Journal for General Philosophy of Science
https://doi.org/10.1007/s10838-025-09734-8

ARTICLE

The Universe's Fine-Tuning Does Call for Explanation

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Accepted: 7 May 2025

Abstract
In recent years, several prominent authors have criticized fine-tuning arguments for failing to show that the universe's purported fine-tuning for intelligent life calls for explanation. In this paper, I provide a systematic categorization and a detailed evaluation of the proffered critiques. I argue that these critiques cast doubt on various instances of fine-tuning reasoning, but fail to undermine fine-tuning arguments' conclusion that the universe's purported fine-tuning for intelligent life calls for explanation. I then explicate the implications of this result for the ongoing philosophical debate concerning the merits of fine-tuning arguments and the conditions under which specific events or states of affairs are justifiably taken to call for explanation.

Keywords Fine-tuning arguments · Life · Anthropic principles · Scientific method · Probability · Explanation

1 Introduction

Over the last few decades, many authors have argued that the universe is *fine-tuned* for intelligent life (henceforth, FT; e.g., Barnes 2012; Barrow and Tipler 1986; Carr and Rees 1979; Carter 1974; Collins 2003; Davies 2006; Leslie 1986; McMullin 1993). The idea is that intelligent life could evolve in this universe only if the values of this universe's fundamental parameters (e.g., initial conditions, constants of physics) would fall within a *highly specific* range, and that this range is *very narrow* compared to the range of values that – according to the best available physical theories – would not permit intelligent life (e.g., Barnes 2018; Bradley 2001; Friederich 2019a; Hogan 2000; Holder 2004; Lewis and Barnes 2016, Ch. 1; Rees 2000; Roberts 2012). Alleged instances of FT involve a wide range of fundamental parameters, including: the value of the cosmological constant (e.g., Durrer and Maartens 2008; Friederich 2019b; Williams 2015); the overall energy density and the relative amplitude of energy density fluctuations in the very early universe (e.g.,

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Published online: 14 November 2025

Garriga and Vilenkin 2006; Lewis and Barnes 2016, Ch. 4; Tegmark and Rees 1998); the relative strength of the four fundamental forces (e.g., Barnes 2012; Carr and Rees 1979; Rees 2000, Ch. 3); and the relative masses of electrons, protons, quarks and neutrinos (e.g., Damour and Donoghue 2008; Jaffe et al. 2009; Tegmark et al. 2005).

Fine-tuning arguments (henceforth, FTAs) build on these alleged instances of FT to infer that FT calls for explanation. The idea is that those alleged instances of FT are *extremely unlikely* to occur "purely by chance" (Carlson and Olsson 1998, 255; also Roberts 2012, 288) and that the probability of FT is *much lower* conditional on the hypothesis that this universe's fundamental parameters have taken values in the range that permits intelligent life purely by chance (henceforth, CHANCE) than it is conditional on non-chance-based explanatory hypotheses (henceforth, ~CHANCE) such as multiverse hypotheses (e.g., Bousso et al. 2009; Hall and Nomura 2008; Leslie 1989, Ch. 4; Smolin 1997), cosmic design hypotheses (e.g., Collins 1999; Holder 2002; Swinburne 1990; White 2018) or to-be-specified future physical theories (e.g., Einstein 1949; Schellekens 2013; Schneider 2022). According to FTAs, FT evidentially favours ~CHANCE over CHANCE in the sense that "it seems to be *extraordinarily unlikely* that the [parameter values] would *just happen* to fall in the narrow life-sustaining range" (Kotzen 2012, 827, emphasis added) and that FT is "*far less unlikely*" given non-chance-based explanatory hypotheses than it is "given the hypothesis that the [parameter values are set] by chance" (Roberts 2012, 288, emphasis added). The idea is that the extreme improbability of FT conditional on CHANCE, together with the availability of prima facie plausible ~CHANCE that make FT considerably less unlikely than it is conditional on CHANCE, indicates that FT calls for some non-chance-based explanation (e.g., Polkinghorne 1991, 77–80; White 2007, 461). As Parfit puts it, "of the range of possible initial conditions, fewer than one in a billion billion would have produced a universe with the complexity that allows for life. If this claim is true […] there is something that cries out to be explained" (Parfit 1998, 4; also Barnes 2018, 254; Susskind 2005, 343).

In recent years, several prominent authors have criticized FTAs for failing to show that FT calls for explanation. In their view, FT is justifiably regarded as a *brute fact*, a cosmic coincidence that we should regard as such (e.g., Bradford 2011; Callender 2004a; Colyvan et al. 2005; Grünbaum 2004; Juhl 2006; Manson 2009; McGrew et al. 2001; Norton 2010; Sober 2009; Worrall 1996). Several objections have been articulated against FTAs. In this paper, I provide a systematic categorization and a detailed evaluation of these objections. I shall argue that the proffered objections cast doubt on various instances of fine-tuning reasoning, but fail to undermine FTAs' conclusion that FT calls for explanation. I will then explicate the implications of this result for the ongoing philosophical debate concerning the merits of FTAs and the conditions under which specific events or states of affairs are justifiably taken to call for explanation.

The paper is organized as follows. Section 2 outlines the argument structure of FTAs and examines various factors that bear on the merits of FTAs. Sections 3–7 explicate and address the most prominent objections that have been put forward against FTAs, namely: the objection from *unjustified probability ascriptions* (e.g., Colyvan et al. 2005; McGrew et al. 2001); the objection from *observation biases* (e.g., Manson 2009; Sober 2009); the objection from *causal ramification* (e.g., Bradford 2011; Juhl 2006); the objection from *mistaken explanatory demand* (e.g., Callender 2004a; Norton 2010); and the objection from *lack of testable explanatory alternatives* (e.g., Grünbaum 2004; Worrall 1996). If correct, my claim that these objections fail to undermine FTAs does not per se substantiate specific non-chance-based explanatory hypotheses for FT, but does vindicate the proffered calls to explain FT. More generally, my evaluation aims to inform the ongoing cross-disciplinary

debate regarding the justifiability of FTAs in at least three respects of general interest to scientists and philosophers of science. First, it addresses a number of influential concerns targeting FTAs' argument structure and alleged pitfalls that build on prima facie plausible empirical and methodological presuppositions. Second, it draws multiple connections between parallel debates about FTAs and scientific explanation that are still insufficiently integrated across the specialized philosophical and scientific literatures. And third, it provides a framework for assessing the proffered calls to explain FT and other instances of fine-tuning reasoning in light of recent developments in cosmology, epistemology and general philosophy of science.

2 Fine-Tuning Arguments: Analysis

FTAs' argument structure may be schematized as follows:

P1. FT, i.e. the universe is fine-tuned for intelligent life.
P2. Pr (FT | ~CHANCE) ≫ Pr (FT | CHANCE), i.e. the probability of FT conditional on ~CHANCE is much higher than the probability of FT conditional on CHANCE.
P3. If FT and Pr (FT | ~CHANCE) ≫ Pr (FT | CHANCE), then we should endorse ~CHANCE, i.e. FT calls for non-chance-based explanation.
C. We should endorse ~CHANCE, i.e. FT calls for non-chance-based explanation.[1]

The following remarks concerning FTAs' argument structure bear on the merits of FTAs.

First, FTAs assume that this universe is *fine-tuned* for intelligent life in the sense that intelligent life could evolve in this universe only if the values of this universe's fundamental parameters would fall within a *highly specific* range, and that this range is *very narrow* compared to the range of values that – according to the best available physical theories – would not permit intelligent life (Sect. 1; also Barnes 2012; Barr and Khan 2007; Bousso et al. 2009; Hawking 1988; Tegmark et al. 2006). The idea is that "out of the range of values these parameters could have taken, only a small [range of values permits intelligent life] and yet the actual values fall in that small range" (Weisberg 2010; 432; also Monton 2006, 405; Weisberg 2012, 708; White 2011, 676). Not all scientists and philosophers debating about FTAs are persuaded that the universe is fine-tuned for intelligent life in this sense (e.g., Adams 2019, Sect. 10, holding that some instances of FT are less numerically impressive than previous works suggest; Manson 2009, holding that various alleged instances of FT are an artifact of calculation mistakes; McGrew et al. 2001, doubting researchers' ability to reliably estimate what combinations of parameter values permit

[1] For other schematizations of FTAs' argument structure see, e.g., Colyvan et al. (2005, 325–326), Manson (2009, 271–274), Monton (2006, 405–407), Roberts (2012, 288–292). Some FTAs treat FT as part of scientists' background information and regard the fact that the values of this universe's fundamental parameters permit intelligent life as the relevant evidence (e.g., McGrew 2016; Sober 2009). However, most FTAs aptly regard FT as the relevant evidence. For what motivated FTAs is not the fact (entailed by our own existence) that the values of this universe's fundamental parameters permit intelligent life, but rather the discovery that intelligent life requires a highly precise match between this universe's parameter values and a very narrow range of parameter values (e.g., Roberts 2012, 292; also Weisberg 2010, 431–432; White 2011, 676). And this discovery was regarded as extremely surprising by scientists (e.g., Boyce and Swenson 2024, 1; Collins 2009, 203–204; Harker 2012, 257–258; Hawthorne and Isaacs 2017, 145).

intelligent life). However, most authors concur that several alleged instances of FT cannot be plausibly explained away simply by appealing to calculation mistakes or to researchers' uncertainty regarding what combinations of parameter values permit intelligent life (e.g., Agrawal et al. 1998; Barnes 2018; Barrow et al. 2008; Davies 2006; Friederich 2019a; Koperski 2014). In fact, many critics of FTAs observe that although "the tuning of some [parameters] may not be as numerically impressive as is sometimes claimed, [FT] is evidently a feature of the world" (Bradford 2011, 1577; also Callender 2004a, 200, Norton 2010, 522).[2]

Second, some critics of FTAs doubt FTAs' assumption that this universe is fine-tuned for *intelligent life* on the alleged ground that "we simply do not know" what forms intelligent life may take (Wilson 1991, 170; also Carlson and Olsson 1998; Harker 2012) and that, therefore, intelligent life could evolve from combinations of parameter values that significantly differ from the combinations we think are required for intelligent life (e.g., Adams 2008; Aguirre 2001; Harnik et al. 2006). These remarks correctly note that different forms of intelligent life may exist besides the carbon-based forms of intelligent life we know. Still, pointing to our current ignorance concerning what forms intelligent life may take does not per se cast doubt on FTAs' assumption that this universe is fine-tuned for intelligent life. For no precise definition of the notion of intelligent life is required to justifiably infer that only highly specific combinations of parameter values would permit the chemical complexity required for intelligent life (e.g., Collins 2009, 215, holding that "if the strength of gravity were smaller or larger by an estimated one part in 10^{60} of its current value, the universe would have either exploded too quickly for galaxies and stars to form, or collapsed back on itself too quickly for life to evolve"; Hawking 1996, 156, holding that "if the rate of expansion one second after the Big Bang had been smaller by even one part in one hundred thousand million million, the universe would have recollapsed before it ever reached its present state").[3]

Third, the term *CHANCE* figuring in FTAs refers to the hypothesis that this universe's fundamental parameters have taken values in the very narrow range that permits intelligent life "purely by chance" (Carlson and Olsson 1998, 255; also Landsman 2016, 113). The idea is that FT can be plausibly 'explained' by referring to "chance alone" without having to invoke explanatory posits such as multiverses, cosmic designers or hitherto unconceived physical laws/mechanisms (Roberts 2012, 288; also McCoy 2019, 1265; Sober 2019, 3). Conversely, the term *~CHANCE* refers to the negation of CHANCE. Three types of ~CHANCE figure prominently in the FTAs literature, namely: *multiverse* hypotheses, which posit the existence of (possibly uncountably) many causally isolated space–time regions, only few of which permit intelligent life (e.g., Bousso et al. 2009; Bradley 2009;

[2] In attempting to determine the probability that the fundamental parameter values would fall within the range that permits intelligent life, many consider changes in the values of specific fundamental parameters, taken individually (holding the values of the other parameters constant). However, considerations of simultaneous changes in the values of multiple fundamental parameters (holding the values of the other parameters constant) also inform attempts to determine the probability that the fundamental parameter values, taken collectively, would fall within the range that permits intelligent life (e.g., Adams 2019, 80–84; McGrew and McGrew 2005, 427; Sober 2019, 62; also Sect. 3 for related discussion).

[3] The claim that only highly specific combinations of parameter values would permit the chemical complexity required for intelligent life by no means entails that this universe is optimal for intelligent life. In fact, various proponents and critics of FTAs concur that, according to the best available physical theories, some combinations of parameter values would lead to universes that are more favorable than this universe to intelligent life (e.g., Adams 2019, 83–84; Barnes 2012, 529).

Friederich 2019a; Hall and Nomura 2008; Leslie 1989, Ch. 4; Smolin 1997; Susskind 2005);[4] *cosmic design* hypotheses, which posit the existence of a cosmic designer who deliberately set all the fundamental parameter values within the very narrow range of values that permits intelligent life (e.g., Barnes 2012; Collins 1999; Craig 2003; Davies 1992, Ch. 7–8; Holder 2004; Swinburne 2004, Ch. 8; White et al. 2018);[5] and appeals to *future physical theories*, which posit that some to-be-specified future physical theories will enable physicists to account for the values of the fundamental parameters in terms of hitherto unconceived physical laws/mechanisms (e.g., Einstein 1949; Schellekens 2013; Schneider 2022).[6] Some of the hypotheses encompassed by ~CHANCE allow for the possibility that some chancy processes may be causally involved in FT (e.g., the actualization of a multiverse may involve chancy processes; a cosmic designer may decide that the values of the universe's fundamental parameters be set by chancy processes; and chancy processes may figure prominently in future physical theories' explanations of FT). Still, all the hypotheses encompassed by ~CHANCE are incompatible with CHANCE in that they deny CHANCE's claim that this universe's fundamental parameters have taken values in the range that permits intelligent life purely by chance.[7]

Fourth, what FTAs take to *call for explanation* is not merely the fact that this universe's fundamental parameters take some specific *value* or other, but rather the highly precise *match* between the values of this universe's fundamental parameters and the very narrow range of parameter values that (according to the best available physical theories) permits intelligent life (e.g., Barnes 2012, 562; Juhl 2006, 270; Roberts 2012, 292; Weisberg 2005, 809). In particular, FTAs' claim that FT calls for explanation indicates not merely that many regard FT as psychologically surprising or desire to find an explanation for FT, but also that "it would be *epistemically unsatisfactory* to leave [FT] unexplained, or to 'explain' it by referring to chance [alone]" (Carlson and Olsson 1998, 257, emphasis added; also Bostrom 2007, 12). The idea is that the probability of FT conditional on ~CHANCE is

[4] The term 'multiverse' is occasionally used to refer to the collection of branching universes posited by the 'many-worlds' interpretation of quantum mechanics (e.g., Deutsch 2002; Leslie 1986). However, in this paper I follow most proponents and critics of FTAs in using the term 'multiverse' to specifically indicate the ensemble of causally isolated space–time regions posited by multiverse hypotheses in the context of FTAs (e.g., Adams 2019, 7; Collins 2009, 204; Friederich 2017, 374; Isaacs et al. 2022, 252, for a similar usage).

[5] I speak of 'cosmic' rather than 'theistic' design since the proponents of cosmic design are not committed to ascribe to the cosmic designer they posit the attributes (e.g., omnibenevolence) that major theistic religions ascribe to God (e.g., Carlson and Olsson 1998, 262; Hawthorne and Isaacs 2018, 138; Monton 2006, 406; van Inwagen 1993, 133).

[6] In commenting on the prospects of future physical theories, Einstein conjectures that it may be "possible logically to lay down such strongly determined laws that within these laws […] completely determined constants occur" (Einstein 1949, 63). However, Einstein presents such logical possibility as "a theorem which at present cannot be based upon anything more than upon a faith in the […] intelligibility of nature" (Einstein 1949, 62). In particular, he notes that "contemporary theoretical physicists [have] entirely differing opinions concerning […] the theoretical foundation of the physics of the future" (Einstein 1949, 81; also Adams 2019, 6, commenting on the "not yet realized […] hope" that a more fundamental theory may enable physicists to derive the large number of Standard Model parameters from a smaller set of parameters).

[7] Distinct ~CHANCE are occasionally presented as rivals (e.g., Carlson and Olsson 1998, 269, on the putative contrast between cosmic design and multiverse hypotheses). However, for my evaluation, all those ~CHANCE can be plausibly clustered together in the same category since their proponents agree both that there is convincing evidence of FT and that FT does call for some non-chance-based explanation. Below I do not take a position concerning the merits of specific ~CHANCE since my defence of FTAs is compatible with different positions concerning the merits of specific ~CHANCE.

much higher than the probability of FT conditional on CHANCE and that this inequality, in turn, gives us strong epistemic reason to reject the view that FT is justifiably regarded as a brute fact and can be plausibly 'explained' by referring to chance alone (e.g., Baras 2022, Ch. 1; also Leslie 1989, 10; White 2007, 457).[8]

Finally, substantiating FTAs' claim that FT calls for explanation requires one to substantiate the claim that the probability of FT conditional on ~CHANCE is much higher than the probability of FT conditional on CHANCE, but does not require one to ascribe *quantitatively precise* probabilities to the propositions figuring in FTAs (e.g., Collins 2009, 241; McGrew 2018, 148; Sober 2012, 361). Also, the probability ascriptions figuring in FTAs are more plausibly taken to express *subjective* beliefs about the degree of evidential support that FT provides to CHANCE (or ~CHANCE) – i.e. the degree to which one should believe CHANCE (or ~CHANCE) given evidence of FT – rather than objective claims about nature (e.g., Bostrom 2002a, 618; Isaacs et al. 2022, 248; Pruss 2005, 409; White 2011, 677). In fact, most authors (including many critics of FTAs) concur that FTAs are "unfairly weakened" if they are "saddled with the requirement that [their] probability claims must be objective claims about nature" (Monton 2006, 407–408; also McGrew and McGrew 2005, 435; Weisberg 2010, 433, for similar remarks). This by no means entails that all the probability ascriptions figuring in FTAs are equally plausible. For not all such probability ascriptions provide equally plausible expressions of the degree of evidential support that FT provides to CHANCE or ~CHANCE (e.g., Baras 2020, 1505; Barnes 2019, 1222–1223). I shall expand in the following sections on the plausibility of different probability ascriptions and on the theoretical and empirical grounds on which such ascriptions are based.[9]

3 Objection from Unjustified Probability Ascriptions

The objection from *unjustified probability ascriptions* holds that FTAs fail to show that FT calls for explanation on the alleged ground that the proponents of FTAs lack an adequate basis to substantiate FTAs' assumption that FT is extremely unlikely to occur purely by chance. The objection proceeds as follows. Assessing the extent to which this universe is fine-tuned for intelligent life requires one to specify the range of fundamental parameter values that permits intelligent life and the probability distributions for these fundamental parameter values (e.g., Adams 2019, 6–7; Manson 2000, 345). However, the objection goes,

[8] For simplicity, I speak as if FT either does or does not call for explanation. My defence of FTAs can accommodate the intuition that FT may call for explanation to a greater or lesser degree (e.g., Baras 2022, 64). For instance, one may say that (other things being equal) the larger the ratio between Pr (FT | ~CHANCE) and Pr (FT | CHANCE), the more FT is justifiably taken to call for some non-chance-based explanation.

[9] For further debate concerning how degrees of evidential support constrain subjective beliefs, e.g., Beisbart and Hartmann (2011), Climenhaga (2024), Norton (2008). The probability of FT conditional on specific ~$CHANCE_i$, taken individually, is lower than the probability of FT conditional on the disjunction of all the proffered ~CHANCE, taken collectively. As a result, the probability of FT conditional on CHANCE may be higher than the probability of FT conditional on some of the proffered ~$CHANCE_i$, taken individually. Still, according to FTAs, the probability of FT conditional on ~CHANCE is much higher than the probability of FT conditional on CHANCE. This, together with the limited number of prima facie plausible ~$CHANCE_i$, purportedly indicates that – for at least some individual ~$CHANCE_i$ – pr (FT | ~$CHANCE_i$) > pr (FT | CHANCE), i.e. FT evidence supports some non-chance-based explanatory hypotheses over the explanatory hypothesis that FT occurs purely by chance.

the range of physically possible values of various fundamental parameters appears to be *potentially unbounded*, leading to an infinite space of physically possible parameter values (e.g., McGrew et al. 2001, 1028; Wenmackers 2023, 55). Moreover, there is *no adequate basis* to ascribe to each region of the infinite space of physically possible parameter values plausible probabilities such that the sum of these probabilities is 1. For those probabilities add up to either 0 – if each region of the infinite space of physically possible parameter values is assigned probability 0 – or infinite – if each region of the infinite space of physically possible parameter values is assigned probability > 0 (e.g., Manson 2009, 281; McGrew et al. 2001, 1027). Hence, the proponents of FTAs lack an adequate basis to demonstrate that it is extremely unlikely that the values of the fundamental parameters would fall within the range that permits intelligent life, and FTAs' assumption that FT is extremely unlikely to occur purely by chance remains unsubstantiated (e.g., Colyvan et al. 2005, 328; McGrew et al. 2001, 1032).[10]

This objection correctly notes that various conceptual and evidential difficulties affect attempts to substantiate FTAs' assumption that FT is extremely unlikely to occur purely by chance. However, I can think of at least two reasons to doubt that the objection undermines FTAs. First, supporting FTAs' assumption that FT is extremely unlikely to occur purely by chance does *not* require the proponents of FTAs to rely on probability distributions defined over an *infinite* space of physically possible parameter values. For the proponents of FTAs can draw on both theoretical reasons and empirical evidence to identify *defensible bounds* on the range of physically possible parameter values (e.g., Koperski 2005, 307, holding that "it is likely that the four basic forces can only take on a limited range of values relative to one another"; Barnes 2019, 1245–1246, holding that "dimensional parameters are bounded by the Planck scale [since] the standard models [in which such parameters figure] are only mathematically well-defined within the Planck limits"). And on most proposed identifications of such bounds, the range of parameter values falling within the identified bounds is wide enough to make the FT constraint significant (e.g., think of Collins' 2009, 215, claim that "the density of matter at the Plank time […] must have been tuned to one part in 10^{60} of the so-called critical density"; also Davis 1987, 146; McGrew 2016, 90; McMullin 2005, 610–611, for additional illustrations).[11]

[10] Some critics of FTAs hold that FTAs' assumption that FT is extremely unlikely to occur purely by chance remains unsubstantiated because such assumption rests on the so-called principle of indifference, which instructs one to assign a uniform probability distribution over the space of physically possible parameter values and regard individual parameter values within such space as equiprobable (e.g., Eva 2019). The idea is that supporting FTAs' assumption that FT is extremely unlikely to occur purely by chance requires the proponents of FTAs to rely on the principle of indifference and that their ignorance concerning the space of physically possible parameter values makes their reliance on such principle unjustified (e.g., Manson 2000, 346–348; McGrew et al. 2001, 1029). I do not expand on this criticism since the proponents of FTAs may support FTAs' assumption that FT is extremely unlikely to occur purely by chance without having to rely on the principle of indifference (e.g., Monton 2006, 410, holding that "there is no need [for the proponents of FTAs to assign] probabilities to each element in the space of possible sets of values of the fundamental [parameters]"; Hawthorne and Isaacs 2017, 151–152, holding that FTAs are not "based on any sort of judgment that all parameter-values are equally likely [or] that all areas of parameter-space with equal size must have equal probability").

[11] Some critics of FTAs object that the best available physical theories "provide no grounds for the parameters to have [their] specific values" and that "reexpressing [this] neutral support as low probability [may lead to] an unwarranted demand for explanation" (Norton 2010, 522). However, the fact that the best available physical theories do not enable scientists to derive the specific values of the fundamental parameters by no means excludes that these theories may favour some parameter values over others (e.g., Hawthorne and Isaacs 2017, 134). Moreover, as the involved critics of FTAs acknowledge, pointing to concerns about neu-

And second, the proponents of FTAs may *support* FTAs' assumption that FT is extremely unlikely to occur purely by chance even in cases where they are *unable* to identify defensible bounds on the range of physically possible parameter values. To illustrate this, consider so-called non-standard probability approaches, which extend the real number line standardly used to express the values of probability functions to a totally ordered field including infinitesimal values, i.e. values that "are infinitesimally greater, or less, than any standard number strictly between 0 and 1" (Vallentyne 2000, 276). Non-standard probability functions can assign infinitesimal probabilities to each possibility such that the probability of each possibility is > 0 and the sum of the probabilities over all possibilities is ≤ 1 (e.g.. Vallentyne 2000, 276; also Benci et al. 2018). These probability functions provide the proponents of FTAs with a mathematically tractable basis to support FTAs' assumption that FT is extremely unlikely to occur purely by chance even in cases where they are unable to identify defensible bounds on the range of physically possible parameter values (e.g., Pruss 2021a, 777–780; also Koperski 2005, 306–311, on the possibility of supporting such assumption in measure-theoretic terms).[12]

A critic of FTAs may object that FTAs' assumption that FT is extremely unlikely to occur purely by chance is *arbitrary* on the alleged ground that the correct probability measure of the set of physically possible parameter values that permit intelligent life is *severely underdetermined* by the available empirical evidence (e.g., Albert 2012, 33–34; Colyvan et al. 2005, 330; Manson 2000, 348). The idea is that FTAs depend on "a subjectively variable sense of which assessments of probabilities are reasonable" and that this dependence renders them "effectively forceless" (McGrew et al. 2001, 1035; also Harker 2012, 253; Sober 2003, 49). However, I doubt that this objection undermines FTAs. For the proponents of FTAs can rely on multiple approaches to address the proffered arbitrariness concern (e.g., Benci et al. 2018; Pruss 2021a, on approaches based on imprecise probabilities). In particular, FTAs' dependence on subjective probability ascriptions does not per se render FTAs 'effectively forceless'. For as noted in Sect. 2, the proponents of FTAs can rely on both theoretical and empirical constraints to *narrow down* the set of putatively plausible subjective probability ascriptions. And various such probability ascriptions support FTAs' assumption that FT is extremely unlikely to occur purely by chance (e.g., Monton 2006, 407–413; Roberts 2012, 301–302). In fact, most authors (including many critics of FTAs) agree that, for all we know, the values of at least *some* fundamental parameters are extremely unlikely to fall within the range that permits intelligent life (e.g., Collins 2009, 240–241; Hawthorne and Isaacs 2018, 139; Kotzen 2012, 827; also Sect. 1). This, in turn, provides prima facie convincing support to FTAs' assumption that FT is extremely unlikely to occur purely by chance.[13]

Footnote 11 (continued)
tral support does not per se undermine FTAs' conclusion that FT calls for explanation (e.g., Norton 2010, 522).

[12] Some critics of FTAs object that every finite range of parameter values is equally narrow compared with an infinite range of physically possible parameter values (e.g., Colyvan et al. 2005, 327). However, as noted by other critics of FTAs, the narrowness of the range of parameter values that permit intelligent life "does affect" how much FT evidence favours ~CHANCE over CHANCE (Sober 2019, 65). In this respect, it would be overly demanding to require that the proponents of FTAs specify exactly how narrow the range of parameter values that permit intelligent life must be to substantiate FTAs (e.g., McGrew et al. 2001, 1032). For "there is no [precise] line" between ranges that are too wide and ranges that are sufficiently narrow to substantiate FTAs, and "the difference [between such ranges] is a matter of degree" (Sober 2019, 65).

[13] A critic of FTAs may further object that due to the highlighted normalizability/arbitrariness concerns, it remains difficult to provide conclusive justification for choosing any particular probability distribution

4 Objection from Observation Biases

The objection from *observation biases* holds that FTAs fail to show that FT calls for explanation on the alleged ground that FTAs derive specious plausibility from various observation selection effects. The objection proceeds as follows. Since we exist, the values of this universe's fundamental parameters *must* have fallen within the range that permits intelligent life (e.g., Carter 1974, 291–298). Moreover, we are guaranteed to *observe* that the values of the fundamental parameters have fallen within the range that permits intelligent life (e.g., Manson 2009, 274–278). As a result, the probability of observing that the values of this universe's fundamental parameters have fallen within such range does not vary depending on whether one assumes ~CHANCE or CHANCE (e.g., Sober 2009, 77–78), and our discovery of FT does not favor ~CHANCE over CHANCE (e.g., Sober 2009, 84; also 2003, 41–47).

This objection correctly notes that various observation selection effects may affect the informativeness of the evidence put forward in debates about FTAs. However, I can think of at least two reasons to doubt that the objection undermines FTAs. First, the evidence supporting FTAs is not the observation (entailed by our own existence) that the values of this universe's fundamental parameters fall within the range that *permits* intelligent life, but rather the previously unexpected finding that only a *very narrow* range of parameter values permits intelligent life (e.g., Hawthorne and Isaacs 2017, 145; White 2011, 676). Hence, our background information that the parameter values fall within the range that permits intelligent life does not per se neutralize the informativeness of FT evidence (e.g., Kotzen 2012, 835–837; Weisberg 2005, 818–819).[14]

And second, the finding that a *very narrow* range of parameter values permits intelligent life *does support* ~CHANCE over CHANCE. For as noted by several critics of FTAs, scientists could have conceivably discovered that a wide range of parameter values permits intelligent life (e.g., Weisberg 2010, 434; also footnote 1 on how scientists expected that a much wider range of parameter values would permit intelligent life). And although the parameter values could have conceivably matched the very narrow range of values required for intelligent life purely by chance, it is extremely unlikely that this highly precise match occurred purely by chance (e.g., Bradley 2012, 437, White 2011, 679; also Parfit 1998, 4,

Footnote 13 (continued)

for the fundamental parameter values (e.g., Landsman 2016, 119). However, as leading critics of FTAs acknowledge, it would be unwarranted to reject FTAs solely because of these concerns since one may raise analogous concerns with regard to a vast range of influential works and widely used approaches in cosmology and statistical mechanics (e.g., McGrew 2018; also Koperski 2005; Pruss 2021b). In light of this consideration, the highlighted normalizability/arbitrariness concerns are more plausibly seen as open problems in epistemology and probability theory than as preconditions for engaging in meaningful debates about the merits of FTAs (e.g., Wenmackers 2023, 55–59, for similar remarks).

[14] A critic of FTAs may object that "once we know that intelligent life exists […] learning that our physics allows for intelligent life via fine-tuning tells us no more about the [probability of ~CHANCE] than the existence of intelligent life told us already" (Weisberg 2010, 433). The idea is that "our old empirical knowledge that intelligent life exists neutralizes the informativeness of fine-tuning data [by making CHANCE or ~CHANCE] equiprobable" (Weisberg 2010, 434). However, most critics of FTAs concur that intelligent life is more to be expected given ~CHANCE than given CHANCE (Weisberg 2010, 433; also 2012, 709). And, as I argue in the rest of this section, the discovery that intelligent life requires a highly precise match between this universe's parameter values and a very narrow range of parameter values is plausibly taken to increase this difference, thereby supporting FTAs (e.g., Dorst and Dorst 2022, 15–19; White 2011, 677, for similar remarks).

holding that it "is hard to believe [that FT] was a mere coincidence […] since, if it were true, the chance of this coincidence occurring would be below one in a billion billion"). That is to say, evidence of FT provides us with *additional* reason to endorse ~CHANCE compared to when we did not know that this universe is fine-tuned for intelligent life (e.g., Bostrom 2002b, Ch. 2). And as various critics of FTAs acknowledge, this holds even if the parameter values' falling within the very narrow range that permits intelligent life was a *precondition* for us to observe FT (e.g., Juhl 2006, 274, holding that "the fact that we would not be around to observe other, 'untuned' values does not [undermine the claim that] the values being 'just right' for [intelligent life] calls for explanation"; also Sober 2019, 70, holding that the observation that "the laws of physics permit life to exist only within a very narrow range of parameter values […] is not undermined" by observation selection effects).[15]

A critic of FTAs may object that FTAs do not withstand scrutiny because the proponents of FTAs typically commit "the fallacy of using *the same* evidence *twice*" in their attempts to boost both the unconditional probability of ~CHANCE – i.e. the probability of ~CHANCE without taking FT evidence into account – and the conditional probability of ~CHANCE on FT (Juhl 2007, 554, emphasis added). The idea is that FT evidence – being obtained in a universe that permits intelligent life – *entails* that the fundamental parameter values permit intelligent life, and that the proponents of FTAs cannot legitimately use such evidence to boost both the unconditional probability of ~CHANCE and the conditional probability of ~CHANCE on FT (e.g., Juhl 2007, 554–555). However, I doubt that this objection undermines FTAs. For the proponents of FTAs can provide reasons and/or evidence for ~CHANCE that do *not* entail that the parameter values permit intelligent life (e.g., Monton 2006, 419–421, on the possibility of relying on a priori arguments, such as the ontological argument, and arguments which appeal to empirical features of the universe that do not entail that the universe is life-permitting, such as some versions of the cosmological argument). In particular, the proponents of FTAs can provide *non-overlapping* sets of empirical findings to boost the unconditional probability of ~CHANCE and the conditional probability of ~CHANCE on FT (e.g., Collins 2009, 243, on the possibility of relying on empirical findings concerning distinct sets of fundamental constants to boost such probabilities; also Friederich 2017, 371–373, for a detailed illustration concerning multiverse hypotheses). That is to say, double counting concerns do constrain the set of reasons and/or evidence that the proponents of FTAs can legitimately use to support FTAs, but do not undermine their ability to support FTAs.[16]

[15] A critic of FTAs may object that since the proponents of FTAs commonly rely on beliefs that entail that this universe permits intelligent life in assessing the probability of ~CHANCE, the proponents of FTAs must abstract from their background information that intelligent life evolved in this universe, and such abstraction makes it difficult to support FTAs (e.g., Monton 2006, 415–418, on the difficulties inherent in determining what probability should be ascribed to ~CHANCE by an agent who is supposedly unaware that intelligent life evolved in this universe). This objection can be addressed by noting that the highlighted difficulty targets FTAs where the relevant evidence is "the proposition that the universe is life-permitting" (Monton 2006, 406–407) and that those FTAs significantly differ from the FTAs defended in this paper, which are motivated by the previously unexpected finding that only a very narrow range of parameter values permits intelligent life (footnote 1; also Roberts 2012, 292–293). In fact, leading critics of FTAs note that the proponents of FTAs may provide reasons and/or evidence that support FTAs and do not entail that the parameter values permit intelligent life (e.g., Monton 2006, 419–421, on various reasons and/or evidence for ~CHANCE).

[16] A critic of FTAs may further object that FTAs can be regarded as more or less plausible depending on what reference classes one uses to describe FT evidence (e.g., Sober 2012; also Halvorson 2018, 131; Pruss 2005, 423, on the possibility of replacing some parameters whose life-permitting range is narrow

5 Objection from Causal Ramification

The objection from *causal ramification* holds that FTAs fail to show that FT calls for explanation on the alleged ground that FT "is an expected consequence of [the causal complexity] of the actual physical world" (Juhl 2006, 269; also Bradford 2011, 1577, holding that "parameter sensitivity [in FT research] arises as a natural consequence of the mathematics of dynamical systems with complex outcomes"). The objection proceeds as follows. The alleged improbability of FT does not per se imply that FT calls for explanation. For "massively low probability events occur all the time" (Worrall 1996, 11), and we take only few such events to call for explanation (e.g., Callender 2004a, 205). Hence, "if we have any reason to believe that [FT is not] a brute fact, it must be something *other than*, or at least *in addition to*, its improbability" (Baras and Shenker 2020, 17, emphasis added; also Harker 2012, 247). As Juhl puts it, "practically any non-microscopic [phenomenon] in the universe is *causally ramified* [i.e.] causally depend[s] for its existence on a large and diverse collection of logically independent facts. […] Yet one does not observe [FTAs] from the existence of a pebble in one's back yard" (Juhl 2006, 271, emphasis added).

This objection correctly notes that the mere fact that an event is improbable does not per se imply that this event is justifiably taken to call for some non-chance-based explanation. However, I can think of at least two interrelated reasons to doubt that the objection undermines FTAs. First, considerations pertaining to the *extreme* improbability that an event occurred *purely by chance* can reliably indicate that such event calls for some non-chance-based explanation. To illustrate this, consider a monkey typing an extended string of text of 5020 letters. The monkey types '*Nel mezzo del cammin di nostra vita…*' and impeccably reproduces the text of the 5020 letters of the first Canto of Dante's *Inferno*. The monkey's typing a meaningful and grammatically correct 5020 letter sequence bears against the hypothesis that the monkey typed such sequence purely by chance. For the set of meaningful and grammatically correct 5020 letter sequences that the monkey can type is a rather minuscule subset of all 5020 letter sequences. To be sure, for any particular sequence of 5020 letters, the probability that the monkey types such sequence is (for all we know) as minuscule as the probability that the monkey types the first Canto of Dante's *Inferno*. Still, even if each sequence of 5020 letters is (for all we know) equally improbable, the probability that the monkey types the first Canto of Dante's *Inferno* purely by chance is much lower than the probability that the monkey types the first Canto of Dante's *Inferno* conditional on prima facie plausible non-chance-based explanatory hypotheses (e.g., Baras 2022, 134; White 2005, 3, on hypotheses involving intentional human manipulation). And one can think of plenty of 5020 letter sequences for which the corresponding inequality fails to hold (e.g., think of most meaningless and grammatically incorrect 5020 letter

Footnote 16 (continued)

with parameters whose life-permitting range is wide). I do not aim here to discuss the general issue of what reference classes one should use to describe the available evidence when assessing competing hypotheses (e.g., Draper 2020; Epstein 2017, for recent debate). For my evaluation, it suffices to note that the proponents of FTAs can ground probability ascriptions such that, on plausible specifications of the relevant reference classes, the set of physically possible parameter values that permit intelligent life gets a much lower probability measure than the set of physically possible parameter values that do not permit intelligent life (e.g., Kotzen 2012, 827; also Koperski 2005, for analogous measure theoretic results).

sequences). Hence, if the monkey types the first Canto of Dante's *Inferno*, we should seek a non-chance-based explanation for the monkey's behaviour.[17]

And second, the proponents of FTAs can *support* FTAs' conclusion that FT calls for explanation by drawing on *specific considerations* besides the extreme improbability of FT. To illustrate this, consider the putative axiological significance of intelligent life, i.e. the putative fact that a universe that permits intelligent life is axiologically significant "in a way that not all kinds of universe are" (Roberts 2012, 298; also Nagel 2012, 47; White 2007, 466). Considerations pertaining to the putative axiological significance of intelligent life may be plausibly taken to provide additional support to FTAs' conclusion that FT calls for explanation besides the support provided by the extreme improbability of FT. In particular, pointing to the putative axiological significance of intelligent life enables us to account for the intuition that only some causally ramified phenomena are justifiably taken to call for explanation. This does not per se exclude that, if one presupposes both that intelligent life evolved in this universe and that intelligent life is causally ramified, then one may justifiably regard it as unsurprising that intelligent life causally depends for its existence on the value of various parameters (e.g., Friederich 2023, Sect. 2.2).[18] Still, considerations pertaining to the putative axiological significance of intelligent life provide a prima facie plausible account of why "one does not observe [FTAs] from the existence of a pebble in one's back yard" (Juhl 2006, 271), whereas one observes many FTAs from the existence of intelligent life.[19]

A critic of FTAs may object that the proponents of FTAs typically *presuppose* (rather than *show*) that intelligent life is axiologically significant (e.g., Colyvan et al. 2005, 336; Landsman, 2016, 120; also Earman 1987, 314, ironically commenting on "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"). In particular, she may hold that when it comes to specifying *what forms* of intelligent life are axiologically significant, the proponents of FTAs either regard only human life as axiologically significant – and thereby fall prey to anthropocentric bias – or regard all conceivable forms of intelligent life as axiologically significant – and thereby lack an adequate basis to determine what combinations of parameter values may permit the existence of forms of intelligent life very different from our own (e.g., Wilson 1991, 172; also Manson 2009, 284, on "Martians, Arcturans, or very smart dolphins"). However,

[17] The inequality between the probability that the monkey types the first Canto of Dante's *Inferno* purely by chance and the probability that the monkey types the first Canto of Dante's *Inferno* conditional on prima facie plausible non-chance-based explanatory hypotheses holds irrespective of whether we happen to know what factors or mechanisms may cause the monkey's behaviour (e.g., Baras 2022, 129–130). Hence, pointing to the alleged fact that, in the case of the universe, we do not know what factors or mechanisms may cause FT does not per se provide reason to doubt the merits of the analogy presented in the main text.

[18] This by no means excludes that the discovery that intelligent life requires a highly precise match between this universe's parameter values and a very narrow range of parameter values may be justifiably regarded as extremely surprising (e.g., footnote no.1 on several scientists; also Baras and Na'aman 2022, 206–210, on how axiologically relevant considerations can influence what events or states of affairs one may justifiably regard as surprising).

[19] If the proponents of FTAs explicitly draw on the assumption that intelligent life is axiologically significant to support FTAs' conclusion that FT calls for explanation, then such assumption should be included in FTAs' argument structure. However, pace some critics of FTAs, appealing to the putative axiological significance of intelligent life would not make FT evidence dispensable (e.g., Manson 2000, 345–348) and would not turn FTAs into different types of arguments (e.g., Draper et al. 2007, 295–296, on cosmological arguments). For as noted in the main text, one may combine FT evidence and appeals to the putative axiological significance of intelligent life to provide mutually reinforcing support for FTAs.

I doubt that this objection undermines FTAs. For no *precise definition* of the notion of intelligent life is required to justifiably infer that only highly specific combinations of parameter values would permit the chemical complexity required for intelligent life (e.g., Sect. 2; also Collins 2009, 215; Hawking 1996, 156). Moreover, the proponents of FTAs may point to *several features* that make different forms of intelligent life axiologically significant and set such forms of intelligent life apart from other causally ramified phenomena while avoiding anthropocentric bias. To illustrate this, consider features such as the ability to explore the cosmos, make moral decisions and ponder the meaning of one's existence. These features make the forms of intelligent life endowed with them axiologically significant and set such forms of intelligent life apart from other causally ramified phenomena while avoiding anthropocentric bias (e.g., Fumagalli 2018; Leslie 1989, Ch. 5; van Inwagen 1993, Ch. 8).[20]

6 Objection from Mistaken Explanatory Demand

The objection from *mistaken explanatory demand* holds that FTAs fail to show that FT calls for explanation on the alleged ground that the occurrence of FT is a more appropriate explanatory stopping point than explanatory posits such as multiverses, cosmic designers and hitherto unconceived physical laws/mechanisms (e.g., Carlson and Olsson 1998, 271; also Callender 2004a, 207, rhetorically asking "will all models of the universe be deficient until physics answers why there is something rather than nothing?"). The objection proceeds as follows. FTAs infer that FT calls for explanation by pointing to the alleged fact that FT is extremely unlikely to occur purely by chance. However, any explanation *has* to take *some* facts as brute, since "every explanatory theory will feature some set of unexplained explainors" (Grünbaum 2004, 598; also Worrall 2004, 66). In particular, FT is justifiably regarded as a brute fact, a cosmic coincidence that we should regard as such (e.g., Norton 2010, 522, holding that "some things just are the way they are and no further explanation is needed").

This objection correctly notes that a call for explanation "cannot be regarded as [justified] merely because [one] experiences a strong feeling of puzzlement, and desires an answer to it" (Grünbaum 1989, 377; also Harker 2012, 256–257). However, I can think of at least two reasons to doubt that the objection undermines FTAs. First, the fact that this universe's fundamental parameter values fall within the *very narrow* range that permits intelligent life constitutes a highly precise – and, for all we know, extremely improbable – match (Sect. 2). The extreme improbability of this match, in turn, makes it epistemically inadequate to simply regard FT as a brute fact. For FT would be a *highly improbable* coincidence given CHANCE. And "there is pressure for scientific or philosophical theories to avoid [highly improbable] coincidences" (Bhogal 2020, 677; also White 2005, 7).

[20] A critic of FTAs may further object that appeals to the putative axiological significance of intelligent life only bear in favour of some specific ~CHANCE (e.g., cosmic design hypotheses), but not others (e.g., multiverse hypotheses). I am not concerned here with assessing whether appeals to the putative axiological significance of intelligent life differentially bear in favour of specific ~CHANCE. For my evaluation, it suffices to note that if appeals to the putative axiological significance of intelligent life bear in favour of specific ~CHANCE, then such appeals a fortiori bear in favour of the set of proffered ~CHANCE over CHANCE.

And second, the alleged fact that *some* things 'just are the way they are' and 'no further explanation is needed' falls short of implying that *FT* is one of those things that 'just are the way they are' and for which 'no further explanation is needed'. In particular, the alleged fact that the probability of FT conditional on ~CHANCE is much higher than the probability of FT conditional on CHANCE yields prima facie convincing support to the proffered calls to provide non-chance-based explanations for FT. As Barnes puts it, "like the probability that [a] burglar correctly guessed the 12-digit code [purely] by chance", the extremely low probability of FT conditional on CHANCE indicates that "we should look for an alternative assumption [on which FT] is not so improbable" (Barnes 2017, 460; also Bostrom 2007, 12, holding that simply "saying that the universe had to be some way or another […] does not on reflection appear to be a satisfactory response").[21]

A critic of FTAs may object that the proffered calls to provide non-chance-based explanations for FT are unjustified on the alleged ground that "there is *little intrinsic* to [events or states of affairs] that marks them as in pressing need of explanation" (Norton 2010, 522, emphasis added) and that "there is *no such thing* as a fact that cannot be taken as brute" (Worrall 2004, 71, emphasis added). The idea is that whether a given event or state of affairs calls for explanation is *relative* to one's background theories/available evidence and that *no single general* property demarcates all and only those events or states of affairs that call for explanation (e.g., Baras 2022, Ch. 3 also Worrall 1996, 13, holding that the aim to identify "rules that [demarcate] the sort of coincidence that cries out for explanation [is] entirely vain"). However, I doubt that this objection undermines FTAs. For substantiating FTAs does *not* require the proponents of FTAs to identify any single general property that demarcates all and only those events or states of affairs that call for explanation, but only requires them to substantiate the claim that *FT* calls for explanation. And the proponents of FTAs can substantiate such claim by demonstrating that (for all we know) FT is extremely unlikely to occur purely by chance and that there are prima facie plausible explanatory hypotheses that (if true) would make FT much less unlikely.[22]

[21] A critic of FTAs may object that also the proponents of FTAs rely on brute facts such as the putative existence of a multiverse or a cosmic designer (e.g., Grünbaum 2004, 598). However, it often makes a critical difference at what stage of investigation brute facts are invoked (e.g., Kitcher 1989, 432, holding that much scientific progress obtains when scientists "reduce the number of types of facts we have to accept as ultimate (or brute)"). This by no means entails that hypotheses positing fewer brute facts always (or even typically) have higher probability than hypotheses positing more brute facts (e.g., Sober 2019, 38). Still, the proponents of FTAs may plausibly hold that we should try to explain FT because, if we find a plausible explanation for FT, such explanation would account for otherwise unexplained features of this universe (e.g., McMullin 2005, 608; Parfit 1998, 24–25; White 2005, 6).

[22] The fact that an explanatory hypothesis, if true, would make an observed phenomenon less unlikely does not per se imply that such explanatory hypothesis is plausible. To see this, consider a sequence of 10 tosses of a seemingly unbiased die, which give the outcome 6666666666. This outcome is justifiably taken to call for some non-chance-based explanation because it is much more likely conditional on the assumption that the die is weighted than conditional on the assumption that each toss is equally likely to land on any side of the die. Moreover, the explanatory hypothesis that there is an invisible magician who chose the observed outcome, if true, would make the outcome less unlikely. However, this does not per se justify regarding such hypothesis as plausible (e.g., Baras 2020, 1512; White 2007, 464, for similar illustrations). That said, most authors (including many critics of FTAs) concur that "if there is a theory that implies that a certain fact has no explanation, and there are [prima facie plausible] alternative theories that would, if true, explain that same fact, that is a reason to [reduce confidence in] the former theory" (Baras 2020, 1512; also Leslie 1989, 10). I expand on the plausibility of alternative explanatory hypotheses for FT in the next section.

7 Objection from Lack of Testable Explanatory Alternatives

The objection from *lack of testable explanatory alternatives* holds that FTAs fail to show that FT calls for explanation on the alleged ground that the hitherto proposed ~CHANCE fail to satisfy minimal requirements of empirical testability. The objection proceeds as follows. Explanatory hypotheses are scientifically adequate to the extent that they are empirically testable (e.g., Popper 1963, Ch. 1) and make accurate and novel empirical predictions (e.g., Lakatos 1970). However, appeals to multiverse hypotheses, cosmic design hypotheses and future physical theories *currently lack* empirical support (e.g., Draper et al. 2007, on the alleged lack of empirical support for multiverse hypotheses; Grünbaum 2004, on the alleged lack of empirical support for cosmic design hypotheses). Moreover, it remains unclear what empirical evidence *could* enable us to test those hypotheses (e.g., Worrall 2004, 67–68). Hence, "by insisting that [FT] cannot just be accepted as brute fact", the proponents of FTAs "cover up [their] inability to achieve any deeper, testable description in some sort of pseudo-explanation" (Worrall 1996, 13).

This objection correctly notes that attempts to provide empirical tests for specific ~CHANCE face significant difficulties.[23] However, I do not think that these difficulties undermine ~CHANCE. For *several* factors *unrelated* to the truth of ~CHANCE, ranging from the backwardness of our technological instruments to our cognitive and epistemic limitations, may explain the alleged lack of empirical support for ~CHANCE (e.g., Fumagalli 2012, 225). For this reason, undermining ~CHANCE would require the critics of FTAs to show not just that ~CHANCE currently lacks empirical support, but also that the *conditional* probability of ~CHANCE being false *given* its alleged lack of empirical support is high. Yet, the critics of FTAs have hitherto failed to offer convincing reasons and/or evidence to think that ~CHANCE's alleged lack of empirical support reliably indicates that ~CHANCE is false. In fact, various critics of FTAs observe that our technological, cognitive and epistemic limitations may prevent us from discovering plausible non-chance-based explanations for FT (e.g., Callender 2004b, 246; also Baras 2019, 1407, holding that "there can […] be states that have an explanation, but given epistemic or cognitive limitations of ours, we […] will never be able to [explain]").

A critic of FTAs may object that even if a number of factors could be invoked to account for ~CHANCE's alleged lack of empirical support, such lack is *presumably* due to ~CHANCE being false (e.g., Grünbaum 2004, 586–590). However, I doubt that this objection undermines ~CHANCE. For undermining ~CHANCE would require the critic of FTAs to show that ~CHANCE's alleged lack of empirical support is *more* plausibly ascribed to ~CHANCE's falsity than to some other factors which suffice to explain (but do not trivially imply) the alleged lack of empirical support for ~CHANCE. And the critics of FTAs have hitherto failed to address this justificatory challenge. A critic of FTAs may further object that the alleged lack of empirical support for ~CHANCE does not have to be *due* to ~CHANCE's falsity to undermine ~CHANCE. In particular, she may maintain

[23] For instance, given that the space–time regions comprising the hypothesized multiverses are assumed to have no causal contact with each other, many hold that multiverse hypotheses are "untestable" (Barnes 2012, 559; also Callender 2004a, 213; Draper et al. 2007, 304). Regarding cosmic design, several authors doubt our ability to reliably discern with what probability a cosmic designer would actualize a fine-tuned universe (e.g., Narveson 2003, 99; Sober 2003, 38; Weisberg 2010, 433). As to future physical theories, it remains obscure what empirical evidence could presently enable us to test claims concerning the hitherto unconceived physical laws/mechanisms that will be posited by such theories (e.g., Einstein 1949, 63, Hempel 1969, 183; Stanford 2006, Ch. 1–2).

that, in the absence of empirical support for ~CHANCE, endorsing ~CHANCE is *arbitrary* (e.g., Baras 2022, 110, holding that "when inquiring into the fundamental conditions of our universe, we have too little to go on"). However, the alleged lack of empirical support for ~CHANCE does not per se exclude that ~CHANCE is empirically testable by us, i.e. that there is some empirical evidence (e.g., empirical evidence of FT) which would enable us to assess the plausibility of ~CHANCE. Moreover, to date, no empirical evidence that clearly bears in favour of CHANCE has been provided by the critics of FTAs. Hence, it remains unclear why exactly endorsing ~CHANCE would be more arbitrary than endorsing CHANCE on empirical grounds.[24]

8 Conclusion

In recent years, several prominent authors have criticized FTAs for failing to show that the universe's purported fine-tuning for intelligent life calls for explanation. In this paper, I have provided a systematic categorization and a detailed evaluation of the proffered critiques. I have argued that these critiques cast doubt on various instances of fine-tuning reasoning, but fail to undermine FTAs' conclusion that the universe's purported fine-tuning for intelligent life calls for explanation. If correct, my claim that the proffered critiques fail to undermine FTAs does not per se substantiate specific non-chance-based explanatory hypotheses for FT, but does vindicate the proffered calls to explain FT.

Acknowledgements I thank two anonymous reviewers, Mario Alai, Dan Baras, Martin Barlow, Luke Barnes, Craig Callender, Gustavo Cevolani, Ciro de Florio, Simon Friederich, Rodney Holder, Jeffrey Kop-erski, Eva Los, Timothy McGrew, Bradley Monton, Elliott Sober and Christian Wütrich for their comments on previous versions of this paper. I also received helpful feedback from audiences at the Italian National Institute of Astrophysics (Brera Astronomical Observatory, Merate), the 21st European Conference on the Foundations of Physics (University of Bristol), the 2023 Triennial International Conference of the Italian Society for Logic & Philosophy of Science (University of Urbino), Saint Joseph University (Philadelphia), the 'PSA around the World 2023 Meeting' of the Philosophy of Science Association, the Faraday Institute for Science and Religion (Cambridge), the Geneva Symmetry Group (University of Geneva), and King's College London.

Funding The Author declares none.

Declarations

Conflict of interest The Author declares none.

[24] Justifiably taking ~CHANCE's alleged lack of empirical support to directly bear against ~CHANCE would require the critics of FTAs to show that ~CHANCE is empirically testable by us. For if ~CHANCE is not empirically testable by us, then indicating that ~CHANCE currently lacks empirical support would not directly bear against it. To be sure, if ~CHANCE is not empirically testable by us, this would arguably bear against the scientific adequacy of ~CHANCE (e.g., Popper 1963, Ch. 1; also Adams 2019, 82–86; Carroll 2019, 300–306; Ellis and Silk 2014, 321–323; Livio and Rees 2020, 12–15, for recent debate). Yet, as indicated in the main text, the alleged lack of empirical support for ~CHANCE does not per se exclude that ~CHANCE is empirically testable by us. Moreover, if a hypothesis' alleged lack of empirical support suffices to render such hypothesis scientifically inadequate, then (given its current lack of empirical support) also CHANCE would fail to qualify as scientifically adequate. And this would be a rather unwelcome implication for many critics of FTAs.

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