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Globular Clusters in Galaxy Halos

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Abstract. Perhaps the most noteworthy of recent findings in extragalactic globular cluster research are the bimodal globular cluster metallicity distributions seen in massive early–type galaxies. We find that the metal–rich globular clusters are closely coupled to the galaxy and share a common chemical enrichment history with the galaxy field stars. The current data also indicate that the high S_N galaxies have proportionately more metal–poor globular clusters, per unit galaxy light, than low S_N galaxies. The gaseous merger model of Ashman & Zepf (1992) has difficulty explaining these trends, whereas they appear compatible with a multiphase collapse scenario. In this scenario, the metal–poor globular clusters are formed at an early stage in the collapse of the protogalactic cloud. The metal–rich globular clusters formed out of more enriched gas, roughly contemporaneously with the galaxy stars. In this sense the metal–rich globular clusters in elliptical galaxies are the analog of the metal–poor halo globular clusters in spirals. The disk globular clusters in spirals may represent a third phase of this formation process.

1 Some Ellipticals have Several Globular Cluster Subpopulations

Although the initial evidence was weak, there are now a handful of convincing cases for bimodal globular cluster color (metallicity) distributions in early–type galaxies (see Forbes, Brodie & Grillmair 1997). This indicates that some ellipticals have more that one globular cluster population. These populations may have formed in distinct star formation episodes from different metallicity gas. The observed metallicity distributions effectively rule out a simple monolithic collapse and provide a strong constraint for any globular cluster formation model. In two cases studied in detail (NGC 4472, Geisler et al. 1996; NGC 1399 Forbes et al. 1997) it appears that the metal–rich globular clusters have metallicities that match the underlying field star metallicity over a wide range in galactocentric radius, and they are more centrally concentrated than the metal–poor globular clusters.

2 The Globular Cluster Metallicity – Galaxy Luminosity Relation

The relationship between globular cluster mean metallicity and parent galaxy luminosity (e.g. Brodie & Huchra 1991; Forbes et al. 1996) needs to be re–

evaluated for the presence of bimodal metallicity distributions. In Figure 1 we plot the mean metallicity of the metal–rich subpopulation against the galaxy luminosity. The metal–rich globular clusters show a good correlation with galaxy luminosity. The metal–poor ones show no correlation. Either there is virtually no Z–L relation for metal–poor globular clusters or there is a 'second parameter effect' causing the significant scatter. Figure 1 clearly indicates that [Fe/H] for the metal–rich globular clusters is closely coupled to the mass of the host galaxy.

3 What is the Origin of the Globular Cluster Subpopulations ?

One possibility for explaining the presence of globular cluster subpopulations is the merger of two spirals (and their globular cluster populations) followed by the subsequent creation of a new population of metal–rich globular clusters (eg Ashman & Zepf 1992). This merger model can also explain many other features of globular cluster systems. In this framework, the expectation is that galaxies with over–abundant globular cluster systems, ie those with high specific frequencies S_N, will have relatively more metal–rich than metal–poor globular clusters. In the merger model this ratio should increase with increasing S_N as larger numbers of new (metal–rich) globular clusters are formed. The observational data (see Forbes, Brodie & Grillmair 1997) show that it *decreases.* Thus a property of high S_N galaxies is that they have relatively more metal–poor globular clusters, in direct contradiction to that expected in the Ashman & Zepf (1992) model.

4 Galaxy and Halo Globular Cluster Formation

Harris and coworkers (eg Harris & Pudritz 1994) have advocated an *in situ* formation for globular clusters. However the existence of two distinct globular cluster subpopulations effectively rules out a simple monolithic collapse. We suggest that in large ellipticals, a two phase collapse occurs. In this scenario, low–metallicity globular clusters are formed slightly before the main phase of galaxy collapse and field star formation. In the next phase the vast majority of field stars form, along with a second population of metal–enriched globular clusters. We call these two phases the 'pre–galactic' and 'galactic' phases.

We expect the metal–rich globular clusters which formed at roughly the same time as the galaxy field stars to be closely coupled. This appears to be the case as shown in Figure 1. We also expect the pre–galactic globular clusters to have a high S_N value associated with them as very few field stars form in the initial phase. Thus high S_N galaxies may simply be those with a higher fraction of pre–galactic (metal–poor) globular clusters. Further details of the multiphase collapse picture can be found in Forbes, Brodie & Grillmair (1997).

In the Milky Way, and by inference spiral galaxies in general, there are two distinct populations of globular clusters associated with the disk and halo components. With reference to the collapse picture above, the halo globular clusters have kinematics and metallicities similar to those of halo stars (Carney 1993). This indicates that halo stars and globular clusters were formed in the halo at much the same time, and may therefore be the spiral galaxy analog to the metal–rich globular cluster population in ellipticals. We speculate that the disk globular clusters in spirals represent a third stage of the collapse process (which is absent in large ellipticals).

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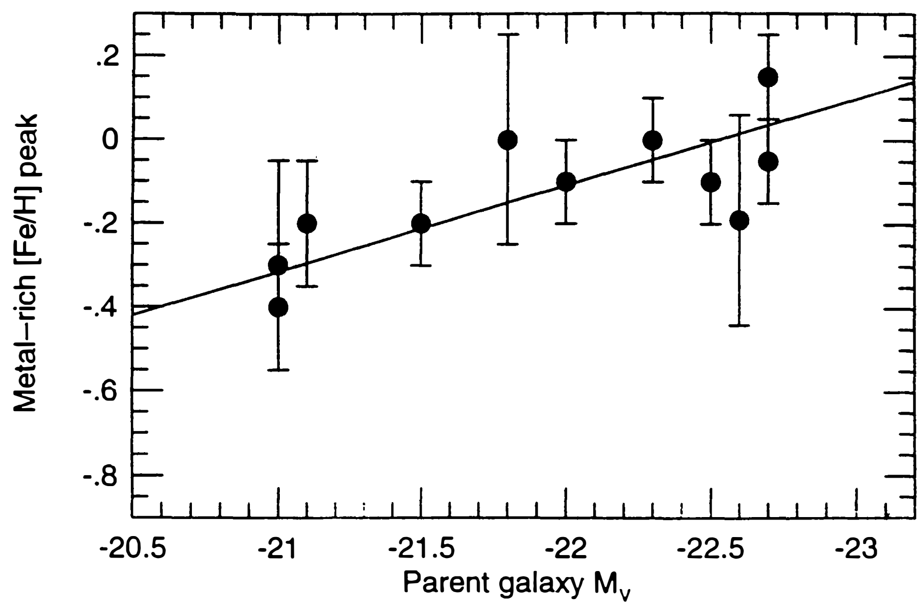

Figure 1. Globular cluster mean metallicity – galaxy luminosity relation for the metal–rich subpopulation. The solid line is a weighted fit to the data. A good correlation between the metallicity of the metal–rich globular clusters and the parent galaxy luminosity is present.

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