Dust and Star Formation in Nearby Dwarf Galaxies

Ted K. Wyder[1], Dale C. Jackson[2], Evan D. Skillman[2], John M. Cannon[3], Robert D. Gehrz[2]

ABSTRACT

We present FIR measurements from the MIPS instrument aboard the *Spitzer Space Telescope* of the dust emission from 13 dwarf galaxies that have distances less than 2 Mpc, span metallicities from $5 - 28\%$ of the solar oxygen abundance, and with SFRs ranging from 10^{-4} to 10^{-1} $M_{\odot}$ yr^{-1}. We compare the "obscured" star formation traced by the FIR images with measurements of the "un-obscured" star formation traced by UV images from the *Galaxy Evolution Explorer (GALEX)* and ground-based Hα fluxes. We find that the ratio of FIR to FUV SFR decreases with oxygen abundance. The Hα SFRs are consistent with both the far-infrared and UV values for the galaxies with the highest star formation rates, but are systematically lower than both of these values at the lowest star formation rates and metallicities.

Subject headings: stars: formation - galaxies : dwarf - galaxies : irregular - galaxies : Local Group - infrared : galaxies - ultraviolet : galaxies - galaxies: ISM

1. Introduction

While much of the bolometric luminosity from star formation in massive spiral galaxies is absorbed by dust and re-emitted in the FIR, much less is known about the FIR emission from dust in low metallicity dwarf galaxies. Understanding the emission from dust in dwarf galaxies is essential in extending measurements of the star formation rates (SFRs) of galaxies to low metallicity. The nearest dwarf galaxies provide an opportunity to explore these issues due to their low heavy element abundances, their proximity, and abundance of corollary data. We have begun compiling integrated measurements of the nearest dwarf galaxies in the FIR, FUV, and Hα, in order to compare the SFRs derived from these different indicators.

[1]California Institute of Technology, MC 405-47, 1200 E. California Blvd., Pasadena, CA 91125

[2]University of Minnesota, Department of Astronomy, 116 Church St. SE, Minneapolis, MN 55455

[3]Macalaster College, Department of Physics and Astronomy, 1600 Grand Ave., Saint Paul, MN 55105

2. Data

Our sample of galaxies includes the thirteen nearest dwarf irregular or transition dwarf galaxies within a distance of 2 Mpc. We do not include the Magellanic Clouds due to their large angular extent on the sky. We have compiled a complete set of data for these galaxies in the UV and the FIR based upon existing measurements in the literature, archival data, and new observations. We have also taken integrated Hα fluxes for these galaxies from the compilation given in Mateo (1998).

The new FIR data consist of MIPS imaging at 24, 70, and 160 μm for 11 of the galaxies. Additional MIPS data for NGC 55 and NGC 6822 were obtained from the *Spitzer* archive (Englebracht et al. 2004; Cannon et al. 2006). All of the galaxies have observations in the *FUV* and *NUV* from *GALEX*. For six of the galaxies, we have taken the integrated fluxes presented in Gil de Paz et al. (2007), while we have made new measurements for the remaining seven galaxies. Nine of the galaxies of the galaxies in our sample have oxygen abundances measured from spectra of their H II regions (Lee et al. 2006). Eleven of the galaxies have distances derived from the magnitude of the tip of the red giant branch from archival *Hubble Space Telescope* data analyzed by Dolphin et al. (2005). For the two galaxies not in included in Dolphin et al. (2005), namely NGC 55 and GR 8, we assume distances based upon observations of Cepheid variable stars (Tolstoy et al. 1995; Pietrzyński et al. 2006).

Images of the 13 nearby dwarf star-forming dwarf galaxies in our sample in the *FUV* from *GALEX* and at 24, 70, and 160 μm from *Spitzer* are shown in Figures 1 – 4. While all of the galaxies are detected in the UV, only nine have convincing detections in the FIR with MIPS. Among the galaxies detected in the FIR, the *FUV* emission tends to be spread across most of the extent of each galaxy, while the FIR tends to be concentrated in more restricted regions, typically coincident with the highest surface brightness UV regions.

3. Results

For the nine galaxies detected by MIPS, we have calculated total FIR luminosities over the wavelength range $3 - 1100$ μm using the relation in Dale & Helou (2002). We use the relations in Kennicutt (1998) to convert the Hα, FUV, and FIR luminosities into SFRs assuming a constant star formation history and a Salpeter (1955) stellar initial mass function. For the total SFR, we simply take the sum of the obscured SFR as traced by the FIR and the unobscured SFR as traced by the FUV. In Figure 5 we plot the ratios of the various SFRs as a function of the oxygen abundance on the left and as a function of the total SFR

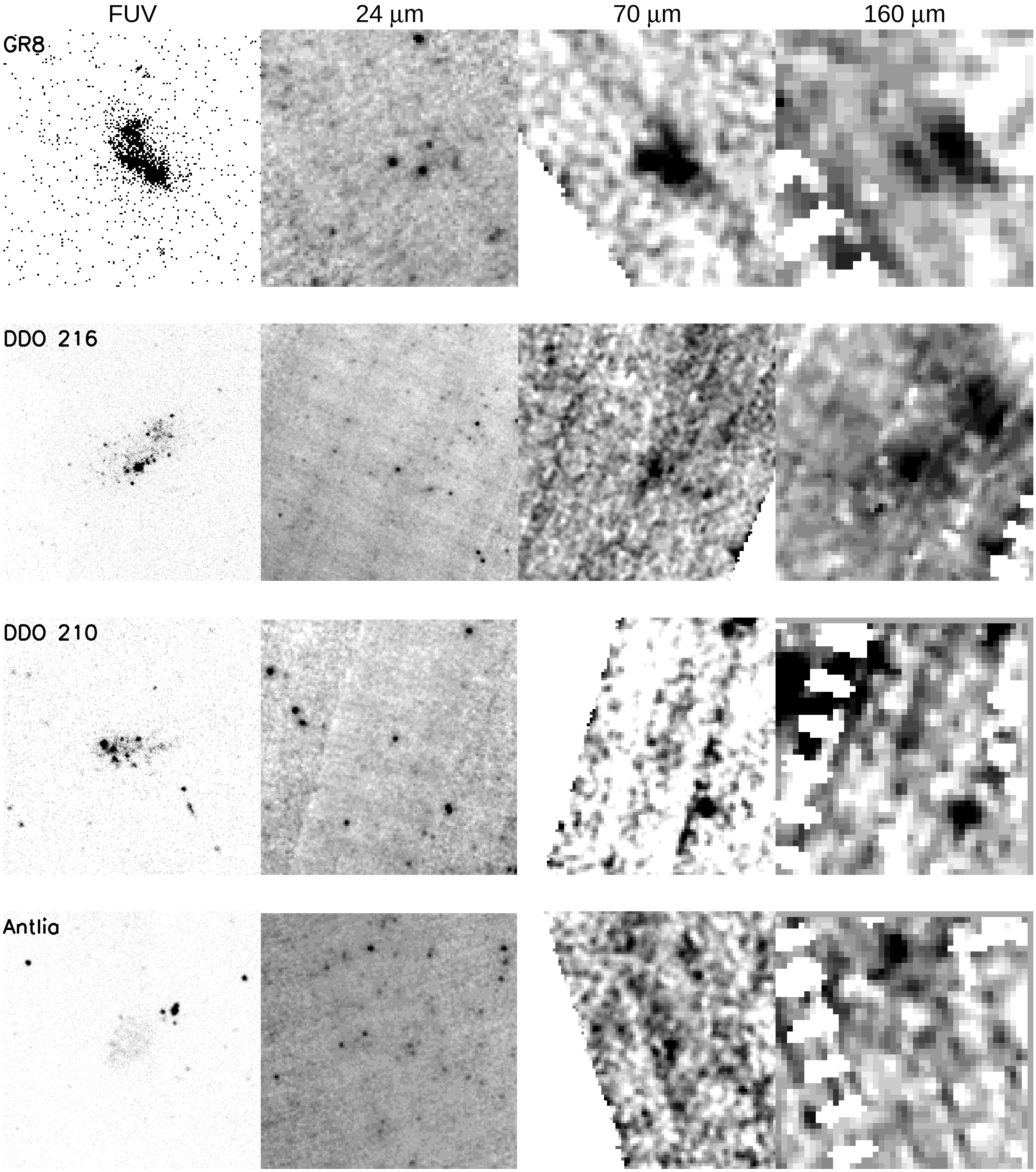

Fig. 1.— *GALEX* UV and *Spitzer Space Telescope* images of the galaxies Antlia, DDO 210, DDO 216, and GR 8. Each row corresponds to the same region of sky for a given galaxy and the images are from left to right: *FUV*, 24μm, 70μm, and 160μm.

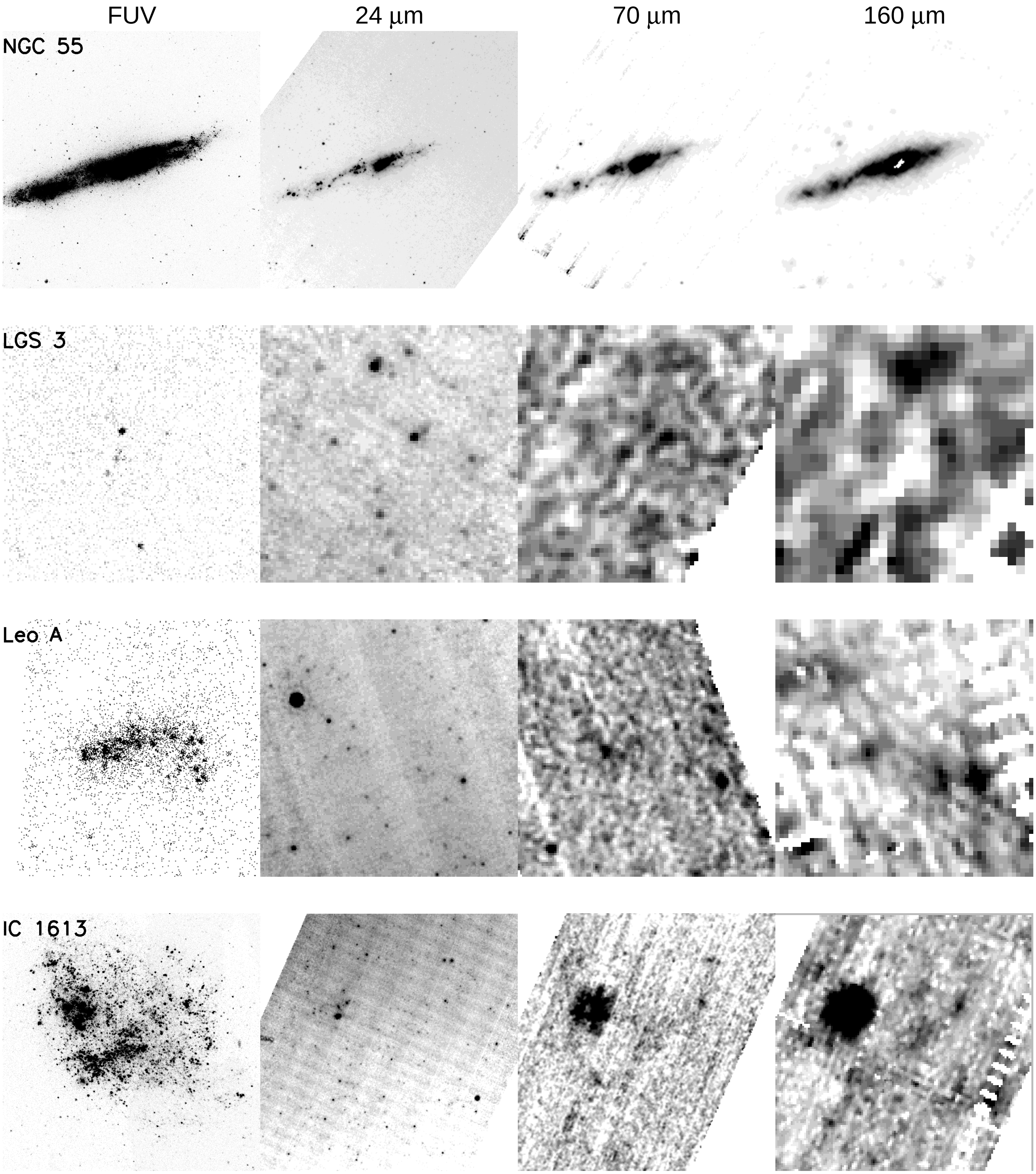

Fig. 2.— *GALEX* UV and *Spitzer Space Telescope* images of the galaxies IC 1613, Leo A, LGS 3, and NGC 55. Each row corresponds to the same region of sky for a given galaxy and the images are from left to right: FUV, 24μm, 70μm, and 160μm.

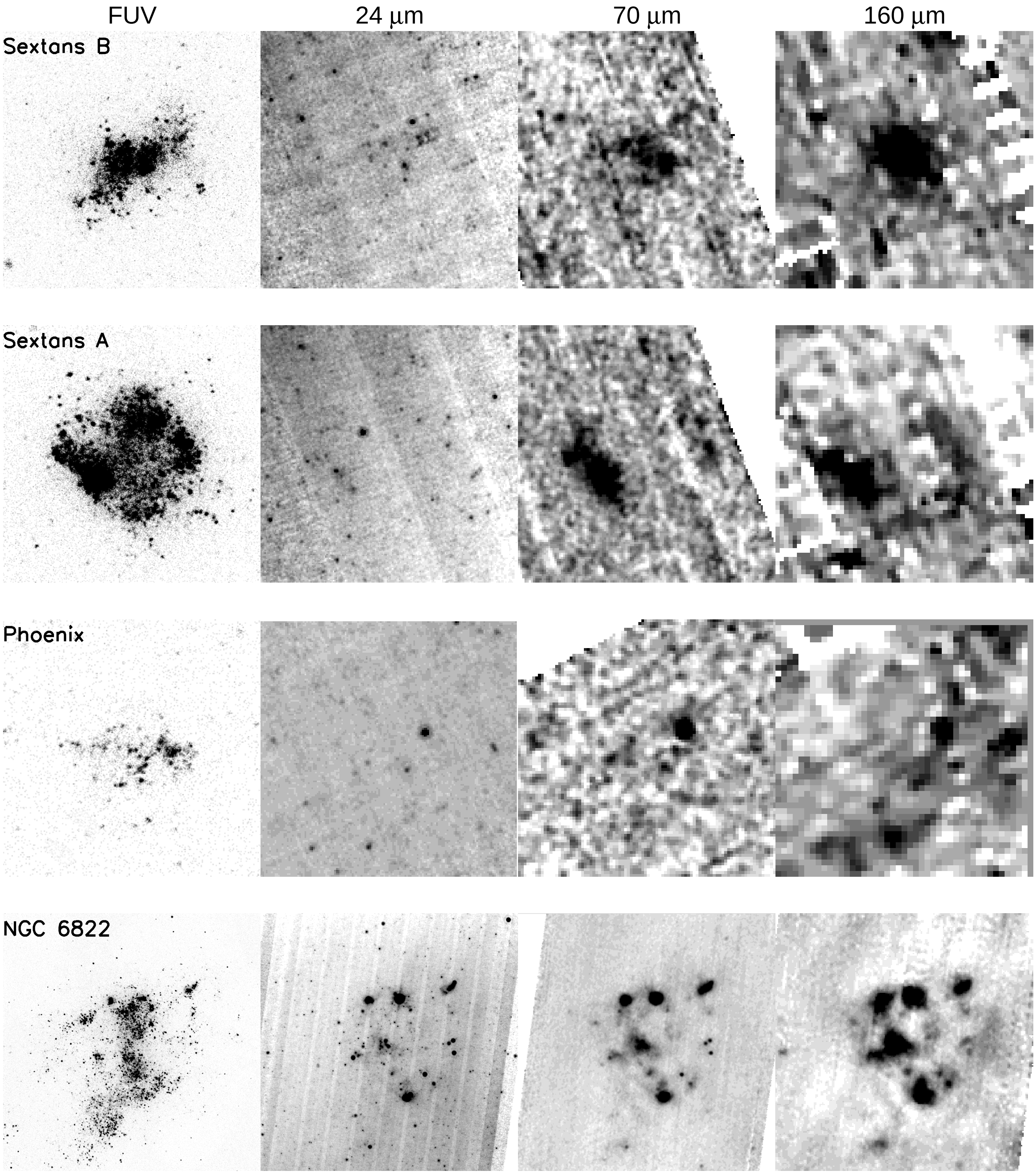

Fig. 3.— *GALEX* UV and *Spitzer Space Telescope* images of the galaxies NGC 6822, Phoenix, Sextans A, and Sextans B. Each row corresponds to the same region of sky for a given galaxy and the images are from left to right: FUV, 24μm, 70μm, and 160μm.

on the right.

The ratio of the FIR and FUV SFRs correlates most strongly with the oxygen abundance. While the SFRs from the FIR and FUV are approximately equal for the most metal rich galaxies in our sample, the ratio decreases to only a few percent for the most metal poor dwarf galaxies. As dust forms from heavy elements, the relative amount of dust would be expected to decrease with the overall metallicity. Thus, an increasing fraction of the UV light emitted by massive stars is able to leak out in lower metallicity galaxies.

The strongest trend as a function of the total SFR is that with the ratio of the Hα and FUV SFRs. For the galaxies in our sample with the highest SFRs, NGC 6822 and NGC 55, the Hα and FUV SFRs are nearly equal while the ratio steadily decreases to just a few percent for the least luminous galaxies. Only the most massive stars with main sequence lifetimes up to $\sim 10^7$ years are capable of ionizing hydrogen while stars with lifetimes up to $\sim 10^8$ years contribute to the FUV luminosity. Assuming that the H II regions in these galaxies are still ionization bounded, the decreasing ratio of $SFR_{H\alpha}/SFR_{FUV}$ would imply a decreasing fraction of the most massive stars. One explanation for this trend is simply due to the very small SFRs in these dwarf galaxies. As the SFR becomes small, stochastic effects due to the small number of massive stars can cause fluctuations in the Hα to FUV ratio. In other words, the chances of observing a galaxy at a time when it has a star massive enough to produce an H II region becomes smaller with decreasing SFR, whereas the FUV light samples a wider range of ages and thus varies less. Indeed, the smallest galaxies in our sample only contain at most a few H II regions, or in the case of DDO 216 just one (Aparicio et al. 1997). On the other hand, it could be possible that the decreasing Hα to FUV ratio is due to variations in the high mass end of the stellar IMF as a function of metallicity or surface density.

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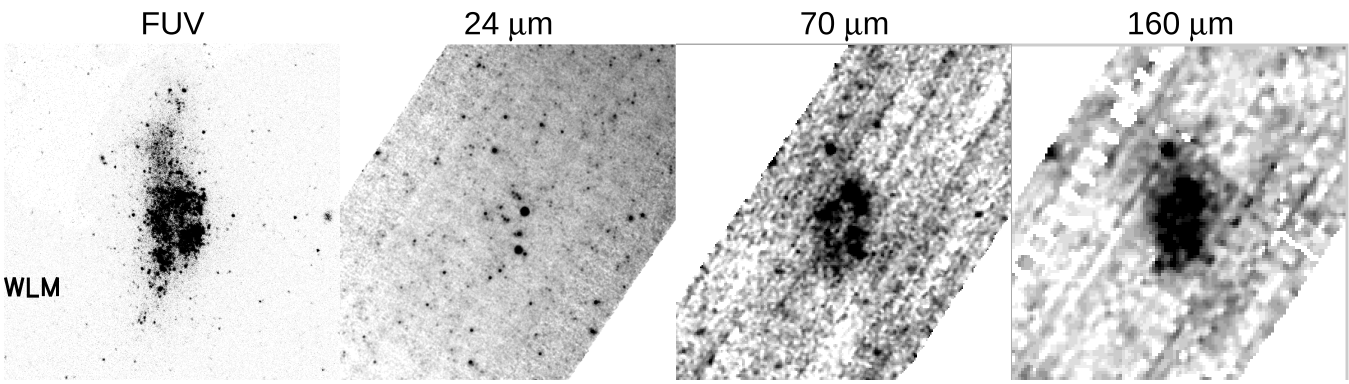

Fig. 4.— *GALEX* UV and *Spitzer Space Telescope* images of the WLM. The images are from left to right: FUV, 24μm, 70μm, and 160μm.

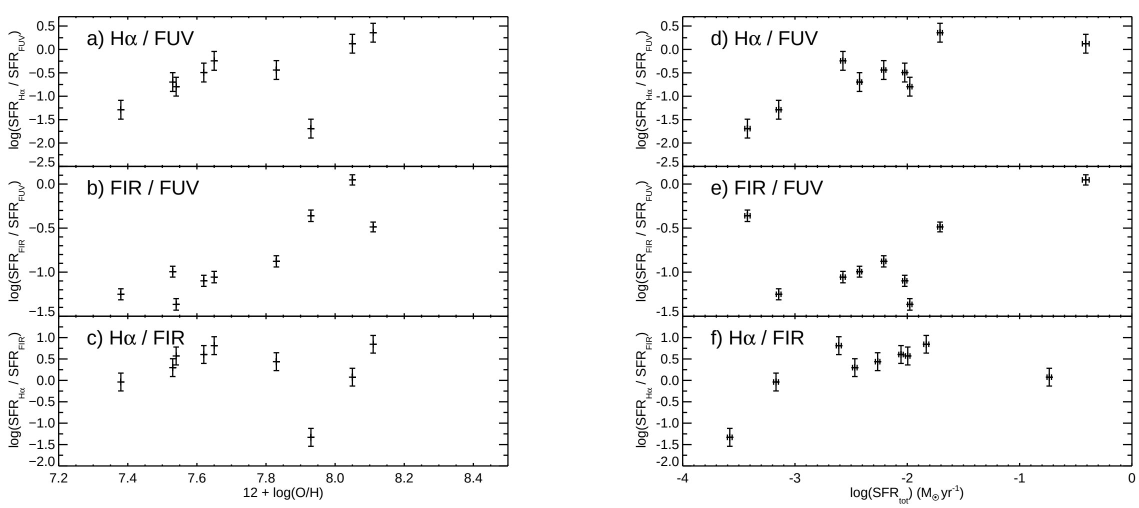

Fig. 5.— The three left panels show the ratio of (a) the Hα to FUV SFR, (b) FIR to FUV SFR, and (c) Hα to FUV SFR as a function of the nebular oxygen abundance $12+log(O/H)$ as compiled in Lee et al. (2006). Panels (d), (e), and (f) on the right show the same ratios except as a function of the total SFR, calculated as the sum of the FIR and FUV SFRs.

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