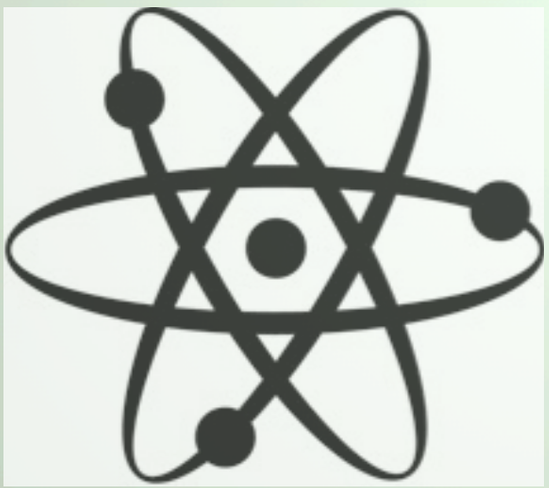
The Fine-Tuning of the Universe for Life



Luke Barnes
University of Sydney

July 9, 2013

lukebarnes.info

FT: In the set of possible physical laws, parameters and initial conditions, the subset that permit the evolution of life is very small.

Leonard Susskind: The Laws of Physics are almost always deadly. In a sense the laws of nature are like East Coast weather: tremendously variable, almost always awful, but on rare occasions, perfectly lovely.

CSIRO PUBLISHING

Publications of the Astronomical Society of Australia, 2012, **29**, 529–564
http://dx.doi.org/10.1071/AS12015

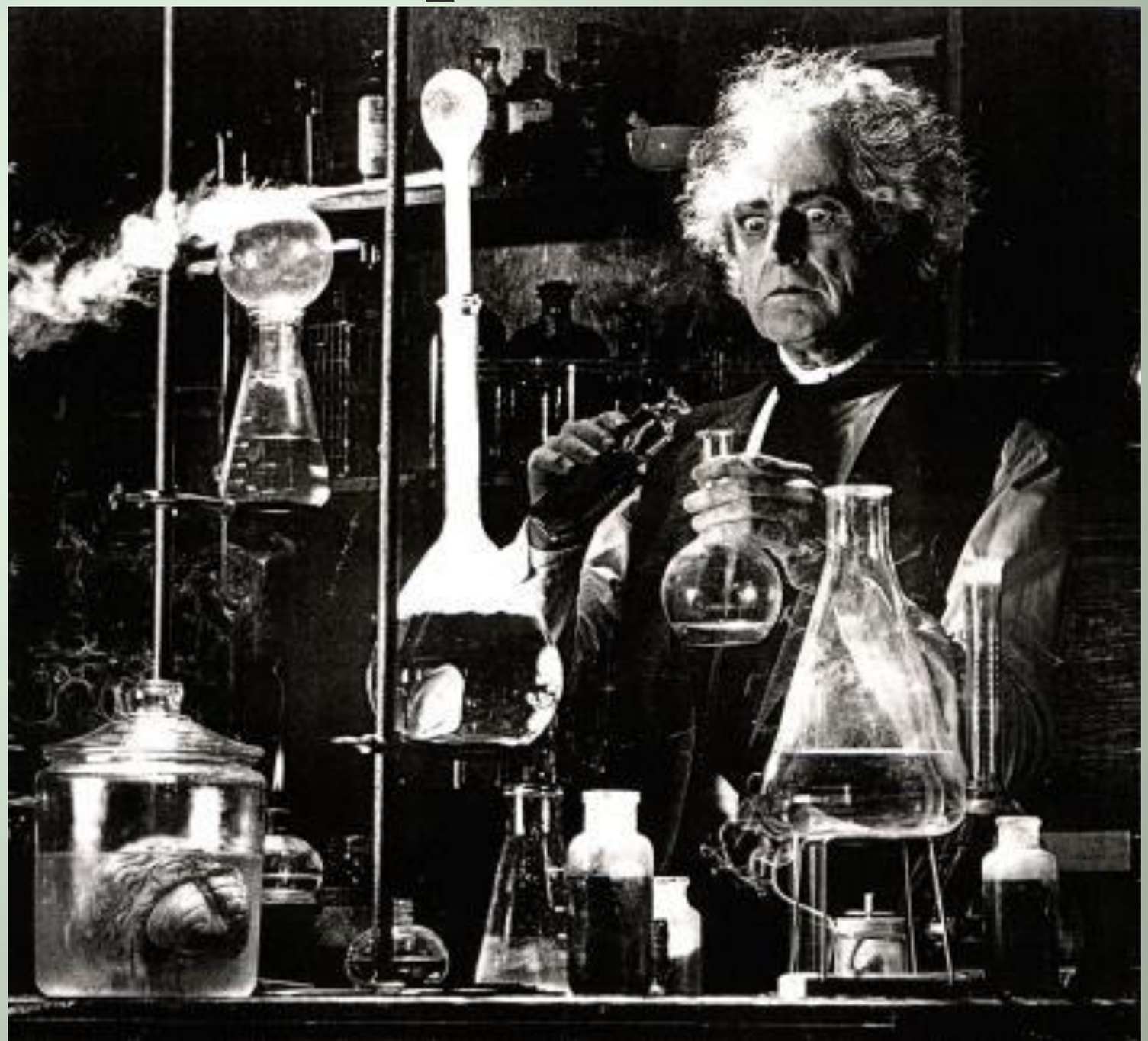
Review

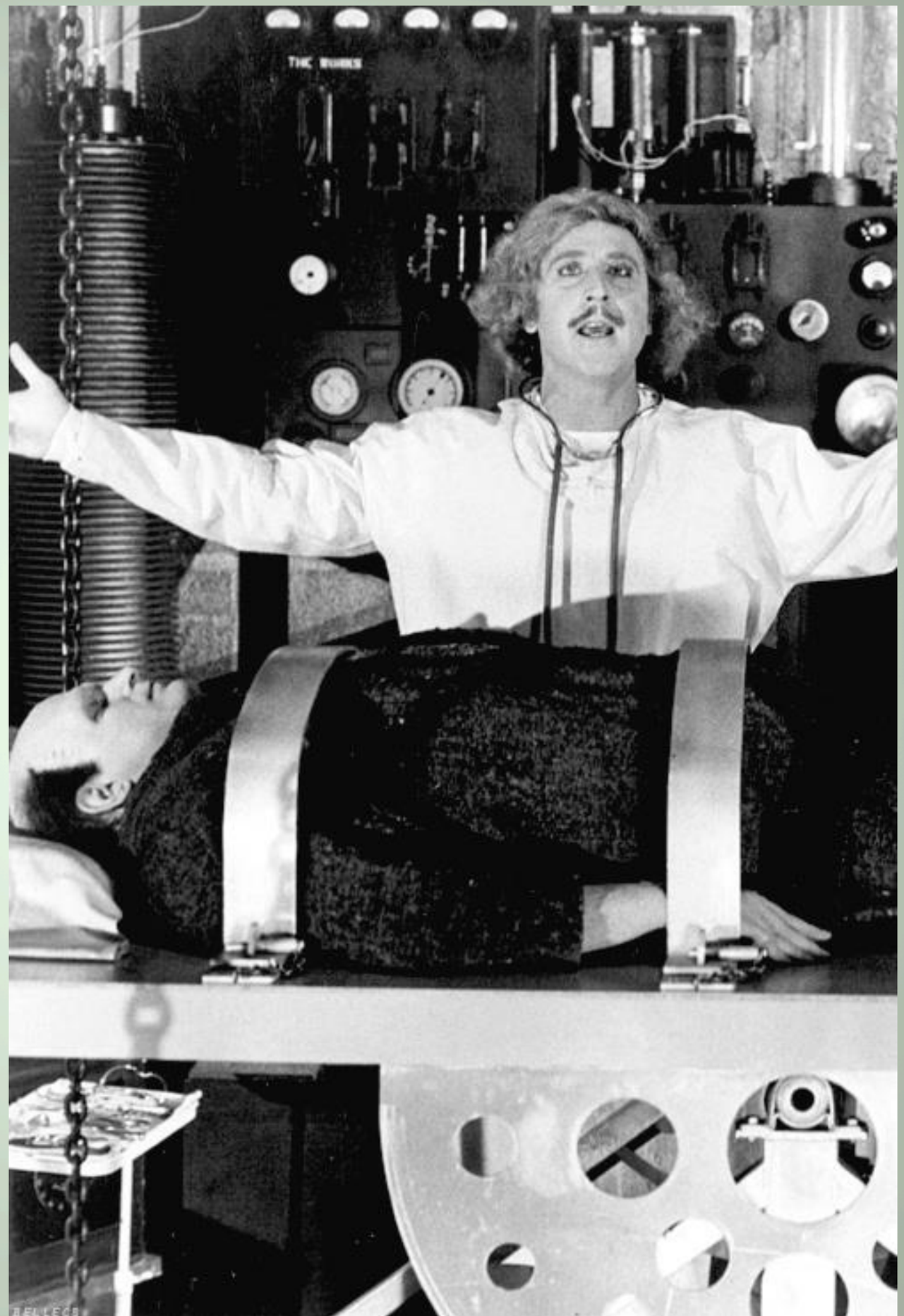
The Fine-Tuning of the Universe for Intelligent Life

L. A. Barnes

Institute for Astronomy, ETH Zurich, Switzerland, and Sydney Institute for Astronomy, School of Physics, University of Sydney, Australia.

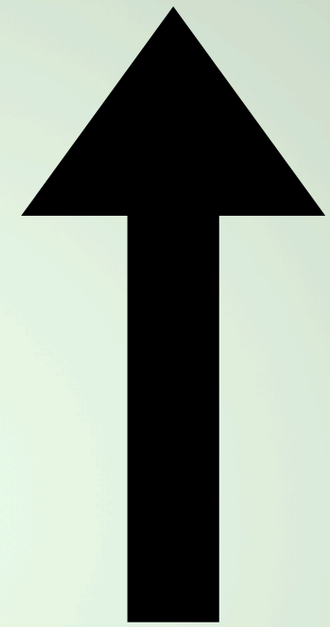
The universe is not an experiment





Reproduction

Metabolism



e⁻ | p,n | EM | Weak force | Strong force

quarks | photon | gluons

Gravity | 3+1 D | Ωd | Ωb | Λ | Q | η | entropy

Cosmology

Reproduction

Metabolism

Biochemistry

Organic chemistry

H

C

O

M

Atoms

Nuclei

Big Bang nucleosynthesis

Stable environment

Planet

Stable orbit

Planet formation

Supernovae

Energy source

Stable star (nucleosynthesis)

Star formation

Galaxies

e^- | p,n | EM | Weak force | Strong force | Gravity | 3+1 D | Ωd | Ωb | Λ | Q | η | entropy

Reproduction

Biochemistry

Organic chemistry

- H
- C
- O
- M

Atoms

Nuclei

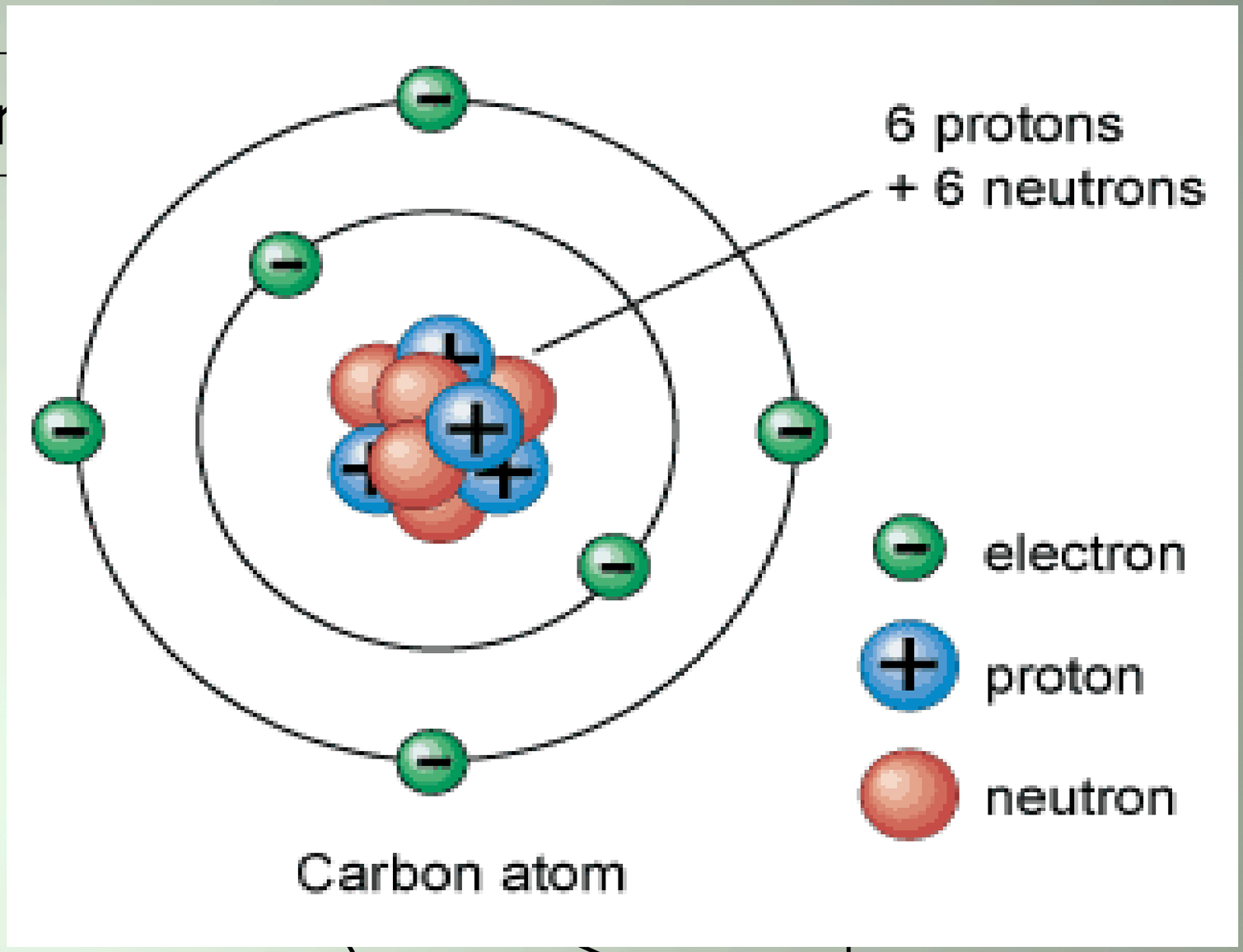
- e^-
- p,n
- EM
- Weak force
- Strong force

Big Bang nucleosynthesis

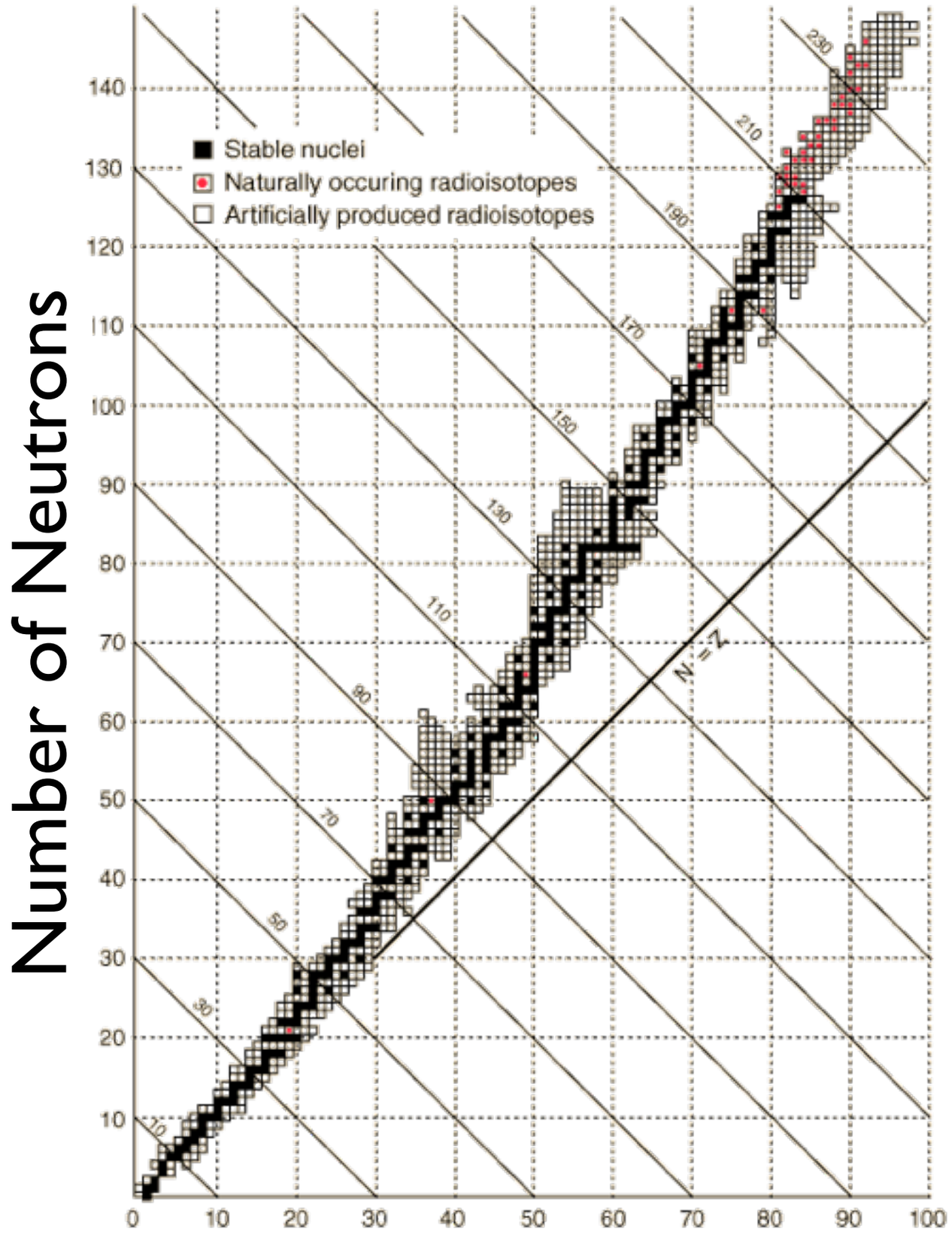
- Gravity
- 3+1 D
- Ωd
- Ωb
- Λ
- Q
- η
- entropy

Supernovae

Galaxies



Carbon atom


Stable nuclei
Naturally occuring radioisotopes
Artificially produced radioisotopes
N = Z
10
30
50
70
90
110
130
150
170
190
210
230
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Number of Neutrons
Number of Protons

Reproduction

Biochemistry

Organic chemistry

H

C

O

M

Atoms

Nuclei

QM

env

Planet

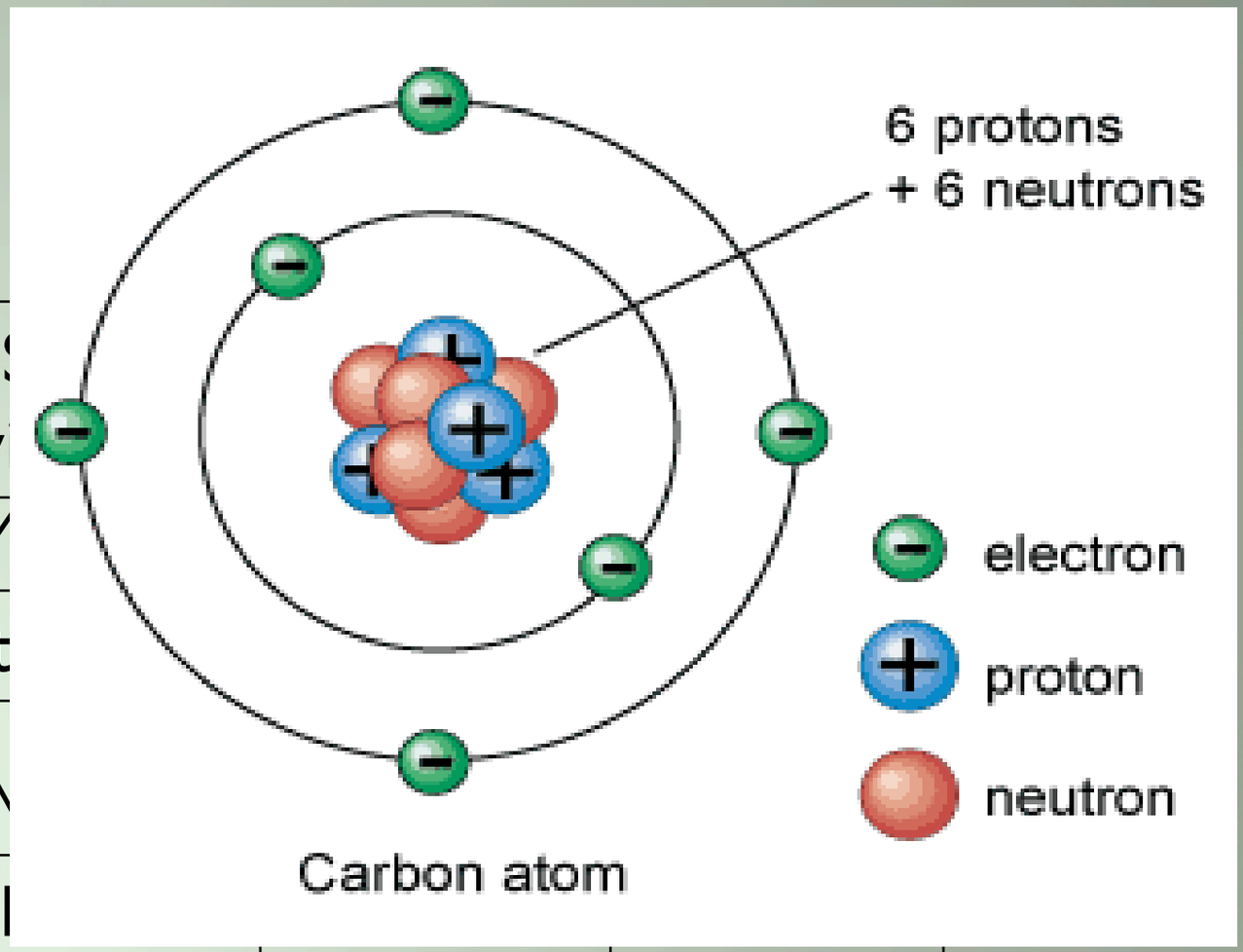
formation

formation

Supernovae

Galaxies

Big Bang nucleosynthesis



e⁻ | p,n | EM | Weak force | Strong force | Gravity | 3+1 D | Ωd | Ωb | Λ | Q | η | entropy

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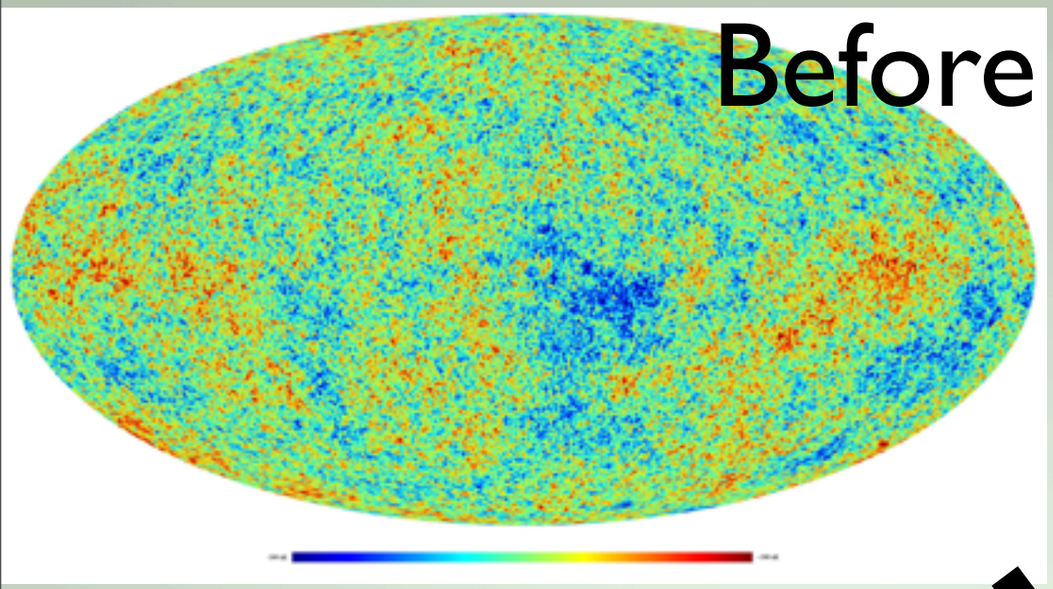

star formation

shocks

supernovae

radiative transfer

stellar winds

stellar radiation

accretion ...

Gravity

thermal physics

dark matter

disk instabilities

angular momentum

black hole formation

quasar feedback

Reproduction

Metabolism

Biochemistry

Organic chemistry

Atoms

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H

C

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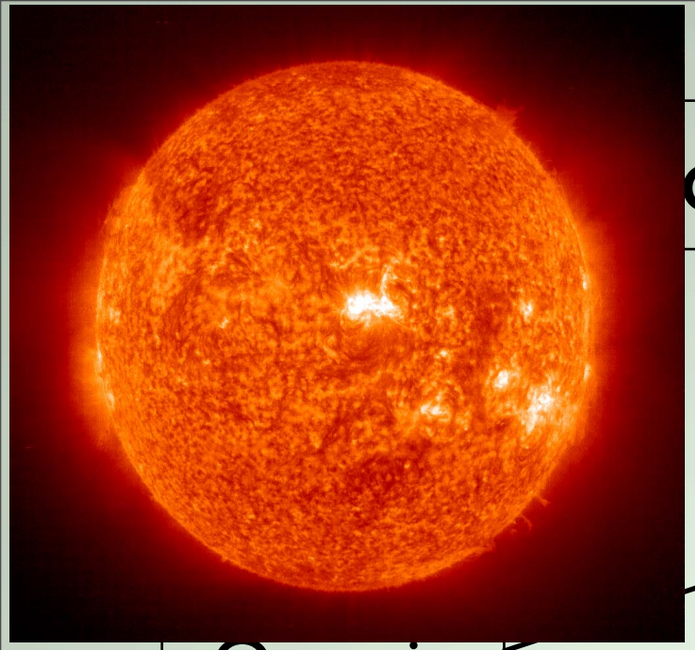

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Planet

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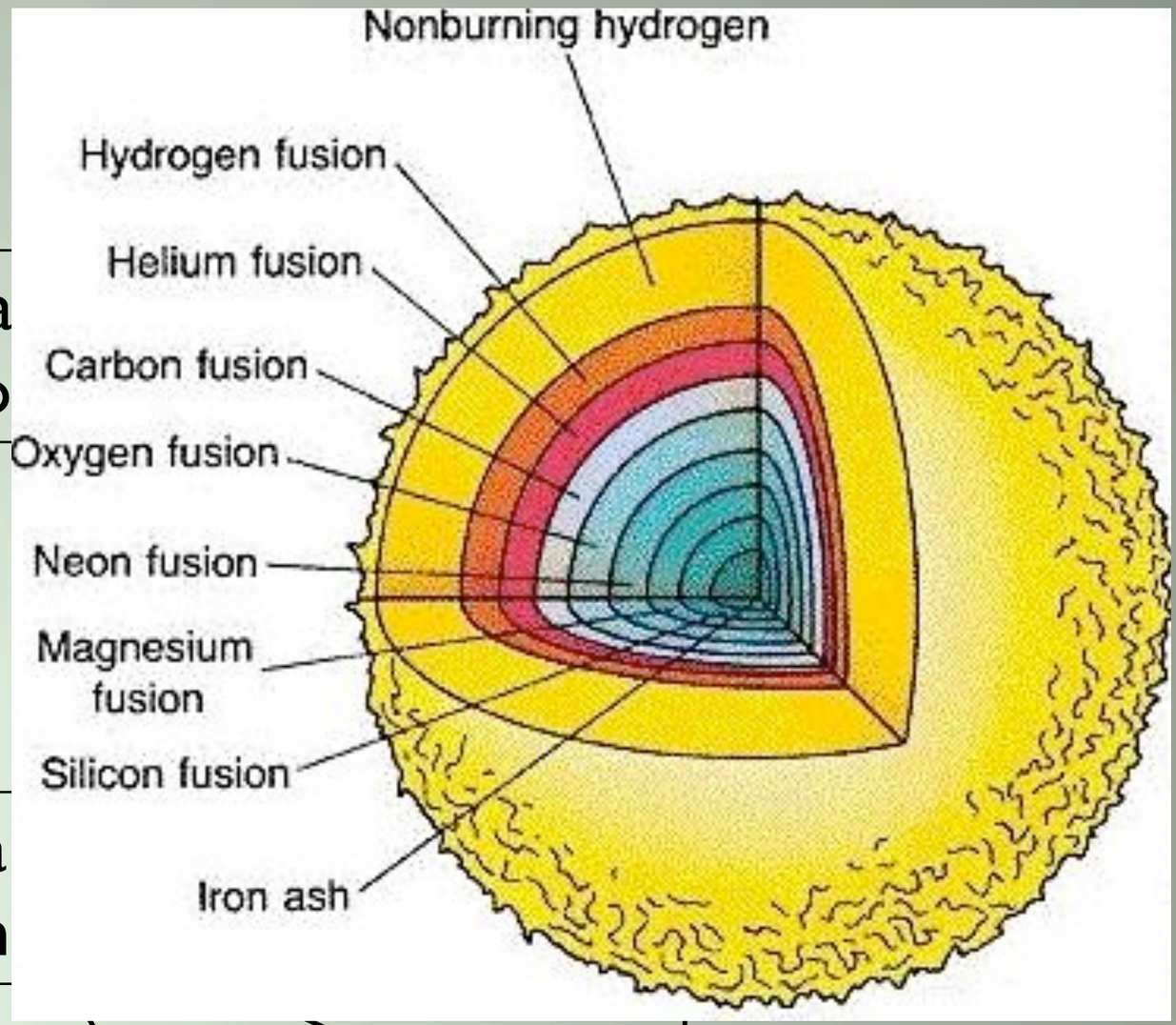

Big Bang nucleosynthesis

Supernovae

Galaxies

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Ωb

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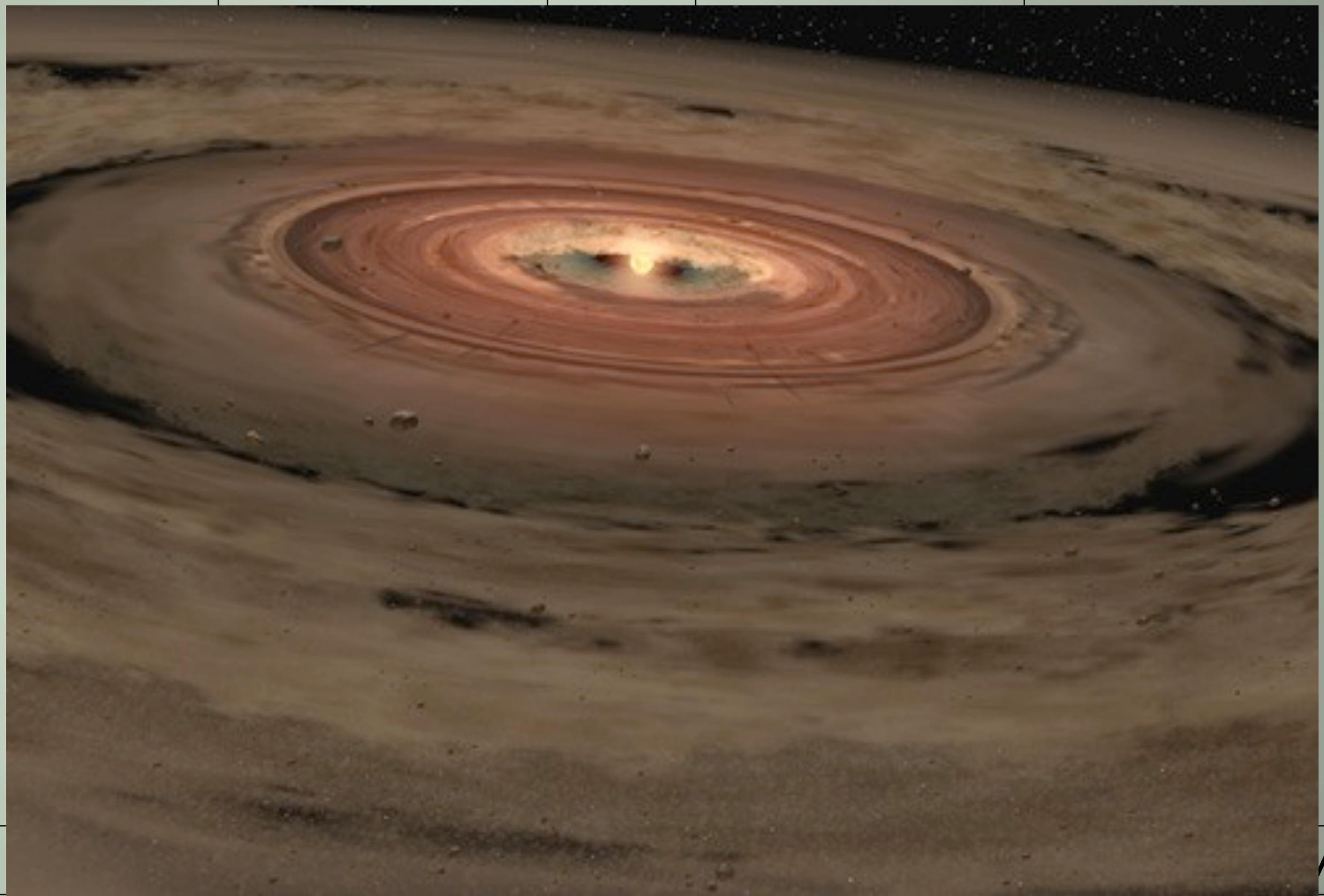
η

entropy



force

force

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e^-

p,n

EM

Weak force

Strong force

Gravity

3+1 D

Ωd

Ωb

Λ

Q

η

entropy

How to wreck everything

How to do Physics

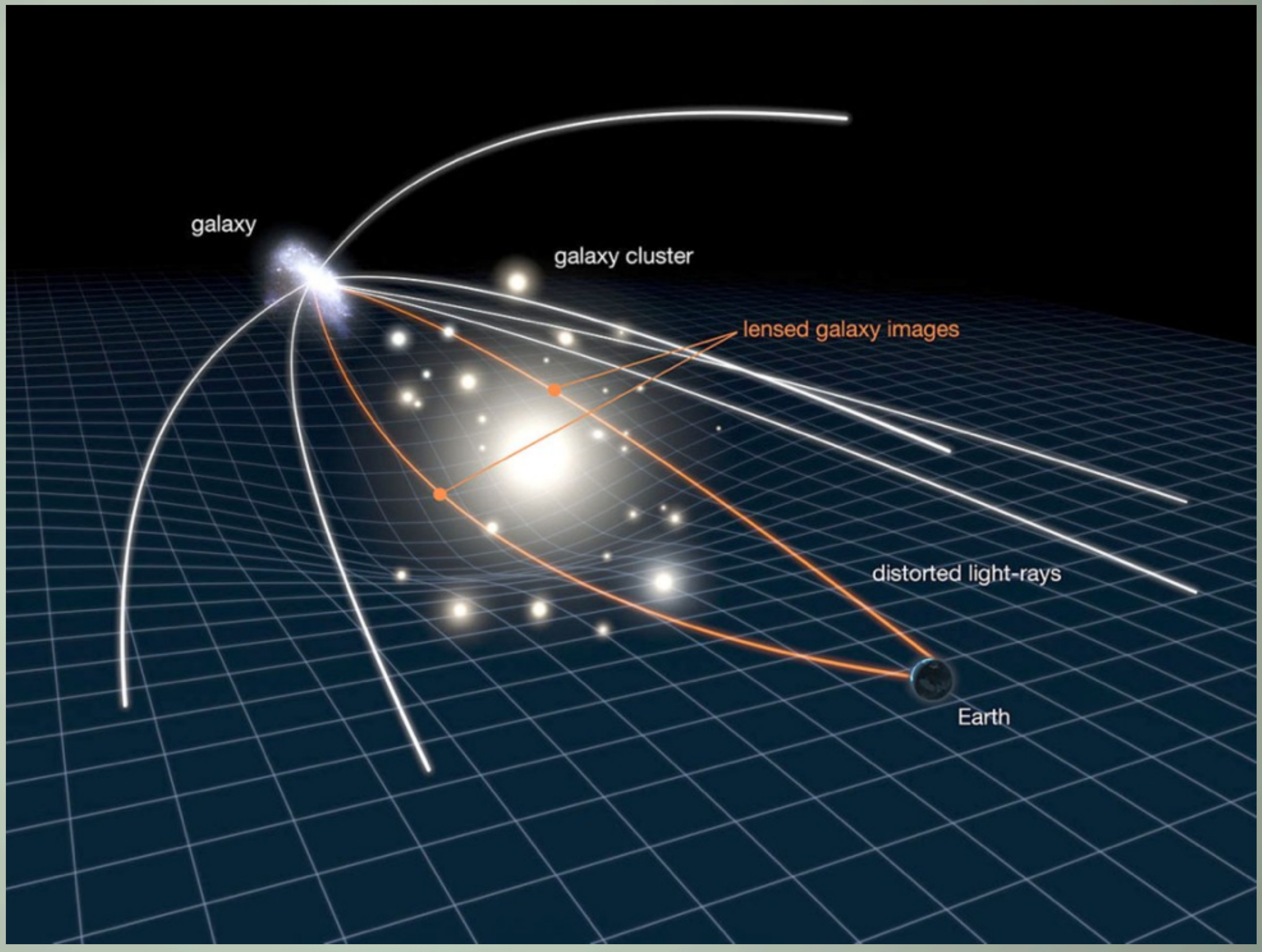
1. Start with a theory T.
2. If T is true, then we expect to observe O_T
3. Our actual observations O are consistent with O_T
4. Therefore ...

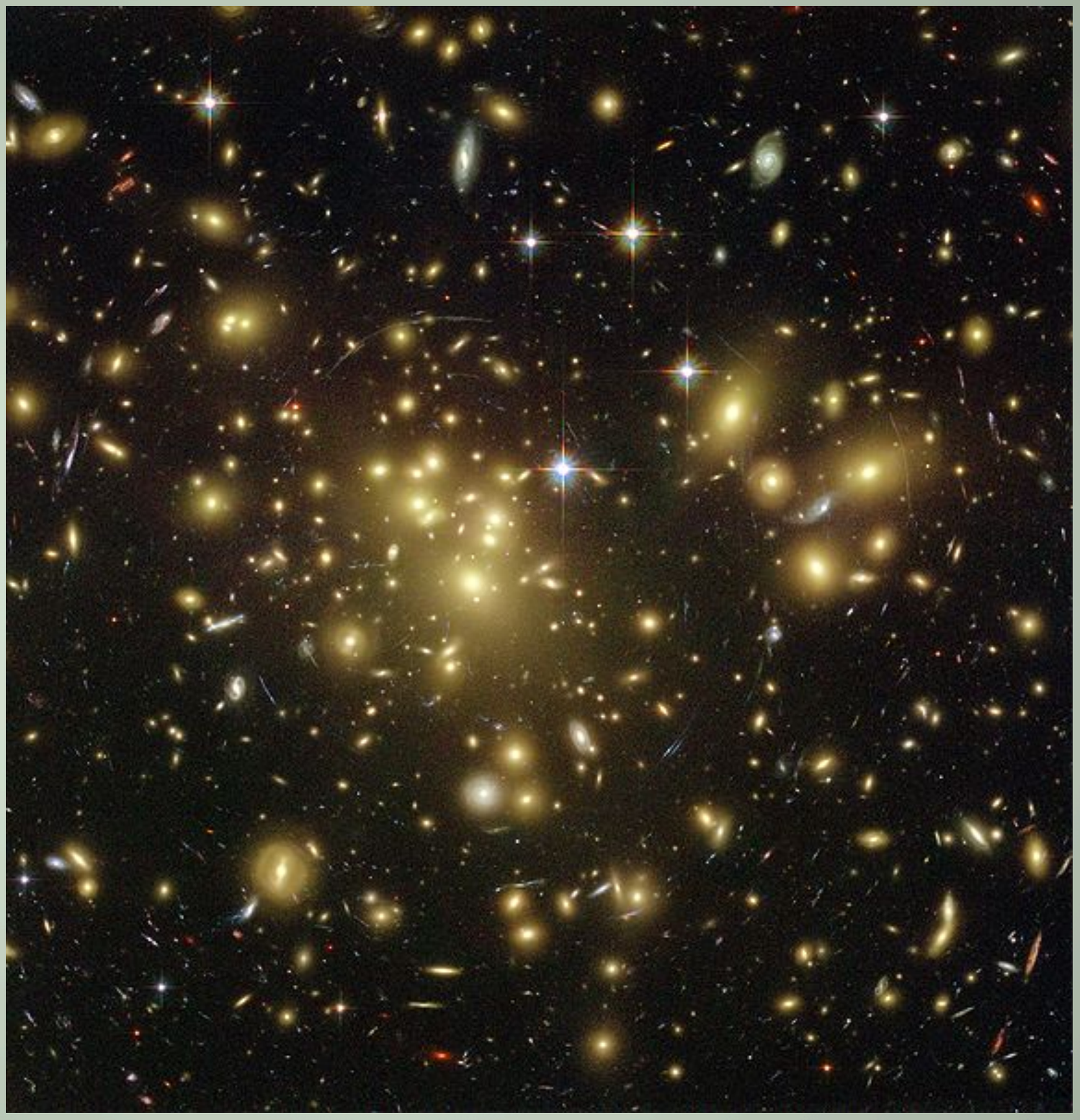
T ...

1. The laws of nature
2. The fundamental constants
3. Initial conditions

T ...

1. Law: An equation (Lagrangian)
2. Constants: the parameters of that equation
3. Initial conditions: parameters of the solution of the equation


galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth



Abell 1689, Hubble Space Telescope

Mike Hudson, University of Waterloo

http://mhvm.uwaterloo.ca/home/fun/

Bayes' Theorem

The Prior

Likelihood - how well does my theory handle the data?

Is my theory right?

$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

The competition ...

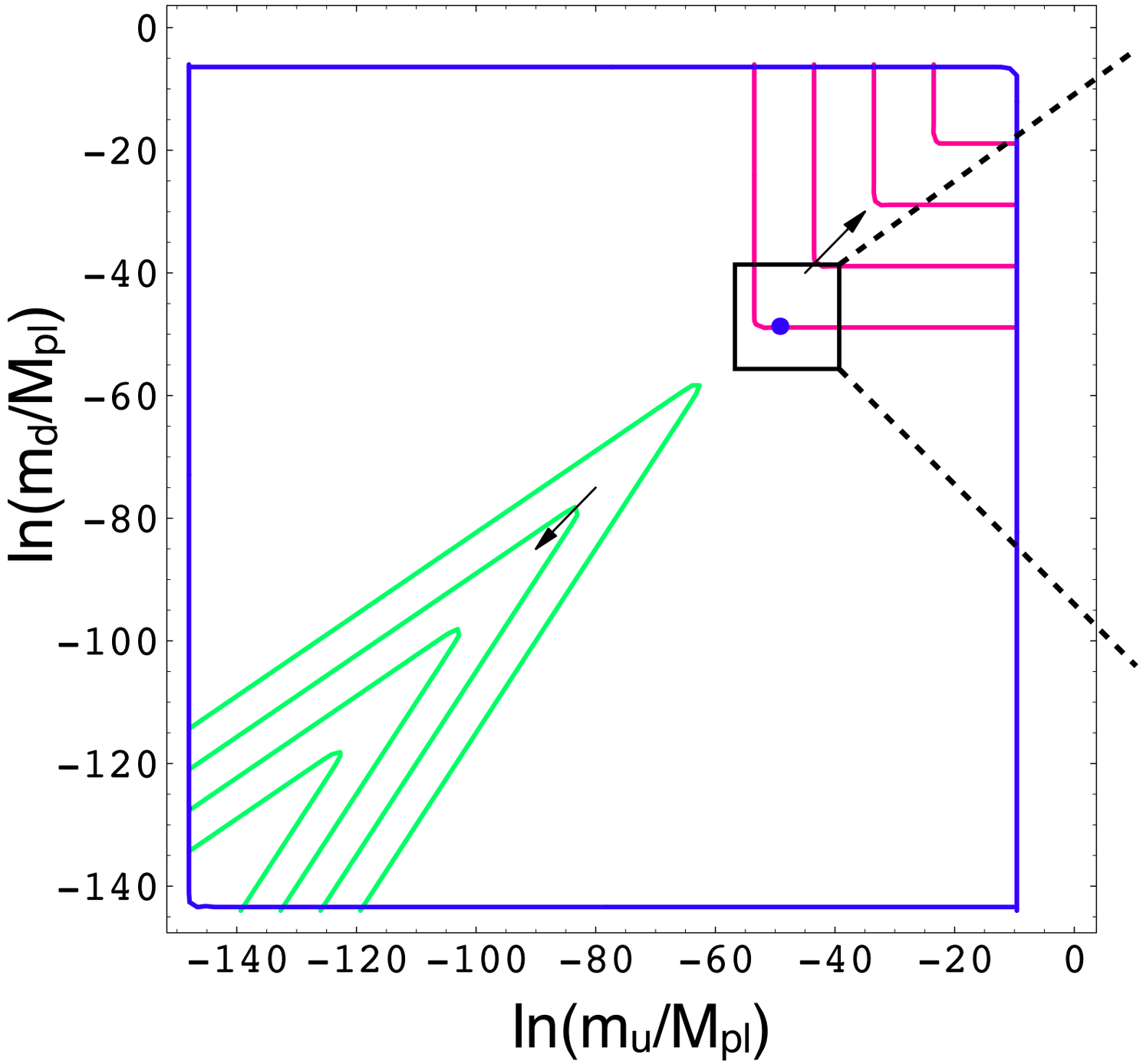
PHYSICAL REVIEW D **76,** 045002 (2007)

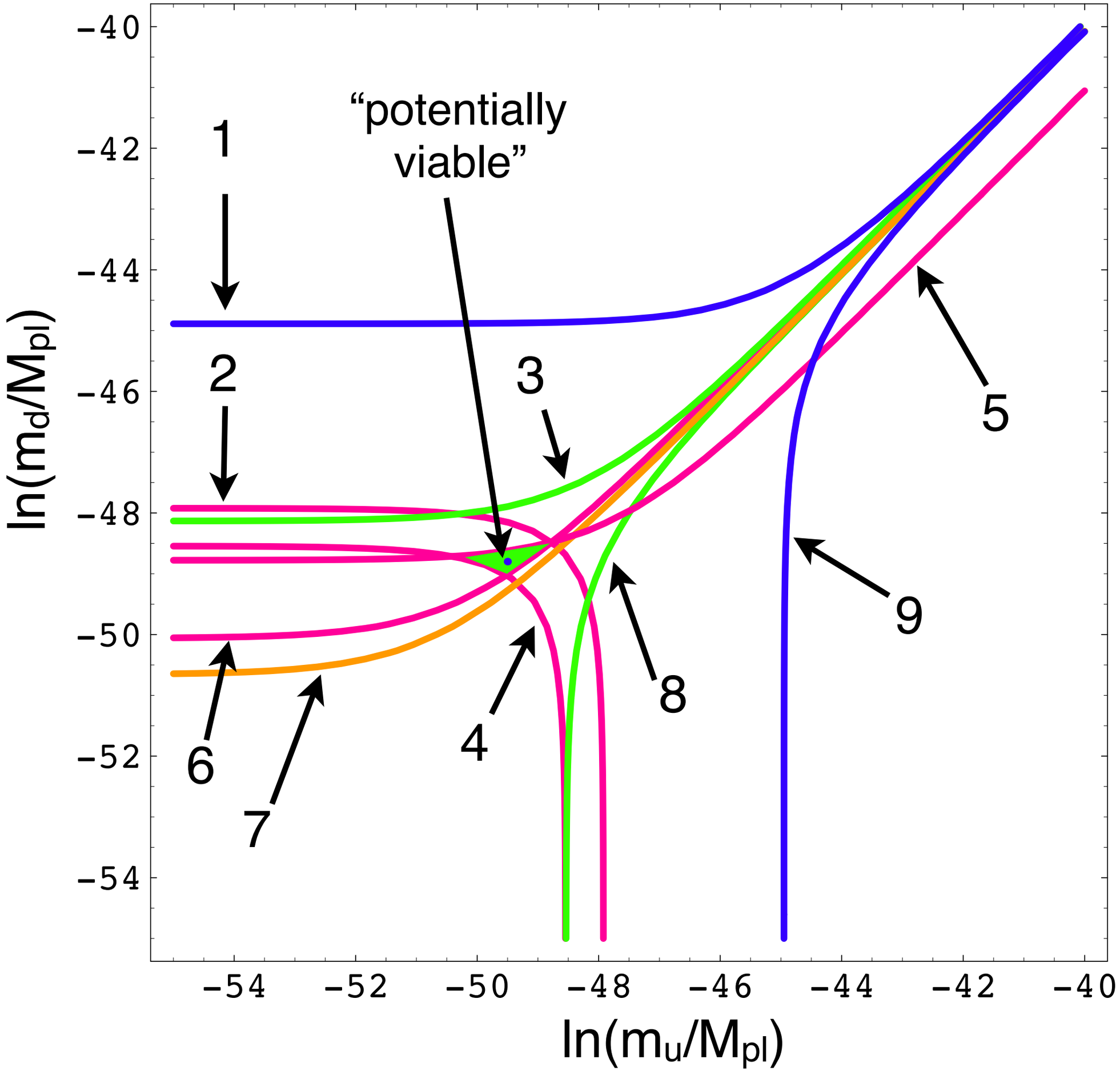
Anthropic tuning of the weak scale and of m_u/m_d in two-Higgs-doublet models

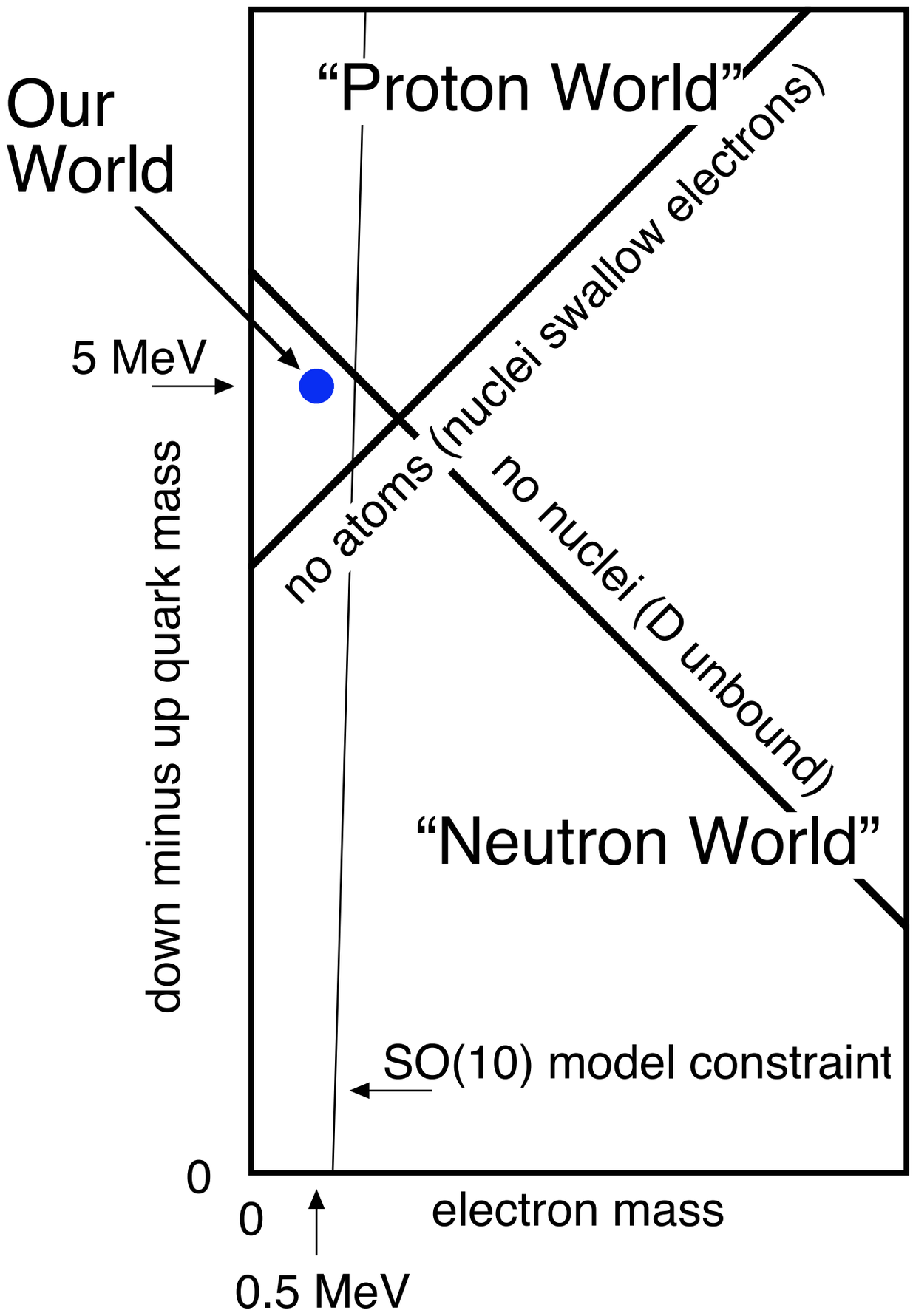
S. M. Barr and Almas Khan

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

(Received 20 April 2007; published 6 August 2007)

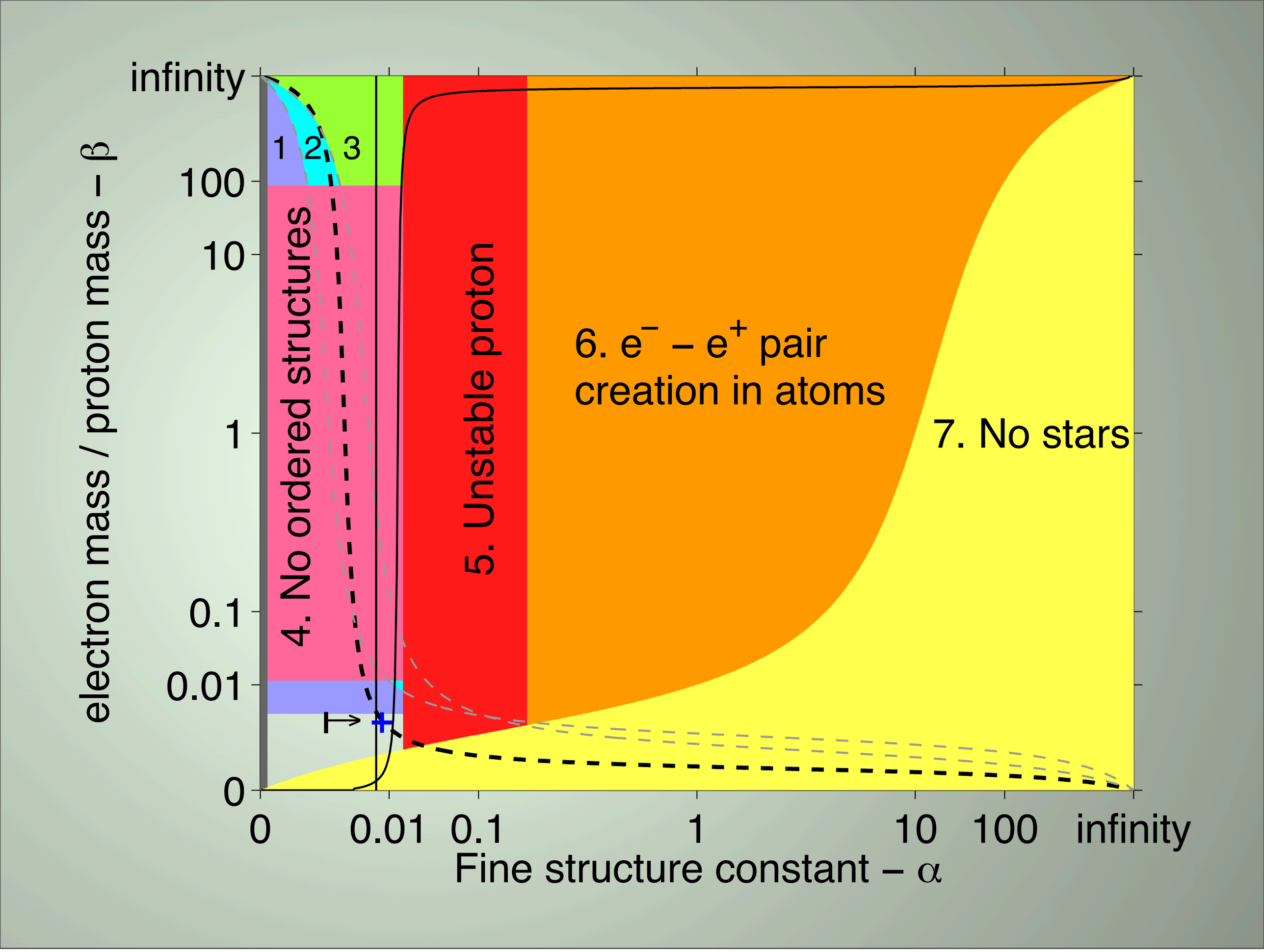



−40
−42
−44
−46
−48
−50
−52
−54
ln(m_d/M_pl)
−54
−52
−50
−48
−46
−44
−42
−40
ln(m_u/M_pl)
"potentially viable"
1
2
3
4
5
6
7
8
9


Our
World
"Proton World"
5 MeV
no atoms (nuclei swallow electrons)
no nuclei (D unbound)
down minus up quark mass
"Neutron World"
SO(10) model constraint
0
0
electron mass
0.5 MeV

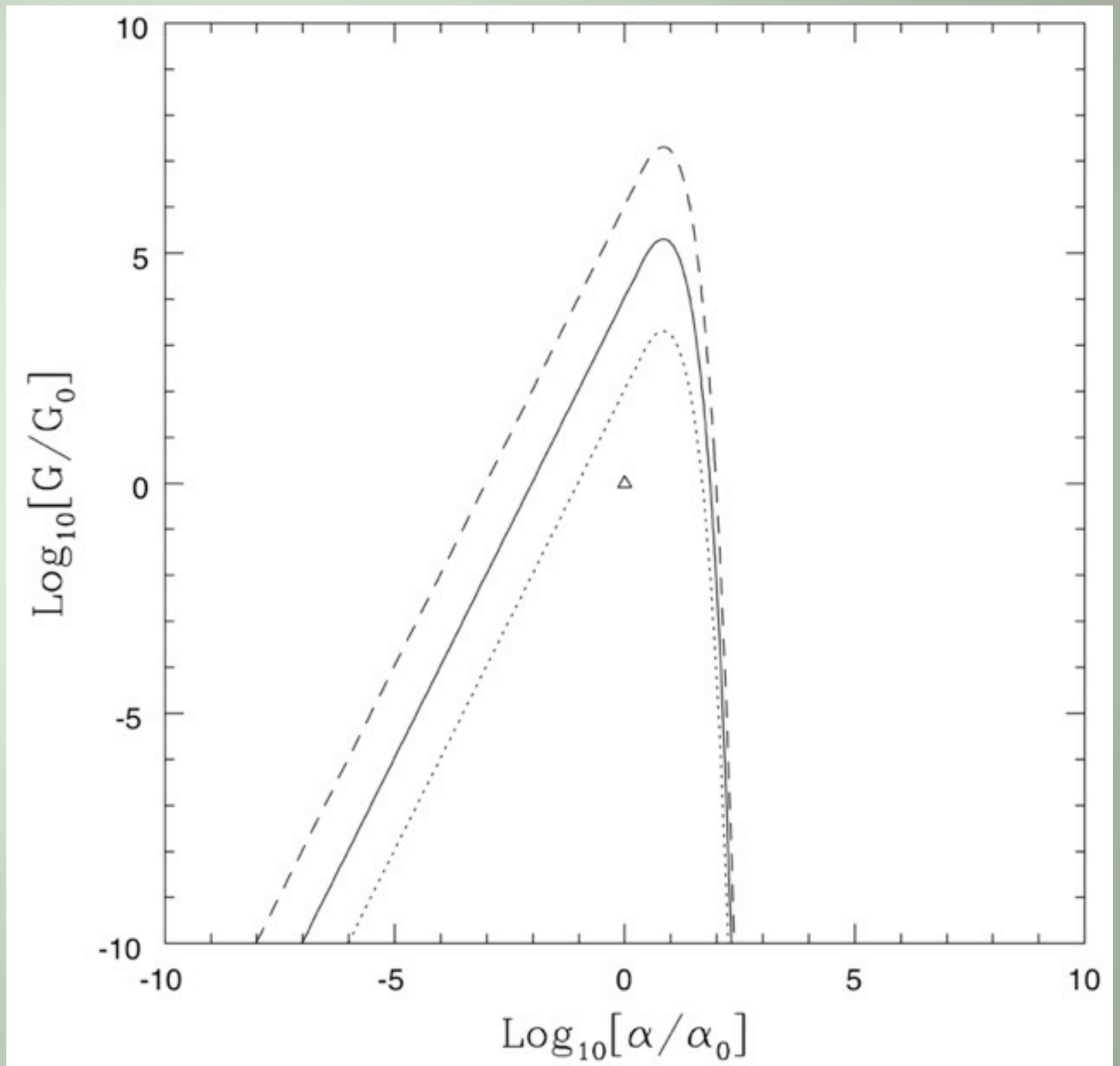
- Damour & Donoghue (2008)

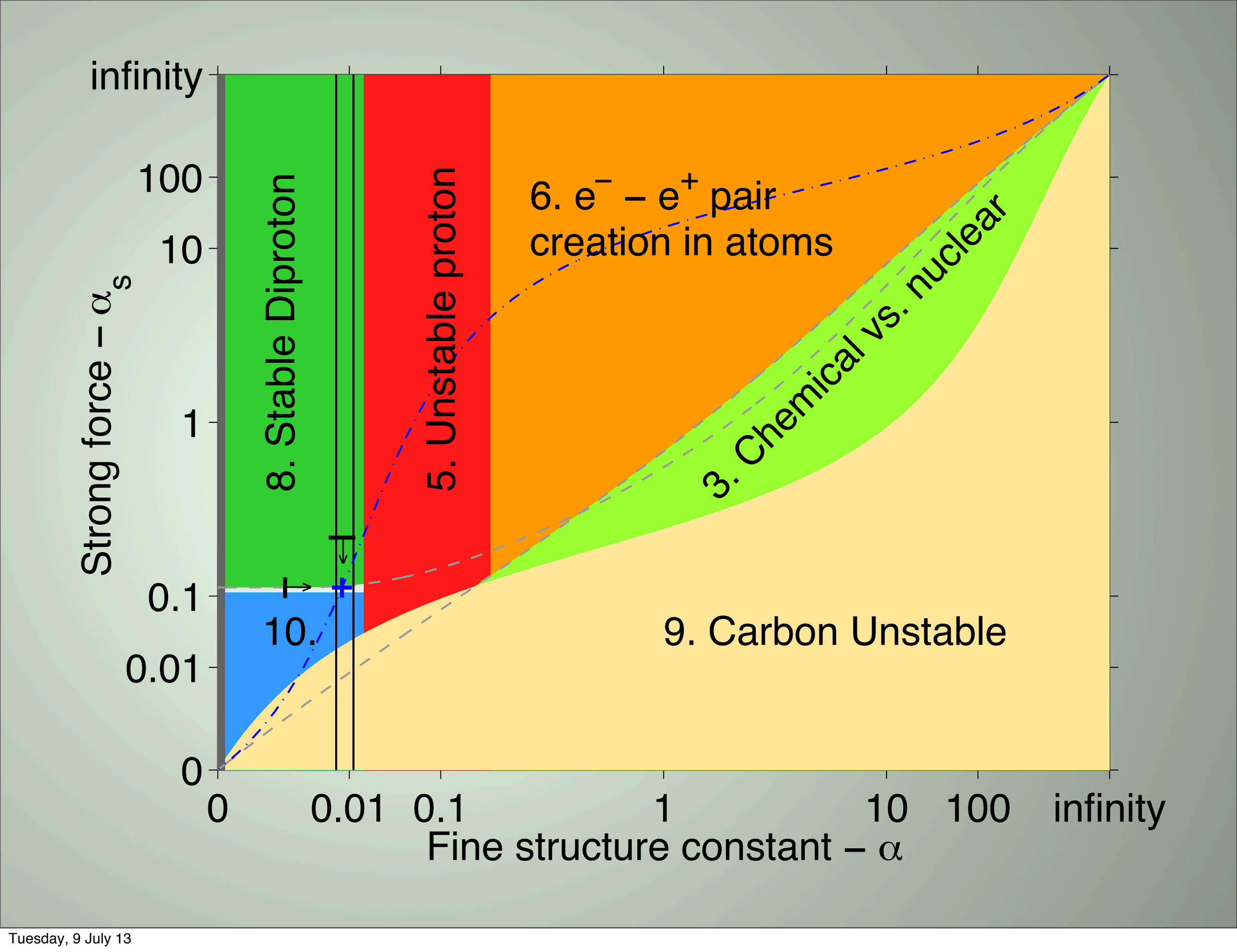
$$0.7 \times 10^{-17} < \frac{v}{m_{pl}} < 3.5 \times 10^{-17}$$


infinity
100
10
1
0.1
0.01
0
electron mass / proton mass – β
1
2
3
4. No ordered structures
5. Unstable proton
6. e⁻ – e⁺ pair creation in atoms
7. No stars
T
0
0.01
0.1
1
10
100
infinity
Fine structure constant – α

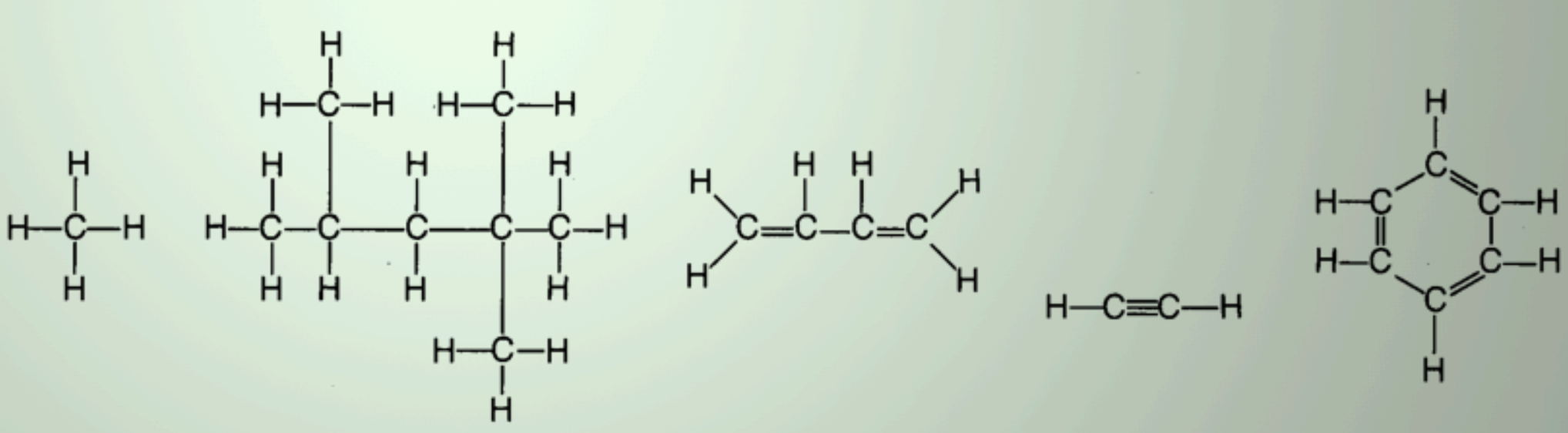
Stars in other universes: stellar structure with different fundamental constants

Fred Adams, Journal of Cosmology and Astroparticle Physics, 2008

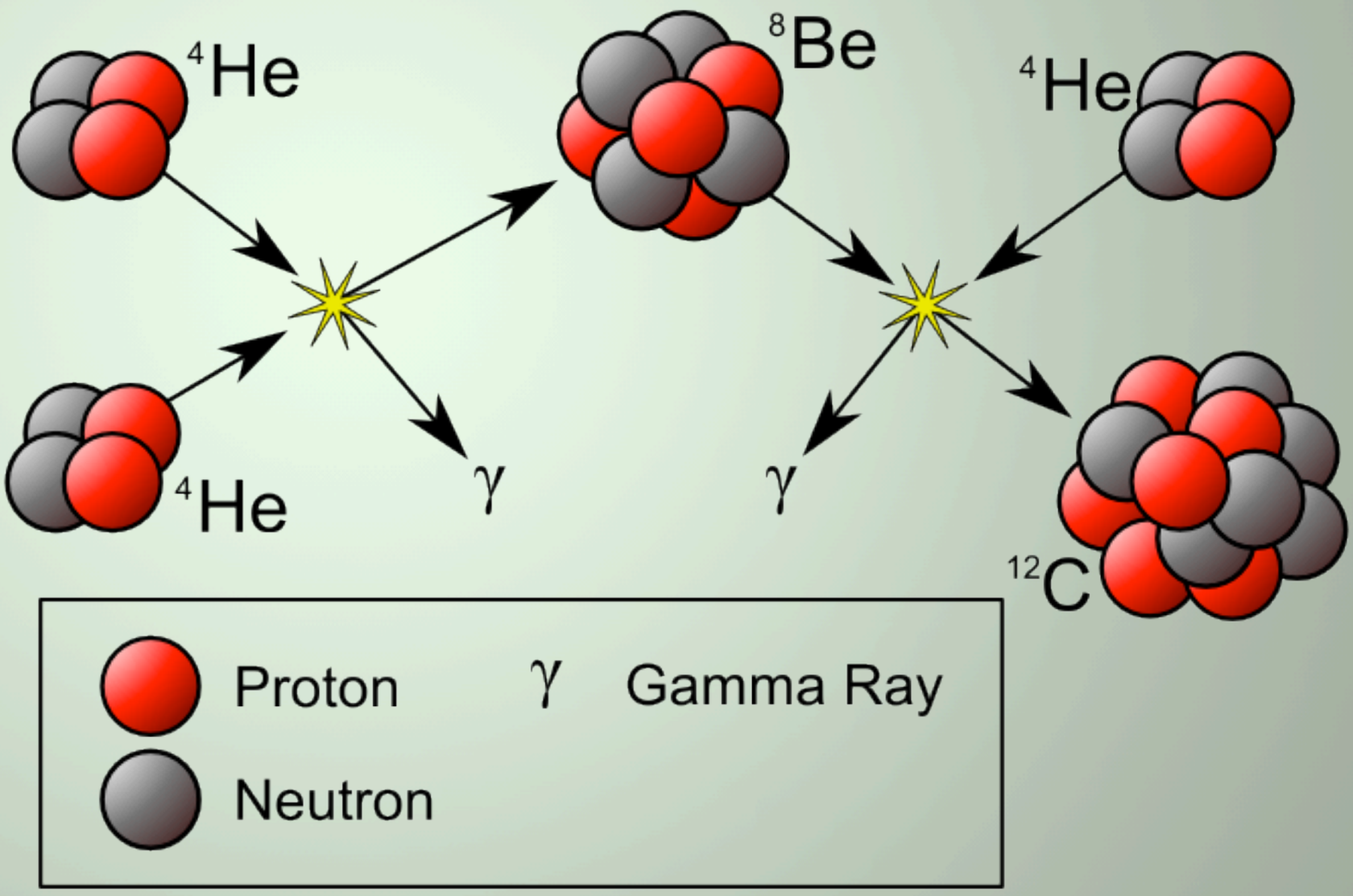



infinity
100
10
1
0.1
0.01
0
Strong force – α_s
8. Stable Diproton
5. Unstable proton
6. e^- – e^+ pair creation in atoms
3. Chemical vs. nuclear
10.
9. Carbon Unstable
0
0.01
0.1
1
10
100
infinity
Fine structure constant – α

1	2	3	4	5	6	7	8	9	10
H	He	Li	Be	B	C	N	O	F	Ne
1	0	1	1	7	~2300	7	2	1	0



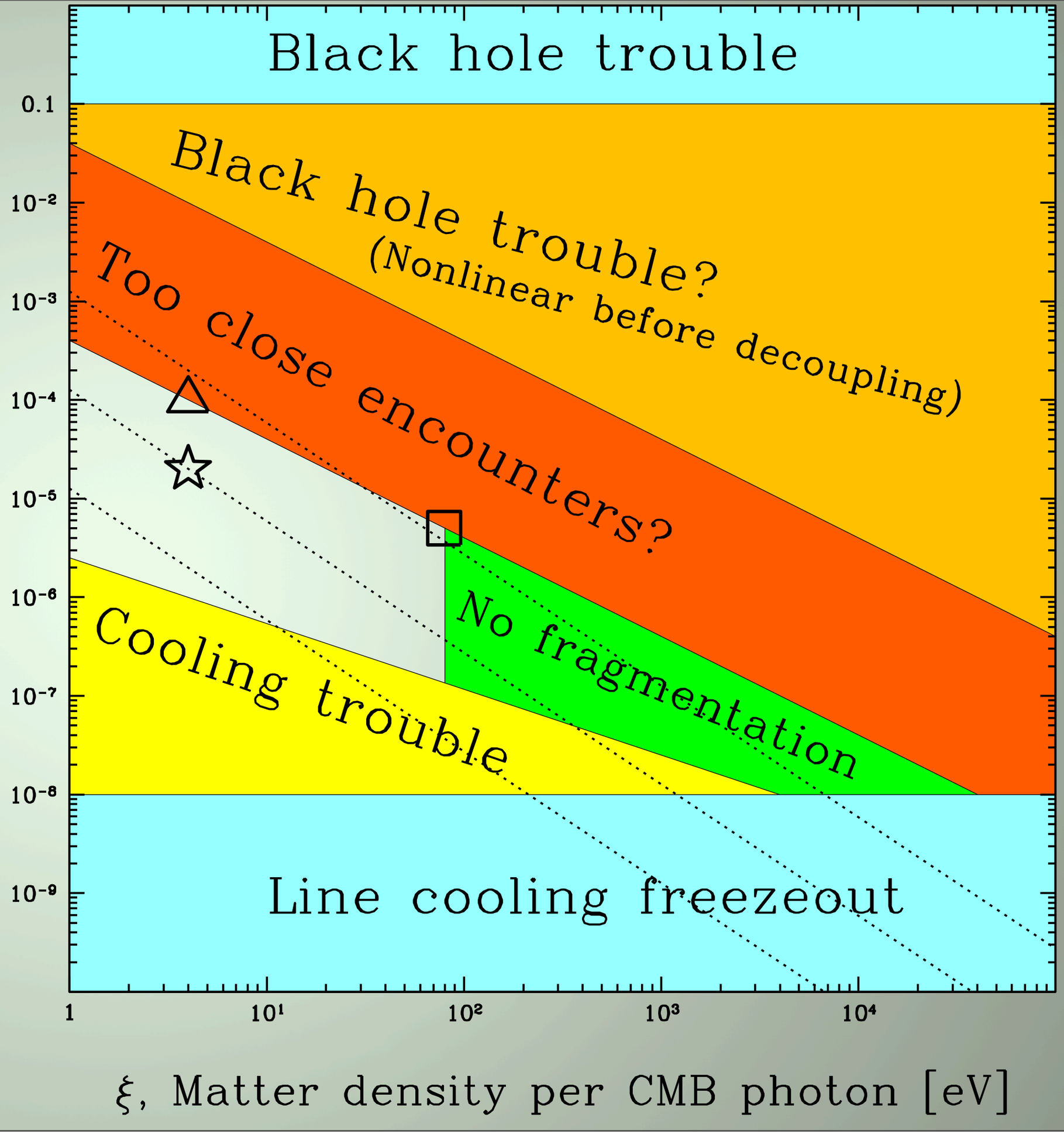
Viability of Carbon-Based Life as a Function of the Light Quark Mass
Epelbaum et al, Physical Review Letters 2013



PHYSICAL REVIEW D **73,** 023505 (2006)

Dimensionless constants, cosmology, and other dark matters

Max Tegmark,[1,2] Anthony Aguirre,[3] Martin J. Rees,[4] and Frank Wilczek[2,1]



PHYSICAL REVIEW D **73,** 023505 (2006)

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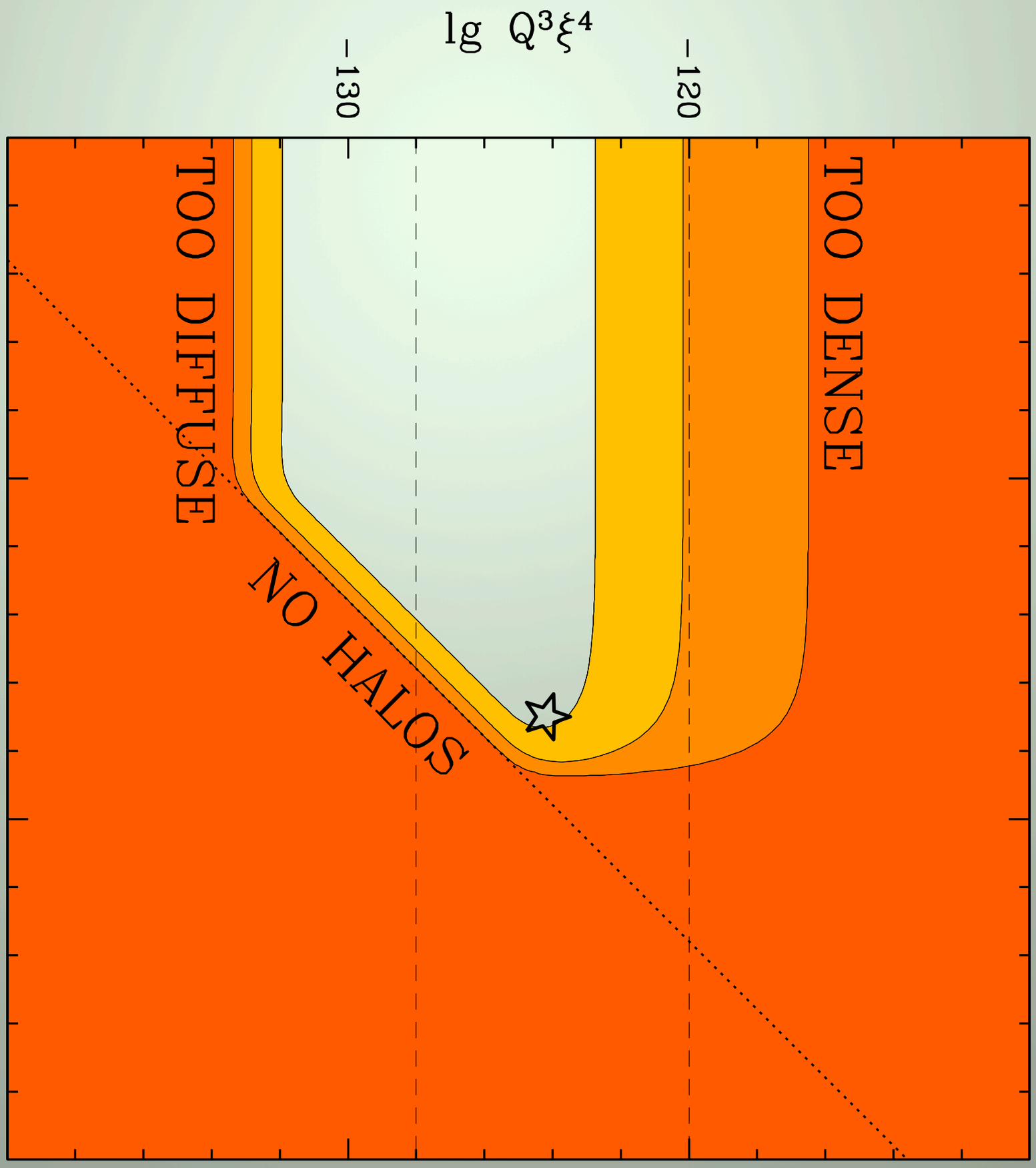


TABLE IV. These constraints (see text) are summarized in Fig. 12.

Constraint	Generally	Fixing (α, β, m_p)	Fixing all but (Q, ξ)
Need nonlinear halos	$\lvert\rho_\Lambda\rvert \lesssim \rho_*$	$\lvert\rho_\Lambda\rvert/\xi^4 Q^3 \lesssim 1$	$Q \gtrsim 10^{-5}(\xi/\xi_0)^{-4/3}$
Avoid line cooling freeze-out	$Q \gtrsim \alpha^2\beta$	$Q \gtrsim 10^{-8}$	$Q \gtrsim 10^{-8}$
Primordial black hole excess	$Q \lesssim 10^{-1}$	$Q \lesssim 10^{-1}$	$Q \lesssim 10^{-1}$
Need cooling in Hubble time	$Q^3\xi_b^2\xi^2 \gtrsim \alpha^{-3}\ln[\alpha^{-2}]^{-16/3}\beta^4 m_p^6/125$	$Q^3\xi_b^2\xi^2 \gtrsim 10^{-129}$	$Q \gtrsim 10^{-6}(\xi/\xi_0)^{-2/3}$
Avoid close encounters		$Q^3\xi_b\xi^3 \lesssim 10^{-123}$	$Q \lesssim 10^{-4}(\xi/\xi_0)^{-1}$
Go nonlinear after decoupling	$\xi Q \lesssim 10^{-3}\alpha^2\beta m_p$	$\xi Q \lesssim 10^{-30}$	$Q \lesssim 10^{-2}(\xi/\xi_0)^{-1}$
Need equality before decoupling?	$\xi \gtrsim 0.05\alpha^2\beta m_p$	$\xi \gtrsim 10^{-28}$	$(\xi/\xi_0) \gtrsim 1/3$
Avoid severe Silk damping	$f_b \lesssim 1/2$	$\xi/\xi_b \gtrsim 2$	$(\xi/\xi_0) \gtrsim 1/3$
Need disk instability	$f_b \lesssim 10^2$	$\xi_c/\xi_b \lesssim 10^2$	$(\xi/\xi_0) \lesssim 20$

Why the cosmological constant is such a problem

..."arguably the most severe theoretical problem in high-energy physics today, as measured by both the difference between observations and theoretical predictions, and by the lack of convincing theoretical ideas which address it"

Burgess & Moore,
The Standard Model: A Primer. (2006)

Why the cosmological constant is such a problem

1. It's actually several problems.

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = T_{\mu\nu}$$

$$\Lambda_{\text{observed}} = -\Lambda + \Lambda_T$$

$$= -\Lambda + \sum \Lambda_{T,i}$$

QFT $\Rightarrow |\Lambda_{T,i}| \sim 10^{120}\, \Lambda_{\text{observed}}$

Why the cosmological constant is such a problem

2. GR won't help.

3. Particle physics probably won't help.

4. It isn't just a problem at the Planck scale, so quantum gravity won't necessarily help.

5. Alternative forms of dark energy have exactly the same problem

Why the cosmological constant is such a problem

6. Since 1998, the solution can't aim for zero

7. If inflation happened, then life-prohibiting acceleration is physically possible. (Inflaton is another contributor to Λ_T).

8. Strong anthropic limit

9. QFT calculation of vacuum energy is known to be correct in some environments.

Why the cosmological constant is such a problem

"[W]e know that electron vacuum energy does gravitate in some situations ... the vacuum polarization contribution to the famous Lamb shift. ... Since this is known to give a nonzero contribution to the energy of the atom, the equivalence principle requires that it couple to gravity. ... Thus we must understand why the zero point energy gravitates in these environments and not in vacuum."

Polchinski (2006, hep-th/0603249)

Number of macroscopic time dimensions

5
4
3
2
1
0

UNPREDICTABLE (elliptic)

UNSTABLE

UNPREDICTABLE (ultrahyperbolic)

Tachyons only

TOO SIMPLE

We are here

UNSTABLE

UNPREDICTABLE (elliptic)

0 1 2 3 4 5

Number of macroscopic space dimensions

Other Cases

- Entropy
  - $10^{-10^{123}}$ (Penrose)
  - $10^{-66000000}$ (Carroll & Tam, 2010)

    ("This is a small number")
- The flatness problem and inflation

Inflation checklist:

1. There must be an inflaton field.

2. Inflation must start.

3. Inflation must last.

4. Inflation must end.

5. The universe must reheat.

6. Inflation must set up the right density perturbations.

Other Cases (?)

- Charge neutrality
- Matter / antimatter
- c? G? ħ?

Other Cases

- Electrons must be fermions
- Gravity must be attractive
- Strong force must be short range
- EM must be “opposites attract”
- Need a quantum regime

FT: In the set of possible physical laws, parameters and initial conditions, the subset that permit the evolution of life is very small.

Leonard Susskind: The Laws of Physics are almost always deadly. In a sense the laws of nature are like East Coast weather: tremendously variable, almost always awful, but on rare occasions, perfectly lovely.

CSIRO PUBLISHING

Publications of the Astronomical Society of Australia, 2012, **29**, 529–564
http://dx.doi.org/10.1071/AS12015

Review

The Fine-Tuning of the Universe for Intelligent Life

L. A. Barnes

1. It's just a coincidence.
2. We've only observed one universe.
3. Low probability events happen all the time.
4. Fine-tuning has been disproved by (insert name here)
5. Evolution will always find a way.
6. This universe is just as unlikely as any other universe.
7. How do we know what would happen in other universes? Go do the experiment!
8. How can the universe be fine-tuned when so much of it is inhospitable to life?

9. Life chauvinism – why think that life is special?
10. We don't even have good definition of life
11. The anthropic principle explains fine-tuning.
12. Whence the prior probability?
13. There could be other forms of life.
14. Deeper physical laws will explain the values of the constants
15. Multiverse
16. Intentional selection

1. Coincidence

Is my theory right?

The Prior

Likelihood - how well does my theory handle the data?

$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

The competition ...

←

2. We've only observed one universe ...

1. Start with a theory T.
2. If T is true, then we expect to observe O_T
3. Our actual observations O are consistent with O_T
4. Therefore ...

3. Low probability events happen all the time ...

The Prior

Likelihood - how well does my theory handle the data?

Is my theory right?

$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

The competition ...

4. Fine-tuning has been disproved by (insert name here)

- Nope.

5. Evolution will always find a way

- No. It won't

6. This universe is just as unlikely as any other universe.

This is only true if you assume that universes are given their properties randomly.

7. Go do the experiment ...

1. Start with a theory T.
2. If T is true, then we expect to observe O_T
3. Our actual observations O are consistent with O_T
4. Therefore ...

8. This universe is mostly inhospitable

- Too much matter → collapse
- Stars are big and energetic. Best keep them at a distance.

- Fine-tuned universe ≠ crammed with life from end to end and start to finish

←

9. Life chauvinism

There is something stunningly narrow about how the Anthropic Principle is phrased. Yes, only certain laws and constants of nature are consistent with our kind of life. But essentially the same laws and constants are required to make a rock. So why not talk about a Universe designed so rocks could one day come to be, and strong and weak Lithic Principles? If stones could philosophize, I imagine Lithic Principles would be at the intellectual frontiers.

Carl Sagan, *Pale Blue Dot*

The Prior

Likelihood - how well does my theory handle the data?

Is my theory right?

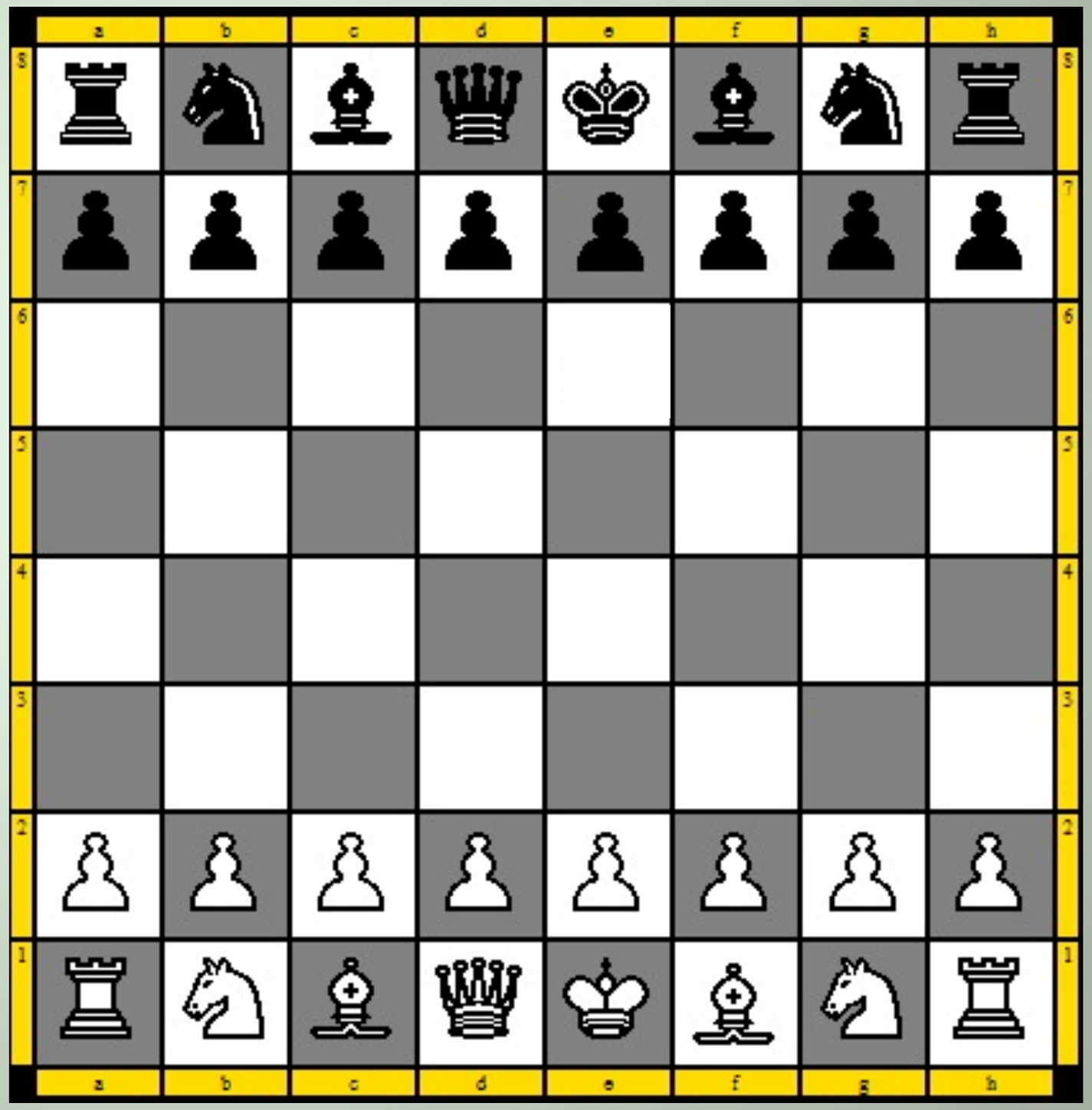
$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

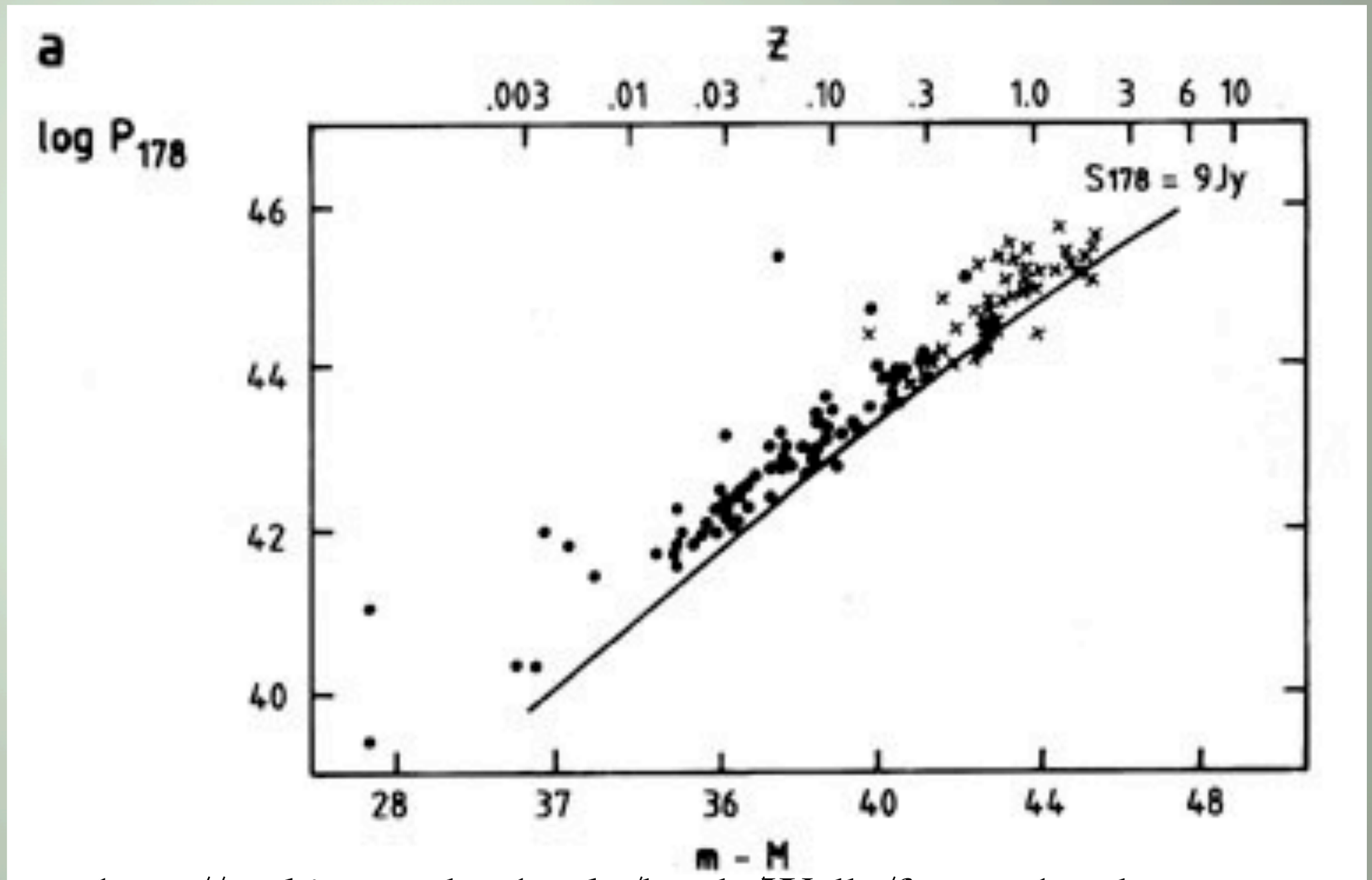
The competition ...

←

10. We don’t even have good definition of life



11. The anthropic principle



http://ned.ipac.caltech.edu/level5/Wall2/frames.html

←

12. Whence the measure?

The Prior

Likelihood - how well does my theory handle the data?

Is my theory right?

$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

The competition ...

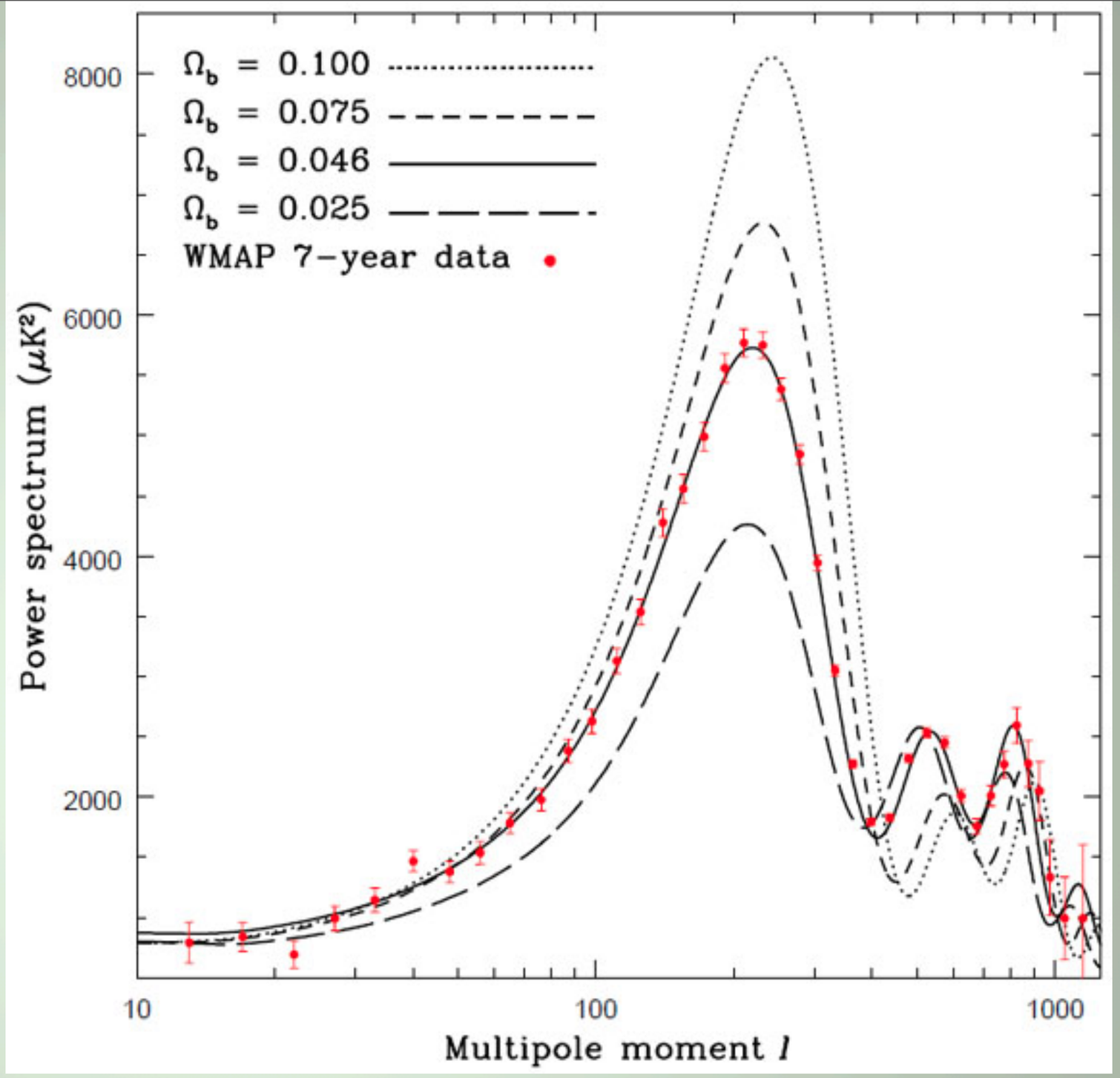
←

12. Whence the measure?

"...it is assumed that [the prior] is either flat or a simple power law, without any complicated structure. This can be done just for simplicity, but it is often argued to be natural. The flavour of this argument is as follows. If [the prior] is to have an interesting structure over the relatively small range in which observers are abundant, there must be a parameter of order the observed [one] in the expression for [the prior]. But it is precisely the absence of this parameter that motivated the anthropic approach."

←

- What is the 9993rd digit of pi?
  - $1 to play, correct guess wins $10
- This is a sequence of the digits of pi which contains that 9993rd digit: 92056001016552563756
- 1USD to play, correct guess wins 10AUD



$$p(\Omega_b|CMB) = \frac{p(CMB|\Omega_b)\ p(\Omega_b)}{\int_0^\infty p(CMB|\Omega_b)\ p(\Omega_b)\ d\Omega_b}$$

13. There could be other forms of life

[Perhaps] Life is extremely robust, and would be likely to arise even if the parameters were very different, whether or not we understand what form it would take. ... We know very little about the conditions under which complexity, and intelligent life in particular, can possibly form. ... Life may be very fragile, but for all we know it may be ubiquitous (in parameter space); we have a great deal of trouble even defining "life" or for that matter "complexity," not to mention "intelligence."

Sean Carroll, *Does the Universe Need God?*

13. There could be other forms of life

Inferior to carbon

Needs similar conditions to form

Silicon is less well suited to support complex chemistry and it seems much less likely that silicon-based life could form than carbon-based life. Thus if aliens ever do visit us, the smart money says we should welcome them with carbon-based cakes and not with silicon-based rocks.

Plaxco and Gross, *Astrobiology: A Brief Introduction* (2011)

←

14. Deeper Laws?

"The equations of the theory [string theory] have no adjustable constants, but their solutions, describing different vacuum states, are characterised by several hundred parameters- the sizes of compact dimensions, the locations of the branes, and so on."

Alexander Vilenkin

14. Deeper Laws?

"It is logically possible that parameters determined uniquely by abstract theoretical principles just happen to exhibit all the apparent fine-tunings required to produce, by a lucky coincidence, a universe containing complex structures. But that, I think, really strains credulity."

Frank Wilczek

15. Multiverse

1. The set of possible universes $\mathcal{M}$.

2.Characterise each universe m in $\mathcal{M}$ by a set of distinguishing parameters, creating equivalence classes. Specify: a) physical laws, b) parameters of those laws, c) which solution of the laws specifies a given m.

3. A distribution function $f(m)$ on $\mathcal{M}$, specifying how many times each possible universe m is realised.

4. A distribution function over continuous parameters needs to be defined relative to a measure π which assigns a probability space volume to each parameter increment.

5. The anthropic subset: if you want to calculate what an observer is likely to see, you need to specify the set of universes which allow the existence of observers.

Ellis, Kirchner, and Stoeger, MNRAS 2004

Likelihood, p(what we observe | multiverse) ...

We can condition on anything we know. Bayes' theorem will automatically discard what's irrelevant.

M = there is a multiverse (with details ...)

O_{us} = this universe contains observers

D_E = there exists a universe whose observers observe D

D_{us} = this universe contains observers who observe D

$D_{us} \Rightarrow D_E$

$D_{us} \Rightarrow O_{us}$

$$P(D_{us}|M)$$

$$= P(D_{us}|O_{us}M)P(O_{us}|M) + P(D_{us}|\bar{O}_{us}M)P(\bar{O}_{us}|M)$$

(Law of total probability)

$$= P(D_{us}|O_{us}M)P(O_{us}|M) + \cancel{P(D_{us}|\bar{O}_{us}M)P(\bar{O}_{us}|M)}$$

($D_{us} \Rightarrow O_{us}$) (AP)

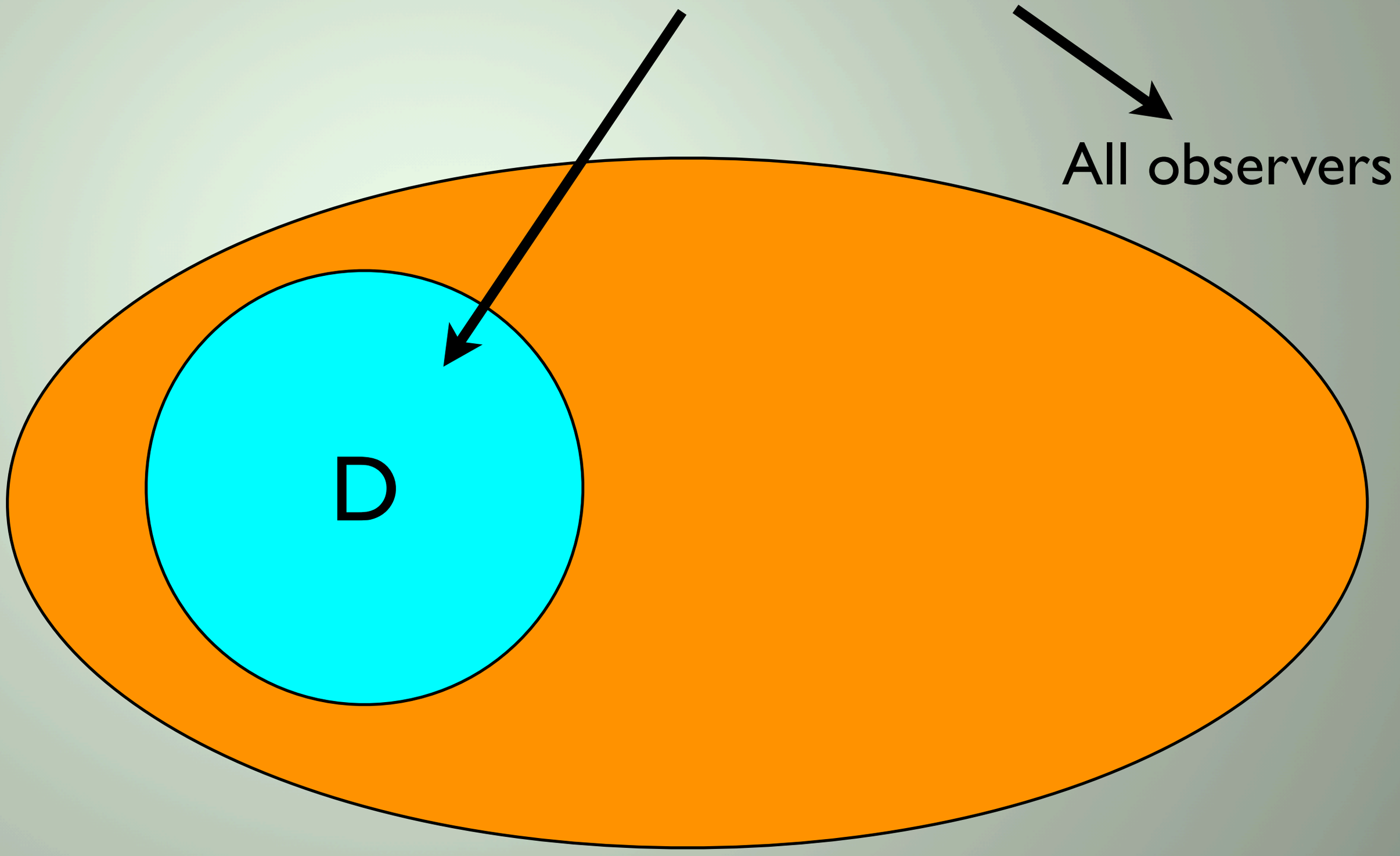
$$= P(D_{us}|O_{us}M)$$

(AP: Anthropic principle)

(Note: p(D_{us} | M) can be small, even if p(D_E | M) is large)

$$P(D_{us}|M) = P(D_{us}|O_{us}M)$$

= Fraction of this over this



On Certain Questions of the Theory of Gases
Boltzmann, Nature 1895

We can rule out any multiverse in which there is a feature of our universe that is very unlikely to be observed by a typical observer ...

... even if that feature is almost certain to appear somewhere in the multiverse

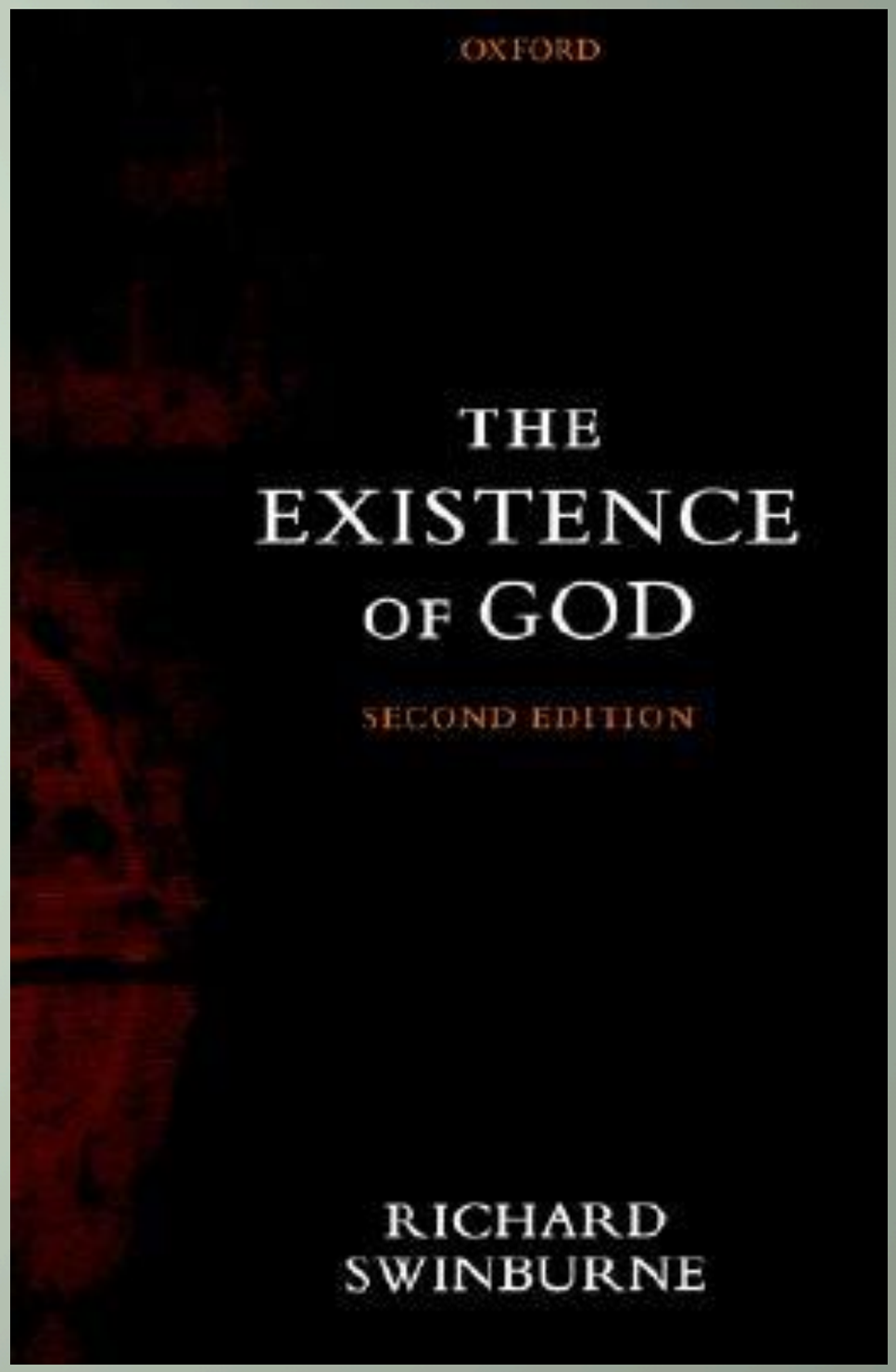
16. Intentional Selection

Protons have mass? I didn't even know they were Catholic.

Woody Allen

Richard Swinburne

God as the best explanation ...



The Prior

Likelihood - how well does my theory handle the data?

Is my theory right?

$$P(T|D) = \frac{P(T)\ P(D|T)}{P(T)\ P(D|T)\ +\ P(\bar{T})\ P(D|\bar{T})}$$

$1 - P(T)$

The competition

←

G: There exists a person who is

Omnipotent

Omniscient

Perfectly free

From which follows that God is an omnipresent spirit, Creator of all logically contingent things (apart from himself), and perfectly good.

Necessary ("supreme brute fact")

A **personal** explanation of an event E involves:

- A **rational agent** P
- An **intention** J that E occur
- Bringing about E is one of P's **basic powers** X

The prior:

"The hypothesis of theism that seeks to explain the existence of the universe and its various features is, as we have seen, a hypothesis of personal explanation; and so it is to be assessed by these criteria. ... [T]heism purports to explain everything logically contingent (apart from itself). In consequence there will be no background knowledge with which it has to fit. It will not, therefore, be a disadvantage to it if it postulates a person in many ways rather unlike the embodied human persons so familiar to us."

G is simple:

"There is a neatness about zero and infinity that particular finite numbers lack. Yet a person with zero powers would not be a person at all. So in postulating a person with infinite power the theist is postulating ... the simplest kind of person that there could be."

More prior information: the existence of the universe

"[Initial/boundary conditions of the universe] would be a finite thing with certain ways of developing built into it and no reason why those particular ways of developing should be built into it, rather than any other ways. There could have been no laws of nature and so complete chaos, or laws that soon ensured the complete elimination of the universe. ... The existence the universe is less simple, and so less to be expected *a priori* than the existence of God."

Even more prior information: the laws of nature

The laws of nature are logically contingent relations between universals. ...

[A] universe without connections between universals would be simpler than one with connections. ... [Thus] it would be very probably that there would be no connections between universals at all - that the universe would be chaotic.

[Alternatively, if we consider the set of all possible such connections ...]

... since there are a very large number of complex ways in which universals could be associated ... it will be at least as probable that one of the complex connections between universals will hold as that one of the simple connections will hold - there being so many more (infinitely many more) of the former. Either way, it is going to be improbable that in a Godless universe there will be simple connections between universals, and so simple laws of nature.

The likelihood ... p(Life-permitting universe | God)

Agents don't necessarily do better than chance.

e.g. choosing lottery numbers based on your kids' birthdays.

Creating a life-permitting universe is within God's powers.

How likely is it that God would form an intention to create a life-permitting universe?

A perfectly free, good being will do any action that is the best action, if there is one, or else some good action and no bad action.

Humanly free agents (morally aware persons with limited free will, power and knowledge) are good.

Creatures with significant freedom and responsibility a ‘space’ - a region of basic control and perception (a ‘body’) and a wider region (the ‘universe’) into which they can extend their perception and control.

If agents are to perform mediated actions, and perceive and understand the wider universe, the universe must be governed by laws of nature.

And so, the existence of humanly free agents with significant freedom requires a physical universe.

Not the multiverse ...

If one universe per hypothesis, Occam's razor

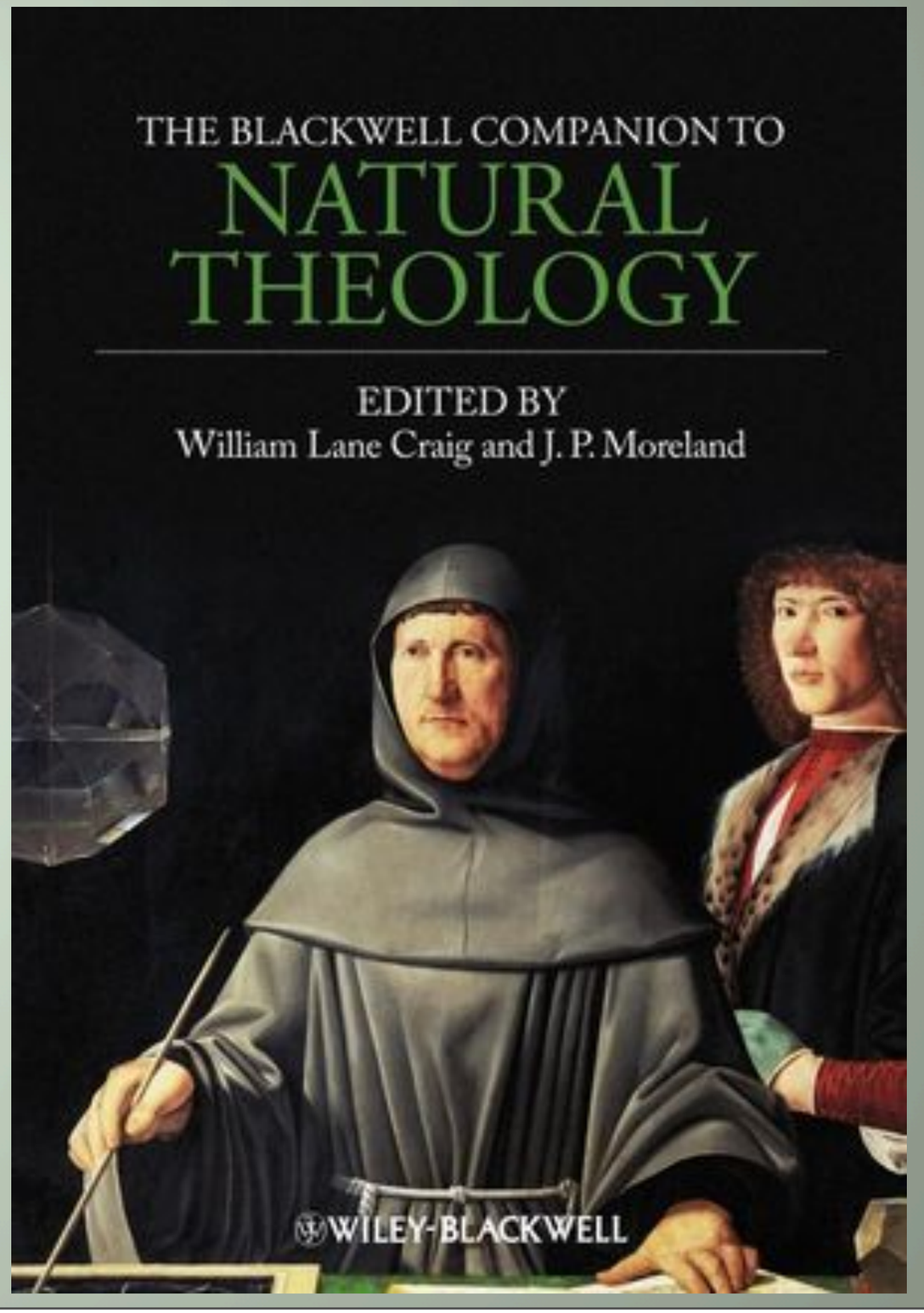
Universe generators are complex: "tantamount to postulating a multiverse that has laws and boundary conditions such that it will contain at some time or other a tuned universe. But then there are an infinite number of logically possible multiverses that do not have this characteristic, and the shape of the problem has in no way changed."

Simple laws, varying only constants and a universe with no generating mechanism are simpler.

Robin Collins

Freaks in the multiverse ...

See also: "Modern Cosmology and Anthropic Fine-tuning: Three approaches" in *Georges Lemaître: Life, Science and Legacy*



Likelihood, p(life | multiverse) ...

We can condition on anything we know. Bayes' theorem will automatically discard what's irrelevant.

M = there is a multiverse (with details ...)

O_{us} = this universe contains observers

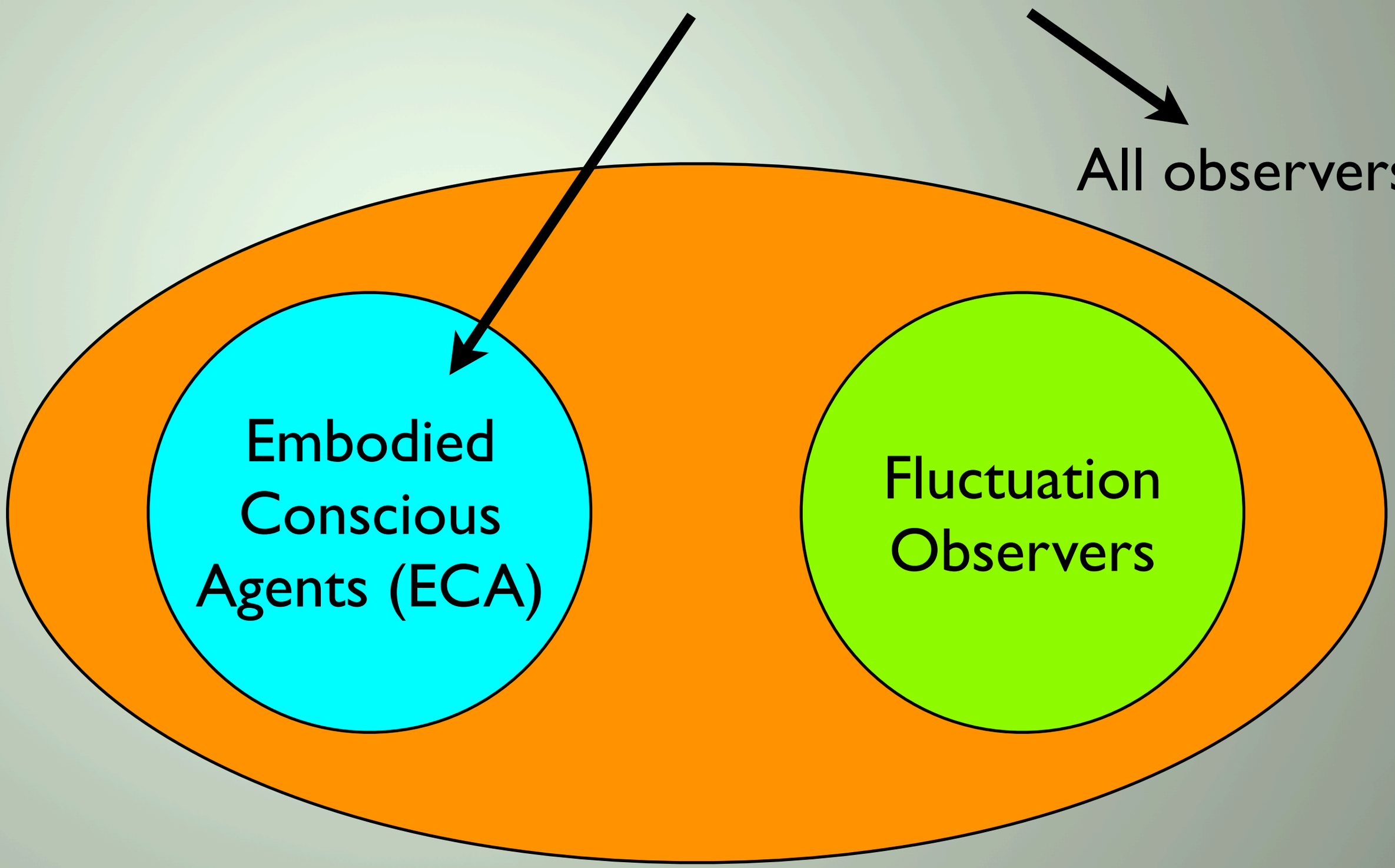
B_E = there exists a universe that contains embodied conscious agents (ECA)

B_{us} = this universe contains ECAs

Embodied Conscious Agents: entities capable of interacting with other life-forms "for good or ill", and interacting with, investigating and exploiting its environment.

$$P(B_{us}|M) = P(B_{us}|O_{us}M)$$

= Fraction of this over this



[This creates] a problem for some types of infinitely expanding universes, since purportedly these could give rise to an unlimited number of fluctuation observers via quantum fluctuations (Davenport & Olum 2010). ... Isolated fluctuation observers would exist in universes in which the fundamental parameters are not fine-tuned, and that this undercuts the ability of a multiverse to explain many other cases of fine-tuning. ...

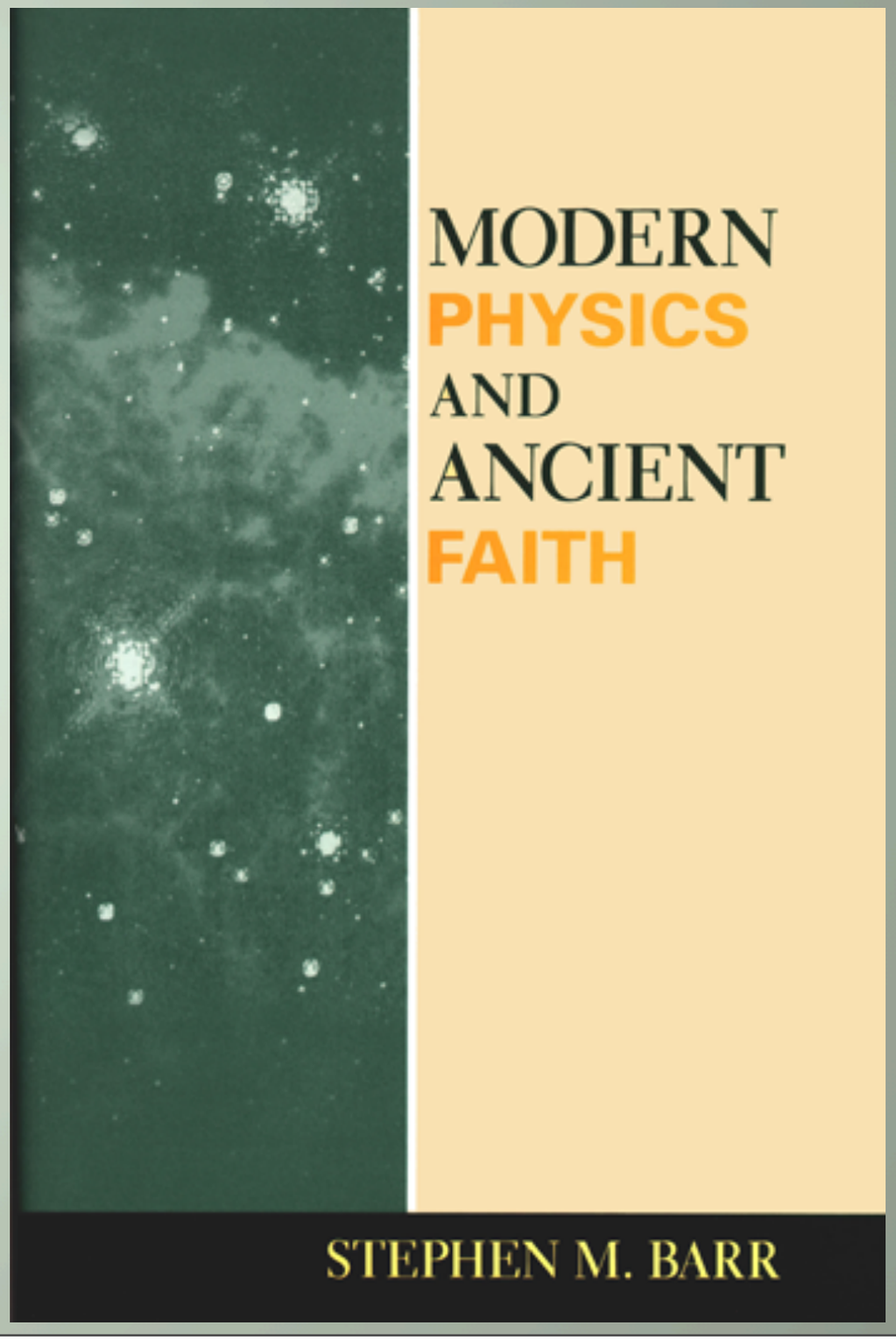
...The existence of these fluctuation observers in non-fine-tuned universes shows that the [chemistry-irrelevant] parameters of physics are not fine-tuned for observers, but rather for ECAs that can significantly interact with each other, and moreover, that can develop scientific technology and discover the universe. Yet, because of its reliance on the observer-selection principle, without additional postulates, the multiverse hypothesis can only take away the surprise that we exist in an observer-structured universe, not in a universe structured for ECAs.

(Note: $p(B_{us} \mid M)$ can be small, even if $p(B_E \mid M)$ is large)

[M]ultiverse advocates could postulate that, contrary to the usual measure used in statistical mechanics, there is a true probability measure that will make it likely that a generic observer will find itself in an ECA-structured universe. In this case, however, the work of explaining the fine-tuning is being done by the right choice of probability measure, not the multiverse hypothesis. Accordingly, it is difficult to see how multiverse advocates do better than single-universe advocates in explaining the fine-tuning. For example, in an attempt to explain the fine-tuning, the latter could also postulate the existence of the right probability measure, namely one that gives a significant probability to the existence of an ECA-structured universe.

Stephen Barr

Order all the way down ...



Order has to be built in for order to come out.

... If the ultimate laws of nature are, as scientists can now begin to discern, of great subtlety and beauty, one must ask where this design comes from. Can science explain it? That is not possible. For if science always explains design by showing it to be part of or a consequence of a deeper and greater design, then it has no way to explain the ultimate design of nature. The ultimate laws of physics are the end of the road of scientific explanation. One cannot go any farther in that direction. Thus, if at the end of that road one is confronted with a magnificent example of what we called 'symmetric structure' in the ultimate laws themselves, then science really has no alternative to offer to the Argument from Design.

[The] blind watchmaker is something even more remarkable than Paley's watches. Paley finds a "watch" and asks how such a thing could have come to be there by chance. Dawkins finds an immense automated factory [the universe] that blindly constructs watches, and feels that he has completely answered Paley's point. ...

It is a remarkable thing that inanimate matter assembled itself into living organisms like dogs and cats and chimpanzees. The fact that it happened according to natural processes makes it no less remarkable; on the contrary, it only shows how remarkable the natural processes of our universe are. ... [O]ur universe's openness to biological evolution appears to be a consequence of the fact that its laws are indeed very special.

More: "11 Responses to Fine-Tuning", commonsenseatheism.com

Books:

The Goldilock's Enigma - Paul Davies

Just Six Numbers - Martin Rees

The Cosmic Landscape - Leonard Susskind

The Anthropic Cosmological Principle - Barrow and Tipler

Universe or Multiverse, edited by Bernard Carr

Articles:

The Fine-Tuning of the Universe for Intelligent Life, Luke Barnes PASA (2012)

Why the Universe is Just So, Craig Hogan

Life at the Interface of Particle Physics and String Theory, A.N. Schellekens

lukebarnes.info