From Cosmology to Theoretical Particle Physics

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JAE Intro Scholarship

University of Valencia, Summer 2012

"Connecting the Physics at LHC with the Universe: Dark Matter"
supervised by Prof. José Bernabéu

- Astrophysical and Cosmological proves
- MSSM with R-Parity: $R = (-1)^{2s+3B+L}$
- Observational status: Direct/Indirect detection and Collider searches

Imperial College London

Erasmus Scholarship: 2012-2013

BSc Final Project:

"Constraints on the time dependence of the Dark Energy equation of state"
Supervised by Prof. Carlo Contaldi

Courses

- QFT
- QED
- Unification
- Advanced Particle Physics
- General Relativity
- Cosmology

MSc for Advanced Physics

University of Valencia 2013-2014

MSc Thesis

- "Kerr-Newman black holes in General Relativity and quadratic Palatini gravity"
  Supervised by Dr. Gonzalo Olmo

Courses

- Cosmology
- QFT I
- QFT II
- QCD
- Electroweak Theory
- Elementary Particles

Quadratic Theories

G. Olmo, D. Rubiera-Garcia, (2012)

$$S\left(g,\Gamma,\Psi_m\right)=\frac{1}{16\pi G}\int d^4x\sqrt{-g}f\left(R,Q\right)+S_m\left(g,\Psi_m\right)$$

$$Q=R_{\mu\nu}R^{\mu\nu}$$

Quadratic Theories

$$S\left(g,\Gamma,\Psi_m\right)=\frac{1}{16\pi G}\int d^4x\sqrt{-g}f\left(R,Q\right)+S_m\left(g,\Psi_m\right)$$

$$Q=R_{\mu\nu}R^{\mu\nu}$$

$$f\left(R,Q\right)=R+l_P^2\left(aR^2+bQ\right)$$

Quadratic Theories

$$f_R \equiv \frac{\partial f}{\partial R},\ f_Q \equiv \frac{\partial f}{\partial Q}$$

$$f_R R_{\mu\nu} - \frac{f}{2} g_{\mu\nu} + 2 f_Q R_{\mu\alpha} R^{\alpha}_{\nu} = 8\pi G T_{\mu\nu}$$

$$P^{\nu}_{\mu} \equiv R_{\mu\alpha} g^{\alpha\nu}$$

Quadratic Theories

$$f_R R_{\mu\nu} - \frac{f}{2} g_{\mu\nu} + 2 f_Q R_{\mu\alpha} R^{\alpha}_{\nu} = 8\pi G T_{\mu\nu}$$

$$P^{\nu}_{\mu} \equiv R_{\mu\alpha} g^{\alpha\nu}$$

$$f_R P^{\nu}_{\mu} - \frac{f}{2} \delta^{\nu}_{\mu} + 2 f_Q P^{\alpha}_{\mu} P^{\nu}_{\alpha} = 8\pi G T^{\nu}_{\mu}$$

$$2 f_Q \hat{P}^2 + f_R \hat{P} - \frac{f}{2} \hat{I} = 8\pi G \hat{T}$$

Quadratic Theories

$$2f_Q\hat{P}^2 + f_R\hat{P} - \frac{f}{2}\hat{I} = 8\pi G\,\hat{T}$$

$$2f_Q\left(\hat{P} + \frac{f_R}{2f_Q}\hat{I}\right)^2 - \frac{f_R^2}{2f_Q}\hat{I} - \frac{f}{2}\hat{I} = 8\pi G\,\hat{T}$$

Vacuum $T_{\mu\nu} = 0$

$$\left(\hat{P} + \frac{f_R}{2f_Q}\hat{I}\right)^2 = \left(\frac{f_R^2}{4f_Q^2} + \frac{f}{4f_Q}\right)\hat{I}$$

$$\hat{P} - \frac{1}{2}R\hat{I} = \left(\sqrt{\frac{f_R^2}{4f_Q^2} + \frac{f}{4f_Q}} - \frac{f_R + 2Rf_Q}{2f_Q}\right)\hat{I}$$

Quadratic Theories

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = - \left(\frac{f_R + 2 R f_Q}{2 f_Q} - \sqrt{\frac{f_R^2}{4 f_Q^2} + \frac{f}{4 f_Q}} \right) g_{\mu\nu}$$

$$\Lambda_{eff} = \frac{f_R + 2 R f_Q}{2 f_Q} - \sqrt{\frac{f_R^2}{4 f_Q^2} + \frac{f}{4 f_Q}}$$

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = - \Lambda_{eff} g_{\mu\nu}$$

Palatini approach

Quadratic Theories

$$f_R R_{\mu\nu} - \frac{f}{2} g_{\mu\nu} + 2 f_Q R_{\mu\alpha} R^{\alpha}_{\nu} = 8\pi G T_{\mu\nu}$$

$$\nabla_\beta \left[\sqrt{-g} \left(f_R g^{\mu\nu} + 2 f_Q T^{\mu\nu} \right) \right] = 0$$

In GR $f = R$, $f_R = 1$ and $f_Q = 0$ so that $\nabla_\beta \left[\sqrt{-g} g^{\mu\nu} \right] = 0$

$$\Gamma^{\rho}_{\mu\nu} = \frac{1}{2} g^{\rho\sigma} \left(\partial_\mu g_{\sigma\nu} + \partial_\nu g_{\sigma\mu} - \partial_\sigma g_{\mu\nu} \right)$$

Reissner-Nordstrom black holes

Palatini approach

$$\nabla_\beta \left[\sqrt{-g}\left(f_R g^{\mu\nu} + 2 f_Q T^{\mu\nu}\right)\right] = 0 \Rightarrow \nabla_\beta \left[\sqrt{-h} h^{\mu\nu}\right] = 0$$

$$\Gamma^\rho_{\mu\nu} = \frac{1}{2} h^{\rho\sigma}\left(\partial_\mu h_{\sigma\nu} + \partial_\nu h_{\sigma\mu} - \partial_\sigma h_{\mu\nu}\right)$$

$$\sqrt{-h}\hat{h}^{-1} = \sqrt{-g}\hat{g}^{-1}\hat{\Sigma}$$

$$\hat{\Sigma} = f_R \hat{I} + 2 f_Q \hat{P}$$

$$\hat{h} = \sqrt{det\hat{\Sigma}}\hat{\Sigma}^{-1}\hat{g}$$

Kerr-Newman black holes

Tool Tetrad Formalism

$$\nabla_\mu F^{\mu\nu} = 0$$

$$e^\mu_a e^a_\nu = \delta^\mu_\nu, \; e^\mu_a e^b_\mu = \delta^b_a$$

$$g_{ab} = e^\mu_a e_{b\mu} = g^{ab}$$

$$\Gamma^a_{bc} = -e^\mu_b e^\nu_c \nabla_\nu e^a_\mu$$

$$g_{ab} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

Debney, Kerr and Schild (1969)

Research Interests

- Cosmology
- Theoretical Particle Physics
- Phenomenology
- Gravitation

Thanks for your attention

Questions are welcome!