Title: Many-worlds and one-world interpretations of quantum theory (Part 1A)

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Abstract:

Many-Worlds and One-World Interpretations of Quantum Theory

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Aim to give a very brief introduction to some of the interesting ideas in the still-very-much-ongoing debate over Everett a.k.a. "many-worlds" interpretations.

Apologies that I can't do justice to many of the thoughtfully and carefully expressed arguments pro and con.

References
- Forthcoming conference at Perimeter "Many Worlds at 50", September 21-24, 2004. See www.perimeterinstitute.ca/Events/Many_Worlds_at_50 (Registration still open; talks will be video archived.)
- Recent meeting at Oxford philosophy of physics dept: http://users.ox.ac.uk/~everett (videos online)
- Arxiv papers by most of the speakers at both meetings (and others).
- Original collection of articles: "The Many-Worlds Interpretation of Quantum Mechanics", DeWitt-Graham (eds), (Princeton Univ. Press, 1973). (Mostly of historical interest now.)

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Everett's 1957 proposal

"This paper seeks to clarify the foundations of quantum mechanics. It presents a reformulation of quantum theory in a form believed suitable for application to general relativity."

"The aim is not to deny or contradict the conventional formulation of quantum theory .... but rather to supply a new, more general and complete formulation, from which the conventional interpretation can be deduced."

"The new theory is not based on any radical departure from the conventional one. The special postulates in the old theory which deal with observation are omitted in the new theory. The altered theory ... has to be analyzed in and for itself before any identification becomes possible between the quantities of the theory and the properties of the world of experience."

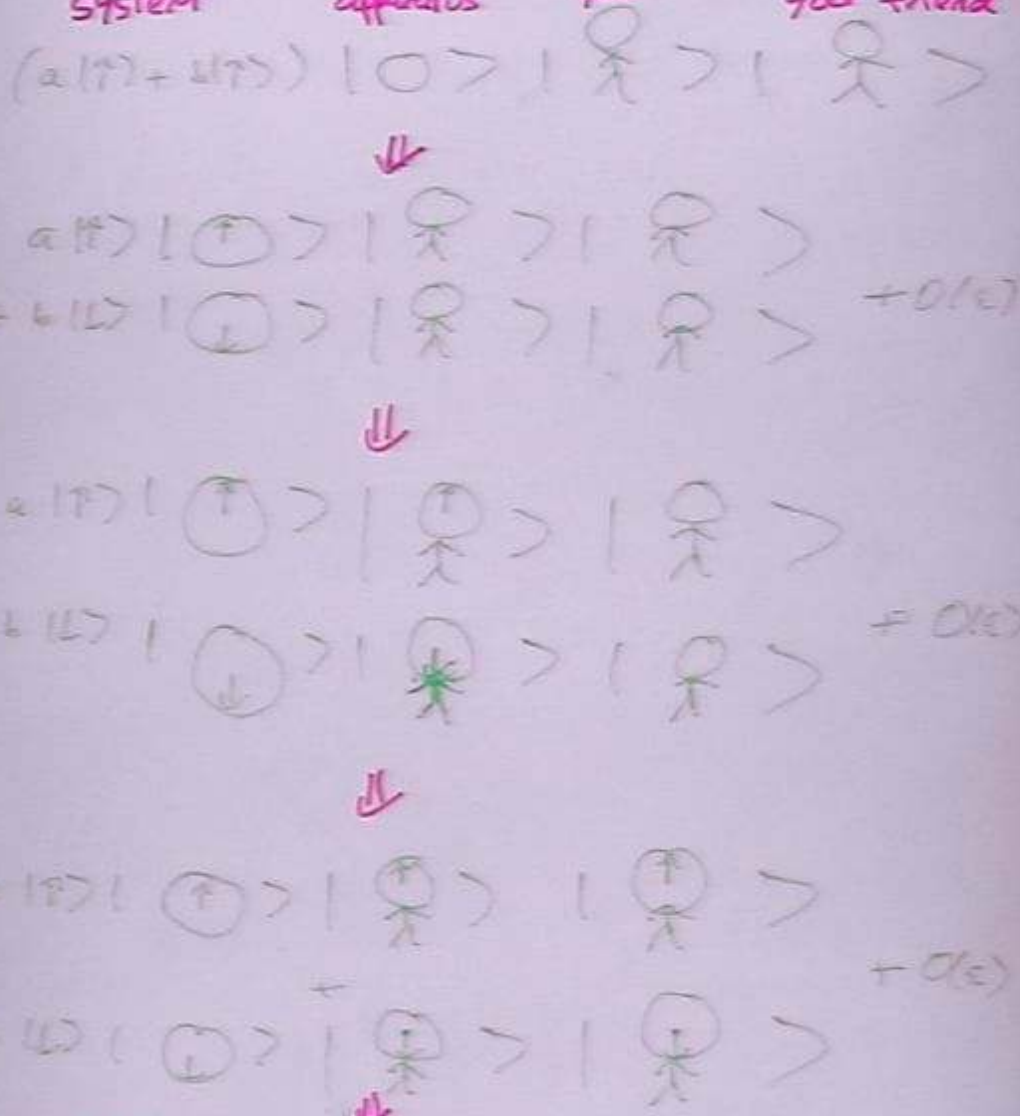
Everett on reality of alternate branches

From the viewpoint of the theory all elements of a superposition (all "branches") are "actual", none any more "real" than the rest. It is unnecessary to suppose that all but one are somehow destroyed, since all the complete elements of a superposition individually obey the wave equation with complete indifference to the presence or absence ("actuality" or not) of any other elements. This total lack of effect of one branch on another also implies that no observer will ever be aware of any "splitting" process.

Arguments that the world picture presented by this theory is contradicted by experience, because we are unaware of any branching process, are like the criticism of the Copernican theory that the mobility of the earth is incompatible with .. common sense .. because we feel no such motion. In both cases .. the theory itself predicts that our experience will be what it in fact is.

The canonical Everettian example

System apparatus you your friend



NO COLLAPSE AT ANY POINT.

Traditional objection I: the "preferred basis" problem

We can write any superposition in infinitely many different ways, e.g.

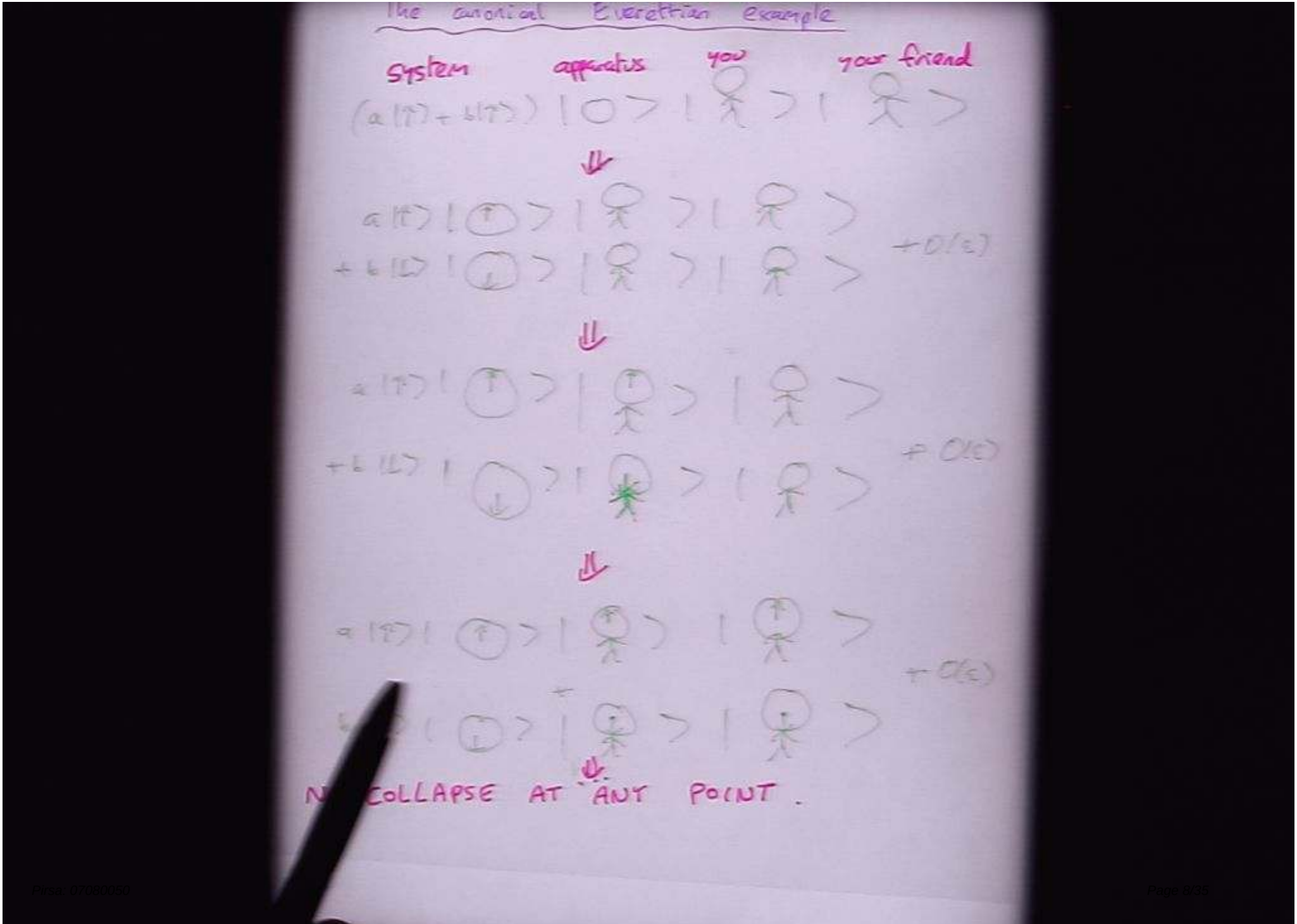
$$a|0\rangle + b|1\rangle = \left(\frac{a+b}{\sqrt{2}}\right)|+\rangle + \left(\frac{a-b}{\sqrt{2}}\right)|-\rangle$$

What justifies using the particular representation

$$a|\uparrow\rangle|\textcircled{1}\rangle|\text{person}\rangle|\text{person}\rangle + b|\downarrow\rangle|\textcircled{2}\rangle|\text{person}\rangle|\text{person}\rangle$$

that seems to suggest an interpretation of a universe "split" into distinct macroscopically coherent branches?

And more generally, what tells us exactly when such splittings occur and exactly what form they take? Do we need a new law of nature to characterise the Everett branches?



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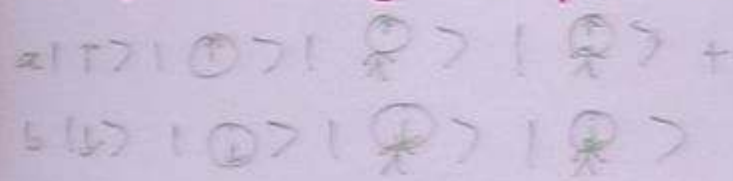

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Are branches of the universal wave function ontologically fundamental, or merely structures it's useful for theorists to consider? And are they precisely defined or necessarily "fuzzy"?

$$|\pm\rangle = \frac{1}{\sqrt{2}}\left(|0\rangle \pm |1\rangle\right)$$

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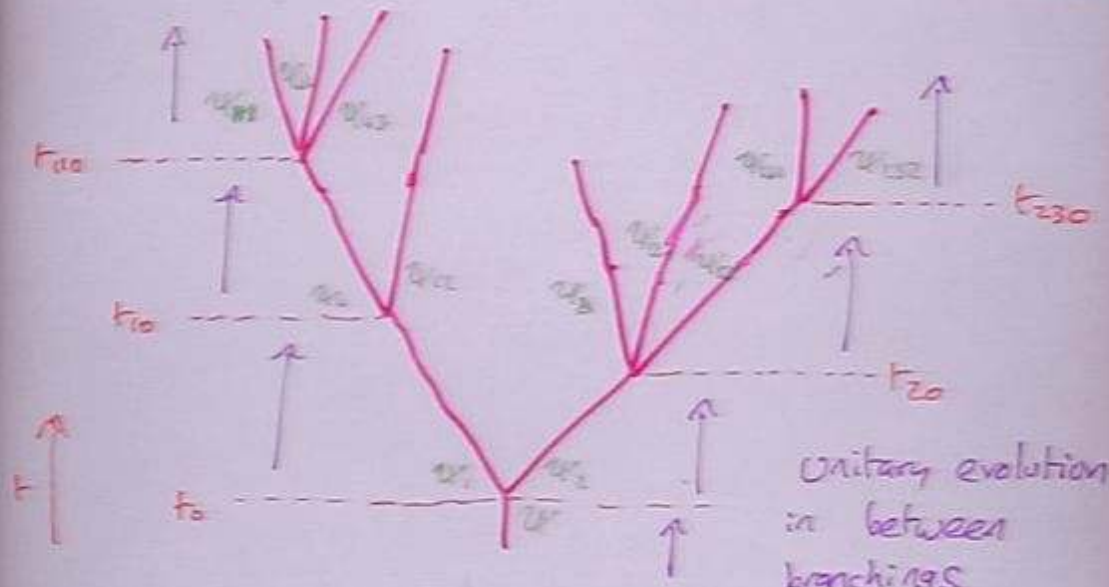
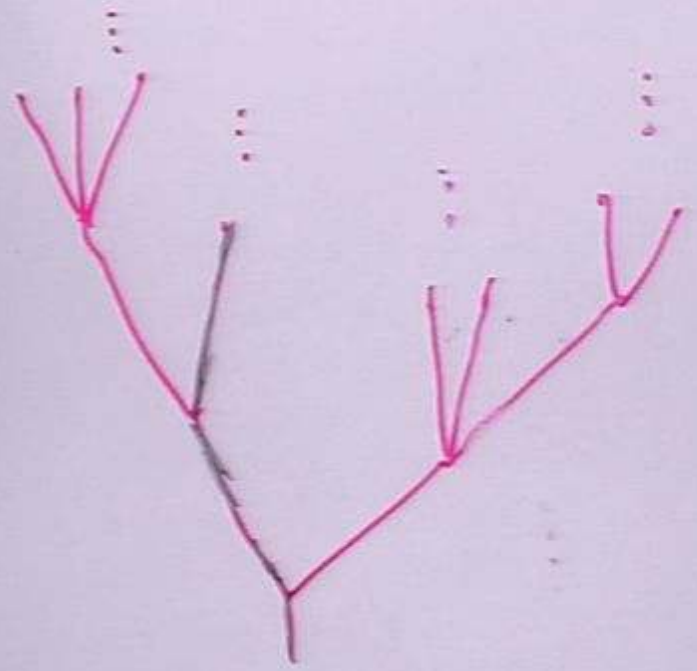
One possible response to the preferred basis problem is "Yes: we need a new law of nature to characterize the Everett branches." A (maybe too simple) example of the sort of thing that might emerge is:

Axioms define for us list of times $\{t_0, t_{10}, t_{110}, \ldots, t_{20}, \ldots t_{230}, \ldots\}$

projective decompositions $\{P^i_0\}, \{P^i_{10}\}, \{P^i_{110}\}, \ldots, \{P^i_{120}\}, \ldots$



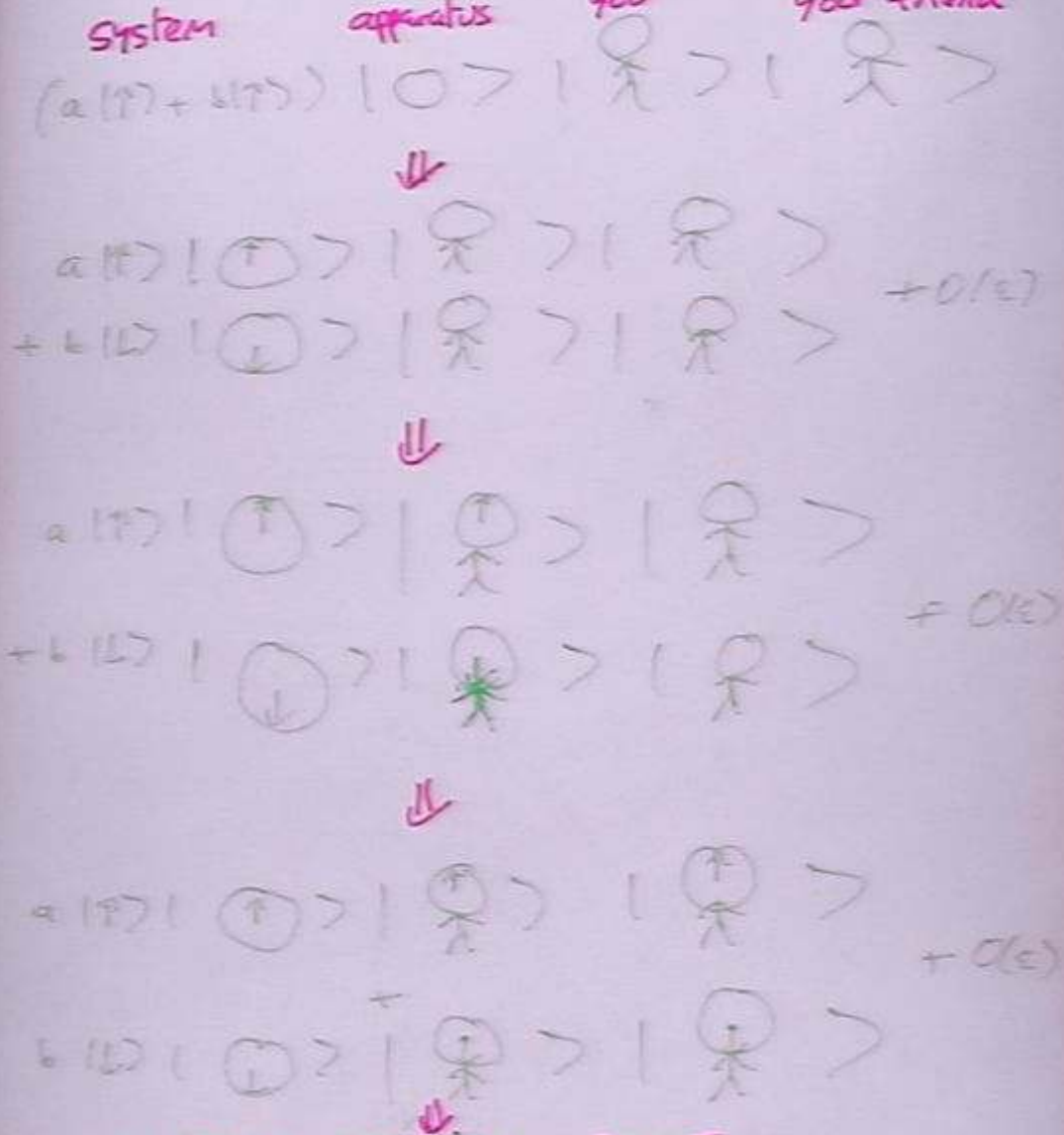
with the property that all branch states at any given time are orthogonal



If we could find a branching law of this type, with a (finite or infinite or continuously infinite) list of ultimately orthogonal branches, it's not so clear why we'd need or want a many-worlds interpretation. We could simply postulate that precisely one branch is randomly chosen, and it describes the real world.

The canonical Everettian example

System apparatus you your friend



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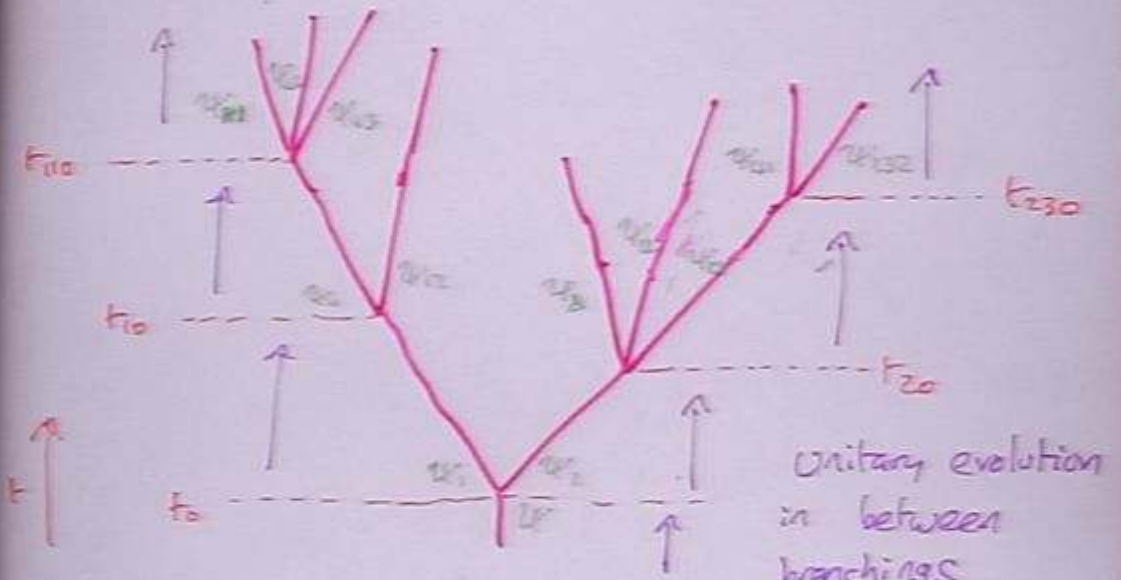
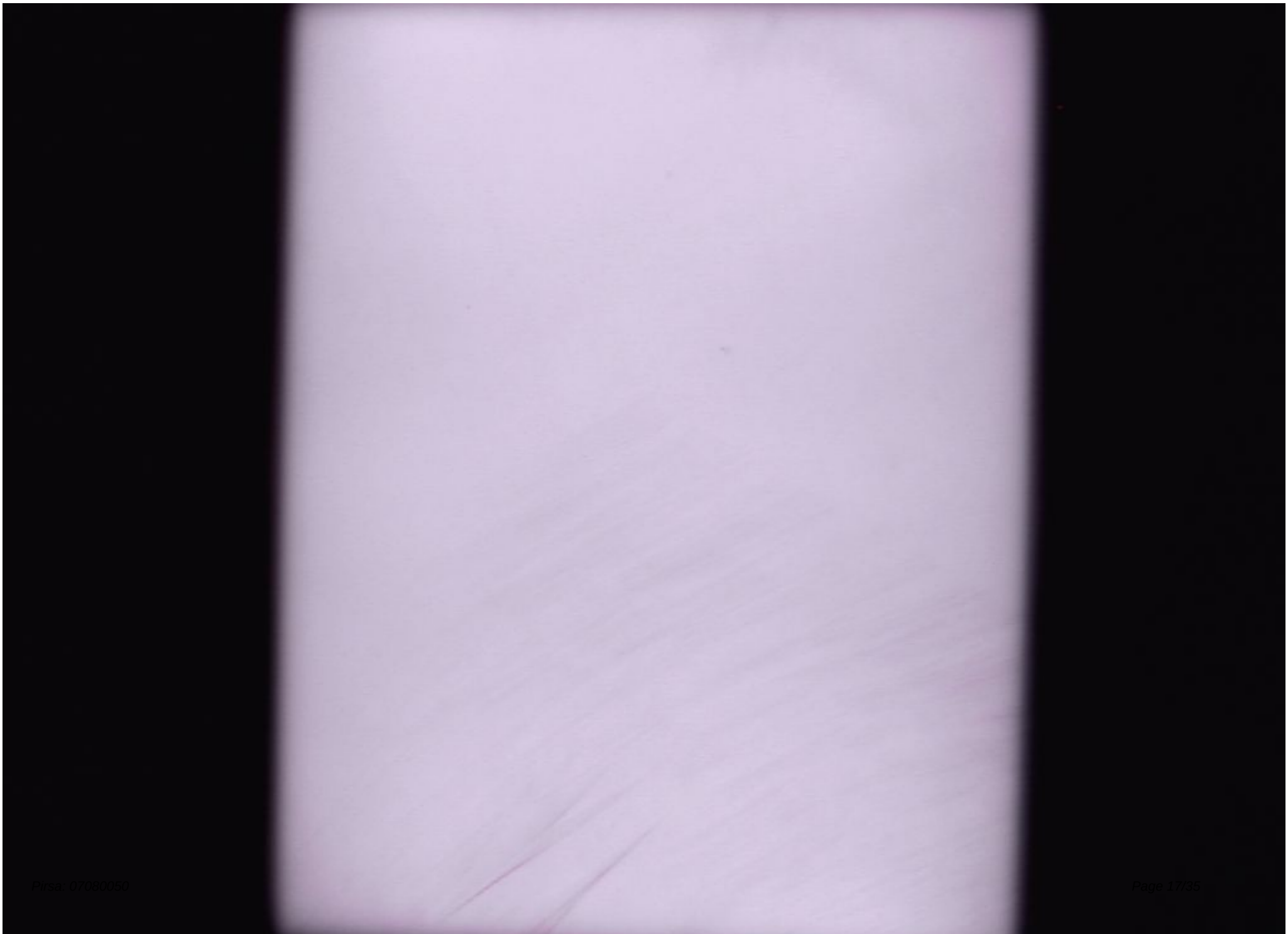
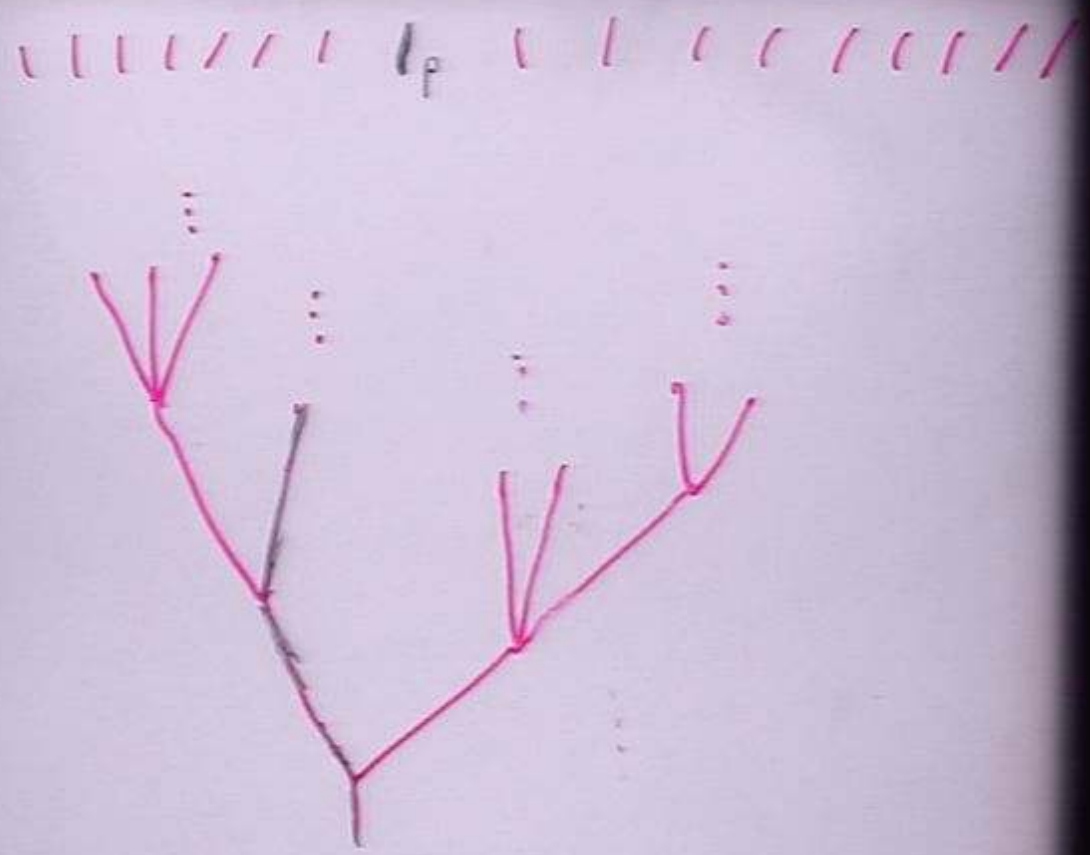


with the property that all branch states at any given time are orthogonal

If we could find a branching law of this type, with a (finite or infinite or continuously infinite) list of ~~all~~ mutually orthogonal branches, it's not so clear why we'd need or want a many-worlds interpretation. We could simply postulate that precisely one branch is randomly chosen, and it describes the real world.





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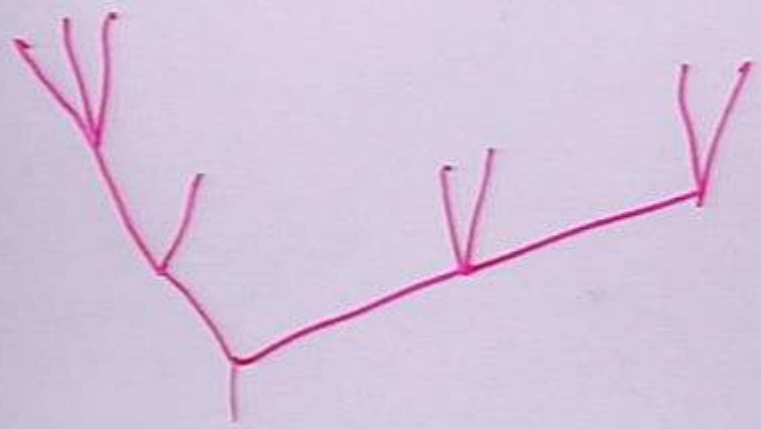
Branching laws for the universal wave function



(1) No one has ever found a good set of mathematical axioms that define a unique tree of orthogonal branches that look like quasiclassical worlds.
(You might think it's easy to toy models, but in realistic models with realistic decoherence mechanisms it's very hard.)

(2) If they did, it would more naturally suggest a one-world interpretation. (But that's fine: would be very interesting in any case.)

(3) See quant-ph/0708.3710 for a much better idea along somewhat related lines.

A commoner response to the preferred basis problem is "No: we don't need a new physical law. Branches are not defined by a fundamental ontology. It appears to us that we're in a definite branch because of the type of creatures we are and the way we interact with the environment." (cf. Jeremy's DefApp option.)

Quite a few physicists have advocated something like this view: Everett, Coleman, Gell-Mann and Hartle, ...
It's lately been elaborated in some detail by Saunders, Wallace and others. The key idea — seemingly implicit in earlier authors' writings and explicit in the case of Saunders and Wallace — is the appeal to a particular theory of mind: functionalism.

Functionalism: the doctrine that what makes something a thought, desire, pain (or any other type of mental state) depends not on its internal constitution, but solely on its function, or the role it plays, in the cognitive system of which it is a part.

(Stanford online Encyclopaedia of Philosophy)

Functionalism applied to the universal wave function

As I understand it, and roughly speaking, the claim is something like this:

If $\Psi(t) = \sum_i \Psi_i(t)$ is an orthogonal decomposition of the universal wave function, valid for some significant time interval, and if some or all of the $\Psi_i(t)$ are individually interpretable as describing macroscopic creatures with brains interacting with a largely classical macroscopic world, then the creatures are real, conscious beings having the experiences described:

$$\alpha(t)\,|\uparrow\rangle\,|\text{"I" experience seeing the pointer up}\rangle + \beta(t)\,|\downarrow\rangle\,|\text{"I" experience seeing the pointer down}\rangle$$

etc.

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etc.

Functionalism and fuzziness

The splitting $\Psi(t) = \sum_{i=1}^{N} \psi_i(t)$ isn't going to be precisely defined. (Indeed, even the number of terms N isn't defined: when do you decide two nearly identical quasi-classical worlds are distinct?) Isn't that going to be a problem for functionalist accounts?

Quantum functionalists (led in particular by Wallace) say NO: higher-level theories are always inherently fuzzy. There's no precise definition of a human being or a brain even in classical theories of mind, but we (allegedly) cope.

"You can't decide to date someone provided they contain a prime number of atoms."

You might not be comfortable with either functionalism* or fuzziness-toleration. (I don't think I am.) But I suggest we run with it for now, since ① no one seems to have an uncontroversially superior account of how minds are related to the physical world

② we need to decide if Everettianism makes perfect sense given this popular (if much debated) theory of mind, or if it runs into deep problems anyway.

* in particular, functionalism applied to components of a universal wave-function decomposition

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Everett and evolution

Suppose we had a quantum theory of gravity, a quantum cosmological theory, an all-powerful computer. Everyone's intuition (on all sides of the debate) is that we should expect at present:

huge or infinite

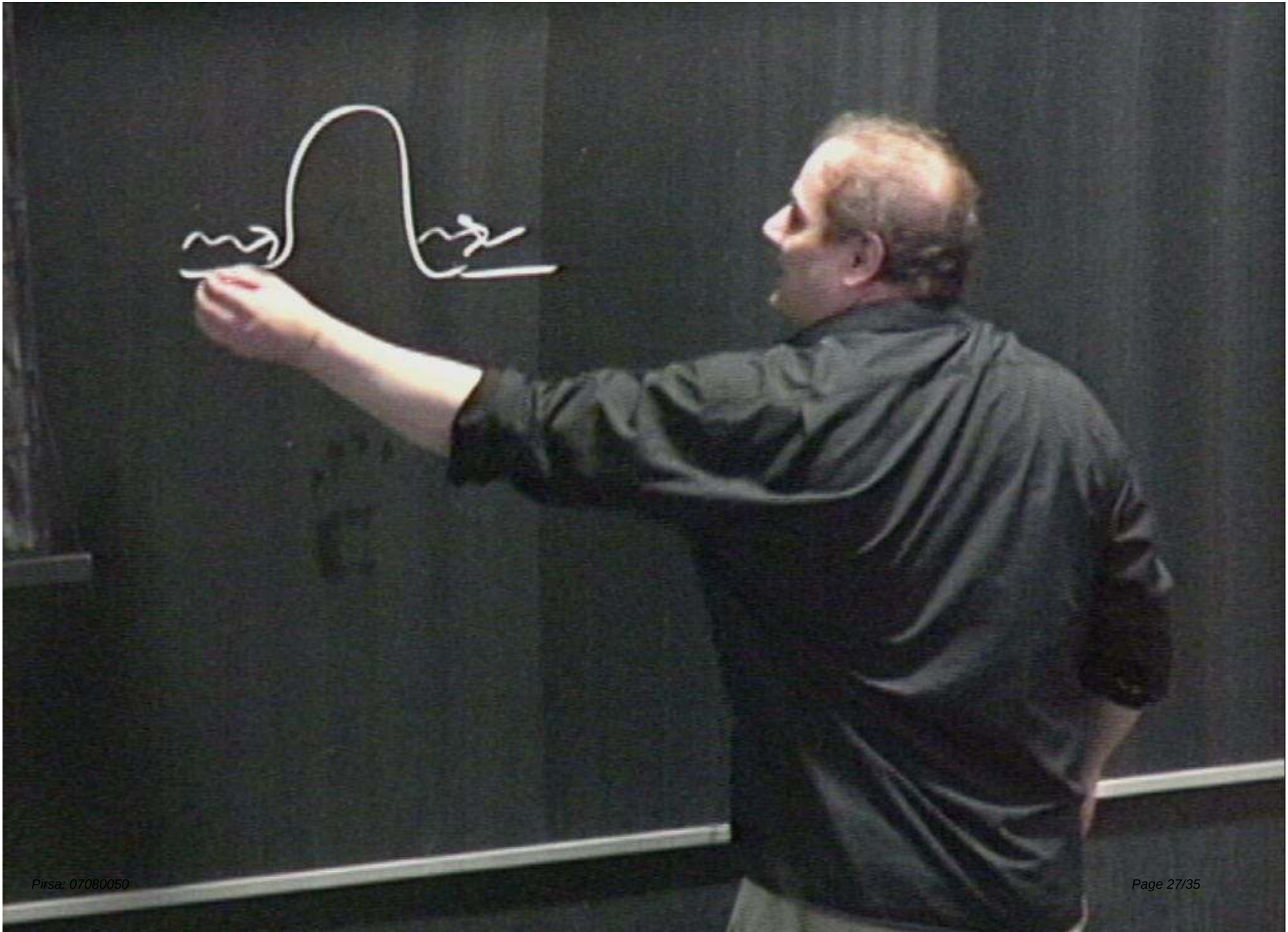
$$\psi \approx \sum_{i=1}^{\infty} \psi_i$$

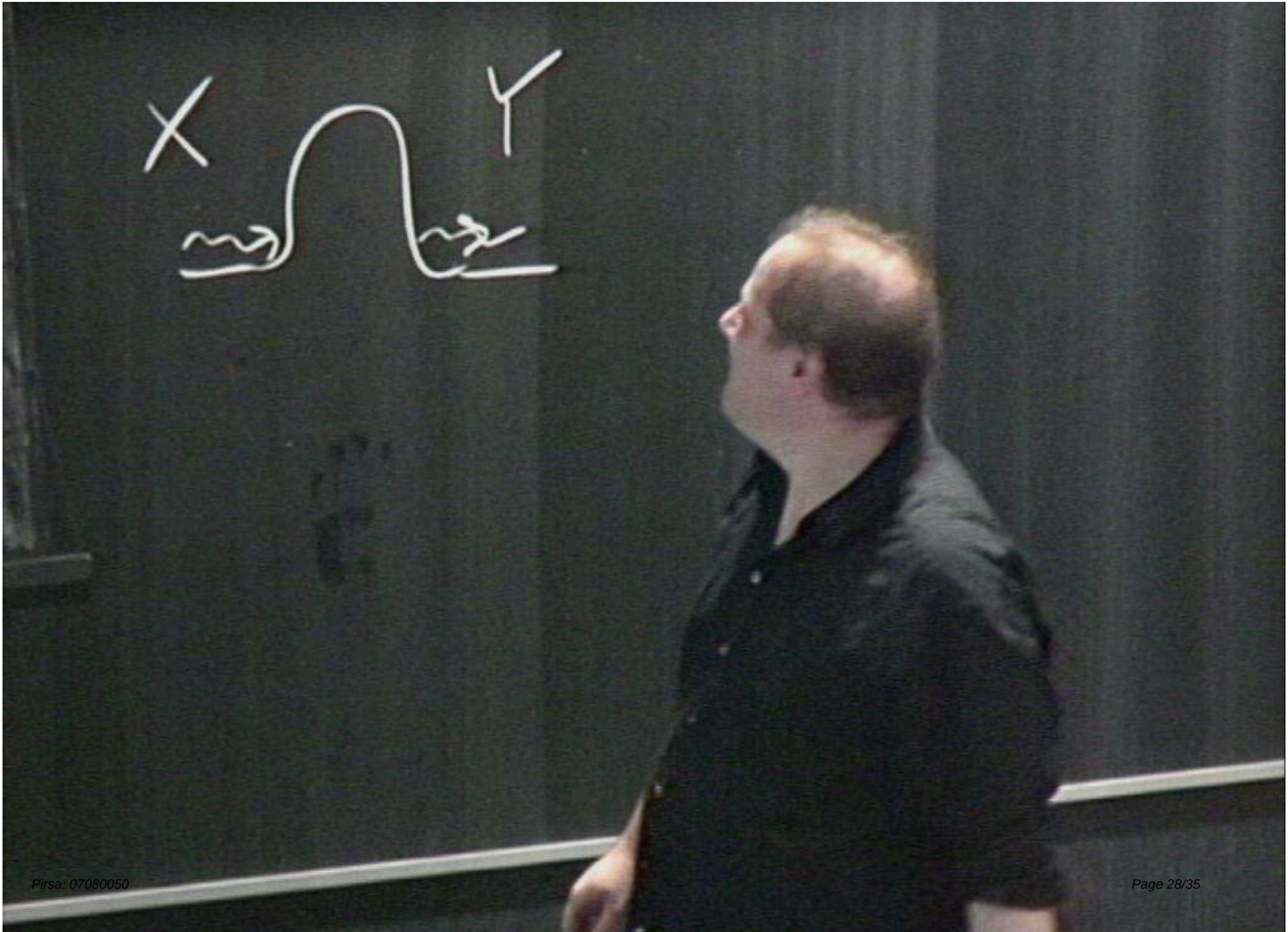
contains quasiclassical worlds with many different arrangements of galaxies, stars, Sun, Earth, Waterloo Lake, ...

-- including human civilizations on Earth with many different evolutionary histories, among which (with smaller amplitude) are some relying on (what in standard q.m. would be) very improbable events.

(Similarly for other lifeforms, terrestrial and extraterrestrial, of course.)

---- including also many civilizations whose experiments led them to non-standard versions of quantum theory, or even to completely different theories.

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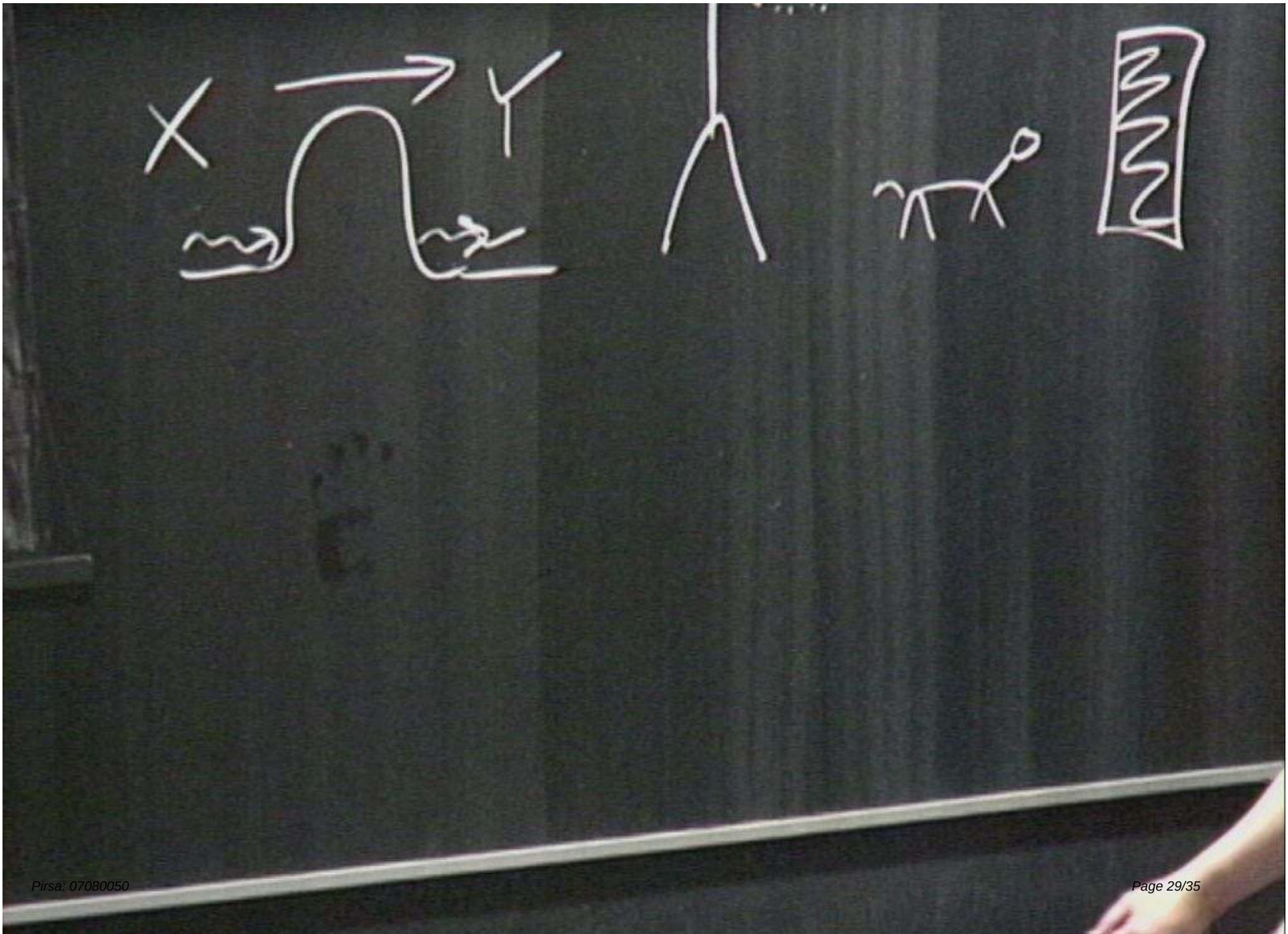
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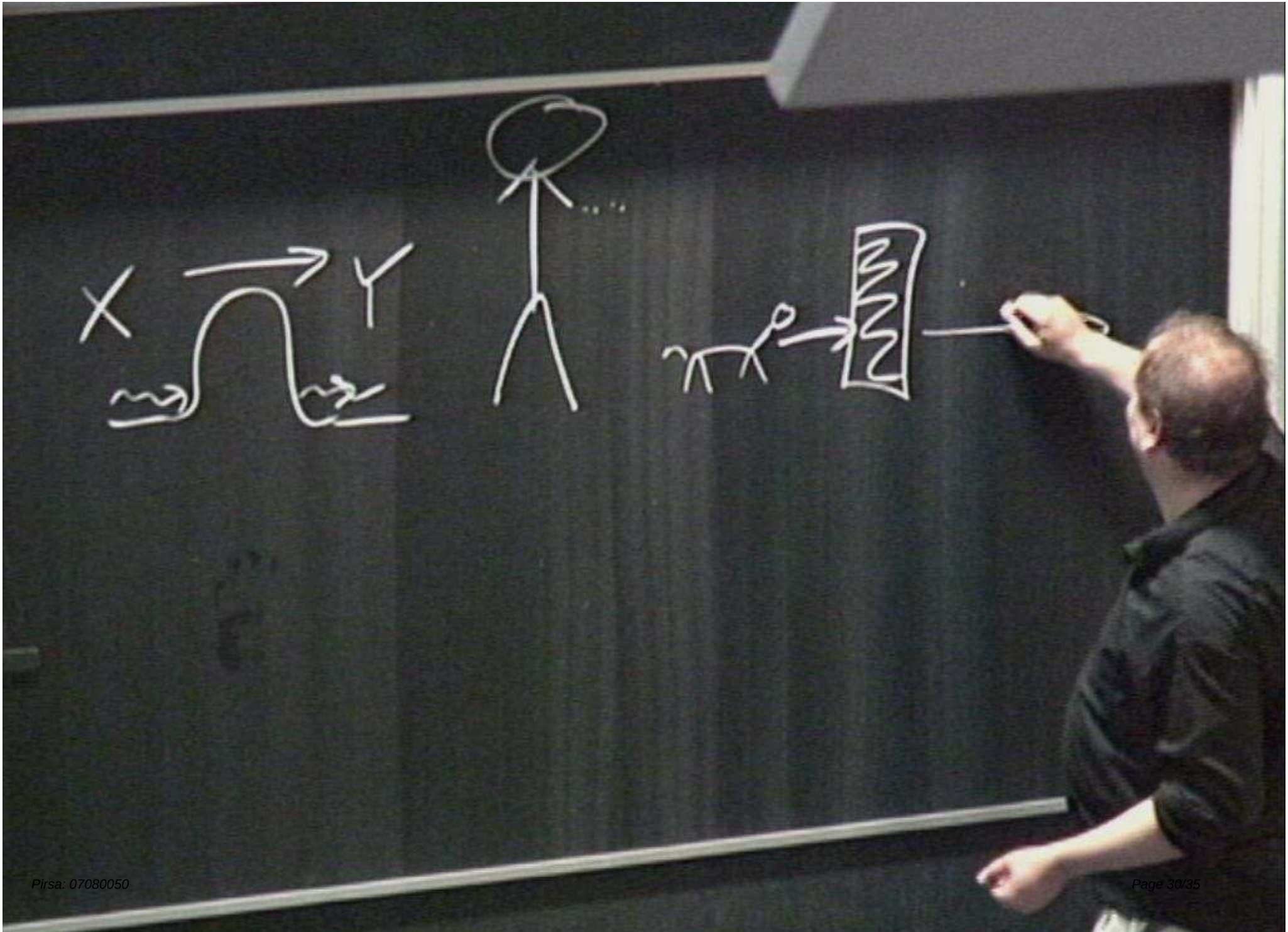
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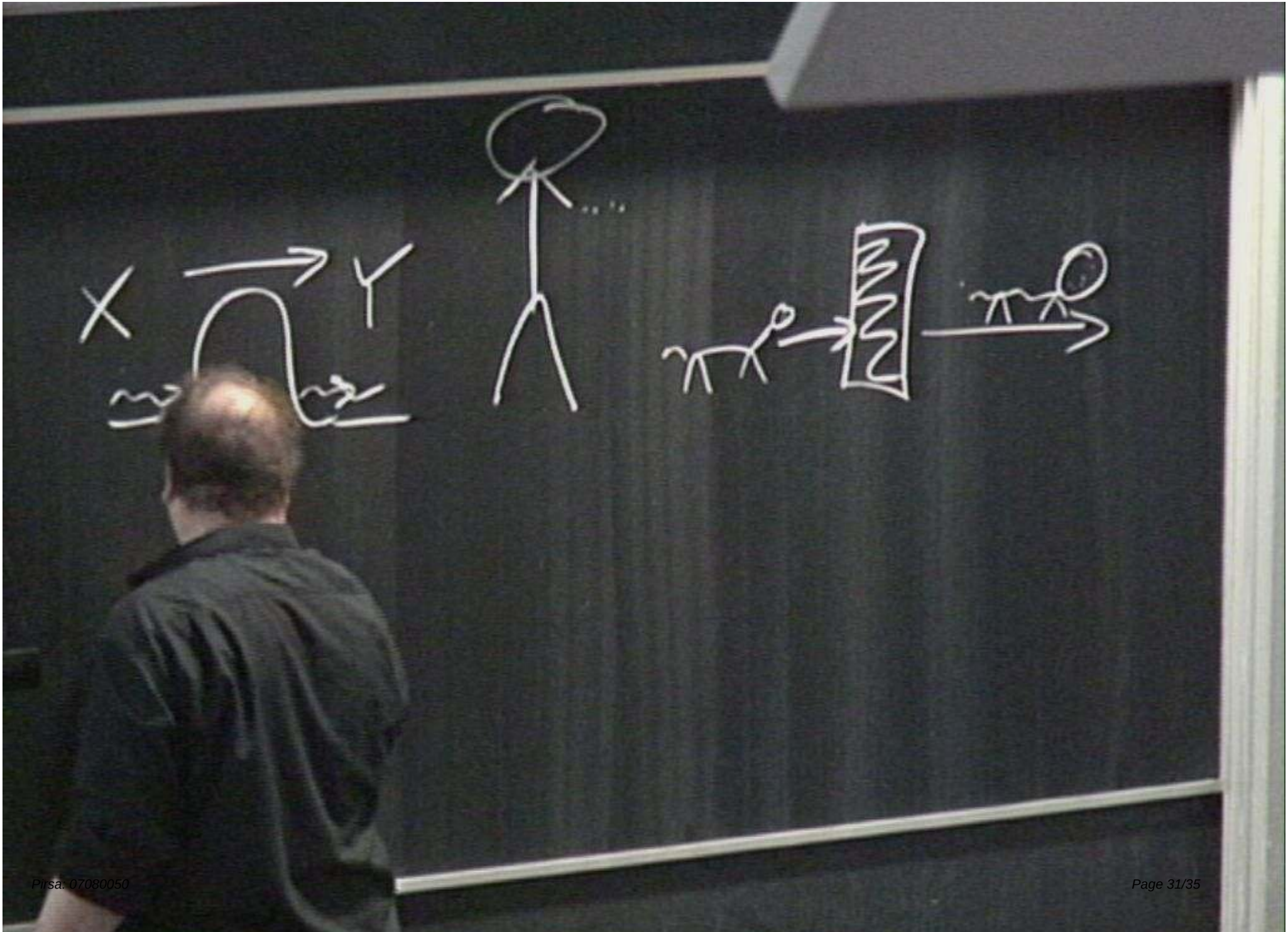
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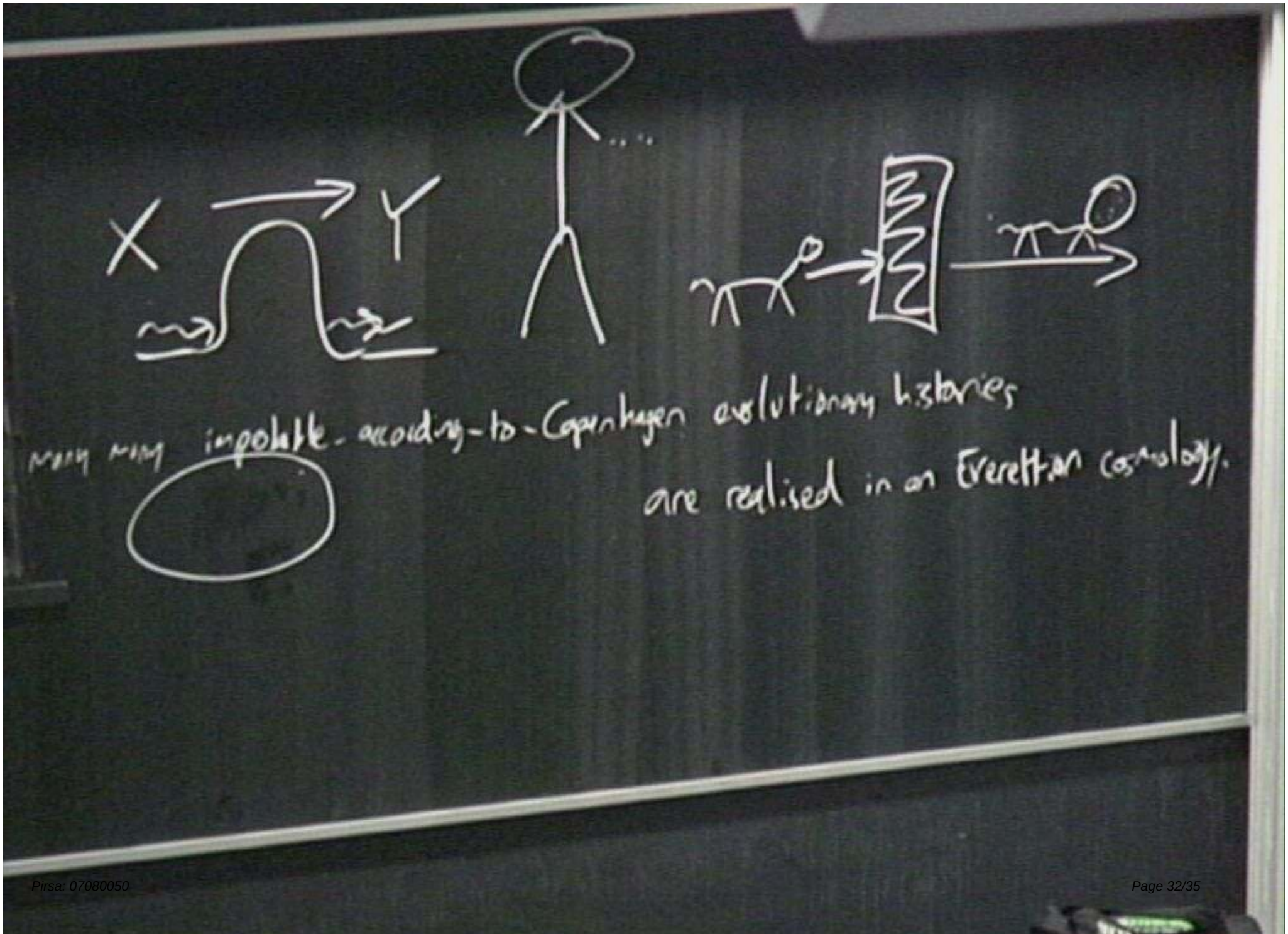
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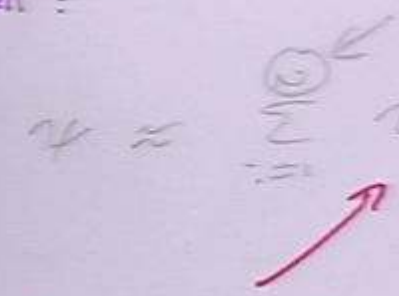

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.... including also many civilizations whose experiments led them to non-standard versions of quantum theory, or even to completely different theories.

A key question for Everettians

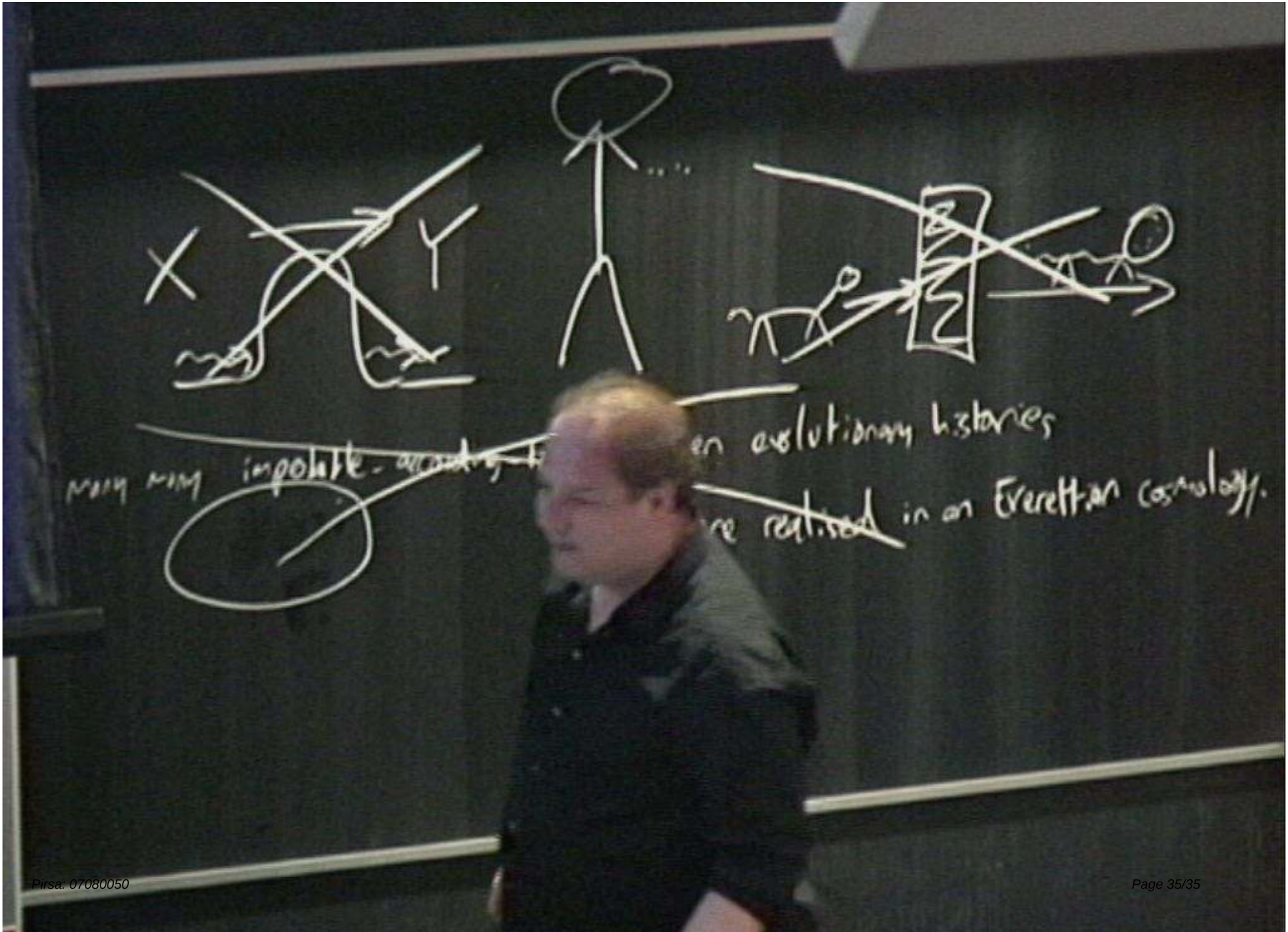
If universal quantum theory (+ quantum gravity + cosmology) is correct, why do we find ourselves to be people from a species that seems to have evolved without relying on deviations from Copenhagen q.m., and to have accumulated experimental data which led us to Copenhagen q.m.?

On a one-world view, the answer could be that no other types of people (or intelligent life) exist. But on an Everettian view, they definitely do exist, in proliferation.

Clearly, Everettians are going to have to say something about $|\psi|^2$ and give some (presumably non-standard) account of probability, to have any hope of answering this.

! Let's be alert to the possibility that Everettians might offer an account of probability that (possibly) addresses some other interesting questions but fails to answer this one.

(Confession: if any Everettian account of probability has succeeded in answering this, then I have so far failed to understand how.)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