# Errata for Gravity: An Introduction to Einstein's General Relativity, *Printings 1-3, A: changes affecting meaning.*

Updated 8/21/2004

The errata that were not corrected in the in the first three printings have been divided into two parts: First *this* list (A) of changes that affect the meaning, clarity or correctness of the text. Second, a list (B), of typos, mispellings, punctuation errors, repeated words, etc which do not change the meaning of the text. Thanks are due to J. David Brown, Dan Crow, John Friedman, Katherine Holley, Matt Lehman, Mario Serna, Robert Nelson, Steve Savitt, and Chester Vause who supplied most of these.

*62, Equation 4.13a:* Replace $(dx^2+dy^2+dx^2)$ with $(dx^2+dy^2+dz^2)$.

*73, Problem 4:* Replace "orbits the Earth" with "orbits the Earth in the same direction it rotates". (Clearer.)

*101, Problem 5.17:* Replace this problem with the following (same problem but better notation):

[C] *(Relativistic Beaming)* A body emits photons of frequency $\omega_*$ at equal rates in all directions in its rest frame. A detector at rest in this frame a large distance away (compared to the size of the body) receives photons at a rate per unit solid angle $(dN/dtd\Omega)_*$ [photons$/(\mathrm{s}\cdot\mathrm{sr})$] that is independent of direction. In an inertial frame $(t',x',y',z')$ in which an observer is at rest the body is moving with speed $V$ along the $x'-$ axis.

1. Derive (5.75) relating a photon's direction of propagation in the rest frame to the direction of propagation in the observer's frame.
2. Find the rate at with photons are received per unit solid angle $dN/dt'd\Omega'$ a large distance away in the observer's frame as a function of angle $\alpha'$ from the $x'-$axis.
3. Find the luminosity per unit solid angle $dL'/d\Omega'$ [erg$/(\mathrm{s}\cdot\mathrm{sr})$] a large distance away as a function of the angle $\alpha'$ in the observer's frame.
4. Discuss the beaming of number and energy in the observer's frame as the velocity of the source approaches the velocity of light.

*115, l2 from bottom:* Replace "... but in which $V/c$ and $gh/c$ may ..." with "... but in which $V/c$ and $gh/c^2$ may ..."

*119, first paragraph:* Replace "derived in Example 6.3.." with "derived in Example 6.2...".

*130, Box 6.2:* The picture is not of Hafele and Keating and not of their clocks. It is of two USNO technicians, George Luther (left) and Bill Dabney (right) boarding similar clocks on an airplane for another purpose. A correct picture of Hafele and Keating on their initial flight is below.

Hafele and Keating on board with their clocks.

Thanks to Robert Nelson of the Satellite Engineering Research Corporation for pointing out this error and supplying the correct picture.

*143, caption to Figure 7.1:* Insert "future" before "light cones". (clearer).

*145, caption to Figure 7.2:* Replace "Inside the light cones..." with "Inside the future light cones...." (clearer).

*146, equation 7.28:* The middle expression should be $d\ell^1 d\ell^2$ not $d\ell^2 d\ell^3$.

*191, after 9.18:* Replace "evaluated at a Schwarzschild radius $R$." with "evaluated at the radius $r = R$ in Schwarzschild coordinates."

*197, last line:* Reference should be to (9.27) not (9.29).

*200, 2 lines above (9.45):* Replace 'From (9.29)' with 'From (9.29) or (9.26)'.

*202, Figure 9.5:* The M in the axis label $\ell$/M should be italic like the rest of math so its $\ell/M$. (The first and second printings had no $M$ at all.)

*207, Figure 9.8:* The vertical axes should be labeled $W_{eff}$ in three places, not $V_{eff}$.

*216, Problem 12:* Replace "around a relativistic star" with "around a relativistic star of mass $M$". (clearer)

*218, Problem 21:* Replace the sentence beginning "Explain why ..." with " Explain why and *estimate* the angle measured from the line of sight on the far side above which the surface could be seen. This would be $\pi/2$ if there were no bending, but less than that because of the bending." (This definition of angle is clearer than "latitude".)

*243, Fig 11.6:* Replace 'parameters governing... sky' with 'parameters specifying the angular speed of lensing object as it moves across the sky and the closest angular approach of the lens to the source (Problems 6 and 7).' .

*245, eq(e):* The factors are too large by an approximate factor of 2. Replace '$1 \times 10^8$' with '$5 \times 10^7$' and replace '9' by '5'.

*247, eq (11.14):* Change $u_{\rm src}$ and $u_{\rm rec}$ to $\mathbf{u}_{\rm src}$ and $\mathbf{u}_{\rm rec}$, that is, the u's in this equation should be boldfaced.

*248, 2nd par, $\ell$1:* If it will fit, replace 'In the tranverse case, $b = 0$ because $\ell = 0$ and the' with 'Photons from the transversely moving matter at $\phi = 0$ or $\phi = \pi$ propogate to the observer along an axis through the center of the disk. They therefore have $b = 0$ and $\ell = 0$ so the' . (Clearer)

*248, 2$\ell$ above (11.22):* Replace 'In this case, the condition that the photon four-momentum be null is enough..' with 'Then, the condition that the photon four-momentum be null (5.70) is enough..'

*249, Figure 11.8:* After ".... July 1994" insert "(Tanaka et.al. 1995).

*259, l6 from bottom:* Replace "Light cones at ..." with "Future light cones at ...".

*264, caption to Figure 12.4:* Replace "orientations of light cones..." with "orientations of future light cones..." (clearer).

*266, Box 12.3:* 4th paragraph, delete "generic" in two places.

*271, caption for Figure 12.6:* Replace "a few light cones are indicated..." with "a few future light cones are indicated..."

*278, Problem 13:* "For instance can she ever see her feet when her head ..." should be "For instance, can she see her feet when her head ...." . (ie delete "ever" in this sentence but leave it in the other two.) (This correction applies only to the third printing. The relevant corrections for earlier printings are in earlier lists.)

*292, eq(13.10):* Replace (13.10) with the following if it fits on one line:

$$\hbar(\text{in cm}^2) = G\,\hbar(\text{in erg}\cdot\text{s})/c^3 \equiv \ell_{Pl}^2 = 2.62\times 10^{-66}\text{cm}^2,$$

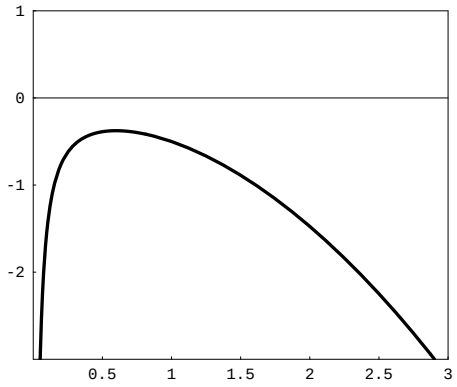
*383, 2$\ell$ after (18.47):* Replace 'that is principle visible. It's the *distance* to the horizon." with 'that is in principle visible. It's denoted by $d_{\text{horiz}}$ because it is the *distance* to the horizon.'

*390, l1-2 of text:* The formula in the sentence beginning "Their total..." is off by a factor of 2. The sentence would should read: "The total duration is therefore $(\pi\Omega/H_0)(\Omega-1)^{-3/2}$. "

*390, eq. (18.70):* The denominator should be raised to the power 3/2 rather than 1/2 so the equation reads:

$$V_{\text{max}} = \frac{2\pi^2}{H_0^3}\left[\frac{\Omega}{(\Omega-1)^{3/2}}\right]^3$$

*394, Fig. 18.9:* The left hand figure actually shows the effective potential for $\Omega_v = .3$ and $\Omega_m = .7$ ie with the values interchanged from those quoted in the caption. The correct figure is below:




*449, Eq. (21.9):* The last equation should for $\chi^{\hat{\phi}}$ have a minus in front of $M/r^3$ on the right hand side, ie so its:.

$$\frac{d^2\chi^{\hat{\phi}}}{dt^2} = -\frac{M}{r^3}\chi^{\hat{\phi}}$$

(This correction applies only to the third printing, this equation is correct in the first two.)

*479, ex. 22.5, line 6:* "at $x+L$" instead of "at $x=L$".