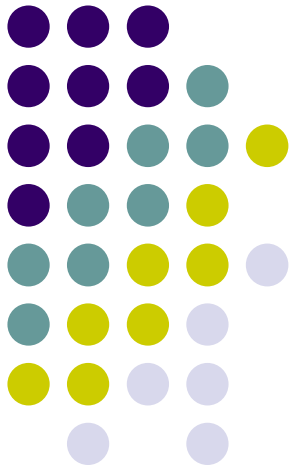
The X-Light

Colors moving in Space-Time

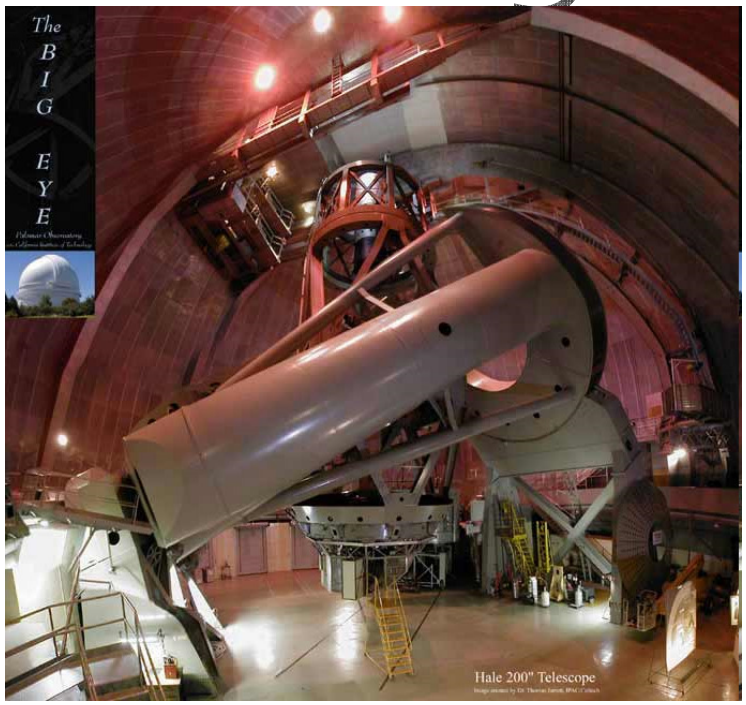
OPTRICKS



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

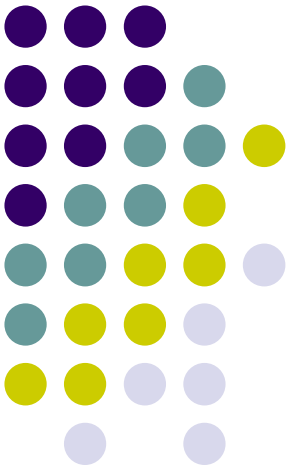
Very Large



Very Small

Powers of Ten Screen Saver.lnk

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



EyeBall Optics

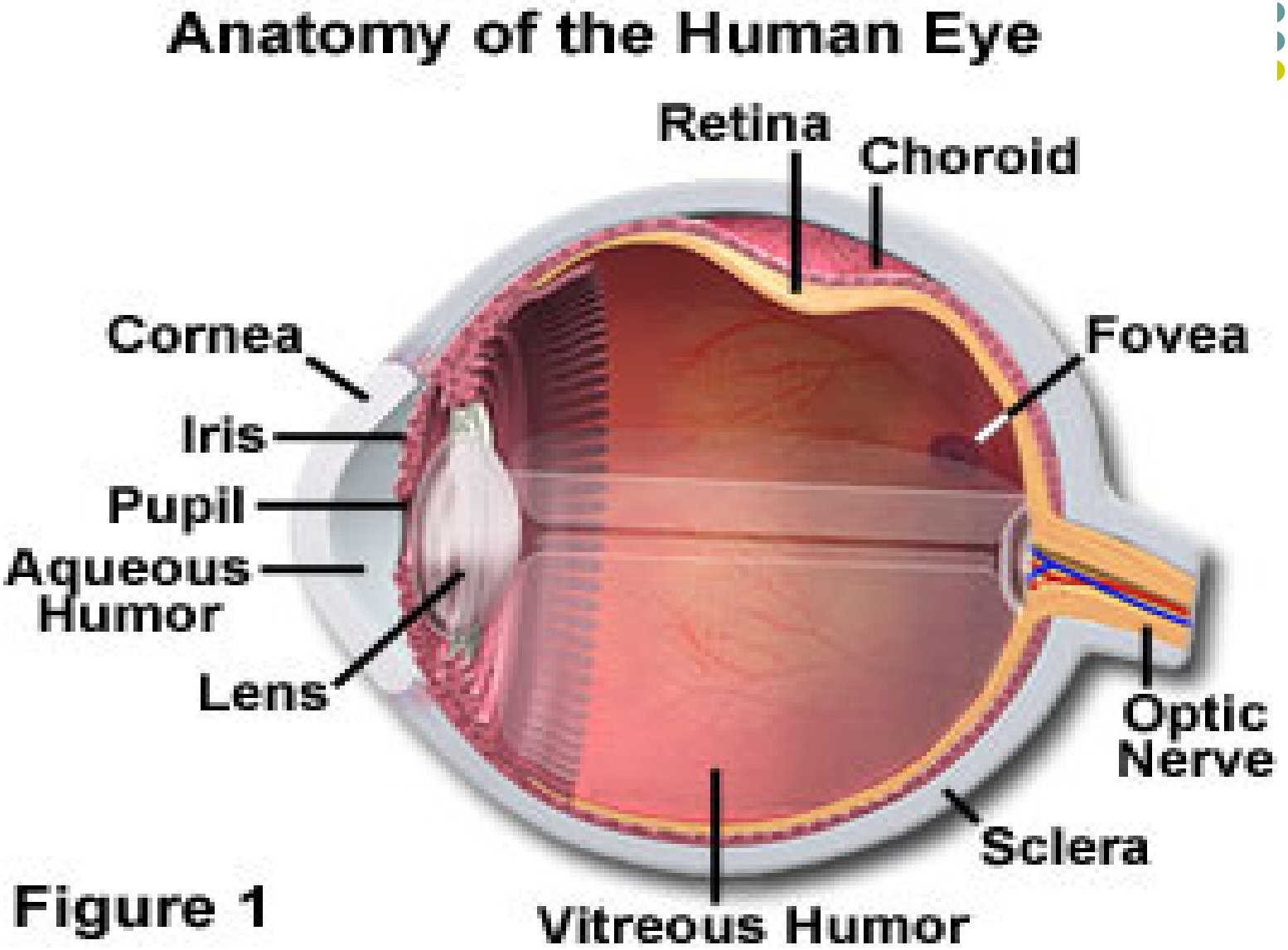
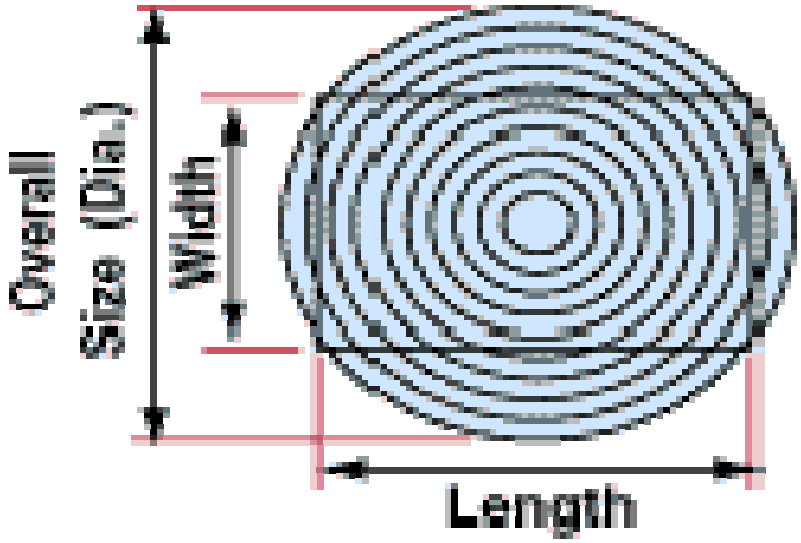
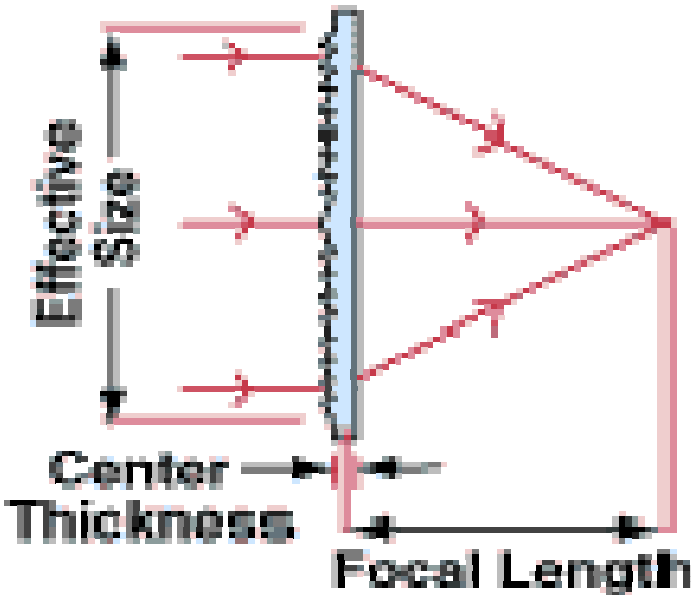


Figure 1

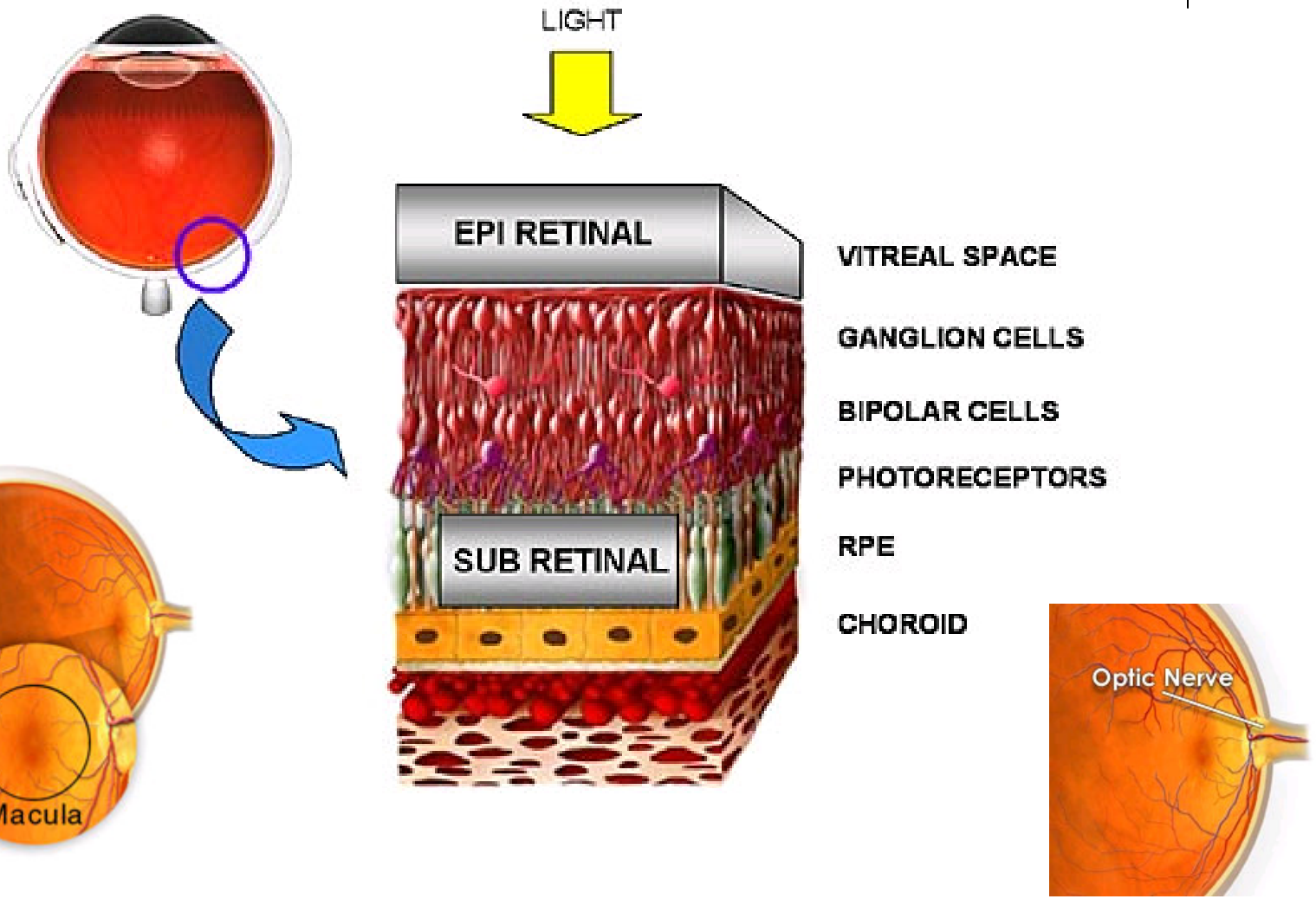
What's a Fresnel Lens Anyway?



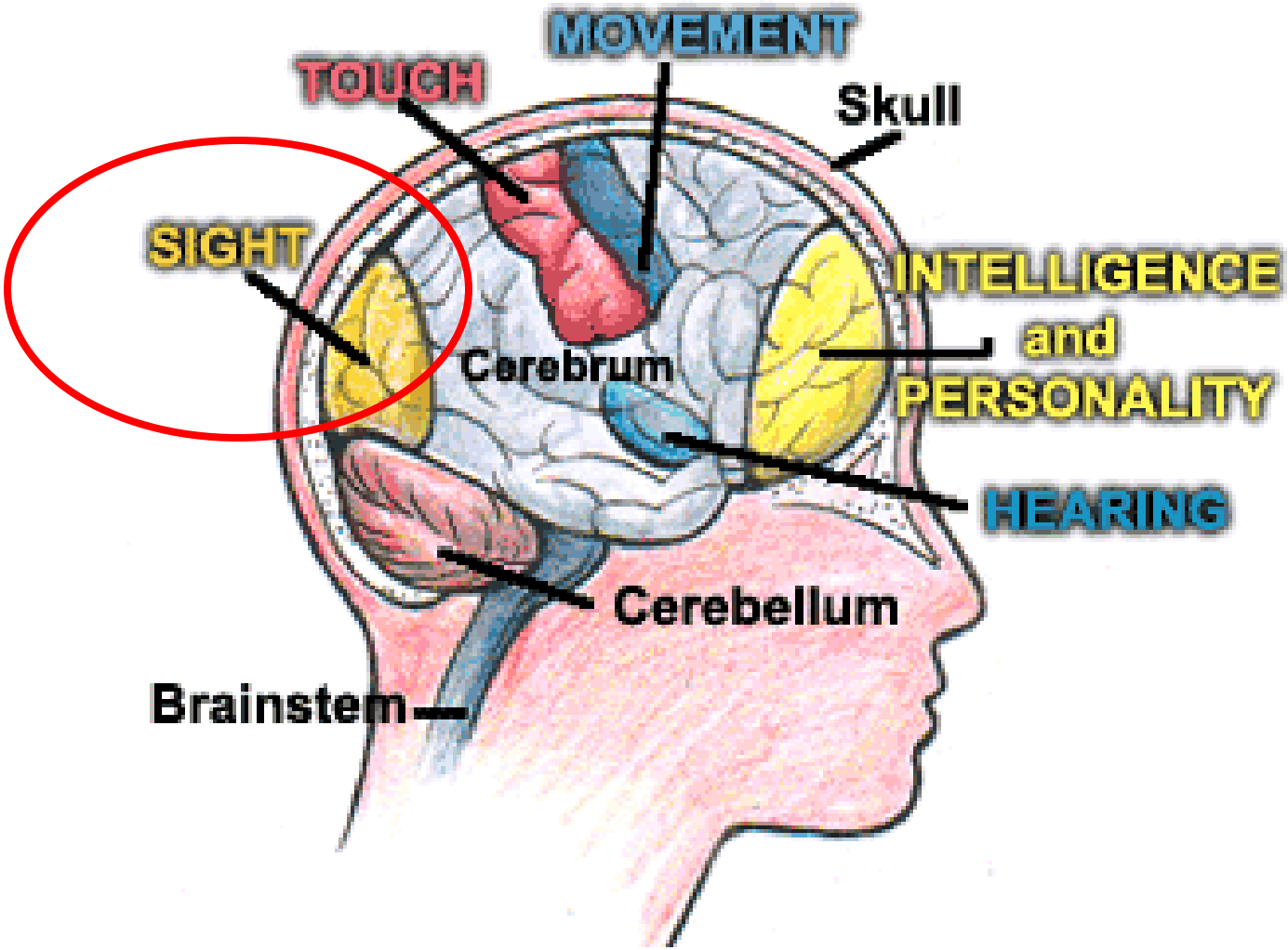


Aberration Examples with overhead projector.

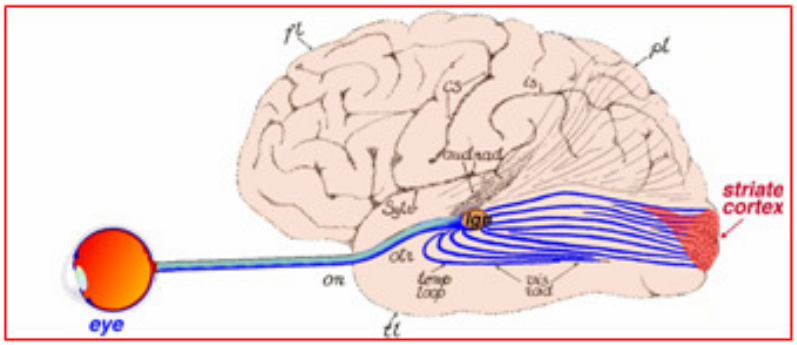
The Retina as a Detector

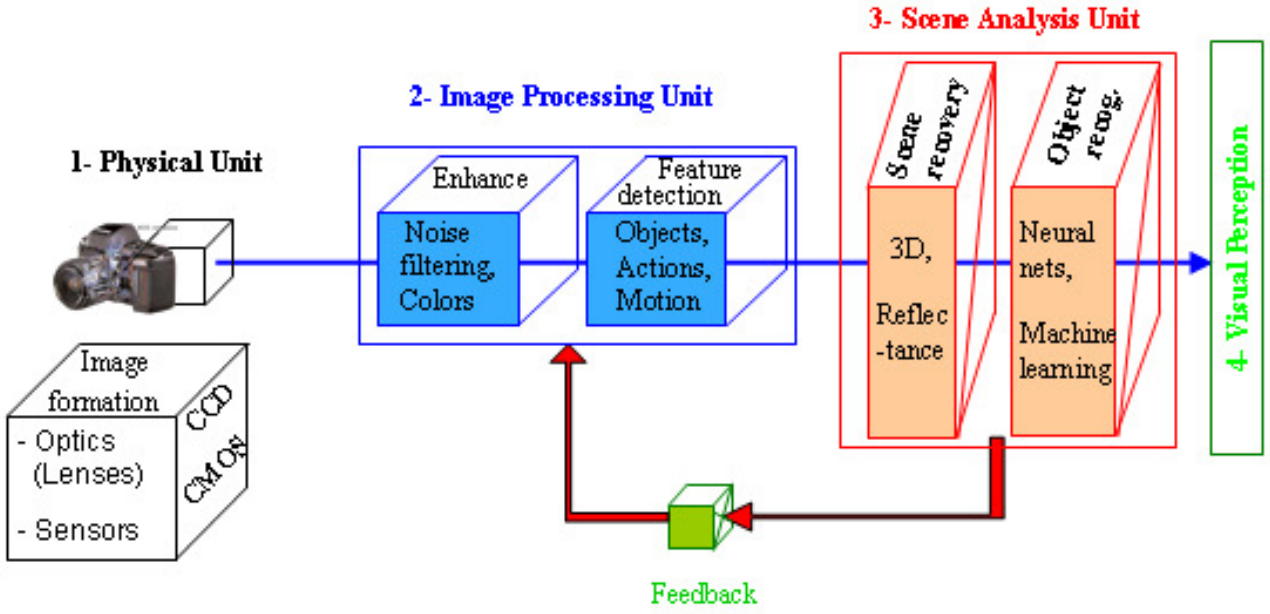


The Brain as a Computer



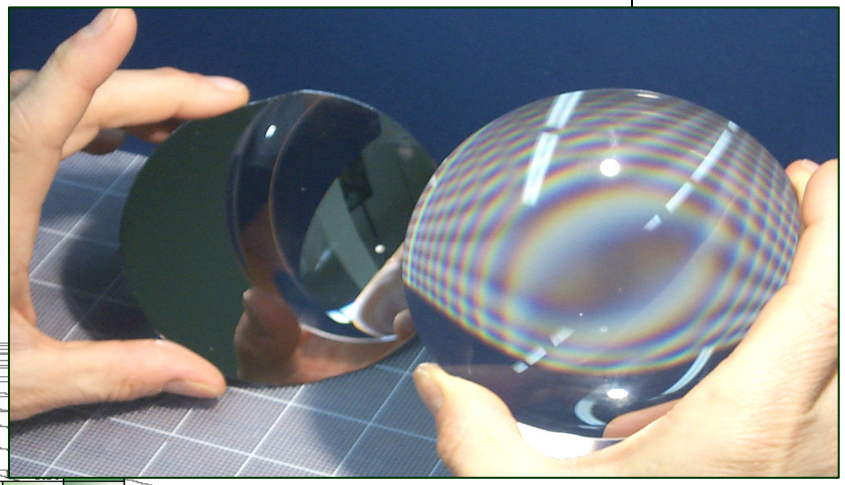
Part II – How Do We "Interpret" the World we "See" Around Us?



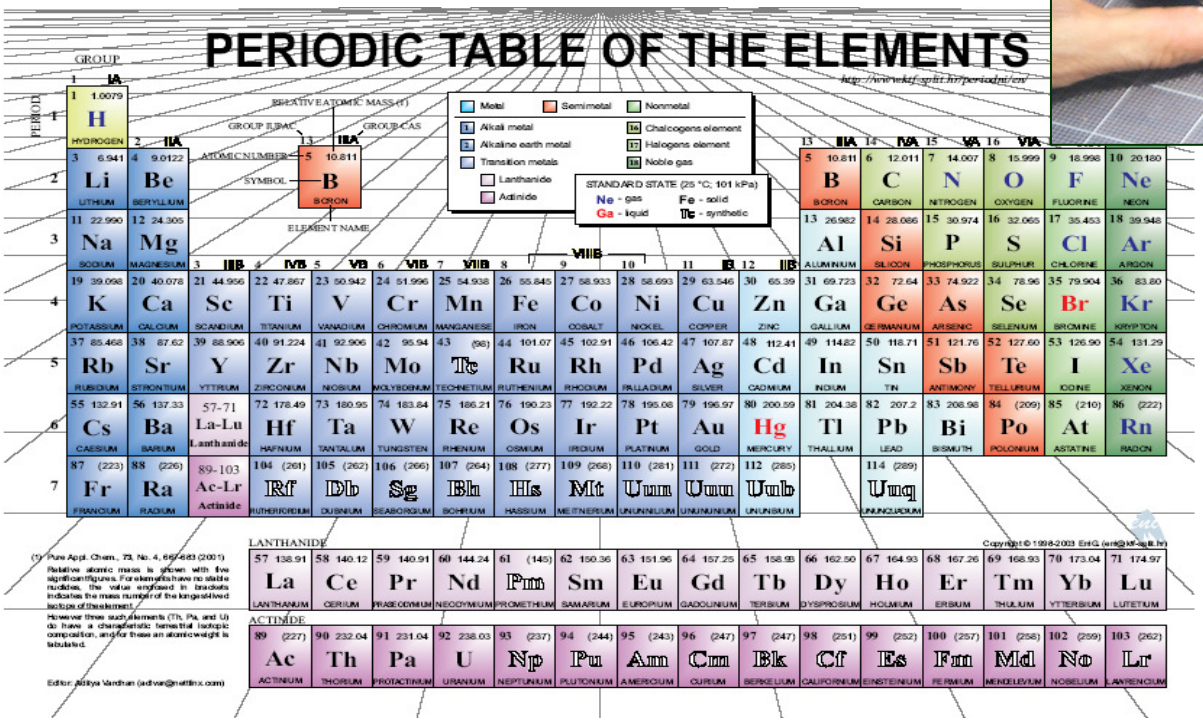


Stages of Computer Vision, Copyright ©2005 F. Keymoux

Optical Engineers Work with Materials That Reflect or Transmit Light



Si – polished silicon wafer
mirror-like reflector

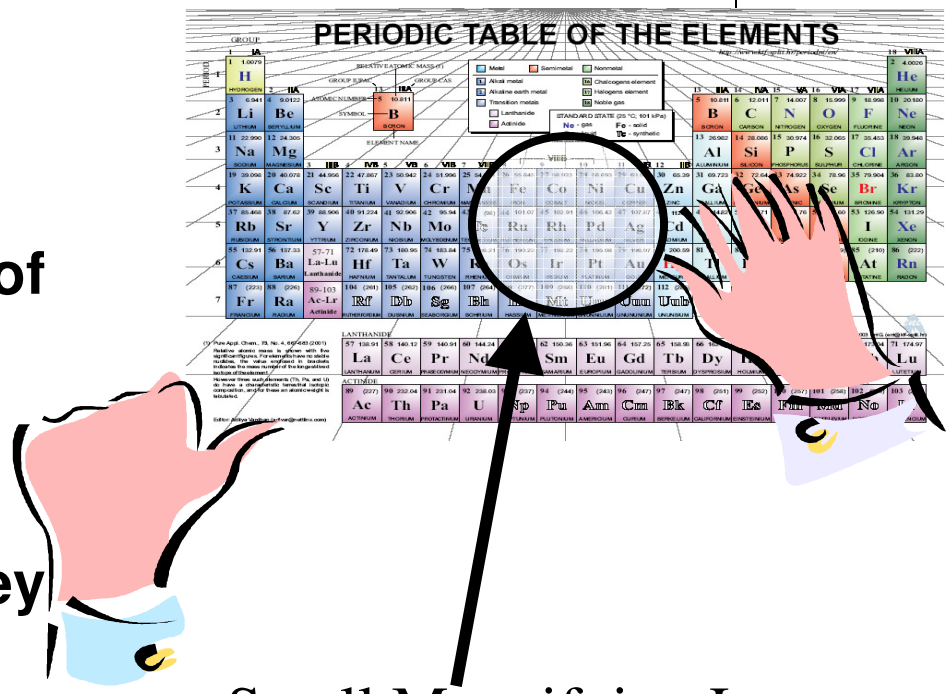


SiO_2 – clear silica lens
focuses light

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??**

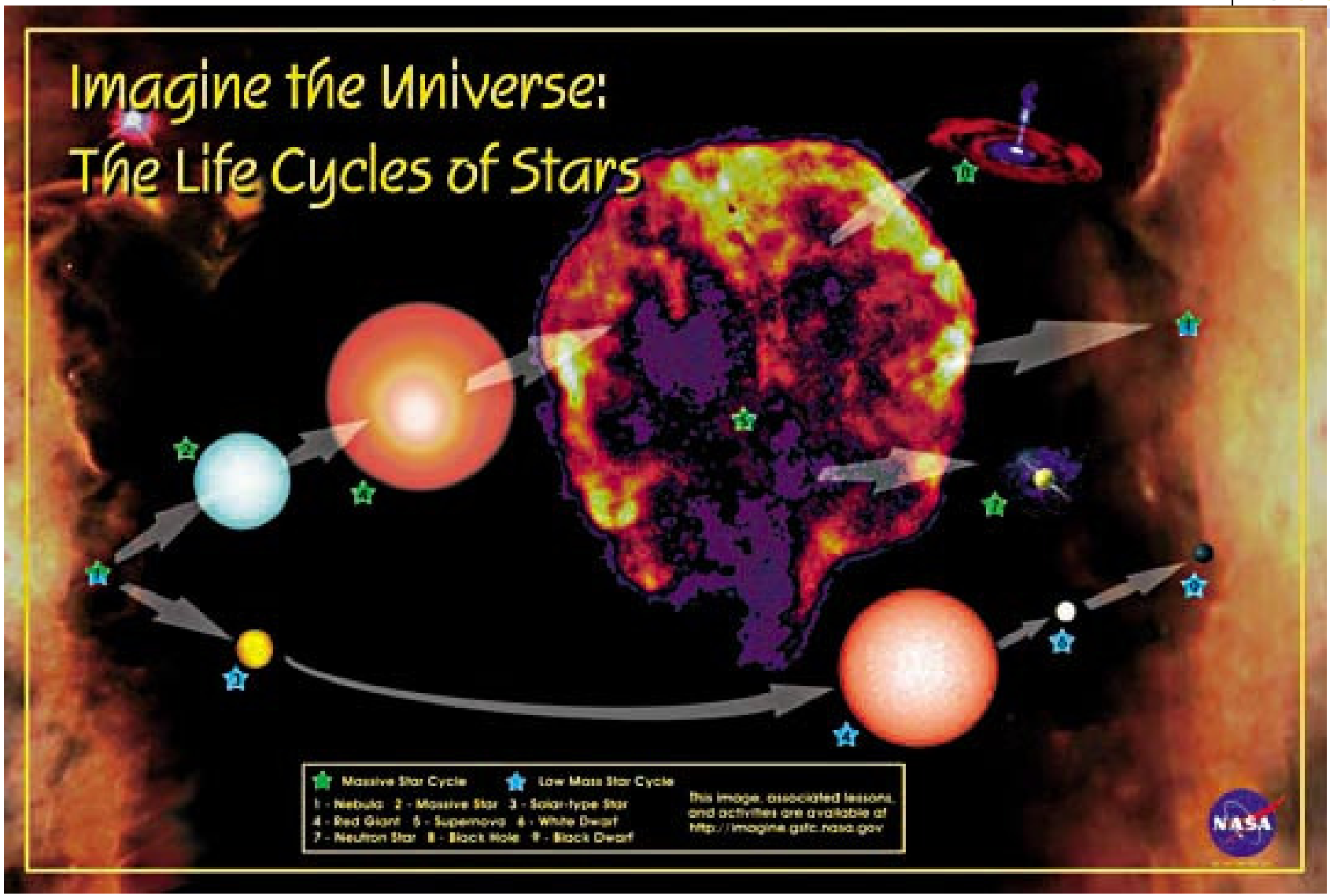


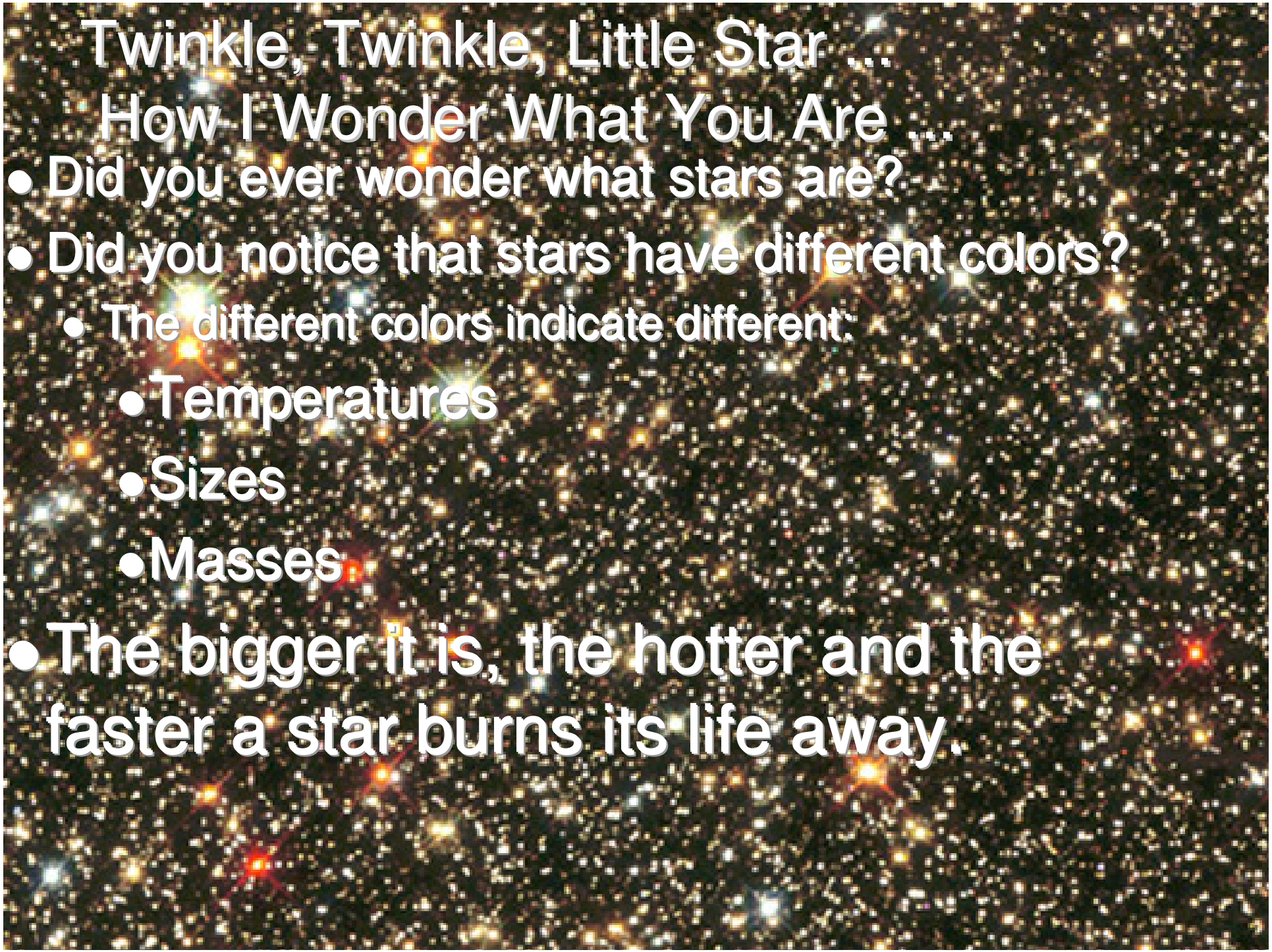
Small Magnifying Lens

Hold the lens about 1 inch above the paper.

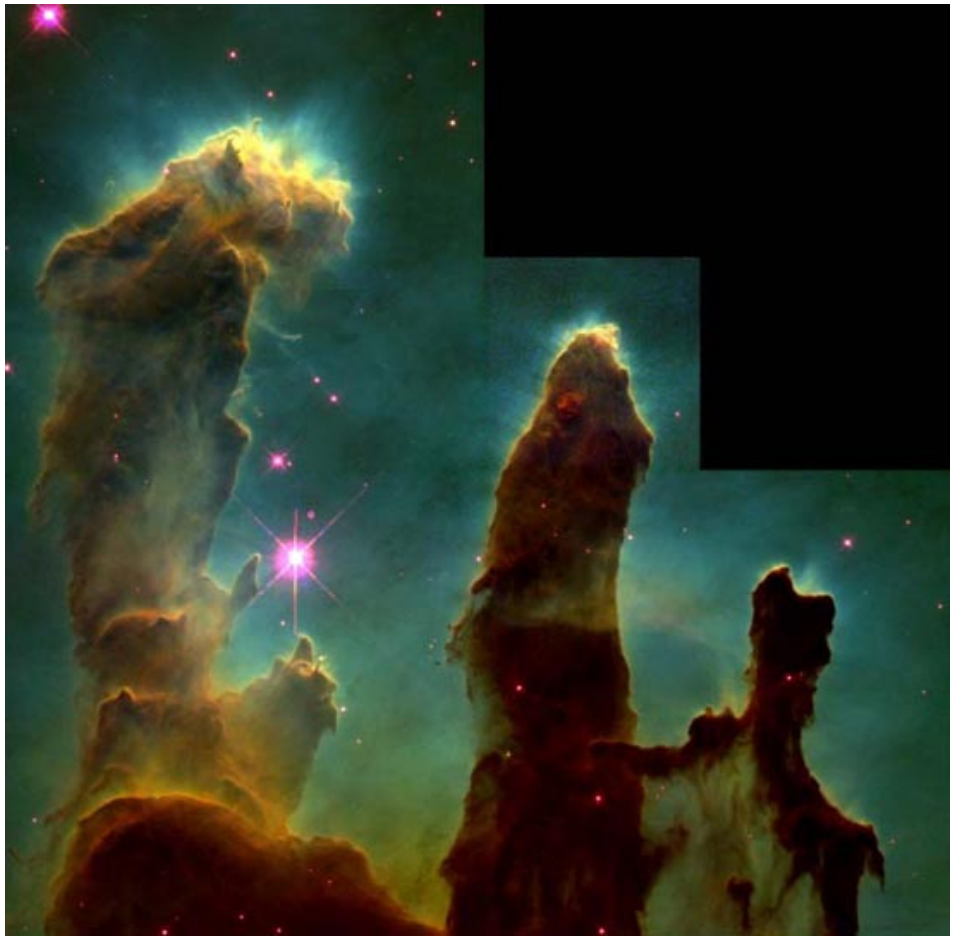
We'll come back to this Periodic Table of Elements a bit later!!!

What Color is That Star? Why?




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

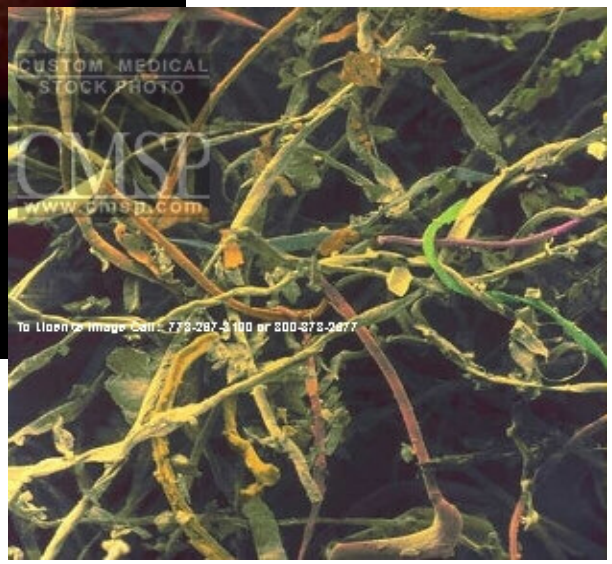


Space is filled with the stuff to make stars.

Stars start from clouds

Clouds provide the gas and dust from which stars form.

But not this kind of dust

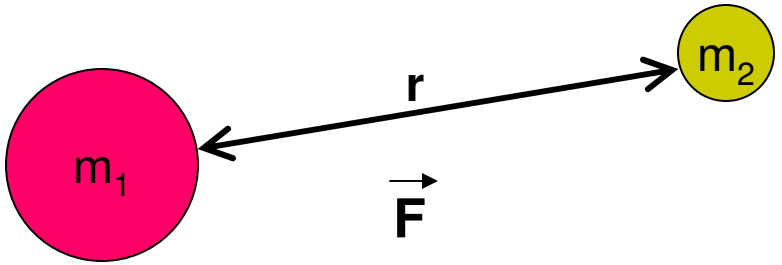


Rather: Irregular Grains
Of Carbon or Silicon

Collapse to Protostar

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

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

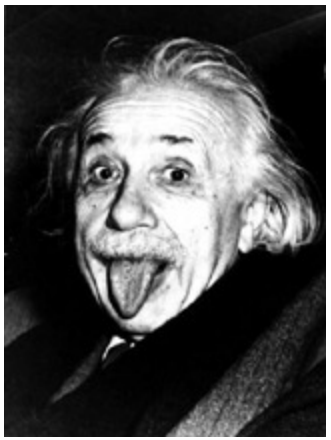


- Contraction causes Temperature and Pressure to slowly increase.

"G" is the universal gravitational constant!!

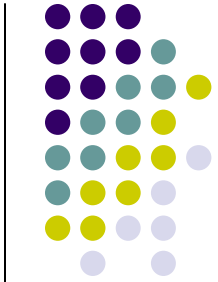
Nuclear Fusion !

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



$E = mc^2$

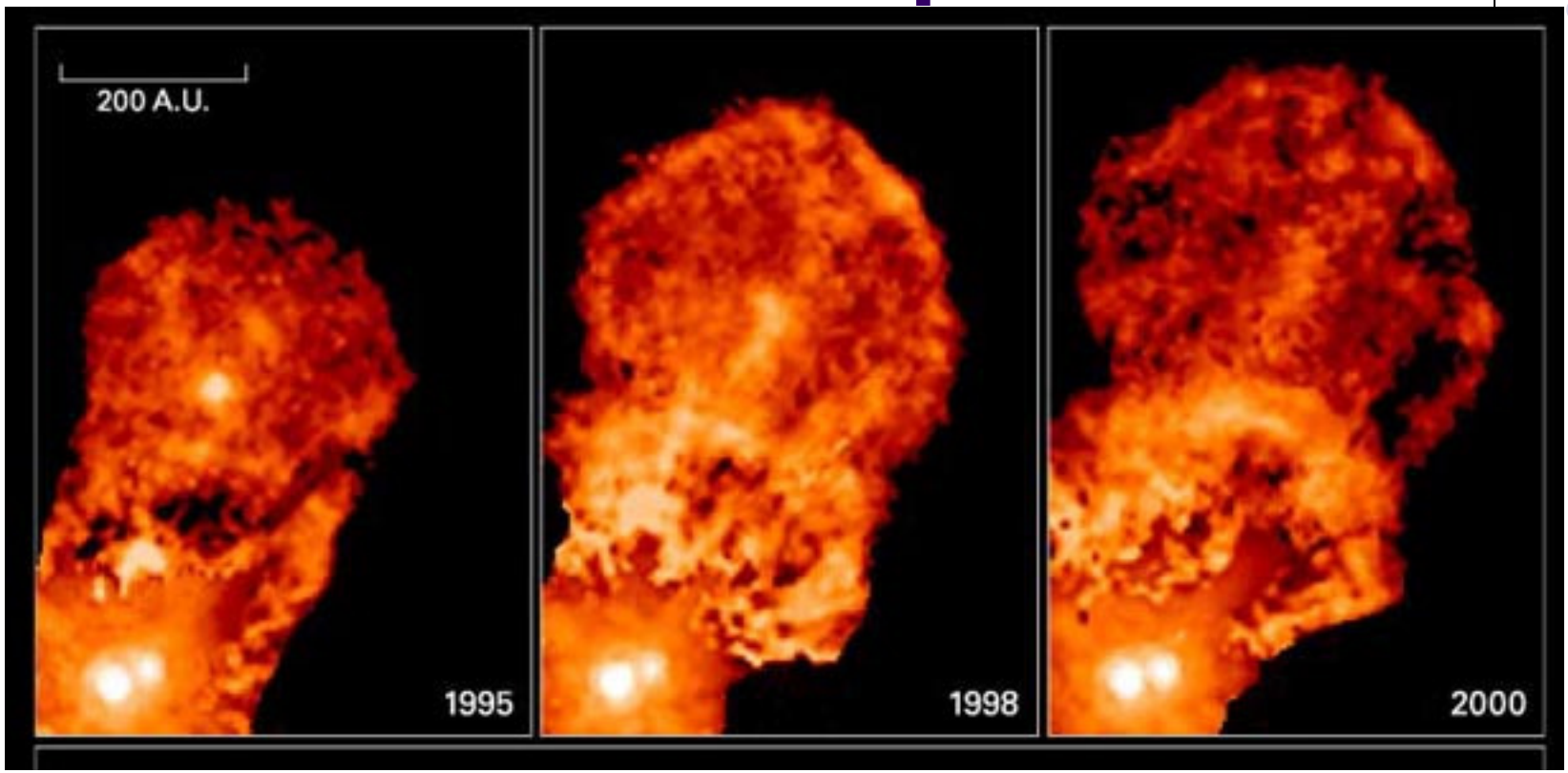
A Balancing Act



- Energy released from nuclear fusion counter-acts inward force of gravity.

- Throughout its life, these two forces determine the stages of a star's life.

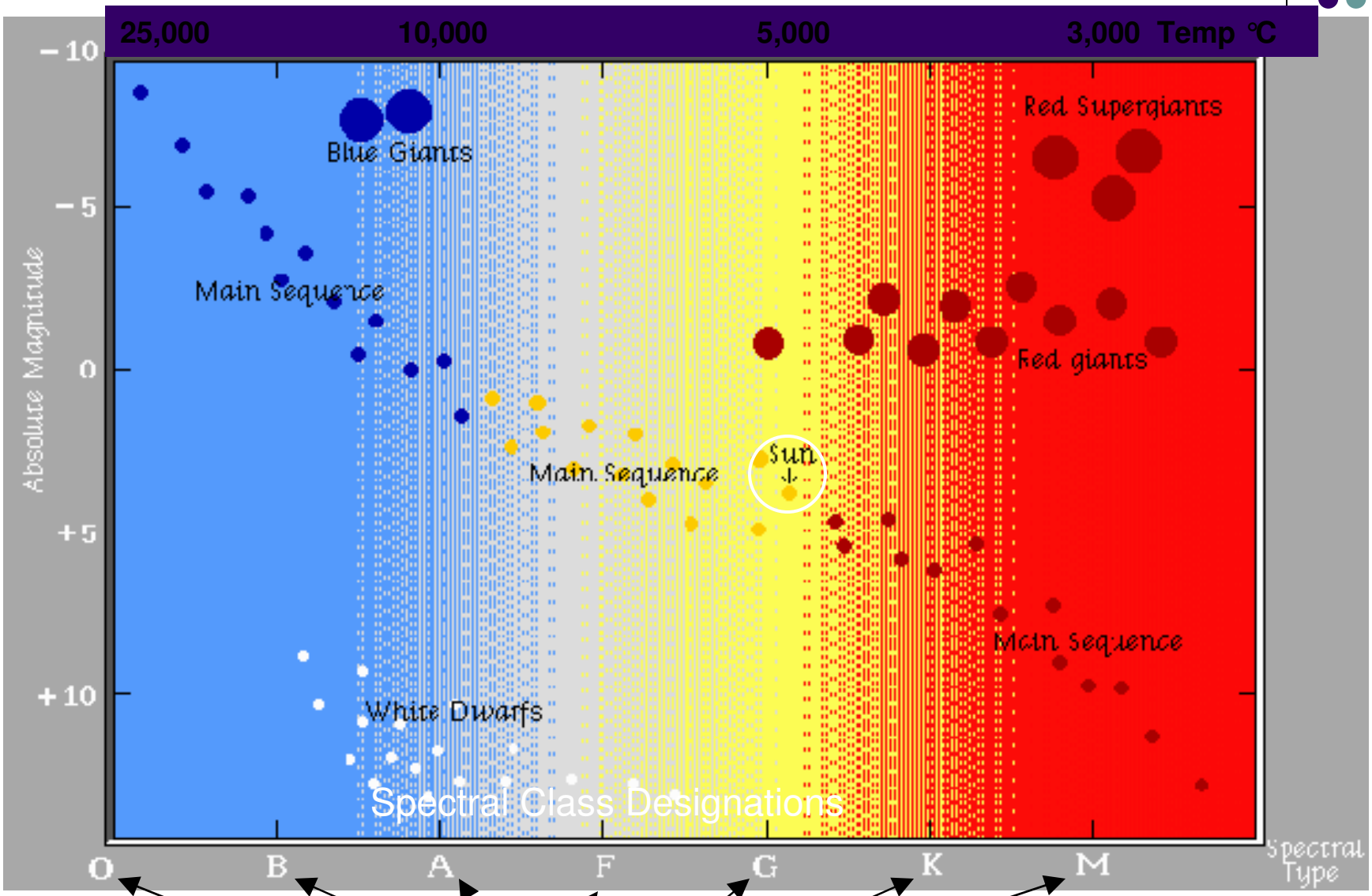
New Stars are not quiet !



Expulsion of gas from a young binary star system

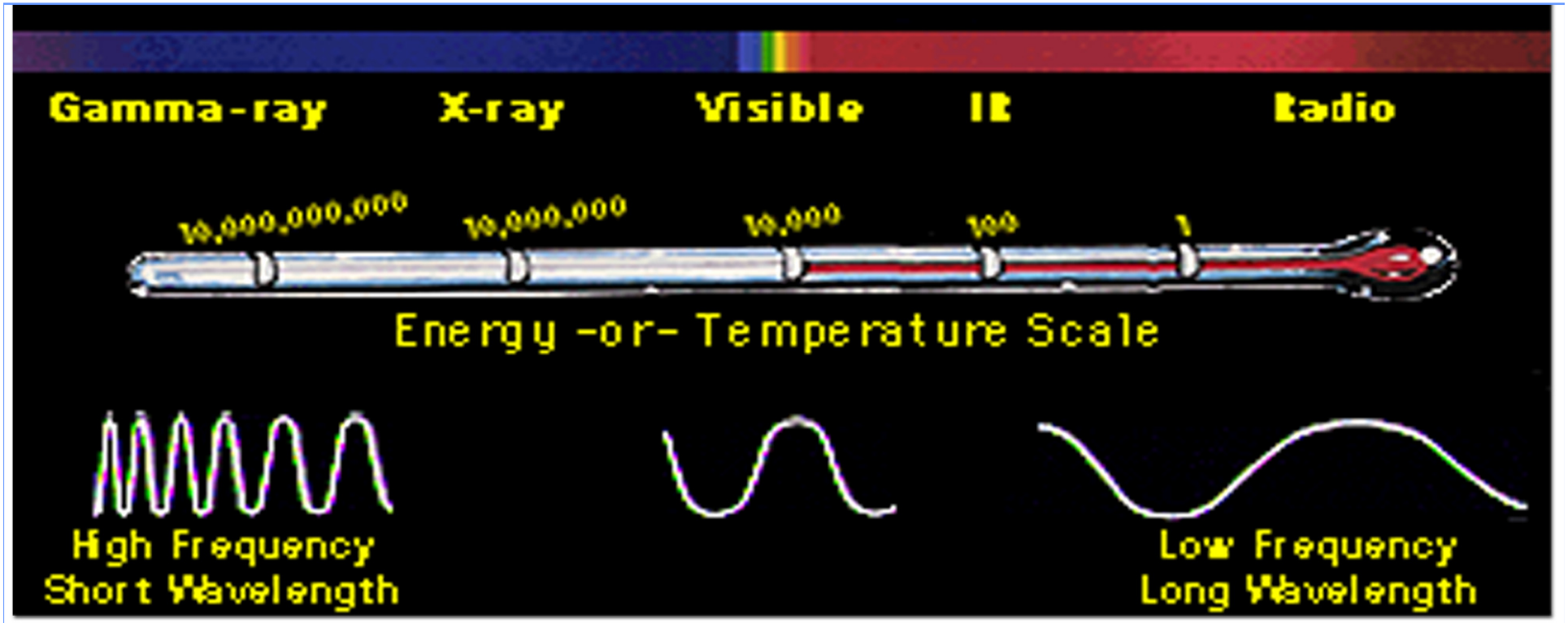
All Types of Stars – Different Colors

Hertzsprung – Russell Diagram



Oh! Be A Fine Girl - Kiss Me !

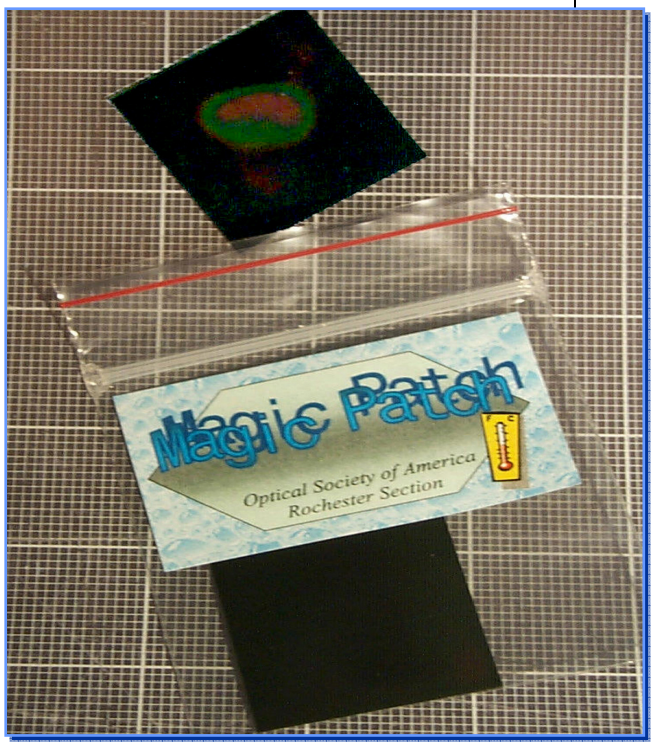
LIGHT - Electromagnetic Spectrum

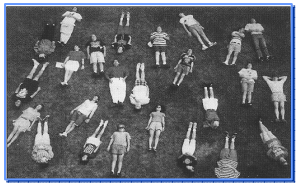


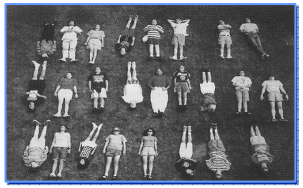
The electromagnetic spectrum. Radio has long wavelengths and low energies, while gamma rays have very short wavelengths and high energies.

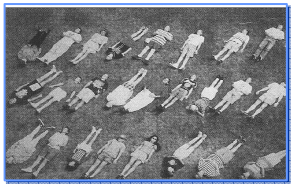
Magic Patch (temperature data vs. color)

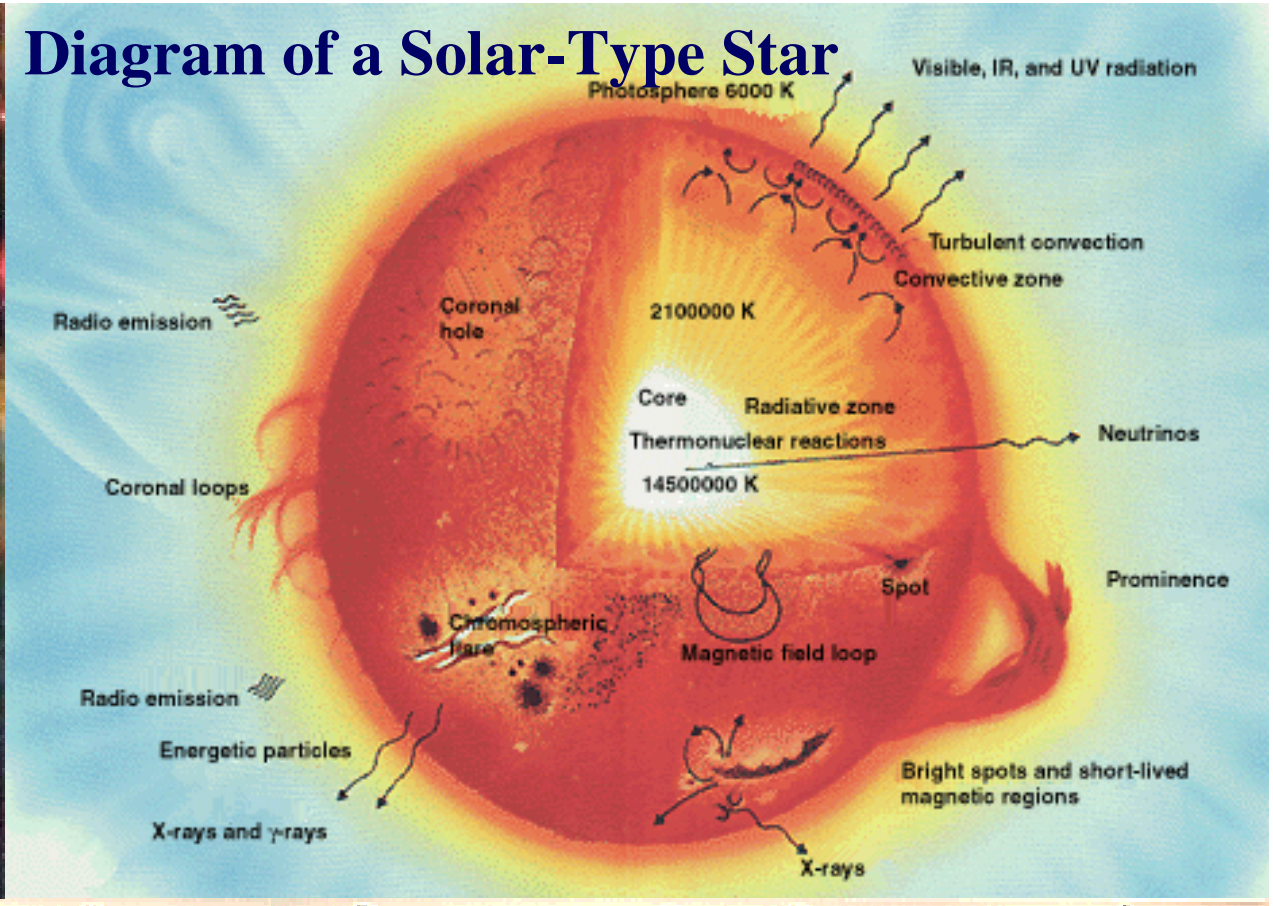
- Place the patch on your wrist and perform the “vampire test.”
- The “*Magic Patch*” changes color with the heat from your body. The “living dead” give off no heat!
- Where do the colors come from?
- Does anyone see a vein or artery?
- This is an example of “selective reflection” by liquid crystals, 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.

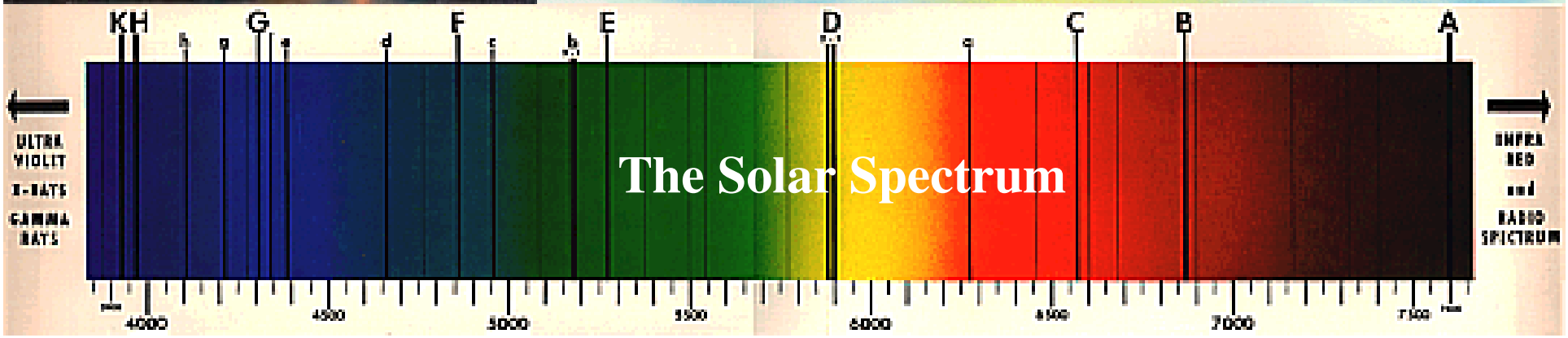






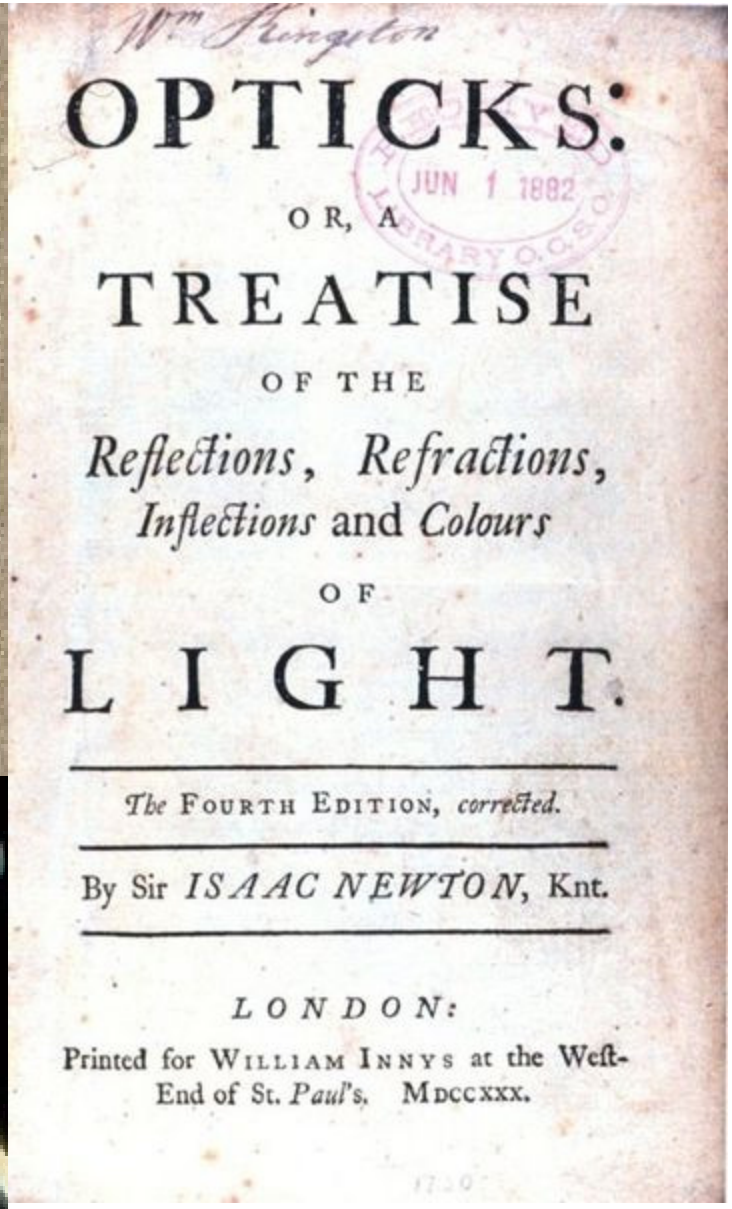






The Optics Institute

of Southern California



Wm Pickering

OPTICKS:

OR, A

TREATISE

OF THE

Reflections, Refractions, Inflections and *Colours*

OF

L I G H T.

The FOURTH EDITION, *corrected.*

By Sir *ISAAC NEWTON*, Knt.

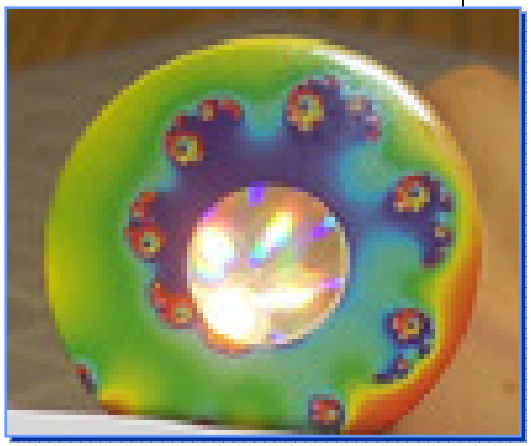
LONDON:

Printed for WILLIAM INNYS at the West-End of St. *Paul's*. MDCCXXX.

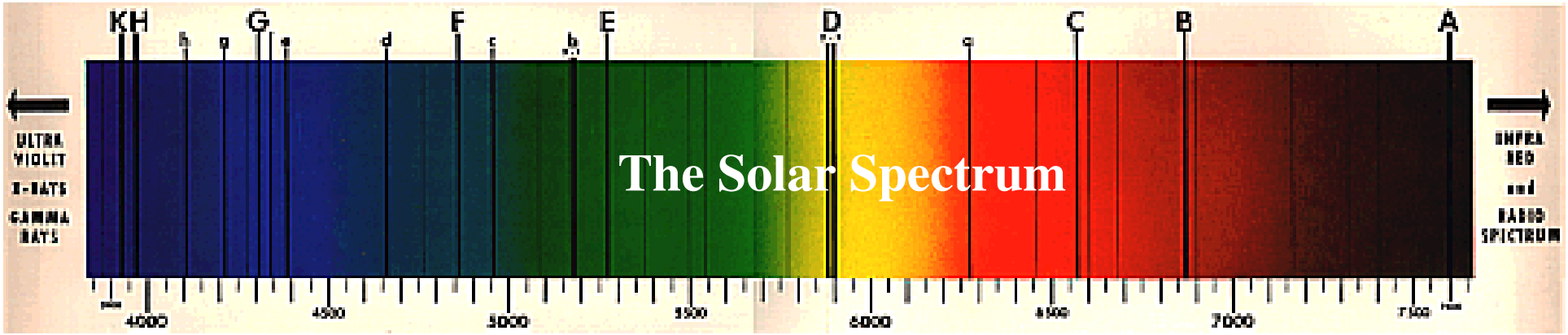
Rainbow Peephole®

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.

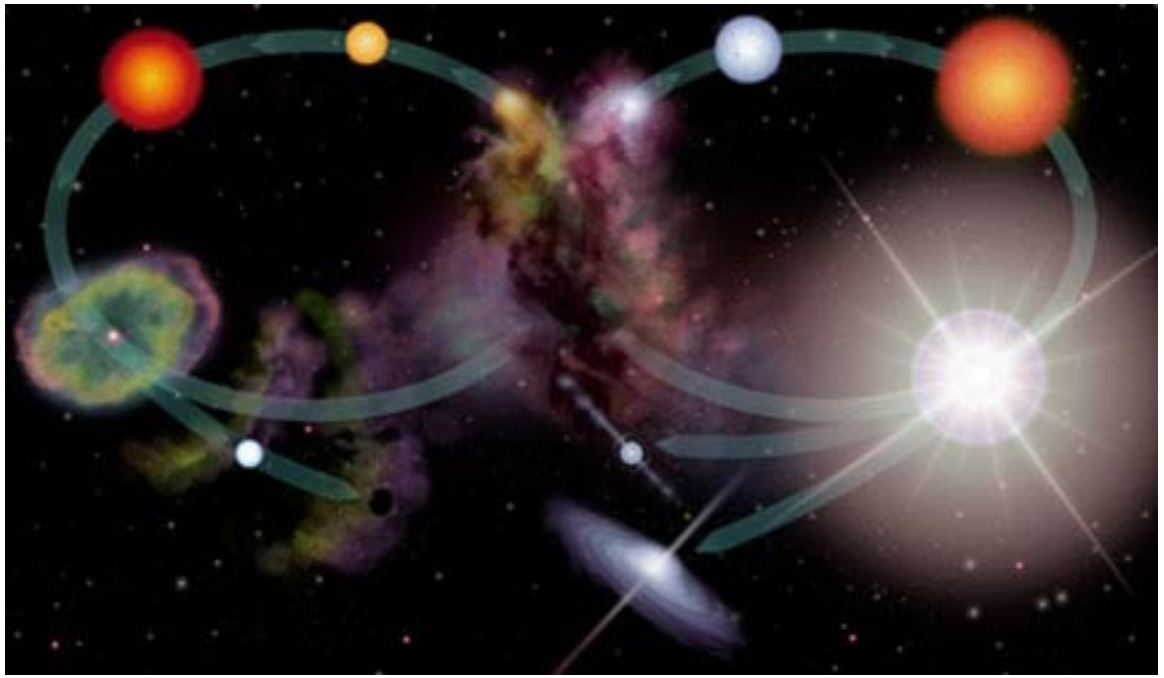


UV
X-Ray
Cosmic

Visible

IR
Radio

Reprise: the Life Cycle

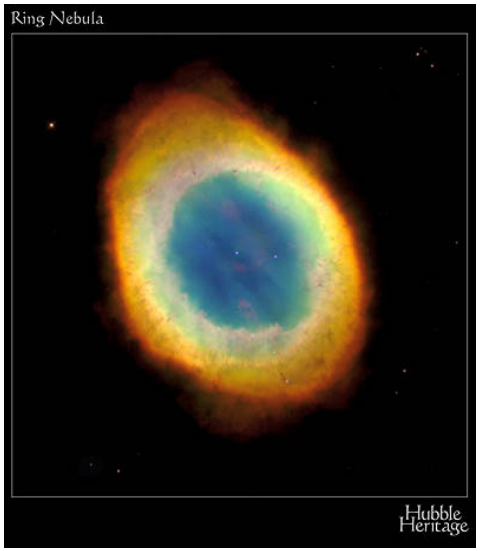


Sun-like Stars

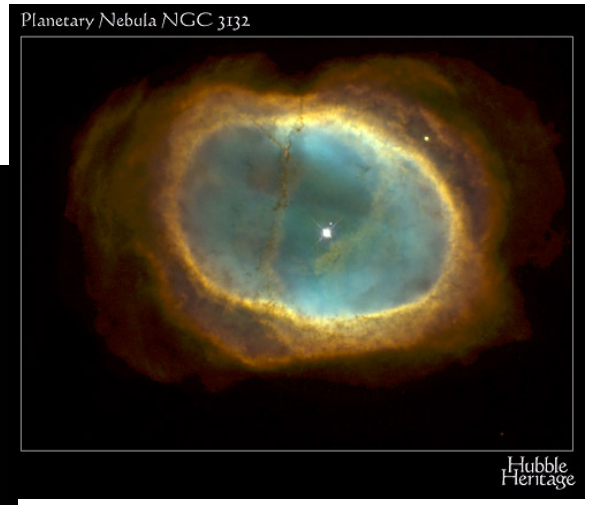
Massive Stars

The end for solar type stars

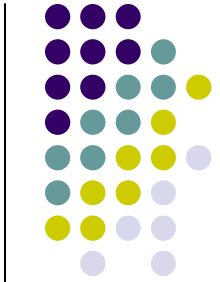
After Helium exhausted, outer layers of star expelled



Planetary Nebulae

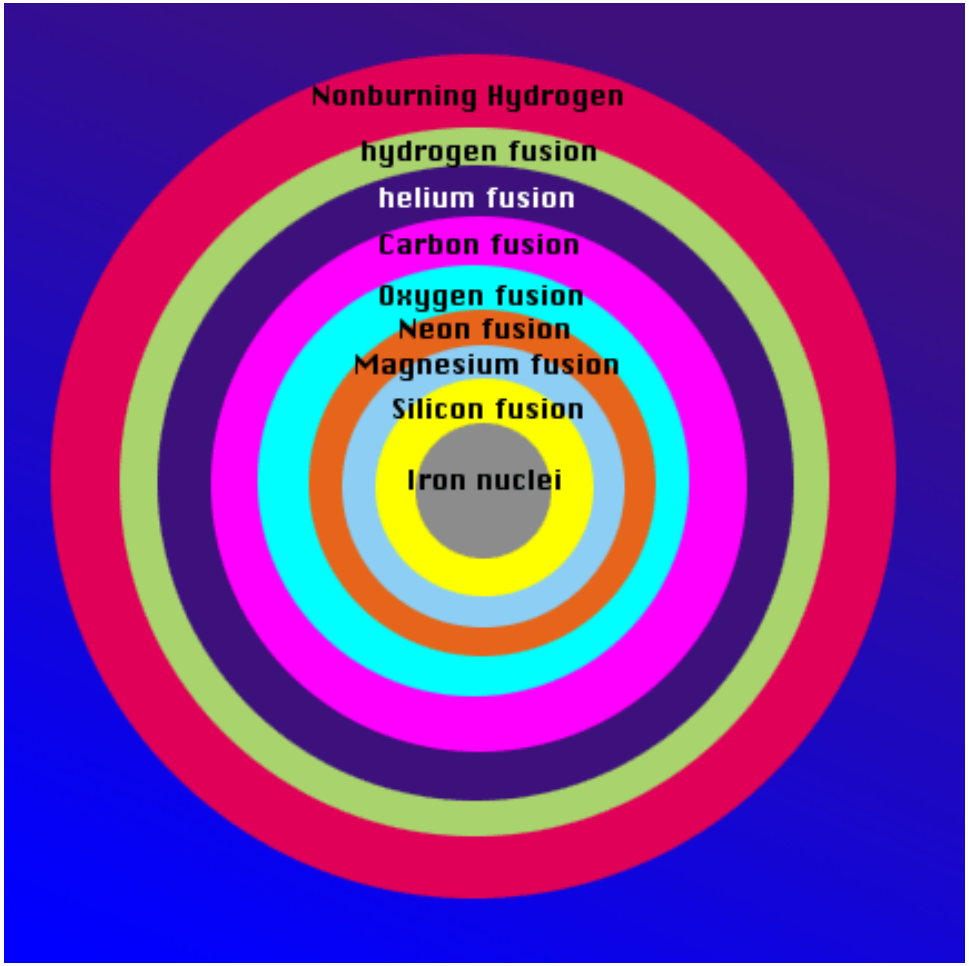


White dwarfs



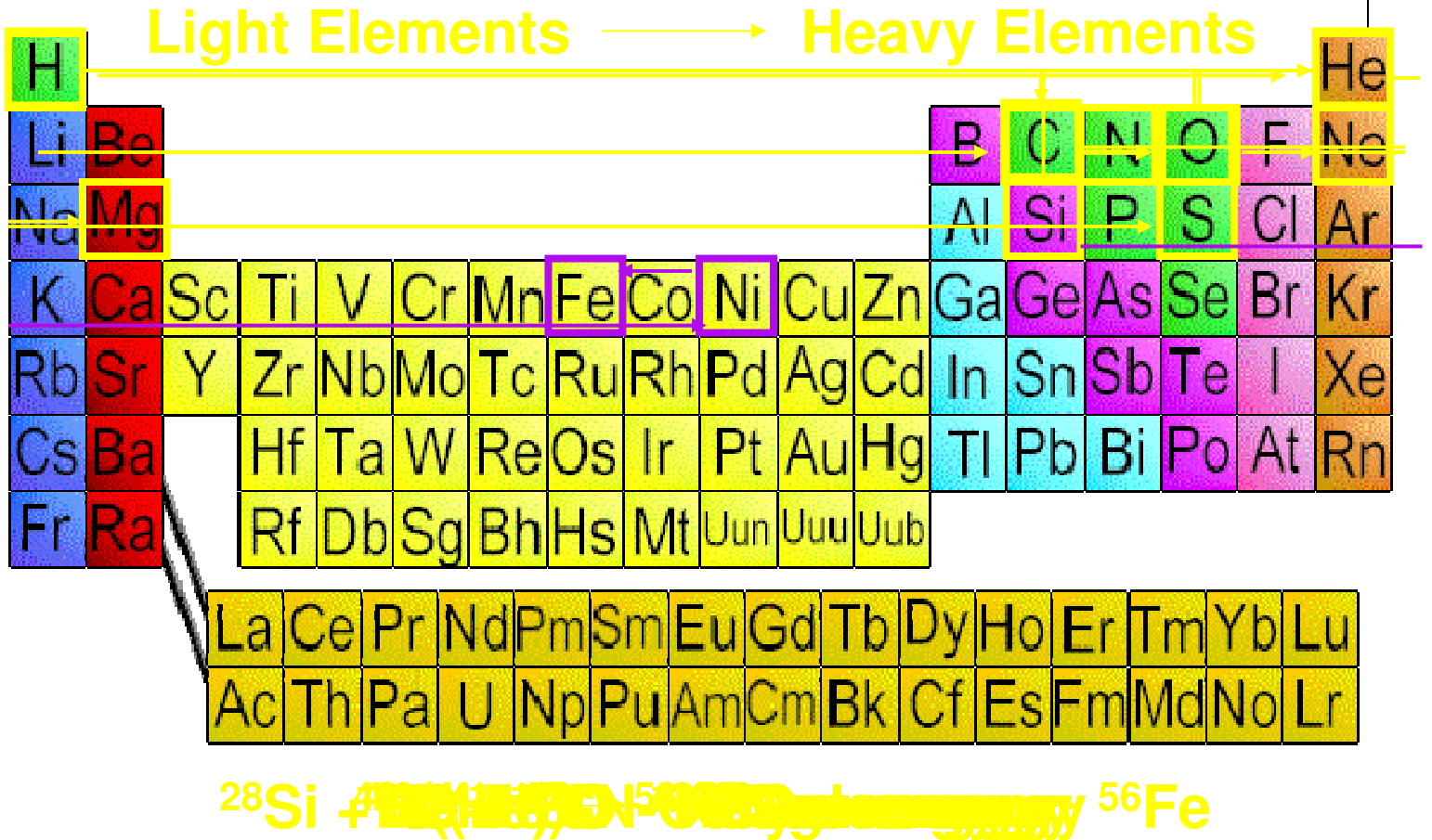
- At center of Planetary Nebula lies a
- White Dwarf.
- Size of the Earth with Mass of the Sun "A ton per teaspoon"
- Inward force of gravity balanced by repulsive force of electrons.

The End of the Line for Massive Stars

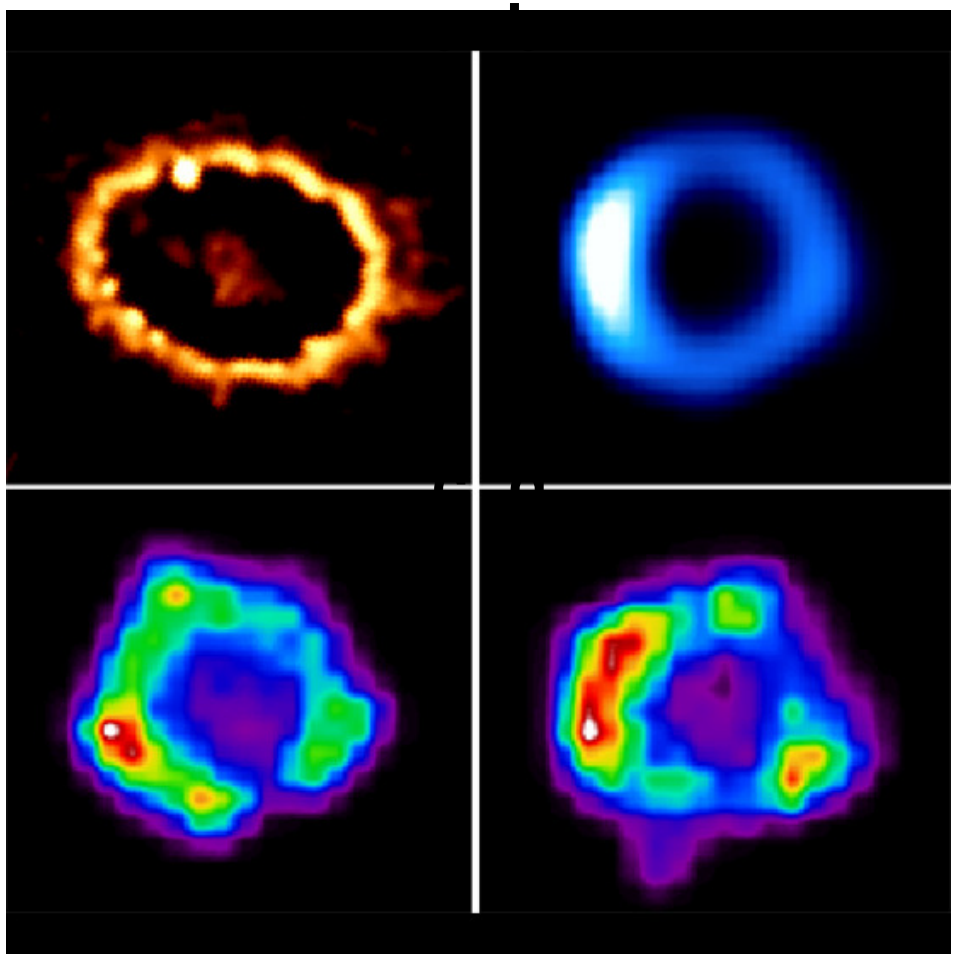


- Massive stars burn a succession of elements.
- Iron is the most stable element and cannot be fused further.
  - Instead of releasing energy, it uses energy.

Periodic Table



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

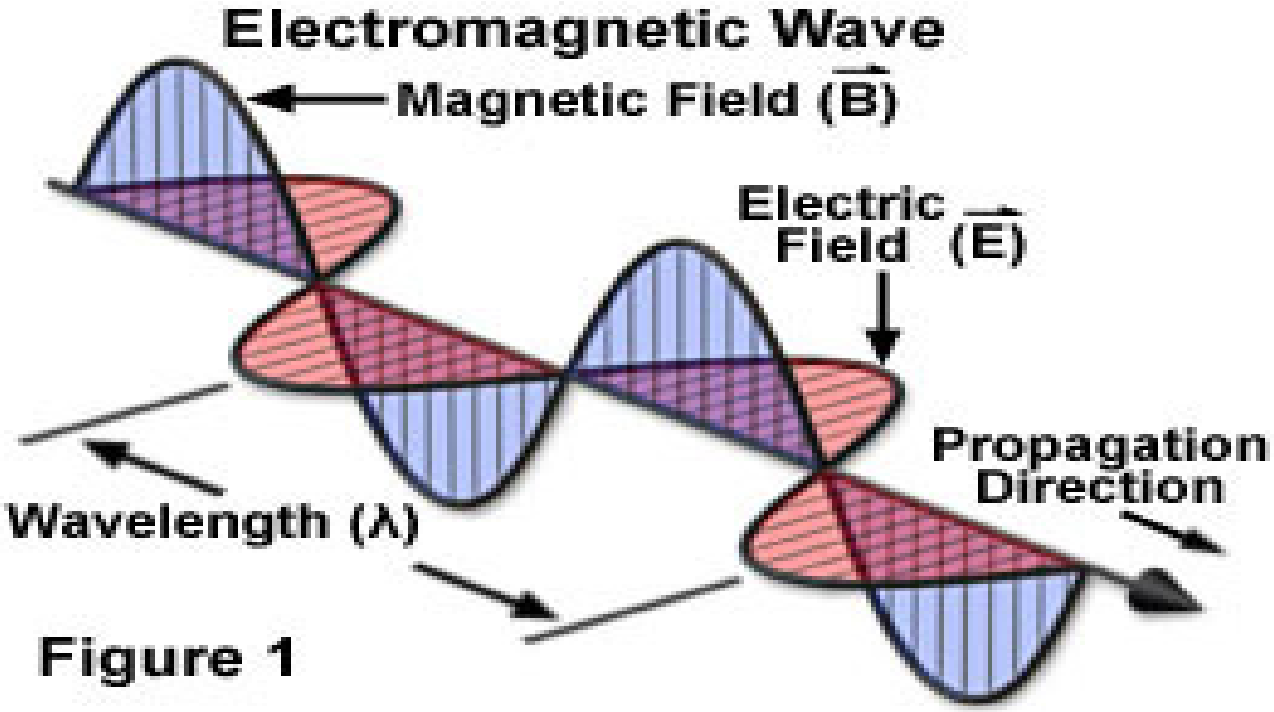
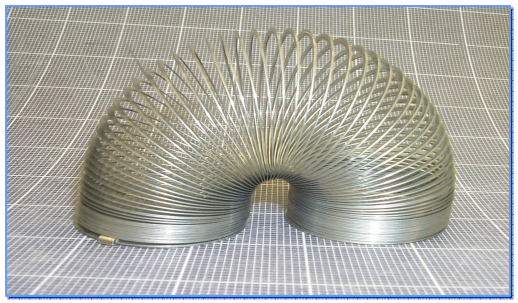
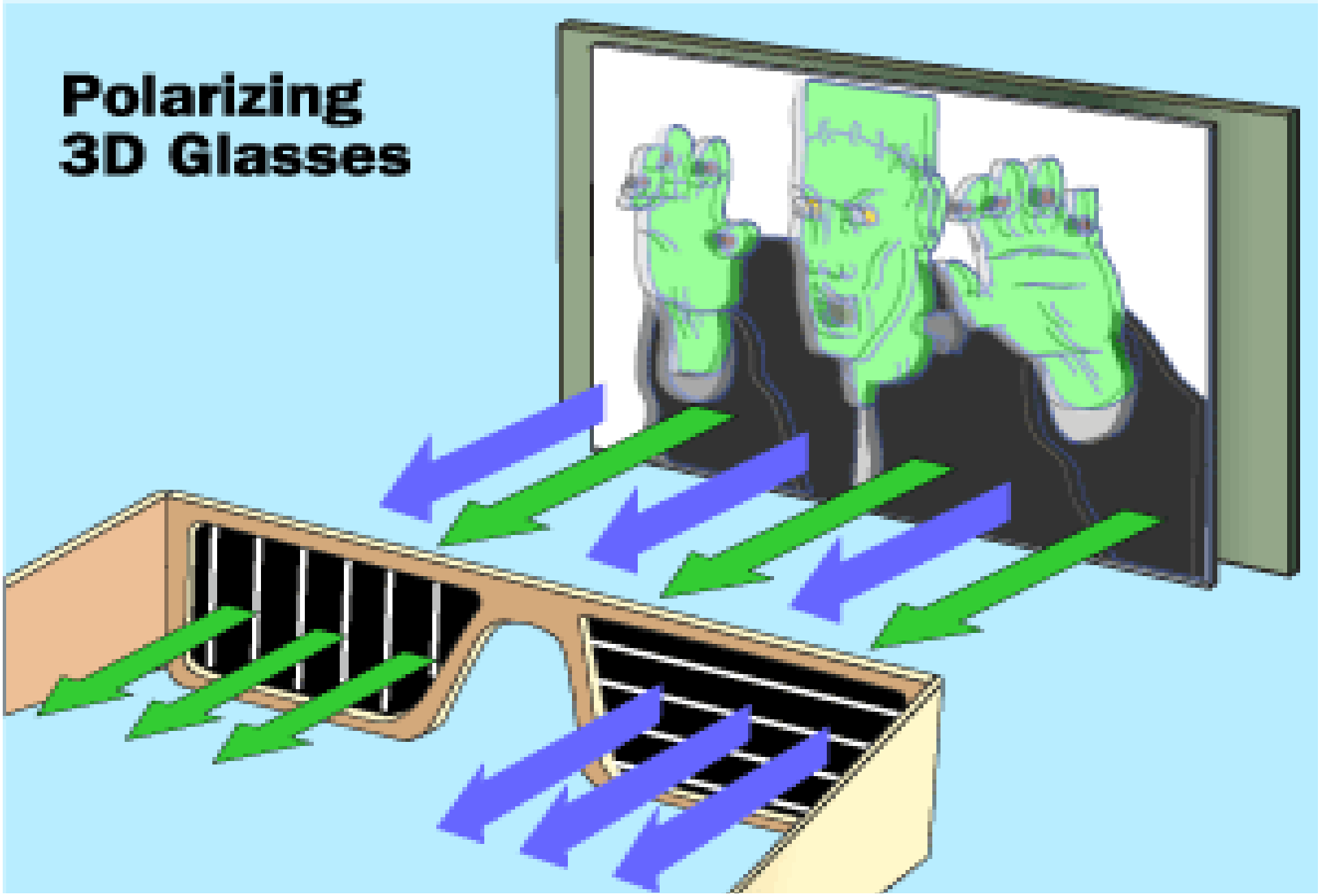


Figure 1



Slinky

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



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

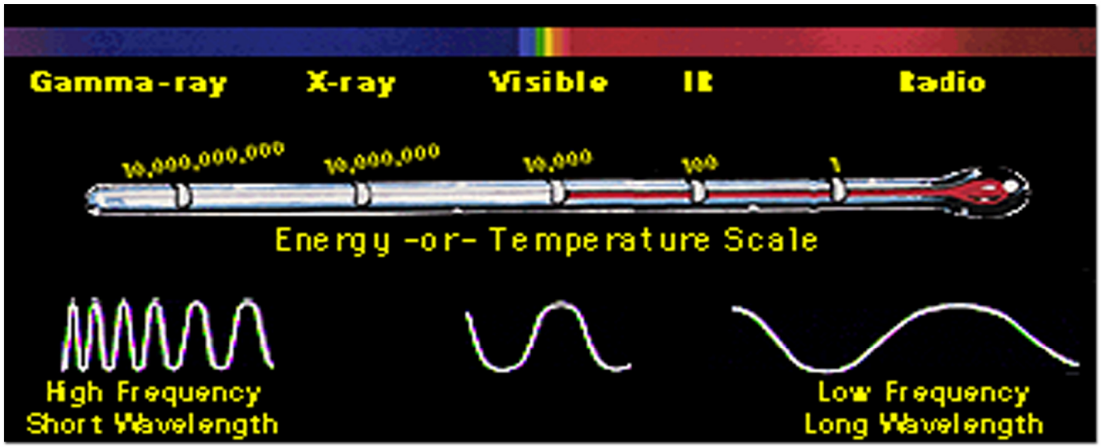
Polarization of Light

- 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

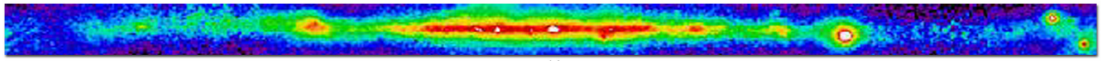
Why we need different types of telescopes to look at outer space

SPACE SCIENCE NEWS
science.nasa.gov
Marshall Space Flight Center



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

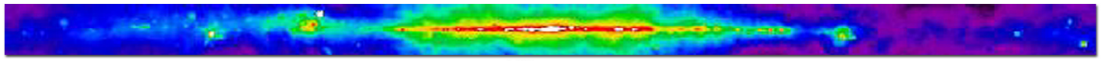
The Multi-Wave Milky Way Galaxy



radio

infrared

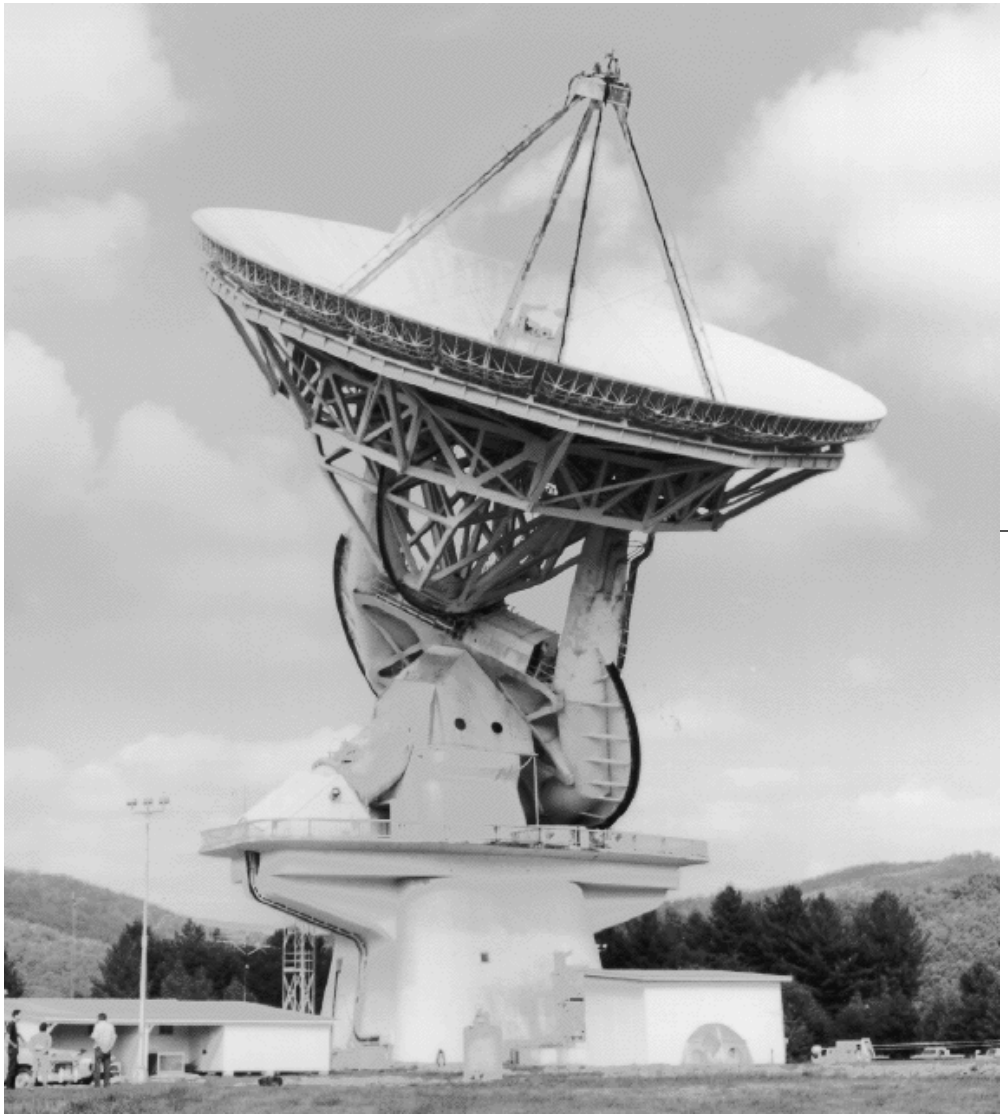
visual



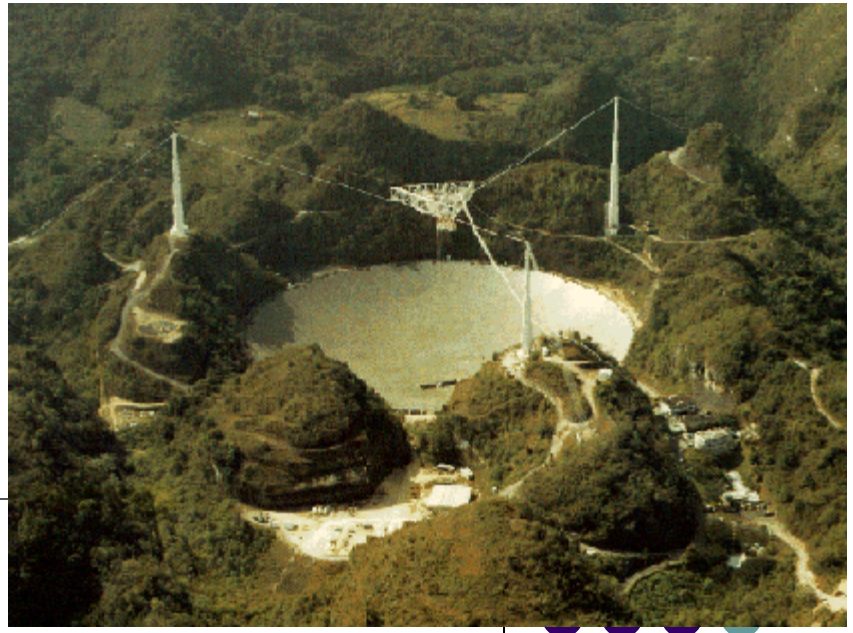
X-ray

gamma ray

http://science.nasa.gov/newhome/headlines/features/ast20apr99_1.htm



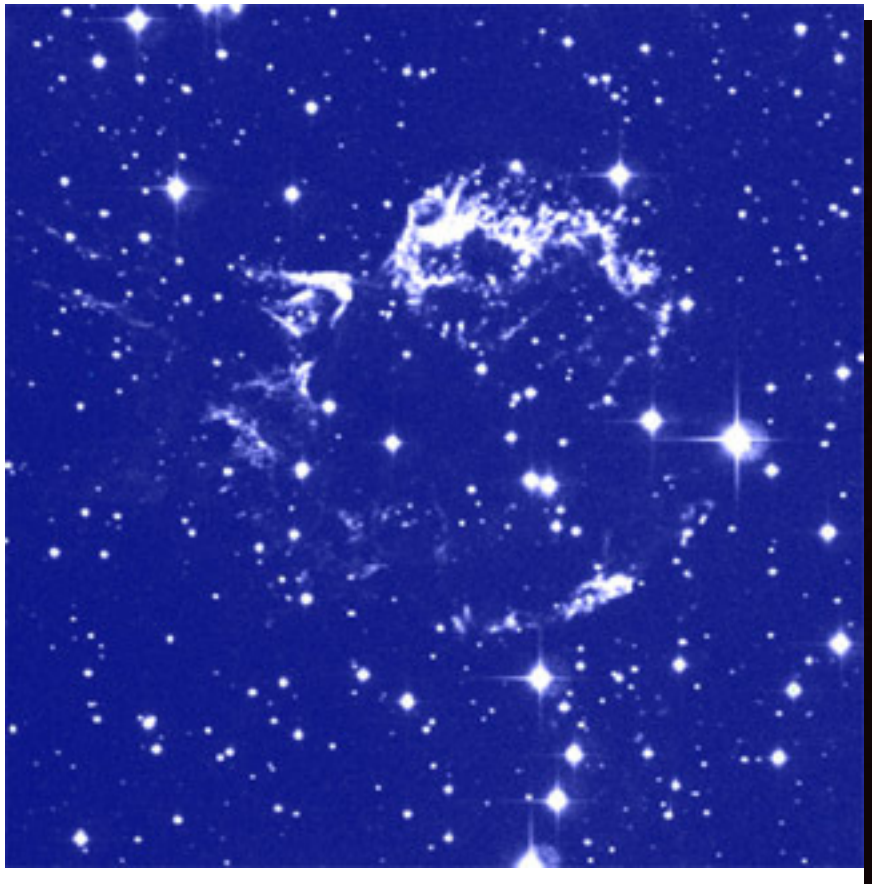
NRAO operates the 140 Foot
Robert C. Byrd Green Bank Radio Telescope



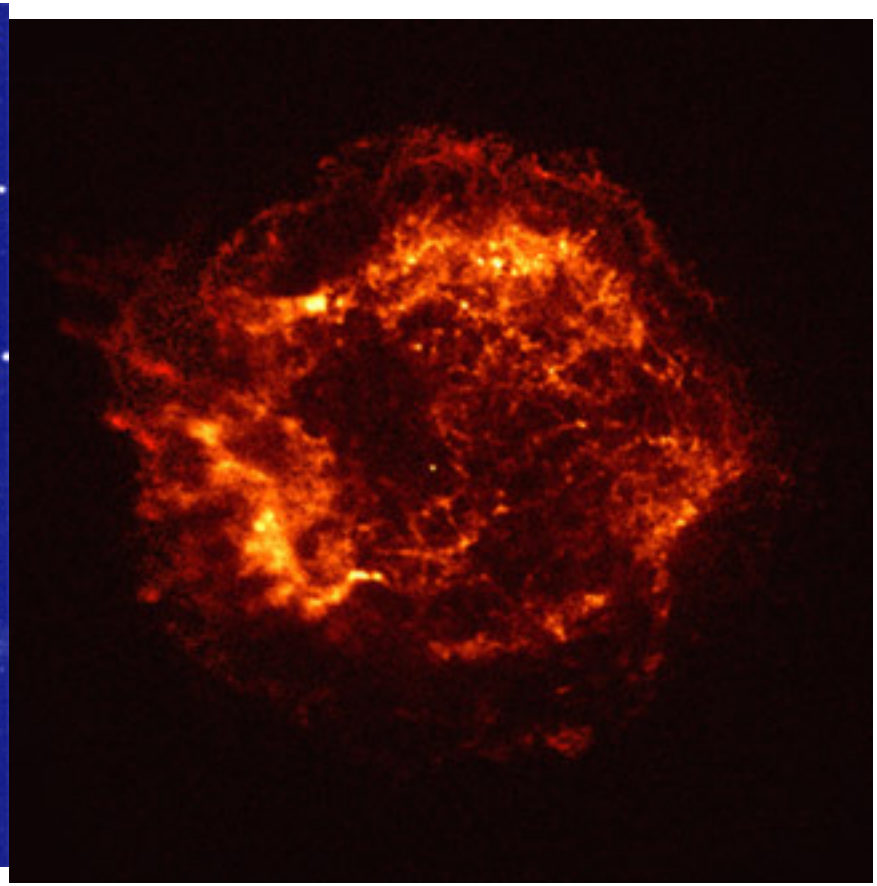
The Arecibo radio telescope is currently the largest single-dish telescope in the world.

Supernova Remnants: Cas A

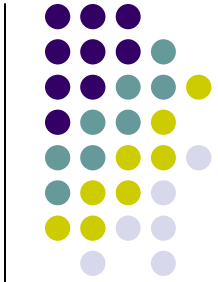
Optical



X-ray



What's Left After the Supernova

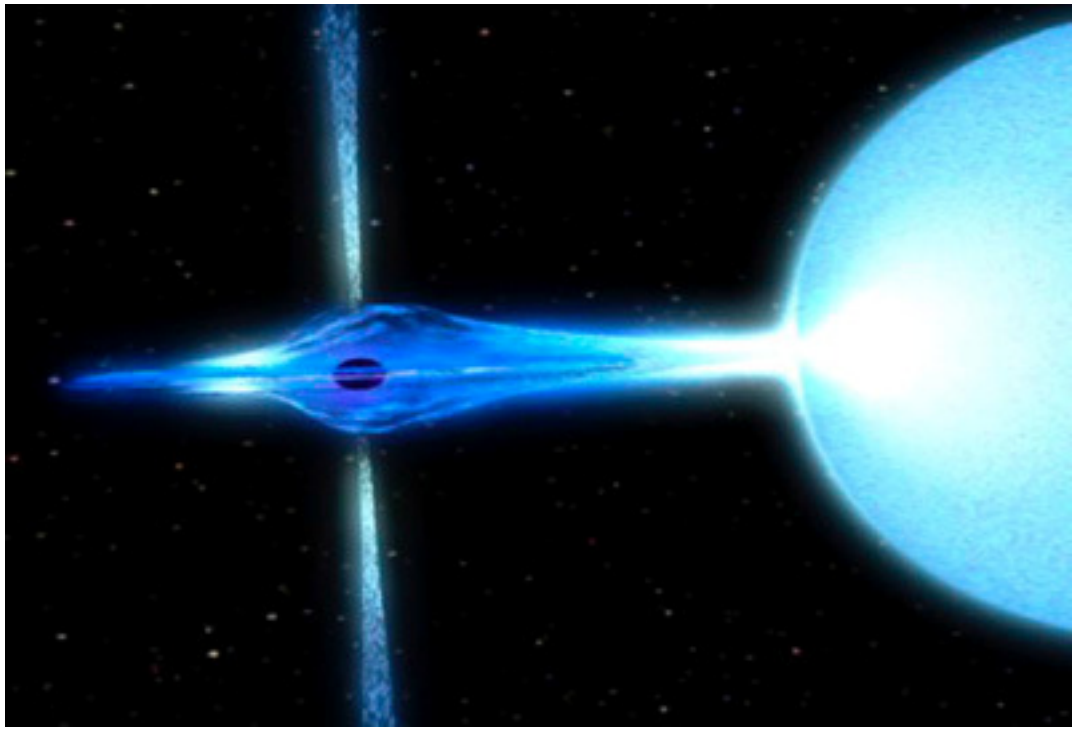


- Neutron Star (If mass of core < 5 x Solar)
- Under collapse, protons and electrons combine to form neutrons.
- 10 Km across

- Black Hole (If mass of core > 5 x 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.

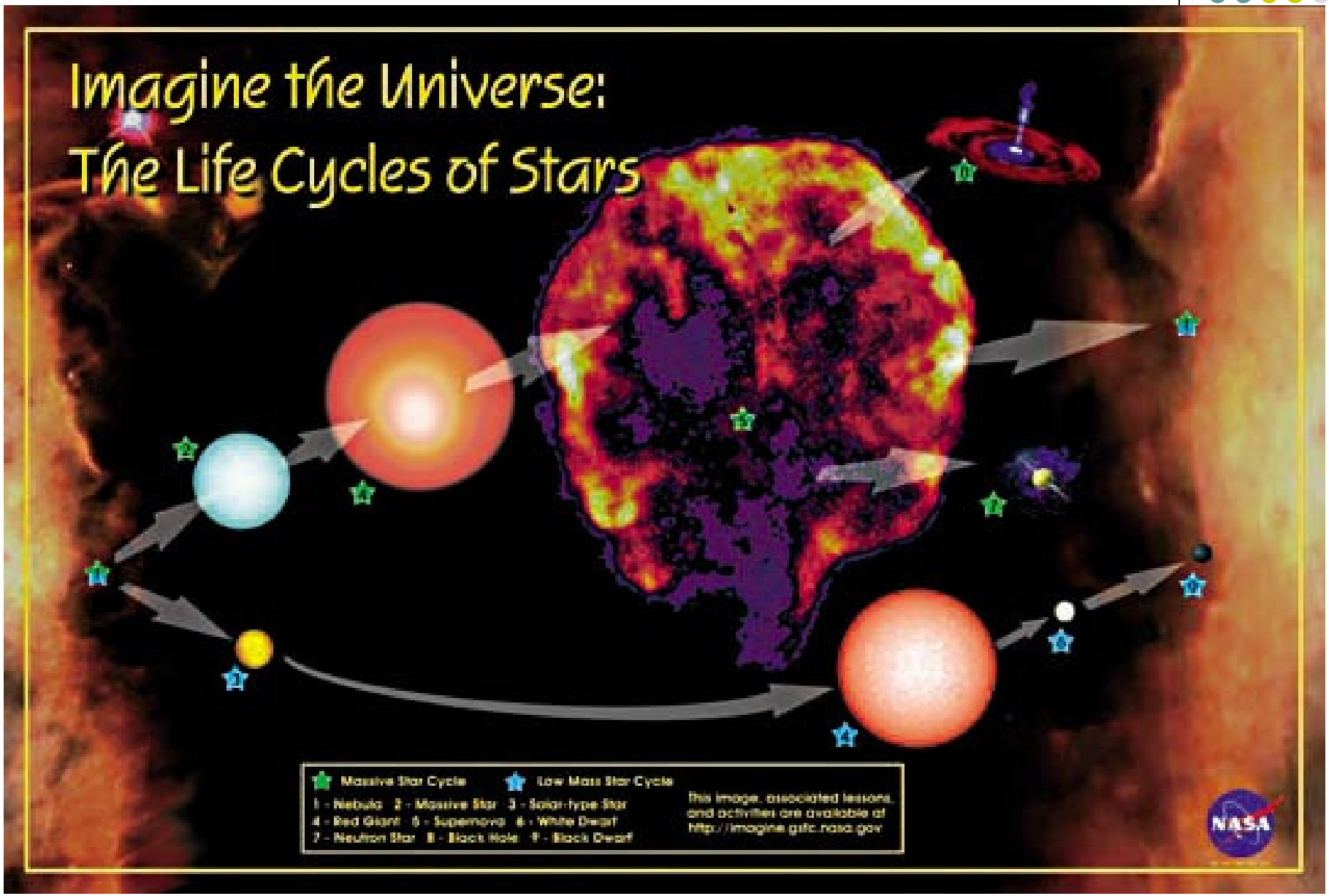


SN interaction with ISM

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!

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