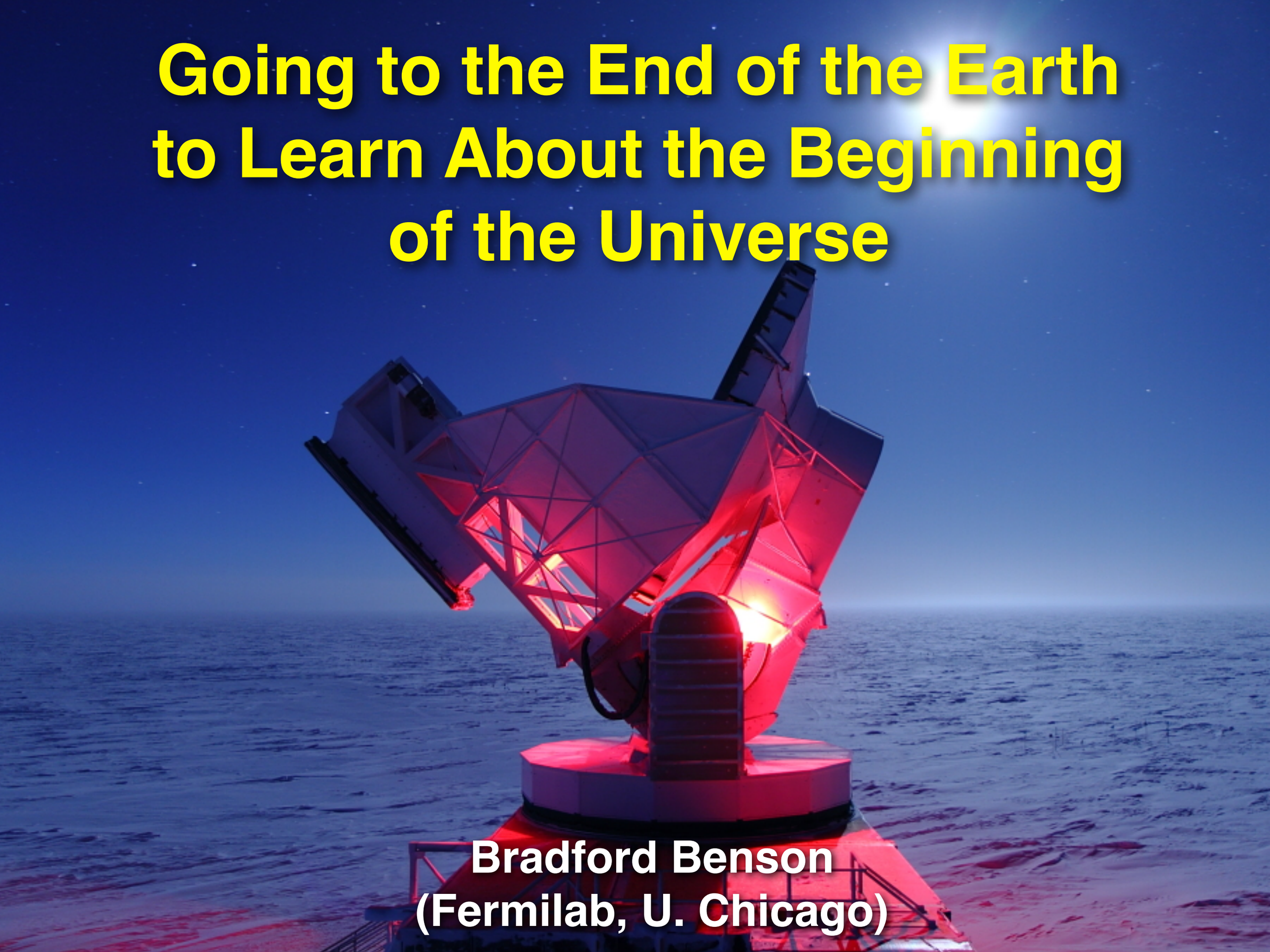
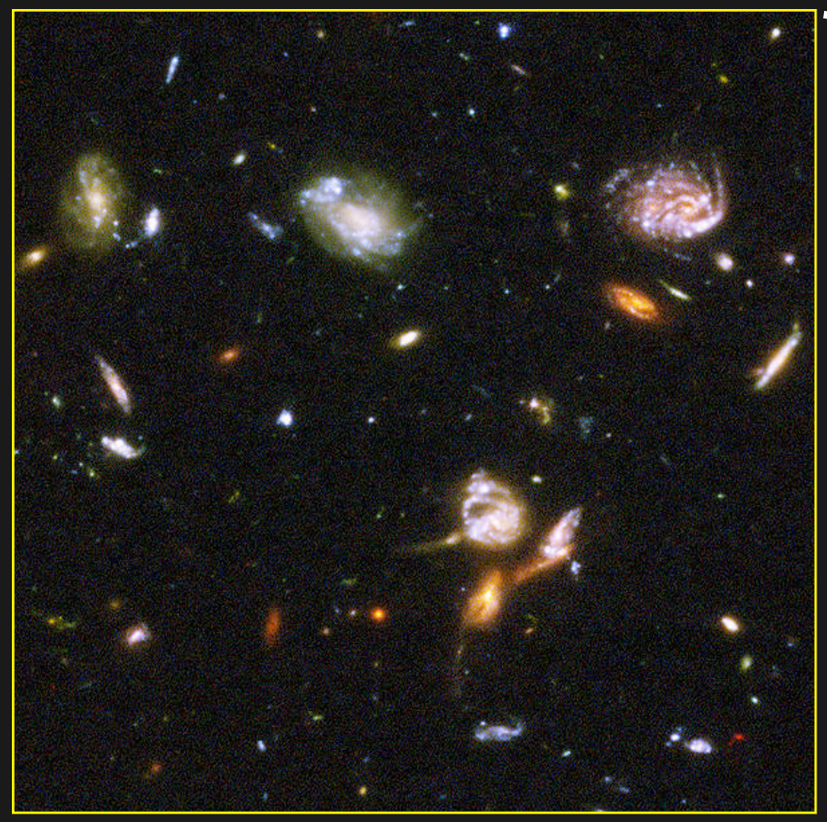
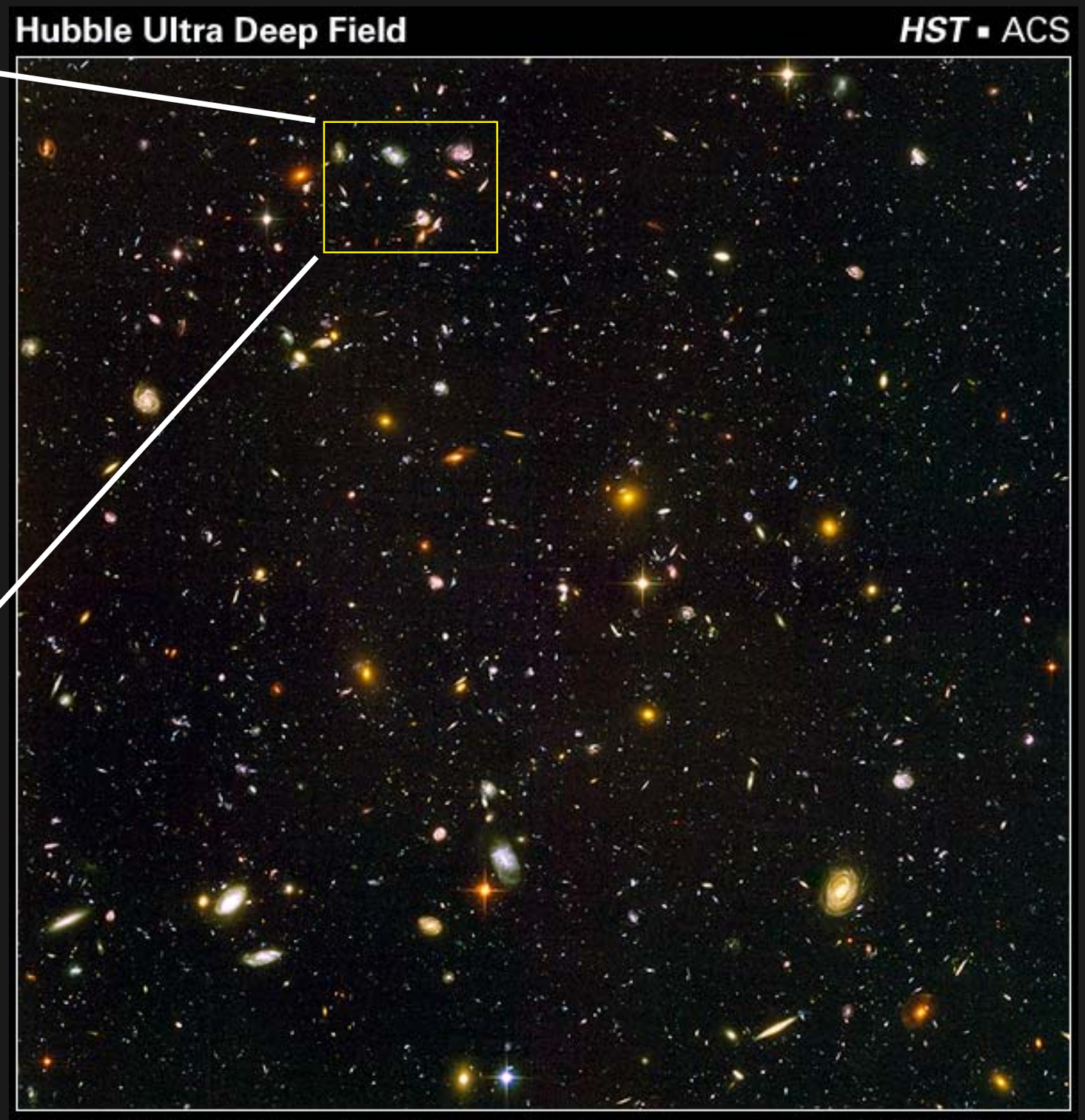
Going to the End of the Earth to Learn About the Beginning of the Universe



Bradford Benson
(Fermilab, U. Chicago)

The Hubble (Space Telescope) Deep Field





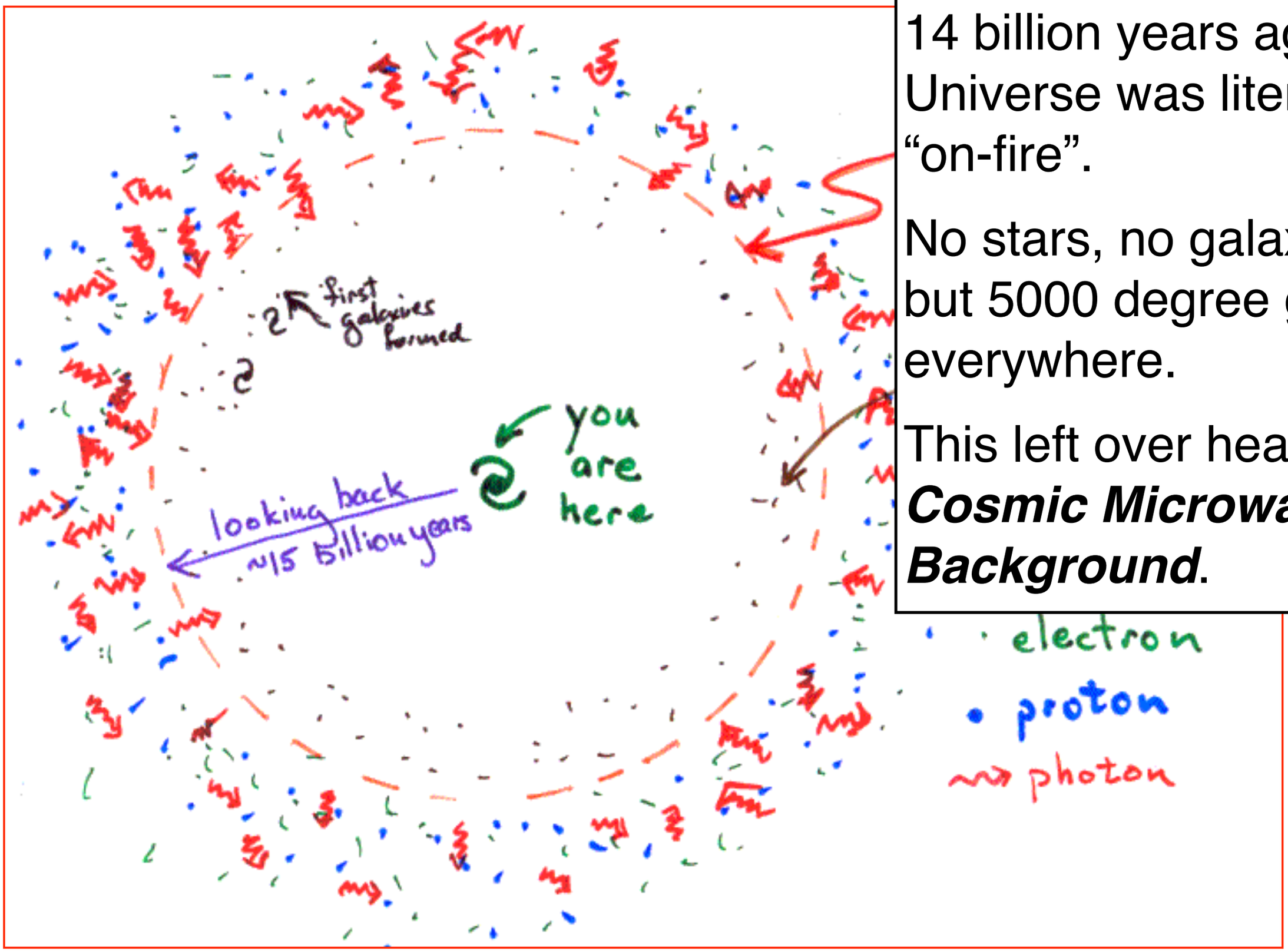
Deepest optical image ever taken
Over 10,000 galaxies in this image!

The Birth of the Big Bang

- Belgian Catholic Priest, Georges Lemaitre used Einstein's Theory of General Relativity to describe an "Expanding Universe"
- In 1927 published a model for a Universe which began as a "***primeval atom***" that was:
  - ***hot and dense,***
  - ***expanding, from an initial "explosion"***
- By 1933, Einstein called Lemaitre's theory :

  "This is the most beautiful and satisfactory explanation of creation to which I have ever listened."

Cartoon of a Big Bang Universe

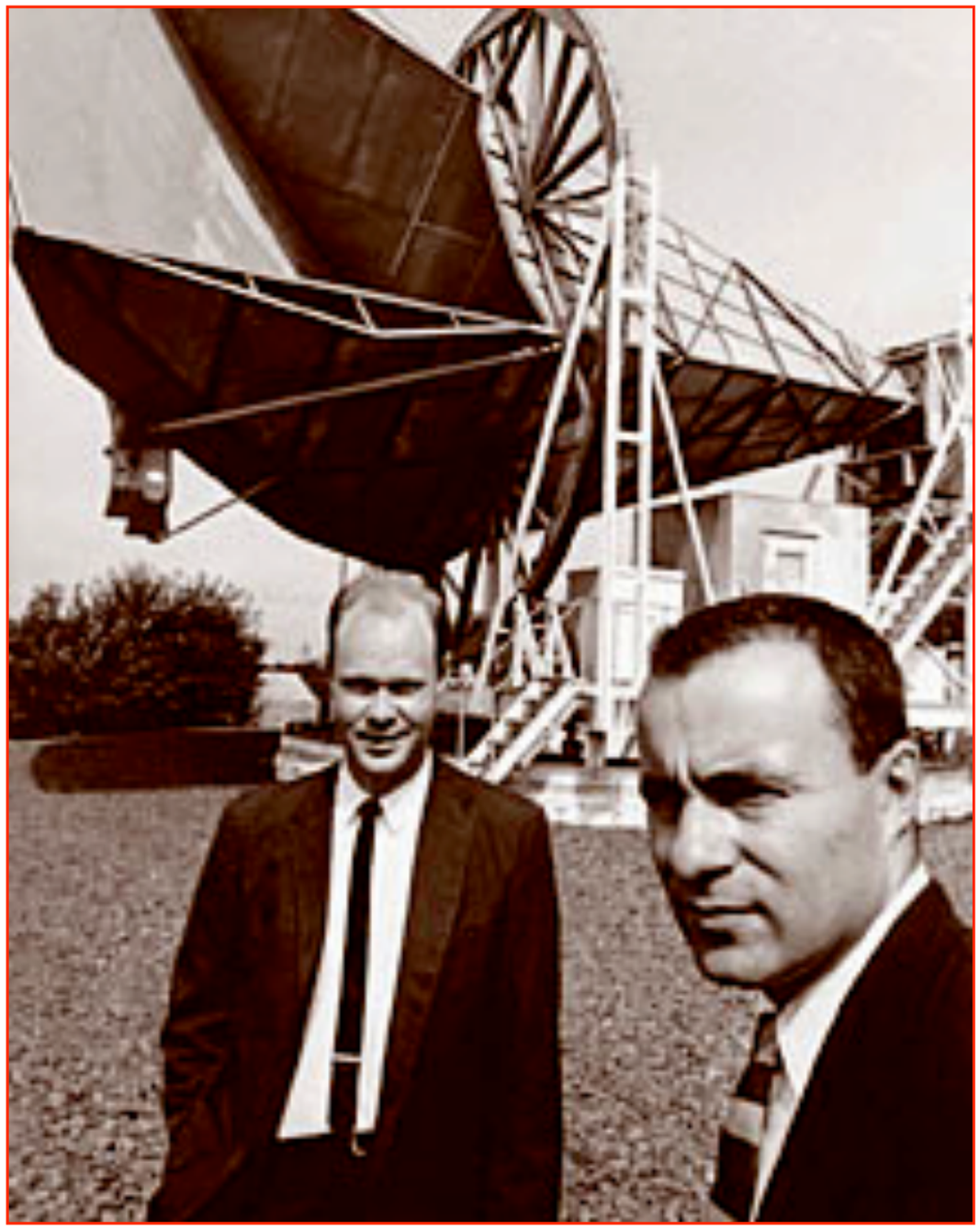


14 billion years ago the Universe was literally “on-fire”.

No stars, no galaxies, but 5000 degree gas everywhere.

This left over heat is the ***Cosmic Microwave Background***.

1965: Discovery of the Cosmic Microwave Background (CMB)



Arno Penzias & Robert Wilson in front of the 20 ft Bell Labs antenna used to discover the microwave background in 1965

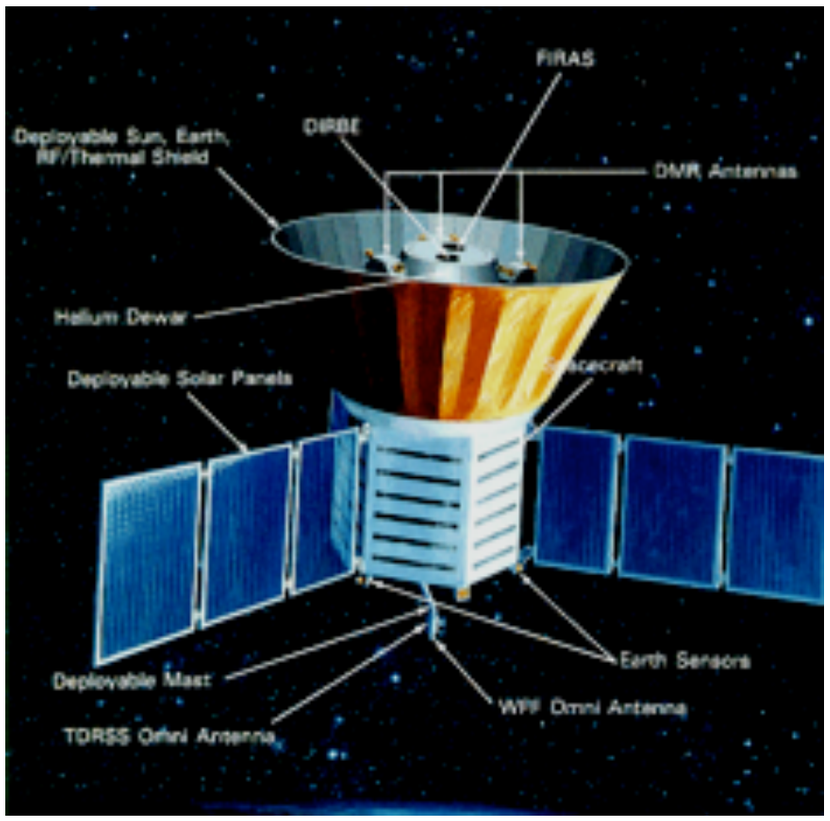
"Smoking Gun" evidence for the Big Bang

Received 1978 Nobel Prize

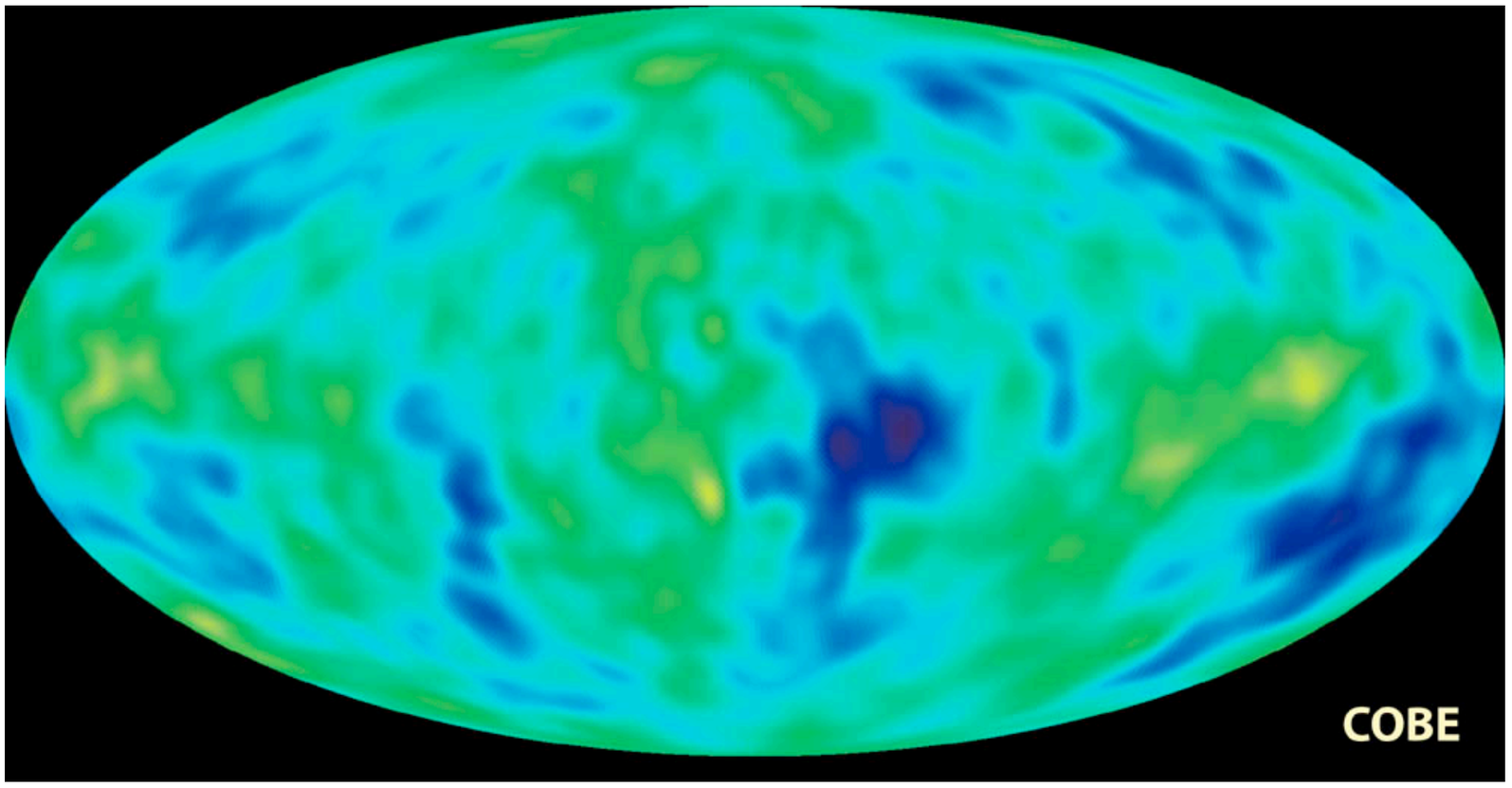
Enormous Impact on Cosmology

1992: Structure in Background Discovered

COBE Satelite
(launched 1987)



Map of the CMB



1 part in 100,000 variation
of ~3 Kelvin radiation

COBE team leaders
John Mather & George Smoot
Received 2006 Nobel Prize

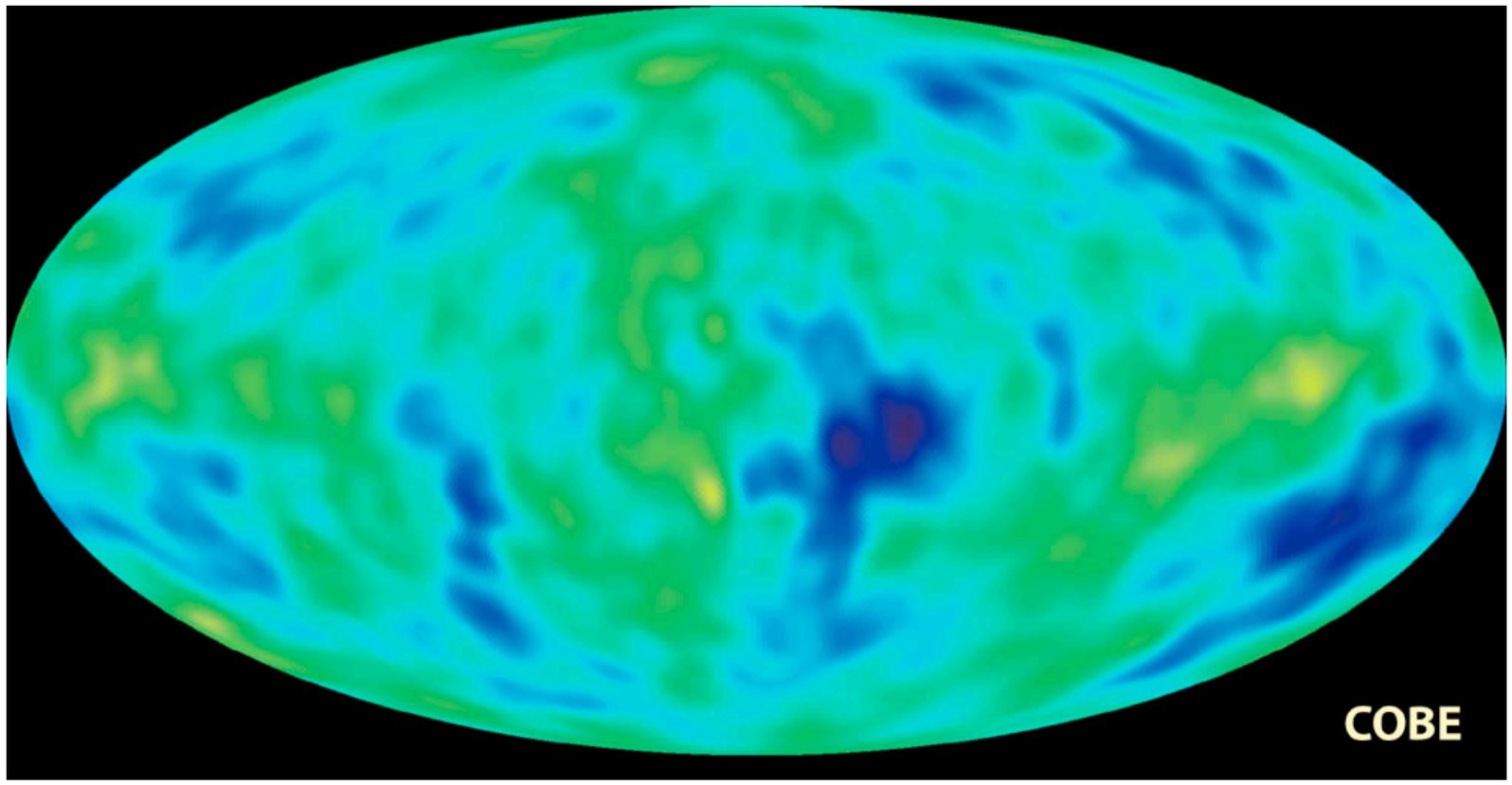
The CMB is a "Baby" Picture of the Universe

THE TIMES

25 April 1992

On the CMB, Prof. Stephen Hawking of Cambridge University, not usually noted for overstatement, said:

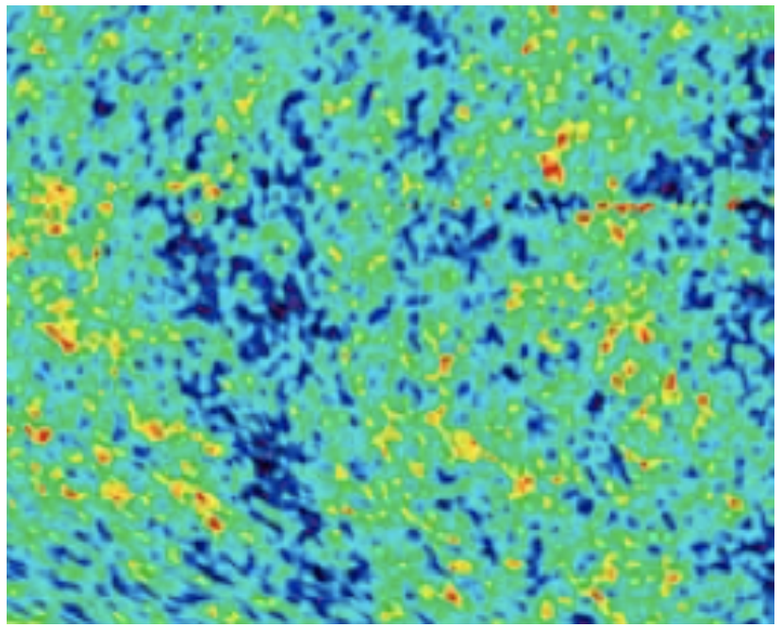
"It is the discovery of the century, if not of all time."



(slide modified from Ned Wright)

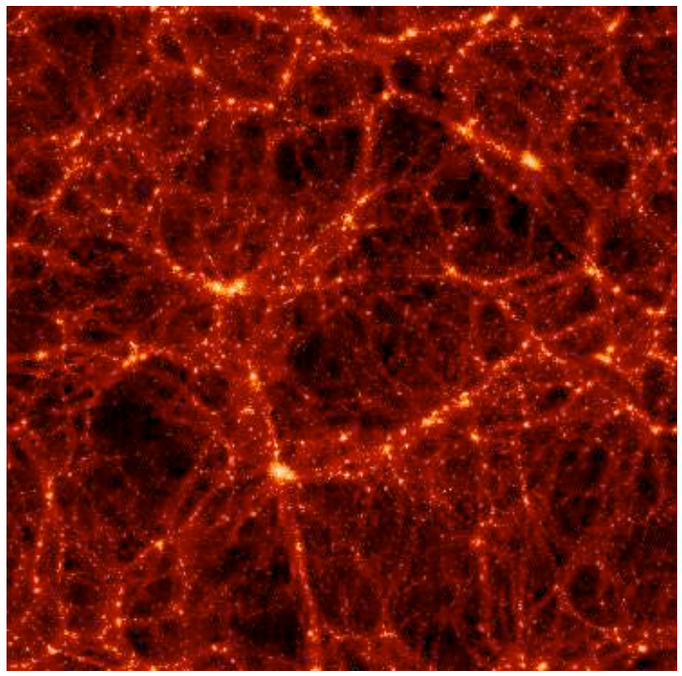
Structure in the Universe in People Equivalent Lifetimes

Cosmic Microwave Background



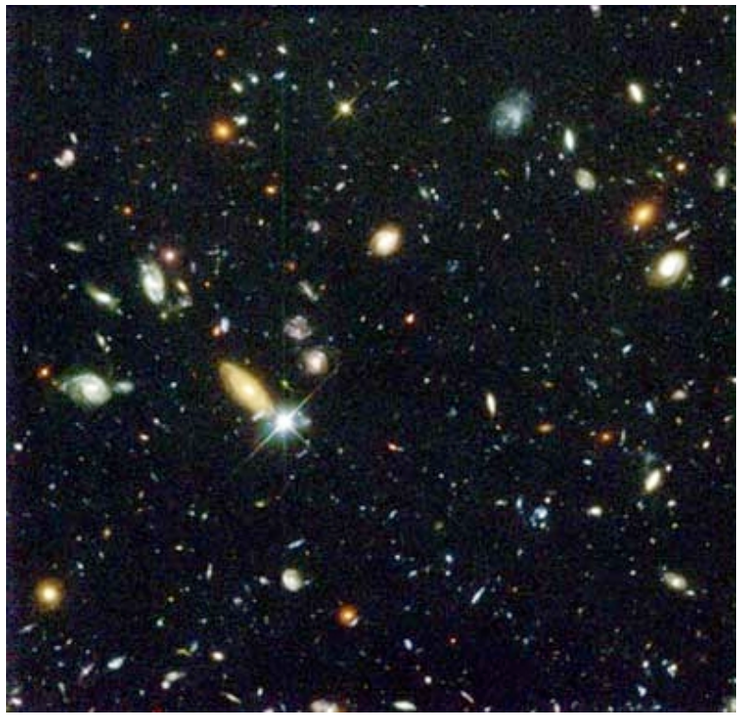
First Several Minutes

Structure Formation

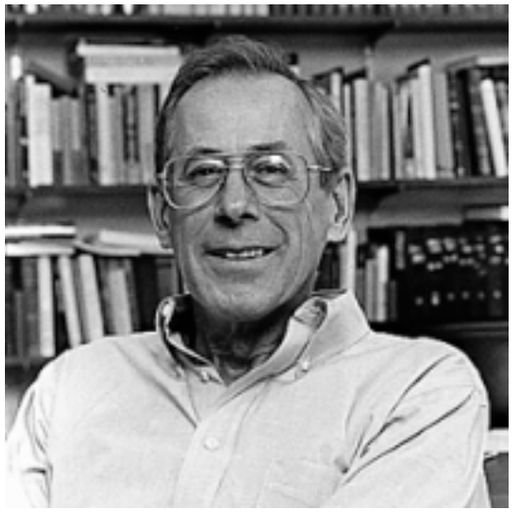


First Few Years

Galaxies and Clusters of Galaxies

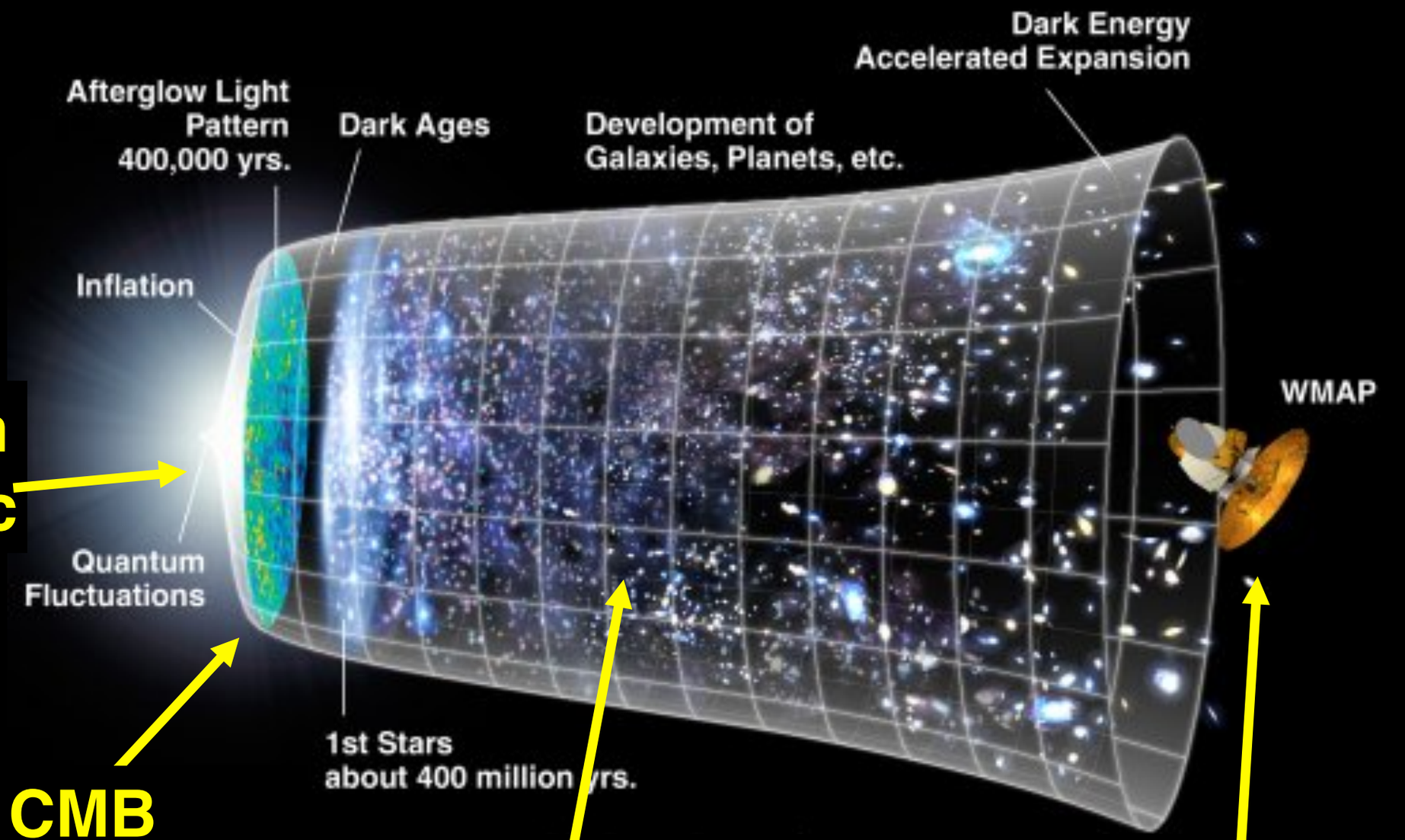


Retirement



The Standard Cosmological Model

(time since Big Bang)



Inflation
10^{-34} sec

The CMB
400,000 years

Peak in
Star Formation
~3 billion years
(3,000,000,000)

Today
14 billion years
(14,000,000,000)

graphic from NASA/WMAP

The South Pole is the best place in the world to observe the CMB

South Pole Environment

- **High Altitude (~10,000 ft)**
- **Extremely Dry**
  - Precipitable water vapor in winter is ~4x less than Chile, ~6x less than Hawaii
- **Stable Atmosphere**
  - During 6-month night, the sky is ~30x more stable than ALMA-site in Chile