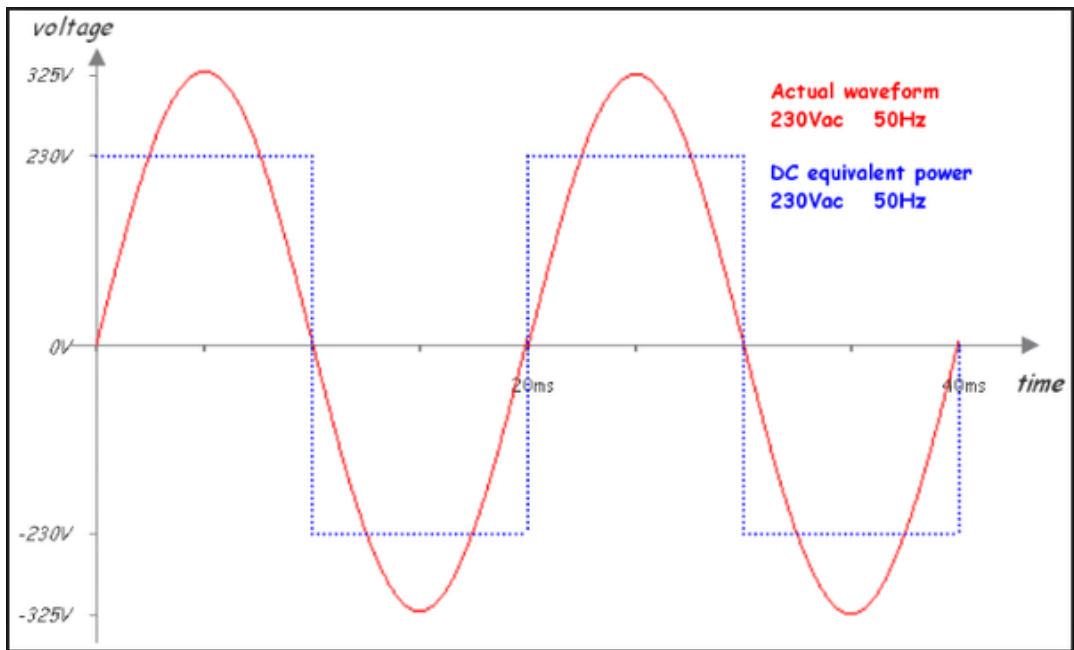
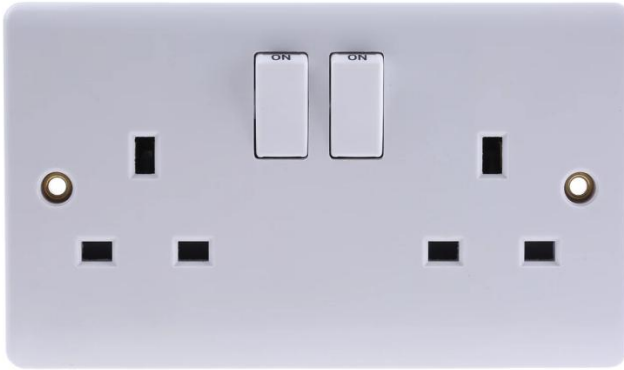


$$f = 5.0 \times 10^1 \text{ Hz}$$

UK 'mains-hum' at 50Hz



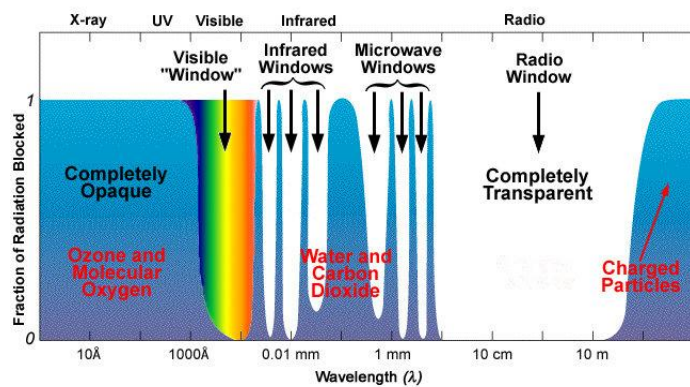
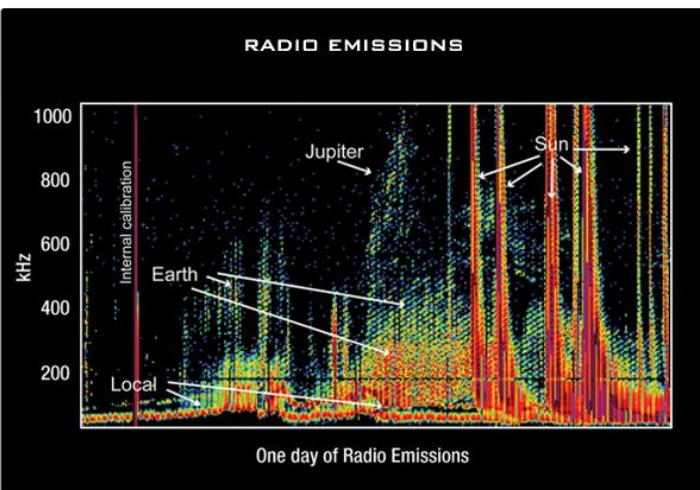
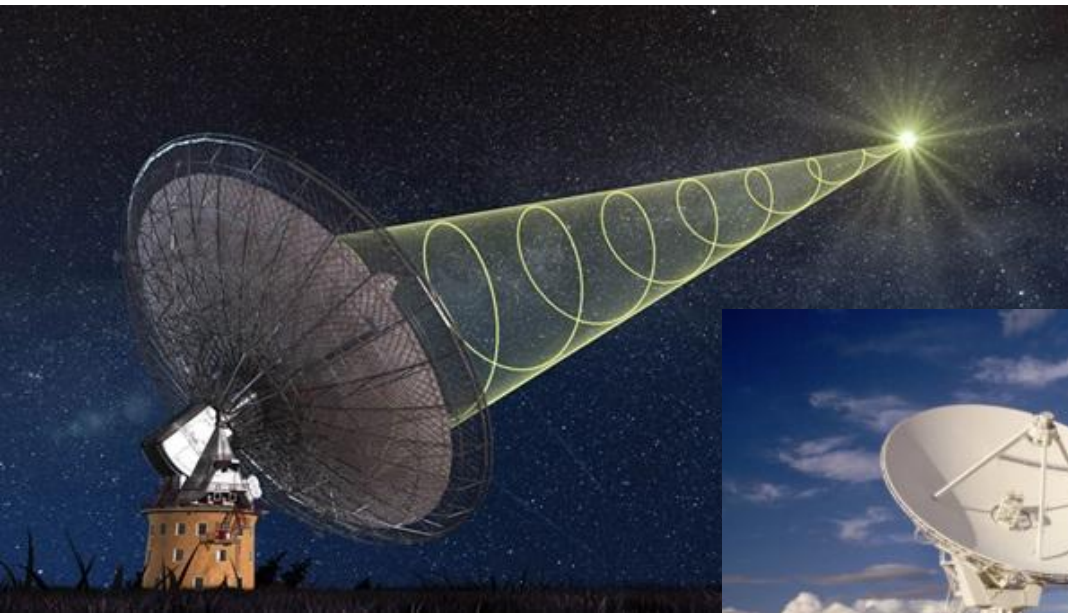
Radio waves

$$\lambda = 6.0 \times 10^6 \text{ m} \quad \text{in air}$$

6,000km

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 5.0 \times 10^5 \text{ Hz}$$



Radio waves

$$\lambda = 6.0 \times 10^2 \text{ m}$$

600m

$$c = f\lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 4.46 \times 10^8 \text{ Hz}$$

446MHz

UHF



Radio waves

$$\lambda = 6.72 \times 10^{-1} \text{ m}$$

67.3cm

$$c = f\lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 8.00 \times 10^8 \text{ Hz}$$

4-G mobile network

800MHz



Microwaves

$$\lambda = 3.75 \times 10^{-1} \text{ m}$$

37.5cm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 2.45 \times 10^9 \text{ Hz}$$

Magnetron in a domestic oven

2.45GHz



Microwaves

$$\lambda = 1.22 \times 10^{-1} \text{ m}$$

12.2cm

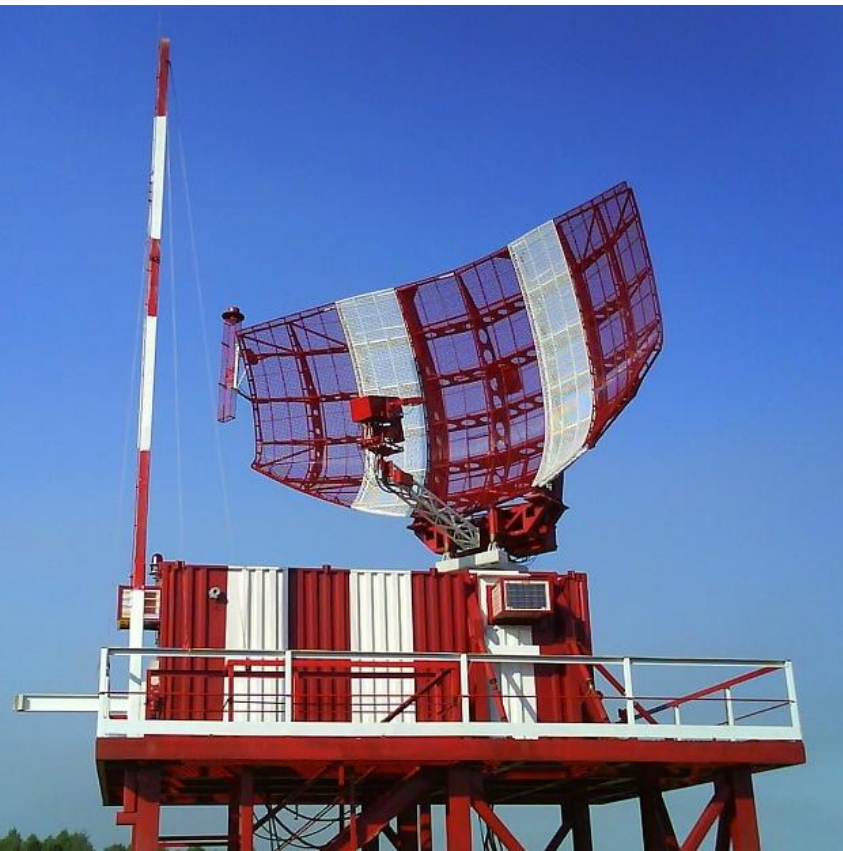
$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 3 \times 10^9 \text{ Hz}$$

RAdio **D**etection
And **R**anging

Primary Radar

3GHz



Microwaves

$$\lambda = 1.0 \times 10^{-1} \text{ m}$$

10cm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 3.4 \times 10^9 \text{ Hz}$$

5-G mobile network

3.4GHz



Microwaves

$$\lambda = 8.8 \times 10^{-2} \text{ m}$$

8.8cm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 1.0 \times 10^{12} \text{ Hz}$$

Terahertz imaging

1THz



Terahertz

$$\lambda = 3 \times 10^{-4} \text{ m}$$

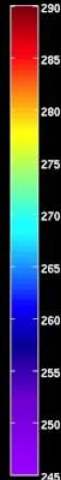
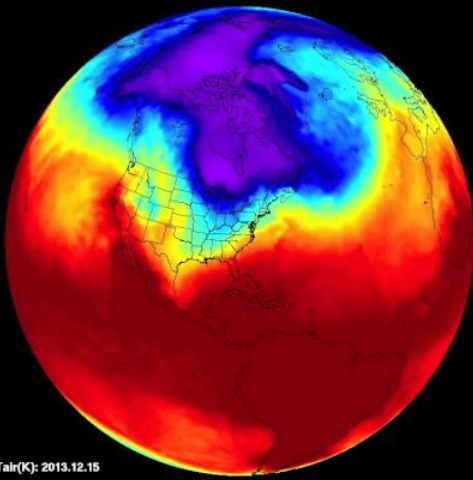
0.3mm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

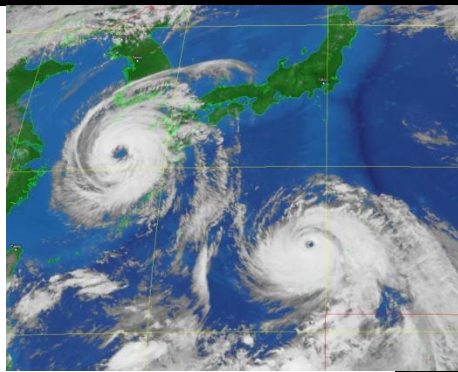
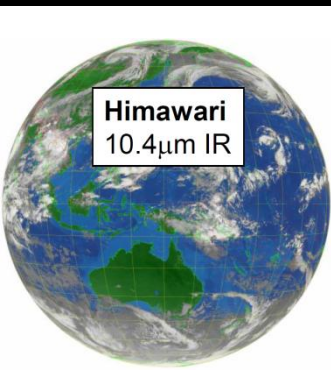
$$f = 1 \times 10^{13} \text{ Hz}$$

Infra-Red (IR) radiation

10THz



NASA/AIRS 850mb Tair(K): 2013.12.15



Infra-Red

$$\lambda = 3 \times 10^{-5} \text{ m}$$

30μm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 4.61 \times 10^{14} \text{ Hz}$$

Red light

461THz



Visible light

$$\lambda = 6.50 \times 10^{-7} \text{ m}$$

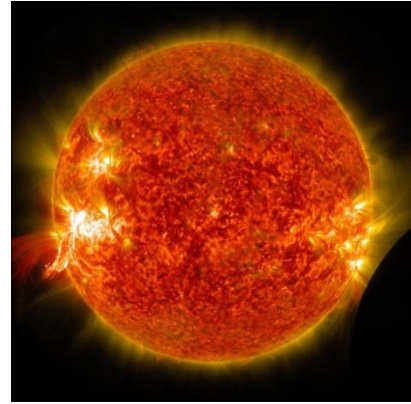
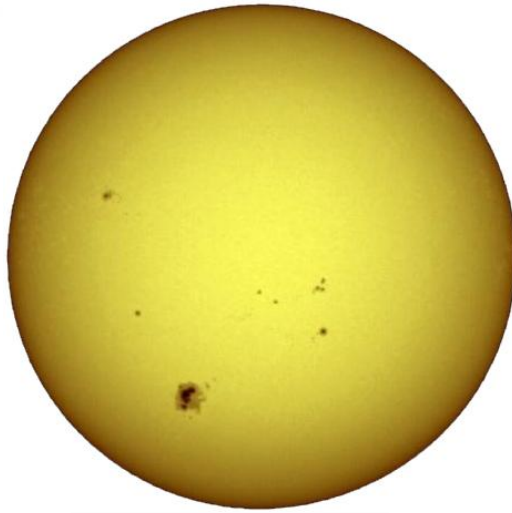
650nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 5.17 \times 10^{14} \text{ Hz}$$

Yellow light

517THz



Visible light

$$\lambda = 5.80 \times 10^{-7} \text{ m}$$

580nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 5.45 \times 10^{14} \text{ Hz}$$

Green light

545THz



Visible light

$$\lambda = 5.50 \times 10^{-7} \text{ m}$$

550nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 6.7 \times 10^{14} \text{ Hz}$$

Blue light

670THz



Visible light

$$\lambda = 4.40 \times 10^{-7} \text{ m}$$

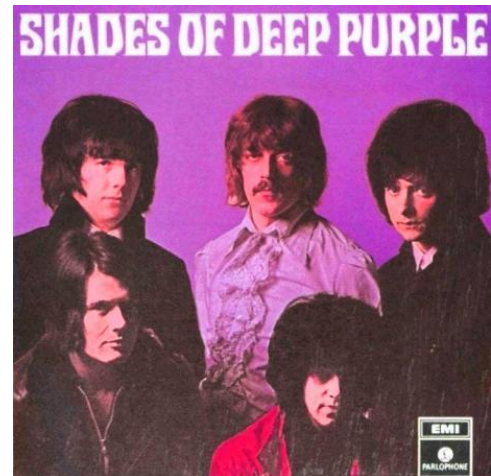
450nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 7.50 \times 10^{14} \text{ Hz}$$

Violet light

750THz



Visible light

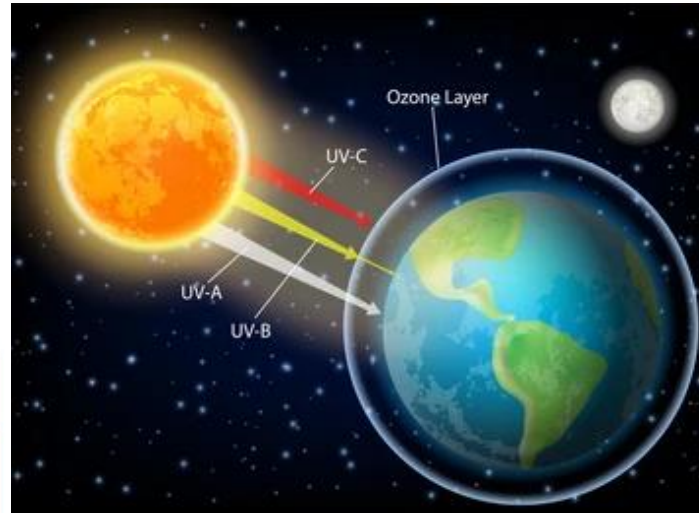
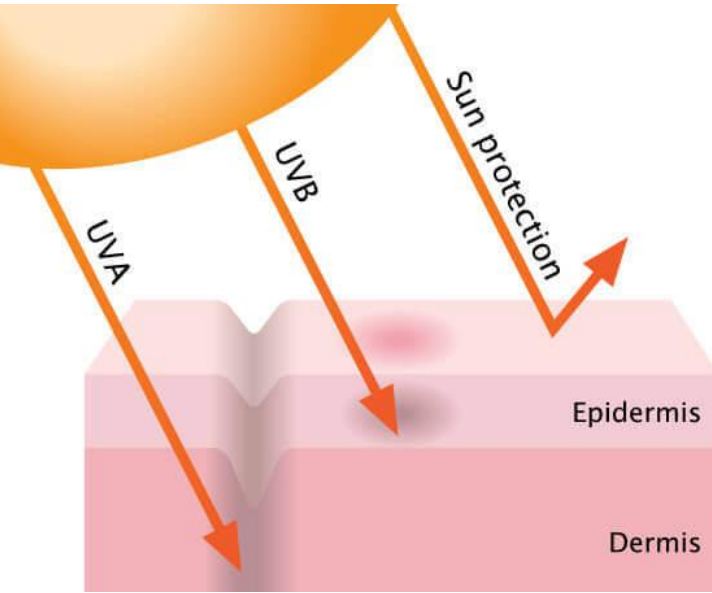
$$\lambda = 4.00 \times 10^{-7} \text{ m}$$

400nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

$$f = 10^{16} \text{ Hz}$$

Ultra-Violet (UV) light



UV

$$\lambda = 3 \times 10^{-8} \text{ m}$$

30nm

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$

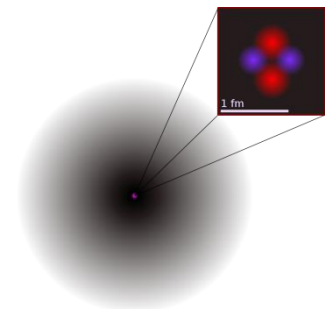
$$f = 10^{18} \text{ Hz}$$



X-ray

$$\lambda = 10^{-10} \text{ m}$$

1 Å = 100 pm

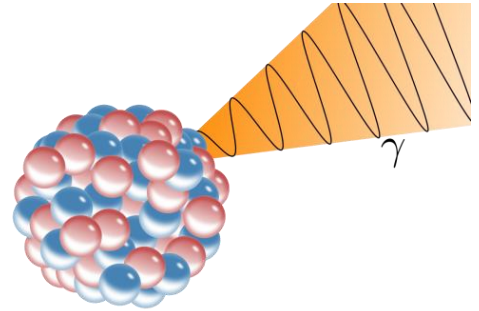
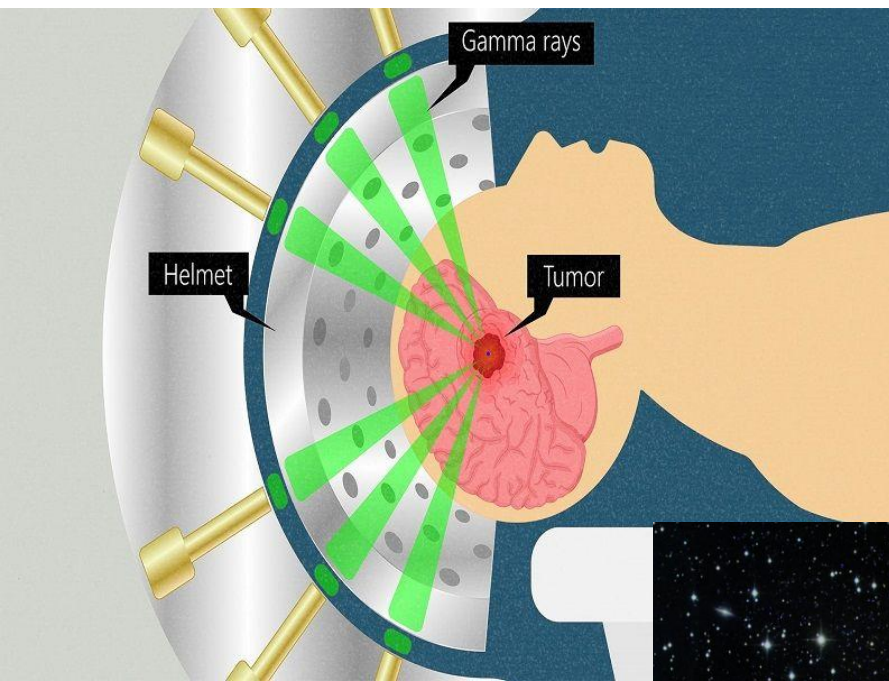


$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$



atomic sizes

$$f = 10^{23} \text{ Hz} \quad \text{or } \underline{\text{higher}}$$

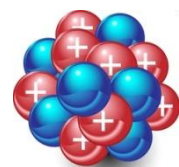


Gamma-ray

$$\lambda = 10^{-15} \text{ m}$$

or smaller

$$c = f \lambda = 3.00 \times 10^8 \text{ m/s}$$



Nuclei size