Extragalactic Star Clusters in Merging Galaxies

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Summary. The study of cluster populations as tracer of galaxy evolution is now quite possible with 8 m class telescopes and modern instrumentation. The cluster population can be used as a good tracer of the star forming episodes undergone by the merging system. We present two young galaxies mergers NGC3256 and NGC4038, and the studies about the young cluster population on those system. We found that the clusters ages are agree with the mergers age and their metallicities are consistent with them being the progenitors of the old metal rich globulars in ellipticals.

1 Introduction

The first ideas about the differences in galaxies’ morphology were that those were due to differences in the initial conditions present at the time of formation, not to any events that may have happened during their evolution. This way, ellipticals looked like ellipticals because they formed through a fast and turbulent collapse; while spirals would go through as low dissipation process that allowed the formation of the disk. However, in the 70’s [Toomre & Toomre(1972)] and [Schweizer(1978)] argued that a big fraction of ellipticals was formed by the merger of two spirals, rather than being ellipticals from the start. The argument was based on observational evidences, where remnants of mergers would present structures that were due to tidal interaction of disks. Looking for other clues to prove or disprove either argument, researchers eventually resourced to globular clusters. Globular clusters have always been very important for the determination of the evolutive history of nearby galaxies. They are bright, numerous and provide an excellent chronometer and age metallicity indicator for the star formation burst from which they originated. In the early 90’s, these studies led to the argument that, since globular clusters are more common in ellipticals than in spirals (higher specific frequency), if the number of globulars is conserved...
during a merger, ellipticals could no possible come from a combination of spirals \cite{van_den_Bergh1990}. The question then become to determine if globulars clusters can be formed during and after a merger event. Evidence soon started to build up that the answer for that is yes \cite{Schweizer1987, Burstein1987, Kumai1993}. Continuing along the lines of these works, we devised as the primary goal of my thesis to investigate the formation of elliptical galaxies as a result of the merger of two spirals, by using the star cluster populations present in the merger as tracers of the merger evolution through a study of their ages, metallicities, masses, sizes, etc. For this we selected a sample of merger systems of different ages, from very young (a few Myrs) to “bona fide” merger remnants (older than 700 Myr). In this work we will present the results of the two younger mergers in our sample: NGC4038/39 and NGC3256.

2 Observations

Globular clusters may be bright and numerous, but in the extragalactic domain, even for the closest mergers the light collecting power of 8m-class telescopes and the high spatial resolution of HST are needed to obtain the data required for a study like this. Starting with HST V and I images from the HST archive, we constructed colour-magnitude diagrams to select our cluster candidates:

- if the candidates are fainter than $V=23$, we have to use a combination of optical and near-IR photometry, comparing the data on colour-colour diagrams with Single Stellar Population (SSP) models.
- if the cluster candidates are brighter than $V=23$, spectroscopic follow-up is possible, and we then compare the properties of the cluster in age-metallicity spectral index diagrams against the values from SSP models.

Our spectroscopy data are mostly Gemini GMOS Multi-Object Spectroscopy (MOS), with one merger observed with the GMOS Integral Field Unit (IFU). Spectra were centered around 5000Å to include several Balmer lines, MgI at 5100Å, and a few iron features.

3 Data reduction and analysis

We followed the standard MOS data reduction procedures using the GEMINI GMOS IRAF package. For each galaxy, the clusters naturally separated in two samples:

- Clusters presenting only absorption lines (hydrogen, magnesium and iron are the most common).
  The radial velocity is accurately determined by using cross correlation of
the absorption lines against a RV stars observed with the same instrumental setup. The age/metallicity indexes are measured using INDEXF [Cenarro et al.(2001)], which correctly takes into account the error propagation from random noise and from the uncertainty in the velocity determination. Once the indexes are measured, we plot them into a diagram such as $H\gamma \times [\text{MgFe}]$ or $H\beta \times [\text{MgFe}]$ [Schweizer & Seitzer(1998)], comparing with indexes from SSP models to obtain a first determination of the age and metallicity.

We then compare our observed spectrum with the model spectrum for that age and metallicity, and determine the internal reddening using the continuum shape. After correcting for the reddening, we re-measure the indexes and refine the age and metallicity determination.

• Clusters with the spectrum dominated by emission lines. Those are by definition young clusters, which still contain enough hot stars to ionize the surrounding gas. For these, we determine the radial velocity using the known emission lines in the spectrum. We then estimate the extinction from the gas in which the cluster is embedded, using the $H\gamma/H\beta$ ratio, assuming a Case B recombination and the [Edmunds & Pagel(1984)] extinction curve. Once the reddening is corrected, we calculate the gas metalicity as a surrogate for the embedded cluster, using the $[\text{O III}]\lambda\lambda 4363,4959+5007$ Å lines and the formulae from [Vacca & Conti(1992)] and [Meyer(1985)] for the oxygen abundance.

4 Results

• NGC4038: The Antennae galaxy. This system is at a distance of 19.2 Mpc, and is a young merger of 200 Myr, with the two merging galaxies still identifiable. From HST and GMOS imaging we selected 29 cluster candidates, of which 16 were confirmed, one being located in the tidal tail. Eight of had a pure absorption spectrum, four have an emission spectrum and four are mixed. In summary, the clusters present the following properties:
  – Magnitudes $16 < V < 21.5$ (Reddening corrected)
  – The absorption line clusters span a range of ages between 70 to just over 300 Myr, with solar metallicity.
  – The emission line clusters are obviously younger, less than 10 Myr, and the metallicity obtained from the emission gas is a little under solar.
  – We find that the internal extinction can be quite large, up to $A_V \sim 2.5$ mag, with the more reddened clusters located closer to the nucleus of the secondary galaxy (NGC4039).

• NGC3256 This is a merger system twice as far as the Antennae and slightly older, but with the two nuclei still separated. The HST and GMOS imaging provided 109 cluster candidates, of which only 31 were spectroscopically
confirmed (this galaxy is at lower galactic latitude so the field was quite contaminated by foreground stars). Three are located in the tidal tail.

- They were still quite bright, despite being twice the distance of the Antennae ones, with $17.5 < V < 22.5$. (Reddening corrected)
- The absorption line clusters span a range of ages quite similar to those in the Antennae, 80 to 300 Myr, but with solar or higher than solar metallicity.
- The young cluster (those with emission lines) seem to present a slightly lower metallicity.
- Again we measure quite a large reddening internal to the galaxy, up to $A_V \sim 3.5$ mag, with more reddened clusters being the ones closer to the center as expected.
- We have also estimated the size of the clusters as between 1 to 10 pc, except the ones in the tidal tail, which are larger (10 to 18 pc).

5 Conclusion

The cluster population is a good tracer of the star forming episodes undergone by a merging system. As we initially proposed, all galaxies in our sample indicate that these new generations of clusters are formed at different epochs and with different metallicities. The cluster population is also a good indicator of the evolution of the merging system, being more uniformly older for the older mergers.

The new populations are systematically more metal rich, which is consistent with the ideas of merging events being what causes the bimodal distribution of clusters in ellipticals. The overall characteristics (sizes, masses) of the new clusters are consistent with them being the progenitors of the old metal rich globulars in ellipticals.

Clusters close to the centre of the merging system can be strongly reddened. This can have a very drastic effect in the resulting colours or in the line indexes and, if not corrected, will yield cluster ages much larger than the actual values. The presence of clusters in the tidal tails of the merging systems, indicates that clusters formed in merger events can be ejected and end up forming part of the intragroup medium.

References

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