(2) Measurements by Pioneer 10 of the magnetic field of Jupiter [L. Davis, Jr., A. S. Goldhaber, and M. M. Nieto, Phys. Rev. Lett. **35**, 1402 (1975)] showed that the range of the electromagnetic force must be at least 5×10^{10} cm. How large is the implied upper bound on the rest mass of the photon? If a green photon races an x-ray photon across the visible universe, how far behind will it finish?

Not worrying about factors of two, we can say that the photon's Compton wavelength $\lambdabar_C$ must be greater than 5×10^{10} cm, so its rest mass $\hbar/\lambdabar_C c$ cannot exceed 7×10^{-49} gm. A green photon has $\lambda \approx 10^{-5}$ cm. If it has the mass just

mentioned its γ is $\lambdabar_C/\lambda$ or 5×10^{15}. Then $1 - \beta = 1/2\gamma^2 = 2 \times 10^{-32}$. For the x-ray photon $1 - \beta$ is negligible in comparison. After racing for 10^{28} cm the green photon will trail by only $2\,\mu$m!