PHI IN THE SKY 2004

Linearized Bekenstein Varying Alpha Models

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Bekenstein Type Model

- $e = e\left(\phi(x^\mu)\right)$

(1) $$\mathcal{L} = \mathcal{L}_\phi + \mathcal{L}_{\phi F} + \mathcal{L}_{\text{other}}$$

(2) $$\mathcal{L}_\phi = \frac{1}{2}\partial^\mu\phi\partial_\mu\phi - V\left(\phi\right),$$

(3) $$\mathcal{L}_{\phi F} = -\frac{1}{4}B_F\left(\phi\right)F_{\mu\nu}F^{\mu\nu} = -\frac{\alpha_0}{4\alpha}F_{\mu\nu}F^{\mu\nu},$$

Linearized case

- Linear coupling

Assuming small change in ϕ:

$$B_F(\phi) = 1 + \zeta_F(\phi - \phi_0) + \frac{1}{2}\xi_F^2(\phi - \phi_0)^2 + \ldots$$

$$-\frac{\triangle\alpha}{\alpha} = \zeta_F(\phi - \phi_0) + \frac{1}{2}(\xi_F - 2\zeta_F)(\phi - \phi_0)^2 + \ldots$$

Linearized case

Linear Potential

$V(\phi)$, $\alpha(\phi)$ always linear functions of ϕ around today for limited period of time $\Rightarrow$ few free parameters

(4) $$V(\phi) = V(\phi_0) + \frac{dV}{d\phi}(\phi - \phi_0)\,, \quad \frac{dV}{d\phi} < 0$$

(5) $$\alpha = \alpha_0 + \frac{d\alpha}{d\phi}(\phi - \phi_0)\ ,$$

Equations of motion

- ϕ source of dark energy

(6) $$H^2 = H_0^2 \left(\Omega_{m0} a^{-3} + \Omega_{r0} a^{-4} + \Omega_\phi\right) \ ,$$

(7) $$\frac{\ddot{a}}{a} = -H_0^2 \left[\frac{\Omega_{m0}}{2} a^{-3} + \Omega_{r0} a^{-4} + \frac{\Omega_\phi}{2}(1 + 3w_\phi)\right] \ ,$$

where

(8) $$\Omega_\phi = \frac{8\pi(\dot{\phi}^2/2 + V(\phi))}{3H_0^2} \ ,$$

and

(9) $$\omega_\phi = \frac{\dot{\phi}^2/2 - V(\phi)}{\dot{\phi}^2/2 + V(\phi)} \ .$$

Equations of motion

(10) $$\ddot{\phi} + 3H\dot{\phi} = -\frac{dV}{d\phi} + \frac{\alpha_0}{4\alpha^2}\frac{d\alpha}{d\phi}F_{\mu\nu}F^{\mu\nu} \, .$$

If $\frac{dV}{d\phi} = 0$ equivalence principle $\Rightarrow |\zeta_F| < 5 \times 10^{-4} \Rightarrow \frac{\Delta\alpha}{\alpha} \simeq 10^{-10}$ (too small!)

Generalized Bekenstein models: ϕ is driven by dark matter couplings [1], ϕ is driven by its own potential [2]

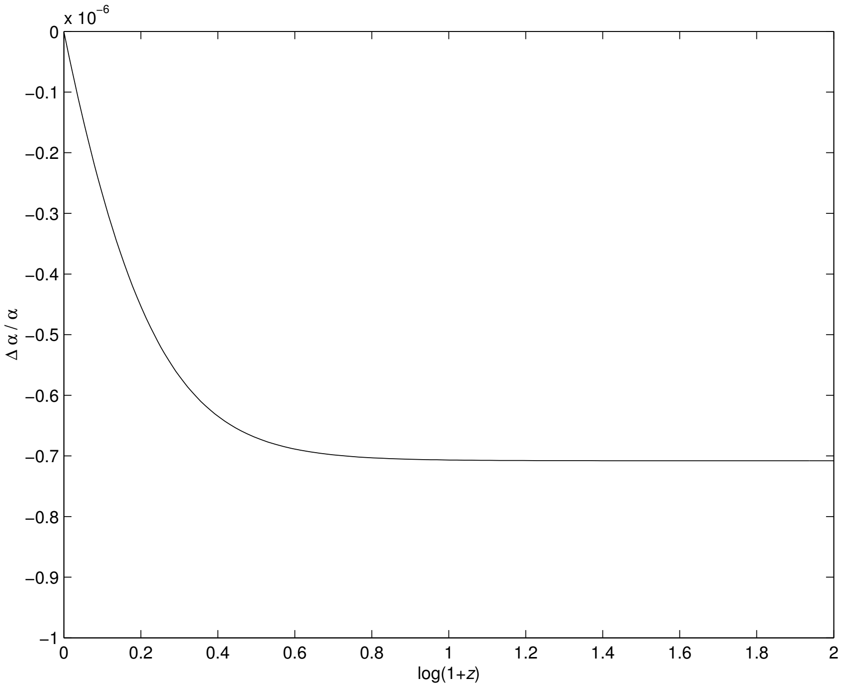
$\dot{\phi}_0, V_0, \frac{dV}{d\phi}, \frac{d\alpha}{d\phi}$ + cosmological parameters $\Rightarrow$

complete description of a particular linearized model

H. B. Sandvik, J.D. Barrow J. Magueijo, Phys. Rev. Lett **88**, 031302 (2002), hep-ph/0110377

E.J. Copeland, N.J. Nunes and M. Pospelov, Phys. Rev. **D69**, 023501 (2004), hep-ph/0307299

Predictions

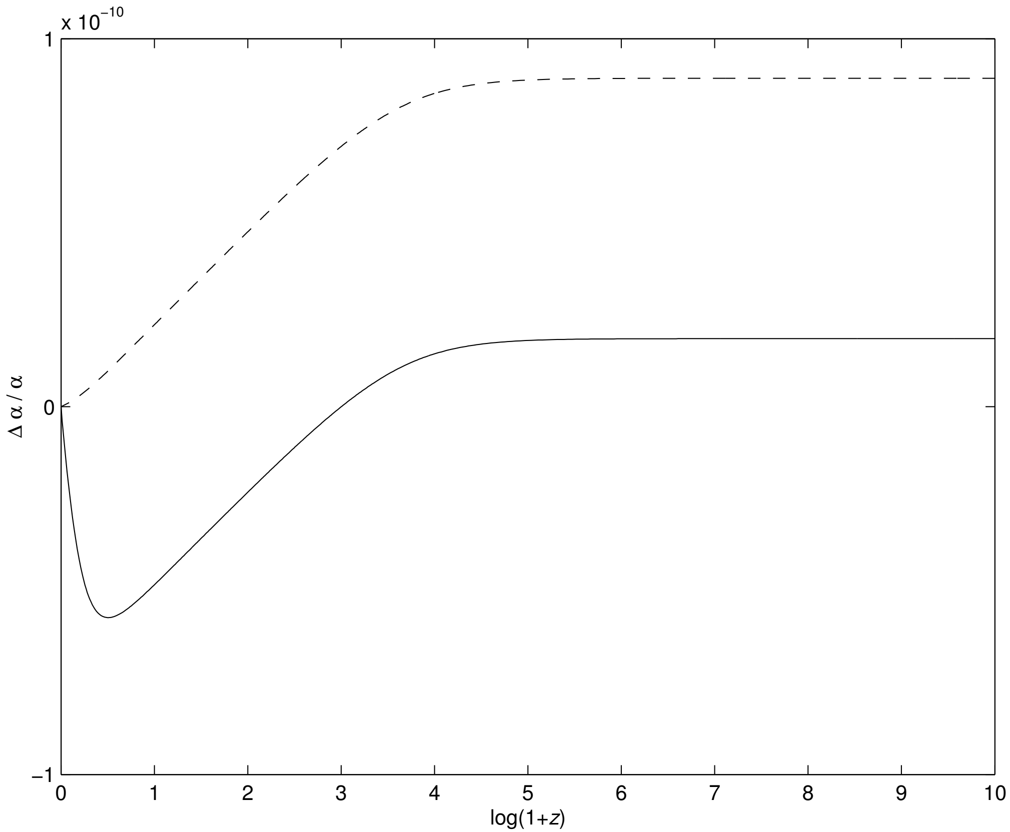


Unambiguously predicted by our model up to a normalization factor

(11) $$\zeta_\alpha \equiv -\frac{dV}{d\phi}\frac{\zeta_F}{H_0^2} .$$

given $\Omega_\phi^0 \simeq 0.7$ and $\omega_\phi^0 \sim -1$

Predictions



- $\frac{dV}{d\phi} \simeq -10^{-6} H_0^2$ (solid line) and $\frac{dV}{d\phi} \simeq 0$ (dashed line)

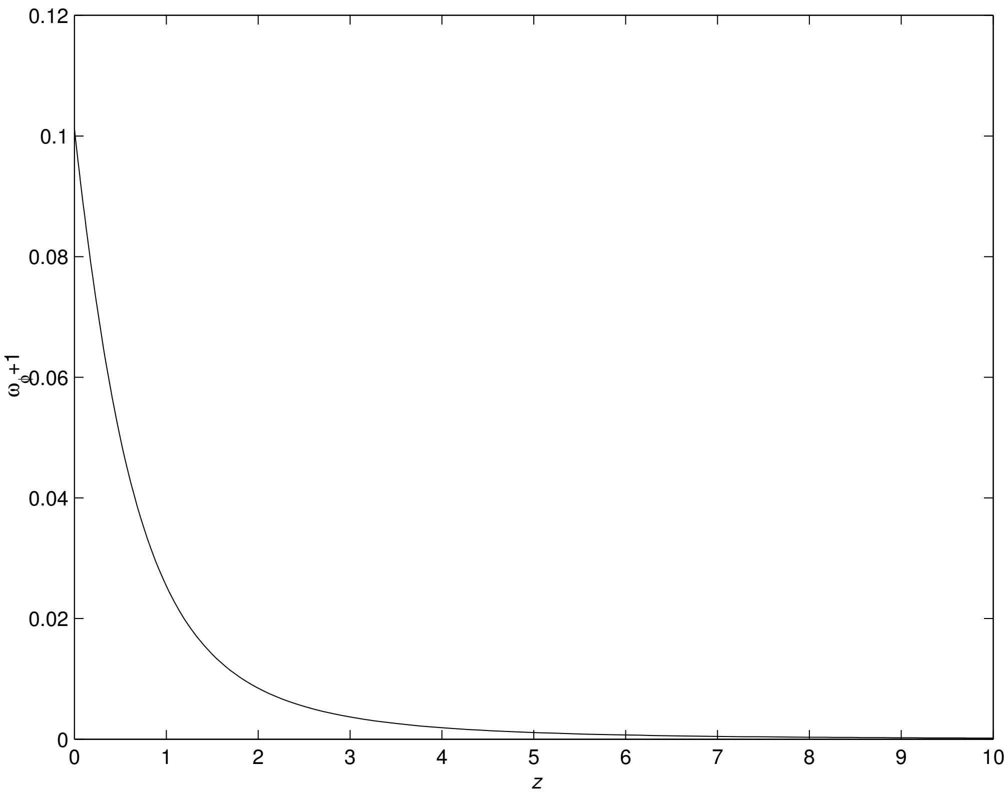
Predictions

Constraints on $\delta\phi \equiv \phi(z=0) - \phi(z=1)$:

$$\delta V \leq \rho_{c0} \Rightarrow \delta\phi \leq 10^{-1}\,. \tag{12}$$

Equivalence Principle $\Rightarrow \delta\phi \geq 10^{-3}$ considering $\frac{\delta\alpha}{\alpha} \sim 10^{-6}$

- $10^{-3} \leq \delta\phi \leq 10^{-1}$
- $-H_0^2 \leq \frac{dV}{d\phi} \leq -10^{-2} H_0^2$

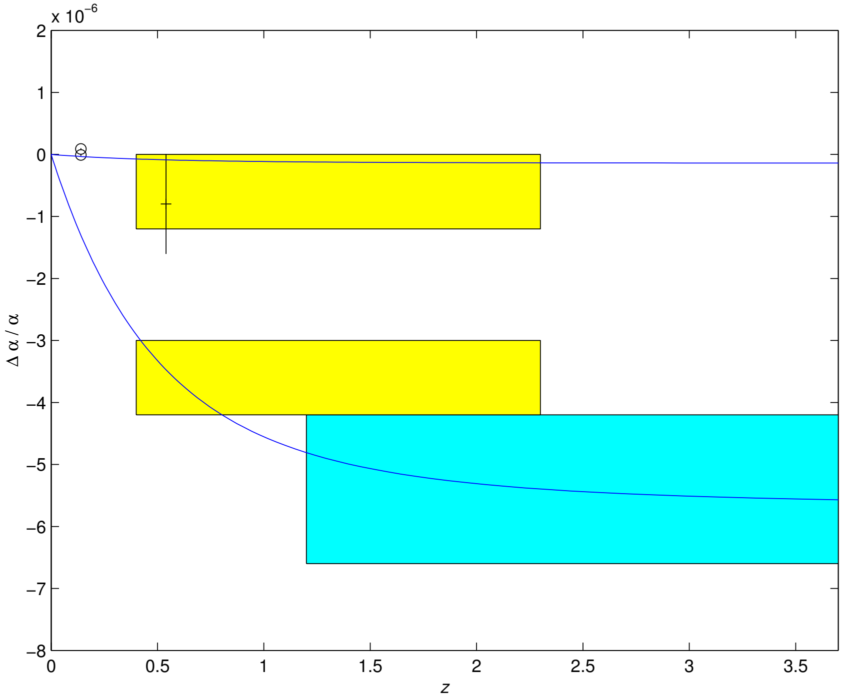


$\Omega_\phi^0 \simeq 0.7$, $\omega_\phi^0 \simeq -1$ and $\frac{dV}{d\phi} \simeq -0.35 H_0^2$

$\omega_\phi \to -1$ in the past

$\frac{dV}{d\phi} = -H_0^2$, $\left(\frac{\Delta\alpha}{\alpha} \simeq 10^{-6}\right) \Rightarrow \left(\omega_\phi^0 - 1\right)_{min}$

Predictions



Oklo ([1], circles), Rhenium decay from meteorites ([2], vertical bar) and quasar data (Murphy *et al.* [3]) blue shaded box, Chand *et al.* ([4], yellow shaded boxes - up with terrestrial isotopic abundances and down with low-metalicity isotopic abundances)

[1] Y. Fujii, Astrophysics. Space Sci **283,** 559 (2003) gr-qc/0212017

[2] K.A.Olive et al., Phys.Rev. **D69**,027701 (2004), astro-ph/0309252

[3] M. T. Murphy, J. K. Webb, and V. V. Flambaum, Mon. Not. Roy Astron. Soc **345** 609 (2003), astro-ph/0210299

[4] H. Chand R. Srianand, P. Petijean, anf B. Aracil (2004), astro-ph/0210299

Conclusions

- Bekenstein Type Model
- Linearized case
- Equations of motion
- Predictions
- Predictions
- Predictions
- Conclusions

- We have studied the linearized class of Bekenstein-type varying α models

- Any realistic Bekenstein model should reduce to these models for a certain time interval around the present day and we are assuming a cosmological time

- Very specific predictions were obtained and compared with existing data:
  - No such linearized model is consistent with **all** existing observational results at different z

- This could be explained by either unknown systematic errors in the observations or linearity breaking down for $t \ll H^{-1}$