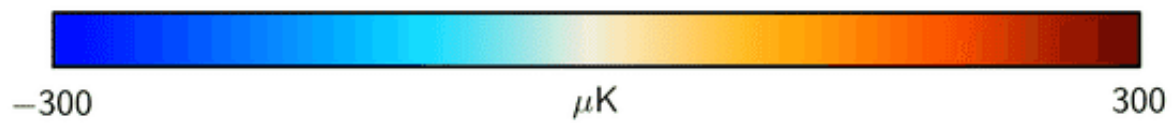
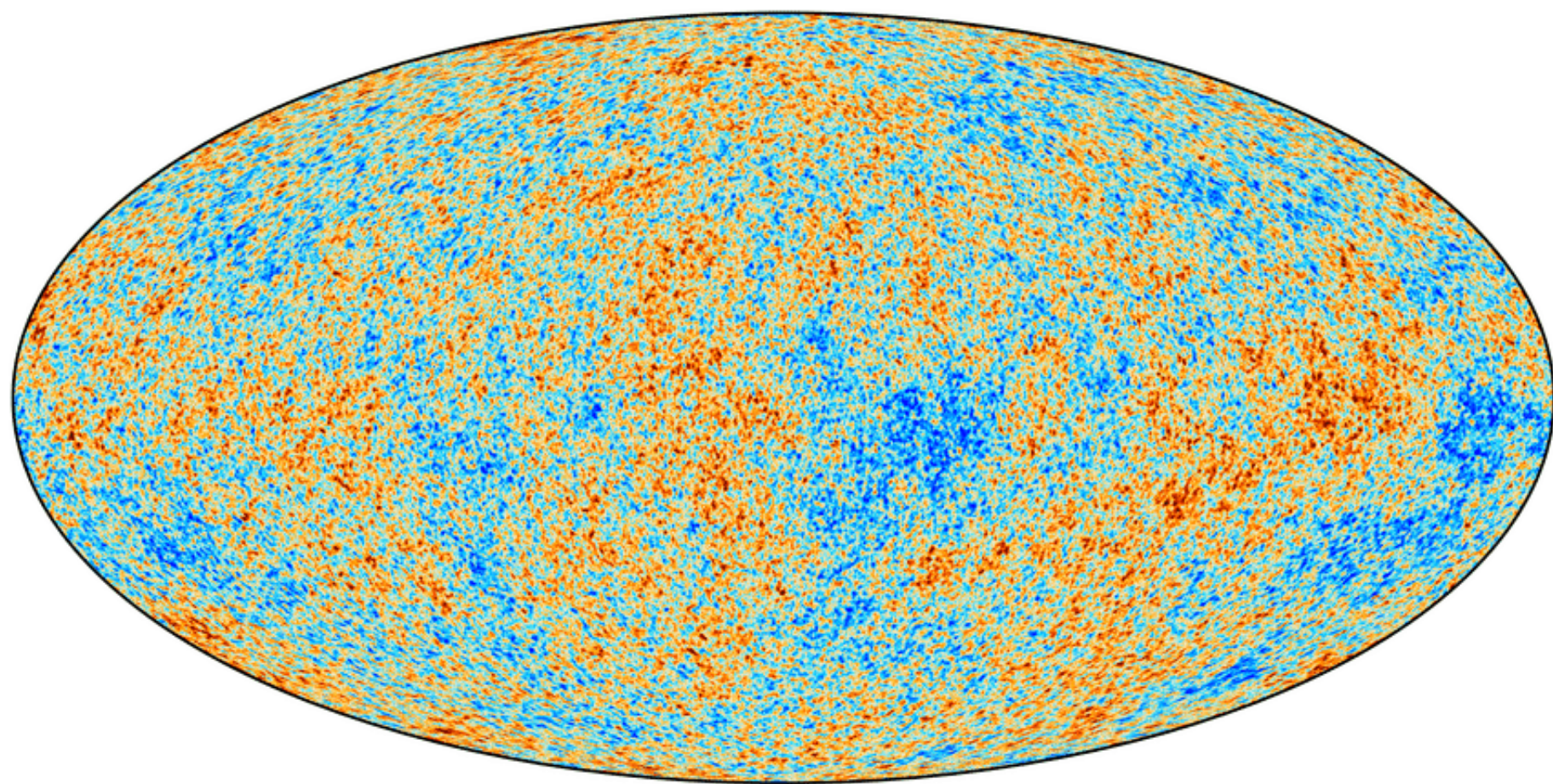


The First Three Minutes Meeting 1

Peter Fisher

January 13, 2021





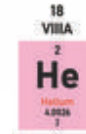
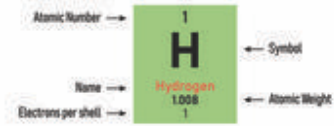
Hubble eXtreme Deep Field (XDF)
Hubble Space Telescope • ACS/WFC • WFC3/IR

NASA and ESA

STScI-PRC12-37



Periodic Table of the Elements



Periodic Table of the Elements

1 IA																												18 VIIIA																	
1 H Hydrogen 1.008																												2 He Helium 4.0026																	
2 IIA																																													
3 Li Lithium 6.94	4 Be Beryllium 9.0122																											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	10												
5 B Boron 10.81																		6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180																							
11 Na Sodium 22.990	12 Mg Magnesium 24.305																											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948												
3 IIB		4 IVB		5 VB		6 VIB		7 VIIB		8 VIII B		9 VIIIB		10 VIIIB		11 IB		12 IIB																											
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798																												
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.94	43 Tc Technetium 98	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.905	54 Xe Xenon 131.29																												
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides		72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222																											
87 Fr Francium 223	88 Ra Radium 226	89-103 Actinides		104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 263	107 Bh Bohrium 264	108 Hs Hassium 265	109 Mt Meitnerium 266	110 Ds Darmstadtium 267	111 Rg Roentgenium 268	112 Cn Copernicium 269	113 Nh Nihonium 270	114 Fl Flerovium 271	115 Mc Moscovium 272	116 Lv Livermorium 273	117 Ts Tennessine 274	118 Og Oganesson 274																											
57		58		59		60		61		62		63		64		65		66		67		68		69		70		71																	
La Lanthanum 138.905	Ce Cerium 140.12	Pr Praseodymium 140.908	Nd Neodymium 144.24	Pm Promethium 145	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.925	Dy Dysprosium 162.50	Ho Holmium 164.93	Er Erbium 167.26	Tm Thulium 168.935	Yb Ytterbium 173.054	Lu Lutetium 174.967																															
89 Ac Actinium 227	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237	94 Pu Plutonium 244	95 Am Americium 243	96 Cm Curium 247	97 Bk Berkelium 247	98 Cf Californium 251	99 Es Einsteinium 252	100 Fm Fermium 257	101 Md Mendelevium 258	102 No Nobelium 259	103 Lr Lawrencium 260																															

Atomic Number → 1
 Symbol ← H
 Name → Hydrogen
 Atomic Weight ← 1.008
 Electrons per shell → 1

- State of matter (color of name)
- GAS
 - LIQUID
 - SOLID
 - UNKNOWN
- Subcategory in the metal-metalloid-nonmetal trend (color of background)
- Alkali metals
 - Alkaline earth metals
 - Transition metals
 - Lanthanides
 - Actinides
 - Post-transition metals
 - Metalloids
 - Reactive nonmetals
 - Noble gases
 - Unknown chemical properties

The Syllabus

Meeting	Date	Assigned Chapter	Major topics
<input type="checkbox"/>			
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

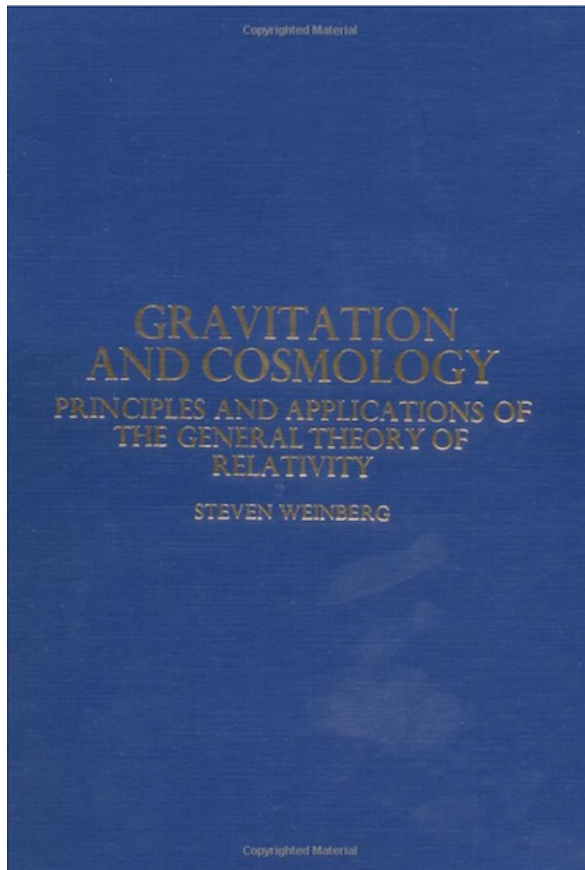
A MODEL OF LEPTONS*

Steven Weinberg†

Laboratory for Nuclear Science and Physics Department,
Massachusetts Institute of Technology, Cambridge, Massachusetts

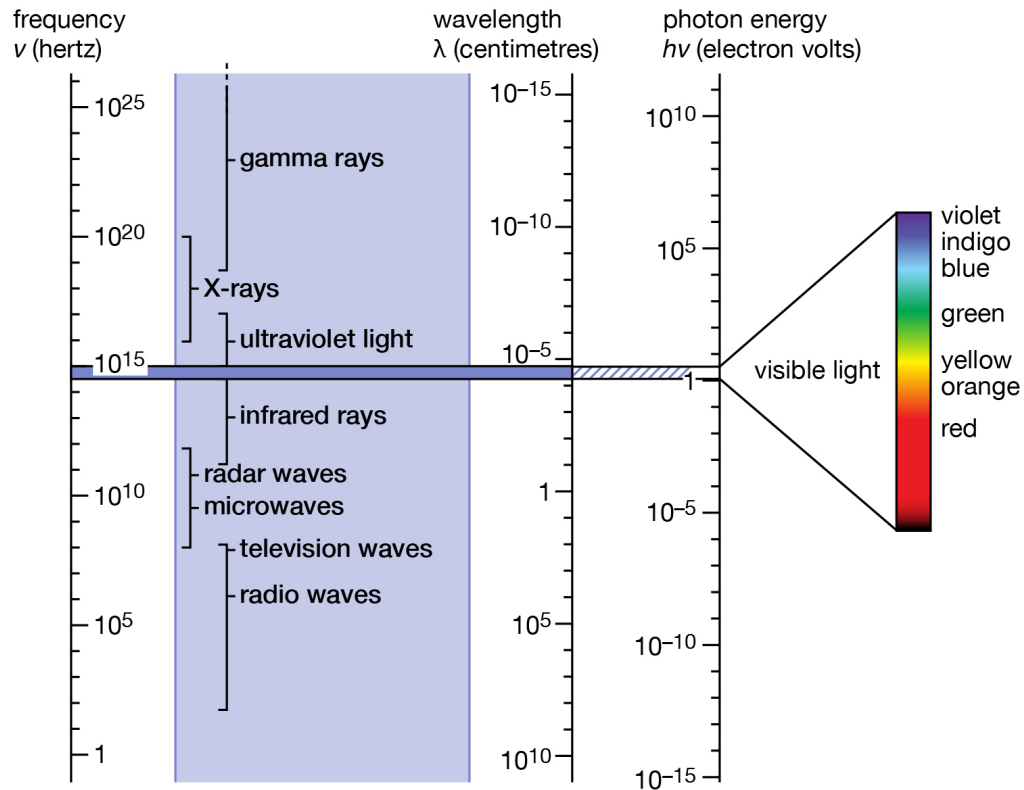
(Received 17 October 1967)

Steven Weinberg (cont.)

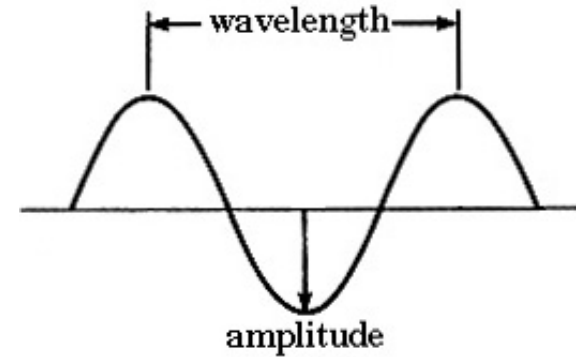


- First edition of “The First Three Minutes”, 1977
- Shares Nobel Prize with Glashow (Harvard) and Salam (1979)
- University of Texas, 1982

Electromagnetic Radiation



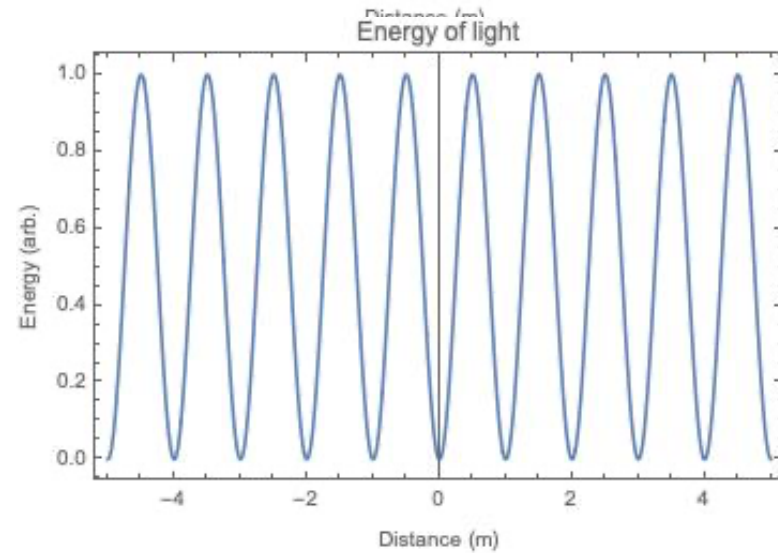
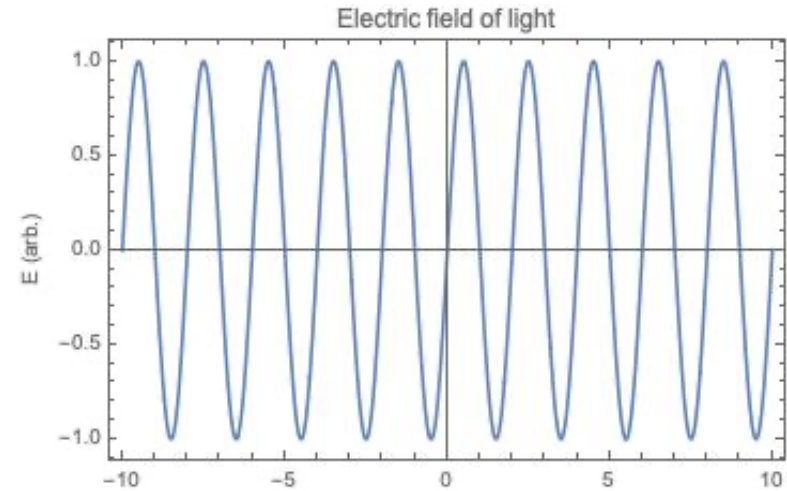
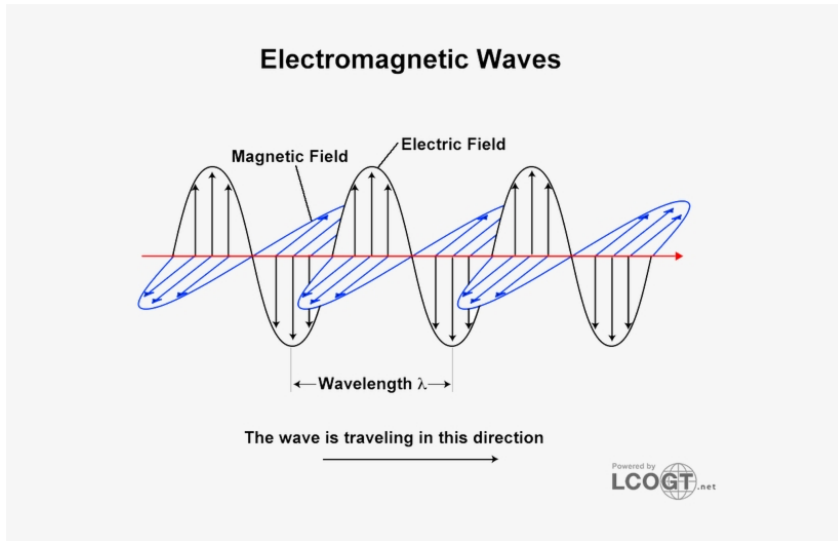
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- Longer frequency, shorter wavelength
- Frequency proportional to energy

Light (cont.)

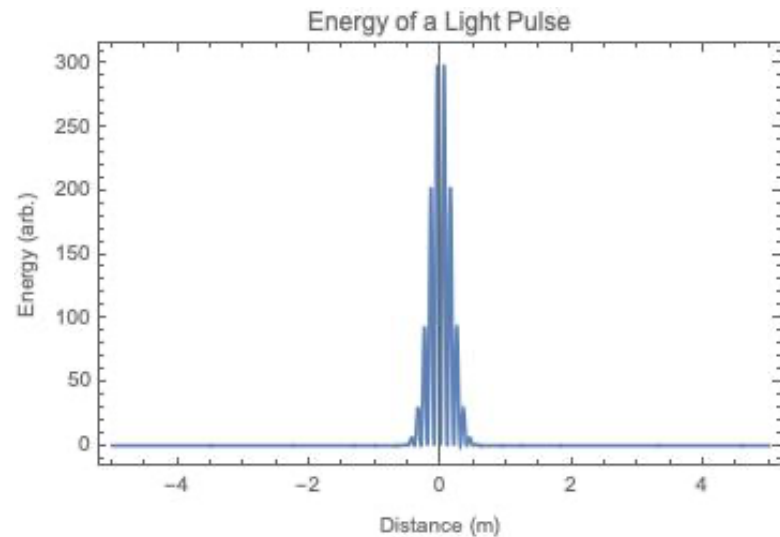
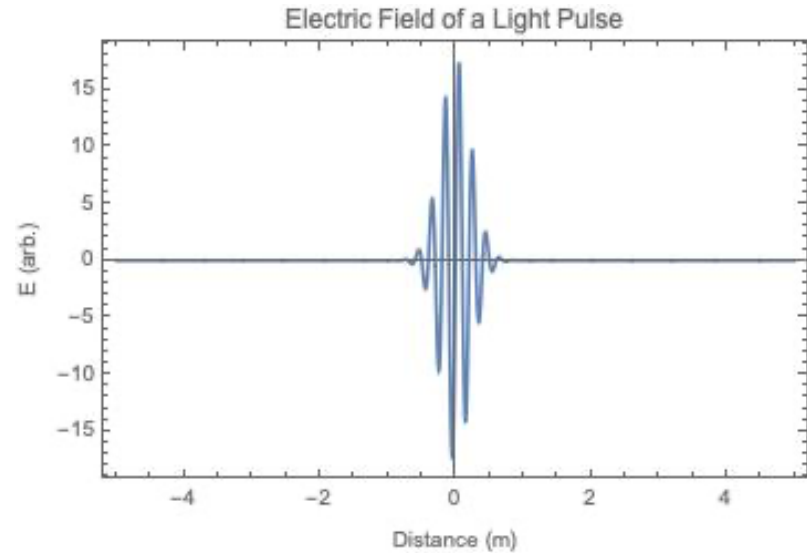
Can treat light as waves of electric and magnetic fields



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 as 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



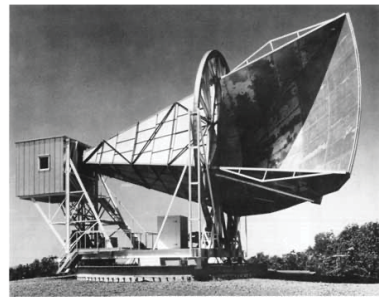
Telescopes

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



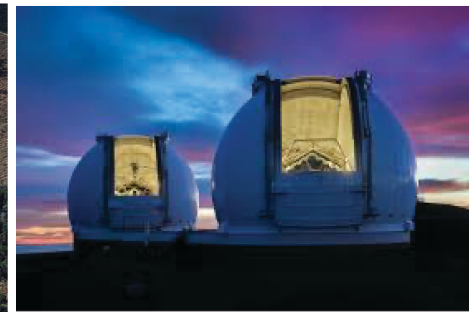
Neutrino, (South Pole)



Radio (Holmdale, NJ)



Grav. Wave (Louisiana & 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 is 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.)

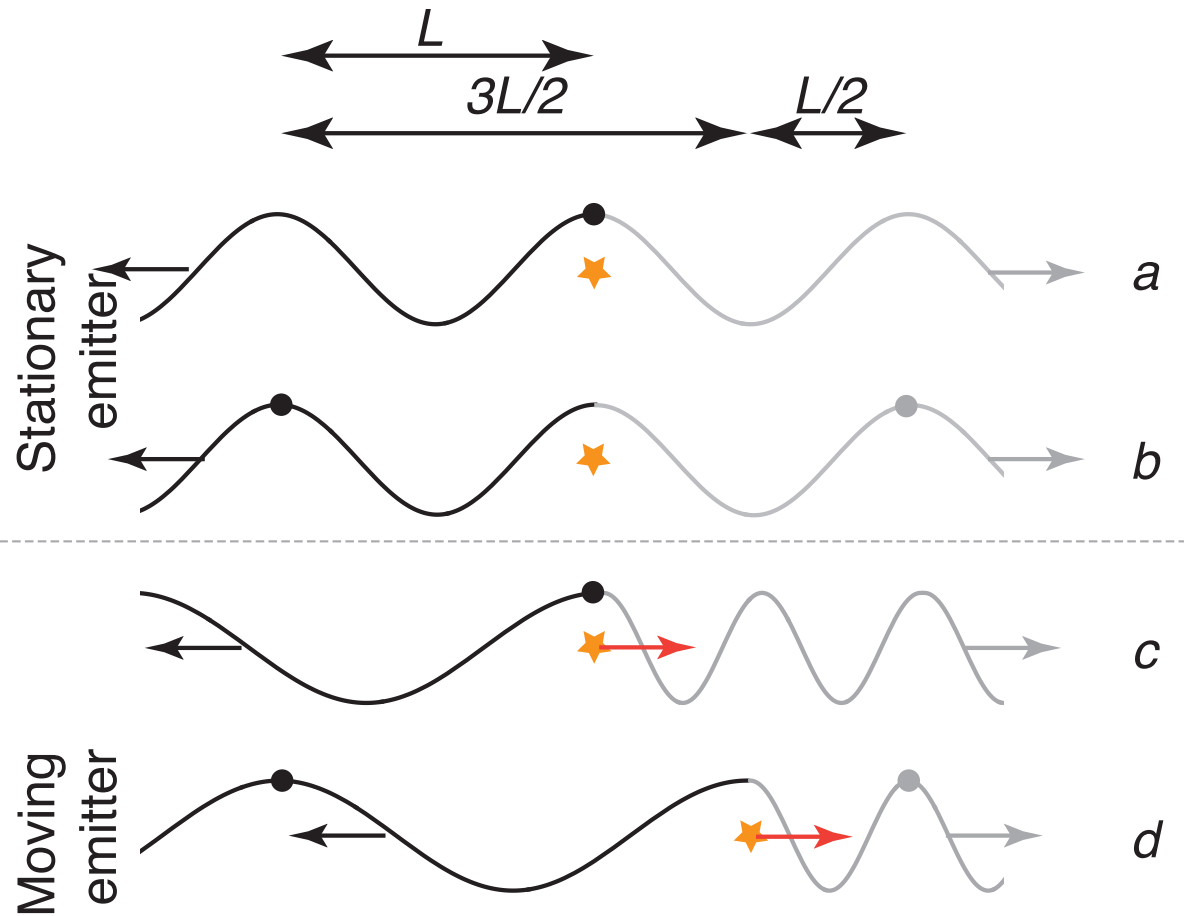
Telescopes do a good job measuring the 2D position on the sky.

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

Distance determination is a great challenge to astronomers.

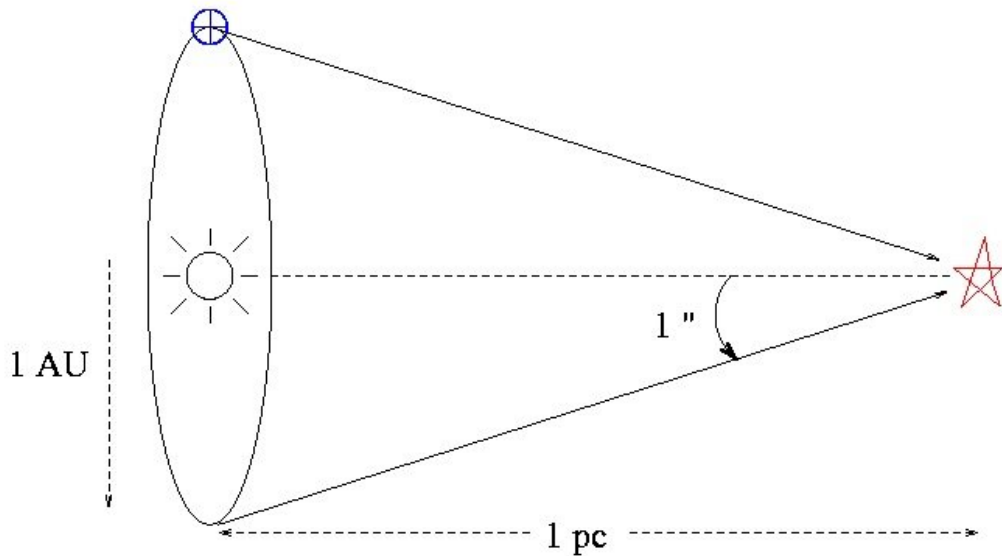
Redshift

- 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