Spectral Energy Distribution of SZ Catalogue

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Outline

- Introduction of CMB and SZ effect
- Cluster classification
- Stacking the sample
- Flux computation
- Uncertainty analysis
- Spectral energy distribution

CMB and SZ effect

- CMB (Cosmic microwave background)
  - photons decoupling at early age of the universe $\mathrm{d}u = \frac{8\pi hc}{\lambda^5}(\exp\frac{hc}{kT\lambda} - 1)^{-1}\mathrm{d}\lambda$
- SZ (Sunyaev-Zel'dovich) effect
  - CMB photons interact with high energy electrons through inverse Compton scattering
  - Spectral energy distribution law

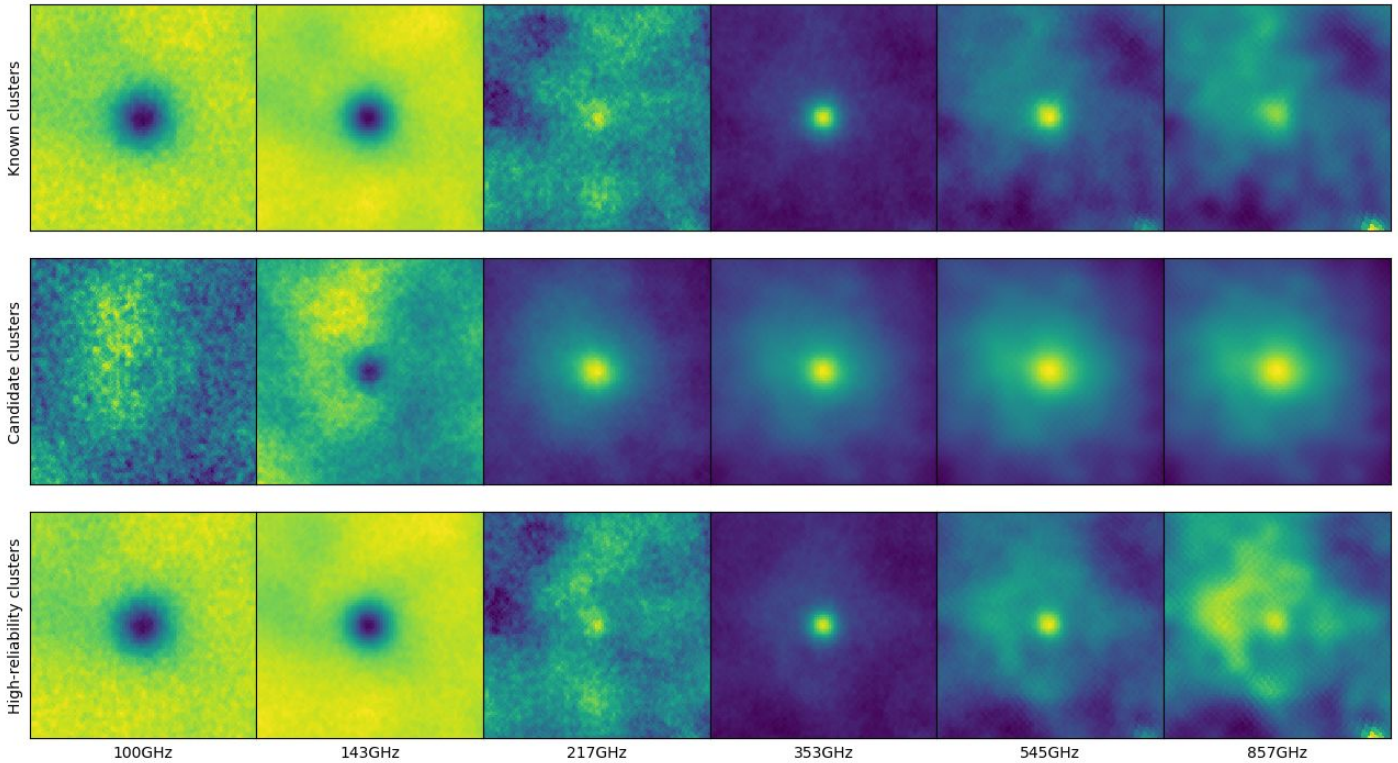
$$\Delta I_{SZ} = yf(x)I_0 \qquad x = h\nu/k_BT_{CMB}, I_0 = 2(k_BT_CMB)^3/(hc)^2$$

$$f(x) = \frac{x^4\mathrm{e}^x}{(\mathrm{e}^x-1)^2}(x\frac{(\mathrm{e}^x+1)}{(\mathrm{e}^x-1)} - 4) \qquad y = \int n_e\frac{k_BT_e}{m_ec^2}\sigma_T\mathrm{d}l$$

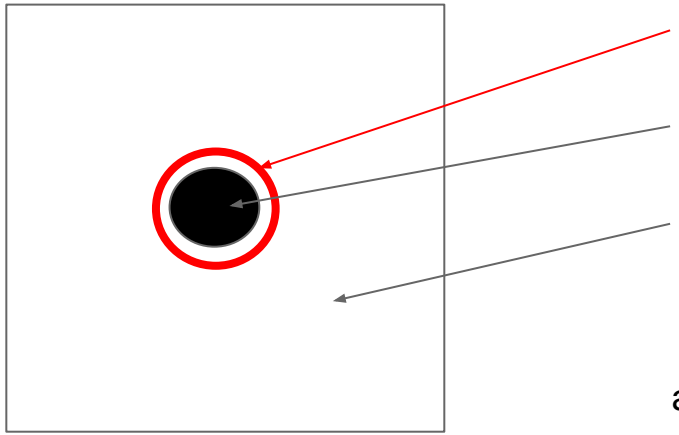
Clusters classification

- known clusters
- high-reliability clusters
- cluster candidates

Stacked signal



Flux computation

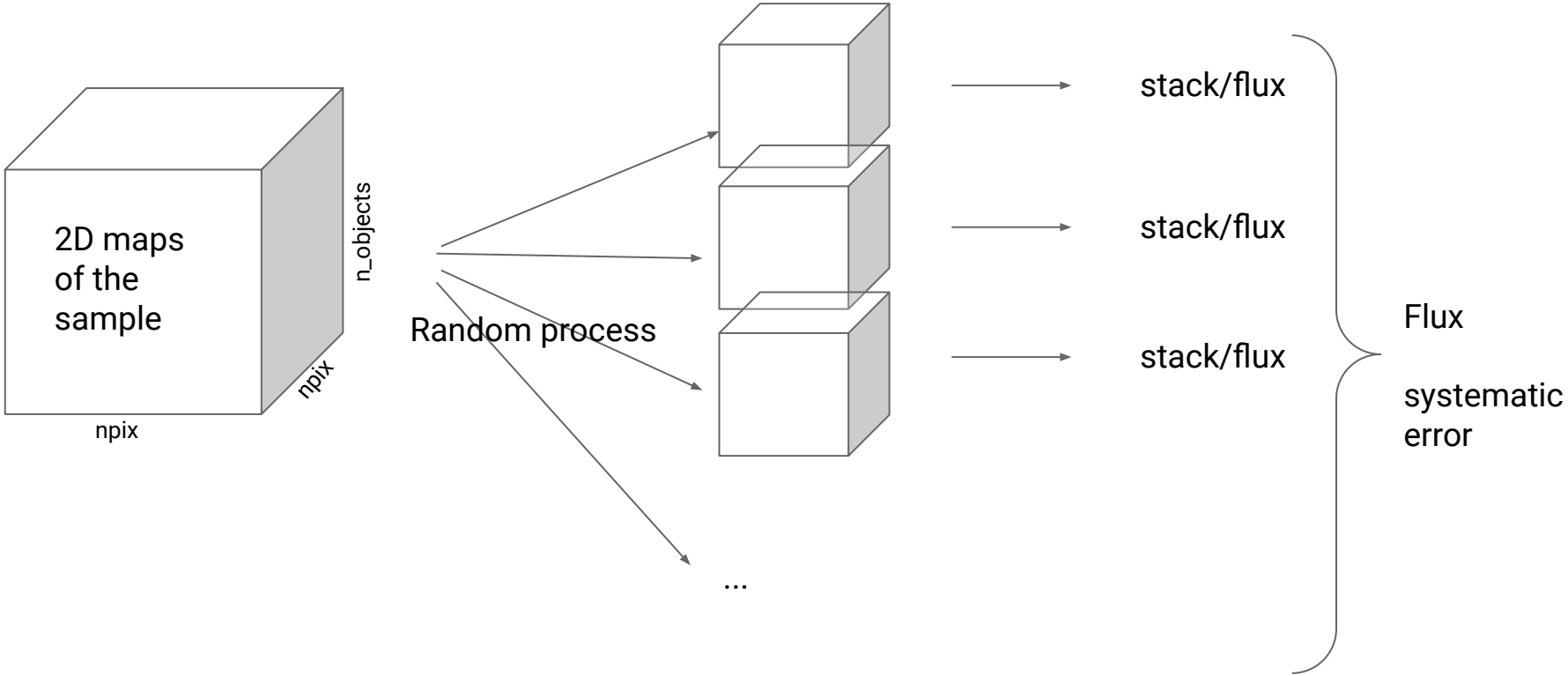


Stack image

aperture(stack, px_size, angle) → boolean mask
    True value if pixel is in the aperture

stack_flux(freq, stack, px_size, angle) → flux value at frequency
    Compute the background per pixel value
    Remove background in aperture
    Integrate flux in aperture

Implementation of the bootstrap technic



Application for all Planck maps

```
def parallel_bootstrap(data_sample, wcs_sample, freq, angle, n_it):

    nfreq = len(freq)
    exe = concurrent.futures.ThreadPoolExecutor()
    future_flux = []
    flux_sample = np.zeros((nfreq, 2))
    for i in range(nfreq):
        future_flux.append(exe.submit(bootstrap_flux, data_sample[i], wcs_sample[i], freq[i], angle, n_it))
    for i in range(nfreq):
        flux_sample[i] = future_flux[i].result()

    return flux_sample
```

Models to fit on the SED

SZ effect :

$$s_{sz} = y_{sz} \cdot f(x)$$

with:

$$x = h\nu / k_B T_{CMB}$$

$$f(x) = \frac{x^4 \mathrm{e}^x}{(\mathrm{e}^x - 1)^2} \left(x \frac{(\mathrm{e}^x + 1)}{(\mathrm{e}^x - 1)} - 4 \right)$$

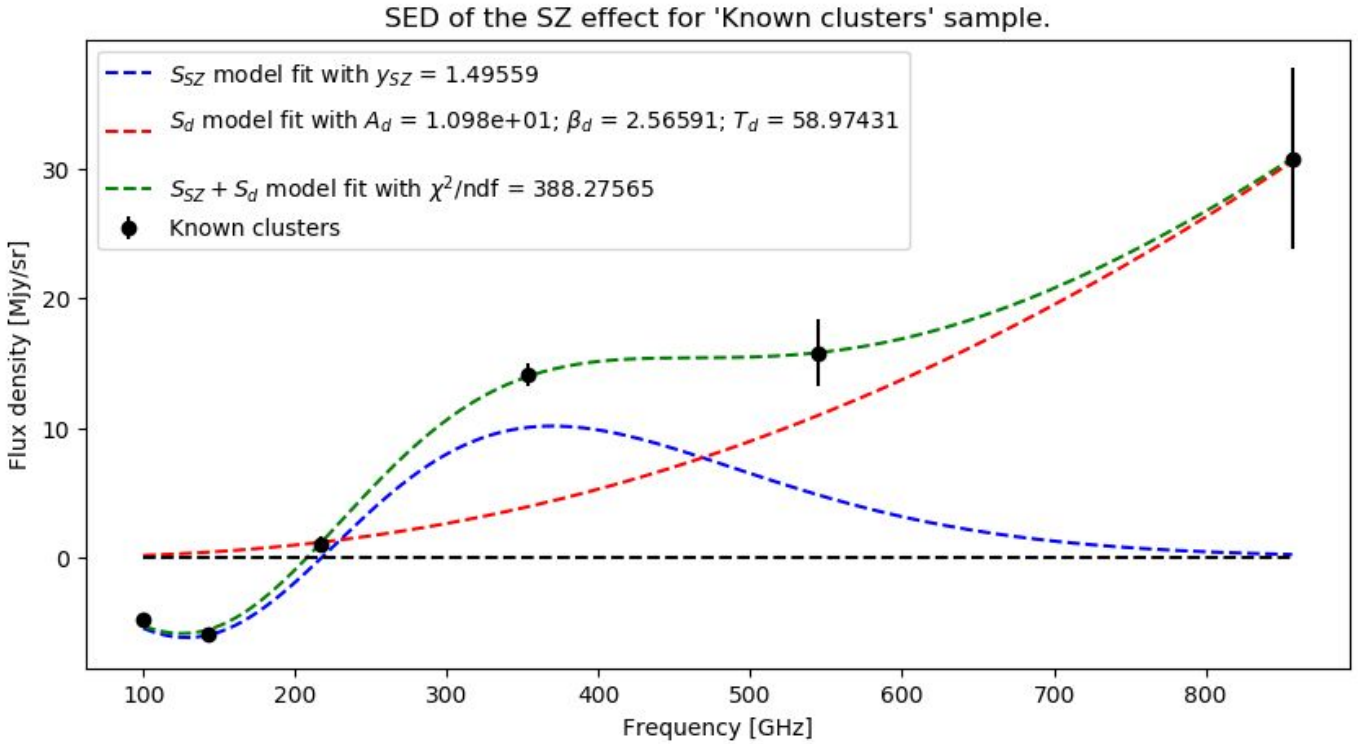
Thermal dust :

$$s_d = A_d \left(\frac{\nu}{\nu_0} \right)^{\beta_d + 1} \frac{\mathrm{e}^{\gamma \nu_0} - 1}{\mathrm{e}^{\gamma \nu} - 1}$$

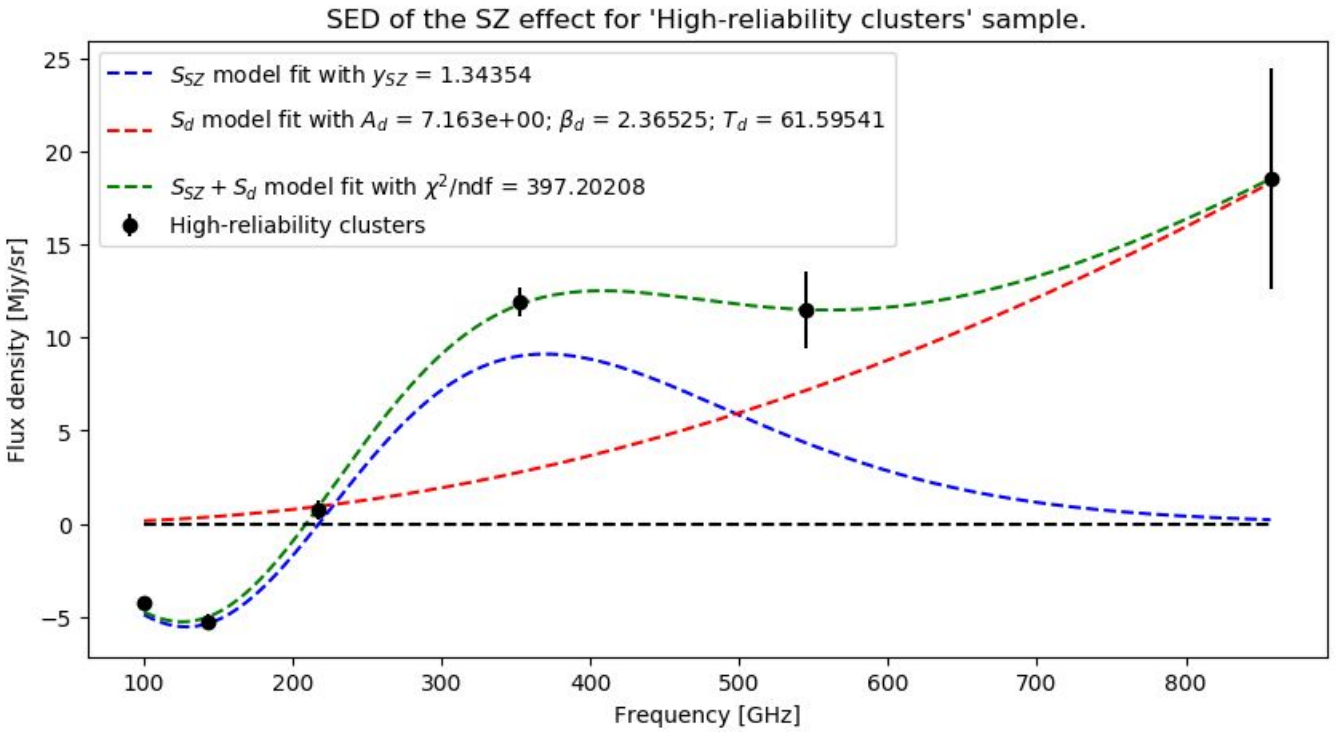
with:

$$\gamma = \frac{h}{k_B T_d}, \ \nu_0 = 545 GHz$$

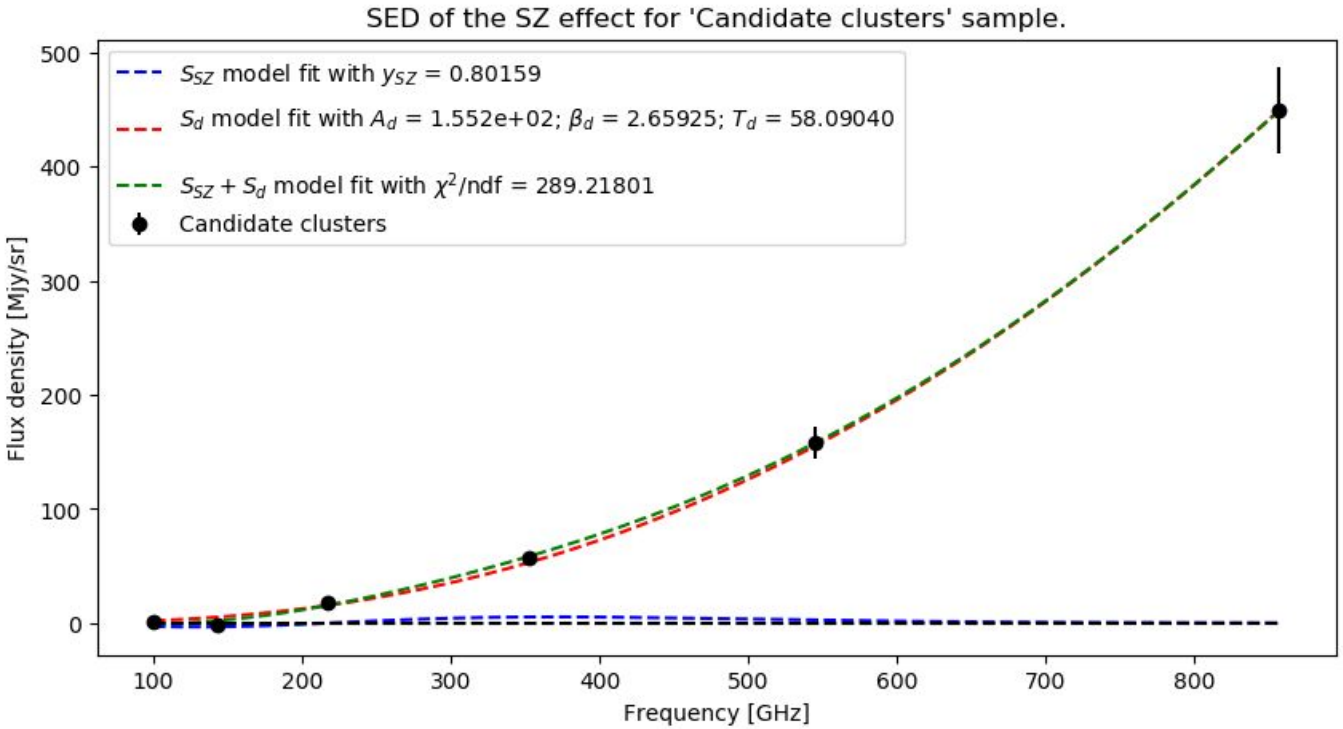
Spectral energy distribution: known clusters



Spectral energy distribution: high-reliability clusters



Spectral energy distribution: candidate clusters



Summary

Thanks for listening