IARD 2020

Observers and observations in physics theories

Is a finite `theory of everything' possible ?

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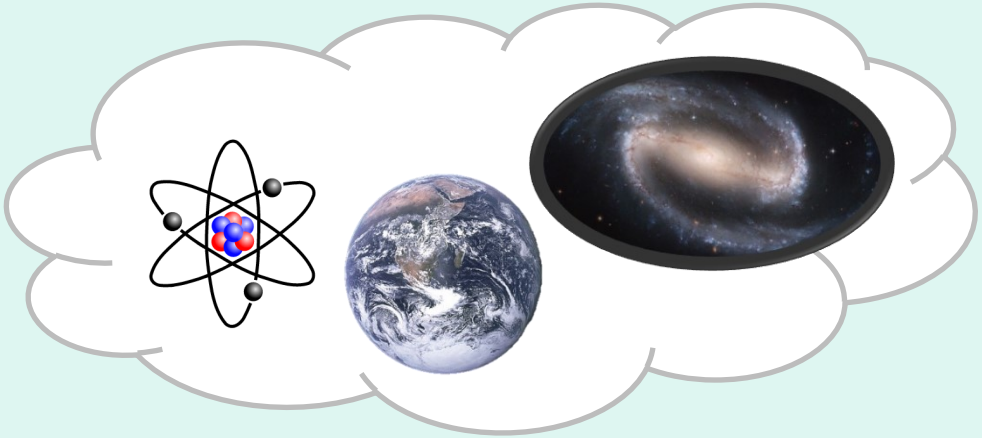
Observers and observations in physics theories

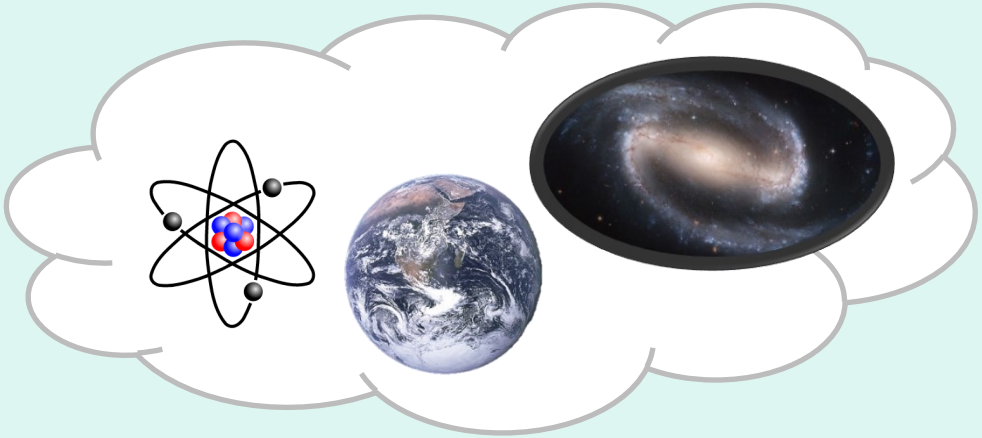


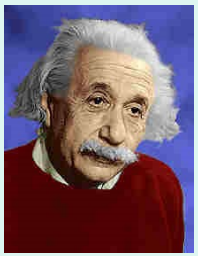
Ultimate universal theory – theory of everything

encompassing the full extent of the universe with a finite number of first principles and inference rules

– finite, deterministic, complete

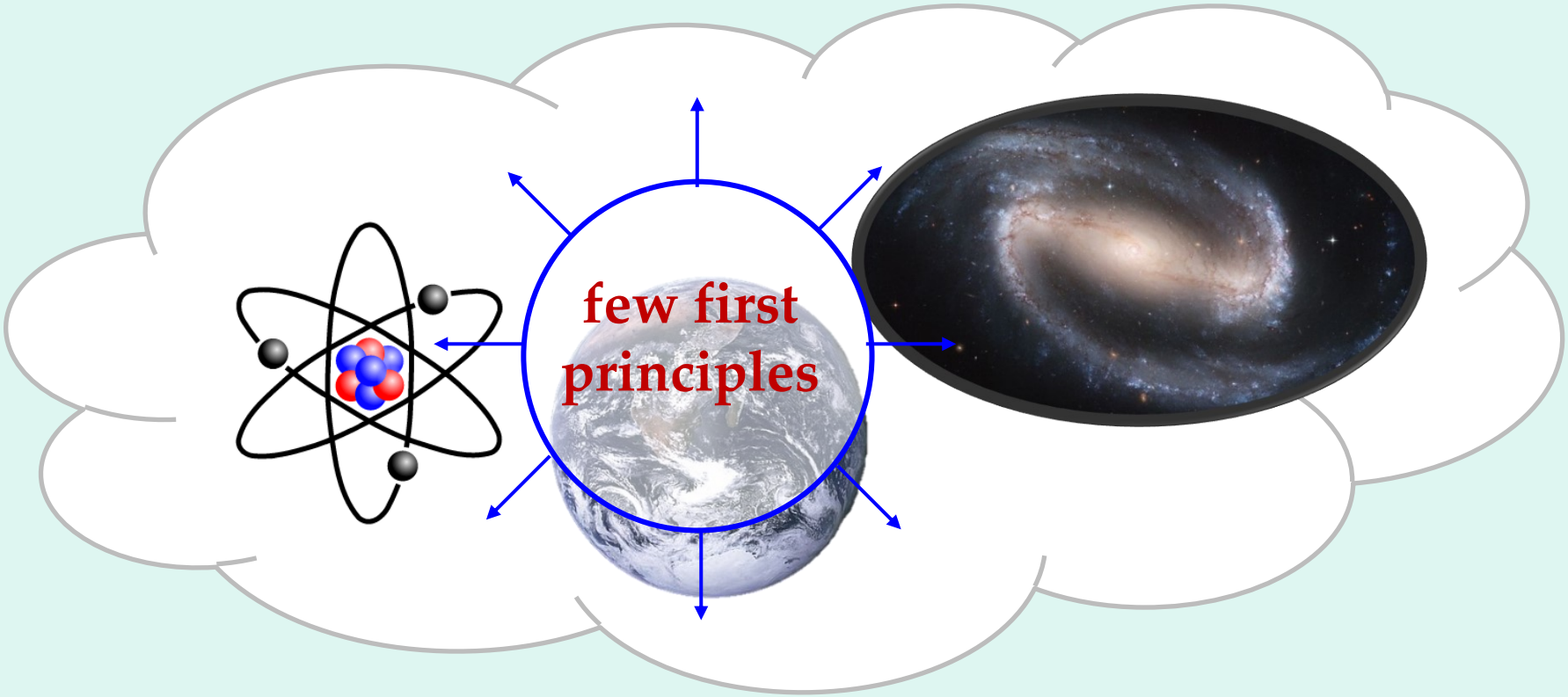
Observers and observations in physics theories





It is the grand object of all theory to make these irreducible elements as simple and as few in number as possible, without having to renounce the adequate representation of any empirical content whatever.

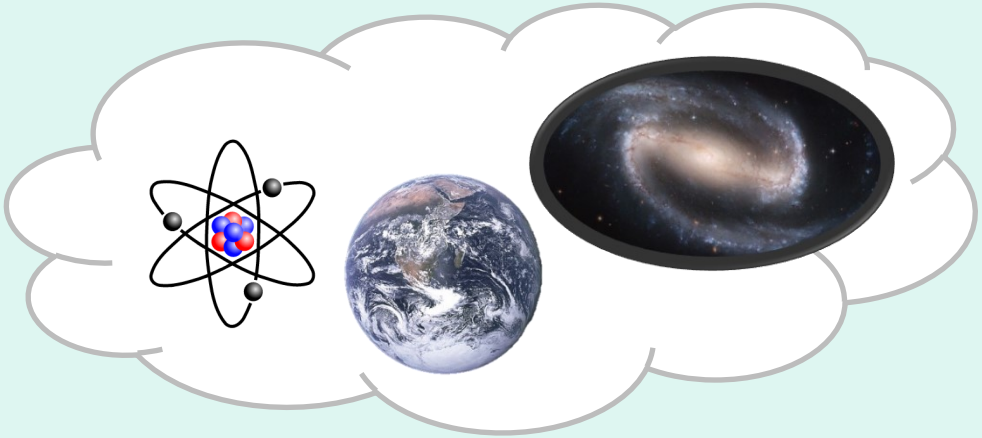
Observers and observations in physics theories



The vision : Few first principles can describe and explain the whole physical world and all that is attached to it, past present and future

?

Observers and observations in physics theories



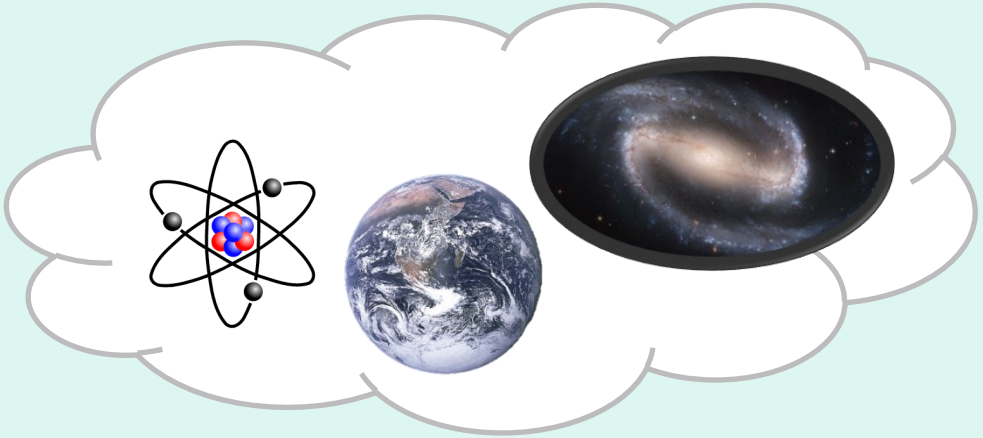
Is the physics that we know today all that there is to know ?

Can we ever be sure that essentially new phenomena will never be observed any more ?

We certainly can't. History tells the opposite ..

Yet the vision is very strong ..

Observers and observations in physics theories

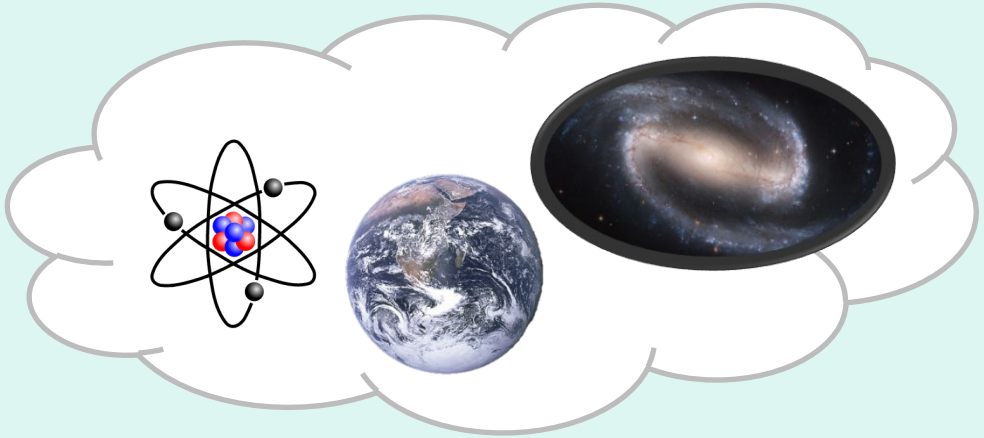


Can we predict, at least speculate into the future, regarding the next phase of physics ?

.. get a glimpse into what is currently beyond the horizon ?

Can we get hints from what is already known ?

Observers and observations in physics theories



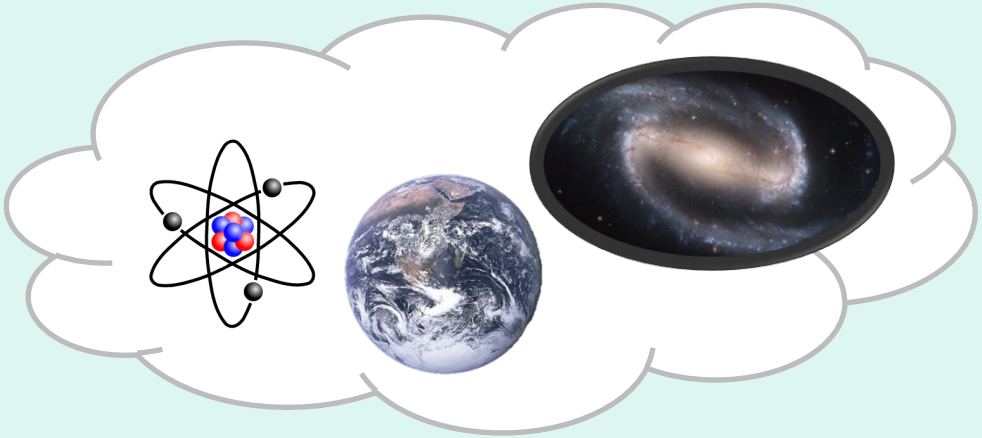
Gödel's incompleteness theorem

Any formal structure, based on a finite number of first principles and inference rules, which is rich enough,

cannot be at the same time both consistent and complete

there will always be propositions that may be formulated within this formal system but are undecidable

Observers and observations in physics theories



Does Gödel's theorem apply to physics?

Observers and observations in physics theories

Universal physics theories

Consistency and completeness, both logically and physically

- **Logical consistency**

  the theory does not produce conflicting predictions.
- **Physical consistency**

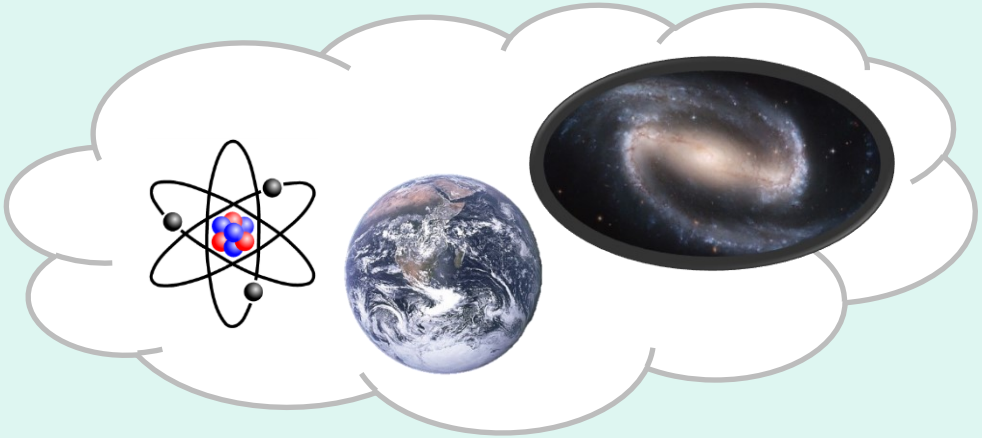
  no predictions that contradict physical observations.
- **Logical completeness**

  all propositions can be uniquely concluded (are decidable).
- **Physical completeness**

  given initial data, the future can be predicted to any desired accuracy.

Determinism

Observers and observations in physics theories



If Gödel's theorem applies to a physics theory, then :

- **The theory cannot be complete**

  $\Rightarrow$ The theory cannot be deterministic

Observers and observations in physics theories

Does Gödel's theorem apply to physics?

The mathematical argument :

Pro : Gödel's theorem is about mathematics in large. Physics uses math as its language, therefore Gödel's theorem must apply to it

Against : Gödel's theorem is about arithmetics.
There are math branches to which Gödel's theorem does not apply (e.g., geometry, analysis).
These are the types of math that physics uses. Therefore there's no reason that Gödel's theorem must apply to physics.

Observers and observations in physics theories

Gödel's theorem

self-referencing

paradoxical self-negation

- **The liar paradox**
- **Russel's paradox**
- **The barber paradox**
- **…**

$\mathcal{G}$ ≡ **$\mathcal{G}$ is not decidable**

Self-reference ⇒
⇒ self-negation ⇒
⇒ undecidability ⇒
⇒ incompleteness

Observers and observations in physics theories

Does Gödel's theorem apply to physics?

Self-reference ⇒

⇒ self-negation ⇒

⇒ undecidability ⇒

⇒ incompleteness

?

Is there self-reference in physics?

Does it lead to incompleteness?

Observers and observations in physics theories

Referencing and self-referencing in physics

1. Observation = referencing in physics

In an act of observation the observer refers to the observed phenomenon

2. Observation = an observable phenomenon

Any observation is an act, is a phenomenon, therefore it is observable

3. Self-observation ⇔ self-referencing

Observers and observations in physics theories

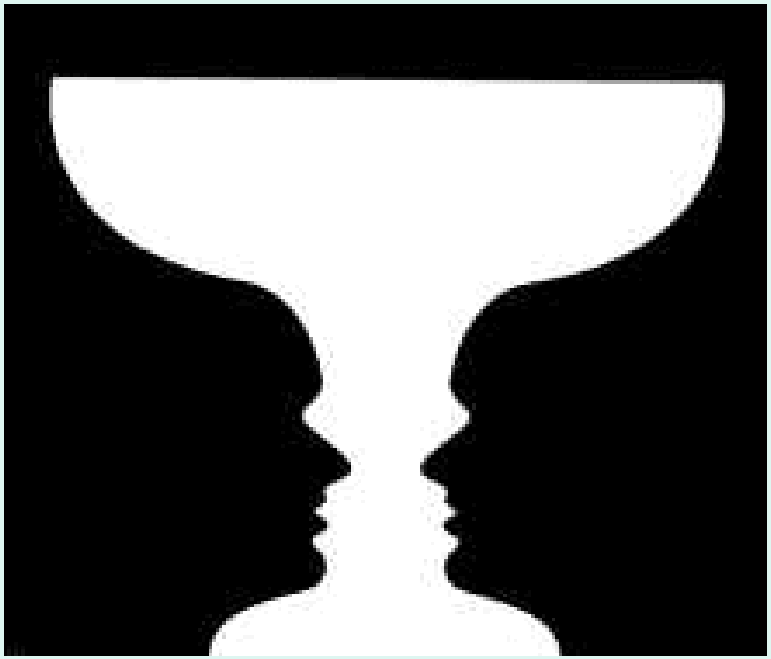
Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations

We can observe how we observe

We can have two different observations: The difference is in the way we focus our attention



Rubin's vase

Observers and observations in physics theories

Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations

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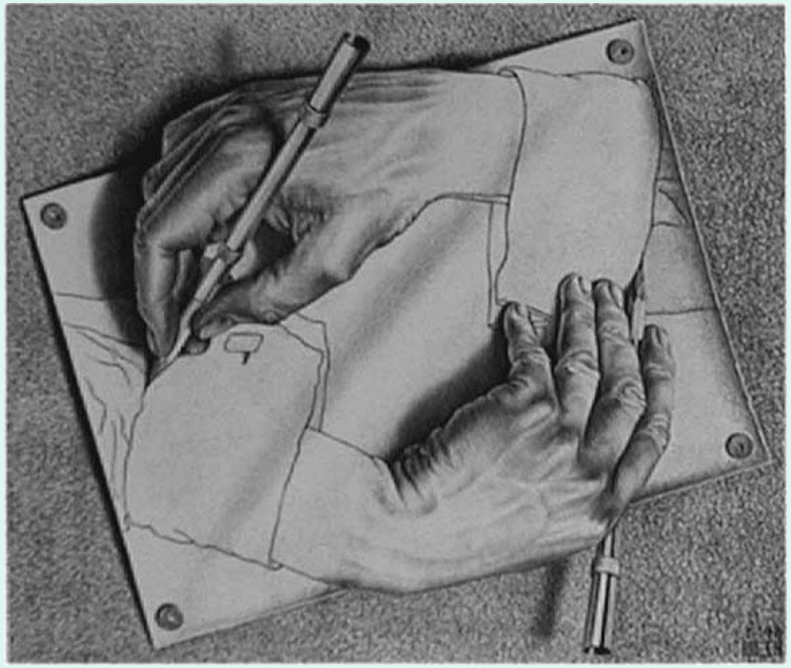


Drawing Hands
M C Escher

Observers and observations in physics theories

Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations

We interpret the world according to the results of our observations

We may observe and interpret the same phenomenon in different modes :

Cup/faces

Wave/particle

Right hand/left hand

Separation/entanglement

…

Observers and observations in physics theories

Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations

We interpret the world according to the results of our observations

We may observe and interpret the same phenomenon in different modes ..

.. and we may observe ourselves making these observations and interpretations

Observers and observations in physics theories

Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations

In an experiment, by choosing the mode of observation, we may change the outcome of the experiment

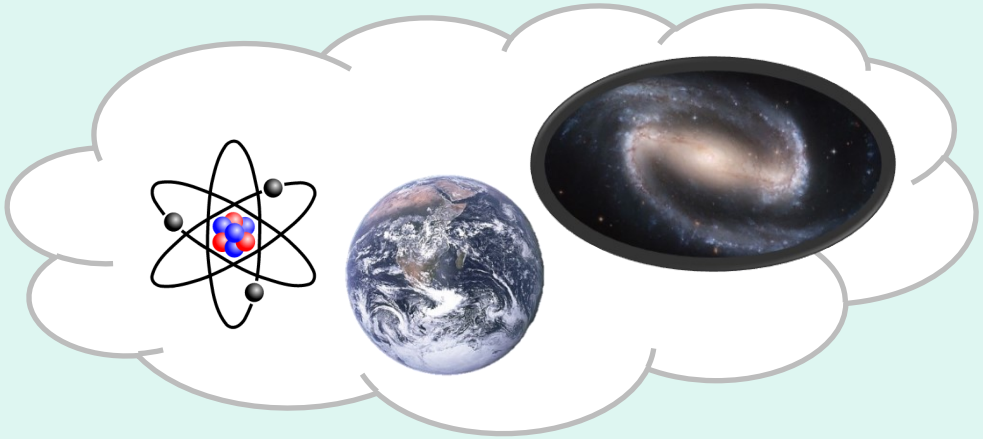
In both drawings :

The experiment = what do we see?

Therefore, the act of observation should be considered as an active part of physical processes

Observers and observations in physics theories

Referencing and self-referencing in physics



Wigner, Wheeler, .. :

Observers are active participants in the physical happening

(Quantum physics)

Observers and observations in physics theories

Referencing and self-referencing in physics

A universal point of view, beyond quantum physics :

Physics is our (human) interpretation of what we observe in the universe

We (humans) are part of the universe, therefore we are both observers and observed

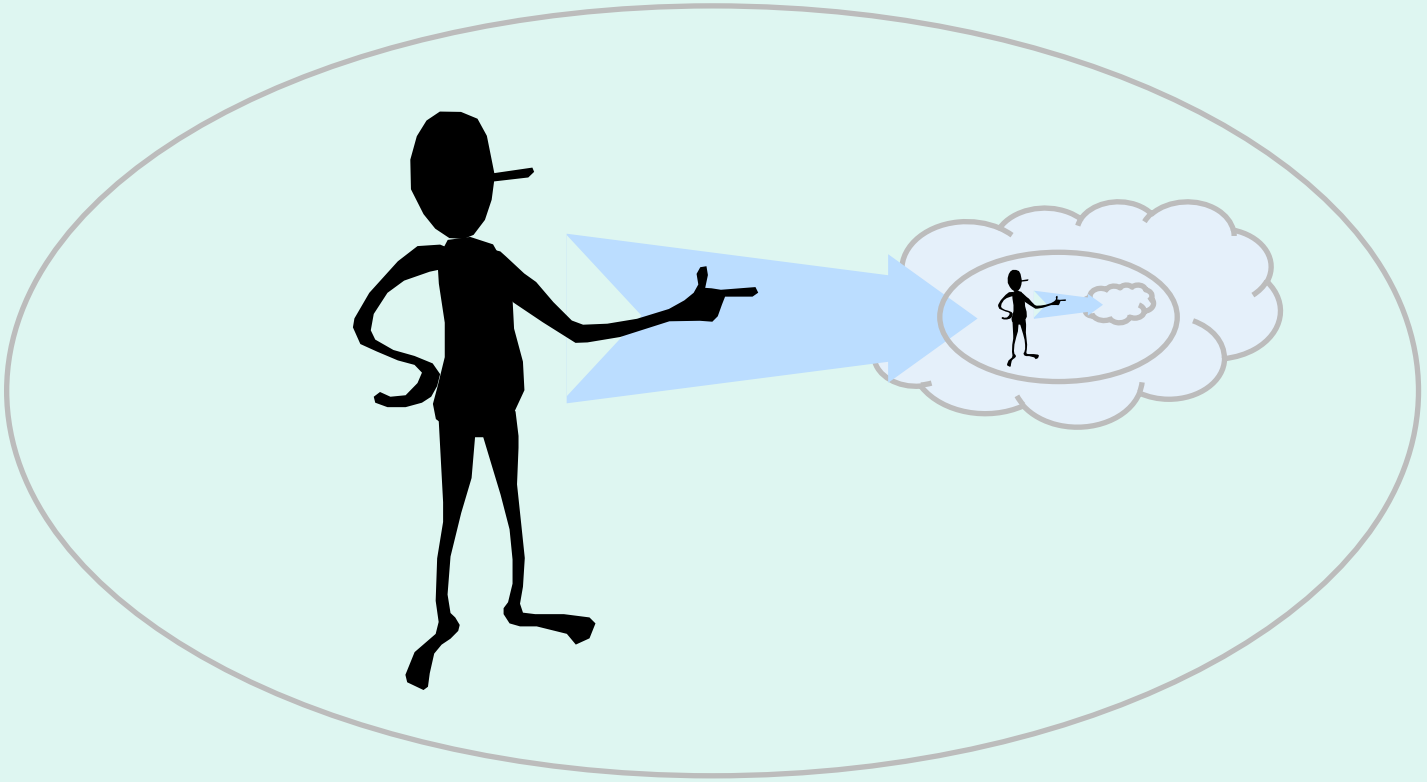
Therefore, our observations should also be considered part of the subject-matter of physics theories

Observers and observations in physics theories

Referencing and self-referencing in physics

Observation = an observable phenomenon

Observations and self-observations



Observers and observations in physics theories

Can physics be complete ?

3rd order observation
Observing 2nd order observations

2nd order observation
Observing 1st order observations

1st order observation
Observing physical phenomena

Observers and observations in physics theories

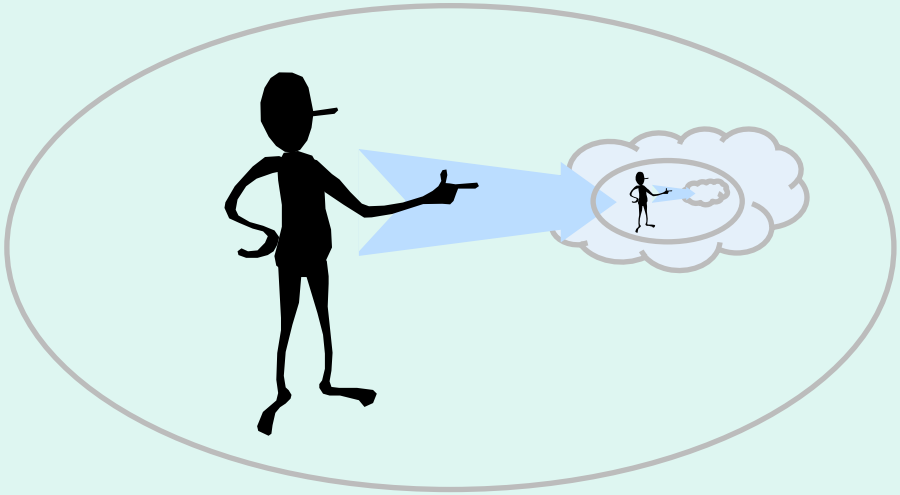
Can physics be complete ?

A hierarchy of observations

3rd order observation

2nd order observation

1st order observation



Levels of observations ⇒ levels of interpretations

Each level ⇒ a more profound insight ⇒
⇒ an essentially new discovery

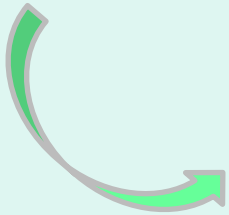
➢ *An endless hierarchy of levels of interpretation*

Observers and observations in physics theories

Can physics be complete ?

A hierarchy of observations

- *New discoveries imply new first principles in the foundation of the theory.*
- *New insights that are not derivable from old ones will be accumulated.*
- *The scientific research will produce more and more insights, understandings and knowledge, within larger and larger theories.*



A never-ending process!

Observers and observations in physics theories

Can physics be complete ?

Observations ⇔ Hierarchies

A never-ending process :

Jacob's ladder

Observers and observations in physics theories

Can physics be complete ?

Observations ⇔ Hierarchies

Profound, fully deep 3-D view

vs.

Flat, depthless 2-D view

Observers and observations in physics theories

Can physics be complete ?

Some people will be very disappointed if there is not an ultimate theory that can be formulated as a finite number of principles. I used to belong to that camp, but I have changed my mind. I'm now glad that our search for understanding will never come to an end, and that we will always have the challenge of new discovery. Without it, we would stagnate. Gödel's theorem ensured there would always be a job for .. physicists.

S.W. Hawking

S. W. Hawking, *Gödel and the end of the Universe*. (2002)
http://www.hawking.org.uk/Godel-and-the-end-of-physics.html

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Thank You

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