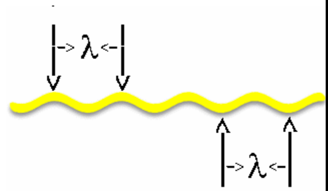
Measuring Motion, Doppler Effect—23 Oct

- Where are the elements in the baby created?
- Measuring motion

Measuring speed without seeing motion

- You are driving 80mph. Just over the crest of a hill, you see a cop car in the distance. In an instant, the cop's computer writes you a ticket.
- Astronomers can measure the speed of a star in orbit around the Milky Way without seeing it move very far. (The orbit takes 200Myr.)
- Q: How can cops & astronomers figure out speed without seeing the object move?
  - A. Measure the wavelength of light from object
  - B. Measure the intensity of light from the object

Wavelength, Frequency



- Wavelength λ = distance between successive crests.

  m   meter

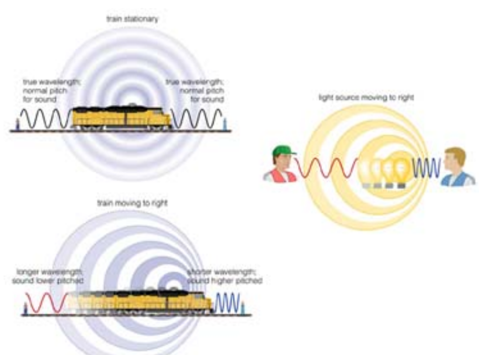
  nm   nanometer (10^{-9}m)

  Å   angstrom (10^{-10}m)
- Wave moves at speed of light c.
- Frequency is rate at which crests pass.
  - $f = c/\lambda$
  - Cycles/second; Hertz

Measuring Motion: Doppler effect

- How do you measure the velocity of a star?
- Velocity = (change in position)/time
  - Measuring how much star moves is not possible, since we cannot go to the star.
- Velocity is encoded in the light that the stars emits.
- Waves emitted from a star moving towards us are bunched together.
  - Star moves between emitting one wave crest and another. Therefore wavelength is shorter.

../Software/Doppler.html



Measuring Motion: Doppler effect

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- Waves emitted from a star moving towards us are bunched together.
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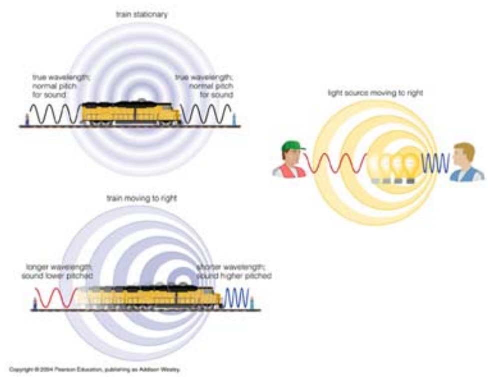
- $\lambda_{observed} / \lambda_{rest} = 1 + v/c$
  - v is speed, positive if star is moving toward us.
  - c is speed of light.
- $\Delta\lambda = \lambda_{observed} - \lambda_{rest}$ is called the shift in wavelength.



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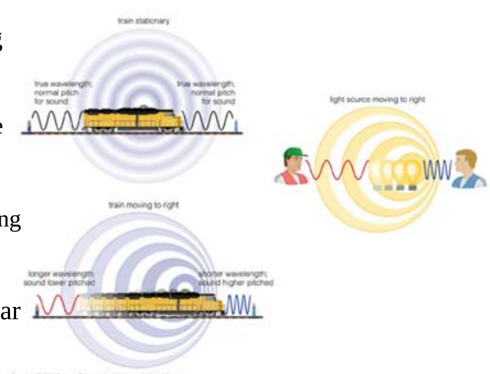
  - In the formula, v is the component of the velocity towards or away from the observer.



Measuring Motion: Doppler effect

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- Key idea: If motion is perpendicular to the line of sight, there is no change in wavelength.
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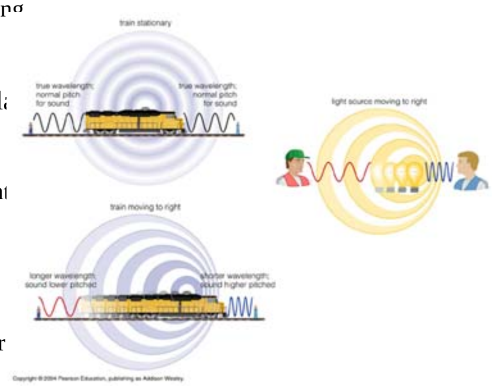
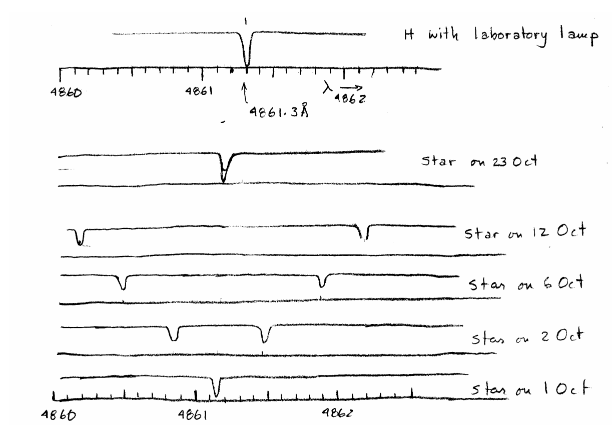
- Terminology
  - $v/c = (\lambda_{observed} - \lambda_{rest}) / \lambda_{rest}$
  - is called a redshift if positive (star is moving away)
  - is called a blueshift if negative (star is moving toward)



Pickering's discovery

- We are interpreting E. C. Pickering's spectra of Mizar (a star in the Big Dipper) in 1889.
  - Spectra showing the Hβ line of hydrogen, which is the blue-green line that we saw with the hydrogen tubes.
  - These are *absorption* spectra: The amount of light is high except at wavelengths where hydrogen absorbs.
- Describe the changes in the spectra.

Changes:

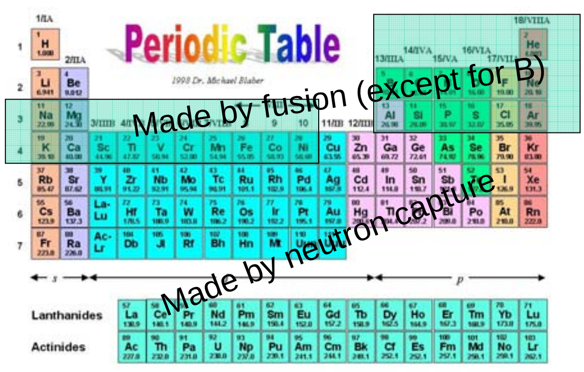


After a supernova, what is left?

- Outer layers expelled into space. New stars may form.
- Core becomes
  - Neutron star. One in Crab. Pulses every 1/30 s.
  - Black hole
- Neutron star
  - Normally neutron→proton+electron+neutrino+energy
  - Pressure is so high that proton+electron+energy→neutron+neutrino
  - Whole star is like a big nucleus of neutrons.
  - Neutrons are degenerate
  - Star is size of Lansing

Making elements heavier than iron

- Lighter elements (He, O, C, Ne, Mg, etc) are made by fusion with a release of energy
  - $4H \rightarrow He$ + energy
  - $3He \rightarrow C$ + energy
- Fe+He→ (heavier element) requires energy. No go.



Neutron capture

- In a supernova, there are free neutrons made by destroying nuclei.
- Nucleus captures neutrons and turns into a heavier nucleus. Inside a nucleus,

  nucleus + n $\rightarrow$ heavier nucleus
- Nucleus may decay into a more stable one.

  $n \rightarrow p + e^{-} + \upsilon$
- Nucleus may capture more neutrons.
- Eventually unstable nuclei decay into stable ones. Some heavy as uranium.

1. If ^{197}Au captures a neutron, it becomes ___. (Au has 79p. Hg has 80p. Pt has 78p.)
   A. ^{197}Hg
   B. ^{198}Au
   C. ^{198}Hg
   D. ^{198}Pt
2. If a neutron in ^{198}Au decays, it becomes ___. (Au has 79p. Hg has 80p. Pt has 78p.)
   A. ^{198}Hg
   B. ^{198}Au
   C. ^{198}Pt

- The net effect is to turn gold into mercury.

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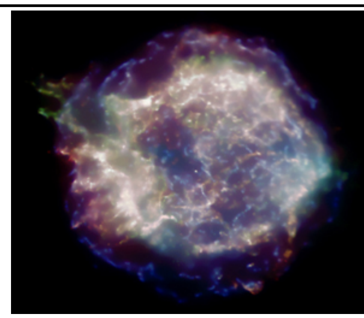

- Calculation of nuclear reactions in a supernova.
- Start with iron and add neutrons
- Look at gold
  - 79 protons, 197-79=118 neutrons

Questions on the Supernova Movie

1. What is the only element at the start? How many neutrons does it have?
2. At what time did some gold form? Gold has 79 protons. Is this gold stable?
3. At the end of the calculation, how many protons does the nucleus with the most protons have?
4. What is the time at the end of the calculation?
5. Are the end products stable?

- “R process movie” at www.jinaweb.org/html/gallery3.html

Where were the elements in the baby made?

- Lighter elements (He, O, C, Ne, Mg, etc) are made by fusion with a release of energy
  - $4H \rightarrow He$ + energy
  - $3He \rightarrow C$ + energy
- Elements heavier than iron are made in supernovae and in gian