Announcements

- WebWorK due on Monday
- Test a week from today!
  - What you'll need:
    - Pen/Pencil/Eraser
    - A basic calculator (It can't be your phone, sorry). If you don't have a friend to borrow from, I have about 6 that I can lend out, but you need to email me if you want one. First come, first served.
    - I'll try to limit how much actual calculator work is needed, but see previous test for an example
  - Old tests and review questions posted
  - The same equation page as posted on the website will be included on the test
  - I'll write a test that takes me under 10 minutes to complete
- Polling: `rembold-class.ddns.net`

The Sky ~~Tonight~~ Tomorrow!

- Happy Fall Equinox tomorrow!
  - Sun will rise directly in the East
  - Will set directly in the West
  - At the equator the Sun will be at zenith at noon
  - Equal hours of day and night

Review Question

What sort of object would you ascribe the below spectra to?

A. A star with surrounding gases
B. A white hot chunk of nickel
C. A helium lamp
D. A diffuse gassy dinosaur

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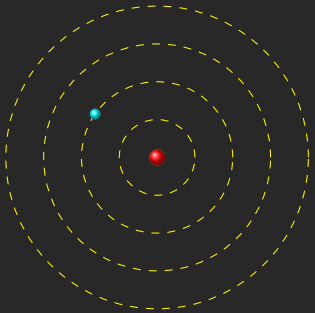
- Why don't stars (made of hydrogen) emit hydrogen lines?
- How can we tell if stars are moving?

Stars $\neq$ Gas Lamps

- Atoms in close proximity to each other mess up each others energy levels



Nice, even energy levels

Lonely atom in thin gas

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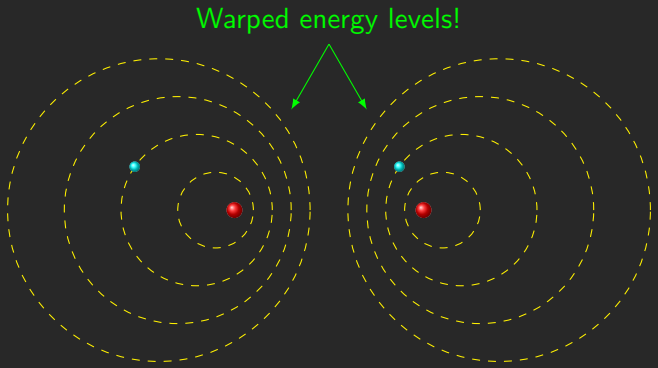
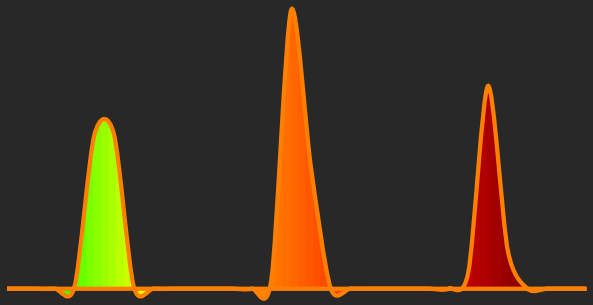


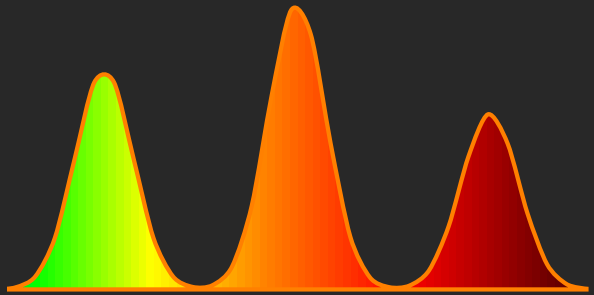
Crowded atoms in dense gas

Evolution of Spectra



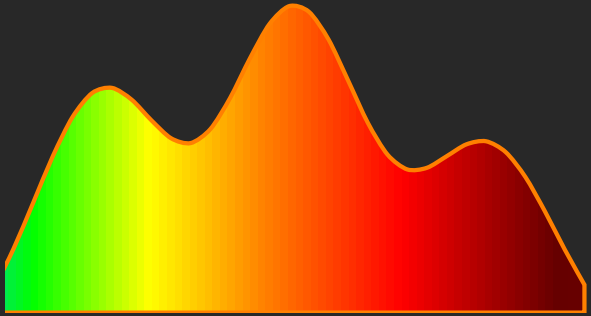
Low Density Gas

Evolution of Spectra



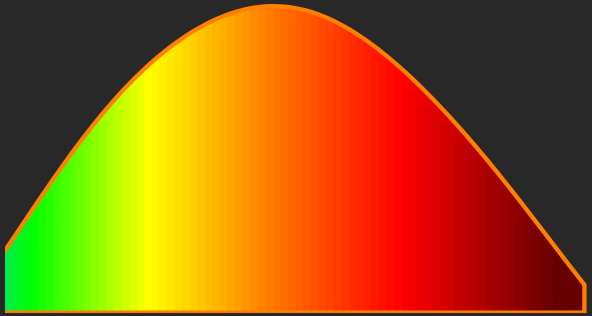
Higher Density Gas

Evolution of Spectra



Even Higher Density Gas

Evolution of Spectra

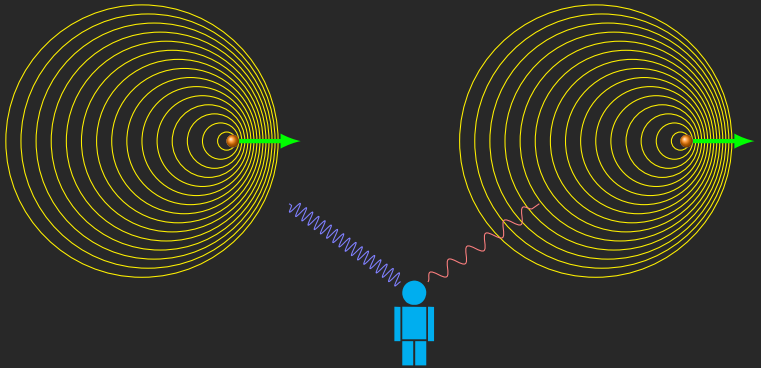


Really Dense Gas

Time to Dopple

The Doppler Effect

- The Doppler effect affects all types of waves, so this includes light!
- Approaching waves get compressed (smaller wavelengths)
- Receeding waves get stretched (larger wavelengths)



Putting Numbers to It

For our purposes:

$$\frac{\lambda_{obs} - \lambda_{rest}}{\lambda_{rest}} = \frac{V}{c}$$

Here:

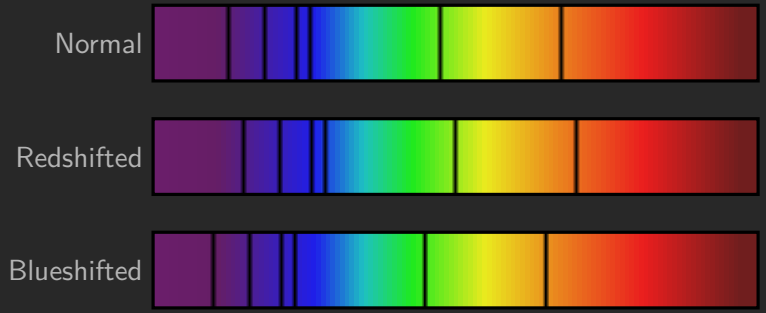
- λ_{obs} is the wavelength you see (observe)
- λ_{rest} is the normal wavelength when not moving
- V is the speed of the light source relative to you
- c is the speed of light

Careful, the sign of V is important!

- a negative V means the source is coming toward you
- a positive V means the source is going away from you

Applications to Astronomy

- We can measure object speeds!
- Approaching objects are blueshifted
- Receeding objects are redshifted



Example Time

Example

As we'll talk about later, things near a black hole can get pretty crazy. Say a unfortunate friend (or maybe a dire enemy) is being sucked into a black hole and shining a 550 nm green laser back at you. If they are traveling at a quarter the speed of light away from you, what wavelength do you perceive the laser to be at?

Telescope Time. . .

Looking at the Eye...

- The Path of Light
  - Enters through pupil
  - Focused by lens
  - Projected onto retina
- Light entering at different angles gets focused in different locations
- Your brain gets information on:
  - Wavelength (color)
  - Direction

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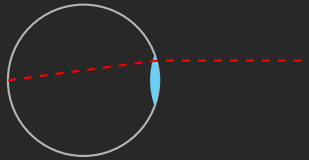

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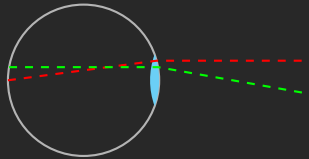


Cameras and Telescopes

- Cameras are the simplest "artificial" eyes
  - Lenses still focus light
  - Film takes the place of your retina
- Telescopes are essentially large cameras
  - May use a mirror to focus instead of a lens
  - "Retina" can be film, photo-plates, or CCD detectors

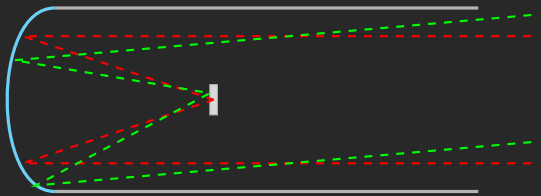
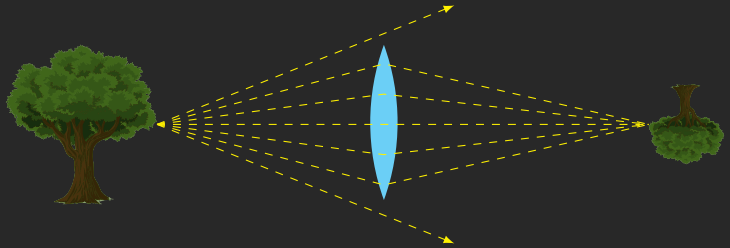


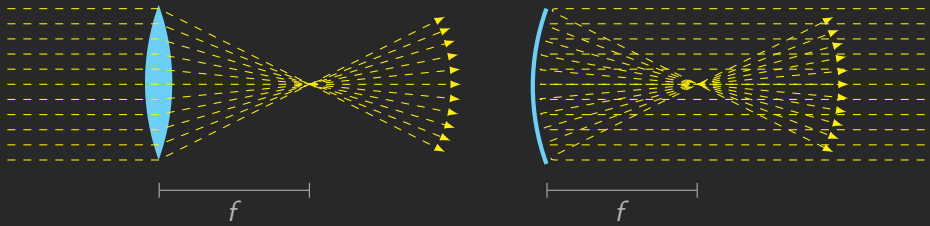
Image Creation

- To see a clear image:
  - Light coming from a single point on the object must go to a *single point* on the image.
- Recall that light emits from a point on the object in all directions, so all of these must be properly redirected to a point on the image



Lenses and Mirrors

- Lenses and mirrors redirect light to focus at a particular point
- Characterized by their focal point or focal length
- Parallel incoming light is redirected through the focal point



Ray Tracing

- Two basic rules:
  - Rays that enter the lens/mirror parallel leave through the focus
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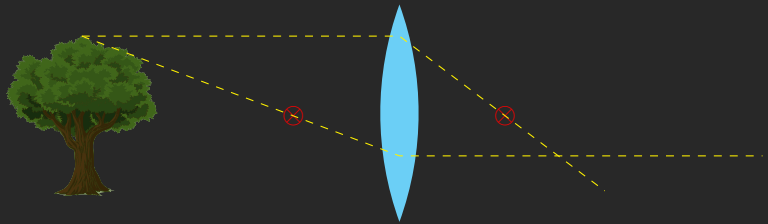
- Recall the focal lengths exist on both sides of a lens!



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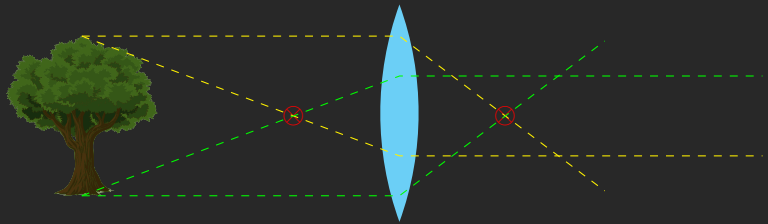

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