DARKNESS

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Darkness = propety of gravitational vacuum, with scale (in empty space) $\sim 10^{-13}$ cm.

Its relevance depends upon choice of GR descriptive language.

Metric (EH) Gravity

$$\mathcal{L} = M_{pl}^2 \sqrt{g}\, R(g) \qquad g = \begin{pmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{pmatrix}$$

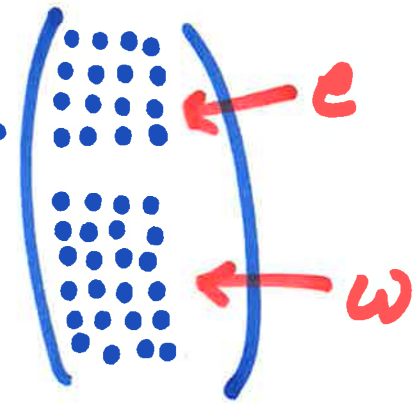
First order (gauge) gravity (EC):

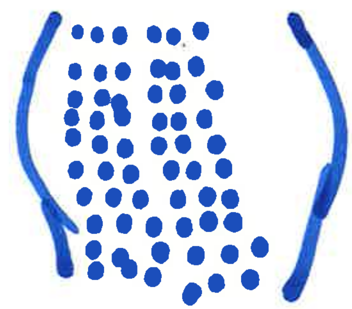
$$\mathcal{L} = M_{pl}^2\, e\, e\, R \qquad e = \begin{pmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{pmatrix}$$

$$g = e \cdot e \qquad R = \begin{pmatrix} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \end{pmatrix} \qquad \begin{pmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{pmatrix} = \omega$$

Mac-Dowell Mansouri Extension of EC:

$$\mathcal{L} = \frac{M_{pl}^2}{\Lambda} F F$$

$A =$ 

$F =$ 

Decomposition of MM to EC:

$$\mathcal{L} = \frac{M_{pl}^2}{\Lambda}\left[RR + \Lambda eeR + \Lambda^2 eeee \right]$$

Important Features of MM:

- It is a gauge theory like QED, QCD, EW
- $\mathcal{L}$ is quadratic in F
- But it is $E \cdot B$-like (NOT $E^2 - B^2$-like)
- Leading term is topological:

$$\int d^4x \left(\frac{M_{Pl}^2}{\Lambda^2} R \tilde{R} \right) = \int dt \left(2\pi \frac{dN}{dt} \right)$$

← DARKNESS

How DARKNESS BEHAVES:

In FRW expanding universe:

$$N(t) \sim \frac{M_{pl}^2}{\Lambda} \int (\dot{a}^3)\, d^3x = \frac{M_{pl}^2}{\Lambda} V(t) \left(\frac{\dot{a}}{a}\right)^3$$

↑ comoving volume

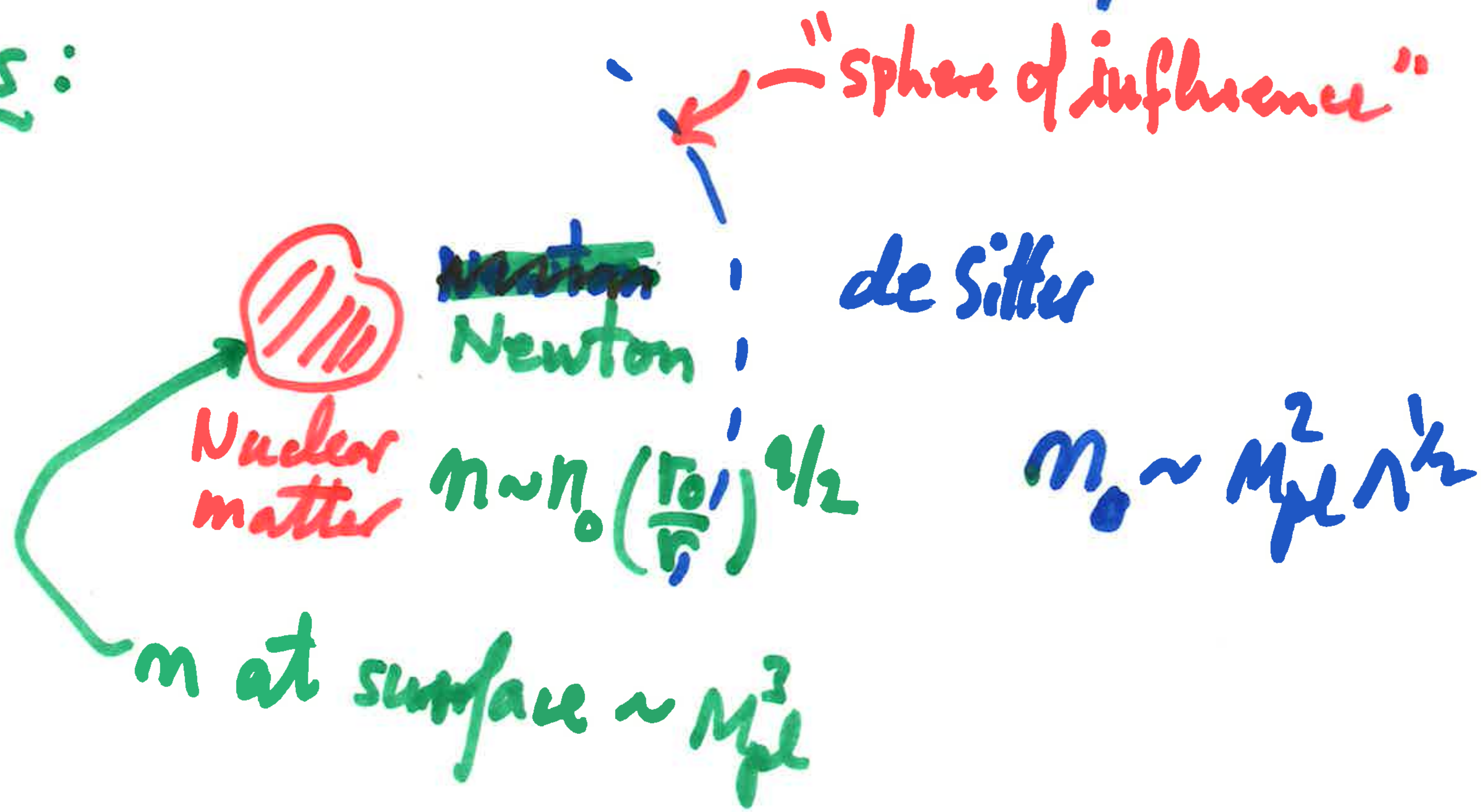
Nowadays (& in the future) $\left(\frac{\dot{a}}{a}\right)^2 \sim \Lambda \Rightarrow n \approx (M_{pl}^2 \Lambda^{1/2}) \sim 10^{39}\,cm^{-3}$

In the past, $n(t)$ was much larger

When $T \sim 50$ MeV $\quad n(t) \sim M_{pl}^3$

"QCD" scale / Zeldovich } $\Longleftrightarrow$ limit of validity of MN description

Sources:



NOTE:

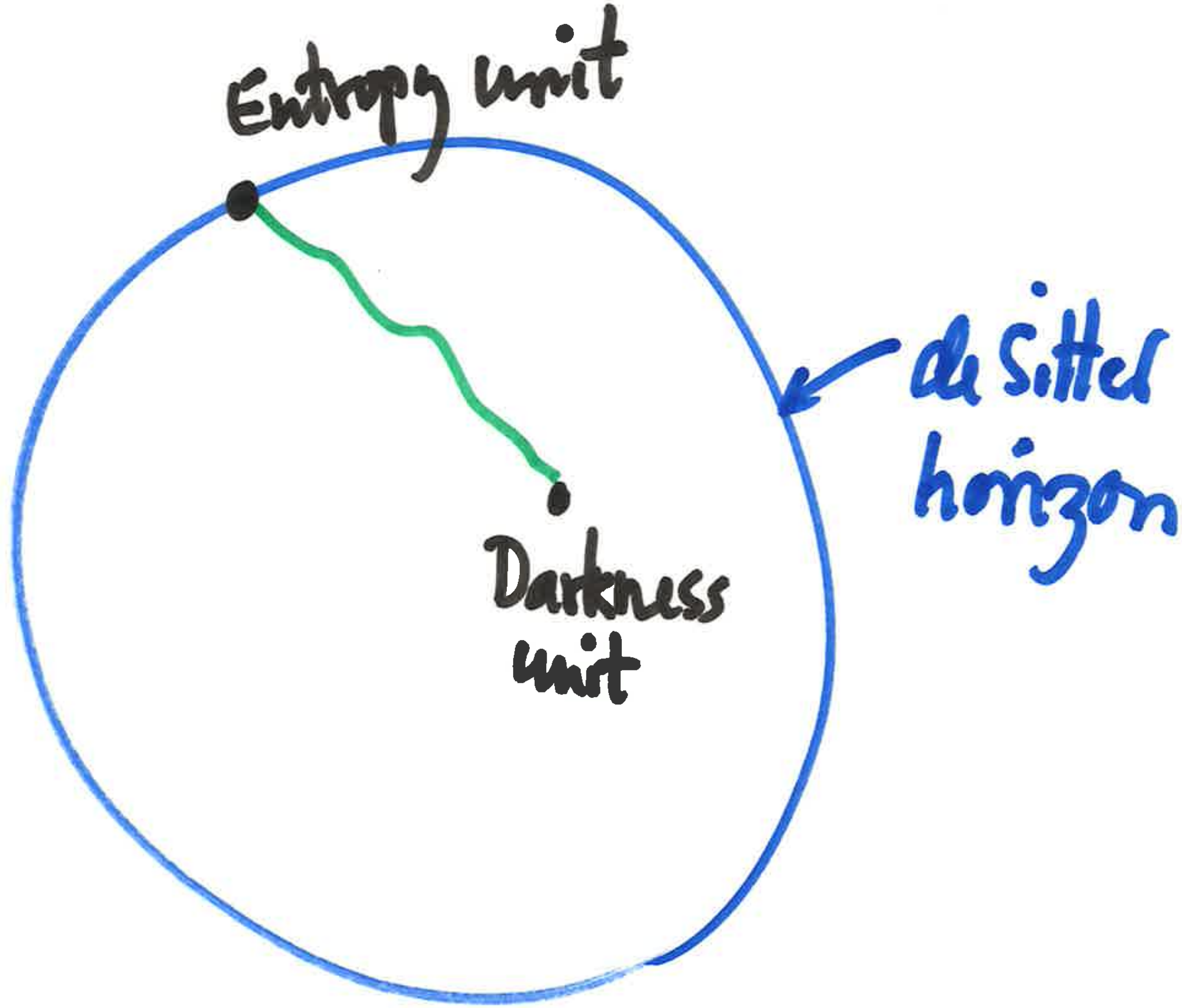
Total amount of darkness in universe dominated by matter:

$$\left.\begin{array}{l}\text{Baryon \#} \sim 10^{80} \\ \text{Darkness/nucleon} \sim 10^{60}\end{array}\right\} \Rightarrow 10^{140}$$

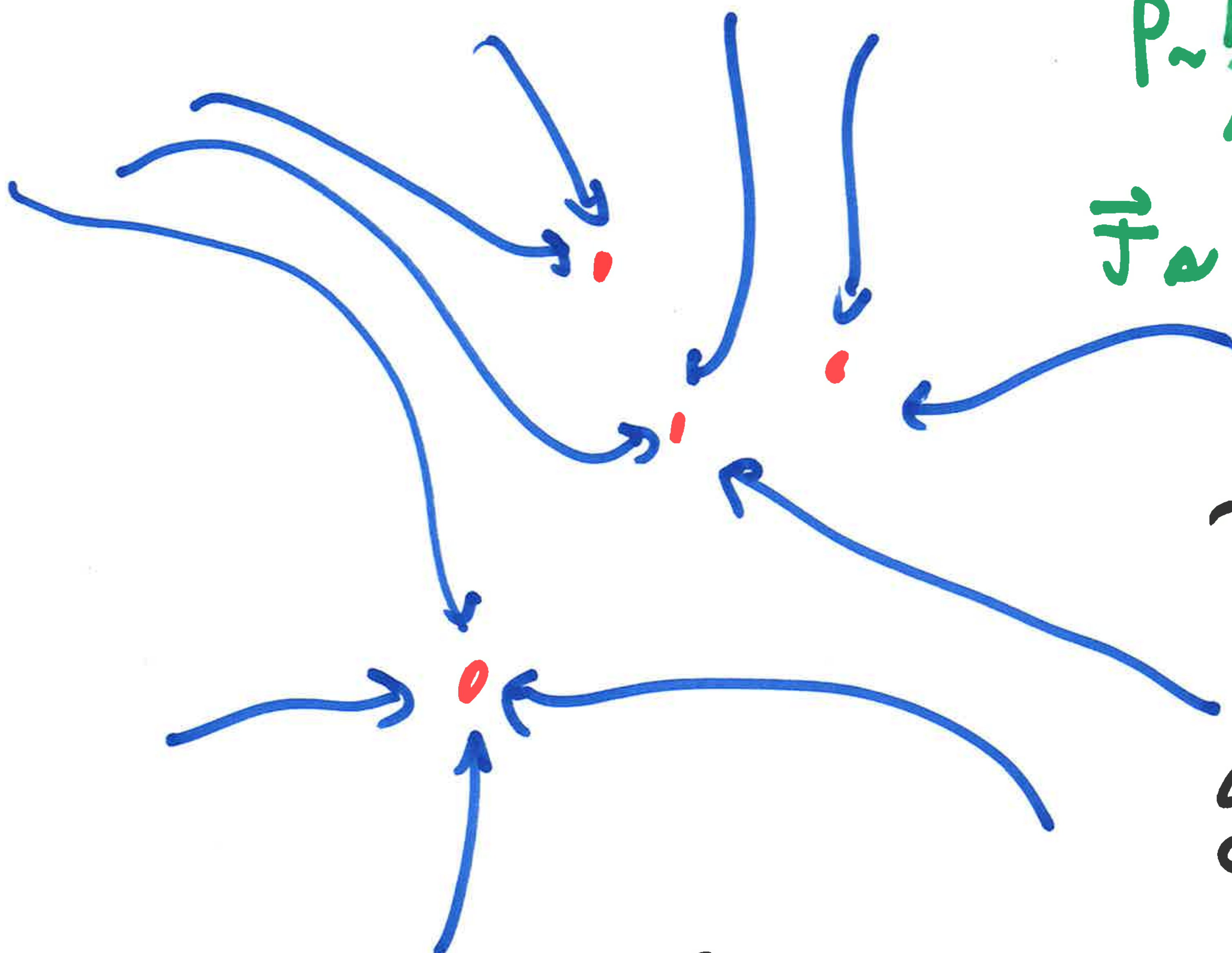
De Sitter density × Volume of universe (inside the horizon)

$$\sim (10^{39}\,cm^{-3}) \times (10^{28}\,cm)^3 \sim 10^{123}$$

Is Darkness = Horizon Entropy?



Newtonian Darkness Flow



$$P \sim \frac{M_{pl}^2}{\Lambda}\sqrt{\det T}$$

$$\vec{F} \sim \frac{M_{pl}^2}{\Lambda}\vec{\nabla}|\vec{g}|^2$$

$$T_{ij} = \nabla_i \nabla_j \phi$$

$$g_i = \nabla_i \phi$$

Comments:

- Is the darkness scale related to

  Λ_{QCD} ?

  q/ℓ mass scale?

  Dark-matter mass-scale?

- QCD/EW/Higg vacuua vs grav. Vacuum.