Freedman • Geller • Kaufmann

Universe

9th Edition

CHAPTERS 5 & 6

Telescopes & the Nature of Light

ELECTROMAGNETIC RADIATION

Energy in transit

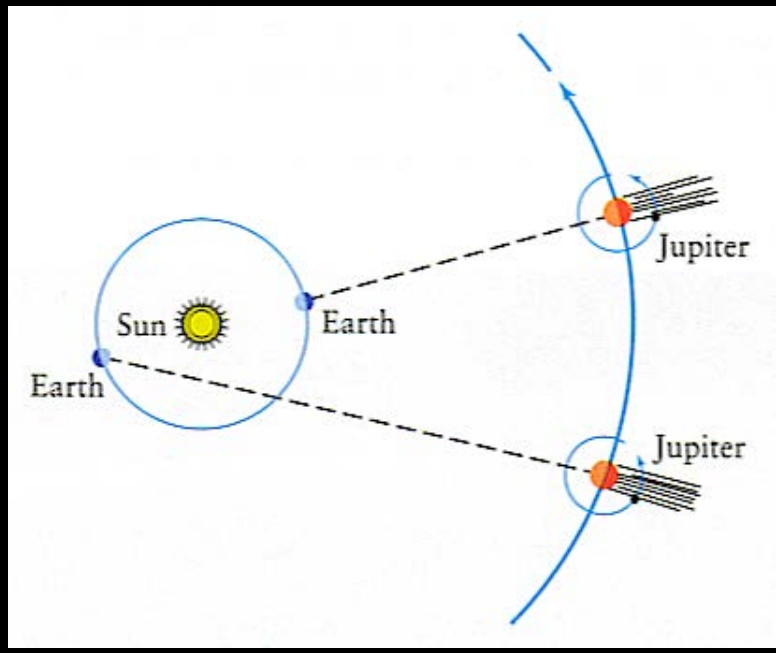
Straight path in vacuum

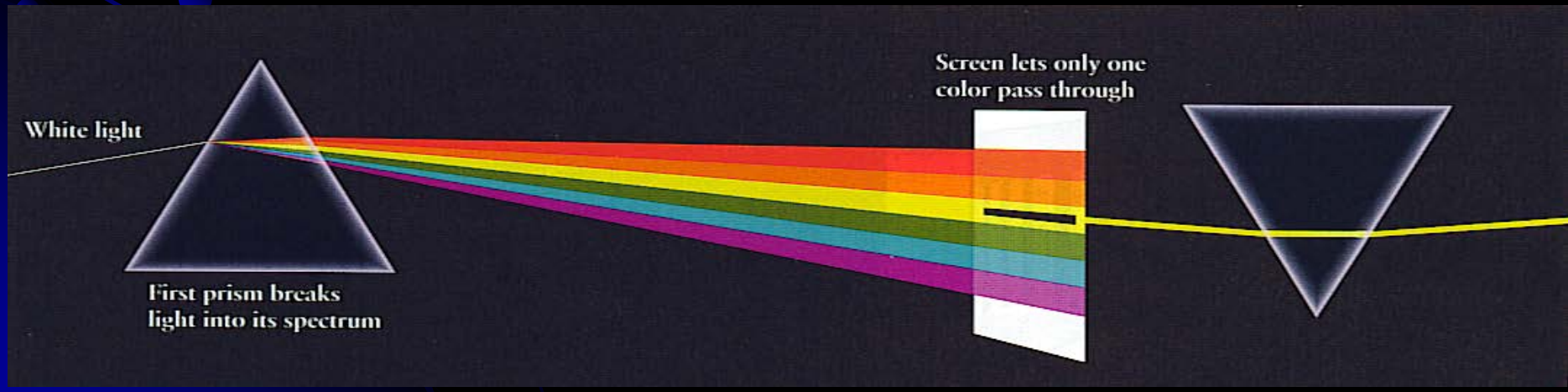
Finite speed:

Olaus Rømer c. 1676

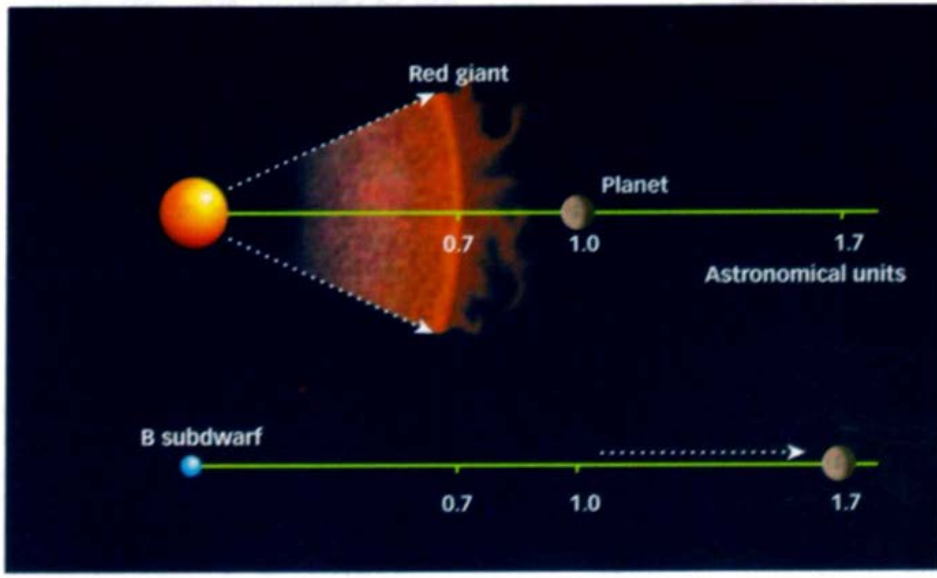
White light is a mix:

Newton c. 1670



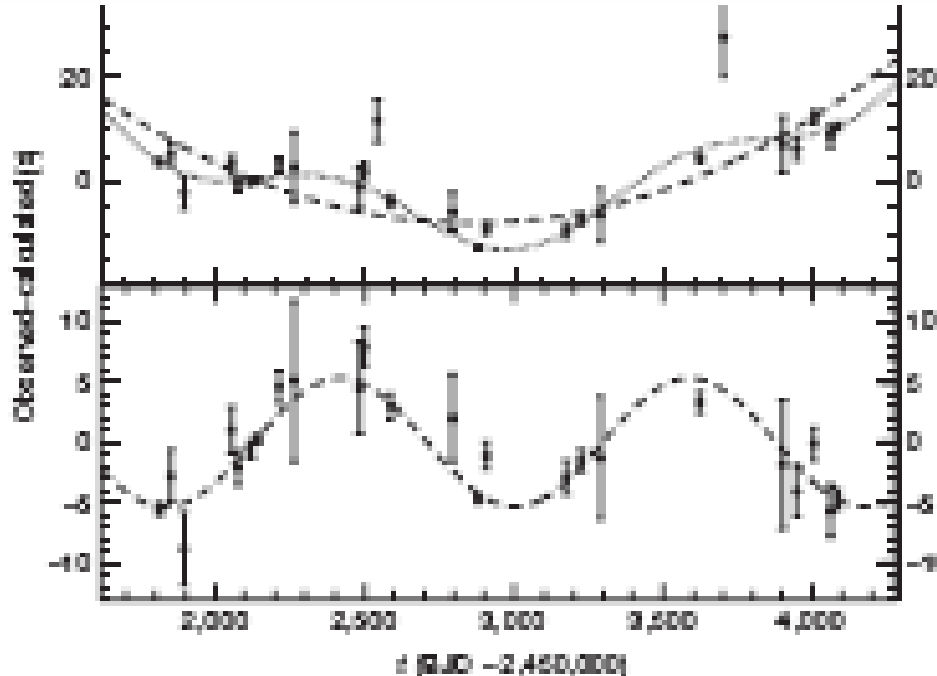


USING LIGHT TRAVEL TIME TO DETECT A PLANET: V391 Pegasi b

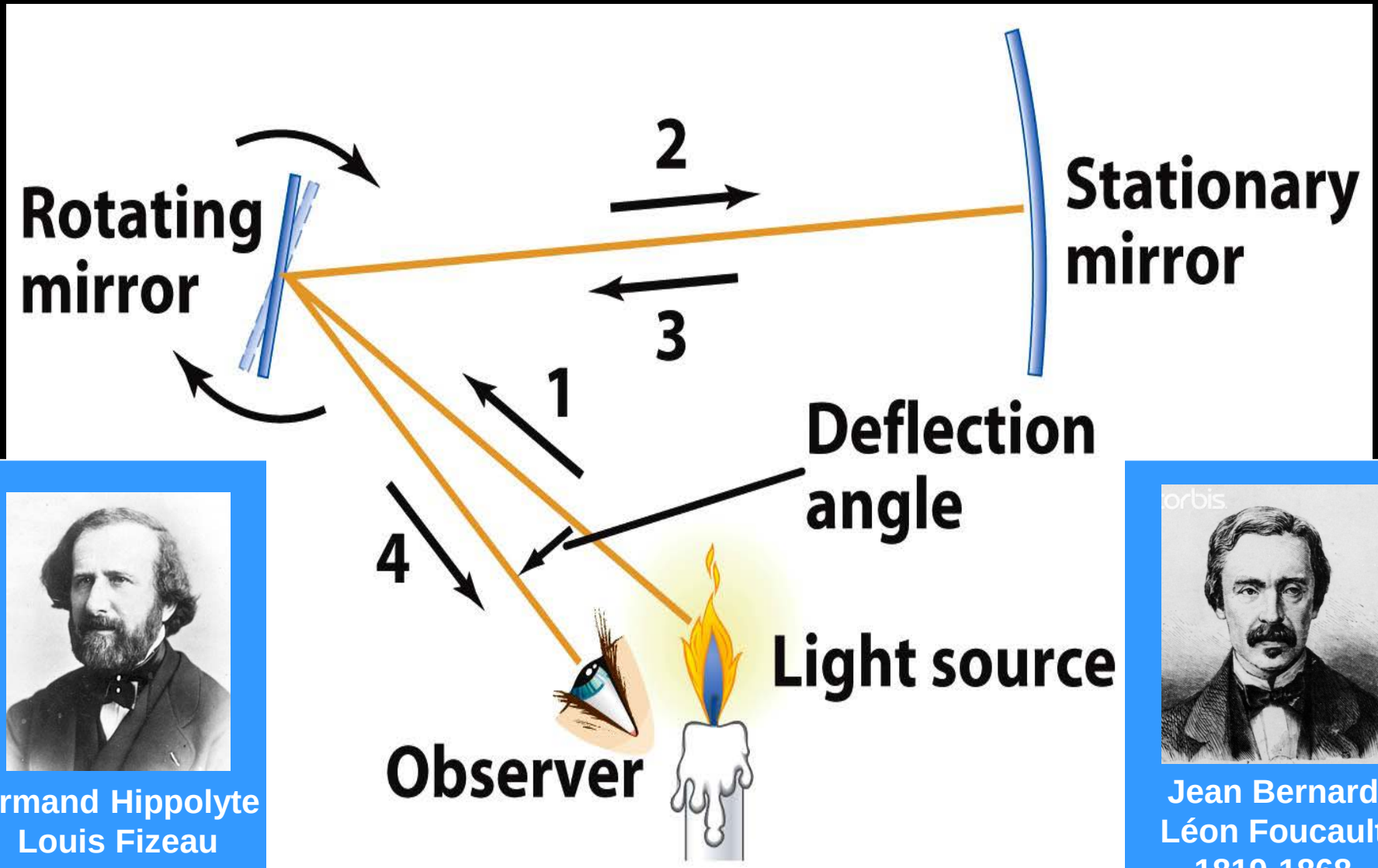


ENDURANCE A recently discovered planet has withstood the swelling of its aging parent star, which expanded nearly to 1 astronomical unit, the size of Earth's orbit (top). The star has since shrunk, and the planet has migrated about 70 percent farther from its parent (bottom).

Science News SEPTEMBER 15, 2007 VOL. 172



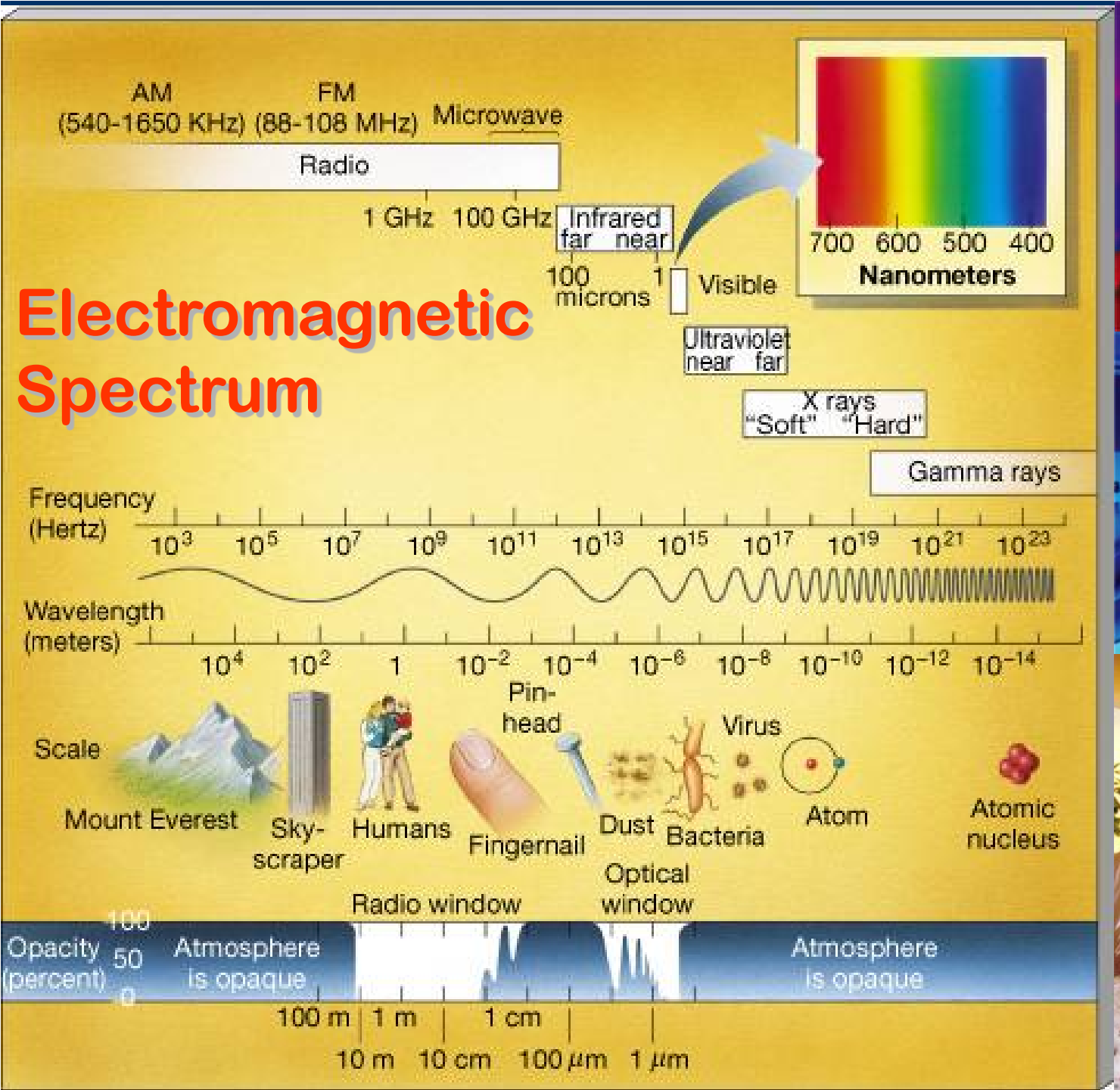
Fizeau-Foucault method for measuring the speed of light

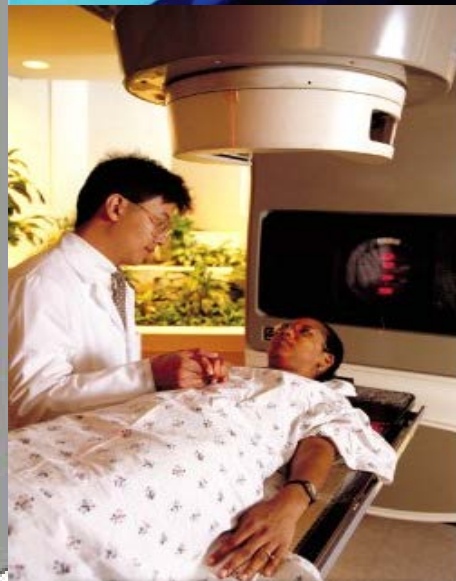


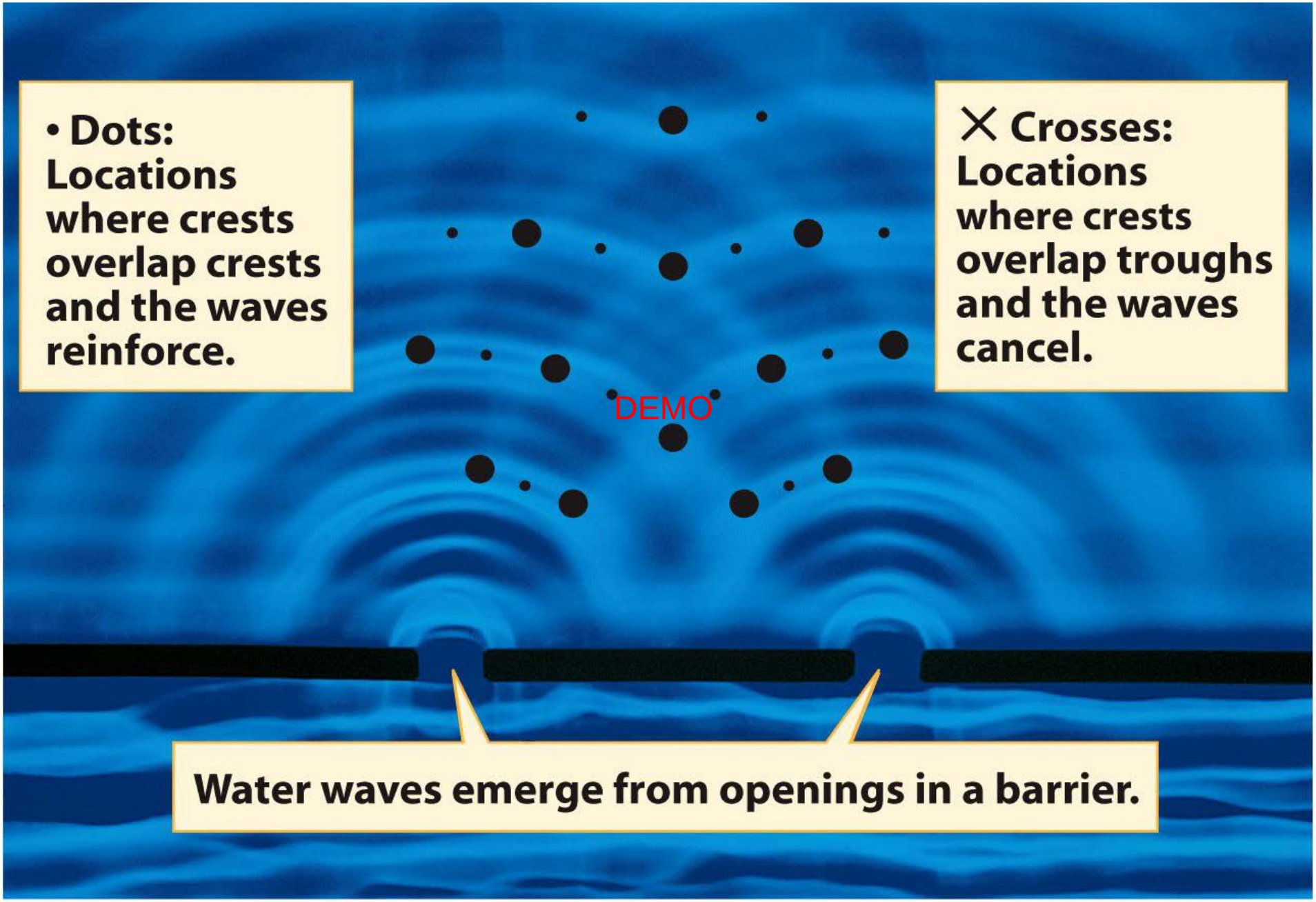
Armand Hippolyte Louis Fizeau 1819-1896

Jean Bernard Léon Foucault 1819-1868

Electromagnetic Spectrum

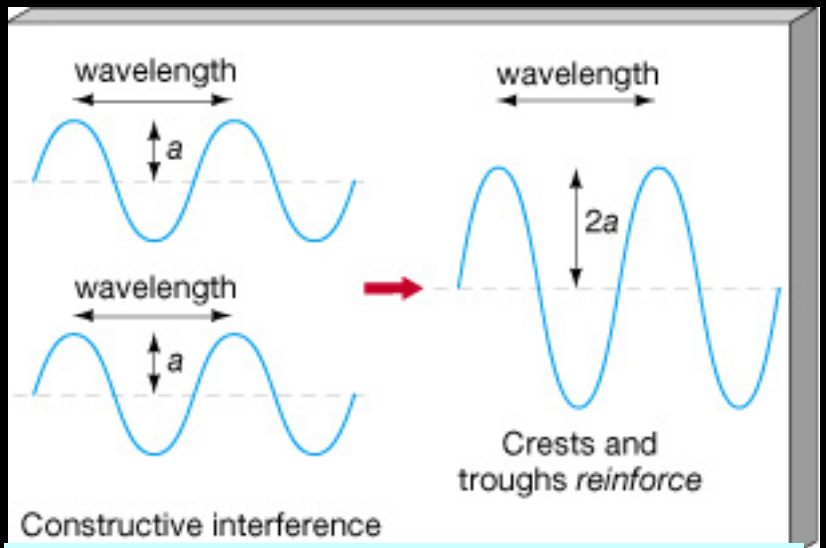




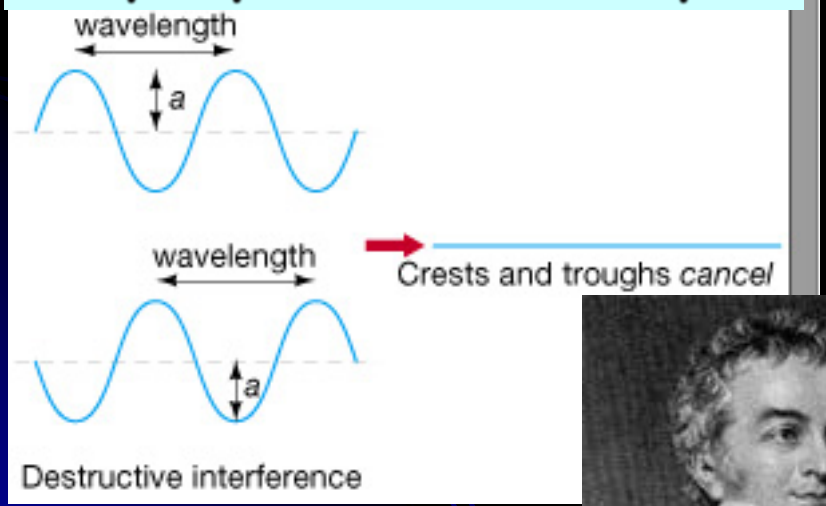


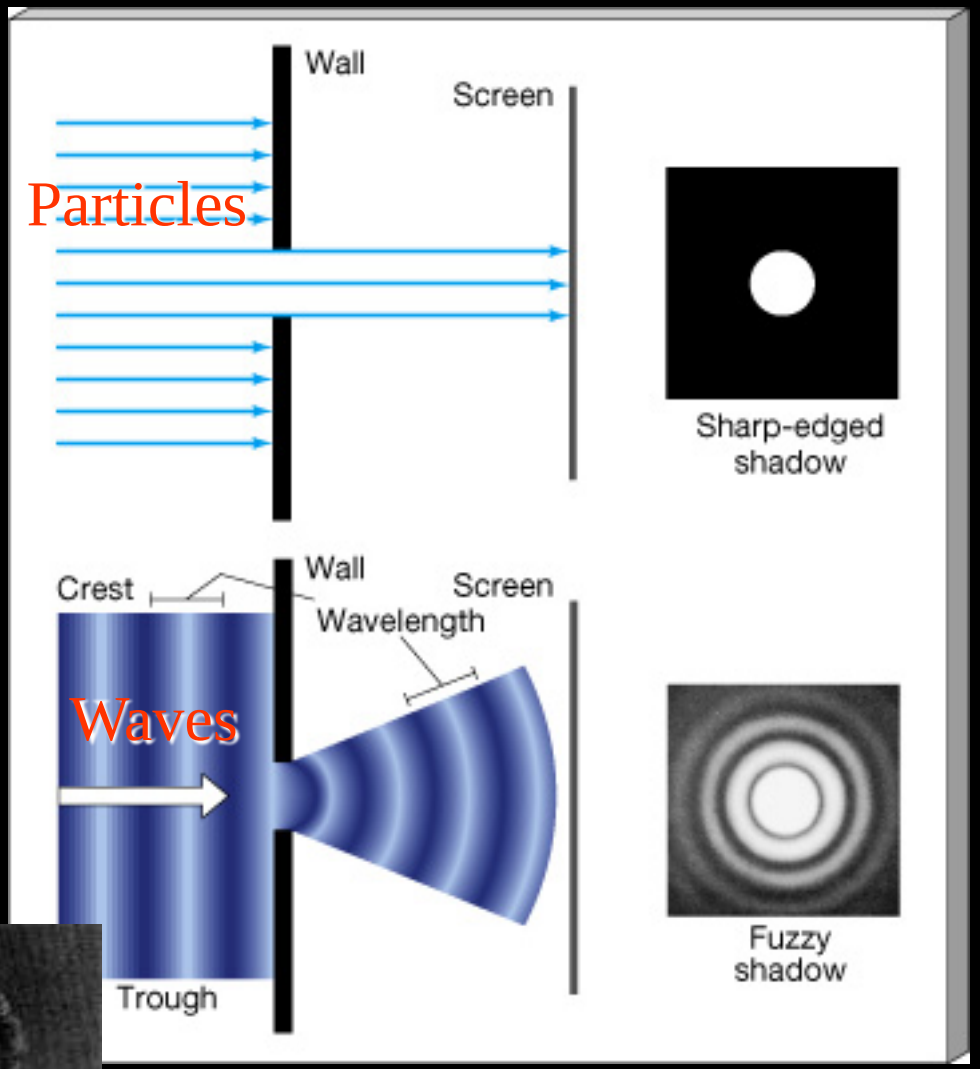
An analogous experiment with water waves

WAVES? Diffraction & Interference



Superposition Principle

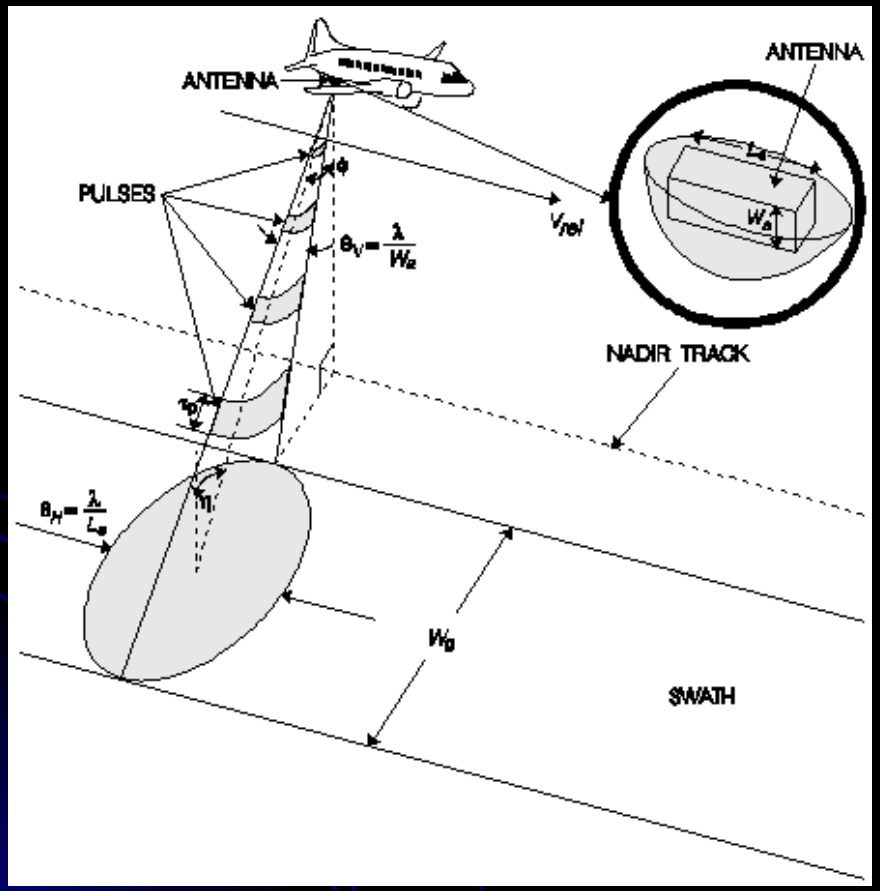




Thomas Young
1773-1829

Slit Experiments
Demo1

Radar Love:
Observing the planets with synthetic aperture radar



PSS colloquium

Friday Feb. 1, 2013

OPS-140

Catherine Neish, Ph.D.
University of Arizona

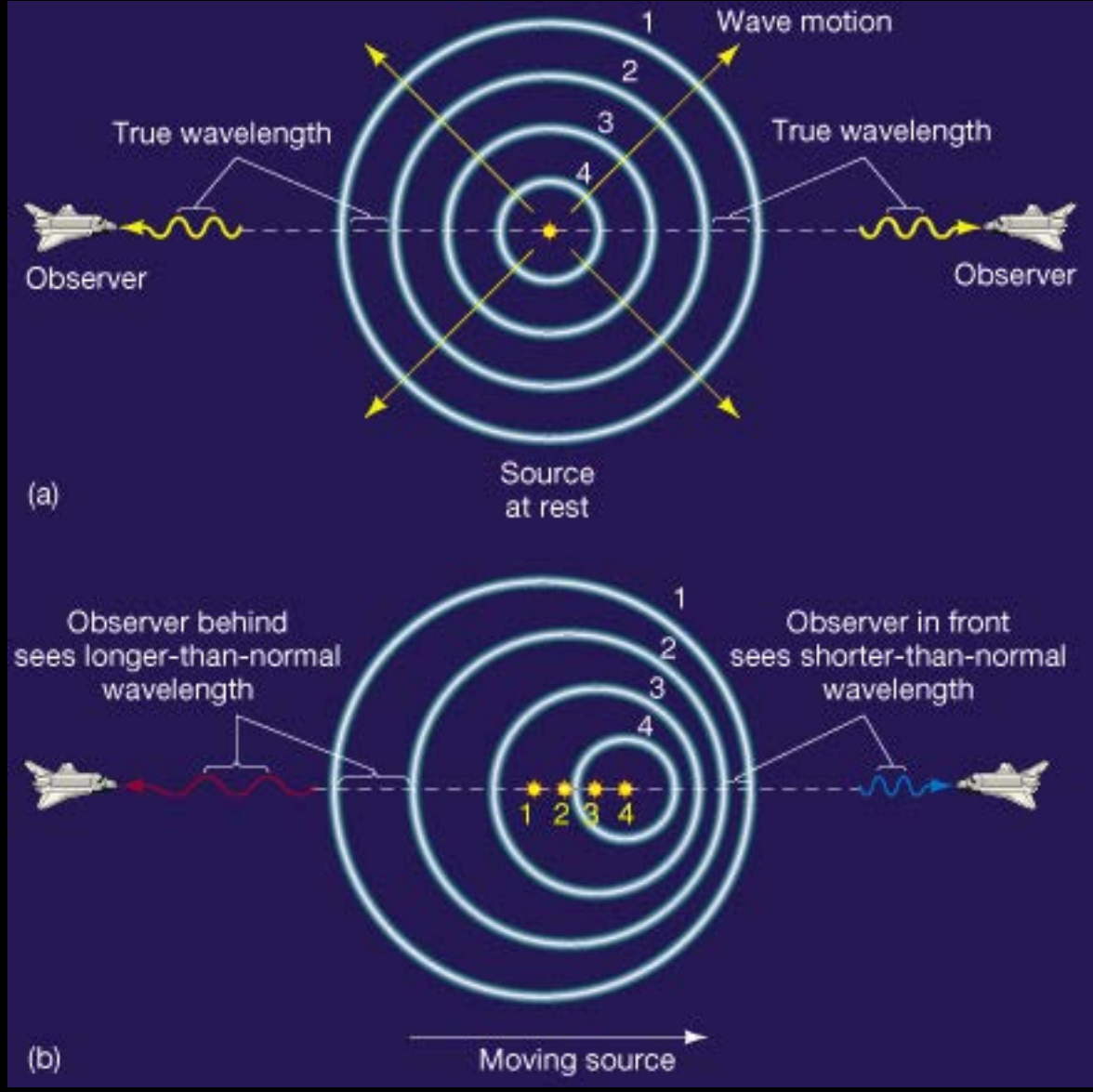
DOPPLER EFFECT

Christian Doppler
1803-1853

$\Delta\lambda / \lambda = v / c$

% shift = % of light speed

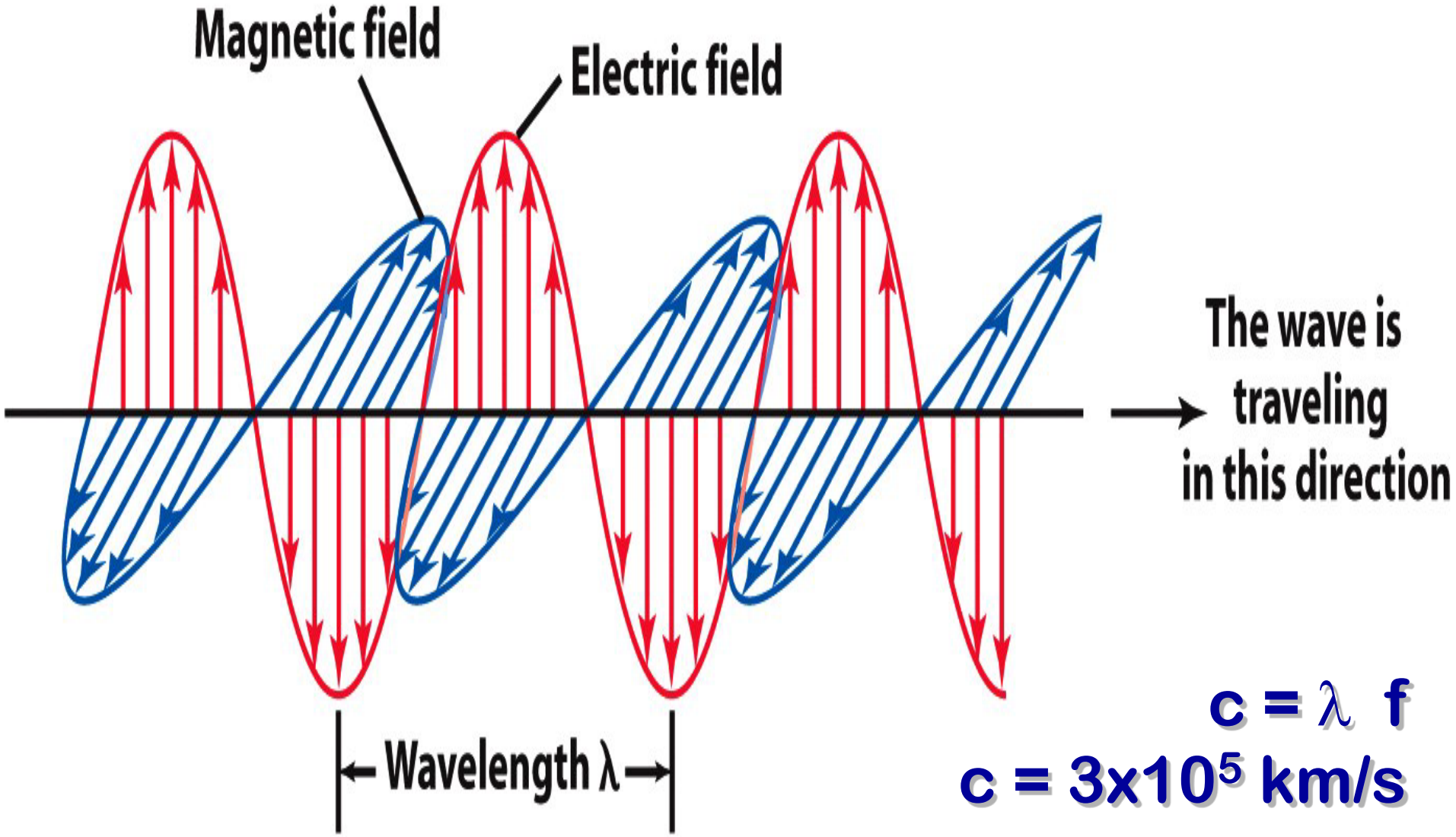
Stellar Velocities



$$\frac{\text{apparent wavelength}}{\text{true wavelength}} = \frac{\text{true frequency}}{\text{apparent frequency}} = 1 + \frac{\text{recession velocity}}{\text{wave speed}}$$

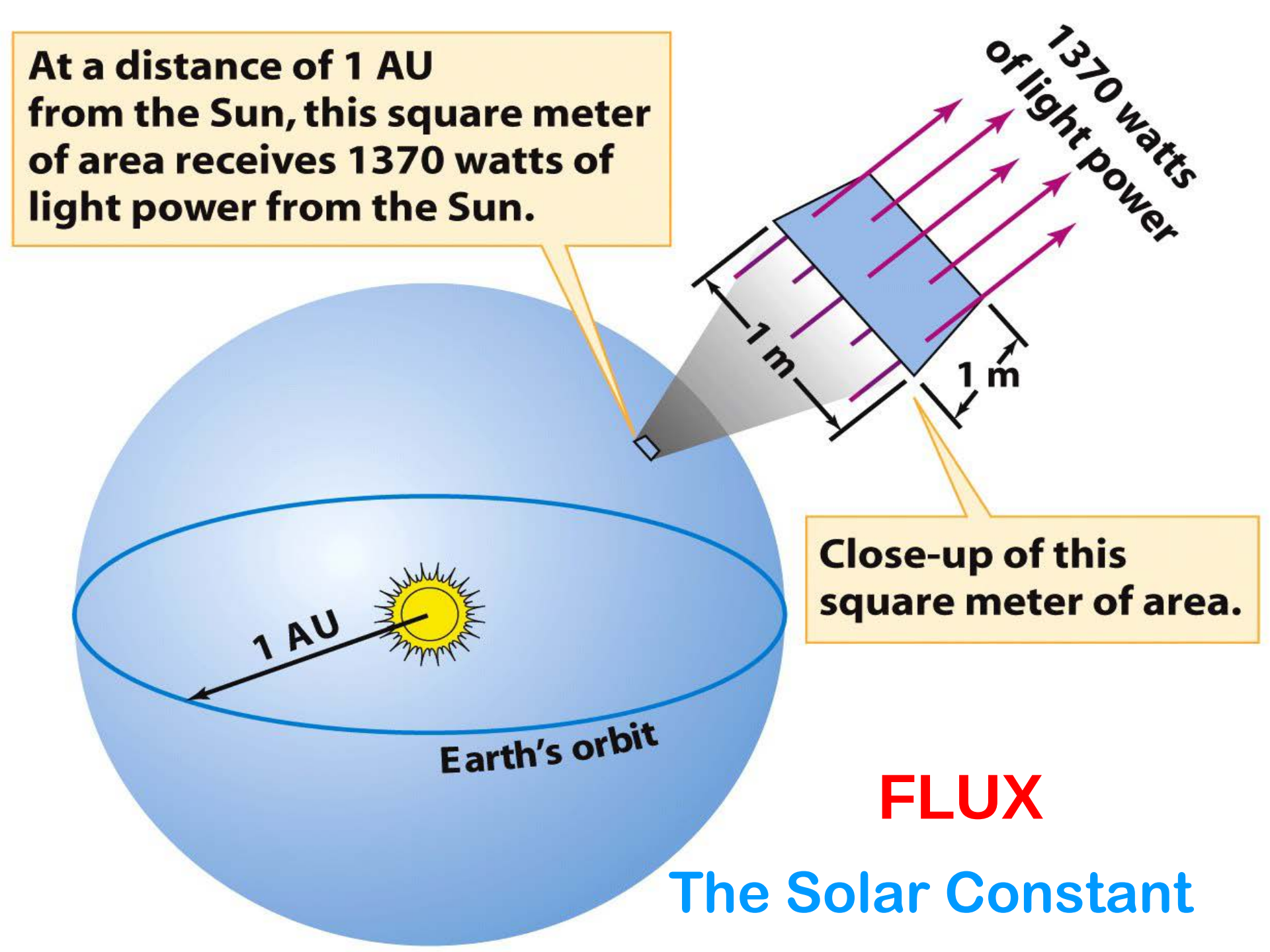
Demo1 Demo2

Why it's called Electromagnetic Radiation



$c = \lambda f$

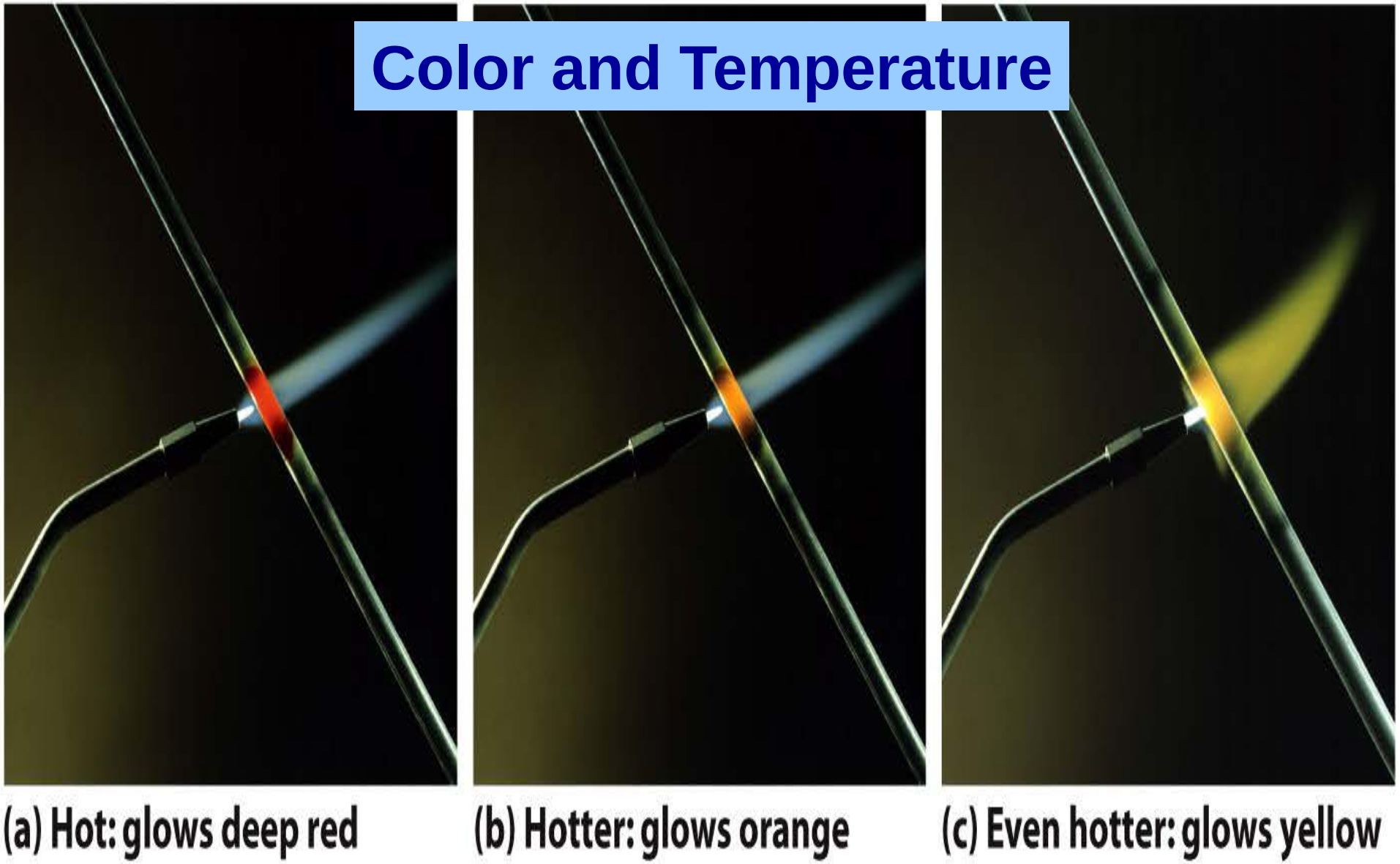
$c = 3 \times 10^5$ km/s



FLUX

The Solar Constant

Color and Temperature



(a) Hot: glows deep red

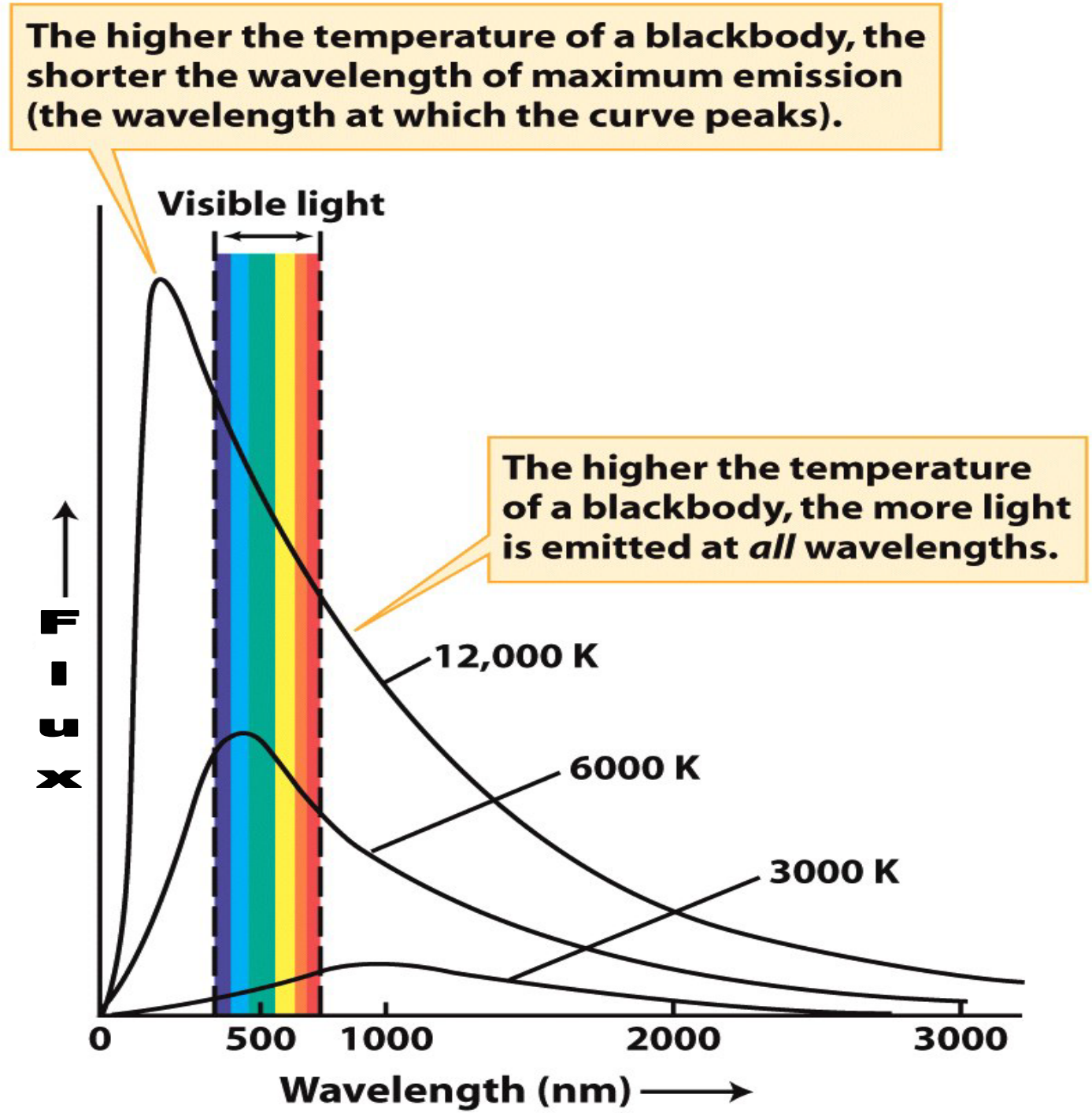
(b) Hotter: glows orange

(c) Even hotter: glows yellow

Wein's Law: $\lambda_{max} = 1 / T$

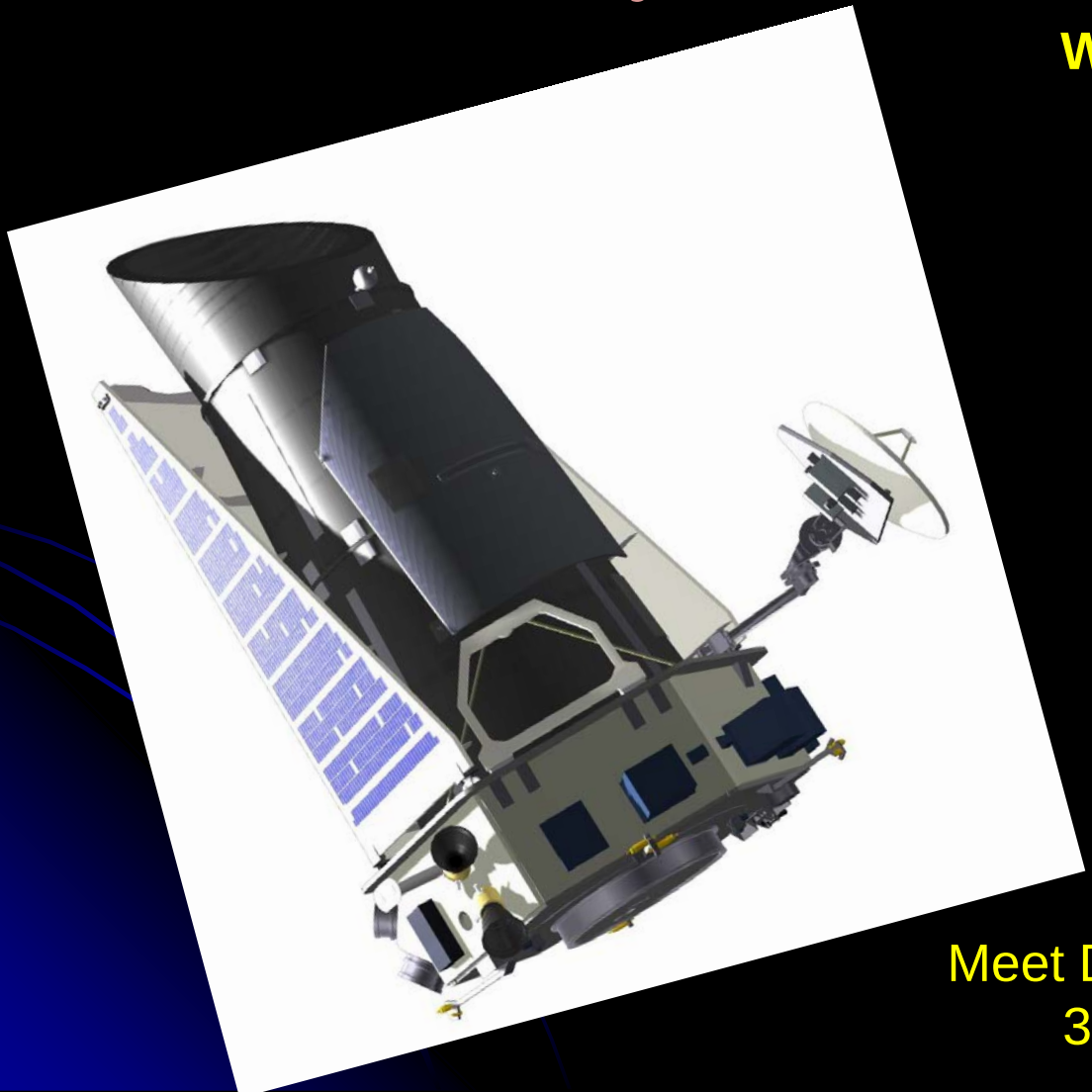
Flux

("brightness") has units of Energy per Second per Area per Wavelength



Physics & Space Sciences Department Colloquium:

NASA's Kepler Telescope Strikes Exoplanetary Gold: Systems with Multiple Transiting Planets



Wednesday, Feb. 6, 2013
4:00-5:00 PM
OPS Room 140

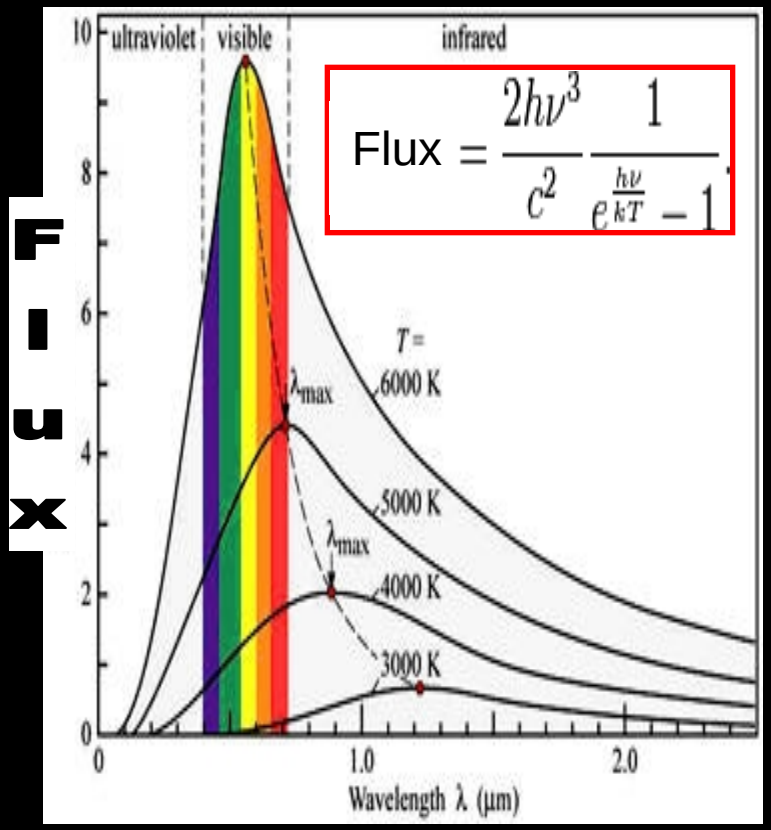
Dr. Darin Ragozzine

University of Florida

STUDENTS ONLY:
Meet Dr. Ragozzine: Wed. Feb. 6
3:00-4:00 in OPS Room 140

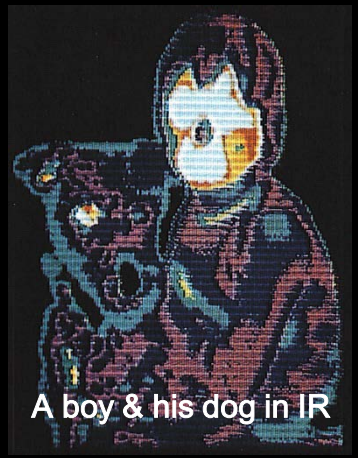
PLANCK: Black Body Radiation

Max Planck
1858-1947



Wein's Law:
Color & Temperature

$\lambda_{max} = 1 / T$

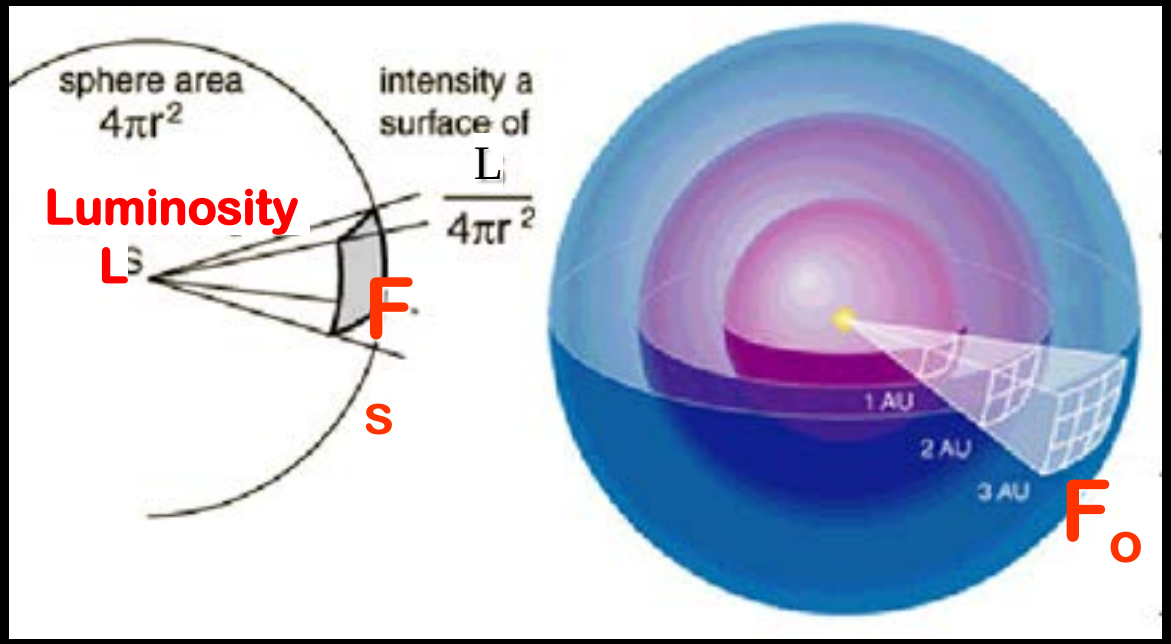


Stefan-Boltzmann Law:
Brightness & Temperature

$F = \sigma T^4$

1918 Nobel Prize:
Seeds of Quantum Theory
Continuous Spectrum

Where the Inverse Square Law Comes From



FLUX = "Brightness"

Planck equation:
MONOCHROMATIC FLUX ($J\ s^{-1}\ m^{-2}\ nm^{-1}$)

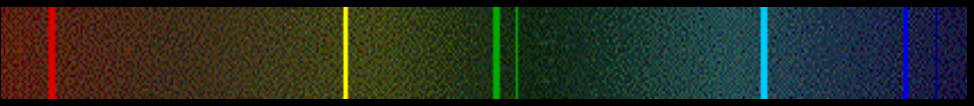
Stefan-Boltzman:
SURFACE FLUX ($J\ s^{-1}\ m^{-2}$)

SURFACE FLUX	F_s	$= \sigma T^4$
LUMINOSITY	L	= Surface Flux . Area
	L	$= \sigma T^4 \cdot 4\pi r^2$
Obs. Flux =	F_o	$= [\sigma T^4 \cdot 4\pi r^2] / 4\pi d^2$

CONTINUOUS SPECTRUM (black body)

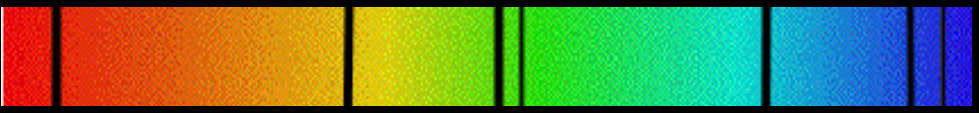
hot solid, liquid or dense gas

***BRIGHT-LINE* SPECTRUM** (emission)

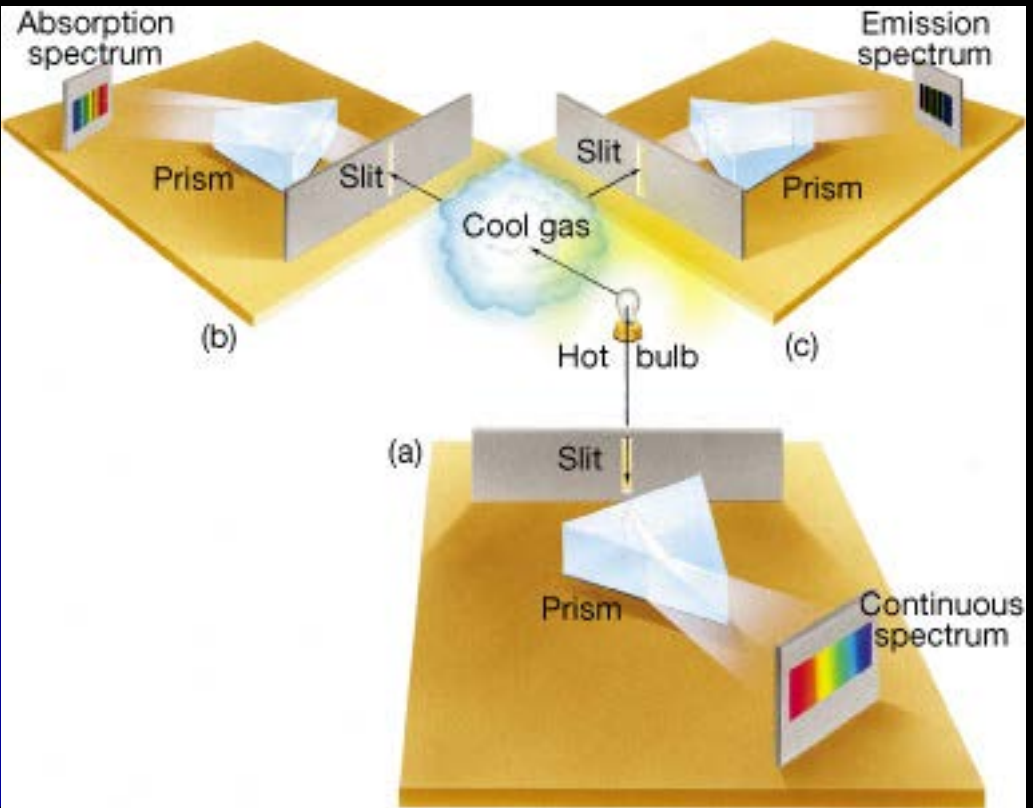


hot low-density gas (demo)

***DARK-LINE* SPECTRUM** (absorption)



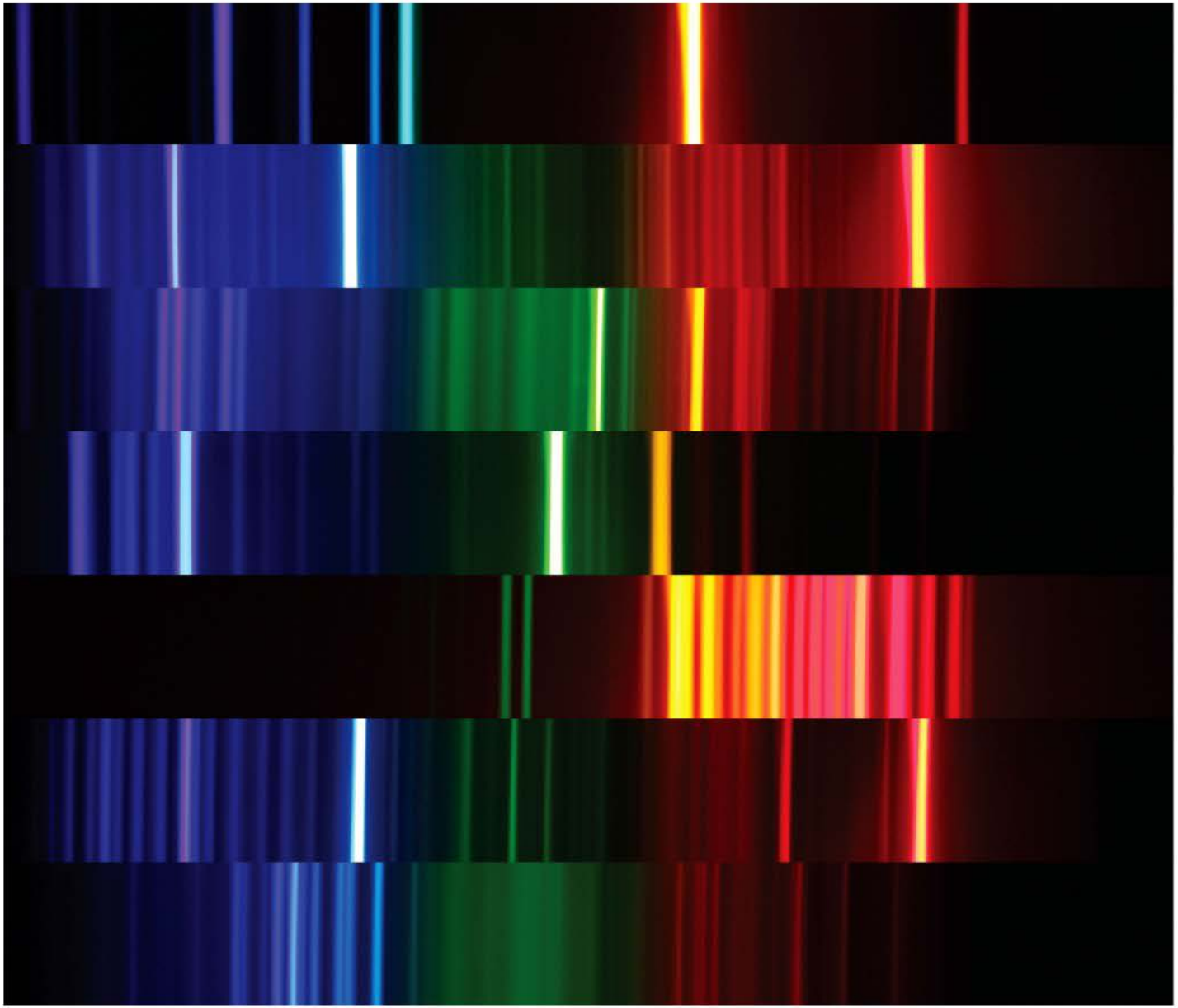
cool gas over black body



KIRCHHOFF's LAWS

Gustav Kirchhoff
1824-1887

EMISSION Spectra



Helium (He)

Hydrogen (H_2)

Krypton (Kr)

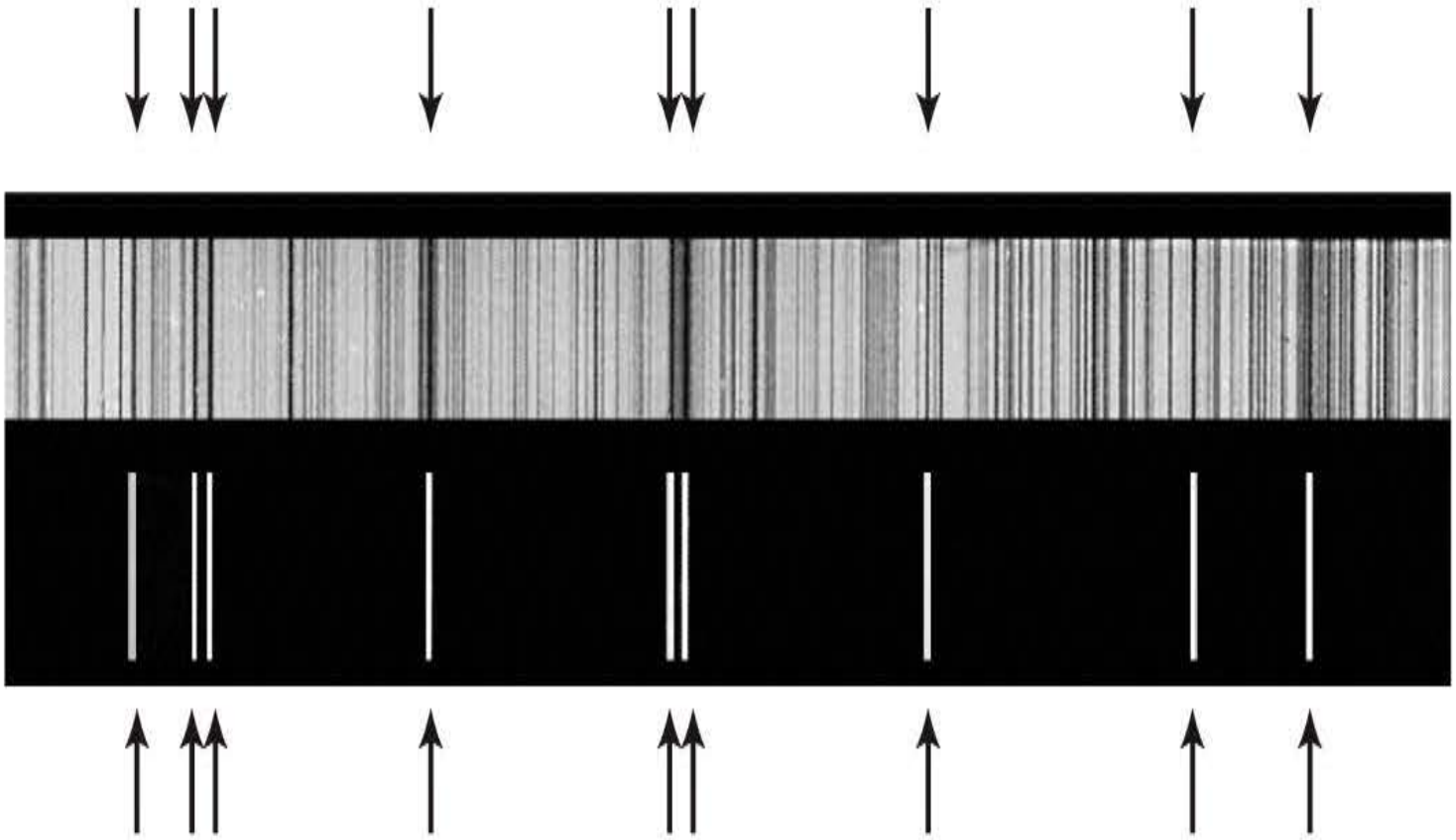
Mercury (Hg)

Neon (Ne)

Water vapor (H_2O)

Xenon (Xe)

A Stellar Spectrum (ABSORPTION)

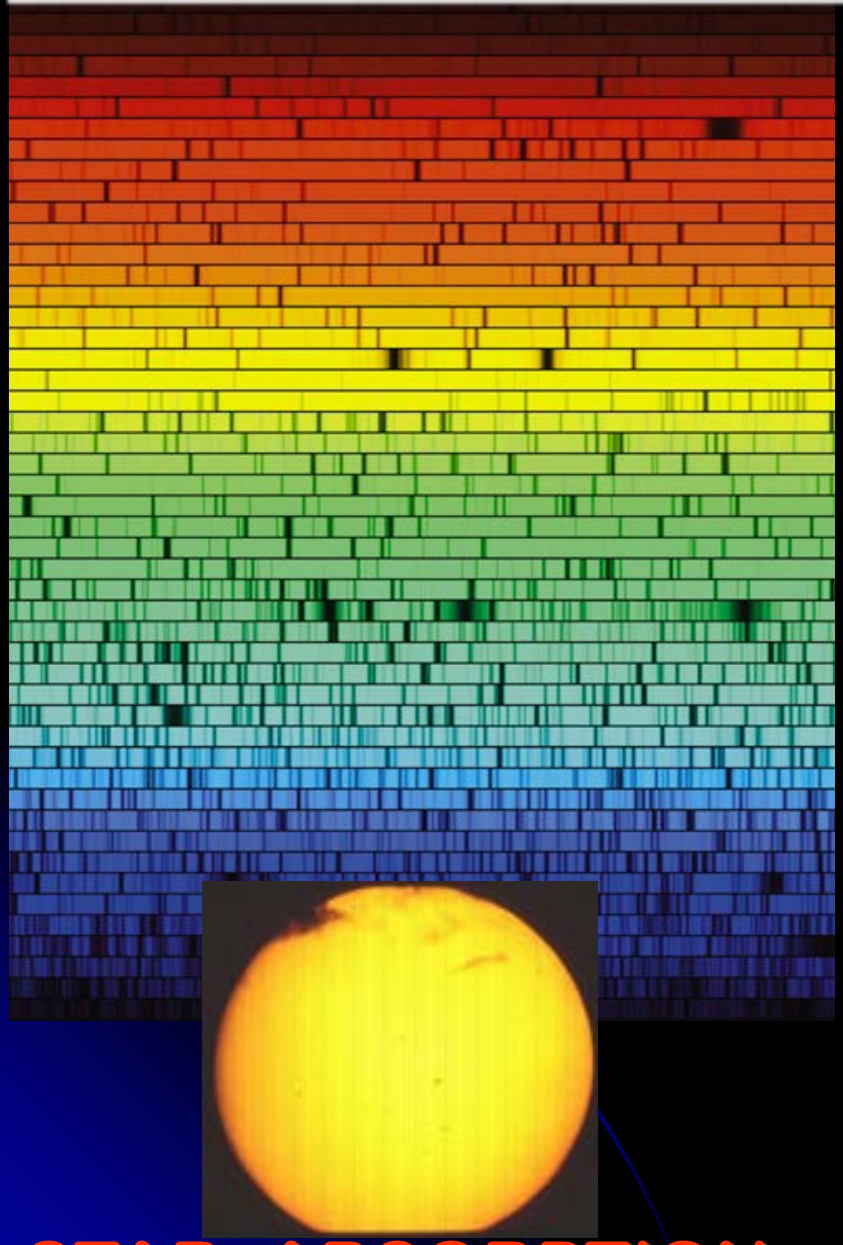


Absorption spectrum of the Sun

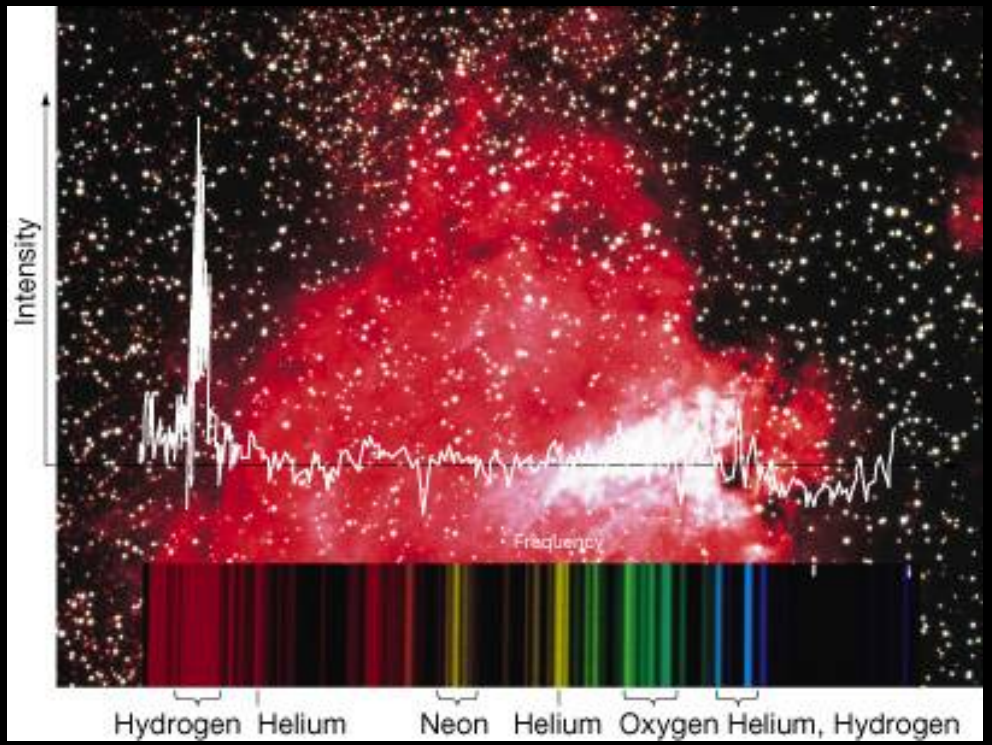
Emission spectrum of iron (in the laboratory on Earth)

For each emission line of iron, there is a corresponding absorption line in the solar spectrum; hence there must be iron in the Sun's atmosphere

SPECTRAL ANALYSIS = Astrophysics



Temperature:	Wein's Law
Pressure:	line fuzziness
Composition:	line patterns
Velocity:	Doppler shift
Rotation:	line shape



STAR: ABSORPTION

NEBULA: EMISSION

FIRST MIDTERM

THURSDAY

FEBRUARY 14th

Chapters 1-6

(HW#2 due same day, 5pm)

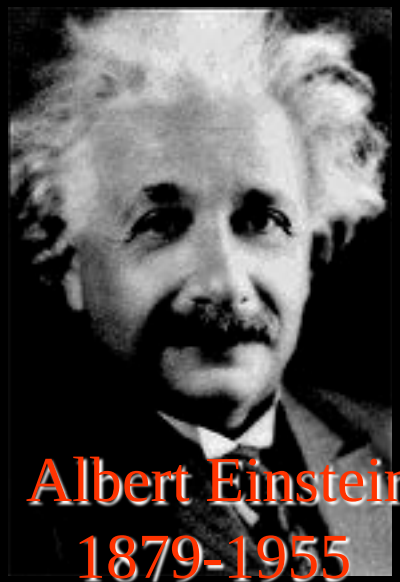
Physics & Space Sciences department colloquium:

The Exoplanet Revolution

Wed., Feb. 13, 2013
4:00-5:00 PM
OPS Room 140

Dr. Brian Jackson
Dept. of Terrestrial Magnetism
Carnegie Institution of Washington

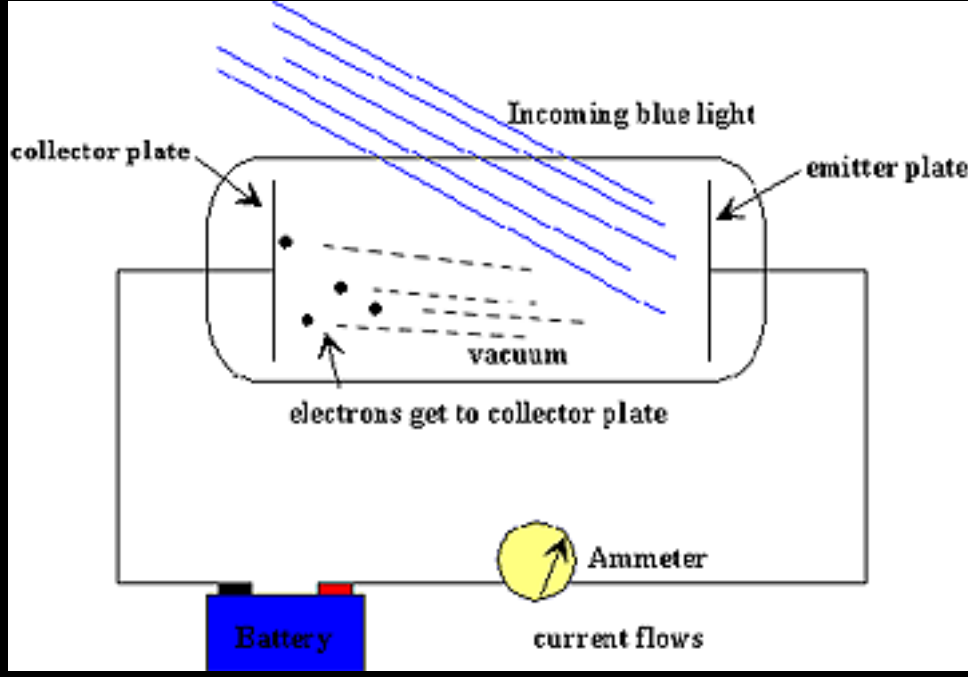
Particle Nature of Light
Photelectric Effect

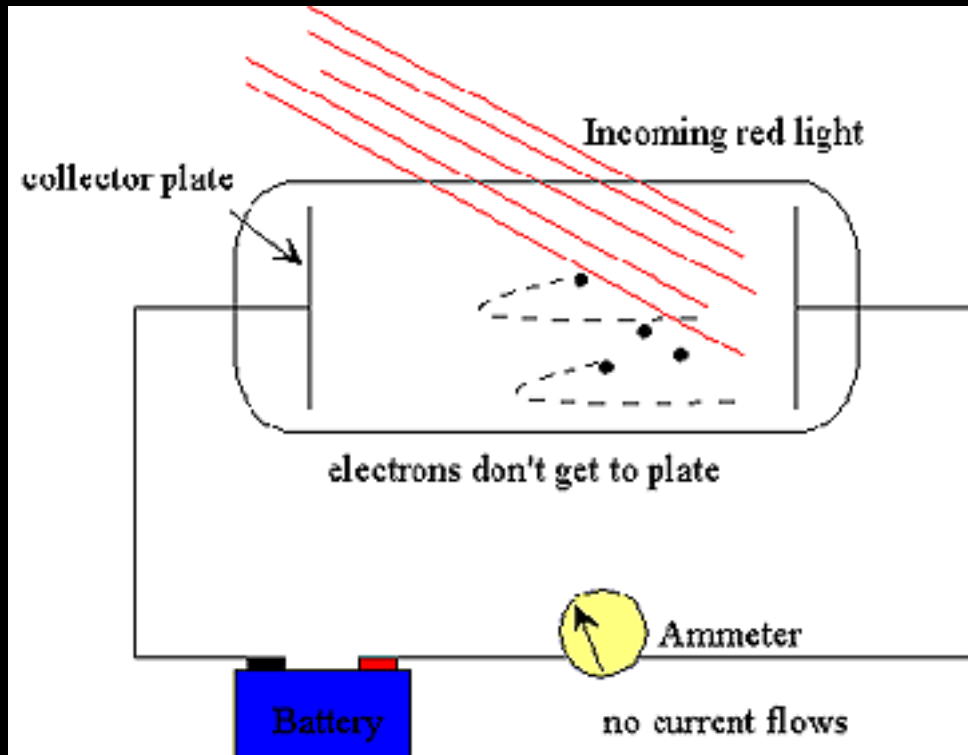


Albert Einstein
1879-1955

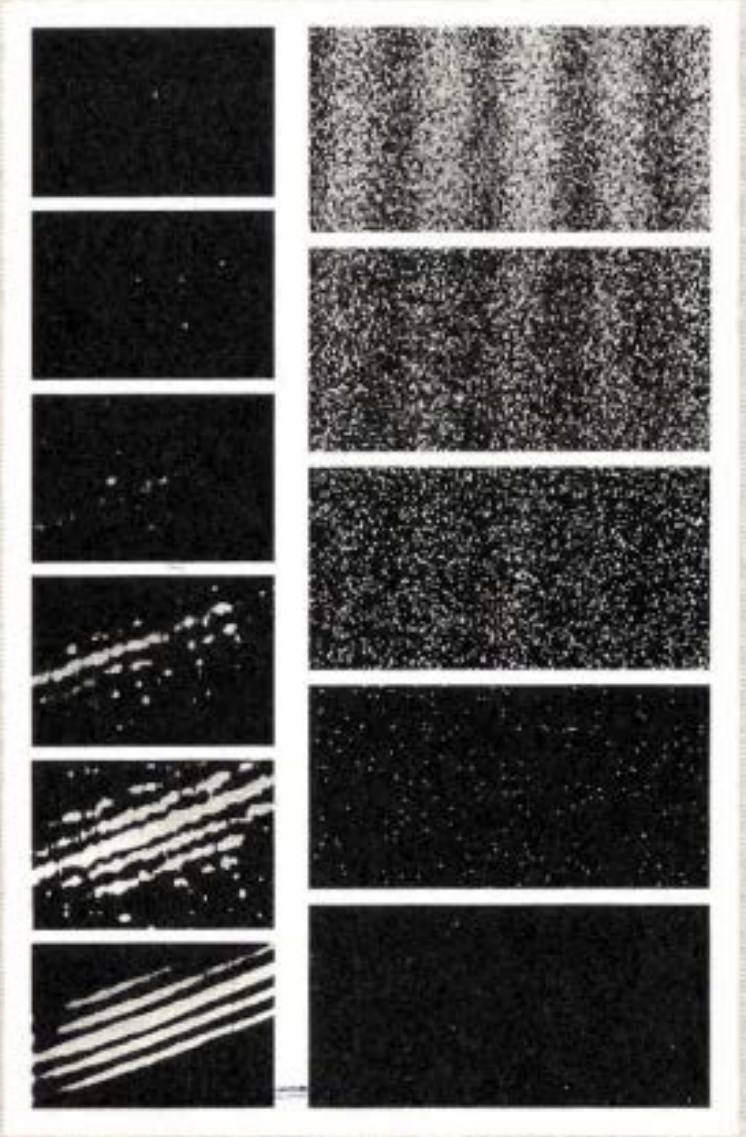
Photon energy $E = h f$
$= hc / \lambda$

1921 Nobel Prize:
Particle or wave?
IT'S BOTH !!!!





Pier Giorgio Merli, Giulio Pozzi, Gian Franco Missiroli
Akira Tonomura, Hitachi Ltd.

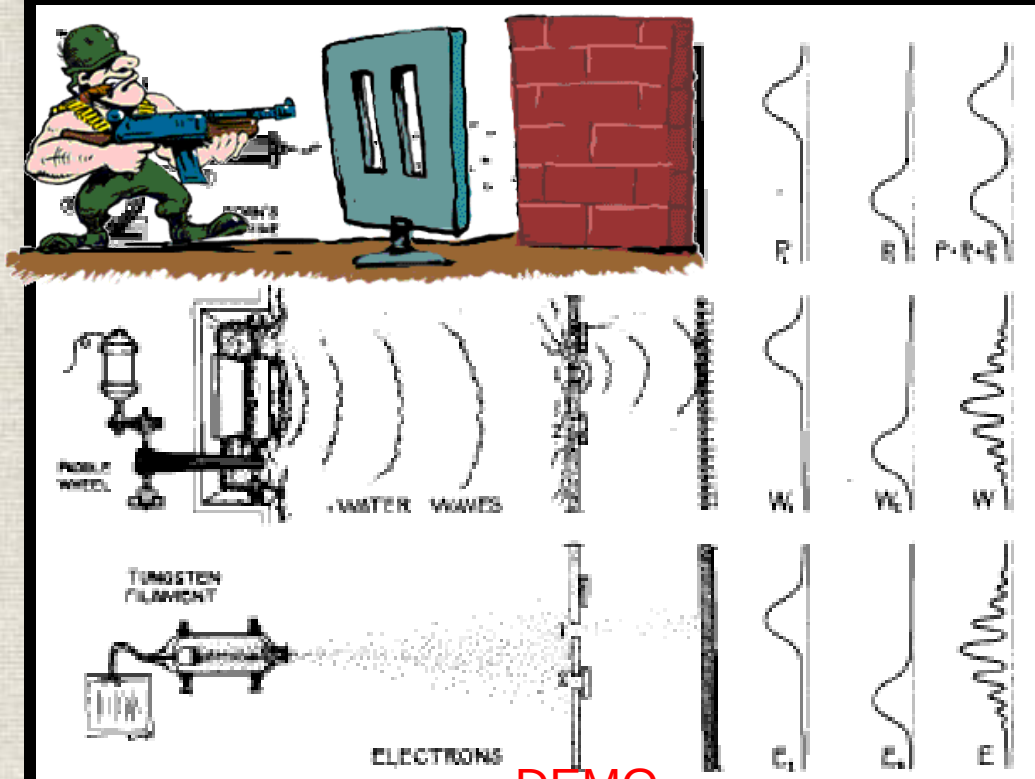


Gradual buildup of electron interference pattern from single electrons, from the Bologna group's 1974 experiment (left), and the Hitachi group's 1989 experiment (right). The Bologna group's normally vertical lines were rotated by a magnetic lens in the electron microscope.

from Robert P. Crease 2003, The Prism & the Pendulum

Electrons are waves? They're BOTH !!!!

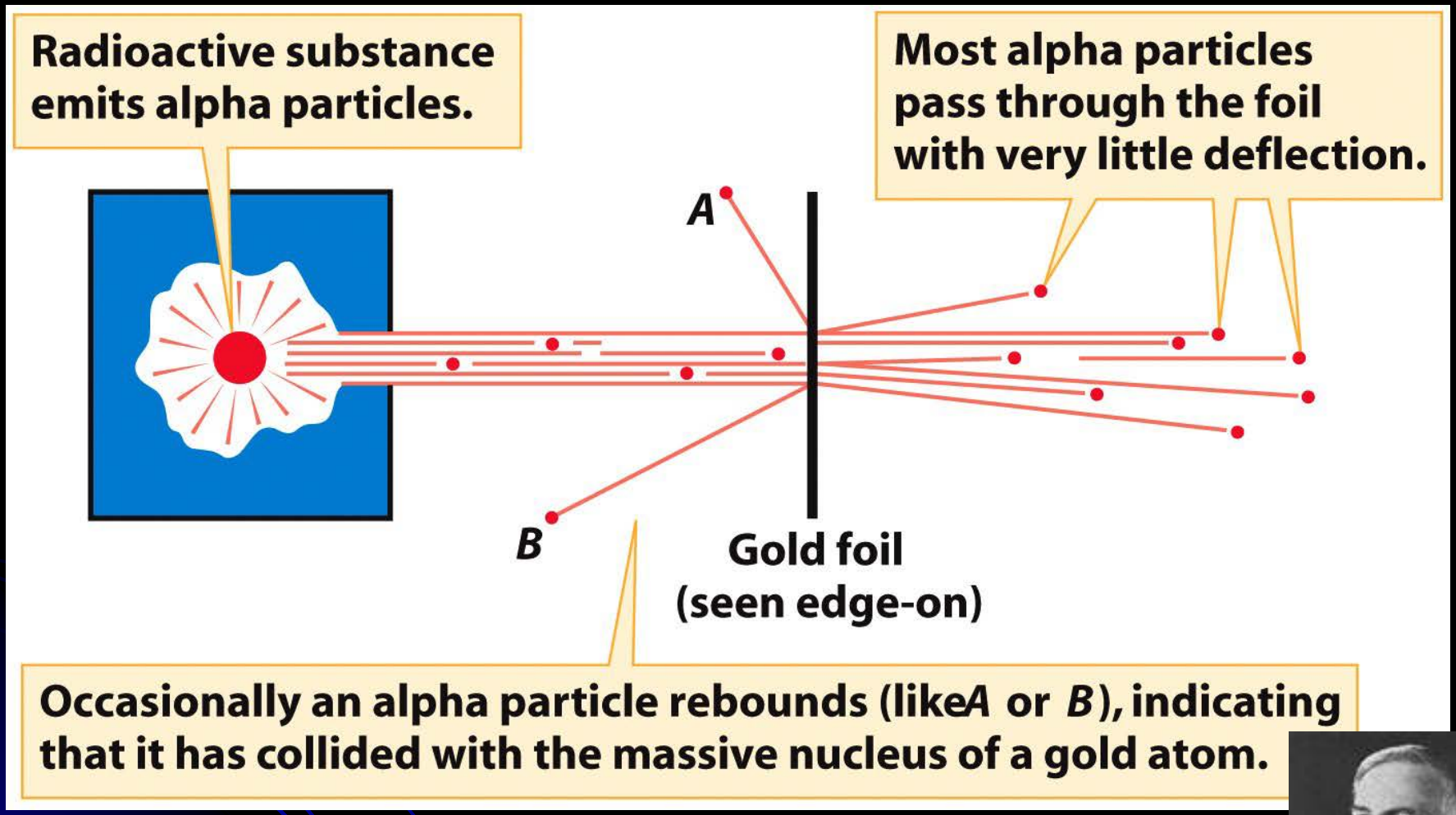
"Wave-Particle Duality"

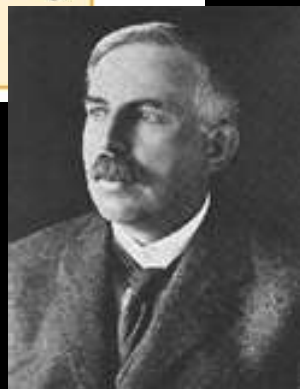


DEMO

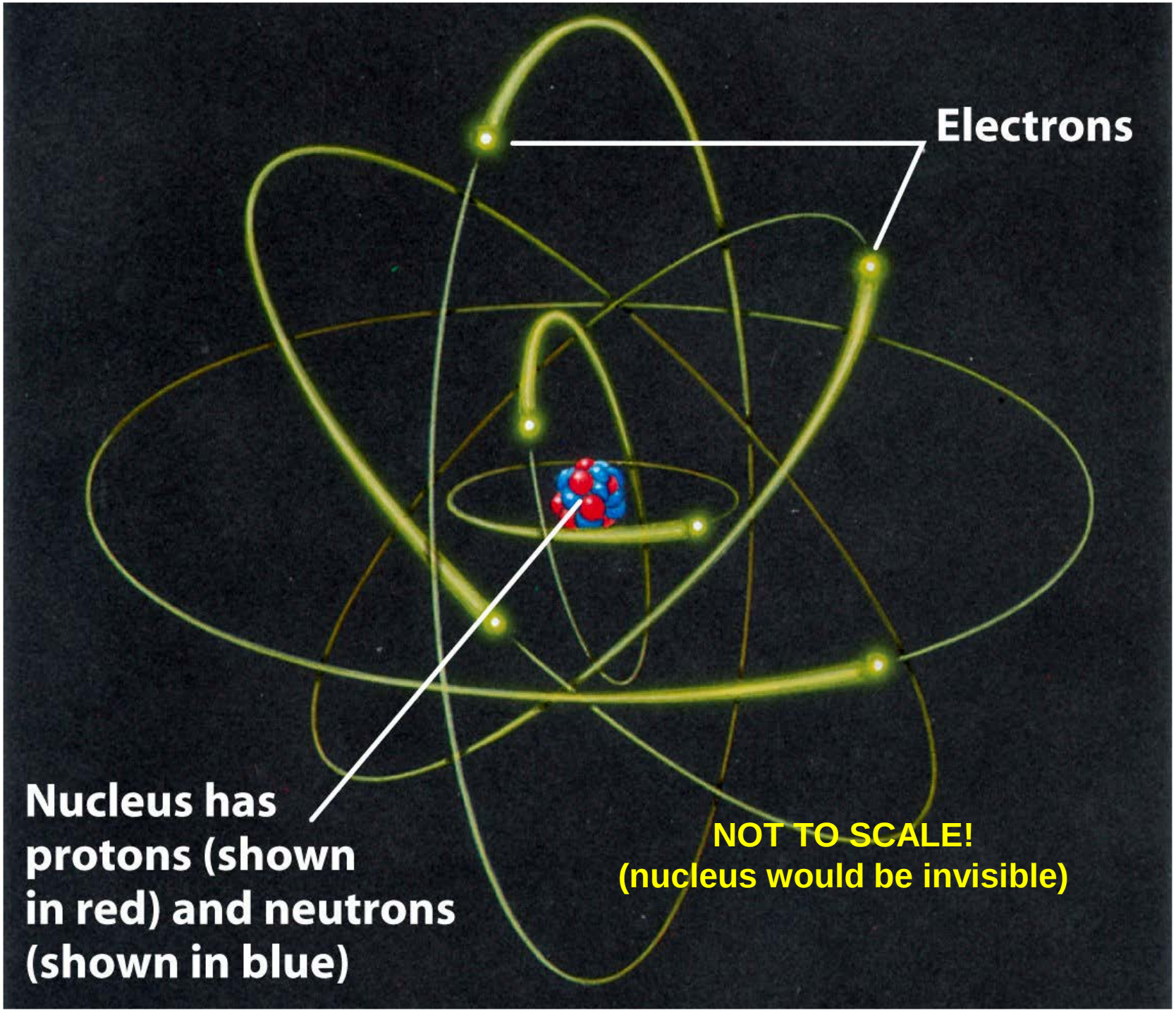
Figure 10.1. Three two-slit experiments, illustrating no interference with "lumpy" objects (bullets), interference with continuous objects (water waves), and interference with seemingly "lumpy" objects (electrons).

Rutherford Model of the Atom





Earnest Rutherford
1871-1937


Electrons
Nucleus has protons (shown in red) and neutrons (shown in blue)
NOT TO SCALE!
(nucleus would be invisible)

ATOMIC STRUCTURE: BOHR c. 1923

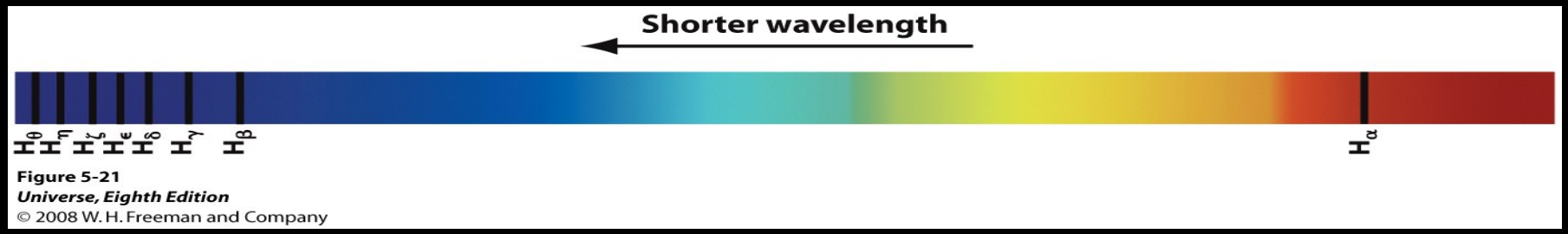
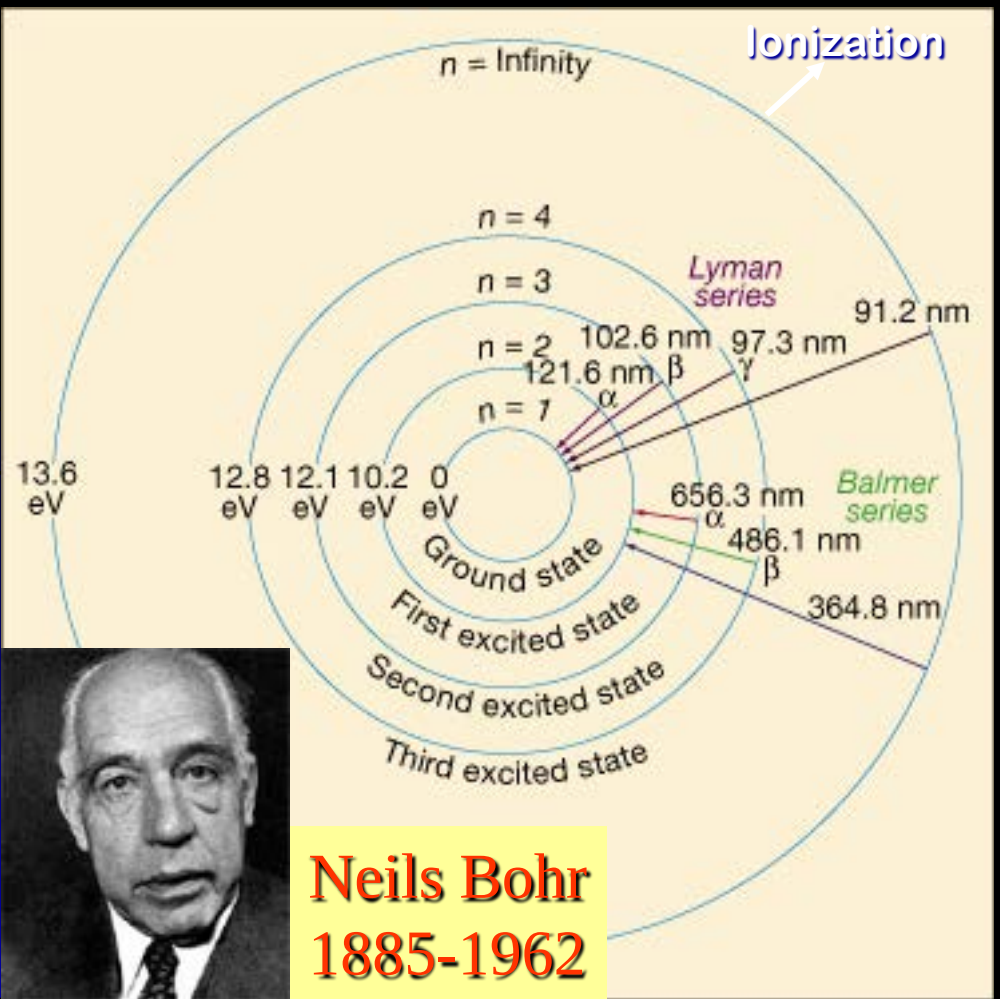


Figure 5-21
Universe, Eighth Edition

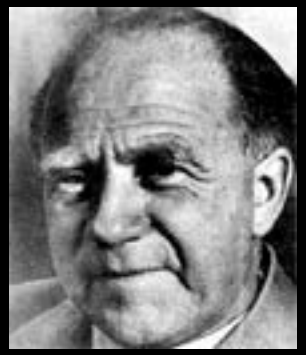


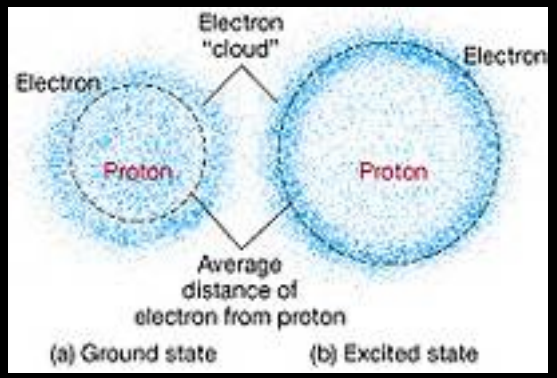
Neils Bohr
1885-1962

e^- down = Emission
e^- up = Absorption

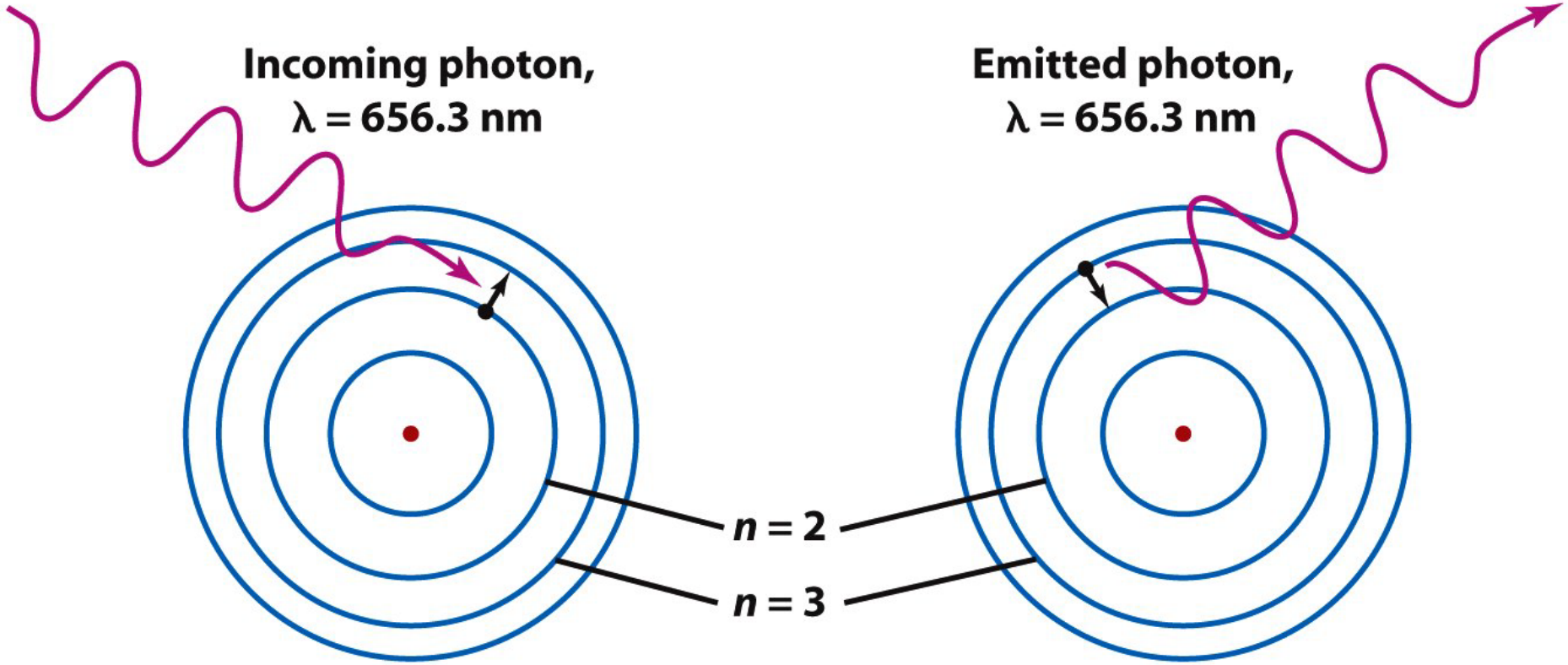
Uncertainty Principle

$$h \sim \Delta E \, \Delta t \sim \Delta p \, \Delta x$$





Werner Heisenberg
1901-1976



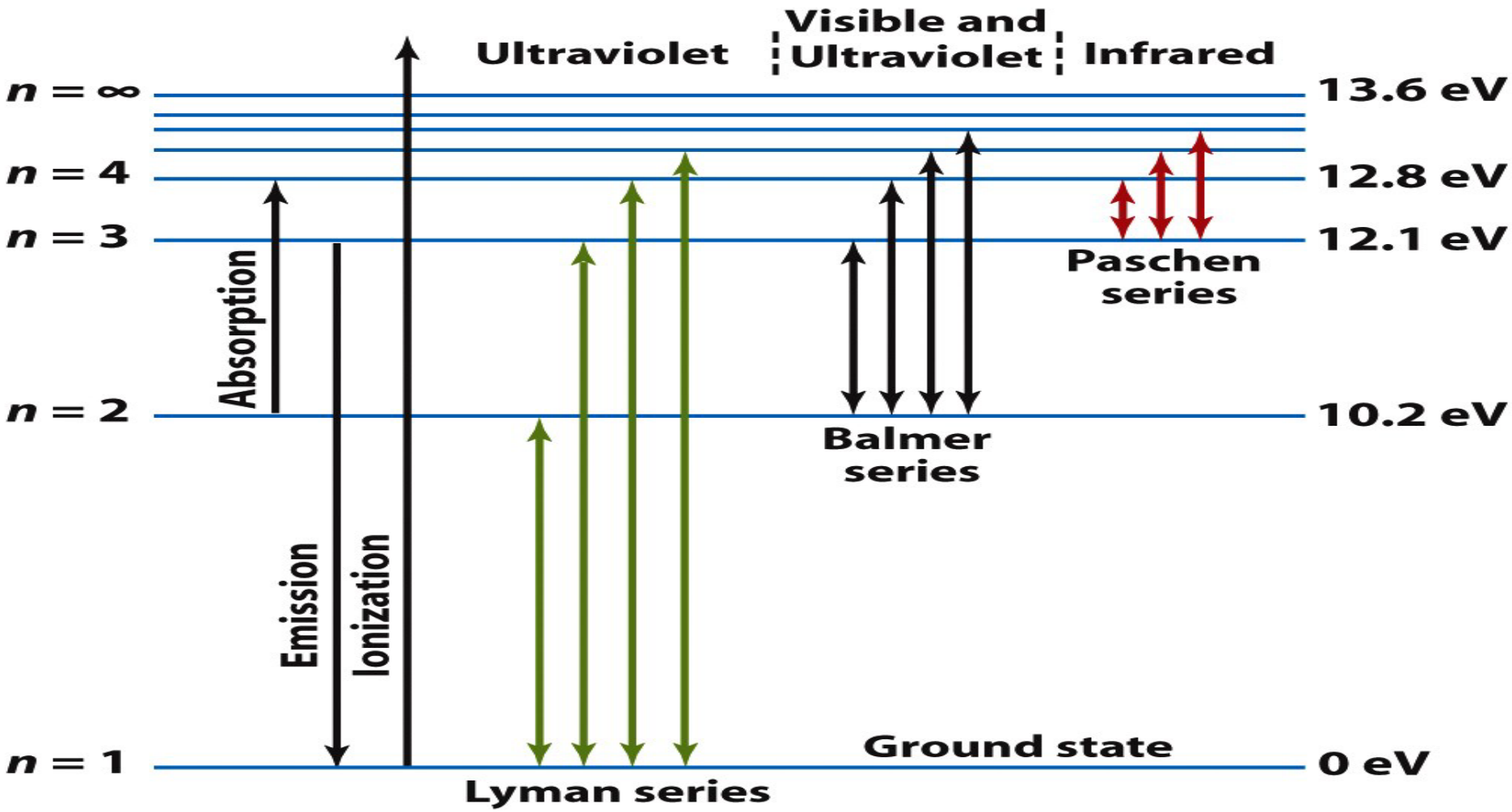
(a) Atom absorbs a 656.3-nm photon; absorbed energy causes electron to jump from the $n = 2$ orbit up to the $n = 3$ orbit

(b) Electron falls from the $n = 3$ orbit to the $n = 2$ orbit; energy lost by atom goes into emitting a 656.3-nm photon

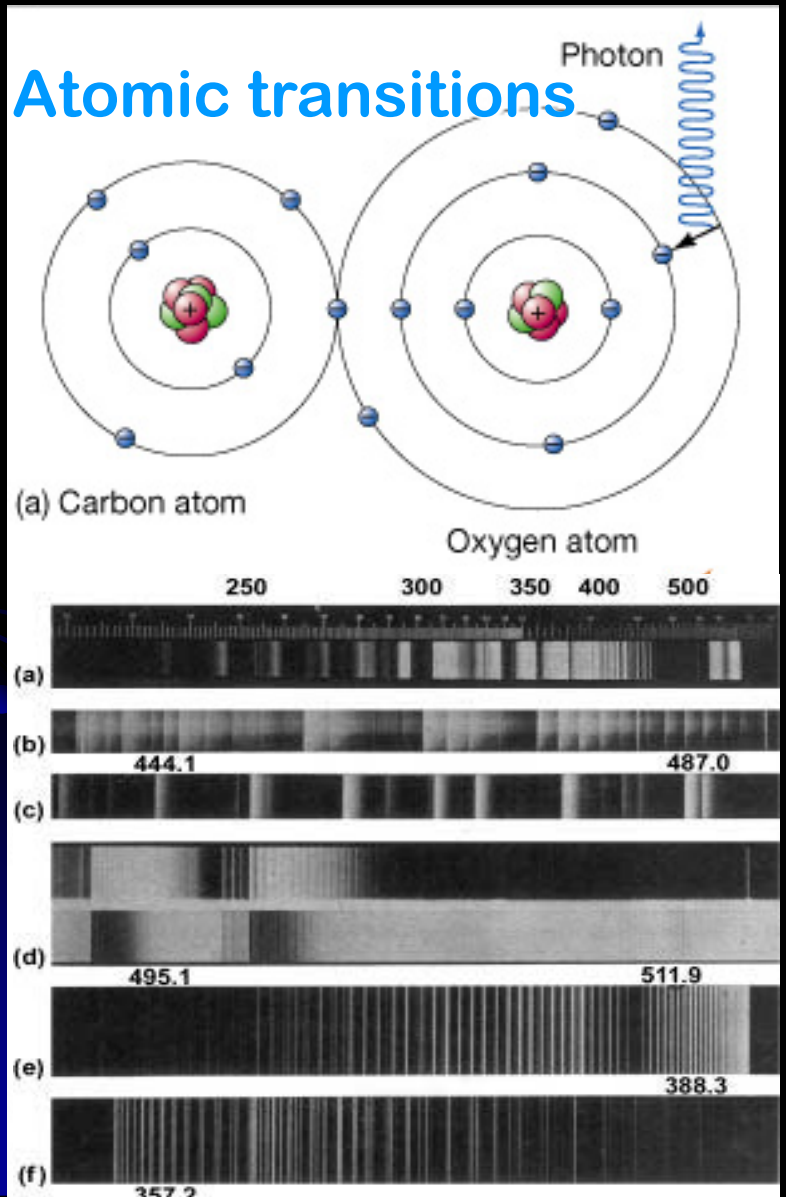
Energy Level Diagram of the Hydrogen Atom

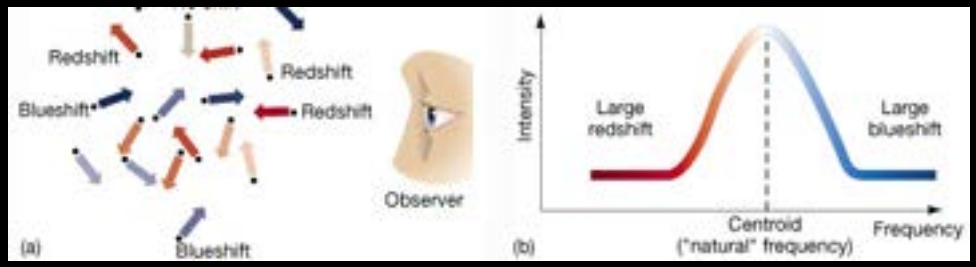
(1 eV = energy of 1 e^- accelerated by 1 volt)

(1 TeV ~ energy of flying mosquito)

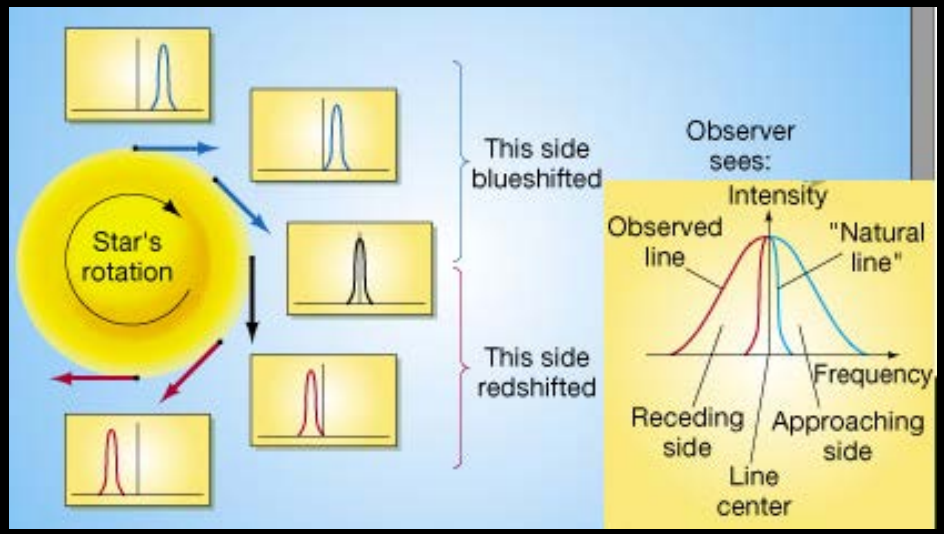


Information in Spectral Lines





Line Broadening



Effect of Rotation

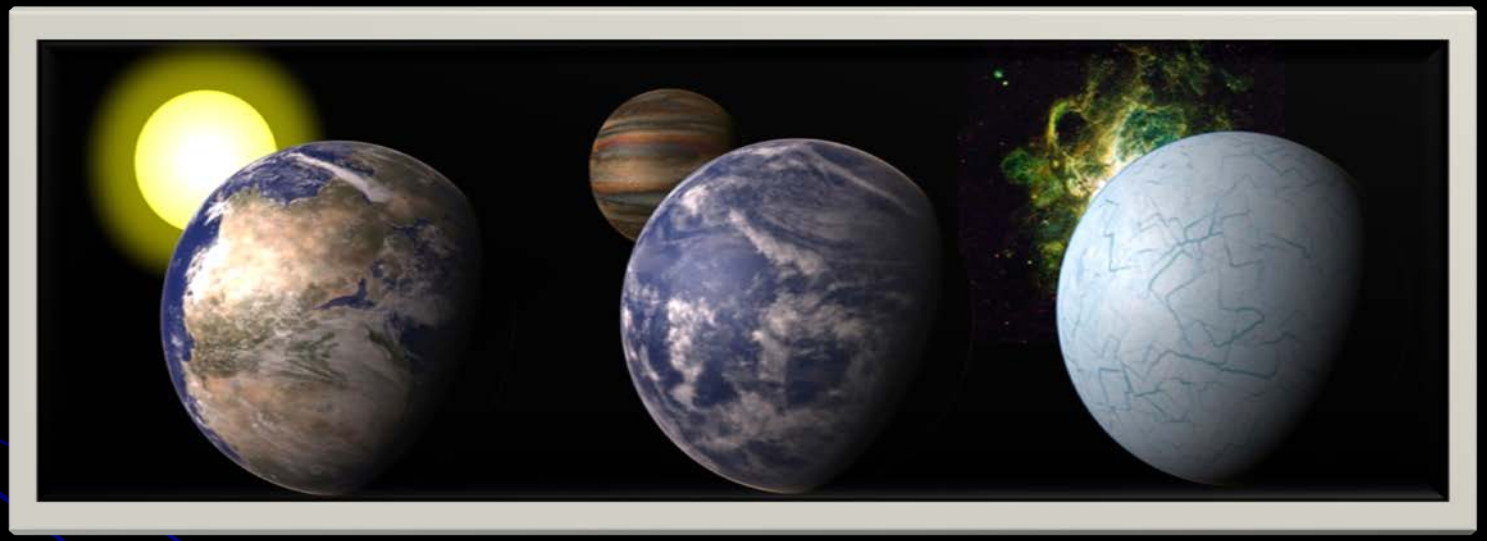
FIRST MIDTERM

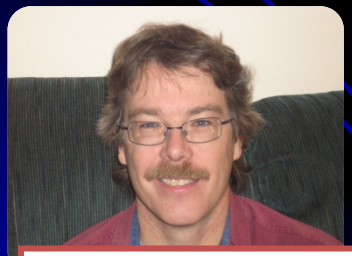
Material Ends HERE

(chapters 1-5)

Physics & Space Sciences Department Colloquium:

Planetary Exploration of Habitable Worlds





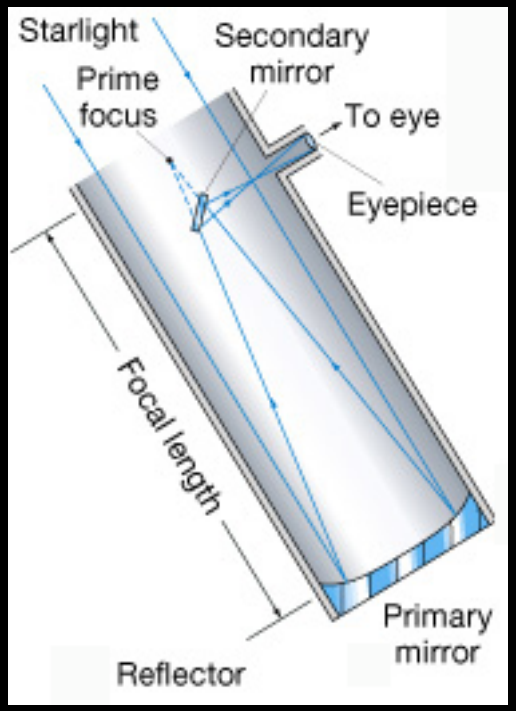
Dr. Dirk Schulze-Makuch
Washington State University

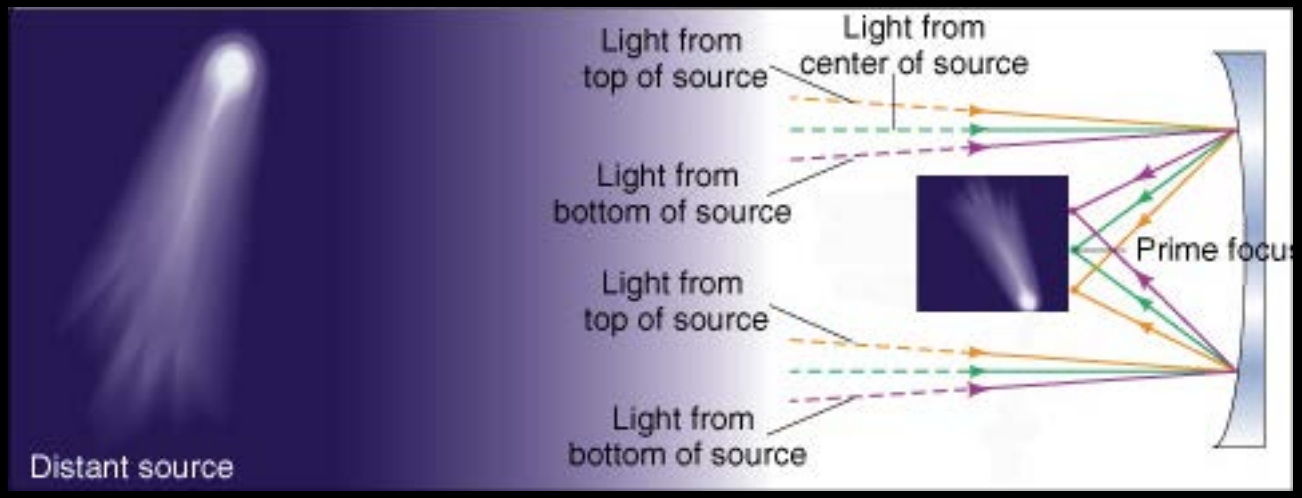
Lecture: Wednesday, February 20, 2013
4:00—5:00 PM
OPS Room 140

ALL STUDENTS: meet Dr. Schulze-Makuch from 3:00-4:00 PM in OPS 140

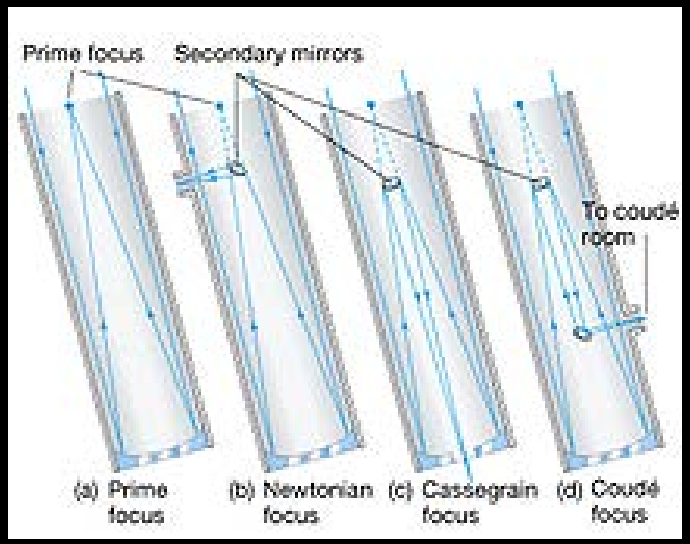
Reflecting Telescopes

∠ Incidence = ∠ Reflectance





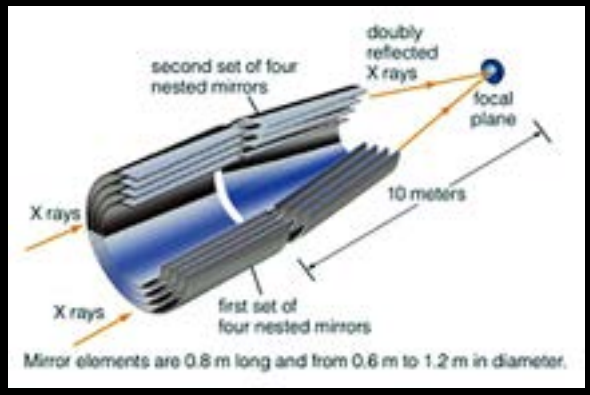
Lensmakers' Equation Still Applies



Advantages:

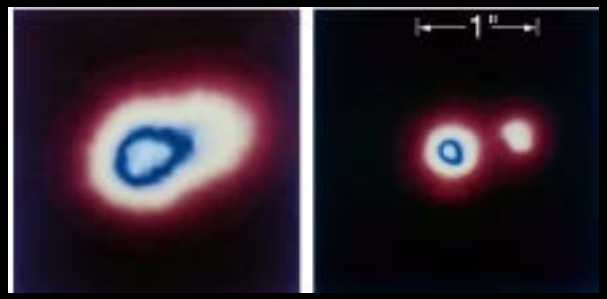
- One surface
- more compact
- No absorption
- Back support
- Multiple mirror
- Few aberrations

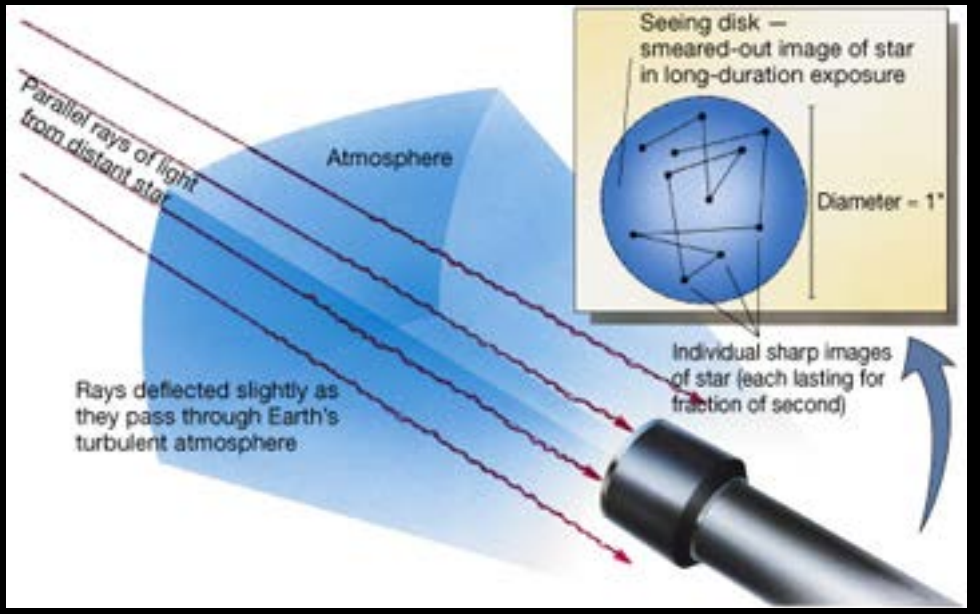
Chandra X-ray telescope



Effects of Earth's Atmosphere: Scintillation, Seeing & Twinkling

Air Turbulence





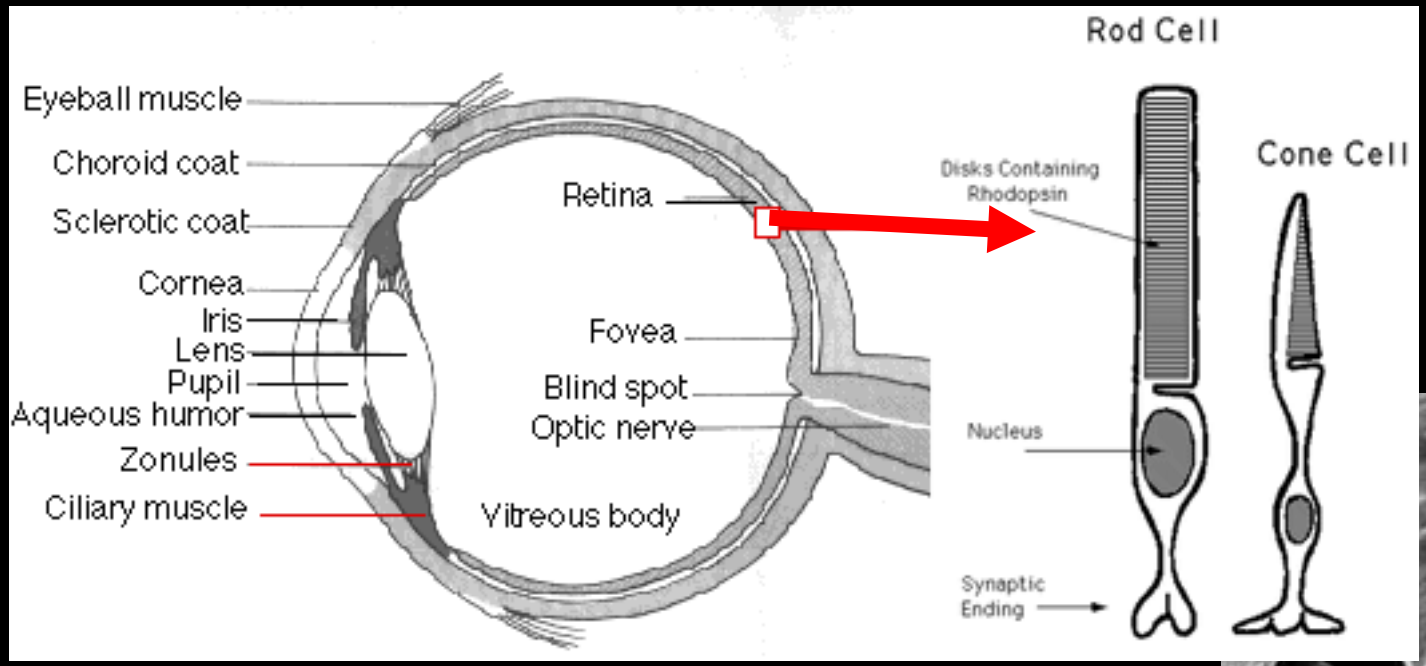
Starfire Optical Range, NM

Solutions:

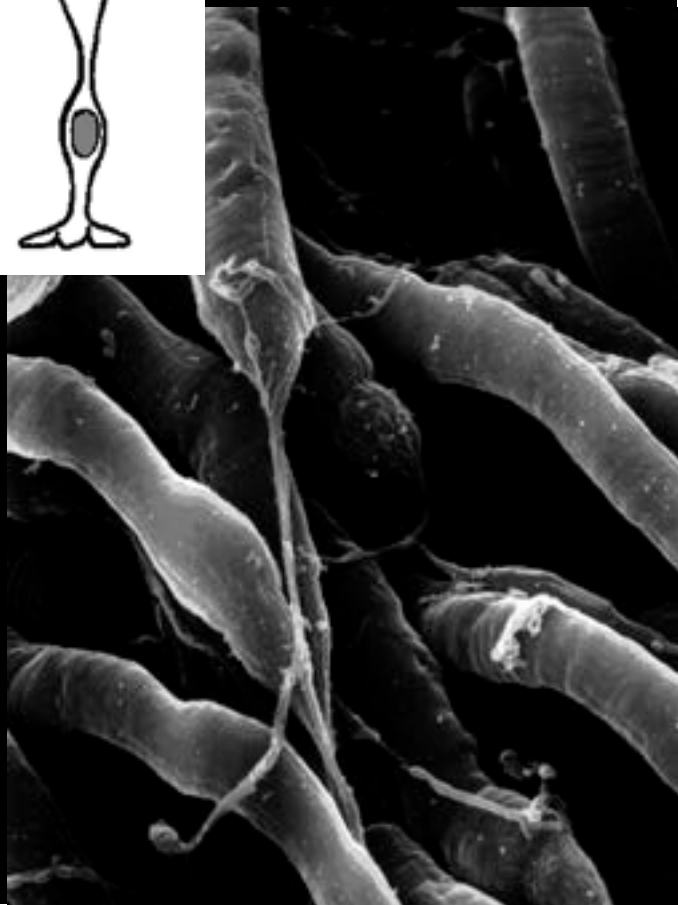
Active optics
Adaptive optics
Space

The Radio Sky at 21-cm

The Human Eye



Rods & Cones: Rhodopsin = "visual purple"



Extremely versatile, portable! BUT:
low q/e (1-2%), 1/30 s exp., subjective

Astronomical Use:
dark adapt for >20 min
eat vitamin A
avoid UV radiation
use averted vision

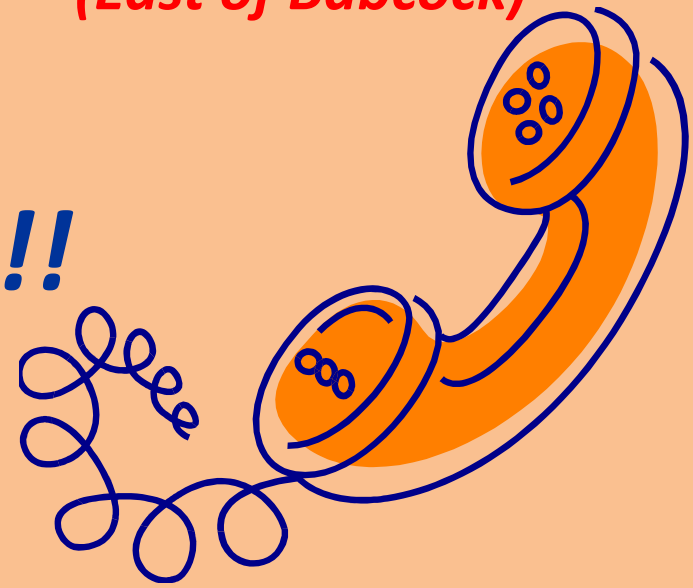
Physics & Space Sciences Dept.

Spring Phone-a-thon!

Thursday, February 21, 2013

6:00-8:00 PM in the new Panther Commons building
(East of Babcock)

FREE Pizza & Drinks!!



Physics & Space Sciences Department Colloquium:

Numerical Modeling of Planetary Atmospheres

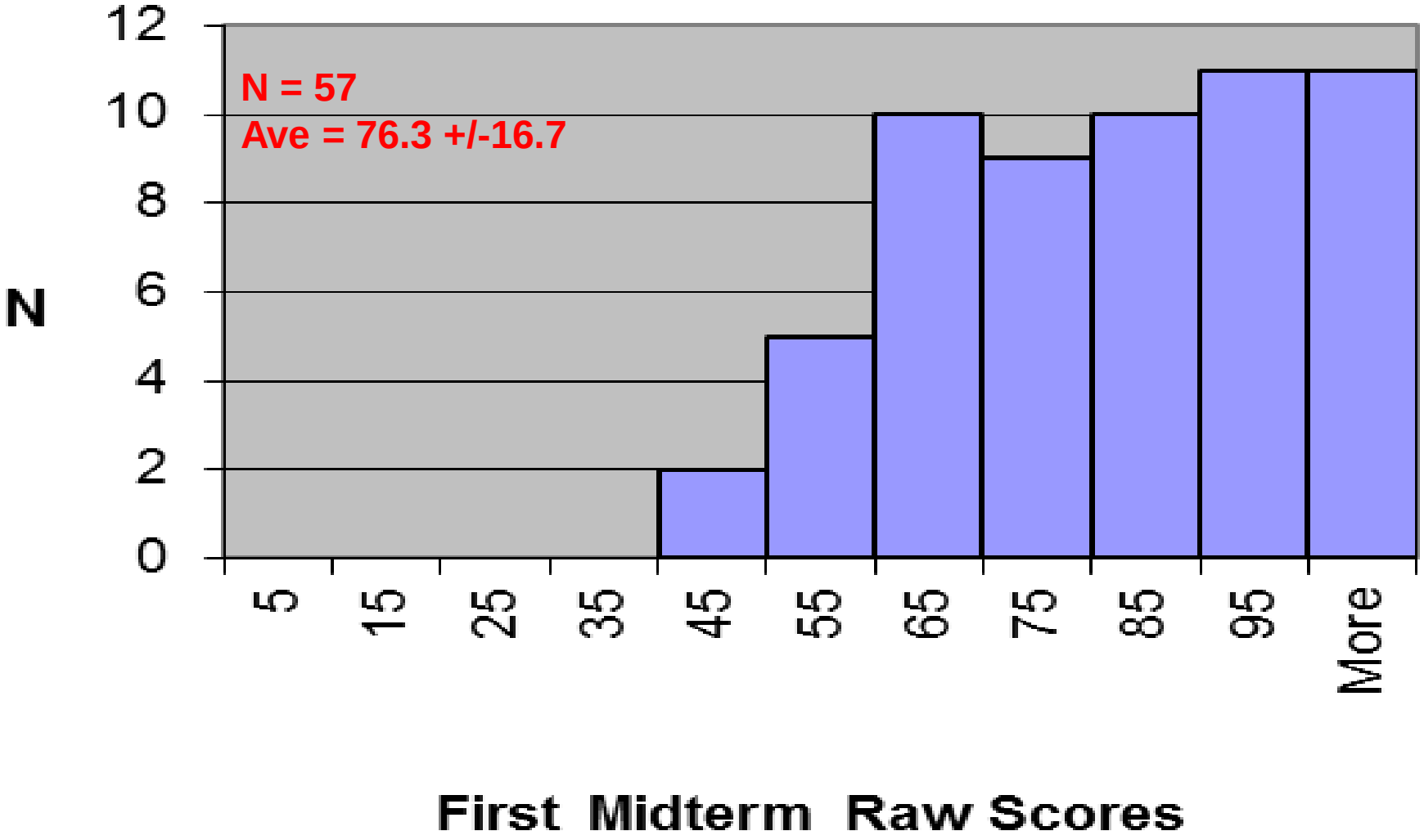
Dr. Csaba Palotai

University of Central Florida

Friday, February 22, 2013
4:00—5:00 PM
OPS Room 140

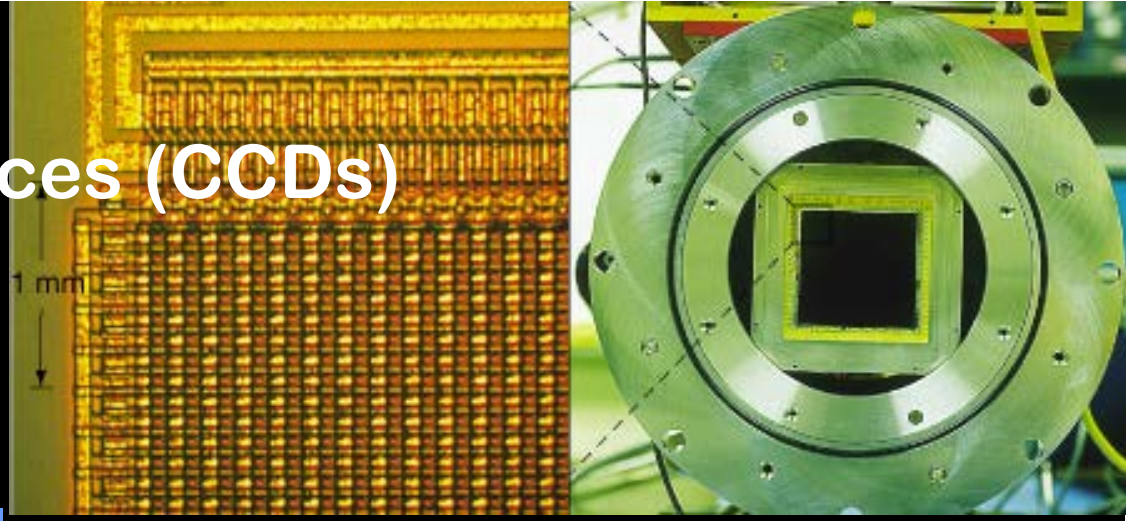
Students ONLY: Come meet Dr. Csaba Palotai Friday from 3:00 – 4:00 pm in Room 140.

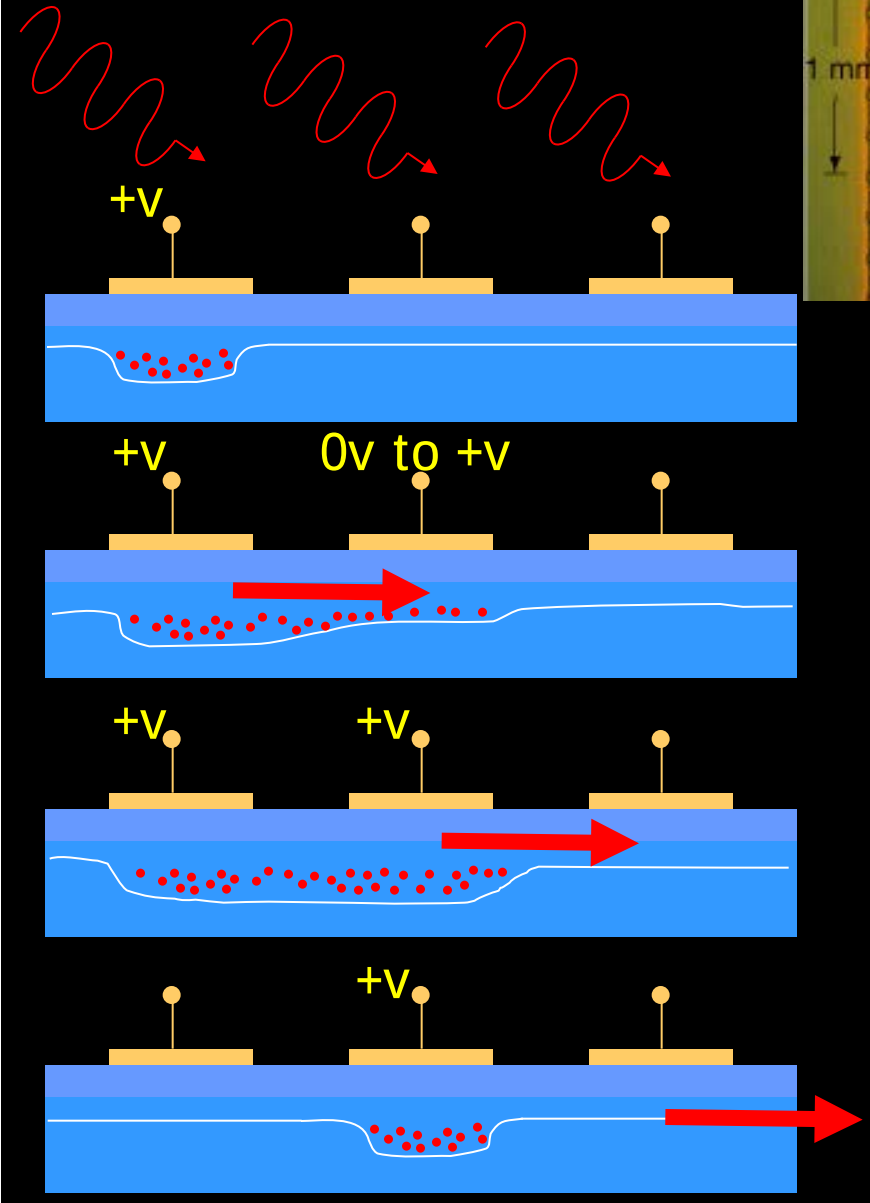
Spring 2013 Intro. Astronomy



Instrumentation:

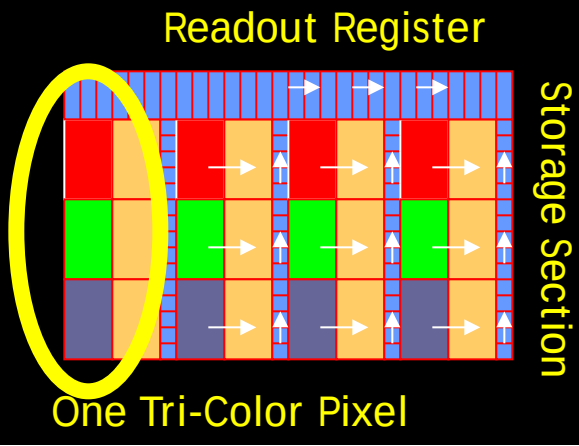
Charge-Coupled Devices (CCDs)





high q/e (>90%)
integrates
digital
linear sensitivity

BUT:
small scale
volatile



Astronomy/Astrophysics Facilities

Southeastern Association for Research in Astronomy

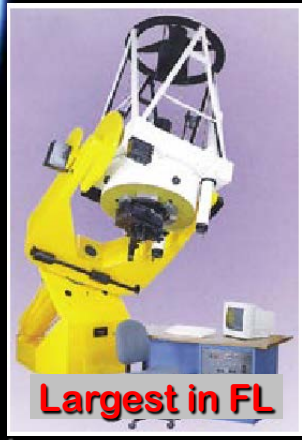
www.saraobservatory.org

SARA-N 1.0-m
Kitt Peak, Arizona

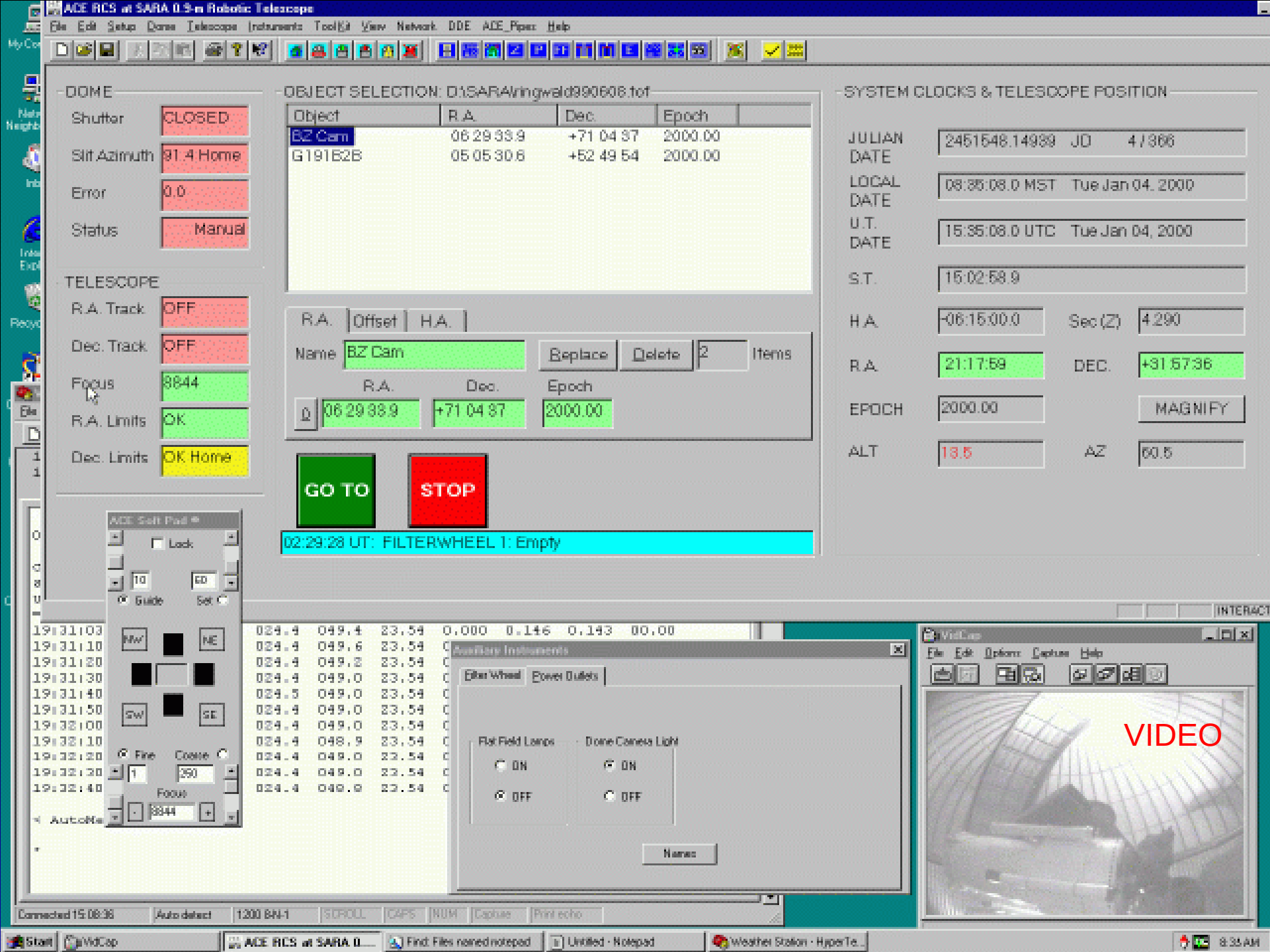
FIT Ortega 0.8-m
Melbourne, FL

Florida Tech (Admin. Inst.)
East Tennessee St. U. (TN)
Valdosta State University (GA)
Florida International U. (FL)
Clemson University (SC)
Ball State University (IN)
Agnes Scott College (GA)
University of Alabama (AL)
Valparaiso University (IN)
Butler University (IN)

SARA-S 0.6-m
Cerro Tololo - Chile



NEWEST ADDITION TO SARA @ Roque de los Muchachos Observatory


ACE RCS at SARA 0.9-m Robotic Telescope
File Edit Setup Done Telescope Instruments ToolKit View Network DDE ACE_Pipes Help
DOME
Shutter CLOSED
Slit Azimuth 91.4 Home
Error 0.0
Status Manual
TELESCOPE
R.A. Track OFF
Dec. Track OFF
Focus 8844
R.A. Limits OK
Dec. Limits OK Home
OBJECT SELECTION: D:\SARA\ringwald990606.tot
Object R.A. Dec. Epoch
BZ Cam 06 29 33.9 +71 04 37 2000.00
G191B2B 05 05 30.6 +52 49 54 2000.00
R.A. Offset H.A.
Name BZ Cam
Replace Delete 2 Items
R.A. Dec. Epoch
0 06 29 33.9 +71 04 37 2000.00
GO TO
STOP
02:29:28 UT: FILTERWHEEL 1: Empty
SYSTEM CLOCKS & TELESCOPE POSITION
JULIAN DATE 2451548.14939 JD 4 / 366
LOCAL DATE 08:35:08.0 MST Tue Jan 04, 2000
U.T. DATE 15:35:08.0 UTC Tue Jan 04, 2000
S.T. 15:02:58.9
H.A. -06:15:00.0 Sec (Z) 4.290
R.A. 21:17:59 DEC. +31 57 36
EPOCH 2000.00 MAGNIFY
ALT 13.5 AZ 60.5
ACE Slit Pad
Lock
Guide Set
NW NE SW SE
Fine Coarse
Focus
Auxiliary Instruments
Filter Wheel Power Outlets
Flat Field Lamps ON OFF
Dome Camera Light ON OFF
Names
VidCap
File Edit Options Capture Help
VIDEO
Start VidCap ACE RCS at SARA 0.... Find: Files named notepad Untitled - Notepad Weather Station - HyperTe... 8:35 AM