Herschel Lensing Survey

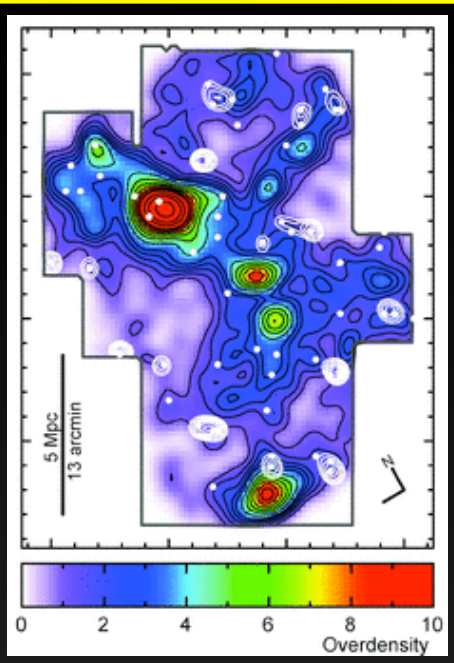
Exploring star formation in cluster galaxies with the Herschel Space Observatory

Tim Rawle

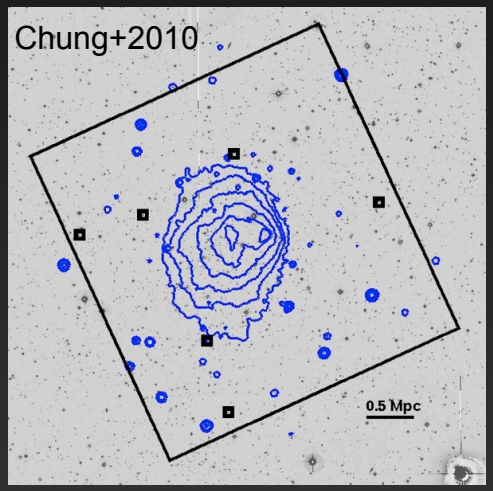
Steward Observatory, University of Arizona

Marie Rex, Eiichi Egami (Steward) Sun Mi Chung (Florida) Dario Fadda (IPAC)
Greg Walth, Maria Pereira, Benjamin Clement (Steward)
and the Herschel Lensing Survey (HLS)

Cluster star formation (Spitzer view)



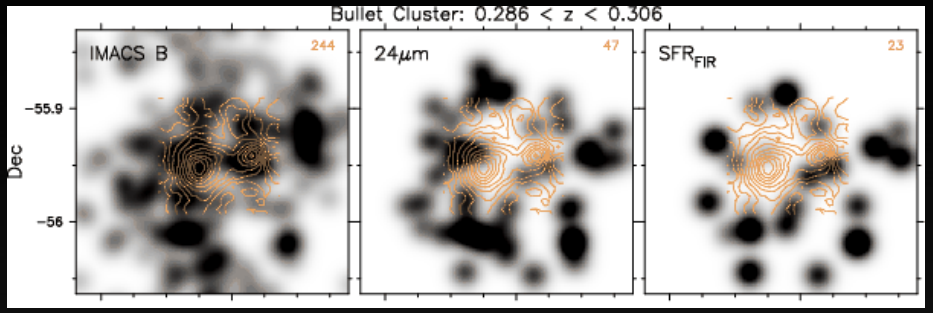
Geach+11 (see also e.g. Fadda+08)



- Wide field mapping of supercluster CL0016+16
- Galaxy over-density relative to COSMOS field
- Fractional excess (white contours):
- $\psi = \dfrac{\text{local fraction of star-forming cluster members}}{\text{average fraction of star-forming field galaxies}}$
- Star formation rates of star-forming galaxies in clusters are not significantly different to identically selected field galaxies
- Clusters contain pockets where galaxies have enhanced probability of undergoing star formation
- Physical process:
  - Pre-processing of galaxies in groups prior to cluster-infall - no cluster process boosting individual galaxy star formation rate

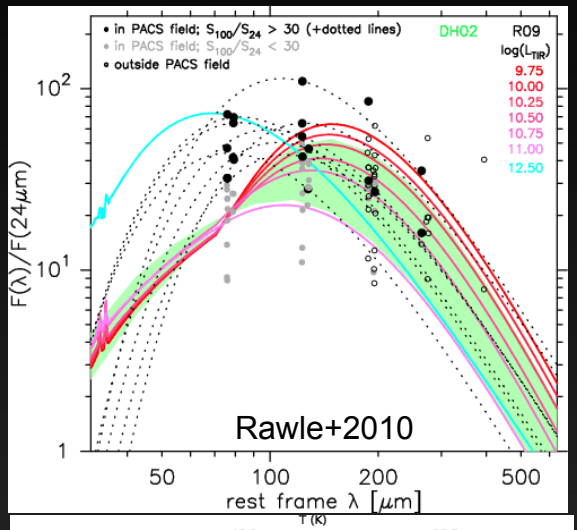
- Bullet cluster (1E0657-56):
  - No spatial correlation between star-forming galaxies and the cluster merger features such as the shock front

Cluster star formation (Herschel era)

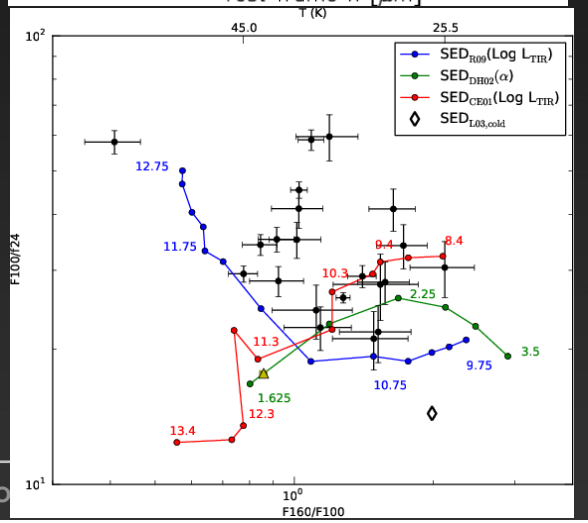


Rawle+2010

- Bullet cluster (1E0657-56):
  - Lack of Herschel detections at small radii (tempting to see a ring, but small numbers)

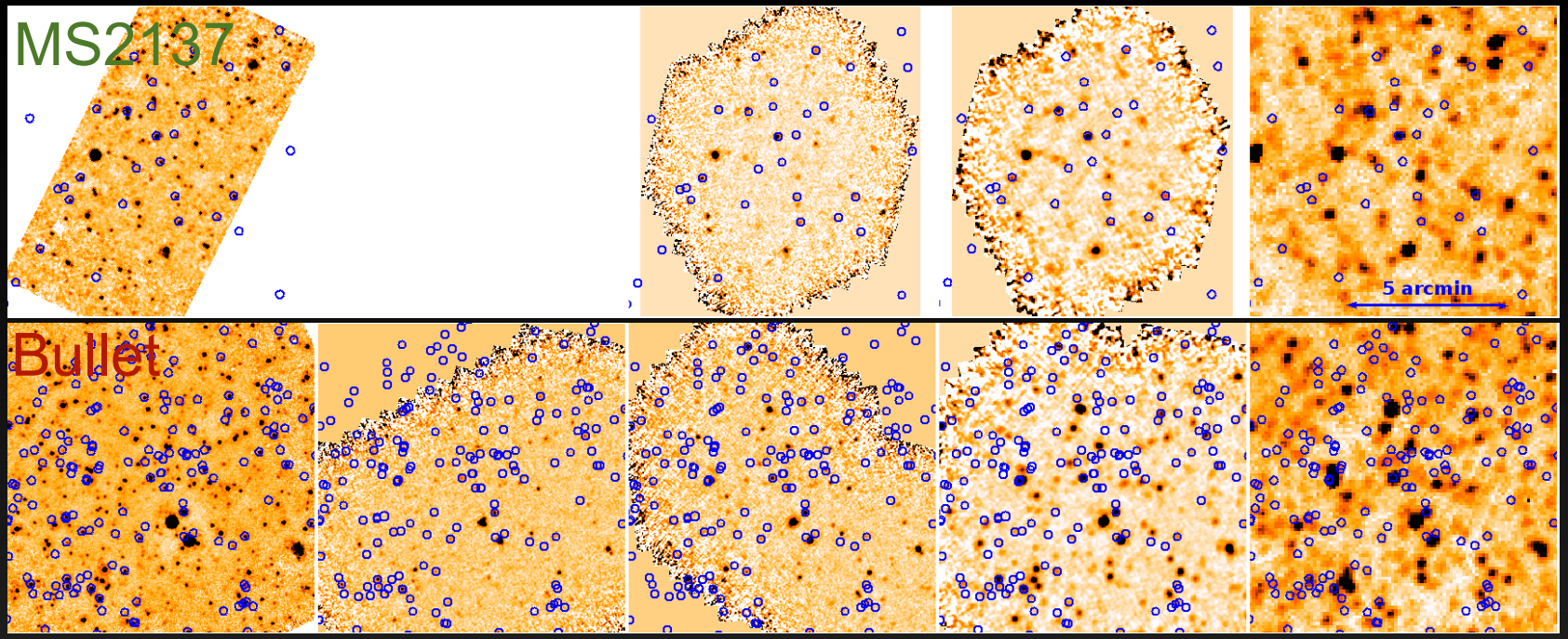


- Excess at 100μm:
  - SEDs of ~40% cluster sources have an excess at 100μm with respect to the FIR templates of comparable luminosity
- PACS colors of these sources highlight the discrepancy with templates (although they also do not agree well with each other)
- Similar sources not seen at high-z (e.g. Rex+10) or in the field populations (e.g. Elbaz+10)
- ...but are seen in the LoCuSS cluster sample (Smith +10, Pereira+10)



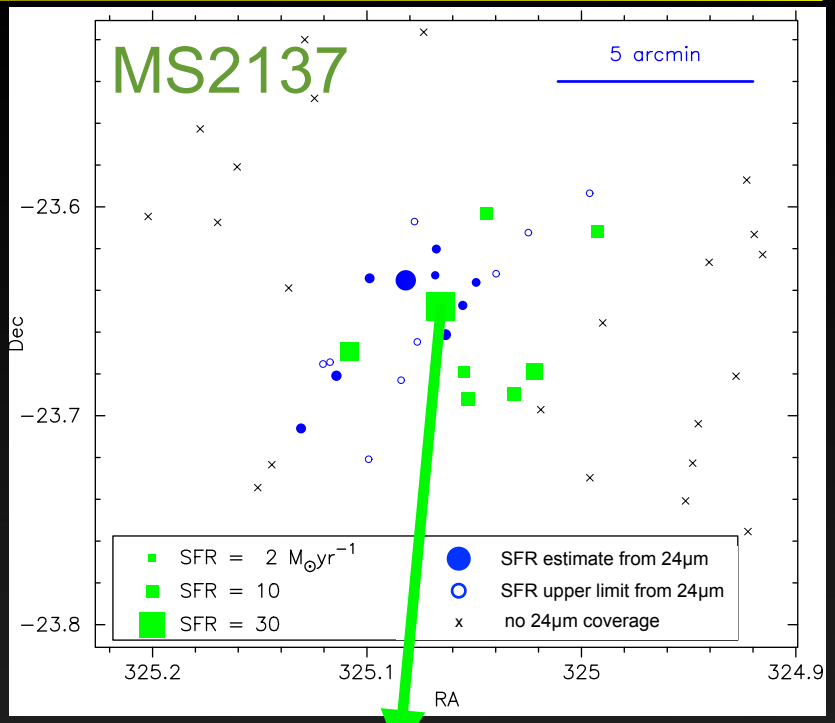
Pereira+2010

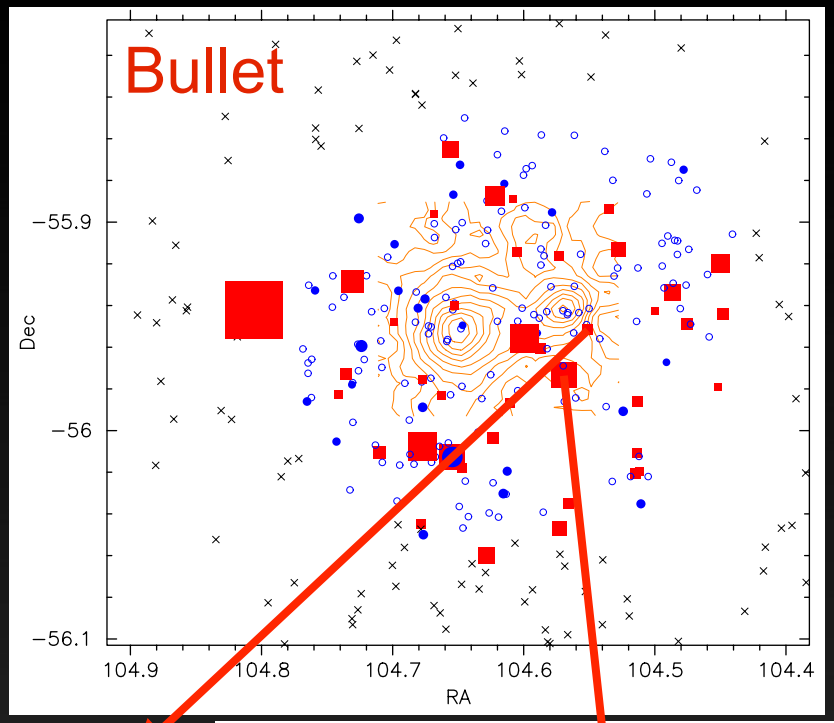
HLS: MS2137 and Bullet Cluster

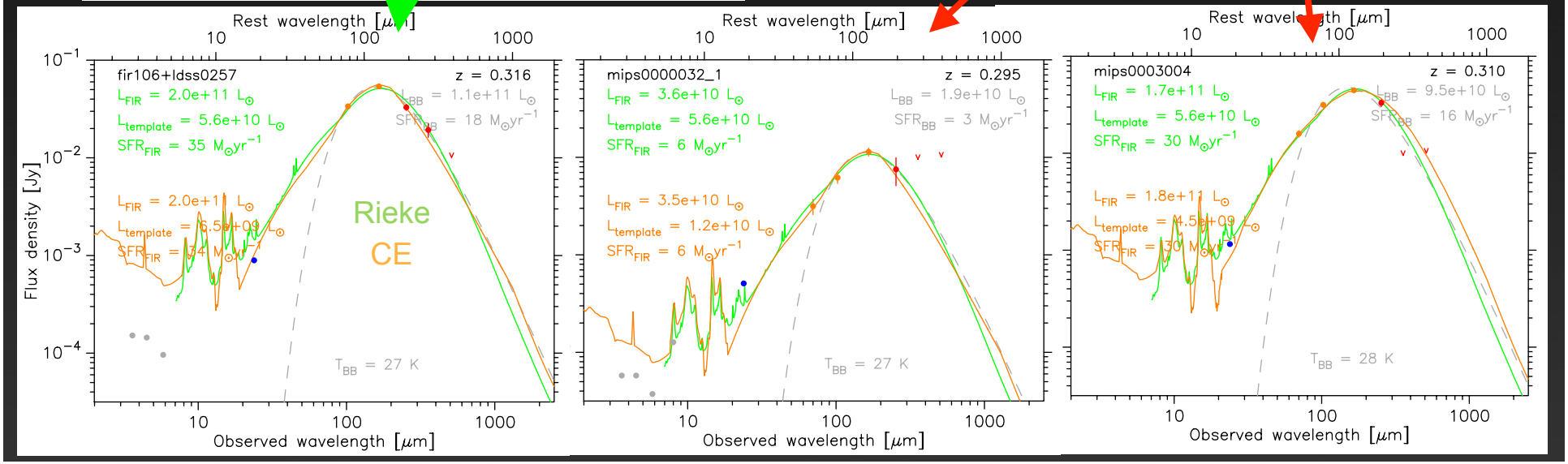


- MS2137: standard HLS coverage + Spitzer 3.6, 4.5, 5.8, 8.0, 24 μm
  - ~8'x8' PACS 100, 160 μm
  - ~18'x18' SPIRE 250, 350 500 μm
  - Spec-zs from Magellan/IMACS+LDSS3 (231 total; 78 in cluster; 11 Herschel detected)
- Bullet cluster: standard coverage + extended PACS coverage
  - ~8'x15' offset from center at 70, 100, 160 μm
  - Spec-zs: IMACS (Chung+10) & CTIO/Hydra (Fadda) (929 total; 371 cluster; 37 in Herschel)
- Foreground field sample:
  - 0.05 < z < 0.26; 20 in Bullet field, 11 in MS2137 field detected by Herschel

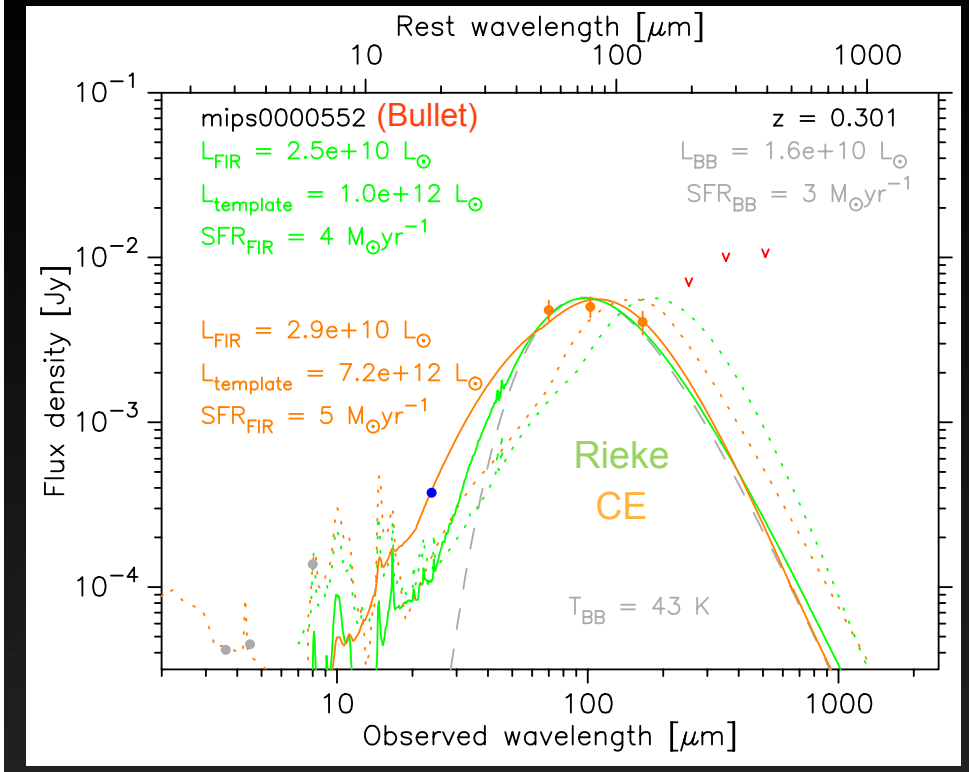
Herschel detections of cluster galaxies

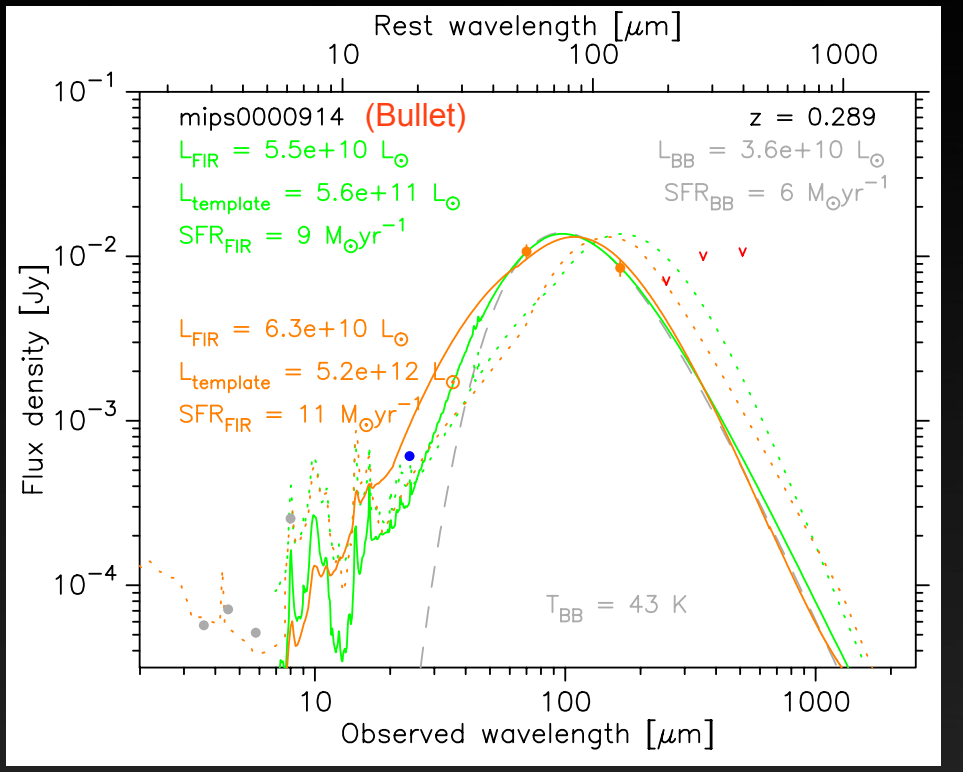






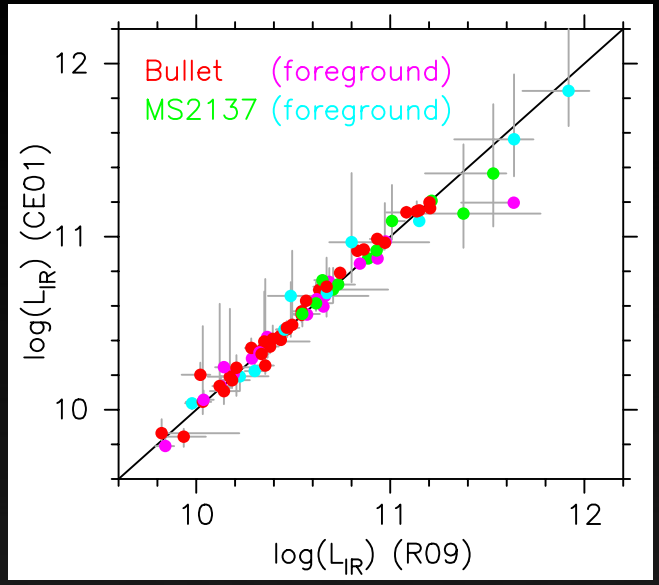
Mis-matched templates - two cases





- Each template (both Rieke and Chary/Elbaz sets) has the FIR shape of a local galaxy of a certain luminosity (solid lines)
- For several of our sources, the best fitting template has a luminosity label ($L_{template}$) much higher than the actual integrated FIR luminosity (L_{FIR})
- The template with luminosity label equal to the integrated label (dotted lines), peak too far red-wards to be a good fit (more pronounced in the Rieke templates)

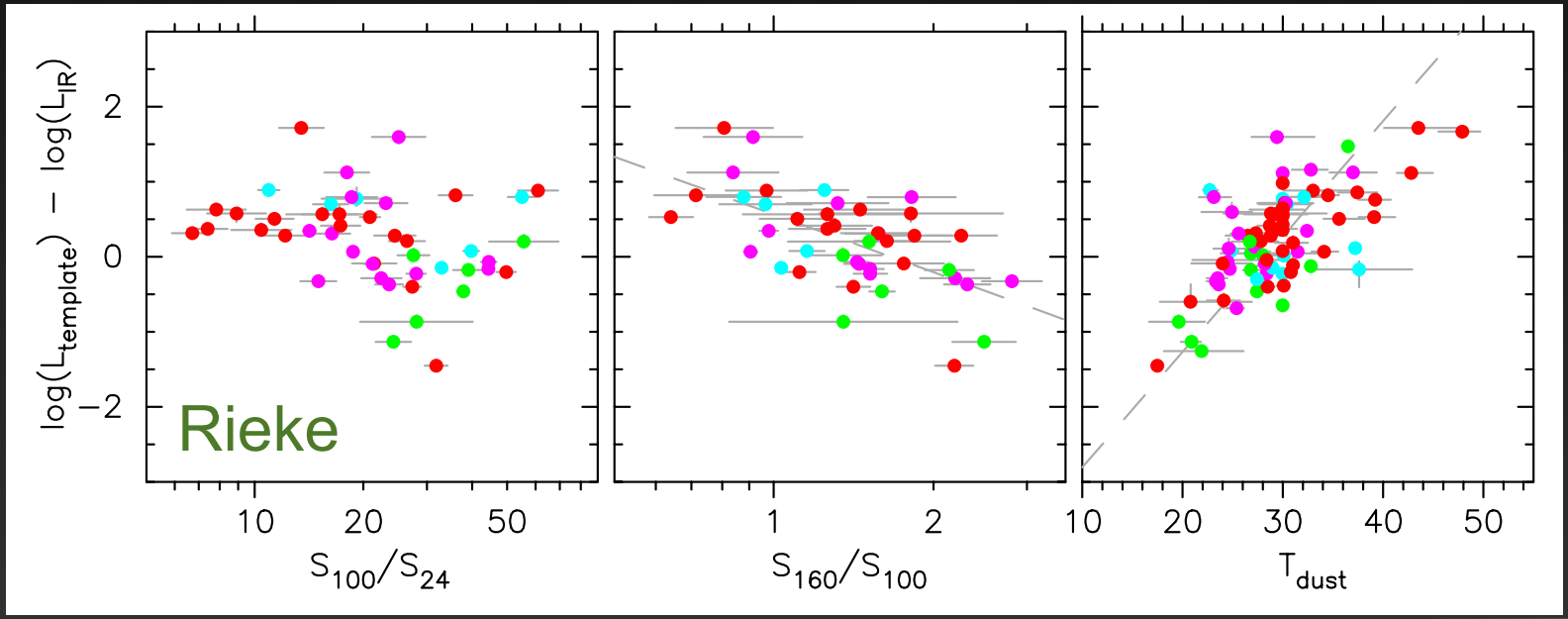
Best fit templates - all cluster sources



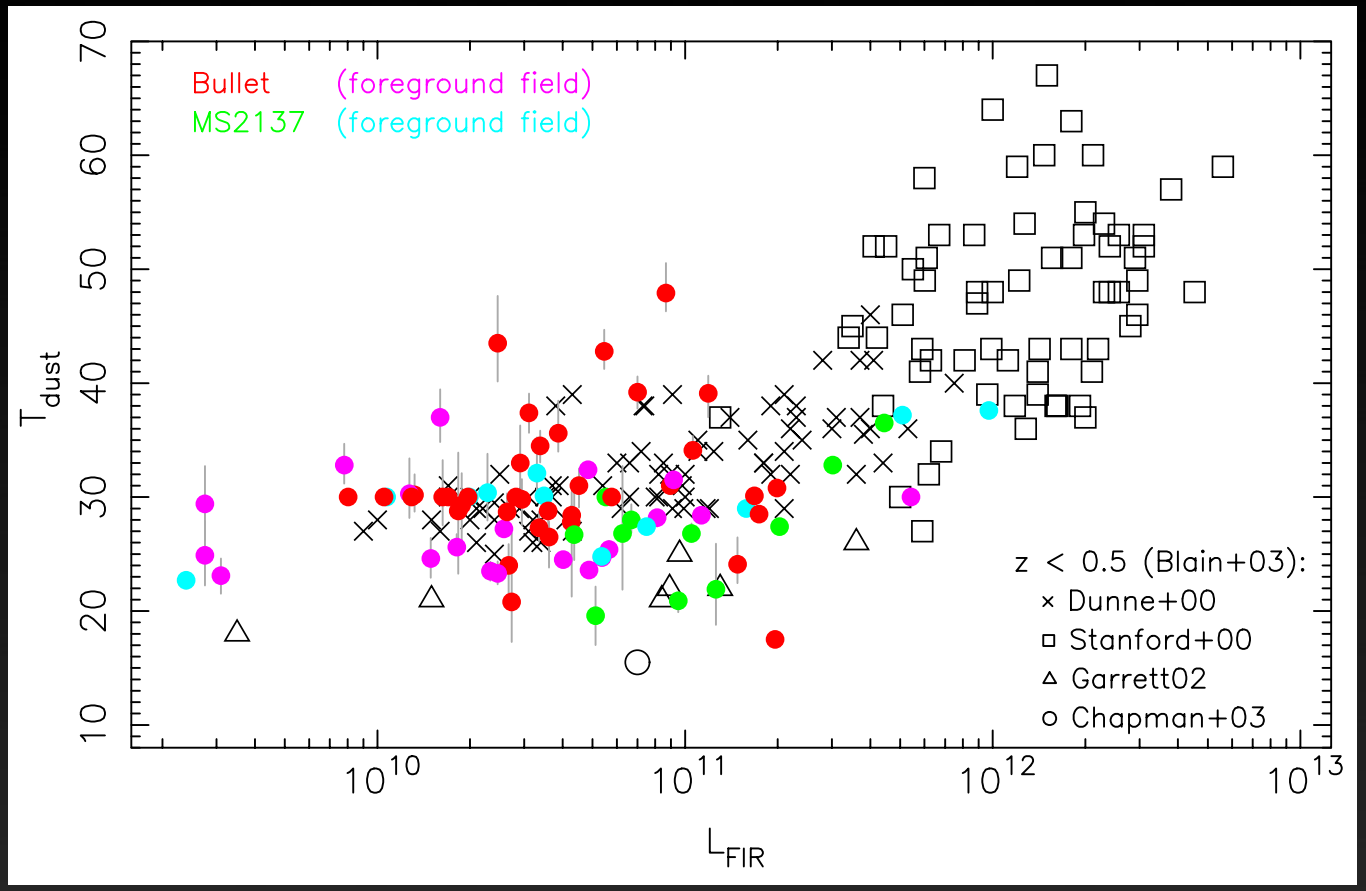
The mismatch between integrated luminosity and best fit template "class" is correlated with 160/100

160/100 traces the peak of the dust component

The template sets can only parameterize variation in dust peak by varying the luminosity class



The L_{IR} – T_{dust} plane



- The Bullet Cluster has at least three galaxies with much warmer dust temperatures (>40K) than sources at similar redshift and luminosity
- We detect no such galaxies in MS2137 or in the foreground field (>3σ different population)
- 6 Bullet Cluster galaxies have T > 36K - warmer than any of our field galaxies (>4σ)

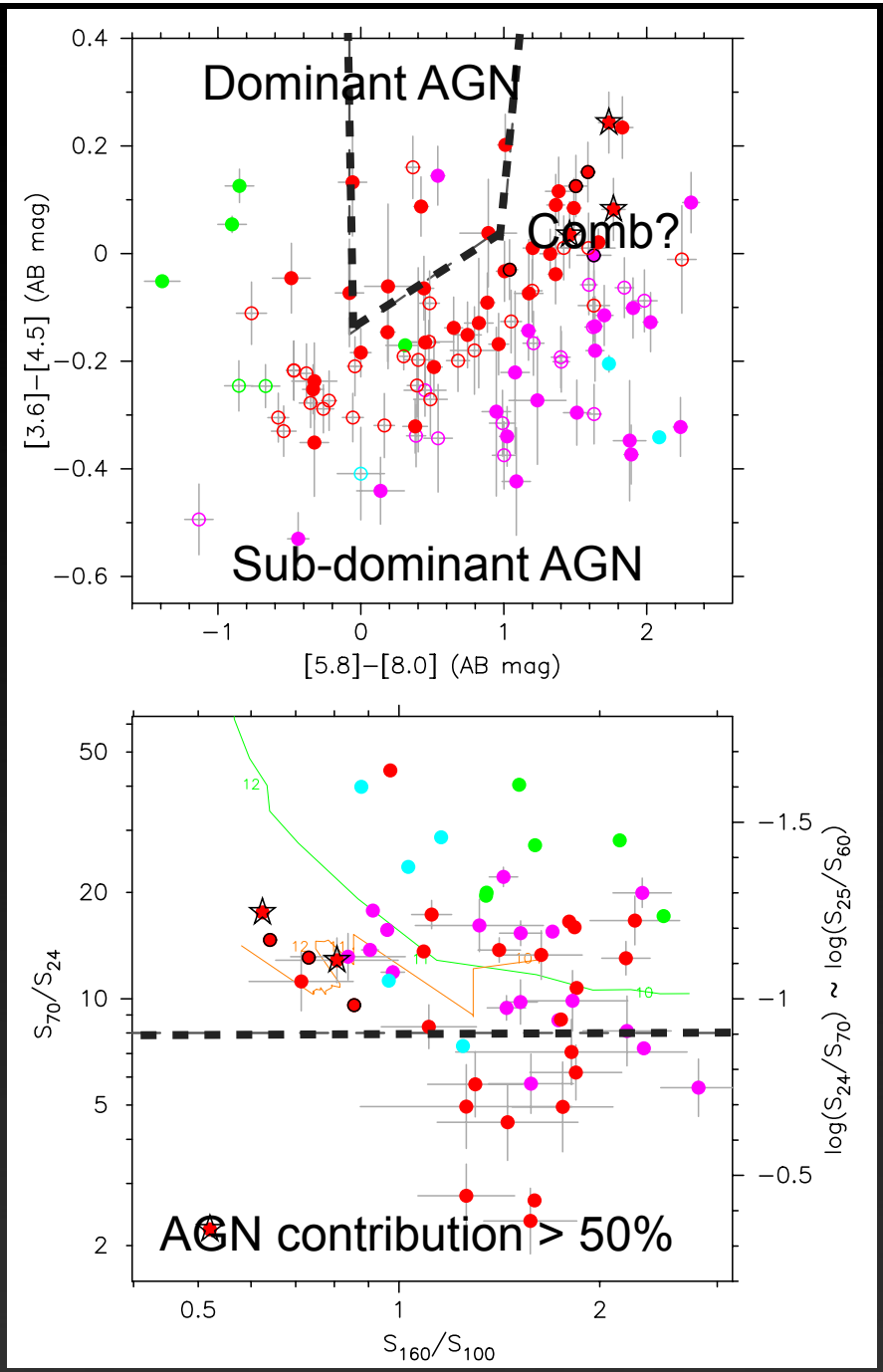
AGN contribution?

Following Stern+05

Two different obscured AGN tracers:
- IRAC colors
- mid--far infrared colors

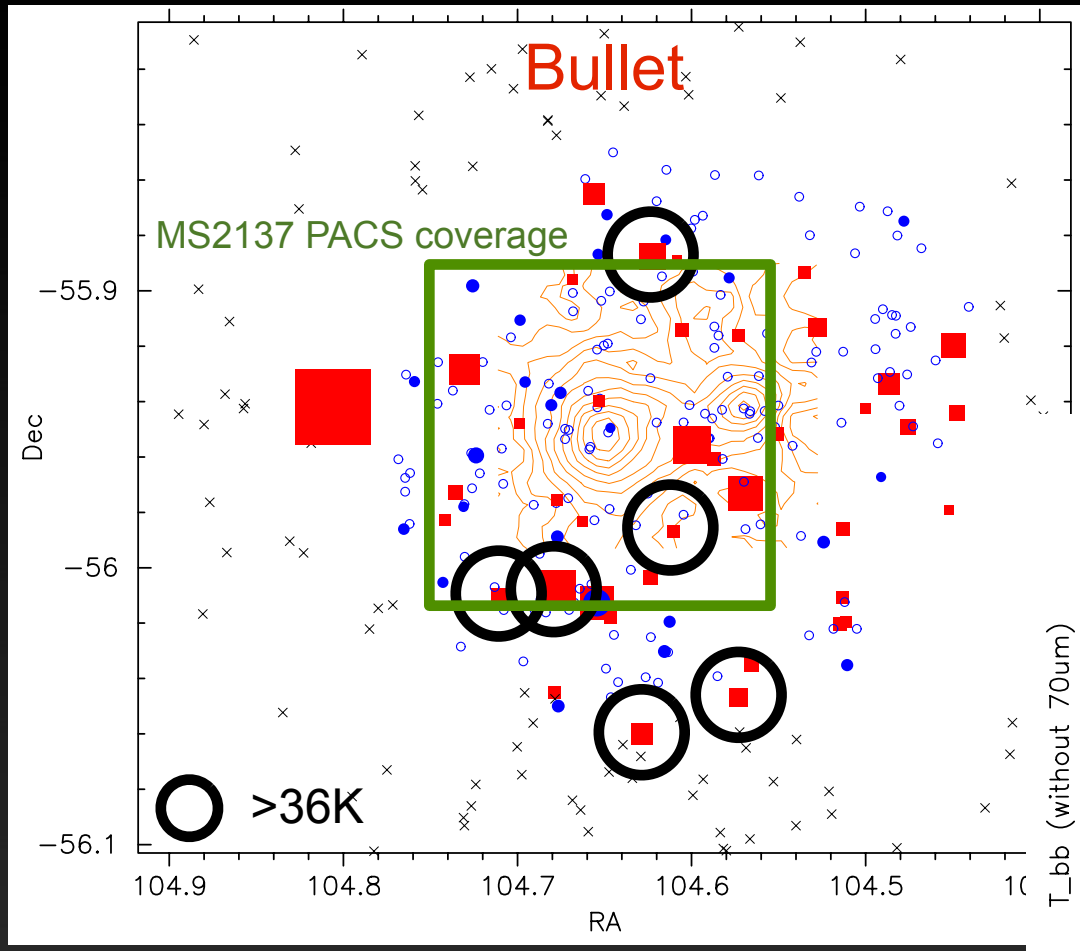
One of the three warmest is likely to have a large AGN component, which likely biases the peak of the dust component

The remaining warm sources may have small AGN contributions, but not dominant in the mid-infrared



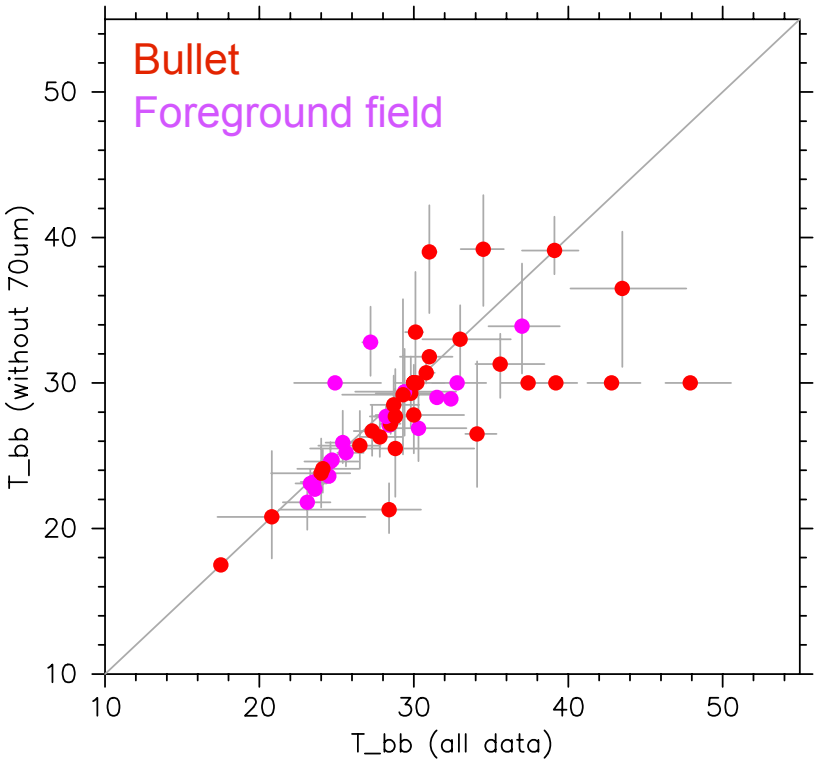
Following Veilleux+09, Hatziminaoglou+10

Unique to cluster mergers?



Normal HLS PACS footprint would only cover one or two of the warm sources (>36K)

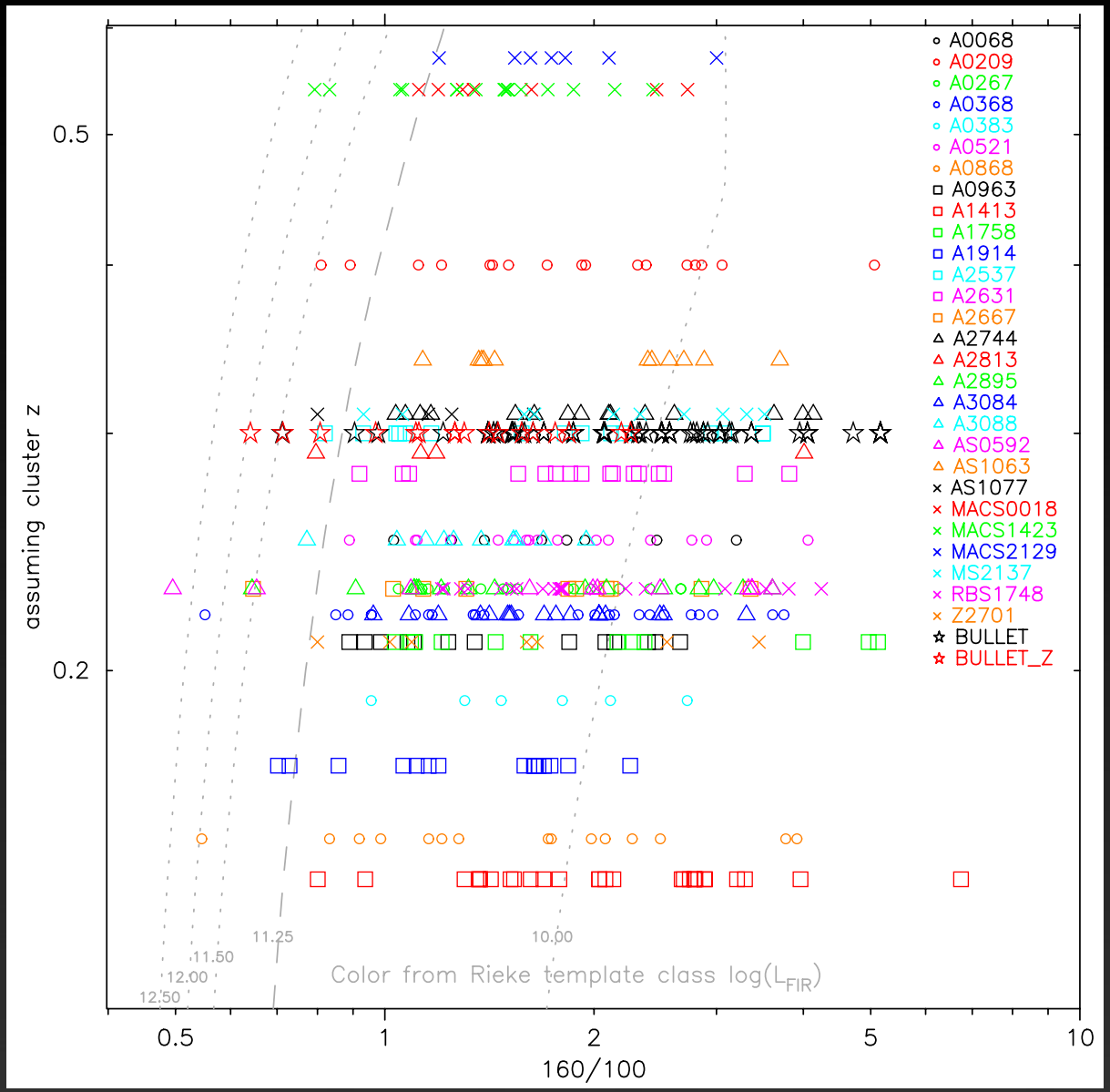
Without 70μm imaging, 2 of the 6 warm sources would still be identified as warm



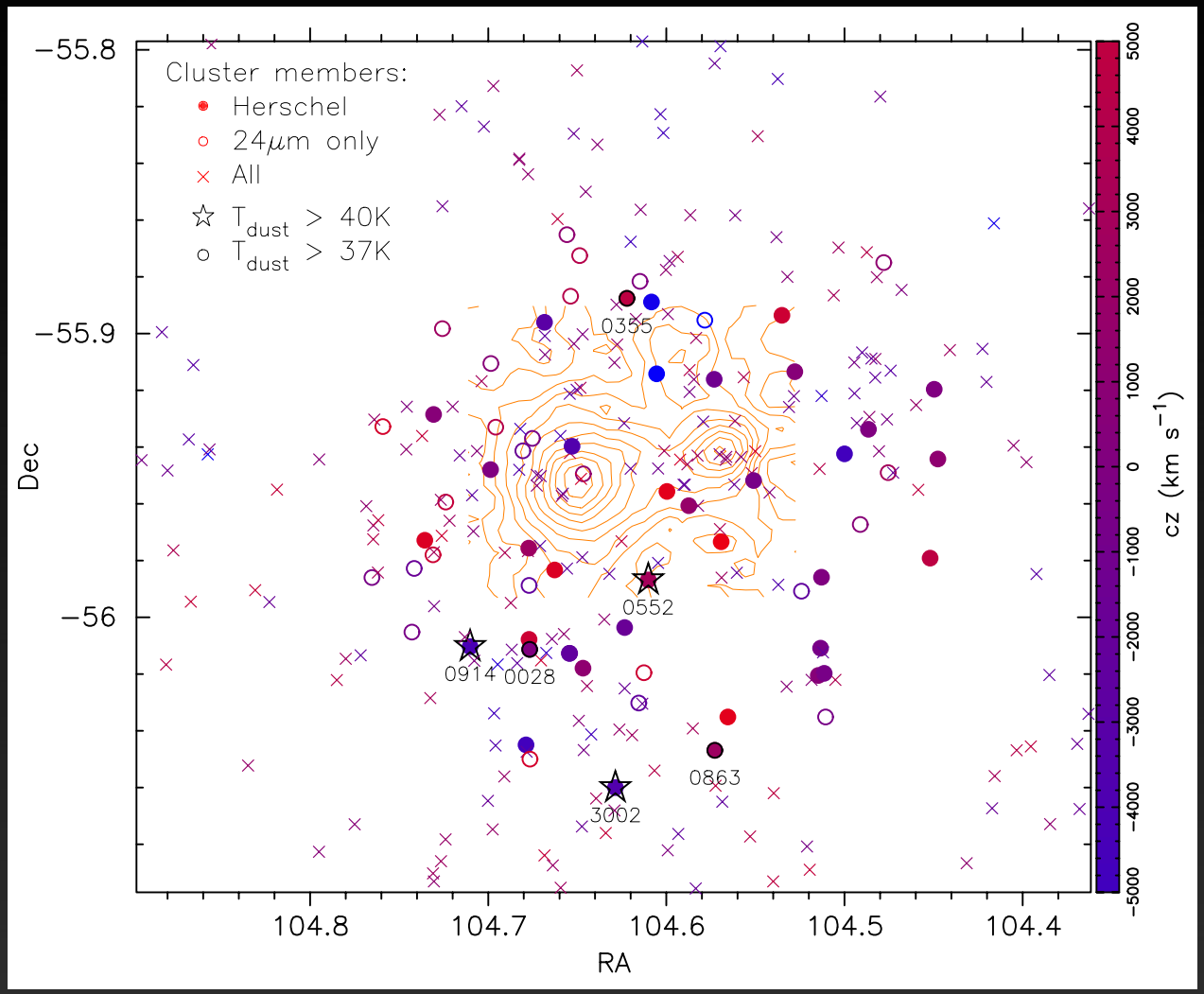
Cannot say the warm dust sources are unique to merging clusters

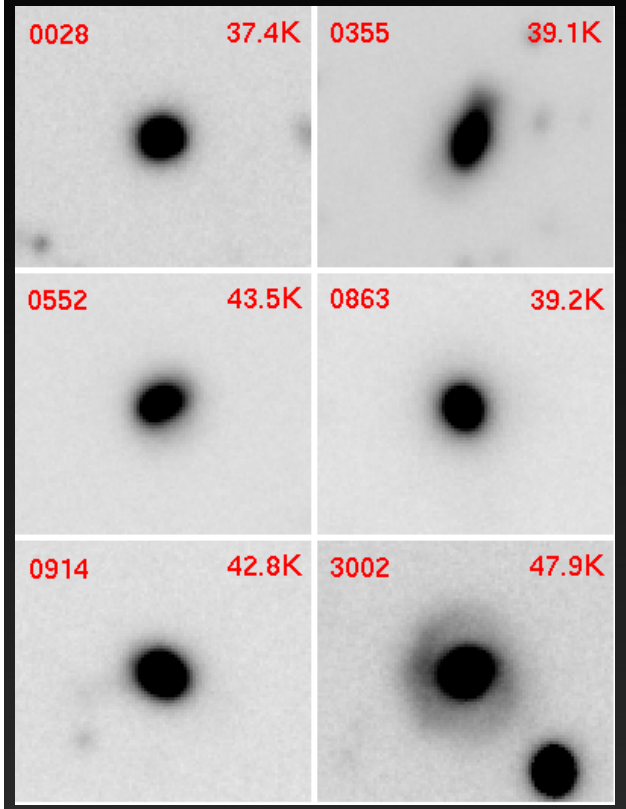
...but do seem cluster specific

All HLS clusters...

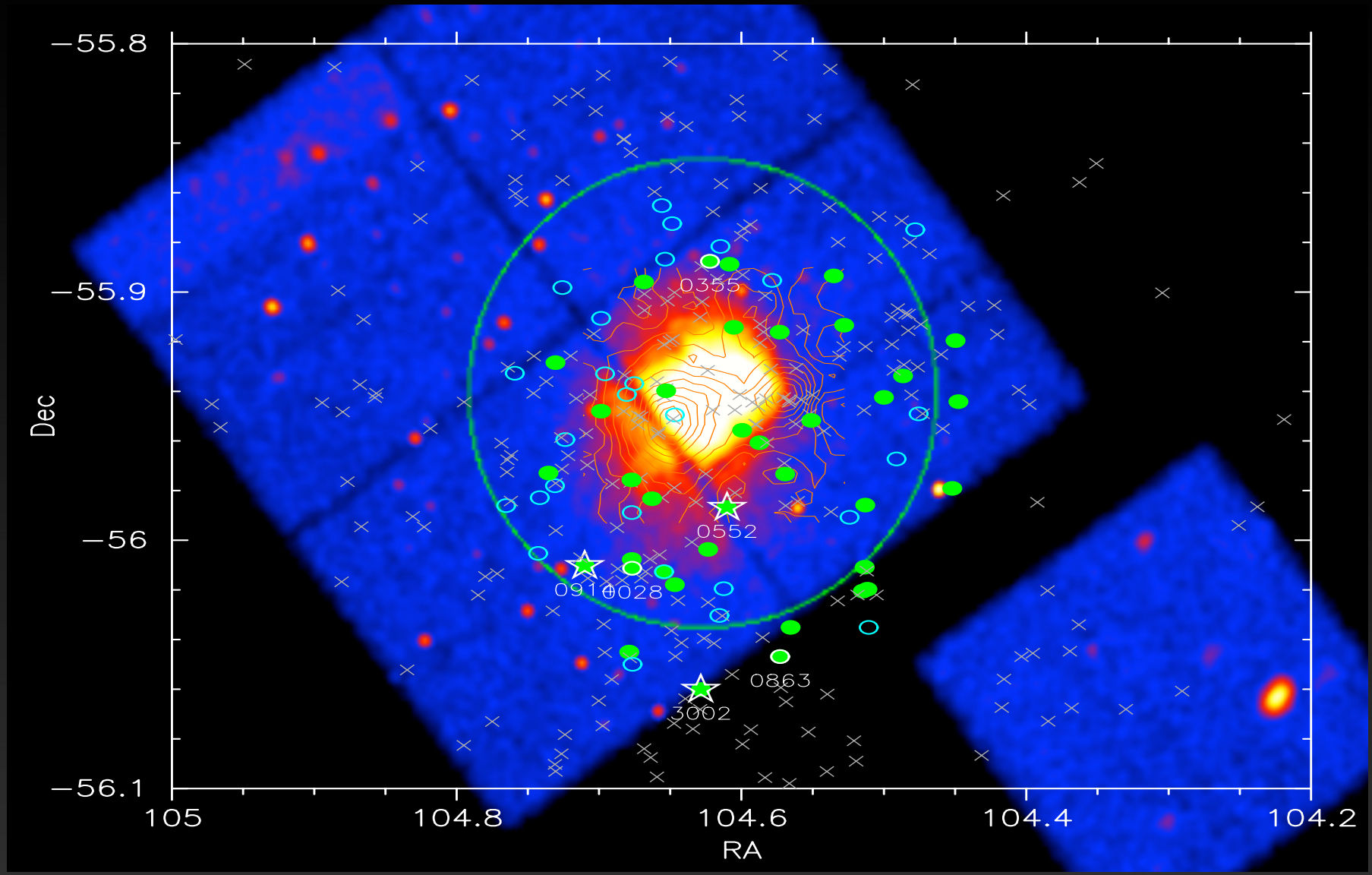


Distribution and morphology





Interaction with hot, dense ICM?



Summary - warm dust in cluster galaxies

- Herschel Lensing Survey
  - 44 massive galaxy clusters
  - PACS (~8'x8') and SPIRE (~18'X18') coverage
  - Estimated ~400-500 cluster members detected by Herschel

- Cluster members...
  - ~50 cluster members detected in Bullet Cluster and MS2137
  - 6 Bullet cluster members have warmer dust components (>36K) than any field galaxies of comparable luminosity
  - (ie ULIRG temperatures but in much lower luminosity systems)
  - Much rarer objects than 40% figure from SDP data
  - AGN doesn't appear to dominate many of these sources

  - Inconclusive as to whether the warm dust temperatures are exclusive to cluster merger environments
  - But galaxies with characteristic dust temperature > 36K so far found only in cluster environments