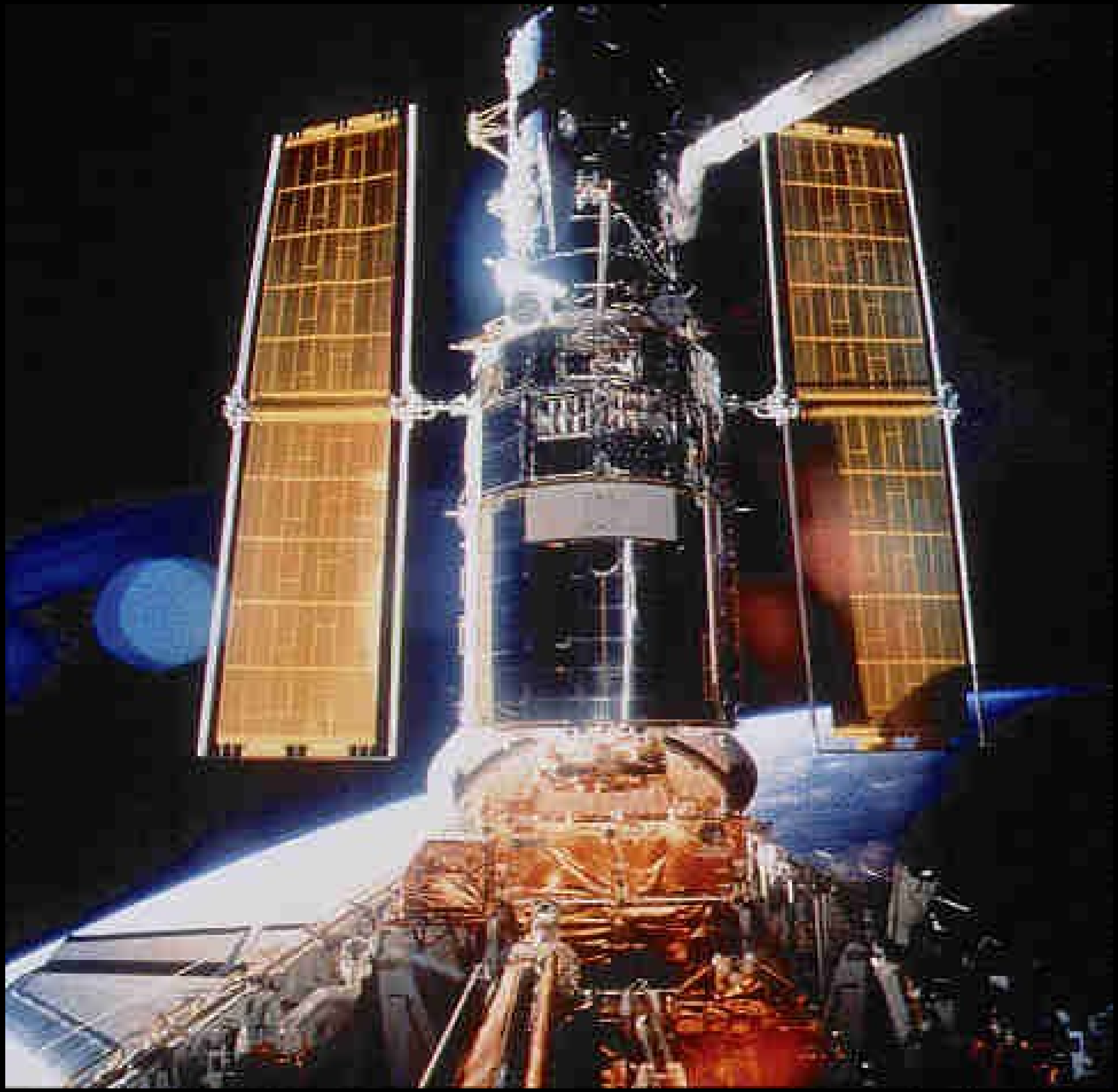
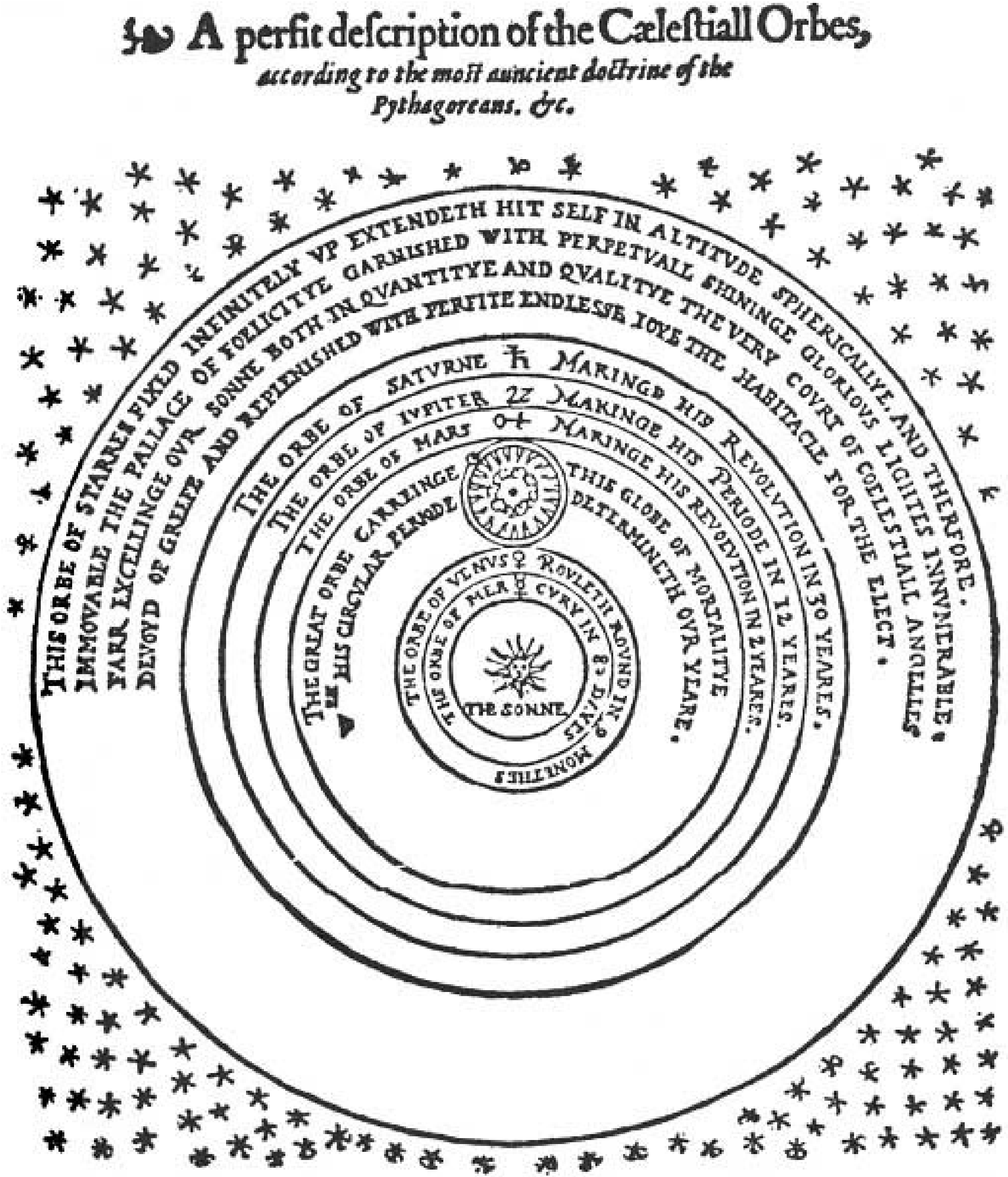
Cosmology

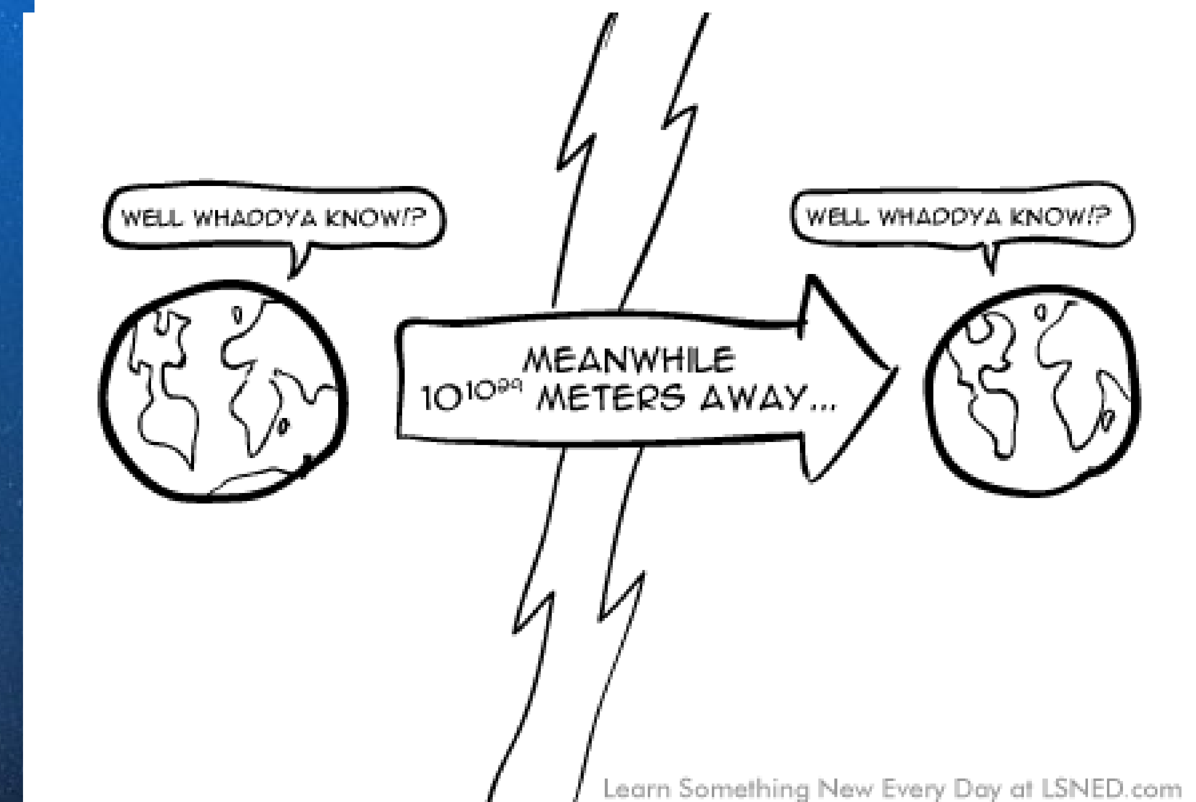


Newton's model

- According to Newton, the universe was:
- Infinite (in time and space)
- Uniform (same everywhere)
- Static (not moving)




3.14159265 km


WELL WHADDYA KNOW!?
MEANWHILE
$10^{10^{29}}$ METERS AWAY...
WELL WHADDYA KNOW!?
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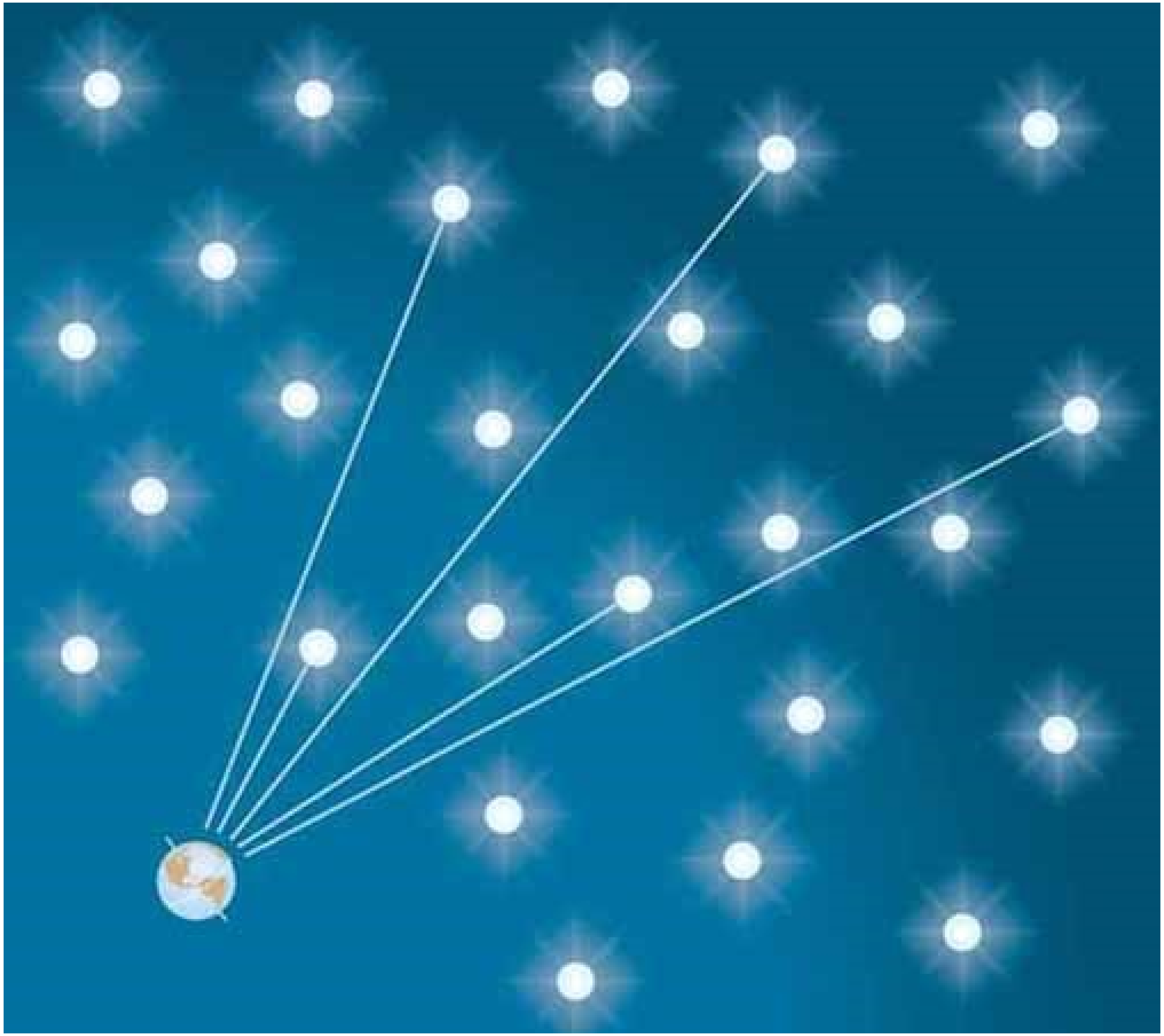
Why is the night sky dark?



Olber's paradox

- If the universe is infinite in size, there must be an infinite number of stars
- Every line of sight should terminate in the surface of a star. Sunglasses anyone?
- We can resolve this in two ways:
- The universe has a finite age, therefore light from distant stars hasn't reached us yet
- The universe is expanding, stretching radiation into the infrared.

Hubble

- Using the biggest telescope in the world, Edwin Hubble discovered some “nebulae” were actually “island universes” or what we now call galaxies

Hubble activity

- Use the data on my website to graph recession velocity vs. distance
- Use the slope of the graph to find the age of the universe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Three main types of galaxies:

- Elliptical
- Spiral
- Irregular

Elliptical Galaxies

- These have a round or slightly elliptical shape
- They tend to be red in color

Spiral Galaxies

- Their rotation helps us understand their spiral arms and mass distribution

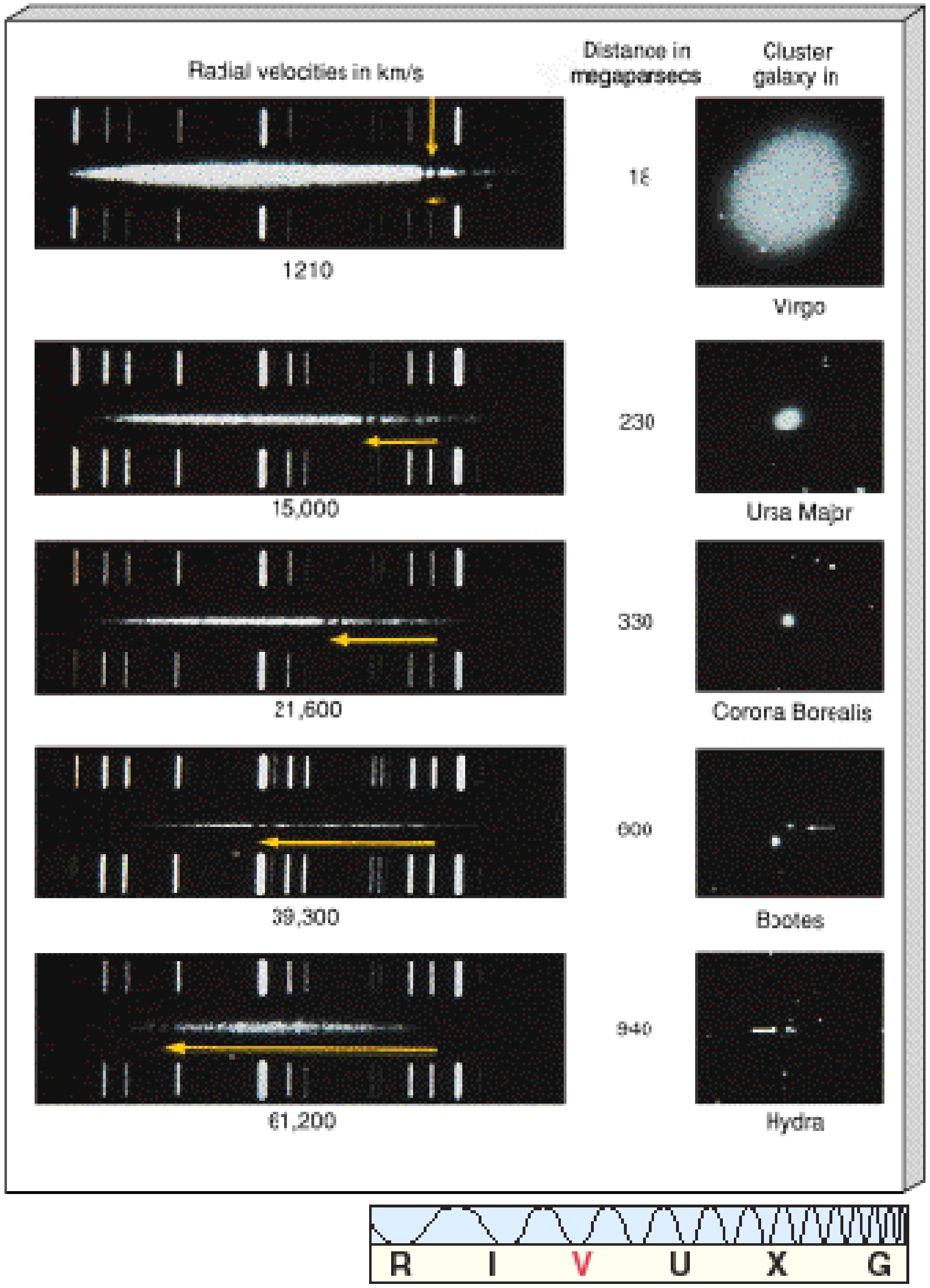
- They can be classified by their "tightness" and bars

Irregular Galaxies:

- These form when two galaxies collide

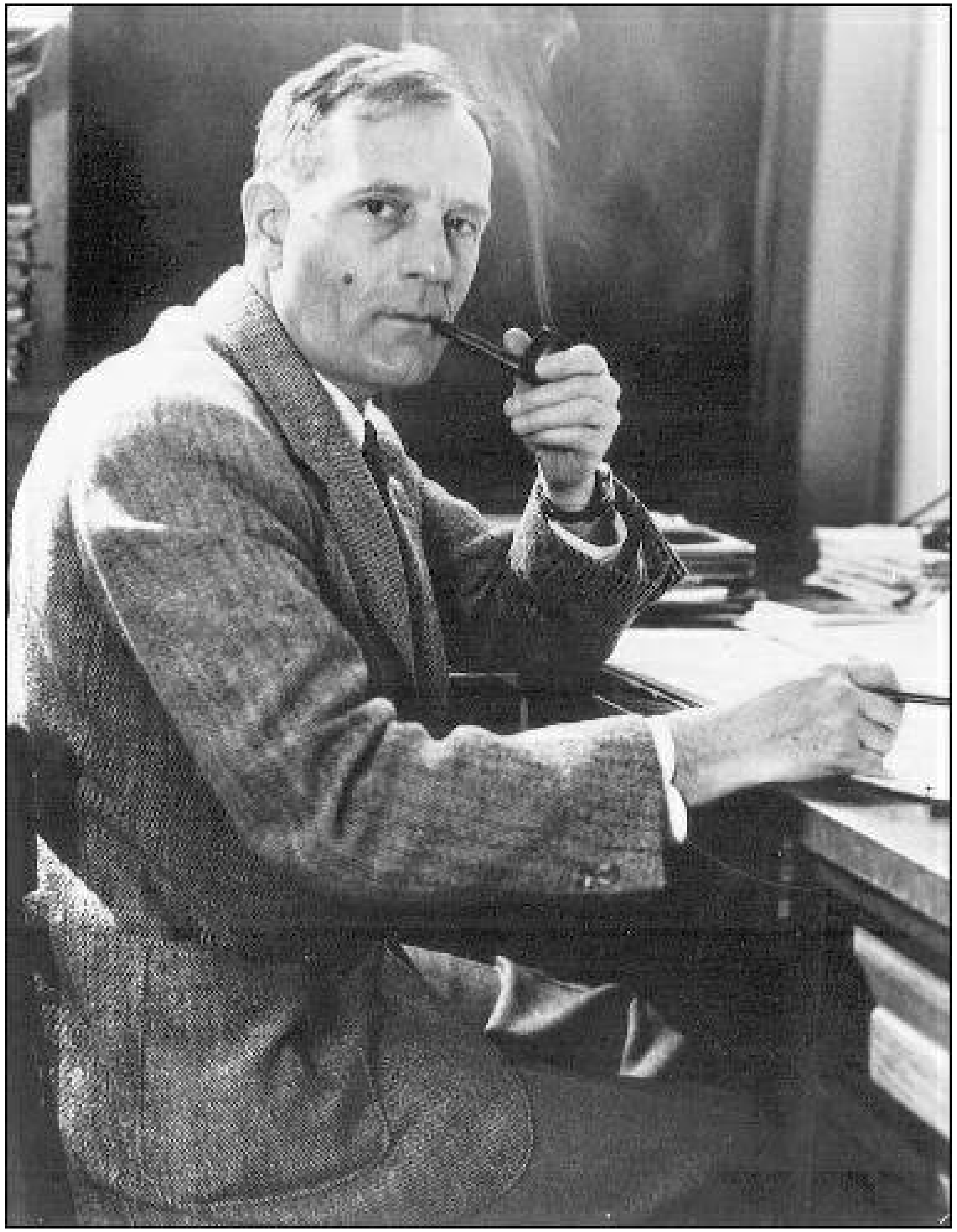
The Doppler Effect

- All distant galaxies were observed to be moving away from us
- The further the galaxy, the larger the redshift



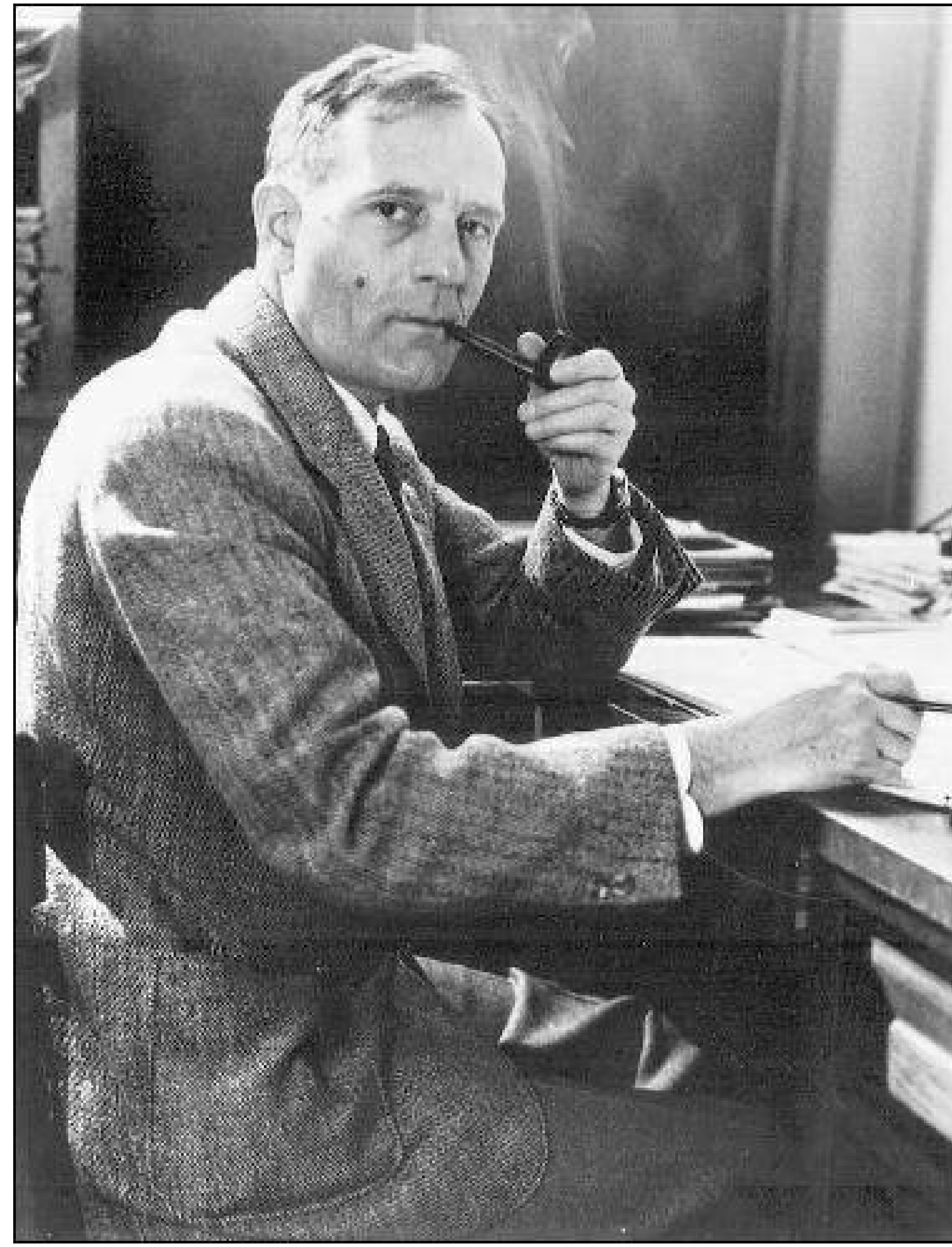
Inflation!

- Hubble then realized the universe must be expanding to account for this "cosmological redshift"



Hubble's law

- Use the data on my website to graph distance vs speed




• Astronomers now believe the universe will not only continue but accelerate!

Redshift z

Ex: Find the recessional velocity of a galaxy if a 440 nm spectral line is redshifted by 23 nm. Redshift z is given by:

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

$$z = \frac{23}{440} = 0.0523$$

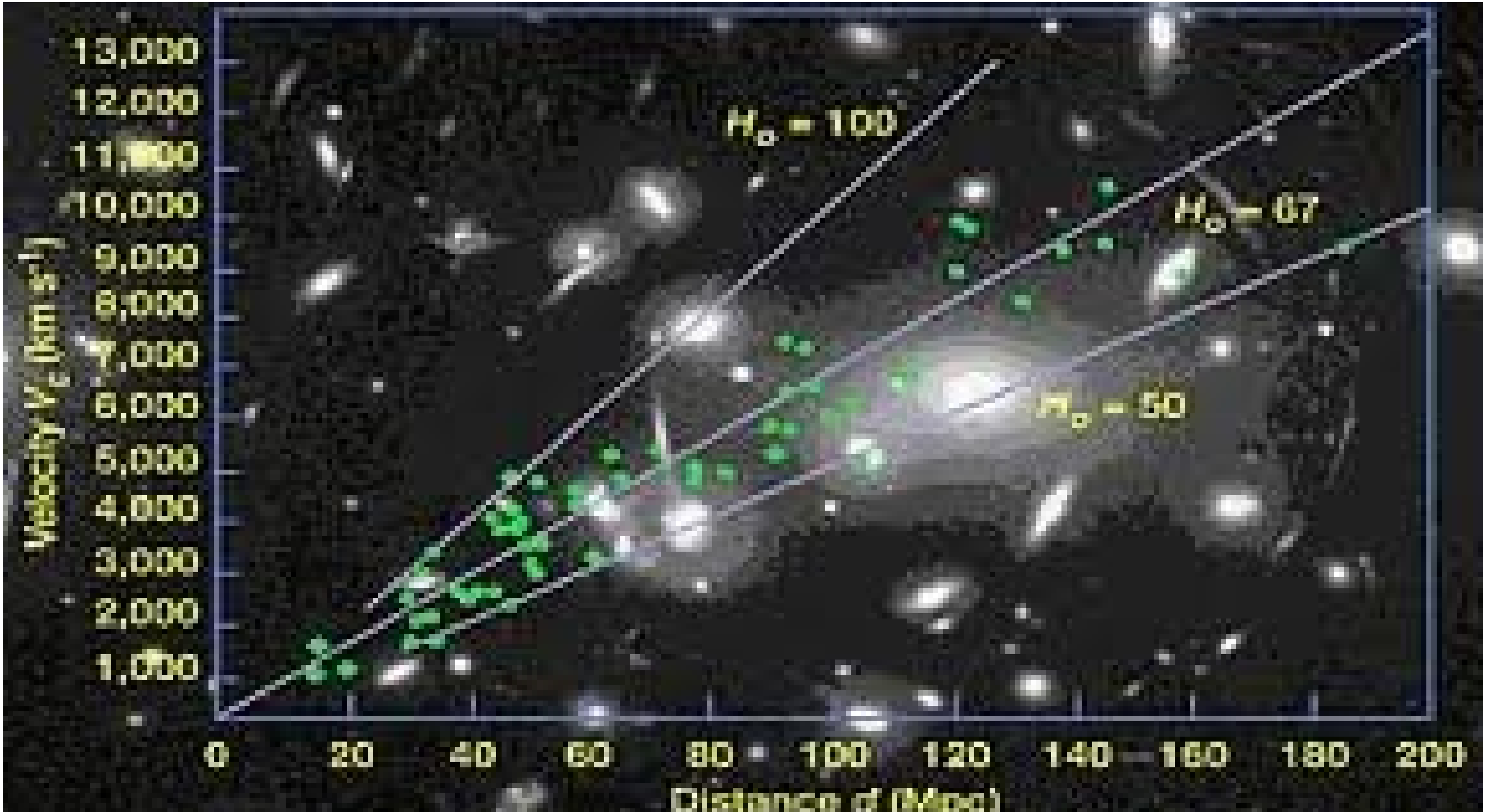
$$v = 0.0523c = 1.6 \times 10^{7} \, m \cdot s^{-1}$$

Hubble's Law

- If we know the redshift of receding galaxies and how far they are away, we can calculate the…
  - Hubble constant!!!
  - Hubble's law tells us the further a galaxy is, the faster it is receding from us:
  - $v=H_0d$

$$H_0 = 71 \frac{km/s}{mpc} = 2.3x10^{-18} s^{-1}$$

$$t_H = \frac{1}{2.3x10^{-18} s^{-1}} = 13.8x10^9 \, years$$

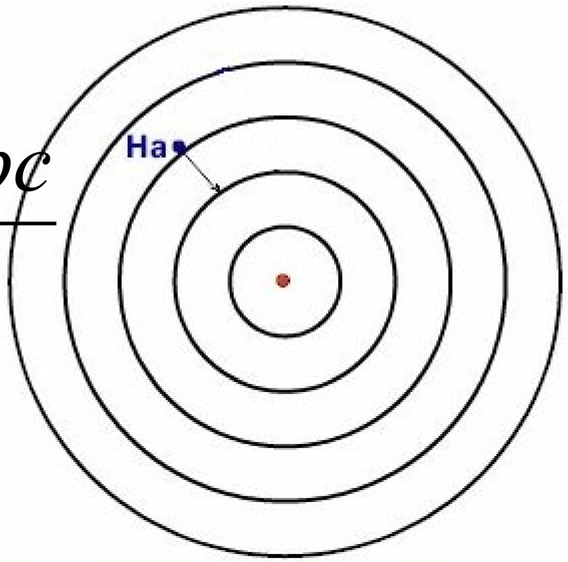


Redshift example

Ex: What wavelength would we expect to observe for the H-alpha Balmer emission line from a galaxy 11 billion light years away (use H=71km·s^{-1}·Mpc^{-1})?

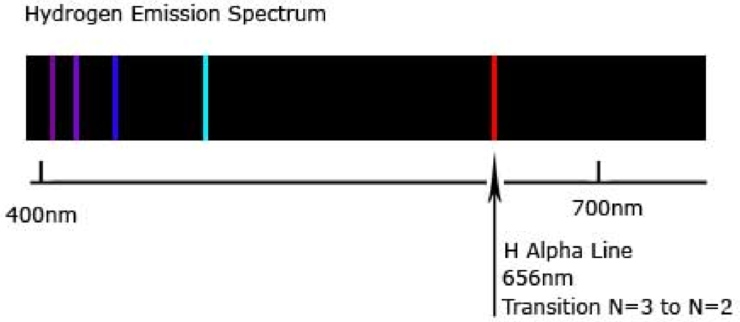
$$v = H_0 d$$

$$\frac{\Delta\lambda}{\lambda} = \frac{71000 m \cdot s^{-1} \cdot Mpc \cdot 3374 Mpc}{3 \cdot 10^8 m \cdot s^{-1}}$$



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

$$\Delta\lambda = 0.798 \cdot 656.3 nm$$



$$\Delta\lambda = 524 nm$$

$$\frac{\Delta\lambda}{\lambda} = \frac{H_0 d}{c}$$

$$\lambda = 524 + 656 = 1180 nm$$

Cosmic Scale Factor R

As the universe expands, scale factor R increases. This provides an alternate explanation to doppler.

Ex: The peak wavelength of the CMB radiation at present is about 1 mm. In the past there was a time when the peak wavelength corresponded to blue light (400 nm). Estimate the scale factor ratio.

$$z = \frac{\Delta\lambda}{\lambda_0} = \frac{R}{R_0} - 1$$

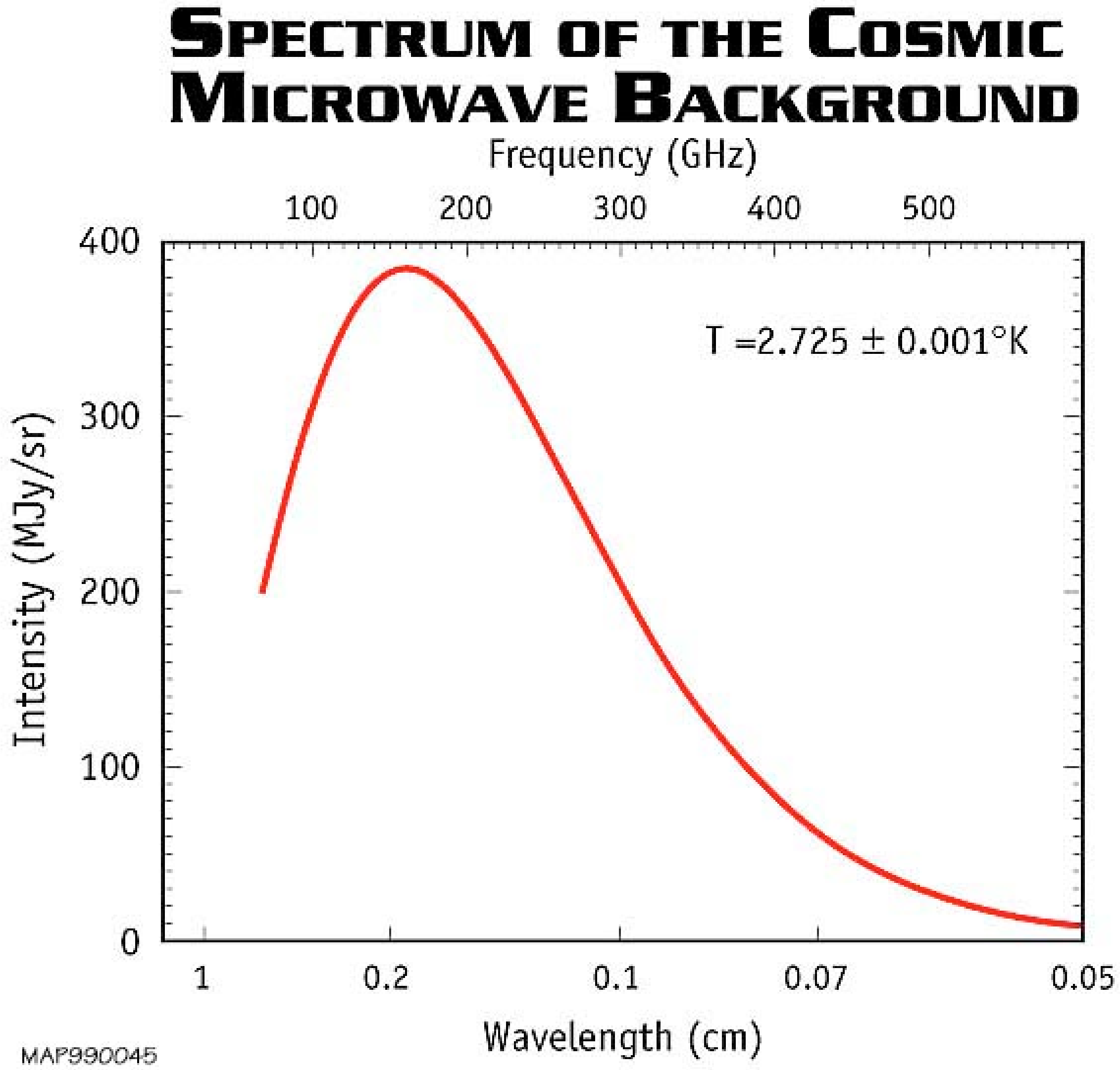
Ex: The peak wavelength of the CMB radiation at present is about 1 mm. In the past there was a time when the peak wavelength corresponded to blue light (400 nm). Estimate the scale factor ratio.

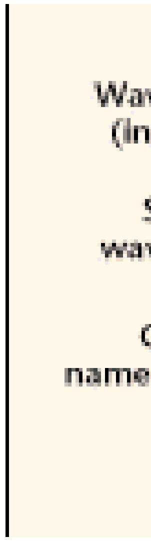
$$z = \frac{\Delta\lambda}{\lambda_0} = \frac{R}{R_0} - 1$$

$$\frac{R}{R_0} = \frac{\Delta\lambda}{\lambda_0} + 1 = \frac{10^{-3} - 400\times10^{-9}}{400\times10^{-9}} + 1 = 2500$$

CMBR

- Ex: show that 2.7K blackbody radiation corresponds to microwave EM radiation





$$\lambda_{\max} T = 2.9\times10^{-3} mK$$

$$\lambda_{\max} = \frac{2.9\times10^{-3} mK}{2.725K} = 1.1mm$$

Questions

- Work on option D questions from my website