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Determining the average SFR of K+A galaxies

Danielle M. Nielsen[1], **Roberto de Propris**[2], **Susan E. Ridgway**[3] **and Tomotsugu Goto**[4]

[1]Dept. of Astronomy, University of Wisconsin – Madison
475 N. Charter Street, Madison, WI 53706, USA

[2]Cerro Tololo Inter-American Observatory, La Serena, Chile

[3]National Optical Astronomy Observatory,
950 N. Cherry Avenue, Tucson, AZ 85719, USA

[4]Subaru Telescope, Hilo, HI, USA

email: nielsen@astro.wisc.edu

Abstract. We stack FIRST survey cutout images of 811 K+A galaxies to derive a mean 1.4 GHz radio image of our sample from which we measure a mean K+A flux density of 56 μJy. We carry out Monte Carlo simulations by randomly selecting radio-quiet white dwarfs to create 10,000 stacks equivalent to our K+A stack. From the measured fluxes of these stacks, we establish a 5σ detection limit of 43 μJy for stacked images. For the average redshift of our sample, we find an mean star formation rate of $\sim$1.7 $M_\odot$ yr^{-1}. We split the sample by age and find a mean radio flux of 60 μJy, which corresponds to a star formation rate of 1.6 $M_\odot$ yr^{-1}, for galaxies with starburst ages less than 250 Myr.

Keywords. galaxies: starburst, radio continuum

1. Introduction

Named for their spectra when discovered, K+A galaxies looked like a K-giant with strong Balmer absorption lines. These galaxies have been classified as post-starburst galaxies as the presence of Balmer absorption lines, and the lack of [OII] and Hα emission lines imply an abrupt truncation of a recent episode of star formation (Dressler & Gunn 1983). K+A galaxies were first discovered in intermediate redshift clusters where many galaxies are found to have star formation highly obscured by dust (Dressler *et al.* 2007). We determine the current star formation rate (SFR) of K+A galaxies to test this scenario.

2. K+A sample & data

We draw a sample of 811 K+A galaxies from the updated catalog of Goto (2007) assembled from DR7 of the SDSS. The redshifts of our sample range from $0.02 < z < 0.4$. Our data are drawn from the Faint Images of the Radio Sky at Twenty Centimeters (FIRST) survey (Becker *et al.* 1995); for each galaxy, we extract a $1'$ cutout from the FIRST database.

3. Radio stacking & Monte Carlo simulation

Many of our sources are too faint to be detected by the FIRST survey (detection limit $\sim$1 mJy), therefore we stack FIRST cutouts of K+A galaxies to create an average radio image of our sample (see White *et al.* 2007). This average K+A galaxy image is shown

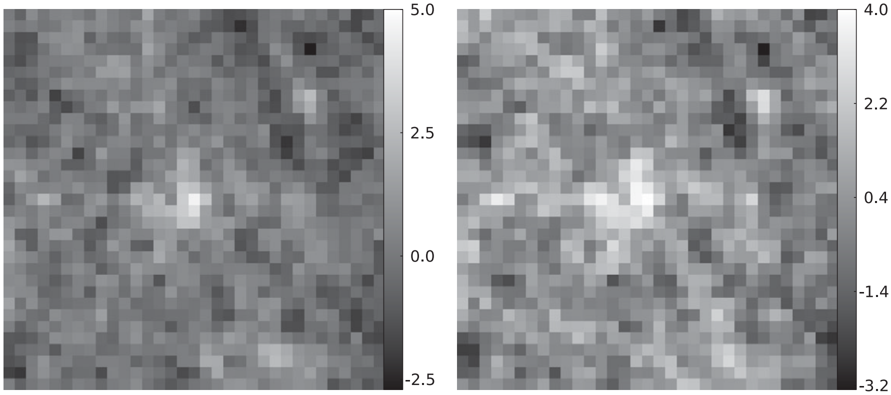

Figure 1. Stacked images of K+A galaxies, greyscale units are in μJy. *Left:* full sample of 811 galaxies. *Right:* 456 K+A galaxies with burst ages less than 250 Myr.

on the left in Fig. 1. We measure the flux in an aperture equivalent to the FIRST beam and find the mean radio flux of K+A galaxies to be 56 μJy.

We estimate the noise of stacked FIRST images with a Monte Carlo simulation. From a catalog of 8,495 white dwarfs – known radio-quiet sources – we create 10,000 stacks of 811 randomly selected white dwarfs (equivalent to the stack of K+A galaxies). We then measure the fluxes of these stacks as before, from which we derive a 5σ detection limit of 43 μJy for our stacked image, thus our average K+A image yields a significant detection.

4. Star formation rate

From the mean 1.4 GHz flux, we calculate the absolute luminosity for the average redshift of our sample, $z = 0.143$. The absolute luminosity can then be converted to a SFR (Yun *et al.* 2001).

$$L_{1.4GHz} = 4\pi D_L^2 S_{1.4GHz}(1+z)^{\alpha}/(1+z), \tag{4.1}$$

$$\text{SFR } (\text{M}_{\odot}\ \text{yr}^{-1}) = 5.9 \times 10^{-22} L_{1.4GHz}, \tag{4.2}$$

For our average K+A galaxy, we find a SFR of 1.7 $\text{M}_{\odot}\ \text{yr}^{-1}$.

5. Selecting "young" sources

Although the full sample shows a low average SFR, we note that there are galaxies with significant detections for a single FIRST image. We find 82 galaxies with fluxes in excess of a 3σ detection (435 μJy); 31 galaxies have fluxes in excess of a 5σ detection (725 μJy). The corresponding SFR calculation for these galaxies ranges from 0.45 to 2,000 $\text{M}_{\odot}\ \text{yr}^{-1}$ indicating another source of 1.4 GHz emission for some galaxies.

To determine if K+A galaxies that have experienced a starburst more recently have greater 1.4 GHz fluxes, we select a subsample of 456 "young" K+A galaxies with burst ages less than 250 Myr and perform the same analysis. Ages are determined from Fig. 2 in which we plot Hδ and D4000 against models from GALAXEV (Bruzual & Charlot 2003). In Fig. 2, galaxies with fluxes in excess of 435 μJy are plotted as filled squares.

Again, we stack this subsample of 456 galaxies (shown on the right in Fig. 1) and find a mean flux of 61 μJy. The Monte Carlo simulation gives a 5σ detection of 58 μJy. Therefore, our subsample is found to be at the detection limit. This flux yields an average SFR of 1.6 $\text{M}_{\odot}\ \text{yr}^{-1}$.

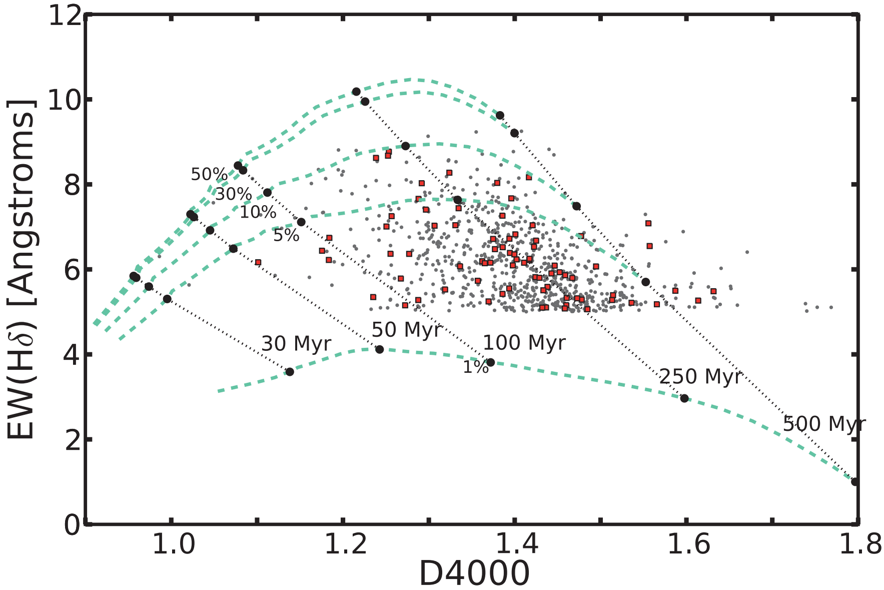

Figure 2. We plot Hδ and D4000 and overplot models to find starburst ages. Dashed lines indicate model galaxies evolved over 10 Gyr with an instantaneous starburst of mass 1, 5, 10, 30 and 50%. The dotted lines indicate 30, 50, 100, 250 and 500 Myr after the burst. Galaxies with 1.4 GHz fluxes greater than 435 μJy are plotted as filled squares and galaxies with less plotted as grey dots.

6. Discussion

We find an average SFR of 1.7 $M_\odot$ yr^{-1} for K+A galaxies. However we find there are individual galaxies with significant (>435μJy) 1.4 GHz detections. The population of galaxies with detections does not correspond to the subsample of "young galaxies which have experience starbursts in the past 250 Myr. Instead this population displays a range of burst ages comparable to that of the full sample. We found the average SFR of galaxies with recent starbursts to be 1.7 $M_\odot$ yr^{-1}.

Our average SFR agrees well with previous work of Goto (2004): for 15 of the nearest K+A galaxies, he found an upper limit of <15 $M_\odot$ yr^{-1}.

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