Cosmology of Veneziano Ghost Inspired Dark Energy in Modified Gravity Framework

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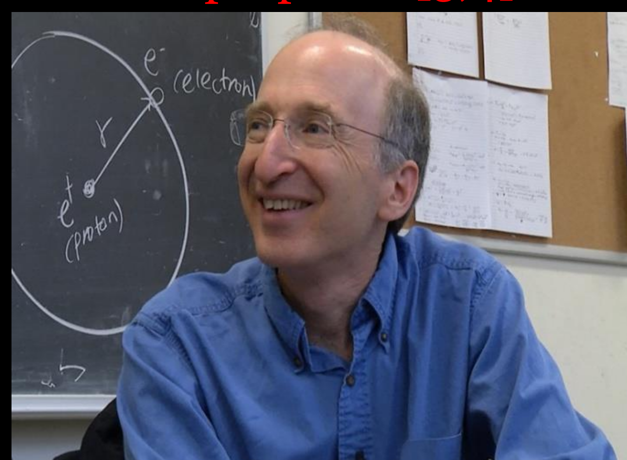
Analyzing nearby and distant Supernovae Type Ia data, Riess et al. [1] and Perlmutter et al. [2] discovered the universe's late-time accelerated expansion.(Noble Prize in Physics, 2011) Once abandoned by Einstein, the cosmological constant Λ has seen a resurgence of interest after this groundbreaking discovery of modern cosmology. Alongside Λ, the simplest dark energy (DE) candidate to explain this late-time acceleration, other DE models with the time-varying equation of state (EoS) parameter have been proposed by various authors. In the present study, we have presented a reconstruction scheme for f(T) gravity, an essential candidate for modified gravity theories. A DE model, so-called Veneziano ghost DE (GDE), has been proposed [3,4].

Adam G Riess



Saul Perlmutter

"All in all, the two research teams found over 50 distant supernovae whose light was weaker than expected – this was a sign that the expansion of the Universe was accelerating."

Press release of The Nobel Prize in Physics 2011

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•A DE model, so-called Veneziano ghost DE (GDE), has been proposed in [5]. The key ingredient of this new model is that the Veneziano ghost, which is unphysical in the usual Minkowski spacetime quantum field theory (QFT), exhibits important physical effects in dynamical spacetime or spacetime with non-trivial topology.

•Veneziano ghost is supposed to exist for solving the U(1) problem in the low-energy effective theory of QCD.

•Although in the flat Minkowski spacetime the QCD ghosts are unphysical and make no contribution, in curved/time-dependent backgrounds, the cancellation of their contribution to the vacuum energy leave a small energy density $\rho \sim \Lambda^3_{QCD}$.

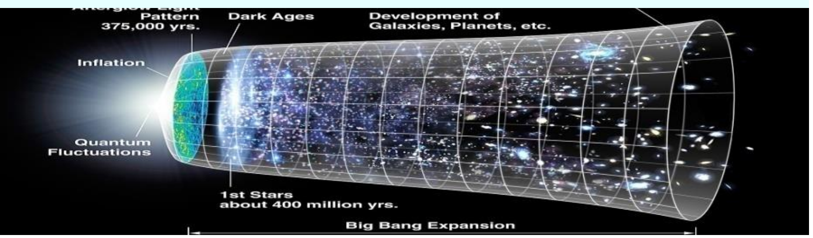
[5] F.R. Urban, A.R. Zhitnitsky, Phys. Lett. B 688, 9 (2010).

Density of GDE

$$\rho_{gde} = \frac{\alpha(1-\epsilon)}{\tilde{r}_h} = \alpha(1-\epsilon)\sqrt{H^2 + \frac{k}{a^2}}\,, \qquad \epsilon \equiv \frac{\dot{\tilde{r}}_h}{2H\tilde{r}_h}$$

Modified teleparallel action for f(T)

$$I = \frac{1}{16\pi G}\int d^4x\sqrt{-g}\,[f(T) + L_m]$$



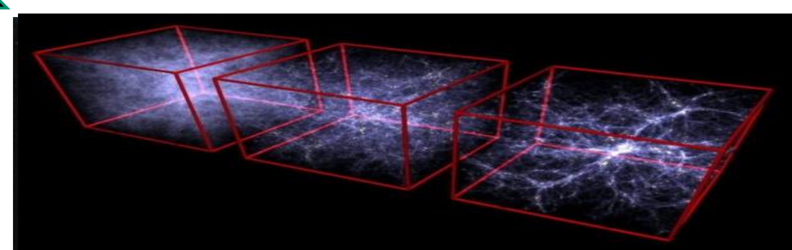
$$\rho_T = \frac{1}{2}(2Tf_T - f - T), \quad \boxed{T = -6H^2} \quad \boxed{a = a_0 t^n} \quad H = \frac{n}{t}$$

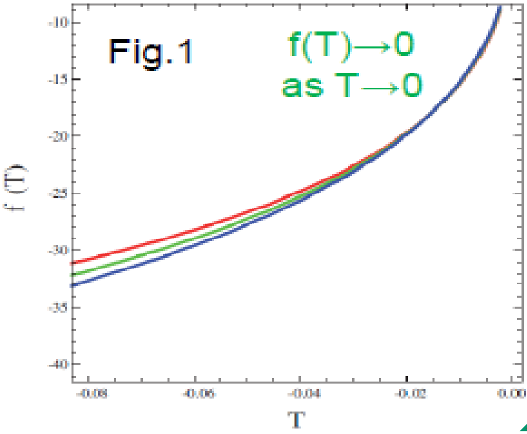
$$p_T = -\frac{1}{2}\left[-8\dot{H}Tf_{TT} + (2T - 4\dot{H})f_T - f + 4\dot{H} - T\right]$$

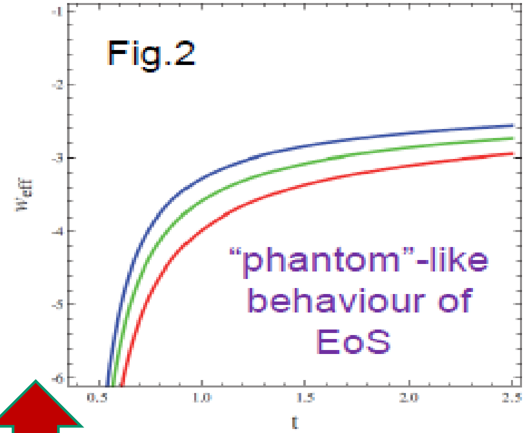
Density contribution due to f(T) gravity

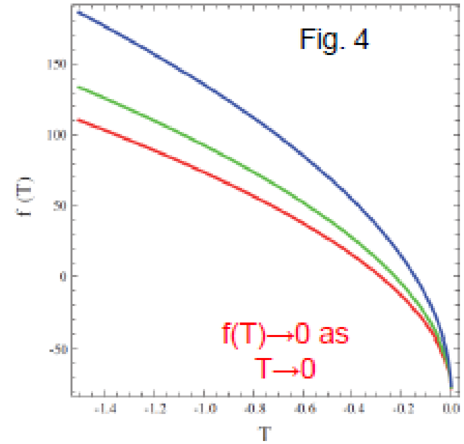
$$\rho_T = \frac{1}{2}\left[t\dot{f} + \frac{6n^2}{t^2} - f\right],$$

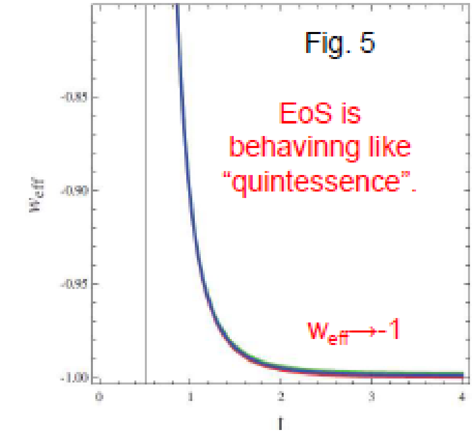
$$p_T = \frac{1}{6nt^2}\left[-18n^3 - t^3\dot{f} + 12n^2(1 + 3\dot{f} + t\ddot{f}) + 3nt^2(f + t\dot{f})\right].$$

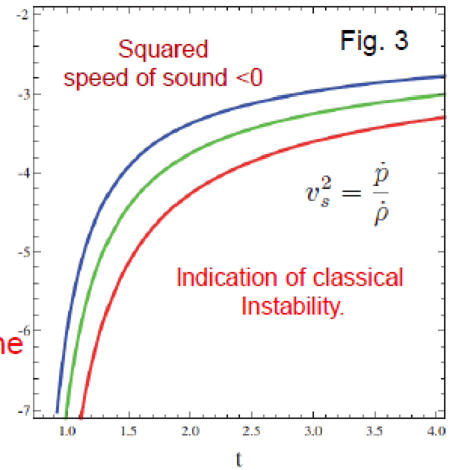




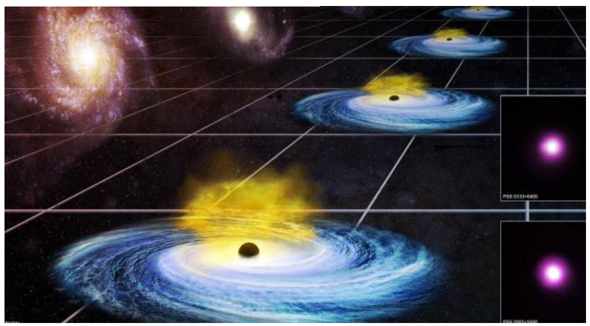


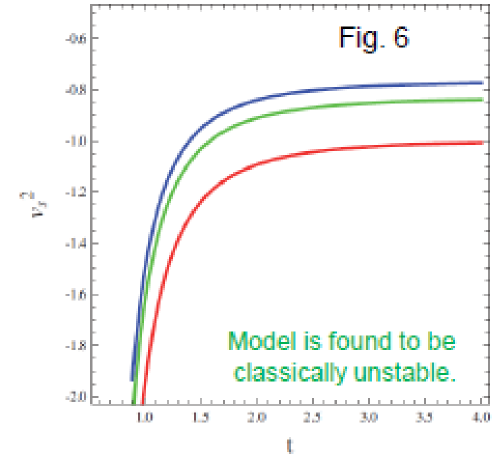






Case I Case II





- In the plots corresponding to Case I we have taken $C_1 = -18$, $n = 1/20$. In all of the plots, red, green and blue lines corresponds to $\alpha = 5.6$, 5 and 4.5, respectively. In fig.1 we have plotted the reconstructed f(T) against torsion T. It is apparent from the figure that $f(T) \rightarrow 0$ as $T \rightarrow 0$.
- Satisfaction of the above condition is a sufficient condition for a realistic model.
- In fig. 2, we plot the effective equation-of-state parameter weff. It is always observed that ($w_{eff} < -1$).
- This indicates "phantom"-like behavior.

- In all the figures under Case II, we have taken $n = 1/20$, $C_1 = -2$ and $C_2 = 2$. Red, green and blue lines corresponds to $\alpha = 3.3$, 3.5 and 3.8, respectively.
- $f(T) \rightarrow 0$ as $T \rightarrow 0$, although the pattern is different from Case I.
- $v_s^2 < 0$, thus it is indicating a classical instability of the model.
- $w_{eff} > -1$ i.e. the EoS is behaving like "quintessence".
- However, with evolution of the universe, w_{eff} is tending to the phantom boundary.

Conclusions

❖In the present work we have studied a reconstruction scheme for f(T) gravity based on QCD ghost dark energy. In the modified field equations we have considered ρ as the ρ_{gde} in a flat universe with power law form of the scale factor. Because of the choice of the scale factor, the ρ_{gde} could be expressed as a function of t. Subsequently, considering the two field equations, we have reconstructed f(T) in two forms described as Case I and Case II, respectively.

❖In both cases $f(T) \to 0$ as $T \to 0$, which indicates a realistic model in both cases. Since both of the forms appear as functions of t, we could get their time derivatives and could successfully reconstruct the density ρ_T and pressure p_T contributions due to torsion T.
Using these reconstructed ρ_T and p_T we could generate effective equation-of-state parameter weff in both cases and we observed that in Case I, $w_{eff} \ll -1$ and, in Case II, $w_{eff} \geq -1$. Thus Case I and Case II generates "phantom"- and "quintessence"-like weff , respectively.

❖One prominent difference was that for Case I we are staying far below the phantom boundary and in Case II it is getting asymptotic at the phantom boundary coming from $w_{eff} > -1$.

❖Based on this difference of the behaviours of w_{eff} it may be interpreted that Case II, represents a more acceptable model at is can show an approach towards the phantom phase of the universe starting from quintessence.

❖Due to non-positivity of the squared sound speed v2s as seen in the plots, both QCD ghost f(T) models are classically unstable against perturbations in flat and non-flat Friedmann-Robertson-Walker backgrounds. This instability problem is consistent with the result presented for QCD ghost dark energy model by Garcia-Salcedo et al. (2013).

Bibliography

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