Multiwavelength Star Formation Indicators

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Abstract We present the results of a multiwavelength study of star formation indicators for a sample of nearby galaxies. The sample spans a wide range in luminosity, star formation rate, metallicity, and morphology. We will discuss our high resolution far-ultraviolet HST/STIS images, ground-based Hα, and VLA 8.4GHz radio images, as well as integrated mid-IR properties. We compare these star formation indicators, present empirical calibrations and discuss the effects of reddening. We also use the data to analyze the relation between star formation rate and the UV/far-IR ratio for our galaxies, as well as the location of ULIGs, SCUBA sources and Lyman Break galaxies in this diagram.

Sample and Data Our sample is composed of 41 star forming galaxies, known to have ISO far-infrared data, the luminosity function of star-forming galaxies, and a range of properties. The data includes Hα, [OIII], [OII] and [NII] emission, as well as a range of photometric observations. We also use the data to analyze the relation between star formation rate and the UV/far-IR ratio for our galaxies, as well as the location of ULIGs, SCUBA sources and Lyman Break galaxies in this diagram.

Figure 1: Examples of the UV (left), Hα (middle) and radio 8.4GHz (right) images obtained in this project. The top row shows M332, and the bottom one ESO400-G03. The Hα and 8.4GHz (3.5cm) images are presented in the same scale. The UV images usually cover a region smaller than the one observed at the other wavelengths, because of the field of view of the STIS (2.5°×2.5°). The area covered by the UV observations is shown as a white square in the Hα images. A major concern involved in comparing these multiwavelength data is the aperture mismatch. However, comparing the Hα and 8.4GHz fluxes measured inside an aperture which matches the UV one with values integrated over the entire galaxy, we find that 3/4 of the cases more than 50% of the flux in these bands originates in the region covered by the UV observations.

Figure 2 (left): The SEDs of the 29 galaxies for which ISO long-wavelength data were available. Galaxies with SEDs dominated by the far-infrared emission of star formation are displayed in red, while those with a comparable contribution from the far-infrared and optical are shown in blue. The SEDs are normalized to the total 24 μm flux. This figure shows that relatively blue SEDs in the optical do not necessarily correspond to blue galaxies in the UV. This reflects the stellar population content of the galaxy, where the optically-brighter populations are likely evolved stars, no longer contributing to the star formation.

Figure 2 (right): The average blue and red SEDs (solid lines) are compared with the ones from low and high reddening starbursts (blue and red dotted lines) from Schmitt et al. (1997). We find that the red SEDs are very similar, but the low reddening SED from Schmitt et al. (1997) underestimates the optical flux of these galaxies. This happens because this SED used optical data obtained with a 20" aperture, thus missing significant amounts of emission from these galaxies.

Figure 3: Comparison between the SFRs (left) and fluxes (right) at different wavelengths. The top row shows the comparison between Hα and UV, the lower row shows the comparison between 1.4GHz with Hα and a starburst bolometric flux, integrated over the entire galaxy. The Hα and UV SFRs were calculated using the Kennicutt (1998) calibrations. The starburst bolometric flux was obtained by adding the infrared, ultraviolet and optical band fluxes, and the SFRs were calculated using the infrared calibration of Kennicutt (1998). In the case of 1.4GHz we derived a new calibration using Starburst 99 supernova rates and the approach described by Condon (1992). This figure also shows the Hα fluxes before (open) and after (solid) the correction for the [NII] contamination. The top panel shows that Hα and UV correlate, but UV gives systematically lower SFRs, by a factor of 5. This difference can be attributed to extinction. Although these two bands correlate, they do not show a good correlation for more extreme cases, and the difference increases with increasing [NII] contamination.

Figure 4: Comparison between the ratio of far infrared 205μm and UV (1500 Å) fluxes and the bolometric SFR (for the galaxies in our sample) with ISO data (bars), Ap 220 (red stars), SCUBA sources (green circles) and Lyman Break Galaxies (blue crosses). This figure shows a trend between SFR and the F IR/F UV ratio. It indicates that the fraction of UV radiation escaping from a galaxy is dependent on increasing luminosity (SFR) by a factor of 2-3. The bottom panel shows that the 1.4GHz and starburst bolometric fluxes and SFRs are very well correlated. However, the radio predicts higher SFRs, by a factor of 2-3. We believe that this systematic difference is due to the approximations involved in the radio calibration.