# Telescopes

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A brief introduction to the common types of telescopes and the ‘Magic Numbers’ that define their performance.

# The Three Magic Numbers
# Diameter – Focal Length – *f* Ratio

- There are really only two ! Given any two you can work out what the third is
- When working out the numbers you need to use the same units – we will use millimetres (mm)
  - Remember to convert inches to millimetres multiply by 25.4

# The Diameter - D

- This is just the diameter of the primary mirror in a reflecting telescope or the lens in a refracting telescope.
- The telescope tube will be a little larger than this

# The Focal Length - fl

- Light rays from distant stars are parallel, the primary mirror or the objective lens brings them to a focus – we will see a diagram later.
- The distance from the mirror or lens that the light comes to a focus is the Focal Length.

# Focal Ratio - *f*

- The Focal Ratio *f* is found by dividing the focal length fl by the Diameter D
  - $f = fl / D$
- Alternatively we often have the diameter and the Focal Ratio
  - $fl = f \times D$
    - E.g. the Kenley Telescope is an 457 mm *f* 4 the focal length is therefore 457 x 4 = 1828 mm

# Magnification

- The magnification depends on both the focal length of the telescope and the focal length of the eyepiece.
- The focal length of the eyepiece is normally marked on it
- The Magnification (M) is calculated by dividing the telescope focal length by the eyepiece focal length

# Fast & Slow Focal Ratios

- Telescopes with a low focal ratio are known as fast or rich field – they have short focal lengths & are compact
- Telescopes with a long focal length are known as slow – they have longer focal lengths and normally longer

# Magnification & Eyepieces

- To obtain a high magnification with a telescope with a short focal length we need an eyepiece with a short length
  - These have low eye relief
  - And are more expensive than a longer focal length.

# Brightness of the image

- The image brightness ( for visual observing) depends on the exit pupil
- This is calculate by dividing the Diameter, D by the Magnification M
  - The maximum brightness will be achieved when the exit pupil is equal to the eye's entry pupil = about 7 mm for our younger members !

# Amount of Light Captured

- The light captured is proportional to $D^2$ i.e. D x D
  - Thus a telescope twice as big will capture 4 times the light = 1.5 magnitudes
  - One 10 times the diameter will capture 100 times more light = 5 magnitudes

# Loss of light

- Remember light is lost at each reflection & when it passes through glass.
  - Modern glasses are quite good for losses
  - Aluminium is quite good in the visible
- The more surfaces / elements the dimmer the image
- Glass surfaces should be coated to reduce the light loss

# Visual Magnitude Limit

- The dimmest star that can be seen depends on both the telescope diameter as well as the magnification
  - = $M_0$ + 2.5 x log (D*10) + 2.5 x log (magnification)
  - Where $M_0$ is the magnitude of the dimmest star that can be seen with the naked eye.
  - It is nor clear if $M_0$ should be reduced when observing from a light polluted site !
- The calculations are automatically done by the spreadsheet I will show you shortly

# Maximum Exit Pupil

- For wide field views you may try using a lower magnification – if this results in an exit pupil much bigger than 8 mm and you are using a reflecting telescope you may find that you see the secondary as a dark area in the centre of the field of view

# Resolution

- The resolution of a telescope is limited by the wave nature of light
- Telescopes with a bigger diameter have a better resolving power
- The resolving power (in arc seconds) can be calculated by dividing 252 by D (mm)
  - However the atmosphere limits the resolution of telescopes to about 1 arc second therefore the maximum practical resolution is achieved by a 250 mm Diameter scope.

# Maximum useful Magnification

- We have already seen that the maximum resolution is determined by the diameter D
- The maximum useable resolution is equal to the Diameter D in mm.

# Field of View

- The field of view is determined by dividing the field of view of the eyepiece by the magnification

# Contrast

- The secondary reduces contrast in the image
  - For examining faint detail on a planet use a refractor
  - The smaller the secondary the less effect it has – Schmitt Cassegrains & Maksutovs are at a disadvantage here
  - The lack of diffraction spikes from the secondary support improves their performance

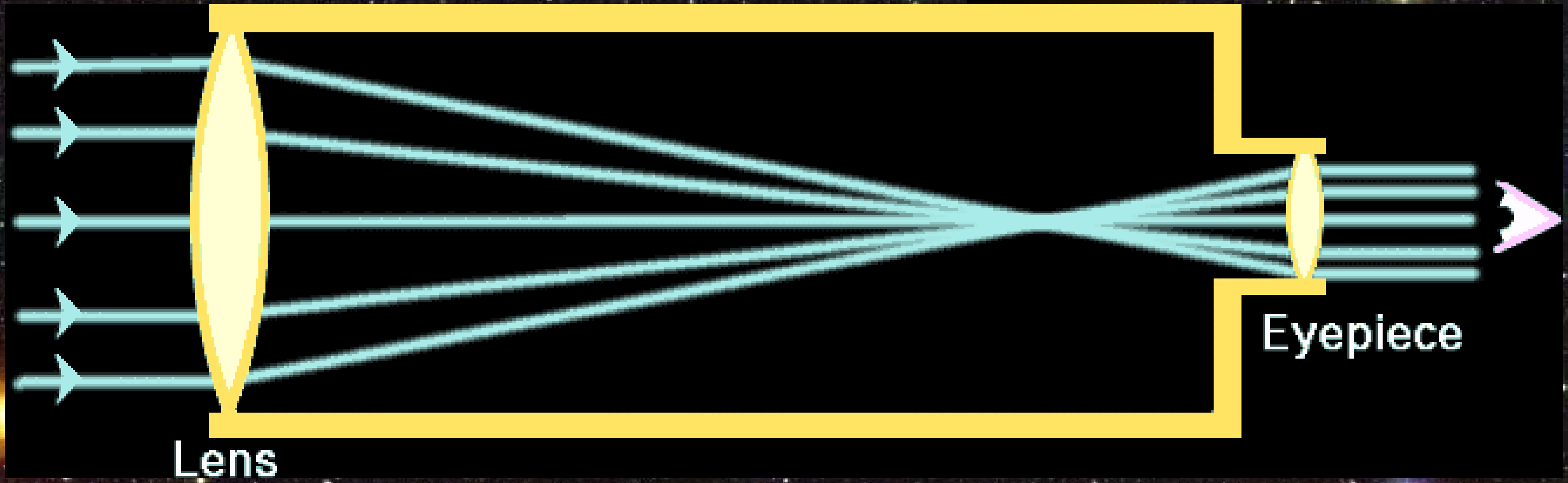
# Calculation Spreadsheet

- I have written a spreadsheet which calculates the details for a telescope
- It will be on the CAS web site for those who have Excel 97. Just download it and put the numbers in for your telescope
- It also does calculations for CDD's

# Types of Telescopes

These are only a summery of the main types – a complete list would take all night

# The Refracting Telescope



# The Newtonian Telescope

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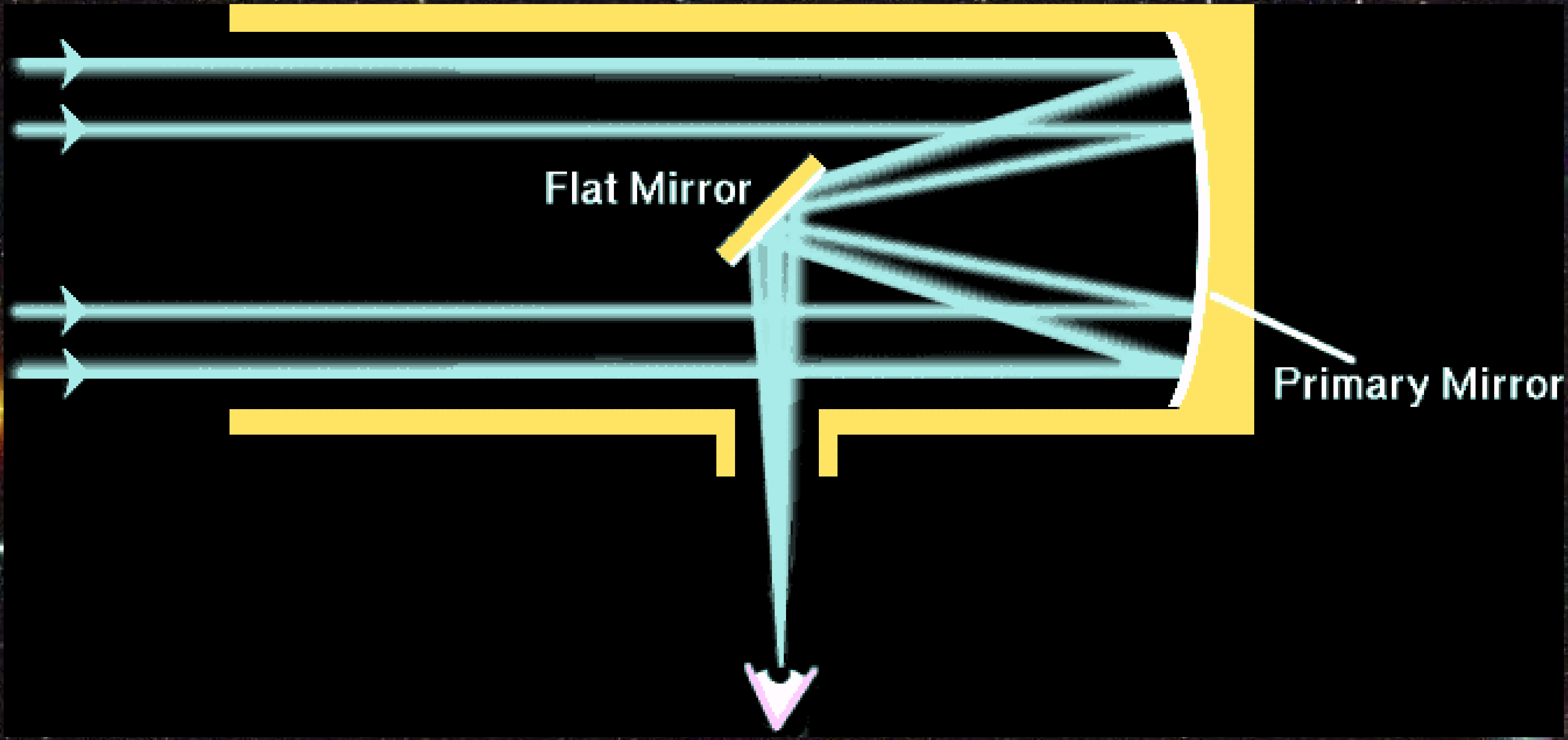
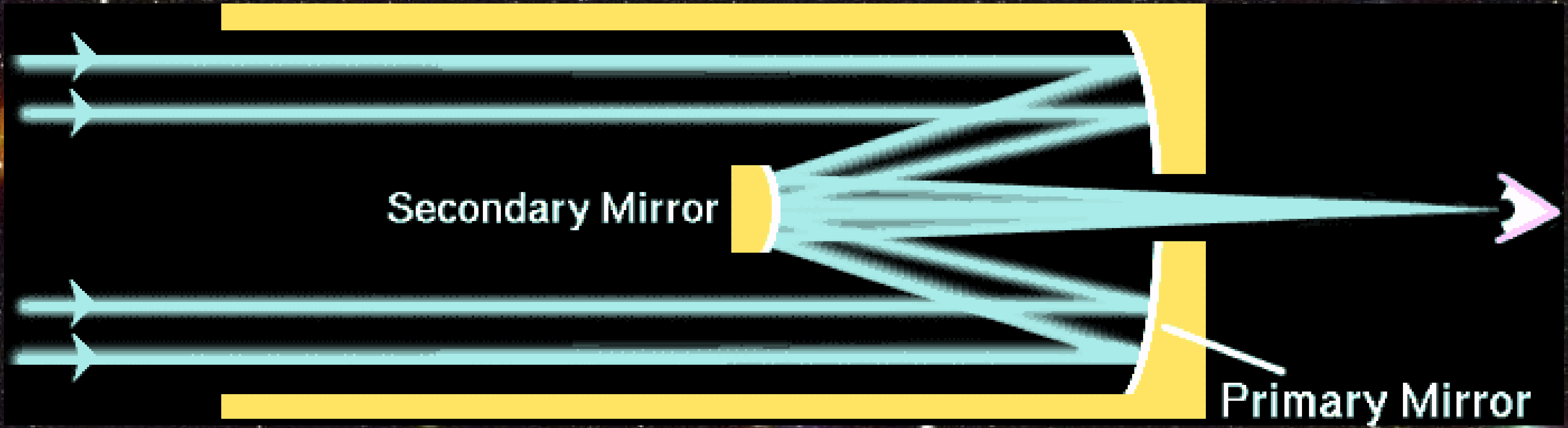


# The Cassegrain Telescope

The Schmitt – Cassegrain & the Maksutov are similar to this but they have a lens at the front that corrects for aberrations and supports the secondary mirror



# Conclusions

- The length of the telescope is determined by it's focal length
- Schmitt – Cassegrain & Maksutov telescopes are popular as the folded light path makes them shorter.