

GAIA and the epistemology of astrophysics

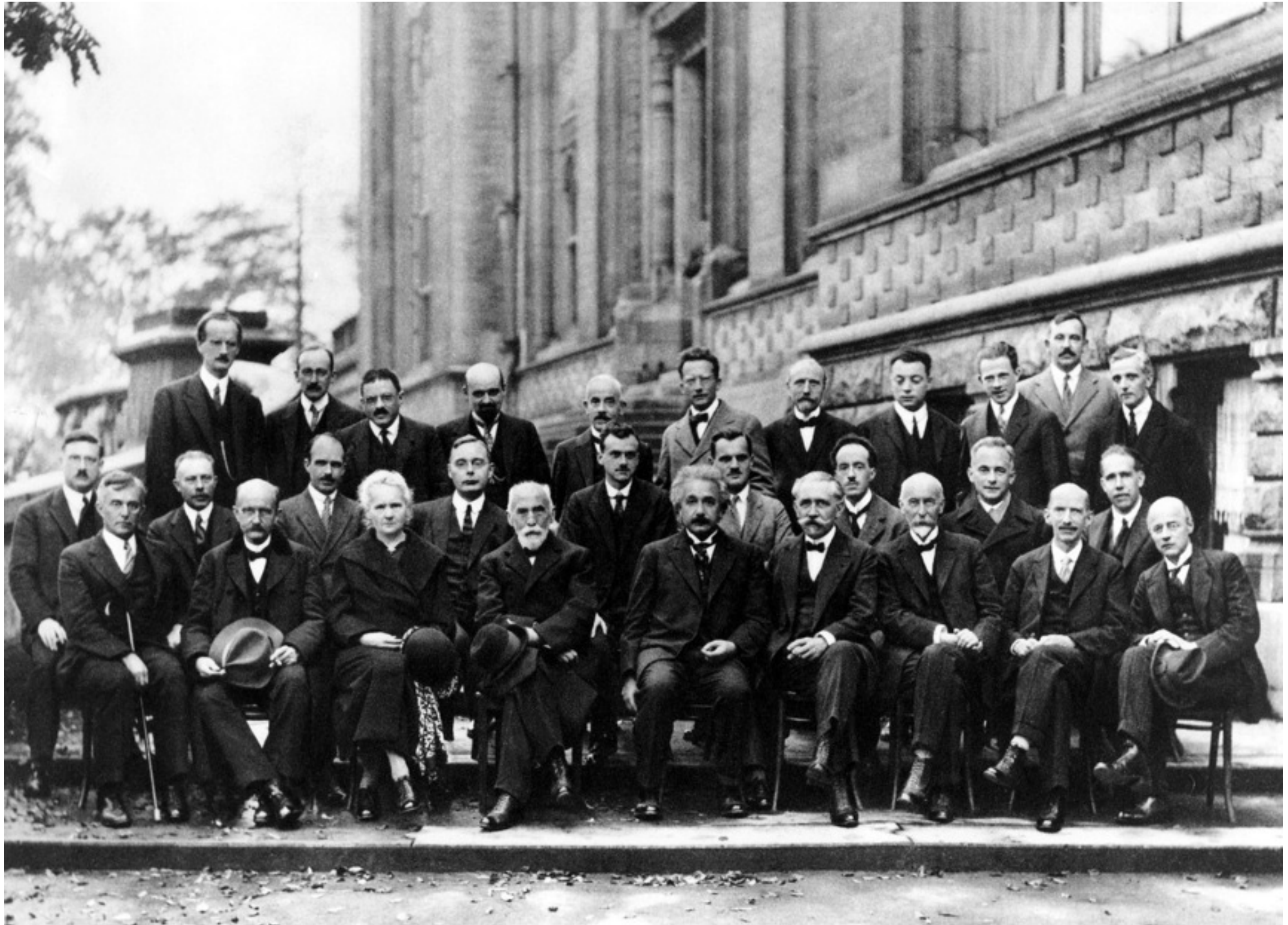
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COSPAR Symposium - Measuring the Universe
2nd February 2015, Vienna



Philosophy and Science - The Old Days



Philosophy and Science - Today



“How can we understand the world in which we find ourselves? How does the universe behave? (...) Traditionally these are questions for philosophy, but philosophy is dead.

Stephen Hawking 2010

Bruce F Press, CC BY 3.0

When a scientist encounters someone inclined to think philosophically, his response should be to say, "I'm moving on, I'm leaving you behind, and you can't even cross the street because you're distracted by deep questions you've asked of yourself. I don't have time for that."

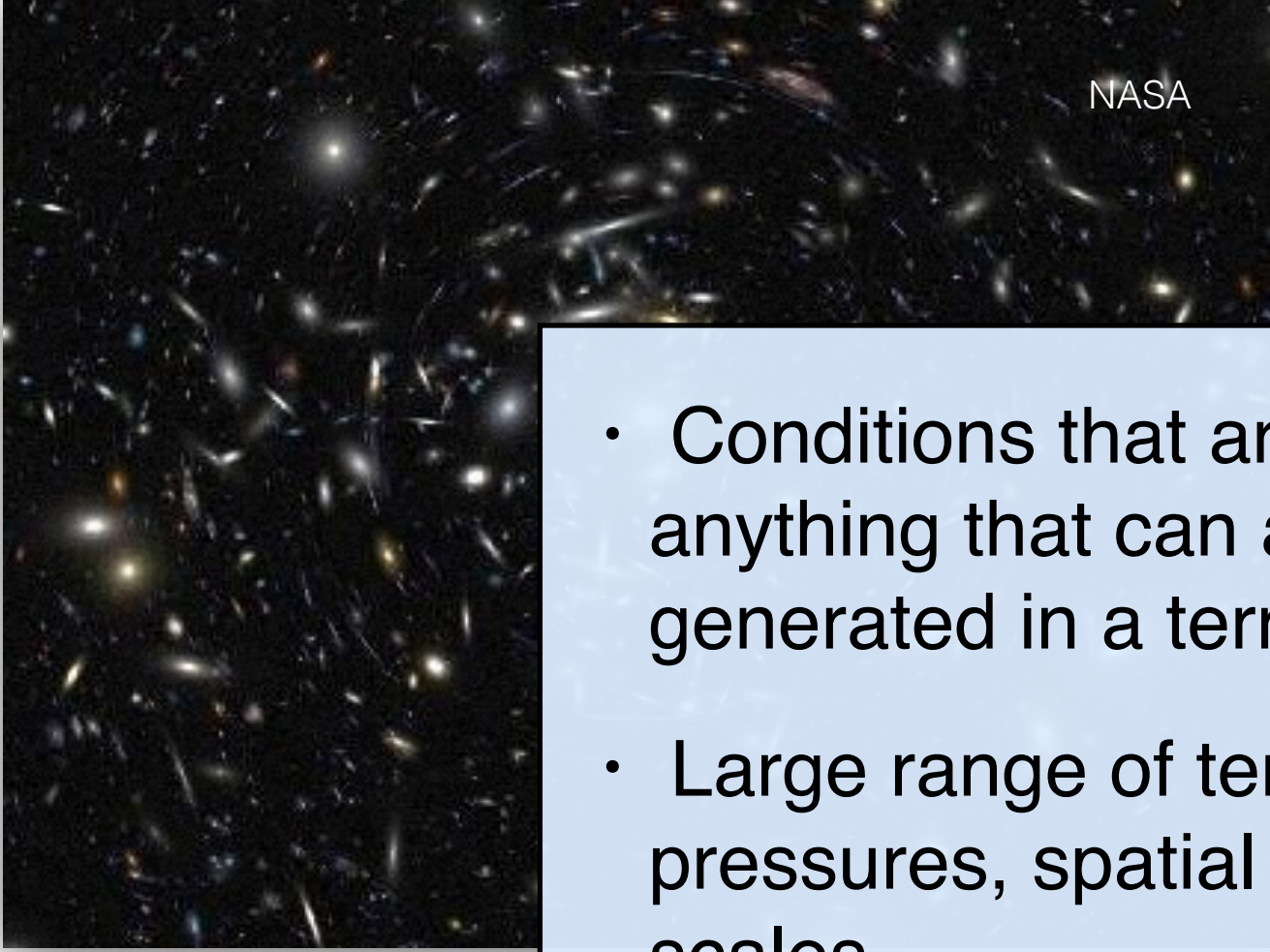
Neil deGrasse Tyson 2014



Is today's science not in need of philosophical reflection anymore?

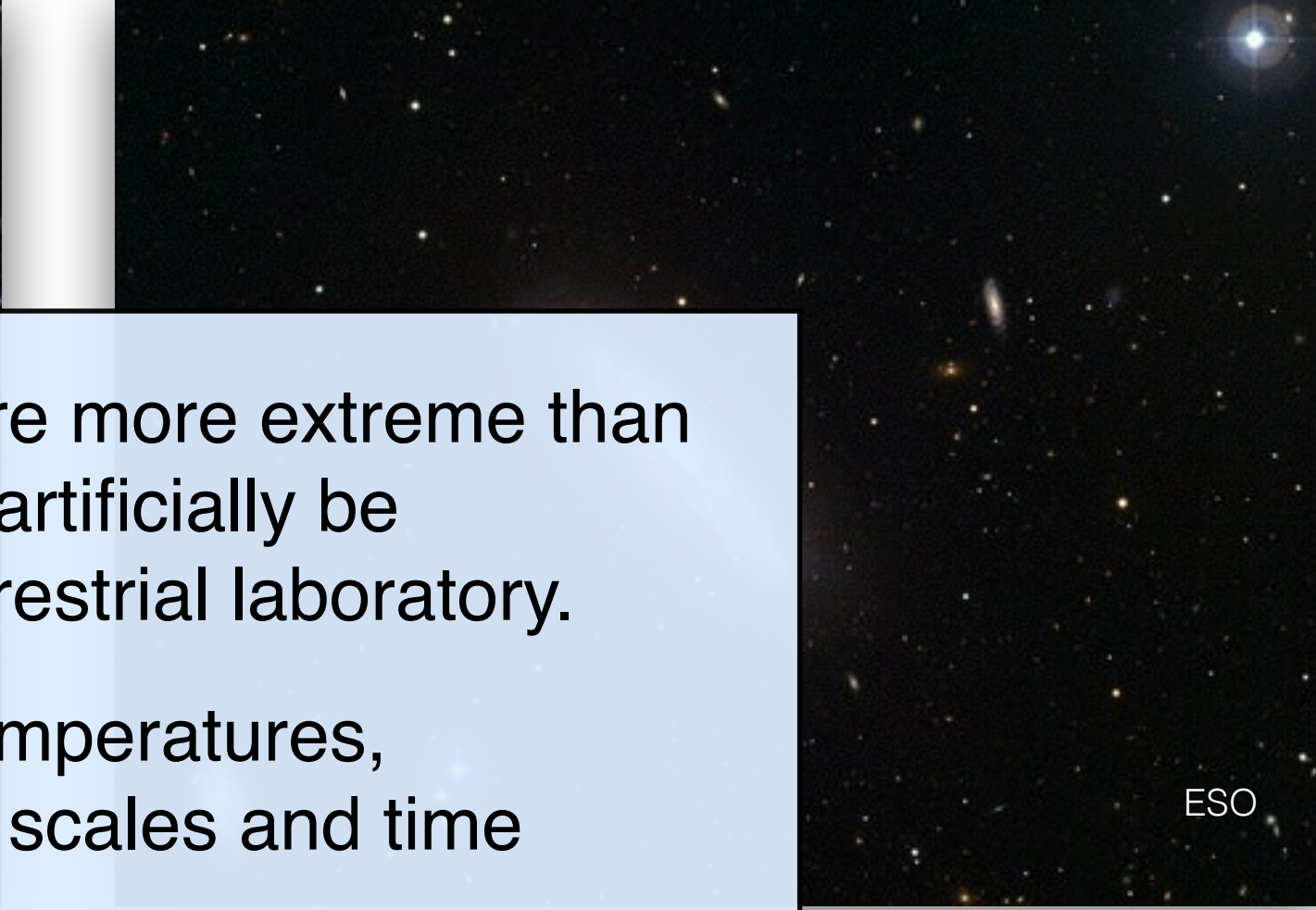
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The case of astrophysics...



NASA

- Conditions that are more extreme than anything that can artificially be generated in a terrestrial laboratory.
- Large range of temperatures, pressures, spatial scales and time scales.
- Very complex systems.
- Astrophysicists are “passive” observers and cannot interact with their objects of research.




ESO



Ultraviolet, GALEX



NASA



Jean-Charles Cuillandre (CFHT), Hawaiian Starlight,

“The technology of astronomy and astrophysics has changed radically since the ancient times, but its method remains exactly the same. Observe the heavenly bodies. Construct models of the (macro)cosmos. In contrast: the methods of the natural sciences have undergone a profound transformation, chiefly in the seventeenth century. Or one might say: the natural sciences came into being then and thereafter, while astronomy is not a natural science at all.”

Ian Hacking 1989

Philosophy of Science

December, 1989

**EXTRAGALACTIC REALITY: THE CASE OF
GRAVITATIONAL LENSING***

IAN HACKING†

*Institute for the History and Philosophy of Science and Technology
University of Toronto*







The Experimental Method

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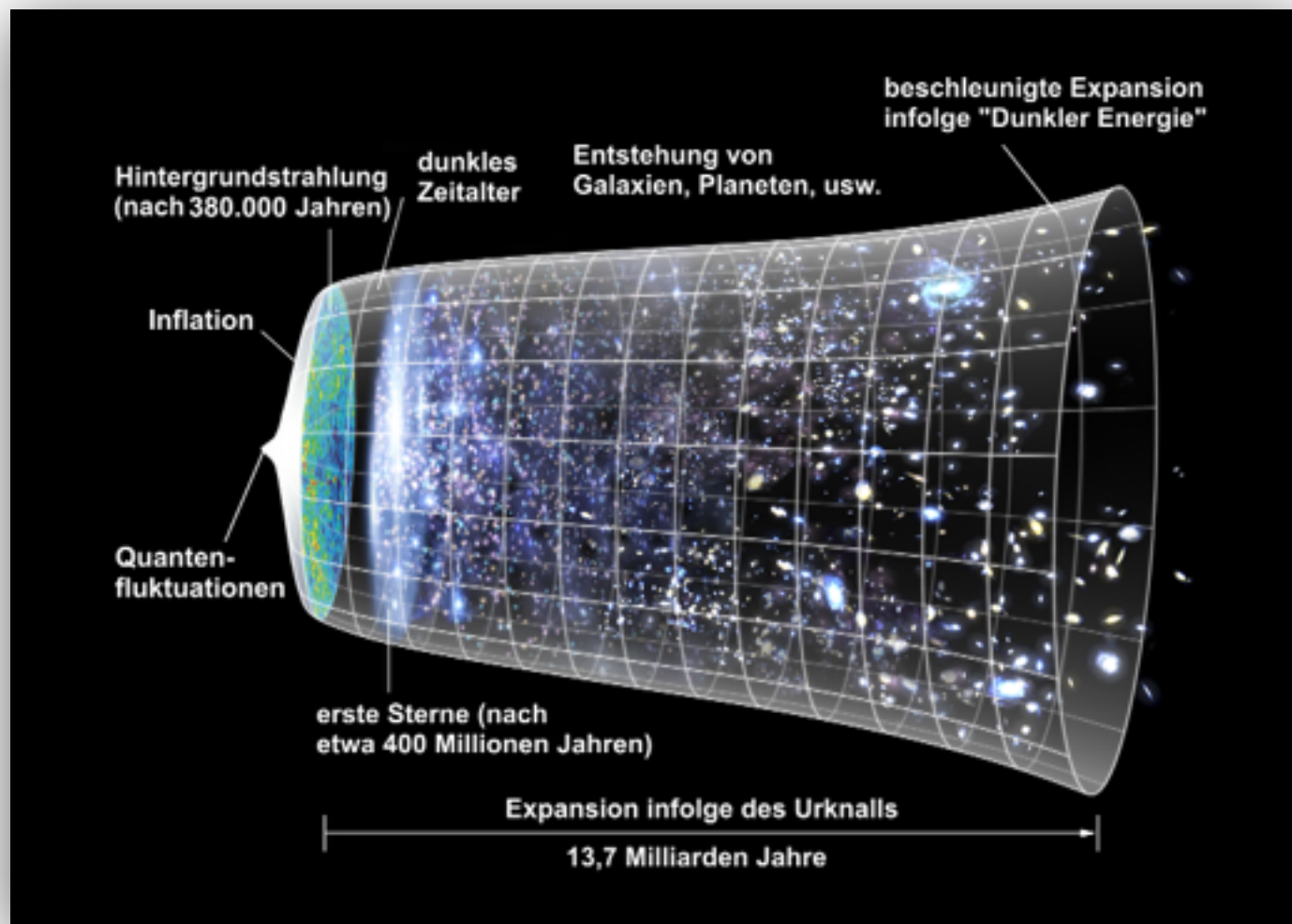
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- Based on a hypothesis from which a test condition C is inferred together with a prediction what should happen if C is realised and the hypothesis is true.
- Check for false negatives / false positives.
- Counterfactual inference: The hypothetical causal relationship between C and the predicted effect should not have also occurred in an identical experimental setup with the test condition not being realised (randomized controlled experiments).

The Astrophysical Method

- “The Sherlock Holmes Method”
- “The Cosmic Laboratory”



NASA / WMAP Science Team / Yikrazuul



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The Sherlock Holmes Method

Understanding of singular instances of objects or a specific process:

- What do the observations tell us about the physics and chemistry at work in the observed region?
- Similar question as in the so called historical sciences: palaeontology, archaeology, aspects of climate research.

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Chicxulub crater



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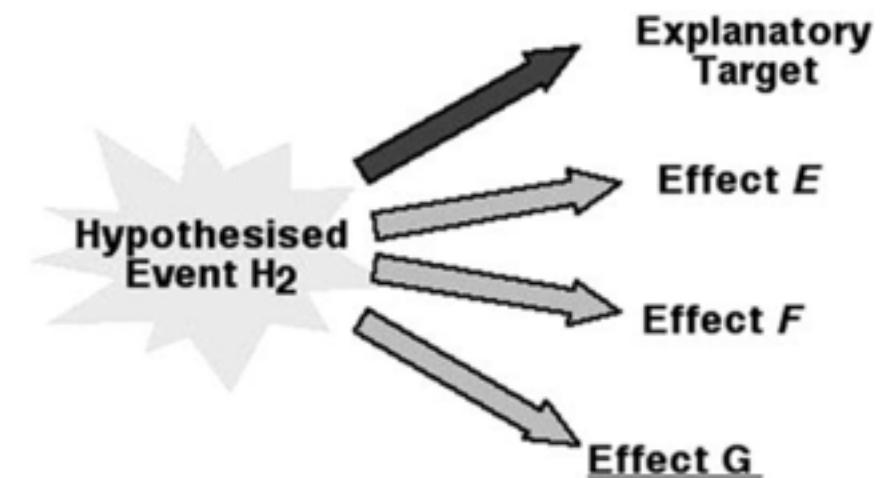
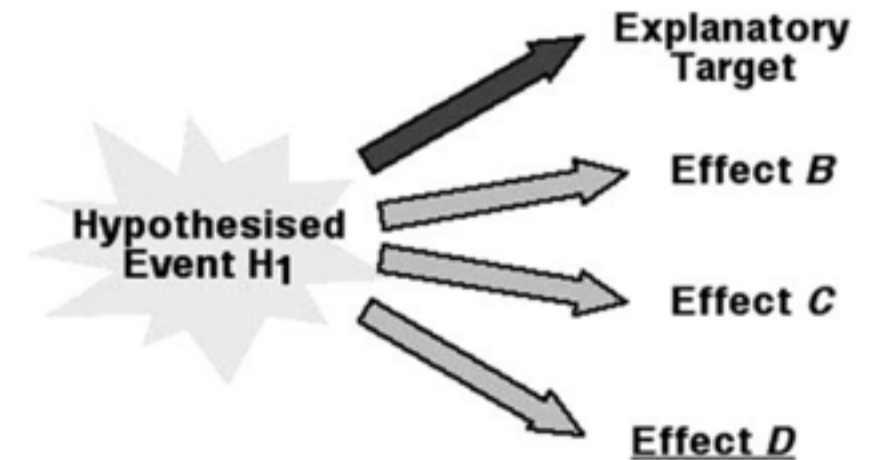
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“We immediately thought it might be a supernova, but needed more clues to back up our claim.”

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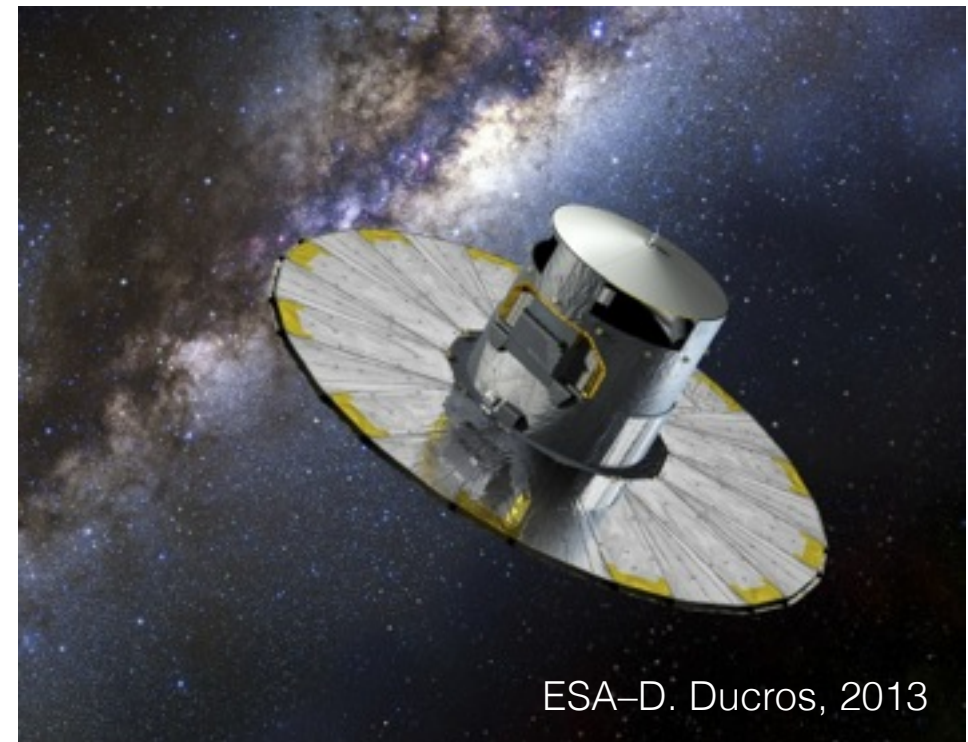
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- More spectral observations from the ground, using the Isaac Newton Telescope (INT) and the robotic Liverpool Telescope on La Palma, in the Canary Islands, Spain.



The Cosmic Laboratory

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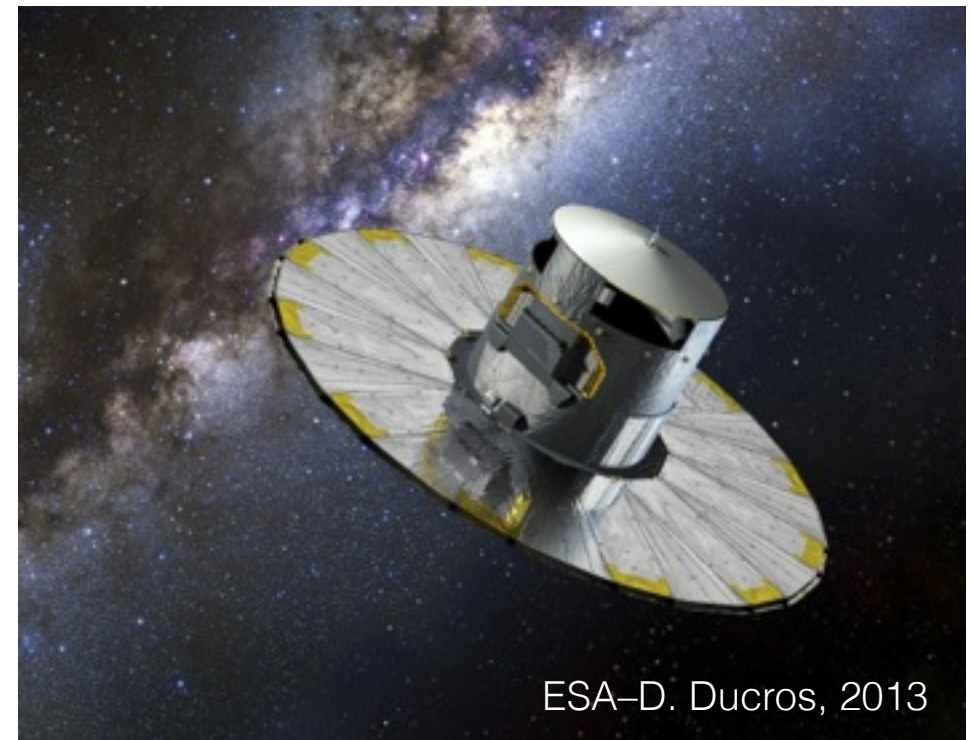
ESA-D. Ducros, 2013

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GAIA:

- Survey a billion stars in our Galaxy and the local galactic neighbourhood
- Detect thousands of planets
- Detect tens of thousands of asteroids
- Find brown dwarfs
- Detect tens of thousands of supernovae in distant galaxies



ESA-D. Ducros, 2013

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Quasi experiments

- No random assignment.
- Possible confounding factors have to be excluded: further experiments or quantitative methods (e.g. multivariate regression, dedicated modelling).

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- However, the evaluation of these quasi-experiments requires the application of sophisticated statistical methods and the use of models and simulations, which in turn are often used as substitutes for traditional experiments.

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There is a vivid discussion within the philosophy of science that is systematically studying these topics.

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The social sciences and philosophy of science is increasingly focussing on questions related to scientific data treatment.

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- Central aspects of both methods are the ubiquitous use of numerical models and the generation of huge amounts of data.
- Instruments like GAIA enable an overwhelming growth of our empirical knowledge. To make the best use of the observations we get, we always need to critically reflect modelling and data processing practices.
- For some of the questions arising in this context philosophical discussions may be helpful. In any case, science policy needs to create an environment in which a critical methodological reflection is rewarded by the system.