A catalogue of local E+A (post-starburst) galaxies selected from the Sloan Digital Sky Survey Data Release 5

Tomotsugu Goto

Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan

Accepted 2007 July 11. Received 2007 June 15; in original form 2007 February 1

ABSTRACT

E+A galaxies have been interpreted as post-starburst galaxies, based on the presence of strong Balmer absorption lines combined with the absence of major emission lines ([O II] or Hα). As a population of galaxies in the midst of transformation, E+A galaxies have been subject to intense research activity. However, it has been difficult to investigate E+A galaxies statistically, as they are extremely rare (<1 per cent of all galaxies in the local Universe). In this paper, we present a large catalogue of 564 E+A (post-starburst) galaxies, carefully selected from half a million spectra from the Sloan Digital Sky Survey Data Release 5. We define E+A galaxies as galaxies with an Hδ equivalent width of >5 Å and no detectable emission in [O II] and Hα. The catalogue contains 564 E+A galaxies, and is thus one of the largest of its kind to date. In addition, we have included the Hα line in the selection in order to remove dusty star-forming galaxies, which could have contaminated previous [O II]-based samples of E+A galaxies by up to 52 per cent. Thus, the catalogue is one of the most homogeneous, as well as one of the largest. The catalogue presented here can be used for follow-up observations and statistical analyses of this rare population of galaxies.

Key words: galaxies: evolution – galaxies: formation – galaxies: interactions – galaxies: peculiar – galaxies: starburst.

1 INTRODUCTION

While investigating high-redshift cluster galaxies, Dressler & Gunn (1983, 1992) found galaxies with mysterious spectra. These galaxies had strong Balmer absorption lines with no emission in [O II]. They were called ‘E+A’ galaxies, as their spectra looked like a superposition of those of elliptical galaxies (Mg 5175, Fe 5270 and Ca 3934,346 absorption lines) and of A-type stars (strong Balmer absorption lines).1 The existence of strong Balmer absorption lines shows that these galaxies have experienced starburst recently (within a gigayear; Goto 2004). However, these galaxies do not show any sign of ongoing star formation, as non-detection in the [O II] emission line indicates. Therefore, E+A galaxies have been interpreted as post-starburst galaxies (i.e. galaxies that have truncated starburst suddenly; Dressler & Gunn 1983, 1992; Couch & Sharples 1987; MacLaren, Ellis & Couch 1988; Newberry, Boroson & Kirshner 1990; Fabricant, McClintock & Bautz 1991; Abraham et al. 1996; Dressler et al. 1999, 2004; Poggianti et al. 1999; Goto et al. 2003a; Goto et al. 2004, 2005, 2007). However, the reason why these galaxies started starburst and abruptly stopped starburst remains one of the mysteries of galaxy evolution.

One of the major difficulties in investigating E+A galaxies has been their rarity; less than 1 per cent of galaxies are in the E+A phase in the present Universe (Goto et al. 2003a). In this paper, we solve this problem by creating a large catalogue of 564 E+A galaxies, carefully selected from the fifth public data release (DR5) of the Sloan Digital Sky Survey (SDSS; Adelman-McCarthy et al. 2006). In addition to its size, because of the availability of the information on the Hα line, this catalogue is one of the most homogeneous of its kind, removing the contamination from Hα emitting galaxies. The catalogue is publicly released2 so that researchers worldwide can use it for statistical analyses and follow-up observations in various wavelengths. Unless otherwise stated, we adopt the best-fitting Wilkinson Microwave Anistropy Probe (WMAP) cosmology: (Ωm, ΩΛ) = (0.71, 0.27, 0.73) (Bennett et al. 2003).

2 CATALOGUE

2.1 Selection

Our new catalogue of 564 E+A galaxies is based on the SDSS DR5 (Adelman-McCarthy et al. 2006). This is the final data release of the

1 Because some E+A galaxies are found to have disc-like morphology (Couch et al. 1994; Dressler et al. 1994; Caldwell & Rose 1997; Dressler et al. 1999), these galaxies are sometimes called ‘K+A’ galaxies. However, Goto (2003) found that the E+A sample with higher completeness has an early-type morphology, and following this discovery, we call these ‘E+A’ galaxies in this paper.

with $H_\beta$; see Goto 2006; Yagi, Goto & Hattori 2006). The 564 $E^+$ galaxies span a redshift range of $0.0327 \leq z \leq 0.3421$, within which the $H_\alpha$ line is securely covered by the SDSS spectrograph. Among 451 759 galaxies which satisfy the redshift and S/N criteria from galaxies with detectable $H_\alpha$ emission, we have found 564 $E^+$ galaxies from the 2dF using only Balmer and [O II] lines, and found that some $E^+$ galaxies in their sample had the $H_\alpha$ line in emission. When the $H_\alpha$ line is not available for $E^+$ selection, because $H_\beta$ and $H_\gamma$ absorption features are subject to emission filling, Blake et al. (2004) suggested that using three Balmer absorption lines ($H_\beta$, $H_\gamma$ and $H_\delta$) can suppress the contamination from galaxies with detectable $H_\alpha$ emission.

### 2.2 Catalogue of 564 $E^+$ Galaxies

Among 451 759 galaxies which satisfy the redshift and S/N criteria with measurable [O II], $H_\beta$ and $H_\alpha$ lines, we have found 564 $E^+$ galaxies. This is one of the largest samples of $E^+$ galaxies to date. The 564 $E^+$ galaxies spans a redshift range of $0.0327 \leq z \leq 0.3421$, within which the $H_\alpha$ line is securely covered by the SDSS spectrograph.

In Fig. 4, we show four example spectra of $E^+$ galaxies with a strong $H_\alpha$ EW of 8.62–9.27 Å. The corresponding $g$, $r$, $i$-composite images are shown in Fig. 5.
3 DISCUSSION

3.1 Redshift distribution

In Fig. 6, we show the redshift distribution of the E+A galaxies. The median redshift is \( z = 0.138 \).

There is a possible peak at the lowest redshift bin (\( z \sim 0.04 \)). The reason for the peak is not certain. We have checked all the images of the \( z < 0.05 \) E+A galaxies by eye to find that all of them show strong H\( \delta \) absorption. This confirms that our selection criteria work properly. However, we suspect that the aperture bias may be one of the causes; the SDSS fibre spectrograph only samples the light within the inner 3 arcsec (Strauss et al. 2002). This does not bring a large bias into the distant E+A galaxies, whose sizes are smaller (the median Petrosian 50 per cent radius of our sample is 1.44 arcsec), but it does bring a large aperture bias to nearby E+A galaxies because of their large apparent size. At \( z \sim 0.04 \), the median physical size (taken from the Petrosian 50 per cent light radius) of E+A galaxies is 2.0 arcsec, whereas the 3-arcsec fibre only collects the light from the inner 1.5 arcsec of radius. In Fig. 7, we plot the ratio of the Petrosian 50 per cent light radius to the fibre radius (1.5 arcsec) as a function of redshift. The figure shows that at \( z \sim 0.04 \), there is a significant number of E+A galaxies a few times larger than the fibre size. Therefore, we recommend the use of a low-redshift cut (e.g. \( z > 0.05 \); see also Gómez et al. 2003; Goto et al. 2003b) when a statistical analysis is performed on the sample.

These nearby E+A galaxies may have remaining star-formation activity outside the 3-arcsec fibre. Nevertheless, it is also true that these galaxies have a post-starburst stellar population within the 3 arcsec of radius. It is still important to investigate what caused the central post-starburst in these galaxies, and thus we keep these nearby E+A galaxies in our sample. Because of their larger apparent size, these E+A galaxies are suitable targets for spatially resolved observations (e.g. Yagi et al. 2006; Yagi & Goto 2006).

In Fig. 8, we show four example spectra of E+A galaxies with a large apparent size of the Petrosian 90 per cent radius of \( > 14 \) arcsec. These E+A galaxies are large enough for detailed morphological/substructural studies. The corresponding \( g, r, i \)-composite images are shown in Fig. 9. There is a hint of possible dynamical disturbances in all four galaxies shown here.

3.2 E+A galaxies in the high-redshift Universe

Our catalogue of E+A galaxies provides us with a useful benchmark for studying the evolution of E+A galaxies in the higher-redshift Universe. Previously, it was found that cosmic star formation density was higher at \( z > 1 \) (Madau et al. 1996). According to Le Borgne et al. (2006), the fraction of the post-starburst galaxies was larger...
Figure 5. Examples of $g$, $r$, $i$-composite images of four E+A galaxies with H$\delta$ EW $>$ 7Å. The images are sorted from low to high redshift. Only the 24 lowest-redshift E+A galaxies are shown. The corresponding spectra are presented in Fig. 4 with the name and redshift. (The spectrum of the same galaxy can be found in the same column/row panel of Fig. 4.)

Figure 6. Redshift distribution of the E+A galaxies.

Figure 7. The ratio of the physical galaxy size (taken from the Petrosian 50 per cent light radius) to the SDSS fibre size is shown as a function of redshift for the E+A galaxies.
Figure 8. Example spectra of four E+A galaxies with the largest Petrosian 90 per cent light radii (>14 arcsec). Each spectrum is shifted to the rest-frame wavelength and smoothed using a 20-Å box. The corresponding images are shown in Fig. 9. (The image of the same galaxy can be found in the same column/row panel of Fig. 9.)

by a factor of 2 at $z \sim 1$ (also see Roseboom et al. 2006). By comparing the fraction of E+A galaxies at different redshifts, we can trace cosmic star formation history in terms of post-starburst galaxies.

In high-redshift cluster environments, E+A galaxies are much more numerous. Pioneering work has been carried out by Dressler et al. (1999) and Poggianti et al. (1999), who found that E+A galaxies ($H\delta$ EW > 3 Å and no detectable emission in [O II]) are significantly more common in 10 clusters at 0.37 < $z$ < 0.56 than in the field (21 ± 2 per cent compared with 6 ± 3 per cent). Later, Tran et al. (2003) found 7–13 per cent of E+A galaxies in three high-redshift clusters at $z = 0.33, 0.58$ and $0.83$, claiming that $>30$ per cent of E+S0 members may have undergone the E+A phase if the effects of E+A downsizing and increasing E+A fraction as a function of redshift are considered; their selection criteria were ($H\delta$EW + $H\gamma$EW)/2 > 4 Å and [O II] EW > −5 Å. In their search for field E+A galaxies among 800 spectra, Tran et al. (2004) measured the E+A fraction at $0.3 < z < 1$ to be 2.7 ± 1.1 per cent, a value lower than that in galaxy clusters at comparable redshifts.4

Taken together with the much smaller fraction of E+A galaxies in the local field, the sudden increase of fractions in distant clusters over all other environments suggests that there is something unique to this time and environment that gives rise to so many E+A galaxies. It is also important to note that E+A galaxies may have heterogeneous origins; in the local Universe, E+A galaxies are preferentially found in the rarefied field regions, whereas at higher redshift E+A galaxies are found in the cluster environment. Considering the large difference in time and environment, E+A galaxies in the local field and high-redshift clusters may have been created by different physical mechanisms. For example, Goto (2005) has shown that local ($z \sim 0.1$) E+A galaxies have more close companion galaxies than average galaxies, showing that the dynamical merger/interaction could be the physical origin of E+A galaxies. However, most E+A galaxies in high-redshift clusters are known not to be major mergers (Dressler et al. 1999).

3.3 Selection criteria of E+A galaxies

We used the selection criteria of $H\delta$EW > 5 Å, $H\alpha$ EW < −3.0 Å and [O II] EW < −2.5 Å to select 564 E+A galaxies (Section 2). However, we caution readers that the number (or fraction) of the selected E+A galaxies strongly depends on the selection criteria. For example, if we relax our criteria to $H\delta$ EW > 4 Å, the number of E+A galaxies increases to 1062 (almost twice as many). With $H\delta$ EW > 3 Å, 2298 E+A galaxies are selected (four times more

4 Note that Balogh et al. (1999) found smaller E+A fractions of 1.5 ± 0.8 per cent in high-redshift clusters ($z \sim 0.25$). However, there has been controversy about whether there is a discrepancy in the fraction of E+A galaxies in high-redshift clusters. See section 5.1 of Dressler et al. (2004) for a detailed discussion.
Figure 9. Examples of $g$, $r$, $i$-composite images of E+A galaxies with the largest Petrosian 90 per cent light radii (>14 arcsec). The corresponding spectra are presented in Fig. 8 with the name and redshift. (The spectrum of the same galaxy can be found in the same column/row panel of Fig. 8.)

Therefore, when comparing samples of E+A galaxies selected from different data sets, it is important to synchronize the selection criteria. Especially, when comparing to a sample at higher redshift, an inconsistency in the selection criteria can produce spurious evolutionary effects.

4 SUMMARY

We have constructed one of the largest catalogues of 564 local E+A (post-starburst) galaxies, carefully selected from the SDSS DR5. The sample is a useful tool for investigating the statistical properties and/or for follow-up observations of this rare, but important population of galaxies.

ACKNOWLEDGMENTS

We are grateful to the referee, Professor A. Dressler, for many insightful comments that improved the paper significantly. We thank Dr M. Yagi, and C. Yamauchi for useful discussions.

The research was financially supported by the Sasakawa Scientific Research Grant from the Japan Science Society.

This research was partially supported by the Japan Society for the Promotion of Science through Grant-in-Aid for Scientific Research 18840047.

Funding for the creation and distribution of the SDSS Archive has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the United States Department of Energy, the Japanese Monbukagakusho, and the Max Planck Society. The SDSS website is http://www.sdss.org/.

The SDSS is managed by the Astrophysical Research Consortium (ARC) for the Participating Institutions. The Participating Institutions are the University of Chicago, Fermilab, the Institute for Advanced Study, the Japan Participation Group, Johns Hopkins University, Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, University of Pittsburgh, Princeton University, the United States Naval Observatory and the University of Washington.
REFERENCES

Goto T. et al., 2003a, PASJ, 55, 771

This paper has been typeset from a TeX/LaTeX file prepared by the author.