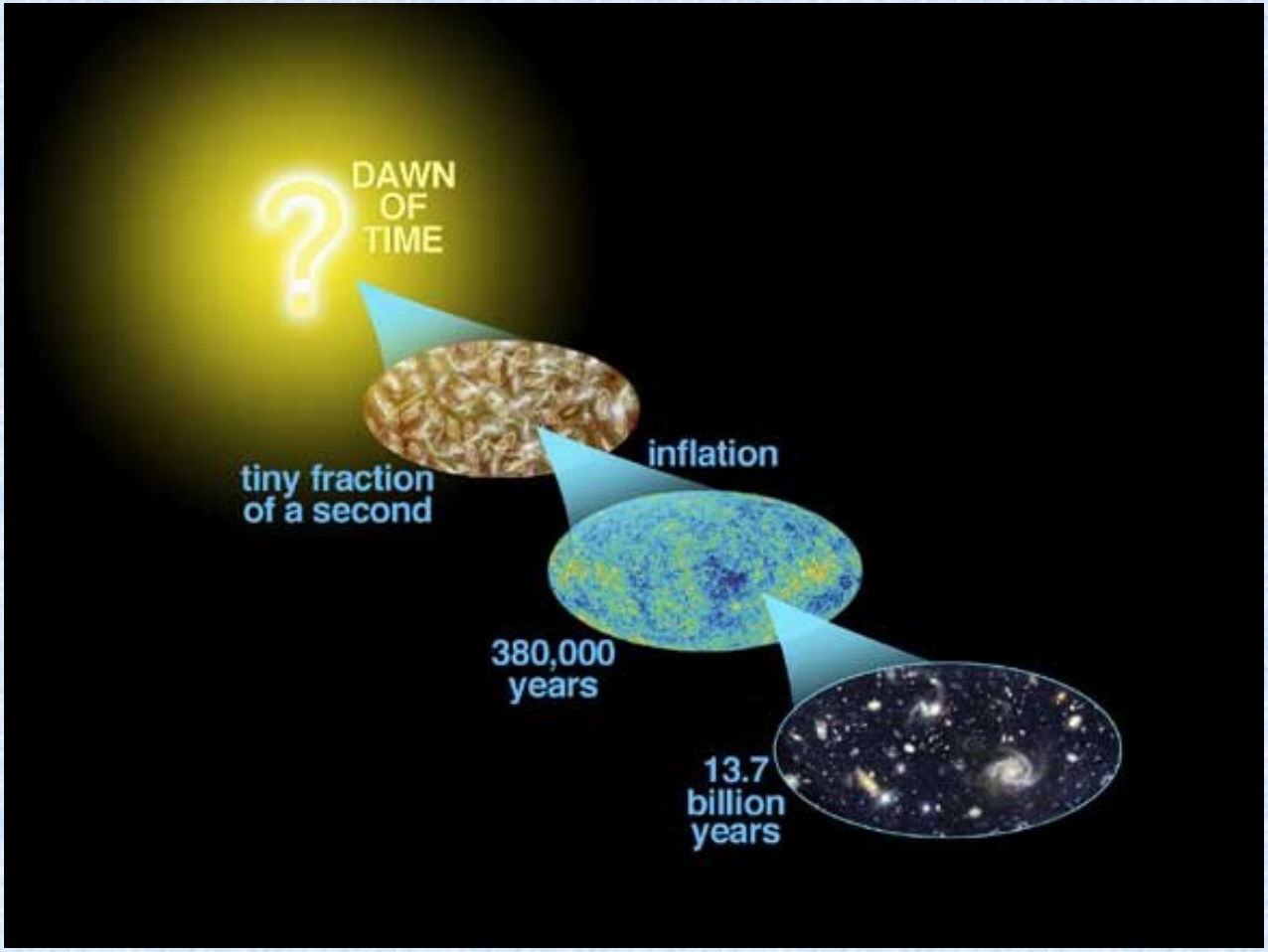
Origins



Lecture 8; April 24 2014

Previously on Origins (Prof Tutino)

- Giordano Bruno and Renassaince Science
- The debate over heliocentrism: the Galileo Affair
- WHAT **I** GOT OUT OF IT:
  - The relation between religion and science is historical and cultural. We need to understand the context of our debate. Scientists need to be aware of their surroundings .
  - In the debate there are issues of "power" in broad terms

Previously on Origins (Prof Hecht)

- Religion is a complex phenomenon which must be understood in its multidimensional components
- Over the course of time and in different cultures the relationship between religion and other areas of knowledge has changed significantly.
- The debate is still open about what is the relation between religion and science in particular, with many points of view, often in contrast

Science and Myth

- Prof Hecht raised the issue as to whether the scientific method is a myth in the sense that it is self-validating and inherently true
- As we will see I do not think this is the case.
- However, it is sometimes incorrectly portrayed or abused as such. For example it is unfortunately common for people to say “it’s science” as a synonym of it’s true.
- Likewise, it is a danger to consider scientists as custodians (or “priests”) of the truth
- My opinion is that the beauty and power of science is exactly that it is not a myth, and we should engage in the public understanding of science and of the scientific method to clarify the distinction

Methodological introduction

- Demarcation: what is science?
  - Remember Prof Hecht's lecture on junk-science
- Falsification: how do you test scientific theories?
  - Measurements and errors
- Repeatibility:
  - Determinism and probability
  - The unexplained and the supernatural
- Corroboration: what is a "good" scientific theory

Science and Epistemology

"Scientist"

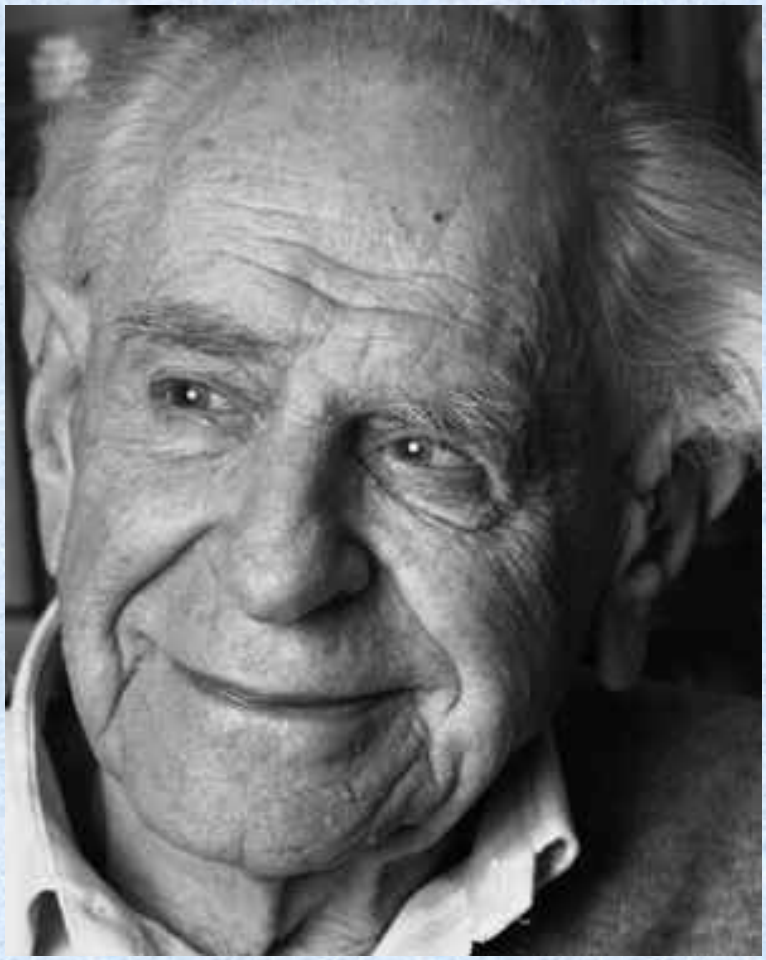
"Epistemologist"

Demarcation: what is science?

- We need to define what is science. Common methodology:
  - INTERACTION
  - QUALITY CONTROL
- In the same way, we need to agree on the meaning of words in order to have a conversation.
- The solution has to be a CONVENTION
  - dependent on history and culture
- DEMARCATION DOES NOT IMPLY RANK. ONE DISCIPLINE IS NOT BETTER THAN ANOTHER

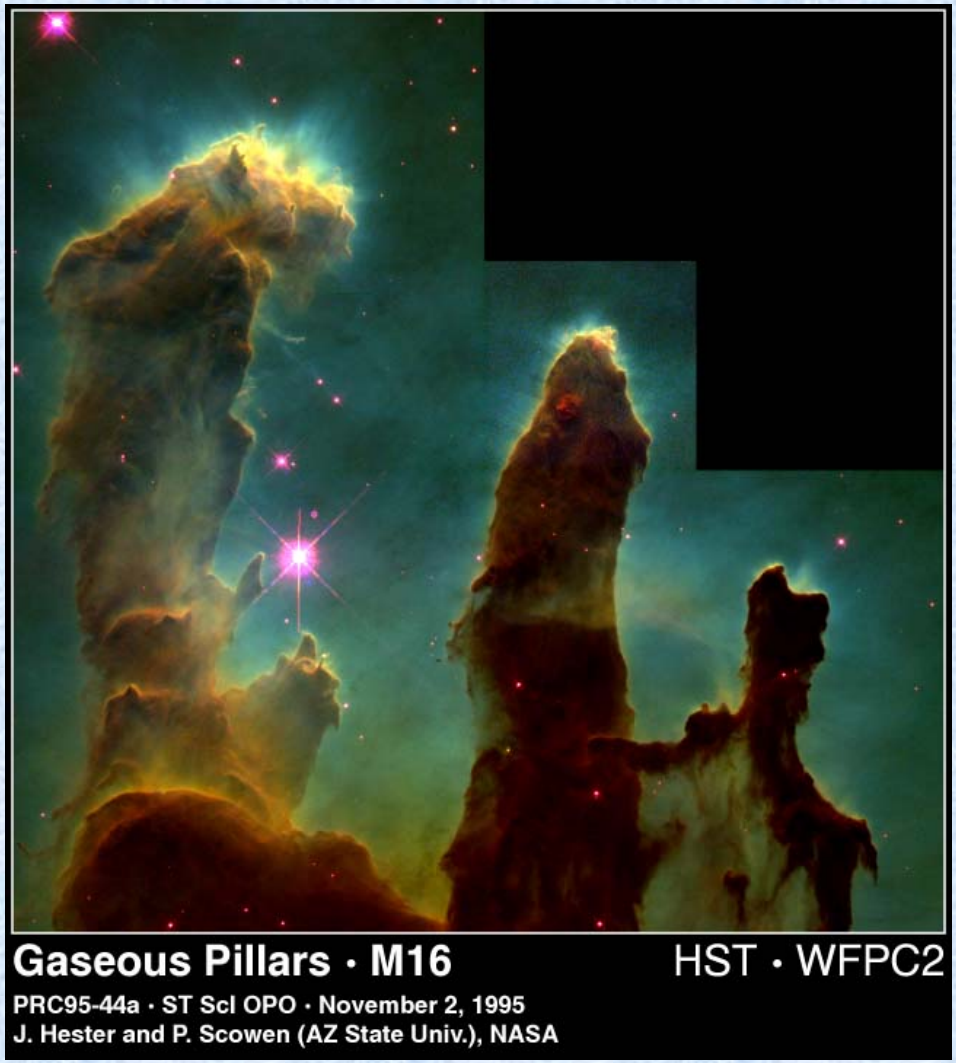
Demarcation: Popper's solution

- The currently agreed solution to the demarcation problem is very well described by Karl Popper:
  Science is falsifiable via experiments
- THE ESSENCE OF SCIENCE IS THAT IT CAN BE PROVEN WRONG
  - IS THIS THE SAME AS MYTH? We will see what Prof Hecht thinks…
- TODAY ALL PRACTICING SCIENTISTS ADHERE TO THIS CONCEPT



Karl Popper 1902-1994

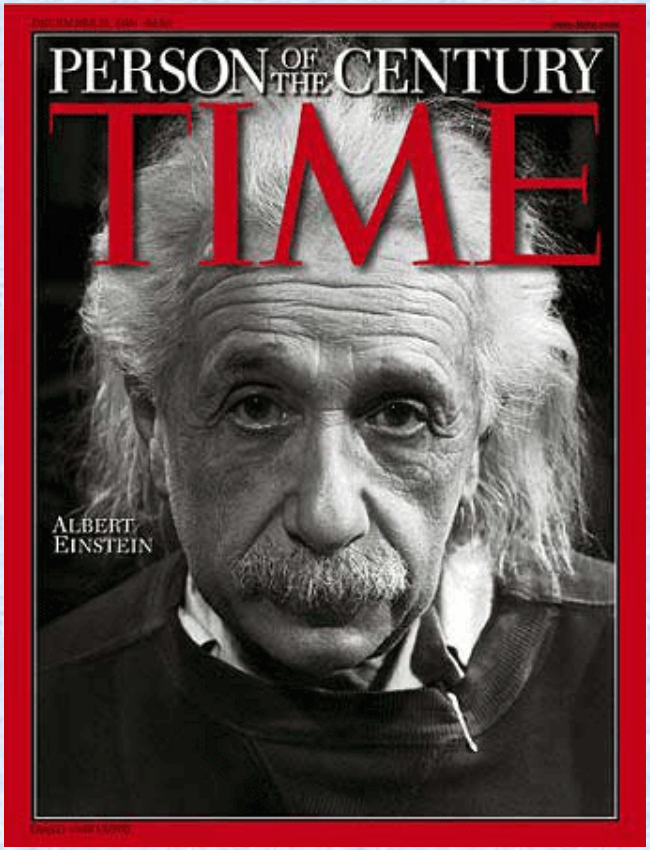
Demarcation does not mean isolation: science and culture



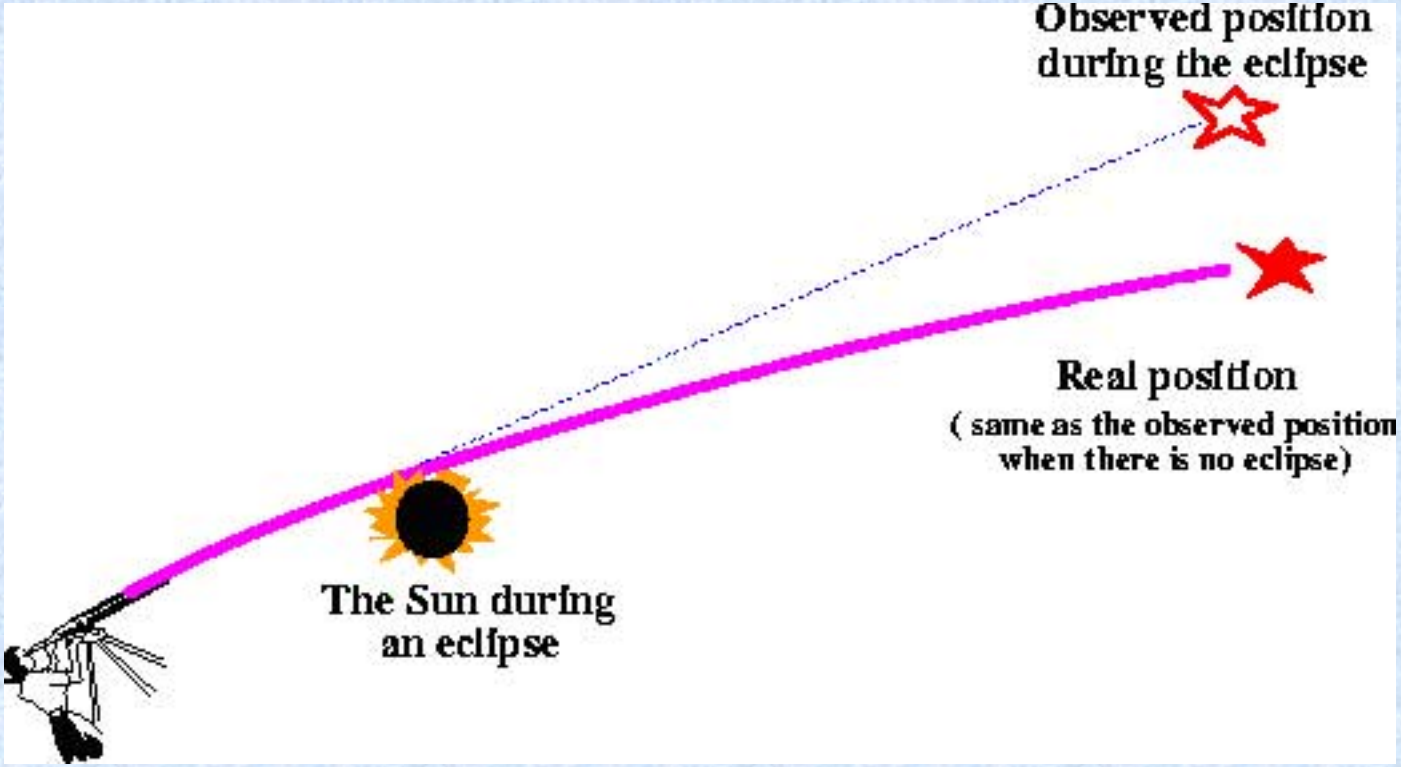
Scientific model or theory

- A scientific theory is a logically self-consistent model or framework for describing the behavior of a related set of natural or social phenomena.
- In general it originates from experimental evidence
- It is always corroborated by experimental evidence, in the form of successful empirical tests.
- In this sense a theory is a systematic and formalized expression of all previous observations that is **predictive, logical and testable (falsifiable)**.
- *Scientific theories are always tentative, and subject to corrections or inclusion in a yet wider theory. A model does not aspire to be a "true" picture of reality.*

Example: gravity, from Newton to Einstein



Example: gravity, from Newton to Einstein

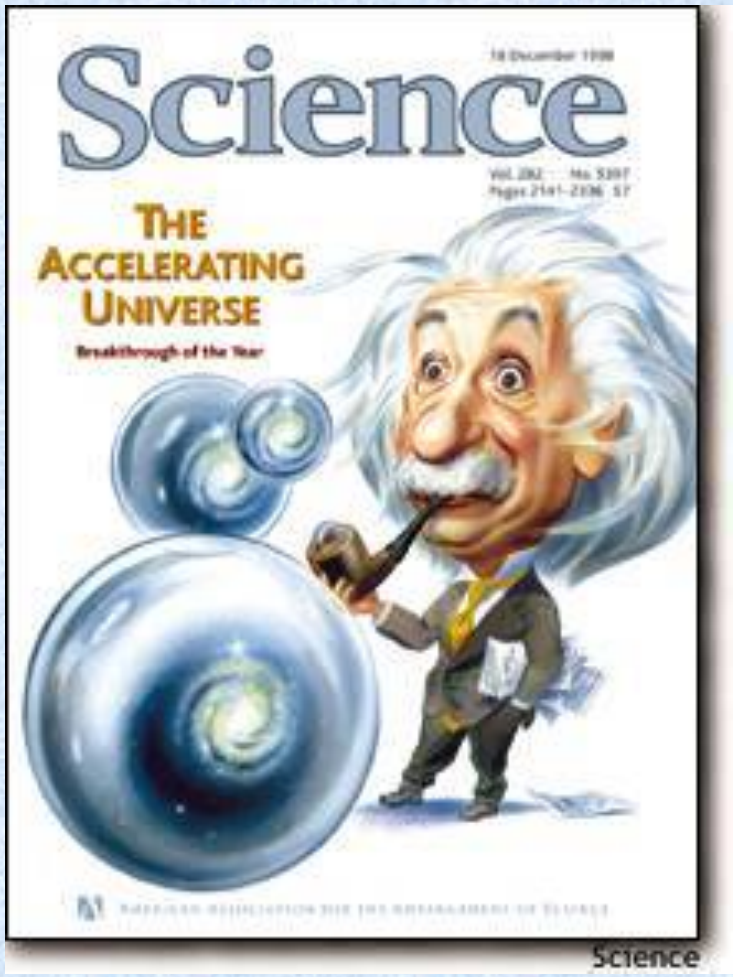


- 1919 solar eclipse measurement: 1.61+-0.40”
- Einstein 1.75”; Newton 0.875”

Measurements

- Measurements must be REPEATABLE
- Measurements have uncertainties
  - A measurement without an uncertainty is meaningless
  - EVERY MEASUREMENT HAS ERRORS
  - HOW TALL ARE YOU?

Physics view of the universe can change dramatically



1929: The universe is expanding

1998: the universe is accelerating

A sociological comment…

- What is a guaranteed way to have a spectacular career in science?
- Prove the current paradigm wrong!
- There is no higher compliment than "transformative" or "revolutionary" science

Probability and science

- The results of experiments are often cast in terms of probabilities.
- The same is true for scientific theories: Probabilistic predictions are not in conflict with the empirical method because they can be falsified

Heisenberg's uncertainty principle

- What does it mean?
- NOT that science is not precise
- It means that some quantities cannot be determined *simultaneously* with infinite precision.
- For example the uncertainty on position and momentum (~speed) is larger than
- $\Delta x \Delta p = h/2\pi$

Physical cosmology: some questions

- Is the Universe evolving?
- If so, how and when did it form?
- How big/old is the universe?
- How/when did galaxies/stars/planets form?
- Is there extraterrestrial life in the Universe?

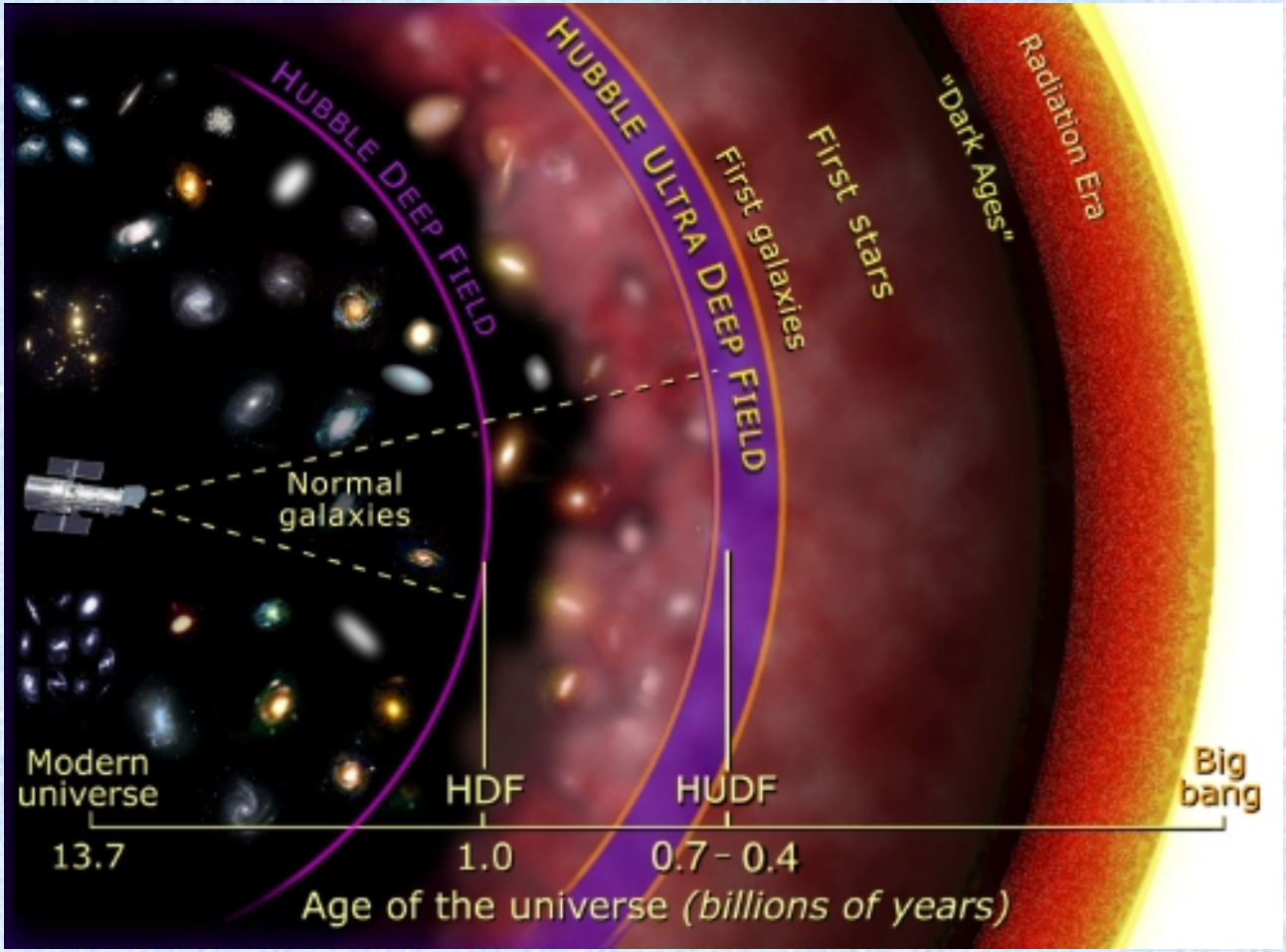
How much these questions are historical and cultural versus perhaps "biological" is not for me to answer.

NOTE THAT THERE IS NO QUESTION ABOUT THE PURPOSE/MEANING OF THE UNIVERSE. WHY?

Physical cosmology

- **Experiments and Observations force us to modify/change our view of the Universe. Examples:**
  - Galileo's observations of Sun spots proved that the heavens are not time-invariant
  - Hubble's measurement of galaxy redshifts showed that the Universe is not static
  - High speed motions of stars in galaxies show that either we do not understand gravity or there is a large amount of "dark matter", i.e. different stuff that the ones that makes you and me (and Earth)

Tools of the trade:
Telescopes as time machines



Physical cosmology: a fundamental dilemma

- Experiments and observations can only be from one point in space and time: Earth now.
- Yet we would like to construct a scientific theory that describes the universe everywhere and at all times.

…and its solution

- Hypothesis: our local sample of the universe is no different from more remote and inaccessible places
- This assumption is deeply rooted in two fundamental principles of physics:
  - The laws of physics (whatever they are!) do not depend on space and time. Popper calls it "*the principle of the uniformity of nature*"
  - Physical explanations of natural phenomena should be as simple as possible (Ockham's razor)

A testable working solution

- We can measure whether we are in anyway in a special place in the Universe.
  - We will discuss this at length in this class
- We can test the laws of physics through observations. Examples:
  - Spectroscopy of distant stars and galaxies to probe atomic physics. Do we see the same transitions?
  - Constants of nature (such as the electron charge). Where they different a few billion years ago?

Unexplained…

- There are plenty of phenomena we do not "understand". Example:
  - How does your cell-phone work?
- However, they are **measurable phenomena with repeatable experiments**
- Technology may appear "magic" or "myth" but it IS FUNDAMENTALLY NOT

…vs magic/miracles

- Magic and miracles imply a behavior that differs than expected - i.e. NON REPEATABLE
- If miracle were proven to exist, this would falsify one of the fundamental hypothesis of science, that is that the laws of nature do not "bend" to people's or (deity's) will.
- SCIENTIFIC EVIDENCE OF MAGIC/MIRACLE WOULD BE MOST REVOLUTIONARY AND TRANSFORMATIVE

A "good" scientific theory

- What constitutes a "good" scientific theory?
- If a theory can never be proven right, how is one theory better than another?
  - Note the use of the derogatory expression "just a theory" by creationists
- According to Popper:
  - The better theory is the one that passes more stringent tests, both in number and in quality
  - The better theory is the more falsifiable one, if it doesn't fail
- Old theories often become limiting cases of new theories
  - (e.g. Newton vs Einstein)

How about validating the method?

- What constitutes a "good" method?
- Is the scientific method good?
- Does the question even make sense?
- My view is that a method is good as long as it allows you to achieve what you want. What do you want?
- The scientific method answers some questions/obtain some results. What are they?
- If we need to answer other questions we need different tools.

Summary

- Demarcation: what is science?
- Falsification: how do you test scientific theories?
  - Measurements and errors
- Repeatibility:
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- Corroboration:
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The End

See you on Tuesday!