Outline

• This Presentation contains slides appropriate for all the sections of the activity.
  – White slides are included (but hidden from the Slideshow) as bookmarks.
  – You will need to show or hide slides according to which sections you are using.
  – Note that some slides include animations – it is recommended that you view the Slideshow itself before presenting it.
Multi-wavelength Astronomy
Introduction Slides
We describe EM radiation by:

- Frequency
- Wavelength

Light travels at:

- 300,000,000 m/s
The Electromagnetic Spectrum

- The EM spectrum is (arbitrarily) split up:
Black Body Radiation

(A-level Only)
“Black Body” radiation

- A **black body** is a **perfect** emitter and absorber of radiation
  - It emits and absorbs radiation with a particular “spectrum”
  - The **shape** of the spectrum is always the same, but the **peak wavelength** changes with temperature.
  - But **not all objects** are black bodies.
  - Atoms, molecules and electrons emit radiation with a different **spectrum** – this is called “**non-thermal radiation**”
Black Body Temperature

- The **wavelength** with most emission is related to the **black body temperature**

\[ \lambda_{\text{max}} \times T = 0.0029 \text{ K.m} \]

\[ T = \frac{0.0029}{\lambda_{\text{max}}} \]
Herschel (+ Planck) Intro

Launch video requires the video file “HP_launch.wmv” (may need to be re-linked)
The Atmosphere

- The Earth’s **atmosphere** blocks radiation at some wavelengths

  - This is why many telescope are in space
Herschel and Planck

Multiwavelength Astronomy
Herschel

Multiwavelength Astronomy
Planck

- 4x4x4m
- 2 tonnes on launch
- 2m mirror
- Cooled to 0.1K
- 2 instruments
- 300-10000 microns
Planck’s view of the sky
Herschel

- 8x4x4m
- 4 tonnes on launch
- 3.5m mirror
- 2500 litres of He
- Cooled to 0.3K
- 3 instruments
- 70-700 microns
Herschel’s view of the sky
Star formation
The Rosette Nebula
The Rosette Nebula
Spectral Regimes

Fill in the wavelength summary table
(Note that slides have animations)
The Spectral regimes

• Fill in the Wavelength Summary Table

• You will need this later.
Multiwavelength Astronomy

• Day-to-day:
  – The Sun (6000 K)
  – Glowing coal (1000 K)

• Astronomy
  – Stars
  – Nebulae (reflected, emission, absorption)

Visible
\[ \lambda = 400-800 \text{ nm} \]
\[ f = 375-750 \text{ THz} \quad T = 3,500-7,000 \text{ K} \]
Ultraviolet

\[ \lambda = 10-400 \text{ nm} \]

\[ f = 0.75-30 \text{ PHz} \quad T = 7,000-300,000 \text{ K} \]

- **Day-to-day:**
  - UV lights
  - The Sun (thermal radiation)

- **Astronomy:**
  - Hot, young stars
X-ray
\[ \lambda = 0.02 - 10 \text{ nm} \]
\[ f = 30 - 1500 \text{ PHz} \quad T = 300,000 - 15,000,000 \text{ K} \]

• Day-to-day:
  – X-ray machines

• Astronomy:
  – Supernovae
  – X-ray binary stars
  – Very hot gas
Gamma-ray
\( \lambda < 20 \text{ pm} \)
\( f > 1500 \text{ PHz} \quad T > 15,000,000 \text{ K} \)

- Day-to-day
  - Nuclear Power stations
  - Nuclear explosions

- Astronomy:
  - Gamma-ray bursts
  - Extremely hot gas

Multiwavelength Astronomy
Near-Infrared
\[ \lambda = 0.8 - 3 \, \mu m \]
\[ f = 100 - 375 \, \text{THz} \quad T = 1,000 - 3,500 \, \text{K} \]

- **Day-to-day:**
  - Hot things
  - Night-vision goggles

- **Astronomy:**
  - Cooler stars
  - Dust is transparent!
Mid-infrared (MIR)
($\lambda=3-30\ \mu\text{m} ; f=10-100\ \text{THz} ; T=100-1000\ \text{K}$)

- **Day-to-day:**
  - Us!
  - Thermal cameras

- **Astronomy:**
  - Warm dust
  - Proto-planetary disks (warm dust!)
Far-Infrared (FIR)
(\(\lambda=30-300\) microns; \(f=1-10\) THz; \(T=10-100\) K)

• Day-to-day:
  - Not much really
  - The atmosphere blocks it all

• Astronomy:
  - Cool dust
Sub-millimetre and millimetre
($\lambda=0.3-3$ mm; $f=0.1-1$ THz; $T=1-10$ K)

• Day-to-day:
  - Airport security systems

• Astronomy:
  - Cold dust
  - The early Universe!
Microwave
\( (\lambda = 3-30 \text{ mm} ; f = 10-100 \text{ GHz} ; T = 0.1-1 \text{ K}) \)

- **Day-to-day**
  - Microwave ovens
  - Some communications

- **Astronomy:**
  - Energetic electrons in magnetic fields
  - The early Universe
Radio

\[(\lambda > 30 \text{ mm} ; f < 10 \text{ GHz} ; T < 0.1 \text{ K})\]

- **Day-to-day:**
  - TV, Radio, communications, satellites, …
  - Wi-fi, RADAR, Bluetooth, …

- **Astronomy**
  - Electrons
  - Neutral hydrogen
Telescope sizes

- The **best possible resolution** a telescope can see depends on the **size of the mirror** and the **wavelength** of light it is measuring.

\[
\text{Resolution (deg)} \sim 60 \times \frac{\text{Wavelength (m)}}{\text{Diameter of mirror (m)}}
\]

\[
\theta \sim 60 \times \frac{\lambda}{D}
\]

1 degree = 60 arcminutes; 1 arcminute = 60 arcseconds

1 degree = 3600 arcseconds
Examples of telescopes

- **Hubble Space Telescope**
  - $D=2.2$ m; $\lambda=500$ nm
  - $\theta=2.3\times10^{-7}$ degrees = 0.8 milliarcsecond

- **Lovell Telescope, Jodrell Bank**
  - $D=76$ m; $\lambda=1$ m
  - $\theta=0.75$ degrees

- **Spitzer Space Telescope**
  - $D=0.7$ m; $\lambda=100$ $\mu$m
  - $\theta=1.4\times10^{-4}$ degrees = 0.5 arcseconds

- **Herschel**
  - $D=3.5$ m; $\lambda=100$ $\mu$m
  - $\theta=2.9\times10^{-5}$ degrees = 0.1 arcseconds
Wavelength Matching activity

Distribute question sheet and images
Suggested group size: 2-3
Match up the wavelengths

• There are 12 objects provided with images in visible light

• You have to match up the other wavelengths for each object
  – Some are quite straightforward…
  – Others are not!

• There is a prize for the highest score!
Matching Activity: Answers

Swap sheets
Answers

- Swap your answer sheet with another group
Crab Nebula

U5 (UIT)  Crab (VLT)  X4 (Chandra)

F7 (Herschel)  Multiwavelength Astronomy  R9 (NRAO)
Centaurus A

- M7 (Spitzer)
- X3 (Chandra)
- F8 (Herschel)
- R7 (NRAO)

Multiwavelength Astronomy
Multiwavelength Astronomy

Antennae

- M6 (Spitzer)
- F1 (Herschel)
- X5 (Chandra)

Antennae (Hubble)

Multiwavelength Astronomy

- R8 (VLA)
Cassiopeia A

M2 (Spitzer)

Cassiopeia A (Hubble)

F2 (Herschel)

R11 (NRAO)

X6 (Chandra)
Large Magellanic Cloud

U4 (Rocket)

LMC (AAO)

X1 (ROSAT)

F3 (Herschel)

Multiwavelength Astronomy

R10 (RAIUB)
Triangulum

U1 (UIT)
M4 (Spitzer)
Triangulum (INT)
X8 (ROSAT)
R2 (NRAO)

Multiwavelength Astronomy
Orion

N1 (VISTA)

M3 (Spitzer)

Orion (Hubble)

X2 (XMM)

F9 (Planck)

Multiwavelength Astronomy
Multiwavelength Astronomy

M81 (Gendler)

U2 (UIT)

M81 (Gendler)

X12 (Chandra)

F5 (Herschel)

Multiwavelength Astronomy

R1 (VLA)
Multiwavelength Astronomy

M87

M5 (IRAS)
M87 (AAT)
X9 (Chandra)
F4 (Herschel)

Multiwavelength Astronomy

R4 (NRAO)
Sombrero

N2 (2MASS)

M1 (Spitzer)

X10 (Chandra)

R3 (VLA)

Sombrero (Hubble)

Multiwavelength Astronomy
Multiwavelength Astronomy

M82

F6 (Herschel)

M8 (Spitzer)

M82 (Gendler)

X11 (Chandra)

R5 (VLA/Merlin)
Multiwavelength Astronomy

Andromeda

U3 (GALEX)

Andromeda (Gendler)

X7 (XMM-Newton)

F10 (Herschel)

Multiwavelength Astronomy

R6 (Effelsberg)
Chromoscope introduction

Requires internet connection or stand-alone version of Chromoscope (see [http://blog.chromoscope.net/download](http://blog.chromoscope.net/download))
Chromoscope

- http://www.chromoscope.net
  - Allows zooming and panning around the sky
  - Fade between wavelengths
Further Investigation

Take your assigned objects and investigate them further

Fill in the question sheet

Multiwavelength Astronomy
Poster Design

• Using what you have learned, design a poster.

• A poster template is available.
Summary Slide

Multiwavelength Astronomy
What have we learned?

• To understand the Universe fully, we need to observe at **multiple wavelengths**

• The **temperature** of an object can affect the wavelength it emits most radiation at.

• Some wavelengths are **blocked** by the Earth’s atmosphere and must be observed **from space**