Энергетический состав Вселенной: новая симметрия

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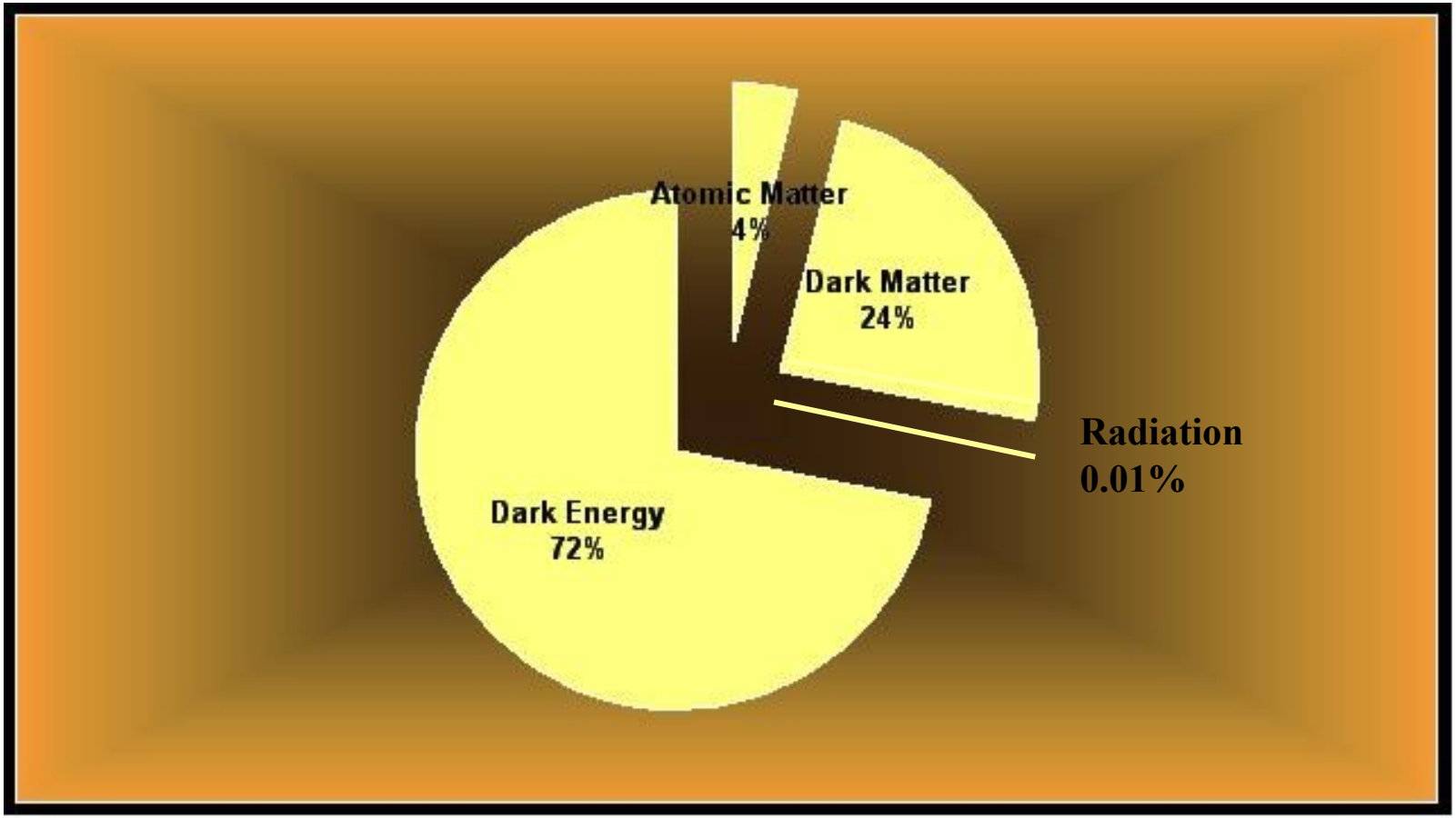
Energy composition of the observed Universe



Accidental? Preposterously complex? Absurd?

In the past, at the Big Bang Nucleosynthesis ($t_{BBN} \sim 100$ sec):

$$\rho_R \sim \rho_{TOT}$$

$$\rho_{DE} \sim 10^{-32}\, \rho_{TOT}$$

$$\rho_{DM} \sim \rho_B \sim 10^{-6}\, \rho_{TOT}$$

In future, at, say, $t \sim 100\ t_0$:

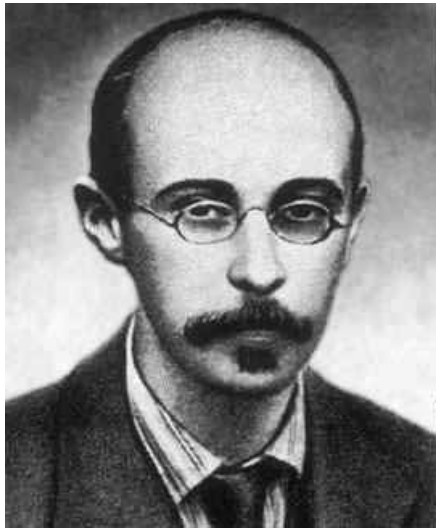
$$\rho_R \sim 10^{-116} \rho_{TOT}$$

$$\rho_{DE} \sim \rho_{TOT}$$

$$\rho_{DM} \sim \rho_B \sim 10^{-90}\ \rho_{TOT}$$

Are there any time-independent energy parameters?

Yes, these are the FRIEDMANN INTEGRALS



Friedmann equation (I)

$$K + U = 0$$

$$(dR/dt)^2 = (A_{DE}/R)^{-2} + A_{DM}/R + A_B/R + (A_R/R)^2$$

$$DE = \Lambda, \quad \Omega = 1, \quad c = 1$$

The Friedmann integrals

$$A_{DE} = M_P (\rho_{DE})^{-1/2}$$

$$A_{DM} = (3/4\pi)\, M_P^{-2}\, M_{DM}$$

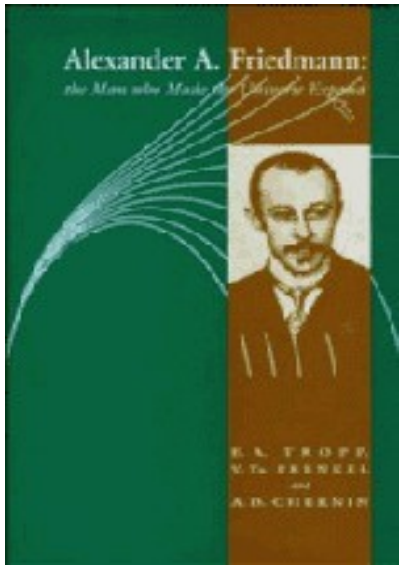
$$A_B = (3/4\pi)\, M_P^{-2}\, M_B$$

$$A_R \approx (3/4\pi)\, M_P^{-1}\, N_R^{2/3}$$

M_{DM}, M_B, N_R are global (say, for the whole observed universe)

covariant conserving values

Natural units: $c = \hbar = 1$; $M_p = (8\pi G/3)^{-1/2} \sim 10^{18}$ GeV



Friedmann equation (II)

$$dS = 0$$

$$R\, d\rho/dt = -3\, \rho\, (1+w)\, dR/dt;$$

Solution: the Friedmann integral

$$A = [M_P^{-2}\, \rho\, R^{\,3(1+w)}\,]^{\,1/(1+3w)}$$

Equation of state: $w = p/\rho$

DE=Λ: $w = -1$; DM: $w = 0$; B: $w = 0$; R: $w = 1/3$

Normalized scale factor: $R(z) = 3/H_0\ (1+z)^{-1}$

Time-independent empirical recipe of the cosmic energy mix

$$A_{DE} \sim A_{DM} \sim A_B \sim A_R \sim 10^{60 \pm 1}\, M_P^{-1}$$

Internal (non-geometrical) symmetry of the cosmic energies

Dark energy is a regular member of the cosmic energy quartet

A special feature of the present epoch:

The four energy densities are approximately equal,

$$\rho_{DE} \sim \rho_{DM} \sim \rho_B \sim \rho_R ,$$

when the Hubble radius is near the Friedmann integral,

$$R_H \sim 1/H_0 \sim A_{DE}$$

Link to fundamental physics

Okun (1988), Weiberg (2000):
Central part of electroweak energy scale $M_{EW} \sim 1000$ GeV

Arkani-Hamed et al. (2000): M_{EW} in "dark physics"

WIMP mass $m_{DM} \sim M_{EW}$

DE density $\rho_{DE} \sim X^{-8} M_P^4 \sim 10^{-120} M_P^4$

Hierarchy number $X \sim M_P/M_{EW} \sim 10^{15}$

1) $A_{DE} \sim X^4 M_P^{-1}$

2) Dark matter freeze-out at z ~ X

$$A_{DM} \sim A_R \sim X^4 M_P^{-1}$$

1) + 2)

$$A_{DM} \sim A_R \sim A_{DE} \sim X^4 M_P^{-1} \sim 10^{60} M_P^{-1}$$

3) Baryons: electroweak baryogenesys??

Cosmology big numbers & Hierarchy phenomenon

Big Baryonic Number: $B = n_R/n_B \sim (m_B/M_P)\, X \sim 10^{12}$

Big Dark Number: $D = n_R/n_{DM} \sim X \sim 10^{15}$

Total number of relic photons: $N_R \sim X^6 \sim 10^{90}$

Total number of WIMPs: $N_{DM} \sim X^5 \sim 10^{75}$

Hierarchy number $X \sim M_P/M_{EW} \sim 10^{15}$

Cosmic internal symmetry

$$A_{DE} \sim A_{DM} \sim A_B \sim A_R \sim (M_P/M_{EW})^4 \; M_P^{-1} \sim 10^{60} \, M_P^{-1}$$

* Unifies the four cosmic energies
* Exists whenever the four energies exist
* Covariant
* Robust
* Approximate
* Originated from gravity-electroweak interplay at the first few picoseconds and related to the hierarchy phenomenon?

References

- Chernin A.D. *Nature* **270**, 250, 1968 ($A_B \sim A_R$)
- ---------- *Physics-Uspekhi* **44**, 1019, 2001
- ---------- *New Astron.* **7**, 113, 2002
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- ---------- *Astrophys. Space Sci.* **305**, 143, 2006
- ---------- *Physics-Uspekhi* **51**, …, 2008