

RECONSTRUCTING THE KINEMATICS OF LANIAKEA USING TYPE IA SUPERNOVAE

arxiv: 2607.11860

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GGI: Exploring new frontiers in cosmology

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EXCELENCIA
MARÍA
DE MAEZTU
04/2025-03/2031



Laniakea - Nature

SIDEREUS NUNCIUS (*THE STARRY MESSENGER*)



Noticing this, and knowing that there was no way in which such alterations could be attributed to **Jupiter's motion**, yet being certain that these were still the same stars I had observed [...]

my perplexity was now transformed into amazement.

*I was sure that the apparent changes belonged not to Jupiter but to the observed stars, and I resolved to pursue this investigation **with greater care and attention.***

Galileo Galilei (1610)

SNE IA COSMOLOGY IN A NUTSHELL



$$\mu = 5 \log \left(\frac{d_L(z)}{\text{Mpc}} \right) + 25$$



$$d_L(z) = \frac{1+z}{H_0} \int_0^z \frac{dz}{\sqrt{\Omega_m(1+z)^3 + 1 - \Omega_m}}$$



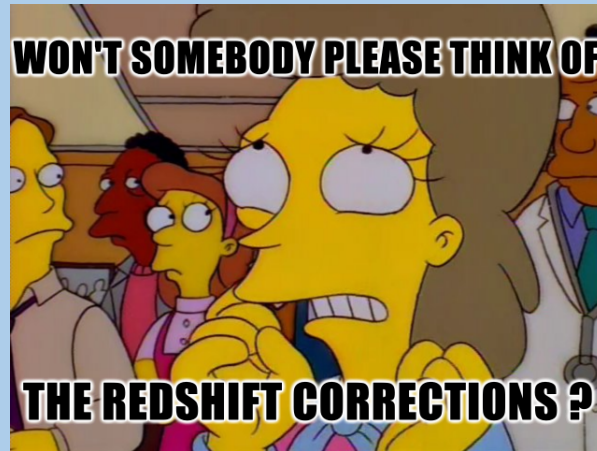
SNE Ia COSMOLOGY IN A NUTSHELL



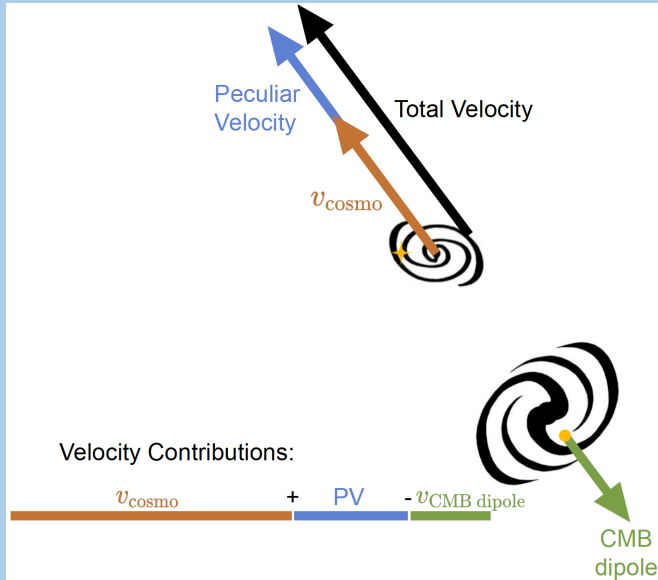
$$\mu = 5 \log \left(\frac{d_L(z)}{\text{Mpc}} \right) + 25$$



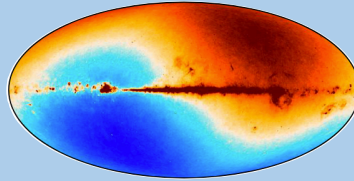
$$d_L(z) = \frac{1+z}{H_0} \int_0^z \frac{dz}{\sqrt{\Omega_m(1+z)^3 + 1 - \Omega_m}}$$



PECULIAR VELOCITIES



Peterson et al., 2022



z_{hel}



z_{cmb}



z_{cos}

$$\mathbf{n} \cdot \mathbf{v}(\mathbf{n}(t_0 - t(z)), t_0) = \mathbf{n} \cdot \mathbf{v}^{(\text{bulk})} + n^i(\alpha_{ij} + \gamma \delta_{ij}) n^j$$

JCAP 04 (2025) 013

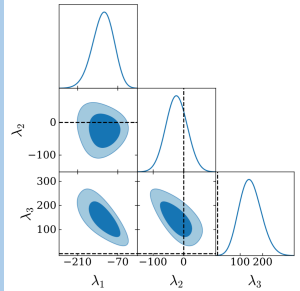
"IT'S NOT YOU, IT'S ME "

arXiv:2403.17741 (astro-ph)

[Submitted on 26 Mar 2024 (v1), last revised 8 Apr 2025 (this version, v2)]

The low multipoles in the Pantheon+SH0ES data

Francesco Sorrenti, Ruth Durrer, Martin Kunz

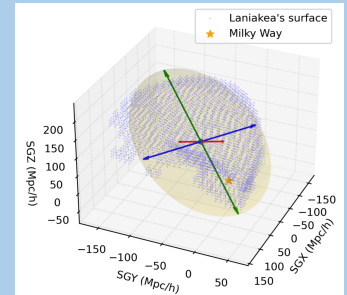


arXiv:2311.00215 (astro-ph)

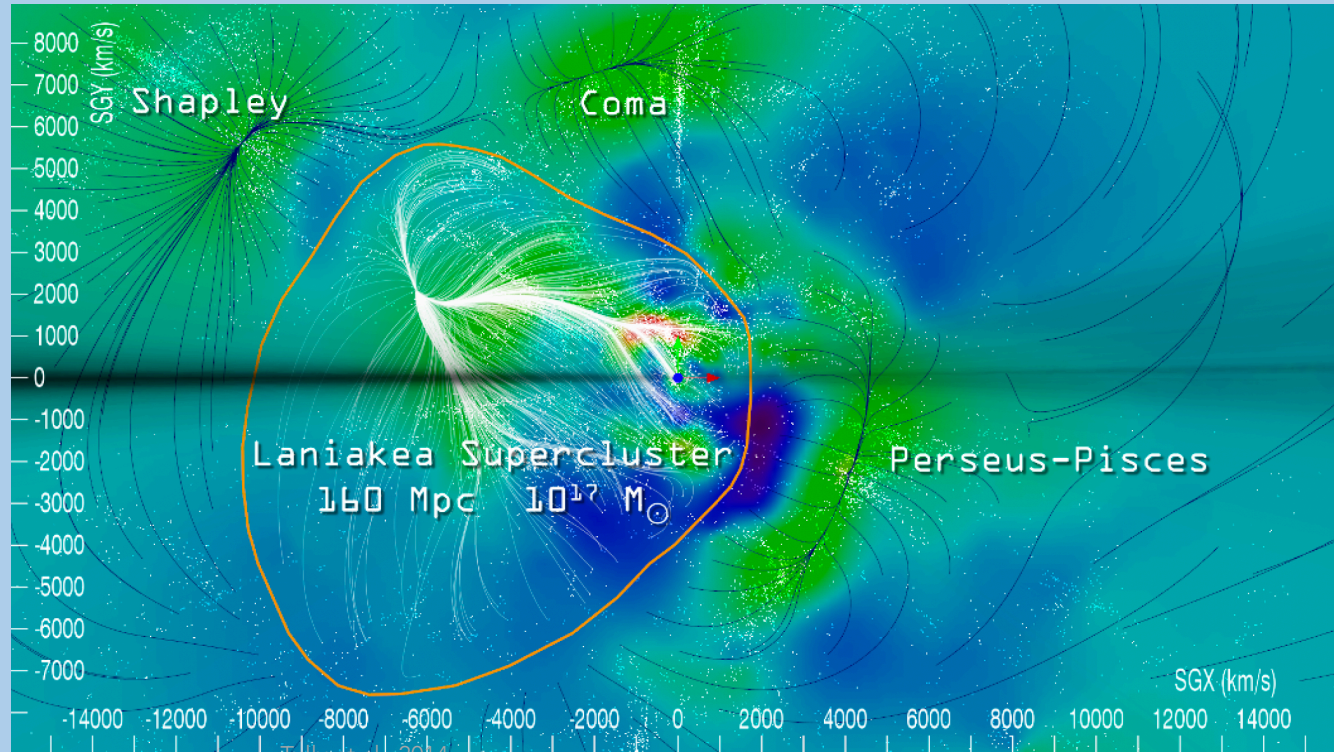
[Submitted on 1 Nov 2023 (v1), last revised 2 Feb 2024 (this version, v2)]

An effective description of Laniakea: impact on cosmology and the local determination of the Hubble constant

L. Giani, C. Howlett, K. Said, T. Davis, S. Vagnozzi

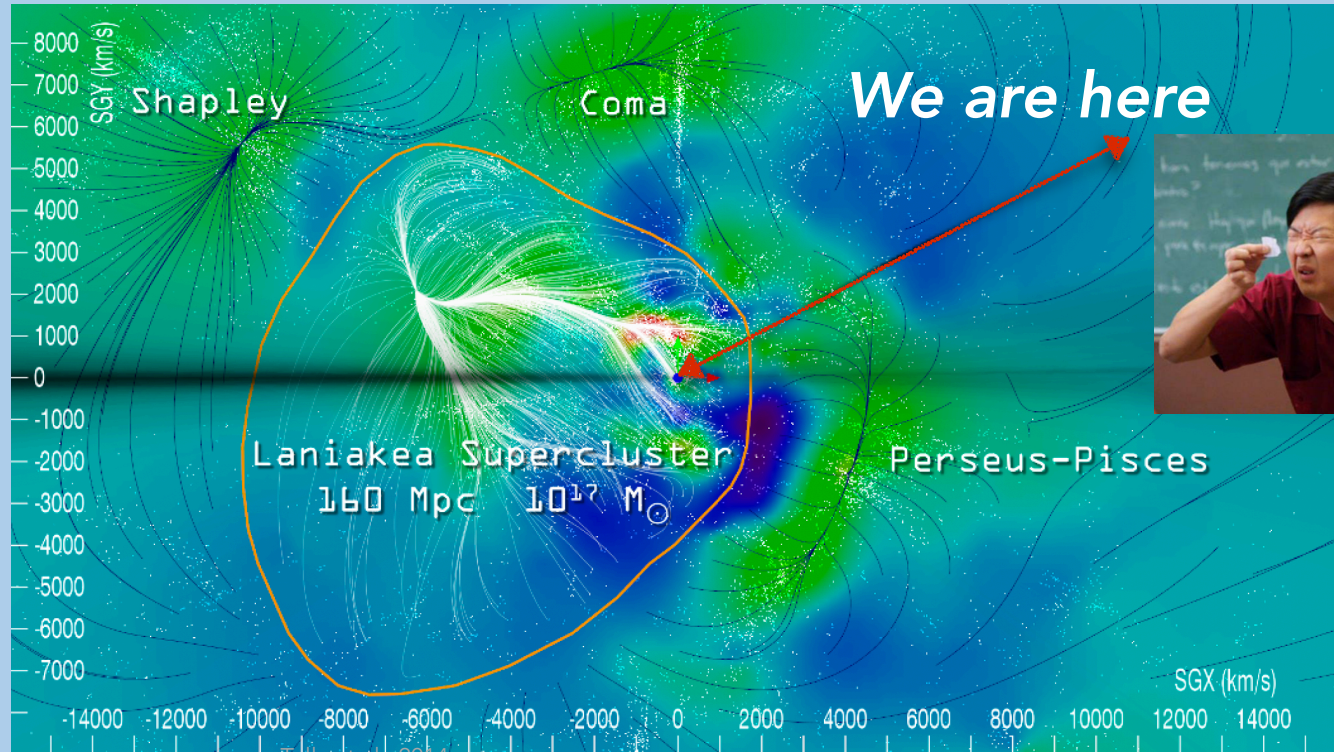


"IMMENSE HEAVEN"



Tully et al., 2014

"IMMENSE HEAVEN"

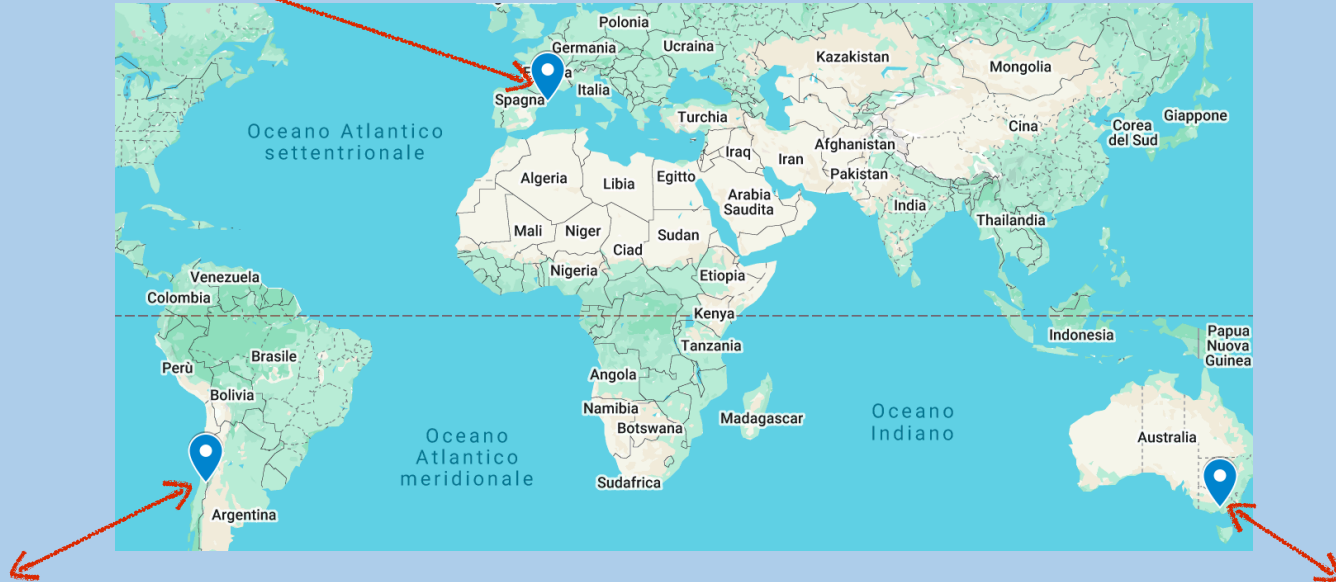


Tully et al., 2014



AN "EXTENSIVE" WORK

Me



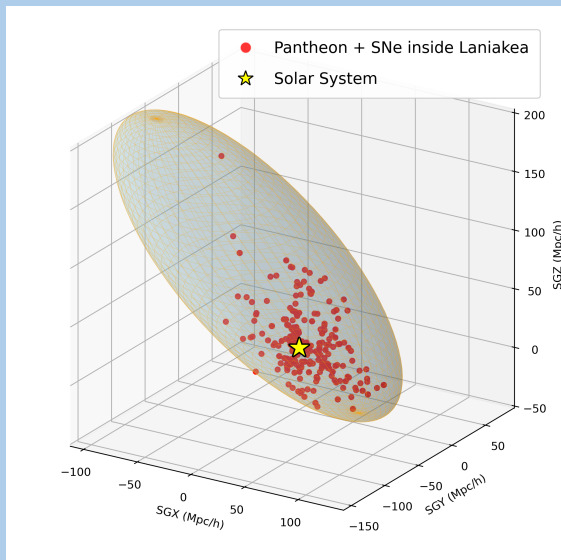
Erick Pastén

Univ. de Santiago de Chile

Leonardo Giani

Swinburne Univ. of Technology

LANIAKEA AND PECULIAR VELOCITIES



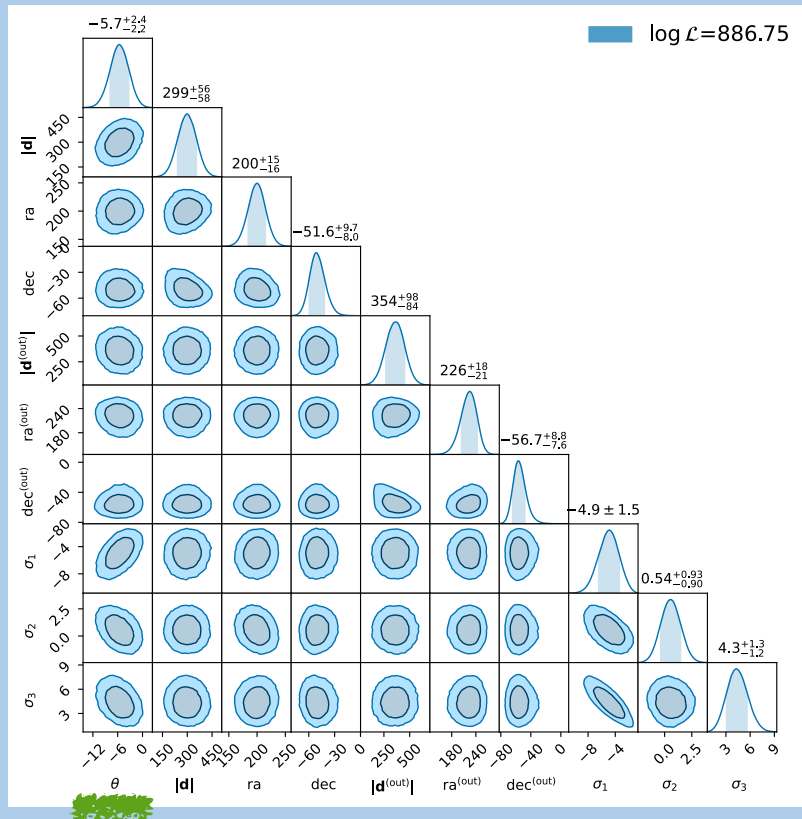
$$v_p \propto \left[\underbrace{\frac{r(z_{\text{cmb}})}{3} \theta^{(in)}}_{\text{Expansion}} + \underbrace{\mathbf{d} \cdot \mathbf{n}}_{\text{Bulk motion}} + r(z_{\text{cmb}}) \underbrace{n^i n^j \sigma_{ij}^{(in)}}_{\text{Shear}} \right]$$

z_{cmb}



z_{cos}

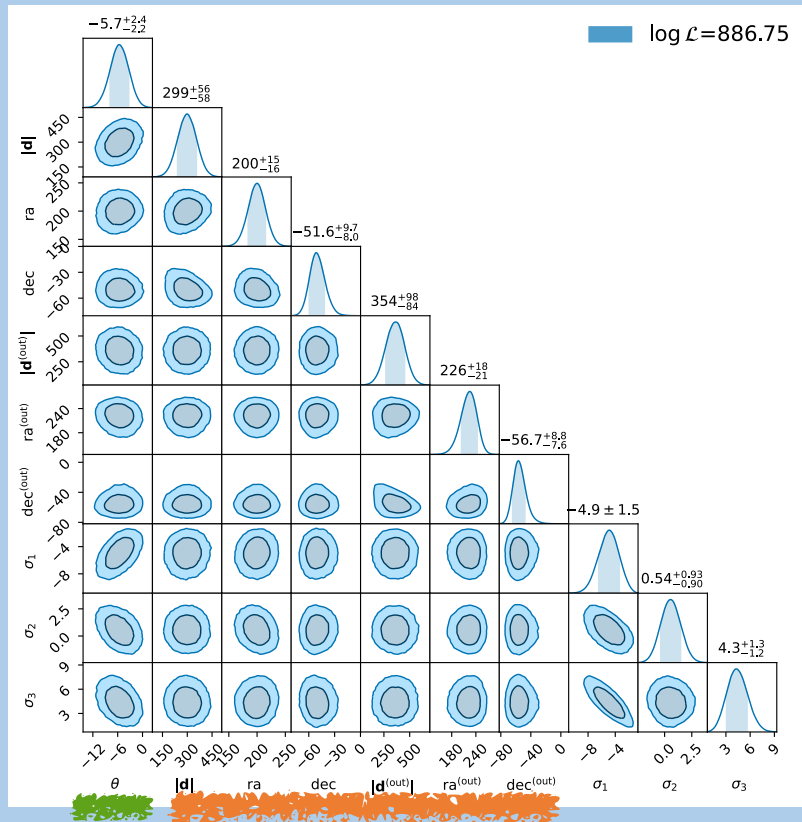
RESULTS



Applying on Pantheon+

- H_0 and Ω_m recovered
- Contracting region / over density

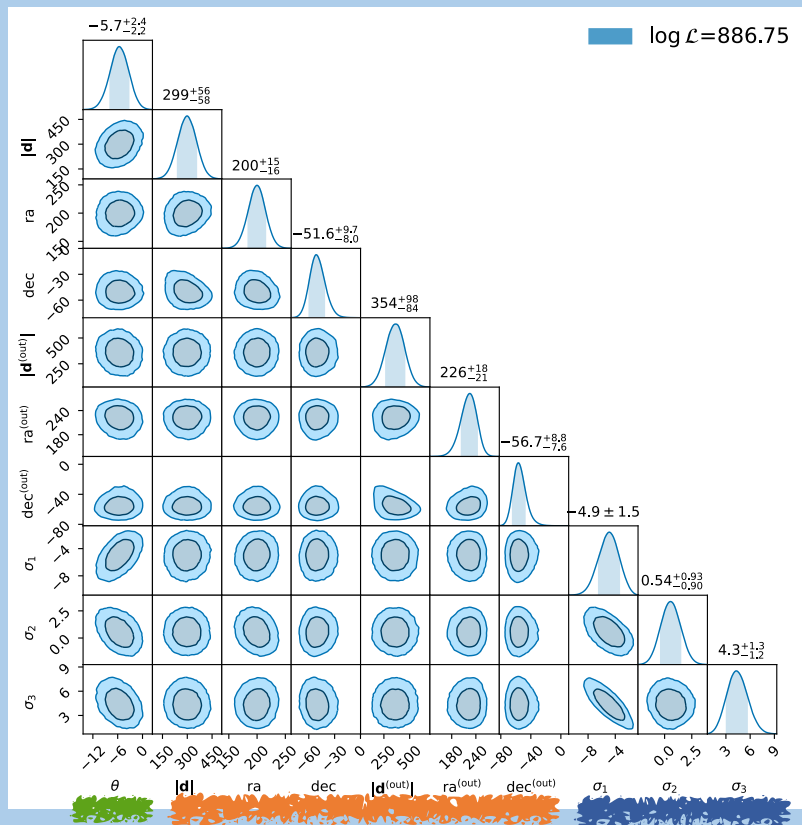
RESULTS



Applying on Pantheon+

- H_0 and Ω_m recovered
- Contracting region / over density
- Bulk direction towards Shapley

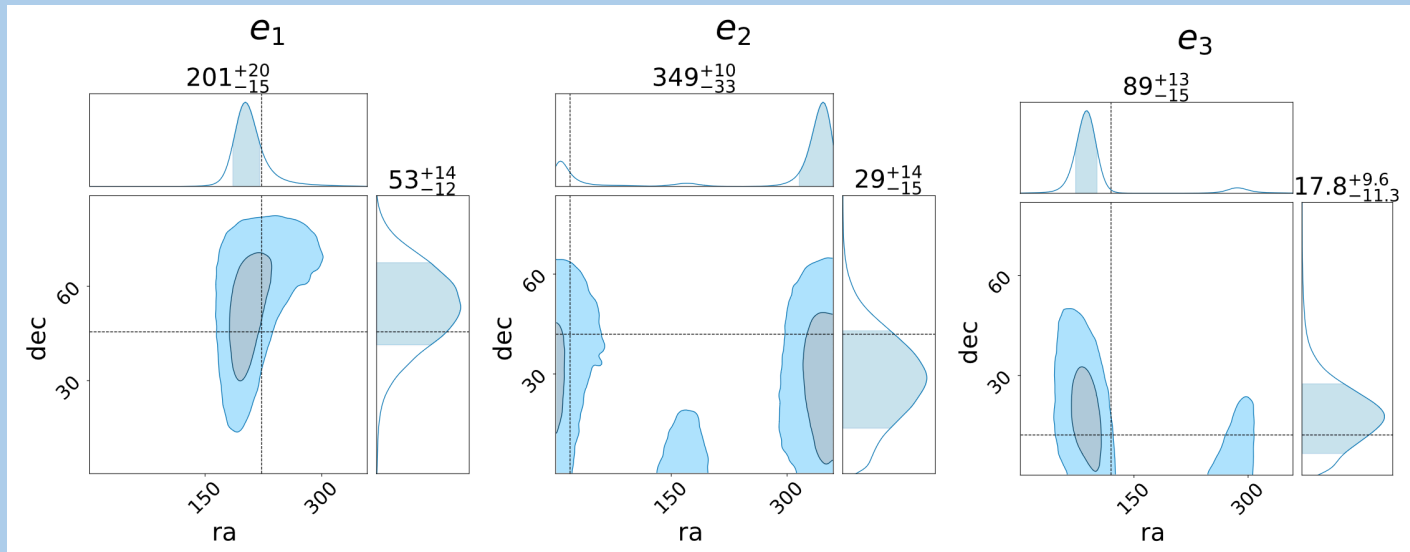
RESULTS



Applying on Pantheon+

- H_0 and Ω_m recovered
- Contracting region / over density
- Bulk direction towards Shapley
- Clear anisotropic pattern

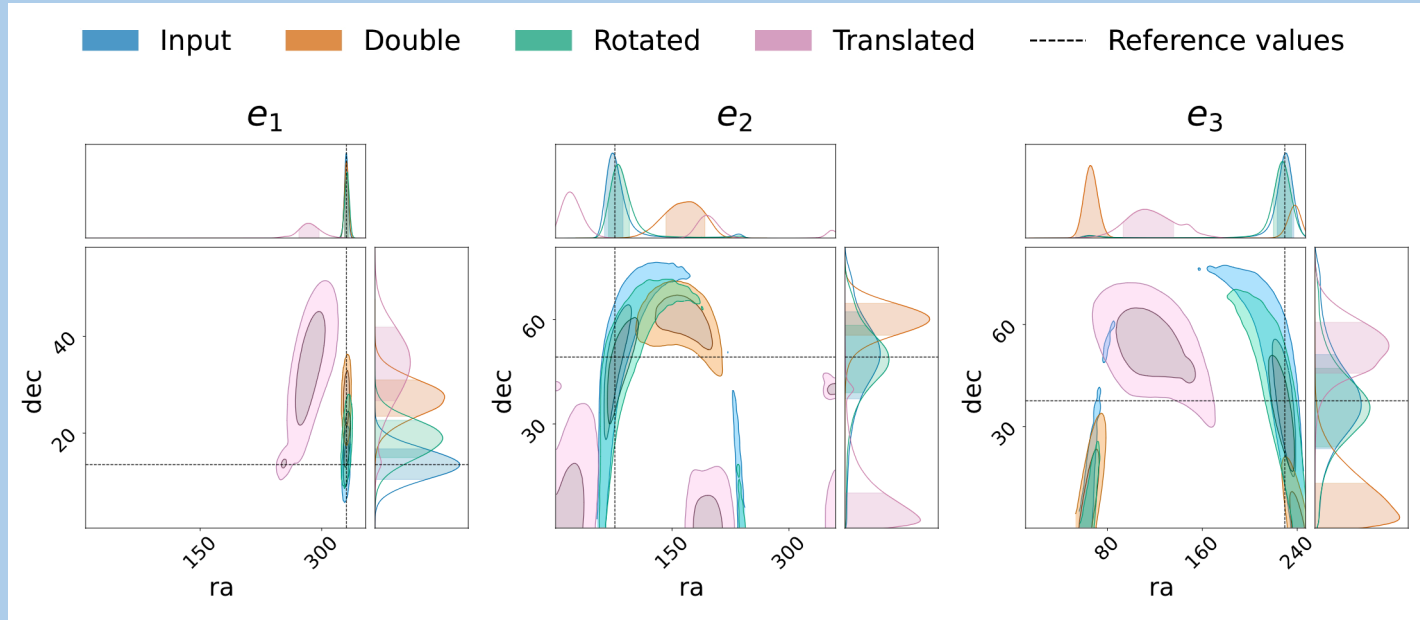
RESULTS - EIGENVECTORS



Consistent with Giani et al. 2023

Luminosity distance anisotropies contain direct
information about the underlying kinematics of nearby large-scale structures

MOCK VALIDATION



The method is especially **robust** when a significant number of external supernovae is not introduced in the selection

CONCLUSIONS



SNe Ia provide **independent route** to describe the **kinematics** of nearby structures

Next steps

Apply to other datasets (ZTF, LSST)

Refine methodology using N-body simulations



Thanks for your attention!

RESULTS - LOW MULTIPOLES

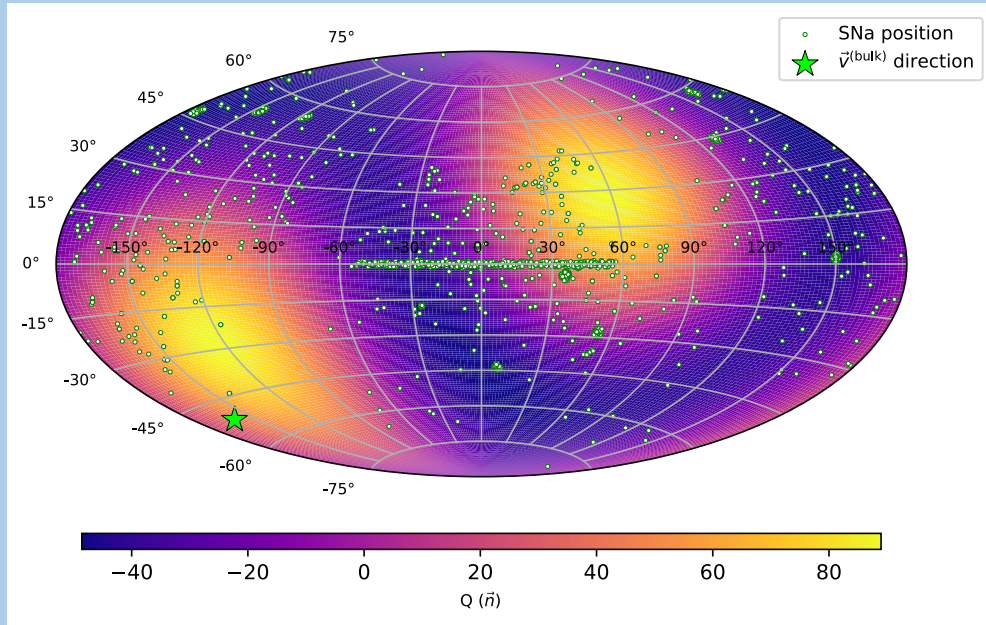
Eigenvalues of α_{ij}

γ [km/s]	$ v^{\text{bulk}} $ [km/s]	ra^{bulk} [°]	dec^{bulk} [°]	H_0 [km/s/Mpc]	Ω_m	λ_1 [km/s]	λ_2 [km/s]	λ_3 [km/s]
-95 ± 44	323 ± 50	199 ± 12	$-51.2^{+5.4}_{-7.0}$	74.1 ± 1.1	$0.317 \pm 0.01_9$	-111^{+40}_{-31}	-12 ± 32	122^{+40}_{-50}

Monopole, dipole, quadrupole are all **detected**

Bulk consistent with CF4 (see Watkins et al., 2023 and Whitford et al., 2023)

RESULTS — QUADRUPOLE $Q(\mathbf{n})$ - LOW MULTIPOLES



$$Q(\mathbf{n}) = \alpha_{ij} n^i n^j$$

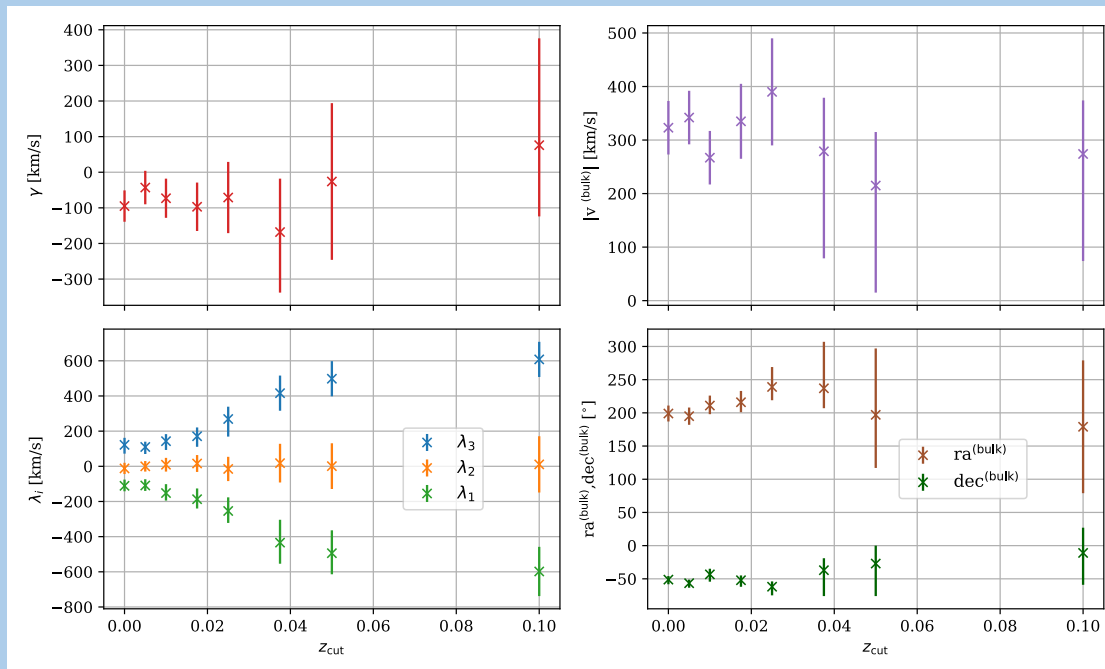
Peak of the quadrupole is **not far** from bulk velocity direction

No strong correlation with the supernova positions is evident

SUMMARY CONSTRAINTS - LOW MULTIPOLES

Negative
monopole:
an infall ?

λ_i significantly
increases with z
while errors stay
 $\sim$ constant



Bulk direction
close to Shapley
Supercluster