The Sun as a Lens

How a shape built to explain particles ends up bending starlight
by exactly Einstein's angle — and how you can check it

A mostly non-technical note for anyone who loves general relativity
— written to be checked by specialists, and read, equations and all, by everyone else —

[Author] · physics.magflowmeters.com

Before we start

If you have ever been struck by the strangest fact in Einstein's gravity — that a heavy object bends light, so a star's apparent place in the sky shifts when its light skims past the Sun — then this short note is for you. The claim it makes is small and entirely checkable. A particular shape, living in thirteen dimensions, was built to explain why nature has the particles and forces it does. It was never built to say anything about bending light. And yet, when you shrink it down to the four dimensions we live in, it reproduces that light-bending — by exactly the angle Einstein predicted and telescopes have measured. Below, that angle is worked out two ways, in the friendly language of lenses, and the two answers are placed side by side.

Two honest words before the punchline, because they matter more than it does. First: matching Einstein's gravity is a test that *every* serious theory has to pass — so passing it is a hurdle cleared, not a proof that the bigger idea is correct. Second: the shape itself is **not derived here**; only its story is told. The question of this note is deliberately narrow, and the kind a measurement could settle: does the light bend by the right amount, and does the shape collapse to Einstein's gravity the way it must? You can read every word skipping every equation and lose none of the story — the math is set off for anyone who wants to check the arithmetic.

1. Where the shape came from (a story, not a derivation)

It started with the kind of thought experiment you can sketch on a napkin. Draw a closed bubble around a region of space and ask the question every physics student is taught to ask: can energy simply appear or vanish inside it? It cannot — energy is conserved. Now insist that this stays true not in flat space but in the warped space-and-time of Einstein's universe, where the very notion of 'how much energy is in here' bends along with the geometry. Follow that one demand carefully, and the bookkeeping it forces on you turns out to be Einstein's field equations themselves. Gravity, from this angle, is just what 'energy is conserved' has to look like once space is allowed to curve.

From that seed grew a construction. A short list of strict requirements — reproduce the known forces as symmetries of a small curled-up space, make matter come out left- and right-handed the way it really is, let no hidden inconsistency survive, keep the whole thing stable — was used as a filter, and the shape that passed was a specific thirteen-dimensional one: our four familiar dimensions, times a tiny internal space. Not one of those requirements said a word about bending light.

Which leaves the natural question: is the shape actually right? The cleanest test we could think of is whether it **collapses back to Einstein's equations** when you shrink it to four dimensions — and the most beautiful version of that test is whether it bends light by the angle the night sky actually shows. That is the test below.

2. Gravity as a lens

Here is the friendliest way into Einstein's light-bending, and it happens to be exactly right. You already know that light slows and bends when it passes into glass or water — that is what a lens does, and it is why a straw looks broken where it enters a glass of water. You may also know that on a hot day light bends as it crosses layers of air of different density, painting that shimmering 'mirage' of water on the road ahead. In every case, light curves toward the region where it travels more slowly.

Einstein's gravity does the very same thing. A mass makes the space around it behave like a lens — like a medium whose 'optical thickness,' its refractive index, rises as you get closer to the mass:

$$n(r) = 1 + 2GM / (c^2 r).$$

Light passing nearby curves toward the mass, exactly as it curves toward the thick middle of a lens. For a ray skimming past at a closest approach b, the total bend works out to

$$\alpha = 4GM / (c^2 b).$$

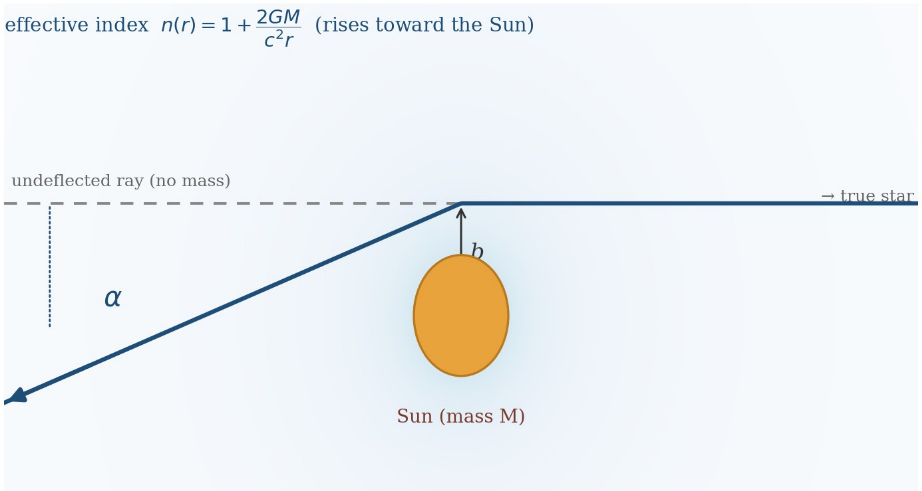

Figure 1. *A mass acts as a gradient-index lens: the effective index n(r) rises toward the Sun, and a ray at closest approach b bends toward it by α = 4GM/(c²b). At the Sun's edge that is 1.75 arcseconds — the angle Eddington measured in 1919.*

Put in the Sun's mass and radius for a ray grazing its edge, and

$$\alpha = 4GM_\odot / (c^2 R_\odot) \approx 1.75 \text{ arcseconds} \text{ —}$$

the tiny angle Arthur Eddington measured during the solar eclipse of 1919, the result that made Einstein world-famous overnight. One detail deserves a pause, because it is the quiet hero of the whole story. That factor of **2** in the index — and so the fact that Einstein's bending is exactly *double* what you'd guess from Newton's gravity alone — arrives in two equal halves: one from the way a mass slows *time*, and one from the way a mass curves *space*. Newton's physics knows only the first half, and so predicts only half the bending (about 0.87 arcseconds). The full, correct answer needs space itself to be curved. Eddington's eclipse didn't just show that light bends — it showed that *space* bends. Keep that in mind: the right answer needs both halves. It is about to matter.

3. The same answer, from the thirteen-dimensional shape

Now the second route — the same bend, this time falling out of the shape. The shape has a 'spacetime part' (the four dimensions we live in) sitting alongside its tiny internal part. When you carefully shrink the internal dimensions away — a standard move called dimensional reduction — the rules left governing the spacetime part turn out to be Einstein's exact master equation for gravity. Physicists call it the Einstein–Hilbert action: the single compact recipe from which all of general relativity unfolds. The shape doesn't hand you a watered-down, Newton-only cousin of gravity. It hands you the real thing:

$$S_4 = (1 / 16\pi G_N) \int \sqrt{(-g)}\, R[g]\, d^4x \quad (+ \text{ small corrections}),$$

with the strength of gravity — Newton's constant — fixed by the size of the curled-up space, and no free dial to tune anywhere in the gravity sector. This is the step that makes the optics come out right. Because the recipe that emerges is the **complete** one and not a simplified version, it describes the full way a mass warps both space and time — both halves of the story from Section 2. Working through the standard textbook steps (the same ones every relativity student does), the shape's gravity gives

$$g_{00} = -(1 + 2\Phi/c^2) \quad [\text{time bends}] \quad \text{and} \quad g_{ij} = (1 - 2\Phi/c^2)\delta_{ij} \quad [\text{space bends}],$$

which is precisely the warping that produces the refractive index $n = 1 + 2GM/(c^2 r)$ of Section 2. The 'space bends' half supplies its half of the factor of two, and the bend is the same 1.75 arcseconds. The two routes meet.

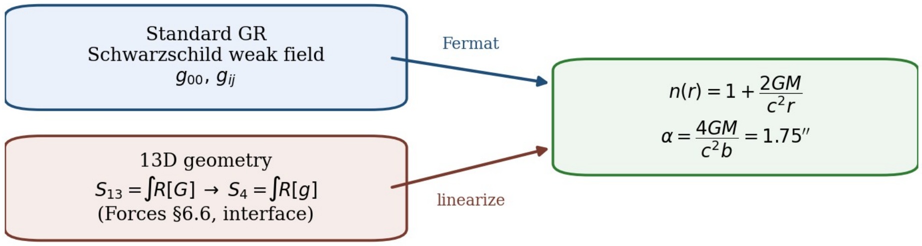

Figure 2. *Two routes, one number. Standard relativity gives the warping of space and time directly; the 13-dimensional shape, reduced to four dimensions, gives the same master recipe and hence the same warping. Both end at the same 1.75-arcsecond bend.*

It is worth being clear about why this is not a trick. The shape was selected by requirements about particles and forces that never mentioned gravity's effect on light. The gravitational recipe is simply what fell out of the same shape when it was reduced. So the agreement between the two routes isn't one calculation wearing two disguises — it's a construction built for entirely different reasons landing, unprompted, on the right answer.

One point of full disclosure, picked up again at the end: the source papers write out the 'time bends' half explicitly, and the 'space bends' half — though forced by the very same recipe — is completed here rather than there.

4. It isn't one number — it's the whole of gravity

Light-bending is the vivid case, but it is really one example of something larger, and the larger thing is the real point. The claim isn't 'one number came out right.' It's that the **entire recipe** for gravity matches Einstein's. And once that is true, everything general relativity predicts in this gentle regime comes along for free, all at once: the slight delay a signal picks up as it passes near the Sun — the 'Shapiro delay' that deep-space navigators at places like NASA's Jet Propulsion Laboratory actually fold into their spacecraft tracking — the tiny change in the ticking of a precise clock deeper in a gravity well, the slow swing of Mercury's orbit, and the bending of starlight. These are not separate victories to be won one at a time; they are the single statement 'the gravity here is Einstein's gravity,' read off in different instruments.

The construction is also honest about the one thing that could spoil it. The recipe lands on pure Einstein gravity **only if** a certain internal size in the shape stays locked in place. If that size were instead free to drift, the resulting gravity would be subtly different — a 'scalar-tensor' cousin — and it would bend light and delay signals by measurably different amounts. This isn't a buried assumption; it's a stated, testable fork in the road. And it connects straight to real measurement: the Cassini spacecraft, tracked by radio as it slipped behind the Sun, pinned the relevant number to within a few parts in a hundred thousand of Einstein's exact value ($\gamma - 1 =$

$(2.1 \pm 2.3)\times10^{-5}$). So the 'locked' version of the shape sits comfortably inside the best measurement we have — and any future result that nudged that number off Einstein's value would rule it out.

5. What this does, and does not, show

To keep the claim exactly the size it should be: reproducing general relativity — even the full version with curved space, not just Newton's gravity — is something *any* candidate theory has to do. Think of it as a crash test. Passing means the construction cleared a hurdle it genuinely could have failed (it might have come out Newton-only, or as the scalar-tensor cousin, or with half the bending) — but passing a crash test does not prove a car is the best on the road. It earns a closer look.

The real evidence for this construction lives elsewhere — in the places where it is not merely recovering physics we already knew, but reaching out and matching measured numbers it was never built to match: the structure of the known forces, the fact that there are exactly *three* families of matter (which comes out as a whole number the shape is forced to count, with no way to dial it to two or four), and a list of particle properties that follow from just four measured inputs. The light-bending check is the front door. If the door is intriguing, that is where the house is.

And for the specialists reading this, the load-bearing question is now narrower and sharper, because everything downstream of it is written out in Appendix A: *does the corpus's 13-to-4-dimensional reduction genuinely land on Einstein's action on the locked-size (Einstein-frame) branch, and do the modulus-freeze and higher-order assumptions keep γ within the Cassini bound?* Everything after that — $\gamma = 1$, the refractive index, the 1.75-arcsecond bend — is derived there step by step. That one joint is where this stands or falls.

6. The seam, now closed

Earlier drafts of this note left one seam exposed: the step from the geometry's master recipe to the full bending of light was said to follow, but not written out. It is now written out in full, in Appendix A. In one breath: starting from the thirteen-dimensional version of Einstein's gravity and shrinking the extra dimensions with their size held fixed, you recover ordinary four-dimensional Einstein gravity; linearizing it gives both halves of the warping — time and space — which fixes the post-Newtonian number $\gamma = 1$, the refractive index $n(r) = 1 + 2GM/(c^2r)$, and the 1.75-arcsecond bend. You do not need to follow the appendix to trust the story; it is there so that anyone who wants to — including an AI you ask to check it — can verify every step.

What remains genuinely conditional is named, not hidden: the thirteen-dimensional starting point must be Einstein's gravity; the size of the internal space must stay locked (if it drifts, gravity becomes a 'scalar-tensor' cousin and the bending changes); no light extra field may survive in the solar-system regime; the heavy Kaluza–Klein modes must stay dormant there; and the small higher-order corrections must keep γ within the measured bound. The Cassini result already pins that bound tightly, and the locked-size version sits inside it.

Appendix A — The full chain, from the 13-dimensional action to the 1.75-arcsecond bend

This appendix writes out, step by step, the derivation summarized in Section 6. It is not required reading for the story; it is here so the claim can be checked. The goal is deliberately narrow: show that, on the locked-internal-size branch, the thirteen-dimensional gravitational action reduces to ordinary four-dimensional general relativity, and that ordinary relativity then gives the full light deflection — both the time and the space parts of the metric, hence $\gamma = 1$, hence 1.75 arcseconds. Conventions: metric signature $(-,+,+,+)$; indices $\mu,\nu = 0$–3 are spacetime, $a,b = 1$–9 are internal. Newton's constant is G_N; the speed of light is c.

A.1 Reducing the 13-dimensional action to 4-dimensional Einstein–Hilbert

Take the gravitational sector of the thirteen-dimensional theory to be its Einstein–Hilbert action, with 13D metric G_{AB}, Ricci scalar $R_{13}[G]$, and gravitational coupling κ_{13}:

$$S_{13}^{\text{grav}} = \frac{1}{2\kappa_{13}^2} \int d^{13}X \sqrt{-G}\, R_{13}[G]$$

For the solar-system gravity check, keep only the massless four-dimensional gravitational zero mode and freeze the internal shape. With $\gamma_{ab}(y)$ the fixed internal metric on $K_9 = K_6 \times S^2 \times S^1_Y$, ℓ the frozen internal length, and V_9 the (constant) internal volume:

$$X^A = (x^\mu, y^a), \qquad \mu,\nu = 0,1,2,3, \qquad a,b = 1,\ldots,9$$

$$ds_{13}^2 = g_{\mu\nu}(x)\, dx^\mu dx^\nu + \ell^2\, \gamma_{ab}(y)\, dy^a dy^b$$

$$K_9 = K_6 \times S^2 \times S^1_Y, \qquad V_9 = \ell^9 \int d^9y\, \sqrt{\gamma} = \text{const}$$

This is the locked-size / Einstein-frame condition made concrete: the internal volume is not a light spacetime field on this branch. The off-diagonal Kaluza–Klein gauge fields and internal excitations exist in the full construction, but are not sourced in this weak-field background, so for this calculation:

$$G_{\mu a} = 0, \qquad \partial_\mu \gamma_{ab} = 0, \qquad \partial_\mu V_9 = 0$$

For the block-diagonal product the determinant factorizes, and the internal integral collapses to the constant volume:

$$\sqrt{-G} = \sqrt{-g}\,\ell^9\sqrt{\gamma}, \qquad \int d^9y\,\ell^9\sqrt{\gamma} = V_9$$

and, for a frozen product geometry, the Ricci scalar splits cleanly into a four-dimensional piece and an internal piece:

$$R_{13}[G] = R_4[g] + \ell^{-2}R_9[\gamma]$$

Substituting both into the action and integrating over the nine internal coordinates gives

$$\begin{aligned} S_{13}^{\text{grav}} &= \frac{1}{2\kappa_{13}^2}\int d^4x\,\sqrt{-g}\int d^9y\,\ell^9\sqrt{\gamma}\left(R_4[g] + \ell^{-2}R_9[\gamma]\right) \\ &= \frac{V_9}{2\kappa_{13}^2}\int d^4x\,\sqrt{-g}\,R_4[g] \;+\; \frac{1}{2\kappa_{13}^2}\int d^4x\,\sqrt{-g}\int d^9y\,\ell^7\sqrt{\gamma}\,R_9[\gamma] \end{aligned}$$

The first term is precisely the four-dimensional Einstein–Hilbert action; the second is a constant vacuum-energy / stabilization contribution that does not affect solar-system bending at this order. Defining Newton's constant by the coefficient out front, and restoring matter and the controlled higher-order corrections:

$$S_4^{\text{grav}} = \frac{V_9}{2\kappa_{13}^2}\int d^4x\,\sqrt{-g}\,R[g], \qquad \frac{1}{16\pi G_N} = \frac{V_9}{2\kappa_{13}^2}$$

$$S_4 = \frac{1}{16\pi G_N}\int d^4x\,\sqrt{-g}\,R[g] + S_{\text{matter}}[g,\Psi] + S_{\text{EFT}}$$

This is the reduction. On the locked-size branch the massless four-dimensional metric is governed by the Einstein–Hilbert action with a constant Newton coupling. (Were the internal volume instead a light, varying field, the coefficient of R[g] would become dynamical and the reduced theory would be scalar-tensor rather than Einstein gravity — the fork named in Section 4.)

A.2 From the action to the full Einstein equations

Varying the four-dimensional action with respect to the metric gives the complete Einstein field equations, with any higher-order corrections collected in a term that is small for the observable being computed:

$$G_{\mu\nu} = \frac{8\pi G_N}{c^4}T_{\mu\nu} + \Delta_{\mu\nu}^{\text{EFT}}, \qquad \left|\Delta_{\mu\nu}^{\text{EFT}}\right| \ll \left|\tfrac{8\pi G_N}{c^4}T_{\mu\nu}\right|$$

The point worth stressing: this is the full tensor equation, not merely its Newtonian (time-component) limit. That is exactly what lets the optics come out with the correct factor of two.

A.3 Linearizing in the weak field

Expand around flat space in harmonic gauge, using the trace-reversed perturbation:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \qquad |h_{\mu\nu}| \ll 1, \qquad h = \eta^{\alpha\beta} h_{\alpha\beta}$$
$$\bar{h}_{\mu\nu} = h_{\mu\nu} - \tfrac{1}{2}\eta_{\mu\nu} h, \qquad \partial^\mu \bar{h}_{\mu\nu} = 0$$

The linearized field equation, taken to the static, non-relativistic limit, reduces to a Poisson equation for the time component:

$$\Box\, \bar{h}_{\mu\nu} = -\frac{16\pi G_N}{c^4} T_{\mu\nu} \quad \xrightarrow{\text{static}} \quad \nabla^2 \bar{h}_{00} = -\frac{16\pi G_N}{c^2}\rho$$

Introducing the (positive) Newtonian potential, the trace-reversed solution sits entirely in the time component, with the spatial and mixed parts vanishing by asymptotic flatness:

$$U(\mathbf{x}) = G_N \int \frac{\rho(\mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|}\, d^3x', \qquad \nabla^2 U = -4\pi G_N \rho$$
$$\bar{h}_{00} = \frac{4U}{c^2}, \qquad \bar{h}_{ij} = 0, \qquad \bar{h}_{0i} = 0$$

A.4 Undoing the trace reversal — the step that earns the space curvature

This is the move the earlier draft left implicit. Computing the trace and inverting the trace-reversal gives the time and space components of the actual metric perturbation — and the spatial part is not zero:

$$\bar{h} = \eta^{\alpha\beta}\bar{h}_{\alpha\beta} = -\bar{h}_{00} = -\frac{4U}{c^2}$$
$$h_{00} = \bar{h}_{00} - \tfrac{1}{2}\eta_{00}\bar{h} = \frac{4U}{c^2} - \tfrac{1}{2}(-1)\left(-\frac{4U}{c^2}\right) = \frac{2U}{c^2}$$
$$h_{ij} = \bar{h}_{ij} - \tfrac{1}{2}\delta_{ij}\bar{h} = 0 - \tfrac{1}{2}\delta_{ij}\left(-\frac{4U}{c^2}\right) = \frac{2U}{c^2}\,\delta_{ij}$$

So the physical metric carries equal time and space pieces:

$$g_{00} = -1 + \frac{2U}{c^2}, \qquad g_{ij} = \left(1 + \frac{2U}{c^2}\right)\delta_{ij}$$

with line element

$$ds^2 = -\left(1 - \frac{2U}{c^2}\right)c^2 dt^2 + \left(1 + \frac{2U}{c^2}\right)\delta_{ij}\, dx^i dx^j + O\!\left(\frac{U^2}{c^4}\right)$$

A.5 Reading off γ, the optical index, and the bend

Comparing this with the standard post-Newtonian metric fixes the parameter γ:

$$ds^2 = -\Big(1 - \frac{2U}{c^2}\Big)c^2dt^2 + \Big(1 + 2\gamma\frac{U}{c^2}\Big)d\mathbf{x}^2$$

$$1 + 2\gamma\frac{U}{c^2} = 1 + 2\frac{U}{c^2} \quad \Longrightarrow \quad \boxed{\gamma = 1}$$

A static metric defines an effective refractive index for light, `n = √(B/A)`; with γ = 1 this is exactly the gradient-index formula used in the main text:

$$ds^2 = -A(r)c^2dt^2 + B(r)\,d\ell^2, \qquad n(r) = \frac{c}{d\ell/dt} = \sqrt{\frac{B(r)}{A(r)}}$$

$$n(r) = \sqrt{\frac{1 + 2\gamma U/c^2}{1 - 2U/c^2}} \simeq 1 + (1+\gamma)\frac{U}{c^2} \quad \xrightarrow{\gamma=1} \quad 1 + \frac{2G_NM}{c^2r}$$

Integrating the transverse gradient of the index along the ray gives the deflection:

$$\alpha = \int_{-\infty}^{+\infty}\Big|\frac{\partial n}{\partial b}\Big|\,dz = (1+\gamma)\frac{G_NM}{c^2}\int_{-\infty}^{+\infty}\frac{b\,dz}{(b^2+z^2)^{3/2}}$$

$$\int_{-\infty}^{+\infty}\frac{b\,dz}{(b^2+z^2)^{3/2}} = \frac{2}{b} \quad \Longrightarrow \quad \alpha = \frac{2(1+\gamma)G_NM}{c^2b} \quad \xrightarrow{\gamma=1} \quad \boxed{\frac{4G_NM}{c^2b}}$$

The role of the space-curvature half is now explicit: with only the time part (γ = 0) the result would be exactly half — the old Newtonian value Eddington's eclipse ruled out:

$$\alpha_{\gamma=0} = \frac{2G_NM}{c^2b} \quad \text{(half the relativistic value: the Newtonian estimate)}$$

And the solar numbers give the familiar figure:

$$G_NM_\odot = 1.327\times10^{20}\,\mathrm{m^3s^{-2}}, \quad R_\odot = 6.96\times10^{8}\,\mathrm{m}, \quad c = 2.998\times10^{8}\,\mathrm{m\,s^{-1}}$$

$$\alpha_\odot = \frac{4G_NM_\odot}{c^2R_\odot} \simeq 8.49\times10^{-6}\ \mathrm{rad} = 1.75''$$

A.6 What remains conditional

The chain closes the derivation given five conditions, none hidden: (1) the 13D gravitational sector is Einstein–Hilbert at the start; (2) the internal volume and shape are frozen / stabilized (the locked-size, Einstein-frame condition); (3) no light scalar-tensor mode survives in the solar-system regime; (4) off-diagonal Kaluza–Klein and internal excitations stay inactive or heavy in that background; and (5) higher-order corrections keep γ within observational bounds. If the volume modulus were dynamical, the theory takes a scalar-tensor form and γ need not equal 1; writing the possible shifts explicitly:

$$S_4 \sim \int d^4x \sqrt{-g}\, F(\varphi) R[g] + \cdots, \qquad \gamma = 1 + \delta\gamma_{\mathrm{WL}} + \delta\gamma_{\mathrm{EFT}}$$

$$\alpha = \frac{4G_N M}{c^2 b}\Big(1 + \tfrac{1}{2}\big(\delta\gamma_{\mathrm{WL}} + \delta\gamma_{\mathrm{EFT}}\big)\Big)$$

Cassini-level solar-system tests require $|\gamma - 1|$ to be no more than a few parts in a hundred thousand, so the branch is genuinely falsifiable: a dynamical modulus, or higher-order corrections large enough to move γ outside that bound, would break this solar-system check. With those conditions stated, the result stands on an explicit calculation rather than on the bare assertion that an Einstein–Hilbert action implies general relativity.

> **Closed result.** On the locked-internal-size branch, the 13-dimensional Einstein–Hilbert action reduces to the 4-dimensional Einstein–Hilbert action for the massless spacetime metric. That gives the full Einstein equations, not merely the Newtonian limit. Linearizing them derives both g_{00} and g_ij, fixes $\gamma = 1$, gives $n(r) = 1 + 2GM/(c^2r)$, and yields $\alpha = 4GM/(c^2b) = 1.75$ arcseconds at the solar limb.

Notes and sources

[1] The full technical treatment of the gravity reduction — the shrinking to Einstein's recipe, the gentle-field limit, and the locked-size condition — is in the source corpus, Paper II ('Forces'), §6.6: physics.magflowmeters.com/articles/Forces.html

[2] A separate, fully hand-checkable consistency calculation — the electromagnetic field energy of a charged shell, worked two ways and agreeing to six figures — is in Paper I ('GUT'), Appendix O.

[3] The lens picture of gravity (effective index, the bending angle, the 1.75-arcsecond solar value) is standard and appears in general-relativity textbooks; Eddington's measurement dates to 1919.

[4] B. Bertotti, L. Iess, P. Tortora, 'A test of general relativity using radio links with the Cassini spacecraft,' Nature 425, 374 (2003) — the source of the precise solar-deflection bound quoted in Section 4.

[5] A companion set of deep-space optical and relativistic-correction calculators (Shapiro delay, light deflection, clock shift, link budgets), with exportable reproducibility certificates, is online at physics.magflowmeters.com/gut/nasa/