264(3): Calculation of Photon Mass and Photon Velocity from x Theory

In the near Newtonian approximation the photon mass m in light deflection due to gravitation can be calculated from:

$$\frac{\alpha}{\epsilon^2 - 1} = \frac{mMG}{2E} \quad -(1)$$

(see Marion and Thornton), where E is the kinetic energy of the photon. So:

$$m = \frac{2}{MG}\left(\frac{\alpha}{\epsilon^2 - 1}\right) E \quad -(2)$$

where

$$\alpha = 1.63992 \times 10^{14} \text{ m} \quad -(3)$$
$$\epsilon = 235{,}735.06$$
$$M = 1.9891 \times 10^{30} \text{ kg}$$
$$G = 6.67428 \times 10^{-11} \text{ kg}^{-1} \text{m}^3 \text{s}^{-2}$$

so

$$\boxed{m = 4.446 \times 10^{-17} E} \quad -(4)$$

In order to estimate E use the Planck distribution for amorphous radiation or for a sharply defined frequency use:

$$E = \hbar\omega \quad -(5)$$

For a sharply defined frequency:

$$m = 4.689 \times 10^{-51} \omega \text{ kgm.} \quad -(5a)$$

The rest frequency of the photon is defined by the de Broglie Theorem: $\hbar\omega_0 = mc^2 \quad -(6)$

For a Planck distribution in amorphous light the energy density in joules per cubic metre is: $-(7)$

$$U = \int_0^\infty \frac{8\pi h}{c^3}\left(\frac{\nu^3 d\nu}{e^{h\nu/kT}-1}\right) = \left(\frac{\pi^2}{15}\frac{k^4}{c^3\hbar^3}\right)T^4$$

$$= 7.566 \times 10^{-16}\, T^4 \quad Jm^{-3}$$

The number of photons per cubic metre is: $-(8)$

$$N = \int_0^\infty \frac{8\pi}{c^3}\left(\frac{\nu^2 d\nu}{e^{h\nu/kT}-1}\right) = \left(\frac{2\zeta(3)}{\pi^2}\frac{k^3}{c^3\hbar^3}\right)T^3$$

$$= 2.029 \times 10^7\, T^3 \text{ per cubic metre}$$

So the energy per photon of the averaged Planck distribution is:

$$E = 3.73 \times 10^{-23}\, T \text{ joules} \quad -(9)$$

So the photon mass is:

$$m = 1.658 \times 10^{-39}\, T \qquad -(10)$$

where T is the temperature of the beam. At the sun's surface

$$T = 5,778\, K \qquad -(11)$$

so

$$m = 9.58 \times 10^{-36}\, kg \qquad -(12)$$

for an amorphous beam grazing the sun.

If it is assumed that the light beam has a sharply defined frequency then for a visible beam

$$f \sim 3 \times 10^{14}\, Hz \qquad -(13)$$

and

$$\omega = 2\pi f = 2 \times 10^{15}\, rad\, s^{-1} \qquad -(14)$$

so from eq. (5a):

$$m = 9.38 \times 10^{-36}\, kg \qquad -(15)$$

These estimates of photon mass are similar to those obtained from Compton scattering in previous work.

The photon velocity can be estimated from eq. (4) using the relativistic kinetic energy

$$E = T = (\gamma - 1) m c^2 \qquad -(16)$$

$$\rightarrow \frac{1}{2} m v^2$$

So:

4) From eqs. (4) and (16):

$$m = 4.446 \times 10^{-17} (\gamma - 1) mc^2 \quad - (17)$$

So

$$\gamma - 1 = \frac{1}{4.01} \quad - (18)$$

using

$$c = 2.998 \times 10^{8} \, ms^{-1} \quad - (19)$$

so

$$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2} = 1.249 \quad - (20)$$

so

$$\left(1 - \frac{v^2}{c^2}\right)^{1/2} = \frac{1}{1.249} = 0.801 \quad - (21)$$

and

$$1 - \frac{v^2}{c^2} = 0.642 \quad - (22)$$

so

$$\boxed{v = 0.598c} \quad - (23)$$