STAR FORMATION IN THE MERGING GALAXY CLUSTER
ABELL 3921

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Abstract. Through a combined optical and radio analysis, we have investigated the possible connection between the dynamical state of the merging cluster A3921 and its star formation properties, reaching the conclusion that the on-going merger is triggering a SF episode in the collision region.

1 Introduction

In the past 25 years, optical observations of clusters have revealed an evolution in galaxy properties with redshift. The fraction of star-forming/post-star-forming cluster objects significantly increases with \( z \), going from \( \sim 1-2\% \) in the local Universe (Dressler 1987) to \( \geq 30\% \) at \( z=0.3-0.5 \) (Dressler et al. 1999). In 1978 Butcher & Oemler reported a strong evolution from redder to bluer colours in cluster galaxies, detecting an excess of blue galaxies at \( z=0.5 \) with respect to lower redshift systems. A debate about the physical origin of this effect began: the observed change of galaxy colours with \( z \) could be simply due to a passive evolution of infalling field galaxies, or it could be strongly affected by environmental effects. In 1983 Dressler & Gunn pointed out for the first time that in fact the blue colour of the population detected by Butcher & Oemler was the result of SF activity. Since then, many different studies have tried to understand the origin of the observed evolution in the SF history of cluster galaxies. Several physical mechanisms have been proposed that may either trigger or weaken SF within clusters (e.g. Dressler & Gunn 1983; Evrard 1991; Bekki 1999; Fujita et al. 1999).

The concordant cosmological model (ΛCDM) predicts the formation and evolution of galaxy clusters through mergers of less massive systems. Due to the large
energies involved in cluster-cluster collisions, a merging event can enhance the efficiency of the physical mechanisms responsible for the evolution of the galaxy SFR. The first observational evidence for a correlation between cluster mergers and SF activity came from the optical analysis of Coma, where an excess of SF/PSF galaxies was observed in the collision region between the main cluster and a group of galaxies (Caldwell et al. 1993). While in several other non-relaxed clusters the collision between subclumps seems to have increased the SF rate (SFR) of the galaxies (e.g. Gavazzi et al. 2003), other analyses show the opposite trend (e.g. Baldi et al. 2001). Therefore, the net role played by the merging event on SF has still to be fully understood. In this picture, a combined optical (Maurogordato et al.), X-ray (Sauvageot et al.) and radio (Ferrari et al.) analysis of a sample of nearby clusters ($z \sim 0.09$), covering all the main phases of the collision process, has been undertaken. The main purpose of this project is to determine the dynamical state of the observed clusters and understand if and how the merging process affects the SF history of cluster members. In the following, we will present the first analysis of the radio observations (ATCA; Ferrari et al., in prep.) of the merging cluster A3921 taking into account our previous optical results (Ferrari et al. 2005, Paper I in the following).

2 Dynamical state of Abell 3921

A3921 ($z = 0.094$) is a cluster with a perturbed morphology. Recent optical (Paper I) and X-ray analysis (XMM observations, Belsole et al. 2005) have shown the presence of two dominant clumps of galaxies: a main cluster centred on the BCG (A3921-A), and an NW sub-cluster (A3921-B) hosting the second brightest cluster member. The comparison of the optical and X-ray properties of A3921 suggests that A3921-B is probably tangentially traversing the main cluster along the SW/NE direction (Paper I; Belsole et al. 2005).

3 Star formation properties

The SF properties of the 104 confirmed cluster members in the central field of A3921 ($\sim 1.8 \times 1.2\text{Mpc}^2$) have been investigated by comparing: a) their spectral features (Paper I), and b) their radio luminosities at 1.344 GHz derived from our new ATCA observations (Ferrari et al., in prep). Based on the presence and strength of the $\text{[OII]}\lambda 3727\text{Å}$ and Balmer lines, the galaxies of A3921 have been classified as (Paper I): a) $k$: passive evolving galaxies; b) $k+a$: PSB(post-starburst)/PSF objects; c) emission line galaxies, in turn divided in $e(a)$: dusty-SB and/or PSF galaxies with some residual SF (Poggianti et al. 1999), $e(b)$: SB’s, and $e(c)$: classical spirals. It emerges that the emission-line galaxies (11) share neither the kinematics nor the projected distribution of the passive cluster members. Most of them are spatially concentrated in the collision region of the two subclusters, suggesting a possible connection between the detected merger and the SF activity in A3921 (Paper I).
Table 1. Top: SFR ($M_\odot$yr$^{-1}$ for $M \geq 0.1M_\odot$) of the emission line cluster members measured through their 1.344 GHz and [OII] luminosities. ID’s correspond to Tables A in Paper I. Bottom: 1.344 GHz luminosities (WHz$^{-1}$) and spectral types of the radio emitting galaxies in A3921 central fields, in which no emission lines have been detected.

The radio luminosity is a dust-independent indicators of SFR, while optical emission lines are not. We have therefore analysed the 1.344 GHz emission in the central field of A3921 in order to shed more light on the SF properties of the confirmed cluster members. The SFRs of the 11 emission line galaxies, derived both from their [OII] emission (Kennicutt 1998) and from their radio luminosities (Condon 1992), are summarised in Table 1. At the mean cluster redshift and with our cosmology ($H_0=75$ km/s/Mpc, $\Omega_m = 0.3$ and $\Omega_{\Lambda} = 0.7$), our limit of radio detection at $3\times\text{r.m.s.}$ corresponds to a minimum detectable SFR($M \geq 0.1M_\odot$) of $3.69 M_\odot yr^{-1}$. In Table 1 we also list the radio emitting cluster members that do not show emission features in their spectra. They are all k-type galaxies. No k+a galaxies have detectable radio emission at our flux limit ($3\sigma=0.147$ mJy/beam, beam=$12'' \times 12''$).

4 Discussion and conclusions

- Emission line galaxies: only two have been detected on the 1.344 GHz map. One (#69) is most likely a Seyfert galaxy (radio and X-ray emission, strong [OII] emission); the other (#57) is a classical spiral (typical: spectral properties, SFR, morphology and colour), whose SFR in optical (Table 1) is underestimated, prob-

| ID | RA$_{12000}$ | Dec$_{12000}$ | Spectral Type | SFR$_{[\text{OII}]}$ | SFR$_{1.344 \text{ GHz}}$ |
|----|--------------|---------------|---------------|----------------------|--------------------------|
| 17 | 22 48 58.98  | -64 21 11.80  | e(a)          | 0.70                 | <3.69                    |
| 45 | 22 49 41.46  | -64 26 24.10  | e(c)          | 0.10                 | <3.69                    |
| 57 | 22 48 39.66  | -64 19 22.30  | e(c)          | 0.61                 | 8.78                     |
| 69 | 22 48 49.07  | -64 23 12.00  | e(b)          | 14.09                | 48.79                    |
| 73 | 22 48 34.84  | -64 23 39.90  | e(c)          | 0.64                 | <3.69                    |
| 81 | 22 49 41.10  | -64 24 05.60  | e(a)          | 0.12                 | <3.69                    |
| 82 | 22 49 38.41  | -64 23 23.80  | e(a)          | 0.40                 | <3.69                    |
| 100| 22 49 41.58  | -64 19 59.00  | e(b)          | 1.74                 | <3.69                    |
| 169| 22 50 01.83  | -64 22 21.80  | e(a)          | 0.31                 | <3.69                    |
| 181| 22 49 26.08  | -64 23 21.40  | e(c)          | 0.24                 | <3.69                    |
| 226| 22 49 11.96  | -64 16 03.90  | e(a)          | 0.43                 | <3.69                    |

| ID | RA$_{12000}$ | Dec$_{12000}$ | Spectral Type | logL$_{1.344 \text{ GHz}}$ |
|----|--------------|---------------|---------------|---------------------------|
| 39 | 22 50 06.48  | -64 24 41.90  | k             | 24.07                     |
| 41 | 22 49 58.18  | -64 25 48.10  | k             | 22.28                     |
| 52 | 22 49 04.78  | -64 20 35.60  | k             | 23.89                     |
| 71 | 22 48 43.36  | -64 23 53.10  | k             | 21.28                     |
| 94 | 22 49 58.14  | -64 20 05.80  | k             | 22.10                     |
ably due to dust obscuration. The remaining (9) emission line galaxies are located in the centre of the cluster, and they have a SFR$_{[OII]}$ much lower than the minimum SFR detectable with our radio observations. Since none of them has actually been detected at radio wavelengths, we confirm their low SFR (<3.7 $M_\odot$yr$^{-1}$) without bias due to dust obscuration. Therefore they could be gas-poor galaxies with very weak SF. This would confirm our hypothesis of Paper I, i.e. not all the SF galaxies in the collision region of A3921 are infalling, gas-rich field galaxies. They could be really located at the cluster centre (and not seen in projection), and their ongoing SF could have been refuelled by the cluster merger.

- k+a galaxies: non-detection at radio wavelengths confirms that they are PSF galaxies.

- Radio emitting galaxies without emission lines: their radio luminosities and spectral types suggest that their radio emission is probably due to a central AGN, rather than to SF$^1$. Among them, one (#41) is associated with the BCG; one, with a distorted radio morphology, to the second BCG (#52); one is located at the cluster centre (#39), and it shows a head-tail morphology possibly associated to the relative motion of the radio source with respect to the dense ICM.

We therefore conclude that SF has been triggered in a fraction of cluster galaxies located in the collision region of A3921.

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$^1$The faintest source (#71) could be either a weak AGN or a SF galaxy (obscured by dust in optical).