The 20th workshop on General Relativity and Gravitation

Yukawa Institute for Theoretical Physics, Kyoto University

Scalar-tensor cosmologies with a potential in the general relativity limit

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Phys. Rev. D78: 083530 (2008) [arXiv:0807.2159]

Phys. Rev. D81: 104007 (2010) [arXiv:1003.1686]

arXiv:1006.1246, accepted Phys. Lett. B

Scalar-tensor theory of gravity in Jordan frame

$$I_{STT} = \frac{1}{2\kappa^2}\int d^4x\sqrt{-h}\left[\Psi R(h) - \frac{\omega(\Psi)}{\Psi}\Psi^{|\alpha}\Psi_{|\alpha} - 2\kappa^2\, V(\Psi)\right] \qquad (1)$$

$$+\int d^4x\sqrt{-h}\mathcal{L}_{matter}$$

- Scalar field is non-minimally coupled to gravity in Jordan frame (scalar and tensor degrees of freedom are mixed)

- Coupling function $\omega(\Psi)$ and potential $V(\Psi)$ characterizing different STT theories, assume positive energy density $2\omega(\Psi)+3>0$, $V(\Psi)>0$.

- Gravitational "constant"is (space)time dependent: $G \sim \Psi^{-1}$, assume $0<\Psi<\infty$

- General relativity limit from weak field approximation (PPN): $\omega \to \infty$ and $\omega^{-3}\,\omega' \to 0$

General goal: explaining dark energy, testing gravity at large scales.

Notice:

- Many proposed modified gravity theories can be cast in the form of scalar-tensor gravity (STG) - higher dimensions, branes, $f(R)$, VSL

- “Attractor mechanism” - wide classes of STG cosmologies dynamically converge to fixed points (Damour, Nordtvedt 1993)

Present work:

- Determine the conditions for attractive fixed points in STG cosmology

- Find the general analytic form of solutions around these fixed points

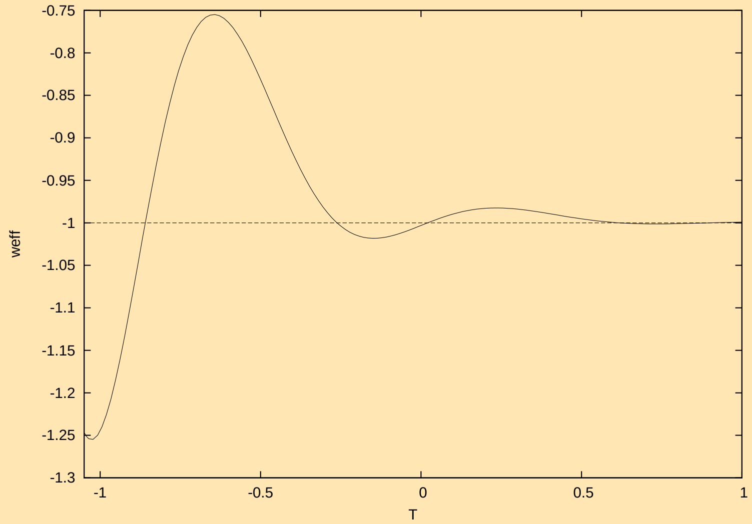
Summary of work done

- We have found and characterized the fixed points of STG cosmology in the case when potential dominates over cosmological matter density (JKS 2008, JKS 2010a).

- In particular, we have also found the general analytic form of solutions around the 'GR' fixed point (JKS 2010b).

- This can be applied to cosmological expansion: can tell whether the solutions of any particular theory have oscillating, phantom crossing etc behavior near GR (JKS 2010b).

Example of oscillating dark energy (JKS 2010))



- Take $\omega(\Psi) = \frac{\Psi}{2(1-\Psi)}$, $\kappa^2 V(\Psi) = V_0 e^{3(1-\Psi)}$, the “GR point” is at $\Psi_\star = 1$.

- Initial conditions satisfy solar System bounds.

- Oscillations of $\mathrm{w_{eff}} = -1$ measured in the units of the analogue of Hubble time, $T = H_\star t = \frac{C_1}{3} t$.