

# Big Bang Cosmology, Higgs Bosons and Genesis

Science and Judaism: A Research Workshop

The Institute for the History and Philosophy of Science and Technology  
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# I'm going to summarize the current science that describes our universe, and reflect on Bereshit

Big Bang Cosmology

Higgs Boson – the “God Particle”

Connection with Bereshit

Some Personal Reflections



# The universe was found to be expanding in 1920s

A RELATION BETWEEN DISTANCE AND RADIAL VELOCITY  
AMONG EXTRA-GALACTIC NEBULAE

By EDWIN HUBBLE

MOUNT WILSON OBSERVATORY, CARNEGIE INSTITUTION OF WASHINGTON

Communicated January 17, 1929

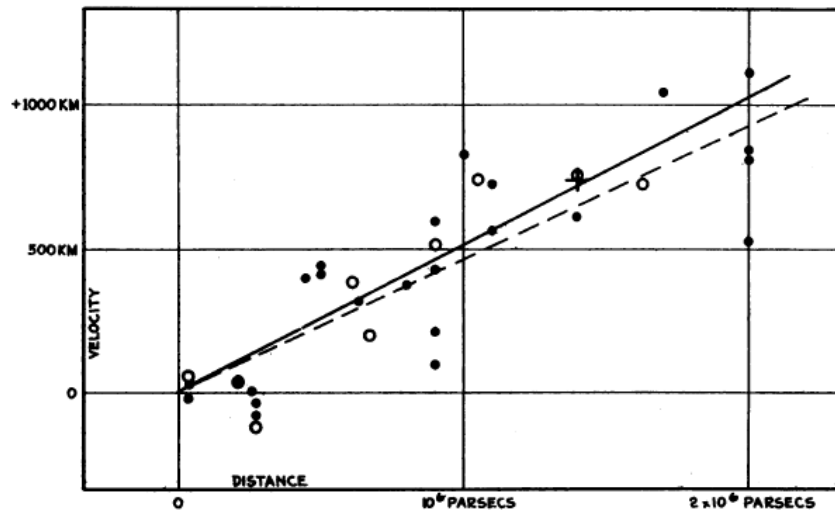


FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

Radial velocities, corrected for solar motion, are plotted against distances estimated from involved stars and mean luminosities of nebulae in a cluster. The black discs and full line represent the solution for solar motion using the nebulae individually; the circles and broken line represent the solution combining the nebulae into groups; the cross represents the mean velocity corresponding to the mean distance of 22 nebulae whose distances could not be estimated individually.

Expansion reported by Georges Lemaître (1927) and then Edwin Hubble (1929), using Cepheid variable stars

All galaxies are receding from us with velocity

$$v = H_0 D$$

where

$H_0$  is Hubble constant ( $\sim 70$  km/s/Mpc), and  
 $D$  is distance in Mpc



# Cosmic microwave background radiation tells us what was taking place 370,000 years after Big Bang

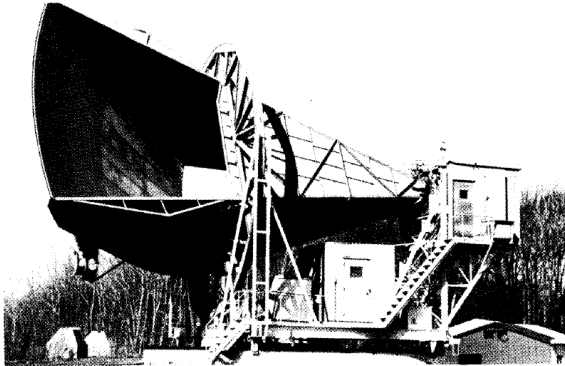


Fig. 1 The 20 foot horn-reflector which was used to discover the Cosmic Microwave Background Radiation.

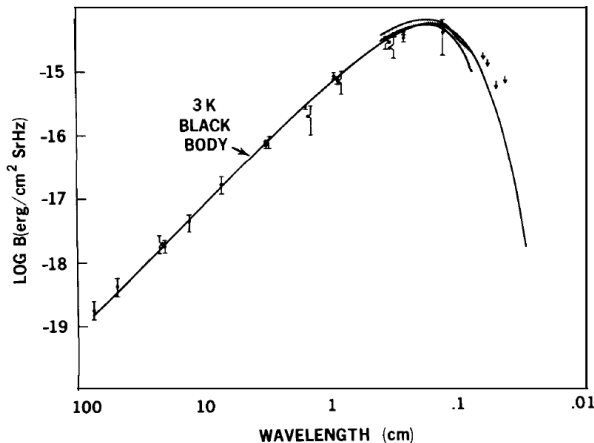


Fig. 12 Measurements of the spectrum of the cosmic microwave background radiation.

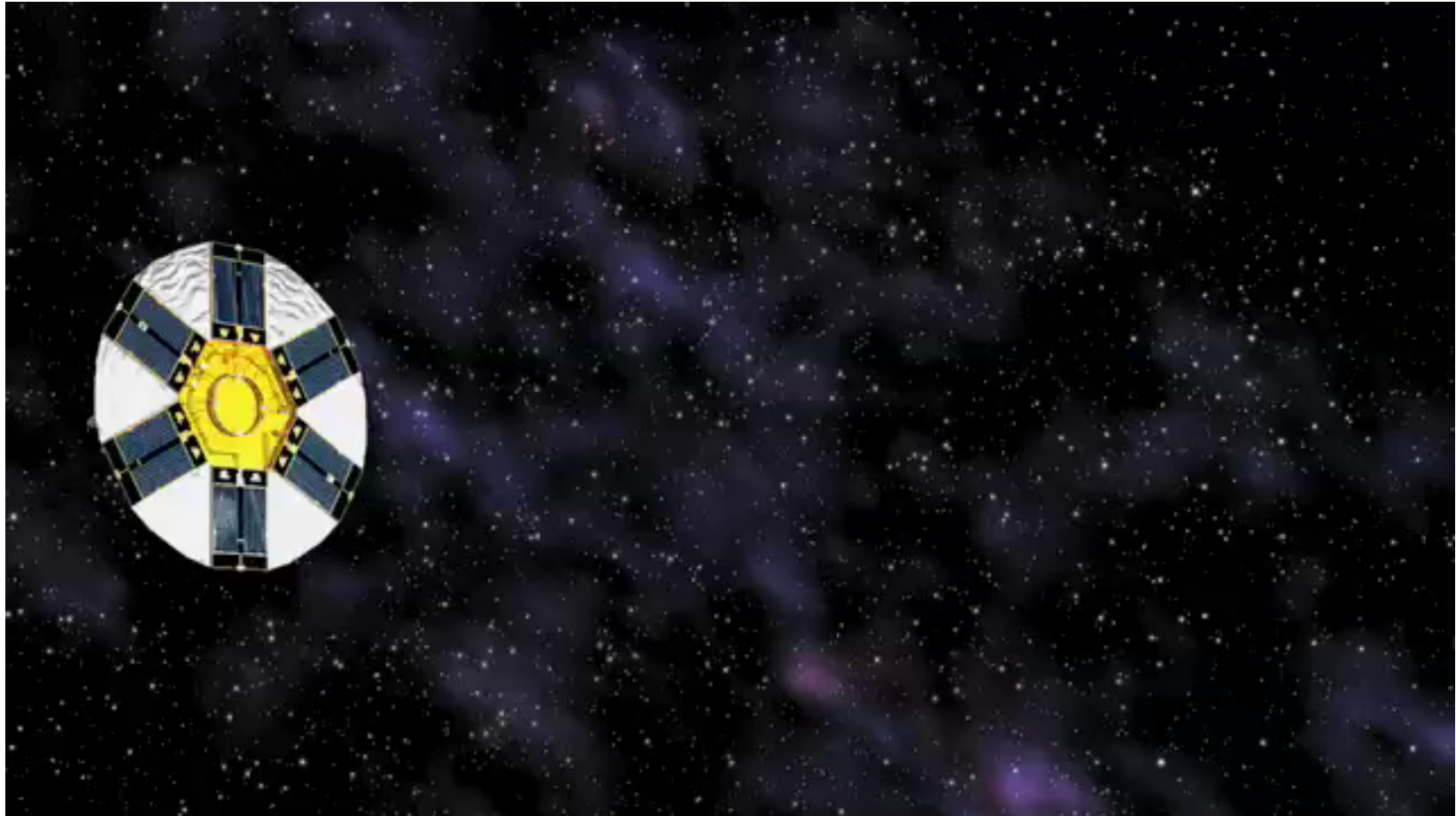
Arno Penzias & Robert Wilson discovered “excess noise” at 21.1 cm wavelength

- Readily interpreted as remnant from the early universe
- Came at the moment neutral atoms could form,  $\sim 3,000^\circ\text{K}$
- Identified as the CMB

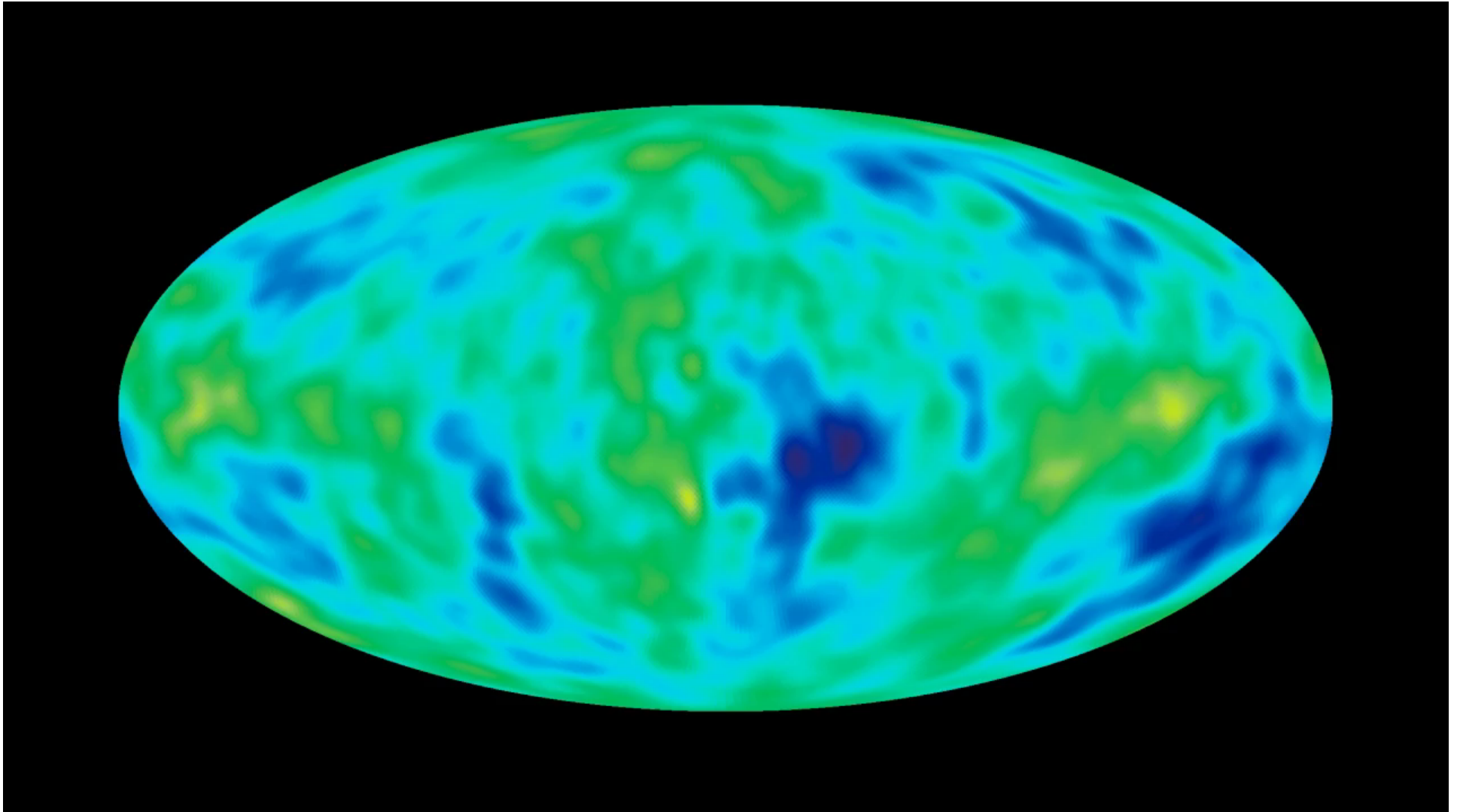
R. Wilson, Nobel Lecture (1978).



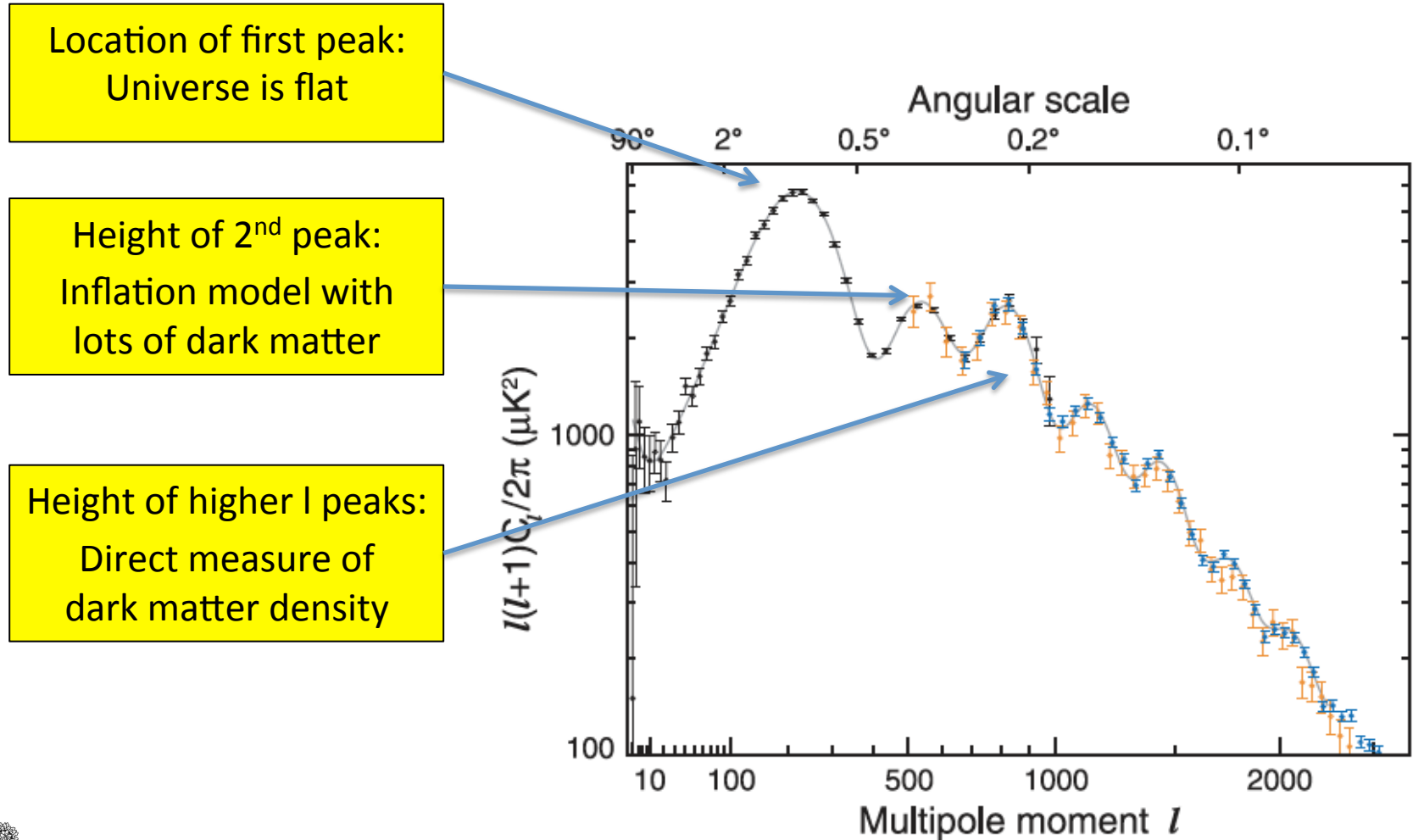
**More recent measurements have been made by many experiments, with WMAP satellite the most recent**



# Over 20 years, CMB has come into clear focus



# The angular size of the fluctuations tell us a great deal of what took place before the CMB was released

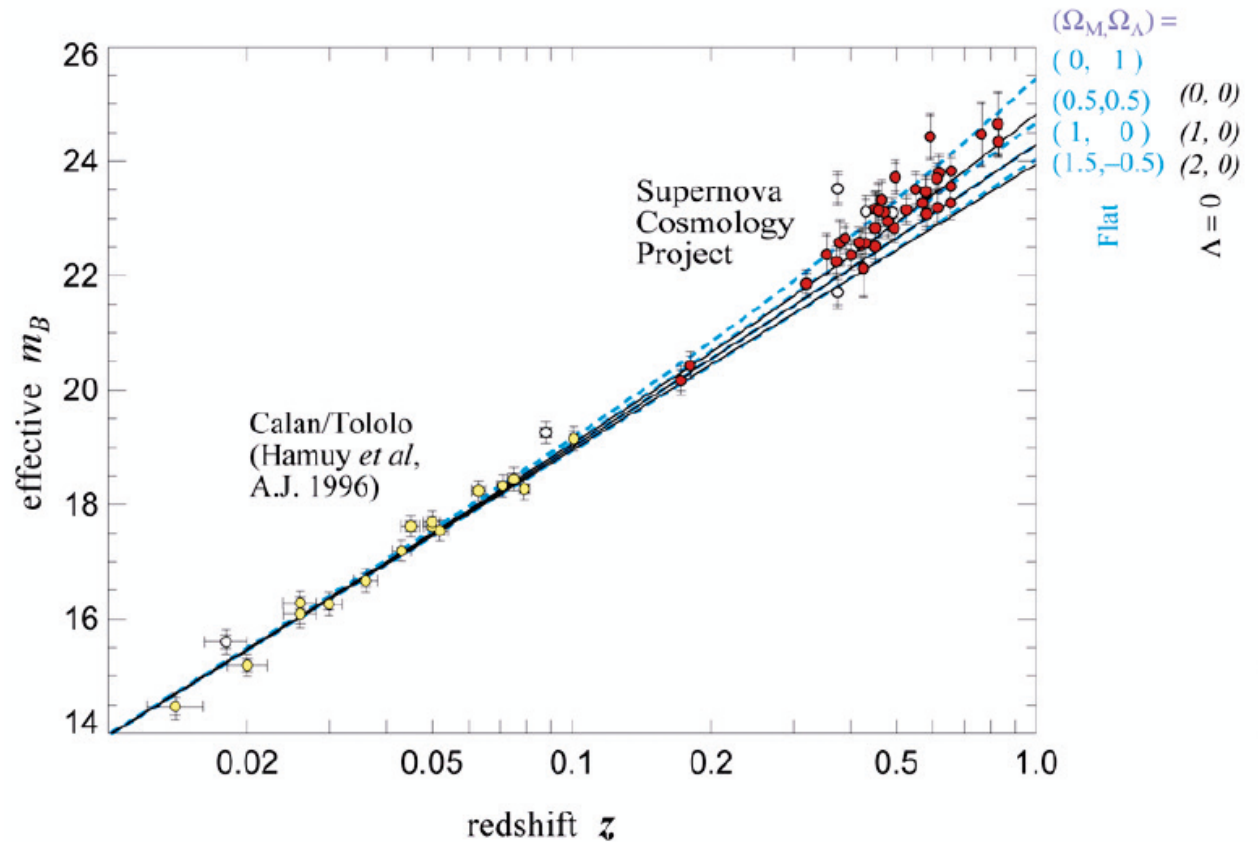


# Detailed observations of galaxies show that the expansion is accelerating

Type 1a supernovae are a good measure of the expansion

Use relationship between apparent brightness,  $m_B$ , versus redshift  $z$

$$1 + z = \lambda_{\text{observed}} / \lambda_{\text{emitted}}$$



S. Perlmutter, Rev. Mod. Phys. **84**, 1127 (2012).





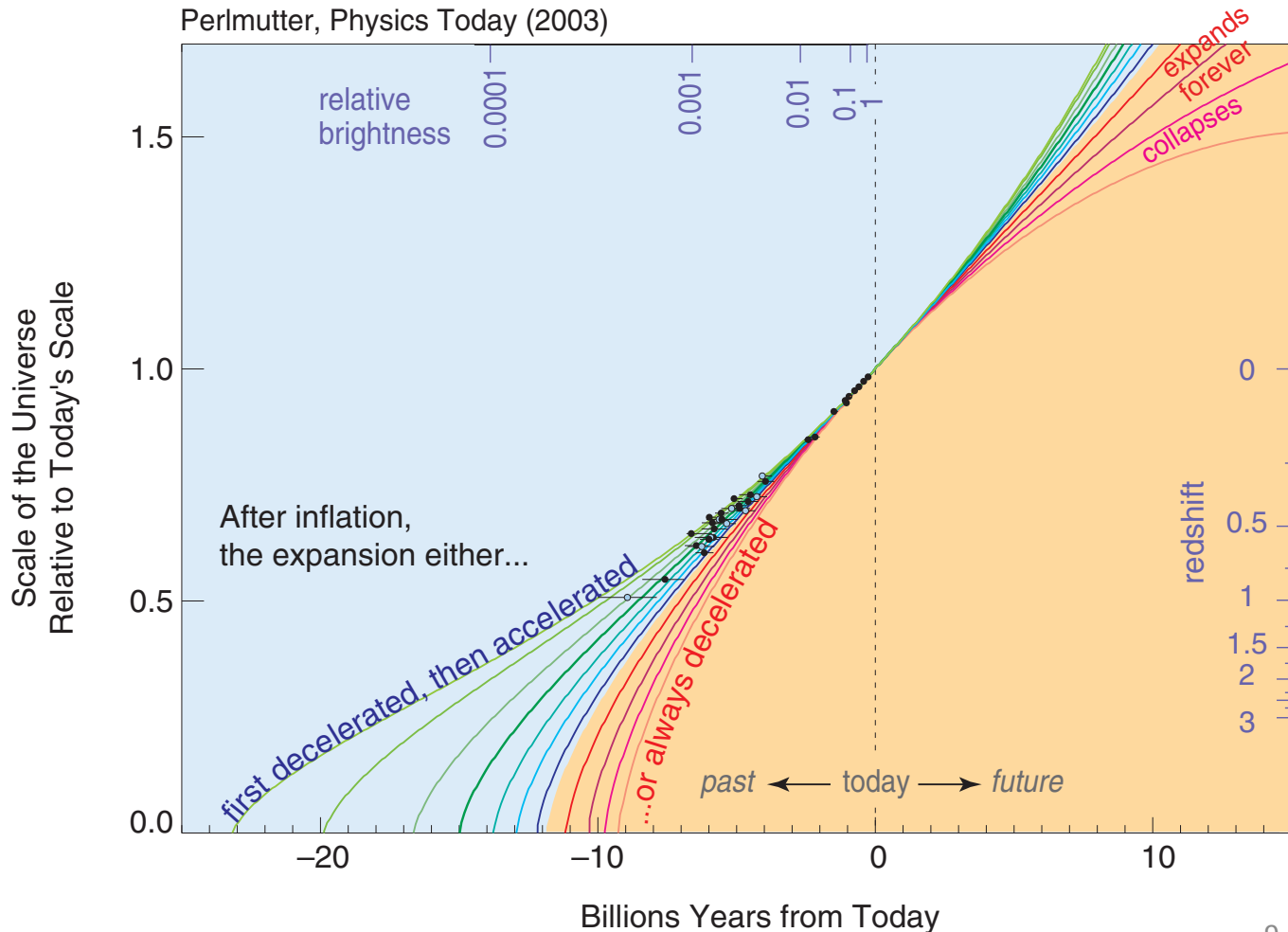
# The supernovae at large redshifts reveal that our universe expansion is accelerating

Observations consistent with an expansion that is accelerating

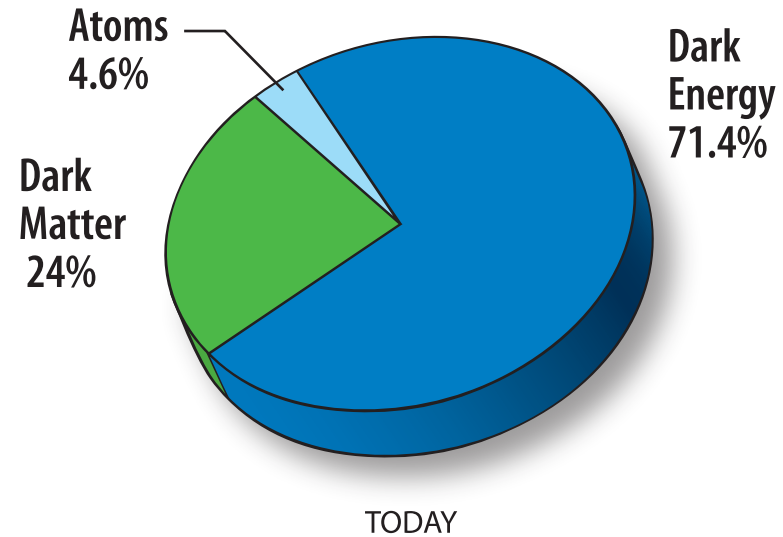
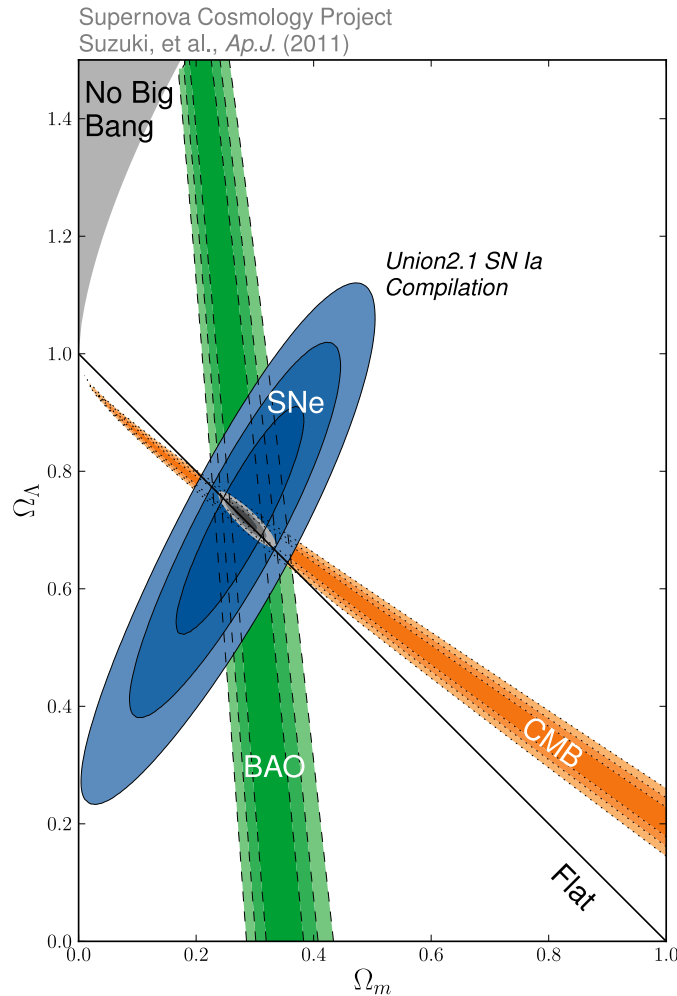
Adam Riess,  
Brian Schmidt,  
Saul Perlmutter  
shared 2011  
Nobel Prize in  
Physics

Expansion History of the Universe

Perlmutter, Physics Today (2003)



# These cosmological data show that 95% of our universe is not ordinary matter

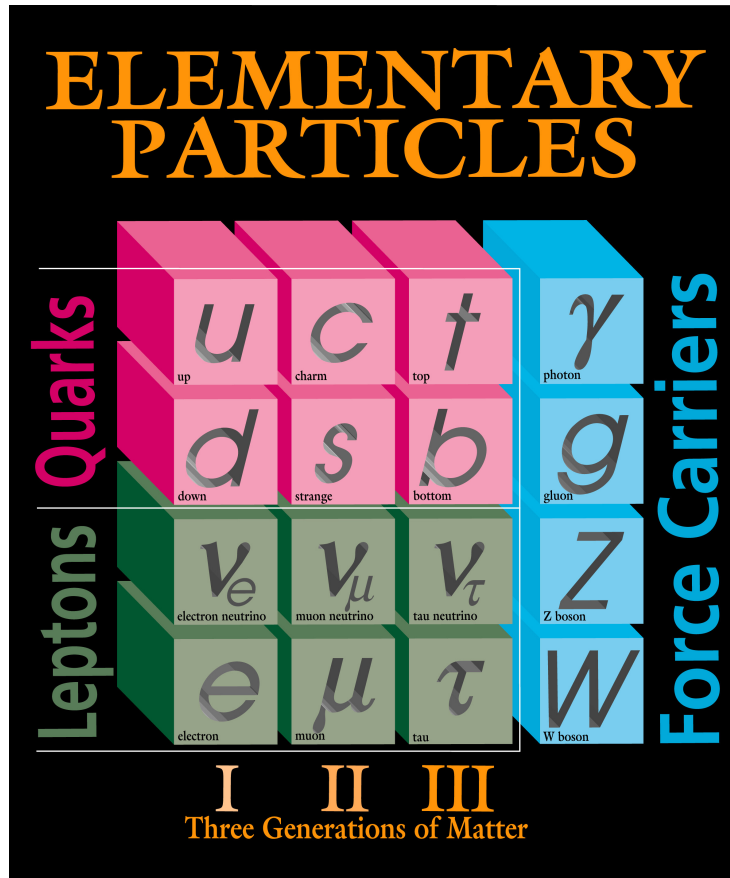


I've left out a host of observations, including

- Galactic rotation curves
- Dark matter lensing
- Nucleosynthesis
- Details about inflation
- Matter-antimatter asymmetry



# The development of the “Standard Model” of particle physics is a spectacular science success story



Fermilab 95-759

Predicted existence of

- Top quark (1995)
- Tau neutrino (2005)
- The Higgs field
  - and an associated particle

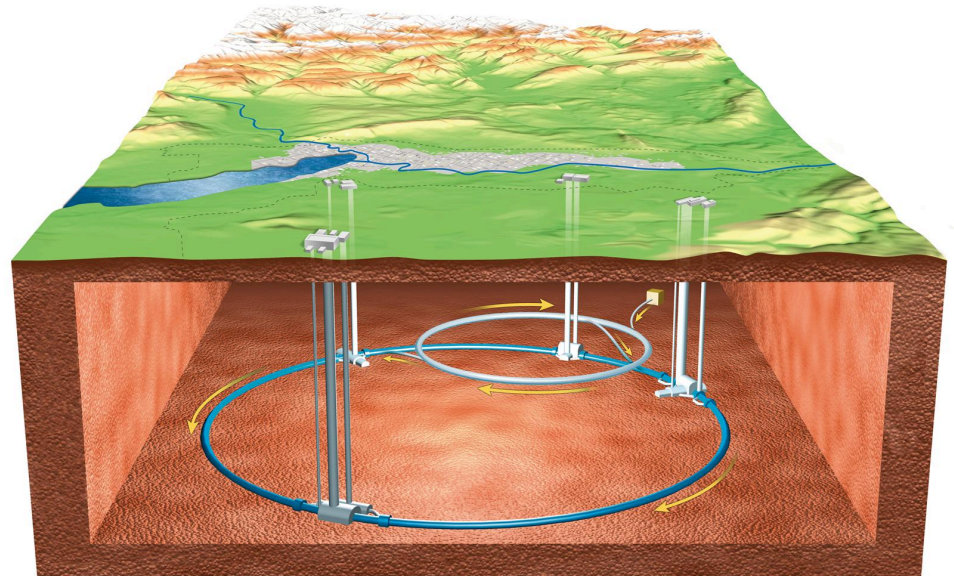


# Search for these rare particles required us to recreate the conditions last seen briefly after the Big Bang

Large Hadron Collider to produce proton-proton collisions at an energy of 14 TeV

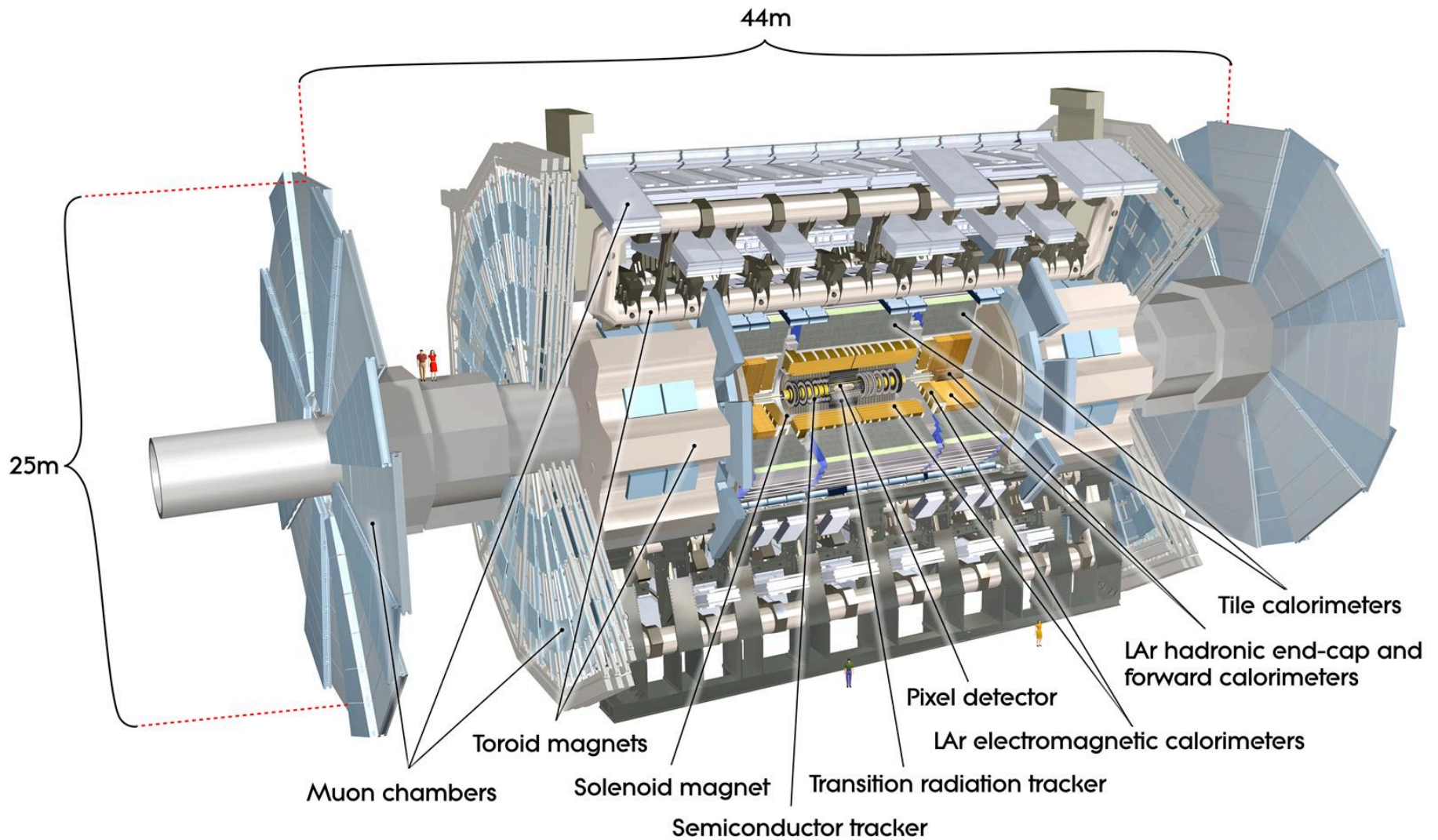
Equivalent to a temperature of  $\sim 10^{12}$  degrees K

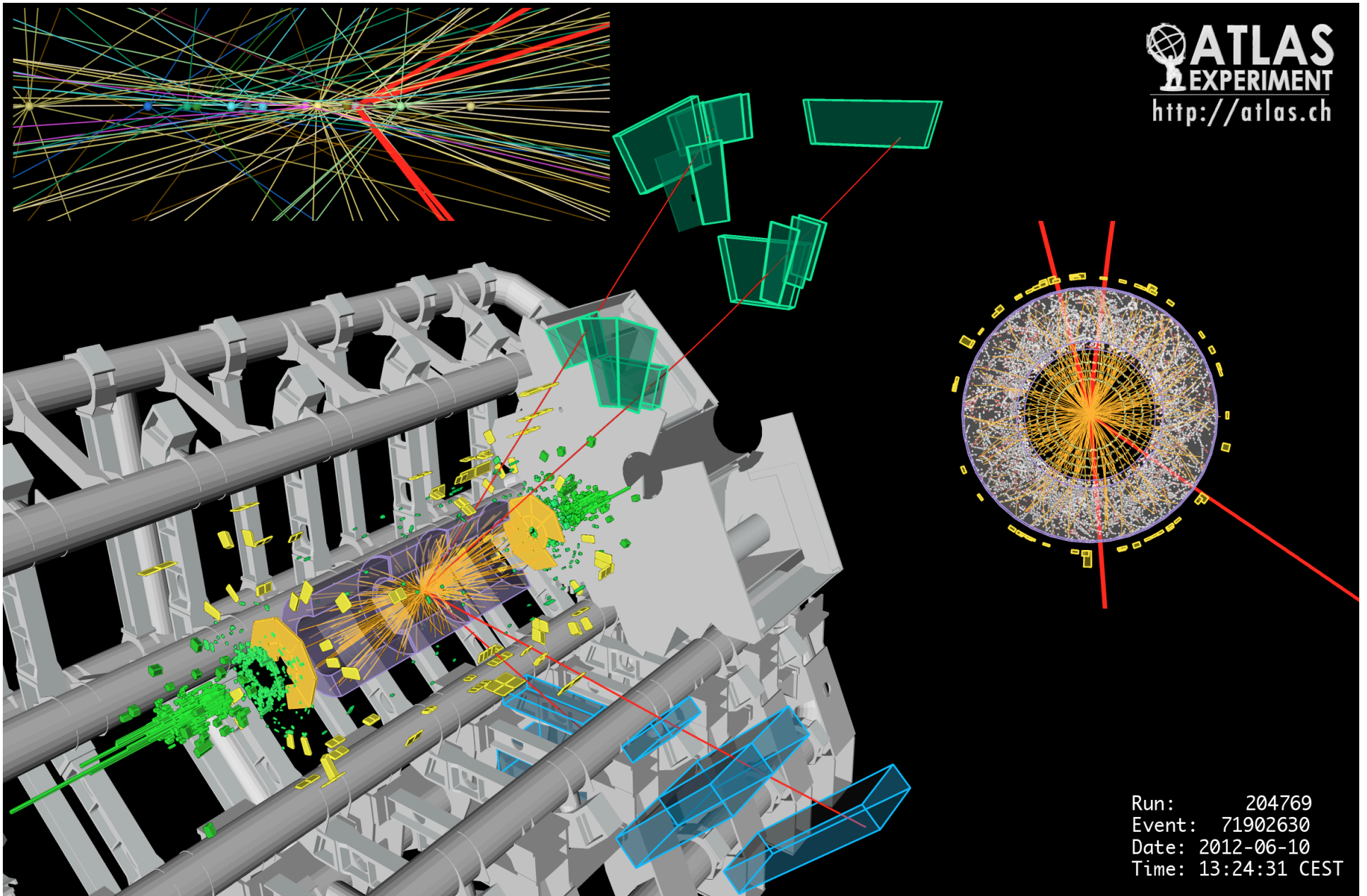
Takes us back to about  $10^{-6}$  s after Big Bang





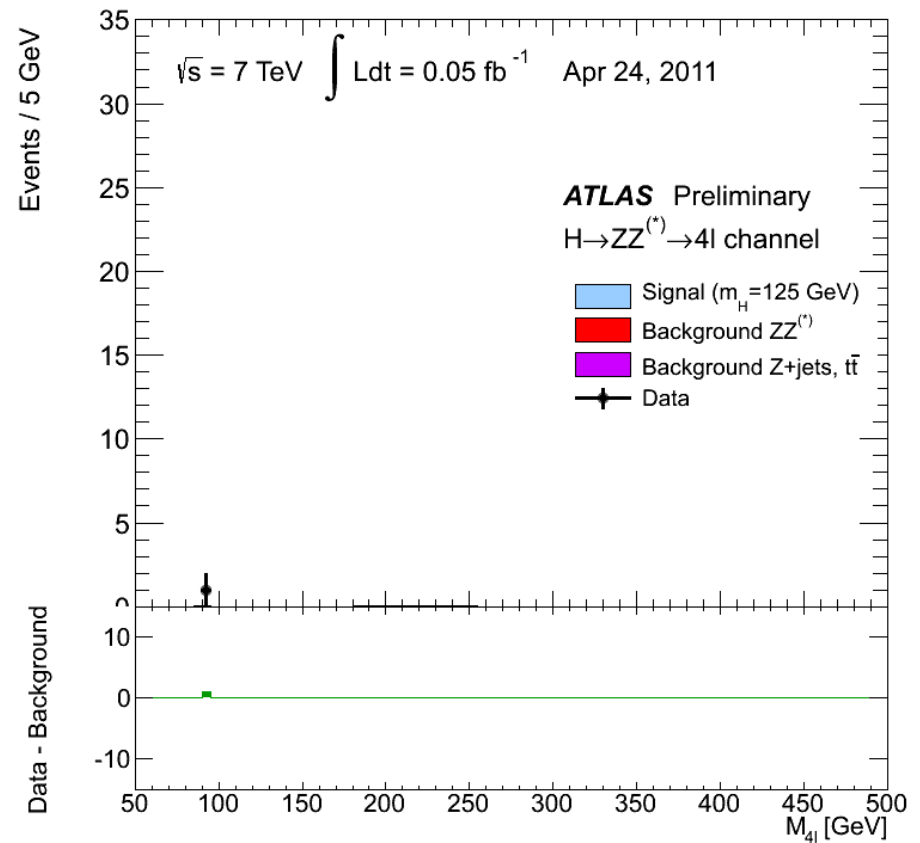
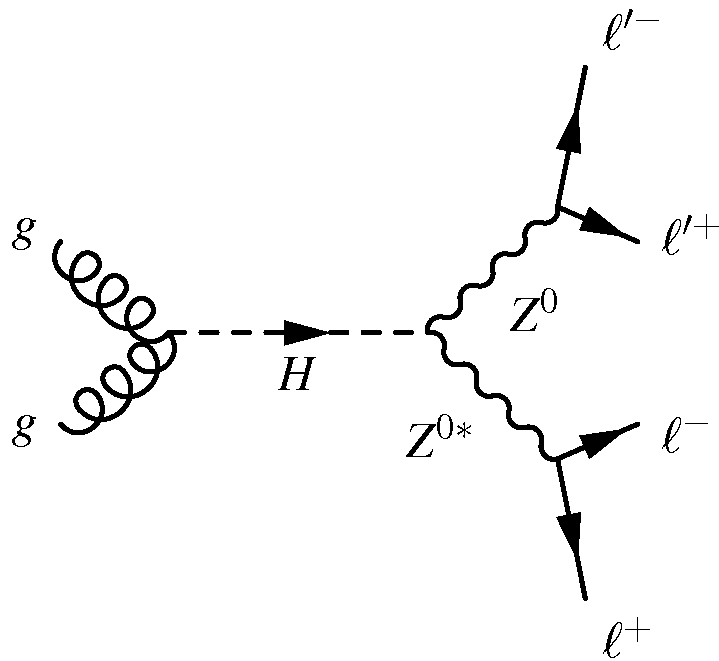
The collisions are observed with detectors that record all the debris created in each collision





# The experiments look for collisions where we see the decay products of a Higgs boson

One of the best modes to search for the Higgs boson is

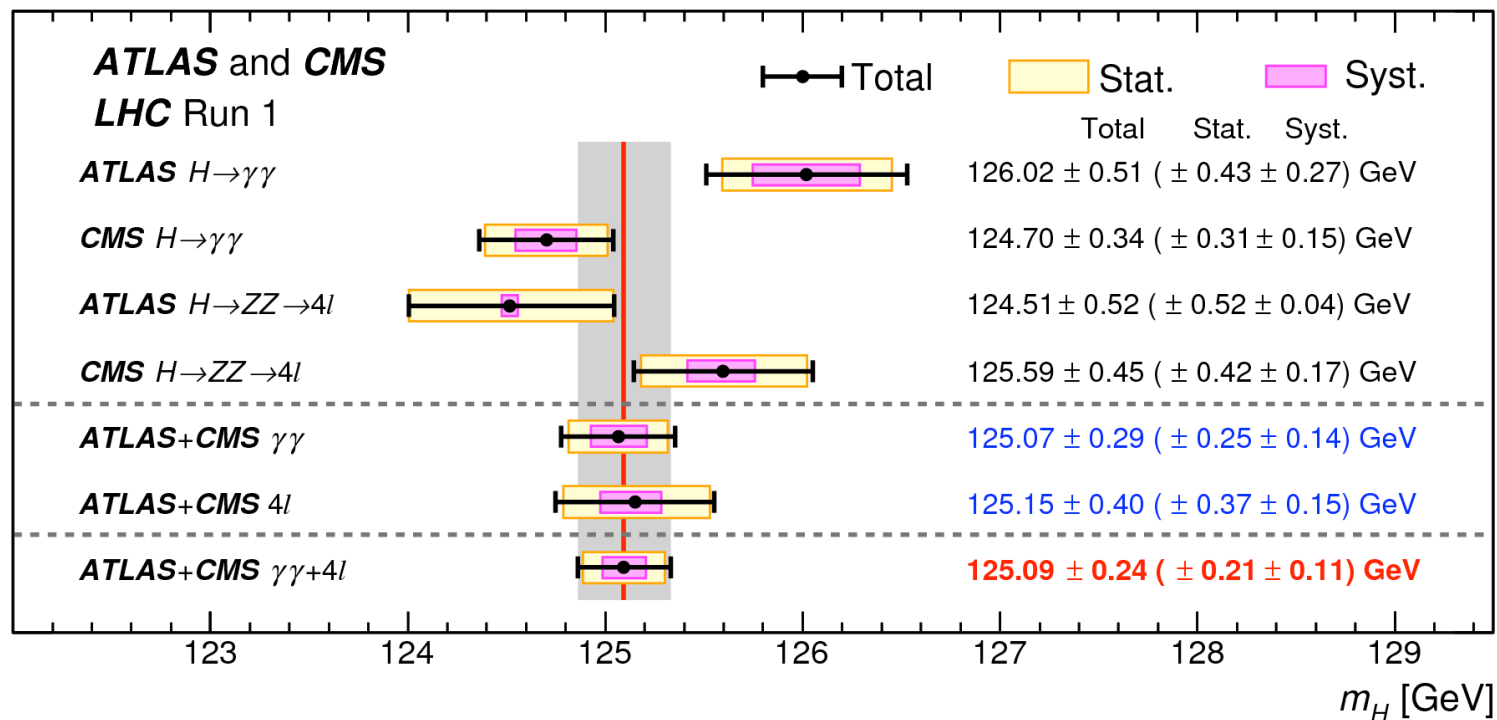




# Discovery of Higgs boson made in 2012 by both the CMS and ATLAS experiments

Observed a particle with a mass of  
 $125.09 \pm 0.24$  GeV

The ATLAS and CMS Collaborations, Phys. Rev. Lett. **114**, 191803 (2012).

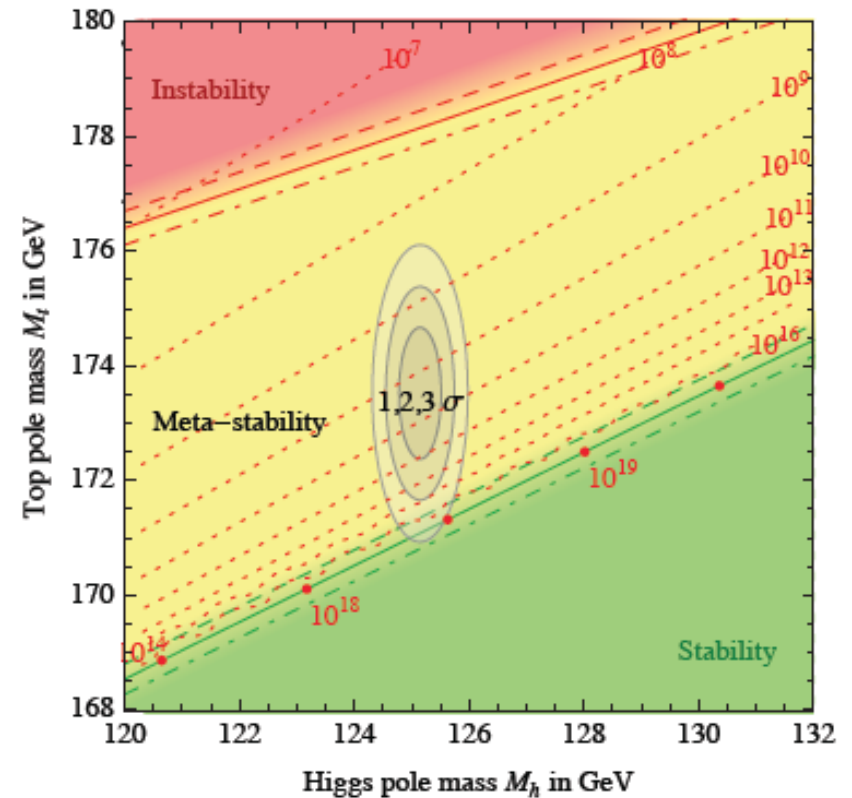


# These “standard models” of cosmology and of particle physics have become the paradigm

Explain the phenomena observed

But big questions remain

- What is Dark Matter
- Why do we live in a matter-dominated universe?
- What is Dark Energy?
- Can gravity be understood as quantum field theory?
- Is our Universe stable?



D. Buttazzo et al., JHEP (2012) 08, 098.



# The tie to the first creation story in Bereshit is striking

בְּרֵאשִׁית, בָּרָא אֱלֹהִים, אֵת הַשָּׁמַיִם, וְאֵת הָאָרֶץ  
וְהָאָרֶץ, הִיְתָה תֵהוֹ וְבֵהוּ וְחֹשֶׁךְ, עַל פְּנֵי תְהוֹם

Very hot, dense  
universe, disordered

*"In the beginning, God created the heaven and the earth. And the earth it was without a form and the darkness covered the face of the deep..."*

וַיֹּאמֶר אֱלֹהִים, יְהִי אֹר; וַיְהִי אֹר;  
וַיְהִי עֶרֶב וַיְהִי בֹקֶר, יוֹם אֶחָד

Photons take over  
within ~1 s

*"And God said: 'Let there be light.' And there was light...And there was evening and there was morning, one day.*

וַיֹּאמֶר אֱלֹהִים, יְהִי רָקִיעַ בְּתוֹךְ הַמַּיִם, וַיְהִי מִבְדִּיל, בֵּין מַיִם  
לְמַיִם

Primordial matter  
condenses into H & He

וַיְהִי עֶרֶב וַיְהִי בֹקֶר, יוֹם שֵׁנִי

*And God said: 'Let there be a firmament in the midst of the waters, and let it separate the waters from the waters....And there was evening and there was morning, a second day.*



## But a sympathetic reading does not give the Biblical story more credibility

- A scientific view requires one to be skeptical of perceived correlations
- The biblical narrative – with its contradictions and difficulties with interpretation – should not be confused with scientific evidence
- But the scientific and biblical account speak to desire to understand our world
- A scientific approach requires commitment to
  - Collect evidence (objectively!)
  - Independent replication
  - Develop model (theorize)
  - Then repeat



The parallel does provide a framework for discussion about the relationship

## THE GENESIS PROJECT: SCIENCE MEETS JEWISH THOUGHT

An exciting new series. Leading Canadian scientists and Jewish thinkers will join us in exploring a modern interpretation of the Seven Days of Creation. No science background required—just bring your curiosity! Four programs in 5777 (2016-2017), three more in 5778 (2017-2018).

Thursday, October 20, 2016  
from 7:00 to 8:30 PM  
at Beth Tzedec Congregation

### Day One—בראשית and the Big Bang: Is God a Particle Physicist?

In the beginning, there was Heaven and Earth—and the Higgs boson. Does Torah contemplate the Big Bang? Does The Eternal One work through physics?

Saturday, December 3, 2016  
from 6:00 to 7:30 PM  
at Temple Emanu-El

### Day Two—The Blessing of Difference: Havdalah, Science and the Senses

An interactive Havdalah service with hands-on science experiments for everyone. Young families particularly welcome. Pizza and snacks.

Thursday, February 9, 2017  
from 7:00 to 8:30 PM  
at Beth Tzedec Congregation

### Day Three—A-Life: Worth Living?

Life begins on the Third Day of בראשית. Soon it will be possible to create artificial life, “A-Life”: designer cells and tissue, and, eventually, entire organisms. What ethical challenges does this pose?

Thursday, April 20, 2017  
from 7:00 to 8:30 PM  
at Temple Emanu-El

### Day Four—The God of Other Planets

On the Fourth Day of בראשית, God creates sun, moon and stars. There are over 3,000 known planets in the universe, many of which might support life. What happens to our notion of ourselves when we discover life elsewhere? How will Judaism respond to another planetary Creation story?

*Made possible thanks to contributions in memory of Jonathan Steiner <sup>21</sup>*

This series is a joint project of Beth Tzedec Congregation and Temple Emanu-El. It is sponsored by the Scientists in Synagogues project, which is organized by Sinai and Synapses in New York and the American Association for the Advancement of Science program of Dialogue on Science, Ethics, and Religion in Washington, DC. Support for the program comes from Clal—The National Jewish Center for Learning and Leadership in New York through the John Templeton Foundation, along with other donors.



# I have my own personal views on the relationship between science and Judaism

I am in awe of the world we live in.

I am deeply engaged in understanding our world.

I understand the power that the practice of science brings to this task.

I recognize our universe has mysteries that science—as we practice it—may never unravel.

The study of Torah reveals elements of who I am beyond my identity as a scientist.

Judaism provides me with a structure that allows me to safely think about what I don't know.

It gives me a language and framework to understand and value my human relationships, both intimate and casual.



# Of course, there are a host of metaphysical questions that I have avoided, but are relevant.

- Was the universe created *ex nihilo*?
- Why something from nothing?
- Is there only one universe, or are we part of a larger “multiverse” scenario?
- How do we understand the success of quantum mechanics—with its “spooky action at a distance”?

