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The Mass Distribution in Disk Galaxies

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Abstract. We present the relative fraction of baryons and dark matter at various radii in galaxies. For spiral galaxies, this fraction measured in a galaxy's inner parts is typically baryon-dominated (maximal) and dark-matter dominated (sub-maximal) in the outskirts. The transition from maximal to sub-maximal baryons occurs within the inner parts of low-mass disk galaxies (with $V_{\rm tot} \leqslant 200$ km s−1) and in the outer disk for more massive systems. The mean mass fractions for late- and early-type galaxies vary significantly at the same fiducial radius and circular velocity, suggesting a range of galaxy formation mechanisms. A more detailed discussion, and resolution of the so-called "maximal disk problem", is presented in Courteau & Dutton, *ApJL*, 801, 20.

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How galaxies arrange their baryonic and non-baryonic matter is the result of numerous complex mechanisms involving their mass accretion history, the depth of the potential well, the initial mass function (which ultimately affects feedback and quenching processes), dynamical friction, dynamical instabilities, and more. Analytical models of galaxy formation strive to predict the ratio of baryonic-to-dark matter mass, $f_{\rm DM}(R)$ (Dutton *et al.* 2007, 2011; Mo, van den Bosch, and White 2010) with mitigated success in light of the above challenges; numerical simulations suffer additional limitations, too.

Can observations provide unique determinations of $f_{\rm DM}(R)$ as ideal constraints to galaxy formation models? Not yet, but, after decades of muddled debates and incomplete data, a clear picture, presented in Courteau and Dutton (2015), seems to be emerging. The two figures below are extracted from that paper.

Fig. 1 captures the following features: 1) Dark matter fraction decreases with galaxy circular velocity; 2) Milky Way mass galaxies ($V_{\rm circ} \sim 220$ km s^{-1}) have, on average at 2.2 disk scale lengths, $f_{\rm DM} \sim 0.5$; and 3) There is significant scatter in dark matter fractions at a given circular velocity driven, at least partly, by size variations.

Fig. 2 shows dark matter fractions versus radius for ΛCDM based models of early and late-type galaxies with circular velocity $V_{\rm circ}(R_{\rm e}) \simeq 230$ km s^{-1} from Dutton *et al.* (2011). For a given halo response, early-type galaxies have lower dark matter fractions than late-type galaxies. These differences are driven by both size (early-types are smaller) and IMF (early-types have heavier IMFs) variations.

The advent of new extensive dynamical models of galaxies based on wide-field integral field surveys, such as CALIFA, MaNGA, SAMI (out to $\sim 1.5R_{\rm e}$), and SLUGGS (reaching $\sim 6 - 10R_{\rm e}$) heralds a promising future for mapping the mass distributions at all radii in galaxies.

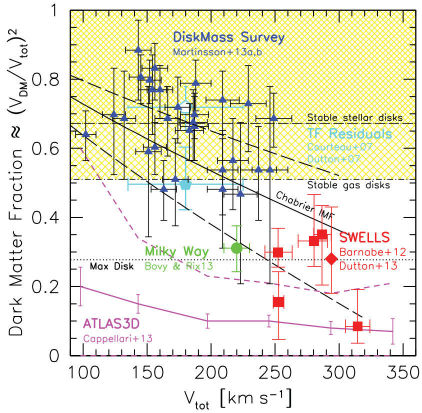

Figure 1. Dark matter fraction at 2.2 disk scale lengths as a function of total circular velocity for samples discussed in the text. A clear trend is observed such that the dark matter fraction decreases with circular speed; indeed below 250 km s^{-1}, dark matter dominates (> 50%) the total mass budget of the galaxy at 2.2 disk scale lengths. The yellow shading shows the stability criteria for stellar disks ($f_{\rm DM} \simeq 0.67$; short-dashed black line and above) and gaseous disks ($f_{\rm DM} \simeq 0.51$). The dotted black line defines a maximal disk. The black line represents a model for galaxy scaling relations assuming a Chabrier initial mass function; the long-dashed black lines are the 1σ dispersion in galaxy sizes. Full references are in Courteau & Dutton (2015).

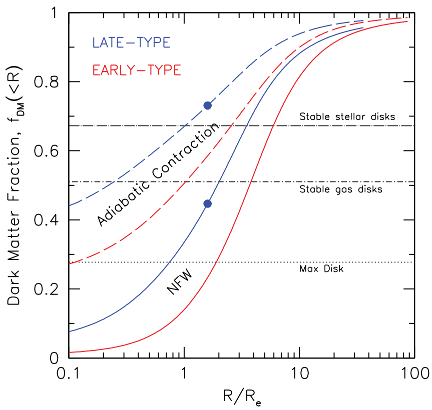

Figure 2. Dark matter fraction as a function of half-light radius, $R_{\rm e}$, for early-type (red lines) and late-type (blue lines) galaxies with circular velocity $V_{\rm circ}(R_{\rm e}) \simeq 230$km s^{-1}. The black horizontal lines are as in Figure 1. Solid lines show models with NFW haloes that follow the concentration-mass relation from ΛCDM from Maccio *et al.* 2008. Dashed lines show models with adiabatically contracted NFW haloes and correspondingly lighter IMFs. The blue dots correspond to 2.2 disk scale lengths for late-type galaxies.

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