

# GHOSTS: The Resolved Stellar Outskirts of Massive Disk Galaxies

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**Abstract.** We show initial results from our ongoing HST/ACS GHOSTS survey of the resolved stellar envelopes of 14 nearby, massive disk galaxies. In hierarchical galaxy formation the stellar halos and thick disks of galaxies are formed by accretion of minor satellites and therefore contain valuable information about the (early) assembly process of galaxies. We detect for the first time the very small halo of NGC 4244, a low mass edge-on galaxy. We find that massive galaxies have very extended halos, with equivalent surface brightnesses of 28-29 V-mag arcsec<sup>-2</sup> at 20-30 kpc from the disk. The old RGB stars of the thick disk in the NGC 891 and NGC 4244 edge-on galaxies truncate at the same radius as the young thin disk stars, providing insights into the formation of both disk truncations and thick disks. We furthermore present the stellar populations of a very low surface brightness stream around M83, the first such a stream resolved into stars beyond those of the Milky Way and M31.

**Keywords.** galaxies: stellar content, galaxies: halos, galaxies: spiral, galaxies: structure, galaxies: evolution, galaxies: individual (M83, NGC 891, NGC 4244)

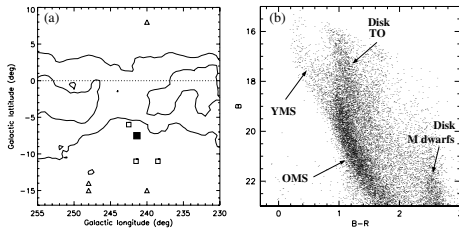
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In recent years we have started to appreciate that the outer banks of galaxies contain valuable information about the formation process of galaxies. In hierarchical galaxy formation the stellar halos and thick disks of galaxies are formed by accretion of minor satellites, predominantly in the earlier assembly phases. The size, metallicity, and amount of substructure in current day halos are therefore directly related to issues like the small scale properties of the primordial power spectrum of density fluctuations and the suppression of star formation in small dark matter halos after reionization.

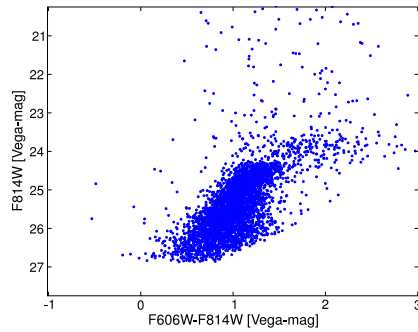
To exploit this information we have started the GHOSTS† survey, which will sample the resolved stellar populations along the major and minor axes of 14 nearby galaxies using HST/ACS and WFPC2. Our data provide color-magnitude diagrams 1.5-2.5 magnitudes below the tip of the Red Giant Branch. We measure the stellar density distribution from star counts down to very low average surface brightnesses, equivalent to ~32 V-mag per square arcsec. We will also obtain spatial information on the metallicity distributions of the Red Giant Branch stars. Our targets have large angular extents and we need several images to sample one principal axis. For the galaxies where we received enough data to create radial profiles, the results have been both remarkable and highly varied.

NGC 4244 has a very small, very metal poor halo below  $\mu_V=30$  mag arcsec<sup>-2</sup> on the minor axis (Seth *et al.* 2007; Fig. 1). In contrast, most massive galaxies, like NGC 253, NGC 891, and M94 have very extended halos; our outermost fields at ~30 kpc still have  $\mu_V\sim 28$  mag arcsec<sup>-2</sup>. M81 has a projected  $r^{-3.5}$  power-law minor axis surface brightness profile, one of the steepest ever seen. M83 seems to be the exception to the expectation

† GHOSTS: Galaxy Halos, Outer disks, Substructure, Thick disks and Star clusters



**Figure 1.** NGC 4244 major and minor axis SDSS  $i_{AB}$ -band luminosity profile (blue solid line, left axis, add about 6.5 to get V-band) and background subtracted star counts (green points, right axis). Dashed lines show exponential disk fits to the inner region. We detect a clear minor axis extended component (Seth *et al.* 2007) and a strong truncation in RGB star counts on the major axis. At the distance of NGC 4244, 100 arcsec equals about 1.8 kpc.



**Figure 2.** Color-magnitude diagram of the tidal stream around M83 at 20 kpc from its center. A very pronounced metal-poor RGB population is detected, with an AGB C-star population ( $F606W-F814W=1.3-2.5$  mag,  $F814W=24$  mag), indicative of a 3–5 Gyr old population. No main sequence or He burning stars are seen to the left of the RGB; this stream has been dead for at least 300 Myr.

that massive galaxies have large halos; at 20 kpc its CMD is already rather sparse. The metallicities of the halos derived from the colors of RGB stars are quite varied, although with more massive galaxies having higher metallicity inner halos, on average.

The RGB stars in the thick disk of NGC 891 and NGC 4244 show a truncation at the same radius as the total light distribution (Fig. 1), suggesting that either truncations are old, or that the old thick disk is affected by similar dynamical effects as the thin disk (bars, spiral arms, disk heating and stripping by dark matter subhalos).

We detect a stream in M83 with a maximum surface brightness of  $26.5 R\text{-mag arcsec}^{-2}$  and FWHM of  $\sim 3$  kpc that has no detectable main sequence nor He burning stars and therefore has had no star formation in the past 300 Myr. However, we find a significant population of AGB C-stars, indicating it had a burst of star formation about 3–5 Gyr ago (Fig. 2).

## Acknowledgements

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## Reference

Seth, A., de Jong, R.S., Dalcanton, J. & the GHOSTS team 2007, *these proceedings*, astro-ph/0701704