Assessing tensions in CMB polarization by extending the Minkowski Functionals framework

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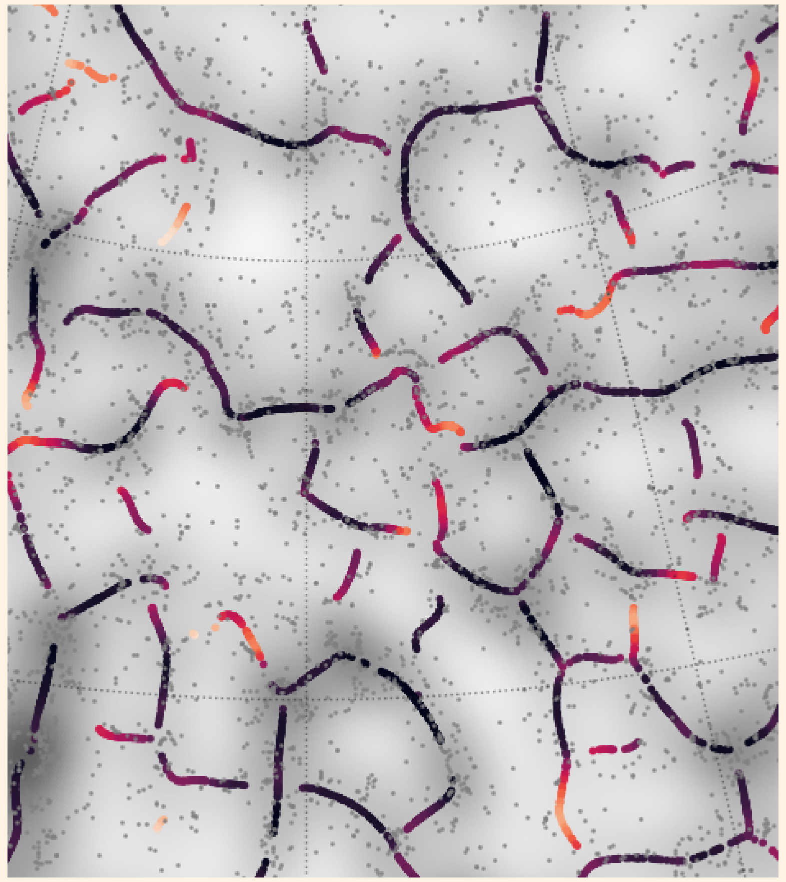
Tensions in Cosmology — September 2022 — EISA, Corfu, Greece

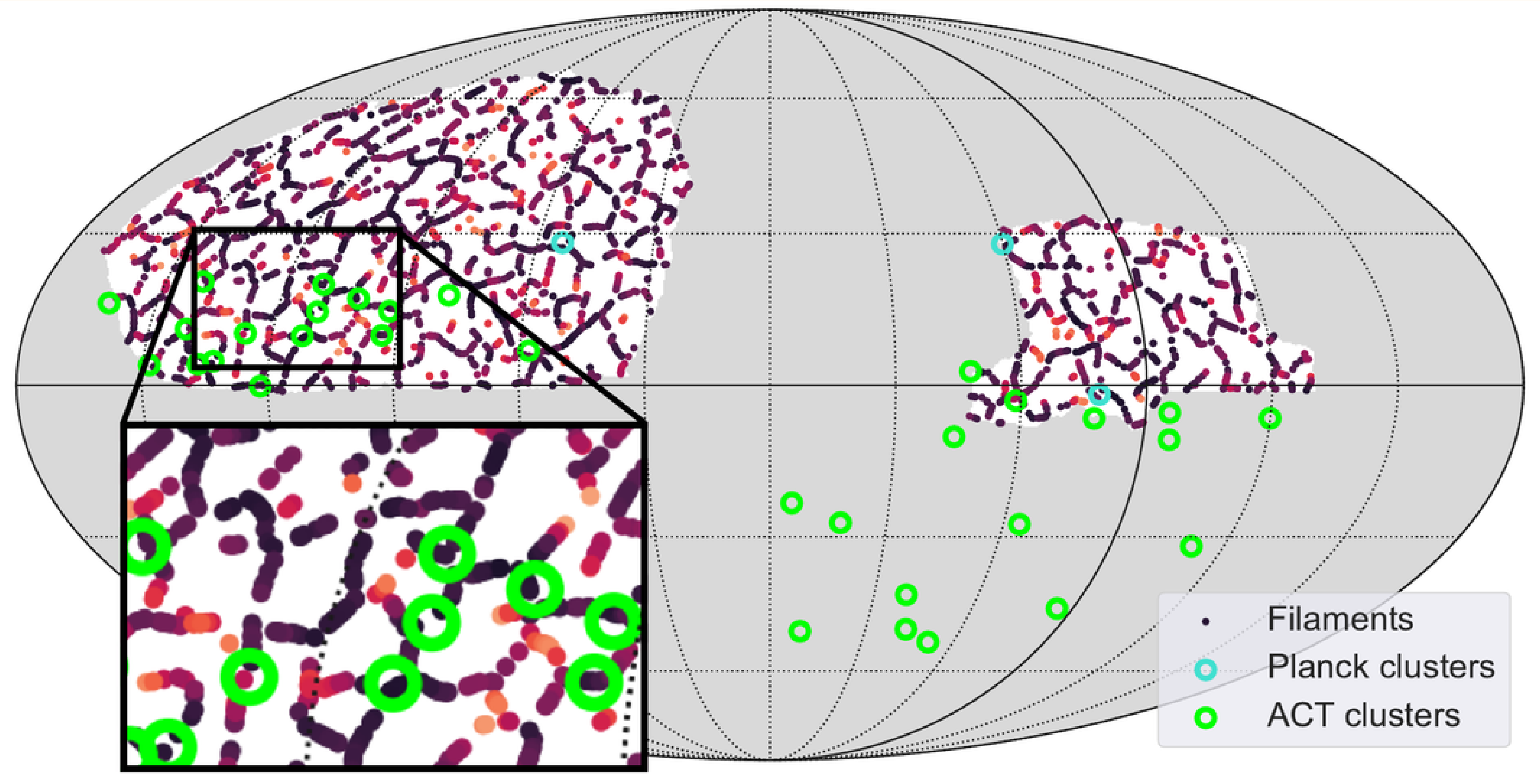
We produced a Cosmic Filaments catalogue

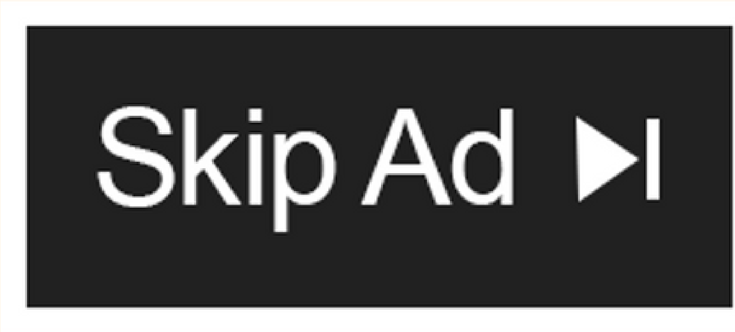
- Publicly available: www.javiercarron.com/catalogue
- *0.05 < z < 2.2*
- Promising results in different topics

A novel cosmic filament catalogue from SDSS data★

Javier Carrón Duque[1,2], Marina Migliaccio[1,2], Domenico Marinucci[3], and Nicola Vittorio[1,2]





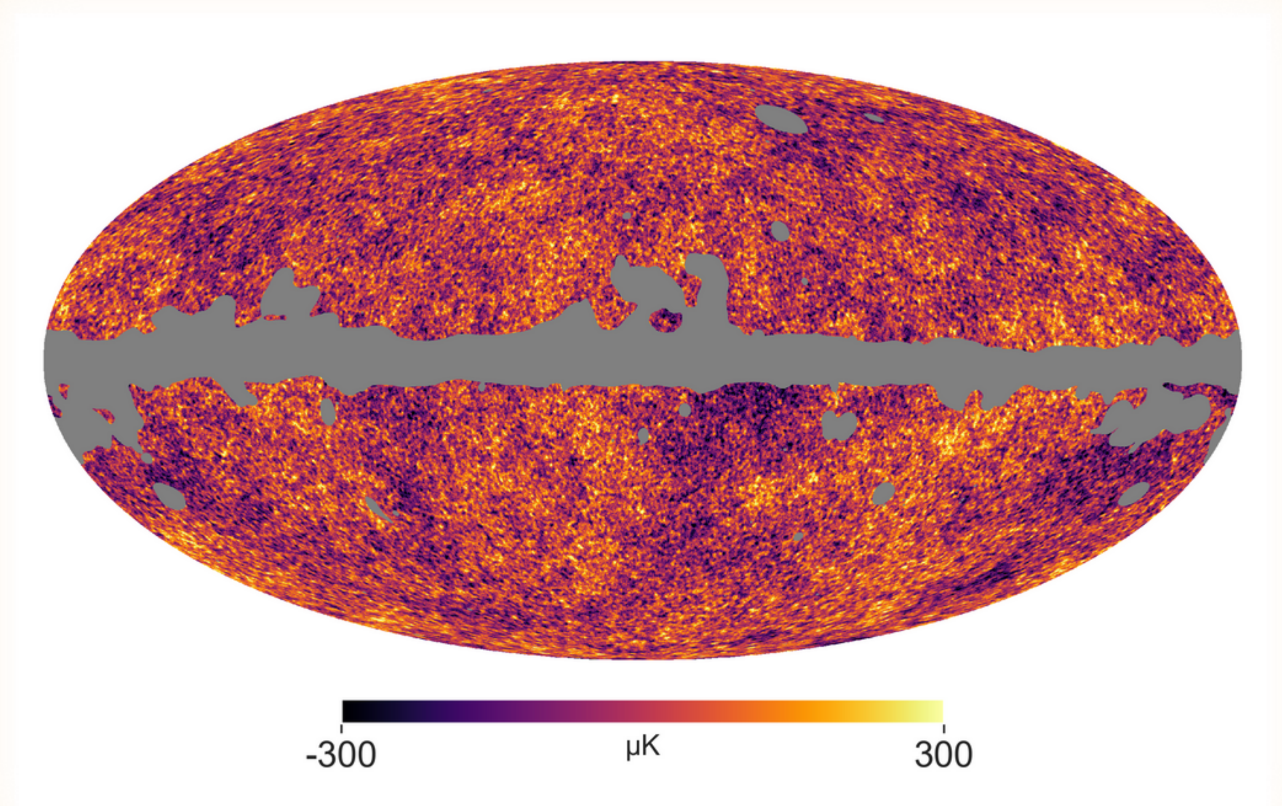


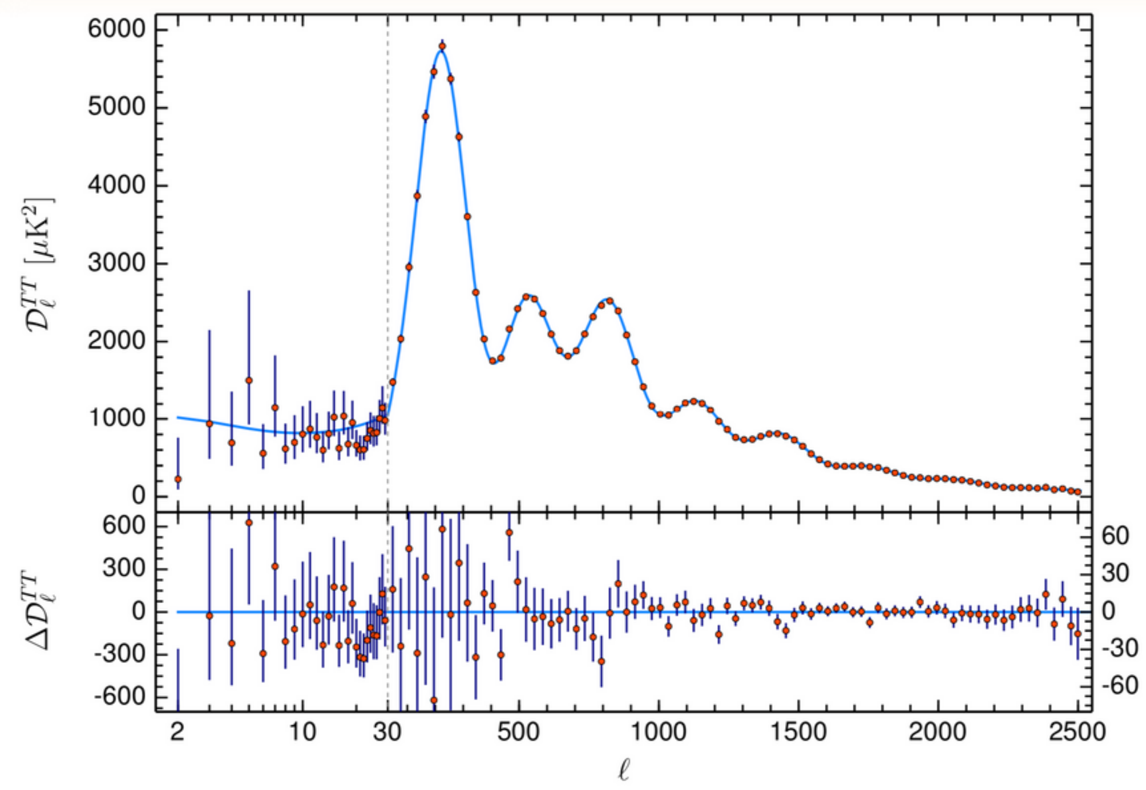
Outline

- Introduction
- Minkowski Functionals on CMB polarization
- Other applications of Minkowski Functionals
- Conclusions

Gaussian fields are easy to describe

- Every point → realization of Gaussian distribution
- Physical process is described by the covariance function (equivalently, power spectrum)





Source: Planck Collaboration

- Blind to non—Gaussianity

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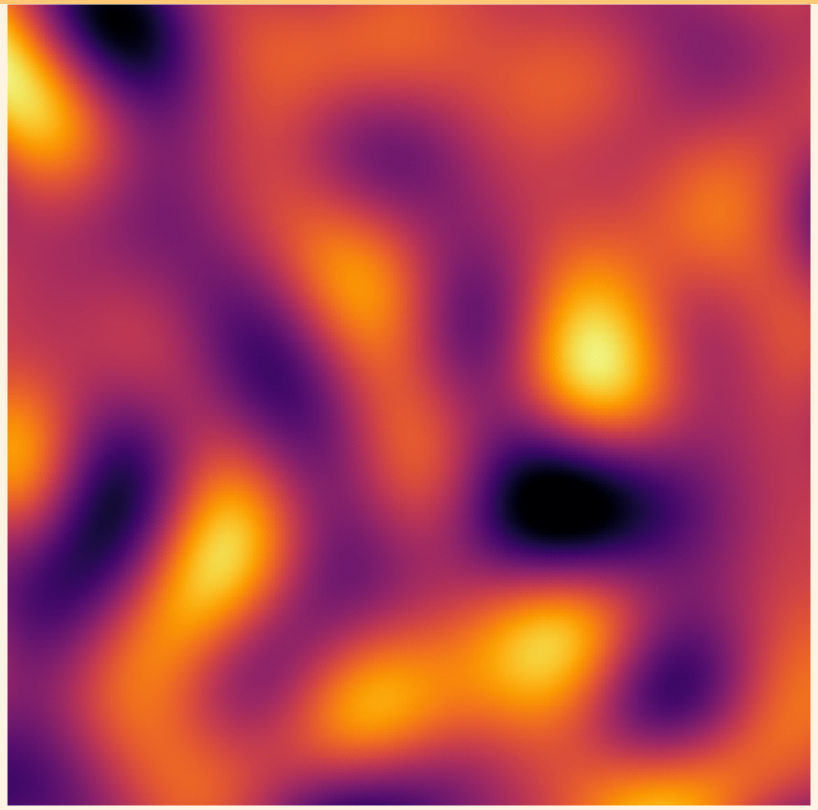
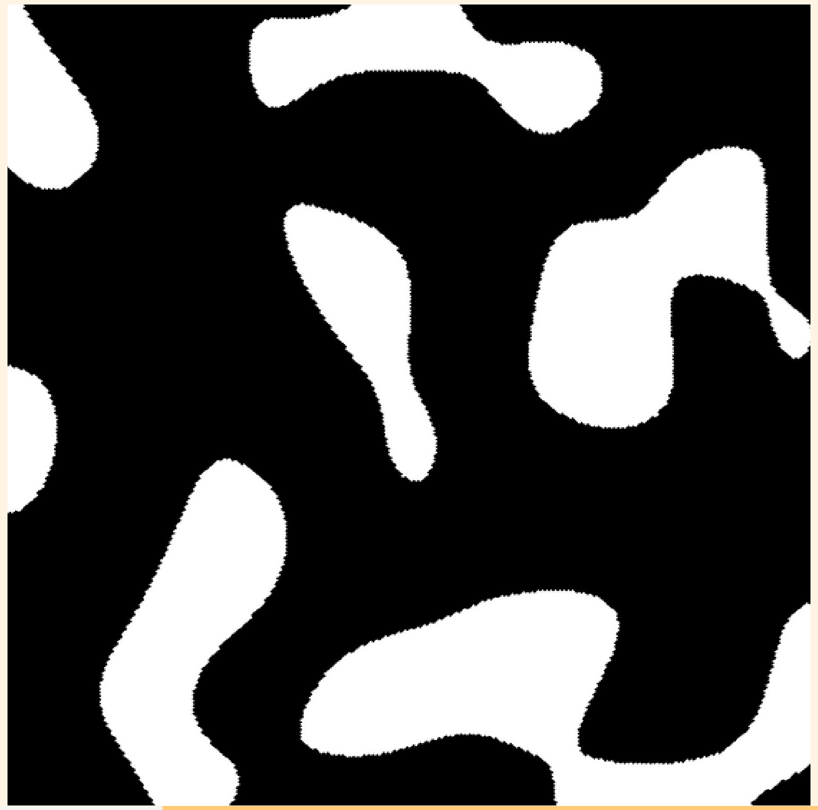
Minkowski Functionals are sensitive to non—Gaussianity

- We consider a field (*e.g.*, T)
- Let u be a threshold (*e.g.*, 2σ)
- We define the **excursion set** $A(u)$ as the regions of the field above u
- Minkowski Functionals are: area of $A(u)$, boundary length of $A(u)$, and Euler—Poincaré characteristic of $A(u)$





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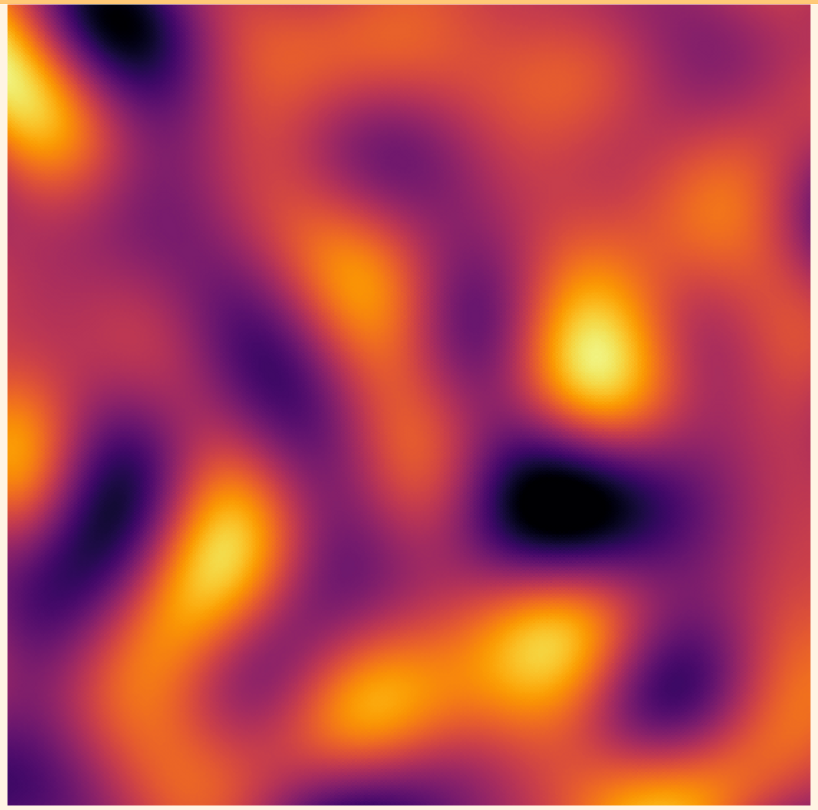
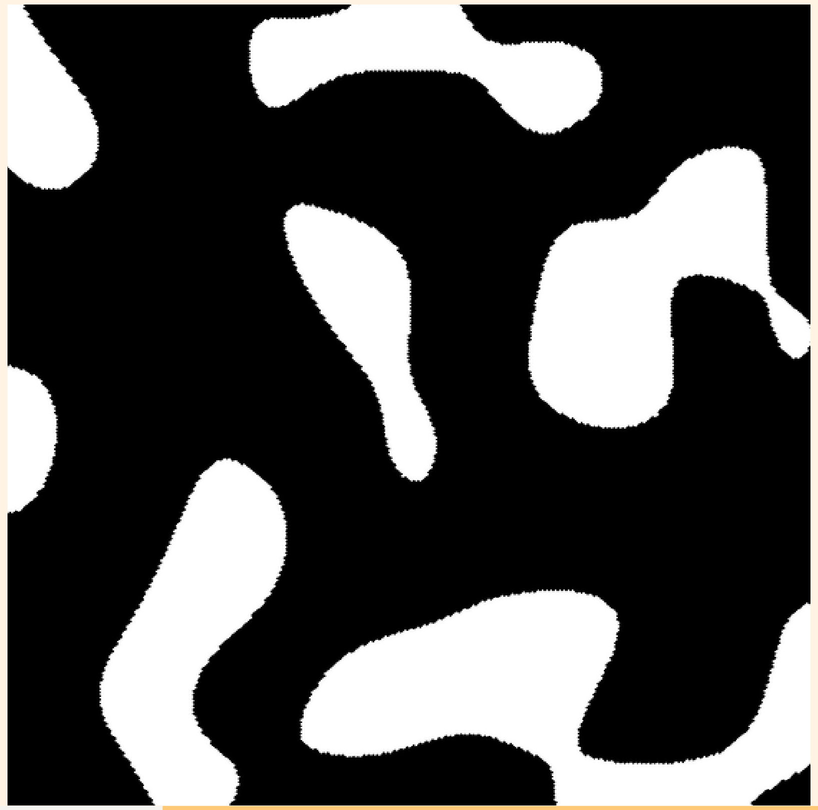


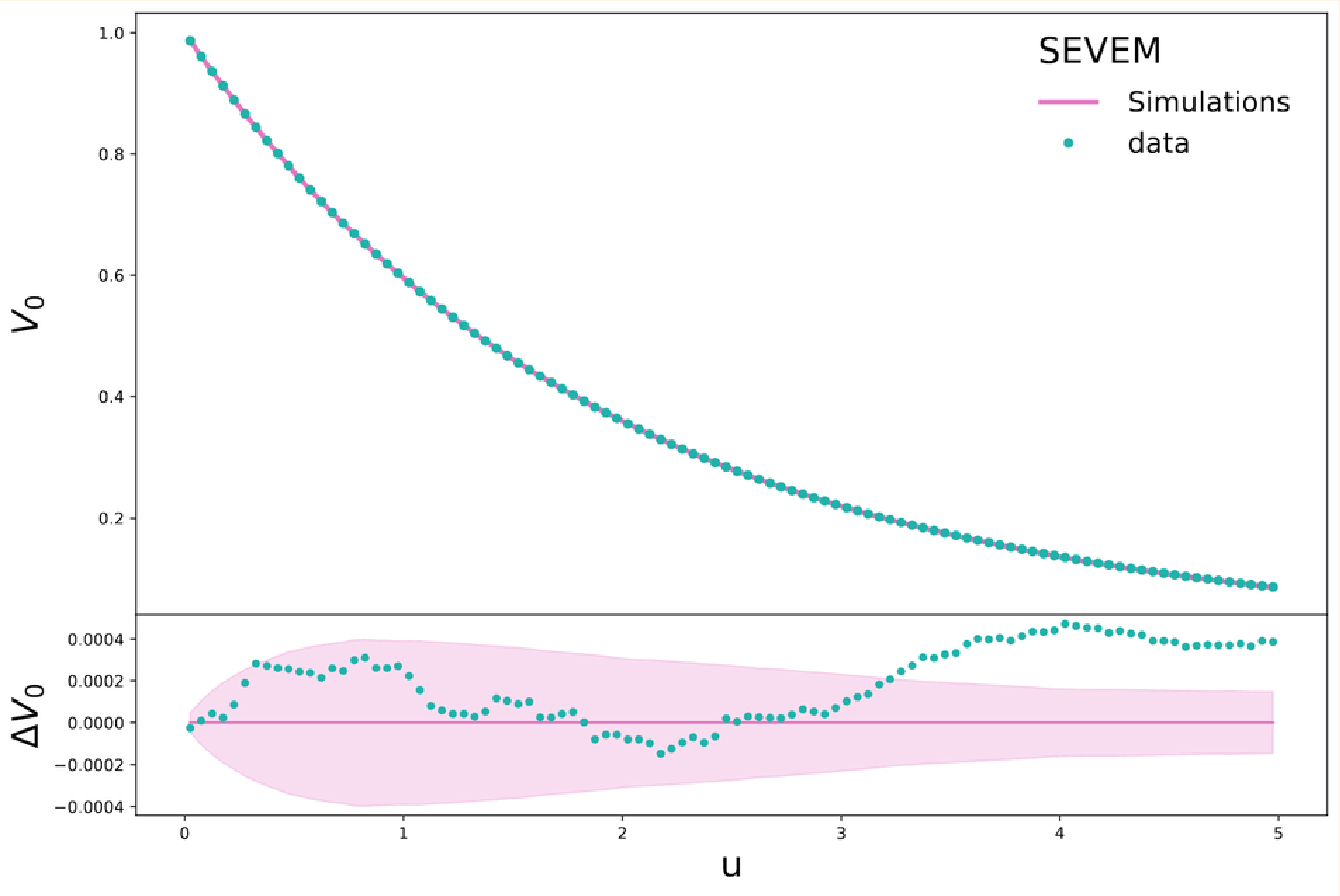
- We consider a field (*e.g.*, *T*)
- Let *u* be a threshold (*e.g.*, 2σ)
- We define the **excursion set** *A(u)* as the regions of the field above *u*
- Minkowski Functionals are: area of *A(u)*, boundary length of *A(u)*, and Euler—Poincaré characteristic of *A(u)*
- MFs can be accurately predicted for Gaussian fields
- Applied to *T* or κ, among others

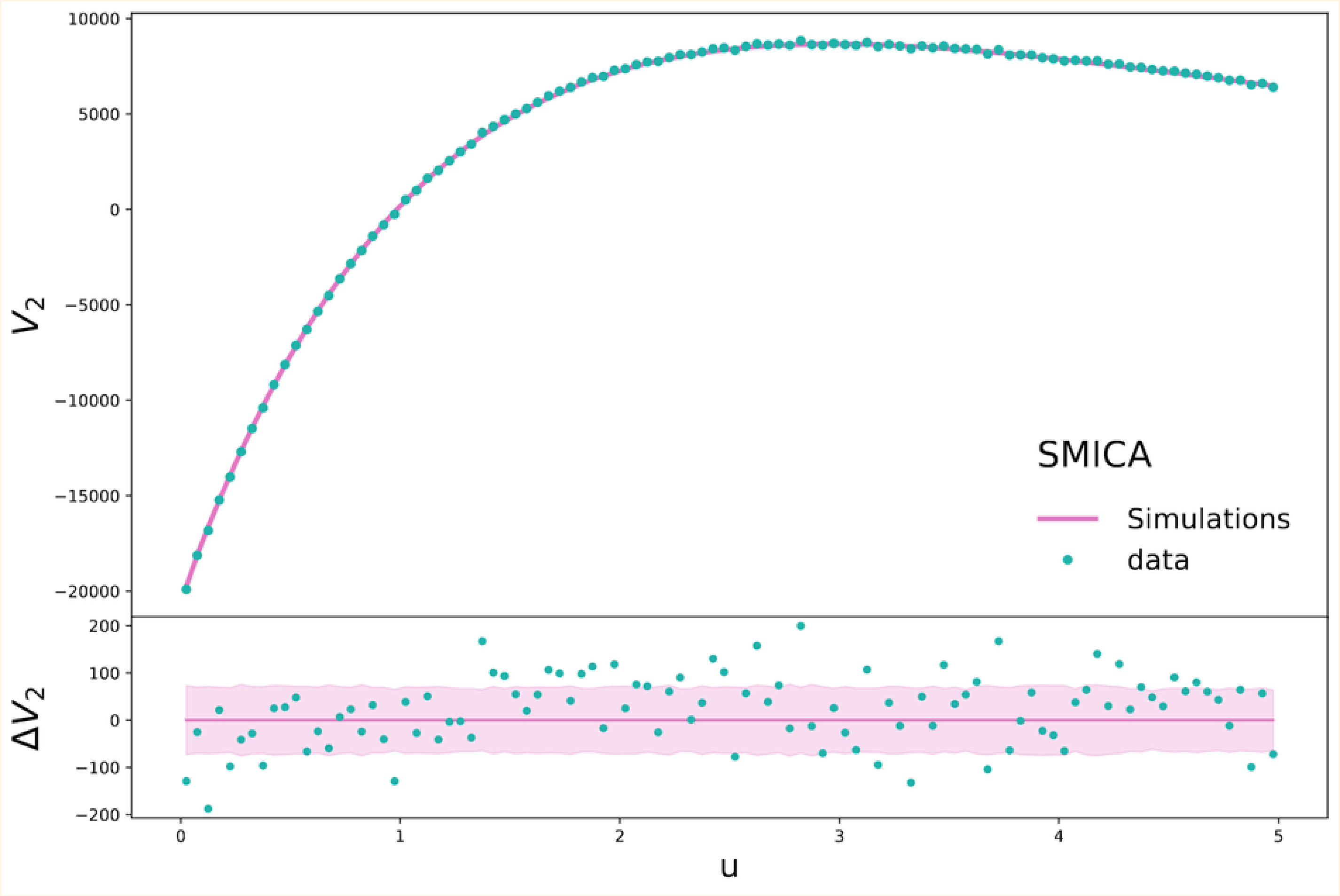


We extend MFs to modulus of polarization P^2

Paper next week!

- We generalize the theoretical formula for $P^2 = Q^2 + U^2$
- Excellent compatibility between theory and Gaussian simulations
- Planck data in agreement with realistic simulations (with anisotropic noise)





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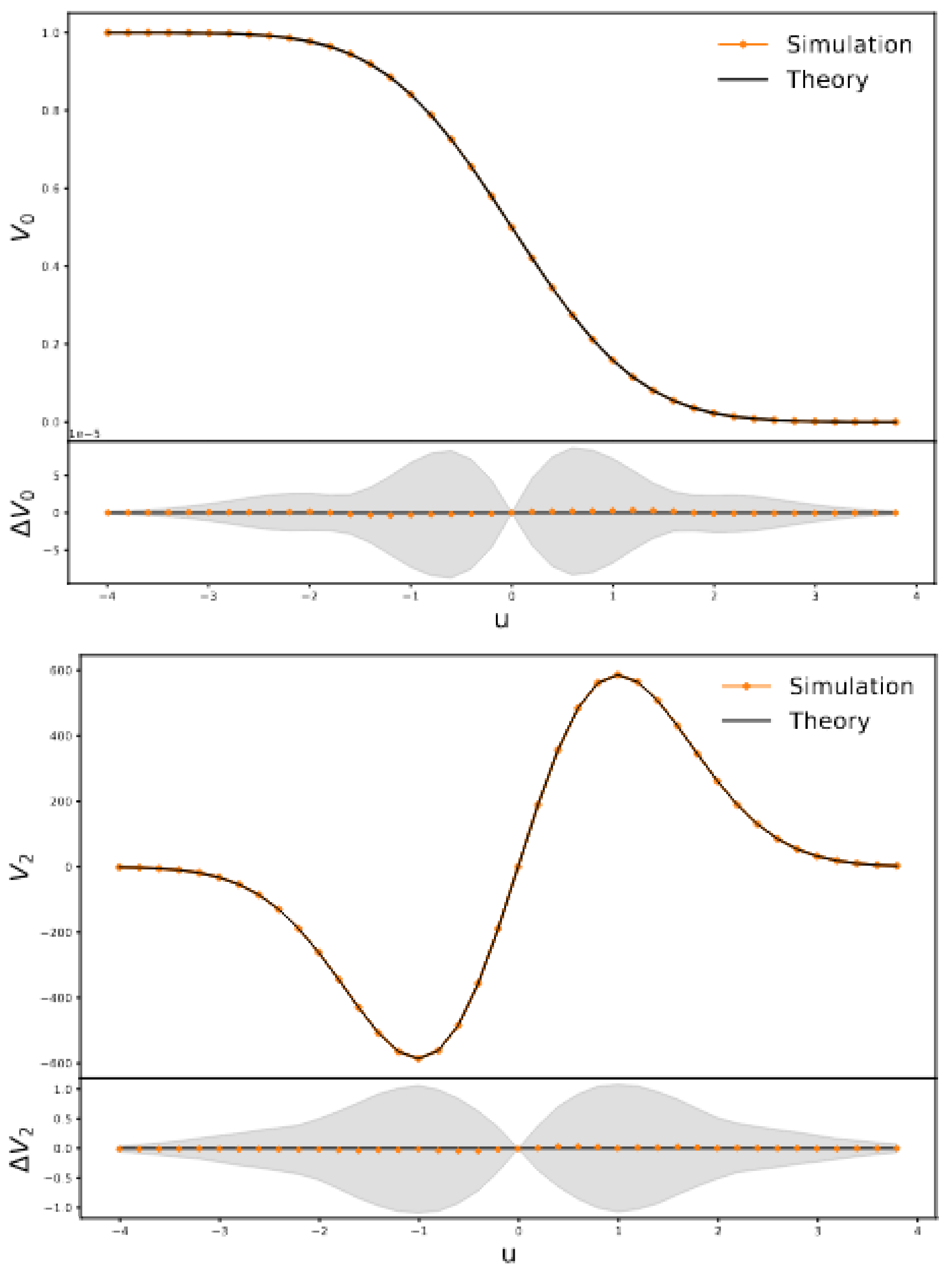
And we extend MFs to full polarization $P(\varphi, \theta, \psi)$

Paper this month

- Full polarization information in

$$f(\phi, \theta, \psi) = Q(\phi, \theta)\cos(2\psi) - U(\phi, \theta)\sin(2\psi)$$

- We obtain the theoretical prediction for the MFs
- Simulations fully compatible with theory



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We explore the non—Gaussianity of Galactic dust

w/ Giuseppe **Puglisi**

- Galactic dust is intrinsically non—Gaussian and anisotropic
- Good realistic simulations should include non—Gaussianities from realistic foreground
- We use MFs to compare several methods to simulate polarized dust emission

MFs can be applied to the CMB power asymmetry

w/ Giacomo **Galloni**

- Typically: variance + Gaussianity $\Rightarrow$ theoretical MFs
- But also: measured MFs + Gaussianity $\Rightarrow$ variance
- Stay tuned for results

We develop Pynkowski as a Python package

- Pynkowski is fully documented and modular
- Theory module: computes the theoretical prediction of different kinds of fields
- Data module: computes the MFs on different kinds of data structures
- Both modules are easy to expand

https://github.com/javicarron/pynkowski

Public next week!

Takeaway points

- **Minkowski Functionals** are useful tools to study **non—Gaussianity**
- It has many unexploited **applications**, from polarization to anomalies
- We created **Pynkowski** to ease the application of MFs to the community

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- **Minkowski Functionals** are useful tools to study **non—Gaussianity**
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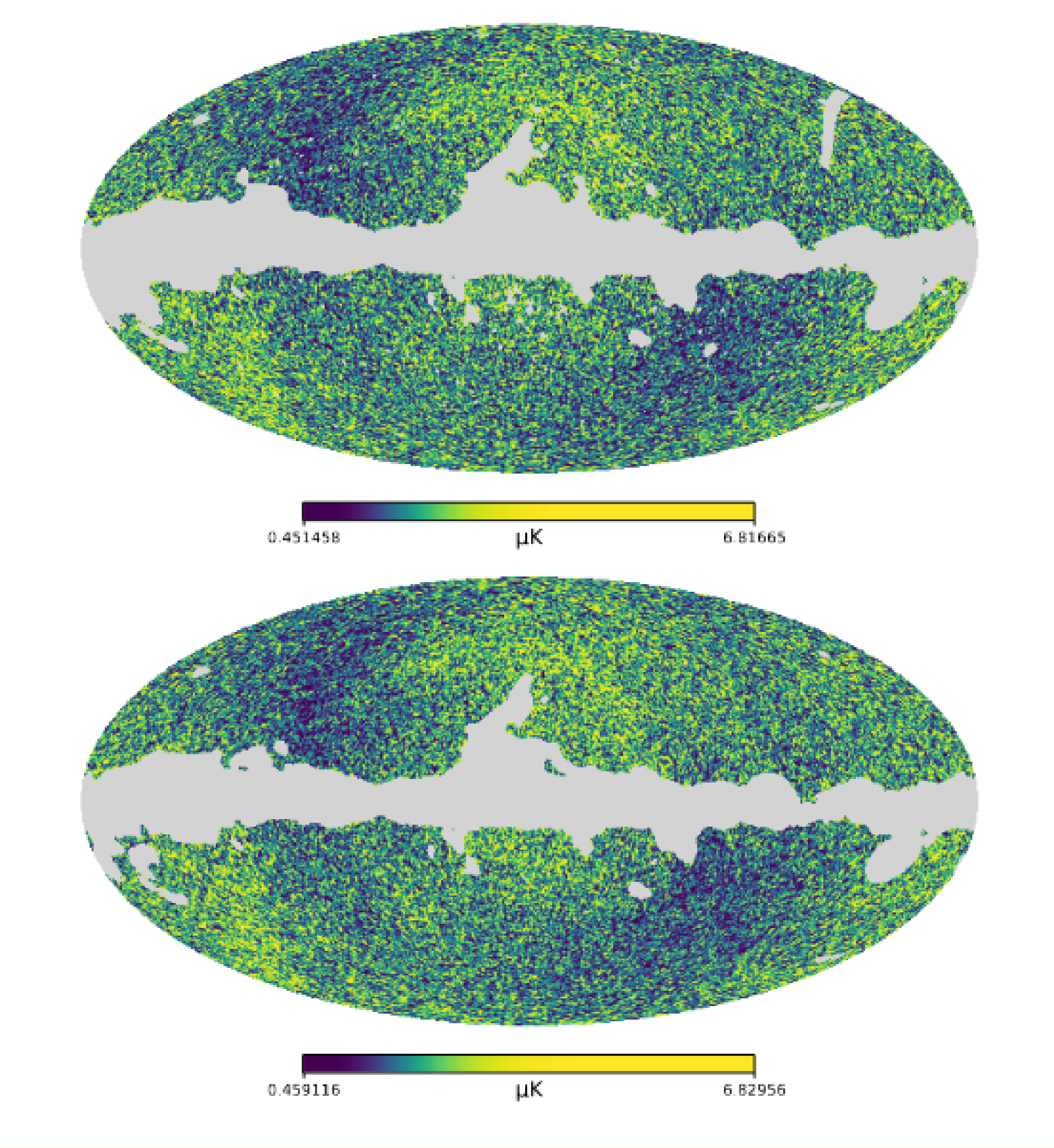
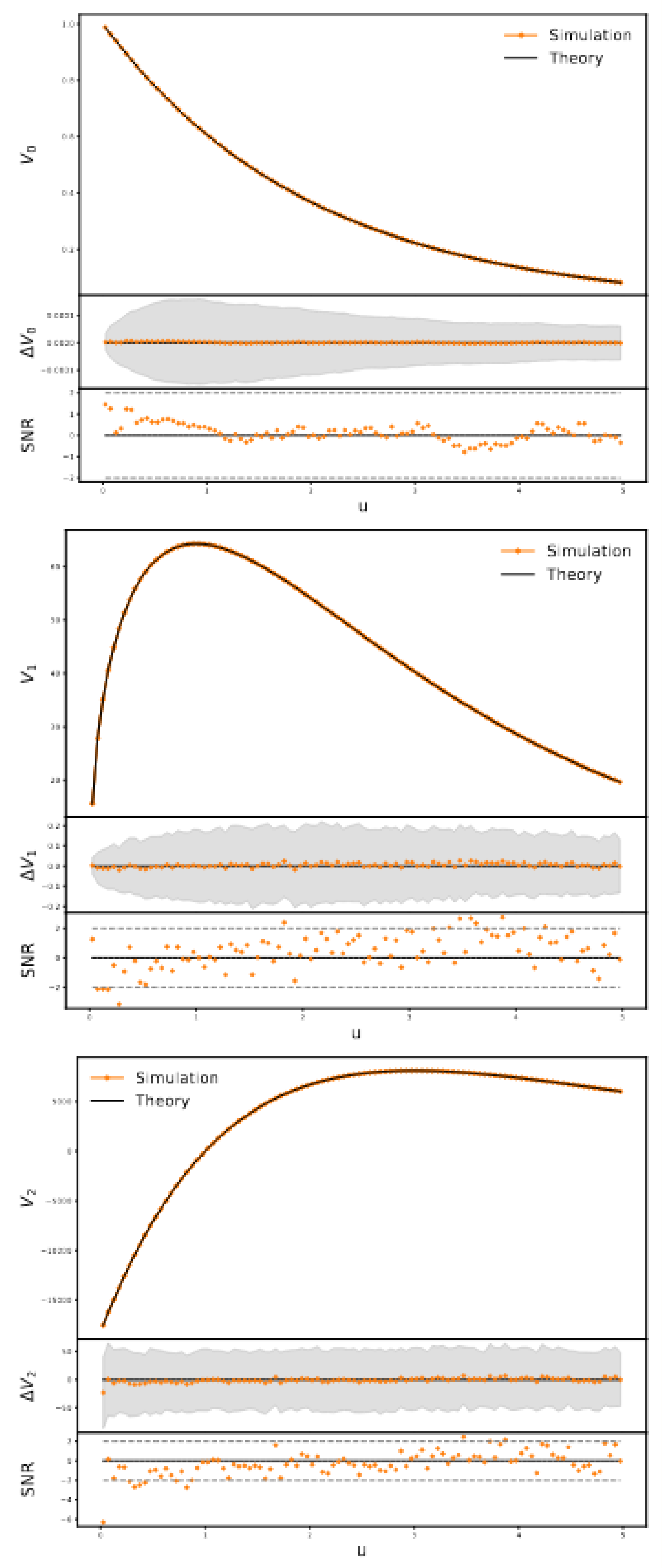
Thank you!

Backup images


0.451458
μK
6.81665
0.459116
μK
6.82956


Simulation
Theory
V_0
ΔV_0
SNR
u
Simulation
Theory
V_1
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Simulation
Theory
V_2
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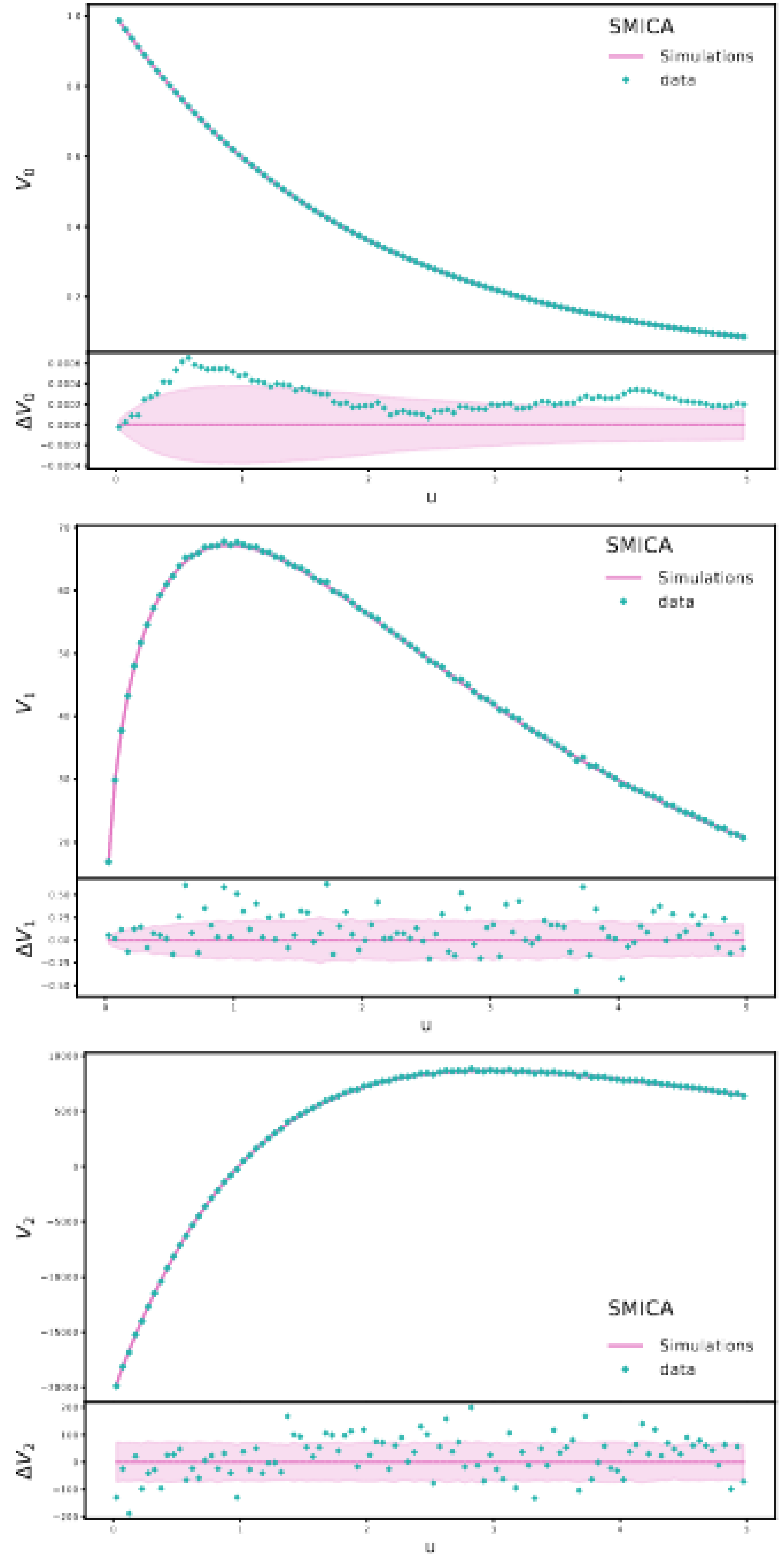

		χ^2	p_{exc} (%)	σ
V_0	SMICA	1.074	30.7	0.37
	SEVEM	0.885	74.0	-0.70
V_1	SMICA	1.135	19.7	0.72
	SEVEM	1.022	43.7	0.09
V_2	SMICA	1.051	39.3	0.27
	SEVEM	1.263	0.09	1.55