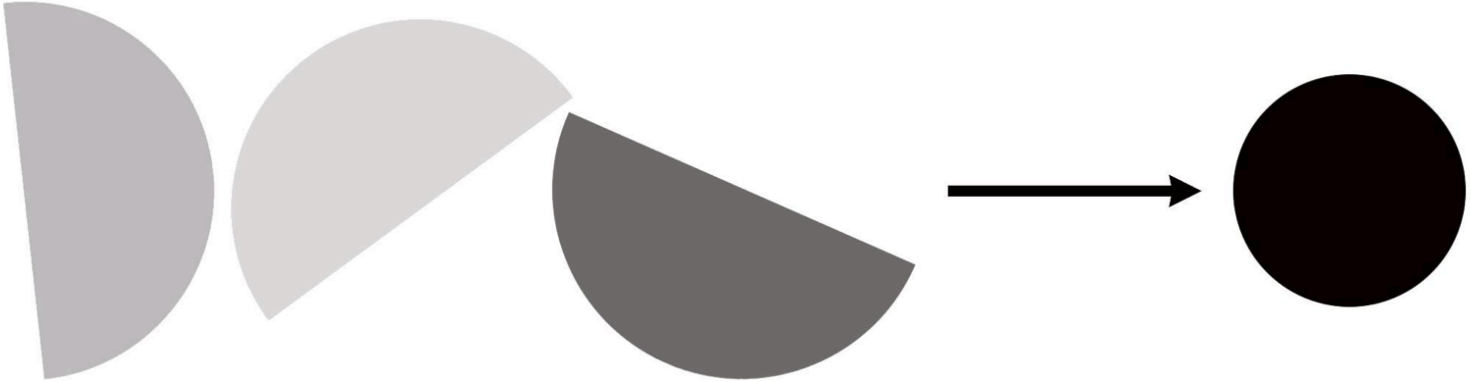
Unification, Evaluation and Development of Theories



Avril Styrman

Unification in Physics and Philosophy May 11th 2019 Helsinki

Contents

Structure of Theories

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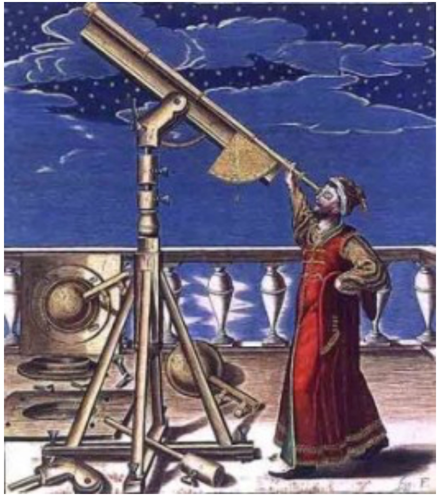
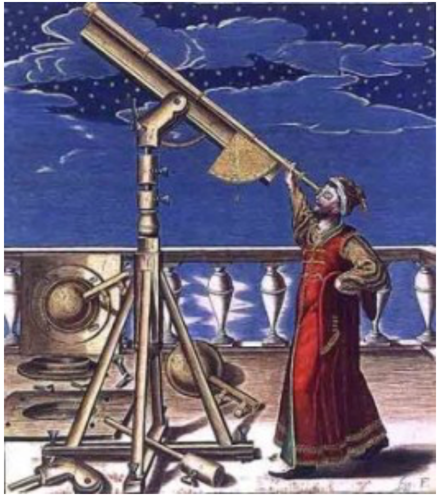
- Perception yields verified commitments (beliefs) in the existence e.g. particles and planets, and their movement



Structure of Theories

- Perception yields verified commitments (beliefs) in the existence e.g. particles and planets, and their movement
- Metaphysical commitments function as the basis of explaining verified commitments, but are themselves unverified



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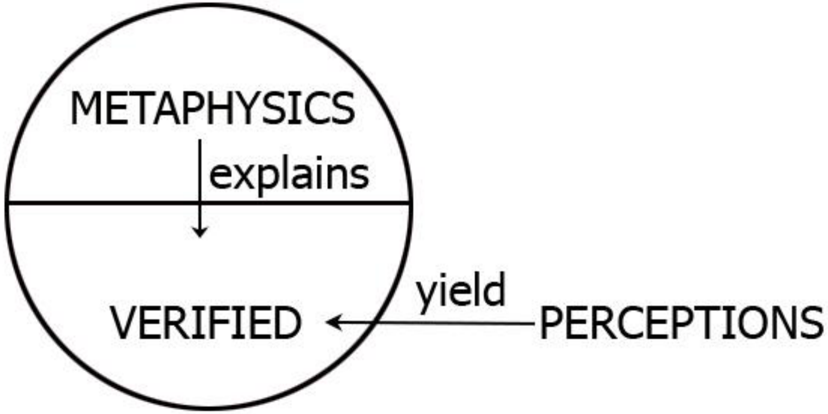
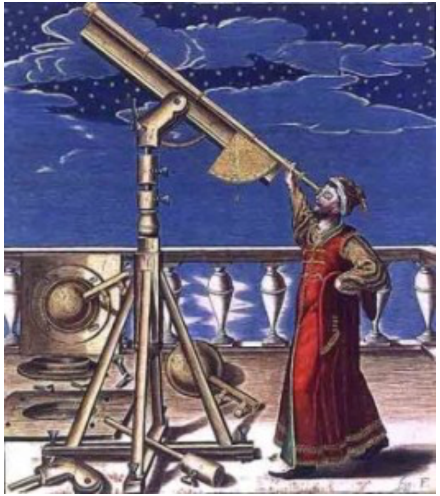
ONTOLOGY: **what exists according to a theory**





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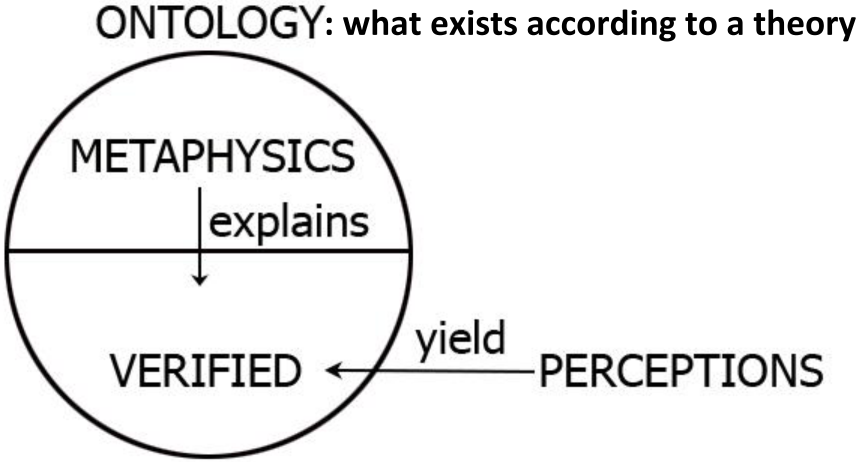
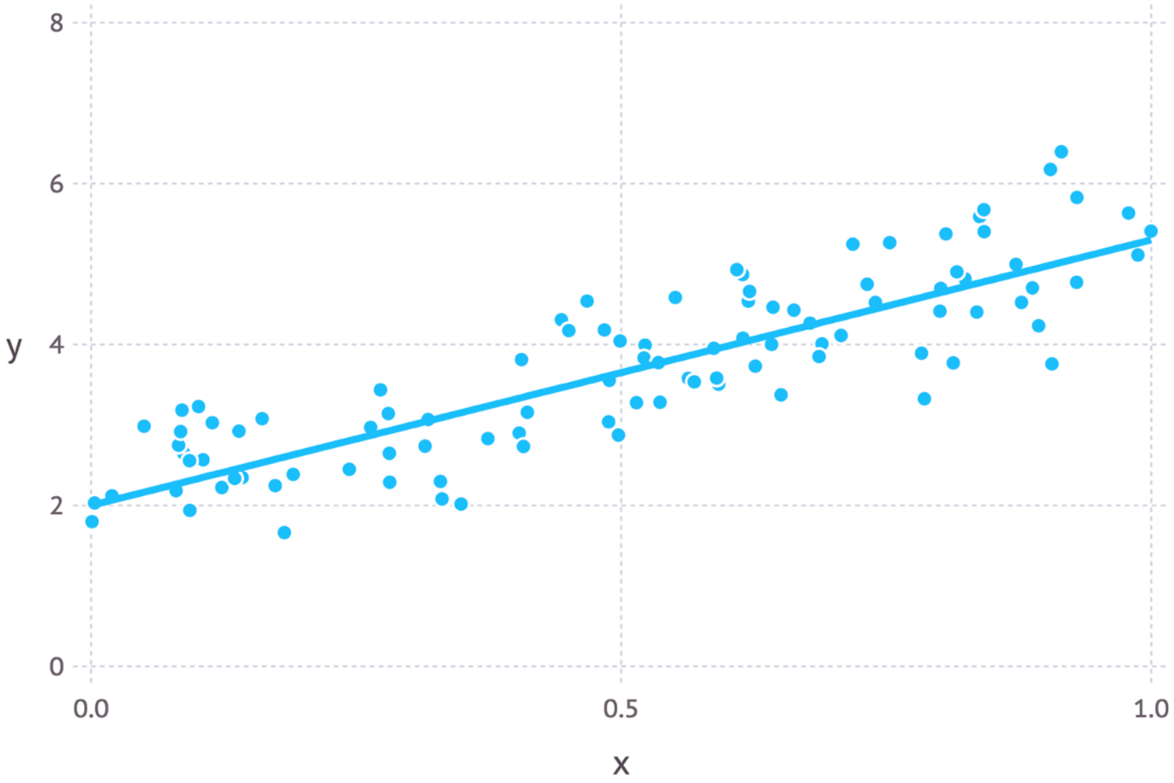


Everything posited by hypothesis is metaphysical: hypotheses of universal laws, unobservables, brute facts, primitives, axioms, unexplained explainers, hypothetical entities and principles

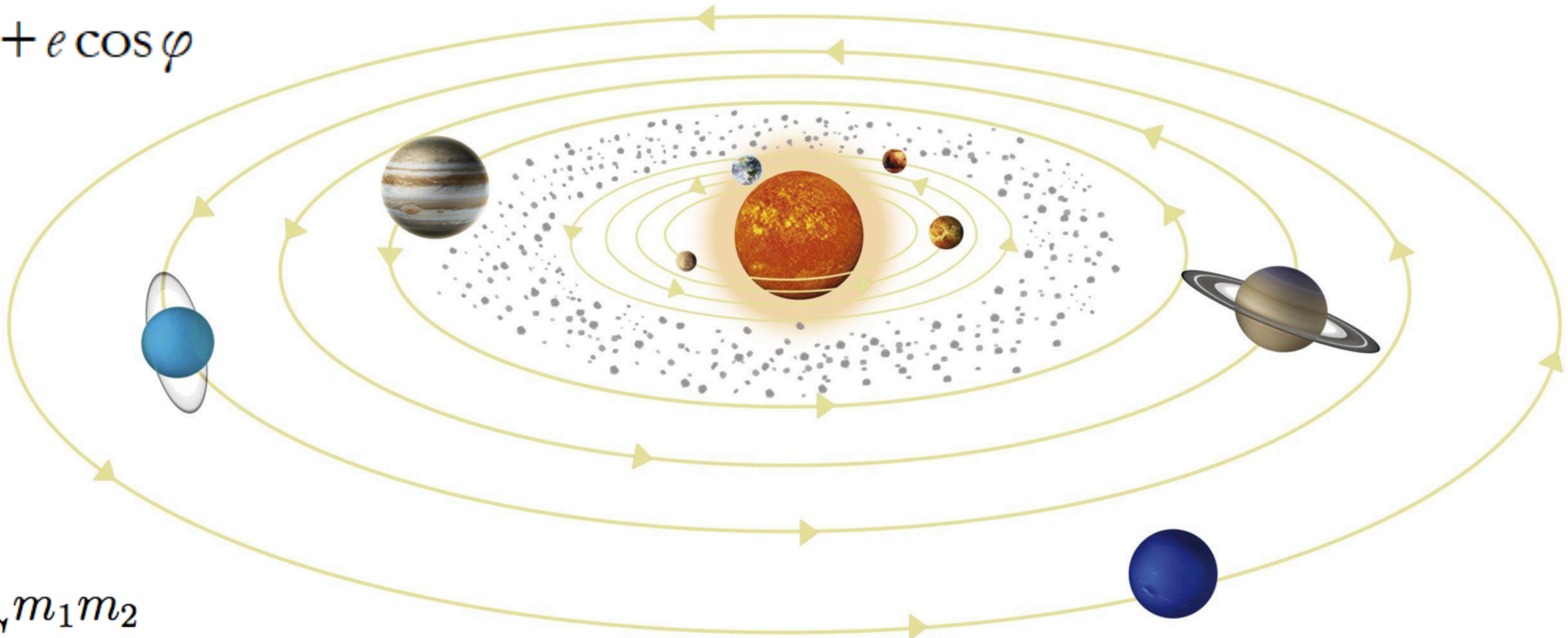
Structure of Theories

1. Observations
2. Regularities
3. Laws



Structure of Theories

$$r = \frac{a\left(1-e^2\right)}{1+e\cos\varphi}$$



$$F = G\frac{m_1 m_2}{r^2}$$

Evaluation of Theories

Evaluation of Theories

- Evaluation of competing theories is about assessing the fitness of their predictions and explanations about the same phenomena, empirical data, perceptions, or verified commitments

Evaluation of Theories

- Of two theories that predict and explain the same phenomena, the most virtuous is the best

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- What are the virtues and how can they be measured?

Evaluation of Theories

- Of two theories that predict and explain the same phenomena, the most virtuous is the best
- What are the virtues and how can they be measured?
  - Evidential: accuracy and depth
  - Unifying power: evidentiality/simplicity
  - Diachronic: development of unifying power over time

Evidentiality

- Can be measured by comparing a theory to empirical evidence

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- Accuracy of predictions and causal depth of explanations

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- Accuracy of predictions and causal depth of explanations

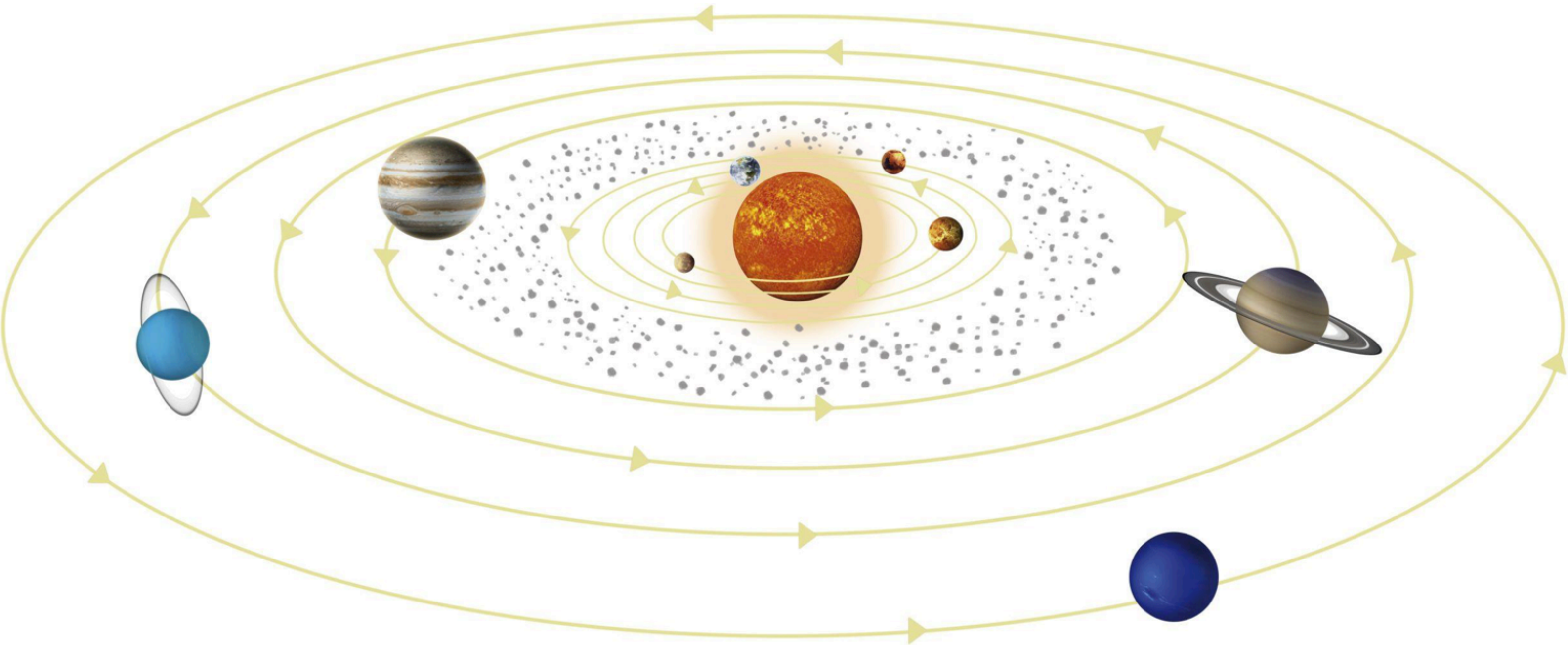
While in the case of an explanation, the final event is known to have happened, and its determining conditions have to be sought, the situation is reversed in the case of prediction: here, the initial conditions are given, and their "effect"—which in the typical case, has not yet taken place—is to be determined.

Carl Hempel. Aspects of Scientific Explanation, p. 234. New York: Free Press, 1965.

Evidentiality

- Can be measured by comparing a theory to empirical evidence
- Accuracy of predictions and causal depth of explanations

Accuracy of predictions



Accuracy of predictions

- Accuracy of predictions is the anchor of theory evaluation
  - Easy to measure
  - Most urgently needed: whenever there is a dire need, it is more important to know how nature behaves than why
  - Other virtues are subjugated to accuracy of predictions

Causal Depth of Explanations

1. Accuracy or the level of detail in which an explanation characterizes phenomena
2. Variability of circumstances where an explanation remains valid
3. Final test: prolificity of accurate predictions

Heather E. Douglas. 76(4):444–463, 2009. Reintroducing prediction to explanation. Philosophy of Science.

Evidentiality is not enough

- The problem of underdetermination: we cannot select between two equally evidential theories based on their evidentiality only; therefore, we must evaluate other virtues too

Unifying Power

- Unifying power, the principle of Economy, parsimony, Ockham’s razor: of equally evidential theories, the simplest is the best

evidentiality/simplicity

E/M

Unifying Power

- A metaphysically simpler theory commits to a smaller number or quantity of hypothetical laws, entities, principles, primitives, brute facts, axioms, unexplained explainers
- A syntactically or mathematically simpler theory has a simpler formulation

evidentiality/simplicity

E/M

Unifying Power

Thomas Aquinas (1225-1274): “If a thing can be done adequately by means of one, it is superfluous to do it by means of several.”
Basic Writings of St. Thomas Aquinas, vol. 2., p. 129. Edited by A.C. Pegis. New York: Random House, 1945.

William of Ockham (1287-1347): “It is vain to do with more what can be done with fewer.”
As quoted in Bertrand Russell, *The History of Western Philosophy,* p. 472. New York: Simon and Schuster, 1945.

Isaac Newton (1642-1727): “We are to admit no more causes of natural things than such as are both true and sufficient.”
Principia, 3rd edition, bk.3

evidentiality/simplicity

E/M

Unifying Power

Eino Kaila (1935): "The smaller … the number of its logically independent basic statements ... in comparison … to the number of different kinds of facts that can be derived from it … the greater is the relative simplicity of the theory."

Eino Kaila. Human Knowledge: A Classic Statement of Logical Empiricism. Translated by Anssi Korhonen. Edited by Juha Manninen, Ilkka Niiniluoto and George A. Reisch, pp. 78-9. Chicago, Illinois: Open Court, 2014.

evidentiality/simplicity

E/M

Unifying Power

Philip Kitcher’s (1981) *unification model*: scientific explaining is about unifying disparate phenomena or a diverse set of facts under a small number of basic principles or patterns.

Explanatory unification. Philosophy of Science , 48:507–531, 1981. Explanatory Unification and the Causal Structure of the World. In Philip Kitcher and Wesley Salmon (eds.) Scientific Explanation, pp. 410-505. Minneapolis: University of Minnesota Press, 1989.

evidentiality/simplicity

E/M

Development of Theories

Development of Theories

Development of unifying power

evidentiality/simplicity

E/M

Development of Theories

Development of unifying power

Unificatory vs. disunificatory development

evidentiality/simplicity

E/M

Development of Theories

Development of unifying power

Unificatory vs. disunificatory development

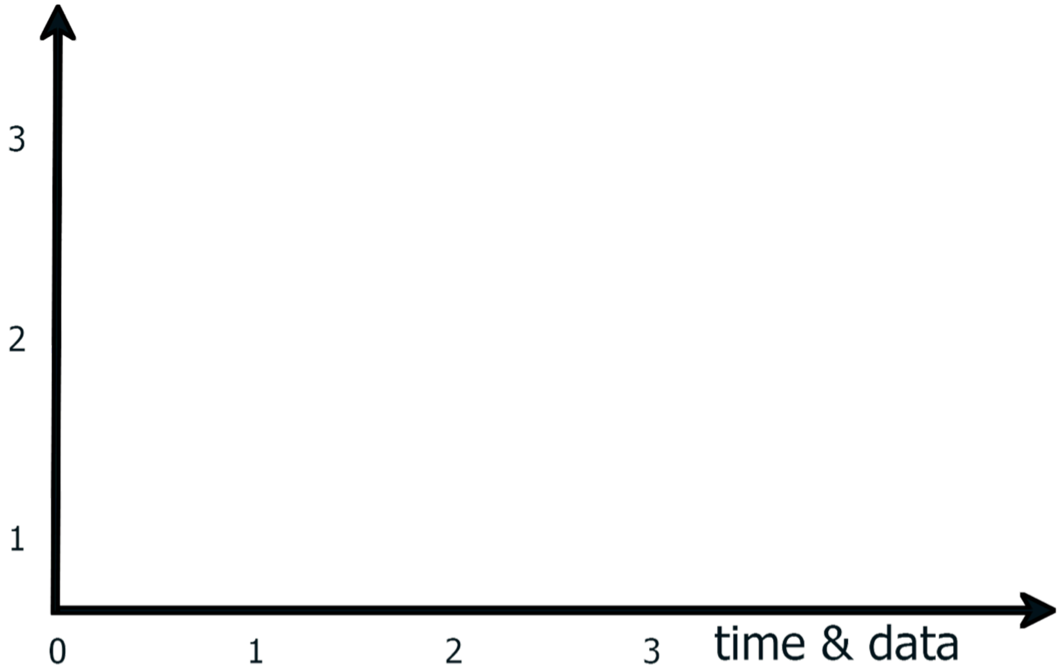
Positive vs. negative development

Success vs. regress

evidentiality/simplicity

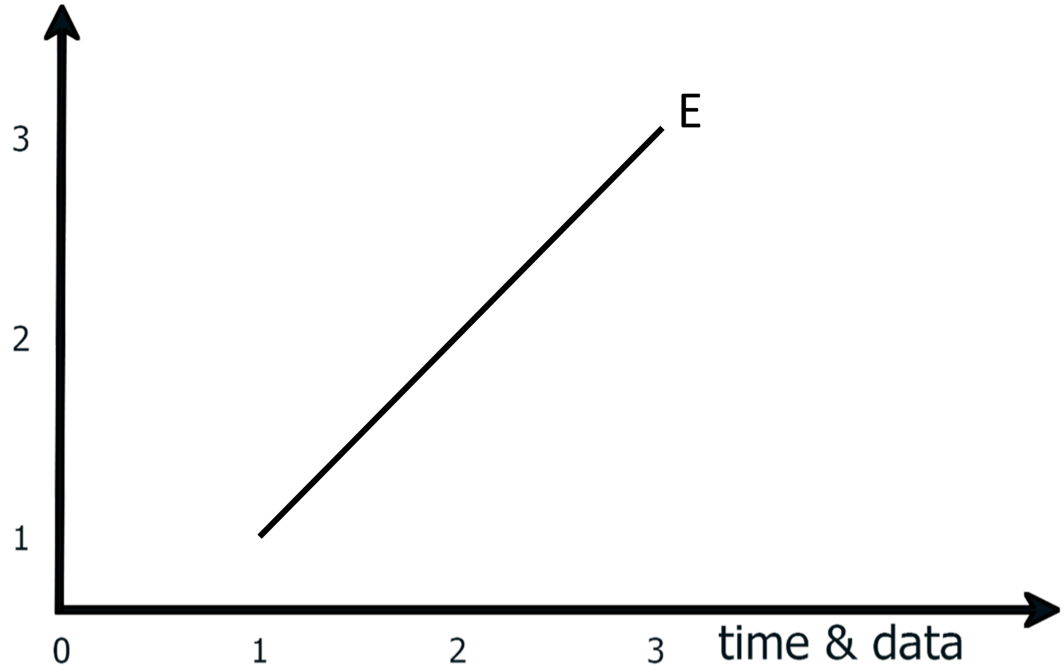
E/M

Development of Theories



time goes forward; the amount of data to be explained grows

Development of Theories



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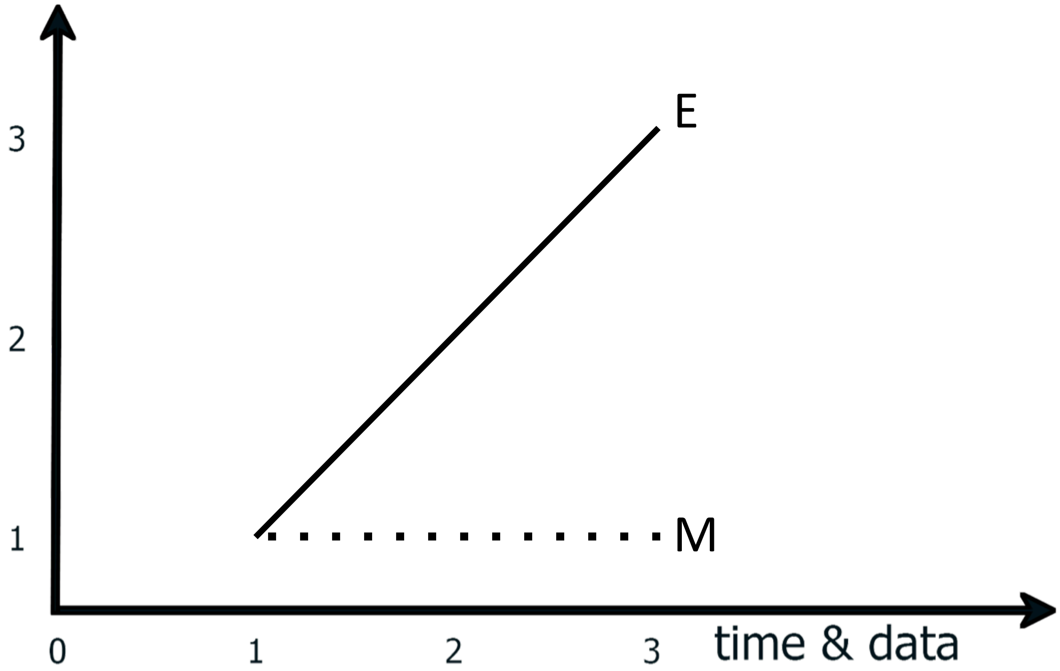

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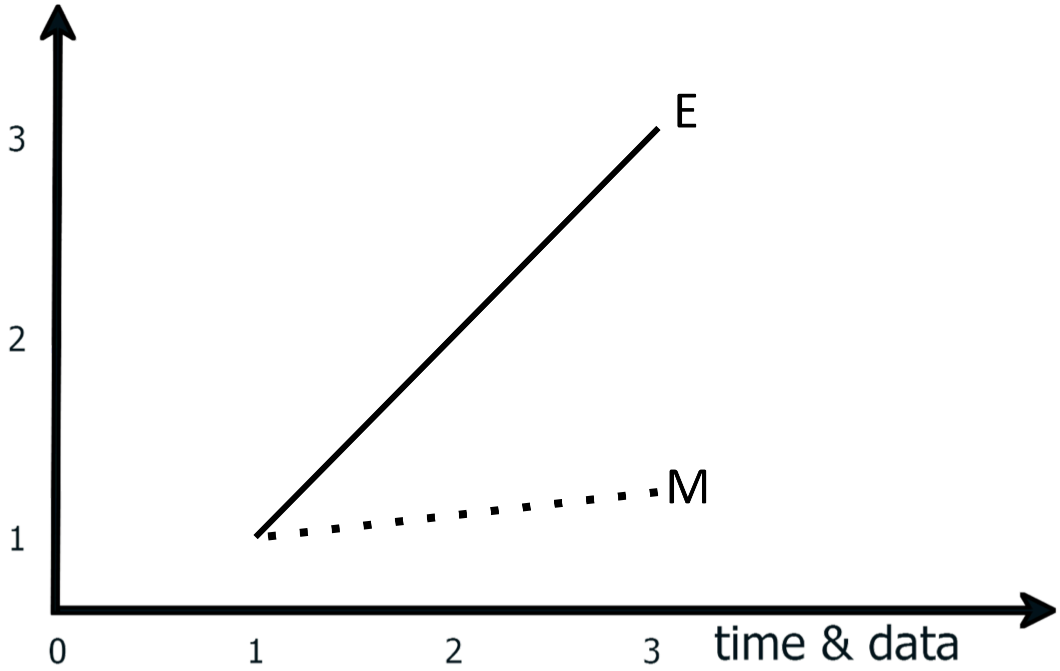

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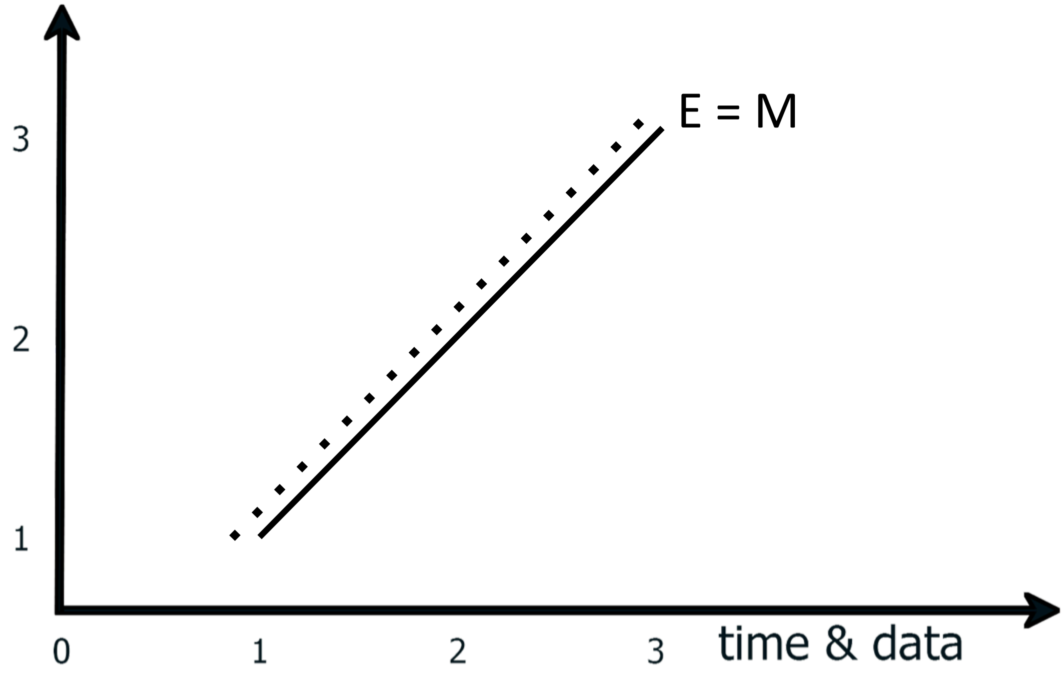

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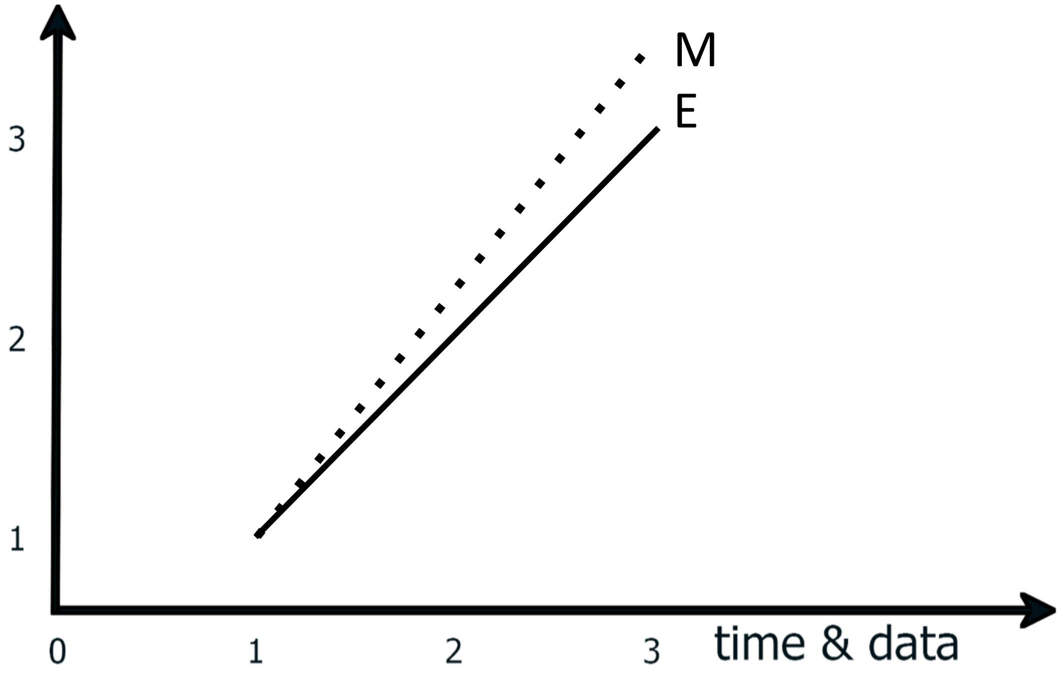

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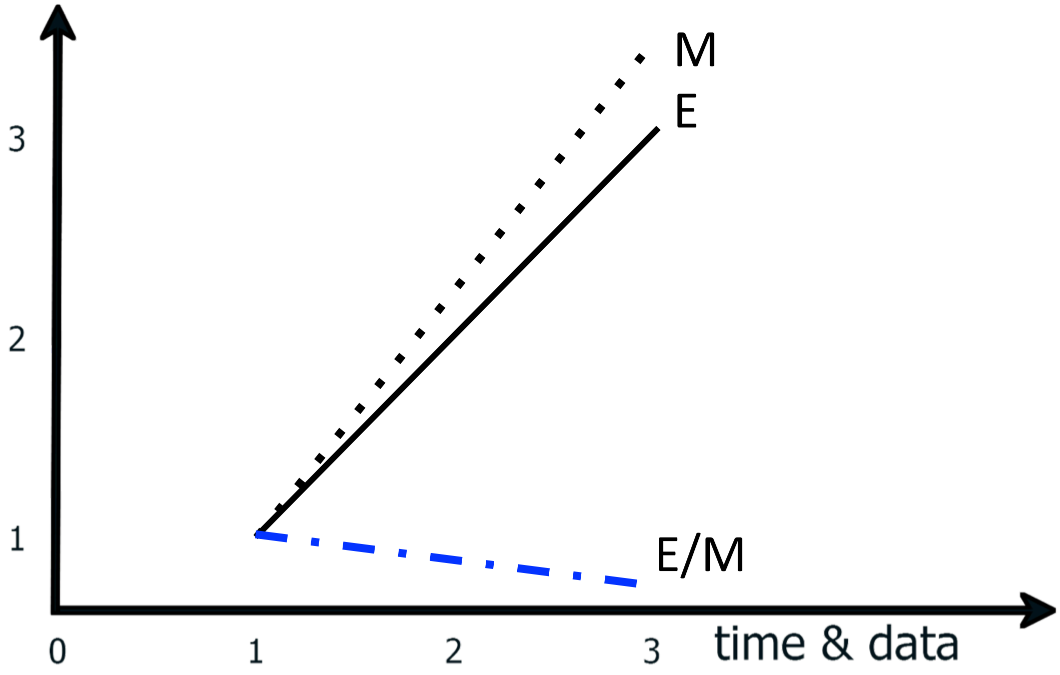

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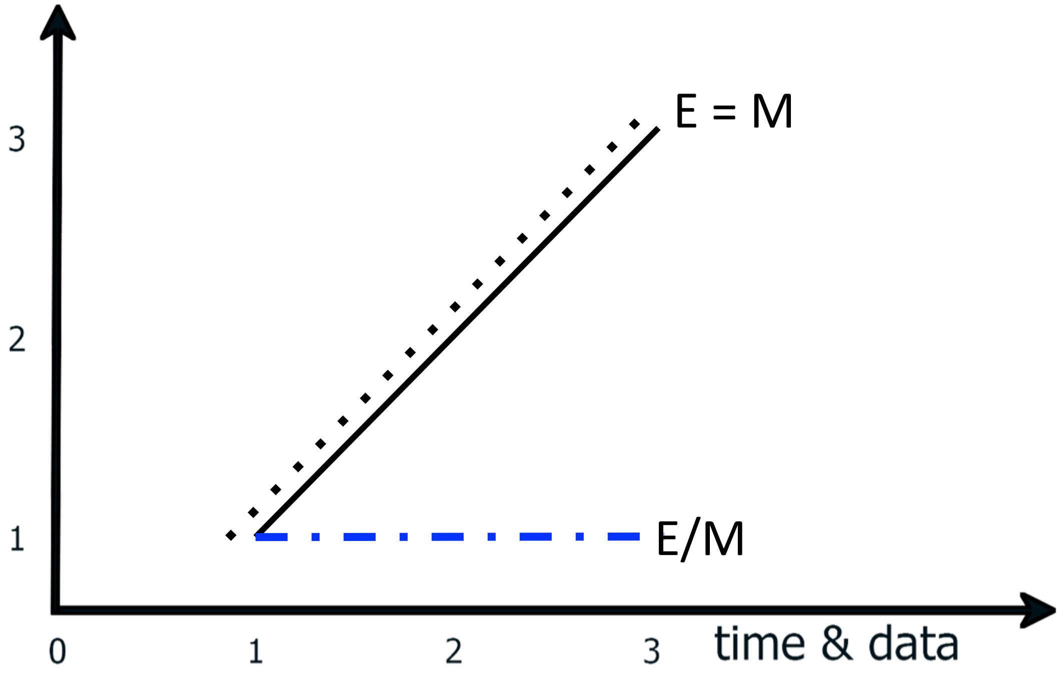

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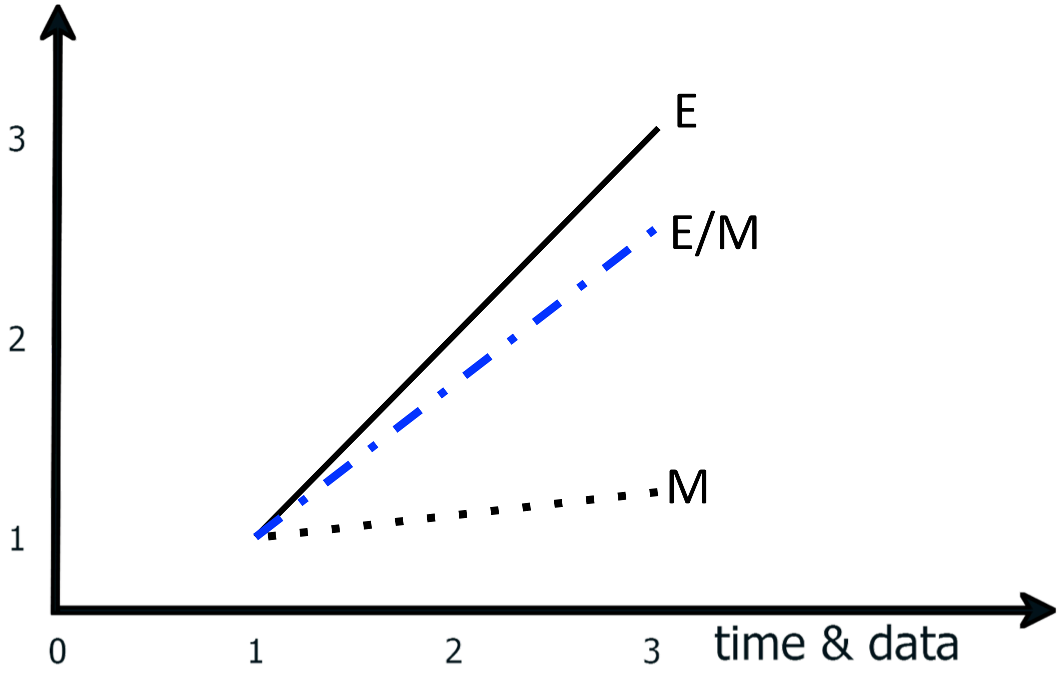

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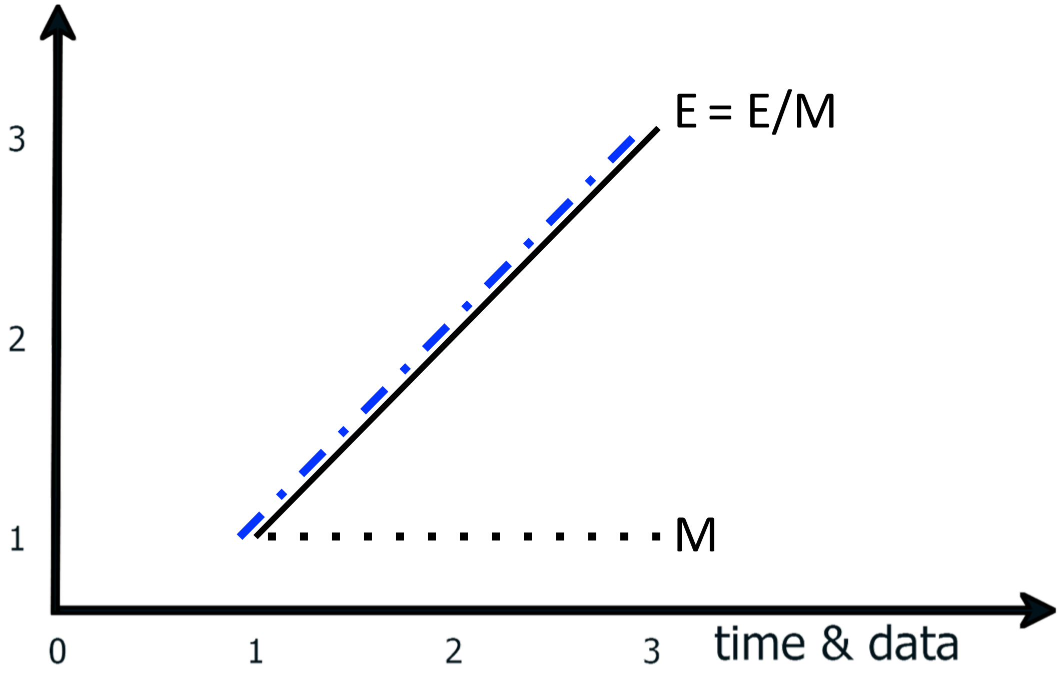

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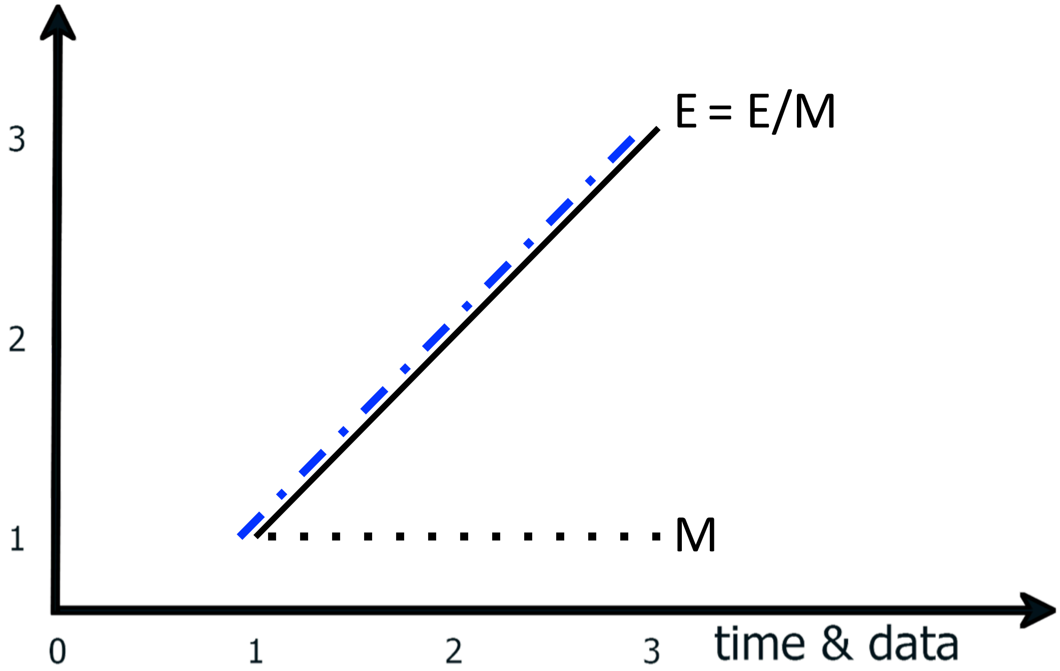
Unificatory Development



-Newtonian mechanics
-Mendeleyev's periodic table of elements

time goes forward; the amount of data to be explained grows; evidentiality grows

Disunificatory Development

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- Parametrisation: when a theory fails to give correct predictions of new data, it can be saved from falsification by accommodating the data by auxiliary parameters

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- Parametrisation: when a theory fails to give correct predictions of new data, it can be saved from falsification by accommodating the data by auxiliary parameters

- When data is accommodated by the aid of additional metaphysics, the reality is so to speak be complemented by hypothetical entities in order to save the theory from falsification

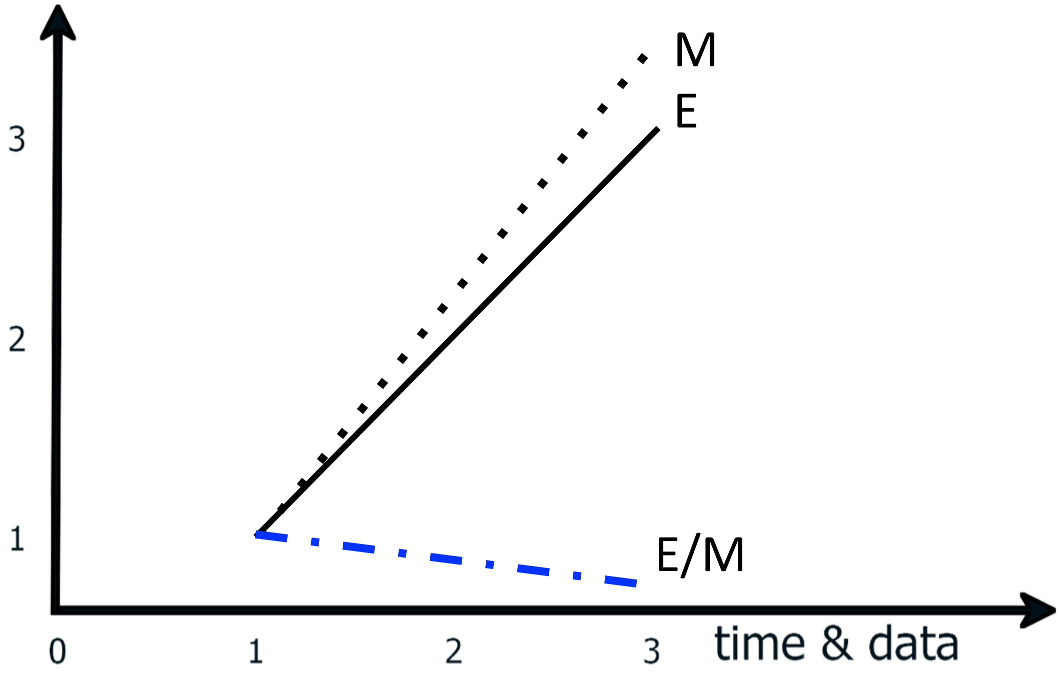
Disunificatory Development

- Parametrisation: when a theory fails to give correct predictions of new data, it can be saved from falsification by accommodating the data by auxiliary parameters

"no conclusive disproof of a theory can ever be produced; for it is always possible to say that the experimental results are not reliable, or that the discrepancies which are asserted to exist between the experimental results and the theory are only apparent and that they will disappear with the advance of our understanding."

Karl Popper. Conjectures and Refutations: The Growth of Scientific Knowledge, p. 50. London: Butler & Tanner Limited, 1963. 4th edition.

Disunificatory Development



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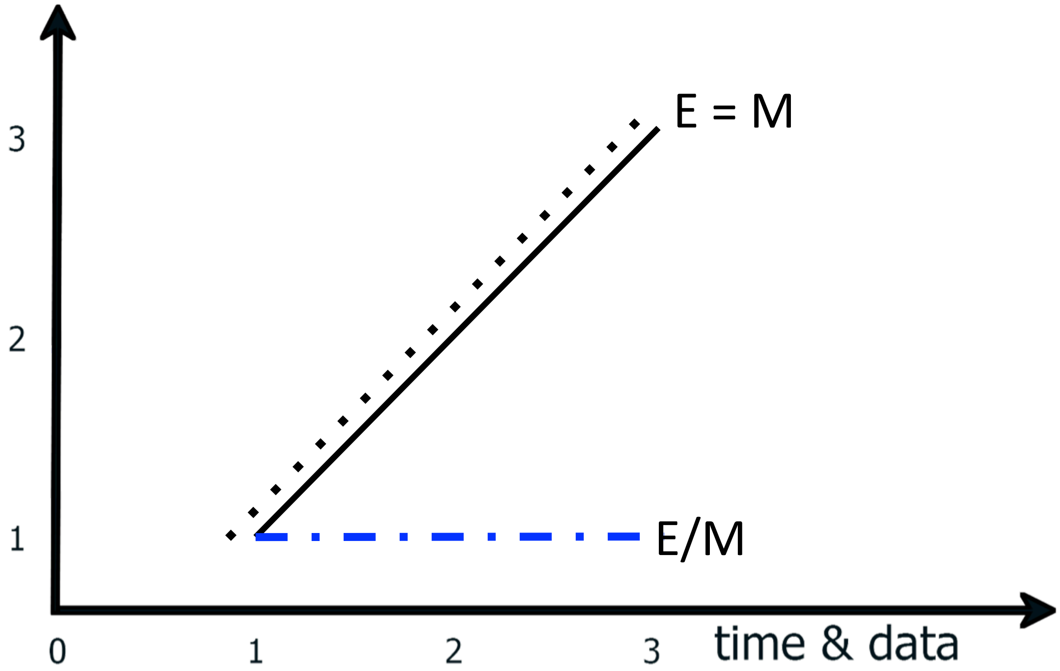

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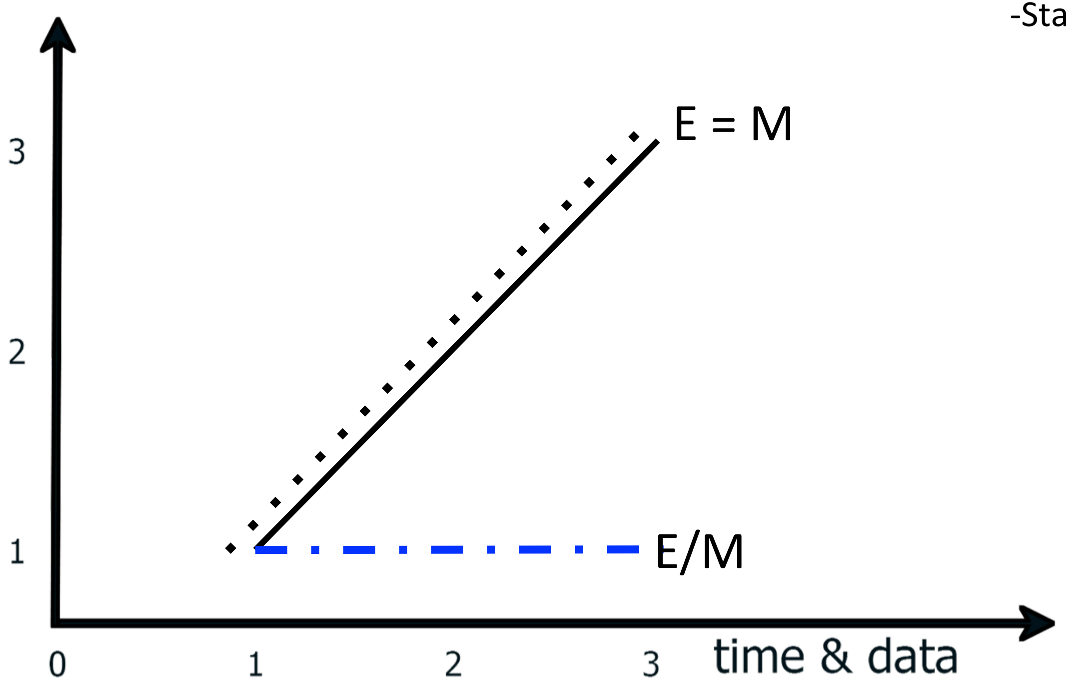
Disunificatory Development

-Standard cosmology (FLRW)



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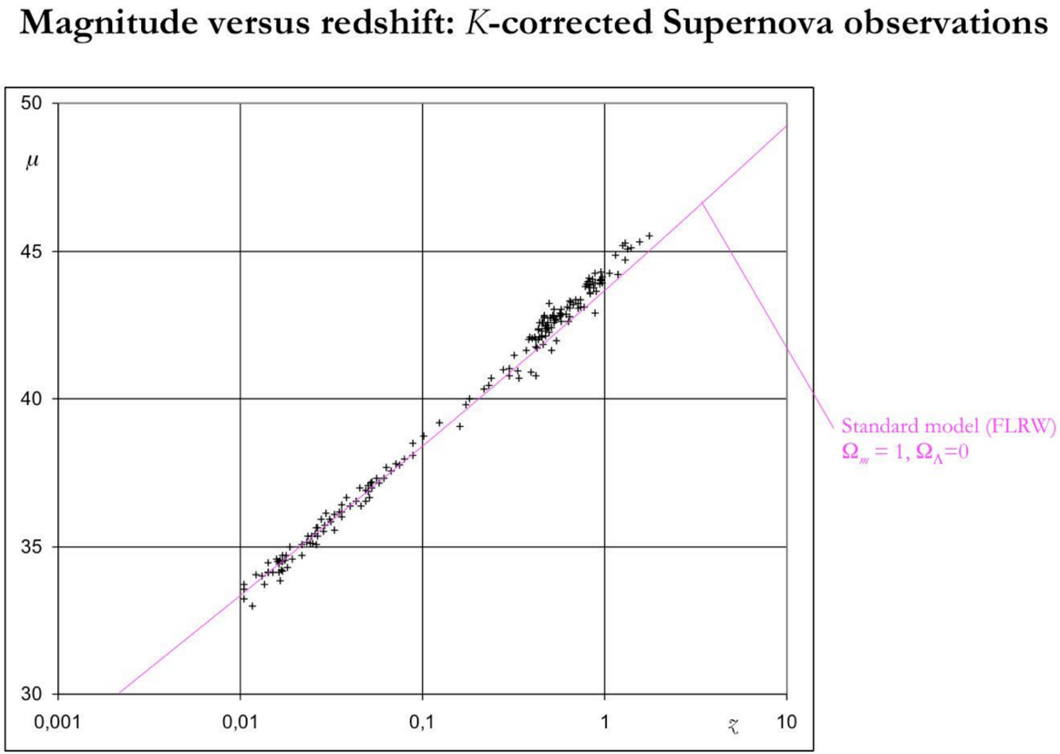
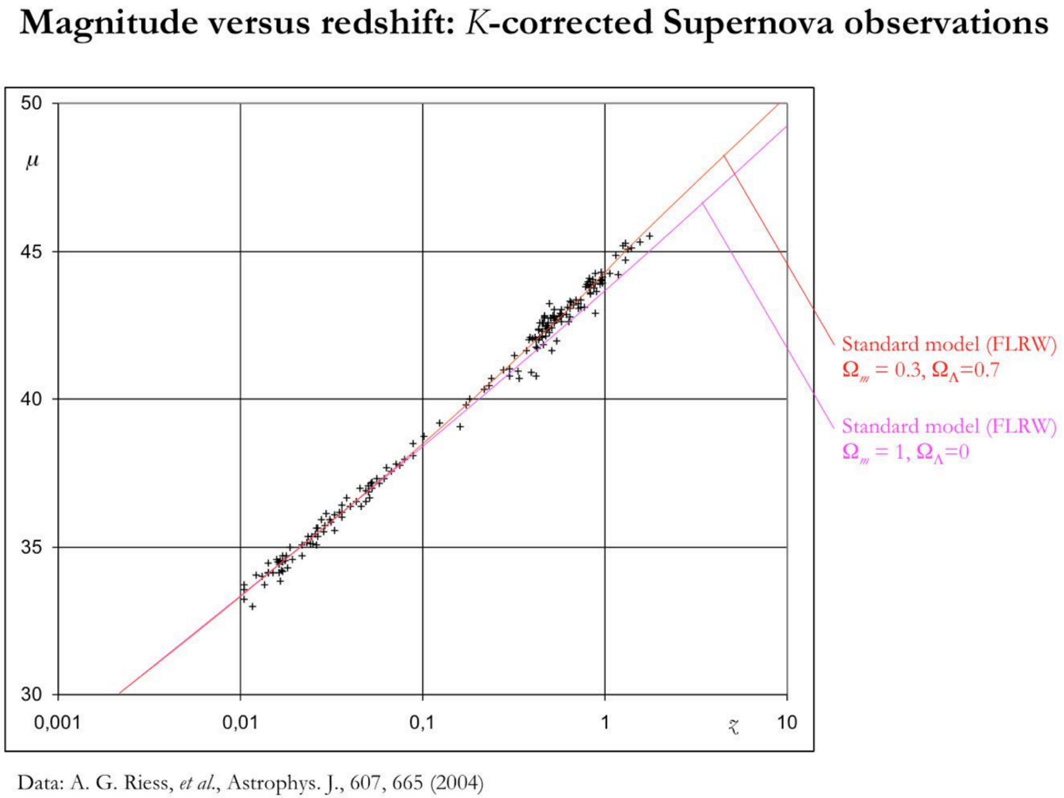


Data: A. G. Riess, *et al.*, Astrophys. J., 607, 665 (2004)

Disunificatory Development



Dark energy is added

Disunificatory Development

Photo: Lawrence Berkeley National Lab | Photo: Belinda Pratten, Australian National University | Photo: Scanpix/AFP

Saul Perlmutter | **Brian P. Schmidt** | **Adam G. Riess**

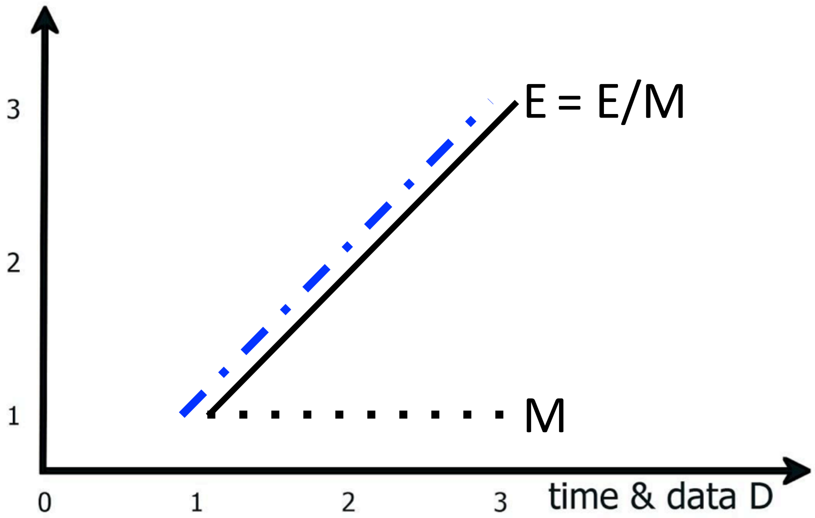
The Nobel Prize in Physics 2011 was awarded *"for the discovery of the accelerating expansion of the Universe through observations of distant supernovae"* with one half to Saul Perlmutter and the other half jointly to Brian P. Schmidt and Adam G. Riess.

Dark energy is added

From Newton to the Present

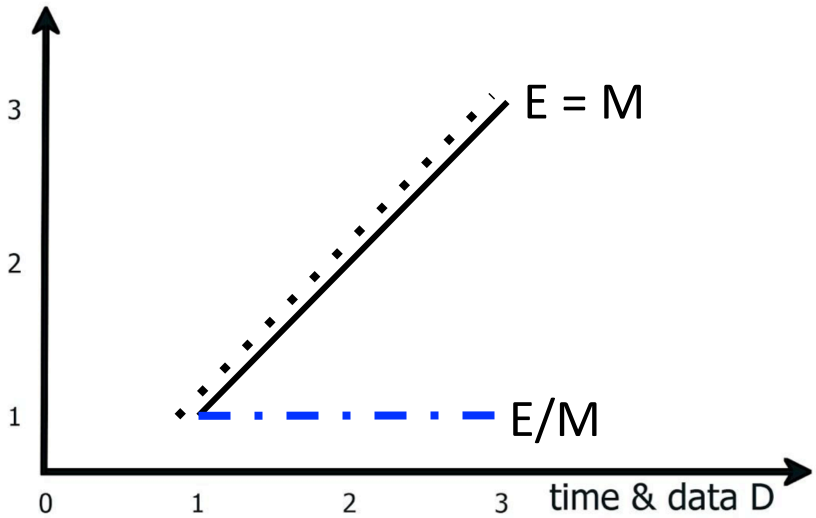
From Newton to the Present

1700->



unificatory development

1900->



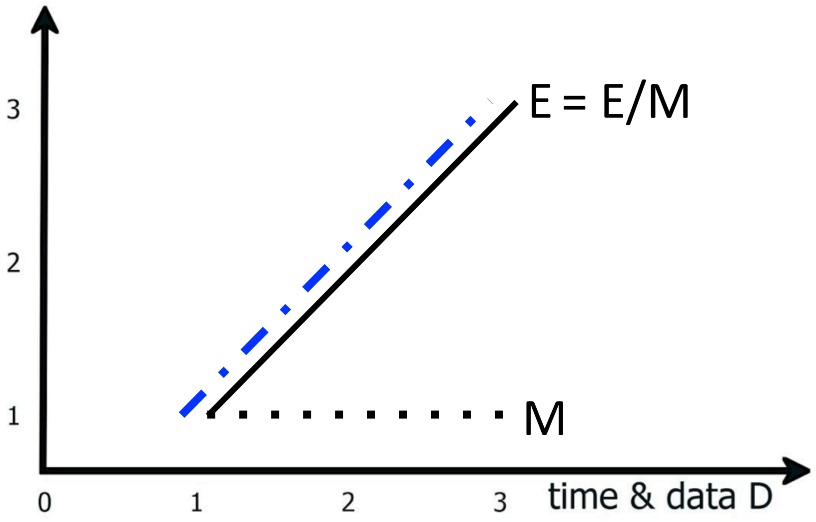
disunificatory development

From Newton to the Present

- Newtonian mechanics was modified and complemented by the theory of relativity and quantum mechanics
  - SR 1905, GR 1915, GR-based cosmology 1917 onward: parametrisation/problems
  - QM 1920’s onward: no consensual ontological interpretation
- Standard model of particle physics 1960’s onward: parametrisation/problems

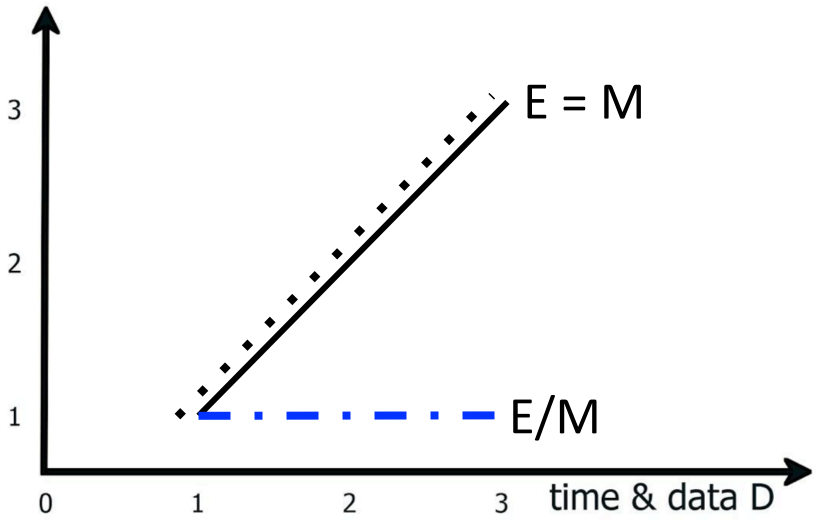
From Newton to the Present

1700->



normal science suffices

1900->

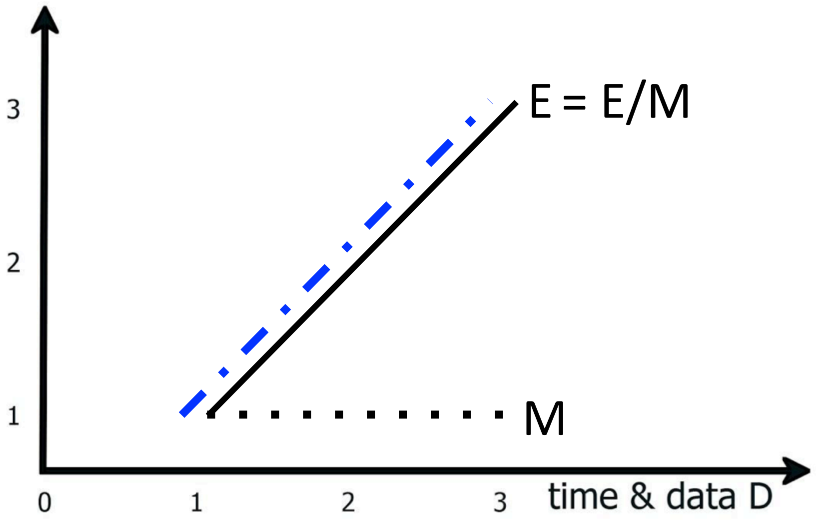


normal science is not enough

From Newton to the Present

1700->

“Failure of existing rules is the prelude to a search for new ones.”
Thomas Kuhn. The Structure of Scientific Revolutions, p. 68. Chicago: University of Chicago Press, 2nd edition, 1970.



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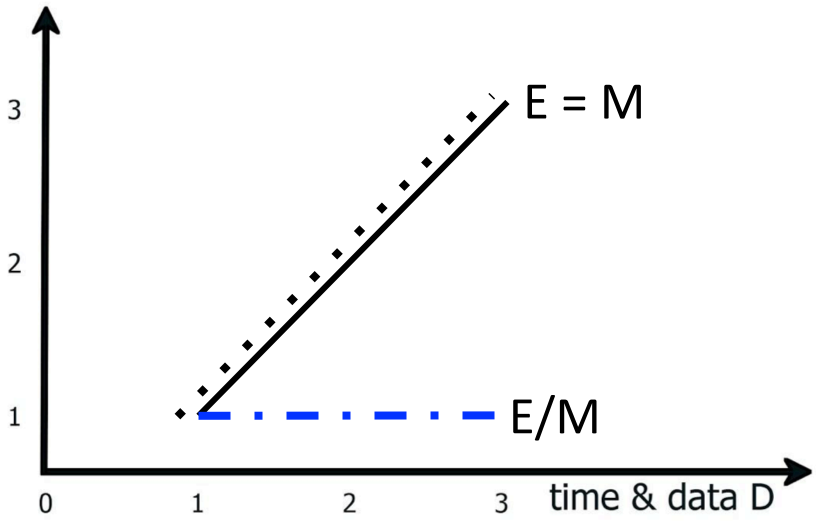
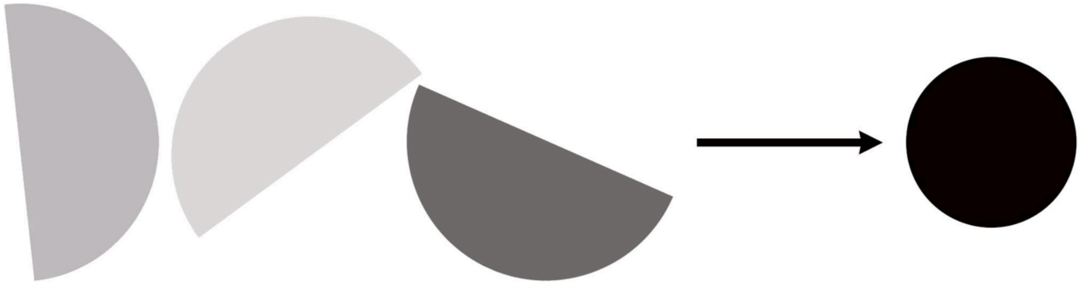


normal science is not enough

The Challenge

1. To invent better theories



The Challenge

1. To invent better theories

2. Dogmatism:
   - Standard physics is highly parametrised and disunified
   - Normal science is not enough; new theories are needed
   - The scientific community effectively repels new theories, because they contradict the standard theories
   - Standard theories are taught to students without criticism, and the tradition goes on

The Challenge

'Normal' science, in Kuhn's sense, exists. It is the activity of the non-revolutionary, or more precisely, the not-too-critical professional: of the science student who accepts the ruling dogma of the day…in my view the 'normal' scientist, as Kuhn describes him, is a person one ought to be sorry for... He has been taught in a dogmatic spirit: he is a victim of indoctrination… I can only say that I see a very great danger in it and in the possibility of its becoming normal... a danger to science and, indeed, to our civilization.

Karl Popper, Normal Science and its Dangers, in I. Lakatos and A. Musgrave (eds.), Criticism and the Growth of Knowledge (1970), pp. 52-3. Cambridge University Press

Summary

- We need new theories that are more unified than the standard theories
- We must objectively evaluate new suggestions against standard theories
- To reach the optimal progress rate of science, we must accept better theories, even when they are different from standard theories

Thank you for your attention