POPULATION III STARS

Spectra and Ionizing Fluxes

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ZAH ZENTRUM FÜR ASTRONOMIE

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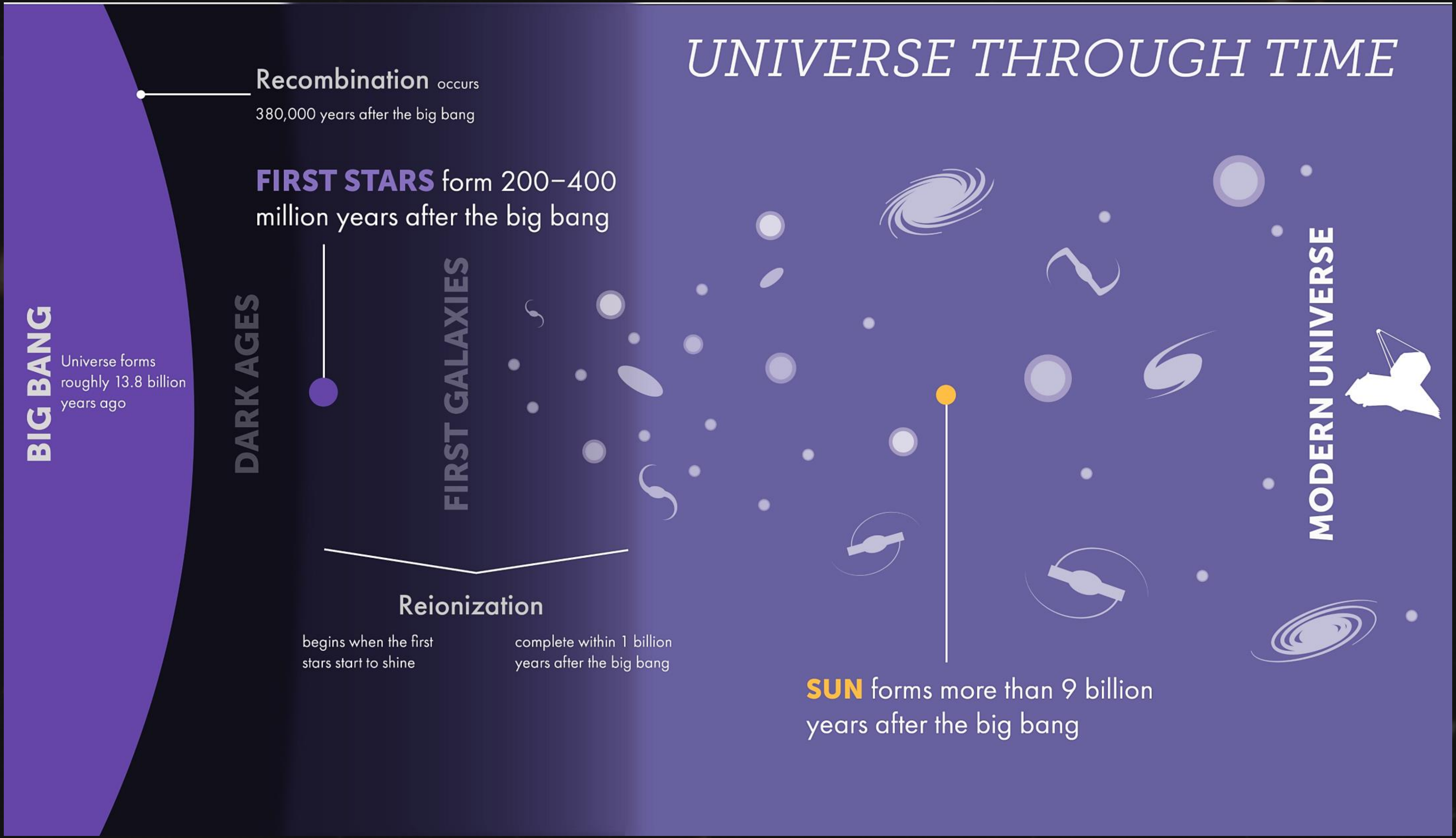
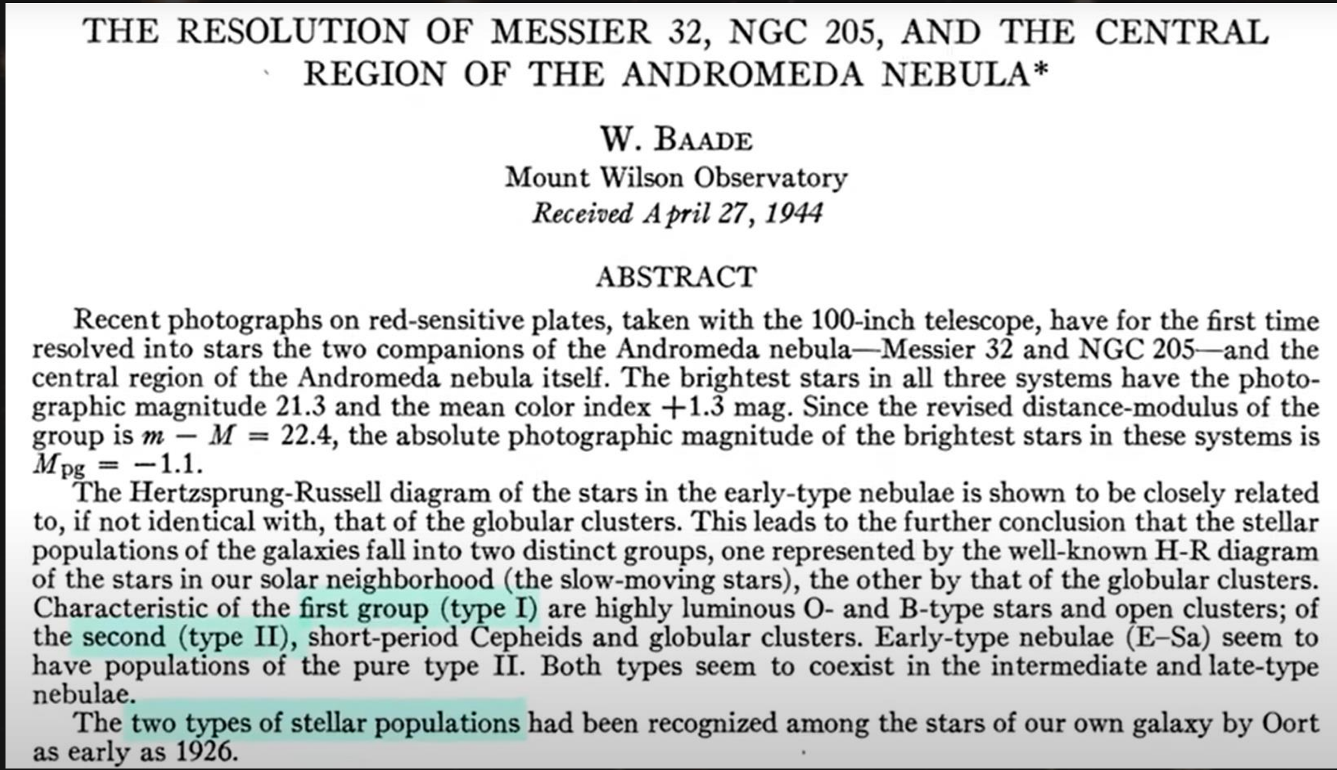


The distance of first-generation stars. Credit: STScI

Naming Stellar Populations


THE RESOLUTION OF MESSIER 32, NGC 205, AND THE CENTRAL REGION OF THE ANDROMEDA NEBULA*

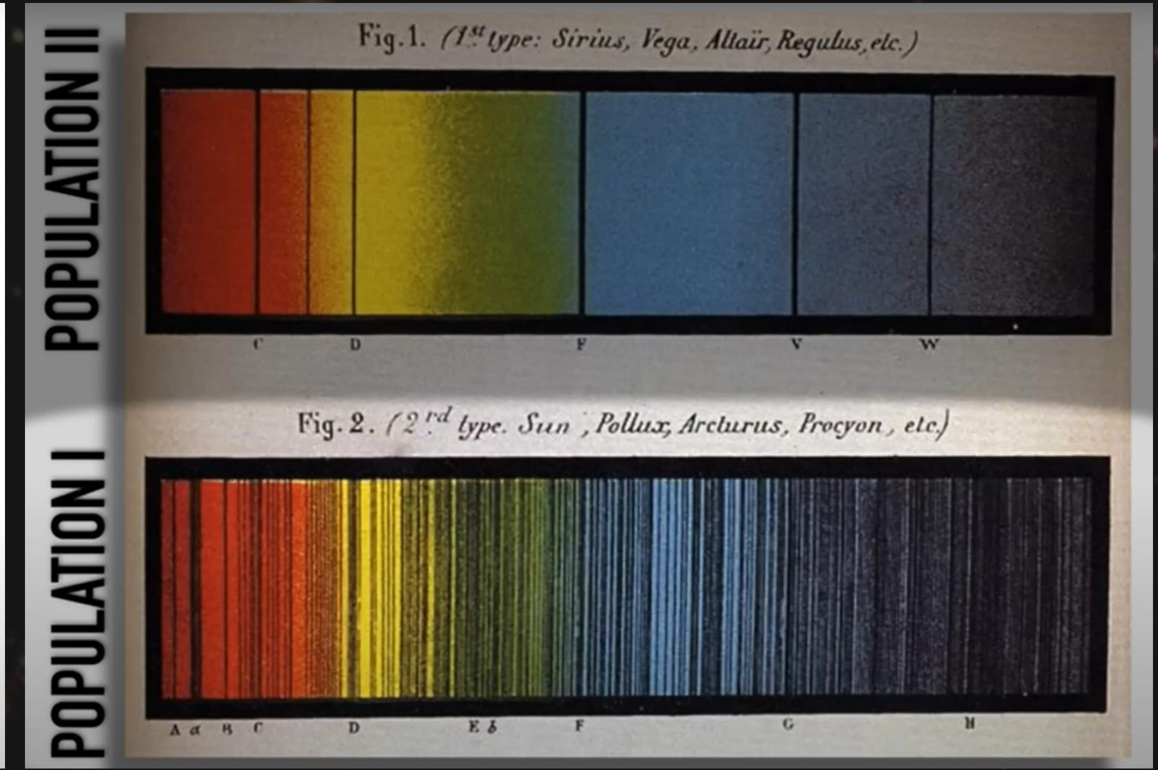
W. Baade
Mount Wilson Observatory
Received April 27, 1944

ABSTRACT

Recent photographs on red-sensitive plates, taken with the 100-inch telescope, have for the first time resolved into stars the two companions of the Andromeda nebula—Messier 32 and NGC 205—and the central region of the Andromeda nebula itself. The brightest stars in all three systems have the photographic magnitude 21.3 and the mean color index +1.3 mag. Since the revised distance-modulus of the group is $m - M = 22.4$, the absolute photographic magnitude of the brightest stars in these systems is $M_{pg} = -1.1$.

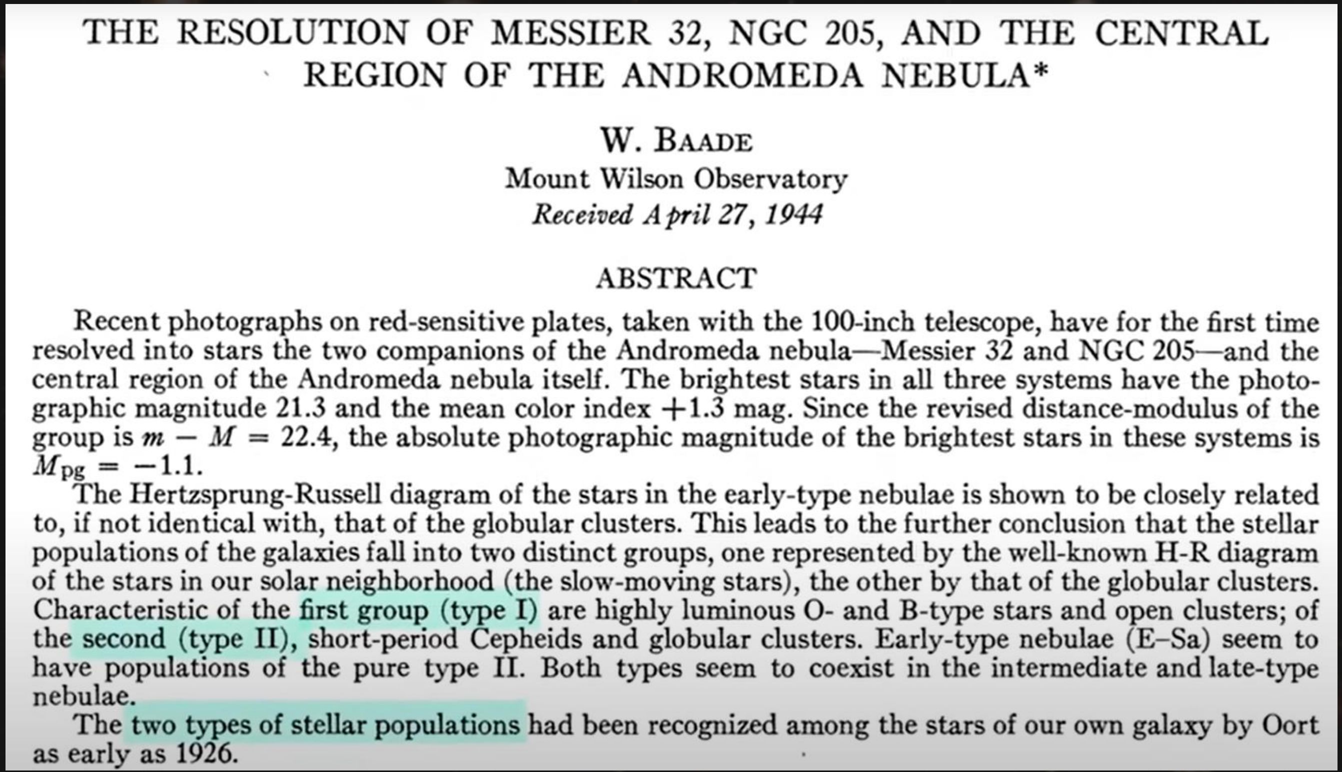
The Hertzsprung-Russell diagram of the stars in the early-type nebulae is shown to be closely related to, if not identical with, that of the globular clusters. This leads to the further conclusion that the stellar populations of the galaxies fall into two distinct groups, one represented by the well-known H-R diagram of the stars in our solar neighborhood (the slow-moving stars), the other by that of the globular clusters. Characteristic of the first group (type I) are highly luminous O- and B-type stars and open clusters; of the second (type II), short-period Cepheids and globular clusters. Early-type nebulae (E–Sa) seem to have populations of the pure type II. Both types seem to coexist in the intermediate and late-type nebulae.

The two types of stellar populations had been recognized among the stars of our own galaxy by Oort as early as 1926.



Credit: Angelo Secchi, 1870

Naming Stellar Populations



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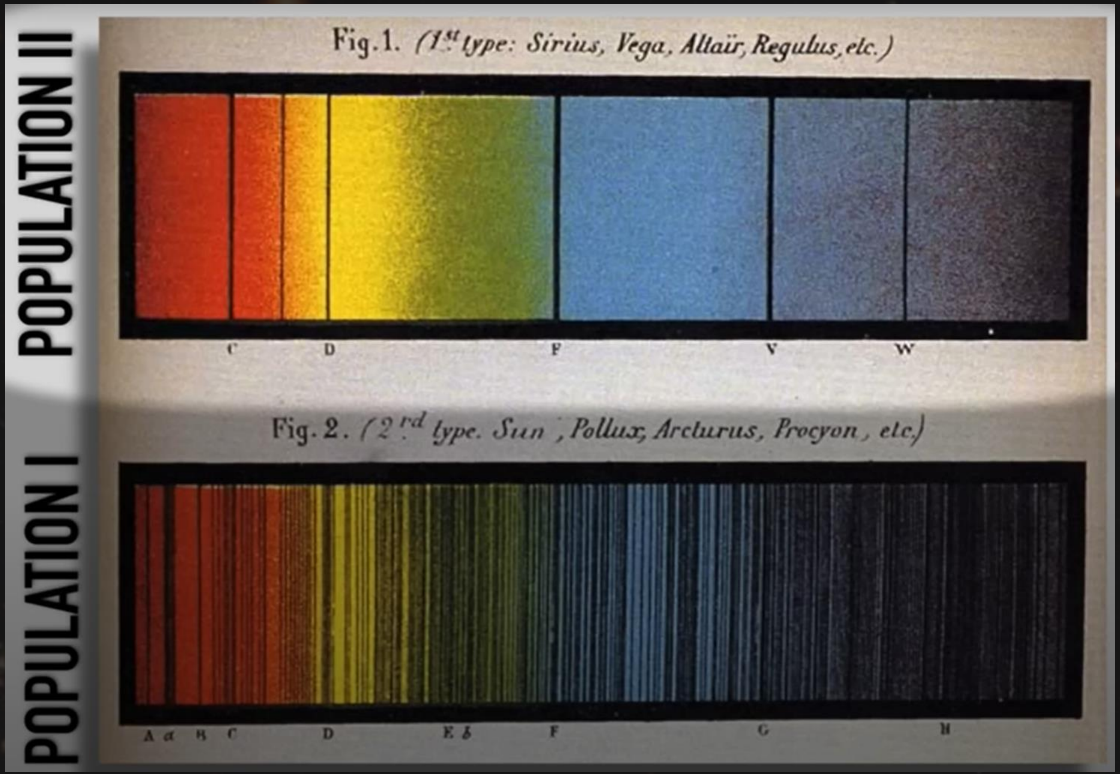
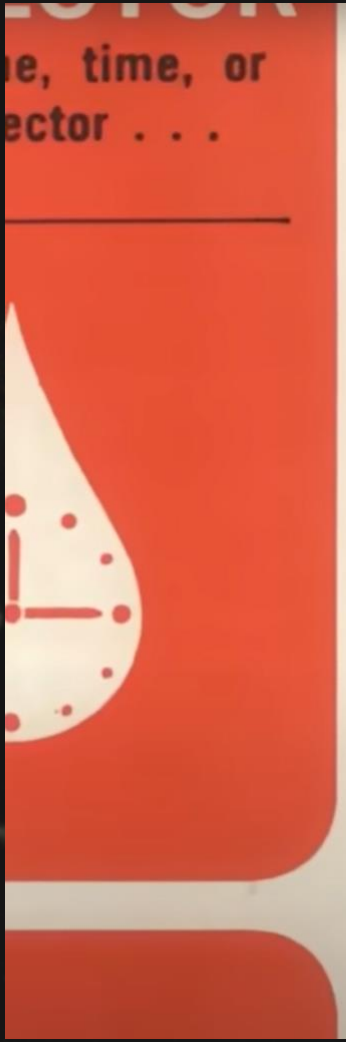


Credit: Angelo Secchi, 1870

FIRST MENTION: POPULATION III STARS



quanta, by ionized hydrogen, due to free-free transitions (changes of an electron's energy near a proton), which absorption and emission occurred mainly during the early, high-temperature stage of evolutionary cosmology. Assuming that the free electrons were then at a temperature of 10^6, he and R. H. Dicke (Princeton) showed that background-radiation quanta detected today were emitted when the density of the universe was about 10^{-15} g/cm³, about 1000 years after the "big bang," and that T_r should be proportional to $\lambda^{\frac{4}{3}}$. That is, 7-cm quanta observed today were 1400-Å quanta emitted about 10^{10} years ago in larger numbers than 500-Å quanta now detectable as 0.25-cm background radiation. If $T_r = 3$°K at $\lambda = 7$ cm, Dicke and Peebles predict $T_r = 0.2$°K at $\lambda = 0.25$ cm, instead of the 3°K observed.

Although the calculations of early

measured directly only in the atmo-
spheres of hot, young, Population-
stars where the abundance Y is abou
40 percent. One hot, B2, Population-I
star in the globular cluster M13 ha
$Y = 20$ percent, and the plot of tem
perature versus luminosity for old Popu
lation-II stars in another globular clus
ter, M3, is consistent with $Y = 13$ per
cent. Since helium is found in stella
interiors and is returned to the inter
stellar medium by supernova explosions
it is generally concluded that the pri
mordial gas clouds, from which the firs
stars were formed, were pure hydro
gen ($Y = 0$). Woolf noted that thes
first-generation "Population-III" star
in our galaxy were probably large (1
solar masses) and short-lived (abou
10^7 yr). They returned material to th
interstellar medium with variou
amounts of helium added, and thus ob
scure the original helium abundance

Credit: Thornton Page, 1966

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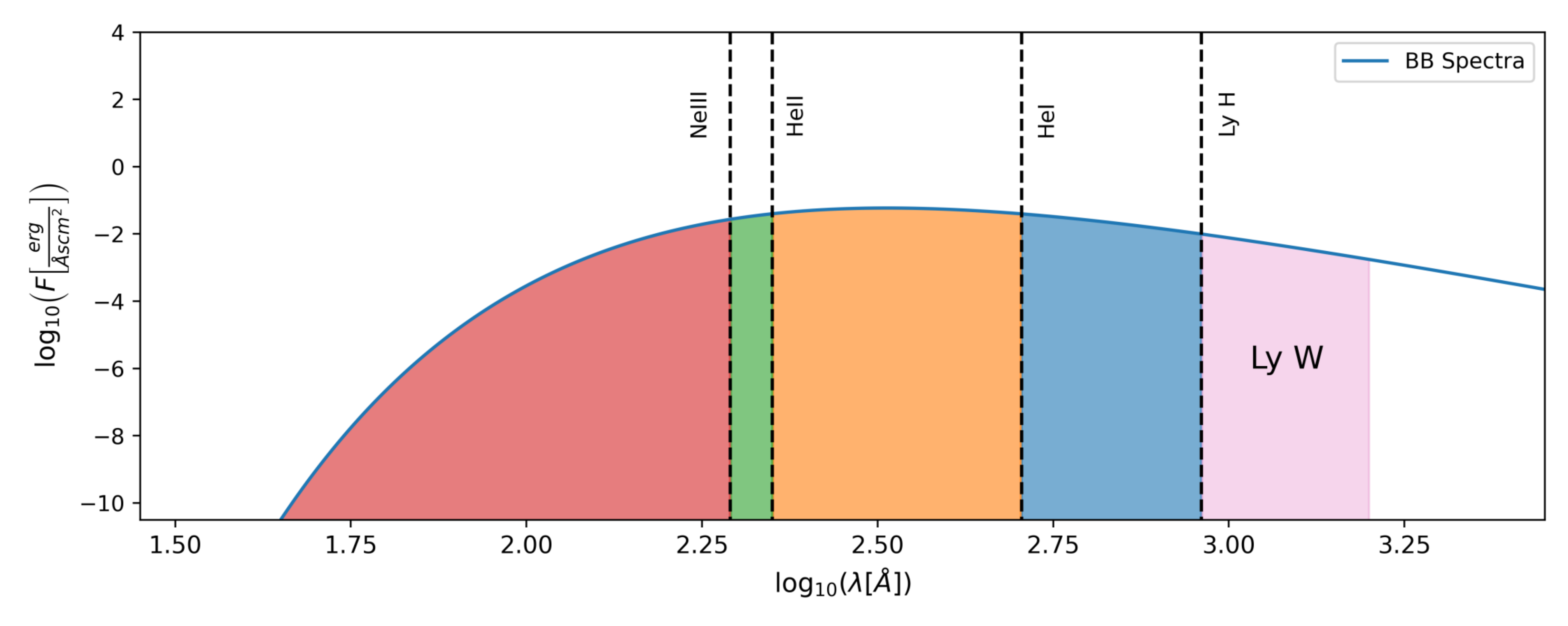
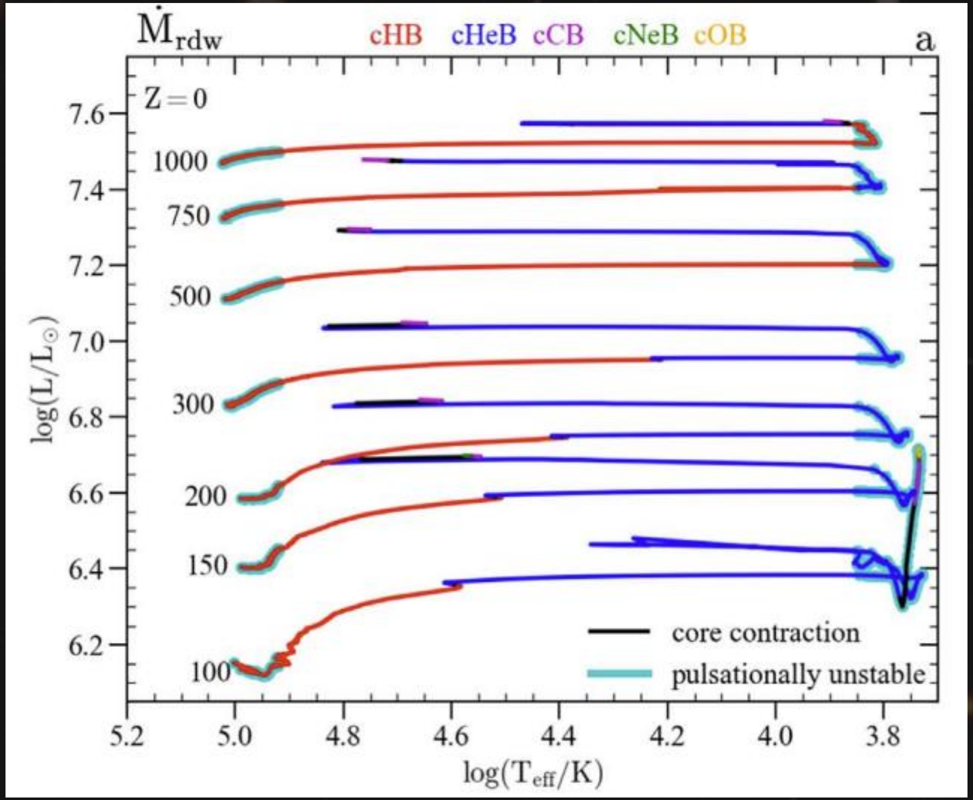
BLACK BODY AS POP III?

750Mo

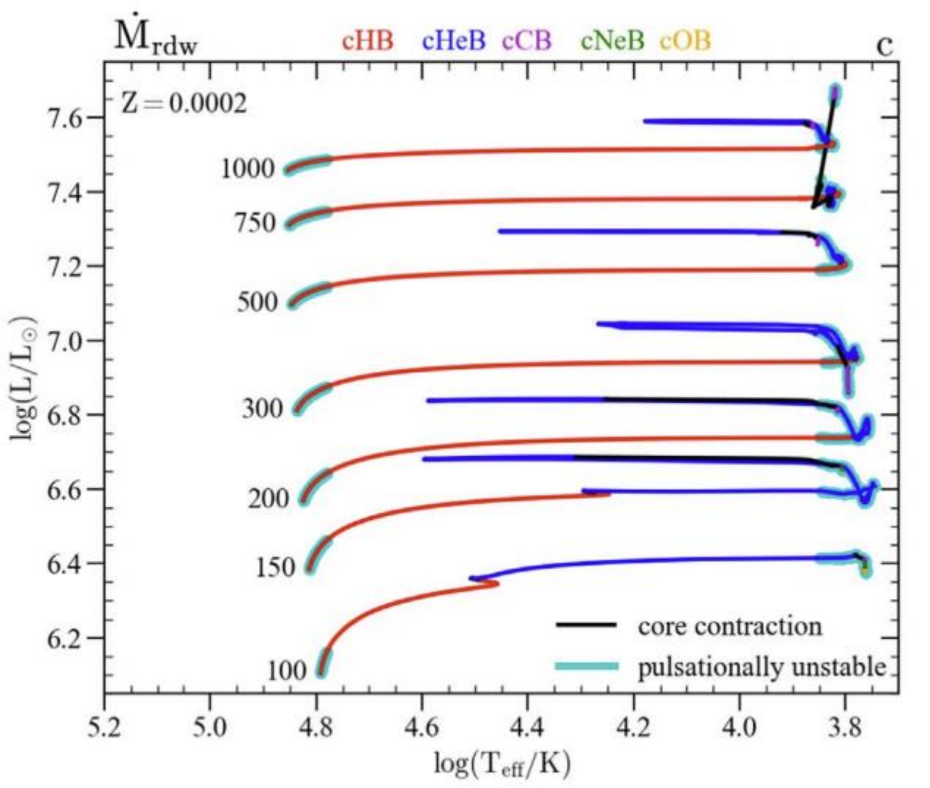


EVOLUTIONARY TRACKS OF POP III STARS

HRD Tracks for Z=0

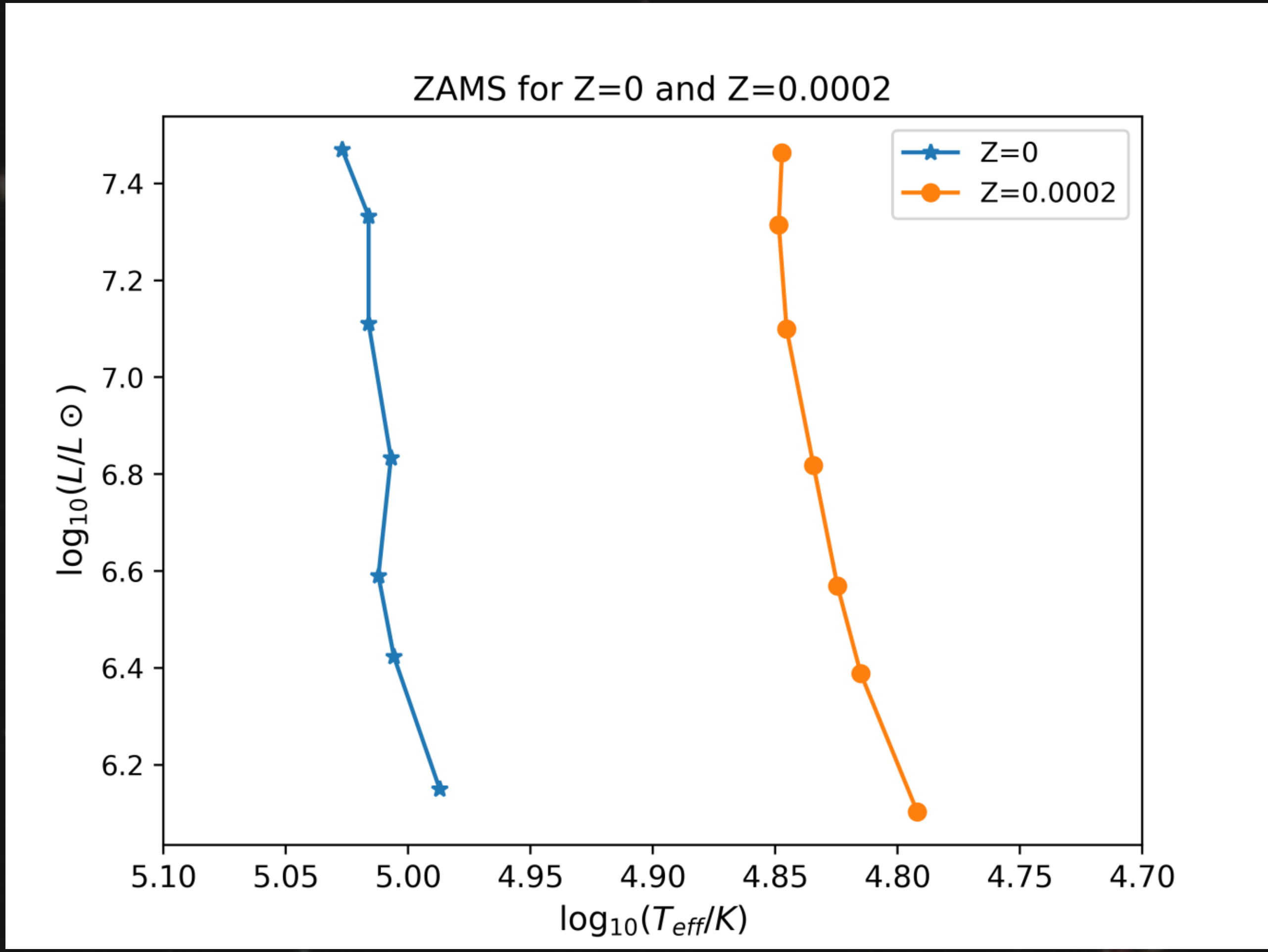


HRD Tracks for Z=0.0002



Credit: Guglielmo Volpato et al 2023

ZAMS for Z=0 and Z=0.0002




```
HEADLINE: 61929.8 100 Solar Mass Attempt  Pop III - Volpato Tracks_LowZ
=============================================================================
TEFF= 61929.8
-RTRANS = 0.60DEX
MDOT = -7.26628
MSTAR = 100.
--------------------  oldstart options  --------------------------------

-OLDSTART
LTESTART


--------------------  abundances  --------------------------------------
xxxxxxxxxx----------xxxxxxxxxx
HYDROGEN:  0.7514    (mass fraction)
CARBON:    3.639E-05 (mass fraction)
NITROGEN:  9.725E-06 (mass fraction)
OXYGEN:    8.8232E-05 (mass fraction)
NEON:      2.0238E-05 (mass fraction)
MAGNESIUM: 8.8583E-06 (mass fraction)
SODIUM:    4.7101E-07 (mass fraction)
ALUMINIUM: 7.632E-07 (mass fraction)
SILICON:   9.549E-06 (mass fraction)
SULFUR:    4.443E-06 (mass fraction)
ARGON:     9.616E-07 (mass fraction)
CALCIUM:   8.8002E-07 (mass fraction)
GENERIC:   1.9027E-05 (mass fraction)

--------------------  stellar parameters  ------------------------------
DENSCON = 1.
LOG L = 6.103
VELPAR: VFINAL (KM/S)= 4533.92 VMIN= 12.  BETA=2.0 RMAX=1000. XXXXXXX
XXXXXXXXXXXXXXXXXXXXXX.......XXXXX.....XXXXX....XXXXX.....XXXXXXX
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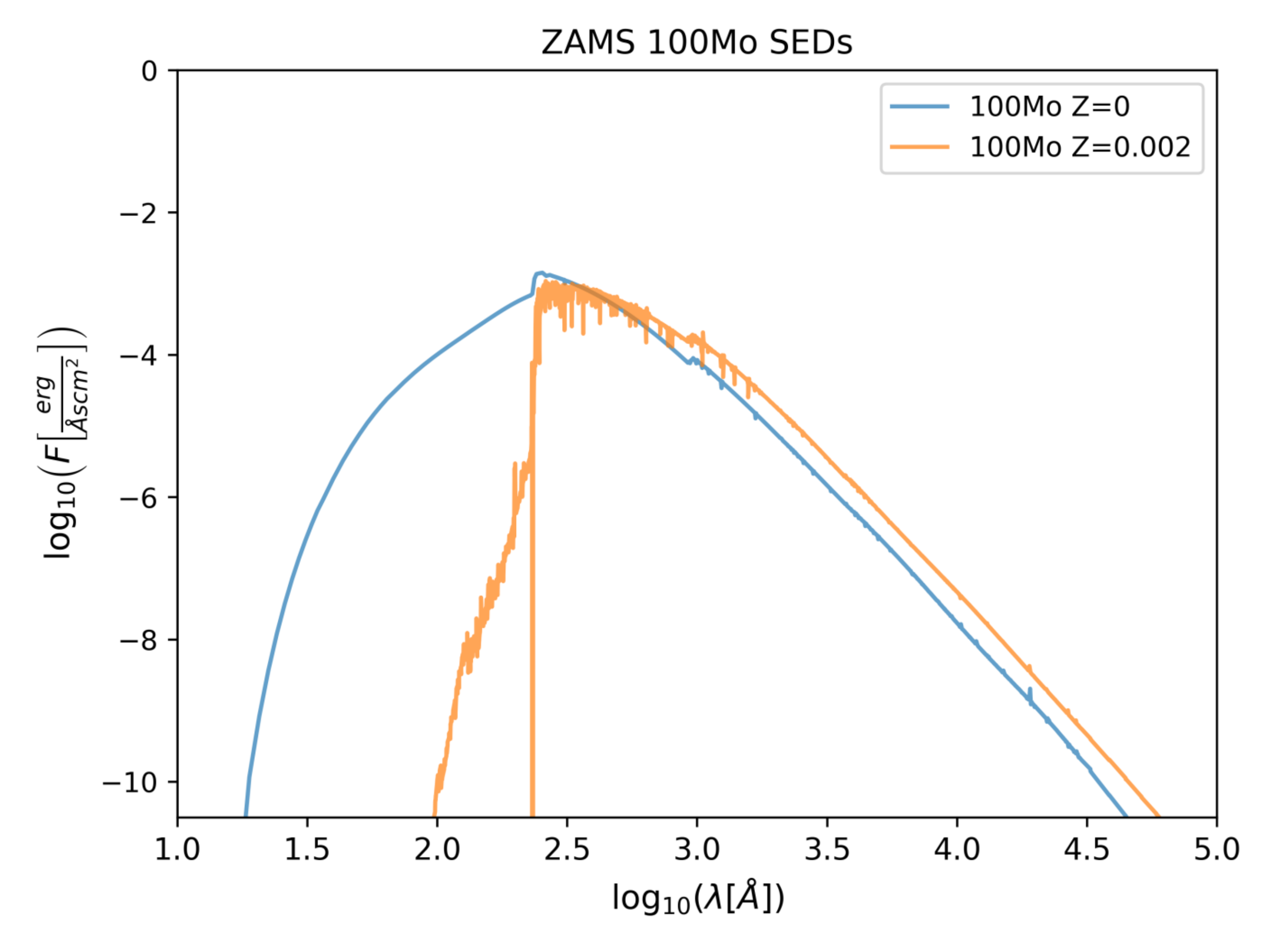
PoWR

- 1-D
- Radiative Transfer
- Comoving Frame
- Spherical Expansion
- Non-LTE

Results

Combined SED: Z=0 and Z=0.0002



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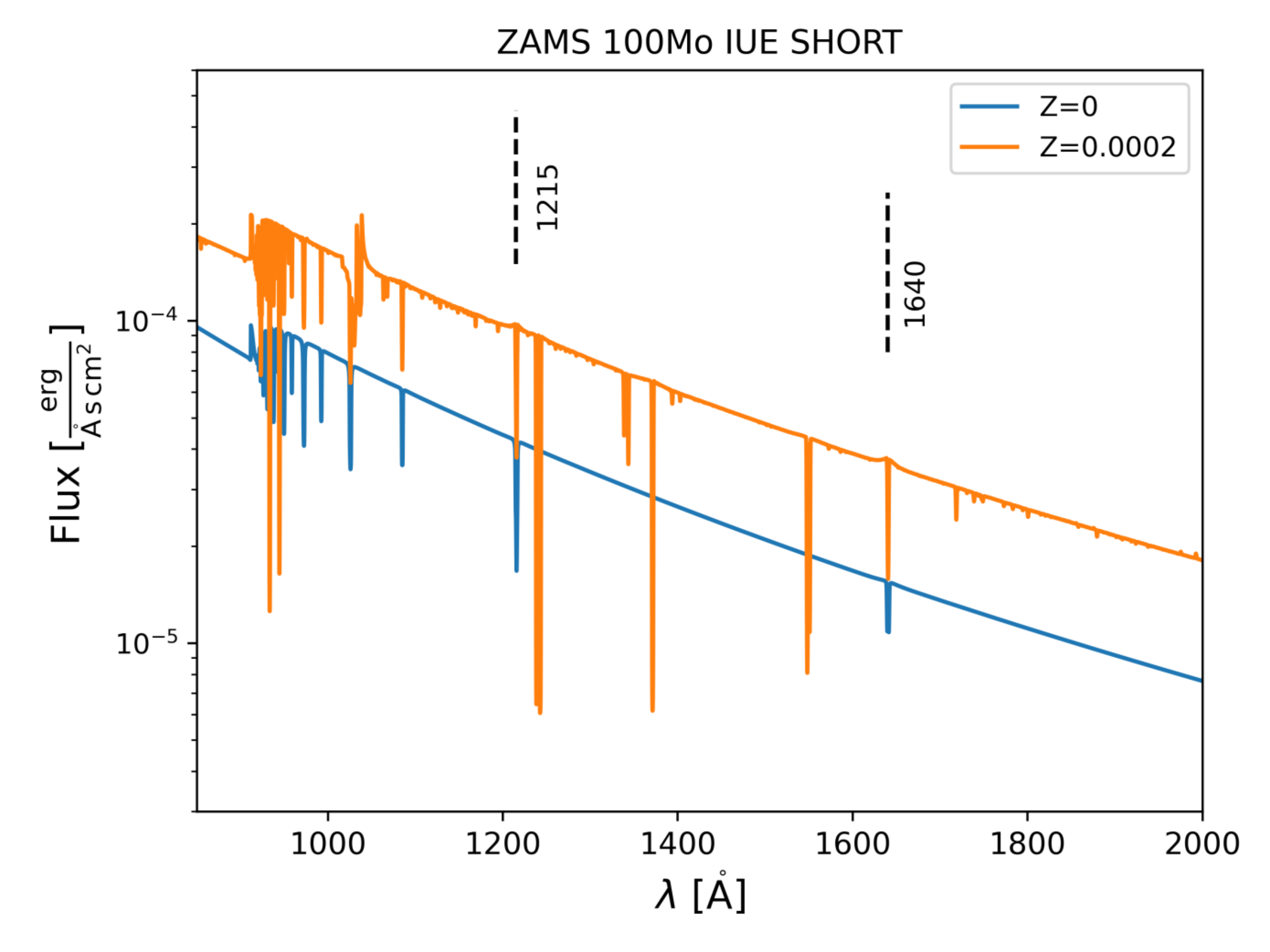
UV spectra: Z=0 and Z=0.0002



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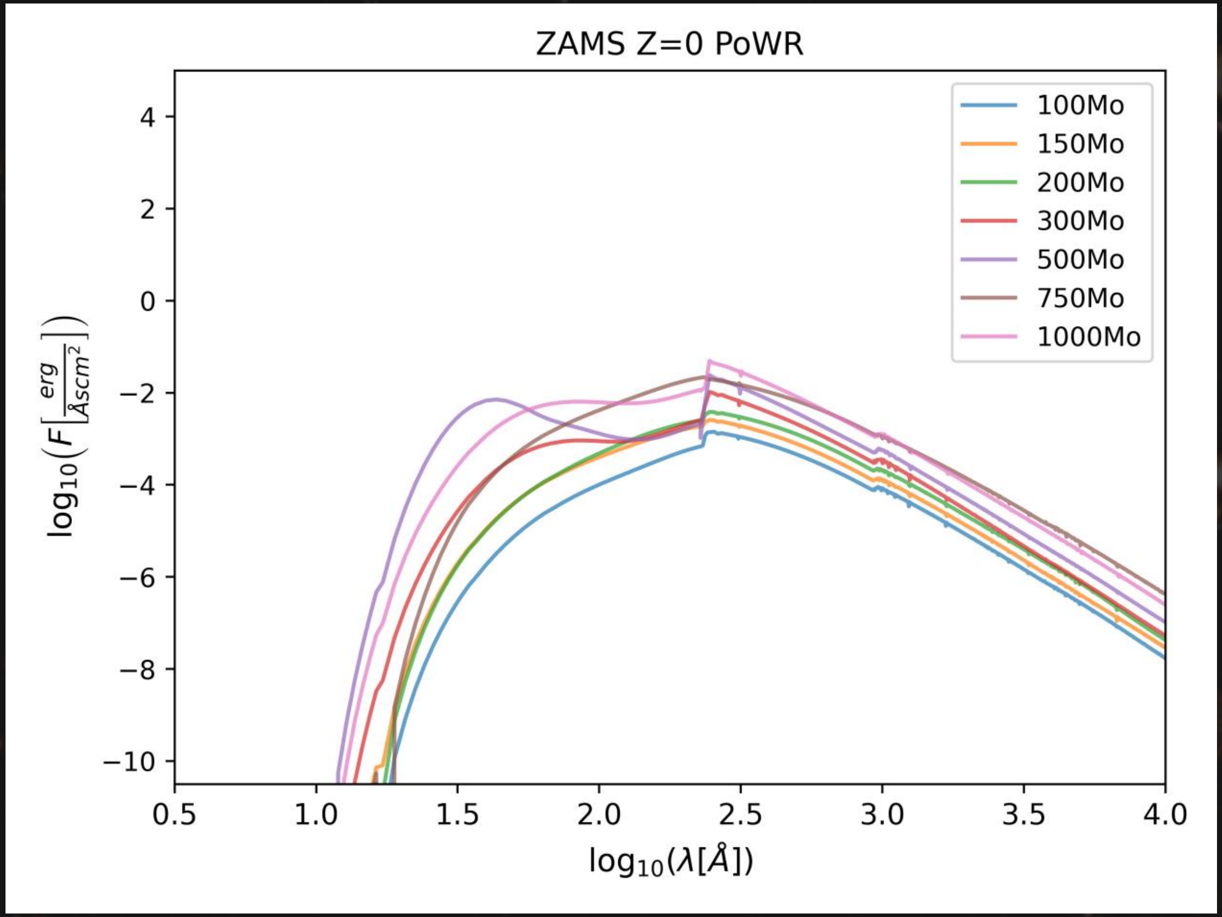
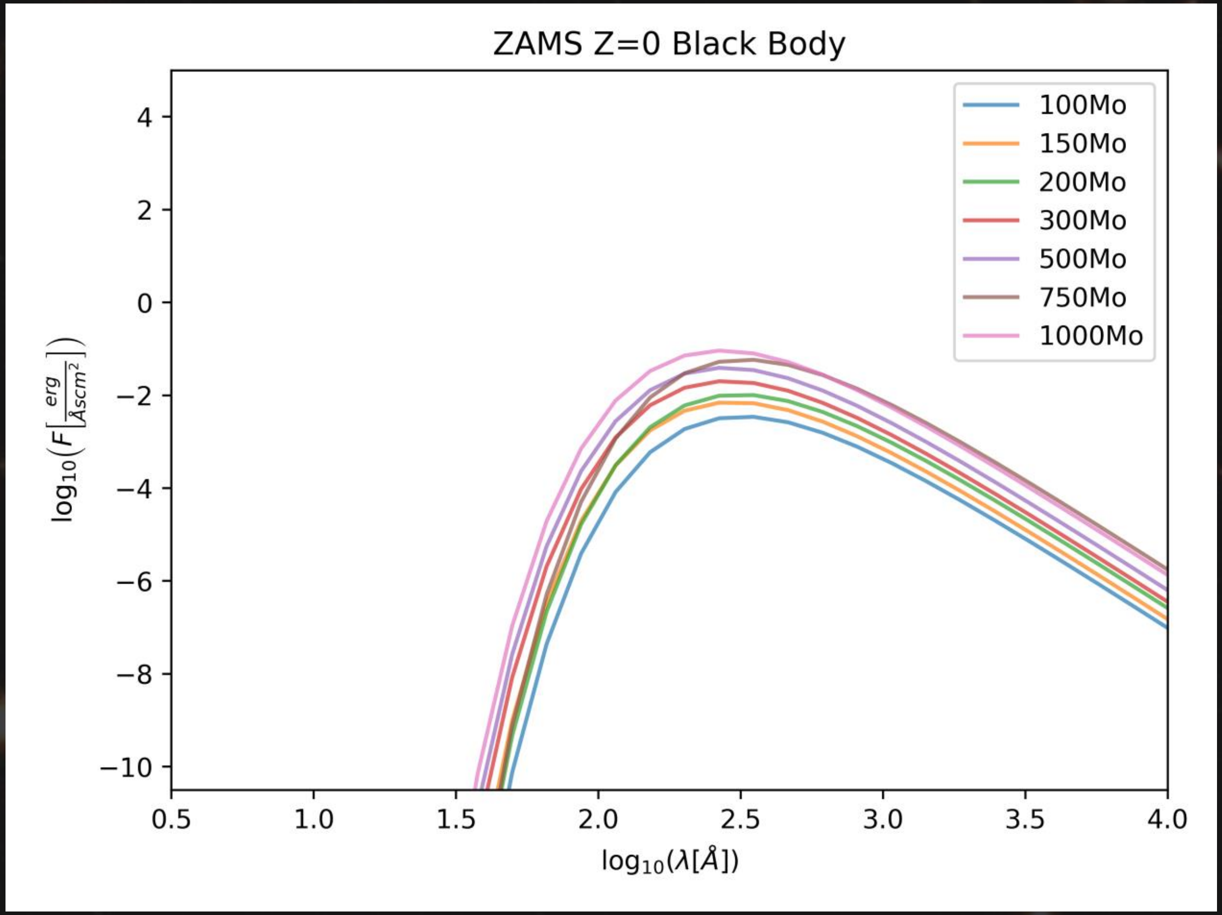
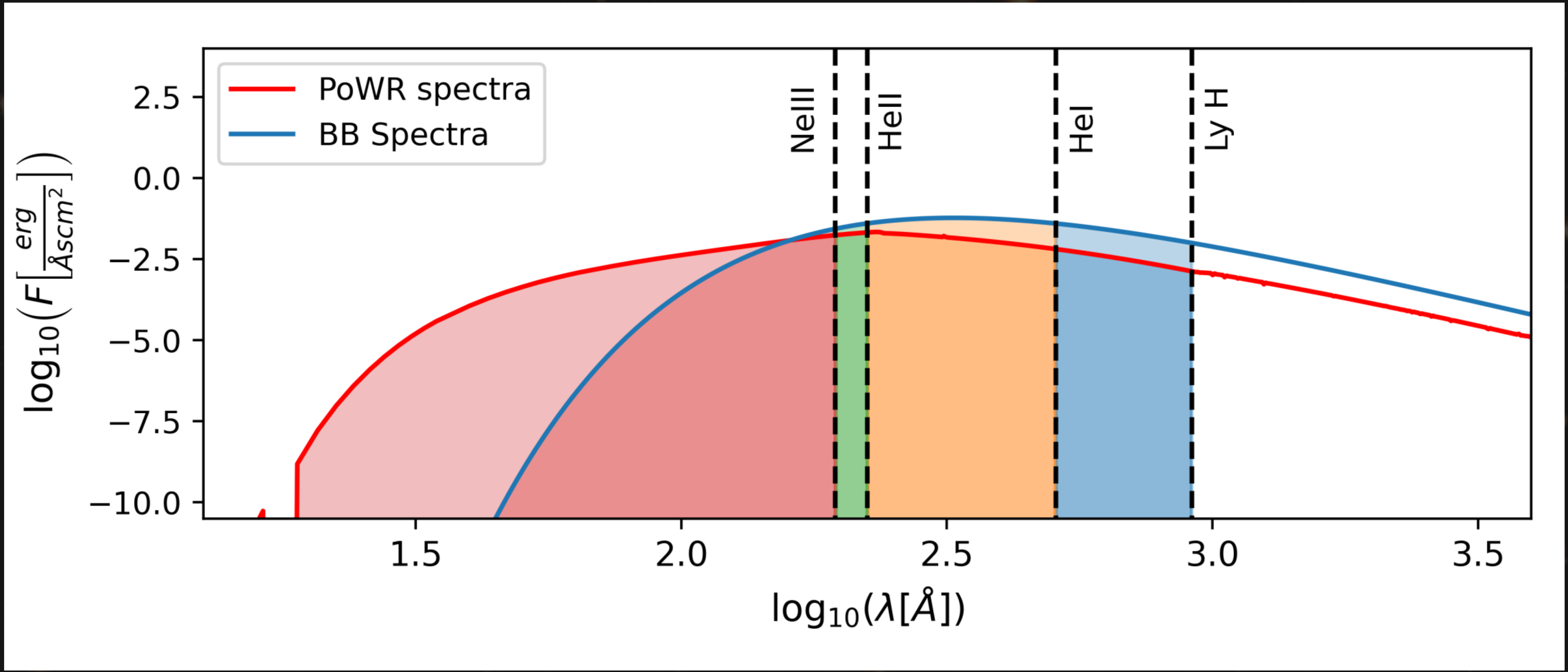
Visual SED Comparison





IONIZING FLUXES

750 Mo



$\log_{10} Q(H)$ for PoWR Model: 51.14

$\log_{10} Q(H)$ for Black Body: 50.73

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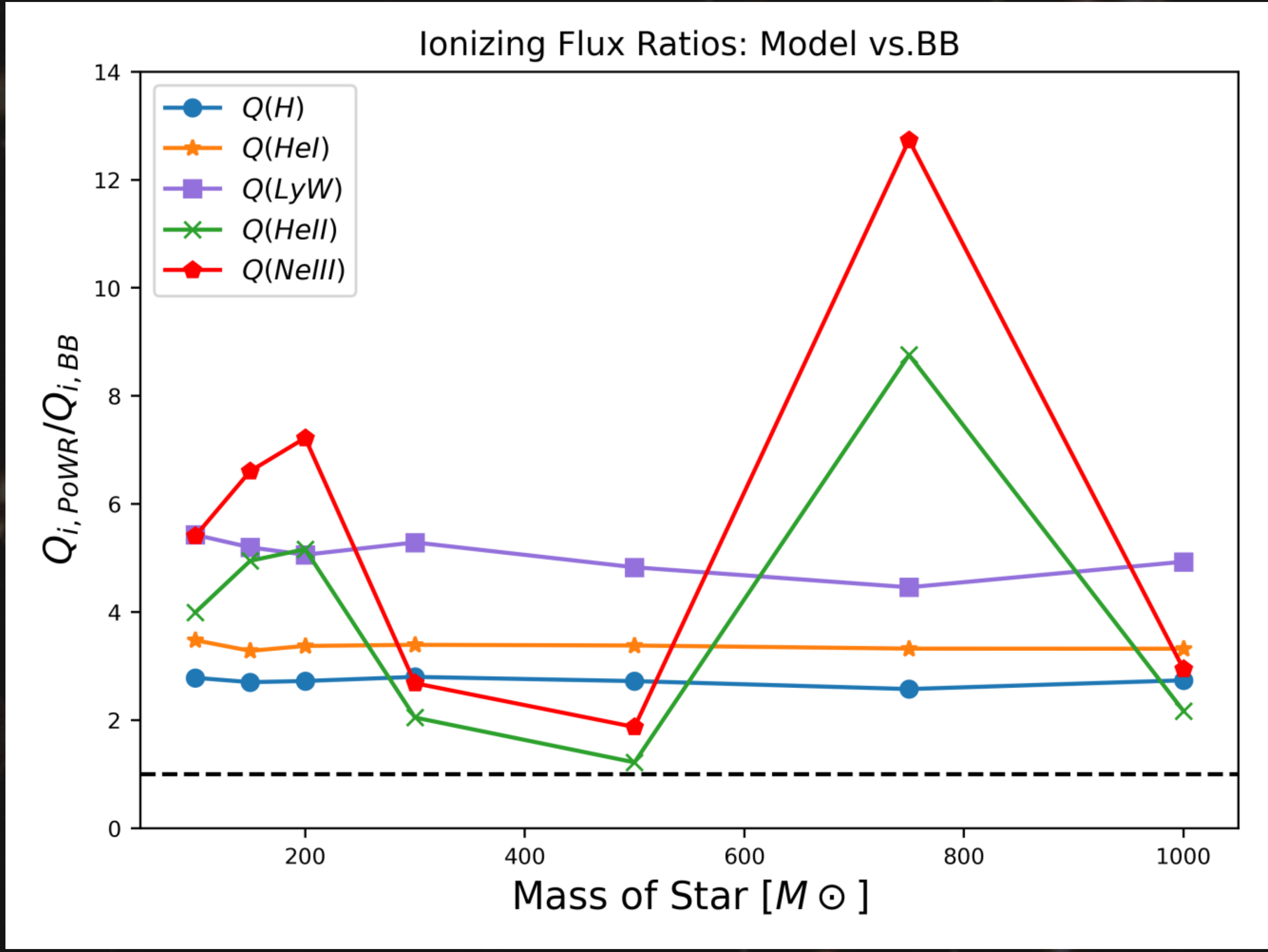
IONIZING FLUX RATIOS

A comparison of Ionizing Fluxes for Pop III model by PoWR and a Black Body

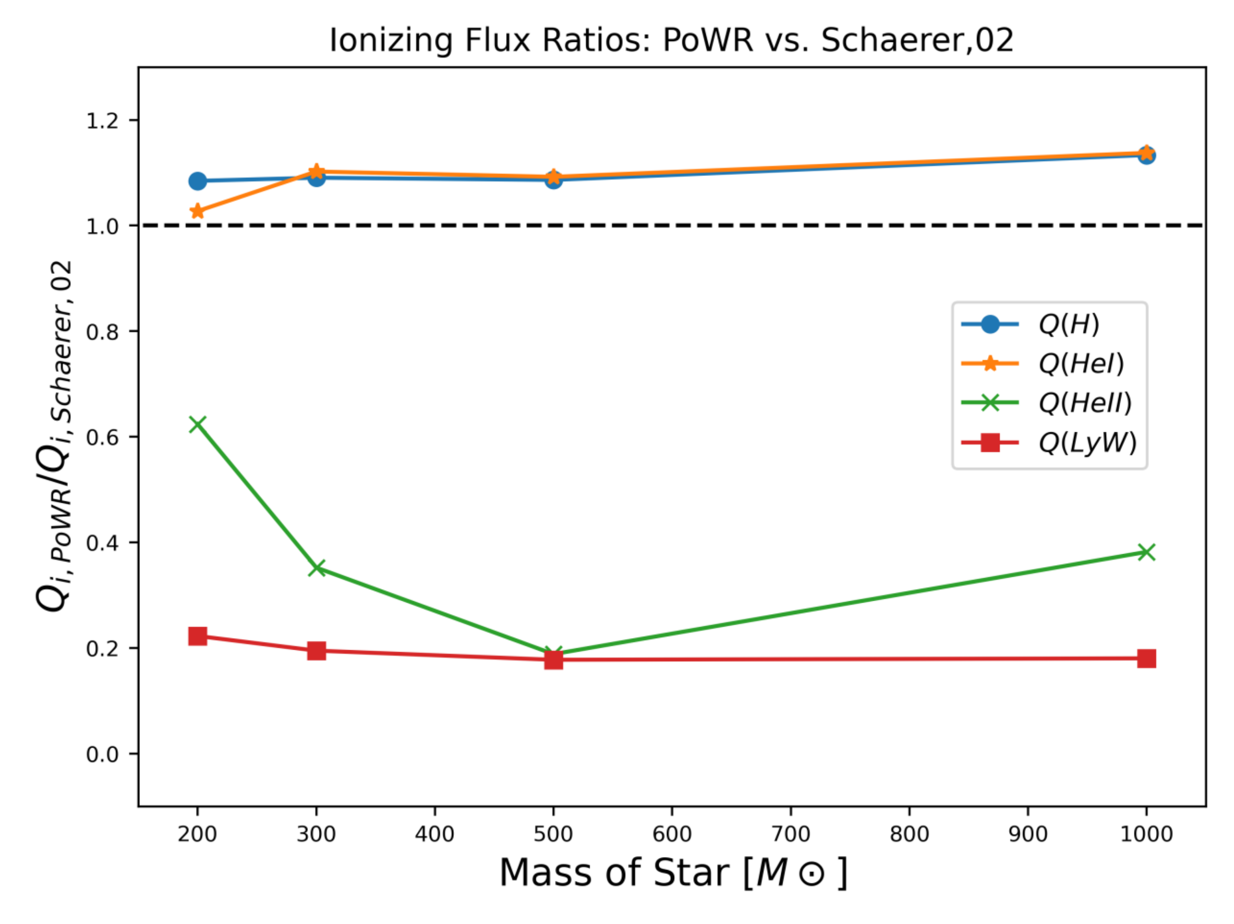
Work	Stellar Mass$[M_\odot]$	$Q(H)$	$Q(HeI)$	$Q(HeII)$	$Q(NeIII)$
Pop III	$100M_o$	49.94	49.74	48.68	48.43
Black Body		49.50	49.20	48.08	47.69
Pop III	$150M_o$	50.20	50.01	49.18	48.95
Black Body		49.77	49.50	48.48	48.13
Pop III	$200M_o$	50.39	50.20	49.30	49.08
Black Body		49.96	49.67	48.59	48.22
Pop III	$300M_o$	50.64	50.47	49.30	49.09
Black Body		50.19	49.94	48.99	48.66



IONIZING FLUX RATIOS

A comparison of Ionizing Fluxes for Pop III model by PoWR and D. Schaerer (2002)

Work	Stellar Mass[$M_\odot$]	$Q(H)$	$Q(HeI)$	$Q(HeII)$	$Q(LW)$
D.Schaerer (2002)	$1000M_o$	51.20	51.05	50.45	51.23
PoWR		49.94	49.74	48.68	50.49
D.Schaerer (2002)	$500M_o$	50.86	50.71	50.11	50.89
PoWR		50.90	50.75	49.38	50.14
D.Schaerer (2002)	$300M_o$	50.60	50.43	49.75	50.64
PoWR		50.64	50.47	49.30	49.93
D.Schaerer (2002)	$200M_o$	50.36	50.18	49.51	50.39
PoWR		50.39	50.20	49.30	49.74



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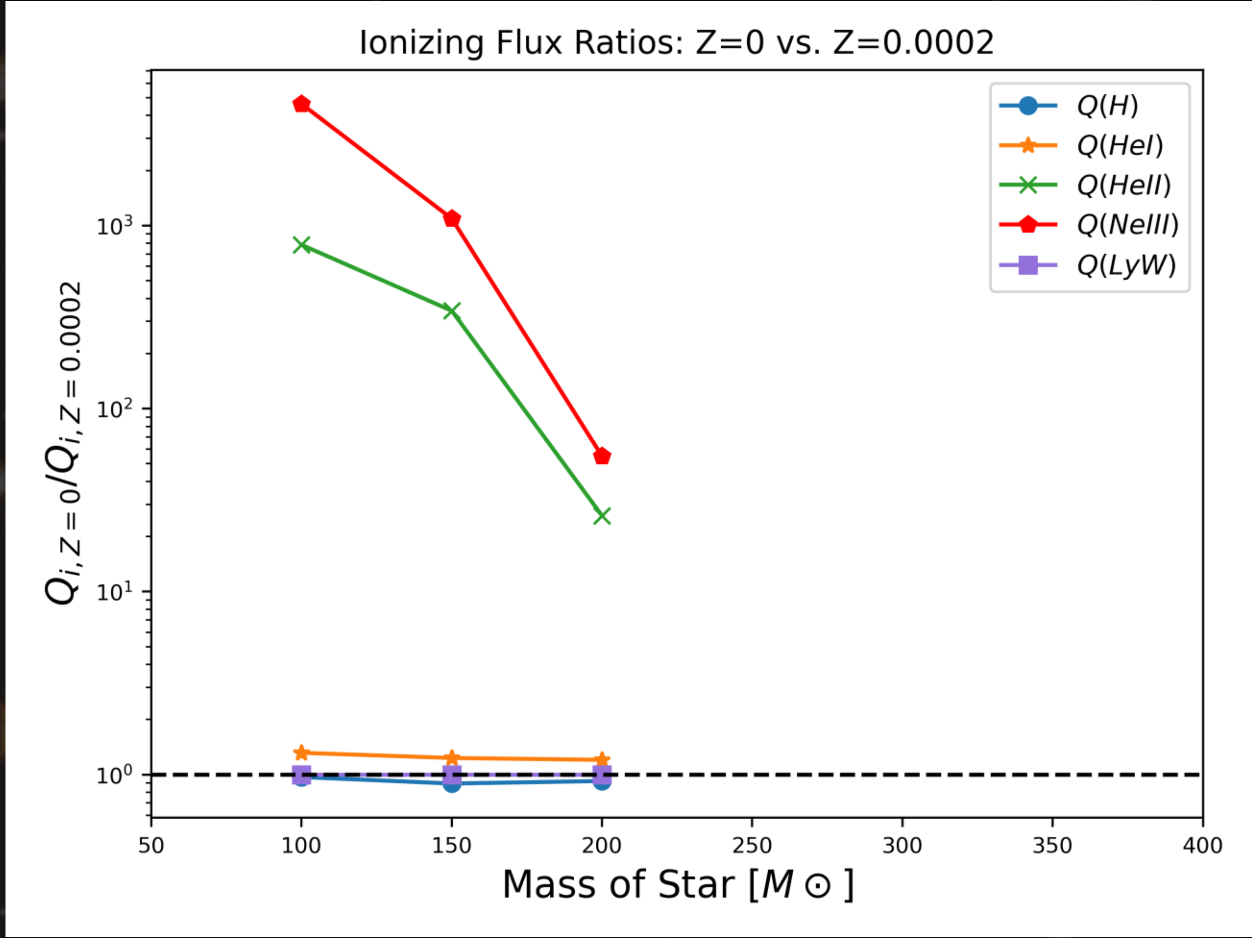
IONIZING FLUX RATIOS

A comparison of Ionizing Fluxes for Pop III model: Z=0 vs Z=0.0002

Metallicity	Stellar Mass[$M_\odot$]	$Q(H)$	$Q(HeI)$	$Q(HeII)$	$Q(NeIII)$	$Q(LW)$
Z=0	$100M_o$	49.94	49.74	48.68	48.43	49.33
Z=0.0002		49.95	49.62	45.79	44.76	49.33
Z=0	$150M_o$	50.20	50.01	49.18	48.95	49.53
Z=0.0002		50.25	49.92	46.64	45.91	49.53
Z=0	$200M_o$	50.39	50.20	49.30	49.08	49.74
Z=0.0002		50.43	50.11	47.89	47.34	49.74



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CONCLUSIONS

- Black bodies underestimate the ionizing fluxes of Population III stars.

- Low metallicity models considerably differ in the ionizing fluxes as compared to zero metallicity models.

- Low metallicity models show additional features in the Spectra that might not actually be observed for Population III stars.