HerMES-Planck Clumps: Clusters of Dusty Galaxies

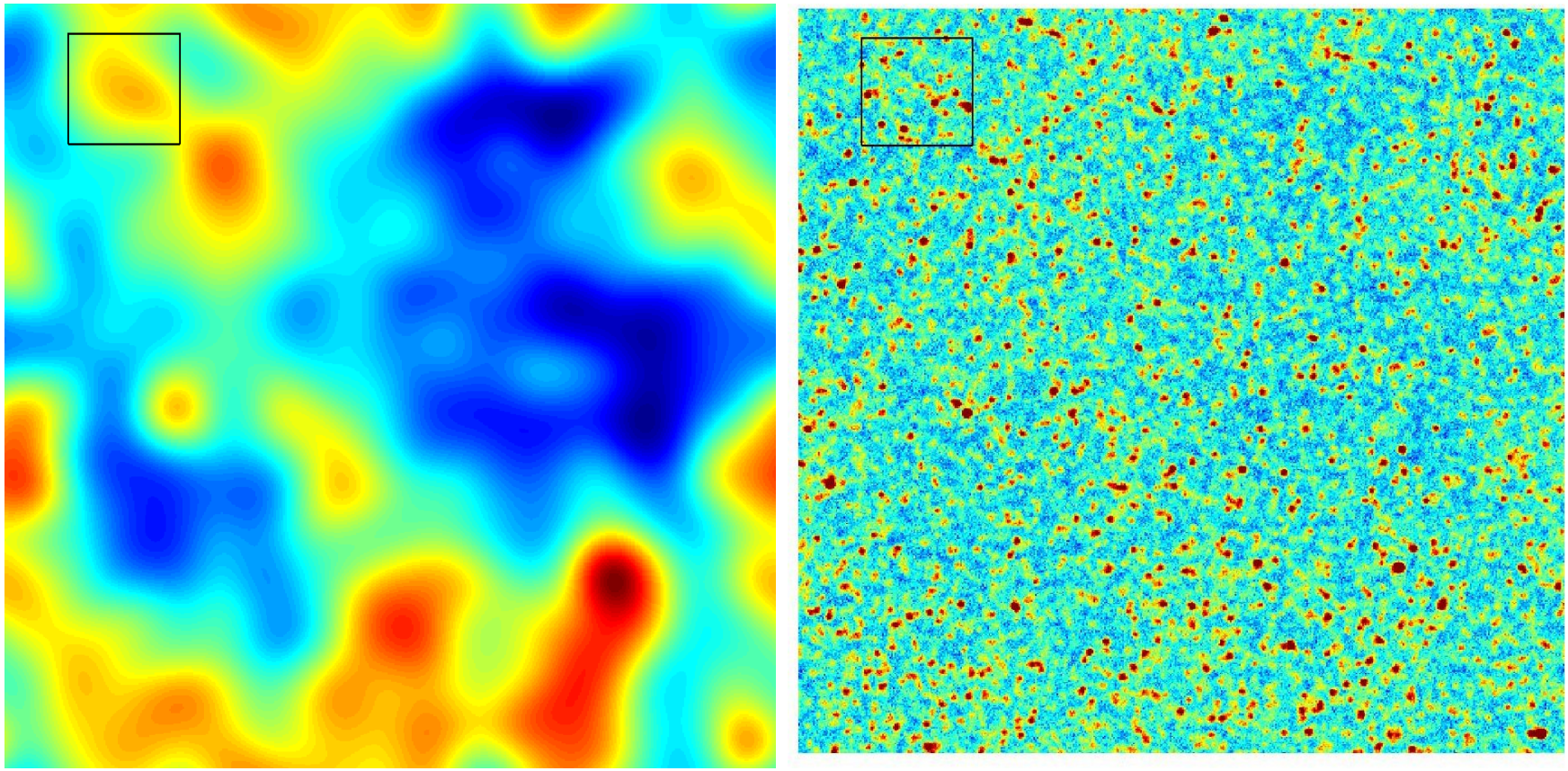
Dave Clements, Filiberto Braglia, Ashley Hyde
Imperial College London
The HerMES Consortium

Outline

- Why try to cross-match Planck sources with Herschel?
- Candidate dusty protoclusters in HerMES
- Follow-up observations & analysis of clumps
- Conclusions: discovery of dusty protoclusters

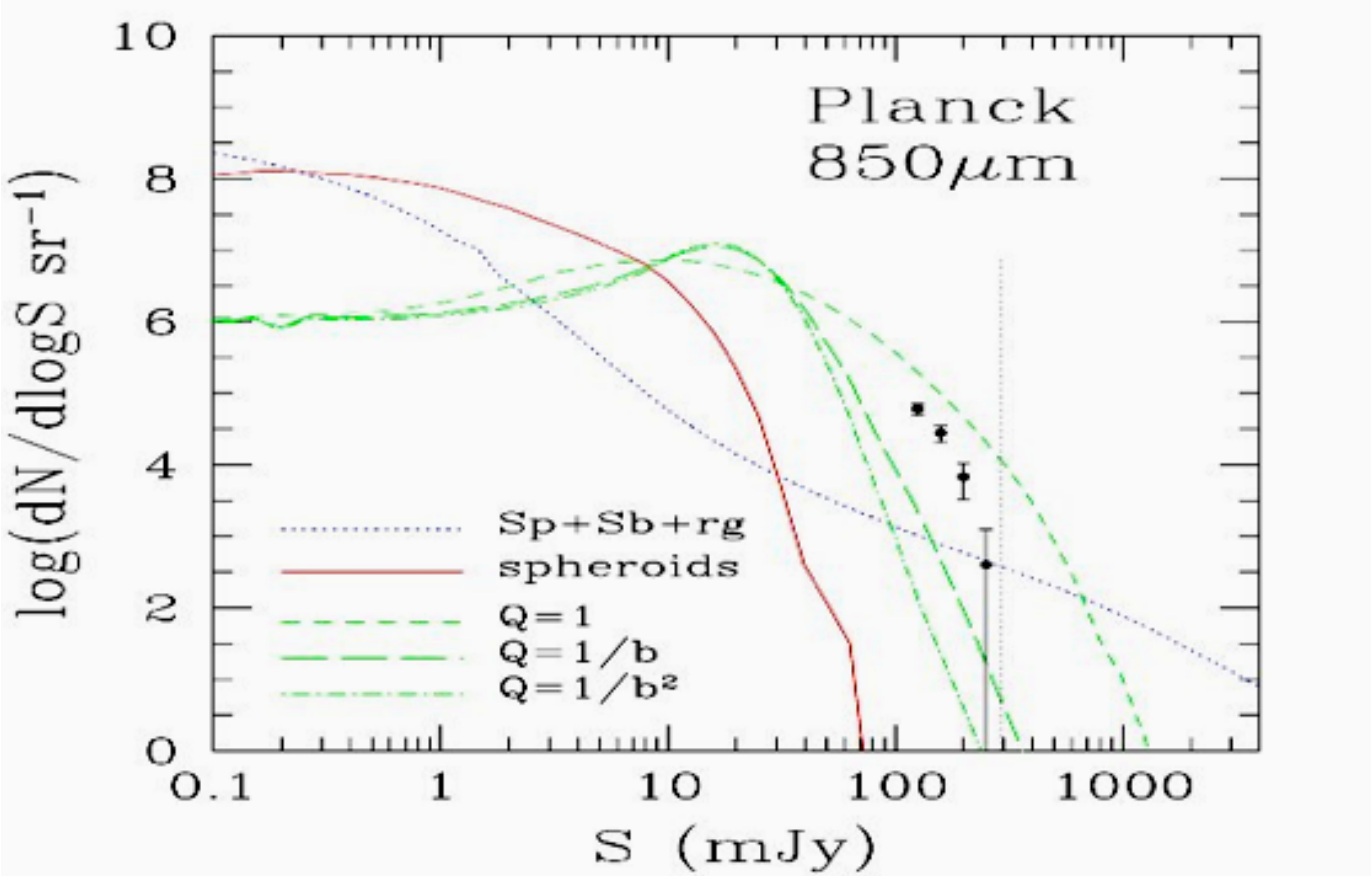
Background

- Granato et al. (2004) predicted a stage in cluster formation where many of the cluster members would undergo a starburst at the same time: dusty protocluster
- Negrello et al. (2005) predicted that these dusty protoclusters could be detected by Planck, since their size would match Planck beam



350 μm Sky: Planck & Herschel

- Simulation by Gonzales-Nuevo of 1sq deg region including protocluster (top left).



Predictions for clumps: Negrello et al., 2005

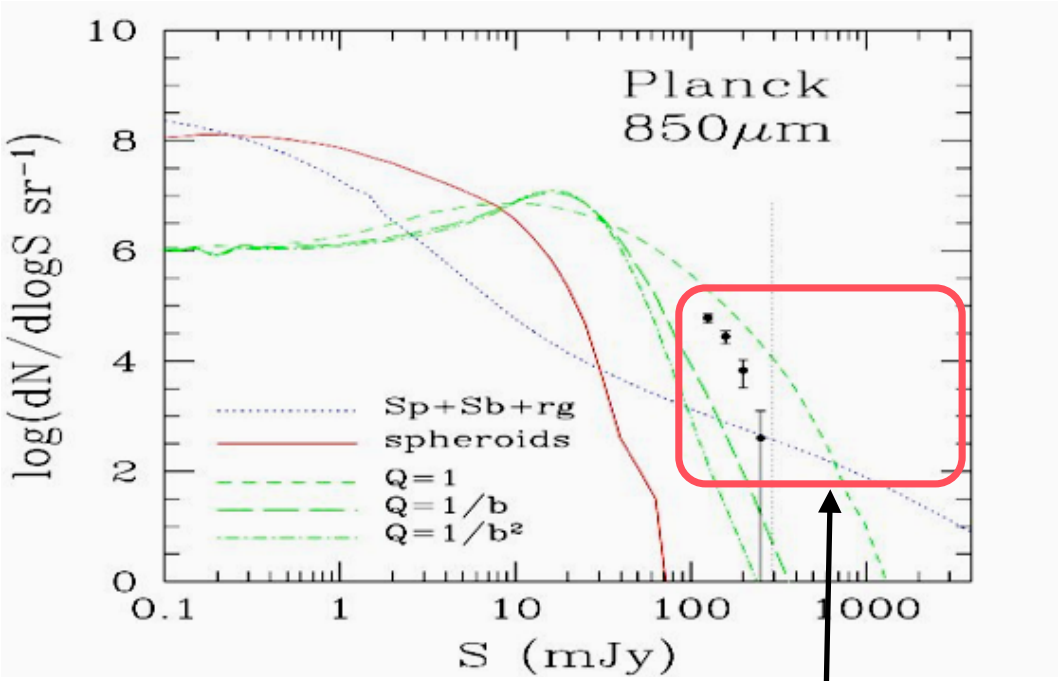
- Green lines show cluster contributions to 850 μm counts of sources with individual counts given by red line for 3 different clustering evolution models.
- Points show the results of numerical simulations

Protocluster Searches using Planck and Herschel

- This suggests a strategy for finding dusty protoclusters
- 1: Use Planck all sky survey to select candidate objects
- 2: Use Herschel to follow up these objects and exclude low-z galaxies, cirrus etc.

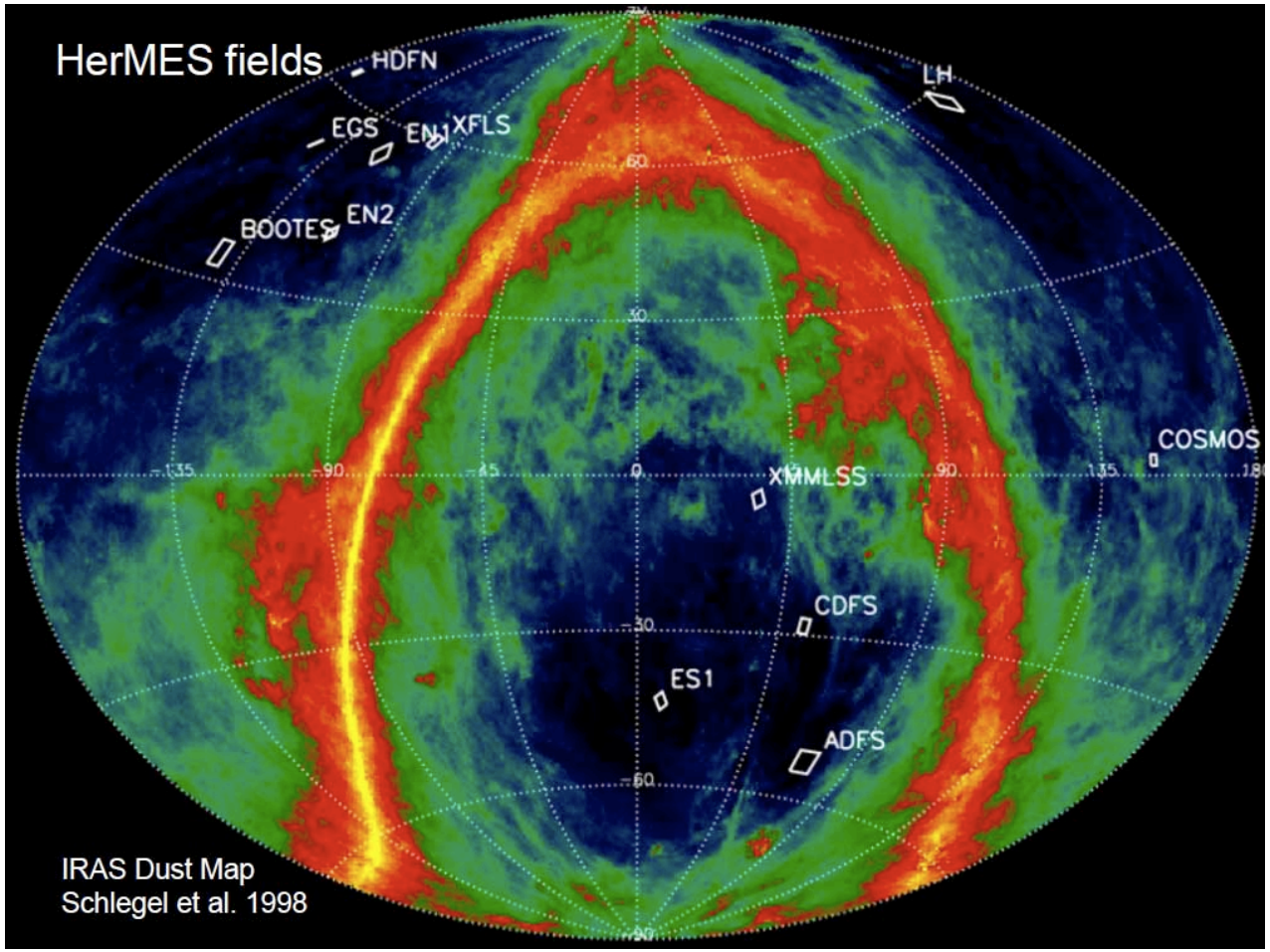
Planck & Herschel Surveys

- Negrello et al. 2005 predict 100 - 10000 clumps per steradian detectable by Planck and Herschel
- Would detect appreciable numbers of these objects in HerMES (90 + 250 sq. deg.) and H-ATLAS (550 sq. deg.) surveys
- Working with 'followup' data that already exists



Fluxes and densities accessible to Herschel Key Programme Surveys

The HerMES Survey



Oliver et al., in press

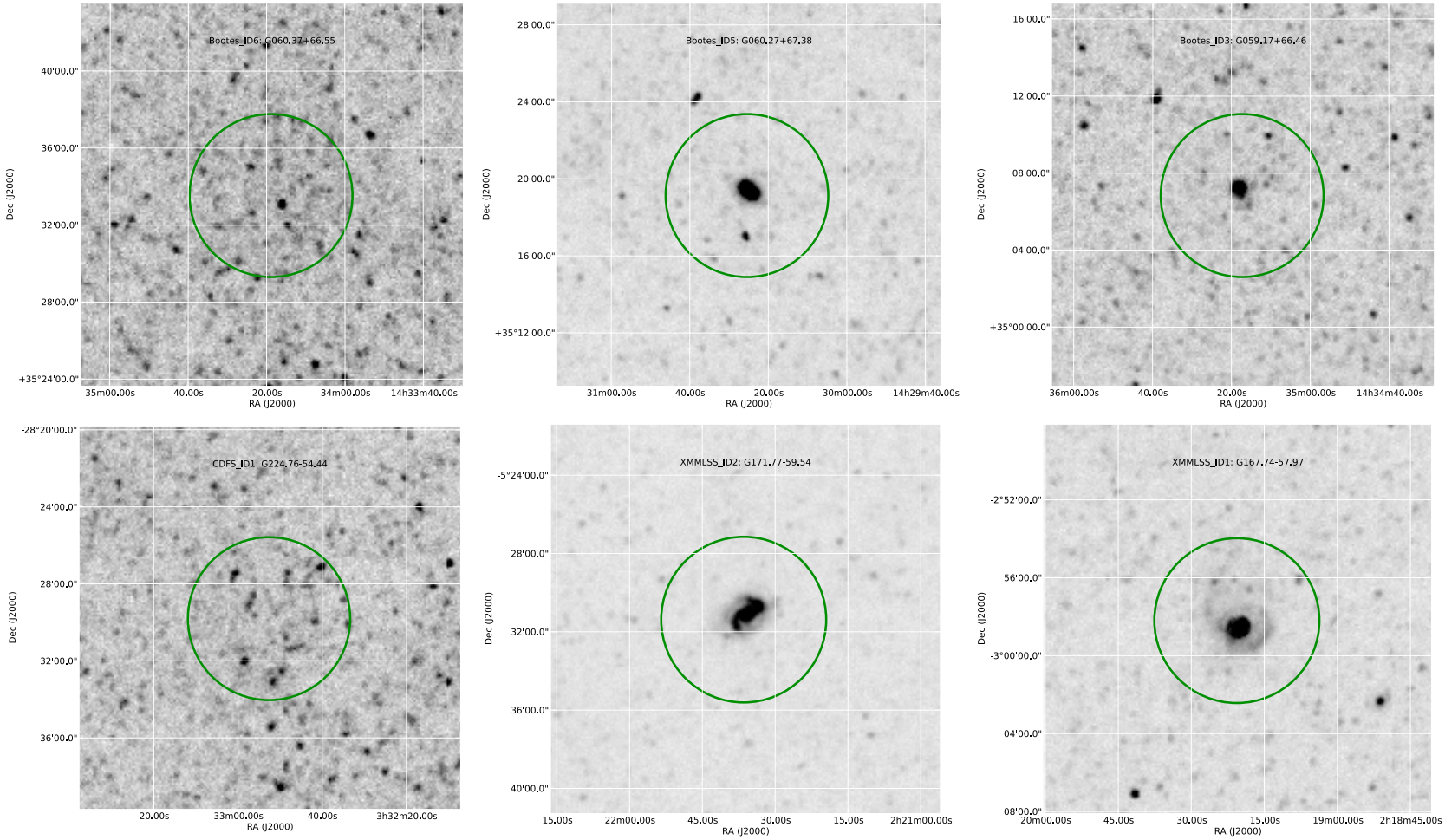
- Largest single Herschel survey programme using SPIRE and PACS
  - 100, 160, 250, 350, 500 micron
  - SPIRE bands to or beyond the confusion limit
  - ~90 sq. deg. already observed

Planck Sources in HerMES

- Expect three classes of sources to be detected by Planck in these fields:
  - Bright nearby galaxies
    - Appear as bright sources in HerMES
  - High latitude cirrus
    - Appear as extended diffuse emission in HerMES
  - Candidate protocluster ‘clumps’
    - Appear as overdensities of less bright sources

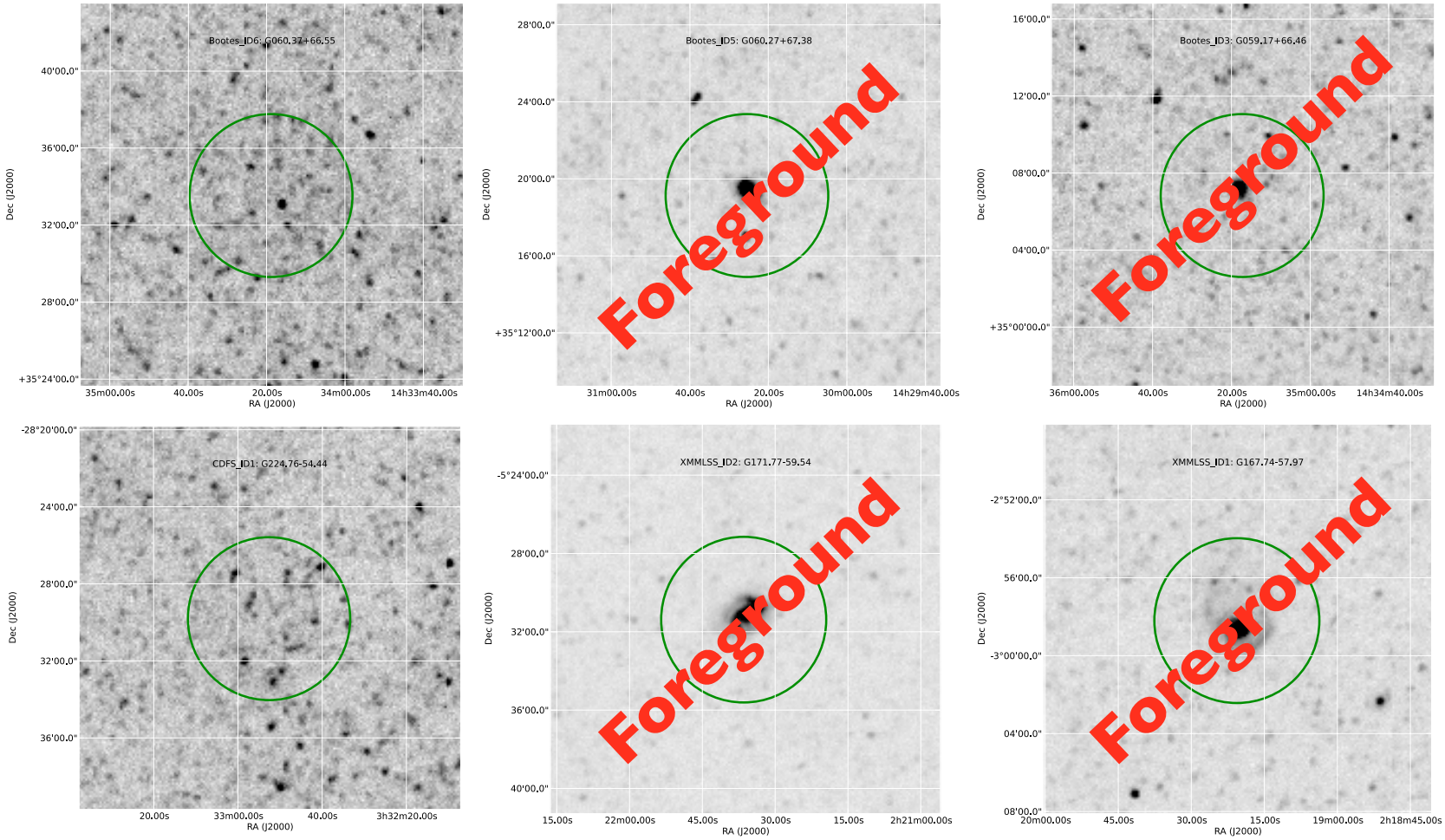
Example Planck Sources

250 micron images of HerMES Planck Sources



Example Planck Sources

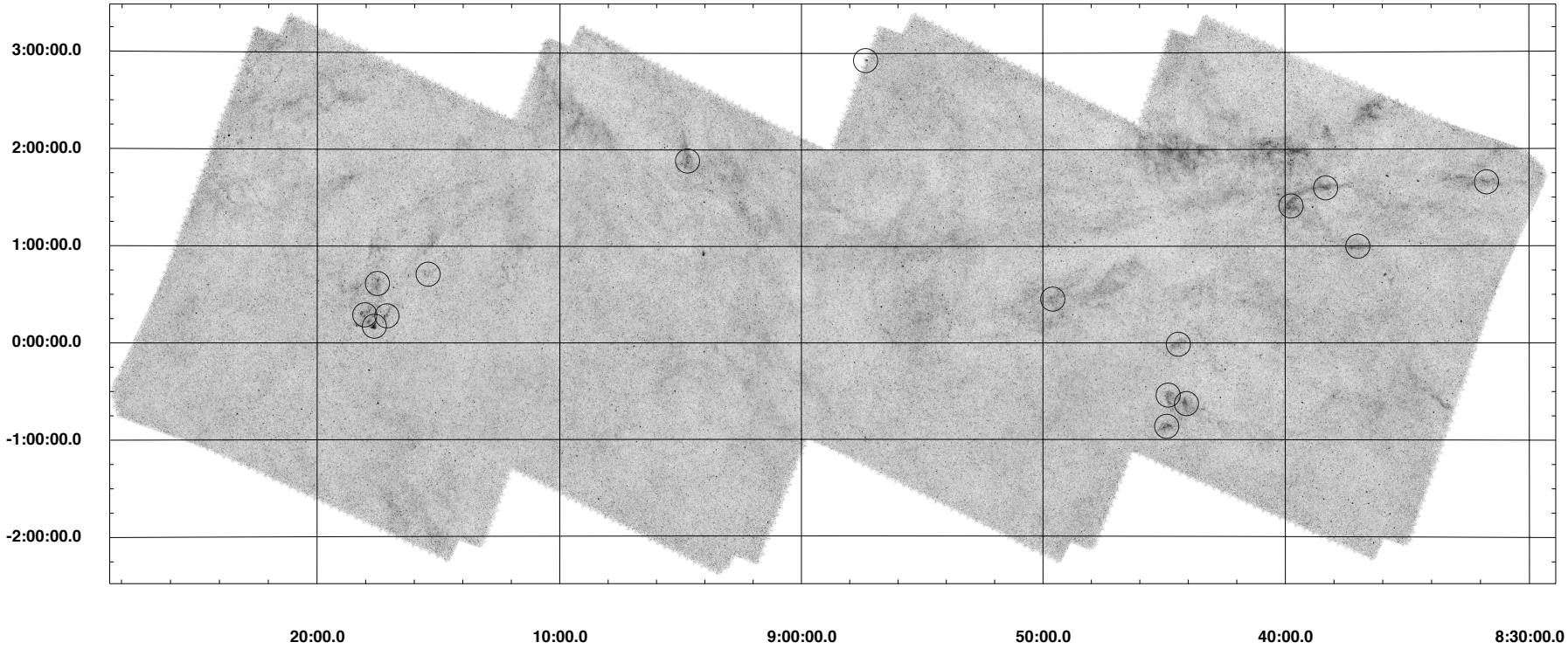
250 micron images of HerMES Planck Sources



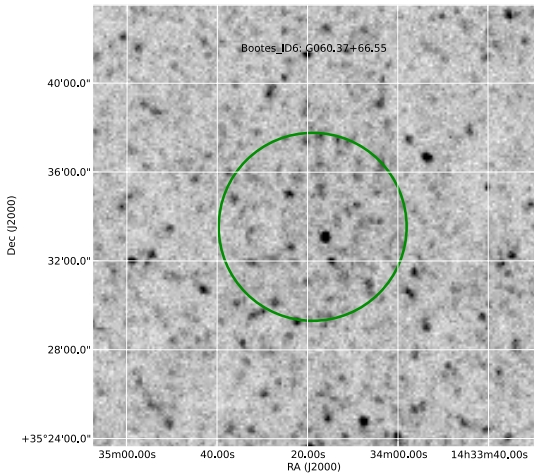
Results Summary

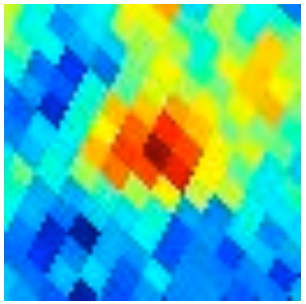
- For 4 well studied HerMES fields (XMMLSS, Bootes, Lockman-SWIRE, CDFS-SWIRE) find:
  - 17 Planck Sources
  - 13 foreground sources (galaxies + Mira)
  - 4 clumps in ~60 sq. deg. => 1 per 15 sq. deg.
    - But not all HerMES fields yet included
  - No cirrus

Can spot cirrus

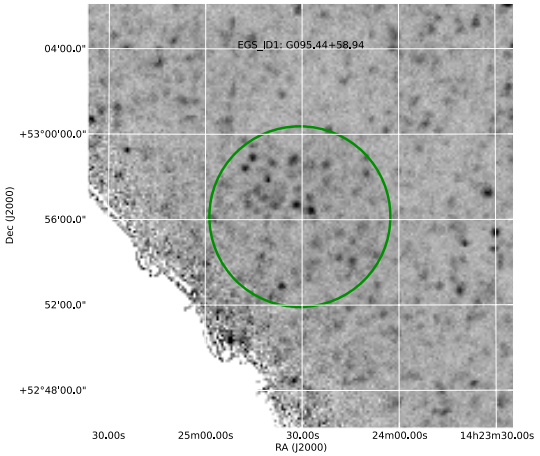


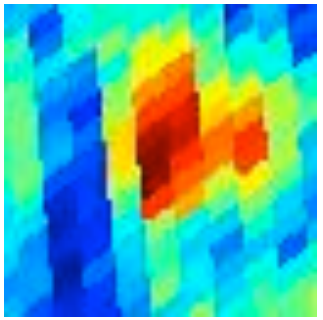
Herranz et al., 2012



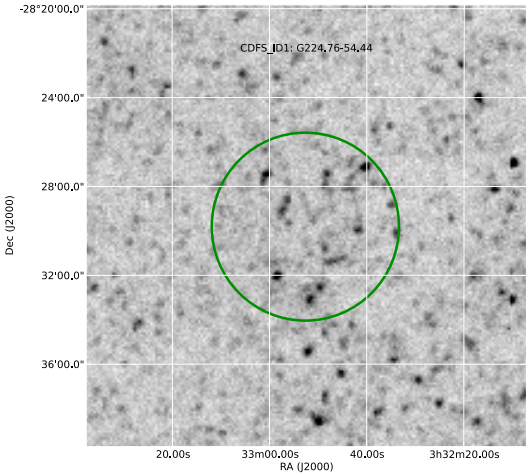


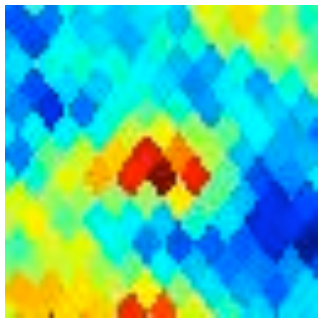
Bootes



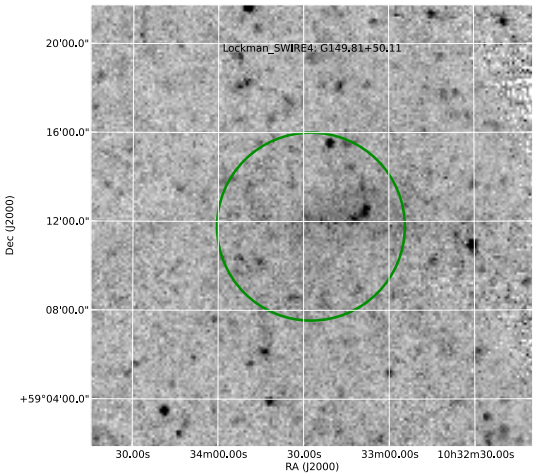


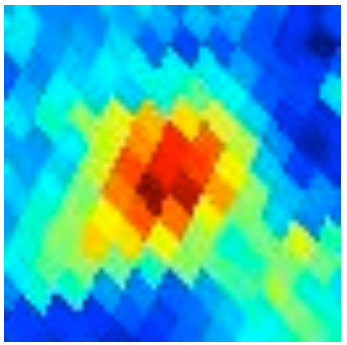
EGS





CDFS-SWIRE

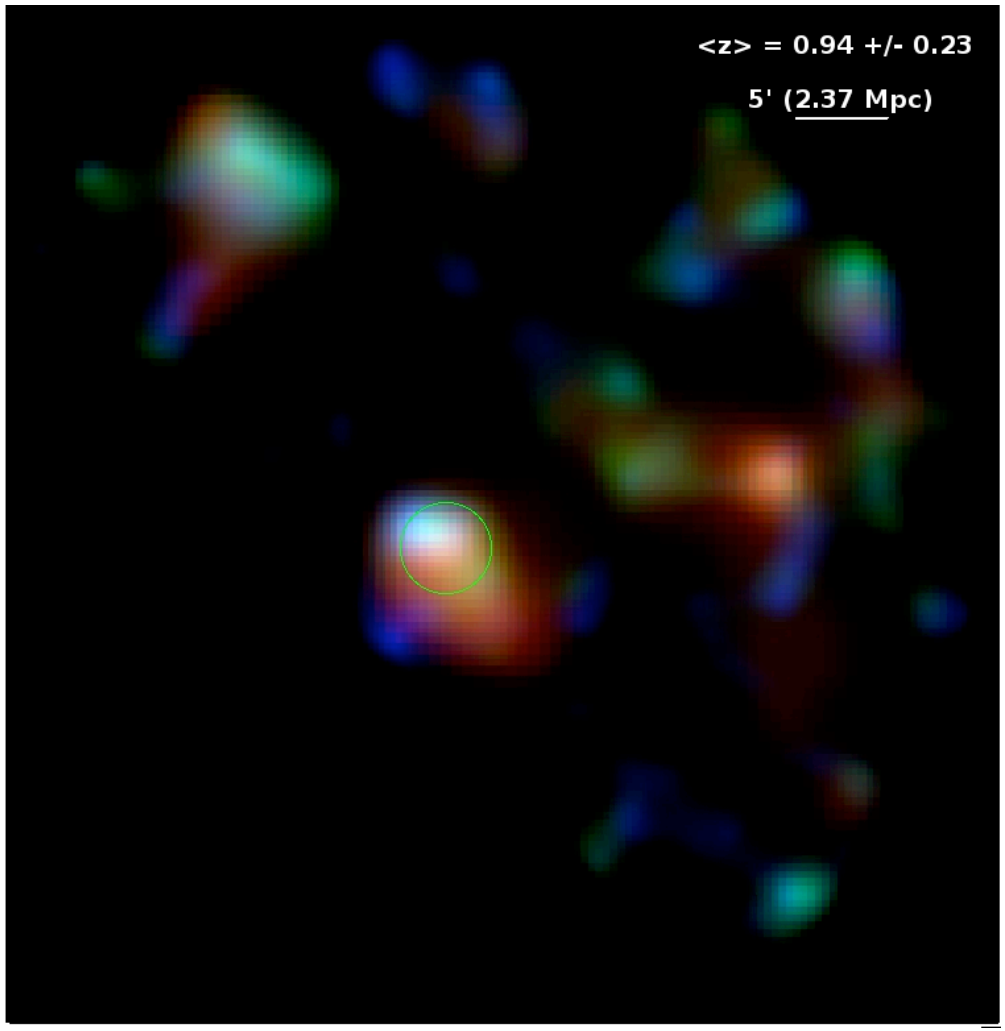




Lockman-SWIRE

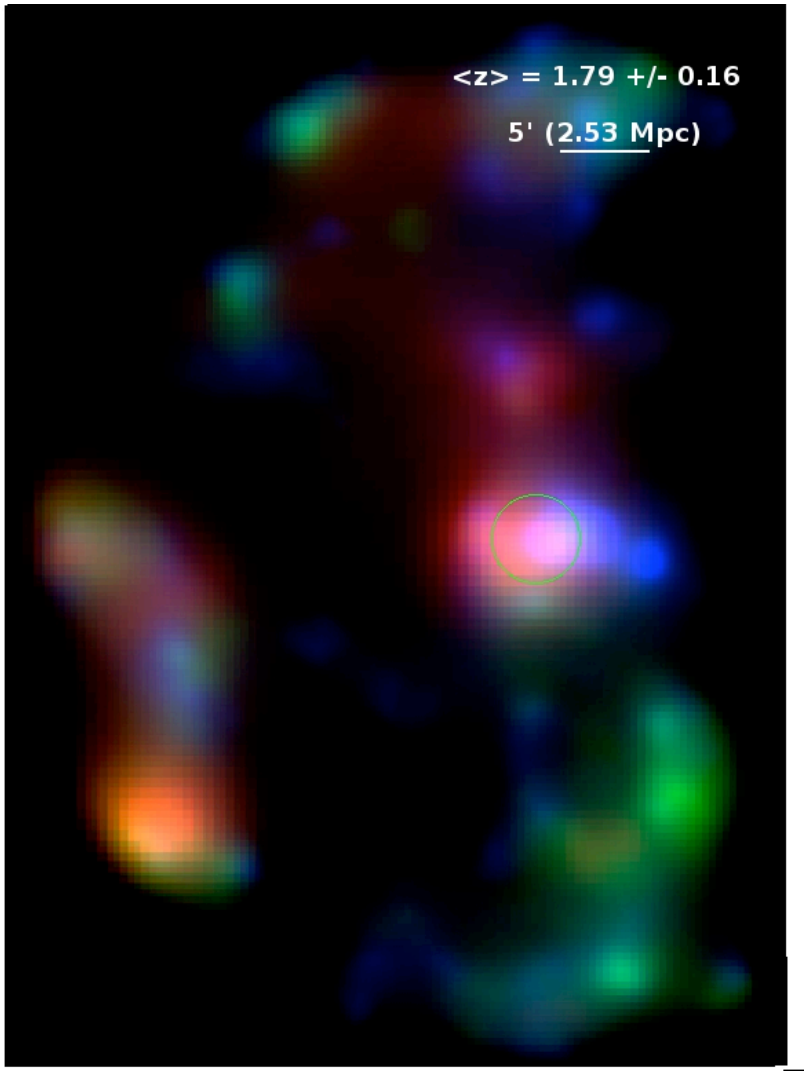
HerMES Catalog Overdensities

Smoothed, flux weighted catalog overdensity image
3 colour:
B=250micron
G=350micron
R=500micron

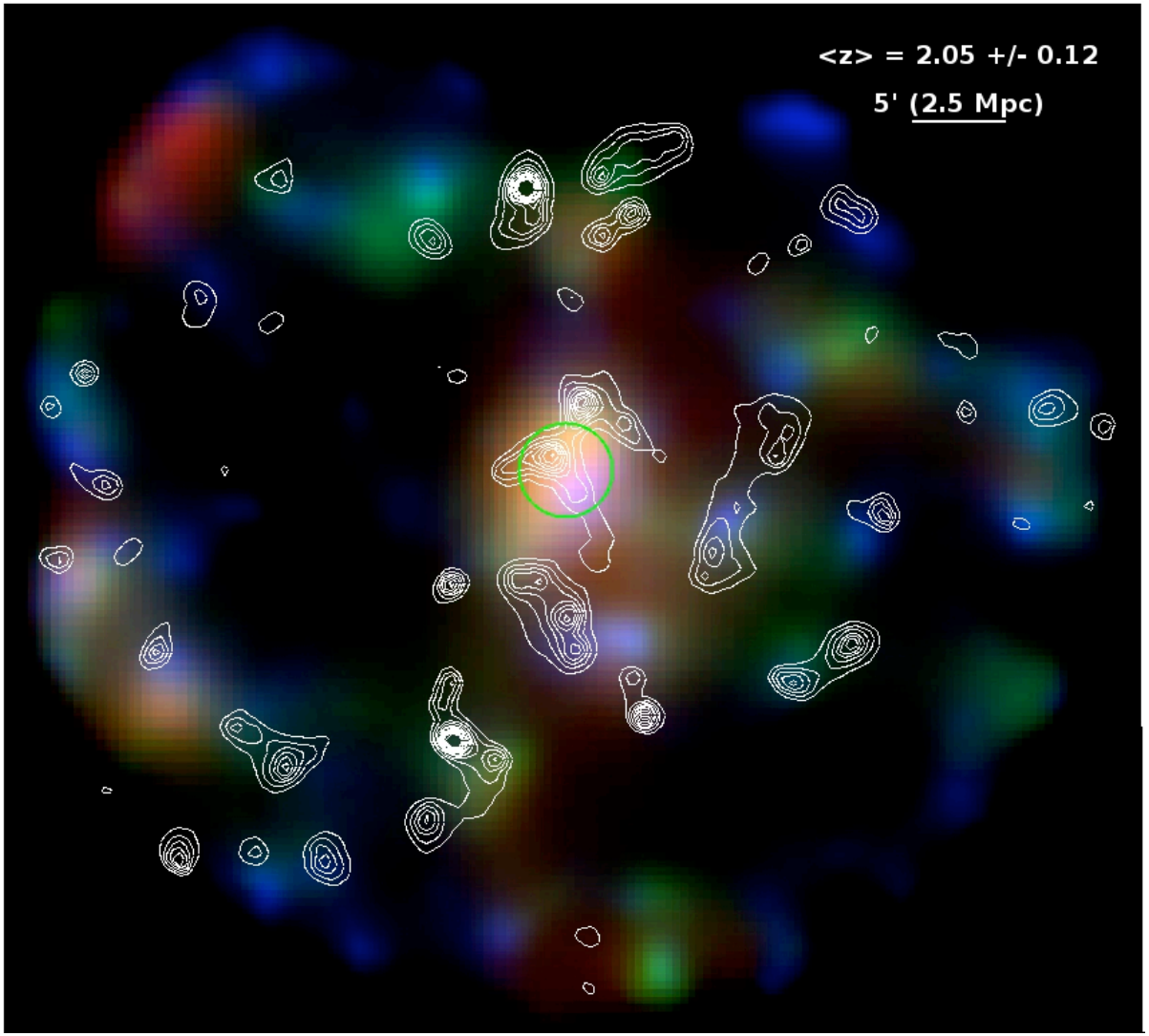


Green circle is Planck beam at position of EGS clump

Lockman Clump

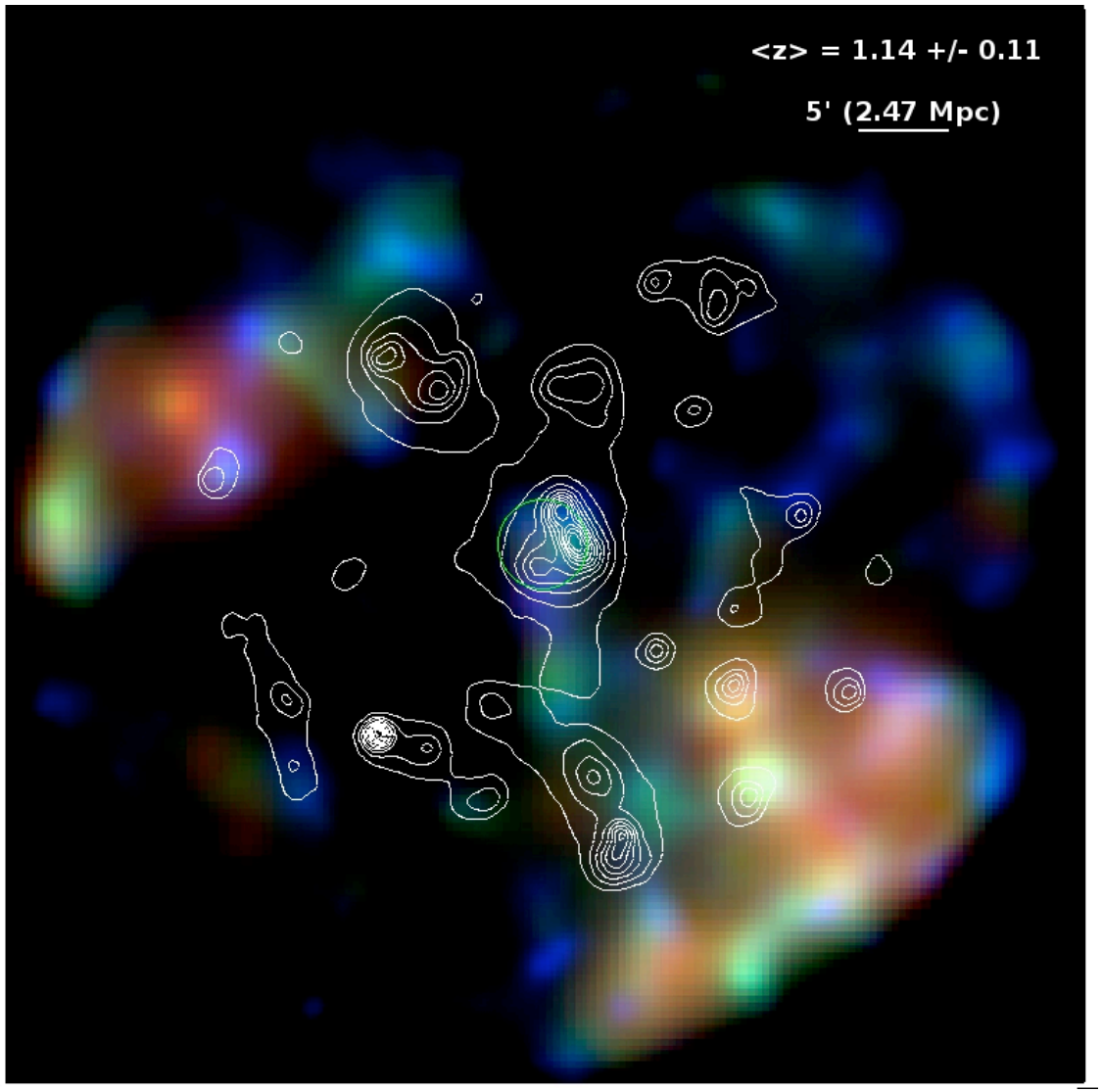


Bootes Clump



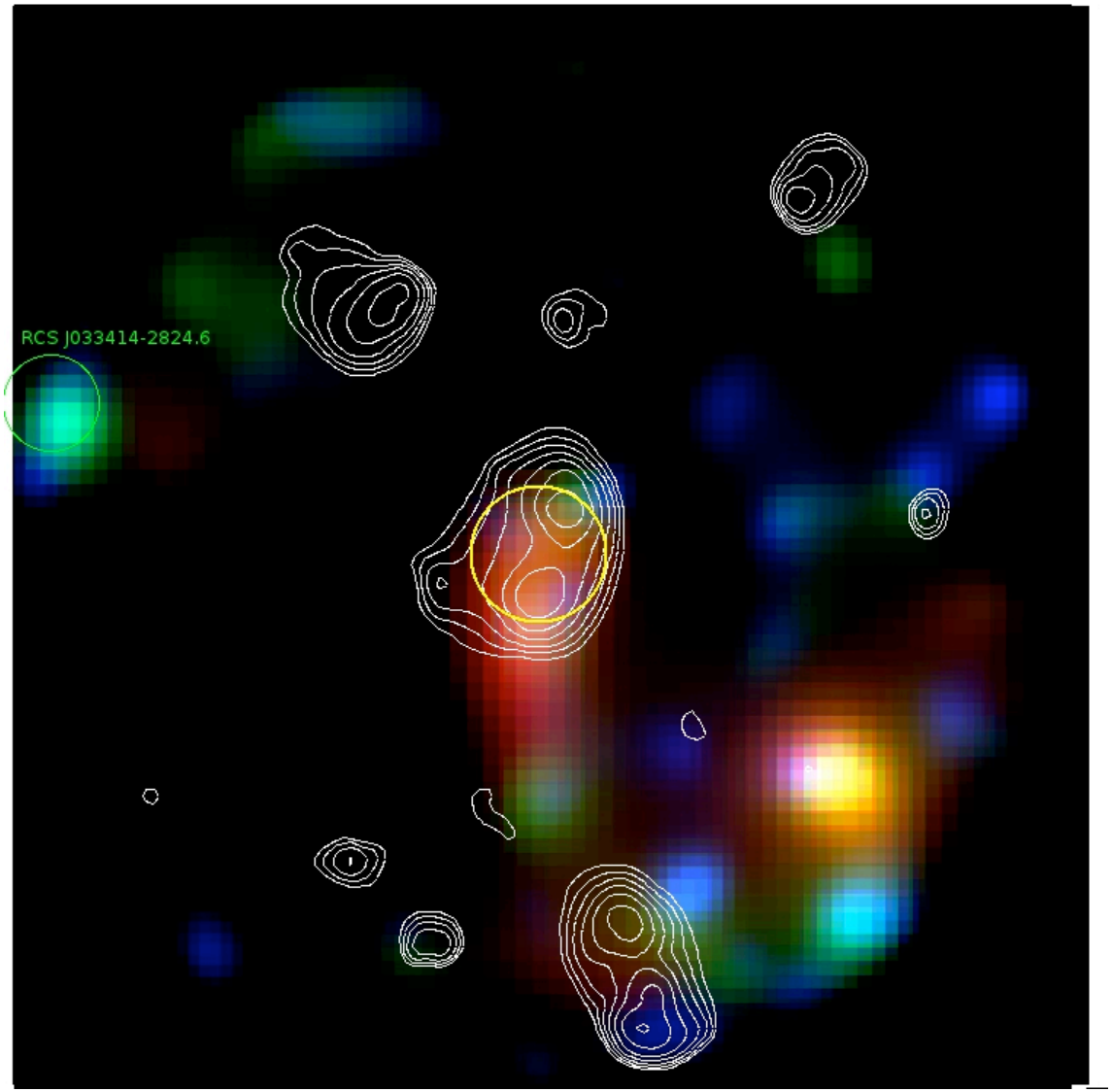
CDF-S Clump

Contours: optical source density at clump photo-z

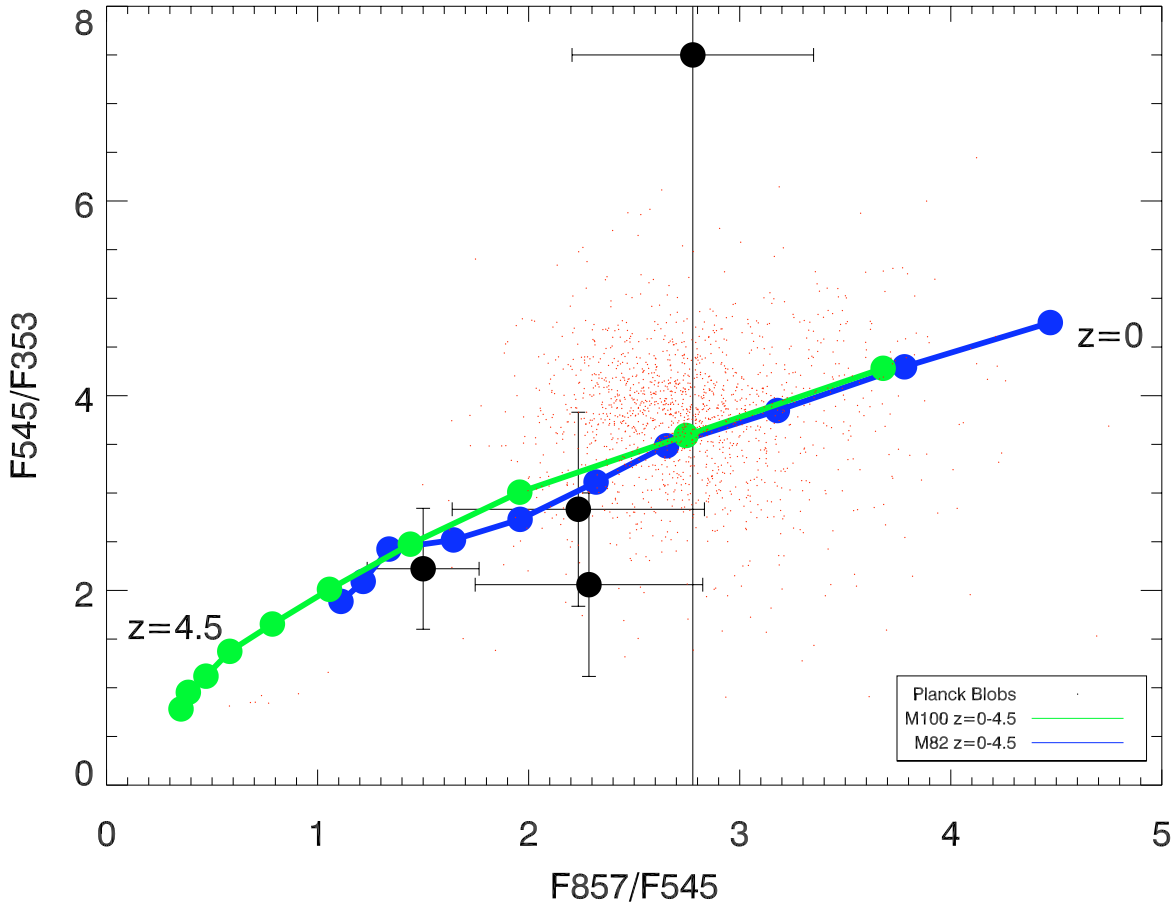


CDF-S Clump

Non-flux weighted map Known z~0.6 galaxy group also detected in HerMES

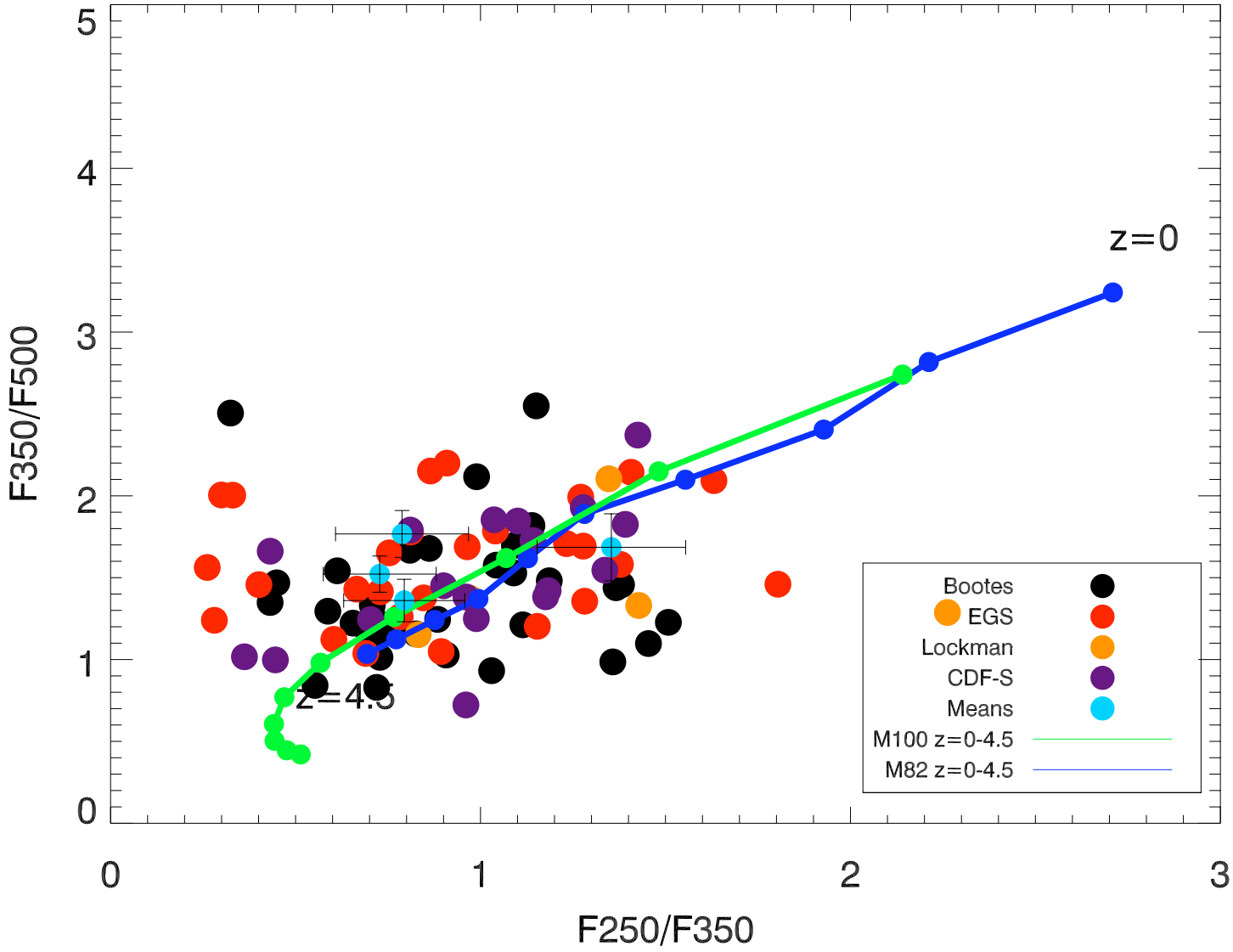


Planck Colours



- Compare clump Planck colours to tracks and rest of ERCSC
- Suggests clumps are redder than local galaxies => high z, especially if star forming

Herschel Colours



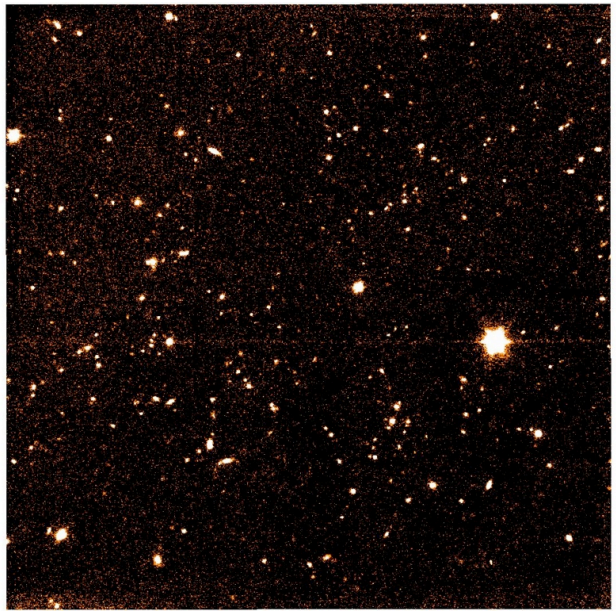
Herschel & Planck Analysis

- Sources are overdensities of dusty galaxies
- Colours in Herschel and Planck suggest high z (z>~1)
- Exactly what would be expected for the proposed dusty protoclusters

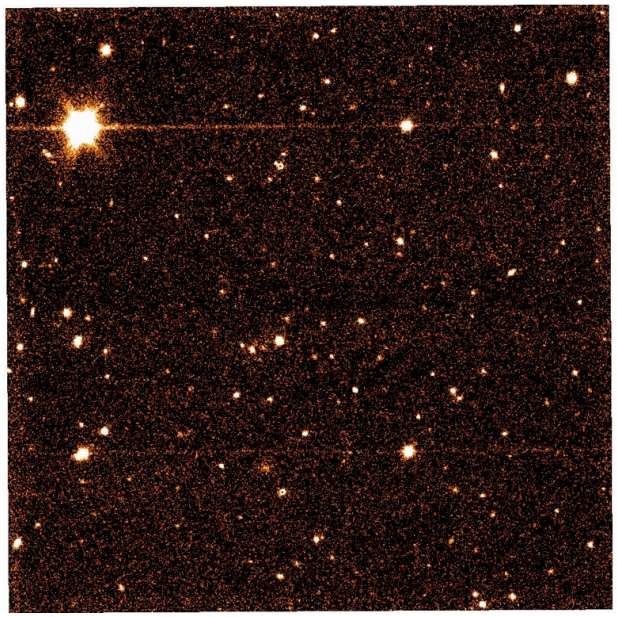
Optical and Near-IR Analysis

- Plentiful ancillary data exist for the CDFS and Bootes clumps
- Near IR J & K imaging for the EGS and Lockman clumps were obtained at TNG
  - FoV quite small so only immediate region around clump was imaged
- Allows us to look for evidence of cluster in CMD or in photo-z distribution

Near-IR Data

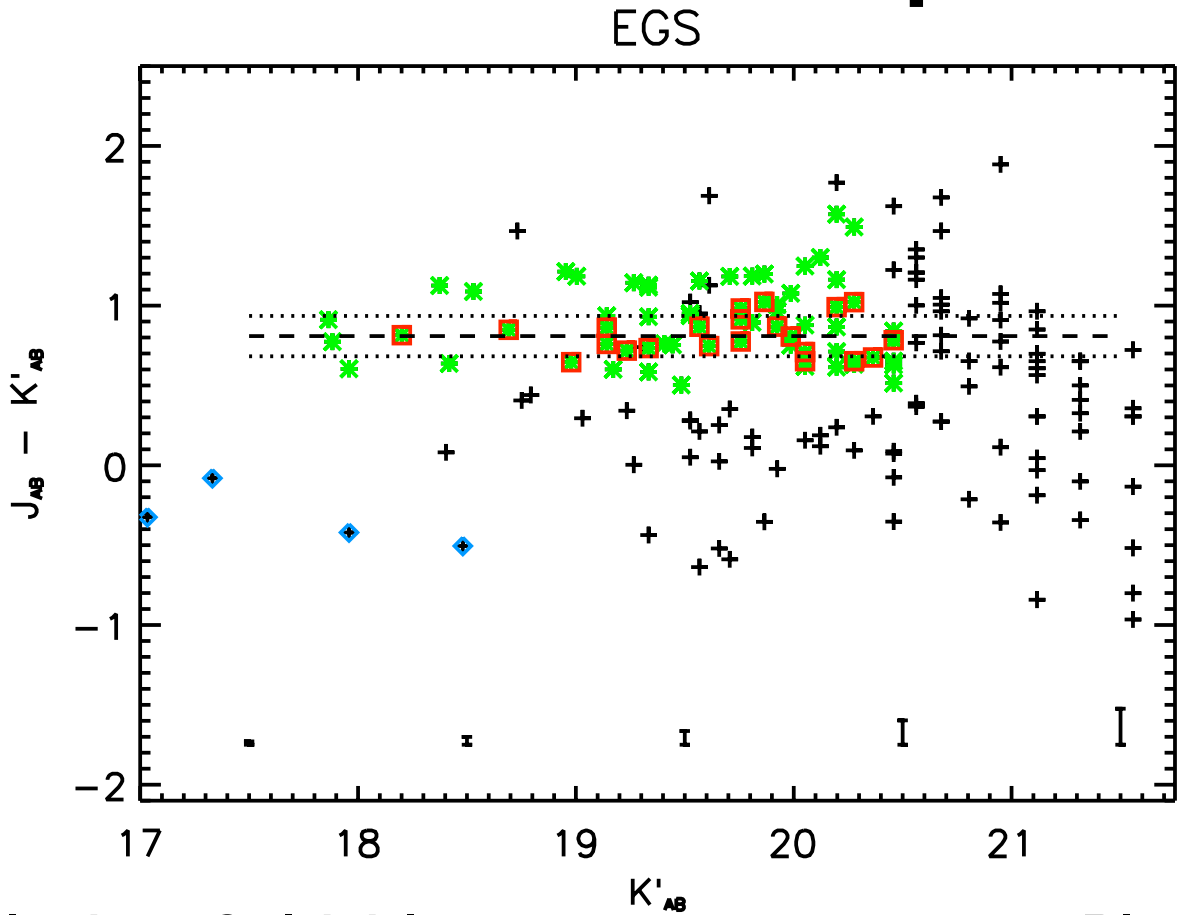


EGS



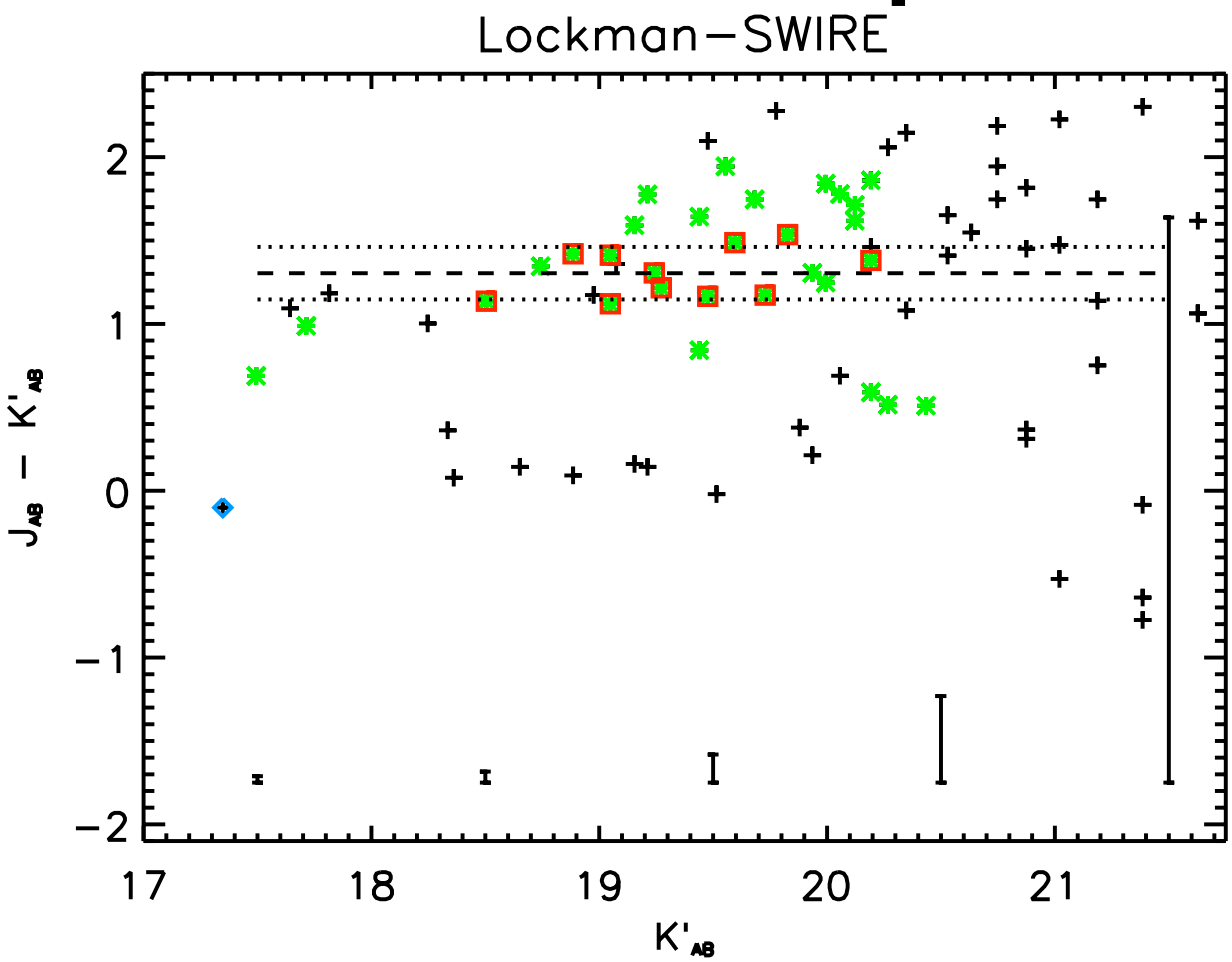
Lockman

Results: Red Sequences

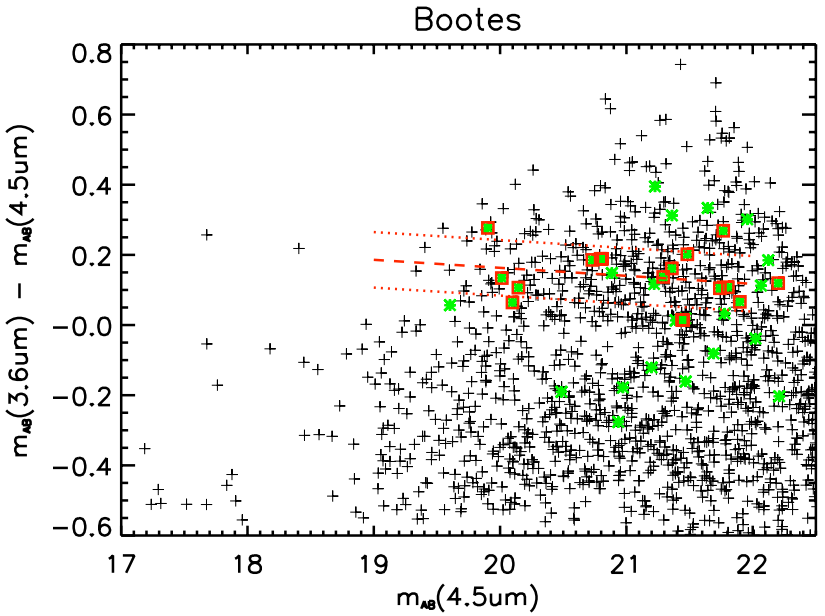


Black = field, blue = stars, green = in Planck beam,
red = within 1' of nominal clump position

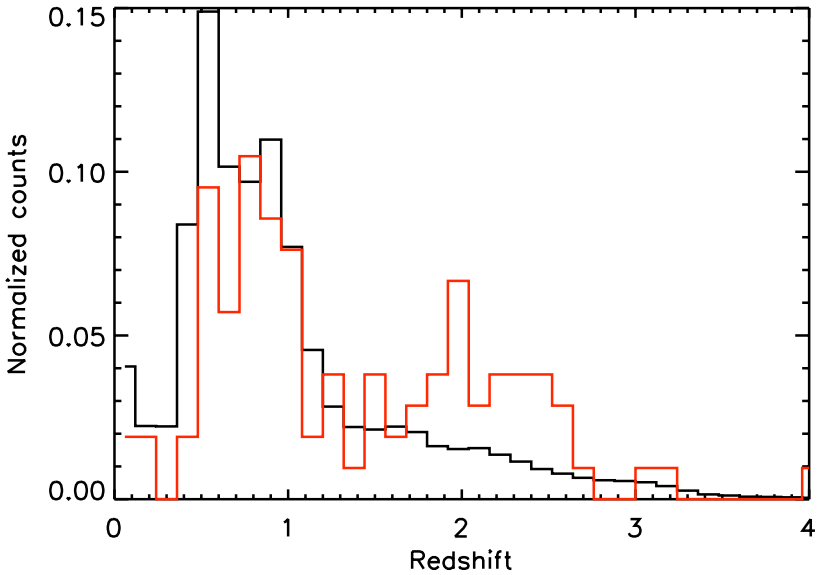
Results: Red Sequences



Bootes

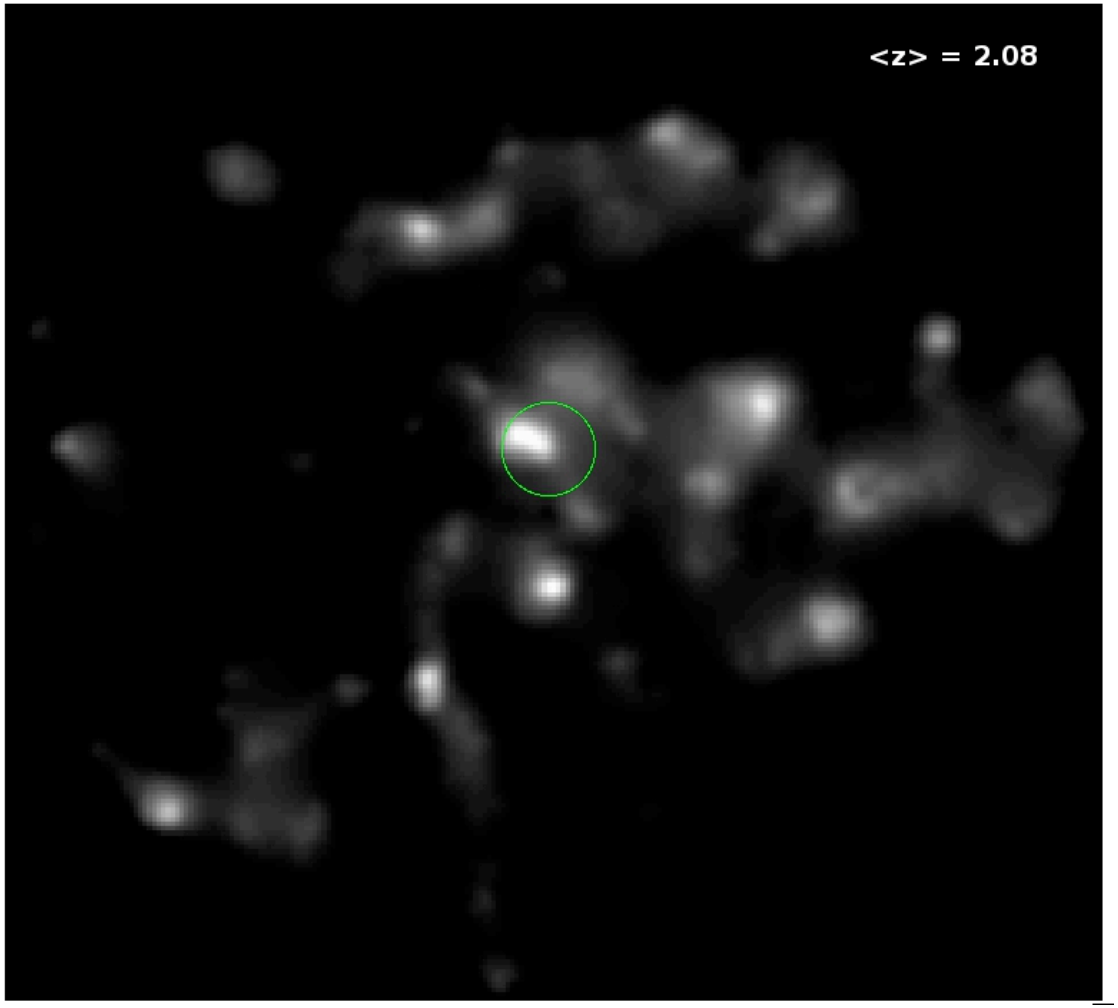


Weak red sequence in IRAC bands

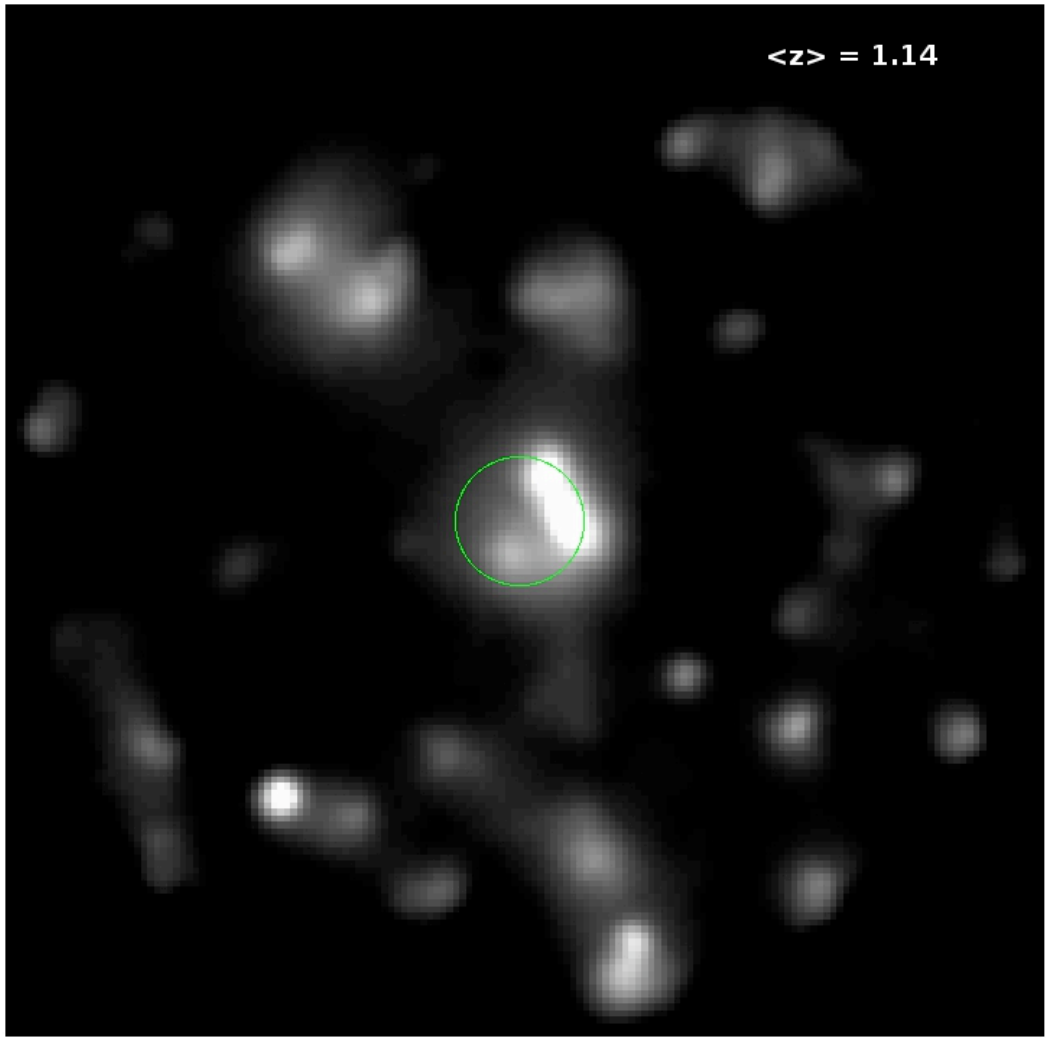


But photo-z analysis suggests overdensity at z~2

Bootes Photo-z

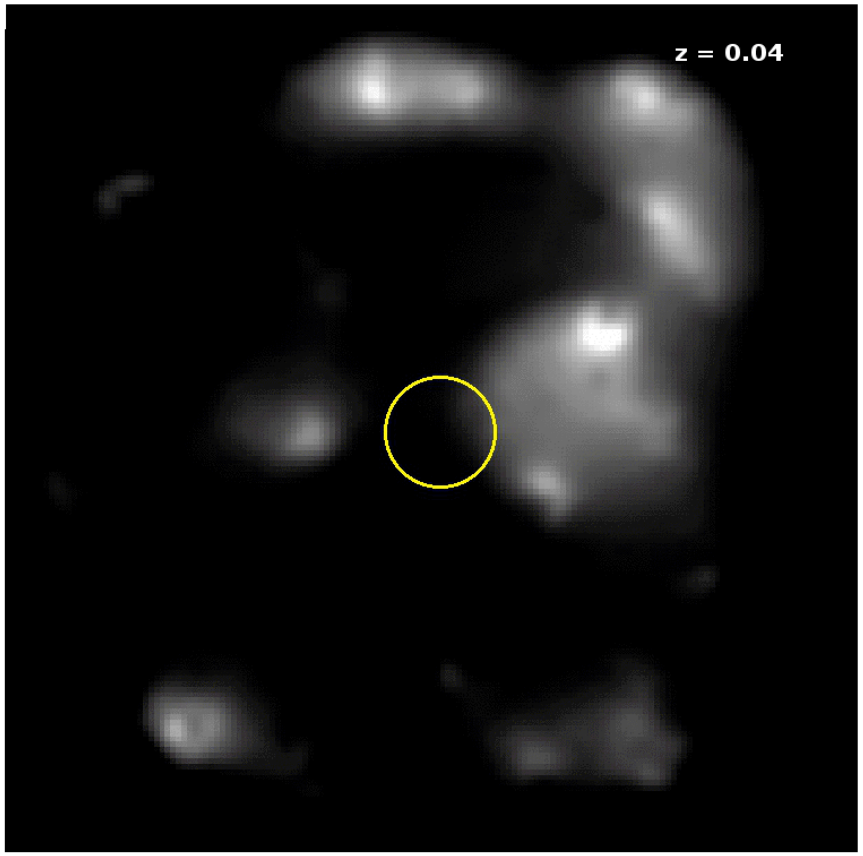


CDF-S

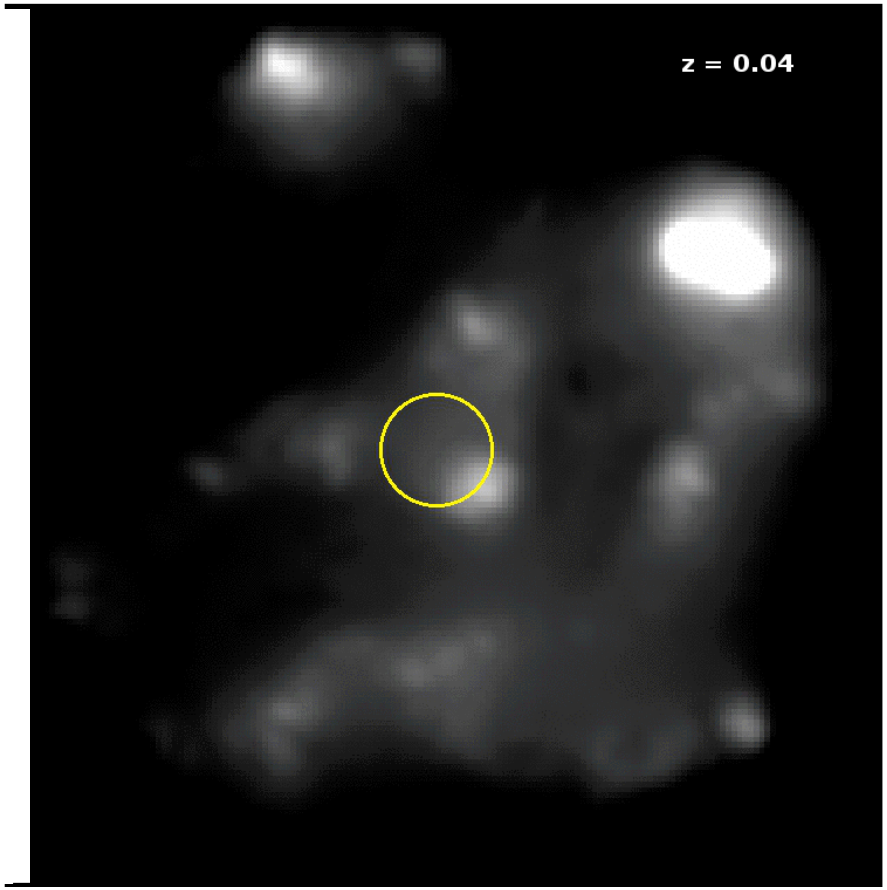


- No red sequence detected but a similar photo-z overdensity

Photo-z Slice Movies



Bootes



CDF-S

Results

- Red sequences consistent with clusters present in three clumps
  - Redshifts estimated from RS are:
  - EGS: z=0.94 ± 0.13; Lockman: z=1.79±0.15
- Bootes photo-z estimate z= 2.04±0.12
  - EaZy with up to 11 bands BRIzJHK+IRAC
- CDFS: no red sequence (young cluster?) but EaZy photoz of: 1.14±0.1

Conclusions

- Dusty Protoclusters exist and are an unexplored aspect of cluster and galaxy evolution
  - Possibly very massive systems at high z
- Can be found by combining Planck and Herschel data
- Cover a wide range of z~ 1 to 2, so far, and more work coming (Herranz et al.; Fu et al.)

What Next?

- Search for clumps in rest of HerMES, HerMES 250 sq. deg. extension and in H-ATLAS 550 sq. deg.
  - some already found
- Followup observations to confirm nature
  - optical spectroscopy, submm imaging, CO, ALMA, HST (some already done)
- Comparison to cluster formation models to see how these novel objects can provide new tests of theory