Cluster winds and how they depend on the stellar population parameters

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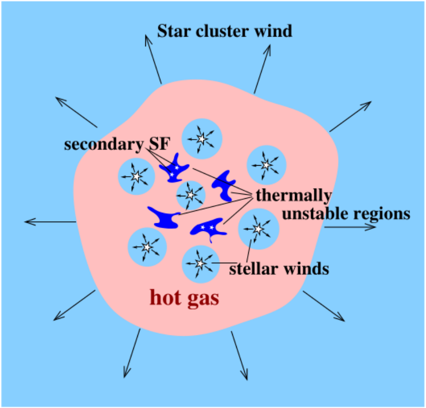
September 17, 2024

Motivation



Credit: R. Wünsch (ASU)

Figure: Phenomenological illustration of how young massive clusters could evolve into globular clusters, creating multiple periods of star formation

Results [1] Stinshoff et al. (in prep.)

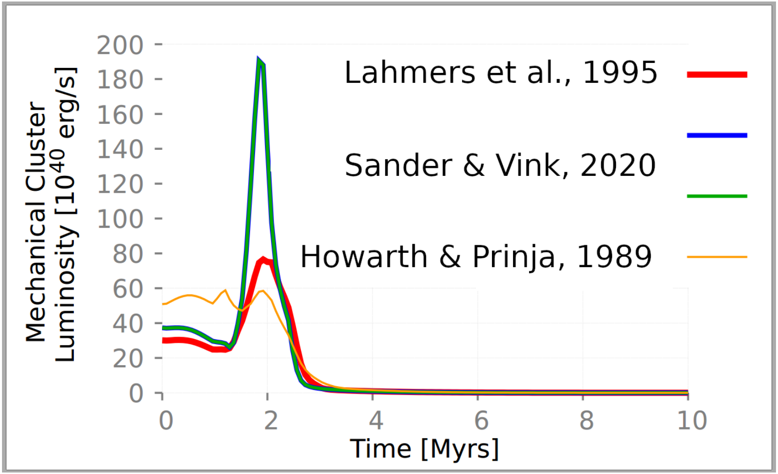


Figure: Population with Kroupa IMF, 500 $M_\odot$ upper mass limit, $Z = 0.25\, Z_\odot$, $L_{SC} = \int \log(0.5 * \dot{M} * v_{wind}^2)$

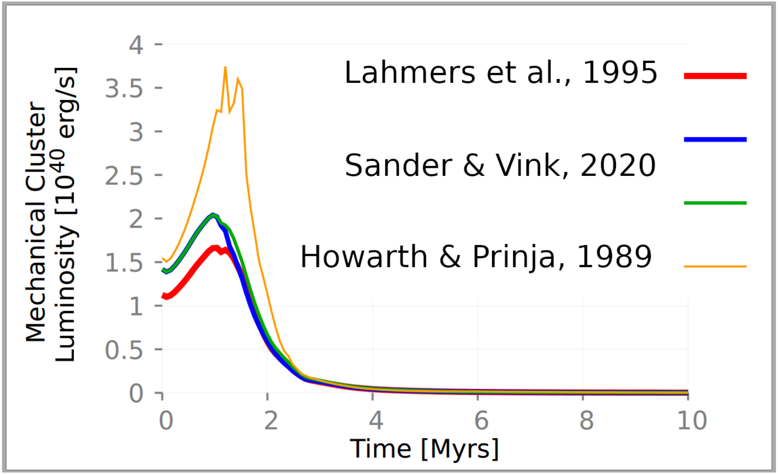
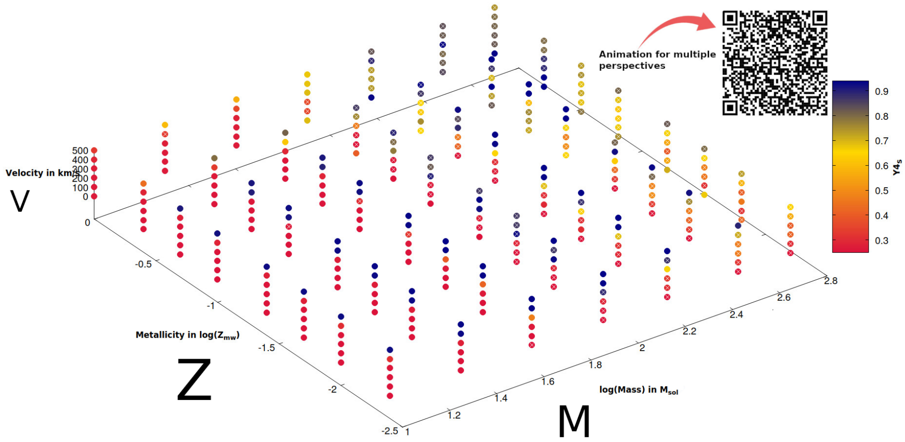


Figure: Population with Kroupa IMF, $\sim$ 500 $M_\odot$ upper mass limit, $Z = 0.0125\,Z_\odot$, $L_{SC} = \int \log(0.5 * \dot{M} * v_{wind}^2)$

Outlook

- Improvement on/Choices of the wind prescriptions
- Addition of more initial rotational velocities
- Investigations of different IMFs

Outlook: The new models - Y_S at TAMS [1] Stinshoff et al., in prep.



Sources

- [1] H. N. Stinshoff et al. (in prep.)
- [2] D. Szécsi and R. Wünsch: "Role of Supergiants in the Formation of Globular Clusters", The Astrophysical Journal, vol. 871, January 2019, p. 20, doi:10.3847/1538-4357/aaf4be
- [3] D. Szécsi, P. Agrawal, R. Wünsch, and N. Langer: "Bonn Optimized Stellar Tracks (BoOST) - Simulated populations of massive and very massive stars for astrophysical applications", Astronomy & Astrophysics, vol. 658, 2022, doi:10.1051/0004-6361/202141536

Sources

- [4] H. J. G. L. M. Lamers, T. P. Snow and D. M. Lindholm: "Terminal Velocities and the Bistability of Stellar Winds", The Astrophysical Journal, vol. 455, 1995. doi:10.1086/176575.

- [5] J. Krtička, J. Kubát, and I. Krtičková: "New mass-loss rates of B supergiants from global wind models", Astronomy & Astrophysics, vol. 647, 2021, doi:10.1051/0004-6361/202039900

- [6] A. A. C. Sander and J. S. Vink: "On the nature of massive helium star winds and Wolf-Rayet-type mass-loss", Monthly Notices of the Royal Astronomical Society, vol. 499, 2020, https://doi.org/10.1093/mnras/staa2712

- [7] I. D. Howarth and R. K. Prinja: "The Stellar Winds of 203 Galactic O Stars: A Quantitative Ultraviolet Survey", The Astrophysical Journal Supplement Series, vol. 69, 1989, doi:10.1086/191321.

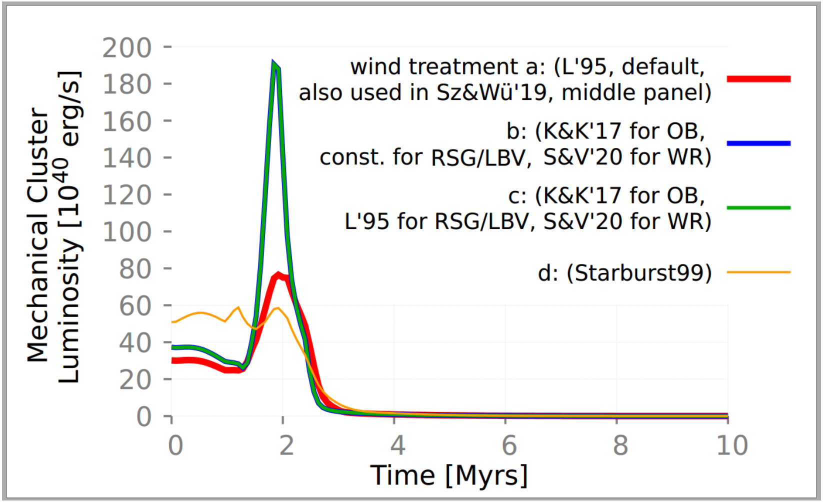


Figure: Population with Kroupa IMF, 500 $M_\odot$ upper mass limit, $Z = 0.25\ Z_\odot$

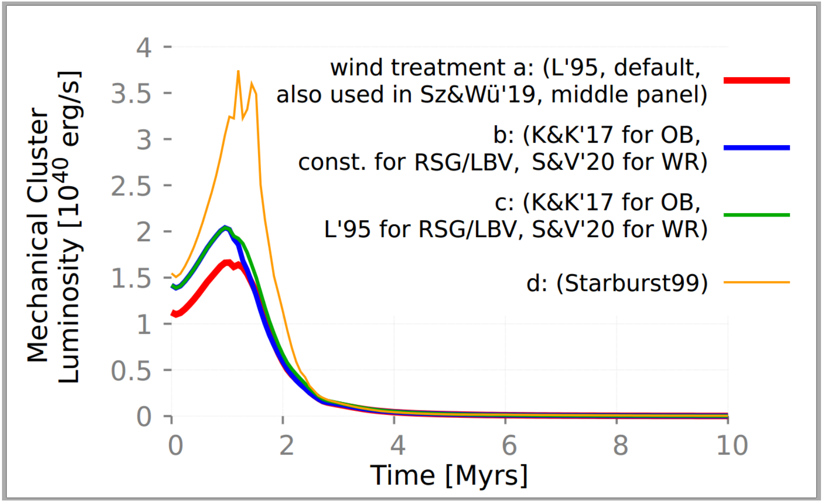


Figure: Population with Kroupa IMF, $\sim 500\ M_\odot$ upper mass limit, $Z = 0.0125\ Z_\odot$

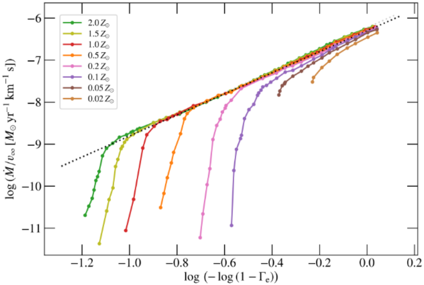


Figure 13. The ratio of $\dot{M}$ and v_∞ as a function of $-\log\,(1-\Gamma_e)$, depicting an essentially Z-independent slope for pure WR-type winds.

$$\log \frac{\dot{M}}{v_\infty} = k\,\log\left[-\log\left(1-\Gamma_e\right)\right] + l$$

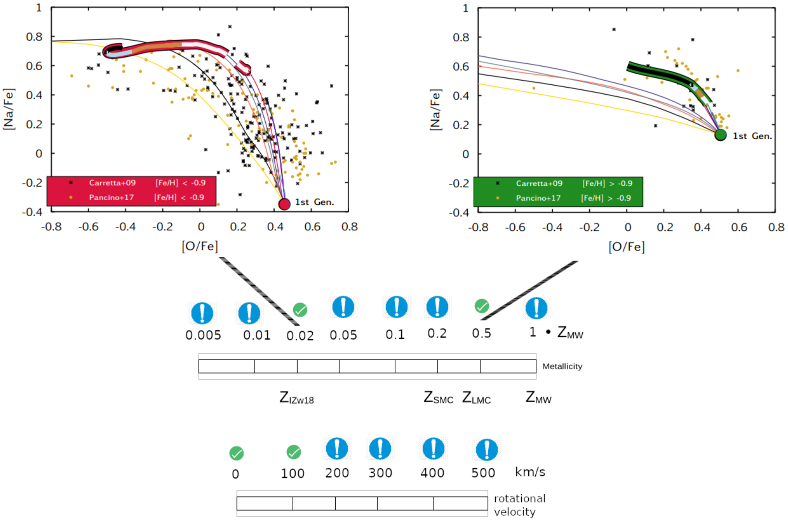
Figure: Wind prescription derived from Sander & Vink 2020

Prescriptions [1] Stinshoff et al. (in prep.)

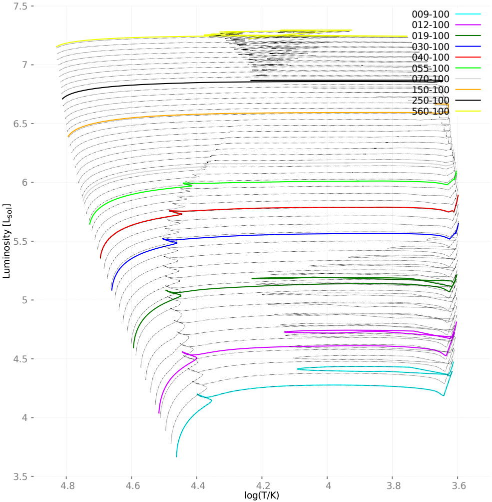
$$v_\infty / v_{esc} = 0.58 + 2.04 \log(R_* / R_\odot)$$

Wind prescription derived from Howarth & Prinja 1989

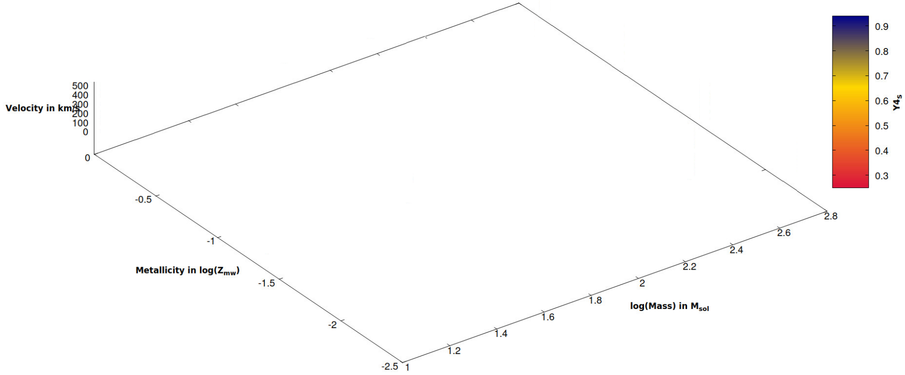
Outlook [2] Szécsi & Wünsch (2019)



BoOST format [3] Szécsi et al., 2022



The new models - Y_S at TAMS [2] Stinshoff et al., in prep.



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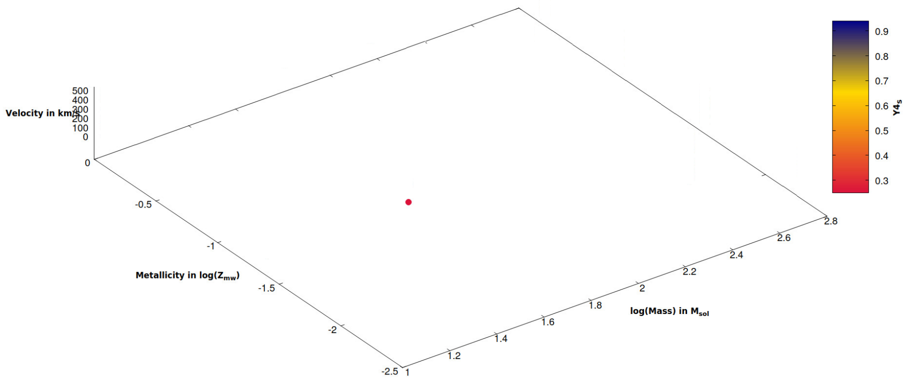

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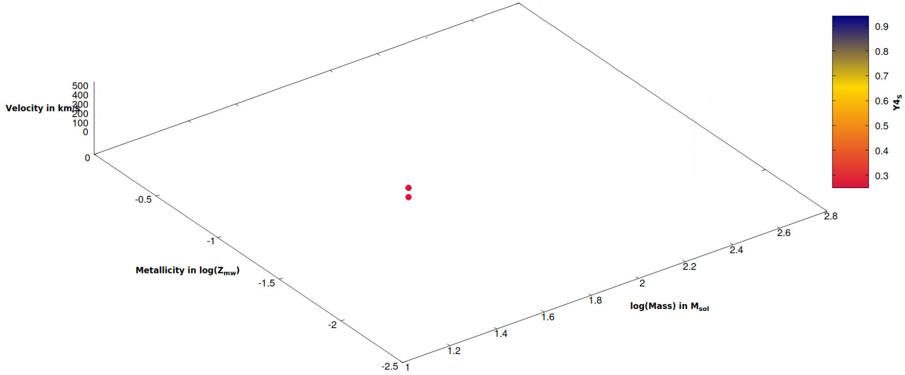

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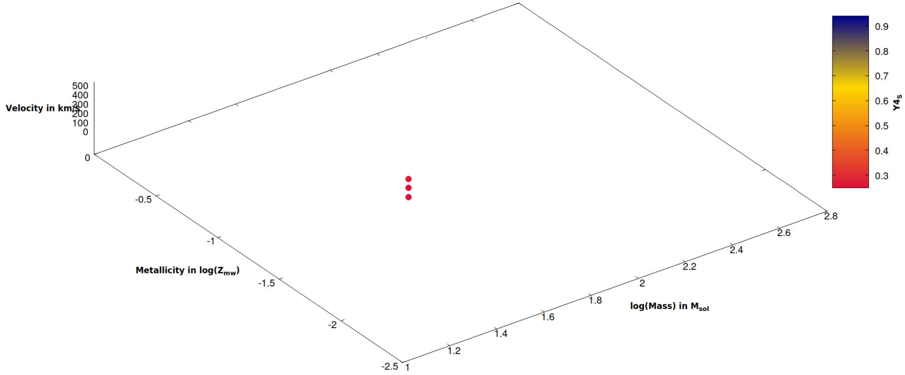

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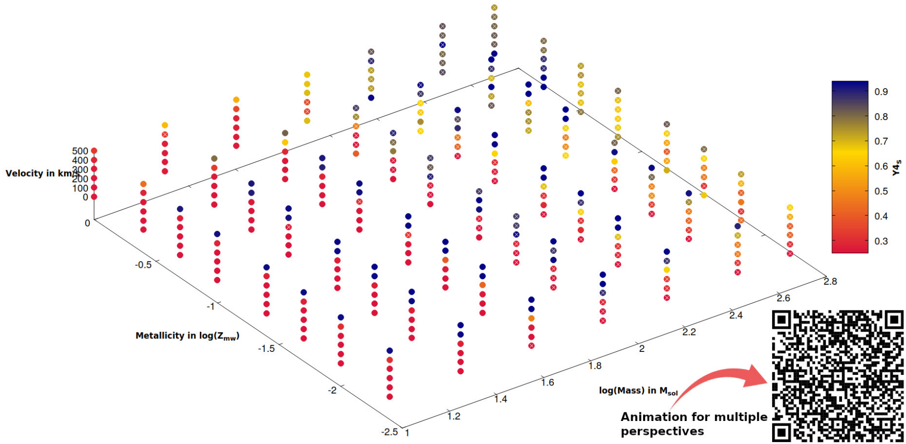
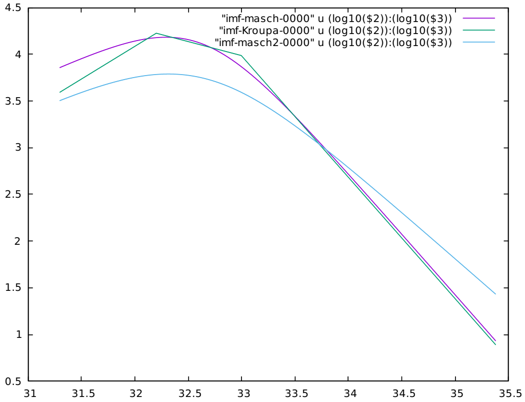
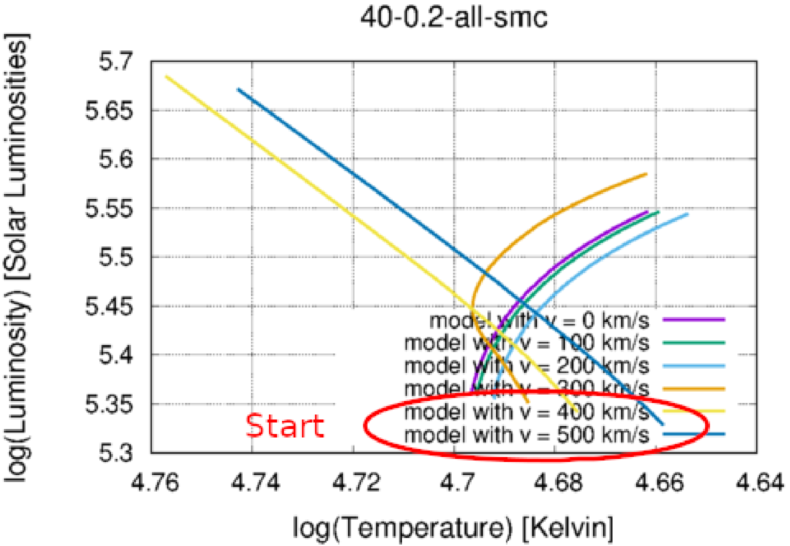


Animation for multiple perspectives

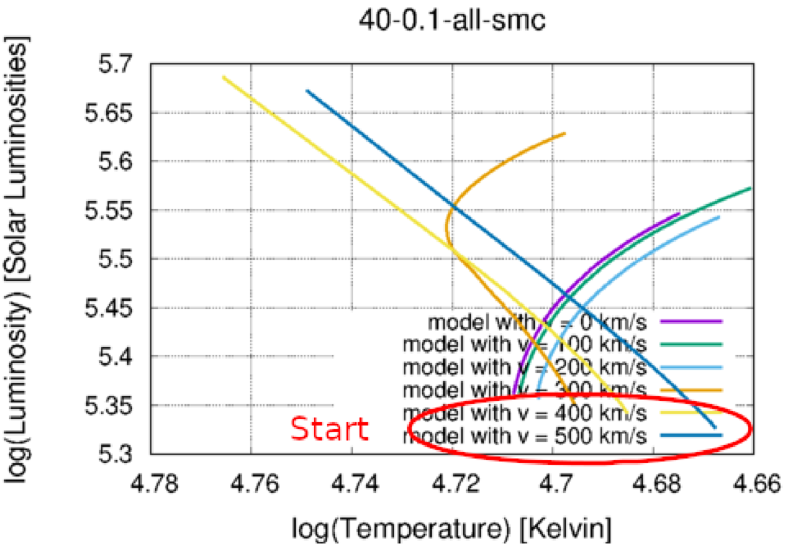
Parameter study [2] Stinshoff et al., in prep.



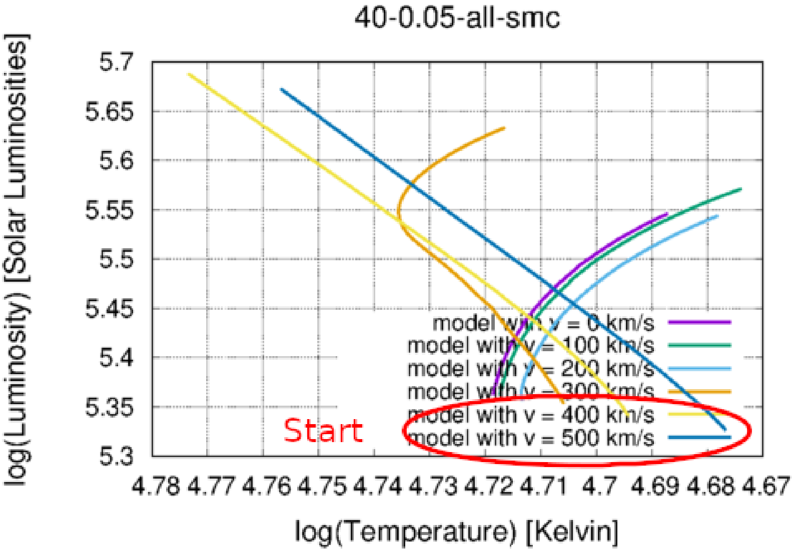
The new models - HRD [2] Stinshoff et al., in prep.



The new models - HRD [2] Stinshoff et al., in prep.



The new models - HRD [2] Stinshoff et al., in prep.



Work in Progress [2] Stinshoff et al., in prep.

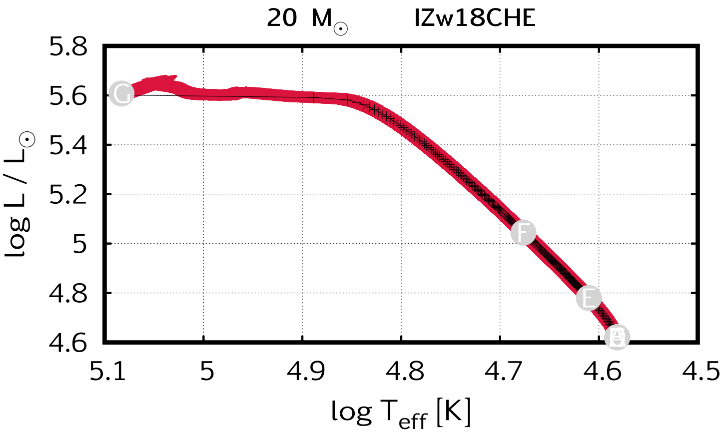
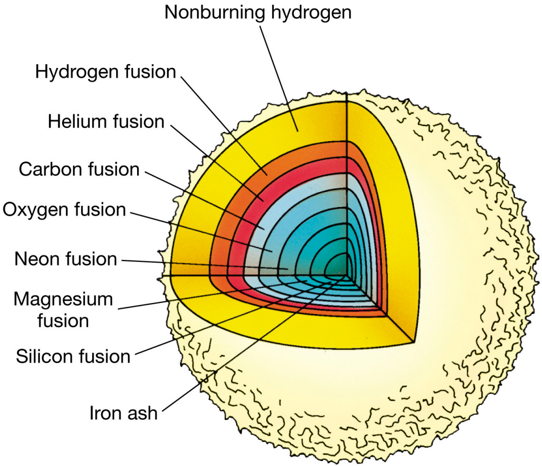


Figure: $v_{rot} = 400\ km/s,\ Z = Z_{IZw18}$

Extra



Nonburning hydrogen
Hydrogen fusion
Helium fusion
Carbon fusion
Oxygen fusion
Neon fusion
Magnesium fusion
Silicon fusion
Iron ash

Extra

$\mathrm{p} + \mathrm{p} \rightarrow {}^{2}\mathrm{H} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$

$\mathrm{p} + {}^{2}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \gamma$

83.30% (pp-I)

$^{3}\mathrm{He} + {}^{3}\mathrm{He} \rightarrow {}^{4}\mathrm{He} + 2\mathrm{p}$

16.70%

$^{3}\mathrm{He} + {}^{4}\mathrm{He} \rightarrow {}^{7}\mathrm{Be} + \gamma$

99.88% (pp-II)

$^{7}\mathrm{Be} + \mathrm{e}^{-} \rightarrow {}^{7}\mathrm{Li} + \nu_{\mathrm{e}}$

$^{7}\mathrm{Li} + \mathrm{p} \rightarrow 2\,{}^{4}\mathrm{He}$

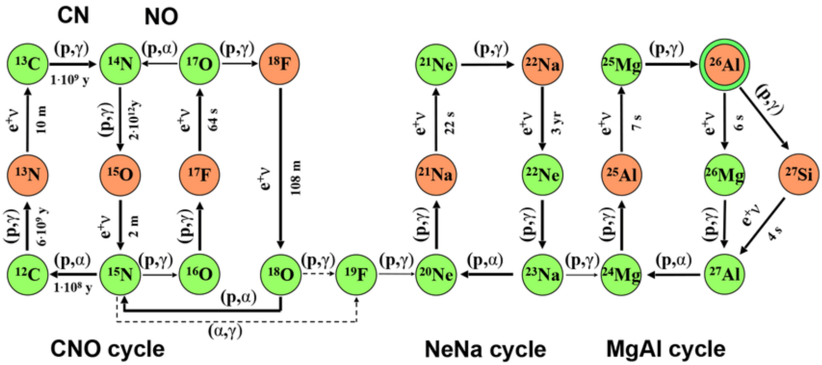
0.12% (pp-III)

$^{7}\mathrm{Be} + \mathrm{p} \rightarrow {}^{8}\mathrm{B} + \gamma$

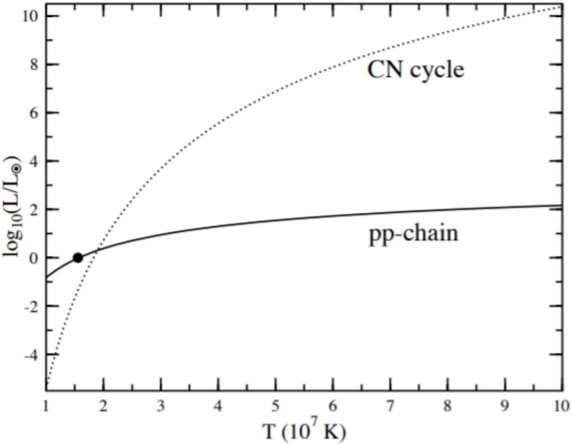
$^{8}\mathrm{B} \rightarrow {}^{8}\mathrm{Be}^{*} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$

$^{8}\mathrm{Be}^{*} \rightarrow 2\,{}^{4}\mathrm{He}$

Extra

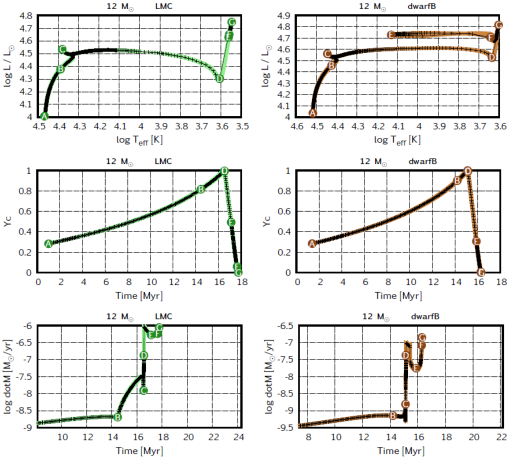

CN
NO
CNO cycle
NeNa cycle
MgAl cycle
(p,γ)
(p,α)
(α,γ)
e+ν
1·10⁹ y
10 m
2·10¹²y
64 s
108 m
6·10⁹ y
2 m
1·10⁸ y
22 s
3 yr
7 s
6 s
4 s

Extra



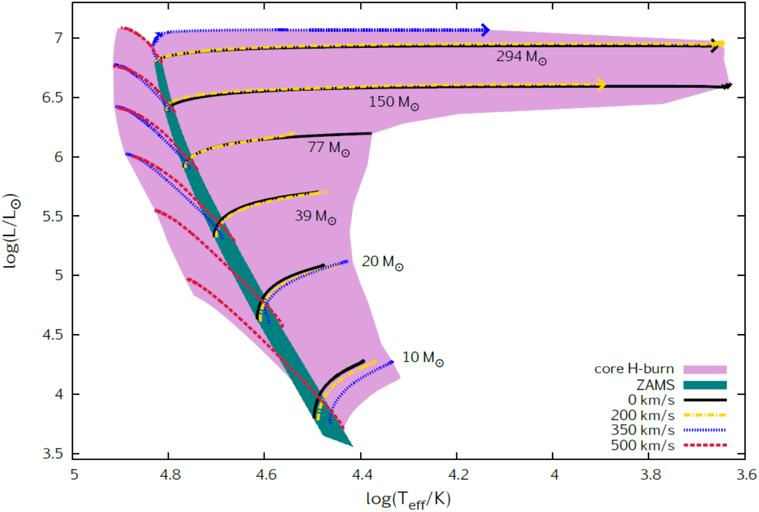
CN cycle
pp-chain
$\log_{10}(L/L_\odot)$
T (10^7 K)
10
8
6
4
2
0
-2
-4
1
2
3
4
5
6
7
8
9
10

Extra



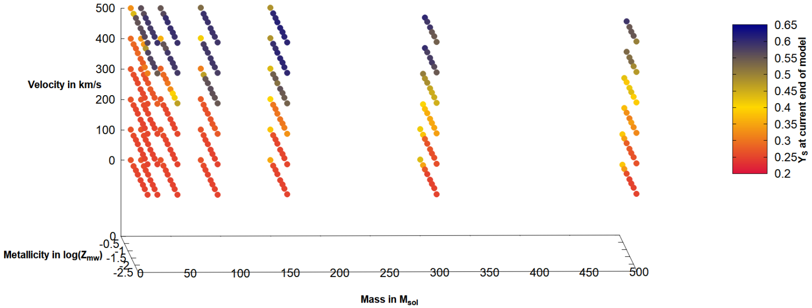
12 $M_\odot$ LMC
log L / $L_\odot$
log T_{eff} [K]
12 $M_\odot$ dwarfB
Yc
Time [Myr]
log dotM [$M_\odot$/yr]

Extra



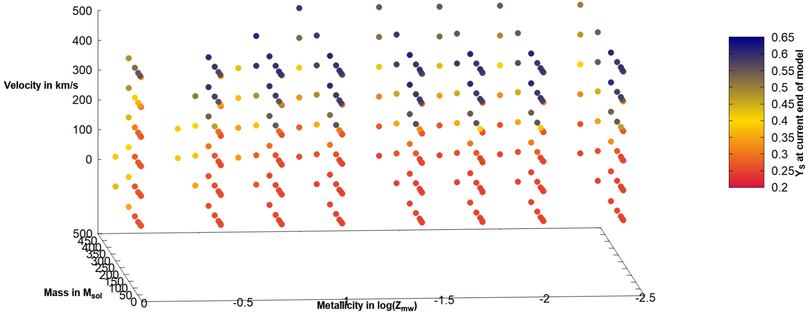
294 M⊙
150 M⊙
77 M⊙
39 M⊙
20 M⊙
10 M⊙
core H-burn
ZAMS
0 km/s
200 km/s
350 km/s
500 km/s
log(L/L⊙)
log(T_eff/K)
7
6.5
6
5.5
5
4.5
4
3.5
5
4.8
4.6
4.4
4.2
4
3.8
3.6

Extra



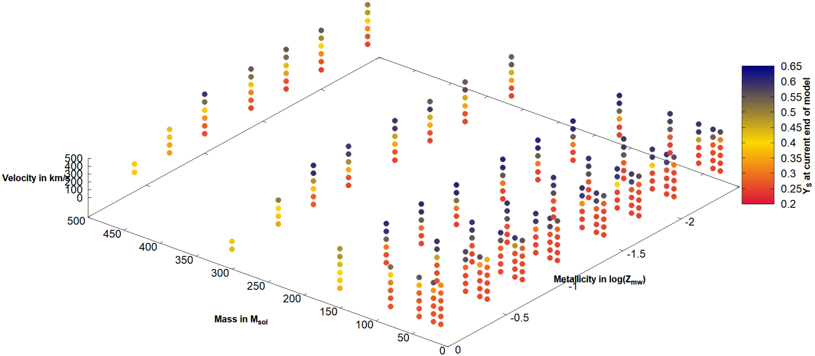
Velocity in km/s
500
400
300
200
100
0
Metallicity in log(Z_{mw})
0
-0.5
-1
-1.5
-2
-2.5
0
50
100
150
200
250
300
350
400
450
500
Mass in M_{sol}
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
Y_s at current end of model

Extra

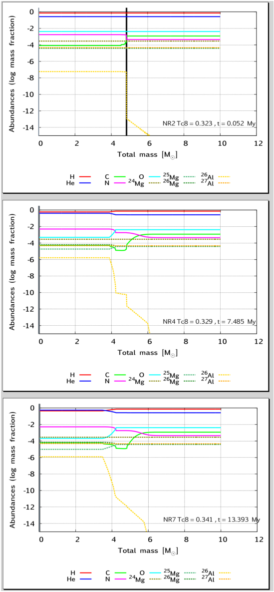


Velocity in km/s
500
400
300
200
100
0
Mass in M_sol
500
450
400
350
300
250
200
150
100
50
0
0
-0.5
-1
-1.5
-2
-2.5
Metallicity in log(Z_mw)
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
Y_s at current end of model

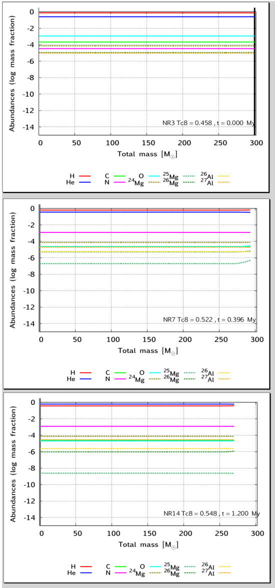
Extra



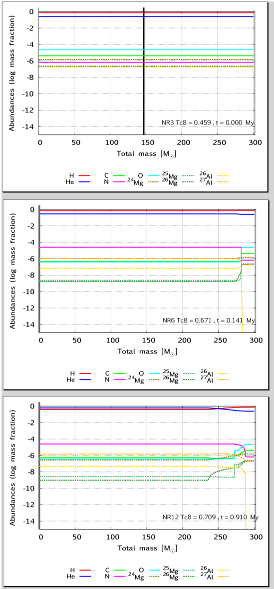
Velocity in km/s
500
400
300
200
100
0
Mass in M_{sol}
500
450
400
350
300
250
200
150
100
50
0
Metallicity in $\log(Z_{mw})$
0
-0.5
-1
-1.5
-2
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
Y_s at current end of model


Abundances (log mass fraction)
Total mass [M☉]
NR2 Tc8 = 0.323 , t = 0.052 My
NR4 Tc8 = 0.329 , t = 7.485 My
NR7 Tc8 = 0.341 , t = 13.393 My
H
He
C
N
O
24Mg
25Mg
26Mg
26Al
27Al

Extra

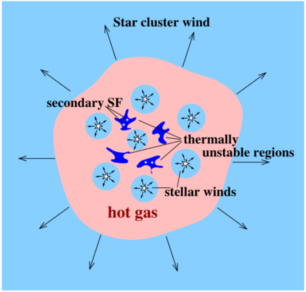

Abundances (log mass fraction)
Total mass [M☉]
NR3 Tc8 = 0.458 , t = 0.000 My
NR7 Tc8 = 0.522 , t = 0.396 My
NR14 Tc8 = 0.548 , t = 1.200 My
H
He
C
N
O
24Mg
25Mg
26Mg
26Al
27Al

Extra



Abundances (log mass fraction)
Total mass [M$_\odot$]
NR3 Tc8 = 0.459 , t = 0.000 My
NR6 Tc8 = 0.671 , t = 0.141 My
NR12 Tc8 = 0.709 , t = 0.910 My
H
He
C
N
O
24Mg
25Mg
26Mg
26Al
27Al

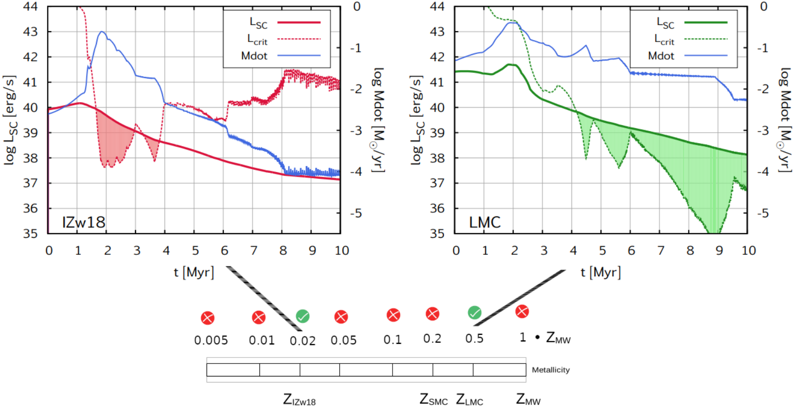
- young massive clusters have winds
  stellar winds → collisions → shocked wind → outflow
- thermal instability, rapid cooling
  if the cluster is massive and compact enough
- dense warm/cold clumps are formed
  cluster gravity ⇒ clumps fall to the centre;
  accumulation ⇒ self-shielding against EUV radiation
- 2nd generation (2G) stars formed
  enriched by products of massive stars chem. evolution



Credit: R. Wünsch (ASU)

Basic parameters:

- L_{SC}, $\dot{M}_{SC} \leftarrow M_{1G}$, stellar evolution tracks
- R_{SC} + eventually radial profile (R_c, β)



44
43
42
41
40
39
38
37
36
35
log L_SC [erg/s]
0
-1
-2
-3
-4
-5
log Mdot [M⊙/yr]
L_SC
L_crit
Mdot
IZw18
LMC
0 1 2 3 4 5 6 7 8 9 10
t [Myr]
0.005
0.01
0.02
0.05
0.1
0.2
0.5
1 • Z_MW
Metallicity
Z_IZw18
Z_SMC
Z_LMC
Z_MW

Extra

STATUS | RESOURCES | DOCUMENTATION

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BONNSAI, the BONN Stellar Astrophysics Interface, is a Bayesian statistical method that is capable of comparing all available observables simultaneously to stellar models while taking observed uncertainties and prior knowledge such as initial mass functions and distributions of stellar rotational velocities into account. BONNSAI can be used to (1) determine probability distributions of fundamental stellar parameters such as initial masses and stellar ages from complex datasets, (2) predict stellar parameters that were not yet observationally determined and (3) test stellar models to further advance our understanding of stellar evolution. A full description of BONNSAI is published in Schneider et al. (2014, A&A, 570, 66).

There are only four steps involved to submit a job:

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2. Provide the observables including their uncertainties.
3. Choose priors and output quantities.
4. Submit your request.

Once your job is finished, you will receive an email with a link to your results.

To start submitting a job, select the stellar models to match your observables to from the above drop-down menu. In case you have any questions, comments or suggestions do not hesitate to contact us. We hope you enjoy using BONNSAI.