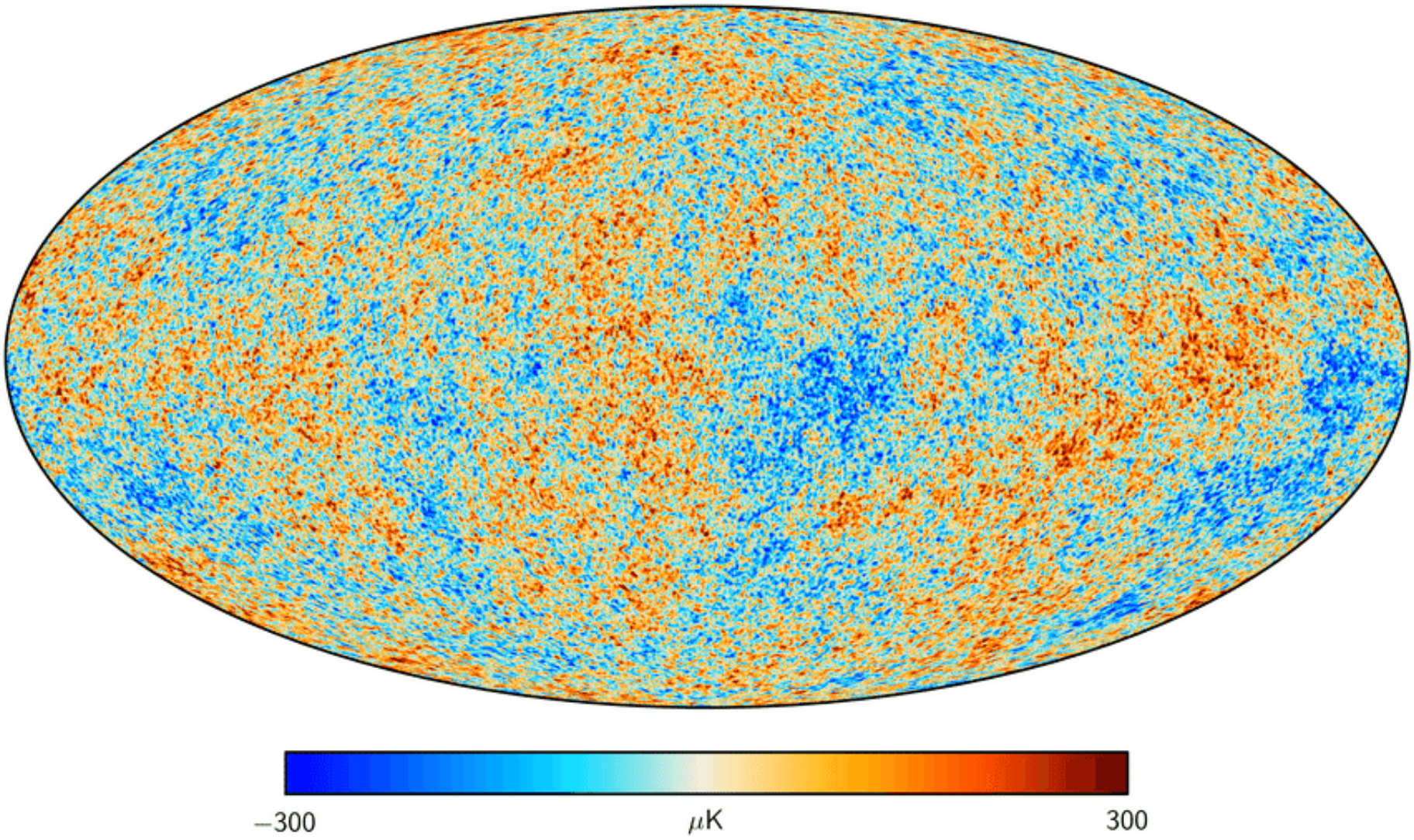
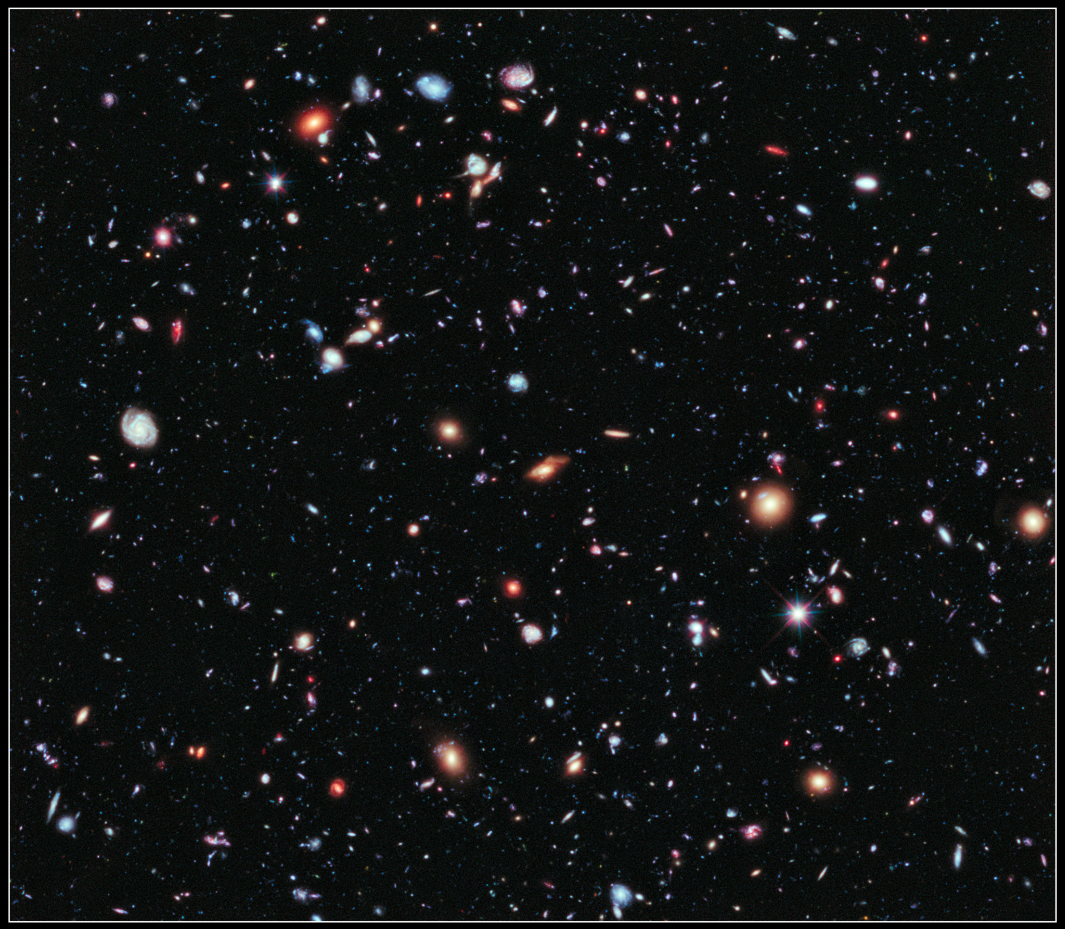
The First Three Minutes
Meeting 1

Peter Fisher

January 13, 2021


−300
μK
300

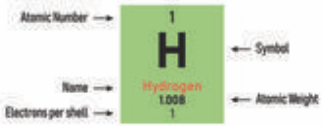


Hubble eXtreme Deep Field (XDF)
Hubble Space Telescope • ACS/WFC • WFC3/IR

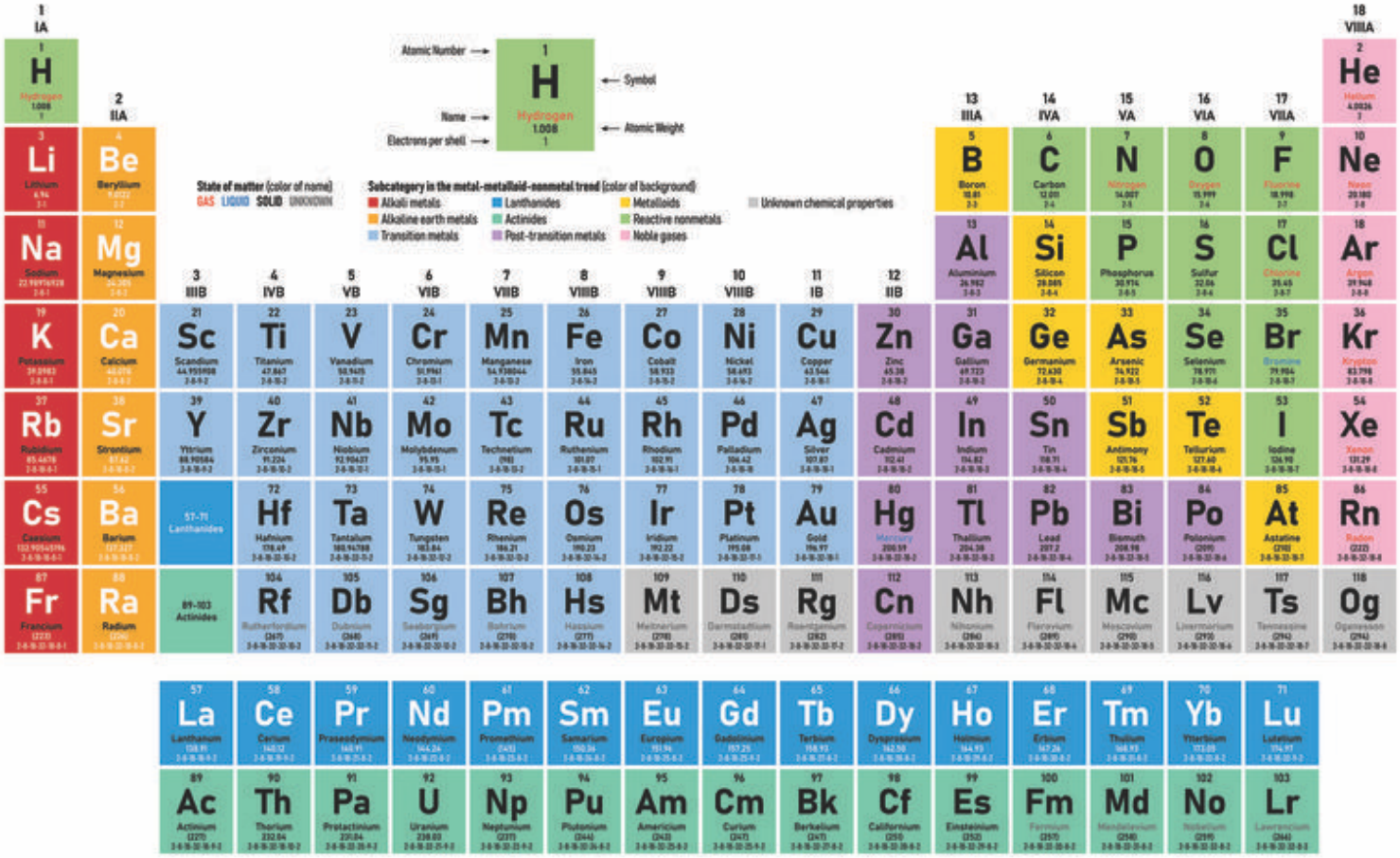
NASA and ESA

STScI-PRC12-37

Periodic Table of the Elements



Periodic Table of the Elements



The Syllabus

Meeting	Date	Assigned Chapter	Major topics
1	January 13, 2021	None	Weinberg, light, telescopes, redshift
2	January 20, 2021	I. Introduction: The Giant and the Cow	Distances in the universe, galaxies
3	January 27, 2021	II. The Expansion of the Universe	Cosmic expansion, Cepheid stars, measuring distances
4	February 3, 2021	III. The Cosmic Microwave Radiation Background	Black body radiation, temperature, radiometers
5	February 10, 2021	IV. Recipe for a Hot Universe	Particle creation and annihilation, the temperature history of the universe
6	February 17, 2021	V. The First Three Minutes	Nuclear reactions
7	February 24, 2021	VI. A Historical Diversion	
8	March 3, 2021	VII. The First One-hundredth second	Quarks, quark-gluon plasma, virtual particles
9	March 10, 2021	VIII. Epilogue: The Prospect Ahead	
10	March 17, 2021	None	Dark energy, nucleosynthesis in stars and neutron stars

Before ”The First Three Minutes”

- Steven Weinberg
- Electromagnetic radiation - radio, light, X-rays, and gamma-rays
- Observations using a telescope
- Measuring velocity - redshift
- Distances in the Universe

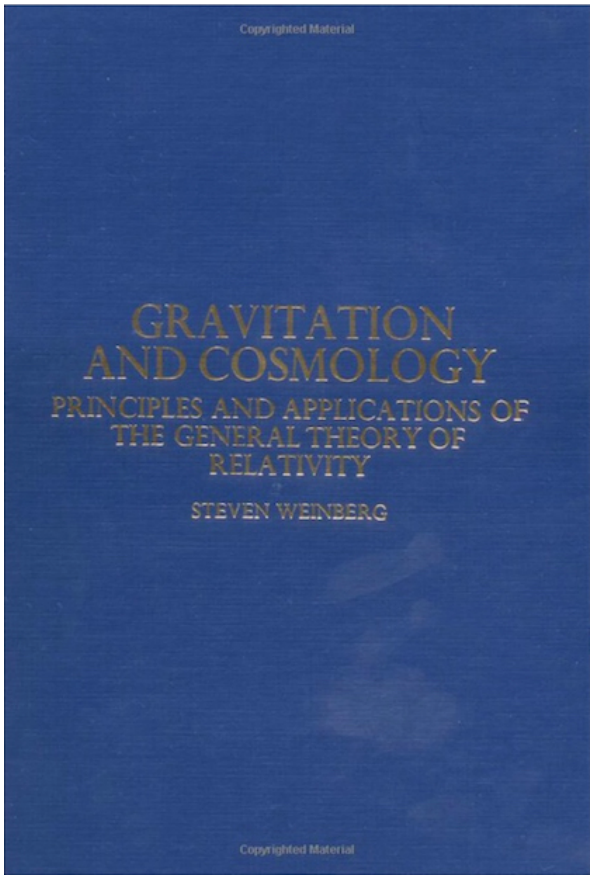
Steven Weinberg

- Born 1933 in New York City
- BS in Physics Cornell 1954
- Ph.D. in Physics Princeton 1957
- Post docs at Columbia, Berkeley
- Lecturer Harvard in 1966, Visiting Professor at MIT, writes the most important paper in particle physics 1967
- "Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity", 1972

A MODEL OF LEPTONS*

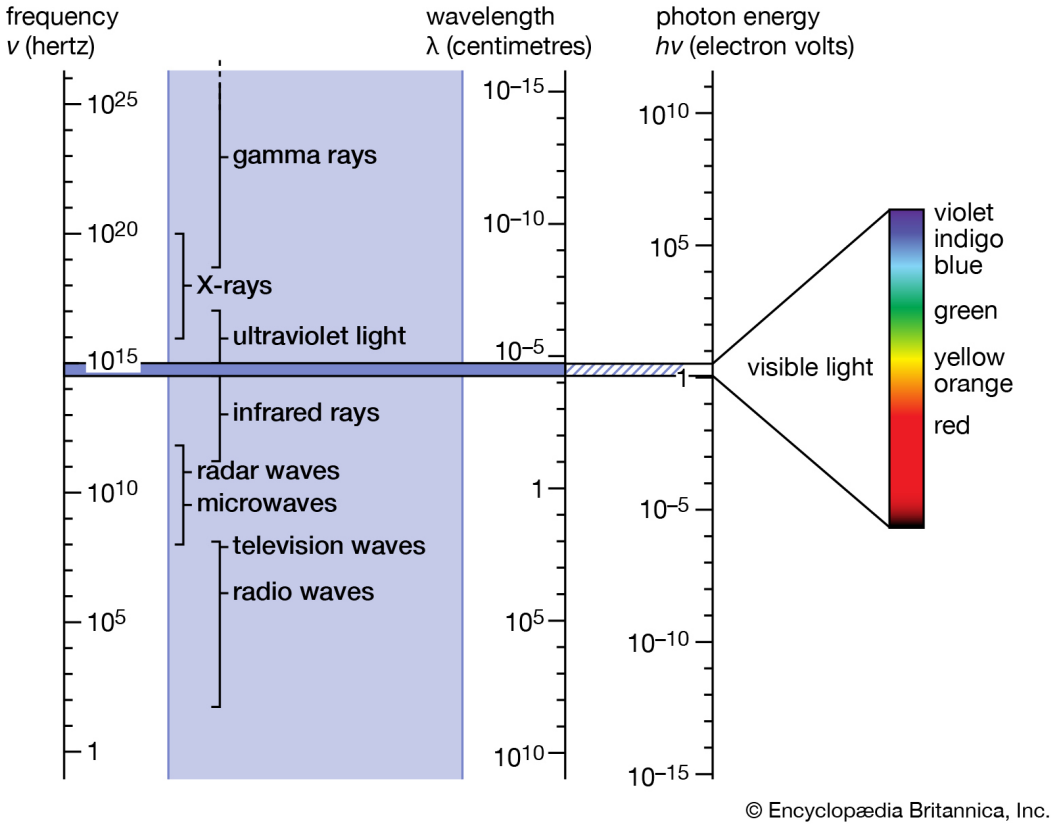
Steven Weinberg†
Laboratory for Nuclear Science and Physics Department,
Massachusetts Institute of Technology, Cambridge, Massachusetts
(Received 17 October 1967)

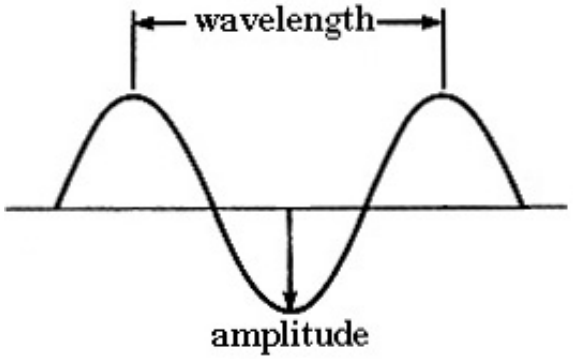
Steven Weinberg (cont.)



- First edition of “The First Three Minutes”, 1977
- Shares Nobel Prize with Glashow (Harvard) and Salam (1979)
- University of Texas, 1982

Electromagnetic Radiation

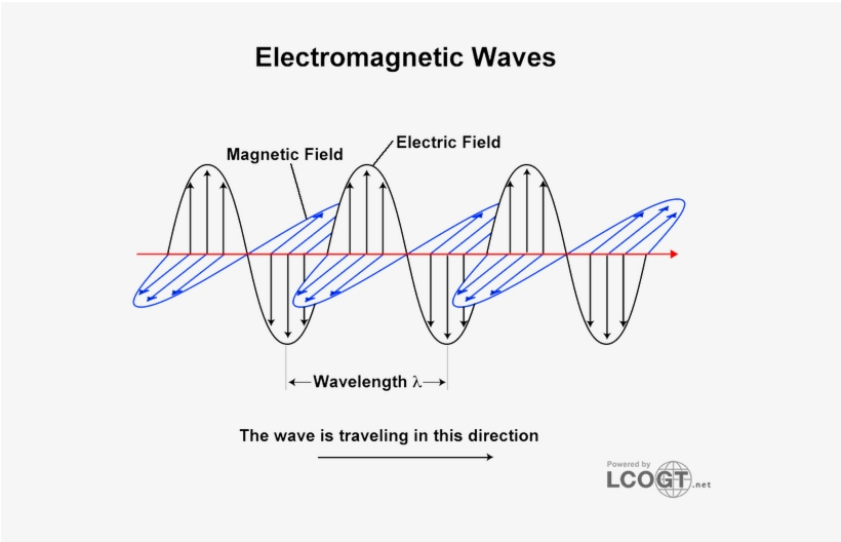


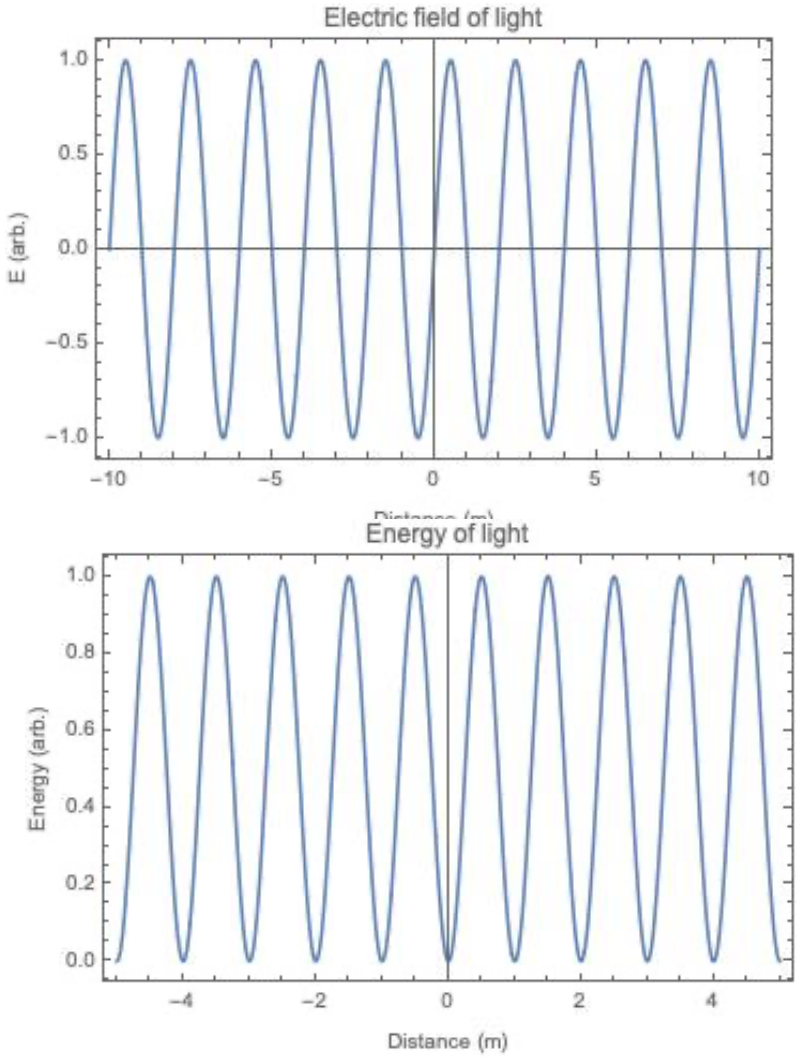


- Longer frequency, shorter wavelength
- Frequency proportional to energy

Light (cont.)

Can treat light as waves of electric and magnetic fields

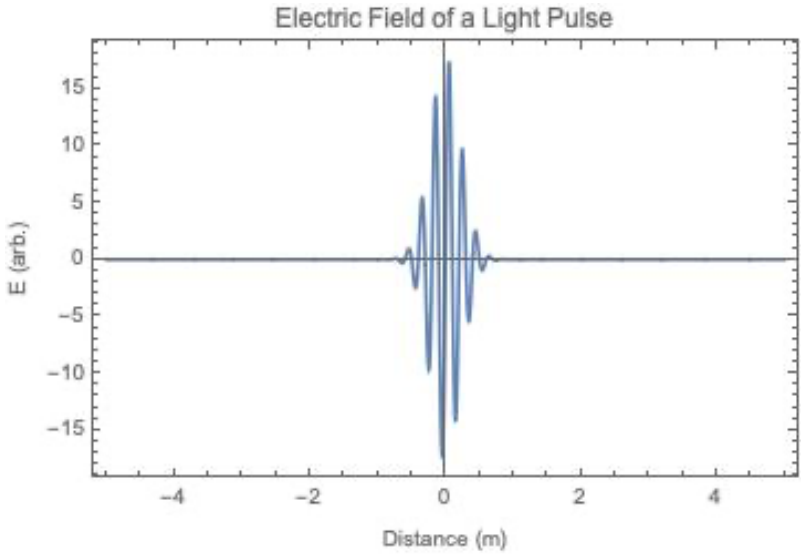


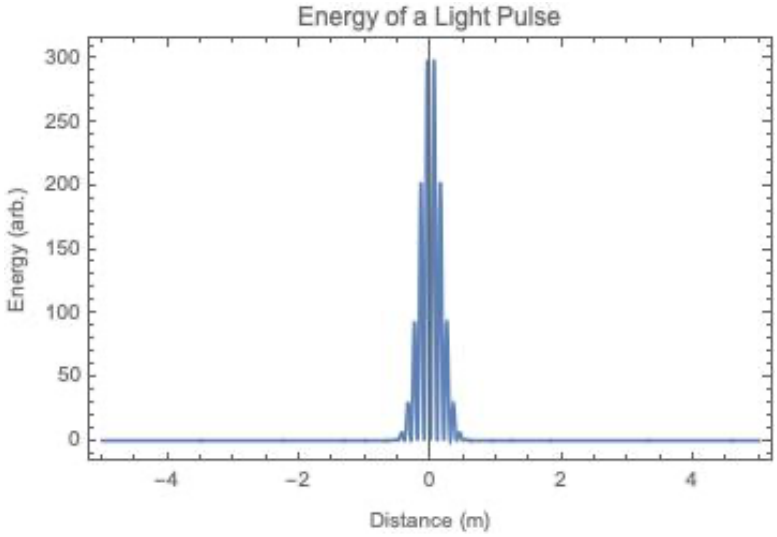


Light particles

Can add up (“superpose”) light waves to make short pulses that act as particles called “Photons (γ)”

Name	Characteristic	How measured
Radio, microwave	As low at 1 mm, 300 GHz	Wavelength or frequency (Hz)
Light	400 – 800 nm	Wavelength
X-rays	100 eV to 50 keV	energy
Gamma rays	50 keV and up	Energy

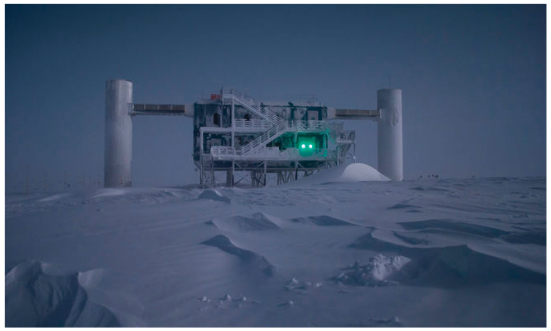




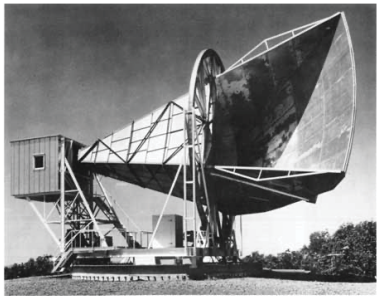
Telescopes

A telescope collects radiation from the sky and maps the angular direction of the incoming radiation onto a focal plane (film, CCD) for storage and later study.

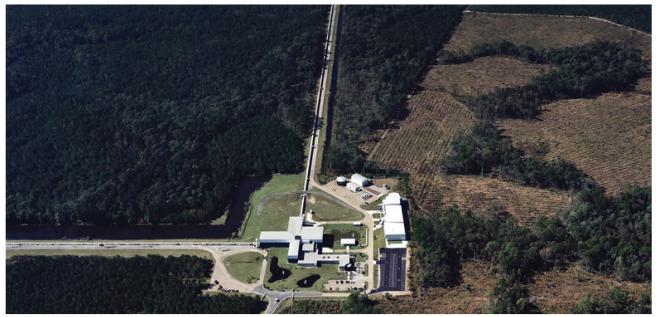
The radiation may be electromagnetic (light, X-rays,γ-rays, microwaves), neutrinos, or gravitational waves. We will mainly talk about electromagnetic radiation



Neutrino, (South Pole)



Radio (Holmdale, NJ)



Grav. Wave (Loiusiana & Washington)

Optical (Hawai'i)

Telescopes (cont.)

Light travels at 300,000 km/s or 1 ft/ns. A telescope collects an image of an object {\em as it was at the time it emitted the light the telescope collects} -- telescope inherently looks back in time.

In Meeting 3, we will learn that the age of the universe if 13.7 billion years. Astronomers routinely observe objects that are 6 billion light years from Earth, so they are looking at objects that are 6 billion years old.

Telescopes (cont.)

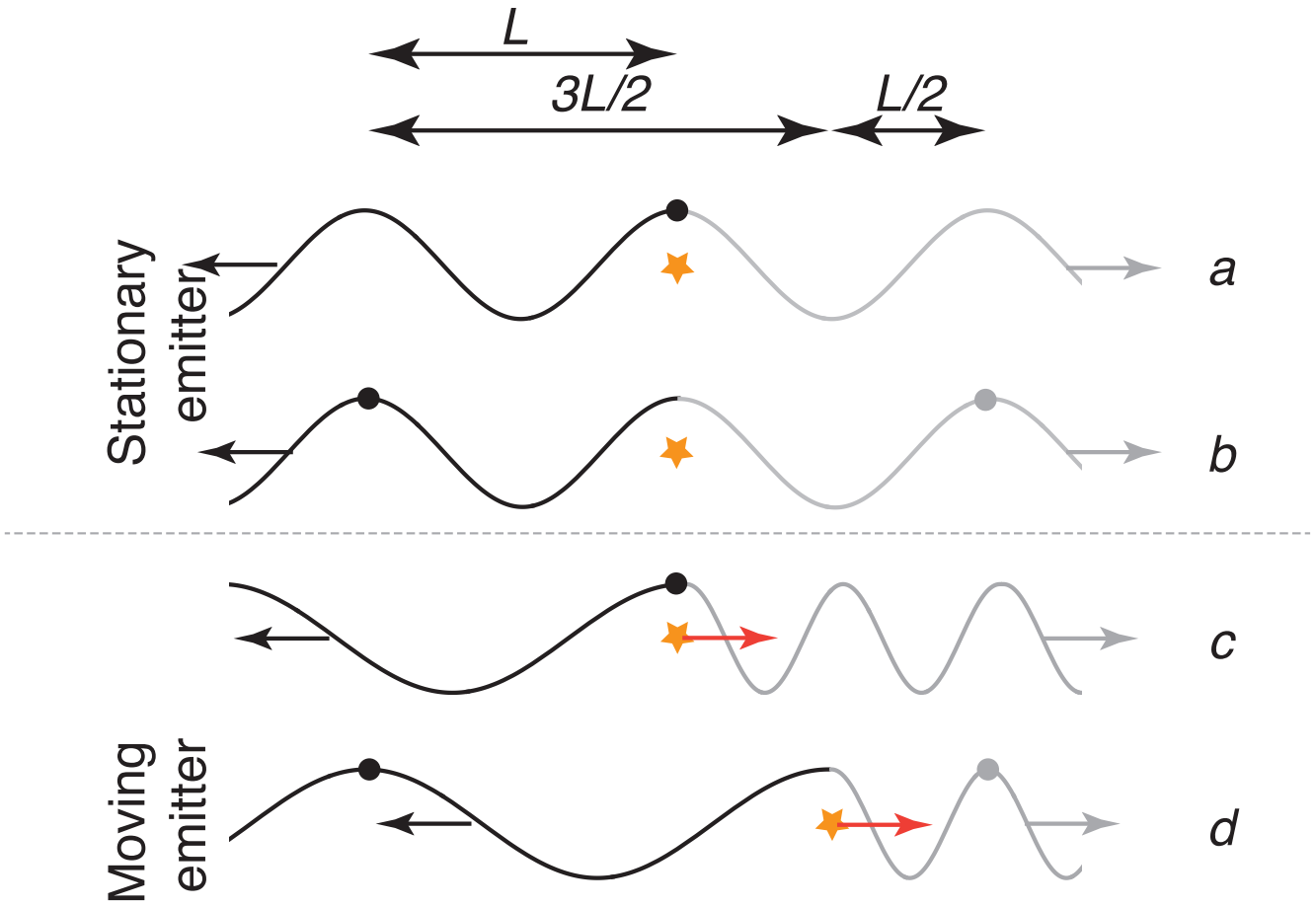
Telescopes to a good job measuring the 2D position on the sky.

Telescope *do not* directly measure the distance to an object.

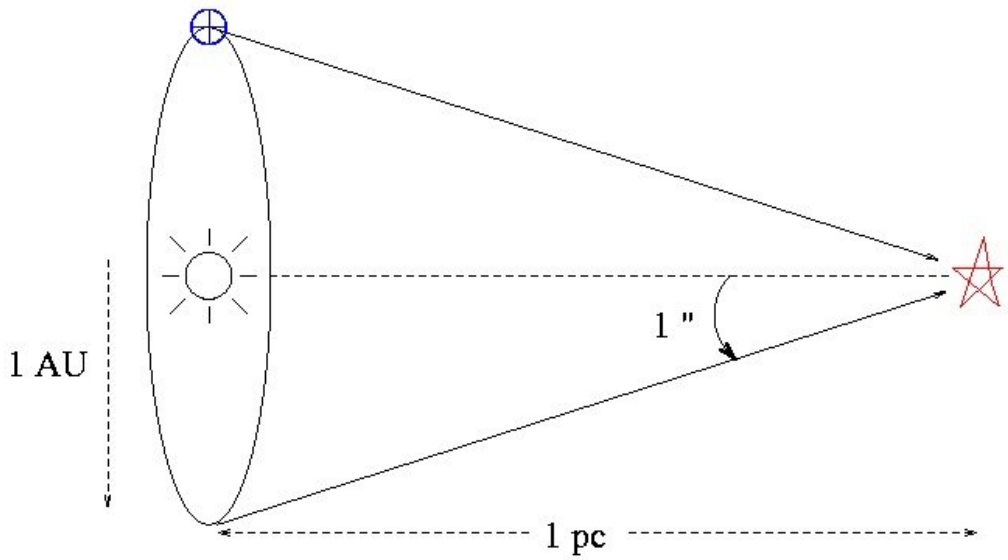
Distance determination is a great challenge to astronomers.

Redshift

- A version of Doppler shift (sound)
- Compresses wave in front
- Stretches wave behind



Distances in Astronomy



- 1 AU=92 million miles
  =150 million km
- 1 light-year=1 ly
  =9 trillion km

1 parsec=1 pc=3.3 ly

Nearest star is 4 ly

Diameter of Milky Way is about 100 kly

Nearest galaxy is 2.5 Mly

Edge of universe is 13.7 Gly