

TRACTATUS QUANTICUS

Niccolò Covoni, Andrea Di Biagio, Carlo Rovelli

WHAT IS THIS CONNECTED TO?

Information → Foundations of Quantum

Perspectivism and the relational quantities appear to be quite universal in physics:

1. Relational observables in classical GR. (Relational locality.)
2. Reference systems. (That can be quantum objects.)
3. Observers are quantum system.

BUT THESE ARE DISTINCT!

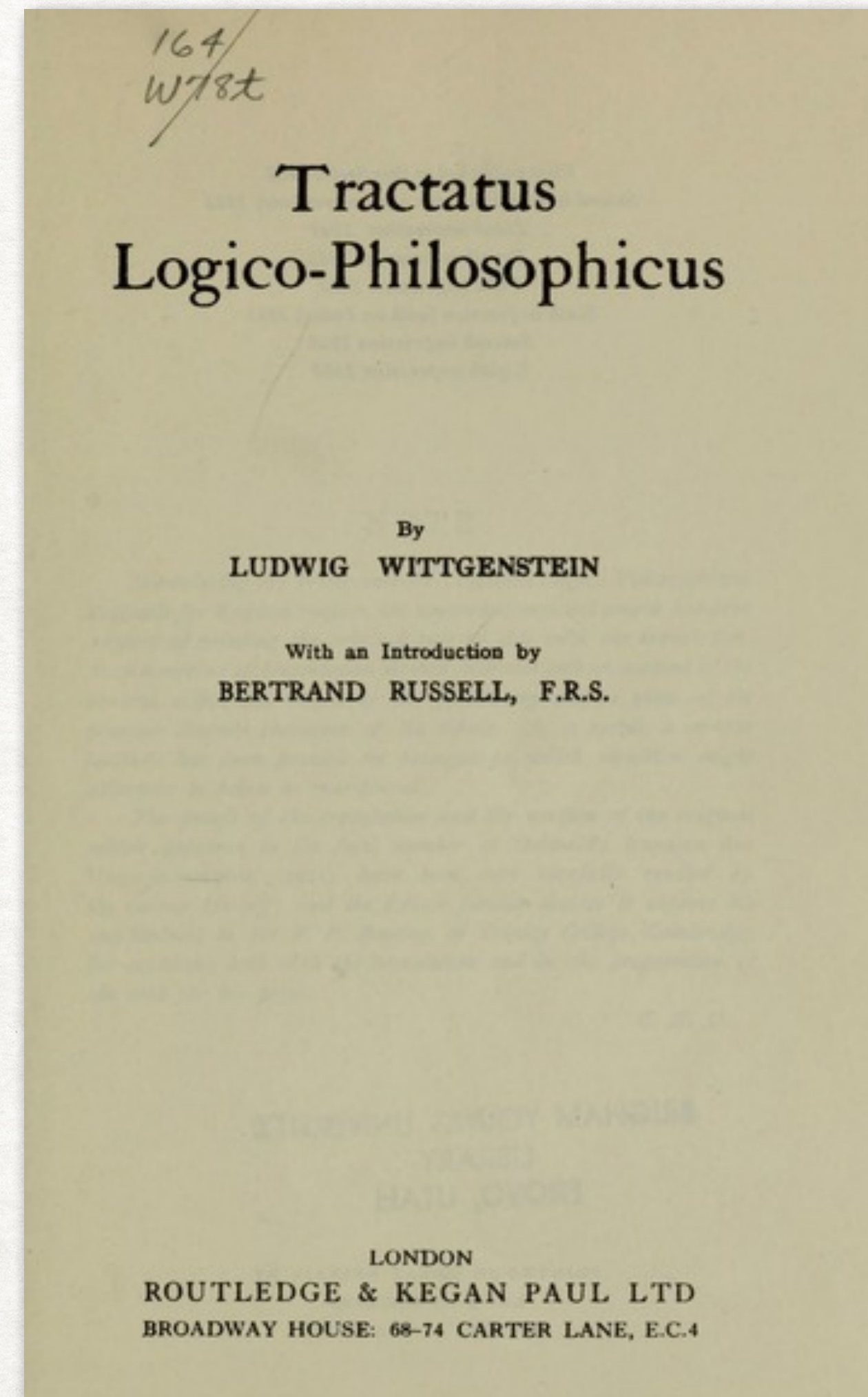
To understand quantum gravity we need to understand how these different relational aspects of Nature work together.

But careful not to confuse them! This happens far too often.

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Niccolò Covoni, Andrea Di Biagio, Carlo Rovelli

1921, Ludwig Wittgenstein



TRACTATUS LOGICO-PHILOSOPHICUS

What we cannot think, that we cannot think:
we cannot therefore *say* what we cannot
think.

5.62 This remark provides a key to the question, to
what extent solipsism is a truth.

In fact what solipsism *means*, is quite correct,
only it cannot be *said*, but it shows itself.

That the world is *my* world, shows itself in
the fact that the limits of the language (*the*
language which I understand) mean the limits of
my world.

5.621 The world and life are one.

5.63 I am my world. (The microcosm.)

5.631 The thinking, presenting subject; there is no
such thing.

If I wrote a book "The world as I found it",
I should also have therein to report on my body
and say which members obey my will and which
do not, etc. This then would be a method of
isolating the subject or rather of showing that in
an important sense there is no subject: that is to
say, of it alone in this book mention could *not* be
made.

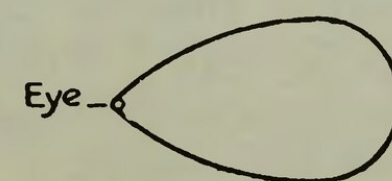
5.632 The subject does not belong to the world but
it is a limit of the world.

5.633 *Where in* the world is a metaphysical subject to
be noted?

You say that this case is altogether like that of
the eye and the field of sight. But you do *not*
really see the eye.

And from nothing *in the field of sight* can it be
concluded that it is seen from an eye.

5.6331 For the field of sight has not a form like this:



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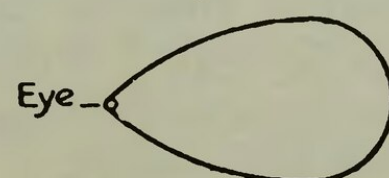
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5.6331 For the field of sight has not a form like this:



1. The world is everything that is the case.
2. What is the case (a fact) is the existence of states of affairs.
3. A logical picture of facts is a thought.
4. A thought is a proposition with a sense.
5. A proposition is a truth-function of elementary propositions. (An elementary proposition is a truth-function of itself.)
6. The general form of a proposition is the general form of a truth function, which is: $[\bar{p}, \bar{\xi}, N(\bar{\xi})]$. This is the general form of a proposition.
7. Whereof one cannot speak, thereof one must be silent.

Simple minded version (actually wrong)



World



Language

The book deals with the problems of philosophy and shows, as I believe, that the method of formulating these problems rests on the misunderstanding of the logic of our language.

Its whole meaning could be summed up somewhat as follows:

What can be said at all can be said clearly; and whereof one cannot speak thereof one must be silent.

1925, Werner Heisenberg, Max Born, Paul Dirac



Born and Jordan – On quantum mechanics.14

$$\begin{aligned}\mathbf{\dot{d}} &= \dot{\mathbf{p}}\mathbf{q} + \mathbf{p}\dot{\mathbf{q}} - \dot{\mathbf{q}}\mathbf{p} - \mathbf{q}\dot{\mathbf{p}} \\ &= \mathbf{q}\frac{\partial \mathbf{H}}{\partial \mathbf{q}} - \frac{\partial \mathbf{H}}{\partial \mathbf{q}}\mathbf{q} + \mathbf{p}\frac{\partial \mathbf{H}}{\partial \mathbf{p}} - \frac{\partial \mathbf{H}}{\partial \mathbf{p}}\mathbf{p}.\end{aligned}$$

From (22), (23), one then has $\mathbf{\dot{d}} = 0$, and $\mathbf{d}$ is a diagonal matrix. However, the diagonal terms of $\mathbf{d}$ are established by the quantum condition (37) precisely. In summary, with the use of the identity matrix $\mathbf{1}$ that is defined by (6), we will get the equation:

$$\mathbf{p}\mathbf{q} - \mathbf{q}\mathbf{p} = \frac{h}{2\pi i}\mathbf{1}, \tag{38}$$

which we call the *sharpened quantum condition* and which we will base all further conclusions upon.

One can infer from the form of this equation that if an equation (A) were derived from (38) then (A) would remain true when one switched $\mathbf{p}$ with $\mathbf{q}$ and simultaneously replaced h with $-h$. For that reason, of the equations:

$$\mathbf{p}^n\mathbf{q} = \mathbf{q}\mathbf{p}^n + n\frac{h}{2\pi i}\mathbf{p}^{n-1}, \tag{39}$$

$$\mathbf{q}^n\mathbf{p} = \mathbf{p}\mathbf{q}^n - n\frac{h}{2\pi i}\mathbf{q}^{n-1}, \tag{39'}$$

only one them can be proved from (38), which can be done by induction quite easily.

We would now like to prove the laws of energy and frequency, as they were expressed above, and first for the case:

$$\mathbf{H} = \mathbf{H}_1(\mathbf{p}) + \mathbf{H}_2(\mathbf{q}).$$

From what was done in § 1, $\mathbf{H}_1(\mathbf{p})$ and $\mathbf{H}_2(\mathbf{q})$ can be formally replaced by the power series:

$$\mathbf{H}_1(\mathbf{p}) = \sum a_n \mathbf{p}^n, \quad \mathbf{H}_2(\mathbf{q}) = \sum b_n \mathbf{q}^n$$

in this. Formulas (39), (39') then allow one to see that:

$$\left. \begin{aligned}\mathbf{Hq} - \mathbf{qH} &= \frac{h}{2\pi i}\frac{\partial \mathbf{H}}{\partial \mathbf{p}}, \\ \mathbf{Hp} - \mathbf{pH} &= -\frac{h}{2\pi i}\frac{\partial \mathbf{H}}{\partial \mathbf{q}}\end{aligned} \right\} \tag{40}$$

and a comparison with the equations of motion (35) will yield:

$$PQ - QP = -i\hbar$$

What have we understood about the world

With

Quantum Mechanics?

(A) Searching for an ontology (observations are explained by a single coherent world).
(Metaphysical scientific realism.)

(B) Seek to **articulate a coherent conceptual structure** to think about reality in the light of quantum phenomena, a conceptual structure that *does not assume the existence of a single absolute reality*

Relational quantum mechanics is an attempt to do (B) in a fully naturalistic manner, **avoiding both metaphysical realism and instrumentalism (or idealism, solipsism...).**

A key to understanding quantum phenomena this way is to think in terms of the information

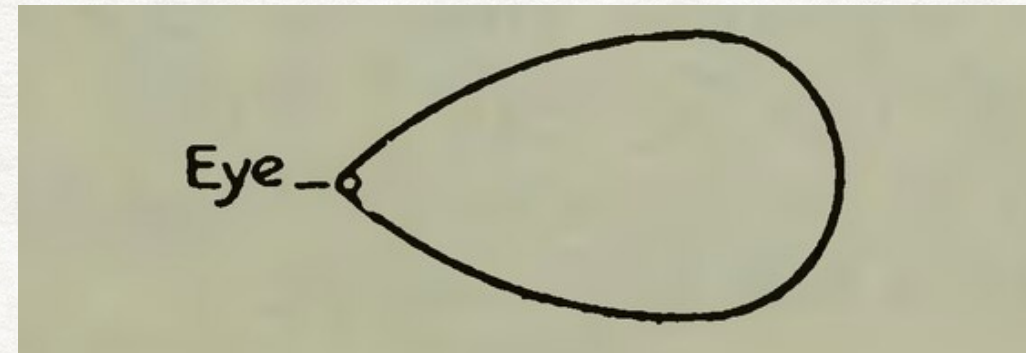
(Everett 1973; Wheeler 1986; CR 1996; Zeilinger 1999; Fuchs, 2002; Hardy, 2001; Brukner and Zeilinger, 2003).

RQM focuses the information (in a precise sense) that different parts of nature have about each other

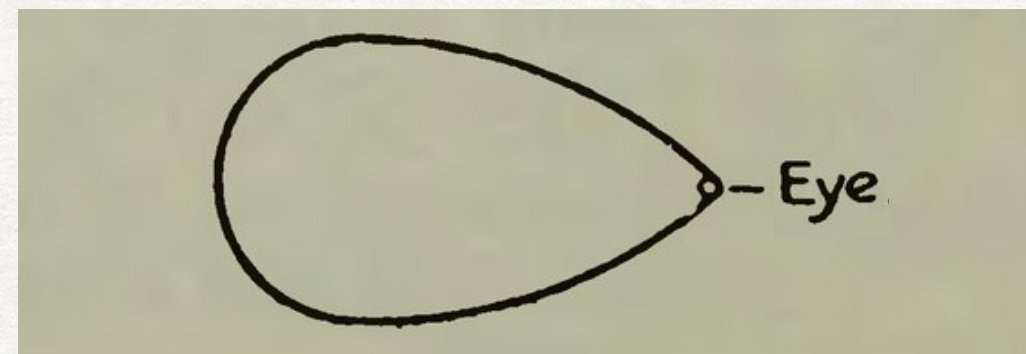
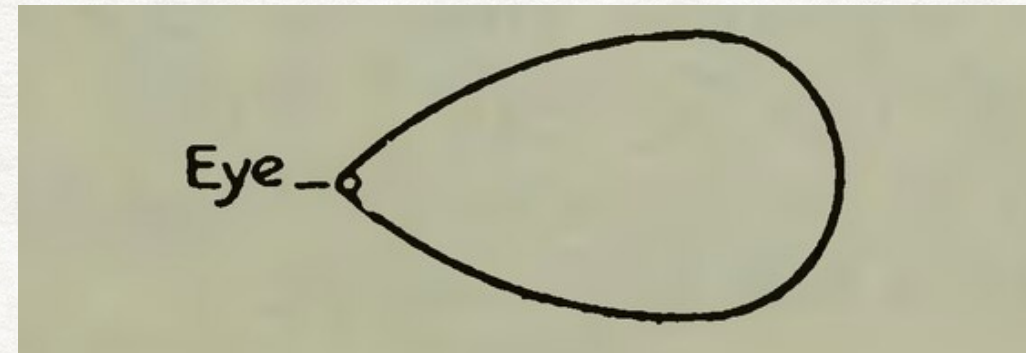
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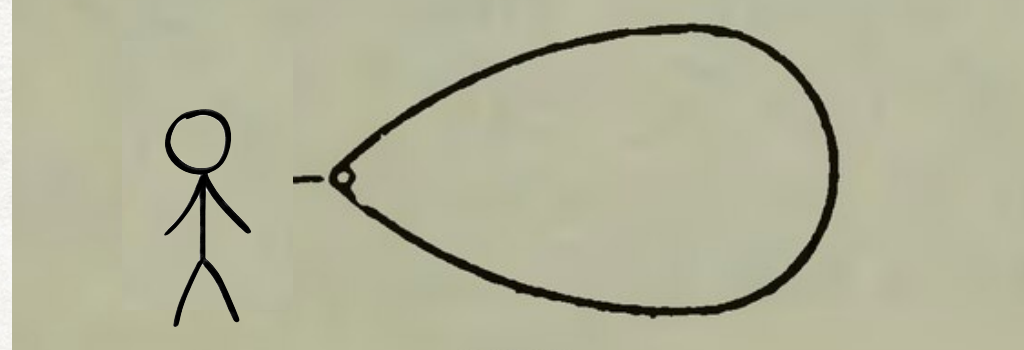
1. The world is everything that is the case from a perspective.
2. My knowledge about the world is a particular kind of perspective.
3. Perspectives themselves are facts, when considered from another perspective.
4. Facts may be expressed as values of variables, which are ways systems interact.
5. Perspectives are transparent to one another, because they are facts.
6. There is nothing wrong with circularity.
7. What we cannot have information about, we must pass over in silence.



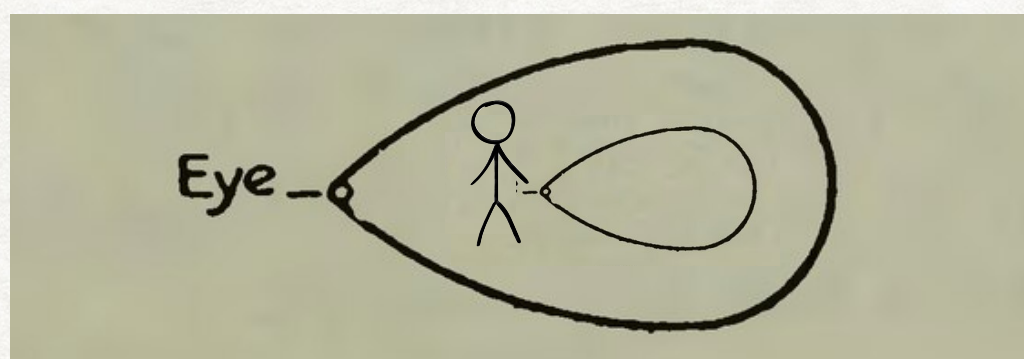
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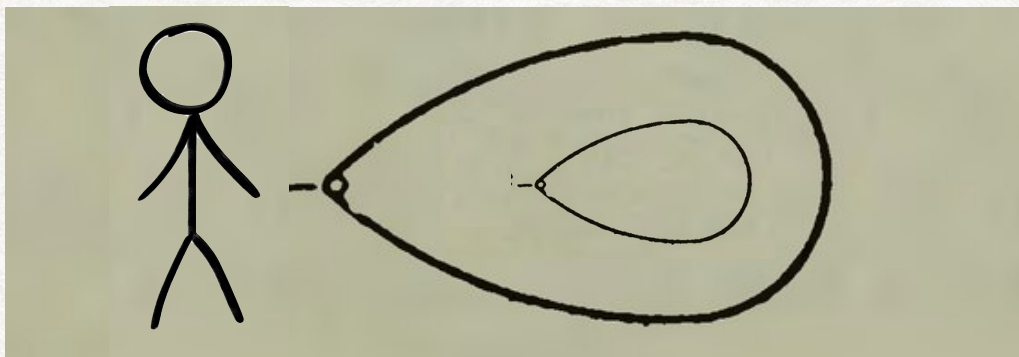
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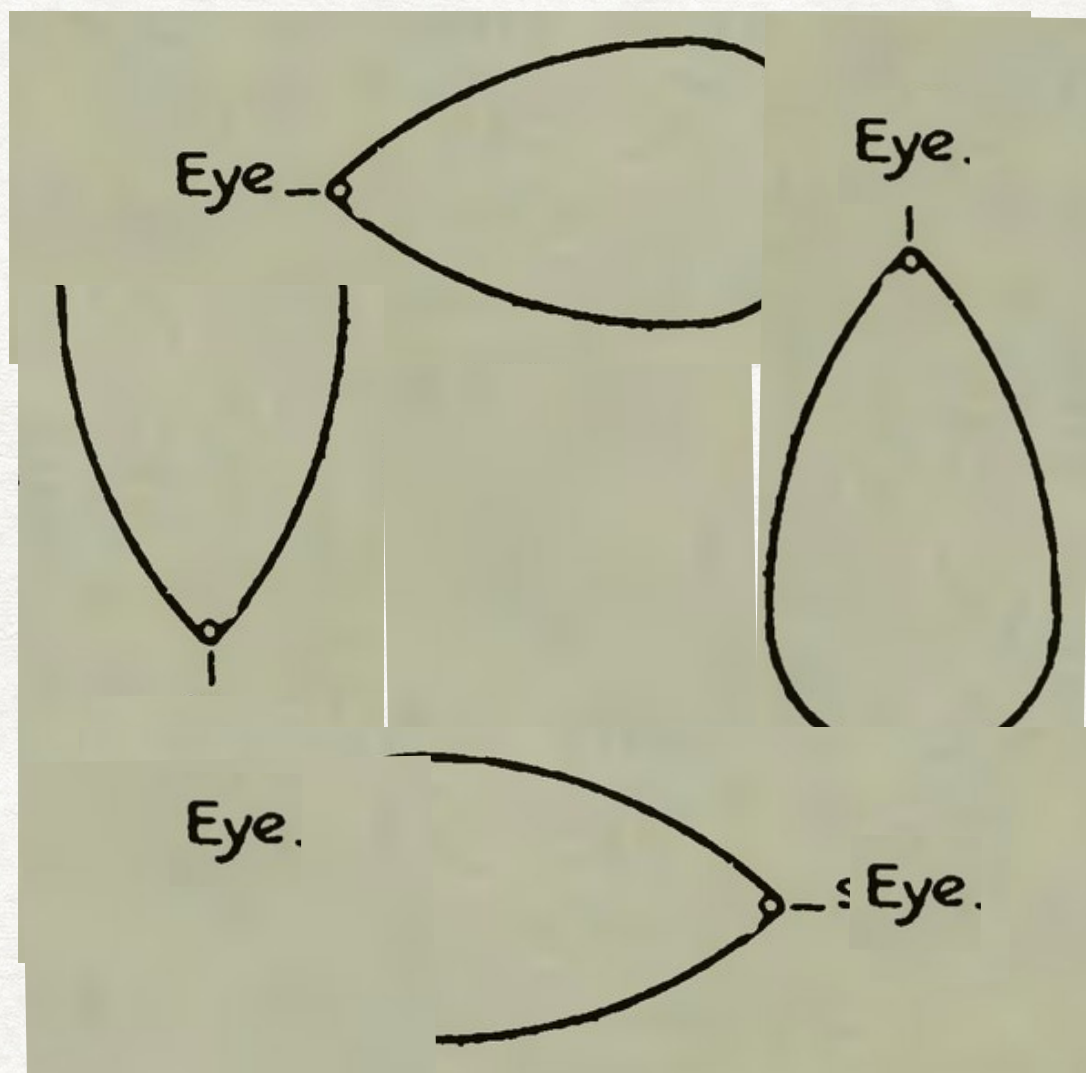
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$$[P, Q] = -i\hbar$$

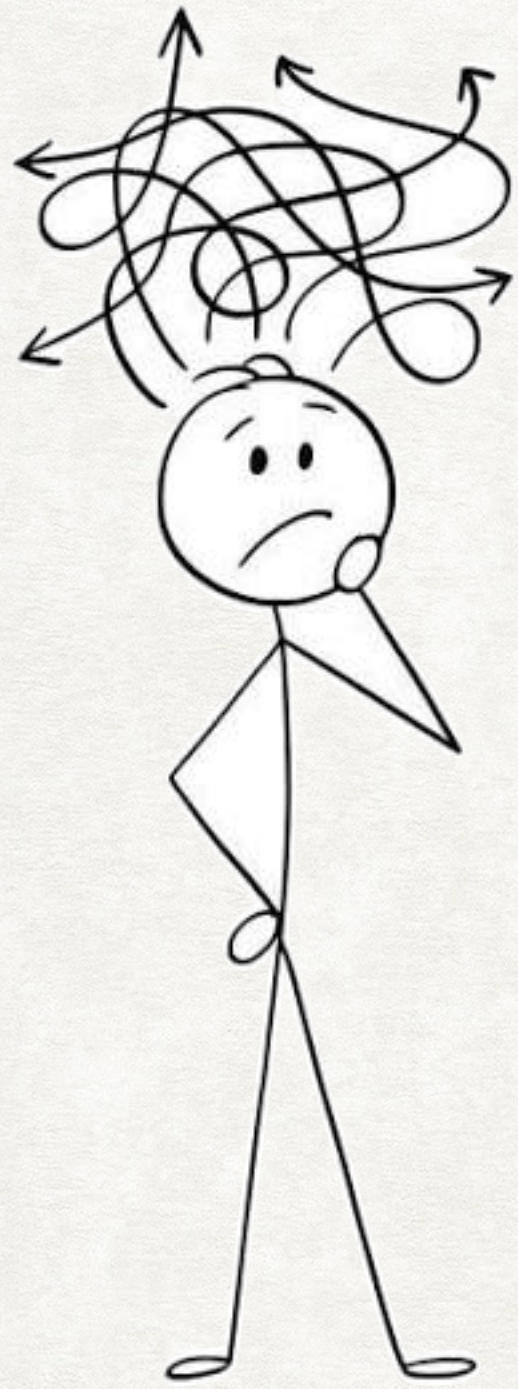
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But what is
REALLY
happening??

Is a question without meaning

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Facts and relative facts in quantum physics

$$\rho, \quad A = a?$$

$$p(a) = \text{tr}[\Pi_a \rho]$$

$$A=a \text{ is a fact iff } p(a) = 1$$

$$p(a, b) = \text{tr}[\Pi_a \Pi_b \rho]$$

$$A=a \text{ is a fact relative to the B observable having the value b iff } p(a|b) \equiv \frac{p(a, b)}{p(b)} = 1$$

It can be shown that the “relative information about B of A”

$$I_{A|B} = \log N_A + \sum_{ab} p(a, b) \log(a|b)$$

Is the expectation value of the increase of information about A that we obtain measuring B.

If we have information about A, another person could learn its value by asking us about it.

There is no disembodied intelligence or supernatural knowledge: information is physical, it is stored in physical variables and their correlations and can therefore be accessed by other systems.

So, whenever we talk about information about some variable or system, it should be understood that we are invariably, although implicitly, talking about information about that variable relative to some other system—generally us.

According to our definitions, then, a fact is always a fact relative to something.

Every fact is a relative fact.

We are a physical system having information.

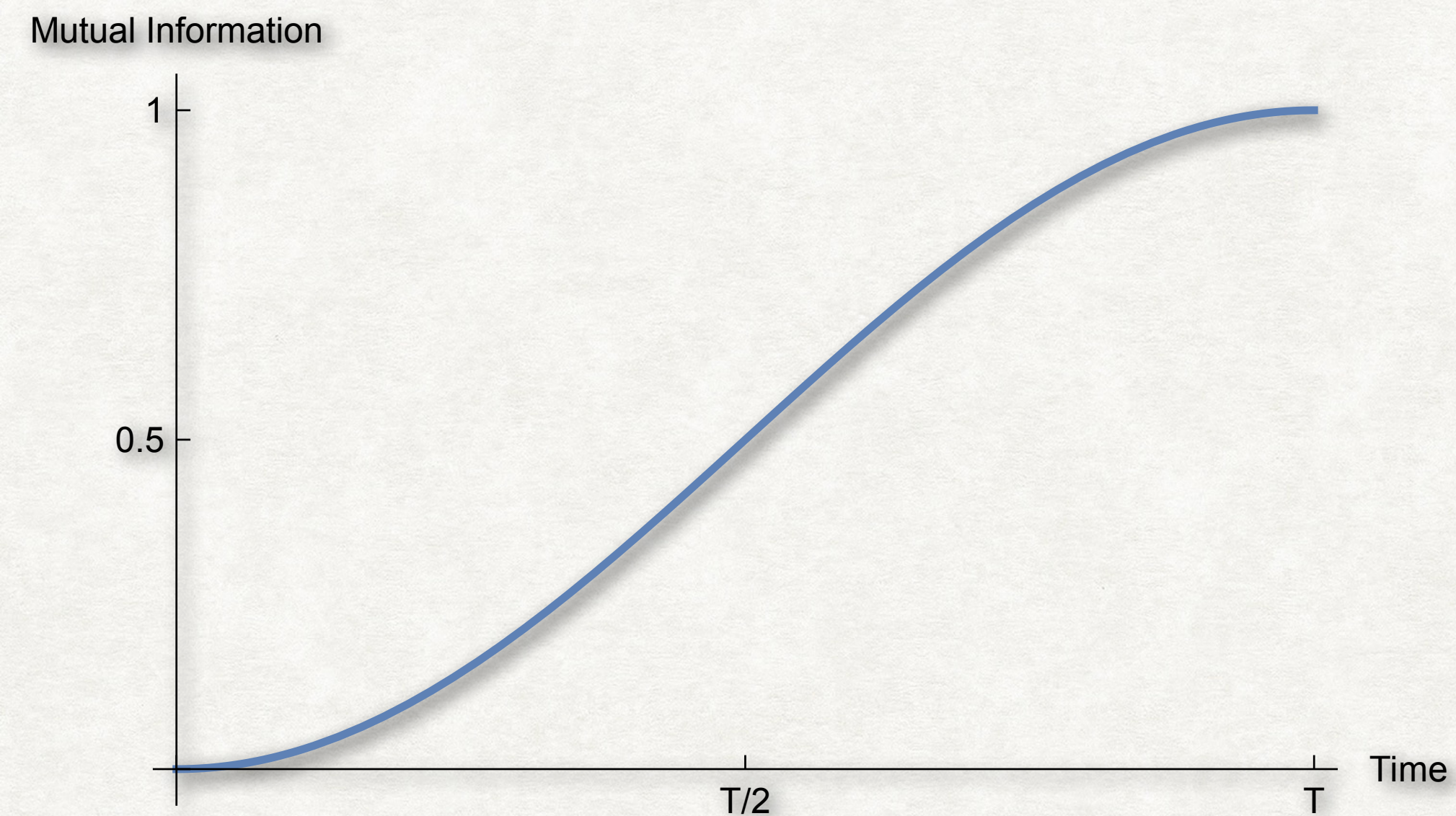
Quantum theory is a theory on the information that physical variables have about one another, including the information that we have about the world.

Every quantum state is a relative state: it summarizes what is and isn't the case with respect to some system, normally us.

While the system is isolated, its state evolves unitarily according to the Schrödinger equation. When we interact with a system, we obtain information about its variables and the state relative to us therefore the state changes in accordance.

The state update upon measurement is not supernatural and can be described, relative to another system, as a continuous process of variables getting correlated.

Measurement is continuous process. The discontinuity is given by the threshold chosen for facts for facts.



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