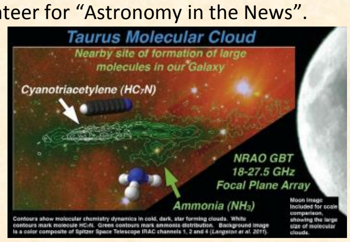
ASTR 1020: Stars & Galaxies

September 11, 2013

- Reading: Chapter 14, section 14.1.
- *MasteringAstronomy* Homework on Light & Matter is due Sep. 13th.
- Volunteer for “Astronomy in the News”.



Clickers reminder

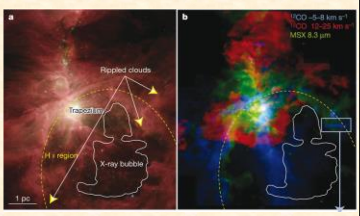
- 50% for any answer
- 100% for correct answer

- 5 free clicker days to take care of technical problems and missed classes.

- Clicker registration problems? Send Lucas an E-mail (Lucas.D.Miller@Colorado.EDU), include clicker number.

Today’s Class: Radio Waves & Molecules

- Types of Spectra.
- Molecules: vibrations & rotations.
- Emission from molecules at radio wavelengths.
- Radio telescopes.



Clicker Question

I measure a line in the lab at 500.7 nm. The same line in a star has wavelength 502.8 nm. What can I say about this star?

A. It is moving away from me.
B. It is moving toward me.
C. It has unusually long spectral lines.

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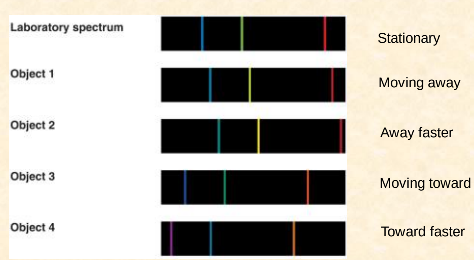
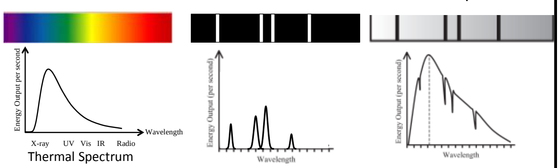
Measuring the Doppler Shift



- We generally measure the Doppler effect from shifts in the wavelengths of spectral lines.

Types of Spectra

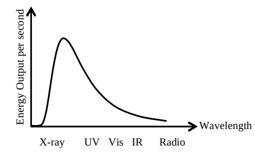
Continuous	Emission	Absorption



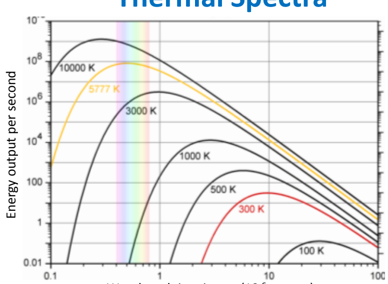
Thermal Spectrum	produced by atoms and molecules	produced by atoms and molecules

Thermal Radiation

- An object that is not transparent (stars, planets, dust) emits all wavelengths of light
- The spectral curve for these objects is shown at right
- The object's temperature determines the wavelength of light where the continuous spectrum peaks



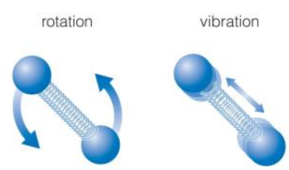
Thermal Spectra



- Where would an object that peaks at radio wavelengths be on this graph?
- What temperature would you estimate the object to be?

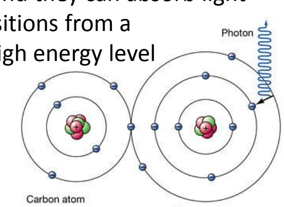
Molecules

- 2 or more atoms bonded together
- Molecules produce emission and absorption spectra in 3 different ways
  1. Electrons in atoms change energy levels
  2. The molecule changes how fast it's vibrating
  3. The molecule changes how fast it's rotating



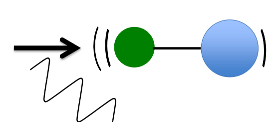
Molecular Electron Transitions and the Emission and Absorption of Visible and UV Light

Just like atoms, molecules can emit light when an electron transitions from a high energy level to a low energy level, and they can absorb light when an electron transitions from a low energy level to a high energy level

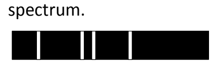


Molecular Vibrations and the Emission of Infrared Light

- When a molecule transitions from a faster vibration (higher energy state) to a slower vibration (lower energy state), the molecule emits a photon of light with an energy equal to the energy difference between the molecule's two vibrational energy states.
- The more arcs (shown below), the faster the molecule vibrates.
- The greater the change in the number of arcs, the greater the change in energy.

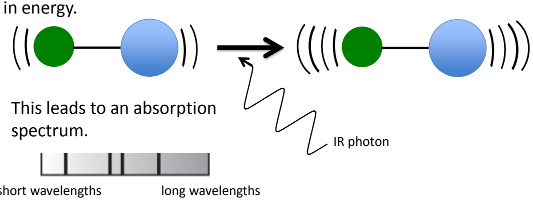


This leads to an emission spectrum.

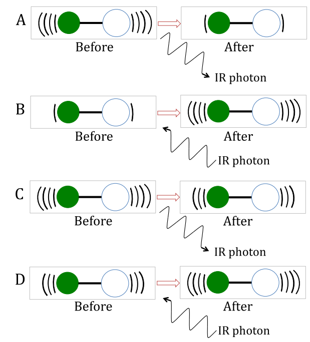


Molecular Vibrations and the Absorption of Infrared Light

- A molecule can also transition from a slower vibration to a faster vibration when it absorbs a photon with an energy equal to the energy difference between the molecule's two vibrational energy states.
- The more arcs, the faster the molecule vibrates.
- The greater the change in the number of arcs, the greater the change in energy.



Clicker Question: Which of the following represents the molecule that is absorbing the lowest energy photon?



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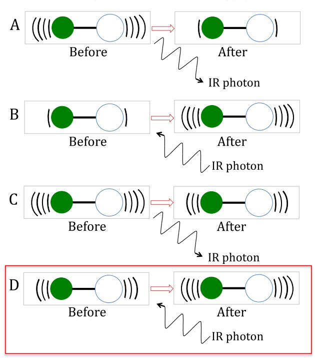
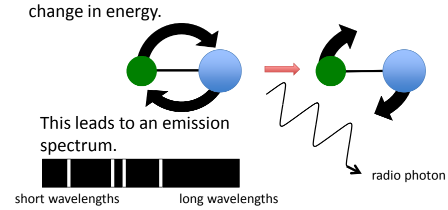


Molecular Rotations and the Emission of Radio Light

- When a molecule transitions from a faster rotation (higher energy state) to a slower rotation (lower energy state), the molecule emits a photon of light with an energy equal to the energy difference between the molecule's two rotational energy states.
- The longer the arrow below, the faster the molecule rotates.
- The greater the change in the arrows' lengths, the greater the change in energy.



Molecular Rotations and the Absorption of Radio Light

- A molecule can also transition from a slower rotation to a faster rotation when it absorbs a photon with an energy equal to the energy difference between the molecule's two rotational energy states.
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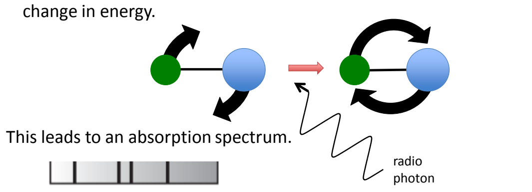

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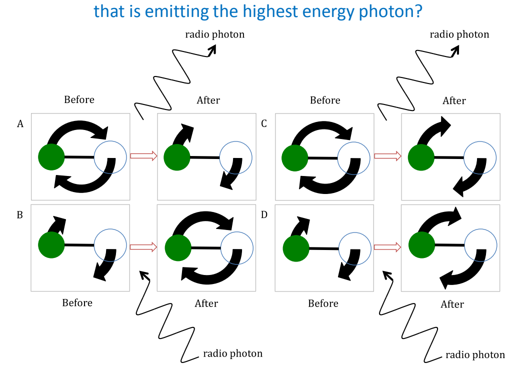

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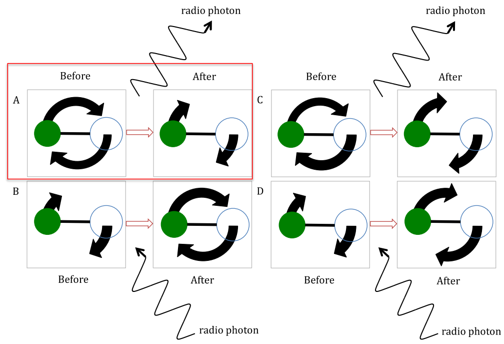
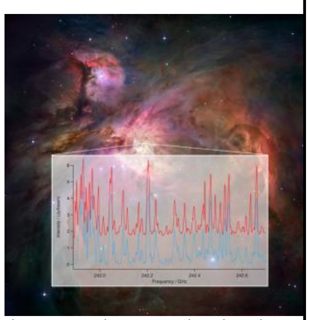


ALMA: *Atacama Large Millimeter Array*

- Using cutting edge techniques, some radio telescopes like ALMA are expanding beyond the traditional range of radio astronomy to include infrared wavelengths
- ALMA is on a high desert plains in northern Chile.

Matching the "Fingerprints"

- Observing the Orion Nebula, radio astronomers find numerous emission lines from the molecule ethyl cyanide (CH_3CH_2CN).
- The red line is the spectrum observed with the ALMA radio telescope in Chile.
- The blue line is the spectrum measured in a laboratory here on Earth.
- The astronomers were able to match the laboratory spectrum of the molecule with the observations of the nebula



Dr. Anthony Remijan of the National Radio Astronomy Observatory explains this technique
http://vimeo.com/49728598

Why Radio *Waves*?

- Because light is an electromagnetic wave, it will cause charged particles to move back and forth
- Radio photons have very low energies but it can move electrons in an antenna easily
- At radio wavelengths the wave nature of light is used to detect radio light from distant objects or your local radio station

http://phet.colorado.edu/en/simulation/radio-waves