The Anthropic Principle: Is Our Universe Special?

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What is (not) the Anthropic Principle?

Copernican Principle: Man has no privileged position in the Universe

- ***Weak Anthropic Principle*** *(WAP)*: 'Our location in the Universe is *necessarily* privileged to the extent of being compatible with our existence as observers' (B. Carter,1974, similarly R.H. Dicke,1957). *Novel touch to confirmation theory: observers are included in data*

- ***Strong Anthropic Principle*** *(SAP)*: The structure of the (present) Universe (including Laws of Nature) *follows* from this compatibility. condition, *reverses the explanatory arrow, adds uniqueness claim Introduced "what if" history into physics ('without Jupiter …')*

- ***Theistic Anthropic Principle*** *(TAP)*: Universe was created with the emergence of observers (Man) among its goals. *Design (Fifth Way)*

Stronger Anthropic claims rely on "fine-tuning for life"

Fine-tuning: The Beryllium Bottleneck (Hoyle)

- (H-C-N-O) life (as we know it) requires both Carbon and Oxygen, C/O ≈ 1/2
- C and O are produced in stars (Big Bang Nucleosynthesis stops at ^{7}Li):

1. $\alpha + \alpha \rightarrow {}^{8}\mathrm{Be}$ ($\alpha = {}^{4}\mathrm{He}^{++}$), which lives 10^{-16} s, long enough for step 2:
2. $^{8}\mathrm{Be} + \alpha \rightarrow {}^{12}\mathrm{C}$, requires excited state of ^{12}C at energy E_H = 7.68 MeV, just above $^{8}\mathrm{Be} + \alpha$ energy, *predicted by Hoyle in 1951, discovered in 1955)*
3. $^{12}\mathrm{C} + \alpha \rightarrow {}^{12}\mathrm{O}$, requires *non-existence* of similar resonance in ^{12}O

E_H bigger: too much O, E_H smaller: too little O (Hoyle: Fine-tuned ≈ 1%)

Fine-tuning of E_H: 1% (Hoyle), 25% (Weinberg), 10^{-5} (Ekström et al, 2010)

Would other (non H-C-N-O) forms of life be possible without this reaction?

H
He
Li
Be
B
C
N
O

Some other cases of “fine-tuning for life”

- neutron-proton (d-u) mass difference: *wrong sign* ⇒ *unstable proton* ⇒ no chemistry as we know it; *right sign but too big by > 10%* ⇒ *no nuclear fusion in stars* (unstable Deuteron, so pp-reaction p + p → D + e + ν changes direction)

- Inhomogeneities (“ripples”) in CMB @ 400.000y: R ≈ 1/10.000 (Martin Rees) *too small* ⇒ *no galaxies, too big* ⇒ *only black holes,* must lie within 10^{-4} - 10^{-6}

- Matter density of Universe: $\Omega \approx \Omega_c$: *too small* ⇒ *expansion too fast*

  too big ⇒ *quick recollapse* (Big Crunch), includes Cosmological constant $\Lambda \approx 0$

  Both Ω and Λ fine-tuned to 10^{-55} (NB Inflation requires even more fine-tuning!)

- Entropy of early Universe: fine-tuned (at low value) to $1/10^{10^{123}}$ (Roger Penrose)

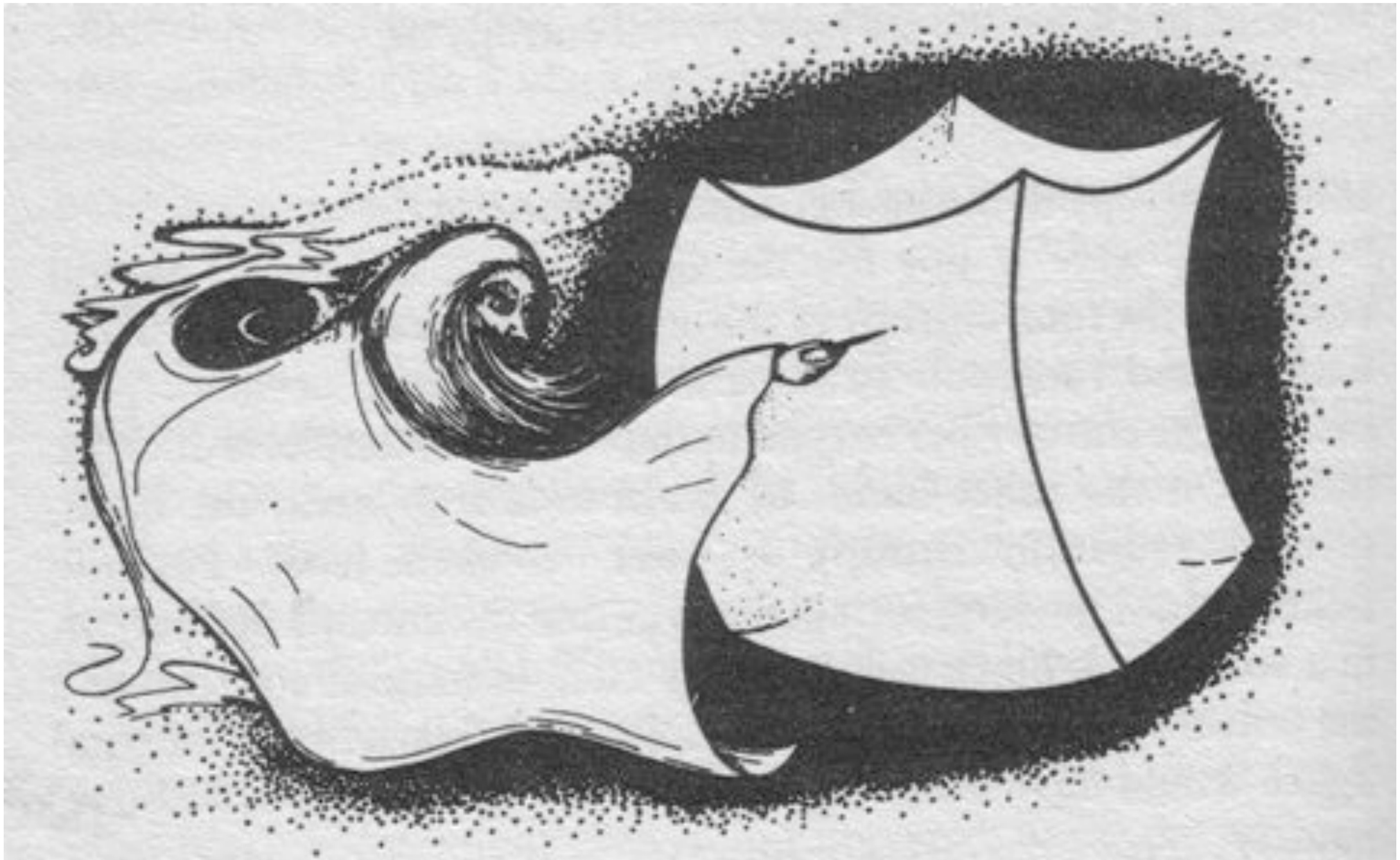
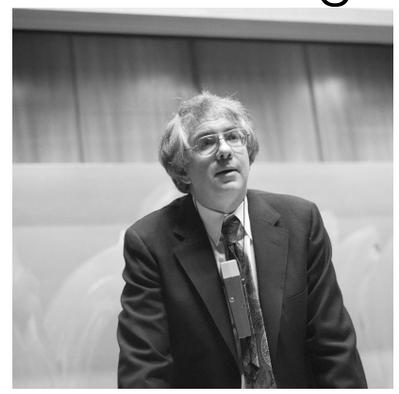


Fig. 7.19. In order to produce a universe resembling the one in which we live, the Creator would have to aim for an absurdly tiny volume of the phase space of possible universes – about $1/10^{10^{123}}$ of the entire volume, for the situation under consideration. (The pin, and the spot aimed for, are not drawn to scale!)

Sober view on fine-tuning: Extreme sensitivity

Phenomenology of Standard Model (of particle physics + hot big bang cosmology) turns out to be *extremely sensitive* to most parameter values

Even Glashow (one of the creators of the Standard Model of PP) got this wrong!



'Imagine a television set with lots of knobs: for focus, brightness, tint, contrast, bass, treble, and so on. The show seems much the same whatever the adjustments, within a large range. The Standard Model is a lot like that. Who would care if the tau lepton mass were doubled or the Cabibbo angle halved? The standard model has about 19 knobs. They are not really adjustable: they have been adjusted at the factory. Why they have their values are 19 of the most baffling meta-questions associated with particle physics.' (S.L. Glashow, 1999)

Actual values do seem "fine-tuned for life" (*but this does not imply that other values would not lead to other "special" features of the Universe*)

Responses to “fine-tuning for life”

Regard fine-tuning as a ***Coincidence***: *“a surprising concurrence of events, perceived as meaningfully related, with no apparent causal connection”* (Diaconis & Mosteller, 1989)

Blind Chance: Universe really *is* a meaningless coincidence, with two further options:

- **Multiverse** plus Weak Anthropic Principle (no other Universe would have us)
  “*The Improbability Principle”* (Hand) = “*The Law of truly large numbers”* (Diaconis & Mosteller):
  “Rare events occur with high frequency in the presence of large numbers of events”
- **Single Universe:** accepting meaninglessness, this is as good as a Multiverse!

Common Cause: lack of causal connection between coinciding events is only *apparent:*

- **Unique Universe:** Yet unknown physical principles fix all constants and conditions at their actual (*seemingly* random) values (Renormalization group fixed points? Quantum gravity?)

  “God would have been unable to make things in a different way or in a different order”
  (Spinoza, *Ethica*)

  Using Bayesian probabilistic hypothesis testing, Fine-Tuning does not prefer any of these options (i.e. Multiverse, Single Random Universe, Meaningless or Designed Unique Universe)

Problems with the Multiverse

- Proposed physical mechanisms are unconvincing:

  Inflation requires even more fine-tuning than life ("*Cane Toad Fallacy*": In 1935 Australia imported 102 cane toads to eat cane beetles affecting sugar cane crop and now has 200M cane toads poisoning all life)

  String theory ("Landscape") confuses the inability to predict anything with the ability to predict everything

- Multiverse hypothesis gives same (Bayesian) probabilistic support to fine-tuning as single Universe hypothesis

Problems with the Argument from Design

- Deriving Design from Fine-Tuning is ultimately *circular*: to get it going, life must *already* be considered meaningful

- (Bayesian) probabilistic support for Design hypothesis is even *weakened* by fine-tuning (Halvorson vs Swinburne):

$$P(D) = P(D, L) + P(D, \text{not-}L) \leq 2P(D, L) \leq 2\,P(L)$$

since $P(D, \text{not-}L) \leq P(D, L)$ by assumption, so the *a priori* probability P(D) of Design gets *smaller* the more precise the fine-tuning for life—and hence the smaller P(L)—is

Indeed, why would God walk a tightrope creating life?

1% of the literature

J. Barrow & F. Tipler, *The Anthropic Cosmological Principle* (OUP, 1986)

R. Breuer, *The Anthropic Principle* (Springer, 1991)

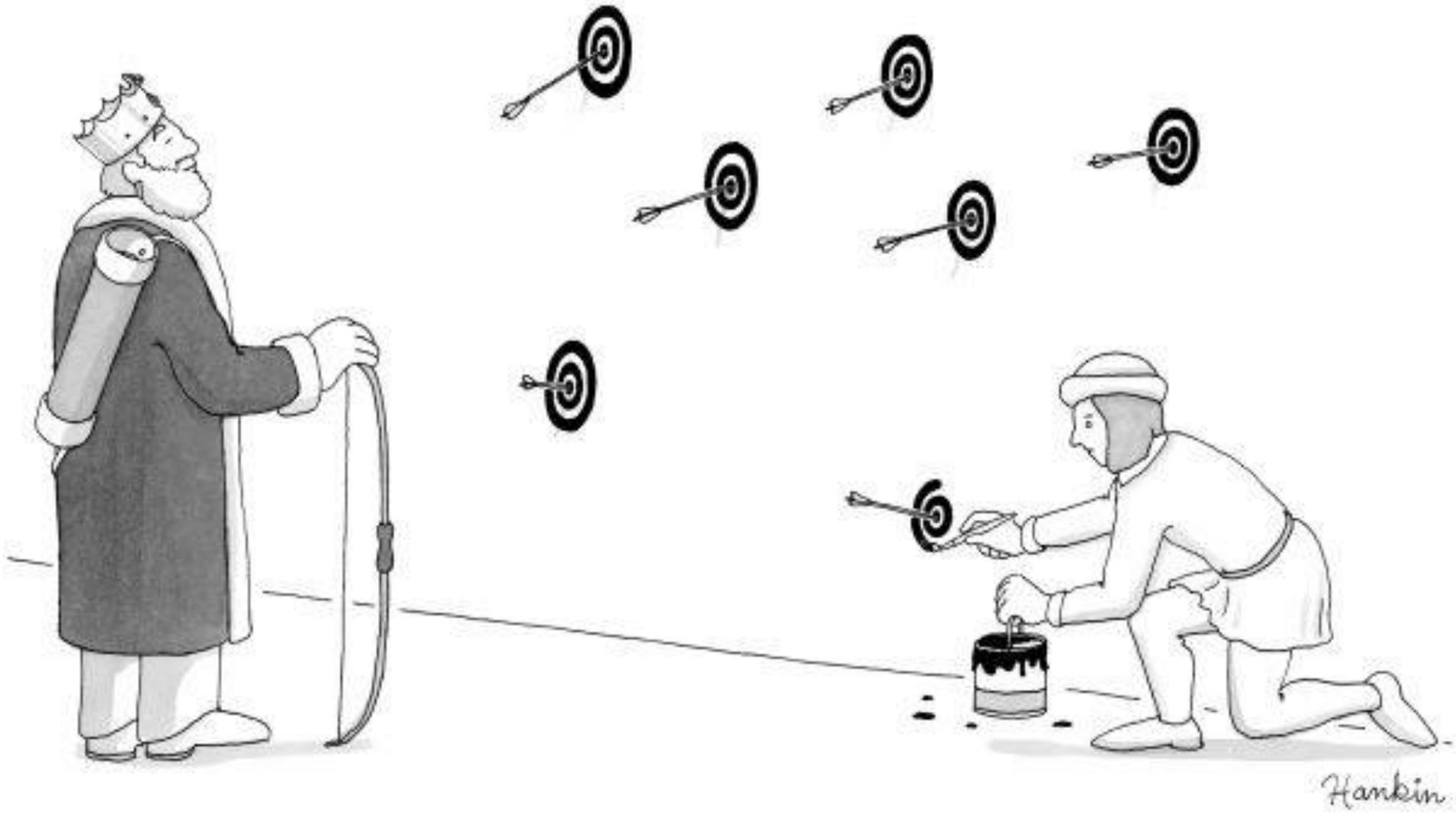
P.D. Ward & D. Brownlee, *Rare Earth* (Copernicus Books, 2000)

C.J. Hogan, Why the Universe is just so, *Rev. Mod. Phys*. (2000)

N. Bostrom, *Anthropic Bias* (Routledge, 2002)

M. Tegmark, A. Aguirre, M. Rees, F. Wilczek, Dimensionless constants, cosmology, and other dark matters, Phys. Rev. D73, 023505 (2006)

N.P. Landsman, The fine-tuning argument (*The Challenge of Chance*, 2016)



‘A mild form of satire may be the appropriate antidote. Imagine, if you will, the wonderment of a species of mud worms who discover that if the constant of thermometric conductivity of mud were different by a small percentage they would not be able to survive.’ (John Earman, 1987)