Supplemental Material

I. GRAVITATIONAL REDSHIFT

With $n = e^{\psi}$ and $\Phi = -\frac{c^2}{2}\psi$, the frequency of a cavity mode scales as

$$\frac{\Delta\nu}{\nu} = -\Delta\psi = -\frac{\Delta\Phi}{c^2}. \tag{1}$$

This reproduces the standard gravitational redshift relation of GR.

II. GRAVITATIONAL LIGHT DEFLECTION

In the weak field, $\psi(r) = 2GM/(c^2 r)$ and $n(r) \simeq 1+\psi(r)$. For a light ray with impact parameter b and coordinate z along the path, $r = \sqrt{b^2+z^2}$. The deflection angle α follows from Fermat's principle:

$$\alpha \simeq \int_{-\infty}^{\infty} \partial_b n(r)\, dz \tag{2}$$

$$= \frac{2GM}{c^2}\int_{-\infty}^{\infty} \partial_b\left(\frac{1}{\sqrt{b^2+z^2}}\right) dz \tag{3}$$

$$= \frac{2GM}{c^2}\left(-b\int_{-\infty}^{\infty}\frac{dz}{(b^2+z^2)^{3/2}}\right) \tag{4}$$

$$= \frac{4GM}{c^2 b}. \tag{5}$$

This reproduces the full Einstein value, including the factor of two that Einstein's 1911 calculation missed. *(Historical note: Einstein's original 1911 prediction gave only half this value.)*

III. SHAPIRO TIME DELAY (RADAR ECHO DELAY)

Photon travel time is

$$T = \frac{1}{c}\int n(r)\, ds \simeq \frac{1}{c}\int\left[1+\frac{2GM}{c^2 r}\right] ds. \tag{6}$$

Relative to flat space, the one-way excess is

$$\Delta t = \frac{2GM}{c^3}\int\frac{ds}{r}. \tag{7}$$

For endpoints at r_1, r_2 with impact parameter b, this gives

$$\Delta t = \frac{2GM}{c^3}\ln\left(\frac{r_1+r_2+L}{r_1+r_2-L}\right), \tag{8}$$

with $L = \sqrt{r_1^2+r_2^2-2r_1r_2\cos\theta}$. The two-way radar delay doubles this to the GR value $4GM/c^3$.

IV. PERIHELION PRECESSION

In isotropic gauge the effective metric to $\mathcal{O}(\Phi/c^2)$ is

$$ds^2 = -\left(1+\frac{2\Phi}{c^2}\right)c^2dt^2 + \left(1-\frac{2\gamma\Phi}{c^2}\right)d\mathbf{x}^2. \tag{9}$$

Here γ is the standard PPN parameter that quantifies spatial curvature per unit Newtonian potential. Its value is fixed by the light-deflection result (5), hence $\gamma = 1$. Minimal coupling of matter to this metric yields the Newtonian limit with 1PN corrections corresponding to $\beta = 1$. The perihelion shift per orbit in the PPN formalism is

$$\Delta\varpi = \frac{6\pi GM}{c^2 a(1-e^2)}\cdot\frac{2-\beta+2\gamma}{3}, \tag{10}$$

which reduces to the GR value $\Delta\varpi = 6\pi GM/[c^2a(1-e^2)]$ when $\beta = \gamma = 1$.

V. COMPARISON TABLE

TABLE I. Weak-field predictions. All classical tests coincide with GR in the weak-field limit; the cavity–atom ratio provides the decisive discriminator.

Observable	**GR**	**DFD**
Gravitational redshift	$-\Delta\Phi/c^2$	$-\Delta\Phi/c^2$
Light deflection	$4GM/(c^2b)$	$4GM/(c^2b)$
Shapiro delay (two-way)	$4GM/c^3$	$4GM/c^3$
Perihelion precession	$6\pi GM/[c^2a(1-e^2)]$	$6\pi GM/[c^2a(1-e^2)]$
Cavity–atom slope	0	$2\Delta\Phi/c^2$