Low Metallicity Massive Stars

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Institut
für
Astronomie

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Low Metallicity Massive Stars

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

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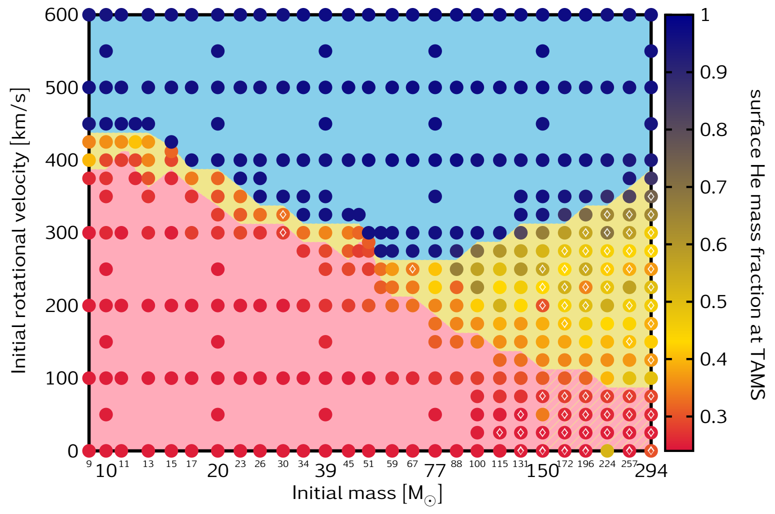

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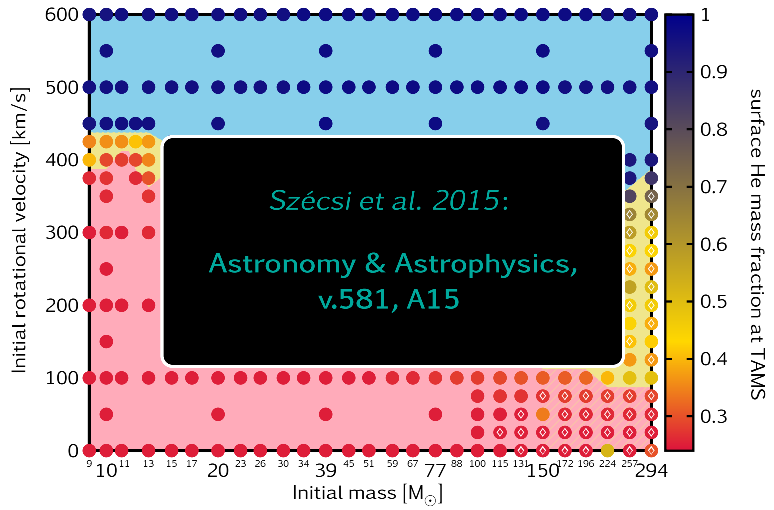

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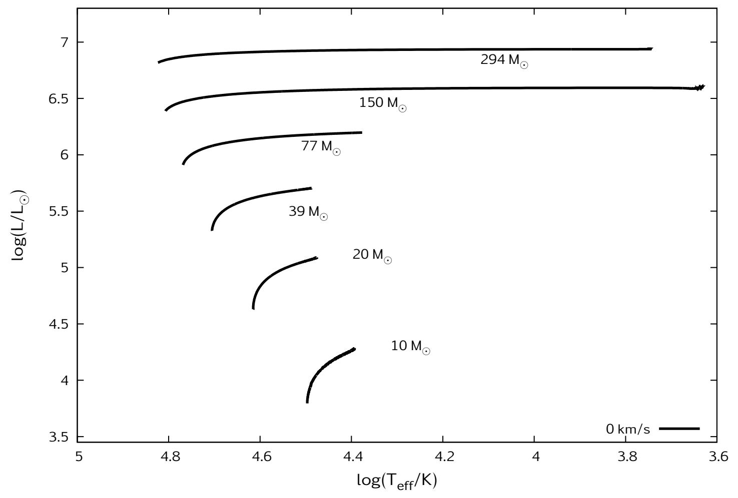

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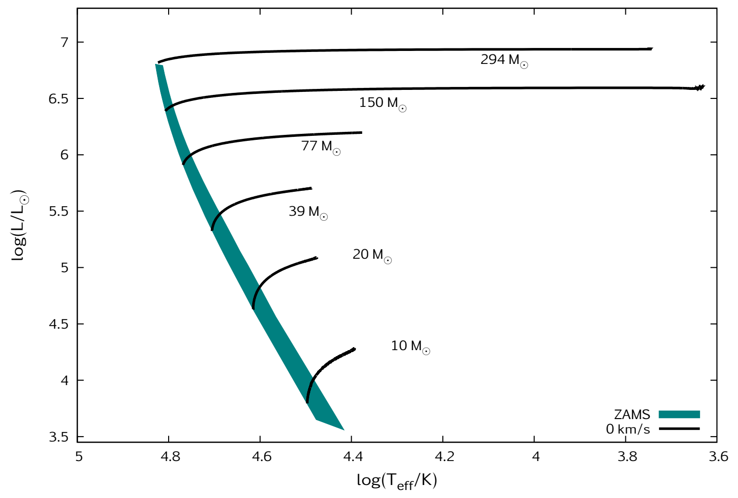

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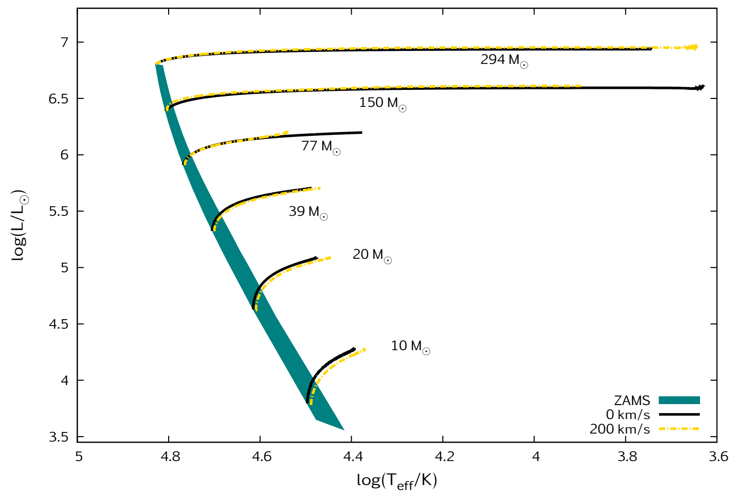

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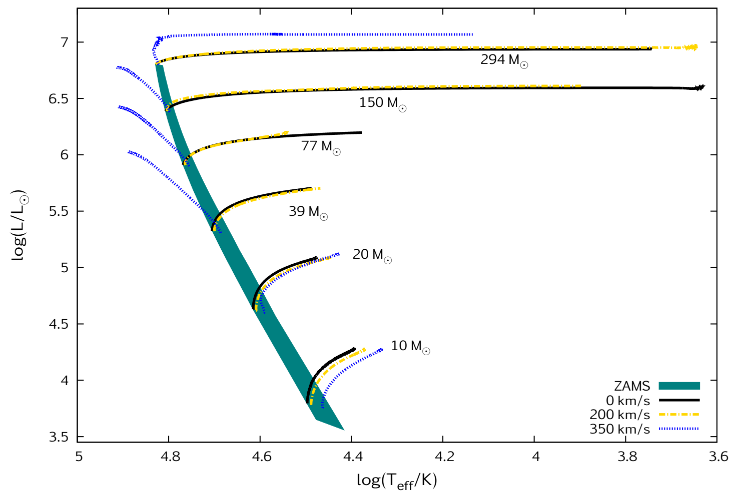

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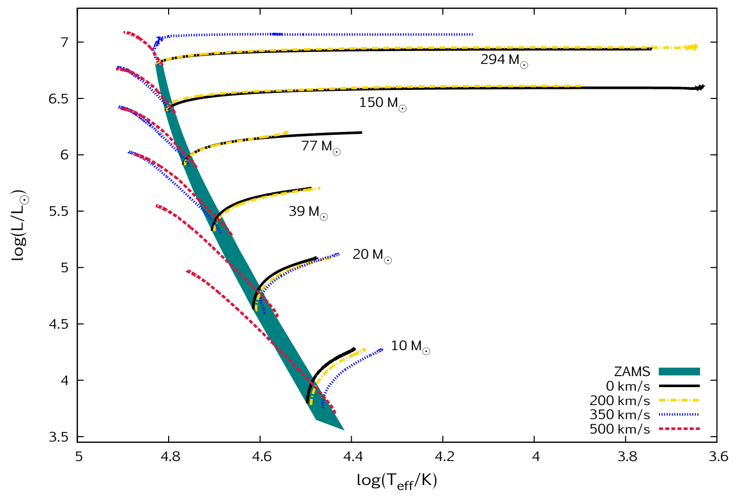

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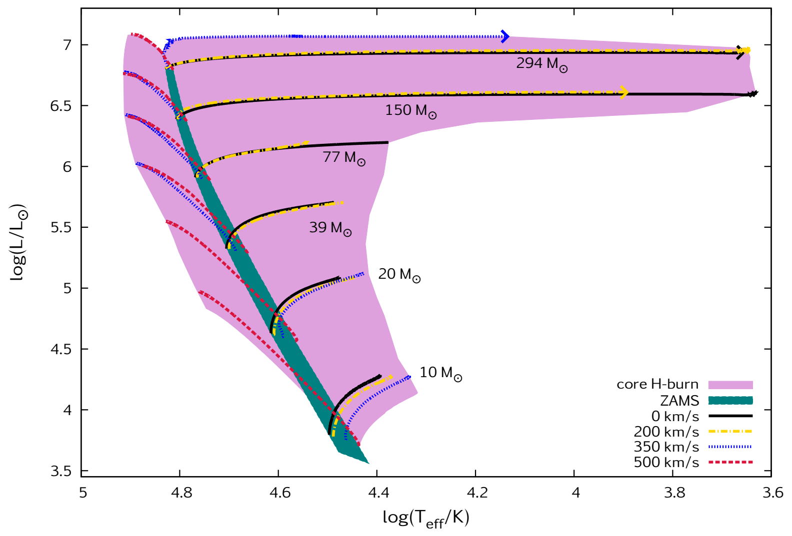

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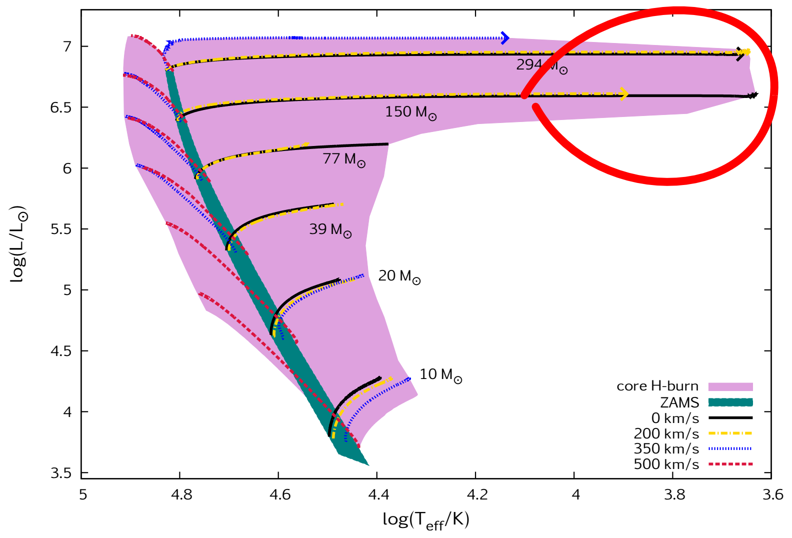

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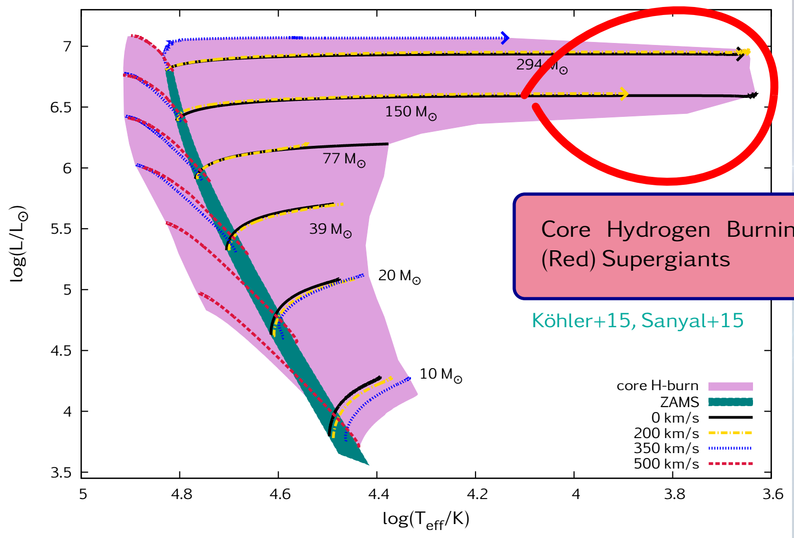

Core Hydrogen Burning
(Red) Supergiants

Köhler+15, Sanyal+15

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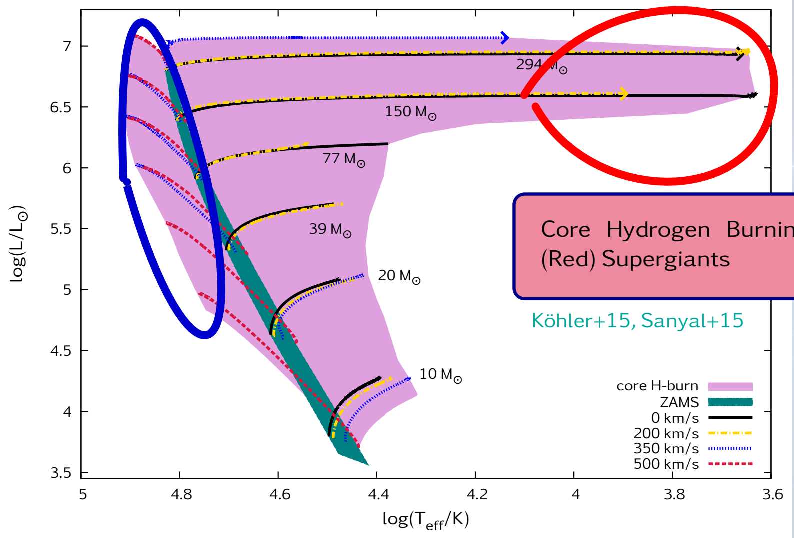

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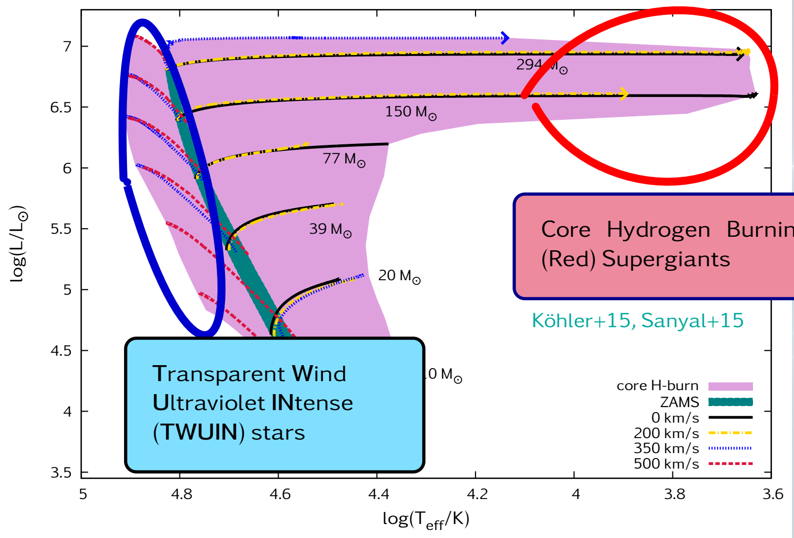

Transparent **W**ind
Ultraviolet **IN**tense
(**TWUIN**) stars

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(TWUIN stars)

– in the

starburst galaxy I Zwicky 18

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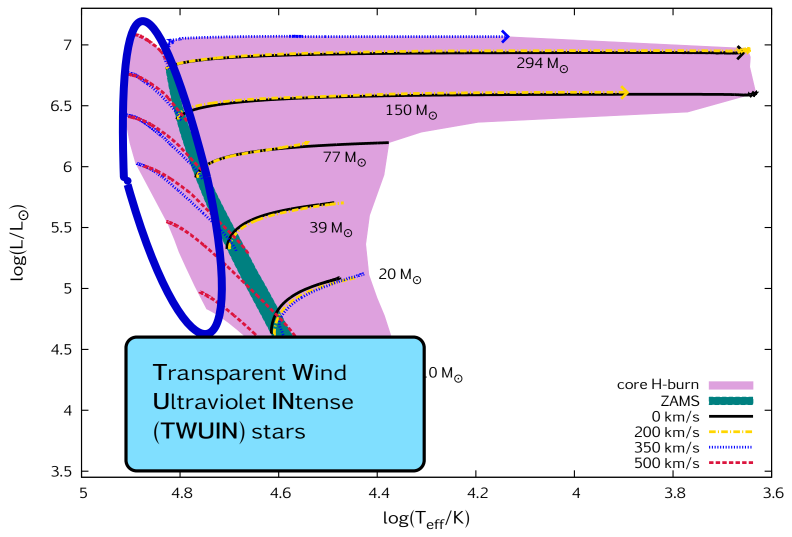

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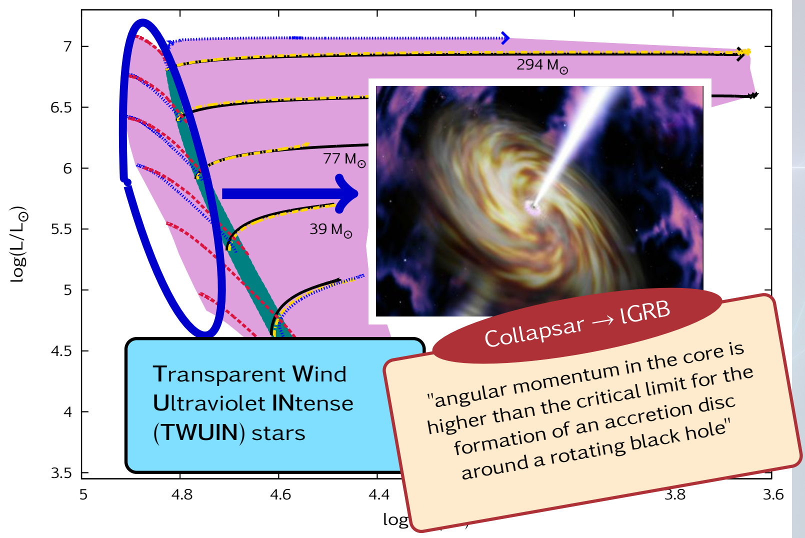

Transparent **W**ind **U**ltraviolet **IN**tense (**TWUIN**) stars

Collapsar → lGRB

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

WR stars?

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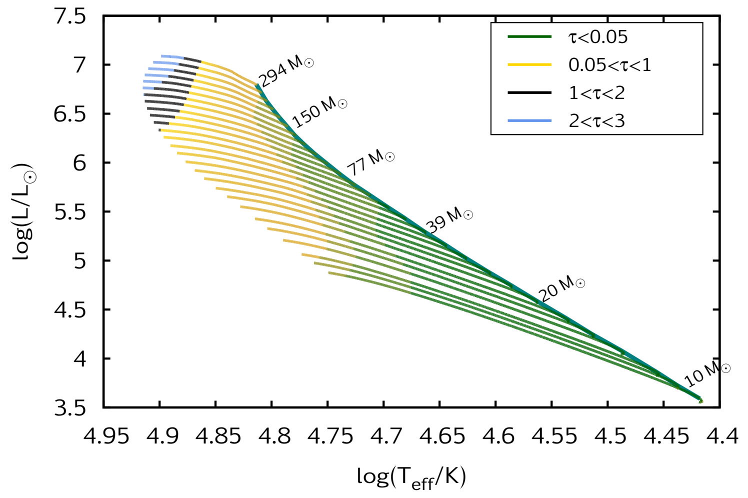
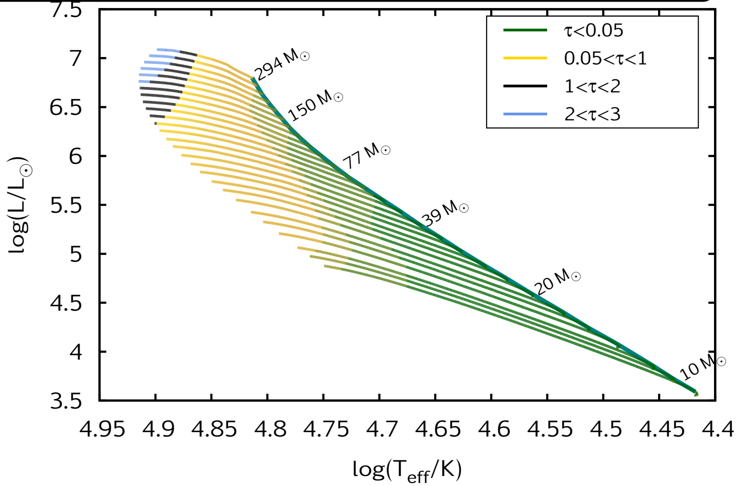

τ<0.05
0.05<τ<1
1<τ<2
2<τ<3
294 M☉
150 M☉
77 M☉
39 M☉
20 M☉
10 M☉
log(L/L☉)
7.5
7
6.5
6
5.5
5
4.5
4
3.5
log(T_eff/K)
4.95
4.9
4.85
4.8
4.75
4.7
4.65
4.6
4.55
4.5
4.45
4.4

WR stars?

Main sequence lifetime: wind optical depth is $\tau \lesssim 1$



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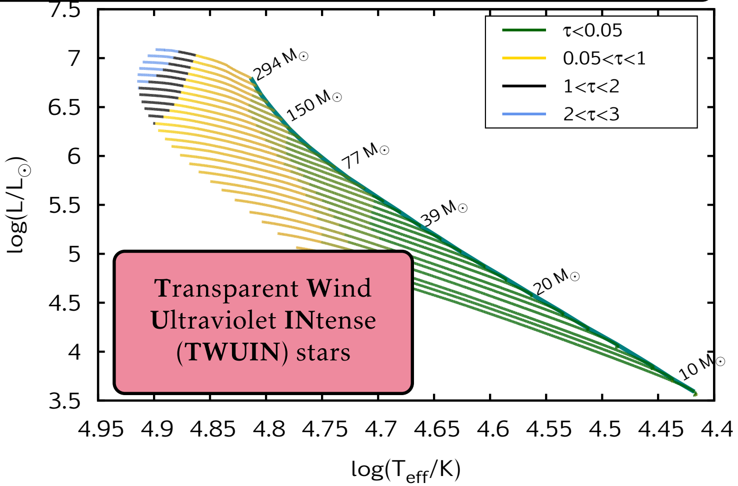

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Transparent Wind UV INtense (TWUIN) stars

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- photoionization!

Do TWUIN stars exist?

I Zwicky 18

- Blue Compact Dwarf Galaxy
- 18 Mpc → local
- SFR: 0.1-1 $M_\odot$/yr
- ionized gas
- low metallicity: 12+log(O/H)=7.17 $\downarrow$ $Z=1/50\ Z_\odot \approx 0.0002$

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

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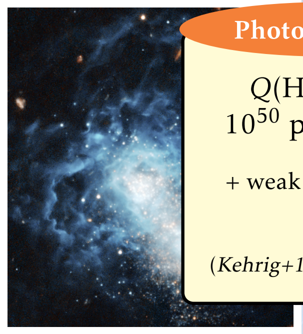


Photoionization

$Q(\text{He II})^{obs} = 10^{50}$ photons s^{-1}

+ weak WR features

(*Kehrig+15,Crowther+06*)

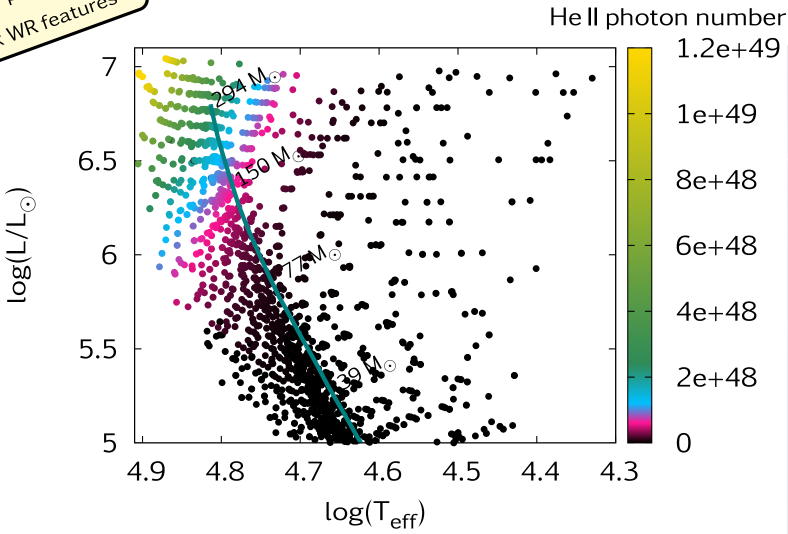
Legrand+07, Aloisi+09, Annibali+13, Kehrig+13, Lebouteiller+13

Photoionization in I Zw 18

Photoionization

$Q(\mathrm{HeII})^{obs} = 1.3 \cdot 10^{50}$ photons s^{-1}

+ weak WR features



Cowther+06, Shirazi+12, Kehrig+15, Heap+15

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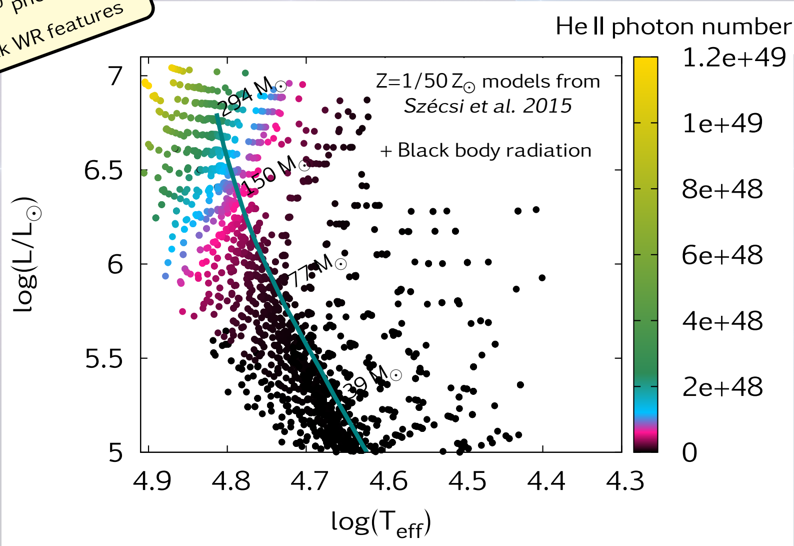

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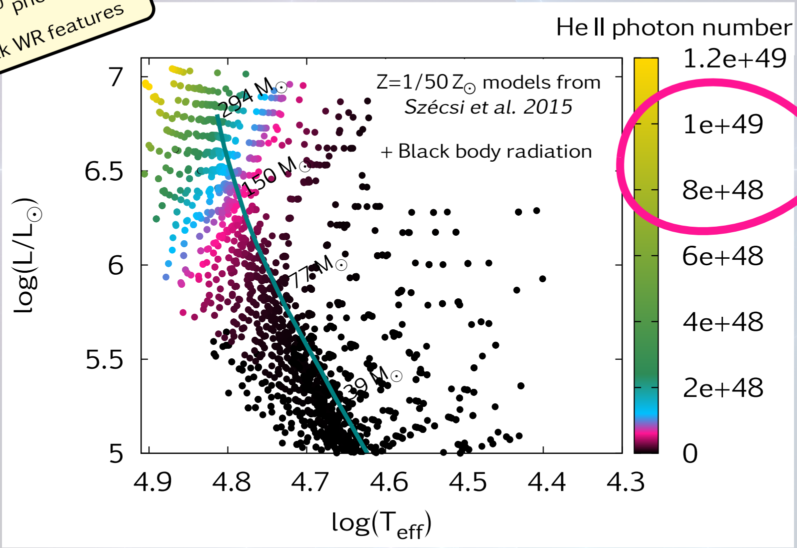

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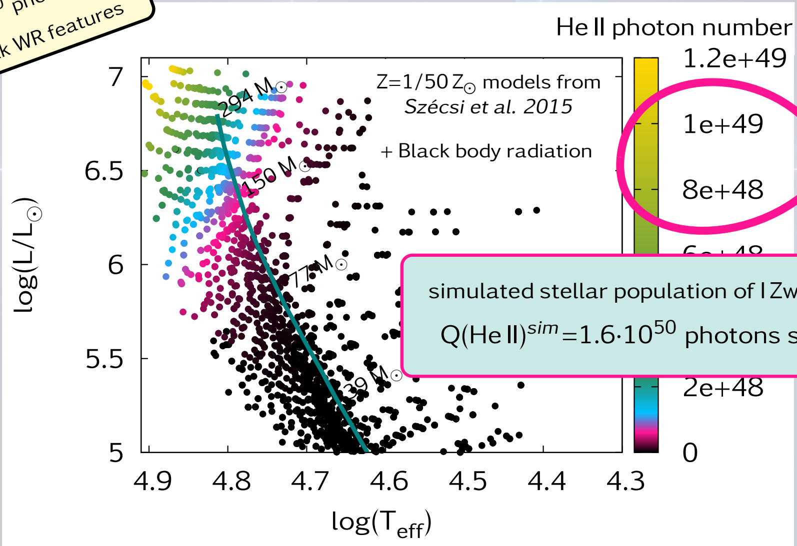

simulated stellar population of I Zw 18:

$Q(\mathrm{He\,II})^{sim} = 1.6 \cdot 10^{50}$ photons s^{-1}

Cowther+06, Shirazi+12, Kehrig+15, Heap+15

Photoionization in I Zw 18

Photoionization

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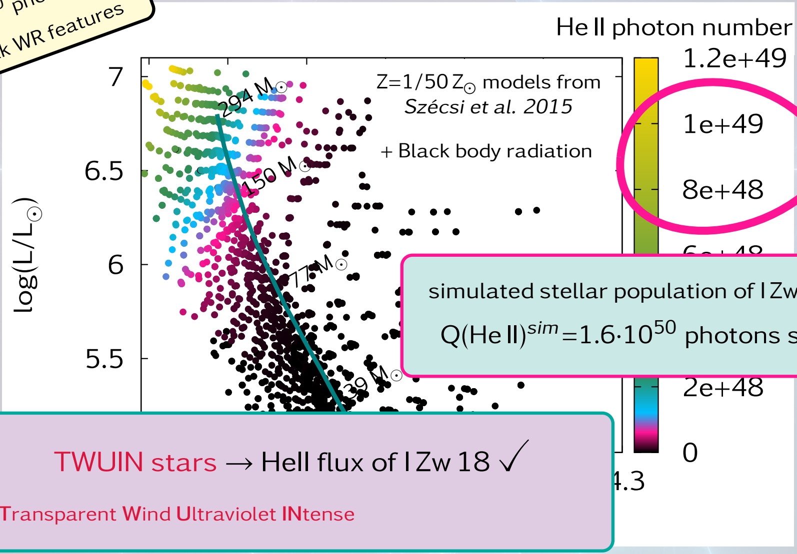

simulated stellar population of I Zw 18:

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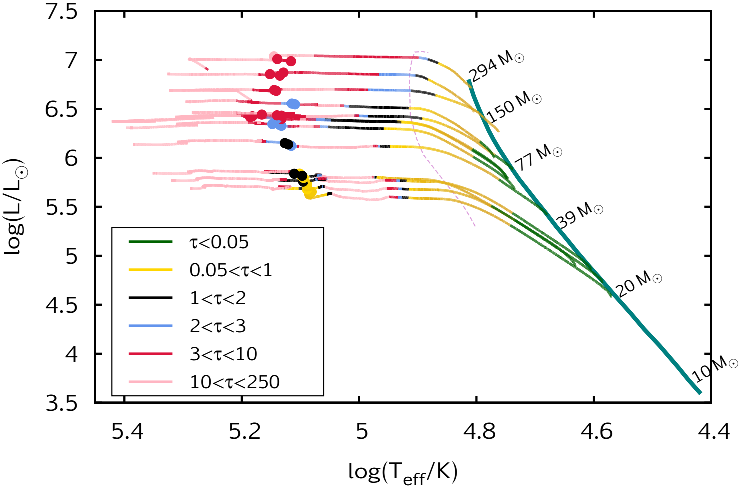
TWUIN stars → HeII flux of I Zw 18 ✓

Transparent Wind Ultraviolet INtense

Cowther+06, Shirazi+12, Kehrig+15, Heap+15

Post-MS phase of TWUIN stars



Takeaway message

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Observation

He II photons

(*Shirazi+12, Kehrig+15*)

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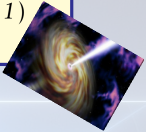
Observation

lGRBs

(*Fruchter+08, Niino'11*)



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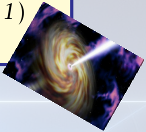
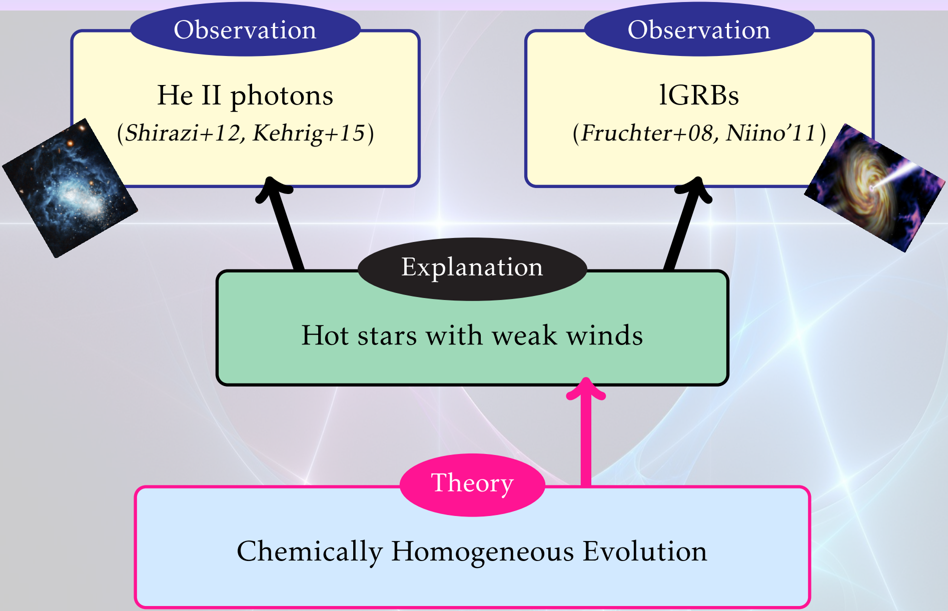


Explanation

Hot stars with weak winds

Takeaway message



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Chemically Homogeneous Evolution

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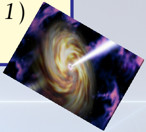

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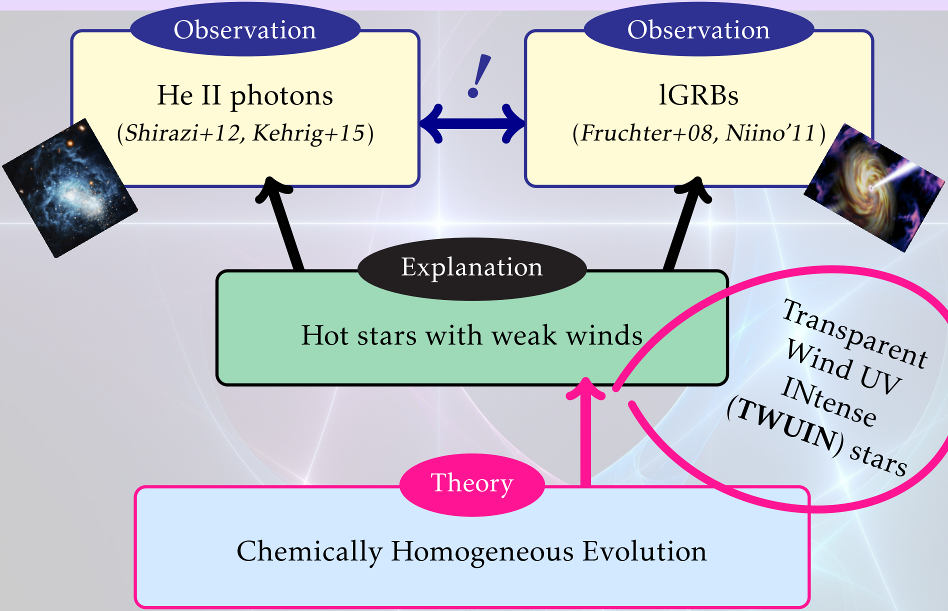

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Transparent Wind UV INtense (**TWUIN**) stars

Theory

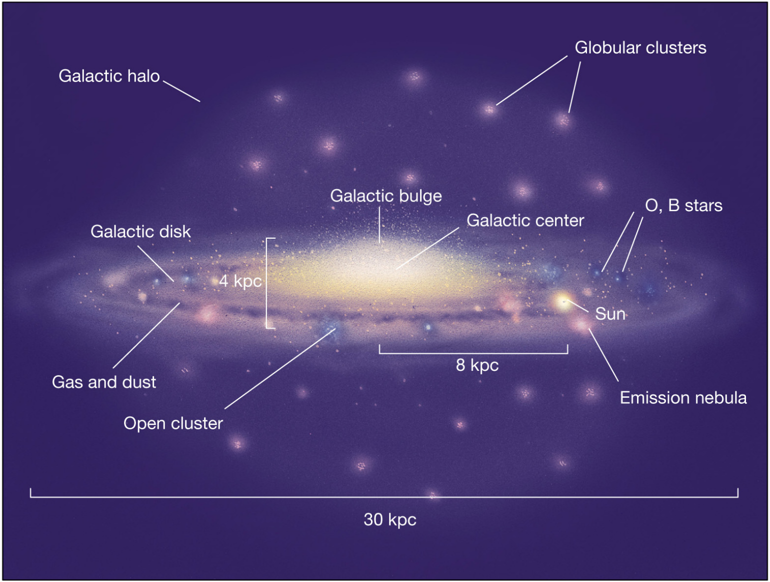
Chemically Homogeneous Evolution

Core Hydrogen Burning Supergiants

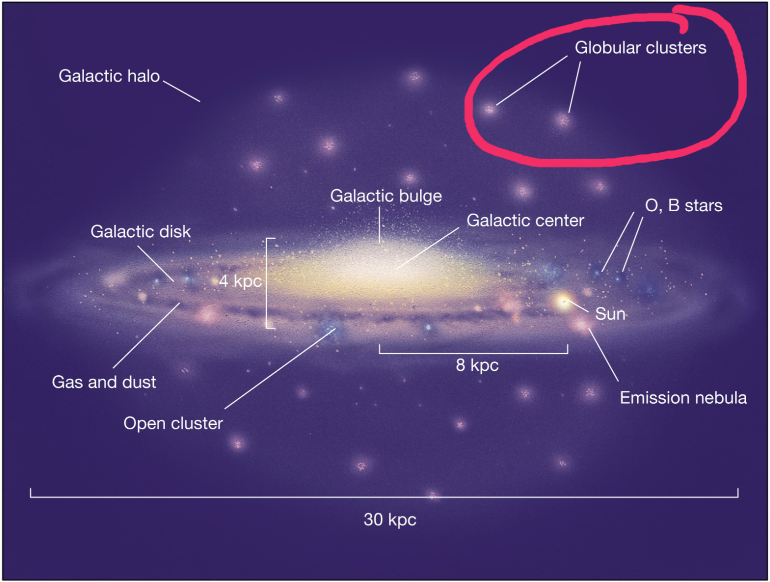
– in the

Early Globular Clusters

Globular Clusters & Abundance Anomalies



Globular Clusters & Abundance Anomalies



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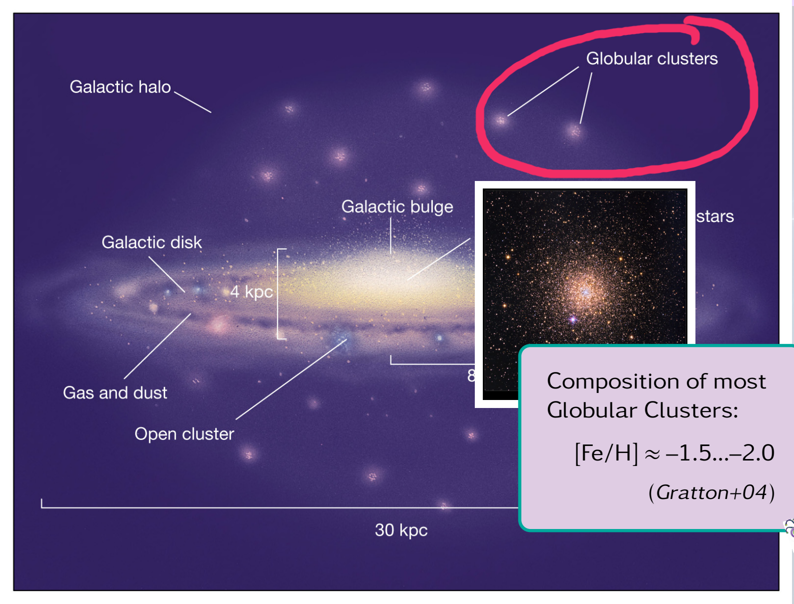

Composition of most Globular Clusters:

$$[\mathrm{Fe/H}] \approx -1.5\ldots-2.0$$

(*Gratton+04*)

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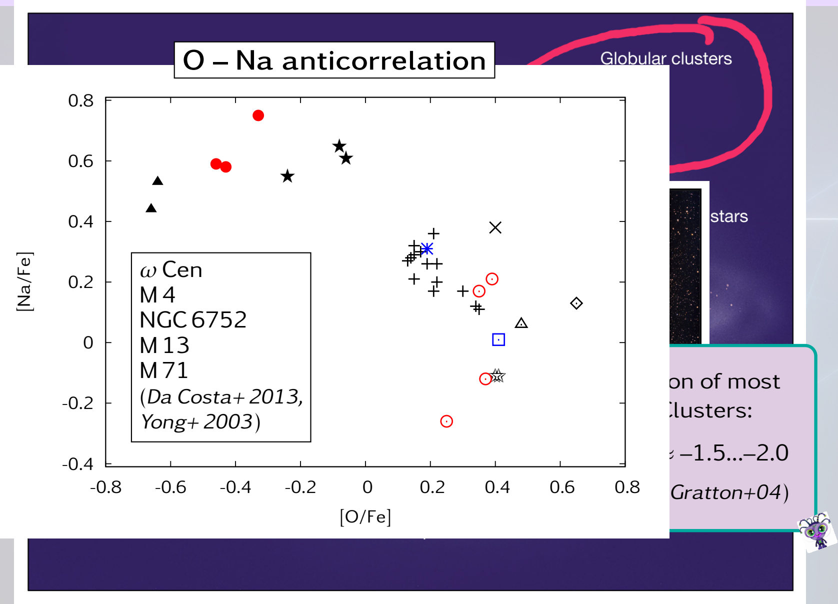

O – Na anticorrelation

ω Cen
M 4
NGC 6752
M 13
M 71
(*Da Costa+ 2013, Yong+ 2003*)

on of most
Clusters:
–1.5...–2.0
Gratton+04)

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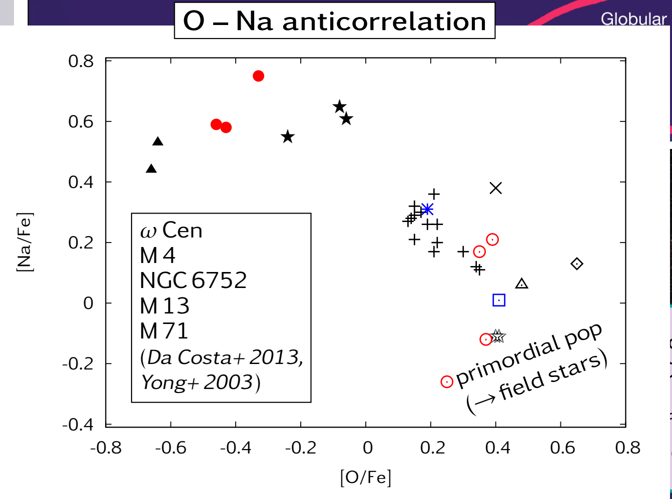

Globular clusters

stars

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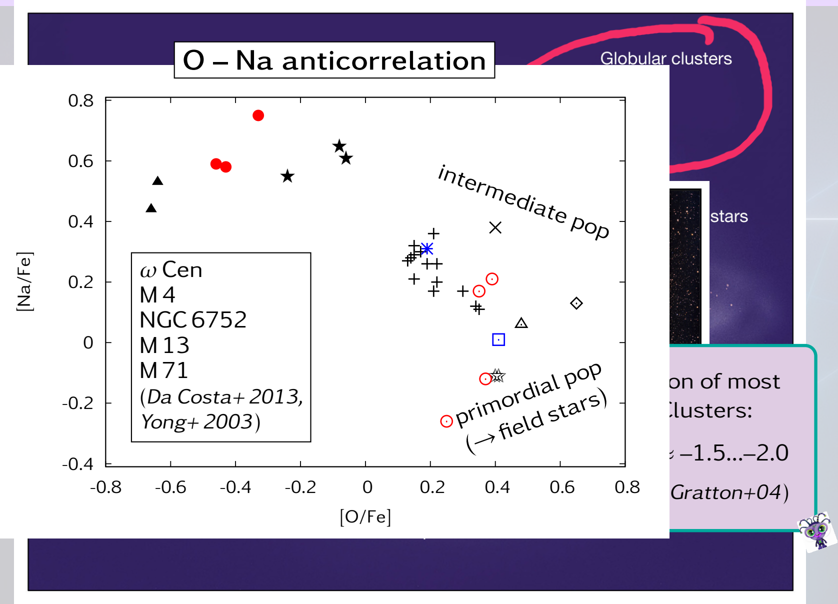

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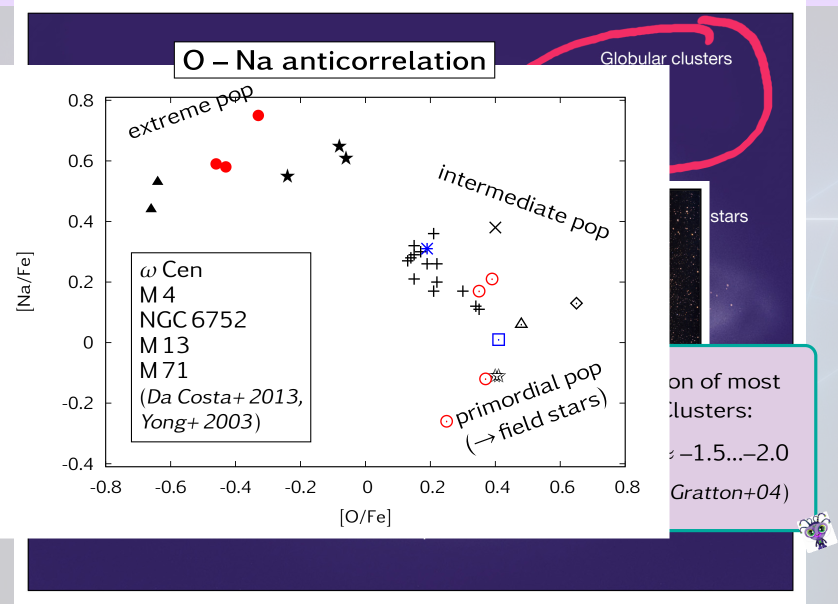

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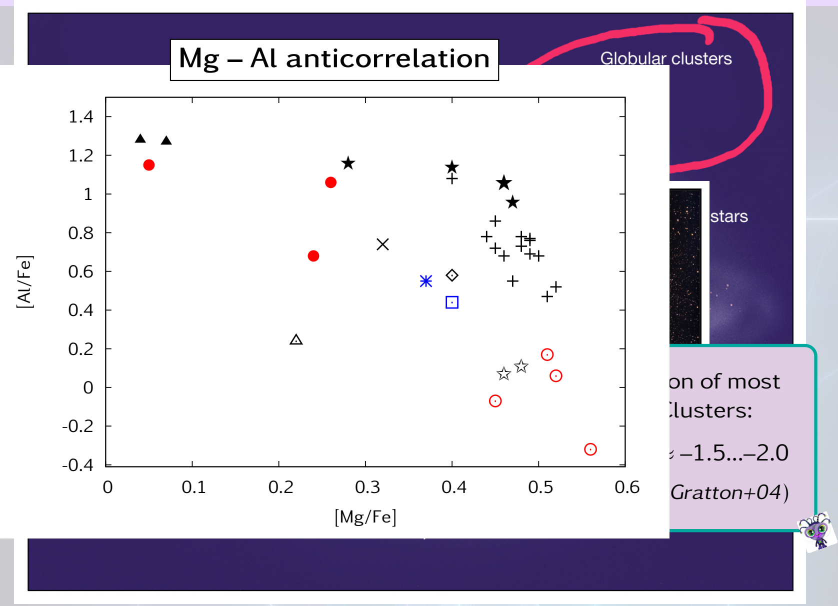

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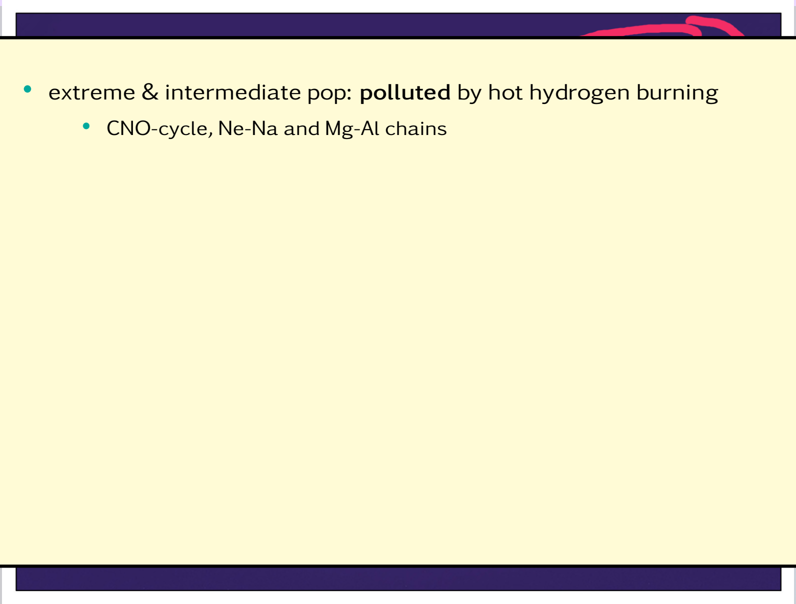
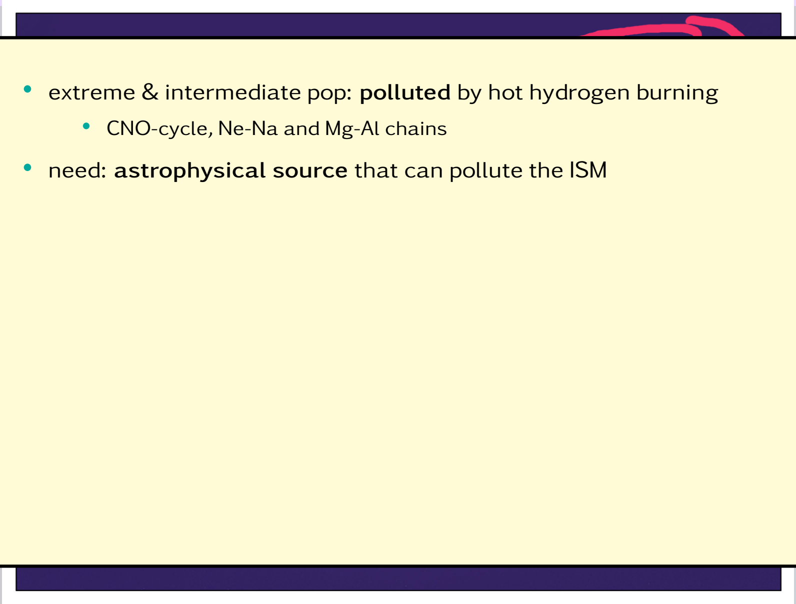


- extreme & intermediate pop: **polluted** by hot hydrogen burning
  - CNO-cycle, Ne-Na and Mg-Al chains

Globular Clusters & Abundance Anomalies



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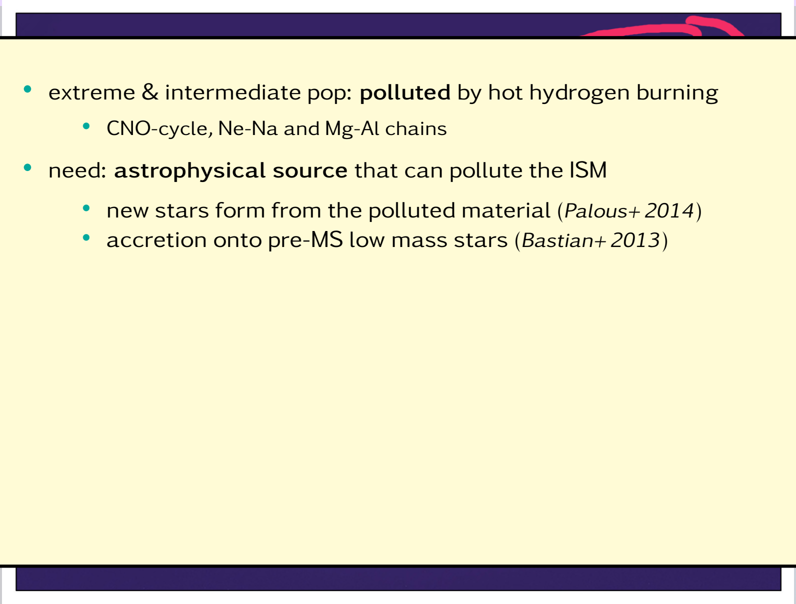

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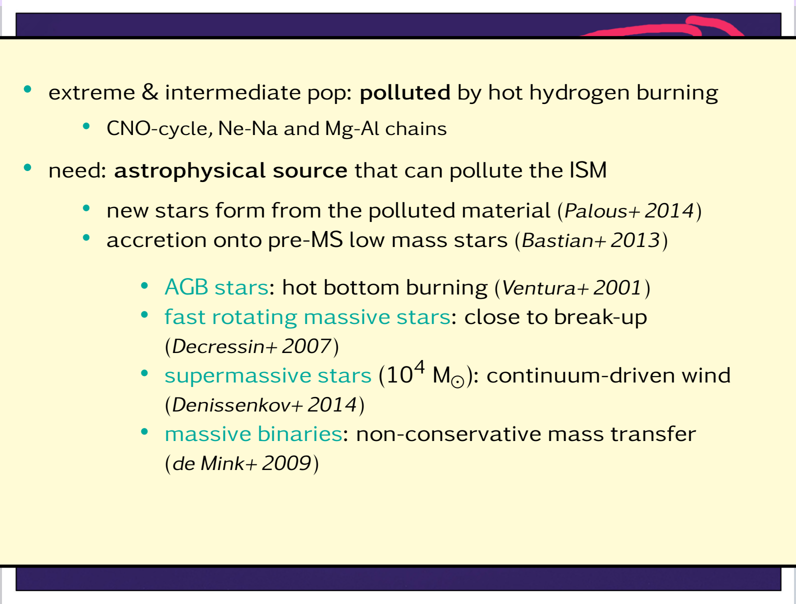

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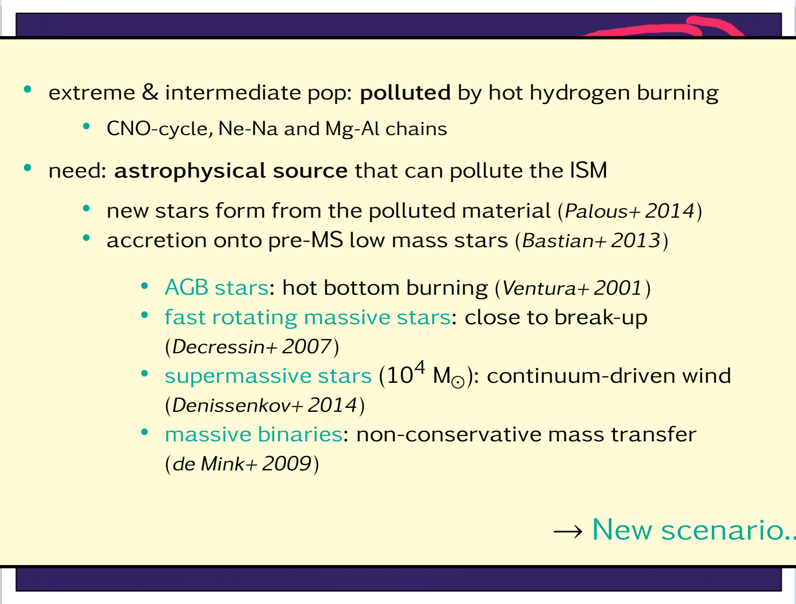
        - AGB stars: hot bottom burning (*Ventura+ 2001*)
        - fast rotating massive stars: close to break-up (*Decressin+ 2007*)
        - supermassive stars (10^4 $M_\odot$): continuum-driven wind (*Denissenkov+ 2014*)
        - massive binaries: non-conservative mass transfer (*de Mink+ 2009*)

Globular Clusters & Abundance Anomalies



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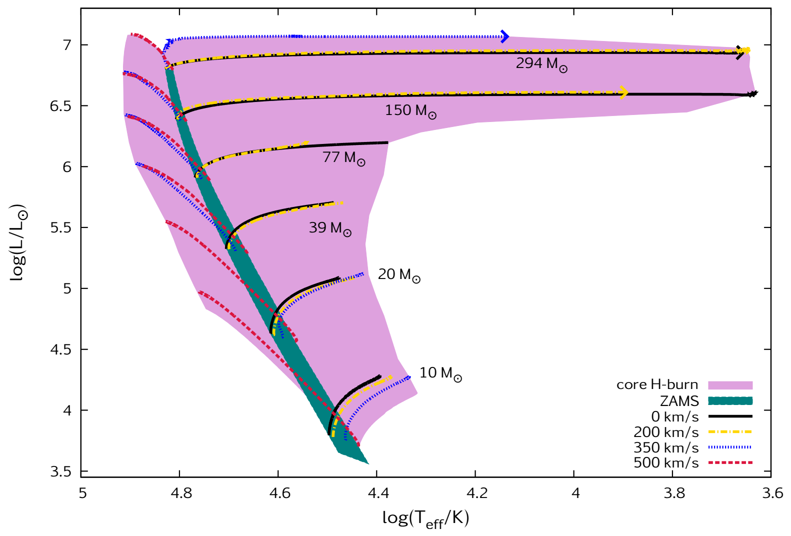
    - AGB stars: hot bottom burning (*Ventura+ 2001*)
    - fast rotating massive stars: close to break-up (*Decressin+ 2007*)
    - supermassive stars (10^4 $M_\odot$): continuum-driven wind (*Denissenkov+ 2014*)
    - massive binaries: non-conservative mass transfer (*de Mink+ 2009*)

→ New scenario...

Evolution of low metallicity massive stars

Szécsi et al. 2015 (A&A)



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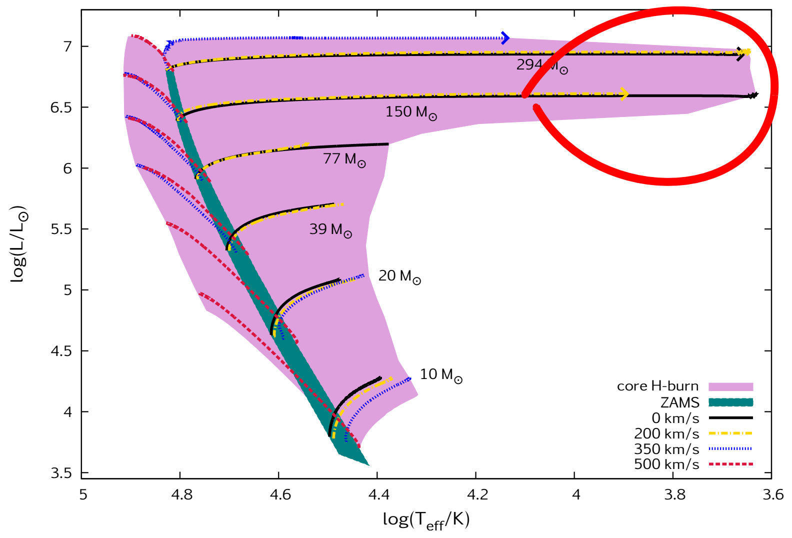

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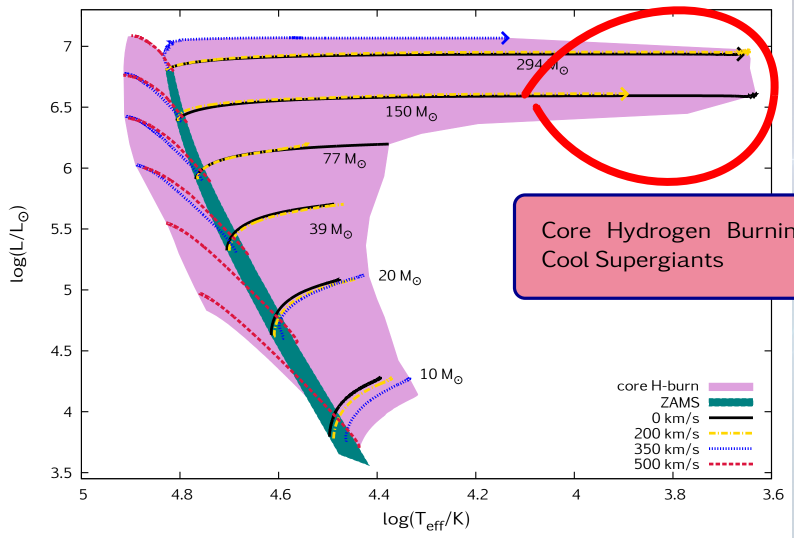

Core Hydrogen Burning
Cool Supergiants

Evolution of low metallicity massive stars

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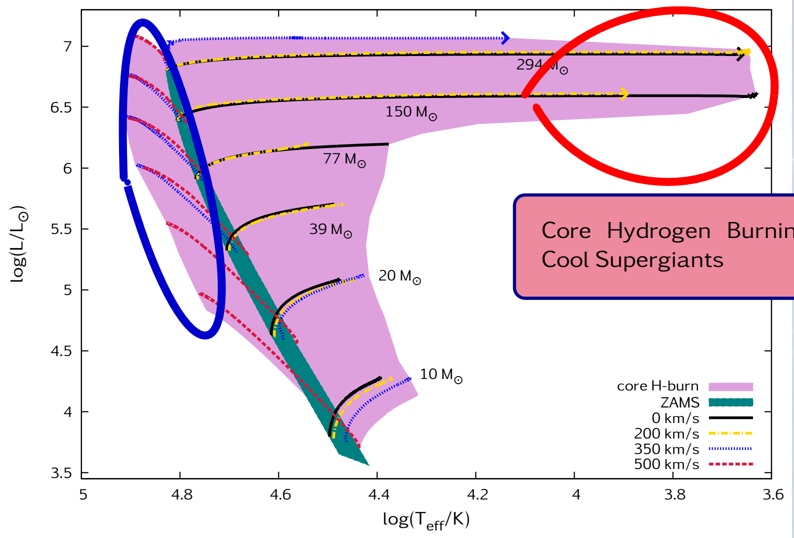

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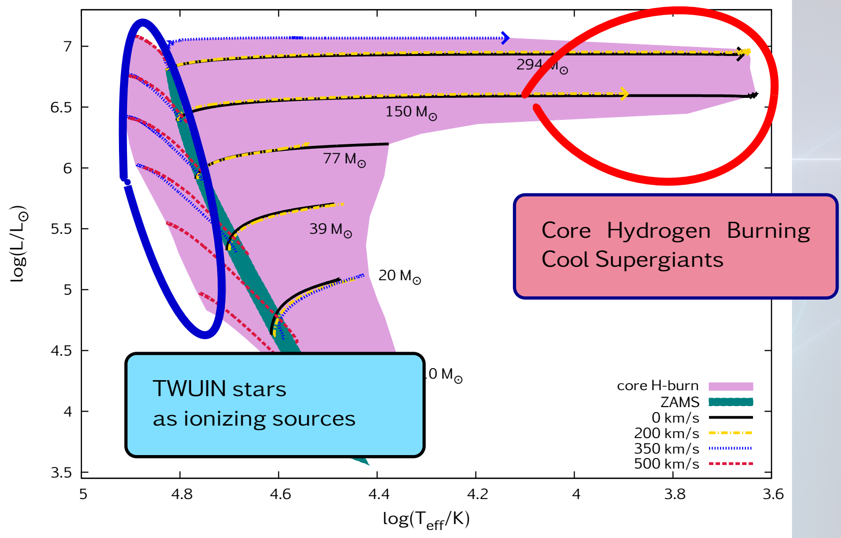
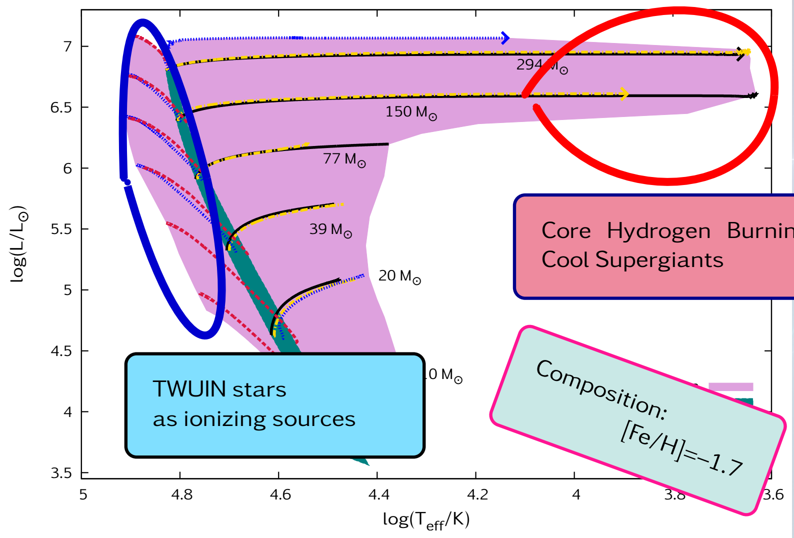


Core Hydrogen Burning Cool Supergiants

TWUIN stars as ionizing sources

Evolution of low metallicity massive stars

Szécsi et al. 2015 (A&A)



Core Hydrogen Burning
Cool Supergiants

TWUIN stars
as ionizing sources

Composition:
$[\mathrm{Fe/H}]=-1.7$

New scenario:

Starforming Supergiant Shells

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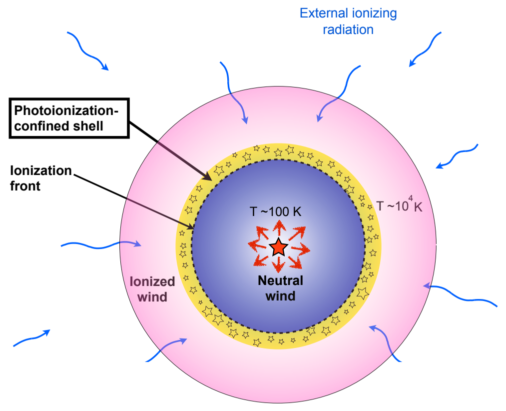
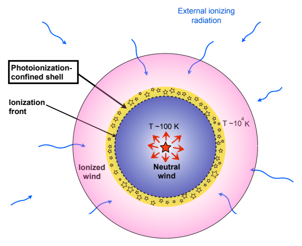
Starforming Supergiant Shells



PICO shell: *Mackey+ 2014 (Nature)*

Simulating the PICO shell



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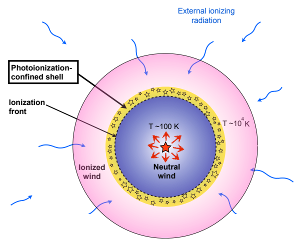

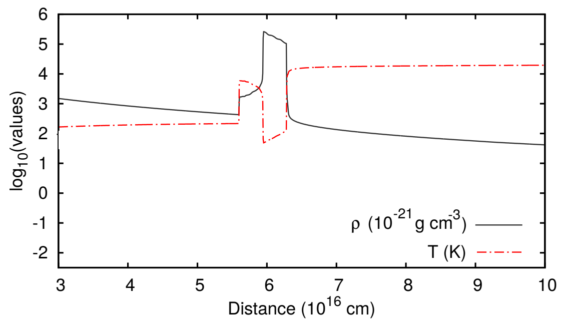

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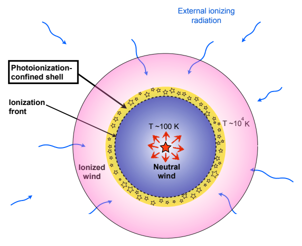
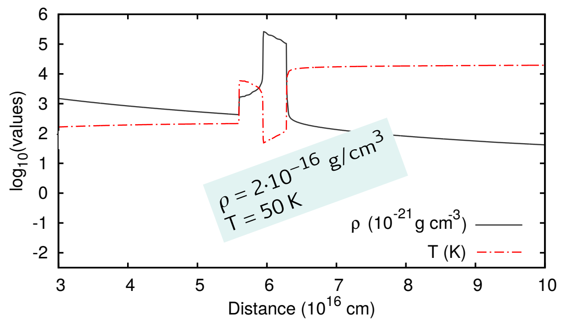
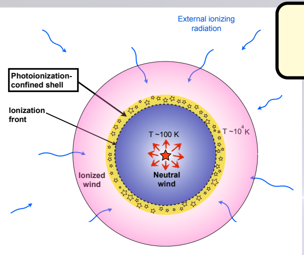


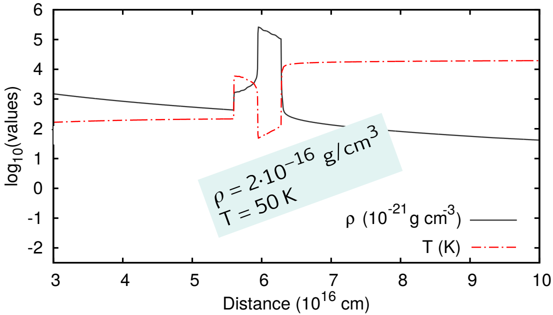


$\rho = 2{\cdot}10^{-16}\ \mathrm{g/cm^3}$
T = 50 K

Simulating the PICO shell



Mass of the photoionization-confined (PICO) shell: ~14 $M_\odot$



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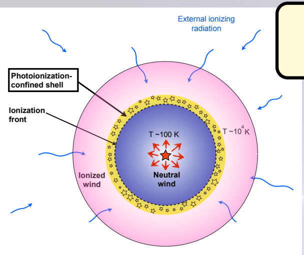
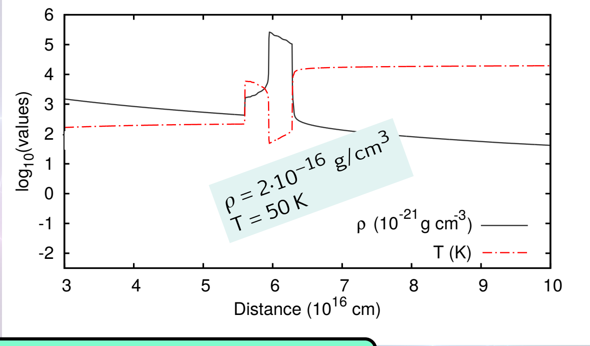
Simulating the PICO shell

Mass of the photoionization-confined (PICO) shell: $\sim 14\ M_\odot$





$\rho = 2{\cdot}10^{-16}\ \mathrm{g/cm^3}$

$T = 50\ \mathrm{K}$

Lifetime of the shell: $\sim 10^5$ yr

>>

Growth timescale of grav. unstable perturbations: $\sim 10^4$ yr

Compared to observations:

O – Na anticorrelation

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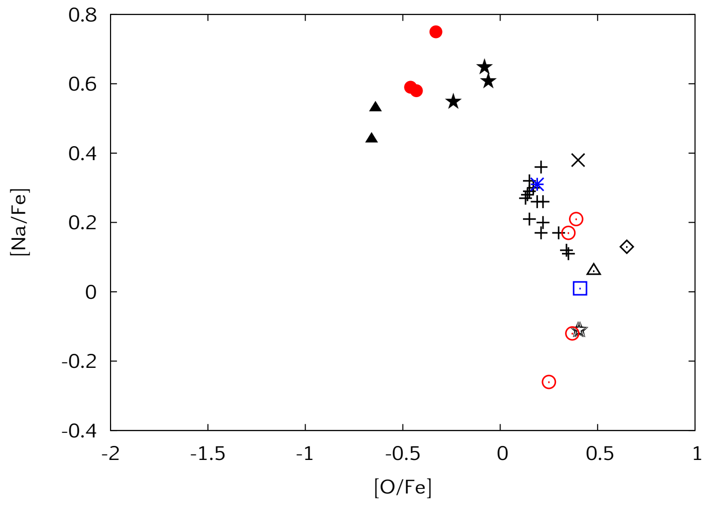

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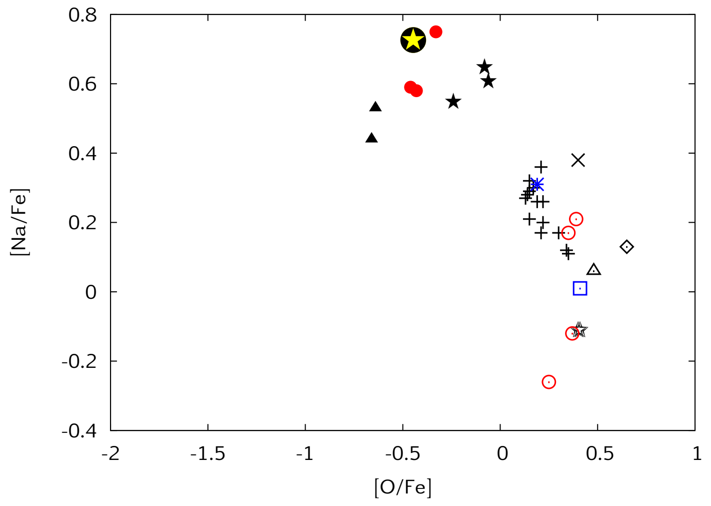

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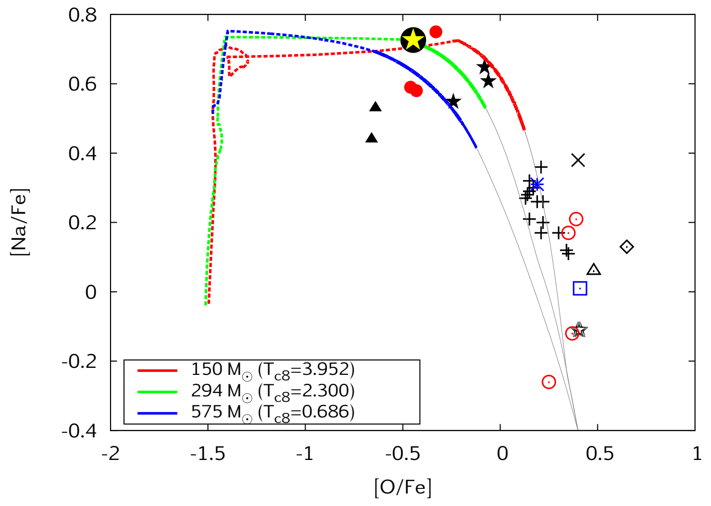

Compared to observations:

Mg – Al anticorrelation

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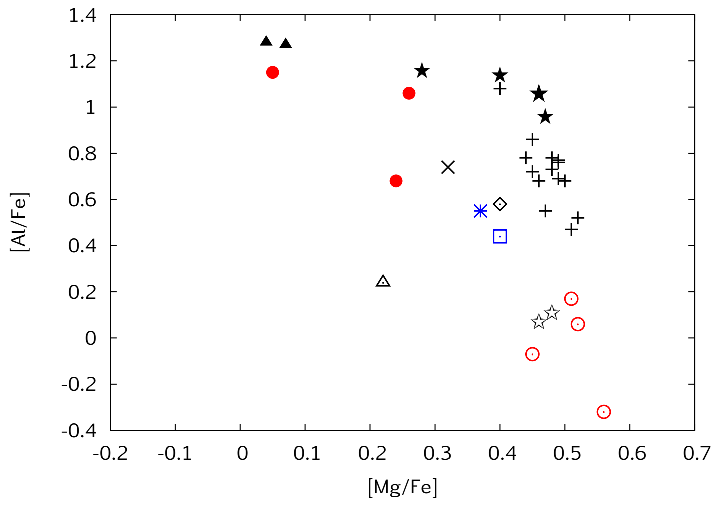
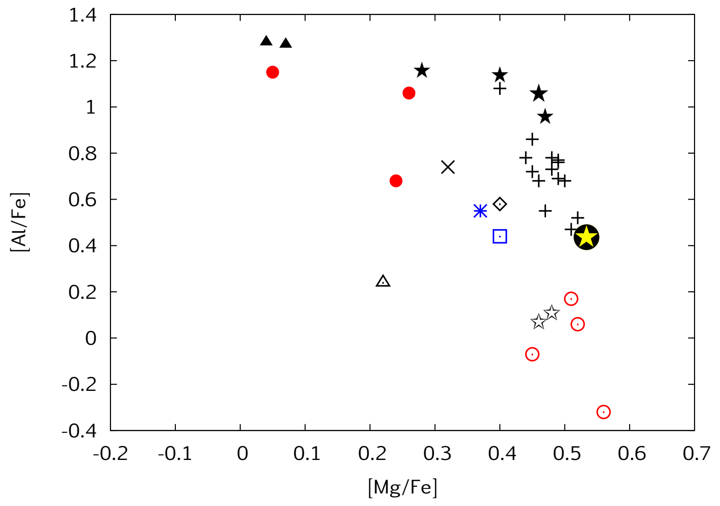


Compared to observations: Mg – Al anticorr.



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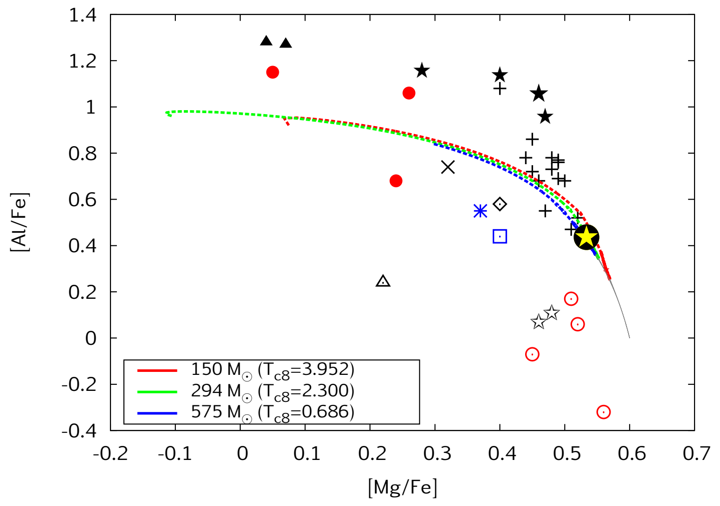

Details

Mass budget

- second generation IMF only contains low-mass stars!

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He-spread

- some GCs (but not all): $Y \sim 0.4$ observed
- shell-stars are predicted to have $Y_{\rm sh}=0.48$
- $\longrightarrow$ undilluted material explains most extreme Y values!
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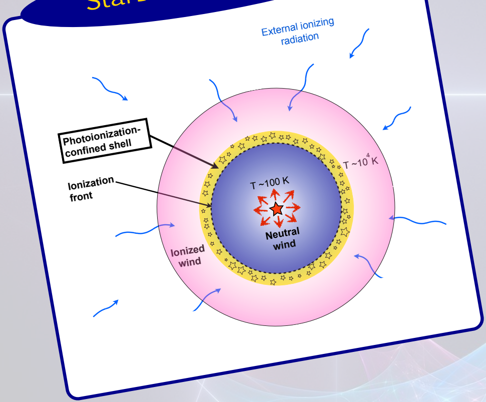
- shell stability...

RSGs as polluters

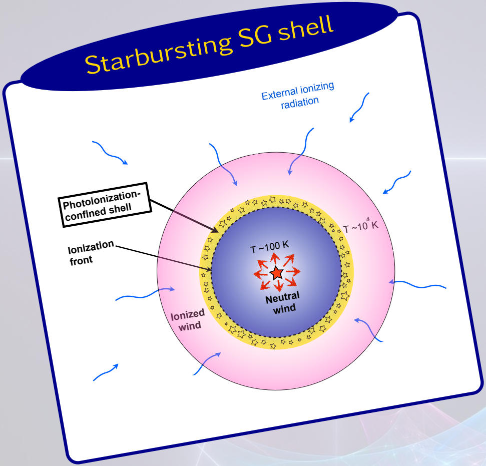
- at low-Z, core-H burning RSGs
- even without PICO shell: contributing to the general pollution of the GC!

Core-H-burning Supergiants in the Early GCs

Starbursting SG shell



Core-H-burning Supergiants in the Early GCs



- early globular clusters
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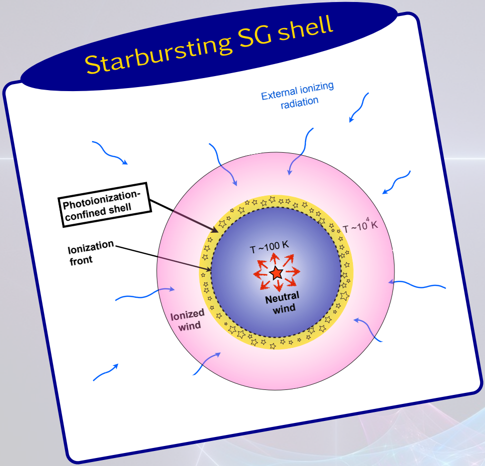
Core-H-burning Supergiants in the Early GCs

Szécsi et al. 2015
(A&A, vol. 581, A15)

Szécsi & Mackey & Langer 2016
(in preparation)



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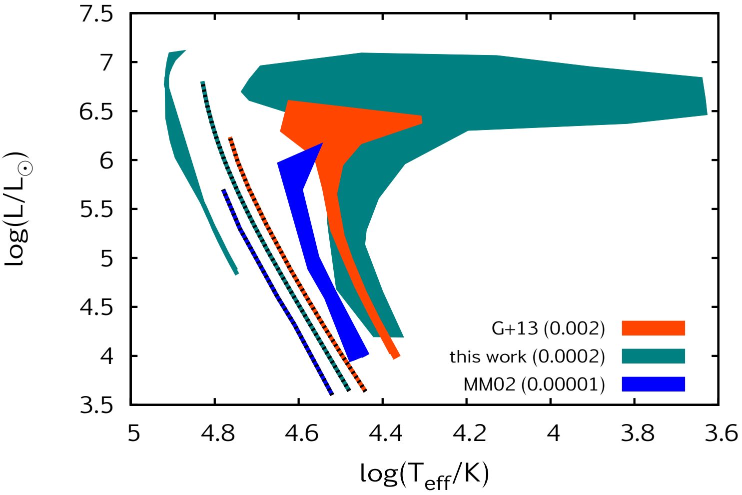
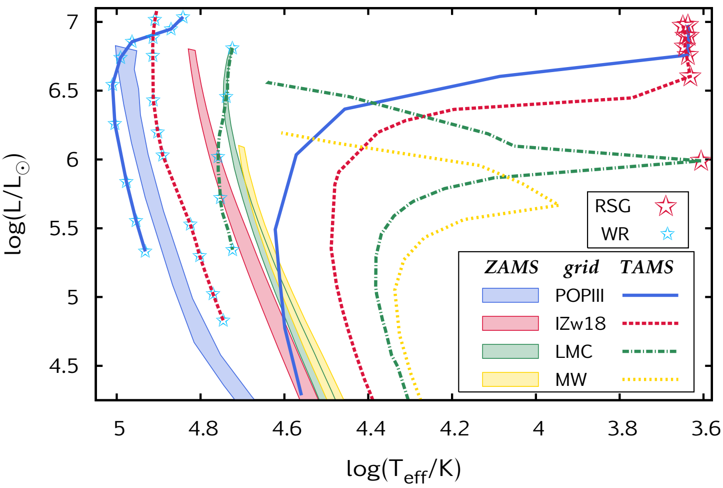
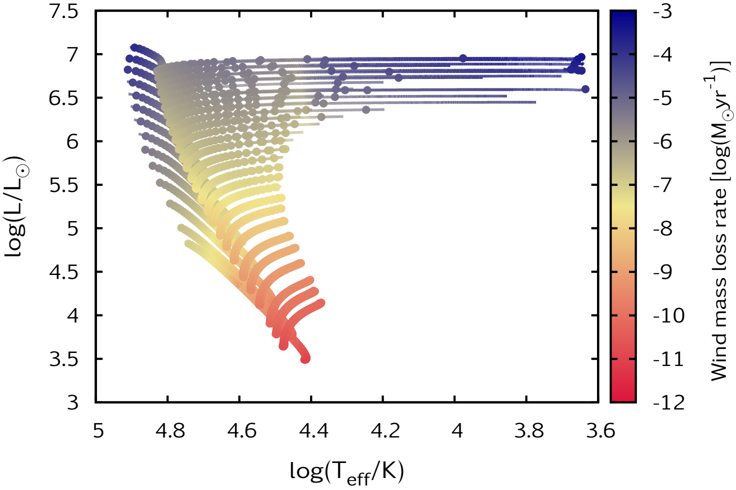
Comparison to the Geneva grids at low-Z



Comparison to Bonn grids ($0<Z<Z_\odot$)



Appendix: Mass loss



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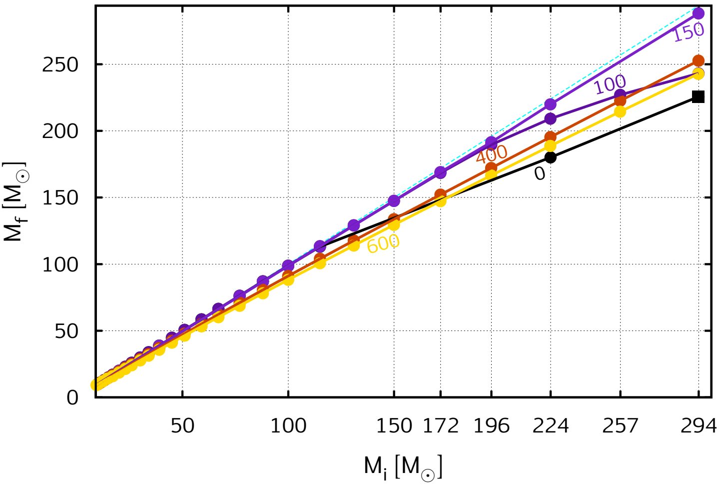

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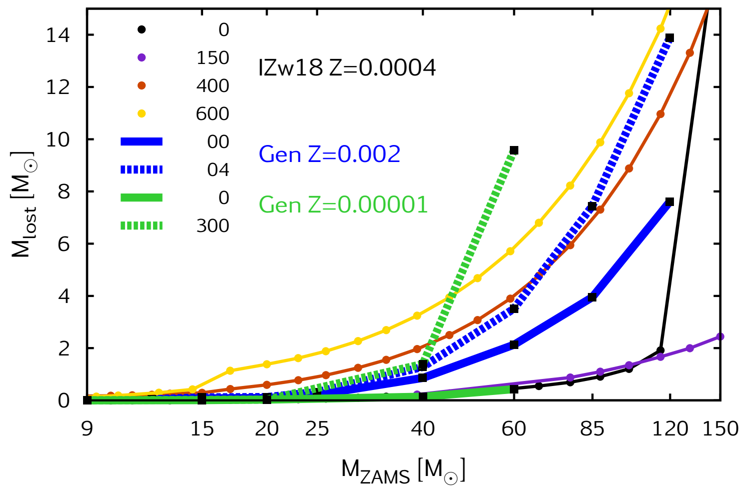

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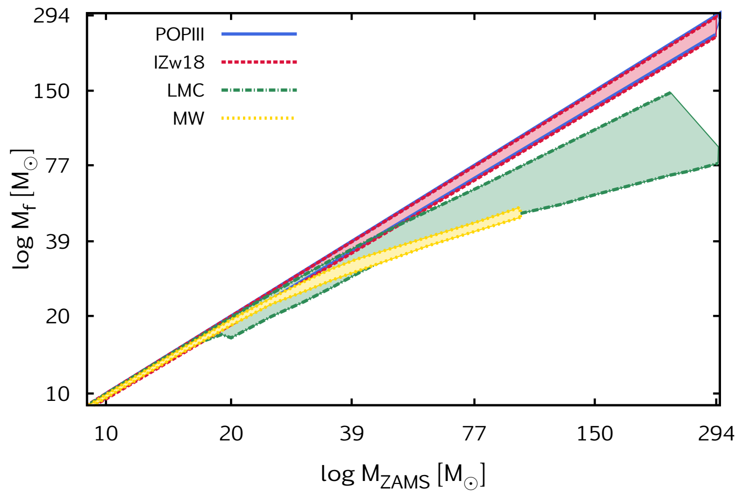
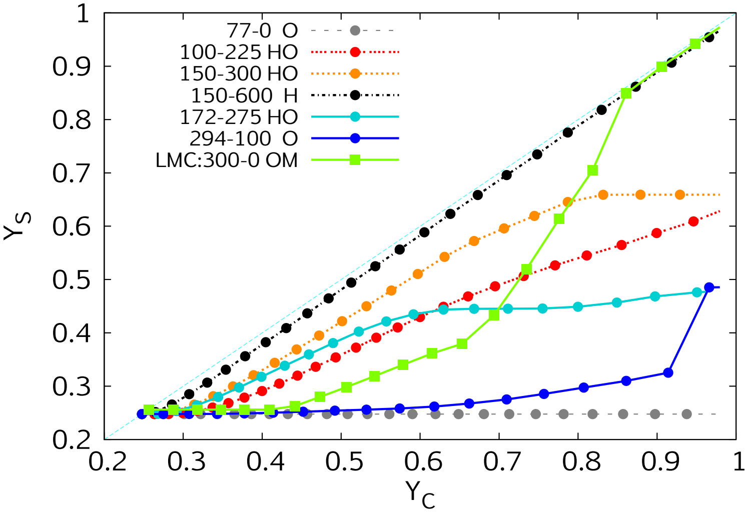
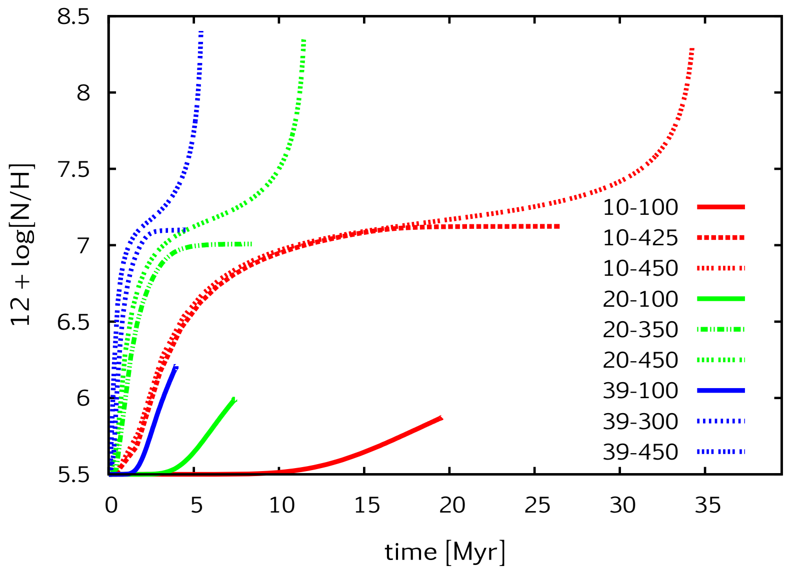


Appendix: Surface Helium



Appendix: Surface Nitrogen



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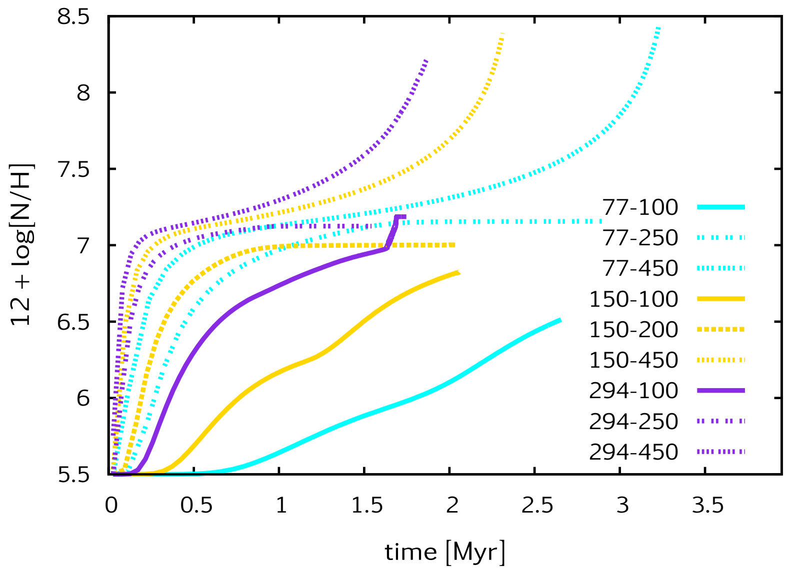
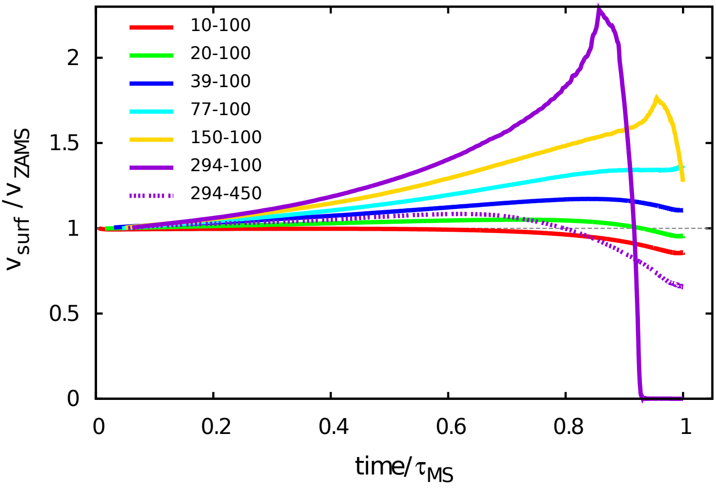
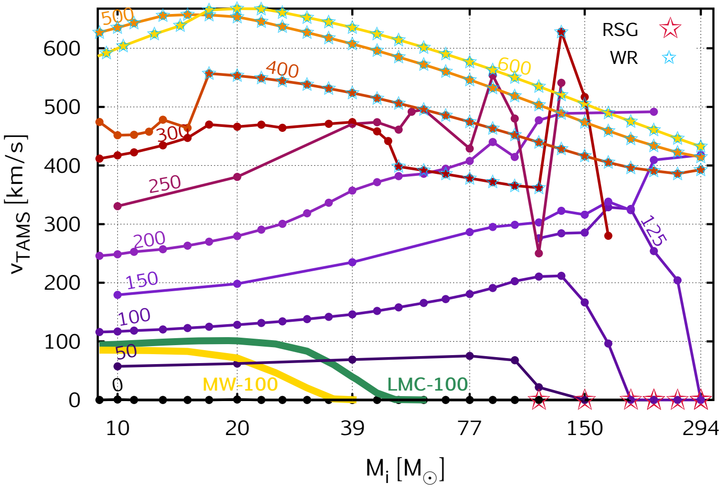


Rotation



10-100
20-100
39-100
77-100
150-100
294-100
294-450
v_{surf} / v_{ZAMS}
0
0.5
1
1.5
2
0
0.2
0.4
0.6
0.8
1
time/τ_{MS}

Appendix: Rotation



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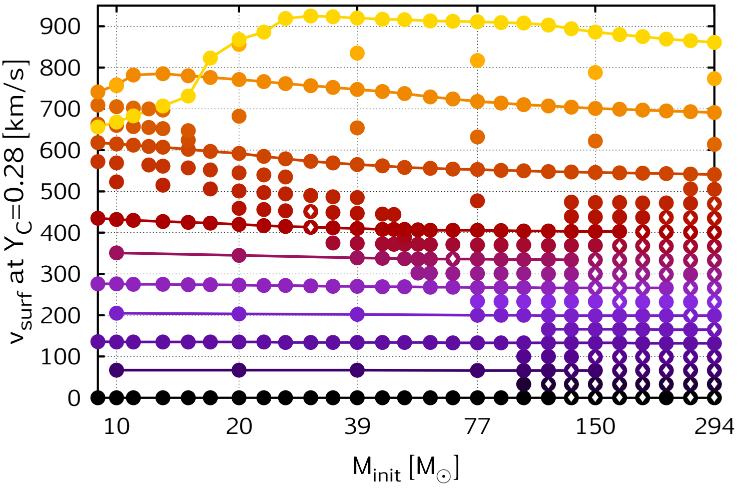

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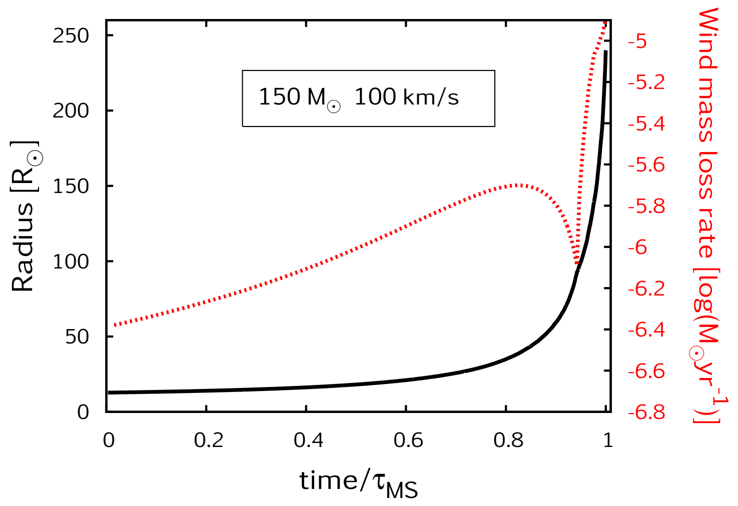

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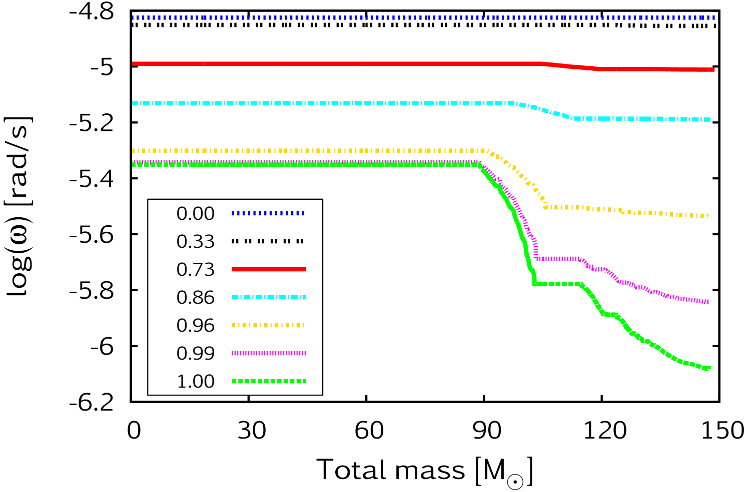

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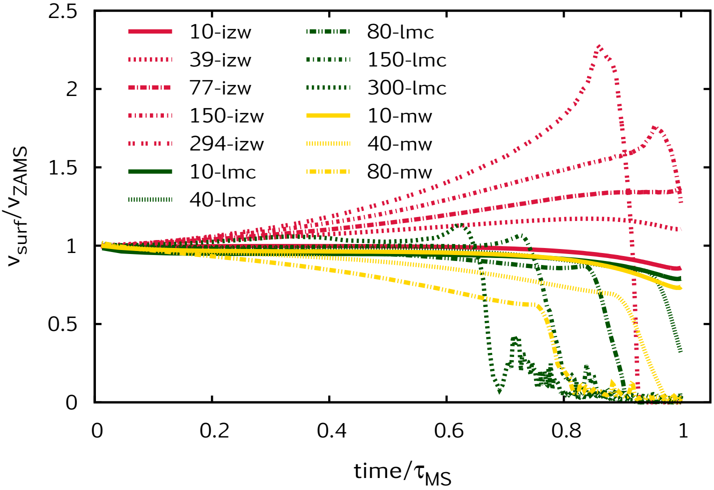

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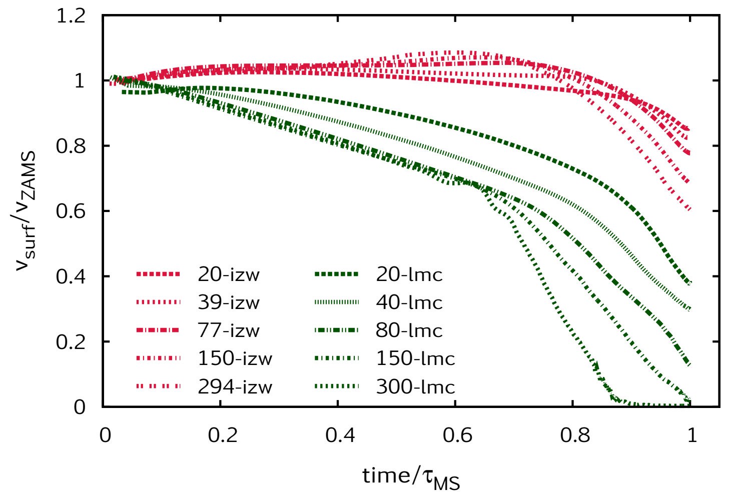

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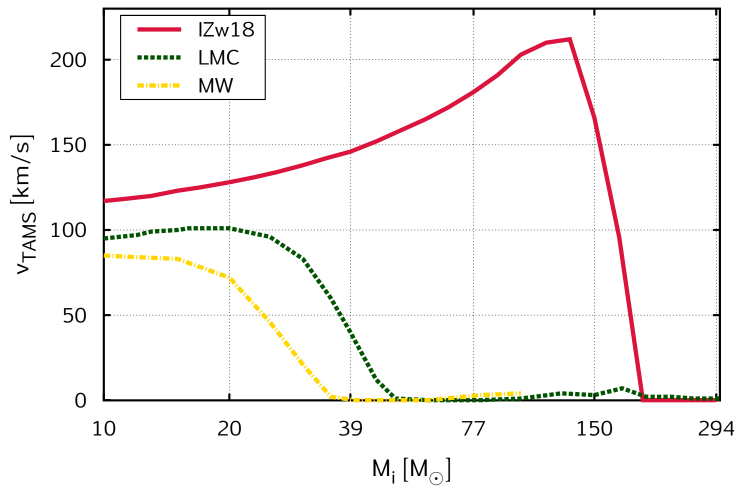
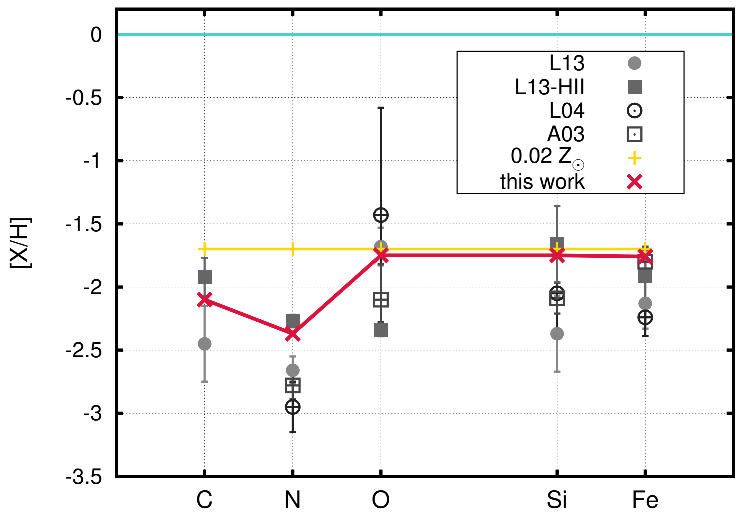
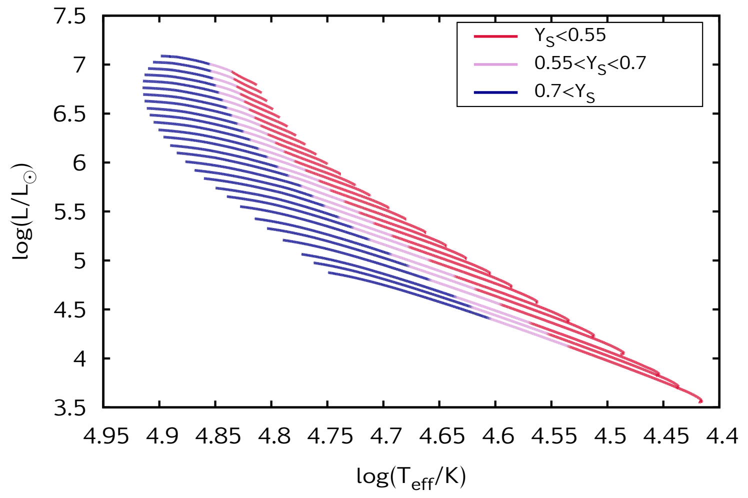


Appendix: Initial Composition



Appendix: Photoionization



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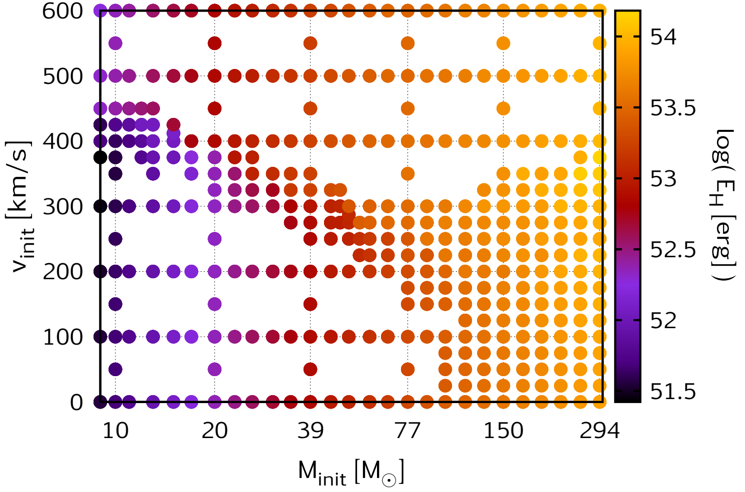

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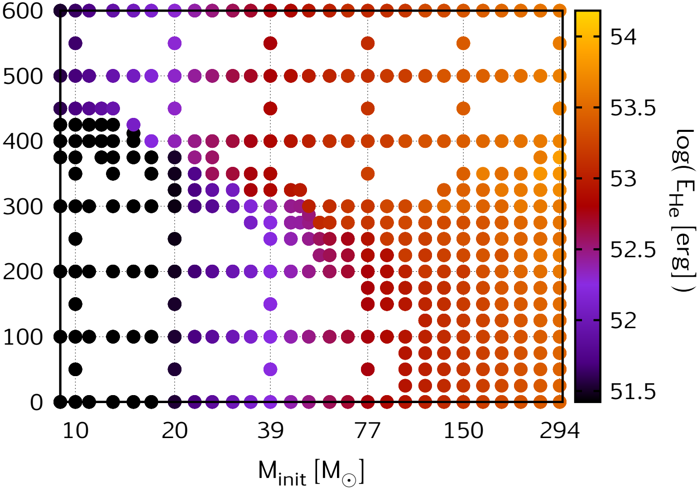

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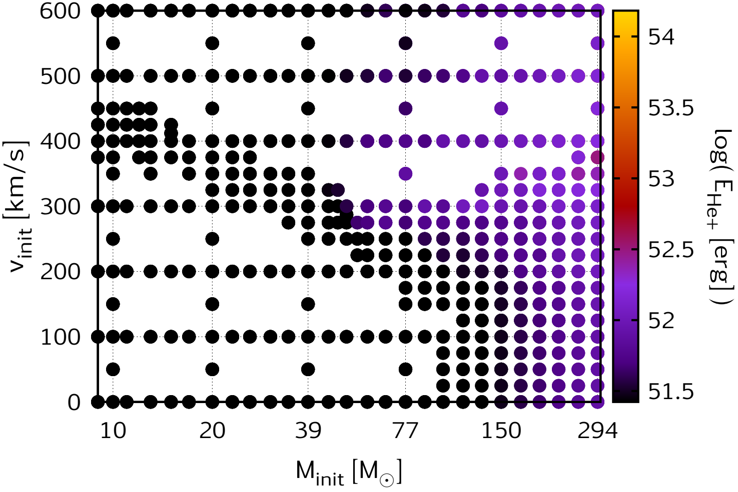

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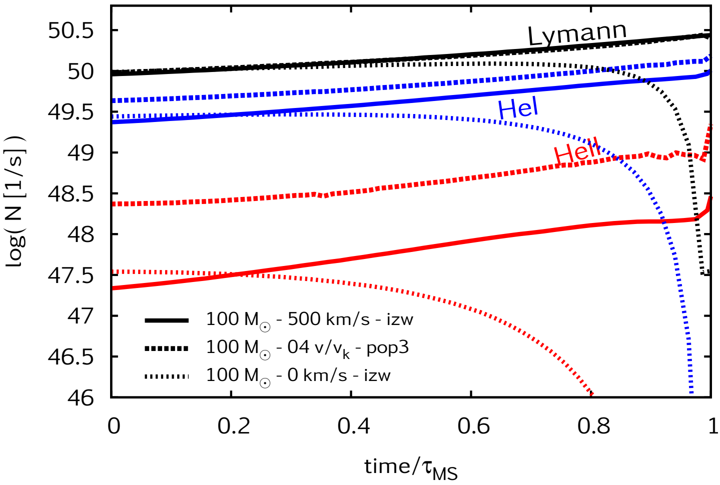

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