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No evidence for evolution in the Far-Infrared-Radio correlation out to z ∼ 2 in the ECDFS

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Abstract. The Far-Infrared Radio Correlation (FRC) is the tightest and most universal correlation known among global parameters of galaxies. Here we present the results of our investigation of the 70 μm FRC of starforming galaxies in the Extended Chandra Deep Field South (ECDFS) out to z > 2. In order to quantify the evolution of the FRC we used both survival analysis and stacking techniques, which gave similar results. We also calculated the FRC using total infrared luminosity and rest-frame radio luminosity, qTIR, and find that qTIR is constant (within 0.22) over the redshift range 0 - 2. We see no evidence for evolution in the FRC at 70 μm, which is surprising given the many factors that are expected to change this ratio at high redshifts.

Keywords. galaxies: evolution, galaxies: formation, infrared: galaxies, radio continuum: galaxies

1. Introduction

The correlation between the far-infrared (FIR) and radio emission for star-forming galaxies in the local Universe was first observed by van der Kruit (1973). The correlation is linear, spans five orders of magnitude of bolometric luminosity and has been shown to hold for a wide-range of Hubble types (e.g. Helou, Soifer & Rowan-Robinson 1985).

The far-reaching nature of the FRC has made it a valuable diagnostic and astronomers have used it to identify radio-loud AGN, define the radio luminosity/SFR relation and, at higher redshifts, estimate distances of sub-mm galaxies with no optical counterparts. Consequently it is of great importance to determine whether the FRC holds at high redshifts.

The FRC may fail at higher redshifts for a number of reasons. Electrons are expected to lose energy by inverse Compton (IC) interactions with the cosmic microwave background (CMB), whose energy density scales as $(1+z)^4$, implying a lower level of radio emission at higher redshifts. Moreover, synchrotron emission is proportional to the magnetic field strength squared, so evolution of magnetic field strength should affect the FRC at higher

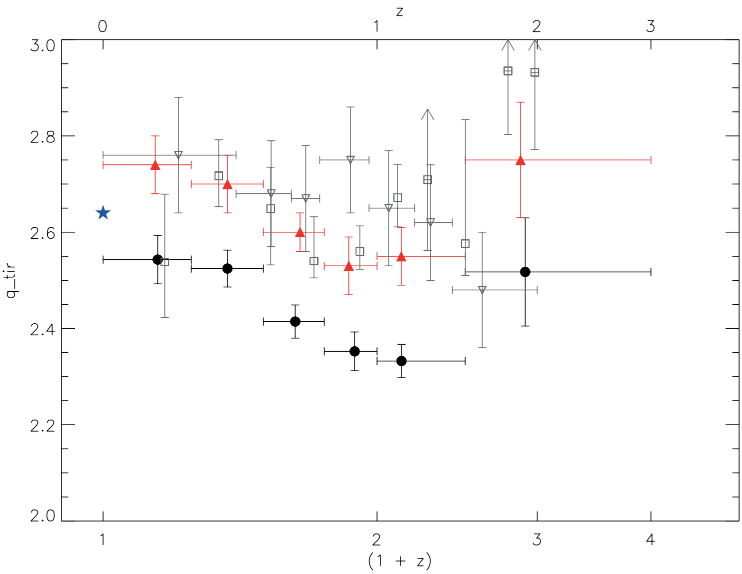

Figure 1. Median q_{TIR} values for different redshift bins. The black filled circles show the median q_{TIR} values for sources with both 70 μm and 1.4 GHz detections and the filled triangles show the median q_{TIR} value for all sources taking into account the lower limits using survival analysis. The grey upside-down open triangles show the median q_{TIR} values derived by Bourne *et al.* (2010) and the grey open squares show the median q_{TIR} values derived by Sargent *et al.* (2010b) for star-forming galaxies. Vertical error bars are standard errors for both our dataset and Bourne's data, but the vertical error bars for Sargent's data are upper and lower 95% confidence levels. The star at $(1+z) = 1$ represents the median $q_{TIR} = 2.64 \pm 0.02$ from Bell (2003).

redshifts. Changes in the spectral energy distributions may also be expected due to evolution in dust properties and metallicity. However, current studies show no firm evidence for evolution in the FRC (e.g., Garrett 2002; Appleton *et al.* 2004; Seymour *et al.* 2009; Bourne *et al.* 2010; Ivison *et al.* 2010a,b; Sargent *et al.* 2010a,b; Huynh *et al.* 2010).

2. Data

Our project studies the FRC's dependence on redshift using deep 70 μm data from the Far-Infrared Deep Extragalactic Survey (FIDEL, PI: Dickinson), which uses the Spitzer Space Telescope, and 1.4 GHz data from the Very Large Array (VLA) in the Extended Chandra Deep Field South (ECDFS). This work is the first to use such deep 70 μm data to study the evolution of the FRC based on individual sources. We focus on 70 μm data because it is an excellent tracer of star-formation as it probes closer to the 100 μm star-formation peak in the IR SED.

Our final catalogue comprises 617 70 μm sources, 91% of which have redshift information, over a third of which are spectroscopically determined. 353 of these sources have radio counterparts from Miller *et al.* (2008). In order to account for the radio non-detections we used both a stacking analysis and Survival Analysis. Our sample detects LIRGs to z $\sim$ 1.25 and ULIRGs to z $\sim$ 3 (Mao *et al.* 2011).

3. The FRC Shows No Evidence for Evolution with z

We computed q_{TIR} for all sources that had redshift information using:

$$q_{TIR} = \log(L_{IR}/L_{1.4\,GHz}), \tag{3.1}$$

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where L_{IR} is the total infrared luminosity, and $L_{1.4GHz}$ is the rest-frame 1.4 GHz luminosity.

Figure 1 shows the median q_{TIR} for only the detected sources (black circles), and for all sources by using survival analysis (red triangles).

Our q_{TIR} values are all within ∼0.22 of each other. Our values agree, within the errors, with the work of Sargent *et al.* (2010b), and also agree with the work of Bourne *et al.* (2010), with the exception of the redshift bins 0.75 < z <1 and z > 1.5, where our values differ by <2σ compared to the values given by Bourne *et al.* (2010) for similar redshift ranges.

4. Summary and Conclusions

We have used the deepest 70 μm data to date to study the FRC out to z > 2 of ULIRGs in ECDFS. To quantify the evolution of the FRC we binned our data in redshift and calculate the FRC using luminosities and find that evolution in q_{TIR} is constrained within 0.22. A more detailed discussion of these results and their implications may be found in Mao *et al.* (2011)

The fact that we see no evidence for evolution is very surprising. Perhaps IC cooling and other effects such as evolution of the magnetic field strength, or evolution of dust properties are insignificant to z ∼ 2, or perhaps there is a complex interplay between these factors conspiring in the preservation of the FRC at higher redshifts.

In the near future *Herschel* will measure the FIR properties of normal galaxies to z ∼ 1, and ULIRGs to z ∼ 4. This will allow us to study the FRC to higher redshifts and hence gain a better understanding of the evolution of star-forming galaxies.

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