Effects on Stellar Evolution From High Mass and Rotation

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Stellar Structure Final PHY 510

April 30, 2019

Introduction

rotating_star.jpg

[loopautostart]video$_3$0$frame_temperature_lev9.mov$ $height = 0.7$

caption

media9

Rotational Effects

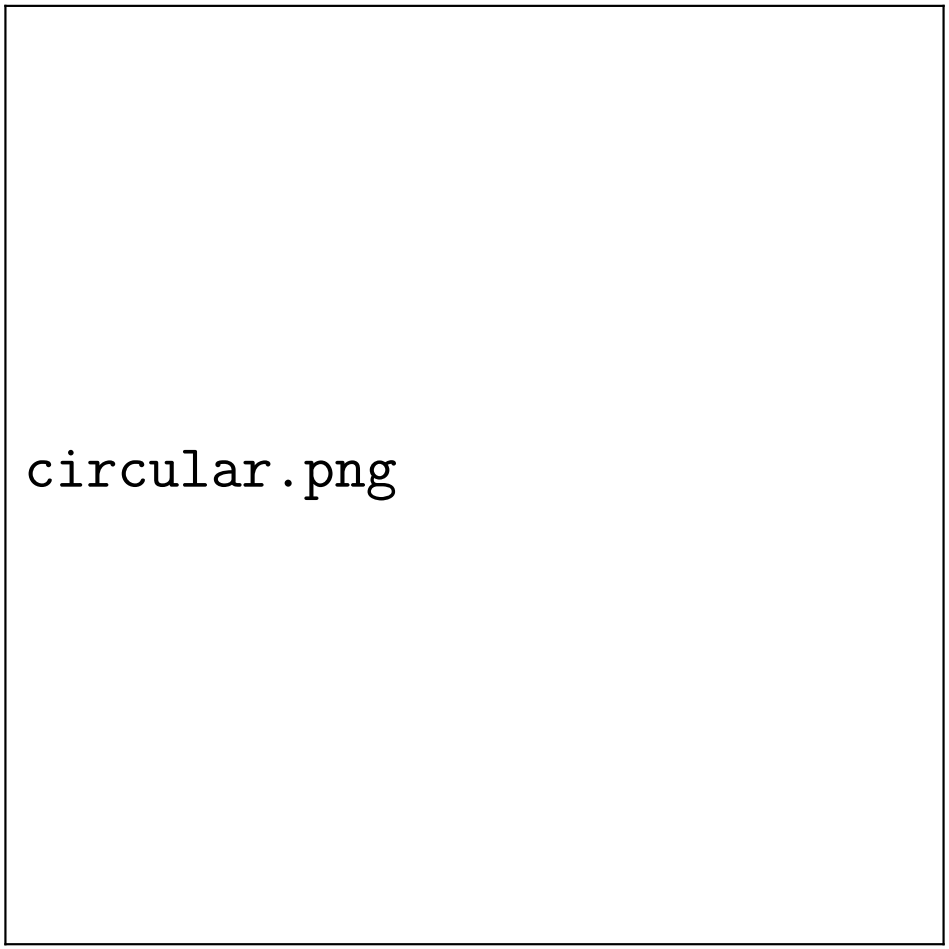


Figure: Circulation currents caused by rotation in a 20 solar mass star with an initial rotational velocity of 300 $\frac{km}{s}$. Meynet & Maeder 2002

Turbulence and Instability

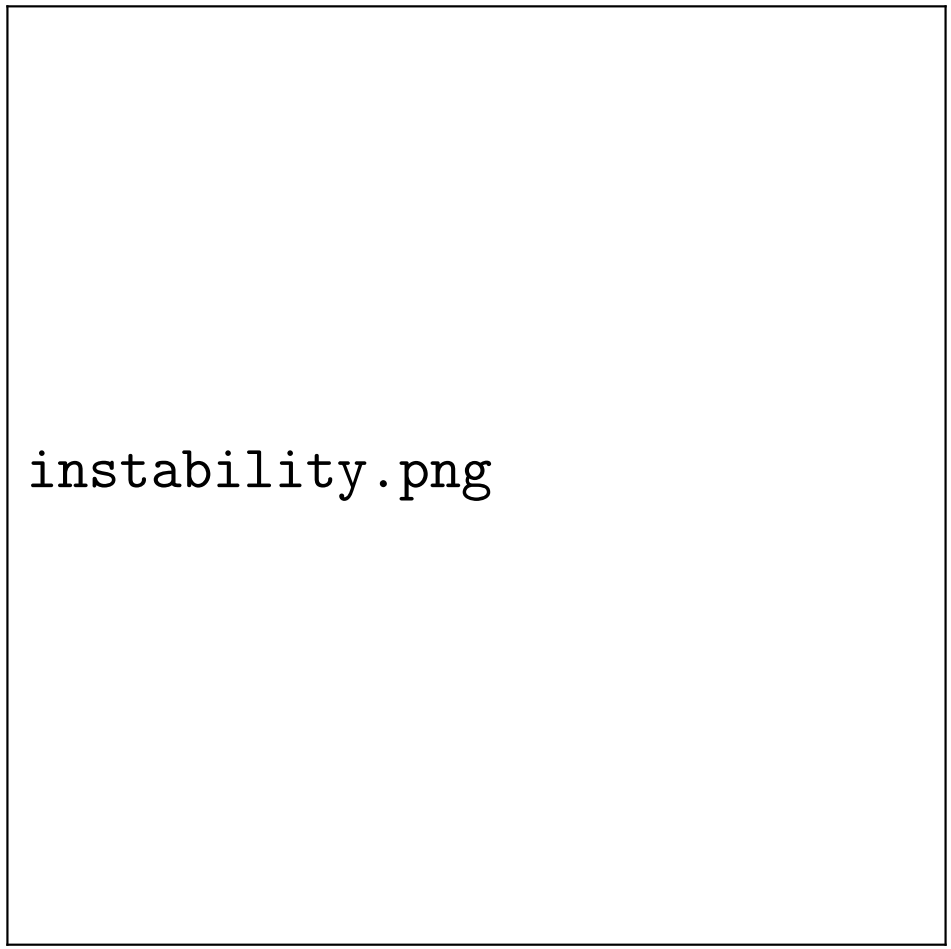


Figure: Li & Li 2006

- Kelvin-Helmholtz "fingers"

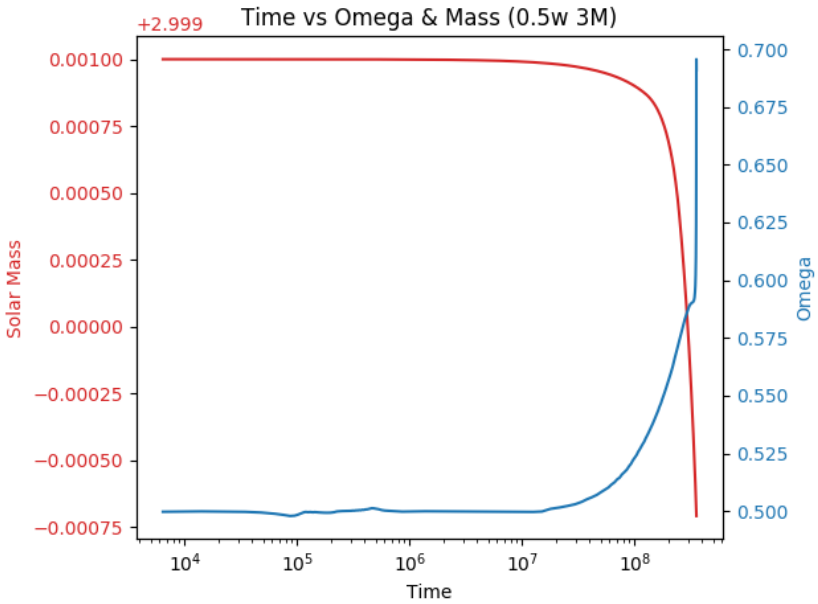
Method

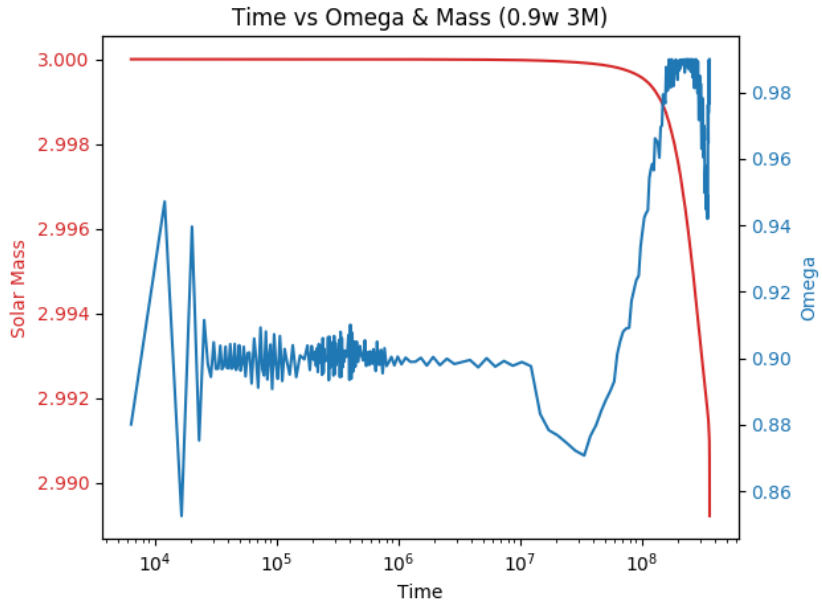
- Use **high_rot_darkening** within **mesa/star**
- Within **inlist_high_rot_darkening**, manipulate initial mass and rotation
- Ran code on *Carnie*, provided by UMassD
- Analyzed data with **python** with added module **mesa_reader**
- Hydrogen burning limits time of run

Mass Loss

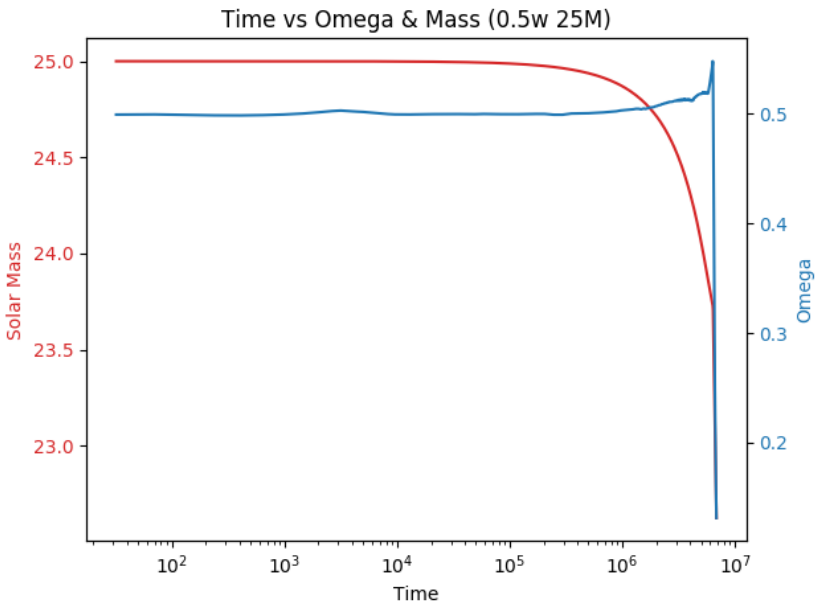
- $\frac{dM(\Omega)}{dt} = \frac{dM(0)}{dt}(\frac{1}{1-\frac{\Omega}{\Omega_{crit}}})^{\zeta}$ (Paxton *et al.* 2013)
- Ω = surface angular velocity, Ω_{crit} = critical angular velocity
- $\Omega_{crit}^2 = (1 - \frac{L}{L_{Edd}})\frac{GM}{R^3}$
- $L_{Edd} = \frac{4\pi cGM}{\kappa}$
- In **MESAstar**, $\zeta = 0.43$ (Langer 1998)
- Solar winds

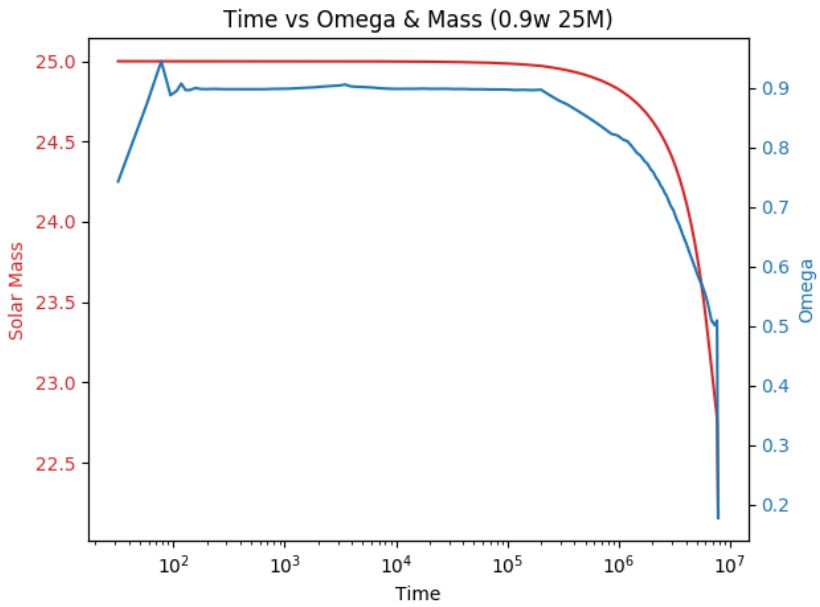
Mass Loss


Time vs Omega & Mass (0.5w 3M)
+2.999
Solar Mass
Omega
Time
0.00100
0.00075
0.00050
0.00025
0.00000
−0.00025
−0.00050
−0.00075
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0.525
0.500
10^4
10^5
10^6
10^7
10^8

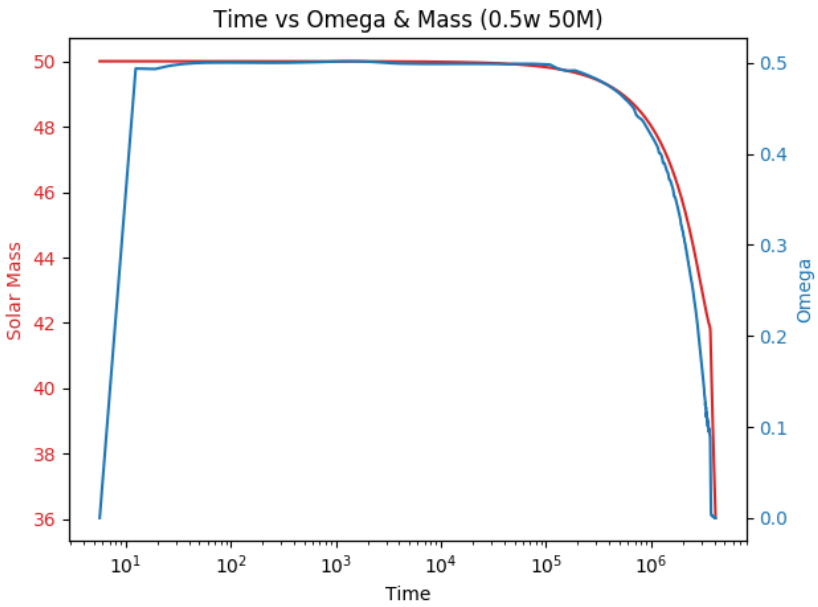

Time vs Omega & Mass (0.9w 3M)
Solar Mass
Omega
Time
3.000
2.998
2.996
2.994
2.992
2.990
0.98
0.96
0.94
0.92
0.90
0.88
0.86
10^4
10^5
10^6
10^7
10^8

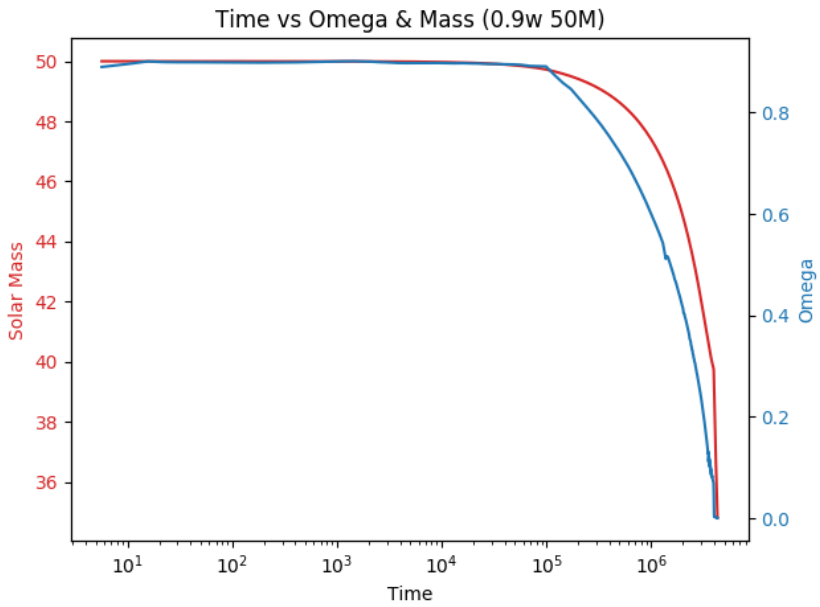
Mass Loss


Time vs Omega & Mass (0.5w 25M)
Solar Mass
Omega
Time
25.0
24.5
24.0
23.5
23.0
0.5
0.4
0.3
0.2
10^2
10^3
10^4
10^5
10^6
10^7

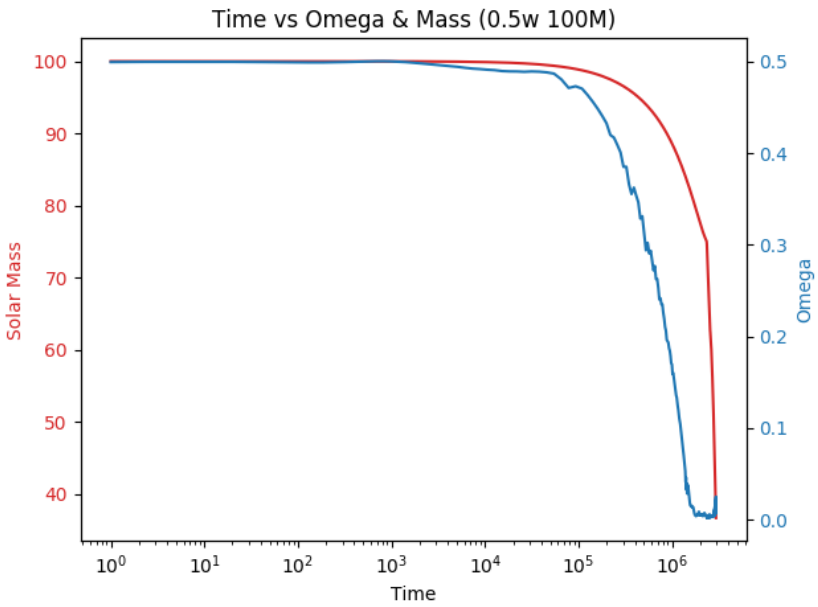

Time vs Omega & Mass (0.9w 25M)
Solar Mass
Omega
Time
25.0
24.5
24.0
23.5
23.0
22.5
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
10^2
10^3
10^4
10^5
10^6
10^7

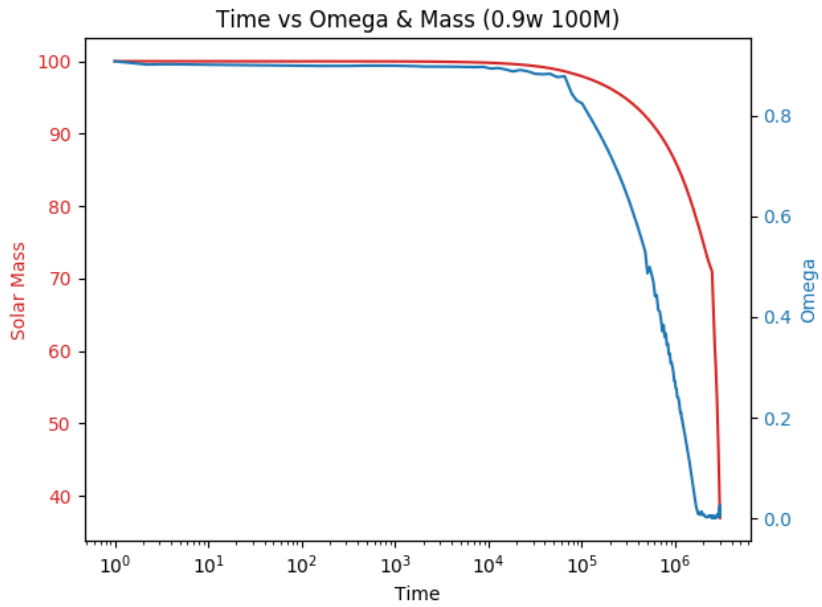
Mass Loss


Time vs Omega & Mass (0.5w 50M)
Solar Mass
Omega
Time
50
48
46
44
42
40
38
36
0.5
0.4
0.3
0.2
0.1
0.0
10^1
10^2
10^3
10^4
10^5
10^6


Time vs Omega & Mass (0.9w 50M)
Solar Mass
Omega
Time
50
48
46
44
42
40
38
36
0.8
0.6
0.4
0.2
0.0
10^1
10^2
10^3
10^4
10^5
10^6

Mass Loss


Time vs Omega & Mass (0.5w 100M)
Solar Mass
Omega
Time
100
90
80
70
60
50
40
0.5
0.4
0.3
0.2
0.1
0.0
10^0
10^1
10^2
10^3
10^4
10^5
10^6


Time vs Omega & Mass (0.9w 100M)
Solar Mass
Omega
Time
100
90
80
70
60
50
40
0.8
0.6
0.4
0.2
0.0
10^0
10^1
10^2
10^3
10^4
10^5
10^6

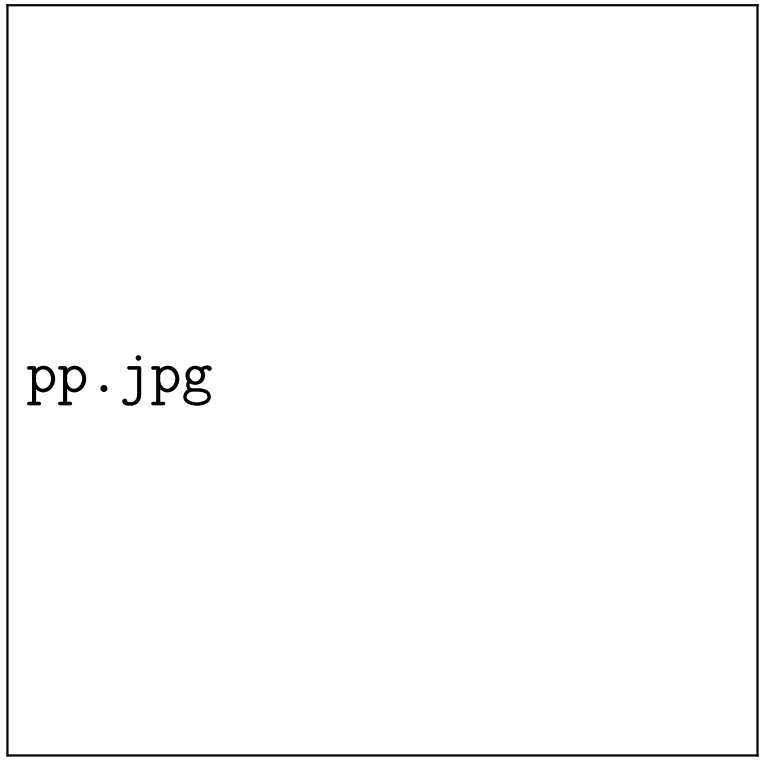
Luminosity

- $L_{proj} = 4 \int \int_{d\Sigma \bullet \ell > 0} F d\Sigma \bullet \ell$ (Paxton *et al.* 2019)
- Luminosity projected along the line of sight to the observer
- Assumed to be isotropic
- $T_{eff,proj} = (\frac{L_{proj}}{\sigma \Sigma_{proj}})^{\frac{1}{4}}$
- From Stefan-Boltzmann Law

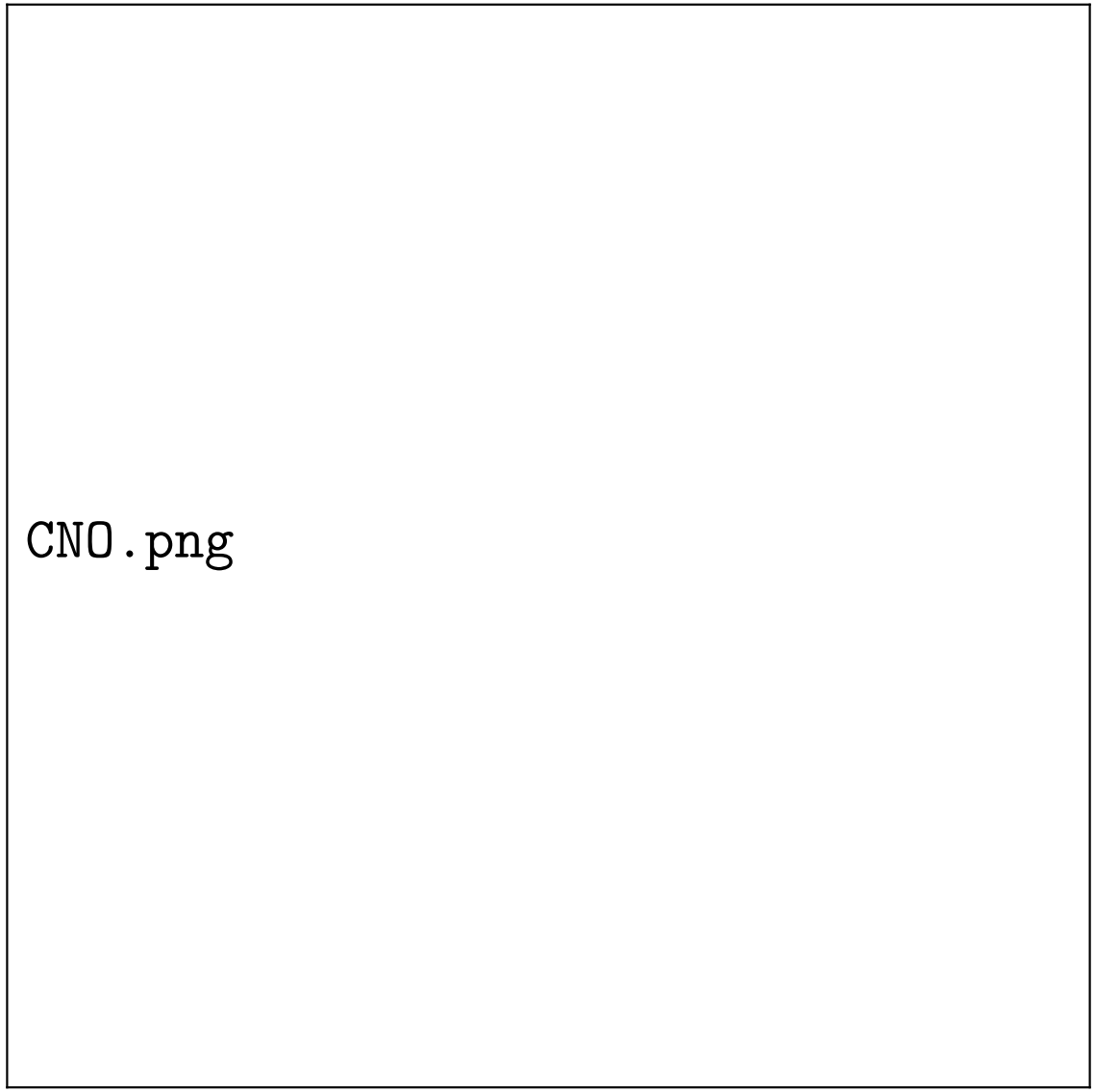
Triple Alpha

Triple_Alpha.png

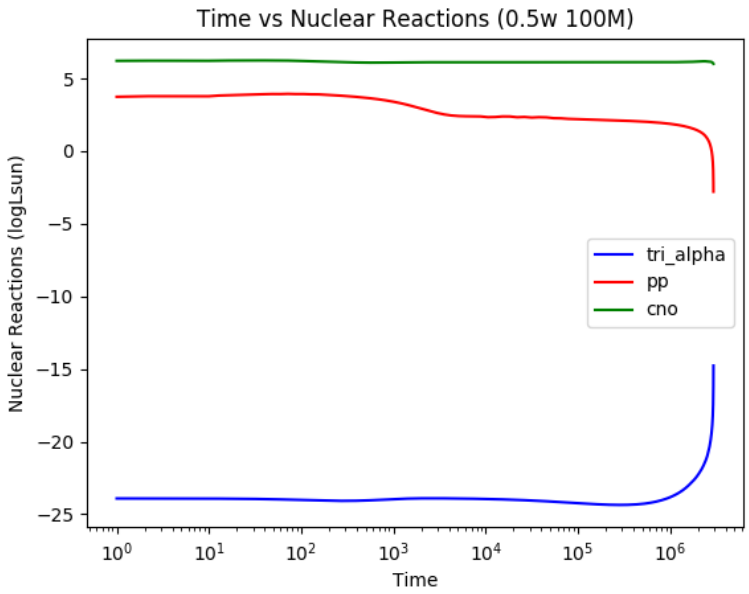
Proton-Proton Chain

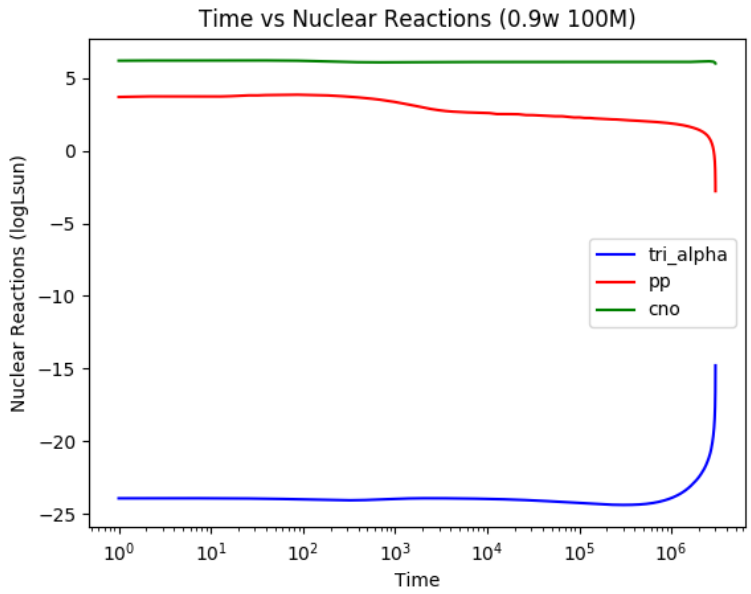


Carbon-Nitrogen-Oxygen Chain

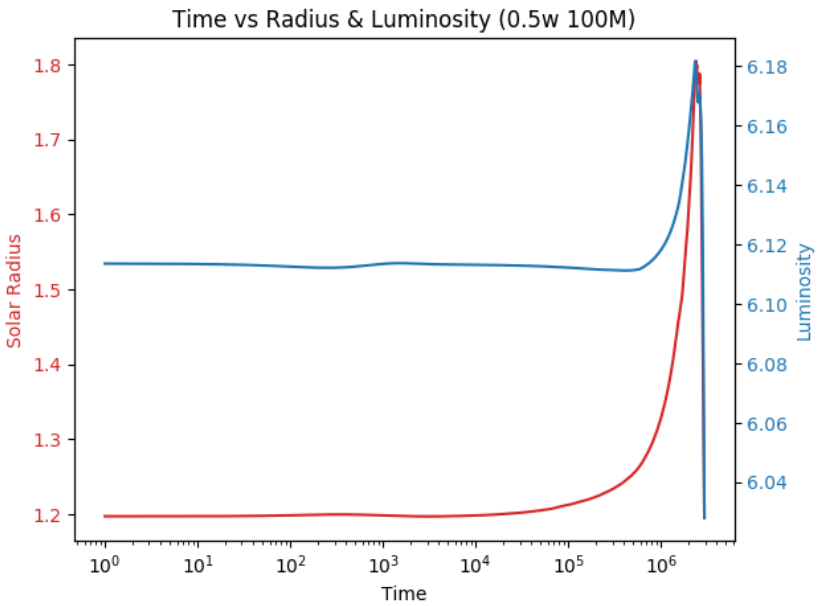


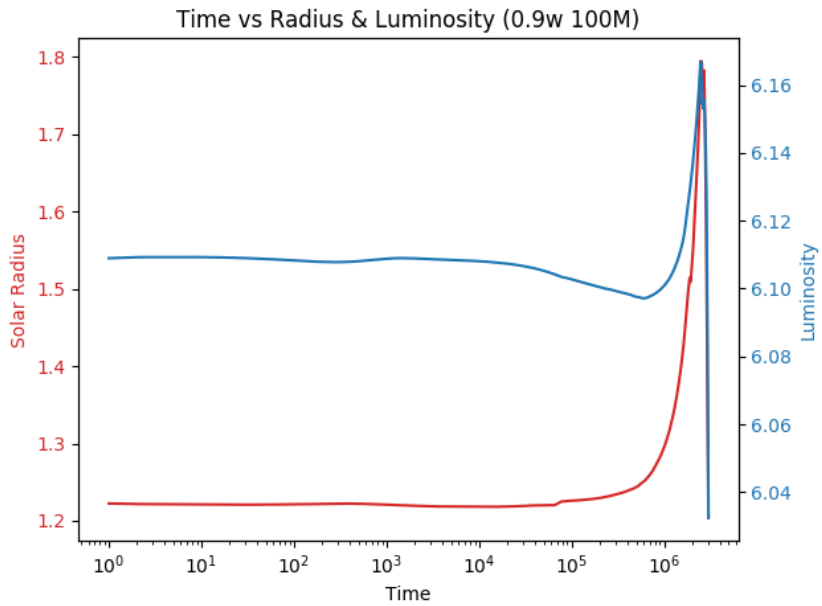
Luminosity


Time vs Nuclear Reactions (0.5w 100M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

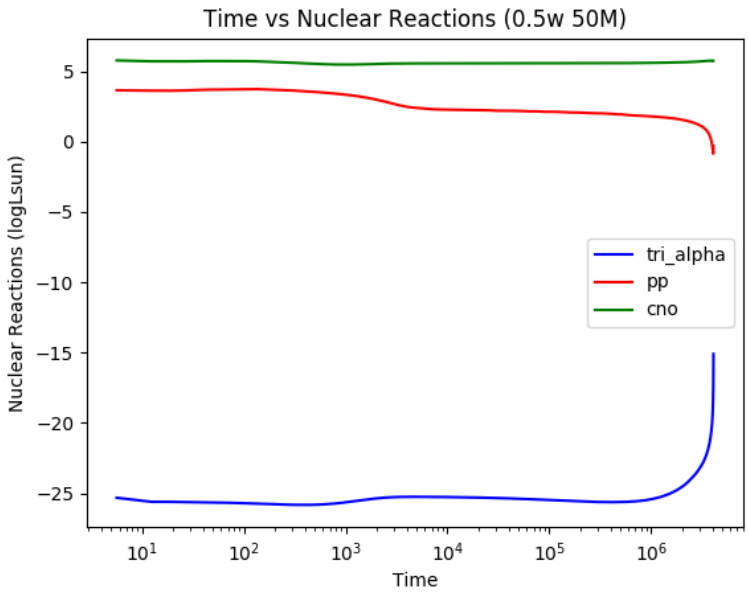

Time vs Nuclear Reactions (0.9w 100M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

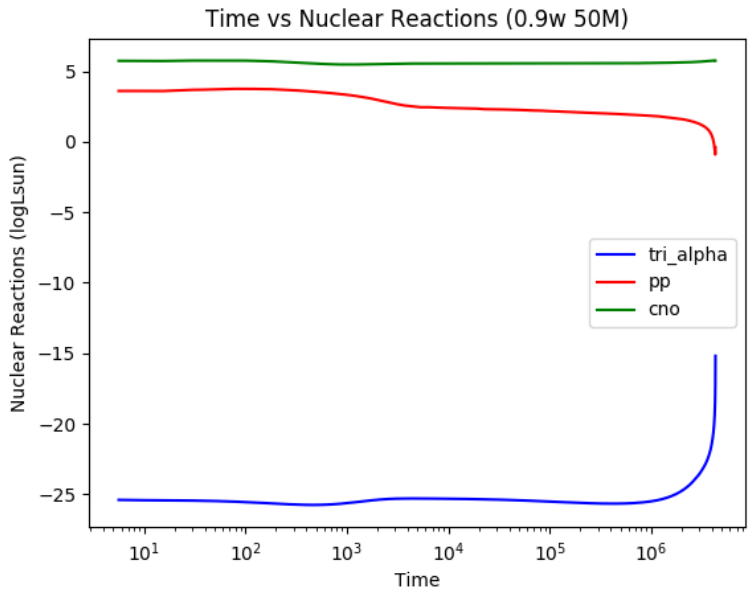
Luminosity


Time vs Radius & Luminosity (0.5w 100M)
Solar Radius
Luminosity
Time
1.8
1.7
1.6
1.5
1.4
1.3
1.2
6.18
6.16
6.14
6.12
6.10
6.08
6.06
6.04
10^0
10^1
10^2
10^3
10^4
10^5
10^6

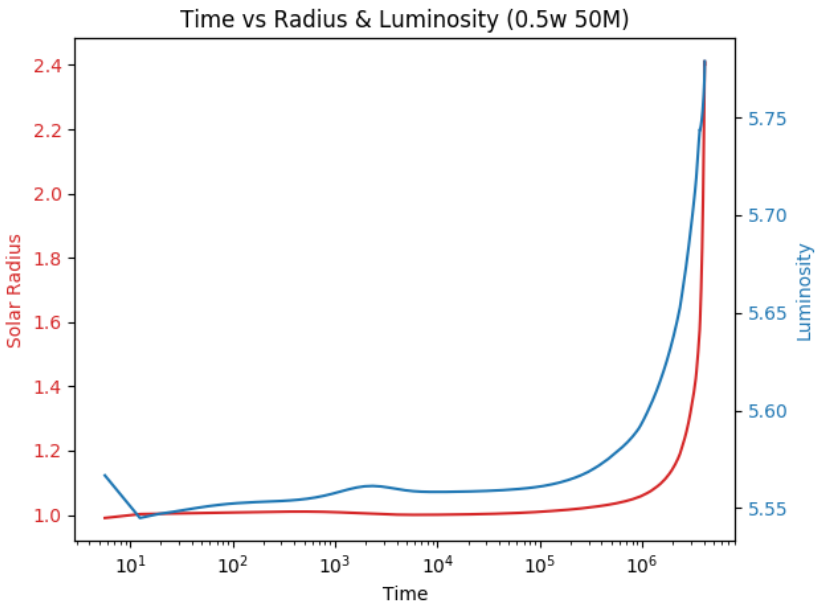

Time vs Radius & Luminosity (0.9w 100M)
Solar Radius
Luminosity
Time
1.8
1.7
1.6
1.5
1.4
1.3
1.2
6.16
6.14
6.12
6.10
6.08
6.06
6.04
10^0
10^1
10^2
10^3
10^4
10^5
10^6

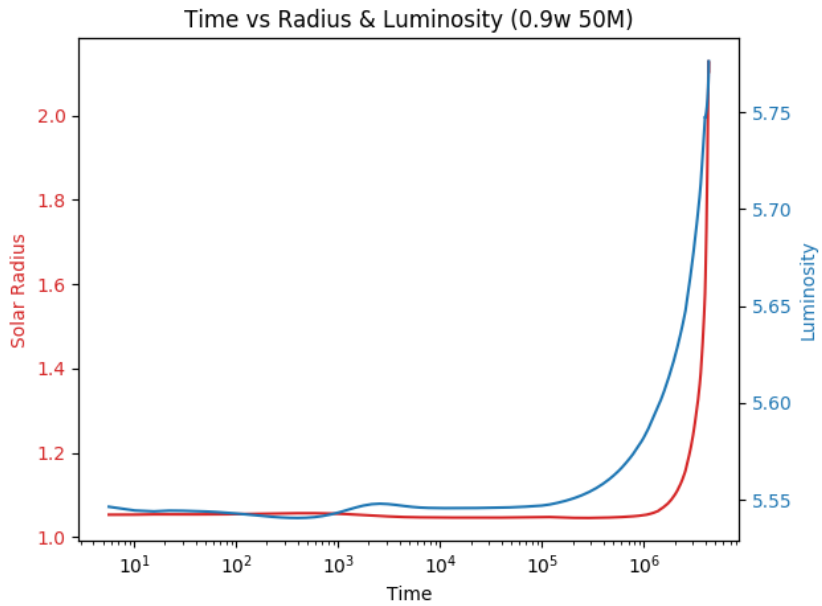
Luminosity


Time vs Nuclear Reactions (0.5w 50M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

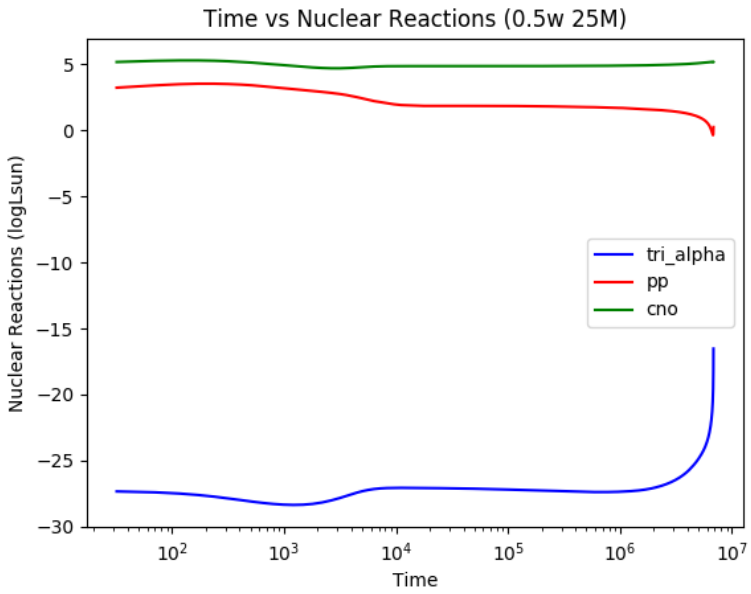

Time vs Nuclear Reactions (0.9w 50M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

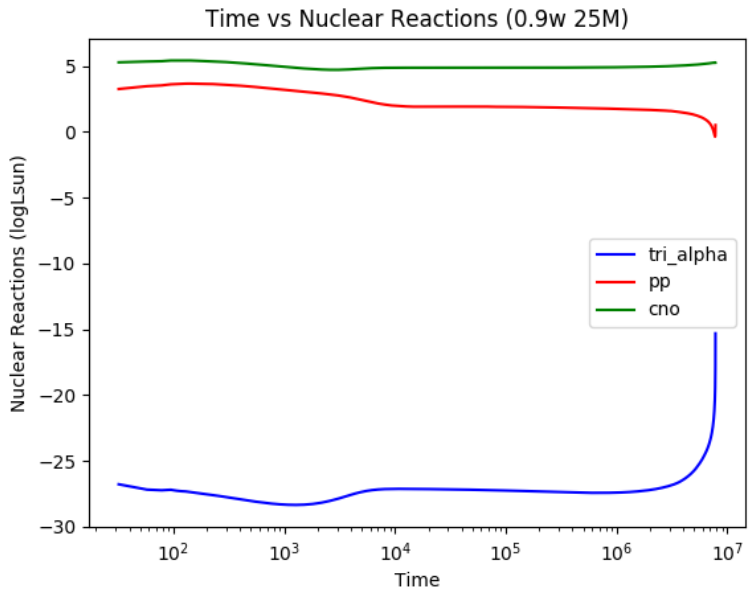
Luminosity


Time vs Radius & Luminosity (0.5w 50M)
Solar Radius
Luminosity
Time
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
5.75
5.70
5.65
5.60
5.55
10^1
10^2
10^3
10^4
10^5
10^6

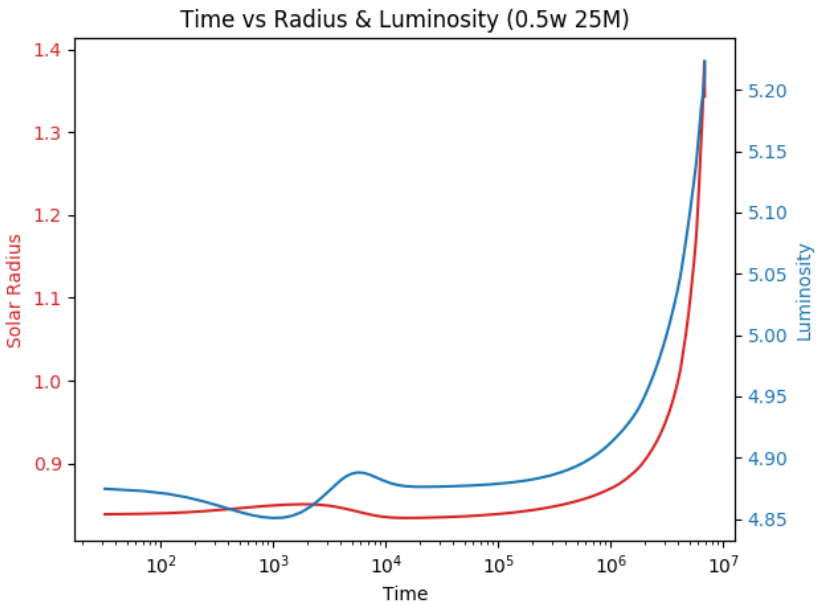

Time vs Radius & Luminosity (0.9w 50M)
Solar Radius
Luminosity
Time
2.0
1.8
1.6
1.4
1.2
1.0
5.75
5.70
5.65
5.60
5.55
10^1
10^2
10^3
10^4
10^5
10^6

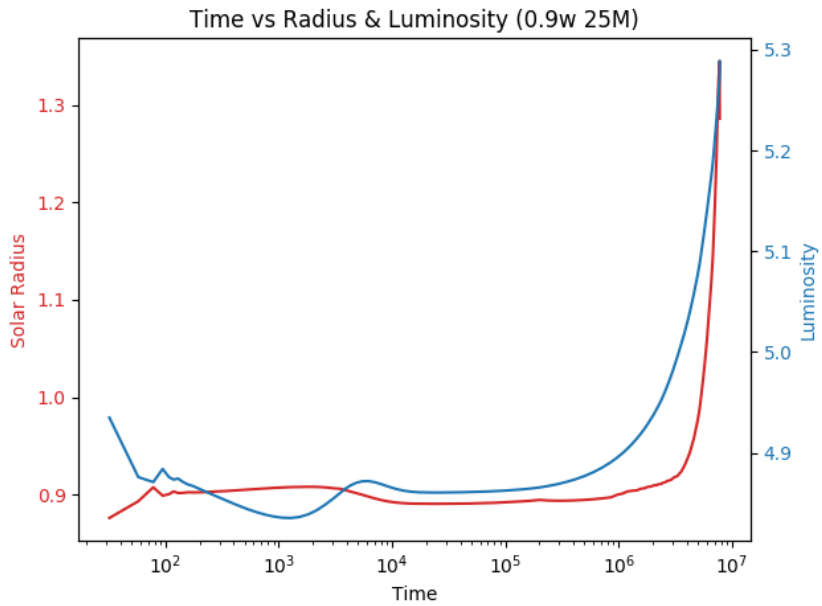
Luminosity


Time vs Nuclear Reactions (0.5w 25M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

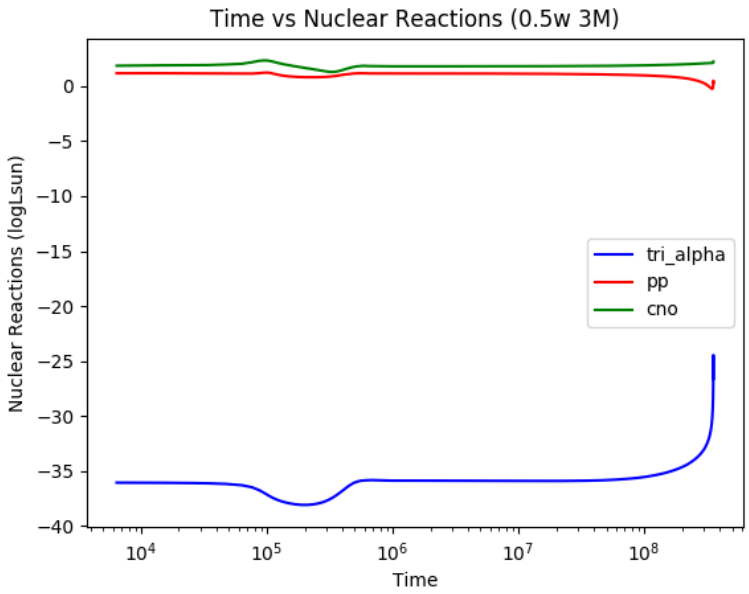

Time vs Nuclear Reactions (0.9w 25M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

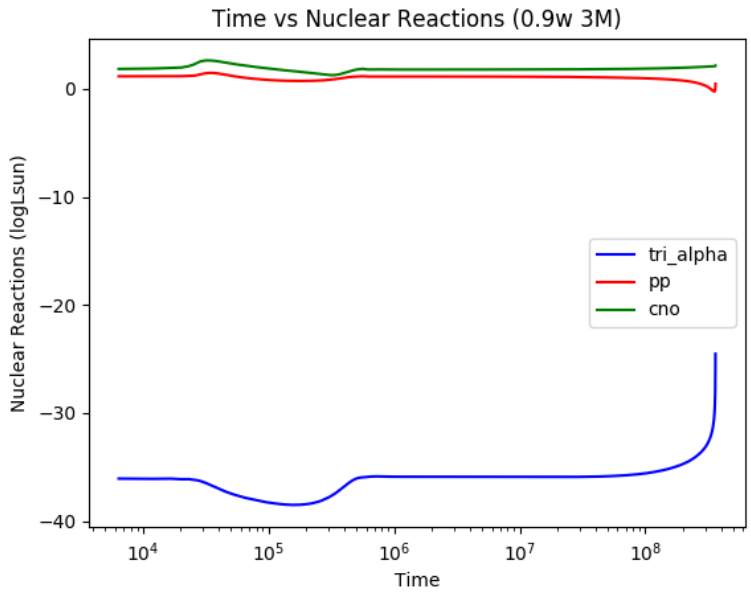
Luminosity


Time vs Radius & Luminosity (0.5w 25M)
Solar Radius
Luminosity
Time
1.4
1.3
1.2
1.1
1.0
0.9
5.20
5.15
5.10
5.05
5.00
4.95
4.90
4.85
10^2
10^3
10^4
10^5
10^6
10^7

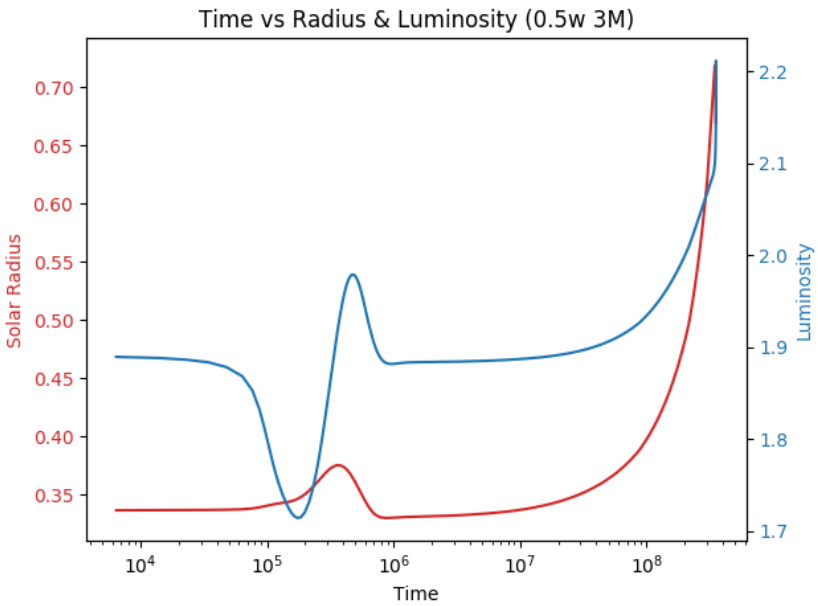

Time vs Radius & Luminosity (0.9w 25M)
Solar Radius
Luminosity
Time
1.3
1.2
1.1
1.0
0.9
5.3
5.2
5.1
5.0
4.9
10^2
10^3
10^4
10^5
10^6
10^7

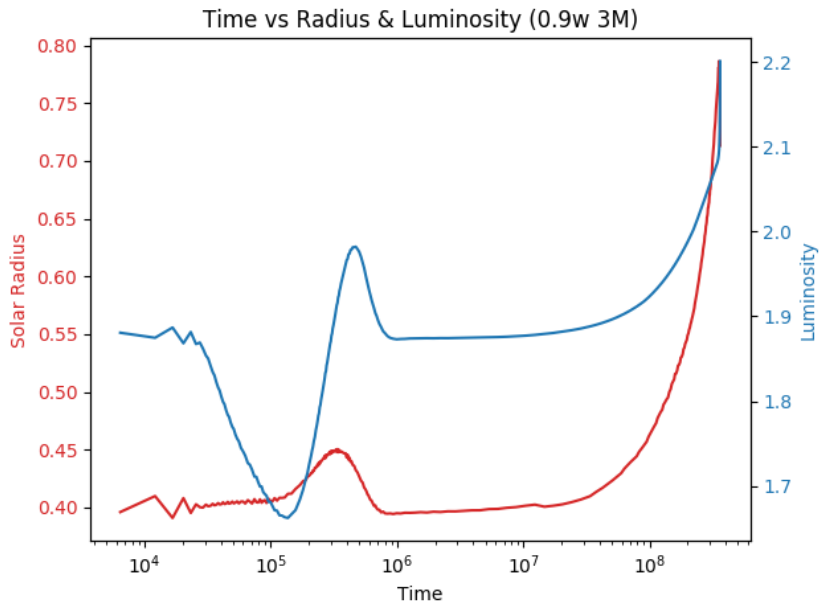
Luminosity


Time vs Nuclear Reactions (0.5w 3M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

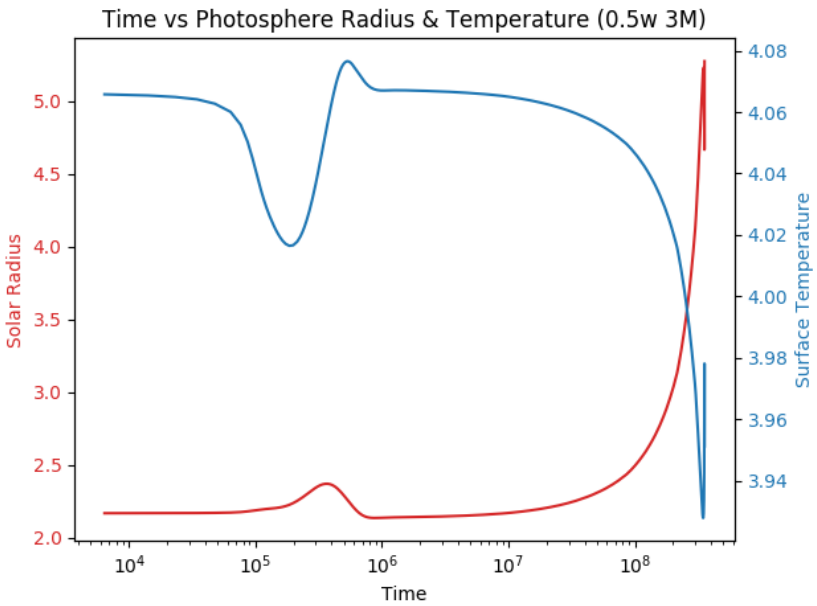

Time vs Nuclear Reactions (0.9w 3M)
Nuclear Reactions (logLsun)
Time
tri_alpha
pp
cno

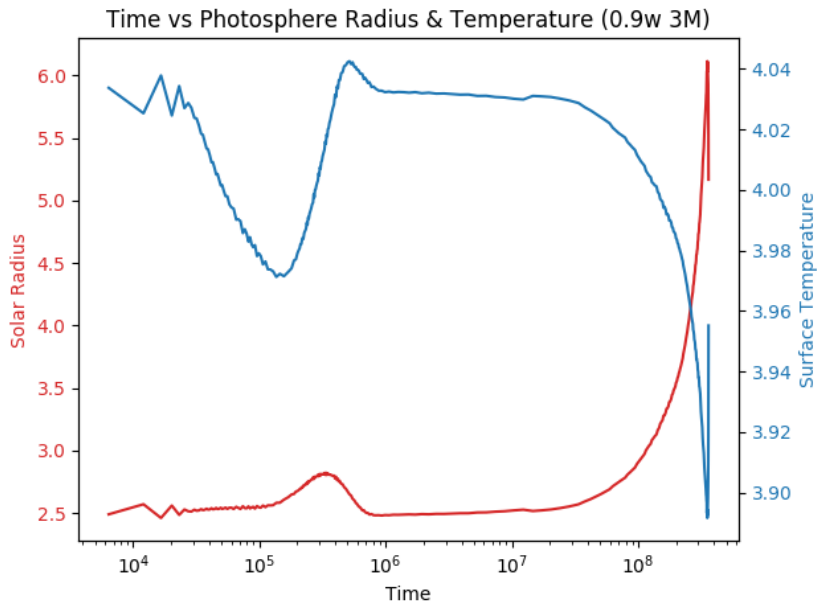
Luminosity


Time vs Radius & Luminosity (0.5w 3M)
Solar Radius
Luminosity
Time
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
2.2
2.1
2.0
1.9
1.8
1.7
10^4
10^5
10^6
10^7
10^8

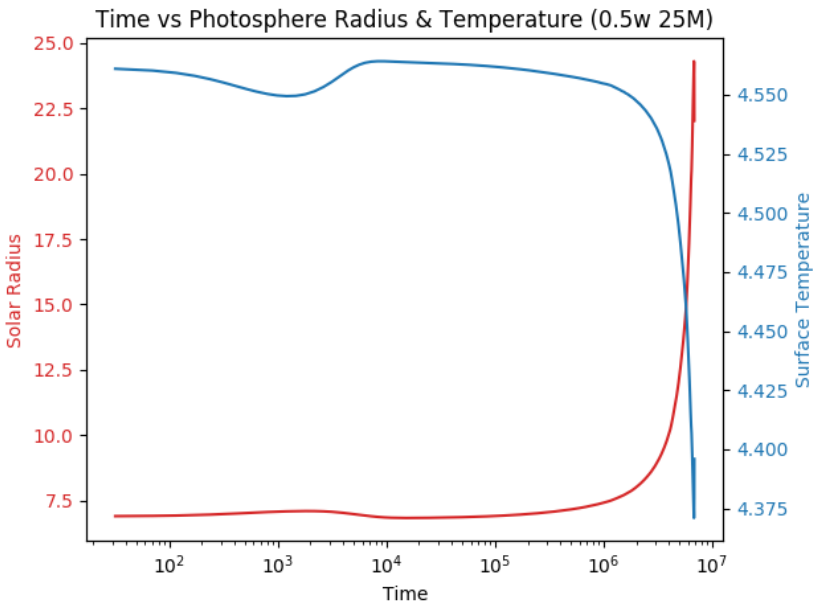

Time vs Radius & Luminosity (0.9w 3M)
Solar Radius
Luminosity
Time
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
2.2
2.1
2.0
1.9
1.8
1.7
10^4
10^5
10^6
10^7
10^8

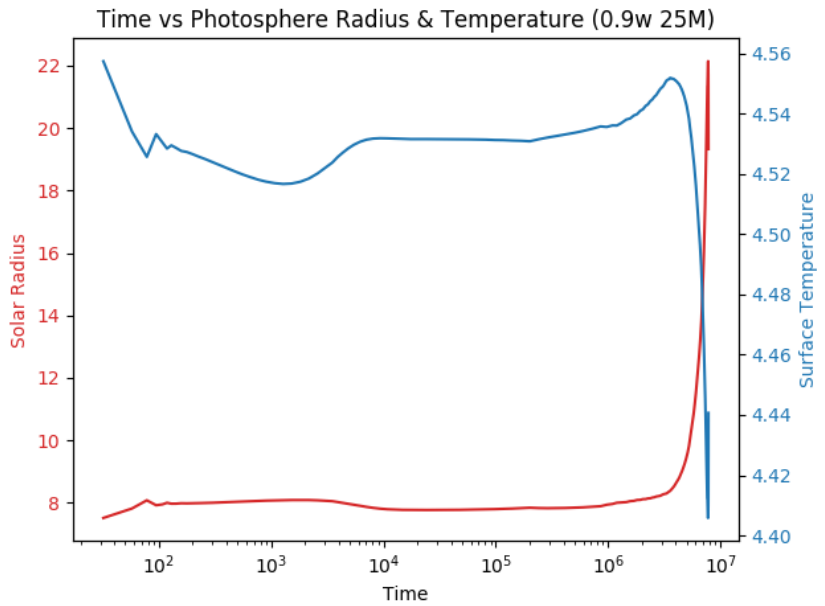
Temperature



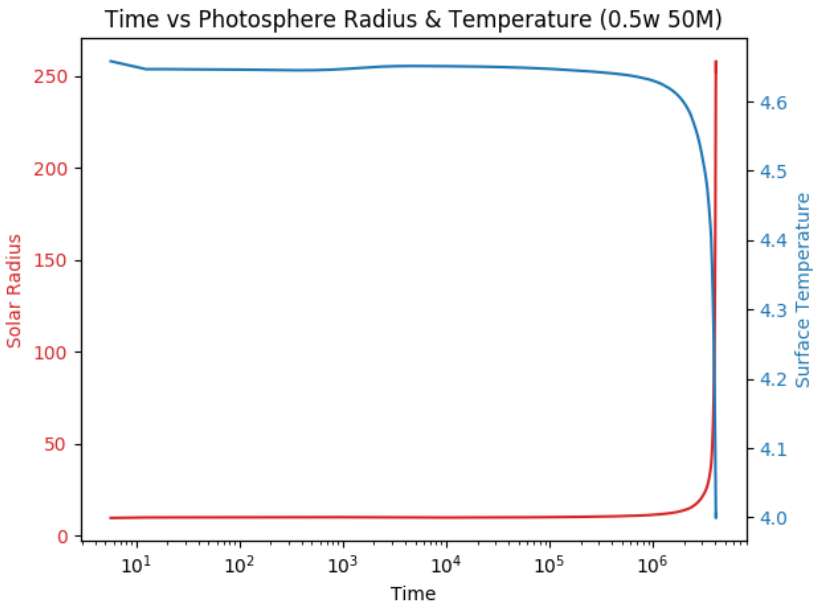


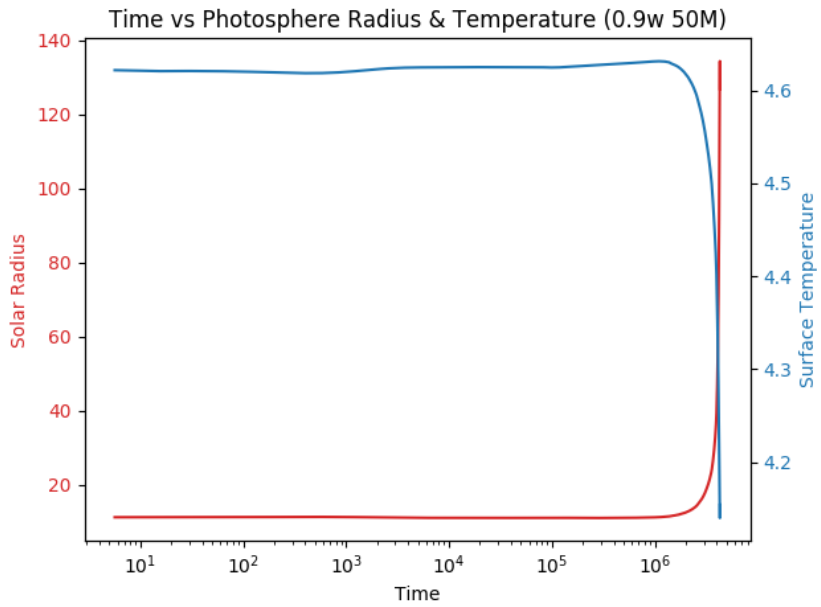
Temperature



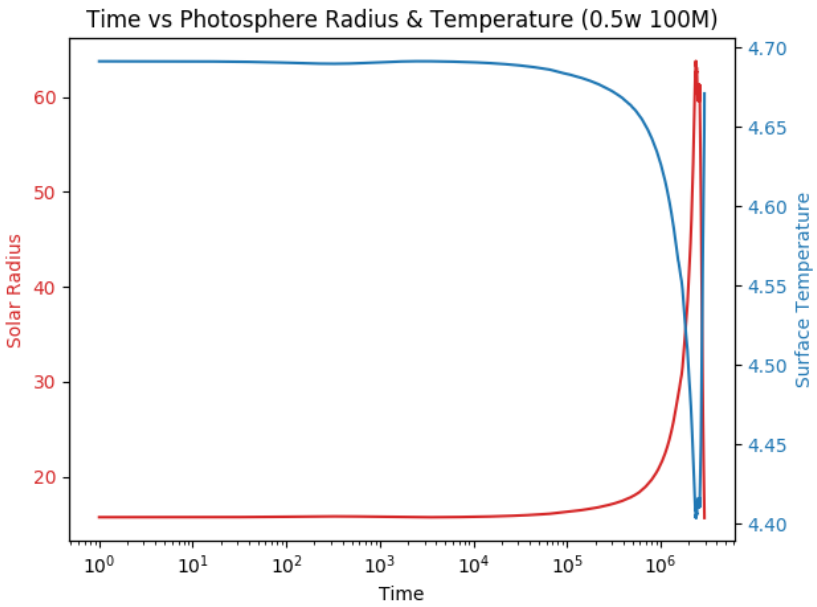


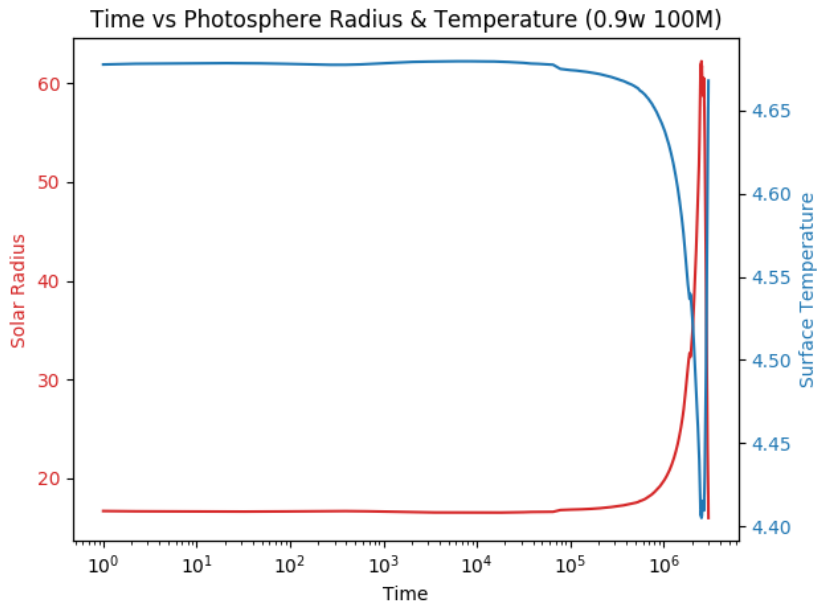
Temperature





Temperature





Future Work

- Continue to explore parameter space of rotation and mass
- Roche-Lobe potential
- Gravitational darkening
- Doppler effect
- Magnetic field