Problems and hopes in nonsymmetric gravity

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based on work done with Tomislav Prokopec and Wessel Valkenburg

Overview

- Introduction and Motivation
- Linearizing NGT
- Instabilities in NGT
- Antisymmetric metric field as dark matter
- Conlusions

Introduction and motivation

Drop the axiom that the metric is symmetric

Einstein, 1945 Moffat, 1995

$$g_{\mu\nu} = G_{(\mu\nu)} + B_{[\mu\nu]}$$

Reasons:

- Generality
- Naturally produce torsion
- Resolve mysterious nature of dark matter/energy

Linearizing NGT I

Most general full lagrangian:

$$\mathcal{L} = \sqrt{-g} g^{\mu\nu} \Big[Q_{\mu\nu} + a_1 P_{\mu\nu} + a_2 \partial_{[\mu} W_{\nu]}$$

$$+ b_1 \mathcal{D}_\lambda W^\lambda_{[\mu\nu]} + b_2 W^\lambda_{[\mu\alpha]} W^\alpha_{[\lambda\nu]} + b_3 W^\lambda_{[\mu\nu]} W_\lambda$$

$$g^{\lambda\delta} g_{\alpha\beta} \Big(c_1 W^\alpha_{[\mu\lambda]} W^\beta_{[\nu\delta]} + c_2 W^\alpha_{[\mu\nu]} W^\beta_{[\lambda\delta]} + c_3 W^\alpha_{[\mu\delta]} W^\beta_{[\nu\lambda]} \Big)$$

$$+ d W_\mu W_\nu + 2\Lambda],$$

Expand, using first order formalism:

$$g_{\mu\nu} = G_{\mu\nu} + B_{\mu\nu} + \rho B_{\mu\alpha} B^\alpha{}_\nu + \sigma B^2 G_{\mu\nu} + \mathcal{O}(B^3)$$

Linearizing NGT II

Result:

$$\mathcal{L}_{\text{Lin}} = \sqrt{-G}\Big[R + 2\Lambda - \frac{1}{12}H^2 + \Big(\frac{1}{4}m^2 + \beta R\Big)B^2 - \alpha R_{\mu\nu}B^{\mu\alpha}B_\alpha{}^\nu - \gamma R_{\mu\alpha\nu\beta}B^{\mu\nu}B^{\alpha\beta}\Big]$$

Remarks:

- $m^2 \propto \Lambda$
- $\gamma = 0$ not allowed
- Torsion is generated
- Equations of motion decouple

Instabilities in NGT

Janssen, Prokopec, 2006

EOM for 'electric' component at beginning of radiation era

$$\left[\partial_0\partial_0 - \frac{(m/H_I)^2 + 4(\gamma-\alpha)}{(m/H_I)^2 - 4(\gamma-\alpha)}\delta^{ij}\partial_i\partial_j + M^2\right]\vec{E} = 0$$

For stability we either need

$$m \gtrsim \sqrt{|\gamma-\alpha|}10^{13}\ \mathrm{GeV} \qquad \text{or} \qquad \alpha = \gamma$$

Similar in Schwarzschild background of neutron star:

$$m \gtrsim \sqrt{|\gamma|}10^{-19}\ \mathrm{GeV} \qquad \text{or} \qquad \gamma = 0$$

Always safe:

$$\alpha = \gamma = 0$$

Not Possible

Antisymmetric metric field as dark matter

Prokopec, Valkenburg 2006

Canonically quantize the field in inflation and 'follow' the dynamics up to today.

- mass: $m = 3 \times 10^{-2} (10^{13}\ \mathrm{GeV}/H_I)^4 eV \rightarrow$ correct energy density for dark matter.
- No interactions $\rightarrow$ highly non-thermal
- Characteristic: peak in the energy density power spectrum at $k_{\mathrm{co}} \simeq \sqrt{m H_0}/(1+z_{eq})^{1/4}$.
- at $z = 10$, $\lambda_{\mathrm{phys}} \propto 1 \times 10^8\ \mathrm{km} \rightarrow$ Early structure formation.
- Gravity gets modified at $m^{-1} \simeq 0.1 \mu m (H_I/10^{13}\ \mathrm{GeV})^4$

Conclusions

- NGT is a natural extension of General relativity
- Now we know what linearized NGT should look like, we don’t know how to get there.
- NGT produces an excellent dark matter candidate