Star formation in the M 81 dwarf Kar 61

Rachel Johnson
Institute of Astronomy, Cambridge CB3 0HA, UK

Abstract

I use HST broad-band images, and ground-based spectroscopy and narrow-band images, to place contraints on the ionizing stellar population in Kar61, an M81 group dwarf spheroidal that contains an emission-line region.

1 Introduction

Kar61 is a dwarf spheroidal galaxy in the M81 group. For a summary of previous work on Kar61 see Karachentsev et al. (2000). Karachentsev et al. (2000) find that the distance of Kar61 is consistent with the M81 distance of 3.63 Mpc, which is adopted here. The 1σ error in the Kar61 distance modulus is $\approx$0.15 mag.

Previous work using ground-based optical images discovered a bright blue off-centre knot (knot B) in Kar61 - a somewhat suprising find in a dwarf spheroidal (Johnson 1997). Another red unresolved knot (knot A) lies at the centre of the smooth diffuse emission. Figure 1 shows a recent HST WFPC2 image obtained by Karachentsev et al. (2000), with the two knots marked. The galaxy is resolved into stars in this image.

Optical spectroscopy of knot B revealed emission lines consistent with ionization by at most a few O stars. The physical parameters obtained from the emission lines are summarized in Table 1 (see Johnson et al. (1997) for more detailed discussion). The ground-based broad-band colours are

$E(B-V)$	0.1	
T_{electron}	<15500 K	electron temperature
N_{electron}	<200 cm^{-3}	electron density
Z	1/17 $Z_\odot$ - 0.5 $Z_\odot$	using models of
Age	2 - 5.2 Myr	Garcia-Vargas et al. (1995)

Table 1: Summary of optical spectroscopy results

also consistent with a young stellar population (Johnson et al. 1997).

A ground-based Hα image was obtained to find the true extent of the emission line region, and this can be used along with the HST images obtained by Karachentsev et al. (2000) to place further constraints on the nature of the ionizing stellar population in knot B. Figure 1 shows the HST V (F606W) and I (F814W) and JKT Hα observations of knot B. It can be seen that there are several bright stars in the same region as the Hα emission.

The reddening corrected (assuming $E(B-V) = 0.1$) Hα luminosity measured from the Hα image is $L(\mathrm{H}\alpha)= 8.07\times10^{37}$ erg s^{-1}. Using the relationship between $L(\mathrm{H}\alpha)$ and number of hydrogen ionizing photons, N_L, $N_L(\mathrm{s}^{-1}) = 7.31 \times 10^{11} L(\mathrm{H}\alpha)$ (Osterbrock, 1989), this gives $N_L = 5.90 \times 10^{49}$ s^{-1}.

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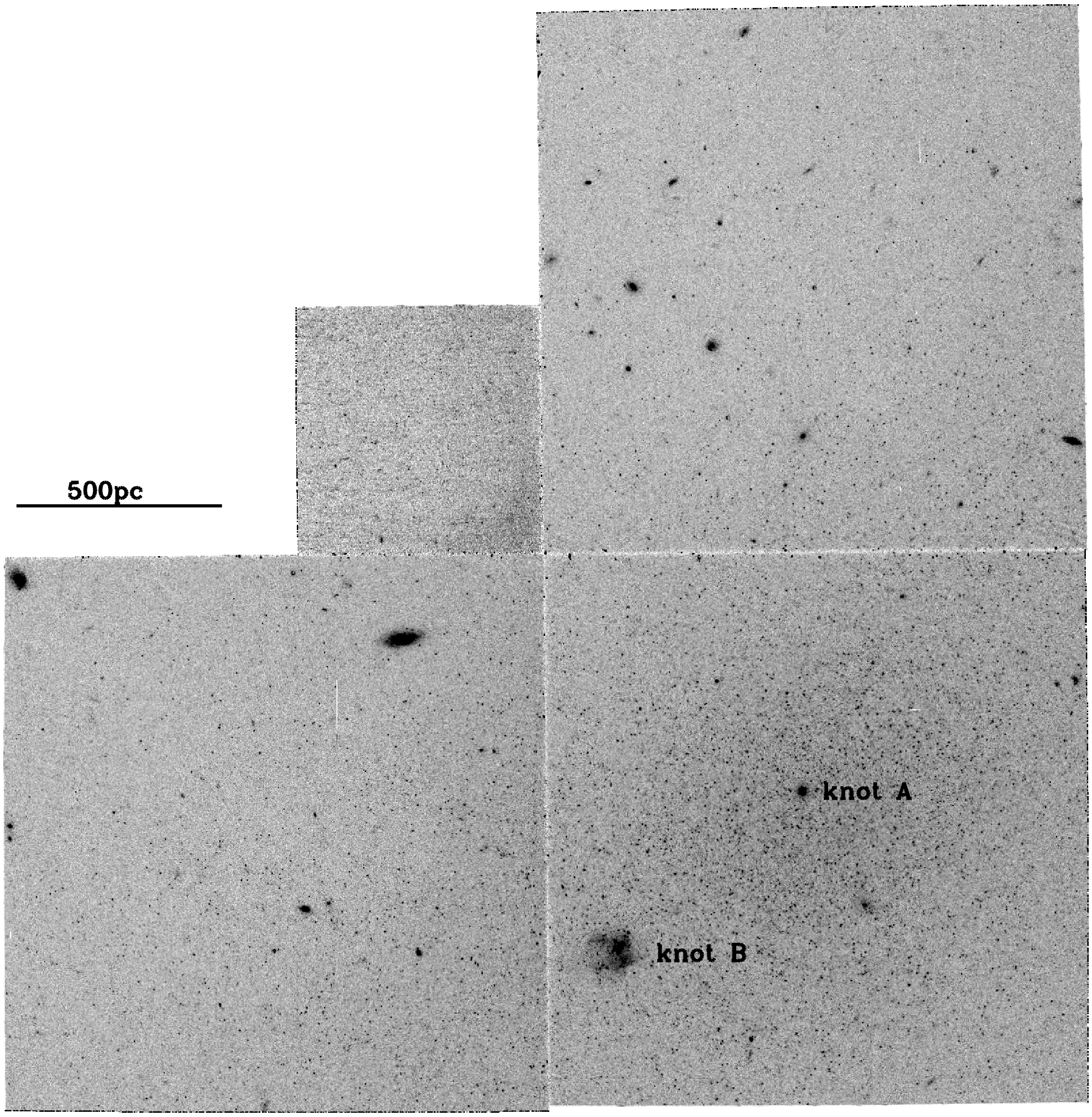
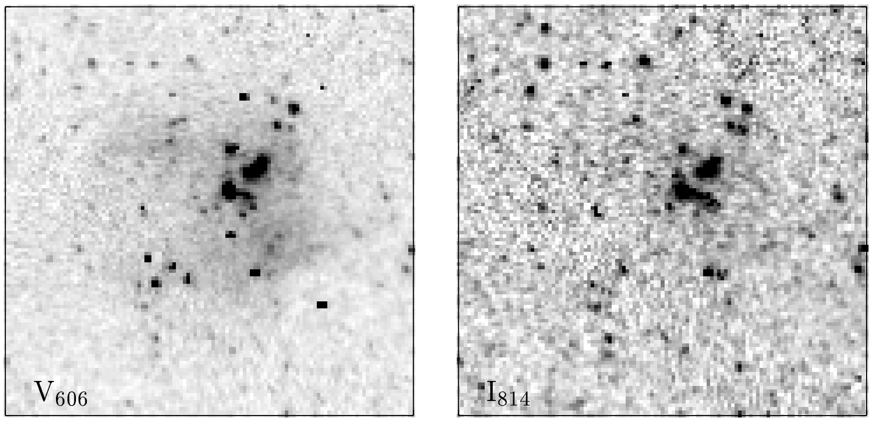


Figure 1: F606W WFPC2 image



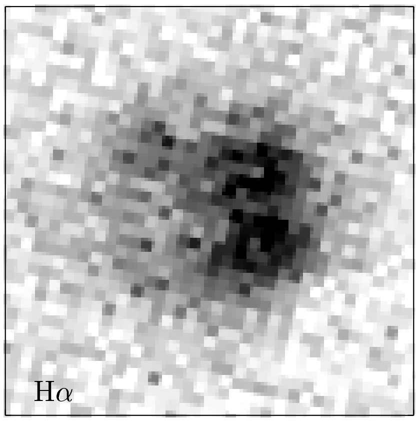


Figure 2: Images of knot B in V,I (HST) and Hα (ground-based)

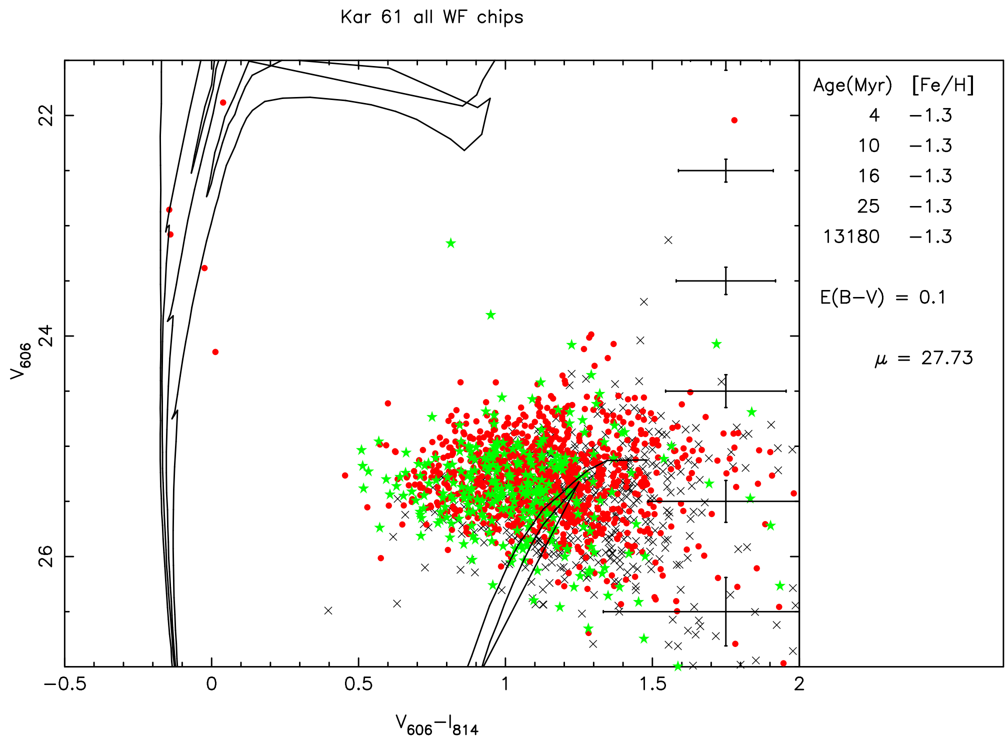


Figure 3: Kar61 colour-magnitude diagram from HST images. Different symbols denote different WFPC2 chips.

The archive HST images were re-examined and psf fitting photometry performed to obtain the colour-magnitude diagram (CMD) shown in Figure 3. Superposed on the CMD are 4 young and 1 old isochrone. These are from Bertelli et al. (1994) and were transformed to the HST instrumental magnitude system by Worthey.

As discussed by Karachentsev et al. (2000) the old stellar population is well fit by an isochrone with metallicity [Fe/H]≈ -1.3 (Karachentsev et al. (2000) show that [Fe/H] $= -2.2$ gives the best fit) and the magnitude of the tip of the RGB is consistent with membership of the M81 group.

There are 5 bright, blue stars in the CMD and they are all contained within knot B. The 5 young isochrones marked in Figure 3 are for ages 4-25 Myr. It can be seen that, the $V-I$ colour is not a good age discriminant. Any differential reddening of the stars will also move them to apparent older ages.

The young star absolute magnitudes have been compared with those in Panagia (1978), who list brightnesses for stars of different spectral type and luminosity class. Each young star absolute magnitude is consistent with its being either a young dwarf or an older giant star. Panagia et al. (1978) also give the number of hydrogen ionizing photons for each star, which can be compared to the number required from the observed emission lines. Unfortunately, this is not a good discriminant of stellar population age. The number of hydrogen ionizing photons predicted by the two extreme cases, all dwarfs or all giants, is 1.29×10^{50} s^{-1} and 9.12×10^{49} s^{-1} respectively.

There are two extreme possibilities for the young stellar population in knotB. The stars could be very young (4Myr) dwarf stars. A worry with this hypothesis is the lack of stars further down the isochrone but above the detection limit ($V_{606} \approx 26$ mag) which should be present for a normal IMF. The second possibility is that most of the stars are older ($\approx$25 Myr) evolved giants. However, not all the stars can be this old, as at least one star with age $<$5 Myr is required to produce the observed [O III]λ5007 emission (Stasińska & Leitherer 1996).

In the future we will carry out simulations of stellar populations of different ages to find the best fitting age for the observed density in the CMD of the young stars. This will allow us to place stronger limits on the required stellar population age and IMF. Model spectra could then be produced for each of the allowed stellar populations and compared with the observed emission line spectrum to produce further constraints.

References

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