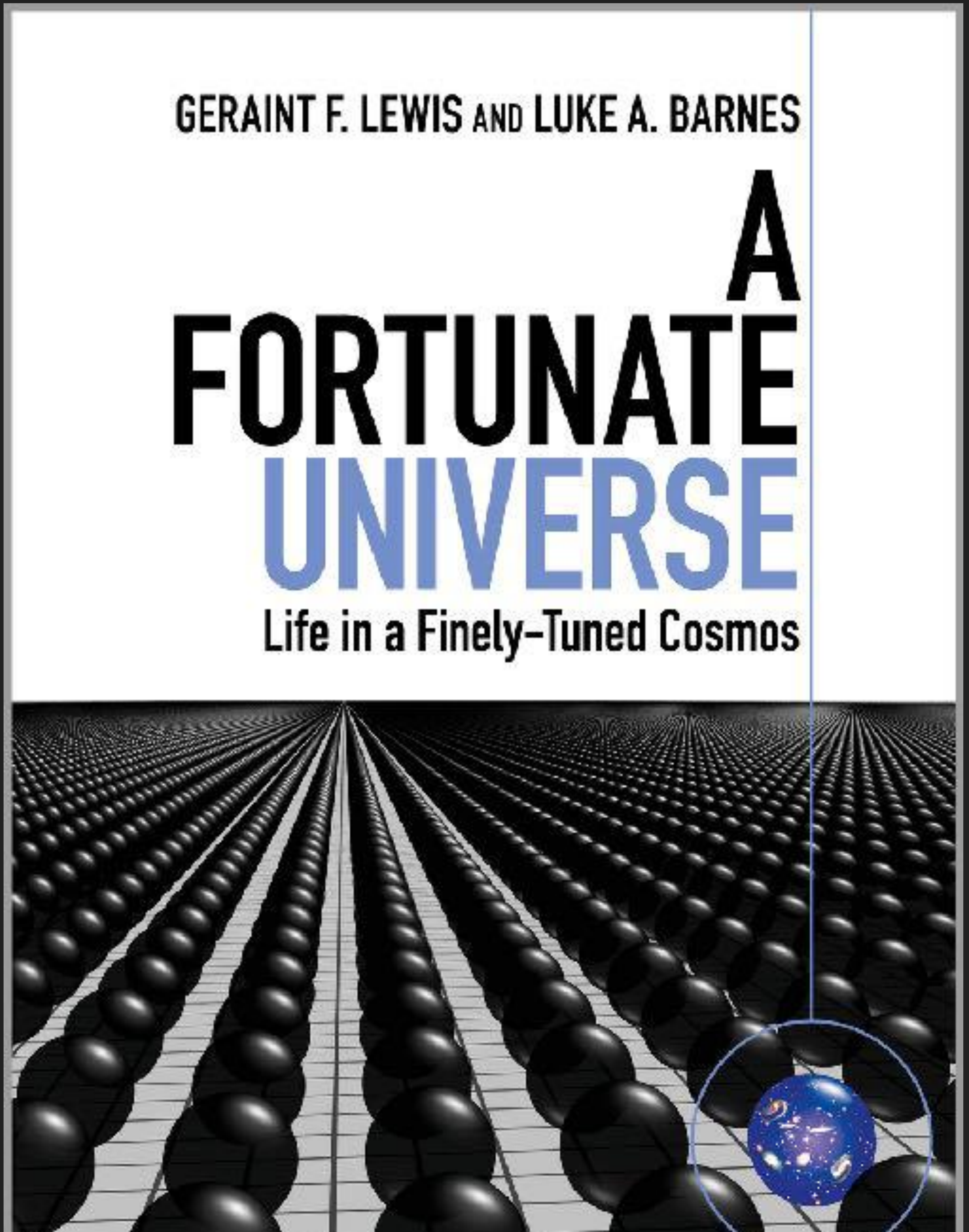
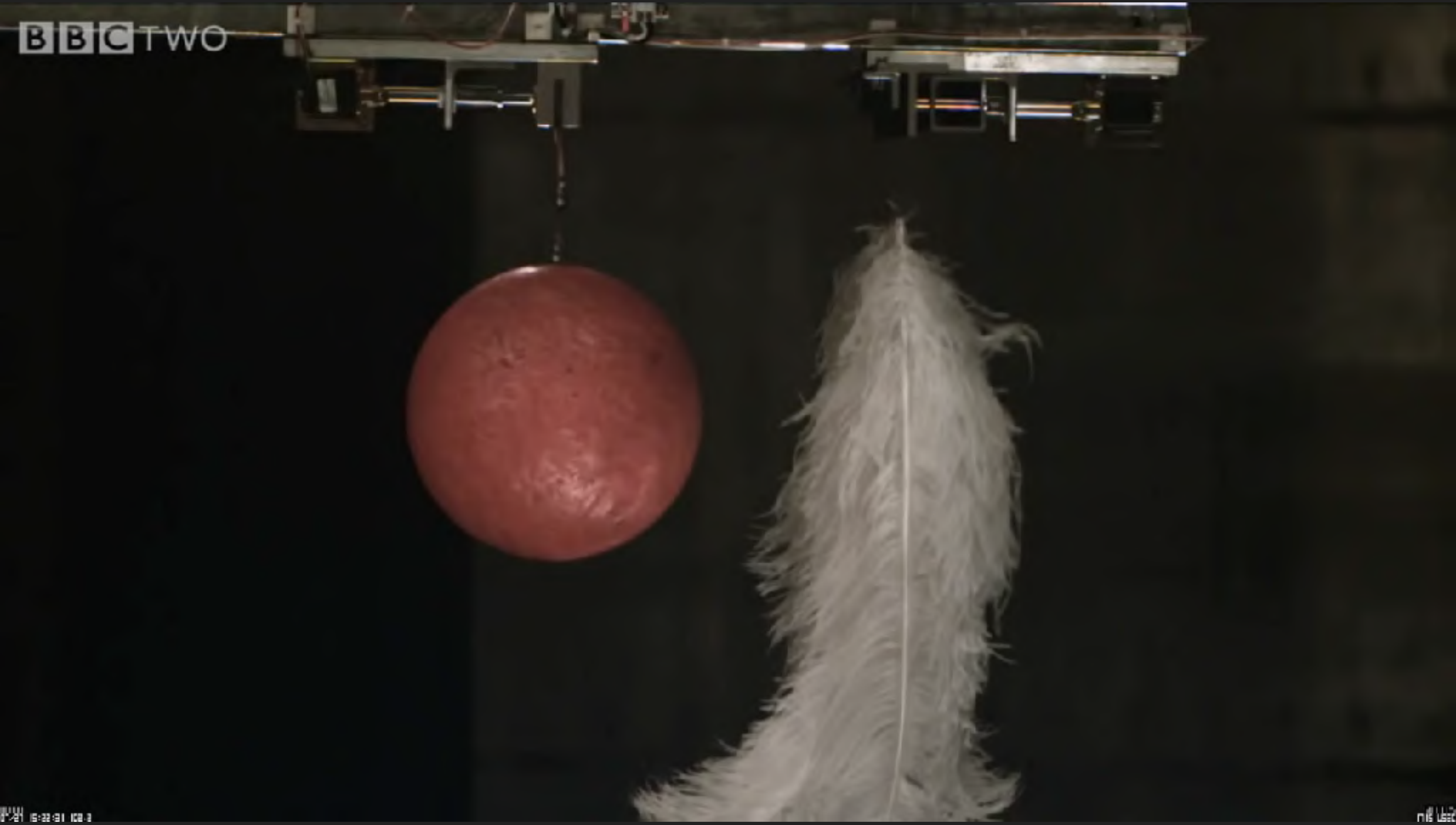
LUKE BARNES UNIVERSITY OF SYDNEY

FINE TUNING: THREE WAYS FORWARD



GRAVITATIONAL AND INERTIAL MASS

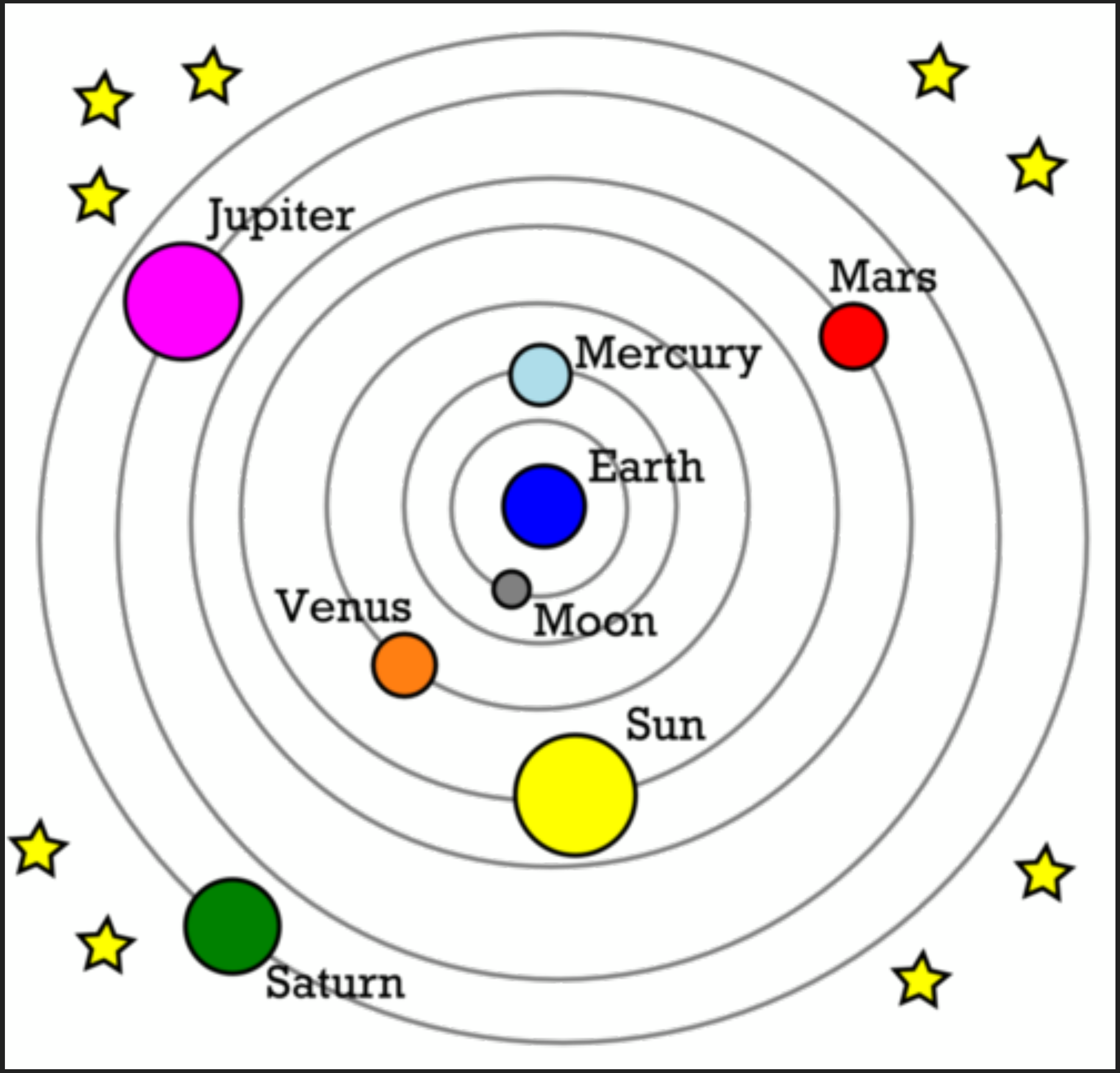


Human Universe, BBC, Episode 4

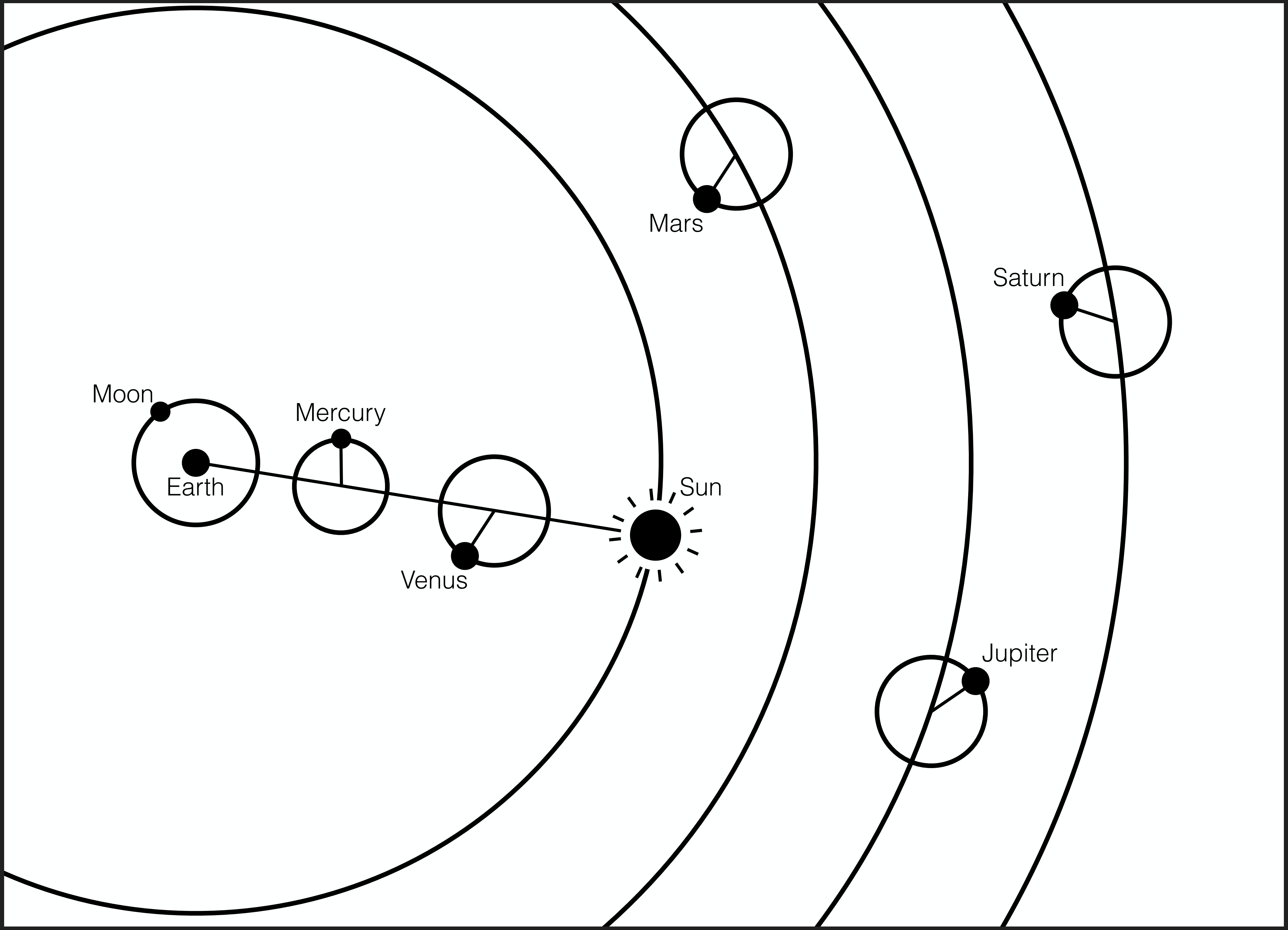
FINE-TUNING IN PHYSICS

- We call a theory fine-tuned when, to explain the data, it must make an unmotivated but suspiciously precise assumption

PTOLEMAIC MODEL



VENUS AND MERCURY



WAY FORWARD 1: BETTER MODELLING

PHYSICAL REVIEW D **76,** 045002 (2007)

Anthropic tuning of the weak scale and of m_u/m_d in two-Higgs-doublet models

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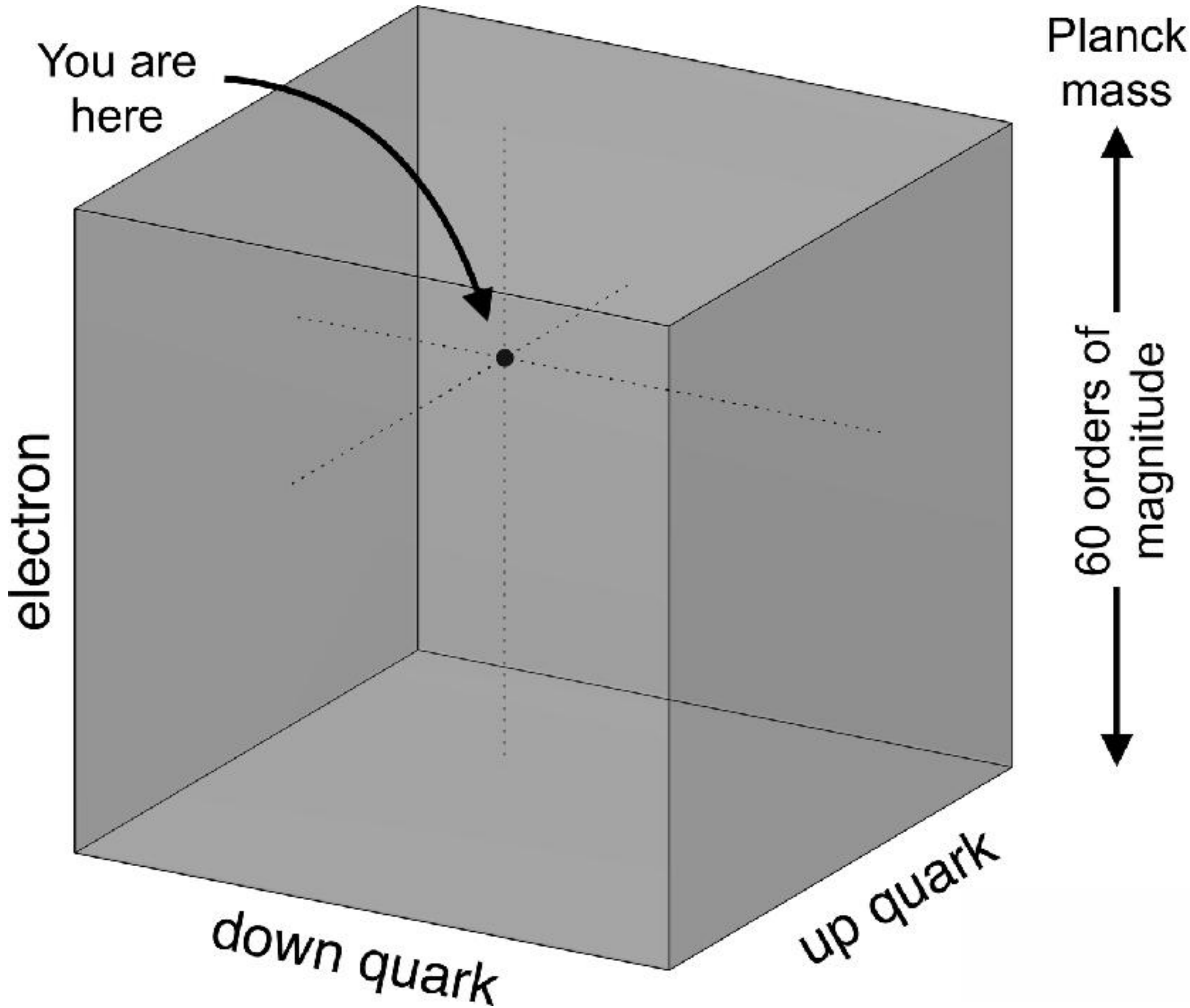
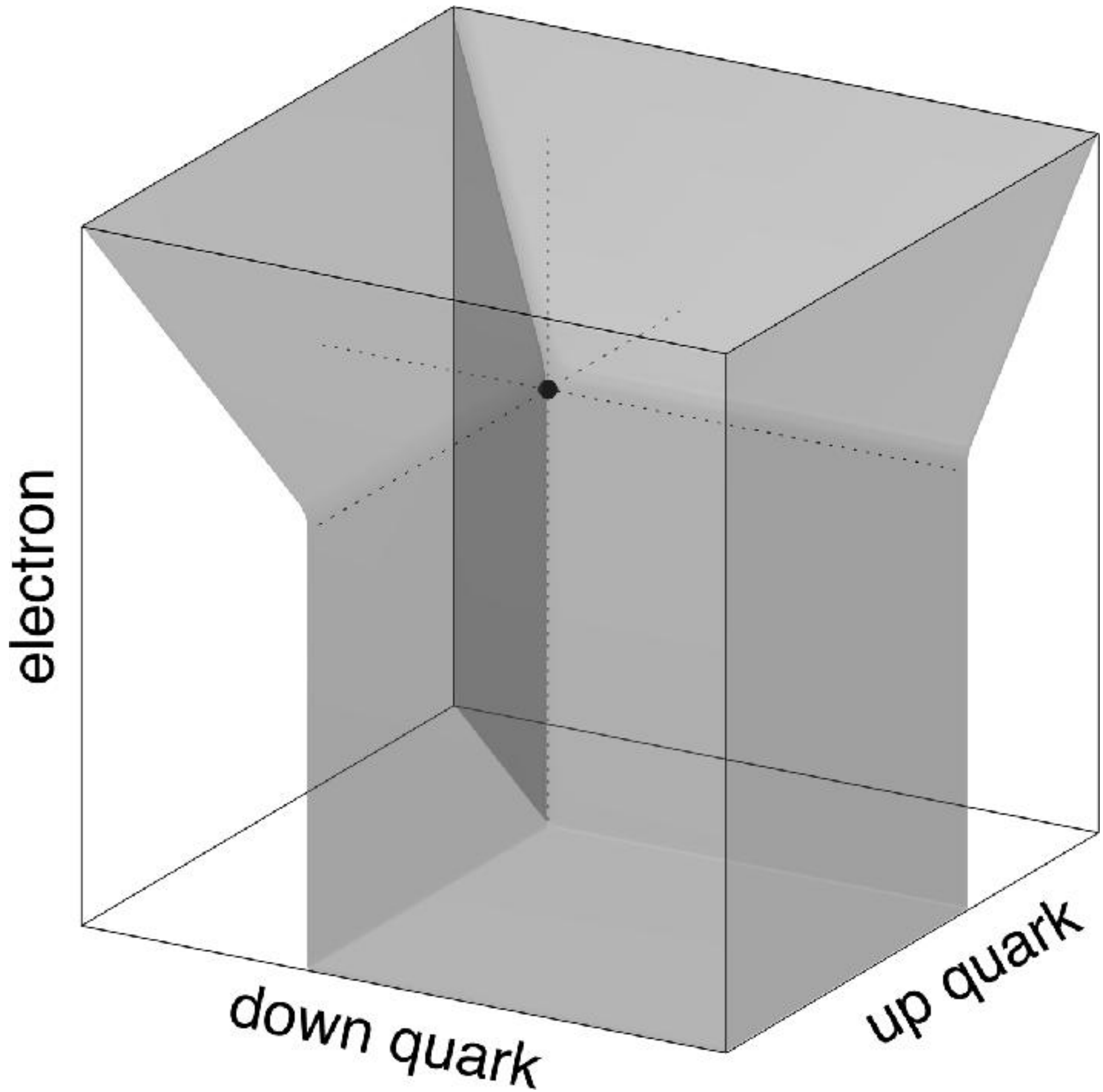
Bartol Research Institute, University of Delaware, Newark, Delaware 19716, USA

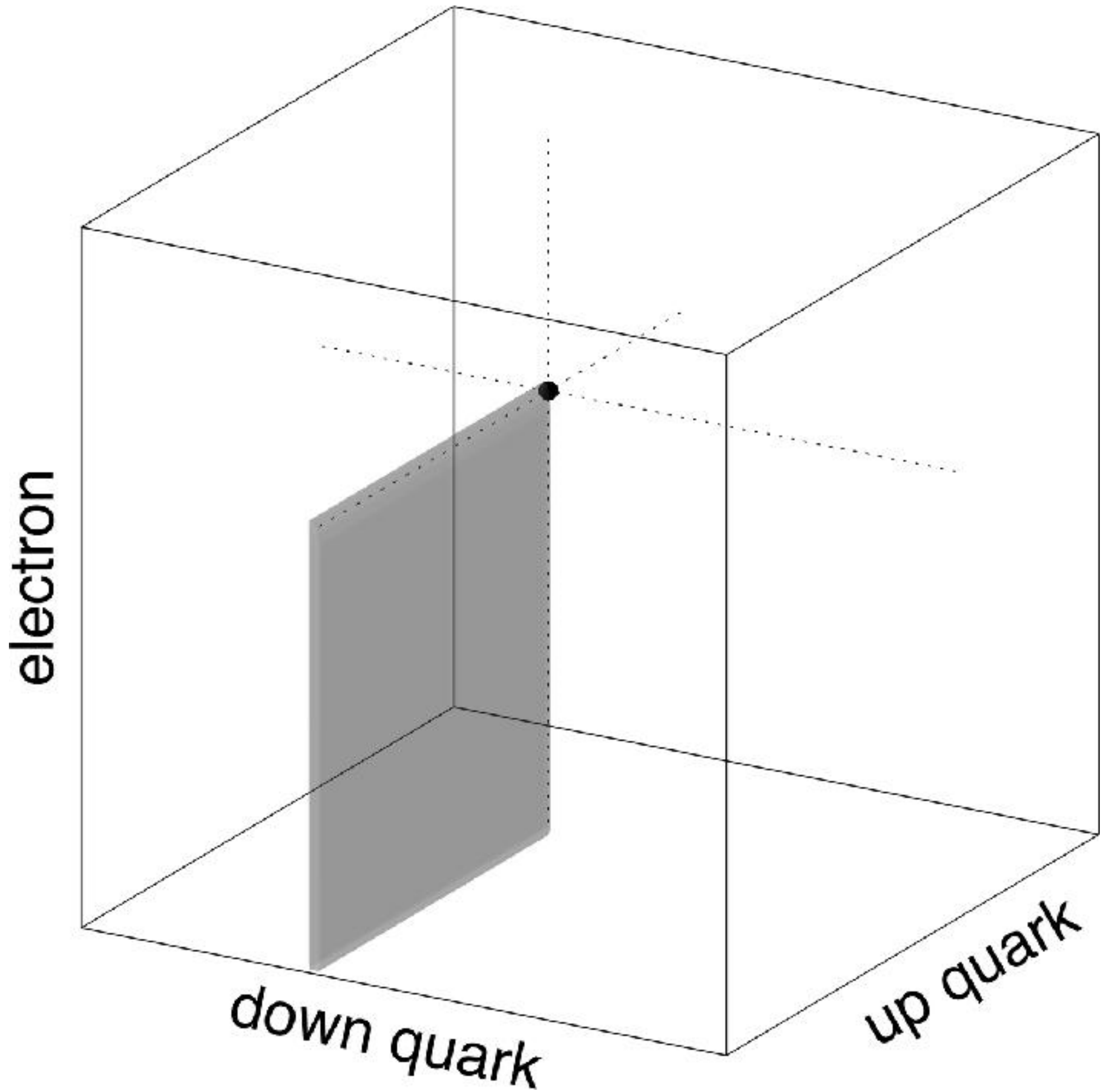
(Received 20 April 2007; published 6 August 2007)

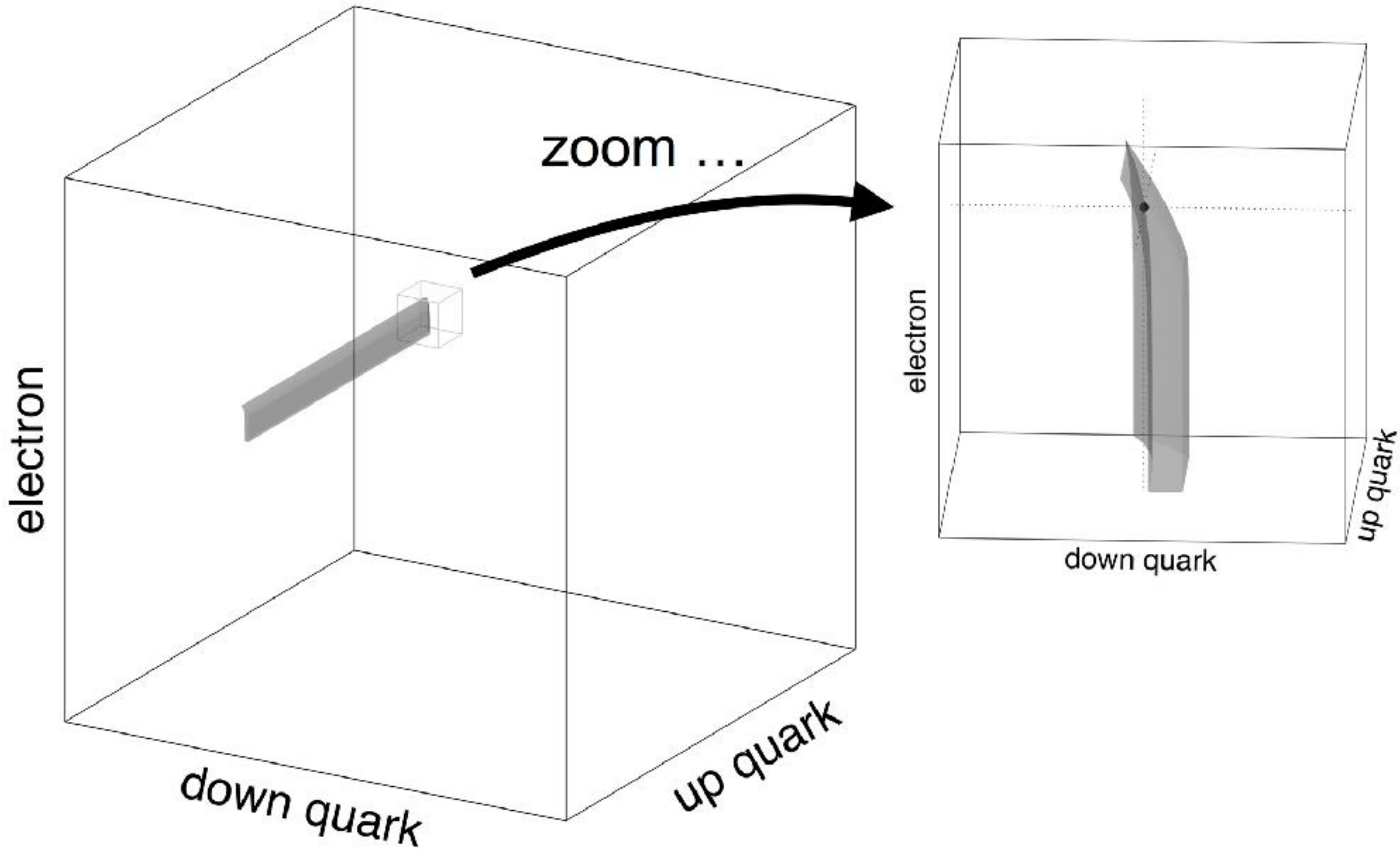
It is shown that, in a model in which up-type and down-type fermions acquire mass from different Higgs doublets, the anthropic tuning of the Higgs mass parameters can explain the fact that the observed masses of the d and u quarks are nearly the same with d slightly heavier. If Yukawa couplings are assumed not to scan (vary among domains), this would also help explain why t is much heavier than b. It is also pointed out that the existence of dark matter invalidates some earlier anthropic arguments against the viability of domains where the standard model Higgs has positive μ^2, but makes other even stronger arguments possible.

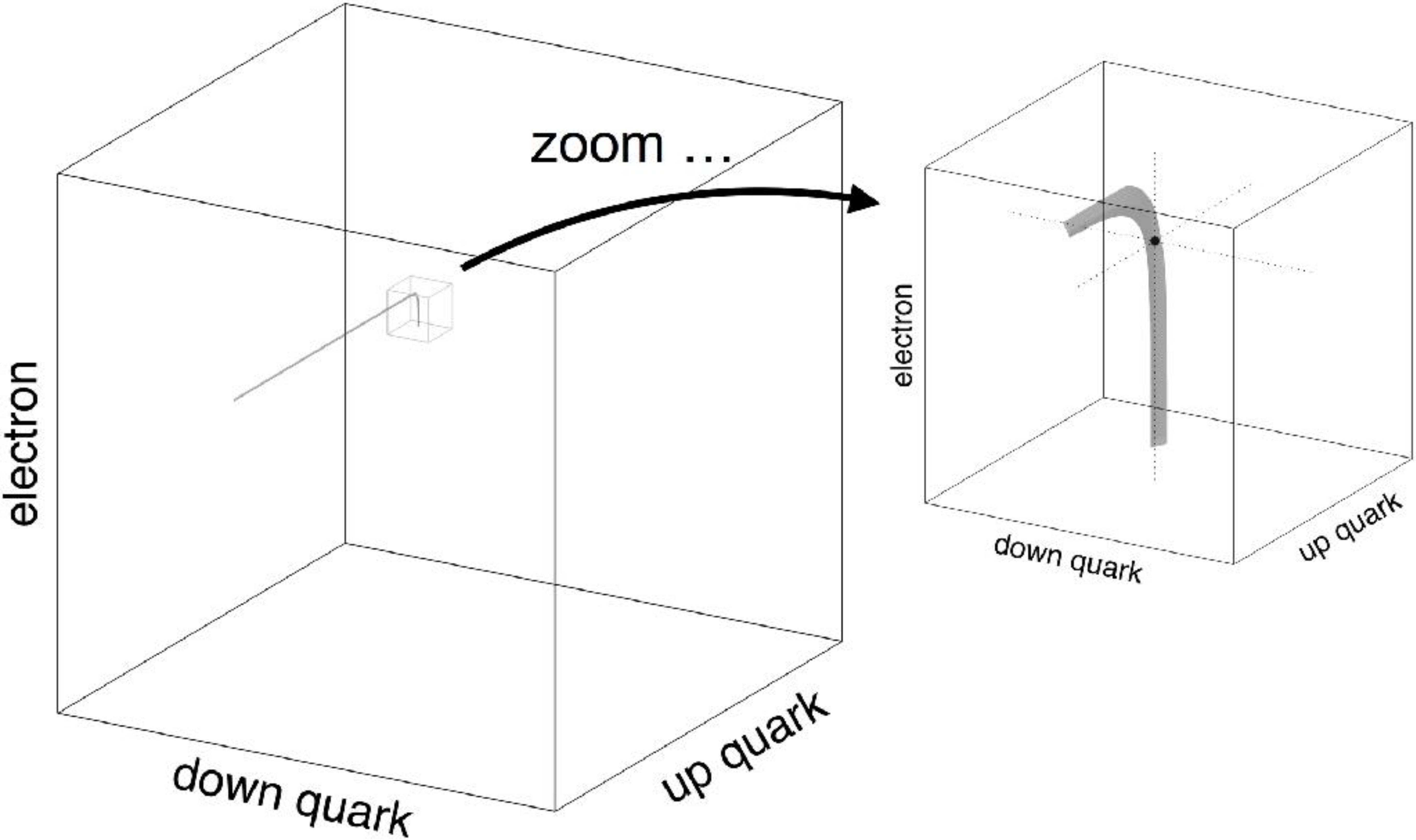
DOI: 10.1103/PhysRevD.76.045002 PACS numbers: 12.10.Dm


You are here
Planck mass
60 orders of magnitude
electron
down quark
up quark


electron
down quark
up quark


electron
down quark
up quark


zoom ...
electron
down quark
up quark
electron
down quark
up quark


zoom ...
electron
down quark
up quark
electron
down quark
up quark

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

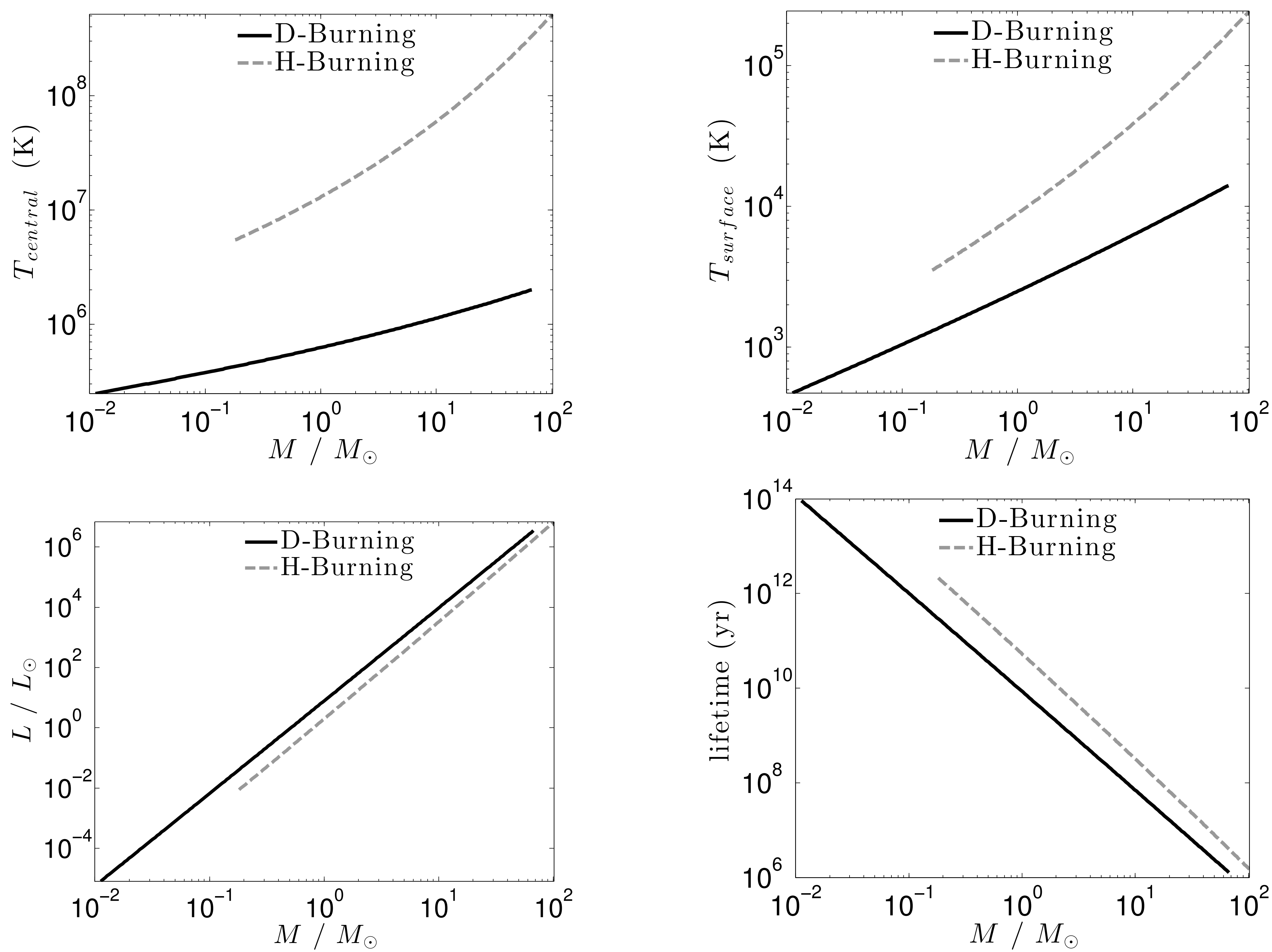
Binding the diproton in stars: anthropic limits on the strength of gravity

Luke A. Barnes

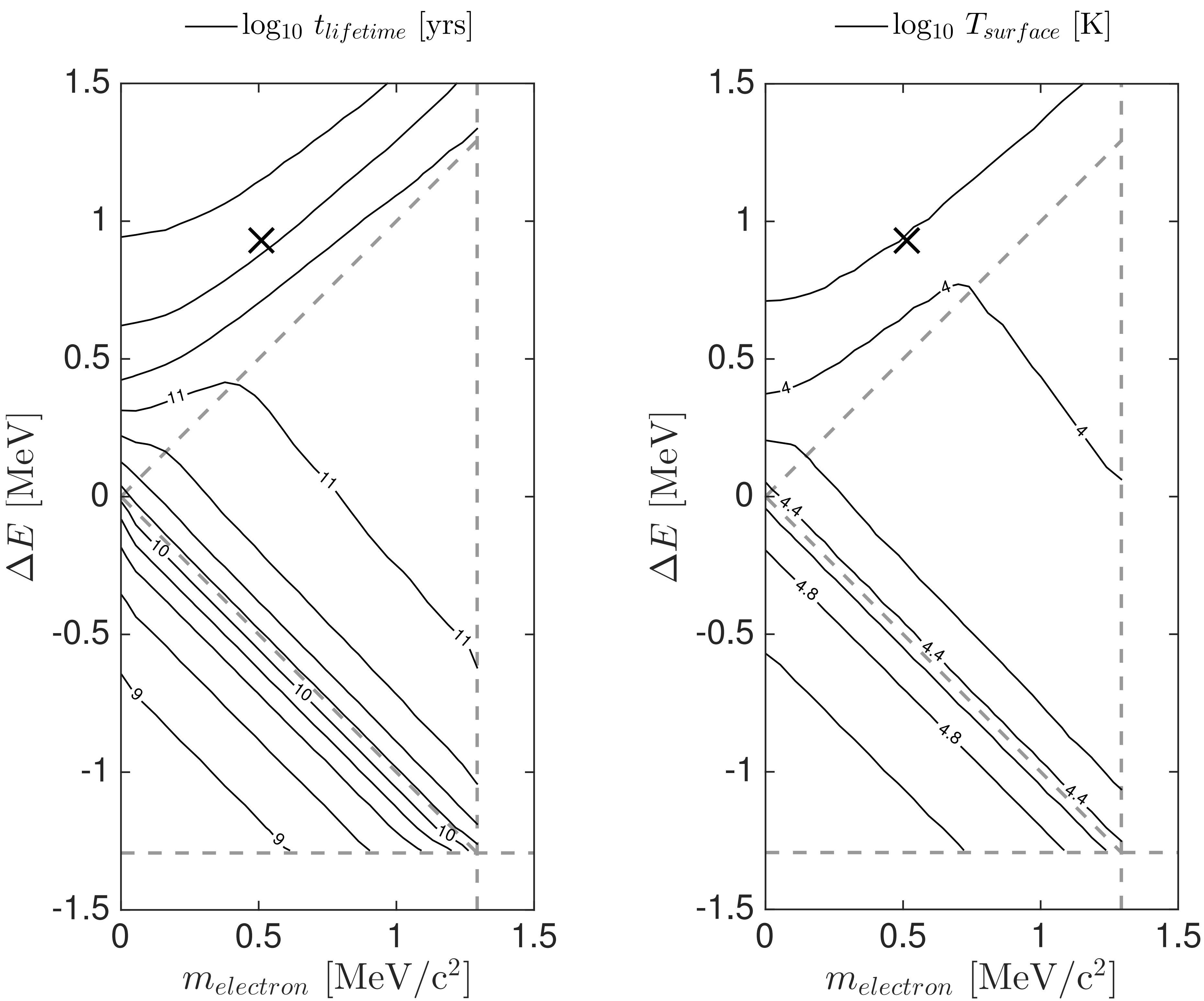
Prepared for submission to JCAP

Producing the Deuteron in Stars: Anthropic Limits on Fundamental Constants

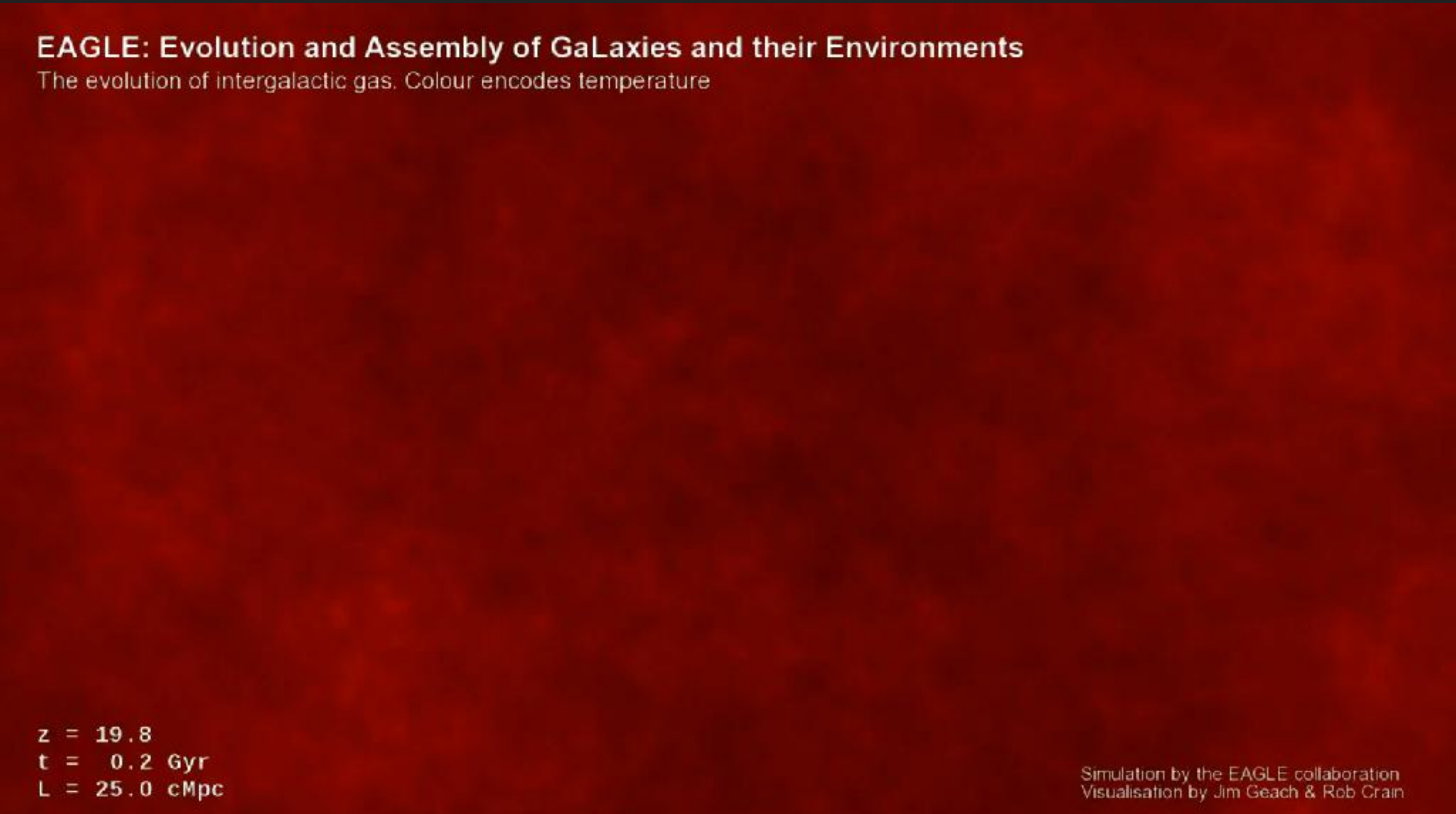
Luke A. Barnes and Geraint F. Lewis[a]



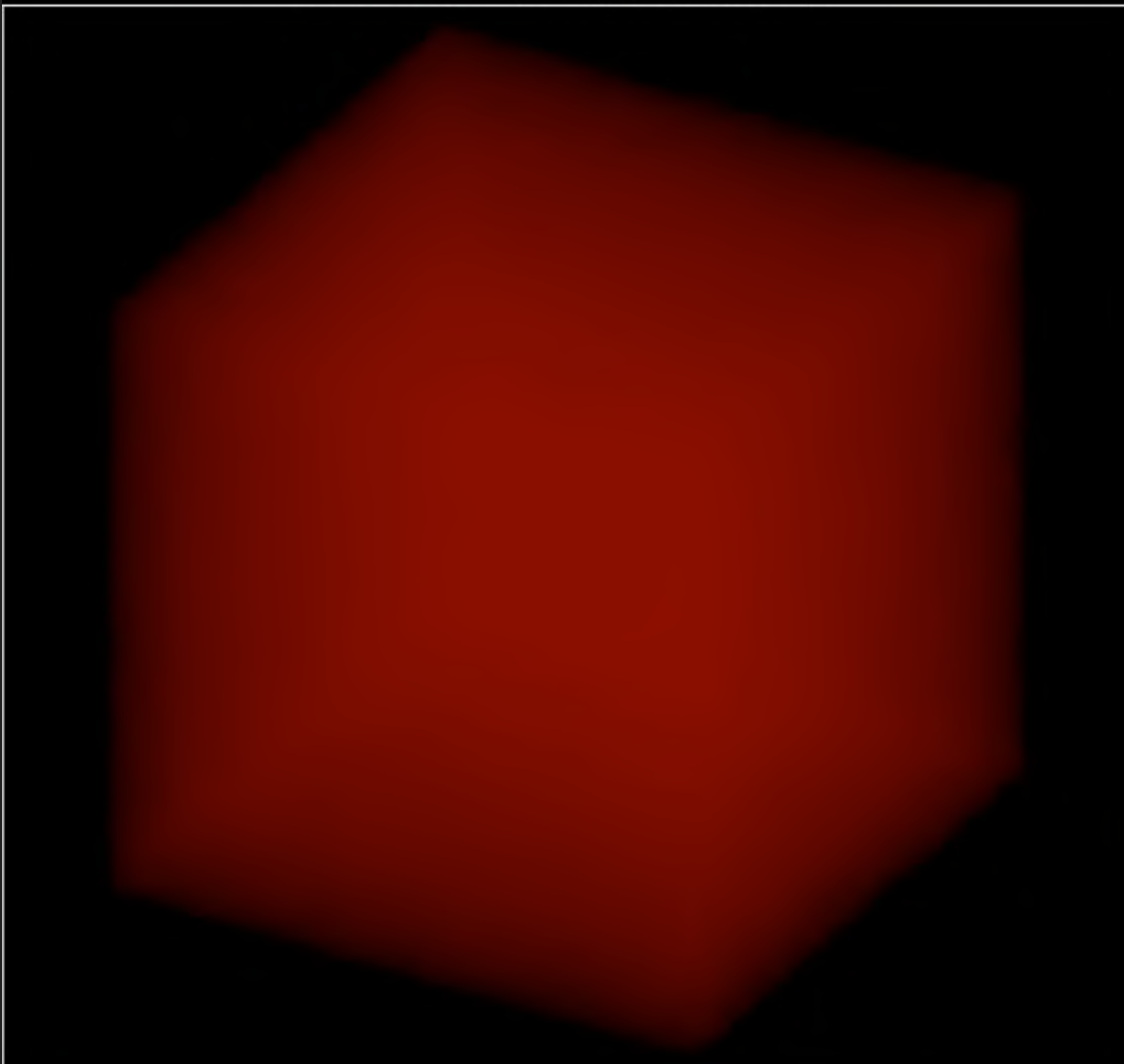
D-Burning
H-Burning
$T_{central}$ (K)
10^6
10^7
10^8
$T_{surface}$ (K)
10^3
10^4
10^5
L / $L_\odot$
10^{-4}
10^{-2}
10^0
10^2
10^4
10^6
lifetime (yr)
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{-2}
10^{-1}
10^0
10^1
10^2
M / $M_\odot$

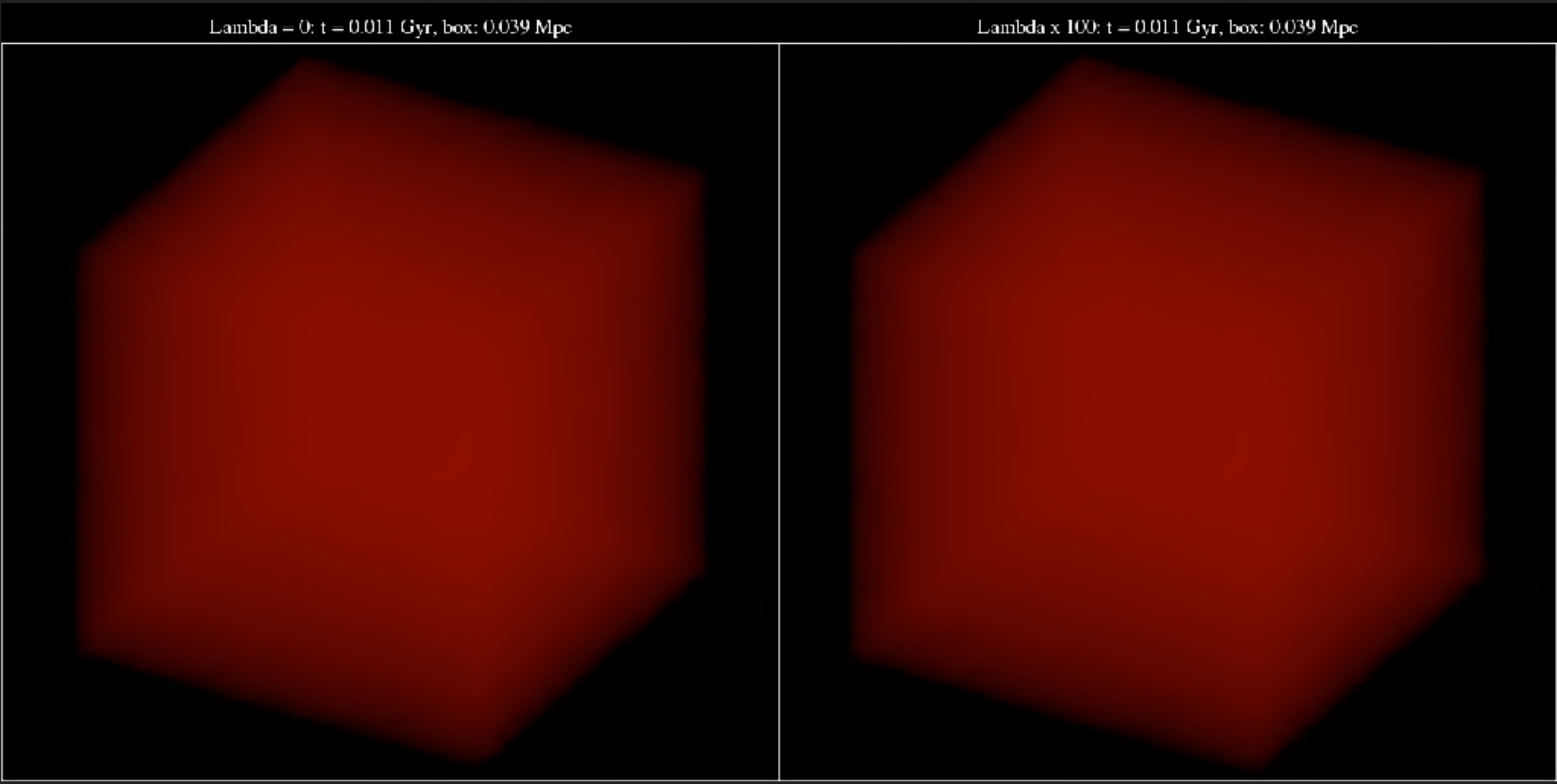


$$\Delta E = B_D - (m_n - m_p)$$


EAGLE: Evolution and Assembly of GaLaxies and their Environments
The evolution of intergalactic gas. Colour encodes temperature
z = 19.8
t = 0.2 Gyr
L = 25.0 cMpc
Simulation by the EAGLE collaboration
Visualisation by Jim Geach & Rob Crain

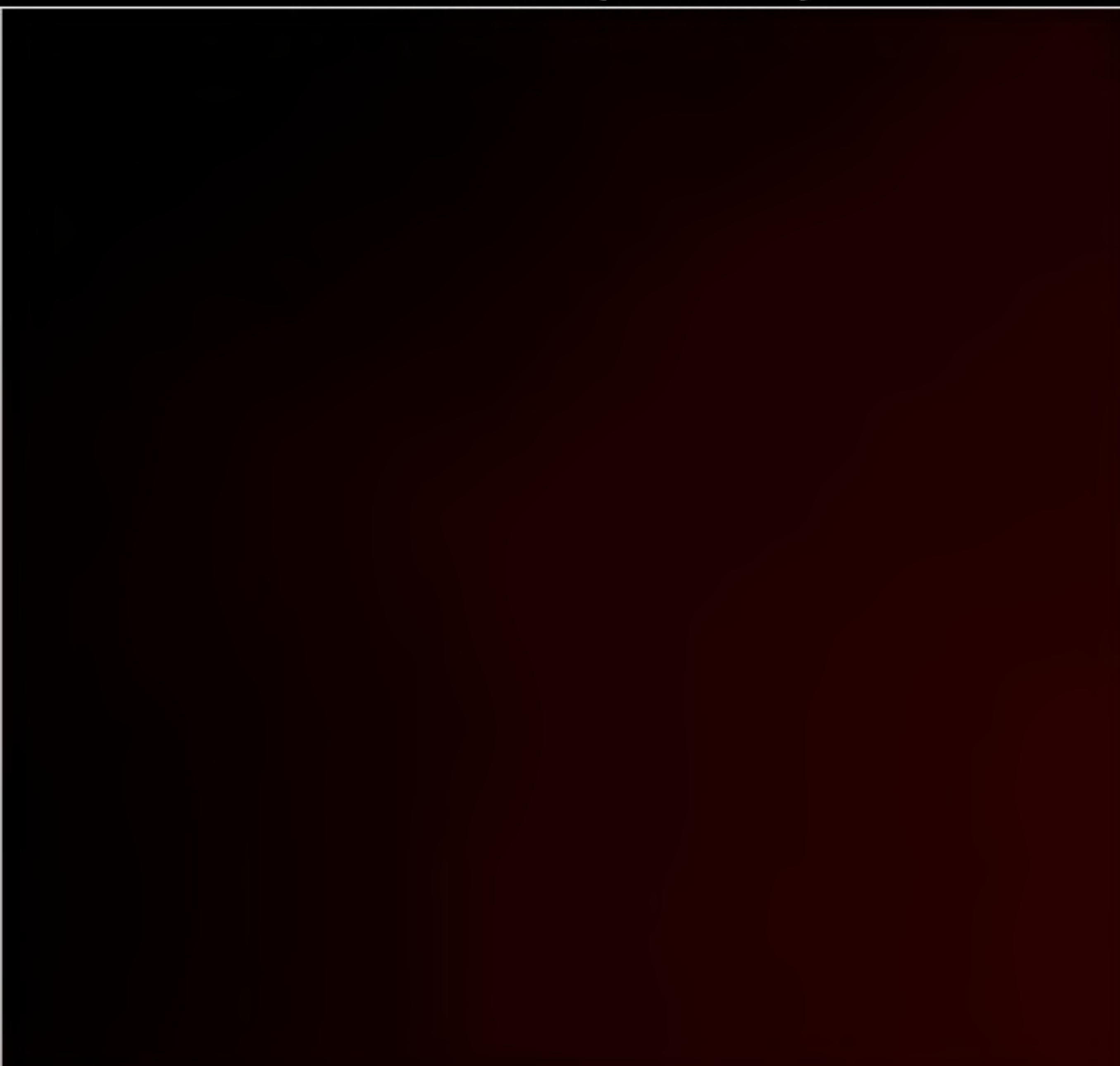
Lambda = 0: t = 0.011 Gyr, box: 0.039 Mpc



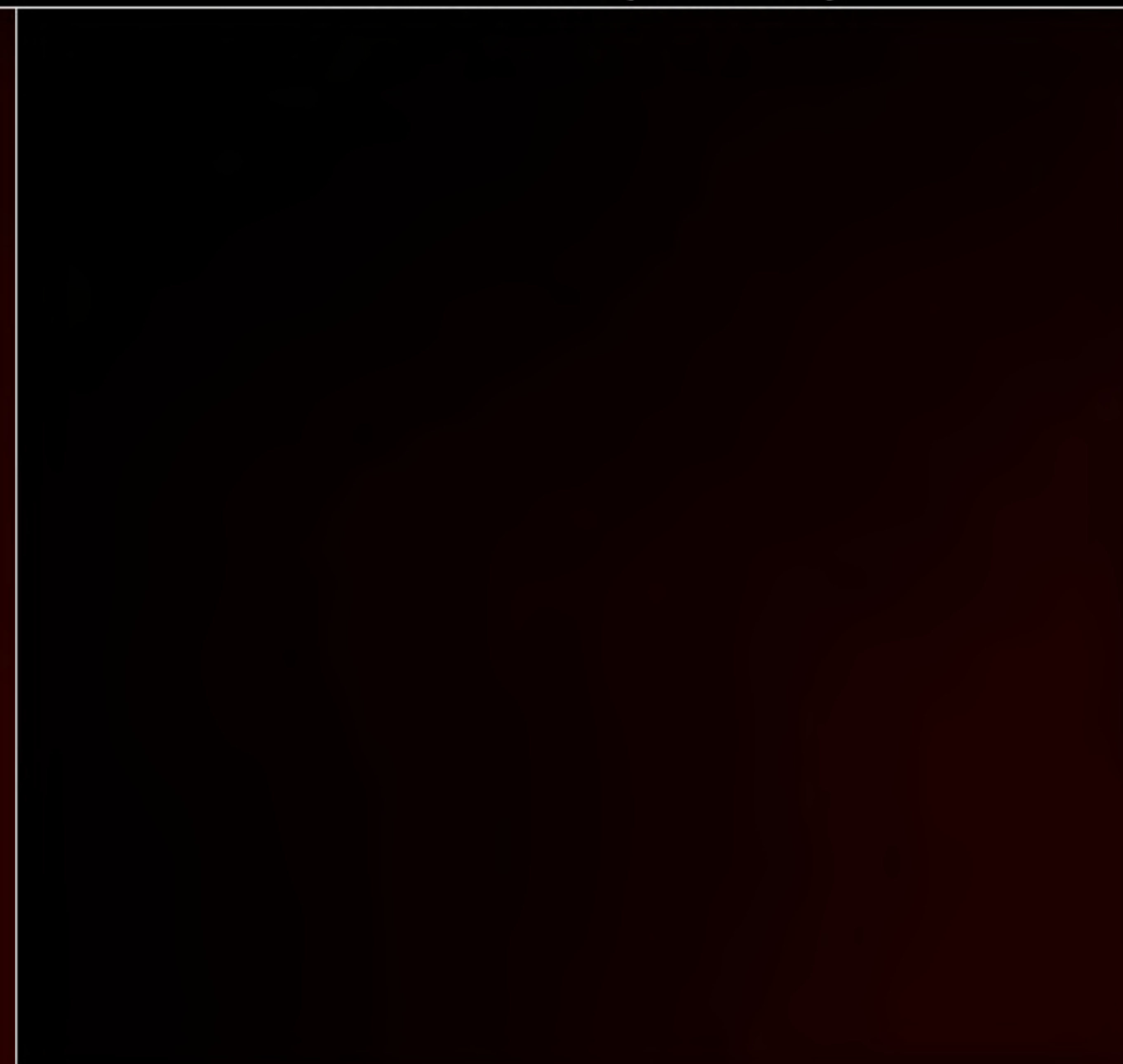


Lambda = 0: t = 0.011 Gyr, box: 0.039 Mpc
Lambda x 100: t = 0.011 Gyr, box: 0.039 Mpc

Lambda = 0: t = 0.011 Gyr, box: 0.039 Mpc



Lambda x 100: t = 0.011 Gyr, box: 0.039 Mpc

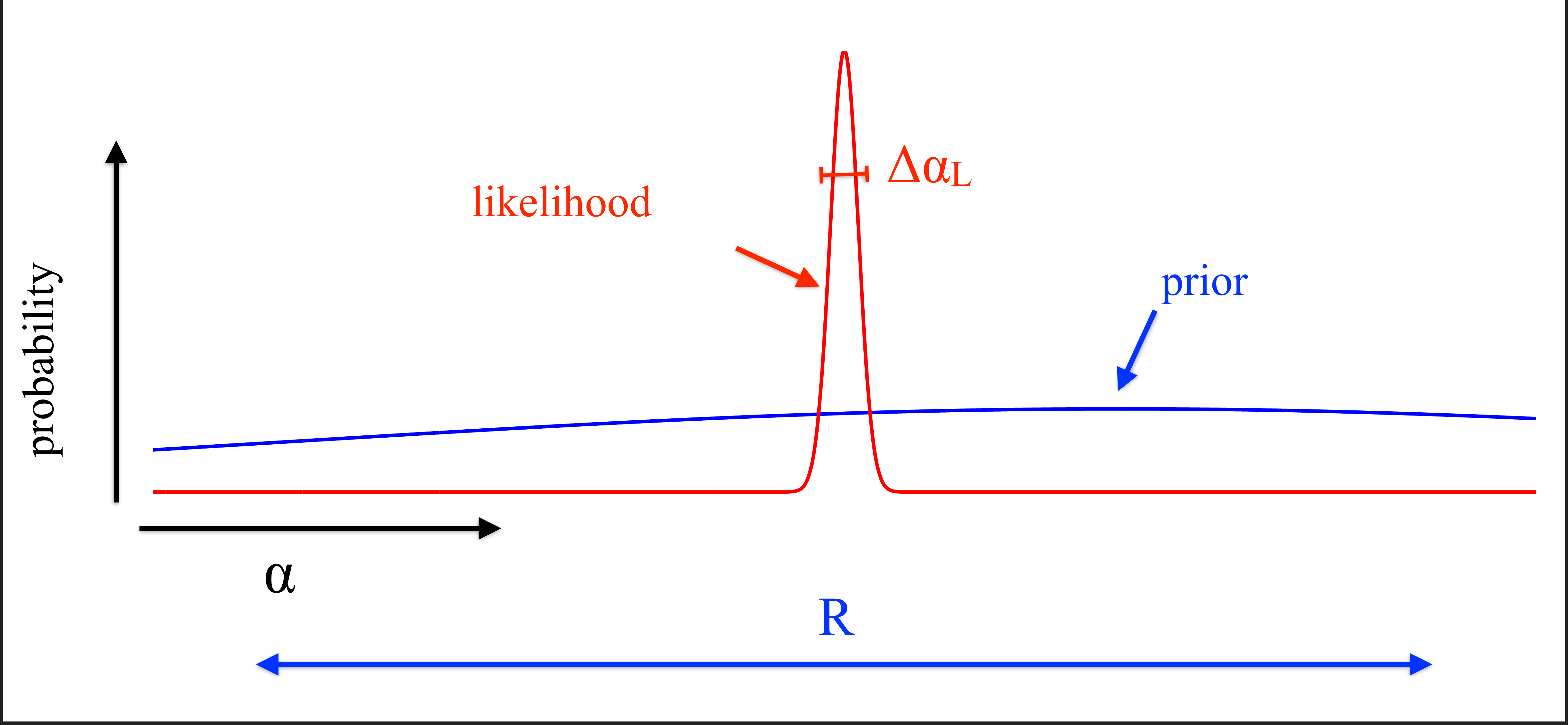


TO DO

- Deuteron binding energy
  - Lattice QCD is "still unclear" on dependence on quark masses
- Supernovae
- Structure formation and cosmic parameters
- Planetary disasters

WAY FORWARD 2: RIGOROUS PROBABILITIES

$$p(D|TB) = \int p(D|\alpha TB)\ p(\alpha|TB)\ d\alpha$$



THE NORMALISATION PROBLEM

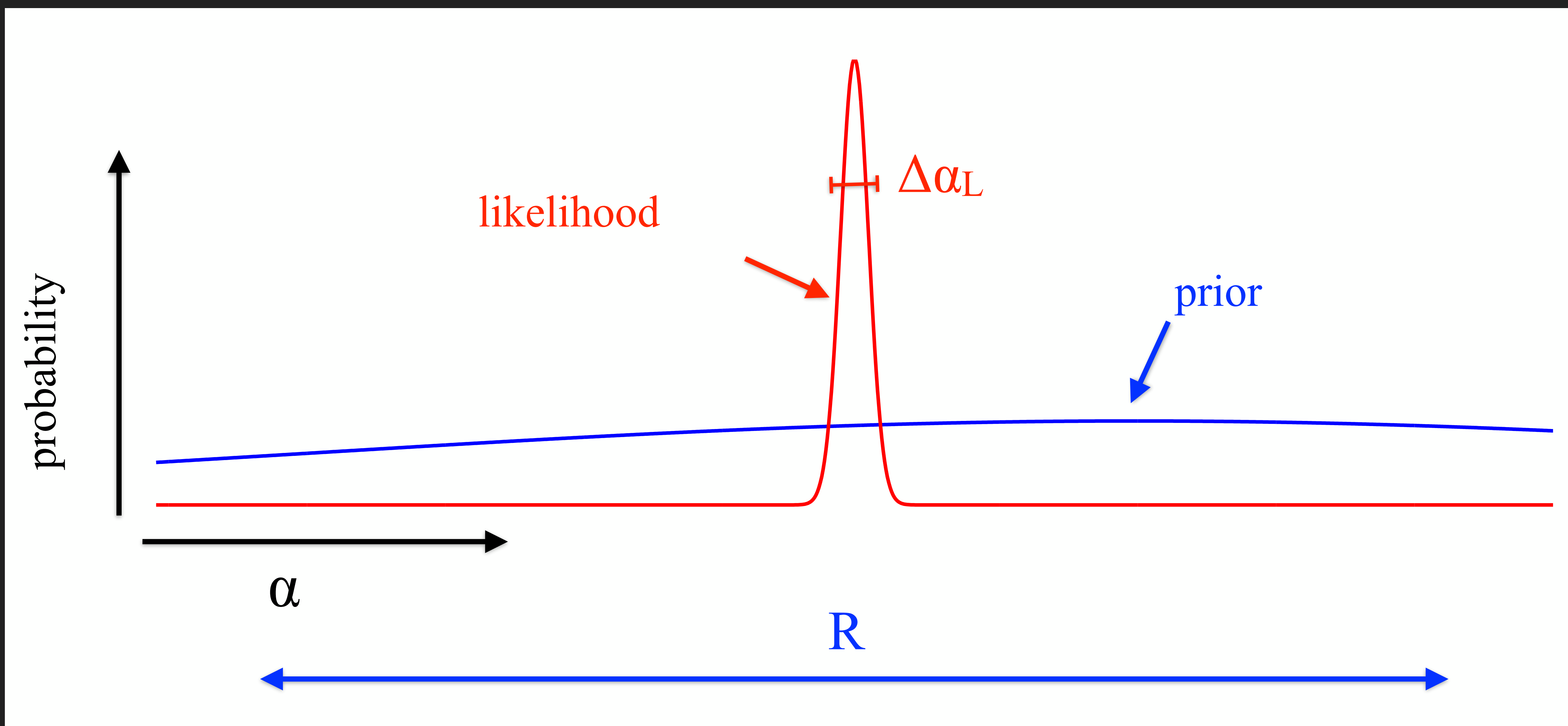
The field of possible values for the parameters appears to be an interval of real numbers unbounded at least in the upward direction. There is no logical restriction on the strength of the strong nuclear force, the speed of light, or the other parameters in the upward direction. We can represent their possible values as the values of a real variable in the half-open interval [0, ∞) …

The critical point is that the Euclidean measure function described above is not normalizable. If we assume every value of every variable to be as likely as every other … there is no way to 'add up' the regions so as to make them sum to one.

McGrew, McGrew & Vestrup (2001)
Probabilities and the Fine-Tuning Argument: A Sceptical View
See also: Colyvan, Garfield & Priest (2005)

$$p(T|DB) = \frac{p(D|TB)\, p(T|B)}{p(D|B)}$$

$$p(D|TB) = \int p(D|\alpha TB)\, p(\alpha|TB)\, d\alpha$$



THE PRIOR OVER PARAMETERS

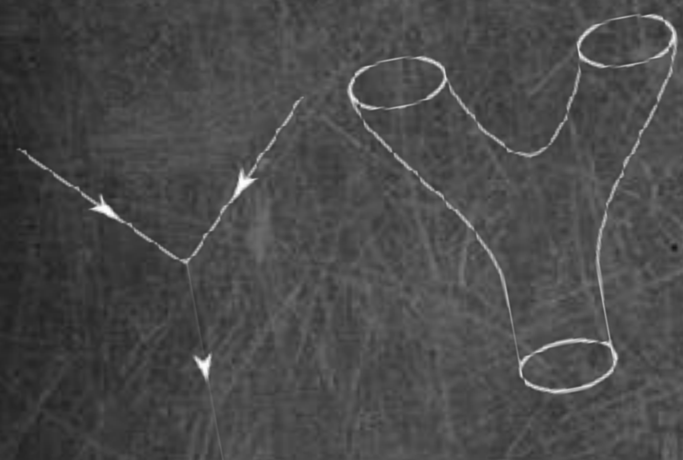
$$p(\alpha|TB)$$

- A normalisable prior must be provided by the theory itself.
  - This is not a special stipulation of fine-tuning, but the general conditions on any theory with free parameters to be (Bayesian) testable.

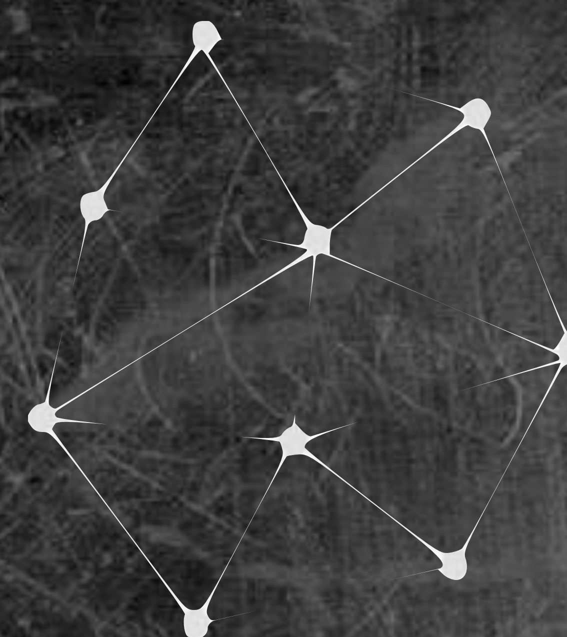
TO DO

- Infinities
  - Paradoxes
  - Infinitesimals? - Brian Pitts
- What do we condition on? Observers?
- Is the multiverse hiding more fine-tuning?

WAY FORWARD 3: THE END OF PHYSICS



$$\mathcal{H} = \frac{1}{2\sqrt{\gamma}} G_{ijkl}\pi^{ij}\pi^{kl} - \sqrt{\gamma}\,{}^{(3)}R = 0$$



$$S = \frac{T}{2}\int \mathrm{d}^2\sigma \sqrt{-h}\,h^{ab} g_{\mu\nu}(X)\partial_a X^{\mu}(\sigma)\partial_b X^{\nu}(\sigma)$$

QUESTIONS

- What would it take for a deeper theory to explain fine-tuning?
  - Uber-symmetry?

$$\mathcal{L} = i\bar{\psi}\gamma^\mu \partial_\mu \psi - m\bar{\psi}\psi - e\bar{\psi}\gamma_\mu A^\mu \psi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}$$

  - Initial conditions?
- Even if we had the ultimate laws, would we still be complaining?
  - Testing naturalism