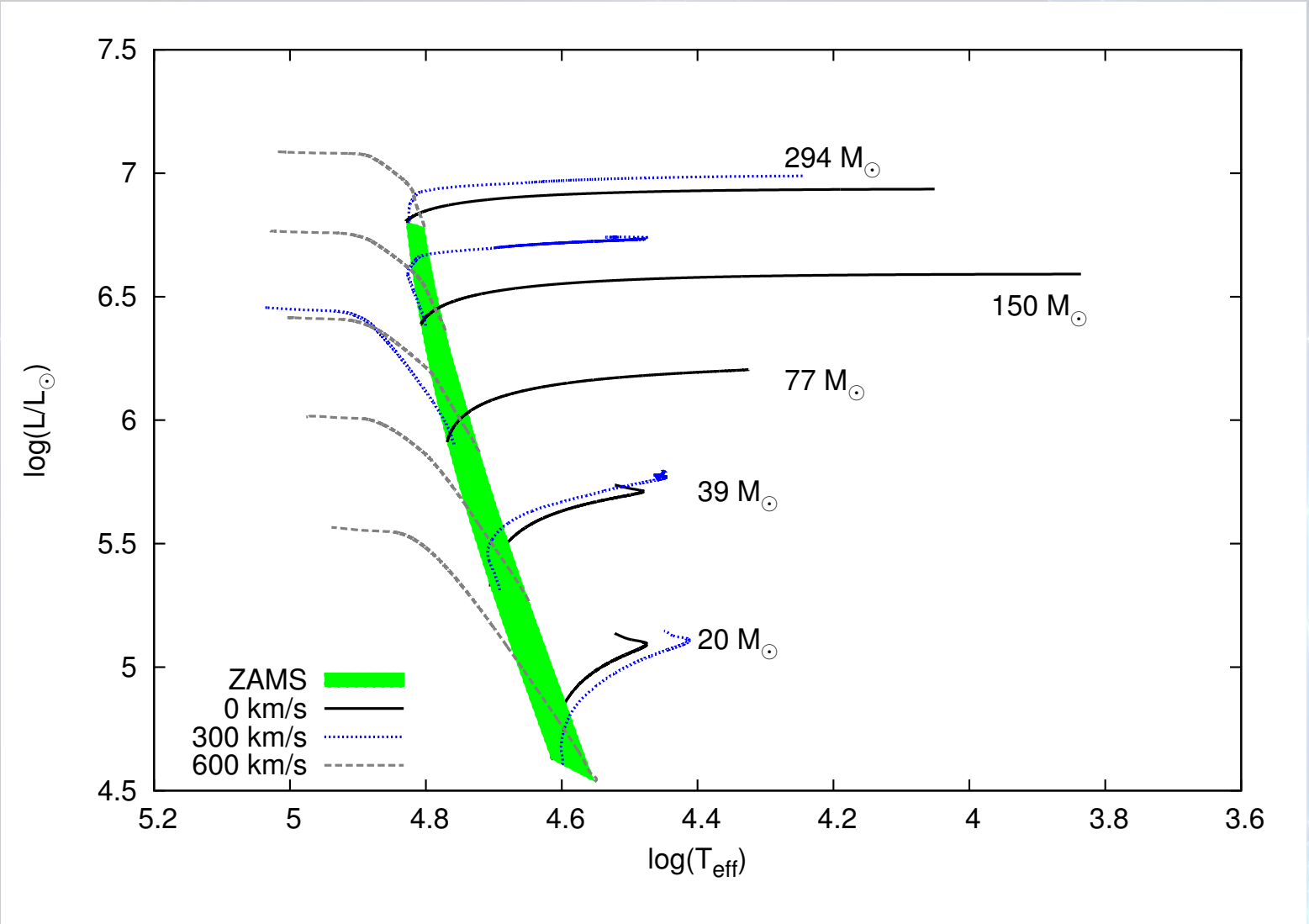
Photoionization fluxes



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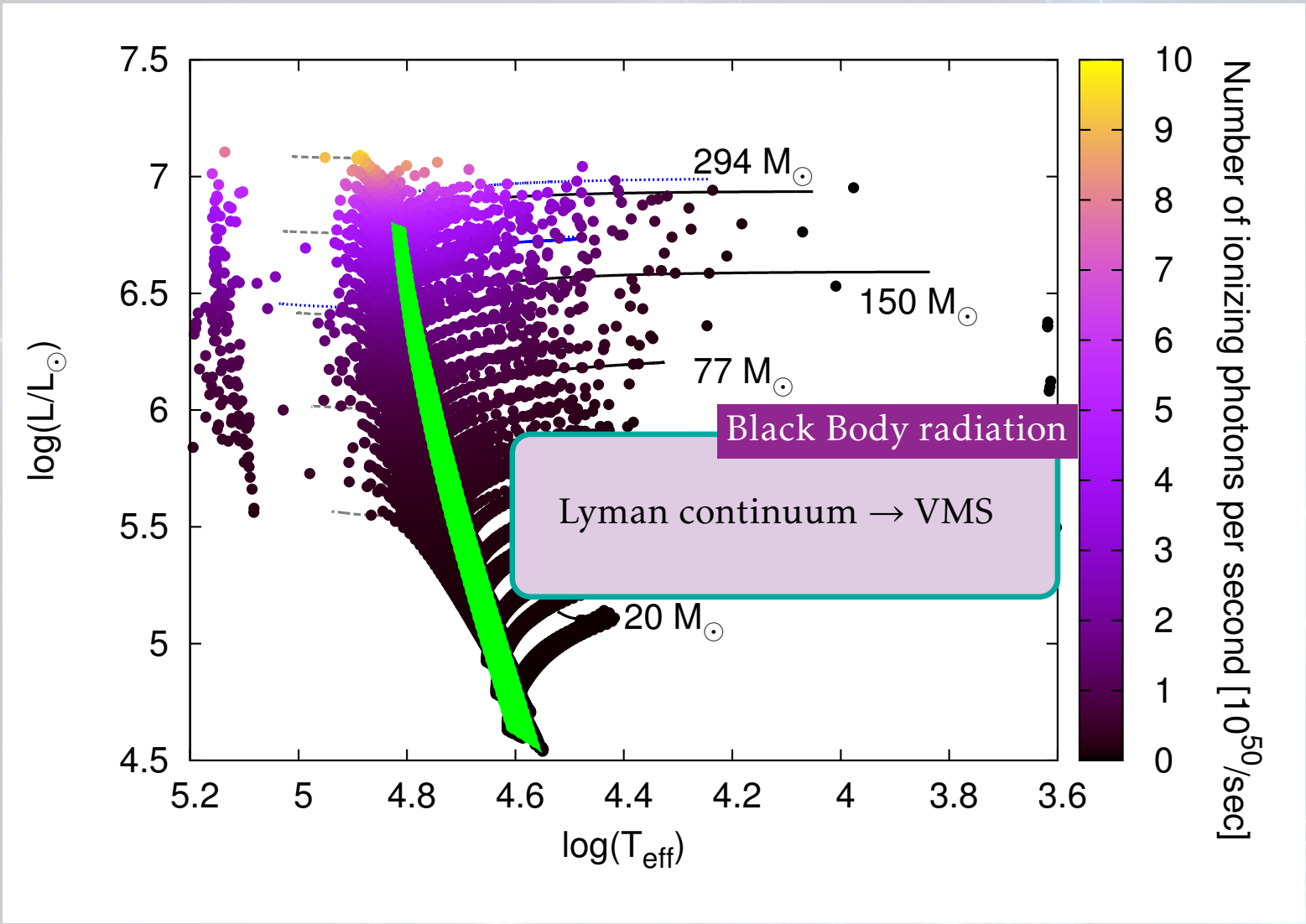

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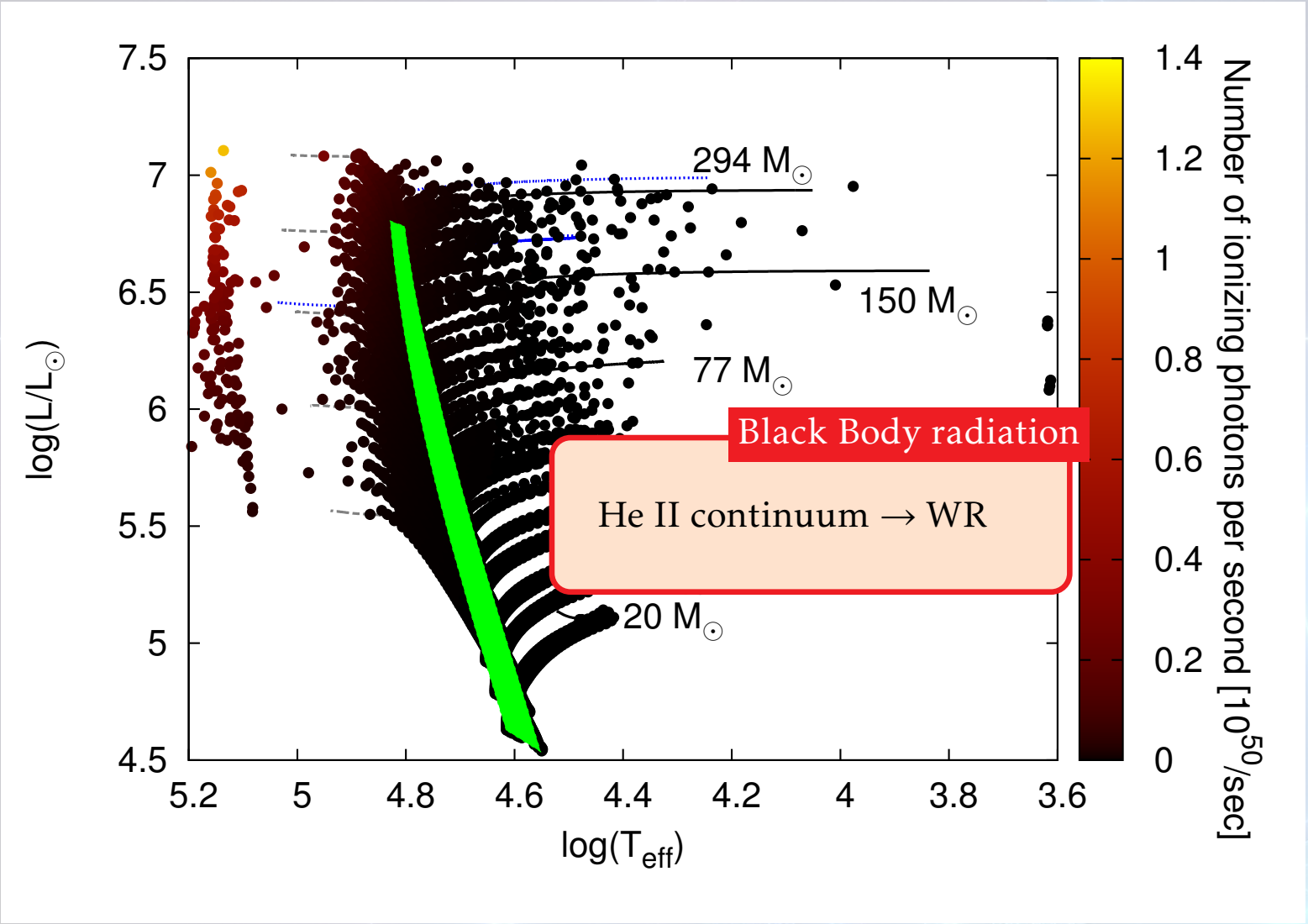
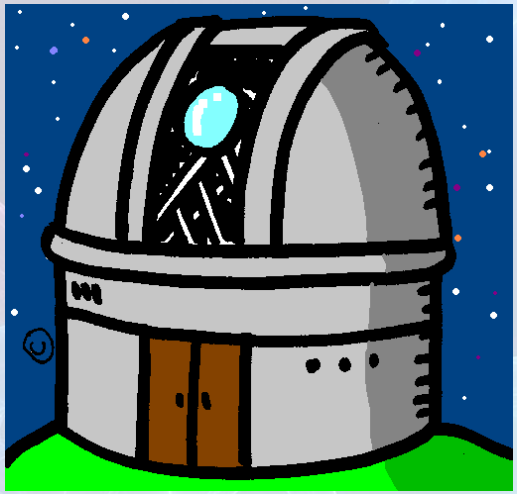


Request for observations!



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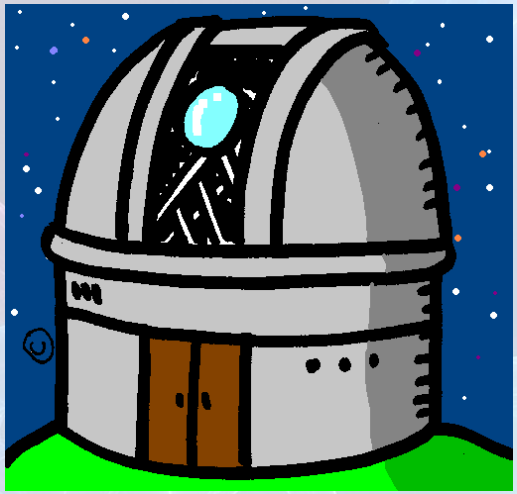

Request for observations!

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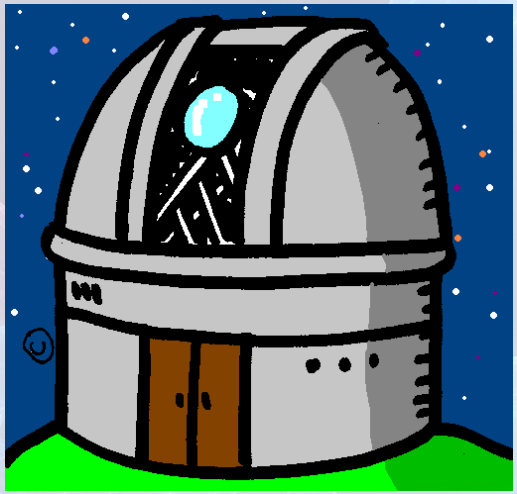
Blue Compact Dwarf Galaxies:
Massive stars at low metallicity



Conclusion and Outlook

- Low metallicity: $0.1 \times Z_{SMC} \rightarrow$
  - very massive stars
  - chemically homogeneous stars
  - long duration GRBs
  - Pair Instability SNe
  - Wolf-Rayet stars

- Binarity is important
  (PhD project of Nicolás González-Jiménez)
- Future: match results to observations,
  update theory of massive stellar evolution

[References]

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

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

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

- Low metallicity environments are important for studying massive stellar evolution
- Needed: detailed observational data of massive stars at low metallicity → BCDs

Thank you for your attention!

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