# Constraining logarithmic f(R,T) model using Dark Energy density parameter

Biswajit Deb
Department of Physics
Assam University, India

**In collaboration with Prof. Atri Deshamukhya**

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## Outline of the Presentation:

- Introduction
- Objective of the work
- Motivation
- Methodology / Calculation
- Result
- Discussion & Conclusion

# 1. Introduction

- Universe starts expanding with an accelerated rate at $z = 1$.*
- Universe contains exotic form of energy (70%) which may cause Late time expansion.*

$$\Omega_m + \Omega_\Lambda = 1$$

$\Omega_\Lambda \rightarrow$ **0.7**

Possible Explanations

$$R_{\alpha\beta} - \frac{1}{2} R\, g_{\alpha\beta} = -8\pi G\, T_{\alpha\beta}$$

$G_{\alpha\beta}$ → Modifying Gravity → f(R), f(G), f(*T*), f(R,T), f(R,G) etc.

Add Cosmological Constant $\Lambda$

$\omega = -1$

$T_{\alpha\beta}$ → Changing EM tensor having component of some exotic fluid with EOS

$$\omega < -\frac{1}{3}$$

→ DARK ENERGY

→ **SCALAR FIELD MODELS**

* Riess, A. G.(1998) The Astronomical Journal, 116(3), 1009

## 2. Objectives

- To constrain following well motivated *f(R,T)* gravity models using DE density parameter.
  - $f(R,T) = R + 16\pi G\,\alpha \ln T$
  - $f(R,T) = R + 16\pi G\,\beta\,T^2$
  - $f(R,T) = R + 16\pi G\,\gamma\,RT$
- To compare different model results.

# 3. Motivation

- ❑ Snehasish et. al. developed a novel way to impose lower bound on model parameter of the simplest *f(R,T)=R+2□T* model through the equation relating to the cosmological constant and critical density of the universe.* It would be interesting to apply this method for other complex forms of f(R,T).

- ❑ First Logarithmic correction to trace term T in f(R,T) theory has been studied by Elizalde et. al.* We have taken simplest f(R,T) model with logarithmic correction to trace T term as

$$f(R,T) = R + 16\pi G\, \alpha \ln T$$

- ✓ Satisfies stability conditions.
- ✓ Satisfies attractive gravity condition.
- ✓ Posses correct cosmological dynamics ? (Needs to be checked)

- ❑ Rest two f(R,T) models under study are well motivated & studied in literature.*


* Gravitation and Cosmology, 26(3), 281-284
* Physics of the Dark Universe, 30, 100618.
* Physics of the Dark Universe, 31, 100768; Astronomische Nachrichten, 342(1-2), 89-95.

# 4. Methodology/Calculation

- Action considered as $S = \int \left[\frac{R}{16\pi G} + \alpha \ln T + L_m\right] \sqrt{-g}\, d^4x$

- This leads to field equations

$$R_{\alpha\beta} - \frac{1}{2} R g_{\alpha\beta} = 8\pi G\, T^{eff}_{\alpha\beta} \quad \text{where} \quad T^{eff}_{\alpha\beta} = T_{\alpha\beta} - \frac{2\alpha}{T}\left(T_{\alpha\beta} - \frac{T}{2} g_{\alpha\beta} \ln T + \Theta_{\alpha\beta}\right)$$

- Assuming the Universe is dominated by perfect fluid, the Stress-Energy tensor and Lagrangian density is

$$T_{\alpha\beta} = (\rho + P) u_\alpha u_\beta - P g_{\alpha\beta}\,,\ L_m = -P \text{ and } T = \rho - 3p$$

- Considering FLRW metric we derived Friedmann Equation as:

$$3H^2 = 8\pi G \left[\rho + \frac{2\alpha}{(\rho - 3P)}\left\{\rho + P + \frac{(\rho - 3P)}{2} \ln\ (\rho - 3P)\right\}\right]$$

- In terms of Equation of state parameter $\omega = P/\rho$

$$3H^2 = 8\pi G \left[\rho + \frac{2\alpha}{(1 - 3\omega)\rho}\left\{(1 + \omega)\rho + \frac{(1 - 3\omega)\rho}{2} \ln\ (1 - 3\omega)\rho\right\}\right]$$

Contd...

- Assuming the Universe is dominated by Dark Energy, substituting $\omega = -1$ in the previous equation yields:

$$3H^2 = 8\pi G(\rho + \alpha \ln 4\rho) \qquad (1)$$

- Friedmann Equation in standard GR with cosmological constant $\Lambda$ is

$$3H^2 = 8\pi G\rho + \Lambda c^2 \qquad (2)$$

- Equating Eq. (1) and Eq. (2) yields:

$$\Lambda = \frac{8\pi G}{c^2}\alpha \ln 4\rho \qquad (3)$$

- Now, the Cosmological Constant is defined as

$$\Lambda = 3\left(\frac{H_0}{c}\right)^2 \Omega_\Lambda \qquad (4)$$

$H_0$ is the current vaule of the Hubble parameter

$\Omega_\Lambda$ is the dark energy density parameter

- Equating Eq. (3) and Eq. (4) yields:

$$\Omega_\Lambda = \frac{8\pi G}{3H_0^2}\alpha \ln 4\rho \qquad (5)$$

Contd...

- At present epoch, density parameter is $\Omega_0 = \frac{\rho}{\rho_{cr}} = 1$

  and the critical density is defined as $\rho_{cr} = \frac{3H_0^2}{8\pi G}$

- Now, replacing ⍰ by critical density in Eq. (5) yields:

$$\Omega_\Lambda = \frac{8\pi G}{3H_0^2}\,\alpha \ln \frac{3H_0^2}{2\pi G} \qquad (6)$$

- From Planck 2018 data* we have

$$\Omega_\Lambda = 0.6889 \pm 0.0056$$

$$H_0 = 67.4 \pm 0.5\ \mathrm{Kms^{-1}MPc^{-1}}$$

- Substituting these values in Eq. (6) we report the lower bound on the model parameter ⍰ as

$$\alpha \geq -9.93 \times 10^{-29}$$

*** *Astronomy & Astrophysics* 641 (2020): A6**

# 4. Results

| Sl. No | $f(R,T)$ Model | Input Parameters needed to constrain | Lower Bound found on the model parameter |
|---|---|---|---|
| 1 | $f(R,T) = R + 16\pi G\,\alpha \ln T$ | Hubble Constant<br>Dark Energy density parameter | $\alpha \geq -9.93 \times 10^{-29}$ |
| 2 | $f(R,T) = R + 16\pi G\,\beta\, T^2$ | Hubble Constant<br>Dark Energy density parameter | $\beta \geq 2.08 \times 10^{24}$ |
| 3 | $f(R,T) = R + 16\pi G\,\gamma\, RT$ | Hubble Constant<br>Dark Energy density parameter<br>Deceleration parameter | $\gamma \geq -9.09 \times 10^{15}$ |

# 5. Discussion & Conclusion

- In this work we tried to constrain model parameters of different f(R,T) gravity models using DE density parameter. We found that for f(R,T) model with logarithmic correction, the lower bound on model parameter is very small. For other two f(R,T) models, the lower bound is quite high.

- We found that for more complex forms of f(R,T), more input parameters are required in this methodology to found the lower bound on the model parameter.

- This method of imposing lower bound on the model parameter using DE density parameter as developed by Snehasish et. al. (Gravitation and Cosmology, 26(3), 281-284) is exclusively model dependent. This method can be applied to other modified gravity models but it requires various constraining parameters besides DE density parameter.

- The lower bound obtained via this method needs to be validated from other sources.

# *Thank You for listening…*