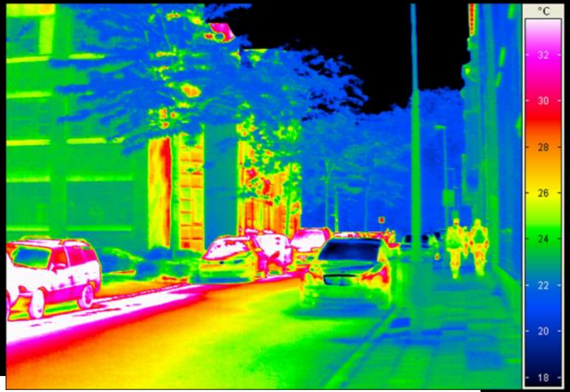
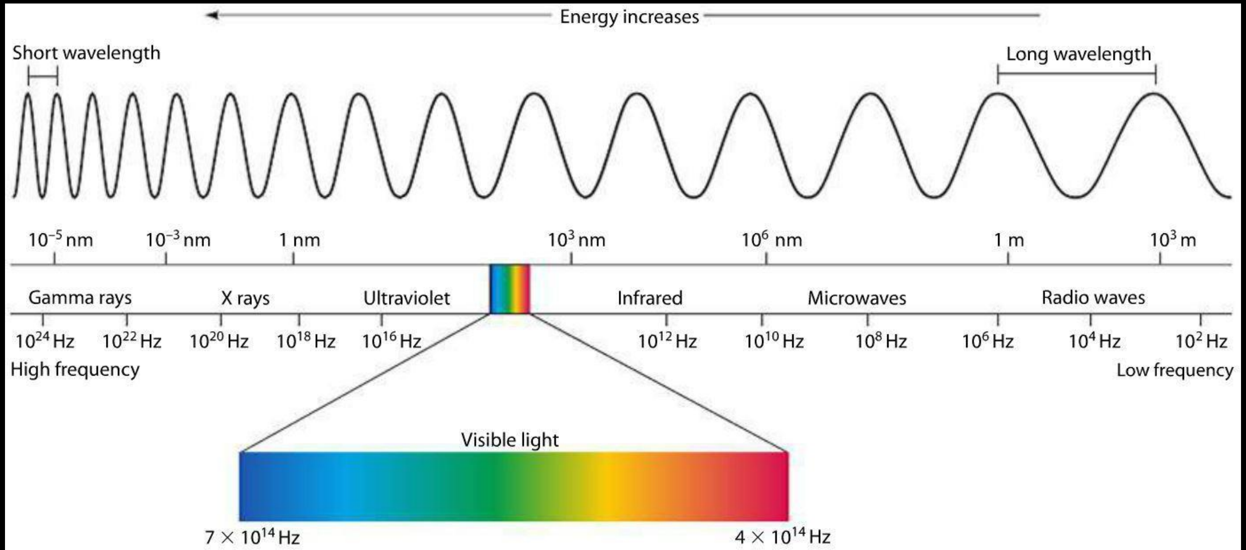
Observational Astronomy

Indian Space Science Olympiad

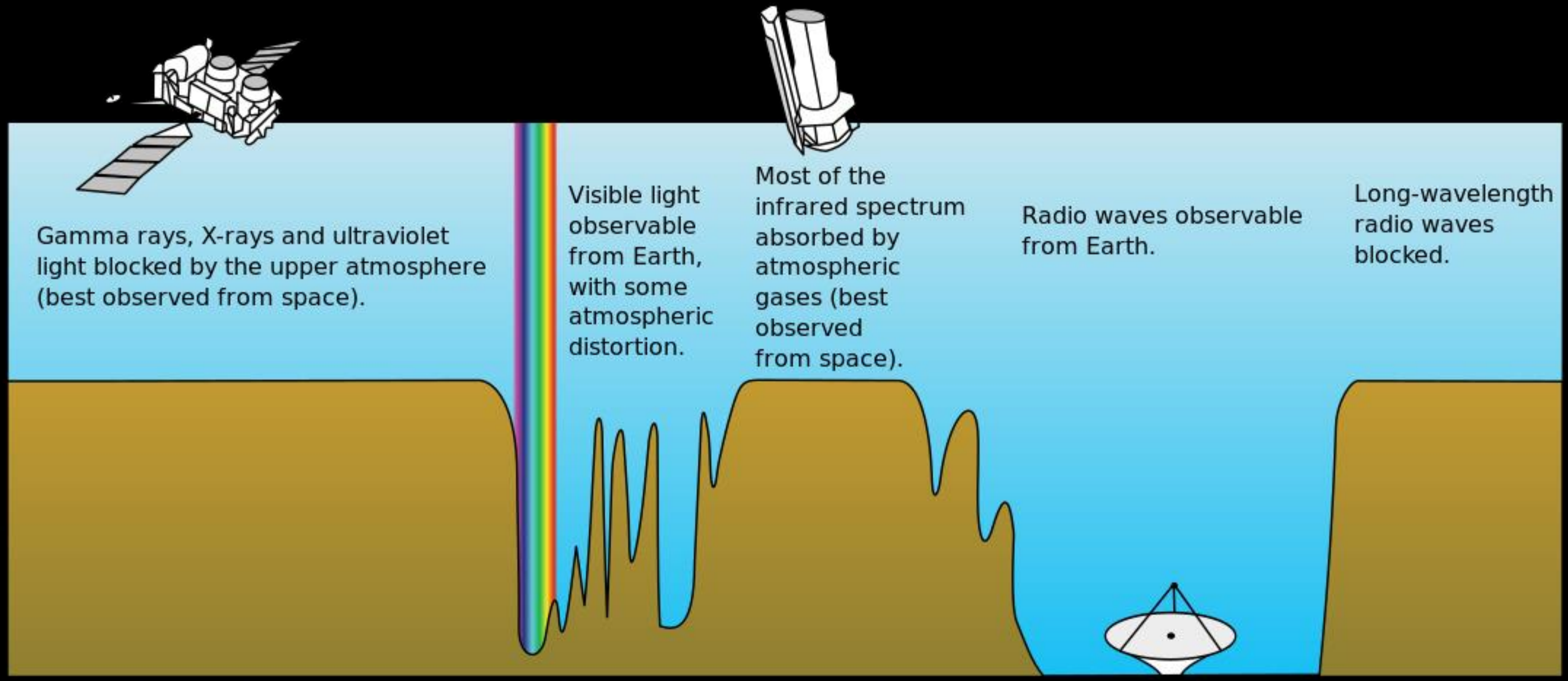

Telescopes

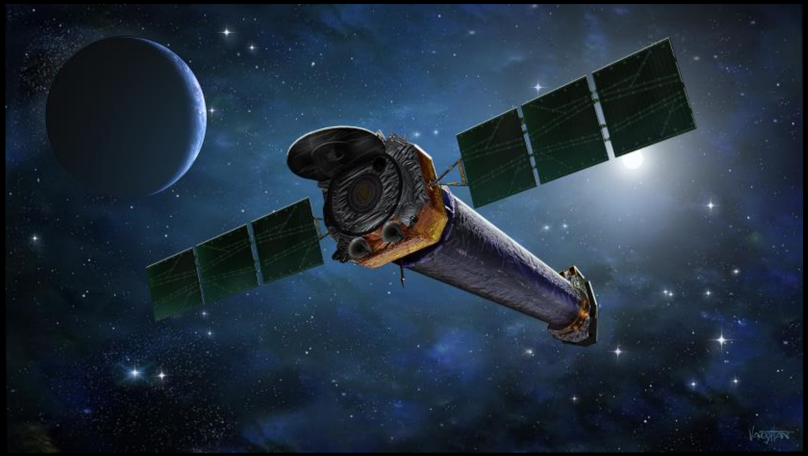
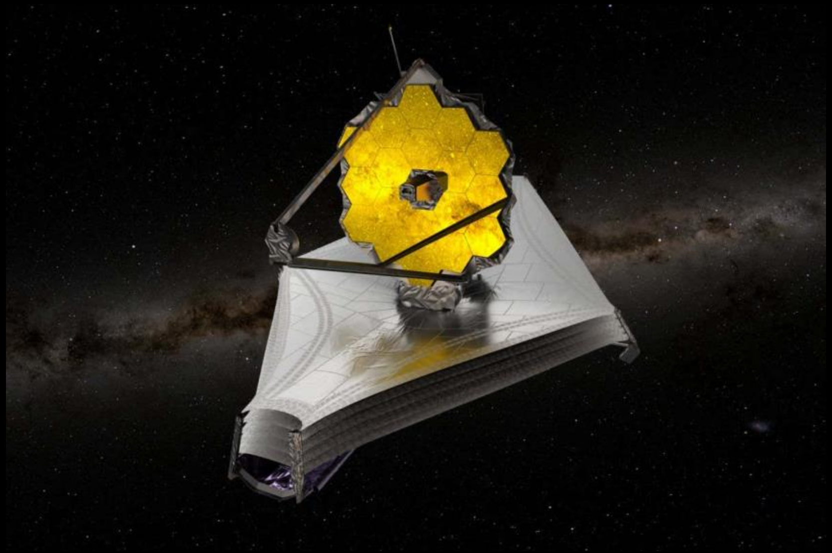

12:08
POTATO
POPCORN
PIZZA
BEVERAGE
FROZEN DINNER
REHEAT
CLOCK
TIME COOK
KITCHEN TIMER
TIME DEFROST
WEIGHT DEFROST
POWER LEVEL
EXPRESS COOK
STOP CLEAR
UNLOCK
START +30 SEC.


°C
32
30
28
26
24
22
20
18

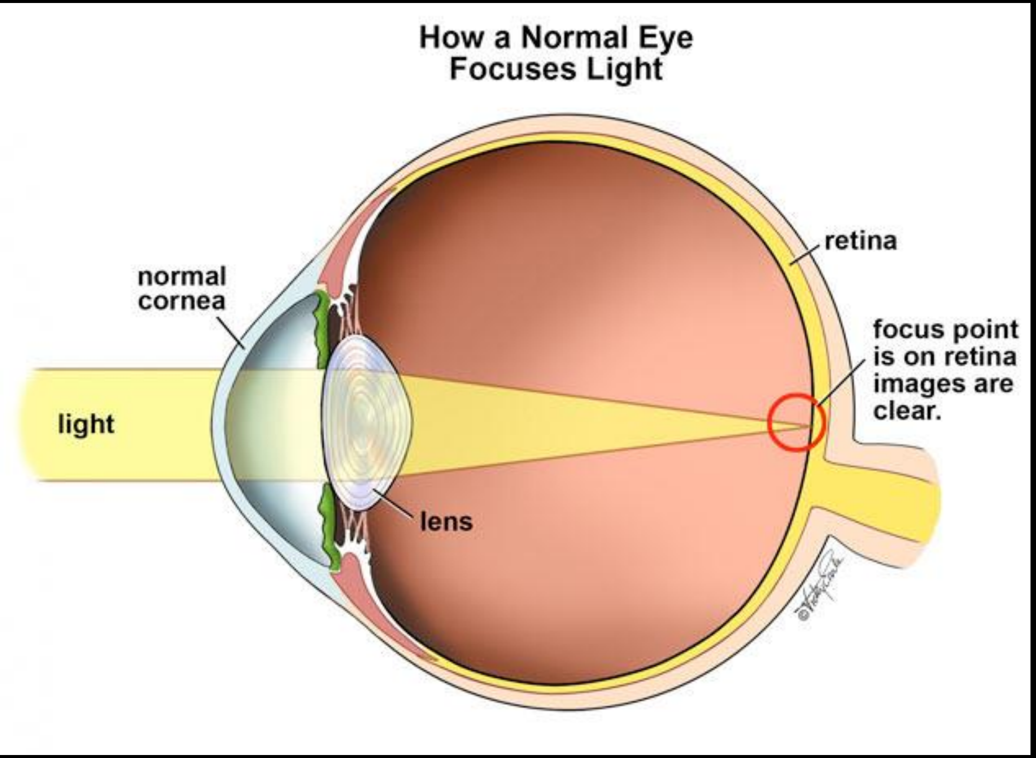

Energy increases
Short wavelength
Long wavelength
10^-5 nm
10^-3 nm
1 nm
10^3 nm
10^6 nm
1 m
10^3 m
Gamma rays
X rays
Ultraviolet
Infrared
Microwaves
Radio waves
10^24 Hz
10^22 Hz
10^20 Hz
10^18 Hz
10^16 Hz
10^12 Hz
10^10 Hz
10^8 Hz
10^6 Hz
10^4 Hz
10^2 Hz
High frequency
Low frequency
Visible light
7 × 10^14 Hz
4 × 10^14 Hz

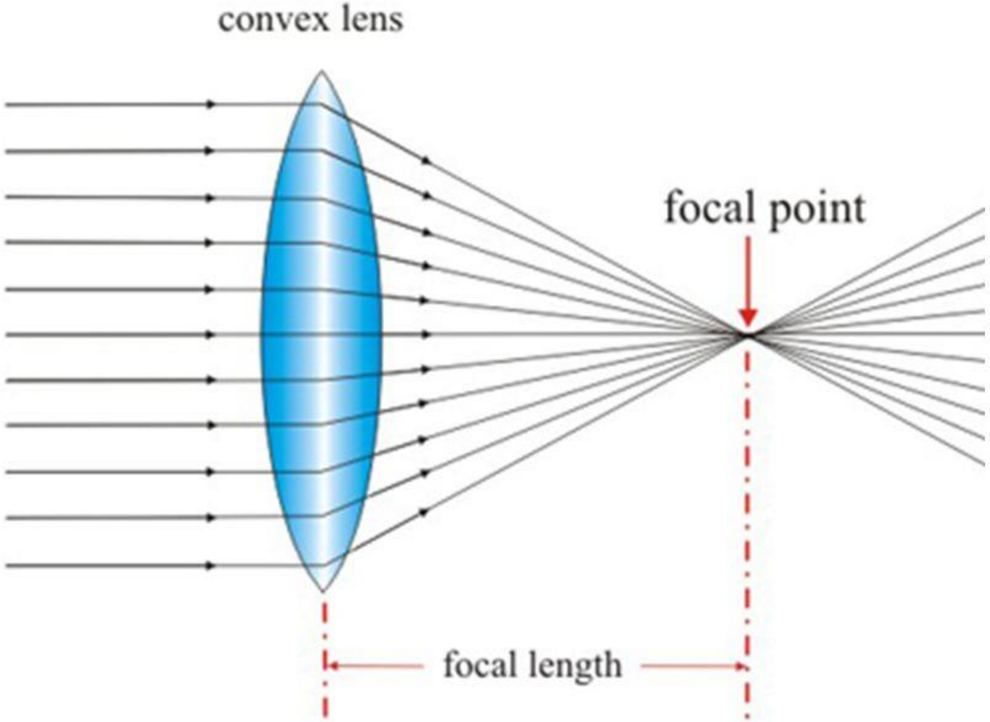

FM
MHz
VOLUME
TUNING

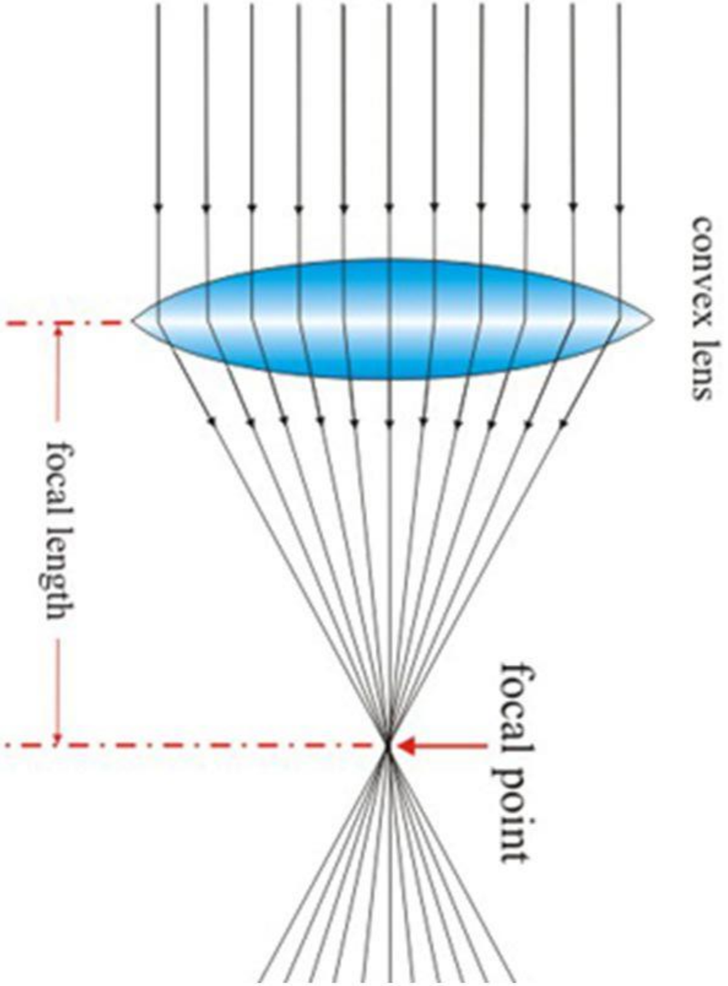

Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gases (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.

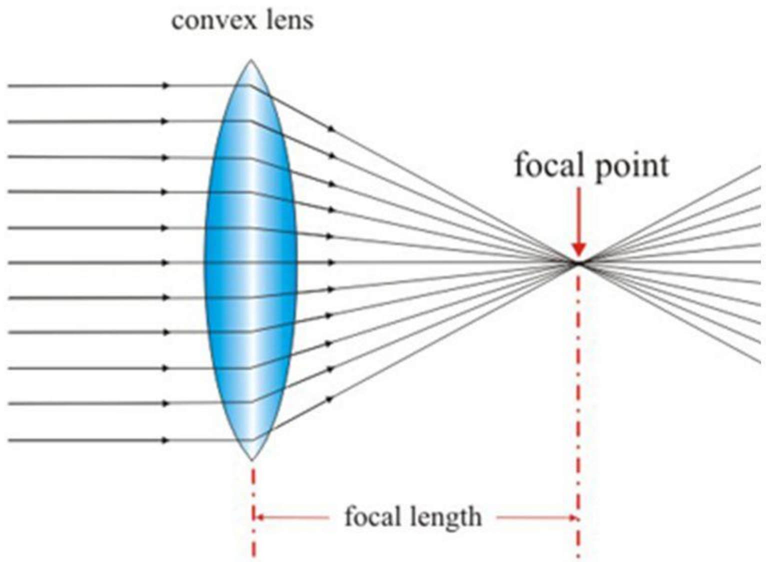




Why Telescopes ?

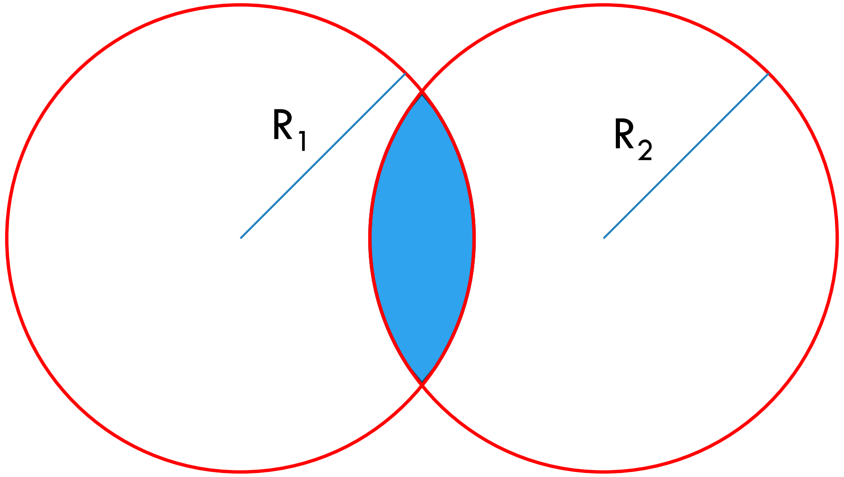




convex lens
focal point
focal length

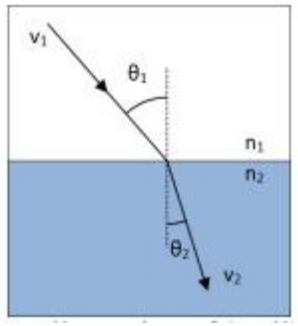

convex lens
focal length
focal point



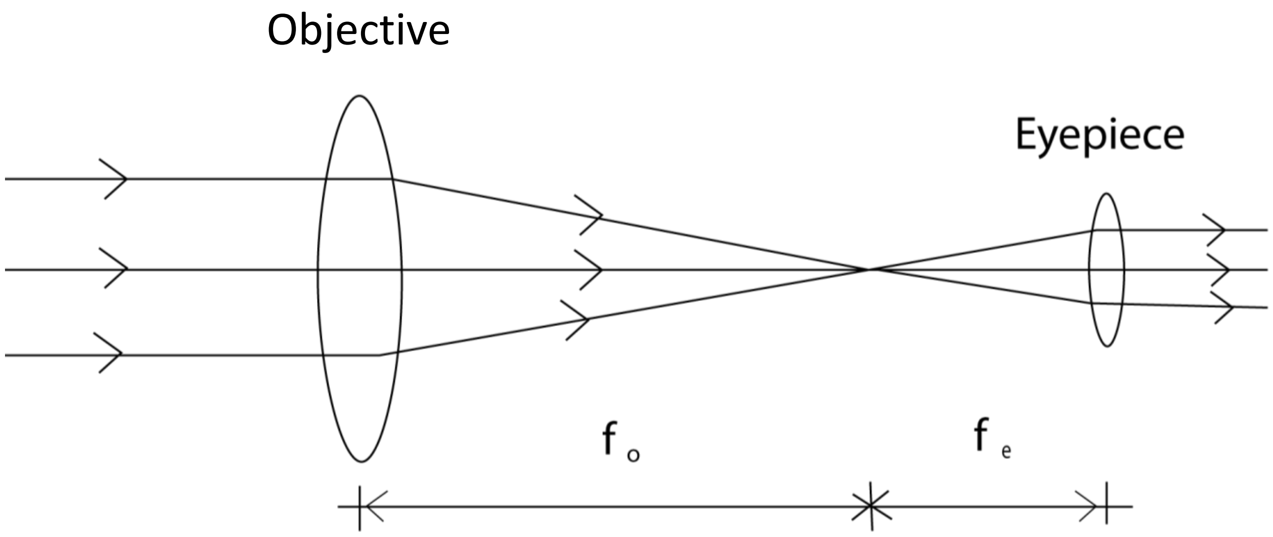
$$\frac{1}{f_\lambda} = (n_\lambda - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$



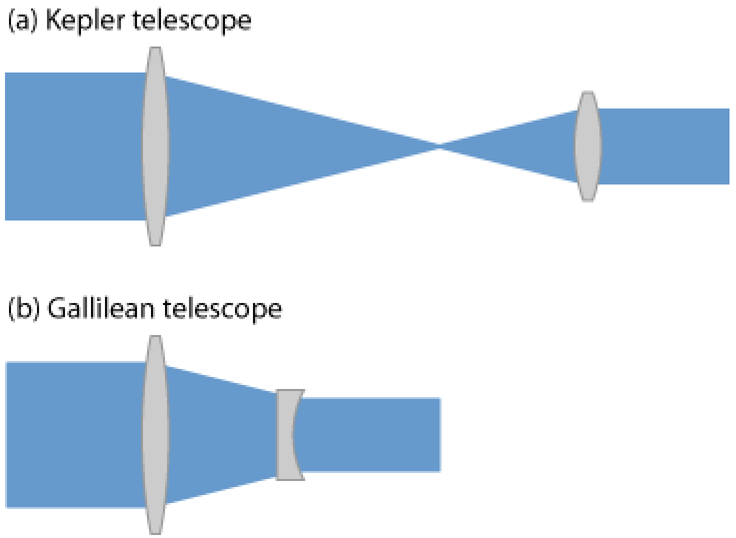
$$\frac{\sin(\theta_1)}{\sin(\theta_2)} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

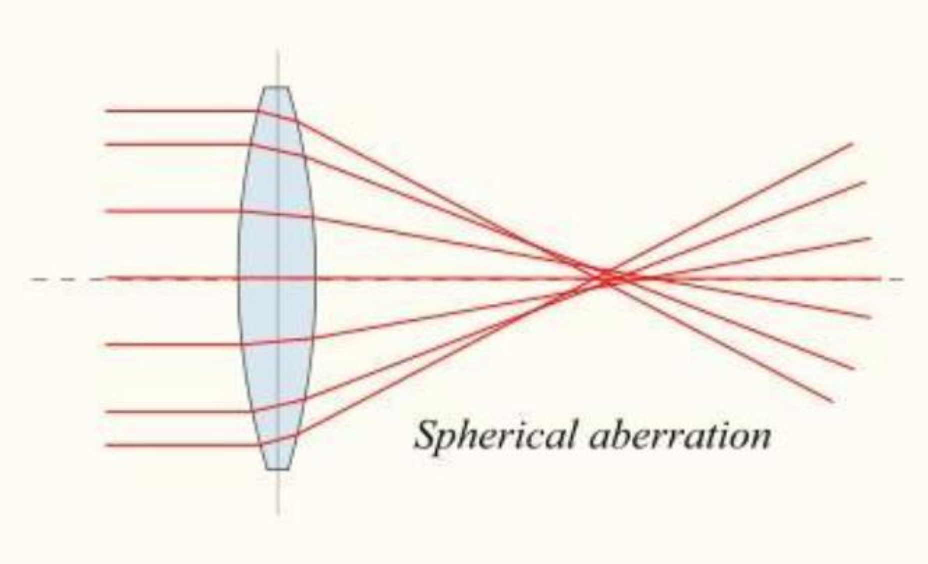


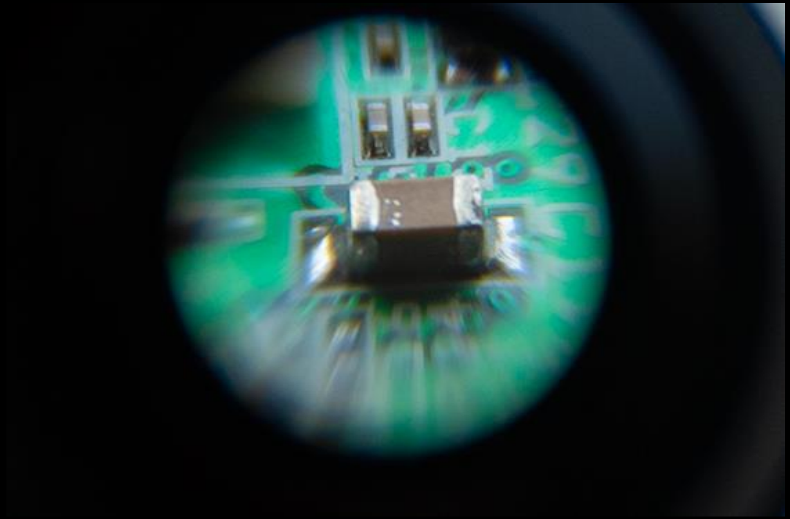
REFRACTING TELESCOPES

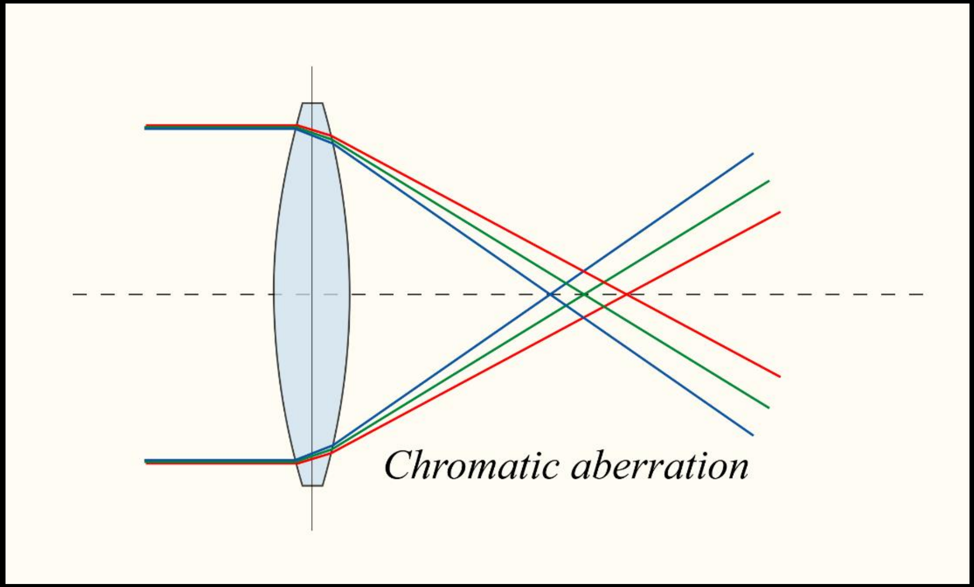


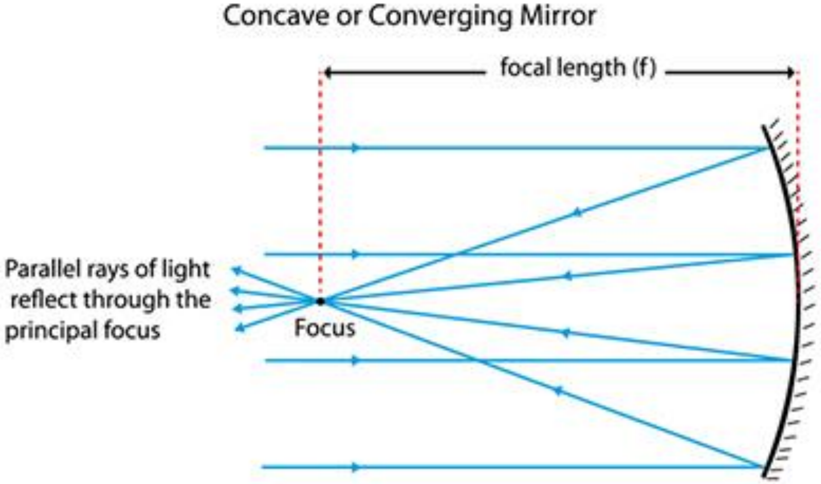
$$m = \frac{f_{\text{obj}}}{f_{\text{eye}}}.$$




Spherical aberration

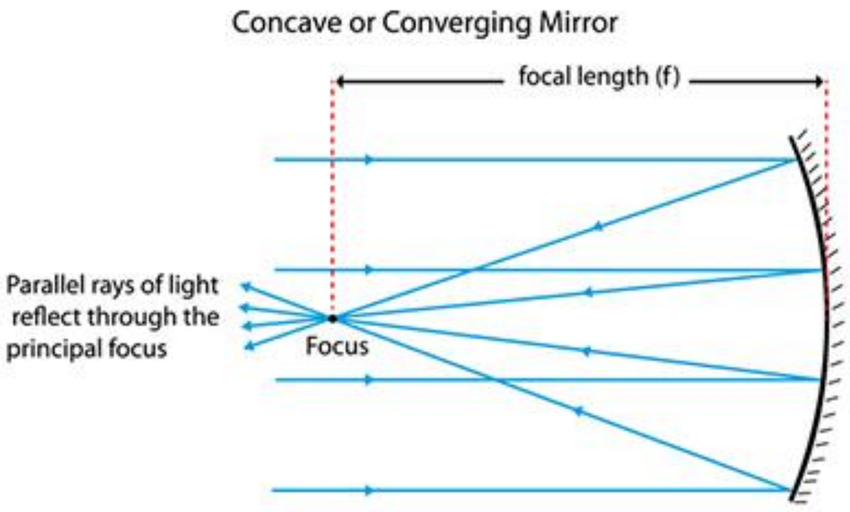



Chromatic aberration

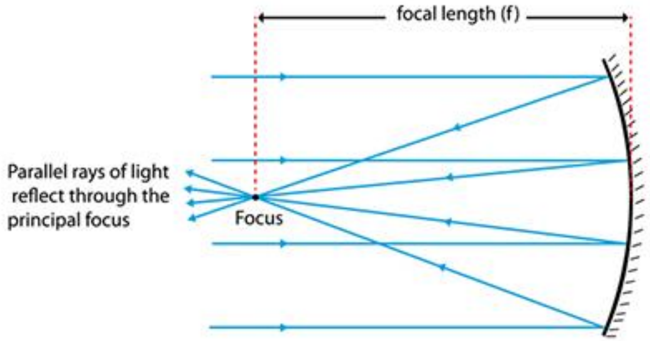


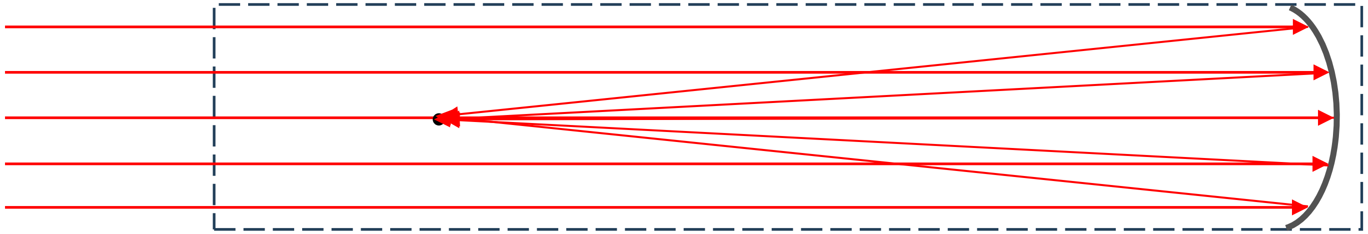
Concave or Converging Mirror
focal length (f)
Parallel rays of light reflect through the principal focus
Focus

$$f = \frac{R}{2}$$

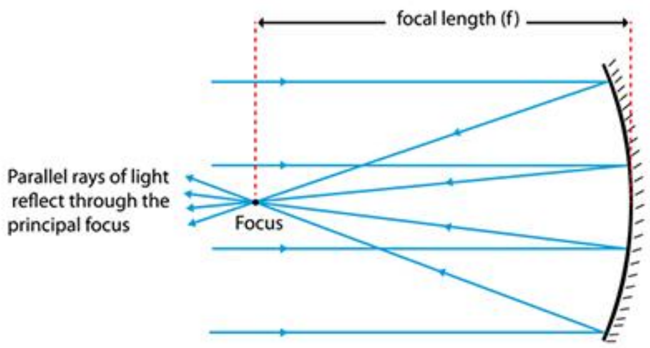

Concave or Converging Mirror
focal length (f)
Parallel rays of light reflect through the principal focus
Focus

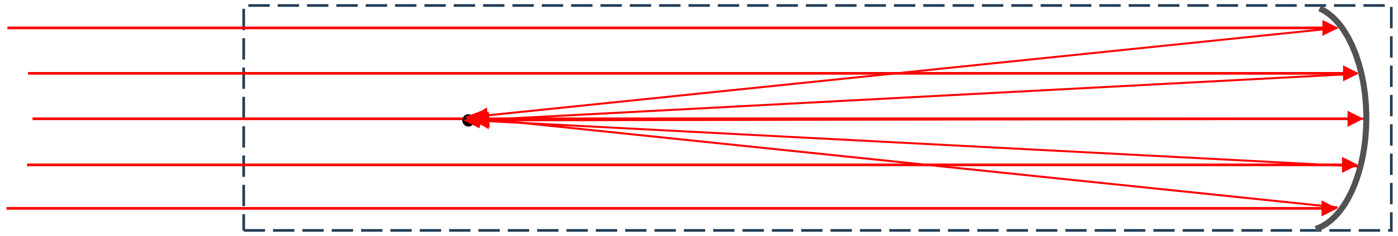
REFLECTING TELESCOPES

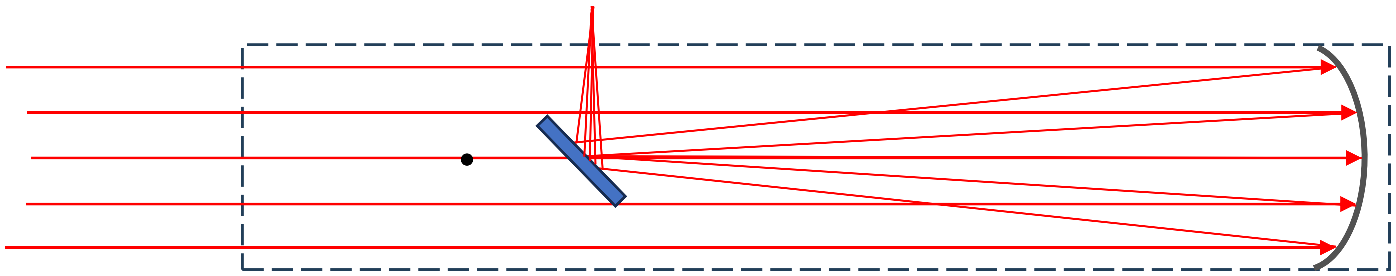




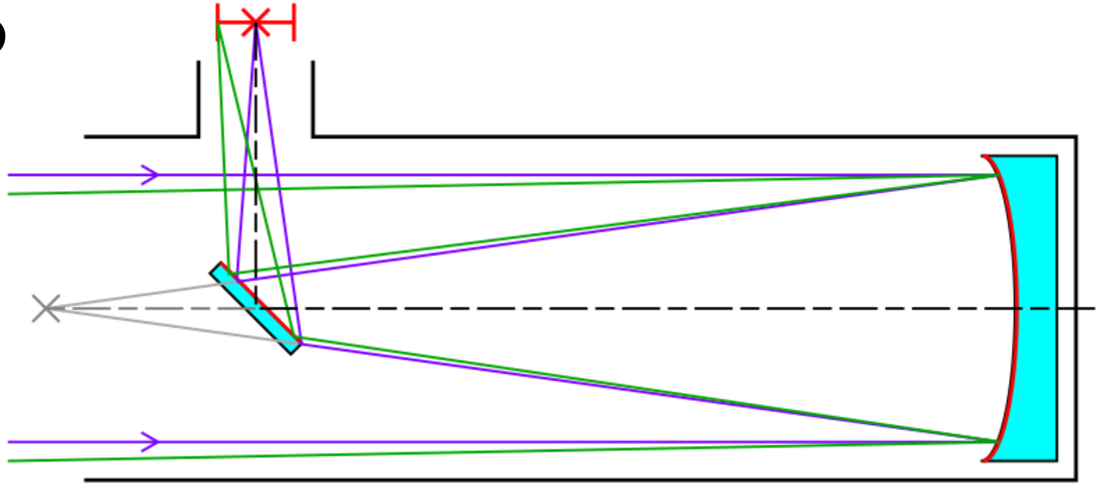
REFLECTING TELESCOPES

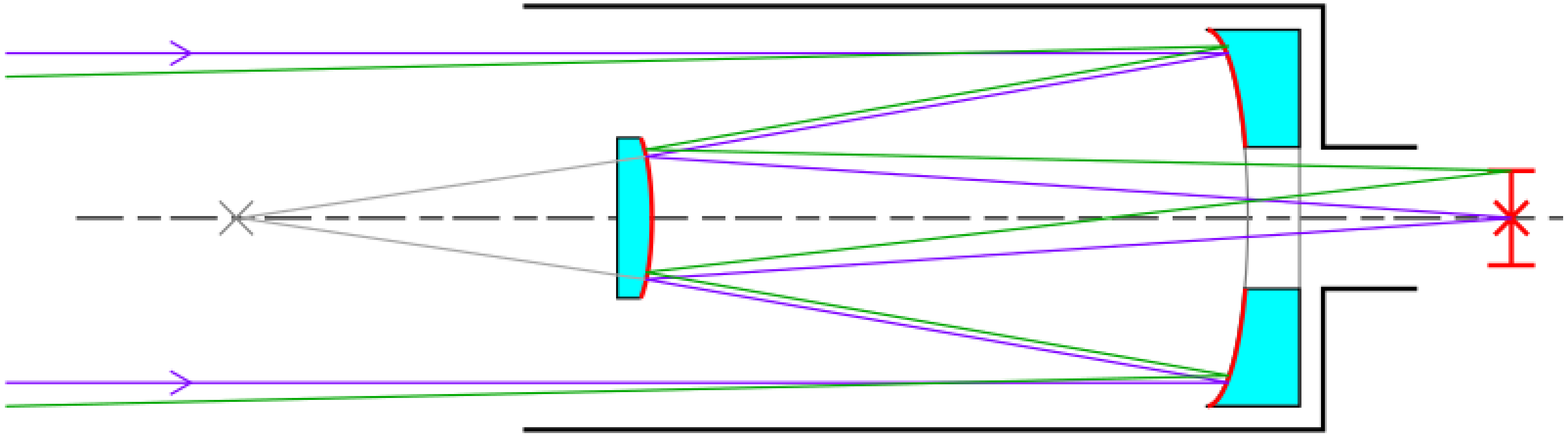




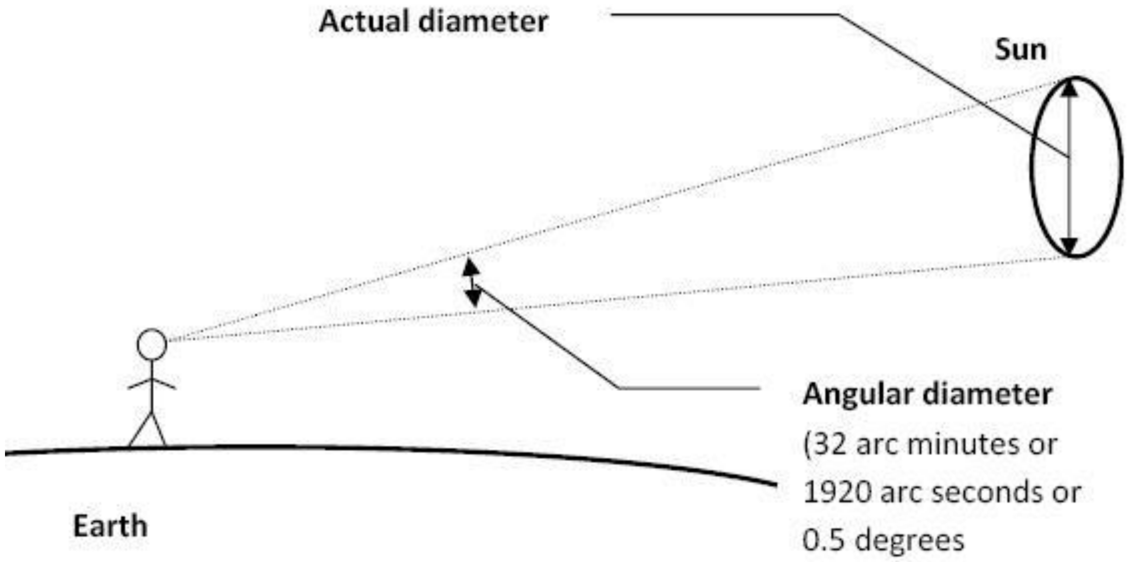


REFLECTING TELESCOPES





Resolution and the Rayleigh Criterion

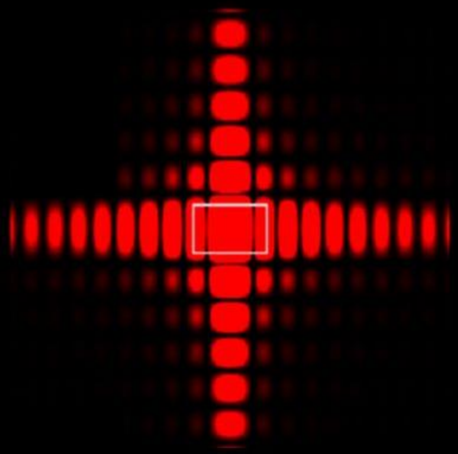


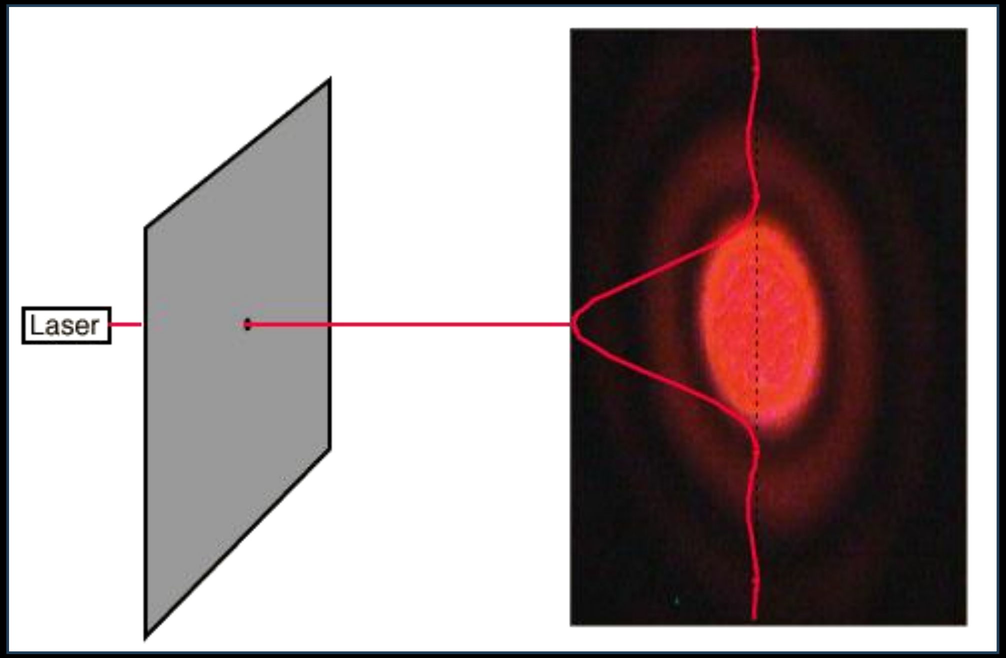
The resolution of a telescope is its ability to separate two point sources into separate images. Under ideal conditions, such as above the atmosphere where there is no turbulence (seeing), the resolving power is limited by diffraction effects.

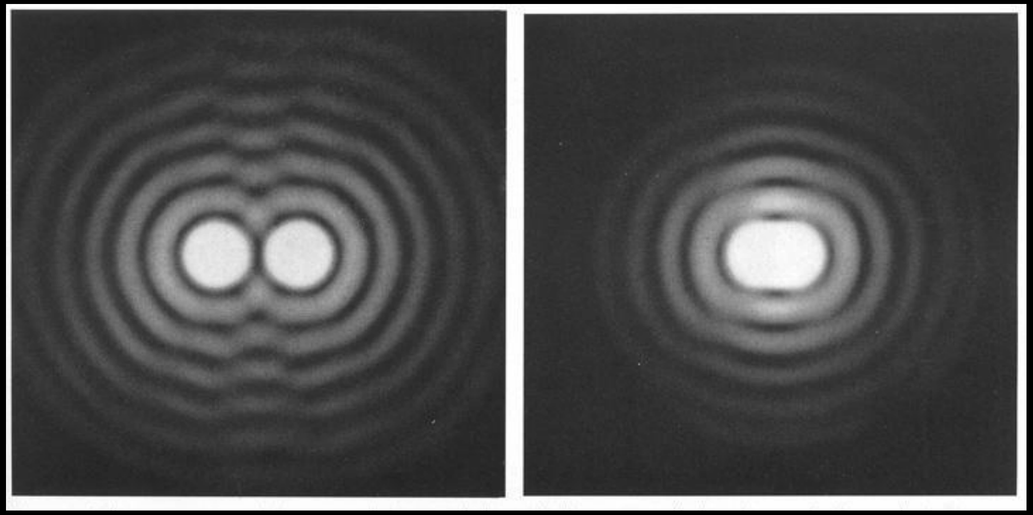
Resolution and the Rayleigh Criterion

Circular aperture

Rectangular aperture

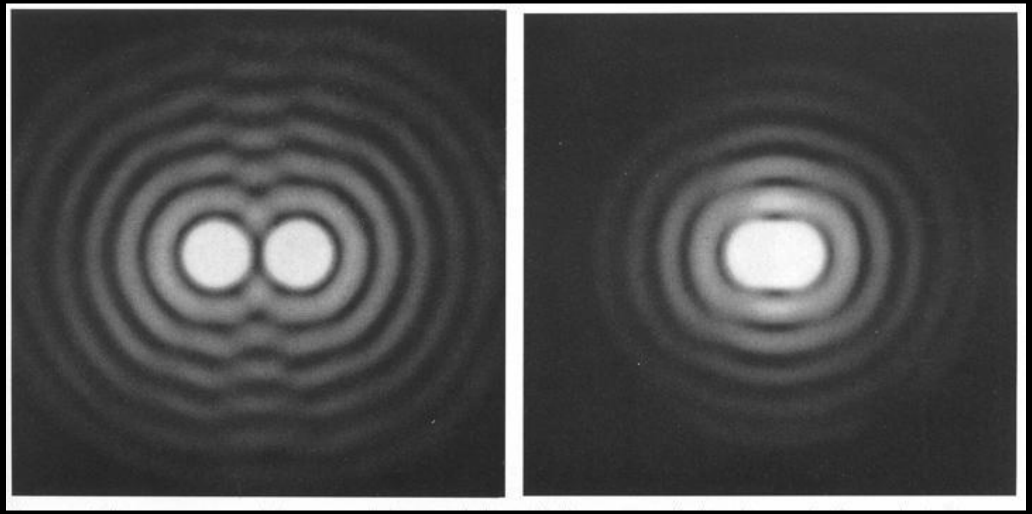






Resolution and the Rayleigh Criterion

$$\theta = \frac{1.22\lambda}{D}$$

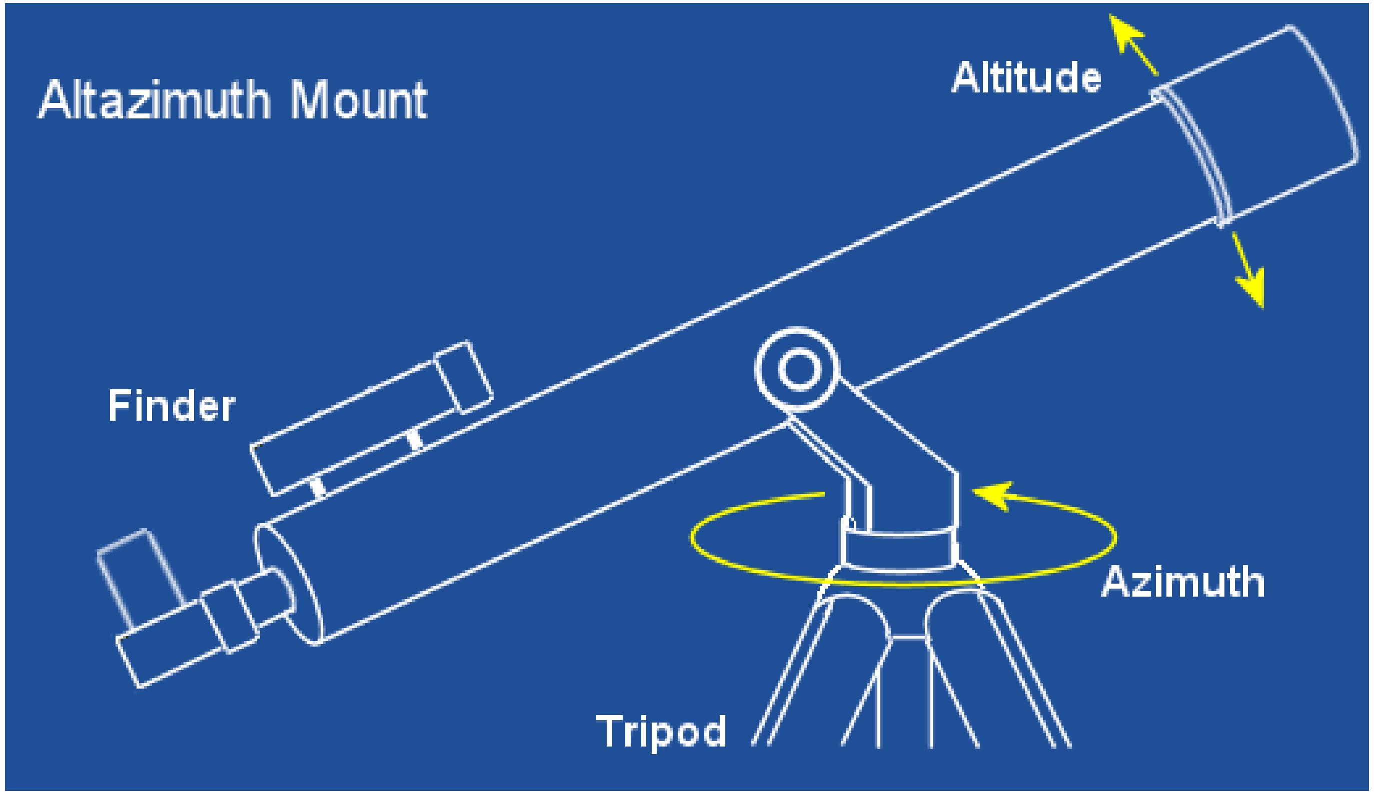


- HST has a Diameter of 2.4 m mirror. Find the Resolution of HST when we observe in UV of wavelength of 121.6 nm

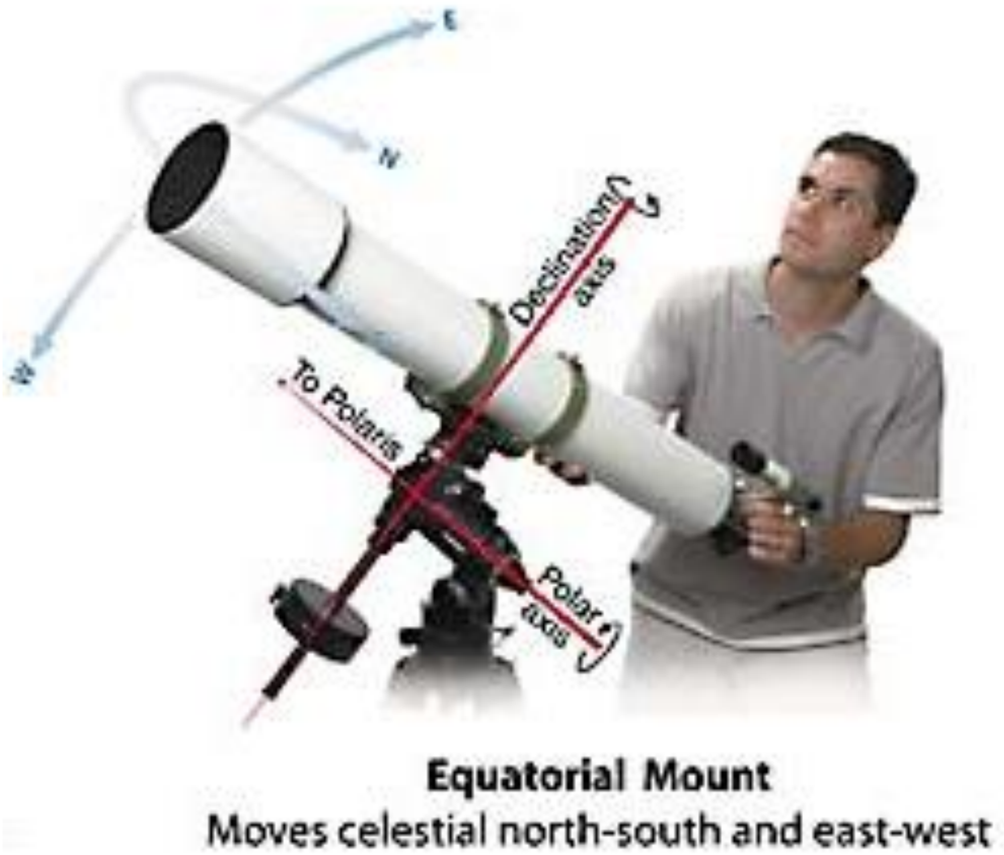
$$\theta = 1.22 \left(\frac{121.6 \text{ nm}}{2.4 \text{ m}} \right) = 6.18 \times 10^{-8} \text{ rad} = 0.0127''.$$

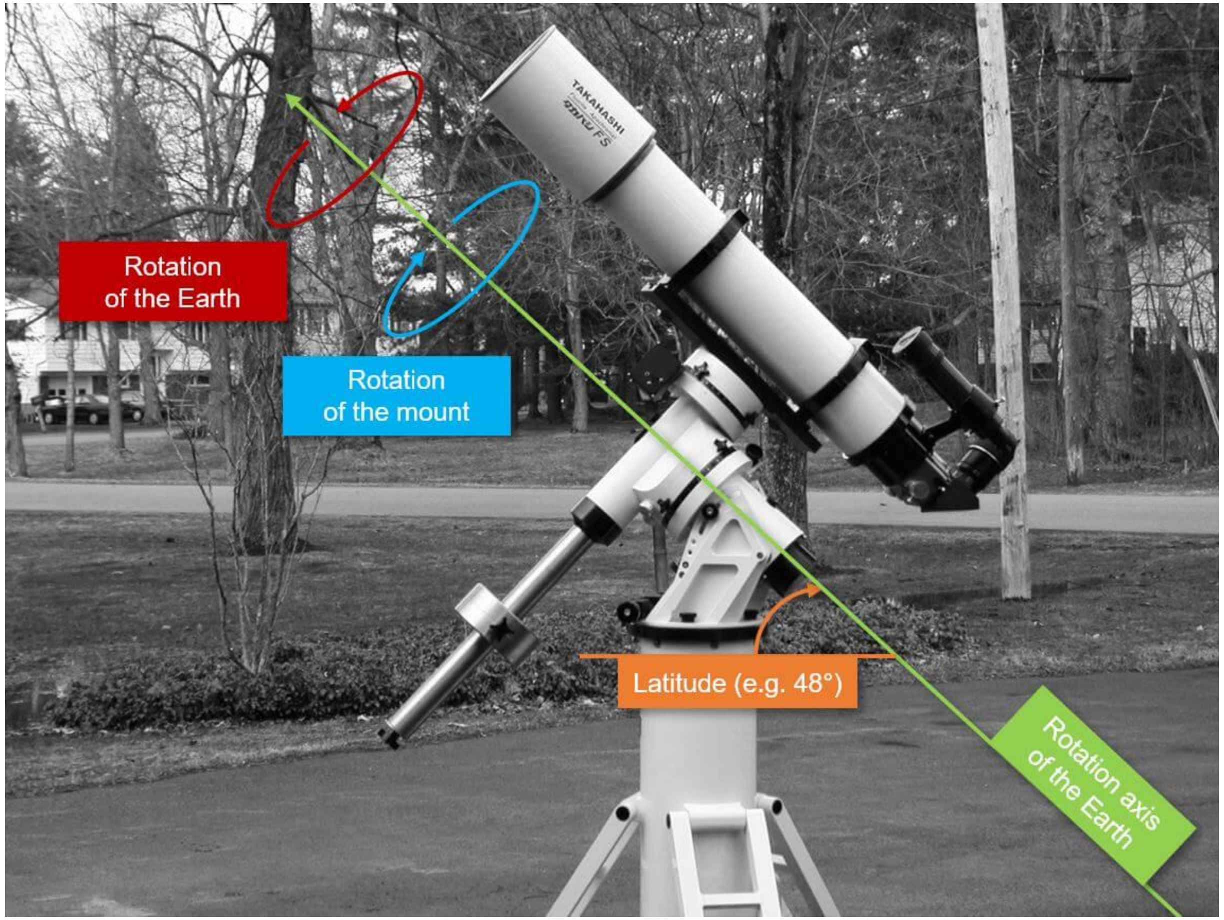
1 radian = 206,265 arcseconds

ALT AZIMUTH MOUNT



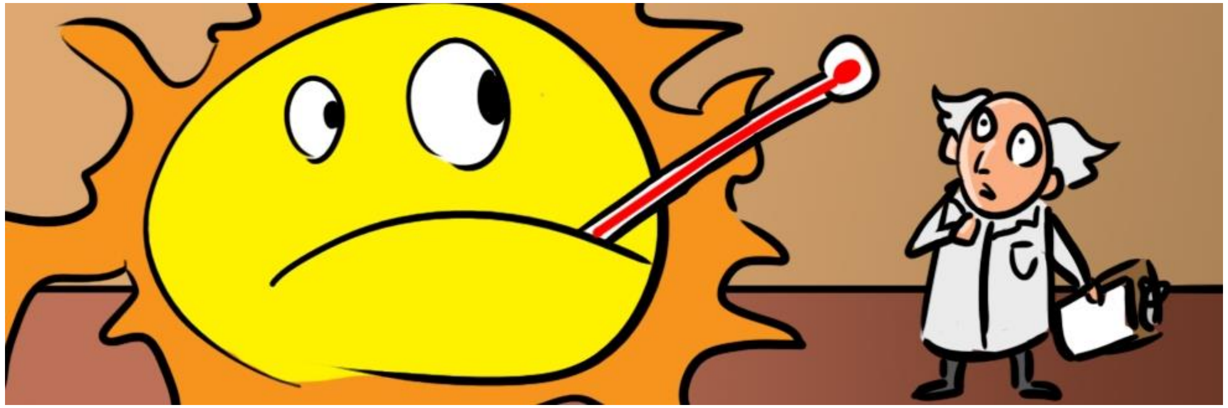
EQUATORIAL MOUNT

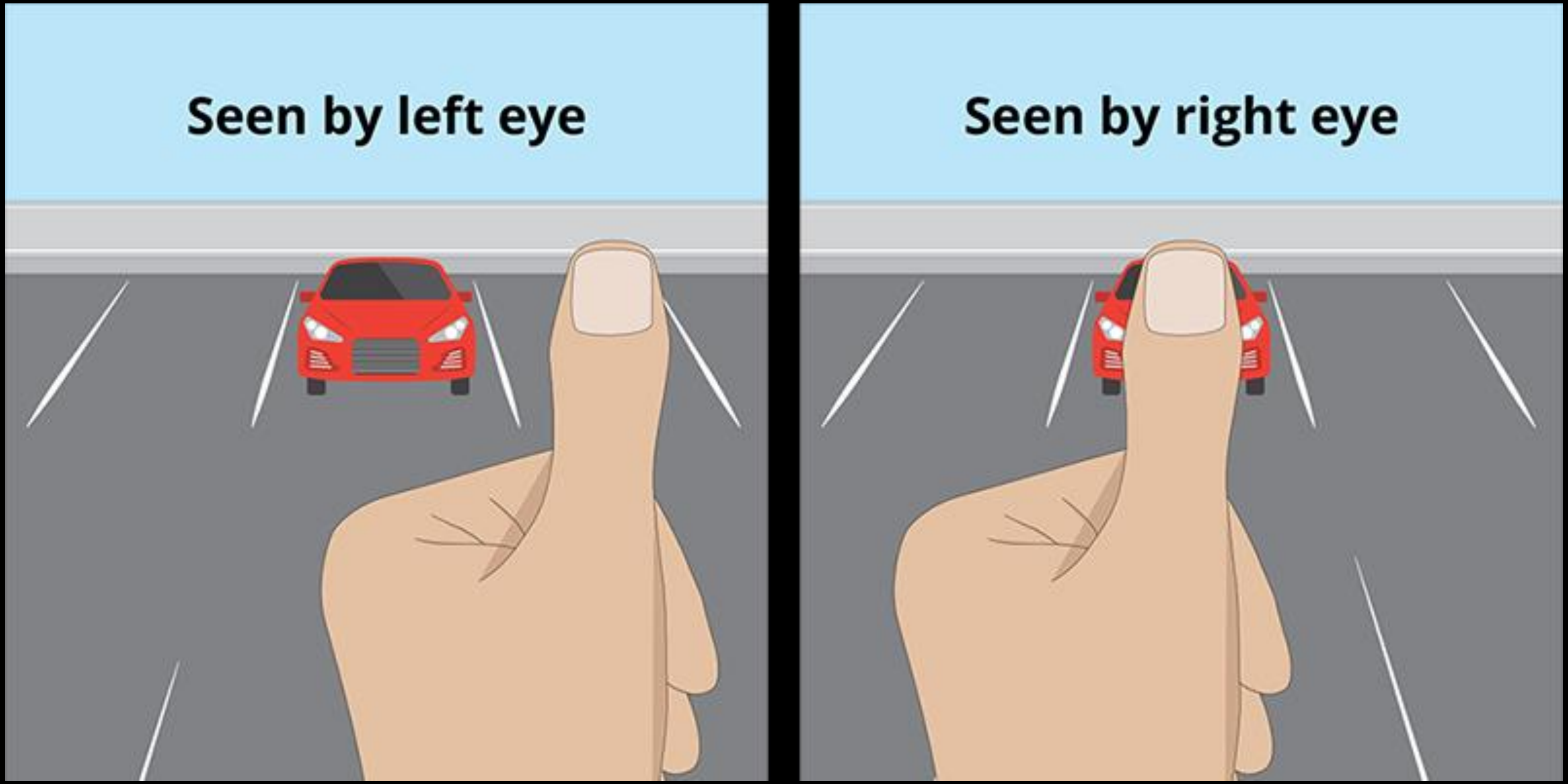


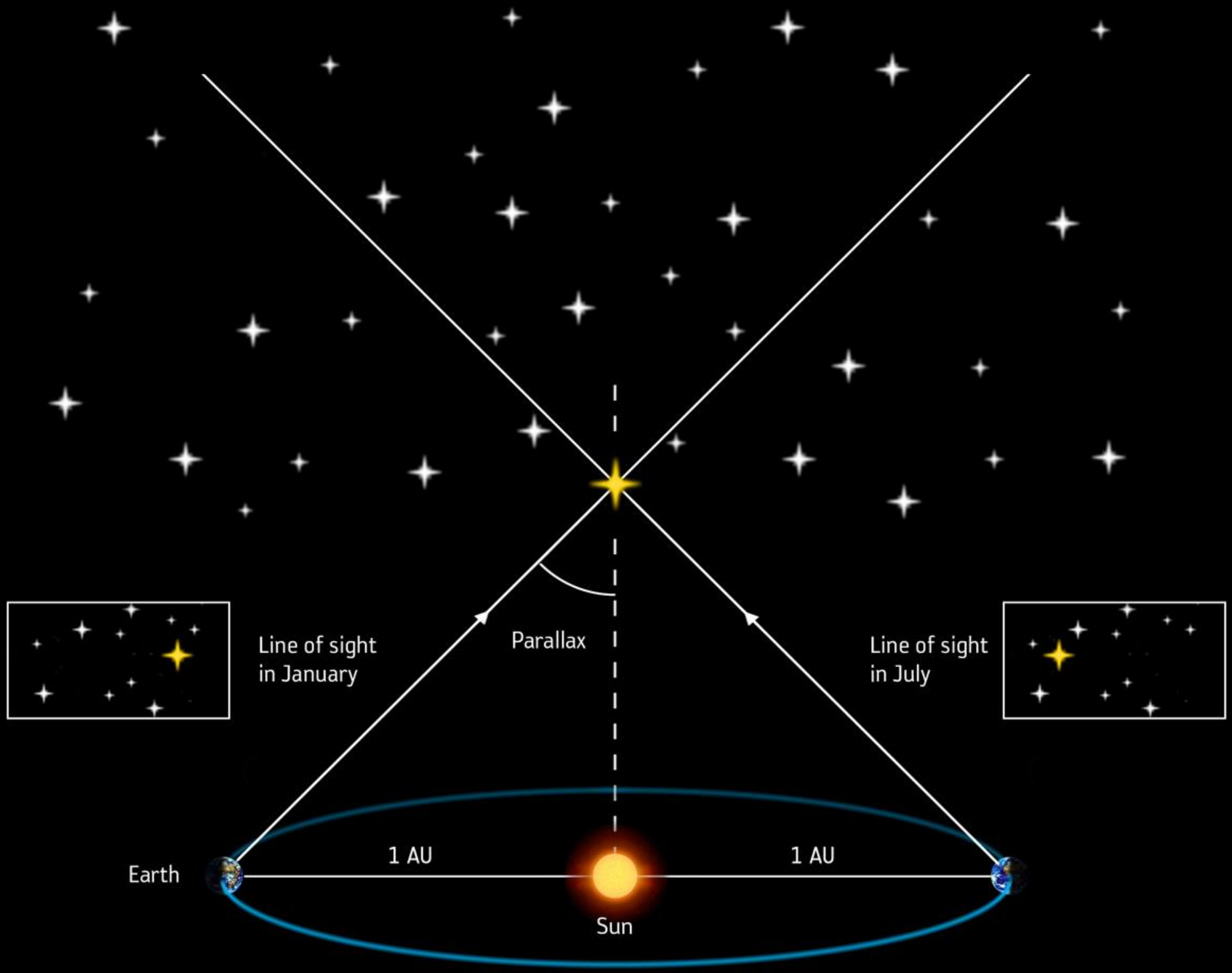


TELESCOPE MOUNTS

- Alt Azimuth
- Equatorial

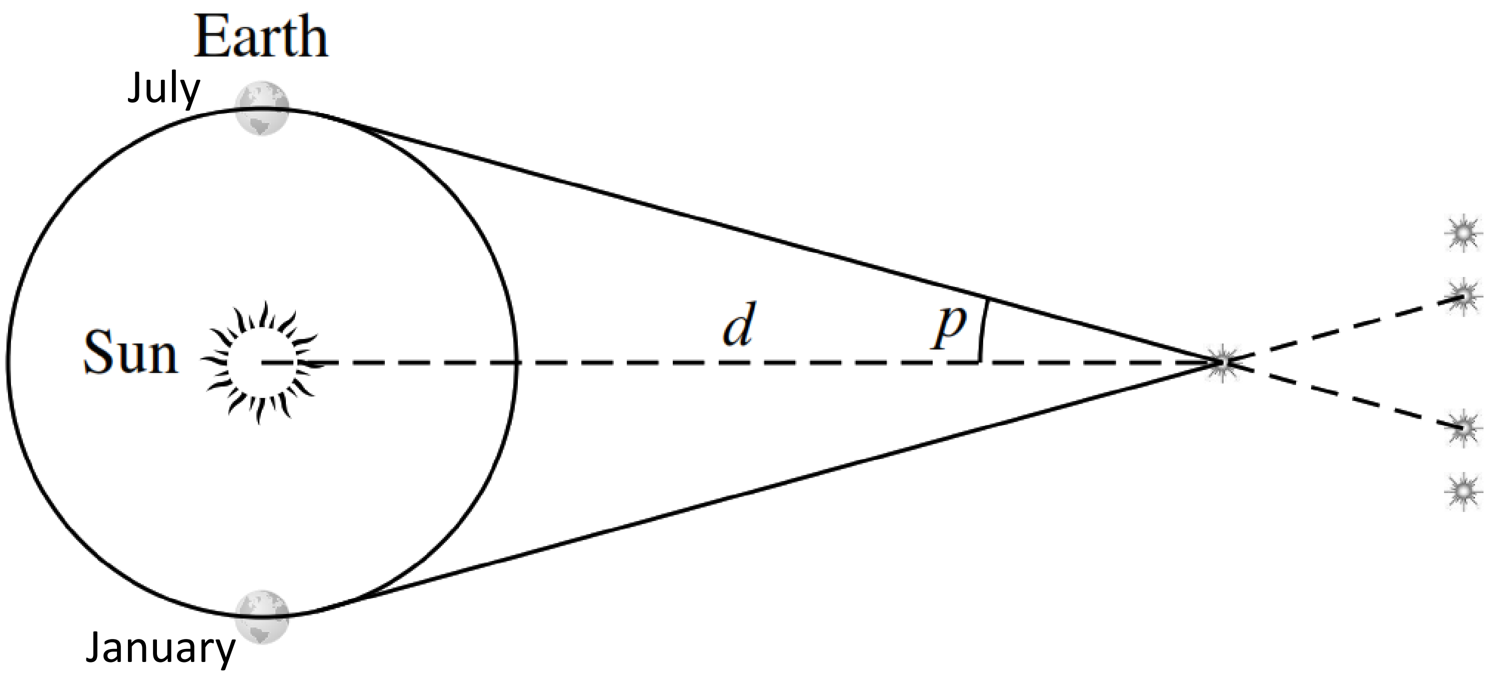



Seen by left eye
Seen by right eye



Line of sight
in January
Parallax
Line of sight
in July
Earth
1 AU
1 AU
Sun

Stellar Parallax

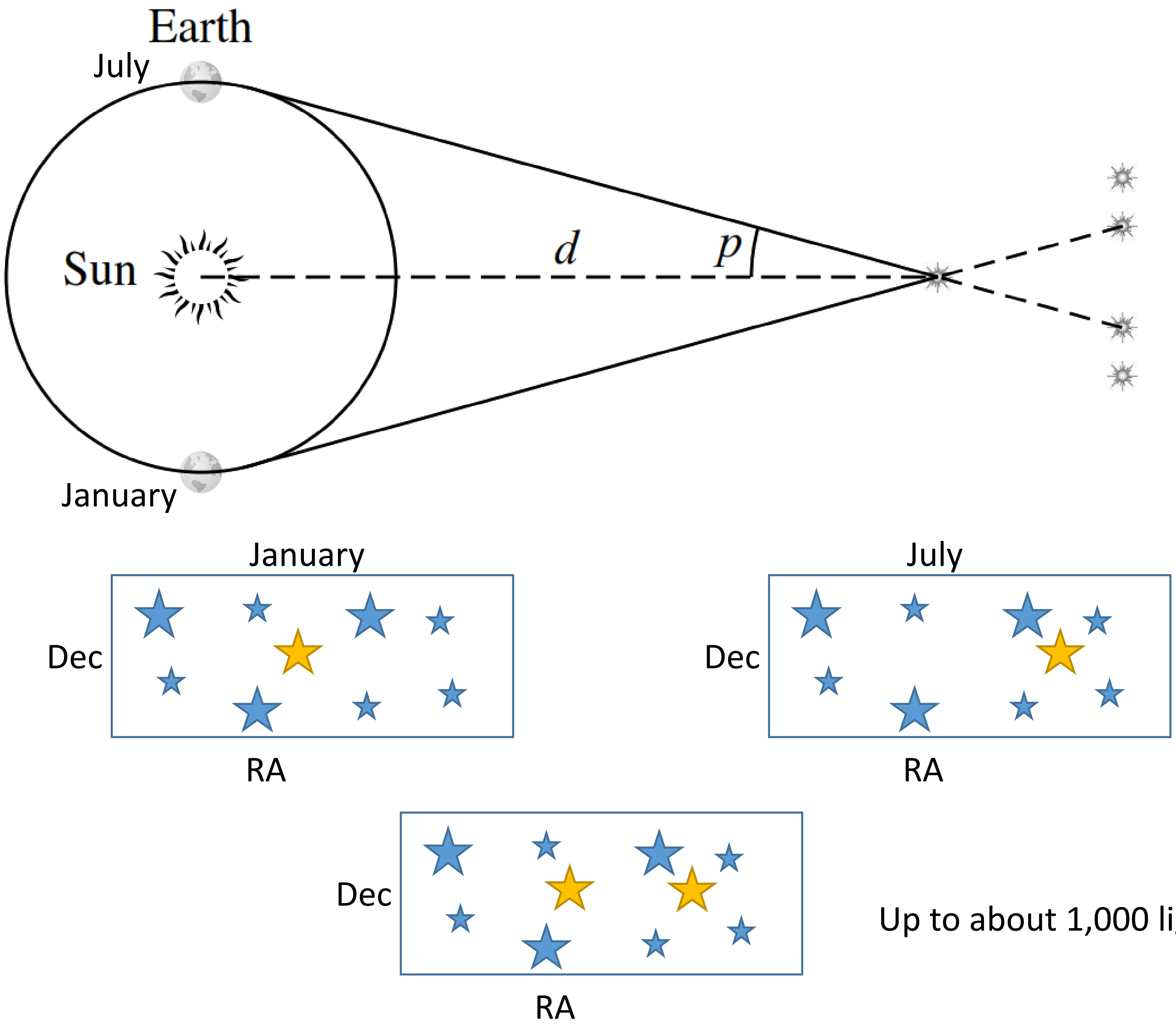


$$d = \frac{1\ \text{AU}}{\tan p} \simeq \frac{1}{p}\ \text{AU}$$

$$d \simeq \frac{206{,}265}{p''}\ \text{AU}$$

$$\boxed{d = \frac{1}{p''}\ \text{pc.}}$$

1 parsec is the distance from which the radius of Earth’s orbit, 1 AU, subtends an angle of 1’’



Up to about 1,000 light-years with current space telescopes

Flux and Luminosity

Luminosity

- **Luminosity (L)** is the total amount of energy emitted by an astronomical object per second in all directions. It is an intrinsic property of the object, meaning it does not depend on the observer's location.
- Measured in **watts (W).**
- $\mathbf{L_{sun}}$=3.846×10^{26}W

Flux

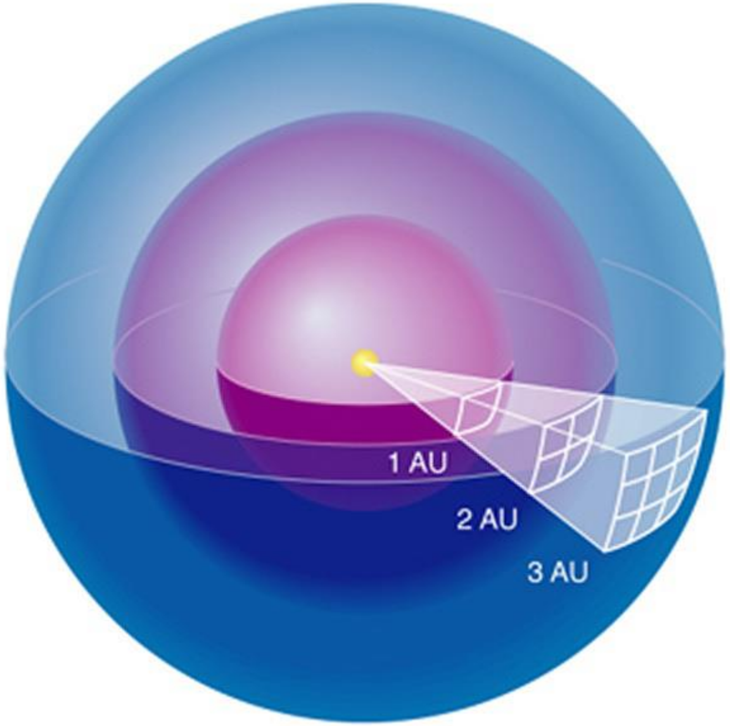
- **Flux (F)** is the amount of energy from an astronomical object passing through a unit area per second. It is an *apparent property*, meaning it depends on the distance between the object and the observer.
- Measured in **watts per square meter (W/m^2)**
- F_{sun}= 1361W/m2

Inverse Square Law of Light

- Brightness is measured in units of Flux
- Total amount of light energy in all wavelengths that passes through unit area per unit time
- Flux received depends on intrinsic luminosity and the distance

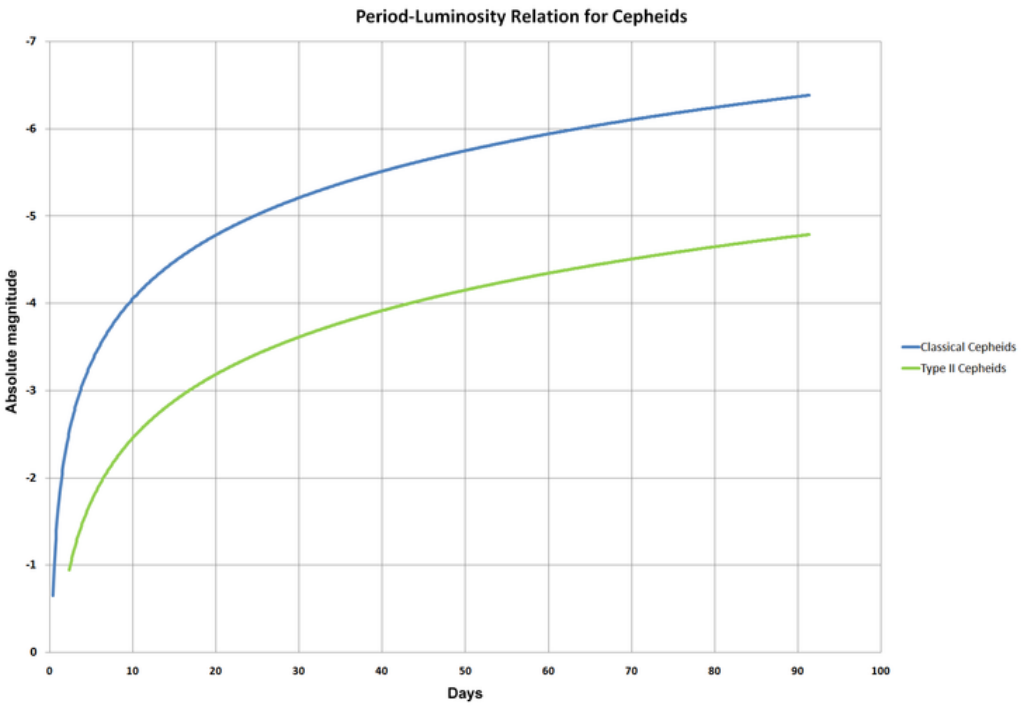
$$F = \frac{L}{4\pi r^2},$$

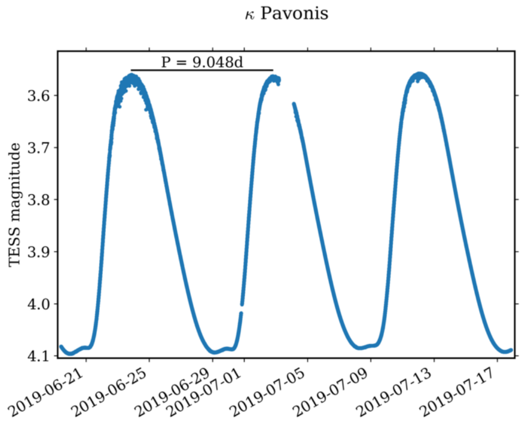
inverse square law for light



Standard Candles - Cepheid Variables

These stars pulsate with a regular period, and their luminosity is directly related to this period. By observing their pulsations, we can infer their distance.



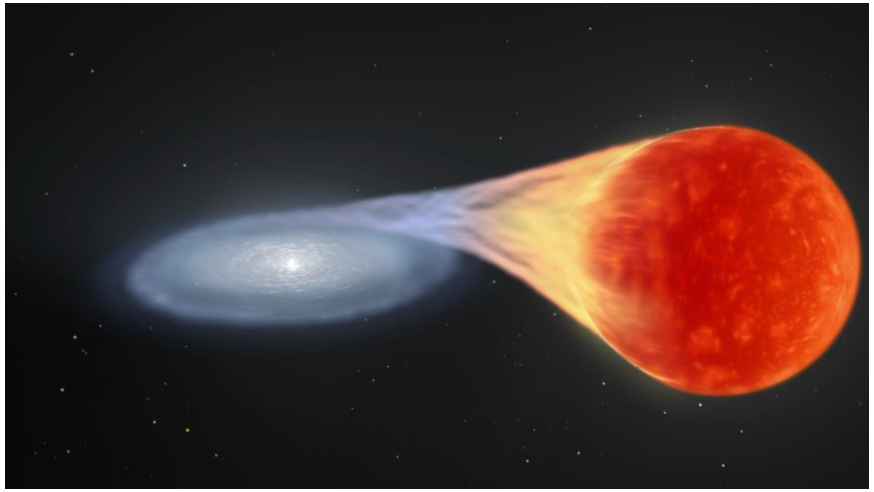


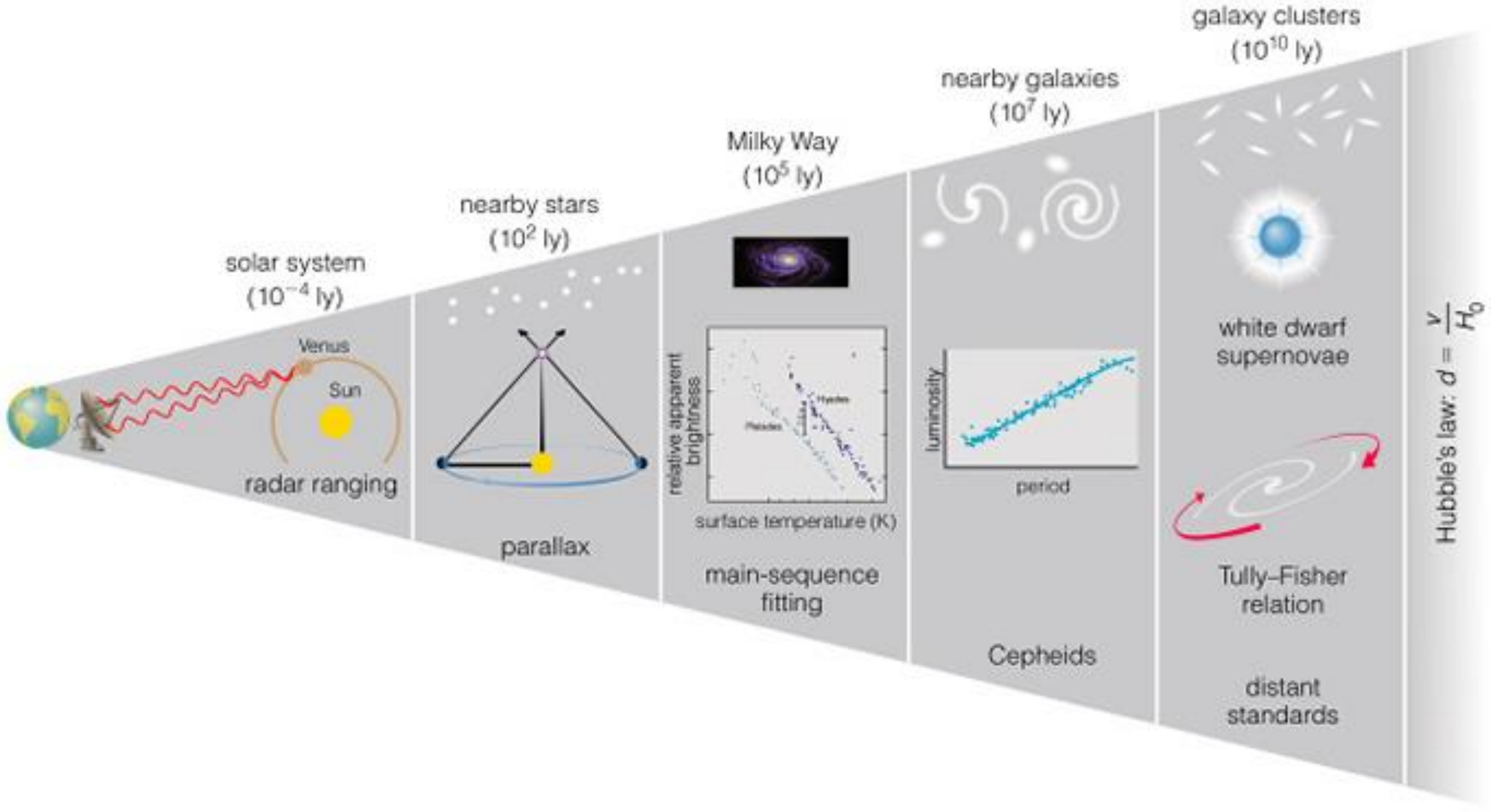
Henrietta Swan Leavitt

Standard Candles – Type 1a Supernova

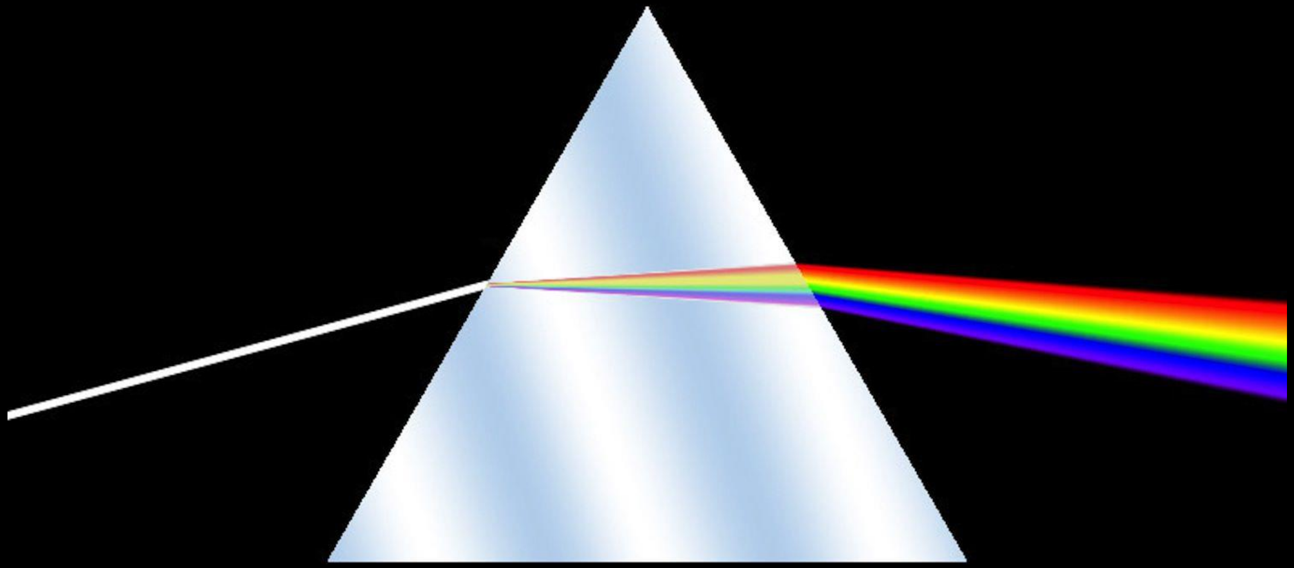
Type Ia Supernovae are a class of supernovae that occur in binary star systems where one of the stars is a **white dwarf**.

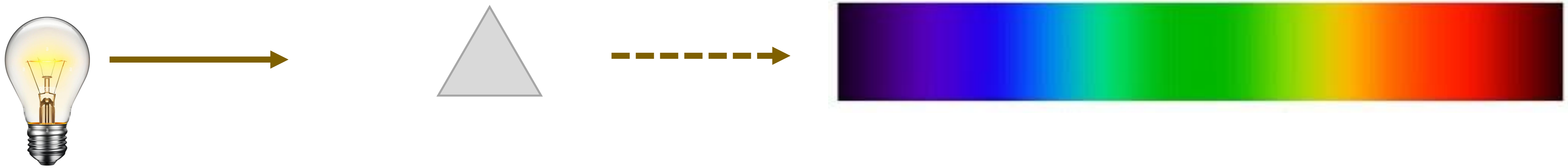
Explosions of white dwarf stars that have a predictable maximum brightness, making them excellent for measuring distances to galaxies.

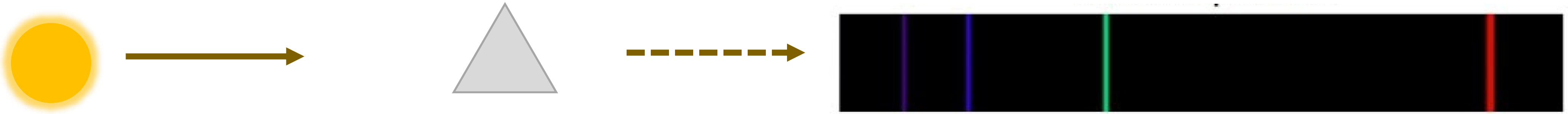


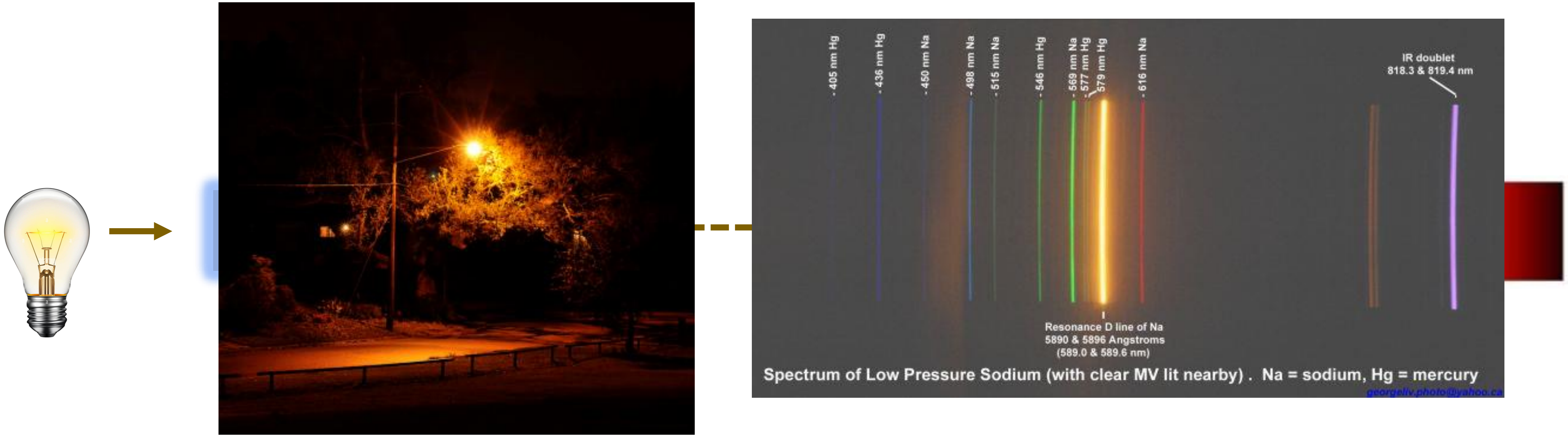

galaxy clusters
(10^{10} ly)
nearby galaxies
(10^{7} ly)
Milky Way
(10^{5} ly)
nearby stars
(10^{2} ly)
solar system
(10^{-4} ly)
Venus
Sun
radar ranging
parallax
relative apparent brightness
surface temperature (K)
main-sequence fitting
luminosity
period
Cepheids
white dwarf supernovae
Tully–Fisher relation
distant standards
Hubble's law: $d = \frac{v}{H_0}$

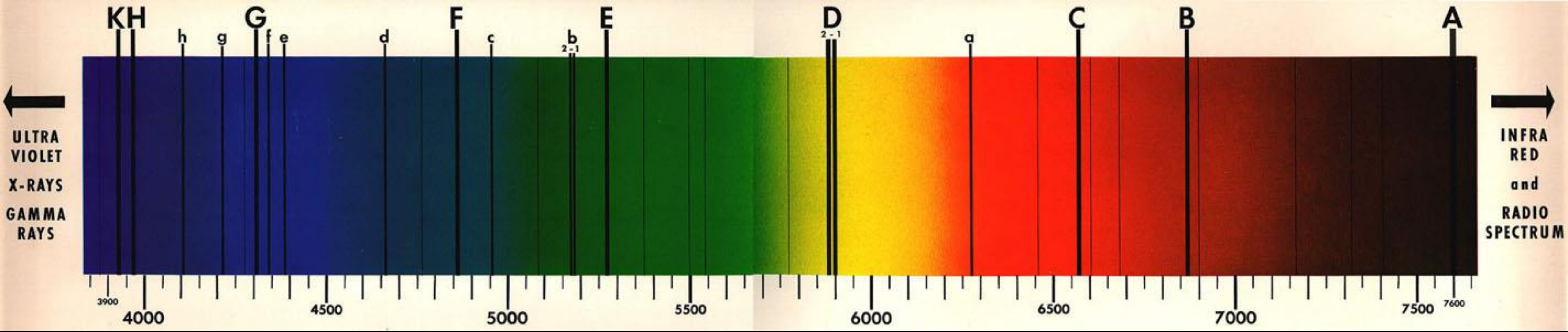
Spectroscopy

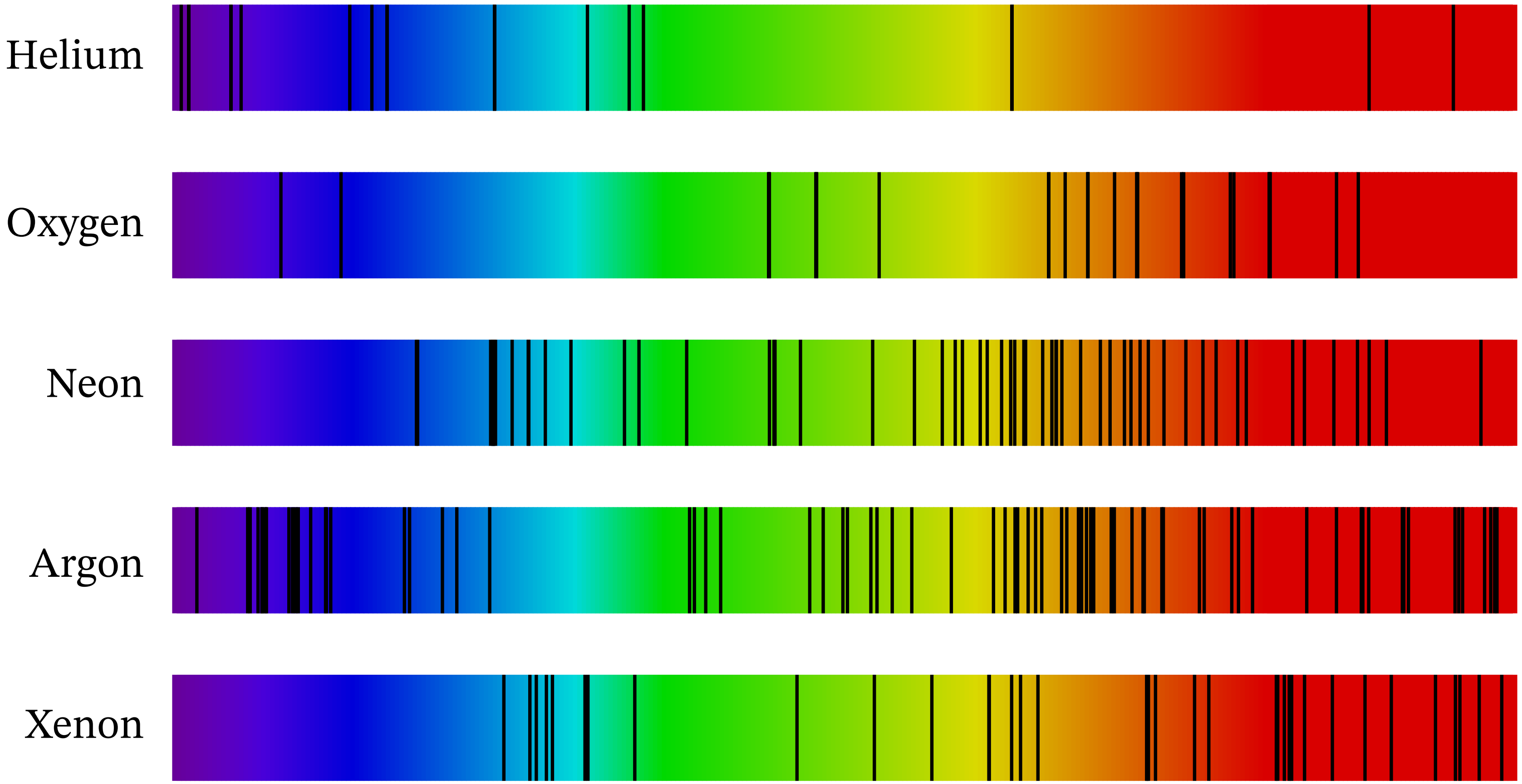


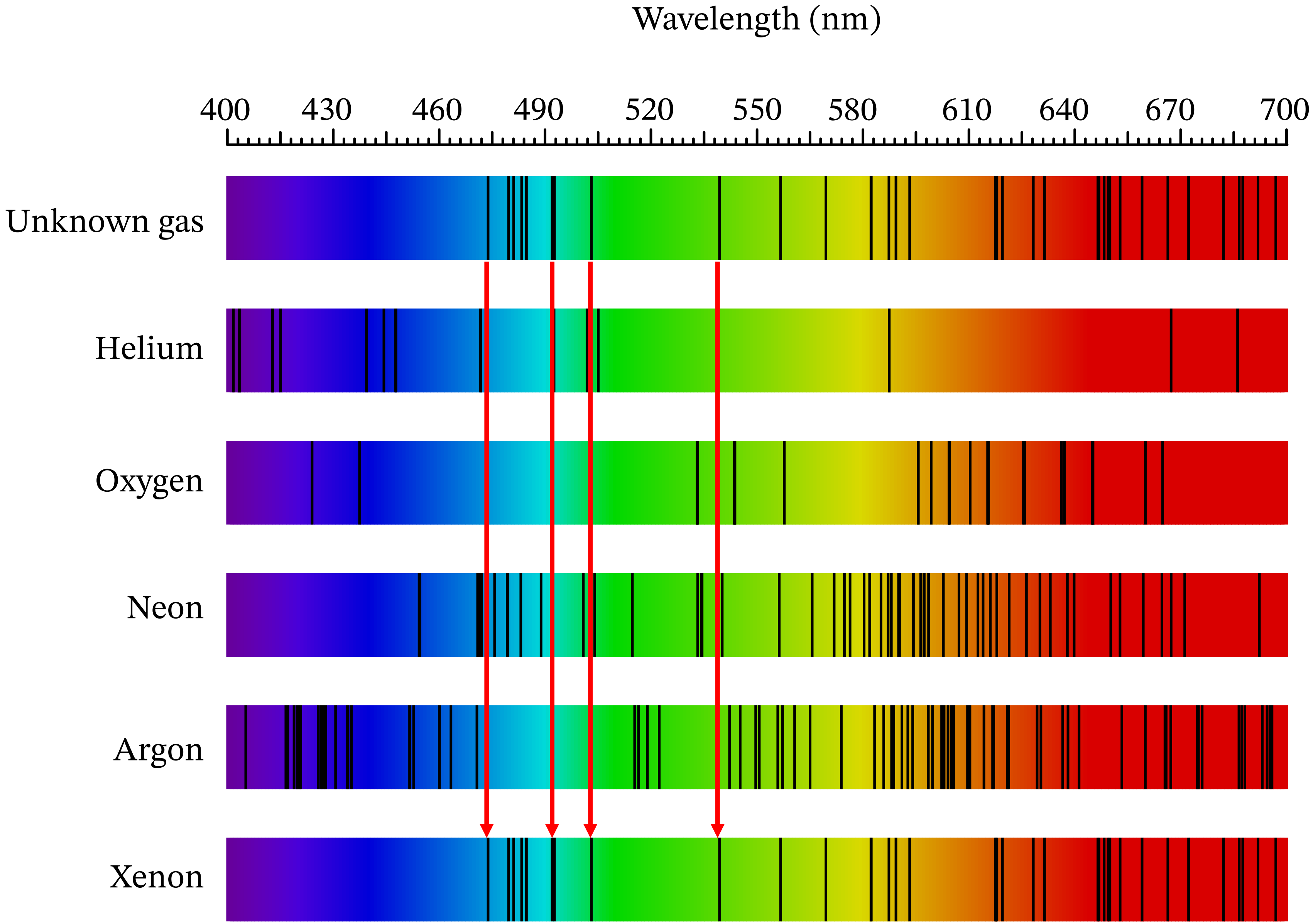




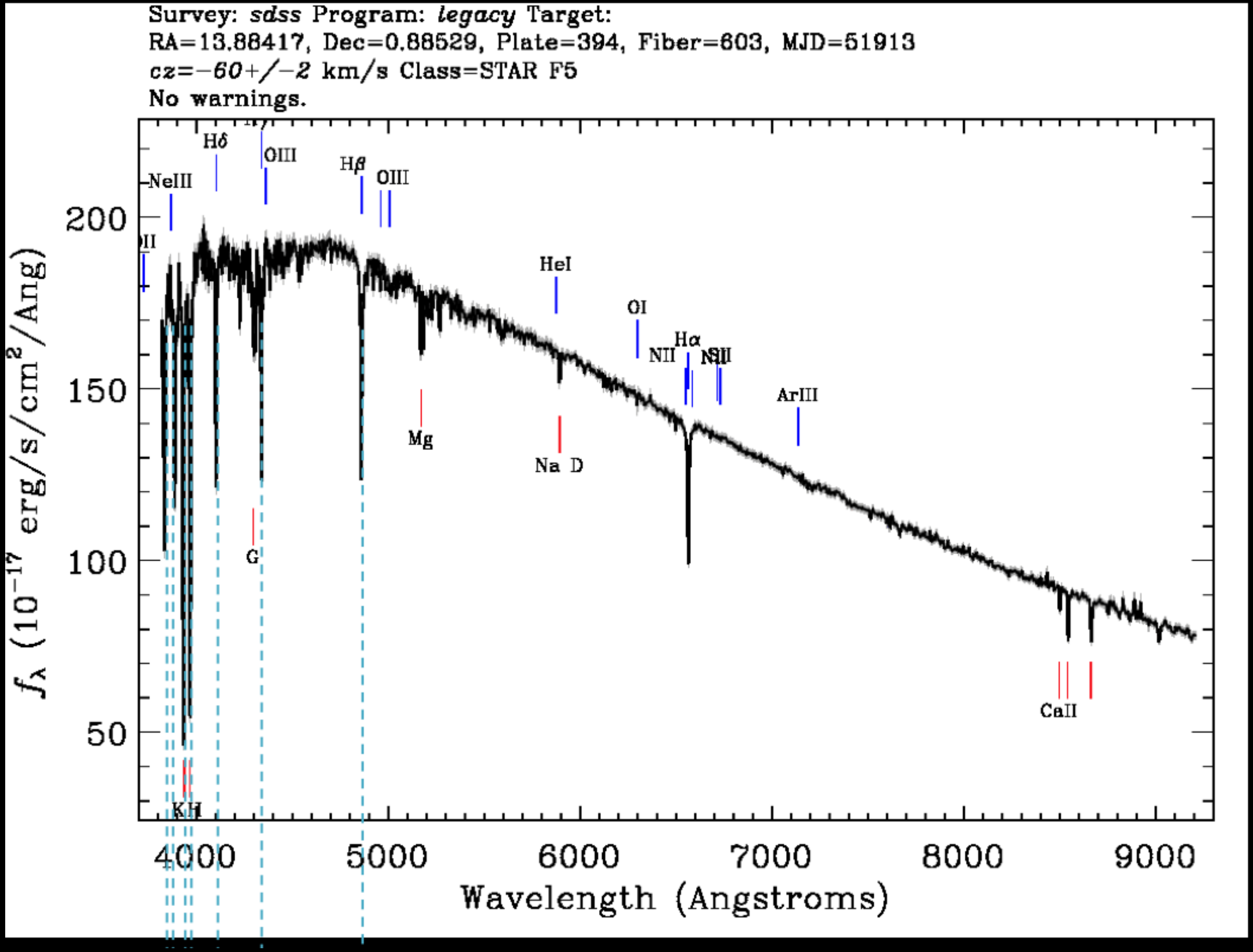

405 nm Hg
436 nm Hg
450 nm Na
498 nm Na
515 nm Na
546 nm Hg
569 nm Na
577 nm Hg
579 nm Hg
616 nm Na
IR doublet
818.3 & 819.4 nm
Resonance D line of Na
5890 & 5896 Angstroms
(589.0 & 589.6 nm)
Spectrum of Low Pressure Sodium (with clear MV lit nearby) . Na = sodium, Hg = mercury


K H
G
F
E
D
C
B
A
h
g
f
e
d
c
b
2 - 1
2 - 1
a
ULTRA VIOLET
X-RAYS
GAMMA RAYS
INFRA RED
and
RADIO SPECTRUM
3900
4000
4500
5000
5500
6000
6500
7000
7500
7600

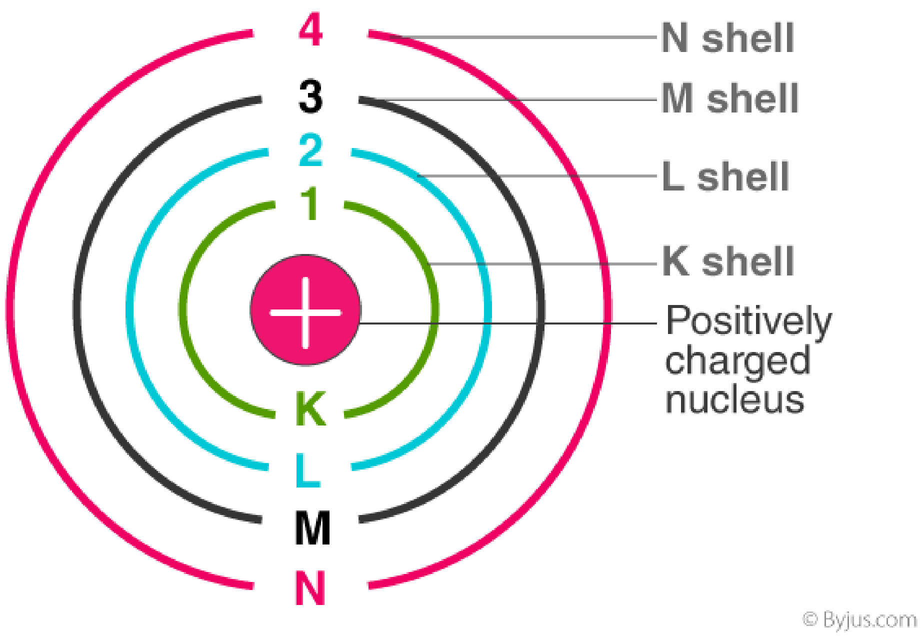

Helium
Oxygen
Neon
Argon
Xenon

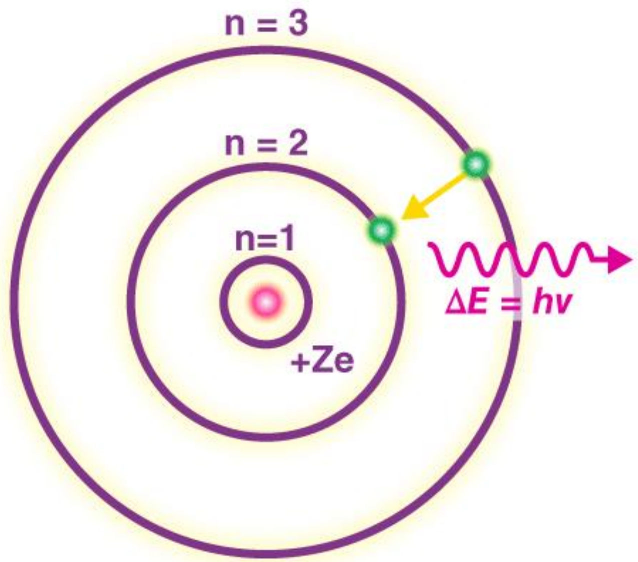


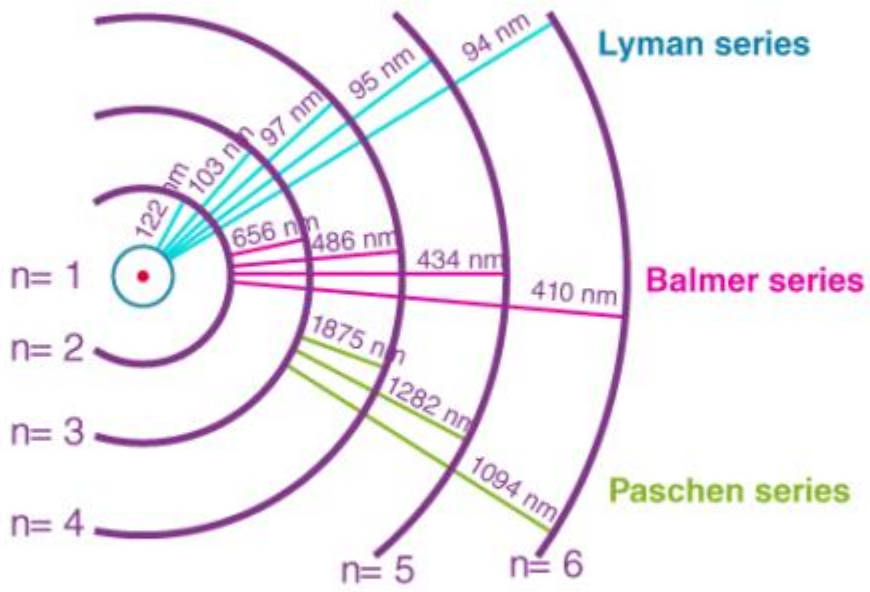
Wavelength (nm)
400
430
460
490
520
550
580
610
640
670
700
Unknown gas
Helium
Oxygen
Neon
Argon
Xenon


Survey: sdss Program: legacy Target:
RA=13.88417, Dec=0.88529, Plate=394, Fiber=603, MJD=51913
cz=−60+/−2 km/s Class=STAR F5
No warnings.
NeIII
Hδ
OIII
Hβ
OIII
HeI
OI
NII
Hα
SII
ArIII
Mg
Na D
G
CaII
K H
200
150
100
50
4000
5000
6000
7000
8000
9000
Wavelength (Angstroms)
f_λ (10^{-17} erg/s/cm^2/Ang)

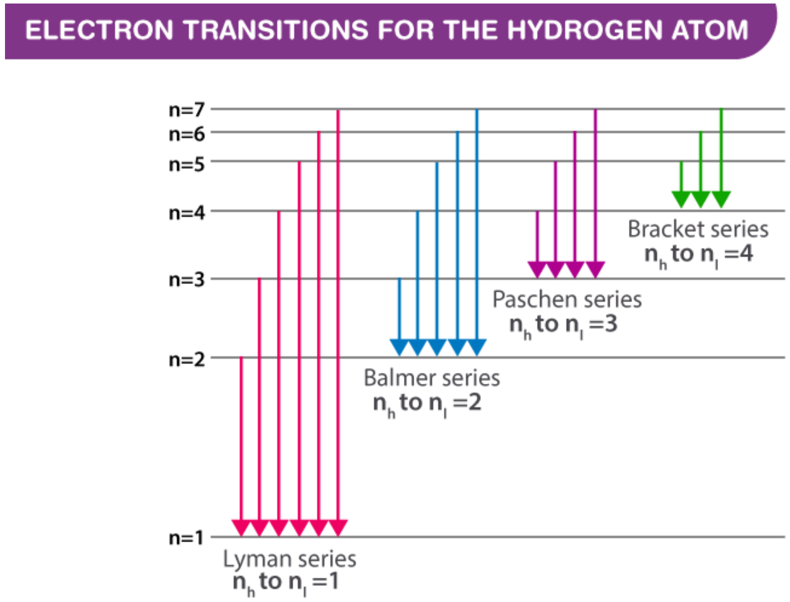
BOHR'S MODEL OF AN ATOM







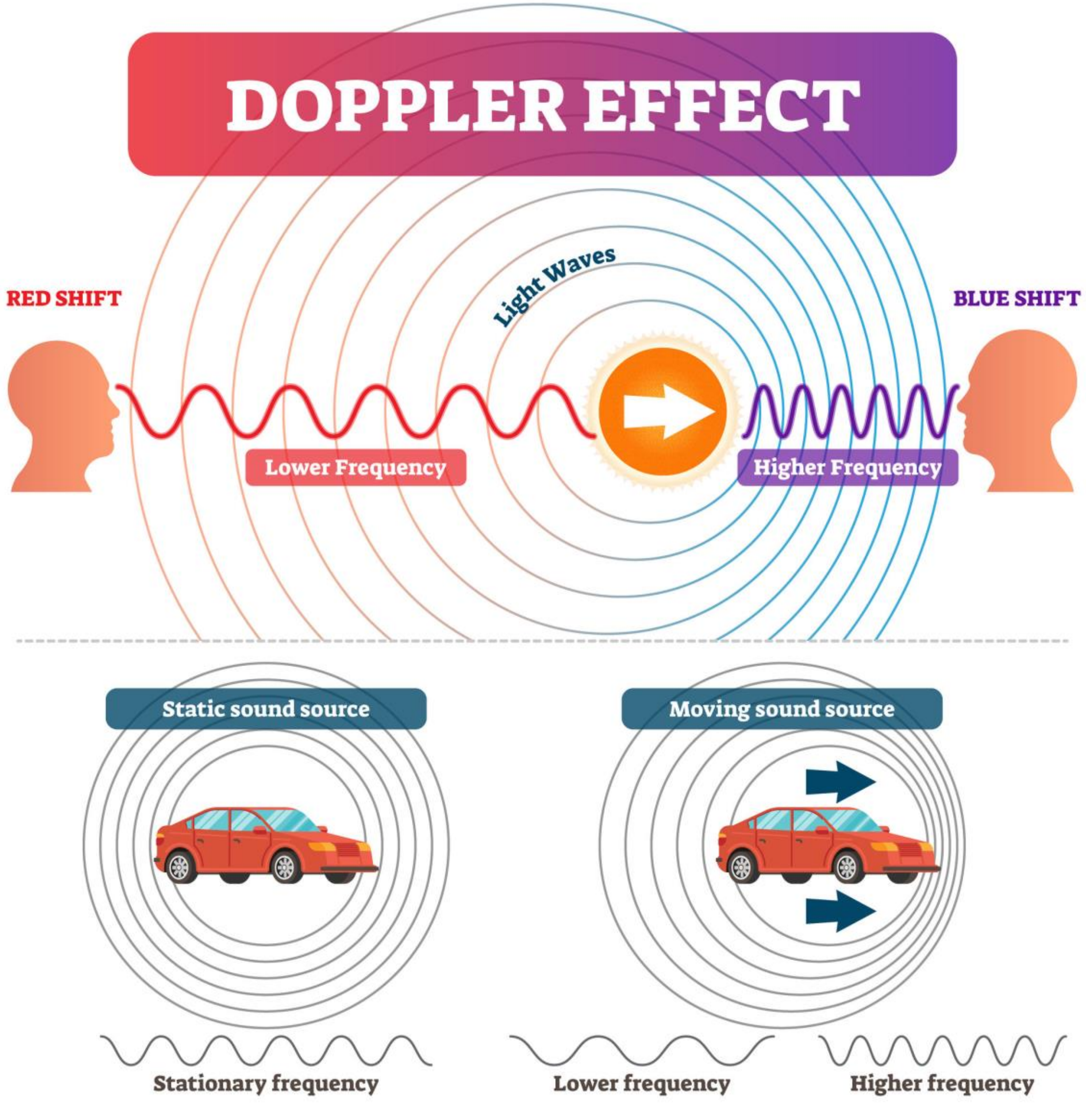
Lyman series
Balmer series
Paschen series
122 nm
103 nm
97 nm
95 nm
94 nm
656 nm
486 nm
434 nm
410 nm
1875 nm
1282 nm
1094 nm
n= 1
n= 2
n= 3
n= 4
n= 5
n= 6



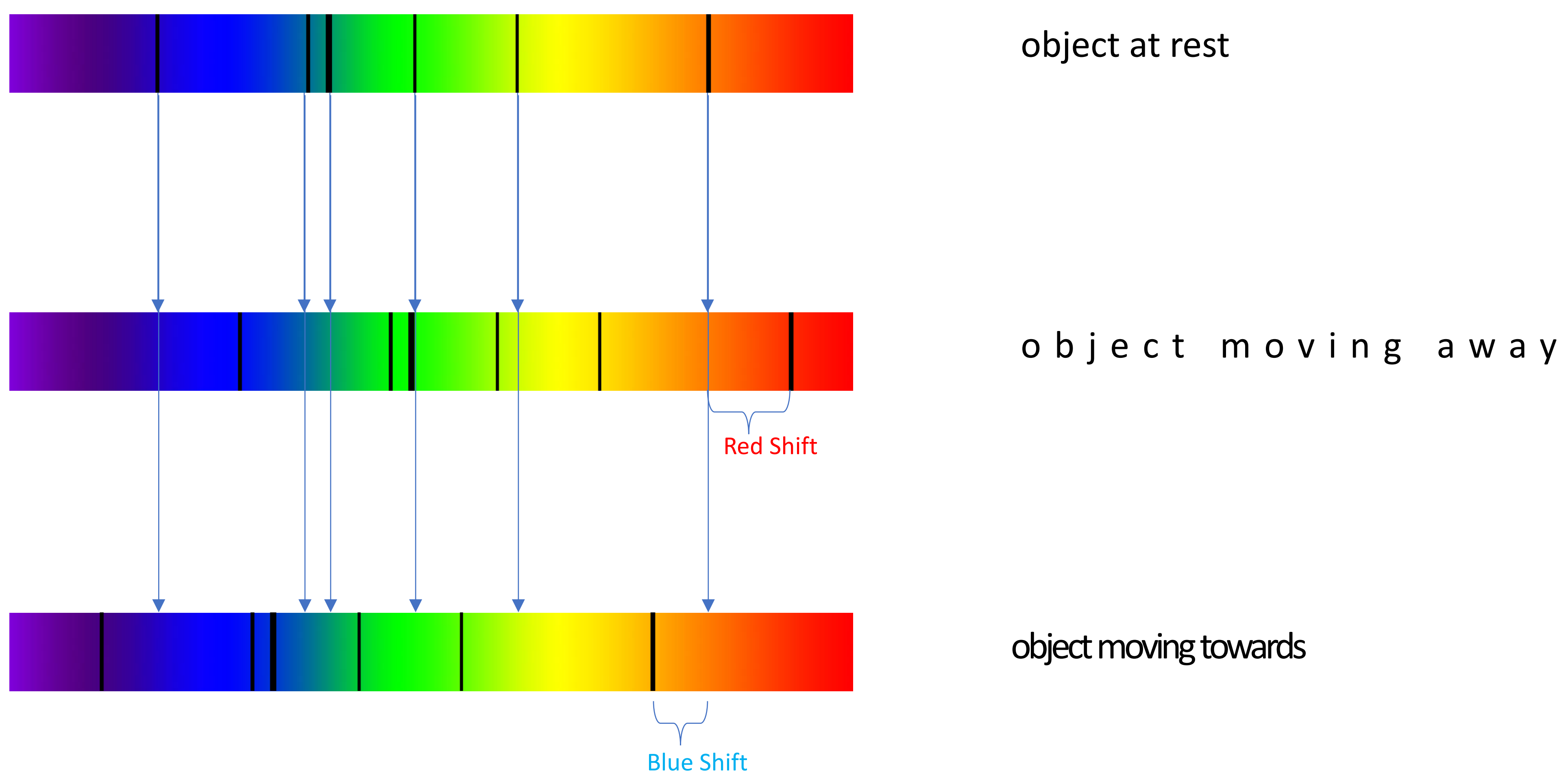
ELECTRON TRANSITIONS FOR THE HYDROGEN ATOM
n=7
n=6
n=5
n=4
n=3
n=2
n=1
Lyman series
n_h to n_l =1
Balmer series
n_h to n_l =2
Paschen series
n_h to n_l =3
Bracket series
n_h to n_l =4

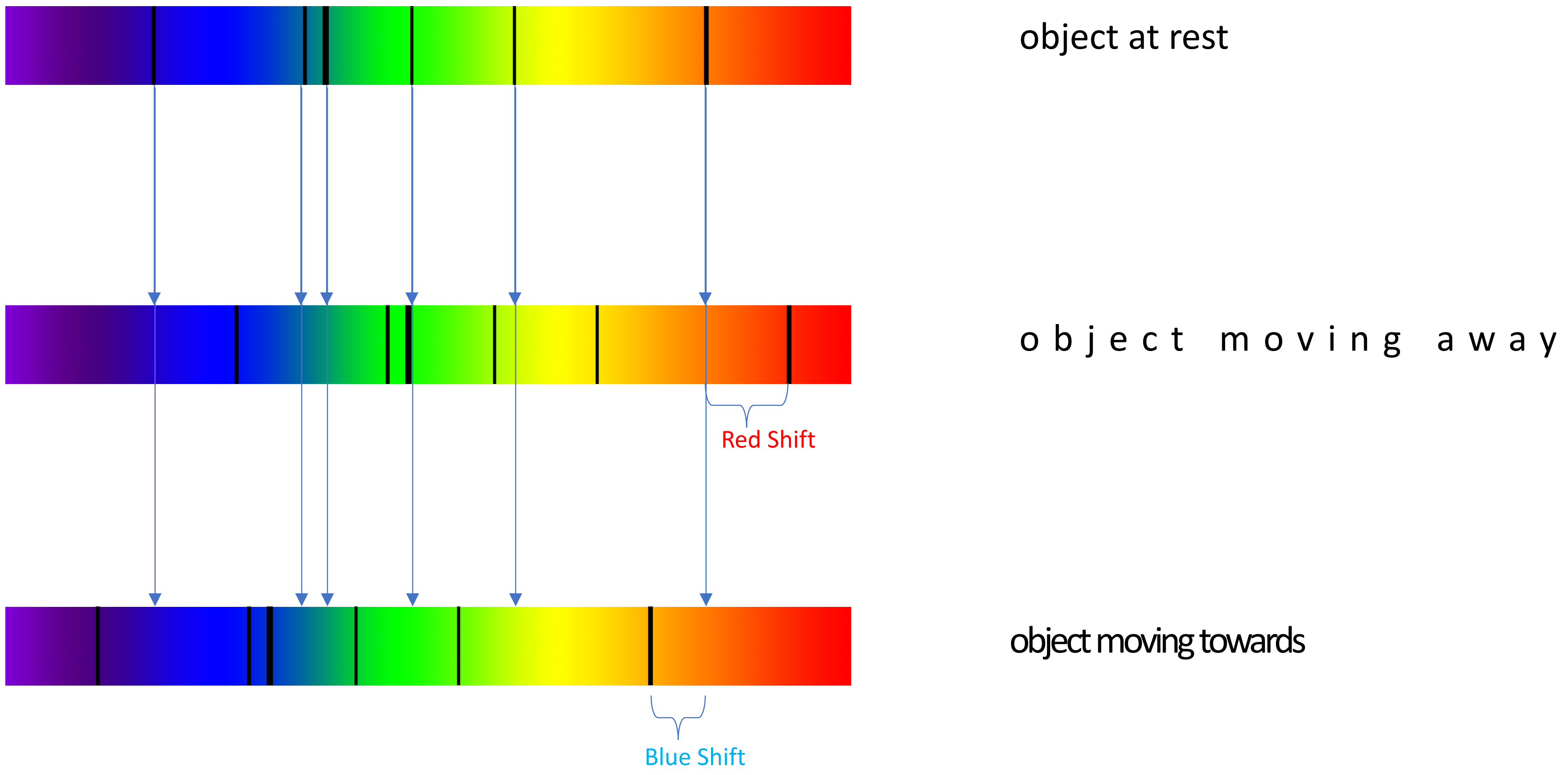
$$\bar{v} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)\ cm^{-1}\ ;\ R_H = 109677\ cm^{-1}$$

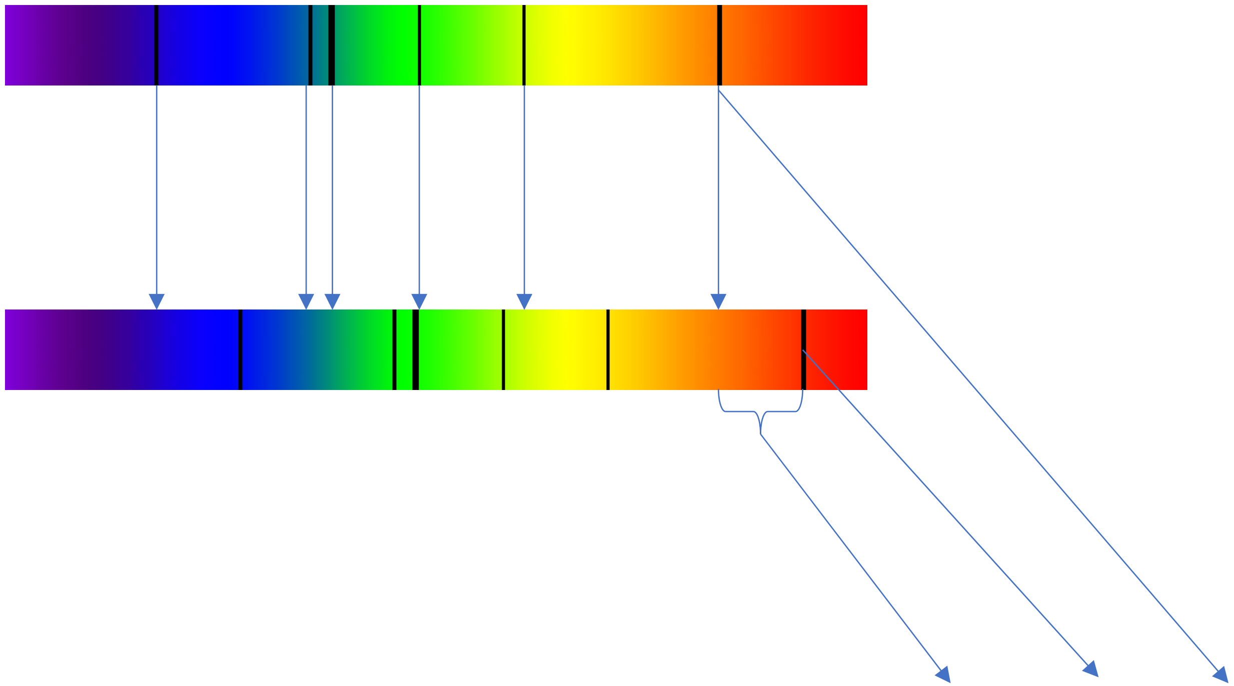
Series	n_1	n_2	Region of spectrum
Lyman	1	2,3,4…..	Ultraviolet
Balmer	2	3,4,5…..	Visible
Paschen	3	4,5,6…..	Infrared
Bracket	4	5,6,7…..	Infrared
Pfund	5	6,7,8…..	Infrared



$$f = f_0\left(\frac{v + v_o}{v + v_s}\right)$$


object at rest
object moving away
Red Shift
object moving towards
Blue Shift


object at rest
o b j e c t   m o v i n g   a w a y
Red Shift
object moving towards
Blue Shift



$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

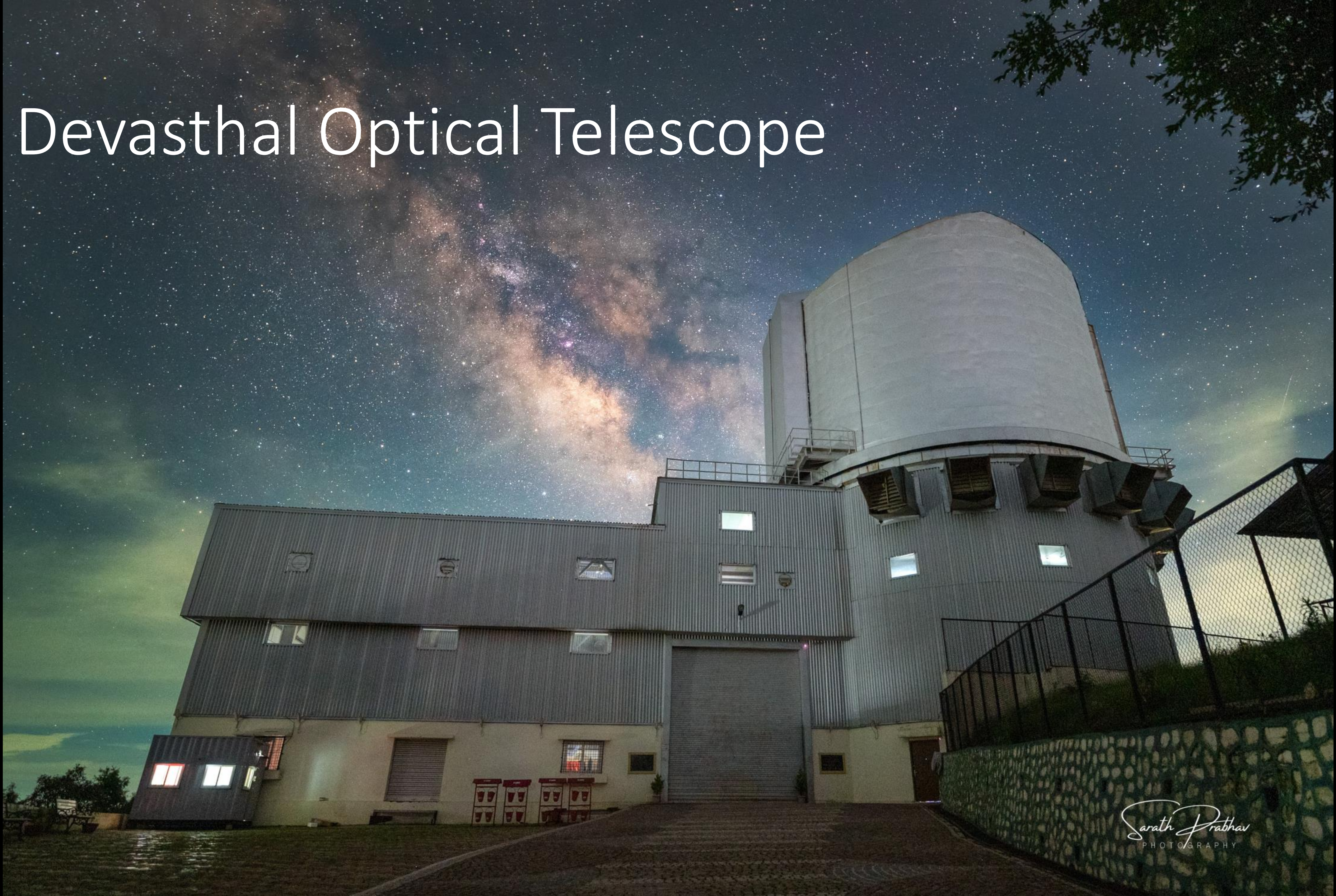
$$z = \frac{\Delta\lambda}{\lambda_0}$$

$$\Delta\lambda = \lambda' - \lambda_0$$

λ' – Observed Wavelength

$\lambda_0 - Rest\ Wavelength$

Devasthal Optical Telescope



3.6m Devasthal Optical Telescope

- Built by Aryabhatta Research Institute of Observational Sciences (ARIES)
- Located at the Devasthal Observatory site near Nainital, Kumaon, India.

Altitude	2540m
Mirror	3.6m
Wavelength	350 nm–5,000 nm
Telescope style	optical telescope Ritchey–Chrétien telescope

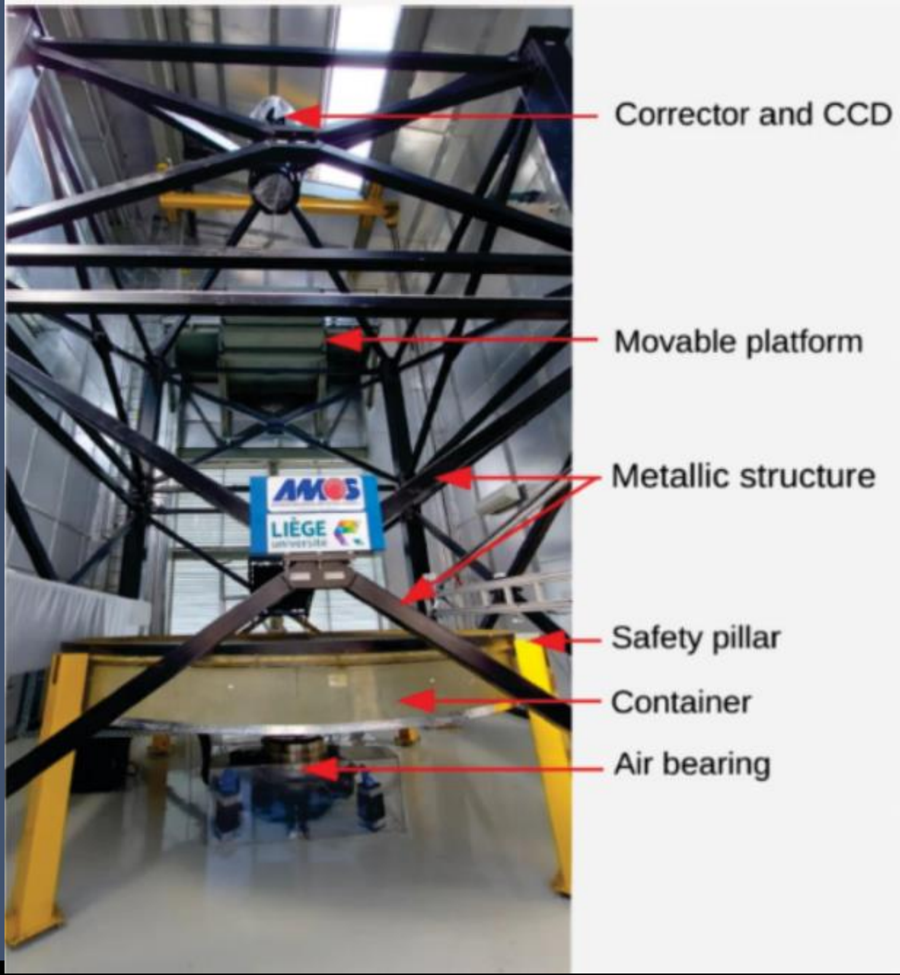
Devasthal Optical Telescope

- India's largest fully steerable optical telescope (3.6 m).
- Equipped with state-of-the-art instruments for optical and near-infrared observations.
- Used for stellar, galactic, and extra-galactic studies.

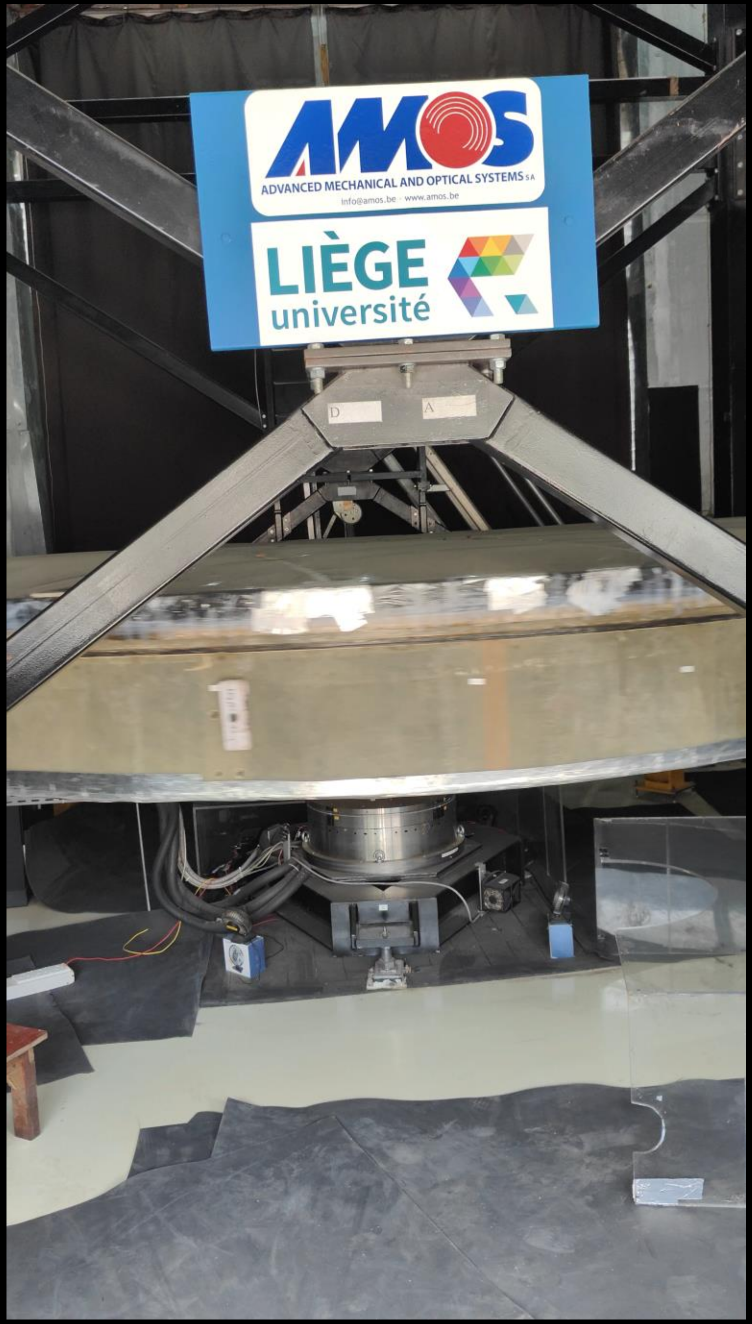
ILMT

Location : Devasthal, Utharaghand
Lat Lon : 29◦21′41.4 69 ′′ N , 79◦41′07′′ E
Alt : 2378 m
First Light : 29 April 2022
Commisioned : 21 March 2023
Filters : SDSS g ′ , r ′ and i ′
Primary Mirror : 4m
Rotation Period : ~8 sec
Focal Length : 8m
Focal Length : 9.43 (Corrector)
Mercury Thickness : 3.5mm
Weight of Hg : 650
Mirror Weight : ~1000 kg
CCD : 4096 X 4096 pixels
Pixel Size : 15microns
FoV : 22.3 arcmin
TDI Scan time : 102 s
Image Size : 36864 x 4096 – 1.25 sq degree
Total Sky coverage over night : 36


Electronic detector
Thin reflecting surface of mercury
Rotating mirror platform


Corrector and CCD
Movable platform
Metallic structure
Safety pillar
Container
Air bearing
AMOS
LIÈGE

Primary Mirror

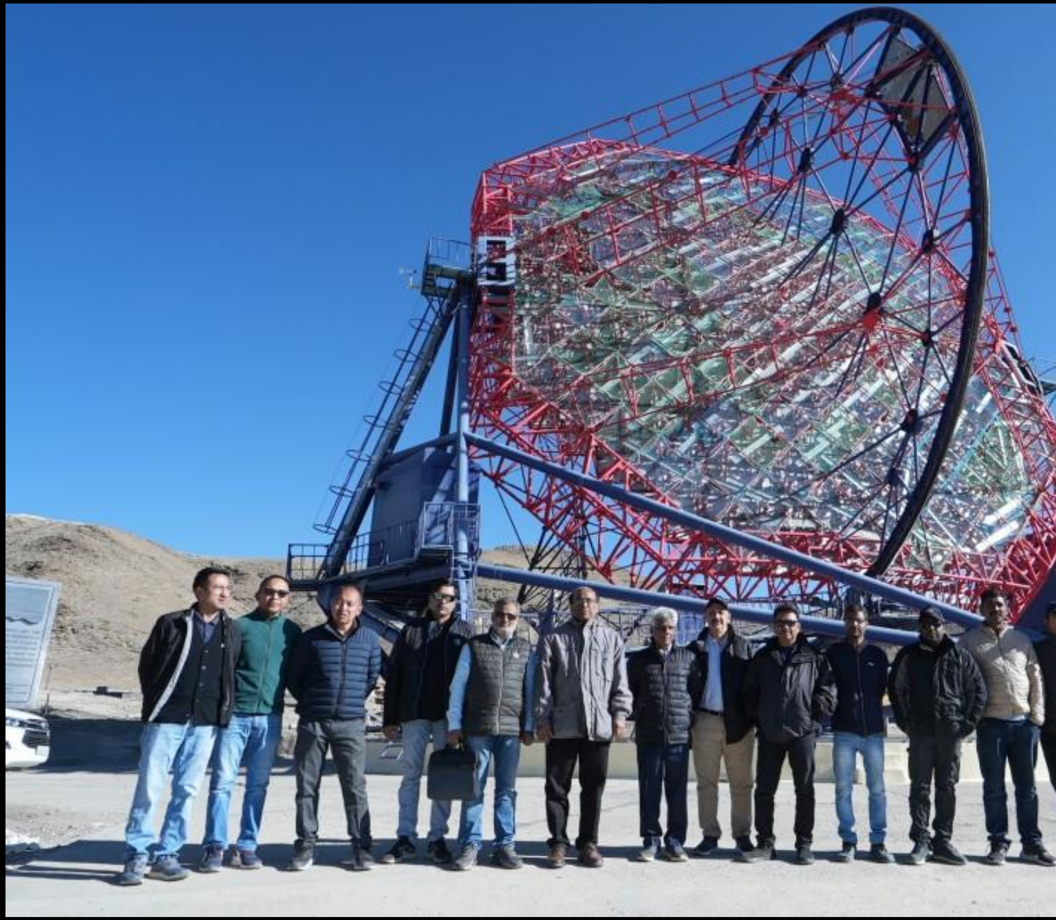


Giant Metre wave Radio Telescope (GMRT)

- Established: 2002
- Operated by: National Centre for Radio Astrophysics (NCRA-TIFR)
- Used for studying cosmic phenomena like pulsars, galaxies, the cosmic web, and hydrogen in the early universe.
- Array of 30 Parabolic Antennas
- Diameter: 45 meters each.
- Total collecting area: ~30,000 square meters.
- Frequency Range: Operates between 50 MHz and 1.5 GHz.

Major Atmospheric Cherenkov Experiment (MACE) telescope

- MACE is designed to detect very high-energy gamma rays indirectly.
- Gamma rays interact with the Earth's atmosphere, producing a cascade of particles that emit Cherenkov radiation
- MACE captures this light to study the sources of these high-energy gamma rays.
- Location: Hanle, Ladakh, India - chosen for its high altitude (4,270 meters)
- Light Collector: A large, 356-square-meter honeycomb structure made up of 356 mirror panels.
- Imaging Camera: A high-resolution camera weighing about 1,200 kilograms.



Vainu Bappu Observatory

- owned and operated by the Indian Institute of Astrophysics.
- It is located at Kavalur in the Javadi Hills, near Vaniyambadi in Tirupathur district in the Indian state of Tamil Nadu.

Altitude	700 meters (2,297 feet)
Established	1986
Vainu Bappu Telescope	2.3 meter reflector
Carl Zeiss telescope	1 meter reflector

Giant Metrewave Radio Telescope

- The Giant Metrewave Radio Telescope (GMRT), located near Narayangaon, Pune in India, is an array of thirty fully steerable parabolic radio telescopes of 45 metre diameter, observing at metre wavelengths.
- It is operated by the National Centre for Radio Astrophysics (NCRA), a part of the Tata Institute of Fundamental Research, Mumbai.

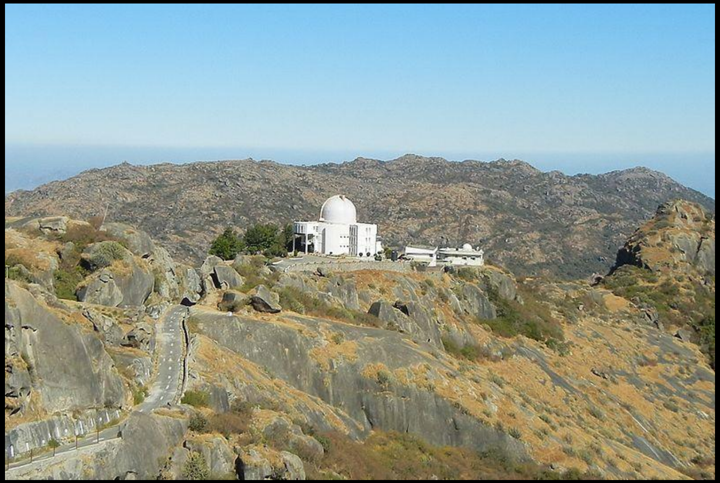
Wavelength	50, 1,500 MHz (6.00, 0.20 m)
First light	1995
Number of telescopes	30
Diameter	45 m (147 ft 8 in)

Kodaikanal Solar Observatory

- The Kodaikanal Solar Observatory is a solar observatory owned and operated by the Indian Institute of Astrophysics.
- Established Year 1895 (British - East India Company)
- Solar data collected by the lab is the oldest continuous series of its kind in India. Precise observations of the equatorial electrojet are made here due to the unique geography of Kodaikanal.
- Director : Annapurni Subramanian 2019–Present

Mount Abu InfraRed Observatory

- The Mount Abu InfraRed Observatory (MIRO) is located near the town Mount Abu in the state of Rajasthan, India. The observatory is at an altitude of 1680 metres and is adjacent to Guru Shikhar, highest peak of the Aravalli Range. The 1.2 m infrared telescopeat It is the first major facility in India specifically designed for ground-based, infrared observations of celestial objects.
- Organization
- Physical Research Laboratory
- Established 1990



Indian Astronomical Observatory

- The Indian Astronomical Observatory (IAO) is a high-altitude astronomy station located in Hanle, India and operated by the Indian Institute of Astrophysics. Situated in the Western Himalayas at an elevation of 4,500 meters (14,764 ft), the IAO is one of the world's highest located sites for optical, infrared and gamma-ray telescopes. It is currently the highest optical telescope in the world. It is India's first dark-sky preserve.
- **Himalayan Chandra Telescope (HCT)**
  - The Himalayan Chandra Telescope is a 2.01 meters (6.5 feet) diameter optical-infrared telescope named after India-born Nobel laureate Subrahmanyam Chandrasekhar. It contains a modified Ritchey-Chretien system. The telescope is remotely operated via an INSAT-3B satellite link which allows operation even in sub-zero temperatures in winter.
- **GROWTH-India Telescope**
  - The GROWTH-India telescope is a 0.7 meter wide-field optical telescope that had first light in 2018. It is the country's first fully robotic research telescope. The telescope is operated jointly by IIT Bombay and the Indian Institute of Astrophysics.

- **IIA-Washington University Cassegrain telescope**
  - Since 2011, the Indian Institute of Astrophysics (IIA) collaborates with the McDonnell Center for the Space Sciences of Washington University in St. Louis to operate two 0.5 meters Cassegrain telescopes.
- **High Altitude Gamma Ray Telescope**
  - The High Altitude Gamma Ray Telescope (HAGAR) is an atmospheric Cerenkov experiment with 7 telescopes setup in 2008. Each telescope has 7 mirrors with a total area of 4.4 square meters. Himalayan Gamma Ray Observatory (HiGRO) was set up at Hanle in collaboration with Tata Institute of Fundamental Research, Mumbai and Bhabha Atomic Research Centre, Mumbai.