Cosmology

HST2024 Study Group 8

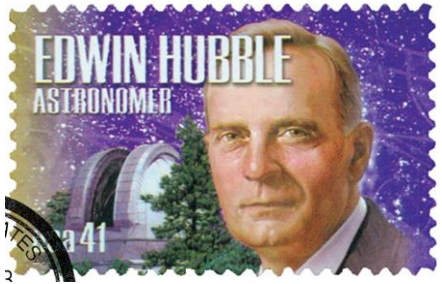
Curriculum & Classroom Connections

Key Ideas

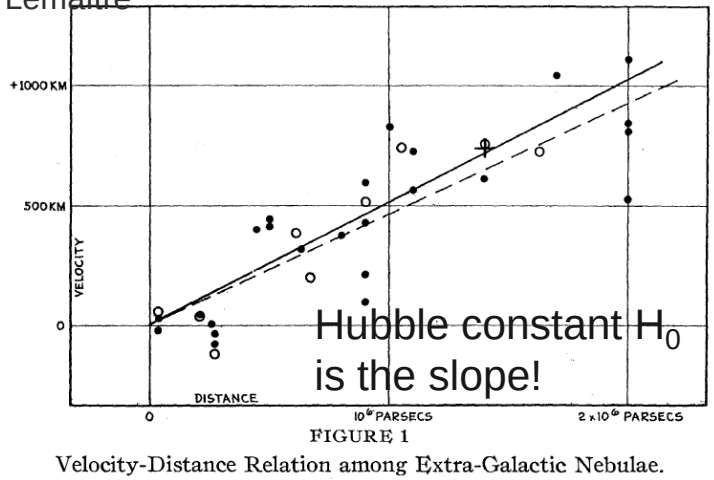
1) Expansion of the universe

- Hubble (–Lemaître) law 1929 (1927)
- velocity = H_0 · distance

redshift

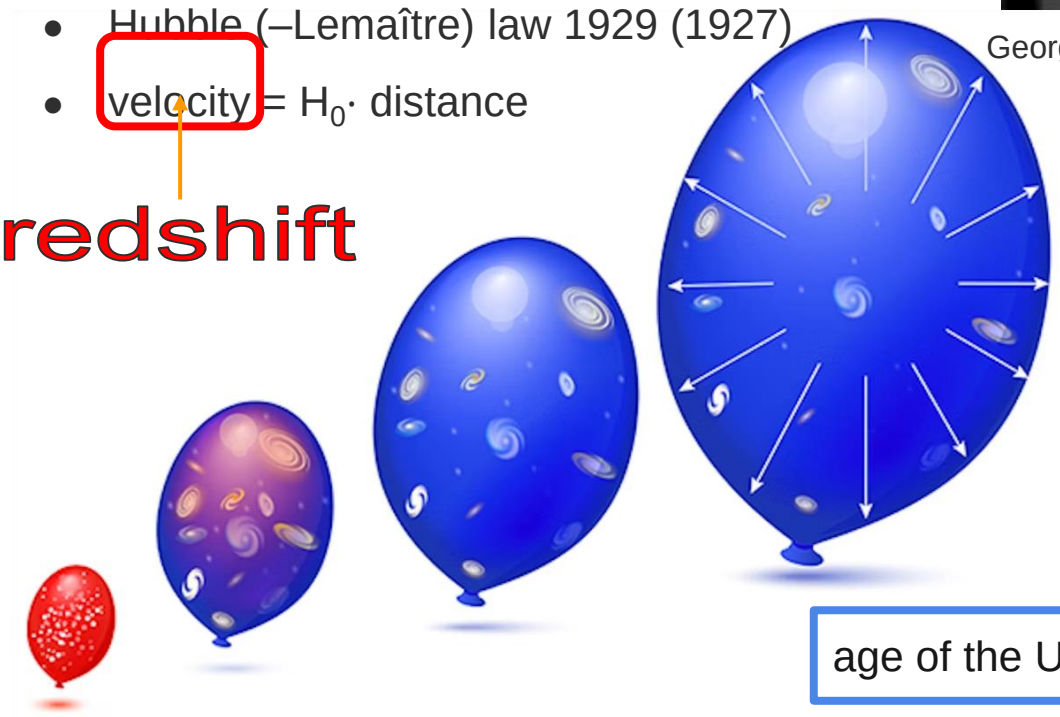


Georges Lemaître



Hubble constant H_0 is the slope!

FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.



age of the Universe ~ H_0^{-1} ~ $14 \cdot 10^9$ y

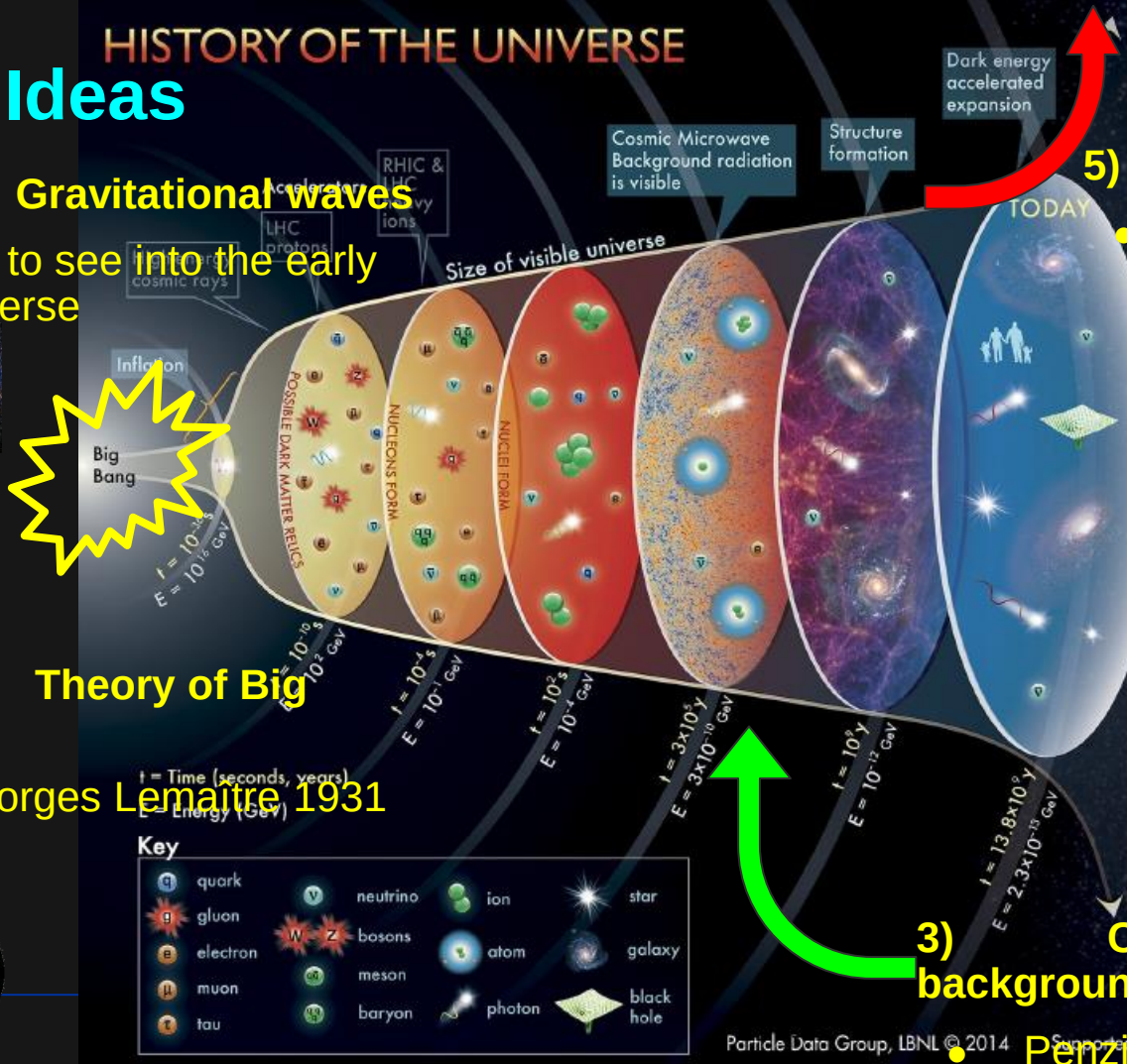
Key Ideas

5) Gravitational waves

- way to see into the early universe

2) Theory of Big Bang

- Georges Lemaitre 1931



3) Cosmic microwave background

- Penzias & Wilson 1965

5) Dark energy

- leads to a repulsive force accelerating the expansion of the universe

4) Dark matter

- galaxies rotating at speeds too big for its observable mass to hold them together

Potential Students' Conceptions & Challenges

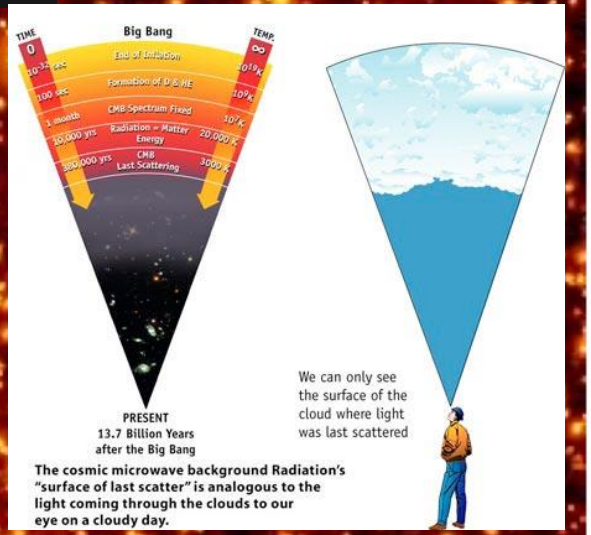
How do my students think?

- Spatial
  - Three dimensional view?
  - Four dimensional?
- Time
  - Real time view of the sky?
  - Everything in the sky is dead
  - A window to the past
- Nature of Science
  - Scientists know the truth
  - No one knows anything
  - Religious/Cultural views
  - Evidence/Theory developments

Background image
Activity: Exploring the Cosmos with Supercomputers

What are my challenges?

- Language
- Cultural References
- Prior knowledge
  - "Knowledge voids"
- Scientific Skills



Youtube video (1 hr)
Dark Matter Explained

Helpful Material & Resources

Educational Resources:
Books:
1. THE COSMIC CODE-A Journey to the Origin of the Universe- by Sophie Domingues-Montanari
2. Cosmic Evolution: The Rise of Complexity in Nature by Eric J. Chaisson
3. Cosmology by V. A. Rubakov, https://arxiv.org/pdf/1804.11230

4.Introduction to Cosmology-A. D. Dolgov
https://www.e-booksdirectory.com/details.php?ebook=4114

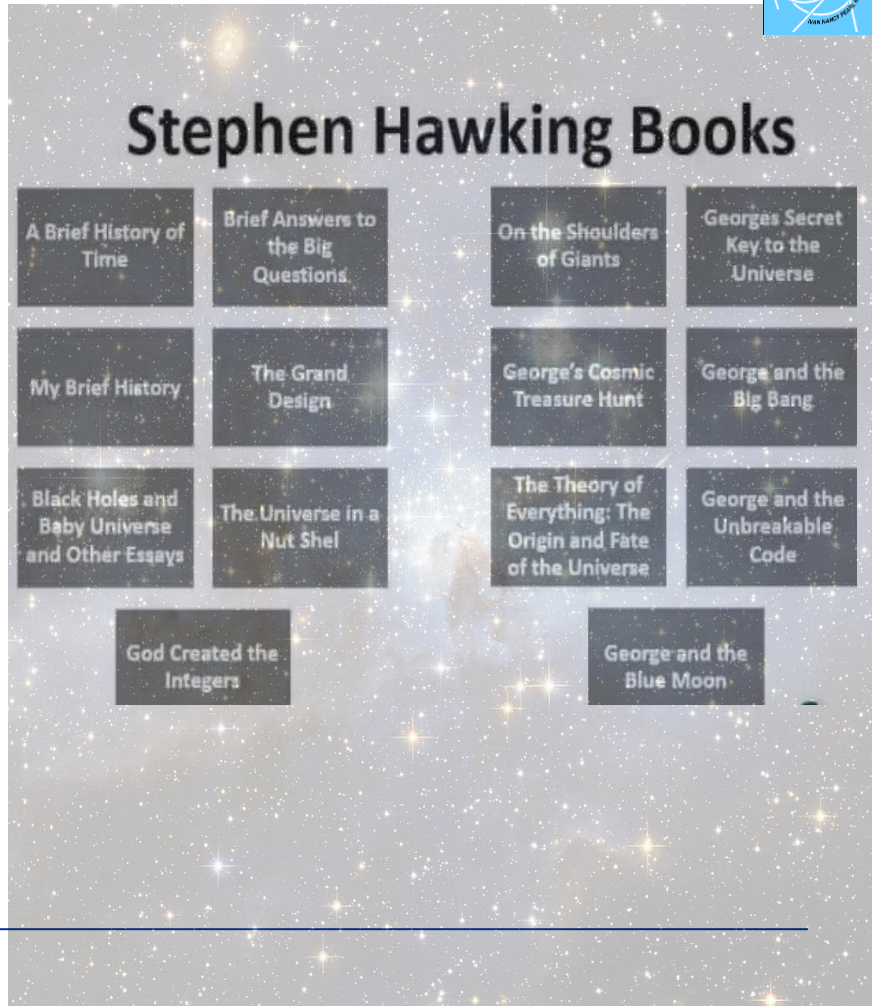
5.Advances in Modern Cosmology- by Adnan Ghribi
https://www.e-booksdirectory.com/details.php?ebook=6400

Online Courses:
https://www.coursera.org/courses?query=astronomy

University of Cambridge https://www.ice.cam.ac.uk/course/cosmology-birth-present-and-fate-our-universe
https://www.classcentral.com/course/youtube-astronomy-and-space-for-children-179123

https://www.edx.org/learn/astronomy

Tutorials and Guides:
NASA WMAP Activities
Esa Cloud Chamber Activity
National Geographic 5 min Video Origin of Universe



Best Practice Example

1. **Online Lab: Hubble's Law and the Expansion of the Universe**

Objective: Students will use real astronomical data to calculate the Hubble constant and estimate the age of the universe.

Procedure:

1. Access an online database of galactic distances and recession velocities
2. Plot the data on a graph (distance vs. velocity)
3. Calculate the slope of the best-fit line to determine the Hubble constant
4. Use the Hubble constant to estimate the age of the universe

Analysis:

- Discuss the relationship between distance and velocity
- Compare the calculated Hubble constant with current accepted values
- Explore the uncertainties in the data and calculations

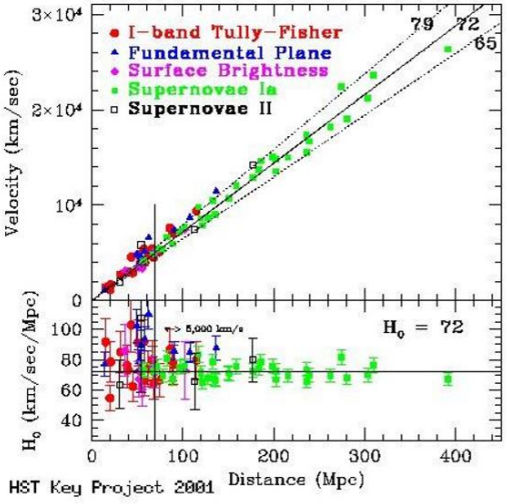
M

- https://www.golabz.eu/lab/hubble-s-law

(the Go-Lab simulator is an interactive tool that can help students grasp the fundamental principles of Hubble's Law)

- https://www.merlot.org/merlot/viewMaterial.htm?id=75282

(for a more comprehensive lab experience, this resource provides a structured lab activity that guides students through the process of understanding and applying Hubble's Law)



Best estimate

72±8 (km/s)/Mpc

(Hubble telescope 2001)

67.8 ± 0.8 (km/s)/Mpc

ESA Planck Surveyor

Best Practice Example

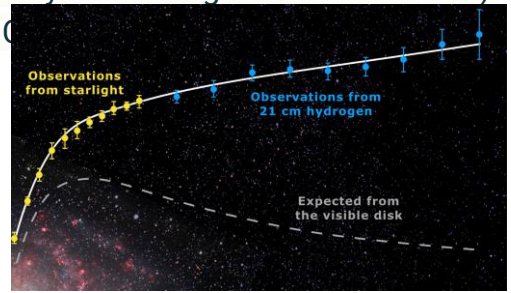
2. Galactic Rotation Curves Activity

Use this activity to demonstrate evidence for dark matter:

- Show students rotation curves of galaxies
- Explain how the observed rotation speeds of outer stars don't match predictions based on visible matter
- Discuss how dark matter explains this discrepancy

Critical Thinking Exercise: Dark Matter Candidates

Engage students in a discussion about potential dark matter particles eg WIMPs (Weakly Interacting Massive Particles) and MACHOs (Massive C



Research Project: Current Dark Matter Experiments

Assign students to research and present on current experiments searching for dark matter, such as:

Xenon Dark matter experiment

https://xenonexperiment.org/

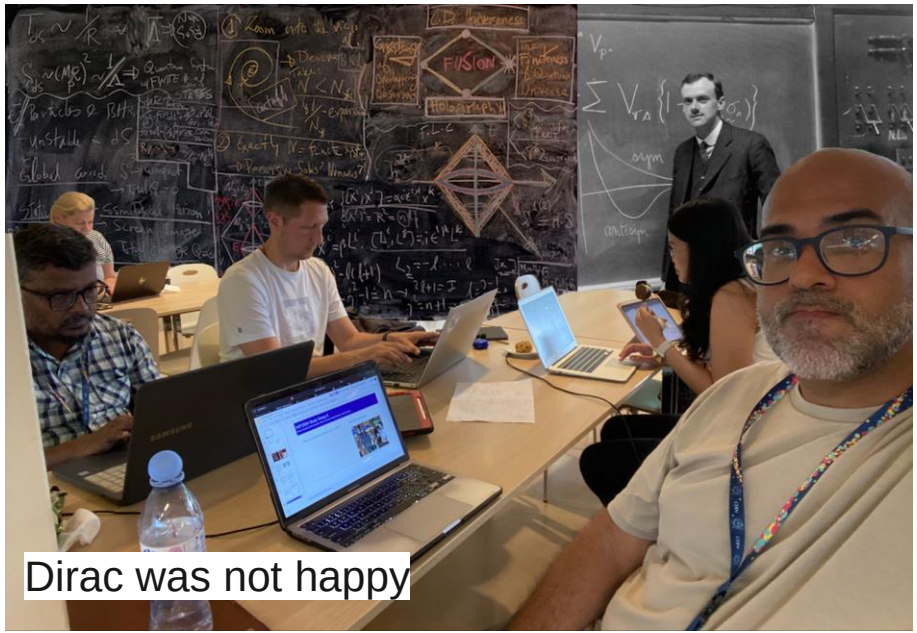
LUX-ZEPLIN (LZ) experiment

https://lz.lbl.gov/

HST2024 Study Group 8

Pearl Nancy Ivan Hugo Jamal

What we'll tell our students we did in CERN



Dirac was not happy

What we actually did!

But Feynman knew the path