A resolution to H0 tension

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ALTECOSMOFUN'21

This will be a FUN talk.

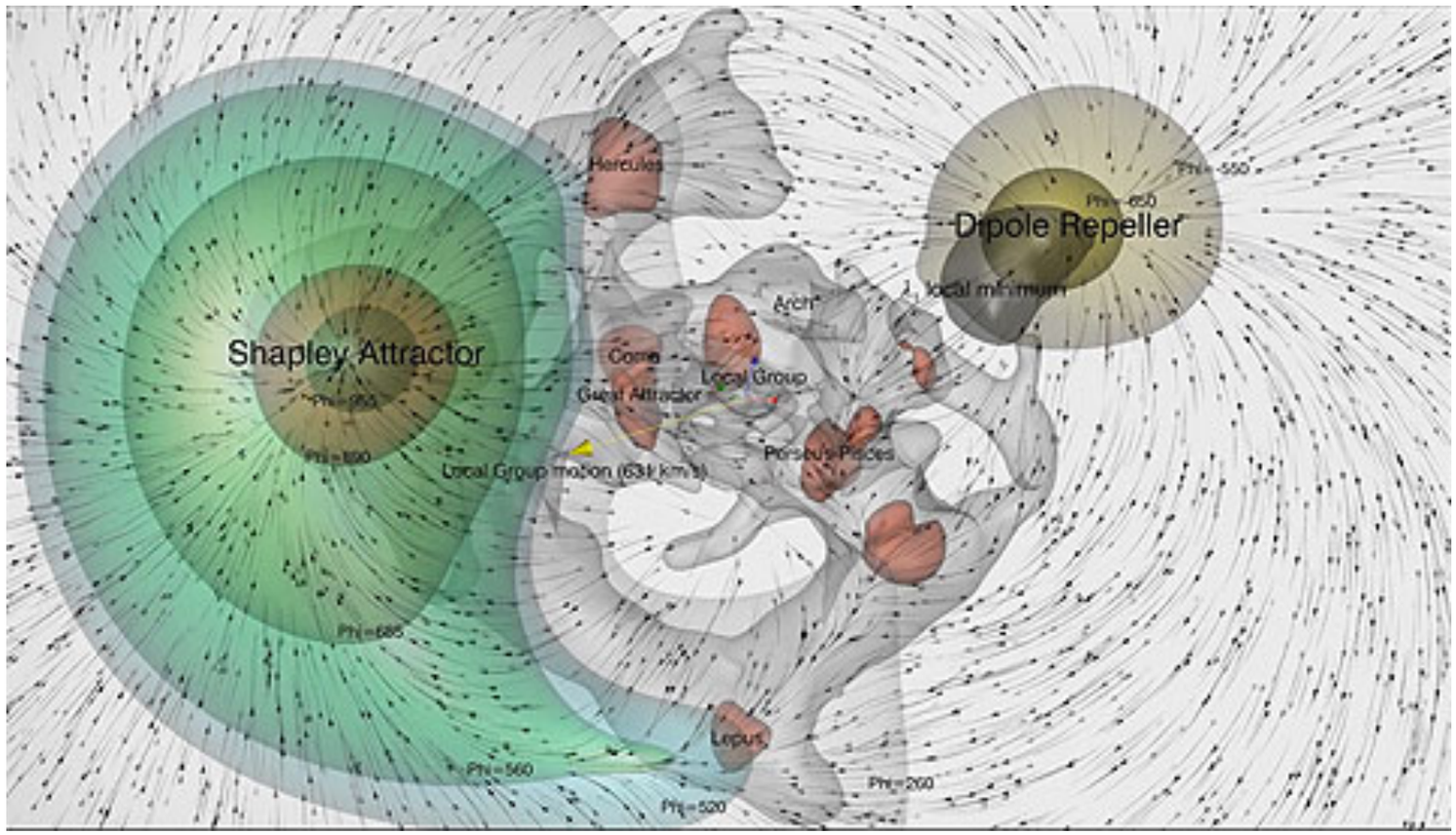
Simply put, IF the Universe is not FLRW...

...THEN there is no H0 tension problem.

It's a simple, yet brilliant resolution.

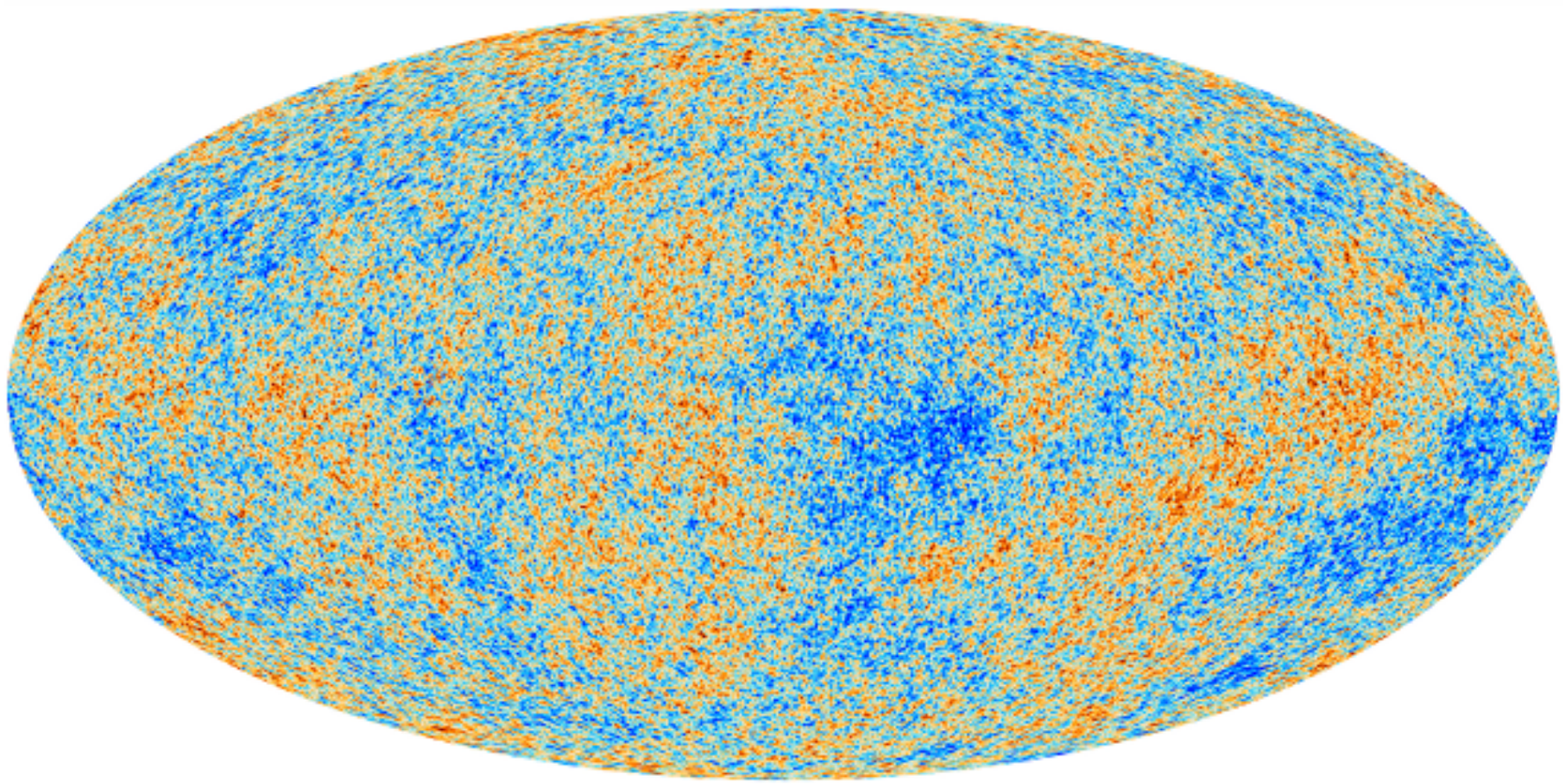
Local Universe is clearly not an FLRW Universe.

Where does it begin?



Hoffman, Pomarède, Tully, Courtois, Nat. Ast. (2017)

CMB represents a snapshot of an FLRW Universe.



But there is a loose end, the CMB dipole.

CMB dipole is measured in mK not μK!!!

The ASSUMPTION is that the dipole is a kinematical effect.

$$v = 369 \pm 0.9 \mathrm{km/s}, \quad (\ell, b) = (263.99 \pm 0.14^\circ, 48.26 \pm 0.03^\circ)$$

Kogut, Lineweaver, Smoot et al. astro-ph/9312056

In an era of cosmological tensions, this ASSUMPTION needs to be checked.

Internal CMB checks seem to recover the dipole, admittedly with large errors (± 100 km/s).

Ferreira & Quartin (2011.08385); Saha et al. (2106.07666)

A cosmic dipole crisis?

There is a long standing discrepancy in the cosmic dipole. Note, CMB dipole at (RA, DEC) ~ (168°, -7°)

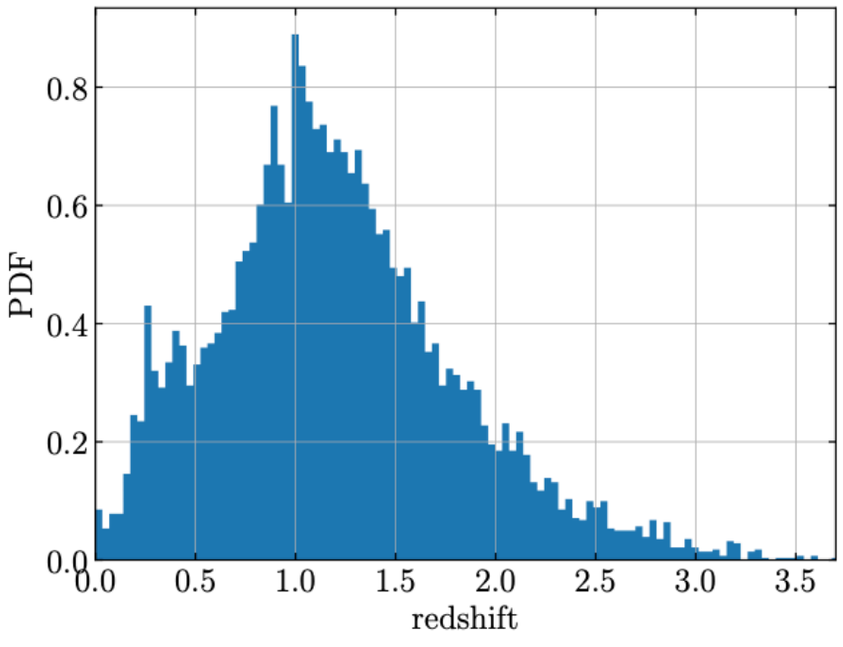
Siewert, Schmidt-Rubart, Schwarz (2010.08366)

consistent with earlier results:

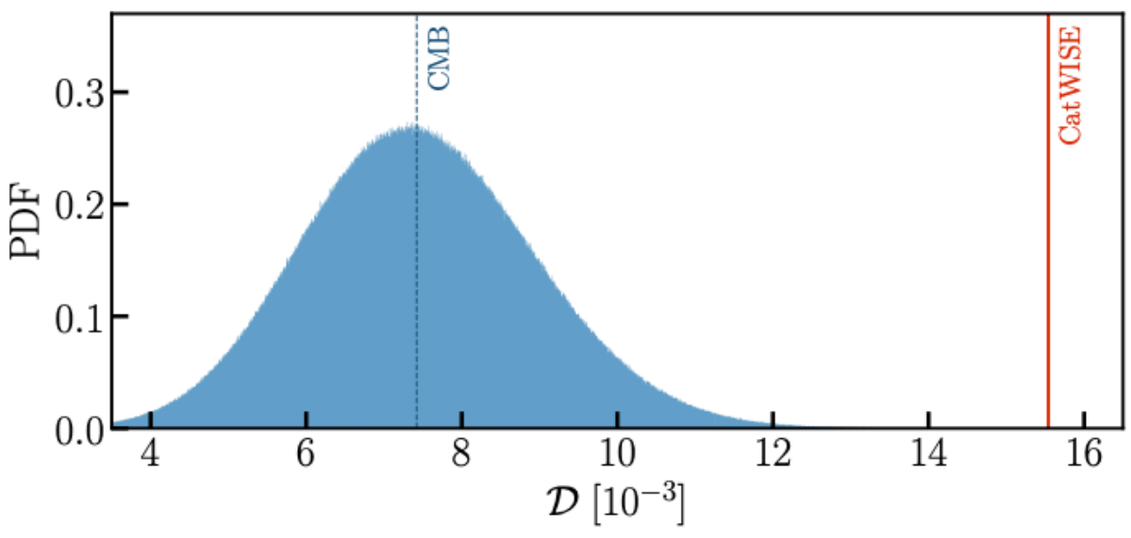
Blake & Wall (2002); Singal (2011); Rubart & Schwarz (2013); Tiwari & Nusser (2016); Bengaly et al. (2018)

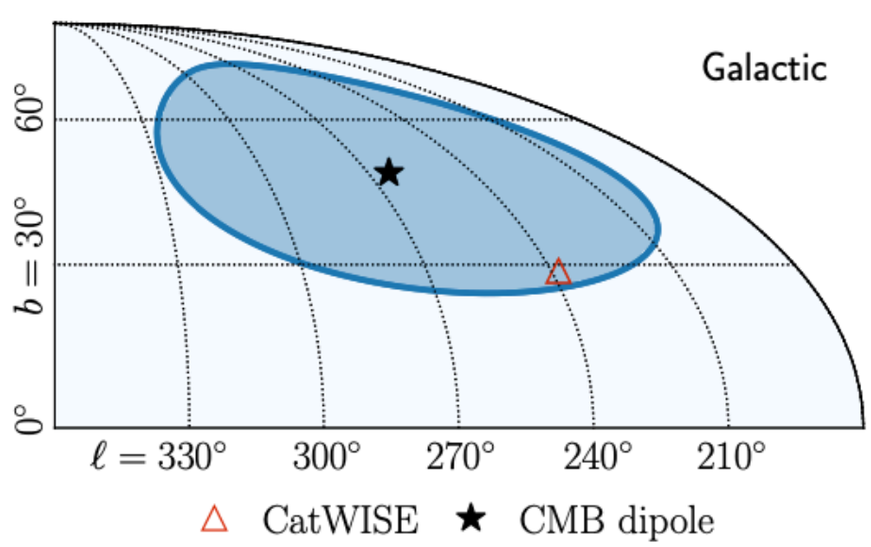
Survey	Mask	f_{sky}	S [mJy]	N	RA [deg]	DEC [deg]	$\Delta\theta$ [deg]	d ($\times 10^{-2}$)	χ^2/dof
TGSS	d	0.72	50	393 447	124.53 ± 4.13	25.66 ± 5.15	53.30 ± 4.02	6.6 ± 0.5	3.19
			100	244 881	135.61 ± 11.57	15.90 ± 11.24	39.33 ± 14.30	6.0 ± 0.8	2.91
			150	173 964	139.53 ± 11.33	12.88 ± 10.74	34.50 ± 13.86	5.9 ± 0.7	1.83
			200	133 547	141.99 ± 11.17	11.52 ± 10.21	31.74 ± 13.29	5.9 ± 0.7	1.65
	n	0.52	50	296 855	132.90 ± 4.57	15.68 ± 5.21	41.43 ± 4.17	6.2 ± 0.5	2.36
			100	179 951	137.25 ± 6.62	14.49 ± 5.39	37.23 ± 6.05	6.3 ± 0.6	1.94
			150	127 244	138.30 ± 6.25	14.96 ± 5.25	36.65 ± 5.63	6.5 ± 0.7	1.72
			200	97 355	138.86 ± 6.12	15.79 ± 5.51	36.69 ± 5.45	6.8 ± 0.8	1.54
WENSS	d	0.17	25	115 808	143.34 ± 19.48	−13.15 ± 4.58	24.99 ± 13.84	3.2 ± 1.0	1.91
			35	95 302	137.85 ± 24.47	−13.29 ± 4.98	30.27 ± 18.99	2.9 ± 0.9	1.77
			45	81 534	131.83 ± 27.76	−11.95 ± 6.28	35.94 ± 22.94	2.8 ± 0.9	1.68
			55	71 643	127.51 ± 29.27	−10.70 ± 6.59	40.10 ± 24.89	2.8 ± 0.9	1.57
	n	0.14	25	93 577	142.20 ± 23.25	−16.20 ± 5.77	26.83 ± 14.94	3.1 ± 0.9	1.88
			35	76 760	138.98 ± 27.58	−16.25 ± 6.16	29.81 ± 18.54	2.9 ± 0.9	1.75
			45	65 494	138.71 ± 34.24	−16.23 ± 7.66	30.06 ± 23.10	2.8 ± 1.0	1.67
			55	57 463	135.43 ± 35.16	−15.39 ± 7.60	32.95 ± 24.13	2.8 ± 1.0	1.56
SUMSS	d	0.16	18	99 835	106.67 ± 12.90	−9.50 ± 11.12	60.62 ± 12.49	3.8 ± 0.9	1.49
			25	75 642	106.18 ± 16.99	−5.11 ± 9.91	61.40 ± 16.79	3.5 ± 1.0	1.58
			35	55 973	108.05 ± 22.64	−4.12 ± 8.92	59.65 ± 20.85	3.4 ± 1.0	1.49
			45	44 403	105.33 ± 25.64	−4.08 ± 8.35	62.35 ± 23.73	3.3 ± 1.1	1.51
			55	36 646	106.72 ± 33.92	−4.92 ± 8.66	60.89 ± 27.50	3.2 ± 1.1	1.40
	n	0.16	18	96 816	106.67 ± 14.53	−9.50 ± 10.03	59.40 ± 14.36	3.8 ± 0.8	1.51
			25	73 356	106.18 ± 17.34	−5.11 ± 8.95	61.16 ± 17.28	3.5 ± 1.0	1.60
			35	54 336	108.05 ± 20.78	−4.12 ± 8.16	61.24 ± 20.09	3.4 ± 1.1	1.51
			45	43 121	105.33 ± 24.68	−4.08 ± 7.93	63.50 ± 23.62	3.3 ± 1.1	1.46
			55	35 574	106.72 ± 30.58	−4.92 ± 8.68	61.60 ± 25.75	3.2 ± 1.2	1.41
NVSS	d	0.66	15	328 207	138.90 ± 12.02	−2.74 ± 12.11	29.23 ± 11.07	1.6 ± 0.3	1.30
			25	209 034	140.02 ± 13.63	−5.14 ± 13.26	27.82 ± 12.17	1.8 ± 0.4	1.23
			35	151 702	140.51 ± 14.14	−8.32 ± 14.52	27.22 ± 12.61	1.8 ± 0.4	1.23
			45	117 617	140.67 ± 14.68	−13.01 ± 16.15	27.52 ± 12.65	2.0 ± 0.6	1.24
			55	95 129	143.86 ± 17.03	−16.45 ± 17.38	25.39 ± 12.76	2.1 ± 0.6	1.23
	n	0.53	15	266 839	156.33 ± 17.80	7.41 ± 17.63	18.44 ± 15.16	1.4 ± 0.4	1.18
			25	169 752	161.02 ± 17.37	2.69 ± 17.12	11.86 ± 13.94	1.6 ± 0.4	1.10
			35	123 037	165.14 ± 18.88	−1.84 ± 18.82	5.82 ± 13.65	1.6 ± 0.5	1.13
			45	95 291	169.15 ± 19.40	−5.99 ± 19.29	1.54 ± 13.05	1.8 ± 0.5	1.10
			55	77 081	173.60 ± 21.09	−9.18 ± 19.47	6.03 ± 13.47	2.0 ± 0.6	1.10

Observation recently extended to QSOs...



Secrest et al. (2009.14826)

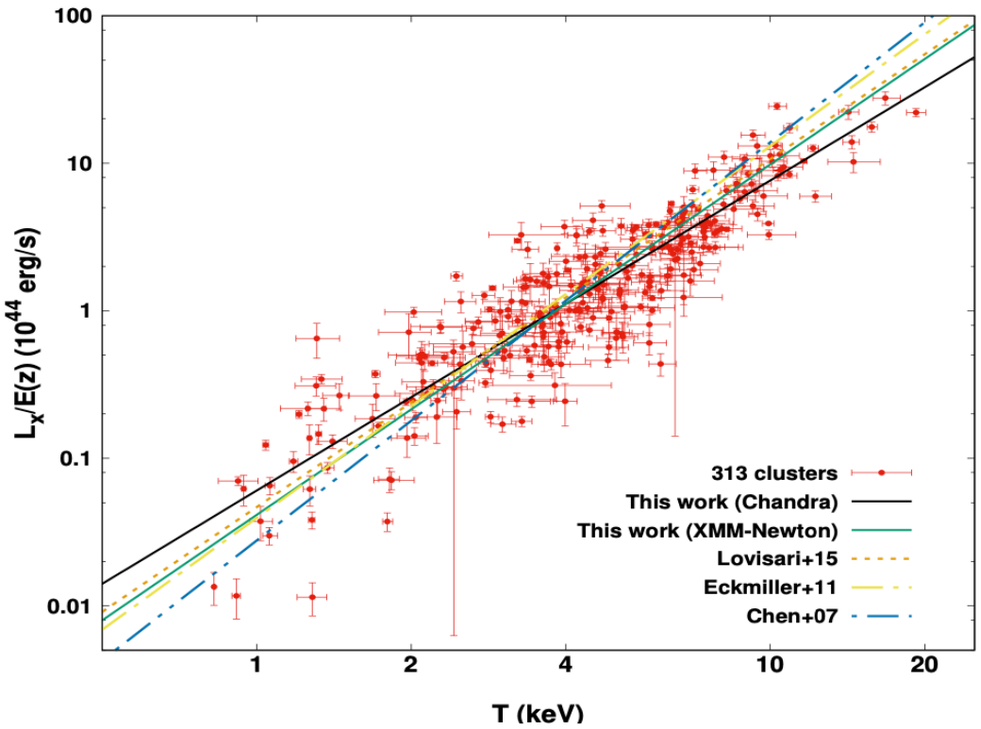




... and Hubble diagrams.

Singal (2106.11968, 2107.09390)

Interesting related work on scaling relations in galaxy clusters up to z ~ 0.3.



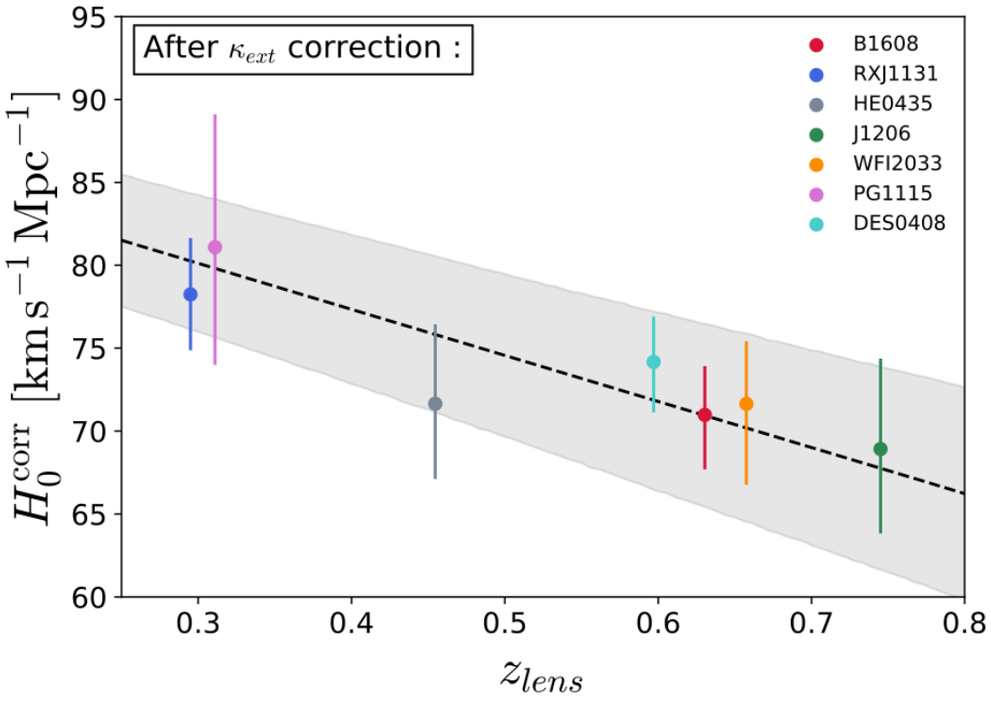
$$\frac{L_X}{10^{44}\ \mathrm{erg/s}} E(z)^{-1} = A \times \left(\frac{T}{4\mathrm{keV}}\right)^B$$

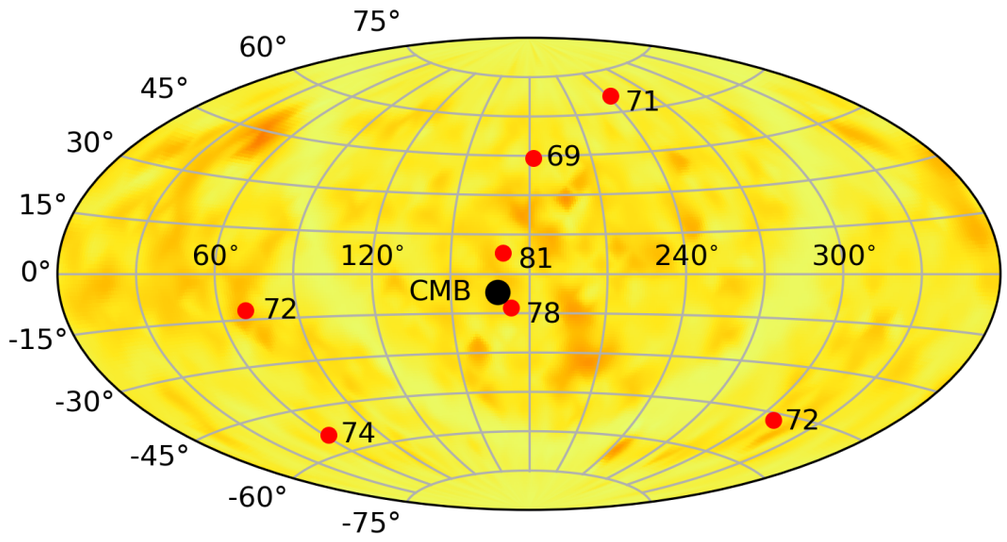
Migkas et al. (2004.03305, 2103.13904)

Anisotropy in the slope, but can be translated into H0 variations across the sky once one assumes Ω_m.

Is HO dancing in the stars?

(YES)





Millon et al. (1912.08027)

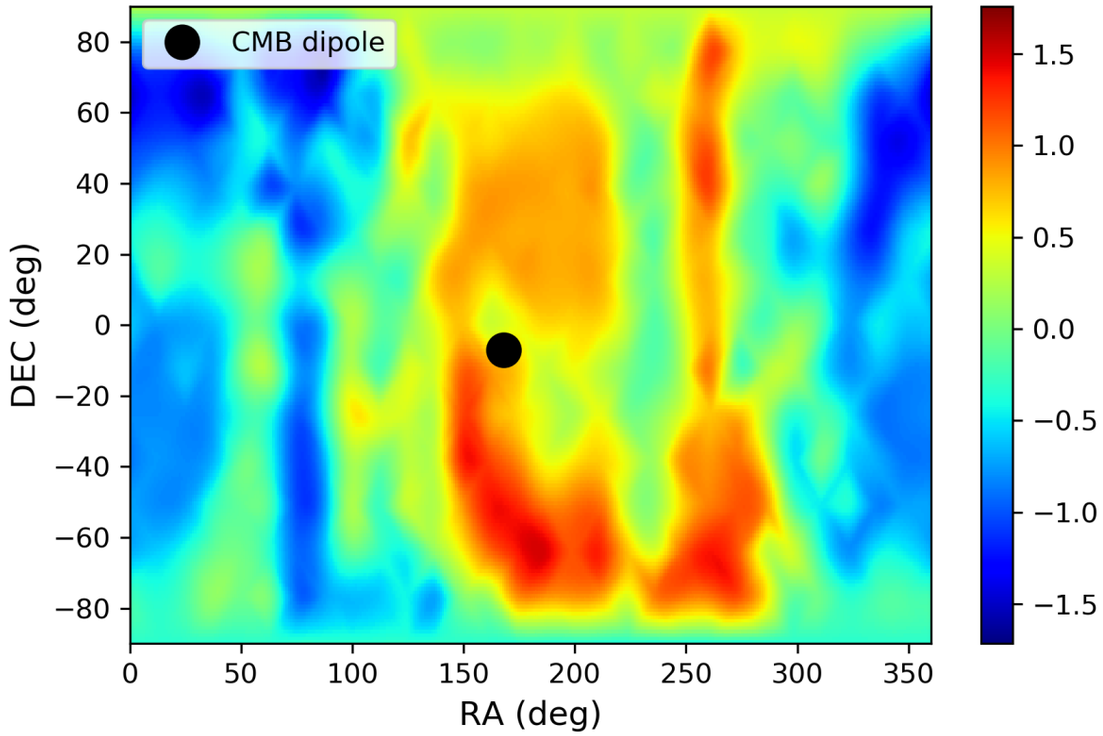
Krishnan et al. (2105.09790)

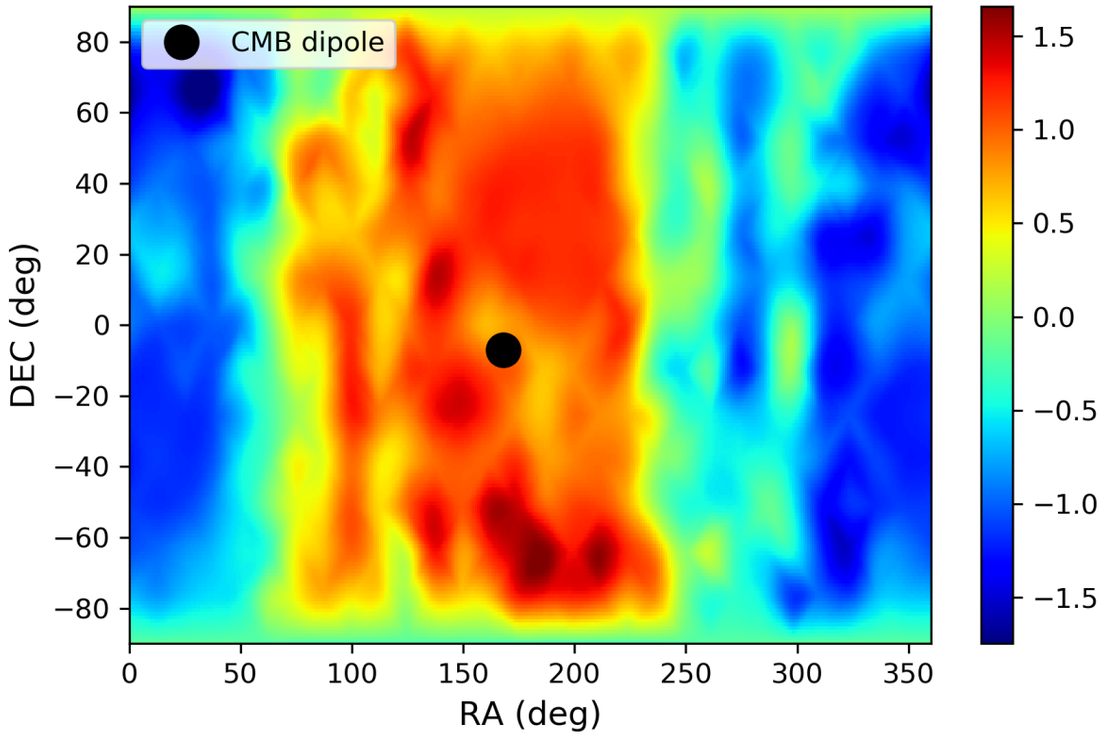
Strongly lensed QSOs have higher H0 values aligned with CMB dipole.

Is this a fluke? NO. Should it concern me? YES.

The same trend is there in Pantheon SN at low significance when one fits the LCDM model with a focus on H0.

Pantheon is in CMB frame by construction.





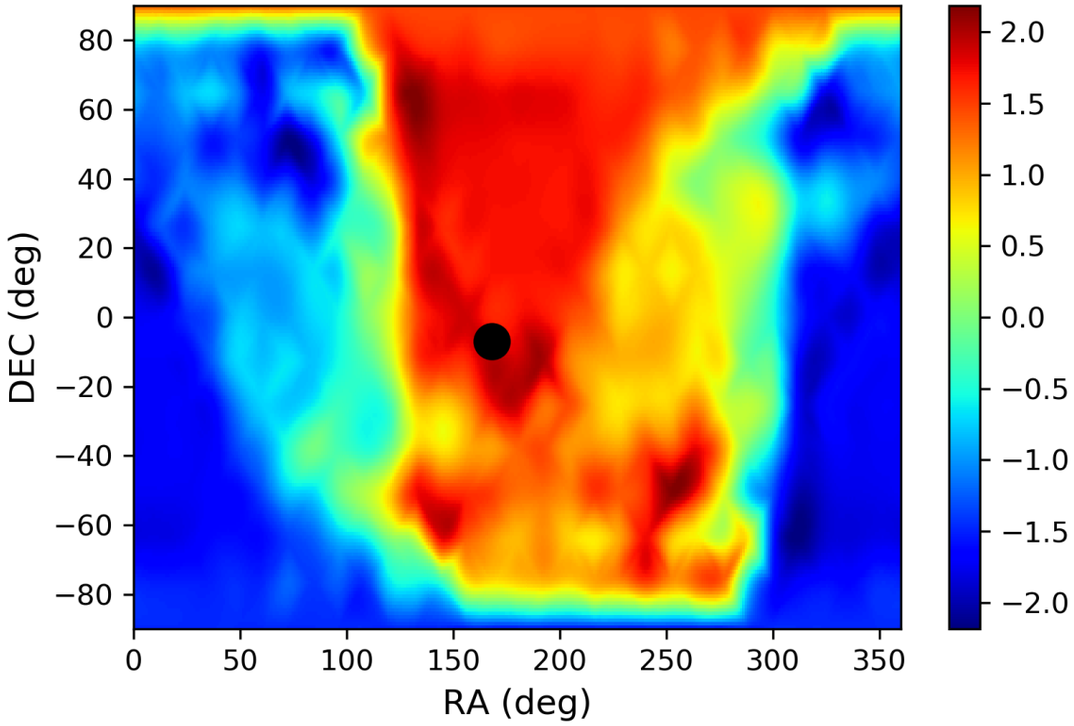
Krishnan et al. (2106.02532)

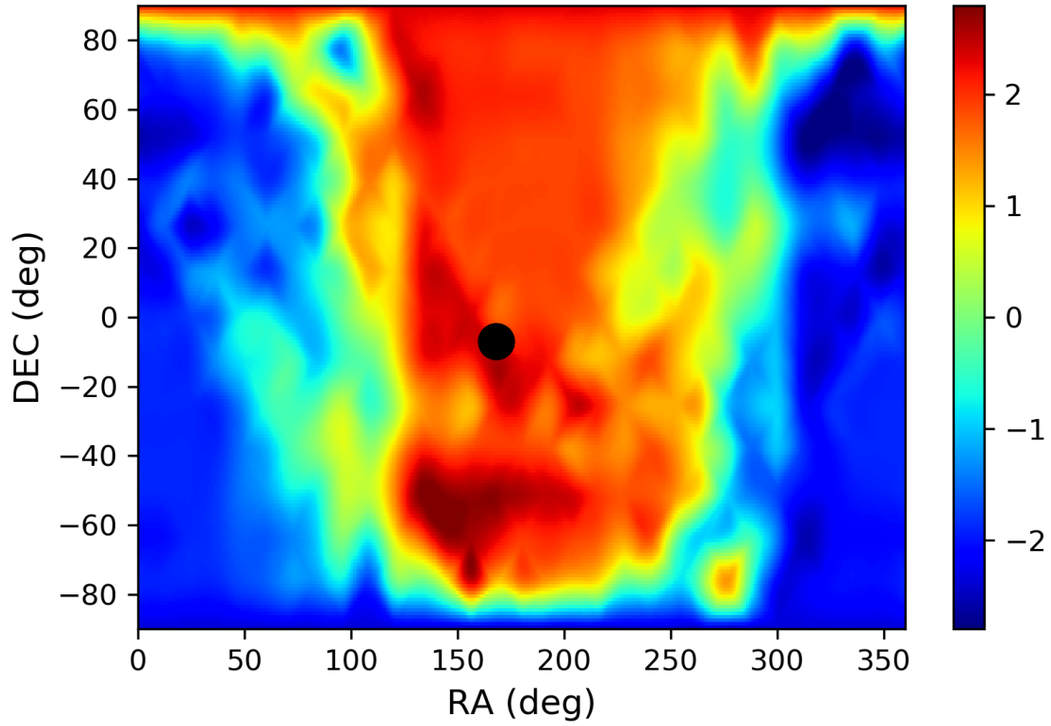
$$\sigma := \frac{(H_0^A - H_0^B)}{\sqrt{(\delta H_0^A)^2 + (\delta H_0^B)^2}}$$

One can see the same thing in Risaliti & Lusso QSOs.

Risaliti, Lusso (1505.07118, 2008.08586)

$$\log_{10}(L_X) = \beta + \gamma \log_{10}(L_{UV}),$$
$$\log_{10}(F_X) = \beta + (\gamma - 1)\log_{10}(4\pi) + \gamma \log_{10}(F_{UV}) + 2(\gamma - 1)\log_{10}(D_L)$$





Luongo et al. (2108.13228)

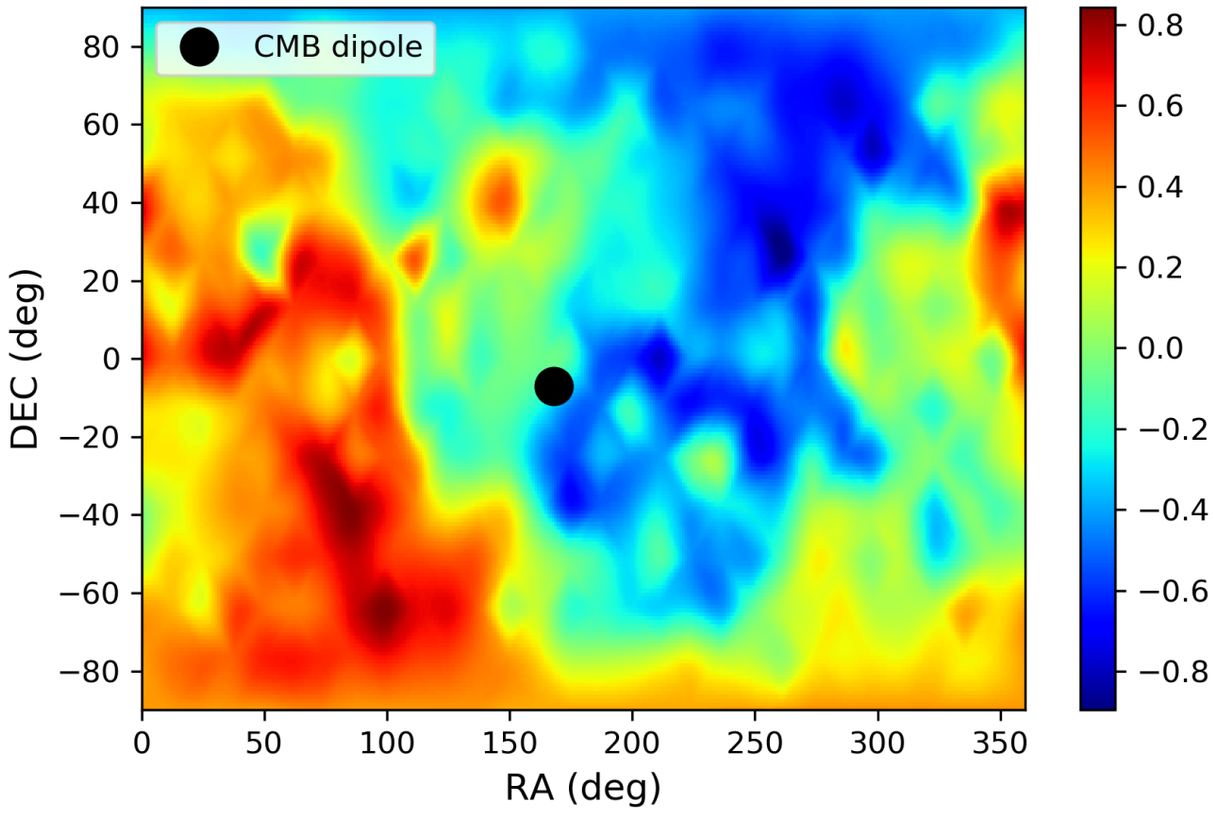
Recently, a sample of 118 GRBs with low scatter has been identified.

Khadka, Ratra et al. (2105.12692)

Amati relation

Amati et al. (0805.0377)

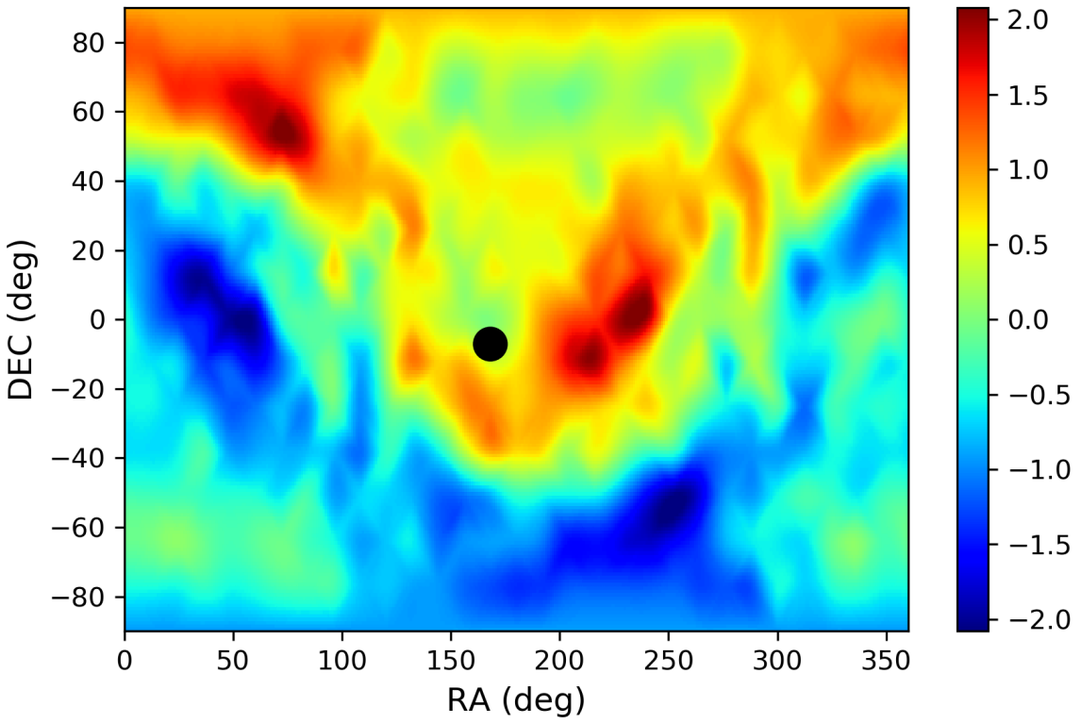
$$\log_{10} E_{\rm iso} = \alpha + \beta \log_{10} E_{\rm p} \qquad E_{\rm iso} = 4\pi D_L^2(z) S_{\rm bolo} (1+z)^{-1}$$



Luongo et al. (2108.13228)

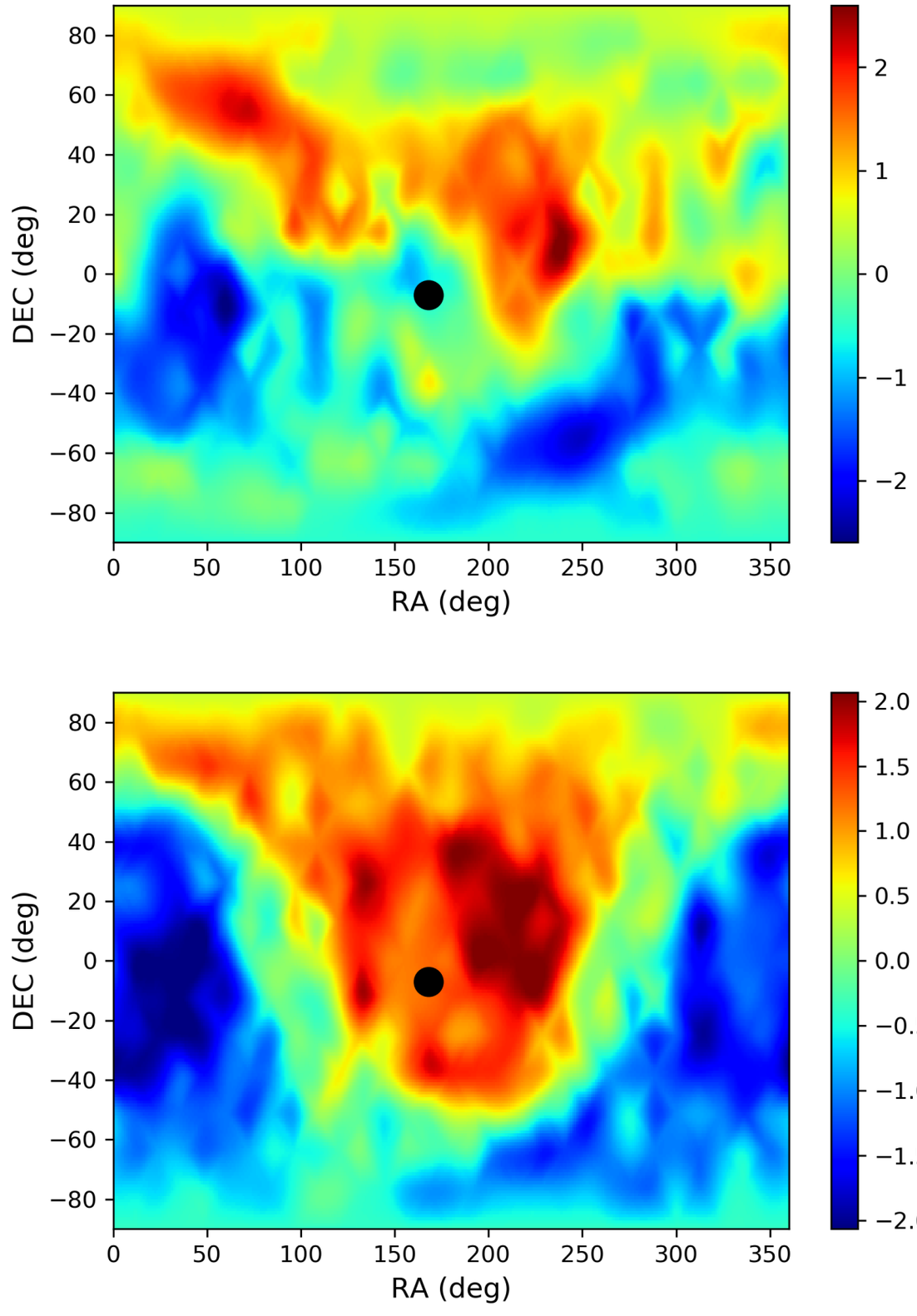
A larger sample of 162, 137 and 106 GRBs.

Dipole appears as scatter cut.



Luongo et al. (2108.13228)

Demianski et al. (1610.00854)



Further coincidences?

The quadrupole-octupole of the CMB align in a plane with normals in the CMB dipole direction.

de Oliveira-Costa et al. (astro-ph/0307282);
Schwarz et al. (astro-ph/0403353)

CMB has an anomalous parity asymmetry that tracks the CMB dipole direction.

Kim, Naselsky (1001.4613); Naselsky et al. (1108.4376)

There are curious regions of QSO polarization alignment and a special axis in the Universe that aligns with CMB dipole.

Hutsemekers et al. (astro-ph/0507274)

APCTP
A Discussion on the Cosmological Principle

Period October 25 (Mon.) - 28 (Thu.), 2021

Venue Online (ZOOM) & #503, APCTP HQ, Pohang, Korea

Overview With the growing significance of cosmological tensions, most notably Hubble tension, "precision cosmology" appears to have hit a speed bump. If the tensions are not due to experimental systematics, then we may be staring at contradictions that challenge the bedrock of cosmology. In this meeting, building on existing evidence that the *cosmological principle* or *FLRW paradigm* may be to blame, we gather international experts to debate the assumption that the Universe is isotropic & homogeneous. Audience participation will be actively encouraged through frequent discussion (Q&A) sessions. We hope the meeting may serve as an instructive bellwether for where the cosmology community currently stands on the FLRW assumption.

Invited Speakers

Pravabati Chingangbam
Chris Clarkson
Tamara Davis
Ruth Durrer
Asta Heinesen
Dragan Huterer
Chethan Krishnan
Roy Maartens
Konstantinos Migkas
David Parkinson
Subir Sarkar
Dominik Schwarz
Douglas Scott
Nathan Secrest
Hee-Jong Seo
Ashok Kumar Singal
George Smoot
Jiro Soda
Christos Tsagas
Shao-Jiang Wang
David Wiltshire
Lu Yin
Wen Zhao

Website https://sites.google.com/apctp.org/cosmoprinciple

Organizers Stephen Appleby (APCTP), Eoin Ó Colgáin (Sogang U.), Shahin Sheikh Jabbari (IPM)

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