Detecting dusty protoclusters with Planck and Herschel

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Dusty protoclusters as FIR sources

- Models predict young (proto-)clusters as bright FIR/ submm 'clumps' detected by Planck
- $\geq 10^3$ clumps/sr, $S_{FIR} \geq 100$ mJy
- Fluxes and densities accessible to Herschel surveys!



Dusty protoclusters as FIR sources

Possible strategy to search for high-z clusters:

- Select compact sources in Planck
- Compare to Herschel sources
- Identify foregrounds
- Follow-up with multi- λ data for physical properties



Planck clumps in HerMES fields

- Select sources from Planck ERCSC, match with HerMES data
- Expected counterparts:
 - Nearby galaxies (bright foregrounds)
 - Cirrus (bright, extended foregrounds)
 - Overdensities of distant galaxies







Herschel 250µm cutouts around Planck clumps

Clumps in HerMES

- 17 clumps in 4 deep HerMES fields
- 13 foregrounds: nearby galaxies, 1 star (o Ceti)
- 4 candidate clusters/protoclusters















FIR/submm colours

Planck and Herschel colours consistent with z≥1 galaxies



Follow-Up & Early Results

Clump Follow-Up - I





- Detected in all Herschel bands at >5σ
 Faint, broad IRAC red-sequence inside Planck beam
- IRAC colours consistent with $z \approx 2$

Clump Follow-Up - I





- Archival BRIzJHK + IRAC photometry
- Peak at z_{phot}=2.05
- Matches position of clump
- Possible large-scale structure

Clump Follow-Up - I



• Significant (>10 σ) overdensity of galaxies at z_{phot} =2 inside Planck beam

No foreground overdensities

Clump Follow-Up - II





• Detected at 250 μ m, 350 μ m (>4 σ) • Faint IRAC red-sequence, consistent with z \approx 1

Clump Follow-Up - II





- Archival Ugriz + IRAC photometry
- Peak at z_{phot} =1.14
- Matches position of clump
- z=0.66 group detected at 250μm

Clump Follow-Up - II



Significant (>12σ) overdensity
 of galaxies at z_{phot}=1.1 inside
 Planck beam

• No fg/bg overdensities

Clump Follow-Up - III





- \bullet Detected in all Herschel bands at ${>}5\sigma$
- SDSS ugriz + dedicated JK' follow-up
- Well-formed red-sequence
- Multiple overdensities inside beam
- z_{phot} = 0.9 (nIR colour, SDSS+nIR photo-z)

Clump Follow-Up - IV





- Detected in all Herschel bands at $>6\sigma$
- SDSS ugriz + dedicated JK' follow-up
- z_{phot} = 1.8 (nIR colour)

Star-formation rates

- FIR SED fitting of Herschel sources inside the Planck beam yields SFRs of several 10-100 M_{\odot}/yr , up to 1000 M_{\odot}/yr
- \bullet Total SFRs of 1000-10000 M_{\odot}/yr
- Stacking suggests even higher (10-30%) SFRs within
 Planck beam



Star-formation rates

Consistent with observations of cosmic SFR!



Summary

 High-z, dusty protoclusters probe the early phases of cluster formation

 Detection is feasible, Planck + Herschel provide a reliable selection criterion

• Does not rely on ICM, SZ, red-sequence, etc: potential for detection of protoclusters in assembly

• Early results in selected HerMES fields show dusty clusters at z of 1-2, more at higher z under analysis (also in H-ATLAS)

Combined search in HerMES+H-ATLAS (600+ sq.deg.)
 expected to yield hundreds of clumps