Extended UV Disks in Low-Mass E/S0 Galaxies and Their Relation to Disk Building

Amanda Moffett, Sheila Kannappan (UNC Chapel Hill), Andrew Baker (Rutgers), and Seppo Laine (SSC/Caltech)

Background

The processes responsible for the buildup of galaxy disks are still an open area of inquiry. The recent discovery of extended ultraviolet (XUV) disks (e.g., Thilker et al. 2005; Gil de Paz et al. 2005), representing ongoing star formation beyond the optical radii and traditional star formation thresholds in late-type galaxies, has provided an intriguing look at galaxy disk growth in progress at *z*~0.

Recent work has also identified a population of non-cluster, low-to-intermediate mass, morphologically defined E/S0s that are surprisingly blue (Kannappan, Guie, & Baker 2009, hereafter KGB), indicating young stars. These blue-sequence E/S0s have substantial cold gas to fuel star formation (KGB; Wei et al. 2010) and may represent a population *regrowing* disks at *z*~0, a process that has been predicted in hierarchical models. Blue-sequence E/S0s increase dramatically in abundance below the gas richness threshold stellar mass at 5 x 10^9 M_{sun} (M_t), the low-mass regime where atomic-gas/stellar mass ratios of order unity become common (Kannappan 2004; Kannappan & Wei 2008).

If the XUV-disk phenomenon is indeed associated with predicted disk regrowth process in early types, we might expect to preferentially observe XUV disks among the blue-sequence E/S0 population. We find instead a surprising but illuminating lack of association between "Type 1" XUV disks and those E/S0s that occupy the low-mass, gas-rich end of the blue sequence.

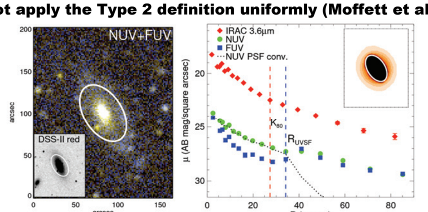
XUV Disk Definitions

Thilker et al. (2007, T07) define XUV disks of two types:

- Type 1: more than one structured UV-bright emission complex beyond a centralized surface brightness contour corresponding to the expected star formation threshold (NUV 27.35 ABmag/arcsec^2, at which radius R_{UVSF} is defined).
- Type 2: FUV–*K* ≤ 4 in a "large" (see T07), optically LSB zone within R_{UVSF} but outside K_{80}, the contour enclosing 80% of the *K*-band luminosity.

Application

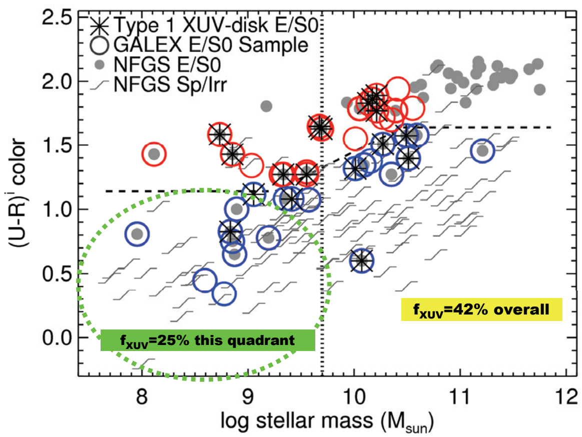
- Type 1: We find 18/43 or a 42(+9/-8)% incidence of Type 1 XUV disks, more than double the 20% frequency found by T07 for a mostly late-type galaxy sample. The morphologies (different from any underlying optical emission), colors (largely consistent with <1 Gyr SSP ages), and independent indicators of star formation potential (Hα or HI detections) characterizing our Type 1 XUV-disk galaxies are broadly consistent with recent star formation and not with being purely an effect of the UV upturn.
- Type 2: Definition has proven problematic to apply to E/S0s, in that R_{UVSF} often lies inside the K_{80} radius, or lies outside but not as far as the definition requires. This problem implies that we cannot apply the Type 2 definition uniformly (Moffett et al. 2009).



NGC 4117, a red-sequence Type 1 XUV-disk galaxy. *Left Panel: GALEX* NUV+FUV color composite with overlay of the NUV-derived star formation threshold. Inset shows the DSS-II red image with the same overlay for scale. *Right Panel: GALEX* and *Spitzer* surface brightness profiles. The black dotted line represents a profile extracted from the 2D convolution of the *GALEX* NUV PSF with the NUV galaxy flux found inside R_{UVSF}. The inset shows the convolved image, demonstrating that the clumpy XUV-disk morphology is not produced by the ~45" shelf in the NUV PSF.

Acknowledgements: We thank S. Jogee for her role in acquiring the *Spitzer* data. We also thank L. Wei, M. Norris, C. Clemens, and A. Leroy for useful discussions. AJM acknowledges support from the NASA Harriett G. Jenkins Pre-doctoral Fellowship Program. We also acknowledge support from the *GALEX* Guest Investigator program under NASA grants NNX07AT33G and NNX09AF69G and the *Spitzer* General Observer program GO-30406.

Sample



XUV disks in our sample of 43 E/S0s with stellar masses primarily below 5 x 10^{10} M_{sun}, where f_{XUV} represents the fraction of Type 1 XUVs we identify. The vertical dashed line indicates the gas richness threshold stellar mass (M_t). This sample encompasses a subsample of the Nearby Field Galaxy Survey (NFGS, Jansen et al. 2000) as well as 5 blue-sequence E/S0s from the "HyperLeda+" sample of KGB, observed in *GALEX* program GI3-0046 (PI Kannappan). The sample also includes CGCG 065-002 (program GI5-042, PI Moffett) and an archival sample of all 12 field E/S0s with compatible *GALEX* and *Spitzer* coverage.

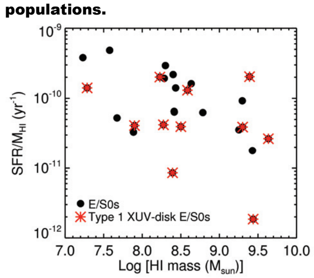
Ubiquity of Type 1 XUV Disks

- We observe a widespread distribution of XUV disks throughout our sample (no preference for red or blue sequence, and XUV stellar mass distribution matches that of the parent sample with 99% Kolmogorov-Smirnov test probability).
- The ubiquity of this phenomenon suggests an association with evolutionary processes that affect the galaxy population broadly, such as gas accretion and/or minor satellite interactions.

Type 1 XUV Disks as Weak or Inefficient Star Formation

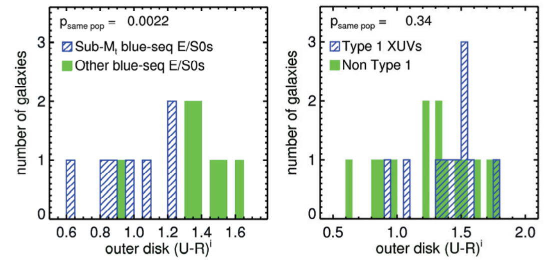
- The high (42%) overall Type 1 XUV-disk incidence we observe could indicate that Type 1 XUV disks are primarily related to inefficient or weak star formation, an interpretation that is consistent with the high 70% rate of XUV disks seen in massive low surface brightness galaxies, which are known for inefficient star formation (Boissier et al. 2008).
- On the low-mass/gas-rich blue-sequence, where E/S0 disk building is expected to be most active, Type 1 XUV-disk galaxies make up 25(+18/-13)% of E/S0s. This XUV-disk fraction is similar to the 20% late-type frequency (T07), implying that *low* Type 1 XUV-disk incidence may be characteristic of strongly disk-building populations.

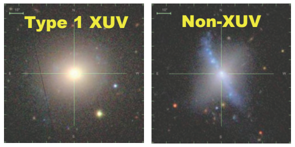
As can be seen in the plot at right, the global (rather than outer disk, which may weaken the signature of any outer disk trend) star formation efficiencies of our Type 1 XUV-disk E/S0s tend to scatter to lower values than for those galaxies without XUV disks. Ansari-Bradley statistical test results imply that the two distributions possibly differ in their dispersions (p_{same}=0.0611).



Indicators of Strong Disk Building

- The bluer colors, including optical outer-disk colors (between the 50%-75% B-band light radii; see left figure below) specifically, and larger gas reservoirs available to fuel star formation for low-mass blue-sequence E/S0s suggest that they are the most strongly disk-building E/S0s.
- In contrast, Type 1 XUV-disk identifications do not show a preference for picking out strong disk building as traced by blue optical outer-disk colors (see right figure below) or galaxies with enhanced gas content (HI masses from Wei et al. 2010).





SDSS color composites of two blue-sequence E/S0s (left galaxy with blue ring) in our sample, illustrating apparent strong star formation activity in a non-XUV-disk galaxy.

- Type 2 XUV-disk morphology may provide a better indicator of the presence of strong disk growth, though issues with the application of the Type 2 XUV-disk definition to an early-type sample (Moffett et al. 2009) complicate this way forward.

Conclusions

- In a sample of 43 field E/S0 galaxies, we have identified a high 42(+9/-8)% frequency of Type 1 XUV disks, representing recent outer-disk star formation, which is more than twice the 20% fraction reported for late types.
- In the low-mass regime (below 5 x 10^9 M_{sun}) where gas fractions rise, Type 1 XUV-disk galaxies make up 25(+18/-13)% of "blue-sequence E/S0s," a recently identified class of gas-rich, non-cluster E/S0s believed to be actively rebuilding disks. This low XUV-disk frequency, which is similar to that found in late types, may imply that *low* Type 1 XUV-disk fractions are a characteristic of populations undergoing active disk growth.
- The low-mass, blue-sequence E/S0 classification clearly picks out strong disk builders, whereas the Type 1 XUV-disk classification does not and may even be a contrary indicator.
- Since existing Type 1 and 2 XUV-disk classifications are problematic tracers of strong disk building in E/S0s, an alternative UV-bright disk definition is needed.

For Further Information:


Amanda Moffett
amoffett@physics.unc.edu


Sheila Kannappan
sheila@physics.unc.edu

References

Boissier, S., et al. 2008, ApJ, 681, 244
Gil de Paz, A., et al. 2005, ApJ, 627, L29
Jansen, R. A., et al. 2000, ApJS, 126, 331
Kannappan, S. J. 2004, ApJ, 611, L89
Kannappan, S. J., Guie, J. M., & Baker, A. J. 2009, AJ, 138, 579 (KGB)
Kannappan, S. J. & Wei, L. H. 2008, in AIP Conf. Ser. 1035 (Melville, NY: AIP), 163
Moffett, A. J., et al. 2009, arXiv:0908.4232
Thilker, D., et al. 2005, ApJ, 619, L79
Thilker, D., et al. 2007, ApJS, 173, 538 (T07)
Wei, L. H., et al. 2010, ApJ, 708, 841