

panco2: ICM pressure profiles from tSZ observations in Python

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Kéruzoré et al., OJA 6 (2023) #9, arXiv:2212.01439









What is panco2?



- Pressure profile measurements useful for cluster science
- panco2: Python library to fit pressure profiles from tSZ data
 - Flexible forward modeling MCMC adapted to mm-wave data
 - Publicly available, documented, and validated on synthetic data
- Early version presented @ mmUniverse 2021



→ 2023: Public! More features! Can be used for any mm-wave dataset!

Outline



• Algorithm

- Forward modeling
- MCMC sampling
- Validation on mock observations
 - Synthetic data
 - Results
- Conclusion

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Algorithm: Schematic overview









Input data



- Map: any flat-sky tSZ map
 - Projection read from FITS header
 - Any units; conversion to *y* can be marginalized over
- Estimate of noise (co)variance in the map
- Extra:
 - Filtering: (1D, 2D) transfer function, beam
 - Point source contamination: positions / fluxes to marginalize over

• ...



• Radially-binned pressure profile





- Radially-binned pressure profile
- Pressure profile integrated along the line of sight Analytical integration (Romero+18)
 - → (B) Compton parameter map





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- (Optional) Conversion to observed units (Conversion to be marginalized over)
 - \rightarrow (D) Filtered, calibrated SZ map





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 - → (D) Filtered, calibrated SZ map
- (Optional) Point source contamination (Fluxes to be marginalized over)
- → Data-like map from model parameters:
 - Pressure profile parameters
 - (Optional) Conversion coefficient & zero level
 - (Optional) Point source fluxes



Algorithm: MCMC sampling



• Realistic model map $M(\vartheta)$ can be compared to input map D through (log-)likelihood:

$$-2\log \mathscr{L}(\vartheta) = \sum_{i} \left(\left[D_{i} - M_{i}(\vartheta) \right] / \Sigma_{i} \right)^{2}$$

summing over pixels i, with Σ the noise RMS map

• If spatially-correlated noise, can include covariance matrix C :

$$-2\log \mathcal{L}(\vartheta) = \left[D - M(\vartheta)\right]^{\mathrm{T}} \mathrm{C}^{-1} \left[D - M(\vartheta)\right]$$

• Can include constraint on integrated tSZ signal for large-scale information:

$$-2\log \mathscr{L}(\vartheta) + = \left(\frac{Y_{$$

- Priors on parameters to be specified by the user: any continuous distribution can be used (specified through <u>spicy.stats</u>)
- Posterior sampled using <u>emcee</u> (multithreaded affine-invariant sampling)
- Samples used to compute credibility intervals on pressure profile + a lot of plots

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Validation on mock observations: Synthetic data





- Goal: validate panco2 on controlled inputs
- Dataset:
 - Three mock clusters (C1, C2, C3), covering different (M_{500}, z)
 - Mock-observed to mimic:
 - Planck y-map (white noise + beam) (Planck 2015 XXII)
 - SPT-SZ y-map (white noise + beam) (Bleem+22)
 - NIKA2 150 GHz map (white noise + beam + TF) (Kéruzoré+20)













C1, SPT





C2, SPT





C2, NIKA2





C3, NIKA2

Results: extra features



Results: extra features





C2, SPT + anisotropic transfer function

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Results: extra features





C2, SPT + spatially correlated noise

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C2, NIKA2 + point sources fitted with tSZ signal

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C2, NIKA2 + point sources masked in the fit

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Summary



- Flexible, fast, accurate Python library to estimate pressure profiles from tSZ maps
 - Flexible:
 - Can work on any input flat-sky map
 - Many analysis options to choose from \rightarrow systematic analyses
 - Fast: validation fits averaged a few minutes on a laptop*
 - Accurate: validation showed unbiased pressure profile estimates
 - For different maps (Planck-like, SPT-like, NIKA2-like, with different clusters)
 - On scales between beam size and map size

* On my laptop; this is not a guarantee!

Code / information availability



- panco2 is publicly available on Github and easy to install: <u>fkeruzore/panco2</u>
- Online documentation includes API documentation and example notebooks: <u>readthedocs</u>
- Paper presenting code & validation is published: <u>arXiv:2212.01439</u>
- Don't hesitate to reach out if you want to use it!

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Documentation					Suggested Workflows Based on your tech stack		
Please read the documentation and running examples at https://panco2.readthedocs.io/en/latest/					Actions Importer Set up		
Installation					Automatically convert CI/CD files to YAML for GitHub Actions.		
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					Python application Configure		

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