BATMAN
Better Accuracy and robusTness of Mass Assessment of Neutrinos

M. Douspis, A. Gorce, S. Henrot-Versillé, L. Hergt, S. Ilić, L. McBride,
M. Muñoz-Echeverría, E. Pointecouteau, L. Salvati, M. Tristram

New analysis of CMB data with a coherent approach of the foregrounds and sytematics.
Focus on extragalactic foregrounds modelling to **tighten constraints on cosmological, astrophysics, and reionisation parameters** by studying:

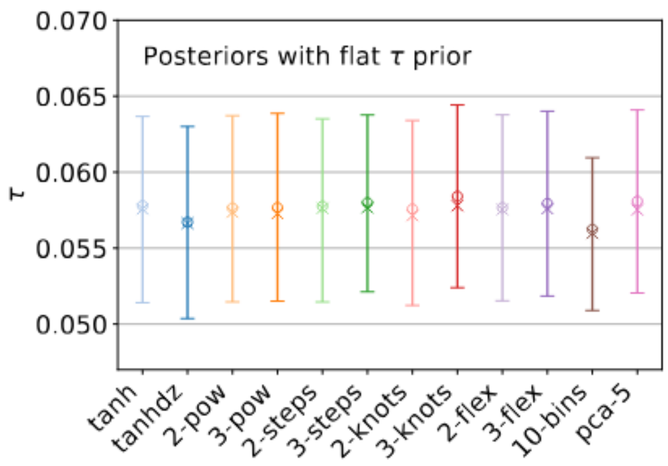
- Hot gas in clusters to better model the tSZ angular power spectrum.
- Emulators of the kSZ angular power spectrum from hydrodynamical simulations varying physical properties of galaxies and gas at high redshift
- Several reionisation models to test the robustness of the CMB constraints on the reionisation optical depth
- A coherent unique CMB likelihood framework using the latest Planck, ACT and SPT data
- Inference from these CMB data and extragalactic foreground templates and models to provide strong constraints on the sum of the neutrinos masses

REIONISATION HISTORY from CMB [1]
Ilić et al, A&A 700 26 (2025)

Accurately characterising the reionisation signature in the CMB is crucial, since it is degenerate with the signal from massive neutrinos:

- Planck PR4 CMB data
- Wide range of models
- Bayesian and Frequentist approaches

➡ Robust estimate of $\tau \approx 0.058 \pm 0.006 \pm 0.0006$ (± stat. ± syst.)
➡ Modest contribution from very early ionisation depending on the model



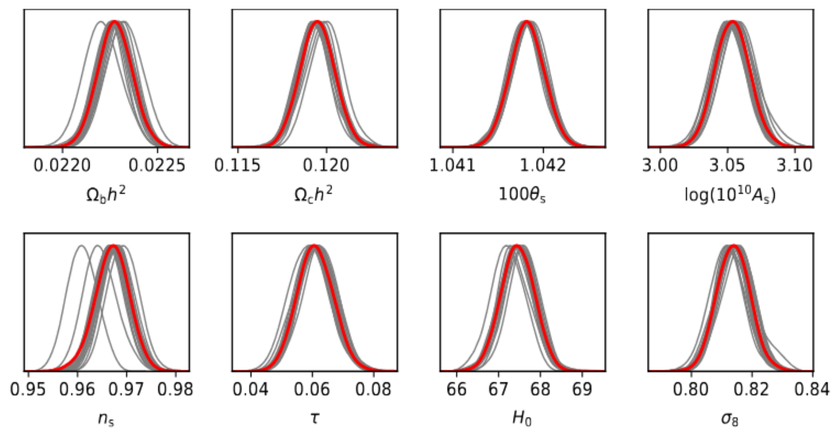
Constraints on the reionisation optical depth from Planck PR4 for the reionisation models considered. The plotted segments represent the 68% credible intervals, where the crosses and circles mark, respectively, the maximum and mean of each posterior, after τ prior-flattening correction

[3] CONSISTENT JOINT CMB LIKELIHOOD
Tristram et al, arXiv:2511.04733

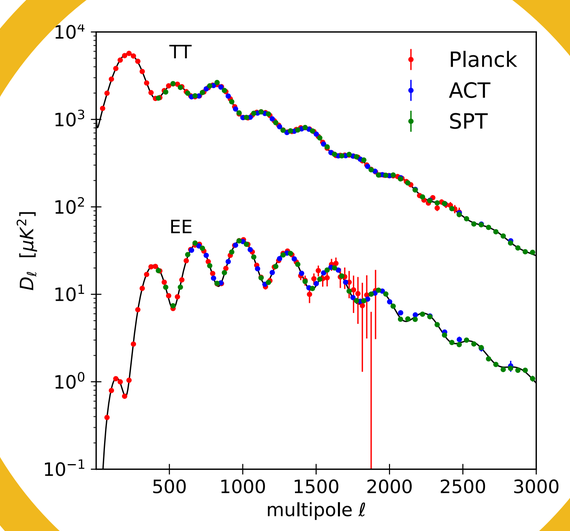
We present a joint analysis of Planck, ACT, and SPT data using a unified likelihood for CMB with common foregrounds and systematics:

➡ Reducing reliance on external priors
➡ Improves parameter robustness
➡ ΛCDM parameters remain stable (under different foreground templates)
➡ Increase uncertainties on ΛCDM extensions

Accurate foreground modelling is shown to be essential for future high-precision CMB surveys. The combined data are consistent with ΛCDM and reduce previously reported tensions such as non-zero curvature and excess lensing.



Posterior distributions for the ΛCDM parameters varying templates for the foreground models (in gray) as compared to the posteriors after marginalisation over the foreground models (in red).



T & E modes of Planck, ACT, SPT datasets used in [3]

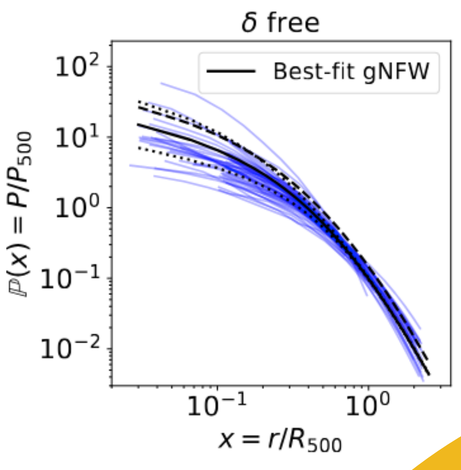
CLUSTER GAS PROFILE for tSZ power spectrum [2]
Muñoz-Echeverría et al, A&A 704 302 (2025)

In a self-similar model of structure formation, galaxy clusters share a universal thermal pressure profile when properly scaled by mass and redshift.

- New method to jointly fit universal profile and individual M500 masses of clusters, accounting for their mutual correlations.
- Application to 24 clusters from the CHEX-MATE XMM-Newton sample spanning $0.07 < z < 0.6$ and masses of $2–14 \times 10^{14}$ M⊙.

➡ Self-similar profile with low scatter and parameter correlations
➡ Well caracterised input to the tSZ power spectrum modelling

Individual data normalised pressure profiles for the 24 clusters when fitting the individual masses with dynamical mass estimates as priors. The solid black profile indicates the best-fit gNFW profile, with the dotted profiles showing the fitted intrinsic scatter. The dashed profiles correspond to the best-fit gNFW for the fixed mass case.

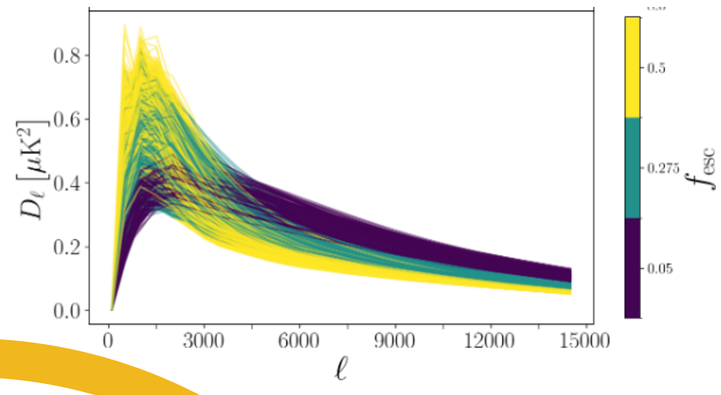


[4] Emulated kSZ power spectrum from SIMULATIONS
McBride et al, arXiv:2511.22309

The patchy kinetic SZ effect stems from CMB photons scattering off ionised bubbles during reionisation

- Analysing the 10 000 LoReLi simulations, we show its power spectrum traces the properties of ionising sources
- Building a kSZ emulator following galaxy properties

➡ Current and future CMB experiments measure the kSZ with sufficient precision to meaningfully constrain reionisation-era galaxy properties, including the ionising escape fraction - with a 14% uncertainty
➡ kSZ additionally provides an independent measurement of the CMB optical depth with near–cosmic-variance-limited precision



The catalogue of patchy kSZ angular power spectra reconstructed from the LoReLi II simulations, coloured by the value of the escape fraction f_{esc}

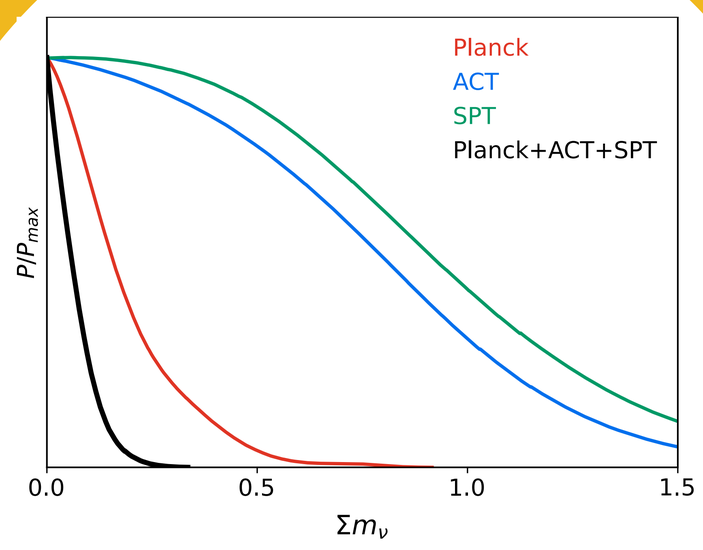
[4] *McBride, Lisa ; Gorce, Adélie ; Douspis, Marian ; Meriot, Romain et al.*, "**Astrophysical constraints from future measurements of the kinetic Sunyaev-Zel'dovich power spectrum**", arXiv:2511.22309

[3] *M. Tristram, M. Douspis, A. Gorce, S. Henrot-Versillé, L. T. Hergt, S. Ilić, L. McBride, M. Muñoz-Echeverría, E. Pointecouteau, L. Salvati,* **"Combining CMB datasets with consistent foreground modelling"**, arXiv:2511.04733

[2] *M. Muñoz-Echeverría, E. Pointecouteau et al, "***CHEX-MATE: towards a consistent universal pressure profile and cluster mass reconstruction***", 2025A&A...704A.302M*

[1] *S. Ilić, M. Tristram, M. Douspis, A. Gorce, S. Henrot-Versillé, L. T. Hergt, M. Langer, L. McBride, M. Muñoz-Echeverría, E. Pointecouteau, L. Salvati,* **"Reconstructing the epoch of reionisation with Planck PR4"**, 2025A&A...700A..26I

[3]



NEXT

To get maximum information from the CMB datasets we will use our common likelihood with cosmology dependent extragalactic foregrounds based on our halo model (tSZ[i], CIB[ii,iii], tSZxCIB) and semi-analytical model (kSZ[iv]).

[i] Douspis et al 2022
[ii] Manyiar et al 2021
[iii] Zagatti et al 2024
[iv] Gorce et al 2022