

The Age of the Universe from Globular Clusters

by Anne M. Lohfink

The comparison of the predicted age of the Universe by a cosmological model to the age of the objects in it has always been a crucial sanity check for every cosmological model. In the past this has already helped to successfully rule out several models and in an exceptional way contributed to our current understanding of the Universe.

Globular Clusters, known to be some of the oldest observable objects in the Universe, are consequently of great interest for finding an estimate for the age of the Universe. By determining the age of stars included in a GC one is able to obtain the age of the structure. Currently there are three promising techniques: the main sequence turn-off point, radioactive dating and white dwarf cooling curves.

The utilization of the turn-off point in the color magnitude diagram of the clusters is a well established method for determining cluster ages and its performance has constantly improved. Using the main sequence turn-off point method requires that stellar astrophysics has to be understood properly and the distance to the clusters has to be determined accurately (a detailed discussion can be found in Vandenberg et al. [2001]). Current uncertainties in stellar astrophysics that are relevant to the calculation of isochrones used are among others: the treatment of convection, Helium diffusion, as well as the effects of rotation. Moreover the initial abundances in the cluster and limits of the knowledge of the opacities and nuclear reaction rates affect the accuracy of the results. Additionally, the turn-off method requires a very good distance estimate, including a correction interstellar reddening. The distances are mainly found using HB stars, in particular RR-Lyrae leading to a dependence on the proper calibration of the distance estimators. This calibration is influenced by the metallicity and evolutionary dependence of the RR-Lyrae stars along with their incorporated uncertainties.

Despite the many still existing caveats, globular cluster ages determined by Krauss et al. [2003] are reasonably constrained. Using a Monte-Carlo method that accounts for the five most influential uncertainties and an M_V of $0.46^{+0.13}_{-0.09}$ mag as a calibration for the RR-Lyrae, they find a lower limit for the age of 11.2 Gyrs and a best fit value of 12.6 Gyrs for the oldest clusters on a 95 % confidence level. In order to get real estimates of the age of the Universe the formation time of the Galaxy itself has to be accounted for and the corresponding corrected best fit age then is 13.6 Gyrs. Comparing with the state-of-the-art cosmological model age prediction, using H_0 from the Hubble Key Project [Freedman et al., 2001], one finds that the ages of globular clusters are in agreement and a matter-dominated, flat universe can be ruled out.

Another way to find cluster ages is the exploitation of the cooling curve of white dwarfs, however, to date there is only one good example for this technique due to the tremendous observing time required. Hansen et al. [2002] find an age of 12 ± 0.7 Gyrs for M4 using HST data. (Note: The error does not include the uncertainty from the theoretical model assumed).

The age of the oldest stars in the Galaxy can generally also be determined via radioactive dating, in particular using uranium and thorium. So far very few measurements exist and their errors are larger than the turn-off or white dwarf cooling methods, for example Hill et al. [2002] find an age of 14.0 ± 2.4 Gyrs.

Despite the numerous uncertainties, all three methods for age determination are in agreement with each other and the current cosmological model.

Freedman W. L., Madore B. F., Gibson, B. K., et al., 2001, ApJ 553, 47

Hansen B. M. S., Brewer J., Fahlman G. G., et al., 2002, ApJL 574, 155

Hill V., Plez B., Cayrel R. et al., 2001, A&A 387, 560

Krauss L. M. and Chaboyer B., 2003, Science 299, 65

Vandenberg D. A., Bolte M. and Stetson P. B., 1996, ARAA 34, 461