The Observer in Cosmology, Classical and Quantum

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How does our being observers affects the scope and content of our knowledge: especially in cosmology---both classical and quantum?

I: The topic without regard to physics:

emphasizing: what is possibility?

II. The topic in classical physics and cosmology:

emphasizing: what is chance?

III. The topic in quantum physics and cosmology:

emphasizing: how to understand quantum theory?!

I: The Observer, regardless of Physics

- 1) 'Subjectivity'
- 2) Selection effects on observation
- 3) The legacy of Kant
- 4) Our (Realist!) verdict: *No worries!*
- 5) An open question: what is a possibility?

II: The Observer in a Classical World

- 1) Problems of principle for 'insiders'?
- 2) Selection effects: the 'A' word…
- 3) Confirming a multiverse theory
- 4) The Srednicki-Hartle proposal: Frameworks

III: The Observer in a Quantum World

- 1) The dreaded quantum!
- 2) The Everett interpretation of the universal state

I: The Observer, regardless of Physics

1) 'Subjectivity'

Democritus: 'By convention hot, by convention cold, but in reality atoms and void'.

… And natural philosophy/physics, from Galileo onwards.

The need to 'close the circle': to recover a description of experience from science's (increasingly arcane!) world-picture.

Nowadays, people emphasize two obstacles:

a) 'qualia': 'science can't give you the smell of chicken soup'
b) 'indexicality': timely action needs 'I','now' 'here'.

2) Selection effects on observation

Eddington's net metaphor.

Beware of biassed sampling!

'What is most probable to happen need not be what is most probable to be observed.'

'Observers are located only in places with special properties. As a trivial consequence, probabilities conditioned on the presence of observers will differ grossly from probabilities per unit volume.'

Our expectations should be conditioned on what we believe about our process of observation.

3) The legacy of Kant

Maybe our beliefs, even our knowledge, have an ineradicable human contribution?

Various meanings for 'ineradicable', 'human': Kant, Carnap, Kuhn …

Ian Hacking (*The Social Construction of What?*) helpfully distinguishes three debates:

Is the content of mature science independent of the path by which we found it?

Does the world have inherent structure?

Is scientific belief stable because of the world, rather than social organization of science?

4) Our (Realist!) Verdict: *No worries!*

In particular, as to 3), the legacy of Kant:

Maybe we (the species or culture or individual) contribute ineradicably to our knowledge.

But that is compatible with all of:

A) a correspondence theory of truth (Aristotle, Tarski);

B) our having good reason to believe theories: whose theoretical claims are true in a correspondence sense.

And it is even compatible with …

C) Our formulating and confirming a theory of the whole world (a TOE): its general propositions (or an elite subset of them) are laws of nature.

The idea of a TOE:

a): Is supported by the amazing unity of nature shown by e.g. the second scientific revolution 1850-1950, and the rise of precision cosmology since ca. 1965…

b): Raises Wigner's question.

5) An open question: what is a possibility?

How much does stating the truth (in everyday life, or science, or philosophy) require accepting non-actual possibilities? For example:

(a) *Deliberation and decision*. How to understand what an agent thinks and does, purely in terms of the one actual course of events?

(b) *Chance*. How can objective tendencies for various possibilities be just a *facon de parler* about the one actual course of events?

(c) *Contingency*. A false theory might have been true, might have even been a TOE: e.g. classical vacuum electromagnetism.

Each possibility is of course non-actual: but real, in some wider sense than 'actual'.

What *EXACTLY* does such a possibility consist of?

This is generally agreed to be a harder question than e.g. the mind-body problem!

Leibniz's possible worlds, revived in modern modal metaphysics: David Lewis's realism.

So there are three kinds of multiverse: logical/ metaphysical; cosmological; quantum/Everett.

II: The Observer in a Classical World

<u>Setting aside cosmology …</u>

As scientific realists, basking in the sunlight of the world-picture of modern science, we worry 'only' that …

The deep question about the nature of possibility is aggravated by the use in classical thermal physics, of objective probabilities. How should we understand these?

But turning to cosmology …

1) Problems of principle for 'insiders'?

Can an agent in a world formulate/believe/know a proposition about the world as a whole (thus including themselves)?

Or does some logical paradox of self-reference lurk here?

We say: 'No worries'. But:

1A) Possibility again! Non-actual initial conditions of the universe cannot be taken as short for, or some sort of analogue of, actual initial conditions of another actual system: there is no such!

2A) *Epistemic* bad news for cosmologists:--

It can be very hard to determine the global structure of a general relativistic spacetime ...

2) Selection effects: the 'A' word…

The current scientific situation:

(i) The degree of fine-tuning is often stunning!

(ii) fundamental theory faces grave difficulties.

The current philosophical situation:

(i) Beware of essentialism about explanation!

(ii) The need to conditionalize on a description of observation depends on the notion of 'biassed sample' and so 'background population'; (cf. orthodox statistics).

But need to conditionalize does NOT depend on:

a) indexicality, i.e. threats of 'Doppelgangers';

b) the actual existence of other observations: in Eddington's metaphor, there might never be another fishing trip!

But to make sense of a probability of a cosmological parameter Λ according to theory T, pr(Λ|T):---

Do we need the actual existence of other domains, where Λ takes other values?

We say: you only need this, if you feel you must ground T's probabilities in actual frequencies, across the cosmos.

3) Confirming a multiverse theory

The predicament:

The self-same mechanism that gives rises to subtle features of the CMB can, under appropriate circumstances, give rise to a multiverse: a set of non-interacting domains.

So: How can we possibly confirm a multiverse theory without ever having direct evidence about the other domains?

We endorse a clarifying scheme that combines proposals of Aguirre, Tegmark, Hartle, Srednicki and Hertog.

Three problems: measure, conditionalization, and typicality.

(1): Measure. What are the elements of the sample space: Domains? Regions of equal volume? Given a sample space: which measure?

(2) Conditionalization. To allow for selection effects: how should we characterize our observational situation?

(3): Typicality. How much 'under the tails' can observation be, without our inferring the theory is disconfirmed?

4) The Srednicki-Hartle proposal: Frameworks

SH define a framework as a conjunction of:

i) a cosmological theory/model T: taken as solving the measure problem, so write: P(/T);

ii) a conditionalization scheme ('selection proposition') C; so consider: P(/T, C)

iii) a xerographic distribution ξ over the domains with non-zero measure according to P(/T, C).

So consider: P(/T, C, ξ)

So P(D / T, C, ξ) is the `first-person' likelihood of seeing data D.

Srednicki-Hartle propose a Bayesian framework, so as to compute degrees of confirmation of the framework: P(T, C, ξ / D).

They and Azhar show, in toy models T (e.g. with finitely many domains), how various conditionalization schemes C, and typicality assumptions ξ, fare in the light of various data D.

III: The Observer in a Quantum World

1) The dreaded quantum!

The measurement problem prompted (specially in the early days) a variety of radical proposals to give the 'observer'---maybe in anodyne form, e.g. as an orthobasis!---a fundamental role.

As realists, we dislike them all! We stand with J S Bell.

But we urge one should go beyond the usual suspects viz.

- Dynamical collapse (Diosi, GRW, Pearle, Penrose …),
- Pilot-wave theory (deBroglie, Bohm, Valentini …)
- Many worlds (Everett, Hartle, Deutsch, Wallace …)

2) The Everett interpretation of Ψ

The idea: a generic branch (better 'history') of Ψ contains a classical multiverse *a la* Part II: i.e. of the type described by Hartle-Srednicki frameworks.

Merits: 1) Ψ provides the probabilities, eg in a consistent-histories approach;

2) Adding appropriate details, it gives probabilities for what we observe;

3) Symmetries can help us calculate probabilities, eg by coarse-graining & by the uncalculable probabilities cancelling out.

Technical questions abound! For example:

A) <u>What is Ψ?</u>

A.1) The *No Boundary Proposal*: sum over all the 4-manifolds and metrics cupping the given 3-metric.

$$\Psi({}^3g) = \Sigma_{4_g} \ \exp[-I({}^4g)/\hbar]$$

A.2) Definition and tractability?

The transition from the Euclidean to the Lorentzian regime?

A.3) Contrast irresponsible popularization!

Some say creation *ex nihilo* is scientifically unproblematic, viz. 'fluctuation from vacuum'.

No!

'Vacuum' means, not 'nothing', but 'lowest energy state of the given system'.

'Quantum fluctuation' means having non-zero amplitude for more than one (typically classical) alternative.

B) How to relate Ψ to inflation, so as to get classical multiverse(s)?

B.1) Worryingly many models of the inflaton.

B.2) Different mechanisms of eternal inflation.

B.3) Various quantum-classical transitions:

i) Different components of the state Ψ

ii) The state Ψ is special e.g. WKB

iii) In some regime, relevant commutators $\to 0$

iv) Preferred quantities: (surely not by decoherence: there is no environment).

The answers to questions in A) and B) must ensure that parameters vary across domains of the ensuing classical multiverse.

C) Hartle, Hawking and Hertog: relate the NB proposal to inflation, using consistent-histories. The general merits recur. Besides, in simple models eg minisuperspace with quadratic potential:

i) Histories labelled by ϕ_0 and exhibit inflation;

ii) Our 'rareness' makes probabilities for what we observe volume-weighted, enhancing inflation (high N_e).

Conceptual questions abound!

D) If the branching is effective, ie approximate , the definition of each classical multiverse---and so e.g. how many domains it has---is ineradicably vague. Is that acceptable?

E) How should we understand probability? The 'usual question to Everett' is much sharper for Ψ . . . .

Conquering the multiverse is hard!

Alexander wept when he heard from Anaxarchus that there were an infinite number of worlds; and his friends asking him if any accident had befallen him, he returns this answer: 'Do you not think it a matter of lamentation that when is such a vast multitude of them, we have not yet conquered one?

From: Plutarch, *On the Tranquillity of Mind*

Nagyon szépen köszönöm !

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Eddington intended his fishing-net metaphor, not as a warning about selection effects, but as a parable to teach more general limitations of the physical sciences. He writes (Philosophy of Physical Science, 1938):

Let us suppose that an ichthyologist is exploring the life of the ocean. He casts a net into the water and brings up a fishy assortment. Surveying his catch, he proceeds in the usual manner of a scientist to systematise what it reveals. He arrives at two generalisations: No sea-creature is less than two inches long. (2) All sea-creatures have gills. These are both true of his catch, and he assumes tentatively that they will remain true however often he repeats it.

In applying this analogy, the catch stands for the body of knowledge which constitutes physical science, and the net for the sensory and intellectual equipment which we use in obtaining it. The casting of the net corresponds to observation; for knowledge which has not been or could not be obtained by observation is not admitted into physical science.

An onlooker may object that the first generalisation is wrong. "There are plenty of sea-creatures under two inches long, only your net is not adapted to catch them." The icthyologist dismisses this objection contemptuously. "Anything uncatchable by my net is *ipso facto* outside the scope of icthyological knowledge. In short, "what my net can't catch isn't fish."

Or — to translate the analogy — "If you are not simply guessing, you are claiming a knowledge of the physical universe discovered in some other way than by the methods of physical science, and admittedly unverifiable by such methods. You are a metaphysician. Bah!"