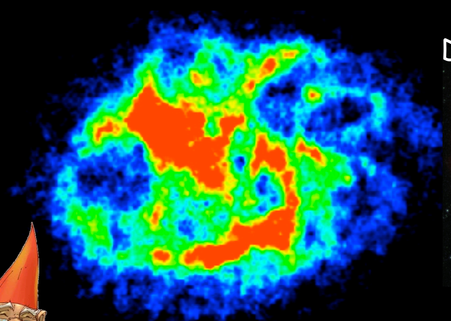
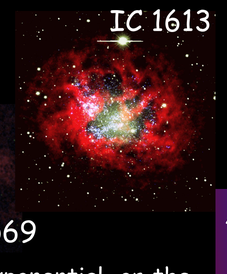


LITTLE THINGS

Radial Color and Mass Profile Trends of Dwarf Irregular Galaxies

Kimberly Herrmann[1], LITTLE THINGS Team

[1]Penn State University- Mont Alto



PennState

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!

ABSTRACT

Radial stellar surface brightness (SB) profiles of spiral galaxies can be classified into three types: (I) single exponential, or the light falls off with one exponential out to a break radius and then falls off (II) more steeply ("truncated"), or (III) less steeply ("anti-truncated"). *Why* there are three different radial profile types is still a mystery, including why light falls off as an exponential at all. Profile breaks are also found in dwarf disks, but some dwarf Type IIs are flat or increasing (FI) out to a break before falling off. Additionally, Bakos, Trujillo, & Pohlen [1] showed that for spirals, each profile type has a *characteristic color trend* with respect to the break location which can be combined with color mass-to-light ratio (M/L) relationships to examine radial *mass* profiles as well. Here we show radial color and mass profile trends for the three main SB types from a large multi-wavelength photometric study of dwarf irregular galaxies (the 141 dwarf parent sample of the LITTLE THINGS galaxies). We explore the similarities and differences between spirals and dwarfs and also between different colors.

I. Introduction

To first order, the disk light in galaxies falls off exponentially. However, broken exponentials are more common [2-6]. (See Fig. 1.) Additionally, Bakos, Trujillo, & Pohlen [1] found color trends for each type. (See Fig. 2, gold points in center row.) Applying a M/L determined from the "U"-shaped (blue then red) color trend of Type II profiles yields a remarkably reduced break in the surface mass density profile. (See the gold profile in the lower central panels of Fig. 2.) Their interpretation is that interactions with spiral arms cause older, redder stars to migrate outwards.

Are there similar color trends in dwarf galaxies, which do not contain spiral arms?

II. Methods

Hunter et al. have collected an incredible photometric data set for 141 dwarf galaxies in up to 11 passbands [2,6-11]. (See Fig. 1.) As with spirals, dwarfs have characteristic radial color trends that are related to the break locations. However, Type II dwarfs have more than one radial color trend. After classification, each radial profile for the FUV-NUV, *U-B*, and *B-V* colors is scaled by the break radius and fit with one or two lines (or natural cubic splines for Type III profiles) before being averaged to isolate the color trends. (See Fig. 3.) Next we used our *B-V* profiles with mass profiles from a subsample [12] to determine M/L as a function of *B-V* for dwarfs and then applied the relationship to determine radial mass profiles for the whole *B-V* sample.

Data for 141 Dwarf Galaxies

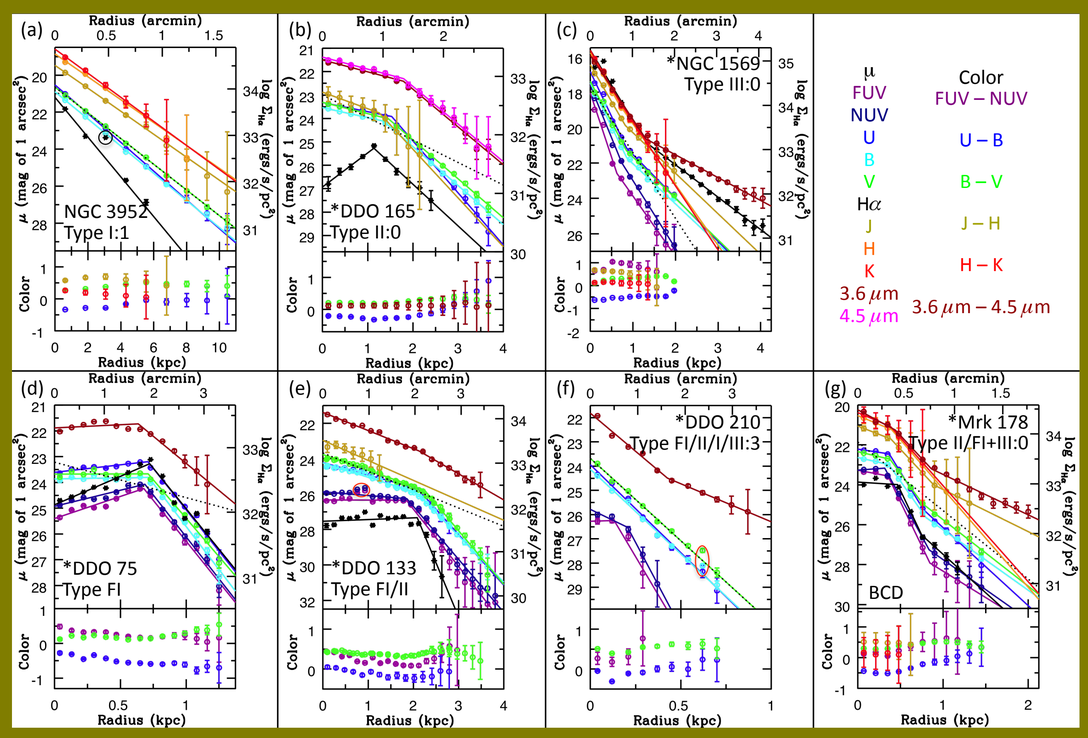
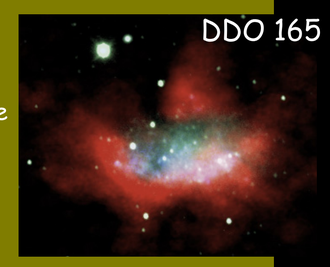


Fig. 1. Surface brightness profiles and radial color distributions for seven representative profile types.

(a): Type I, single exponential, minority
(b): Type II, "truncated", i.e., steeper fall-off beyond break, majority for late-type disks
(c): Type III, "anti-truncated", i.e., shallower outer fall-off, more common in early-type disks
(d): Type FI, special subcategory of II only found in dwarfs
(e): Type FI/II combination (i.e., some bands FI but others II)
(f): Multiple Types; DDO 210 is the only galaxy where *all* the profile types are represented (such that types are listed generally blue to red)
(g): Mixed; an example galaxy best fit by *two* breaks



Note that:
(1) the dotted black line is the best Type I fit to the *V*-band data,
(2) LITTLE THINGS dwarfs are indicated with an asterisk preceding the name,
(3) eliminated data points are circled such that red indicates that all contained points are eliminated whereas black or blue indicate only Hα or *U* data eliminated, respectively, and
(4) numbers after a colon indicate the following:
- 0 = all forced to be broken,
- 1 = all forced to be single,
- 3 = at least one forced to be single whereas others forced to be broken.

See the "appendix" for similar plots for the full sample of 141 dwarfs consisting of 96 dIm, 26 BCD, and 19 Sm galaxies. The multi-wavelength data come from various sources: Hα [7], *UBVJHK* [2], 3.6 and 4.5 μm [8+data from several *Spitzer* Legacy projects: The Local Volume Legacy (LVL) and the Spitzer Infrared Nearby Galaxy Survey (SINGS)], and *FUV* and *NUV* [9,10,12].

For much more information, see Paper I (Profiles and Statistics).

III. Results

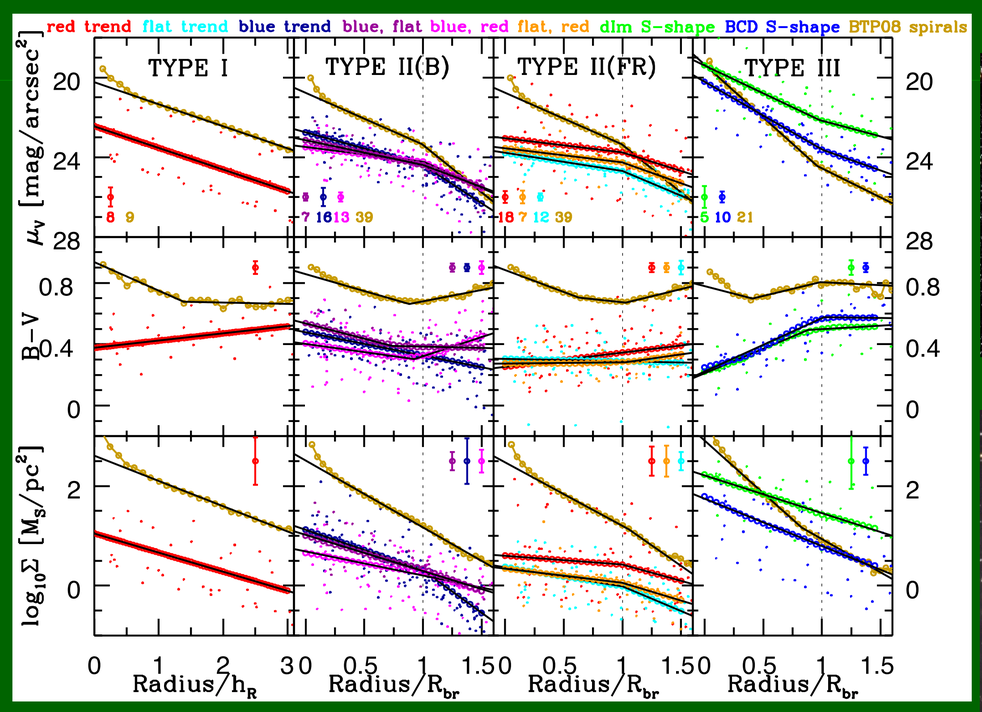
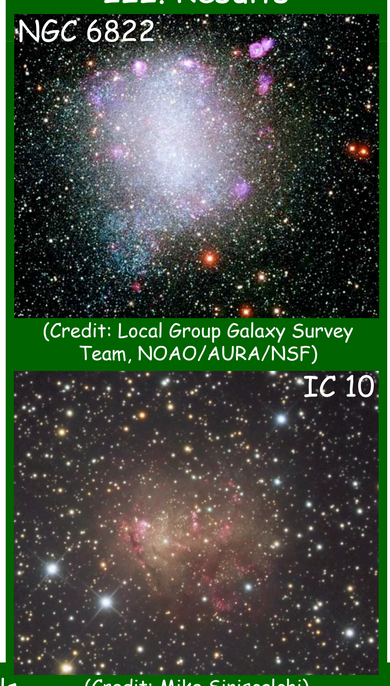


Fig. 2. Averaged Surface Brightness, Color, & Mass Profiles for 141 Dwarfs & 69 Spirals. Tiny dots show data for individual galaxies whereas large data points indicate averages. Error bars are σ/√N where σ is the scatter and N is the number of galaxies.
Top row: SB profiles; spiral data from [1] (transformed from g' and r' data)
Middle row: *B - V* color profiles; spiral data from [1] (transformed from g' and r' data)
Bottom row: *V*-band surface mass density profiles determined by applying color-to-M/L relations derived for dwarfs and those of Bell et al. [13] for spirals from [1]



(Credit: Local Group Galaxy Survey Team, NOAO/AURA/NSF)

(Credit: Mike Siniscalchi)

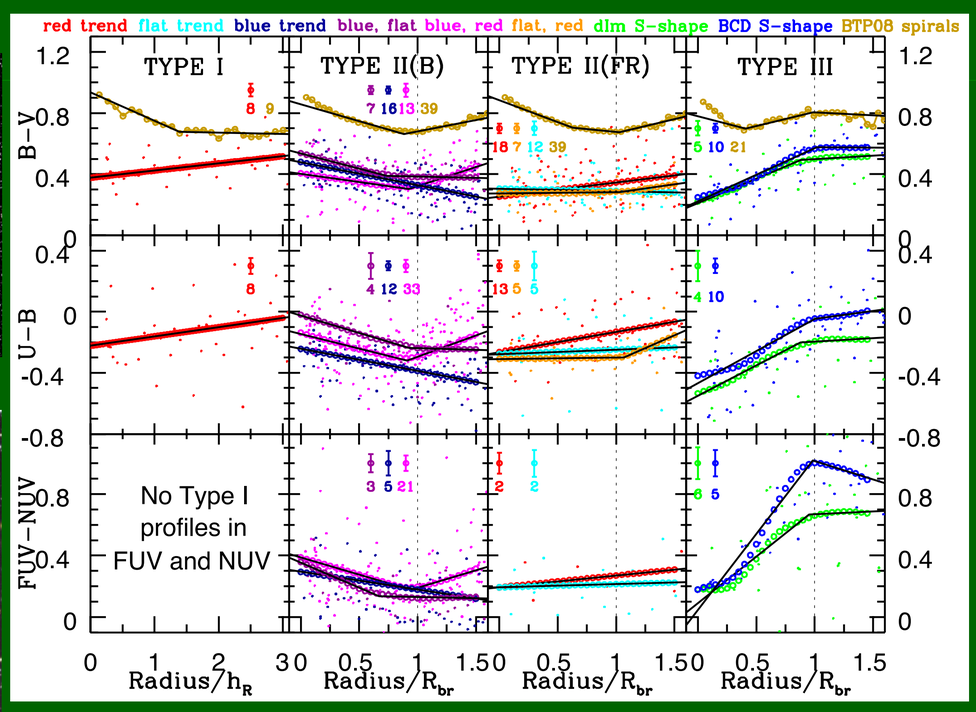


Fig. 3. Averaged Color Profiles (*B-V*, *U-B*, and FUV-NUV) for 141 Dwarf sample. See Fig. 2 for explanations of the data point sizes.

IV. Discussion

Radial Color Trends:

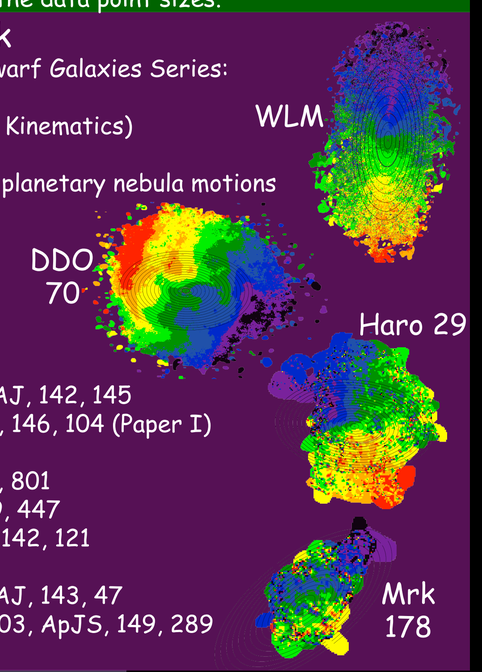
The color trends in dwarfs do not completely parallel those in spirals. The inner regions differ since all spirals have an initial blue trend (due to a radial decrease in age and metallicity, [14]) whereas only some Type II dwarfs share this inner trend. (See Fig. 3.) However, the outer trend in Type IIIs is very similar in both spirals and dwarfs- in all three colors explored here. In Type I spirals, the outer colors are ~constant but in Type I dwarfs the colors get slightly redder. The majority of Type II dwarfs share the spiral "U" shape whereas others have (in order of decreasing frequency): a general blue or red trend, no trend at all (flat), or blue then flat or flat then red. Color trends can change between the three different colors explored for a single galaxy and there are some outliers.

Radial Mass Profiles:

We find broken mass radial profiles for broken SB profiles in most cases except for Type III dwarfs and Type II dwarfs with "U" shaped colors (blue then red) or blue then flat color trends. That the break roughly disappears in the mass profile of "U" Type II dwarfs agrees with the results found in spirals (even without spiral arms!), but a single exponential fall off in the mass profile of Type III dwarfs differs from the remaining break in the mass profile of Type III spirals.

V. Future Work

Upcoming Papers in Stellar Surface Brightness Profiles of Dwarf Galaxies Series:
II. Color Trends and Mass Profiles
III. Relationship to HI Gas in LITTLE THINGS (Profiles and Kinematics)
IV. Two-dimensional images and Asymmetries and Modeling
Additional analysis: Probing stellar motions across breaks via planetary nebula motions



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