LIMITS ON $|\delta|$ FROM COSMIC OBSERVATIONS

$$c_e \equiv c_\gamma(1+\delta)$$

Case A: $\delta > 0$

A1 - The bound from highest electron energy:

If $\delta > 0$, electrons become superluminal for energies greater than $m_e(2\delta)^{-1/2}$ and rapidly lose energy by "vacuum Cherenkov radiation". Since the highest energy of cosmic ray electrons observed, ~ 1 TeV, must be less than this, this implies $\delta < 1.3 \times 10^{-13}$.

A2 - The bound from extragalactic γ-$\gamma \to e^+e^-$:

The existence of electron-positron pair production for γ-ray energies up to ~ 20 TeV in the spectrum of Mkn 501 gives $|\delta| < 1.3 \times 10^{-15}$, two orders of magnitude better than the cosmic-ray electron bound, A1 (Stecker & Glashow 2001).

Case B: $\delta < 0$

The bound from the highest energy cosmic γ-ray observed:

If $\delta < 0$, a photon with energy exceeding $m_e(2/|\delta|)^{1/2}$ could decay into an electron-positron pair (kinematically allowed). Since γ-rays of energies up to ~ 50 TeV have been observed from the Crab nebula, this implies $|\delta| < 2 \times 10^{-16}$.

CONSTRAINTS ON QUANTUM GRAVITY(?)

According to Ellis *et al.* 1998 & Amelino-Camelia, *et al.* 1998, the back reaction of the vacuum would lower the effective velocity of electron so that

$$\delta \simeq -E/M_{QG} + ...$$

We find

$$-\delta \leq 2 \times 10^{-16} \quad \text{for} \quad E = 5 \times 10^4 \text{GeV},$$

since 50 TeV γ-rays have been seen coming from the Crab Nebula.

This implies

$$M_{QG} = -E/\delta \;\geq \sim 25 M_{Pl}.$$

This is, of course, an inconsistency which would appear to rule out this theory.