



Illustration: M. Muñoz-Echeverría

panco2: ICM pressure profiles from tSZ observations in Python

Florian Kéruzoré, Argonne National Laboratory
mmUniverse23, June 2023

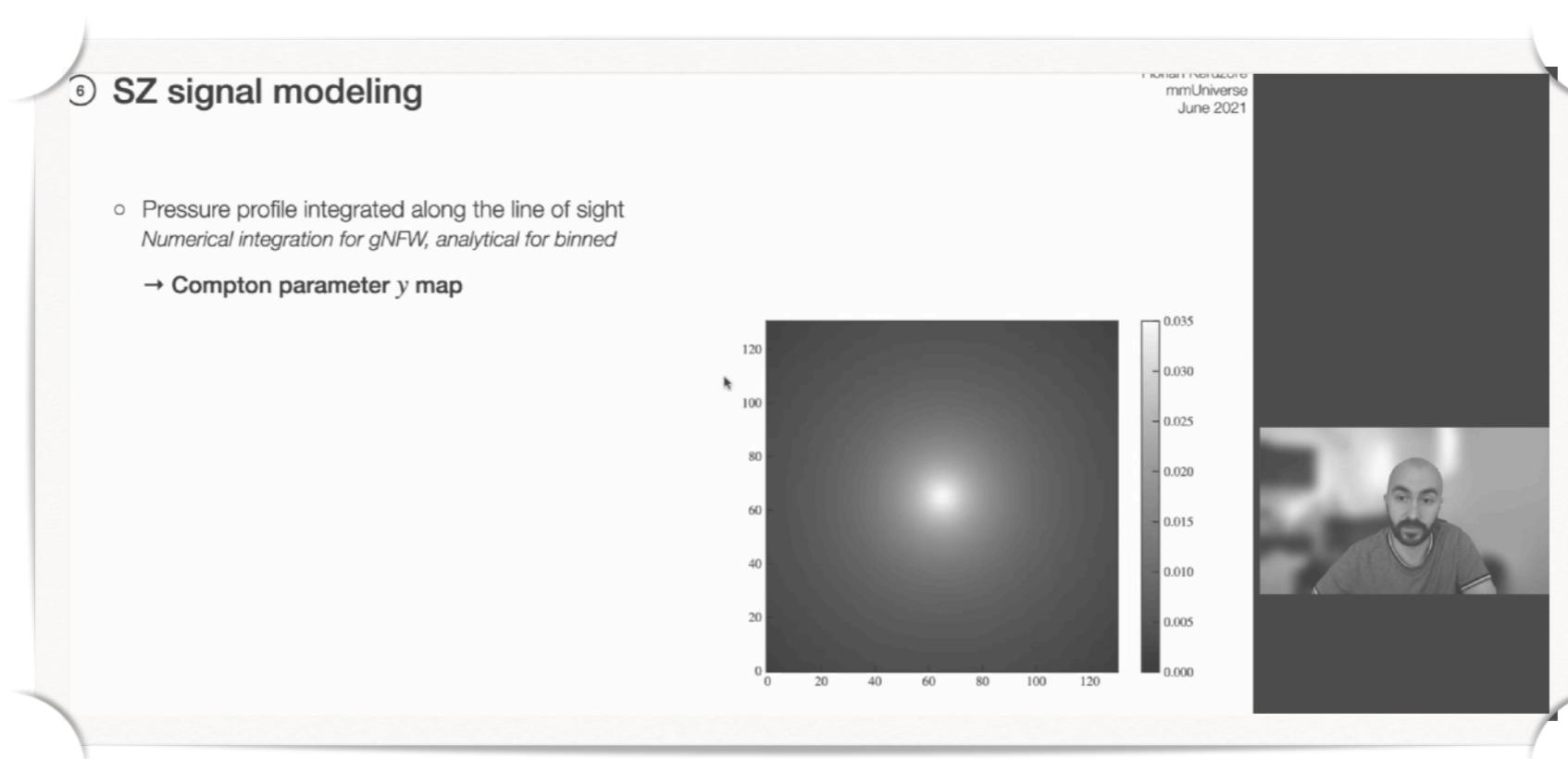
Kéruzoré et al., OJA 6 (2023) #9, arXiv:2212.01439



Argonne National Laboratory is a
U.S. Department of Energy laboratory
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- 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

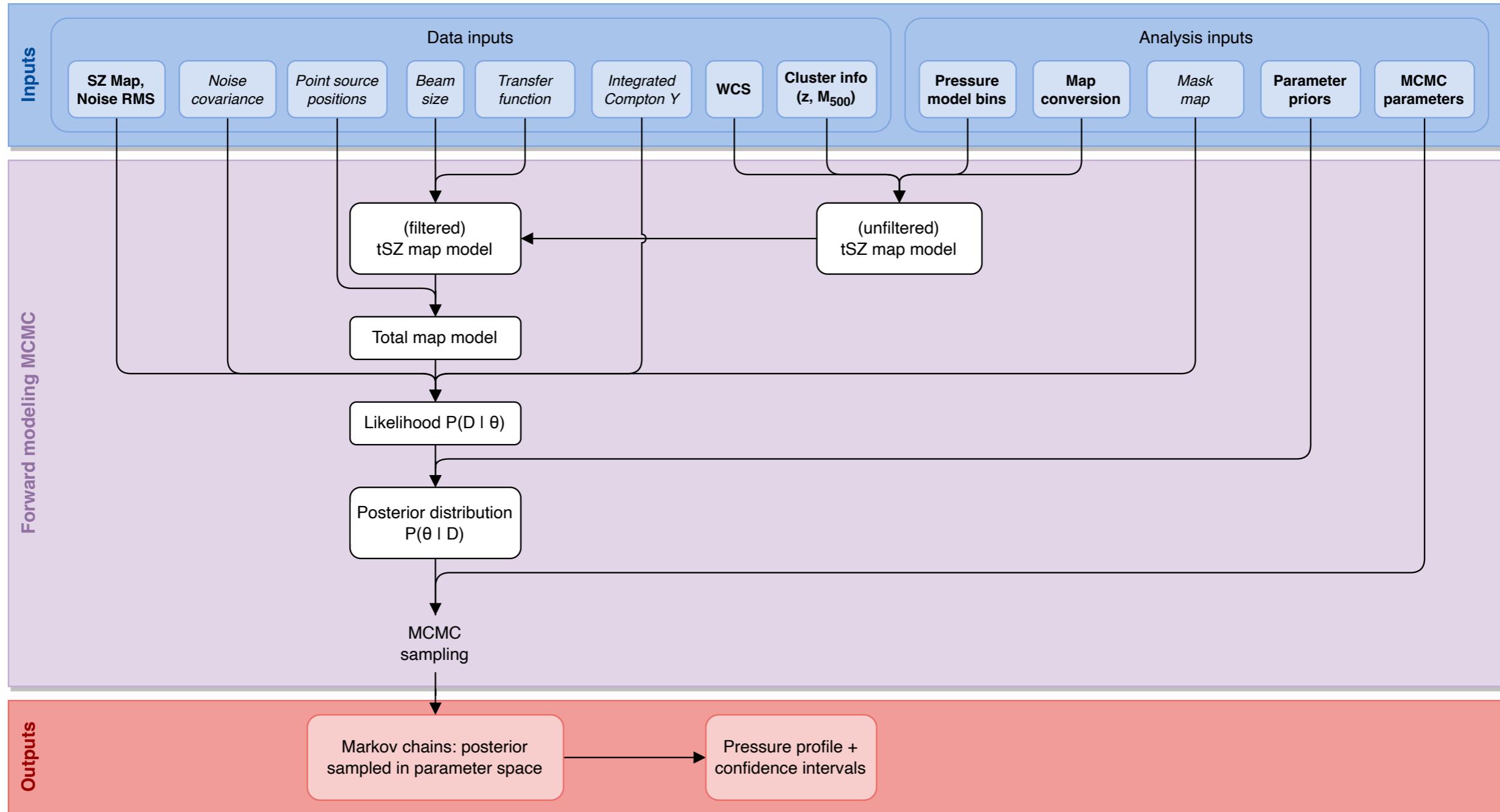


→ 2023: Public! More features! Can be used for any mm-wave dataset!

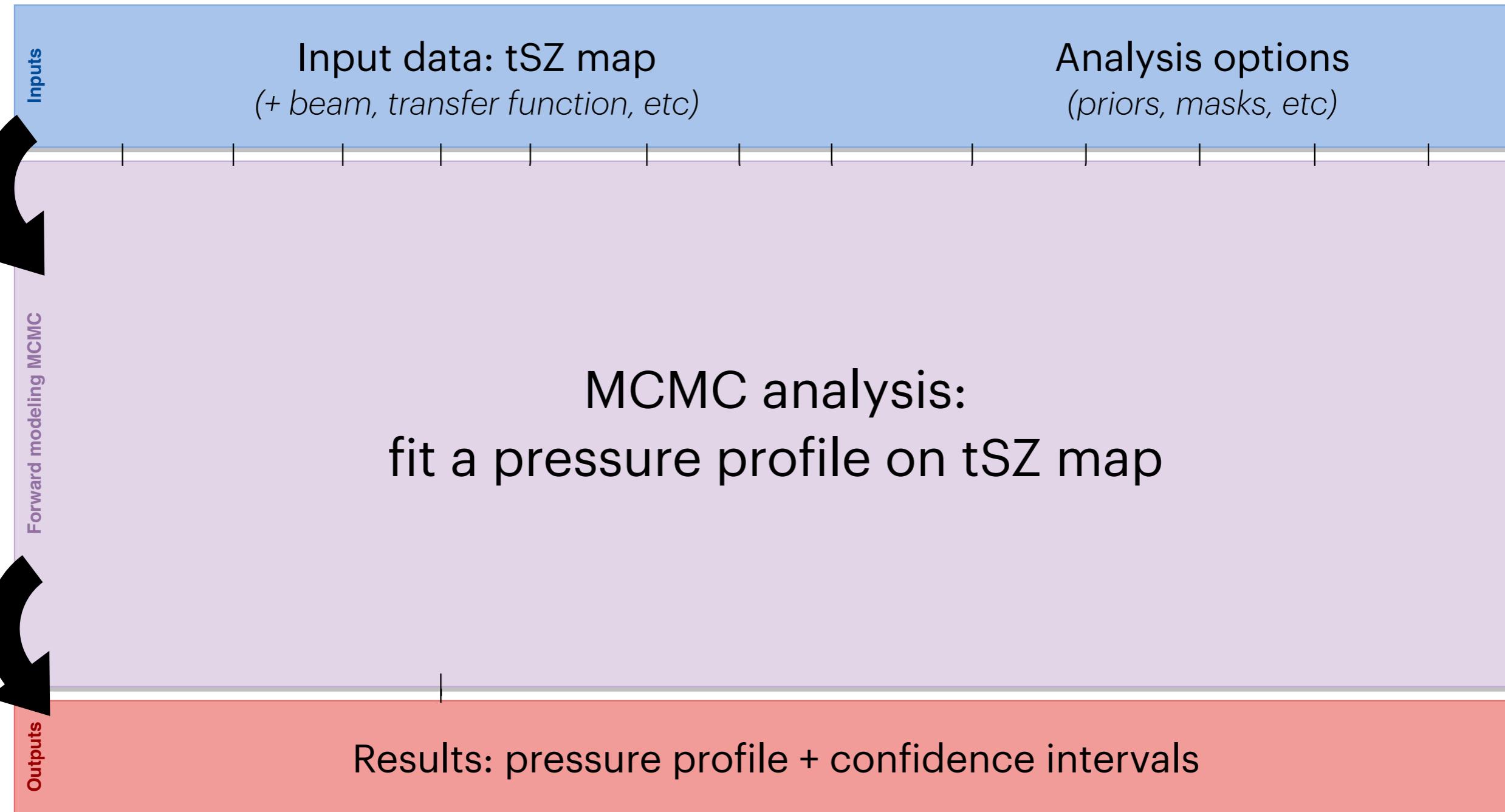
- **Algorithm**
 - Forward modeling
 - MCMC sampling
- **Validation on mock observations**
 - Synthetic data
 - Results
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Algorithm: Schematic overview



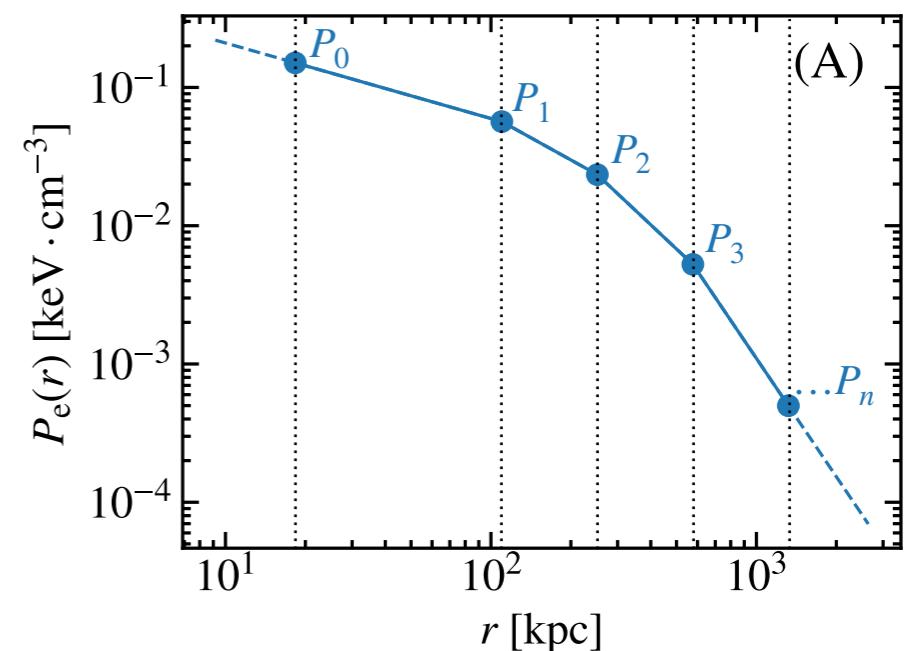
Algorithm: Schematic overview



- 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
 - ...

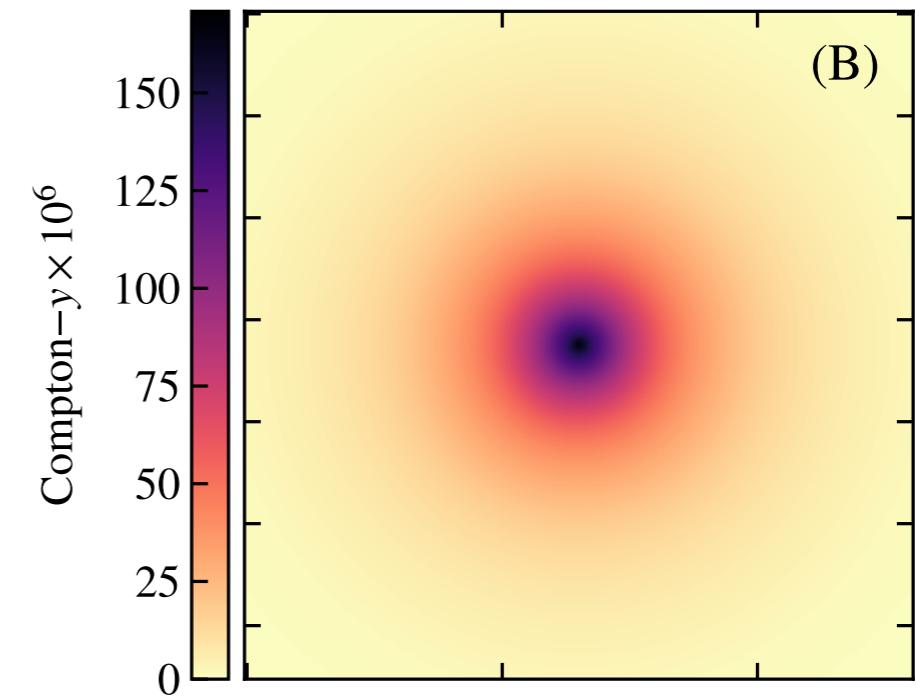
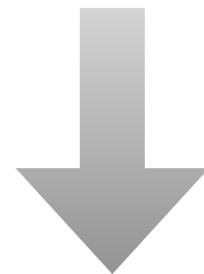
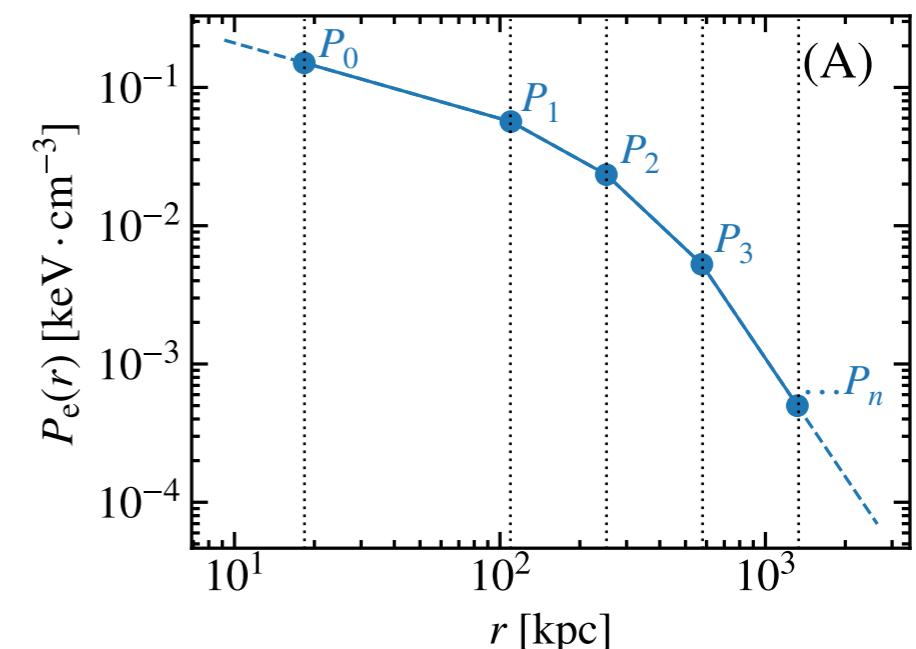
Forward modeling of tSZ map

- Radially-binned pressure profile



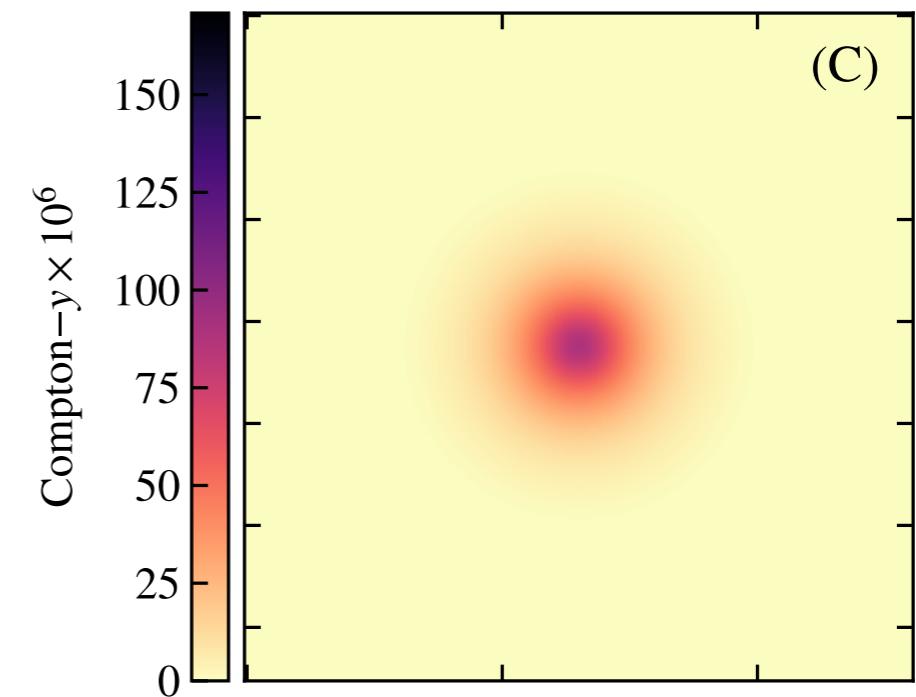
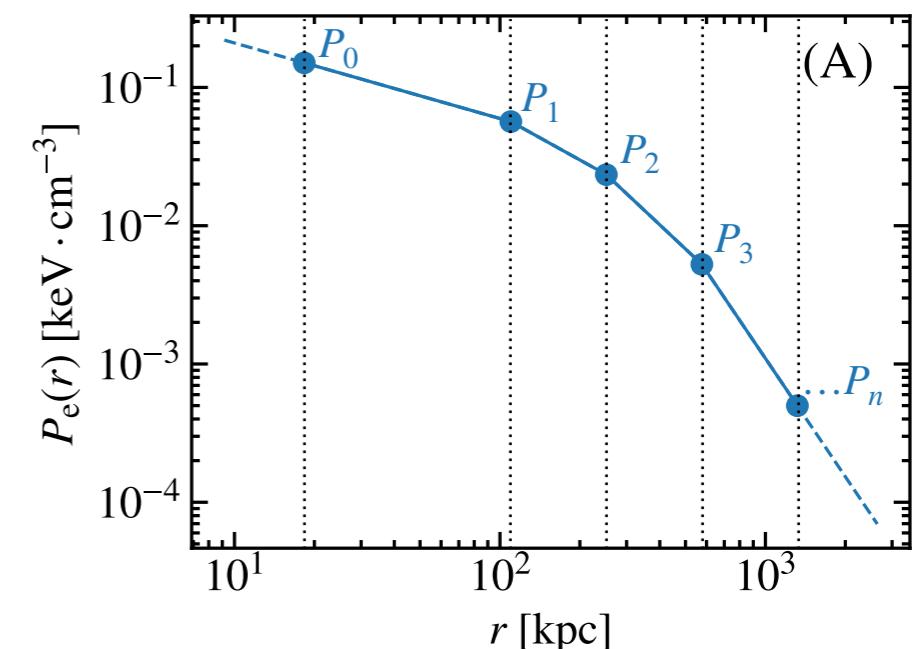
Forward modeling of tSZ map

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



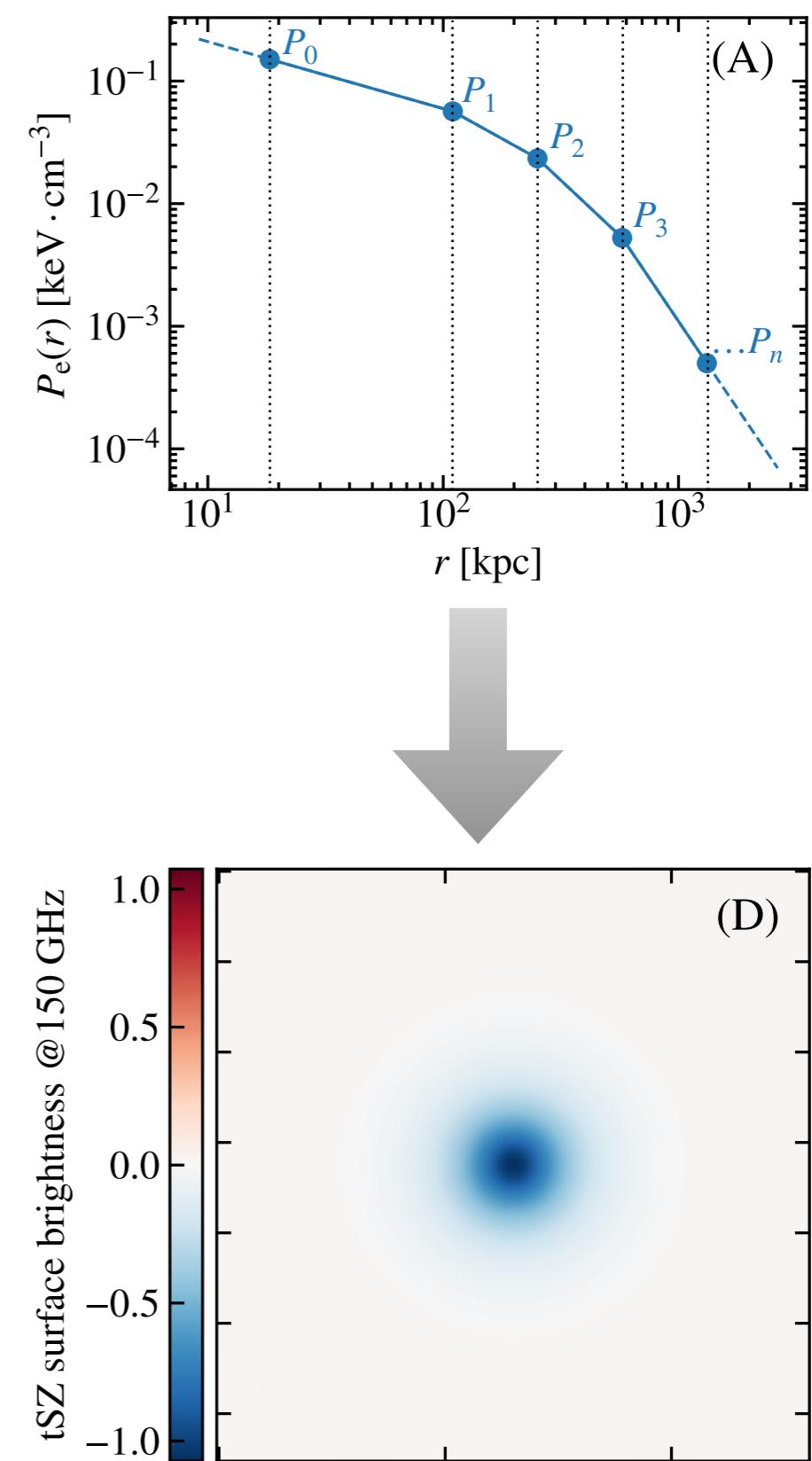
Forward modeling of tSZ map

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 - (B) Compton parameter map
- Convolved by the beam (PSF smearing)
and transfer function (filtering)
 - (C) Filtered (data-like) γ map



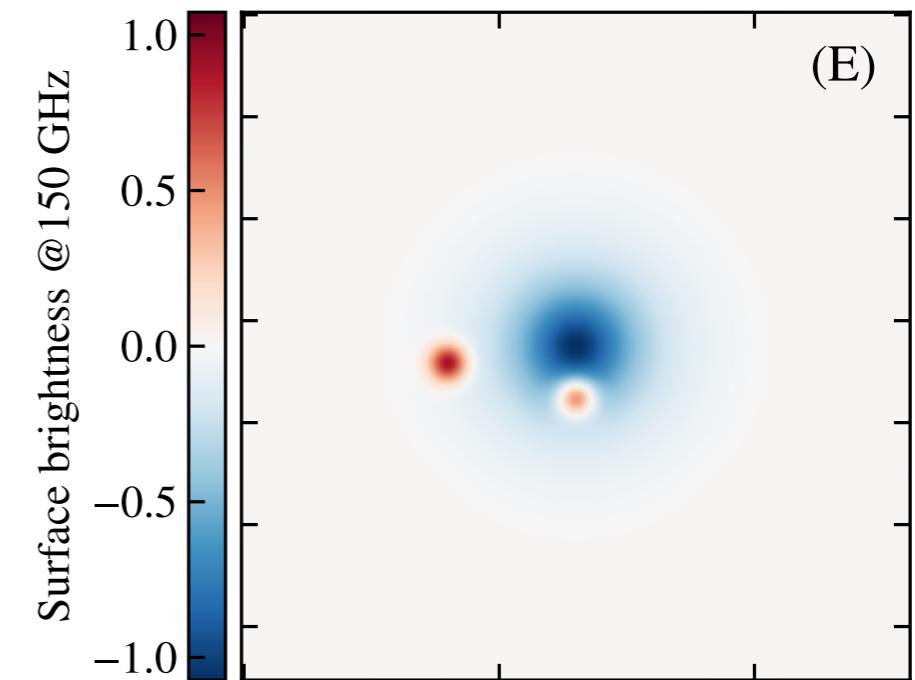
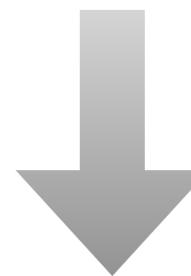
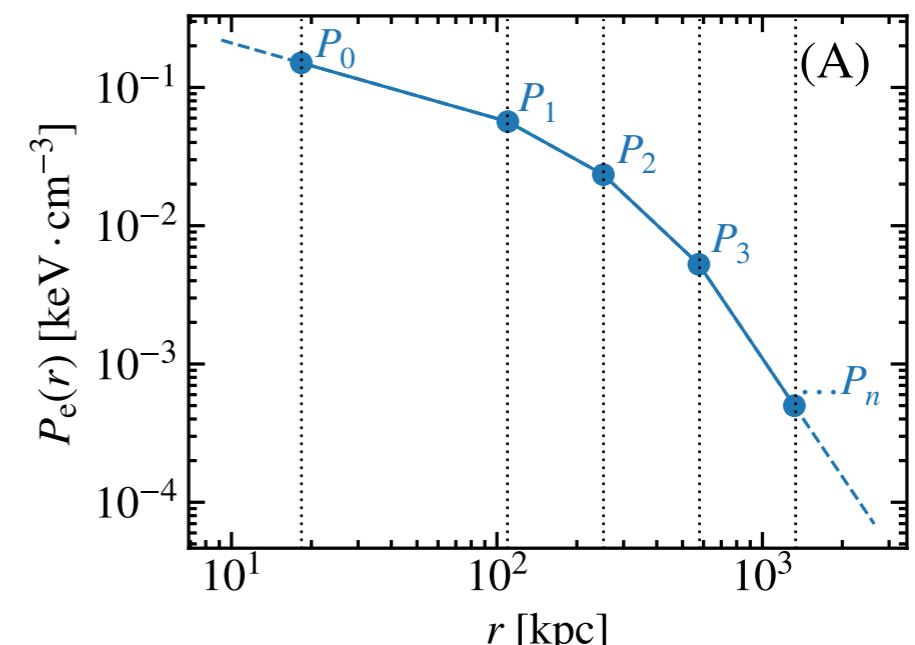
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- (Optional) Conversion to observed units
(Conversion to be marginalized over)
 - (D) Filtered, calibrated SZ map



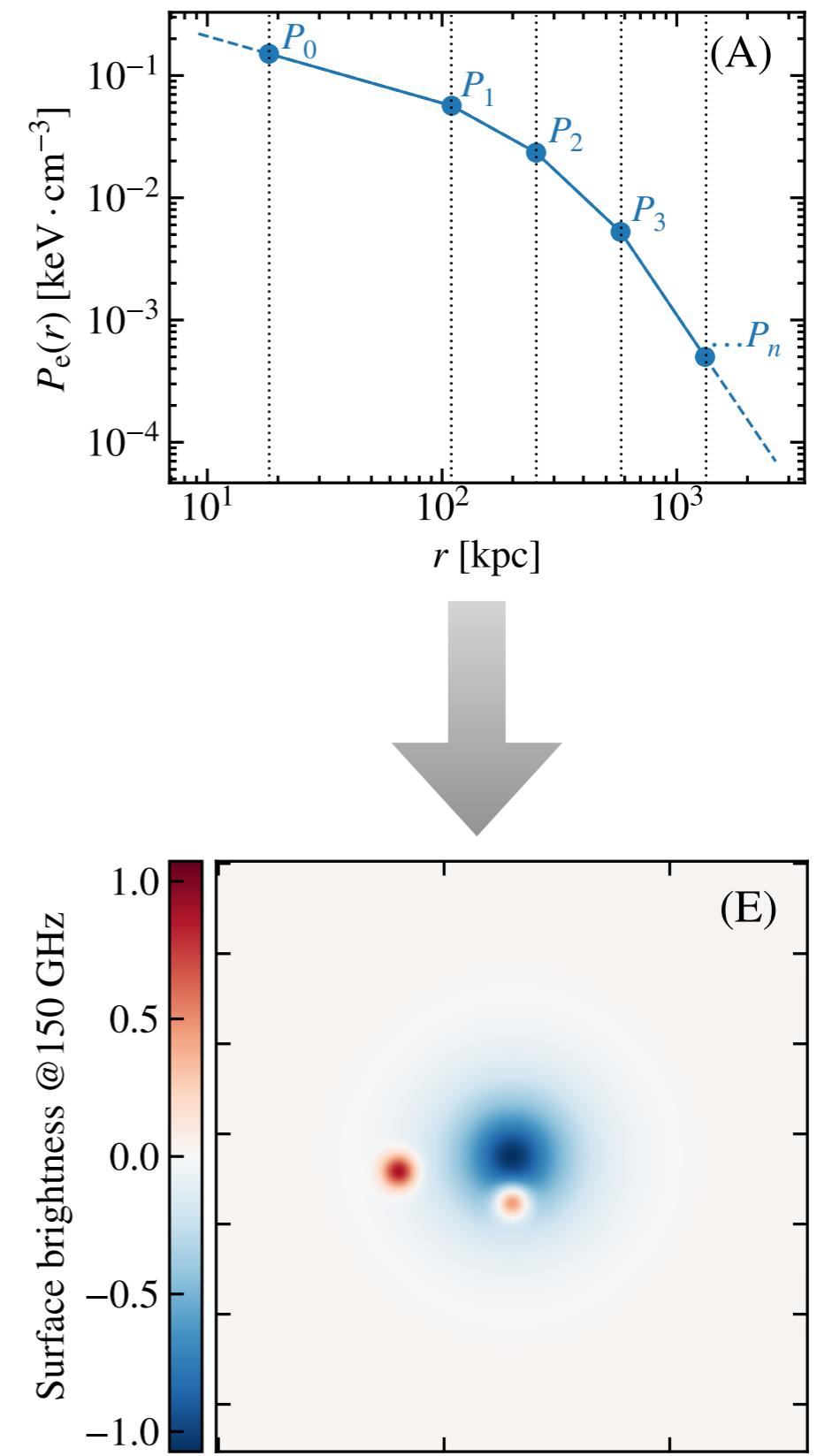
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(Fluxes to be marginalized over)
- **Data-like map from model parameters:**
- Pressure profile parameters
 - (Optional) Conversion coefficient & zero level
 - (Optional) Point source fluxes



Algorithm: MCMC sampling

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

$$-2 \log \mathcal{L}(\vartheta) = \sum_i \left([D_i - M_i(\vartheta)] / \Sigma_i \right)^2$$

summing over pixels i , with Σ the noise RMS map

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

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

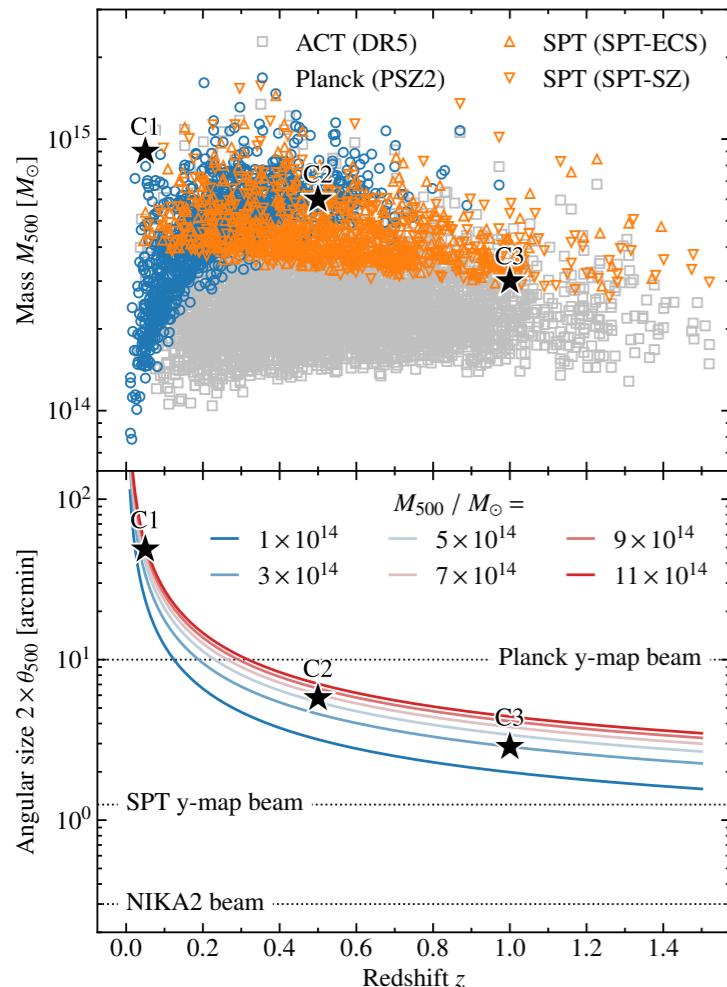
- Can include constraint on integrated tSZ signal for large-scale information:

$$-2 \log \mathcal{L}(\vartheta) + = \left(\frac{Y_{<R}^{\text{meas.}} - 4\pi \frac{\sigma_T}{m_e c^2} \int_0^R P_e(r) r^2 dr}{\Delta Y_{<R}^{\text{meas.}}} \right)^2$$

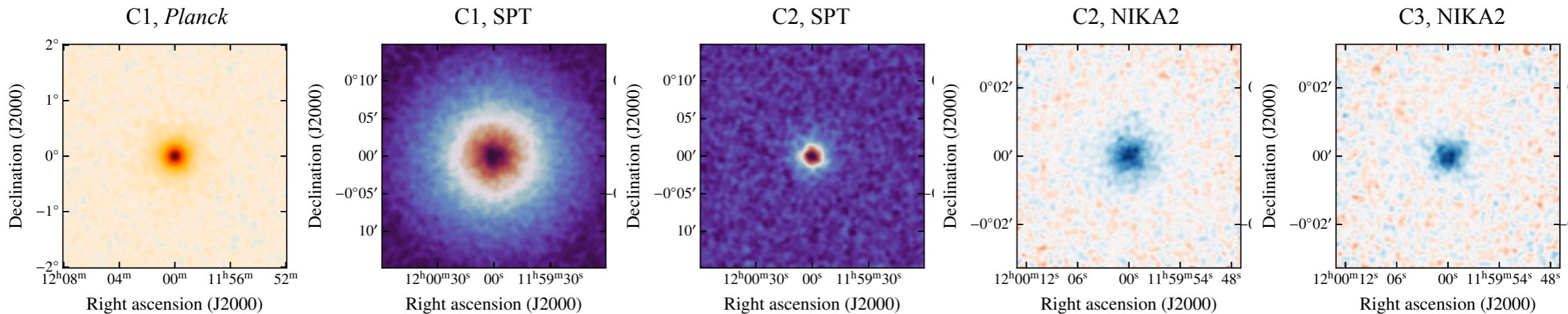
- Priors on parameters to be specified by the user: any continuous distribution can be used (specified through `spicy.stats`)
- Posterior sampled using `emcee` (multithreaded affine-invariant sampling)
- Samples used to compute credibility intervals on pressure profile + a lot of plots

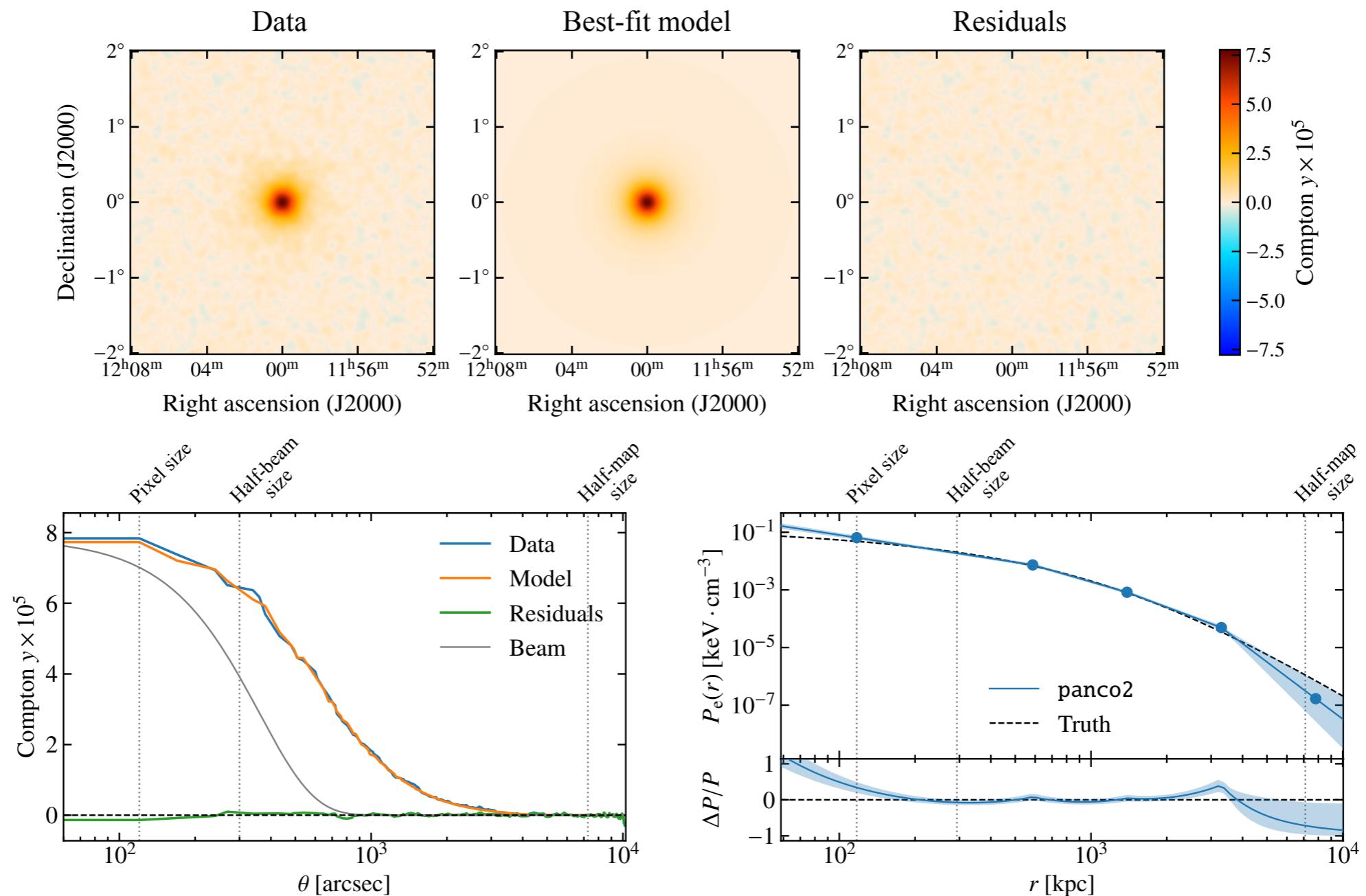
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Validation on mock observations: Synthetic data



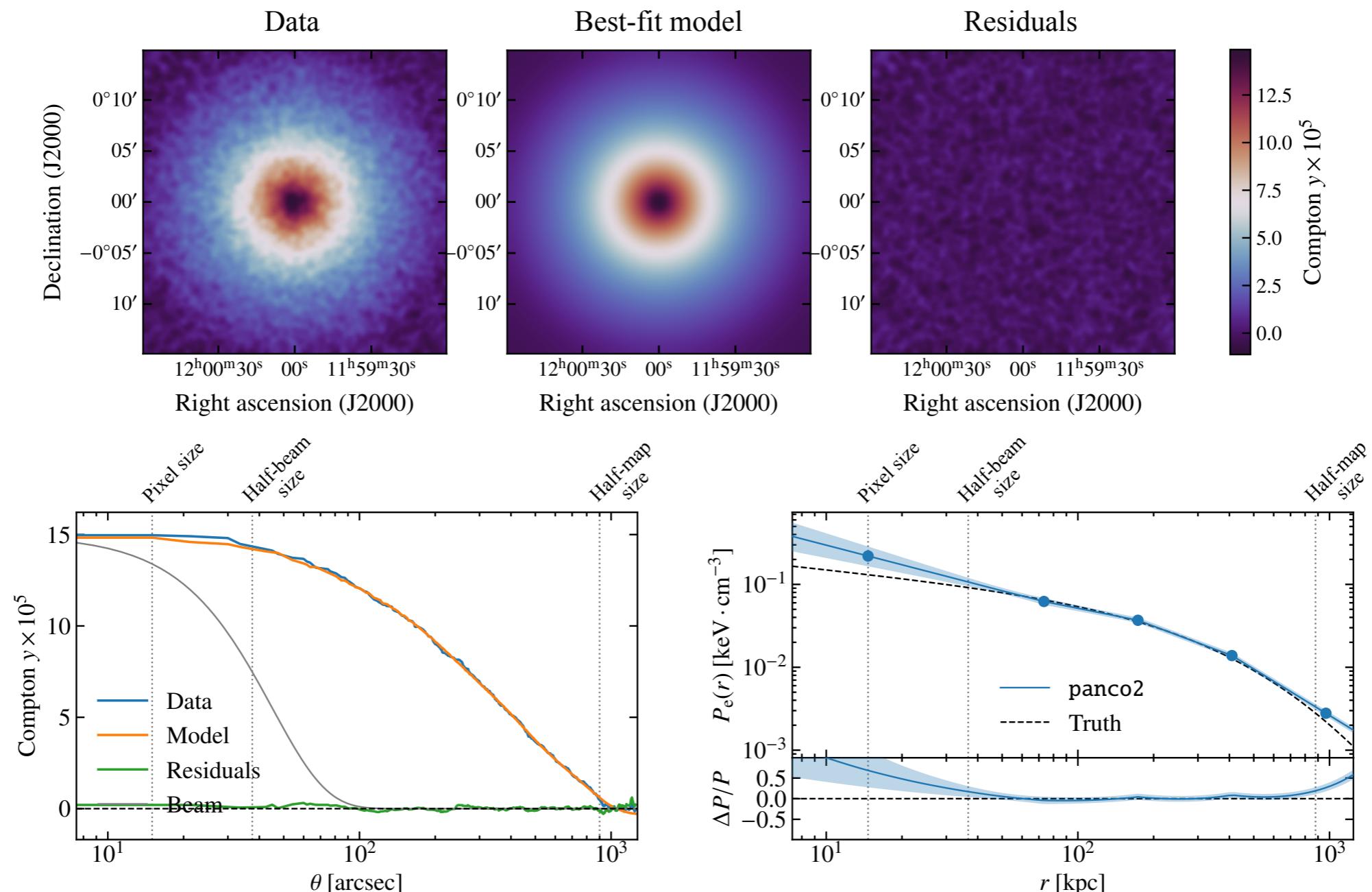
- Goal: validate `panco2` on controlled inputs
- Dataset:
 - Three mock clusters (C1, C2, C3), covering different (M_{500} , z)
 - Mock-observed to mimic:
 - Planck y-map (white noise + beam) (Planck 2015 XXII)
 - SPT-SZ y-map (white noise + beam) (Bleem+22)
 - NIKA2 150 GHz map (white noise + beam +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



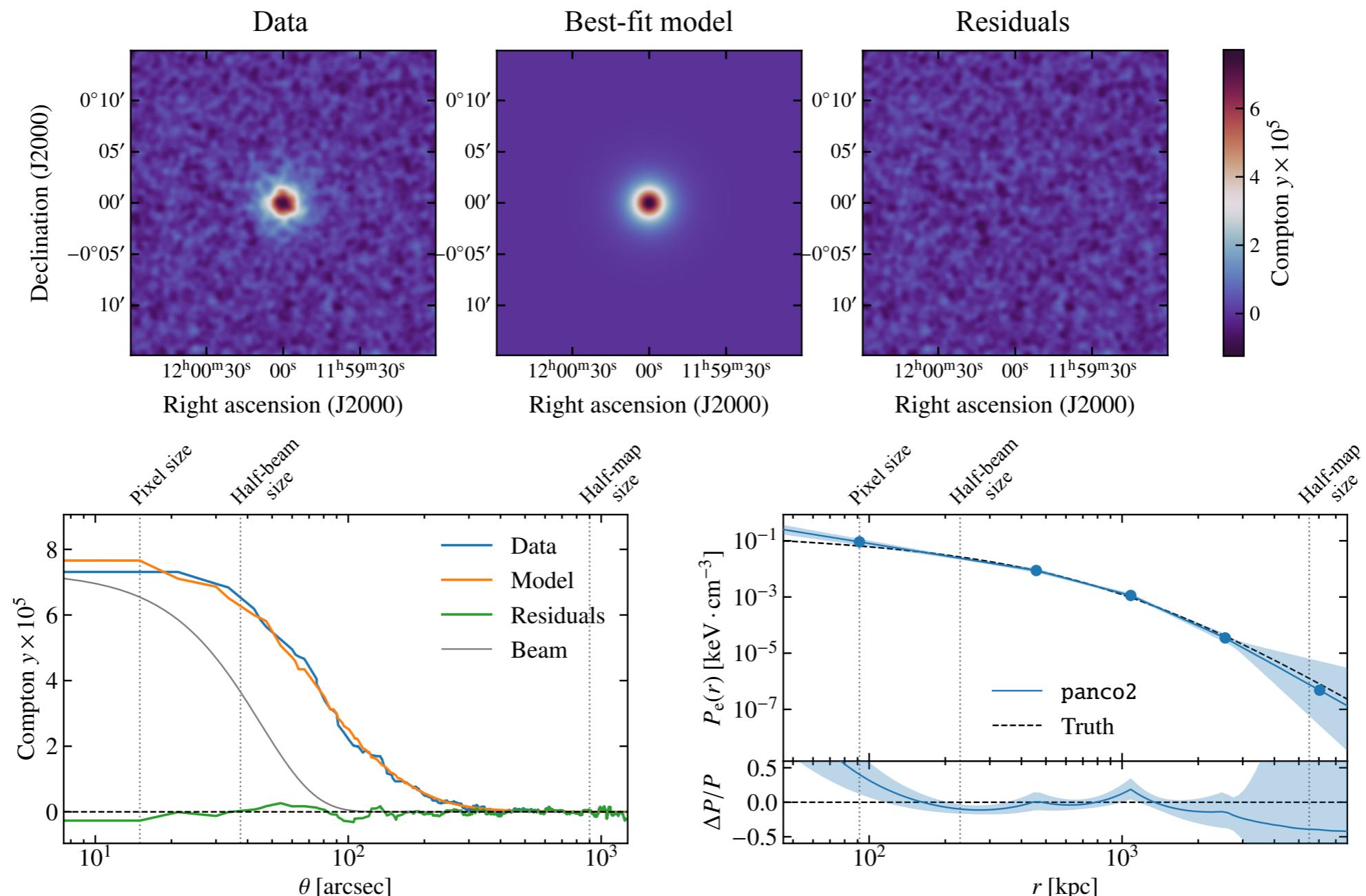


C1, *Planck*

Results

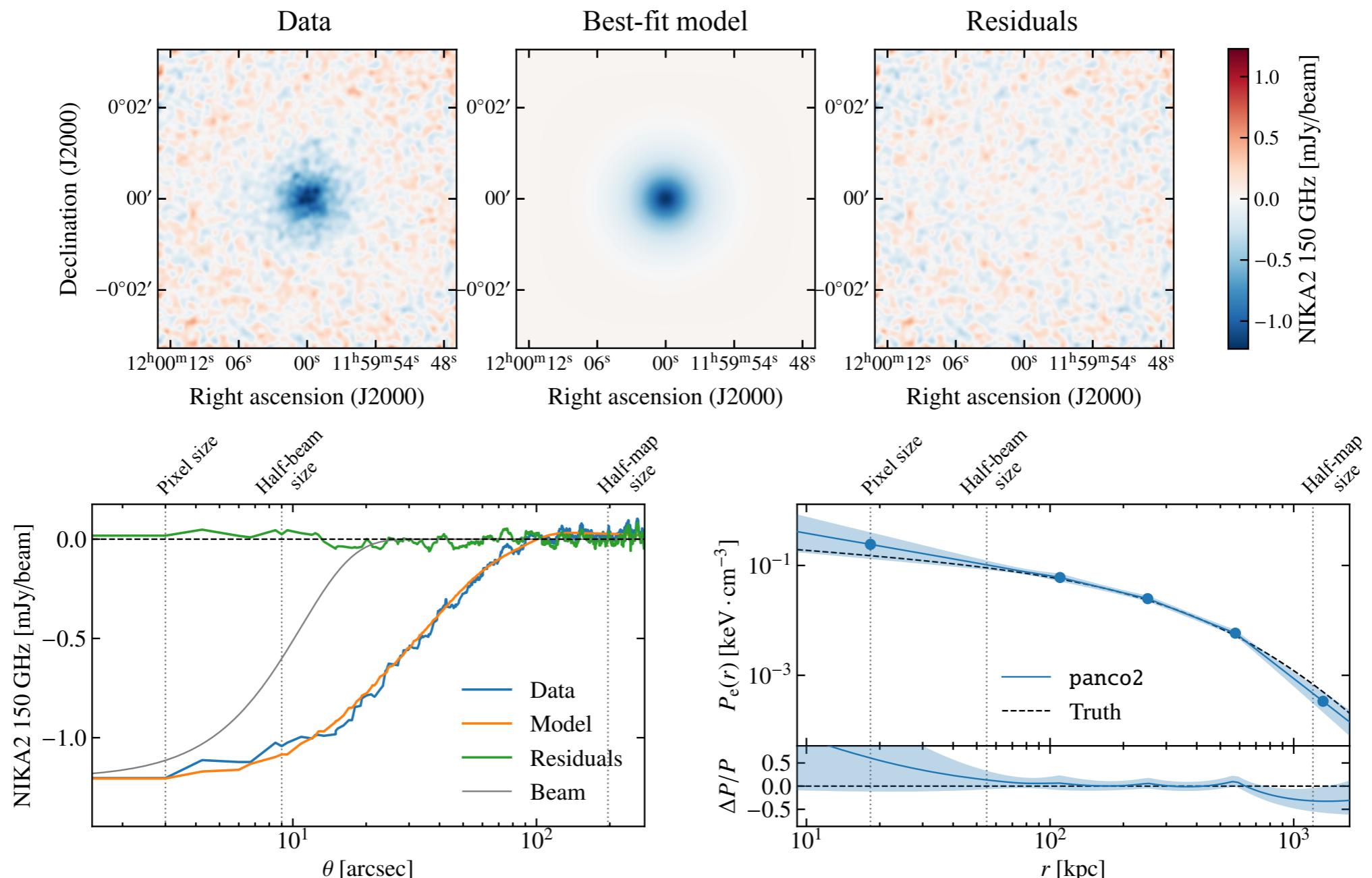


C1, SPT

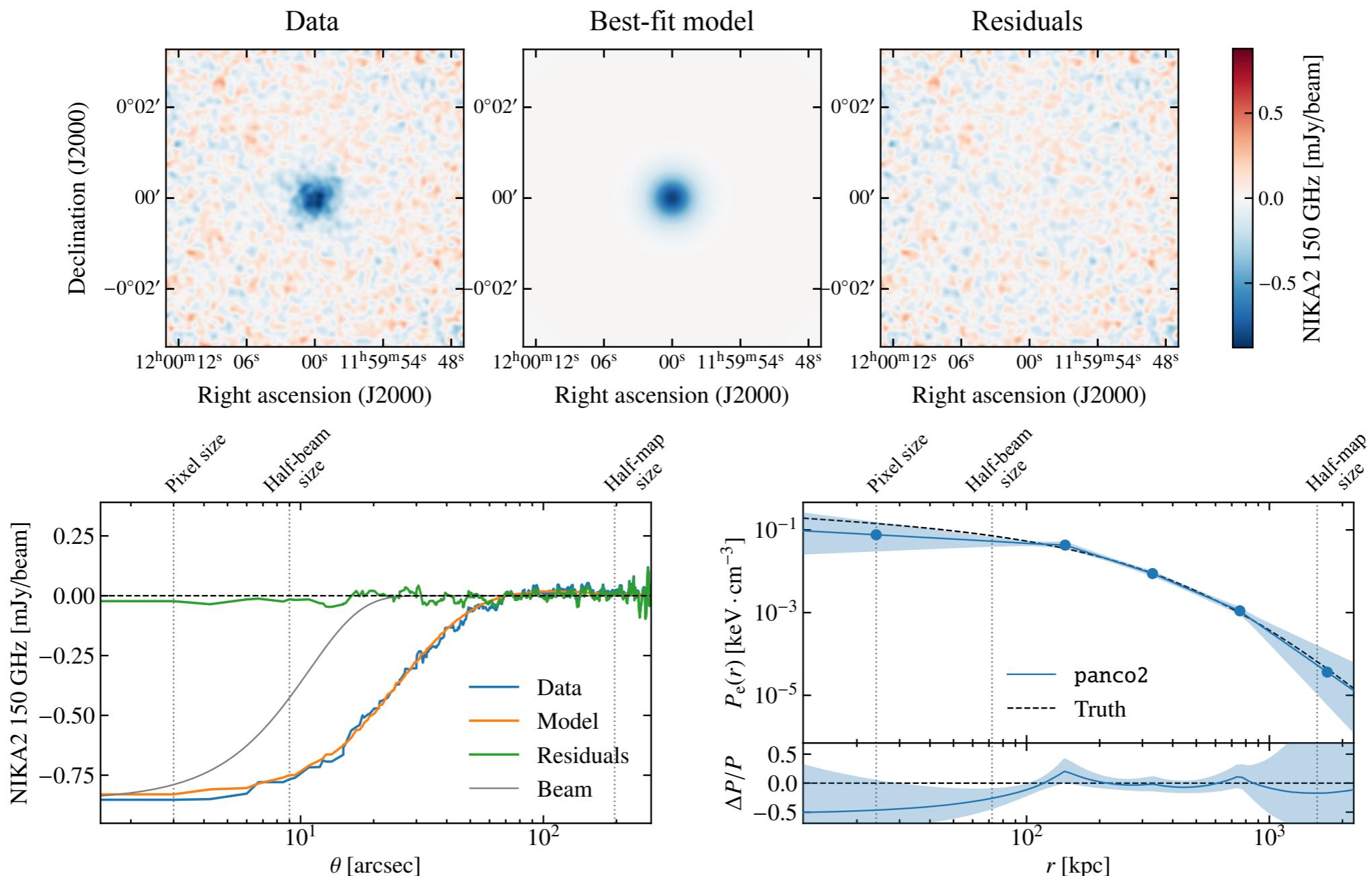


C2, SPT

Results



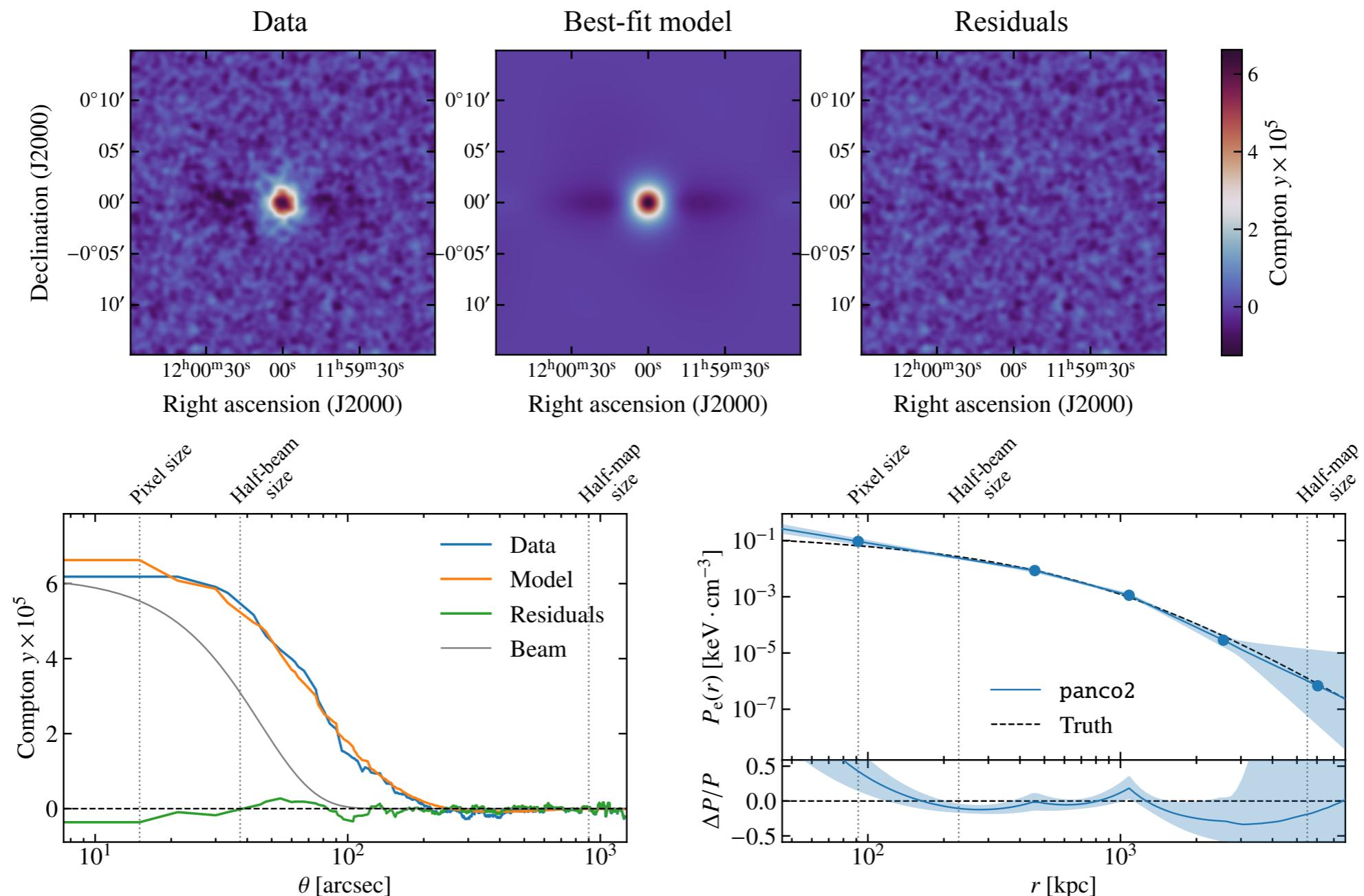
C2, NIKA2



C3, NIKA2

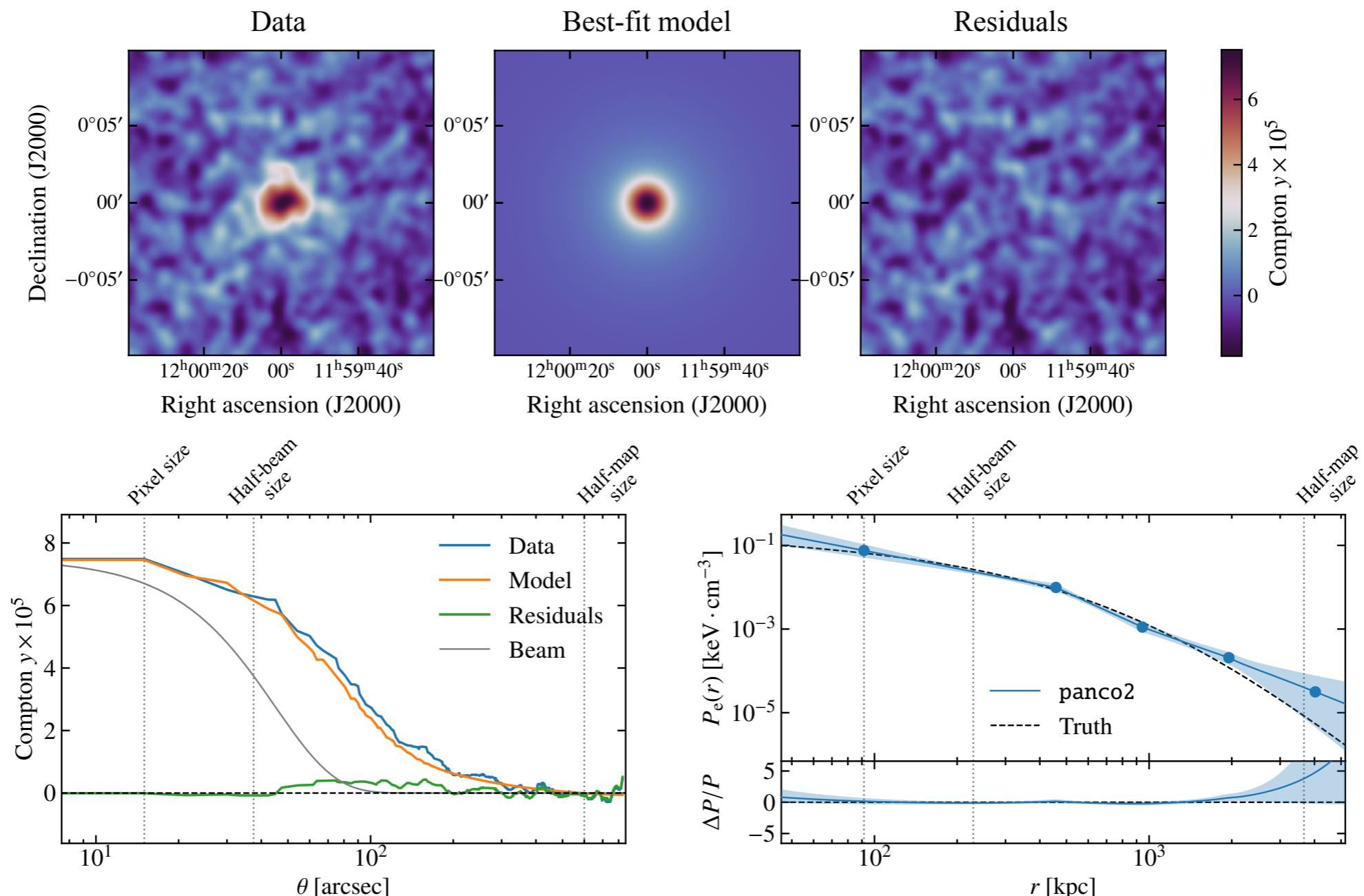
Results: extra features

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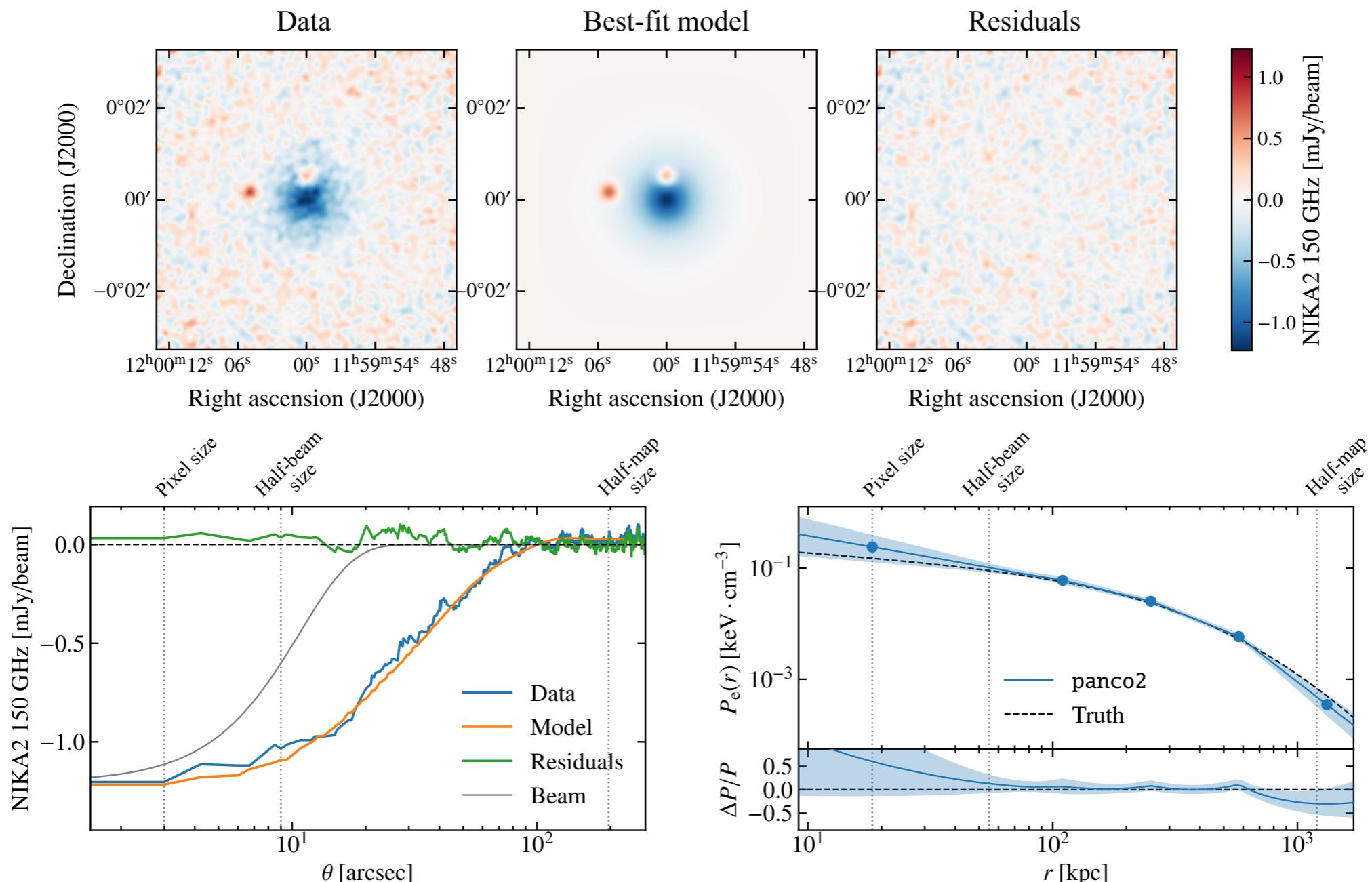
C2, SPT + anisotropic transfer function

Results: extra features



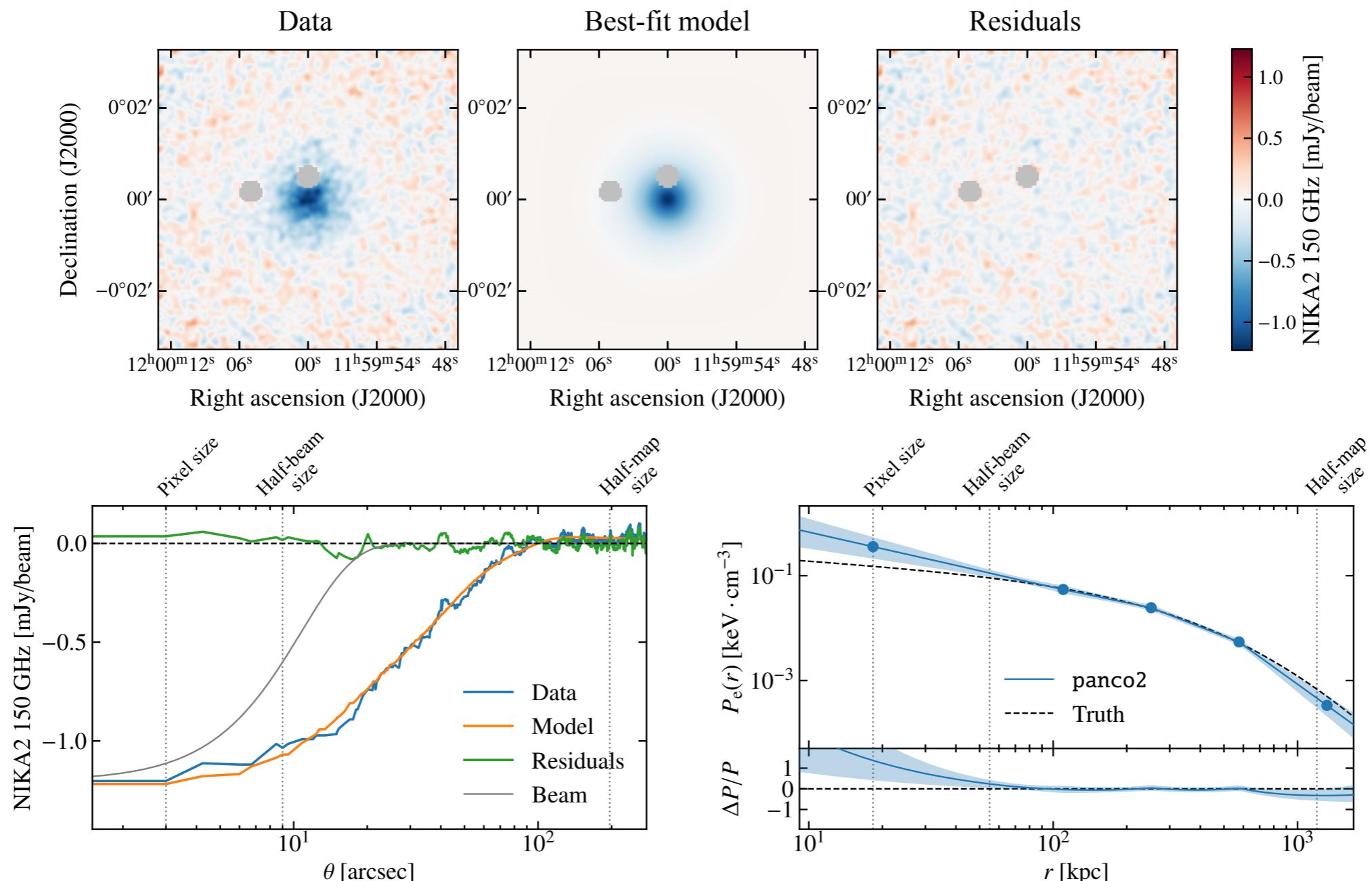
C2, SPT + spatially correlated noise

Results: extra features



C2, NIKA2 + point sources fitted with tSZ signal

Results: extra features



C2, NIKA2 + point sources masked in the fit

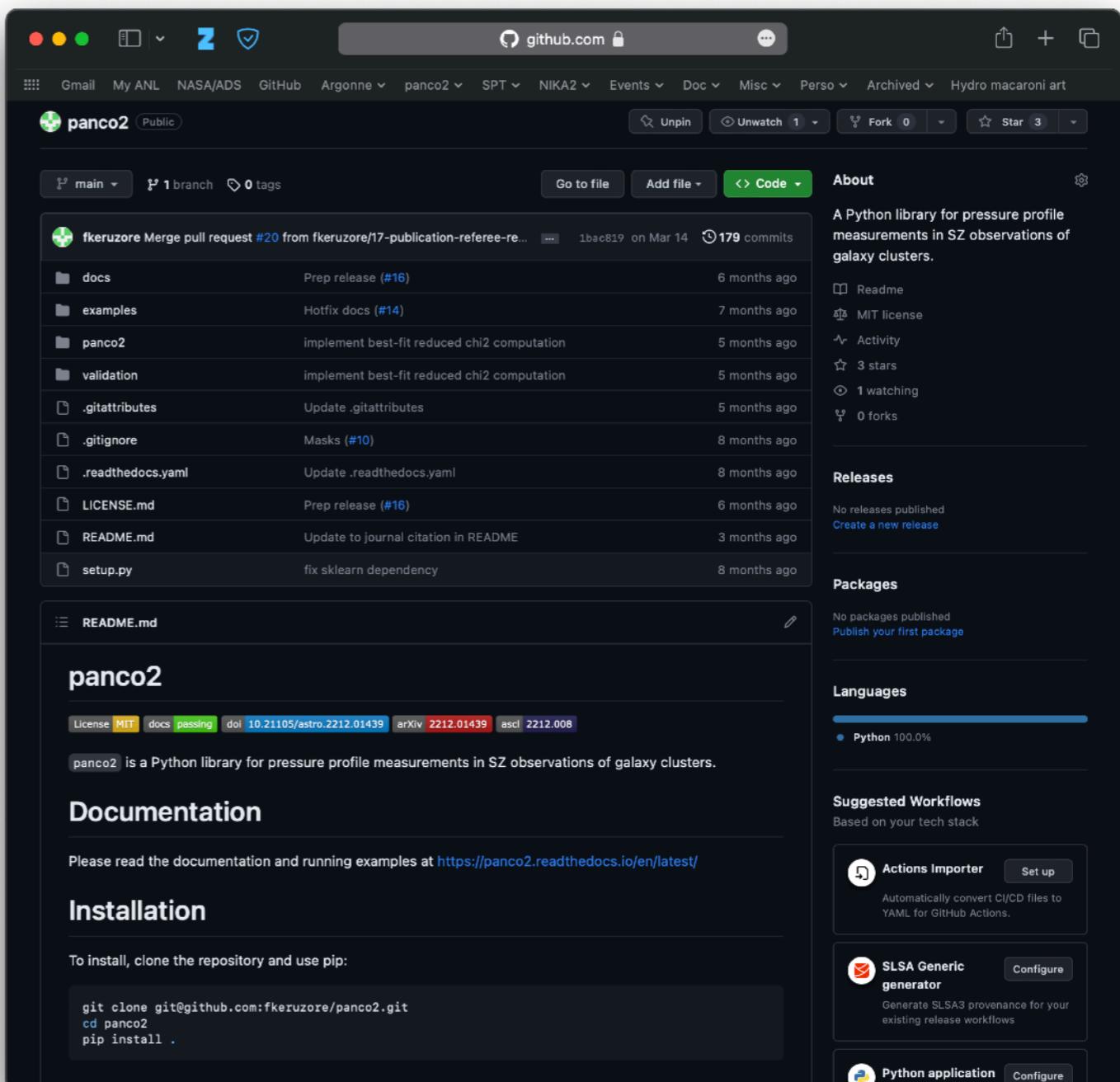
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- **Flexible, fast, accurate** Python library to estimate pressure profiles from tSZ maps
 - **Flexible:**
 - Can work on any input flat-sky map
 - Many analysis options to choose from → systematic analyses
 - **Fast:** validation fits averaged a few 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!

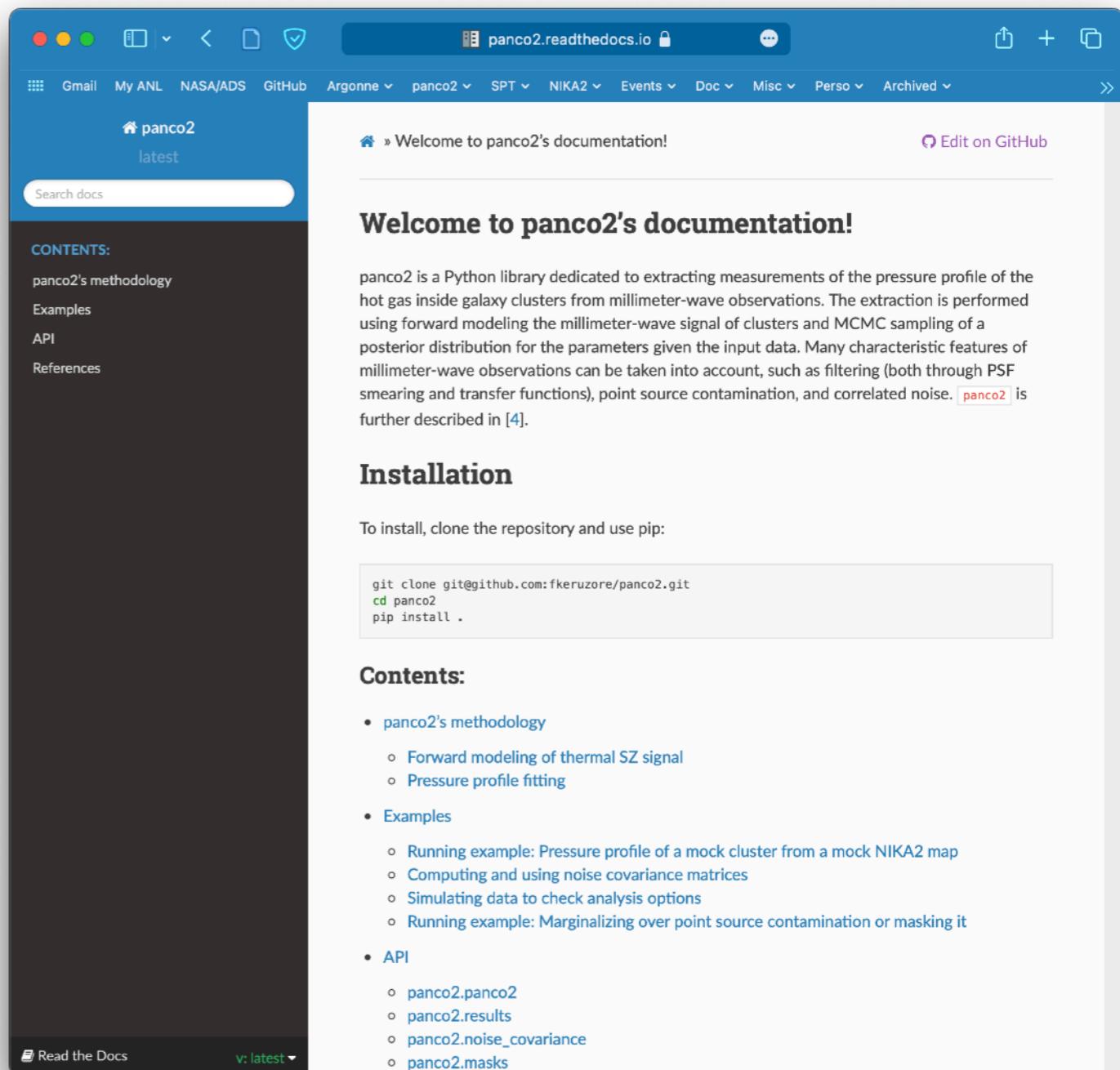
Code / information availability

- panco2 is publicly available on Github and easy to install: [fkeruzore/panco2](https://github.com/fkeruzore/panco2)
- Online documentation includes API documentation and example notebooks: [readthedocs](https://readthedocs.org/projects/panco2/)
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