The Evolution of Dust in Optically Selected Galaxies with Herschel-ATLAS

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ABSTRACT

We use the largest ever sub-millimetre sky survey to explore how the dust content of optically selected galaxies depends on colour, luminosity and redshift. Using a stacking technique we find that the dust mass is strongly dependent on a galaxy's colour and its stellar mass or luminosity. Galaxies of a given stellar mass are also found to have higher dust masses at increasing redshifts.

INTRODUCTION

The Herschel-ATLAS[1] provides the first truly large-area survey of the sub-millimetre sky, hence it offers a unique opportunity to explore the dust content of a large sample of galaxies selected in the optical. We exploit the H-ATLAS science-demonstration phase (SDP) with SPIRE imaging in three bands (250, 350 & 500µm) of a 14.4 deg^2 region of sky centred at 9^{h}06^m, +0°30'. This region coincides with the GAMA survey[2] which offers FUV-NUV-*ugrizYJHK* photometry from GALEX, SDSS and UKIDSS-LAS, and redshifts for around 120,000 galaxies.

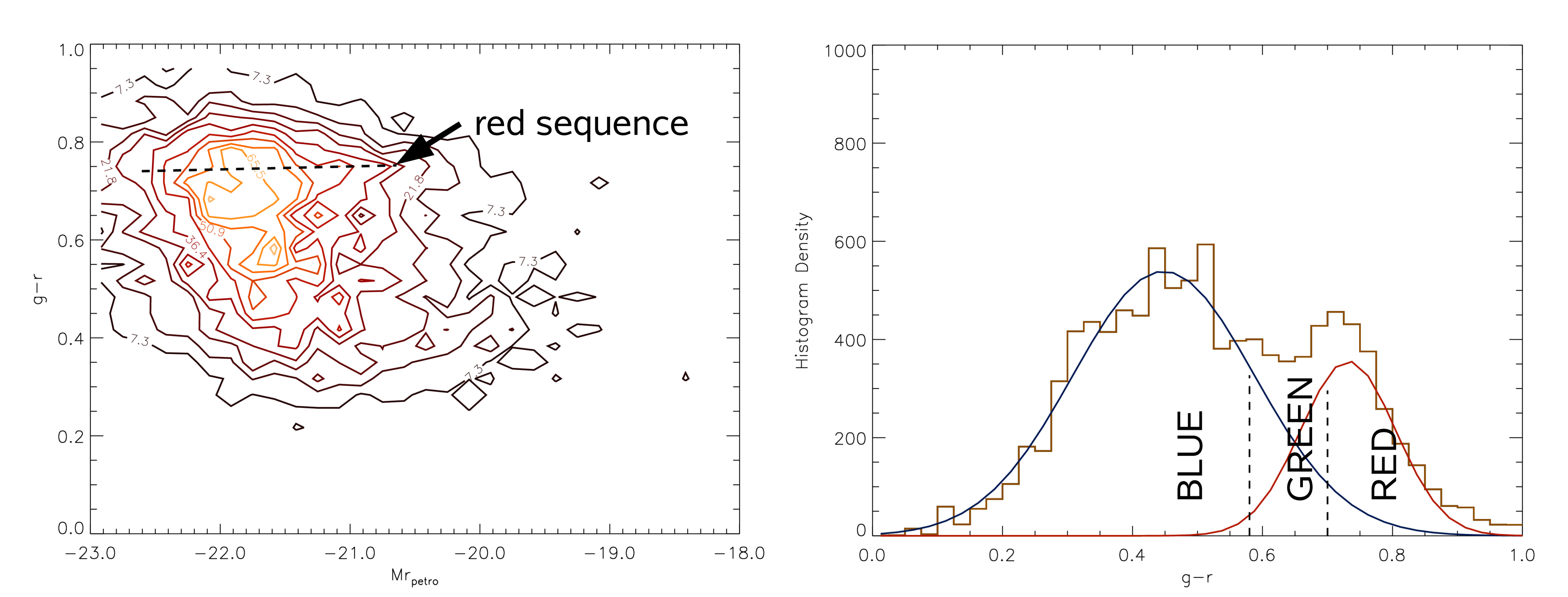

Figure 1: The distribution of *g-r* (rest-frame) vs. absolute magnitude *Mr* weighted by $1/V_{max}$ (left) is relatively independent of *Mr*. The weighted *g-r* histogram across all *Mr* (right) can therefore be fitted with two Gaussian functions, and blue, green and red bins are based on these fits.

STACKING OPTICALLY SELECTED GALAXIES

We select a galaxy sample limited to $r < 19.8$ from the GAMA catalogue, utilising GAMA spectroscopic redshifts where available and photometric redshifts from the optical-near-infrared photometry otherwise. Our sample consists of 10,359 galaxies between redshifts of $0.01<z<0.35$. To investigate sub-mm properties of the full sample, we divide the sample in bins and stack galaxies in each bin. Stacking allows us to measure an average signal for sources beneath the noise and confusion limits of the SPIRE sub-mm images. We use the median value of fluxes measured as point sources in the SPIRE maps, making reasonable assumptions to correct for double-counting in the stacks and using an error estimator which includes instrumental noise, confusion and uncertainty of the median. The sample is divided into three redshift bins and three bins of optical colours (see Fig.1, 2). Each of these bins is further split by absolute magnitude *Mr* or stellar mass M_{star} (obtained using *KCORRECT*[3]) before stacking.

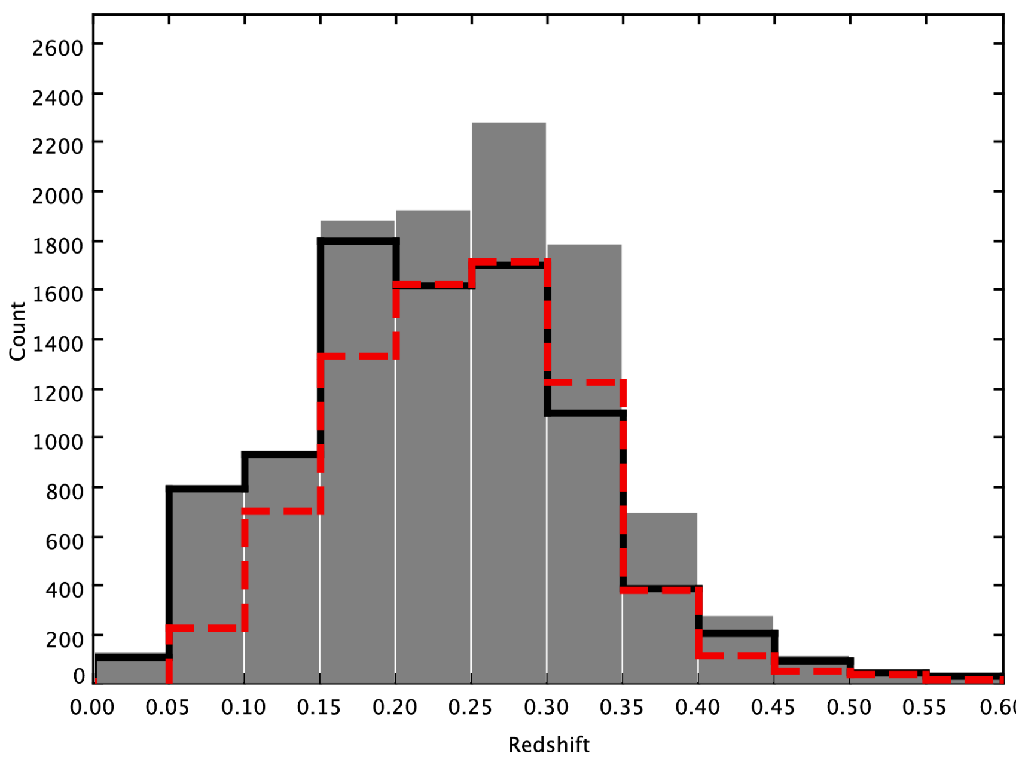

Figure 2: Histograms of spectroscopic (black line) and photometric (red line) redshifts available for our sample. The shaded histogram shows the final distribution of redshifts used (choosing spectroscopic where available). The sample was limited to $z<0.35$ due to incompleteness beyond this redshift.

RESULTS

Sub-mm fluxes are converted to rest-frame luminosities assuming a modified blackbody dust SED with a single temperature of 26K and emissivity β=1.5 (the median values fitted to H-ATLAS galaxies in the SDP)[4]. Stacked 250µm luminosities are shown in Fig. 3 as a function of redshift, colour, absolute magnitude and stellar mass. The strong linear correlation between optical (*Mr*) and sub-mm luminosities of blue galaxies extends from *Mr* = -18 to -22. For green galaxies the relation flattens at the bright end, perhaps due to a mixed population with different compositions at each end of the magnitude range.

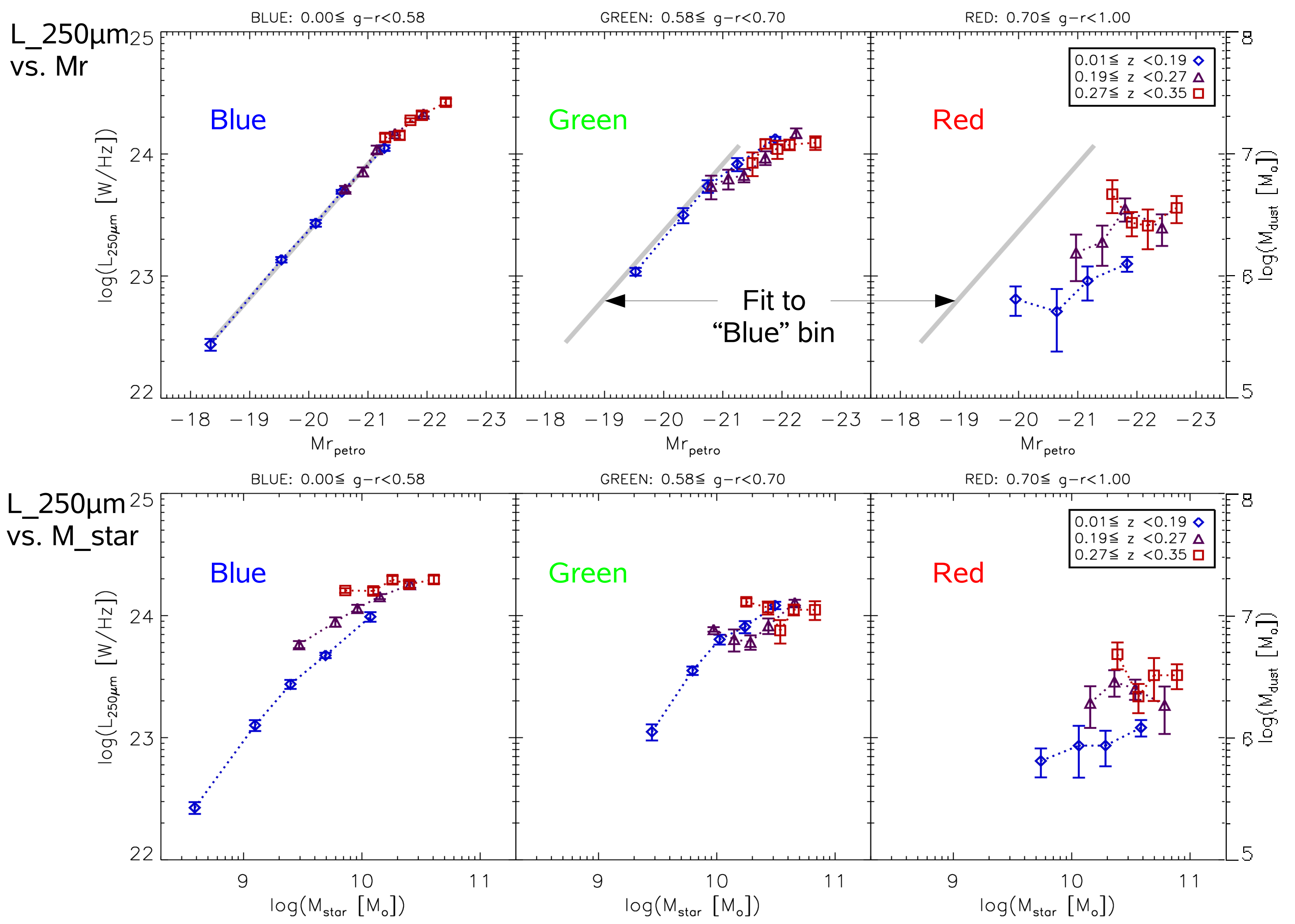

Figure 3: Top: Stacked 250µm luminosities as a function of *g-r* colour (left to right), redshift (blue to red) and *Mr* (x-axis) reveal trends in the dust emission (other SPIRE bands show consistent results). Blue galaxies follow a strict correlation between (median) optical and sub-mm luminosities, but the correlation breaks down for the brightest green galaxies and for red. Red galaxies have much lower sub-mm luminosities (therefore dust mass) which increase with redshift. **Bottom:** Stacking by M_{star} instead of *Mr* reveals an evolution for blue galaxies also. This may be hidden when stacking by *Mr* because of degeneracy between *Mr* & *z*.

The green and blue samples occupy roughly the same locus in Fig. 3 and therefore are likely to be dominated by galaxies of similar intrinsic properties. But red galaxies lie on a different relation and are fainter in the sub-mm, so they must have less dust than blue galaxies of the same stellar mass. This is consistent with the picture that optically red galaxies are passive. The dust luminosity of all (especially red) galaxies of a fixed stellar mass increases with redshift over this range, implying an increasing amount of dust-obscured star formation.

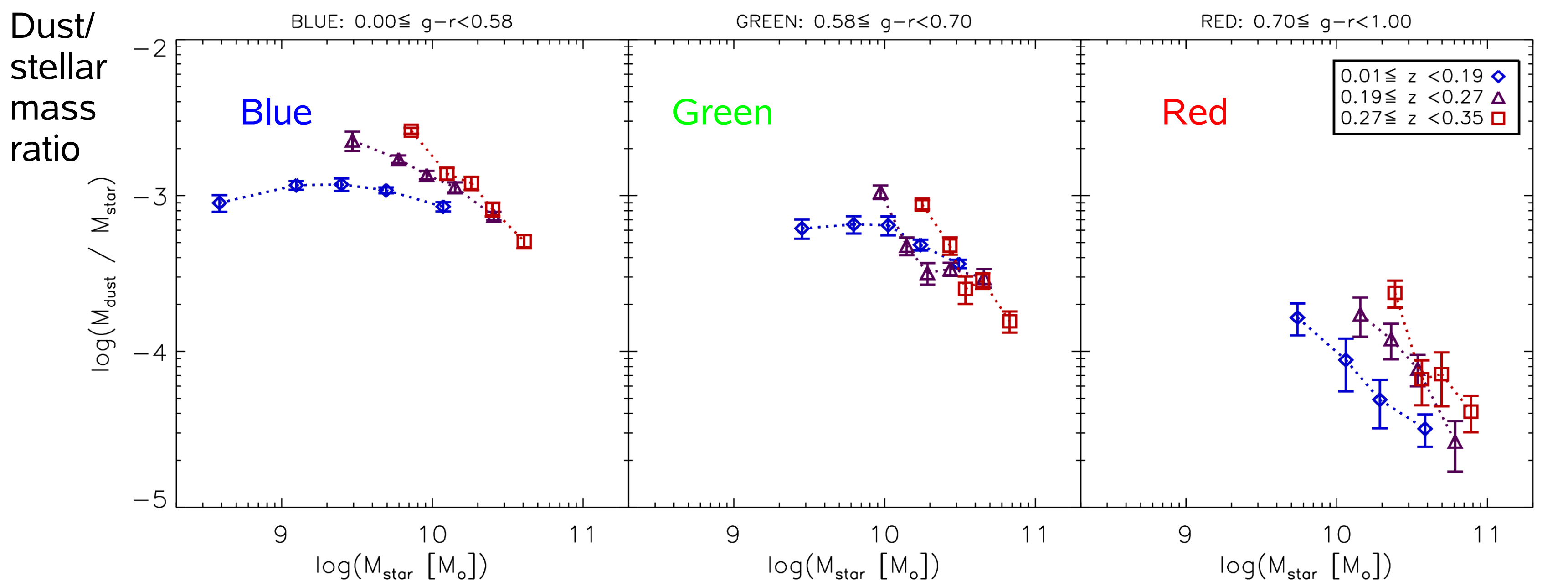

Figure 4: Median dust per stellar mass inferred from the 250µm luminosities follows a different relationship with stellar mass for galaxies of different colours and at different redshifts.

250µm luminosities can be converted to dust masses assuming that the dust mass is dominated by a cold dust component with *T*=19K and assuming $\kappa_{250\mu m}$=0.89m^{2}kg^{-1} (Fig. 3 auxilliary axis).[5] Under this assumption the behaviour of M_{dust}/M_{star} vs. M_{star} (Fig. 4) steepens with increasing redshift and is steepest for red galaxies. These results indicate that the rules determining the dust properties of galaxies are different between red and blue galaxies, and at different redshifts.

CONCLUSIONS

Our results reveal systematic differences between the dust properties of red and blue optically-selected galaxies. While blue galaxies follow a strong correlation between sub-mm and optical luminosity, the connection is much weaker in the red sample. Red galaxies are much fainter in the sub-mm than blue galaxies of comparable stellar mass, indicating a passive nature. All samples undergo a significant increase in dust per stellar mass from z~0.1 to z~0.3, implying higher rates of star formation and dust production at higher redshifts, even over this relatively short range of around 2Gyr in cosmic time.

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[1] Eales et al. 2010, PASP, 122, 499; [2] Driver et al. 2010, arXiv:1009.0614; [3] Blanton & Roweis 2007, AJ, 133, 734; [4] Dye et al. 2010, A&A, 518, L10; [5] Dunne et al. 2010, arXiv:1012.5186.