

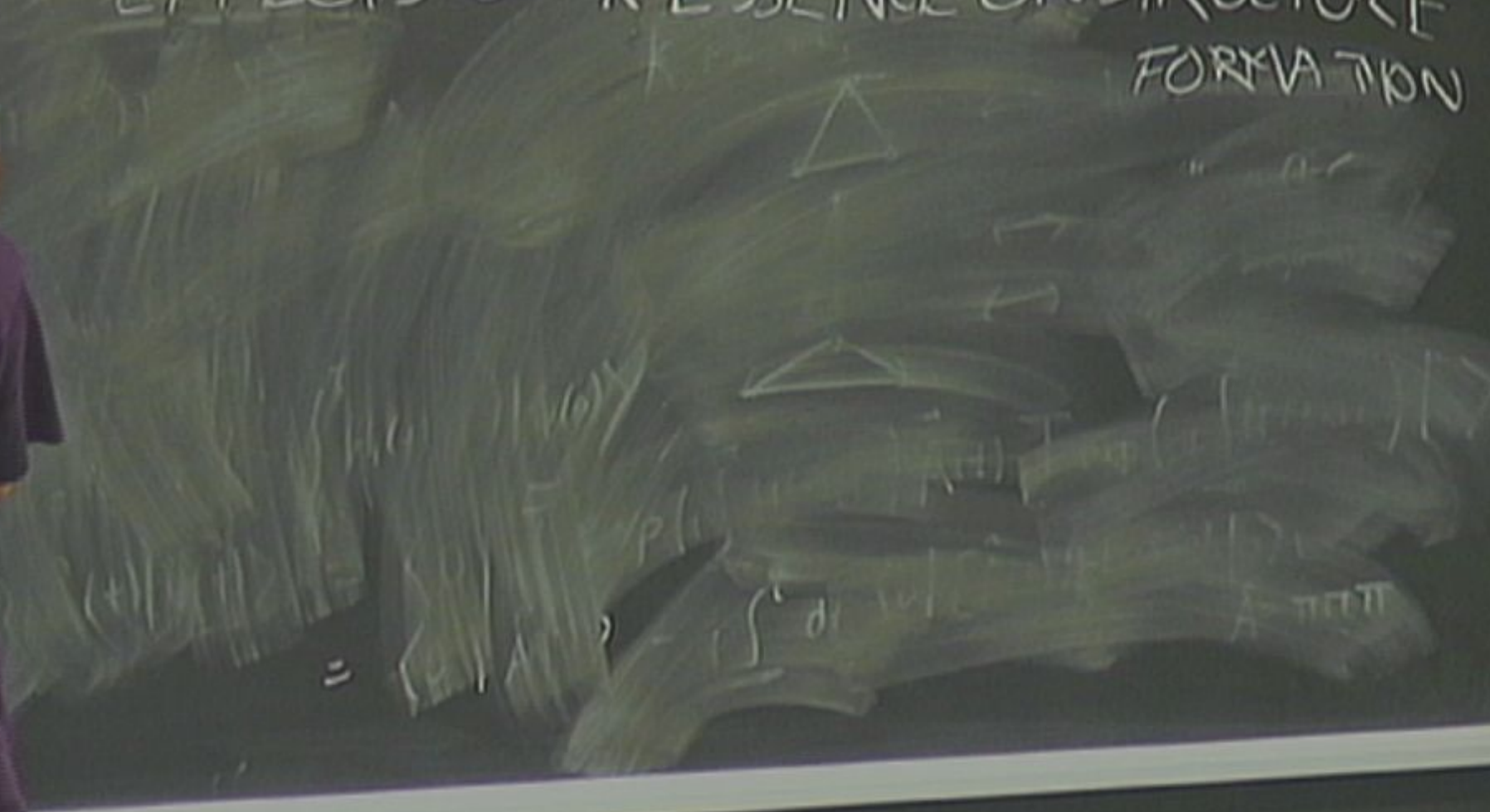
Title: Undergrad Research Project Talk

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Abstract:

EFFECTS OF K-ESSENCE ON STRUCTURE FORMATION



$$5 \quad \lambda \ll d_H$$

$$ds^2 = (1 - \frac{2GM}{r}) dt^2 - \frac{dr^2}{1 - \frac{2GM}{r}} - r^2 d\Omega^2$$

$$a^2 \left(\frac{dr}{dt} \right)^2$$

$$\lambda \ll d_H$$



$$ds^2 = (1 + 2\psi) dt^2 - a^2 (1 - 2\psi) (dr^2 + r^2 d\Omega^2)$$

max $\psi \ll \pi \pi$

distance

$$\psi \ll 1H$$

Π [unclear]

$arXiv$

$$ds^2 = \left(1 - \frac{\dot{a}^2 r^2}{a^2} + 2\psi\right) dt^2 - \left(1 + \frac{\dot{a}^2 r^2}{a^2} - 2\psi\right) dr^2 + \dots$$

d^2

distance

$$\psi \ll 1$$

II

arXiv

$$ds^2 = \left(1 - \frac{\dot{a}^2 r^2}{a^2} + 2\psi\right) dt^2 - \left(1 + \frac{\dot{a}^2 r^2}{a^2} - 2\psi\right) dr^2 + \dots$$

$$\phi = \frac{1}{2} \frac{\dot{a}^2 r^2}{a^2} + \psi$$

$$\frac{d^2 r}{dt^2} = -\nabla \phi = -\frac{2\pi G}{3} (\rho + p) + \psi$$

$$P = \frac{1}{3} \rho c^2$$

$$= -\frac{GM}{r^2} - \frac{GM}{r^2} = -\frac{GM}{r^2}$$

$$\lambda \ll d_H$$

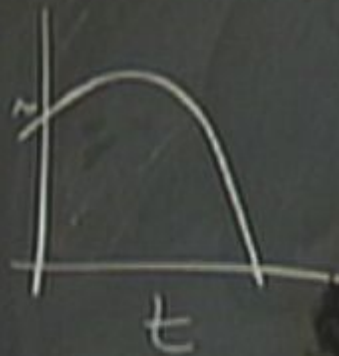


$$ds^2 = (1 + 2\psi) dt^2 - a^2 (1 - 2\psi) (dr^2 + r^2 d\Omega^2)$$

$$R = a(t) r$$

$$T_{in} \approx t + \frac{1}{2} a \dot{a} r^2$$

$$r = A(1 - \cos \theta) \quad t = T_0 + B(\theta - \sin \theta) \quad A^2 = GMB^2$$



$$S = \frac{SP}{P} \quad S \ll 1$$

$\lambda_i \sim H \lambda_i$ at $t = t_i$

$$\frac{1}{2} \lambda_i^2 = \frac{1}{2} H_i \lambda_i^2$$

$$\frac{\lambda_i}{\lambda_i} =$$

$$\left(\frac{1}{2} \partial^2 \varphi \partial \sigma \varphi + \dots \right)$$

$$E = -k_i \delta_i$$

INFLATION

$$\text{FRW } ds^2 = -dt^2 + a^2(t) \left[\frac{dr^2}{1-kr^2} + d\Omega^2 \right]$$

$$\text{FRIEDMANN } \left(\frac{\dot{a}}{a} \right)^2 = \frac{8\pi G \rho}{3} - \frac{k}{a^2} \quad \frac{\ddot{a}}{a} = -\frac{4\pi G}{3} (\rho + 3p)$$

$$H^{-1} = \text{Hubble radius} \quad a = e^{Ht} \quad H = \text{constant} \quad \nabla_\mu T_{\nu}^{\mu} = 0$$

$$\frac{p}{\rho} < -\frac{1}{3}$$

$$S_M = \int d^4x \sqrt{|g|} \left(\frac{1}{2} g^{\mu\nu} \partial_\mu \varphi \partial_\nu \varphi - V(\varphi) \right)$$

$$T_{\mu\nu} = \partial_\mu \varphi \partial_\nu \varphi - g_{\mu\nu} \left(\frac{1}{2} \partial^\sigma \varphi \partial_\sigma \varphi + V(\varphi) \right)$$

$$\rho = \frac{\dot{\varphi}^2}{2} + V(\varphi) \quad p = \frac{\dot{\varphi}^2}{2} - V(\varphi)$$

t



$$\dot{\lambda}_i \approx H_i \lambda_i \text{ at } t = t_i$$

$$K_i = \frac{1}{2} \dot{\lambda}_i^2 = \frac{1}{2} M_i v_i^2$$

$$U_i = \frac{GM}{r_i} = K_i(1 + \delta_i)$$

$$E = -K_i \delta_i$$

INFLATION

λ_m $t = \text{Lagrange}$

$$\dot{\lambda} = 0$$

$$\Rightarrow \begin{pmatrix} \lambda_m = 1 + \frac{\delta \lambda_i}{\delta} \\ \delta \end{pmatrix}$$

λ_i at t

$$A = \frac{\lambda_i}{2} \frac{1 + \delta_i}{\delta_i} \quad B = \frac{1 + \delta_i}{2 \delta_i \omega}$$

$$\Rightarrow X(F'(X))^2 = ka^2$$

$$X \rightarrow X_0$$

$$p = 3X^2 F$$

$$\Rightarrow X(F'(X))^2 = ka^{-6}$$

$$ds^2 = (1 + 2\psi) dt^2$$

$$\Rightarrow X(F'(X))^2 = ka^{-6}$$

$$ds^2 = (1+2\psi)dt^2 - (1-2\psi)a^2(dr^2 + r^2 d\Omega^2)$$

$$X = \frac{1}{2} \frac{(1-2\psi)^2}{r^2} - \frac{1}{2} (1+2\psi) \frac{a^4}{r^2} \quad X = \frac{1}{2} g^{\mu\nu} \partial_\mu \psi \partial_\nu \psi$$

$r \rightarrow a(t)r$

$$\ddot{\psi}(1-4\psi) + \dot{\psi} \left(3H(1-4\psi) - 4\dot{\psi} + \frac{1}{F} \frac{\partial F'}{\partial t} (1-4\psi) \right) - \Phi'' - \left(\frac{2}{r^2} + \frac{1}{F} \frac{\partial F'}{\partial r} \right) \Phi' = 0$$

$$\nabla^2 \psi = 4\pi G (\rho_m + \rho_p)$$

$$\frac{GM}{r^2} - \frac{GM}{r^2} = -\frac{GM}{r^2}$$

EFFECTS OF K-ESSENCE ON STRUCTURE FORMATION

$\phi \ll \psi \quad \rho_\phi = 3\rho_\psi$

$$\ddot{\phi}(1+4\psi) + \phi \left((1-4\psi) - 4\psi - \frac{x}{x-x_0} \phi(1-4\psi) \right) = 0$$

$\phi \gg x_0$

$$\frac{(1+2\psi)}{c^2} \frac{(4\psi)}{(1+2\psi)(1+2\psi)}$$

$$\frac{G M}{r^2} - \frac{G S M_i}{r^2} = - \frac{G M}{r^2}$$

EFFECTS OF K-ESSENCE ON STRUCTURE FORMATION

$$\phi' \ll \phi \quad P_\phi = 3\pi x^2 = 0$$

$$\ddot{\phi}(1+4\psi) + \phi(3H(1-4\psi) - 4\psi - \frac{x}{x-x_0} \phi(1-4\psi)) = 0$$

$$\phi(1-4\psi)(x-x_0) = c(t)$$

$$x = \frac{1-2\psi\phi}{2} \quad x \gg x_0$$

$$\dot{\phi} = \frac{c(t)(1+2\psi)}{2}$$

$$\frac{c(t)}{2}$$

$$-\frac{GM}{r^2} - \frac{GM}{r^2} = -\frac{GM}{r^2}$$

EFFECTS OF K-ESSENCE ON STRUCTURE FORMATION

$$\phi' \ll \phi \quad P_\phi = 3\pi x^2 = \left[\frac{c_2(x)(1+4\psi)}{a^4} \right]$$

$$\ddot{\phi}(1+4\psi) + \phi(3\pi(1-4\psi) - 4\psi - \frac{x}{x-x_0} \phi(1-4\psi)) = 0$$

$$a^3 \phi(1-4\psi)(x-x_0) = c(t)$$

$$X = \frac{1-2\psi}{2} \phi^2 \quad X \gg X_0$$

$$\dot{\phi} = \frac{c(t)}{(1+2\psi)}$$

$$X = \frac{(1+2\psi)(c(t))^2}{a^2}$$

ψ_1

$$= \left[\frac{c(t)}{a} \right]^2$$

$$\frac{GM}{r^2} - \frac{GM}{r^2} = -\frac{GM}{r^2}$$

EFFECTS OF K-ESSENCE ON STRUCTURE FORMATION

$$\phi' \ll \phi \quad P_\phi = 3\pi x^2 = \left[\frac{G_2(\lambda)(1+4\psi)}{a^4} \right]$$

$$\phi(1+4\psi) + \phi(3H(1-4\psi) - 4\psi - \frac{x}{x-x_0} \phi(1-4\psi)) = 0$$

$$e^{\phi(1-4\psi)(x-x_0)} = c(t)$$

$$X \approx \frac{1-2\psi}{2} \phi' \quad X \gg X_0$$

$$X = \frac{1}{2} g_{11} \delta^{11} \phi$$

$$\dot{\phi} = \frac{(1+2\psi)}{(1+2\psi)}$$

$$X = \frac{(1+2\psi)(1+2\psi)}{(1+2\psi)(1+2\psi)}$$

$$\nabla^2 \psi = 4\pi G (\delta \rho_p + \delta \rho_m)$$

$$\rho_p = \rho_p(t) + \delta \rho_p \left(\frac{a_1}{a} \right)^3 \Theta(r_0 - r) \left(1 + 4\epsilon (\psi - \psi(r_0)) \right) + 4 \frac{\rho_p}{a^3} (\psi(r, t) - \psi(r, t_1))$$

$$\nabla \psi = 4\pi G (\delta \rho + \delta m)$$

$$P\phi = P_0(t) + \delta P_0 \left(\frac{a_i}{a}\right)^4 \theta(r_0 - r) (1 + 4(\psi - \psi(r_0))) + 4 \frac{P_0}{a^2} (\psi(r, t) - \psi(r_0, t))$$

$r < r_0$

$$\psi(r, t) = -\frac{4\pi G \rho_0 r^2}{2} - \frac{G}{r_0} \int_0^r 4\pi r_1^2 [\rho_0 + \delta \rho_0] dr_1$$

$r < r_0$

$$\psi(r, t) = -\frac{\delta P_0 r^2}{6} - \frac{\delta P_0 \sigma^2 \left(\frac{r_0}{r}\right)^4}{6}$$

$r > r_0$

$$\psi(r, t) = -\frac{\delta P_0 r^2}{6} - \frac{\delta P_0 \sigma^2 \left(\frac{r_0}{r}\right)^4}{6}$$

$$d_M \dot{\phi} \partial_\nu \phi - g_{\mu\nu} \left(\frac{1}{2} \partial^\sigma \phi \partial_\sigma \phi + V(\phi) \right)$$

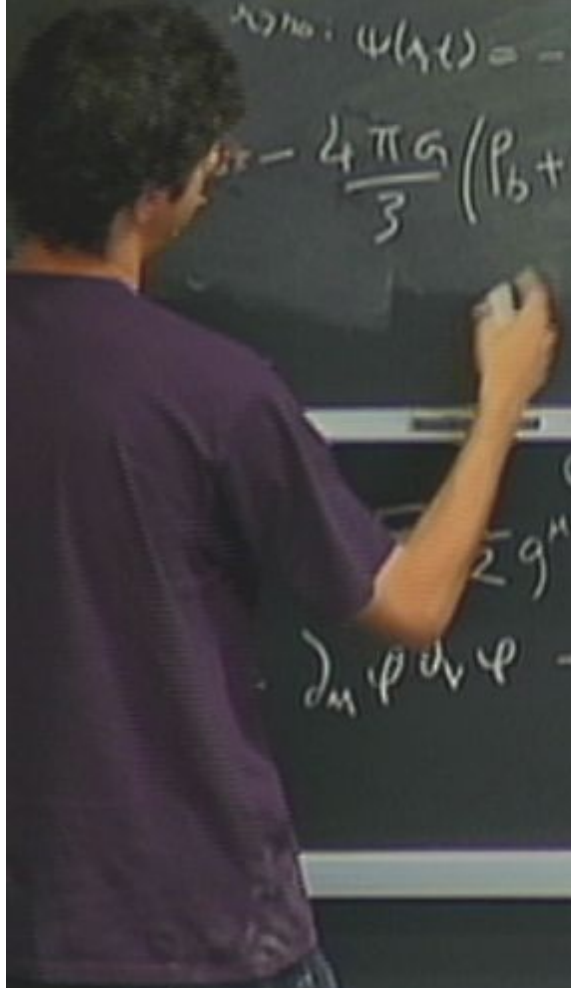
$$\varphi = \frac{1}{4\pi\epsilon_0} \frac{q}{r} + \frac{1}{4\pi\epsilon_0} \frac{q}{r} + \dots + 4 \frac{q}{a^2} (\varphi(r, t) - \varphi(r_0, t))$$

$$\varphi(r, t) = -\frac{4\pi\epsilon_0 q}{3} p_b r^2 - \frac{q}{\lambda} \int_0^{\lambda} 4\pi r^2 \left[\epsilon \checkmark \right] dr$$

$$\varphi(r_1, t) = -\frac{\delta p_b r^2}{6} - \frac{\delta p_b \cdot \sigma \left(\frac{r_1}{a} \right)^4}{6}$$

$$\varphi(r_2, t) = -\frac{\delta p_b r^2}{6} - \frac{\delta p_b \cdot \sigma \left(\frac{r_2}{a} \right)^4}{6}$$

$$- \frac{4\pi\epsilon_0 q}{3} (p_b + 3p_b)$$



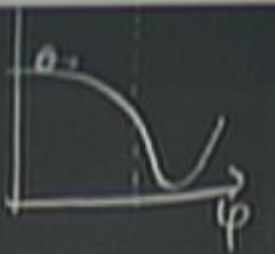
$$P = -P$$

$$\frac{1}{2} g^{\mu\nu} \partial_\mu \varphi \partial_\nu \varphi - V(\varphi)$$

$$\partial_\mu \varphi \partial_\nu \varphi - g_{\mu\nu} \left(\frac{1}{2} \partial^\sigma \varphi \partial_\sigma \varphi + V(\varphi) \right)$$

$$E = \frac{\dot{\varphi}^2}{2} + V(\varphi)$$

$$P = \frac{\varphi^2}{2} - V(\varphi)$$



$$\nabla^2 \psi = 4\pi G (\delta \rho_p + \delta \rho_m)$$

$$\delta \rho_{p0} = 0 \text{ or } \rho_{p0}$$

$$\rho_p = \rho_{p0} + \delta \rho_{p0} \left(\frac{a_i}{a}\right)^3 \theta(r_0 - r) \left(1 + 4\psi \sim \psi^2\right) + 4 \frac{\rho_{p0}}{a^3} (\psi(r, t) - \psi(r_0, t)) \sim \psi^2$$

$$\psi(r, t) = -\frac{4\pi G \rho_{p0} r^2}{3} - \frac{G}{a^3} \int_0^r 4\pi r'^2 \rho_p dr'$$

$$\frac{\delta \rho_p r^2}{\delta} - \frac{\delta \rho_{p0} \sigma^2 \left(\frac{a_i}{a}\right)^3}{\delta} - \frac{\delta \rho_{p0} r^2}{\delta} - \frac{1}{\delta} \frac{\delta \rho_{p0}}{a^3} \left(\frac{a_i}{a}\right)^3$$

$$\left(\rho_{p0} + 3\rho_{p0}\right) - \nabla^2 \psi$$

$$z_i = 0 \text{ or } z_c \rightarrow z = 100$$

$$\frac{\delta \rho_p}{\rho_{p0}} = \frac{\delta \rho_m}{\rho_{m0}} = 0.12$$

$$z = 2.9 \quad r_{vir} = 0.9 \delta m$$

$$z = 2.7$$

$$r_{vir}$$