Physics, Metaphysics, and the Problem of Progress

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The Ultimate Aspirations of Physics

- 'The ultimate goal of physics is to find what is jocularly referred to as a 'theory of everything', from which all else can be derived.' (Tegmark and Wheeler 2001).
- 'The supreme task of the physicist is to arrive at those universal laws of nature from which the cosmos can be built up by pure deduction' (Einstein 1918)
- 'It's the ultimate goal in physics – a Theory of Everything that captures all the fundamental features of reality in a simple set of equations.' (*New Scientist* 6 June 1998).

The Ultimate Aspirations of Physics

> *"– A Theory of Everything that captures all the fundamental features of reality in a simple set of equations"*

Given these aspirations, what can philosophers do for you?

1. Help determine what it means to be 'fundamental'.
   - Eg. recent work on 'grounding'.
2. Help determine what is fundamental.

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What metaphysicians do

- Structuralism: ‘relational structure is ontologically fundamental and individual objects are not’ (Ladyman 2007).
- Humeanism: ‘no necessary connections at the fundamental level’ (Bhogal and Perry 2017).
- Configuration space realism: ‘configuration spaces [are] fundamental, [or] derivative of structures defined on ordinary spacetime’ (North 2013; Myrvold 2014)
- The direction of time (Albert 2000 / Maudlin 2008): ‘the passage of time [is] a fundamental, irreducible fact’.
- QFT (Fraser 2008): ‘rigorous forms of the interacting theory cannot sustain a ‘quanta’ interpretation in which the fundamental entities are countable’
- Substantivalism: ‘spacetime points... are the fundamental particulars’ (Armstrong 1997)

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What metaphysicians do

- ‘In a nutshell, metaphysics is the study of the fundamental structure of reality’ (Bigaj and Wüthrich 2017, p. 8)
- ‘Metaphysics, at bottom, is about the fundamental structure of reality’ (Sider 2011)
- ‘Metaphysics [is] the systematic study of the most fundamental structure of reality’ (Lowe 2006)

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The relation between physics and metaphysics

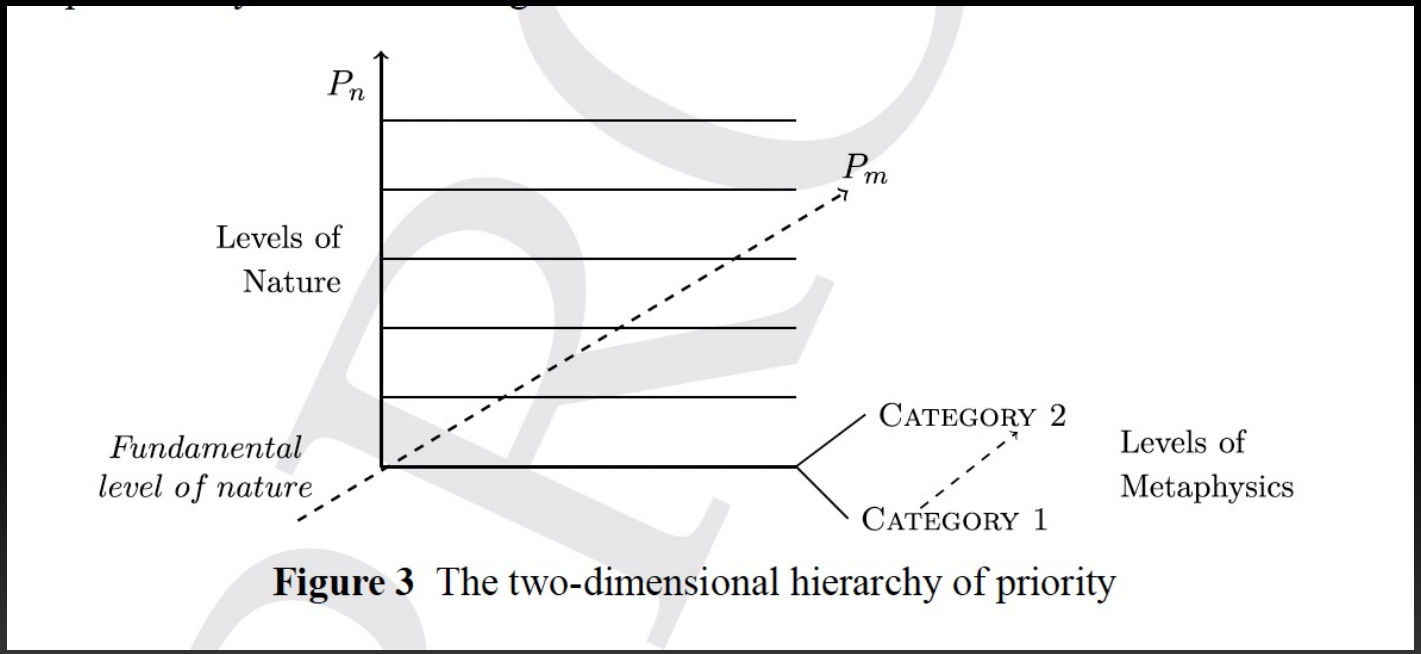

Figure 3 The two-dimensional hierarchy of priority

from *Fundamentality and Grounding*, 2022.

The Ultimate Aspirations of Physics

A picture of highly analogous and mutually beneficial pursuits.

- ‘Metaphysics is continuous with physics.’ (Lange 2009)

- These are **teleological** continuities.
- Quineans often emphasize the **methodological** continuities also.

The Ultimate Aspirations of Physics

I claim: emphasizing these *teleological* and *methodological* analogies between physics and metaphysics has obscured crucial *theoretical* and *axiological* disanalogies.

1. Physics and naturalistic metaphysics both aim to describe the fundamental.
2. Neither has yet succeeded.
3. Physics can however meaningfully be said to be *making progress*.
   - Physics has a serviceable notion of 'approximate truth'
4. No such notion of 'approximate truth' available in metaphysics.

C. As such, no clear value attaches to contemporary metaphysics of physics.

Objections: (i) there are other notions of scientific progress that apply to metaphysics; (ii) many scientific claims do not seem to approximate either and yet we think they are here to stay.

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Progress in physics

3. *Contemporary physicists can meaningfully be said to be* ***making progress****.*

Two questions: (i) what do we mean, and (ii) is it true?

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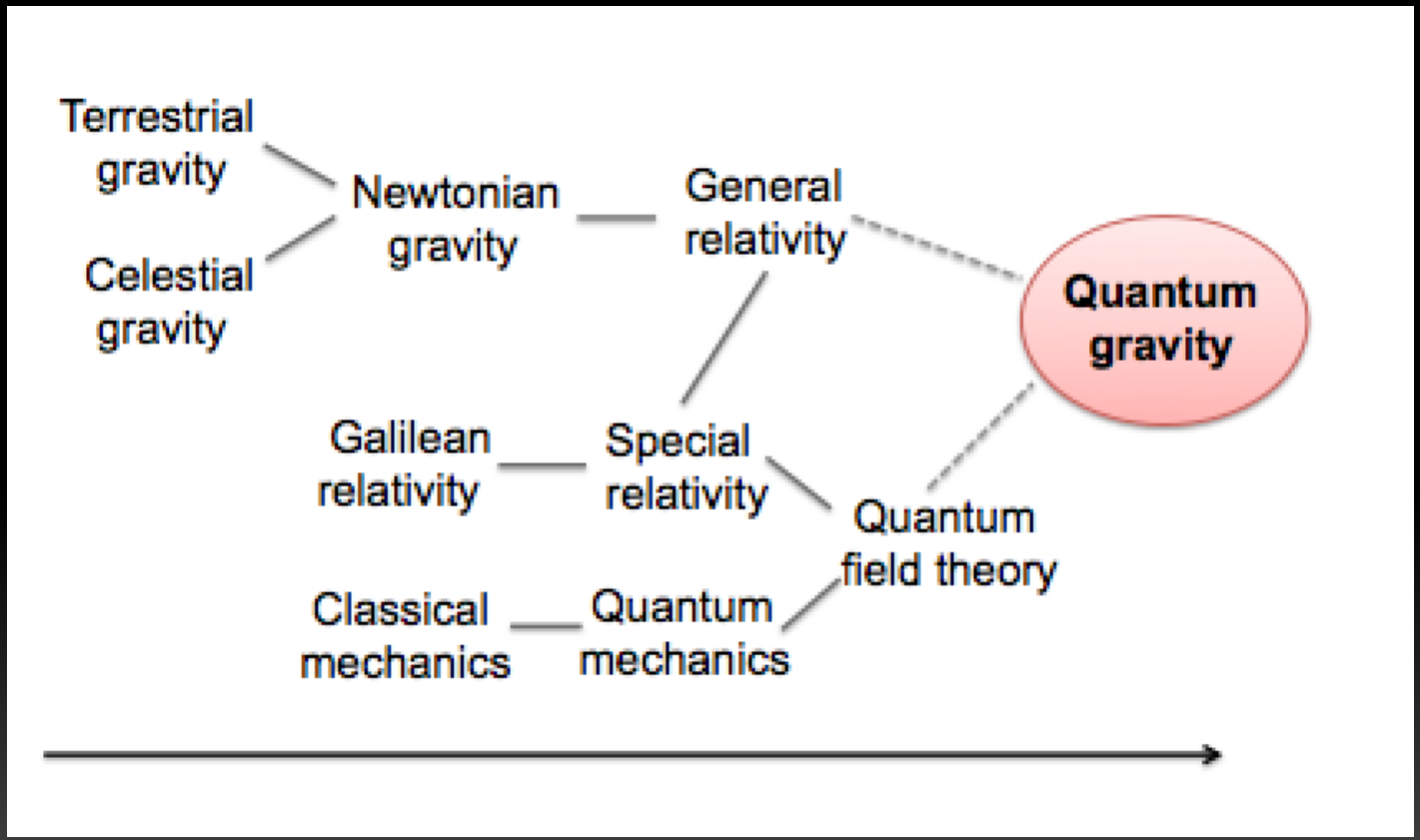

There is undeniably progress at the *empirical* level.
The 'realism' debate is about whether there is *epistemic* progress: whether we know more now about the deep structure of the world.

Progress in physics

Epistemic progress = the production of *better approximations to the truth*.

> *[T]he historical progress of the mature sciences is largely a matter of successively* ***more accurate approximations*** *to the truth about both observable and unobservable phenomena. Later theories typically build upon the (observational and theoretical) knowledge embodied in previous theories (Boyd 1983)*

will take the realism expressed here for granted.

Question: when can we talk about 'better approximations to the truth'?

Progress in physics: a definition

A common answer: we can talk about progress when there is CORRESPONDENCE between successive theories (Post 1971).

- 'The overriding theory should degenerate (within experimental accuracy) into the other theory within that range of cases in which that other theory has proved successful'.
- 'According to special relativity theory, classical mechanics is correct only in the limiting case $v/c \to 0$, but yields successful predictions at low values of v/c to an extent depending on the accuracy of the experiment'.

$$t' = \frac{1}{\sqrt{1-(\frac{v}{c})^2}}t \quad \xrightarrow[v/c \to 0]{} \quad t' \approx t$$

- 'That there be a descriptive nesting relation between our current theories and the next generation of theories is a precondition for understanding the next generation of theories as refinements of our current theories.' (Barrett, 'Approximate Truth and Descriptive Nesting', 2008)

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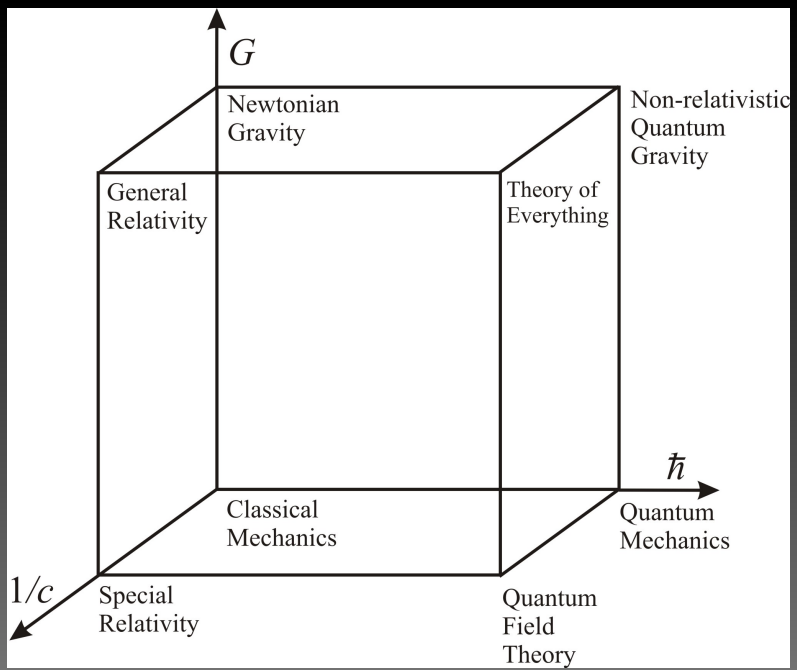
Progress in physics: scope

This feature is held to be very common within physics.

- '**Quite generally**, the thesis may be put this way: no theory that ever 'worked' adequately turned out to be a blind alley... there is **continuous progress...**' (Post)
- 'It **typically happens** ... that when some hitherto dominant theory T is superceded by T', T1 is in the relation of correspondence to T [i.e., T is a "limiting case" of T1]' (Watkins (1978)



Progress in physics: specificity

However, in its strongest form this applies only to mathematicalized theories.

- 'I shall deal largely with physics, not because it is particularly successful as a science (it is not)... It is however the most formalized into an abstract, ramified system, and therefore most suitable for analysis' (Post)
- 'It seems unlikely that similar considerations will apply to any other branch of empirical science' (Saunders 1993).

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Progress in physics: value

The notion of progress that correspondence furnishes seems to be very special.

- 'My claim is not merely that there is an element of continuity in change, which is necessarily the case in all human activity, but that in science part of the content of the old theory is **preserved**, as far as one can tell, for ever; not just in the next theory, but throughout all future theories...' (Post)
- 'So scientific theories, far from dropping off like withered leaves in the course of time, appear to be endowed under certain restrictions with eternal life; every famous theoretical discovery of the day will doubtless undergo certain restrictions on future development, and yet remain for all time the essence of a certain sum of truths'. (Nernst, 1916)

Progress in physics: value

> *'To use a comparison, we could say that creating a new theory is not like destroying an old barn and erecting a skyscraper in its place. It is rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists, and can be seen, although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up. (Einstein and Infeld 1938, 158–9; quoted in van Fraassen 2006, 300.)*

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Progress in metaphysics

- We have seen that there are continuities in intent between science and metaphysics.
- Some think this licenses analogous talk of progress in metaphysics.

> *To the extent that metaphysics is closely motivated by science, we should expect to make progress in metaphysics iff we can expect to make progress in science. In Chapter 2 we indicate at length why we hold fallibilism about science to be compatible with optimism about epistemic progress in science.* ***This argument carries directly over to scientifically motivated metaphysics****. (Ladyman and Ross 2007)*

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Naturalistic metaphysics

- Recall picture of NM as 'finishing the job' of physics.
- Standardly involves answering questions of **fundamental ontology** and **fundamental ideology** (Quine 1951).

  'While the ontological commitments of a theory are the entities it posits, a theory's ideological commitments are the primitive concepts it employs'.

- Ontic structuralism $\rightarrow$ fundamental ontology
- Humeanism $\rightarrow$ fundamental ideology ($\Diamond$ and $\Box$ operators).

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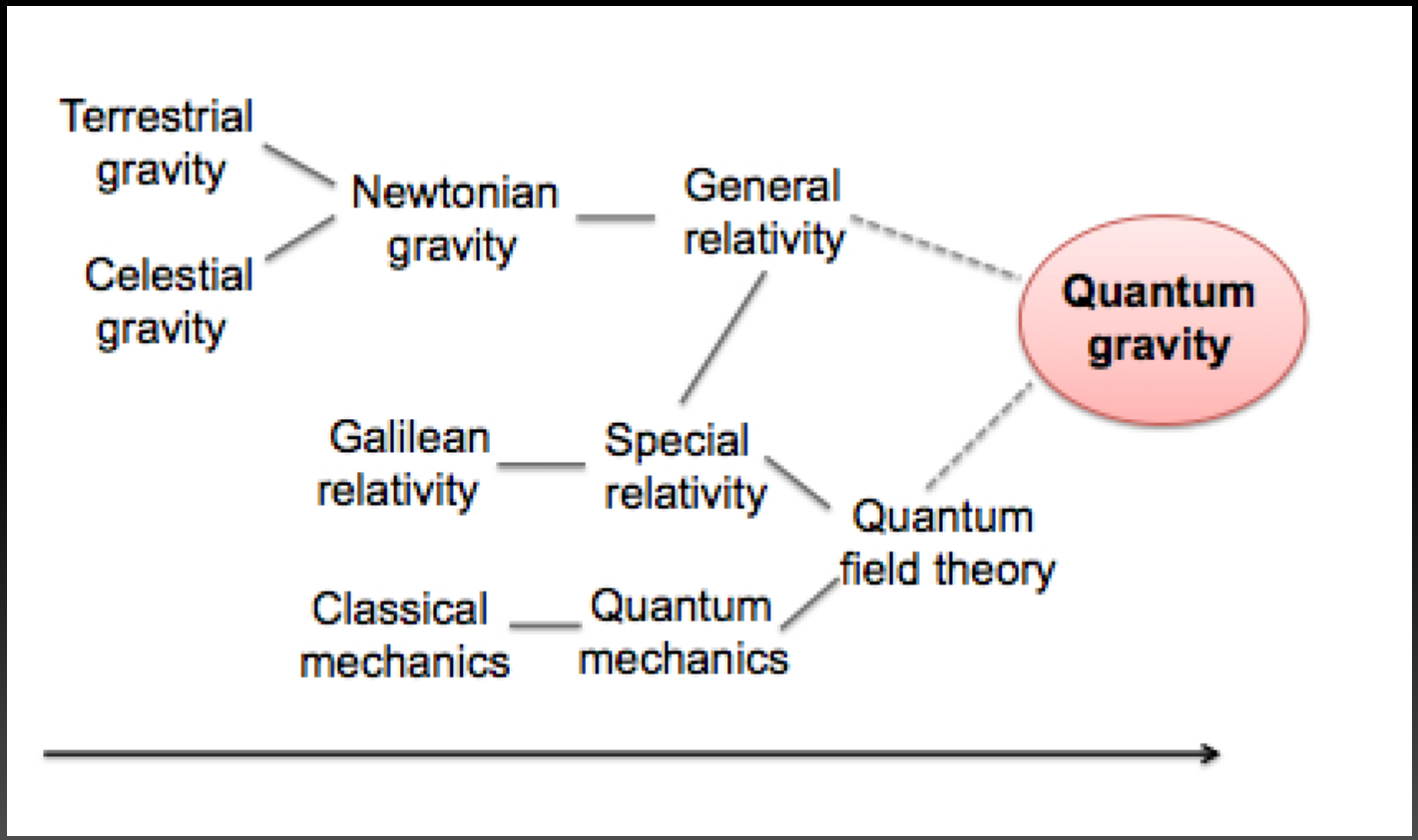
Metaphysics and theory change



Metaphysics and theory-change: OSR

OSR: ‘relational structure is ontologically fundamental and individual objects are not’ (Ladyman and Ross 200); objects ‘are at best a derivative category’ (French 2011).

- Interpret this as: there are no fundamental intrinsic properties.
- Eg. Maxwell 1971: ‘structure is whatever is not intrinsic’.

Metaphysics and theory-change: OSR

- Take ourselves to have established OSR if we can show that fundamentally there are no intrinsic properties.
- Bird 2007: 'no-one has suggested that properties like charge, rest mass and spin are not intrinsic'.
- I claim QFT challenges this (McKenzie 2016).
- Here $m(f_1) = m(E, f_2 ... f_n)$
- [illegible] in the $E \rightarrow \infty$ limit.
  - An intrinsic property: one 'an object has solely in virtue of how it is, independently of its surroundings' (Cameron 2009, McKitrick, 2003; Dunn 1990; Lewis 1986).

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- Here $m(f_1) = m(E, f_2 ... f_n)$
- If there are too many (or too few) fields then $m(f_1)$ undefined in the $E \rightarrow \infty$ limit.
  - An intrinsic property: one 'an object has solely in virtue of how it is, independently of its surroundings' (Cameron 2009, McKitrick, 2003; Dunn 1990; Lewis 1986).

Metaphysics and theory-change: OSR

- Suppose then that **fundamentally there are no intrinsic properties** is true in QFT.
- Expect QFT to be superseded by a theory that presents the fundamental very differently.
- The naturalist must be open to the metaphysics being different in that theory.
- If so, OSR may be **wrong**.
- Question: can the metaphysical claim we have arrived at – OSR – in the context of QFT be *approximately* true?
  - 'Fundamentally, there are no intrinsic properties.'
  - Equivalently: 'Fundamentally, all properties are extrinsic'.
    - 'Extrinsic properties... are those that are not intrinsic' (Cameron 2009, McKitrick 2003, Lewis 1986..)
  - Try saying 'approximately all' or 'approximately extrinsic'.

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‘Approximately all’?

- ‘In order for the appeal to extrinsic [properties]... to offer any support to noneliminative OSR... it should be the case that **not just some, but all** [essential] properties of the particles described by quantum theory are extrinsic. (Chakravartty 2012).
- Berghofer 2017: ‘OSR and QFT: Are there intrinsic properties at the fundamental level of reality?’

[31] To be sure, I do not want to suggest that these are the only two intrinsic properties of quantum fields. However, they best fit the flow of the argument. To refute MMOSR it, of course, suffices to identify one intrinsic property at the most fundamental level, i.e., to show that there is one intrinsic property exhibited by quantum fields.

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Metaphysics and theory-change: OSR

Can we say that the properties are 'approximately extrinsic'?

- I claim: when we say 'x is approximately ϕ', we mean 'x is *at best* approximately ϕ' – so not ϕ strictly speaking.
- So 'approximately extrinsic' $\rightarrow$ 'not extrinsic'.
- But then it's intrinsic:
  - 'Extrinsic properties are those which are not intrinsic.' (Cameron op cit; McKitrick op cit; Lewis 1986...)
- A generic phenomenon of metaphysics: defines properties in mutually exclusive and jointly complete pairs.

Metaphysics and theory-change: Humeanism

'Contemporary Humeans hold that the totality of the world consists of a mosaic of fundamental categorical properties/quantities and relations instantiated throughout spacetime (the 'Humean mosaic'). Categorical properties are properties whose instantiations in a region of space time don't necessitate anything about property instantiations in wholly distinct regions. Humeans claim that there is no fundamental necessity in nature connecting spatio-temporally non-overlapping events in non-overlapping portions of space-time...

In contrast, non-Humeans think that there is fundamental necessity in nature. Some non-Humeans hold that nomological necessity resides in fundamental properties/quantities themselves. They thus deny that all fundamental properties are categorical. At least some fundamental properties are claimed to be such that it follows from their natures that if one is instantiated in a region some other properties are instantiated in distinct regions... Other non-Humeans hold that laws are themselves fundamental features of reality.' (Loewer 2012)

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Metaphysics and theory-change: Humeanism

Can Humeanism be approximated?

- All turns on 'categorical property': a property with 'no essential or other non-trivial modal character' (Bird 2007).
  - Contrasted with dispositions: to be fragile = to be such that if you *did* hit it, it *would* break.
- Can we approximate 'Fundamentally, all properties are categorical?
- Try: 'approximately all' or 'approximately categorical'.
- 'Approximately all': then one or two non-categorical properties.
- But this entails commitments to primitive modal ideology.
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Metaphysics and theory-change: summary

- No clear sense in which the claims of metaphysics can be said to be 'approximately true': metaphysical claims and concepts have an 'all or nothing' character.
- Thus slight departures from exactness flip them into the opposing doctrine.
- A somewhat general feature: philosophical positions are fundamentally

  "based on deliberately conflicting visions of things, and there just is no way to 'have it both ways'. To deprive them of their contriety is to deprive them of their substance.... Where there is no enemy to attack, there is no position to defend.' (Rescher 1985, 14-15; 35).

However, raises questions about what the value is of engaging in metaphysical speculation today.

Response 1: other dimensions of progress

Salimkhani and Rolffs (ms) argue that science progresses in other ways: by ruling things out.

> *That a 'new' theory T_{new} is shown to 'contain' an 'old' theory T_{old} in some limit is not what signifies large parts of what can legitimately be called progress in science. That some approximation relation holds between two successive theories may be a sufficient condition for progress, but it certainly is not necessary.*
>
> *Truth approximation is ... [sometimes] rather taken to be about the exclusion of candidate theories as such: excluding candidate theories narrows down the list of candidate theories and thereby encircles the true theory.*

Example: ruling out candidate models of the Higgs with $m_h <$ XGeV. Importantly, 'scientific progress can eliminate metaphysical claims that are in conflict with the reminaing theoretical possibilities.'

Response 1: other dimensions of progress

- This is progress by falsification.
- This recalls some criticisms of Popper: falsification is not itself progress unless it facilitates getting close to the truth.
- So even if it is the case that science falsifies certain metaphysical claims, that may not itself be progress if there is no notion of getting closer to the truth.
  - Cf. Bird's distinction between something (such as the getting of a grant) *promoting* as opposed to *constituting* scientific progress (2007).
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- It is also questionable that metaphysical claims are likely incompatible with future theories even if incompatible with our present theories.
  - , Eg, the return of presentism in some models of GR or QG:
    - '[Presentism] certainly has better prospects in GR as compared with SR' (Reid and Qureshi-Hurst, 2020)
  - Cassirer 1923: 'the history of metaphysics wavers between opposing tendencies, without being able to deduce one form the other, or to reduce them to another.'
- Given the rich deductive relations that exist between them, it is much harder to think of the same *physical* theories reappearing at more fundamental levels.

Response 1: other dimensions of progress

- It is also questionable that metaphysical claims are likely incompatible with future theories even if incompatible with our present theories.
  - , Eg, the return of presentism in some models of GR or QG:
    - '[Presentism] certainly has better prospects in GR as compared with SR' (Reid and Qureshi-Hurst, 2020)
  - Cassirer 1923: 'the history of metaphysics wavers between opposing tendencies, without being able to deduce one form the other, or to reduce them to another.'
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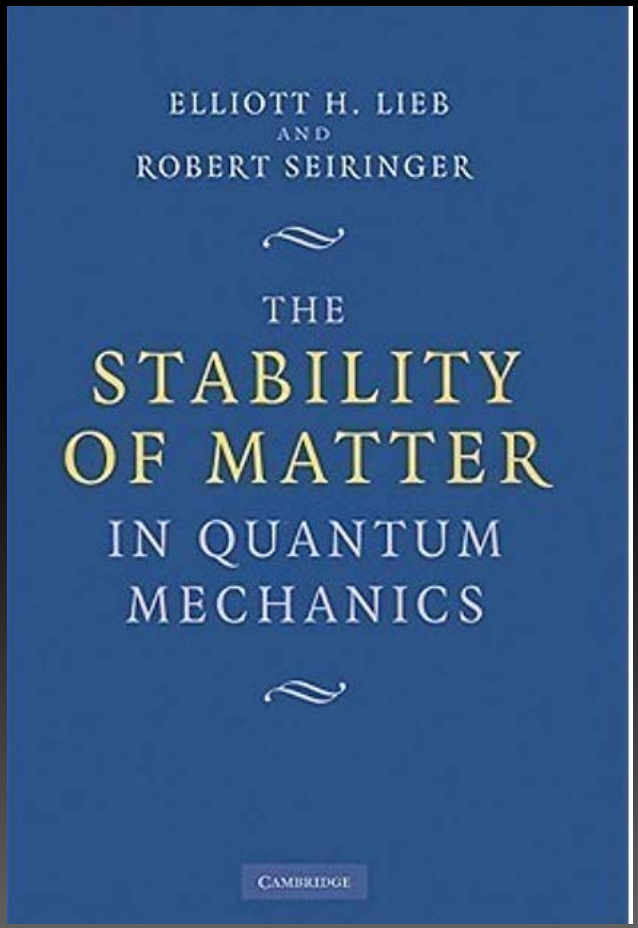
Response 2: misdiagnosis

- There are also scientific claims that have an ‘all-or-nothing’ character.
- Yet that we think are here to stay.
- Why then can’t this be the case for metaphysics?

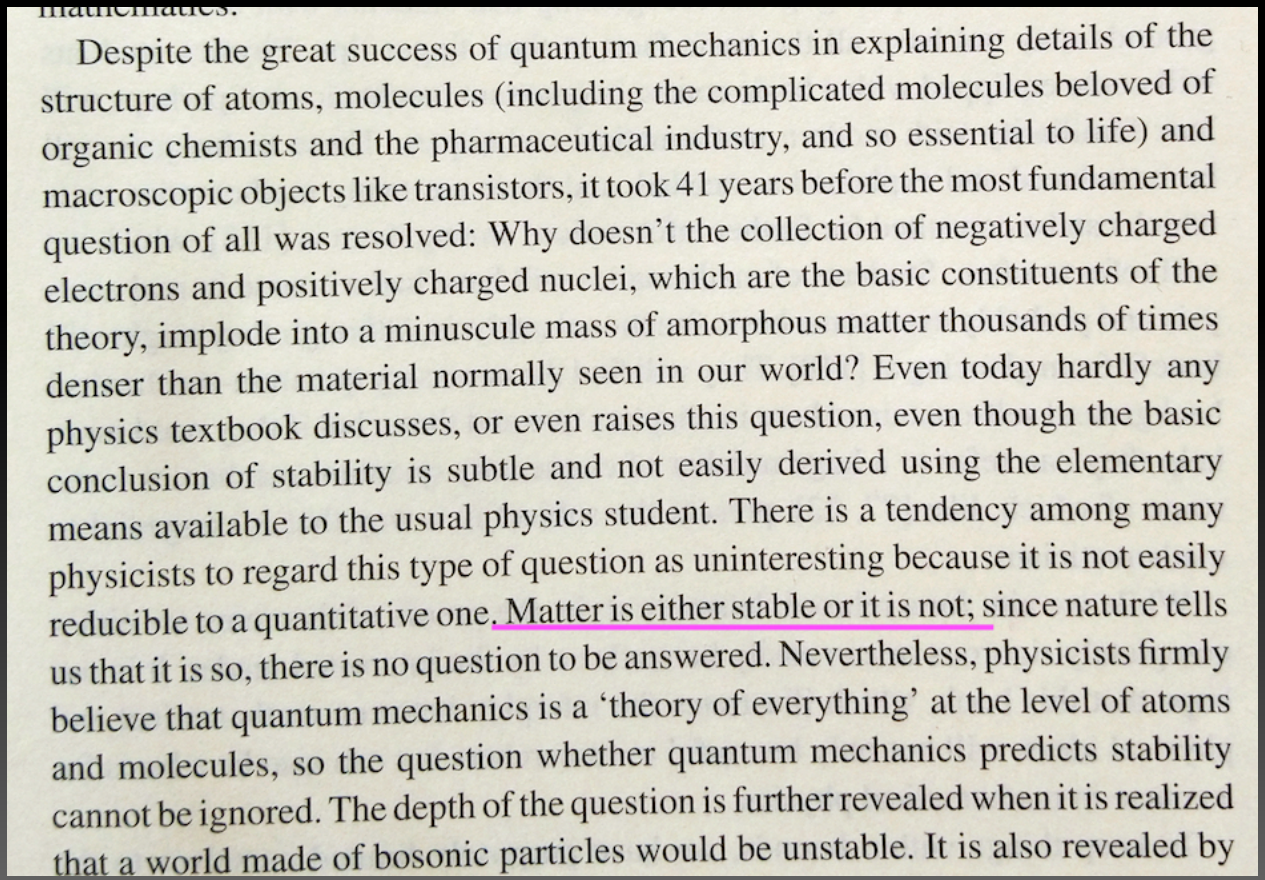
Response 2: misdiagnosis.



First question of stability: 'Why don't the point-like electrons fall into the (nearly) point-like nucleus? (p. 2)

Response 2: misdiagnosis.

‘Stability of the first kind only requires that the energy of such a system is not arbitrarily negative.’



Despite the great success of quantum mechanics in explaining details of the structure of atoms, molecules (including the complicated molecules beloved of organic chemists and the pharmaceutical industry, and so essential to life) and macroscopic objects like transistors, it took 41 years before the most fundamental question of all was resolved: Why doesn't the collection of negatively charged electrons and positively charged nuclei, which are the basic constituents of the theory, implode into a minuscule mass of amorphous matter thousands of times denser than the material normally seen in our world? Even today hardly any physics textbook discusses, or even raises this question, even though the basic conclusion of stability is subtle and not easily derived using the elementary means available to the usual physics student. There is a tendency among many physicists to regard this type of question as uninteresting because it is not easily reducible to a quantitative one. Matter is either stable or it is not; since nature tells us that it is so, there is no question to be answered. Nevertheless, physicists firmly believe that quantum mechanics is a 'theory of everything' at the level of atoms and molecules, so the question whether quantum mechanics predicts stability cannot be ignored. The depth of the question is further revealed when it is realized that a world made of bosonic particles would be unstable. It is also revealed by

Response 2: misdiagnosis.

- Stability established through derived inequalities on the kinetic and potential energies (the Heisenberg uncertainty principle).
- Since QM is a limit of a relativistic theory, we can assume that those inequalities are approximately correct.
- If so, this claim about stability is likely here to stay.
- The problem then can't be that it is failure to approximate that causes the problem for metaphysics.

So what is the problem?

- The problem is that claims of metaphysics are unstable even under small perturbations of the underlying theory.
- In a nutshell: 'the metaphysics of approximately classical physics is not an approximation to the metaphysics of classical physics' (*On the Prospects for an Effective Metaphysics*, forthcoming).

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- In QM, position eigenstates are not continuous.
- Schrödinger argued that the lack of spatio-temporal continuity meant the category of objects had to be abandoned (Bitbol 2007).
- The reason is that without continuity we cannot unambiguously re-identify particles over time.

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in order to ascertain the individuality and identity of the particles.

The alternative criterion, in classical mechanics, is merely their having distinct positions at a given instant, these positions being connected to distinct past histories through different continuous trajectories. This criterion was called "genidentity" by H. Reichenbach after K. Lewin [21]. As Schrödinger himself noted in his letter to Margenau, it was already proposed by Boltzmann [22] in 1897: "The discontinuity removes the univocal identification. Would you believe it, that Boltzmann, in his *Principe der Mechanik*, right in the beginning, underlines this point in what he calls his *Ertes kinematisches Grundgesetz*. This was a few years before Planck's great discovery, I think about in 1897." [23]

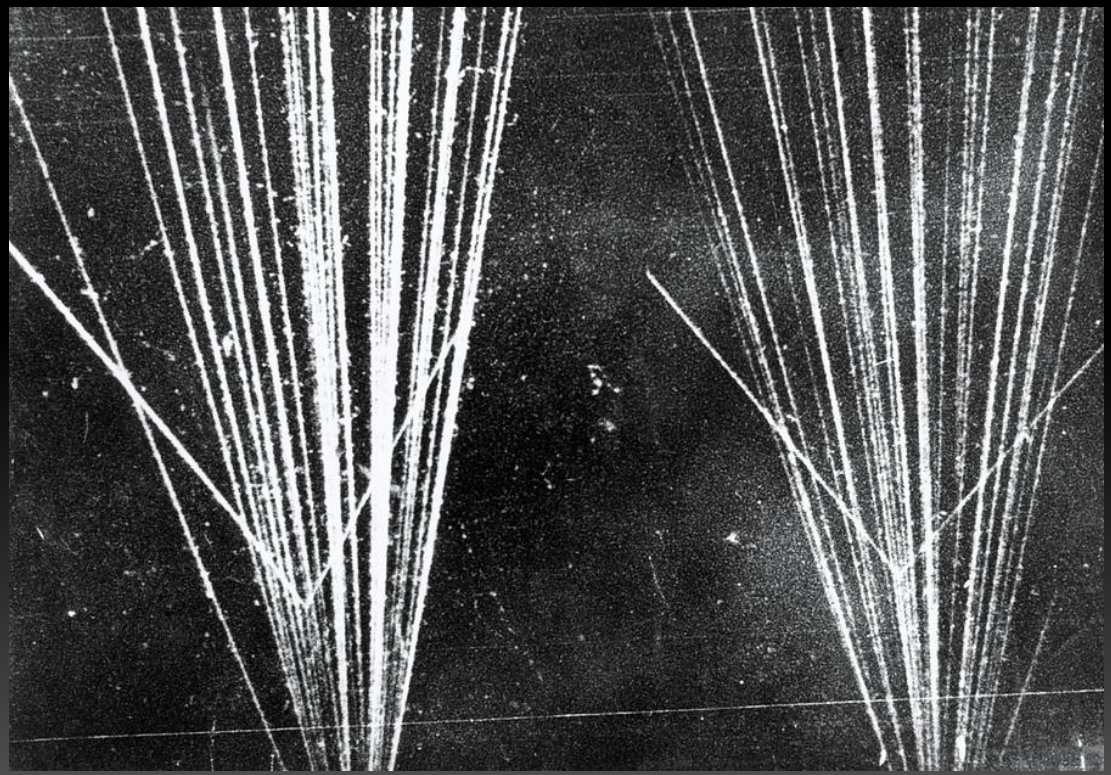
Response 2: misdiagnosis.

"[I]f one cannot ascribe

with certainty a given droplet in a cloud chamber to a given particle, then, one cannot in general ascribe the droplet to *another* given particle either. The absence of a criterion for ascertaining the sameness of *one* "particle" is all-pervasive and challenges the very possibility of making sense of the concept of an individual particle. Each observation must eventually be considered as an isolated event, not to be related to any kind of spatio-temporal continuant; the particle itself accordingly dissolves in one or several scattered events: "When you observe a particle of a certain type, say an electron, now and here, this is to be regarded an isolated event." [28] It is only the superficial linear appearance of some gatherings of events (i.e., tracks in Wilson cloud chamber) that tends to remind one of the trajectory of a particle. But, according to Schrödinger this must be considered as an illusion: "... it is better to regard a particle not as a permanent entity but as an instantaneous event. Sometimes these events form chains that give the illusion of permanent beings." [29] Just the same type of illusion as the one which

Response 2: misdiagnosis.

One can show that the position eigenstates are virtually certain to lie very close to what Newtonian physics would predict for a particle trajectory (Rosaler 2015).



However, *the trajectory is still discontinuous*.
⇒ Classical physics approximates quantum; classical metaphysics does not.

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- This raises questions of what the value is in engaging in metaphysics prior to a final theory.
- However, one can *modus tollens* this *modus ponens* and argue that the value of metaphysics lies elsewhere than in describing the world correctly.

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