Fact-Checked Science

PAPER CHECK · COSMOLOGY

Friedmann universes are unstable, but the match to dark energy rests on a miscalculation

Three mathematicians at UCL and UC Davis prove, in a formal expansion, that universes of pressureless matter described by Friedmann's equations are unstable to spherical perturbations at the Big Bang [1 p. 1], and propose that the resulting departures from Friedmann expansion, rather than dark energy, might explain the accelerating universe [1 pp. 3–4][1 p. 23]. In our analysis the instability grows at the textbook rates of cosmic structure, and at the order that measures acceleration every solution expands like an open universe without dark energy, which slows down [1 p. 20][1 p. 22]; the match to dark energy that the paper quotes comes from a 2017 formula that gives the cosmological constant the scaling of curvature [6 p. 14]. S0 News linked UC Davis's blog post on the paper under the label "No Dark Energy" [5][4]. We read the published paper in full and compared it with the version posted before review; the episode we could read only as its title and description.

By Fact-Checked Science · Published October 31, 2026

OUR ANALYSIS marks our own reasoning and calculations, among them the redshift–distance terms for flat ΛCDM and for the 2017 paper's formula, the eigenvalues re-derived from the paper's equations and what they mean for a shell of matter, and the verdicts are our assessment. Everything else comes from the numbered sources. For the paper [1], p. gives a page of its published version, § a section, eq. an equation, Thm a theorem and fn a footnote, as numbered there; the version its authors posted before review [2] is cited only where the two are compared. For the 2017 paper [6], p. gives a page and eq. an equation of its journal version; for the review history [3], Referee 1, Referee 2 and Decision name its documents.

A real instability, long familiar to cosmology, and a match to dark energy that rests on a miscalculation

OUR ASSESSMENT

0.775

Q, the term of the supernova Hubble diagram that measures acceleration, for a flat universe with 70% dark energy as a cosmological constant, by the standard formula [10 eq. 46][10 eq. 20]. The paper quotes 0.425, from a 2017 formula that gives the cosmological constant the redshift scaling of curvature (our analysis) [1 p. 22][6 p. 14].

$q_0 \geq 0$

the deceleration parameter of every one of the paper's solutions at the order that fixes Q [1 p. 20], by our reading: at that order each is an ordinary Friedmann universe without dark energy [1 p. 1][1 fn 1], which slows down or coasts [1 p. 22]. Supernovae fitted with Friedmann models measure $q_0 < 0$ [11 Abstract][13 Abstract].

$t^{2/3}$

how the instability grows for a shell of matter at every order of the paper's expansion, by our reading of its eigenvalues [1 eq. 2.29]: the growth of cosmic structure, the subject of Lifshitz's 1946 paper [25], and at first order the flatness problem [24].

THE CLAIMS

OVERSTATED

"No Dark Energy"

S0 News's label on its link to UC Davis's blog post about the paper [5][4]

The paper proposes an alternative: instabilities that "provide a natural mechanism for an accelerated expansion without recourse to a cosmological constant or dark energy" [1 p. 1]. It calls its cosmology a programme "to determine whether" the instability is the source of the acceleration [1 p. 23], fits no data, and says its conclusion holds with dark energy added too [1 p. 24]. At the order that measures acceleration its solutions slow down (our analysis, section 4), while supernovae [13 Abstract], the cosmic microwave background (CMB) [14 Abstract] and baryon acoustic oscillations (BAO) [15 Abstract], fitted with Friedmann models, measure the acceleration independently. An untested proposal is not a finding that there is no dark energy. See section 5.

TRUE

"In the present paper, we give a theorem stating that the Friedmann spacetimes are in fact all unstable to radial perturbation, at every order."

The paper's introduction [1 p. 2]

The mathematics holds where we could check it: linearising the equations as printed gives the paper's eigenvalues, 2/3 and −1 at first order and 4/3 and −1/3 at second [1 eq. 2.29] (our analysis). It is not news to cosmology, though. For a shell of matter, the two eigenvalues at every order give the growing and decaying modes of a matter-dominated universe, $t^{2/3}$ and t^{-1} (our analysis), the subject of Lifshitz's paper of 1946 [25]; and the first-order instability is the flatness problem that inflation was proposed to solve [24]. The paper itself says both instabilities were known [1 p. 3]. Its proofs are in an unrefereed preprint [1 p. 4], and whether its expansions converge to actual solutions is left for later [1 p. 9][7 p. 6]. See section 3.

OVERSTATED

"Thus instabilities inherent in the Einstein–Euler equations provide a natural mechanism for an accelerated expansion without recourse to a cosmological constant or dark energy."

The paper's abstract [1 p. 1]

"Accelerate away" means "generically distinct from" a Friedmann universe, in the words of its Theorem 2.9 [1 p. 21]: a departure from the open universe, which the authors' preprint calls "an advancing or retarding" of one of its velocity terms [7 p. 18], not an expansion that speeds up. At the order that fixes the supernova term Q [1 p. 20], every solution is a Friedmann universe without dark energy [1 p. 1][1 fn 1], and such a universe decelerates (our analysis). A model centred on us could still show an apparent acceleration at higher orders, as void models do [18 Abstract]; the paper computes none, and such models have failed other tests (section 5). It computes no observable of its own, fits no data and calls the cosmology a programme [1 p. 23]. See section 4.

FALSE

"A calculation using the current model of the k = 0 Friedmann spacetime with 70% dark energy by virtue of a cosmological constant gives the value Q = 0.425."

The paper's §2(i), which adds that dark energy and its own solutions both "take values within the narrow range 0.25 ≤ Q ≤ 0.5", citing its authors' 2017 paper [1 p. 22][6 p. 15]

By the standard relation $Q = (1 - q_0)/2$ [10 eq. 46], a flat universe with 70% dark energy as a cosmological constant has $q_0 = -0.55$ and $Q = 0.775$, and as the share of dark energy runs from none to all, Q runs from 0.25 to 1 [10 eq. 20][10 eq. 49] (our analysis). The 0.425 and the third-order −0.1804 come from the 2017 paper's eq. 3.39, which gives the cosmological constant the $(1 + z)^2$ redshift dependence of spatial curvature; our script reproduces its 17/40 and −433/2400 exactly from that formula [6 p. 14][6 p. 15]. The published version repeats the numbers, unchanged from the submitted one [1 pp. 22–23][2 pp. 20–21], and its Figure 3 now marks where the present universe lies "given the current experimental values of H_0 and Q" [1 p. 22], treating 0.425 as measured (our analysis). ΛCDM's value lies outside the 0.25–0.5 its solutions can reach. See section 4.

OVERSTATED

"mathematical proof that … the current model of the expanding universe is not viable"

UC Davis's blog post on the paper, its first paragraph [4]

The paper proves an instability of what it calls the "standard model" [1 p. 5], the flat universe of matter, the Einstein–de Sitter model, among Friedmann universes it defines as those "with zero cosmological constant" [1 fn 1], within an expansion whose convergence it leaves for later [1 p. 9]. It argues, but does not prove, that the flat Friedmann universe is "implausible as a physically observable model, with or without dark energy" [1 p. 24], and a footnote calls ΛCDM's cosmic coincidence "the hallmark of using an ad hoc correction to the equations when it is the underlying solution that is wrong" [1 fn 4]. ΛCDM fits the CMB, the BAO and the supernovae [14 Abstract][15 Abstract], and the instability is already part of it, as the growth of structure (our analysis, section 3). See section 7.

MISLEADING

"produce a special place where we must lie"

Blake Temple, in the blog post, of ΛCDM and of a spherically symmetric universe alike [4]

In the paper, ΛCDM's special place is first a time: we live when matter and dark energy have similar densities [1 fn 4], a coincidence that every observer in the universe shares. The paper also points to "a small angular dependence in the microwave background radiation" and suggests that "all current models seem to place Earth in some sort of special place" [1 fn 8]: large-angle patterns in the CMB, aligned with the solar system's orientation and motion, which the study it cites allowed might not be cosmic at all [26 Abstract], and that Planck finds in an otherwise ΛCDM-like sky [27 Abstract]. They are a puzzle for ΛCDM, not a place its fits need us to be; the paper's own model needs the Milky Way "sufficiently centred" on the extra acceleration [1 p. 23] (our analysis). The Copernican principle is about position, and tests of it on scales of billions of light years rule out spherical "void" models big enough to stand in for dark energy [22 Abstract][23 Abstract], as do the combined data [21 Abstract]. See section 5.

1 · THE PAPER

A mathematics paper in *Proceedings A*, the latest step in a programme going back to 2009

Christopher Alexander of University College London and Blake Temple and Zeke Vogler of UC Davis ask whether a universe of pressureless matter that starts as a Friedmann universe stays one when it is perturbed at the Big Bang [1 p. 1]. The paper is peer reviewed and open access. The journal's site answered our tools with a bot check, which we do not attempt, so we first read the version the authors posted before review; the site's owner then supplied the published version, which this page follows [1][2].

WHAT WE READ

The published version

The version of record, 25 pages, in full, compared throughout with the preprint posted before review, arXiv:2510.14228v1. The abstract is unchanged but for spelling; the title, a footnote's definition and some explanations changed between the preprint and publication [1][2].

STATUS

Peer reviewed

Received October 27, 2025; two referees; accepted subject to minor revisions on February 25 and in final form on March 12, 2026; published in the May 15 issue and online on May 27 [1][3].

LICENCE

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For the paper [1], its preprint [2] and its published review history [3], so its figures may be adapted and the referees quoted, with credit.

What the authors did

They write Einstein's equations for a perfect fluid, "assuming zero cosmological constant", in spherical symmetry, in coordinates built so that the flat (k = 0) Friedmann universe of pressureless matter stands still, as a rest point they call SM "for standard model" [1 p. 5]. Their spatial variable is ξ = r/t, distance from the centre in units of how far light has travelled since the Big Bang, and they keep 0 < ξ < 1, about out to the Hubble radius [1 p. 5]. Expanding smooth solutions in even powers of ξ gives, at each order n, a system of 2n ordinary differential equations, which they call the STV-ODE, after Smoller, Temple and Vogler [1 p. 5][1 §2(c)]. They find its rest points and their eigenvalues at every order and follow the underdense solutions from the Big Bang into the far future [1 §2(c)–(h)]. No data are fitted [1]. They grant that ΛCDM "appears to account for most of the cosmological data" [1 p. 3].

A programme going back to 2009

In 2009 Temple and Smoller proposed that self-similar waves left over from the radiation era could add an "anomalous acceleration" to the standard model of cosmology, and called the next-order correction "a prediction" [8 Abstract][9 Abstract]. In 2017 Smoller, Temple and Vogler evolved such a wave to the present and wrote that it was shown to "match the accelerations of dark energy up to second order" [6 p. 1]. The new paper completes their eigenvalue analysis and corrects the 2017 paper in two places [1 fn 12][1 fn 21]. It says its rigorous proofs are in a 99-page preprint of 2024, which no journal has published [1 p. 4][7]. Joel Smoller died shortly before the 2017 paper appeared, and the paper is dedicated to him [1 p. 4].

The aim and the caveats, in the authors' words

Friedmann spacetimes are the expanding, uniform universes of standard cosmology; k is the sign of their spatial curvature.

> *"… we present this with an eye toward exploring the possibility that accelerations away from Friedmann spacetimes generated by the instability at the Big Bang could potentially account for the anomalous acceleration of the galaxies."*
>
> Alexander, Temple and Vogler [1 pp. 3–4]

> *"Here we limit ourselves to developing the asymptotic analysis and will address the existence theory in subsequent publications."*
>
> Alexander, Temple and Vogler [1 p. 9]

> *"Of course, this would require the Milky Way galaxy to be sufficiently centred on that part of the acceleration which is present over and above a background k < 0 Friedmann spacetime in order to account for the apparent uniformity of the galaxies in opposite directions of observation."*
>
> Alexander, Temple and Vogler [1 p. 23]

Funding, interests and what changed before publication

The work was supported by EPSRC project EP/S02218X/1 and ERC starting grant 101078061 (SINGinGR) to Alexander, and by the American Institute of Mathematics SQuaRE programme, and the authors declare "no competing interests" [1 p. 24]. The referees asked for a shorter introduction, clearer wording and more physical explanation of the eigenvalues and figures, including whether SM includes Λ [3 Referee 1][3 Referee 2]. The published version settles that in its first footnote, which now defines Friedmann spacetimes as those "with zero cosmological constant" [1 fn 1], and adds definitions, a reading of its second figure [1 p. 21] and a closing comment on comoving models of dark energy [1 p. 24]. Its abstract is unchanged, its theorems are the same in substance, though renumbered, and its comparison with dark energy is unchanged (section 4).

2 · WHAT IT PROVES

The flat Friedmann universe is a saddle: every smooth solution agrees with a Friedmann universe at leading order, and most then drift from it

In the paper's variables, the flat universe of pressureless matter is one rest point, SM, and empty Minkowski space is another, M. The eigenvalues of SM decide what solutions that start near it do [1 eq. 2.27][1 eq. 2.29].

STEP 1

Two rest points

SM, at (4/3, 2/3, 40/27, 2/9, …), is the flat Friedmann universe; M, at (0, 1, 0, …), is empty space, where every underdense solution ends up [1 eq. 2.27].

STEP 2

Eigenvalues at every order

$\lambda_{An} = 2n/3$ and $\lambda_{Bn} = (2n - 5)/3$: 2/3 and −1 at first order, 4/3 and −1/3 at second, both positive from the third on [1 eq. 2.29]. A choice of time origin the authors call "time since the Big Bang" removes the −1, which only shifts the clock [1 §2(f)].

STEP 3

Friedmann at leading order

With that choice, every solution smooth at the centre agrees at leading order with a Friedmann universe, open (k < 0), flat or closed; the open ones lie on the path from SM to M [1 p. 1][1 §2(e)].

STEP 4

Drifting, then returning

Underdense solutions, the family $\mathcal{F}$, generically drift, at intermediate times, from the open universe they agree with at leading order, at every order from the second [1 p. 1][1 Thm 2.9], and return to it as t → ∞, faster than they approach empty space [1 Thm 2.8]. The size of the drift, set by a free parameter b/a, "can be arbitrarily large" [1 p. 19].

What the paper proves, proposes and leaves for later

Stated as proved	The eigenvalues [1 eq. 2.29]; agreement with a Friedmann universe at leading order [1 p. 1]; the rates at which underdense solutions return to it, $\lvert\rho - \rho_F\rvert \leq C\,t^{-5}$ at a fixed radius [1 Thm 2.8]; their drift at intermediate times [1 Thm 2.9]; and a Big Bang that is generically not self-similar beyond leading order [1 Thm 2.10]. The proofs are in the authors' 2024 preprint [1 p. 4][7].
Proposed	$\mathcal{F}$ as "the maximal asymptotically stable family of solutions" into which underdense perturbations evolve [1 p. 3]; and the cosmology, as a programme [1 p. 23], for which the framework "provides a setting in which these issues of physics and cosmology can be addressed quantitatively" [1 p. 24].
Left for later	Whether the expansions converge to actual solutions, "the existence theory" [1 p. 9] (the preprint "formally assume[s] convergence" [7 p. 6]); overdense, closed universes [1 p. 8]; the radiation era [1 p. 23]; and redshifts, to which the authors "will return" [7 p. 18].
Argued in the conclusions	That the instability makes the flat Friedmann universe "implausible as a physically observable model, with or without dark energy" [1 p. 24].

Scope: perturbations spherically symmetric about one centre, in the era of pressureless matter, with ξ < 1; for the open universe the coordinates are regular out to ξ ≈ 0.816 [1 p. 5][1 Thm 2.7].

3 · WHAT THE INSTABILITY IS

Cosmology's familiar instability: the growth of structure, and at first order the flatness problem

The paper itself notes that galaxies are "presumed" to have formed through "local gravitational instabilities", and that the flat Friedmann universe was known to be unstable to a change in its curvature [1 p. 3]. Its eigenvalues are those two instabilities, order by order (our analysis).

The paper's eigenvalues, and what they mean for a shell of matter

ORDER N	EIGENVALUES OF SM, λ_A AND λ_B [1 EQ. 2.29]	DENSITY CONTRAST OF A SHELL OF MATTER (OUR ANALYSIS)	IN STANDARD COSMOLOGY
1	2/3 and −1	$t^{2/3}$ and t^{-1}	A change of curvature, $\lvert\Omega - 1\rvert$ growing like $t^{2/3}$ (our analysis): the flatness problem [24]; and a shift of the Big Bang's time, which fades [1 §2(f)]
2	4/3 and −1/3	$t^{2/3}$ and t^{-1}	The growing and decaying modes of linear perturbations in a universe of pressureless matter, here for a radial profile like r^{2n-2} (our analysis); the subject of Lifshitz's paper of 1946 [25]
3	2 and 1/3	$t^{2/3}$ and t^{-1}	
n	2n/3 and (2n − 5)/3	$t^{2/3}$ and t^{-1}	

OUR ANALYSIS

Why the eigenvalues are the textbook modes

The paper's density variable is $z = \kappa\rho r^2$ (not the redshift of section 4) [1 §2(a)], and z_{2n} is the coefficient of $\xi^{2n} = (r/t)^{2n}$ [1 §2(c)]. If a perturbation of z_{2n} grows like t^λ, the density contrast of a given shell of matter, whose radius grows like $t^{2/3}$ in the flat universe, changes like $t^{\lambda - (2n - 2)/3}$. With the paper's $\lambda_{An} = 2n/3$ and $\lambda_{Bn} = (2n - 5)/3$ [1 eq. 2.29], that is $t^{2/3}$ and t^{-1} at every order: the familiar growing and decaying modes of small density perturbations in a universe of pressureless matter, the subject of Lifshitz's paper of 1946 [25]. At first order the growing mode is a change of curvature: the paper's eigenvalue 2/3 belongs to the open and closed Friedmann universes themselves [1 p. 6][1 p. 14]. Their density drifts away from the critical density as $\lvert\Omega - 1\rvert \propto 1/(aH)^2$, which grows like $t^{2/3}$ when matter dominates: the flatness problem that inflation was proposed to solve [24]. The second eigenvalues turn positive from the third order on only because ξ = r/t shrinks at a fixed radius; for a shell of matter they decay. Our script checks the eigenvalues from the printed equations (section 9).

In standard cosmology, the engine, not a flaw

This instability is how standard cosmology makes galaxies: tiny ripples in a nearly uniform young universe grow under their own gravity, as the paper itself recalls [1 p. 3]. The paper also says the CMB's fluctuations "argue strongly for the critical (k = 0) Friedmann spacetime" [1 p. 2], and the CMB with BAO measures the curvature as "consistent with a flat universe, $\Omega_K = 0.001 \pm 0.002$" [14 Abstract]. The universe is observed very close to the solution the paper calls unstable: that is where the flatness problem [24] starts, not evidence against the model (our analysis).

What is new, and what is still to come

New: a systematic treatment of the instability at every order in these variables, the family $\mathcal{F}$ of underdense solutions and the part of it that leaves SM, and the result that the Big Bang is generically not self-similar beyond leading order [1 Thm 2.9][1 Thm 2.10]. This is mathematics, and it passed peer review [3]. The published version adds that the instability could create accelerations "far enough out to be observed on the largest length scale of observation, beyond the length scales of local fluctuations identified in the microwave background radiation" [1 p. 24]. On any scale, though, a perturbation of a universe of matter grows at the rates above, and a large one centred on us is what the tests of section 5 probe (our analysis). Still to come: the proofs are in an unrefereed preprint [1 p. 4][7], and the authors have not yet shown that their expansions converge to actual solutions [1 p. 9][7 p. 6].

4 · FROM INSTABILITY TO ACCELERATION

At the order that measures acceleration every solution slows down, and the match to ΛCDM uses a wrong formula

Supernovae trace the expansion through luminosity distance d_L against redshift z: $H_0 d_L = z + Qz^2 + Cz^3 + \ldots$. In any Friedmann universe the second-order term is set by the deceleration parameter, $Q = (1 - q_0)/2$ [10 eq. 46], so an accelerating universe, with $q_0 < 0$, has Q above 0.5 [11 Abstract].

OUR ANALYSIS

What "accelerate away" means here

The paper's Theorem 2.9 says its solutions are "generically distinct from, and hence accelerate away from" the open Friedmann universe they agree with at leading order [1 p. 21]. The authors' preprint describes the departure as "an advancing or retarding" of one of the velocity terms [7 p. 18], and the published version's reading of its Figure 2 has two trajectories that "accelerate away from k < 0 Friedmann according to the $\pm R_g$" [1 p. 21], one for each sign: it can go either way, and it is a departure from that open universe, not an expansion that speeds up. The paper calls k < 0 "the case analogous with a positive cosmological constant" [1 p. 8]. Both raise the rate of expansion, but only the constant makes it accelerate (the working, below).

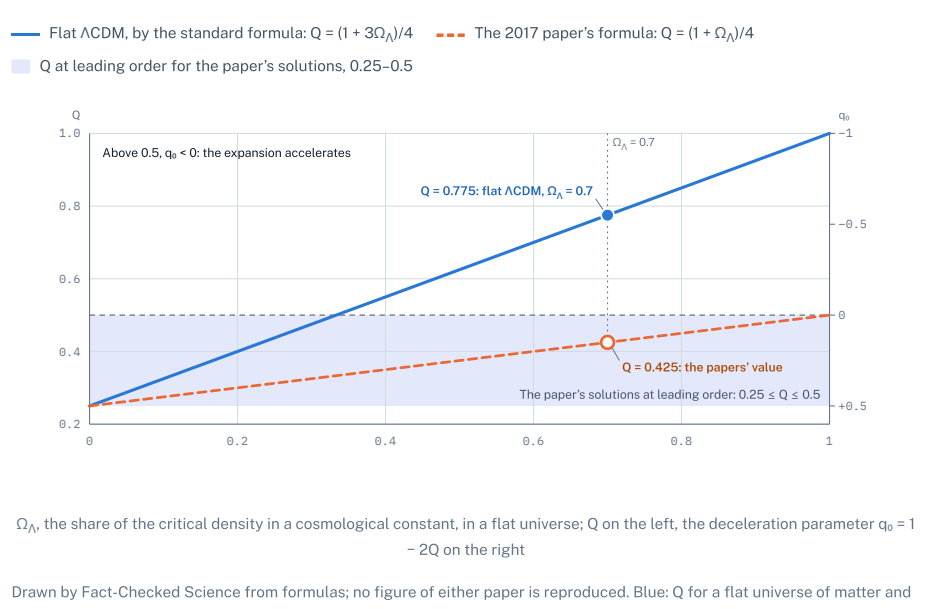
OUR ANALYSIS

Q is fixed at leading order, where every solution slows down

In the paper's words, "The Hubble constant and the quadratic correction to redshift versus luminosity is determined at order n = 1" [1 p. 20], and at that order every solution is a Friedmann universe without dark energy [1 p. 1][1 fn 1]. For the underdense family that means an open universe of matter, whose deceleration parameter q_0 lies between 0.5 and 0, decelerating (Q between 0.5 and 0) or at most coasts. So Q lies between 0.25 and 0.5, the very range the paper gives [1 p. 22]. Supernovae fitted with Friedmann models found $q_0 < 0$ at 2.8σ and 3.9σ in 1998 [11 Abstract], and DES's supernovae alone "now require acceleration ($q_0 < 0$ in ΛCDM) with over 5σ confidence" [13 Abstract].

Q, the supernova term that measures acceleration, against the share of dark energy

OUR ANALYSIS



Ω_Λ, the share of the critical density in a cosmological constant, in a flat universe; Q on the left, the deceleration parameter $q_0 = 1 - 2Q$ on the right

Drawn by Fact-Checked Science from formulas; no figure of either paper is reproduced. Blue: Q for a flat universe of matter and a cosmological constant, from $Q = (1 - q_0)/2$ and $q_0 = (1 + 3w_0)/2$ [10 eq. 46][10 eq. 20]. Orange: the same quantity from the 2017 paper's eqs. 3.38 and 3.39 [6 p. 14], which the 2026 paper quotes [1 p. 22]. Band: the range the 2026 paper gives for its solutions [1 p. 22]. The points mark $\Omega_\Lambda = 0.7$, the value both papers compare with [1 p. 22][6 p. 6]. Below the dashed line at $q_0 = 0$ the expansion slows. Planck's $\Omega_m = 0.315$, which needs $\Omega_\Lambda = 0.685$ in a flat universe, gives Q = 0.764 (our analysis) [14 Abstract].

OUR ANALYSIS

The working: where 0.425 comes from, and what ΛCDM gives

The standard result. In a Friedmann universe, $H_0 d_L = z + \tfrac{1}{2}(1 - q_0)z^2 - \tfrac{1}{6}(1 - q_0 - 3q_0^2 + j_0 + kc^2/H_0^2a_0^2)z^3 + \ldots$, whatever its contents [10 eq. 46]. Each component's density scales as $(1 + z)^{3(1+w)}$, where w is its pressure over its density: a cosmological constant has w = −1 and keeps the same density, and a component scaling as $(1 + z)^2$ has w = −1/3, the scaling of curvature [10 eq. 48]. For a flat universe $q_0 = (1 + 3w_0)/2$, with w_0 the density-weighted mean of the w's [10 eq. 20][10 eq. 49]. With 30% matter (w = 0) and 70% cosmological constant, $w_0 = -0.7$, $q_0 = -0.55$ and Q = 0.775; the third-order term is C = −0.274.

The 2017 formula. Smoller, Temple and Vogler compute the redshift–distance relation for "dark energy theory" from a flat-universe integral, $H_0 d_E = (1 + z)\int dy/\sqrt{\mathcal{E}(y)}$, with $\mathcal{E}(z) = \Omega_\Lambda(1 + z)^2 + \Omega_M(1 + z)^3$, their eqs. 3.38 and 3.39 [6 p. 14]. $\mathcal{E}$ is the square of the Hubble rate relative to today's, so the cosmological constant carries the $(1 + z)^2$ of curvature: w = −1/3 in place of −1. Then $w_0 = -0.233$, $q_0 = +0.15$ and Q = 0.425, the value of a universe that slows down. Expanding their formula, our script gives exactly their Q = 17/40 and C = −433/2400 [6 p. 15]; the standard formula gives 31/40 and −219/800. The 2017 paper's own footnote says Q "is determined by the value of the so-called deceleration parameter" [6 p. 5], which, as usually defined, is −0.55 for 70% dark energy, not +0.15.

What follows. The 2017 paper tuned its wave to give Q = 0.425 at the present day, "in agreement with the values of H and Q" of its dark-energy model [6 p. 6], and the paper repeats 0.425 and the range 0.25–0.5 as properties of dark energy, in its published version as in its submitted one [1 p. 22][2 p. 20]. The published version goes further: its Figure 3, it says, marks where the present universe lies "given the current experimental values of H_0 and Q" [1 p. 22], so it treats 0.425 as the measured value, while supernovae fitted with Friedmann models give $q_0 < 0$, that is, Q above 0.5 [13 Abstract]. The paper builds on these numbers: it places the difference between Friedmann universes with and without a cosmological constant at third order, where its free parameter b acts, calling it "the order of the discrepancy" [1 p. 20]. With the cosmological constant's actual scaling, ΛCDM's Q is 0.775, outside the 0.25–0.5 that the paper's solutions can reach at leading order; the difference starts at second order, where those solutions are fixed. So neither version of the paper shows that the instability matches dark energy at second order. The error is in the 2017 paper, in its journal version as in its preprint [6 p. 14], and the new paper inherits its numbers, after review as before it [1 pp. 22–23][2 pp. 20–21].

EXACT MATCH · OUR ANALYSIS

17/40, −433/2400

The 2017 paper's Q and C [6 p. 15], reproduced exactly from its eq. 3.39 by our script; the standard formula gives 31/40 and −219/800.

SUPERNOVAE NEARER · OUR ANALYSIS

0.07–0.36 mag

How much brighter supernovae would look at redshifts 0.1, 0.5 and 1 under the 2017 benchmark than under flat ΛCDM with 70% dark energy: 0.07, 0.25 and 0.36 magnitudes, by numerical integration.

THE THIRD ORDER · OUR ANALYSIS

−0.274

ΛCDM's C by the standard formula, against the −0.180 that the 2017 paper set beside its wave model's predicted +0.359 [6 p. 18], as the new paper repeats [1 p. 23].

No observable, no data

The paper computes no distance, deceleration parameter or Hubble diagram of its own, and fits no supernova, BAO or CMB data. Its only numbers are the 2017 paper's [1 pp. 22–23]. It calls its solutions "rich enough to mimic the effects of dark energy at all orders" [1 p. 24], though not at second order, where Q ≤ 0.5 (our analysis), and says that the redshift–distance relation to fourth order would be needed to tell whether a universe lies in its unstable manifold [1 p. 20][1 p. 23]: a family with a free parameter at every order, which predicts nothing until those parameters are fixed (our analysis). The 2017 paper's one prediction, C = +0.359, came with the remark that the actual C "appears to be beyond current observational data" [6 p. 18]. A footnote calls the 2017 third-order term consistent with "an expansion rate that is slowing relative to the predictions of dark energy" [1 fn 23], citing recent surveys [16 Abstract][17 Abstract], but makes no comparison; those surveys still find an accelerating expansion (our analysis, section 5).

Smooth models and the deceleration parameter

Spherically symmetric universes of pressureless matter, the Lemaître–Tolman–Bondi models, have long been tried as stand-ins for dark energy [20 Abstract]. Vanderveld, Flanagan and Wasserman showed that, without a weak singularity at the observer's position, such models "must have a positive central deceleration parameter", though an apparent acceleration is possible at non-zero redshifts [18 Abstract]; the paper cites them [1 p. 3]. The authors' preprint answers the same weak-singularity point, as Romano made it in 2010, arguing that the singularity is an artefact of the coordinates and that there is "actually no inconsistency" with their smooth solutions [7 p. 94][7 p. 95]. Whichever is right, the paper's own range for Q, at most 0.5, agrees with a positive or zero q_0 at the centre [1 p. 22] (our analysis).

5 · THE EVIDENCE IT WOULD HAVE TO MEET

Acceleration is measured three independent ways, and spherical models centred on us have failed their tests

Our check of the largest supernova set covers the evidence for dark energy and the current hint that it changes. The expansion and its acceleration are measured, not assumed: DES's supernovae alone require acceleration, within the standard model's fit, at more than 5σ [13 Abstract].

Supernovae

In 1998 the High-Z team found distant supernovae "10% to 15% farther than expected" without a cosmological constant, and $q_0 < 0$ at 2.8σ and 3.9σ [11 Abstract]; the Supernova Cosmology Project found an open universe without one does not fit the data well, and a positive constant at 99% confidence [12 Abstract]. DES's sample alone now requires acceleration at more than 5σ [13 Abstract].

The CMB

Planck's final analysis finds "good consistency with the standard spatially-flat 6-parameter ΛCDM cosmology", with a matter density $\Omega_m = 0.315 \pm 0.007$; with BAO, the curvature is "consistent with a flat universe, $\Omega_K = 0.001 \pm 0.002$" [14 Abstract]. For a flat universe, that much matter needs about 70% dark energy, and gives Q = 0.764 (our analysis).

BAO

DESI's second data release finds "The results are well described by a flat Λ cold dark matter (ΛCDM) model", and that their distance–redshift relation "matches those from recent compilations of supernovae (SNe) over the same redshift range" [15 Abstract], from more than 14 million galaxies and quasars and independently of the supernovae.

Spherical models with us near the centre

If we lived near the centre of a large region of low density, the supernovae could be explained without dark energy, and supernovae at redshifts of about 0.1–0.4 could test it [19 Abstract]; a spatial variation in the Hubble rate does the work [20 Abstract]. The paper's solutions are of this kind: spherically symmetric universes of matter, around a centre we would have to sit near [1 p. 23]. The published version sets them apart from earlier void models, built to tend to the flat universe far away, whose critics it says its analysis "appears to support" [1 fn 25]. Its own solutions tend to an open universe far away, but they too need us near their centre, the arrangement the tests below probe, and the paper tests none of them against the data (our analysis). Tested on the full CMB spectrum, supernovae, BAO, the local Hubble rate and more, "voids are in severe tension with the data" [21 Abstract]. The kinetic Sunyaev–Zel'dovich effect, CMB light scattered by electrons in moving gas, "rules out the adiabatic void model as a viable alternative to dark energy" [22 Abstract]; and with the Big Bang's timing left free to vary, the kSZ effect together with the supernovae, the small-angle CMB and the local Hubble rate still "effectively rules out simple LTB models as an explanation of dark energy" [23 Abstract].

OUR ANALYSIS

A special time is not a special place

The paper's footnote on ΛCDM points to what is called the cosmic coincidence: "the ΛCDM model also places the Universe in a special place in time when the energy density of classical matter and dark energy are on the same order" [1 fn 4]. That is a puzzle about when we live, and every observer in the universe today shares it. The paper also points to "a small angular dependence in the microwave background radiation" and suggests that "all current models seem to place Earth in some sort of special place" [1 fn 8]. The study it cites found the largest patterns in the CMB aligned with the solar system's orientation and motion, and allowed that they might not be cosmic at all [26 Abstract]; Planck confirms such "anomalies" in temperature, finds the CMB otherwise consistent with ΛCDM and claims no matching anomalies in polarization [27 Abstract]. They are a puzzle for ΛCDM, not a place its fits need us to be. The Copernican principle concerns where we are: whether we sit at a centre. The paper's model needs us near one [1 p. 23], and the tests above probe exactly that. The two are not alike, and the second is the one that has been tested and found wanting [22 Abstract][23 Abstract].

Dark energy may be changing, and that is a different question

The surveys the paper's footnote cites prefer a dark energy that changes over time, at about 3σ: DES's final BAO and supernovae give "tentative evidence for non-ΛCDM physics" [16 Abstract], and DESI's extended analysis finds that evidence "robust and stable under different modeling choices" [17 Abstract]. These are fits of dark-energy models to a Friedmann universe; they keep the acceleration and question only the cosmological constant (our analysis). The site rates "Dark energy changing over time" Unconfirmed on its supernova page.

6 · THE REVIEW HISTORY

Two referees asked about presentation, not about data, and one praised a quantitative analysis the paper only quotes from 2017

The journal publishes its review history: two referee reports, two decision letters and the authors' response, under CC BY 4.0 [3]. We read all of it except the response, a PDF attachment we did not open.

From submission to acceptance

DATE	ITEM	WHAT IT SAYS
October 16, 2025	Preprint	Posted to arXiv as "The Instability of the Critical Friedmann Spacetime at the Big Bang as an Alternative to Dark Energy" [2]
October 27, 2025	Received	Received by the journal, as printed on the published paper [1 p. 1]
December 15, 2025	Referee 1's report	"I strongly recommend the paper for publication", with eight minor points of presentation [3 Referee 1]
February 11, 2026	Referee 2's report	Questions on abbreviations, notation and the physical meaning of the eigenvalues and figures [3 Referee 2]
February 25, 2026	Decision	"accepted for publication subject to minor revisions" [3 Decision, round 1]
March 5, 2026	Authors' response	A PDF attachment; not read [3]
March 12, 2026	**Decision**	**Accepted "in its final form", with no further referee comments [3 Decision, round 2]; published as "The instability of critical and underdense Friedmann spacetimes at the Big Bang as an alternative to dark energy" [1]**

In the referees' words

Quoted verbatim, typos included, under the review history's CC BY 4.0 licence. FLRW is the Friedmann–Lemaître–Robertson–Walker spacetime.

> *"This finding is very interesting and extremely important, because it indicates that dark energy might not needed to explain the anomalous expansion of the universe."*
>
> Referee 1 [3 Referee 1]

> *"A quantitative analysis of the deviation from FLRW for intermediate times reveals that this effect could indeed account for the anomalous expansion of our universe which is usually explained by dark energy."*
>
> Referee 1 [3 Referee 1]

> *"SM corresponds to Standard Model of Cosmology FLRW model with or without \Lambda ?"*
>
> Referee 2 [3 Referee 2]

OUR ANALYSIS

What the review did and didn't test

Both referees read the paper as mathematics and asked about its presentation [3 Referee 1][3 Referee 2]. Referee 1 also credits it with "a quantitative analysis" showing the effect "could indeed account for the anomalous expansion" [3 Referee 1], but the paper contains none of its own, before review or after: its only numbers are the 2017 paper's, with the benchmark error described in section 4 [2 pp. 20–21][1 pp. 22–23]. Neither report mentions the observations of acceleration, the need for us to sit near the centre, the earlier tests of spherical models or the proofs in the preprint. Referee 2's question, whether SM is the standard model with or without Λ, goes to the heart of the matter: in the paper SM is the flat universe without it [1 p. 5][1 p. 14], and the published version now says so in its first footnote, which defines Friedmann spacetimes as those "with zero cosmological constant" [1 fn 1]. The title changed between submission and publication, adding the underdense spacetimes [2][1]; the other changes are listed in section 1, but the authors' reply itself we did not read.

7 · THE BLOG POST

UC Davis's post turns a proposal into a proof and a disproof

UC Davis published "Taking Dark Energy Out of the Equation" on May 27, 2026, the day the paper appeared online [4][1]. It reports the paper's mathematics fairly in places, and in others says much more than the paper does.

The post's statements, against the paper

THE POST SAYS	THE PAPER	OUR VERDICT
The mathematicians "provide mathematical proof" that the instabilities mean "the current model of the expanding universe is not viable" (first paragraph) [4]	Proves an instability of the flat universe without dark energy [1 p. 14], in a formal expansion, and argues it is "implausible" as an observable model [1 p. 24]	OVERSTATED
Friedmann spacetimes are unstable at small and large scales at the Big Bang, "making it the most unstable solution of all" (fifth paragraph, the writer paraphrasing Temple) [4]	Unstable "at every order" [1 p. 2]; compares no solutions' instability	UNSUPPORTED
Temple: "Unstable solutions in physics and science are considered not physical" [4]	The universe is observed close to the flat solution the paper calls unstable [14 Abstract][1 p. 2], and structure grows by this instability (our analysis)	OVERSTATED
Temple: "like Einstein's static model, the Friedmann spacetimes are all unstable to radial perturbation" [4]	The paper's theorem [1 p. 2]	TRUE
Temple: this "appears to rule out the Lambda-cold dark matter model" as a "viable stable solution" of Einstein's equations, "with or without dark energy" [4]	Argues the flat Friedmann universe is "implausible … with or without dark energy" [1 p. 24]; ΛCDM is not a stable solution and doesn't need to be: its structure grows by this instability (our analysis), and it fits the data [14 Abstract][15 Abstract]	MISLEADING
Temple: the Big Bang should "look exactly like a Friedmann spacetime near the center", with "accelerations away from Friedmann far from the center" [4]	Agreement at leading order [1 Thm 2.8] and departures at higher orders in ξ [1 Thm 2.9][1 Thm 2.10]; "accelerations" relative to an open universe	TRUE
The team "found that the accelerating expansion of the universe is a direct consequence" of the equations [4]	A proposed mechanism and a programme [1 pp. 3–4][1 p. 23]; no observable computed; decelerating at leading order (section 4)	OVERSTATED
Temple: ΛCDM and a spherically symmetric universe both "produce a special place where we must lie" [4]	A special time for ΛCDM [1 fn 4], and large-angle patterns in the CMB that the paper also counts [1 fn 8]; a special position for the paper's model [1 p. 23] (section 5)	MISLEADING
Funded by the UK's EPSRC and AIM's SQuaRE programme [4]	Both did fund it; the post omits the ERC starting grant [1 p. 24]	TRUE
Temple: the instability "suggests a simpler, more natural explanation" than dark energy [4]	An opinion; the paper's own case is in section 4	Not rated

The post is © UC Davis and quoted briefly; its headline, "Taking Dark Energy Out of the Equation", is not rated. Our verdicts on its first statement and its Copernican quotation are claims 5 and 6 in the panel.

8 · THE EPISODE

A three-word label on a link, and nothing else to check

S0 News linked UC Davis's blog post under the label "No Dark Energy" [5][4]. No transcript was available, so the episode's own words could not be checked; we rate only the label.

The label, beside its sources

The label goes further than the blog post, which says the mathematicians are "challenging" the idea that dark energy drives the acceleration [4], and much further than the paper, which proposes a mechanism, fits nothing and calls the cosmology a programme [1 p. 23]. The paper even says its conclusion "does not change with the addition of dark energy" [1 p. 24]: it allows dark energy and the instability together.

The episode's title

None of the three phrases of "Superflare Cycle 2030s, Cosmic Ghosts, Solar Impact" is about this paper [5], so none is rated here. The episode's superflare study is checked on our page on the TESS superflare rate, and its story on the storm of March 2026 on our page on the storm's effects at the ground.

9 · REPEAT OUR NUMBERS

A script for the redshift–distance terms and the eigenvalues

The script expands the luminosity distance in exact fractions for flat ΛCDM [10 eq. 46], the 2017 formula [6 p. 14], an open universe of matter and the Einstein–de Sitter universe, cross-checks Q through Visser's relations, integrates the distances numerically, and linearises the paper's equations to recover its eigenvalues [1 eq. 2.29].

cosmography_check.py

Q and C for each model, the Visser cross-check, distance moduli at redshifts 0.1, 0.5 and 1, the rest points and eigenvalues of the paper's second-order equations, and the density contrast each eigenvalue implies; Python standard library only · 9 KB

cosmography_check.txt

The script's output, as run for this page · 4 KB

Run it

`python3 cosmography_check.py` prints the results; `python3 cosmography_check.py out.txt` writes them to a file, as the text file here was made.

10 · LIMITS

What this check could and couldn't see

First built from the submitted version

The journal's site answered our tools with a bot check, which we do not attempt, so the page was first built from arXiv:2510.14228v1. The site's owner then supplied the published version, and every statement about the paper was checked again against it; its §2(i) repeats the 2017 numbers [1][2].

The authors' response unread

It is a PDF attached to the review history, which we did not open [3].

Proofs not checked

We re-derived the eigenvalues from the printed equations, not the 99 pages of proofs, which no journal has yet reviewed; the authors defer the convergence of their expansions [7][1 p. 9].

No re-run of 2017

We did not repeat the 2017 simulation behind C = +0.359 [6 p. 18]; our point concerns the dark-energy benchmark it was compared with.

No transcript

The episode's own words could not be checked; we rate only its label on the link to the blog post [5].

Numbers from abstracts

We read only the abstracts of the supernova papers [11 Abstract][12 Abstract], of DES's two analyses [13 Abstract][16 Abstract], of Planck's papers [14 Abstract][27 Abstract] and DESI's [15 Abstract][17 Abstract], and of the papers on spherical models [18 Abstract][19 Abstract], [20 Abstract][21 Abstract] and [22 Abstract][23 Abstract] and on the CMB's anomalies [26 Abstract]; the Lifshitz and Guth papers are cited only for their subjects [25][24].

What would change these verdicts

01

A correction of the dark-energy benchmark by the authors would change how claim 4 is described, not its verdict on the statement quoted here, which the published version keeps.

02

A fit of the paper's solutions to supernova, BAO and CMB data, with us near the centre, that matched them as well as ΛCDM does, would bear on claims 1 and 3.

03

The episode's transcript, which could show what S0 News said about the paper beyond its label.

OUR ANALYSIS

Bottom line: sound mathematics about a long-known instability, with no evidence yet that it replaces dark energy.

The paper proves, in a formal expansion, that smooth spherical perturbations of a matter-filled Friedmann universe grow and decay at the rates standard cosmology already knows, and that they carry the solution away from a Friedmann universe for a while [1 eq. 2.29][1 Thm 2.9]. At the order that measures acceleration, its solutions are open universes without dark energy, which slow down [1 p. 20][1 p. 22]; the match to dark energy it quotes rests on a 2017 formula that gives the cosmological constant the scaling of curvature [6 p. 14]; and it fits no data. Acceleration is measured independently by supernovae [13 Abstract], the CMB [14 Abstract] and BAO [15 Abstract], and spherical models centred on us have failed the tests of the Copernican principle [22 Abstract][23 Abstract].

Sources

Bracketed numbers refer to this list. For the paper [1], read in full in its version of record, p. gives a page of that PDF (25 pages, numbered as printed; p. 1 carries the abstract), § a section, eq. an equation, Thm a theorem and fn a footnote, all as numbered there. The page was first built, on October 31, 2026, from the version its authors posted before review, arXiv:2510.14228v1 [2], because the journal's site answered our tools with a bot check that we do not attempt; later that day the site's owner supplied the version of record, and the page was revised against it. [2] is now cited only where the two versions are compared, and there p. gives a page of its PDF. For the 2017 paper [6], p. gives a page and eq. an equation of its journal version; for the authors' preprint of proofs [7], p. gives a page and § a section. For the review history [3], Referee 1, Referee 2 and Decision, round 1 or round 2, name its documents. For Visser (2004) [10], eq. gives an equation of its arXiv version. For the episode [5] no transcript was available: we read its title and the links and labels in its description, and quote nothing else of it. For the other sources, Abstract marks the abstract; where only an abstract or a record was read, the entry says so. Q is the second-order term in the expansion of the luminosity distance in powers of redshift, and q_0 the deceleration parameter. Links checked October 31, 2026.

1 Alexander, C., Temple, B., and Vogler, Z. (2026). The instability of critical and underdense Friedmann spacetimes at the Big Bang as an alternative to dark energy. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 482(2338), 20250912. Received October 27, 2025, and accepted March 12, 2026, as printed on its first page; published in the issue of May 15, 2026, and online on May 27, by its Crossref record. Peer reviewed; open access, CC BY 4.0. Competing interests, in the authors' words: "We declare we have no competing interests." Funded by EPSRC project EP/S02218X/1 and ERC starting grant 101078061 (SINGinGR) to Alexander and by the American Institute of Mathematics SQuaRE programme. Read in full: the version of record, 25 pages, which the site's owner downloaded from the journal in a browser and supplied on October 31, 2026, after the journal's site had answered our scripts, our fetching tool and our own browser tab with a bot check, which we do not attempt. p. gives a page, § a section, eq. an equation, Thm a theorem and fn a footnote, as numbered there. Its title on submission was "The Instability of the Critical Friedmann Spacetime at the Big Bang as an Alternative to Dark Energy".

2 Alexander, C., Temple, B., and Vogler, Z. (2025). The Instability of the Critical Friedmann Spacetime at the Big Bang as an Alternative to Dark Energy. arXiv:2510.14228, version 1, posted October 16, 2025, eleven days before the journal received the manuscript, under the title the paper was submitted with; CC BY 4.0. We call it the submitted version, though it may not be the manuscript the journal received: the referees' page and line numbers show that the one they read was laid out differently. Read in full, as its PDF (23 pages) and arXiv's HTML rendering, and compared word by word with the published version [1]. The page was first built from it; it is now cited only where the two versions are compared, and p. gives a page of its PDF.

3 Proceedings of the Royal Society A (2025–2026). Peer review history of manuscript RSPA-2025-0912: the reports of two anonymous referees, of December 15, 2025 (doi:10.1098/rspa.2025.0912/v1/review1), Referee 1, and of February 11, 2026 (…/v1/review2), Referee 2; the decision letters of February 25 and March 12, 2026 (…/v1/decision1, …/v2/decision1), Decision, round 1 and round 2; and the authors' response of March 5, 2026 (…/v2/response1). Published through Web of Science under CC BY 4.0. Read in full in Web of Science's free view on October 31, 2026, except the authors' response, a PDF attachment we did not open; the reports are quoted verbatim, typos included.

4 Watry, G. (May 27, 2026). Taking Dark Energy Out of the Equation. UC Davis, blog post; the episode's link to the paper. Read in full; quoted briefly, © UC Davis.

5 SpaceWeatherNews (S0) (October 31, 2026). Superflare Cycle 2030s, Cosmic Ghosts, Solar Impact | S0 News Oct.31.2026. YouTube video, https://www.youtube.com/watch?v=_8YfY0JF4Cc, published at 11:32 UT. No transcript was available when this page was made, so we read only its title and the links and labels in its description, as our collector recorded them, and could not quote the episode's own words. "No Dark Energy" is the episode's label on its link to UC Davis's blog post [4].

6 Smoller, J., Temple, B., and Vogler, Z. (2017). An instability of the standard model of cosmology creates the anomalous acceleration without dark energy. *Proceedings of the Royal Society A* 473(2207), 20160887. Peer reviewed; © 2017 the authors, published by the Royal Society, all rights reserved, so it is quoted briefly and none of its figures is redrawn. We read its abstract, §1 with Theorem 1.1, and §3e and §3g in the journal version, as posted on Temple's university page, and the same passages in its preprint, arXiv:1412.4001v1 (December 2014), whose LaTeX source confirms the form of its eq. 3.39 (3.18 there). p. gives a page and eq. an equation of the journal version.

7 Alexander, C., Temple, B., and Vogler, Z. (2024). Cosmic Accelerations Characterize the Instability of the Critical Friedmann Spacetime. arXiv:2412.00643, version 1, December 1, 2024; CC BY 4.0. The paper's ref. [2], where it says its proofs are: a preprint of 99 pages, not peer reviewed, with no journal version in Crossref on October 31, 2026. We read its abstract, its introduction and its §15, not its proofs; p. gives a page and § a section.

8 Temple, B., and Smoller, J. (2009). Expanding wave solutions of the Einstein equations that induce an anomalous acceleration into the Standard Model of Cosmology. *Proceedings of the National Academy of Sciences* 106(34), 14213–14218. Abstract only, as deposited with Crossref.

9 Smoller, J., and Temple, B. (2012). General relativistic self-similar waves that induce an anomalous acceleration into the standard model of cosmology. *Memoirs of the American Mathematical Society* 218(1025); online November 3, 2011. Abstract only, as deposited with Crossref.

10 Visser, M. (2004). Jerk, snap and the cosmological equation of state. *Classical and Quantum Gravity* 21(11), 2603–2615. Read in its arXiv version, gr-qc/0309109: §2, with eq. 20, and §4–5, with eq. 46, its luminosity-distance Hubble law, and eqs. 48 and 49, on the equation of state; eq. gives an equation of that version.

11 Riess, A. G., Filippenko, A. V., Challis, P., et al. (1998). Observational evidence from supernovae for an accelerating universe and a cosmological constant. *The Astronomical Journal* 116, 1009–1038. Abstract only, in its arXiv version (astro-ph/9805201).

12 Perlmutter, S., Aldering, G., Goldhaber, G., et al. (1999). Measurements of Ω and Λ from 42 high-redshift supernovae. *The Astrophysical Journal* 517, 565–586. Abstract only, in its arXiv version (astro-ph/9812133).

13 DES Collaboration, Abbott, T. M. C., et al. (2024). The Dark Energy Survey: cosmology results with ~1500 new high-redshift type Ia supernovae using the full 5 yr data set. *The Astrophysical Journal Letters* 973, L14. CC BY 4.0. Abstract only, as deposited with Crossref.

14 Planck Collaboration, Aghanim, N., et al. (2020). Planck 2018 results. VI. Cosmological parameters. *Astronomy & Astrophysics* 641, A6. Abstract only, as deposited with Crossref.

15 DESI Collaboration, Abdul Karim, M., et al. (2025). DESI DR2 results. II. Measurements of baryon acoustic oscillations and cosmological constraints. *Physical Review D* 112, 083515. CC BY 4.0. Abstract only here, as deposited with Crossref; our supernova page read more of it.

16 DES Collaboration, Abbott, T. M. C., et al. (2026). Dark Energy Survey: implications for cosmological expansion models from the final DES baryon acoustic oscillation and supernova data. *Physical Review D* 113, 063530. The paper's ref. [31]. Abstract only, in its arXiv version 2.

17 Lodha, K., Calderon, R., Matthewson, W. L., Shafieloo, A., et al. (2025). Extended dark energy analysis using DESI DR2 BAO measurements. *Physical Review D* 112, 083511. CC BY 4.0. The paper's ref. [10]. Abstract only, in its arXiv version.

18 Vanderveld, R. A., Flanagan, É. É., and Wasserman, I. (2006). Mimicking dark energy with Lemaître–Tolman–Bondi models: weak central singularities and critical points. *Physical Review D* 74, 023506. The paper's ref. [18]. Abstract only, in its arXiv version (astro-ph/0602476).

19 Clifton, T., Ferreira, P. G., and Land, K. (2008). Living in a void: testing the Copernican principle with distant supernovae. *Physical Review Letters* 101, 131302. The paper's ref. [7]. Abstract only, in its arXiv version.

20 Enqvist, K. (2008). Lemaître–Tolman–Bondi model and accelerating expansion. *General Relativity and Gravitation* 40, 451–466. Abstract only, in its arXiv version.

21 Moss, A., Zibin, J. P., and Scott, D. (2011). Precision cosmology defeats void models for acceleration. *Physical Review D* 83, 103515. Abstract only, in its arXiv version.

22 Zhang, P., and Stebbins, A. (2011). Confirmation of the Copernican principle at Gpc radial scale and above from the kinetic Sunyaev–Zel'dovich effect power spectrum. *Physical Review Letters* 107, 041301. Abstract only, in its arXiv version.

23 Bull, P., Clifton, T., and Ferreira, P. G. (2012). Kinematic Sunyaev–Zel'dovich effect as a test of general radial inhomogeneity in Lemaître–Tolman–Bondi cosmology. *Physical Review D* 85, 024002. Abstract only, in its arXiv version.

24 Guth, A. H. (1981). Inflationary universe: a possible solution to the horizon and flatness problems. *Physical Review D* 23, 347–356. Cited for its date and subject; we read only its Crossref record.

25 Lifshitz, E. (1946). On the gravitational stability of the expanding universe. *Journal of Physics (USSR)* 10, 116–129; republished in English as a Golden Oldie, Republication of: On the gravitational stability of the expanding universe, *General Relativity and Gravitation* 49, 18 (2017). Cited for its date and subject; we read the republication's Crossref record and the description on the publisher's page.

26 Copi, C. J., Huterer, D., Schwarz, D. J., and Starkman, G. D. (2006). On the large-angle anomalies of the microwave sky. *Monthly Notices of the Royal Astronomical Society* 367(1), 79–102. The paper's ref. [25], cited in its footnote 8. Abstract only, in its arXiv version (astro-ph/0508047).

27 Planck Collaboration, Akrami, Y., et al. (2020). Planck 2018 results. VII. Isotropy and statistics of the CMB. *Astronomy & Astrophysics* 641, A7. Abstract only, in its arXiv version (arXiv:1906.02552).

METHOD

How this was checked

On October 31, 2026, we checked every statement, number, quotation and citation on this page against its source. The paper's published text sat behind a bot check on the journal's site, for our scripts, our fetching tool and our own browser tab alike, which we do not attempt, and we found no other copy; so the page was first built from the version its authors posted before review, read in full [2], with the published version's abstract, title and metadata, and the journal's published review history, all of it except the authors' response [3]. Later that day the site's owner supplied the published version, which we read in full and revised the page against [1]. We also read, in part, the authors' 2017 paper in its journal version and its preprint, with the preprint's LaTeX source for one equation [6], and their 2024 preprint of proofs [7]; UC Davis's blog post in full [4]; the episode's title and description, since no transcript was available [5]; Visser's paper on the cosmological expansion in part [10]; and 17 other papers as abstracts and two as records, on the authors' programme, the evidence for acceleration, spherical models, the CMB's anomalies and the history of the problem: the 27 sources listed. Every quotation was checked word for word against its saved source.

The verdicts and the items tagged "Our analysis" are our own assessment, built on the cited sources. They include the redshift–distance terms Q and C for flat ΛCDM, for the 2017 paper's formula, for an open universe of matter and for the Einstein–de Sitter universe; the cross-check of Q through Visser's relations; the luminosity distances behind the 0.07–0.36 magnitudes; the paper's eigenvalues, re-derived from its equations, and our reading of them as the growing and decaying modes of a universe of matter; Q for Planck's matter density; and our reading of what the paper, its review and the blog post do and do not say.

Our script, hosted on this page, does that arithmetic from formulas typed from the sources: the redshift–distance terms in exact fractions and the distances by numerical integration (Simpson's rule). It reproduces the 2017 paper's Q = 17/40 and C = −433/2400 exactly from its eq. 3.39, and the paper's rest points and eigenvalues from its eqs. 2.48–2.51, which are the same in both versions; we checked the submitted version's against arXiv's HTML rendering of them. We did not check the paper's proofs, which are in its 99-page preprint [7], or re-run the 2017 simulation behind its predicted C = +0.359 [6]; and we did not read the authors' response to the referees.

A fresh reviewer then read the built page against the sources and recomputed claim 4 by three independent methods, reproducing 31/40 for flat ΛCDM and the 2017 paper's 17/40 and −433/2400 exactly; it re-ran our script, whose output matched the hosted file byte for byte. The changes that followed: the footnote on a slowing expansion is now quoted as written, "slowing relative to the predictions of dark energy"; everything then known only from arXiv's version 1 was credited to the submitted version; "accelerate away" is no longer glossed as faster expansion, since the authors' preprint calls the departure "an advancing or retarding"; claim 6 now answers the paper's argument that the CMB's large-angle anomalies give ΛCDM a special place too, and its verdict stands; the supernovae's $q_0 < 0$ is said to rest on Friedmann fits; the paper's placing of the dark-energy difference at third order is shown to fail at second; Temple's qualifier "viable stable solution", Bull et al.'s combined test and the sources read for the 2017 paper are given exactly; the rates and judgments that Lifshitz and Guth were cited for are now marked as our analysis; the funding row of section 7 is rated True; and several smaller wordings, locators and the script's comments were corrected.

The revision against the published version followed the same day. A script compared the two versions word for word, and we read every difference that was more than spelling or numbering, from the title and abstract to the theorems, equations, footnotes and figures. The abstract and the equations our script uses are unchanged; the title is new; the first footnote now defines Friedmann spacetimes "with zero cosmological constant", which settles one referee's question; definitions, a reading of the second figure, a closing comment on comoving models of dark energy and other explanations were added; one figure was dropped and a footnote's criticism of void models moved to the conclusion; and theorems, sections, footnotes, figures and references were renumbered. Section 2(i) repeats the 2017 numbers, so claim 4's False now rests on the published text. Every quotation and locator for the paper was moved to the published text and checked against it by script, and every verdict was checked again: none changed. A fresh reviewer then checked the revision against the published text. It confirmed every quotation and all but two locators, which were corrected, and found two published changes that the page now reports: Figure 3 is said to mark the present universe "given the current experimental values of H_0 and Q", and the conclusion places the authors' effect beyond the scale of the CMB's local fluctuations and apart from earlier void models.

This page was researched and written with Claude, an AI assistant made by Anthropic, and then re-checked against its sources in a separate verification pass.

The verdicts on this page

FALSE	The evidence contradicts the claim.
MISLEADING	Contains something true but leaves a false impression, usually by leaving out key context.
OVERSTATED	Has some basis but claims much more than the evidence supports.
UNSUPPORTED	No evidence we could find backs it up, though it hasn't been strictly disproven.
TRUE	The evidence supports the claim.

All ten verdicts, and how we check

CORRECTIONS

Corrections and changes

If we get something wrong, we fix it and record the change below with the date. If a correction changes a verdict, the log says what the old verdict was.

Change log

Oct 31, 2026	Revised against the paper's published version, which the site's owner supplied: every quotation, number and locator for the paper now comes from it, by page, section, equation, theorem and footnote, and the submitted version is cited only where the two are compared. The published §2(i) repeats the 2017 benchmark, Q = 0.425 and the range 0.25 ≤ Q ≤ 0.5, so claim 4's False rests on the published text, and the page no longer says that the published section was not seen. Section 1 now gives the dates, the authors' statement of no competing interests and what changed before publication, among it the first footnote's new definition of Friedmann spacetimes, "with zero cosmological constant"; four wordings in the page's quotations now follow the published text ("standard model", "sufficiently centred", "redshift versus luminosity" and footnote 4's "when it is the underlying solution that is wrong"). A fresh review of the revision then added, to claim 4 and section 4, that the published version treats 0.425 as one of "the current experimental values", and to sections 3 and 5 its new comment placing the effect beyond the scale of the CMB's local fluctuations and apart from void models, with our answer; it also added the received date to section 6 and fixed two locators and smaller wordings. No verdict changed.
Oct 31, 2026	Published on factchecked.science after a full check against the sources. Built from the paper's submitted version (arXiv:2510.14228v1), because the published text sat behind a bot check, with its published abstract and review history, the authors' 2017 paper and 2024 preprint, UC Davis's blog post and the episode's label (no transcript was available): six claims rated on the site's scale, one the episode's, three the paper's and two the blog post's, with our own arithmetic on the redshift–distance terms and the paper's eigenvalues, whose script is hosted on the page. Before publication, a fresh review confirmed claim 4 independently; after it, the page quotes the submitted version's footnote on a "slowing" expansion exactly, credits what it knows only from arXiv's version 1 to the submitted version, drops the gloss of "accelerate away" as faster expansion, answers the paper's CMB argument in claim 6 (verdict unchanged), qualifies the supernova evidence as Friedmann fits, rates the blog post's funding line True, and fixes smaller wordings, locators and the script's comments.

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