GEMS: Exploring the formation of Elliptical galaxies

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Introduction & Abstract:

There exist two different scenarios for how elliptical galaxies are created. They could be assembled during a monolithic collapse in a single starburst (Eggen, Lynds & Sandage, 1962), or they could be created in merging events of two spiral galaxies (Tammann & Toomre, 1972; Khochfar, 2005). None of these models can fully explain the present-day galaxy population. The key discriminant between these two scenarios is the question, whether elliptical (red-sequence) galaxies build up at late times or not.

It is known that the red-sequence (RS) indeed does build up at late times (Bell, Borch et al., 2006, figure 1). This growth cannot happen in RS-galaxies themselves, they are dead and non-star-forming. So, why do their total mass increase then? It is important to know how that growth happens (Mergers, both "dry" and "wet" (Burkholder, 1992). Disk fading in bulge-disk galaxies (Conseco et al., 1996), environment, gas-stripping... (Gunn & Gott, 1972). To solve this question, we have to look for the progenitors of red-sequence galaxies. One possibility could be blue elliptical galaxies, quickly assembled spheroids where young, blue populations of stars still exist (or star formation still happens).

We used COMBO-17 (Wolf et al., 2003), a multi-spectral survey that returns very accurate (σ[σm]~ 0.02, see figure 2) redshifts for around 900 galaxies in the COMBO survey field (Extended Chandra Deep Field South) in a redshift of z~0.9, and GEMS (Rix et al., 2004), the HST-coverage of the same area. By using GALFIT and Gim2D, 2D fitting codes that were thoroughly tested (see left box below) within GEMS, to derive galaxy sizes, we find (see right box below) that massive Blue Elliptical galaxies (BEs) seem to be able to evolve into Red Ellipticals galaxies (REs), while low-mass BEs seem to either grow a galactic disk and evolve back into disk galaxies, or are disk galaxies that just form a bulge. Future work includes the quantitative comparison of the space density of BEs to the space density of mergers (Bell et al., 2006, table 1). The merger rate of massive galaxies, the usage of 24-µm and X-ray GEMS-data to identify high SF-rates and AGN and spectroscopic follow-up observations of BEs (old stars create absorption lines in the spectra, SF creates emission features, key to dynamical masses) and the investigation of the impact of the environment, mainly by using STAGES, another HST-survey, centered on Abell Cluster 501/502.

Galaxy 2-D profile fitting, GALFIT & Gim2D

GALFIT (Penston et al. 2002) and Gim2D (Schirmer, 1999) are two widely applied 2D fitting codes in the field of quantitative galaxy fitting and morphology. We extensively tested and used GALFIT and Gim2D for science within GEMS. The basic considerations for using and application of these two codes within GEMS is the usage of (i) a finite element mesh, (ii) minimal parameter guesses, (iii) postage stamp construction, and (iv) deblendimation and masking of overlapping sources.

During the testing only single-component Sersic profiles where fit to all data, as we did for real galaxies in GEMS. The Sersic profile is given by $r_e = r_e^{(n-1)}$, and represents a more general form of the exponential light-profiles seen in galactic disks (n=1) and the R1/4-law (de Vaucouleurs law) known to represent the profile shape of a typical early-type galaxy (n=4), both profiles shown in figure 3. This profile can be used to simultaneously separate these two types of galaxies by using a Sersic index cut of e.g. 2.5, as shown in figure 4. This was done by us and many other groups.

We found that both codes can recover galaxy parameters quite well, GALFIT being more robust, with less scatter and less systematic effects (see x-axis). Given the fact that GALFIT is also many times faster, easier to set up in an automated way and able to simultaneously fit second component in parallel, we recommend GALFIT as the code of choice for large surveys.

Blue spheroidal galaxies

We can divide the population of BEs into two regimes in the mass-size diagram (figure 8). One regime shows the same space density distribution as red-sequence galaxies do, the other shows the same relation as disk galaxies. Blue galaxies should evolve in a certain way once their star-formation is shut off. This fading and reddening can be estimated from stellar population models and is indicated as the red arrow in the figure. The green arrows in figure 9. Figure 9 at the X-axis shows how much BEs (other than MB, depending on color-cut) can fade on the red sequence, the Y-axis shows how much galaxies have to fade in order to fall on the mag-size-relation of red-sequence galaxies.

It seems as if massive galaxies are in place to, with passive evolution, evolve into red elliptical galaxies and form the red sequence at lower redshift. This is true and gives the fact that both a merging process and the passive evolution onto the red-sequence take roughly 1 Gyr. Massive BEs should have roughly the same space density as mergers. This will have to be examined in the future.

Low-mass BEs seem to be off the model. They can still evolve passively into REs. The question is, what is the redshift at which they do they evolve back into disk-dominated galaxies? Are they disk galaxies that are currently growing bigger and therefore classified as elliptical? Answering this question will also be future work and requires the usage of other wavelength data to be able to distinguish between blue galaxies that have high SF-rates and AGN.

Is there indication that these effects is environment dependent? This question will be answered by comparison of the GEMS data, to results from STAGES, another HST-survey, center on the galaxy cluster Abell 501/502.