A big outstanding question in cosmology: Tension in the Hubble Constant

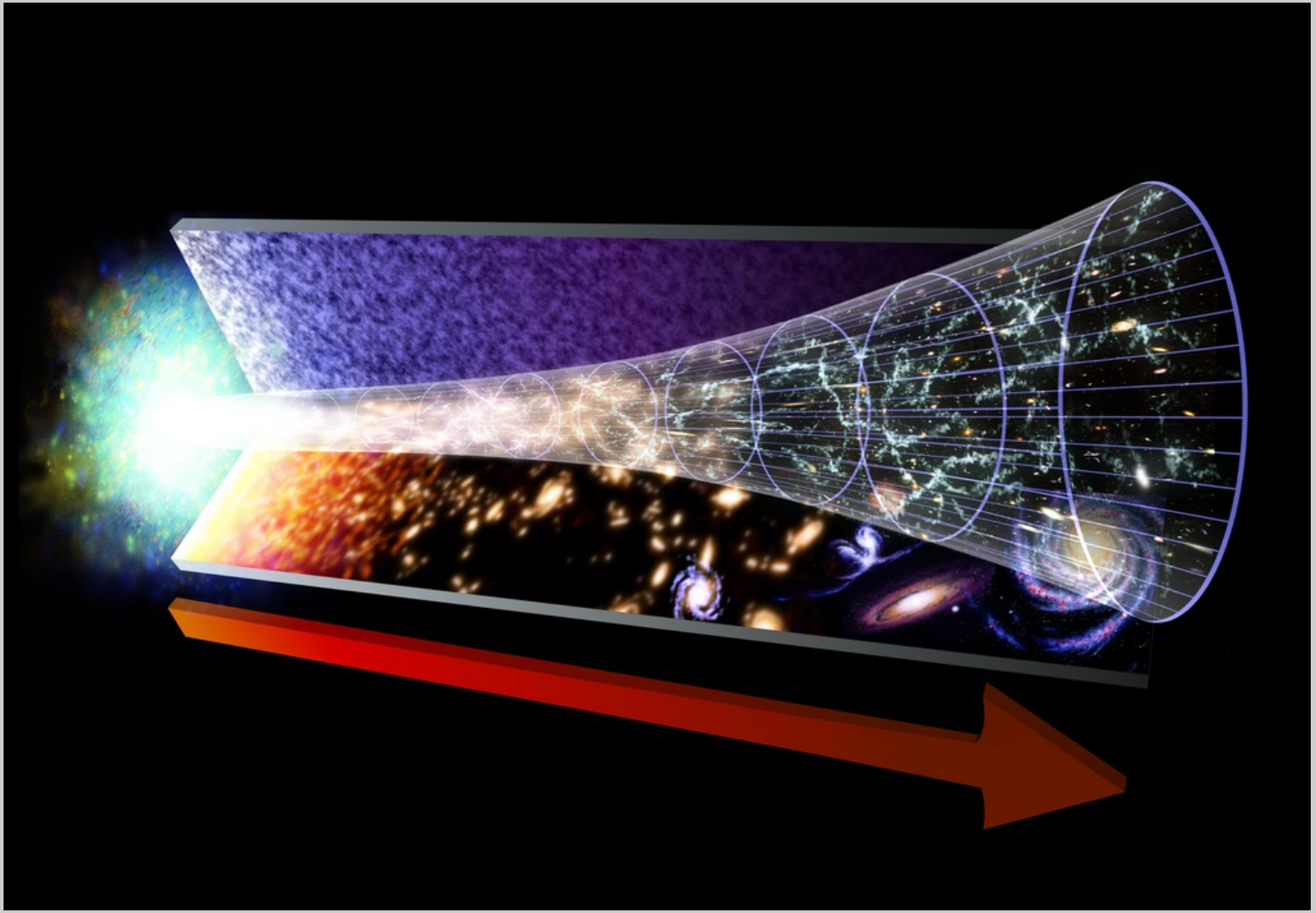
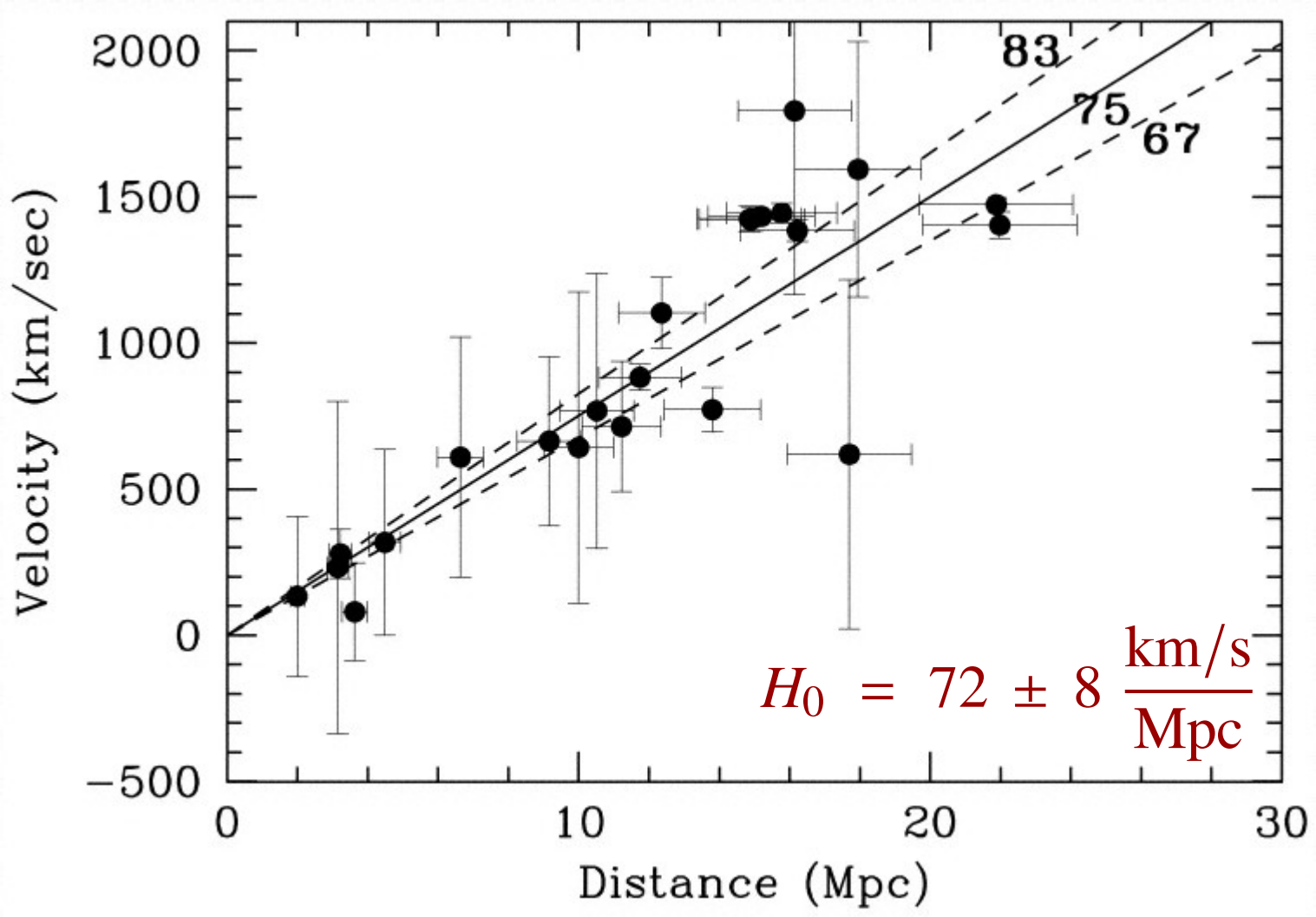


Image: NASA/GSFC

Dr. Rob Knop

Science Circle, Second Life, 2019-09-28

The Hubble Constant is the current expansion rate of our Universe



Freedman et al., 2001, ApJ, 553, 47

Edwin Hubble, 1929

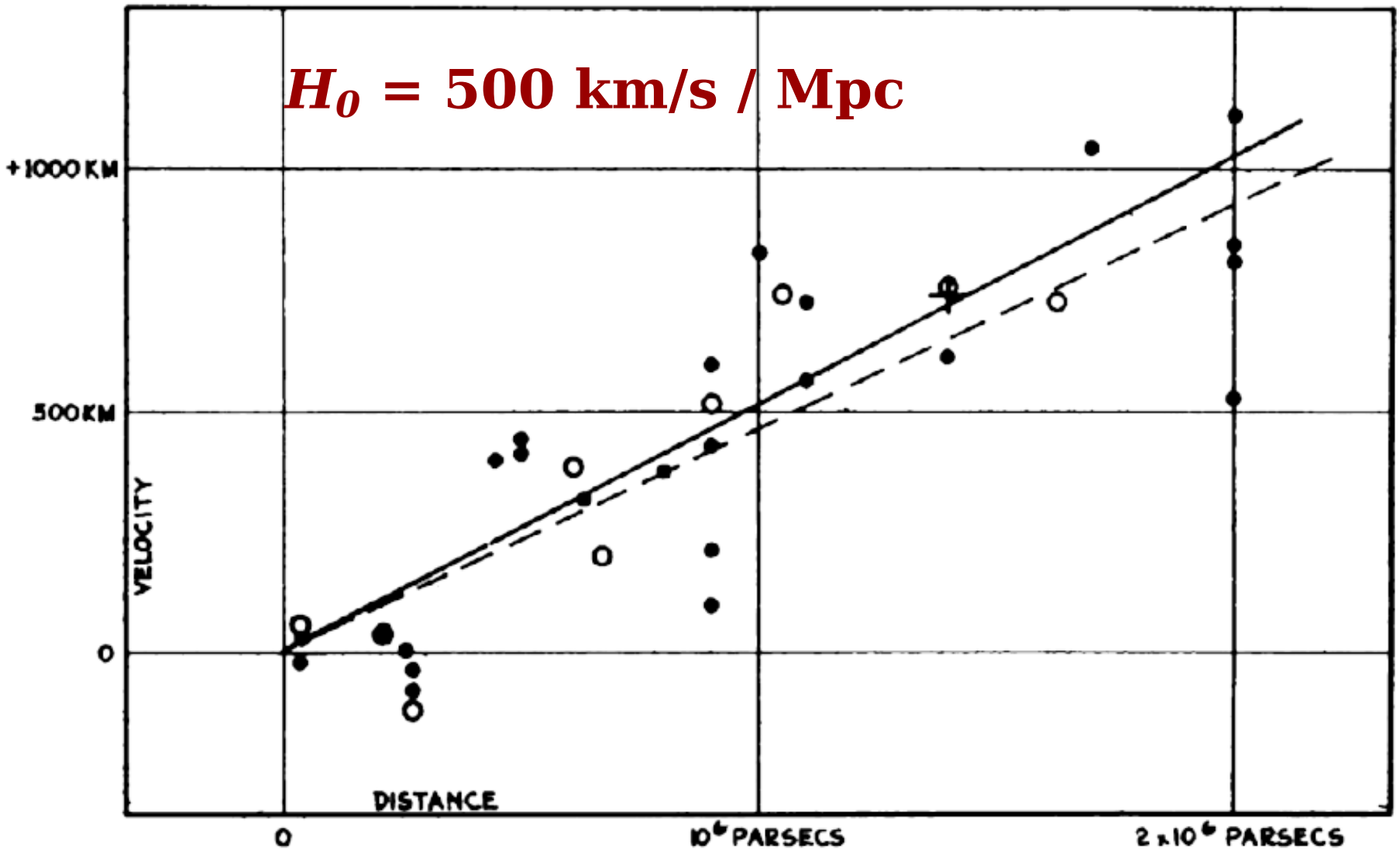


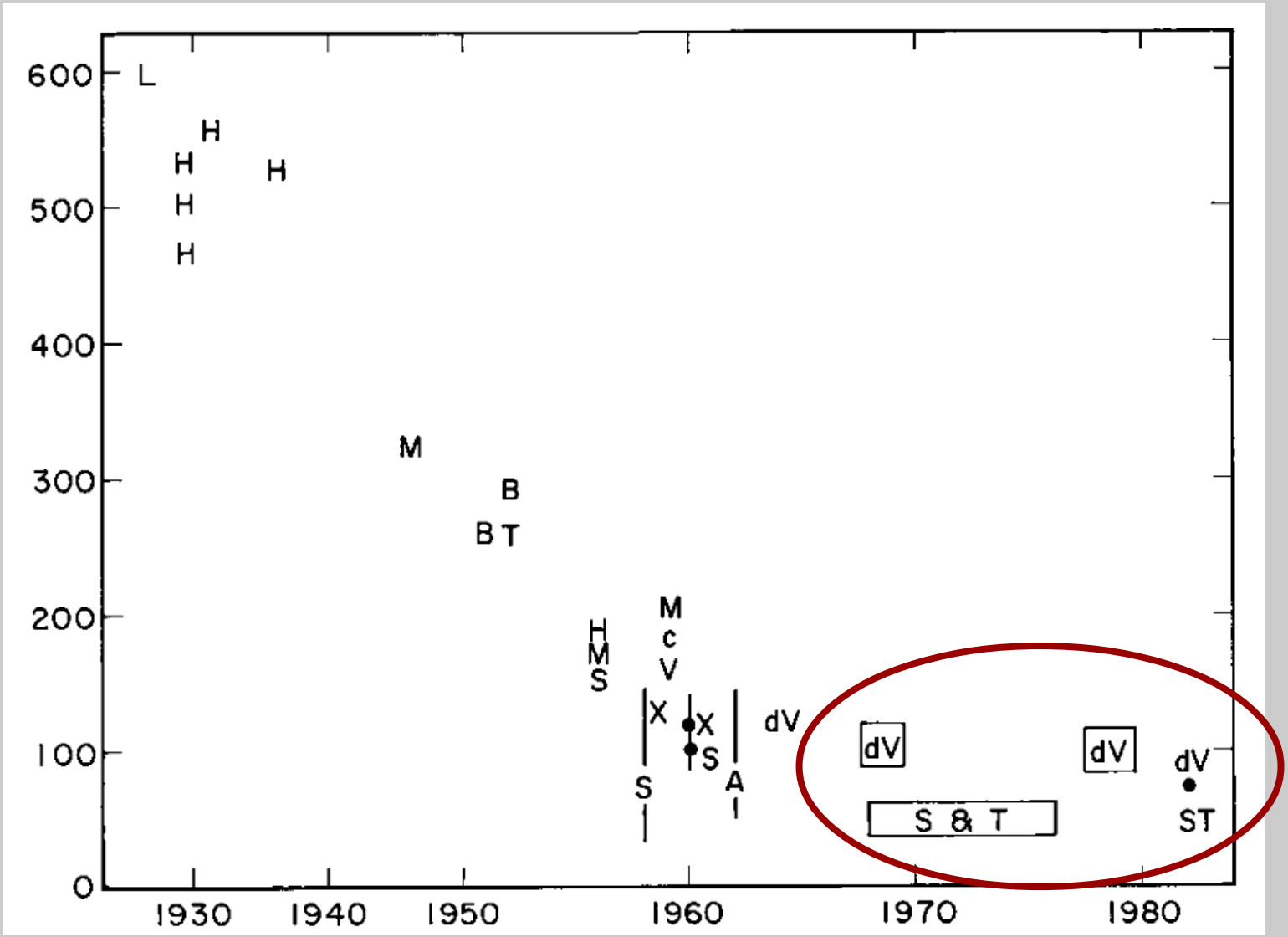
FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

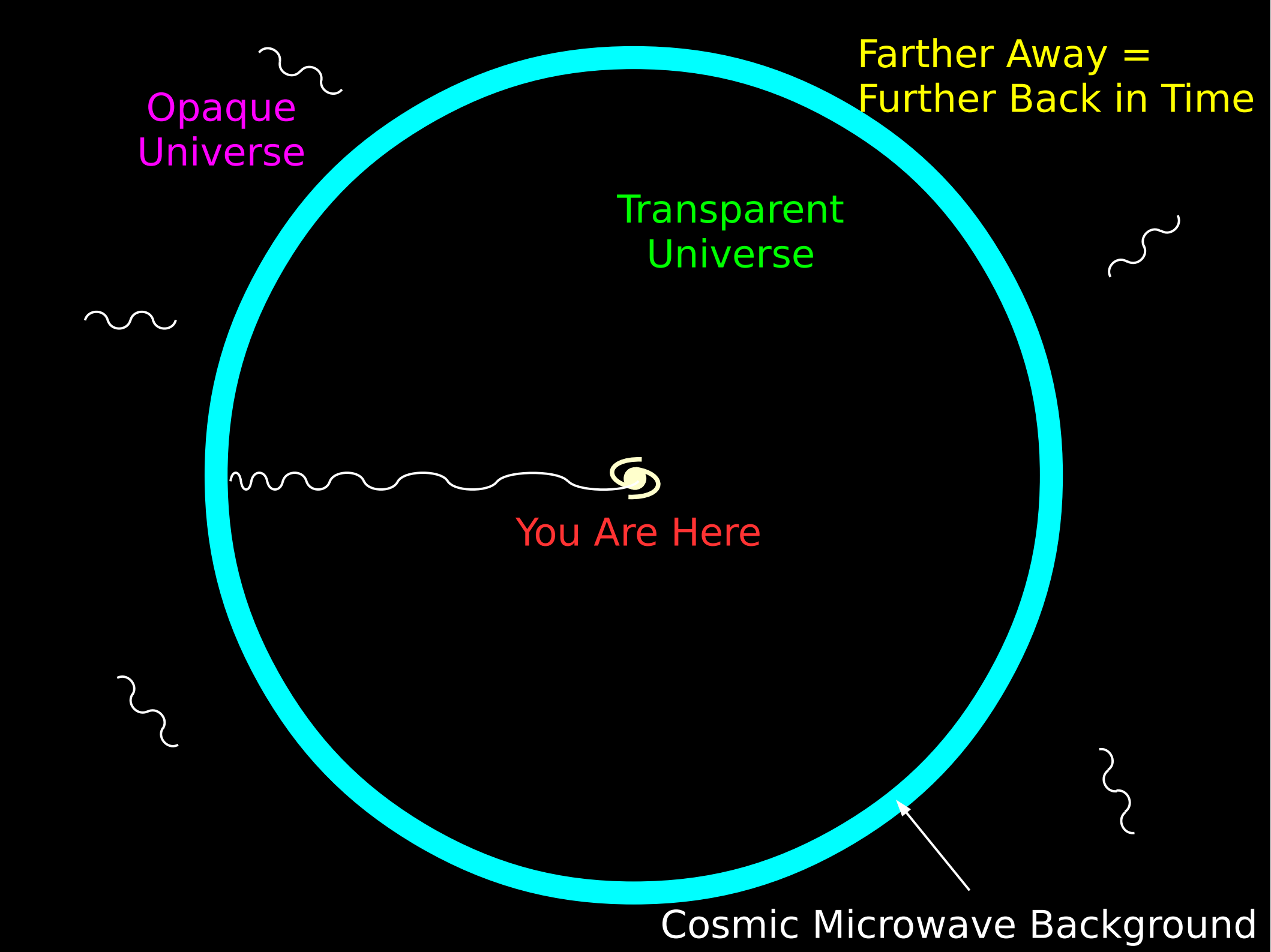
(Note: Lemaître 1927, Freedman 1922, et al.)

Hubble, 1929, PNAS, 15, 168

Hubble Constant Estimates through the mid-80s



Trimble, 1997, Space Science Rev. 79, 793


Farther Away =
Further Back in Time
Opaque
Universe
Transparent
Universe
You Are Here
Cosmic Microwave Background

COBE : The Cosmic Background Explorer

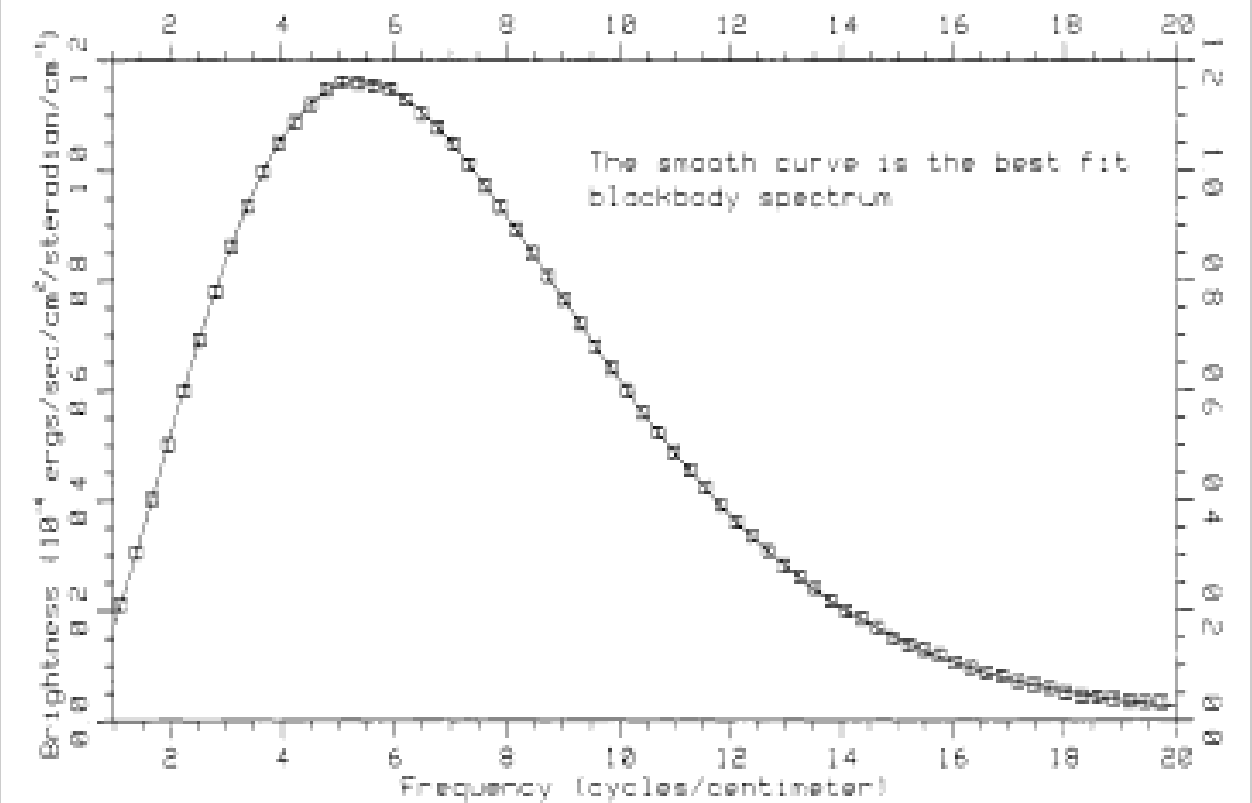
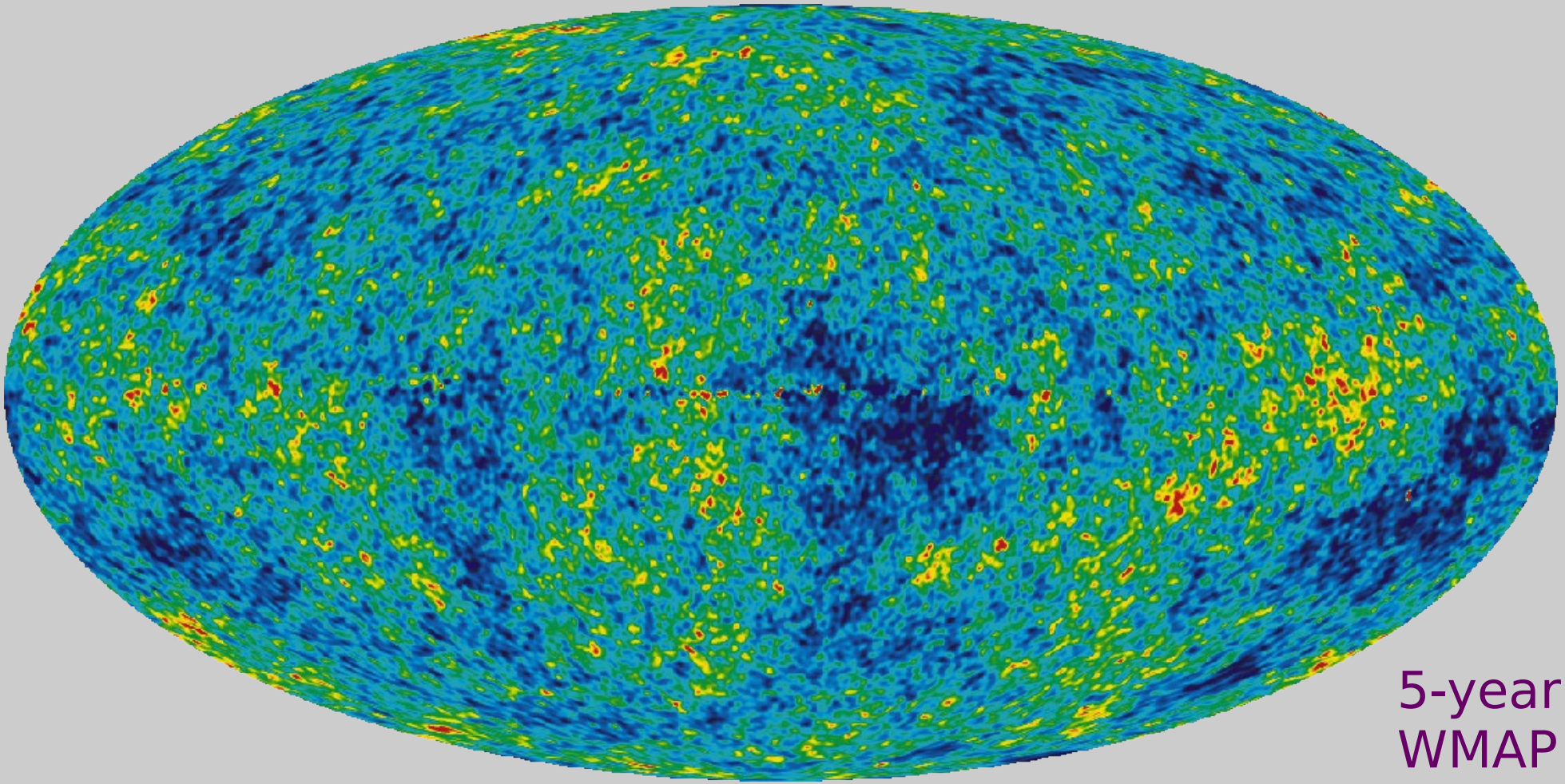


FIG. 2.—Preliminary spectrum of the cosmic microwave background from the FIRAS instrument at the north Galactic pole, compared to a blackbody. Boxes are measured points and show size of assumed 1% error band. The units for the vertical axis are 10^{-4} ergs s^{-1} cm^{-2} sr^{-1} cm.

Mather *et al.*, 1990, ApJ, 354, L37

- The spectrum of the CMB perfectly matches a blackbody at 2.74K
- This temperature is *consistent* across the sky to 1 part in 1000

CMB Anisotropy 2 : Fluctuations



5-year
WMAP
Data

Maximum fluctuation amplitude : 75 μK

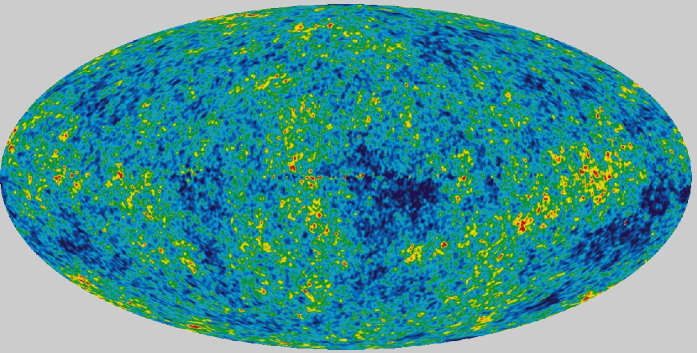
(The CMB is smooth to one part in 40,000)

Bennet et al., 2014, ApJ, 749, 135

"The 1% Concordance Hubble Constant"

Distance Ladder Measurements

$H_0 = 73.0 \pm 2.4$ km/s / Mpc



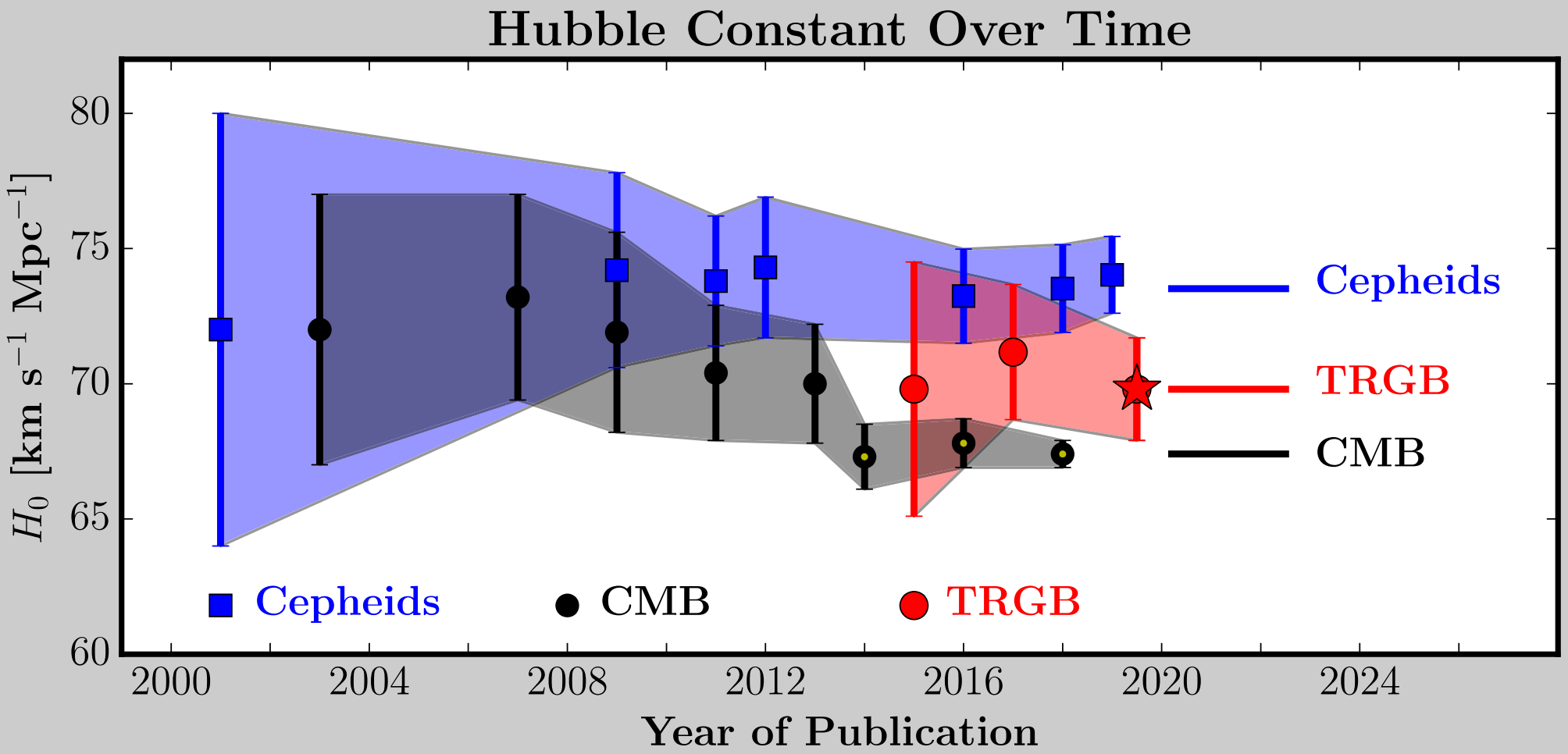
CMB Measurements

WMAP: $H_0 = 68.76 \pm 0.84$ km/s / Mpc

Planck: $H_0 = 67.3 \pm 1.2$ km/s / Mpc

Concordance Value : 69.6 ± 0.7 km/s / Mpc

< 2σ tension



Freedman et al., 2019, ApJ, 882, 34

Our fundamental model of the history of our Universe:

The Big Bang

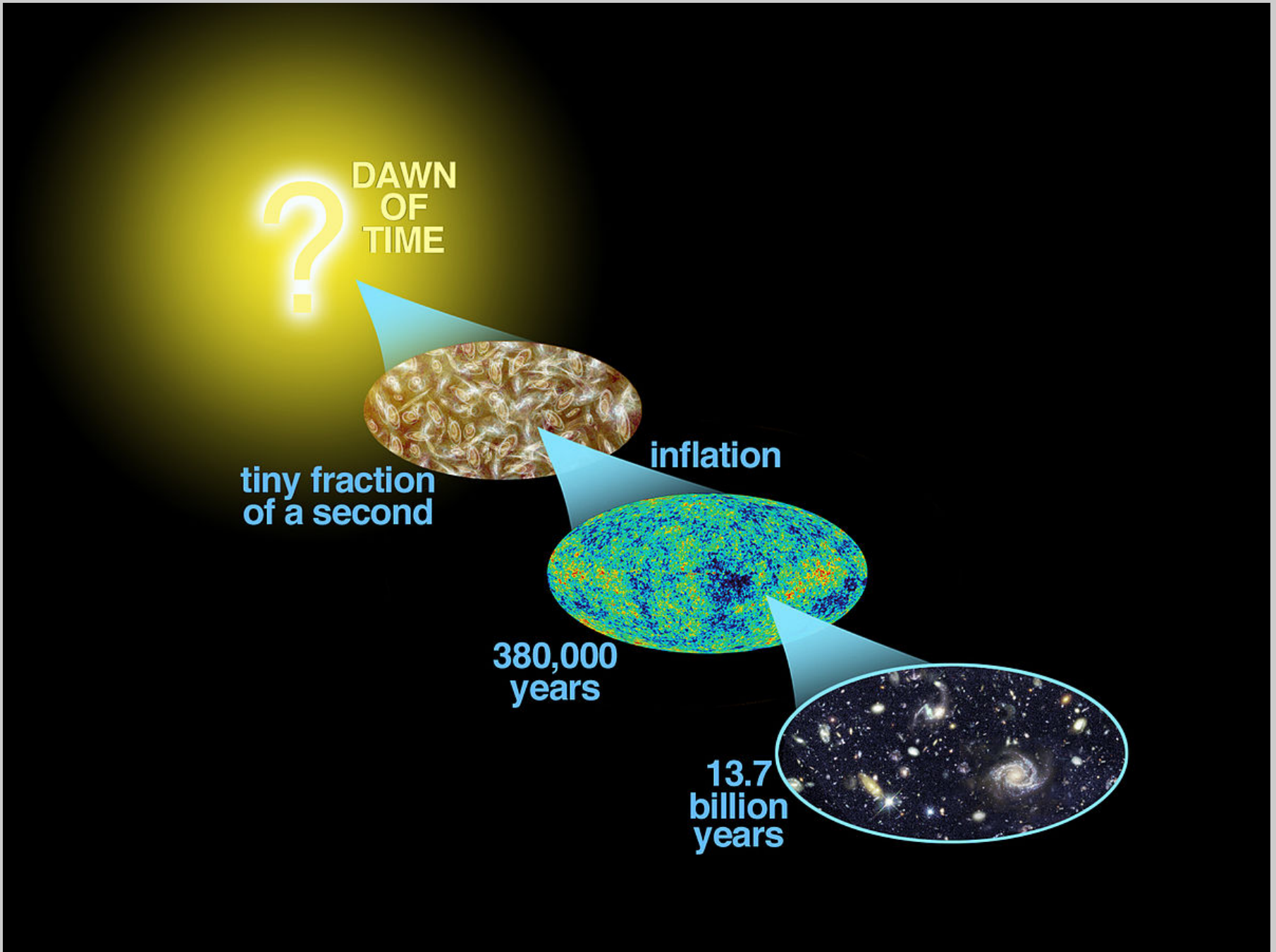


Image: NASA/WMAP Science Team

Our current specific Big Bang model:

ΛCDM

Λ = Cosmological Constant

= Dark energy is vacuum energy

CDM = “Cold” dark matter

= Dark matter particles are blobbed around galaxy clusters; particles move much less than the speed of light

Resolving the Hubble Tension

- Unidentified systematics in one or more methods for determining H0
- ΛCDM isn’t quite right (1) — dark energy is more complicated than vacuum energy
- ΛCDM isn’t quite right (2) — Dark Matter isn’t strictly cold, or interacts in ways we don’t know
- We live in a local low-density region that affects “nearby” measurements of H0
- Something else