



Announcements

- WebWorK due Wednesday
- Test on Friday!
 - Study materials have been posted
 - Solutions to study materials have been posted
 - Equation sheet is posted
 - You need to bring writing implements, a basic calculator (can't be your phone) and a positive attitude!
 - Email me if you'd like to use one of my limited number of backup calculators
 - Today is the last day of content which is testable
- Lab tonight is on Light, which **is** on the test
- Polling: `rembold-class.ddns.net`



Astronomy News!

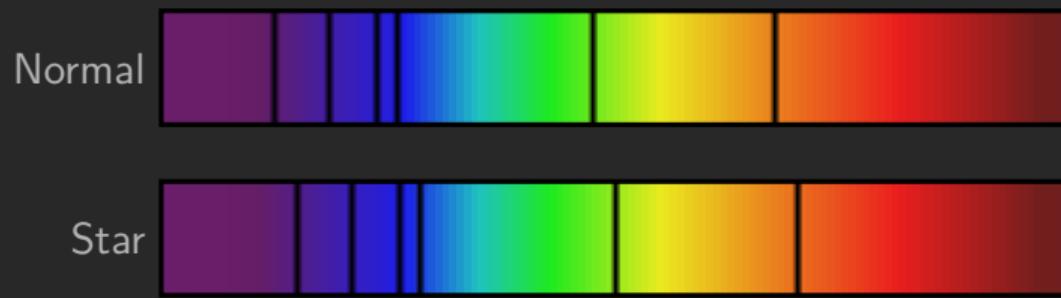
- JAXA deploys two small rovers to the surface of asteroid Ryugu!
- Orbiter lowered to about 55 meters to drop off rovers and then resumed orbit
- Rovers move by “hopping” in the weak gravity
- Third larger rover to be released in October





Review Question

The image below is a normal spectrum, and then the second is the observed spectrum of a distant star. How is the star moving relative to Earth?

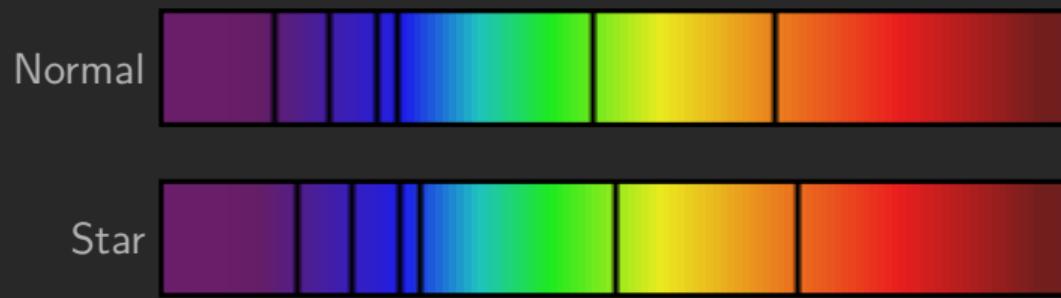


- A. Away from us
- B. Towards us
- C. Not moving at all
- D. Only moving sideways to us



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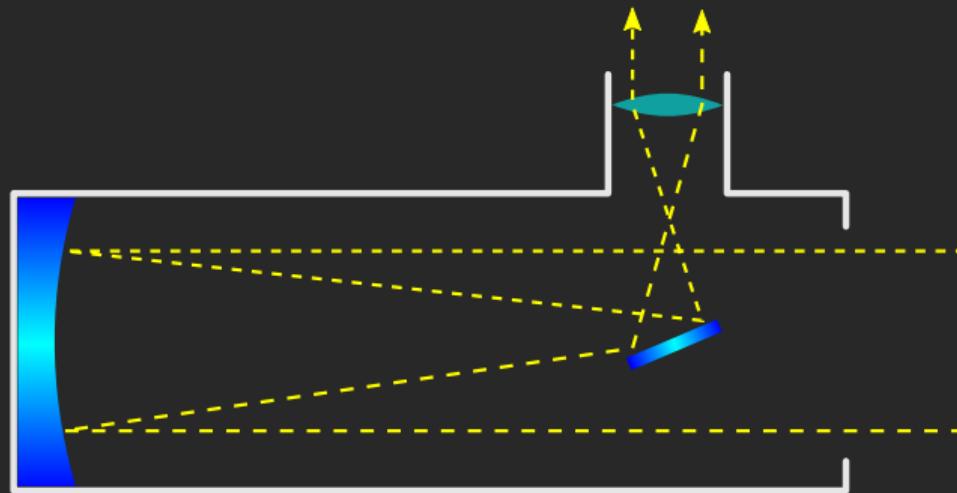


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Telescopes for Visual Observing

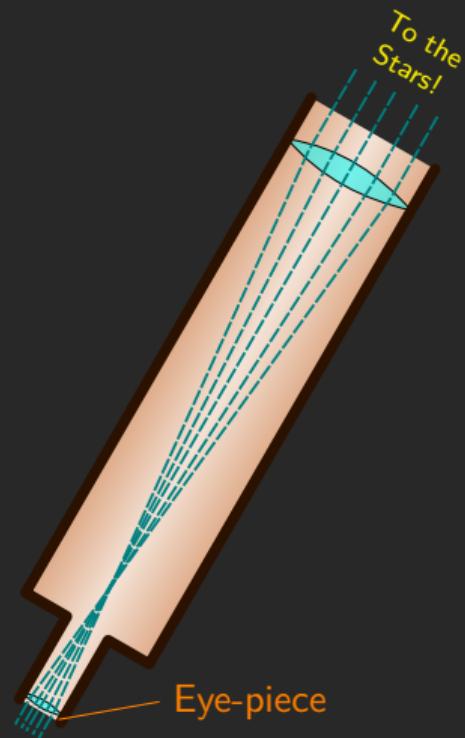
- If using your eye as your “detector” on a telescope, then the optics is a bit more complicated
- Need an eye-piece to make the light rays parallel again so that your eyeball can then process them correctly



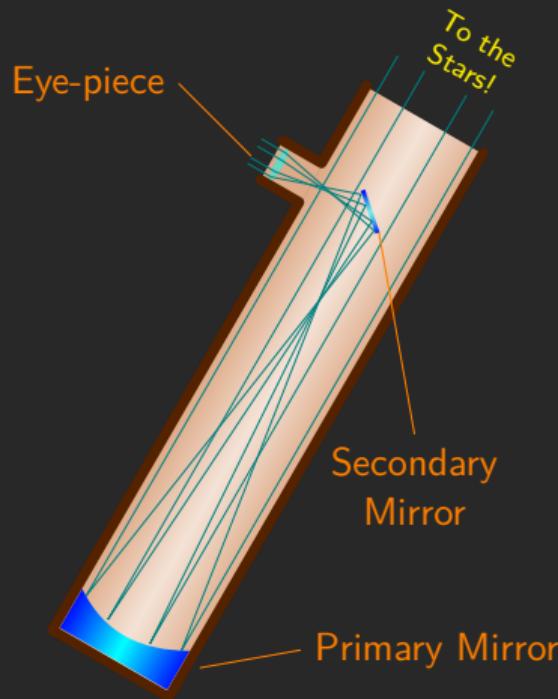


Refracting Telescopes

- Use a lens to focus light
- Classic and simple style
- Difficult to make very large
 - Lenses get huge and heavy



Reflecting Telescopes



- Use a mirror as the primary means of focusing light
- Can be made quite large!
- Variant with hole in primary mirror
 - Schmidt-Cassegrain





Optical Telescope Example: MRO





Optical Telescope Example: MRO





Optical Telescope Example: MRO





Radio Telescope Example: VLA





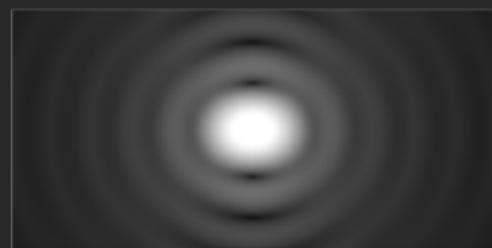
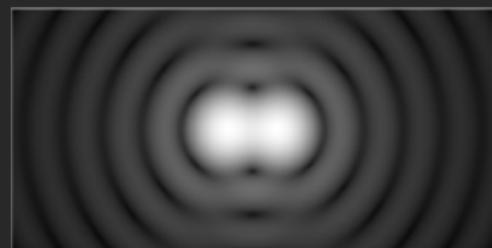
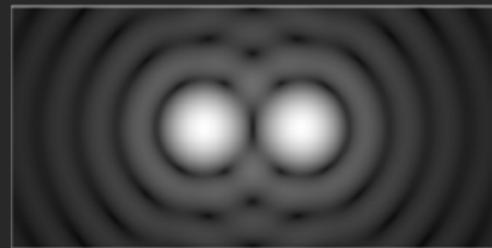
Radio Telescope Example: VLA





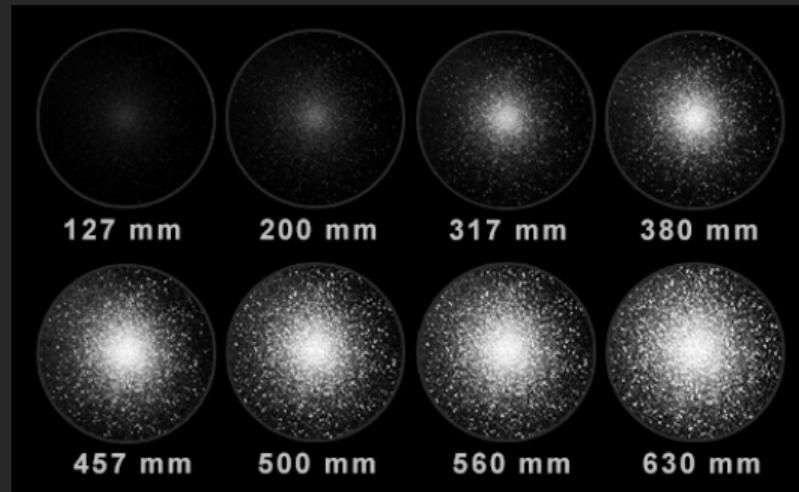
Imaging: What You Care About

- Aperture Size: the light collecting area
- Angular Resolution: how much angular detail you can see
- Field of View: how much of the sky you can see at once



Aperture Size

- Related to the size of the telescope
- Or more precisely, to the size of the telescope's primary mirror
- A larger telescope will gather more light in a particular amount of time, bringing out dim details or brightening the image in general





Angular Resolution: The Diffraction Limit

- Light behaves in part like a wave
 - Light passing through any opening thus has its rays bent slightly



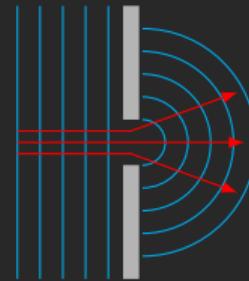
- The Diffraction Limit depends on the ratio of the wavelength to opening

$$\text{Smallest Angle} \propto \frac{\text{Wavelength}}{\text{Diameter of Opening}}$$



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Size Does Matter

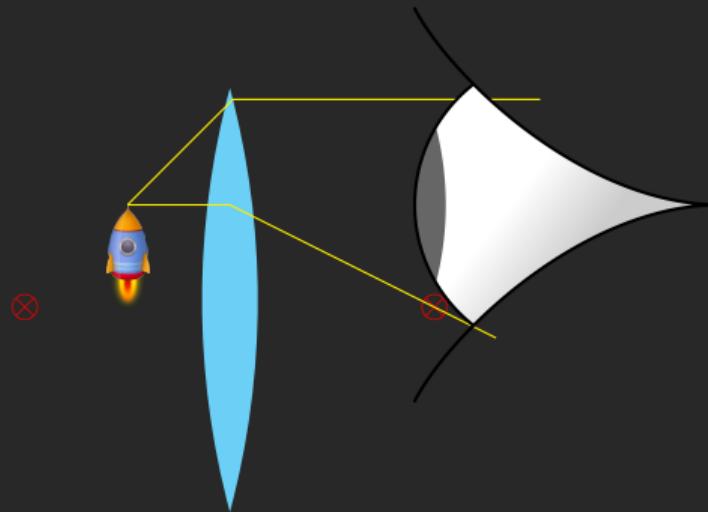
- Larger telescopes have a smaller diffraction limit and thus greater angular resolution
- But ground based optical telescopes are more limited by atmospheric effects
- Radio telescopes need to be large for good angular resolution owing to the large wavelength of radio waves





Magnification vs Field of View

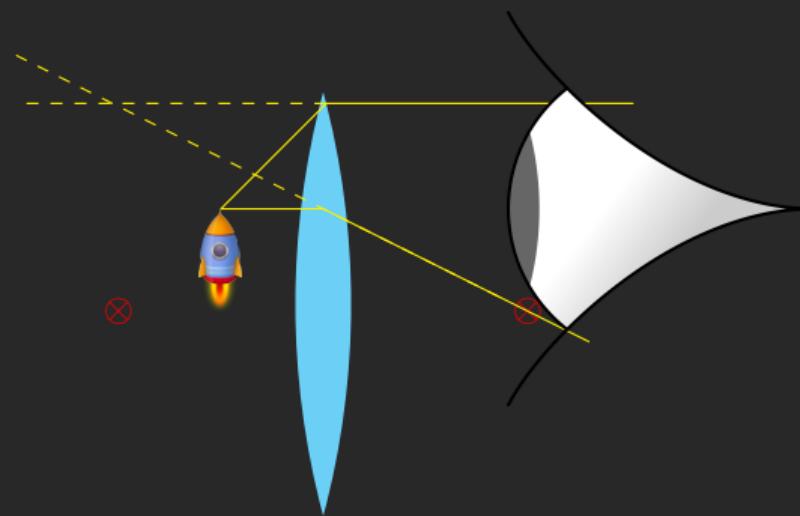
- Magnification and Field of View are inversely related
 - One goes up, the other goes down
- Eye-piece optics primarily responsible for magnification
 - Increases the apparent size of the object
 - Can help overcome diffraction limits of your eye





Magnification vs Field of View

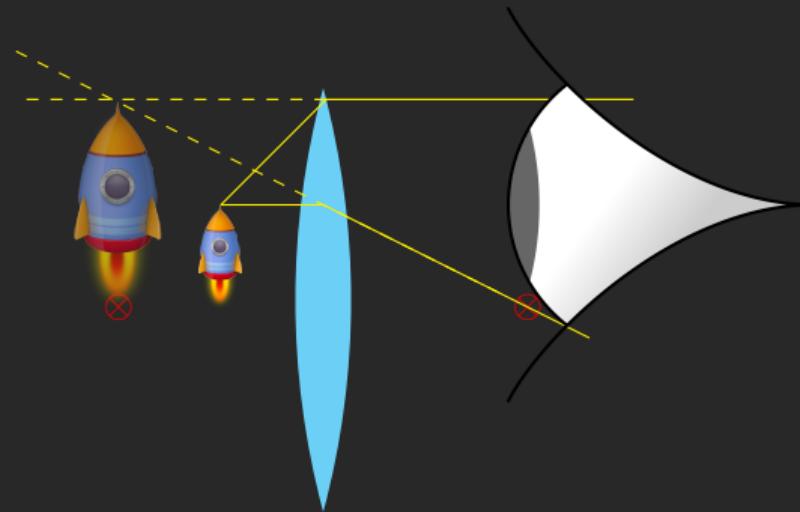
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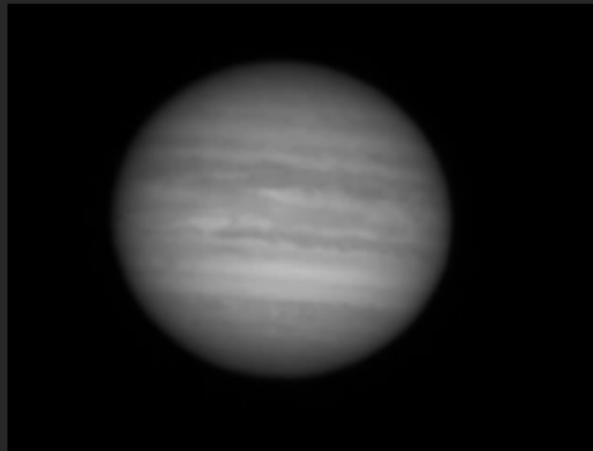
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What Do We Mean By “Seeing”

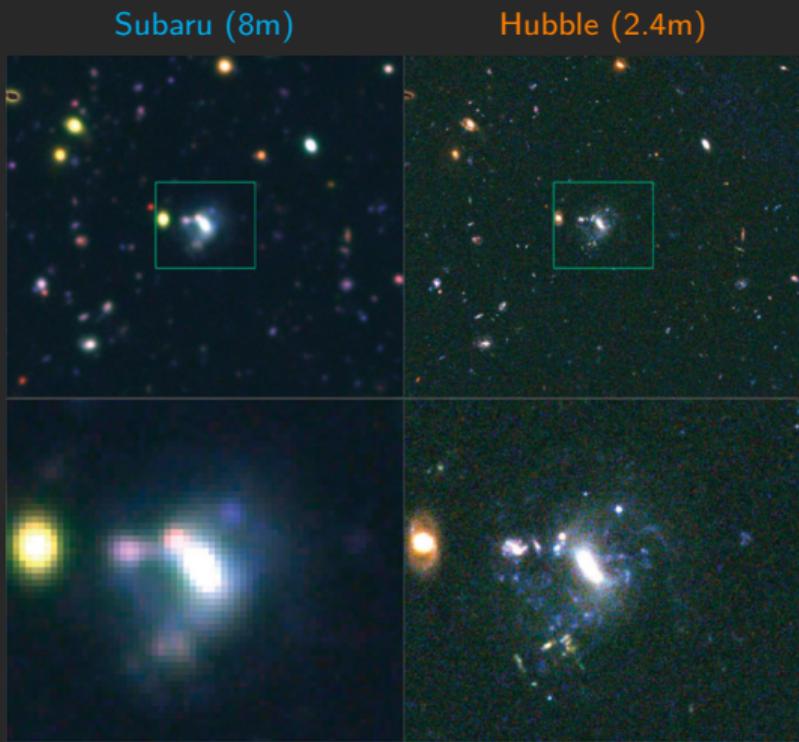
- Atmospheric variations limit angular resolution of optical telescopes on Earth
 - Makes stars twinkle
 - Distorts the rays cast from the star
- “Seeing” describes how calm the nightly atmospheric distortion is
 - Excellent Seeing has minimal distortion (Left)
 - Poor Seeing has very obvious distortion (Right)





Where the View is Better

- Best seeing on Earth is a fraction of an arcsecond
- Even small telescopes in space are useful!

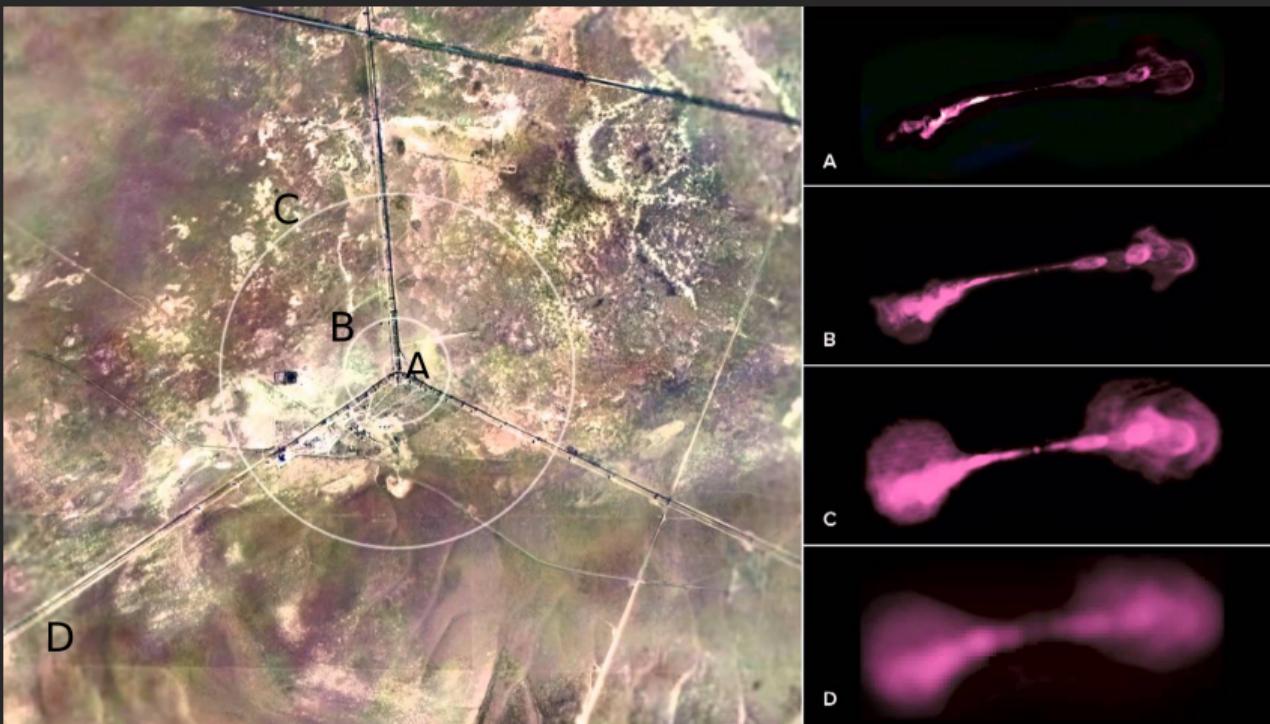




Interferometry

- Requires many telescopes working together
- Light waves interfere with one another when they enter the telescope
- Can electronically reconstruct the data from many telescopes
- Radio:
 - VLA
 - VLBA
- Millimeter:
 - ALMA

VLA Resolutions





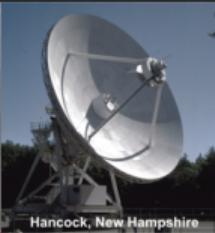
Owens Valley, California



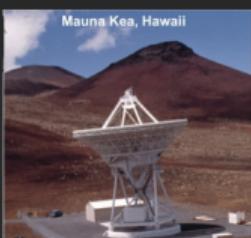
Brewster, Washington



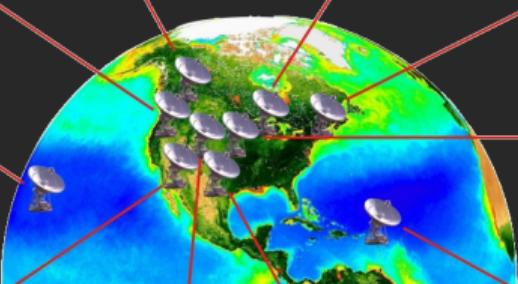
North Liberty, Iowa



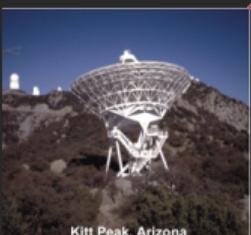
Hancock, New Hampshire



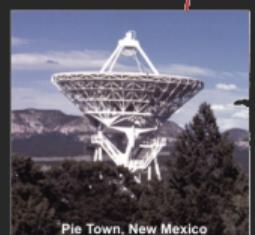
Mauna Kea, Hawaii



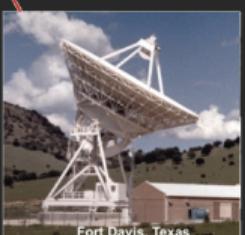
Los Alamos, New Mexico



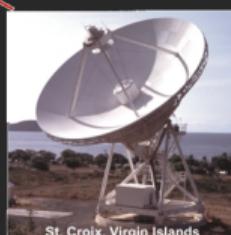
Kitt Peak, Arizona



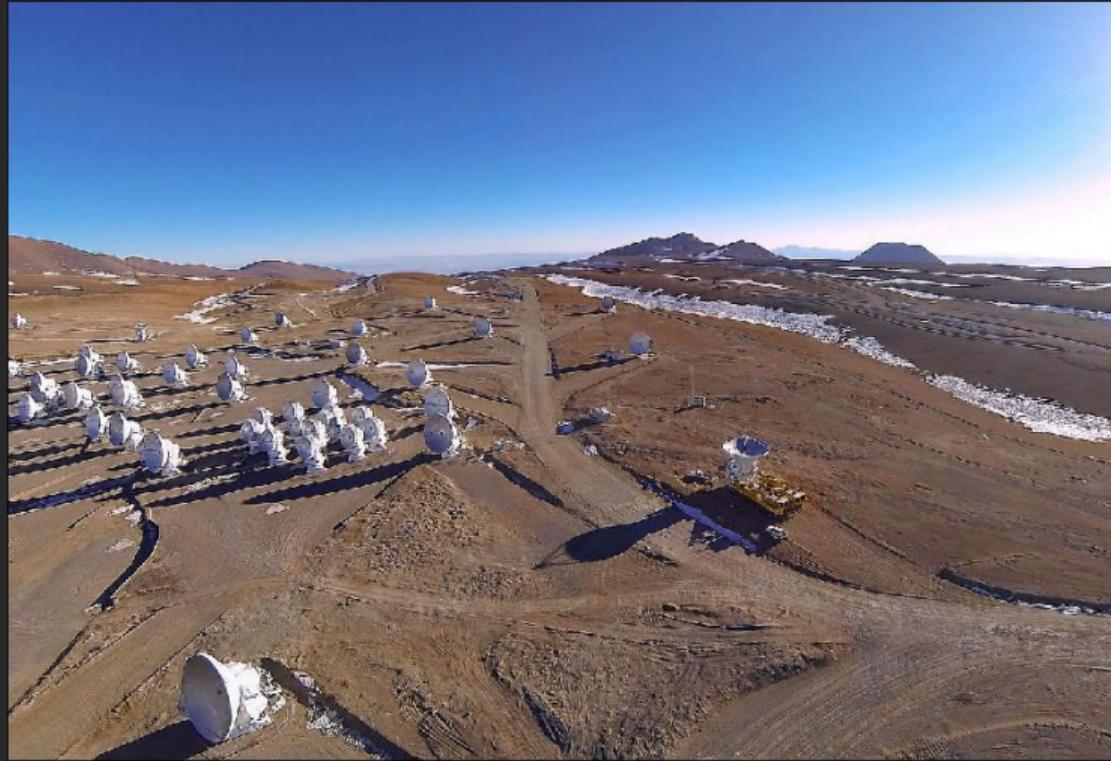
Pie Town, New Mexico



Fort Davis, Texas



St. Croix, Virgin Islands





Test Questions?

Anything you want to ask or review?