FULL TITLE
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Extended Light in E/S0 Galaxies and Implications for Disk Rebirth

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Abstract. The recent discovery of extended ultraviolet (XUV) disks around a large fraction of late-type galaxies provides evidence for unexpectedly large-scale disk building at recent epochs. Combining *GALEX* UV observations with deep optical and *Spitzer* IR imaging, we search for XUV disks in a sample of nearby low-to-intermediate mass E/S0 galaxies to explore evidence for disk rebuilding after mergers. Preliminary visual classification yields ten XUV-disk candidates from the full sample of 30, intriguingly similar to the ~30% frequency for late-type galaxies. These XUV candidates occur at a wide range of masses and on both the red and blue sequences in color vs. stellar mass, indicating a possible association with processes like gas accretion and/or galaxy interactions that would affect the galaxy population broadly. We go on to apply the quantitative Type 1 and Type 2 XUV-disk definitions to a nine-galaxy subsample analyzed in detail. For this subsample, six of the nine are Type 1 XUVs, i.e., galaxies with UV structure beyond the expected star formation threshold. The other three come close to satisfying the Type 2 definition, but that definition proves problematic to apply to this sample: the NUV-derived star formation threshold radii for our E/S0s often lie inside the 80% K_s-band light (K_{80}) radii, violating an implicit assumption of the Type 2 definition, or lie outside but not as far as the definition requires. Nonetheless, the three otherwise Type 2-like galaxies ("modified Type 2 XUVs") have higher star formation rates and bluer FUV − NUV colors than the Type 1 XUVs in the sample. We propose that Type 1 XUVs may reflect early or inefficient stages of star formation, while modified Type 2 XUVs perhaps reflect inside-out disk regrowth.

1 Background

The ability of disk galaxies to survive in a violent universe filled with merger events is one of the central mysteries remaining in our understanding of galaxy evolution. A partial solution to this puzzle may be that while disks can be destroyed by galaxy-galaxy mergers (yielding E/S0 morphologies), they can also be reborn at a later time. Recent work has identified a population of low-to-intermediate mass, morphologically defined E/S0 galaxies that are surprisingly

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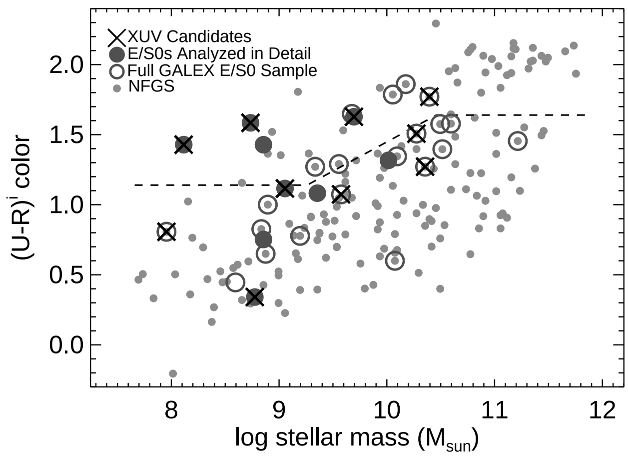

Figure 1. Our E/S0 sample in color-stellar mass space. The dashed line divides the red and blue sequences. The full 30-galaxy E/S0 sample is denoted by large filled and open circles, the ten visually identified XUV-disk candidates in this sample by crosses, and the nine-galaxy subsample considered in detail by large filled circles. The small grey dots indicate objects in the Nearby Field Galaxy Survey (Jansen et al. 2000a), the source of most of our E/S0s.

blue (Kannappan, Guie, & Baker 2009), indicating young stars. They occupy low density environments and have substantial cold gas to fuel star formation. Could these galaxies indeed be regenerating late-type morphology? The recent *GALEX* discovery of extended ultraviolet (XUV) disks (e.g., Thilker et al. 2005; Gil de Paz et al. 2005), representing very young stars around late-type galaxies, has provided tantalizing evidence for large-scale disk building at $z = 0$. Here we search for XUV emission in E/S0 galaxies to examine evidence for disk regrowth after mergers. Our sample includes 30 E/S0s selected to be representative of the red and blue sequences in a stellar mass range primarily below ~5 x 10^{10} $M_\odot$ (Fig. 1), where many E/S0s have substantial gas. Nine of these have fully reduced data, enabling detailed analysis.

2 Type 1 and 2 XUV disks

Thilker et al. (2007) define XUV disks of two types. A Type 1 XUV disk has more than one structured UV-bright emission complex beyond a central surface brightness contour corresponding to the anticipated star formation threshold (NUV 27.35 AB mag arcsec^{-2}). A Type 2 XUV disk has FUV(AB) $-$ K_s(AB) ≤ 4 in a "large" (i.e., area at least 7 times the enclosed area of the K_{80} contour) optically low surface brightness (LSB) zone within the expected star formation threshold but outside K_{80}. At present we can apply Thilker's definitions to only the nine galaxies with fully analyzed data, so we apply a third, more subjective identification method to our full 30-galaxy E/S0 sample in §3.

Applying the Type 1 XUV-disk definition to our subsample yields a 6/9 or ~67% incidence of XUV disks of this type and one borderline case with fainter

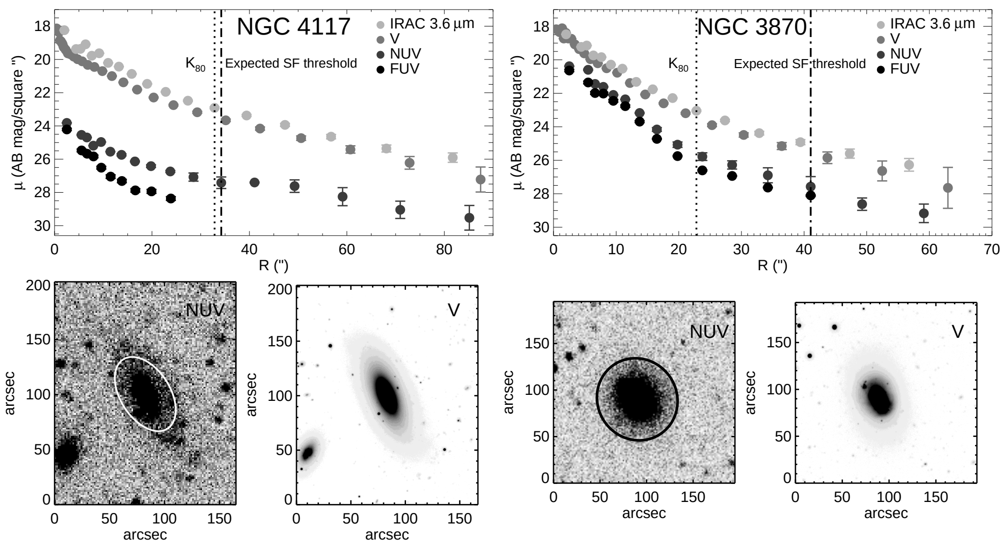

Figure 2. *Left Panels* - NGC 4117 - Top: Multi-wavelength surface brightness profiles. Bottom: *GALEX* NUV with overlay of the expected star formation threshold and Mosaic V with matched spatial scale. *Right Panels* - NGC 3870 - Same as for NGC 4117.

extended emission. An example of a Type 1 XUV disk is NGC 4117 (Fig. 2 left panels), one of several identified on the red sequence. Its NUV imaging shows clumpy UV morphology outside the anticipated star formation threshold. We note, however, that the Type 1 requirement of structured emission is sometimes difficult to apply consistently to galaxies like those in our sample, which have a smaller extent on the sky than those considered in Thilker's defining sample, so their structure is blurred by the relatively low angular resolution of *GALEX*.

The implicit assumption of the Type 2 XUV-disk definition, that the expected star formation threshold lies outside the K_{80} contour, is satisfied in our sample primarily for E/S0s with "spiral-like" or even bluer colors, for example NGC 3870 (Fig. 2 right panels). This definition's lack of applicability to many galaxies in our sample is intriguing. Figure 3 shows that as the ratio between the K_{80} radius and the expected star formation threshold radius increases for our sample objects, indicating centrally concentrated star formation, the star formation rate tends to decrease. Conversely, three of our UV-bluest E/S0s (NGC 3870, NGC 3011, and IC 692, the borderline Type 1 case) do have their star formation thresholds outside K_{80} and satisfy the Type 2 requirement of FUV - $K_s \leq 4$ in the LSB zone between the K_{80} and threshold radii (converting from IRAC 3.6 μm to K_s-band intensity following Leroy et al. 2008). Although the LSB zone is not "large" as for a standard Type 2 XUV, these galaxies have bluer UV colors and higher star formation rates than our Type 1 XUVs (Fig. 3), so we label them "modified Type 2" XUVs. Within the constraints of small number statistics, these results suggest that Type 1 morphology may be indicative of inefficient star formation or star formation just beginning, while the bluer disks forming in modified Type 2 XUVs may reflect inside-out disk regrowth.

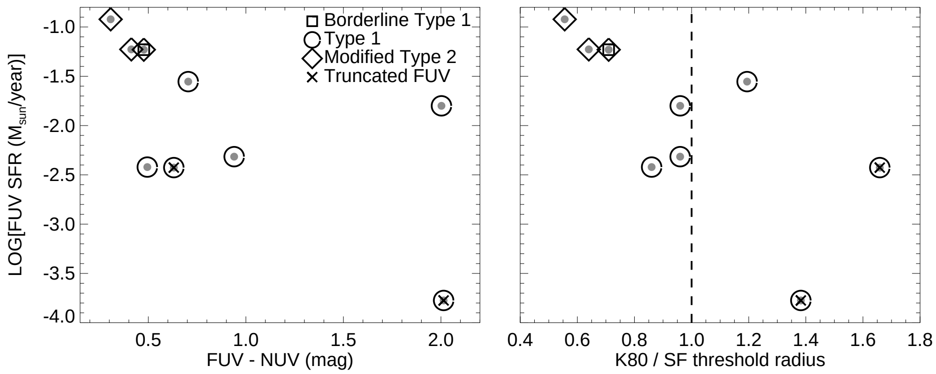

Figure 3. *Left* - FUV-derived star formation rate versus FUV − NUV color, both measured within the radius of the last detected point in the FUV profile. *Right* - SFR vs. the ratio of the K_{80} radius to the expected star formation threshold radius. The dashed line marks a ratio of one. Only foreground extinction corrections have been applied.

3 Continuing Work: The Full Sample

As a precursor to completing the data analysis necessary to apply Thilker's Type 1 and 2 definitions to our full 30-galaxy sample, we apply a third, more subjective identification method. An XUV disk in this third method is defined as having extended UV emission relative to the optical in a visual comparison of NUV and SDSS g-band images. By this preliminary identification ∼33% of our sample are XUV candidates, similar to the ∼30% fraction for late-type galaxies (Thilker et al. 2007). For the nine-galaxy subsample analyzed in detail, this method yields 5/9 or ∼56% incidence of XUV disks, which is actually lower than the frequency of XUVs identified using Thilker's Type 1 and 2 criteria. Our preliminary identification of XUV-disk morphologies in E/S0s at a wide range of masses and on both the red and blue sequences may indicate an association with processes like gas accretion and/or galaxy interactions that affect the galaxy population broadly, perhaps contributing to disk regrowth after mergers.

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