JENAM 2010 – Lisbon, Portugal, September 6 -7, 2010

Symposium 2: Environment and the Formation of Galaxies: 30 years later

Alfonso Aragon-Salamanca (INVITED TALK)

Title: *Galaxy evolution in clusters since z~1*
Authors: *Alfonso Aragon-Salamanca*

Abstract: *Galaxy clusters provide some of the most extreme environments in which galaxies evolve. They are therefore excellent laboratories to study the age-old question of "nature" vs. "nurture" in galaxy evolution. In this talk I will review some of the key observational results obtained during the last decade on the evolution of the morphology, structure, dynamics, star-formation history and stellar populations of cluster galaxies since the time when the universe was half its present age.*

Olga Cucciati (CONTRIBUTED TALK)

Title: *The role of galaxy stellar mass in the colour-density relation up to z~1*
Authors: *Cucciati, Iovino, Kovac, Scodeggio, Lilly, and the zCOSMOS Team*

Abstract: *It is well known that galaxy properties correlate with the local environment in which galaxies reside. In contrast, it is still matter of debate why and when these environmental dependences originate, and whether only one "main" property depends on environment, thus driving all the others environmental dependences via the correlations among properties themselves. Using the first zCOSMOS spectroscopic data (about 10000 galaxies), we analyze density effects on galaxy U-B colour, D4000 Angstrom break and specific star formation rate up to z=1, with local environment ranging from very low densities up to the highest density peaks. We pay attention at the role of both luminosity and stellar mass in selecting galaxy populations for environmental studies, and in particular we focus on the triple colour-mass-density relation, disentangling environmental effects on the two properties.*

Gabriella De Lucia (INVITED TALK)

Title: *Modelling the evolution of galaxies as a function of environment*
Authors: *Gabriella De Lucia*

Abstract: *I will give a summary of galaxy evolution processes in hierarchical cosmologies and of their relative importance at different masses, times, and environments. I will discuss processes that are commonly included in modern semi-analytic models of galaxy formation, and I will comment on recent results and open issues.*

Alan Dressler (INVITED REVIEW)

Title: *Galaxies and their environments -- past, present, and future*
Authors: *Alan Dressler*

Abstract: *My title expresses a double purpose, to talk about how our ideas of galaxy evolution have changed in 30 years, and to discuss how the nature of galaxy interactions with their environment has itself evolved from the early universe to the present epoch. My 1980 study of morphology of cluster galaxies took place in the context of a simple and largely ad-hoc model of structure formation that preceded the paradigm of hierarchical clustering in a CDM universe. In that context a correlation of galaxy type with local density was unexpected and received with some skepticism. Today, in contrast, we have a surplus of ideas that explain all or part of this correlation. From my perspective, the morphology-density relation owes mainly to environmental effects that took place in the first 1-2 billion years --- gas-rich major mergers, accretion of gas and satellites, and AGN activity among them. It has become clear during these past three decades, however, that later processes such as ram-pressure stripping, tidal interactions, and gas-poor mergers continue to shape the ways galaxies respond to their environment. Constructing a coherent and complete picture of the most important processes is a worthwhile, achievable goal for this decade.*

Ignacio Ferreras (CONTRIBUTED TALK)

Title: *Does environment affect the star formation histories of elliptical galaxies?*
Authors: *Ignacio Ferreras, Anna Pasquali, Ben Rogers, Sugata Kaviraj*

Abstract: *Elliptical galaxies provide one of the best test beds to study the standard paradigm of galaxy formation via hierarchical build-up. One key observable is the effect of environment on the star formation history of galaxies (SFH), providing a potentially powerful way to constrain the baryonic physics behind this theory. Using the process of Principal Component Analysis on a 7,000-strong sample of early type galaxies from SDSS, we derive two model independent parameters to investigate their star formation histories. One of these two parameters is found to be mostly sensitive to average stellar age, the other sensitive to small amounts of recent star formation. This result was confirmed using GALEX NUV photometry. We investigate the effect of environment in two ways: I. Dark Matter Halo masses of galaxy groups from the catalogue of Yang et al. II. Close pairs involving only early-type galaxies (i.e. a prototypical dry merger precursor). We find that while environment plays a secondary role to stellar mass it has a measurable effect on the SFH of elliptical galaxies, with close pair interactions a possible cause for the recent star formation seen in these systems.*

Ruth Grutzbauch (CONTRIBUTED TALK)

Title: *Galaxy properties in different environments at high redshift in the GOODS NICMOS Survey*
Authors: *R. Grutzbauch, R. W. Chuter, C. J. Conselice, A. E. Bauer, A. F. L. Bluck, F. Buitrago, A. Mortlock*

Abstract: *In this study we investigate the influence of stellar mass and local density on galaxy rest-frame colour and star formation rates at redshifts between $1.5<z<3$ based on observational data from*

a deep HST H-band survey of unprecedented depth, reaching a stellar mass completeness limit of log $M_* = 9.5\ M_o$ at z=3. We find that galaxy colour, SFR and specific SFR depends strongly on galaxy stellar mass at all redshifts up to z~3. We detect a very weak but significant influence of local galaxy density on rest-frame (U-B) colour over the whole redshift range, which does not seem to be caused by stellar mass trends alone. To summarize, our data suggests that stellar mass is the most important factor in determining the SFRs and colours of galaxies in the early universe up to z~3. Local density has a small but significant additional effect, which depends on stellar mass: low-mass galaxies are marginally redder in high relative overdensities, while high-mass galaxies in overdense regions tend to have bluer colours. The red sequence is built up very early and emerges at z~2.7, which is when the most massive galaxies start to appear red due to decreasing star formation rates and the subsequent passive evolution of their stellar populations. This process might happen in the most dense local environments, suggesting that some of the star formation happening in the more massive galaxies is triggered by environment-related processes such as galaxy interactions and merging.

Boris Haeussler (CONTRIBUTED TALK)

Title: *Are boxy/disky Ellypticals dependent on environment?*
Authors: *Haeussler, B.; Gray, M.; STAGES collaboration*

Abstract: *Boxy and disky isophotes in elliptical galaxies are an imprint of their formation history, equal mass mergers of spiral galaxies and major mergers of ellipticals forming boxy ellipticals and un-equal mass mergers of spiral galaxies forming disky ellipticals. It is therefore interesting to examine the boxyness of early-type galaxies, particularly Ellipticals, as a function of environment in large cluster systems, especially as N/body simulations also predict a higher number of disky versus boxy ellipticals in overdense regions. Using high-resolution HST data from the STAGES survey, centered on the Abell901/902 supercluster and with 1/4 deg^2 one of the biggest HST surveys in existence, we investigated this dependence. Taking extreme care of the setup of the codes used (particularly ELLIPSE), we ran the analysis on a sample of 292 Ellipticals inside and outside the cluster at a redshift of z~0.163 and 266 S0 galaxies at the same redshift range for testing purposes, one of the biggest samples examined for this effect. Although other groups have found environmental dependencies before, I will show that no such dependence is found in the STAGES survey data. The ratio of boxy to disky galaxies stays constant over the whole range of environment and galaxy density present in the field examined.*

Gerhard Hensler (CONTRIBUTED TALK)

Title: *Ram-pressure-stripped galaxies - Which are their survivors?*
Authors: *Gerhard Hensler, Alessandro Boselli, Kristina Sternig*

Abstract: *Galaxies that fall into the gravitational potential of galaxy clusters experience the existence of hot tenuous intra-cluster gas. Ram pressure pushs the interstellar medium out of galaxies, easier for the low-mass galaxies and therefore already in the outermost cluster regions. Normal spiral galaxies are observed in the act of gas stripping within the denser intra-cluster medium. Numerical models over the last years are performed with different numerical schemes and match almost equally with the observations of ram-pressure stripping (RPS) galaxies. Since such models almost always consider only constant ram-pressure conditions they finish at the maximum effect and mostly do not follow the further*

path of stripped galaxies to their apocentric orbit when the ram pressure declines. There, however, the appearance of galaxies with RPS-truncated gaseous disks lacks in the outskirts of clusters. Their radial distribution should clearly differ from that of normal morphologies. Theoretically, two possible outcomes can be imagined: One possibility is that additional dispersal effects, like e.g. Kelvin-Helmholtz instability or heat conduction, withdraw the remaining gas and produce disk-dominated S0s. If gaseous disks survive the RPS they could also re-organize their gas distributions by radial pressure effects and can be identified as HI-deficient spirals. We studied both candidates in the Virgo cluster and will present their radial distributions.

Kelly Hess (CONTRIBUTED TALK)

Title: *Galaxy Groups in the Coma-A1367 Supercluster*
Authors: *Kelley M. Hess, Eric M. Wilcots, Martha P. Haynes, Riccardo Giovanelli*

Abstract: *Groups of galaxies may be the dominant environment in determining galaxy evolution. The combination of close encounters and major mergers may stimulate star formation and AGN activity, and may be responsible for "pre-processing" of galaxies as they fall into clusters. We combine the HI observations of galaxy groups in the Coma-Abell 1367 Supercluster from a 4 degree wide strip of the ALFALFA survey between +24d and +28d from 11h to 14h, with pointed Hα observations from the WIYN 0.9 m telescope. The presence of HI is a measure of the star formation potential of a galaxy, and its spatial distribution reveals the history of recent and on-going interactions between galaxies and with their local environment, while Hα observations reveal the current star formation activity. The groups we observe, determined from 2MASS, span a range of global environments from highest density sub-clumps falling into the center of the Coma cluster, to groups that make up the filament between the Coma and Abell 1367, to poor groups that exist on the edges of voids. We present the HI mass function and global star formation rates for the galaxy groups in an attempt to understand the role of environment in driving galaxy evolution.*

Jeffrey Kenney (INVITED TALK)

Title: *Ram Pressure Stripping and Gravitational Interactions in Groups and Clusters*
Authors: *Jeffrey Kenney*

Abstract: *I review the observational evidence for ram pressure stripping in nearby group and cluster galaxies, and the roles of ram pressure stripping, tidal interactions and starvation in cluster galaxy evolution. I describe several diagnostic indicators of active ram pressure, and how to distinguish ram pressure stripping from tidal interactions. Both effects play a significant role in transforming the populations of spirals and dwarfs in the densest regions of the universe.*

Sadegh Khochfar (INVITED TALK)

Title: *Gravity at work: How high density environments regulate galaxy properties*
Authors: *Sadegh Khochfar*

Abstract: *We present results on how the conversion of gravitational potential energy from infalling satellites in high-density environments is able to influence the evolution of galaxies. We focus on the star formation history and formation epoch of galaxies, and show how these can be brought into better agreement with observation once gravitational heating is considered. Gravitational heating has a contribution comparable to that of AGNs, and can provide significant heating at late time in clusters, stopping cooling flows in them. We will show results of a detailed investigation on the magnitude of these effects and the epoch at which they occur.*

Francesco La Barbera (CONTRIBUTED TALK)

Title: *The optical+NIR (grizYJHK) Fundamental Plane of Early-type Galaxies: Dependence on local and global environment*
Authors: *La Barbera, F., Lopes, P.A.A., de Carvalho, R.R., de La Rosa, I.G., Berlind, A.A.*

Abstract: *Using a sample of 39,993 Early-Type galaxies (ETGs) for which data is available from SDSS and UKIDSS, we have undertaken a Spheroid's Panchromatic Investigation in Different Environmental Regions (SPIDER). We focus on the environmental dependence of the optical+NIR Fundamental Plane (FP) relation. The environment is characterized through local (e.g. galaxy density) and global (e.g. parent group mass) observables, using the largest 3D group/cluster catalog generated from SDSS at low redshift ($z<0.1$). We find a strong variation of the FP offset with local density in all wavebands, with the variation depending on the galaxy parent halo mass. A clear environmental dependence of the FP slopes is also detected: the "tilt" of the FP is larger for groups relative to field ETGs, and the variation of FP slopes with waveband depends on the galaxy parent halo mass. These results provide important clues for the galaxy evolution scenario, as they constrain the variation of stellar population properties, and dynamical-to-stellar mass fraction, as a function of galaxy mass.*

Ewa Lokas (CONTRIBUTED TALK)

Title: *The grouping, merging and tidal stirring of dwarf galaxies in the Local Group*
Authors: *Ewa Lokas*

Abstract: *I will present the results of a study of the evolution of a population of subhaloes in a simulated Local Group from the point of view of the effects it may have on the origin of different types of dwarf galaxies. I will focus on the processes of tidal stripping of the satellites, their interaction, merging and grouping. The tidal stripping manifests itself in the transition between the phase of mass accretion and mass loss seen in most subhaloes, which occurs at the moment of infall on to the host halo, and the change of the shape of their mass function with redshift. Although the satellites often form groups, they are loosely bound within them and do not interact with each other. Mergers between prospective subhaloes are significant only during an early stage of evolution but such events could*

contribute to the formation of more distant early-type Milky Way companions. I will also describe high resolution simulations of individual two-component dwarf galaxies with a disk evolving in the tidal field of the Milky Way and mergers of disky dwarfs. I will demonstrate that both can lead to the formation of dwarf spheroidal galaxies by morphological transformation of their stellar components and the transition from ordered to random motion of the stars.

Gary Mamon (CONTRIBUTED TALK)

Title: *The line-of-sight velocity modulation of star formation diagnostics in and near galaxy clusters: observations and theory*
Authors: *Gary Mamon, Smriti Mahajan & Somak Raychaudhury*

Abstract: *Analyzing diagnostics of recent star formation of galaxies around 268 clusters with SDSS data, we show that the trends of decreasing star formation with increasing projected radius are modulated by the absolute line-of-sight velocity. We then deproject the fraction of recent starburst galaxies (RSBGs) and use cosmological simulations to calibrate models involving virial, infall and backsplash populations to explain the observed velocity modulation of the radial trends. Our analysis provides us a quantitative measure of how star formation is quenched during the first passage through a cluster.*

Amata Mercurio (CONTRIBUTED TALK)

Title: *ACCESS: NIR luminosity function and stellar mass function of galaxies in the Shapley supercluster environment*
Authors: *Mercurio A., Merluzzi P., Haines C. P., Busarello G., Smith R. J., Lucey J. R.*

Abstract: *I will present the near-infrared luminosity and stellar mass functions of galaxies in the core of the Shapley supercluster at z=0.048 based on the K-band observations carried out at the United Kingdom Infra-Red Telescope with the Wide Field Infrared Camera in conjunction with B- and R-band photometry from the Shapley Optical Survey. I will examine environmental effects on galaxy properties, showing both luminosity (LF) and stellar mass functions (SMF) in three regions selected according to the local galaxy density. This analysis is part of a science project ACCESS (http://www.oacn.inaf.it/ACCESS/) aimed to identify and understand which physical mechanisms are responsible of galaxy evolution as function of galaxy mass and environment in the Shapley supercluster. We have found a significant increase in the faint-end slope going from high-density to low-density environments, while a faint-end upturn at $M_K > -21$ becomes increasingly apparent in the lower density regions. The SMF of supercluster galaxies is characterized by an excess of massive galaxies that are associated with the brightest cluster galaxies. While the value depends on the environment, increasing by 0.2dex from low- to high-density regions, the slope of the galaxy SMF does not vary with the environment. By comparing our findings with cosmological simulations, we conclude that the environmental dependences of the LF are not primarily due to variations in the merging histories, but to processes which are not treated in the semi-analytical models, such as tidal stripping or harassment. In field regions, the SMF shows a sharp upturn below , close to our mass limit, suggesting that the upturns seen in our K-band LFs, but not in the SMF, are due to this dwarf population. The environmental variations seen in the faint end of the K-band LF suggest that these dwarf galaxies, which are easier to strip than their more massive counterparts, are affected by*

tidal/gas stripping upon entering the supercluster environment.

Paolo Serra (CONTRIBUTED TALK)

Title: *Neutral hydrogen in early-type galaxies: the importance of environment*
Authors: *Paolo Serra and the Atlas3D team*

Abstract: *I will present the result of a large observational campaign to observe neutral hydrogen (HI) in the volume limited Atlas3D sample of nearby early-type galaxies. Observations were made with the Westerbork telescope, and are establishing the HI properties of early-type galaxies with an unprecedented combination of depth, angular resolution and statistics. We find that ~50% of all early-type galaxies outside the Virgo cluster contain HI (in striking contrast with the ~0% detection rate known to hold inside Virgo). Of these, about half host regular, rotating HI discs/rings, which can be concentrated inside the stellar body of the galaxy or extended up to tens of stellar effective radii. Regular HI distributions are found mostly in galaxies living in very low-density environments, while early-type galaxies living in intermediate environments (e.g., galaxy groups) are characterised by disturbed HI morphology, indicative of recent and on-going gas stripping/accretion. I will discuss the lessons that neutral hydrogen can teach us about the formation and evolution of these galaxies in different environments.*

David Sobral (CONTRIBUTED TALK)

Title: *From poor fields to rich clusters: the detailed role of the environment on galaxy formation and evolution at z~1*
Authors: *David Sobral, Philip Best, Ian Smail, Jim Geach, Michele Cirasuolo, HiZELS collaboration*

Abstract: *At z=0, clusters are primarily populated by red, elliptical and massive galaxies, while star-forming, spiral and lower-mass galaxies are common in low-density environments. Understanding how and when these differences were established is of absolute importance for our understanding of galaxy formation and evolution, but, currently, and despite some progress, results at high-z remain contradictory. By taking advantage of the widest and deepest HI narrow-band survey at z~1 over the COSMOS and UKIDSS UDS fields, we will detail how star-formation activity, morphology, colour, downsizing trends and the HI luminosity function depend on environment over the full range of local densities at z~1 (from poor fields to rich groups and clusters, including a confirmed super-cluster with a striking filamentary structure) and show that previously contradictory results can be completely reconciled by probing such a wide range of environments and, most importantly, by understanding the important inter-relations between environment, stellar mass, merging activity and colour at z~1.*

Daniel Thomas (CONTRIBUTED TALK)

Title: *Environment and self-regulation in galaxy formation*
Authors: *D. Thomas, C. Maraston, K. Schawinski, M. Sarzi, J. Silk*

Abstract: *The environment is known to affect the formation and evolution of galaxies considerably best visible through the well-known morphology-density relationship. In this paper we study the effect*

of environment on the evolution of early-type galaxies by analysing the stellar population properties of 3,360 galaxies morphologically selected by visual inspection from the SDSS in the redshift range 0.05<z<0.06. We find that the distribution of ages is bimodal with a strong peak at old ages and a secondary peak at young ages around ~ 2.5Gyr containing about 10 per cent of the objects. This is analogue to 'red sequence' and 'blue cloud' identified in galaxy populations usually containing both early and late type galaxies. The fraction of the young, rejuvenated galaxies increases with both decreasing galaxy mass and decreasing environmental density up to about 45%. The rejuvenated galaxies have lower alpha/Fe ratios than the average and most of them show signs of ongoing star formation through their emission line spectra. All objects that host AGN in their centres without star formation are part of the red sequence population. We confirm and statistically strengthen earlier results that luminosity weighted ages, metallicities, and alpha/Fe element ratios of the red sequence population correlate well with velocity dispersion and galaxy mass. Most interestingly, however, these scaling relations are not sensitive to environmental densities and are only driven by galaxy mass. We infer that early-type galaxy formation has undergone a phase transition a few billion years ago around z~0.2. A self-regulated formation phase without environmental dependence has recently been superseded by a rejuvenation phase, in which the environment plays a decisive role possibly through galaxy interactions.

Sheona Urquhart (CONTRIBUTED TALK)

Title: *An environmental Butcher-Oemler effect in intermediate redshift X-ray clusters*
Authors: *Sheona Urquhart, Jon Willis, Henk Hoekstra*

Abstract: *For a sample of 66 X-ray selected galaxy clusters with well determined X-ray temperatures spanning the range 1<kT(keV)<12, we present uniform CFHT Megacam g and r photometry. These clusters occupy the redshift interval 0.04<z<0.41. We investigate the colour bimodality of the cluster galaxy populations and compute blue fractions using the criteria derived from Butcher and Oemler (1984). We identify a clear environmental dependence of cluster blue fraction in that cool (low mass) clusters display higher blue fractions than hotter (higher mass) clusters. Also computed is the local galaxy density using the fifth nearest neighbour distance as a measure of local environment. In doing this, the effects of the global environment (ram pressure stripping) can be compared with those of the local environment (galaxy-galaxy interactions).*

Rien van de Weygaert (CONTRIBUTED TALK)

Title: *The Void Galaxy Survey*
Authors: *Rien van de Weygaert, Kathryn Stanonik, Erwin Platen, Burcu Beygu, Jacqueline van Gorkom, Thijs van der Hulst, Miguel Aragon-Calvo, et al.*

Abstract: *The void galaxy survey consists of a multiwavelength - optical, infrared, ultraviolet and radio-observational study of void galaxies. The galaxies are located in the deepest troughs of voids that were identified from the SDSS DR7 survey sample. The identification is uniquely based on a pure (tessellation-based) geometric procedure, guaranteeing an objective census of the void galaxy population in the nearby Universe. The aim of the project is to compare the physical intrinsic properties of void galaxies and to assess in how far they differ from the regular field population in terms of morphology, brightness, colour, star formation activity and (HI) gas content and morphology.*

With these galaxies living in the most pristine regions in the local Universe, the survey will yield essential insights on the first stages of galaxy formation and on environmental influences on the galaxy formation process. In this presentation, we will present the first results of our program. This will involve a discussion of the finished pilot program of 15 galaxies, along with some of the unique constellations we have encountered. Amongst others, special attention will be devoted to the polar ring galaxy we have found in a tenuous wall between voids and on the elongated group of three void galaxies. Also, we report on the recent finding of a constellation of three void galaxies within the deep interior of a void, one surrounded by stellar streams, embedded within a common highly elongated mantle of neutral hydrogen.

Simone Weinmann (INVITED TALK)

Title: *The dependence of galaxy properties on environment at low redshift*
Authors: *Simone Weinmann*

Abstract: *It has long been known that galaxy properties depend on local galaxy density, indicating that galaxy evolution progresses differently in different environments. Thanks to the advent of large galaxy survey, this dependency can now be quantified in detail. I will report on results from the SDSS combined with cluster and group catalogues, which allow us to parameterize environment in terms of group mass and group-centric radius instead of local density. Comparing galaxies in different environments at fixed stellar mass helps us to understand how exactly environment impacts on star formation rates, colours, metallicities and morphologies. I will explain why new results seem to indicate that galaxy structure, as measured by concentration or bulge-to-total ratio, is in fact independent on environment, and that previous results that indicated the opposite mainly come from comparing galaxies at different stellar masses, and from the use of morphological indicator that depend on star formation rates. Finally, I will argue that all environmental effects seen at galaxy masses greater than around $5x10^9$ M_o can be explained by "starvation", and that more violent mechanisms like ram-pressure stripping of the cold gas in the galaxy are less important.*

Eric Wilcots (CONTRIBUTED TALK)

Title: *The Symbiotic Relationship Between the Environment and Evolution of Galaxies in Groups*
Authors: *Eric M. Wilcots, Malanka Riabokin*

Abstract: *The vast majority of galaxies reside in groups and it is becoming increasingly clear that much of the transformation of galaxies occurs in groups prior to their infall into larger clusters. We report on the results of a radio survey that shows how the evolution of the group environment influences the evolution of the resident galaxies and how feedback resulting from the evolution of individual galaxies influences their larger environment. We also show that the onset and impact of feedback in groups is itself a function of the environment.*

David Wilman (CONTRIBUTED TALK)

Title: *The origin of the morphology-density relation*
Authors: *David Wilman, Gabriella de Lucia, John Mulchaey*

Abstract: *The origin of the morphology-density relation is one of the longest standing puzzles in extragalactic astronomy, predating even Dressler's 1980 quantification of the z=0 relation in galaxy clusters. A number of important questions can be asked:*
** Why do most galaxies with insignificant levels of star formation also contain massive pressure-dominated stellar systems (ellipticals or massive bulges in S0s)?*
** How do we explain the relative lack of evolution in the fraction of massive ellipticals since z~1, and their overabundance in high density regions and halo cores?*
** Why do most passive galaxies newly formed since z~0.5 retain their disks as S0s, and why is the S0 fraction - density relation much flatter than for ellipticals, such that they are commonly found in low mass groups?*
** Can we explain the ubiquity of hot halo gas in both ellipticals and S0s in all environments in the context of ICM-ISM interactions?*
We present data supporting the posits behind these questions, and going some way towards answering them: the environmental dependence of morphological types at different redshifts and the morphological dependence of hot halo gas in clusters, groups and field environments. We then present the results from a new recipe for morphological evolution in mergers, inspired by SPH simulations, and applied to a semi-analytical model. This goes some way to explain the origin of the morphology-density relation and the relative importance of the myriad physical processes usually invoked as potential explanations.