

There Are Three Equivalence Principles

— Weak, Einstein, Strong: More Precision Does Not Reach the Third — [Paper 165]

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— *From thinking to syncing.* —

ABSTRACT

The single phrase “equivalence principle” names three claims differing both in what they assume and in how they are tested. This paper calls them by name and shows in numbers that the third is not a refined version of the first. **NO NEW PHYSICAL LAW IS CLAIMED** — nothing here contradicts general relativity. First, in the weak equivalence principle the mass cancels only because inertial and gravitational mass were identified. Writing $m_g/m_i = 1 + \delta$ returns δ to the acceleration, and the Eötvös parameter η is exactly $\delta_1 - \delta_2$. What must be moved is composition (Section 2). Second, Einstein's equivalence principle answers a different question. The redshift over a tower of 22.5 m is 2.45506×10^{-15} , and a GPS clock differs from one on the ground by $+45.719 \mu\text{s}$ gravitationally, $-7.21337 \mu\text{s}$ from velocity, for a net $+38.5056 \mu\text{s}$ per day (computed here). None of these numbers depends on what the clock is made of (Section 3). Third, and this is the core. The strong equivalence principle requires self-gravity. A violation appears as $m_g/m_i = 1 + \eta_N U/(Mc^2)$, and the binding-energy fraction is 1.4365×10^{-26} for a 1 kg laboratory sphere, 1.8829×10^{-11} for the Moon, 4.1768×10^{-10} for the Earth, 1.2735×10^{-6} for the Sun and 0.10337 for a neutron star. The Earth exceeds a laboratory mass by 2.9×10^{16} — sixteen orders of magnitude (Section 4). Fourth, a laboratory test of the weak principle therefore barely constrains the strong one. Even at $\eta < 10^{-15}$, laboratory masses bound only $\eta_N < 7 \times 10^{10}$ — no constraint at all. The same precision applied to the Earth–Moon pair gives $\eta_N < 2.5 \times 10^{-6}$ (Section 5). Fifth, general relativity satisfies all three and Brans–Dicke only the first two. At $\omega = 40000$ one has $\gamma - 1 = -2.5 \times 10^{-5}$ and $\eta_N = 2.5 \times 10^{-5}$. Only $\omega \rightarrow \infty$, that is general relativity, gives $\eta_N = 0$ exactly (Section 6).

Scope of this paper: NO NEW PHYSICAL LAW IS CLAIMED — nothing here contradicts general relativity. The distinction among the three principles, the Nordtvedt effect and the Brans–Dicke parametrisation are **all standard**. **Nor does this paper assert experimental values** — what is shown is the conversion, “if η falls below such a value then η_N falls below such another”, and every conversion here was computed in this paper. What is added is **computing the binding-energy fraction for five bodies and exhibiting the sixteen orders between them, setting side by side what one precision buys in a laboratory and on the Earth–Moon pair, and writing, for each of the three, what must be moved for it to move.**

1. Notation and position

Write m_i for inertial mass and m_g for gravitational mass, $\eta = 2(a_1 - a_2)/(a_1 + a_2)$ for the Eötvös parameter and η_N for the Nordtvedt parameter.

Position: Paper 66 showed that the “local c ” and the “coordinate c ” have distinct roots, and Paper 134 wrote that the 4 in light bending is $2(1 + \gamma)$ with γ a measured quantity. This paper treats η_N , which stands beside that γ , and separates the three principles.

2. WEP: the mass cancels because it was identified

Observation 2.1

Newton's equation of motion is $m_i a = GMm_g/r^2$. The mass cancels only when $m_i = m_g$, and writing $m_g/m_i = 1 + \delta$ gives $a = (1 + \delta)GM/r^2$.

Verification 2.2: To first order, for two bodies,

if η falls below	then $ \delta_1 - \delta_2 $ falls below
10^{-11}	10^{-11}
10^{-13}	10^{-13}
10^{-15}	10^{-15}

(QED)

Observation 2.3

η and $|\delta_1 - \delta_2|$ are the same number. A test of the weak principle measures the failure of the identification $m_i = m_g$, and nothing else. What must be moved is the composition of the bodies.

3. EEP answers a different question

Verification 3.1: The gravitational redshift over a tower of $h = 22.5$ m is gh/c^2 .

gh/c^2	2.45506×10^{-15}
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Verification 3.2: A GPS clock (semi-major axis 26561 km) against one on the ground, per day.

gravitational (the satellite runs fast)	+45.719 μ s
velocity (the satellite runs slow)	−7.21337 μ s
net	+38.5056 μ s

(QED)

Observation 3.3

Neither number depends on what the clock is made of. What these test is that the laws do not depend on where the laboratory is or how fast it moves — local position invariance and local Lorentz invariance.

Observation 3.4

So refining a weak-principle experiment leaves part of the Einstein principle untested. An experiment that varies composition and one that varies position are different experiments. The same distinction is needed as in Paper 123, where what moves is not the clock but the worldline.

4. The core: the strong principle requires self-gravity

Fact 4.1: A violation of the strong principle appears as $m_g/m_i = 1 + \eta_N U/(Mc^2)$, where U is the gravitational binding energy, and for a uniform sphere $U/(Mc^2) = \frac{3}{5} GM/(Rc^2)$.

Verification 4.2

body	radius (m)	$ U /(Mc^2)$
a 1 kg laboratory sphere (density 8000)	0.031018	1.4365×10^{-26}
the Moon	1.7374×10^6	1.8829×10^{-11}
the Earth	6.371×10^6	4.1768×10^{-10}
the Sun	6.957×10^8	1.2735×10^{-6}
a neutron star (1.4 solar masses, 12 km)	1.2×10^4	0.10337

The Earth exceeds the laboratory mass by 2.9076×10^{16} , and the Earth–Moon difference is 3.9885×10^{-10} . (QED)

Observation 4.3

Sixteen orders of magnitude. As far as self-gravity is concerned, a laboratory body barely exists.

5. What one precision buys, in a laboratory and on a planet

Verification 5.1: Converting a bound on η into a bound on η_N .

if η falls below	laboratory masses give $\eta_N <$	the Earth–Moon pair gives $\eta_N <$
10^{-11}	6.961×10^{14}	0.02507
10^{-13}	6.961×10^{12}	2.507×10^{-4}
10^{-15}	6.961×10^{10}	2.507×10^{-6}

(QED)

Observation 5.2

Reaching $\eta < 10^{-15}$ in a laboratory bounds η_N only at about 10^{11} — which constrains nothing. The same precision on the Earth–Moon pair gives about 10^{-6} .

Observation 5.3

An experiment testing the strong principle is not a refined version of one testing the weak principle. It is a different experiment on different bodies. No amount of precision reaches the third from a laboratory bench — seventeen orders of magnitude are not closed by better apparatus.

Observation 5.4

This paper asserts no measured value. What it gives is the conversion alone — the relation “if η falls below this then η_N falls below that”, and that relation was computed here.

6. Which theory satisfies which

Verification 6.1: In Brans–Dicke theory with parameter ω one has $\gamma = (1 + \omega)/(2 + \omega)$ and $\beta = 1$, so the Nordtvedt parameter is $\eta_N = 4\beta - \gamma - 3 = 1/(2 + \omega)$.

ω	γ	$\gamma - 1$	η_N
5	0.857142857143	−0.1429	0.1429
500	0.998007968127	−1.992 × 10 ^{−3}	1.992 × 10 ^{−3}
40000	0.99997500125	−2.5 × 10 ^{−5}	2.5 × 10 ^{−5}
∞ (general relativity)	1	0	0

(QED)

Observation 6.2

Brans–Dicke satisfies the weak and Einstein principles for every ω and violates the strong one for every finite ω . Only $\omega \rightarrow \infty$, that is general relativity, gives $\eta_N = 0$ exactly.

Observation 6.3

So the strong principle is what separates general relativity from its nearest rivals. The other two do not separate them — both theories satisfy those. The sentence “the equivalence principle has been confirmed” says nothing about choosing between theories until it says which one.

Observation 6.4

η_N stands where Paper 134 placed γ . Both are numbers that take a particular value in general relativity without being forced by any principle.

7. The census

Observation 7.1

principle	what it says	what moves it	where it is measured
weak (WEP)	falling does not depend on composition	composition	a laboratory suffices
Einstein (EEP)	special relativity holds locally	the laboratory's place and speed	a laboratory suffices
strong (SEP)	it holds for self-gravitating bodies too	the binding-energy fraction	astronomical bodies needed

Observation 7.2

These are not one principle at three strengths. The third is not reached from the first by improving precision — it needs another body.

8. Conclusion

1. The η of WEP is the failure of $m_i = m_g$ itself (Ver. 2.2): composition is what moves it.
2. EEP measures quantities independent of material (Ver. 3.1, 3.2): 2.45506×10^{-15} ; $+38.5056 \mu\text{s}$ per day.
3. Binding-energy fractions differ by sixteen orders (Ver. 4.2): 1.4×10^{-26} against 4.2×10^{-10} .
4. One precision buys things seventeen orders apart (Ver. 5.1): 7×10^{10} against 2.5×10^{-6} .
5. Only general relativity gives $\eta_N = 0$ (Ver. 6.1).
6. The third is a different experiment, not a refined one (Obs. 7.2).

Closing: Three principles under one name appear to lie along a single line. They do not. No refinement of the first arrives at the third, and reaching the third means leaving the bench and borrowing a planet.

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