Sec. 4 Results

Question. Is the star formation model implemented for the Auriga simulations capable of producing a population of star particles that is consistent with the observed properties of the Milky Way (MW) globular cluster system (GCS)?

- What data do we have available for MW and M31?
  → Sec. 4.0 on p. 2

- Does Auriga's star formation model produce sufficient star particles with the right age and metallicity ([Fe/H]) to be consistent with the MW GCS?
  → Sec. 4.1 on p. 4

- Does Auriga's star formation model produce sufficient star particles with the right age and radial distribution to be consistent with the MW GCS?
  → Sec. 4.2 on p. 4

- Does Auriga's star formation model produce sufficient star particles with the right age, metallicity ([Fe/H]) and radial distribution to be consistent with the MW GCS?
  → Sec. 4.3 on p. 4

Question. What does the picture look like when broaden the scope to consider spirals in the Local Group (i.e. including Andromeda/M31)?

Assumption I. All star particles in the Auriga simulations with age $>$ 10 Gyr are globular cluster candidates.

Justification

i) VandenBerg et al. (2013) measured [Fe/H] of 55 globular clusters in the MW and obtained age-estimates. The mean age of the MW GCS is 11.9 Gyr with a dispersion of 0.9 Gyr. Furthermore, only one of the 55 GC age-estimates is below 10 Gyr.

ii) Renaud et al. (2017) performed one simulation of a MW-like galaxy (down to z=0.5, $T_{\mathrm{lookback}} \approx 5$ Gyr) and performs the entire analysis using a subset of star particles with ages $>$ 10 Gyr that is referred to as 'globular cluster candidates'.

Weaknesses

i) Pfeffer et al. (2018) show that star clusters do not simply follow the same distribution as the field stars. In our approach we don't just oversample the 'real' population of globular clusters (by ignoring/excluding dynamical evolution), but the retrieved distributions of old star particles in the simulations may not even faithfully represent the 'true' distribution of globulars.

ii) Caldwell et al. (2011) measured [Fe/H] of 87 globular clusters in M31 and obtained age-estimates. The mean age is 10.8 Gyr with a dispersion of 2.3 Gyr. Furthermore, 27 GCs have age-estimates below 10 Gyr, with a minimum age-estimate of 4.8 Gyr. Perhaps an age cut of 6 Gyr would would be more appropriate for M31, see Fig. **??**.

4.0 Available data for the Milky Way and Andromeda

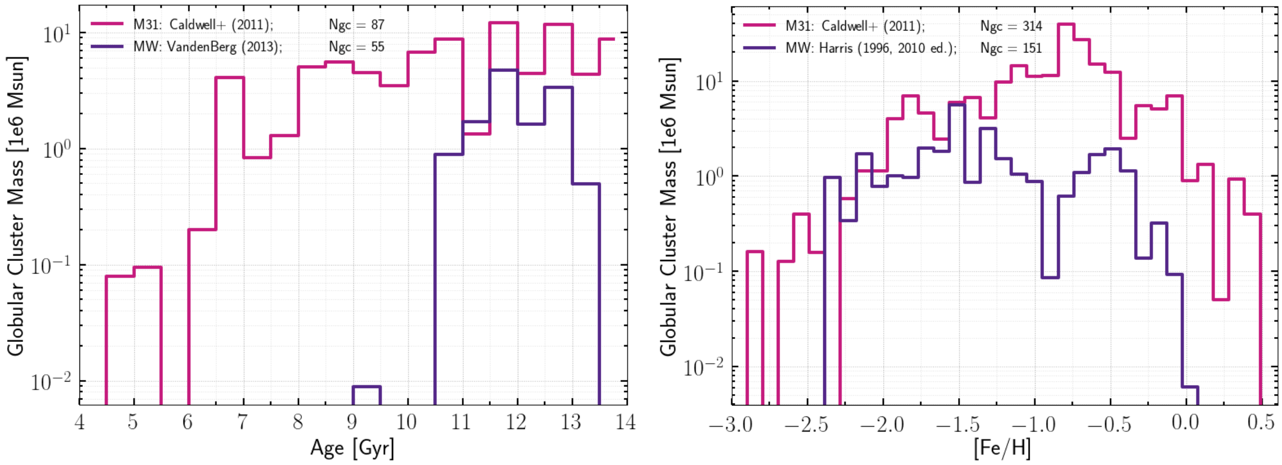

Fig. 1: *Left:* Mass-weighted age distribution of 55 GCs in the MW (data from VandenBerg et al., 2013) and 87 GCs in M31 (data from Caldwell et al., 2011). *Right:* Mass-weighted [Fe/H] distribution of 151 GCs in the MW (data from Harris, 1996, 2010 ed.) and 314 GCs in M31.

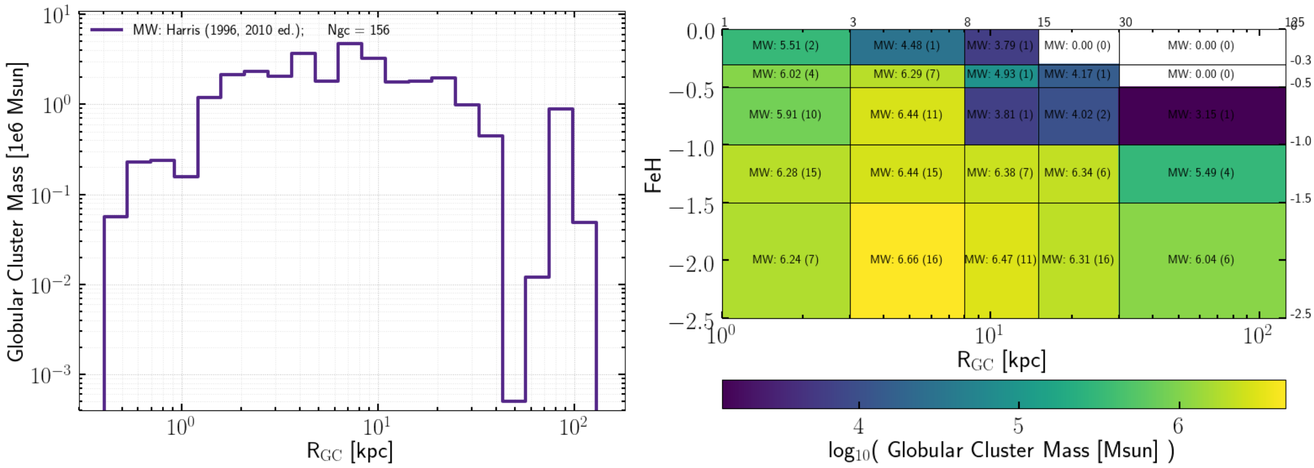

Fig. 2: *Left:* Mass-weighted R_{GC} distribution of 156 GCs in the MW. *Right:* Mass-weighted [Fe/H]-R_{GC} distribution of 151 GCs in the MW (data from Harris, 1996, 2010 ed.), which is 98.19 % of the total MW GCS mass.

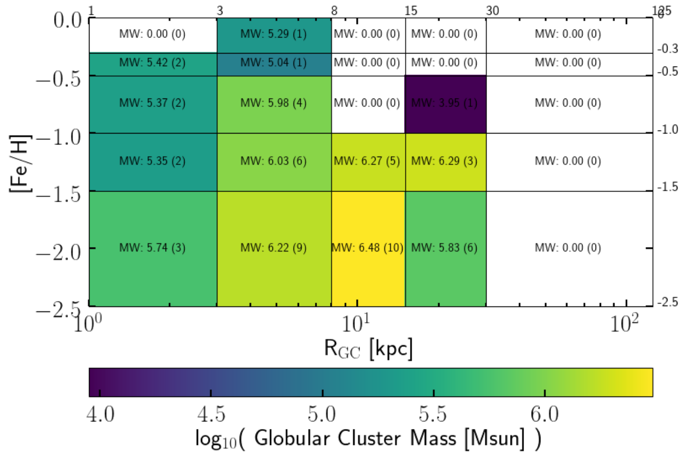

Fig. 3: Mass-weighted [Fe/H]-R_{GC} distribution of 55 GCs in the Milky Way (data from VandenBerg et al., 2013), which is 43.27% of the total MW GCS mass.

Table 1: The [Fe/H]-R_{GC} plot is generated using scipy.stats.binned_statistic_2d. This table shows a manual calculation of Msum and Ngc in each bin for debug purposes, just to check that scipy's built-in method is used correctly. Data from Harris (1996, 2010 ed.).

xmin	xmax	ymin	ymax	Ngc	Msum	$\log_{10}$(Msun)
1	3	-2.5	-1.5	7	1.7e+06	6.24
1	3	-1.5	-1.0	12	1.9e+06	6.27
1	3	-1.0	-0.5	9	7.7e+05	5.89
1	3	-0.5	-0.3	4	1.0e+06	6.02
1	3	-0.3	0	2	3.2e+05	5.51
3	8	-2.5	-1.5	16	4.6e+06	6.66
3	8	-1.5	-1.0	12	2.4e+06	6.37
3	8	-1.0	-0.5	10	2.5e+06	6.39
3	8	-0.5	-0.3	6	1.9e+06	6.29
3	8	-0.3	0	1	3.0e+04	4.48
8	15	-2.5	-1.5	11	3.0e+06	6.47
8	15	-1.5	-1.0	6	1.9e+06	6.27
8	15	-1.0	-0.5	1	6.5e+03	3.81
8	15	-0.5	-0.3	1	8.5e+04	4.93
8	15	-0.3	0	0	0.0e+00	-inf
15	30	-2.5	-1.5	16	2.1e+06	6.31
15	30	-1.5	-1.0	6	2.2e+06	6.34
15	30	-1.0	-0.5	2	1.0e+04	4.02
15	30	-0.5	-0.3	1	1.5e+04	4.17
15	30	-0.3	0	0	0.0e+00	-inf
30	125	-2.5	-1.5	6	1.1e+06	6.04
30	125	-1.5	-1.0	4	3.1e+05	5.49
30	125	-1.0	-0.5	1	1.4e+03	3.15
30	125	-0.5	-0.3	0	0.0e+00	-inf
30	125	-0.3	0	0	0.0e+00	-inf
Data from VandenBerg et al. (2013, 55 GCs)						
1	3	-2.5	-1.5	3	5.5e+05	5.74
1	3	-1.5	-1.0	2	2.2e+05	5.35
1	3	-1.0	-0.5	2	2.3e+05	5.37
1	3	-0.5	-0.3	2	2.6e+05	5.42
1	3	-0.3	0	0	0.0e+00	-inf
3	8	-2.5	-1.5	9	1.7e+06	6.22
3	8	-1.5	-1.0	5	9.1e+05	5.96
3	8	-1.0	-0.5	4	9.6e+05	5.98
3	8	-0.5	-0.3	1	1.1e+05	5.04
3	8	-0.3	0	1	1.9e+05	5.29
8	15	-2.5	-1.5	10	3.0e+06	6.48
8	15	-1.5	-1.0	4	1.3e+06	6.13
8	15	-1.0	-0.5	0	0.0e+00	-inf
8	15	-0.5	-0.3	0	0.0e+00	-inf
8	15	-0.3	0	0	0.0e+00	-inf
15	30	-2.5	-1.5	6	6.8e+05	5.83
15	30	-1.5	-1.0	3	1.9e+06	6.29
15	30	-1.0	-0.5	1	8.9e+03	3.95
15	30	-0.5	-0.3	0	0.0e+00	-inf
15	30	-0.3	0	0	0.0e+00	-inf
30	125	-2.5	-1.5	0	0.0e+00	-inf
30	125	-1.5	-1.0	0	0.0e+00	-inf
30	125	-1.0	-0.5	0	0.0e+00	-inf
30	125	-0.5	-0.3	0	0.0e+00	-inf
30	125	-0.3	0	0	0.0e+00	-inf

4.1 Distribution of metallicity [Fe/H]

4.2 Distribution of Galactocentric radii R_{GC}

4.3 Distribution of [Fe/H]-R_{GC}

References

Caldwell N., Schiavon R., Morrison H., Rose J. A., Harding P., 2011, AJ, 141, 61

Harris W. E., 1996, AJ, 112, 1487

Pfeffer J., Kruijssen J. M. D., Crain R. A., Bastian N., 2018, MNRAS, 475, 4309

Renaud F., Agertz O., Gieles M., 2017, MNRAS, 465, 3622

VandenBerg D. A., Brogaard K., Leaman R., Casagrande L., 2013, ApJ, 775, 134