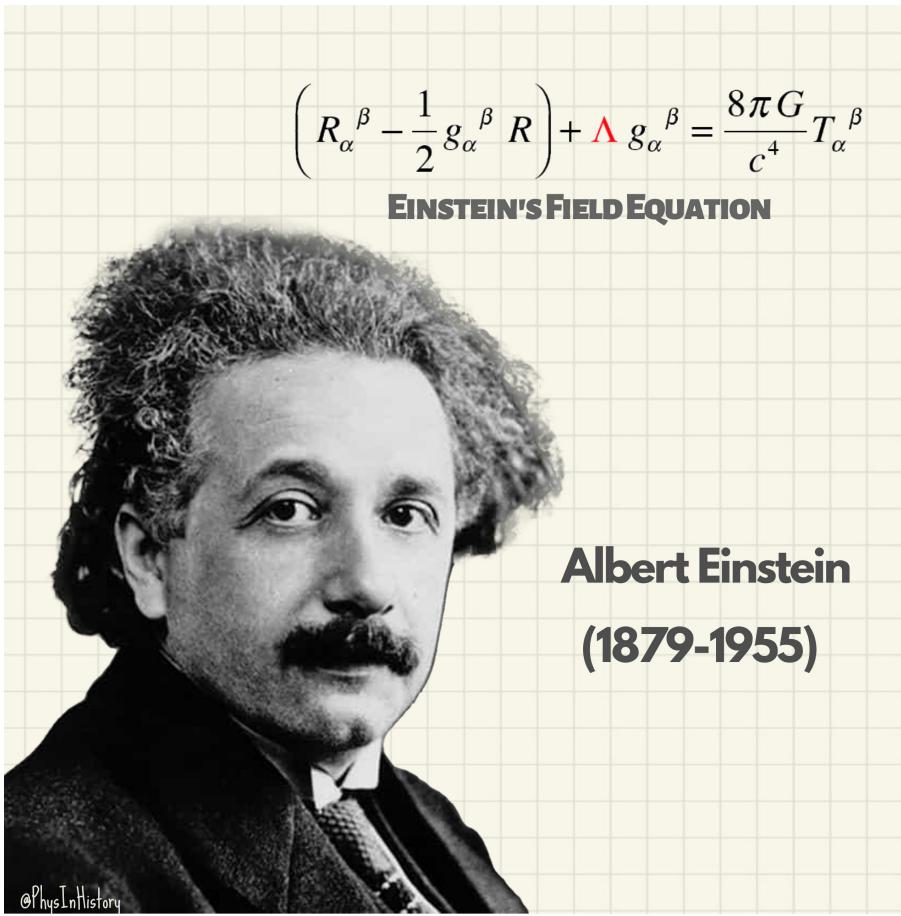

Hubble Constant

SEUNGWU YOO

Hubble-Lemaître Law

- Question from General Relativity theory : Our universe is static or not?
 - Einstein claimed the Cosmological constant (Λ) to ‘make’ universe static
 - Lemaître claimed ‘expanding’ universe, known as ‘Big Bang theory’



Hubble-Lemaître Law

- Edwin Hubble, measured radial velocity and distance of some ‘Extragalactic galaxies’
- Hubble compares velocity and distance
 - He constructed linear regression
- The Hubble-Lemaître law: $v = H_0 d$
 - H_0 : Hubble constant

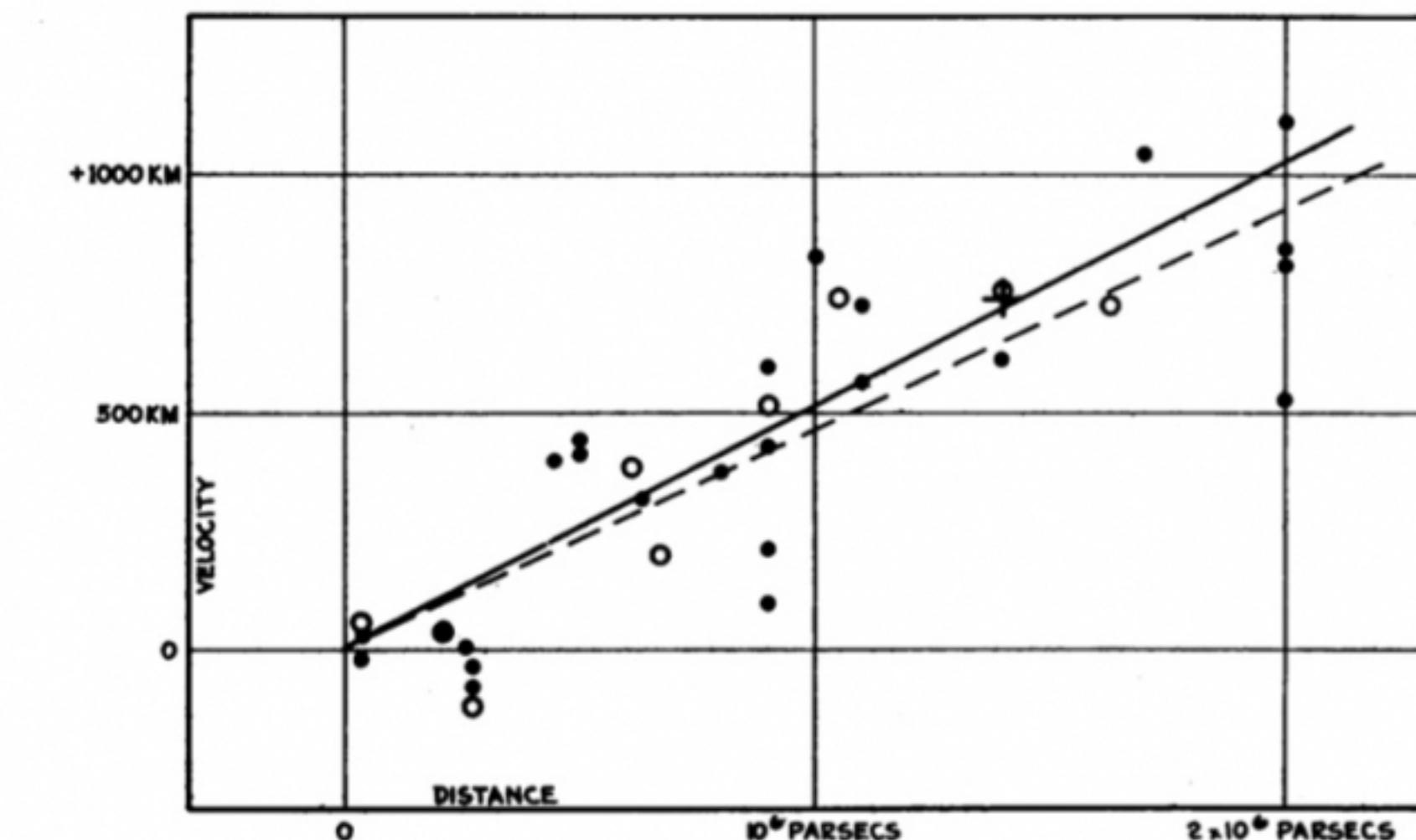
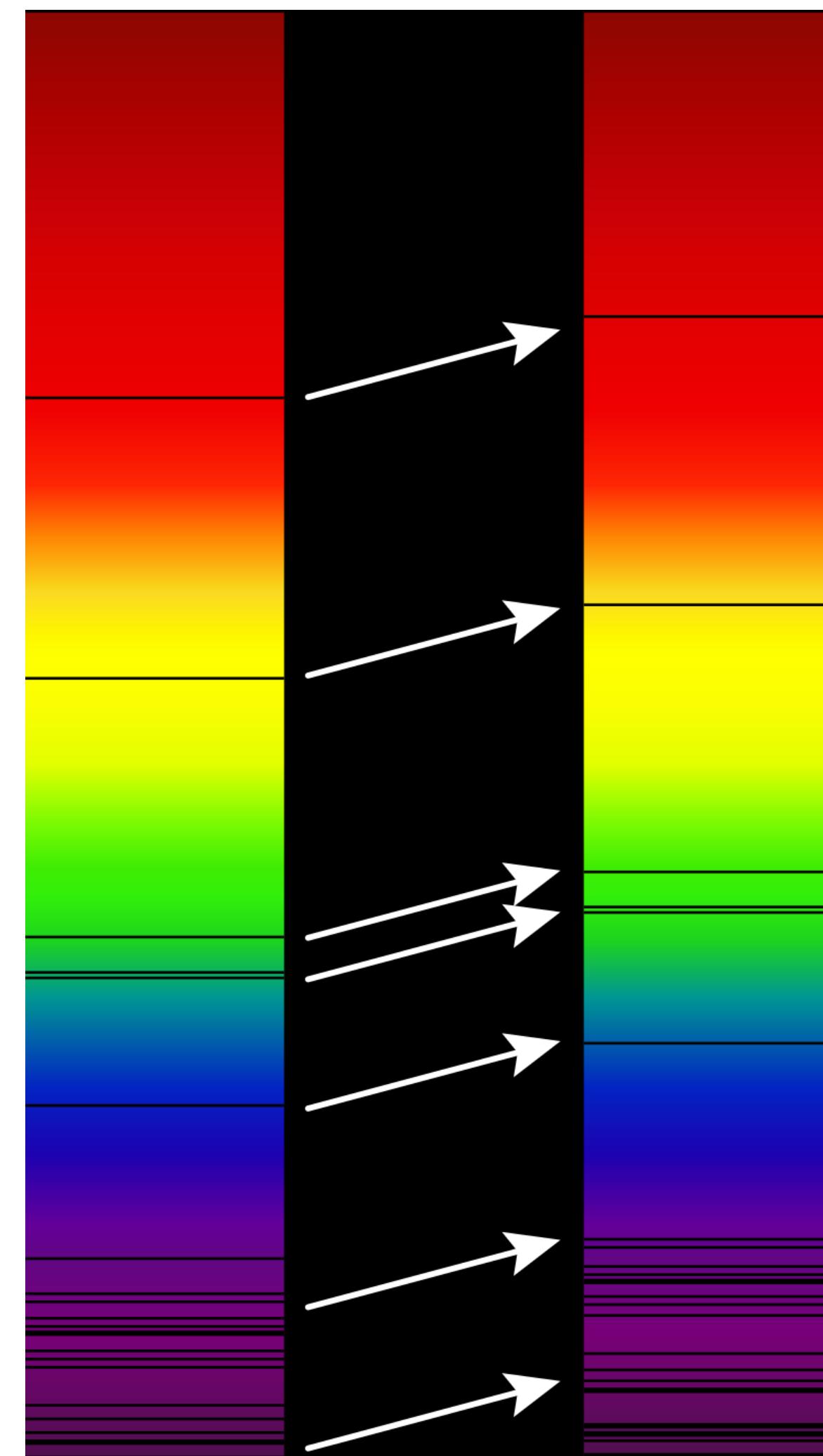


FIGURE 1
Velocity-Distance Relation among Extra-Galactic Nebulae.



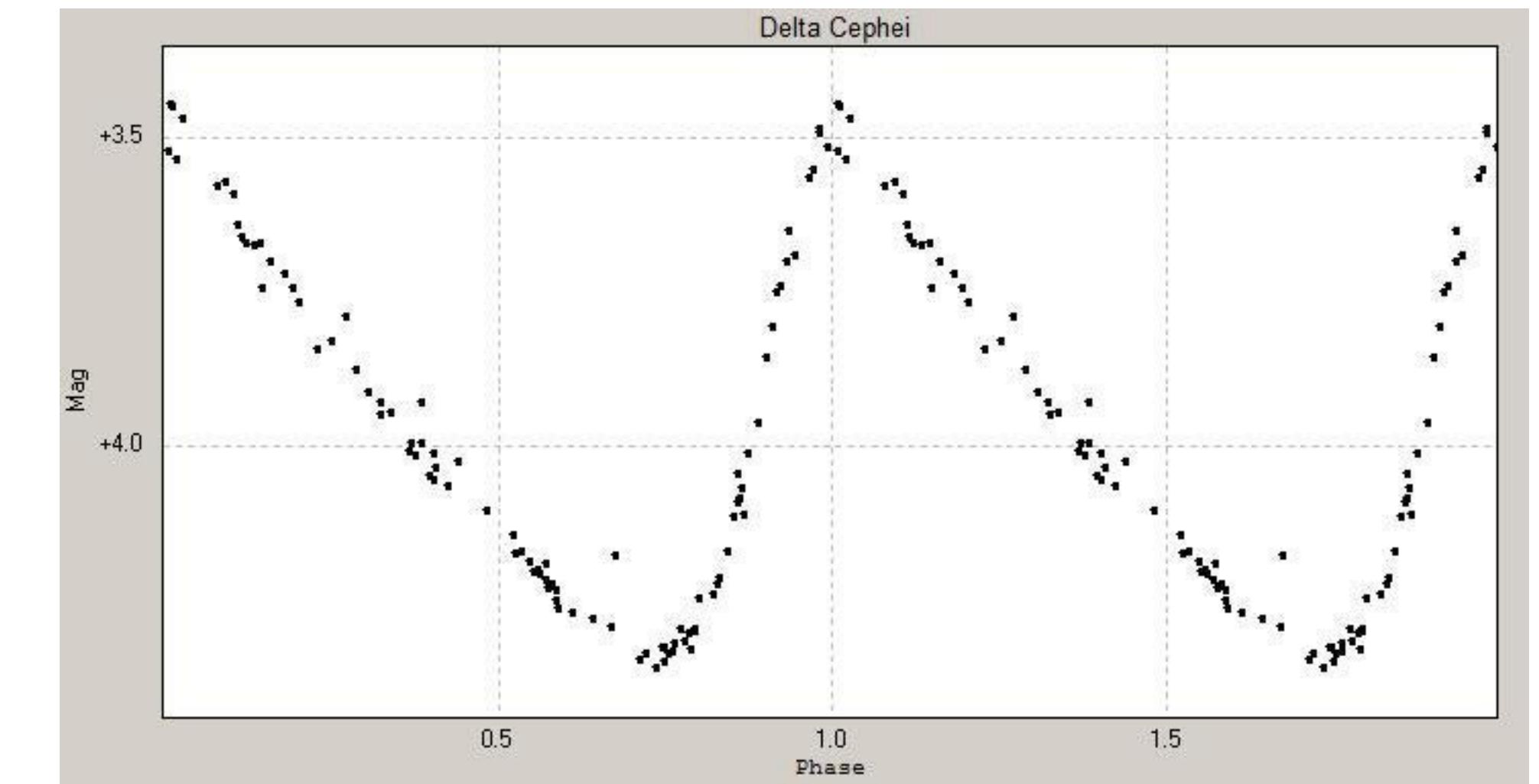
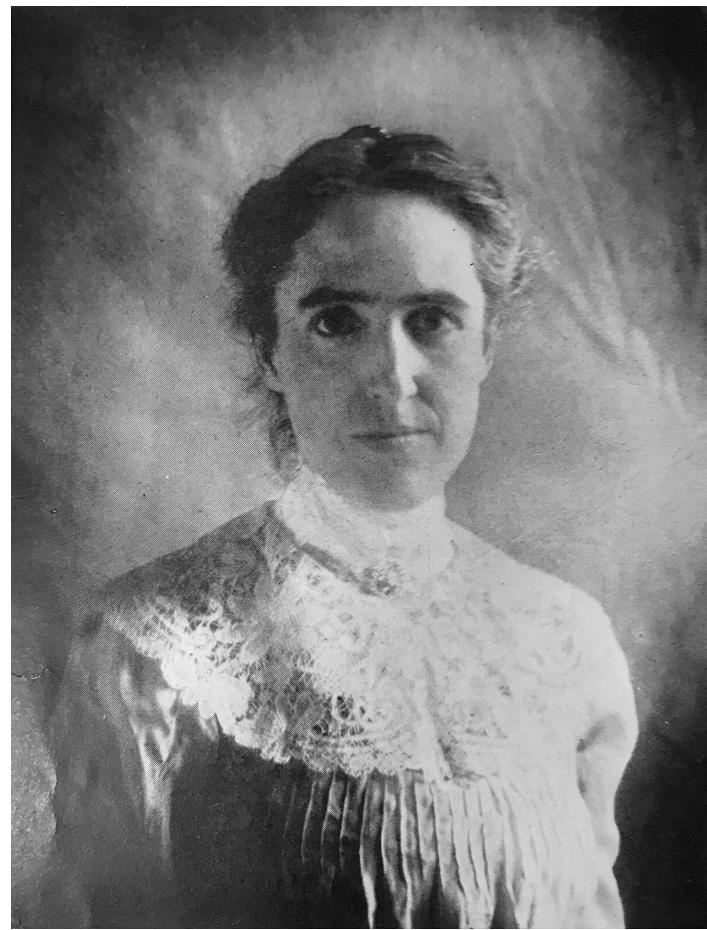
Redshift

- Spectroscopy can give us redshift
- We can measure radial velocity with redshift
- $v = cz$



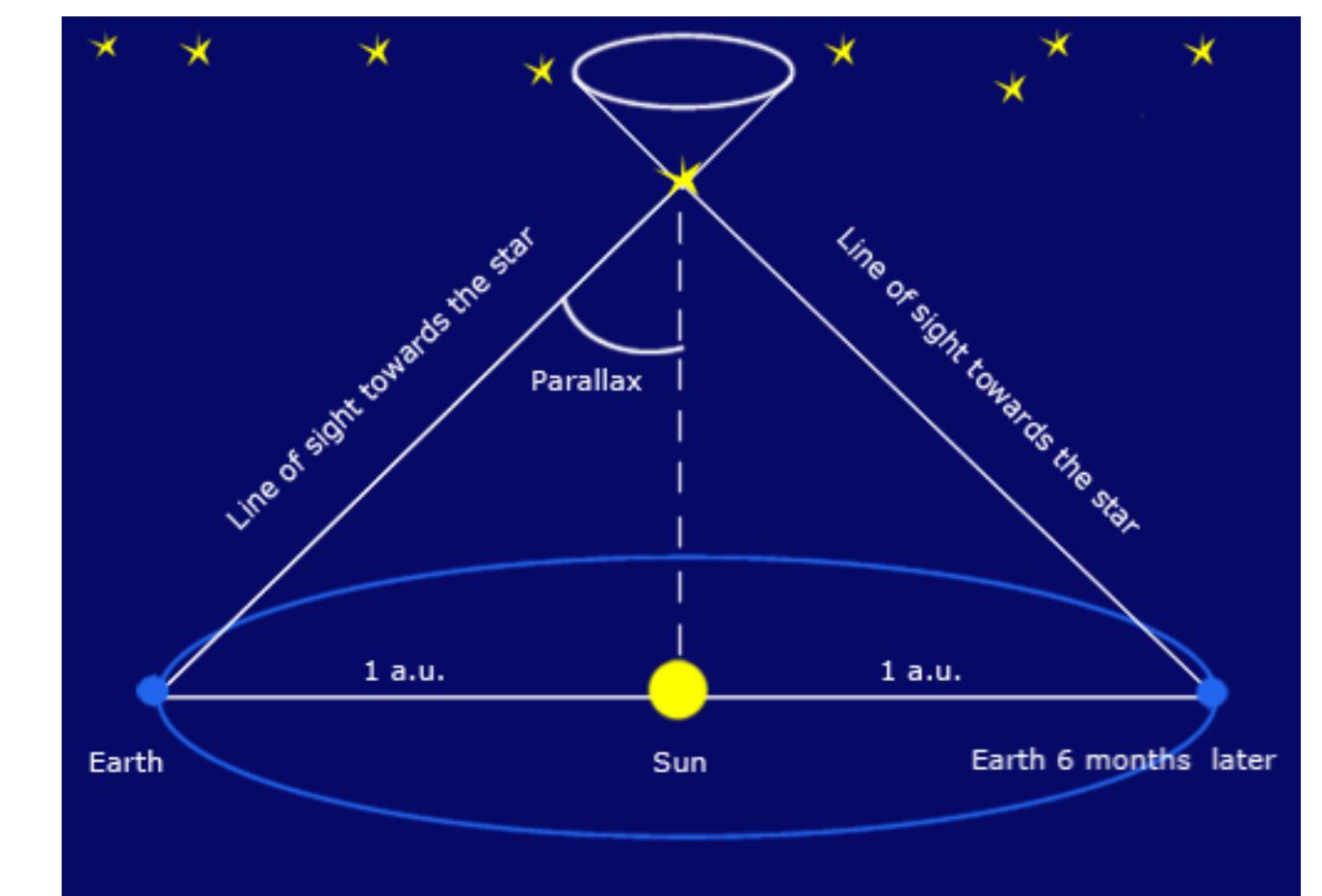
Distance

- Hubble measured distance with Cepheid variables in extragalactic galaxies.
- Henrietta Swan Leavitt found luminosity - period relation of Cepheid variables.



Distance ladder

- How did Henrietta Swan Leavitt find luminosity - period relation of Cepheid variables?
 - She used actual distance to Cepheid variables in Magellanic Cloud
 - We know distance to Magellanic Cloud with 'stellar parallax'
- We know luminosity - period relation of Cepheid by stellar parallax
 - Can we know other distance measuring method by Cepheid?



Distance ladder

- Several distance measuring methods are linked
- Cosmicflow-4: Measure distance and redshift
 - Construct map of universe

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Cosmicflows-4

R. Brent Tully¹, Ehsan Kourkchi¹, Hélène M. Courtois², Gagandeep S. Anand³, John P. Blakeslee⁴, Dillon Brout⁵, Thomas de Jaeger¹, Alexandra Dupuy⁶, Daniel Guinet², Cullan Howlett⁷, Joseph B. Jensen⁸, Daniel Pomarède⁹, Luca Rizzi¹⁰, David Rubin¹¹, Khaled Said⁷, Daniel Scolnic¹², and Benjamin E. Stahl¹³

¹ Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA; tully@ifa.hawaii.edu

² University of Lyon, UCB Lyon 1, CNRS/IN2P3, IUF, IP2I Lyon, France

³ Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA

⁴ Gemini Observatory & NSF's NOIRLab, 950 North Cherry Avenue, Tucson, AZ 85719, USA

⁵ Center for Astrophysics, Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA

⁶ Korea Institute for Advanced Study, 85, Hoegi-ro, Dongdaemun-gu, Seoul 02455, Republic of Korea

⁷ School of Mathematics and Physics, The University of Queensland, Brisbane, QLD 4072, Australia

⁸ Department of Physics, Utah Valley University, 800 West University Parkway, Orem, UT 84058, USA

⁹ Institut de Recherche sur les Lois Fondamentales de l'Univers, CEA Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

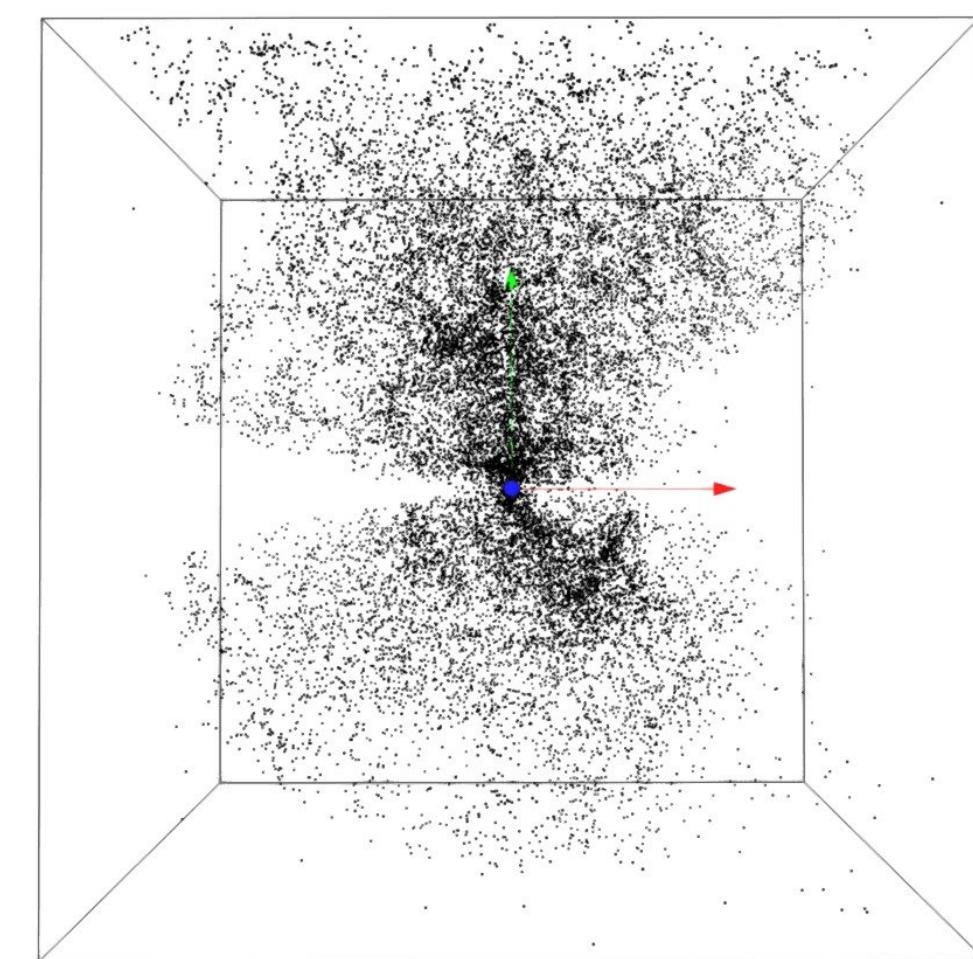
¹⁰ W.M. Keck Observatory, 65-1120 Mamalahoa Highway, Kamuela, HI 96743, USA

¹¹ Department of Physics & Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA

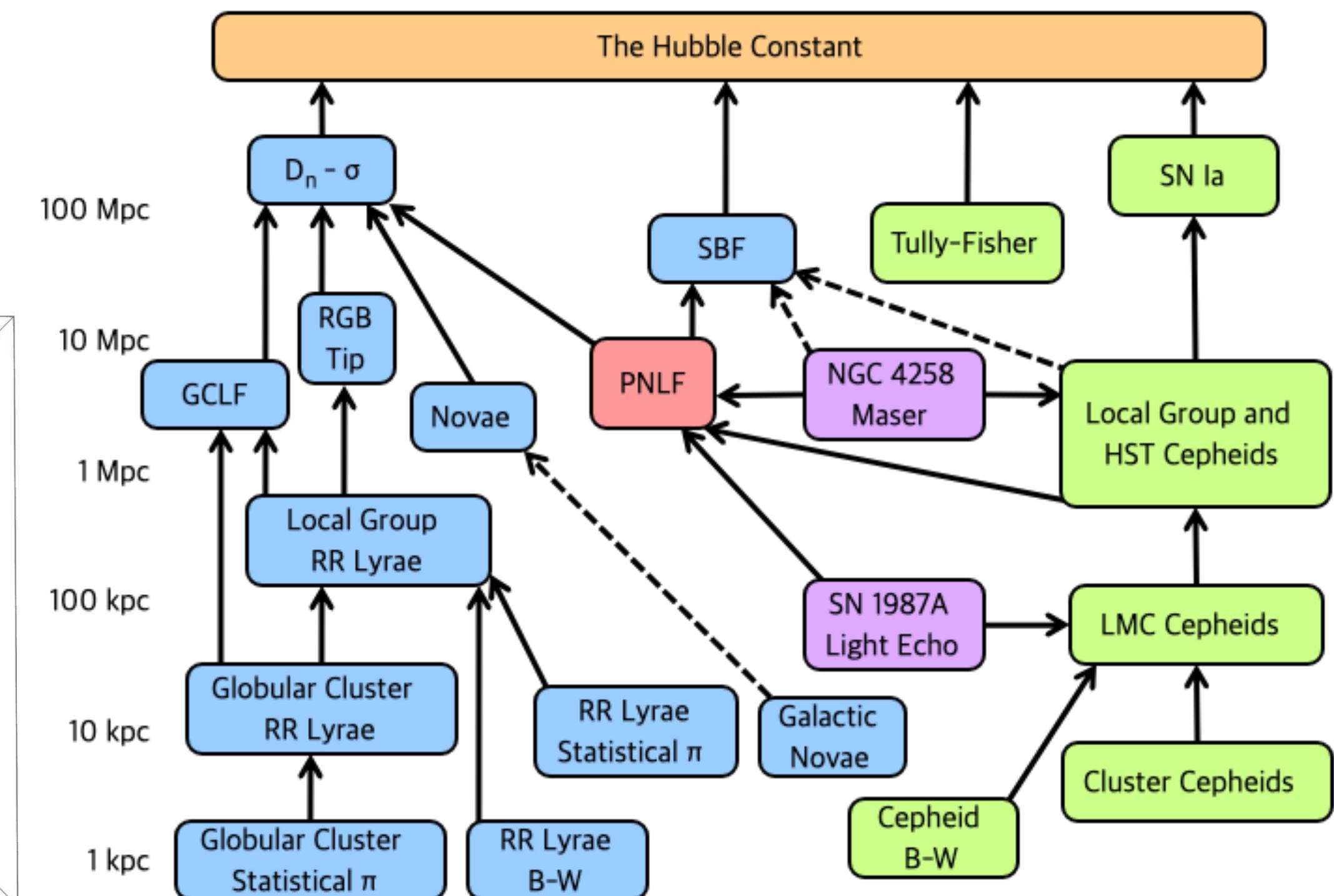
¹² Department of Physics, Duke University, Durham, NC 27708, USA

¹³ Department of Astronomy, University of California, Berkeley, CA 94720-3411, USA

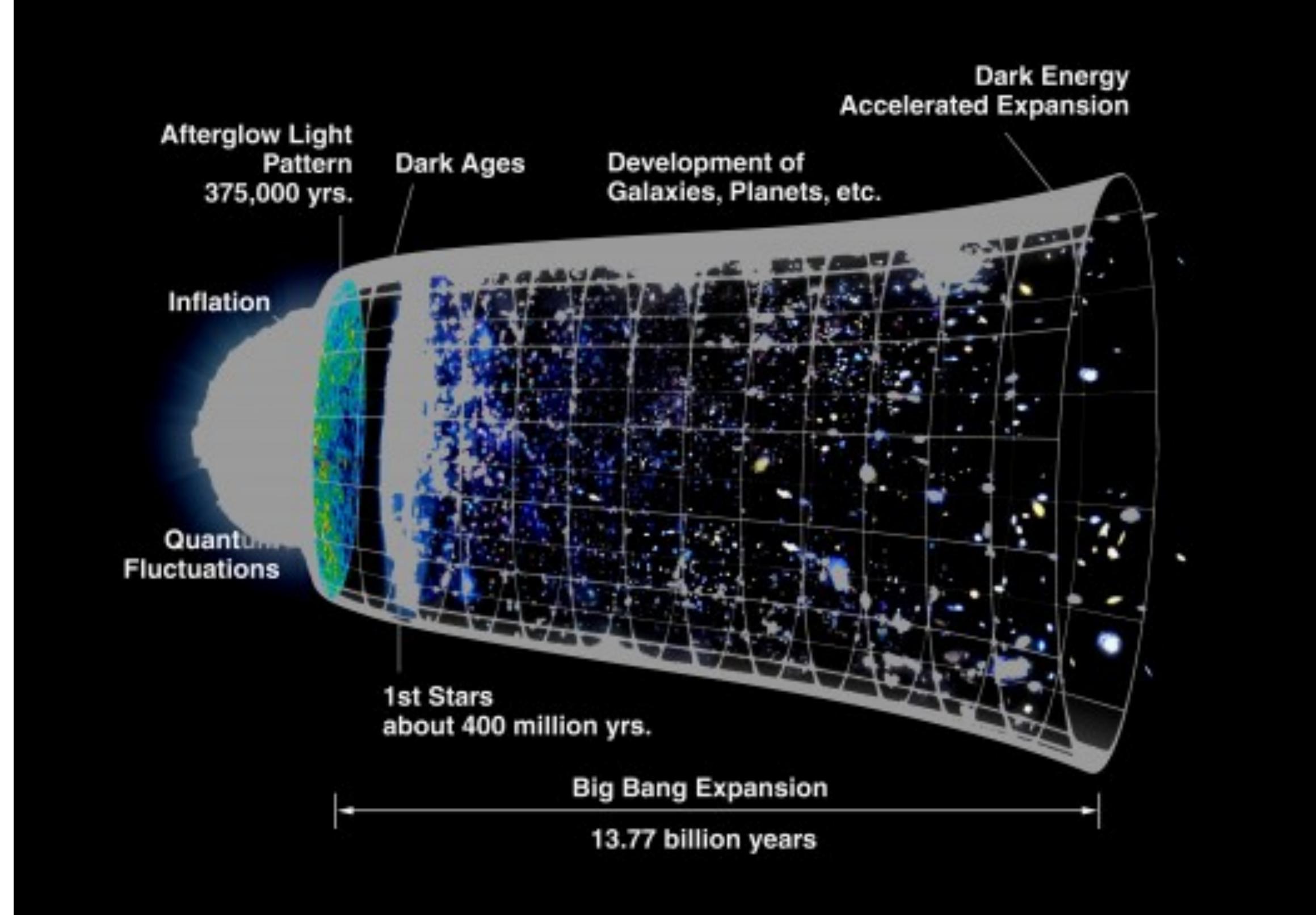
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Extragalactic Distance Ladder

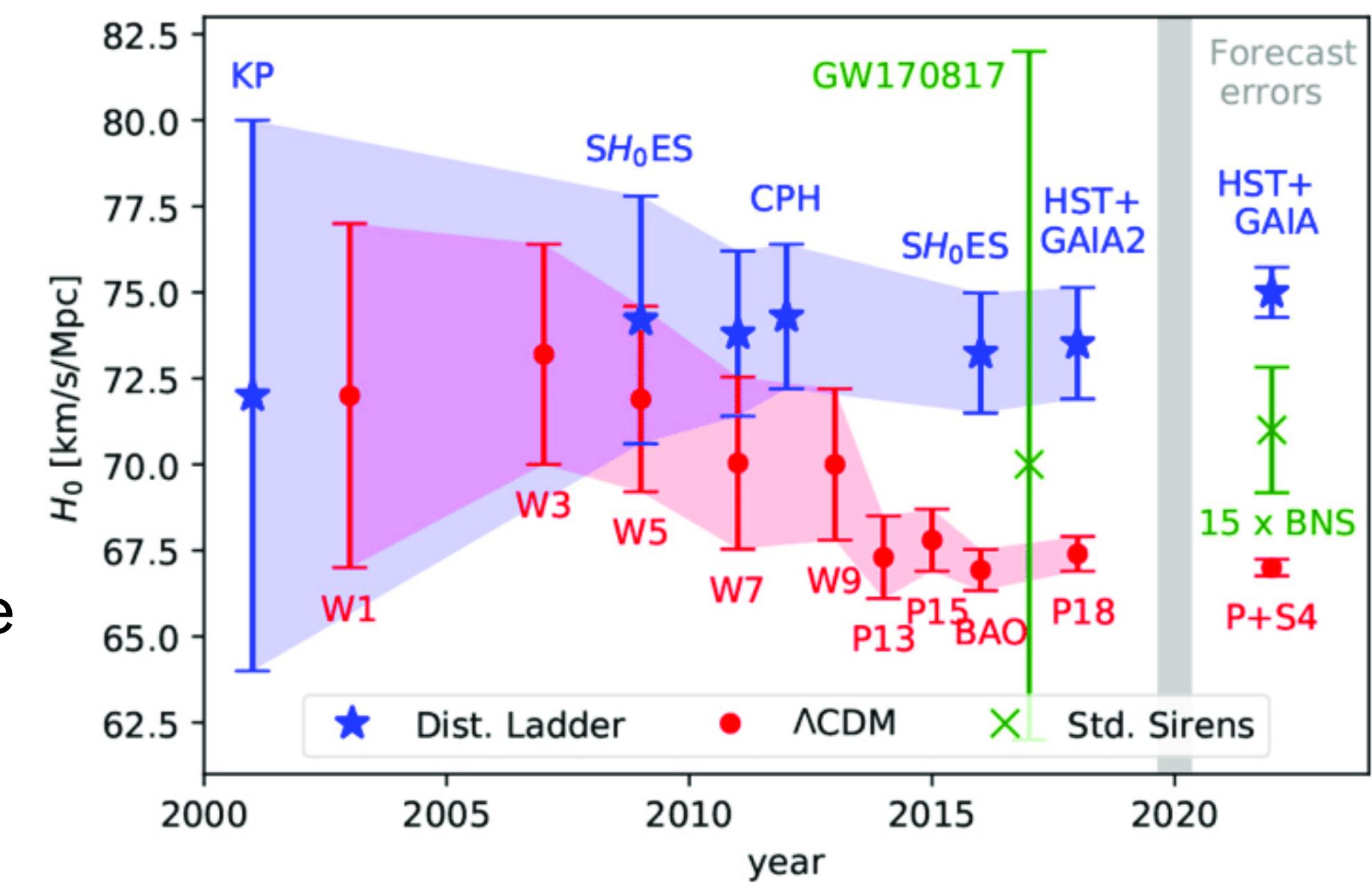


Why should we measure Hubble constant?



Hubble tension

- Today, astrophysicists try to measure Hubble constant with several methods
 - Distance ladder
 - CMB (Λ CDM)
 - Gravitational waves (Standard Sirens)
- The each result doesn't match in appropriate error range



HW

- Please check the jupyter notebook
- Calculate Hubble constant with velocity and distance data from ‘spectroscopy’ lecture
- Plot cone diagram
- Calculate Hubble constant with velocity and distance data from ‘spectroscopy’ lecture