Haloes and truncations observed in face-on nearby galaxies

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Abstract

We use data from the IAC Stripe 82 Legacy Project to study the surface photometry of 22 nearby, face-on to moderately inclined spiral galaxies. The reprocessed and combined *g*′, *r*′ and *i*′ images allow us to probe the galaxy down to 29-30 *r*′-magnitudes/arcsec^2 and thus reach into the very faint outskirts of the galaxies. Truncations are found in three galaxies. An additional 15 galaxies are found to have an apparent extended stellar halo. Simulations show that the scattering of light from the inner galaxy by the Point Spread Function (PSF) can produce faint structures resembling haloes, but in general this effect is insufficient to fully explain the observed haloes. The presence of these haloes and of truncations is mutually exclusive, and we argue that the presence of a stellar halo can hide a truncation. Furthermore, we find that the onset of both the stellar haloes and the truncations scales tightly with galaxy size. Nineteen galaxies are found to have breaks in their profiles, the radius of which also correlates with galaxy size.

Introduction

Truncations in edge-on galaxies have been observed for decades (e.g., van der Kruit 1979), but have been proven elusive in face-on galaxies. Two main families of models have been proposed for the origin of truncations: Suppression of star formation below a certain gas density threshold for local instability; and one in which the truncation corresponds to a maximum in the specific angular momentum distribution of the present disk, and might correspond to that in a protogalaxy.

The expected surface brightness levels of truncations in face-on galaxies are similar to those of stellar haloes. These stellar haloes are the remnants of the merger process which in ΛCDM cosmology is thought to have shaped current-day galaxies. Detecting and characterizing such haloes thus has immediate and important consequences for our understanding of galaxy formation and evolution.

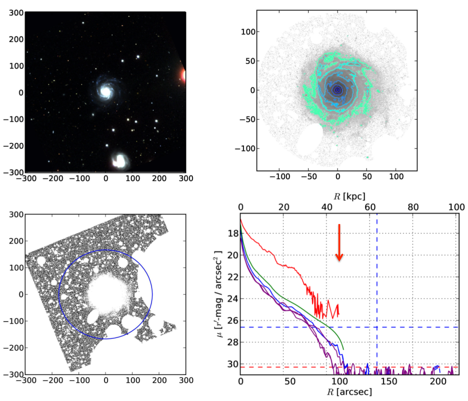
Data and Sample

We use very deep imaging provided by the IAC Stripe 82 Legacy Project (Fliri & Trujillo 2015), which reaches depths of 29-30 mag/arcsec^2. In order to reach fainter levels, we add light in three bands, *g*′, *r*′ and *i*′, and we do this for a sample of 22 face-on to moderately inclined spiral galaxies at distances from around 20 to just over 100 Mpc. Figure 1 illustrates the quality of our images.

Masking of back- and foreground sources and modelling of residual background gradients is of the utmost importance, and is illustrated in Figure 2.

Fig. 1 (right)

Imaging and background of IC 1516. Top left: RGB image. Scale in arcsec. Top right: : Image optimized to show faint outer regions. Lower left: Corrected background. Holes are due to masking. Lower right: various radial profiles, showing the truncation in this galaxy (indicated with arrow).



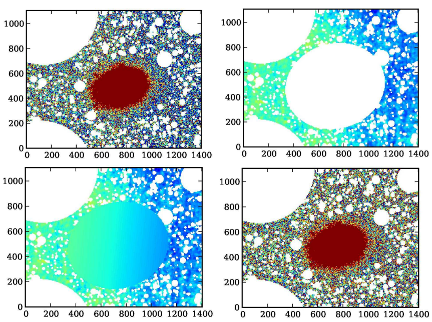
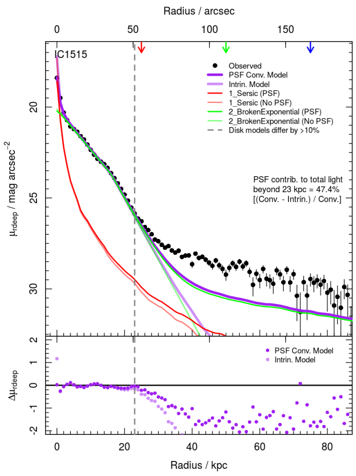


Fig. 2

Overview of the background modelling process, NGC 941. Top left: original image with objects masked. Top right: model created for the sky, excluding the galaxy. Lower left: sky model including the galaxy. Lower right: final image with sky model subtracted from observation. Colour scales from -1.0 to 1.0 ADU.

Fig. 3

Radial surface brightness profiles, and test whether the PSF can create an artificial halo, for IC 1515. Red curves: Sersic fit to the inner galaxy, corresponding to the bulge, the light line before and the dark line after convolution with the PSF. Green: broken exponential, again before and after convolution. Purple: sum of the two. The data points are above the purple line, indicating roughly equal amounts of stellar halo and PSF-scattered light in the outskirts.



Results

The analysis of our data incorporates a number of novelties, aimed both at ensuring that detections of truncations and other features is reliable, and at quantifying the possible effects of the background and Point Spread Function (PSF; for details see our Peters et al. MNRAS paper).

From the radial profiles we deduce that truncations are seen in three of our 22 galaxies (see Figure 1). In 15 other galaxies, the profiles flatten at faint levels, which we interpret as evidence for stellar haloes (Figure 3). These occur typically at surface brightness levels of >28 mag/arcsec^2, and at radii of >20 kpc. Truncations and stellar haloes relate jointly to the size of their galaxy (Figure 4), but are never observed in the same galaxy, possibly because the latter make the detection of the former impossible. We observe distinct breaks in most galaxies, occurring further in and at higher surface brightness which also relate to the size of their host (Figure 4).

Detailed modelling of the PSF, using combined profiles of very bright and faint stars, shows that a substantial fraction of the light in the outer parts is scattered light from the disk regions of the galaxy (Figure 3). However, the flattening of the profiles can only be fully explained by a combination of PSF effects and stellar haloes, which we thus observe to be common.

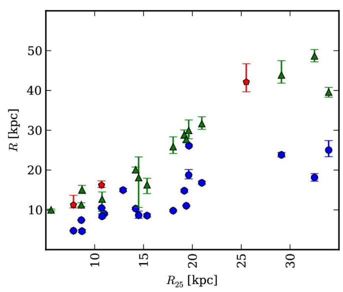


Fig. 4

Correlation of R_{25}, indicative of the size of a galaxy, with the various feature radii *R*. Red squares: truncations. Blue circles: breaks. Green triangles: haloes.

Conclusions

From careful analysis of extremely deep imaging from the IAC Stripe 82 Legacy Project of a sample of 22 relatively face-on galaxies, we find evidence for truncations in 3 galaxies, and for stellar haloes in another 15. PSF effects are important at faint levels, but cannot completely remove the need for stellar haloes to explain the observed flattening of profiles in most galaxies.

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