

The Scale of Astrophysics

IB PHYSICS | ASTROPHYSICS

IB Physics Data Booklet

Sub-topic D.1 – Stellar quantities	Sub-topic D.2 – Stellar characteristics and stellar evolution
$d \text{ (parsec)} = \frac{1}{p \text{ (arc-second)}}$ $L = \sigma AT^4$ $b = \frac{L}{4\pi d^2}$	$\lambda_{\text{max}} T = 2.9 \times 10^{-3} \text{ m K}$ $L \propto M^{3.5}$
Sub-topic D.3 – Cosmology	Sub-topic D.5 – Further cosmology (HL only)
$z = \frac{\Delta\lambda}{\lambda_0} \approx \frac{v}{c}$ $z = \frac{R}{R_0} - 1$ $v = H_0 d$ $T \approx \frac{1}{H_0}$	$v = \sqrt{\frac{4\pi G\rho}{3}} r$ $\rho_c = \frac{3H^2}{8\pi G}$

Anything look familiar?

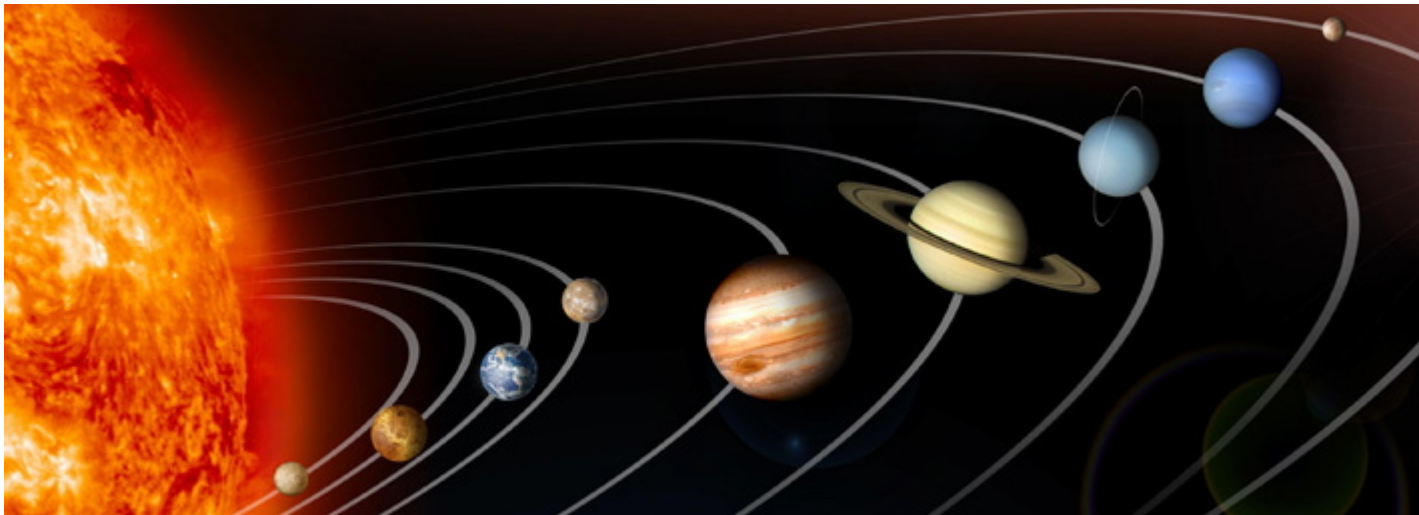
It's a Great Big Universe...



Animaniacs - Yakko's Universe

The Solar System

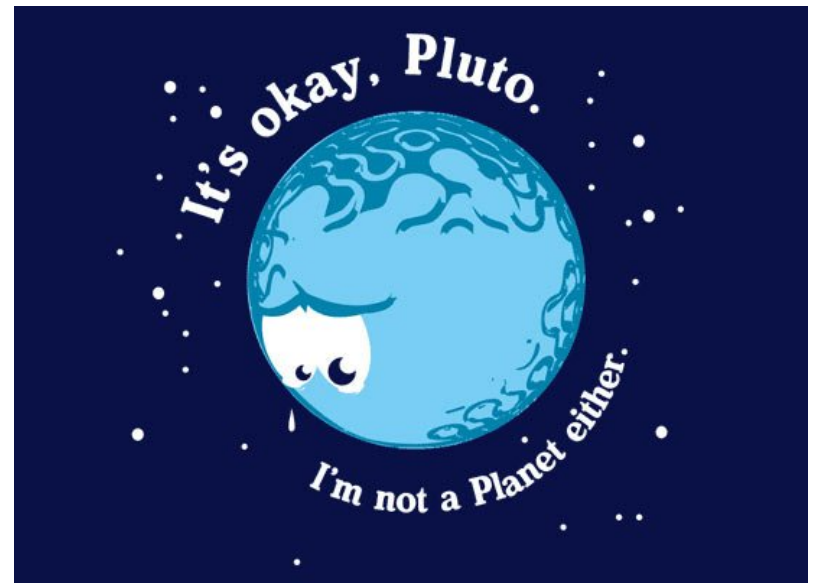
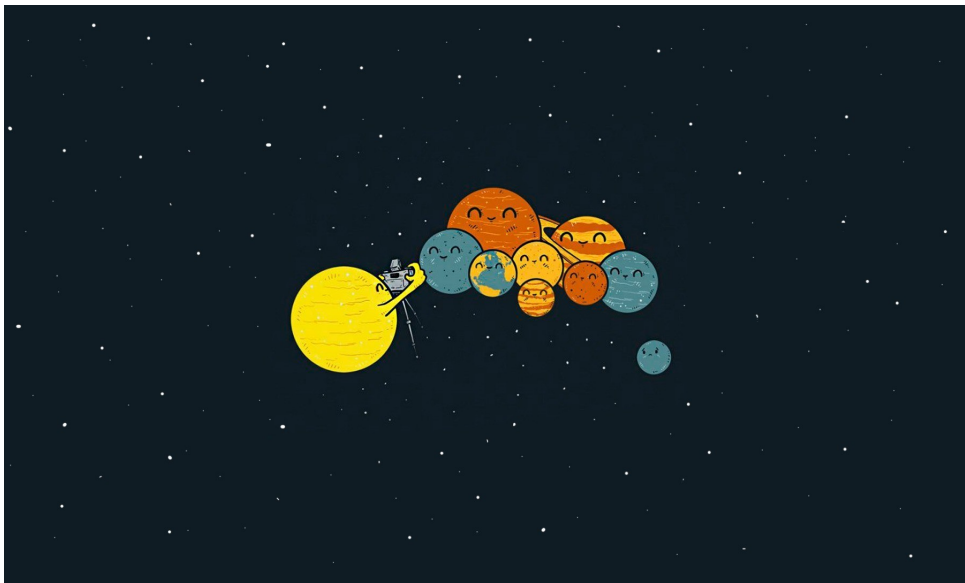
	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Diameter [km]	4,880	12,104	12,756	6,787	142,800	120,000	51,800	49,500
Distance to Sun [$\times 10^8$ m]	58	107.5	149.6	228	778	1,427	2,870	4,497



Poor Pluto... :'(

Definition of a Planet (as of 2006)

A celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighbourhood around its orbit.



Measuring Distances

Speed of Light: $c =$

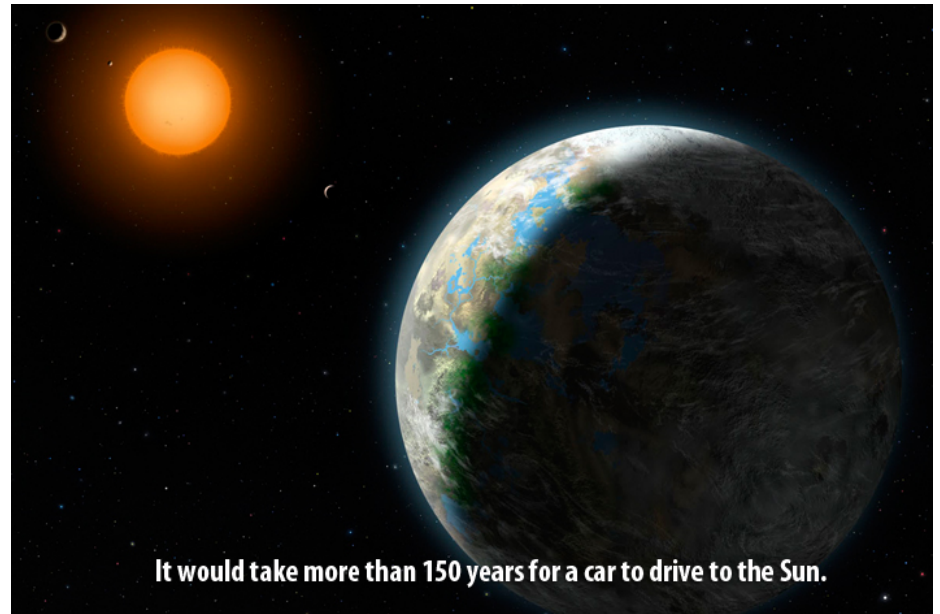
How far is one light year (ly)



Measuring Distances

Average Distance between
the Earth and the Sun

$$1.5 \times 10^{11} \text{ m}$$



Measuring Distances

1 light year (ly) = 9.46×10^{15} m

The distance that light travels in an earth year

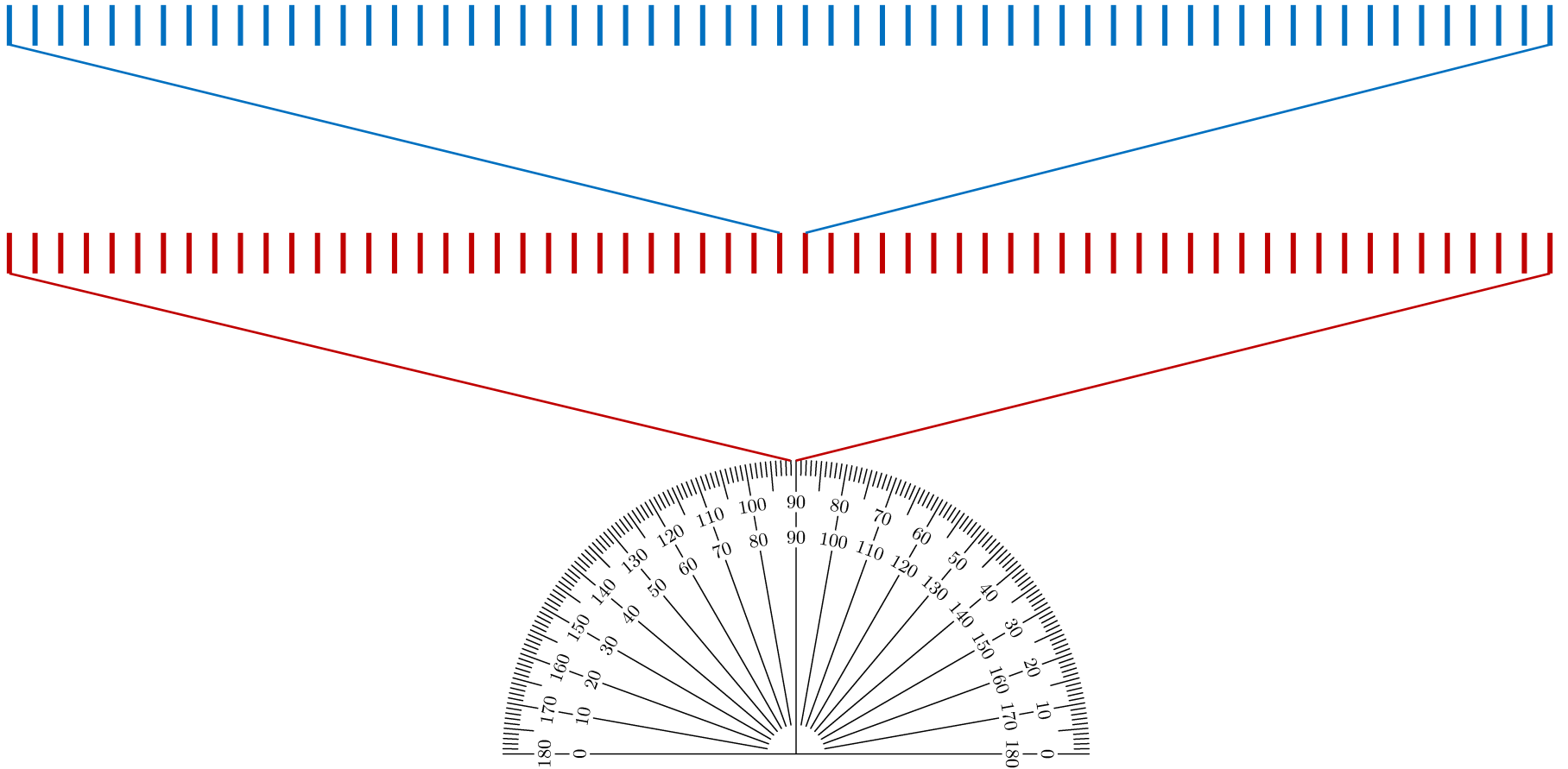


1 astronomical unit (AU) = 1.50×10^{11} m

The average distance between the earth and the sun



Measuring Angles

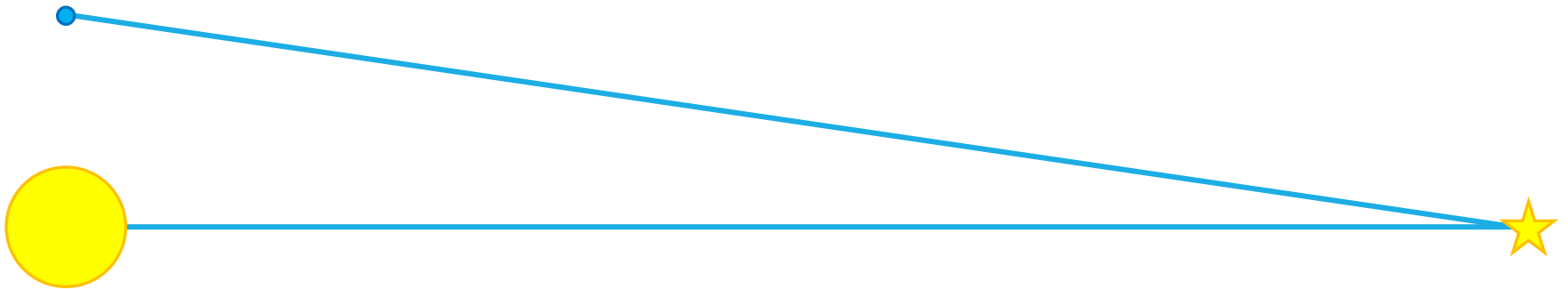


Parsecs

1 parsec (pc) = 3.26 ly

distance at which the mean radius of the earth's orbit subtends an angle of one second of arc.

parsec stands for parallax angle of one second



Parsecs

Why is this claim a little odd?



“It's the ship that made the Kessel run in less than 12 Parsecs.”

IB Physics Data Booklet

Unit conversions

$$1 \text{ radian (rad)} \equiv \frac{180^\circ}{\pi}$$

$$\text{Temperature (K)} = \text{temperature (}^\circ\text{C)} + 273$$

$$1 \text{ light year (ly)} = 9.46 \times 10^{15} \text{ m}$$

$$1 \text{ parsec (pc)} = 3.26 \text{ ly}$$

$$1 \text{ astronomical unit (AU)} = 1.50 \times 10^{11} \text{ m}$$

$$1 \text{ kilowatt-hour (kWh)} = 3.60 \times 10^6 \text{ J}$$

$$hc = 1.99 \times 10^{-25} \text{ J m} = 1.24 \times 10^{-6} \text{ eV m}$$

Stefan-Boltzmann constant

$$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$$

Coulomb constant

$$k = 8.99 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

Permittivity of free space

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

Permeability of free space

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

Speed of light in vacuum

$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

Planck's constant

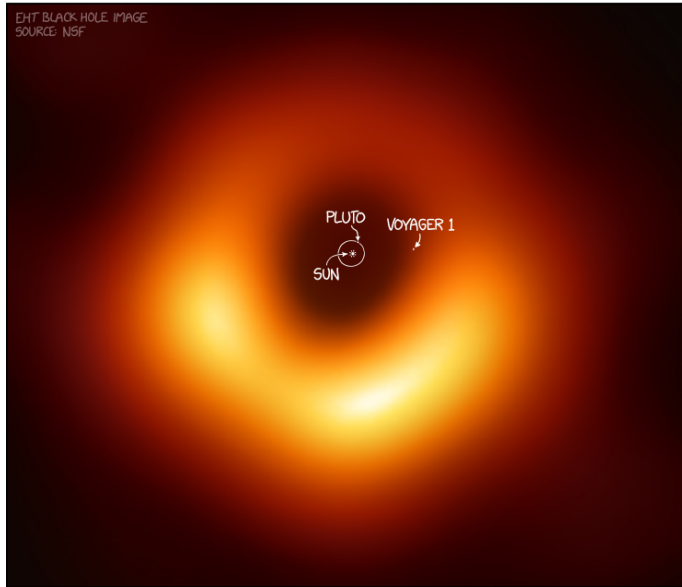
$$h = 6.63 \times 10^{-34} \text{ J s}$$

Elementary charge

$$e = 1.60 \times 10^{-19} \text{ C}$$

The Black Hole – by the numbers

SIZE COMPARISON:
THE M87 BLACK HOLE
AND
OUR SOLAR SYSTEM



Just bigger than our solar system
6.5 billion times the mass of the Sun
55 million light years from Earth



The Science Behind the Picture



Remember: $1^\circ = 3600$ arcseconds

1 arcsecond = $1,000,000 \mu\text{as}$

**60 μas is about the same as resolving a picture of an orange sitting on the surface of the moon*

The Science Behind the Picture

Each observation day, a telescope site tied to the EHT captures roughly 350 terabytes of data. That's around 10 times the amount of data collected daily at the Large Hadron Collider.

Photo credit: Nicolas Aros Marza

APEX Telescope



MIT Haystack Observatory



Each telescope of the EHT produced huge amounts of data, which were stored on high-performance helium-filled hard drives and flown to specialized supercomputers at the Max Planck Institute for Radio Astronomy and MIT Haystack Observatory to be combined into an image.

