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 pẹ̀lú most precise baryon-acoustic ruler yet, láti six million objects. Lórí own rẹ̀, ruler náà agree pẹ̀lú standard model tí dark energy jẹ́ constant. Preference fún evolving dark energy hàn nìkan nígbà DESI combine pẹ̀lú 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 ṣe answer.

Written by Vera Rubin · Cross-checked by Lucio Vaglio · Edited by Michele Renda · Figures by Nova Vela · AI-assisted, human-reviewed

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Ruler kan tí a fi sound ṣe

Ní ìbẹ̀rẹ̀ àgbáyé, ṣáájú ìràwọ̀, hot plasma ti ordinary matter àti light ń “dún.” Pressure waves ń rìn nínú rẹ̀ ní ju half speed of light lọ, títí àgbáyé fi tutù tó fún atoms láti form, ringing náà sì dúró — ó freeze preferred ijìnnà kékeré kan sínú distribution of matter. Distance yẹn, *sound horizon*, jẹ́ nípa 150 megaparsecs lónìí (roughly 490 million light-years), ó sì hàn gẹ́gẹ́ bí slight excess ti ìṣùpọ̀ ìràwọ̀ tí ijìnnà yẹn yà, ní gbogbo ìtọ́sọ́nà àti epoch. Cosmologists pe e ní **baryon acoustic oscillation (BAO)**, wọ́n sì lo o gẹ́gẹ́ bí standard ruler: wọn bí frozen scale náà ṣe rí lórí sky ní distances tó yàtọ̀, o sì lè chart bí àgbáyé ṣe expand kọjá history rẹ̀.

Dark Energy Spectroscopic Instrument (DESI) ni a kọ́ láti wọn ruler yẹn dáadáa ju ẹnikẹ́ni lọ. First dátà release rẹ̀ map BAO scale nínú ìṣùpọ̀ ìràwọ̀, quasars àti Lyman-alpha igbó ti distant gas clouds — ju objects six million lọ, kọjá seven redshift bins láti redshift 0.1 sí 4.2. Láti yọ ènìyàn expectation kúrò nínú èsì, ẹgbẹ́ náà run ìtúpalẹ̀ *blind*, wọ́n hide cosmological answer lọ́wọ́ ara wọn títí ọ̀nà fi locked. Ní margin ńlá, èyí ni most precise BAO measurement tí a ti ṣe.

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

Kí ni DESI?

Dark Energy Spectroscopic Instrument jẹ́ 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 bẹ́ẹ̀ ó àkọsílẹ̀ spectra ti nípa 5,000 ìṣùpọ̀ ìràwọ̀ àti quasars lẹ́ẹ̀kan, ó ka redshift object kọọkan láti bí expanding àgbáyé ṣe stretch light rẹ̀, ó sì kọ three-dimensional map ti millions. Léyìn náà a infer dark agbára láti bí map yẹn ṣe fi cosmic expansion hàn bí ó ṣe ń yí pẹ̀lú àkókò. Fún whole chain — láti robotic fibres sí acoustic ruler — wo How DESI works.

àkọlé tó tàn ká láti èsì yìí ni pé dark agbára bóyá kì í ṣe constant — pé mysterious thing tó ń accelerate expansion àgbáyé lè ń *weakening* pẹ̀lú àkókò, tó lè crack standard cosmological àwòṣe. Claim yẹn kì í ṣe invented, ṣùgbọ́n rọrùn láti over-read. Honest ẹ̀dà 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 mìíràn — 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 abẹ́lẹ̀ àti supernova àpẹẹrẹ — strength rẹ̀ sì shift pẹ̀lú which supernova àpẹẹrẹ.

Standard ruler, àti ọ̀nà méjì tí dark energy lè vary

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

Nínú standard àwòṣe, ΛCDM, dark agbára jẹ́ *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 jẹ́ exactly -1, everywhere àti always.

Láti ìdánwò èyí, o lè relax assumption ní ọ̀nà méjì. Simpler ọ̀kan ni kí w jẹ́ constant mìíràn (ṣì fixed in àkókò) — "wCDM." Richer ọ̀kan ni kí w change bí àgbáyé ṣe expand, described pẹ̀lú numbers méjì: w_0, value today, àti w_a, how fast it drifts. "w_0w_aCDM" àwòṣe yìí dín kù sí ΛCDM 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 níhìn-ín: dark agbára tí repulsive síi ní past, tó ń ease off now.

Ohun tí àwọn olùkọ̀wé ṣe

- Wọ́n wọn BAO scale láti first year DESI dátà — ìṣùpọ̀ ìràwọ̀, quasars àti Lyman-alpha igbó — ju six million objects lọ nínú seven redshift bins spanning $0.1 < z < 4.2$.
- Wọ́n run ìtúpalẹ̀ **blind**, wọ́n hide cosmological èsì títí methodology fi fixed, láti guard against confirmation bias.
- Wọ́n fit standard flat ΛCDM àwòṣe sí DESI BAO alone, léyìn náà combine pẹ̀lú big-bang-nucleosynthesis prior àti cosmic microwave abẹ́lẹ̀ (CMB) láti Planck àti ACT.
- Wọ́n extend àwòṣe ní ọ̀nà méjì: constant dark-energy w (wCDM), àti time-varying w_0w_a (w_0w_aCDM).
- Wọ́n ìdánwò time-varying àwòṣe nípa combining DESI+CMB pẹ̀lú yàtọ̀ type Ia supernova compilations méta

— Pantheon+, Union3 àti DES-SN5YR — dípò selecting ọ̀kan.
- Wọ́n place ààlà lórí summed neutrino mass, wọ́n sì check how those ààlà move tí dark-energy abẹ́lẹ̀ bá allowed to vary.

Ohun tí wọ́n rí

- **DESI BAO alone consistent pẹ̀lú standard àwòṣe.** Matter density jẹ́ $\Omega_m = 0.295 \pm 0.015$, àti nígbà dark agbára allowed constant w, $w = -0.99^{+0.15}_{-0.13}$ — basically cosmological-constant value -1.
- Combined pẹ̀lú CMB àti lensing rẹ̀, 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 pẹ̀lú nucleosynthesis àti CMB acoustic scale instead).
- **Nínú time-varying àwòṣe, combinations prefer evolving dark agbára** — $w_0 > -1$ àti $w_a < 0$. Preference jẹ́ 2.6σ fún DESI+CMB; pẹ̀lú supernova àpẹẹrẹ ó di 2.5σ, 3.5σ, tàbí 3.9σ fún Pantheon+, Union3, tàbí DES-SN5YR respectively. Sigma ń wọn ijìnnà láti standard-model expectation; 5σ ni usual discovery threshold, kò sì túmọ̀ sí pé interpretation correct — guide.
- Left free, summed neutrino mass tightly bounded — lábẹ́ 0.072 eV (95% ìgbẹ́kẹ̀lé) fún DESI+CMB — ṣùgbọ́n ìwé ìwádìí sọ kedere pé bound yìí loosens substantially tí dark-energy abẹ́lẹ̀ allowed to depart láti ΛCDM.

Ohun tí èyí kò fi ẹ̀rí múlẹ̀

- Kò fi hàn pé dark agbára evolving. DESI ruler funra rẹ̀ consistent pẹ̀lú cosmological constant; hint evolution hàn nìkan nínú *combined* fits, àti nínú richer two-parameter àwòṣe.
- Kò túmọ̀ sí "ΛCDM dead" tàbí "Einstein wrong." Strongest number, 3.9σ, below 5σ convention fún discovery, standard àwòṣe sì ṣì 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 bẹ́ẹ̀ sí external dataset jẹ́ hint fún follow-up, kì í ṣe measurement tí a bank.
- DESI-*alone* lean sí $w_0 > -1$ driven **partly by single anomalous kókó** — redshift-0.51 ìṣùpọ̀ ìràwọ̀ bin tí sits slightly high against ΛCDM. Ṣùgbọ́n ìwé ìwádìí ṣe homework rẹ̀: ó treat kókó náà bí statistical fluctuation, ó sì fi hàn pé replacing *gbogbo* low-redshift ($z < 0.6$) DESI measurements pẹ̀lú older SDSS leaves dark-energy èsì unchanged. Odd kókó tug DESI alone; **kò prop up combined hint**. Independent ẹgbẹ́ ti tún examine role rẹ̀.
- Neutrino-mass ààlà **kò model-independent**. Ó tight nìkan tí abẹ́lẹ̀ expansion fixed sí ΛCDM; relax that, bound relax.

Báwo ni ẹ̀rí ṣe lágbára tó?

- **Very lágbára gẹ́gẹ́ bí ijìnnà measurement.** BAO ruler jẹ́ ọ̀kan nínú cleanest irinṣẹ́ nínú cosmology, DESI's is most precise yet, blind ìtúpalẹ̀ sì jẹ́ safeguard tó tọ́ against reading hoped-for answer sínú dátà.
- **Genuinely intriguing, not decisive gẹ́gẹ́ bí dark-energy claim.** 2.6σ preference láti DESI+CMB, rising sí 3.9σ pẹ̀lú most constraining supernova set, jẹ́ èsì tó yẹ sí i telescope àkókò — kì í ṣe èsì tó overturn àwòṣe.

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

- ìwé ìwádìí ṣọ́ra pẹ̀lú ara rẹ̀: ó report significance mẹ́ta 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 ṣe pàtàkì?

Fún quarter-century, “dark agbára” àti “cosmological constant” ti fẹrẹẹ di synonyms, nítorí gbogbo measurements consistent pẹ̀lú w of exactly -1. DESI jẹ́ dataset àkọ́kọ́ tó precise tó bẹ́ẹ̀ 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. Ṣùgbọ́n kan náà precision jẹ́ kí a rí bí hint ṣe conditional: alive nínú some dátà combinations, quiet nínú others, sensitive jù sí which supernova catalogue paired pẹ̀lú DESI. Posture tó tọ́ kì í ṣe 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” ṣe rí nínú cosmology, ó yẹ ká report rẹ̀ gẹ́gẹ́ bí maybe.

Àkótán kedere

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

Àwọn orísun

DESI Collaboration, arXiv:2404.03002 (published in JCAP)
`https://arxiv.org/abs/2404.03002`

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