Extragalactic point sources in total intensity and polarisation: lessons from Planck

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Outline

Point Sources lessons learnt from Planck:

• Lesson 1: You can NOT make them disappeared!
• Lesson 2: You can NOT mask the entire sky!
• Lesson 3: Get ready to make your hands dirty!
• Lesson 4: Expect the unexpected!
• Lesson 5: Know your enemy!
• Conclusions
Sky coverage of 5 GHz surveys in equatorial coordinates: GB6 (Gregory et al. 1996) (blue), PMNE (Griffith et al. 1995) (dark green), PMNS (Wright et al. 1994) (red), PMNT (Griffith et al. 1994) (light blue), and PMNZ (Wright et al. 1996) (magenta). The white regions are "holes" in these surveys that have been covered exploiting the NVSS and the SUMSS.

Lesson 1: PS removal

BEST IDEA! Using known radiosources at lower frequencies ... (e.g. PIC)

<table>
<thead>
<tr>
<th>Pro</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Known positions</td>
<td>Baricentre with more than one source?</td>
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<tr>
<td>Known flux at lower frequencies</td>
<td>Spectral index?</td>
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<td>Variability?</td>
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Lesson 1: PS removal

SECOND BEST IDEA! Detect and subtract!

- In real life PS removal is never perfect!
- Residuals bias due to positional, shape and intensity uncertainties.
- To determine residuals bias accurate simulations or additional precise statistical analyses are required. (Scodeller & Hansen, 2013)
Lesson 2: PS masking

BEST IDEA! Mask the known sources!

• How many? Which ones? (stat info)
• How much area to mask? (intensity info)
• In all channels? (spectral information)
• Same issues in Polarization!

Leach et al. 2008
Lesson 2: PS masking

SECOND BEST IDEA! Mask detected sources!

- Detection pipeline needed
- Different CompSep methods require different masks!
- Number of masks grow exponentially!
  - Single/multiple channels, CS methods, detection pipelines, ...
- Compromise: **Common Mask**
Even from the cosmological point of view you can not avoid to detect the point sources.

- Planck delivered 4 incremental PS catalogues
  - ERCSC, PCCS, PCCS2(+pol), PCNT (multi-frequency)
- Better to maintain 2-3 methods
  - Be ready for internal fighting to choose these methods!
  - Optimal for internal validations
  - Should be reliable and well tested.
  - Different methods for different tasks! (single/multi freq., polarization, ...)
- Completeness vs. Reliability
- See Lopez-Caniego’s talk tomorrow!
Lesson 4: Unexpected results

The Planck list of high-redshift source candidates (PHZ)

(anticipated by Negrello et al. 2007, preliminary results Herranz et al. 2012)

• 2151 PS located in the cleanest 26% of the sky exhibiting an excess in the submillimeter compared to their environment.

• These sources are considered as high-z source candidates (z>1.5-2).

• Followed-up with Herschel: proto-clusters (93%) and strongly lensed galaxies (3%)

PHZ, Planck Intermediate results. XXXIX
Planck 2015 results.
XXVI
Planck Intermediate results. VII 2013
Planck Early results.
XIII 2011

Lesson 5: PS statistical properties

[Image of a graph showing spectral index distributions for different frequencies, with histograms for 30-44 GHz, 44-70 GHz, 100 GHz, 143 GHz, 217 GHz, 353 GHz, 545 GHz, and 545-857 GHz. The graph includes labels for the number of sources at each frequency.]
and a minimal contamination from unlensed galaxies in the submillimeter to produce a statistical and photometric unbiased sample of the sky. When completed, H-ATLAS will cover 24 square degrees (deg$^2$) efficaciously than those exploited so far in the radio at millimeter wavelengths.

Furthermore, the frequency of lensing events is low, but even a small number of highly magnified SMGs can substantially affect the shape of the bright tail of the submillimeter counts are excess SMGs at very bright density, above which it is straightforward to recognize the number counts (the number of galaxies at a given brightness) of dust-obscured star-forming galaxies; and radio sources powered by active galactic nuclei. Strongly lensed SMGs dominate over un-lensed SMGs at high redshift ($z \approx 0.3$), spiral and starburst galaxies. H-ATLAS uses the Spectral Mapping Array and MAMBO photometry for the background source [Fig. 1]. Submillimeters survey (H-ATLAS) represents the bright tail of the submillimeter counts are excess SMGs at very bright density, above which it is straightforward to recognize the number counts (the number of galaxies at a given brightness) of dust-obscured star-forming galaxies; and radio sources powered by active galactic nuclei. Strongly lensed SMGs dominate over un-lensed SMGs at high redshift ($z \approx 0.3$), spiral and starburst galaxies. H-ATLAS uses the Spectral Mapping Array and MAMBO photometry for the background source [Fig. 1].

Table 1. Photometric and spectroscopic redshifts of the five gravitationally lensed SMGs at very bright density, above which it is straightforward to recognize the number counts (the number of galaxies at a given brightness) of dust-obscured star-forming galaxies; and radio sources powered by active galactic nuclei. Strongly lensed SMGs dominate over un-lensed SMGs at high redshift ($z \approx 0.3$), spiral and starburst galaxies. H-ATLAS uses the Spectral Mapping Array and MAMBO photometry for the background source [Fig. 1].

Curto et al. 2013
Negrello et al. 2010

Lesson 5: PS statistical properties

Sub-mm galaxies, the unexpected barrier!
Lesson 5: PS statistical properties. Polarization

Just a few detections!

Sub-mm galaxies, the unexpected barrier!!!

Planck 2015 results. XXVI
Curto et al. 2013

Assumed IR pol. ~1%
Concerning the values we found for the lognormal distribution of Galactic and extragalactic regions of the sky. The right-hand panels show the residual maps that are plotted after subtracting the median map from the external region of the stacked patches. The left-hand panels also indicate the position of the median map.

Bonavera et al. 2017a,b
Sub-mm galaxies, the unexpected barrier!!!
Conclusions

• PS removal vs PS masking: choosing the least worst option
  • PS removal uncertainties introduce unknown residuals bias, to be determine.
  • **New opportunities with surveys in the same bands: ALMA, Herschel, SPT, ...**
  • PS masking reduce the available sky and complicate the power spectrum estimations.

• You can NOT avoid PS detection (see Lopez-Caniego’s talk)
  • Very important from the astrophysical point of view, of course!

• Knowing the PS statistical properties allows us to anticipate future issues: (see Puglisi’s talk)
  • Sub-mm galaxies, the unexpected barrier!!!