

ASTRONOMICAL TECHNIQUES

Structure :

- **Basic Optical Definitions for Astronomy**
 - Magnification
 - Light Gathering Power
 - Resolving Power and Diffraction Limit
- **Optical Telescopes**
 - Types of Reflecting Telescopes
 - Telescope Mountings
 - Space Telescopes
- **Detectors and Their Use with Telescopes**

BASIC OPTICAL DEFINITIONS FOR ASTRONOMY :

Telescopes :

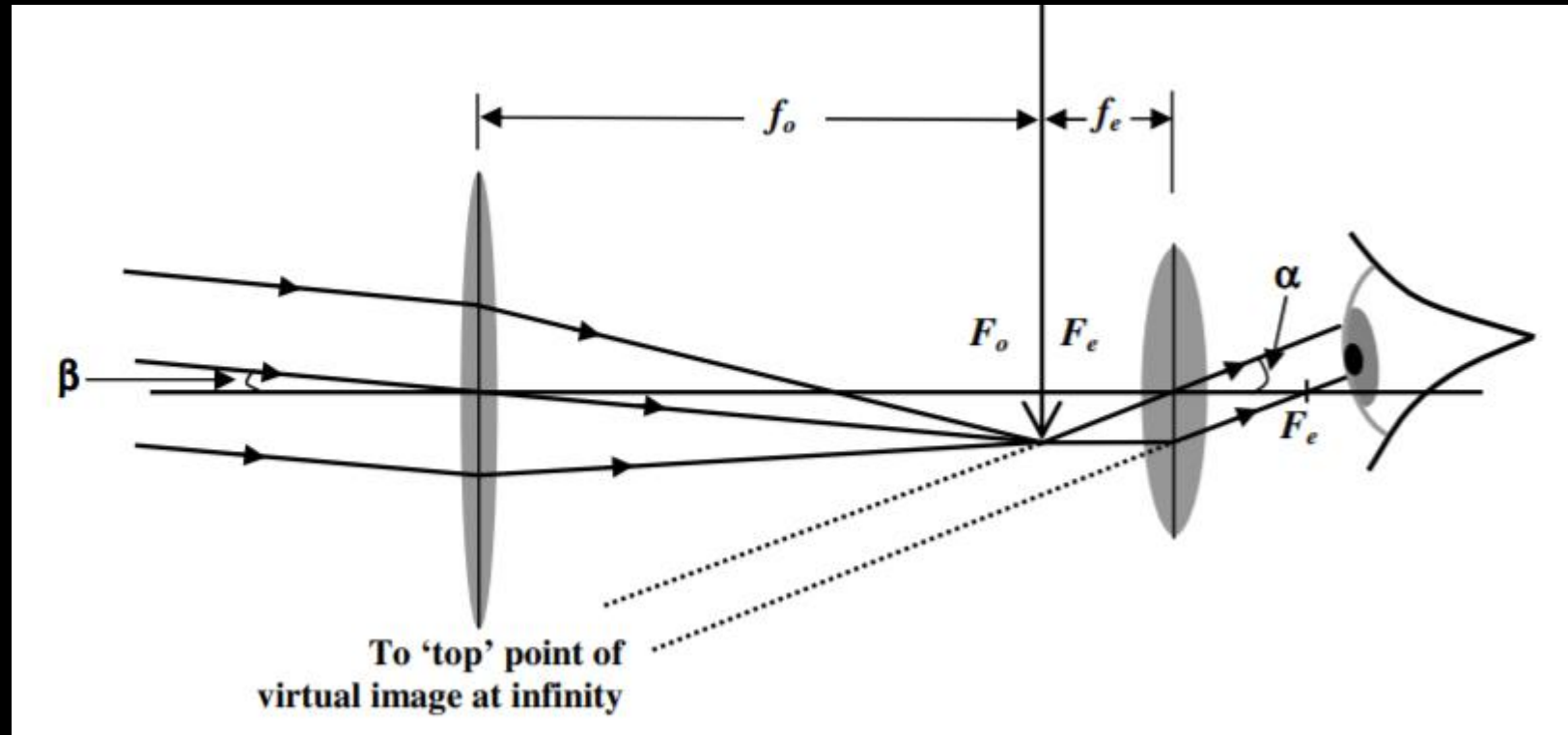
- Not just to magnification device
- Also resolving power and light gathering power

MAGNIFICATION :

- magnifying power refers to the ability to make the image appear bigger

MAGNIFICATION :

- magnifying power refers to the ability to make the image appear bigger



The image of a distant object is formed at the focal plane of the objective. The rays entering the eye are rendered parallel by the eye-piece. The eye sees the image at infinity

Where.

: the angle subtended by a distant object at the objective of a telescope is β

: the angle subtended by the virtual image at the eye is α ,

$$A. M. = \frac{\alpha}{\beta} \quad (\text{by definition})$$

For calculation, $A. M. = \frac{f_o}{f_e}$

For example,

if a telescope has an objective with a focal length of **60 cm** and an eyepiece of focal length **0.5 cm**, its angular magnification is **60/0.5**, or **120 times**. We say that the magnification is **120 X**.

Light Gathering Power :

- refers to its ability to collect light from an object
- Proportional to the area of the objective

Now, the area of a circular lens or mirror of diameter D is $\pi\left(\frac{D}{2}\right)^2$.

Thus, the ratio of light gathering powers of two telescopes is given by

$$\frac{LGP_1}{LGP_2} = \left(\frac{D_1}{D_2}\right)^2$$

For example,

a telescope of 100mm diameter can gather $(100/8)^2 = 156.25$ times more light than a human eye with a typical pupil diameter of 8 mm.

Resolving Power and Diffraction Limit :

- Resolving power determines the ability to reveal fine detail of an object
- whether we see the airy discs distinct or overlapping each other, depends on the resolving power
- two stars are said to be just resolved when we can just infer their images as two distinct Airy discs
- Rayleigh criterion is used to resolve the airy discs

Rayleigh criterion

Two equally bright stars are said to be resolved when the central maximum of one diffraction pattern coincides with the first minimum of the other.



Resolving a pair of two equally bright stars in :

(a) the stars are easily resolved

(b) the stars are just resolved

(c) too close and not resolved

The **diffraction limit of resolution (R)** of a telescope is defined as :

$$R \text{ (in radians)} = (1.22 \lambda / D)$$

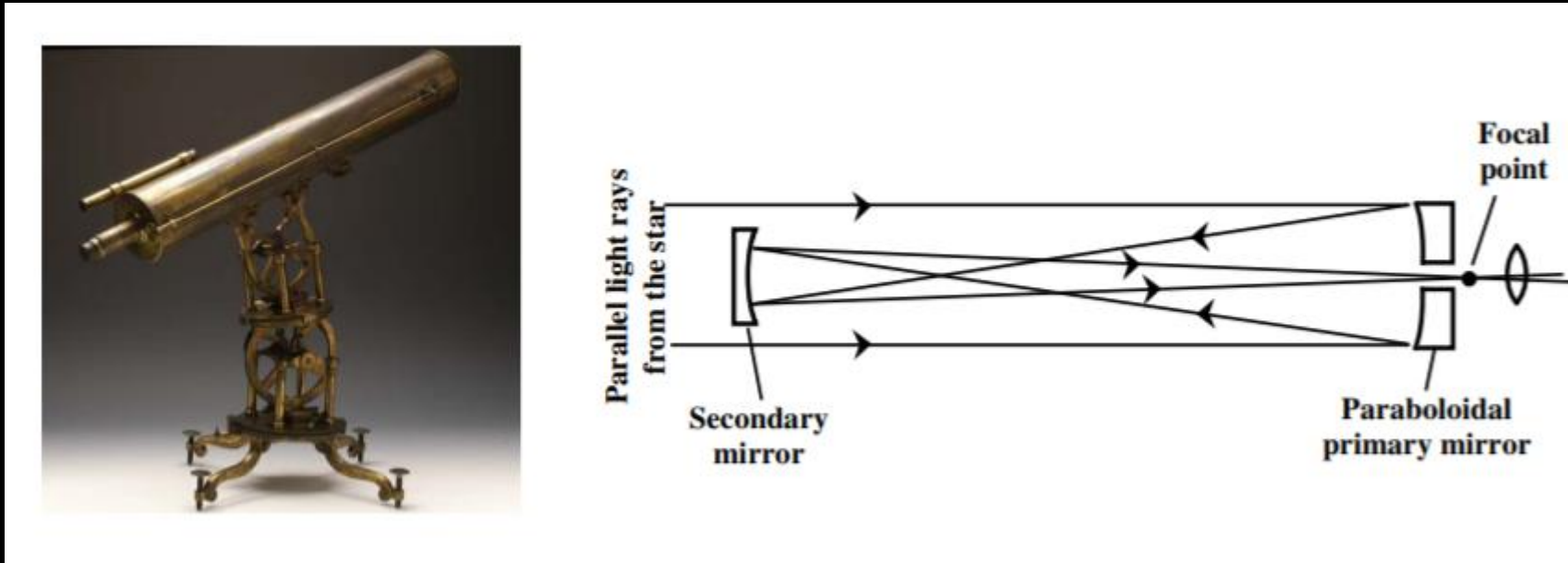
the smaller the value of R, the better is the instrument's ability to resolve nearby objects.

OPTICAL TELESCOPES :

- In today's time we use **reflecting telescopes**
- **Refracting telescopes** became outdated very soon because :
 - (i) it was difficult to make good large lenses required for large gathering area
 - (ii) large lenses were very heavy and balancing the telescope became difficult
 - (iii) lenses suffered from optical aberrations.

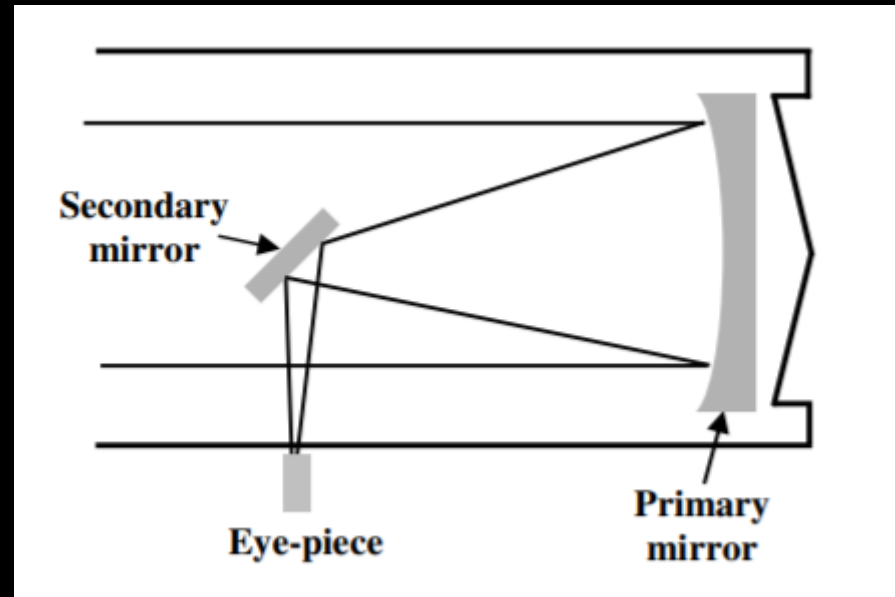
TYPES OF REFLECTING TELESCOPES :

James Gregory of Scotland (1638-75) proposed the first design for a **reflecting telescope** in which he used a **paraboloidal mirror** as the objective (primary mirror) to minimize chromatic and spherical aberrations.



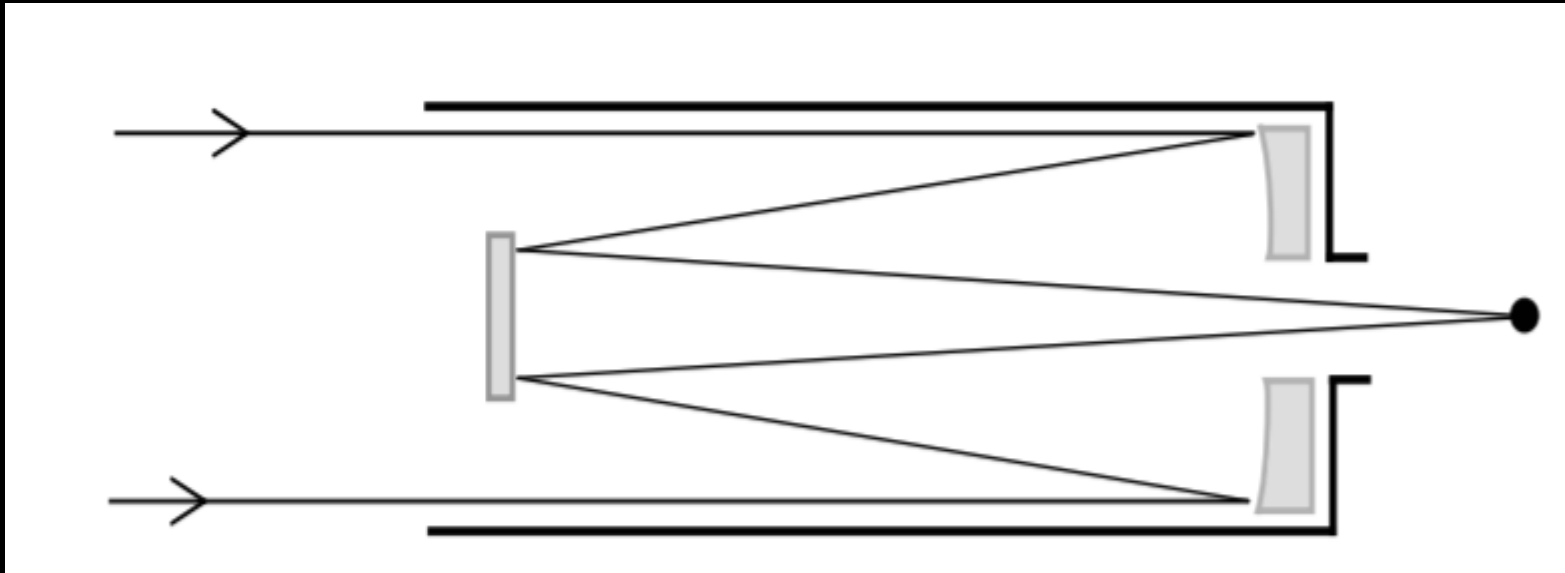
****Gregorian reflecting telescope with equatorial mounting; ray diagram for the telescope**

- Gregorian telescope was not satisfactory and **Newton** (1642- 1727) built a **working reflector**.
- Newtonian telescope uses a parabolic primary but a flat mirror as a secondary, which is set at 45° to the axis of the tube. The light is brought to a focus at the side of the telescope where the eyepiece is placed.



****Newtonian reflecting telescope**

Cassegrain reflecting telescope

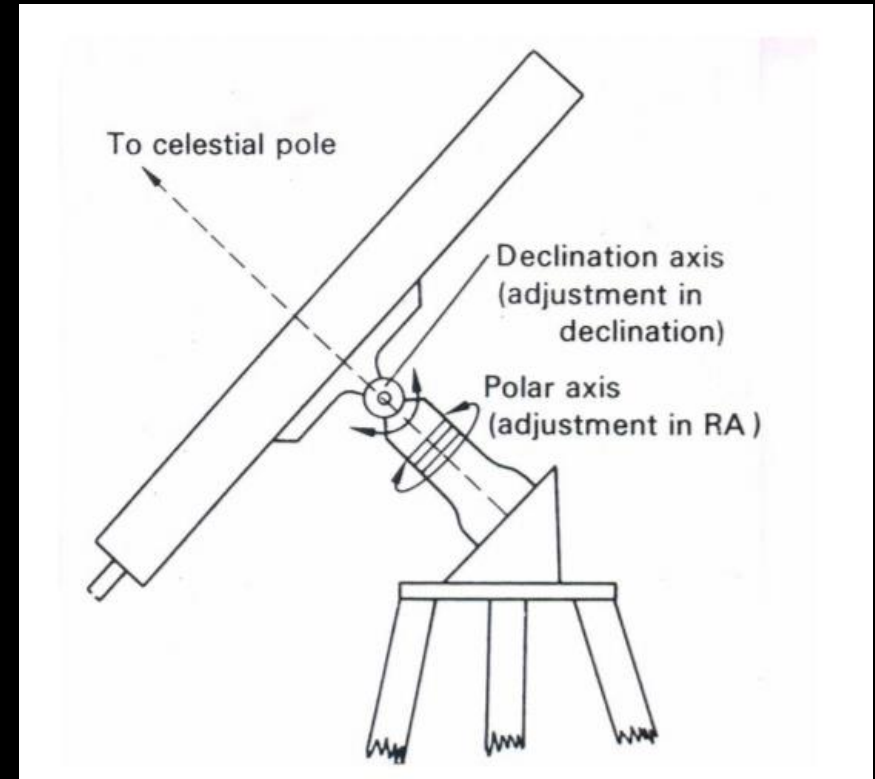


Now-a-days the most commonly used telescope is the Cassegrain type with a central hole in the primary mirror which allows the light to come out for placing an eyepiece or any other general detector or instruments.

Telescope Mountings :

(1) Equatorial mounting :

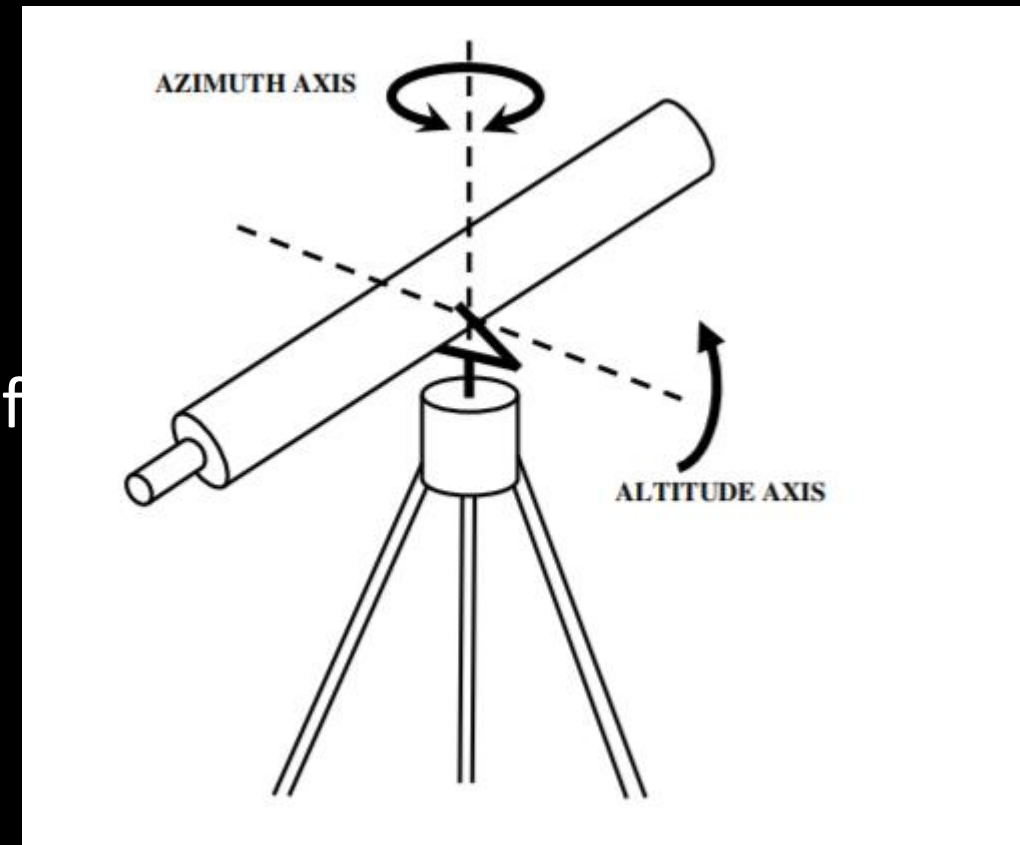
- Most of the small telescopes (less than 1 m) use the **equatorial mount**.
- Heavier than altitude-azimuth mounting
- Hence not used with very big telescopes



(2) Altitude-azimuth Mounting :

- All modern telescopes (larger than 2 m diameter) use **Alt-Azimuth type** mount.

Major limitation- **altitudes and azimuths** of objects **change** with the location of the observer and with time for the same Observer.



Space Telescopes :

- For light collection, one could fabricate telescopes of increasingly large diameters.
- But these will be limited by the effect of the **Earth's atmosphere**.
- So if we put a telescope in space, then the Earth's atmosphere would not be a limiting factor, and we could achieve diffraction-limited images.

- **THE “HUBBLE SPACE TELESCOPE”**



- The **active** and **adaptive** telescopes are the latest instruments in use today.
- In the **active telescopes**, the shape of the primary mirror can be changed according to the observer's need.
- In the **adaptive telescope** the changes in the shape of the primary mirror are done in a controlled manner depending upon the changes in the Earth's atmosphere during night.

DETECTORS AND THEIR USE WITH TELESCOPES

- Detectors are used for measuring the light output from a telescope and play a major role in obtaining information about the stars, galaxies, etc

Detectors are used with telescopes in the following two modes of operation:

- **Imaging:** This involves taking direct pictures of star fields and extended objects like gas clouds or galaxies.
- **Photometry:** This involves measuring total brightness, spectrum etc. of single objects

Types of Detectors :

- Detectors used in the imaging mode are mainly 2-dimensional (2D type) like - **photographic emulsion**, **human eye** and the most modern detector, the **charge-coupled device (CCD)**
- Detectors used for photometry of single objects are 1D type (one dimensional), since they receive photons from one object only. The **photometer** is a 1D detector.

Photometer :

- It is used more commonly for stars whose light output varies with time, called **variable stars**.
- most important component of a photometer is a **photomultiplier tube**.

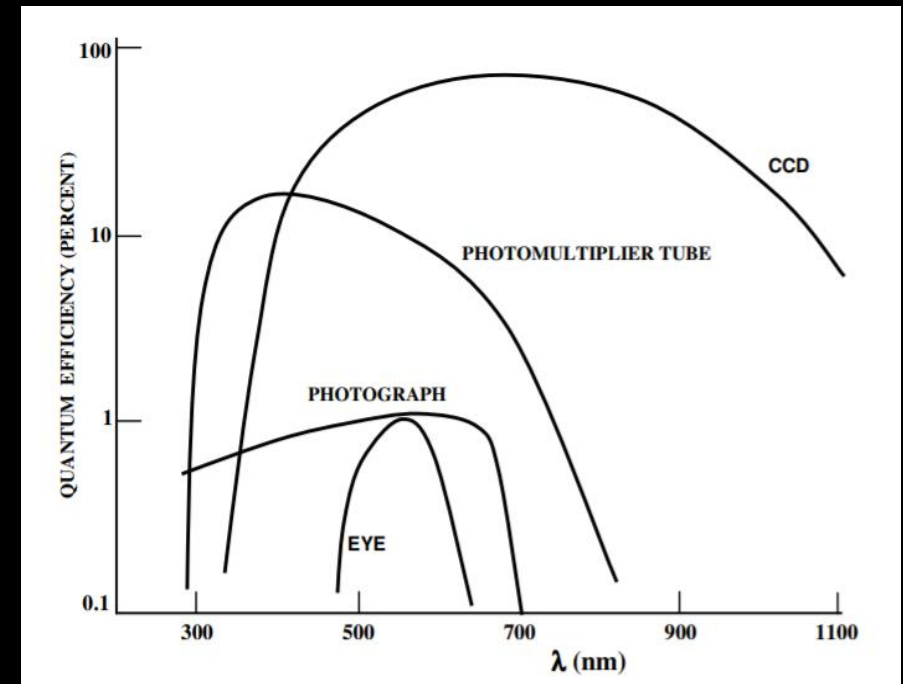
Charge-coupled device :

- contains a large number (~ millions) of microscopic light detectors arranged in an array.
- detect both bright and faint objects in a single exposure.
- brightness and colour can be measured to high precision.

Efficiency of a Detector :

- Defined on the basis of **Quantum Efficiency (Q.E)**
- **Quantum efficiency** is the ratio of number of photons actually detected (or recorded) by it to the number of photons recorded by an ideal and perfect detector

Quantum efficiency of various detectors in terms of wavelength of light



THANK YOU...