A Deep Herschel View of Obscured Star Formation in the Bullet Cluster

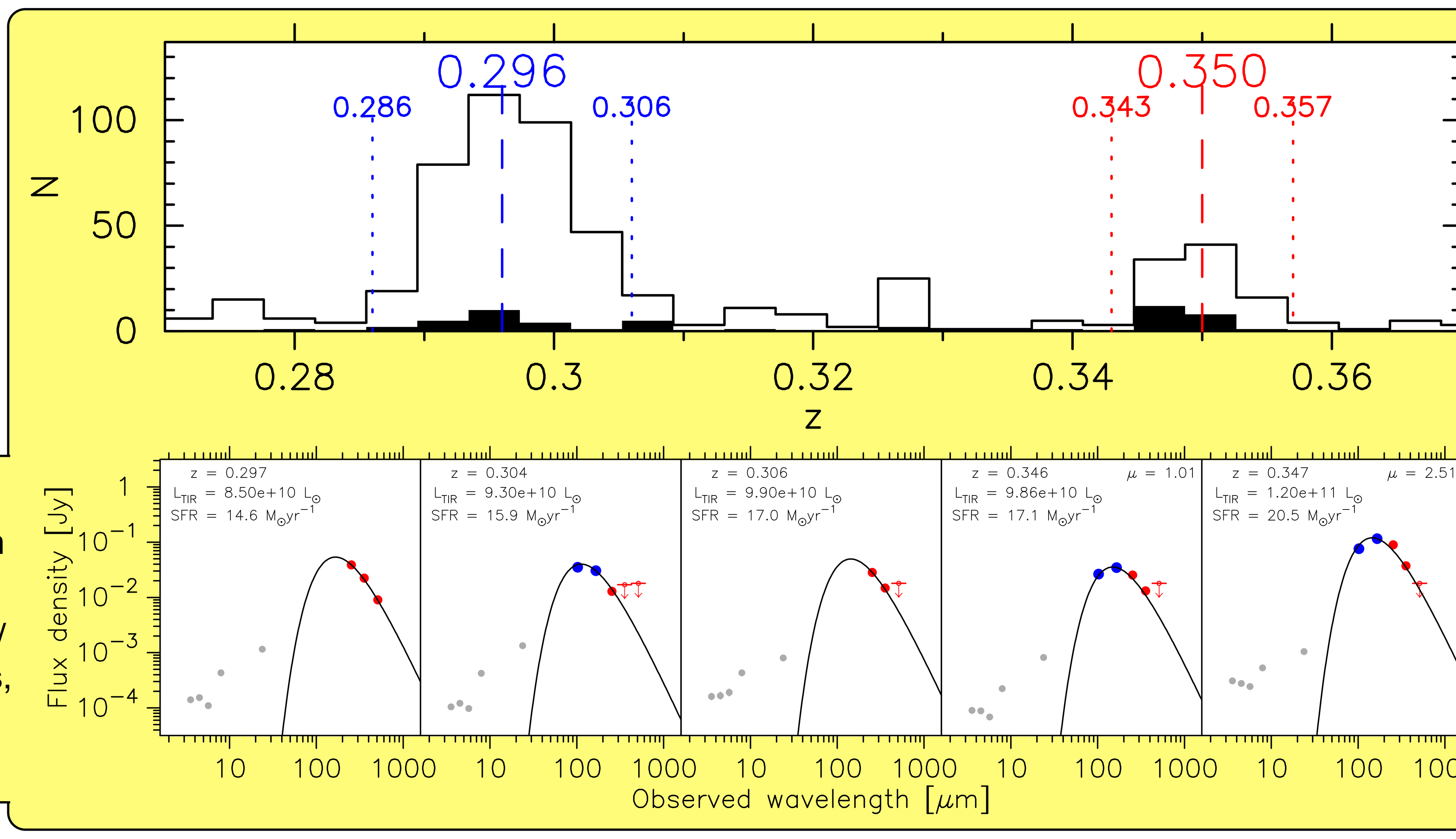
T. D. Rawle[1], S. M. Chung[2], D. Fadda[3], M. Rex[1], E. Egami[1], P. G. Perez-Gonzalez[4,1], for the HLS Collaboration

[1]Steward Observatory, University of Arizona [2]University of Florida [3]NASA Herschel Science Center, CalTech [4]Universidad Complutense de Madrid

We use deep 5-band (100–500μm) Herschel data from the Herschel Lensing Survey (HLS), to constrain the far-infrared luminosity, and hence total obscured star formation rate, of spectroscopically confirmed cluster members within the Bullet Custer (1E0657-56).

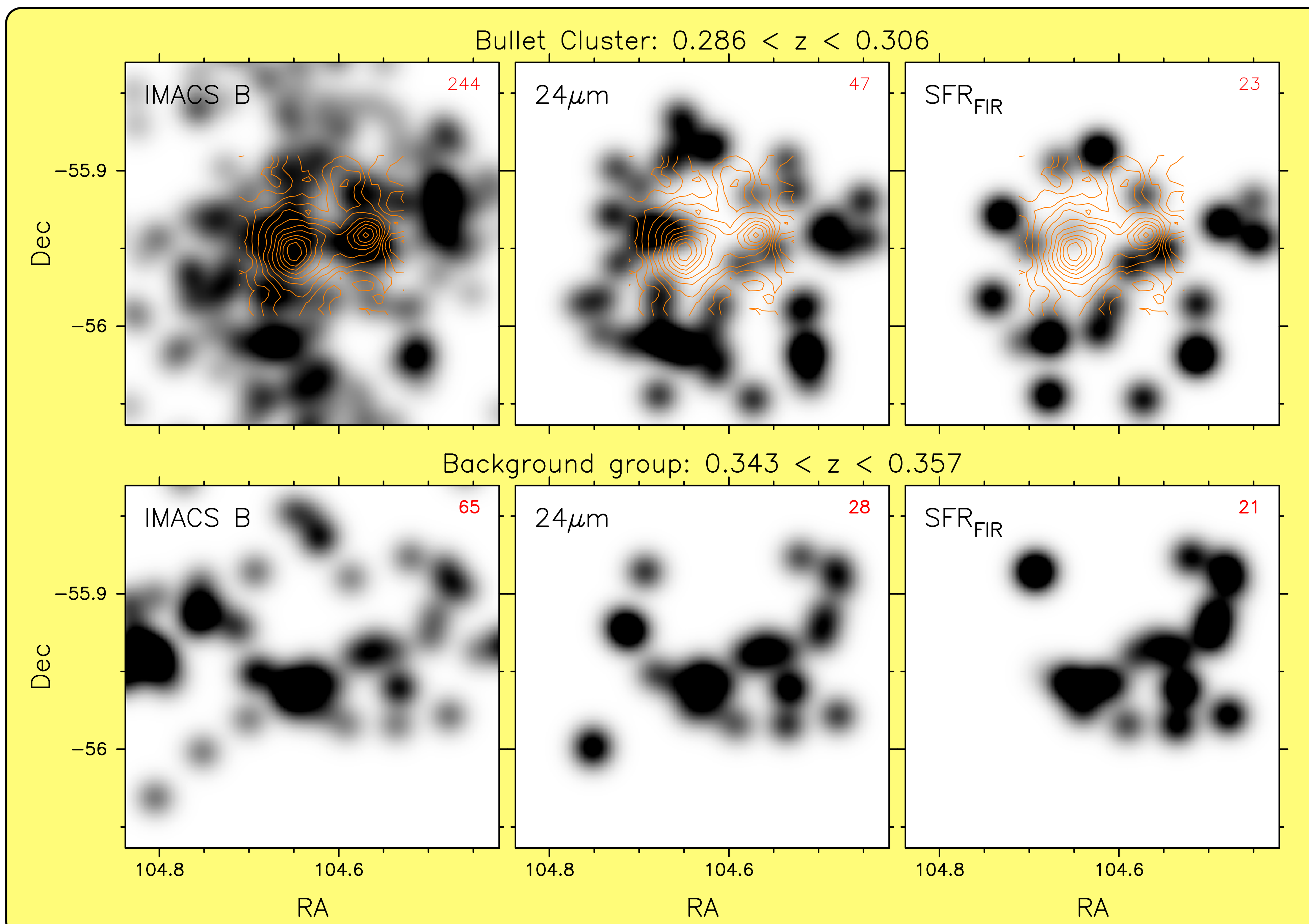
The Bullet Cluster (z=0.3) is a recent collision of two clusters in the plane of the sky (Markevitch+04), offering a unique laboratory for the study of star formation in a dynamic environment. A recent mid-infrared study (Chung+09) concluded that ram pressure from the merger event had no significant impact on the star formation rates of nearby galaxies.

Using 5 band (PACS+SPIRE; 100–500μm) data from the Herschel Lensing Survey (HLS), we can accurately constrain the dust component and hence the obscured star formation rate (SFR_{FIR}) in these cluster galaxies.



Upper: Spectroscopic redshift distribution for galaxies in the Bullet Cluster field (outline). Herschel detected galaxies are shown filled. The smaller background system (z=0.35) has a higher fraction of IR bright galaxies than the Bullet Cluster (z=0.3).

Lower: Observed SEDs for five of the most FIR luminous galaxies in the sample. Blue/red = PACS/SPIRE; grey = IRAC/MIPS. Redshift and, for background system galaxies, magnification factor μ, are displayed at the top of each panel. L_{TIR} and SFR_{FIR} are derived from the best fit, single-temperature blackbody (black line).



Smoothed density maps for B-band flux (left), 24μm flux (central) and SFR_{FIR} (right) for the Bullet Cluster (upper row) and z=0.35 system (lower). SFR in the Bullet Cluster appears to exhibits a radial trend. In the z=0.3 system, IR and optical flux trace similar distributions, whereas in the Bullet Cluster, B-band flux is centrally concentrated, away from the IR, indicating a different trend in dust retention for the two systems. While 24μm and SFR_{FIR} generally trace the same distribution, there are significant outliers: bright 24μm sources with relatively low SFRs, and vice versa.

The total SFR of the 23 Herschel-detected Bullet Cluster galaxies is 144 ± 14 $M_\odot yr^{-1}$. The 21 galaxies in the background system are, on average, ~50% more active, with a total SFR = 207 ± 9 $M_\odot yr^{-1}$. This suggests that cluster–cluster mergers are not important for triggering FIR starbursts.

While the 24μm and Herschel FIR SFR density maps generally trace the same distribution, there are significant outliers: i.e. bright 24μm sources with relatively lower SFRs, and vice versa.

Left panel: Ratio of SFR_{FIR} (derived from the FIR blackbody) to SFR_{24} (estimated from 24μm via Rieke+09 templates) versus S_{100}/S_{24}. For galaxies without PACS data, 100μm flux is estimated from the blackbody fit. 40% of the cluster members have severely under-predicted SFR_{24}. The same galaxies are also systematically redder in S_{100}/S_{24}. Is this the main source of the SFR_{24} under-prediction?

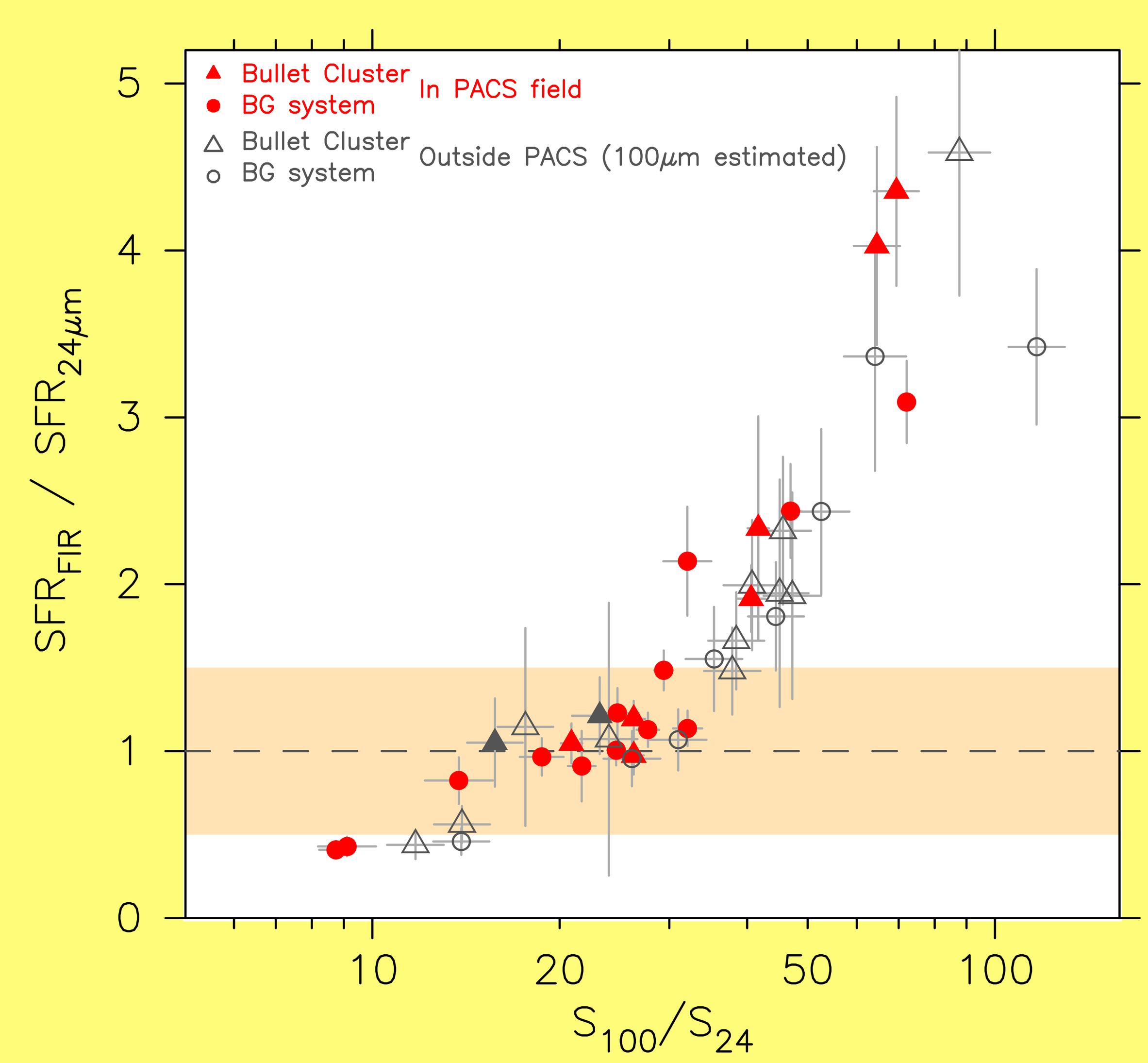
Right: Observed Herschel fluxes normalized at λ_{obs}=24μm (λ_0=18μm). Rieke+09 average templates (red→pink) plus one example high-L_{TIR} template (cyan). Locus of low-activity templates from Dale02 (α = 1.8–2.5) shaded green. The major discrepancy with under-predicted observations is at 100μm (λ_0=75μm).

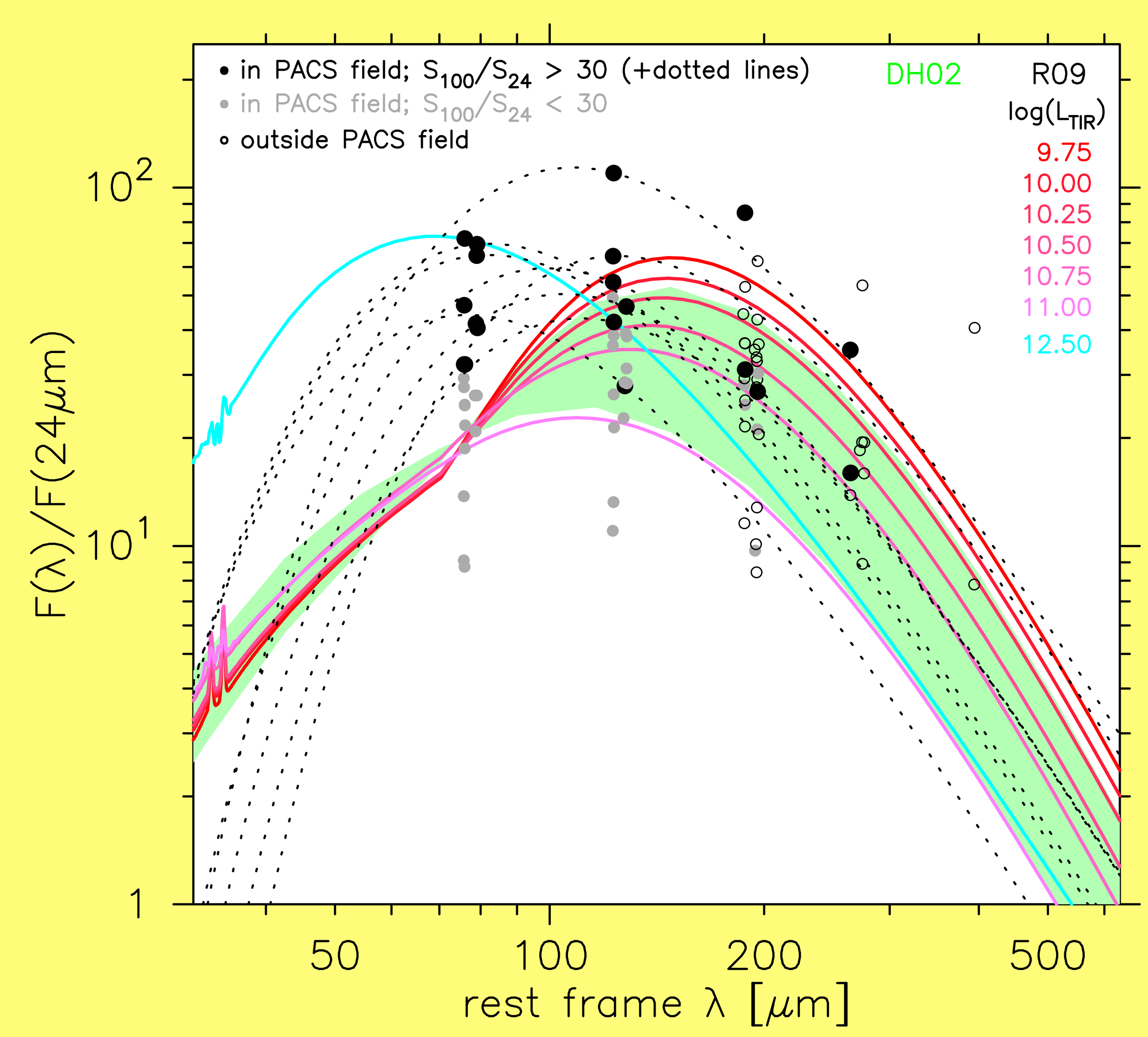
Templates spanning the observed range in L_{TIR} agree well for λ_0 ≳ 200μm. However, at 100μm there are 8 significant outliers. We define 100μm excess galaxies as S_{100}/S_{24} (rest frame S_{75}/S_{18}) > 30.

100μm excess galaxies account for ~40% of cluster members detected with PACS, and cover the entire range of L_{TIR} sampled. Above a nominal luminosity limit of $10^{10}L_\odot$, 55% of Bullet Cluster galaxies show the excess, but only 35% of galaxies in the background system. This may indicate a trend with environment, or could be due to the off-centre view of the latter system (i.e a potential radial trend).

SPIRE data discounts generally colder dust as the root cause, and AGN are unlikely to be a factor as no 100μm excess galaxy has a predicted AGN fraction >30%. Additional warm dust may be the source.

The high-z field sample in the HLS companion paper Rex+10, finds no galaxies with a comparable excess at λ_0=75μm. This shows that the phenomenon could be redshift dependent or cluster specific.





Conclusions

- Herschel detects ~50% more obscured SF in a z=0.35 background system than in the Bullet Cluster, so cluster-cluster mergers may not be important for triggering FIR starbursts. The spatial distribution of optical flux compared to this SF suggests a different trend in dust retention between the two systems.
- SFR_{FIR} agrees well with template-estimated SFR_{24} for 60% of galaxies. However, the remaining 40% display a significant excess at 100μm (λ_0≈75μm) compared to the templates. This excess is not found in any of the high-z field sample galaxies.

Based on the letter: Rawle, T. D. et al. A&A, submitted, Herschel Special Issue (**trawle@as.arizona.edu**); **References:** Chung, S. M. et al. 2009, ApJ, 691, 963; Dale, D. A. & Helou, G. 2002, ApJ, 576, 159; Markevitch, M. et al. 2004, ApJ, 606, 819; Rieke, G. H. et al. 2009, ApJ, 692, 556; Rex, M. et al. 2010, A&A, submitted, Heschel Special Issue