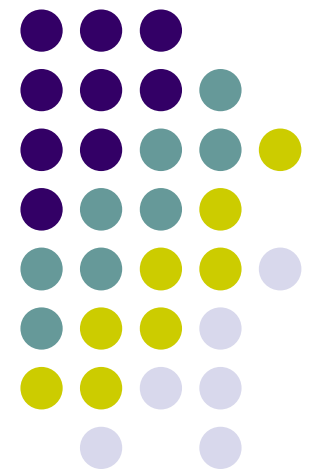


The X-Light

Colors moving in Space-Time



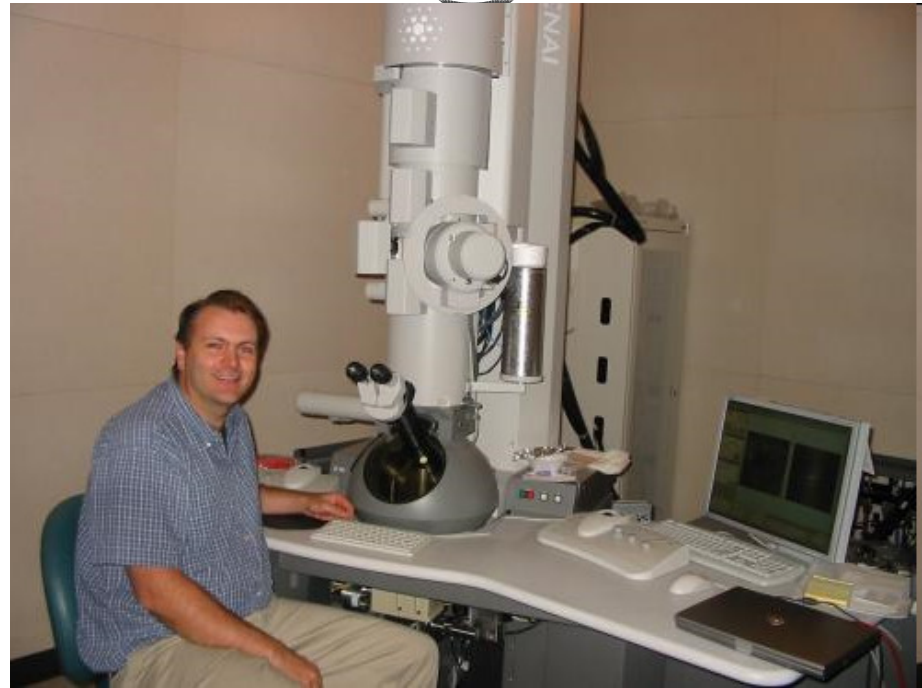
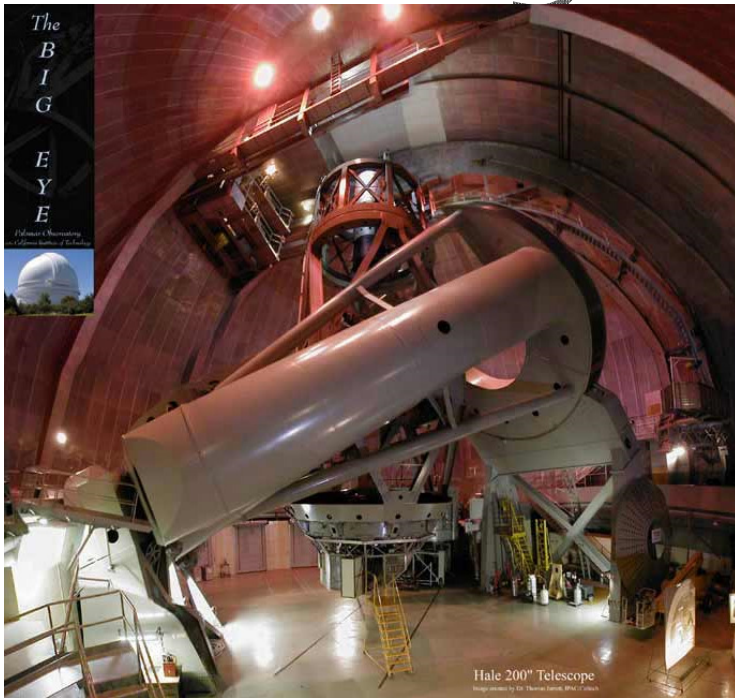
OPTRICKS



Donn M. Silberman
Founding Director
The Optics Institute
Of Southern California

Lambert Elementary School
Tustin Unified School District
Tustin, California
March 4, 2009
1 pm to 2 pm

Very Large



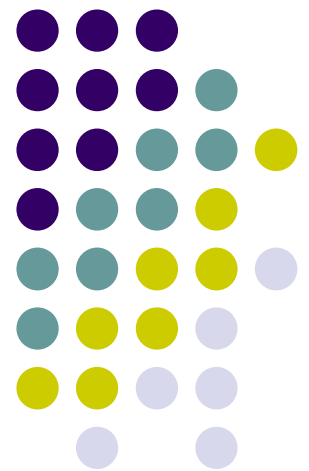
Very Small



Powers of Ten Screen Saver.Ink

Part I – How Do We “See” the World Around Us?

'Fictional' Fiction!



EyeBall Optics

Anatomy of the Human Eye

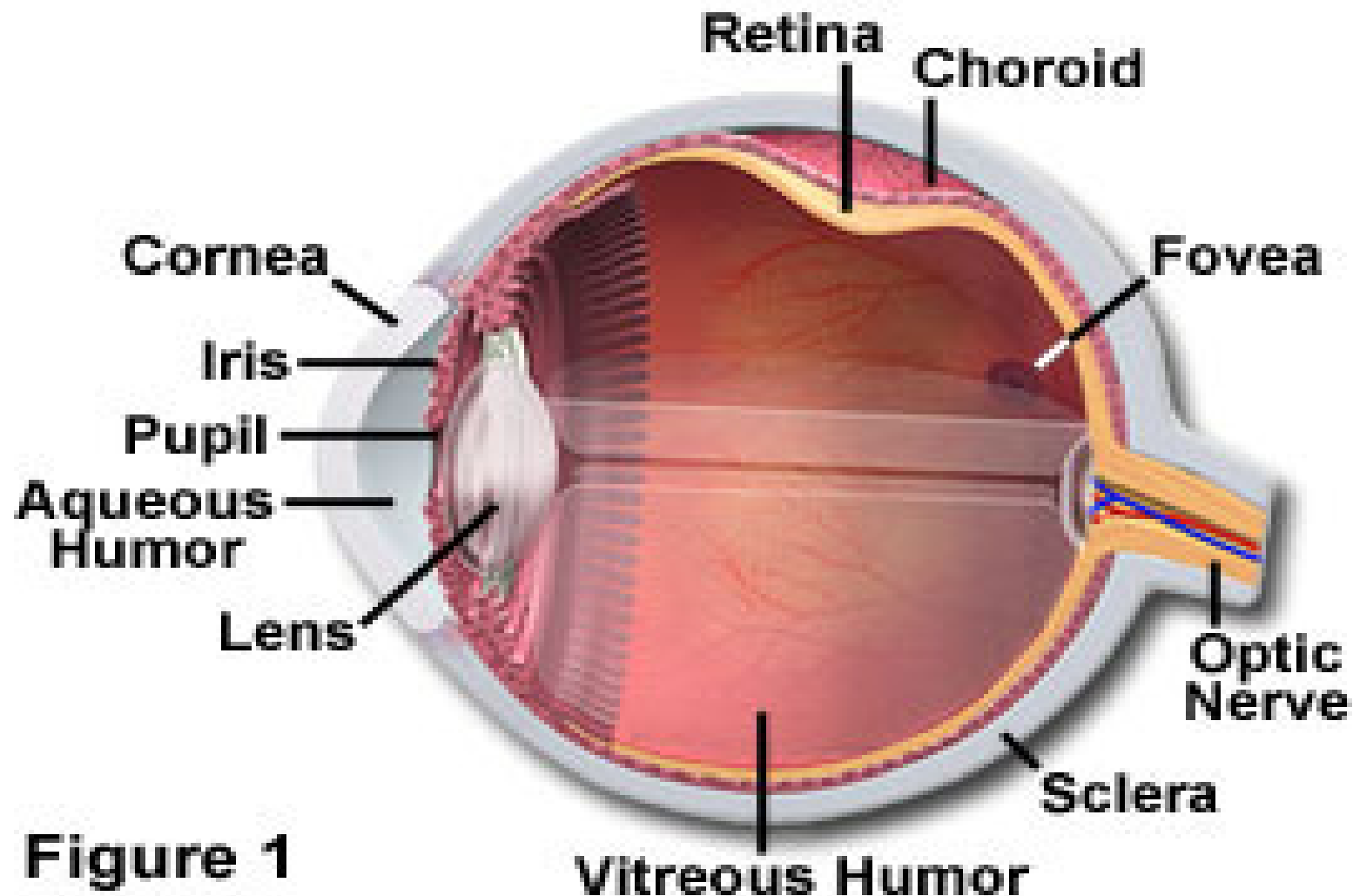
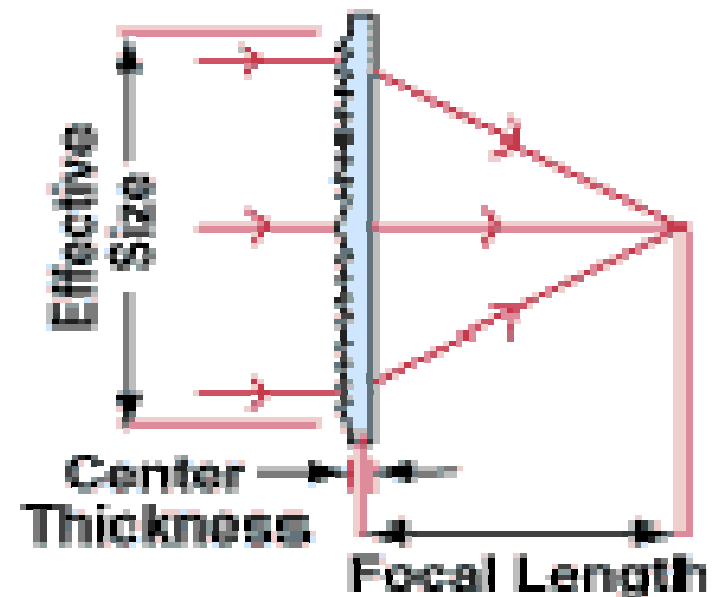
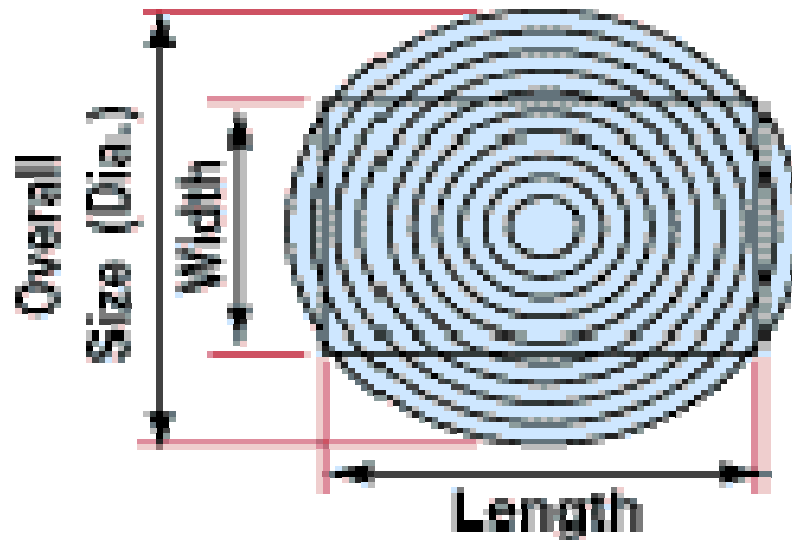


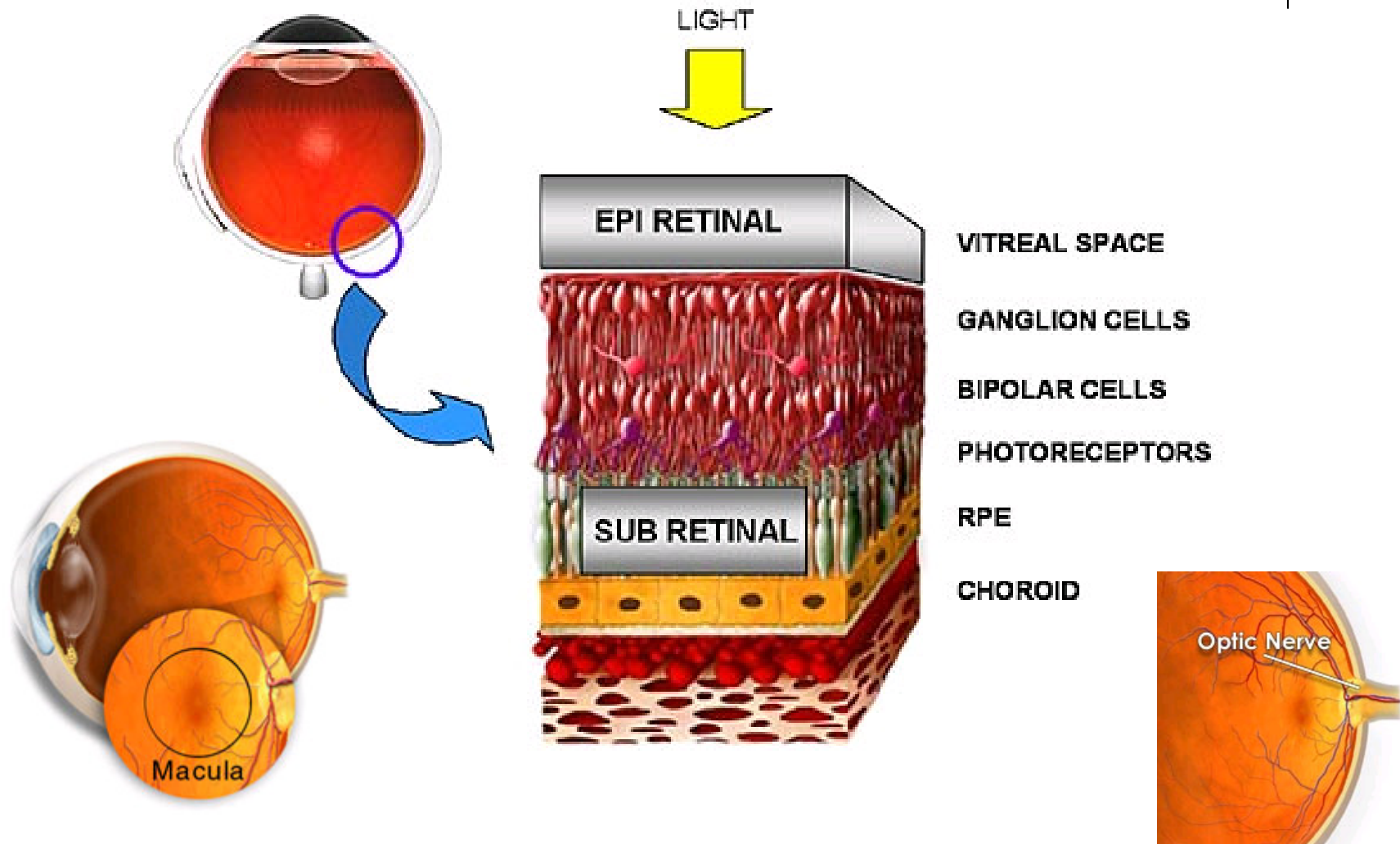
Figure 1

What's a Fresnel Lens Anyway?

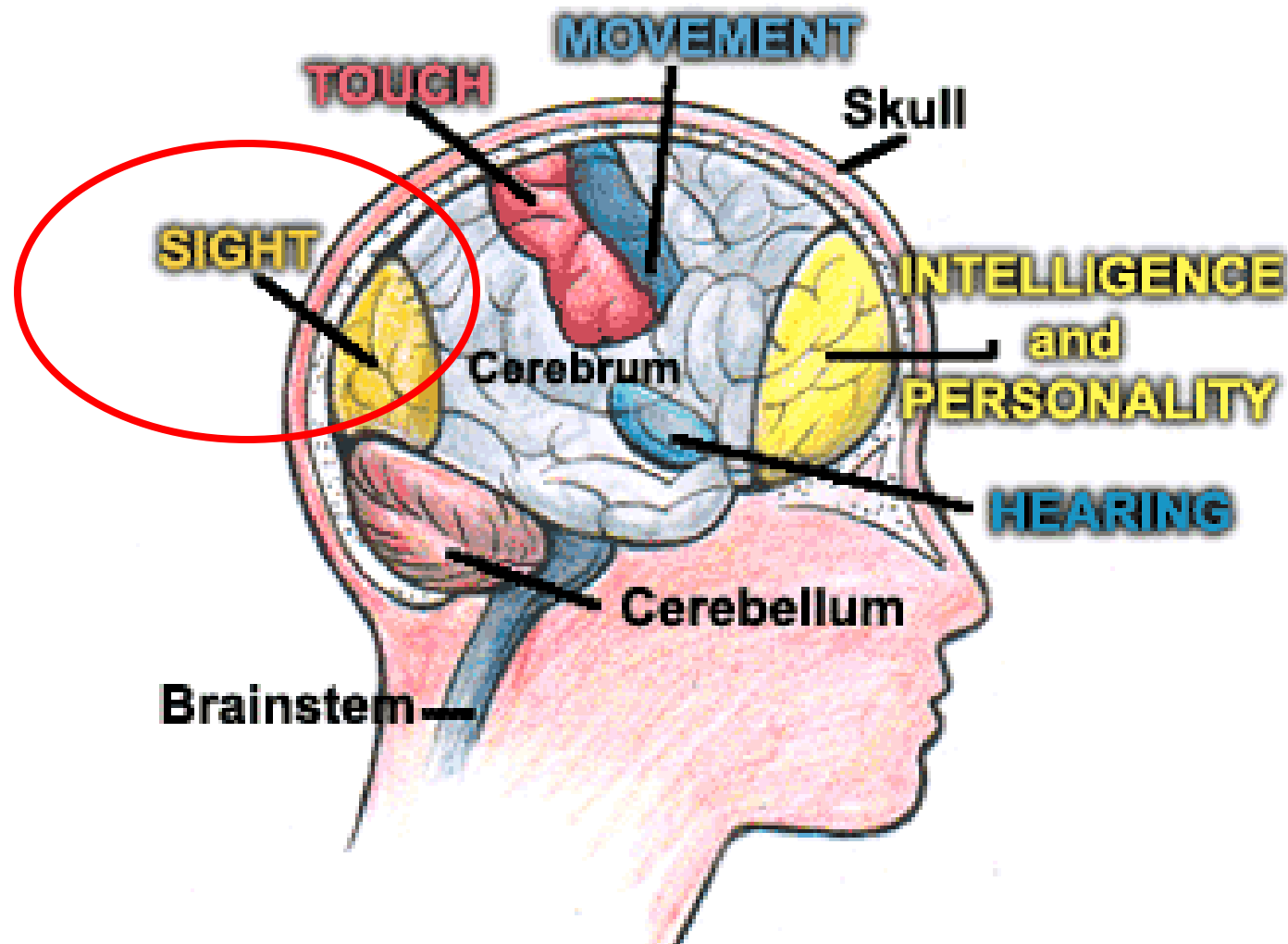
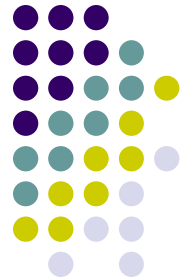


Aberration Examples with overhead projector.

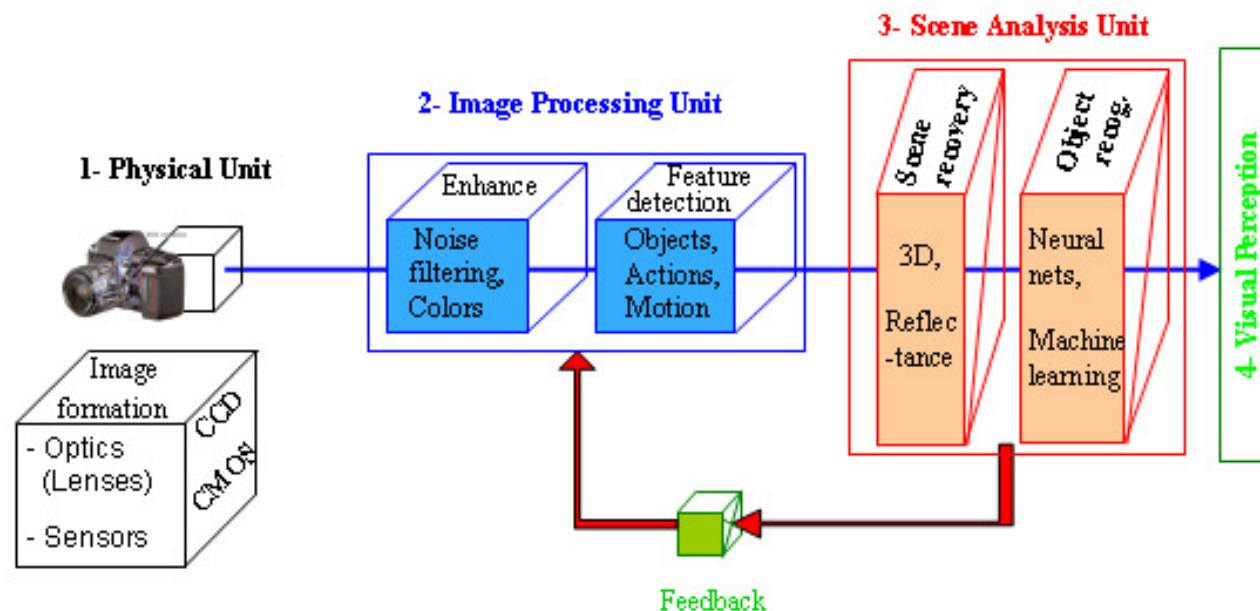
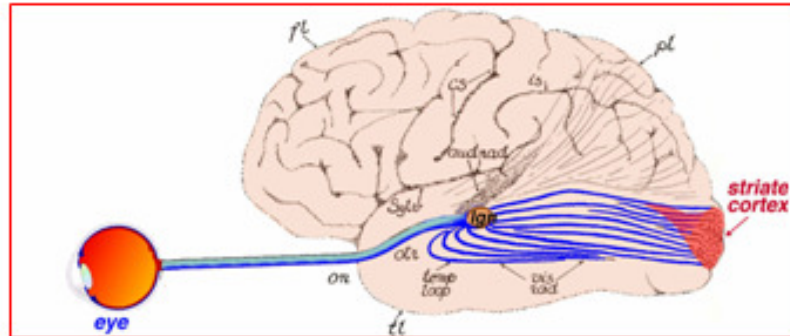
The Retina as a Detector



The Brain as a Computer



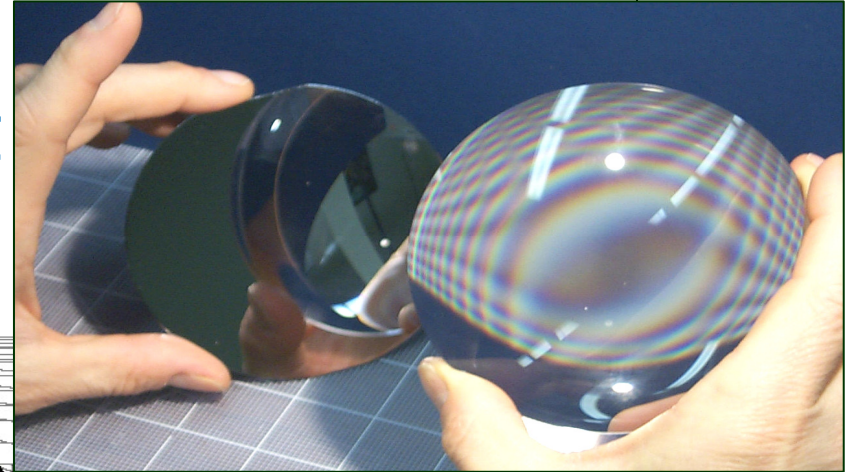
Part II – How Do We “Interpret” the World we “See” Around Us?



Optical Engineers Work with Materials That Reflect or Transmit Light



Si – polished silicon wafer
mirror-like reflector



SiO₂ – clear silica lens
focuses light

PERIODIC TABLE OF THE ELEMENTS

<http://www.kent.edu/~chem/periodic/en/>

GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
PERIOD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18							
1	IA 1.0079 H HYDROGEN																								
2	Li 6.941 LITHIUM	IIA 9.0122 Be BERYLLIUM																							
3	Na 22.990 SODIUM	Mg 24.305 MAGNESIUM																							
4	K 39.098 POTASSIUM	Ca 40.078 CALCIUM	Sc 44.956 SCANDIUM	Ti 47.867 TITANIUM	V 50.942 VANADIUM	Cr 51.996 CHROMIUM	Mn 54.938 MANGANESE	Fe 55.845 IRON	Co 58.933 COBALT	Ni 58.693 NICKEL	Cu 63.546 COPPER	Zn 65.39 ZINC	Al 69.723 ALUMINUM	Si 72.64 SILICON	P 30.974 PHOSPHORUS	S 32.06 SULFUR	Cl 35.453 CHLORINE	Ar 39.948 ARGON							
5	Rb 85.468 RUBIDIUM	Sr 87.62 STRONTIUM	Y 88.906 YTTORIUM	Zr 91.224 ZIRCONIUM	Nb 92.906 NIOBIUM	Mo 95.94 MOLYBDENUM	Tc 98.906 TECHNETIUM	Ru 101.07 RUTHENIUM	Rh 102.91 RHODIUM	Pd 106.42 PALLADIUM	Ag 107.87 SILVER	Cd 112.41 CADMIUM	In 114.82 INDIUM	Sn 118.71 TIM	Sb 121.76 ANTIMONY	Te 127.60 TELLURIUM	I 126.90 IODINE	Xe 131.29 XENON							
6	Cs 132.91 CAESIUM	Ba 137.33 BARIUM	La-Lu 57-71 Lanthanide	Hf 178.49 HAFNIUM	Ta 180.95 TANTALUM	W 183.84 TUNGSTEN	Re 186.21 RHENIUM	Os 190.23 OSMIUM	Ir 192.22 IRIDIUM	Pt 195.08 PLATINUM	Au 196.97 GOLD	Hg 200.59 MERCURY	Tl 204.38 THALLIUM	Pb 207.2 LEAD	Bi 208.98 BISMUTH	Po (209) POLONIUM	At (210) ASTATINE	Rn (222) RADON							
7	Fr (223) FRANCIUM	Ra (226) RADIUM	Ac-Lr 89-103 Actinide	Rf (261) RUTHENIUM	Db (262) DUBNIUM	Sg (266) SEABORGIUM	Bh (264) BOHRIUM	Hs (277) HASSIUM	Mt (268) MEITNERIUM	Uun (281) UNUBIUM	Uun (272) UNUBIUM	Uun (285) UNUBIUM	Uuq (289) UNUQUADIUM												

(*) Pure Appl. Chem., 73, No. 4, 695-693 (2001)

Relative atomic mass is given with two significant figures. For elements with no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of that element.

However, for such elements (Tl, Pb, and U) data on characteristic terrestrial isotopic composition, and for those an atomic weight is tabulated.

Editor: Aditya Venkatesh (adven@netnet.com)

LANTHANIDE

57 138.91	58 140.12	59 140.91	60 144.24	61 (145)	62 150.36	63 151.96	64 157.25	65 158.93	66 162.50	67 164.93	68 167.26	69 168.93	70 173.04	71 174.97
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
LANTHANUM	CERIUM	PRASEODYMIUM	NEODYMIUM	PRIMUMIUM	SAMARIUM	EUROPIUM	GADOLINIUM	TERBIUM	DYSPROSIUM	HOLMIUM	ERBIUM	THULIUM	YTERBIUM	LUTETIUM

ACTINIDE

89 (227)	90 232.04	91 231.04	92 238.03	93 (237)	94 (244)	95 (243)	96 (247)	97 (247)	98 (251)	99 (252)	100 (257)	101 (258)	102 (259)	103 (262)
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
ACTINIUM	THORIUM	PROTACTINIUM	URANIUM	NEPTUNIUM	PLUTONIUM	AMERIUM	CURCIUM	BERKELIUM	CALIFORNIUM	ESBENIUM	FERMIUM	MENDELVIUM	NOBELIUM	LAVENCIUM

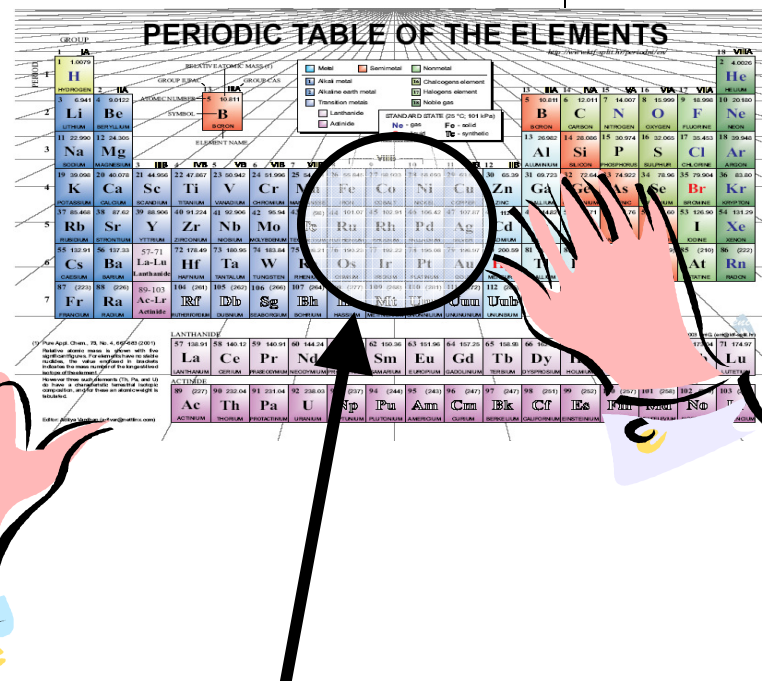
Copyright © 1998-2003 ENIG (enig@kent.edu)

Magic Dots

Most printed material is made up of lots of Dots!!



- Have you ever wondered how printing works?
- Most modern printers use lots of dots to make up the text & images that you see.
- Do you know what color ink they use?
- Use the small magnifying lens to look at the Periodic Table. Do you see the Magic Dots??



Small Magnifying Lens

Hold the lens about 1 inch above the paper.

We'll come back to this Periodic Table of Elements a bit later!!!



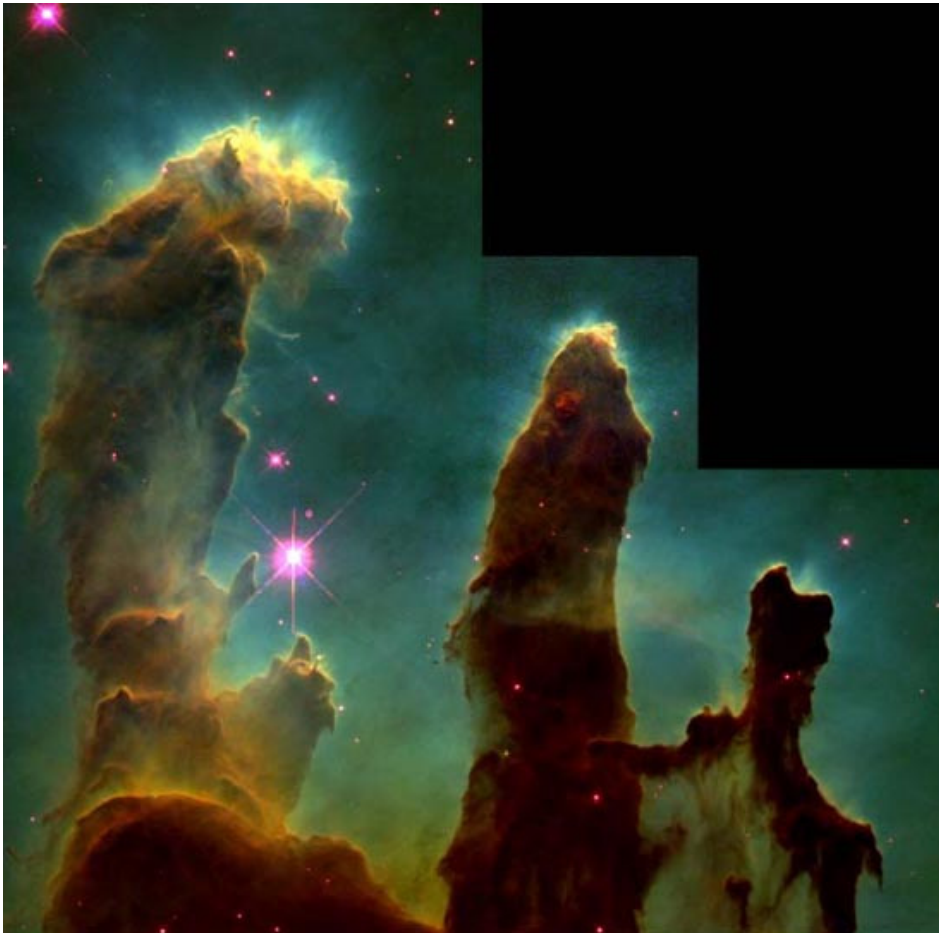


Twinkle, Twinkle, Little Star ...

How I Wonder What You Are ...

- Did you ever wonder what stars are?
- Did you notice that stars have different colors?
 - The different colors indicate different:
 - Temperatures
 - Sizes
 - Masses
- The bigger it is, the hotter and the faster a star burns its life away.

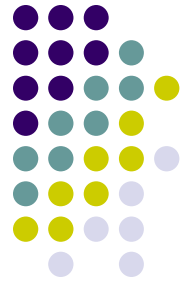
Stellar Nursery



**Space is filled
with the stuff to
make stars.**



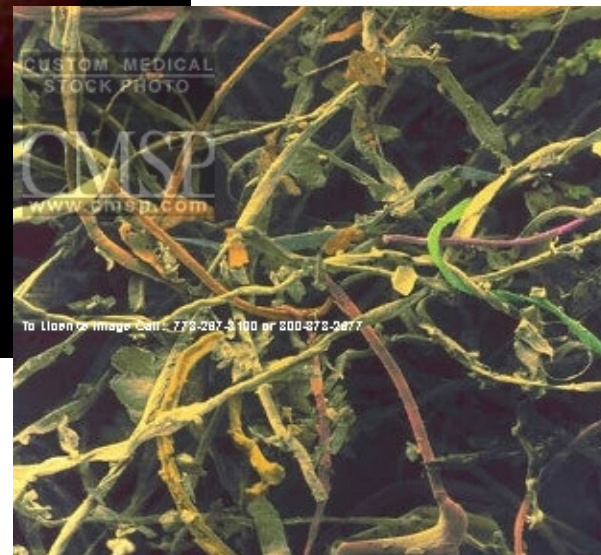
Stars start from clouds



**Clouds
provide the
gas and dust
from which
stars form.**



But not this kind of dust



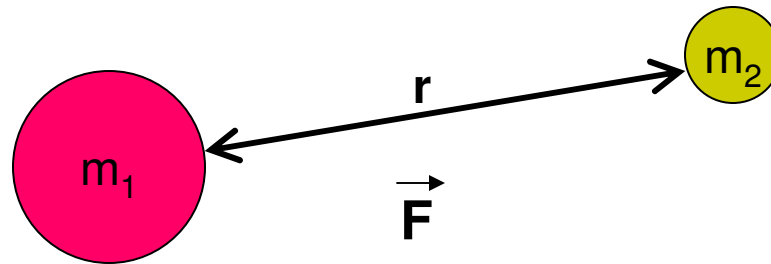
**Rather: Irregular Grains
Of Carbon or Silicon**



Collapse to Protostar

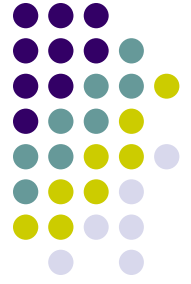
- Stars begin with slow accumulation of gas and dust.
- Gravitational attraction of Clumps attracts more material.

$$F = \frac{Gm_1m_2}{r^2}$$



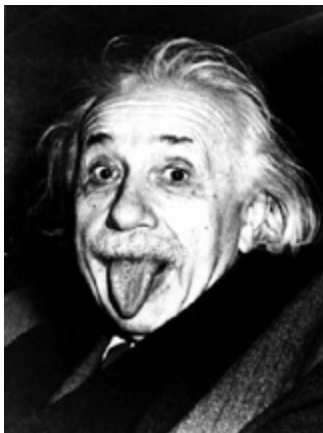
- Contraction causes Temperature and Pressure to slowly increase.

“**G**” is the universal gravitational constant!!

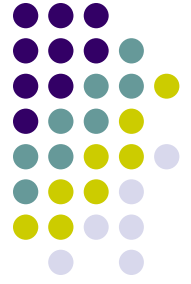


Nuclear Fusion !

- At 15 million degrees Celsius in the center of the star, fusion ignites !
- $4 (^1\text{H}) \rightarrow ^4\text{He} + 2 e^+ + 2 \text{ neutrinos} + \text{energy}$
 - Where does the energy come from ?
 - Mass of four $^1\text{H} >$ Mass of one ^4He



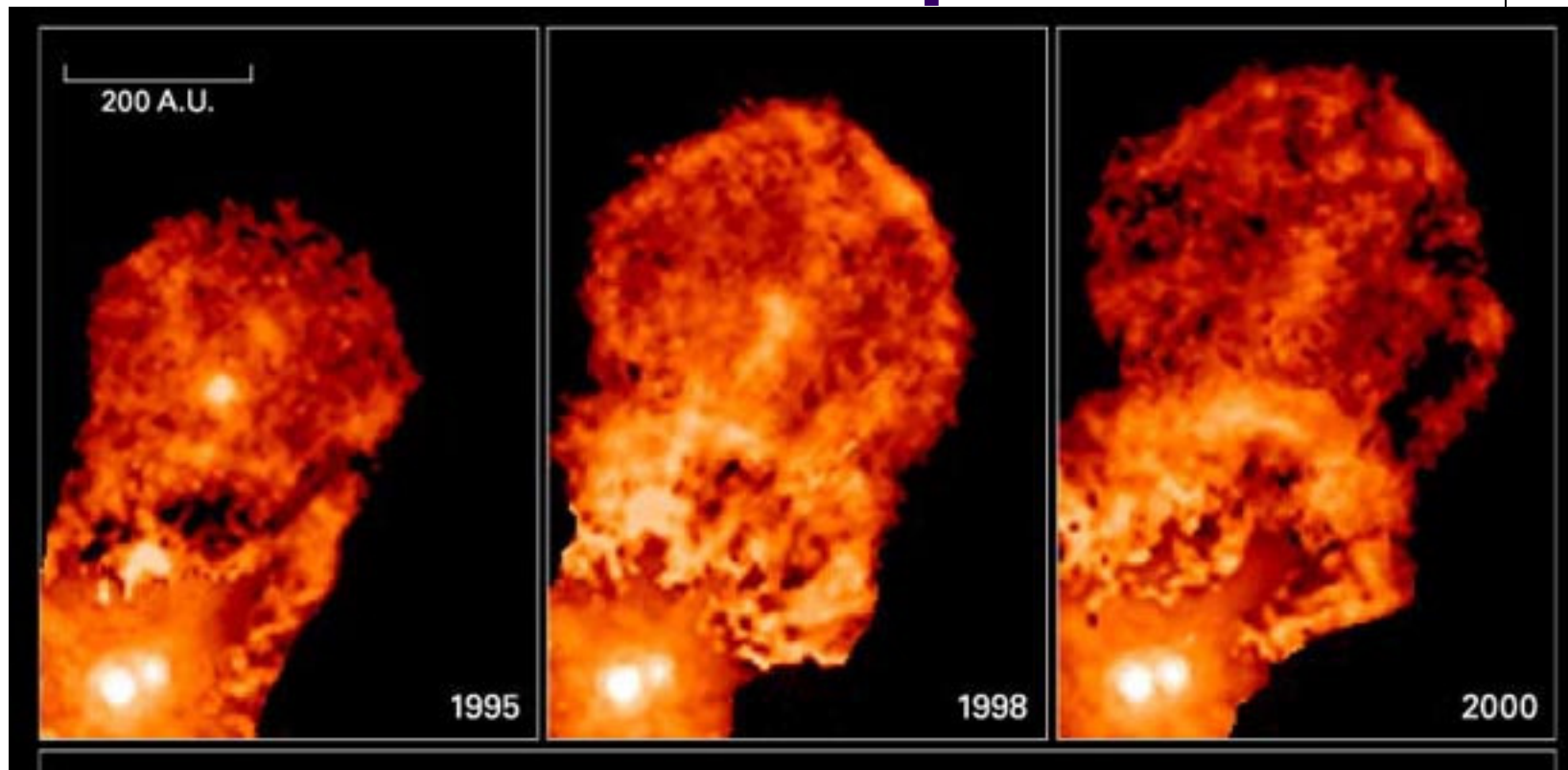
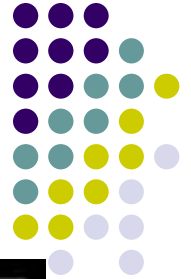
$$E = mc^2$$



A Balancing Act

- Energy released from nuclear fusion counteracts inward force of gravity.
- Throughout its life, these two forces determine the stages of a star's life.

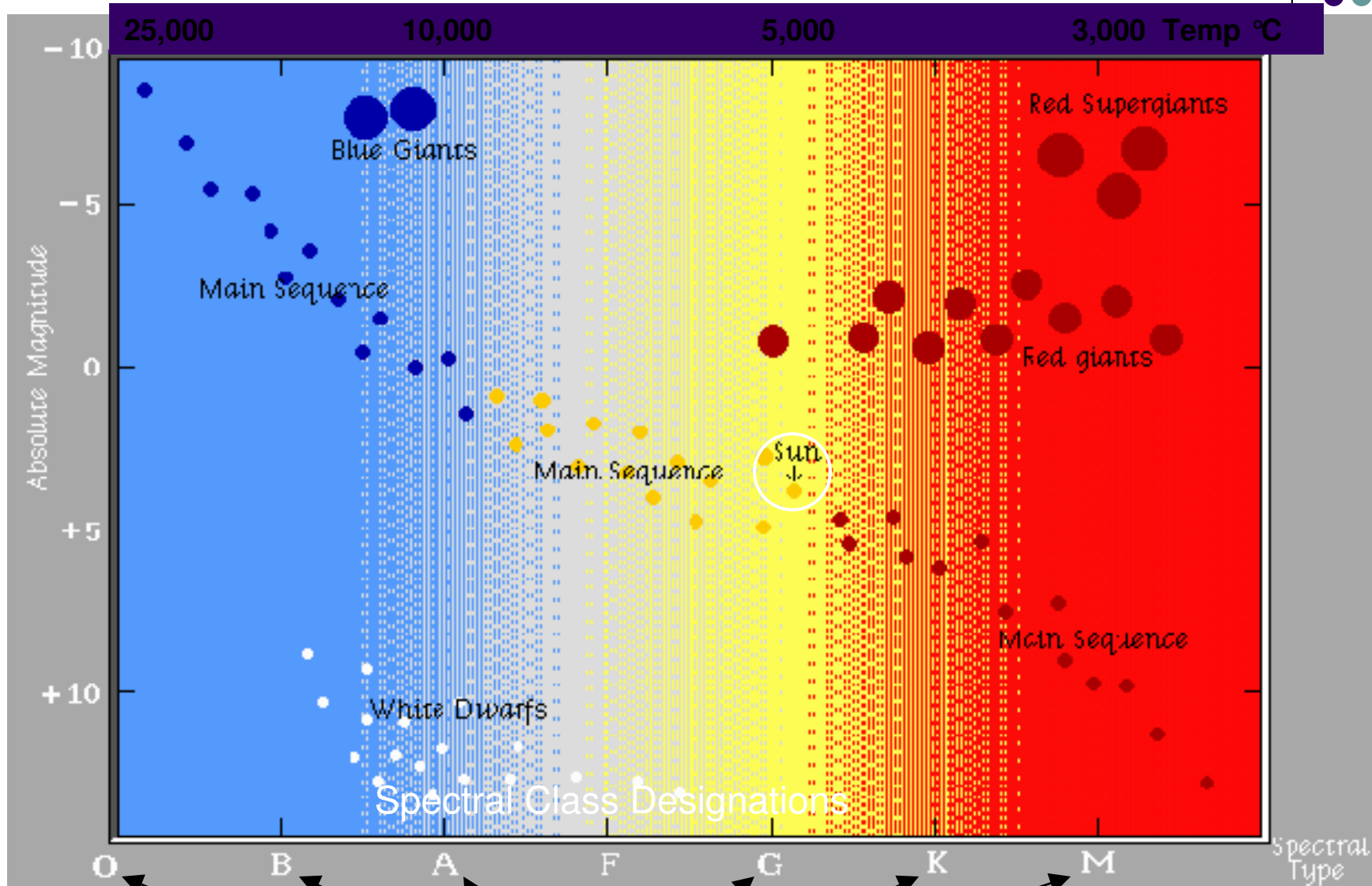
New Stars are not quiet !



Expulsion of gas from a young binary star system

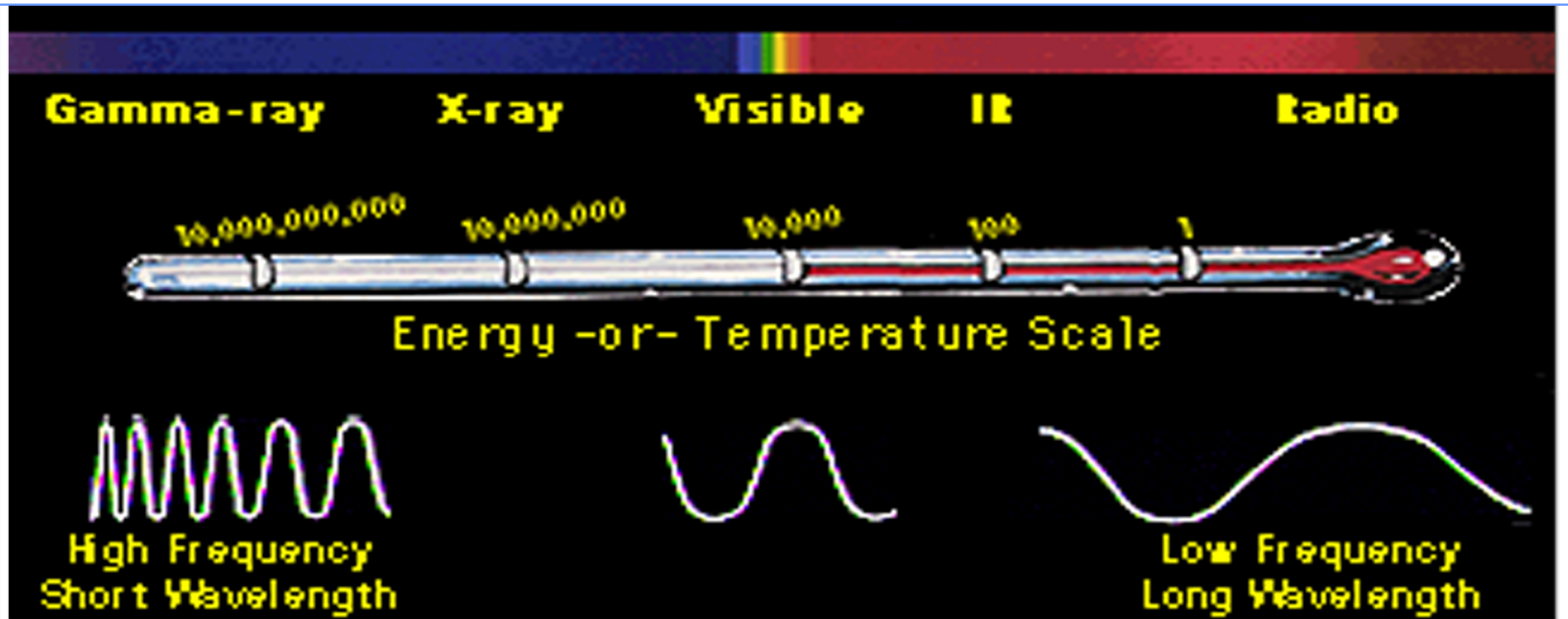
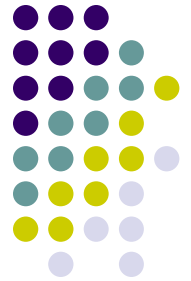
All Types of Stars – Different Colors

Hertzsprung – Russell Diagram



Oh! Be A Fine Girl - Kiss Me !

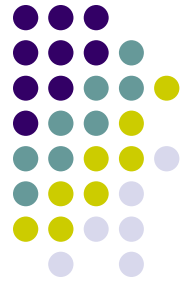
LIGHT - Electromagnetic Spectrum



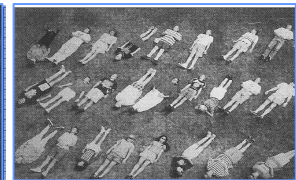
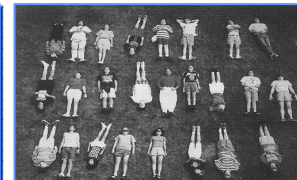
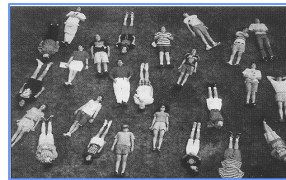
The electromagnetic spectrum. Radio has long wavelengths and low energies, while gamma rays have very short wavelengths and high energies.

Magic Patch

(temperature data vs. color)



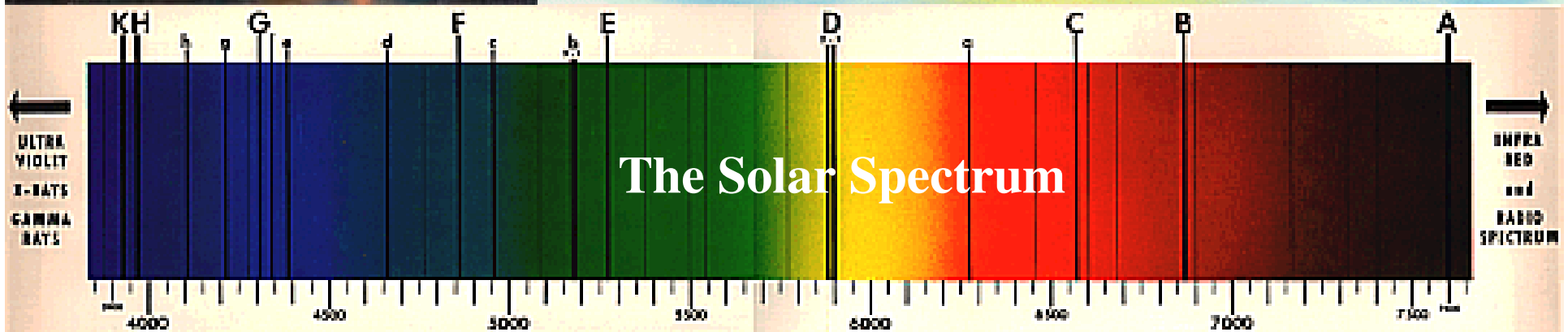
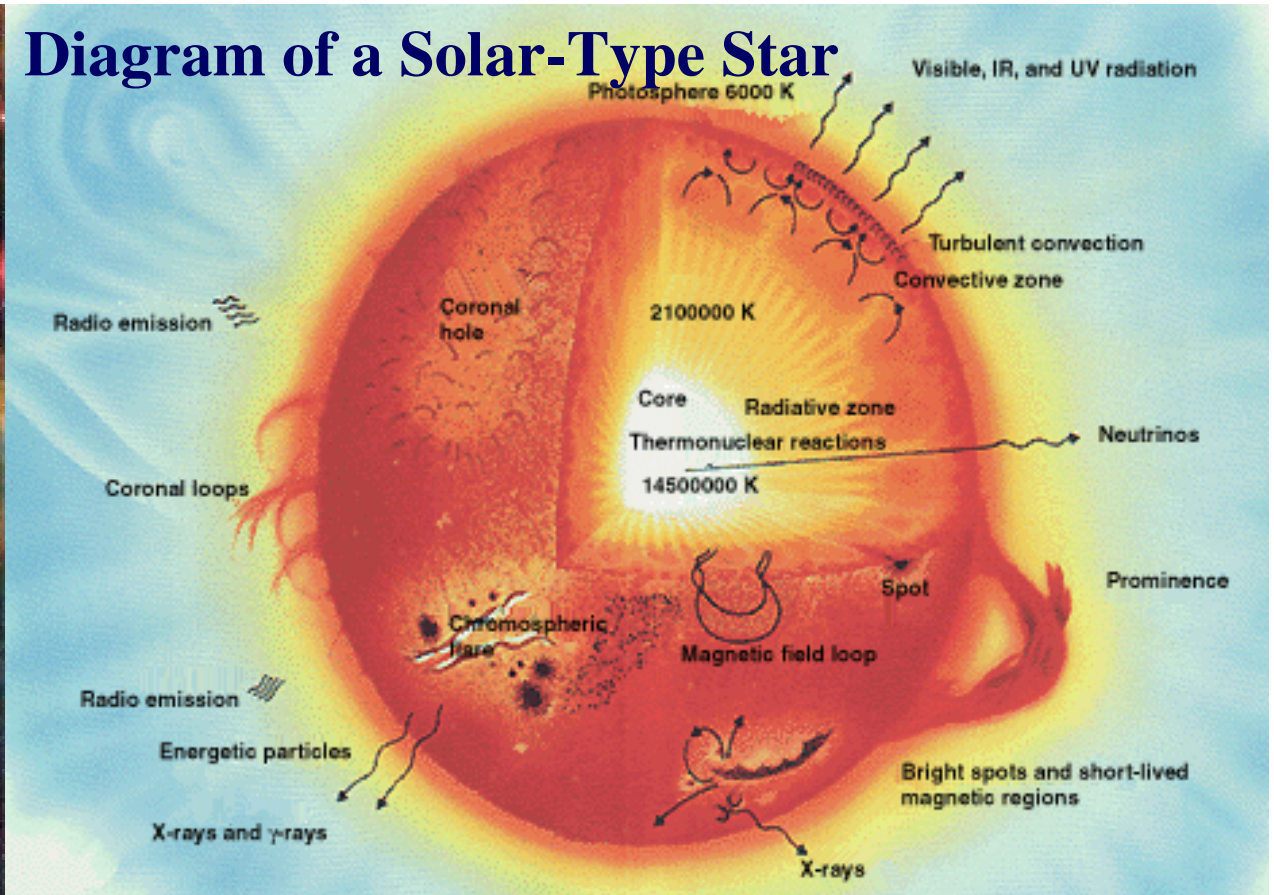
- Place the patch on your wrist and perform the “vampire test.”
- The “*Magic Patch*” changes color with the heat from your body. The “living dead” give off no heat!
- Where do the colors come from?
- Does anyone see a vein or artery?
- This is an example of “selective reflection” by liquid crystals, painted onto the black paper.
- Liquid crystal are “ordered,” just like the students across the page.
- Scientists use liquid crystals to build displays for watches and computer games.



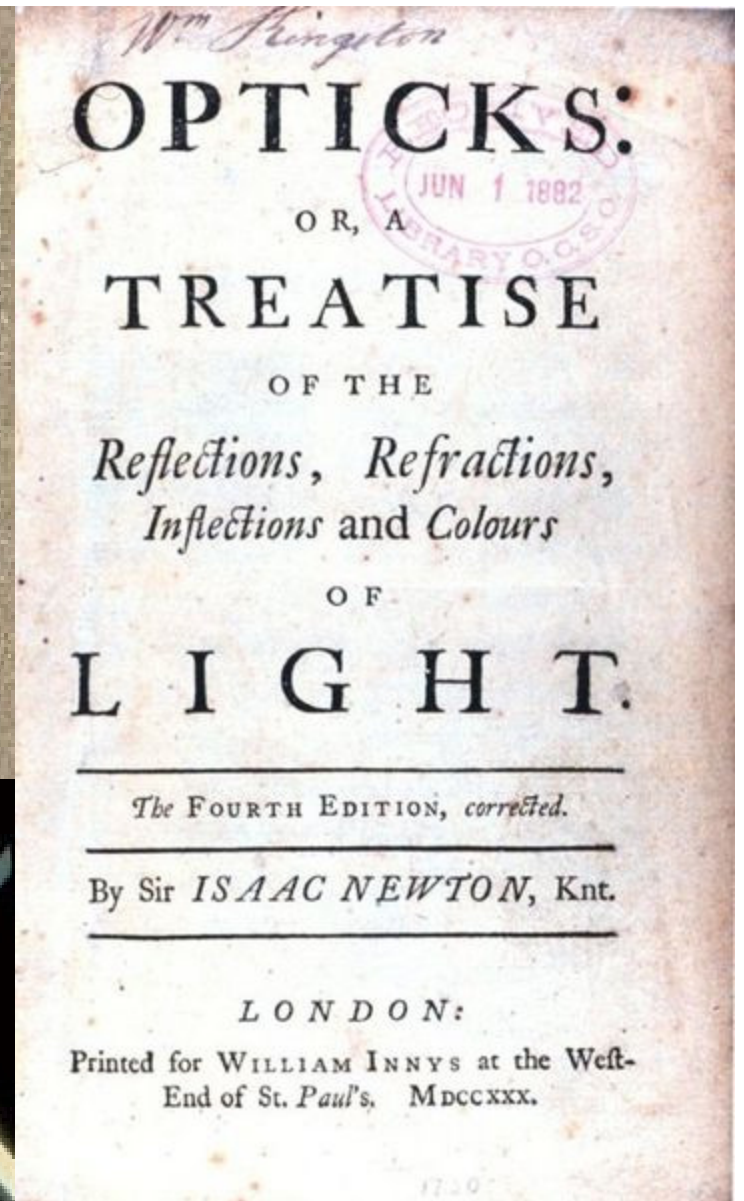
Carina Nebula



Diagram of a Solar-Type Star



The Optics Institute
of Southern California

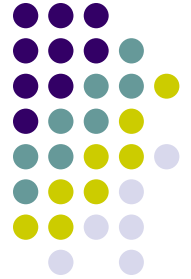


Wavelength = Color

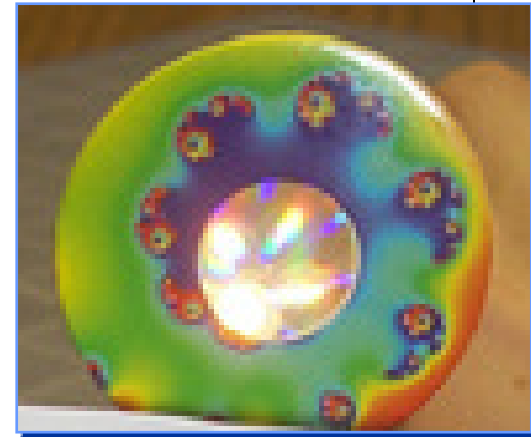


Rainbow Peephole®

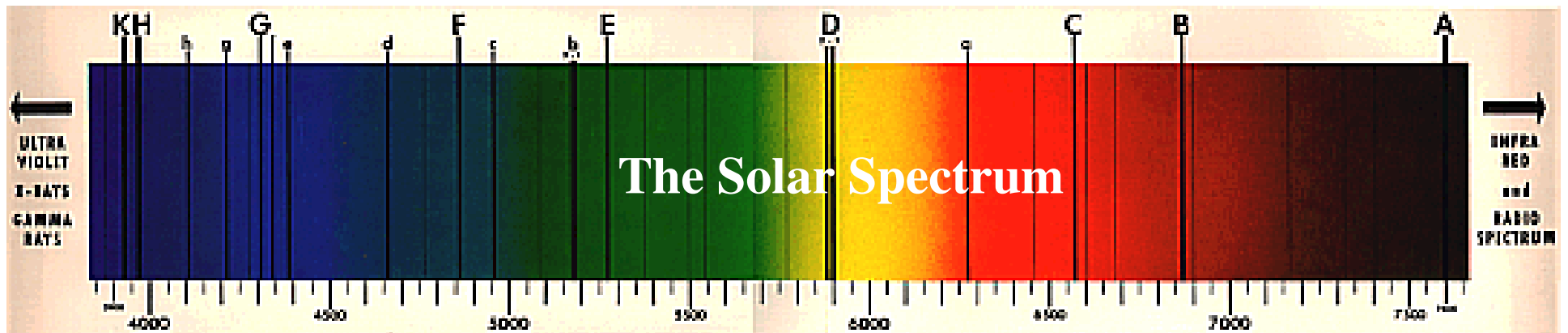
Diffraction Gratings



- Light is “redirected” in passing through the plastic peephole to the eye.
- Where do the colors come from?
- Do you see a regular pattern?
- Identify the colors. Are they the same in each spot?
- Does the pattern change if the light is close or far from the peephole? How?
- Do you see colors from the room lights?
- The regular array of bumps on the plastic peephole's surface allows us to see the color in white light through “diffraction.”



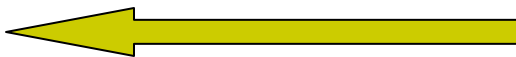
We can know what is in the light source by understanding the spectrum.



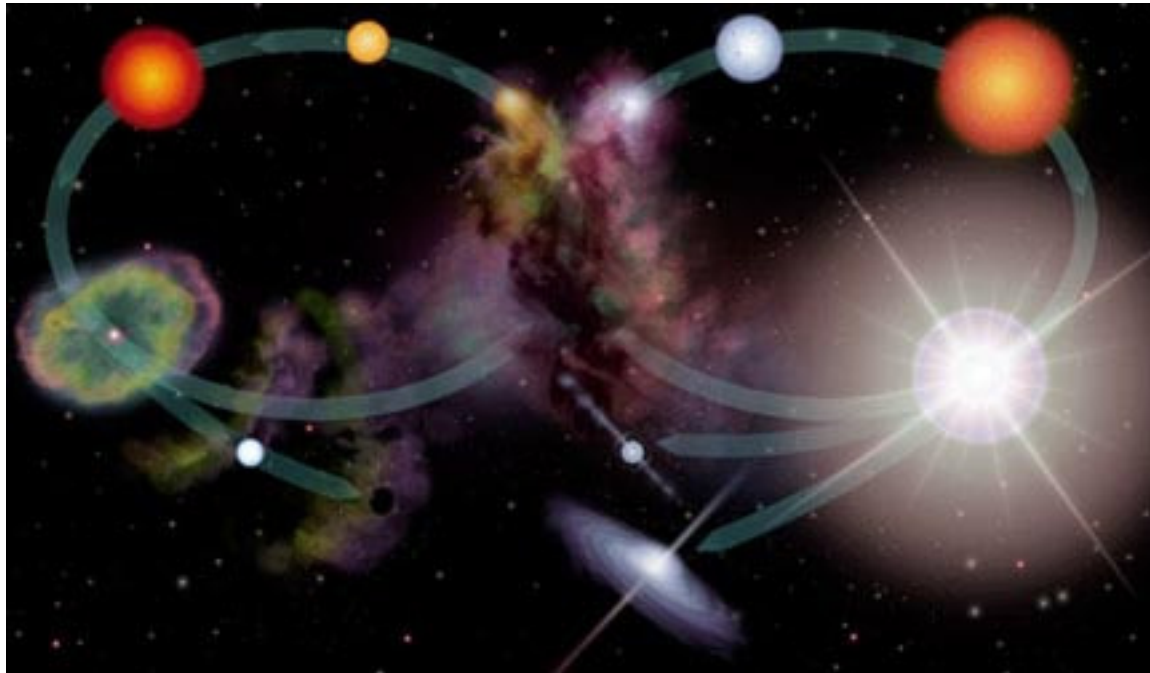
UV
X-Ray
Cosmic

Visible

IR
Radio

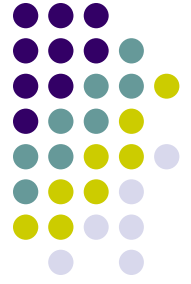


Reprise: the Life Cycle



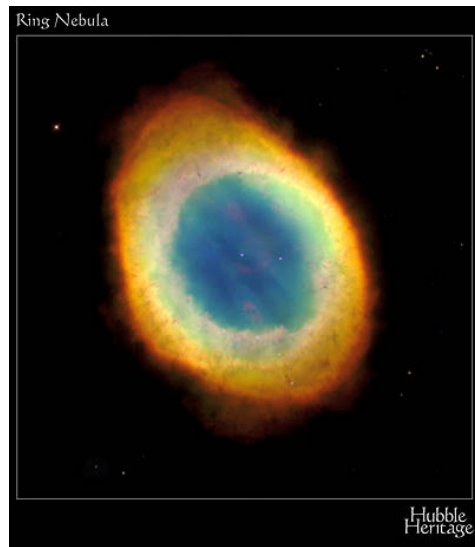
Sun-like Stars

Massive Stars

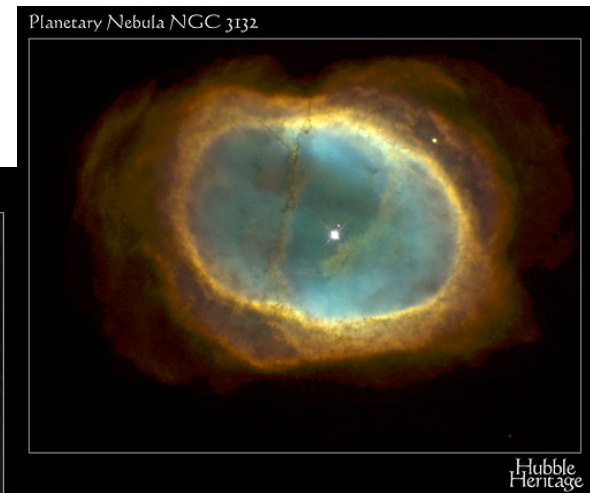


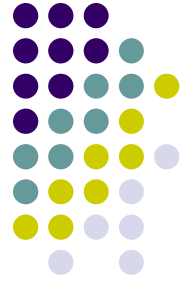
The end for solar type stars

After Helium exhausted, outer layers of star expelled



Planetary Nebulae

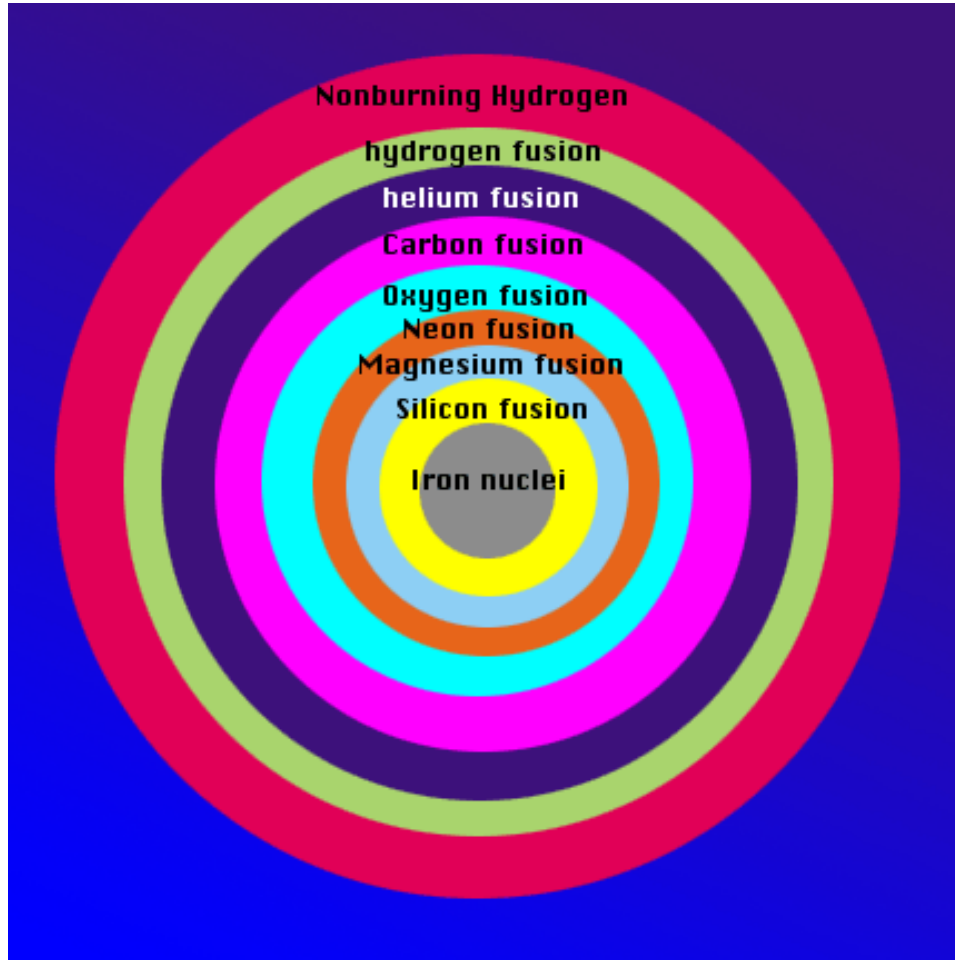




White dwarfs

- At center of Planetary Nebula lies a
- White Dwarf.
- Size of the Earth with Mass of the Sun “A ton per teaspoon”
- Inward force of gravity balanced by repulsive force of electrons.

The End of the Line for Massive Stars



- Massive stars burn a succession of elements.
- Iron is the most stable element and cannot be fused further.
 - Instead of releasing energy, it uses energy.



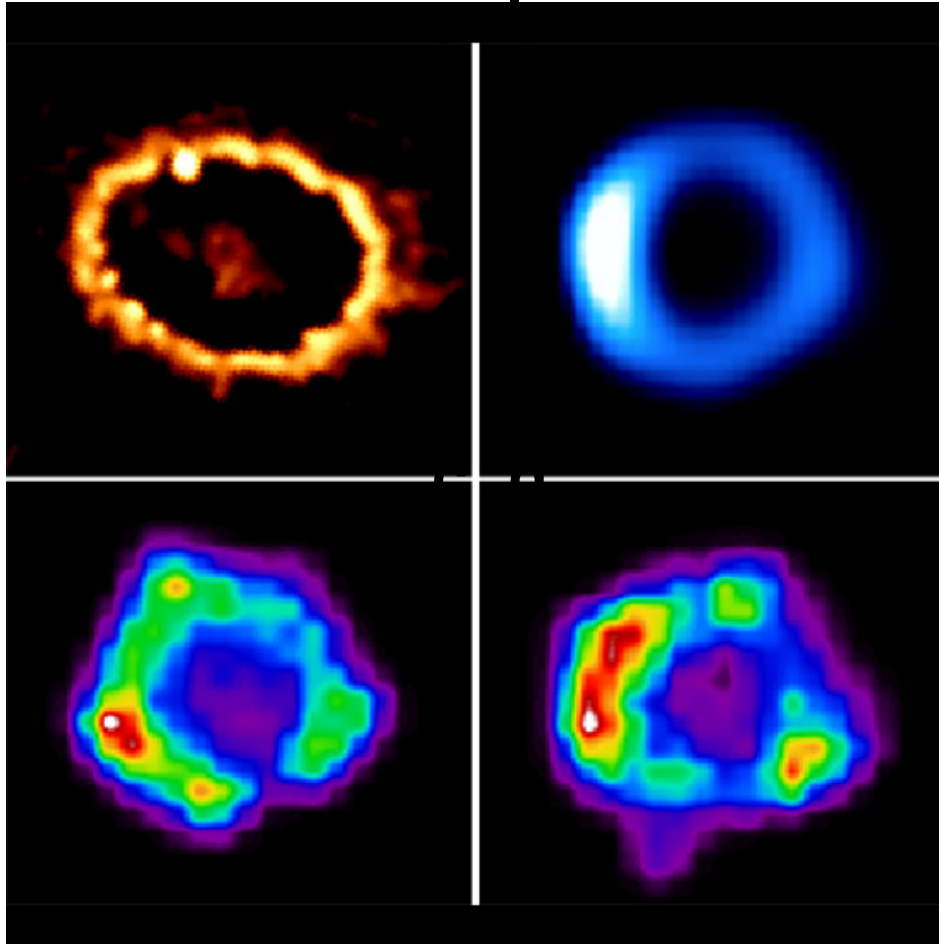
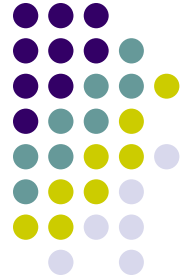
Periodic Table

Light Elements → Heavy Elements

H																		He
Li	Be											B	C	N	O	F	Ne	
Na	Mg											Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub							
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

^{28}Si + ^{10}B → ^{37}Cl + ^1H + ^{56}Fe

Supernova Remnants: SN1987A



a) Optical - Feb 2000

- Illuminating material ejected from the star thousands of years before the SN

b) Radio - Sep 1999

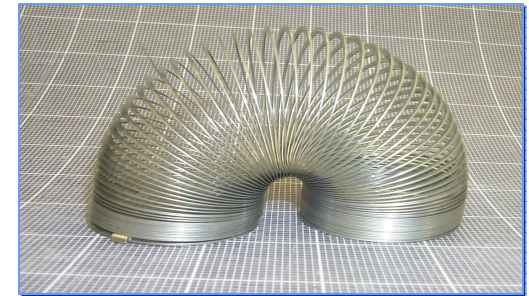
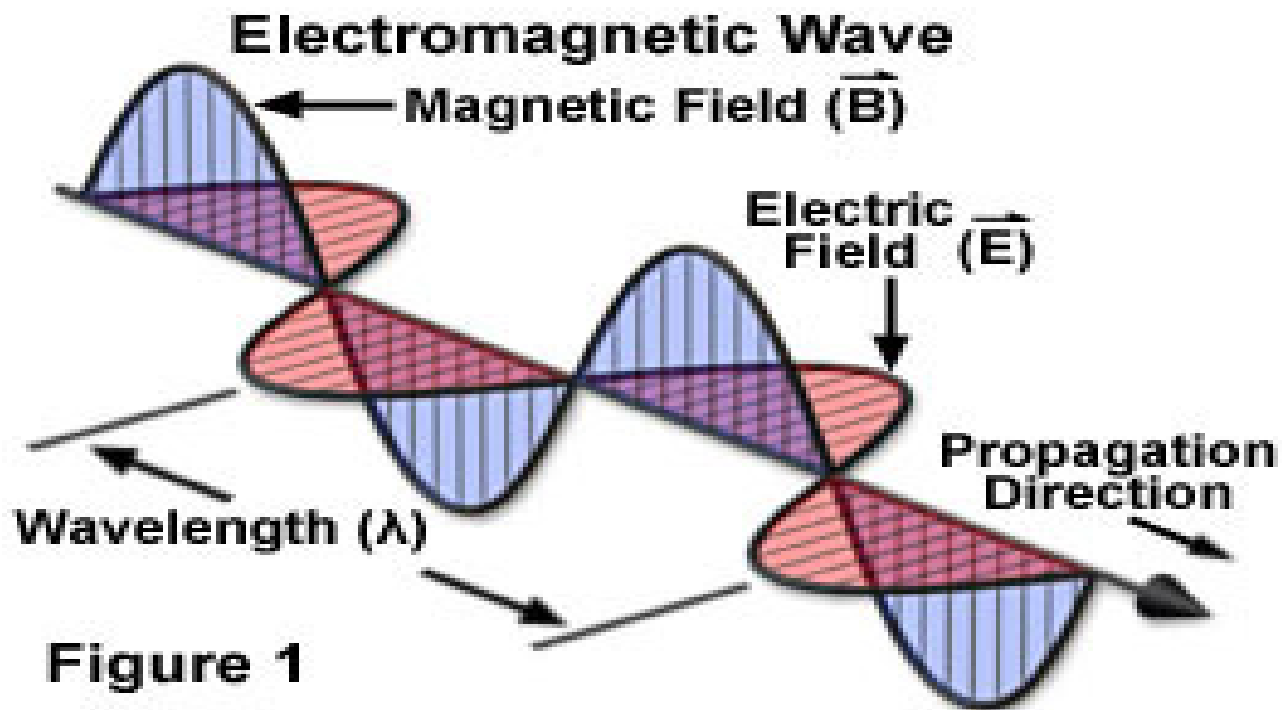
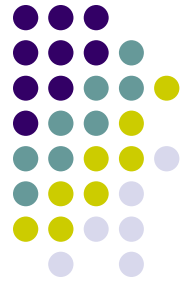
c) X-ray - Oct 1999

d) X-ray - Jan 2000

- The shock wave from the SN heating the gas

What is Light??

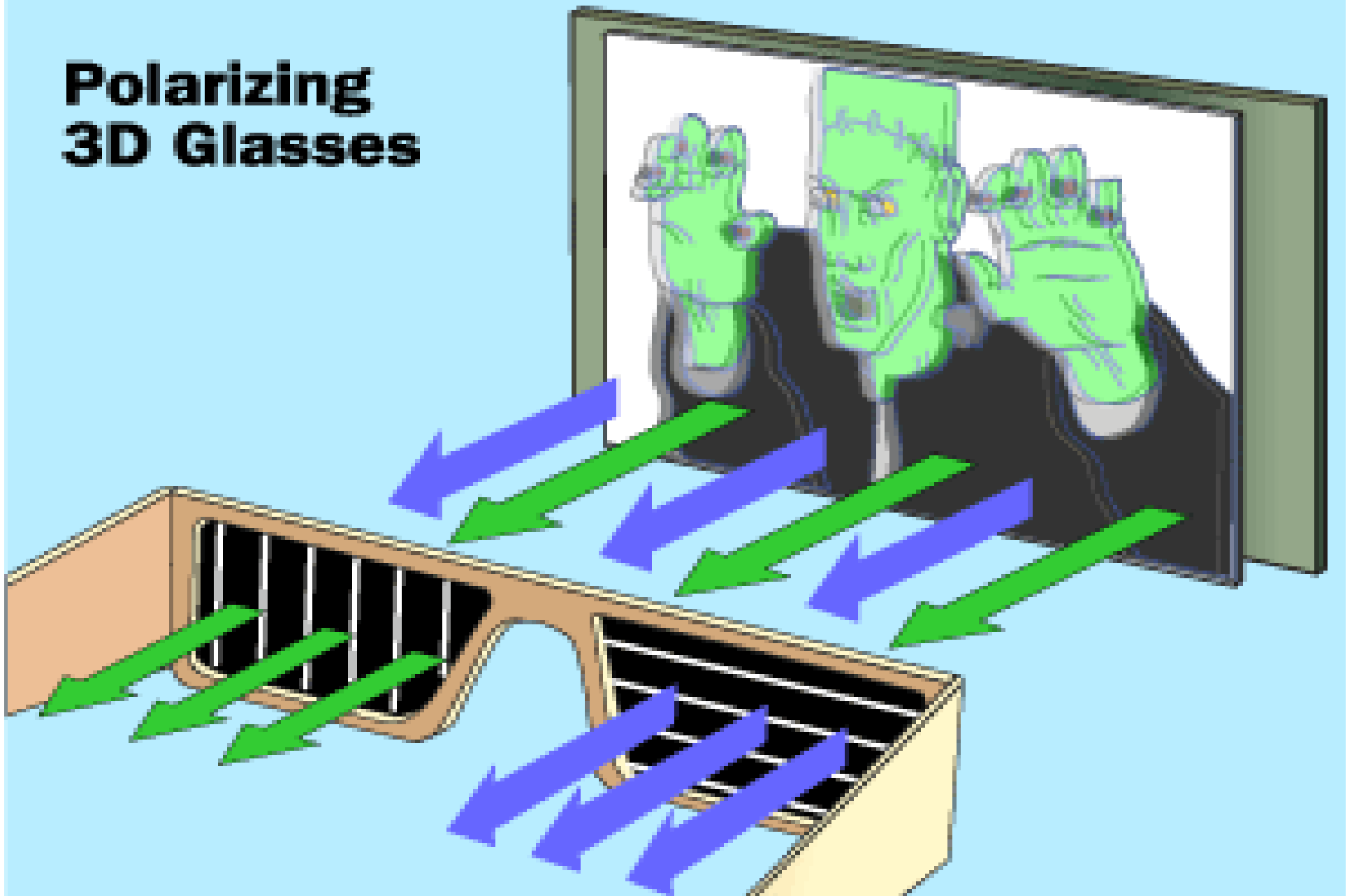
Light is Like a Vibrating Wave



Slinky

- Figure 1
- Light is like pure energy with no rest mass (because it is never at rest!!)

Polarizing 3D Glasses

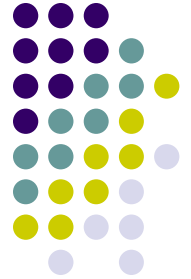


The polarized glasses allow only one of the images into each eye because each lens has a different polarization. Image courtesy of howstuffworks.com

Magic Stripes

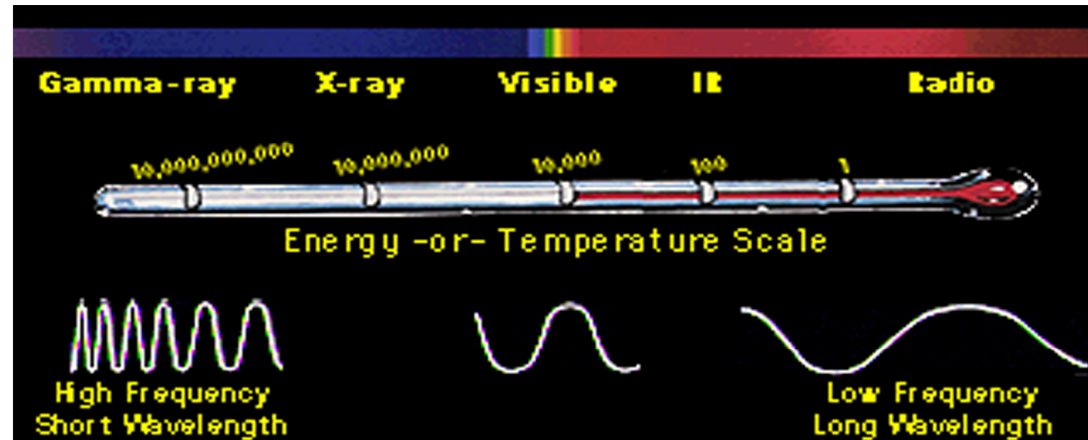
Polarization of Light

- Where do the colors come from?
- Make your own polariscope and find the stripes in the plastic and glass materials.
- Geologists, identify minerals with polarized light microscopes.
- Civil engineers examine stresses inside structures with transparent models and a polariscope.



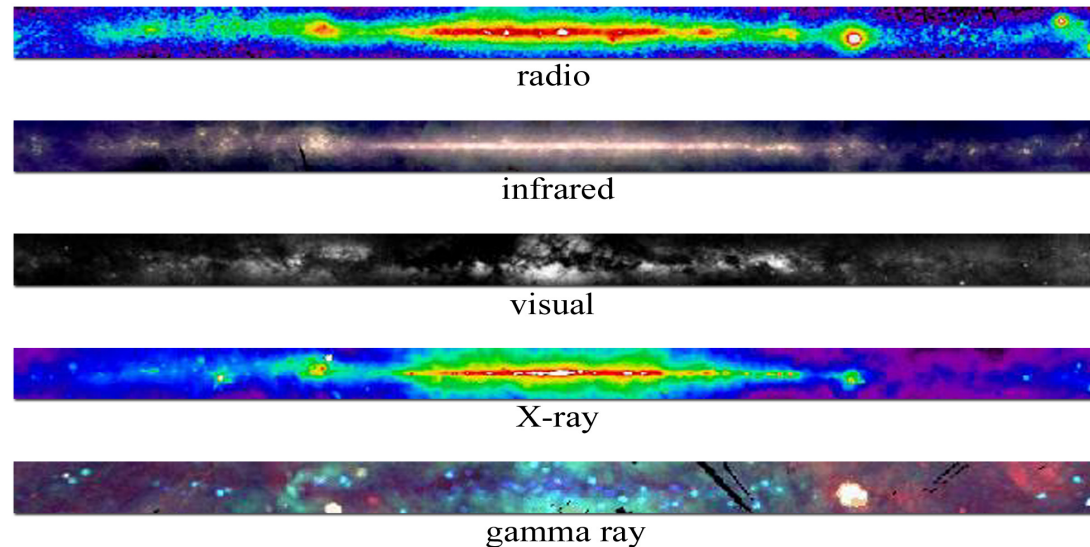
It takes more than one kind of telescope to see the light

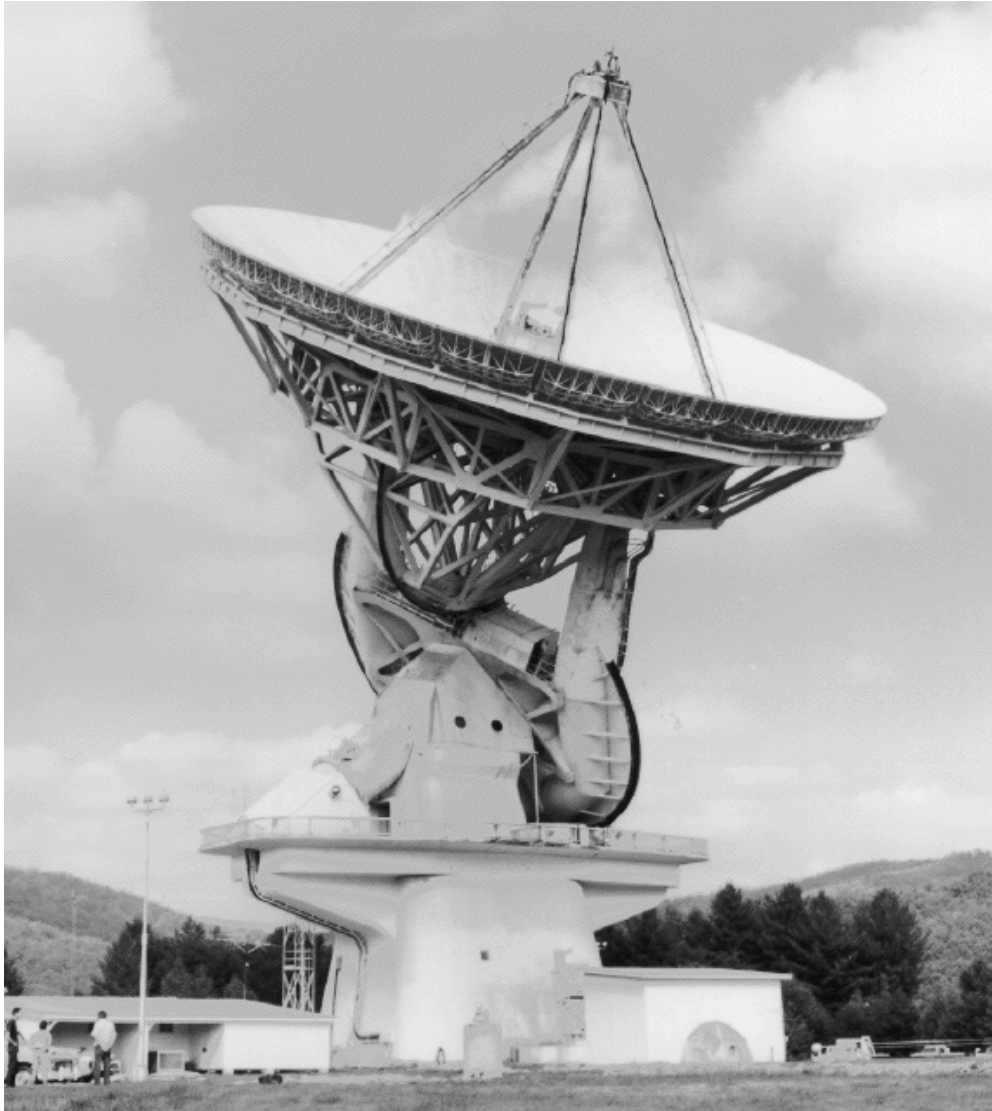
Why we need different types of telescopes to look at outer space



The electromagnetic spectrum. Radio has long wavelengths and low energies, while gamma rays have very short wavelengths and high energies.

The Multi-Wave Milky Way Galaxy





NRAO operates the 140 Foot
Robert C. Byrd Green Bank Radio Telescope

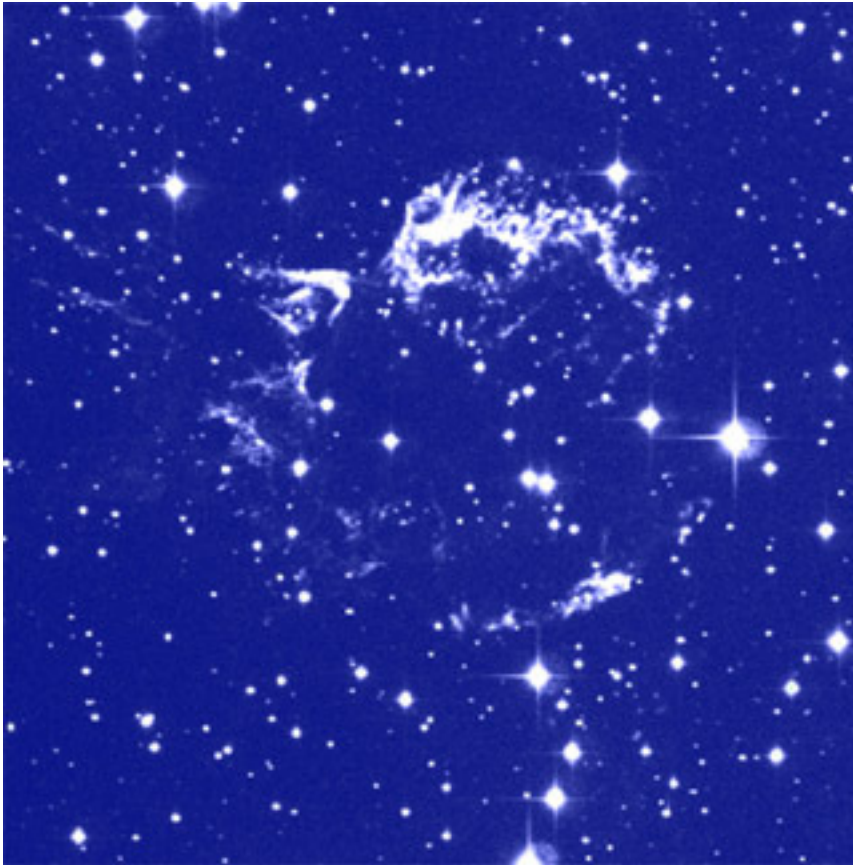


The [Arecibo radio telescope](#) is currently
the largest single-dish telescope
in the world.

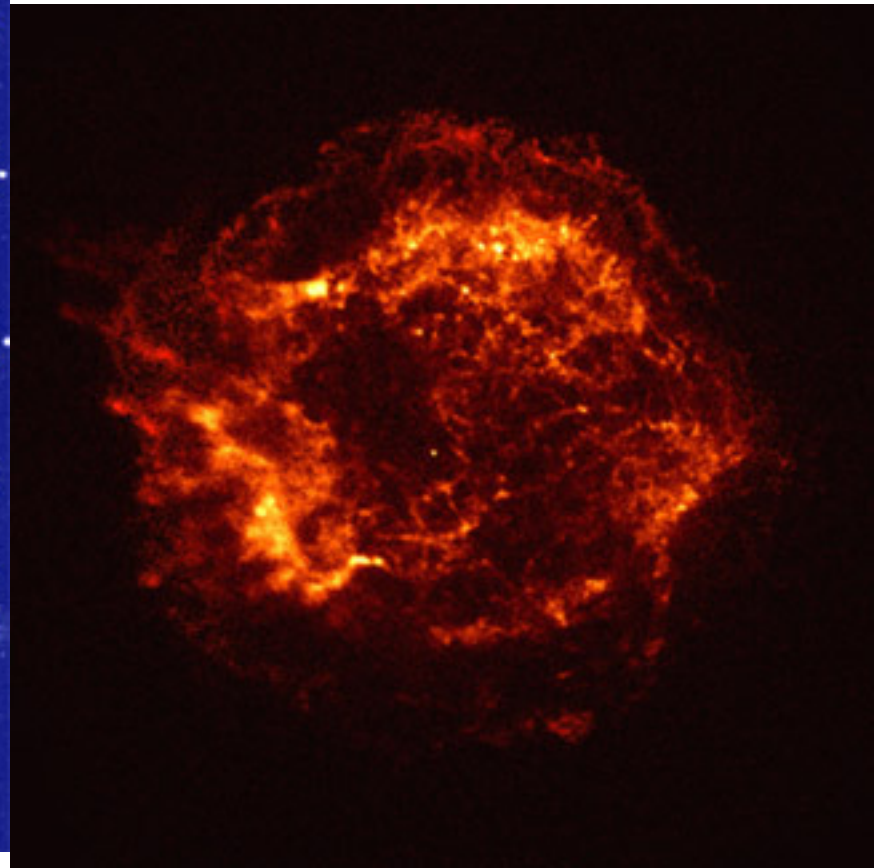


Supernova Remnants: Cas A

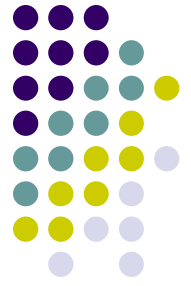
Optical



X-ray

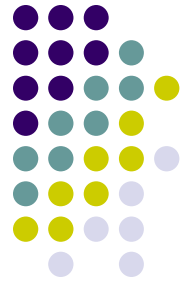


What's Left After the Supernova

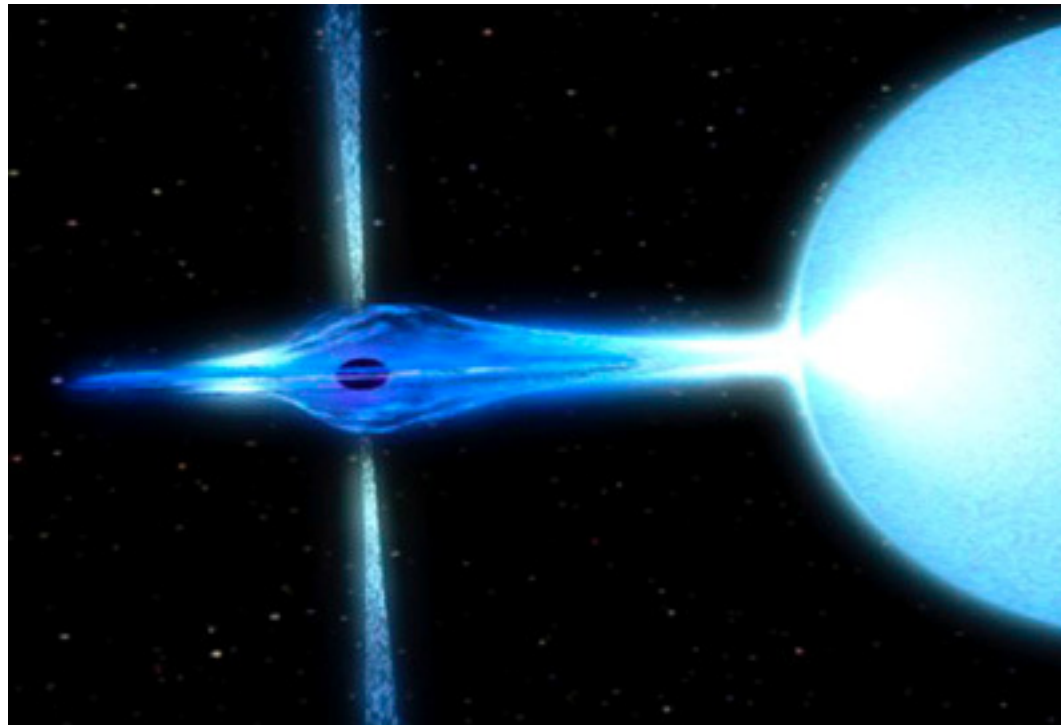


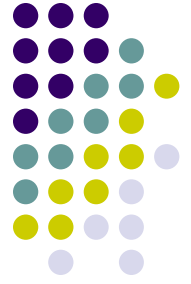
- Neutron Star (If mass of core $< 5 \times \text{Solar}$)
 - Under collapse, protons and electrons combine to form neutrons.
 - 10 Km across
-
- Black Hole (If mass of core $> 5 \times \text{Solar}$)
 - Not even compacted neutrons can support weight of very massive stars.

A whole new life: X-ray binaries



In close binary systems, material flows from normal star to Neutron Star or Black Hole. X-rays emitted from disk of gas around Neutron Star/Black Hole.





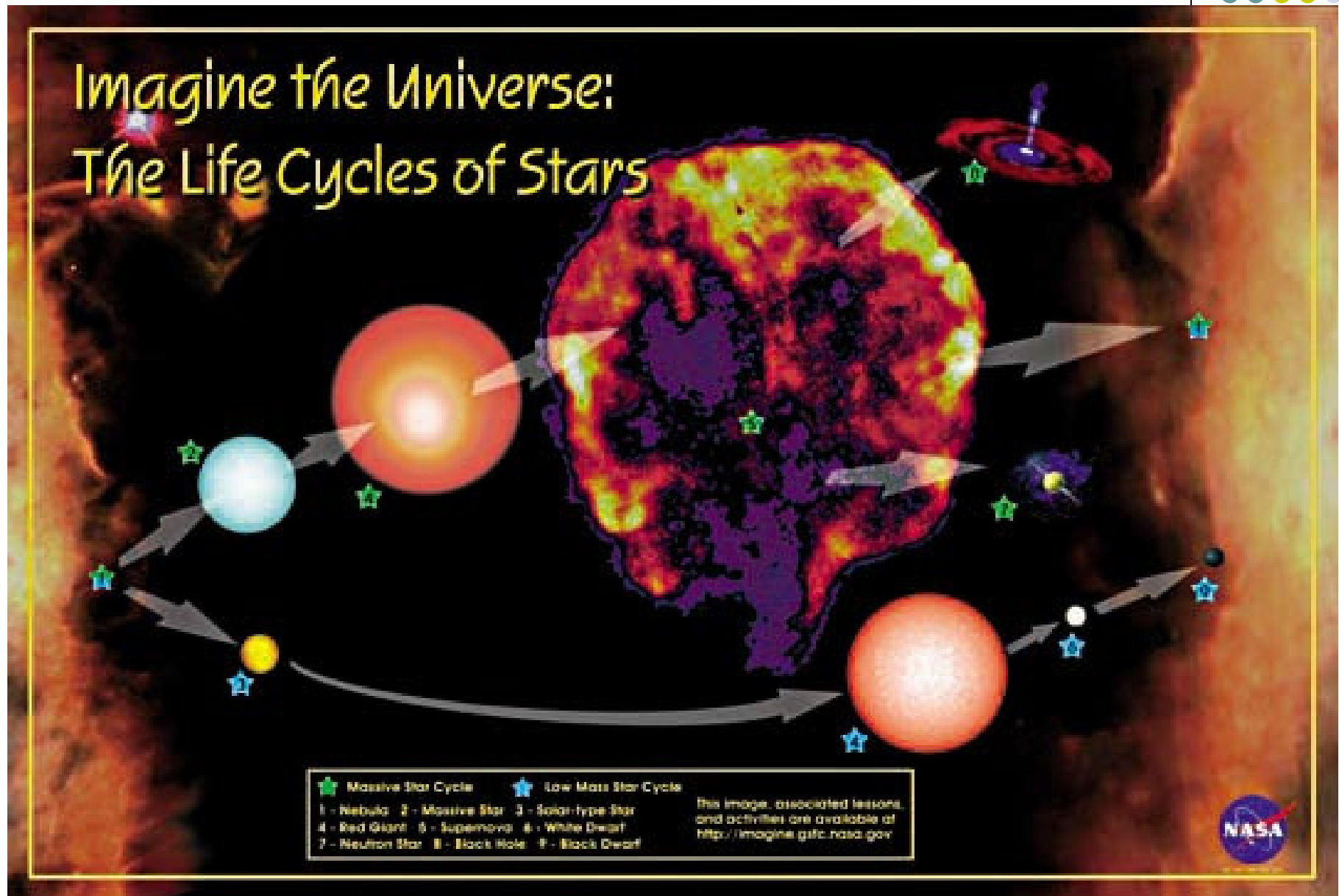
SN interaction with ISM

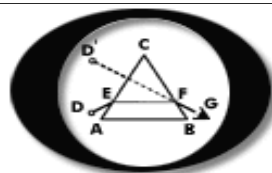


Supernovae compress gas and dust which lie between the stars. This gas is also enriched by the expelled material.

This compression starts the collapse of gas and dust to form new stars.

Which Brings us Back to ... Why Stars have different colors!





OPTICAL SOCIETY
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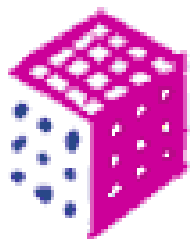


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