Galaxy Mergers as a Function of Environment. Using the Structural Parameters of Residual Images.

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A)THE STAGES SURVEY.

STAGES is a multiwavelength project designed to investigate the **impact of environment in galaxy evolution.** Its target is the A901/902 supercluster. It is is located at z=0.165. It harbors different environments with different densities. This dataset is best suited to study galaxy interactions, which are more frequent in clusters.
STAGES has obtained an ACS/HST F606W complete scan of the cluster.
There is a wealth of aditional data to complement the ACS/HST observations, including photo-zs, SEDs and stellar masses, derived from the COMBO-17 observations. There are also X-ray (XMM-Newton), infrared (Spitzer), UV (Galex), radio (GMRT), and spectroscopic (2dF) observations for selected subsamples.
STAGES has been used to study galaxy groups, strong lensing, and the evolution of spiral galaxies as they enter galaxy clusters. The purpose of the present work is to study the galaxy merger fraction as a function of morphology and environment.

B)MAIN IDEAS AND SAMPLES.

***IDEAS:** Study of the merger fraction of galaxies via structural parameters. Galaxies involved in merger episodes will have disturbed morphologies. High asymetries, shreddedness and multiple nuclei are clear symptoms.
Previous studies only made use of the information contained in the direct images of galaxies. This work deepens in this line of work by exploring the **information contained in the residual images** of galaxies after subtracting a smooth Sérsic model. **This model represent the largest galaxy** in merging episodes. Residual images will contain information about the smaller galaxies involved in the merger, and the morphological disturbances of the large galaxy.

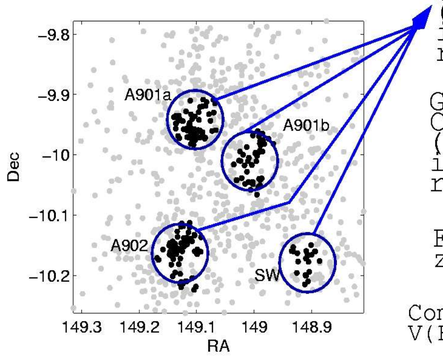
***SAMPLES:** Mass selected sample (log M/M_{sun}>9.0) in three different environments (Field, Cluster, and Cluster Core environments) with morphologies. The parent sample is taken from the STAGES ACS/HST observations.

Sample Breakdown:

- 453 Field Galaxies (88 E, 59 S0, & 306 Sp).
- 719 Cluster Galaxies (167 E, 193 S0, & 359 Sp) of which,
- 165 are Cluster Core Galaxies (53 E, 60 S0, & 52 Sp).

54/1171 objects were **visually** found to be mergers (large symbols in lower panels).
Which of the remaining 1117 objects are also mergers?

Samples used in this work.



Black points: Cluster core subsample. (Objects @z~0.17 in high density regions.)

Grey points: Cluster subsample. (Objects @z~0.17 in lower density regions.)

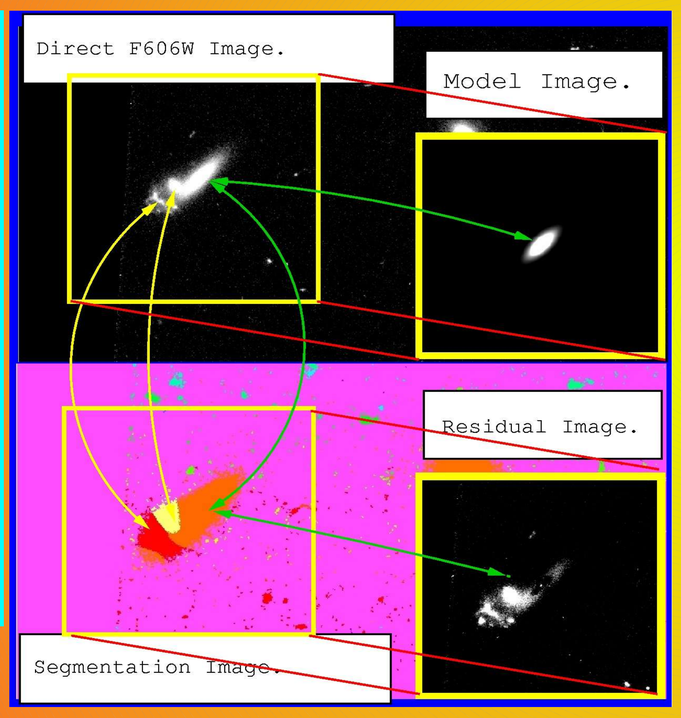
Field subsample. z~0.1 and z~0.25.

Comoving volumes ratio V(Field)/V(Cluster)=510

C)Detecting Mergers using GALFIT+Structural Parameters.

C.1)Use of GALFIT to create a Sérsic model.

We create a Sérsic model using the **GALFIT** code. The GALFIT configuration used is set up by **Galp-Hyt**.
*GALFIT fits the sources using a **Sérsic model.** In the figure to the right, the problem source is the one with green arrows.
*GALFIT fits the closest sources to the problem objects again with Sérsic models. These objects are the ones with yellow arrows in the figure.
*GALFIT uses an **exponential disk** to fit the surface brightness distribution of more distant sources.
In the sample figure to the right, it is seen that the problem galaxy (marked with the green arrows) is **merging with two close galaxies** (marked with yellow arrows). The model image is seen as an inset inside the upper panel. **In the residual image (shown as a inset inside the lower panel) only the model to the target galaxy is removed.**
GALFIT also uses the SEXtractor **segmentation image.** This image classifies the pixels in images to help GALFIT make a better use of the information contained in the more relevant pixels. The segmentation image example is shown in the lower panel.



C.2)Structural Parameters. The CAS and G-M20 parameters.

The CAS and G-M20 parameters are the most commonly used set of parameters in works studying the merger fraction of galaxies using structural analysis.
- C measures the light concentration.
- A measures the asymetricity of the light distribution.
- S measures the smoothness of the surface brightness distribution.
- G measures how evenly is the light distributed.
- M20 measures how shredded is the light distribution.

Up to now, all studies have used the information contained in the direct images. **This is the first work to explore the information contained in the residual images after subtracting a smooth Sérsic model.**

$$C = 5\times\log\left(\frac{R_{80}}{R_{20}}\right)$$

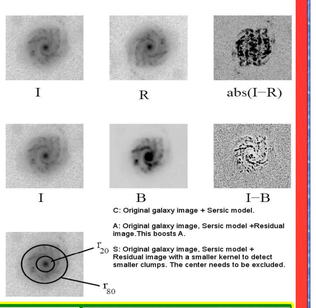
$$A = min\left(\frac{\sum|I_0 - I_{180}|}{\sum|I_0|}\right) - min\left(\frac{\sum|B_0 - B_{180}|}{\sum|I_0|}\right)$$

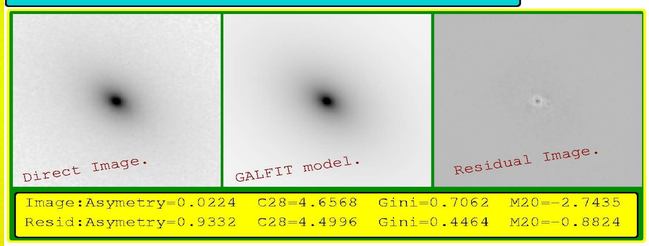
$$S = 10\times\left[\frac{\sum(I_{x,y} - I^{\sigma}_{x,y})}{\sum I_{x,y}} - \frac{\sum(B_{x,y} - B^{\sigma}_{x,y})}{\sum I_{x,y}}\right]$$

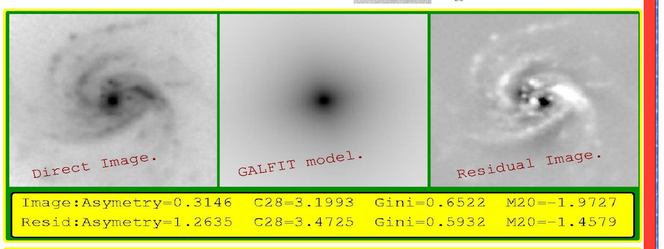
$$G = \left(\frac{1}{|\bar{f}|\times n\times(n-1)}\sum_{i=1}^{n}(2\times i - n - 1)\right)$$

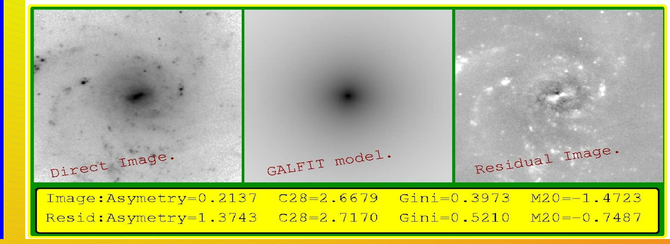
$$M_{20} = \log\left(\frac{\sum M_i}{M_{Tot}}\right) \quad While \quad (\sum f_i) < 0.2\times L_{Tot}$$

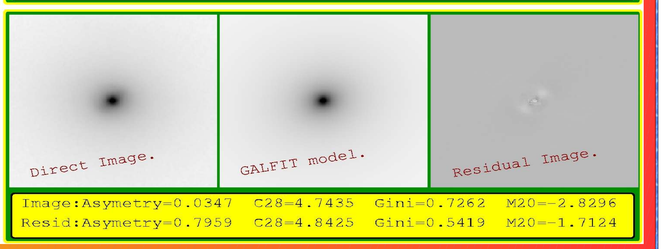
Concentration. Asymetry. Clumpiness.
Gini index. M20.





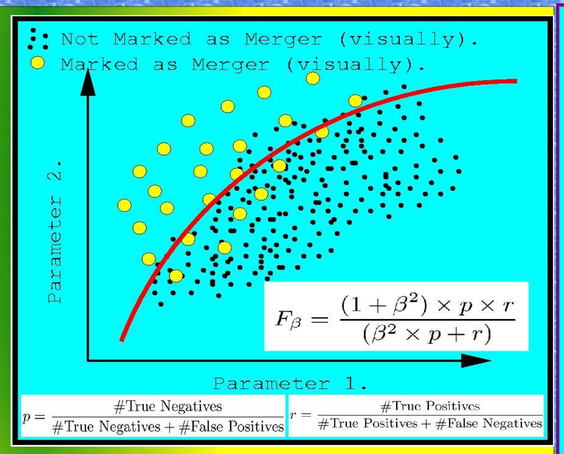






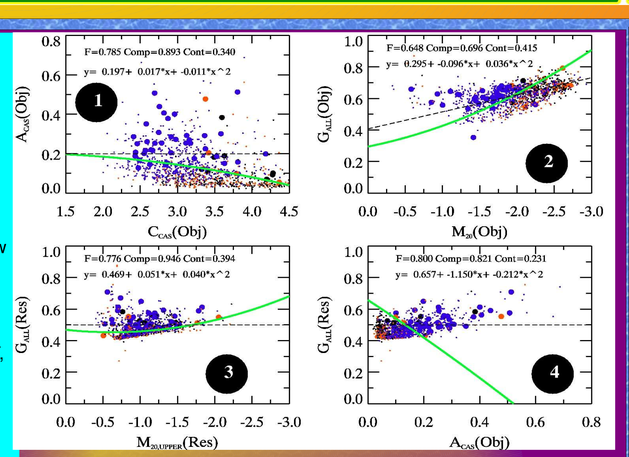
D)Best Parameters to Estimate Merger Fraction?

F is the **"Sample Purity"**.
Weighted (β=0.25) harmonic average of "sensitivity (r)" and "specificity (p)".
Red line is constructed so that F is maximized.
- True Pos:Merger above line.
- True Neg:Not Merger below line.
- False Pos:Not Merger above line.
- False Neg:Merger below line.



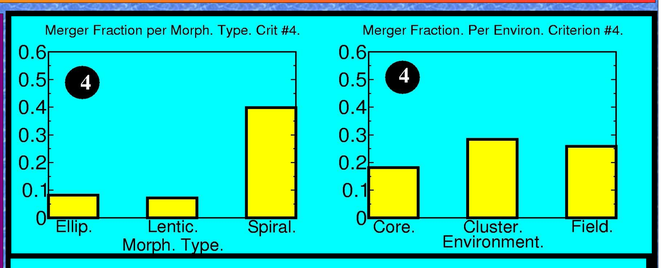
E)Comparison Between Several Combinations.

Which is, then, the best combination?
*Asymetry(Obj)+Concentration(Obj). Diagnostic **#1**: Good F, high completeness, higher contamination.
*Gini(Obj)+M20(Obj). Diagnostic **#2**:Low F, low completeness, high contamination.
*Gini(Res)+M20(Res). Diagnostic **#3**: Good F, optimal completeness, high contamination.
*Gini(Res)+A(Obj). Diagnostic **#4**:Very good F, high completeness, low contamination.
Different diagnostics yield samples of different qualities, depending on the scientific goals of the required sample.
Merger fractions for the best diagnostic (**diag 4**) are shown in the histograms to the right.



Red points: Ellipticals
Black points: Lenticulars.
Blue points:Spirals.

Purities, completeness and contamination for each diagnostic is given in each panel.



F)Summary and Conclusions.

1)We have developed a **method to detect mergers.** We use GALFIT+Structural Parameter analysis.
2)The Gini index(residuals)+Asymetry(Direct Image) produces the best overall merger sample. Use of G(Residuals)+M20(Residuals) attains 95% completeness.
3)Mergers are mainly found in Sp systems. E and S0 hosts have already processed their guests.
4) Mergers are rare in the Core. They are common in Cluster and Field.