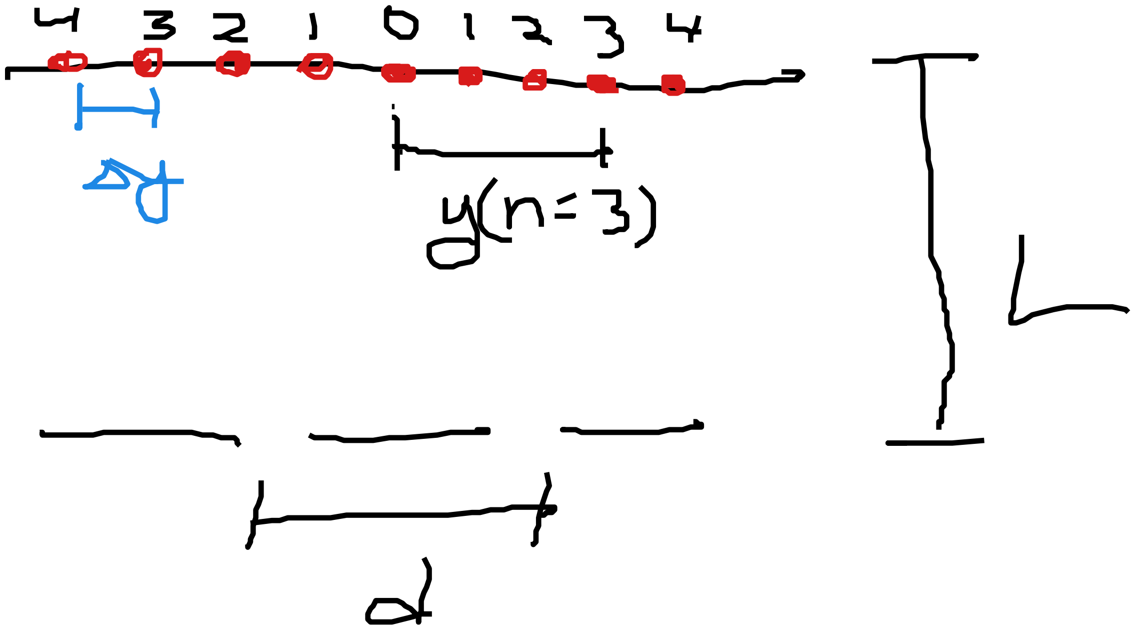
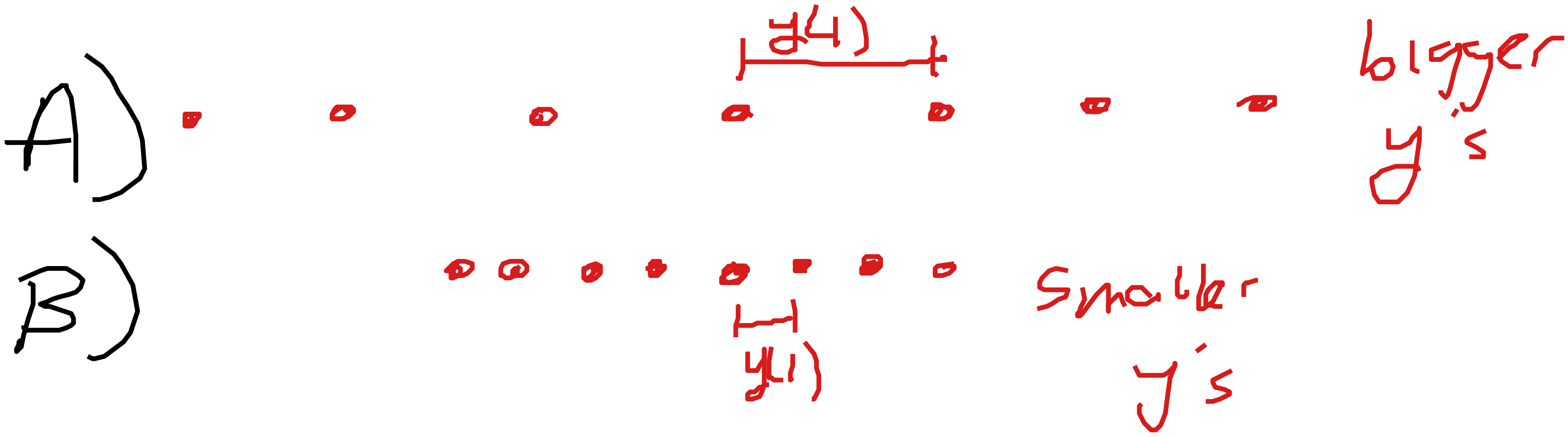


5λ

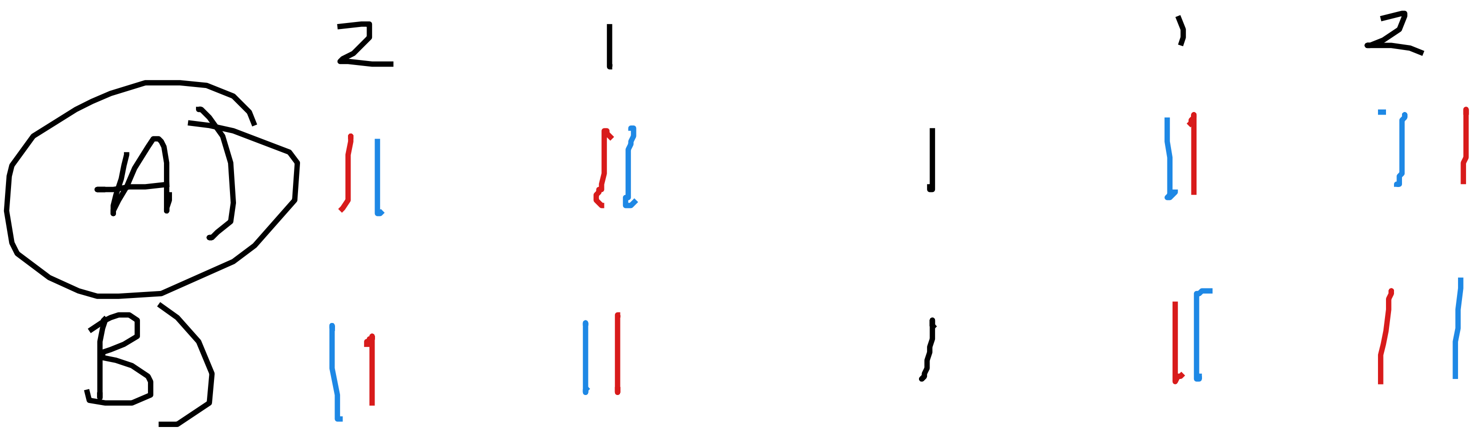
$$y(n) = \frac{n\lambda L}{d}$$

$$\Delta y = \frac{\lambda L}{d}$$



Diffraction Gratings

use the same formula



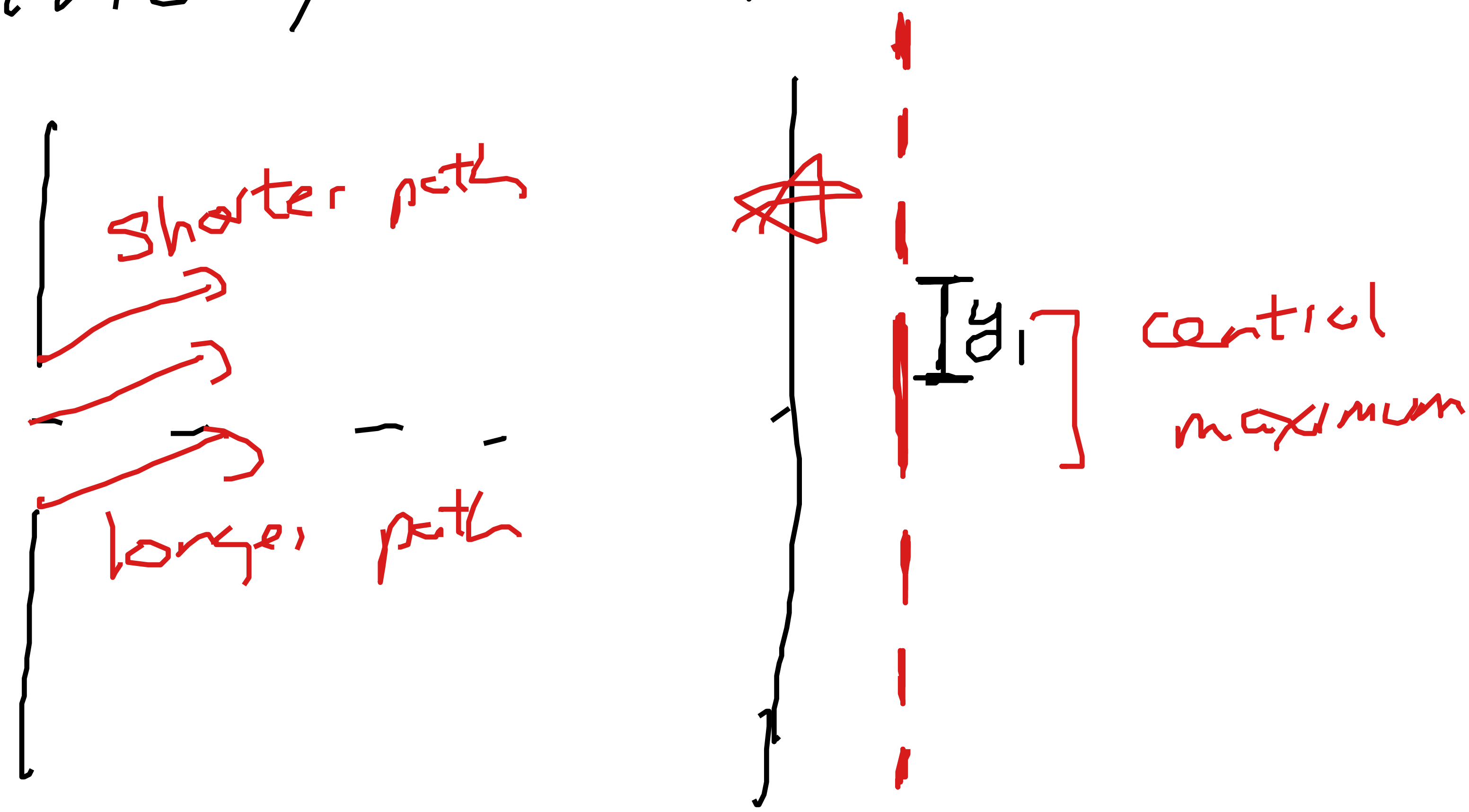
red: $\lambda = 650\,nm$

blue: $\lambda = 450\,nm$

Which is correct pattern?

Diffraction

- shine single λ light through a single thin slit



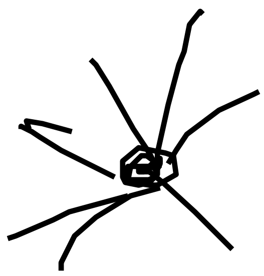
$$y_1 = \frac{\lambda L}{a}$$

width of central maximum: $\frac{2\lambda L}{a}$

smaller slit, wider central maximum

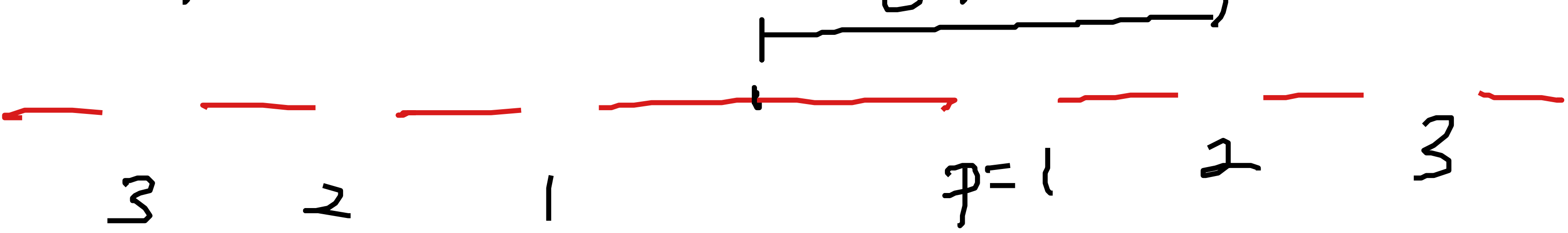
Diffraction can make small light sources look bigger

- our pupils act as small slits — diffraction pattern on our retina



as if our eyes have a minimum resolution (pixel size)

Diffraction Pattern

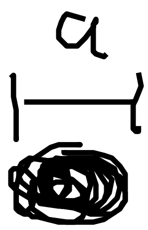


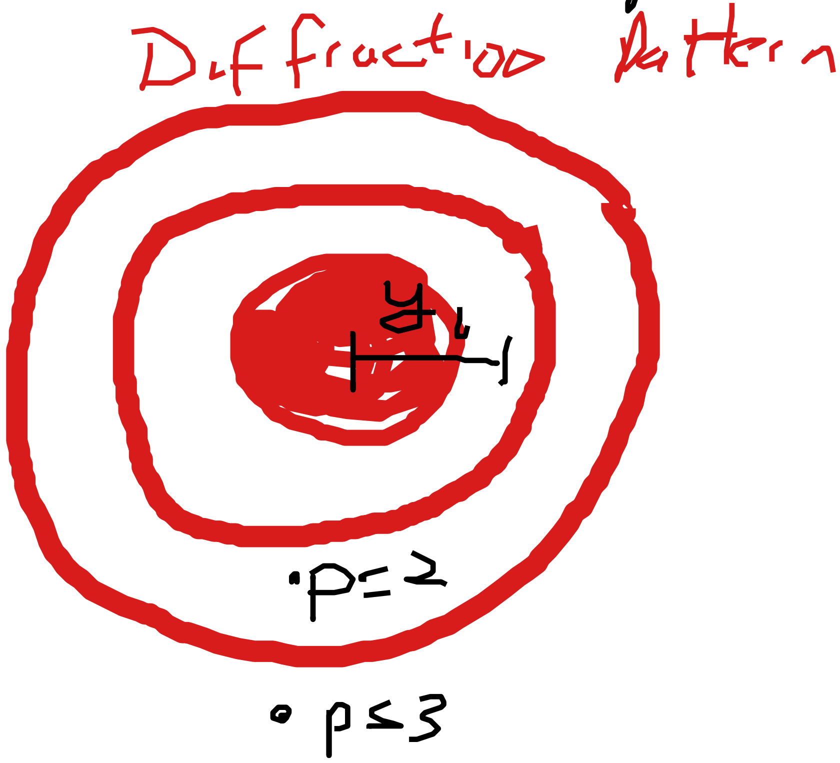
p : labels of <u>dark</u> spots

$$y(p) = \frac{\lambda L p}{a}$$

a : width of slit

For a circular aperture,

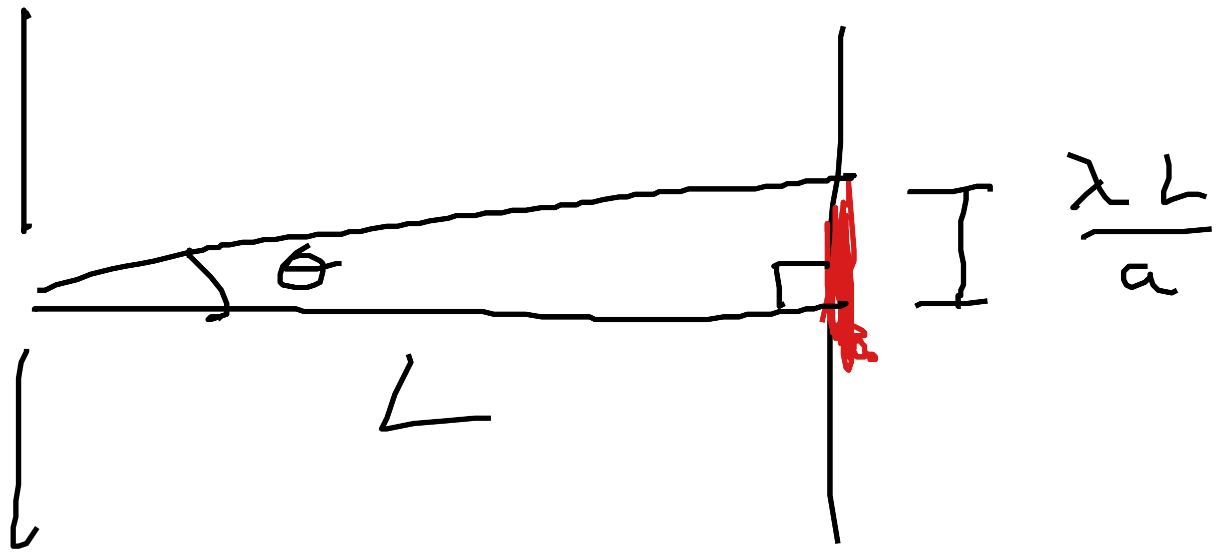




$$y_0(p) = 1.22\frac{\lambda L p}{a}$$

All light sources (eg stars) have a minimum radius of

$$1.22\frac{\lambda L}{a}$$



θ : angular half width of central maximum

$$\tan\theta = \frac{\lambda L / a}{L} = \frac{\lambda}{a}$$

if θ small ($<10^\circ$)

$\tan\theta \approx \theta$ in radians

$$\theta = \frac{\lambda}{a}$$

circular aperture

$$y(p) = 1.22 \frac{\lambda L}{a}$$

$$\theta(p) = 1.22 \frac{\lambda}{a}$$

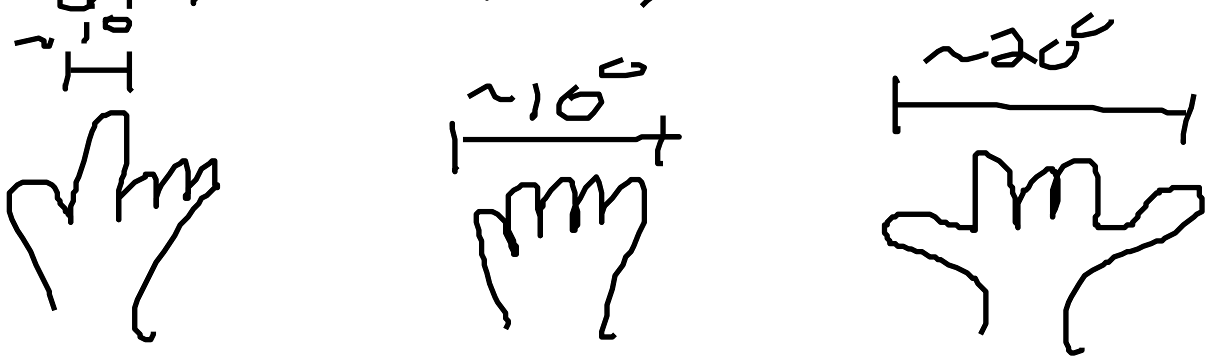
→ angle to the pth dark spot

width of central maximum

$$w = \frac{2.44 \lambda L}{a}$$

$$\rightarrow \theta = 2.44 \frac{\lambda}{a}$$

Hold your hand out at arm's length



Moon & Sun ~ $\frac{1}{2}°$ across

Two stars next to each other

$a = 6\,mm$ across (pupil at night)

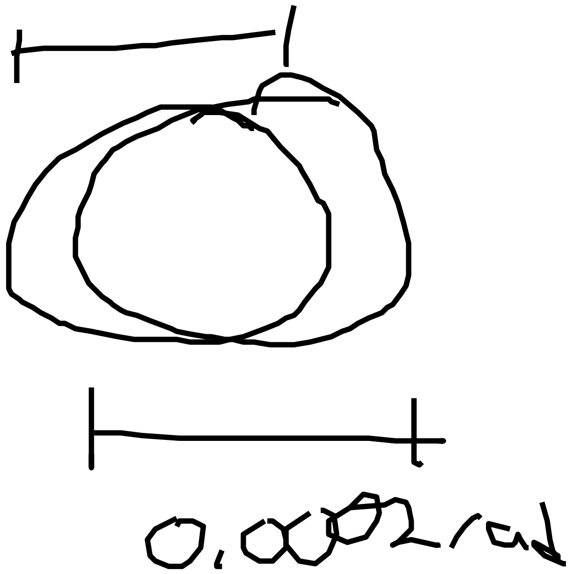
$\lambda = 500\,nm$

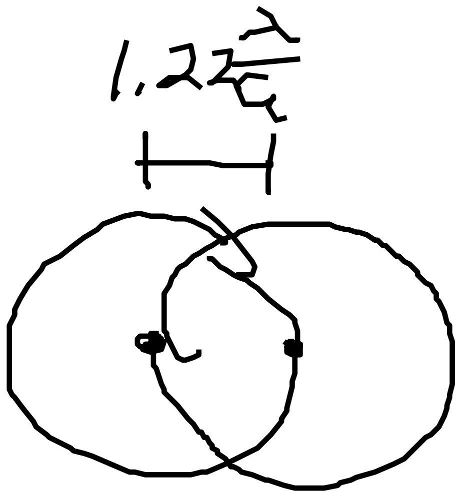
$$\theta_{width} = 2.44\frac{\lambda}{a} = 2.44\frac{500\times10^{-9}\,m}{6\times10^{-3}\,m}$$

of each star

$= 0.0002$ radians ($0.012°$)

if Stars are too close together they look like one star





Rayleigh criterion: if center of one central maximum is outside the central maximum of the other, then the lights can be distinguished.

$$\theta_{min} = 1.22\frac{\lambda}{a}$$

minimum angular separation between two sources to tell them apart

if two sources are same distance L away, then

$$S_{min} = 1.22\frac{\lambda L}{a}$$

is minimum distance apart

to read this E,

.2mm in 12 pt font ⟷ E ⟷ I need this distance > s_{min}

$$s_{min} = 1.22 \frac{(500nm) L}{3mm}$$ ← pupil size in day.

$$s_{min} = 0.0002 L$$

$$.2mm = 0.0002 L$$

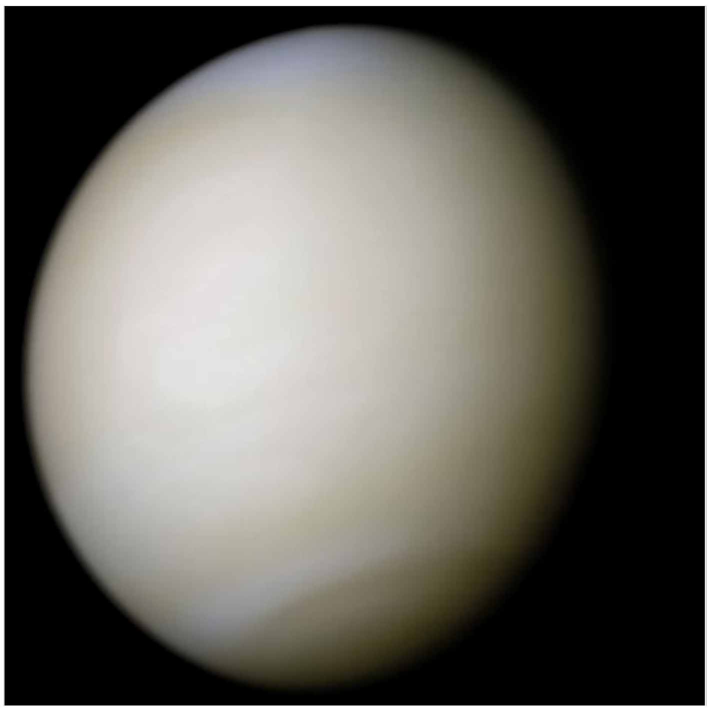
$$\rightarrow L = \frac{.2 \times 10^{-3}}{.0002} = 1m$$

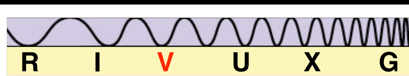
max distance

Why do we use radio telescopes?

Venus

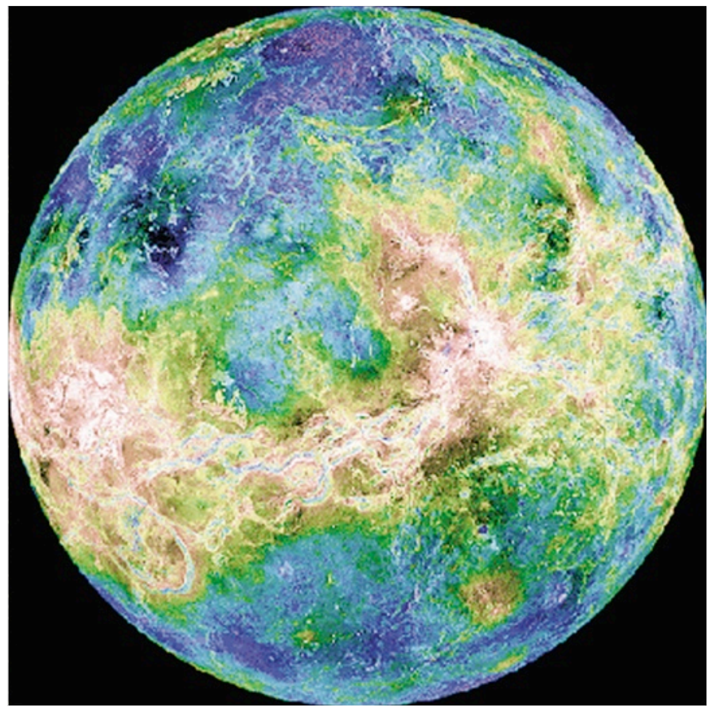
seen in visible light

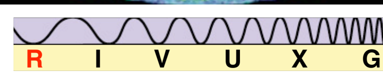




visible light is smaller than cloud droplets, so can't get through

seen in radio frequencies (false color image)



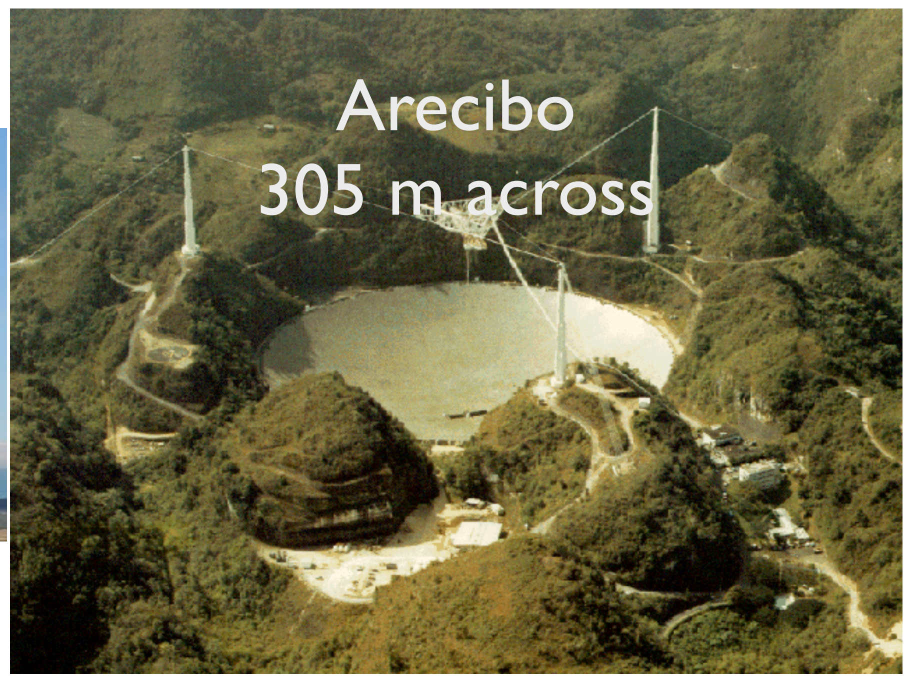


radio waves are bigger than droplets, so they pass through

Radio waves have large wavelengths, so they can only see large details

$$\text{Resolution} \approx 1.22 \, \frac{\text{wavelength}}{\text{aperture}} \times \text{distance}$$

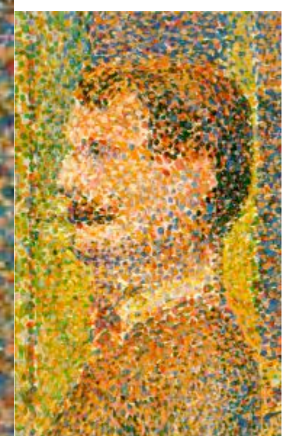
To compensate for this, radio telescopes have larger apertures



The smaller the resolution, the more detail can be seen.

What is this?





Detail from
Parade de Cirque
Georges Seurat

Diffraction can be a good thing!