An Introduction to Astronomical Telescopes

http://www.bbc.co.uk/science/0/20937803

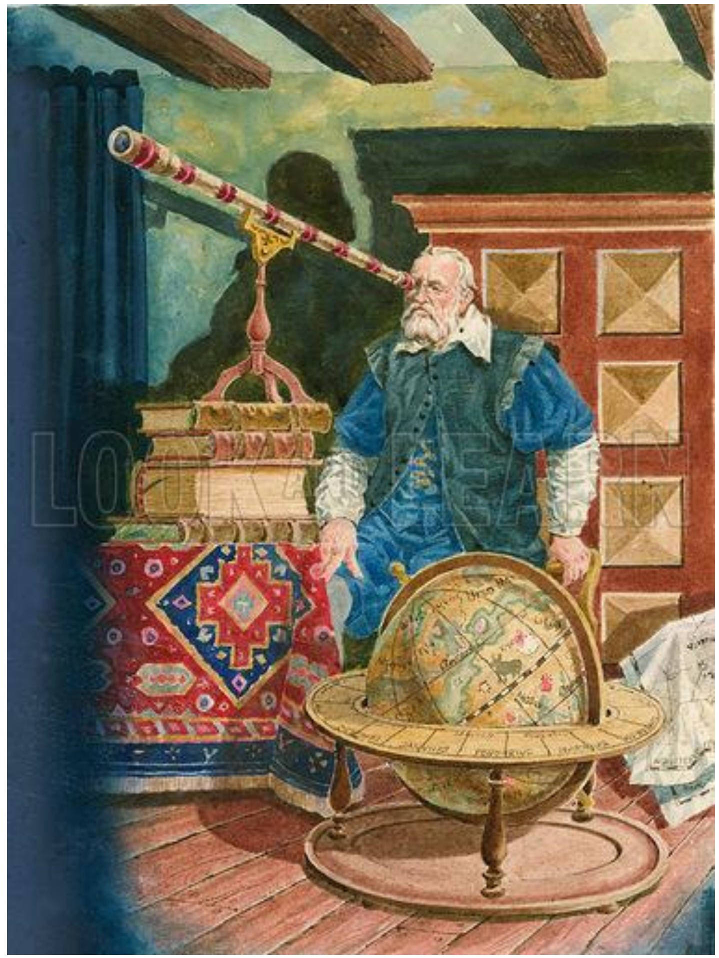
This Power Point presentation was prepared in 2017 for Delta Rehabilitation Center, Snohomish WA.

http://www.deltafoundation.com/

Delta has a small observatory and a 10 inch Meade Cassegrain reflector telescope, which had the distinction of capturing Supernova 1999by in NGC 2841 during it's peak brightness. The Rochester Academy of Science website accepted this image into its data pool

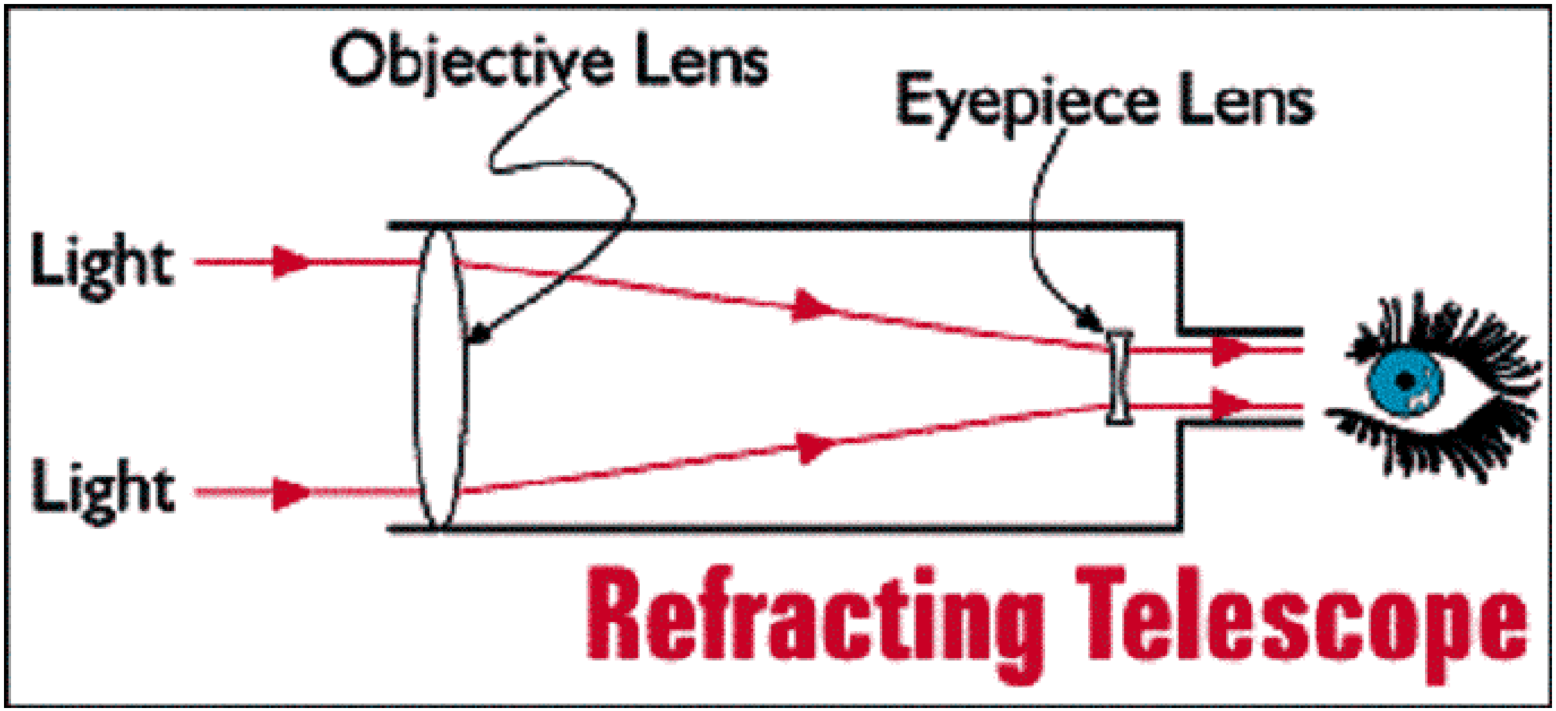
http://www.deltafoundation.com/astronomy.htm

The First Telescope was invented by Galileo Galilei in 1609.
It had a convex objective lens and a concave eyepiece
in a long tube.



http://www.lookandlearn.com/blog/1006/1006/

A telescope with lenses is called
A refracting telescope

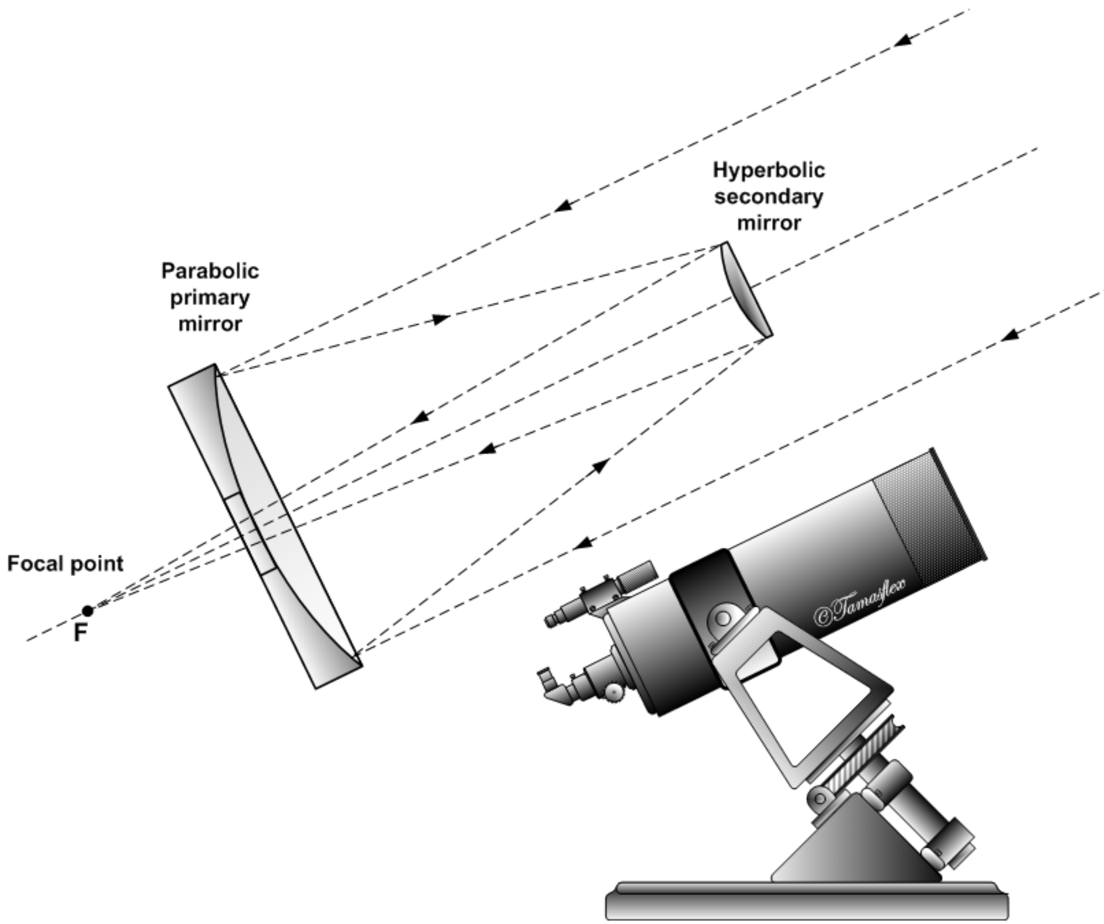


http://binoculas.net/does-refracting-telescope

10 “ Meade Cassegrain Reflecting Telescope

http://www.rainydaymagazine.com/RDM2009/Home/January/RDMHomejanuary.htm

Cassegrain Reflector



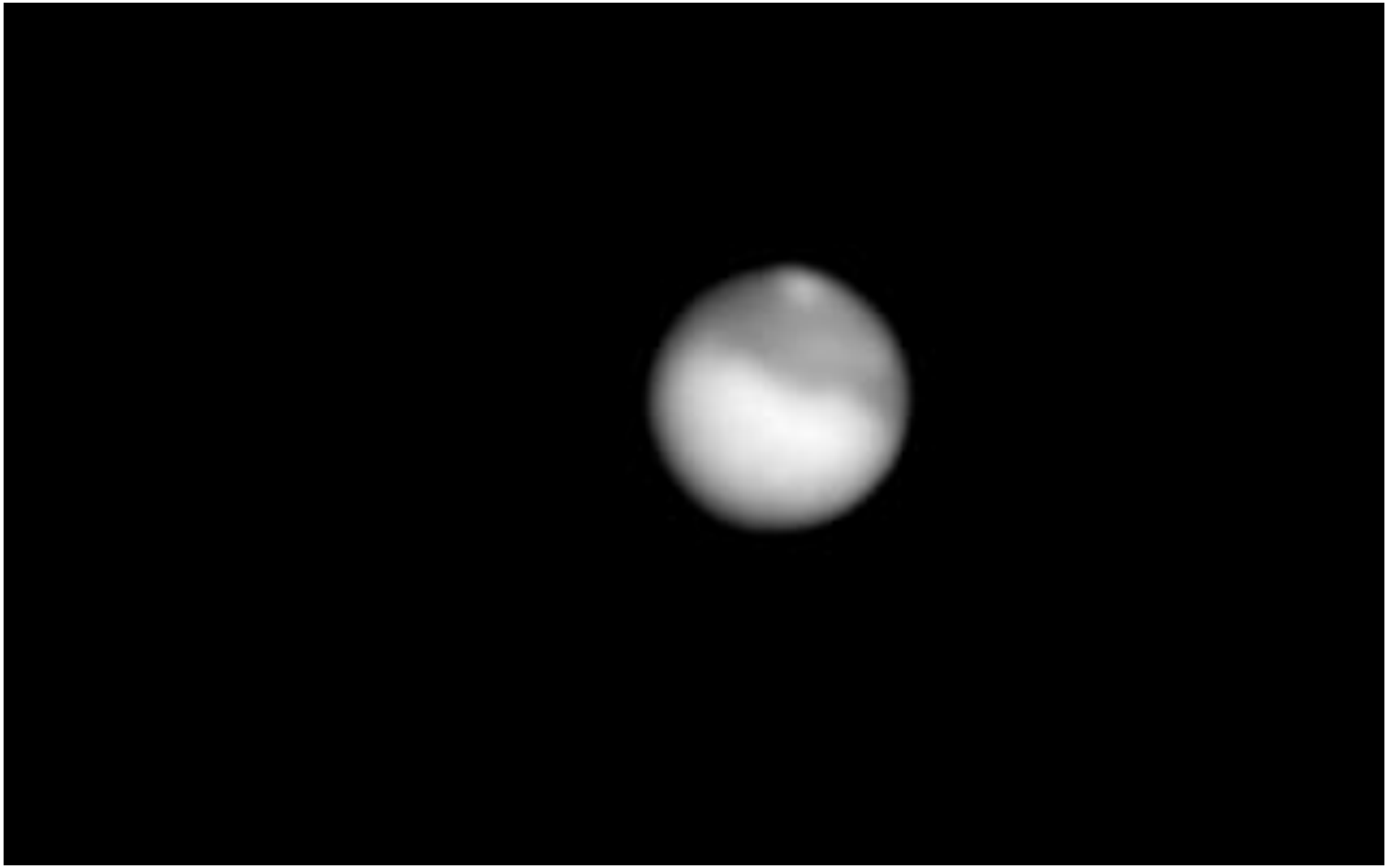
The Cassegrain scope reflects light back and forth in the telescope tube, allowing a much shorter telescope for its diameter.

https://en.wikipedia.org/wiki/Cassegrain_reflector

Appenine mountains on moon taken using Delta scope

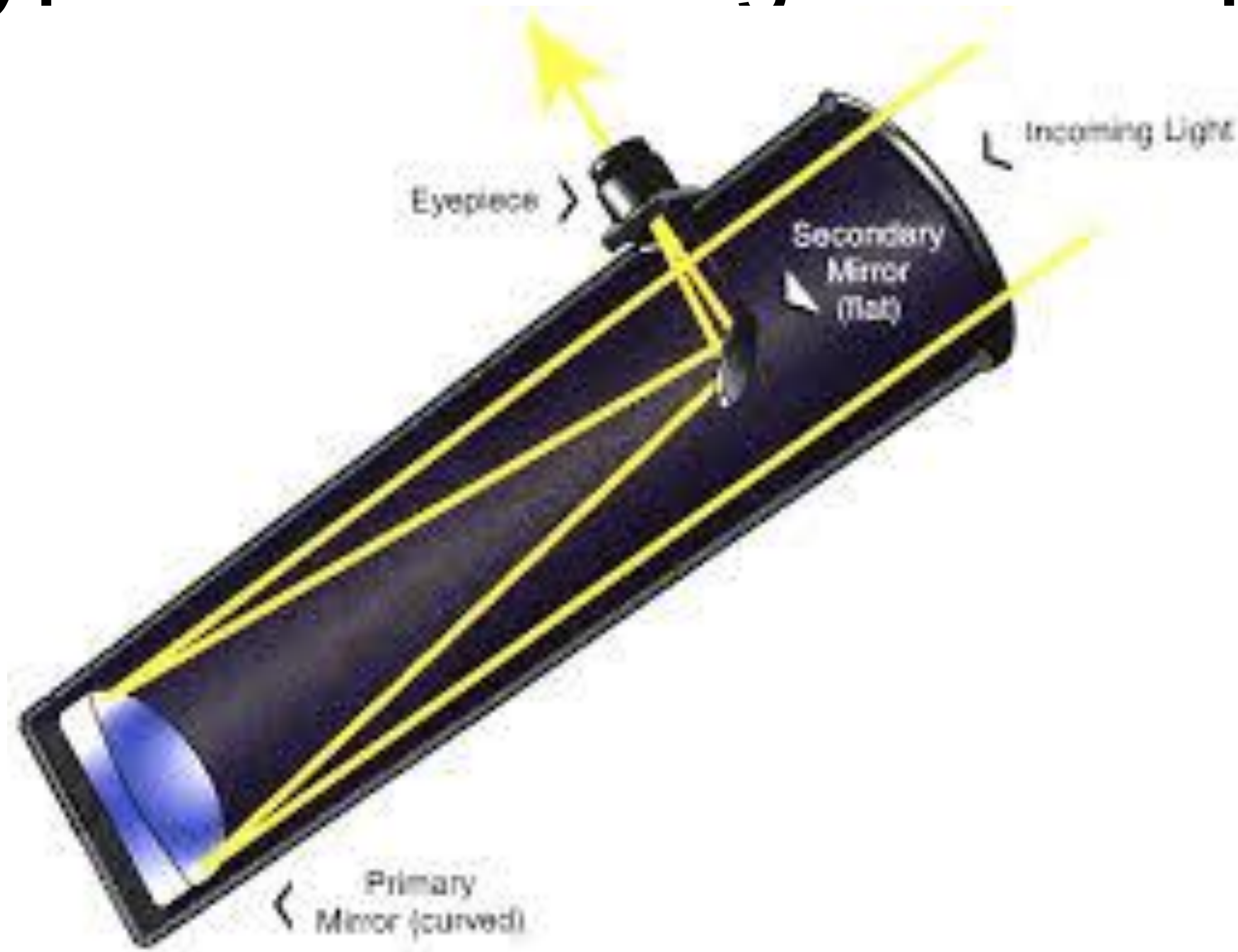
Crater Aristillus on moon taken using Delta scope

Mars taken using Delta scope



Martians?

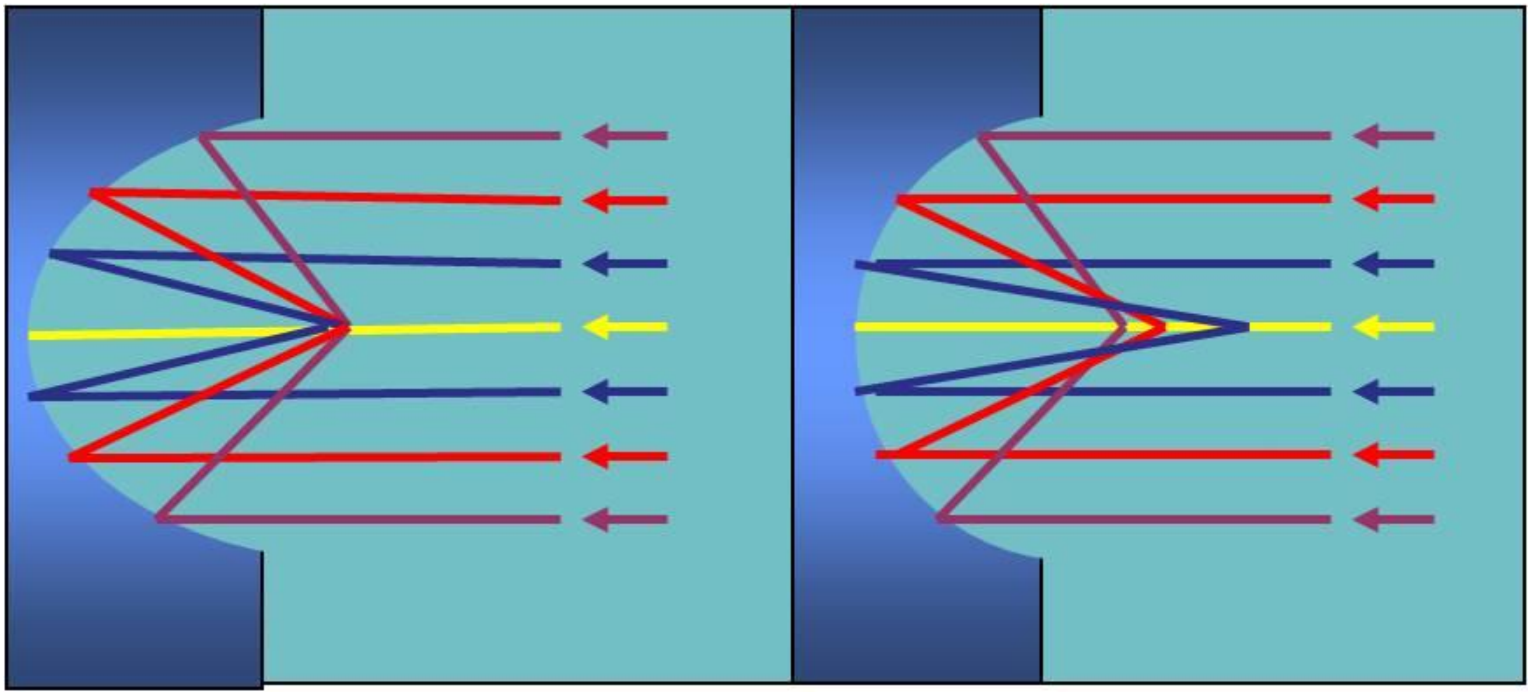
Typical Reflecting Telescope



Light from the object enters the tube, is reflected by a curved mirror back to a diagonal mirror where it reflected to the eyepiece.

http://www.fortworthastro.com/beginner5.html

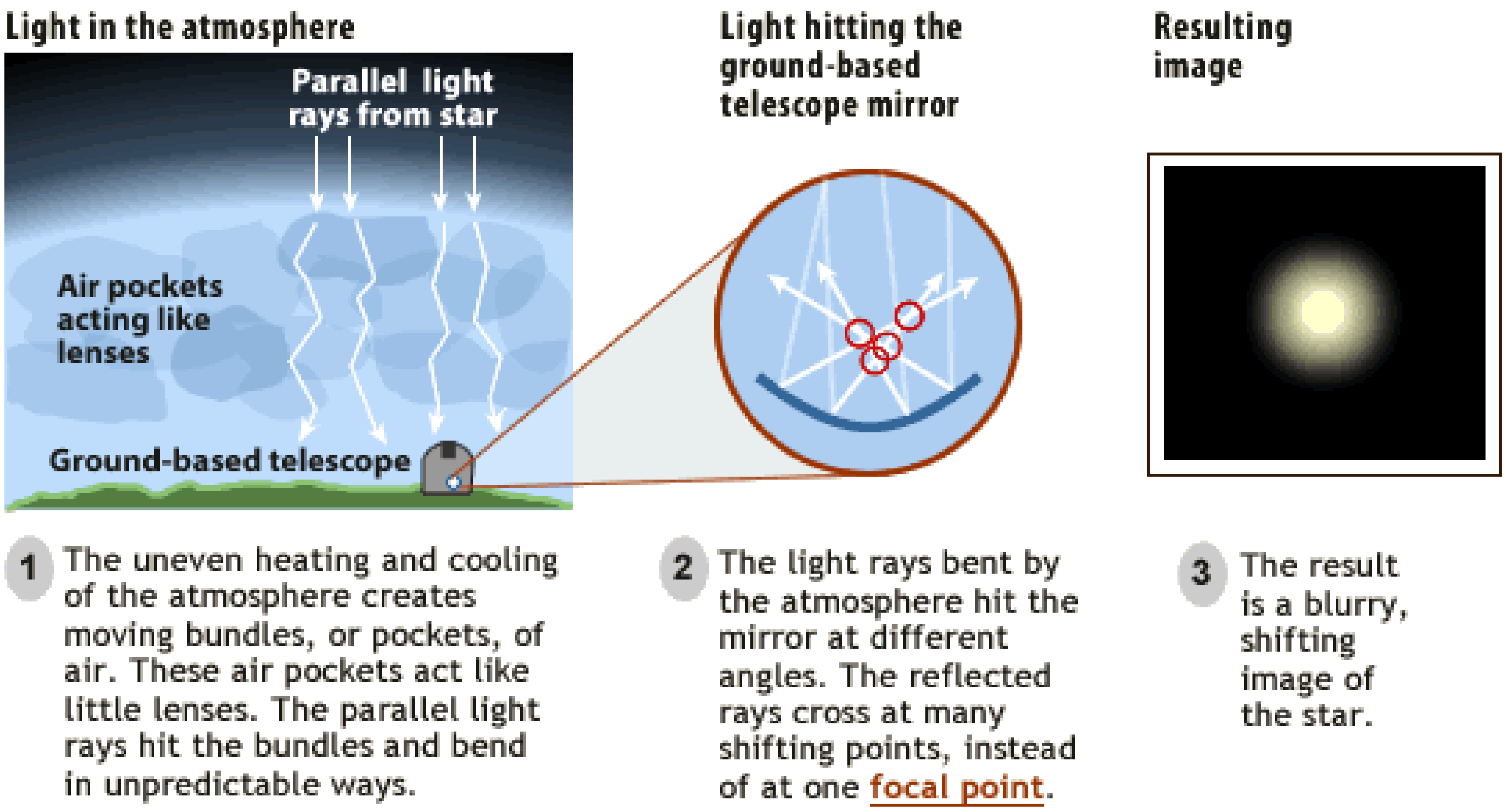
A parabolic mirror focuses light at a point



Reflecting telescopes use parabolic mirrors, which focus light at a point. Spherical mirrors focus light at different points along the axis of the telescope.The resulting distortion is called spherical aberration.

http://www.astronomyasylum.com/telescopeopticstutorial.html

Atmospheric Distortion



Even with a parabolic mirror, optical telescopes still have a problem: atmospheric distortion, which causes stars to appear to twinkle

http://amazingspace.org/resources/explorations/groundup/lesson/basics/g18a/

The largest optical telescopes are reflectors, and are usually on high mountains to reduce atmospheric distortion.

https://en.wikipedia.org/wiki/List_of_largest_optical_reflecting_telescopes

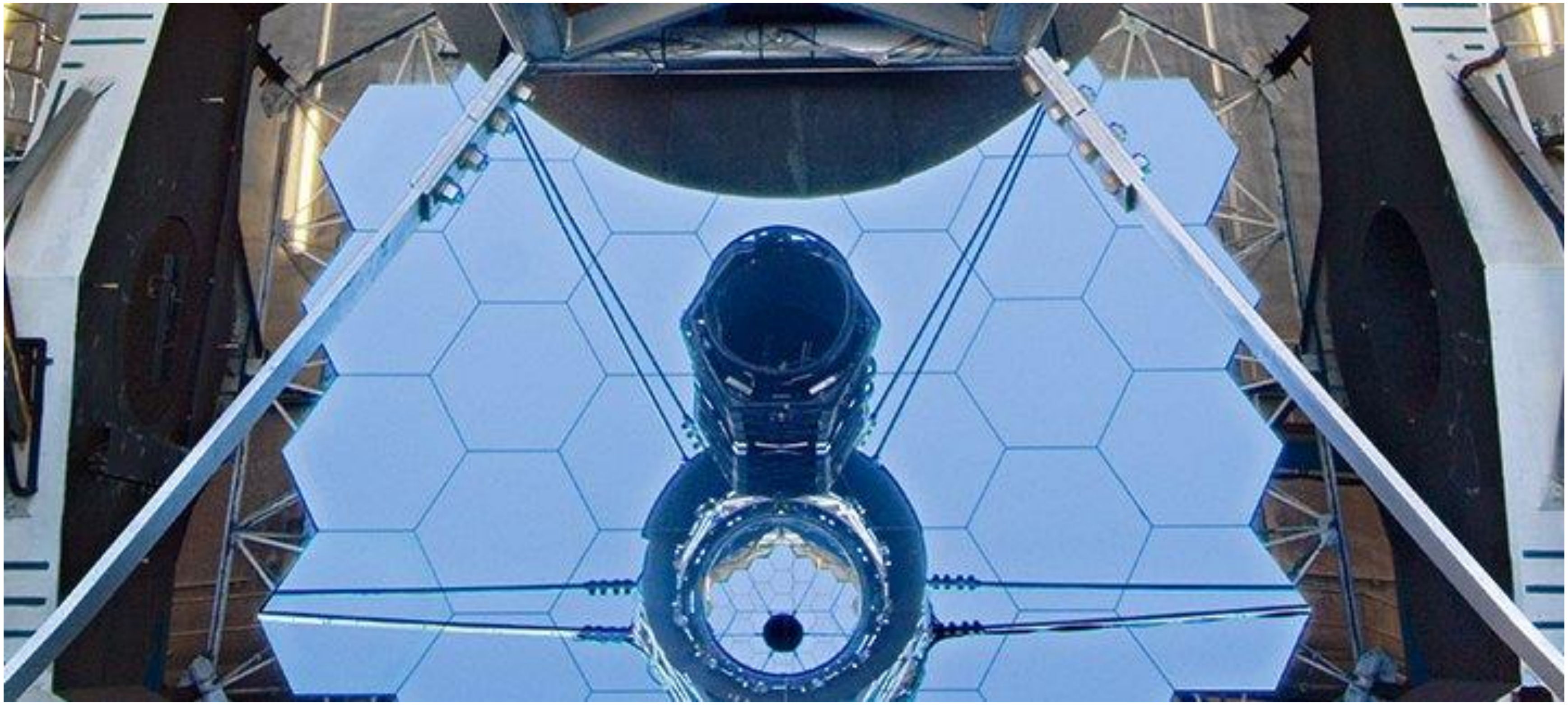
The twin Keck scopes on Maunakea in Hawaii are at 13,600 ft elevation

http://hyperphysics.phy-astr.gsu.edu/hbase/Solar/palomar.html

Large mirrors are difficult and expensive to produce and transport. The alternative is to build large mirrors in segments, which can be controlled by computerized adaptive optic systems, to form, in effect, a single large curved mirror. Above is model of Keck mirror

http://astronomy.swin.edu.au/keck/

Looking down on the 36 Keck mirror segments

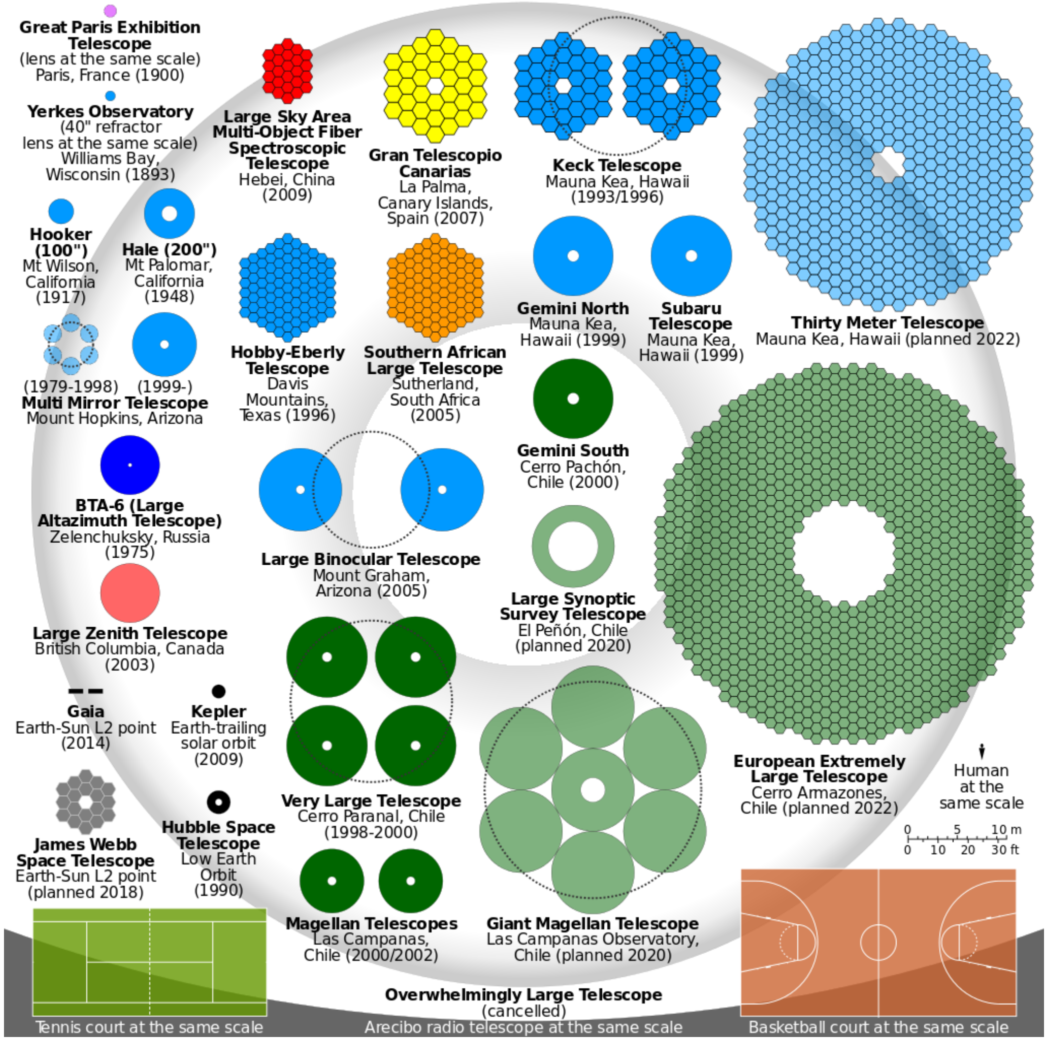


http://www.astro.caltech.edu/research/keck/

These adjustments also counter the effect of gravity as the telescope moves, as well as other environmental and structural effects that can affect the mirror shape.

https://en.wikipedia.org/wiki/W._M._Keck_Observatory

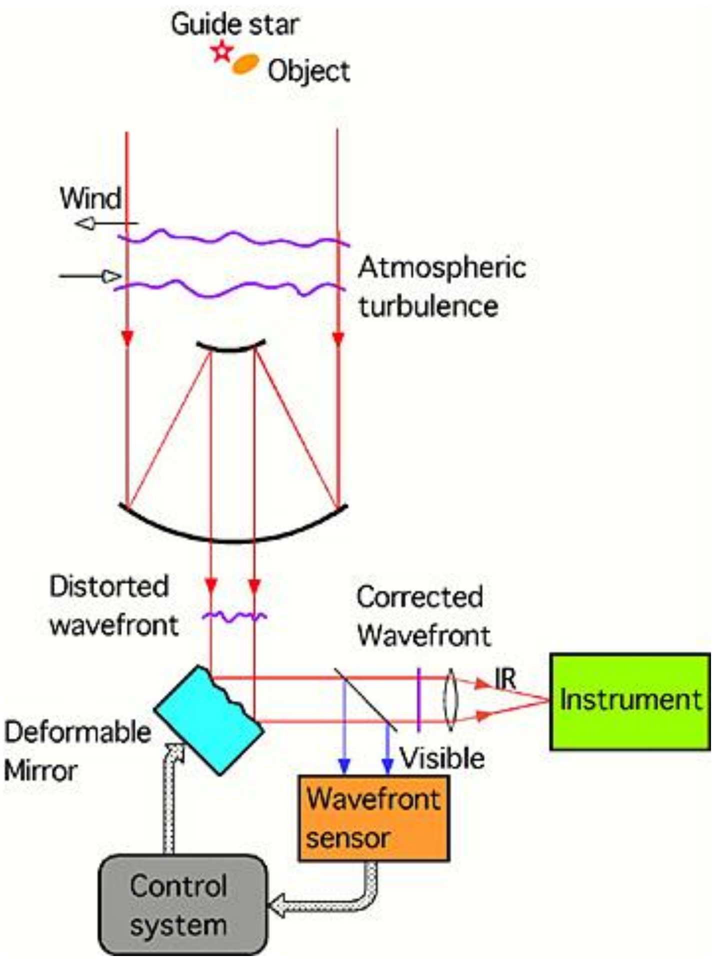
Primary mirrors of largest optical telescopes: note the size of a human in lower right; note size of Keck mirrors in top row.



https://en.wikipedia.org/wiki/List_of_largest_optical_reflecting_telescopes

Natural Guide Star AO

Even on mountain tops, atmospheric distortion is significant.
The solution again is Adaptive Optics.

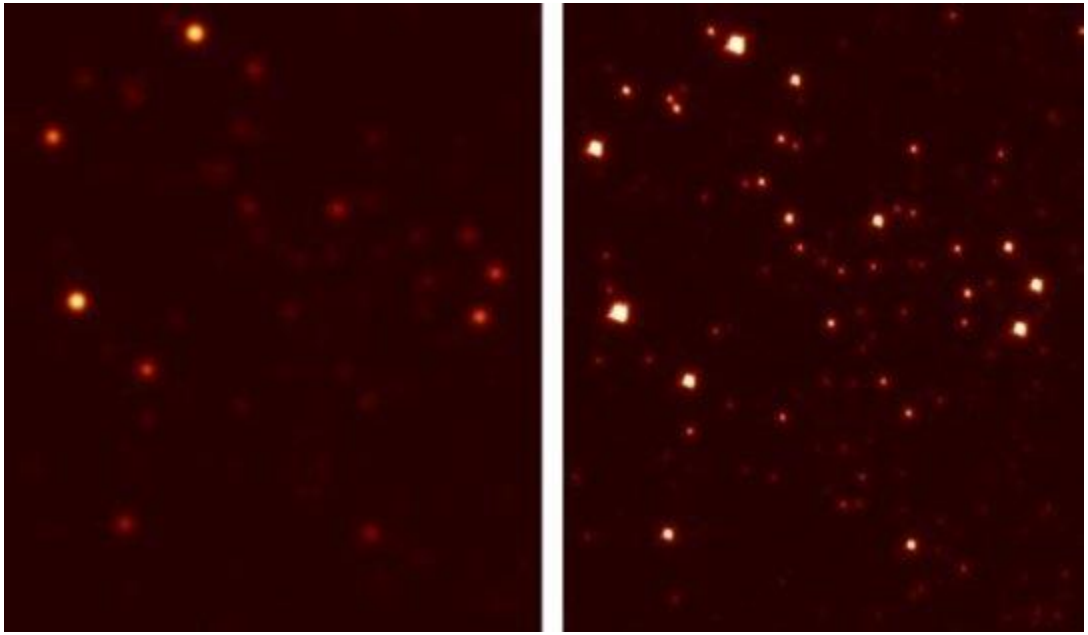


Light from a “guide” star near the telescope target falls on the adaptive optics system, where small sensors continuously monitor changes in the direction of light waves from the guide star. The sensors send this information to a computer, which controls the movements of actuators attached to the backs of the mirror segments.

https://str.llnl.gov/str/Guidestr.htm

https://www.subarutelescope.org/Pressrelease/2006/11/20/index.html

Since the guide star is very close to the telescope target, the corrections to the guide star image also correct the image of the telescope target.

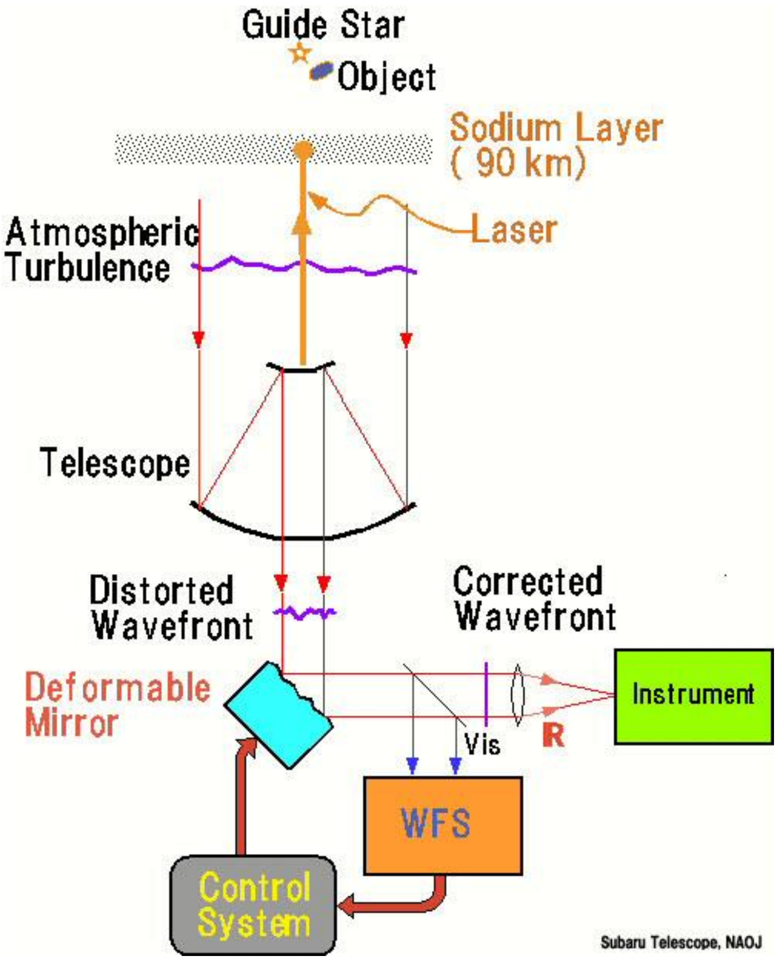


Without AO With AO

https://www.sciencedaily.com/releases/2010/08/100804133354.htm

Laser Guide Star AO

Often there is no natural guide star near the object.



The solution is to create an artificial guide star using a laser to excite sodium atoms 60 miles above the earth. The sodium atoms are present in a thin shell around the earth, created by micrometeorites which vaporize as they enter the upper atmosphere.

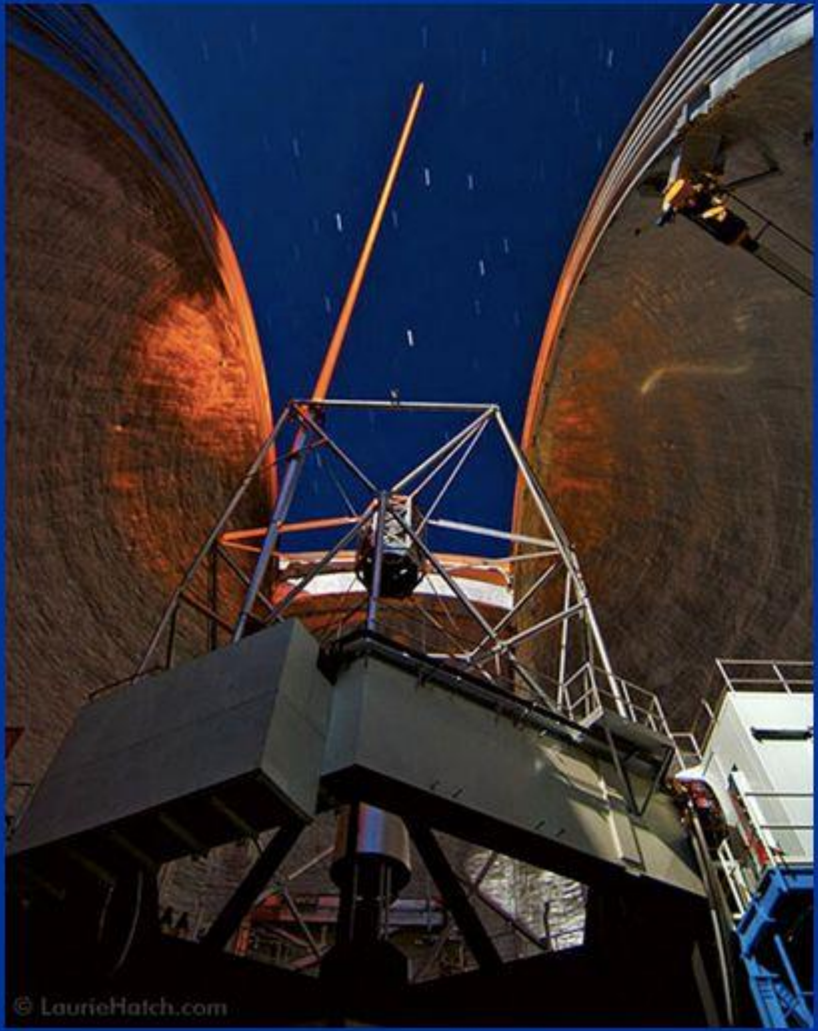
The process of creating an artificial guide star is called “Laser Guide Star Adaptive Optics”

https://str.llnl.gov/str/Guidestr.htm

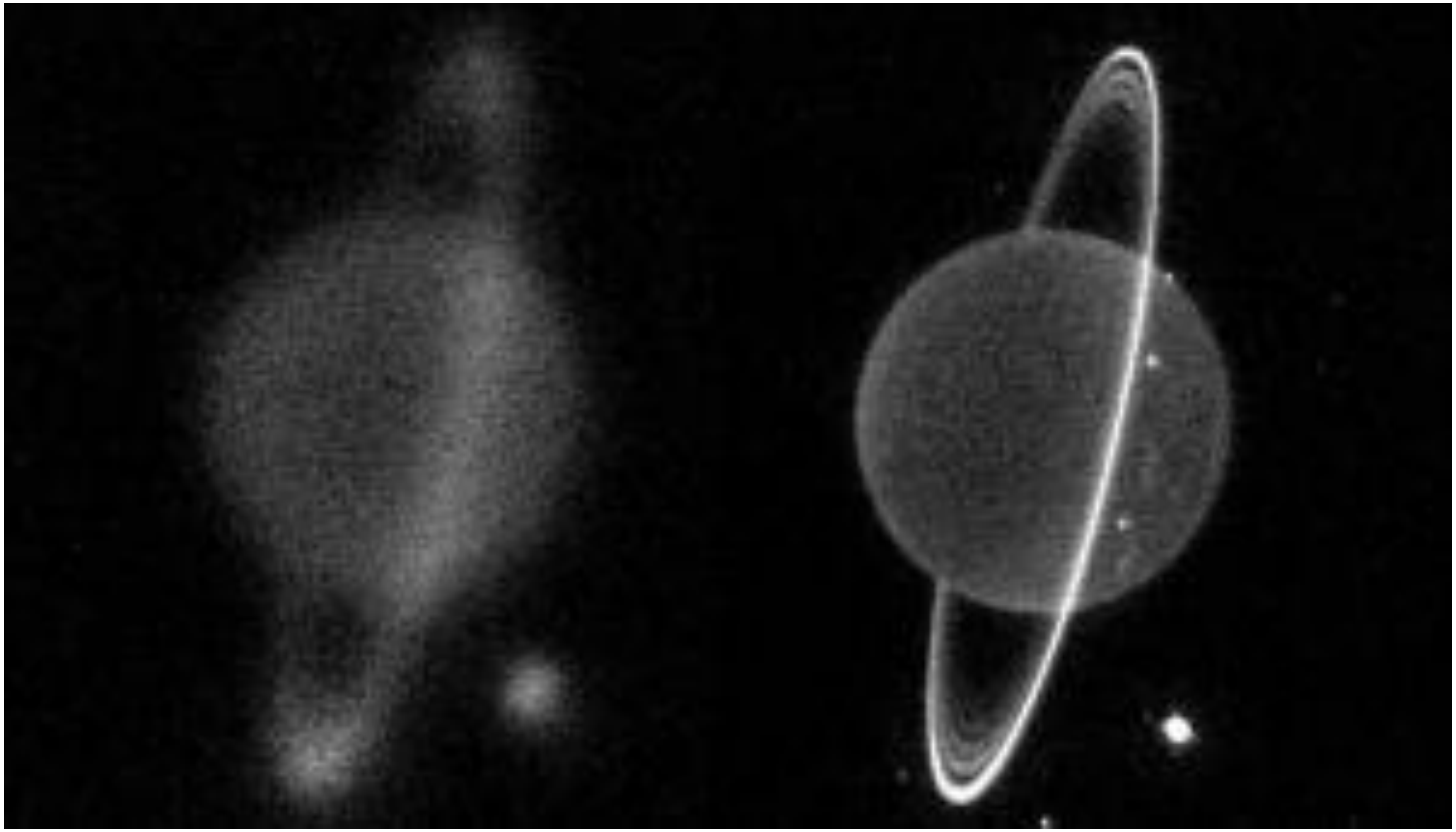
https://www.subarutelescope.org/Pressrelease/2006/11/20/index.html

Keck laser guide star

Francois Wildi Obseratoire Geneve: Slideplayer.com

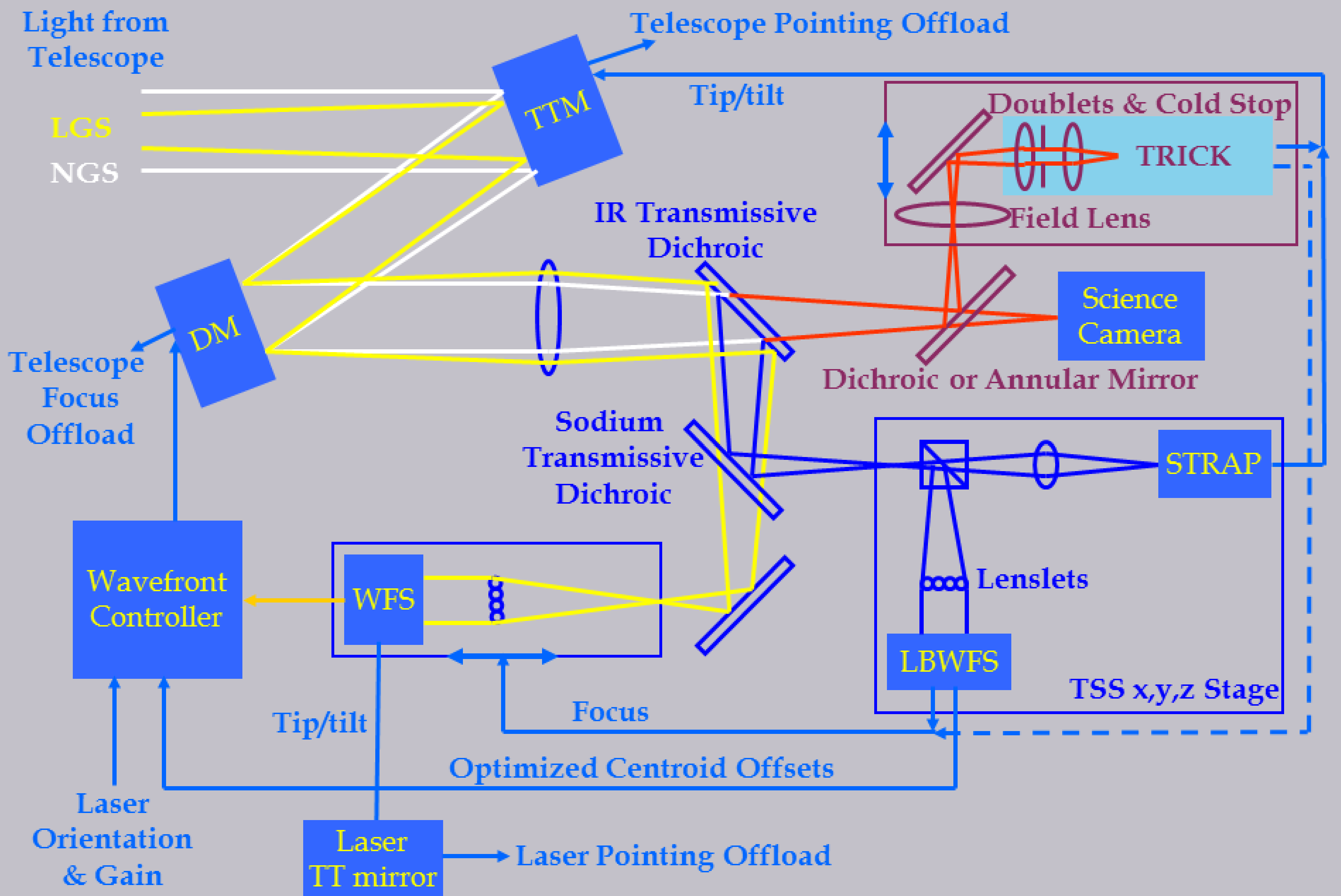


Keck: Uranus without and with adaptive optics



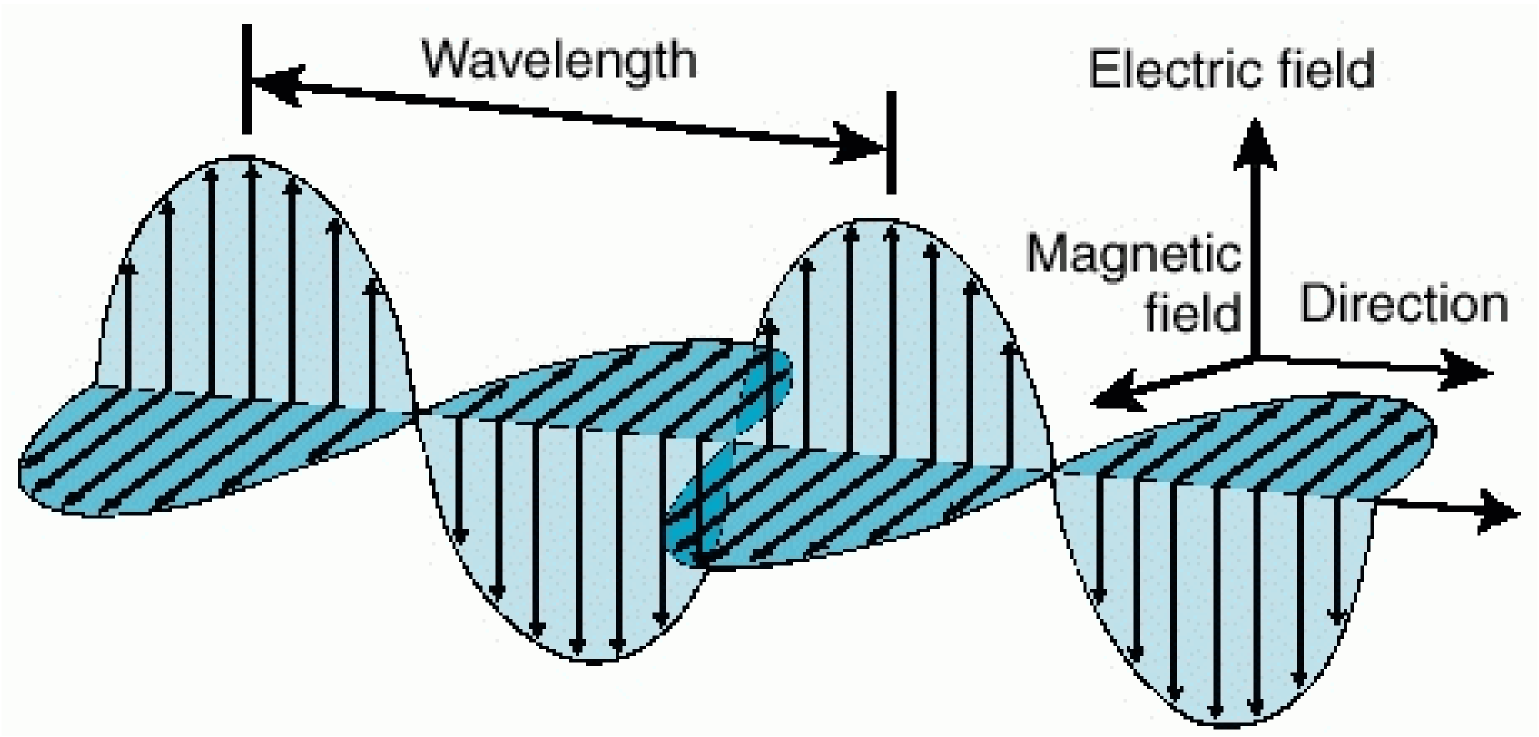
http://www.keckobservatory.org/support/ngao

Keck Adaptive Optics



https://www2.keck.hawaii.edu/optics/lgsao/images/lgs_layout.png

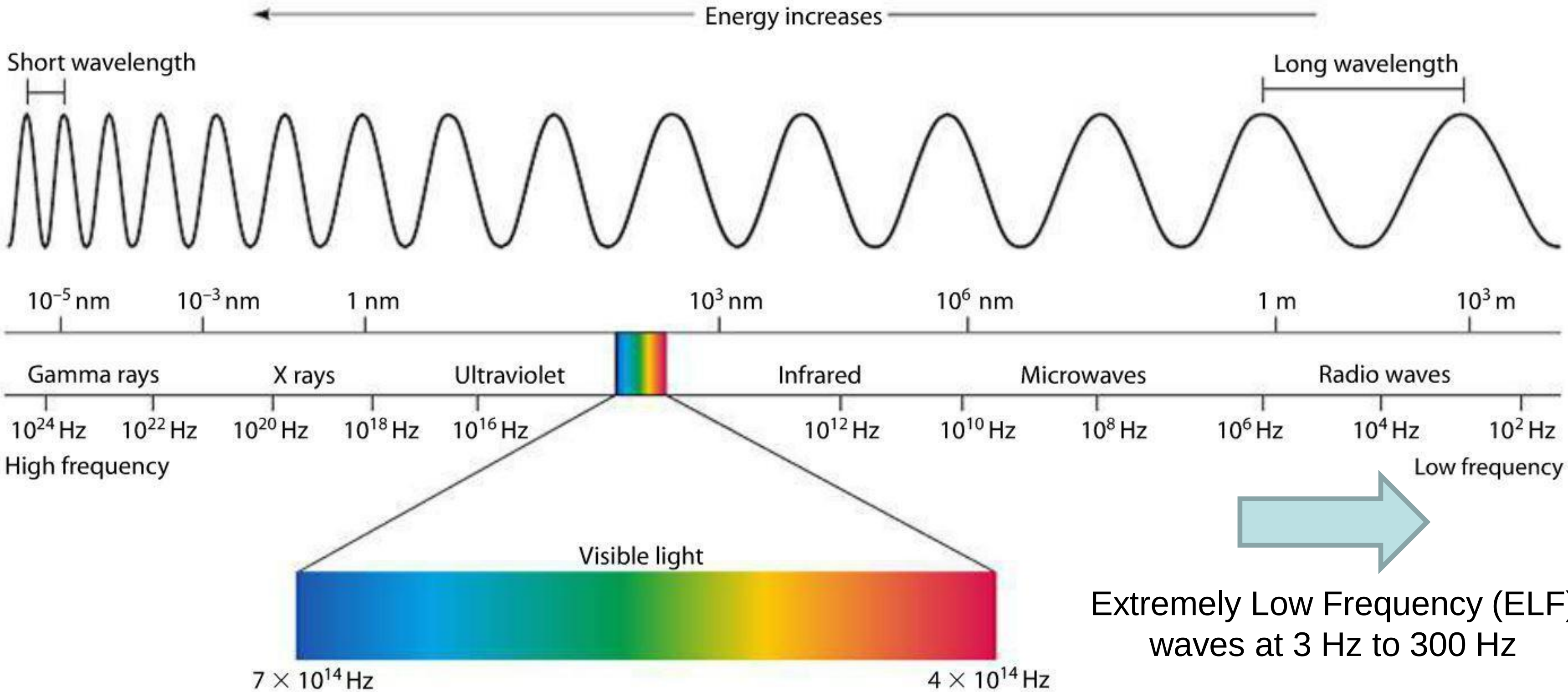
An electromagnetic wave



All of these optical telescopes work by getting light from the star or planet.
A ray of light is an electromagnetic wave.

https://www.wonderwhizkids.com/conceptmaps/EM-Radiation.html

Electromagnetic Spectrum



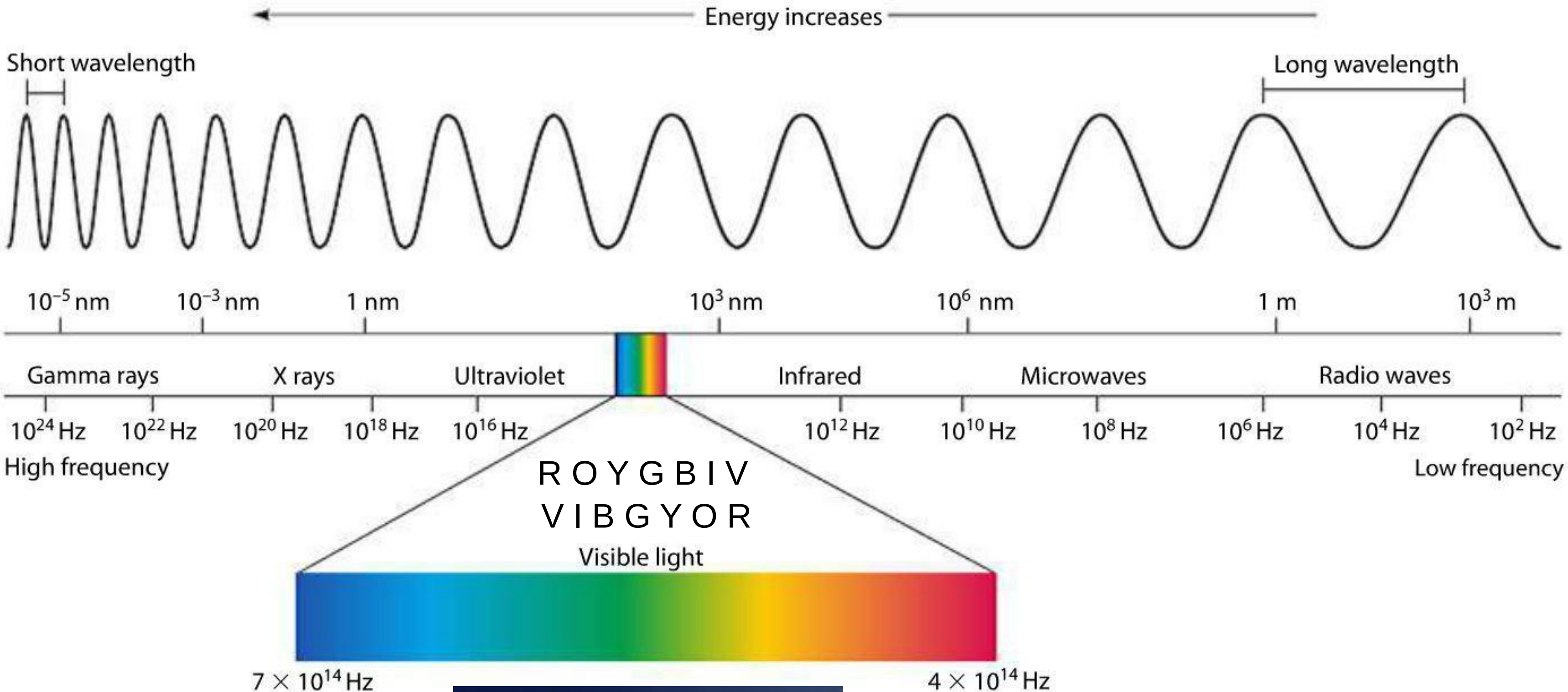
Extremely Low Frequency (ELF) waves at 3 Hz to 300 Hz

Electromagnetic waves include a whole spectrum of different wavelengths, from cosmic rays through visible light to microwaves, radio waves, and ELF waves

https://www.studyblue.com/notes/note/n/module-3-waves-and-the-electromagnetic-spectrum/deck/8054719

Optical Scopes see light

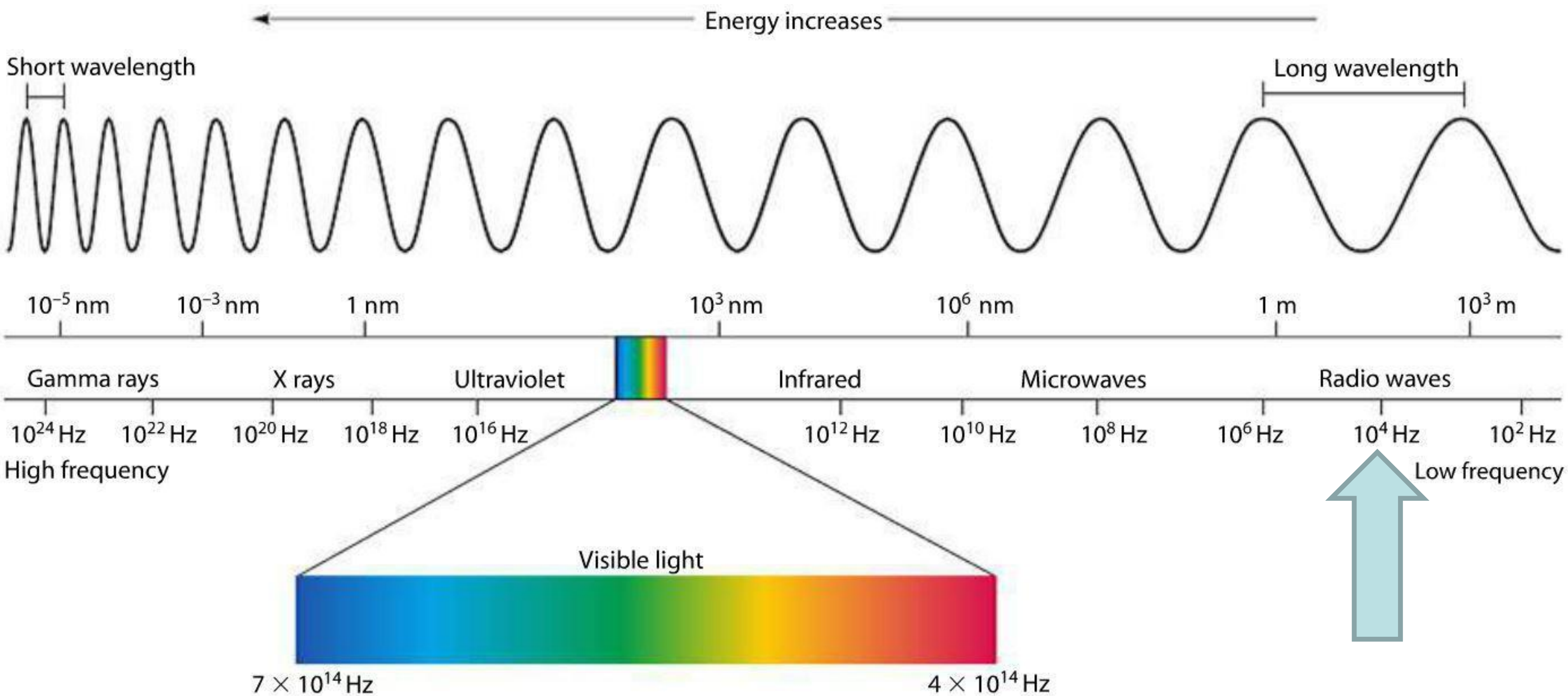
Remember Keck and all other optical scopes work
by getting light from the star or planet



https://www.studyblue.com/notes/note/n/module-3-waves-and-the-electromagnetic-spectrum/deck/8054719

Radio scopes “see” radio waves

which are much longer and lower in frequency than light waves



Radio scopes can see through space dust and even cloudy skies; and it does not have to be dark

https://www.studyblue.com/notes/note/n/module-3-waves-and-the-electromagnetic-spectrum/deck/8054719

Greenbank Radio Telescope West Virginia

https://astronomynow.com/2015/03/31/race-to-detect-gravitational-waves-intensifies

Very Large Array Telescope, New Mexico

Radio waves from different radio scopes can also be added together by computers to get a better picture

https://www.dreamstime.com/royalty-free-stock-photos-very-large-array-radio-telescope-satellite-dishes-sunset-new-mexico-usa-image35263148

This process is called Aperture synthesis,
and produces images having the same angular resolution as an instrument the size of the entire collection.
https://en.wikipedia.org/wiki/Aperture_synthesis

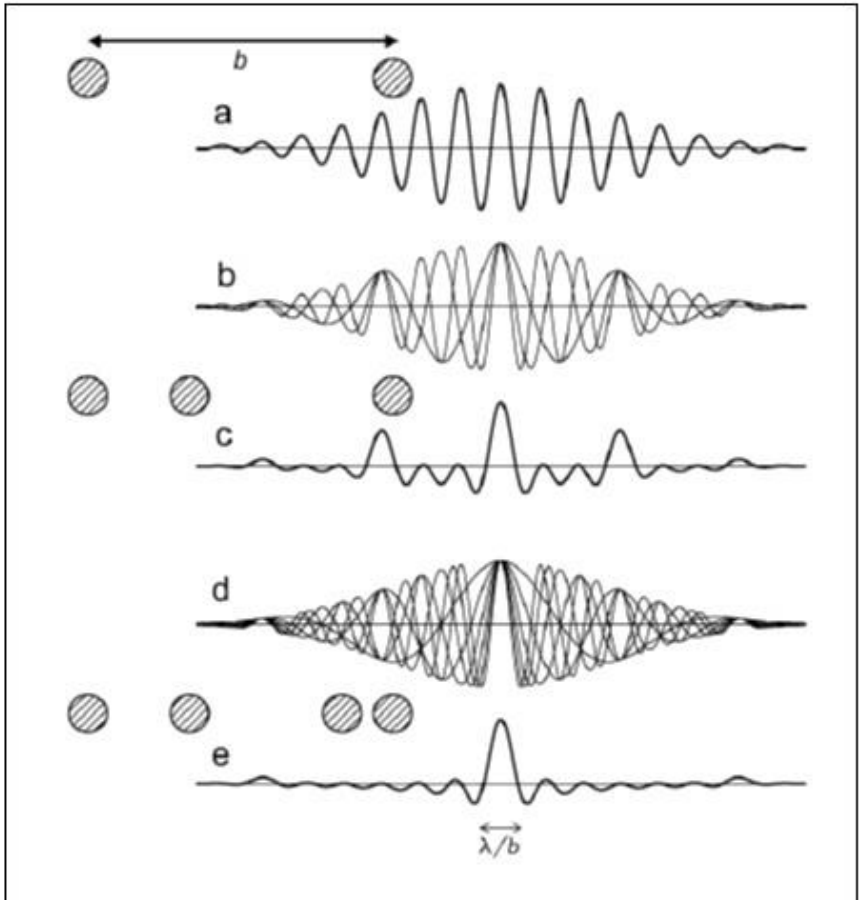


Figure 9.2. Improvement in field pattern quality (the images are

http://ircamera.as.arizona.edu/Astr_518/interferometry1.pdf

The resolution however, depends on the number of telescopes in the array

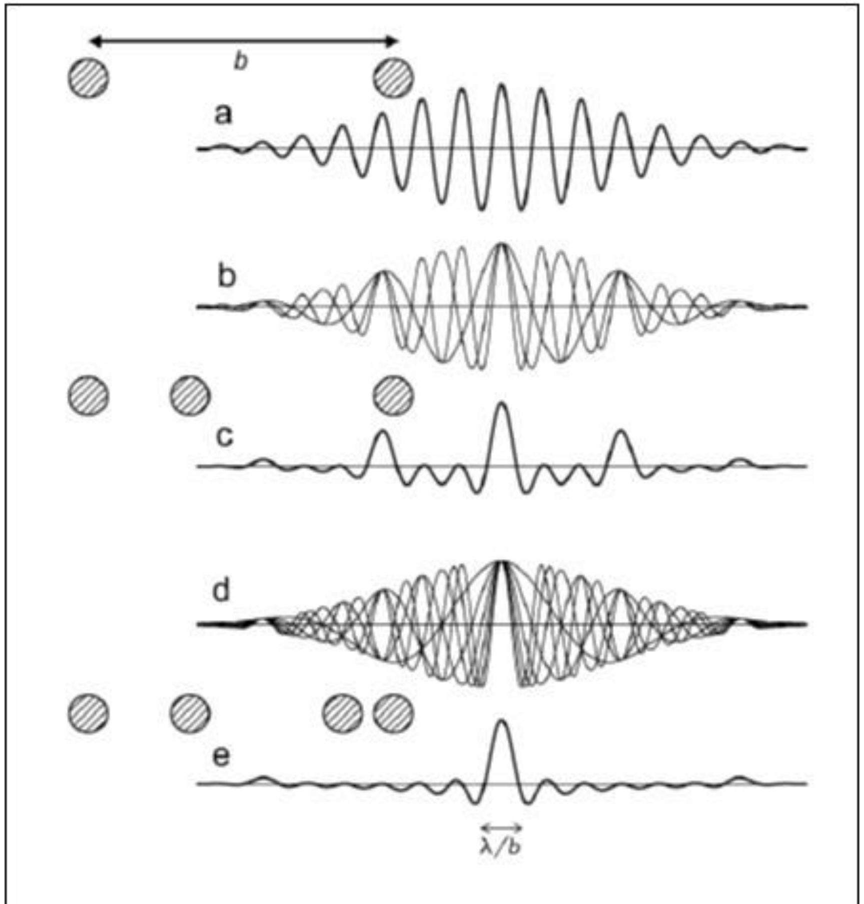
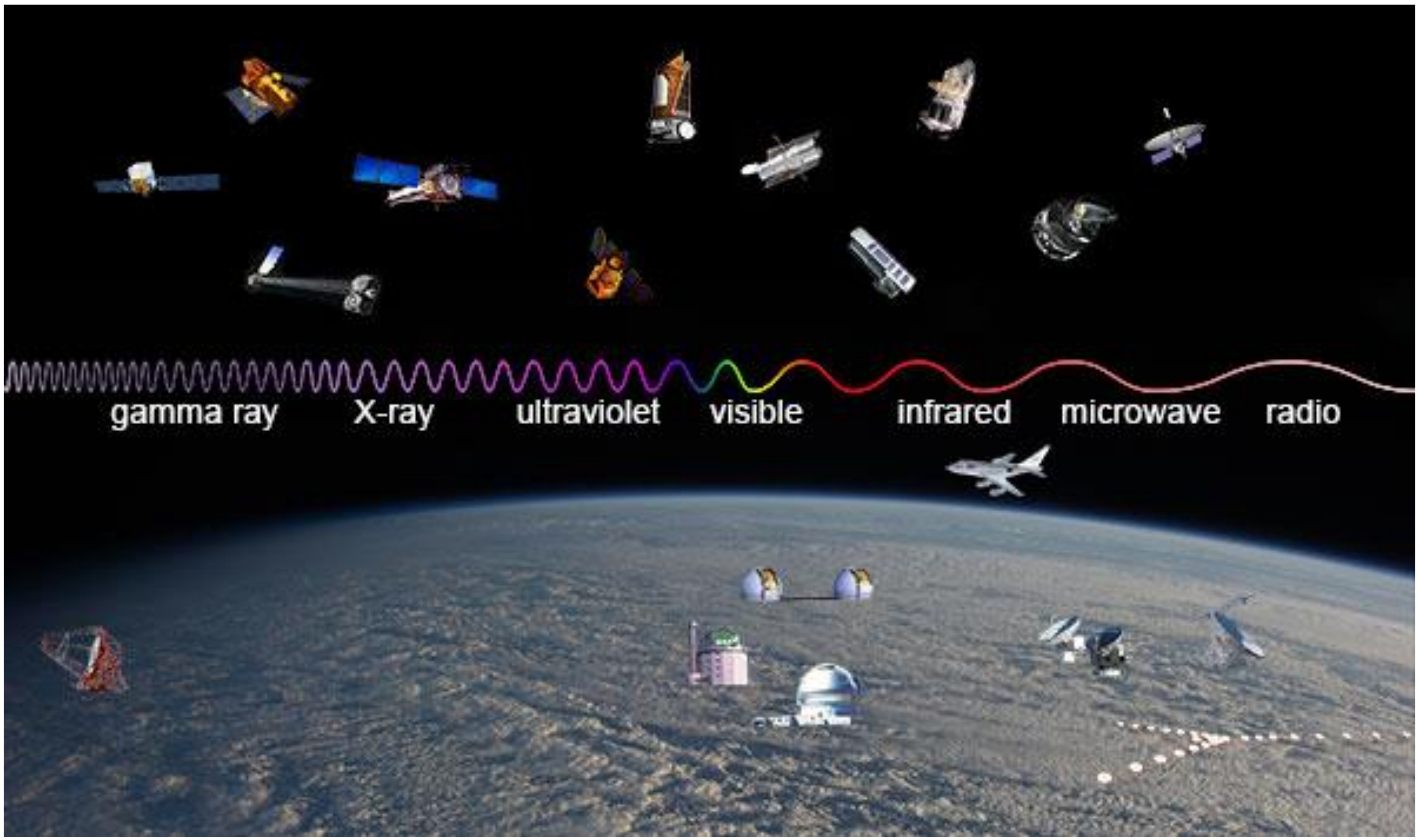


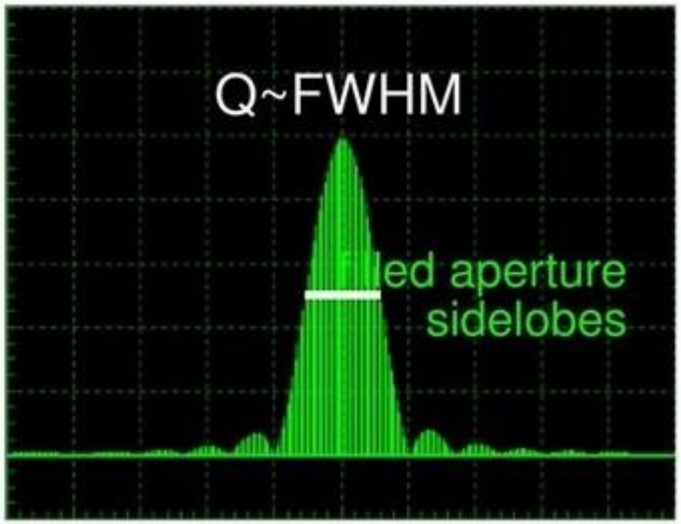
Figure 9.2. Improvement in field pattern quality (the images are

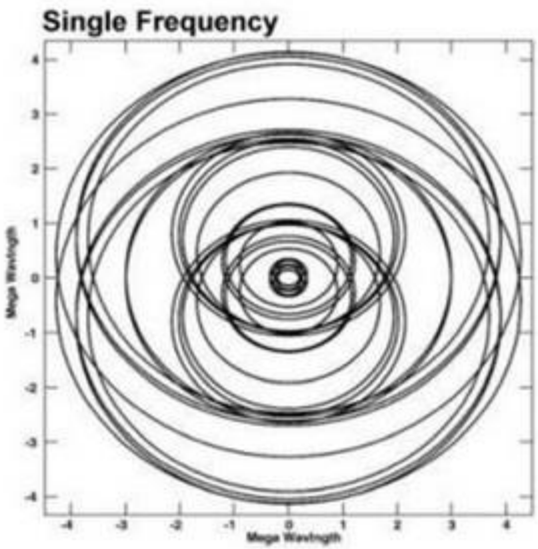
Observatories across the EM spectrum



https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum_observatories1.html

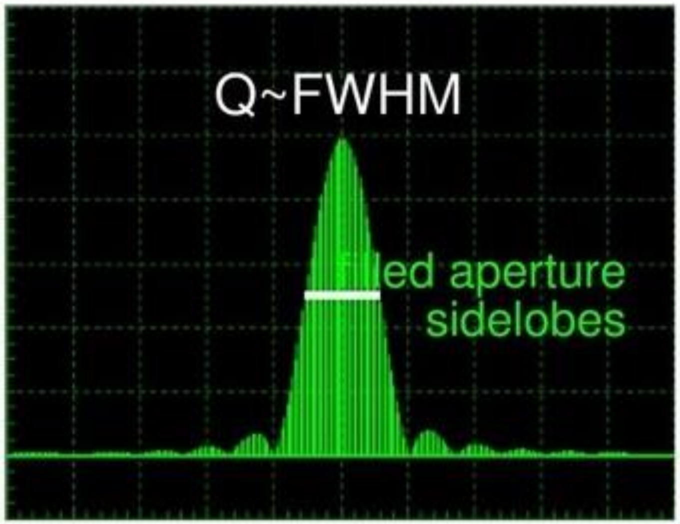
- One antenna: maximum resolution q~l/***D***
  - ***D*** 25 m, l 21 cm (n 1.4 GHz) gives q~0.5^{o}

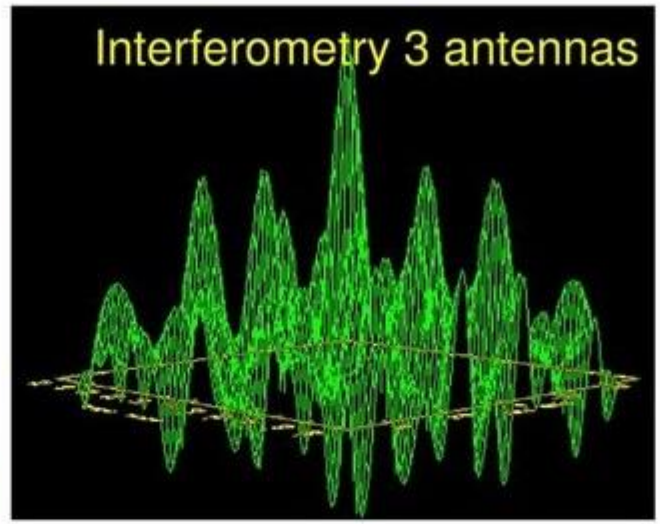




- Many antennas:
  - Maximum resolution q~l/***B***
  - ***B*** ~200 km at l 21 cm gives q~0.2 arcsec

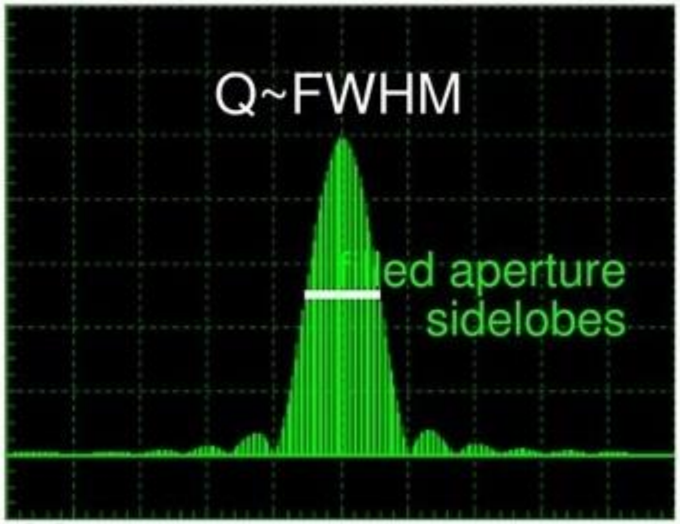
- One antenna: maximum resolution q~l/*D*
  - *D* 25 m, l 21 cm (n 1.4 GHz) gives q~0.5°

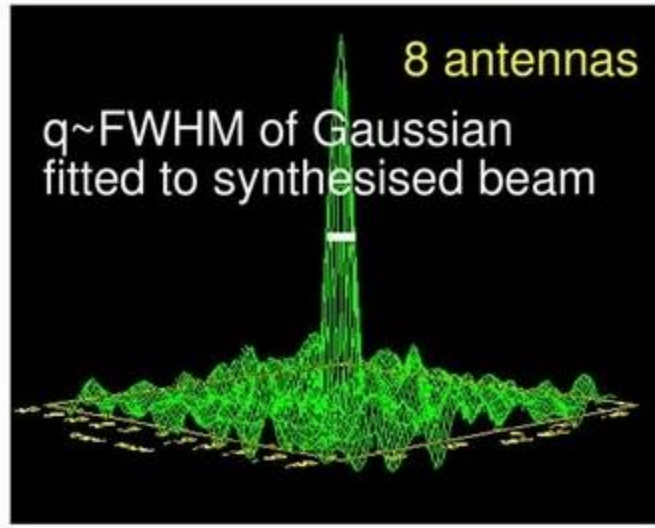




- Many antennas:
  - Synthesised beam is Fourier transform of uv tracks
  - Gaps in uv coverage make sidelobes in beam

•One antenna: maximum resolution q~l/*D*
–*D* 25 m, l 21 cm (n 1.4 GHz) gives q~0.5°





•Many antennas:
- Maximum resolution q~l/*B*

–More antennas means fewer sidelobes