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Stellar Populations in the Antennae (NGC 4038/9): Exploring a Galaxy Merger Pixel By Pixel

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Abstract. We use B, V, and K-band images of the Antennae in a detailed analysis of its stellar populations. Significant large and small-scale spatial variations in the stellar populations are found by examining images pixel by pixel. Flux ratio, or linear color, diagrams allow us to find the stellar populations present in each pixel using a novel technique. This is done through a comparison of the colors of pixels to those of well-studied populations such as elliptical/S0 galaxies, Magellanic Cloud clusters, and Sc galactic nuclei, in addition to stellar population models. This technique allows us to study not only star clusters, but also the diffuse light present in the Antennae. From these flux-ratio diagrams, a luminosity-weighted de-reddened age image of the Antennae is constructed. Our analysis technique complements and extends results based on Hubble Space Telescope images.

1. Stellar Populations

The Antennae (NGC 4038/39) is a well-known example of a strongly interacting pair of spiral galaxies viewed nearly face-on. This favorable geometry allows us to examine the stellar populations in the disks of these galaxies without confusion due to inclination or heavy dust obscuration as seen in more advanced mergers. We have acquired high-quality optical and near-infrared photometry of the Antennae as part of the OSU Bright Galaxy Survey (Frogel et al. 1996), and are using these data to examine the star formation history in the Antennae on a pixel-by-pixel basis.

Each pixel in images of the Antennae will be composed of either a purely old population like that in E/S0 galaxies, a young population with a range of ages from a current starburst to a few Gyr, or some combination of the two. IR and optical colors provide a natural way to sort out these populations, as demonstrated by the work of Frogel (1985). We have adopted observations of E/S0 galaxies from Persson, Frogel, & Aaronson (1979) as templates for the old population, and Magellanic Cloud (MC) clusters with a range of ages as templates for the younger populations. These are shown in Figure 1a, where we plot these data on a linear color-color diagram (F_B/F_V corresponds to $B-V$, while F_K/F_V corresponds to $V-K$). E/S0 data are plotted as open circles, and a box is drawn around them. The MC clusters are plotted as filled triangles; they form a sequence in age. A line is fit through them. A Bruzual & Charlot

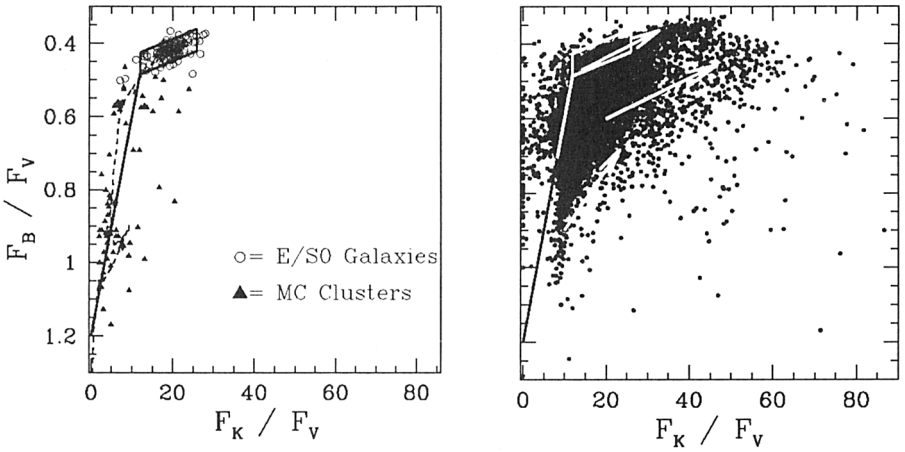

Figure 1. E/S0 galaxies and MC cloud clusters are plotted in Figure 1A. A box is fit around the E/S0 galaxies; and a line is fit through the MC clusters. A BC96 model for solar metallicity is plotted with a short dashed line. In Figure 1B, pixels from the Antennae, reddening vectors for A_V of 1.0, the line fit through the MC clusters, and the box fit around the E/S0 galaxies are plotted.

(1996) model for a single stellar population using a delta function burst, Salpeter initial mass function, and solar metallicity is plotted in alongside the MC line in Figure 1a. Each point along the MC cluster line is assigned an age corresponding to the nearest point on this stellar population model.

Data for the Antennae are plotted in Figure 1b. To assign a relative age to a given pixel, we examine where the pixel's color lands relative to the E/S0 and MC cluster loci. Pixels from the Antennae which lie within the E/S0 box are assigned an age of 10 Gyr, whereas pixels landing along the MC cluster locus are assigned the age from the population model. Most pixels, however, lie outside these loci because they contain composite populations, or because of translation in the color-color plane due to dust extinction. If the reddening is relatively small ($F_V/F_K < 26$), we model a pixel's observed color as a linear combination of an old and young population. Pixels with $F_V/F_K \geq 26$ are dereddened using a Cardelli et al. (1989) reddening law. From estimates of the fractional contribution to each pixel from young and old populations, a reddening-independent luminosity-weighted age for each pixel is calculated.

2. Luminosity-Weighted De-reddened Age Map

Figure 2 shows the location of different stellar populations present in the Antennae. The southern galaxy (NGC 4039) harbors a large old disk population as evidenced by the large number of pixels with a 10 Gyr old population. This implies that NGC 4039 may have been an early-type spiral (Sa?) before interacting with NGC 4038. NGC 4038 shows star-formation in its nucleus, in an

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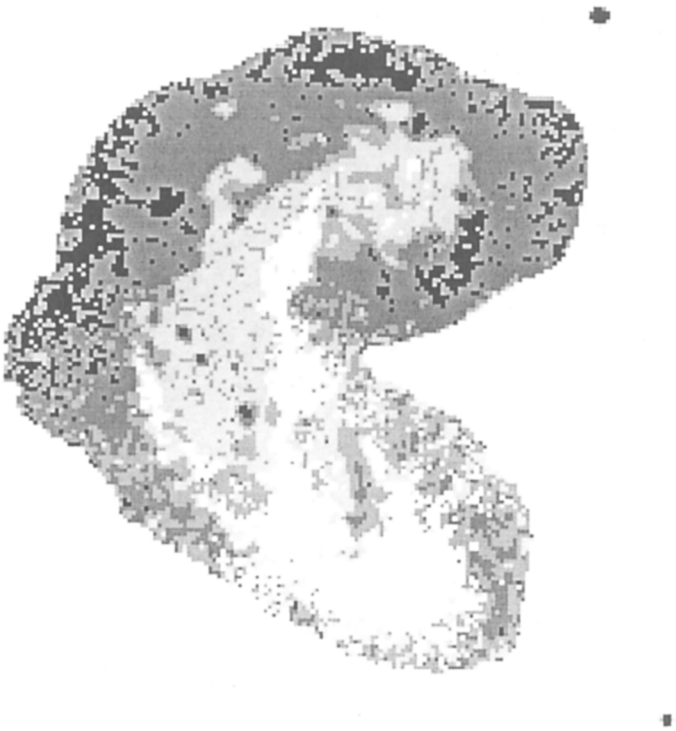

Figure 2. A luminosity-weighted de-reddened age map of the Antennae galaxies. Black regions contain populations < 4 Gyr old; white regions contain populations that $\gtrsim 10$ Gyr old.

arm extending from its nucleus, and in localized regions north of the nucleus in the "interaction region" toward the west. NGC 4038 contains many young super-star clusters and large amounts blue diffuse light. Diffuse blue light follows the super-star clusters and continues south into the "interaction region."

References

Bruzual, A.G., & Charlot, S. 1993 ApJ, 405, 538

Cardelli, J.A., Clayton, G.C., & Mathis, J.S. 1989, ApJ, 345, 245

Frogel, J.A., Quillen, A.C., & Pogge, R.W. 1996, in "New Extragalactic Perspectives in the New South Africa", eds. D.L. Block & J.M. Greenberg (Dortrecht: Kluwer), 65.

Persson, S. E., Frogel, J. A., Aaronson, M. 1979, ApJS, 39, 61

Persson, S. E. et al. 1983, ApJ, 266, 105

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Myung Gyoon Lee and Monica Rubio participate in the SOC-hop during the conference banquet.

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