**Activity Outline**

This is a brief introduction to the “Multiwavelength Universe” classroom activity. There is at least 2-2.5 hours of material here, so pick and choose accordingly, or split across wavelengths and cover in multiple sessions. Slides are provided for the teacher to illustrate all the sections.

**Introduction**

* **What is EM radiation?** (5-10 minutes)
  + Inc. list of wavelengths in EM spectrum (few minutes)
  + Wavelength and frequency
* Optional extra: Herschel introduction (variable length)
* **Black Body Radiation** (A-level only – 10-15 mins)
  + Inc. Wein’s displacement law
* Optional extra: Draw Black Body curves on the board
* Optional extra: telescope resolutions (A-level only – 10-15 mins)
  + Introduce ~/D
  + Calculate resolution for e.g. Hubble, Lovell, Spitzer, Herschel

**Spectrum activities (optional)**

* Emission examples at each wavelength (15-20 mins)
  + Fill in wavelength summary sheet
  + Frequency and temperature suggested for A-level students only
  + Ask for examples in real life
  + Ask and/or give examples in astronomy

**Online Wavelength matching activity (recommended)**

* Match objects at different wavelengths (20 mins)
  + Suggest groups of 2-3 students
  + Suggested illustrative examples (easier): Crab Nebula, or Cas A
  + X-ray and Radio are quite hard to match
  + Overall score is in the bottom right
  + Paper version also available (requires a lot of colour printing!)
    - Answers at the end of this pack

**Additional research (optional)**

* In their groups of 2-3, or individually
* Use links provided to find more information about objects (30 mins)
  + Suitable questions suggested in question sheet
  + Possible homework activity...
  + Optional: introduce them to Chromoscope [www.chromoscope.net](http://www.chromoscope.net)
* Optional extra: report back to class
* Optional extra: design poster about objects (template available in package)

For any questions, or to get more details, please contact:

**Chris North**

School of Physics and Astronomy

Cardiff University

Email: [chris.north@astro.cf.ac.uk](mailto:chris.north@astro.cf.ac.uk)

Tel: 02920 870 537

Or visit <http://herscheltelescope.org.uk/education>

**Multiwavelength Objects**

For the objects below, write down the numbers of the corresponding images at other wavelengths.

**Crab**



X-ray Ultraviolet

Far-Infrared Radio

**Centaurus A**



X-ray Mid-Infrared

Far-Infrared Radio

**Antennae**



X-ray Mid-Infrared

Far-Infrared Radio

**Cassiopeia A**



X-ray Mid-Infrared

Far-Infrared Radio

**Large Magellanic Cloud**



X-ray Ultraviolet

Far-Infrared Radio

**Triangulum**



X-ray Ultraviolet

Mid-Infrared Radio

**Orion**



X-ray Near-Infrared

Mid-Infrared Far-IR

**M81**



X-ray Ultraviolet

Far-Infrared Radio

**M87**



X-ray Mid-Infrared

Far-Infrared Radio

**Sombrero**

X-ray Near-Infrared



Mid-Infrared Radio

**M82**



X-ray Mid-Infrared

Far-Infrared Radio

**Andromeda**



X-ray Ultraviolet

Far-Infrared Radio

**Links to Objects**

Below are links to the various objects. The codes in brackets are the name you may find it under.

Links are given for finding the object in Chromoscope, as well as a few other links to more details.

Using Chromosope:

* Click the link to open Chromoscope with the object centred.
* Use the “+” and “-” keys (or buttons on the screen) to zoom in and out, and drag the sky around to explore the region.
* Turn on and off constellation labels buy pressing “L”
* Use the slider in the top right to fade between wavelengths shown.
* You can re-order the wavelengths by dragging their names in order to easily compare different wavelengths.
* For more help, press the “h” key.

**Crab (M1)**

**Chromoscope:** <http://www.chromoscope.net/?l=-175.4429&b=-5.7847&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Crab_Nebula>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m1.html>

**Chandra:** <http://chandra.harvard.edu/photo/1999/0052/>

**Spitzer:** <http://www.spitzer.caltech.edu/Media/mediaimages/sig/sig05-004.shtml>

**Herschel:** <http://herschel.cf.ac.uk/results/crab-nebula>

**Centaurus A (NGC 5128)**

**Chromoscope:** <http://www.chromoscope.net/?l=-50.4844&b=19.4172&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Centaurus_A>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/cenA.html>

**Chandra:** <http://chandra.harvard.edu/photo/2008/cena/>

**Herschel:** <http://herschel.cf.ac.uk/results/centaurus>

**Antennae (NGC 4038)**

**Chromoscope:** <http://www.chromoscope.net/?l=-73.0444&b=42.4614&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Antennae_Galaxies>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/ant.html>

**Chandra:** <http://chandra.harvard.edu/photo/2000/0120/>

**Spitzer:** <http://spitzer.caltech.edu/images/1266-ssc2004-14a%20-Fire-Within-the-Antennae-Galaxies>

**Cassiopeia A (Cas A)**

**Chromoscope:** <http://www.chromoscope.net/?l=111.7353&b=-2.1299&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Cassiopeia_A>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/casA.html>

**Chandra:** <http://chandra.harvard.edu/photo/2006/casa/>

**Spitzer:** <http://www.spitzer.caltech.edu/Media/releases/ssc2005-14/release.shtml>

**Large Magellanic Cloud (LMC)**

**Chromoscope:** <http://www.chromoscope.net/?l=-79.5344&b=-32.8887&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Large_Magellanic_Cloud>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/lmc.html>

**Herschel:** <http://herschel.cf.ac.uk/results/centaurus>

**Triangulum (M33)**

**Chromoscope:** <http://www.chromoscope.net/?l=133.6106&b=-31.3308&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Triangulum_Galaxy>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m33.html>

**Spitzer:** <http://spitzer.caltech.edu/images/2625-sig09-003-Multispectral-Triangulum-Galaxy-3-Channel>

**Orion (M42)**

**Chromoscope:** <http://www.chromoscope.net/?l=-150.9866&b=-19.3813&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Orion_Nebula>

**Chandra:** <http://chandra.harvard.edu/photo/2007/orion/>

**Spitzer:**

<http://www.spitzer.caltech.edu/Media/releases/ssc2006-21/ssc2006-21a.shtml>

**Vista:** <http://www.eso.org/public/news/eso1006/>

**M81**

**Chromoscope:** <http://www.chromoscope.net/?l=142.0920&b=40.8999&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Messier_81>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m81.html>

**Chandra:** <http://chandra.harvard.edu/photo/2008/m81/>

**Spitzer:** <http://spitzer.caltech.edu/images/2126-sig07-009-Multiwavelength-M81>

**M87**

**Chromoscope:** <http://www.chromoscope.net/?l=-76.2224&b=71.4990&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Messier_87>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m87.html>

**Chandra:** <http://chandra.harvard.edu/photo/2008/m87/>

**Sombrero (M104)**

**Chromoscope:** <http://www.chromoscope.net/?l=-61.5396&b=51.1494&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Sombrero_Galaxy>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m104.html>

**Chandra:** <http://chandra.harvard.edu/photo/2007/sombrero/>

**Spitzer:** <http://www.spitzer.caltech.edu/Media/releases/ssc2005-11/release.shtml>

**M82**

**Chromoscope:** <http://www.chromoscope.net/?l=141.4094&b=40.5667&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Messier_82>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m82.html>

**Chandra:** <http://chandra.harvard.edu/photo/2006/m82/>

**Andromeda (M31)**

**Chromoscope:** <http://www.chromoscope.net/?l=121.1741&b=-21.5727&w=2.00&o=g,x,v,a,f,m,r&z=6>

**Wikipedia:** <http://en.wikipedia.org/wiki/Andromeda_Galaxy>

**Cool Cosmos:** <http://coolcosmos.ipac.caltech.edu/cosmic_classroom/multiwavelength_astronomy/multiwavelength_museum/m31.html>

**Chandra:** <http://chandra.harvard.edu/photo/2006/m31/>

**Spitzer:** <http://www.spitzer.caltech.edu/Media/releases/ssc2005-20/release.shtml>

**Herschel:** <http://herschel.cf.ac.uk/results/andromeda-galaxy>

**Further Research**

1) What object are you looking at? Describe what it looks like at first sight.

2) Describe where it is in the sky. Is it in the Northern or Southern hemisphere as seen from Earth? Are there any nearby constellations?

3) How far away is it? Is that inside or outside our Galaxy?

4) Describe what type of object it is. Can you find any other pictures of it?

5) Does it look particularly different in any particular wavelengths? Does that tell you anything about it?

6) What can you learn by comparing the appearance of the object at different wavelengths? What is it made of?

7) What is happening to the object? Is it doing anything?

**Wavelength Summary Table**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Spectral regime** | **Wavelength** | **Frequency** | **Temperature** | **Types of objects** |
| **Gamma Ray** | <20 pm | >1500 PHz | >15,000,000 K |  |
| **X-ray** | 0.02-  10 nm | 30-  1500 PHz | 300,000-  15,000,000 K |  |
| **Ultraviolet (UV)** | 10-  400 nm | 0.75-  30 PHz | 7000-  300,000 K |  |
| **Visible** | 400-  800 nm | 375-750 THz | 3500-  7000 K |  |
| **Near-Infrared (NIR)** | 0.8-  3 m | 100-  375 THz | 1000-  3500 K |  |
| **Mid-infrared (MIR)** | 3-  30 m | 10-  100 THz | 100-  1000 K |  |
| **Far-infrared (FIR)** | 30-  300 m | 1-  10 THz | 10-  100 K |  |
| **Sub-mm and millimetre** | 0.3-  3 mm | 0.1-  1 THz | 1-  10 K |  |
| **Microwave** | 3-  30 mm | 10-  100 GHz | 0.1-  1K |  |
| **Radio** | >30 mm | <10 GHz | <0.1 K |  |

**Multiwavelength Objects (Answers)**

For the objects below, write down the numbers of the corresponding images at other wavelengths.

**Crab**



X-ray **X4** Ultraviolet **U5**

Far-Infrared **F7** Radio **R9**

**Centaurus A**



X-ray **X3** Mid-Infrared **M7**

Far-Infrared **F8** Radio **R7**

**Antennae**



X-ray **X5** Mid-Infrared **M6**

Far-Infrared **F1** Radio **R8**

**Cassiopeia A**



X-ray **X6** Mid-Infrared **M2**

Far-Infrared **F2** Radio **R11**

**Large Magellanic Cloud**



X-ray **X1** Ultraviolet **U4**

Far-Infrared **F3** Radio **R10**

**Triangulum**



X-ray **X8** Ultraviolet **U1**

Mid-Infrared **M4** Radio **R2**

**Orion**



X-ray **X2** Near-Infrared **N1**

Mid-Infrared **M3** Far-IR/Microwave **F9**

**M81**



X-ray **X12** Ultraviolet **U2**

Far-Infrared **F5** Radio **R1**

**M87**



X-ray **X9** Mid-Infrared **M5**

Far-Infrared **F4** Radio **R4**

**Sombrero**

X-ray **X10** Near-Infrared **N2**



Mid-Infrared **M1** Radio **R3**

**M82**



X-ray **X11** Mid-Infrared **M8**

Far-Infrared **F6** Radio **R5**

**Andromeda**



X-ray **X7** Ultraviolet **U3**

Far-Infrared **F10** Radio **R6**