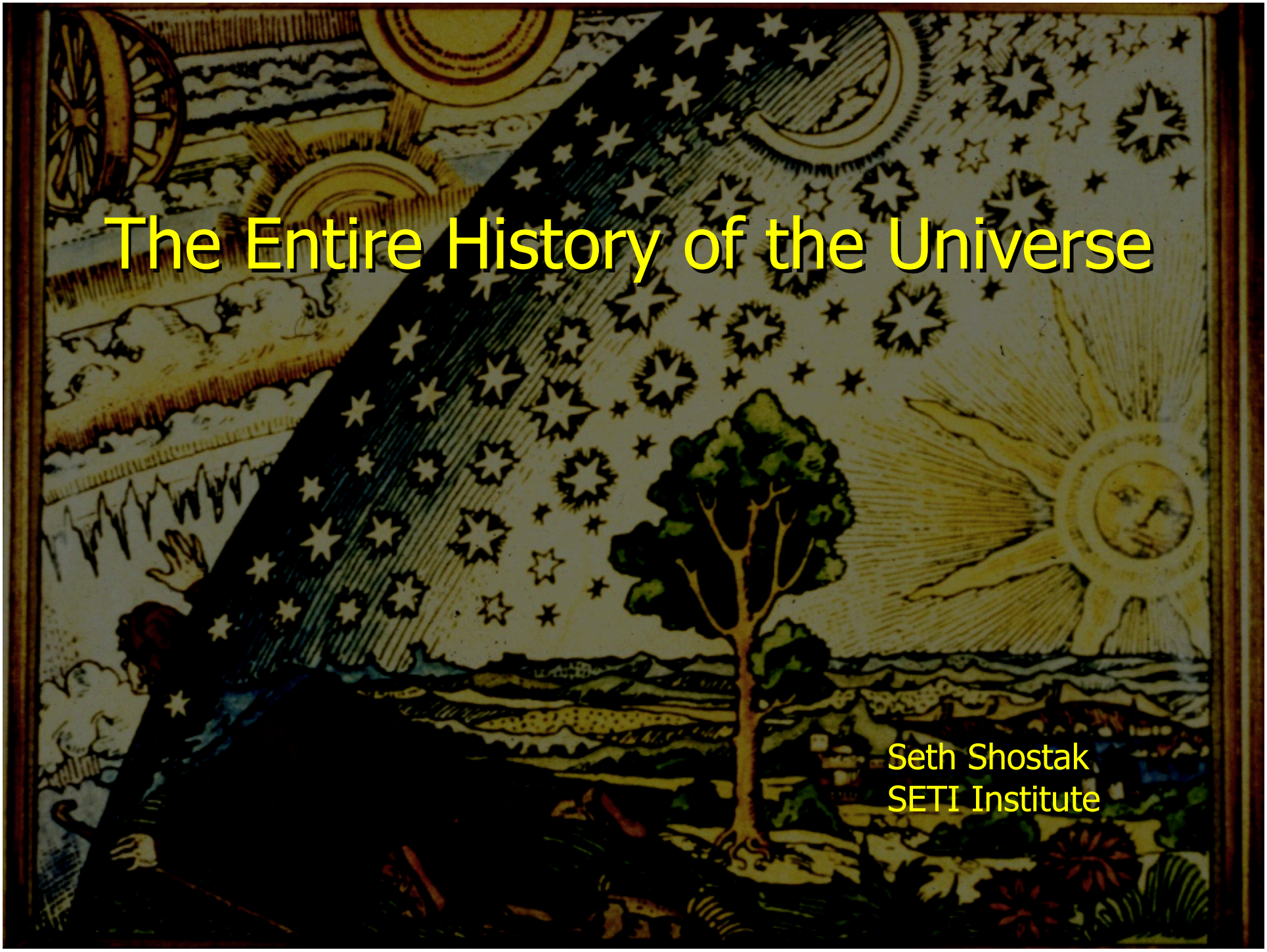
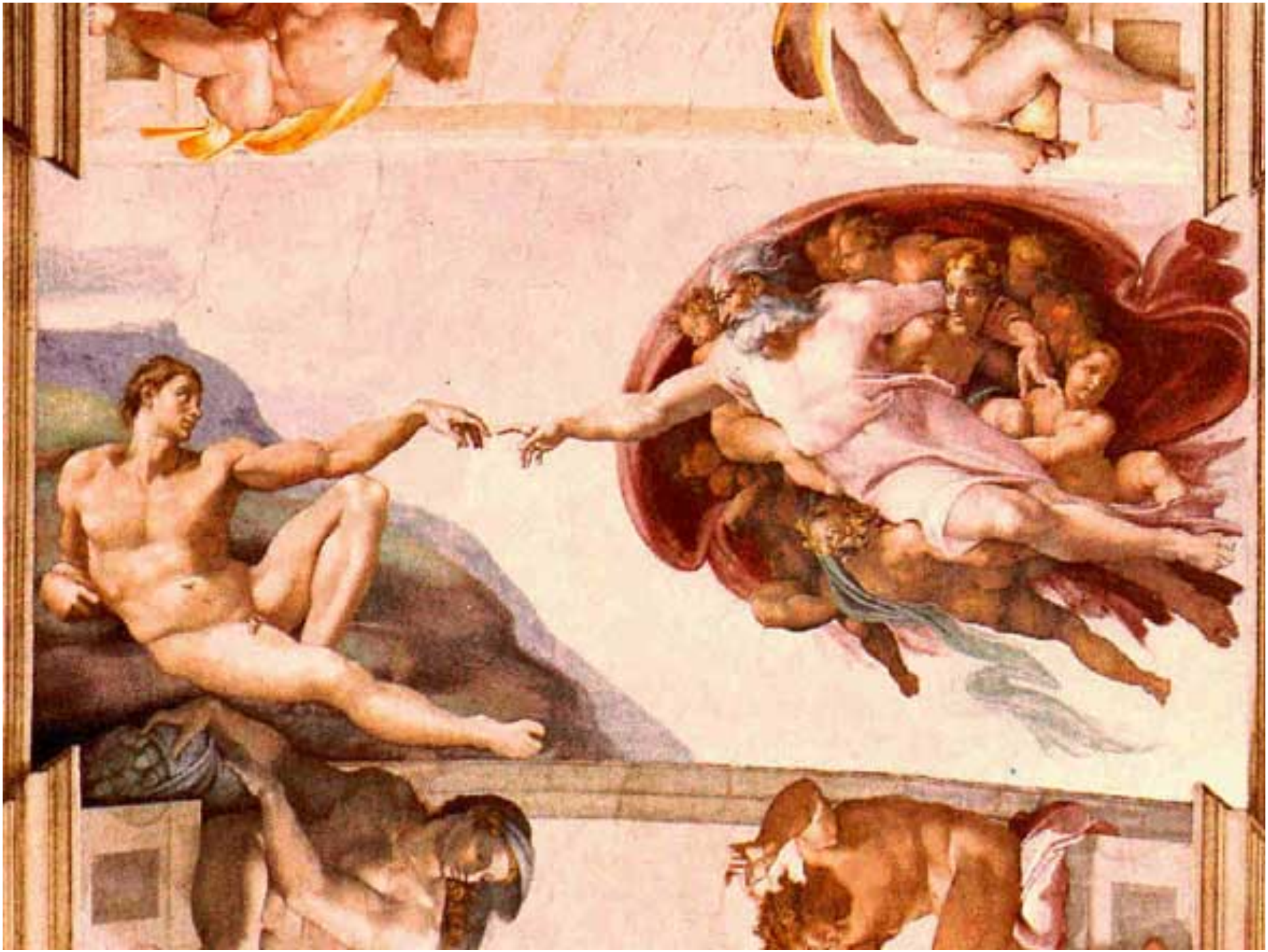
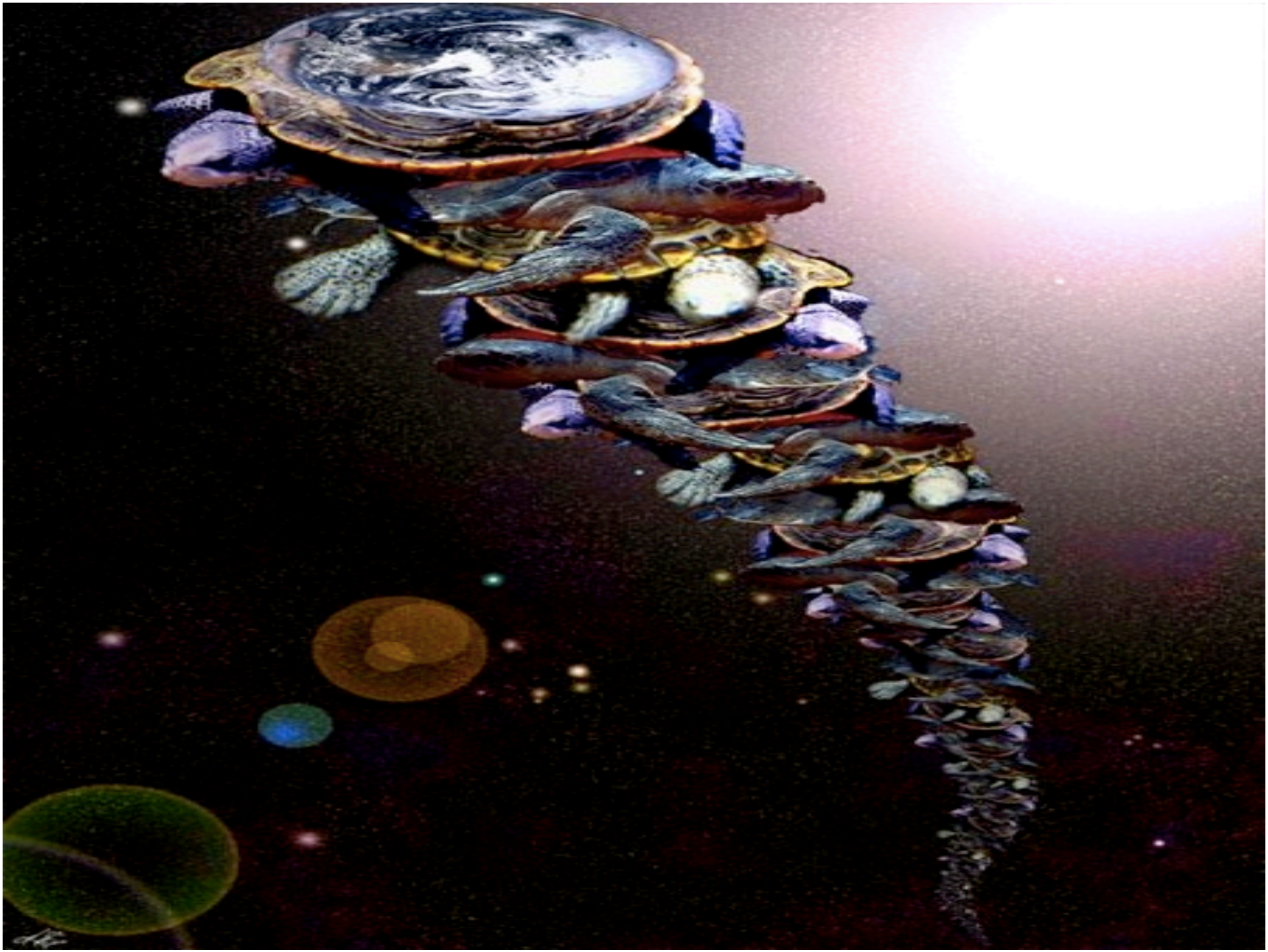
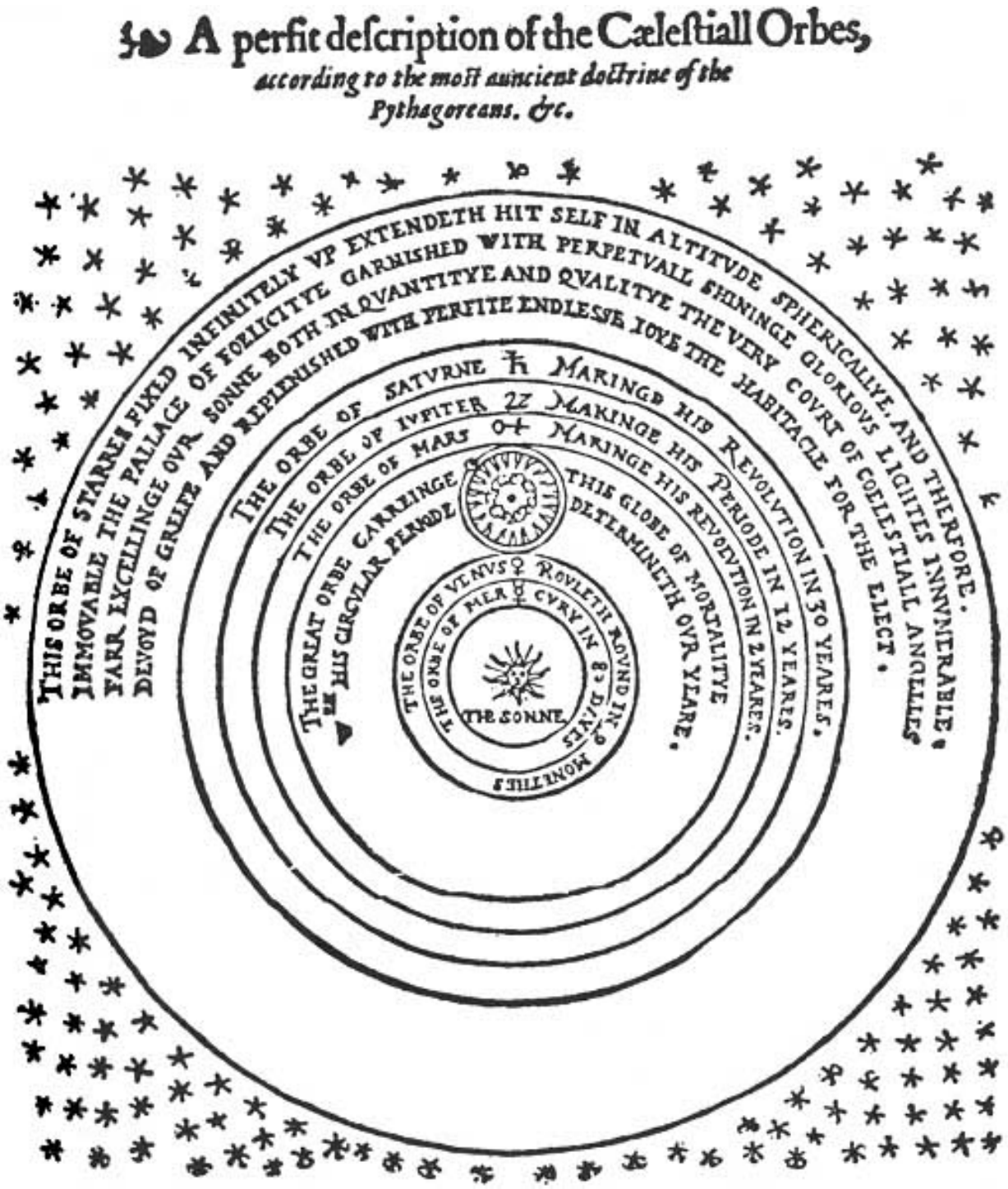
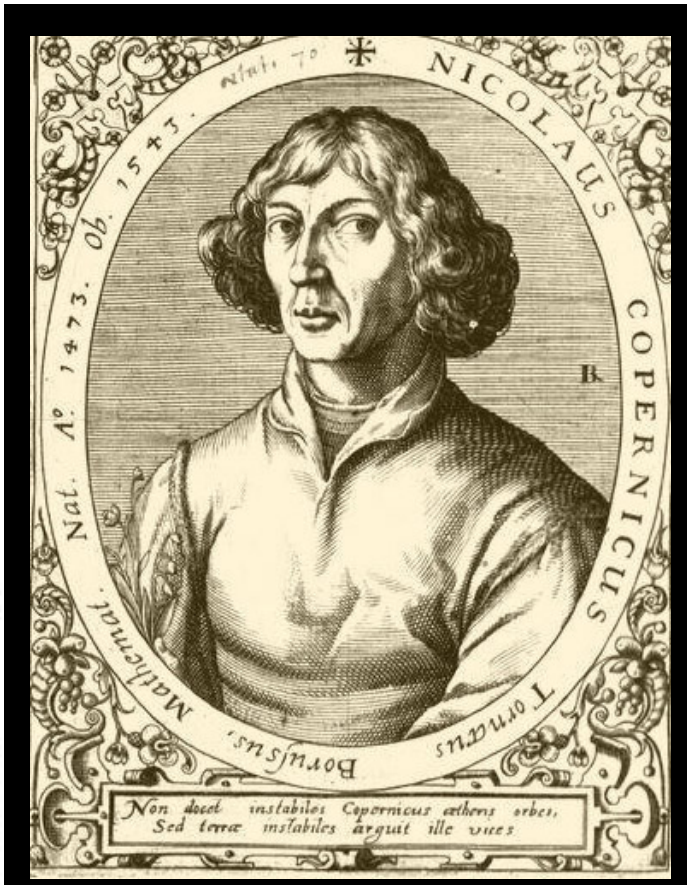

The Entire History of the Universe
Seth Shostak
SETI Institute









Nicolaus Copernicus

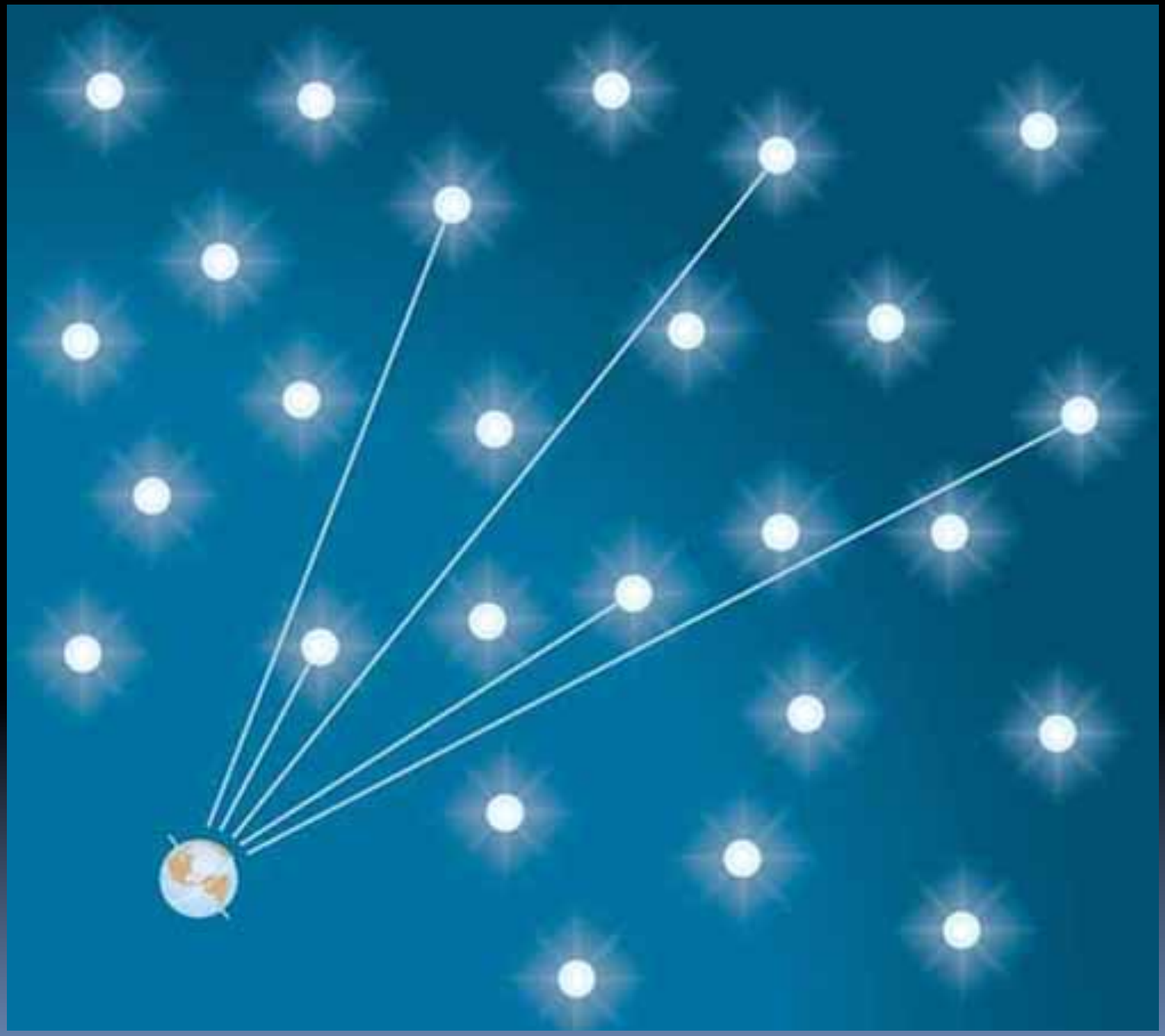
(1543)

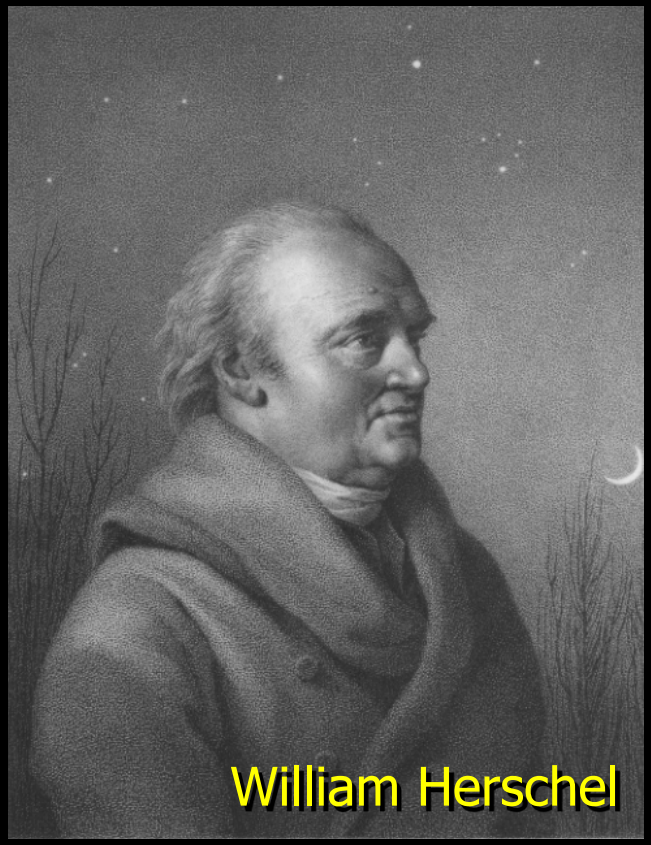

But what was beyond the solar system?


An immediate problem: the sky was dark at night!

Olbers' Paradox

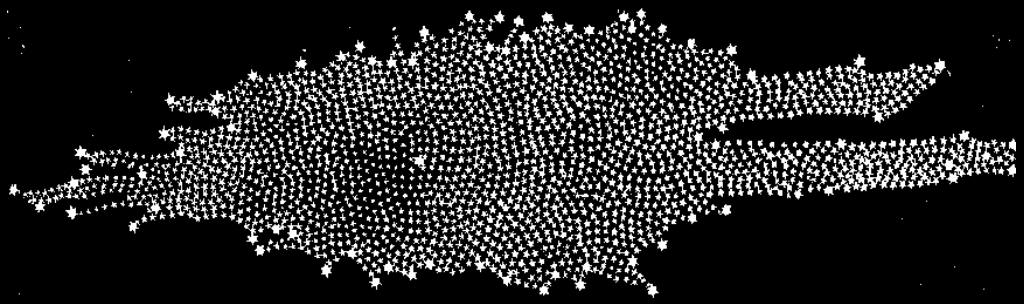
(1826)

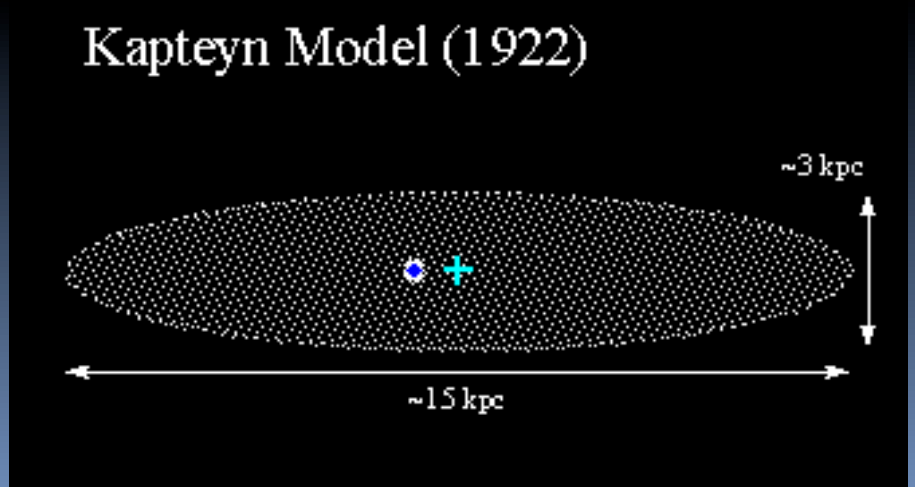




William Herschel

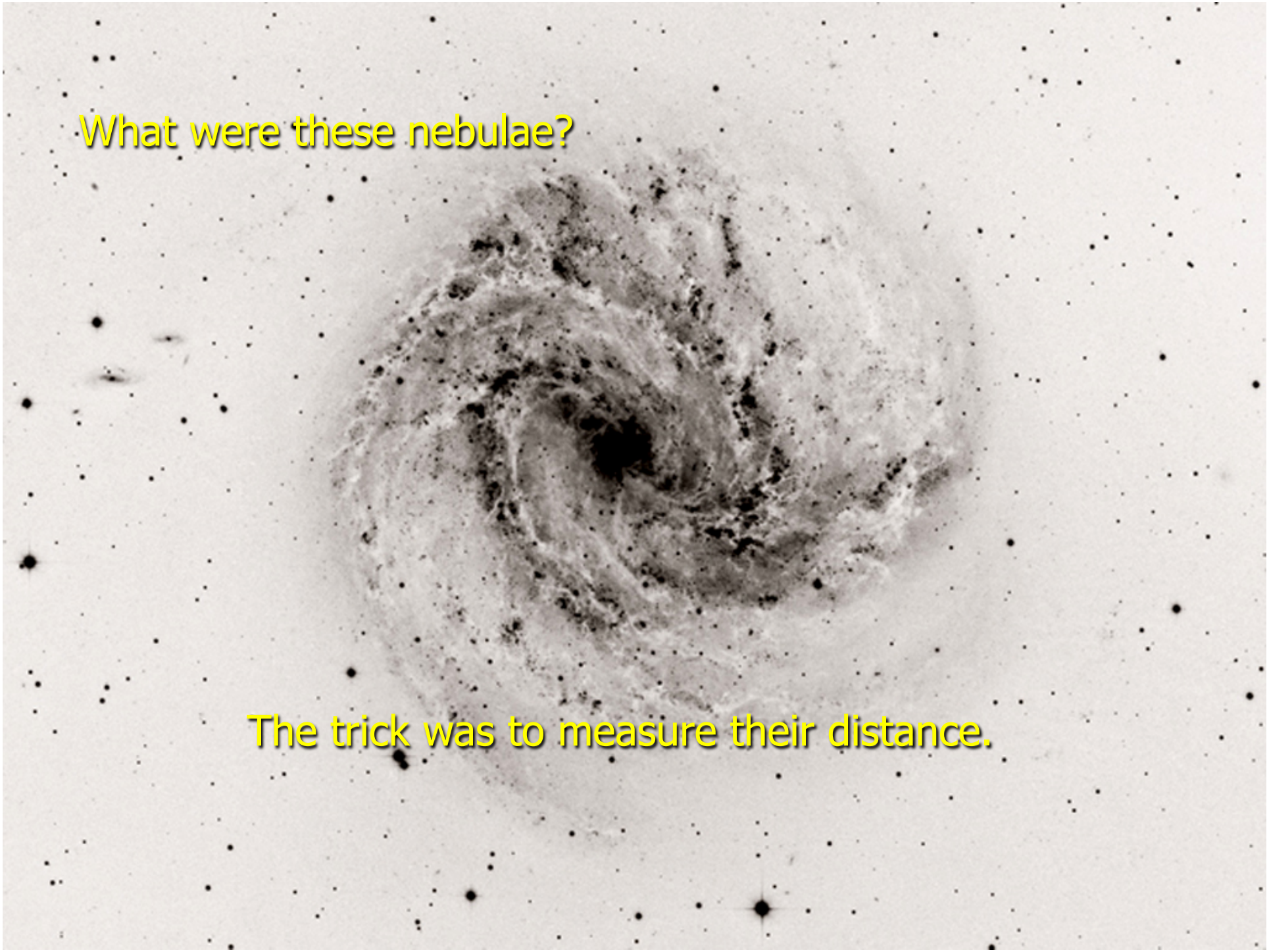
Mapping the universe …





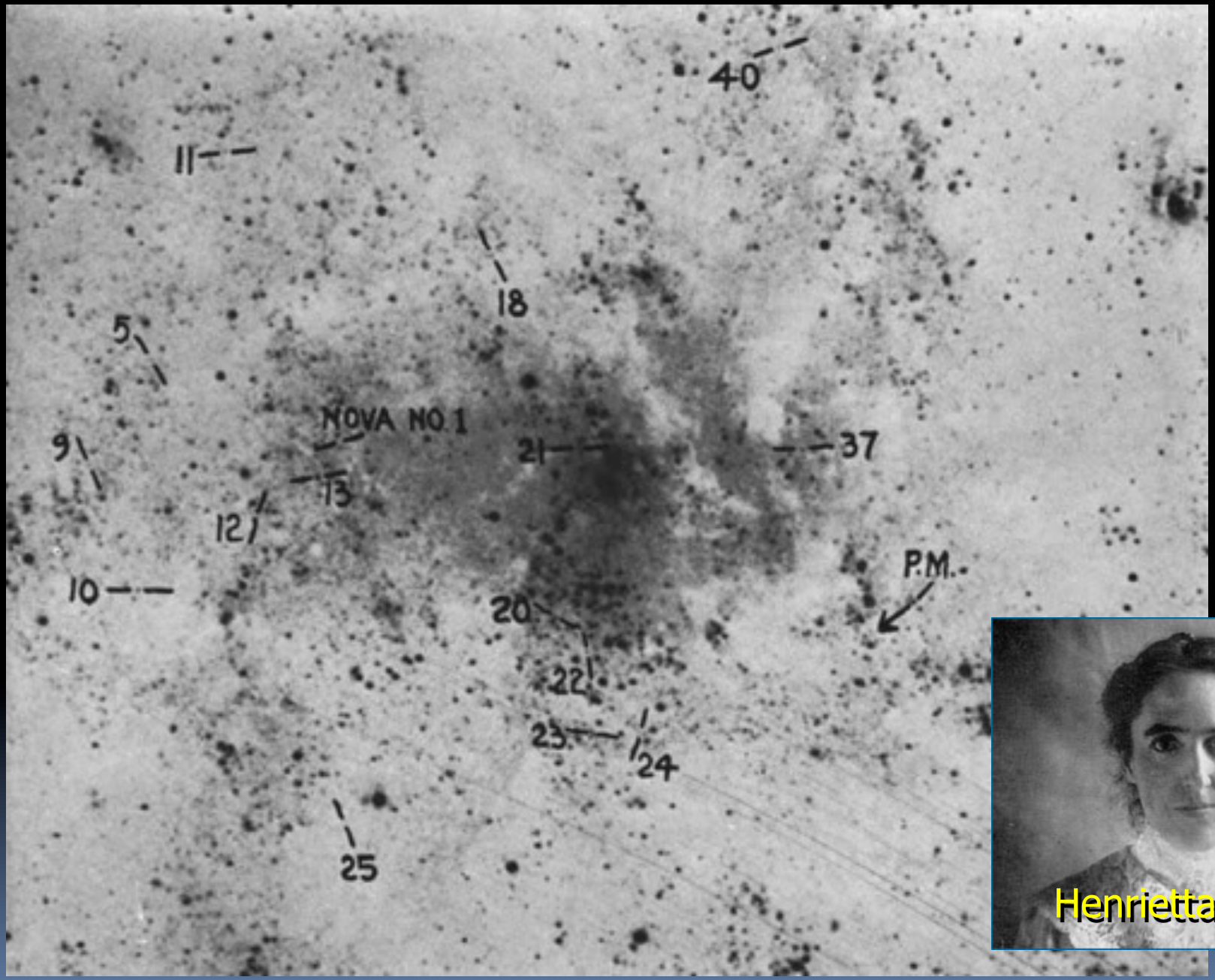
J. C. Kapteyn


In the next century, 5 major revolutions in cosmology:
1. Nebulous objects were really galaxies
2. Expansion of the universe
3. The need for “inflation”
4. The apparent presence of dark energy
5. The multiverse

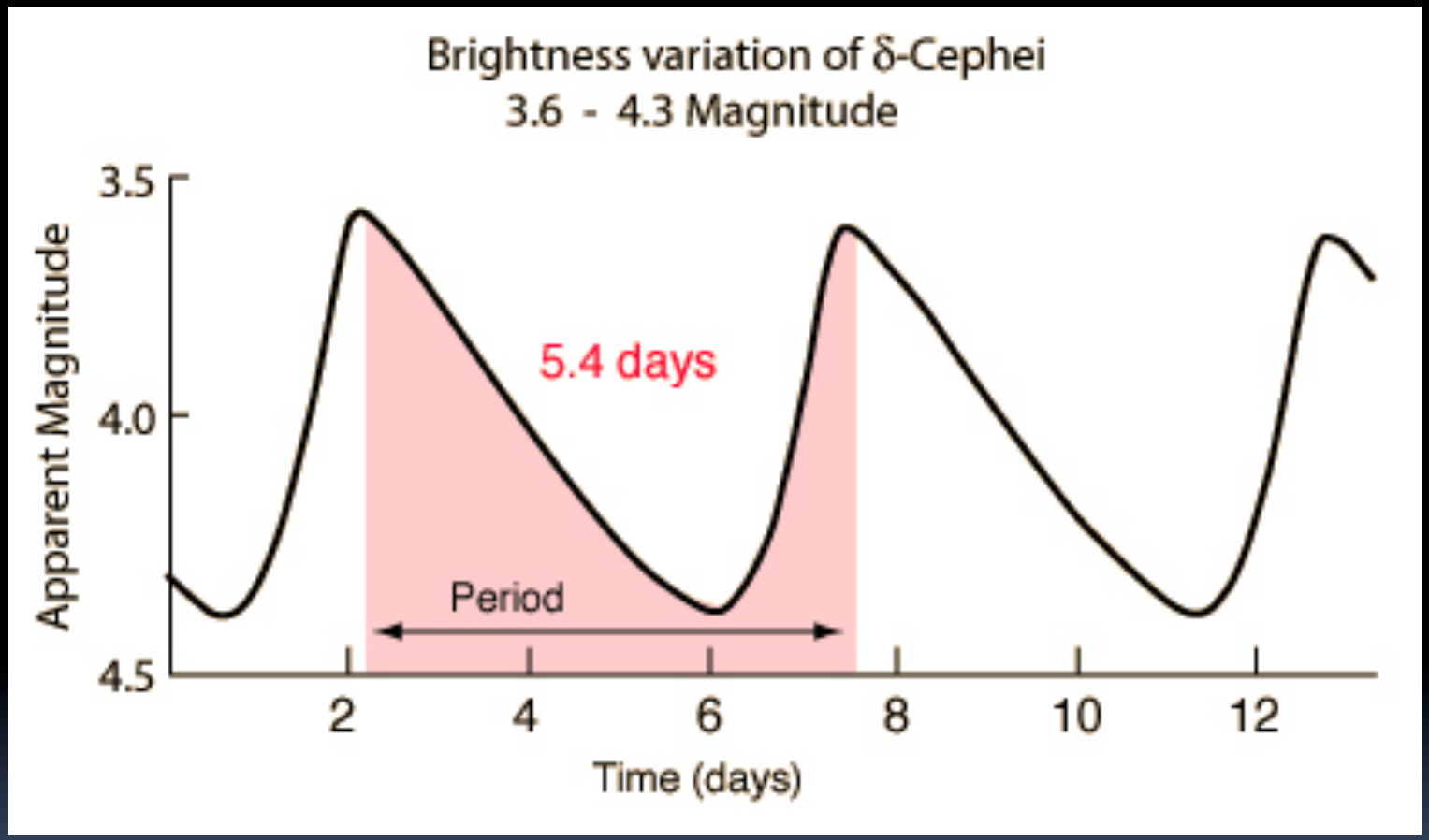

What were these nebulae?
The trick was to measure their distance.

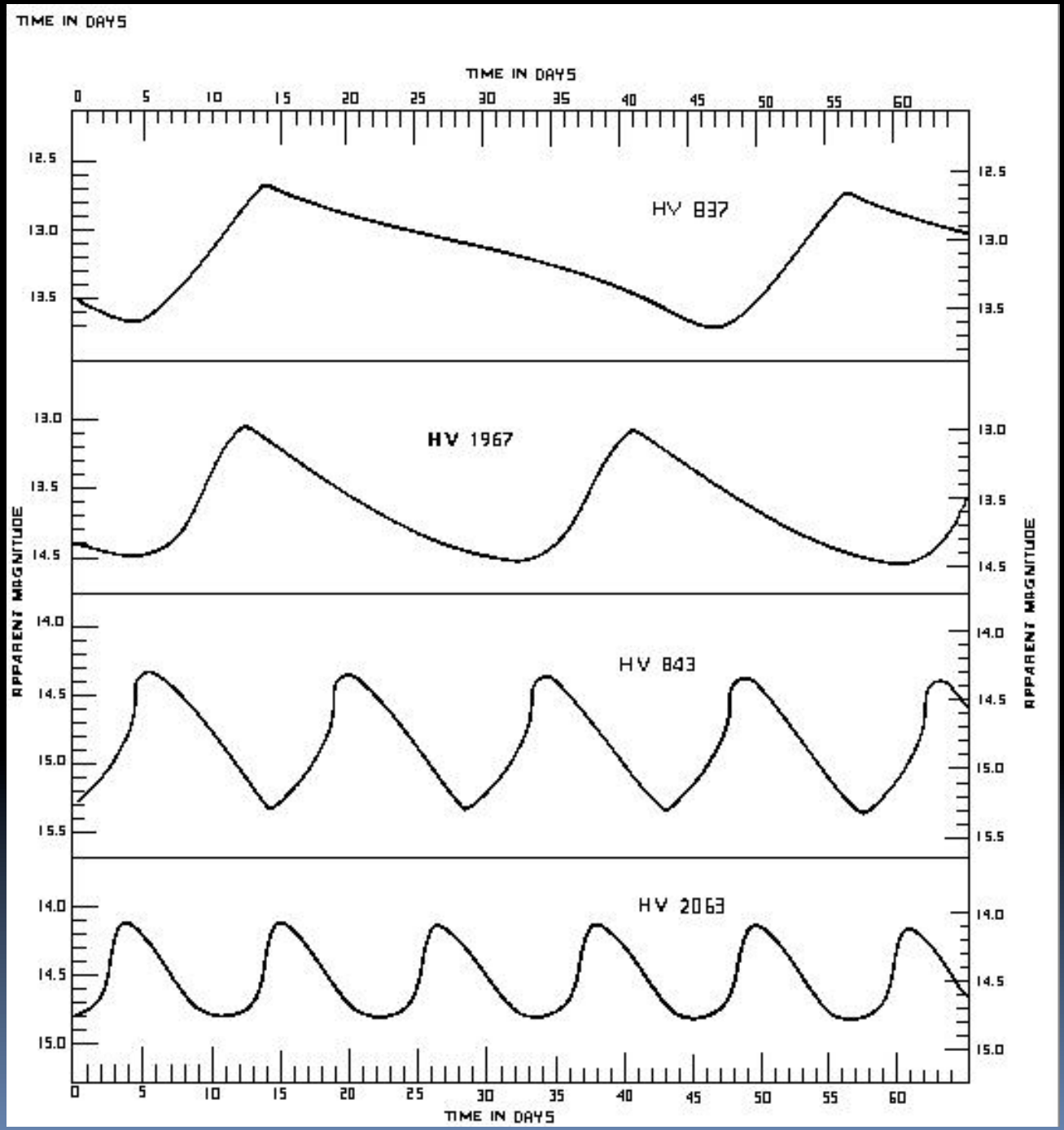
How do we know their distance?

Need a standard candle!

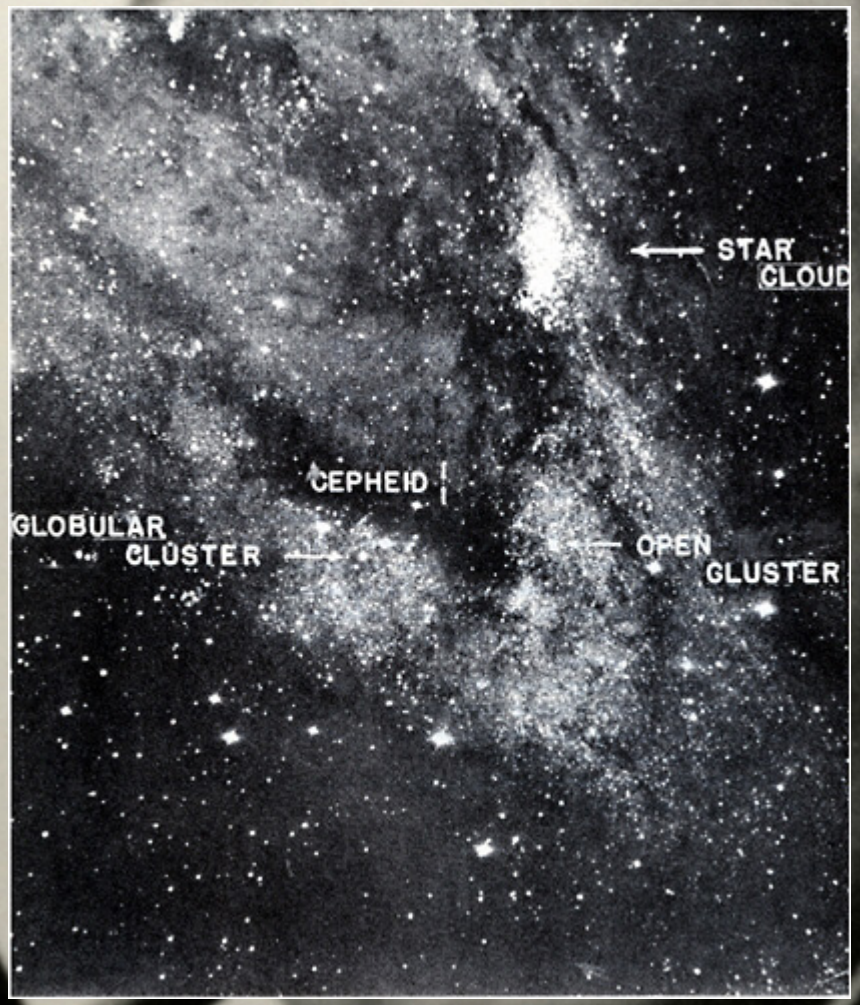

40
11
18
5
NOVA NO 1
9
21
37
13
12
P.M.
10
20
22
23
24
25

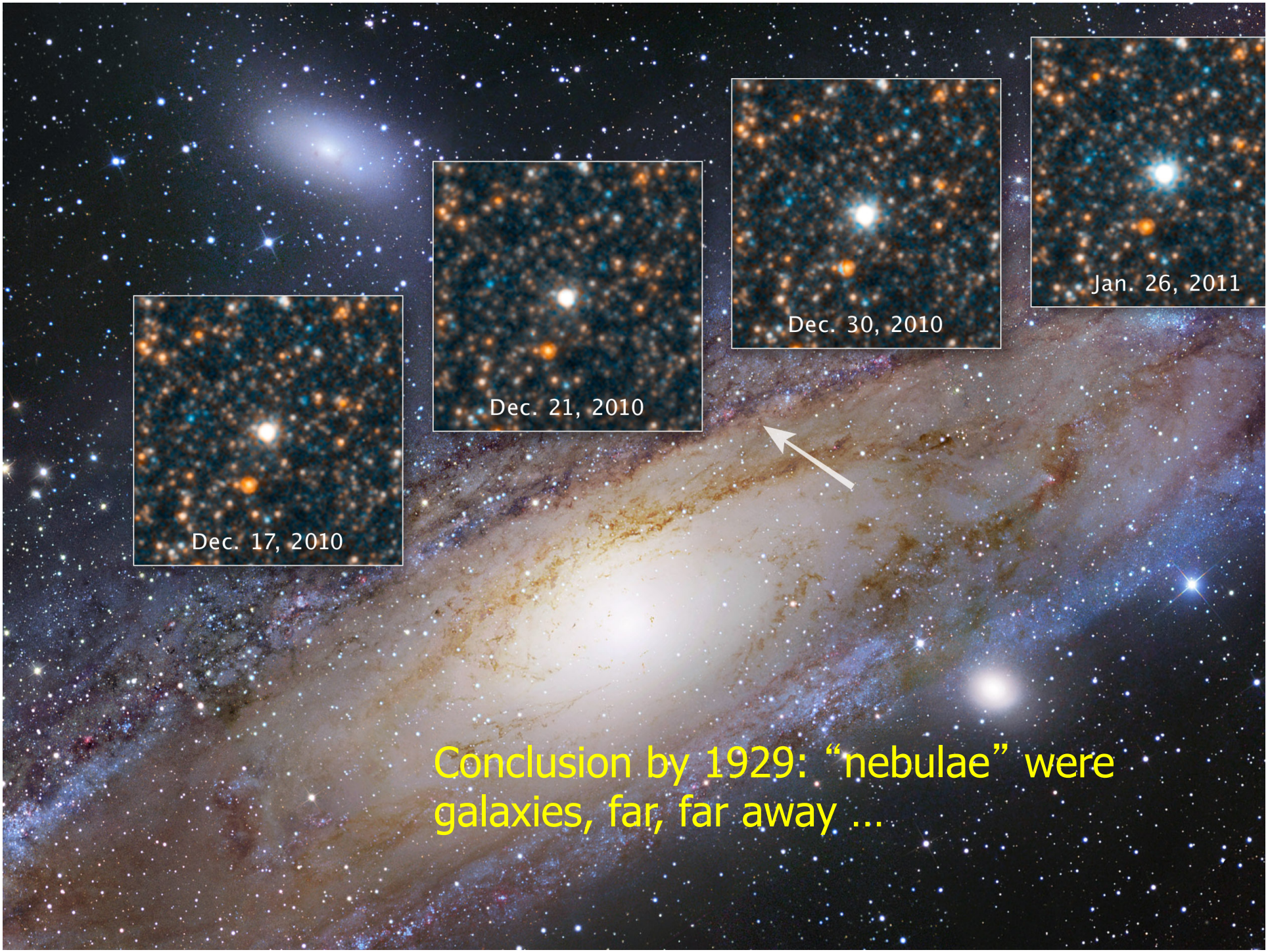

Henrietta Levitt


Brightness variation of δ-Cephei
3.6 - 4.3 Magnitude
Apparent Magnitude
3.5
4.0
4.5
5.4 days
Period
2
4
6
8
10
12
Time (days)


TIME IN DAYS
TIME IN DAYS
0 5 10 15 20 25 30 35 40 45 50 55 60
HV 837
HV 1967
HV 843
HV 2063
APPARENT MAGNITUDE
APPARENT MAGNITUDE
TIME IN DAYS

Cepheid variable stars in Andromeda galaxy




Dec. 17, 2010
Dec. 21, 2010
Dec. 30, 2010
Jan. 26, 2011
Conclusion by 1929: “nebulae” were galaxies, far, far away ...


In the next century, 5 major revolutions in cosmology:
1. Nebulous objects were really galaxies
2. Expansion of the universe

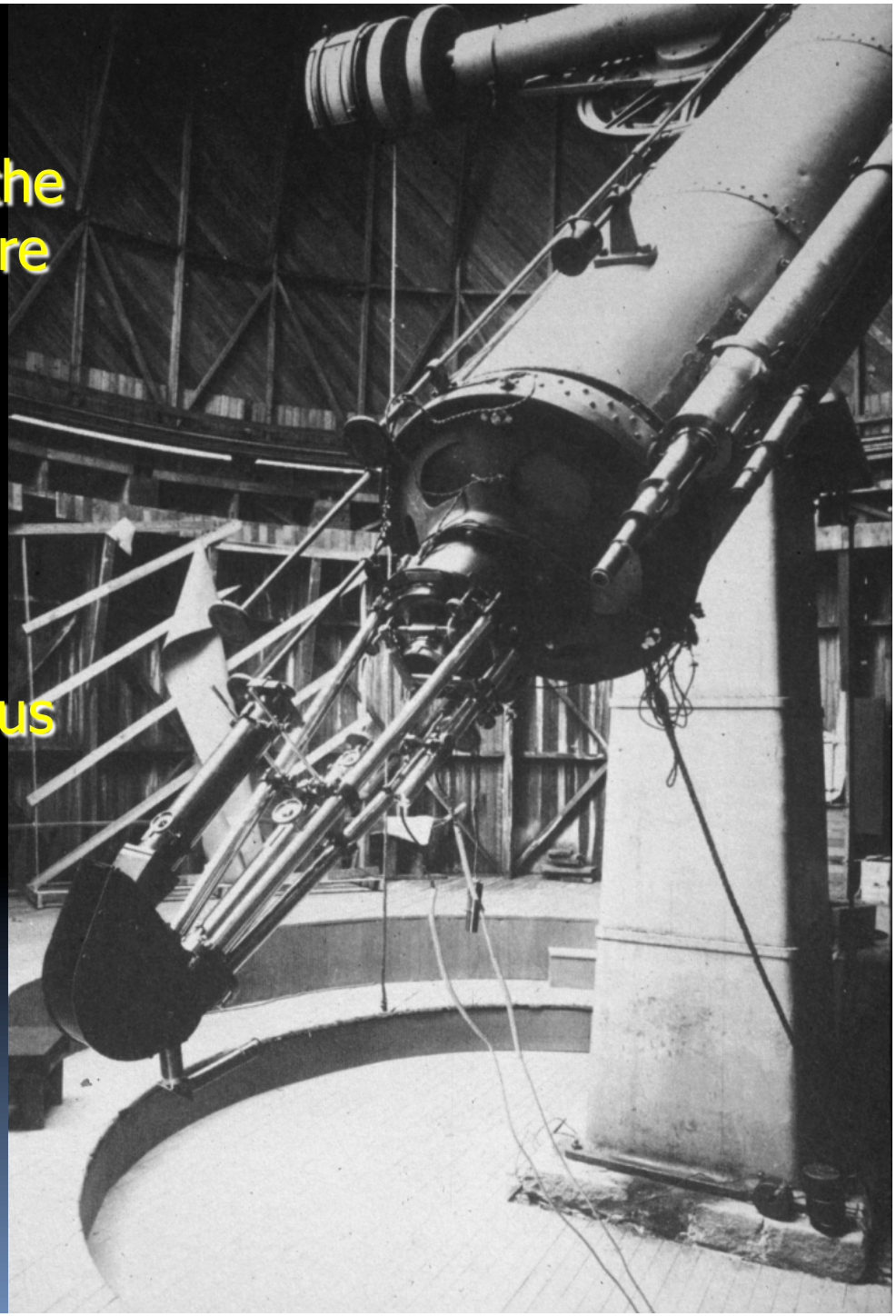
Vesto Slypher

(1911)

Used Bruce spectrograph at the Lowell Observatory to measure the Doppler shift of nebulae.

Results:

Some were coming towards us
Most were moving away

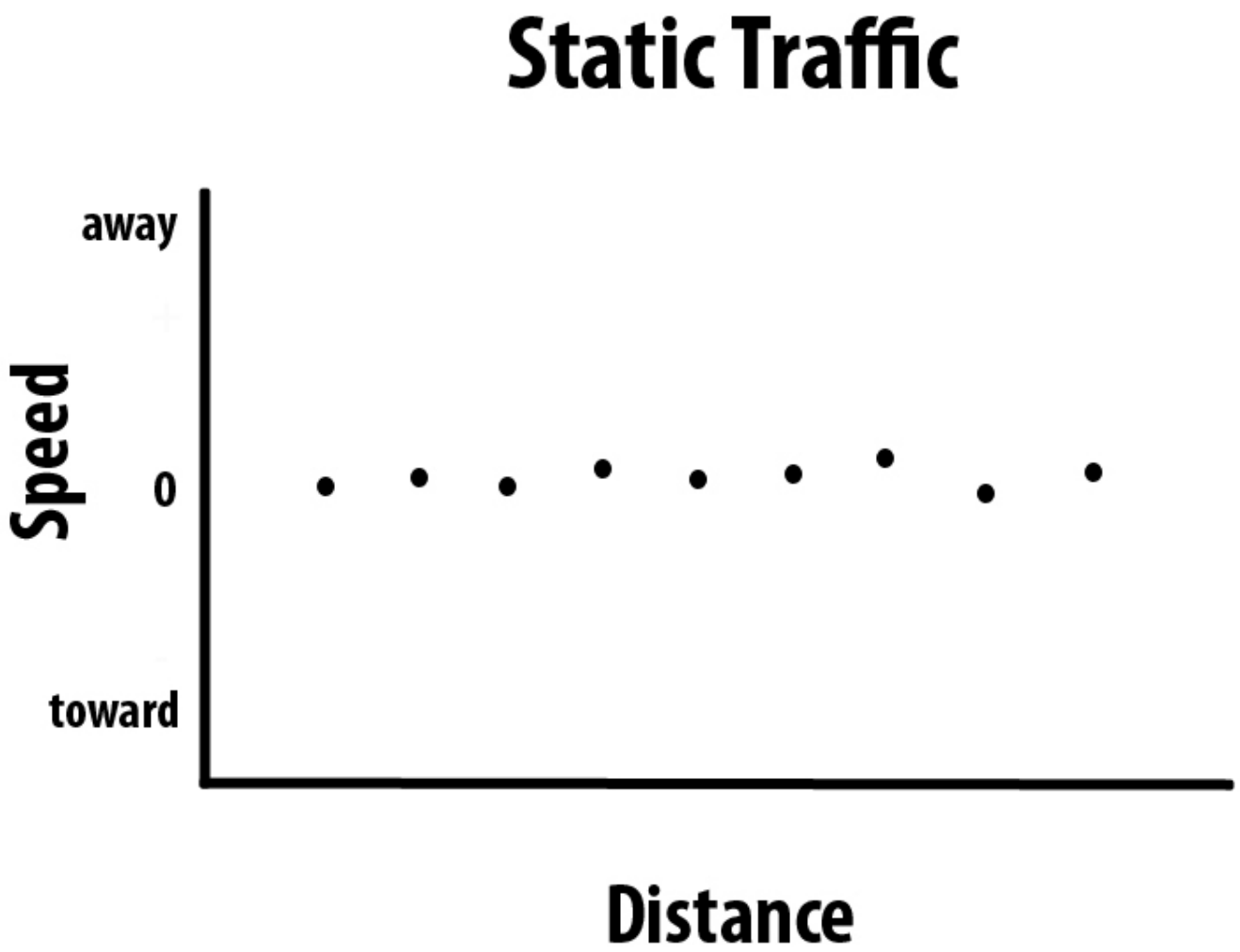


0 mph

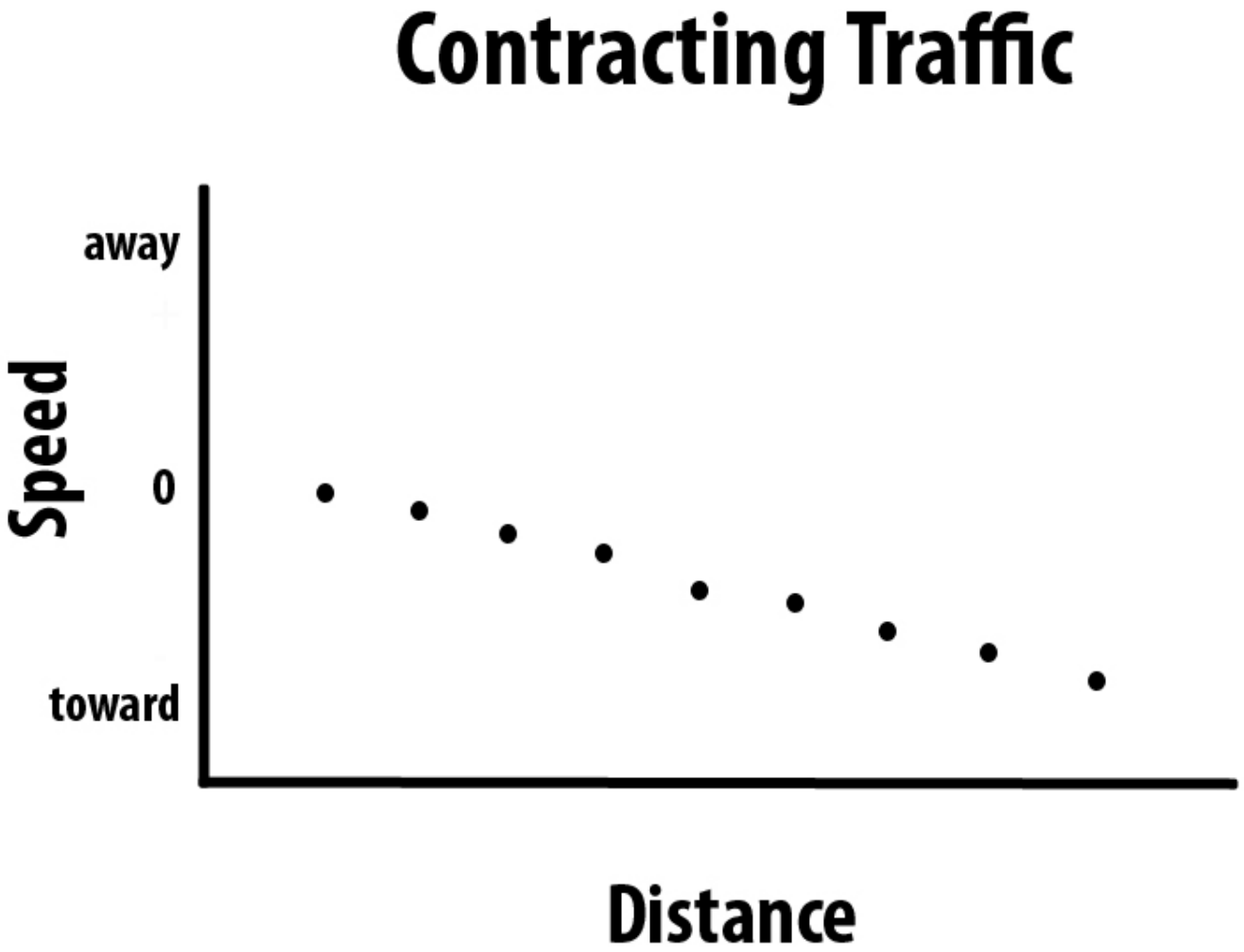
0 mph

0 mph

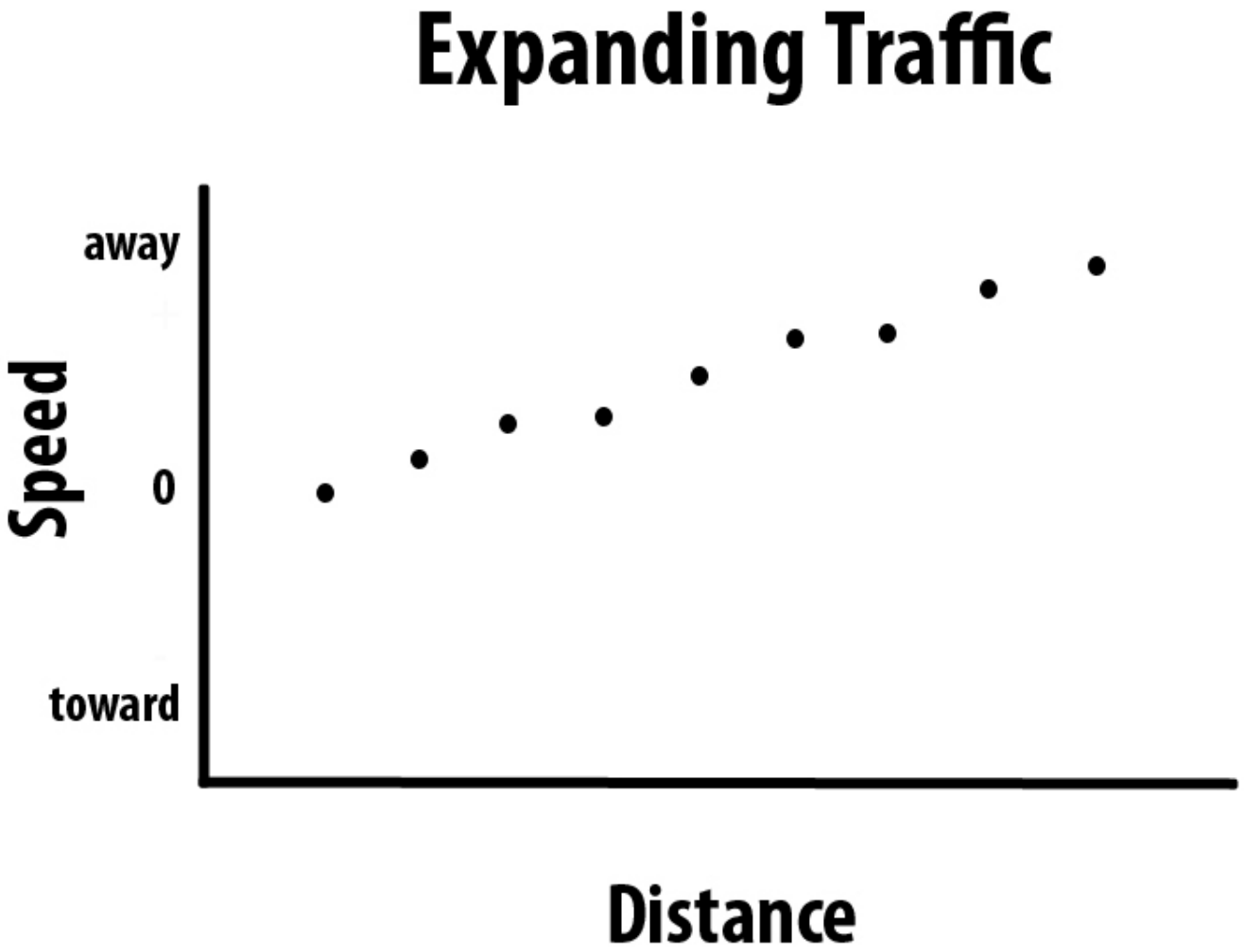
0 mph


Static Traffic
away
Speed
0
toward
Distance


8 mph
6 mph
4 mph
2 mph


Contracting Traffic
away
Speed
0
toward
Distance


8 mph
6 mph
4 mph
2 mph

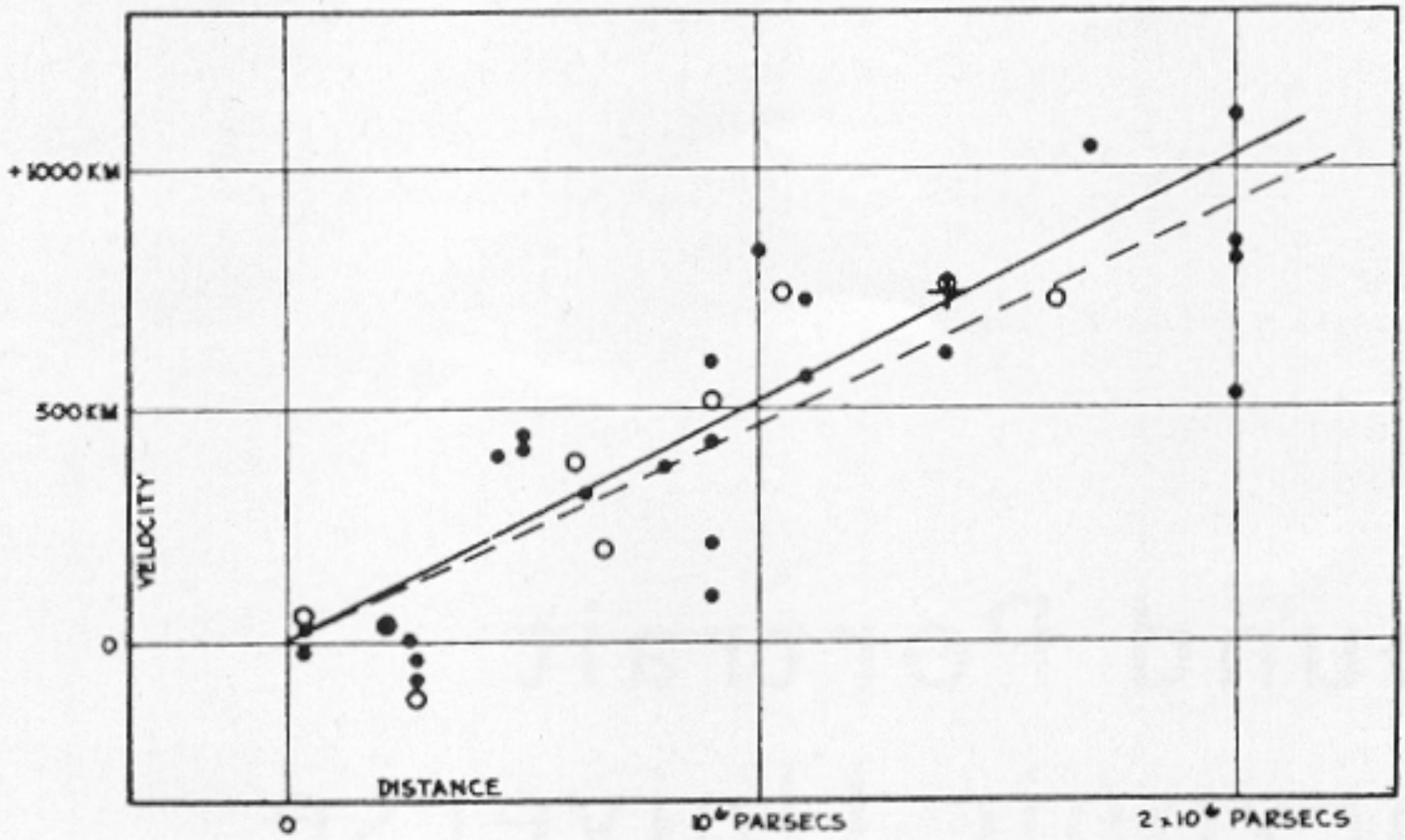

Expanding Traffic
away
Speed
0
toward
Distance

Edwin Hubble

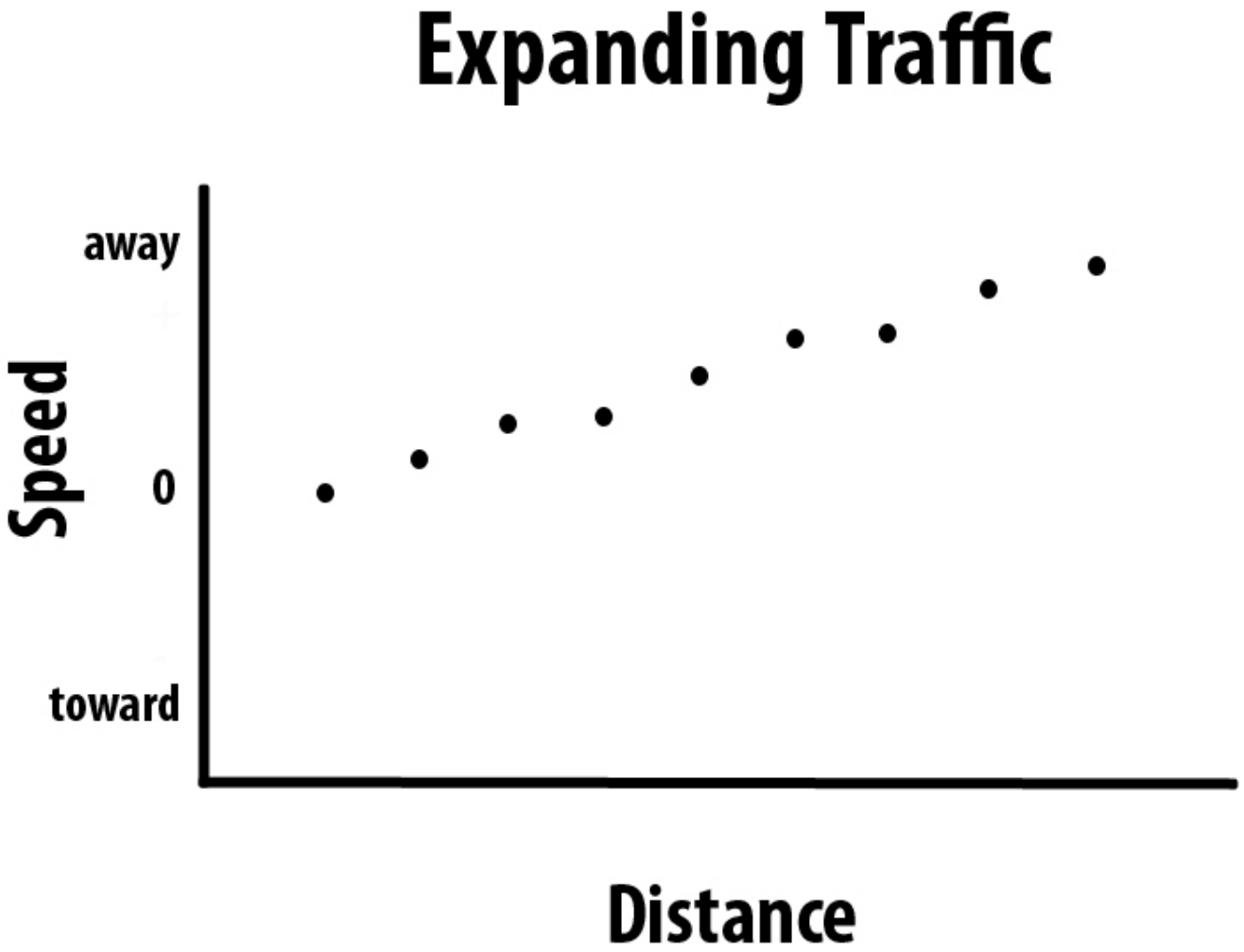
1889 - 1953

Milton Humason

Henrietta Levitt

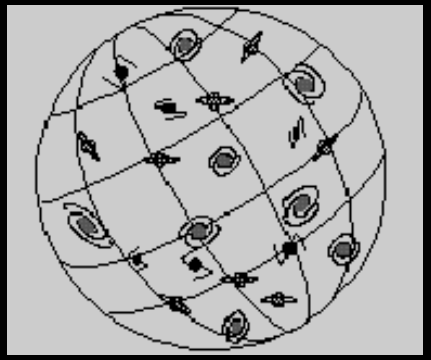


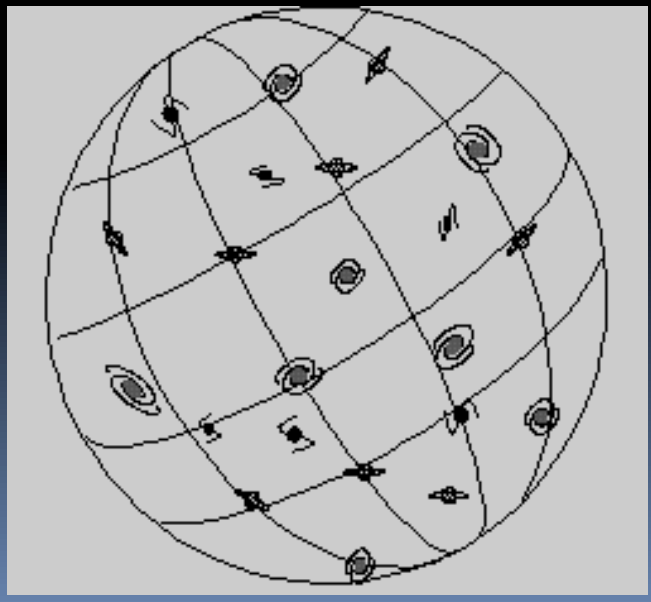
Hubble's Original Plot


Expanding Traffic
away
Speed
0
toward
Distance

Expanding universe

- Hubble discovered that we live in an *expanding universe.*

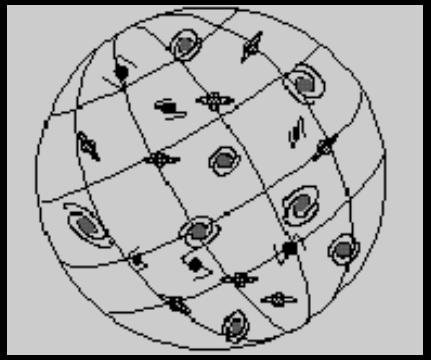


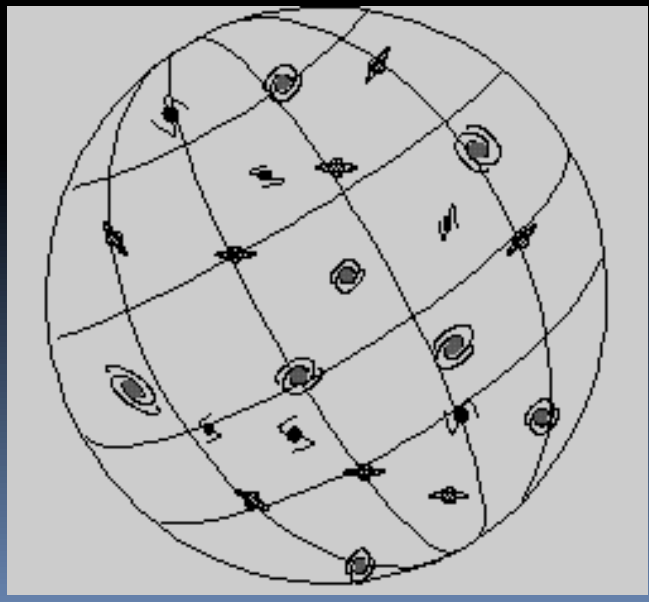


Big Bang

- Based on this, in the 1940s, George Gamow proposed that the universe started with a big explosion

- Fred Hoyle jokingly called it the *Big Bang*



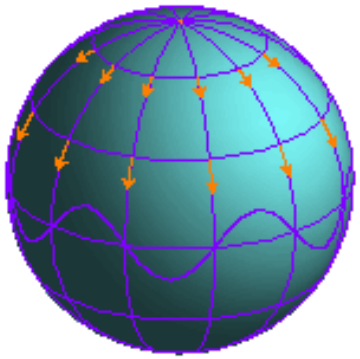


Cosmic microwave background

- If there was a Big Bang, the universe immediately following would have been very hot, $>10^{12}$ K, and flooded with short wavelength gamma rays

Cosmic microwave background

- As the universe expanded, the short wavelength radiation would be stretched into longer, millimeter waves (1.1mm), producing the *cosmic microwave background* (CMB)

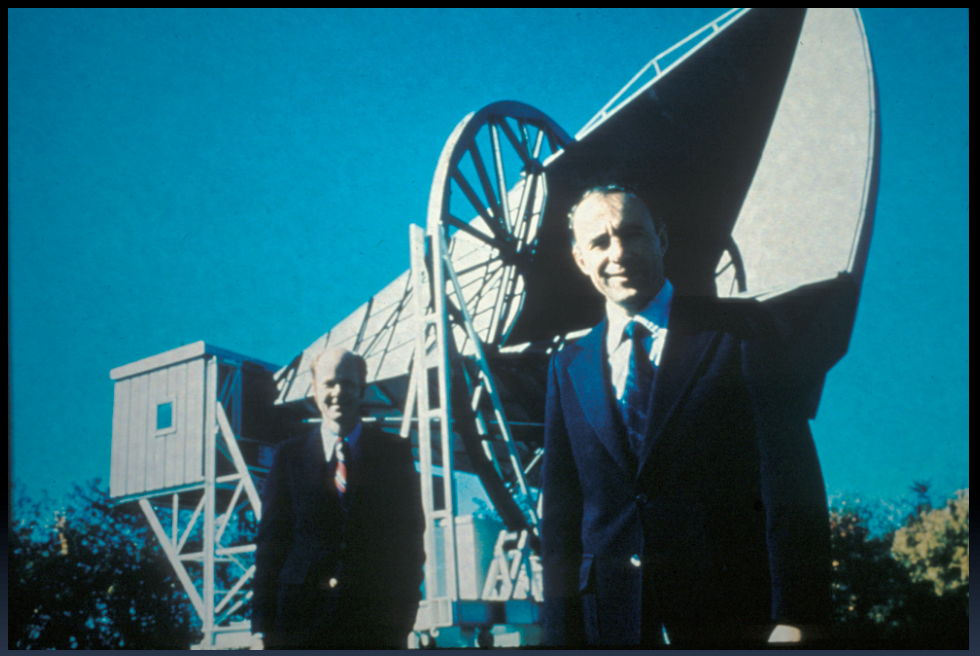


Cosmic microwave background

- So, detection of cosmic microwave background radiation would be evidence for a Big Bang.

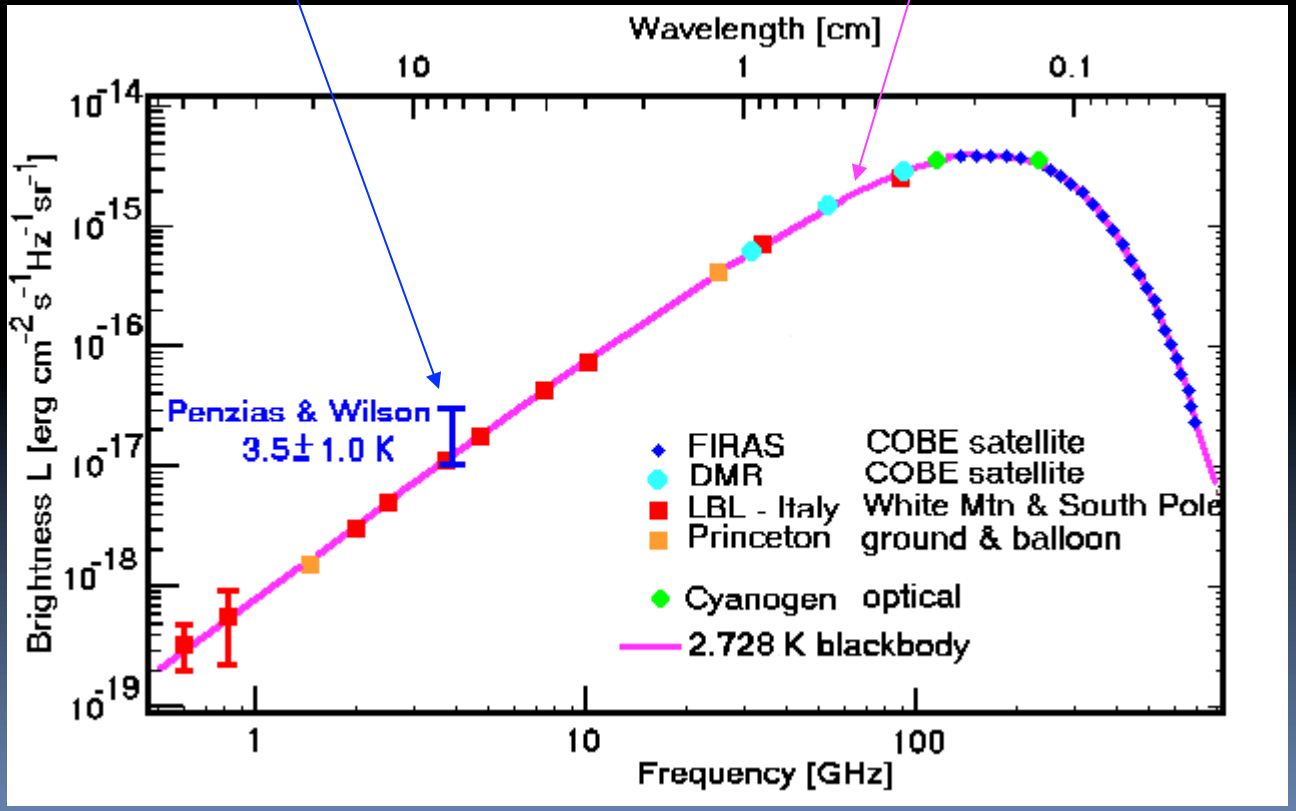
Cosmic microwave background

- Arno Penzias and Bob Wilson, working on a Bell Labs communications antenna in 1964, detected a faint background noise in all directions



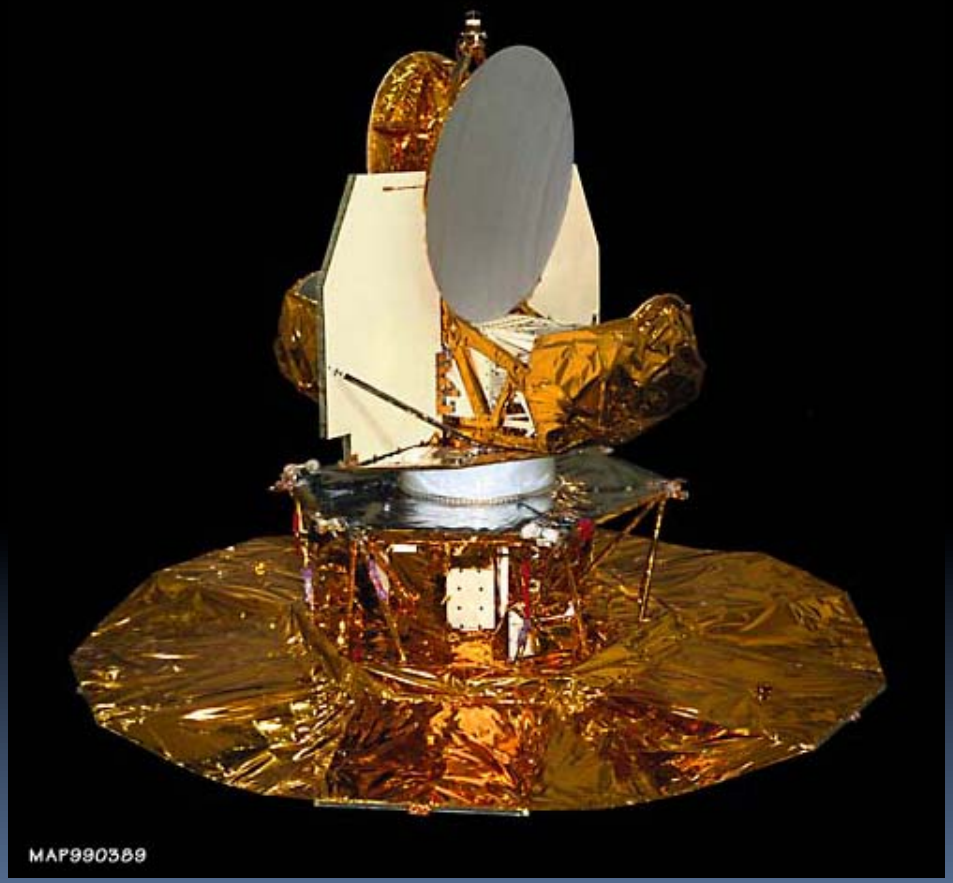
Cosmic microwave background

- Their data point (and many since then) fit the curve for a 2.728 K black body!

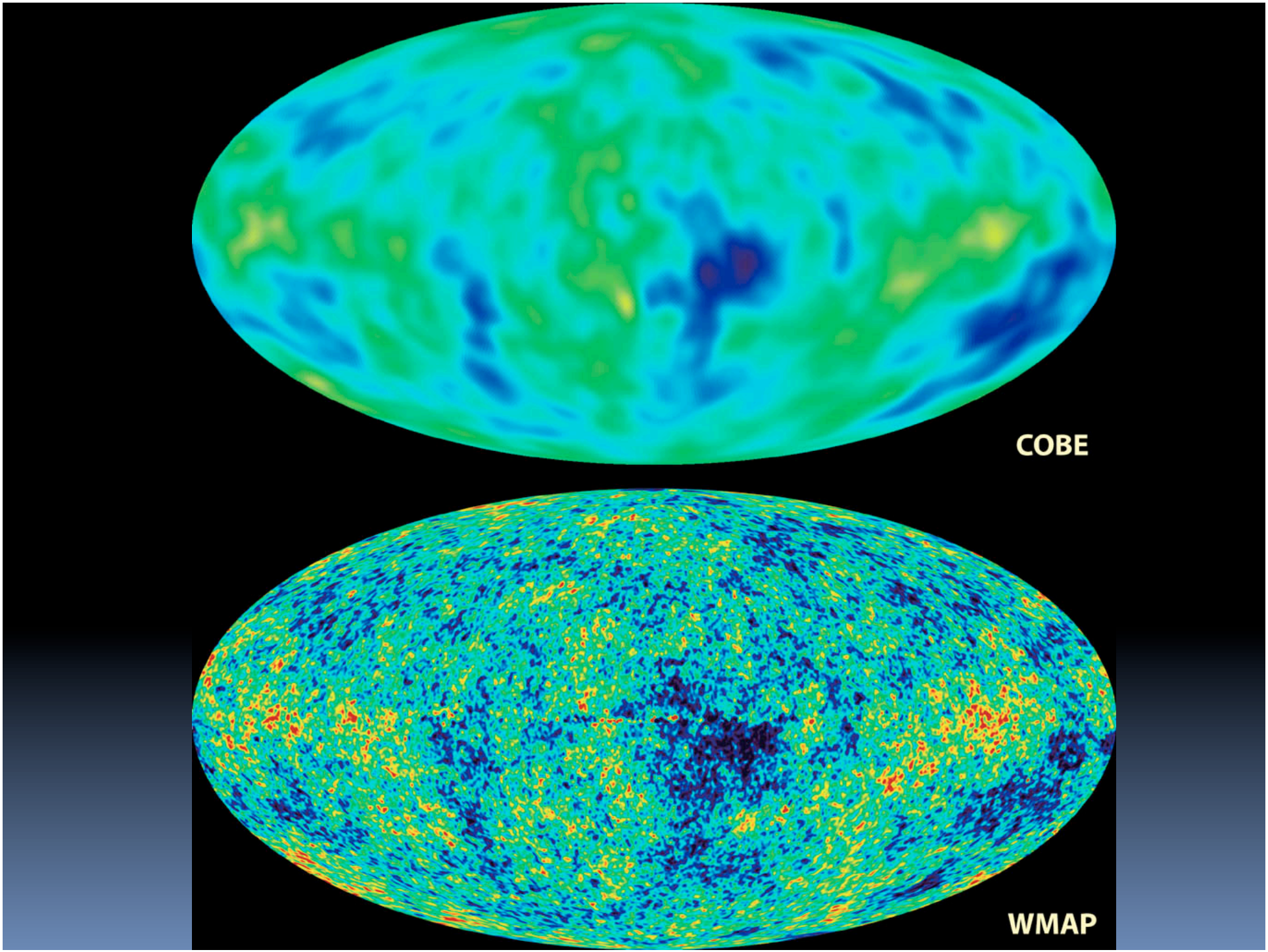


WMAP (NASA)

- The Wilkinson Microwave Anisotropy Probe mapped the temperature fluctuations of the CMB radiation with much higher resolution, sensitivity, and accuracy than COBE. (Launched in 2001)

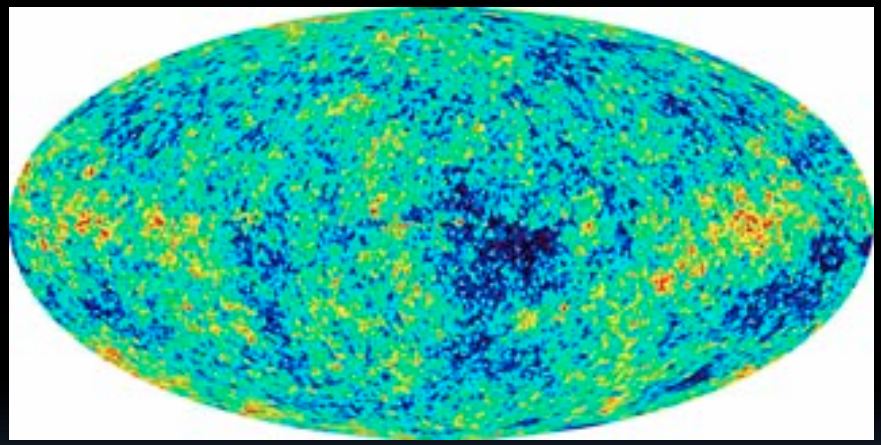


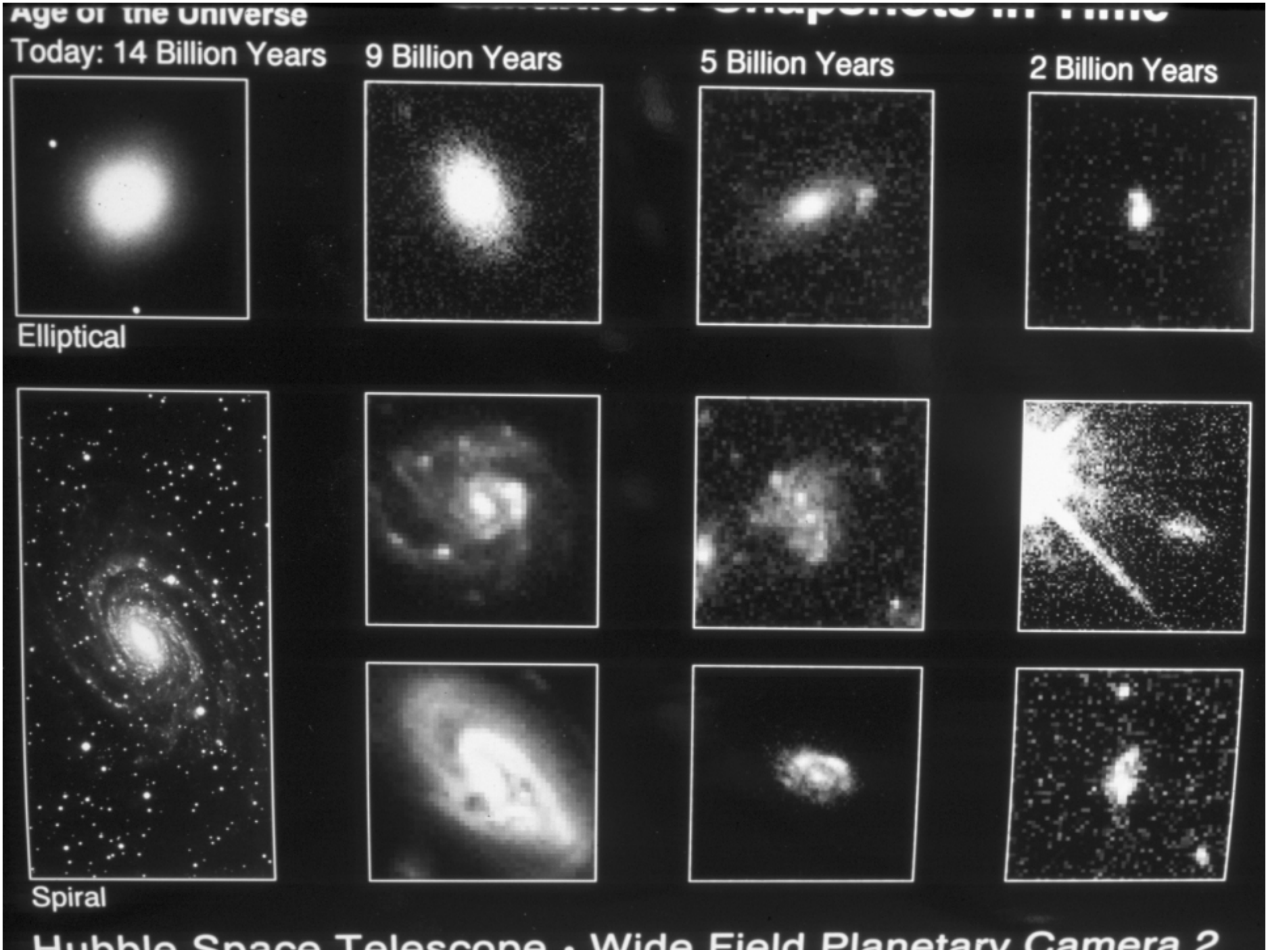
WMAP satellite

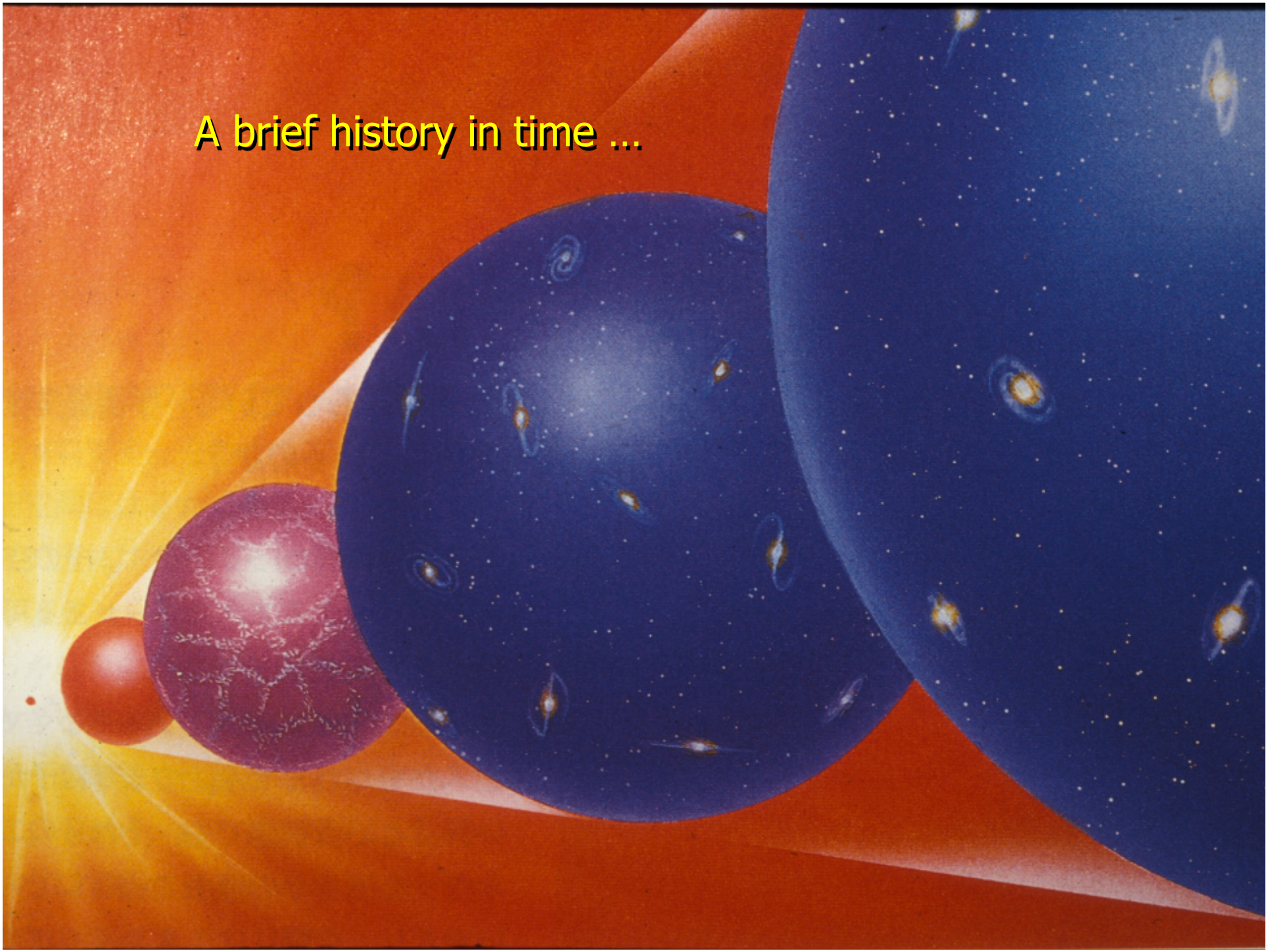

COBE
WMAP

WMAP

- All-sky picture of the infant universe from WMAP.
- The WMAP image reveals 13 billion+ year old temperature fluctuations (shown as color differences) that correspond to the seeds that grew to become the galaxies.

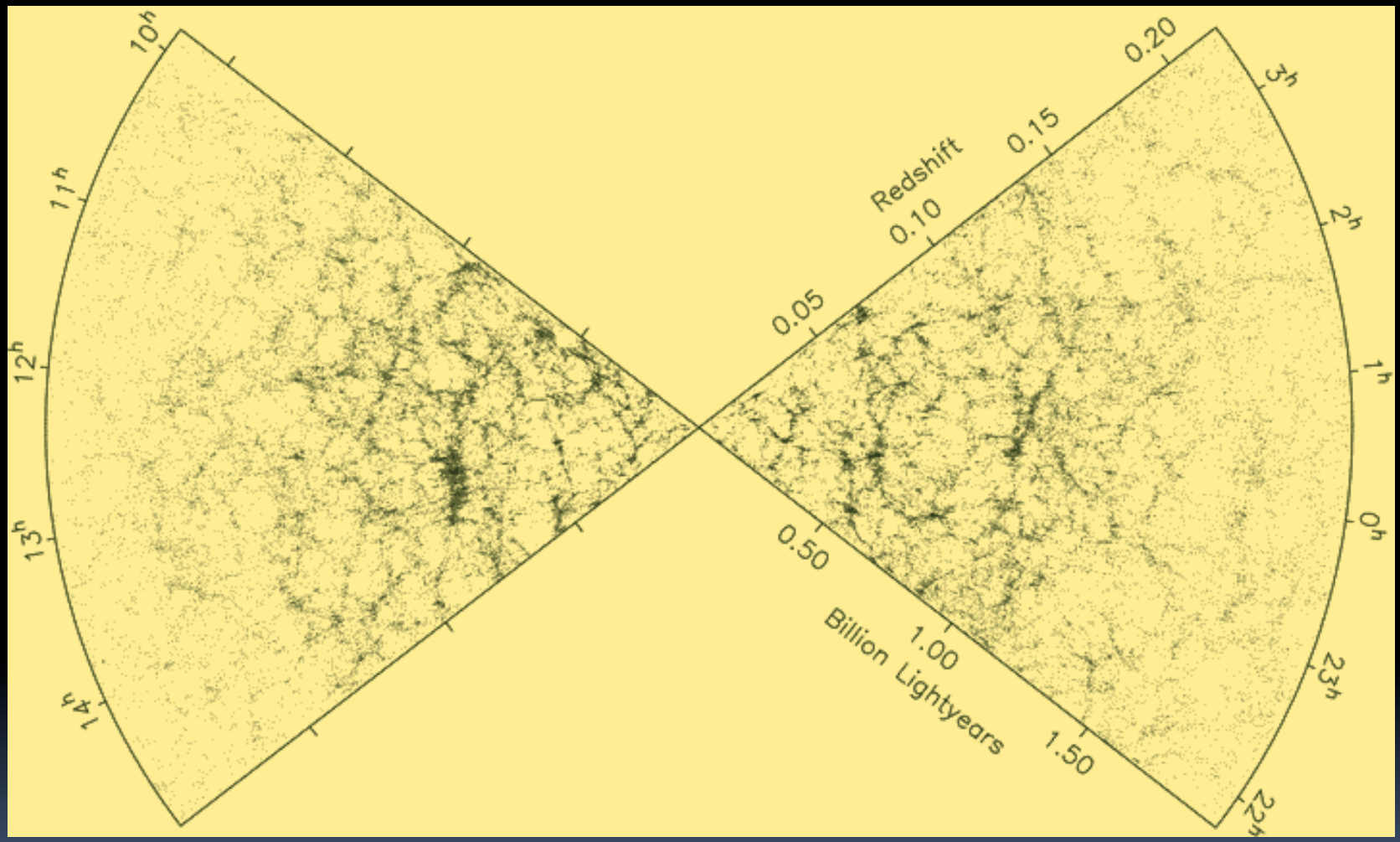


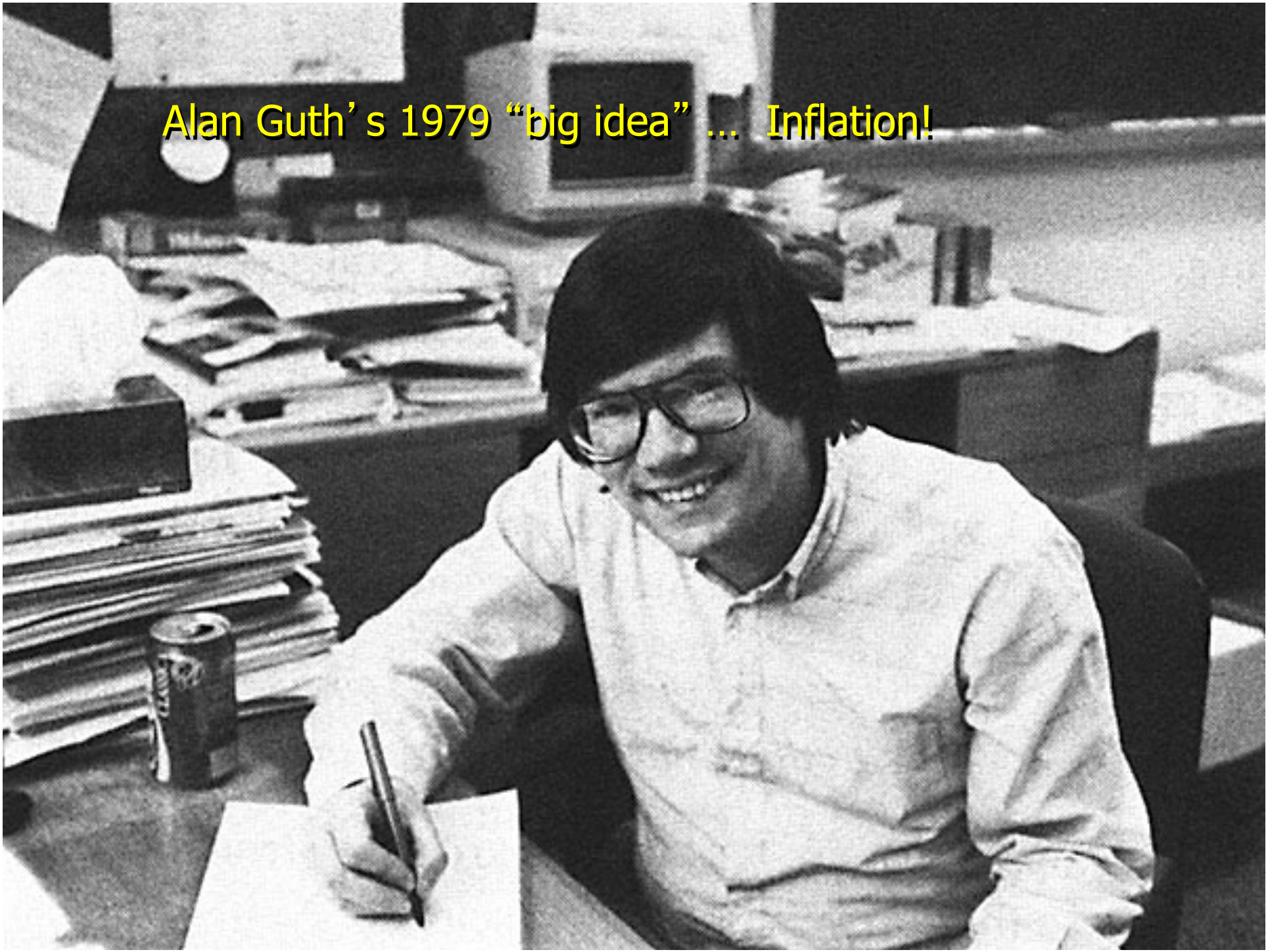

Age of the Universe
Today: 14 Billion Years
9 Billion Years
5 Billion Years
2 Billion Years
Elliptical
Spiral
Hubble Space Telescope • Wide Field Planetary Camera 2

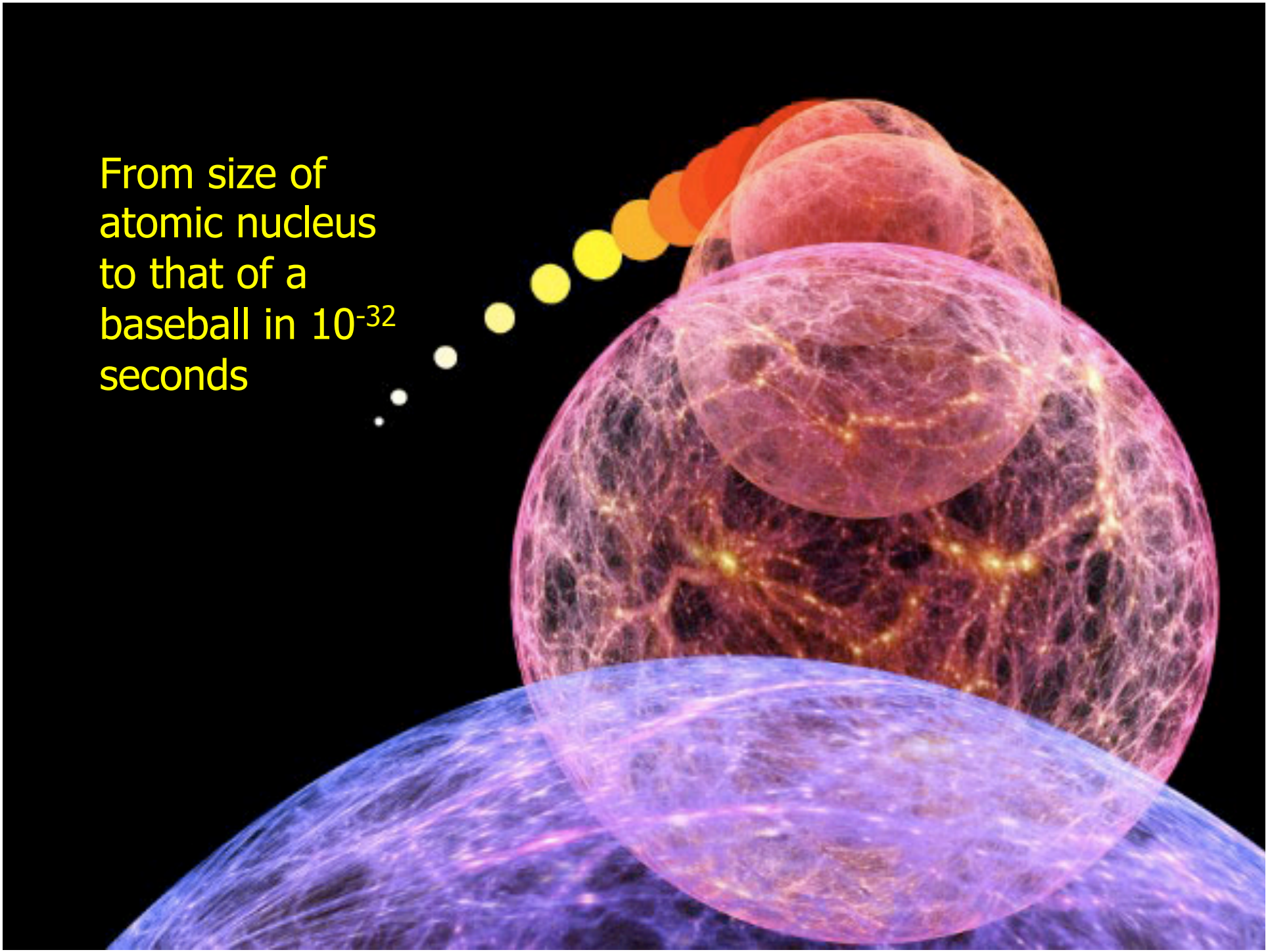

A brief history in time …

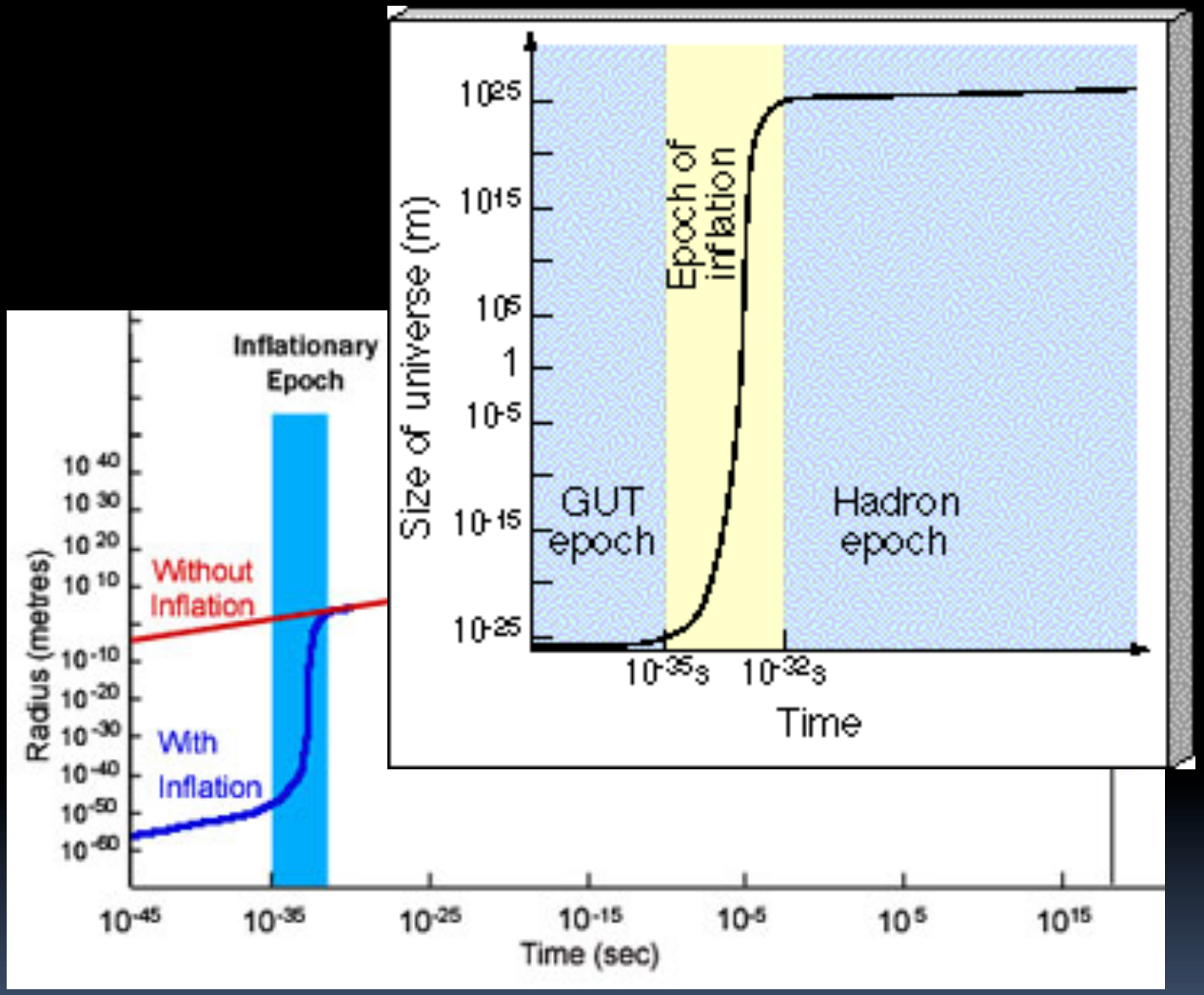

1. Nebulous objects were really galaxies
2. Expansion of the universe
3. The need for “inflation”


Homogeneity of universe presents a problem ...


10h
11h
12h
13h
14h
Redshift
0.05
0.10
0.15
0.20
3h
2h
1h
0h
23h
22h
0.50
1.00
1.50
Billion Lightyears


Alan Guth's 1979 "big idea" … Inflation!

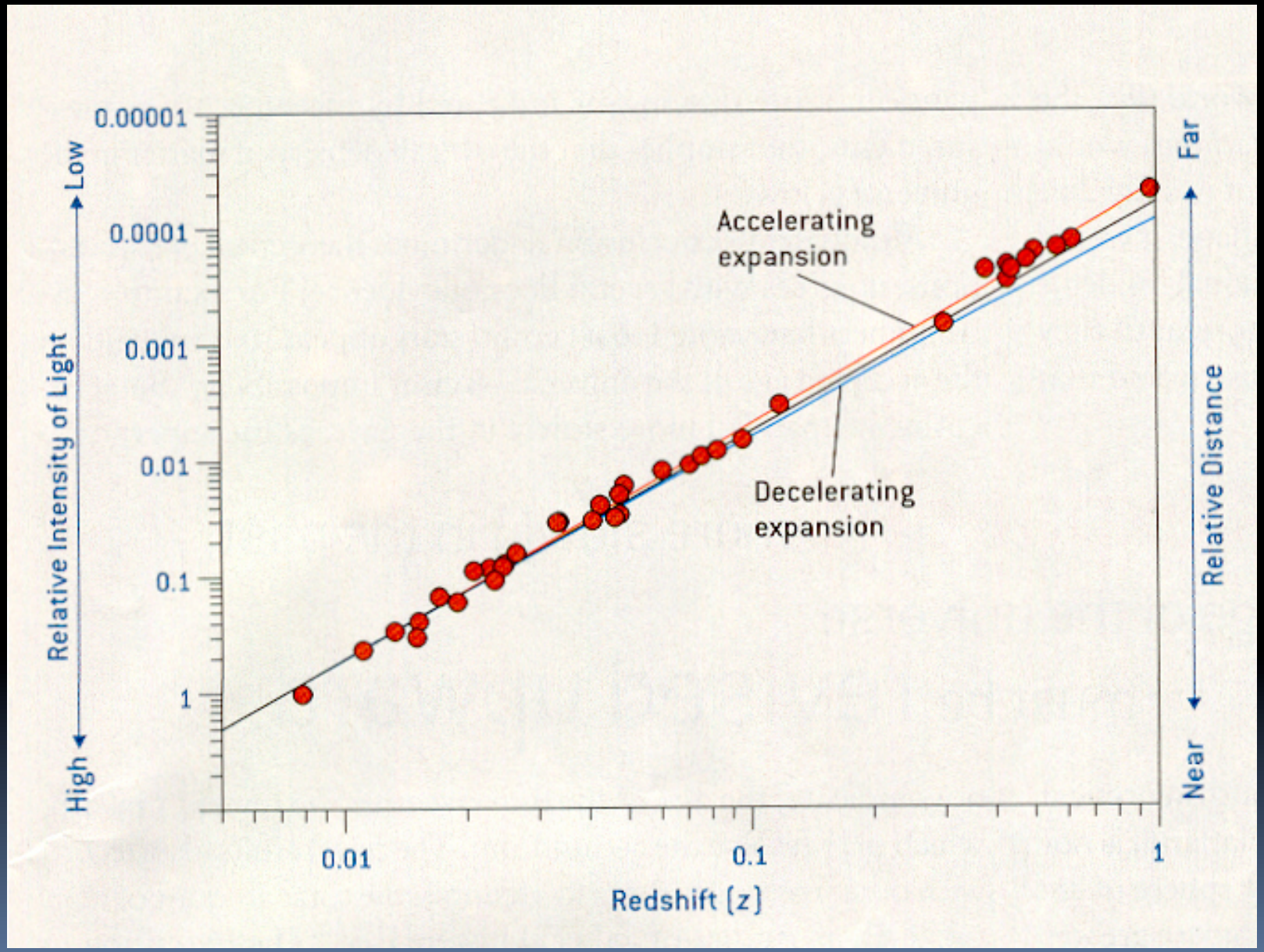

From size of
atomic nucleus
to that of a
baseball in 10^{-32}
seconds

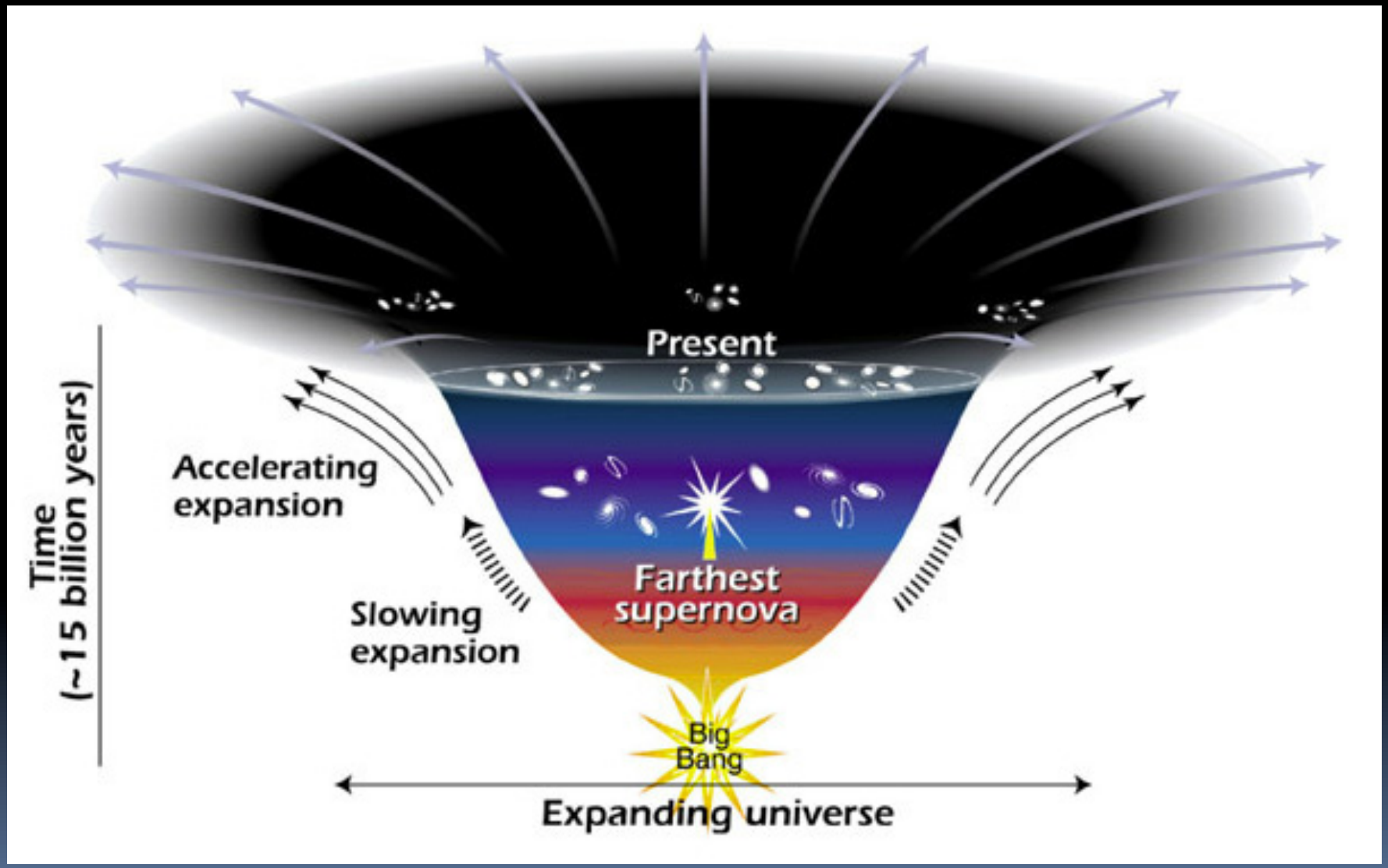

Inflationary Epoch
Without Inflation
With Inflation
Radius (metres)
Time (sec)
Size of universe (m)
Epoch of inflation
GUT epoch
Hadron epoch
Time


1. Nebulous objects were really galaxies
2. Expansion of the universe
3. The need for “inflation”
4. The apparent presence of dark energy

Has the expansion always been at the same rate?

Study the change in expansion velocity …


0.00001
0.0001
0.001
0.01
0.1
1
Low
High
Relative Intensity of Light
Accelerating
expansion
Decelerating
expansion
Far
Near
Relative Distance
0.01
0.1
1
Redshift (z)

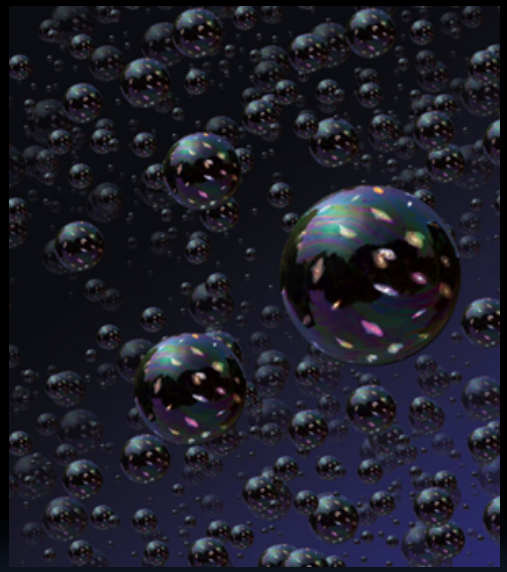

Present
Accelerating expansion
Slowing expansion
Farthest supernova
Big Bang
Time (~15 billion years)
Expanding universe


1. Nebulous objects were really galaxies
2. Expansion of the universe
3. The need for “inflation”
4. The apparent presence of dark energy
5. The multiverse

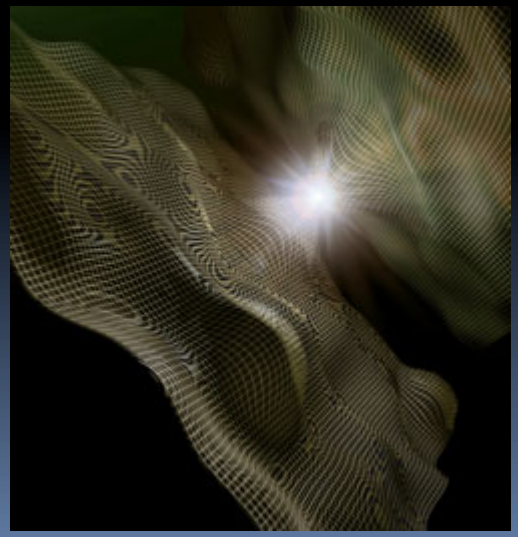

So … interesting question: What was
there before the Big Bang?

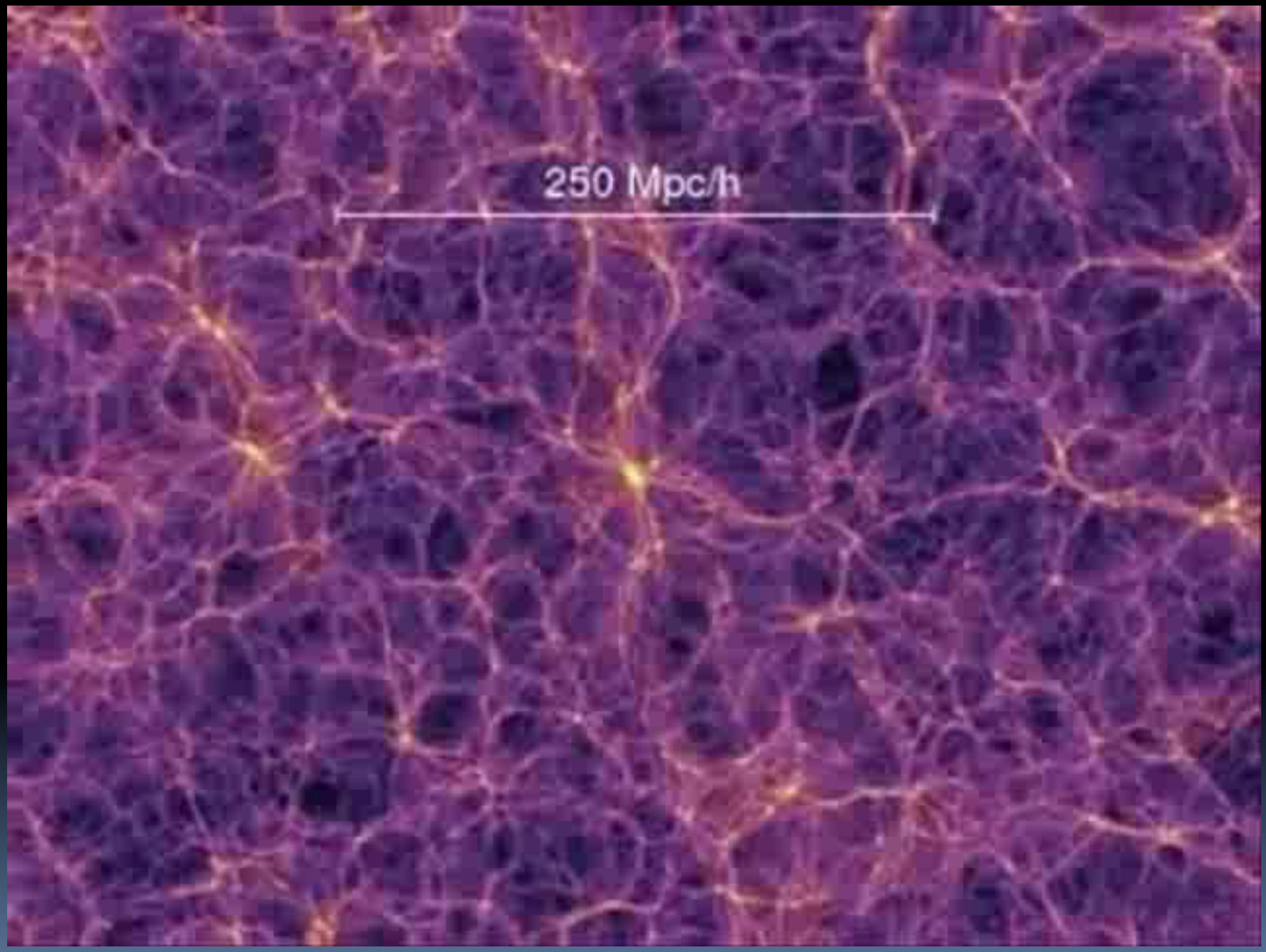
Eternal Inflation

Multiverse



Colliding Branes




250 Mpc/h

And … the future?