Properties of dusty galaxies at high and low redshifts

Kate Rowlands
With: Loretta Dunne, Simon Dye, Alfonso Aragon-Salamanca, Elisabete da Cunha, Dan Smith, Steve Maddox, Haley Gomez + the Herschel ATLAS consortium

University of St Andrews

Email - kerowlands@googlemail.com

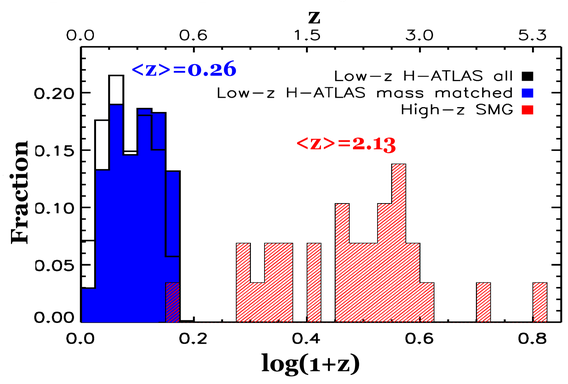
Introduction - High redshift submillimetre galaxies (SMGs) are the most actively star-forming and dusty galaxies in the Universe. Constraining the properties of these galaxies is important for understanding the evolution of massive galaxies and galaxy evolution models in general. Using panchromatic data from the UV to the submillimetre, we explore the physical properties of a sample of ~250μm rest-frame selected galaxies at high redshift, and compare them to dusty galaxies at low redshift selected in a similar way, to investigate the differences in the dusty galaxy populations over cosmic time.

Sample ~250μm rest-frame selected

SMG sample (0.48<z<5.31)– from Magnelli et al. (2012)

- 850μm+PACS/SPIRE (100-500μm) detection.
- Robust multiwavelength counterpart (radio and/or 24μm).
- Spectroscopic redshift + optical-NIR photometry.

} 29 galaxies with good SED fits, 26 at z>1



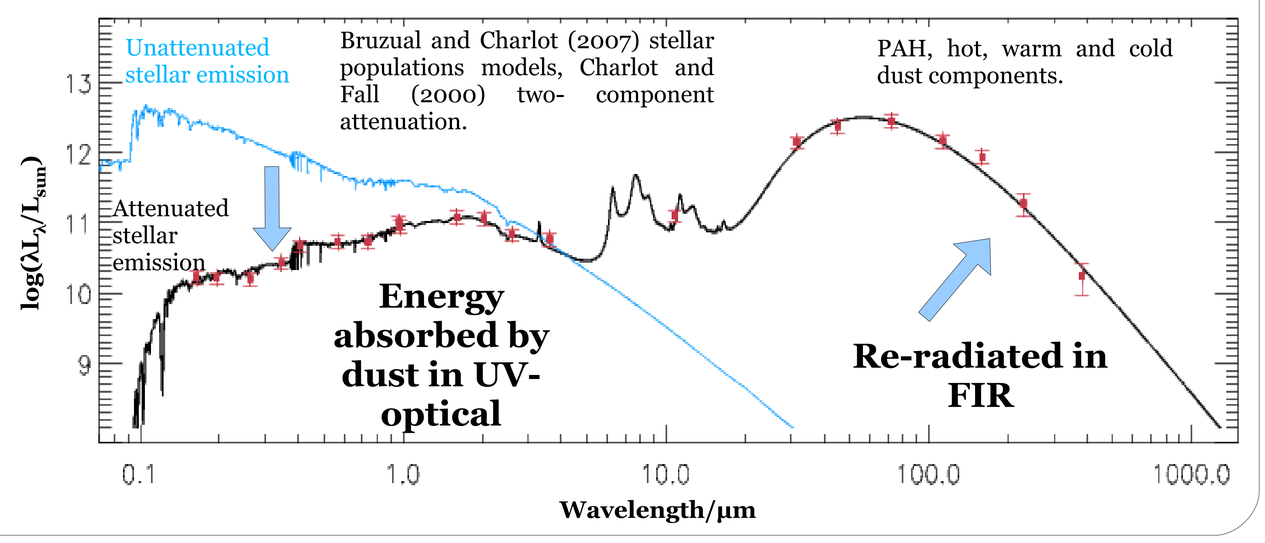
H-ATLAS sample (0.005<z<0.5)

- 250μm 5σ detection.
- Reliable optical counterpart (Smith et al. 2011).
- Spectroscopic redshift + GAMA optical photometry (Hill et al . 2011) + good SED fit (Smith et al. 2012)
- Matched in stellar mass to SMG sample.

} 843 galaxies

SED fitting - MAGPHYS

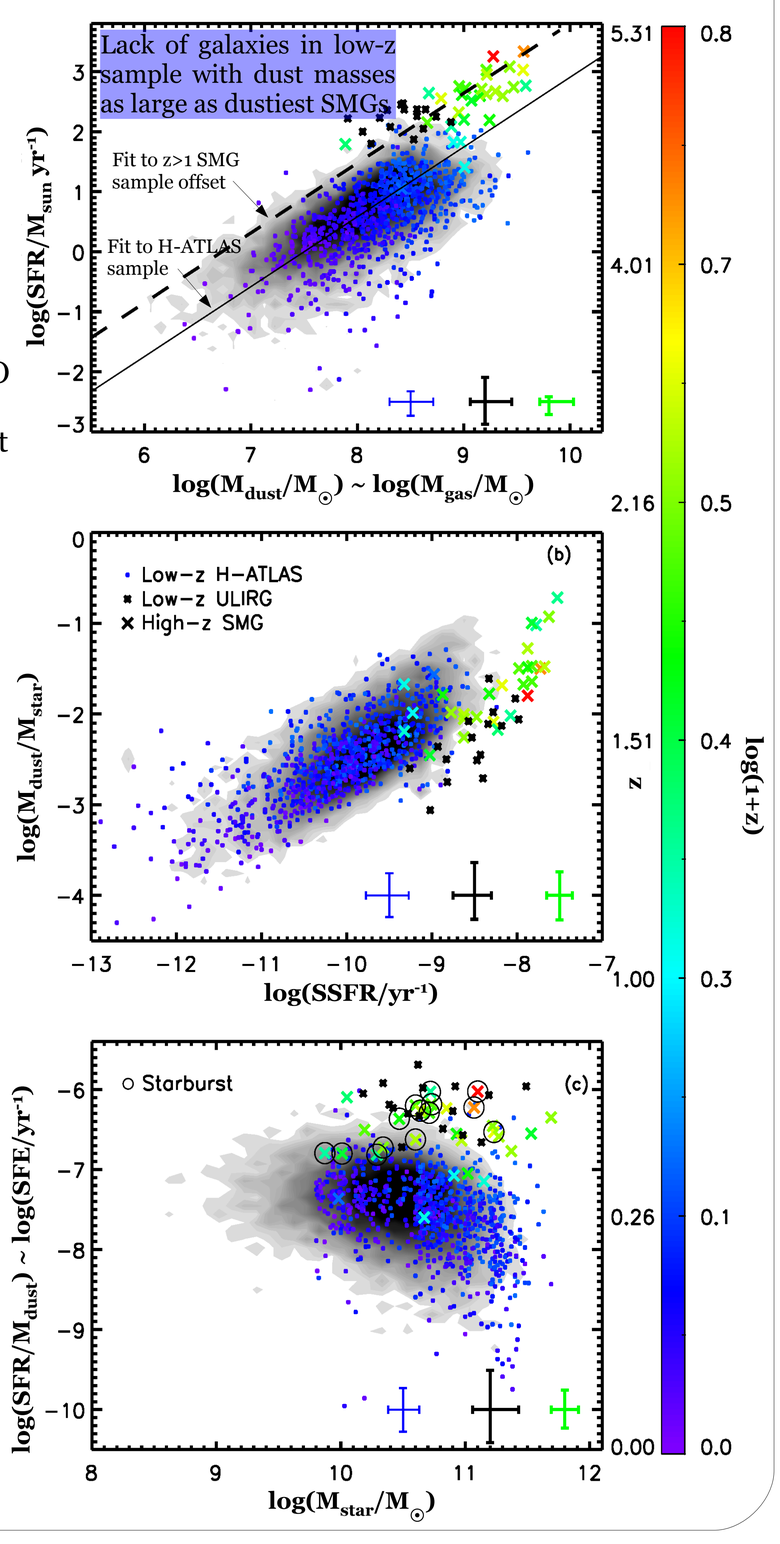
- Energy balance model - da Cunha et al. (2008).
- Bayesian approach - statistical constraints on physical parameters:
  - Compare observed galaxy SED to large library of models which encompass all parameter combinations.
  - Build marginalised likelihood distribution of physical parameters - compute χ^2 goodness of fit for each model – generate probability density function (PDF).



Properties of ~250μm rest-frame selected galaxies

- z>1 SMG $<M_{star}> = 6.3 \times 10^{10}\ M_\odot$.
- z>1 SMG <SFR>=390 $M_\odot$/yr, factor of 110 higher than SFR of low-z H-ATLAS galaxies.
- Lack of highly star-forming galaxies at low-z not a volume effect, H-ATLAS Phase 1 co-moving volume comparable to SMG survey volume (1×10^8 Mpc $^{-3}$).
- SMGs have higher M_{dust} ($<M_{dust}> = 6.9 \times 10^8\ M_\odot$) than low-z H-ATLAS galaxies ($<M_{dust}> = 1.5 \times 10^8\ M_\odot$).
- Larger space density of galaxies with highest dust masses at high-z, galaxies would have been detected in H-ATLAS should they exist at low-z.
- Consistent with **strong evolution in dust content of massive, dusty galaxies with redshift,** in agreement with Dunne and Eales 2001, Dunne et al. 2003, Eales et al. 2010, Dunne et al .2011, Bourne et al. 2012.

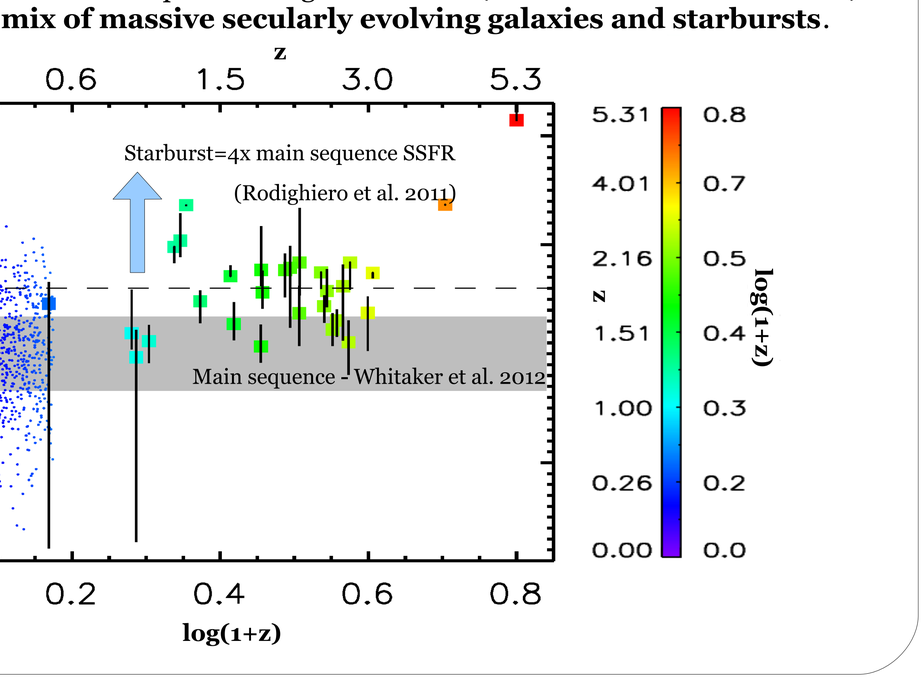
- $M_{dust} \propto M_{gas}$ → SMGs have higher gas masses than low-z dusty galaxies (assuming constant metallicity).
- **At fixed Mdust SMGs are offset in SFR by 0.9 dex** relative to low-z dusty galaxies → higher gas fraction → **higher star-formation efficiency**. Consistent with CO studies of SMGs (Greve et al. 2005, Genzel et al. 2010) Offset cannot be accounted for by differences in dust emissivity.
- SMGs have M_{dust}/M_{star} consistent with upper end of low-z distribution, but SSFR of SMGs much higher than low-z galaxies.
- $M_{dust}/M_* \propto f_g/(1-f_g)$. **At the same gas fraction SMGs have more star-formation activity.**
- **SMGs form stars more efficiently** than low-z dusty galaxies of similar stellar mass
  - Mergers?
    or
  - Dynamical instabilities in high gas fraction disks?



Stacked SEDs

For stacking method see Smith et al. 2012

- Mass matched stacked SED is representative of H-ATLAS sample at z<0.35.
- Majority of dust luminosity in SMGs originates from star-forming regions.
- At lower redshifts dust luminosity is dominated by diffuse ISM.



The nature of star formation in dusty galaxies

- ~6% of low-z galaxies classified as starbursts
- Population of massive, dusty galaxies below the main sequence; these may be shutting down their star formation, but still harbour a substantial amount of dust (**Rowlands et al. 2012**).
- ~40% of the SMGs lie above main sequence at a given redshift (but be aware selection effects). **SMG population is a mix of massive secularly evolving galaxies and starbursts**.

Conclusions

- SMGs: significantly higher SFRs, dust masses, effective dust temperatures and obscuration than z<0.5 dusty galaxies selected to have a similar stellar mass. Differences between the high and low-z dusty galaxies may be driven by an increase in gas fraction at high-z.
- Majority of dust luminosity in SMGs originates from star-forming regions, at low-z dust luminosity is dominated by diffuse ISM.
- At the same dust mass SMGs are offset towards a higher SFR compared to the low redshift H-ATLAS galaxies. This is not only due to the higher gas fraction in SMGs but also because they are undergoing a more efficient mode of star formation.
- ~40% of SMGs lie above main sequence of star formation at a given redshift. SMG population is a mix of massive secularly evolving galaxies and starbursts.

References - Bruzual G and Charlot S., 2003, MNRAS, 344, 1000 · Bourne N., et al. 2012, MNRAS, 421, 3027 · Charlot S., Fall S. M., 2000, ApJ, 539, 718 · da Cunha E., Charlot S., Elbaz D., 2008, MNRAS, 388, 1595 · da Cunha E., et al. 2010, A&A, 523, A78 · Dunne L. and Eales S., 2001, MNRAS, 327, 697 · Dunne L., Eales S., and Edmunds M., 2003, MNRAS, 341, 589 · Eales S., et al. 2010, A&A, 518, L23 · Genzel R., et al. 2010, MNRAS, 407, 2091 · Greve T. R., et al. 2005, MNRAS, 359, 1165 · Hill D. T., et al., 2011, MNRAS, 412, 765 · Magnelli et al. 2012, A&A, 538, A155 · Rodighiero G., et al., 2011, ApJL, 739, L40 · Rowlands et al. 2012, MNRAS, 419, 2545 · Smith D. J. B., et al., 2011, MNRAS, 416, 857 · Smith D. J. B., et al., 2012, MNRAS, 427, 703 · Whitaker et al. 2012, ApJL, 754, L29