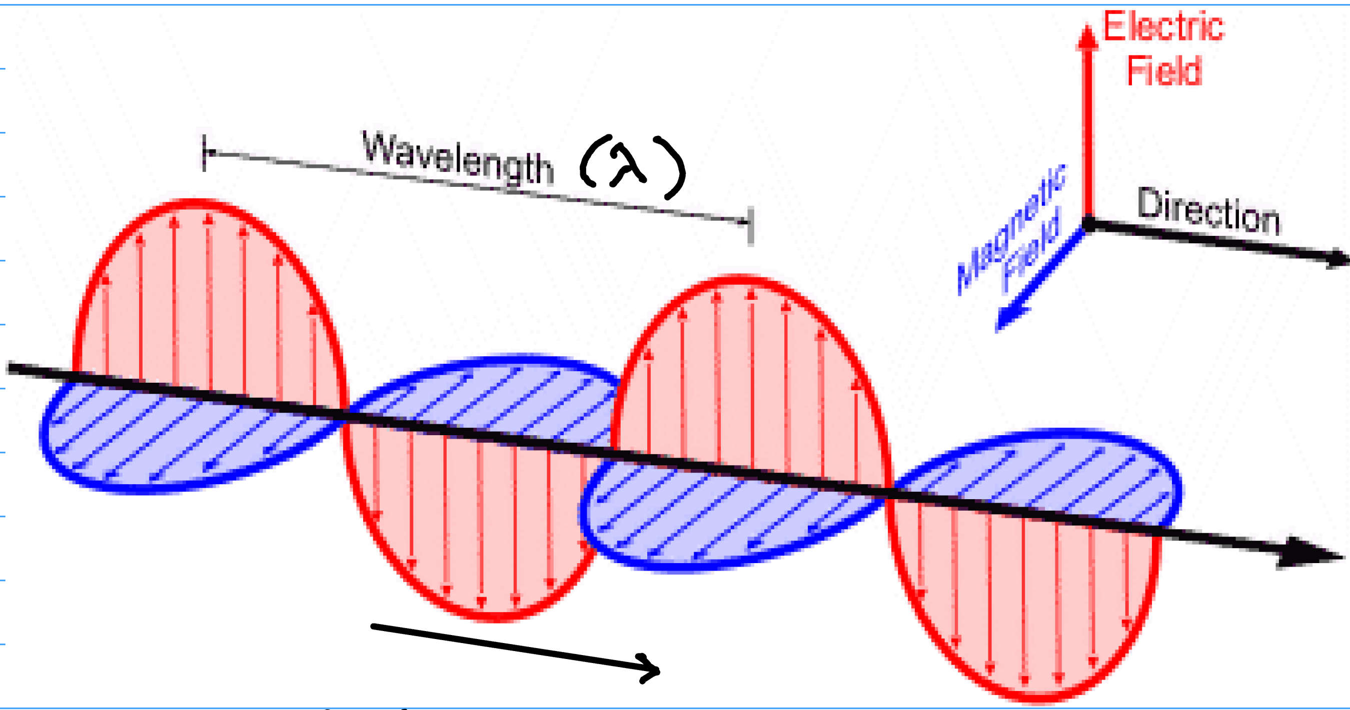
LIGHT AND TELESCOPES

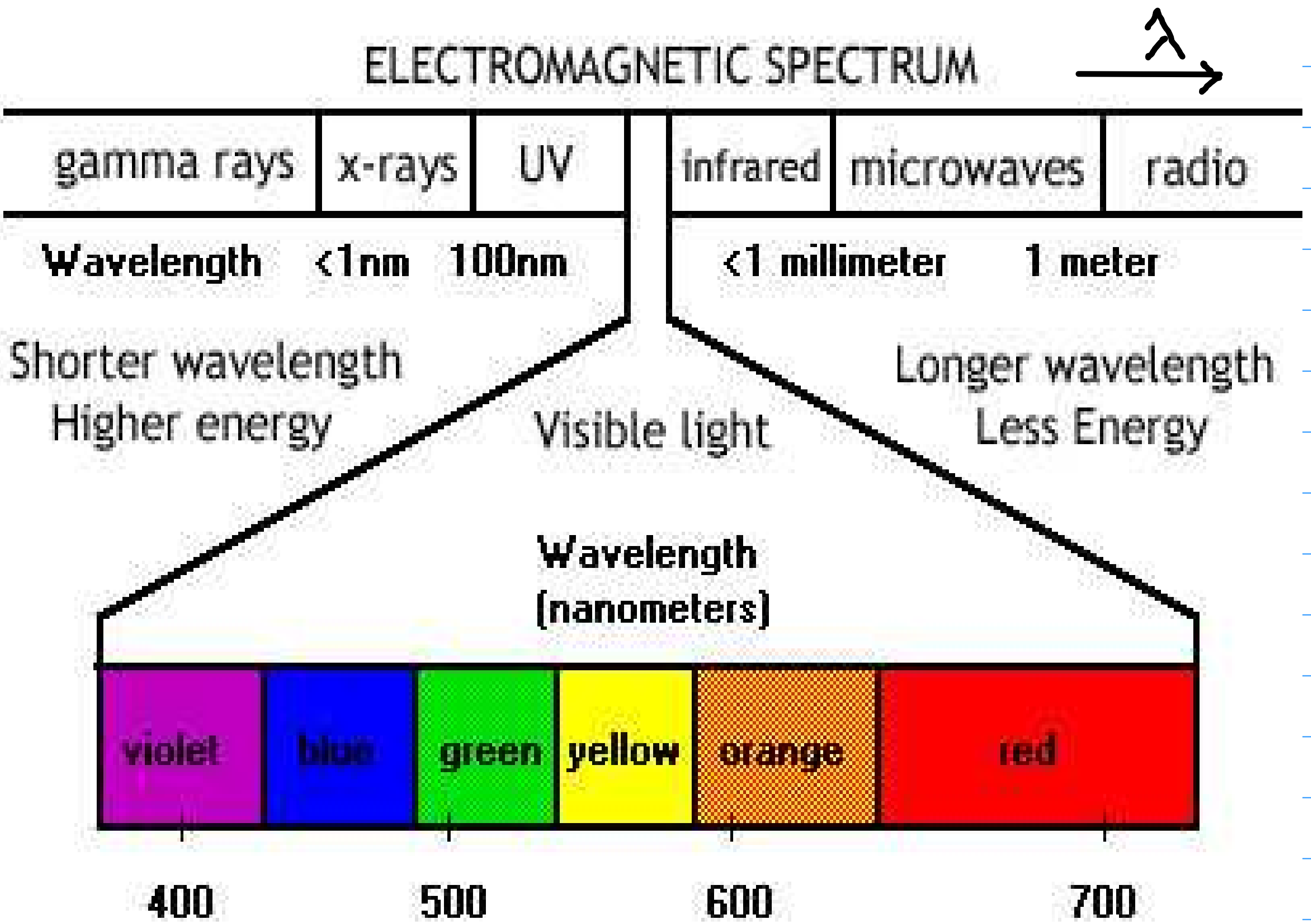
ALL INFORMATION ABOUT STARS IS OBTAINED FROM THE LIGHT THEY EMIT USING VARIOUS PHYSICAL LAWS.

THE LIGHT THAT WE SEE IS JUST ONE EXAMPLE OF ELECTROMAGNETIC WAVE:



SPEED OF PROPAGATION

$c = 300{,}000\ km/s$

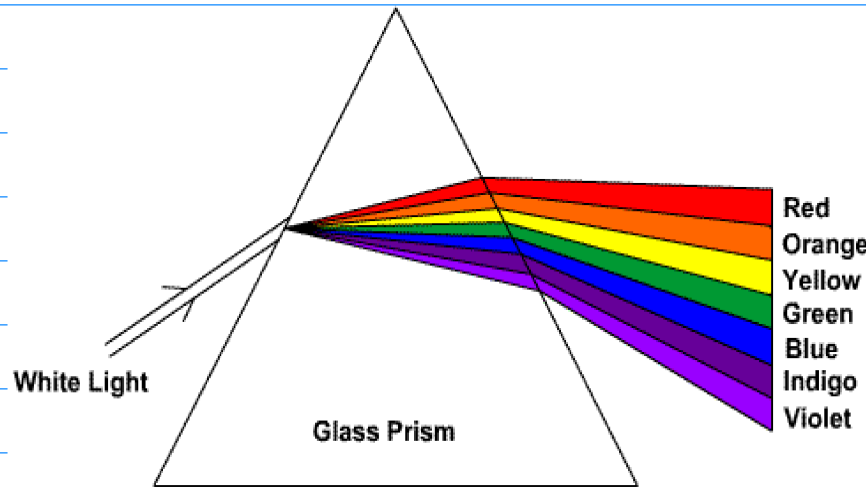


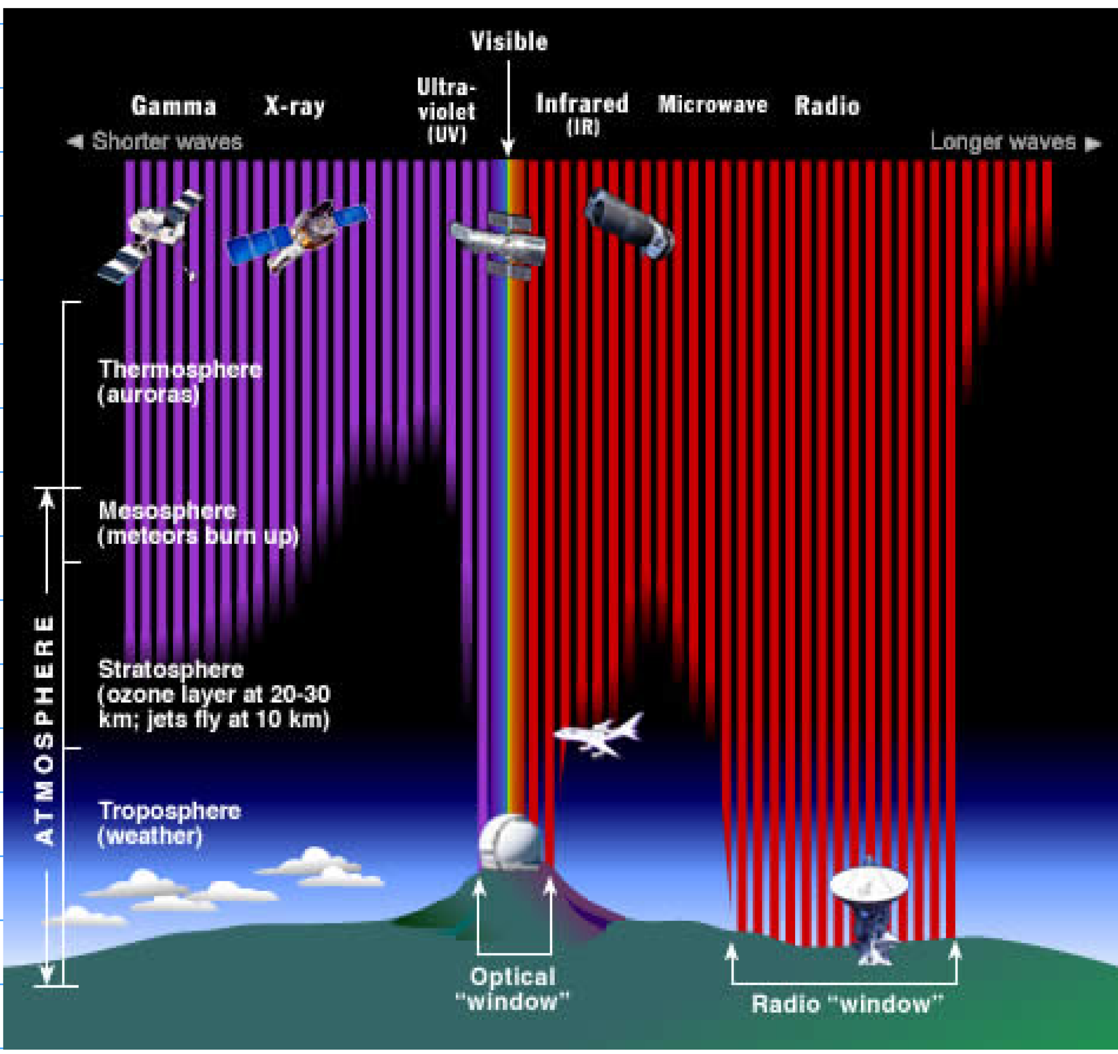
$$1\,nm = 10^{-9}\,m$$

↑ NANOMETER

THE WAVELENGTHS OF VISIBLE LIGHT RANGE FROM ABOUT 400 nm (VIOLET) TO ABOUT 700 nm (RED).

THE WHITE LIGHT COMING FROM THE SUN IS A MIXTURE OF ALL VISIBLE WAVELENGTHS:





ATMOSPHERIC WINDOWS:

THE EARTH'S ATMOSPHERE IS NOT TRANSPARENT TO ALL THE WAVELENGTHS FROM THE OUTER SPACE.

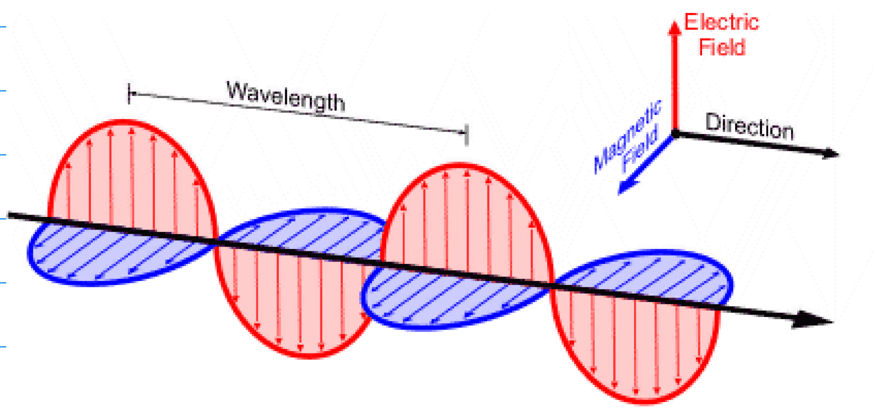
THE HIGHEST PARTS OF THE ATMOSPHERE BLOCK THE GAMMA-RAYS, X-RAYS AND SOME RADIOWAVES.

THE OZONE (O_3) LAYER BLOCKS MOST OF THE UV RADIATION.

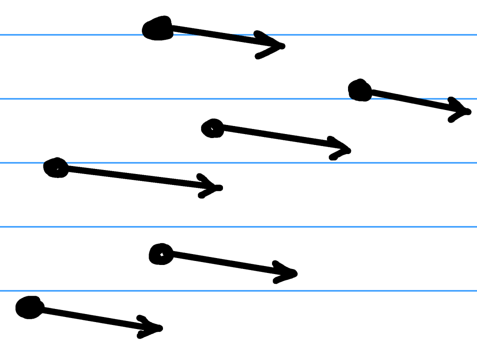
WATER VAPOR AND CO_2 BLOCK SOME IR AND RADIO WAVES.

WHEN ONE EXAMINES THE INTERACTION BETWEEN THE ELECTROMAGNETIC RADIATION AND MATTER ONE FINDS THAT THE RADIATION CARRIES THE ENERGY IN DISCRETE PACKETS CALLED <u>PHOTONS</u>.

THE WAVE-PARTICLE DUALITY:



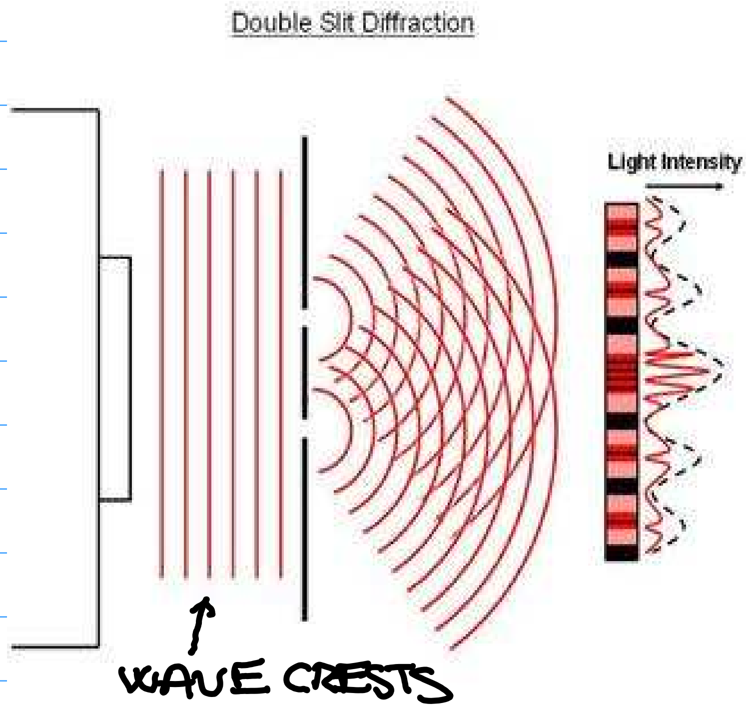
$\Longleftrightarrow$



ELECTROMAGNETIC WAVE

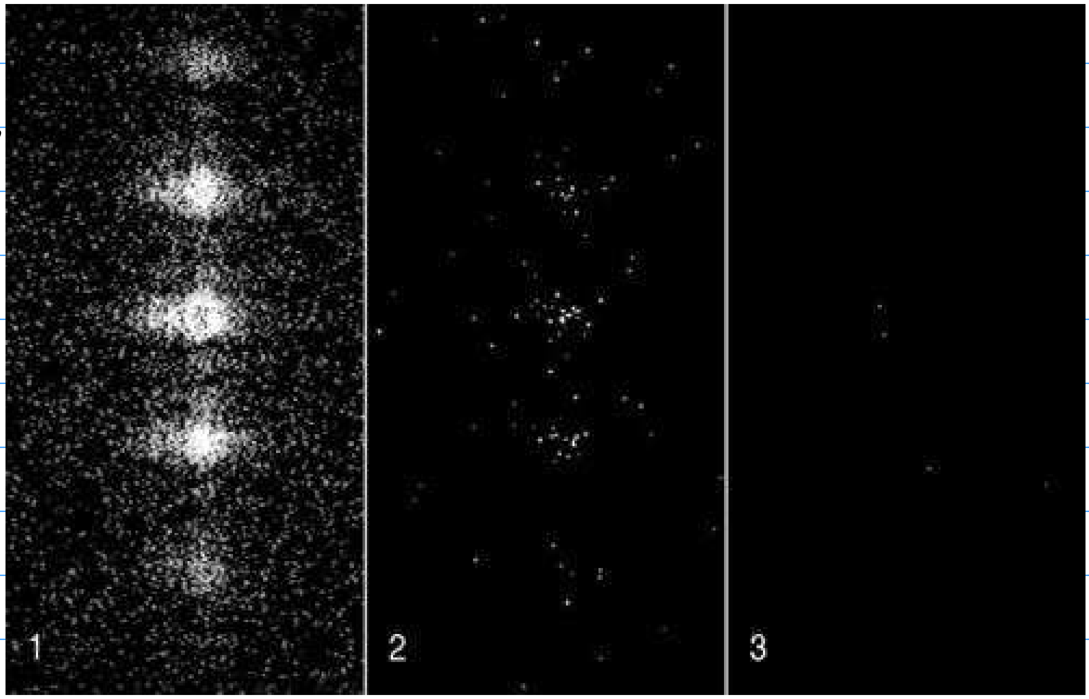
A BEAM OF PHOTONS

ELECTROMAGNETIC RADIATION PROPAGATES THROUGH SPACE AS A WAVE:



ELECTROMAGNETIC RADIATION INTERACTS WITH MATTER AS A BEAM OF PHOTONS:

HIGH INTENSITY OR A LONG EXPOSURE TIME



LOW INTENSITY OR A SHORT EXPOSURE TIME

THE ENERGY OF THE PHOTON IS DETERMINED BY THE WAVELENGTH OF RADIATION

$$E = \frac{hc}{\lambda}$$

PHOTON ENERGY (E)

WAVELENGTH OF RADIATION (λ)

$h = 6.63 \times 10^{-34}\ W/s^2$ – PLANCK'S CONSTANT

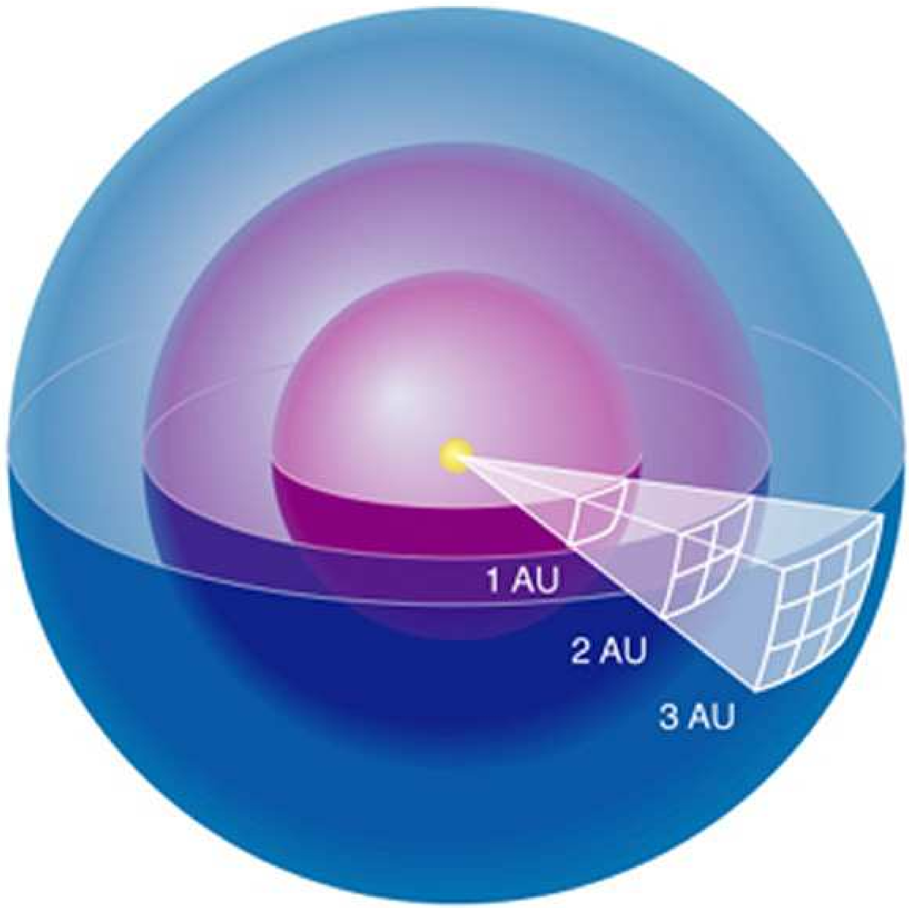
$c = 3.00 \times 10^{8}\ \frac{m}{s}$ – THE SPEED OF LIGHT IN VACUUM

HENCE, THE SHORTER THE WAVELENGTH (λ), THE HIGER THE PHOTON ENERGY (E) AND VICE VERSA.

THE SHORT WAVELENGTH PHOTONS (GAMMA-, X-RAY-, AND UV-PHOTONS) HAVE LARGE ENOUGH ENERGY TO DAMAGE THE LIVING CELLS. HENCE THE FACT THAT THE EARTH HAS AN ATMOSPHERE WHICH BLOCKS MOST OF THOSE PHOTONS MADE THE LIFE ON IT POSSIBLE.

TELESCOPES

THE AMOUNT OF LIGHT ENERGY FROM A DISTANT SOURCE THAT ENTERS THE EYE IS SMALL AND LIMITTED BY THE SIZE OF THE EYE:



$$B = \frac{L}{4\pi d^2}$$

BRIGHTNESS = THE ENERGY RECEIVED PER UNIT AREA AND UNIT TIME

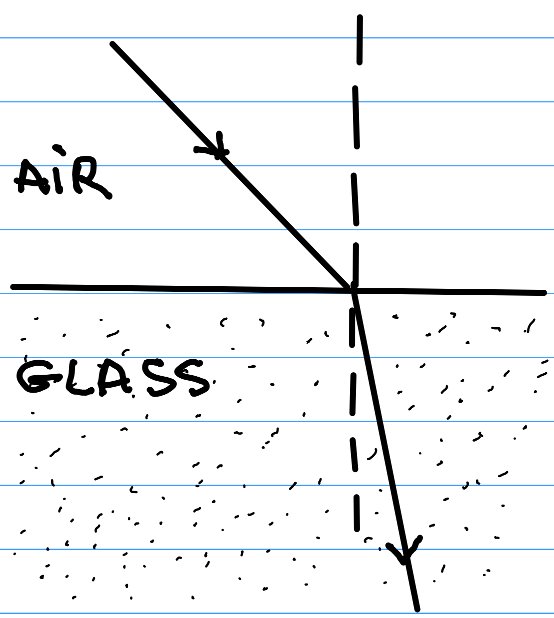
LUMINOSITY = THE ENERGY OUTPUT PER UNIT TIME

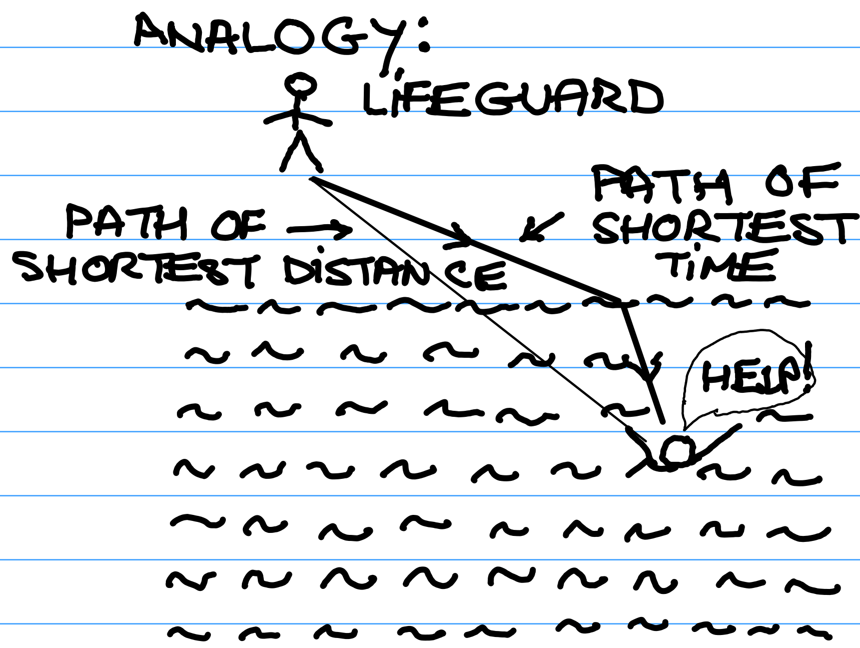
THE **DISTANCE** FROM THE SOURCE

MORE LIGHT ENERGY CAN BE COLLECTED BY USING:

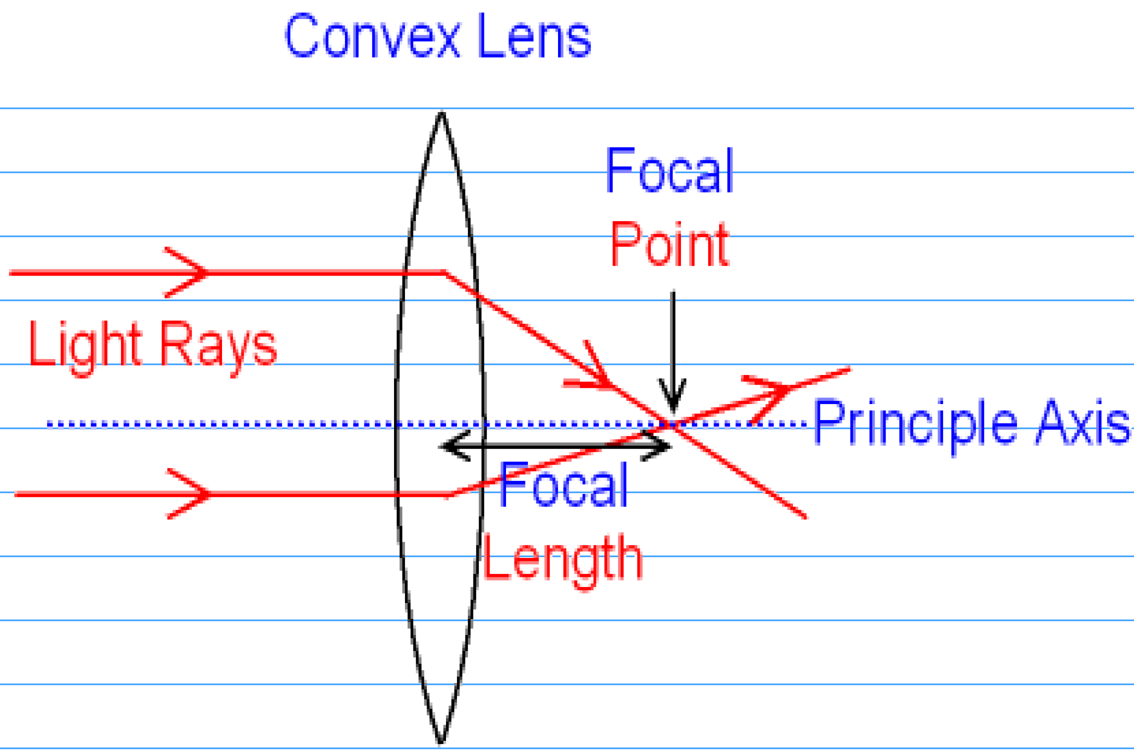
1) REFRACTION OF LIGHT BY A CONVEX LENS,
2) REFLECTION OF LIGHT BY A CONCAVE MIRROR.

REFRACTION: THE SPEED OF LIGHT PROPAGATION DEPENDS ON THE MEDIUM — IT IS LOWER IN GLASS THAN IN THE AIR. AS A RESULT, THE LIGHT RAYS BEND WHEN THEY GO FROM ONE MEDIUM TO ANOTHER:

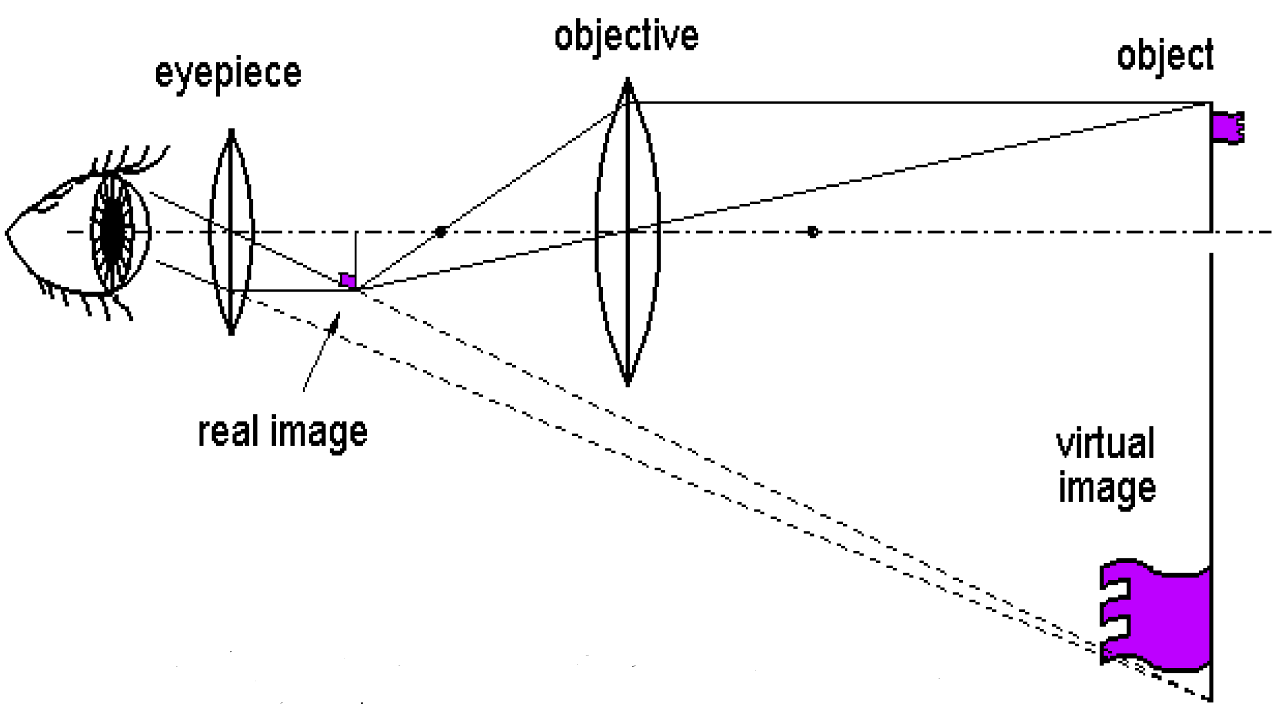




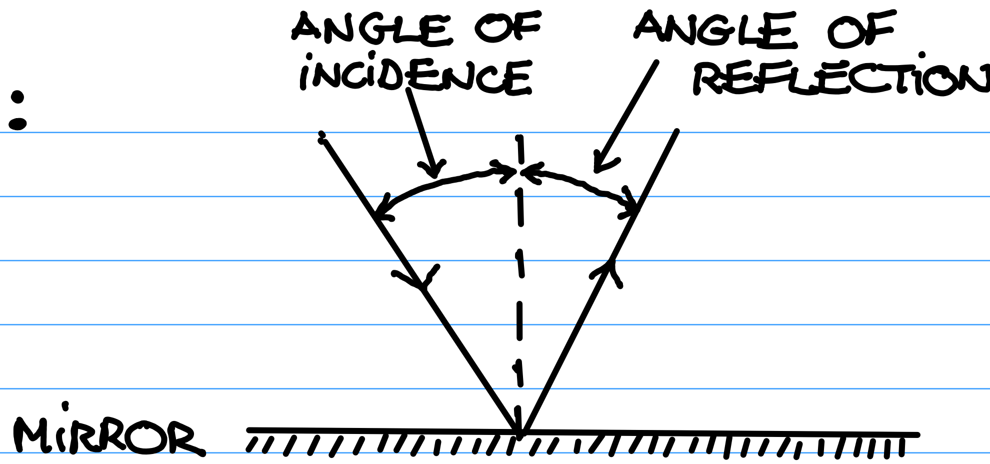
IN EITHER CASE THE PATH IS THE ONE THAT MINIMIZES THE TIME OF TRAVEL.



TO ENLARGE THE IMAGE NEAR FOCUS THE SECOND LENS - THE EYEPIECE IS USED:

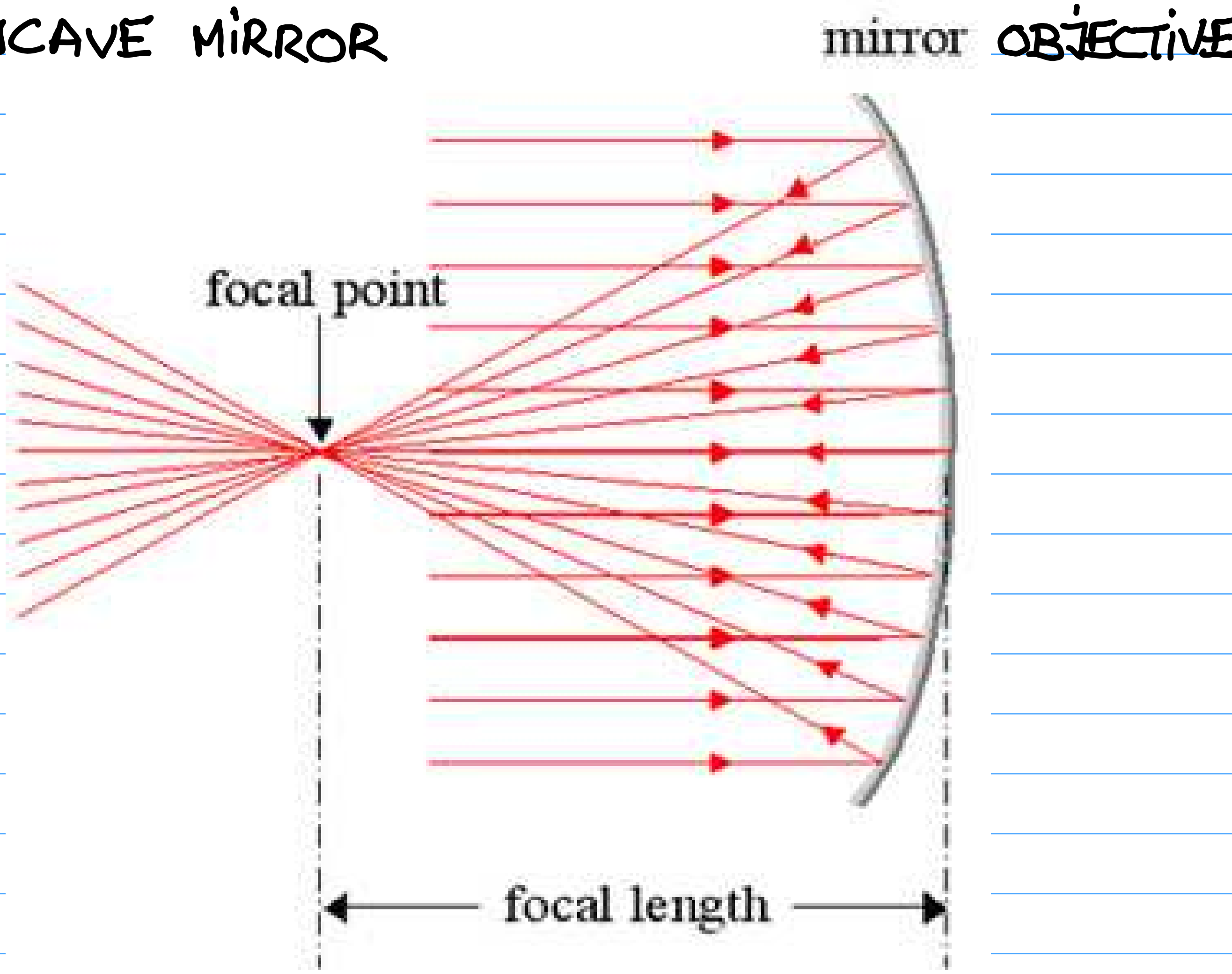


REFLECTION:



ANGLE OF INCIDENCE = ANGLE OF REFLECTION

CONCAVE MIRROR

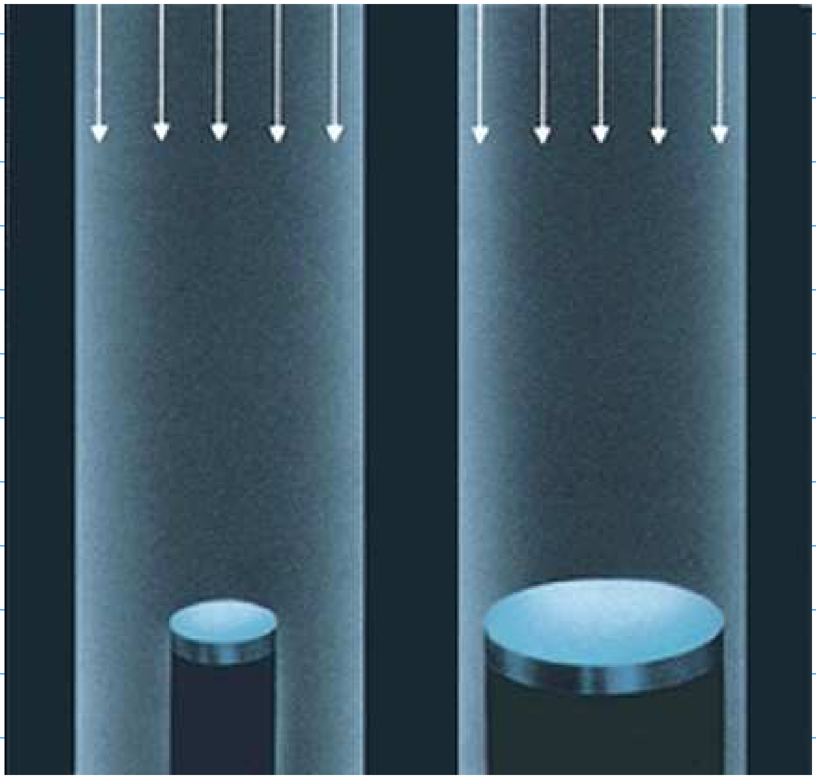


A LENS OR A MIRROR THAT IS USED TO COLLECT LIGHT IS CALLED THE OBJECTIVE.

TELESCOPE WHICH USES A LENS AS THE OBJECTIVE IS CALLED REFRACTOR.

TELESCOPE WHICH USES A MIRROR AS THE OBJECTIVE IS CALLED REFLECTOR.

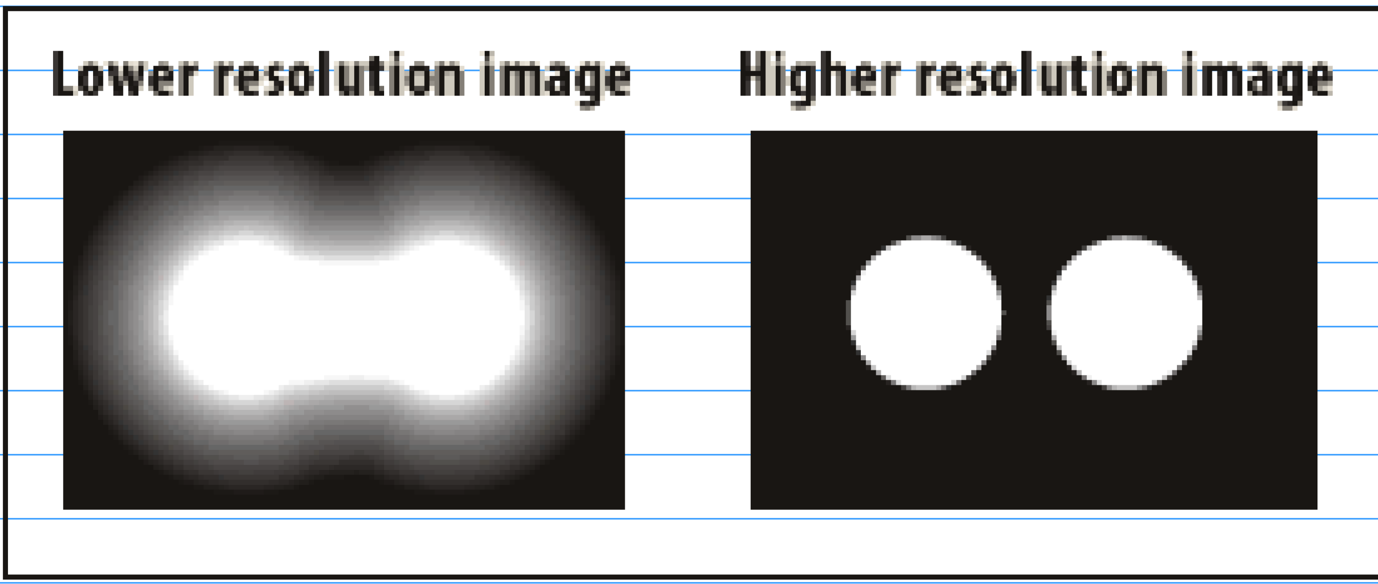
THE MOST IMPORTANT PROPERTY OF A TELESCOPE IS THE LIGHT GATHERING (OR COLLECTING) POWER, AND IS PROPORTIONAL TO THE CROSS-SECTIONAL ~~AREA~~ OF THE OBJECTIVE, WHICH IS PROPORTIONAL TO THE SQUARE OF ITS DIAMETER:

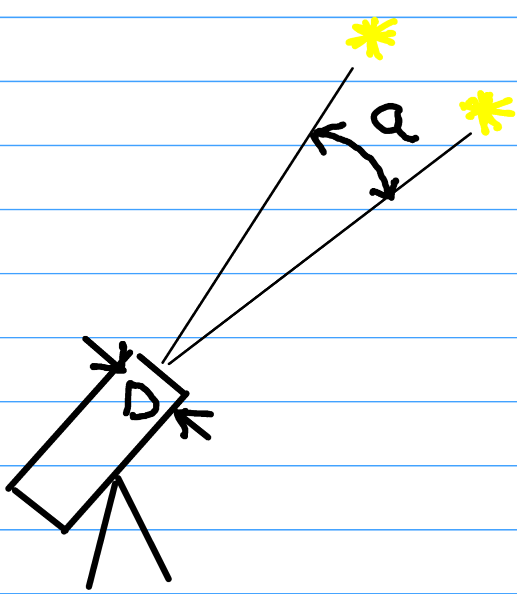


LIGHT GATHERING POWER $\propto D^2$

D ← DIAMETER OF THE OBJECTIVE (MIRROR OR LENS)

THE SECOND IN IMPORTANCE IS THE **RESOLVING POWER** OF THE TELESCOPE WHICH IS THE ABILITY TO RESOLVE TWO OBJECTS AS SEPARATE:





THE TWO STARS WILL BE SEEN AS SEPARATE IF

$$D > 0.02 \frac{\lambda}{a}$$

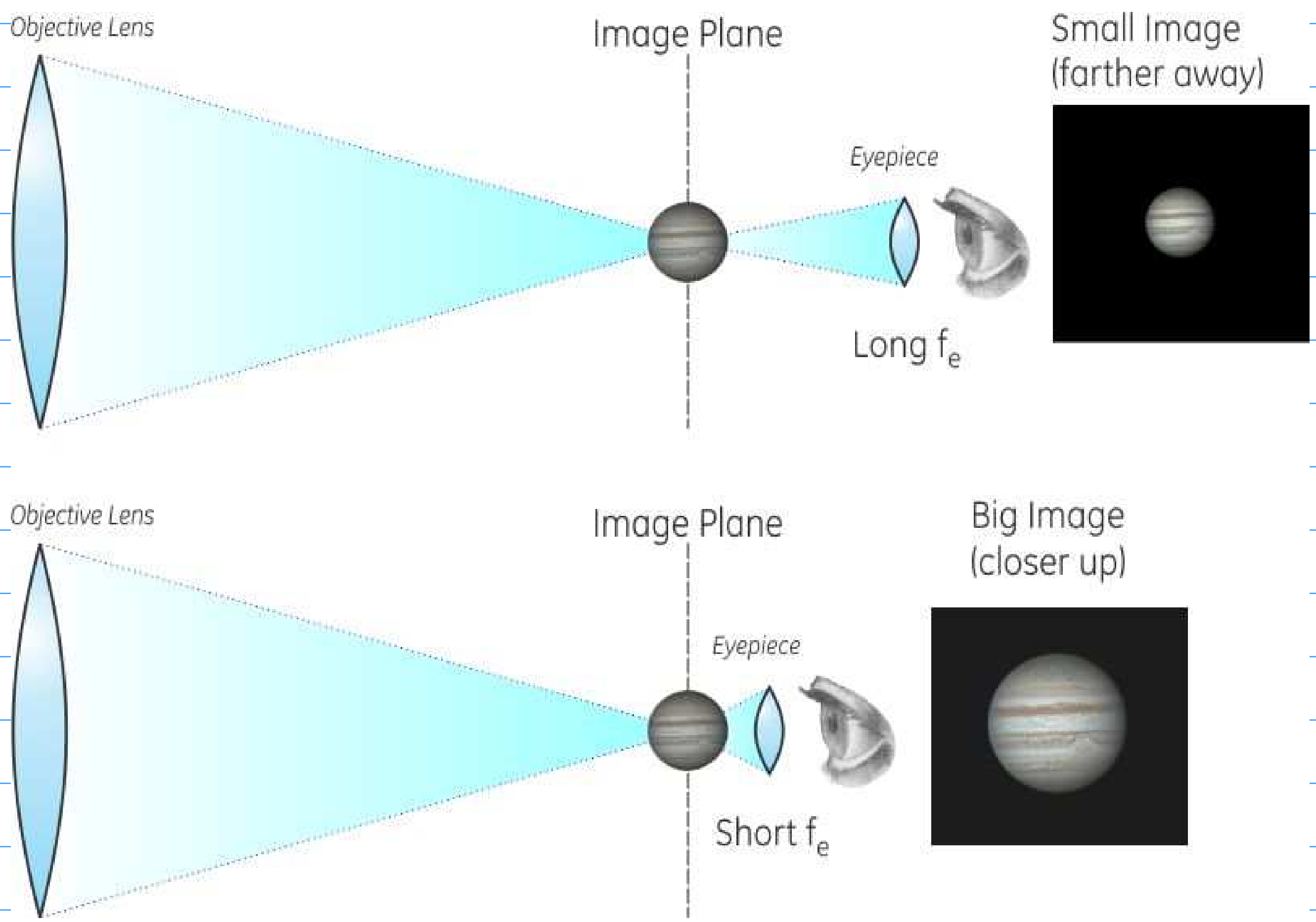
D IN cm

λ IN nm

a IN SECONDS OF ARC

HENCE, THE LARGER THE DIAMETER OF THE OBJECTIVE, THE HIGHER IS THE RESOLVING POWER.

THE LEAST IMPORTANT PROPERTY OF A TELESCOPE IS THE <u>MAGNIFYING POWER</u>:

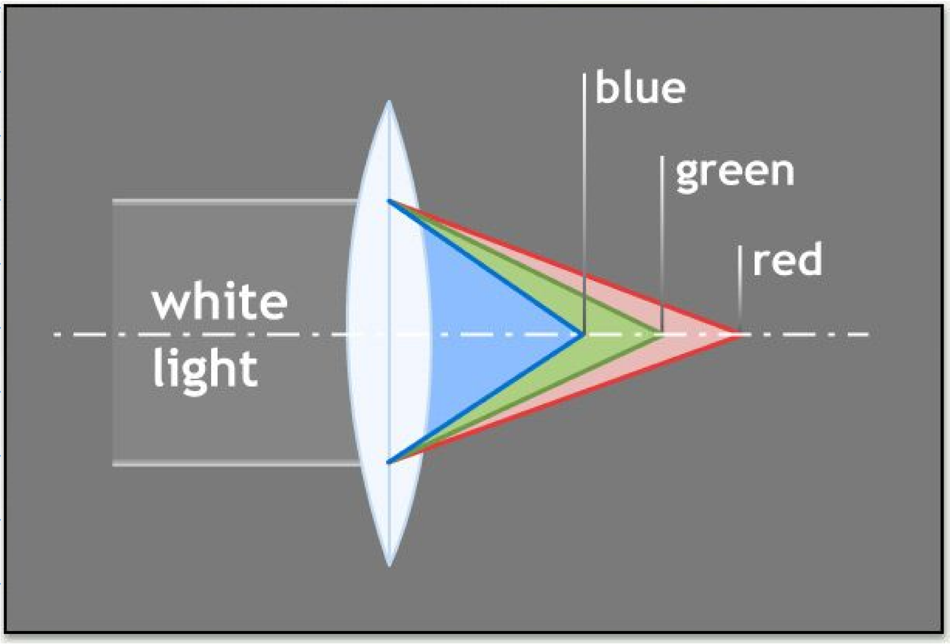


$$\text{MAGNIFYING POWER (OR MAGNIFICATION)} = \frac{\text{FOCAL LENGTH OF THE OBJECTIVE}}{\text{FOCAL LENGTH OF THE EYEPIECE}}$$

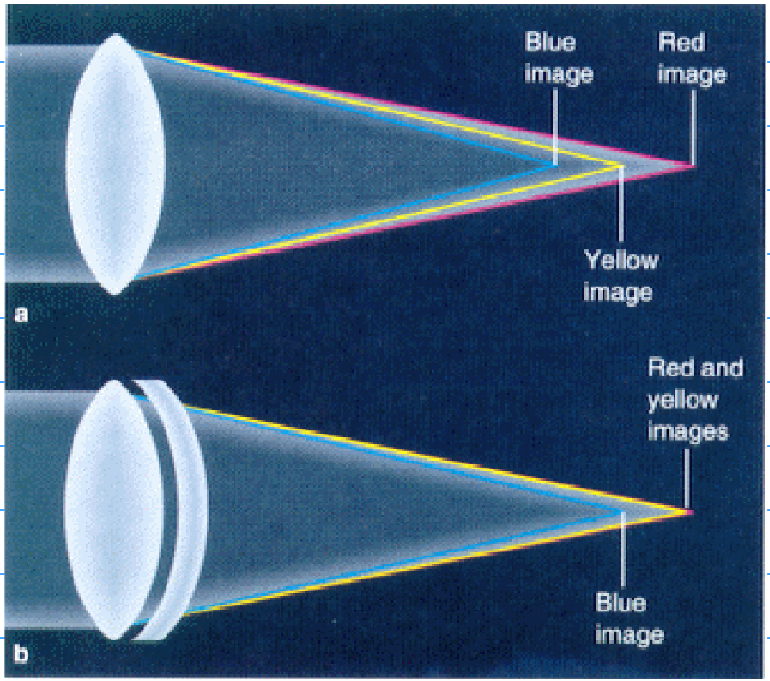
<u>NOTE</u>: AS THE MAGNIFICATION INCREASES THE IMAGE BECOMES LESS BRIGHT AS THE SAME AMOUNT OF LIGHT ENERGY IS SPREAD OVER LARGER AREA.

PROBLEMS WITH REFRACTING TELESCOPES:

1) <u>CHROMATIC ABERRATION</u> – EACH WAVELENGTH IS REFRACTED BY A DIFFERENT AMOUNT AND DIFFERENT COLORS HAVE DIFFERENT FOCAL POINTS:



A PARTIAL CURE WITH ACHROMATIC LENSES:



FOCUS TOGETHER RED AND YELLOW BECAUSE THE EYE IS MOST SENSITIVE TO THOSE COLORS.

2) IT IS DIFFICULT TO MAKE LARGE DIAMETER LENSES WITHOUT DEFECTS (E.G. TINY AIR BUBBLES).

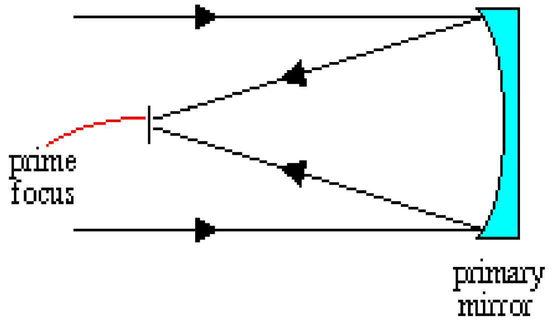
3) MECHANICAL DEFORMATION OF THE LENS BECOMES A PROBLEM WHEN ITS DIAMETER (AND WEIGHT) BECOMES LARGE.

THE LARGEST REFRACTING TELESCOPE IS YERKES TELESCOPE AT UNIVERSITY OF CHICAGO WITH OBJECTIVE 1 m IN DIAMETER.

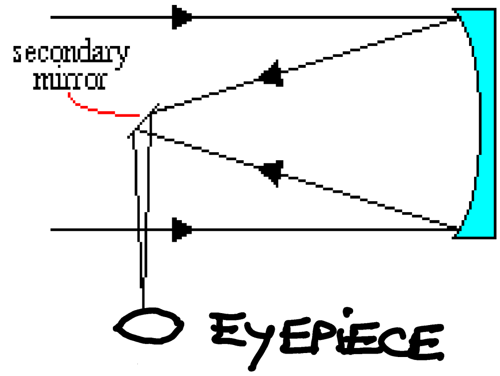
FOR THESE REASONS MOST OF TODAY'S TELESCOPES (BOTH RESEARCH AND NONPROFESSIONAL) ARE REFLECTORS.

Reflecting Telescopes

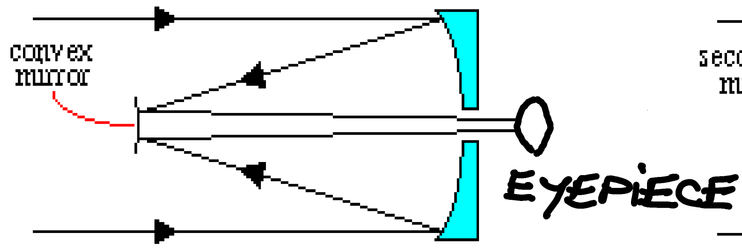
Prime FOCUS



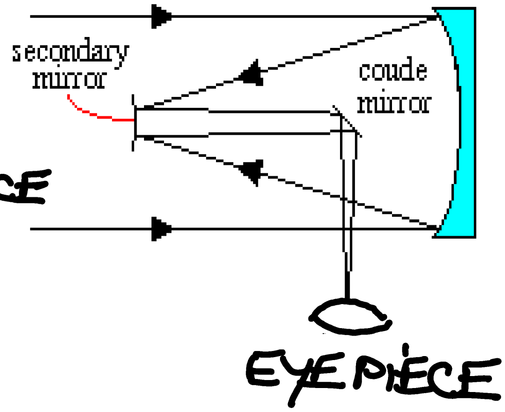
Newtonian FOCUS



Cassegrain FOCUS



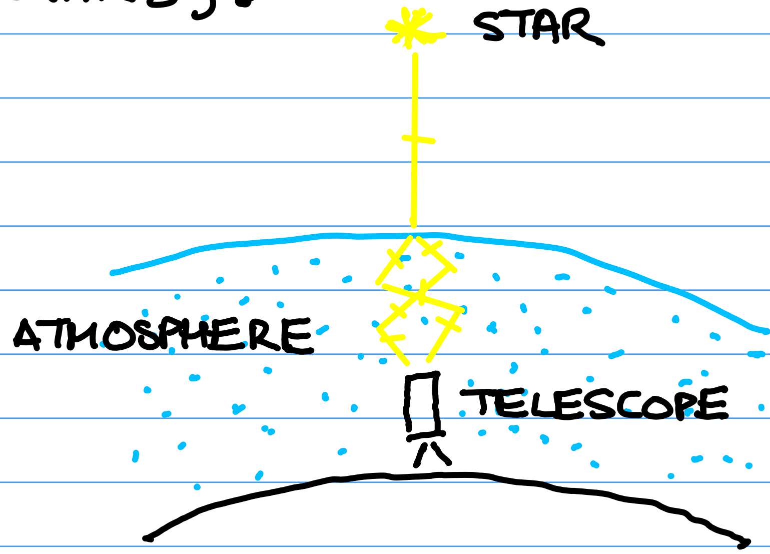
Coude FOCUS



IN VERY LARGE TELESCOPES THE OBSERVATION IS DONE AT THE PRIME FOCUS.

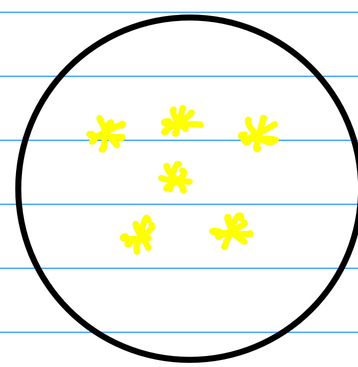
GEMINI NORTH,
MANUA KEA, HAWAII
8m – OBJECTIVE

ALL GROUND BASED TELESCOPES SUFFER FROM ATMOSPHERIC BLURRING (TWINKLING OF STARS):



TURBULENCE IN THE ATMOSPHERE REFRACTS STARLIGHT QUICKLY IN RANDOM DIRECTION

TELESCOPIC VIEW



MULTIPLE IMAGES ARE CREATED IN A LONG EXPOSURE

TO ACHIEVE THE BEST VIEWING CONDITIONS THE TELESCOPE SHOULD BE LOCATED HIGH, IN DRY AND CLEAR CLIMATES: CANADA-FRANCE-HAWAII TELESCOPE (CFHT) - A 3,6 m TELESCOPE LOCATED ATOP MANUA KEA, HAWAII; EUROPIAN SOUTHERN OBSERVATORY IN CHILEAN ANDES; 10 m KECK TELESCOPE (CALTECH & UC), MANUA KEA, HAWAII, ...

OBSERVATORIES IN SPACE:

HUBBLE SPACE TELESCOPE, 2.4 m OBJECTIVE

INFRARED SPACE OBSERVATORY (ISO)

CHANDRA - X-RAY OBSERVATORY

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