PRICE FOR NEUTRINO SUPERLUMINALITY

Alexander Vikman (CERN)

*



XLVIIth Rencontres de Moriond, EW 2012

 $\star \star \star \star$

This talk is based on

e-Print: arXiv:1109.5685 [hep-ph]

JHEP 1202 (2012) 134

in collaboration with Gia Dvali

Sunday, March 4, 2012

We are theoretical physicists, therefore we cannot and do not check this



 \diamond

OPERA:

 $\frac{v_{\nu} - c}{c} = (2.48 \pm 0.28 \,(\text{stat}) \pm 0.30 \,(\text{sys})) \times 10^{-5}$

* Neutrino propagate in a metric $g_{\alpha\beta}^{(\nu)} = g_{\alpha\beta} + \delta g_{\alpha\beta}$ different from gravitational $g_{\mu\nu}$ by $|\delta g_{\alpha\beta}| = \epsilon \sim 10^{-5}$

$$(\eta_{\alpha\beta} + \delta g_{\alpha\beta}) \ \overline{\nu} \gamma^{\alpha} \partial^{\beta} \nu$$

* Only possible if the Lorentz symmetry is spontaneously broken by a background

* SN 1987A bis background is *local*, sourced by the Earth?

Known Earth's Backgrounds

* Magnetic Field $B_{\oplus} \sim 0.1 \,\mathrm{Gauss}$

$$\delta g_{\mu\nu} = \frac{c_1 F_{\mu\lambda} F^{\lambda}_{\nu} + c_2 F_{(\mu\lambda} \overline{F}^{\lambda}_{\nu)}}{M_{\rm B}^4} \longrightarrow M_{\rm B} \sim 1$$

* Gravitational Field
$$\delta g_{\mu\nu} = \frac{G_{\mu\nu}}{M_g^2}$$

Low Strong Coupling Scale!

L eV

 $M_{\rm g} \sim 10^{-16} \,\mathrm{eV} ~~ \sim \left(M_{\rm Pl} M_{\rm g}^2\right)^{1/3} \sim 10^{-1} \,\mathrm{eV}$

Unknown Backgrounds?

* *local* effect — general decomposition in *massive* degrees of freedom:



 $\delta g_{\alpha\beta} \,\overline{\nu} \,\gamma^{\alpha} \,\partial^{\beta} \nu \simeq \delta g_{\alpha\beta} T^{\alpha\beta}_{(\nu)} + \text{energy conservation} \ \partial_{\alpha} T^{\alpha\beta}_{(\nu)} \simeq 0$

On this level only massive spin 2 field survives!

 \diamond

Pauli-Fierz Lagrangian:

 $h^{\mu\nu} \mathcal{E}h_{\mu\nu} + m^2 (h_{\mu\nu}h^{\mu\nu} - h^{\mu}_{\mu}h^{\nu}_{\nu})$

But other particles are not superluminal!

This massive spin 2 field is not universal!

 $\frac{h_{\alpha\beta}T^{\alpha\beta}_{(\nu)}}{M_{*}}$

 $h_{\alpha\beta} T^{\alpha\beta}_{(\text{other particles})}$

Neutrino Metric Sourced by the Earth

$$g_{00}^{(\nu)} = \left(\left(1 - \frac{1}{3}\epsilon\right) + \epsilon\right)\eta_{00}, \quad g_{ij}^{(\nu)} = \left(1 - \frac{1}{3}\epsilon\right)\eta_{ij},$$

where $\epsilon \equiv \frac{M_{\oplus}}{4\pi M_* M R_{\oplus}}$

superluminality $\rightarrow \epsilon < 0 \rightarrow M_*M < 0$

Sign asymmetry! - Off Diagonal Antigravity...

OPERA $\rightarrow M_*M \sim 10^{-4}M_P^2$

Naive Constraints

* 5th force $M > 10^2 \div 10^6 M_{\rm Pl}$

* Star cooling and BBN $M_* > 10^8 \,\mathrm{GeV}$

one can choose $M_* \sim 10^{-6} M_{\rm Pl} \& M \sim 10^2 M_{\rm Pl}$

* Linear approximation works because for the Vainshtein radius $R_{\rm V} \sim ((M_{\oplus}/M^2)m^{-4})^{1/5} \sim 10^5 \,\mathrm{cm} \ll R_{\oplus}$

Strong coupling

For the "scalar part" of the graviton $h_{\mu\nu}^{\text{LL}} = \varphi \eta_{\mu\nu} + \frac{\partial_{\mu}\partial_{\nu}\varphi}{m^2}$

 $T^{\alpha\beta}_{(\nu)}$ is not conserved ! There are weak and neutral currents!

$$g \frac{\partial_{\mu} \varphi \,\partial^{\mu} \bar{\nu} \,\gamma^{\alpha} \ell_{\nu} W_{\alpha}^{+}}{m^{2} M_{*}} \quad \text{and} \quad \frac{g}{\cos \theta_{w}} \frac{\partial_{\mu} \varphi \,\partial^{\mu} \bar{\nu} \,\gamma^{\alpha} \nu Z_{\alpha}}{m^{2} M_{*}}$$

very low strong coupling scale of the strength of Dark Energy!

$$\Lambda = (m^2 M_*)^{1/3} \sim 10^{-3} \,\mathrm{eV}$$

Conclusions:

no good theoretical model - always rather low strong coupling

Surgical Operations

OPERATION

PAYMENT

ABDOMEN

Resection of bowel	\$150.00
Removal of gall bladder	125.00
Gastrectomy	150.00
Laparotomy or other cutting into	
abdominal cavity for diagnosis or treatment of	
organs therein (unless otherwise specified)	100.00

ABSCESSES

Abscesses, deep, incision and drainage 40.00

AMPUTATIONS

1 1 4

Leg or thigh	75.00
Arm, forearm, entire hand, or entire foot	50.00
Shoulder, hip	100.00
Superluminal Neutrinos.	

 $\langle \bullet \rangle$