Surface Brightness Profile Breaks in Dwarf Galaxies

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A Riddle:

Look at a galaxy! Its disk light
Falls exponentially- is that right?
If you look deeply, often you'll see
Signs of us- in both Types II and III!
Why do we exist? Explore the gas,
Motions near and far. Profile the mass.
Search with care; do whatever it takes.
We are Surface Brightness Profile Breaks!

Recently it has been well shown that there are three different surface brightness profile types in spiral galaxies: (I) the minority, where the light falls off with a single exponential; (II) truncated, the majority, where the light falls off with one exponential to a break radius and then falls off more steeply; and (III) anti-truncated, where the light falls off with a more shallow exponential beyond the break radius. Additionally, Bakos, Trujillo, & Pohlen (2008) showed that each type has a characteristic color trend with respect to the break location. In dwarf disk galaxies, however, there is a fourth type which is perhaps a special Type II case: the light profile is flat on the inside and then falls off exponentially beyond the break radius. Here we show the different color trends for these four profile types from a large photometric study of dwarf disk galaxies and explore the similarities and differences between spirals and dwarfs.

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1. Introduction

- To first order, disk light in galaxies falls exponentially
- Large studies [1-4] have shown breaks in the exponential fall-off
- Type II: truncated, majority; steeper fall off [2] (Fig 1, top center)
- Type III: anti-truncated; shallower fall off [1] (Fig 1, top right)
- Bakos, Trujillo, & Pohlen [5] found color trends in spiral galaxies for each type (See Fig 1, central panels)
- They averaged profiles & colors from 69 spirals with deep photometry
- In Type II, they found a U-shaped color trend (bluer then redder)
- Are there similar color trends in dwarf galaxies?
- Hunter & Elmegreen [3] presented surface photometry for 141 dwarfs and found that ~30% have a broken surface brightness profile
  - 96 Im (irregular), 20 Sm (bridge between spirals and irregulars), 25 BCD (blue compact dwarfs) [6]
- Dwarfs have a 4th type: flat inside (FI), then falling off (Fig 2, right-most top panel)
- Further examination indicates that more profiles may be broken

2. Method (on data from [3])

- Re-examine all profiles and quantitatively reclassify into 4 Types via a program which statistically finds the best break location (R_{break})
- Fit slopes to the individual component trends of the 141 dwarfs
- Some have two breaks (10), excesses (25)
- For the color analysis, eliminate 11 without B-V color information
- Scale radius by R_{break} and fit with natural cubic splines (for averaging purposes)
- Isolate broken samples that extend 1.5 R_{break} and Type I samples farther than 3 h_R (scale length); 17 profiles are too short
- Remove galaxies with large uncertainties (10) in B-V as well as 8 clear outliers (see appendix)
- Plot the profiles and colors of the remaining 95 and look for color trends

3. Results

- General color trends from sample of 95: (See Fig 2, lower panels)
  - I: slight reddening between 1 to 3 scale lengths (6; red) or
  - I: pretty flat (4; cyan)
  - II: flat to break, then slight reddening trend (22; red) or
  - II: bluer to break, then pretty flat (18; violet) or
  - II: basically just flat (9; cyan) or
  - II: bluer to break, then slight reddening (6; magenta) (U shape)
  - III: clearly redder to break, then pretty flat (20)
    - slightly stronger color gradient in BCDs (blue) than Ims (green)
  - FI: flat to ~1.5 x break, then slight red trend (10; cyan)
- Fractions of types out of the full sample of 141 dwarfs:

	Total	I	II	III	FI	Combo
BCDs	25	4(16.0%)	3(12.0%)	13(52.0%)	2(8.0%)	3(12.0%)
Sms	20	1(5.0%)	16(80.0%)	1(5.0%)	1(5.0%)	1(5.0%)
Ims	96	11(11.5%)	59(61.5%)	11(11.5%)	9(9.4%)	6(6.2%)

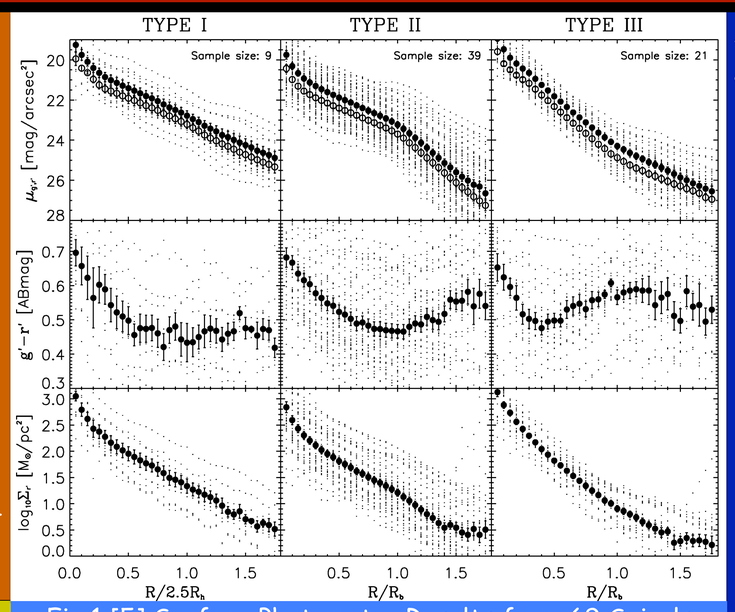

Fig 1 [5] Surface Photometry Results from 69 Spirals
In each panel, tiny dots indicate the data for the individual spirals whereas the large data points indicate the averages. Error bars are $\sigma/\sqrt{N}$ where σ is the scatter and N is the number of galaxies. Top row: Surface brightness profiles of spirals; filled and open circles represent r'-band and g'-band data, respectively. Central row: (g' – r') color profiles. Bottom row: r'-band surface mass density profiles determined by applying color-to-M/L relations of Bell et al. [7]

Fig 2 Surface Photometry Results from 95 Dwarfs
In each panel, tiny dots indicate the data for the individual spirals whereas the large data points indicate the averages. Error bars are $\sigma/\sqrt{N}$ where σ is the scatter and N is the number of galaxies. See Results section for color explanations.
Top row: Surface brightness profiles.
Bottom row: (B – V) color profiles.

4. Discussion

- Comparison to spirals
  - Color trends:
    - The main color trend in spirals is a bluing before the break [5]
    - For dwarfs, the only sign of this is a weak trend in ~50% IIs
    - Ignoring the initial blue trend:
      - Type III have very similar color shape (spirals & dwarfs)
      - Some Type I have similar color shape (spirals & dwarfs)
    - For dwarfs, Type IIs have 4 different color shapes:
      - Blue then flat is slight majority (27/69)
      - Flat then red comes next (22/69)
      - Just basically flat is third (12/69)
      - Spiral blue then red is minority in dwarfs (8/69)
      - (Note: 12 short and 2 uncertain II colors were used here)
    - Type FI have a primarily constant color
  - Type Distribution:
    - 85 int incl late spirals: 10% I, 60% II, 30% III [2]
    - 66 barred early-types: 27% I, 42% II, 24% III, 6% II & III [4]
    - 141 late dwarfs: 11% I, 55% II, 18% III, 7% 2 breaks, 9% FI

5. Conclusions & Future Work

- Some color trends do exist for different types of profile breaks in dwarfs, but they do not completely parallel those in spirals
- Perhaps the best exception is the Type IIIs; similar trend of reddening to the break and then staying constant
- Some dwarf Is and IIs have similar outer profiles shapes as spirals
- ~50% of dwarf IIs have a slight bluing trend (seen in all spirals)
- Similar percentages occur between the different types, with the majority being II, even though dwarfs have an extra type (FI)
  - However, BCDs are primarily III and Sms are strongly II

- More work to do, still:
  - Statistical comparisons of R_{break}, μ_0, h_R, h_{Rin}/h_{Rout}…
  - Look for possible profile Type trends with galaxy characteristics
  - Comparisons between bands (FUV,NUV,UBVJHK,3.6μm,4.5μm,Hα)
  - Examine additional colors besides B-V
  - Convert color trends to M/L and estimate the stellar mass profiles
  - Examine gas mass profiles in LT dwarfs with and without breaks
  - Compare LT break locations to rotation curve turnover radii
  - Probe stellar motions across breaks via planetary nebulae (PNe)
    - Any differences in gas mass profile or PN motions?

6. References

[1] Erwin, P., Beckman, J.E., & Pohlen, M. 2005, ApJ, 626, L81-L84
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[7] Bell, E.F., McIntosh, D.H., Katz, N., & Weinberg, M.D. 2003, ApJS, 149, 289