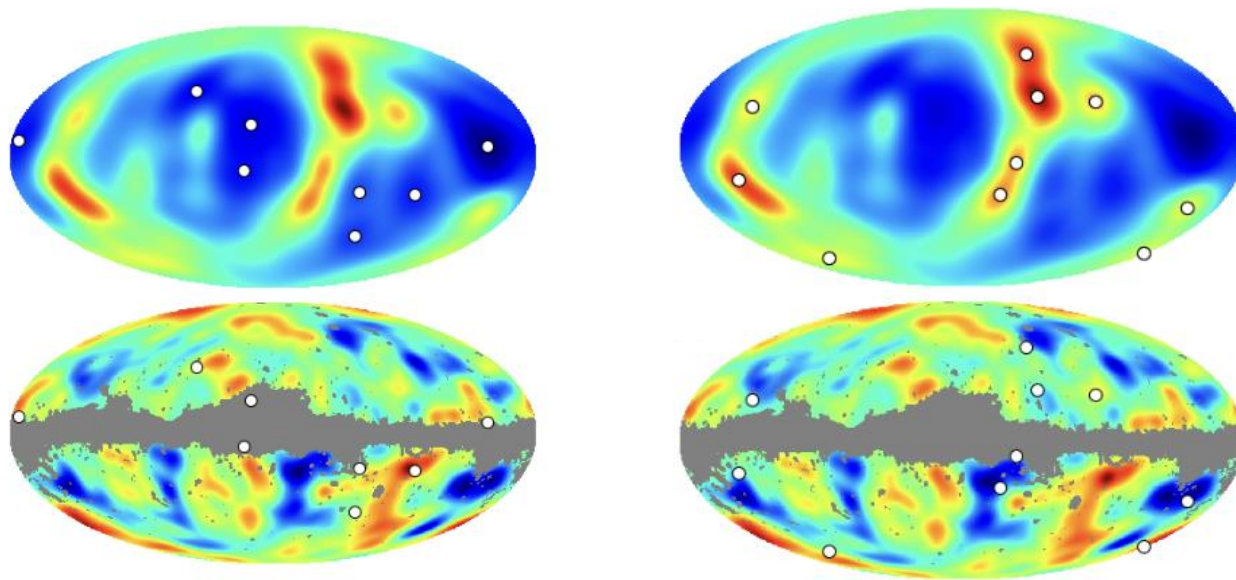


Unexplained Correlation between CMB and Local Matter Density Field



Marcos Cruz

Instituto de Física de Cantabria

Dark Matter 2025, Santander

- <https://arxiv.org/pdf/2407.17599>






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Unexplained correlation between the Cosmic Microwave Background temperature and the local matter density distribution

M. Cruz ^{a,*} E. Martínez-González ^a C. Gimeno-Amo ^{a,b} B.J. Kavanagh ^a
and M. Tucci ^c

^a*Instituto de Física de Cantabria (CSIC-Universidad de Cantabria),
Avda. de los Castros s/n, 39005 Santander, Spain*

^b*Departamento de Física Moderna, Universidad de Cantabria,
Avda. de los Castros s/n, 39005 Santander, Spain*

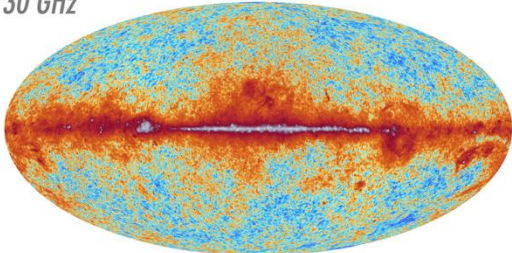
^c*Department of Astronomy, University of Geneva,
ch d'Écogia 16, 1290 Versoix, Switzerland*

E-mail: cruz@ifca.unican.es, martinez@ifca.unican.es,
gimenoc@ifca.unican.es, kavanagh@ifca.unican.es, marco.tucci@unige.ch

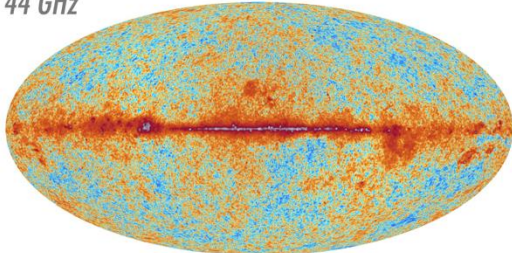
CMB: Planck Data

The 2015 Planck view of the sky

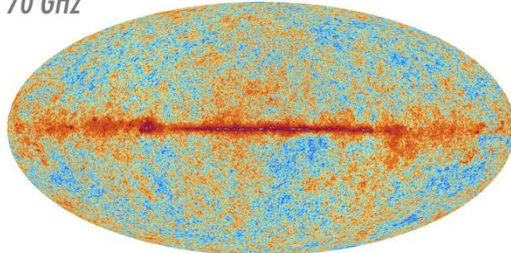
30 GHz



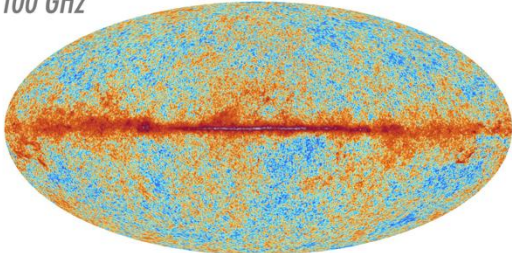
44 GHz



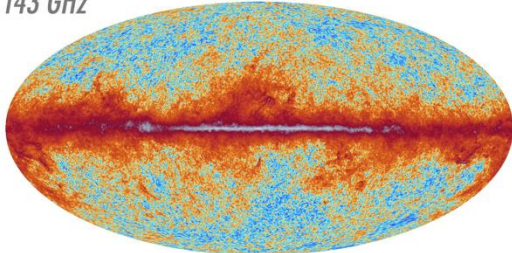
70 GHz



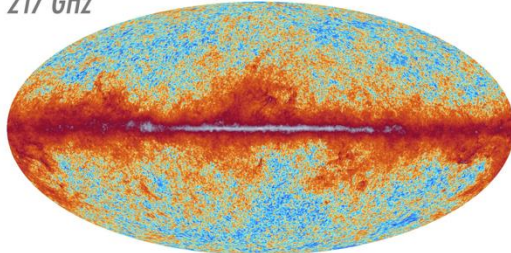
100 GHz



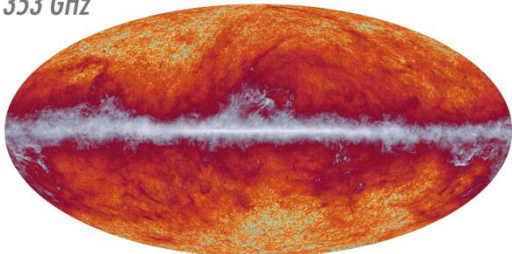
143 GHz



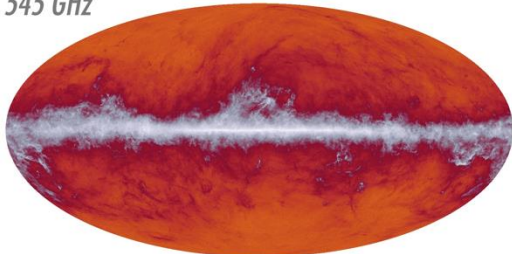
217 GHz



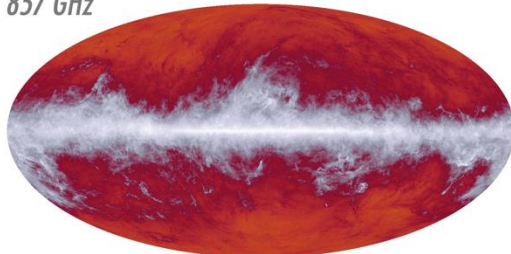
353 GHz



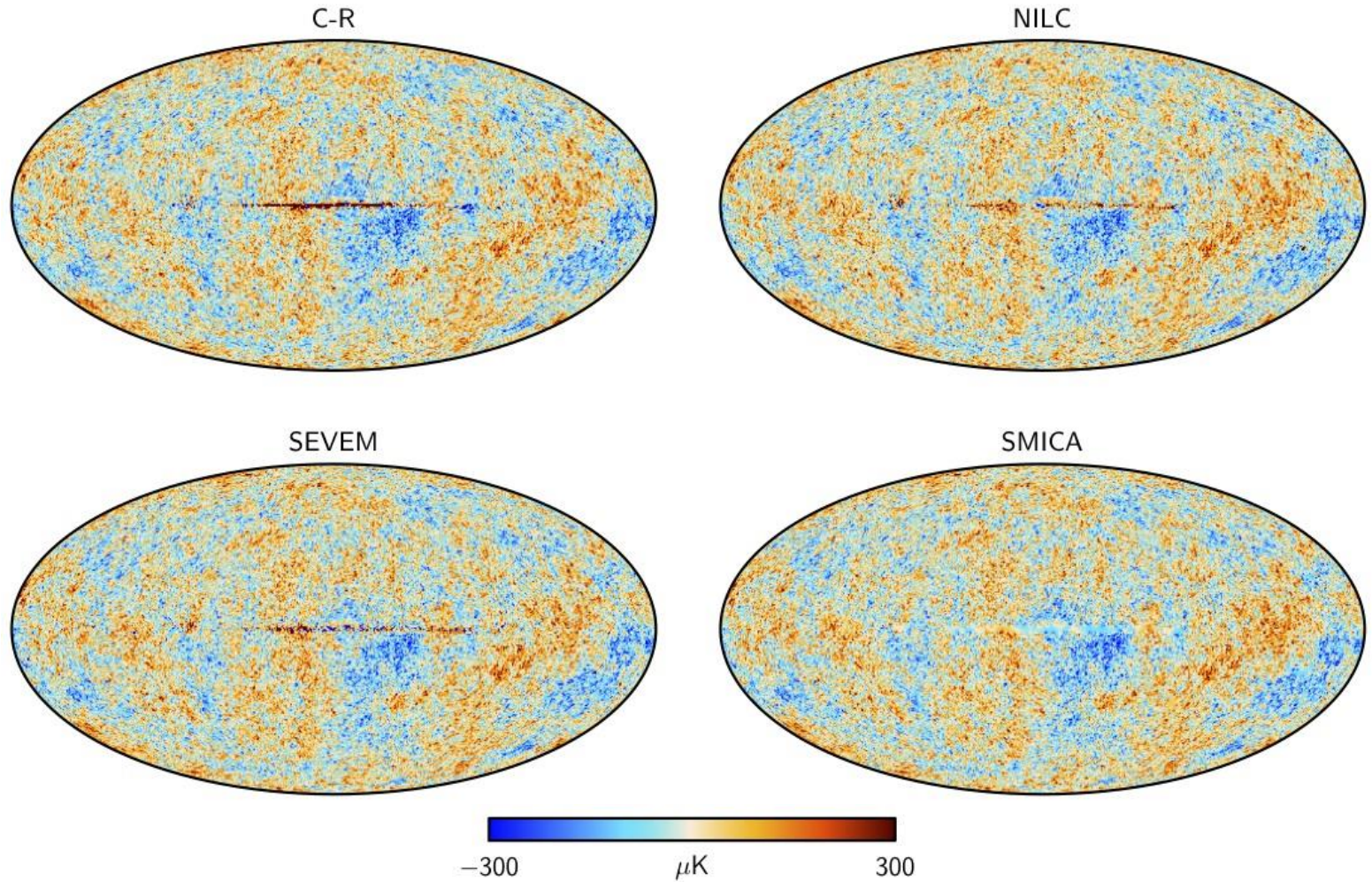
545 GHz



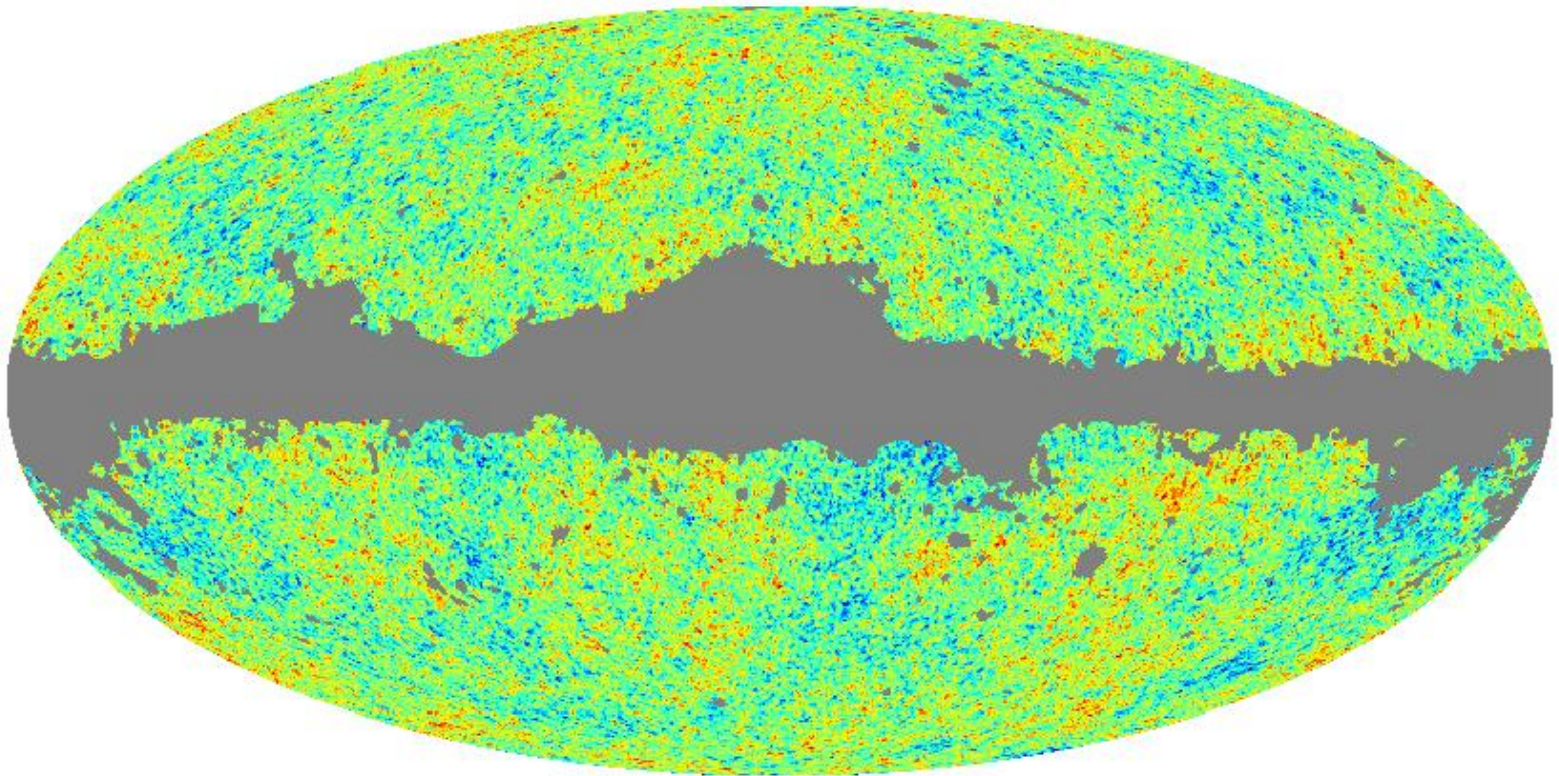
857 GHz



Clean CMB maps



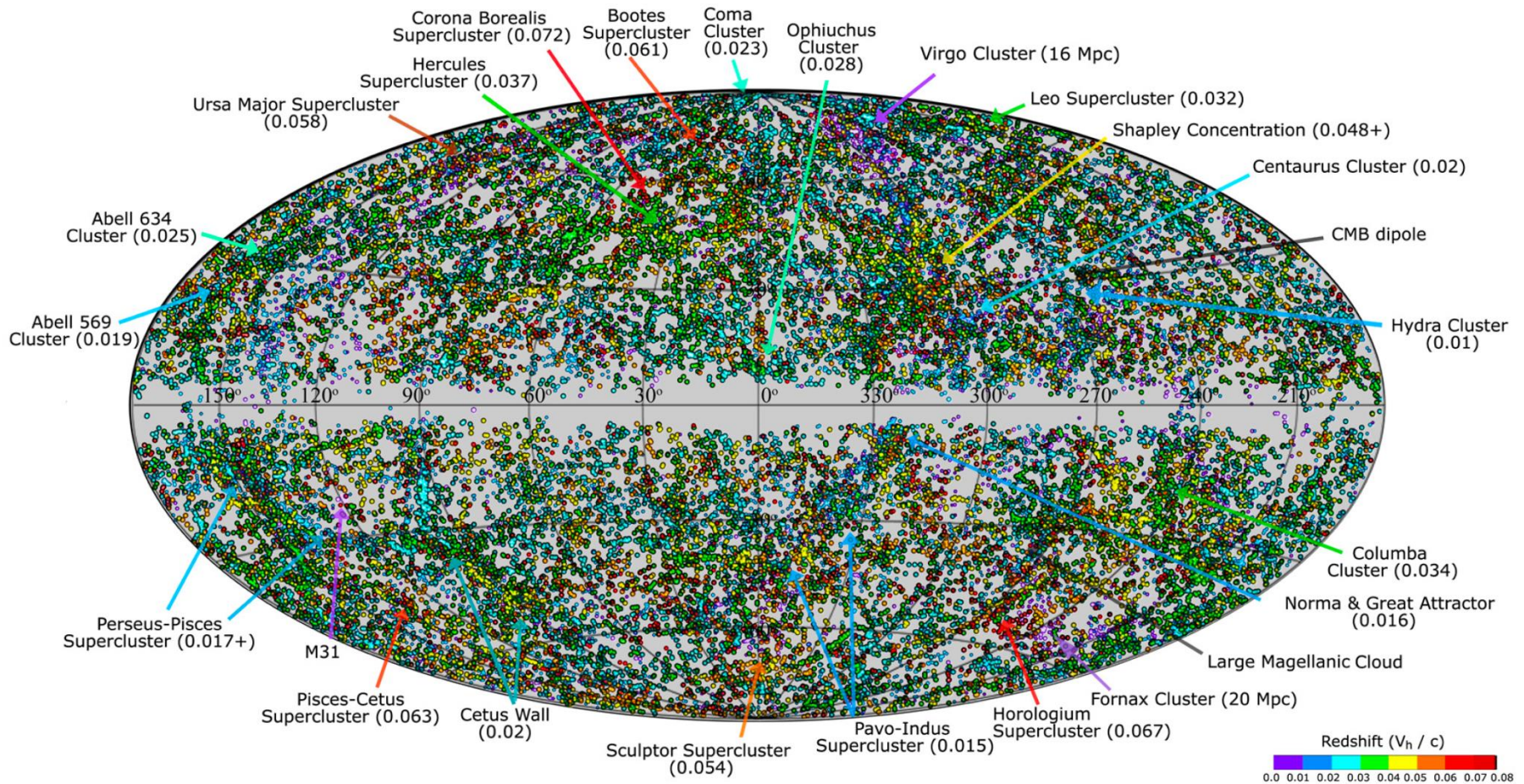
Common Mask



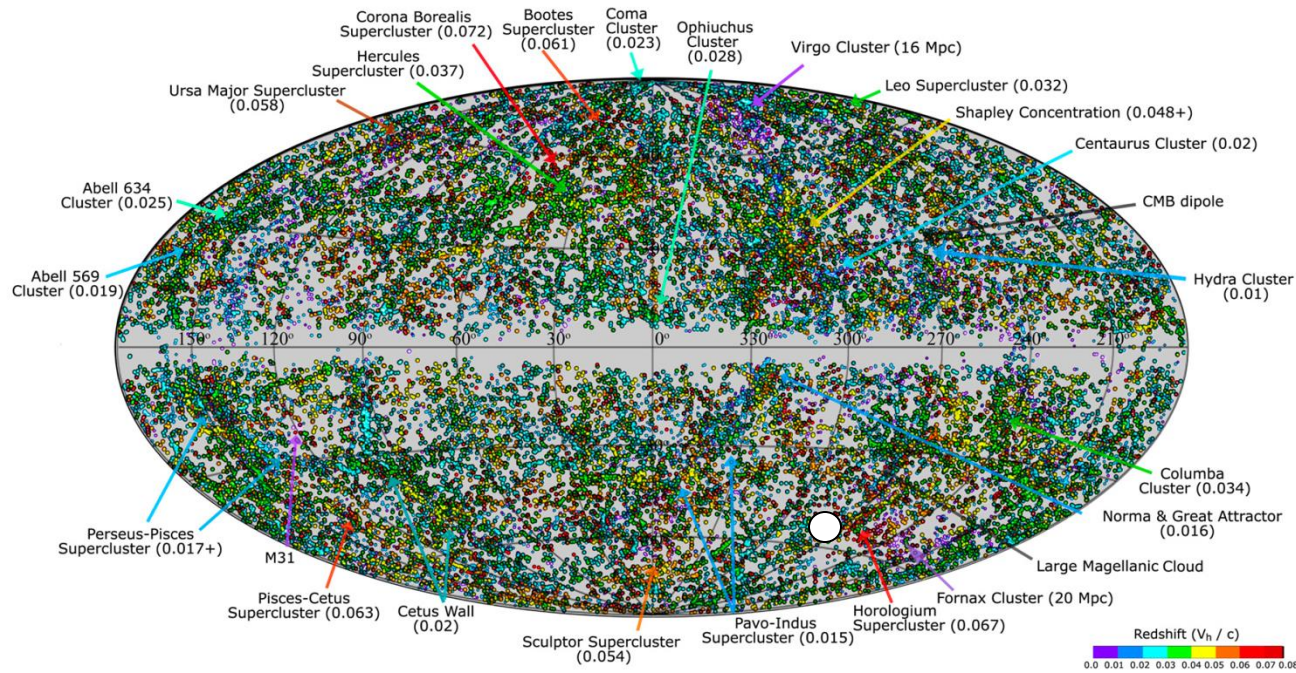
2 MASS Redshift Survey (2MRS)

- 44 599 galaxies, $z \leq 0.1$, $K \leq 11.75$ mag, $b > |5^\circ|$
- The catalogue includes
 - redshifts
 - isophotal radii
 - morphological types 20 860 objects, $K \leq 11.254$ mag , $b > |10^\circ|$

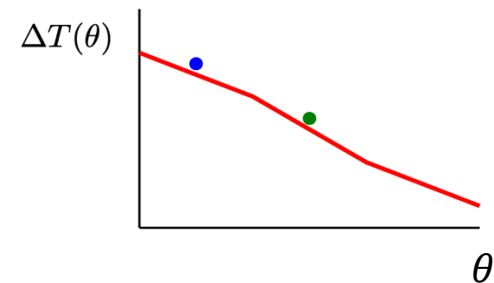
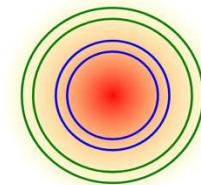
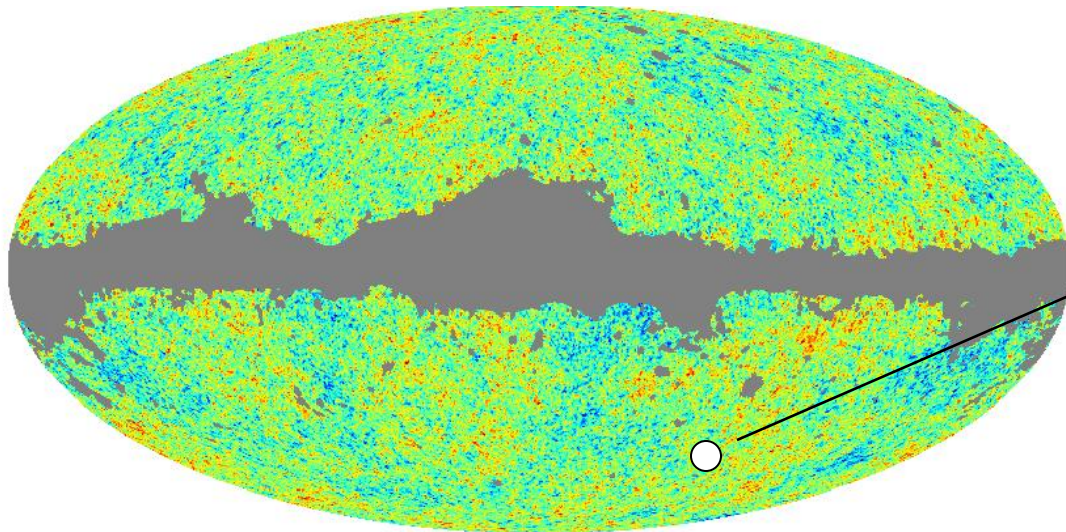
2 MASS Redshift Survey (2MRS)



CMB mean radial profile on galaxy positions

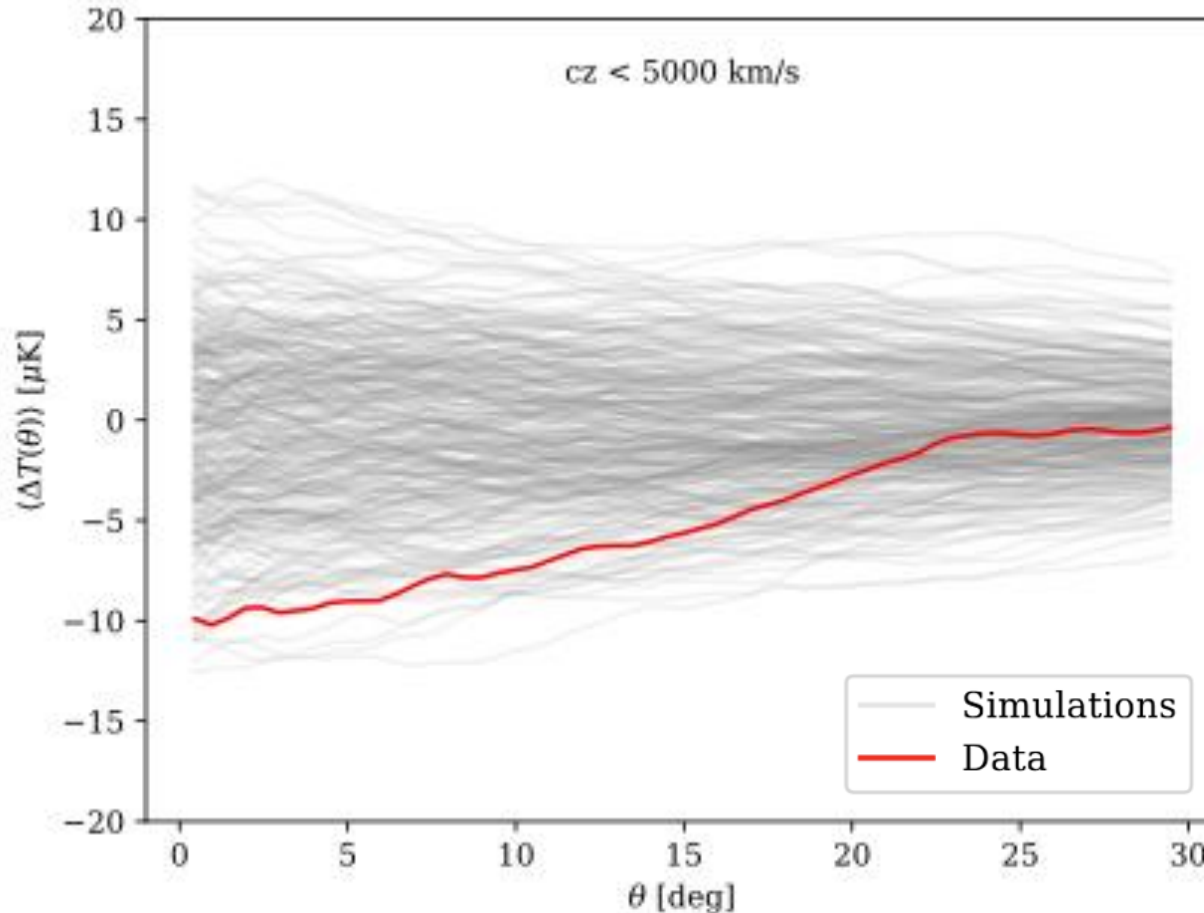


Huadra *et al.*



CMB mean radial profile on galaxy positions

$$v = cz = 5000 \text{ km s}^{-1} \Rightarrow z \approx 0.017 \Rightarrow d \approx 50 \text{ Mpc } h^{-1}$$

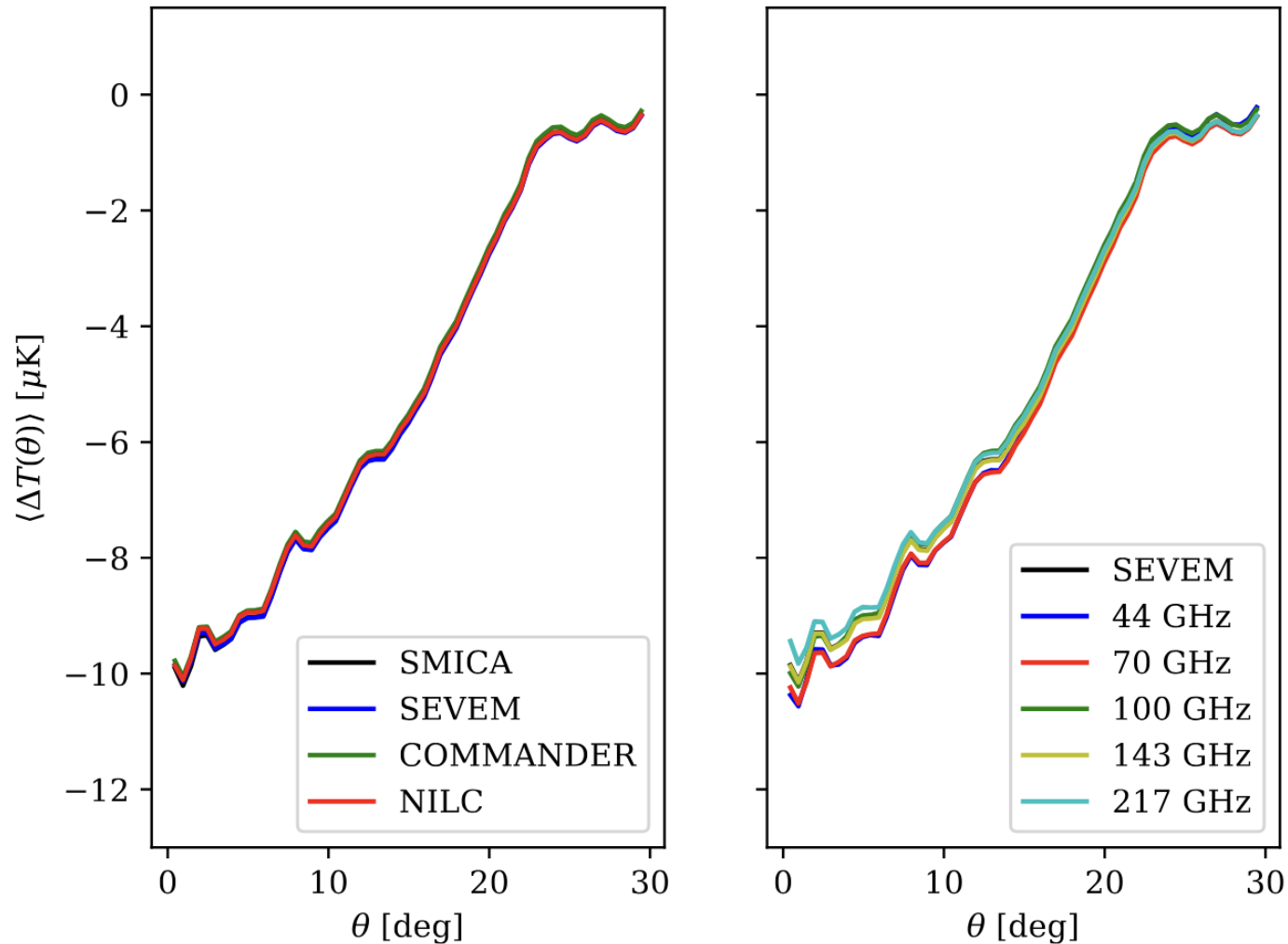


Luparello et al 2023

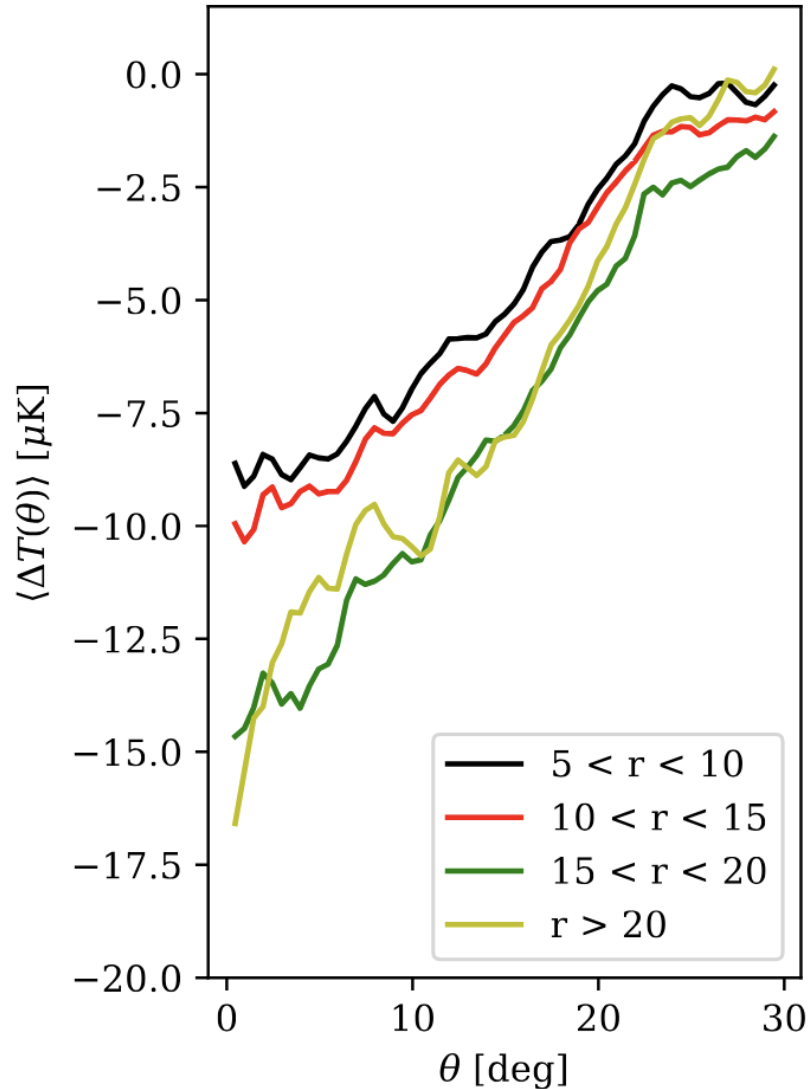
Hansen et al 2024

Cruz et al 2025

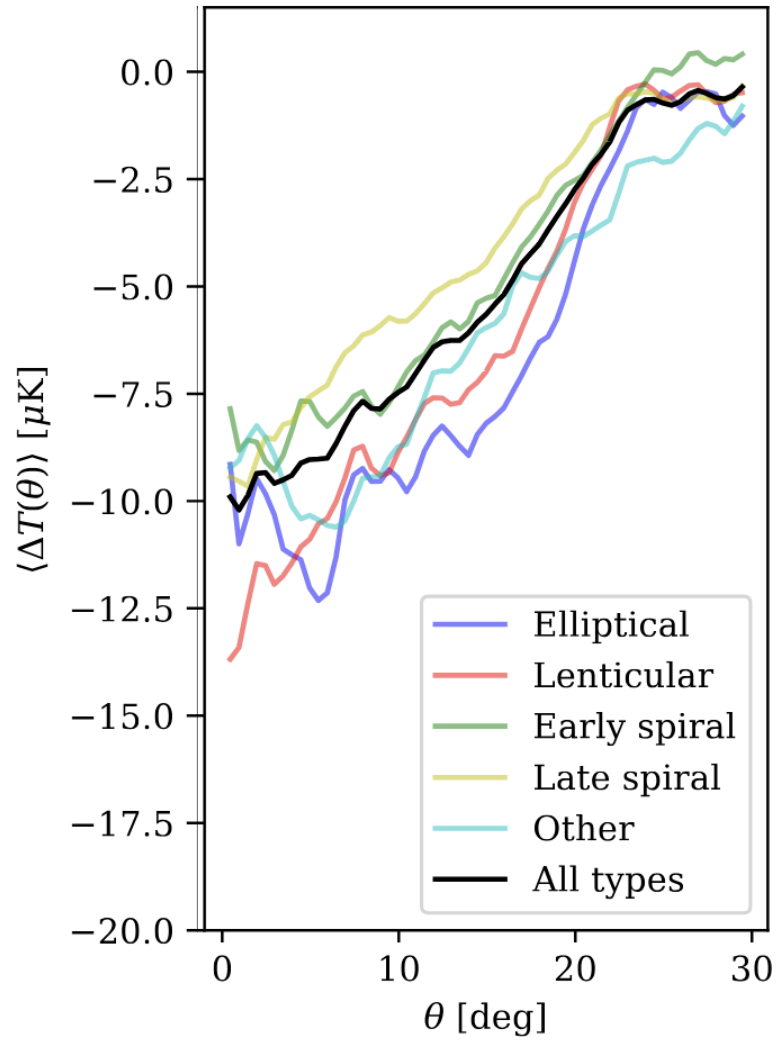
Cleaning method and frequency dependence



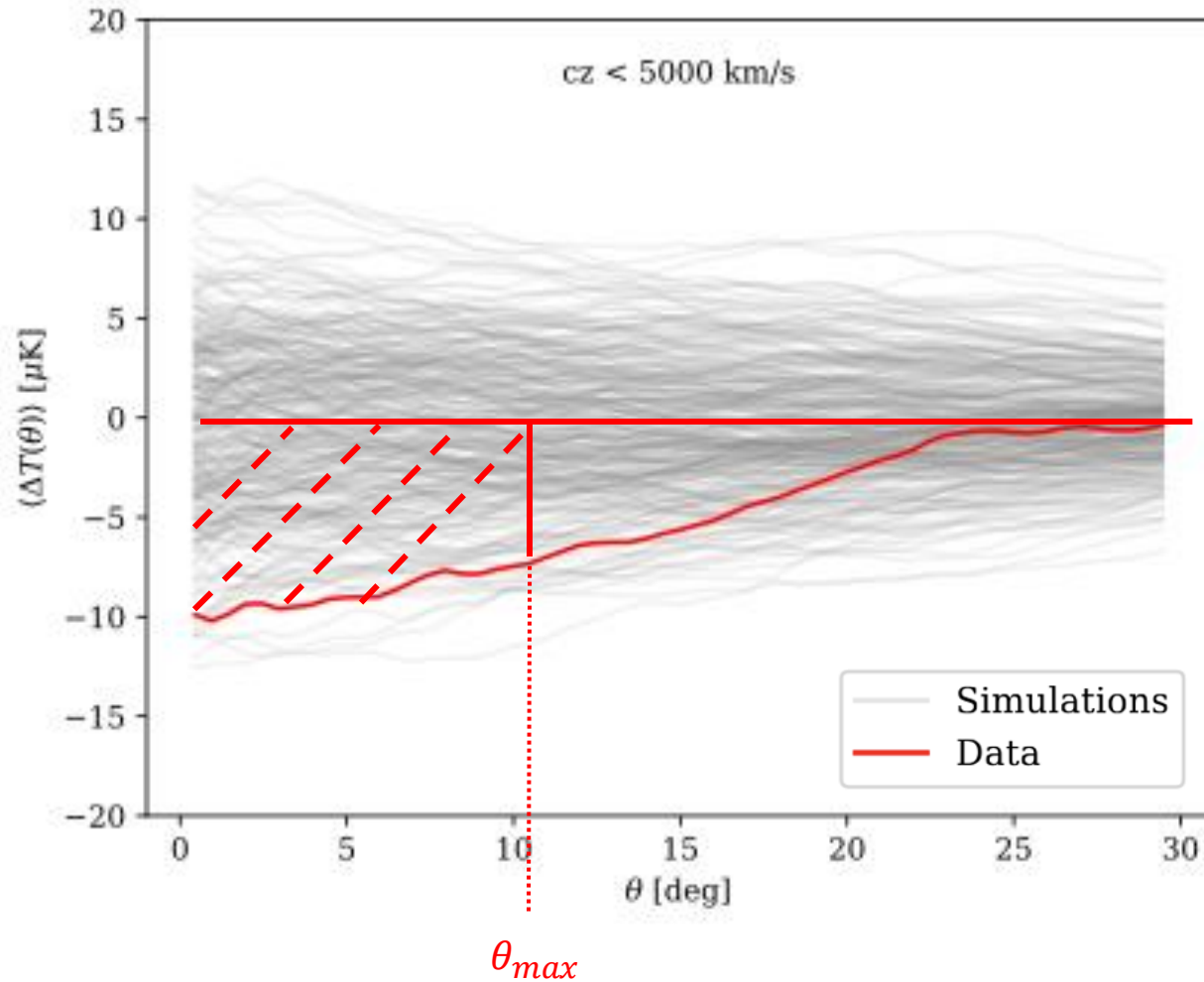
Galaxy size dependence



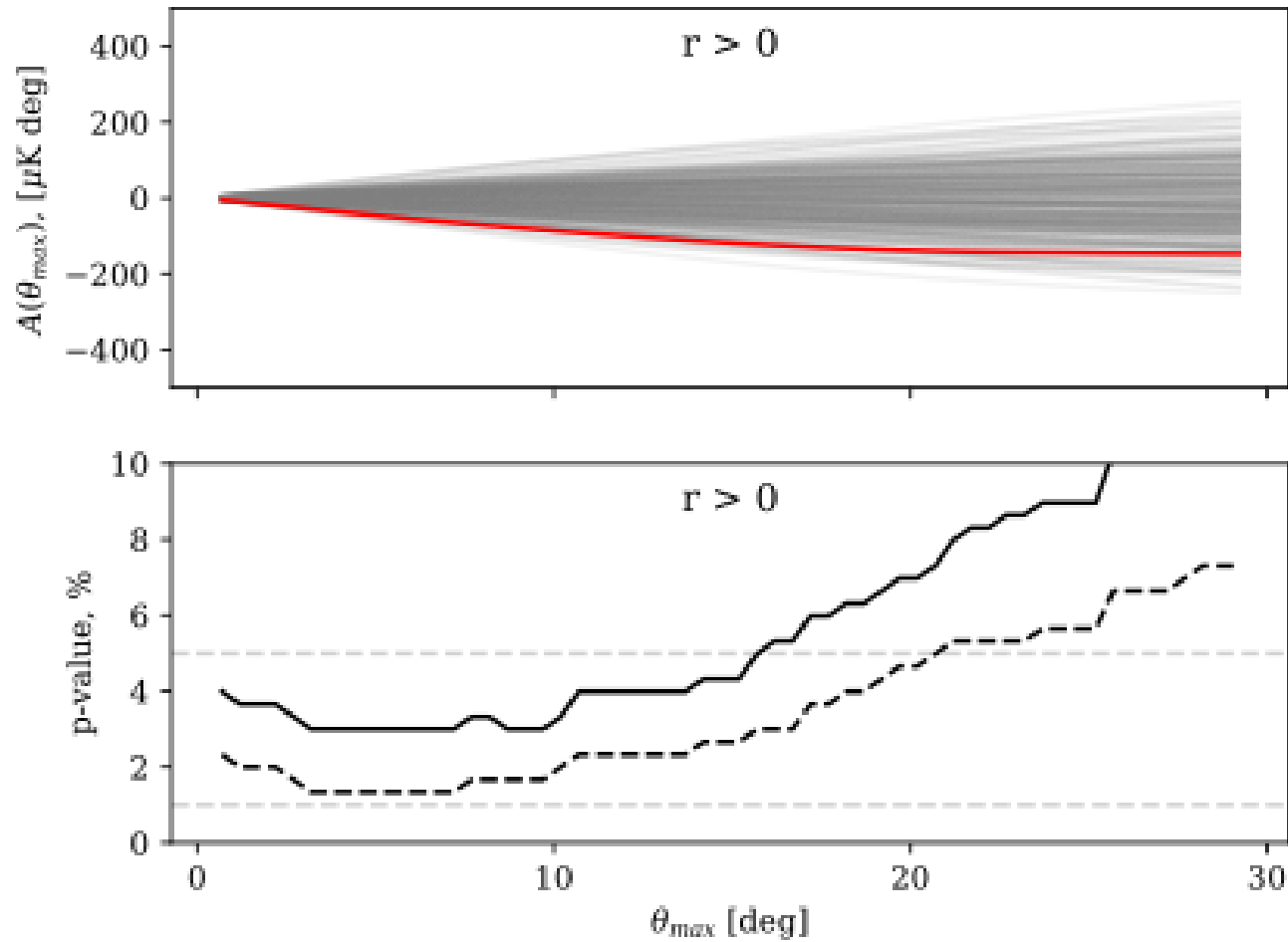
Galaxy type dependence



Significance analysis: Area



Significance analysis: Area



Matter density correlation?

- No frequency dependence
- No dependence on galaxy type
- Signal present for all galaxy sizes
- Signal extends over large angular scale

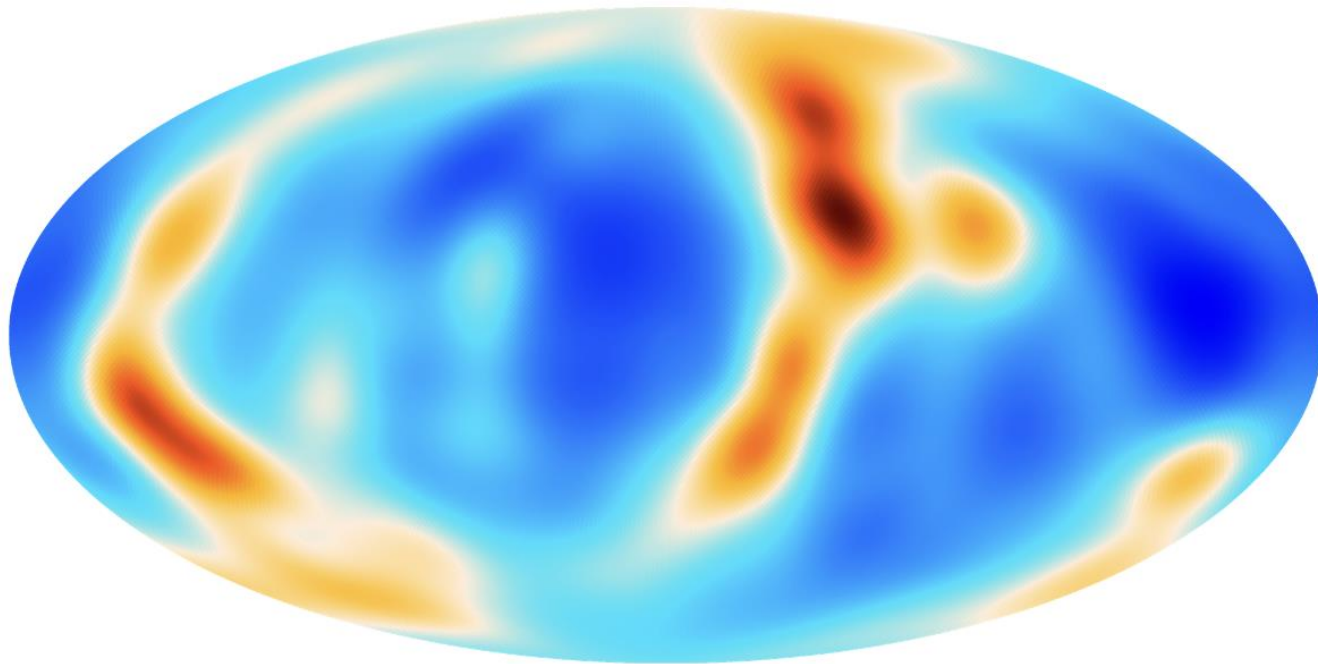
- Matter density correlation?

COntstrained Realizations from All-sky Surveys CORAS

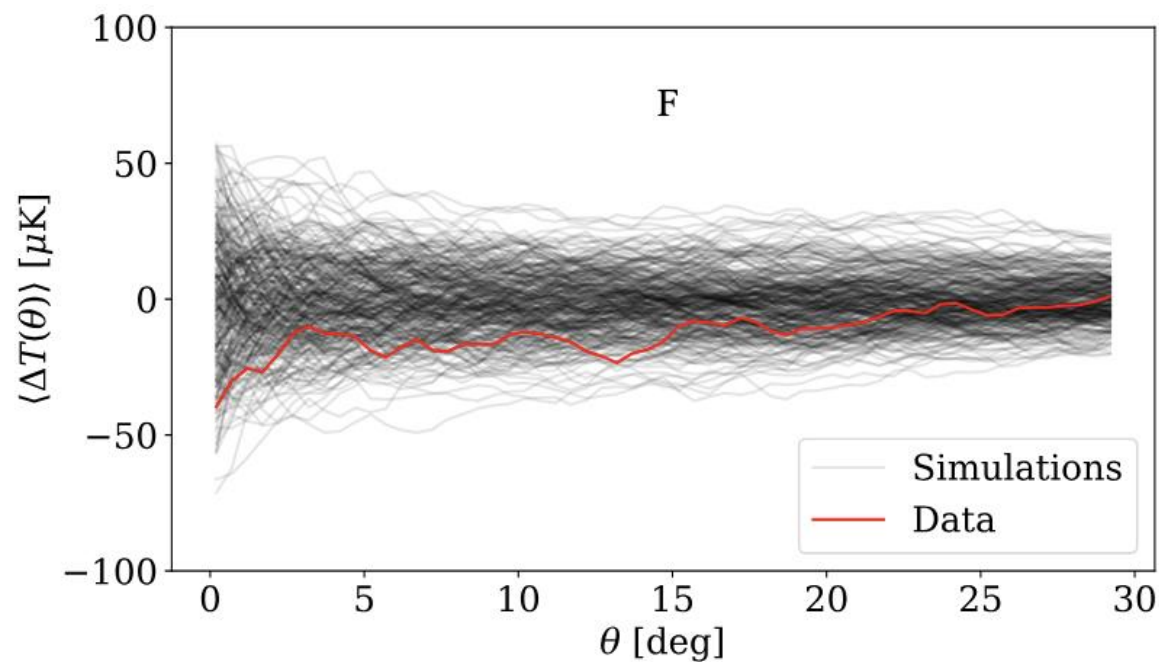
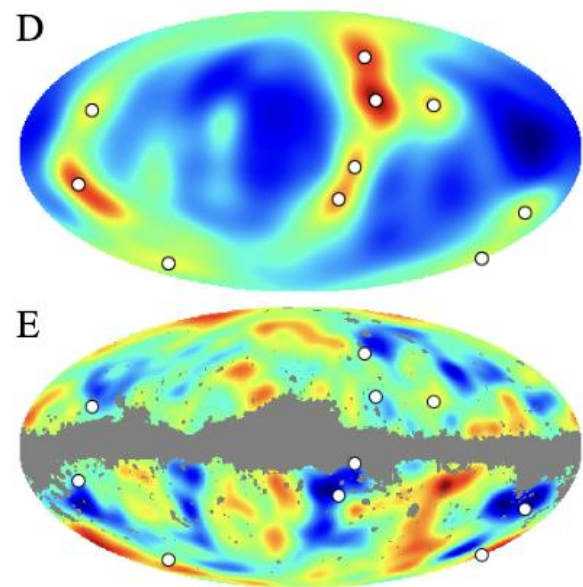
- 2MRS matter density and peculiar velocity field
- Regular cartesian grid from -200 Mpc/h to $+200$ Mpc/h in steps of 2 Mpc/h.
- We generate projected density maps

CORAS projected density map

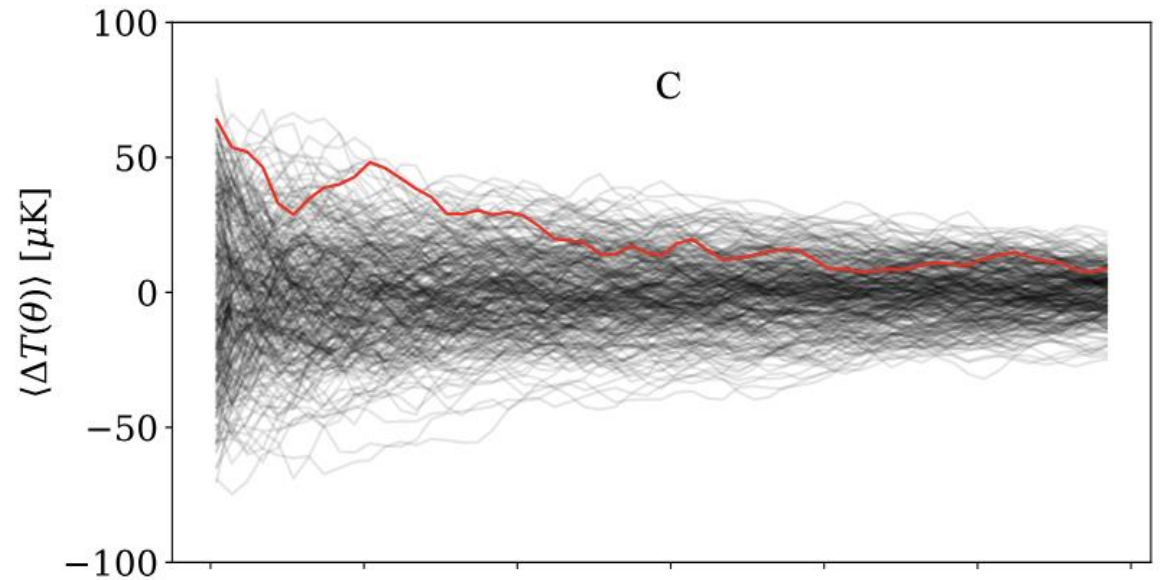
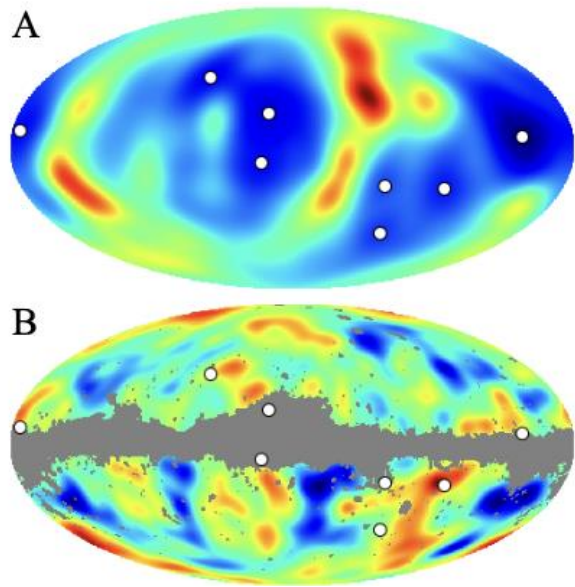
0 – 50 Mpc/ h



CMB mean radial profile on density maxima positions



CMB mean radial profile on density minima positions



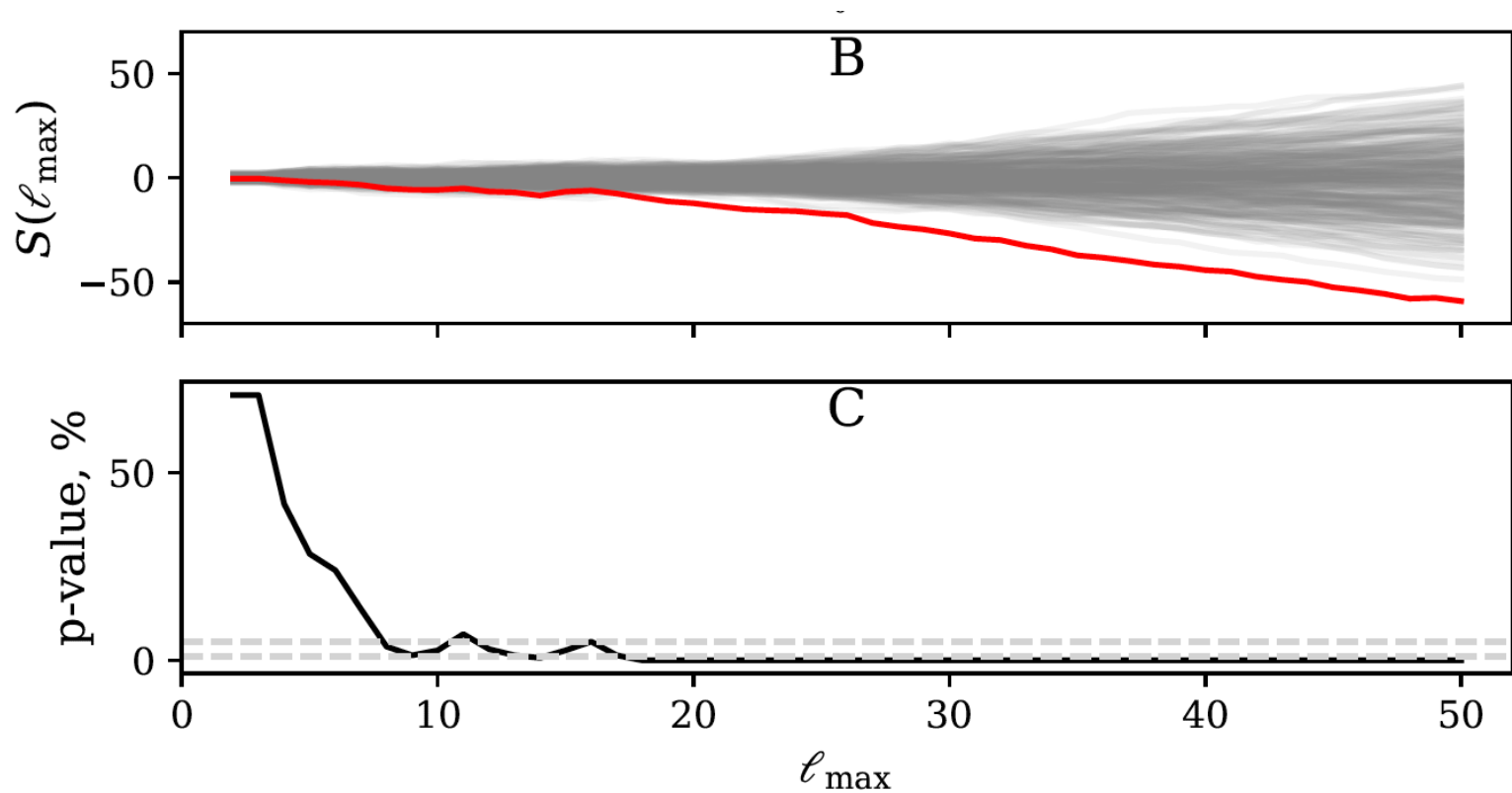
Significance: Correlation in harmonic space

$$\frac{\Delta T}{T_0}(\vec{n}) = \frac{T - T_0}{T_0}(\vec{n}) = \sum_{\ell=1}^{\infty} \sum_{m=-\ell}^{\ell} a_{\ell m} Y_{\ell m}(\vec{n}), \quad \ell \sim 180^\circ / \theta$$

$$X_\ell = \frac{1}{2\ell + 1} \sum_{m=-\ell}^{\ell} a_{\ell m}^{\text{CMB}} a_{\ell m}^{\text{density*}}$$

$$S(\ell_{\text{max}}) = \sum_{\ell=2}^{\ell_{\text{max}}} \frac{X_\ell}{\sigma_\ell}$$

Significant correlation for $\ell_{max} \gtrsim 15$



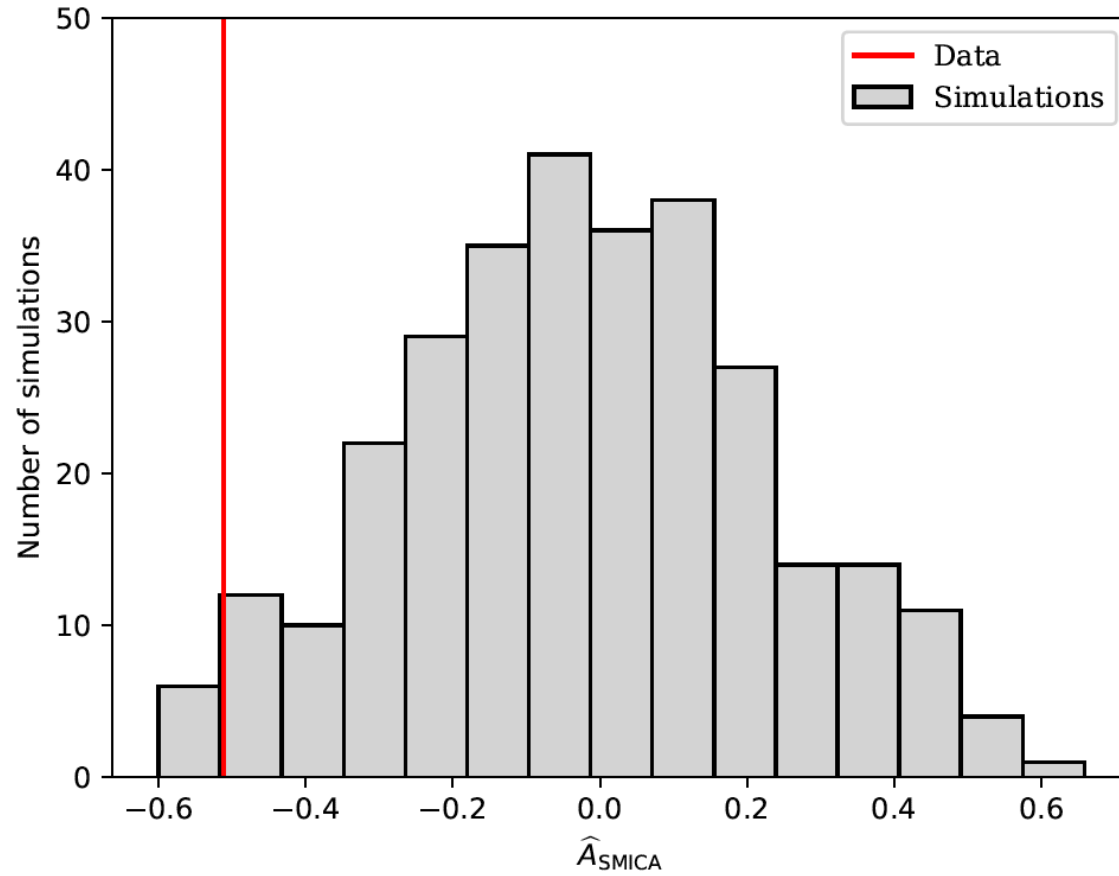
Bayesian template fit

$$\chi^2 = (\mathbf{D} - \mathbf{A}\mathbf{T})^T \mathbf{\Sigma}^{-1} (\mathbf{D} - \mathbf{A}\mathbf{T}),$$

- \mathbf{D} = Data = Planck Data
- \mathbf{T} = Template = Projected density map
- \mathbf{A} = Amplitude
- $\mathbf{\Sigma}$ = CMB Covariance matrix

$$\Sigma_{ij} = \sum_{\ell=0}^{\ell_{\max}} \frac{2\ell + 1}{4\pi} C_{\ell} b_{\ell}^2 P_{\ell}(\cos \theta_{ij})$$

Best fit amplitude: $A = -0.5$



Bayesian model selection

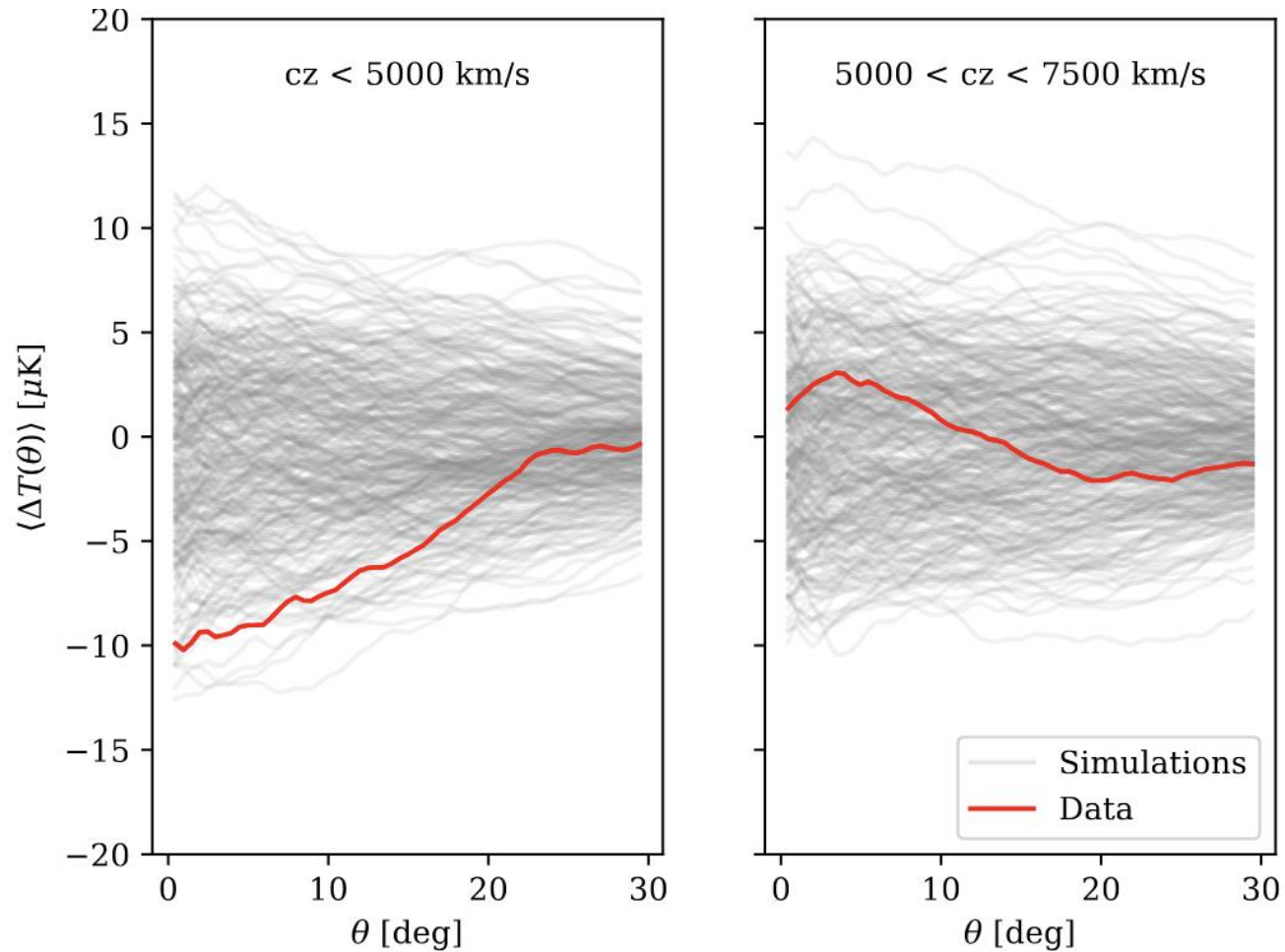
- $H_0: A = 0 \Rightarrow$ Template (density map) not present
- $H_1: A \neq 0 \Rightarrow$ Template (density map) present

Bayesian Evidence: $\mathcal{Z} = \int \mathcal{L}(A)\pi(A) dA$

Bayes Factor: $\mathcal{B} \Rightarrow \mathcal{Z}_1/\mathcal{Z}_0$

- Consider flat prior – $-2 < A < 2$
- Bayes factor for CMB simulations: p -value 4% – 5%

Discussion: No effect beyond 50 Mpc/h



Discussion

- Physical effect only affecting local Universe?
- Statistical Fluke due to *a posteriori* statistics effects?
 - Significance in 1% - 5% range
 - No correlation beyond 50 Mpc/h
- Correlation can not be accurately determined beyond 50 Mpc/h
 - CORAS dark matter distribution is not well determined beyond 50 Mpc/h (Lilow & Nusser 2021)

Discussion

- Thermal SZ: frequency dependence
- Kinematic SZ: Low amplitude $\ll 10 \mu K$
- ISW: Positive correlation at low z , not anticorrelation
- Patchy screening: Damping, not anticorrelation
- Dark Matter?
 - Thomson-like scattering? Damping, not correlation
 - Photon-axion conversion? Frequency dependence
 - Compton-like scattering with Millicharged DM?

References

Monthly Notices

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ROYAL ASTRONOMICAL SOCIETY




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Advance Access publication 2022 December 2

<https://doi.org/10.1093/mnras/stac3491>



The cosmic shallows – I. Interaction of CMB photons in extended galaxy haloes

Heliana E. Luparello ^{1,*}, Ezequiel F. Boero,^{1,2} Marcelo Lares ^{1,2}, Ariel G. Sánchez ^{3,4} and Diego Garcia Lambas^{1,2}

¹Instituto de Astronomía Teórica y Experimental, CONICET-UNC, Córdoba, X5000BGR, Argentina

²Observatorio Astronómico de Córdoba, UNC, Córdoba, X5000BGR, Argentina

³Max-Planck-Institut für extraterrestrische Physik, Giessenbachstr. 1, D-85748 Garching, Germany

⁴Universitäts-Sternwarte München, Fakultät für Physik, Ludwig-Maximilians-Universität München, Scheinerstrasse 1, D-81679 München, Germany

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**Astronomy
&
Astrophysics**

LETTER TO THE EDITOR

A possible common explanation for several cosmic microwave background (CMB) anomalies: A strong impact of nearby galaxies on observed large-scale CMB fluctuations

Frode K. Hansen^{1,2}, Ezequiel F. Boero^{2,3}, Heliana E. Luparello², and Diego Garcia Lambas^{2,3}

¹ Institute of Theoretical Astrophysics, University of Oslo, PO Box 1029, Blindern, 0315 Oslo, Norway

e-mail: frodekh@astro.uio.no

² Instituto de Astronomía Teórica y Experimental, CONICET-UNC, Córdoba, Argentina

³ Observatorio Astronómico de Córdoba, UNC, Córdoba, Argentina

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CrossMark

Does the Correlation between 2MRS Galaxies and the CMB Indicate an Unmodeled CMB Foreground?

Graeme E. Addison 

The William H. Miller III Department of Physics and Astronomy, Johns Hopkins University, 3400 N. Charles St., Baltimore, MD 21218-2686, USA;

gaddison@jhu.edu

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A $p < 0.0001$ detection of CMB cooling in galactic halos and its possible relation to dark matter.

Frode K. Hansen¹, Diego Garcia Lambas^{2,3,4}, Heliana E. Luparello², Facundo Toscano² and Luis A. Pereyra²

¹ Institute of Theoretical Astrophysics, University of Oslo, PO Box 1029 Blindern, 0315 Oslo, Norway, e-mail: frodekh@astro.uio.no

² Instituto de Astronomía Teórica y Experimental (IATE), CONICET-UNC, Córdoba, Argentina

³ Observatorio Astronómico de Córdoba, UNC, Córdoba, Argentina

⁴ Comisión Nacional de Actividades Espaciales (CONAE), Córdoba, Argentina

March 14, 2025