Outline

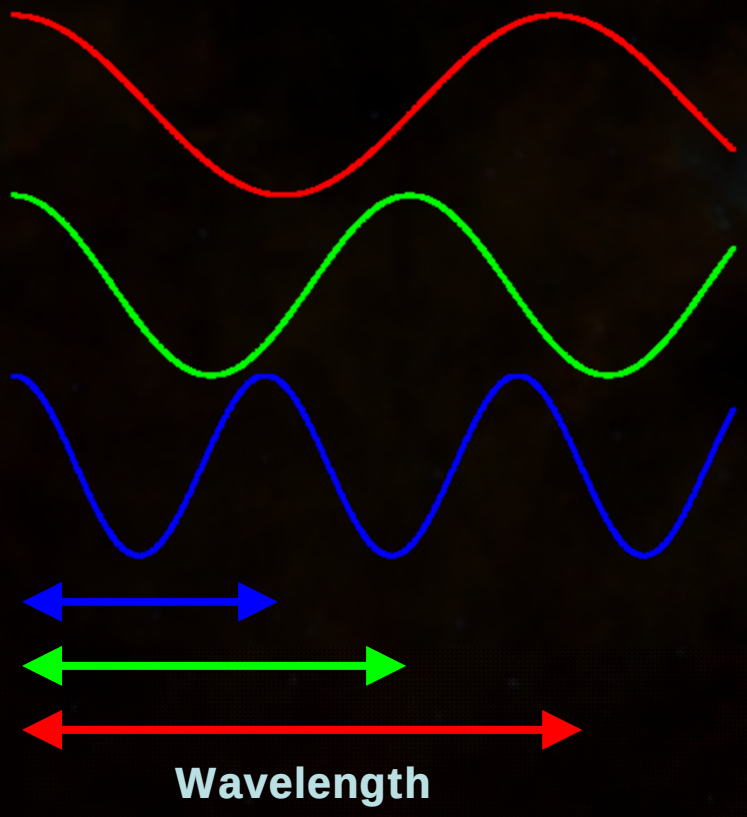
- This Presentation contains slides appropriate for all the sections of the activity.
  - White slides are included (but hidden from the Slideshow) as bookmarks.
  - You will need to show or hide slides according to which sections you are using.
  - Note that some slides include animations – it is recommended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

Multi-wavelength Astronomy

Introduction Slides

Electromagnetic radiation

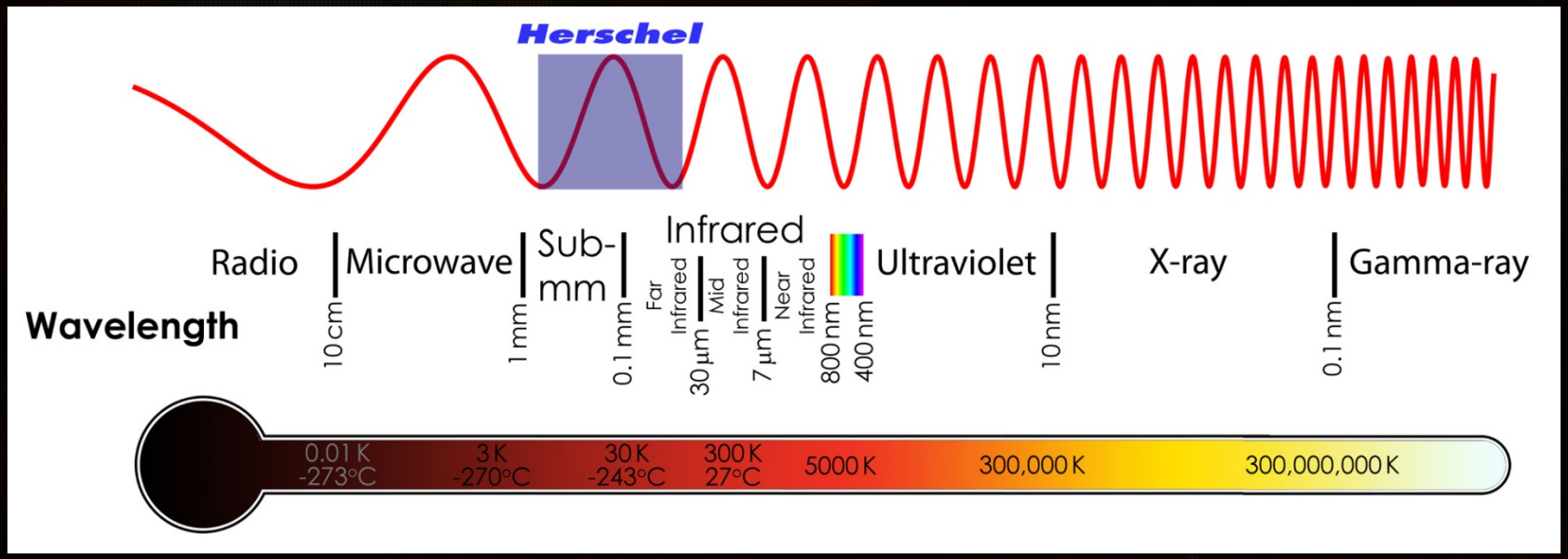
- We describe EM radiation by:
  - Frequency
  - Wavelength



- 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**

Max. wavelength (m) x Temperature (K) = Wien's Displacement Constant

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

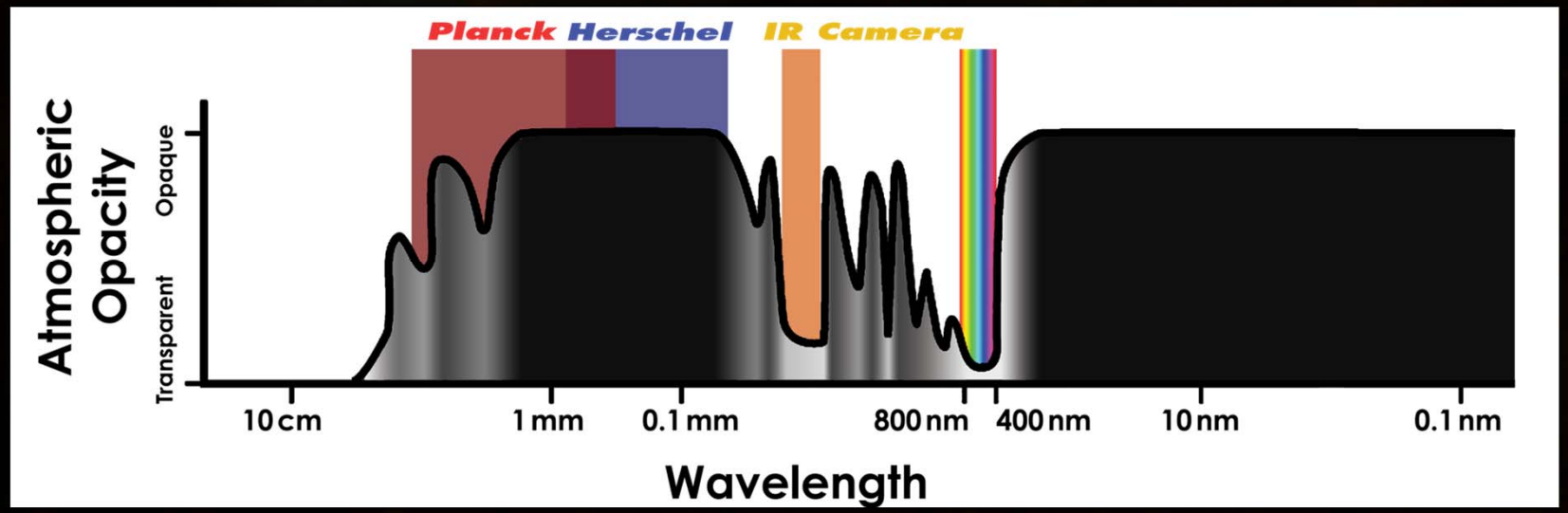
$$T = 0.0029 / \lambda_{max}$$

Herschel (+ Planck) Intro

Launch video requires the video file "HP_launch.wmv" (may need to be re-linked)

The Atmosphere

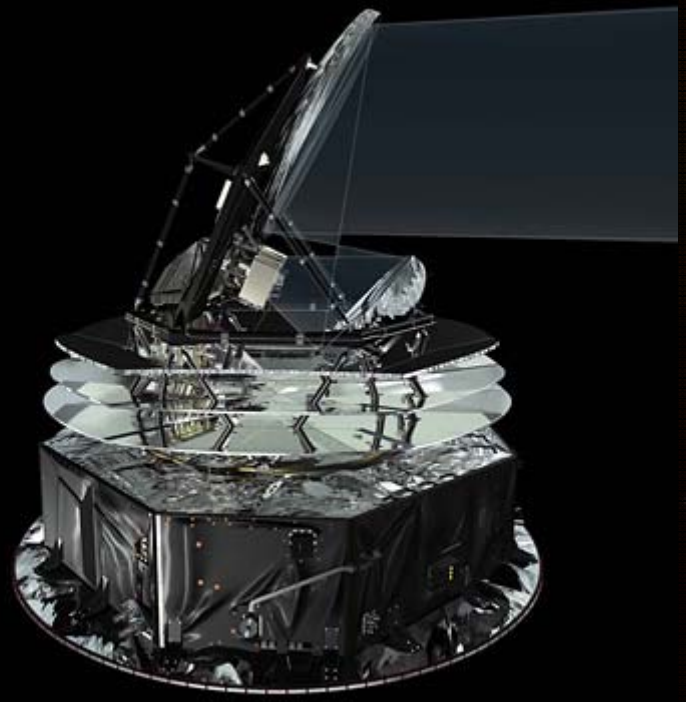
- The Earth's **atmosphere** blocks radiation at some wavelengths
  - This is why many telescope are **in space**



Herschel and Planck

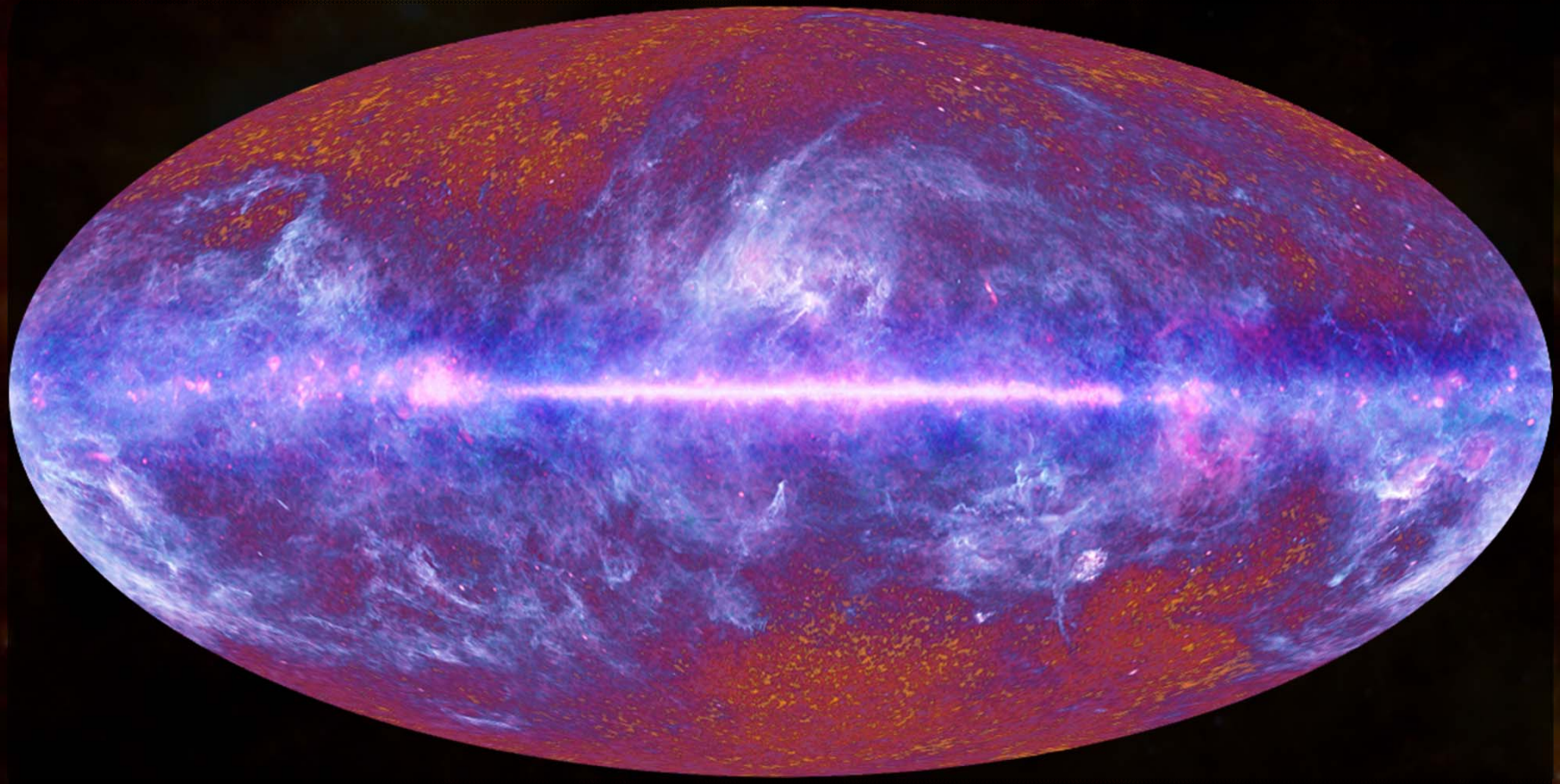
Herschel

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.

Visible

λ=400-800 nm

f=375-750 THz T=3,500-7,000 K

- Day-to-day:
  - The Sun (6000 K)
  - Glowing coal (1000 K)
- Astronomy
  - Stars
  - Nebulae (reflected, emission, absorption)

Ultraviolet

λ=10-400 nm

f=0.75-30 PHz T=7,000-300,000 K

- Day-to-day:
  - UV lights
  - The Sun (thermal radiation)
- Astronomy:
  - Hot, young stars

X-ray

λ=0.02-10 nm

f=30-1500 PHz T=300,000-15,000,000 K

- Day-to-day:
  - X-ray machines
- Astronomy:
  - Supernovae
  - X-ray binary stars
  - Very hot gas

Gamma-ray

λ<20 pm

f>1500 PHz T>15,000,000 K

- Day-to-day
  - Nuclear Power stations
  - Nuclear explosions
- Astronomy:
  - Gamma-ray bursts
  - Extremely hot gas

Near-Infrared

λ=0.8-3 μm

f=100-375 THz T=1,000-3,500 K

- Day-to-day:
  - Hot things
  - Night-vision goggles
- Astronomy:
  - Cooler stars
  - Dust is transparent!

Mid-infrared (MIR)

(λ=3-30 μm ; f=10-100 THz ; T=100-1000 K)

- Day-to-day:
  - Us!
  - Thermal cameras
- Astronomy:
  - Warm dust
  - Proto-planetary disks (warm dust!)

Far-Infrared (FIR)

(λ=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

(λ=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

(λ=3-30 mm ; f=10-100 GHz ; T=0.1-1 K)

- Day-to-day
  - Microwave ovens
  - Some communications
- Astronomy:
  - Energetic electrons in magnetic fields
  - The early Universe

Radio

(λ>30 mm ; f<10 GHz ; T<0.1 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 ; λ=500 nm
  - θ=2.3x10^{-7} degrees = 0.8 milliarcsecond
- Lovell Telescope, Jodrell Bank
  - D=76 m ; λ=1 m
  - θ=0.75 degrees
- Spitzer Space Telescope
  - D=0.7 m ; λ=100 μm
  - θ=1.4x10^{-4} degrees = 0.5 arcseconds
- Herschel
  - D=3.5 m ; λ=100 μm
  - θ=2.9x10^{-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!

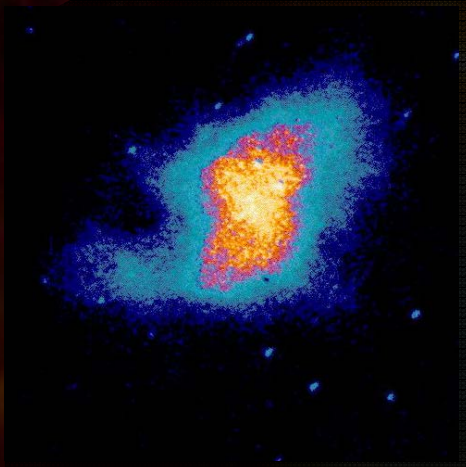
Matching Activity: Answers

Swap sheets

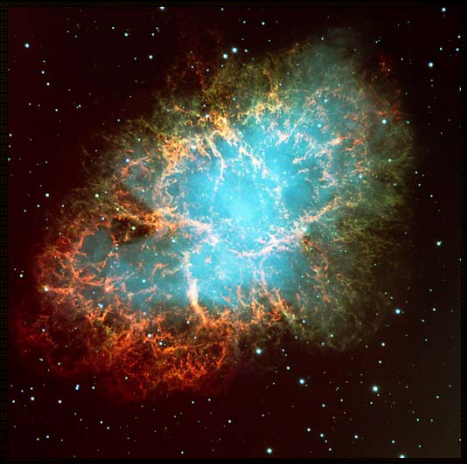
Answers

- Swap your answer sheet with another group

Crab Nebula

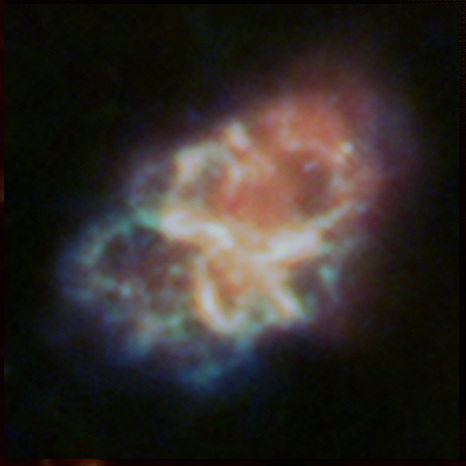


U5 (UIT)

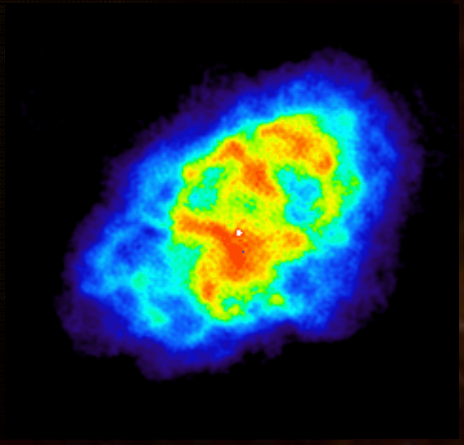


Crab (VLT)

X4 (Chandra)



F7 (Herschel)



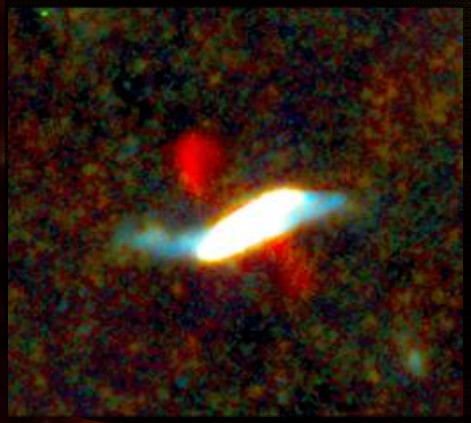
R9 (NRAO)

Centaurus A

M7 (Spitzer)

Centaurus A (NOAO)

X3 (Chandra)



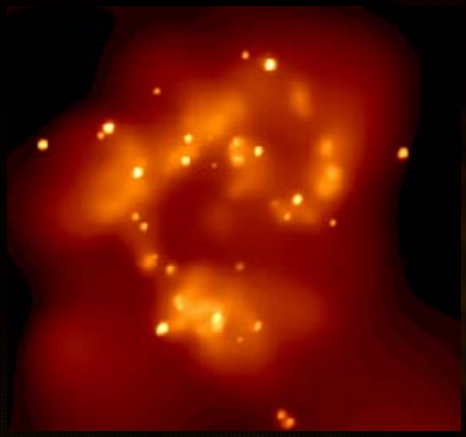
F8 (Herschel)

R7 (NRAO)

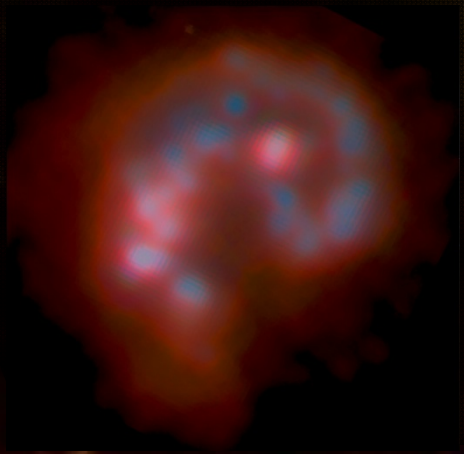
Antennae

M6 (Spitzer)

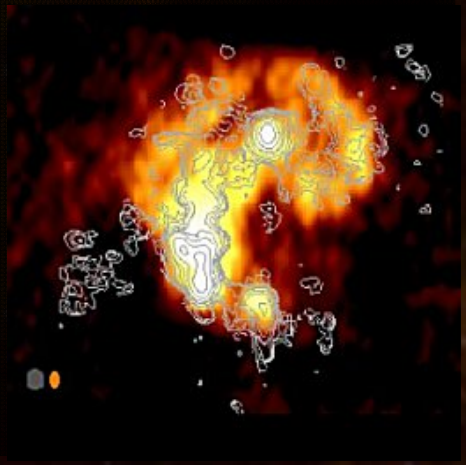
Antennae (Hubble)



X5 (Chandra)



F1 (Herschel)

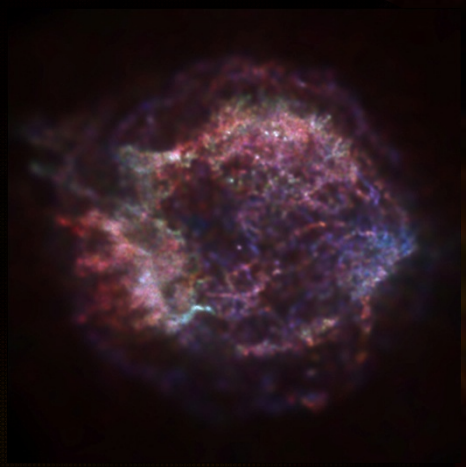


R8 (VLA)

Cassiopeia A

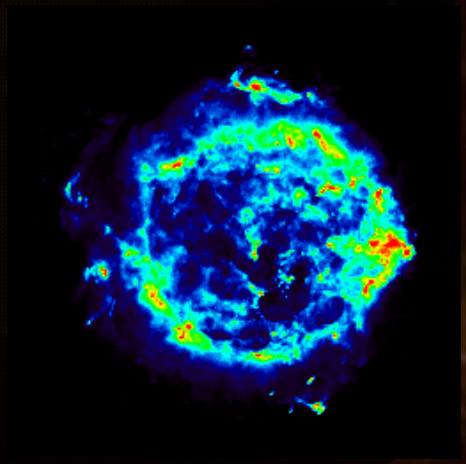
M2 (Spitzer)

Cassiopeia A (Hubble)



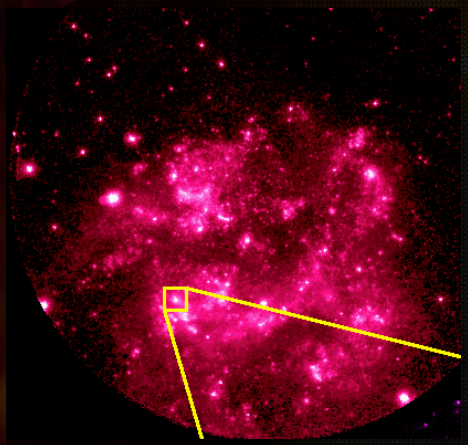
X6 (Chandra)

F2 (Herschel)



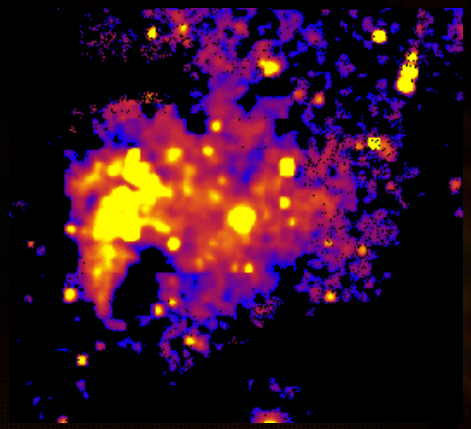
R11 (NRAO)

Large Magellanic Cloud



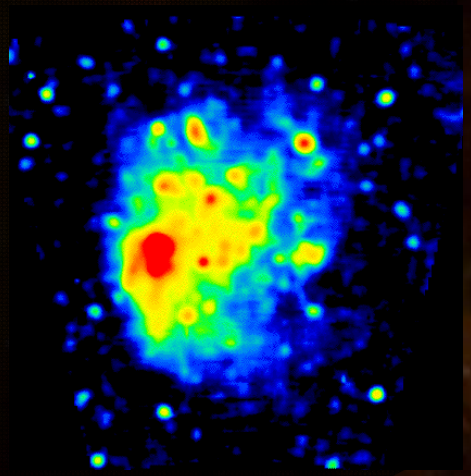
U4 (Rocket)

LMC (AAO)



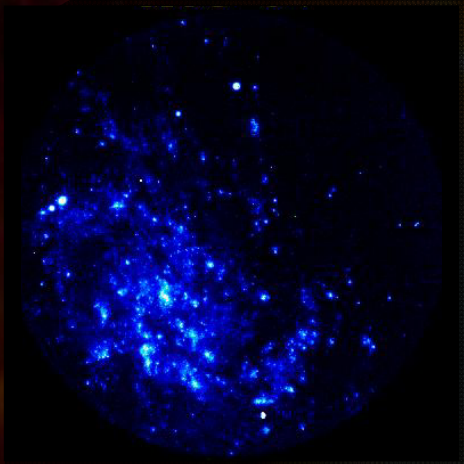
X1 (ROSAT)

F3 (Herschel)



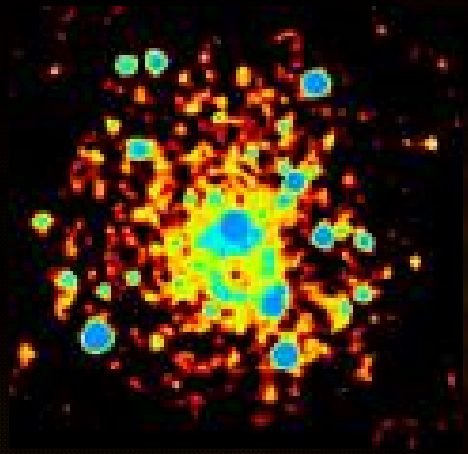
R10 (RAIUB)

Triangulum



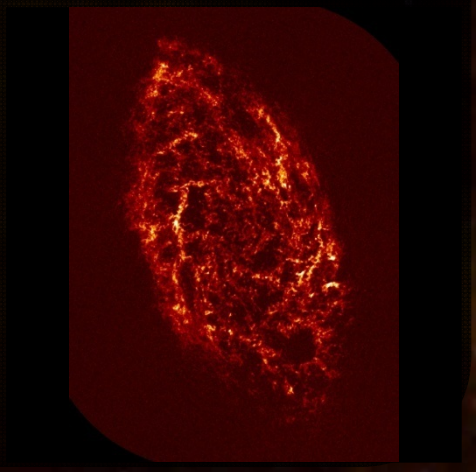
U1 (UIT)

Triangulum (INT)



X8 (ROSAT)

M4 (Spitzer)

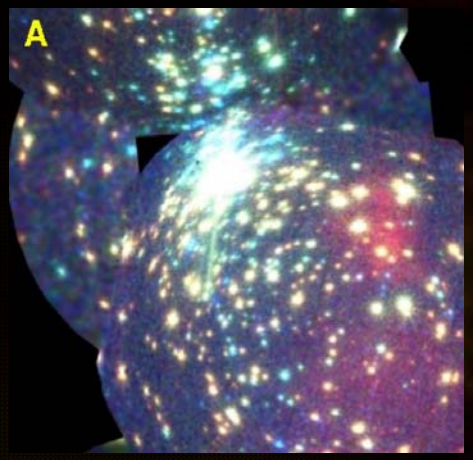


R2 (NRAO)

Orion

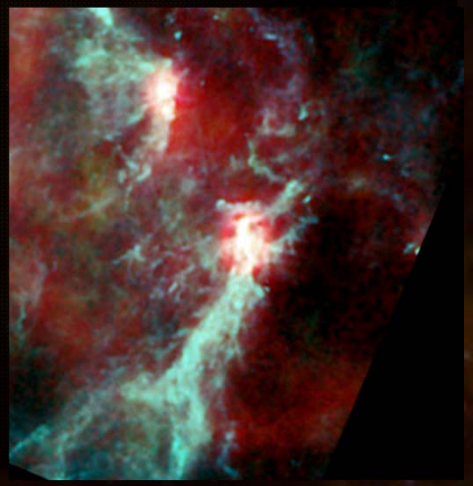
N1 (VISTA)

Orion (Hubble)



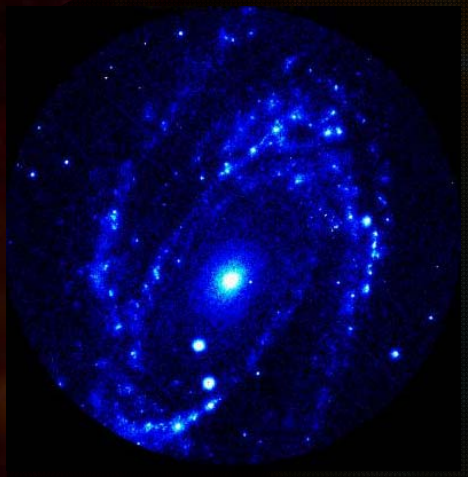
X2 (XMM)

M3 (Spitzer)

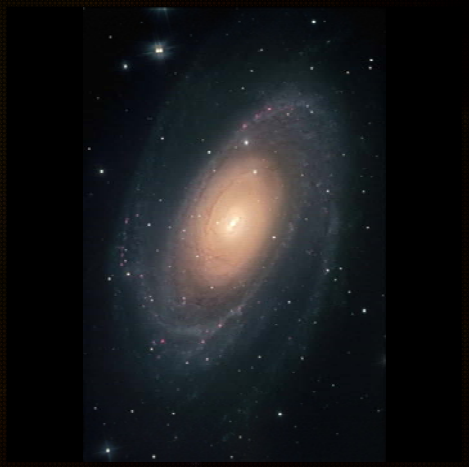


F9 (Planck)

M81



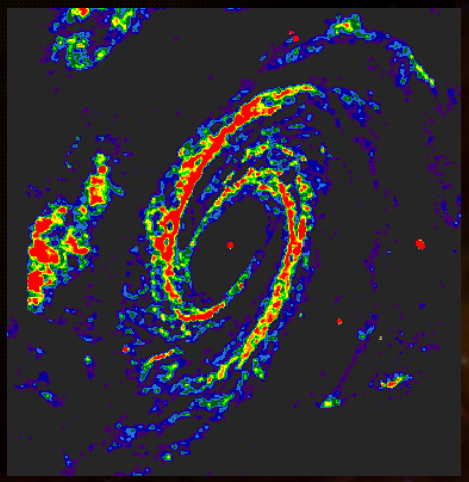
U2 (UIT)



M81 (Gendler)

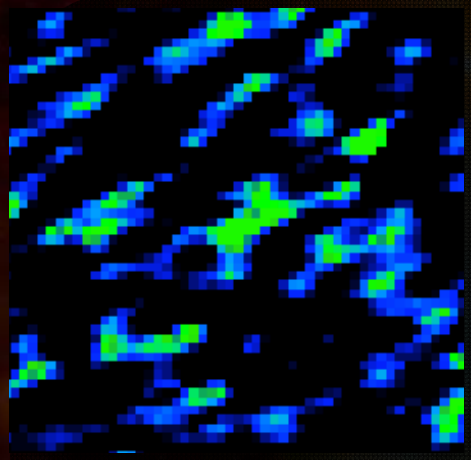
X12 (Chandra)

F5 (Herschel)



R1 (VLA)

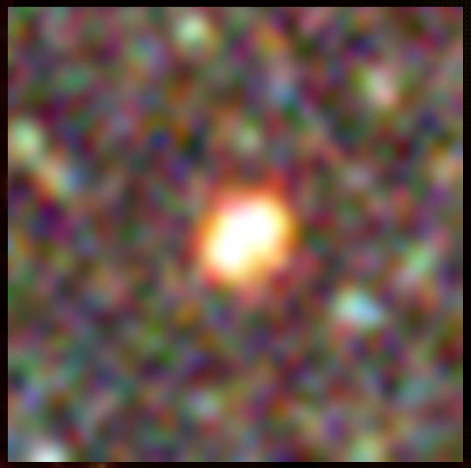
M87



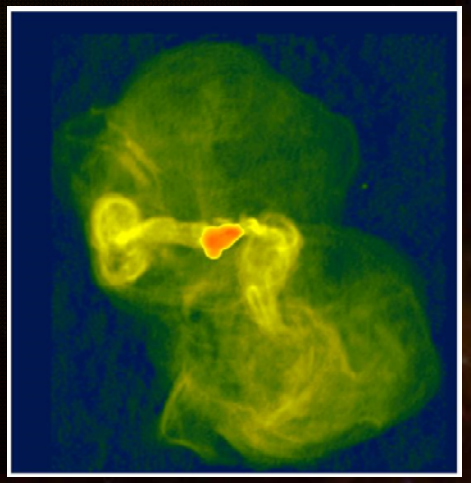
M5 (IRAS)

M87 (AAT)

X9 (Chandra)



F4 (Herschel)



R4 (NRAO)

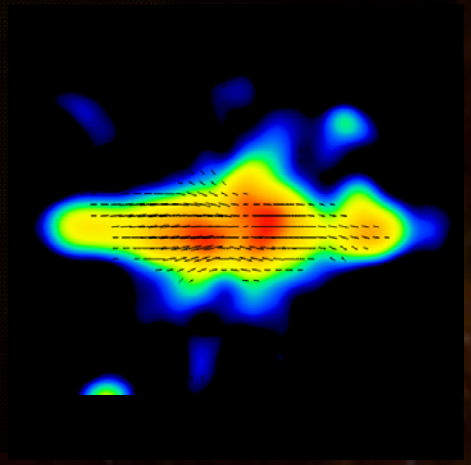
Sombrero

N2 (2MASS)

Sombrero (Hubble)

X10 (Chandra)

M1 (Spitzer)

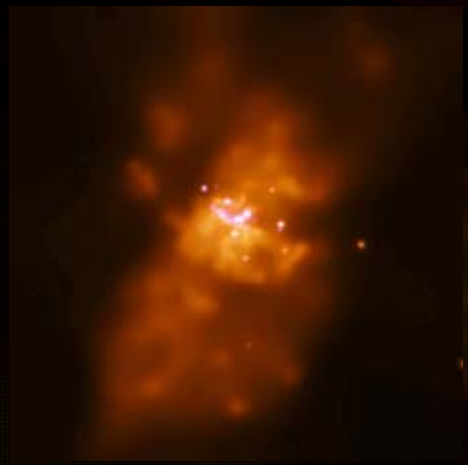


R3 (VLA)

M82

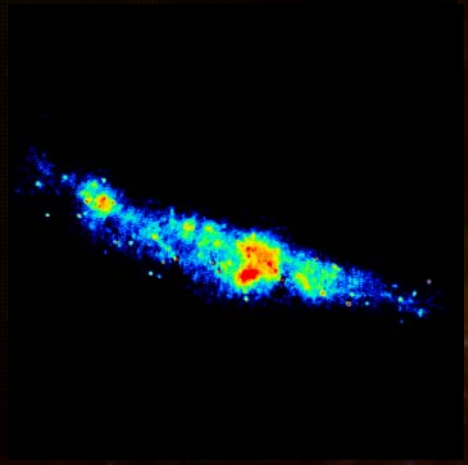
M8 (Spitzer)

M82 (Gendler)



X11 (Chandra)

F6 (Herschel)



R5 (VLA/Merlin)

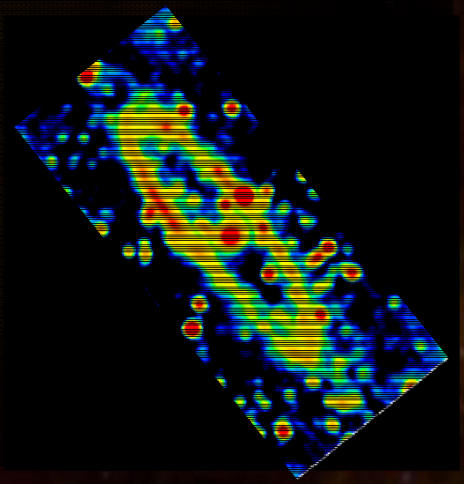
Andromeda

U3 (GALEX)

Andromeda (Gendler)

X7 (XMM-Newton)

F10 (Herschel)



R6 (Effelsberg)

Chromoscope introduction

Requires internet connection or stand-alone version of Chromoscope (see 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

Poster Design

- Using what you have learned, design a poster.
- A poster template is available.

Summary Slide

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**