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RECENT STAR FORMATION HISTORY OF THE DWARF IRREGULAR GALAXY SEXTANS A FROM *HST* OBSERVATIONS

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RESUMEN

Hemos obtenido datos fotométricos con WFPC2 del *Telescopio Espacial Hubble* de las estrellas resueltas en la galaxia enana irregular Sextans A (D = 1.4 Mpc). Construimos diagramas de color-magnitud en V e I a un límite de 26 en V. Los diagramas de color-magnitud muestran varias poblaciones claramente separadas. Lo más importante para la historia reciente, son las estrellas que queman helio (QHe) que se encuentran en la parte más azul de la fase de "lazo azul". Usamos estas estrellas azules QHe como un indicador para la localización de formación de estrellas durante los últimos 700 Myr. Existe una progresión de edad entre las regiones de formación estelar, indicando que esta formación puede propagarse a través de la galaxia.

ABSTRACT

We obtained WFPC2, *Hubble Space Telescope*, photometric data of the resolved stars in the nearby (D = 1.4 Mpc) dwarf irregular galaxy Sextans A. We constructed color-magnitude diagrams (CMD) in V and I to a limit of 26 in V. The CMDs show several clearly separated populations. Most important for the recent history are He-burning stars (HeB) that are in the bluest part of the so-called "blue-loop" phase. We used these blue HeB stars as a tracer for the location of star formation over the past 700 Myr. There is an age progression between the regions of star formation, indicating the star formation may be propagating through the galaxy.

Key words: **GALAXIES: INDIVIDUAL (SEXTANS A) — GALAXIES: STELLAR CONTENT — STARS: FORMATION**

1. INTRODUCTION

Dwarf irregular (dI) galaxies are excellent laboratories for studying the star formation process. They are gas-rich, have low metallicity, show little differential rotation, and contain active star formation (see Gallagher & Hunter 1984). The simpler dynamics make them easier to study than larger spiral galaxies. In addition, they provide a test for the accuracy of modern stellar evolution models at very low metallicity.

The star formation process is most directly probed by determining the star formation history (SFH) of the galaxy. For galaxies in or near the Local Group, it is possible to obtain photometry of the resolved stars and observe star formation events directly from the color-magnitude diagram (CMD; e.g., Smecker-Hane et al. 1994). The LMC and SMC are the closest gas-rich candidates (e.g., Mateo 1988; Gallagher et al. 1996); however, interaction with our Galaxy complicates their evolution. Many excellent attempts have been made from the ground to obtain SFH's of non-interacting dI's (e.g., Tosi et al. 1991; Gallart et al. 1996; Tolstoy 1996). Vast

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improvement can be made through use of the *Hubble Space Telescope* (*HST*). The superior angular resolution of the *HST* defeats much of the crowding of stellar images which greatly affects stellar photometry in systems at distances of order 1 Mpc.

Sextans A (DDO 75, A 1008-04) is a gas-rich dI with active star formation. Its metallicity has been measured to be ∼4% solar from H II region spectroscopy (Skillman, Kennicutt, & Hodge 1989). The H I is concentrated in two clumps, which correspond to the major star forming regions (Skillman et al. 1988). The H I observations also indicate that the gas rotates in solid body rotation. Sextans A is located on the periphery of the Local Group at a distance of ∼ 1.4 Mpc (Sandage & Carlson 1982; Piotto, Capaccioli, & Pellegrinni 1994; Sakai, Madore & Freedman 1996).

2. COLOR-MAGNITUDE DIAGRAM

The *HST* observations were obtained on 1 December 1995, and consisted of WFPC2 images in three filters: F439W (4000 s), F555W (1800 s) and F814W (1800 s). The stellar photometry was extracted using a modified version of the PSF fitting program DoPHOT (Schechter, Mateo, & Saha 1993; Saha et al. 1996). Artificial star tests showed the data to be 50% complete down to V = 25.9, B = 25.5, and I = 25.2.

The CMD is shown in Figure 1. The blue plume has been resolved into two separate populations. The well-defined MS containing stars as young as 10 Myr. Just redward of the MS is a clearly separate population that corresponds with massive stars in their core helium burning phase (HeB stars). This is the bluest extent of the so-called "blue-loop" phase. The magnitude of the HeB stars is well correlated with age over the past 1 Gyr (Bertelli et al. 1994). Thus, we can use the HeB stars to trace the recent SFH within the galaxy. We also see a population of massive, evolved, red supergiants that are possible counterparts to the blue HeB stars.

In addition to the young populations, there is an older population that includes a well-defined RGB and a few AGB stars. Just at the limit of photometry are hints of the red clump stars and horizontal branch.

The luminosity functions for the MS and the blue HeB stars are shown in Figure 2. Based on the MS turnoff alone, we are only able to probe back 100 Myr. There are no obvious features over this time period.

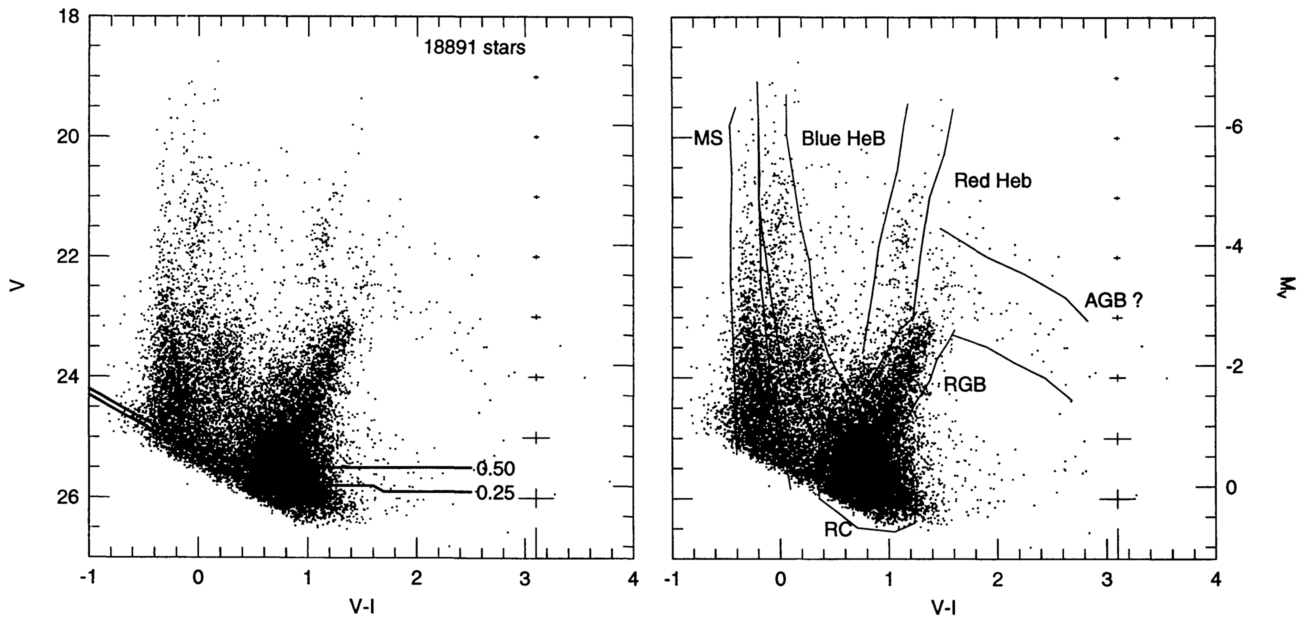

Fig. 1. On the left is the CMD in V and I for Sextans A. The points have been corrected for interstellar reddening; A_V = 0.10 and A_I = 0.05. The crosses on the left indicate the average error at the given V magnitude. The lines near the bottom indicate the completeness at levels 0.25 and 0.5. The right axis shows the absolute V magnitude assuming a distance modulus of 25.8. On the right, the major populations have been outlined and labeled. These include: the main sequence (MS), blue He-Burning stars (Blue HeB), red He-Burning stars (red HeB), red giant branch (RGB), red clump (RC), and assymptotic giant branch (AGB).

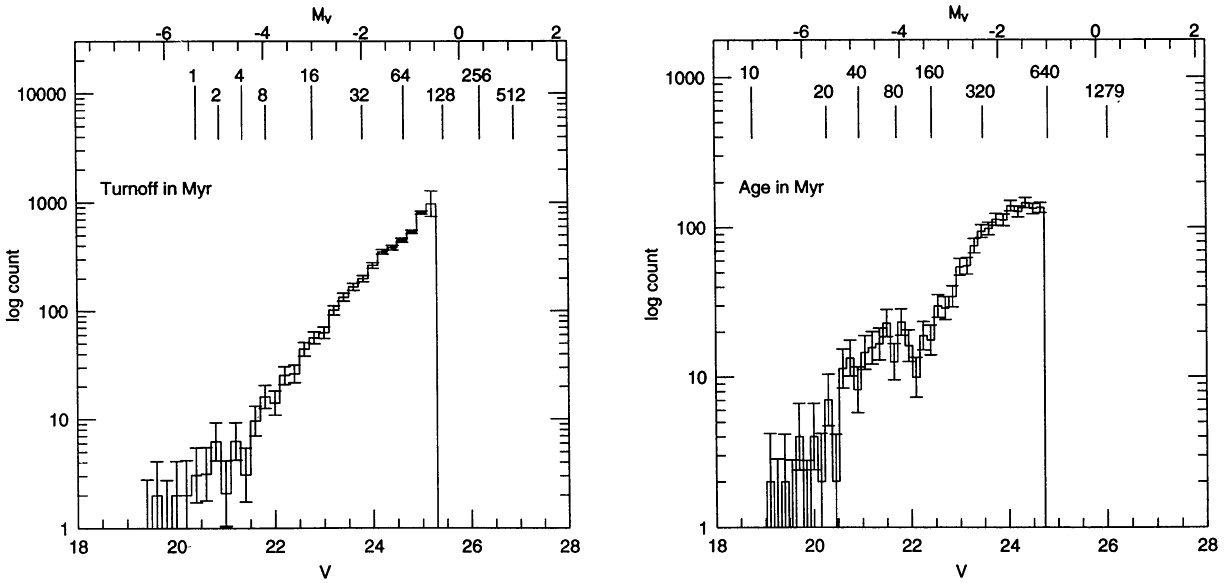

Fig. 2. The Left panel shows the V luminosity function of the MS stars, while the right panel shows the same for the blue HeB stars. The bin width is 0.2 mag for the MS and 0.15 for the blue HeB stars. The data have been corrected for reddening and incompleteness. The errors reflect Poisson noise and errors from the incompleteness correction. Marked above are the ages for each population based on theoretical isochrones (Bertelli et al. 1994).

Similar to the MS turnoff age, we can assign an age to each magnitude along the track of blue HeB stars (Bertelli et al. 1994). Using this dating method, we are able to extend the SFH to almost 700 Myr. At 80 Myr there is a flattening of the luminosity function, indicating a lower rate of star formation.

3. SPATIAL DISTRIBUTION

We have mapped the spatial density distribution of several populations (Figure 3). The young association in the lower right is densely populated with MS stars. This association has a dense clump of HI (Skillman et

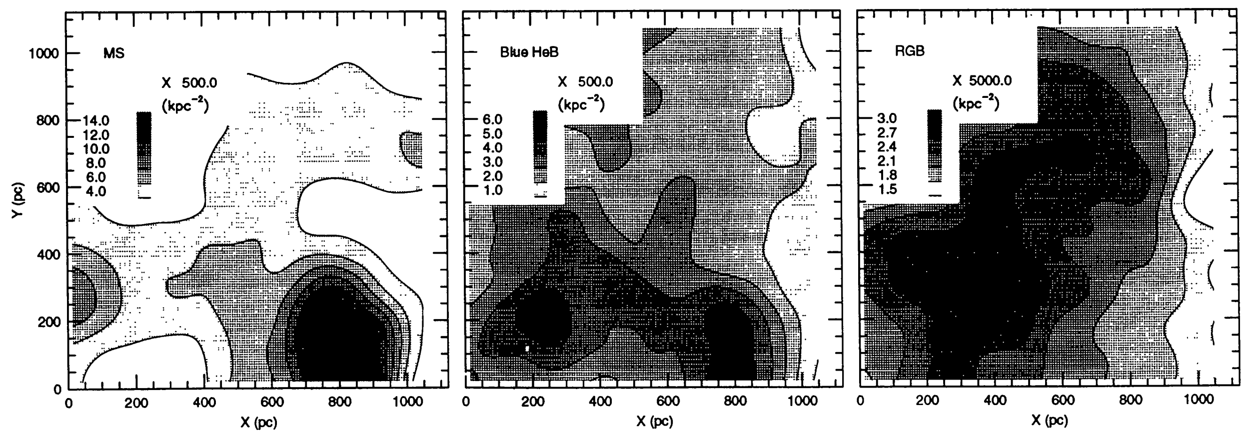

Fig. 3. This shows the spatial density of three populations of stars within Sextans A in both contours and greyscale. The maps have been convolved with a Gaussian with σ=50 pc. One star per convolution beam is 50 kpc^{-2}. The left panel is the MS, the middle is the blue HeB stars, and the right is the RGB.

al. 1988) and several bright H II regions (Hodge, Kennicutt, & Strobel 1994). There is also a low density bridge that extends to the left. This bridge does not align with the pattern of H I gas or the H II regions.

The blue HeB stars are not strongly clustered in the young association, but do reside in the low density bridge to the left. These stars are, on average, older than the MS stars, and thus indicate where the star formation has occurred in the recent past.

The distribution of the RGB stars is quite different from that of the younger stars. They form a bar through the middle of the galaxy, corresponding to an H I depression. The bar may be related to the dynamical bar postulated by Skillman et al. (1988).

4. RECENT STAR FORMATION HISTORY

We have calculated the spatial distribution of blue HeB stars in a series of different age frames separated by 10 Myr. This shows us the location of star formation within Sextans A over the past 600 Myr (see Figure 4). The oldest star formation shown, at 570 Myr, appears as a diffuse region in the lower part of the image. As time progresses, we see a patch of star formation move in from the lower left corner. This appears to propagate toward the center of the image, peaking at about 370 Myr. This event then fades away as the young association in the lower right comes to prominence at 200 Myr. The movie suggests that the star formation may have propagated from region to region, as we see low level bridges connecting them.

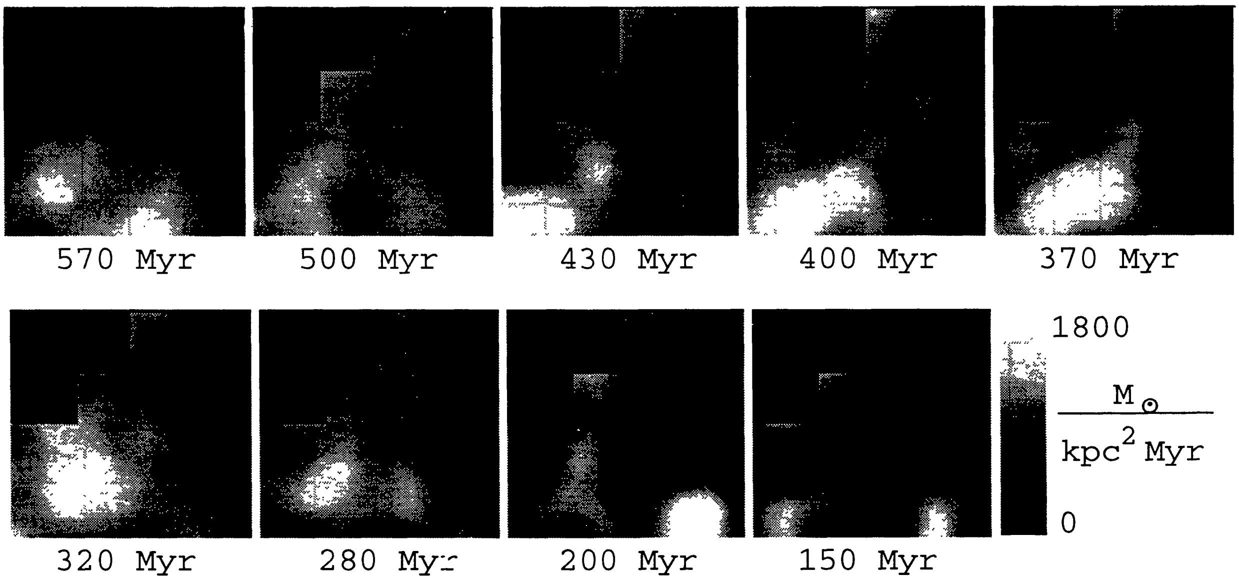

Fig. 4. A gallery of nine frames showing the density of blue HeB stars in Sextans A over time. Each frame is 1 kpc on a side. The time shown is the number of years in the past. The ages were determined from the relations of Bertelli et al. (1994). Each frame was convolved with a gaussian with σ_x = 84 pc. The series of frames were also convolved in time with σ_t=30 Myr.

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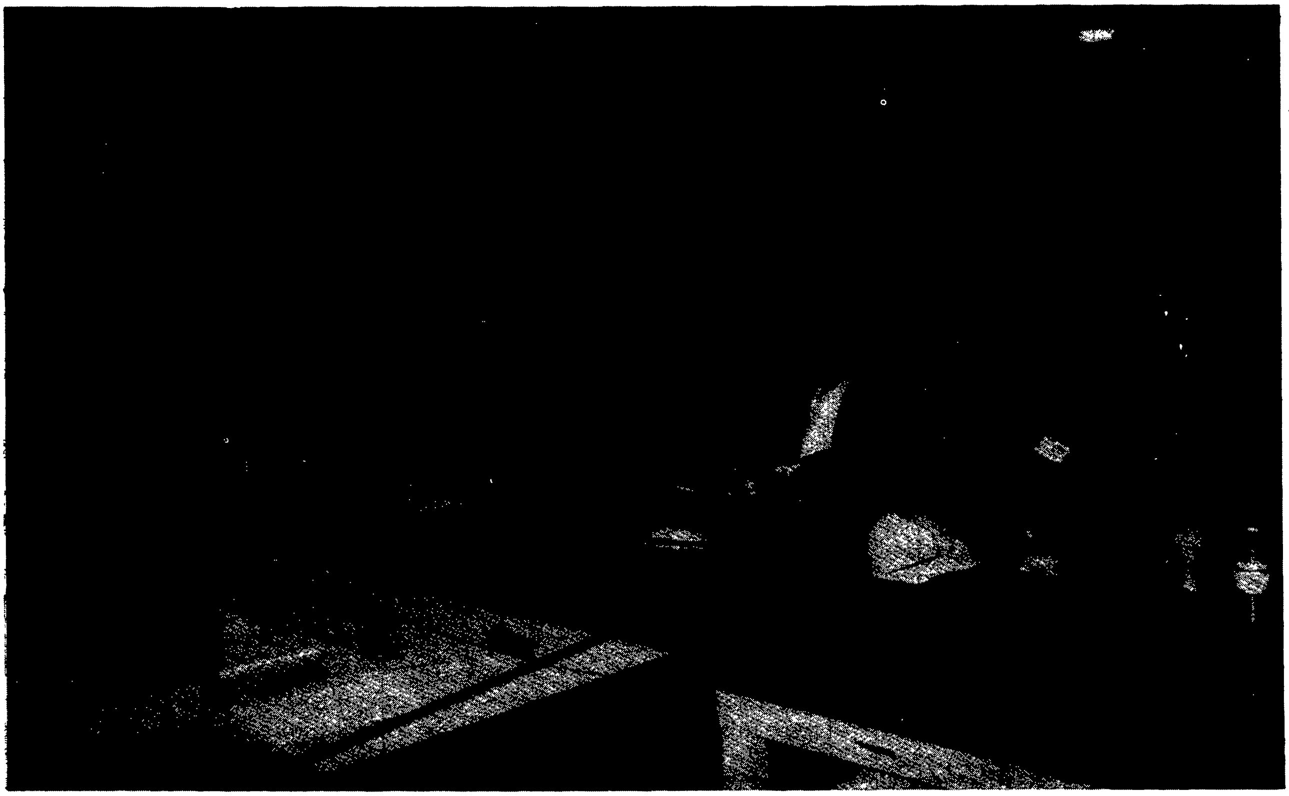

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