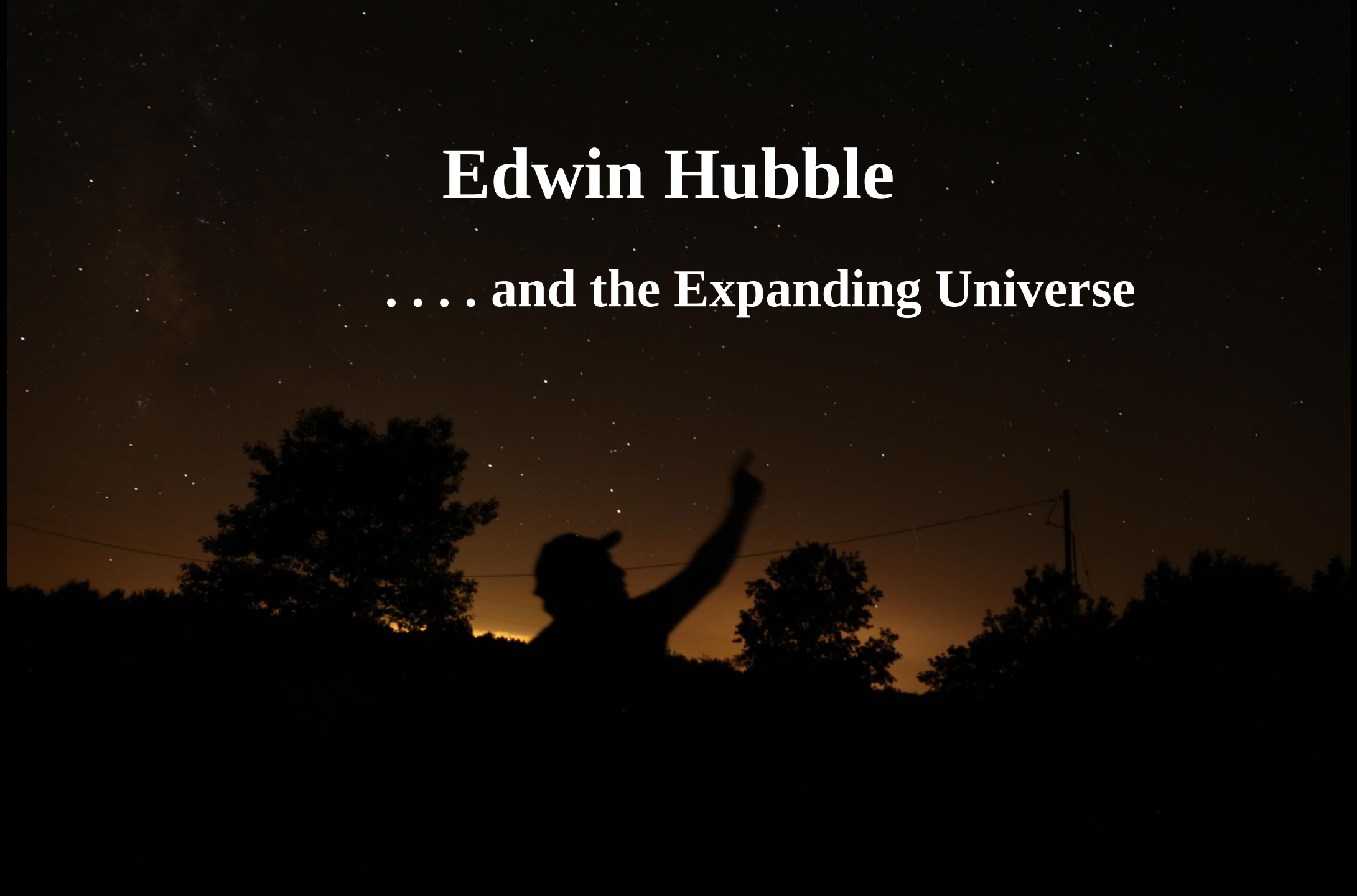
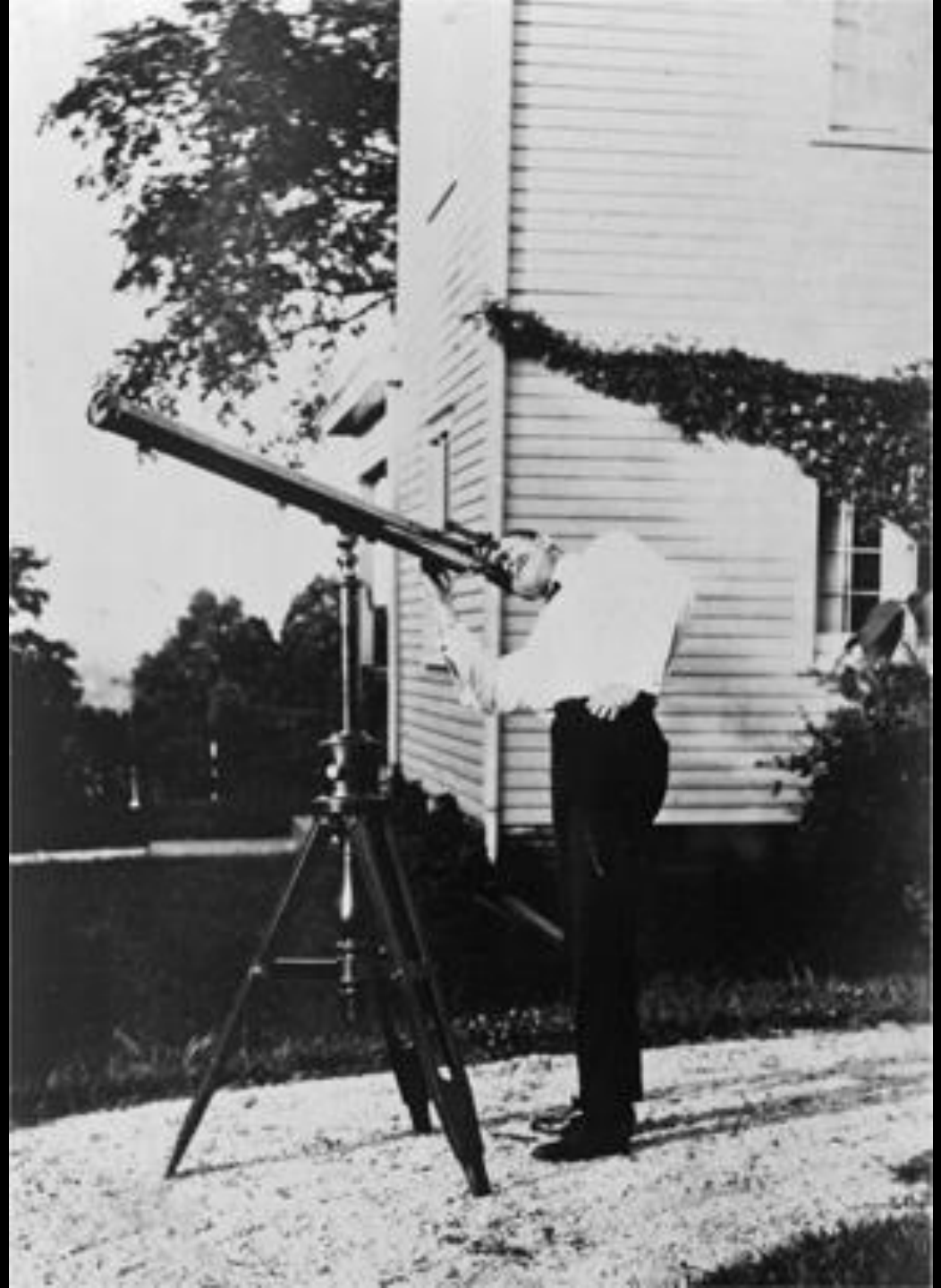


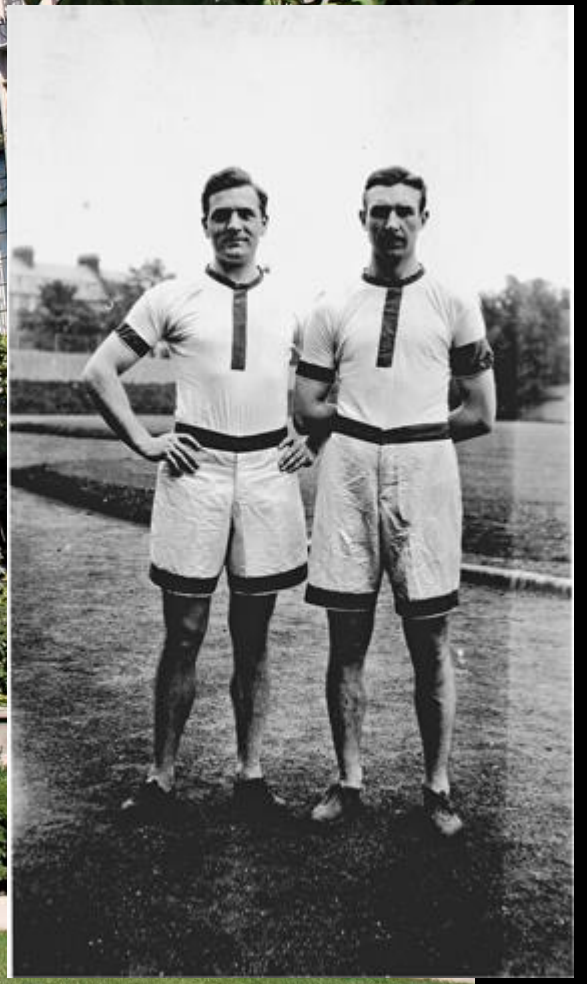
Edwin Hubble

. . . . and the Expanding Universe




BY JULES VERNE
THE
MOON VOYAGE
CONTAINING
FROM THE EARTH TO THE MOON
AROUND THE MOON
LONDON: WARD LOCK AND TYLER

University of Chicago

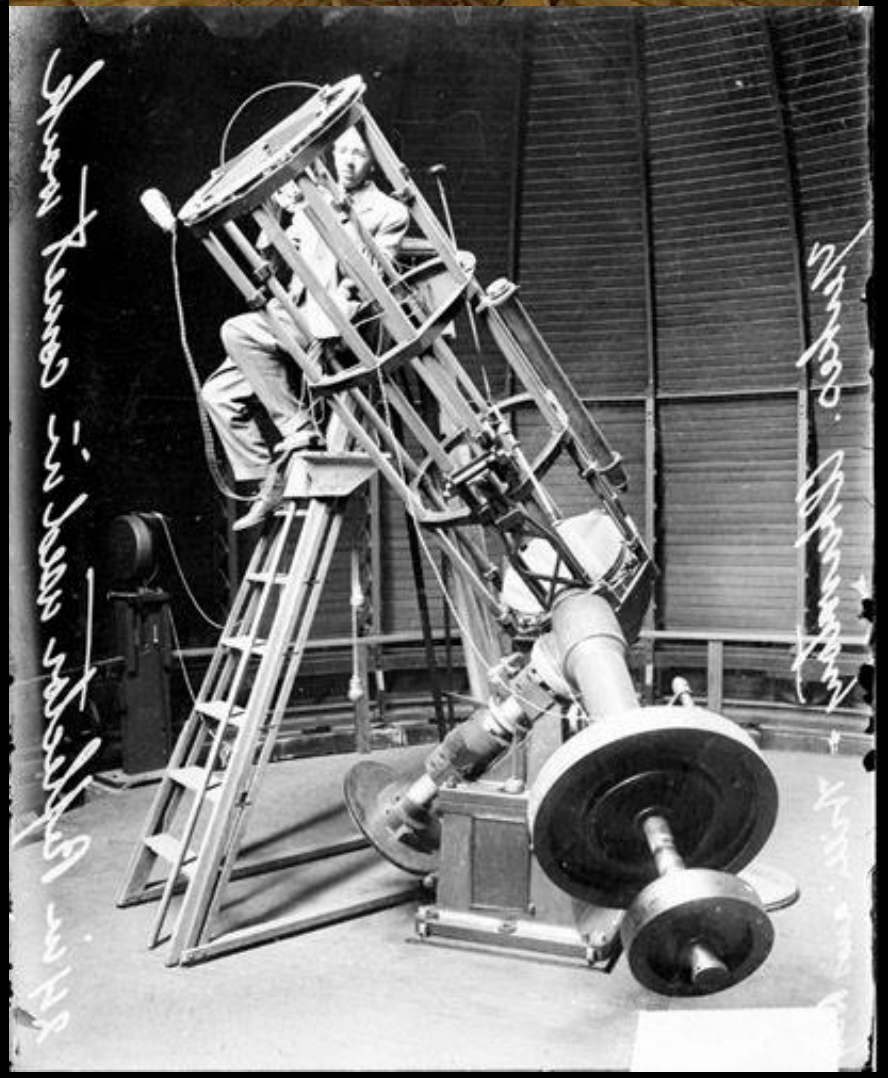


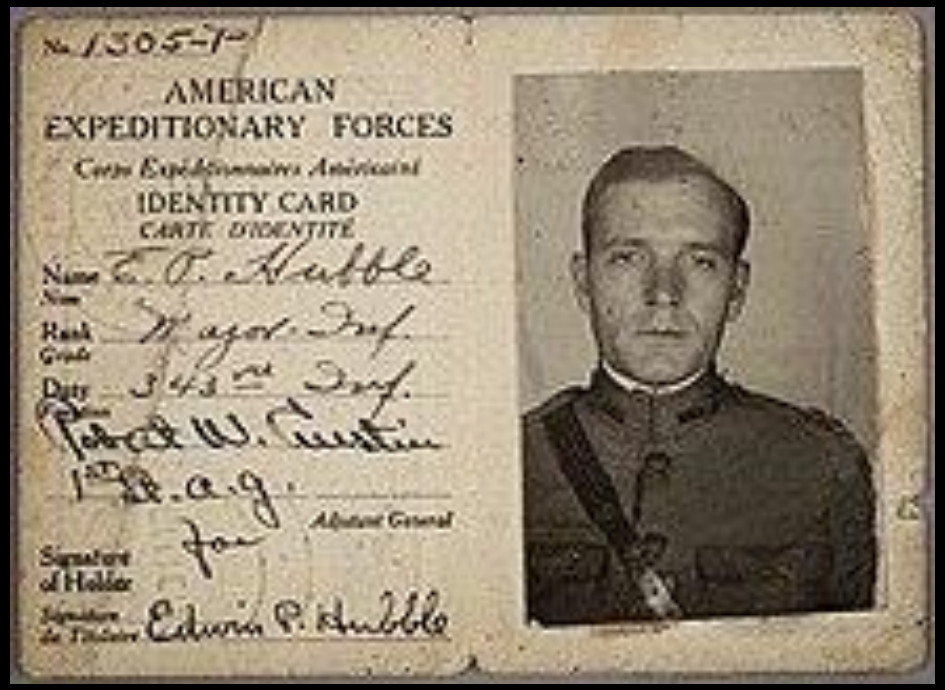
Queens College at Oxford University

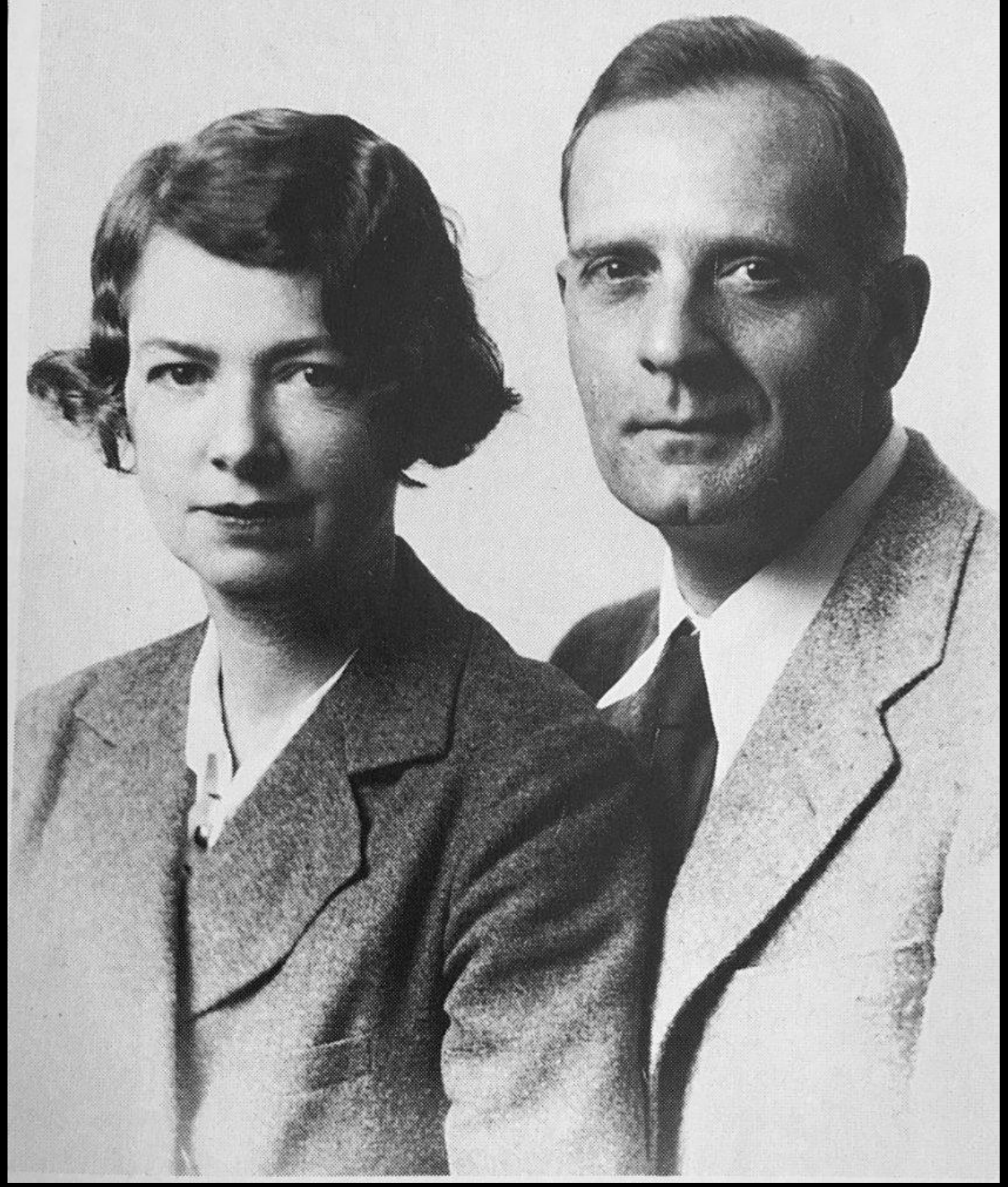

Emilio
Segrè
Visual
Archives

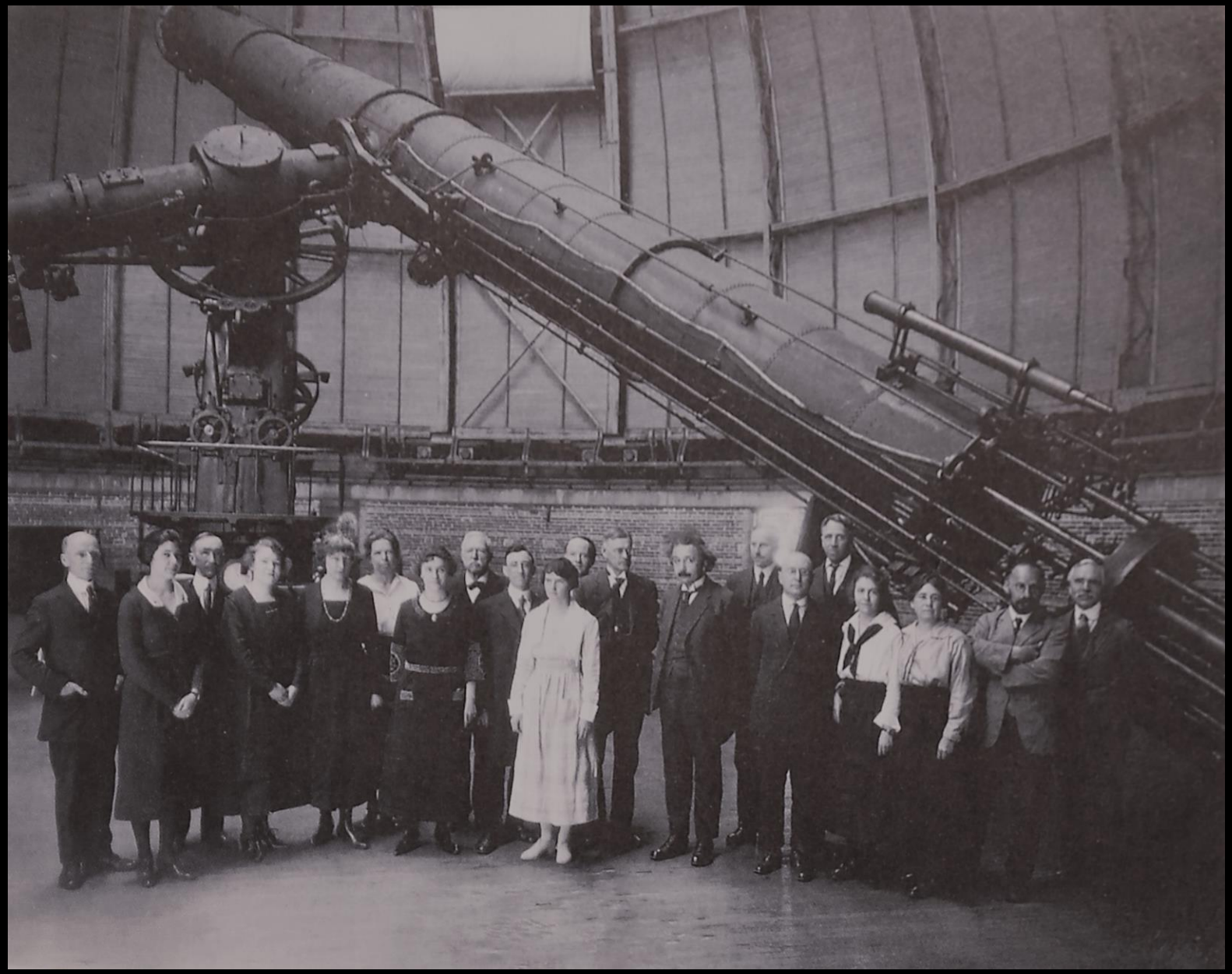

School

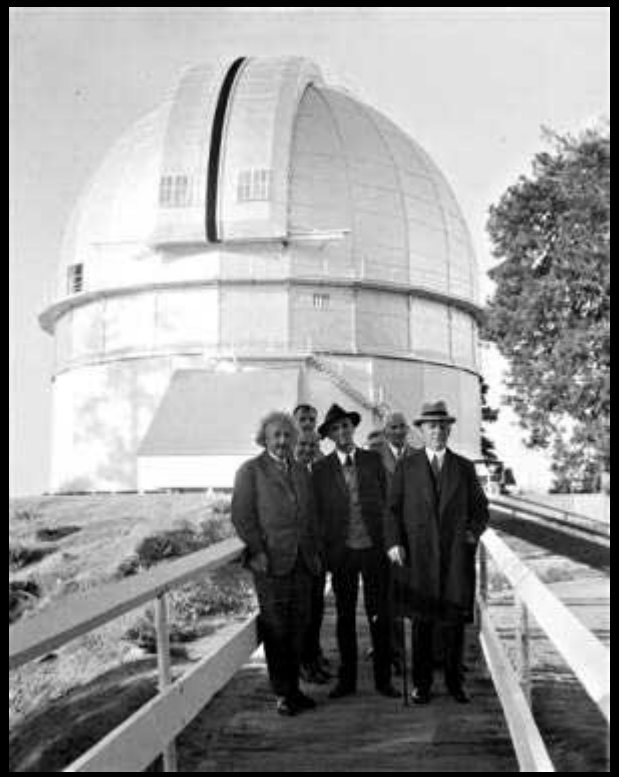
Yerkes Observato

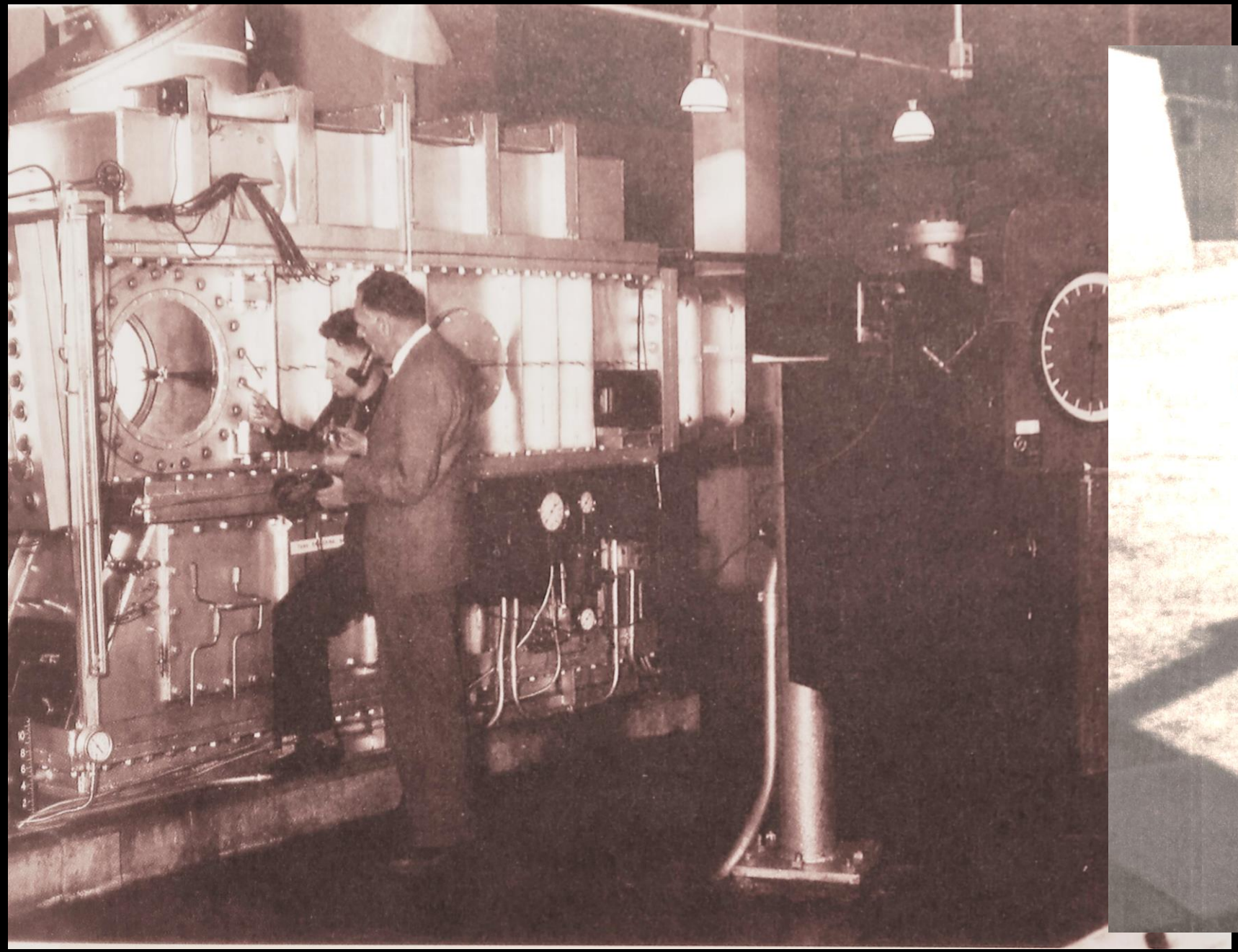



No. 1305-1
AMERICAN
EXPEDITIONARY FORCES
Corps Expéditionnaires Américains
IDENTITY CARD
CARTE D'IDENTITÉ
Name
Nom
E. P. Hubble
Rank
Grade
Major Inf.
Duty
Poste
343rd Inf.
Robt W. Curtin
1st Lt. A.G.
Adjutant General
for
Signature of Holder
Signature du Titulaire
Edwin P. Hubble





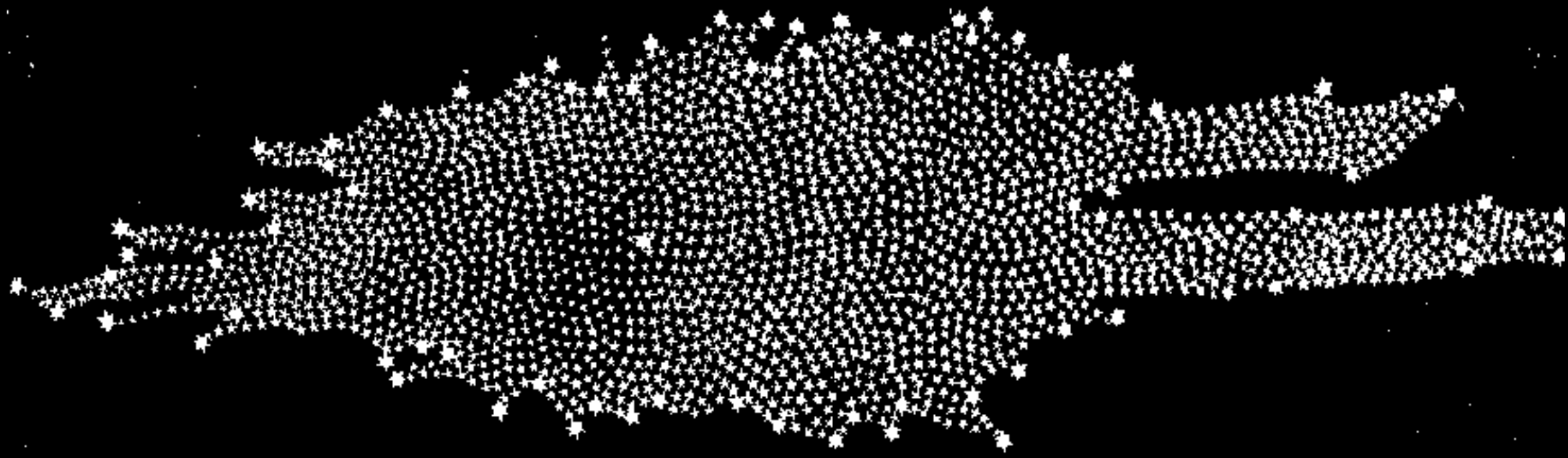




Mt Wilson Observatory

M

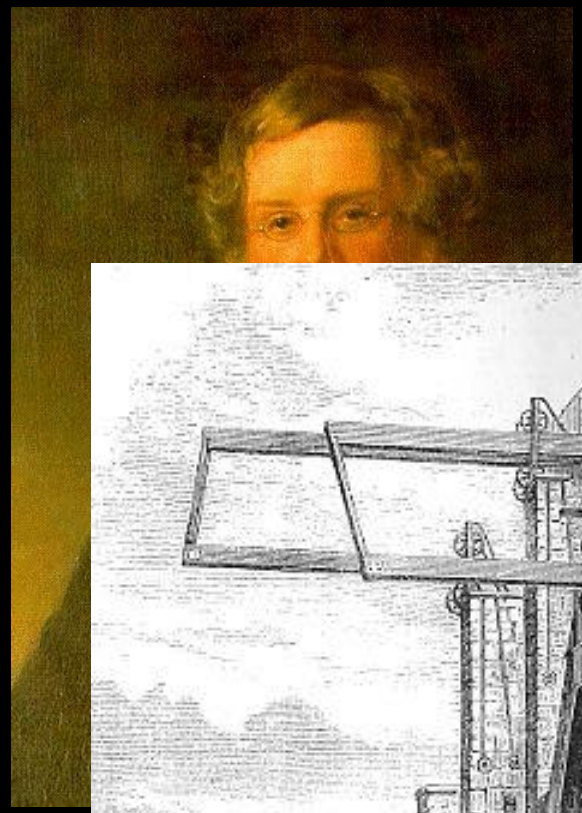
Early Milky Way diagram

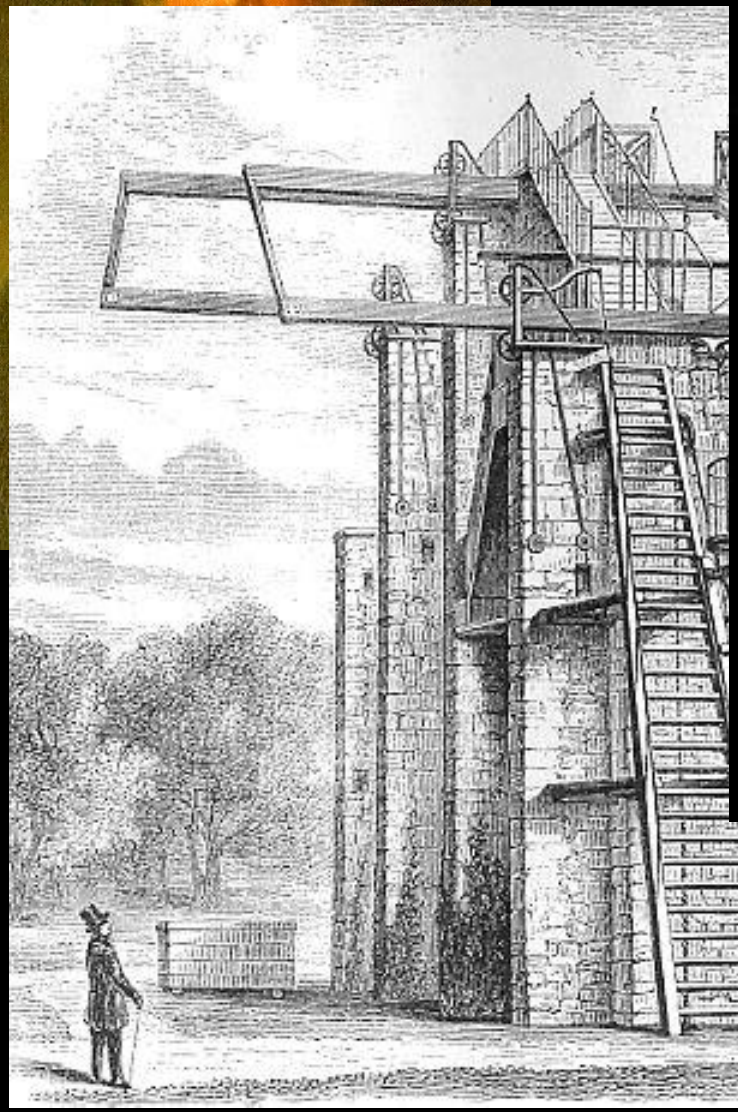


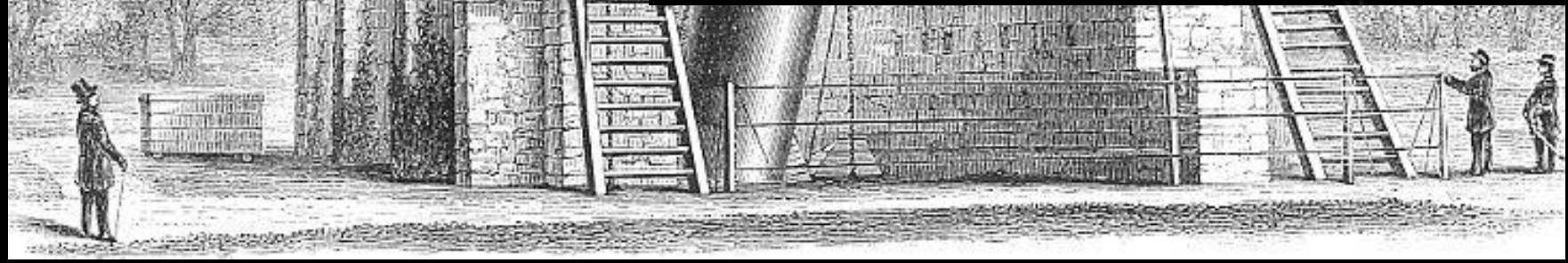
Kapteyn, 1922

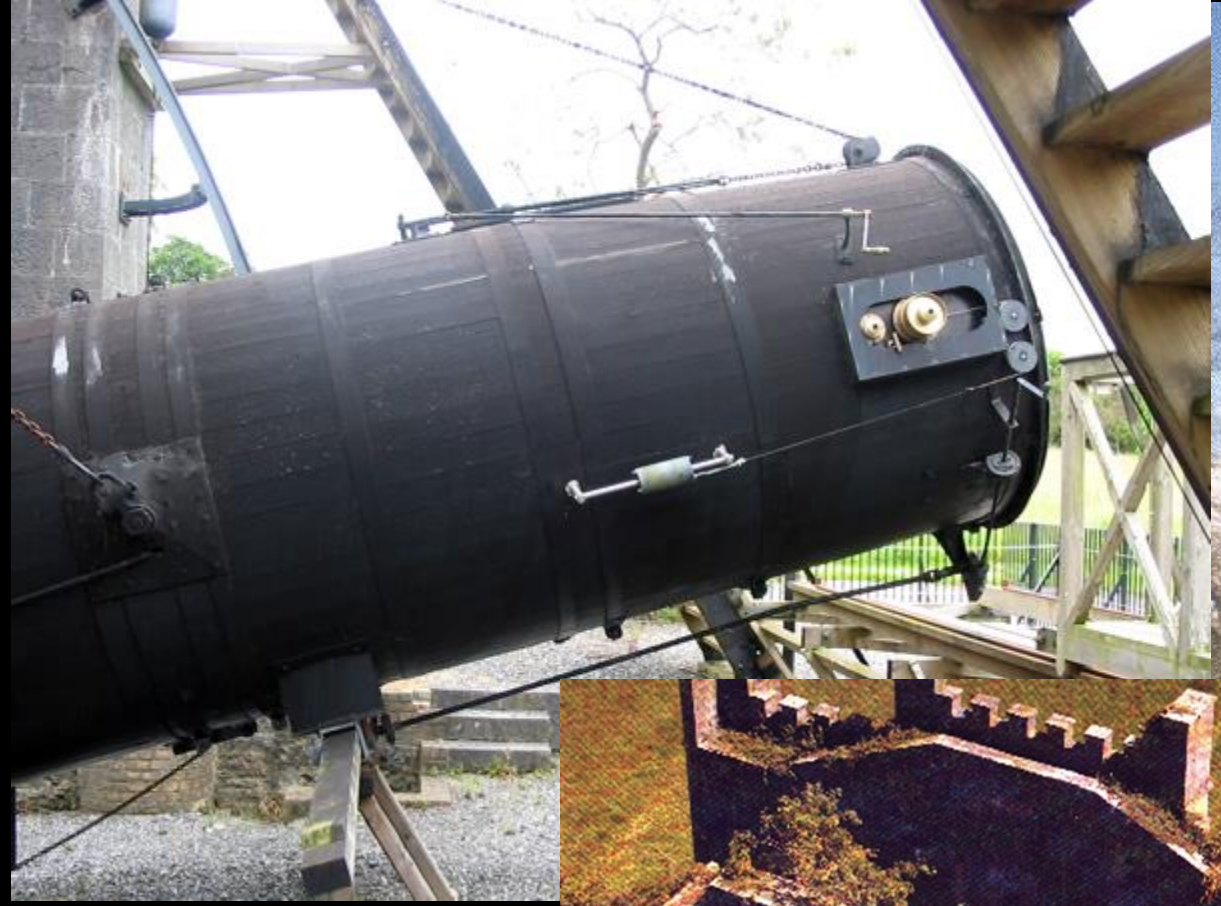
“Spiral Nebula”

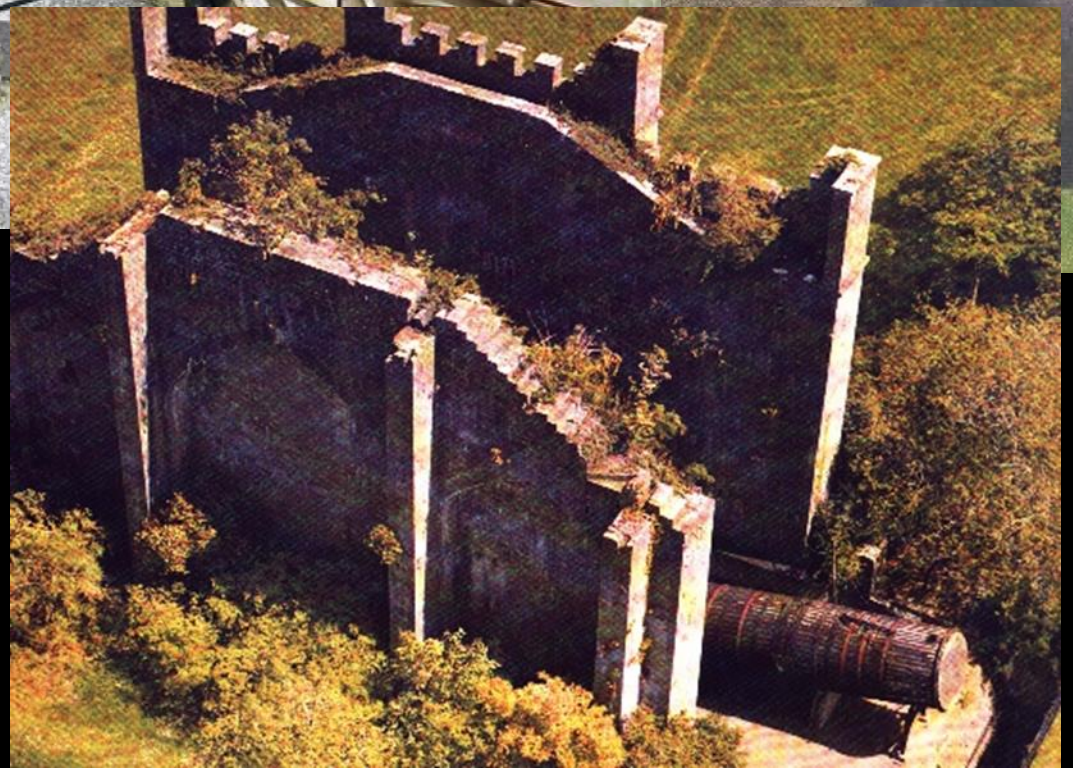
- Fuzzy things seen through the telescope
- 1845 . . . . Earl of Rosse . . .72-inch telescope with metal mirror. Sketched “nebulae.”



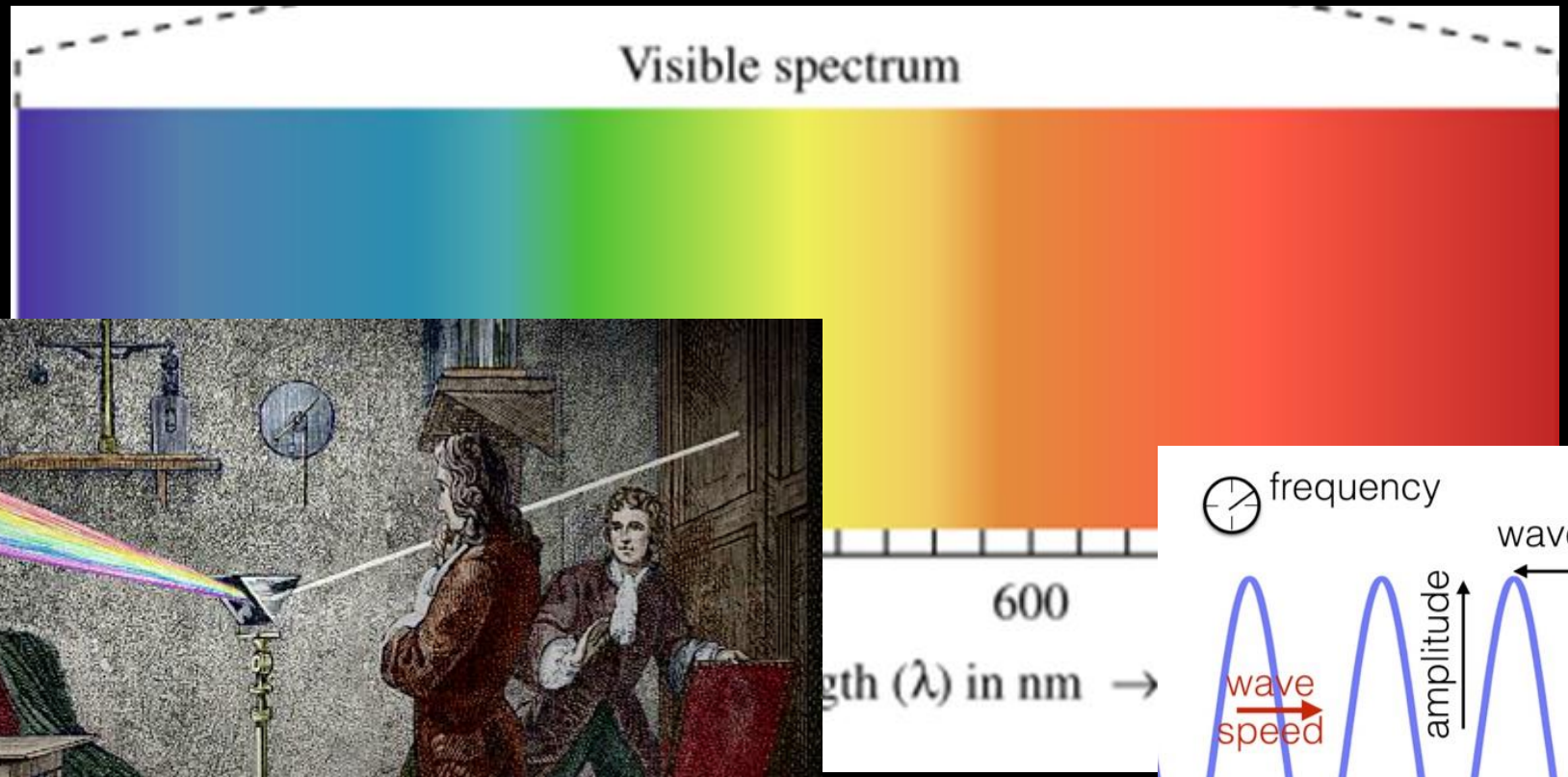


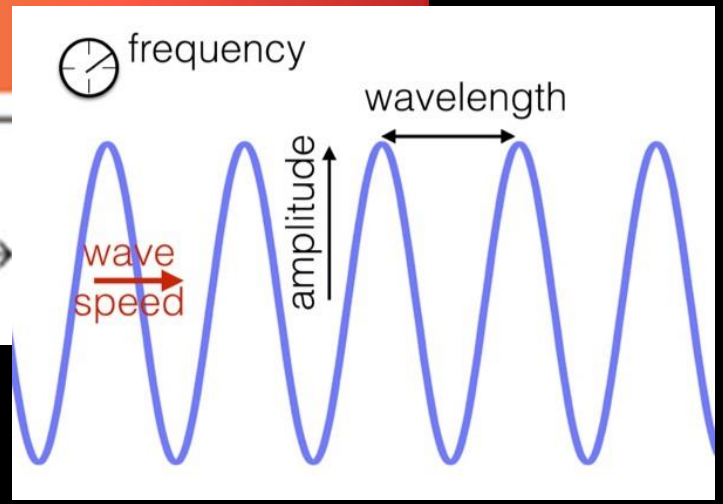


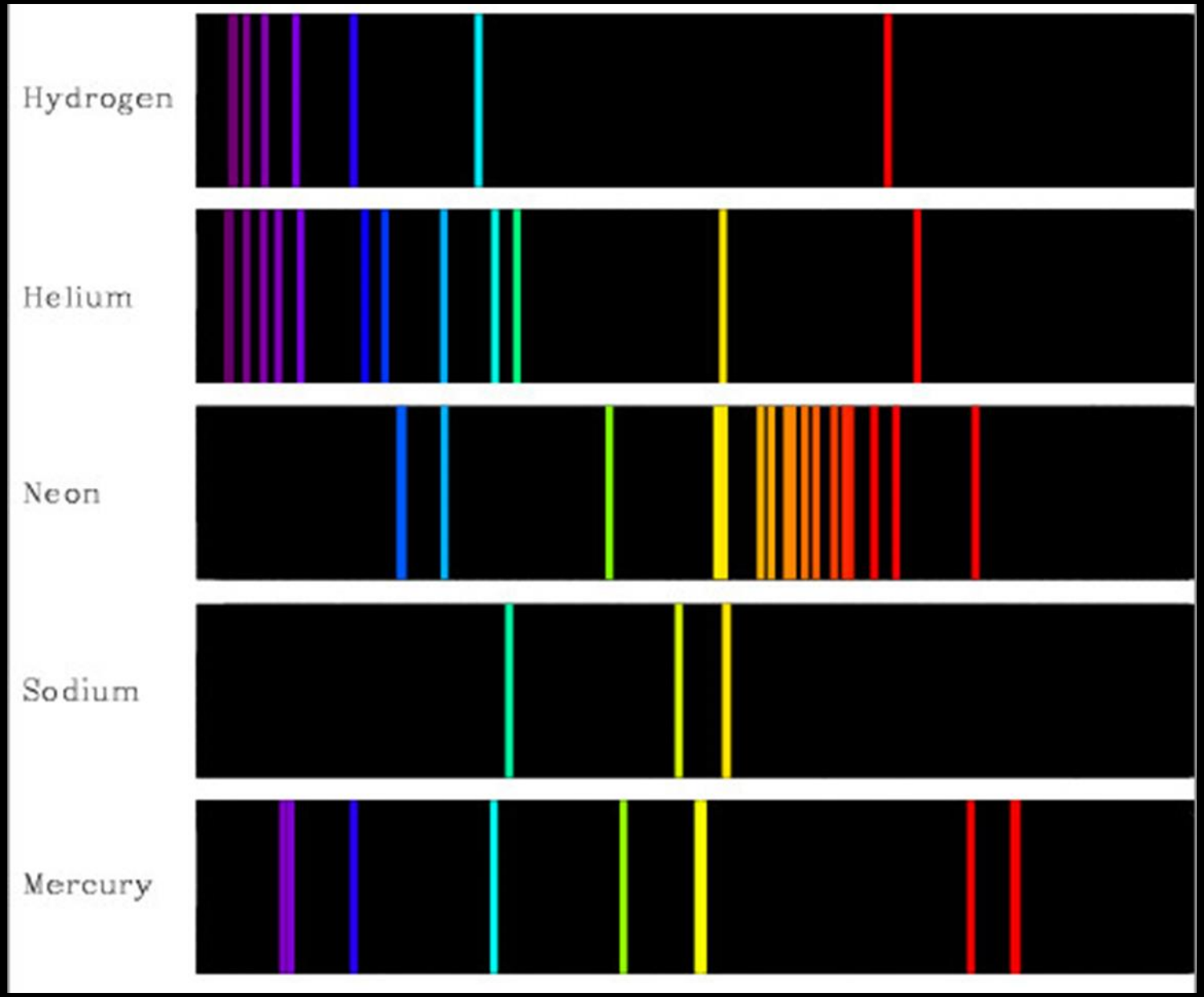


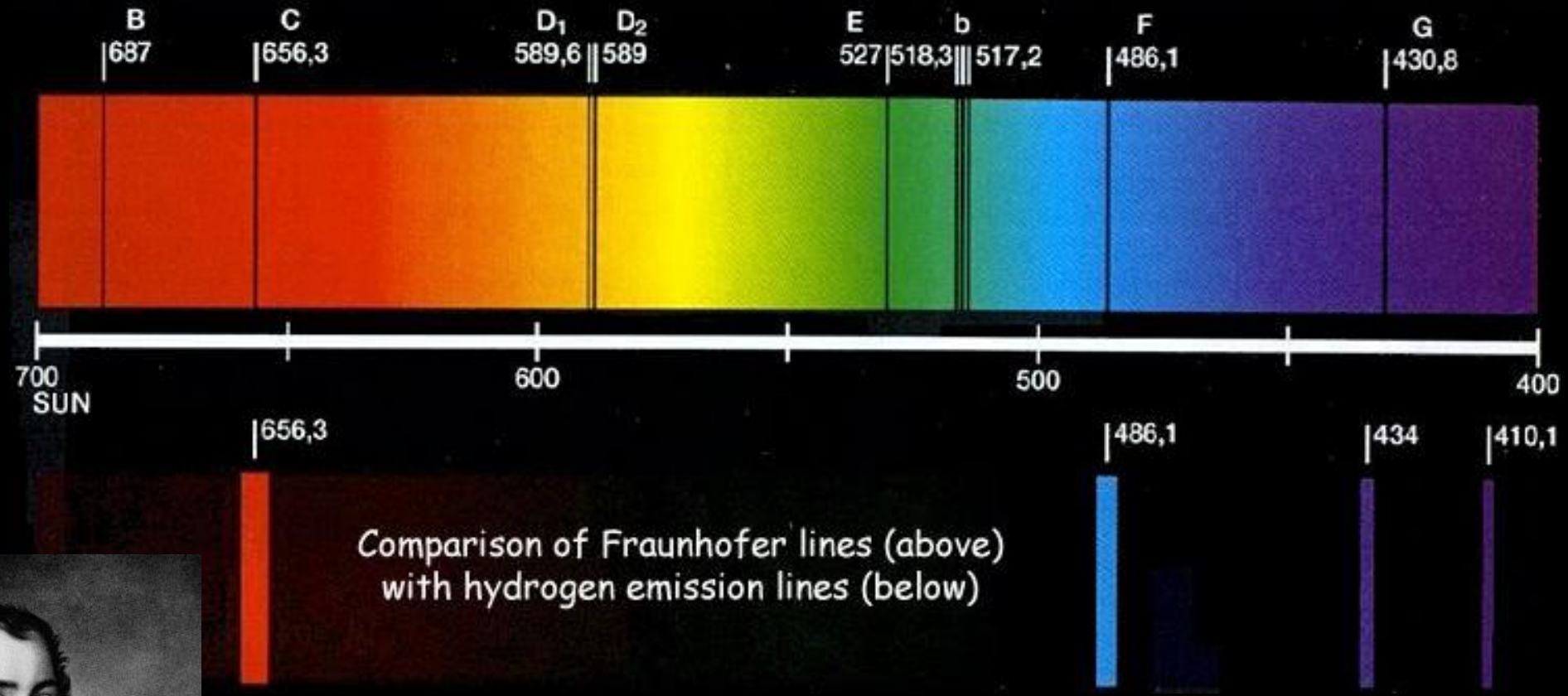


Let's talk "light" for a moment

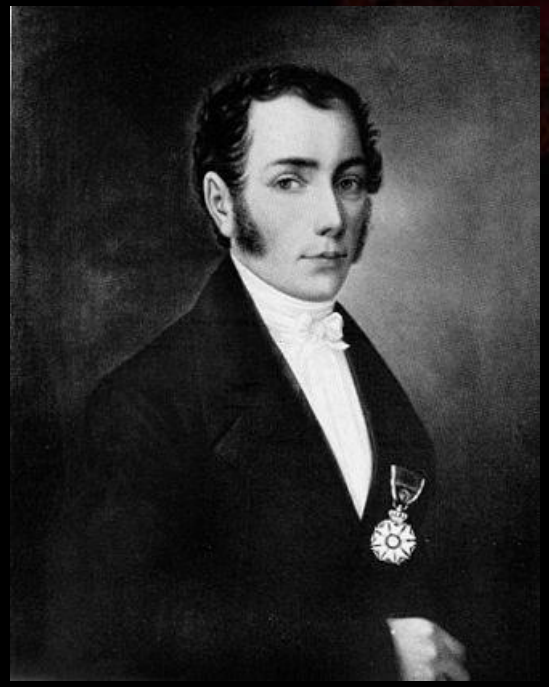





Hydrogen
Helium
Neon
Sodium
Mercury

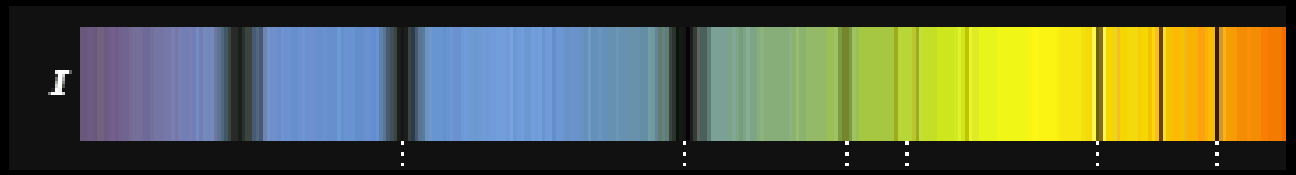


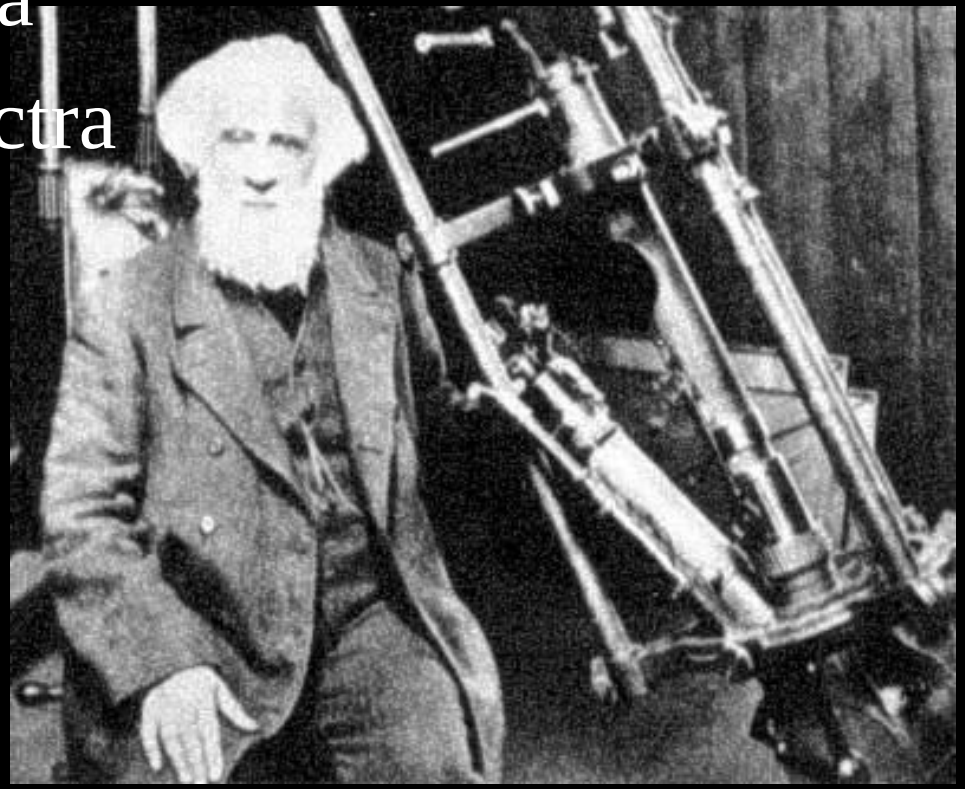
Comparison of Fraunhofer lines (above)
with hydrogen emission lines (below)

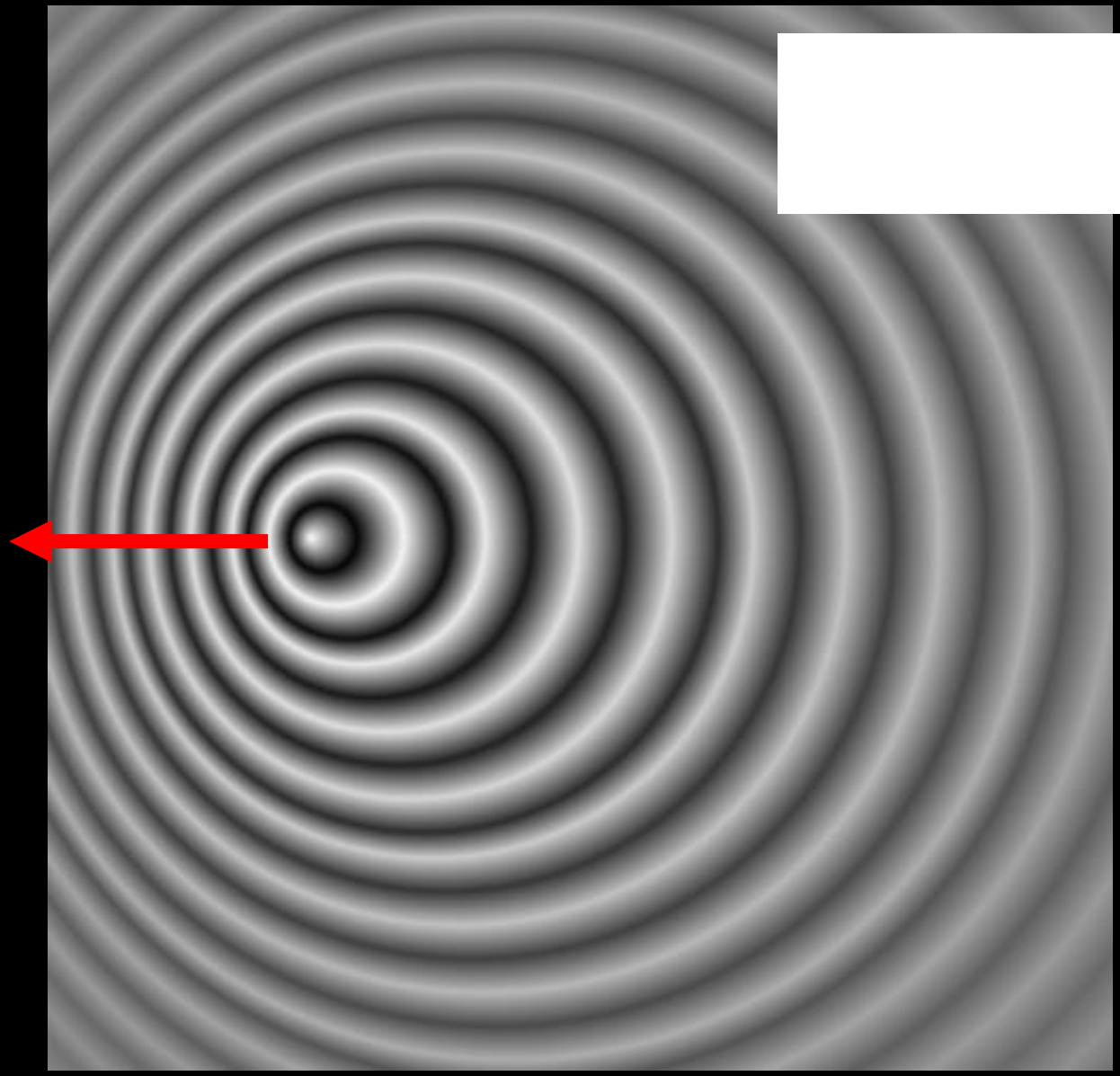


William Huggins

- Telescope on 2nd floor of apartment
- Orion Nebula ⟶ emission spectra
- Spiral Nebula ⟶ absorption spectra







UNSHIFTED

Not moving

REDSHIFTED

Moving away

BLUESHIFTED

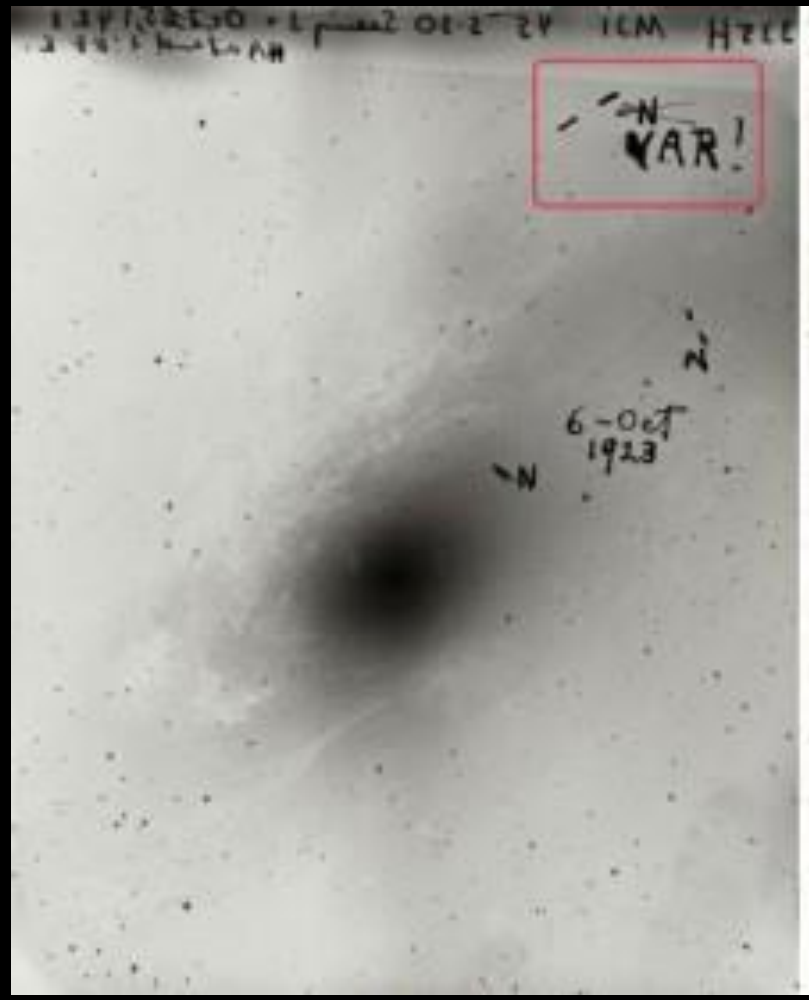
Moving towards

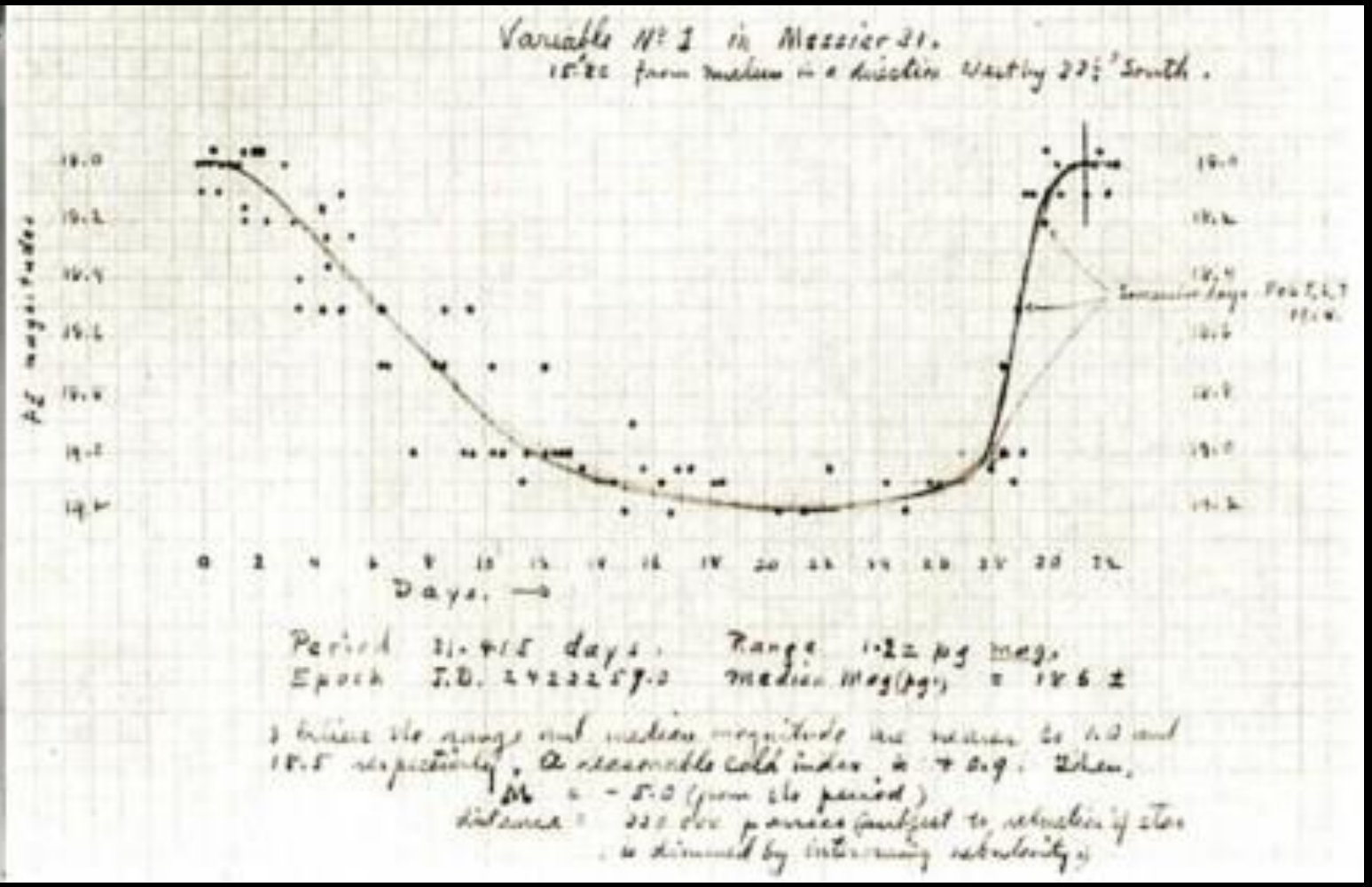
Curtis/Shapley Debate

- A tie . . . .
- Shapley underestimated the distances to the "spiral nebulae" but . . .
- Curtis underestimated the size of the Milky Way!

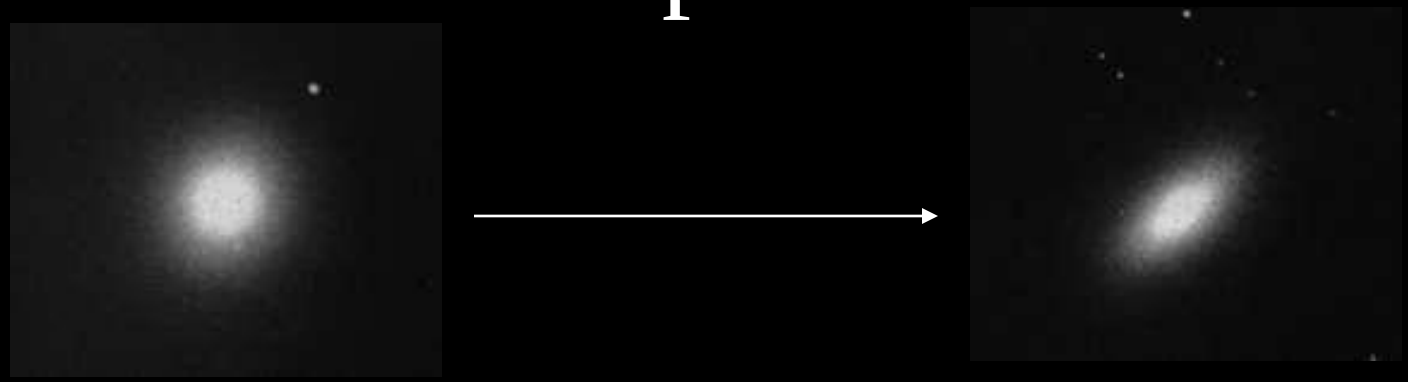
The proof? Edwin Hubble resolved the "Andromeda Nebula" into stars in 1924.

Cepheid variables in “Andromeda Nebula”

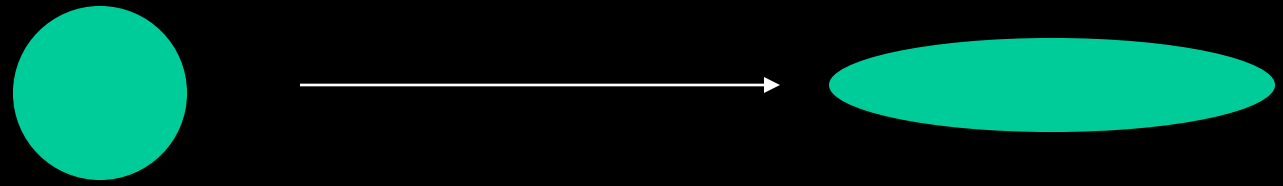




Ellipitcals



E0 E7



This is how WE see the galaxy
old stars, reddish, little star formation

Spirals

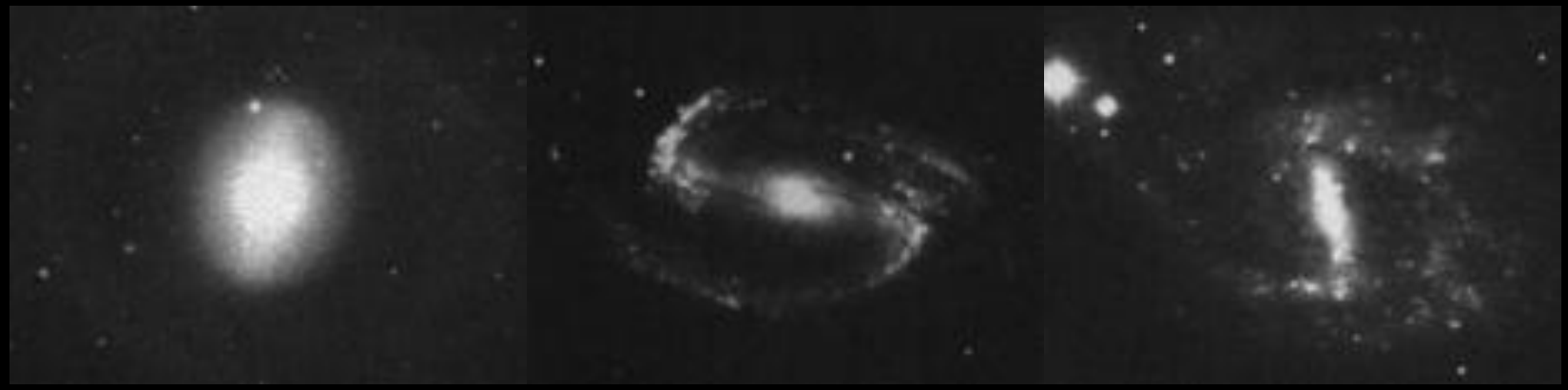
Sa

Sb

Sc

Disk-like with “arms,” young stars, active star formation, bluish

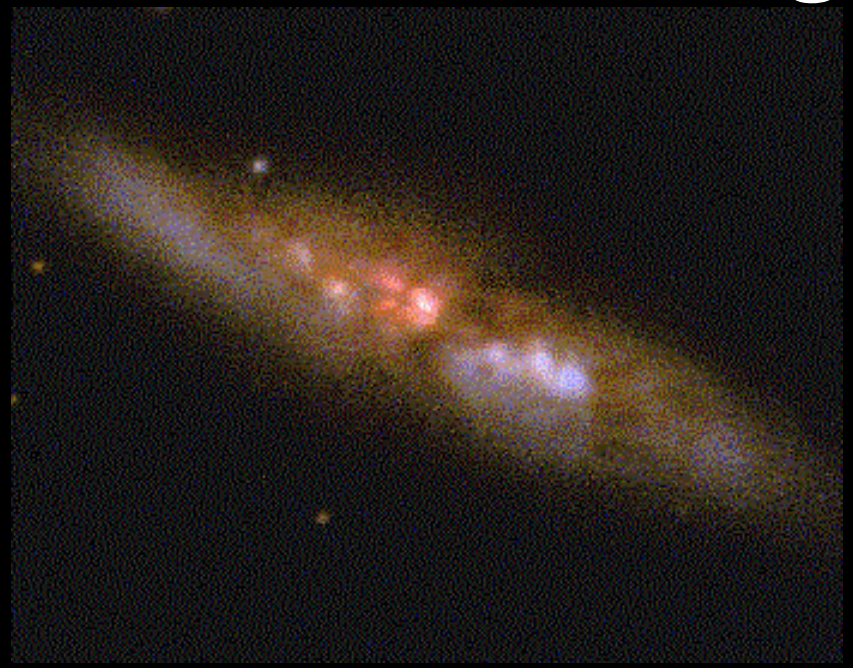
Barred Spirals



SBa SBb SBc

Spirals with bar-like structure through nucleus

Irregulars



Basically blobs without much structure at all

Andromeda Galaxy, M31
Sb

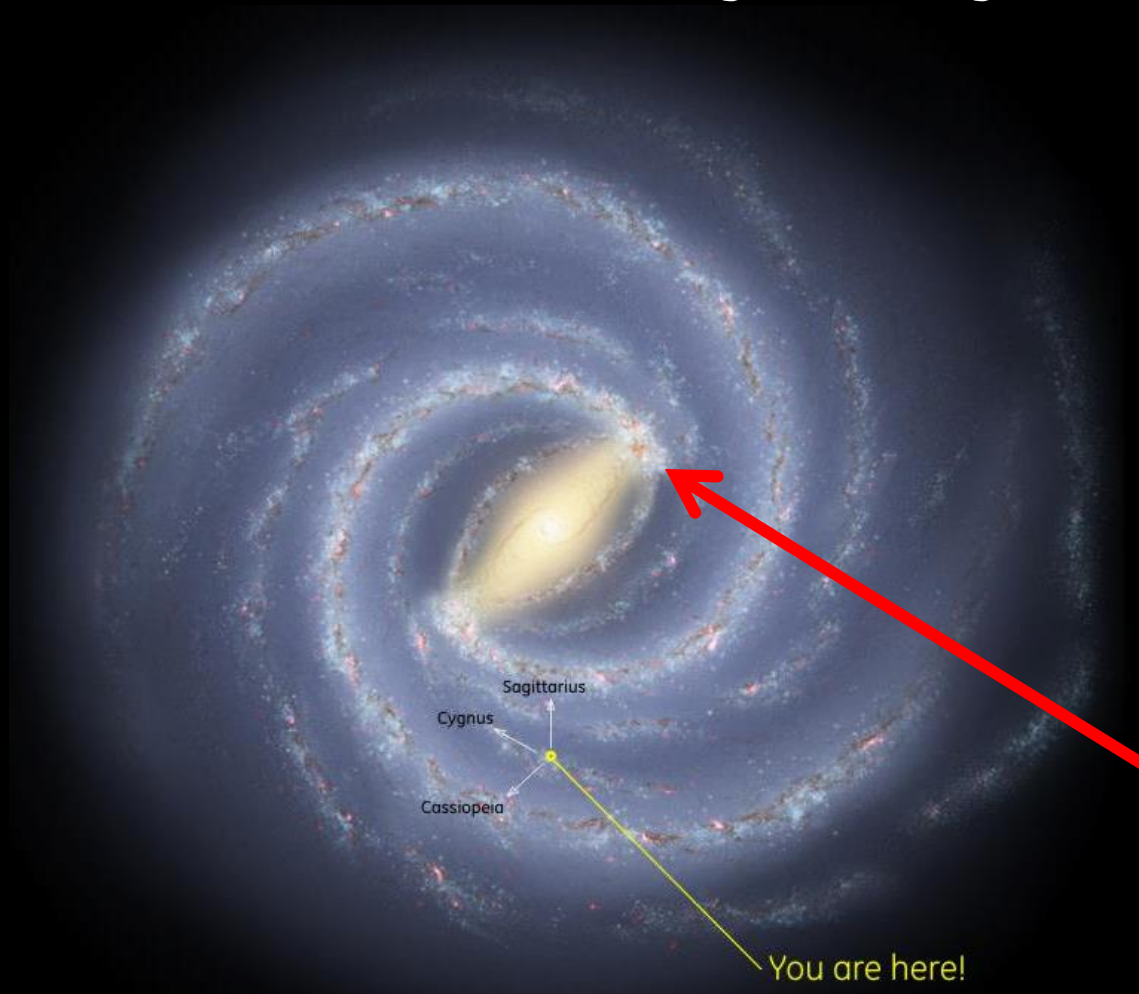

Whirlpool Galaxy, M51
Sc

NGC 1300 in Eridanus

SBb

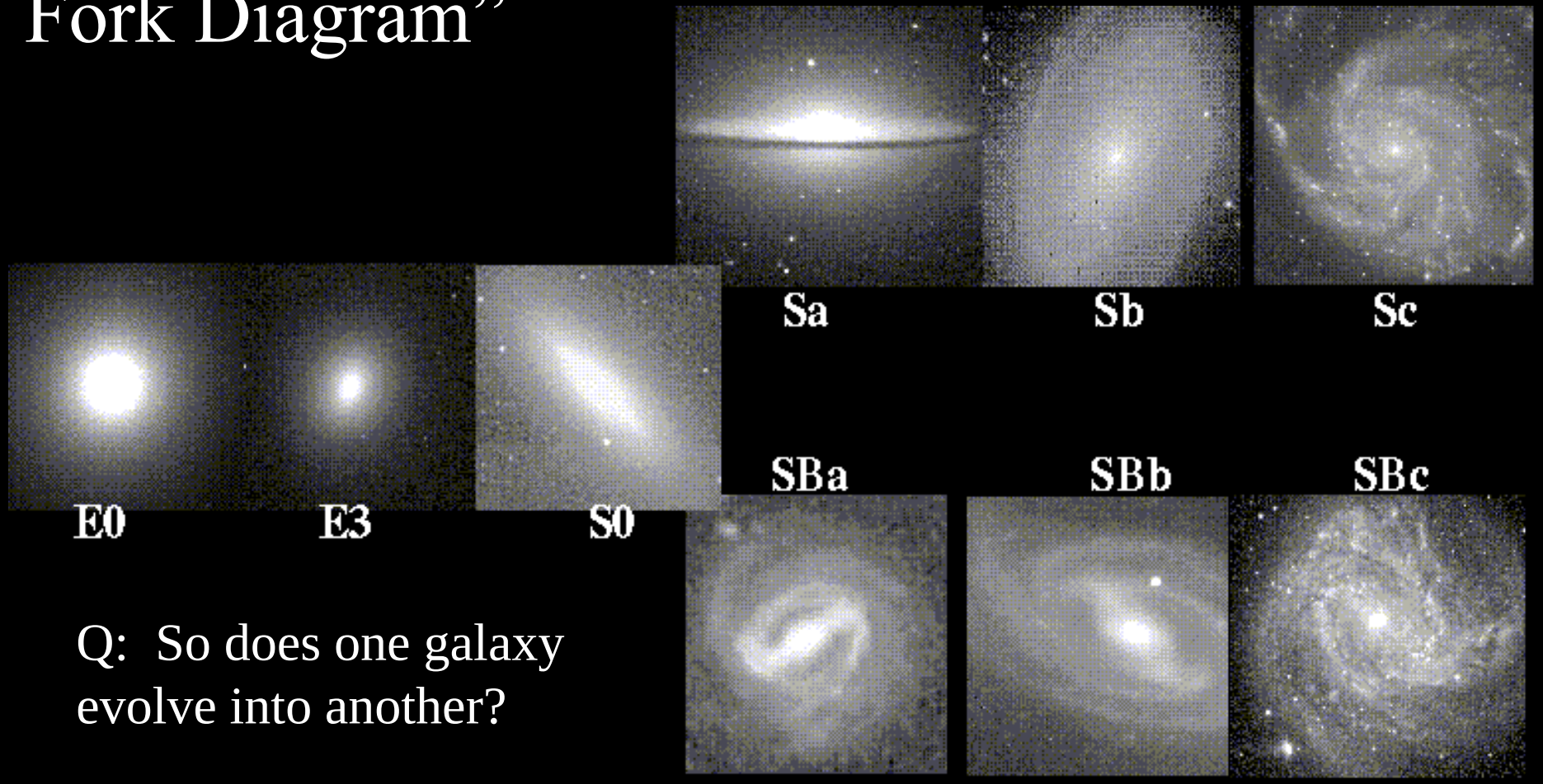
Small Magellanic Cloud
IRR

The Milky Way?



A Bar!

Hubble's "Tuning Fork Diagram"



Q: So does one galaxy evolve into another?

Answer . . . . . No!

- Two kinds of stars:

1) "Population I" – spiral arms, young, more "metals," roughly circular orbits, bright blue stars, and the Sun, too.
2) "Population II" – halo of galaxy, older, lower in "metals," globular clusters, eccentric orbits

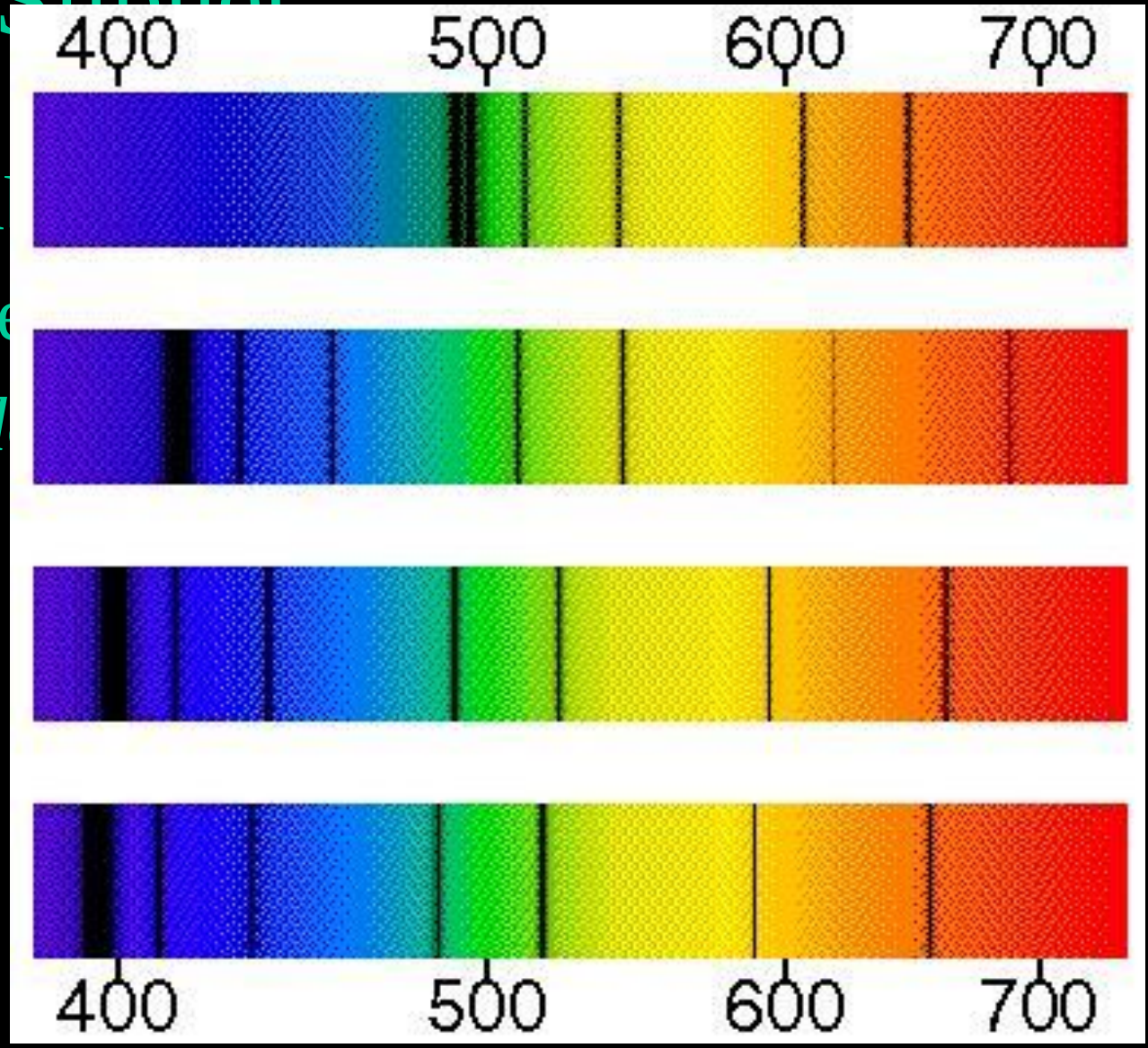
Walter Baade (German),
1942

Vesto Slipher

ppler shifts in a

e shift, the faste

edshifts . . . . . *d*



Putting it all together . . .

Velocity

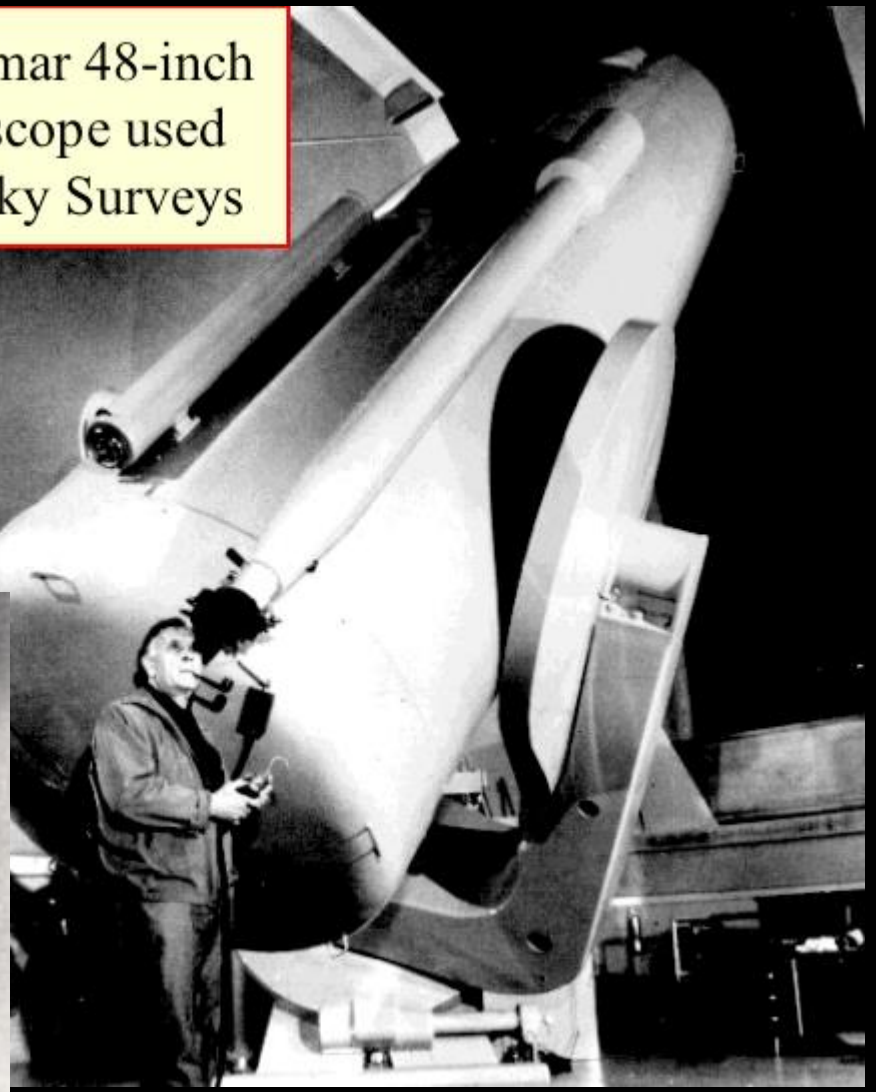
- Redshift in spectrum

Distance

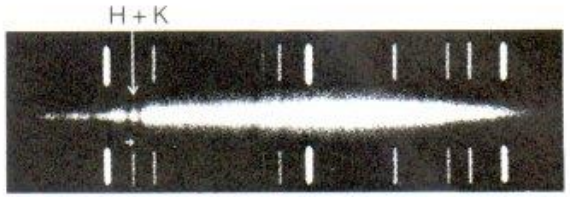
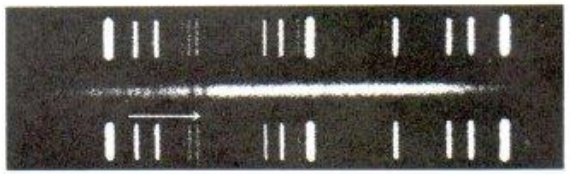
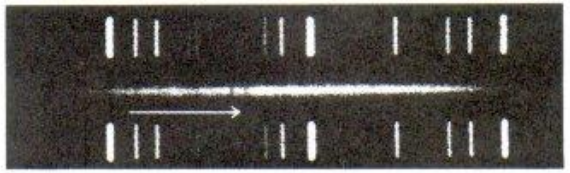
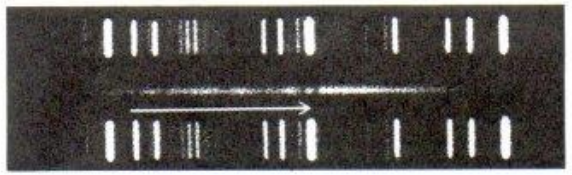
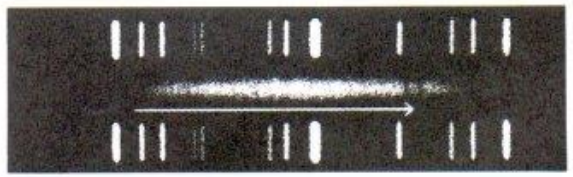
- Distance indicators
  - Cepheid Variables
  - Supernovae
  - Brightest galaxy in cluster

Edwin Hubble, 1929

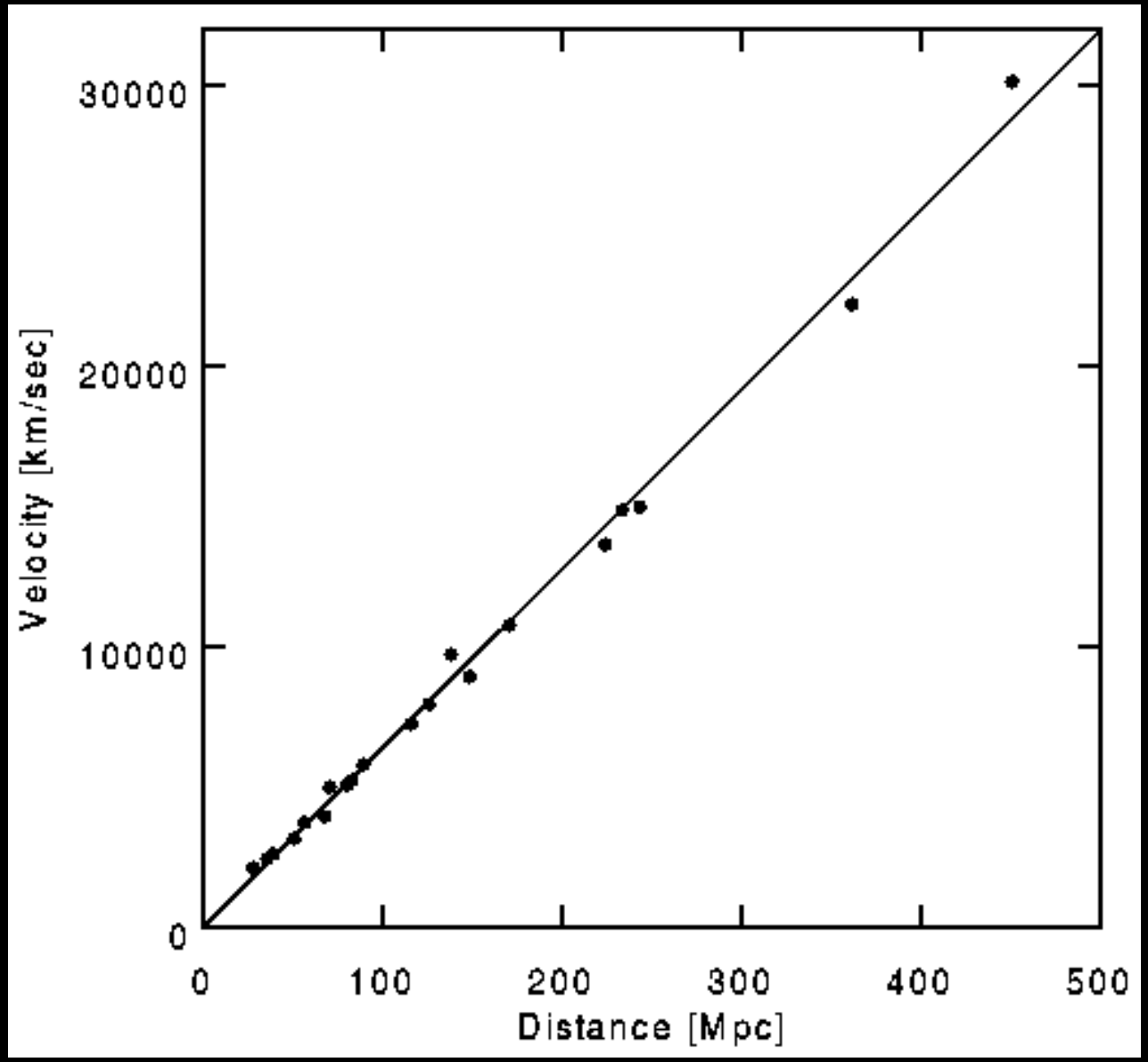
Palomar 48-inch Telescope used for Sky Surveys



Relation Between Redshift and Distance for Remote Galaxies

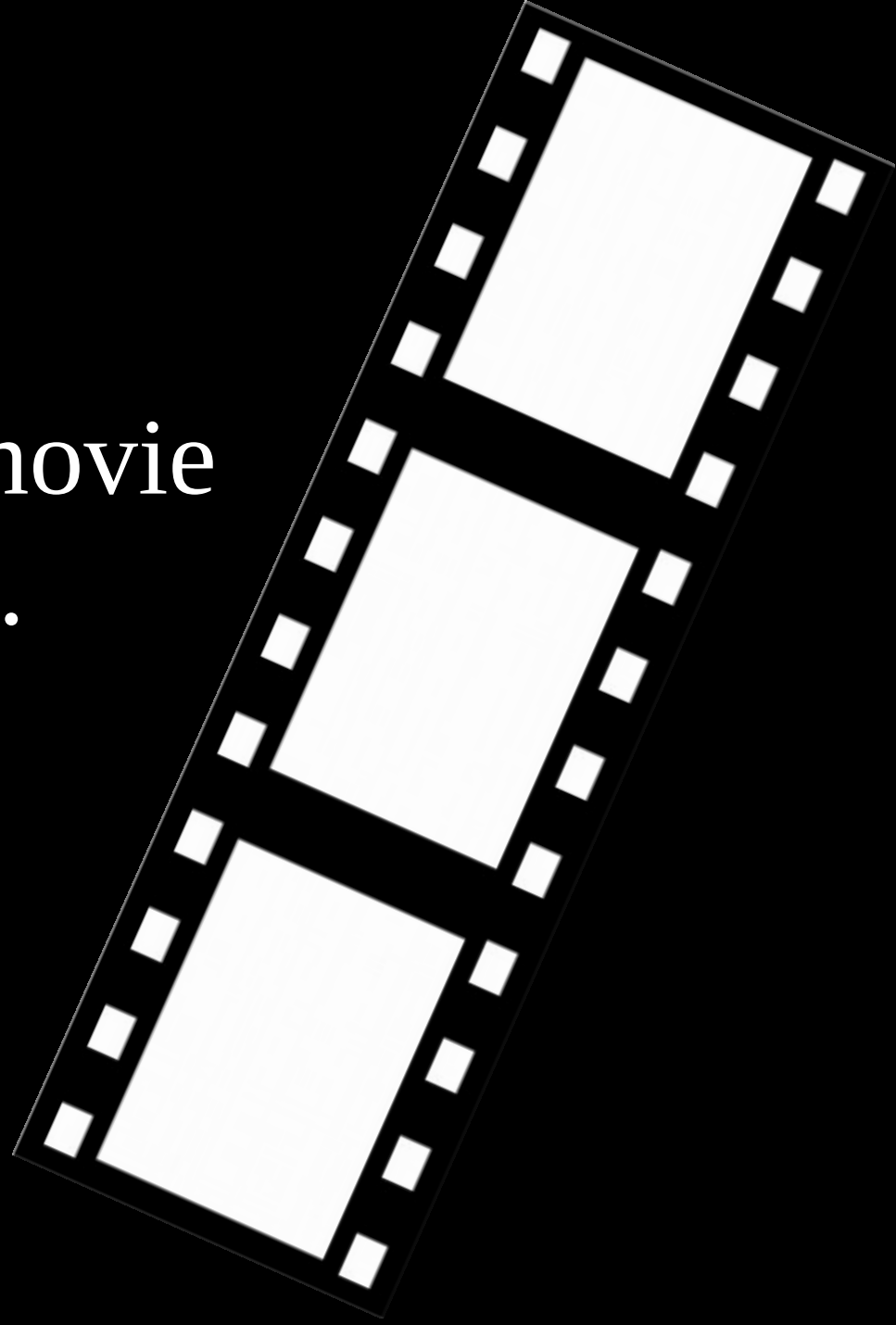
Galaxy, Part of Cluster in:	Estimated Distance (megaparsecs)	Redshift
 Virgo	15	 1200 km/s
 Ursa Major	190	 15,400 km/s
 Corona Borealis	280	 22,000 km/s
 Boötes	490	 39,400 km/s
 Hydra	760	 60,600 km/s

Note, in general, how the apparent size of the galaxy relates to redshift.



Straight line! Slope . . . V = H x d

What if we run the movie backwards? . . . .



- If Galaxies are flying apart . . . .they'll be farther apart in the future . . . .
- That means they were closer together in the past . . . . .
- How close could they get? And why are they flying apart?

Hello, "Big Bang Theory"

(name came from a Catholic priest)

IF the Big Bang happened . . . Predictions:

1) Expansion . . . . . .OK
2) ¼ of Hydrogen changed to Helium
3) “Smoking Gun”

Expansion . . . . an example

- Space is expanding . . . .galaxies aren't moving that much
- Raisins in bread in an oven
- "Galaxies on a balloon"
- Hubble constant determines how fast it's expanding . . . . meaning . . .
- 1/H = age of the universe! Here's how . . .

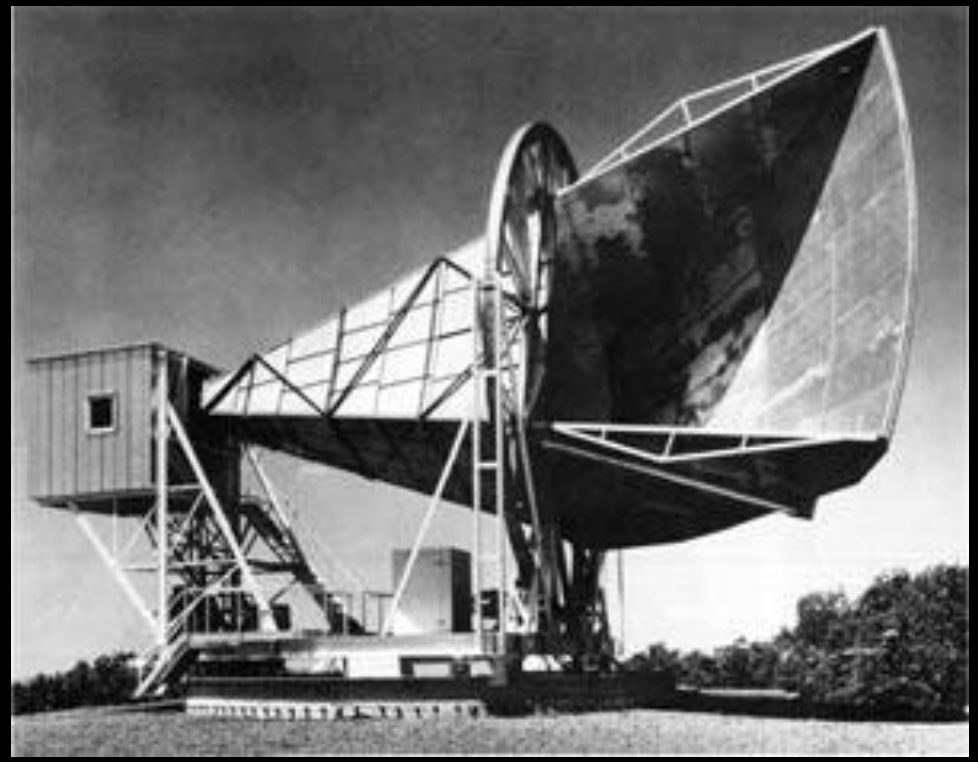
H to He . . What do we see?

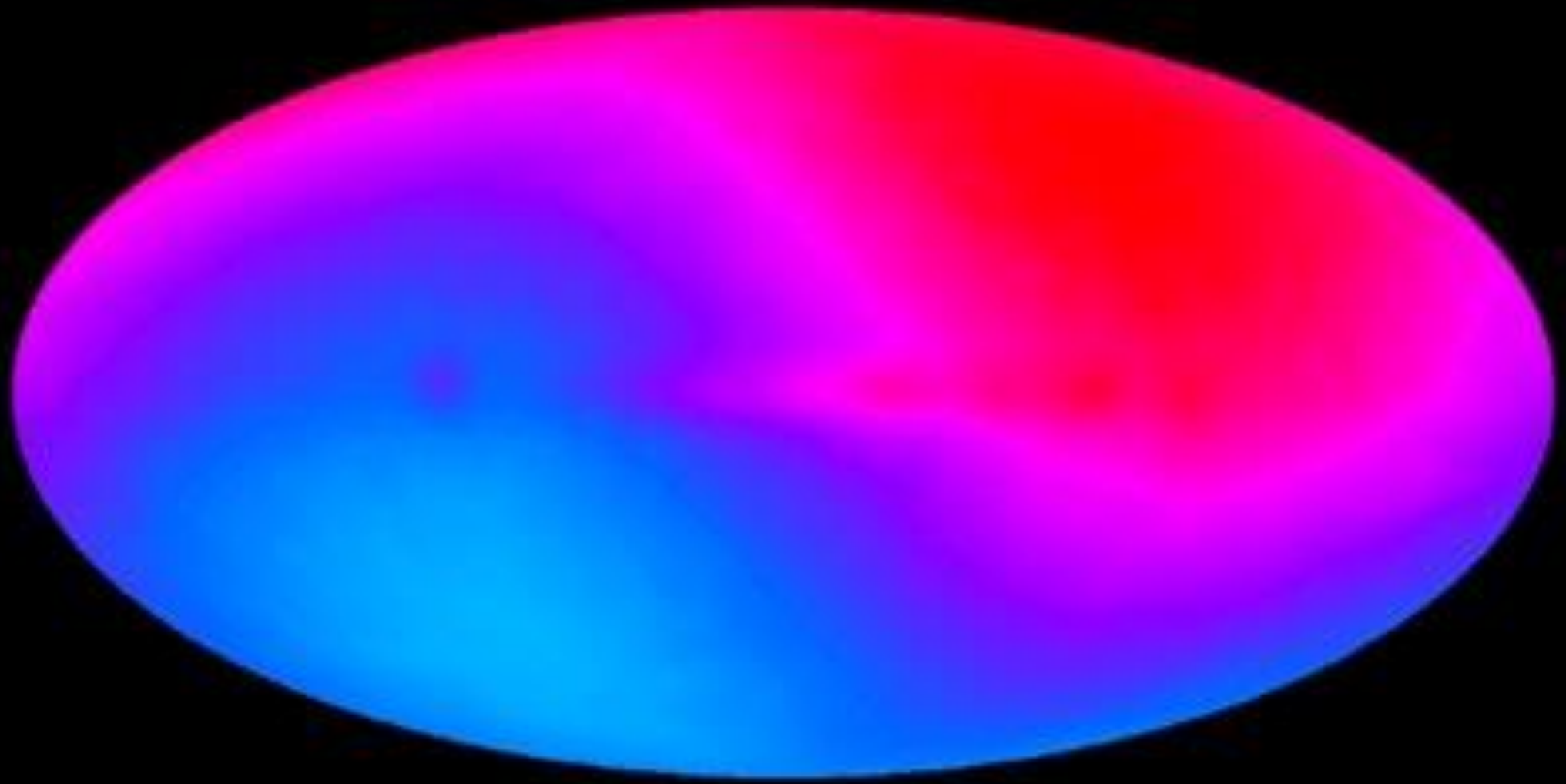
- Young stars . . . . . .~30%
- Globular clusters . . . . ~30%
- Nebula in Milky Way . . . . . ~29%
- Nebula in SMC . . . . . ~25%
- Nebula in M33 . . . . . .~34%

- Doesn’t *prove* Big Bang! Theory is *consistent* with observations!

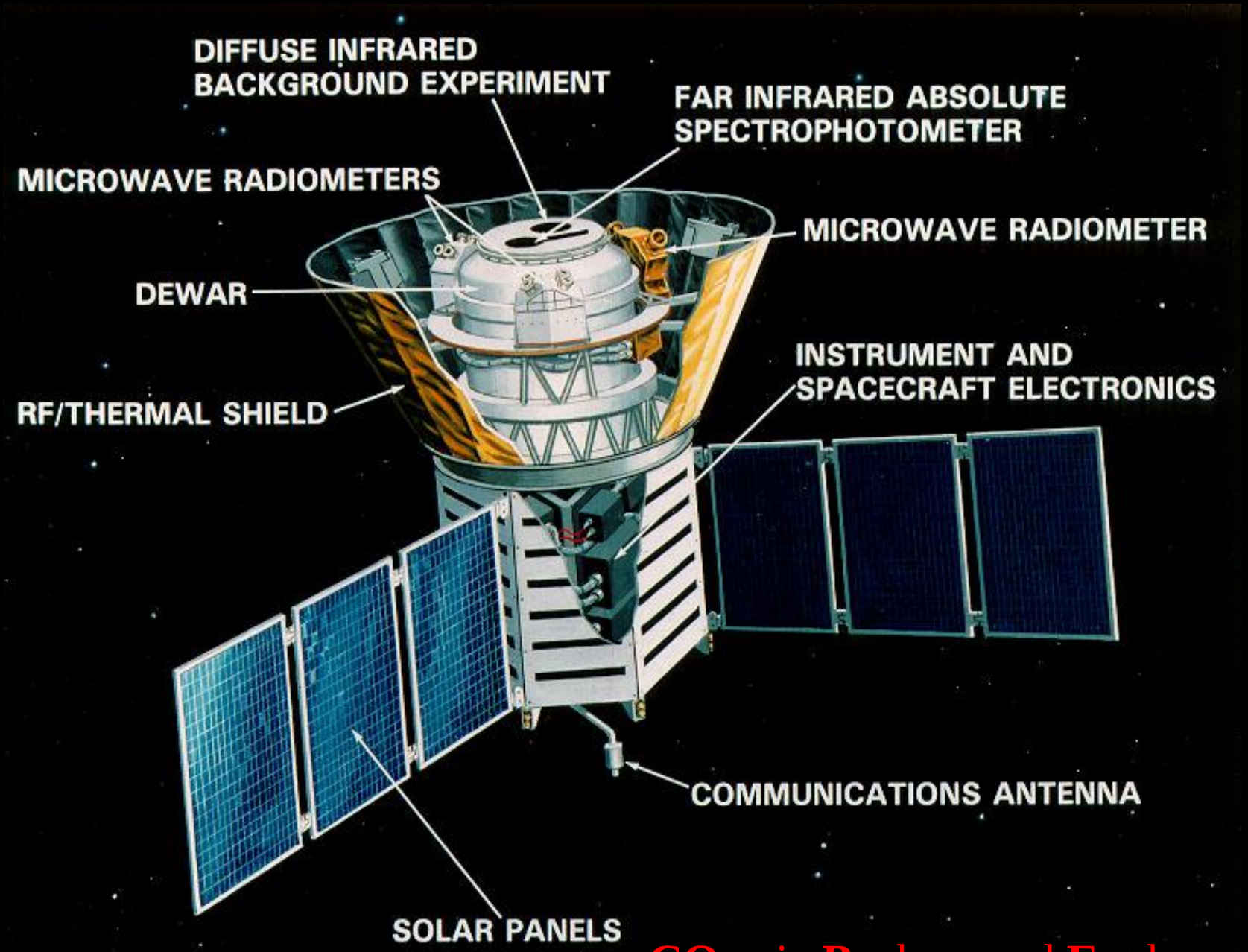
“Smoking Gun?” (Cosmic CSI)

- `Penzias & Wilson (1965) – Bell Labs testing a radio telescope, looking for source of static coming from all directions.
- “Thin dielectric film . . . . . .”
- 1978 Nobel Prize
- T = 2.7K, λ = 1.1mm
  & smooth

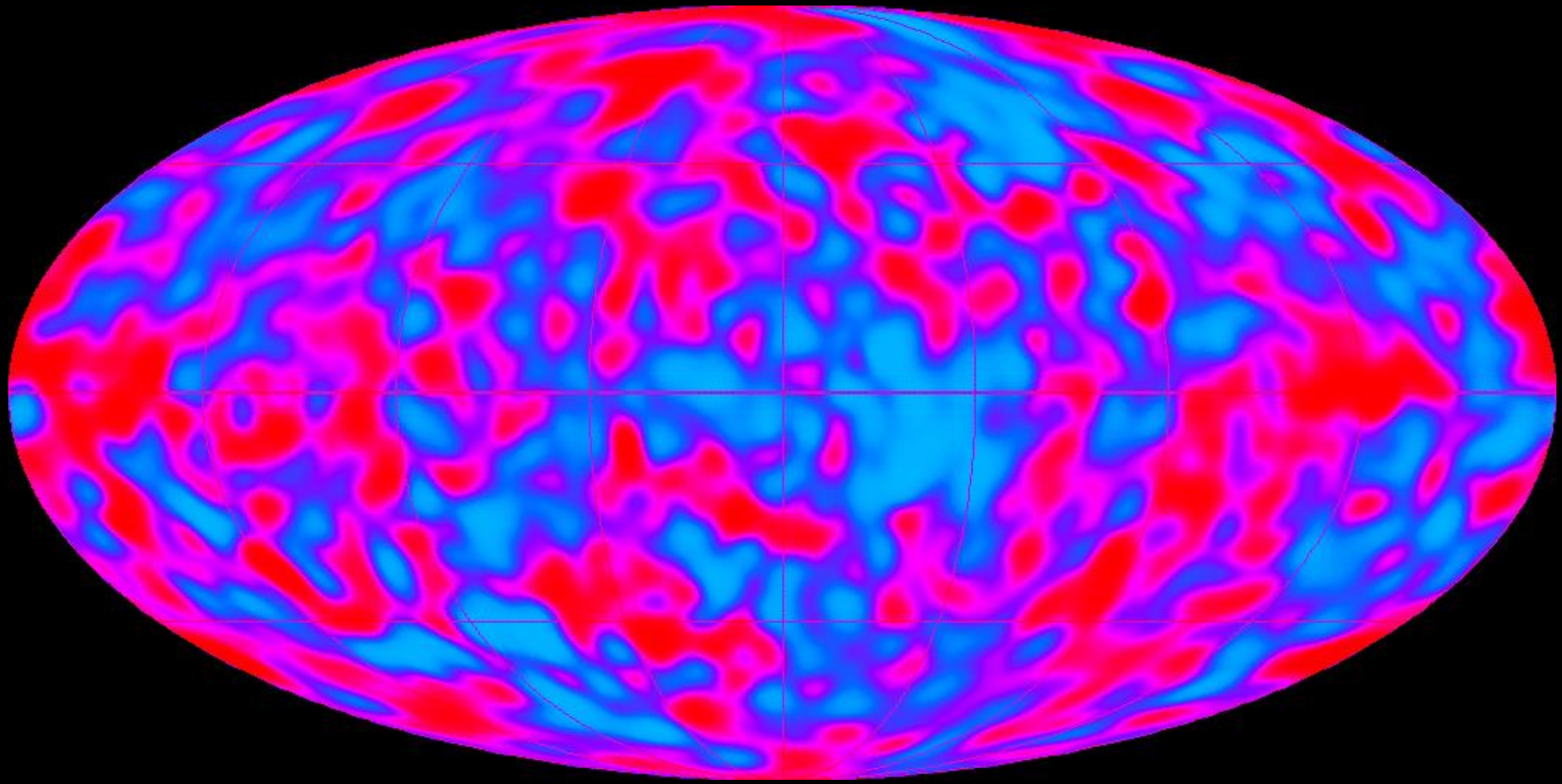




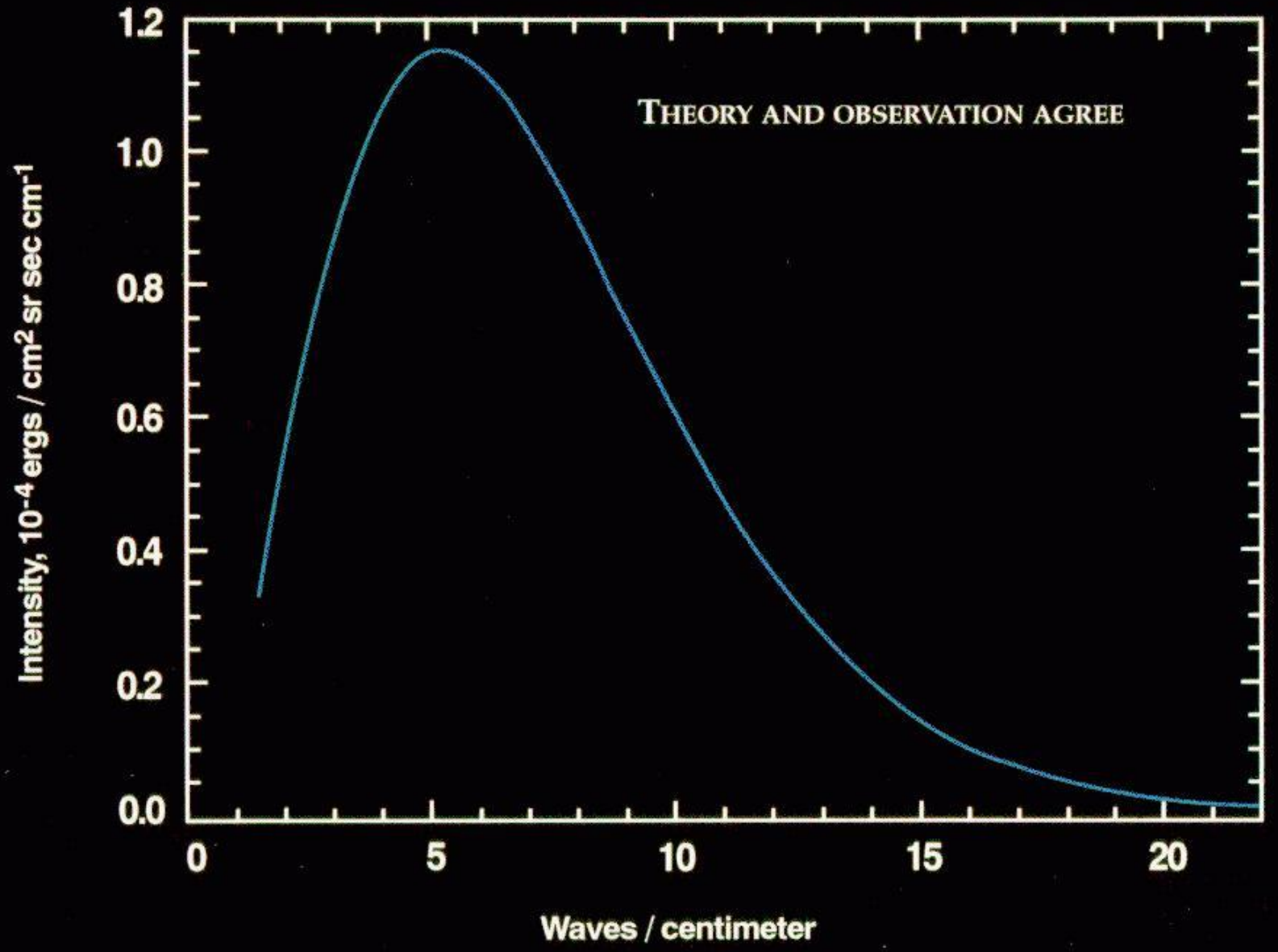
Problem: It's perfectly smooth . . . . How to you go from smooth radiation to a clumpy universe? (Galaxies)



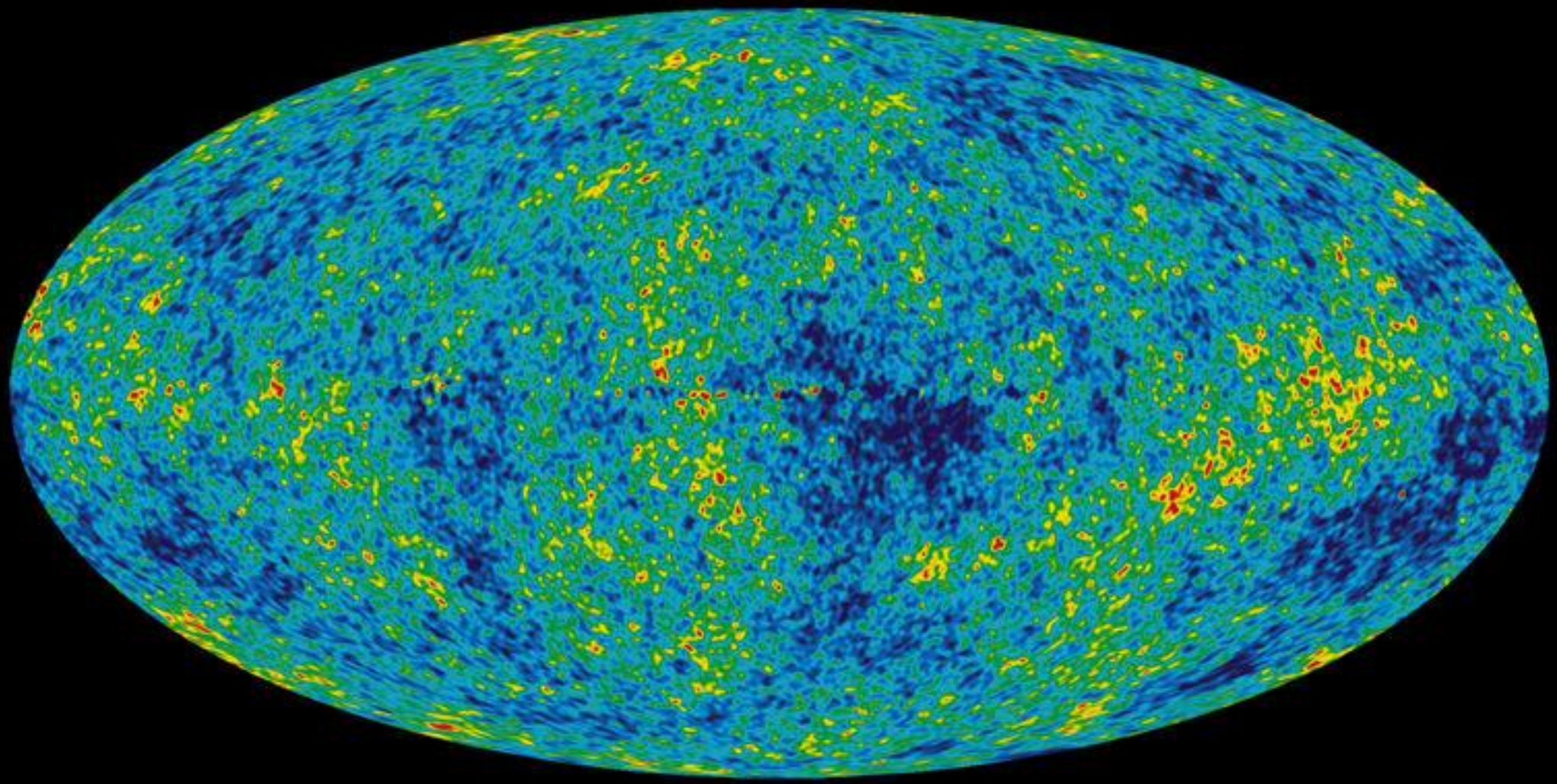
COsmic **B**ackground **E**xplorer

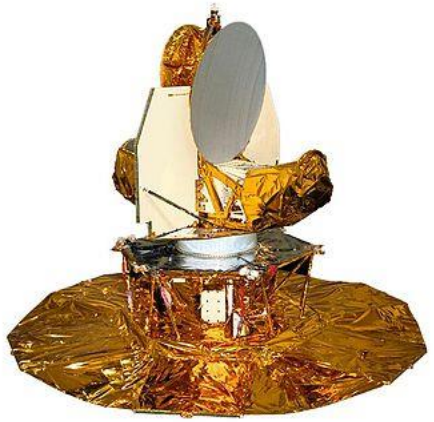


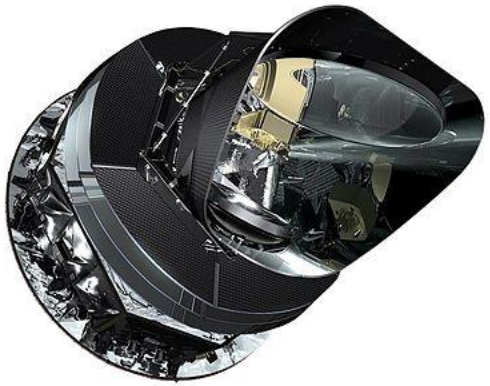
Cosmic Microwave Background Spectrum from COBE

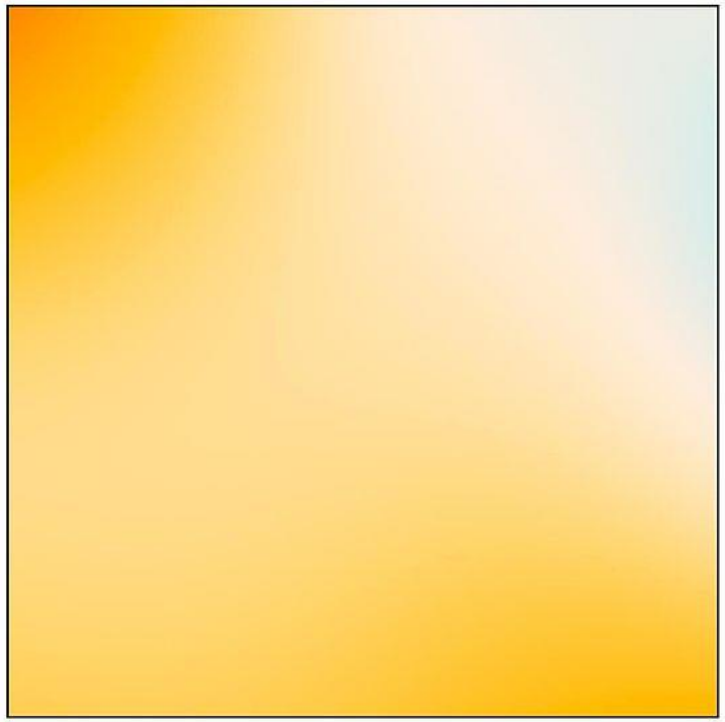


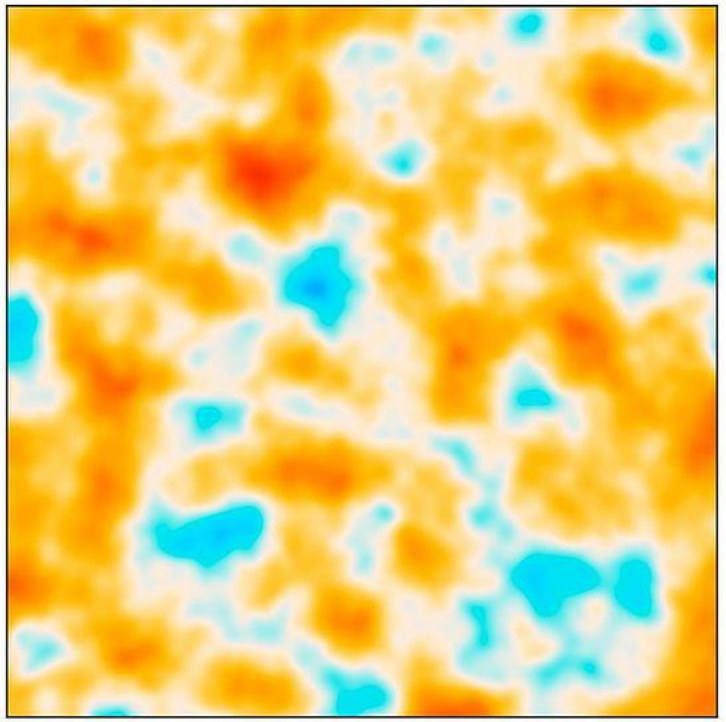
WMAP

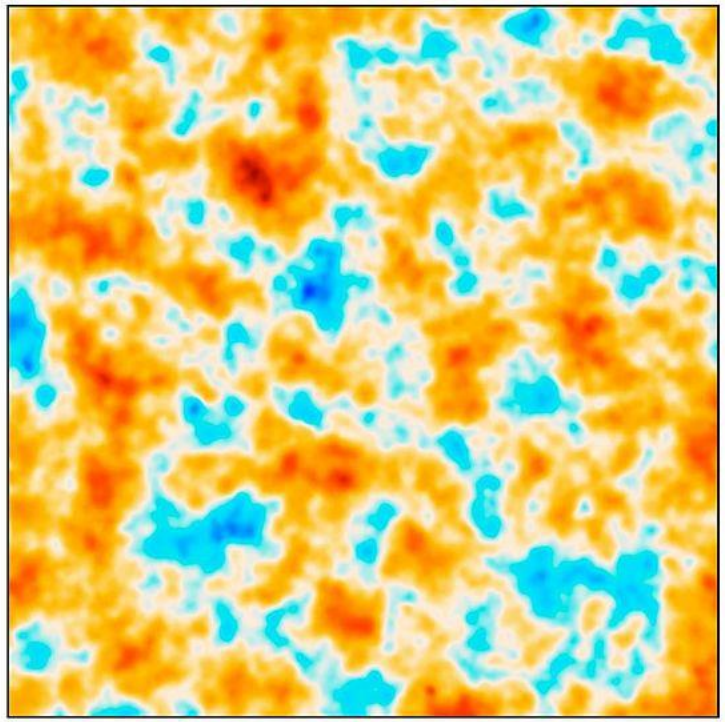












COBE

WMAP

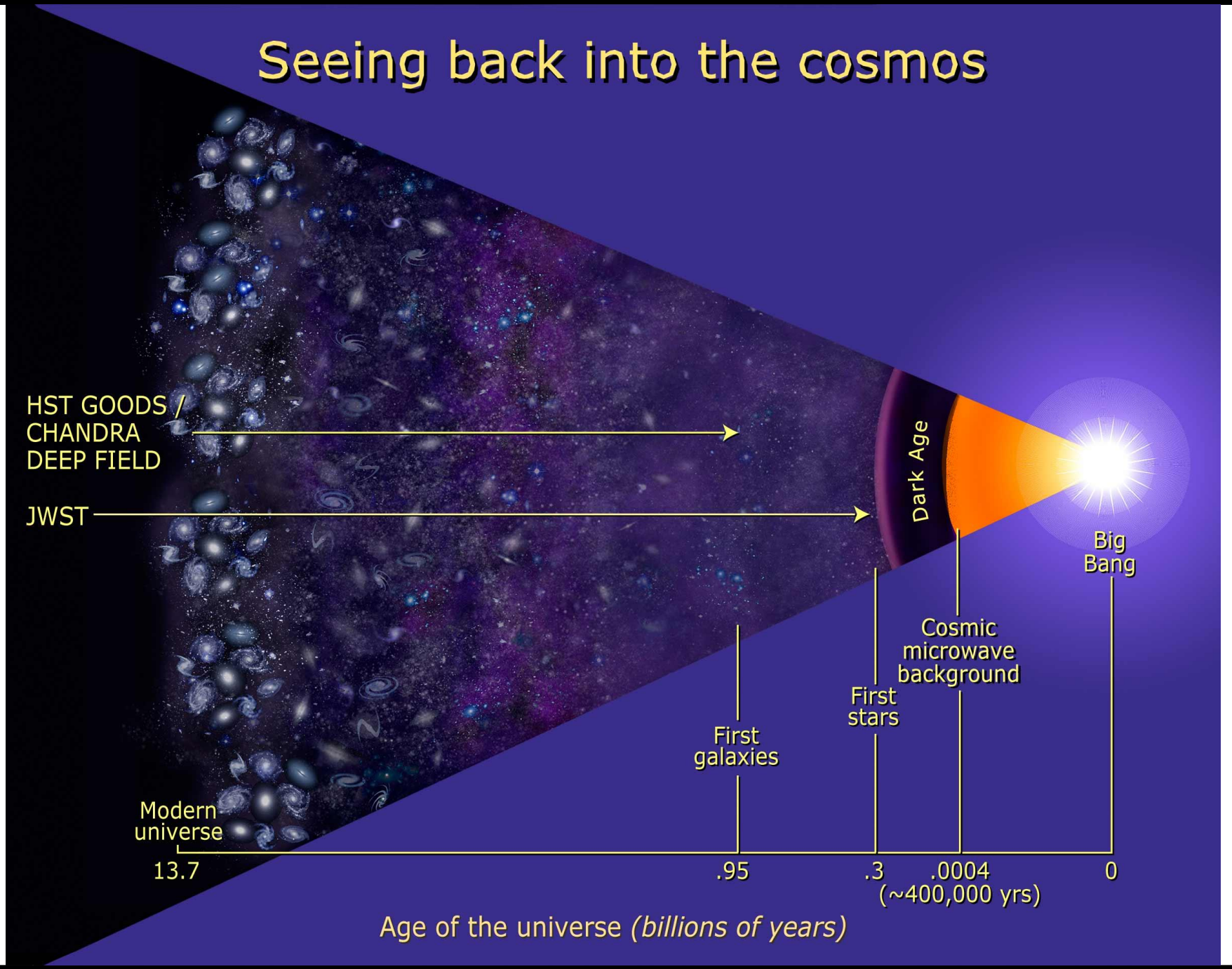
Planck

“Big Bang” misconceptions . .

- Big Bang is theory of how the universe began (Nope – we don’t know how it began, but it’s a theory of how it evolved afterwards)
- “The Big Bang was a big boom!” (Nope, start of expansion – no explosion)
- “The universe is expanding into something” (nope, space itself is expanding)
- “Then what happened before the Big Bang?” (Space=Time . . No space, then no time . . . No one knows!)

Big Bang misconceptions . .

- “If all galaxies are moving away, we must be at the center of it all” (nope, it would look this way from any galaxy)
- “What’s outside of the universe?” (??? We can only see what light reaches us – could be infinite)


Seeing back into the cosmos
HST GOODS / CHANDRA DEEP FIELD
JWST
Dark Age
Big Bang
Cosmic microwave background
First stars
First galaxies
Modern universe
13.7
.95
.3
.0004
(~400,000 yrs)
0
Age of the universe (billions of years)

Let’s take a picture of
. . . .nothing . . .

Hubble Deep Field **HST WFPC2**

ST ScI OPO January 15, 1996 R. WIlliams and the HDF Team (ST ScI) and NASA

Distant Supernova in the Hubble Deep Field
Hubble Space Telescope • WFPC2

NASA and A. Riess (STScI) • STScI-PRC01-09

Follow this . . . .

- Type I Supernova are in distant galaxies . . .
- . . .so they blew up long ago . . . (far away, means long ago)
- Type I Supernova have known true brightness = can calculate distance
- Spectra shows us redshift in absorption lines = velocity
- Can use Hubble Law, too: v = H x d
- *Problem . . . . . Supernova were too faint! Farther than expected.*
- **Conclusion – expansion is accelerating!!!**


Dark Energy
73%
Atoms 4%
Cold
Dark
Matter
23%