Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany first minute topics in the dome video

Why high energies?

Glossary

Wavelength – the distance from one peak or trough to another - measured in metres

Frequency – number of waves/cycles per second – Hertz HZ

Energy – measured in Electron Volts

Luminosity - the total amount of energy emitted by an astronomical object per unit time

Key Questions

- What is High Energy astrophysics?
  - Simply put, the study of astronomical objects from wavelengths at the high end of the electromagnetic spectrum.
- Why study astronomical objects at these high energies?
  - In our day to day lives we see with our eyes in what is called the optical part of the electromagnetic spectrum (EM spectrum). The em spectrum is a scale which shows us all the different types of radiation there is and what wavelengths they are at. High Energy refers to Gamma rays and X-rays. Astronomers will often observe the properties of astronomical objects using these different wavelengths as each one could potentially reveal hidden features about the astronomical object only seen at those wavelengths.
- What can these different wavelengths tell us?
  - X-ray Data
    - **Images** - X-ray's act more like particles than as waves and as such detectors can collect individual X-rays (known as photons). The detectors collect information such as the number of photons that are being collected, the energy of each individual photon, or how fast they hit the detector. They are also able to measure the time that the photon hit and also where it came from.
    - **Spectra** – A spectra is a chart or a graph that shows the intensity of light being emitted by the astronomical object being observed. Spectra can tell us information such as what elements the object is made up of and how much of that element is present. It can tell us how many X-rays are coming from the object at a particular energy, the temperature, density, mass, distance, luminosity, and how fast it is moving.
  - **Gamma Rays**
    - These are the most energetic form of the EM spectrum and come from the most extreme places in the universe. They can travel great distances in space without being absorbed by intergalactic dust and gas. They are ideal for studying distant regions of space as well as looking into regions of the Milky Way Galaxy otherwise obscured. We can use also use them to look further into black holes, active galaxies, solar flares, supernova and neutron stars.

(Remember that light can act as both a wave and a particle. Particles of light are called photons. High Energy photons such as X-rays and Gamma rays behave more like particles than waves).

Additional ideas, activities and web links

Activities

Ideas for teachers:

- You can buy spectral glasses that will allow the wearer to see the visible part of the spectrum (the rainbow) wherever there is light cast on or from an object around them (note please do not look directly at the sun with them). Nice to use when talking about the different parts of the em spectrum

Web Links

- EM spectrum - http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html
- The above article also contains a nice image of how far EM radiations can reach to the Earth's surface.
- For the specific properties of each type, see the following table - http://imagine.gsfc.nasa.gov/science/toolbox/spectrum_chart.html
- This is a good site explaining what we can see from different types of EM radiation given of from astronomical objects - http://science.hq.nasa.gov/kids/imagers/ems/uv.html
- Nice article on gamma rays - http://imagine.gsfc.nasa.gov/science/toolbox/gamma_ray_astronomy1.html

Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany second minute topics in the dome video

Hot and Energetic Universe – The Sun

Glossary

Prominence – A solar prominence (also known as a filament) is a large, bright arc of plasma extending outward from the Sun's surface. It flows along the Sun's strong magnetic field lines. Sometimes they can erupt sending the plasma out into space in what is known as a Coronal Mass Ejection or CME.

Plasma – a hot gas of electrically charged hydrogen and helium.

Sun Spots – dark, cool regions on the photosphere. They are dark because they are colder than the surrounding regions. They are caused by interactions with the Sun's magnetic field and occur over regions of intense magnetic activity.

Solar Flares – a large explosion due to the sudden release of magnetic energy that has built up in the solar atmosphere due to twisted magnetic field lines crossing and reconnecting. Explodes with a force greater than millions of hydrogen bombs

Solar Wind – Stream of rapidly moving charged particles from the corona. Due to the extremely high temperature of the corona, the Sun's gravity cannot hold on to it.

Key Questions

- The video refers to an "active sun", first what do we know about the Sun?
  - Main thing is it is a STAR not a PLANET
  - It is made up of gas, mainly Hydrogen (70%) and Helium (28%)
  - Has defined layers
    - The inner layers - Core, Radiative Zone and Convection Zone.
    - The outer layers - Photosphere, Chromosphere, Transition Region and Corona.
  - Has a magnetic field
  - It is a Yellow Dwarf Star – it will eventually expand and become a red giant, before dying to become a white dwarf.
  - It is 4.5 billion years old and has about 5 billion years left before it dies
- Why do we say it is active?
  - There are many processes that the Sun undergoes for it to be referred to as an 'active star'
    - Prominences
    - Sun Spots
    - Solar Flares
    - Solar Wind
- What colour is the Sun?
  - Red? Yellow? Maybe Orange? This is the colour that we see it most represented as but in fact it is WHITE. We see it appear as the other colours mostly at sunrise and sunset and this is due to the Earth's atmosphere and the scattering of light. (See link below)

Additional ideas, activities and web links

Activities

- Life and death of stars – http://chandra.harvard.edu/resources/flash/stellar_evolution.html
- NASA Space Maths - http://spacemath.gsfc.nasa.gov/sun.html

Web Links

- Stellar evolution - http://astronomy.swin.edu.au/cosmos/S/stellar+evolution
- Missions Supporting the Study of the Sun-Earth Connection - http://www.nasa.gov/mission_pages/sunearth/missions/index.html
- Sun's layers - http://www.thesuntoday.org/the-sun/solar-structure/
- Why the sun appears Red at sunset – http://www.optics4kids.org/home/content/what-is-optics/scattering/why-is-the-sky-blue-why-are-sunsets-red/
- Sun Facts - http://space-facts.com/the-sun/
- Great video and explanation from NASA of prominence - https://www.nasa.gov/mission_pages/sunearth/news/News022411-monsterprom.htmlhttps://www.nasa.gov/mission_pages/sunearth/news/News022411-monsterprom.html

Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany third minute topics in the dome video

Hot and Energetic Universe – Quasars, Blazars and Radio Galaxies (Active Galactic Nuclei AGN)

Glossary

Accretion disc - An accretion disc is a flat, disc-like structure of gas that rapidly spirals around a larger object

Radio Waves - an electromagnetic wave with a frequency between about 10^4 and 10^{11} or 10^{12} Hz

Key Questions

- What is a quasar?
  - A quasar or a quasi-stellar radio source is an accretion disc surrounding a supper massive black hole. The strong pull of its gravity attracts other objects and gas towards it to fuel its disc. When these objects get sucked into the black hole, there is a massive collision of material which causes an enormous output explosion of radiation energy and light. This explosion is seen as a jet or flare and is a distinct characteristic of quasars.
  - It is very energetic and one of the most distant objects that is part of a family called Active Galactic Nuclei (AGN).
  - They emit radio, light and X-ray waves and are the brightest objects in our universe.
  - They only live in galaxies with supermassive black holes (see black hole notes).
  - They are very old – When we see objects in space, we are essentially looking back in time as the light from objects travels so far to reach us. As quasars are the most distant objects we know, we are looking back through time some 10 – 15 billion years ago. The further away they are, the further back in time astronomers are looking.
  - They are called quasi-stellar as through a telescope they look like small stars.

- Ok so what is the difference between a Quasar, Blazar and a Radio galaxy?
  - Essentially it is how the supermassive black hole with its accretion disc and jets is looked upon from here on Earth:
    - Jets perpendicular to our view it is radio galaxy.
    - Jets at an angle, it is a quasar.
    - Jets looking straight on, it is a blazar.

Additional ideas, activities and web links

Additional Ideas and Activities

- Quasars
  - Nice article that goes a bit more in depth - http://www.space.com/17262-quasar-definition.html
  - Simpler explanation of a quasar - http://www.kidsastronomy.com/quasar.htm
  - A nice set of questions and answers - http://www.phys.vt.edu/~jhs/faq/quasars.html
- Quasars, Blazars and Radio Galaxies
  - Nice article with a bit more depth - http://www.universetoday.com/73222/what-is-a quasar/
  - Nice article just on blazars - http://www.universetoday.com/30594/blazars/
  - Radio Galaxies – 2 nice blog articles with more in depth background to the nature of radio galaxies:
    - https://blog.galaxyzoo.org/2014/02/03/the-curious-lives-of-radio-galaxies-part-one/
    - https://blog.galaxyzoo.org/2014/02/04/the-curious-lives-of-radio-galaxies-part-two/

Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany third minute topics in the dome video

Hot and Energetic Universe – Pulsars

Glossary

Magnetosphere – this is the region of space surrounding an astronomical object in which the magnetic field of that object controls charged particles.

Electromagnetic wave - An electromagnetic wave is a transverse wave that has both an electric field and magnetic field. The two fields are perpendicular (at right angles) to each other as well as to the direction of travel of the wave.

Key Questions

- What exactly is a pulsar?
    - A pulsar is a rotating very magnetic neutron star which pulses because it rotates. Its behaviour is analogous to that of a lighthouse. Although the beam of light from a lighthouse is constant, ships out a sea see a pulse of light because the light is rotating.
- So what is a neutron star?
    - A neutron star is the result when a massive star ends it life in a supernova explosion (see separate sheet for supernova explanation). It becomes a very small star with a lot of mass contained within it. It also increases its spin speed. All stars rotate but as they get smaller there rotation increase just like an ice skater when they pull their arms in close, they speed up.
- So what exactly is this pulse?
    - Although we see it as a pulse it isn't really, it is a stream of radio waves that travel along the axis of the magnetic field as it rotates with the neutron star. As the neutron stars magnetic field and its rotational field are not exactly aligned this causes the pulse effect that we observe. Hence we see a pulse, once every rotation which leads to the pulse appearance.
- How is the pulse created?
    - The beam originates from the rotational energy of the neutron star, the spinning magnetic field generates an electric field. The region above the surface of the pulsar that is dominated by the magnetic field is called the magnetosphere. In this region, charged particles (protons and electrons) are accelerated by the strong electric field and thus create an electromagnetic beam. Any time charged particles are accelerated they radiate light.

Additional ideas, activities and web links

Additional Ideas and Activities

Web Links

- Pulsar - http://imagine.gsfc.nasa.gov/science/objects/pulsars1.html
- Nice explanation can be found here - http://www.universetoday.com/25376/pulsars/
- Good video description – more in depth science
https://www.youtube.com/watch?v=2LyWfBt6cxk
- More in depth physics of a pulsar
    - http://www.cv.nrao.edu/course/astr534/Pulsars.html
    - http://www.astrophysicsspectator.com/topics/degeneracy/NeutronStarPulsarLight.html

Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany second minute topics in the dome video

Hot and Energetic Universe – Black Holes

Glossary

Speed of Light – 'unit c' = $3x10^8$ ms^{-1} equivalent to $6.71x10^8$ mph

Accretion disc - An accretion disc is a flat, disc-like structure of gas that rapidly spirals around a larger object

Key Questions

- What is a Black hole?
  - You would describe it as a region of space that has such a strong gravitational effect, that nothing can escape from it, not even light.
- How do you get a black hole?
  - Super massive stars die to become black holes. Once they have burned up all of their nuclear fuel, they expand before collapsing in on themselves.
- There are two common types: Stellar-mass and supermassive black holes.
  - Stellar-mass are created when massive stars explode, the mass of the black hole left behind is the mass of a few suns.
  - Supermassive black holes are in the center of galaxies and their mass is the equivalent of millions or even billions of suns.
- The event horizon, what's that?
  - When people talk about black holes they will commonly talk about the "event horizon", this is the point of no return. By which once you reach this point you will never be able to escape from the black hole.
- If black holes are black, how do astronomers see and find them?
  - You cannot really see a black hole, as it is black, but what you can see is the swirl of material known as the accretion disc around it. This also gives off radiation that allows astronomers to detect the black holes. As objects are falling in, they heat up and give off radiation. They are also detected by the gravitational effects they have on objects and light nearby.

Additional ideas, activities and web links

Activities

- Speed of Light (for comparison)
  - It would take you 1.26 seconds to get from the Earth to the Moon travelling at the speed of light
  - Car going at 60mph would take just under 6 months
  - Boeing 747 at 600mph ~ 16 days
  - Walking at 3mph ~ 478 million steps, so walking non-stop 9 years
- You can purchase some good posters which display the timelines for the life of all the different types of stars, when searching look up stellar evolution.

Web Links

- Life and Death of Stars:
  - nice simple explanation http://www.nasa.gov/audience/forstudents/9-12/features/stellar_evol_feat_912.html
  - More in depth - http://astronomy.swin.edu.au/cosmos/S/stellar+evolution
  - More detailed - http://www2.le.ac.uk/departments/physics/research/xroa/astronomical-facilities-1/educational-guide/copy_of_stars/stellar-evolution
- 10 facts about black holes - http://www.universetoday.com/46687/black-hole-facts/
- Some nice analogies to use from this article on black holes http://www.kidsastronomy.com/black_hole.htm

Integrated Activities in the High Energy Astrophysics Domain (AHEAD)

Notes and activities to accompany first minute topics in the dome video

Observing the Cosmos outside of our planet

Glossary

Twinkling – (Scientific name – stellar scintillations) is due to the light from a star being distorted due to thermal turbulences of the air in the Earth's atmosphere.

Orbit - a regular, repeating elliptical path that one object in space takes around another one.

Lagrange Point – This is a point between the Sun and the Earth by which their gravitational effects are equal. It means a satellite placed here can maintain its position with both the Sun and the Earth. At the L_2 point, the same effect happens but it is the 'night' side of the Earth where the position is.

Heliocentric Orbit – An orbit in which the sun is at the center. All planets, comets, and asteroids in the Solar System are in this type of orbit.

Key Questions

- Sometimes we need to use telescopes that are above the Earth's atmosphere known as space telescopes or space based observatories, why might this be? – Three main reasons:
  - The Earth's atmosphere means we do not have a clear view to distant astronomical objects in space (why stars twinkle)
  - The atmosphere blocks out Infrared, UV , X-rays and Gamma rays that can also be observed and tell us more about the features of astronomical objects (see separate sheet)
  - Light pollution.

- Space Based observatories generally come in two types:
  - Ones that map the entire sky (surveys)
  - Observatories which focus on selected astronomical objects or parts of the sky.

- What sort of orbit or position are space based observatories?
  - Earth Orbit – Medium (between 2,000 kilometers (1,243 miles) and 36,000 kilometers (23,000 miles) above the Earth's surface) and Low (between 160 kilometers (100 miles) and 2,000 kilometers (1,240 miles) above the Earth's surface).
  - Sun - Earth L_2 Lagrange Point
  - Heliocentric Orbit

Additional ideas, activities and web links

Activities

- Some of the more well know space observatories also have paper models that you can print off, cut and stick together to produce a replica. Here are a few:
  - https://science.nasa.gov/kids/the-universe/universe-spacecraft-paper-models/
  - http://spacecraftkits.com/free.html

Web Links

- NASA's Great Observatories - http://www.nasa.gov/audience/forstudents/postsecondary/features/F_NASA_Great_Observatories_PS.html
- Comprehensive list of space-based observatories with links - https://www.ras.org.uk/education-and-careers/for-university-students/133-space-based-observatories
- Lagrange L_2 point – A good easy to follow explanation - http://www.esa.int/Our_Activities/Operations/What_are_Lagrange_points