Dynamical Evolution of Dense Stellar Systems
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Stellar Exotica in 47 Tucanae

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Abstract. We have used far-ultraviolet spectroscopy and broad-band photometry to identify and study dynamically-formed stellar exotica in the core of 47 Tucanane. Here, we present a subset of our main results, including: (i) the spectroscopic confirmation of three cataclysmic variables; (ii) the discovery of stripped sub-giant core in a binary system with a dark primary; (iii) the discovery of a Helium white dwarf; (iv) the discovery of a blue straggler with a white dwarf companion.

Keywords. globular clusters: individual (47 Tuc), ultraviolet: stars, stars: novae, cataclysmic variables, stars: white dwarfs, stars: blue stragglers, stellar dynamics

1. Introduction

Stellar collisions and near misses can create various exotic stellar populations in globular clusters. For example, direct stellar collisions can create blue stragglers (BSSs), whereas 2-body and 3-body encounters may produce cataclysmic variables (CVs) and X-ray binaries (XRBs). Some of these dynamically-formed populations can, in turn, affect the evolution of their host clusters. Stellar exotica are thus key tracers of the dynamical processes that drive cluster evolution.

Many of the most interesting dynamically-formed objects (such as all BSSs, CVs and XRBs) are characterized by spectral energy distribution that peak at much shorter wavelengths than ordinary clusters members. Surveys at X-ray (e.g. Grindlay *et al.* 2001; Pooley *et al.* 2002; Heinke *et al.* 2003) and ultraviolet (UV) wavelengths (e.g. Knigge *et al.* 2002, 2003, 2006; Dieball *et al.* 2005a, 2005b, 2007) are therefore particularly useful for finding and studying these objects. Here, we present a brief overview of results from a far-UV *spectroscopic* survey of the core of 47 Tuc that we have carried out with STIS onboard HST. The combination of our far-UV spectra with broadband optical photometry obtained with HST/ACS turns out to be extremely powerful in identifying and classifying the various types of stellar exotica in this cluster.

2. Cataclysmic Variables

Fig. 1 shows far-UV spectra and broad-band SEDs of three previously known CV candidates in our survey area. All of these are X-ray sources (Grindlay *et al.* 2001; Heinke *et al.* 2005) and exhibit variability at both optical (Edmonds *et al.* 2003a, 2003b) and far-UV wavelengths. All three exhibit clear C IV 1550 Å and He II 1640 Å emission lines, confirming their CV classification. The time-resolved far-UV spectroscopy of the brightest source – AKO 9 – was already studied in detail by Knigge *et al.* (2003). The

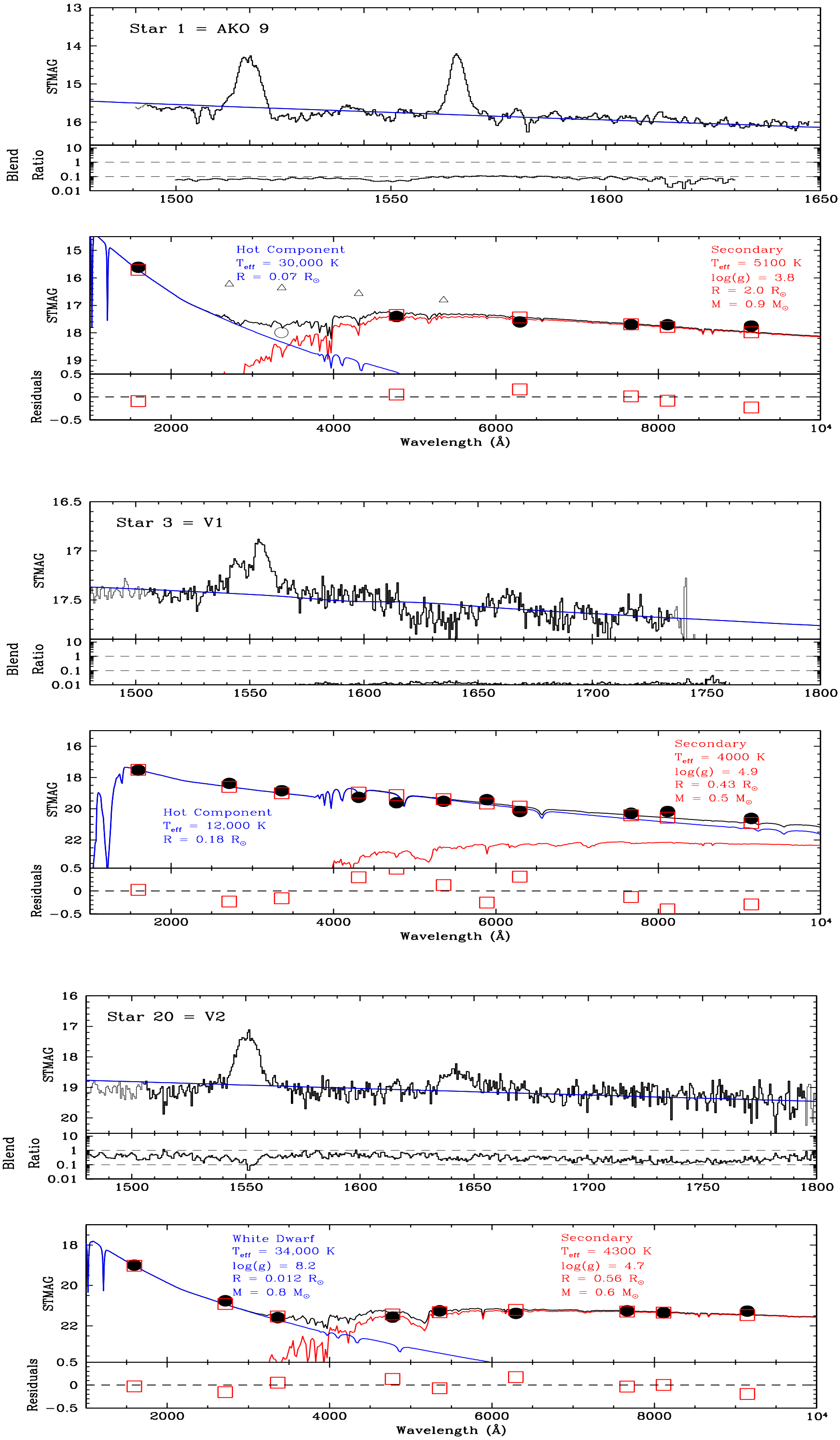

Figure 1. Far-UV spectra and broad-band SEDs of three previously suspected CVs in 47 Tuc. All three display obvious emission lines and the donor star is definitely detected in two of them.

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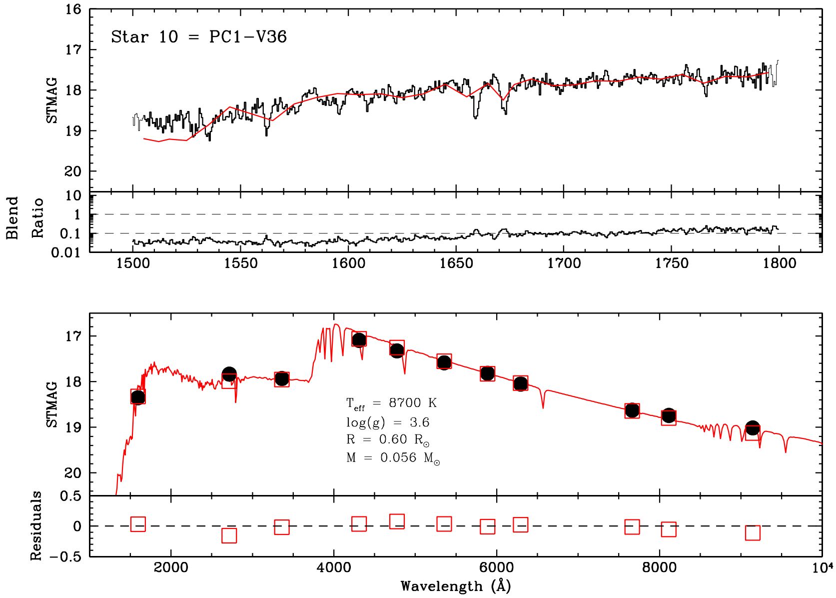

Figure 2. Far-UV spectrum and broad-band SED of PC1-V36. This object is probably an 8 hour binary system containing a dark, compact primary and a stripped sub-giant secondary.

secondary star is detected in two of the object; in both cases, the donor properties are consistent with orbital periods above the CV period gap (c.f. Knigge 2006). Only one other object in our spectroscopic database displays marginally convincing evidence for line emission.

3. A Stripped Sub-Giant in an 8-hour Binary

Fig. 2 shows the far-UV spectrum and SED of PC1-V36, a previously known variable star in 47 Tuc (Albrow *et al.* 2001). The optical light curve suggests that the object is a binary system with a likely orbital period of about 8 hrs in which a (nearly) Roche-lobe filling donor produces most of the light. Our new spectroscopy and photometry can be described by a single component SED, but implies very unusual parameters for the donor: $T_2 \simeq 8700$ K, $\log g \simeq 3.6$ and $R_2 \simeq 0.6$ $R_\odot$, suggesting a donor mass of only about $M_2 \simeq 0.055$ $M_\odot$. The implied mean density is completely consistent with that expected for a Roche-lobe filling star in an 8 hr binary system. We suspect the donor is the remnant of a sub-giant that has been stripped of most of its envelope, either due to mass-transfer in a pre-existing binary, or in the aftermath of the dynamical encounter that may have formed the binary. The primary is not detected and may thus itself be a compact stellar remnant (i.e. a massive white dwarf (WD) or a neutron star).

4. A Helium White Dwarf

Fig. 3 shows the far-UV spectrum and SED of a newly discovered low-mass Helium white dwarf. This is only the second directly detected He WD in 47 Tuc (Edmonds *et al.* 2001), and the first outside a milli-second pulsar system. He WDs are generally thought to be formed only in binary systems, where the progenitor can lose significant amounts

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of mass to a companion. We see no sign of such a companion in our data, which may suggest that it is again a dark, compact stellar remamnt.

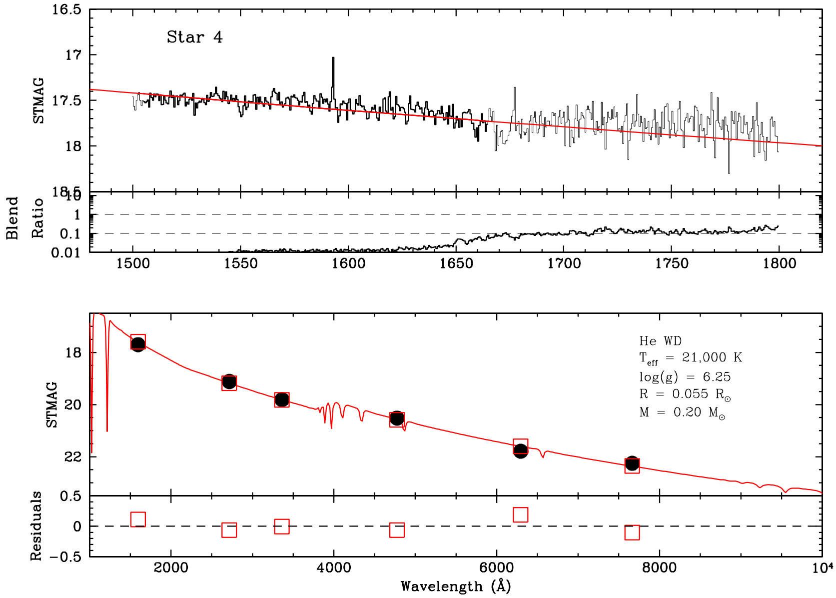

Figure 3. Far-UV spectrum and broad-band SED of a newly discovered Helium WD in 47 Tuc. There is no sign of a binary companion.

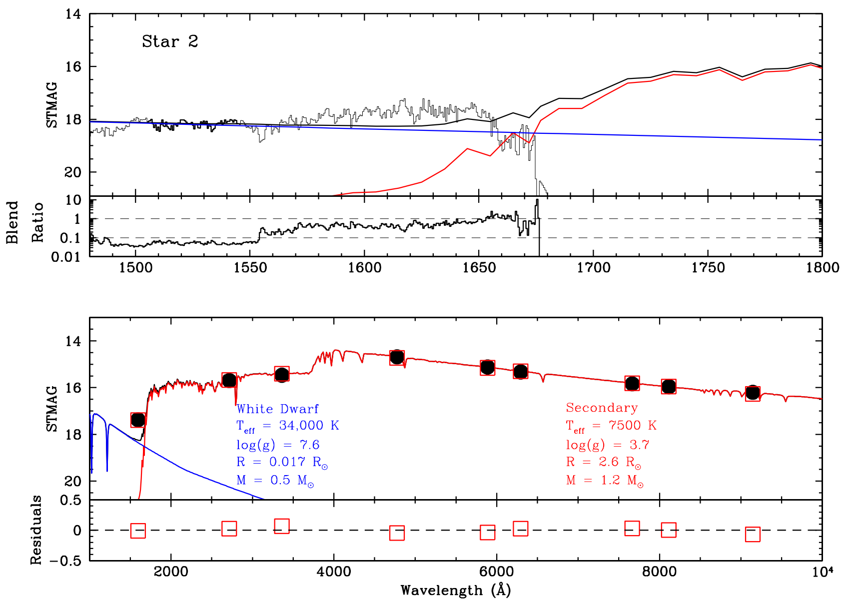

Figure 4. Far-UV spectrum and broad-band SED of a previously known blue straggler in 47 TUc. The spectrum shows a strong far-UV excess at the shortest wavelength, suggesting that the BSS is in a binary system with a hot WD.

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5. A Blue Straggler with a White Dwarf Companion

Fig. 4 shows the far-UV spectrum and SED a BSSs in 47 Tuc (where the classification is based on its position in optical and far-UV CMDs). The far-UV spectrum, however, extends to much shorter wavelengths than would be expected for a "normal" BSS (with spectral type A or F). However, the far-UV excess can be accounted for self-consistently if the BSS is in a binary system with a hot WD. This, in turn, suggests that a specific formation scenario for this particular BSS, namely case B mass transfer from the WD progenitor.

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