MCMD w2 – Stellar population with clusters

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1 First exercise

We are provided as series of power law probability distributions of the stellar masses m in a cluster. Using Monte Carlo importance sampling with the function $g(m) = m^{-2.2}$ we construct a random number generator for the masses according to the specified distribution.

A star will explode as a supernova if its mass is above 8 sun masses. We wish determine the probability for a cluster to contain at least one supernova explosion according to the size of the cluster. We generate 10000 different clusters for each size and sample the statistics. For the cluster sizes $N_* = 100$, 300 and 1000 the probabilities are 0.30, 0.67 and 0.98 respectively.

The probabilities for clusters in the range 50 to 5000 stars are provided in Fig 1.

I a cluster of 5000 stars we sample the number of supernova exploding stars and find a mean and median of 18 stars, the lower quartile is 15 and the upper quartile is 21 stars.

We are told our sun is believed to have formed in cluster with containing material from a star with mass above 25 solar masses. Sampling the presence of stars with masses above 25 solar masses from clusters of different sizes, again with 10000 iterations for each size, we find that the probability of having at least a single star above that threshold is above 0.1 for $N_* \geq 212$, above 0.25 for clusters with $N_* \geq 568$ and above 0.5 for clusters with $N_* \geq 1390$. Without further knowledge of the probability distribution of different cluster sizes the naïve analysis above yields the expectation that the cluster which hosted the sun probably contained 1390 or more stars.

2 Follow up

We now consider clusters each with a million different stars, and generate 10000 different iterations of this cluster size. These are time evolved over 15 Gyr in steps of 1 Gyr.

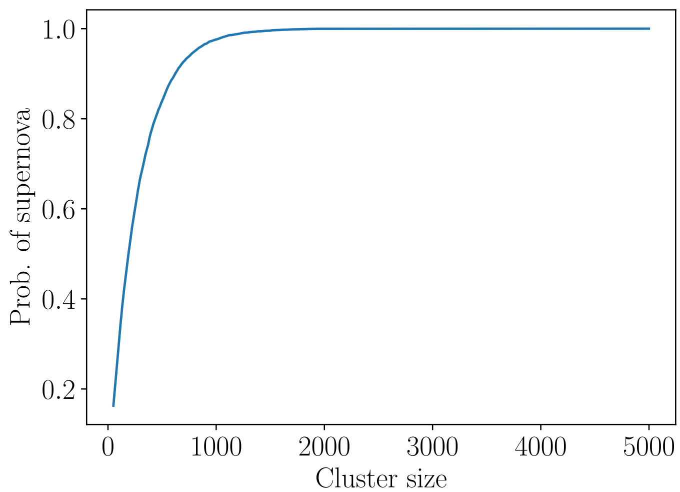

Figure 1: Probability for the cluster to contain a supernova. Estimated from 10000 different clusters per size.

The mean, upper and lower quantile for the populations of main sequence stars, black holes, neutron stars and white dwarfs are provided in Fig 2-5 respectively. Note that due to the large cluster size, the prob. distribution is sharply peaked, as evidenced by the narrow quartile ranges. Only the distribution of black holes has a noticeable interquartile range which makes sense given that black hole masses are furthest away in the tail of the distribution.

After 12 Gyr the mean number of objects are 857964 main sequence stars, 350 black holes, 3280 neutron stars and 138405 white dwarfs.

We also find the total mass and luminosity ratio for the cluster as a function of time, see Fig. 6-7.

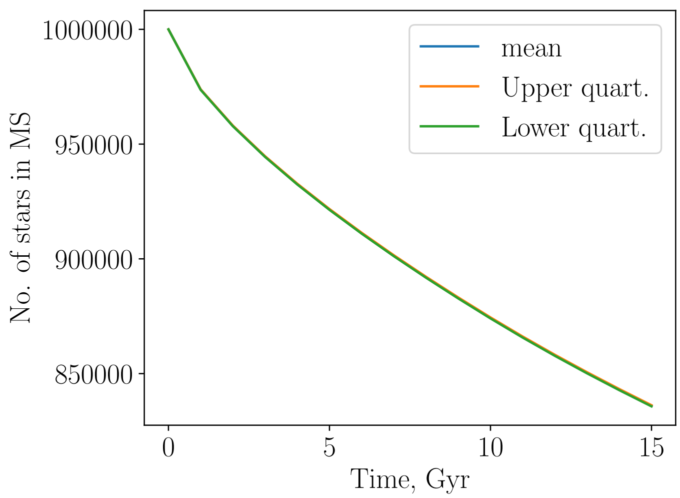

Figure 2: Population of main sequence stars.

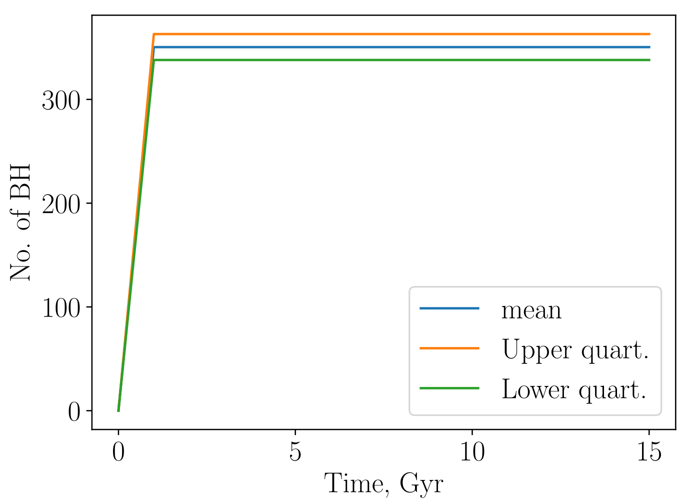

Figure 3: Population of black holes.

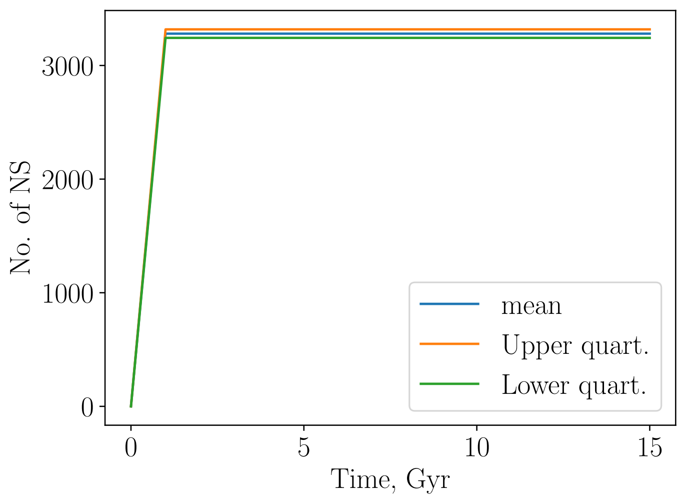

Figure 4: Population of neutron stars.

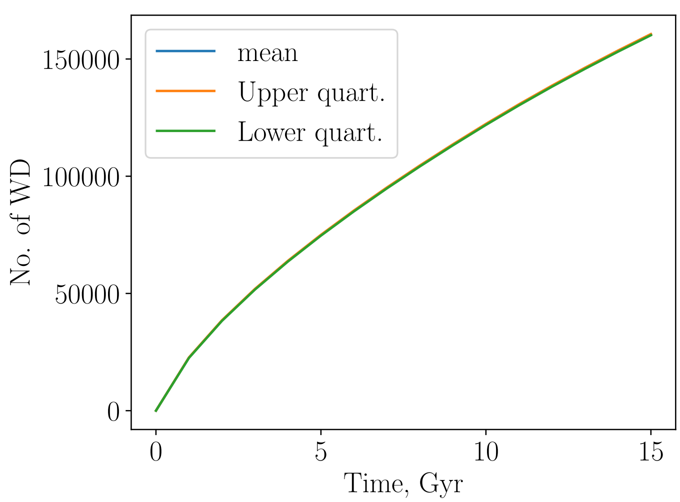

Figure 5: Population of white dwarfs.

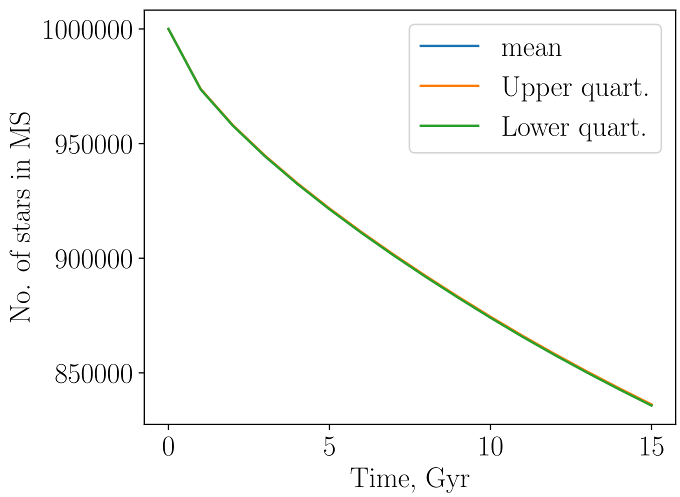

Figure 6: Cluster mass.

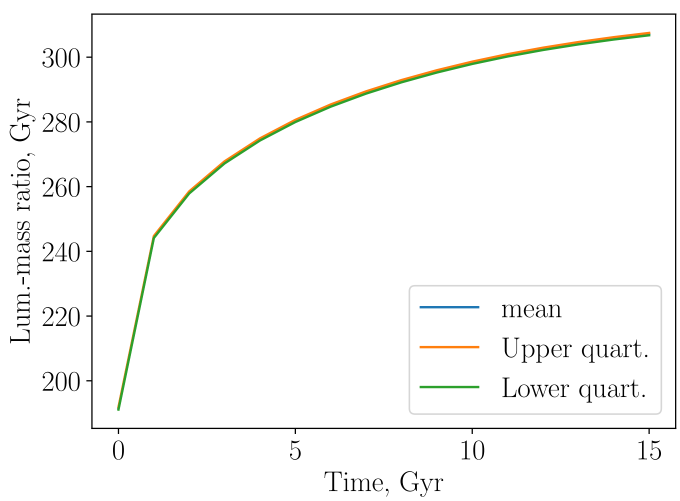

Figure 7: Luminosity/mass ratio.