What Color is That Star? Why?

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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.
- Contraction causes Temperature and Pressure to slowly increase.

\[ F = \frac{G m_1 m_2}{r^2} \]

“\( G \)” is the universal gravitational constant!!
Nuclear Fusion!

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

$$E = mc^2$$
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

Spectral Class Designations

- O
- B
- A
- F
- G
- K
- M

Oh! Be A Fine Girl - Kiss Me!
Diagram of a Solar-Type Star

The Solar Spectrum

Carina Nebula
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, Li, Be, B, C, N, O, F, Ne, 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

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

\( ^{28}\text{Si} \rightarrow ^{56}\text{Fe} \)
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

- We can make a slinky vibrate like a wave of light.
- A slinky vibrating with one length is like light of one wavelength.
- We can stretch the slinky to make longer wavelengths or different colors of light.
- Light is like pure energy with no rest mass (because it is never at rest!!)
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

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.
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.
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!

Imagine the Universe: The Life Cycles of Stars

- Massive Star Cycle
- Low Mass Star Cycle

1. Nebula
2. Massive Star
3. Solar-type Star
4. Red Giant
5. Supernova
6. White Dwarf
7. Neutron Star
8. Black Hole
9. Black Dwarf

This image, associated lessons, and activities are available at http://imagine.gsfc.nasa.gov
Thank You from The Optics Institute Of Southern California

Questions, comments, ……

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