



The CLEAN PAPER

WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

DESI cosmic ruler tó sharp jù, àti careful “bóyá” nípa dark energy

DESI wọn expansion history universe pèlú most precise baryon-acoustic ruler yet, láti six million objects. Lóri own rẹ, ruler náà agree pèlú standard model tí dark energy jẹ constant. Preference fún evolving dark energy hàn nìkan nígbà DESI combine pèlú CMB àti supernova sample — 2.6σ sí 3.9σ depending on sample, below discovery threshold, sensitive sí data pairing. Real question made precise, kì í ẹe answer.

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Ruler kan tí a fi sound ẹ

Ní ìbèrẹ̀ àgbáyé, ǵáájú ìràwò, hot plasma ti ordinary matter àti light ní “dún.” Pressure waves ní rìn nínú rẹ̀ ní ju half speed of light lọ, títi àgbáyé fi tutù tó fún atoms láti form, ringing náà sì dúró — ó freeze preferred ìjìnnà kékeré kan sínú distribution of matter. Distance yẹn, *sound horizon*, jẹ nípa 150 megaparsecs lóní (roughly 490 million light-years), ó sì hàn gégé bí slight excess ti ìṣùpò ìràwò tí ìjìnnà yẹn yà, ní gbogbo ìtọ̀sọ̀nà àti epoch. Cosmologists pe e ní **baryon acoustic oscillation (BAO)**, wọn sì lo o gégé bí standard ruler: wọn bí frozen scale náà ẹ̀ rí lórí sky ní distances tó yàtò, o sì lè chart bí àgbáyé ẹ̀ expand kojá history rẹ̀.

Dark Energy Spectroscopic Instrument (DESI) ni a kọ láti wọn ruler yẹn dáadàa ju ẹ̀nikẹ̀ni lọ. First dátà release rẹ̀ map BAO scale nínú ìṣùpò ìràwò, quasars àti Lyman-alpha igbó ti distant gas clouds — ju objects six million lọ, kojá seven redshift bins láti redshift 0.1 sí 4.2. Láti yọ ẹ̀nìyàn expectation kúrò nínú ẹ̀sì, ẹ̀gbẹ̀ náà run ìtupalẹ̀ *blind*, wọn hide cosmological answer lówọ̀ ara wọn títi ọ̀nà fi locked. Ní margin nílá, ẹ̀yí ni most precise BAO measurement tí a ti ẹ̀.



DESI wà lórí Nicholas U. Mayall 4-metre Telescope ní Kitt Peak, Arizona. Instrument náà feed thousands of optical fibres sí spectrographs, tó ní yí positions lórí sky sí spectra àti redshifts fún millions of ìṣùpò ìràwò àti quasars.

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Kí ni DESI?

Dark Energy Spectroscopic Instrument jẹ spectrograph lórí Nicholas U. Mayall 4-metre telescope ní Kitt Peak, Arizona. Kò “rí” dark agbára taara — kò sí ohun tó lè rí i nítorí dark agbára kò emit light. Dípò bẹ̀ẹ̀ ó àkọ̀sílẹ̀ spectra ti nípa 5,000 ìṣùpò ìràwò àti quasars lẹ̀ẹ̀kan, ó ka redshift object koṣkan láti bí expanding àgbáyé ẹ̀ stretch light rẹ̀, ó sì kọ three-dimensional map ti millions. Lẹ́yìn náà a infer dark agbára láti bí map yẹn ẹ̀ fi cosmic expansion hàn bí ó ẹ̀ ní yí pẹ̀lú àkókò. Fún whole chain — láti robotic fibres sí acoustic ruler — wo How DESI works.

àkólé tó tàn ká láti èsì yí ni pé dark agbára bóyá kí í ẹ̀ constant — pé mysterious thing tó ní accelerate expansion àgbáyé lè ní *weakening* pẹ̀lú àkókò, tó lè crack standard cosmological àwòṣe. Claim yẹn kí í ẹ̀ invented, ṣùgbón rọ̀rùn láti over-read. Honest èdà specific síi, ó sì interesting síi: DESI ruler funra rẹ̀, **alone**, agree pẹ̀lú plain-vanilla àwòṣe. Hint of tuntun physics hàn nìkan nígbà tí o combine DESI pẹ̀lú dátà mǐràn — strength hint náà sì depend lórí which other dátà you choose.

DESI baryon-acoustic ruler by itself consistent pẹ̀lú constant dark agbára (cosmological constant). Preference fún *evolving* dark agbára emerge nìkan nígbà DESI combine pẹ̀lú cosmic microwave abẹ̀lẹ̀ àti supernova àpẹ̀rẹ̀ — strength rẹ̀ sì shift pẹ̀lú which supernova àpẹ̀rẹ̀.

Standard ruler, àti ọ̀nà méjì tí dark energy lè vary

BAO scale jẹ *standard ruler*: nítorí a mọ true length rẹ̀ láti physics of early àgbáyé, comparing true length pẹ̀lú apparent ìwọ̀n ní ìjìnnà kan sọ iye tí àgbáyé ti expand nígbà yẹn. Measured kojá many distances, ruler náà trace whole expansion history — ohun tí dark agbára govern.

Nínú standard àwòṣe, Λ CDM, dark agbára jẹ *cosmological constant*: fixed agbára density of empty space tí kò yí. Physicists label ìhùwàsí rẹ̀ pẹ̀lú “equation of ipò” parameter, w , tí fún true cosmological constant jẹ exactly -1 , everywhere àti always.

Láti idánwò èyí, o lè relax assumption ní ọ̀nà méjì. Simpler ọ̀kan ni kí w jẹ constant mǐràn (sì fixed in àkókò) — “wCDM.” Richer ọ̀kan ni kí w change bí àgbáyé ẹ̀ expand, described pẹ̀lú numbers méjì: w_0 , value today, àti w_a , how fast it drifts. “ w_0w_a CDM” àwòṣe yí dín kù sí Λ CDM ní kókó $w_0 = -1$, $w_a = 0$. Preference fún w_0 greater than -1 pẹ̀lú w_a negative ni ohun tí “evolving dark agbára” túmọ̀ sí nìhìn-ín: dark agbára tí repulsive síi ní past, tó ní ease off now.

Ohun tí àwọn olùkòwé ẹ̀

- Wọ̀n wọ̀n BAO scale láti first year DESI dátà — ìṣùpò ìràwò, quasars àti Lyman-alpha igbó — ju six million objects lọ nínú seven redshift bins spanning $0.1 < z < 4.2$.
- Wọ̀n run itúpalẹ̀ **blind**, wọ̀n hide cosmological èsì títi methodology fi fixed, láti guard against confirmation bias.
- Wọ̀n fit standard flat Λ CDM àwòṣe sí DESI BAO alone, lẹ́yìn náà combine pẹ̀lú big-bang-nucleosynthesis prior àti cosmic microwave abẹ̀lẹ̀ (CMB) láti Planck àti ACT.
- Wọ̀n extend àwòṣe ní ọ̀nà méjì: constant dark-energy w (wCDM), àti time-varying w_0w_a (w_0w_a CDM).
- Wọ̀n idánwò time-varying àwòṣe nípa combining DESI+CMB pẹ̀lú yàtò type Ia supernova compilations mèta

— Pantheon+, Union3 àti DES-SN5YR — dípò selecting ọkan.

- Wọn place ààlà lóri summed neutrino mass, wọn sì check how those ààlà move tí dark-energy abẹlẹ bá allowed to vary.

Ohun tí wọn rí

- **DESI BAO alone consistent pẹlú standard àwòṣe.** Matter density jẹ $\Omega_m = 0.295 \pm 0.015$, àti nígbà dark agbára allowed constant w , $w = -0.99^{+0.15}_{-0.13}$ — basically cosmological-constant value -1 .
- Combined pẹlú CMB àti lensing rẹ, DESI gives $\Omega_m = 0.307 \pm 0.005$ àti Hubble constant $H_0 = 67.97 \pm 0.38$ km s⁻¹ Mpc⁻¹ (68.52 ± 0.62 when paired pẹlú nucleosynthesis àti CMB acoustic scale instead).
- **Nínú time-varying àwòṣe, combinations prefer evolving dark agbára** — $w_0 > -1$ àti $w_a < 0$. Preference jẹ 2.6σ fún DESI+CMB; pẹlú supernova àpẹrẹ ó di 2.5σ , 3.5σ , tàbí 3.9σ fún Pantheon+, Union3, tàbí DES-SN5YR respectively. Sigma ní wọn ijinnà láti standard-model expectation; 5σ ni usual discovery threshold, kò sì tùmọ sí pé interpretation correct — guide.
- Left free, summed neutrino mass tightly bounded — lábẹ 0.072 eV (95% ìgbẹkẹlẹ) fún DESI+CMB — ògbón ìwé ìwádíí sọ kedere pé bound yí loosens substantially tí dark-energy abẹlẹ allowed to depart láti Λ CDM.

Ohun tí èyí kò fi ẹrí múlẹ

- Kò fi hàn pé dark agbára evolving. DESI ruler funra rẹ consistent pẹlú cosmological constant; hint evolution hàn nìkan nínú *combined* fits, àti nínú richer two-parameter àwòṣe.
- Kò tùmọ sí “ Λ CDM dead” tàbí “Einstein wrong.” Strongest number, 3.9σ , below 5σ convention fún discovery, standard àwòṣe sì ẹ̀ good fit sí DESI alone.
- èsì **kò sample-independent**. Yí supernova compilation padà, significance move láti 2.5σ sí 3.9σ — ju full sigma kan lọ. àmì tó sensitive bẹẹ sí external dataset jẹ hint fún follow-up, kì í ẹ̀ measurement tí a bank.
- DESI-alone lean sí $w_0 > -1$ driven **partly by single anomalous kókó** — redshift-0.51 ìṣùpò ìràwọ̀ bin tí sìts slightly high against Λ CDM. Ògbón ìwé ìwádíí ẹ̀ homework rẹ: ó treat kókó nàà bí statistical fluctuation, ó sì fi hàn pé replacing *gbogbo* low-redshift ($z < 0.6$) DESI measurements pẹlú older SDSS leaves dark-energy èsì unchanged. Odd kókó tug DESI alone; **kò prop up combined hint**. Independent ẹ̀gbẹ̀ tí tún examine role rẹ.
- Neutrino-mass ààlà **kò model-independent**. Ó tight nìkan tí abẹlẹ expansion fixed sí Λ CDM; relax that, bound relax.

Báwo ni ẹ̀rí ẹ̀e lágbara tó?

- **Very lágbara gégé bí ijinnà measurement.** BAO ruler jẹ ọkan nínú cleanest irinṣẹ nínú cosmology, DESI’s is most precise yet, blind itupalẹ̀ sì jẹ safeguard tó tó against reading hoped-for answer sínú dátà.
- **Genuinely intriguing, not decisive gégé bí dark-energy claim.** 2.6σ preference láti DESI+CMB, rising sí 3.9σ pẹlú most constraining supernova set, jẹ èsì tó yẹ sí i telescope àkókò — kì í ẹ̀ èsì tó overturn àwòṣe.

Main reason fún caution ni spread across supernova àpẹẹrẹ; òhàkòwé tún check pé anomalous BAO kókó kan kò drive èsì.

- ìwé ìwádíí sọra pẹ̀lú ara rẹ̀: ó report significance méta ways dípò quoting largest, ó sì flag model-dependence ti neutrino èsì. Overreach, níbi tí ó bá wà, wá nínú retelling.

Kí nìdí tí ó fi ẹ̀ ẹ̀ pàtàkì?

Fún quarter-century, “dark agbára” àti “cosmological constant” ti fẹ̀rẹ̀ di synonyms, nítorí gbogbo measurements consistent pẹ̀lú w of exactly -1 . DESI jẹ́ dataset àkókò tó precise tó bẹ̀ẹ̀ tí, combined pẹ̀lú others, ó lè *ask* bóyá -1 náà drifts — kí answer má jẹ́ flat no. Èyí jẹ́ gidi shift nínú what dátà lè do. Sùgbón kan náà precision jẹ́ kí a rí bí hint ẹ̀ conditional: alive nínú some dátà combinations, quiet nínú others, sensitive jù sí which supernova catalogue paired pẹ̀lú DESI. Posture tó tó kí í ẹ̀ dismissal tàbí early revolution. Ó jẹ́ láti wo next larger DESI release àti independent supernova àpẹẹrẹ, kí a rí bóyá drift firm up tàbí fade. Èyí ni “genuine maybe” ẹ̀ rí nínú cosmology, ó yẹ́ ká report rẹ̀ gégé bí maybe.

Àkótán kedere

DESI ti wọ̀n expansion history àgbáyé pẹ̀lú best baryon-acoustic ruler yet, láti six million objects. Lóri own rẹ̀, ruler náà agree pẹ̀lú standard àwòṣe tí dark agbára jẹ́ constant. Combine pẹ̀lú cosmic microwave abẹ̀lẹ̀ àti supernova àpẹẹrẹ, preference emerge fún dark agbára tó ní change over àkókò — ní 2.6σ sí 3.9σ , depending on which supernovae. Real, interesting hint ni, kì í ẹ̀ discovery: below threshold, significance yí pẹ̀lú dataset pairing. Dark agbára lè be evolving. DESI ti mú ìbèèrè yẹn precise enough láti yẹ́ ká béèrè — kò tì answer rẹ̀.

Àwọn orísun

DESI Collaboration, arXiv:2404.03002 (published in JCAP)

<https://arxiv.org/abs/2404.03002>

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