Dust in Galaxy Clusters: Modeling at Millimeter Wavelengths and Impact on Planck Cluster Cosmology

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Outline

- Dust in clusters at crossroads between Astrophysics and Cosmology
- Modeling dust in clusters
- Implication for Planck cluster science
Dust in clusters and Astrophysics

Planck SZ “stacks” of ~260,000 Locally Brightest Galaxies @ z~0.1 (SDSS)
Dust in clusters and Astrophysics

Planck SZ “stacks” of ~260,000 Locally Brightest Galaxies @ z~0.1 (SDSS)

Standard SZ Matched Multi-Filter biased at low mass \( \Rightarrow \text{dust!} \)

Stellar mass

Planck Intermediate XI 2013
Planck SZ “stacks” of ~300,000 quasars 0.1<z<5 (BOSS)

Joint SZ+dust
Matched Multi-Filter

Verdier et al. 2016
Dust in clusters

Astrophysics (at mm wavelengths)

- Dust dominates over SZ emission for halos $M_{500}<2\times10^{13}M_\odot$ (@z=0.1)
- Dust: major emission of the quasars (@all z)

- Traces SFR
- Constrains stellar feedback in the IGM
Dust in clusters and Cosmology

CMB prediction
(2.5 times more clusters than observed)
How to reconcile Planck CMB and SZ counts?

- Primary CMB?
- Cluster mass calibration?
How to reconcile Planck CMB and SZ counts?

- Primary CMB?
- Cluster mass calibration?
- Selection function of SZ surveys?
- New physics? Neutrino mass?
- Baryonic effects in the mass function?
Dust in clusters

**Astrophysics (at mm wavelengths)**
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- Dust: major emission of the quasars ($@all\ z$)
  - Traces SFR
  - Constrains stellar feedback in the IGM

**Cosmology (at mm wavelengths)**
- Dust may impact SZ size and flux estimation
- Dust may have some impact on SZ survey completeness
  
  Need to assess the impact on science results of SZ experiments!
Dust in clusters

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**Planck!**
Dust in clusters: previous work

Planck cluster stacks vs. frequency

see also H. Bourdin’s talk
Outline

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The De Zotti et al. 2016 dust model

Model based on Herschel data of field and cluster galaxies (Alberts et al. 2014, 2016) and on spectral energy distributions from Cai. et al. 2013

No information on spatial distribution & no cross-check with Planck 857GHz
PSZ2 distribution and De Zotti et al. model (0<z<1)

Melin et al. in prep.
Dust in clusters: Planck data

PSZ2 stacked profile @ 857GHz

PSZ2 average matched filter flux

Melin et al. in prep.
Dust in clusters: best fits

Normalisation of the L_{IR}-M relation

External slope of the GNFW profile

Melin et al. in prep.
Dust in clusters: best fits

PSZ2 stacked profile @ 857GHz

PSZ2 average matched filter flux

Melin et al. in prep.
• Dust in clusters at crossroads between Astrophysics and Cosmology

• Modeling dust in clusters

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Dust in clusters: impact on cluster size recovery

Melin et al. in prep.
Dust in clusters: impact on cluster size recovery

Melin et al. in prep.
In the study by Melin et al. (in prep.), the impact of dust on cluster size recovery is investigated. The graph illustrates the relationship between the injection and post-processing with dust, showing the distribution of cluster sizes before and after dust correction.

The x-axis represents $\theta_{500}^{yz}$ in arcmin, while the y-axis shows $\theta_{500}$ blind, w/ dust. The scatter plot indicates the variability in cluster sizes with and without dust correction. The inset histogram highlights the ratio of sizes, suggesting a distribution that is skewed towards smaller values.

The data points are distributed along a range of scales, with a notable concentration around the 1:1 line, indicating that the dust correction method is effective in recovering cluster sizes. The red and blue lines on the graph may represent regression lines or confidence intervals, providing a visual indication of the trend in the data.
Dust in clusters: impact on cluster size recovery

Melin et al. in prep.
Dust in clusters: impact on cluster size recovery

Melin et al. in prep.
Dust in clusters: impact on cluster flux recovery

Melin et al. in prep.

Very small effect: ~2% bias low for SZ flux <10^{-3} \text{arcmin}^2
Dust in clusters: impact on survey completeness

Melin et al. in prep.

Maximum: ~<9% loss in [0.5, 0.8]
Negligible shifts in cosmological parameters
Does not help to reconcile low-z and high-z counts
Conclusions

• Dust model based on De Zotti et al. 2016 and Planck 857GHz (normalization of $L_{\text{IR}}$-M and profile)

• Only **small impact on individual cluster flux** (~<2%) and negligible impact on cluster size estimation

• **Planck size overestimation not due to dust.** Most probably due to profile mismatch between the Matched Multi-Filter and cluster profiles

• **Small impact on survey completeness** (~<9% for $z$ in [0.5-0.8]) and negligible shifts of cosmological parameters

• SZ future (e.g. **CMB-S4**: dust will matter. Crucial to look at the impact on SZ science (will depend on resolution, sensitivity, frequency coverage)
Backup slides
The SZ Matched Multi-Filter (MMF)

MMF assumes
- SZ frequency spectrum
- SZ cluster profile
- noise cross-power spectra

Herranz et al. 2002
Melin, Bartlett, Delabrouille 2006

Minimum variance and unbiased SZ flux
The SZ Matched Multi-Filter (MMF)

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Planck maps

Minimum variance and unbiased SZ flux… if cluster emission is SZ only

BIAS if other emissions

Filtered map
Selection function of SZ surveys?

Planck cluster stacks vs. frequency

Planck Results XXIII 2015

Melin et al. in prep.