Globular Cluster Systems in the Coma Galaxies

The technique of CCD imaging has been used at the CFHT to produce enormous increases in the region of space where extragalactic globular cluster systems can now be studied. In two recent papers published simultaneously in Astrophysical Journal Letters (vol. 315 no. 1), William E. Harris (McMaster University), and Laird Thompson (IFA Hawaii) and Frank Valdes (NOAO), have reported the discovery of globular clusters around the supergiant ellipticals of the Coma Cluster.

The Coma Cluster is at a redshift of 7000 km/s, which corresponds to a linear distance of about 100 megaparsecs for a typical Hubble constant of 70; it is the nearest example of an extremely rich, centrally condensed, and dynamically evolved system of galaxies and is at the center of a still larger supercluster. The Coma core is dominated by two supergiant ellipticals, NGC 4874 and 4889, which lie at the center of a dense swarm of hundreds of other E and S0 galaxies. Because of its extreme distance — almost 6 times farther away than the Virgo System — the Coma galaxies have for many years been regarded as a kind of ‘ultimate target’ for the detection of globular clusters around E/S0 galaxies using ground-based photometry; if globular clusters are essentially similar in galaxies of similar types, then the ones in the Coma supergiants were expected to appear in significant numbers only at a magnitude level B=25. At such faint levels, contamination of the photometry by large numbers of other types of images (mostly faint, nearly starlike background galaxies) becomes a serious concern, and it is only the combination of the excellent CFHT seeing with high-QE CCD detectors that has finally produced success.

Of the two supergiants in Coma, NGC 4874 appears to be the one at or near the dynamical center of the whole cluster (its radial velocity is nearest the cluster mean, it lies nearest the center of the giant X-ray halo suffusing the Coma core, and it contains a nuclear radio source). An intriguing correlation that has emerged clearly in the last few year is that the large E galaxies at the centers of rich clusters all appear to have anomalously large populations of globular clusters: ‘their specific frequencies’ S (number of globular clusters per unit galaxy luminosity) are about 3 times higher than the normal levels for

Figure 16: The central Coma supergiant elliptical NGC 4874, taken with the RCA1 CCD camera at the prime focus of the CFHT by W.E. Harris. The picture shown is the sum of six 20-minute exposures in B; the stellar images on the composite frame have a FWHM of 0.8 arcsec. A swarm of faint starlike images (the brightest globular clusters around NGC 4874) are just barely visible in the envelope of the galaxy. The other galaxies in the picture are other, smaller, E/S0 members of the Coma cluster; for a Coma distance of 100 Mpc, the linear scale of the picture is 60 x 100 kpc.

Figure 17: After careful digital processing of the previous picture to remove most of the light from the big central galaxy, many more faint starlike images are apparent on the frame. Shown here is one quadrant of the previous picture (the nucleus of NGC 4874 itself appears at lower right). The faintest plainly visible images here are at a B magnitude of 26; they are clearly concentrated toward the center of NGC 4874, indicating the presence of a globular cluster system.
E/S0 galaxies in general. But only a few such centrally
dominant galaxies are close enough that their globular clusters
are easily within reach from ground based imaging (M87 in
Virgo, NGC 1399 in Fornax, NGC 3311 in Hydra). Obtaining a
more complete picture of the characteristics of globular cluster
systems in all types of environments — as well as using them
eventually as 'standard candles' for a Population II calibration
of the Hubble constant — thus requires pressing outward to the
largest possible distances. By analogy with the systems in
Virgo, Fornax, and Hydra, NGC 4874 was a logical candidate
for a high-specific-frequency galaxy.

The results published in tandem by Harris and by
Thompson and Valdes have dramatically confirmed the
suspicion that this central Coma giant has a large cluster
system, and were obtained by two mutually complementary
observing techniques. Harris used the RCA1 CCD camera at
prime focus to observe both NGC 4874 and 4889, to obtain a
direct comparison between the two systems and a picture of the
wide-field structure of their cluster systems, (the field of PF was
2.1 x 3.4 arcmin, or ~40 x 70 kpc at Coma). By contrast,
Thompson and Valdes obtained their data with the rapid-guider
ISIS camera at Cassegran; the much smaller field and better
image sampling (56 x 56 arcsec at 0.11 arcsec/pixel) allowed
them to select out a 'pure' sample of the starlike globular cluster
images in a single field near NGC 4874, free of contamination
from background galaxies.

Both studies confirm that globular clusters appear in no-
ticeable amounts between B = 24.5 and 25.0, and increase
rapidly in number up to the photometric limit near B = 26. The
frequency distribution with magnitude is just as expected if the
cluster population is similar to that in the Virgo giant M87,
dispersed fainter by the Coma/Virgo Hubble distance ratio of
~5.5 (3.7 magnitudes). For NGC 4889, Harris finds that its
clusters follow a similar magnitude distribution but are about 3
times less populous, just what would be expected if its cluster
system were more 'normal'. These results provide additional
confirmation for the view that a galaxy needs to be not just a
giant elliptical, but also must be in a position of central dom-
nance, if it is to produce an anomalously high population of
globular clusters.

Two other highlighted results came out of these studies.
One is that the radial distribution of clusters around NGC 4874
(discussed by Harris) seems to be considerably less centrally
concentrated than the halo light of the galaxy itself, and thus
may belong to a dynamically 'earlier' epoch of formation.
Second is the surprising discovery by Thompson and Valdes
that their program field appears to have an excess population
of small, faint dwarf galaxies (with a rather flat magnitude
distribution from B = 24 to 26, in marked contrast to the globular
clusters which rise rapidly in number to the photometric limit).
On the basis of galaxy clustering statistics it seems unlikely that
these can be background objects, and Thompson and Valdes
conclude that NGC 4874 (and possibly other large galaxies in
extremely dense Coma-like environments?) possesses an
extensive retinue of dwarf galaxies.

The existence of anomalously large specific frequencies S
 closely associated with central supergiant ellipticals is a puzz-
ling phenomenon to explain, and does not fit in well with any
current theoretical scenarios, such as the ideas that these big
central galaxies obtained hordes of extra clusters through
mergers, tidal interactions, or condensations out of 'cooling
flows'. Since S is the ratio of globular clusters to halo stars, and
since both type of halo objects are treated the same way in
these dynamical processes, systems of especially high S do not
result. Furthermore, the characteristics of the globulars them-

selfs are no different in the giant anomalous systems than
in other, completely normal E galaxies: within the bounds of
current observations, they have the same distribution over
absolute magnitude, the same photometric colors (metallici-
ties), and the same distribution in space around their parent
galaxies. It seems necessary to suppose that the clusters
formed in a fairly well defined initial epoch of their own, with an
efficiency relative to the rest of the galaxy halo that was uniquely
higher in these special environments. But the reasons for this
remain unknown in any detail.

One of the most exciting points of interest associated with
the Coma discovery remains the simple fact that they are by far
the most distant galaxies in which globular clusters have been
found (by almost a factor of three over the previous record-
holder, the Hydra cluster). The region of space in which these
most ancient Population II objects can be studied is far larger
than was previously realized; the key has been to employ the
best modern techniques with observations from a site like
Mauna Kea.

W. E. Harris