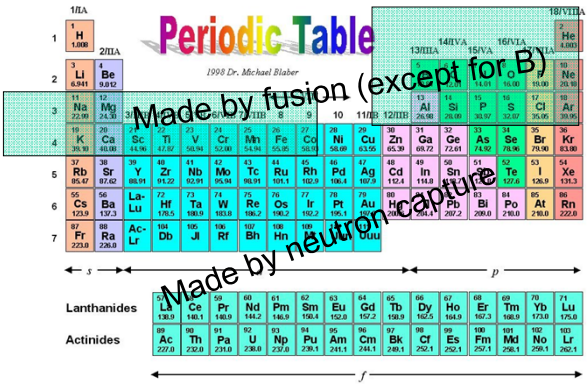
Measuring Motion, Doppler Effect—22 Oct

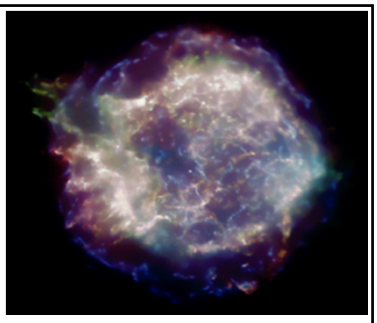
- Where are the elements in the baby created?
- Measuring motion

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 → He + energy
  - 3He → C + energy
- Elements heavier than iron are made in supernovae and in giant stars.



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 → 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.

- 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

"R-process move" www.jinaweb.org/html/gallery3.html

- Calculation of nuclear reactions in a supernova.
  - Black is stable.
  - Colors indicate abundance. Red, yellow, green, blue in order of decreasing abundance.
  - Start with iron and add neutrons
  - Look at gold: 79 protons, 197-79=118 neutrons

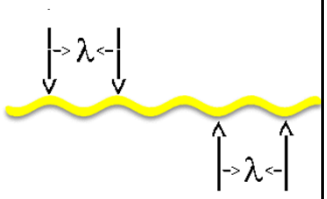
1. What is the only element at the start? How many neutrons does it have?
2. At what time did some gold form? Gold has 79 protons. Is this gold stable?
3. At the end of the calculation, how many protons does the nucleus with the most protons have?
4. What is the time at the end of the calculation?
5.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

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

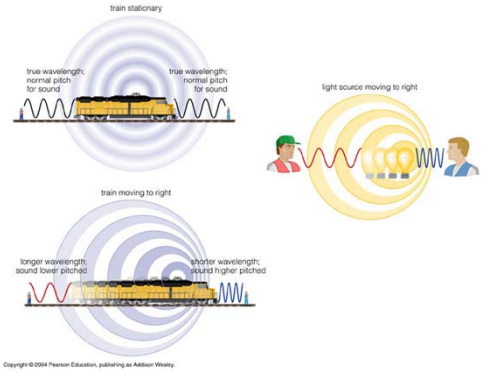
- Wavelength λ = distance between successive crests.
  m meter
  nm nanometer (10^{-9}m)
  Å angstrom (10^{-10}m)
- Wave moves at speed of light c.
- Frequency is rate at which crests pass.
  - $f = c/\lambda$
  - Cycles/second; Hertz



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



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 away from us.
  - c is speed of light.
- $\Delta\lambda = \lambda_{observed} - \lambda_{rest}$ is called the shift in wavelength.

1. A cop on the corner of Shaw & Farm Lane is watching you speed through the intersection of Wilson Rd. & Farm La. On his radar gun, the radar waves are
   A. spread apart because of your speed.
   B. scrunched together because of your speed.
   C. not affected by your speed.

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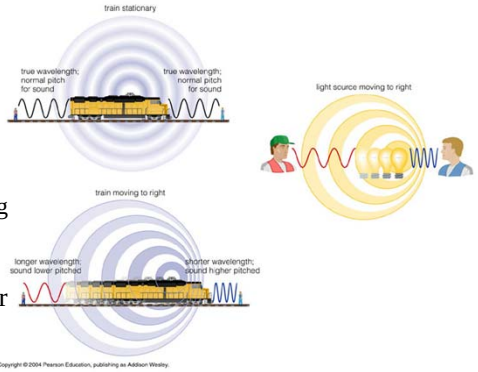
- Key idea: If motion is perpendicular to the line of sight, there is no change in wavelength.
  - In the formula, v is the component of the velocity towards or away from the observer.



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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)