Status and updates of the “Sparse representations for spectral imaging algorithms”

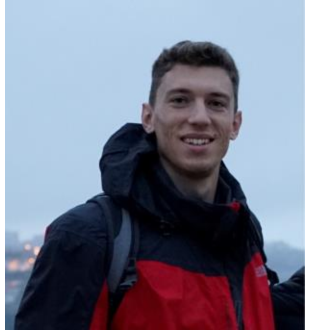
F. DE LUCA – M. FALTELLI – S. FERRETTI

The research group

One of the main astrophysical interests of our group consists in the study of galaxy clusters, using observed (and simulated!) data at millimetre and X-ray wavelengths from space and ground-based telescopes such as Planck, SPT, XMM-Newton, and Chandra telescopes.

Pasquale Mazzotta

Hervé Bourdin



Marco Faltelli

Simone Ferretti

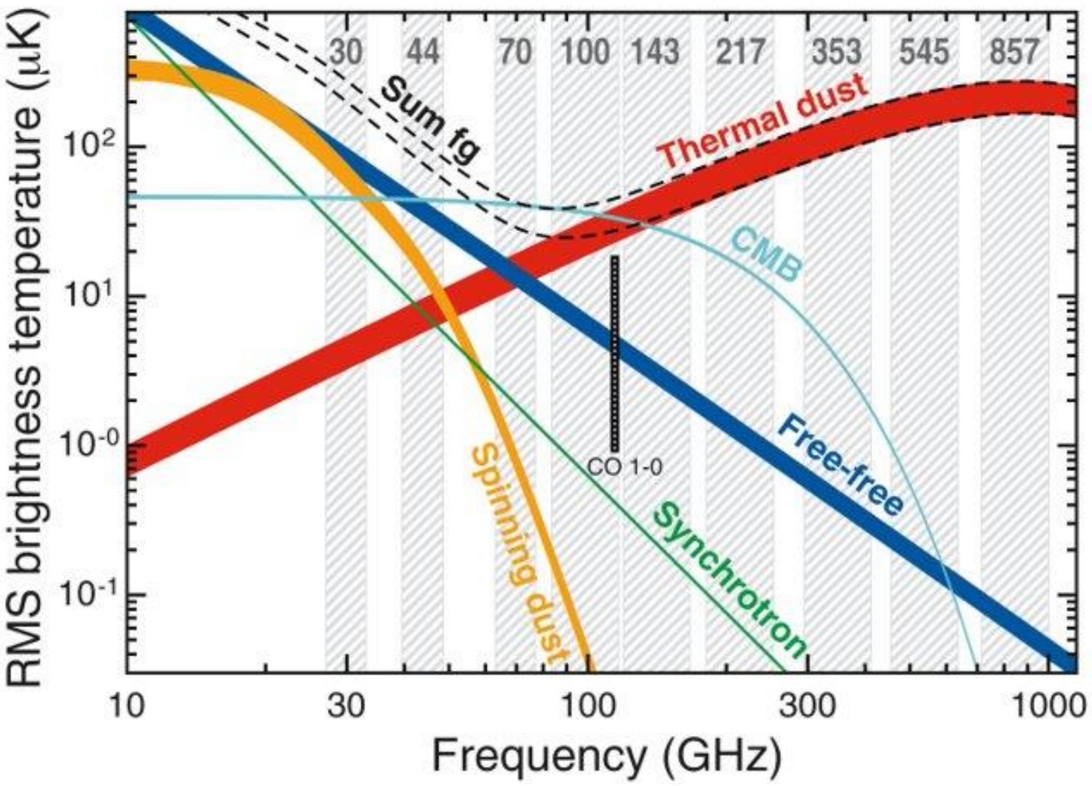
Federico De Luca

Astrophysical goals of the project

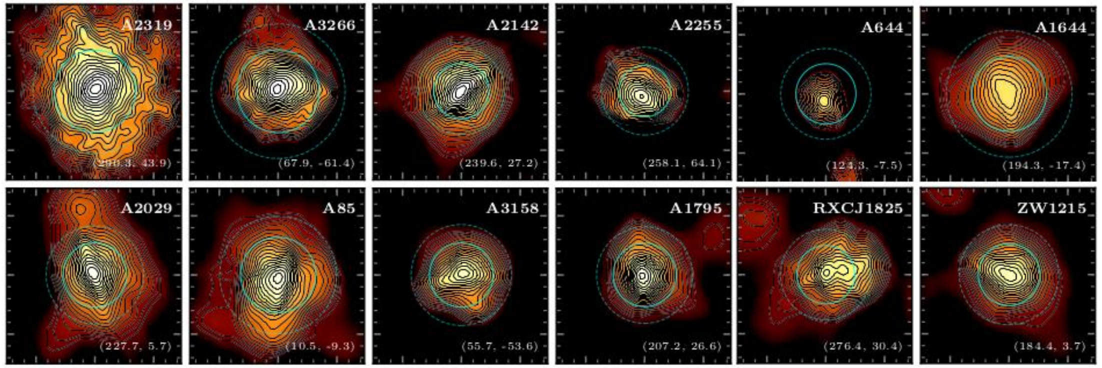
Millimetre signal from Galaxy clusters:
Sunyaev–Zel'dovich effect (IC scattering of CMB photons to hot electrons within the clusters).

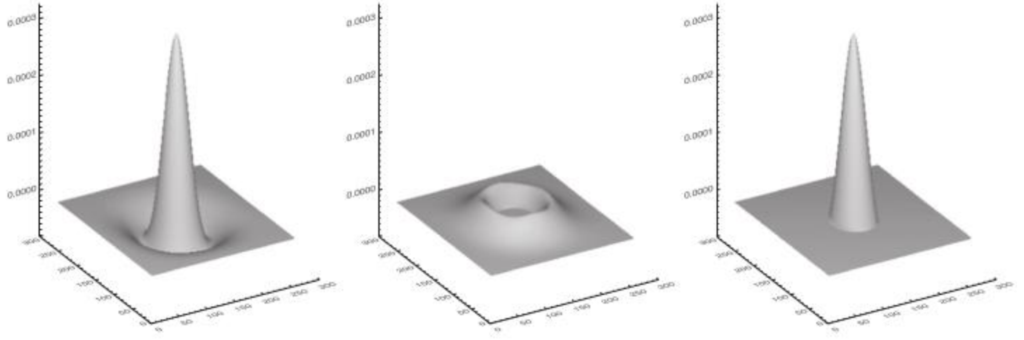
Problems:
Foregrounds and background contaminations from dust content of our Galaxy, the CMB itself, point sources (other galaxies in the l.o.s. or within the clusters), etc.

We need a component separation algorithm to separate all the possible signals!



The algorithm, in brief





- Evolution of the work done in Bourdin[1] et al. (2015) and Baldi[1] et al. (2020): Spectral imaging of the thermal Sunyaev–Zel'dovich effect.
- Signals from the HFI instrument onboard Planck telescope are recovered using wavelet transform.

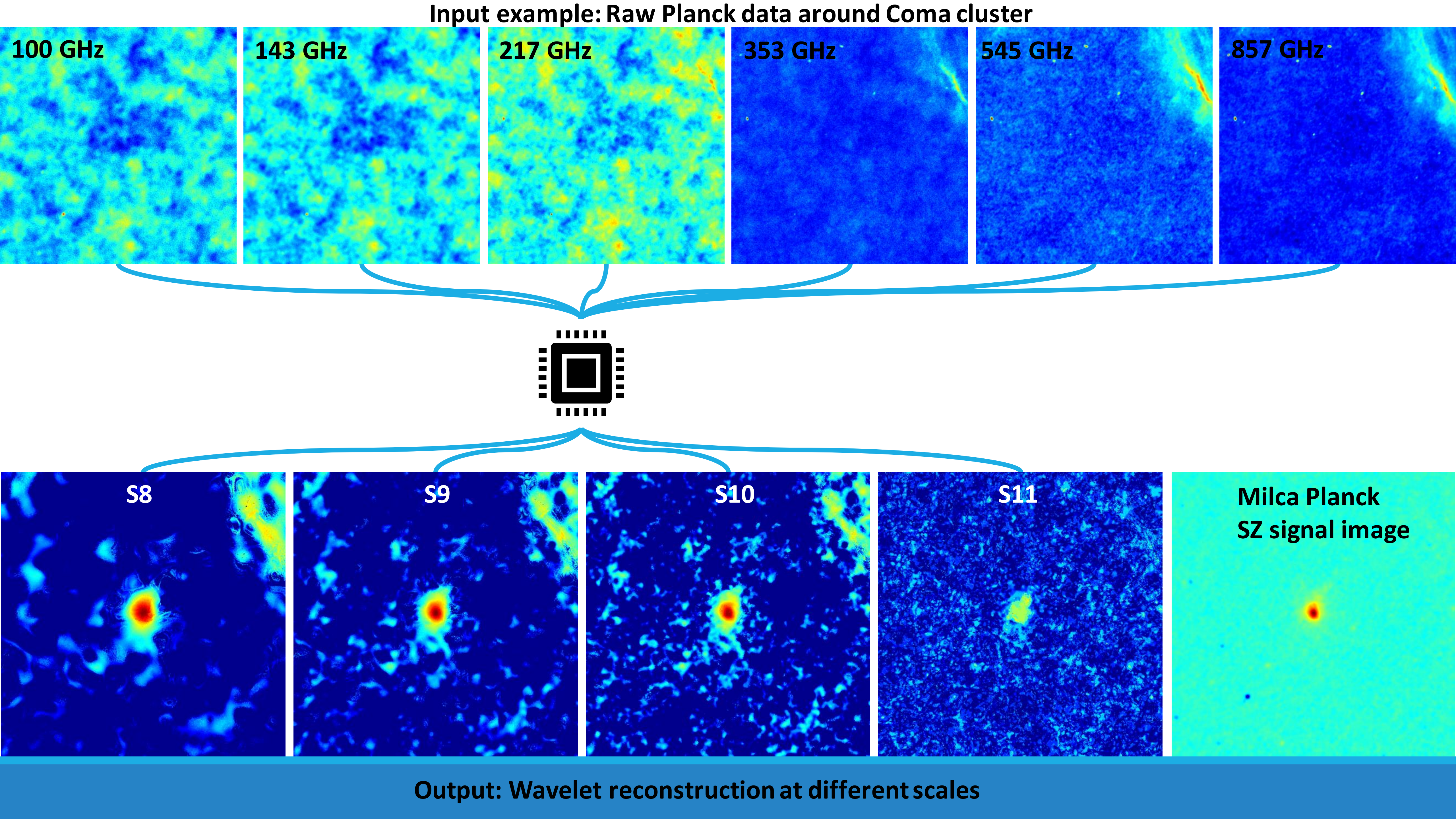
[1]DOI: 10.1088/0004-637X/815/2/92
[2]DOI: 10.1051/0004-6361/201936165

Advantages of wavelet formalism:

• With respect to Fourier transform, wavelets create a representation of the signals in both the time and frequency domains.

• Signal is sparse in wavelet bases, while noise is dense (can be removed via thresholding).

• The spatially variable template are then estimated considering a weighted χ^2 estimate.


Input example: Raw Planck data around Coma cluster
100 GHz
143 GHz
217 GHz
353 GHz
545 GHz
857 GHz
S8
S9
S10
S11
Milca Planck
SZ signal image
Output: Wavelet reconstruction at different scales

Technical Details

Dell PowerEdge R640

- 40 Cores (w/HT)
- 128 GB Ram

All Sky Maps

- 4 maps (different wavelet scales)
- 25 GB each
- ~50x10^6 pixels

Mpfit

- 4 fits
- each fit: ~200 iterations per tile

GOALS

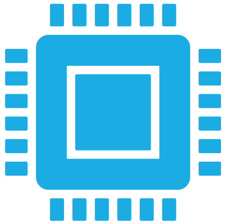
Porting the code from IDL Language to an Open-Source Programming Language

Meet the other IVOA requirements (e.g. fits/hdf5)

Optimize the code

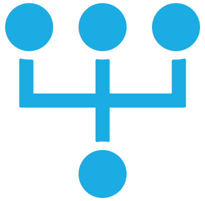
Make the code usable in HPC Clusters

Ongoing work – initial state



IDL code, multi-threaded
(single server, 40 cores)

Data kept in proprietary
.sav files



Built-in IDL functions for I/O

~1 day of computation/scale

Ongoing work – current state

C + OpenMP code, multi-threaded (single server, 40 cores)

Data kept in open .fits files

Cfitsio library for I/O

~ 10 minutes of computation/scale

Final Goals

- Inclusion of more instrument (e.g. SPT, ACT) with finer angular resolutions
- More astrophysical components
- Higher number of wavelet scales
- Bootstrap or MCMC error budget estimates
- Porting on multiple nodes (OpenMP + MPI)
- Test application on GPUs
- Porting and simulations on HPC clusters
  - Estimated Requirements: ~1000CPU hours - ~50GB RAM usage