Squeezing the SPIRE maps

Multivariate analysis of the SPIRE maps: Using PCA as a basis for P(D) fluctuation analysis

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HERMES

Herschel is pushing our understanding of galaxy formation and evolution deep into the far-infrared. Here we use Herschel-SPIRE maps to obtain new observational constraints for models. Our method efficiently accesses higher statistical moments in multi-colour data, reducing the dimensionality of the analysis with 95% of information from three bands in one dimension. These show some tension with current best models.

Current map statistics and analysis from HerMES

Stringent observational constraints are needed to distinguish between successful galaxy formation and evolution models. As models improve, higher-order and more subtle statistics will be required to discriminate between models.

	Single Band	Cross Band
Variance (σ^2, cross spectra)	Nguyen+ '10	Viero+ '13
Higher-Order (skew, kurtosis, P(D))	Glenn+ '10	This study

Table 1: Where this study sits with other HerMES papers analysing statistical properties

Nguyen et al 2010: Calculation of confusion noise in each Herschel-SPIRE band

Viero et al 2013: Cross power spectra, finding the covariance at multiple scales

Glenn et al 2010: Probability of deflection P(D) analysis for each Herschel-SPIRE band

This study: How to access the full statistical distribution (covariance and higher) across maps in all three SPIRE bands

Are higher-order statistics required?

A probability of deflection (P(D)) analysis is able to access higher-order statistics. However, a full 3D P(D) analysis would be computationally restrictive. Observable strong covariance between bands shows there is information to extract across bands.

Herschel-SPIRE maps are source-confused. This implies colour properties of sources can be found best using the maps rather than extracted sources. Further, since ~67% of infrared background (Viero+ '13b) has been attributed to known sources, map-based approaches give access to this hidden information.

A map is the position and flux of sources convolved with the instrument's beam. P(D) analyses make use of this by finding a histogram of pixel fluxes and deconvolving the beam to recover the number counts of sources whilst keeping the full statistical distribution.

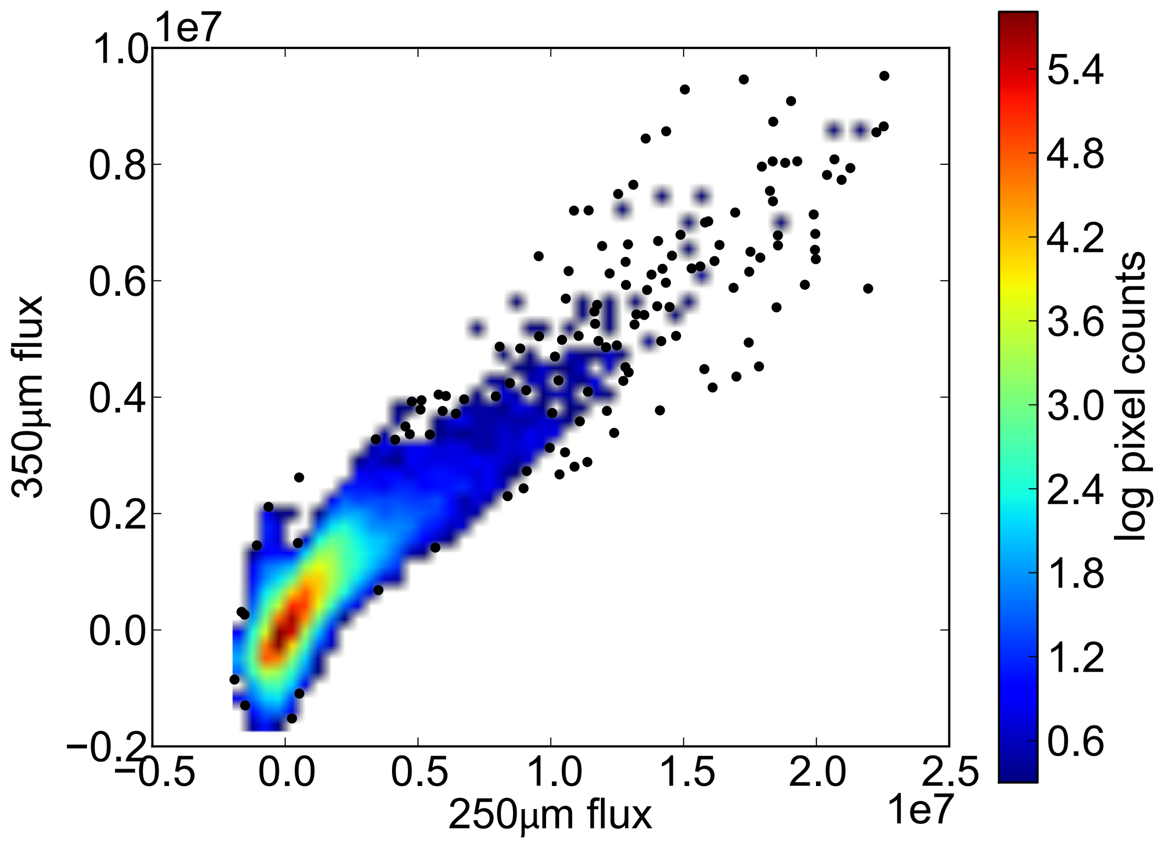

Fig 1: Pixel density plot for the HerMES COSMOS field in the 250μm and 350μm fluxes. For similar and 3D plot please follow the QR code link or go to http://bit.ly/18RkCyD

Principle Component Analysis can project most of the information to one axis

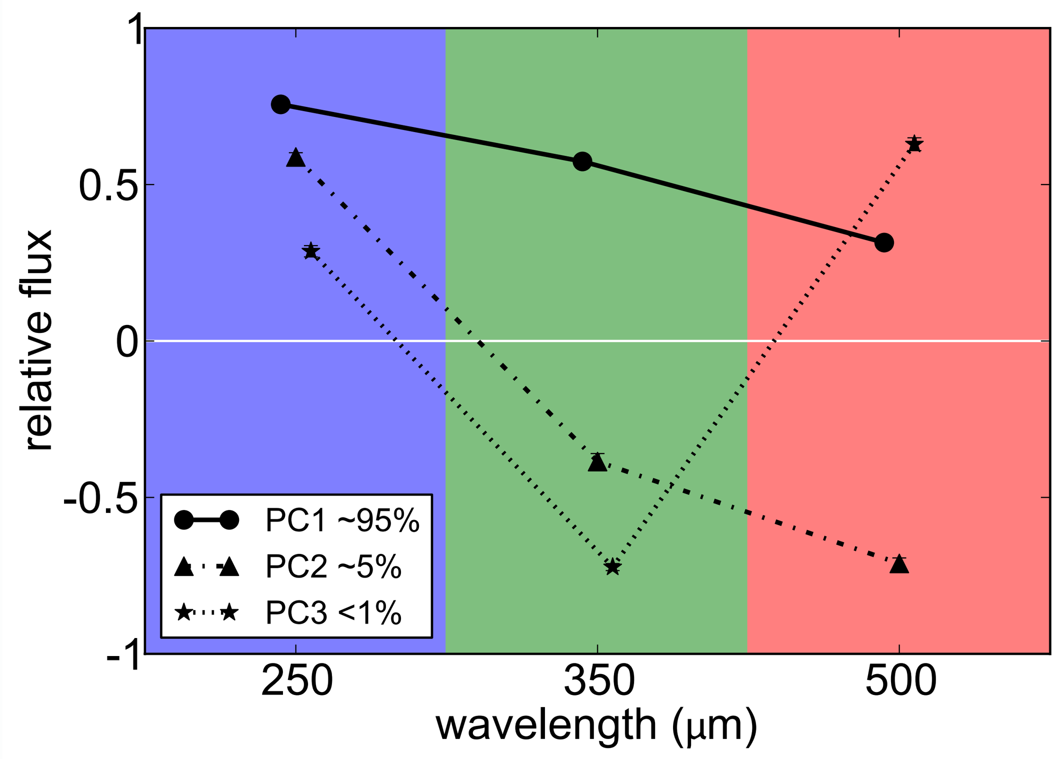

Fig 2: The three PCs and the amount of information they encode

We use Principle Component Analysis (PCA) to find the Principle Components (PCs) of the pixel fluxes across the Herschel-SPIRE bands. We bring information from co-moments into one axis and can thus reduce the dimensionality of the problem.

We in effect rotate the data in Fig 1 into a new coordinate system along the directions of greatest variance (which are often driven by physical features). The PCs are shown in Fig 2. PC1 captures 95% of the variance and closely follows source intensity. PC2 and PC3 may encode some degenerate redshift and dust temperature information.

Approximately 99% of information about the maps can be reconstructed from contributions from PC1 and PC2 alone. From Fig 3 we can see the sources with highest intensity in PC1, whereas a large contribution from PC2 implies a large k-correction/temperature shift from PC1.

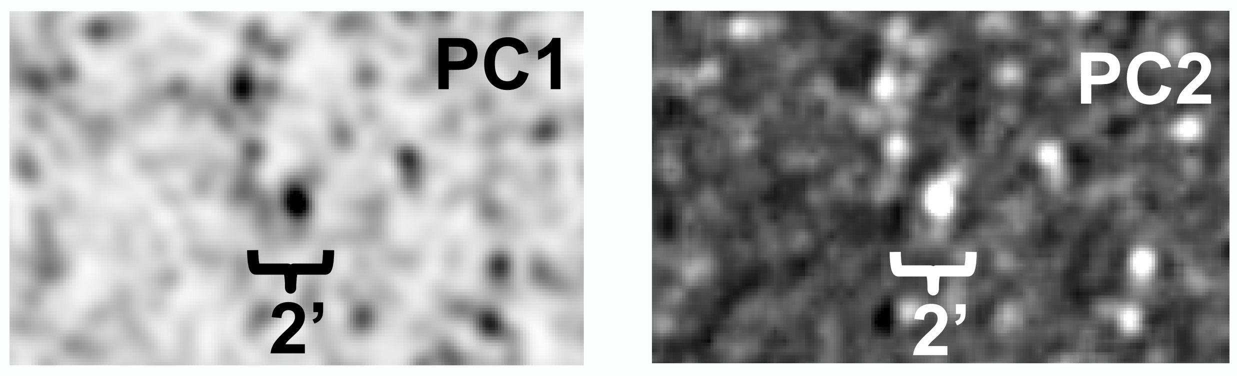

Fig 3: Contributions from PC1 and PC2 in the HerMES COSMOS field.

P(D) of rotated simulated maps shows where model improvement is most needed

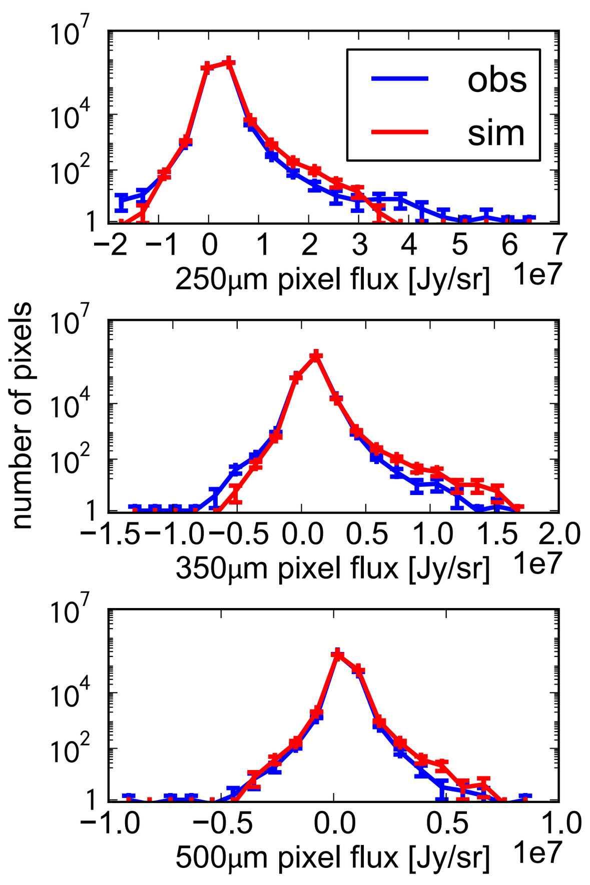

Fig 4: Flux P(D) plots real vs simulated COSMOS maps

A P(D) analysis on the rotated real and simulated maps in Fig 5 yields the greatest deviation along PC1 by an order of magnitude. The model can therefore be best improved by fitting to PC1.

The Viero+ '13a model was successfully fitted to cross-power spectra and source counts from Glenn+ '10'. P(D) analysis in Fig 4 on COSMOS shows deviation on the same order of magnitude in all three SPIRE bands. The model will fit to all three distributions with the same priority.

In contrast, the rotated P(D) analysis puts most of the information along one axis. Fitting models to PC1 constrain the model across all fluxes.

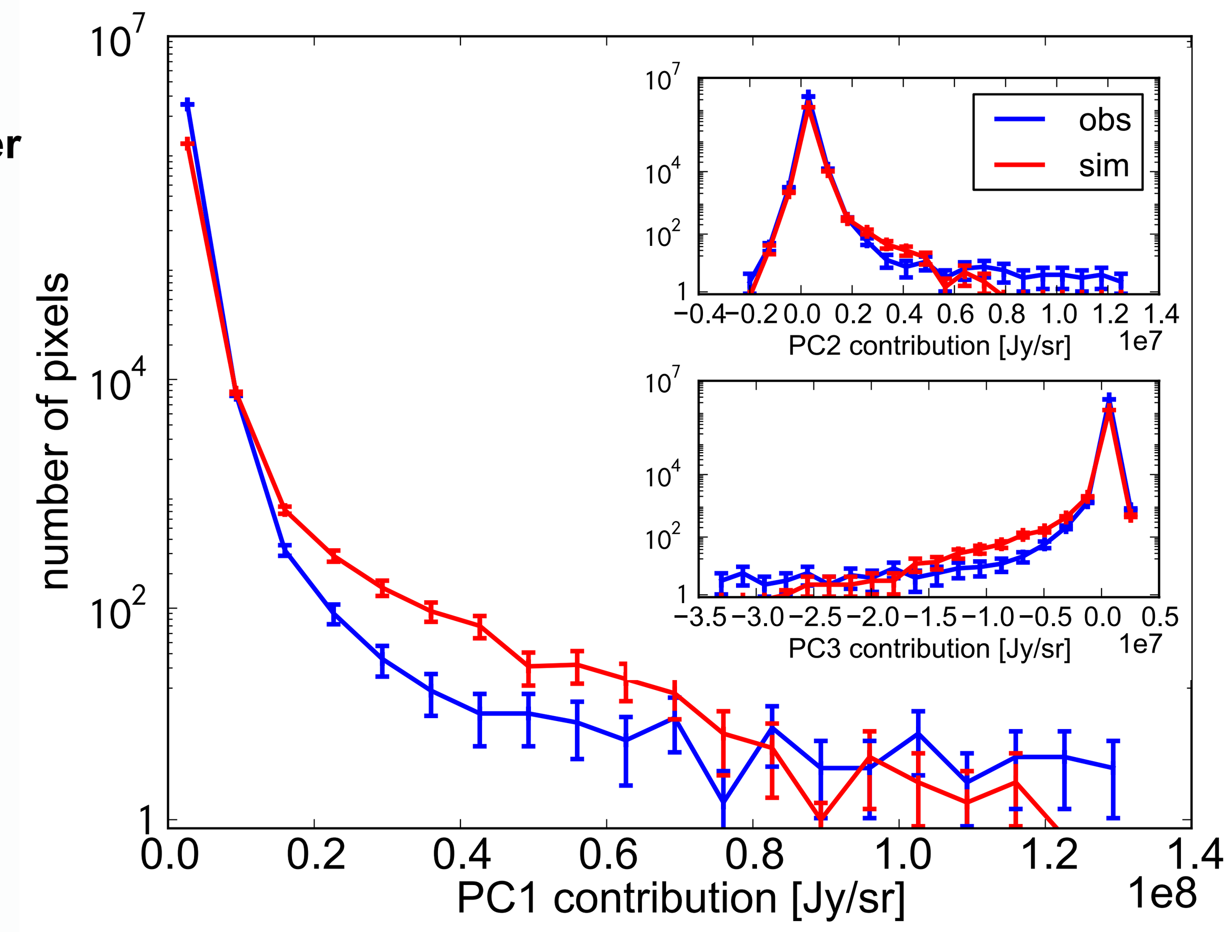

Fig 5: PC contribution P(D) plots real vs sim COSMOS maps

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