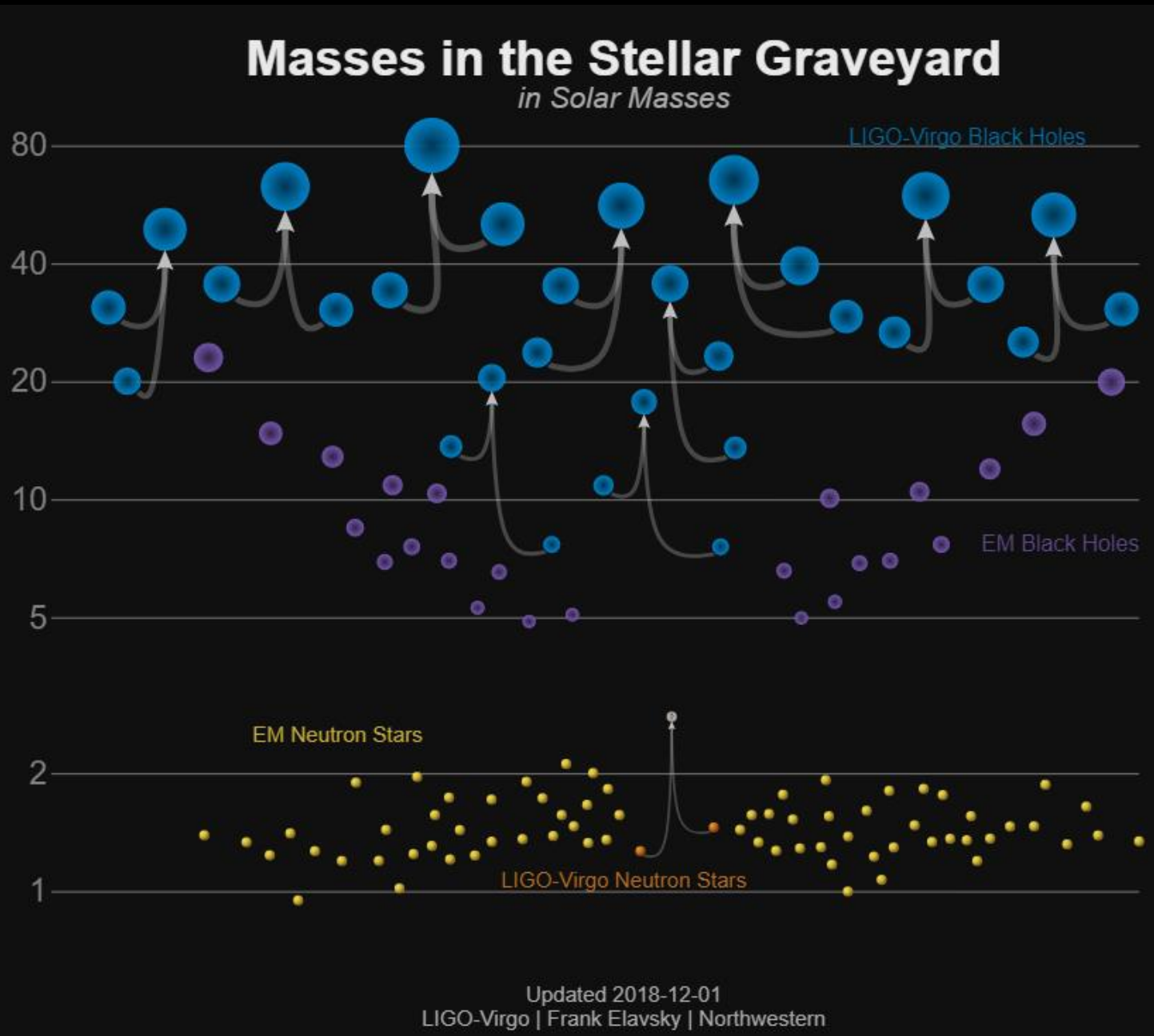
Astrophysics of gravitational wave sources

Lecture 2: Single star evolution

Ondřej Pejcha

ÚTF MFF UK


Masses in the Stellar Graveyard
in Solar Masses
80
40
20
10
5
2
1
LIGO-Virgo Black Holes
EM Black Holes
EM Neutron Stars
LIGO-Virgo Neutron Stars
Updated 2018-12-01
LIGO-Virgo | Frank Elavsky | Northwestern

How do we approach complex, unsolved problems?

Orbital decay timescale due to gravitational wave emission

Gravitational wave strain

$$h_{ij}(t) = \frac{2G}{c^4 r} \ddot{I}_{ij}^{TT}(t - r/c)$$

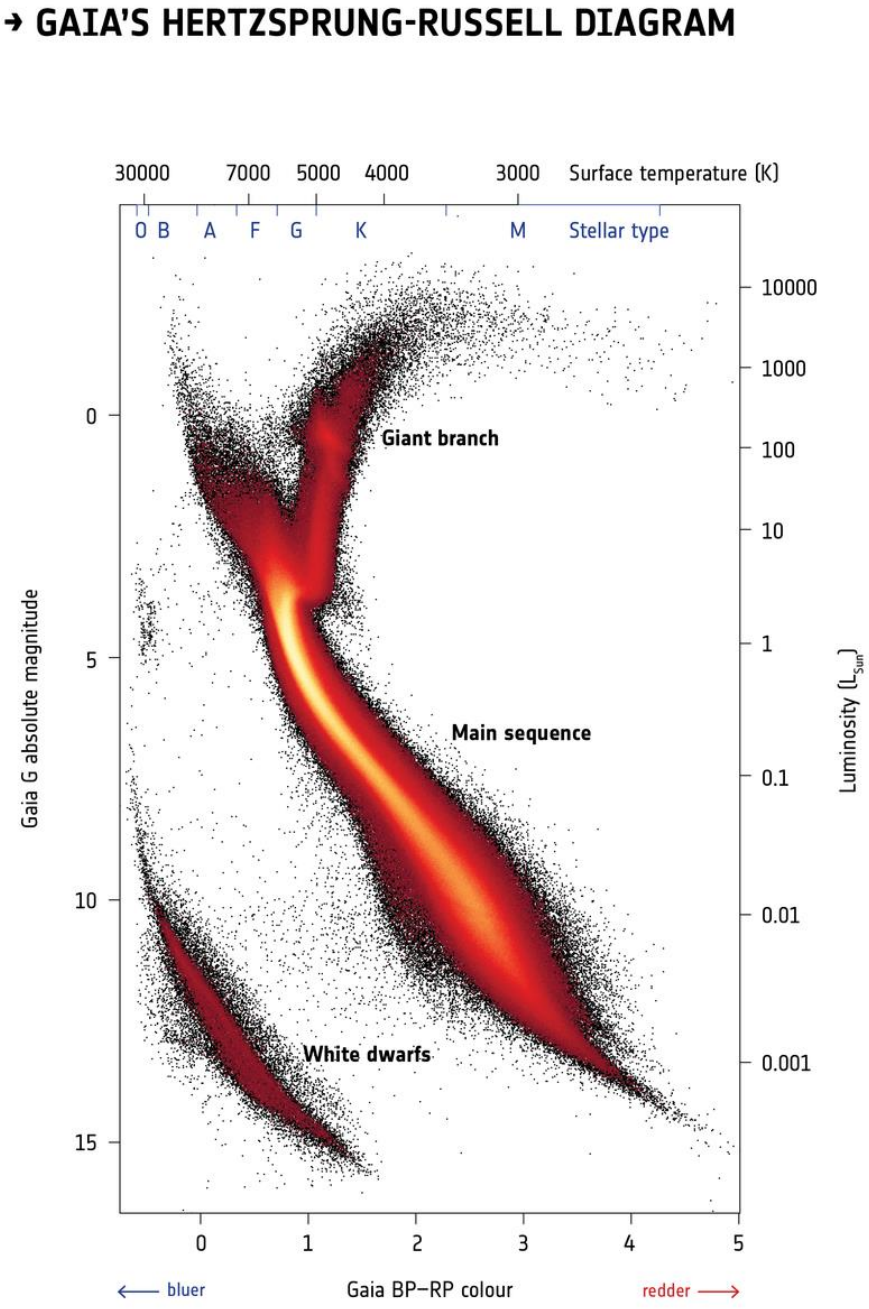
Energy flux of gravitational waves

$$-\langle \dot{E} \rangle = \frac{32}{5} \frac{M_1^2 M_2^2 (M_1 + M_2)}{a^5}$$

Orbital decay timescale

$$t_{\mathrm{GW}} = \frac{5a^4}{256 M_1 M_2 (M_1 + M_2)}$$

Main parameters of stars



Separation of stellar timescales

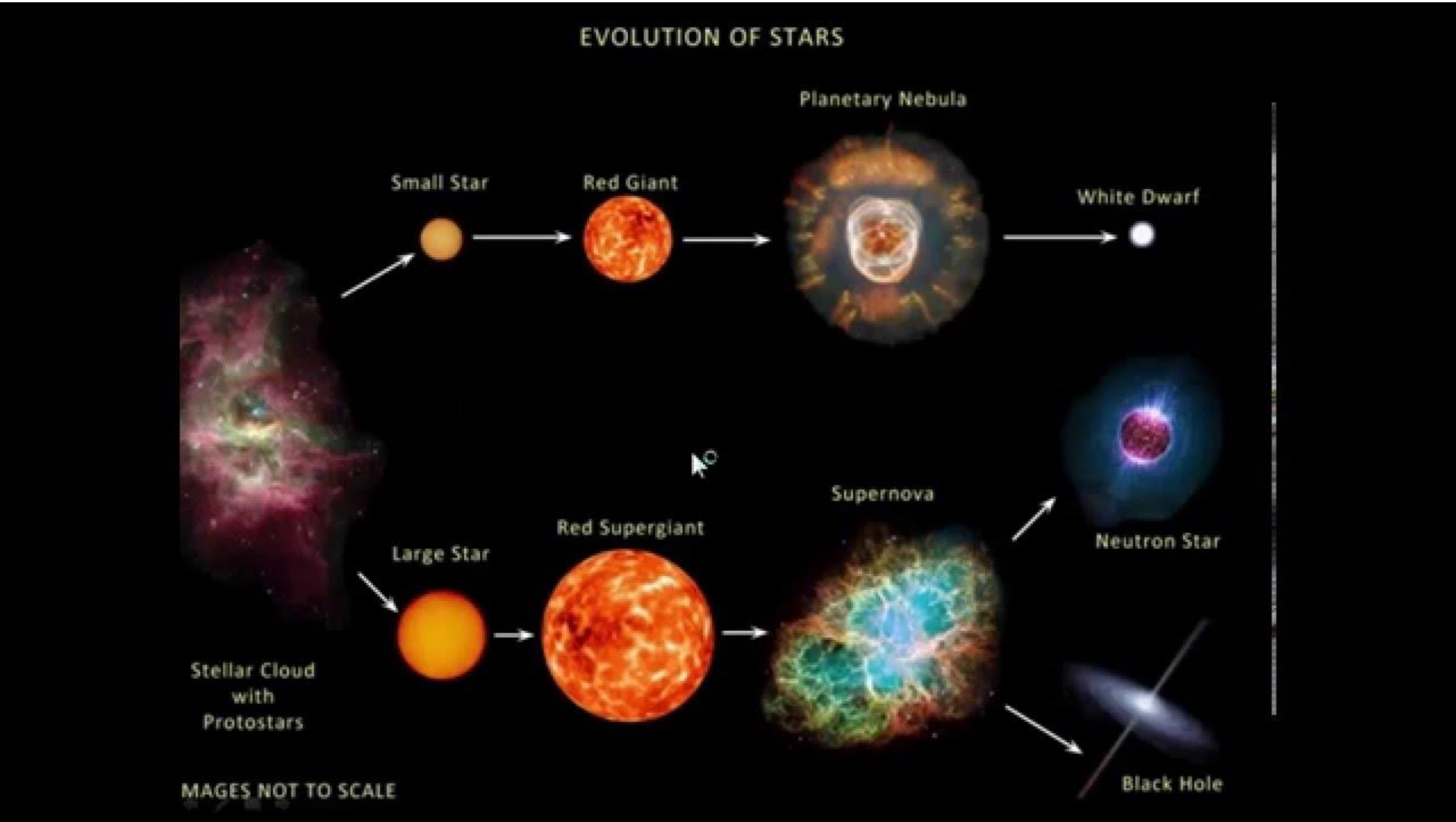
- Dynamical (free-fall, sound-crossing) timescale
- (Viscous timescale)
- Thermal (Kelvin-Helmholtz) timescale
- Nuclear timescale

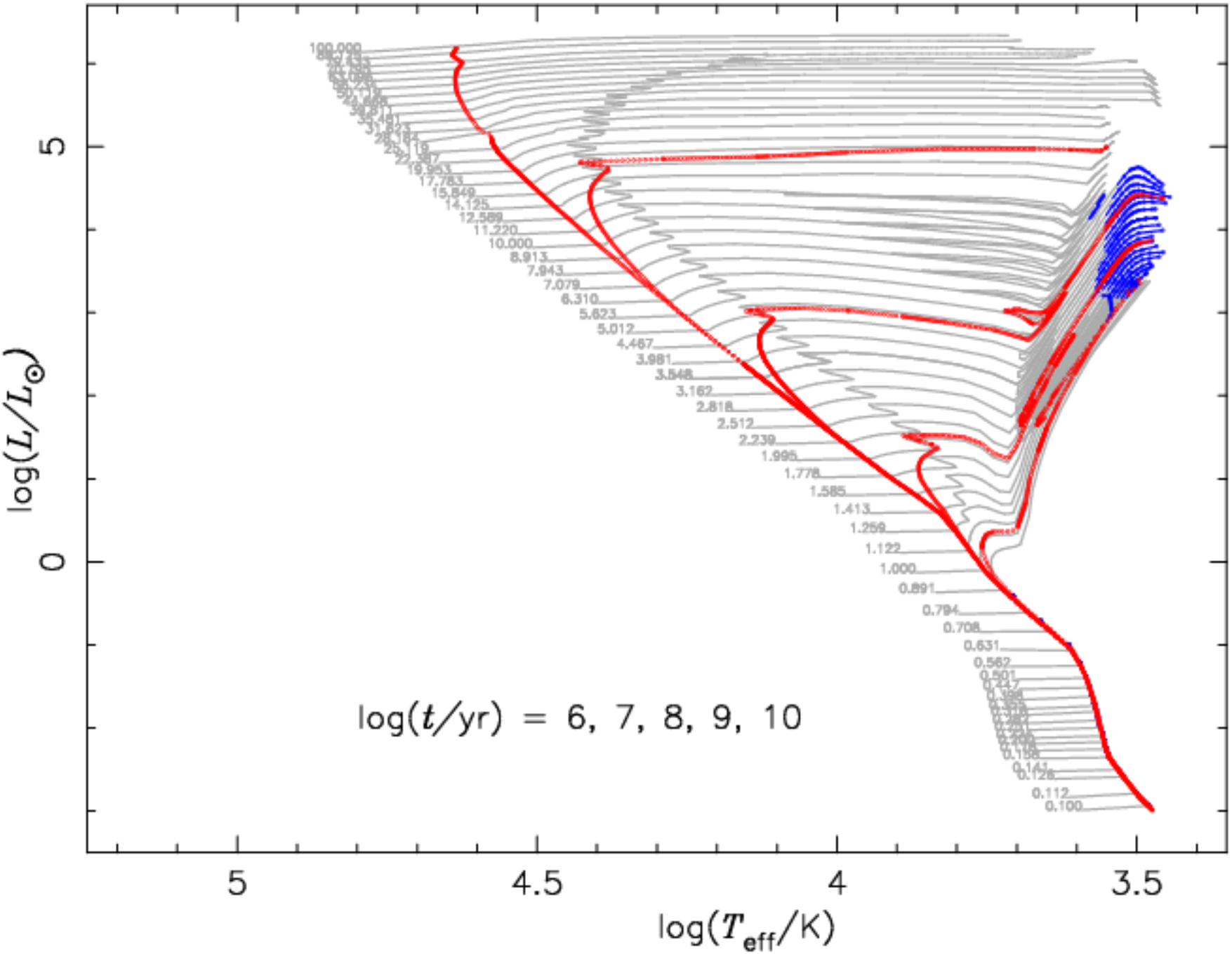
Stellar structure

Virial theorem

Homology relations

Stellar evolution




log(L/L⊙)
5
0
log(T_eff/K)
5
4.5
4
3.5
log(t/yr) = 6, 7, 8, 9, 10

Order-of-magnitude astrophysics

Does a 15 solar mass star release more energy during its stellar lifetime or when it explodes as a supernova? Which form of energy release is likely to have more impact on the surrounding interstellar medium?