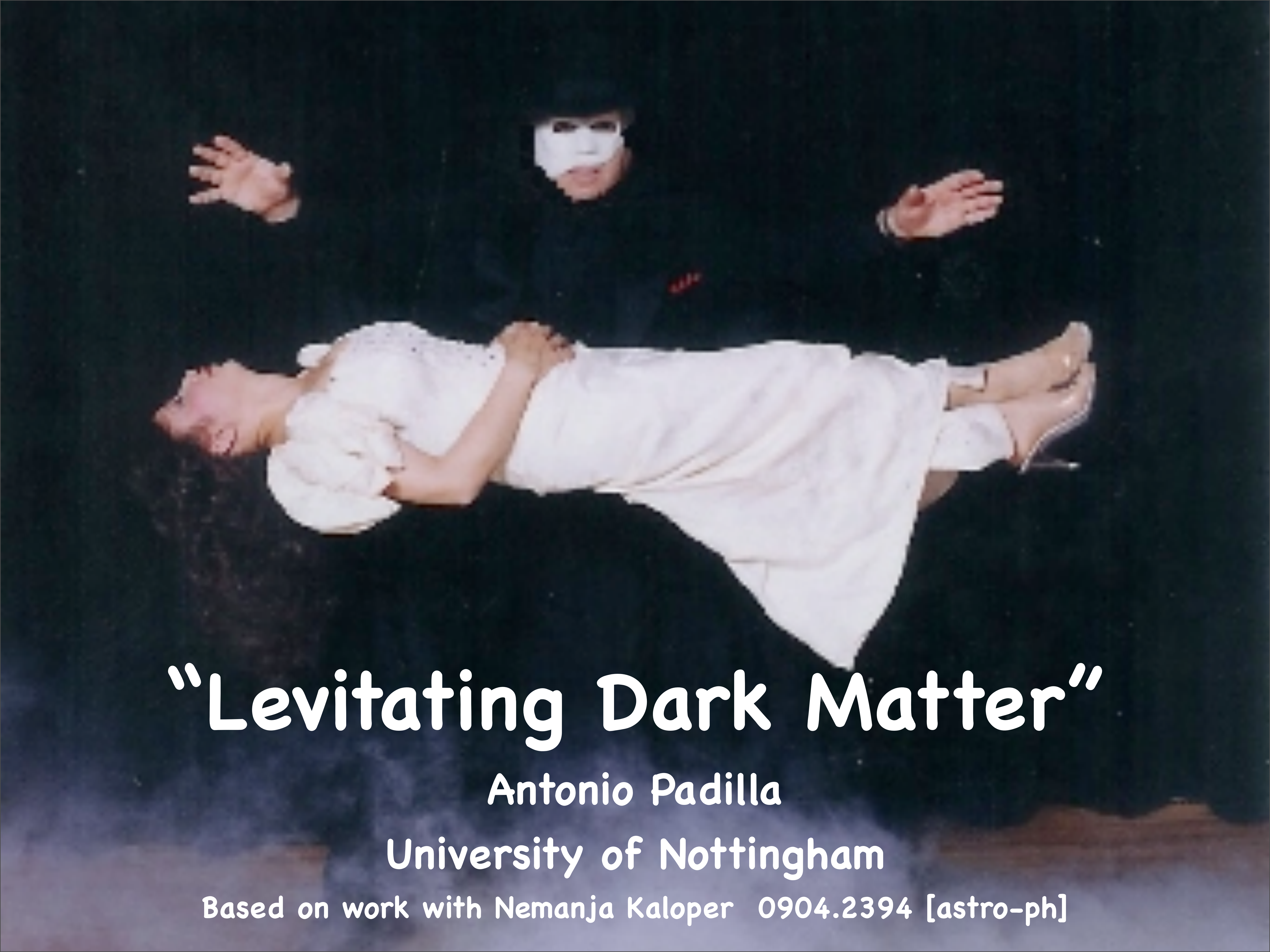


“Levitating Dark Matter”

Antonio Padilla

University of Nottingham

Based on work with Nemanja Kaloper 0904.2394 [astro-ph]

Outline of Talk

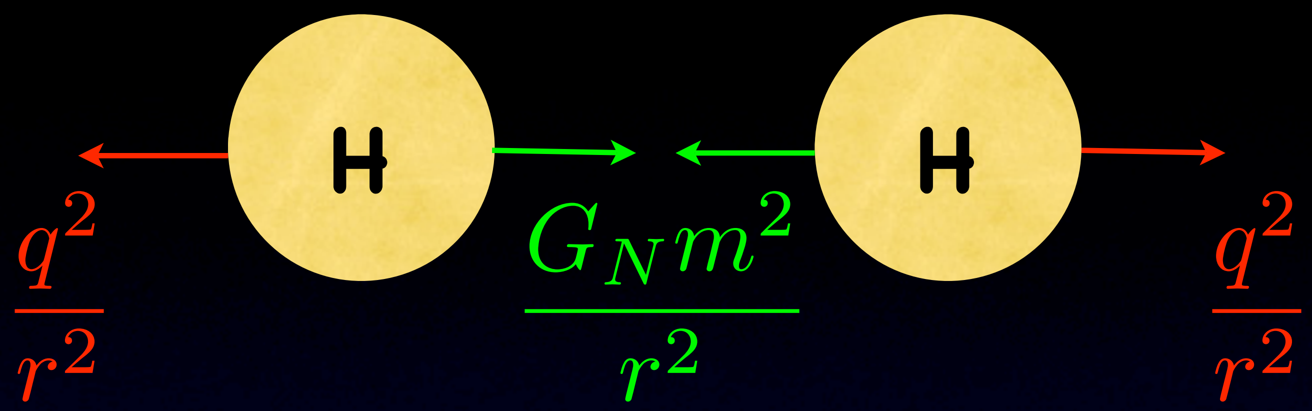
- Some old ideas that got away
- Introducing dark electrodynamics and dark charges
- Introducing the “leviton”
- Leviton cosmology and the effect upon data interpretation
- What next?

Some old ideas that got away...

The electrostatic Universe

Lyttleton & Bondi (1959)

The electrostatic Universe



Lyttleton & Bondi (1959)

- Assume that hydrogen carries a small monopole charge, q
- For this to impact on cosmology need electrostatic repulsion to be the order of gravitational attraction, ie

$$q \sim \frac{m}{m_{pl}} \sim 10^{-18} \text{ for } m \sim \text{GeV}$$

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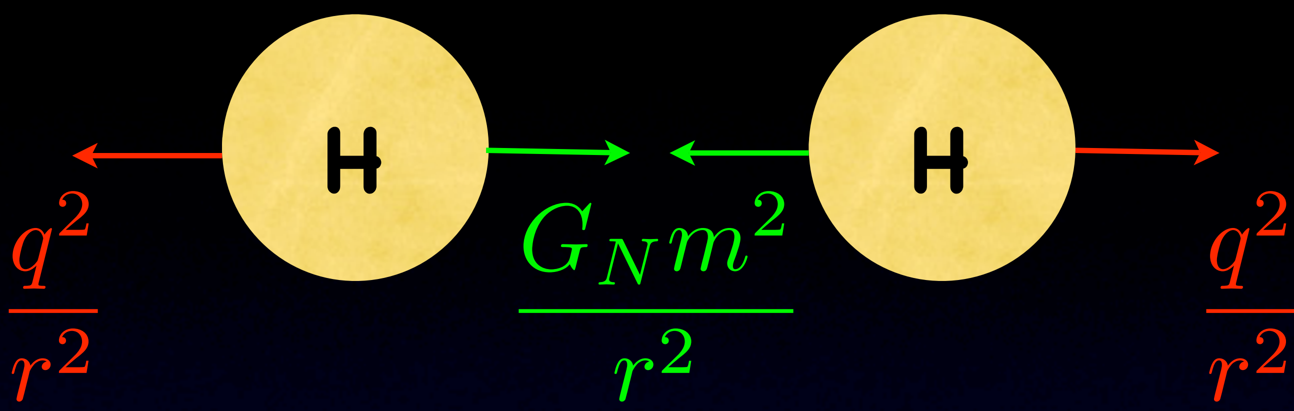

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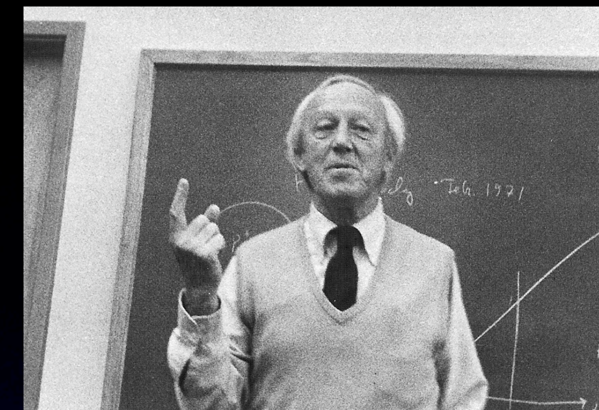
King (1960) placed strong bounds on the relative charge of the proton and the electron

$$q \lesssim 10^{-22}$$

Alfven-Klein Cosmology

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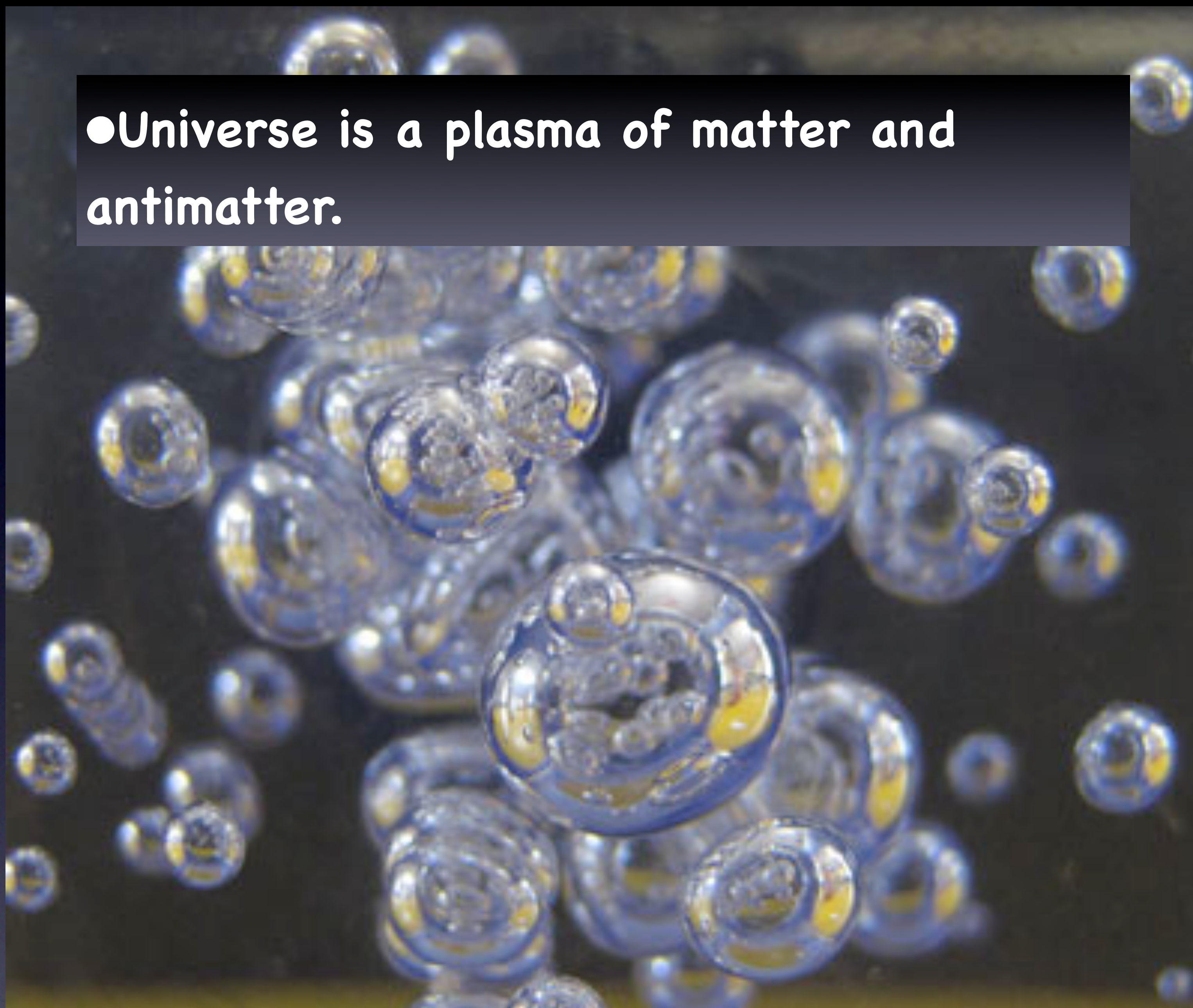

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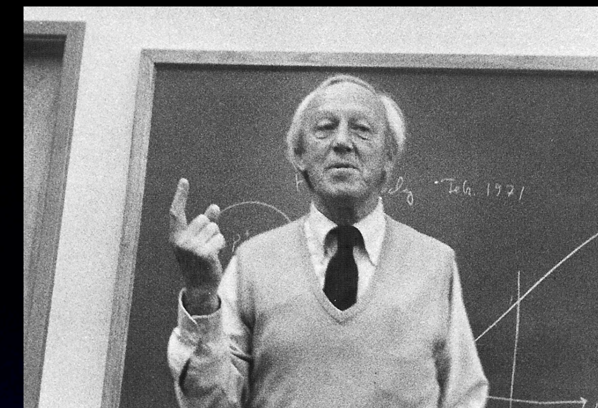

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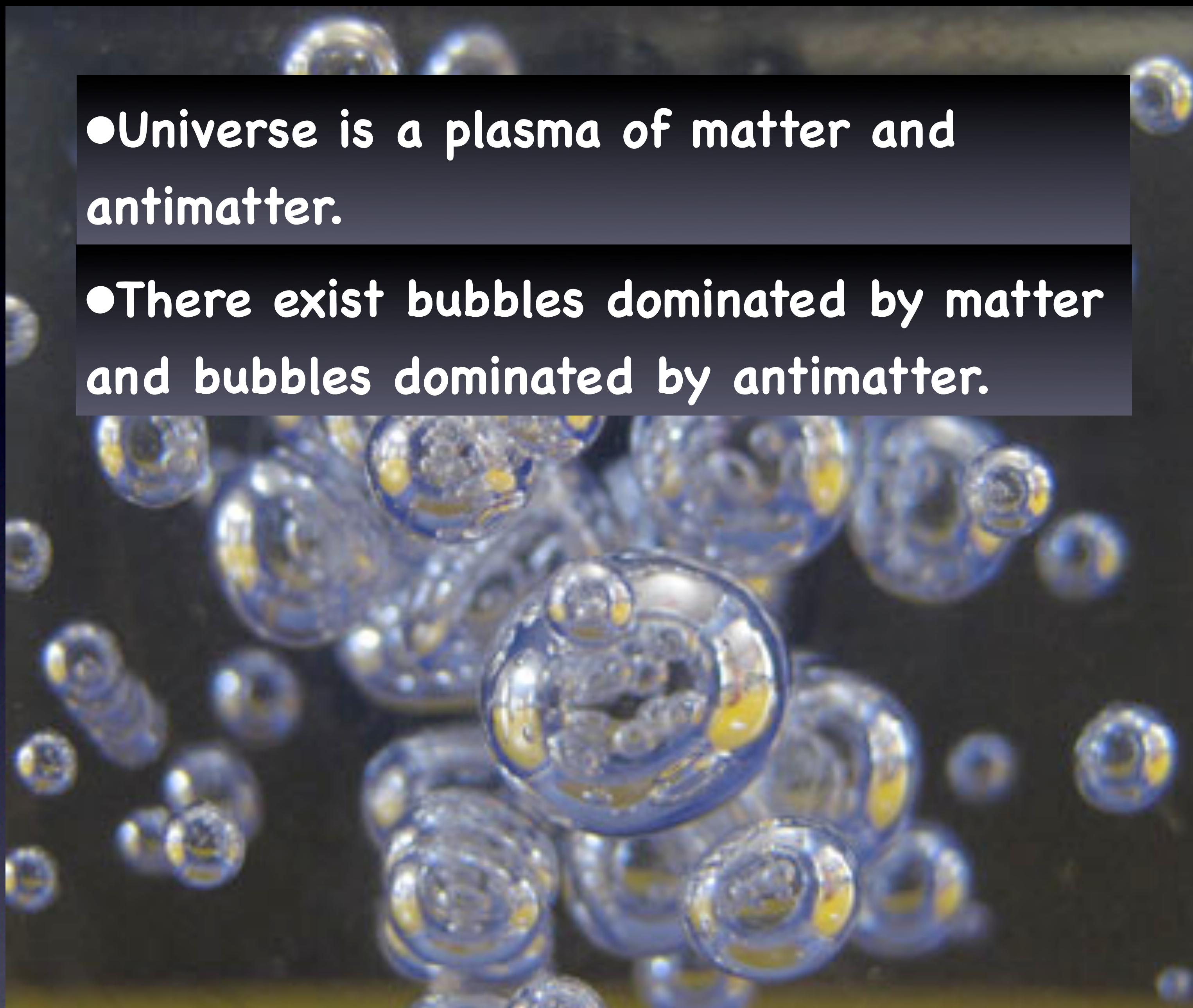

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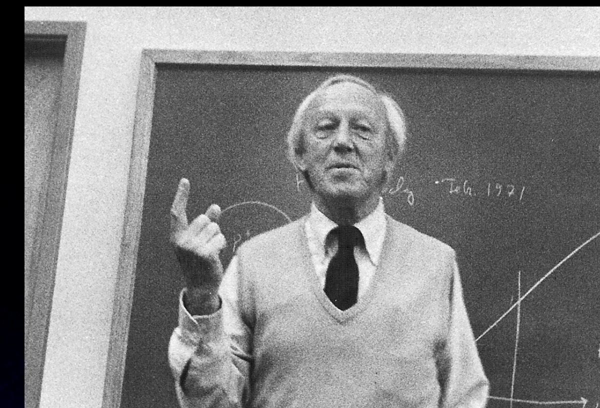

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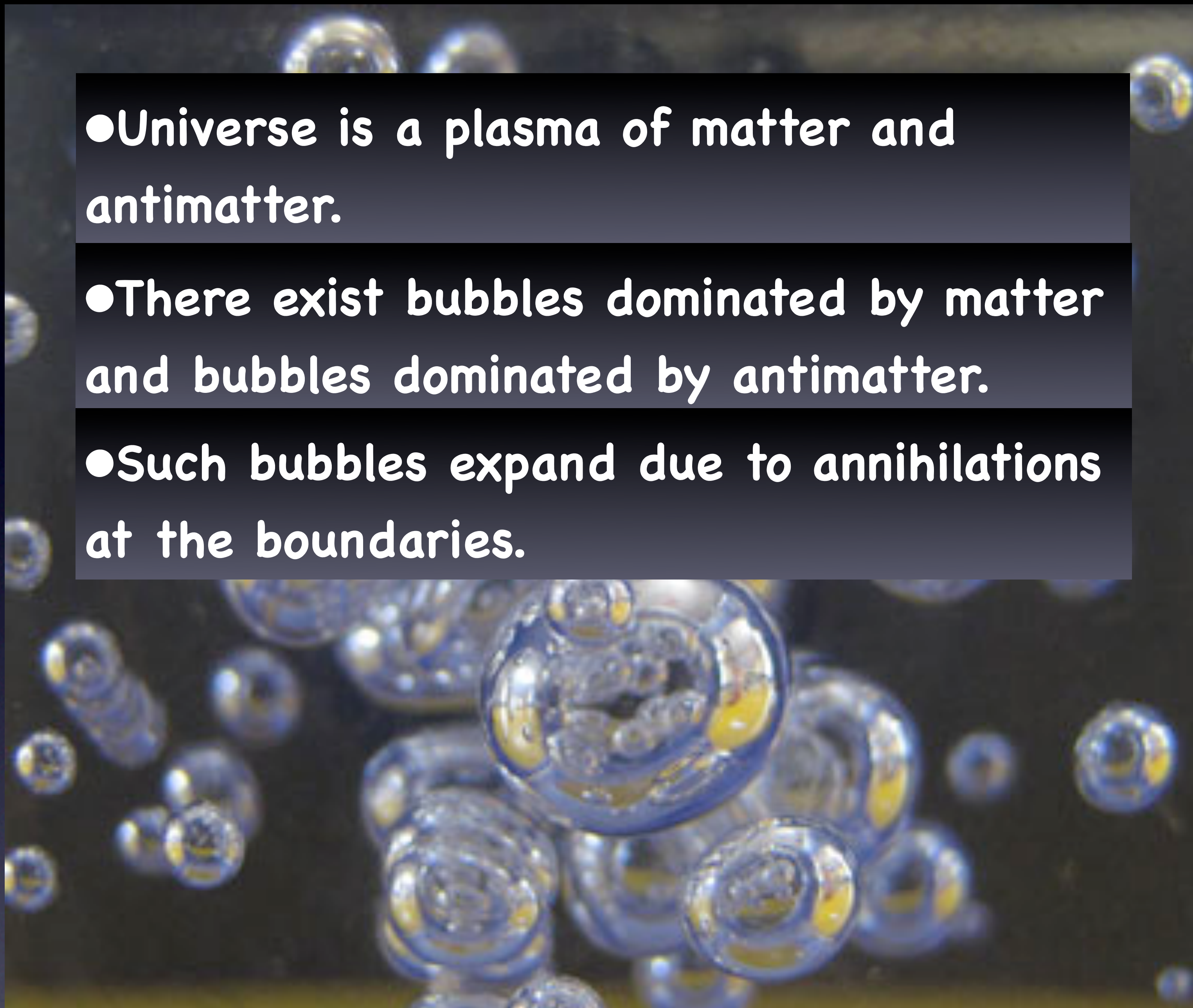

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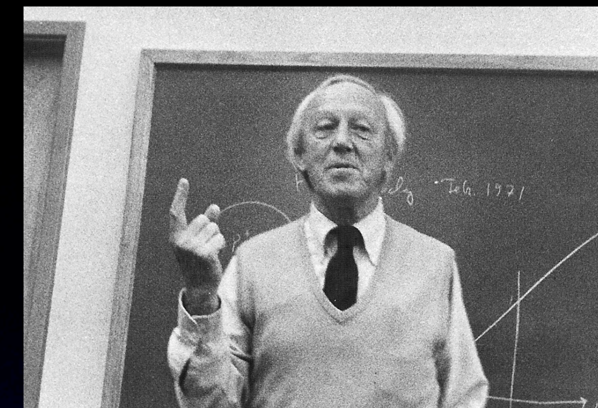

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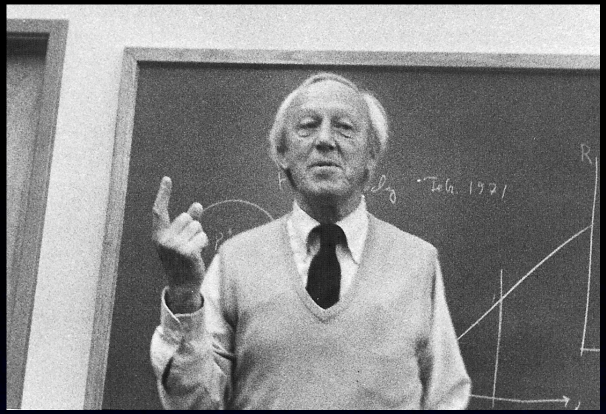
The Alfven landscape!



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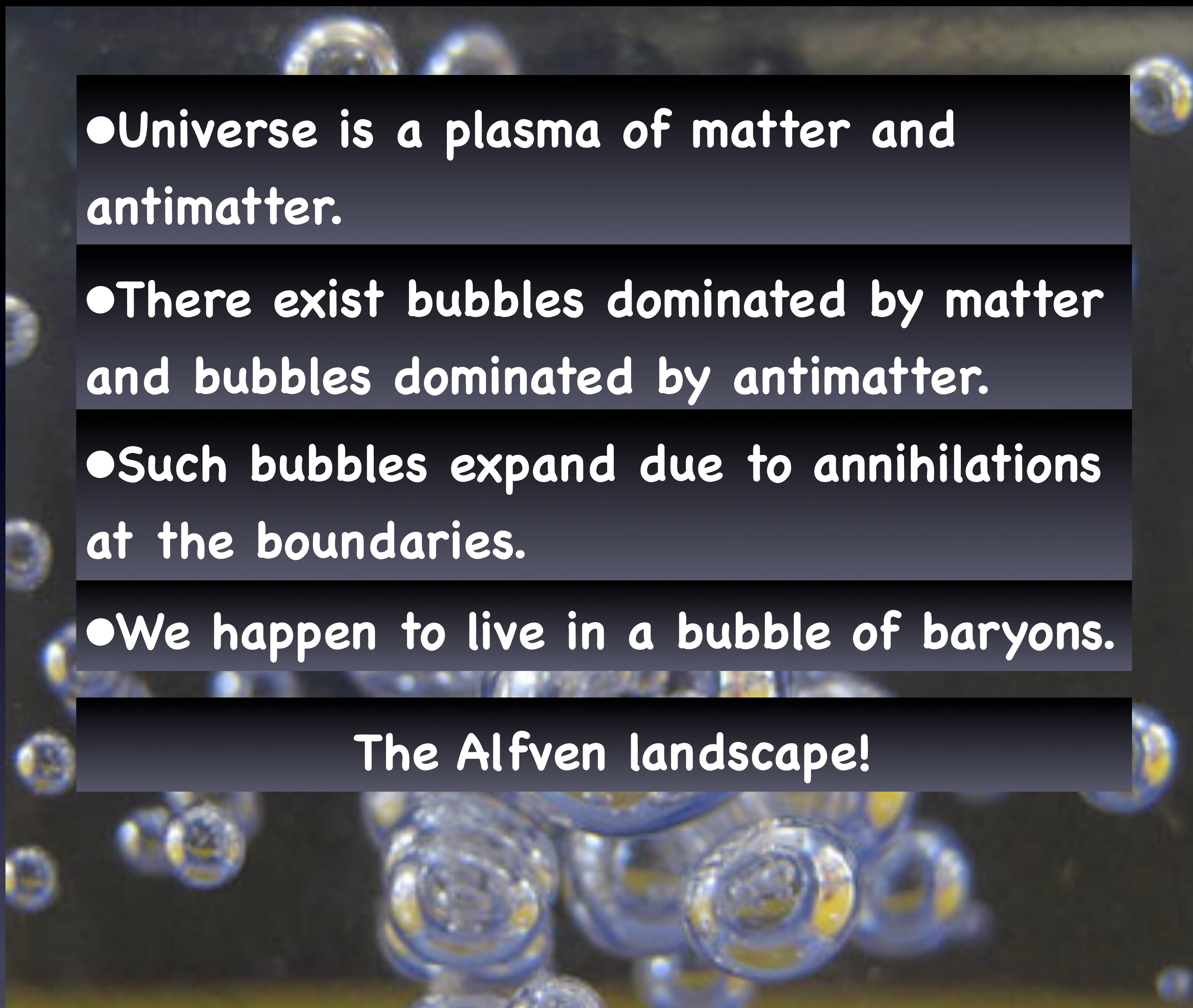

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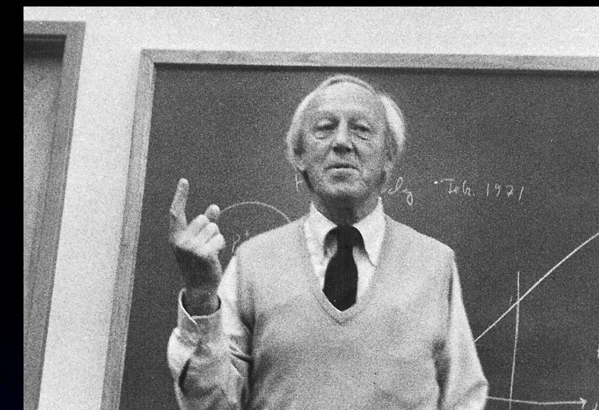

Alfven & Klein (1962)

Difficulties with observed isotropy of CMB and light element production, unless the bubble radius is superhorizon.

Let us retain the "spirit" of these ideas, and apply them to the dark sector

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- Assume (for now) that the dark U(1)′ is unbroken.
- Assume that our Hubble patch contains a net overall charge.

Other considerations and motivations

- Note that if our charged DM particle has TeV mass and short range weak scale interactions with the remaining dark sector, a "WIMPless miracle" can occur and it can have the right relic abundance to make up a significant fraction of dark matter in our Universe (Feng & Kumar, 2008)

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- For TeV mass particles, the bound on the dark fine structure constant is

$$\alpha' \lesssim 10^{-3}$$

(Ackerman et al, 2008)

(compare with King’s bound $\alpha_{\rm eff} \sim q^2 \lesssim 10^{-44}$ for the visible sector)

Other considerations and motivations

- Dark U(1)'s are prevalent in string theory. Theoretical considerations (holographic, charged BH (in)stability) suggest that gauge forces should not be weaker than gravity. For gauge coupling g, this suggests an effective theory cut-off $\Lambda \lesssim g m_{pl}$ with stable particles of mass below or around the cut-off. (Arkani-Hamed et al, 2007)

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Call this particle the "leviton"

Weighing the Universe

Archimedes was asked by King Hiero II to find a way to check that the Royal crown was as golden as it appeared, without causing any damage.

He compared the buoyancy of the crown to the buoyancy of a golden reference sample (his probe)

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In cosmology we use the same principles to weigh the Universe...only now we use a number of different probes and have to correlate the results

Care with probes

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$$M_{\mathrm{star}} = M$$

M,Q

m,q

Charged probe feels a radial force per unit mass, $\frac{F}{m} = -\frac{G_N M}{r} + \frac{q}{m}\frac{Q}{r}$
and, being ignorant of its charge, records a mass

$$M_{\mathrm{star}} = \left(1 - \frac{1}{G_N}\frac{q}{m}\frac{Q}{M}\right) M$$

Leviton cosmology

charge-to-mass ratio for probe

charge-to-mass ratio for charged background

$$H^2 = \frac{8\pi G_N}{3}\rho_{\rm total} - \frac{8\pi}{3}\left(\frac{q}{m}\right)_{\rm probe}\left(\frac{q}{m}\right)_{\rm background}\rho_{\rm charged}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G_N}{3}(\rho+3p)_{\rm total} + \frac{4\pi}{3}\left(\frac{q}{m}\right)_{\rm probe}\left(\frac{q}{m}\right)_{\rm background}(\rho+3p)_{\rm charged}$$

total cosmological mass density

$$\rho_{\rm total} = \rho_{DE} + \rho_{\rm neutral} + \rho_{\rm charged}$$

Care with probes

$$1 = \sum_i \Omega_i - \frac{\left(\frac{q}{m}\right)_{\rm probe}\left(\frac{q}{m}\right)_{\rm background}}{G_N}\Omega_{\rm charged}$$

Deceleration parameter

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If we write the deceleration parameter in terms of the "effective" dark energy, we find

$$q = \frac{1}{2} + \frac{3}{2}\tilde{w}_{DE}\tilde{\Omega}_{DE}$$

where

$$\tilde{w}_{DE} = w_{DE}\left(1 + \frac{\left(\frac{q}{m}\right)_{\rm SN}\left(\frac{q}{m}\right)_{\rm background}}{G_N}\frac{\Omega_{\rm charged}}{1 - \Omega_{DM}}\right)$$

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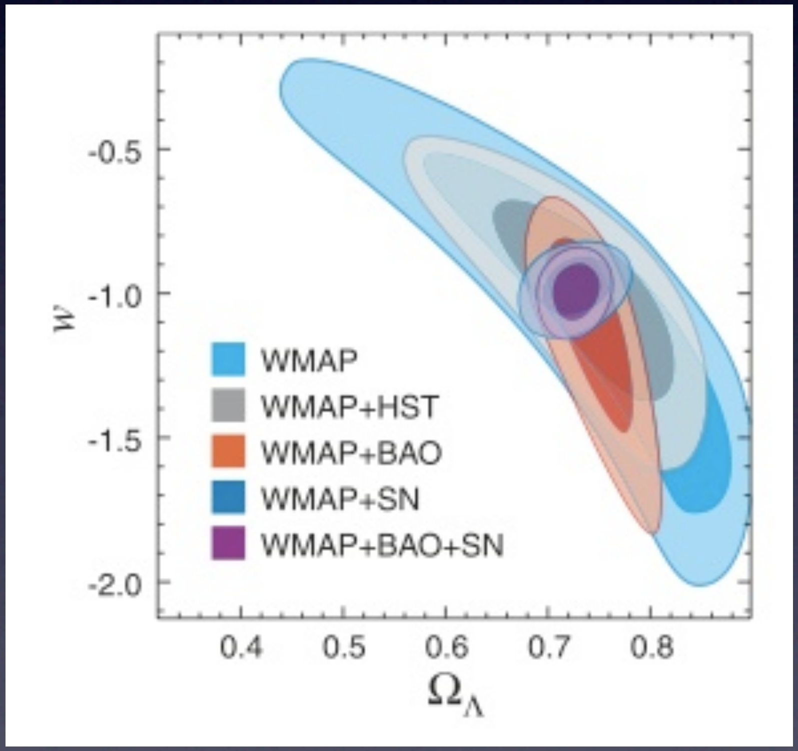
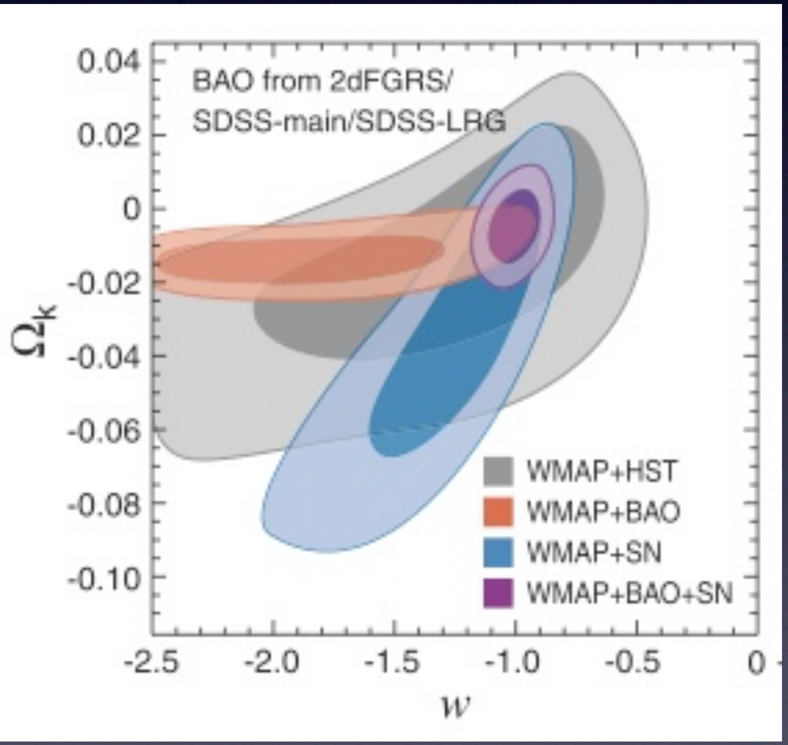
By ignoring the gauge repulsion in the SN probe, we erroneously deduce a more negative equation of state!

The leviton alters how one should interpret the data...





WMAP collaboration, 2008

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- Failing to account for the charged nature of the SN probe can trick us into believing that $w<-1$, for example. This happens without the need to introduce any pathologies such as phantom fields.
- Can explain the anomalous Hubble flow seen at around 100-300 MPc (Kashlinsky et al 2008) using galactic overdensities of charged DM, with a locally increased gauge repulsion.

What next?

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- Luminosity distance, and BAO
- CMB and the acoustic peak structure
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After a more careful analysis of the data, the big questions are:

- What are the bounds on the fraction of DM that may be charged under the dark U(1)′?
- How much can this affect our perceived EoS for DE?


Thanks

Leviton cosmology from GR

A system of levitons distributed on a general FRW background is described by a generalized McVittie solution (Kastor & Traschen, 1993)

$$ds^2 = -V(x,t)^{-2}dt^2 + a^2(t)V(x,t)^2 d\mathbf{x}^2, \qquad A = \frac{dt}{V}$$

$$V(t,x) = 1 + \sum_i \frac{\mu_i}{a(t)|x - x_i|}, \qquad H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G_N}{3}\rho_{\text{neutral}}$$

We can extract the Hubble parameter by writing this solution as a sub-horizon perturbation about the observers local Lorentz frame, in Newtonian gauge

We recover the leviton cosmology displayed earlier