

# The Beginning and The End

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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)
$z = \frac{\Delta\lambda}{\lambda_0} \approx \frac{v}{c}$ $z = \frac{R}{R_0} - 1$ $v = H_0 d$ $T \approx \frac{1}{H_0}$	$v = \sqrt{\frac{4\pi G\rho}{3}} r$ $\rho_c = \frac{3H^2}{8\pi G}$

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

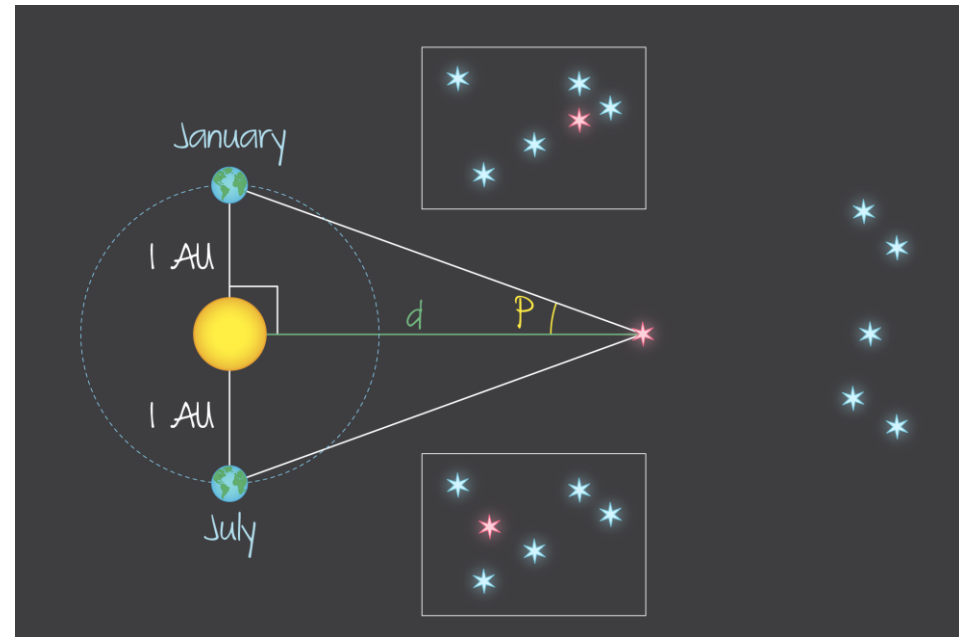
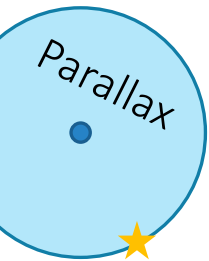
# Measuring the Universe



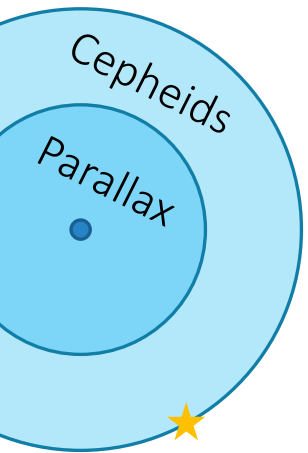
# Distance | Parallax

$$d \text{ (parsec)} = \frac{1}{p \text{ (arc second)}}$$

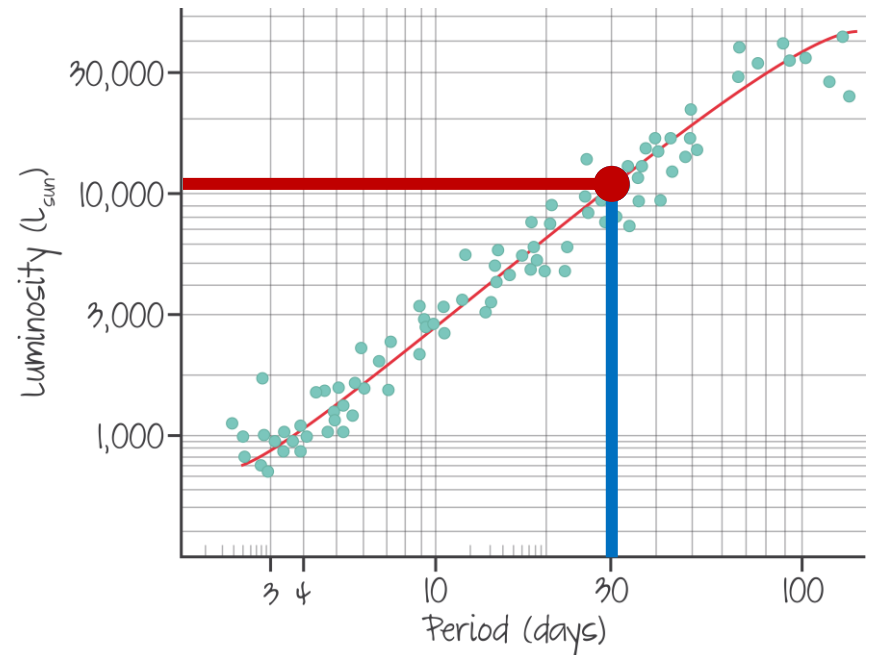
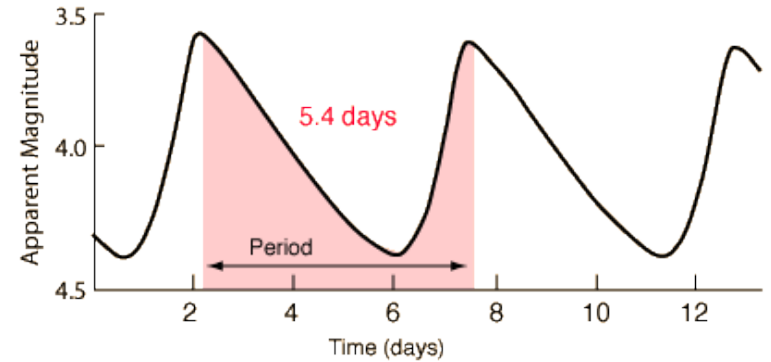
1 parsec (pc) = 3.26 ly



# Distance | Cepheid Variables

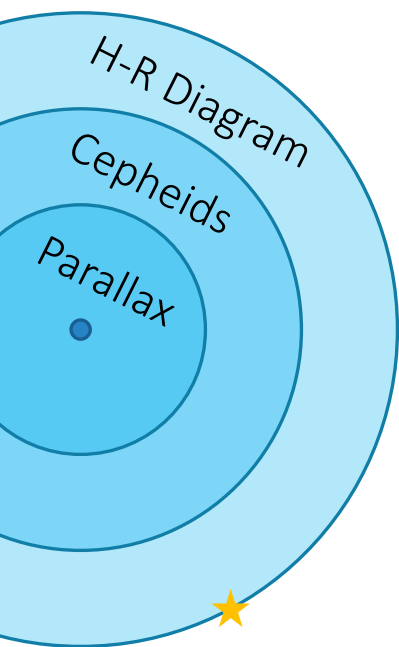


$$b = \frac{L}{4\pi d^2}$$



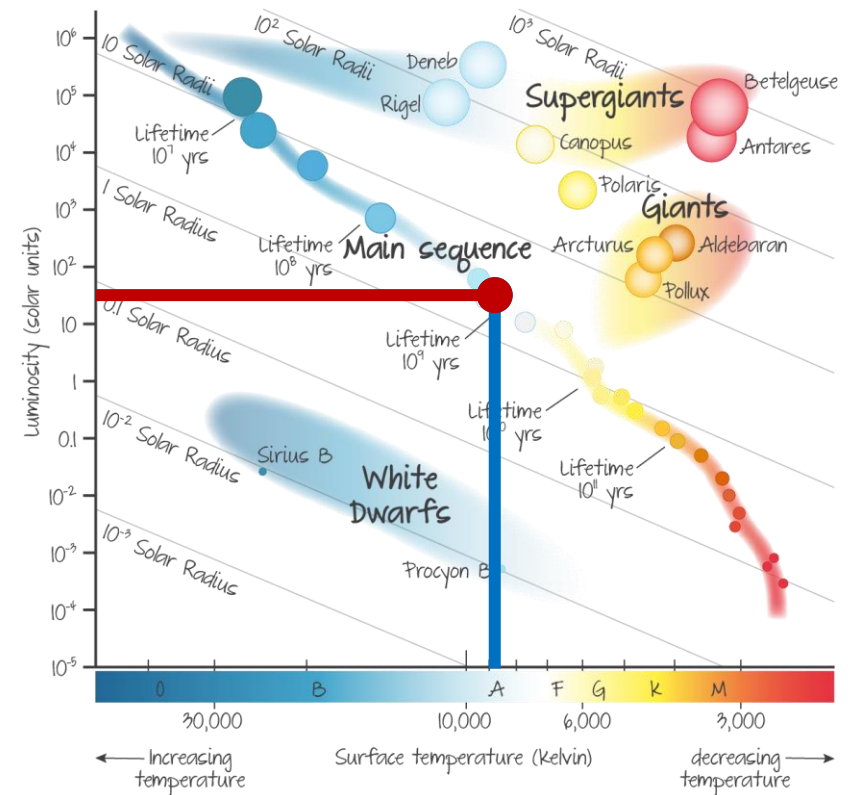


# Distance | H-R Diagram

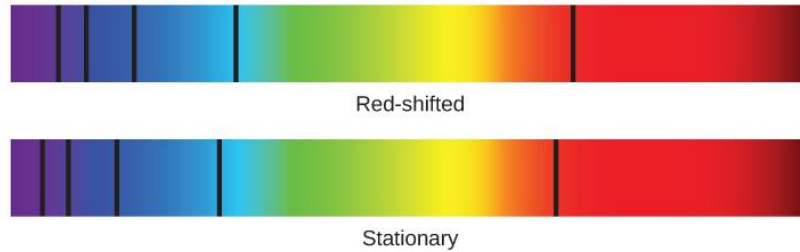
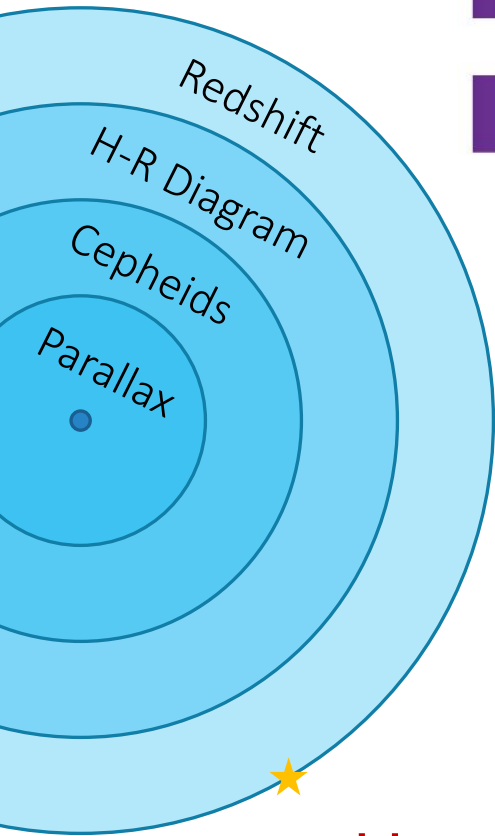


$$b = \frac{L}{4\pi d^2}$$

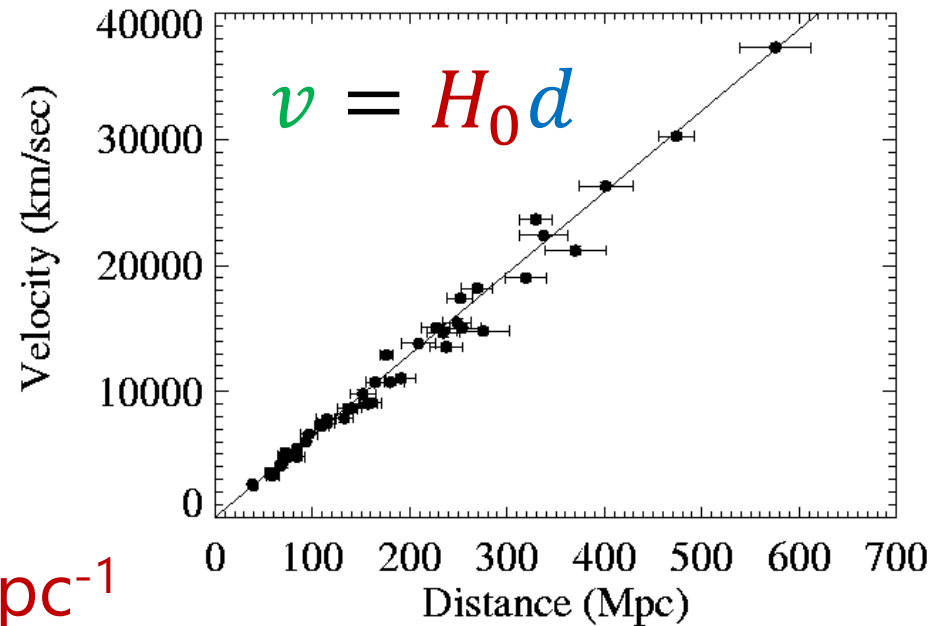
$$\lambda_{\max} T = 2.90 \times 10^{-3} \text{ mK}$$



# Distance | Redshift & Hubble's Law



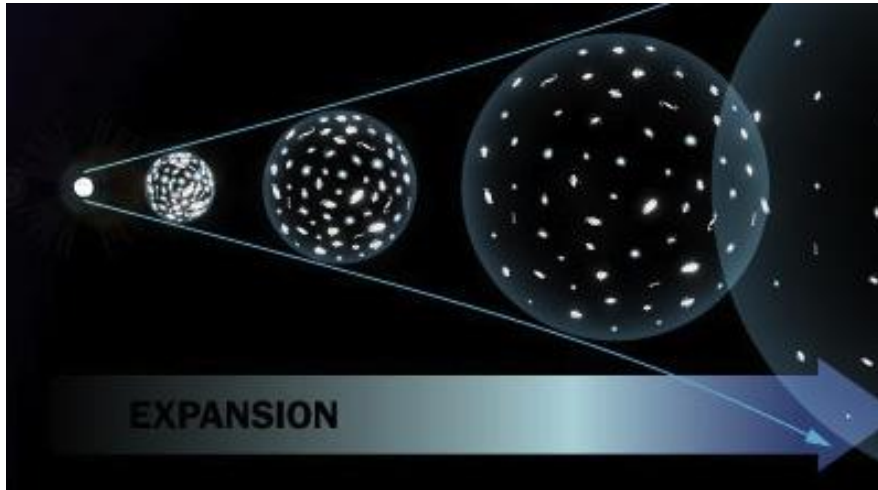
$$z = \frac{\Delta\lambda}{\lambda_0} \approx \frac{v}{c}$$



$$H_0 \approx 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$$



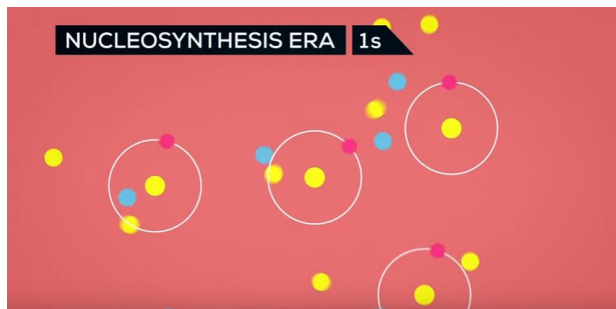
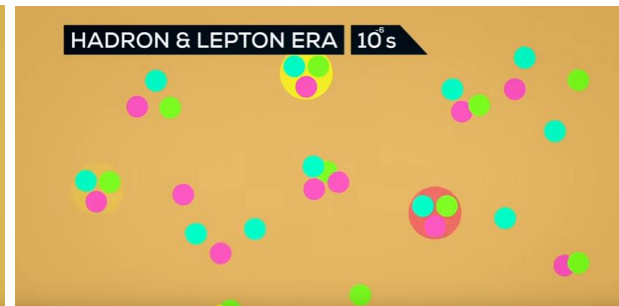
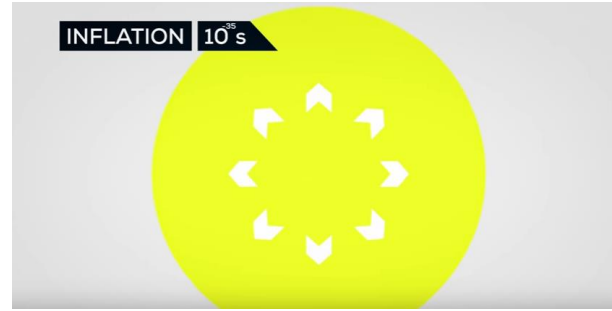
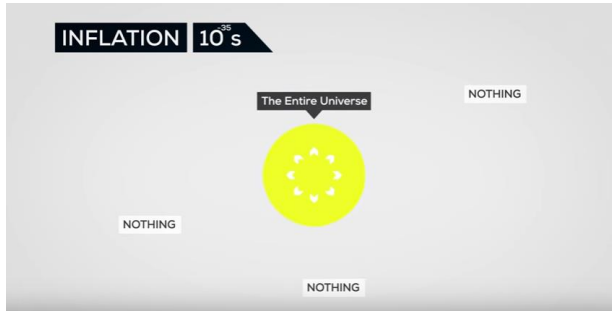
# How Old is the Universe?



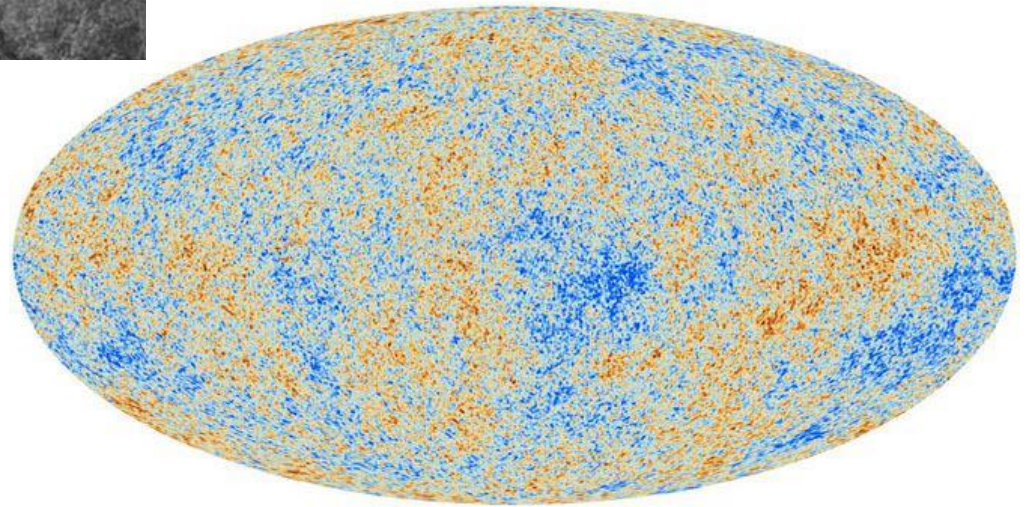
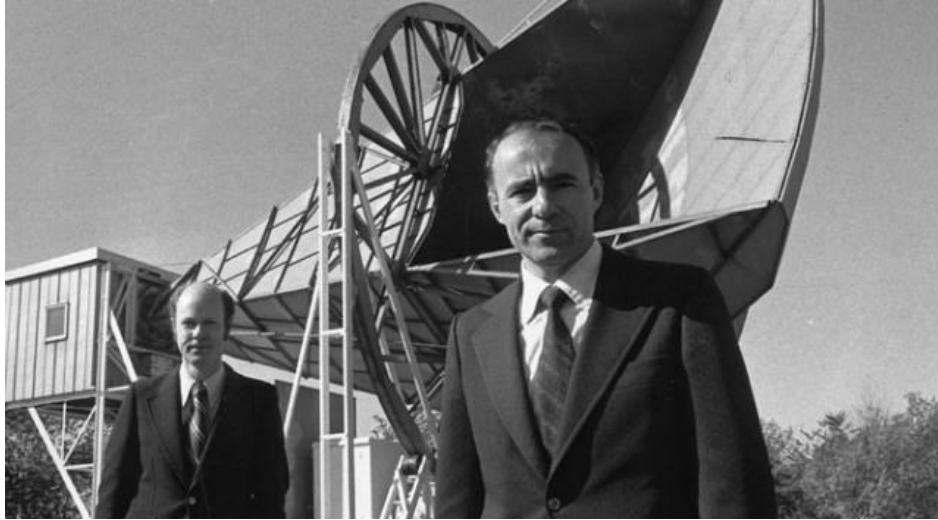
$$v = H_0 d$$

$$H_0 \approx 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$$

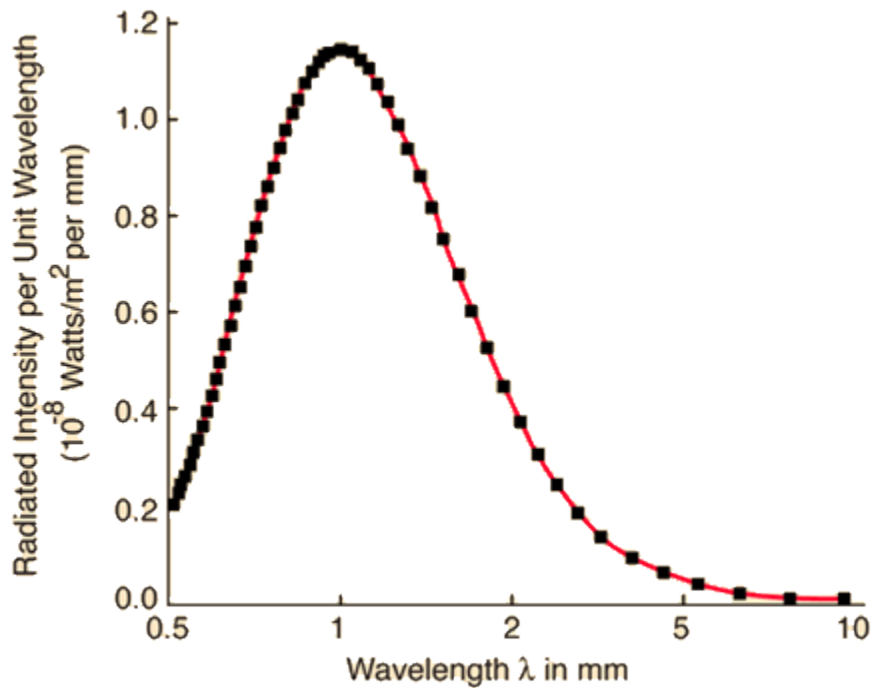
# The "Big Bang"



# Where's the Evidence??



# Cosmic Microwave Background



# What's Next?

1. Static and Infinite
2. Expanding and slowing to a stop
3. Expanding, slowing, and contracting in a “big crunch”
4. Expanding and accelerating

