**Image Analysis of the LITTLE THINGS Galaxies**

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Dwarf galaxies are the most abundant galaxy type in the universe. We would like to better understand how these galaxies form stars, and how these processes differ from star formation in large galaxies. Using GALEX data as well as data taken from LITTLE THINGS team members, images of these galaxies can help answer some questions so as to better understand how star formation occurs in dwarf galaxies.

**What is a young star cluster’s visual definition, and how can it be differentiated from nearby foreground/background stars and nearby galaxies?**

Images used to analyze the LITTLE THINGS galaxies included far ultraviolet (1516 Å) and V-band (~5500 Å) images, as well as 2-color (FUV-NUV) and HI images for comparison. Far ultraviolet (FUV) images that were used included stars with a subtracted sky, and were geometrically fit to have the same dimensions as the V-band images. As young star clusters are still very hot, they appear brightest in FUV. The continuum of the galaxy appears brighter in V-band as its temperature is cooler than that of the star clusters. A smoothing algorithm was used on the V-band images of each galaxy, and that was then subtracted from the FUV image—this removed the continuum from each galaxy, leaving only the hot stars. Leftovers were not always single stars, but apparent star groupings or “knots”. These were defined as target regions, or young star clusters.

**Is there structure in the outer disk, and if so, how far out is it?**

After analyzing images of all the LITTLE THINGS galaxies—there is structure due to star formation present in almost all of the outer disks. How far out this structure is present varies with the history of each galaxy. A few prominent groups were present—compact dwarfs, dwarfs with holes due to star formation, and dwarfs that appeared to have interacted/collided with another nearby galaxy. It appears as though the distance at which the furthest structure is seen is dependent on which of these groups the galaxy falls under. The furthest apparent structure in each galaxy has been calculated in scale lengths, and the results of each group are shown below. Rfuv is the visual distance of the target region measured, and Rd is the distance in disk scale lengths the target region is located at (disk scale lengths calculated by Diedre Hunter).

**Procedure**

To analyze these images, the continuum of the galaxy had to be subtracted, leaving only the clumpy star forming regions. To do this, the first method that was tried was using a smoothing algorithm—boxcar and gauss were both used—on the V-band images and then subtracting the smoothed image from the V-band image. The next method was to smooth/subtract the V-band image from the FUV image—for this to be done, the V-band image had to be scaled to match the FUV image. This was done by picking 3 points on each galaxy, recording their FUV and V-band’s average pixel value through implot, and dividing each FUV value by each V-band value. These three numbers were then averaged, and that number was used to multiply the V-band image to match the FUV image. From there, the scaled V-band image was smoothed using the gauss smoother (a sigma of 17 was the preference, but sigmas of 5,10,30 were also used). This smoothed image was then subtracted from the FUV image, and from there star forming regions were determined with the final image. These final images of each galaxy were compared with their 2-color images (FUV-NUV) so as to determine what stars/regions in question were actually in the galaxy vs. foreground/background stars and objects, based on their color and brightness. Comparisons were also done with images of these galaxies published in the Melena et. al. 2009 paper. The first galaxies analyzed were the ones also published in Melena et. al. 2009 to get a good handle on what star forming regions should look like from someone else’s perspective. From there, galaxies were analyzed based on distance—closest galaxies were analyzed first, moving out.

Target regions were circled on each galaxy’s final image, and these images were saved and used to measure the distance of each region in disk scale lengths. This was done using images of each galaxy w/annuli on top of the galaxy, each annuli corresponding to a distance in disk scale lengths—these images and distances were provided by Diedre Hunter. Each galaxy’s final image with highlighted target regions was compared with the annuli images to determine the distance to each region in disk scale lengths. Each galaxy’s furthest target region was used for the graphs seen below.









The results appear to be inconclusive, however—there are a few galaxies that belong in more than one group, which is helpful in better interpreting the results. There are several compact dwarfs that appear to have interacted with a nearby galaxy—Haro 29, Mrk178, NGC 3738, and NGC 4163. Haro 29 has structure out to 2.593 RD, Mrk178 has structure out to 4.403 RD, NGC 3738 has structure out to 1.552 RD, and NGC 4163 has structure out to 2.343 RD. These should be treated as “special cases” as there isn’t an apparent pattern visible from these four galaxies. Shown below are compact dwarfs and dwarfs that have interacted with a nearby galaxy without these special cases.





The results are scattered for the dwarfs that have apparent interaction history, however—this is an acceptable result as galactic interaction can have many different results. However, all of these galaxies show structure at least 2 RD or greater, the furthest structure being seen close to 5 RD.

The results are more conclusive for the compact dwarfs—it appears as though star formation is only occurring out to about 2 RD, which corresponds with the accepted structure of compact dwarfs, where most star formation is occurring near the center.

The dwarfs with holes in the HI as well as the absence of stars are intriguing—it appears as though these holes are due to early star forming events, and the only stars leftover from these are old, cool stars that don’t appear bright in the FUV. Structure is seen much further out in these galaxies—in most of them, structure is seen between 2-5 RD, with the furthest structure being seen at 6 RD.

The conclusions drawn from these data show that apparent star formation, or structure occurs much further out in the disk for galaxies that have undergone an interaction of some sort or have had star forming events occur in the past. This could be due to a change in the density of the HI in these galaxies—star formation events “blowing holes” in the HI could cause nearby regions of HI to increase in density, sparking star formation further out in the disk. For interacting galaxies, a similar situation could be present—interaction, or collision could cause some regions of HI to decrease in density, while other HI regions could increase in density due to gas from both galaxies combining, also sparking star formation further out in the disk. This could be true for galaxies such as DDO 154 and NGC 6822, which appear “stretched out” from a possible interaction, and have structure near the furthest regions of HI.

Based on these conclusions, it appears as though star formation doesn’t “naturally” occur far out in the disks of dwarfs—something has to happen to spark this, such as star formation or galactic interaction.