GRBs and Stellar Evolution: A Review of Progenitor Theories

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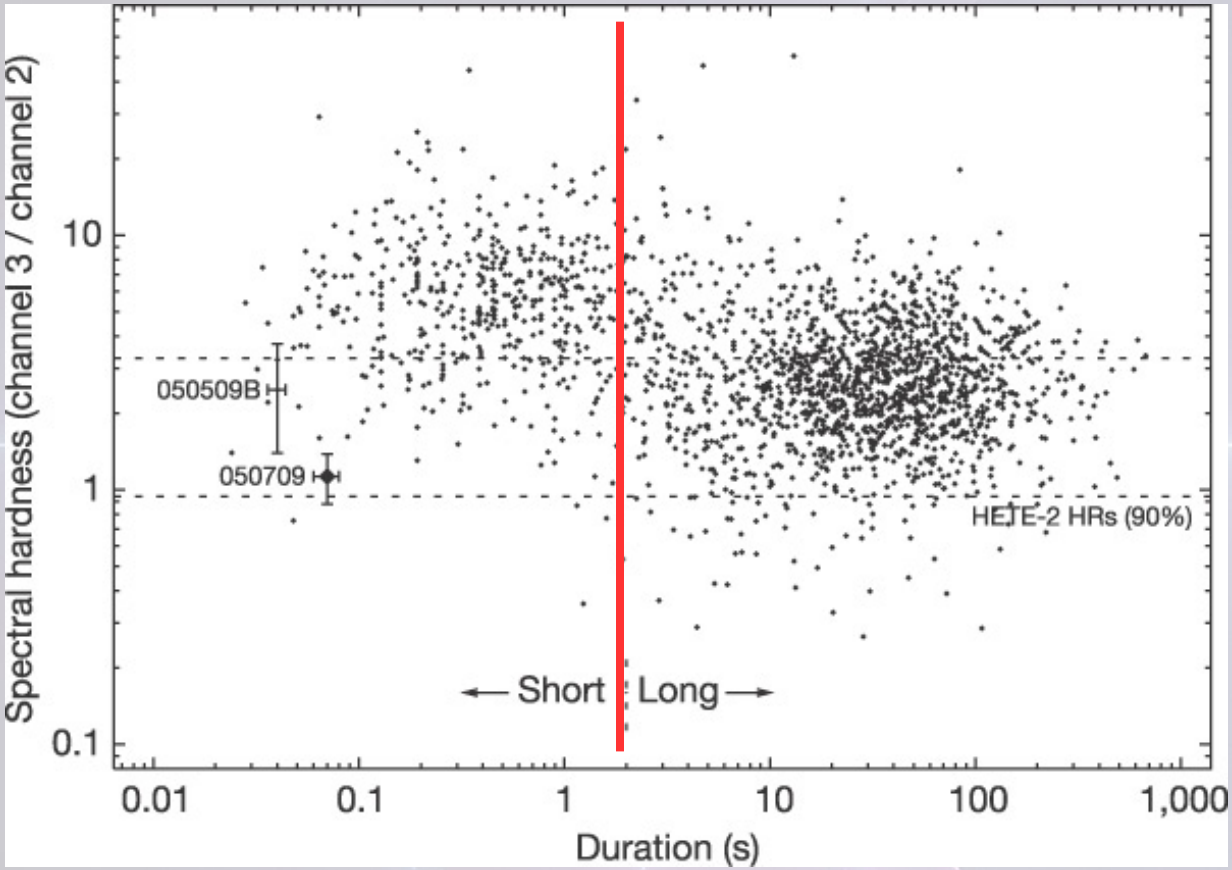
European Weak of Astronomy and Space Sciences (EWASS)

Prague, 26th June 2017

At least two, physically distinct types of objects



Credit: Hjorth+2005

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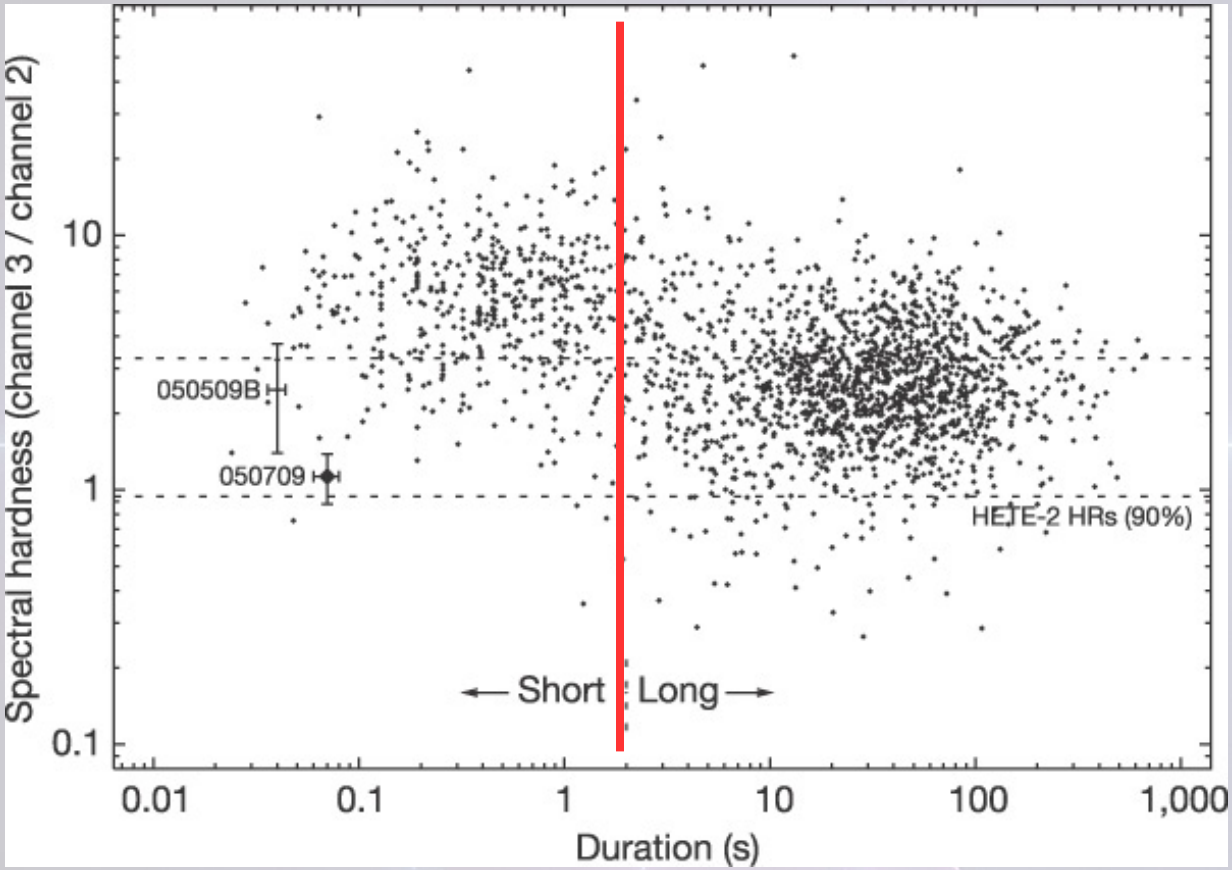

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Massive Stars at collapse

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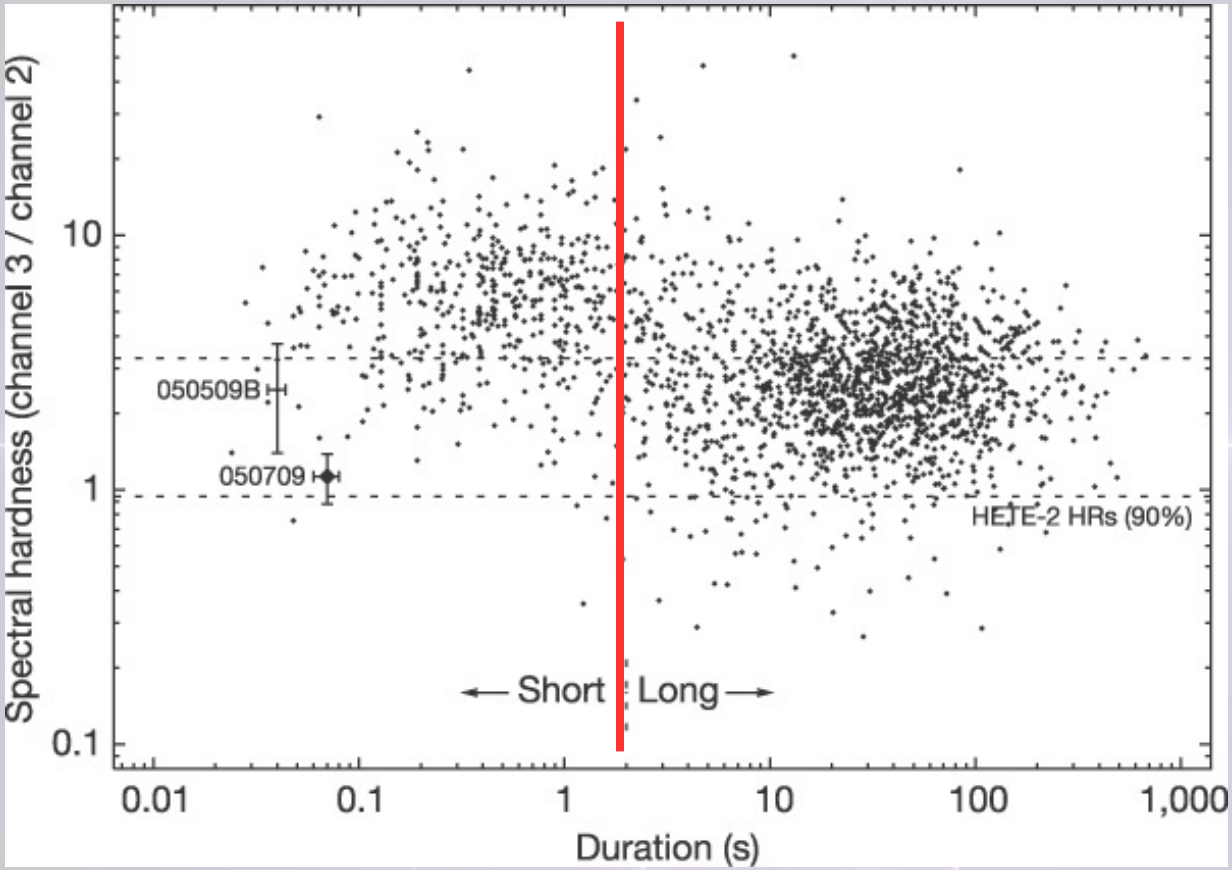

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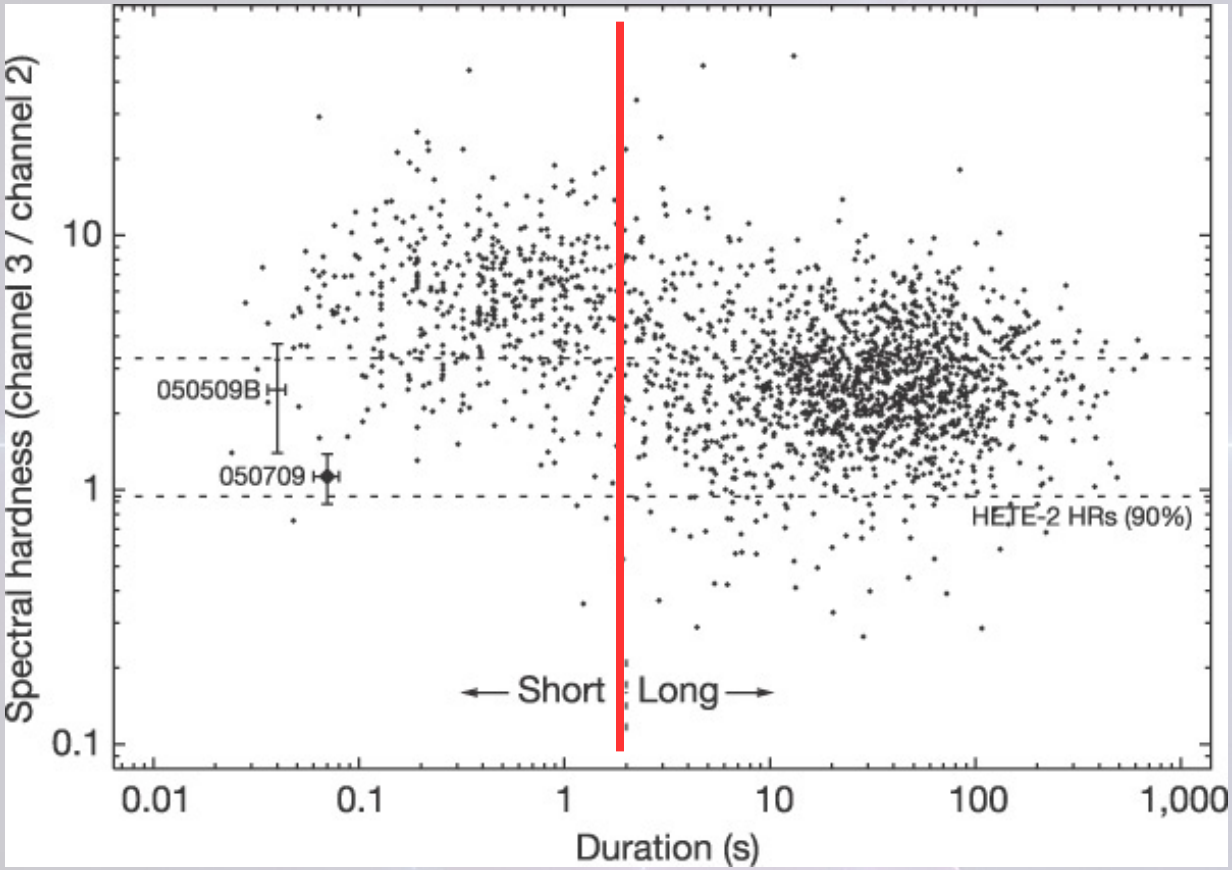

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Progenitor models...

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Short/hard GRBs:

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See the review of Berger+14

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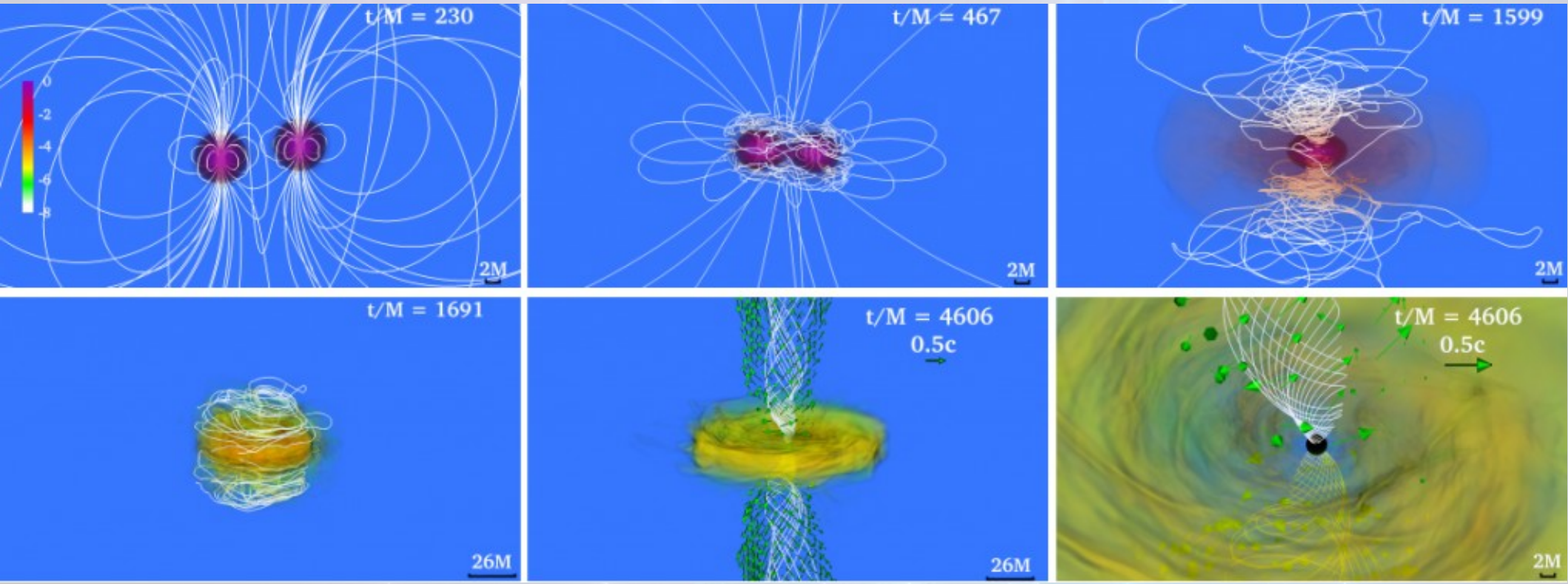

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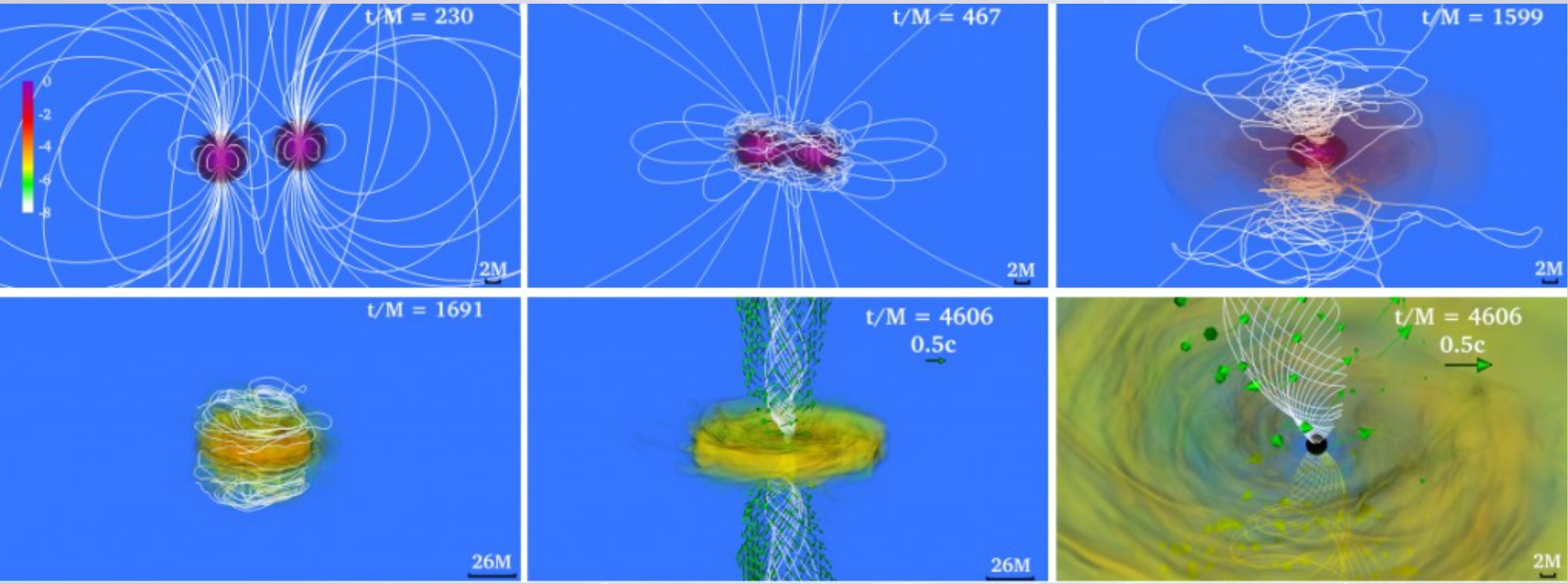

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BH-BH (?!)

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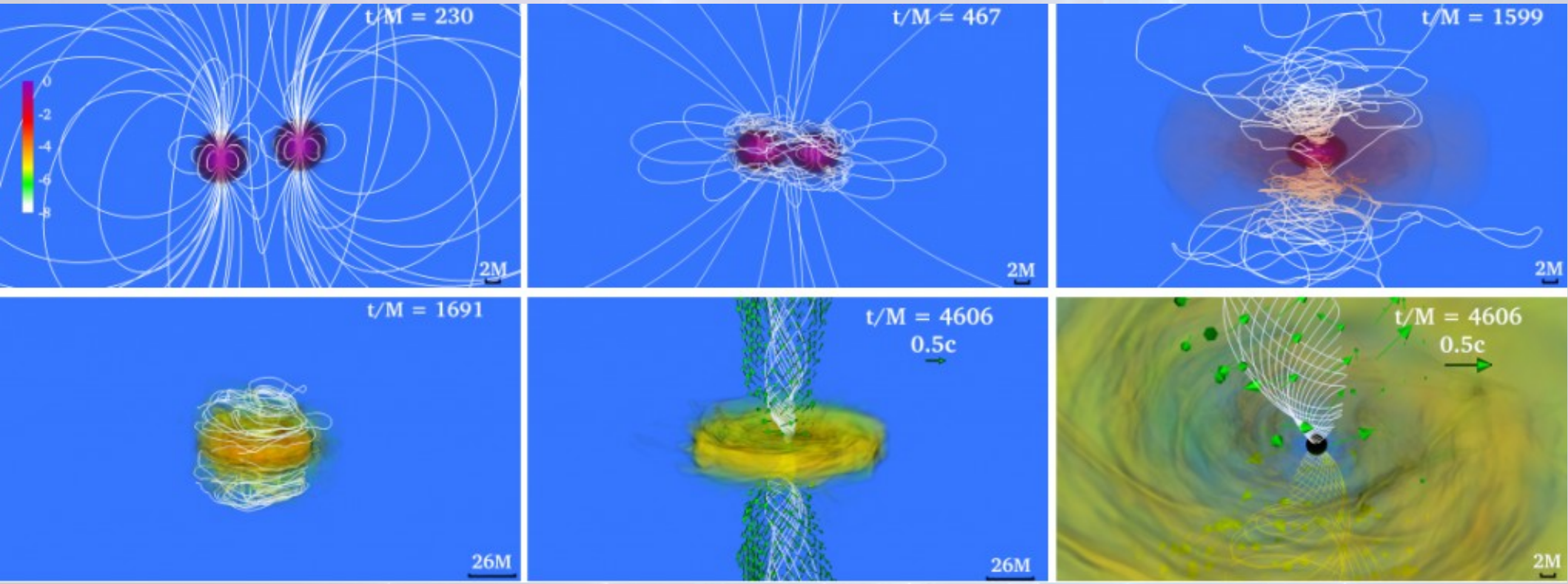

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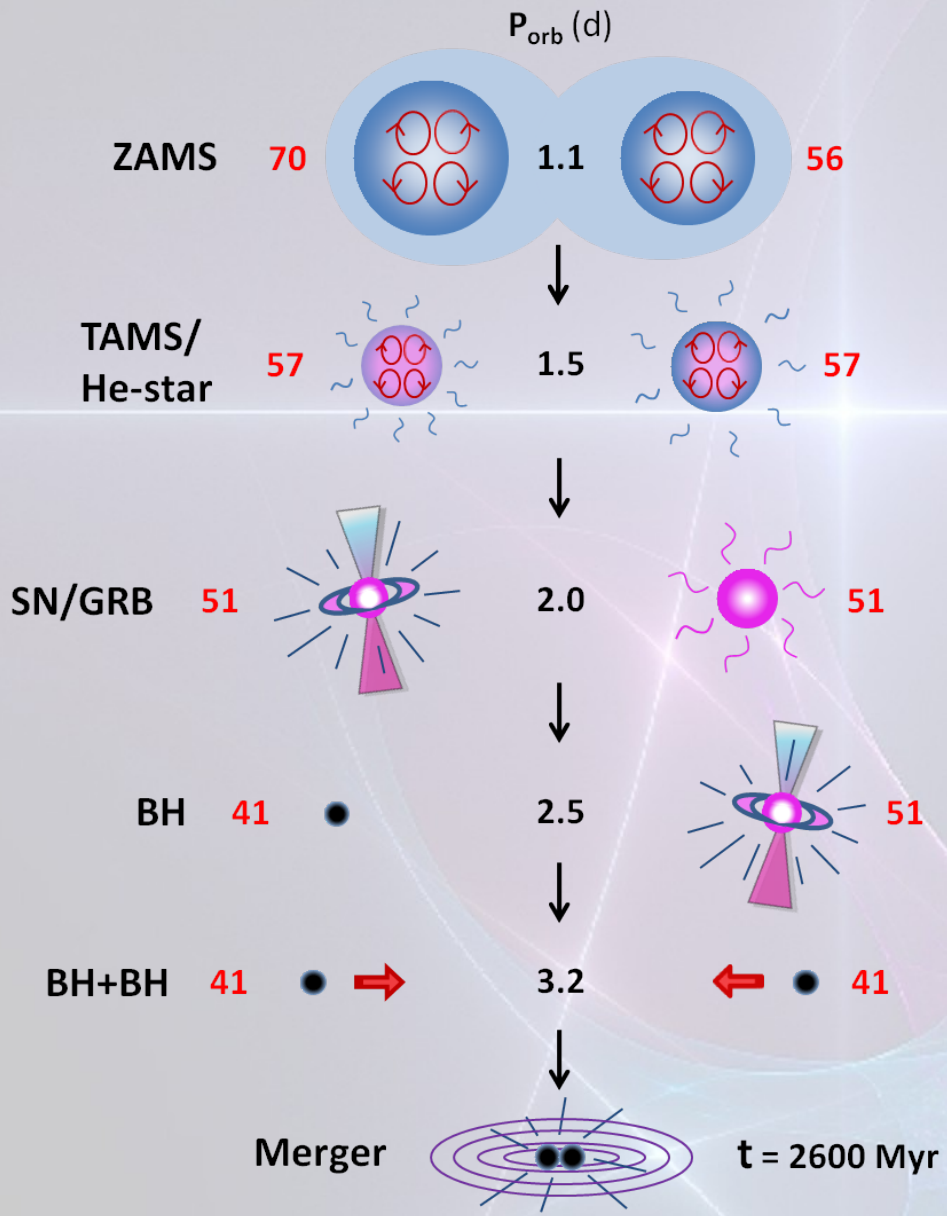

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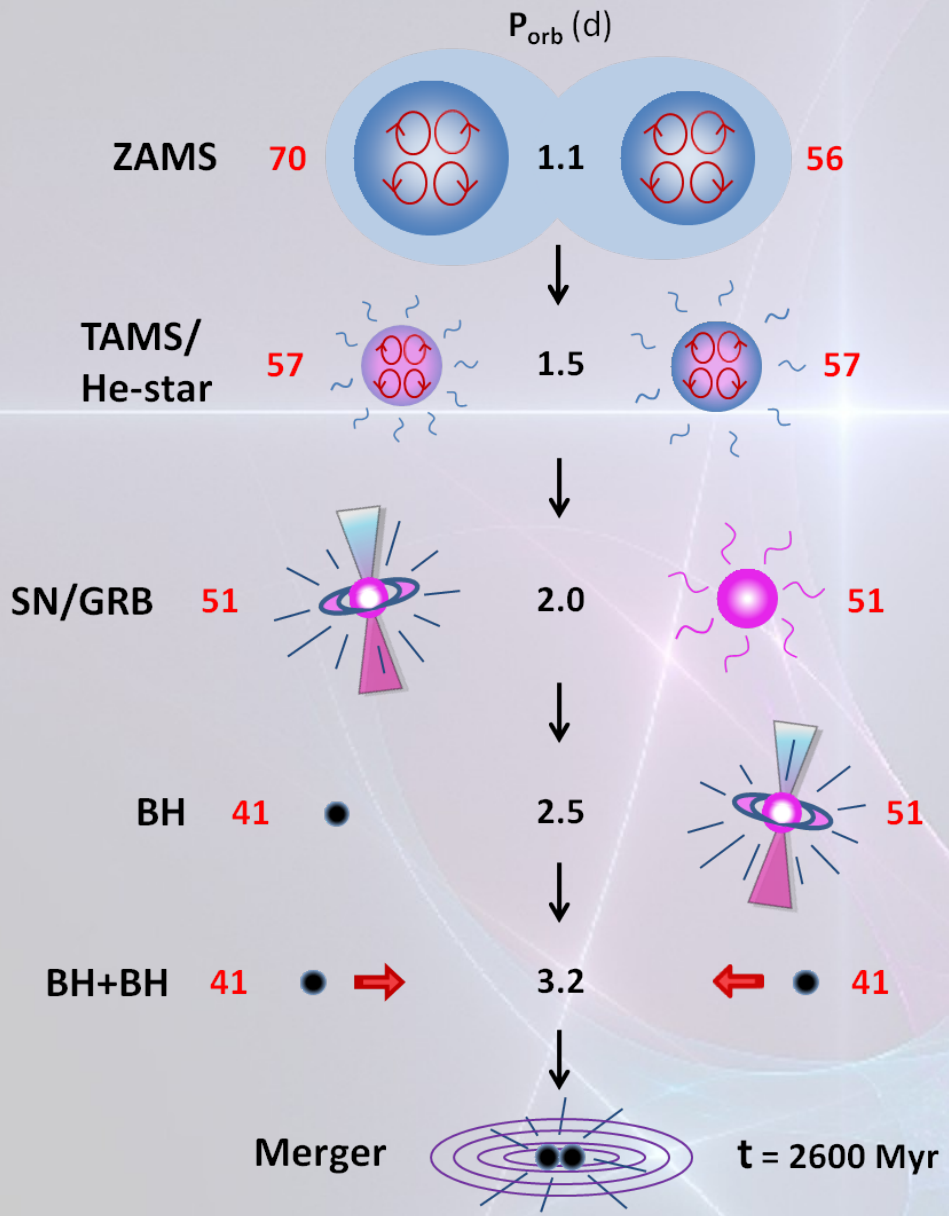

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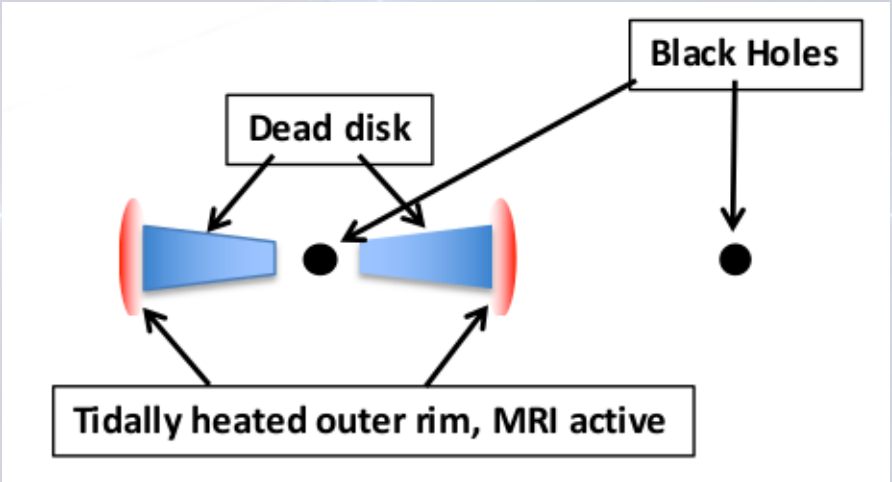
Perna+16:

second SN may be weak → long-lived disk from stellar envelope



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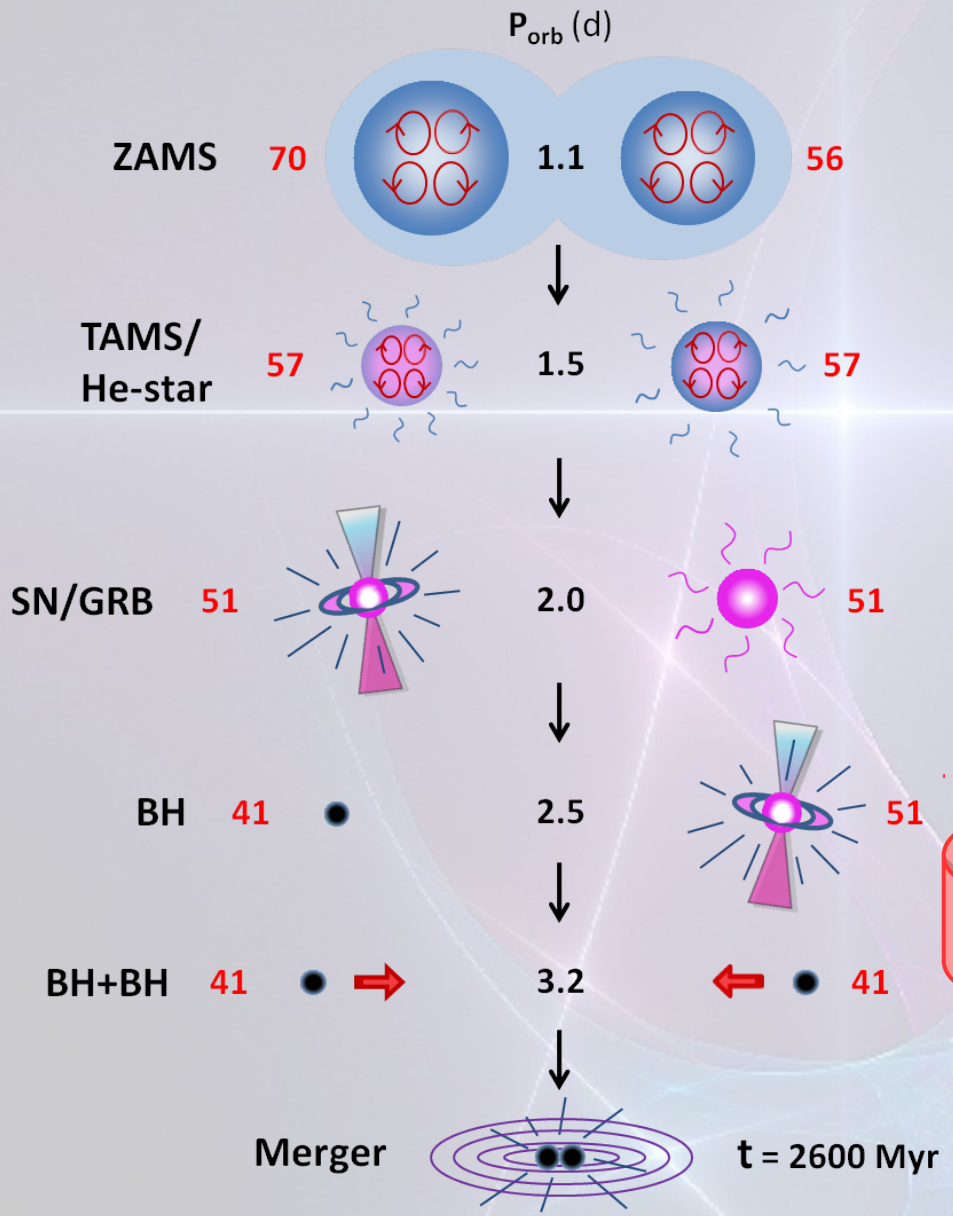

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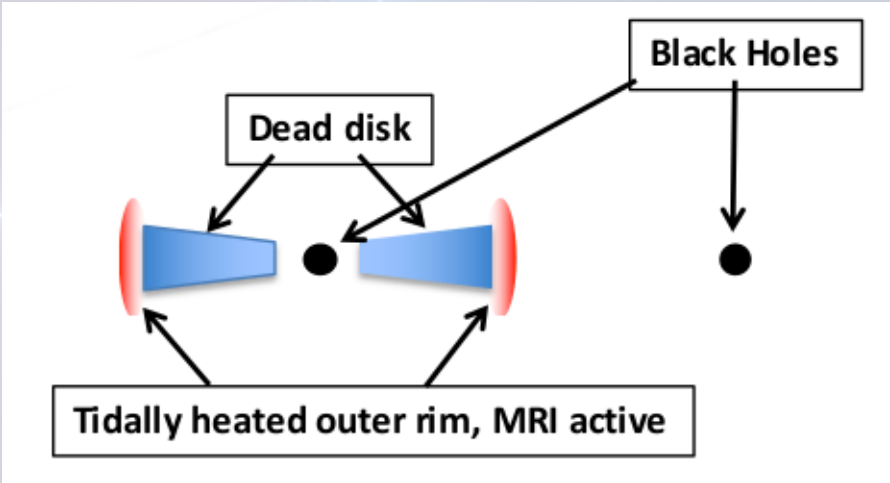

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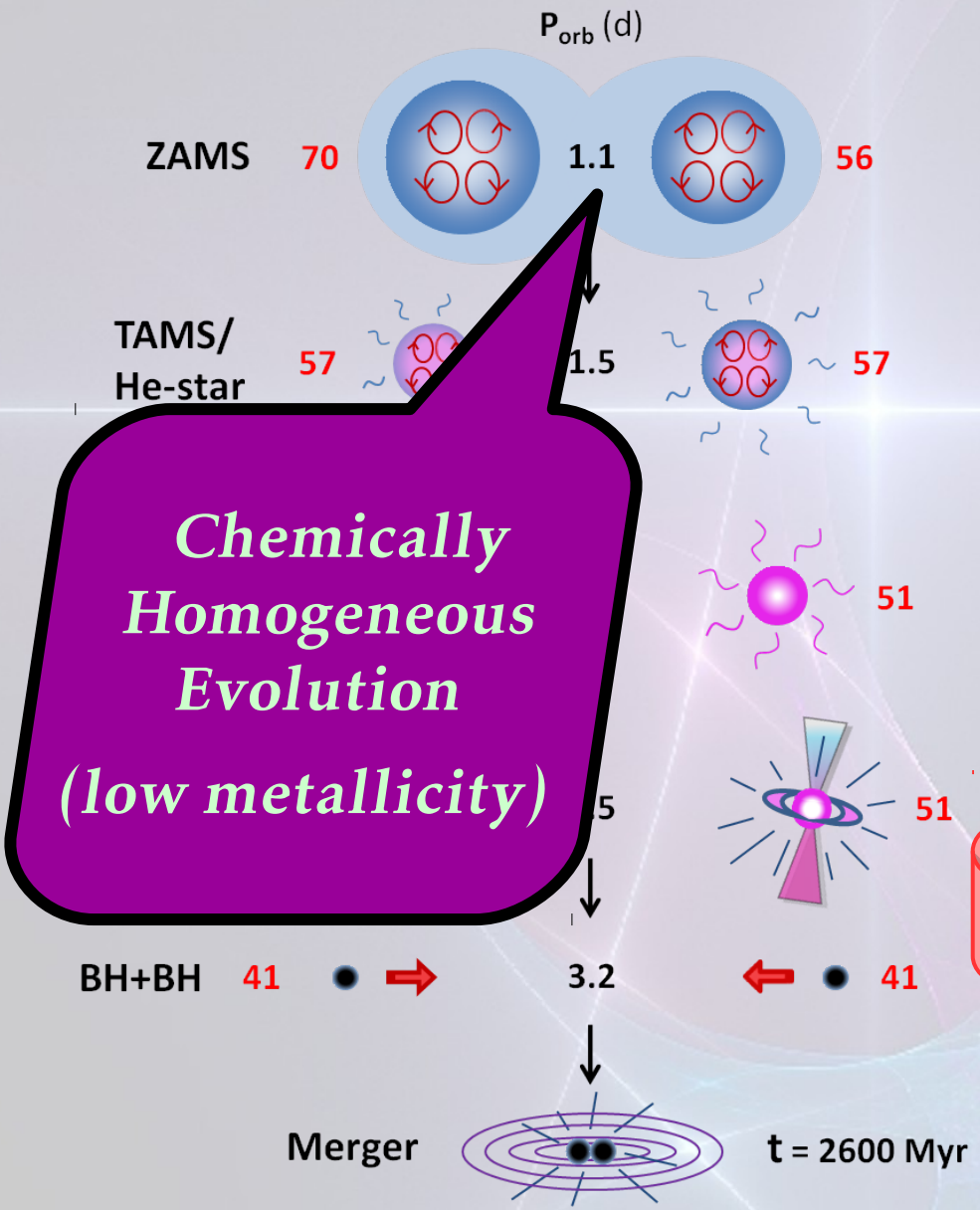

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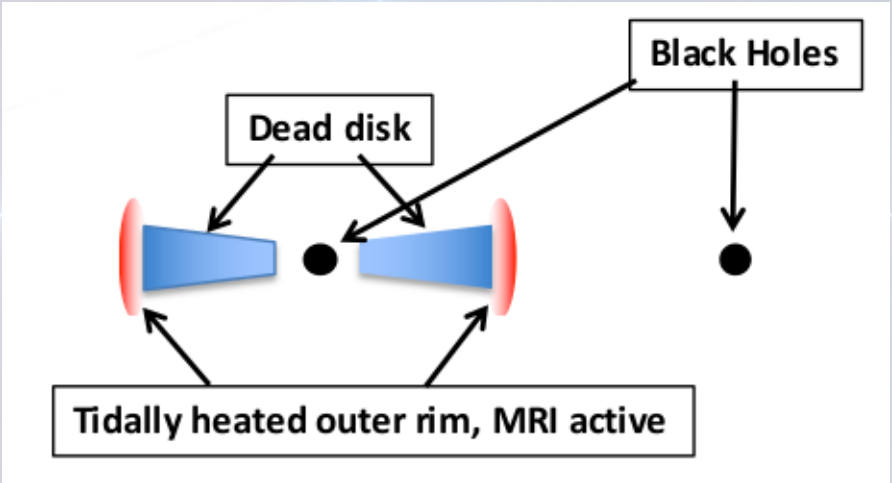

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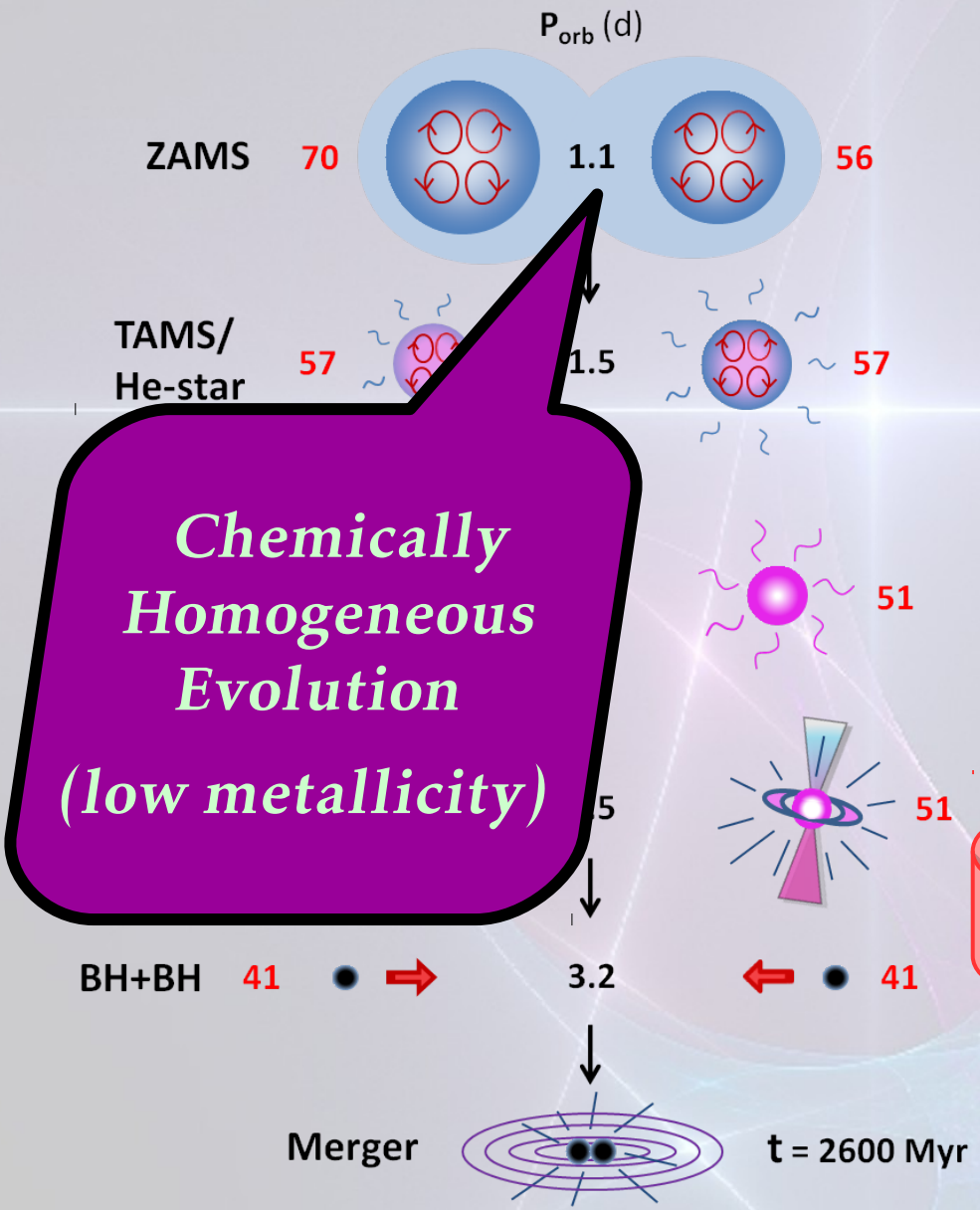

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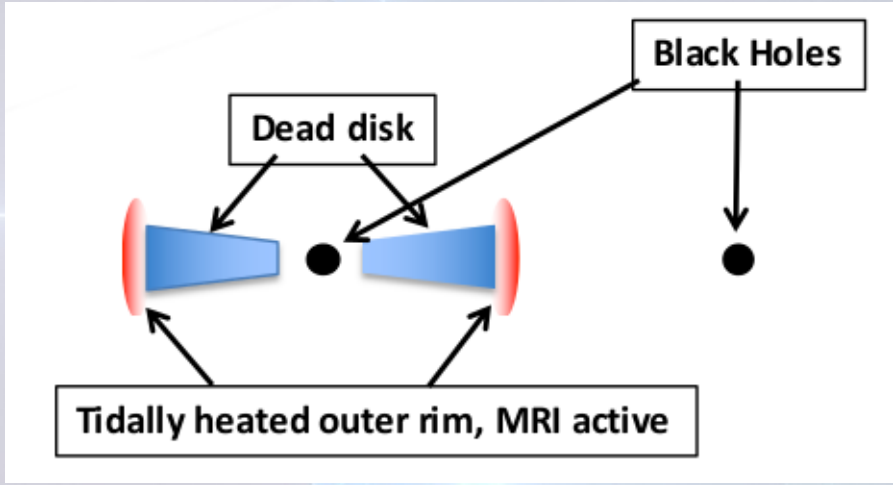

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Other models:

Zhang'16 – one of the BHs is charged

Belczynski+16, Kruckow+16 – common envelope evolution

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Special requirements depend on astrophysical scenario

Collapsar scenario

Magnetar scenario

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Woosley'93, Macfadyen+99, Yoon+05, Woosley+06

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MacFadyen+01, Metzger+11, Rowlinson+13, Greiner+15

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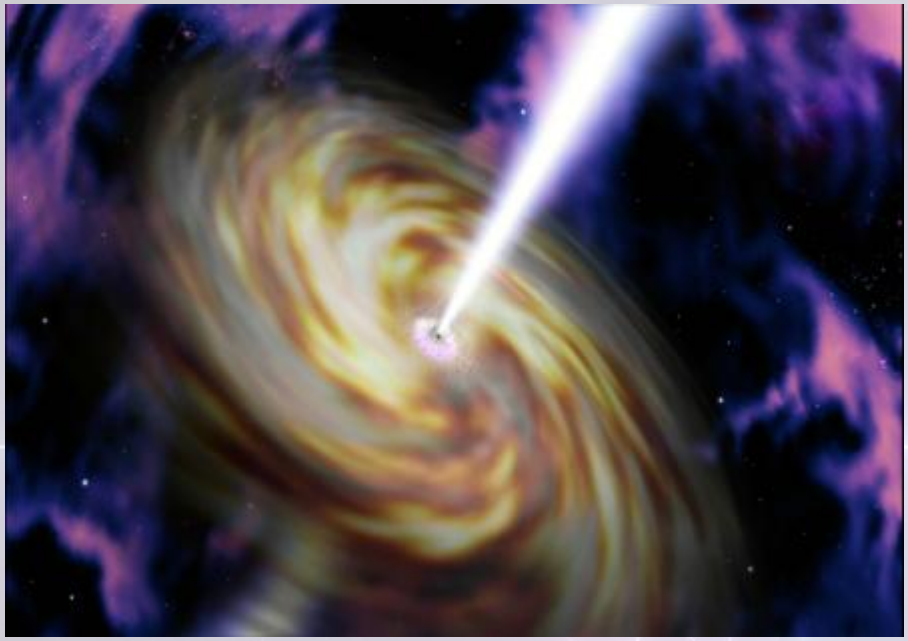

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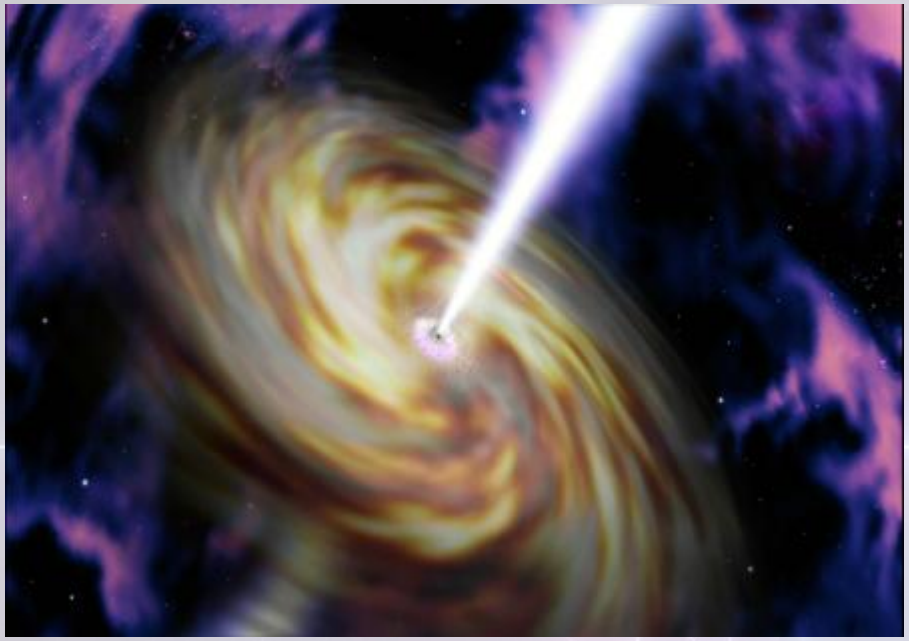

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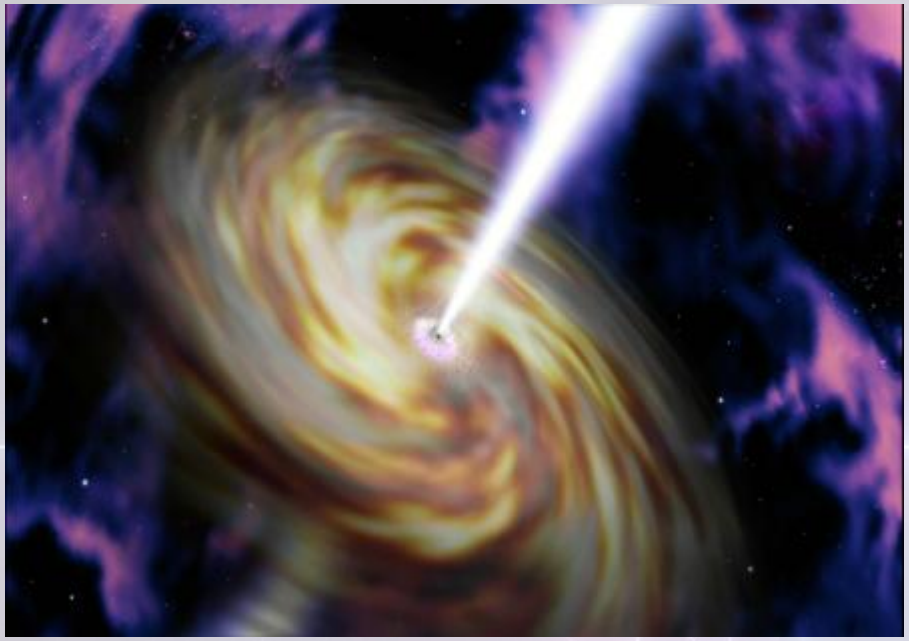

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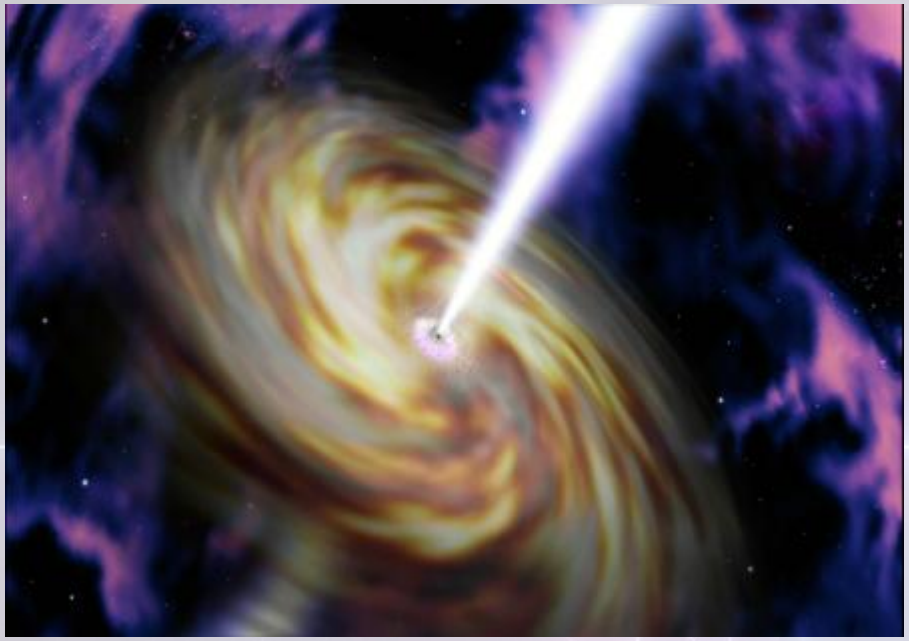

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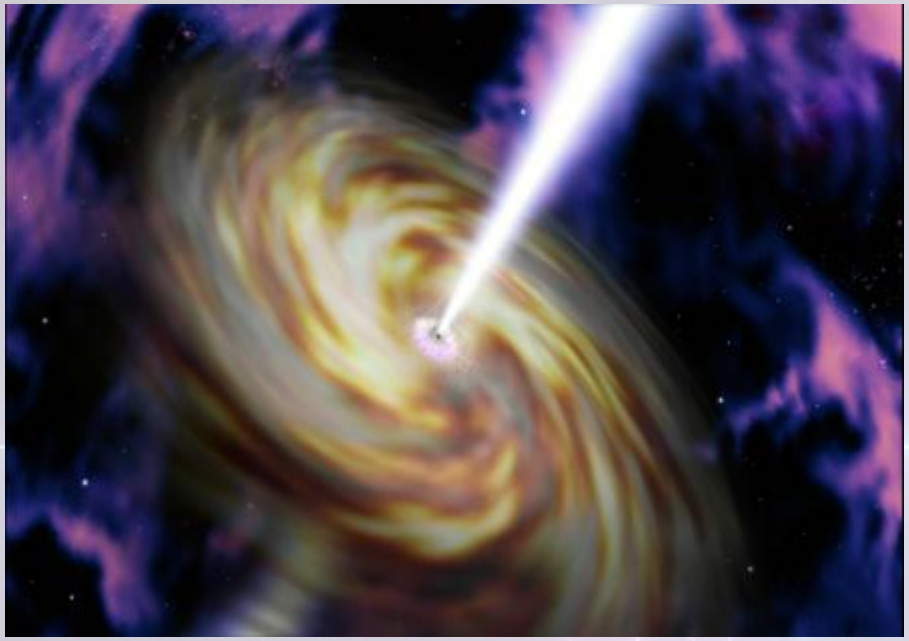

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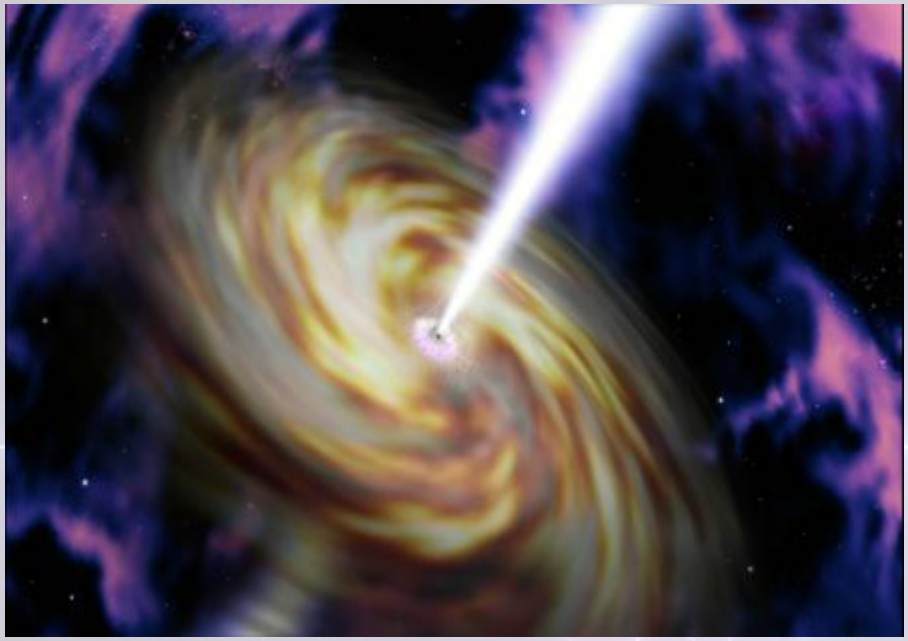

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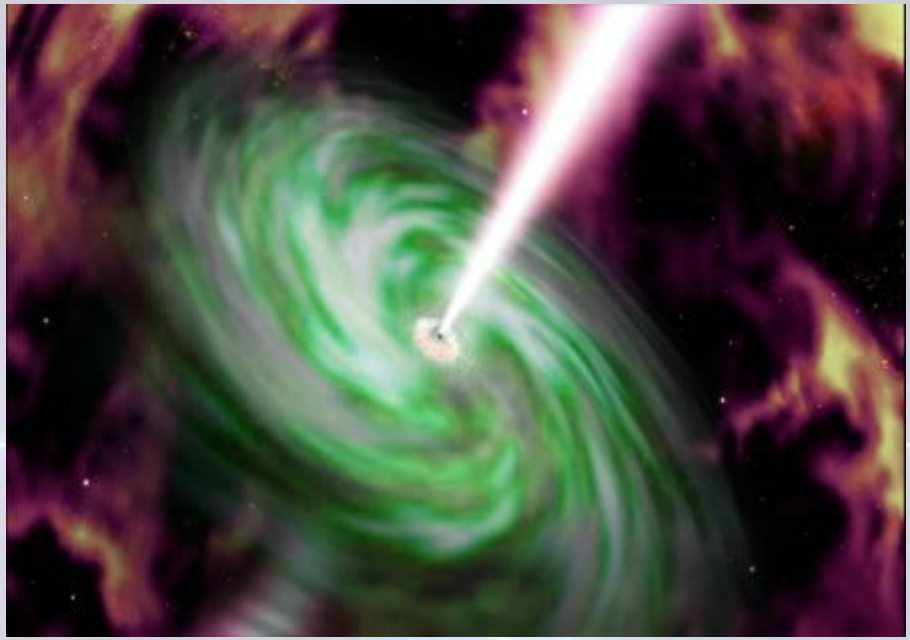

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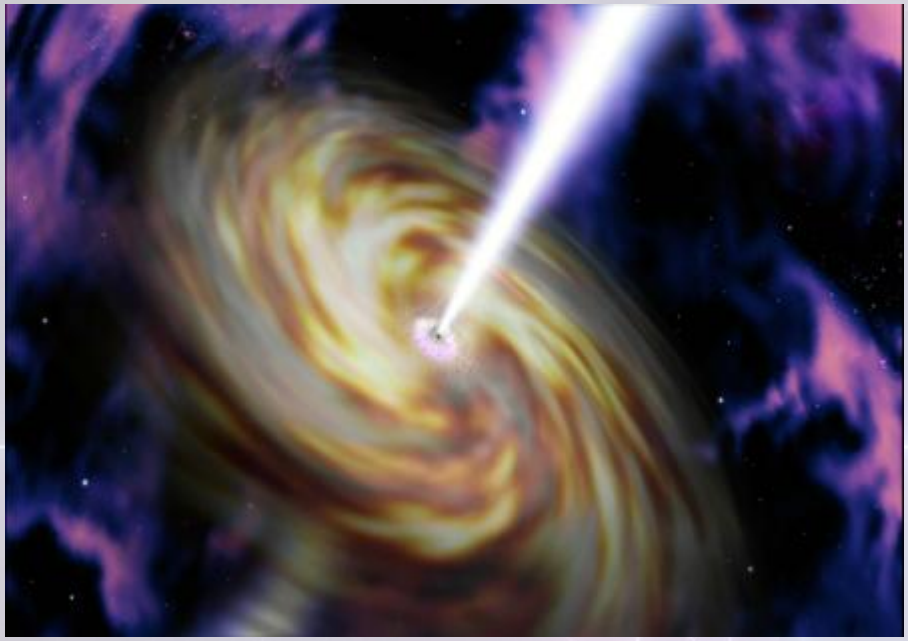

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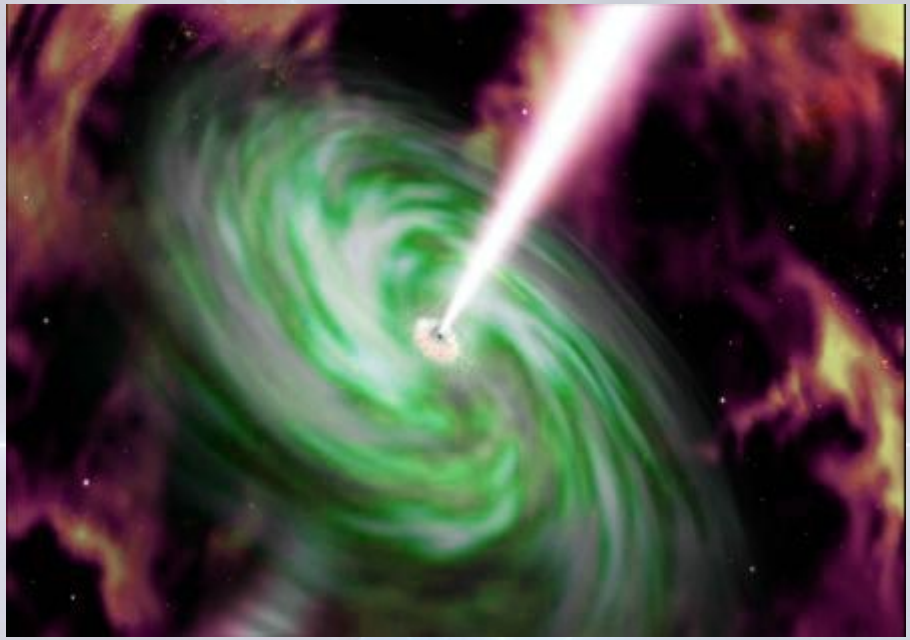

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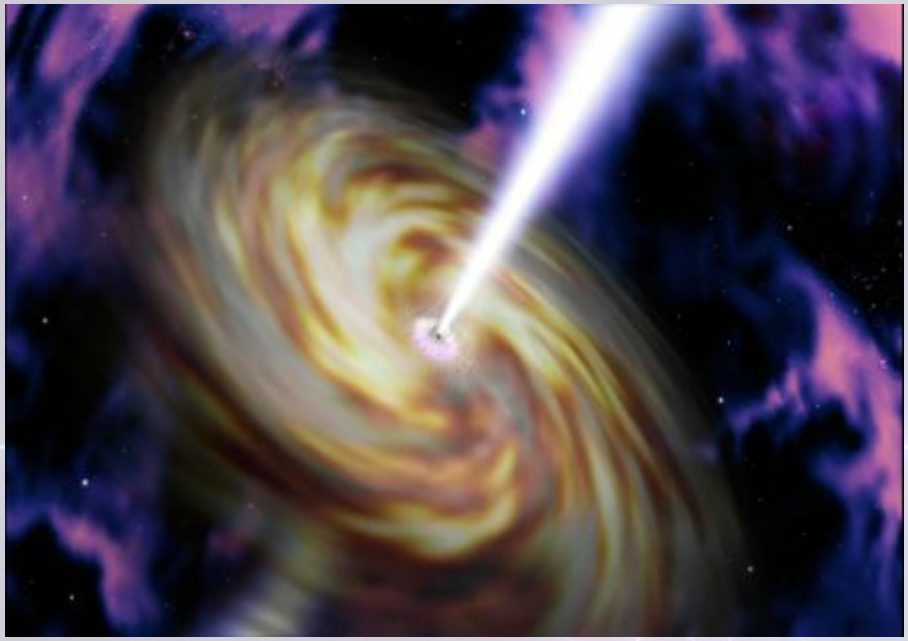

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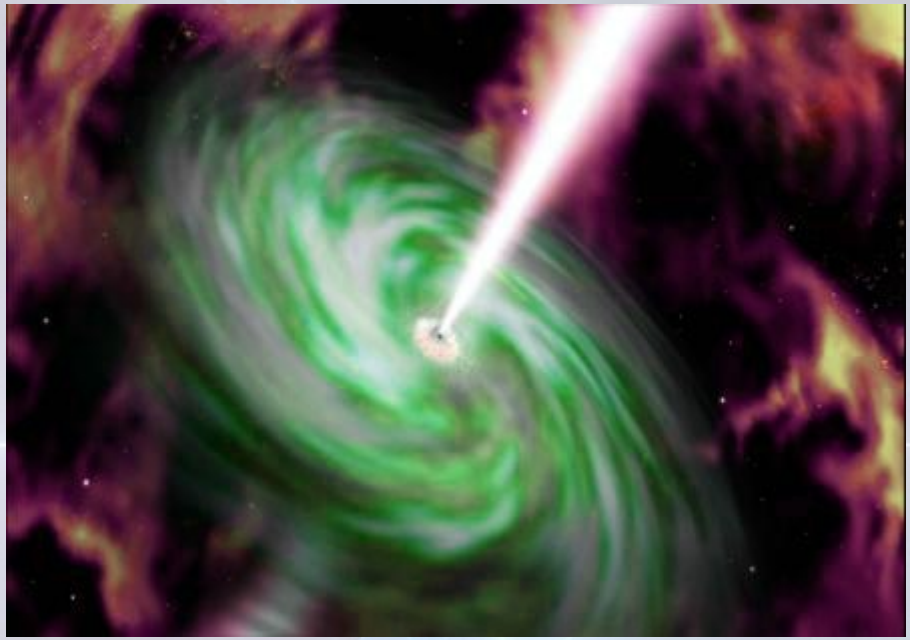

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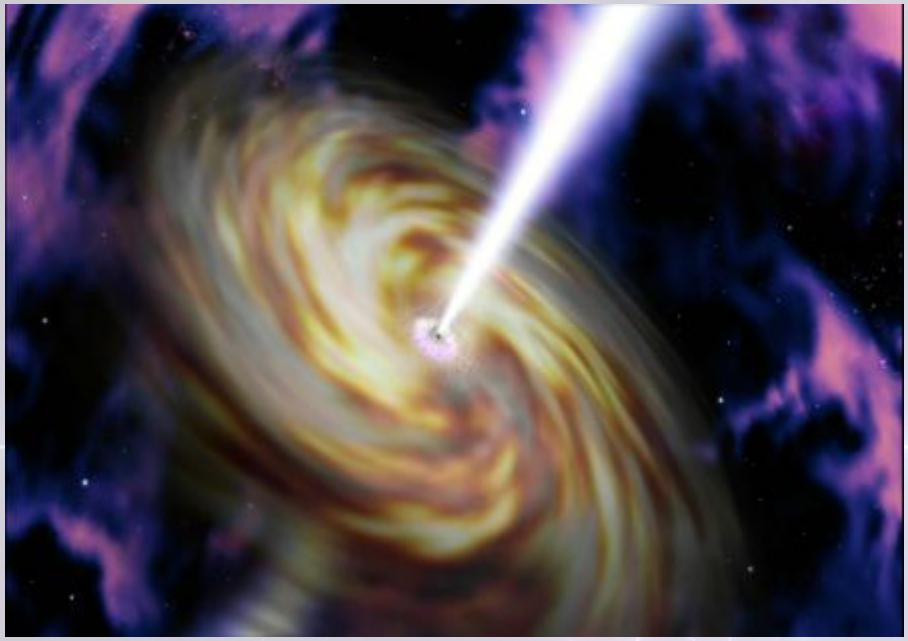

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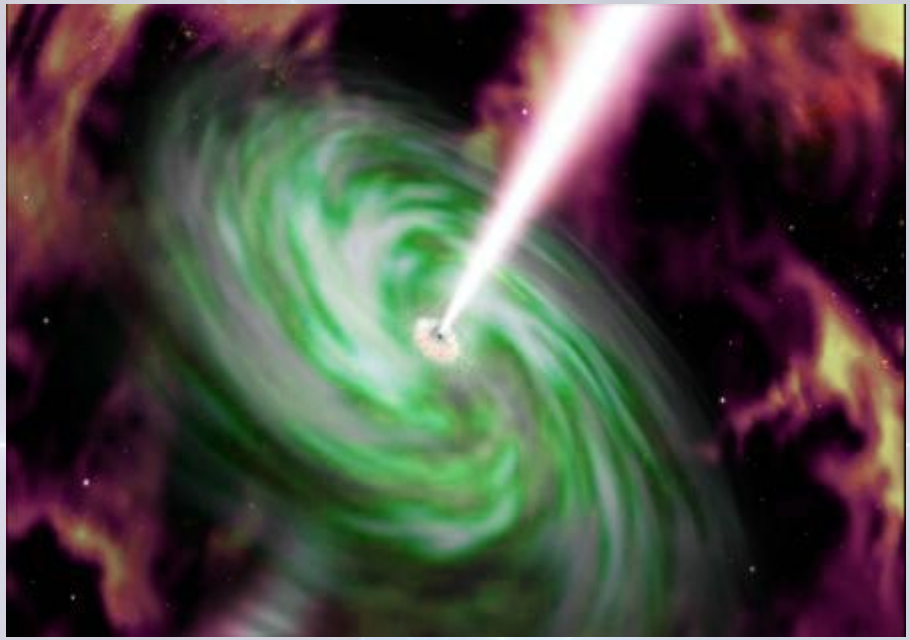

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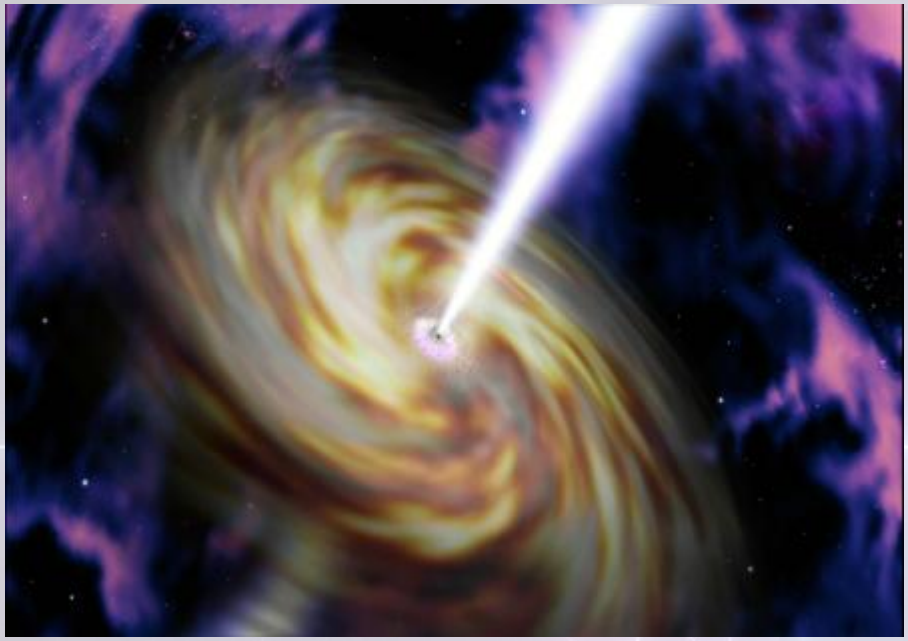

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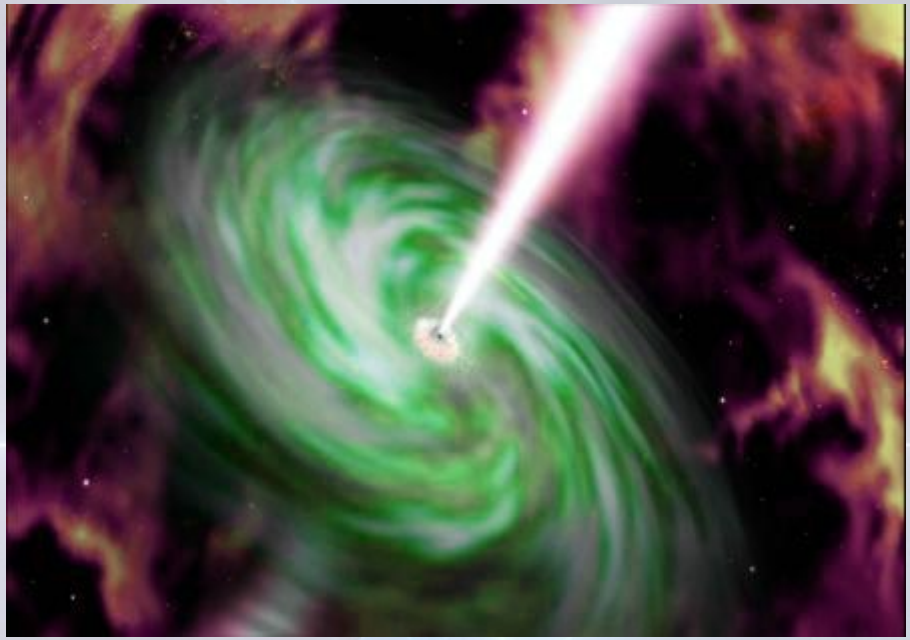

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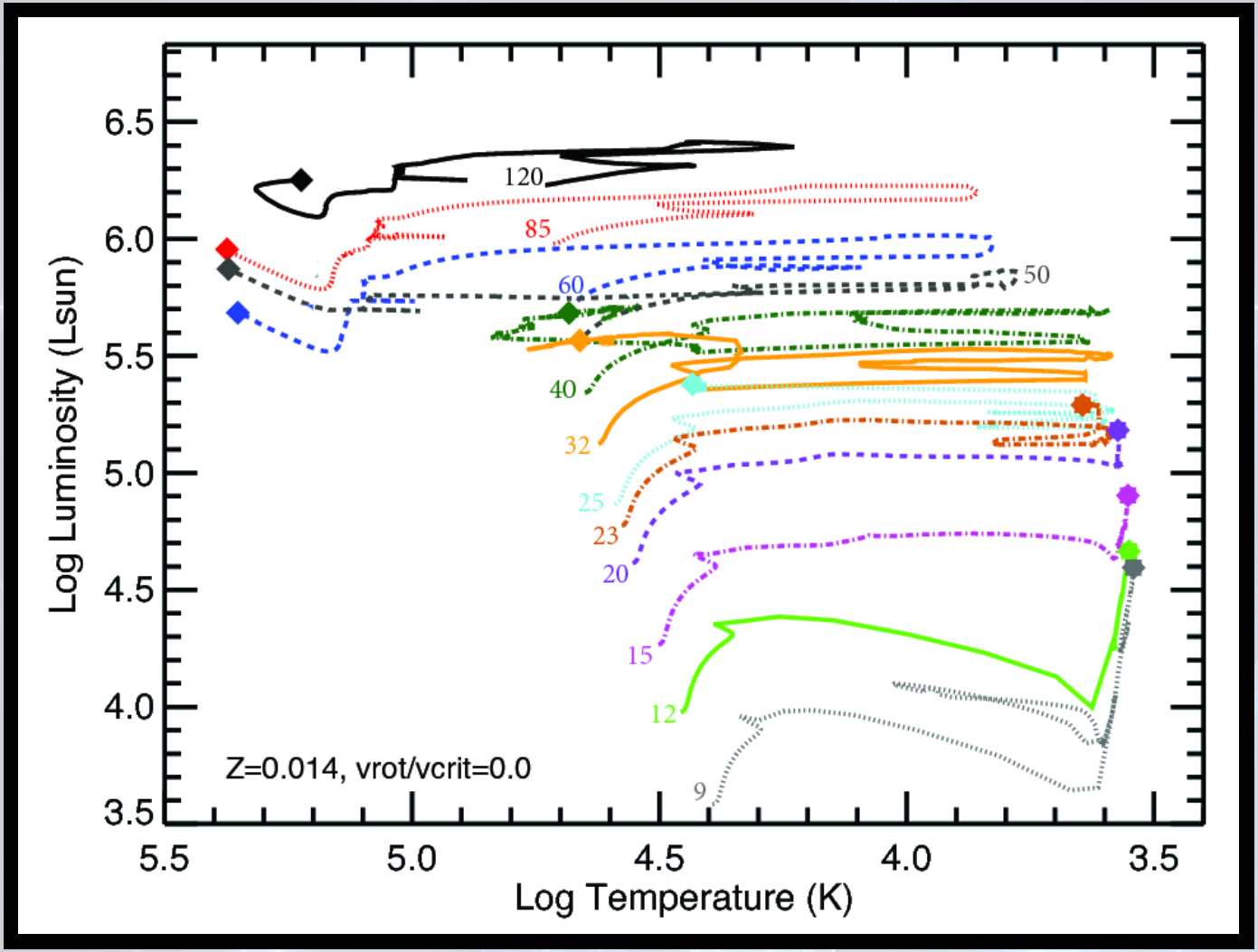

Groh et al. 2013

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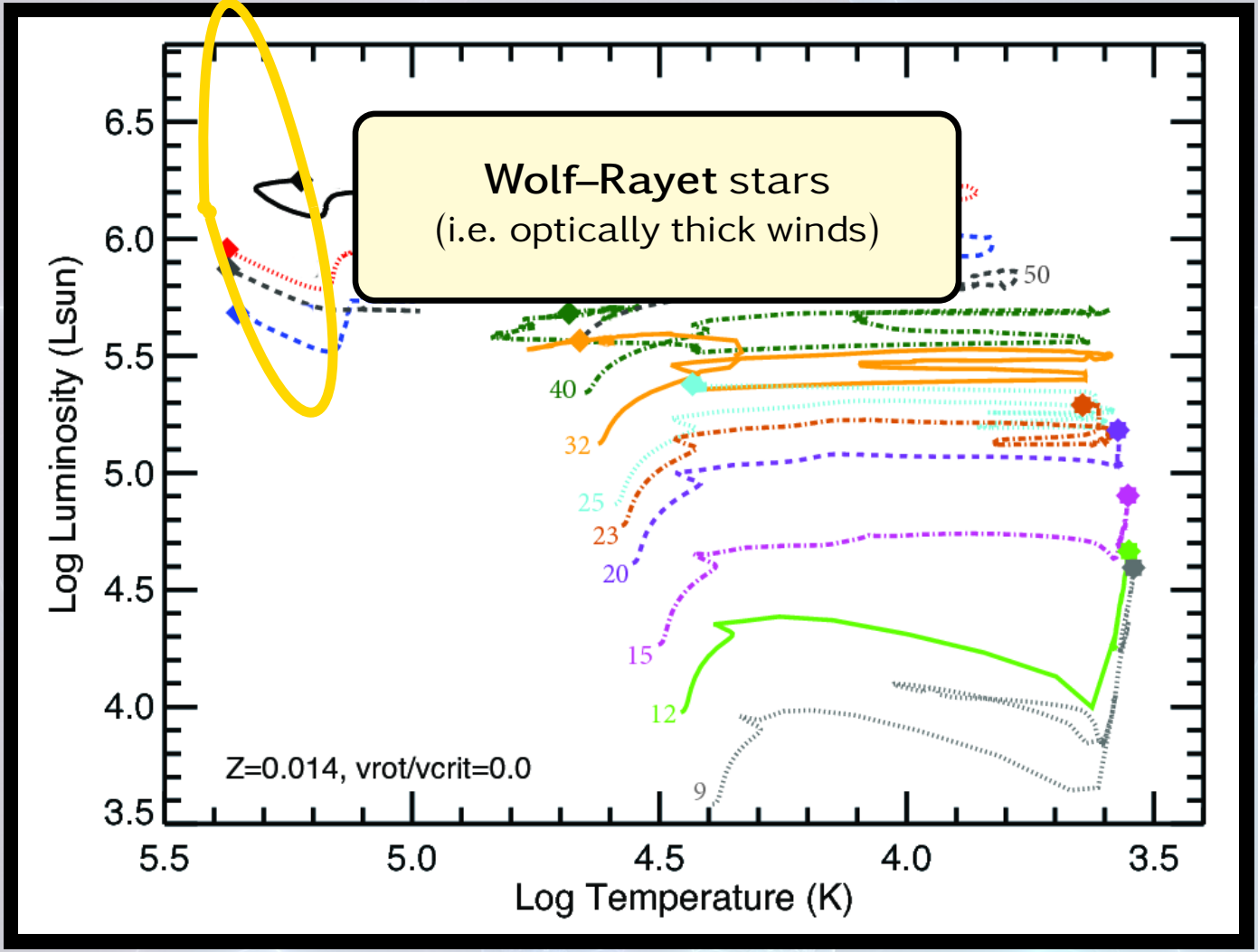

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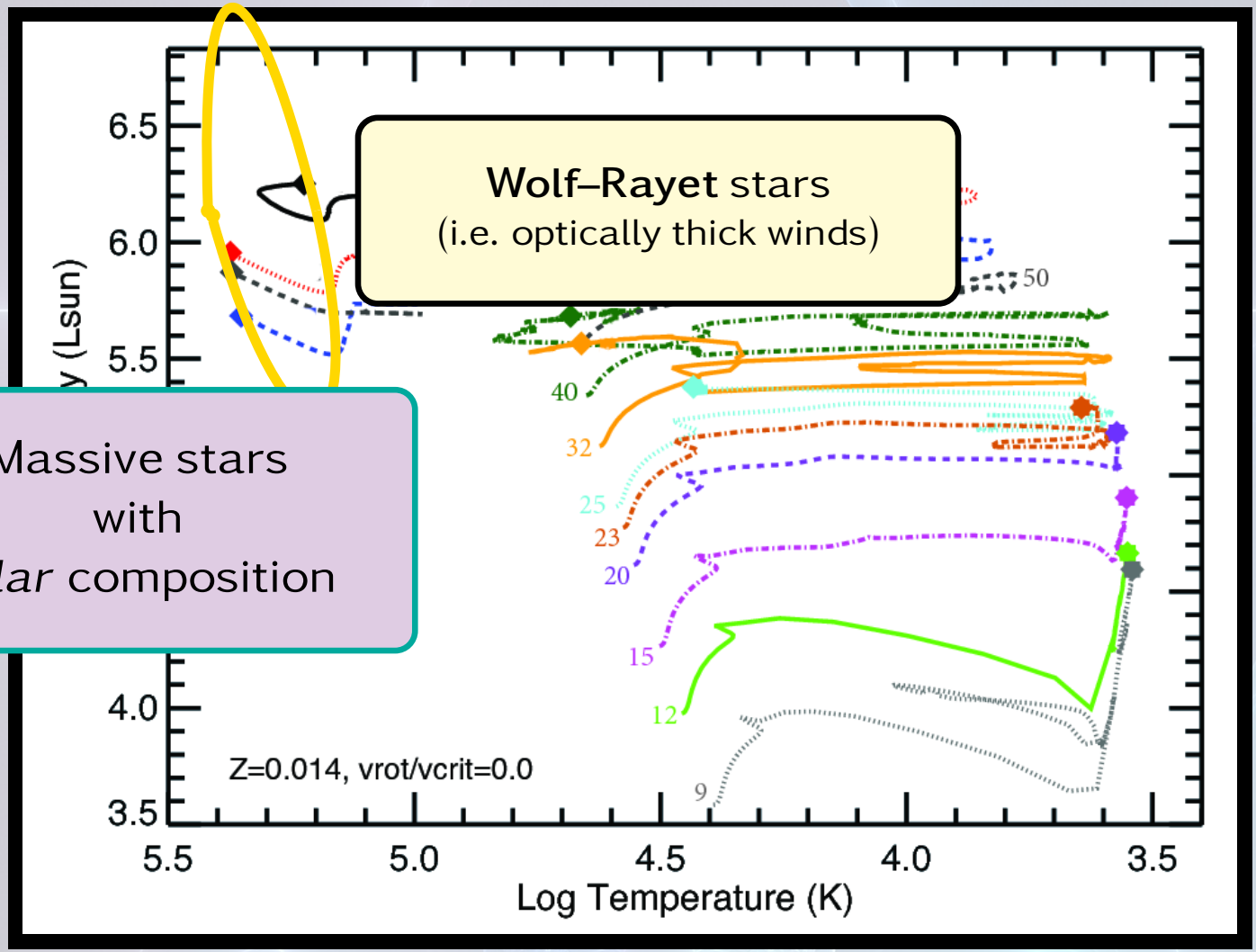

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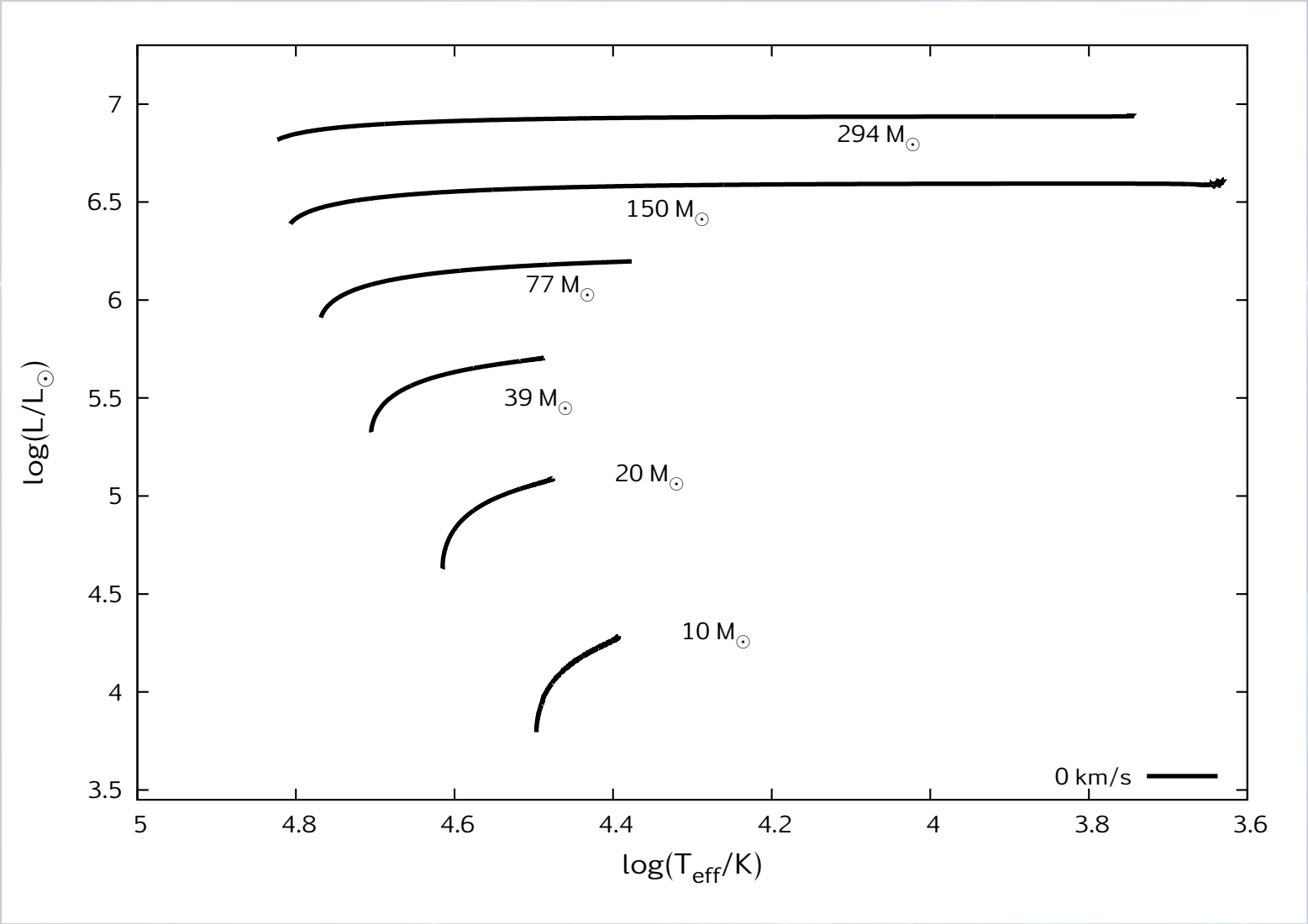

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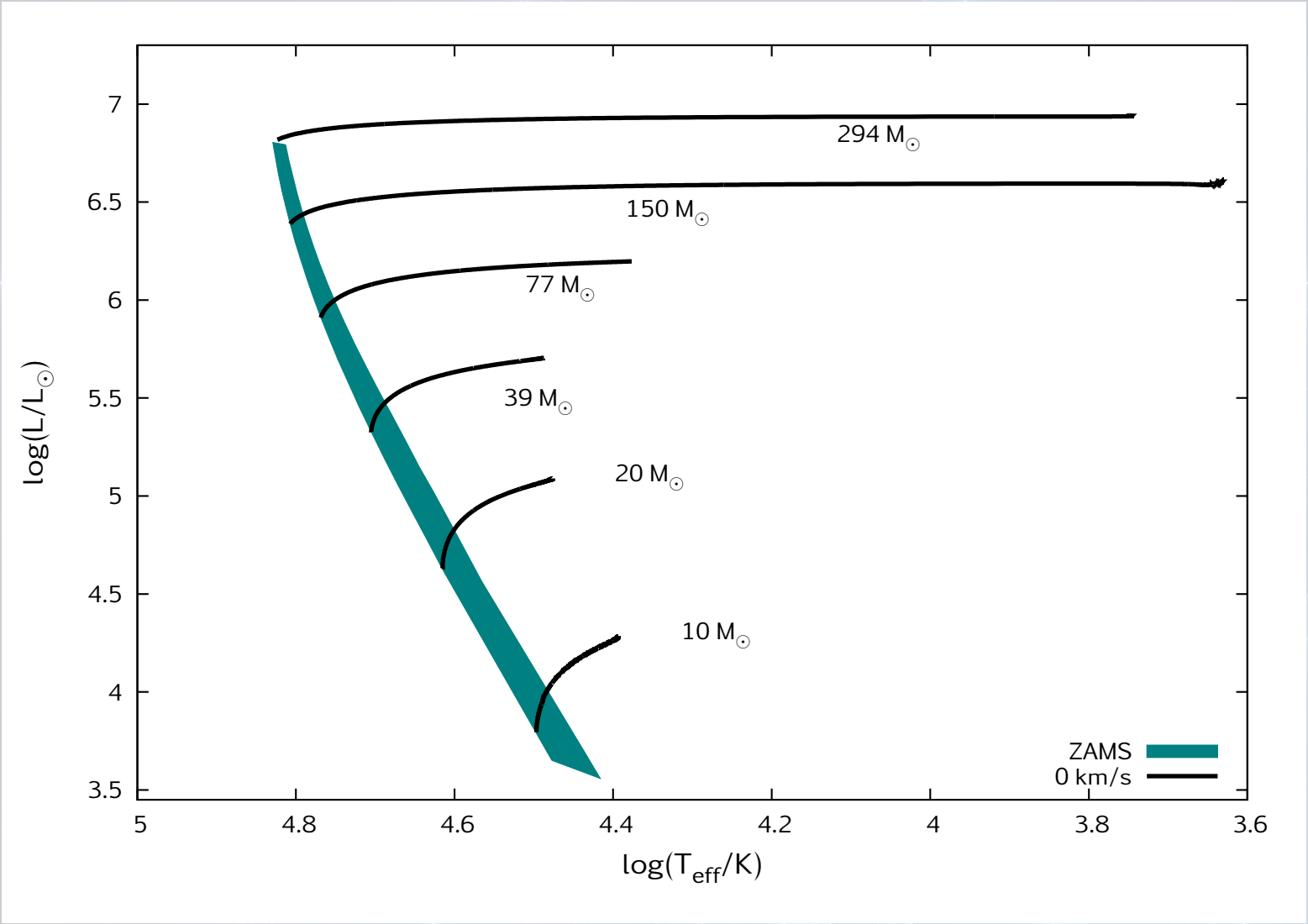

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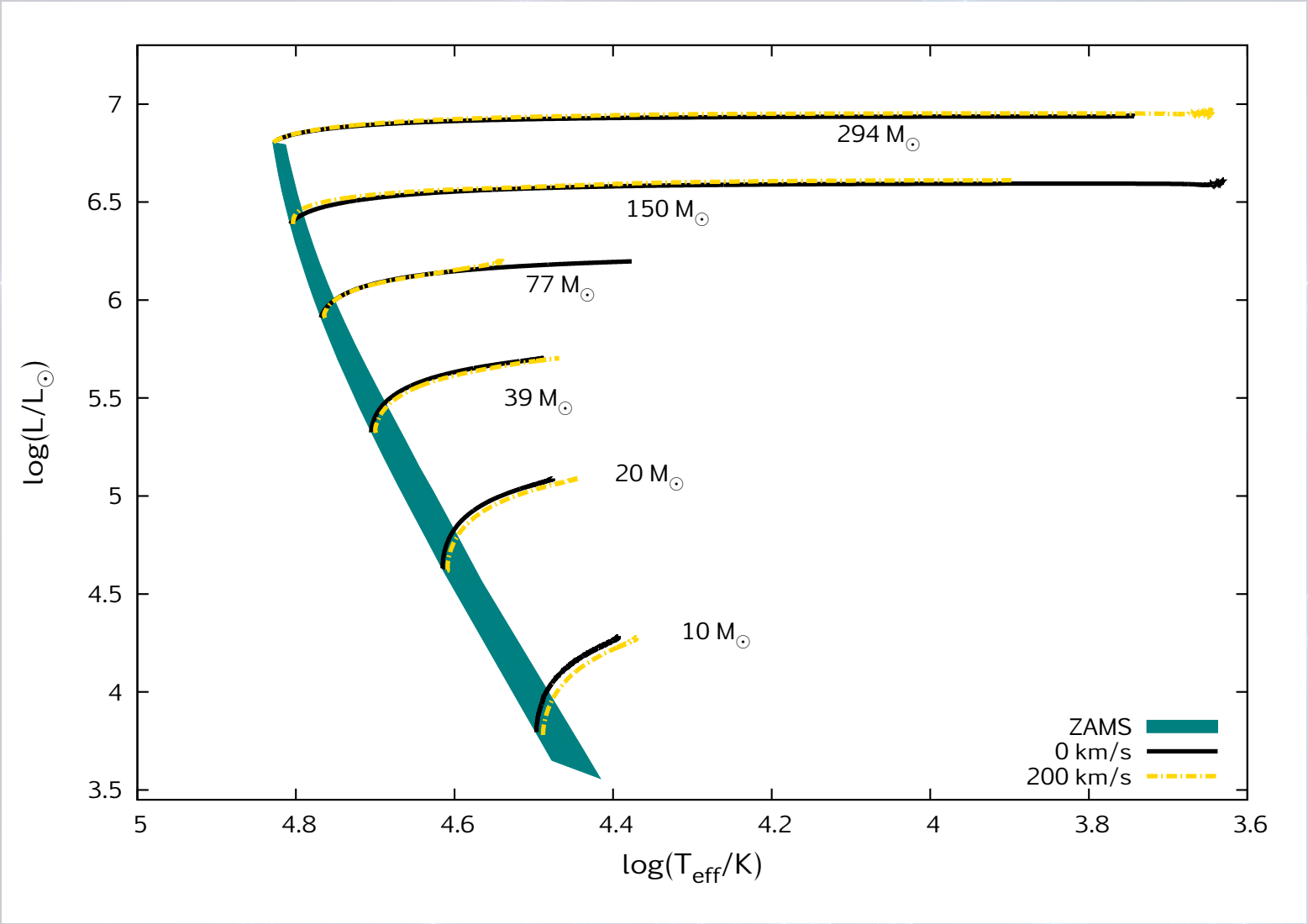

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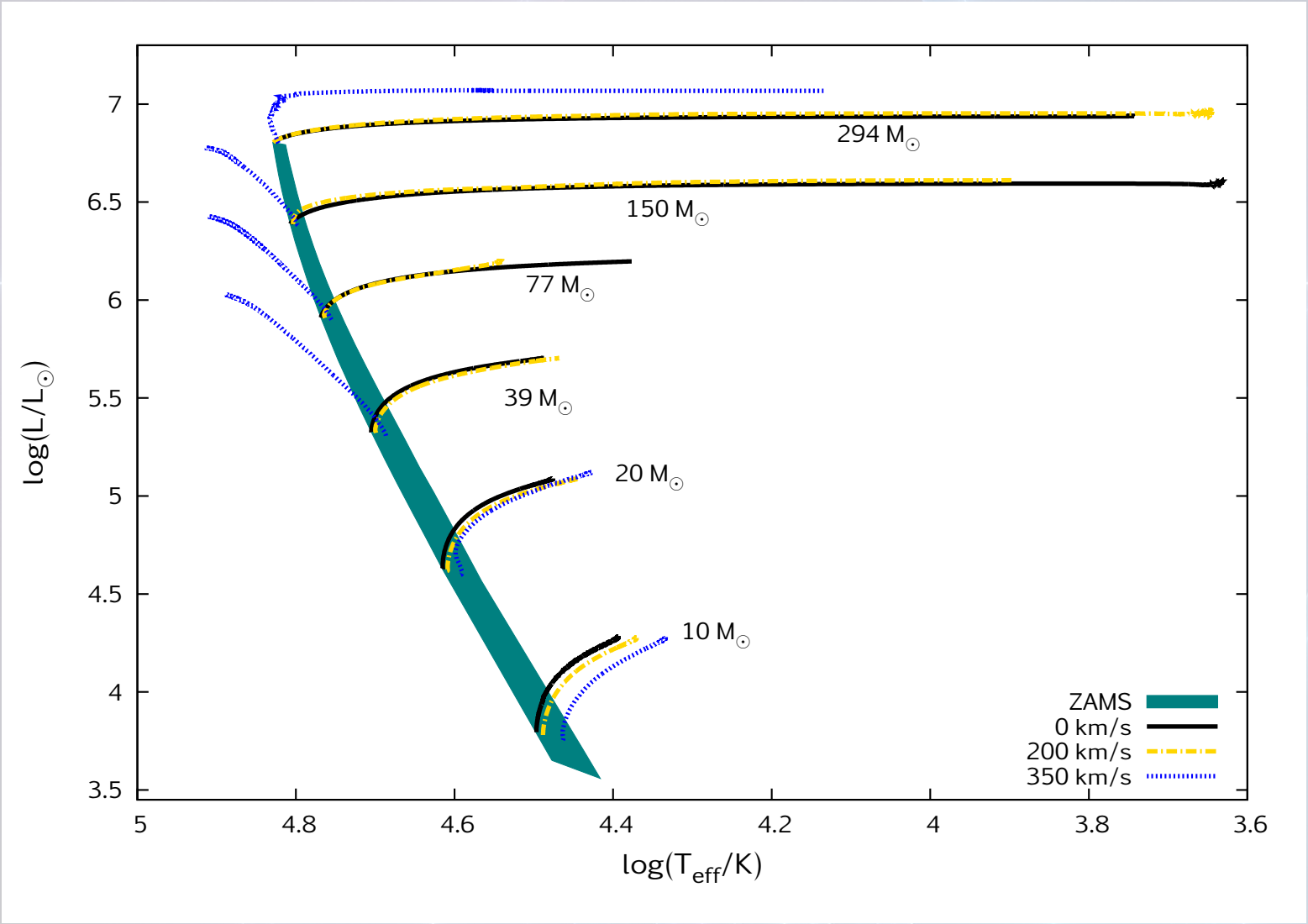
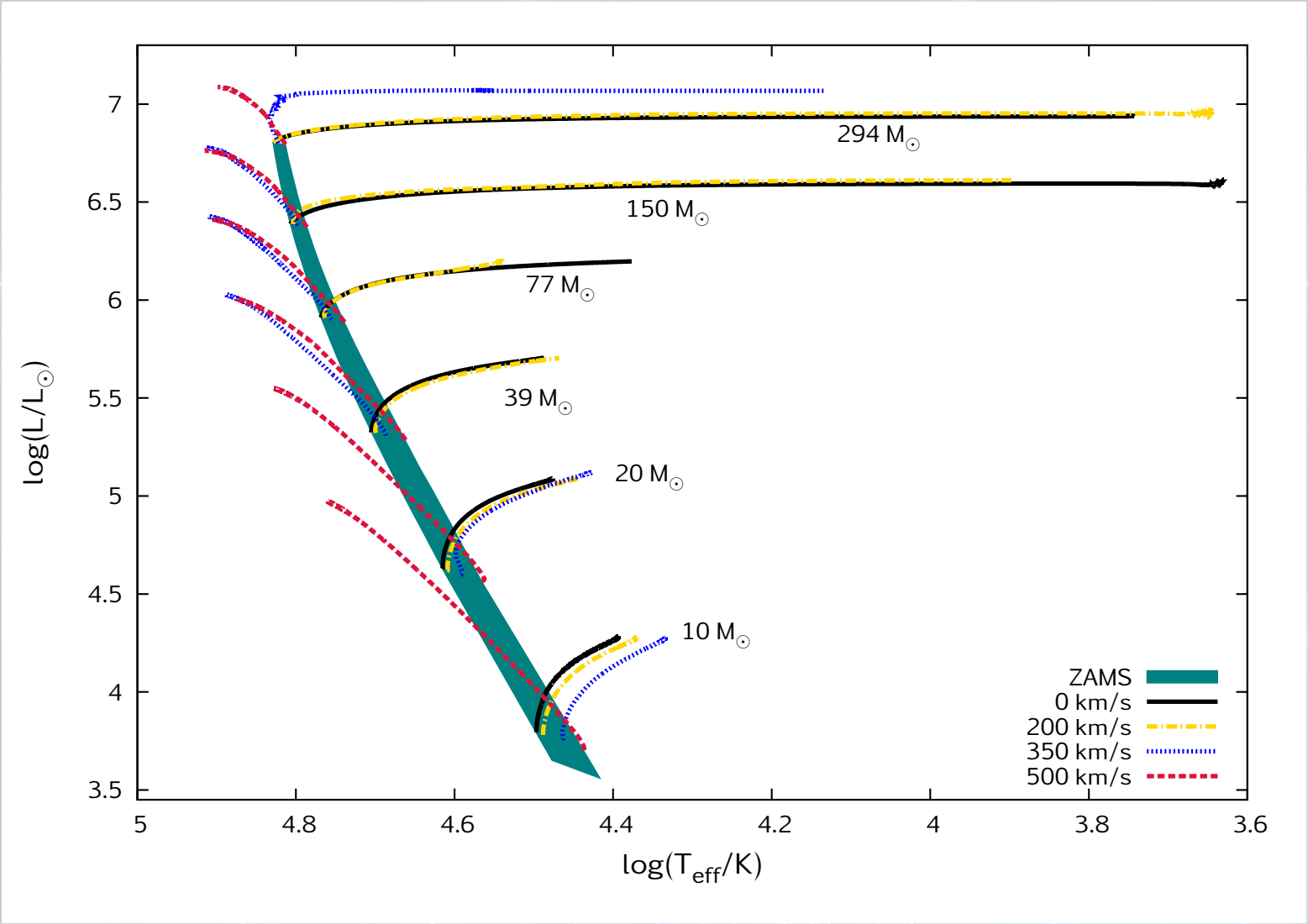


Low Metallicity Massive Stars

Szécsi et al. 2015 (Astronomy & Astrophysics, v.581, A15)



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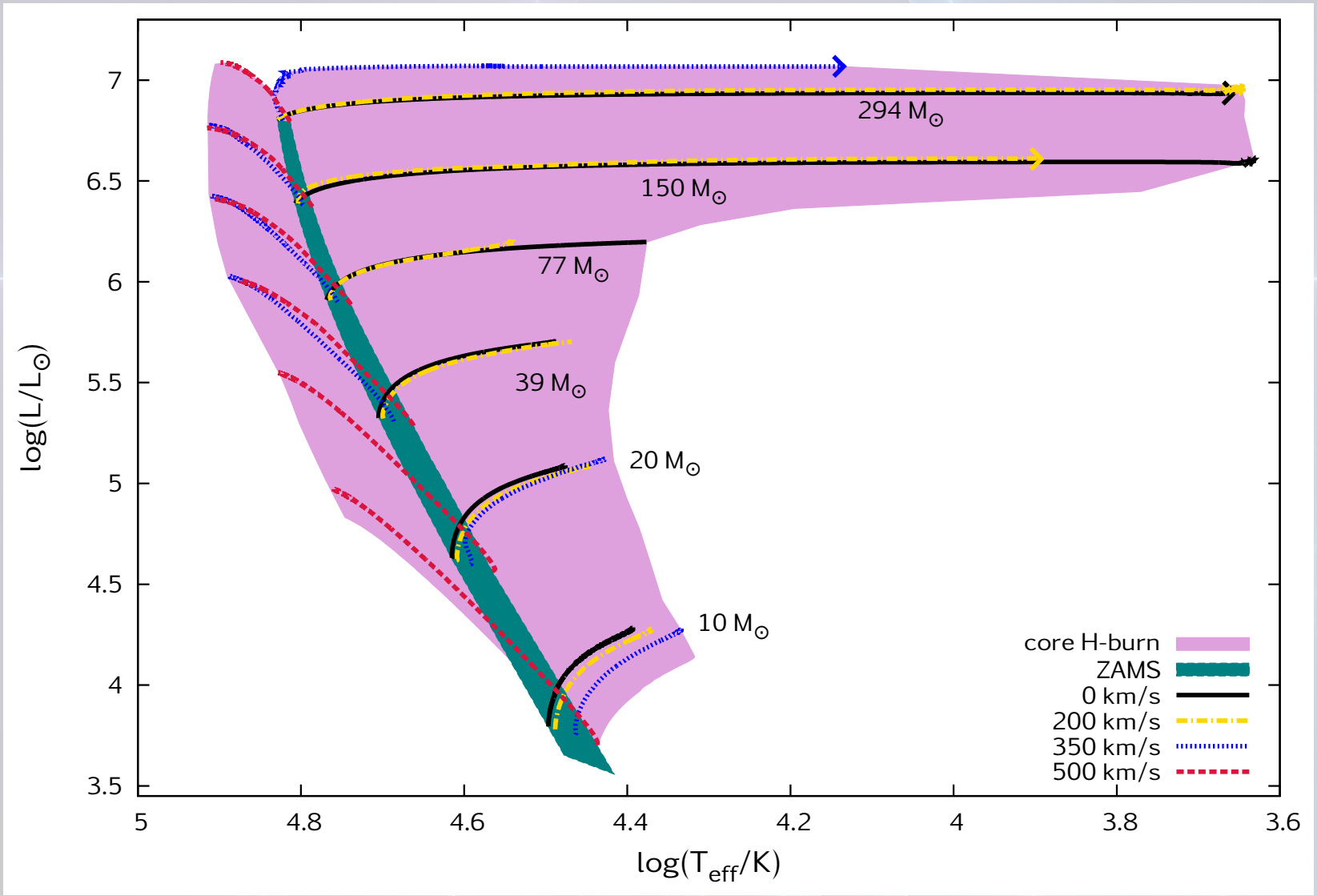

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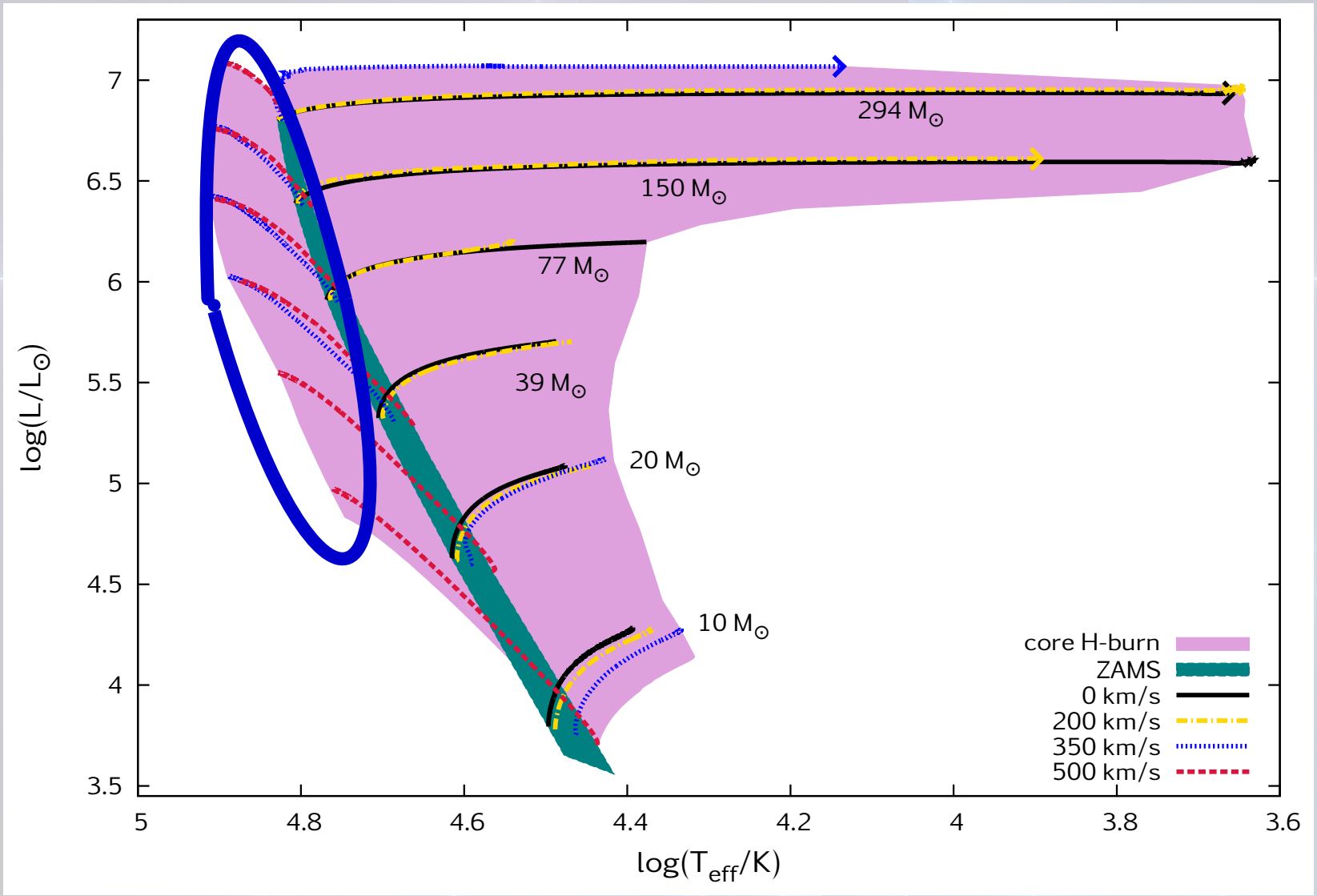

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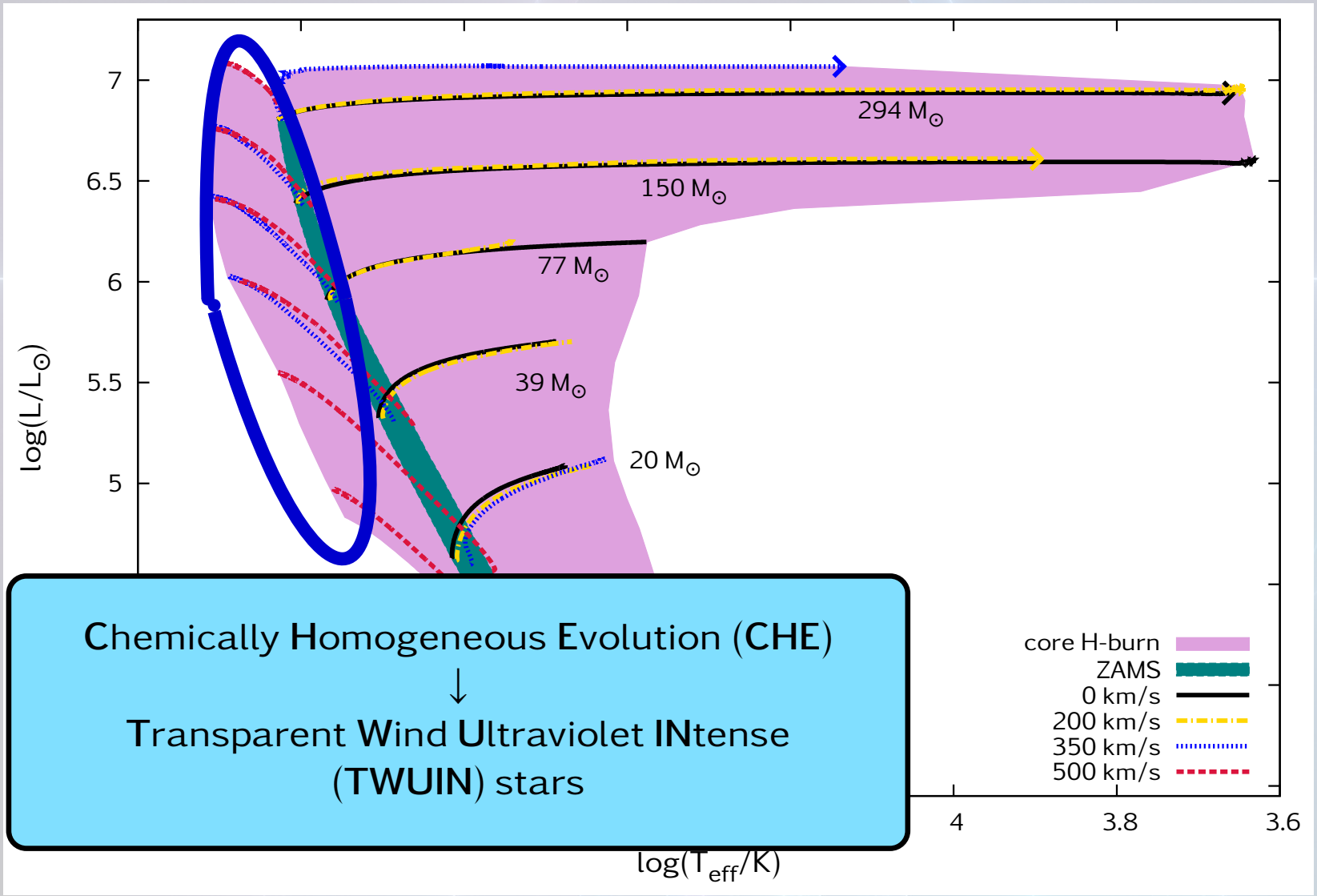

Chemically Homogeneous Evolution (**CHE**)

↓

Transparent **W**ind **U**ltraviolet **IN**tense (**TWUIN**) stars

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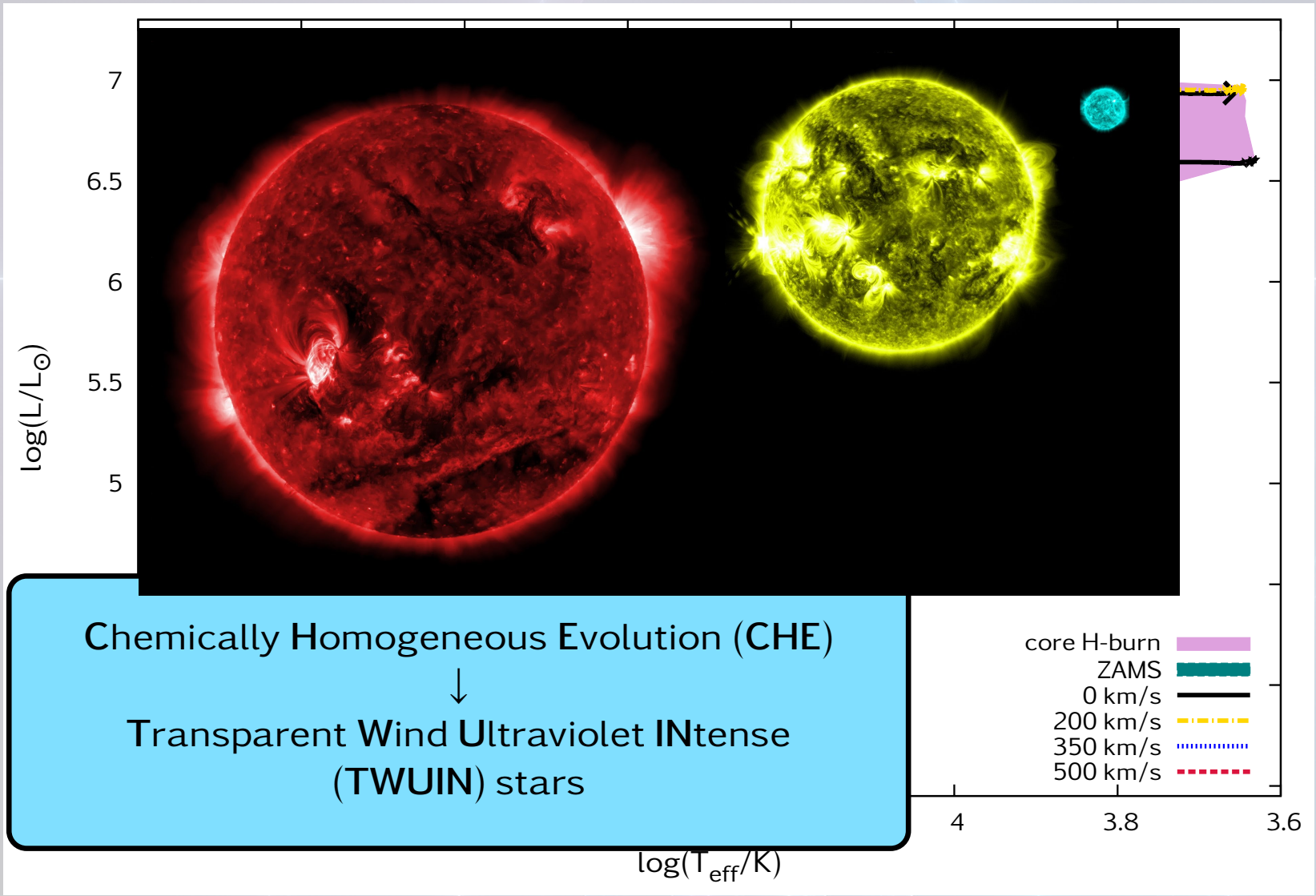

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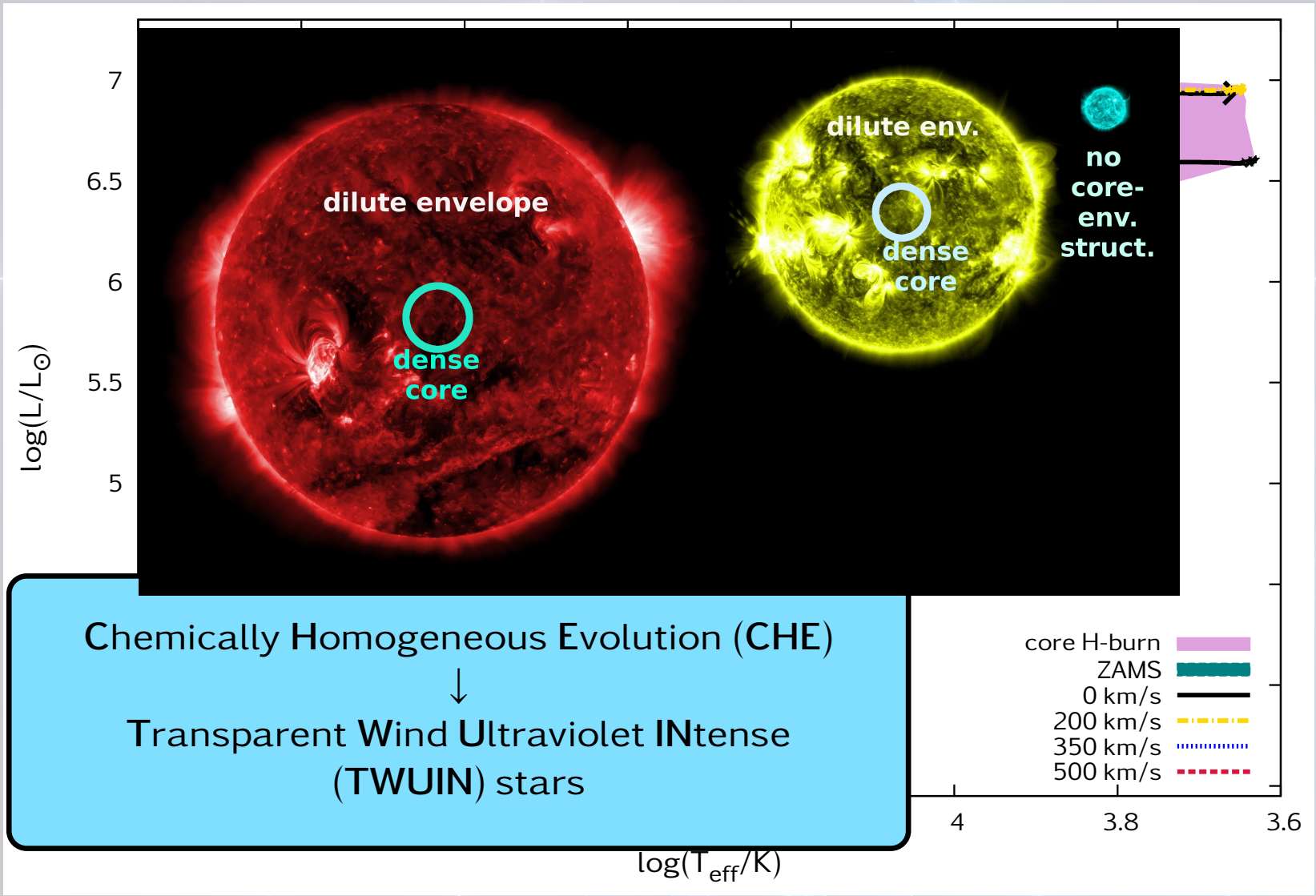

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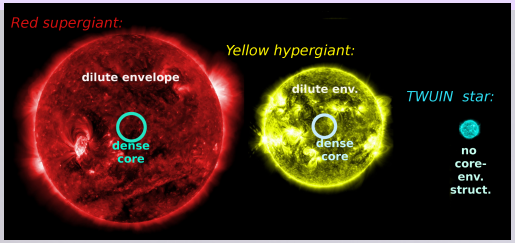
Transparent **W**ind **U**ltraviolet **IN**tense (**TWUIN**) stars

What do we know about TWUIN stars?



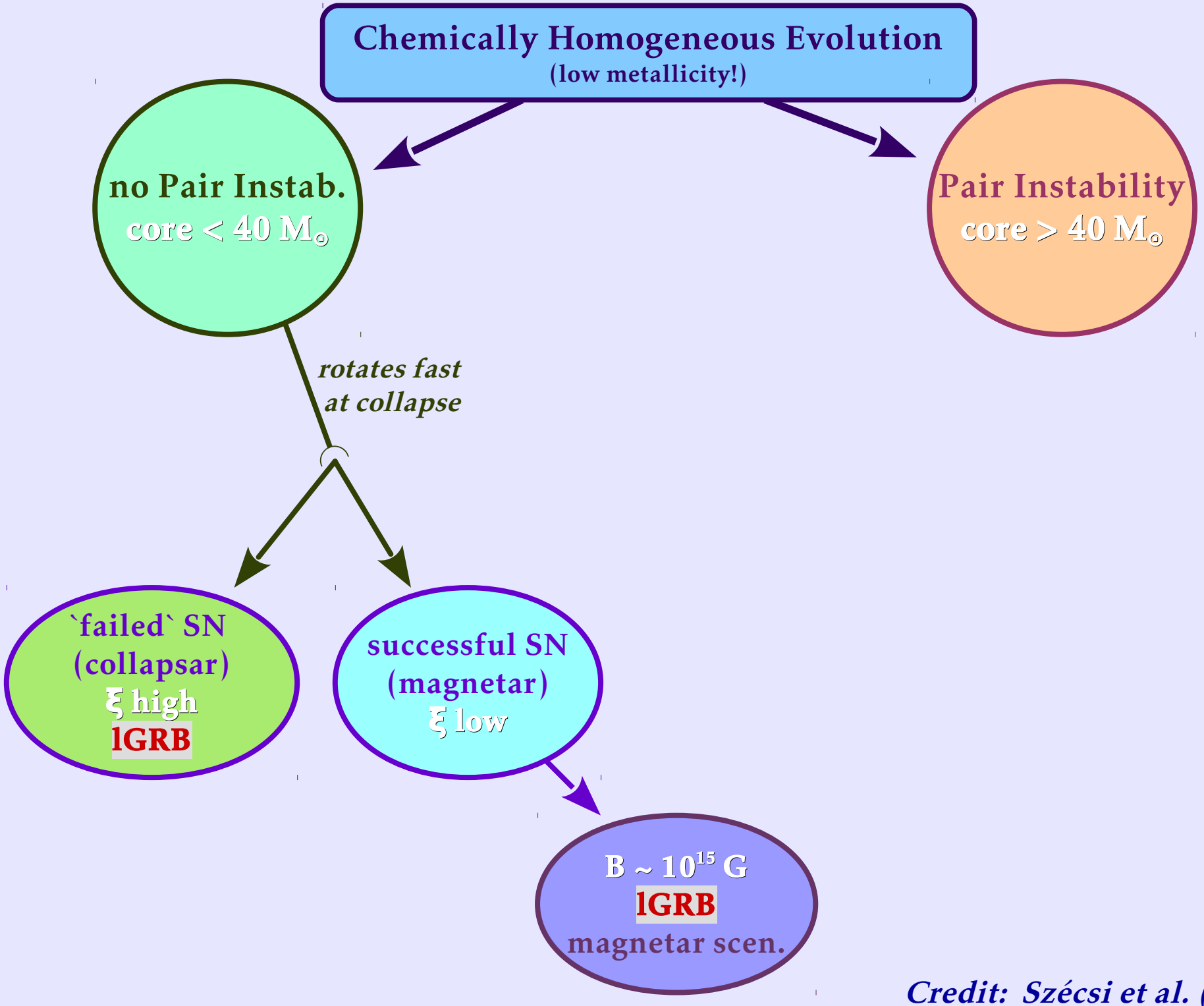
TWUIN stars =
*T*ransparent *W*ind *U*V *IN*tense stars

- form via Chemically *Homogeneous* Evolution
- *Massive* Stars + fast rotation + low-metallicity
- theoretical prediction, but under intense investigation
  Szécsi+15, Köhler+15, Yoon+06, Yoon+12, Marchant+16,
  de Mink+16, Szécsi+17 *(in prep.)* etc.

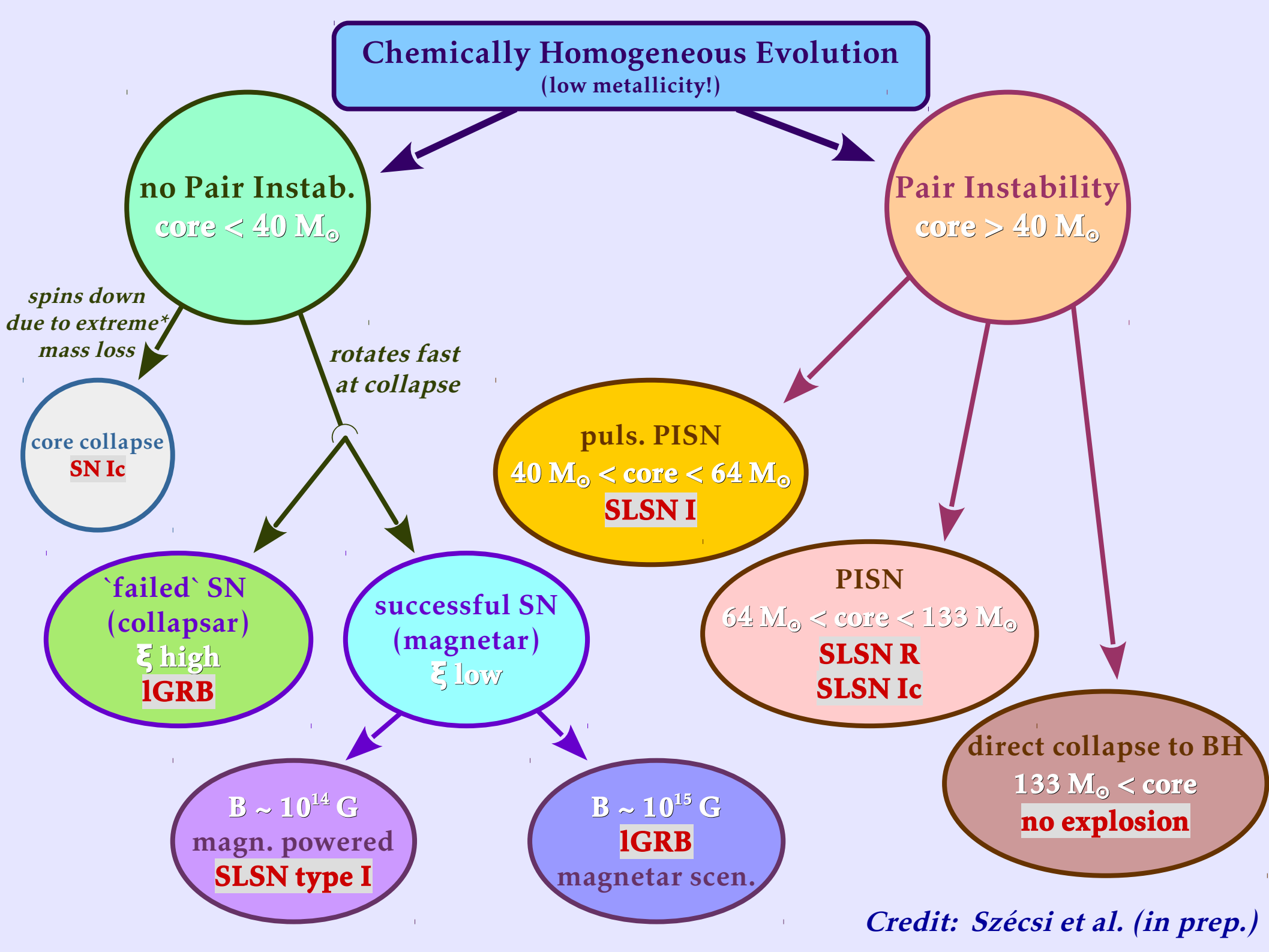
...computing a grid of synthetic TWUIN spectra (in progress ☺)

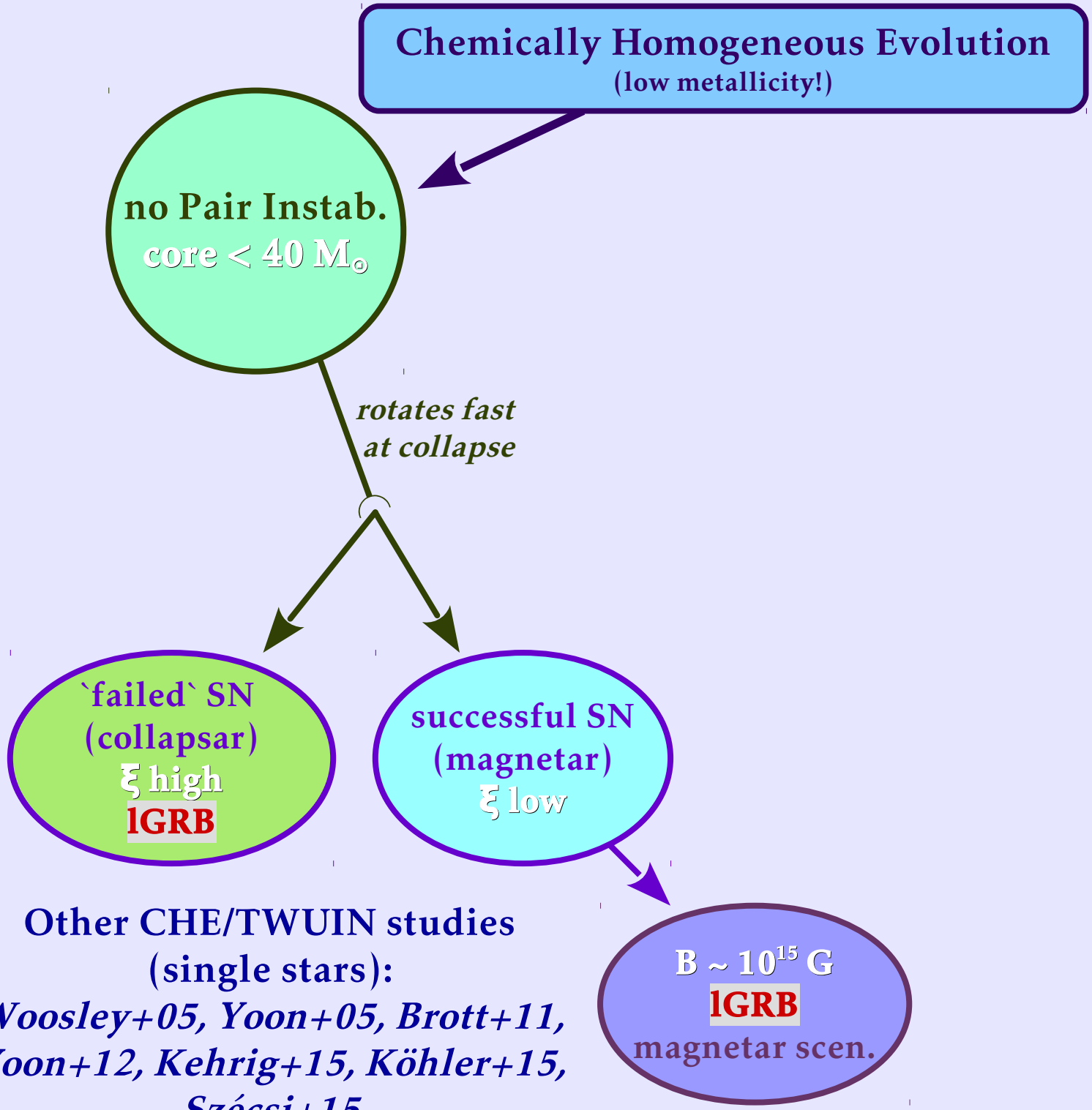
D. Szécsi (CZ), J. Kubát (CZ),
B. Kubátová (CZ), A. Sanders (GE),
J. Krtička (CZ), F. Tramper (SP),
W.R. Hamann (GE)

- NOT Wolf–Rayet stars, because *Weak* Wind
- but: *IONIZATION*!



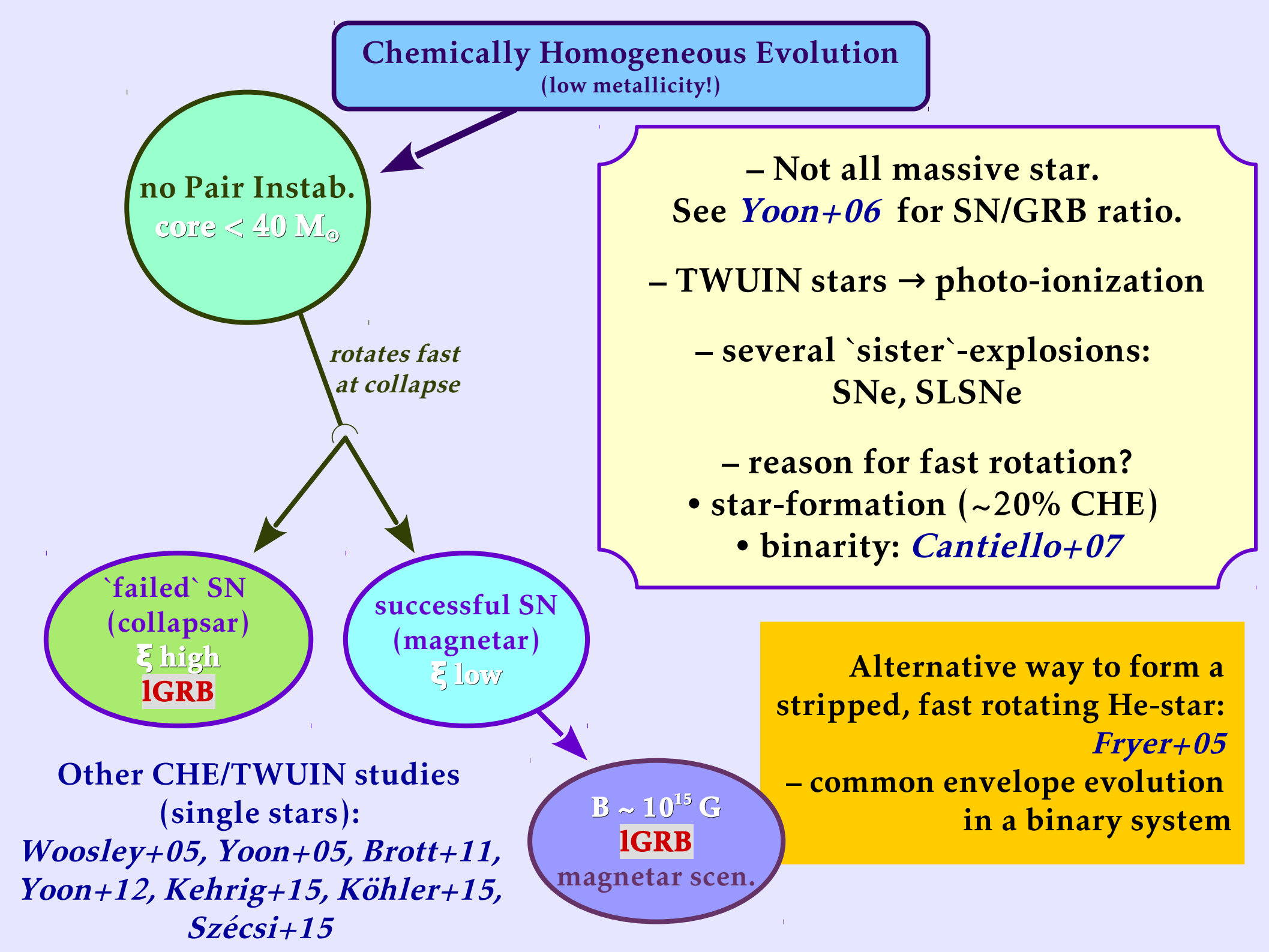
Credit: Szécsi et al. (in prep.)


Chemically Homogeneous Evolution
(low metallicity!)
no Pair Instab.
core < 40 M⊙
Pair Instability
core > 40 M⊙
spins down
due to extreme*
mass loss
rotates fast
at collapse
core collapse
SN Ic
puls. PISN
40 M⊙ < core < 64 M⊙
SLSN I
`failed` SN
(collapsar)
ξ high
lGRB
successful SN
(magnetar)
ξ low
PISN
64 M⊙ < core < 133 M⊙
SLSN R
SLSN Ic
direct collapse to BH
133 M⊙ < core
no explosion
B ~ 10^14 G
magn. powered
SLSN type I
B ~ 10^15 G
lGRB
magnetar scen.
Credit: Szécsi et al. (in prep.)



Other CHE/TWUIN studies (single stars):

Woosley+05, Yoon+05, Brott+11, Yoon+12, Kehrig+15, Köhler+15, Szécsi+15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(collapsar)
ξ high
lGRB
successful SN
(magnetar)
ξ low
B ~ 10^15 G
lGRB
magnetar scen.
– Not all massive star.
See Yoon+06 for SN/GRB ratio.
– TWUIN stars → photo-ionization
– several `sister`-explosions:
SNe, SLSNe
– reason for fast rotation?
• star-formation (~20% CHE)
• binarity: Cantiello+07
Alternative way to form a
stripped, fast rotating He-star:
Fryer+05
– common envelope evolution
in a binary system
Other CHE/TWUIN studies
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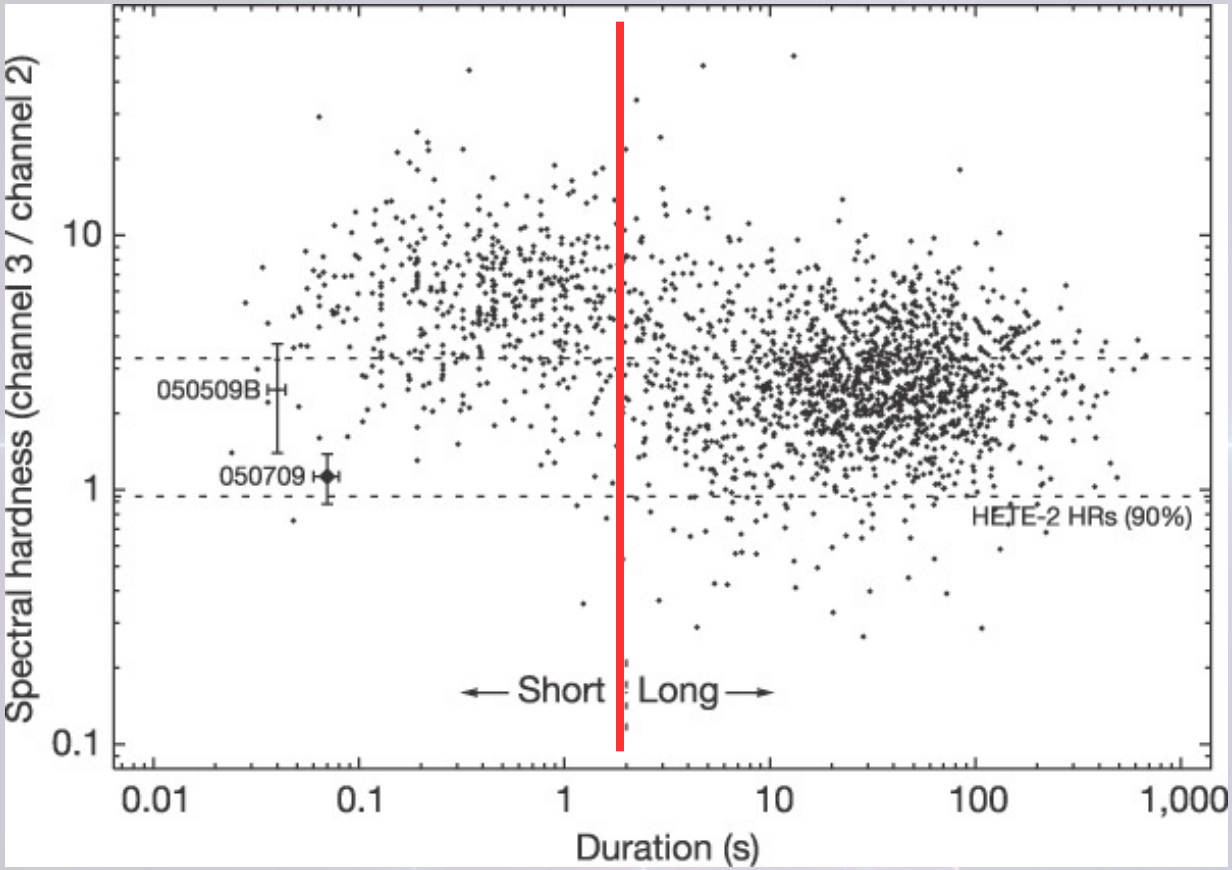
How may GRBs form? *A review by Dorottya Szécsi*



Credit: Hjorth+2005

Long/soft:

Massive Stars at collapse

Short/hard: two Compact Objects at merger

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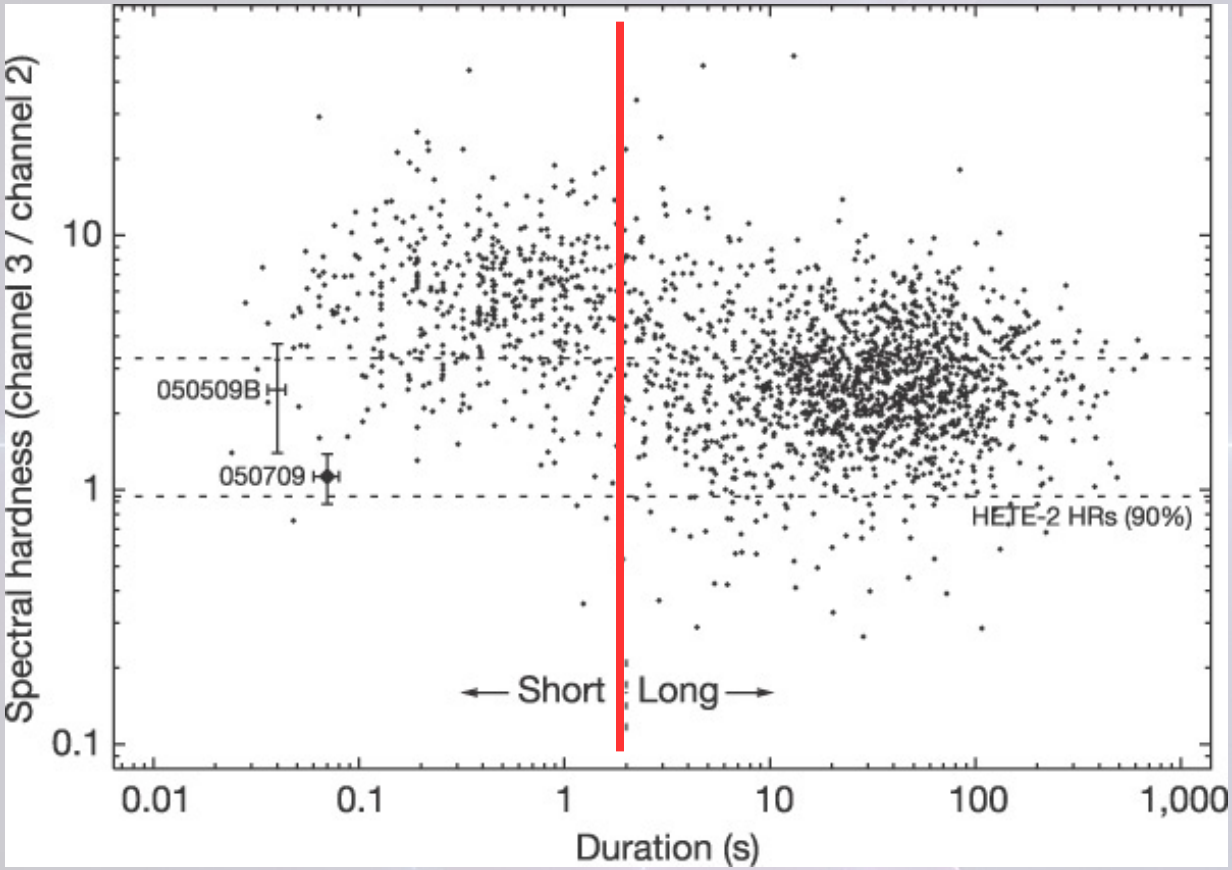

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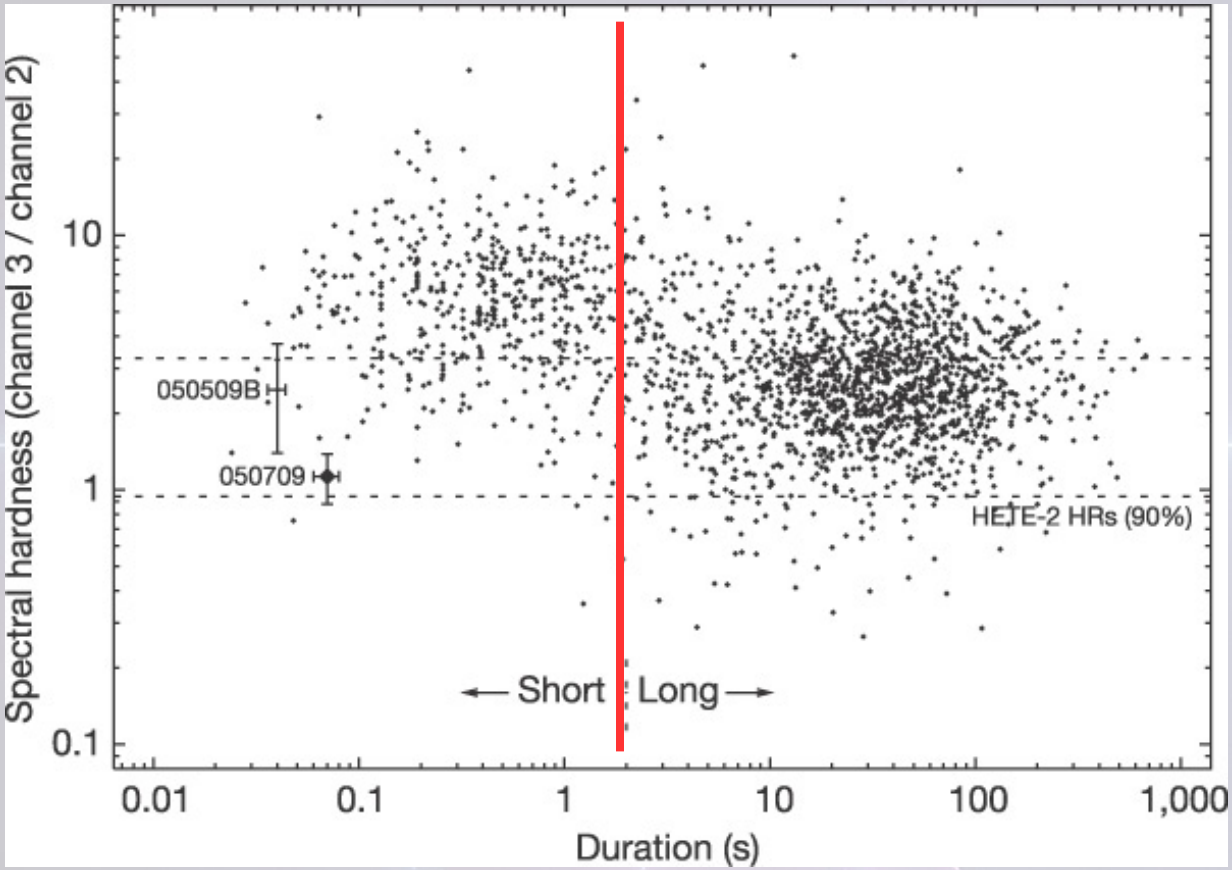

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Back to I Zw 18

I Zwicky 18

- Blue Compact Dwarf Galaxy
- 60 million lightyears $\rightarrow$ local
- star formation rate: 0.1 $M_\odot$/yr
- ionized gas
- low metallicity: Z=1/50 $Z_\odot$

Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Lebouteiller+13

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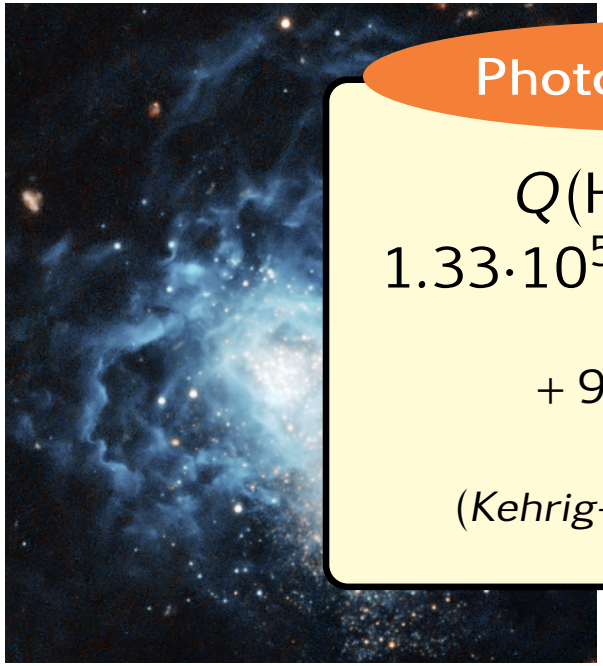

Photoionization

$Q(\mathrm{HeII})^{obs} = 1.33 \cdot 10^{50}$ photons s^{-1}

+ 9 WC stars

(*Kehrig+15, Crowther+06*)

Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Lebouteiller+13

Photoionization in I Zw 18

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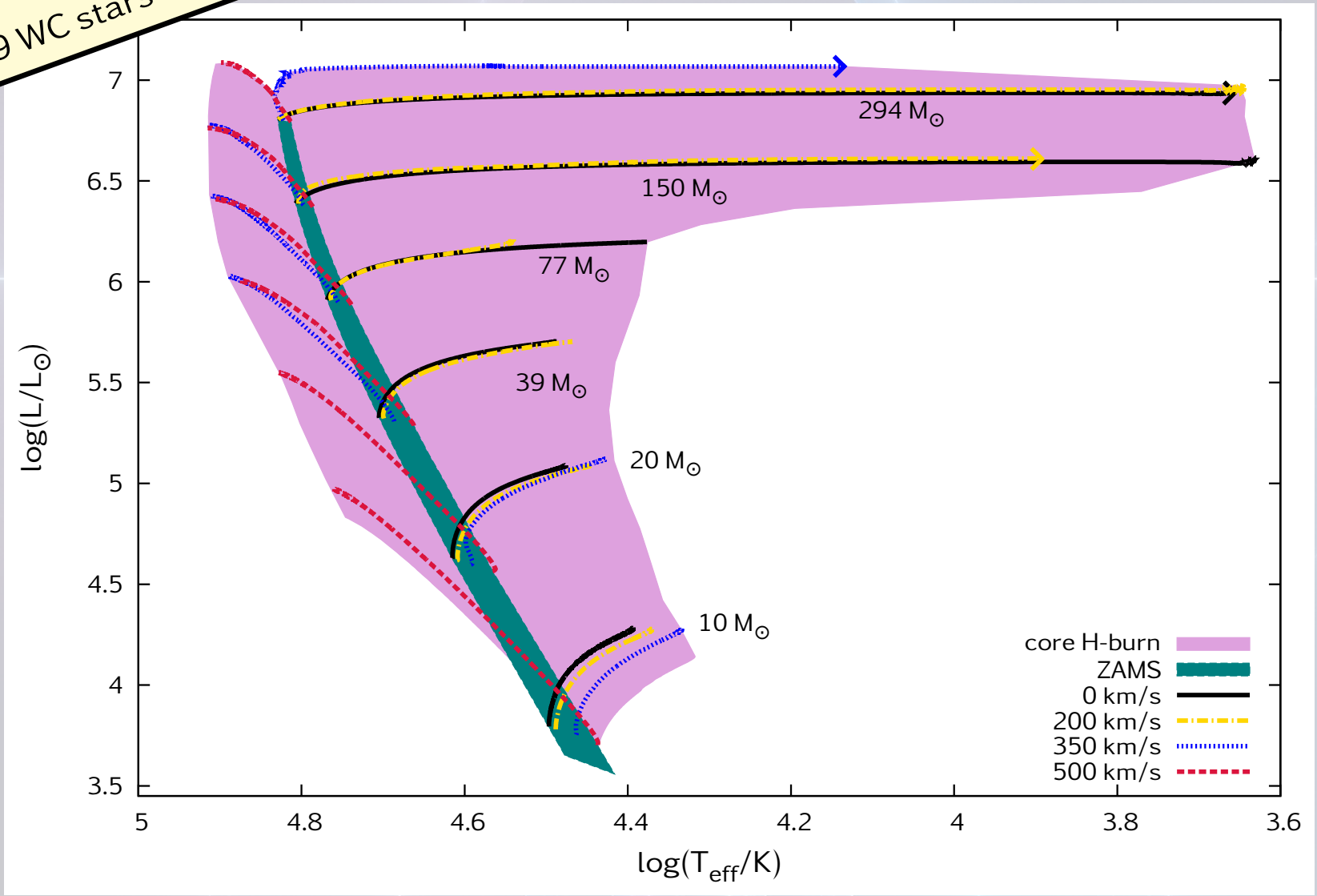

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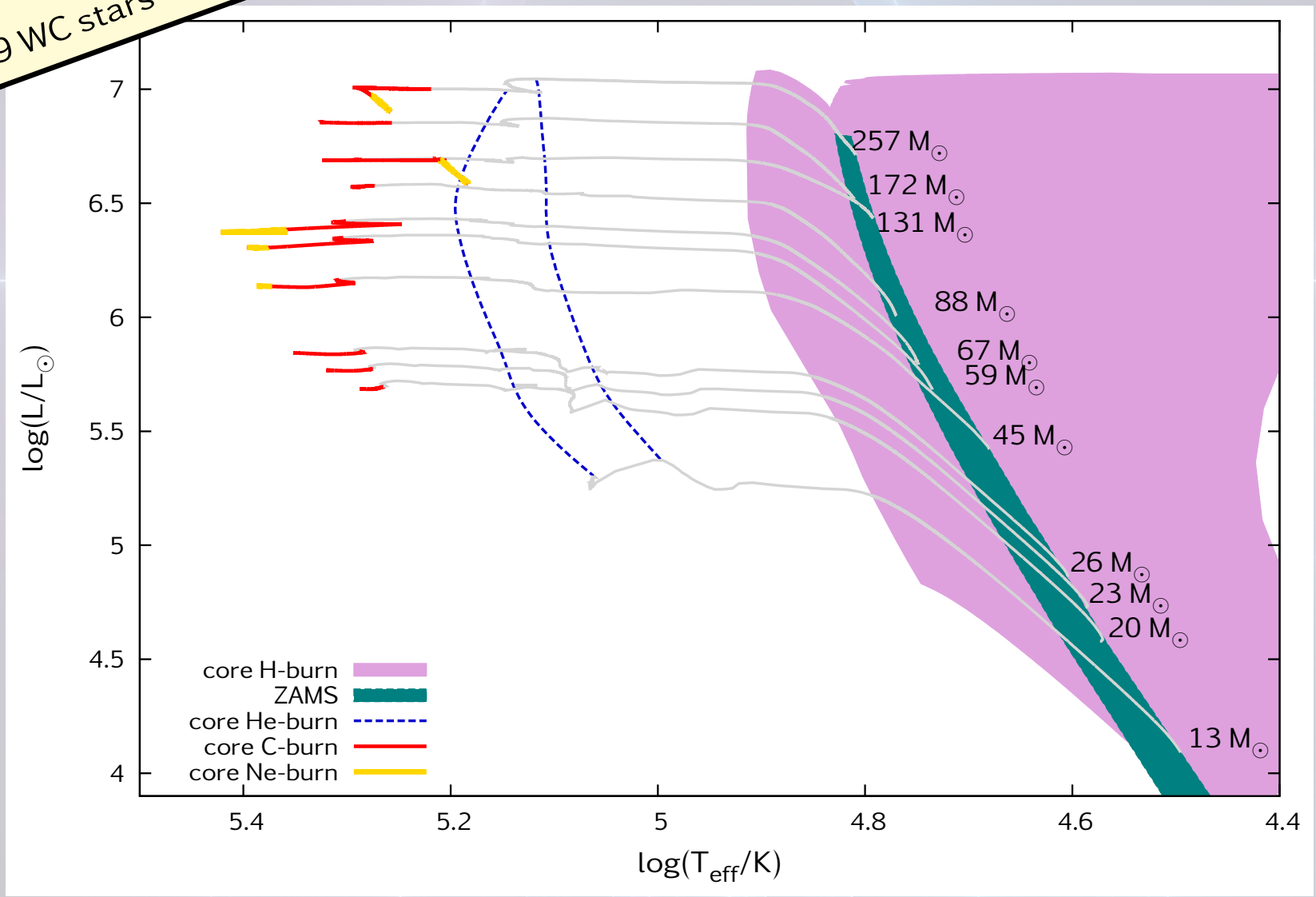

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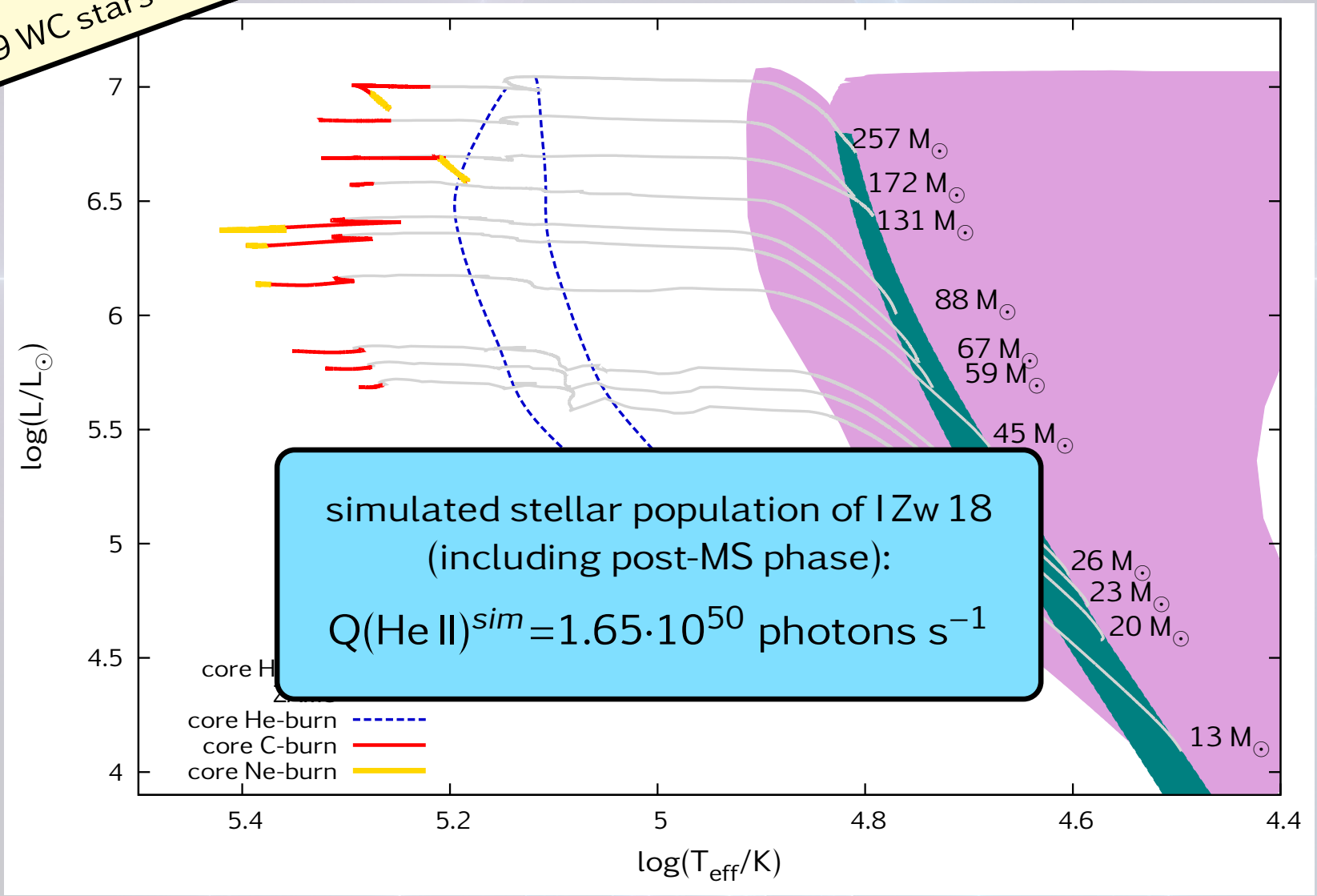

simulated stellar population of I Zw 18 (including post-MS phase):

$Q(\mathrm{He\,II})^{sim} = 1.65 \cdot 10^{50}$ photons s^{-1}

Photoionization in I Zw 18

Photoionization

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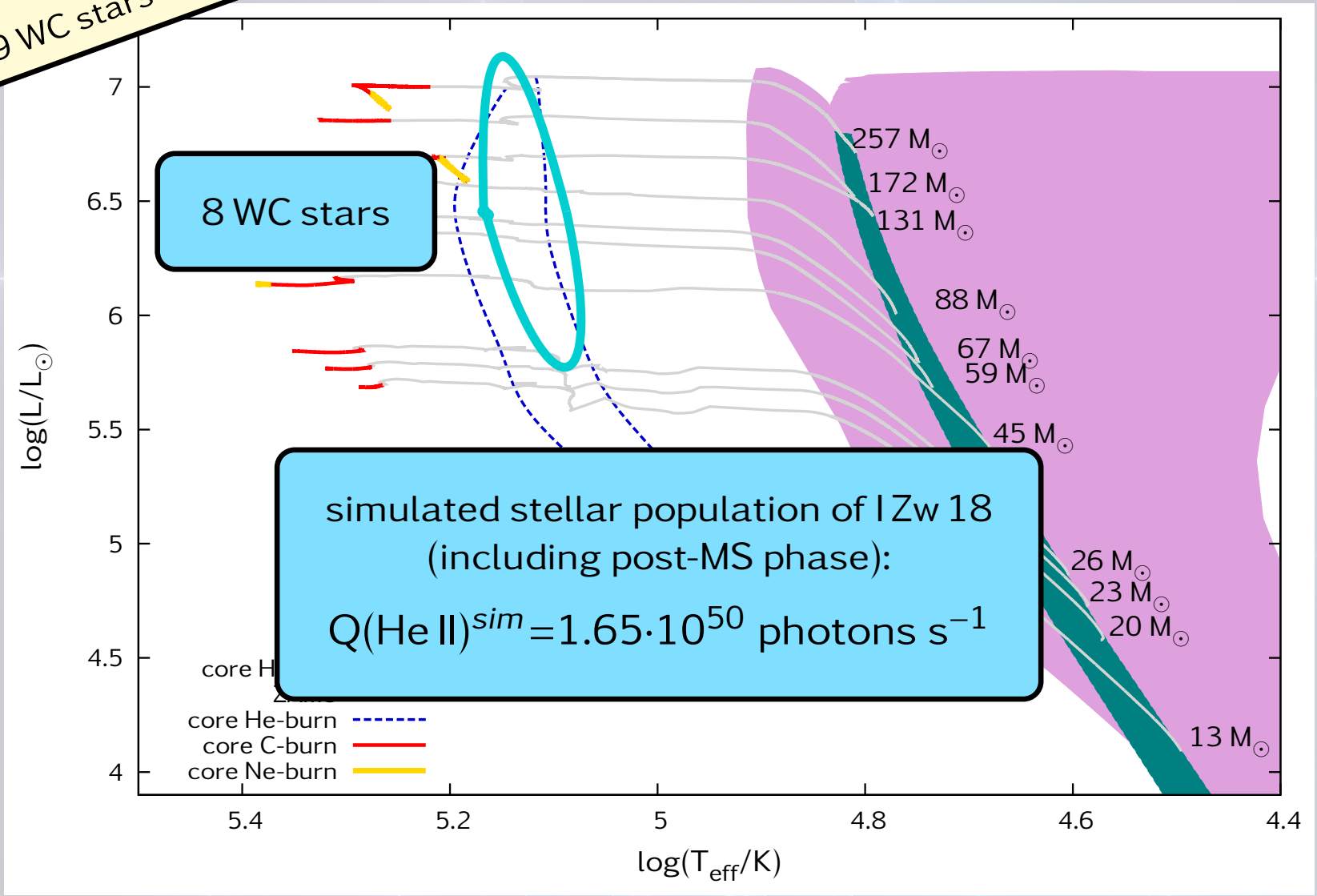

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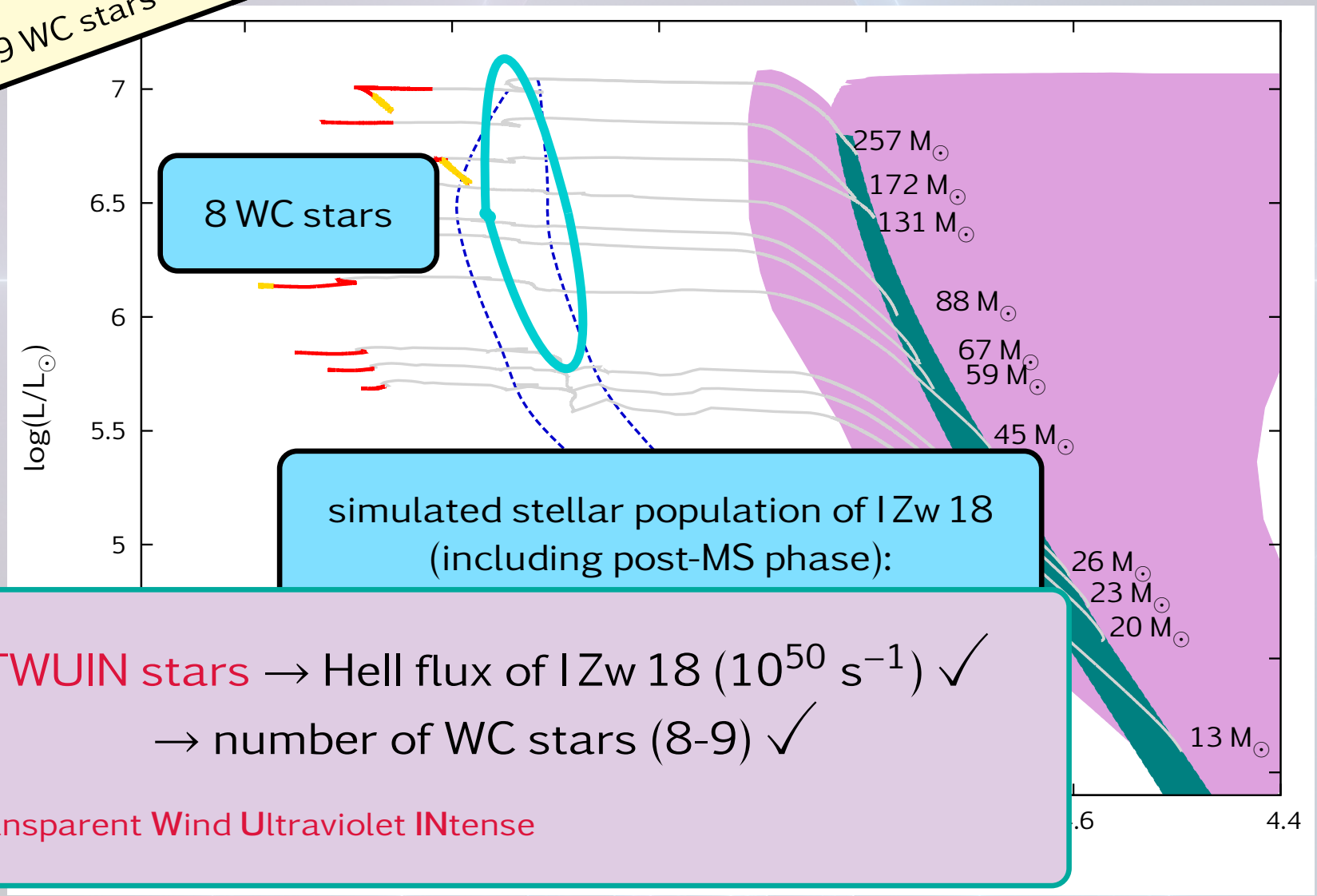

TWUIN stars → HeII flux of I Zw 18 (10^{50} s^{-1}) ✓

→ number of WC stars (8-9) ✓

Transparent **W**ind **U**ltraviolet **IN**tense