Twinkle, Twinkle Little Star, How Can I Work Out What You Are?

Key Stage 4 Programme – 2016-2017

Teacher Name: Dr Heil

Pupil Name_____

Timetable and Assignment Submission

Fill this in with your teacher.

Timetable – Tutorials

Tutorial	Date	Time	Location
1			
2			
3			
4			
5			
6			

Timetable – Homework Assignments

Homework Assignment	Description	Due Date
Tutorial 1		
Tutorial 2		
Tutorial 3		
Tutorial 4		
Tutorial 5		

Assignment Submission – Lateness and Plagiarism

Lateness	
Submission after 4.00pm on	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

KS4 Programme 2016-17 – Pupil Feedback Report

Grade	Marks	What this means
1st	70+	Performing to an excellent standard at A-Level
2:1	60-69	Performing to a good standard at A-Level
2:2	50-59	Performing to an excellent standard at current key stage
3rd	40-49	Performing to a good standard at current key stage
Working towards a pass	0-39	Performing below a good standard at current key stage
Did not submit	DNS	No assignment received by The Brilliant Club

Lateness	
Any lateness	10 marks deducted
Plagiarism	
Some plagiarism	10 marks deducted
Moderate plagiarism	20 marks deducted
Extreme plagiarism	Automatic fail

Name of RIS Teacher			
Title of Assignment			
Name of Pupil			
Name of School			
ORIGINAL MARK / 100		**FINAL MARK / 100**	
DEDUCTED MARKS		**FINAL GRADE**	

If marks have been deducted (e.g. late submission, plagiarism) the teacher should give an explanation in this section:

Learning Feedback Comment 1 - *Communication*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 2 – *Research*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Learning Feedback Comment 3 – *Logic and Reasoning*	
What you did in relation to this Key Learning Priority *Enter feedback here*	**How you could improve in the future** *Enter feedback here*
Resilience Comment	
How you showed learning resilience during the course *Enter feedback here*	**How you could build learning resilience in the future** *Enter feedback here*

Example

Contents

Course Rationale Page 5
Course Map Page 6
Mark Scheme Page 7
Glossary of Keywords Page 8
Tutorial 1 Page 9
- Astronomical Objects Page 10
- Tutorial 1 Homework – Baseline Test Page 11

Tutorial 2 Page 12
- Photon Absorption Page 13
- Tutorial 2 Homework Page 13

Tutorial 3 Page 14
- Calculating Black-Body Peaks Page 15
- Tutorial 3 Homework Page 17

Tutorial 4 Page 18
- Extrinsic Variability Task Page 18
- Intrinsic Variability Task Page 20
- Tutorial 4 Homework Page 21

Tutorial 5 Page 22
- Case study: M82 X-2 Page 22
- Tutorial 5 Homework – Final Assignment Page 24

Appendix 1: Referencing Page 25
Appendix 2: University Application Guidance Page 26

Course Rationale

Despite great leaps forward in the technology powering astronomical observations, we are still not capable of making direct pictures of most of the points of light in our sky. Yet astronomers can very confidently state that this one is a star, but this is a black hole. How can astronomers state these things so confidently? This course will explain the methods used to figure out what each object observed by astronomers is.

Pupils will gain an understanding of how observing light from across the whole Electromagnetic Spectrum allows astronomers to build a broader picture of each astronomical object. They will learn what methods can be applied to analyse data from these objects and finally begin to think about the future of astronomy. In the process of doing this, pupils will develop key skills such as how to structure essays and communicate in a scientific fashion. They will also learn how to research new topics, developing their own independent learning - a vital skill for their futures.

Initially we will build on students' current understanding of the Electromagnetic (EM) Spectrum, introducing the concept of light as particles which have specific energies. We will emphasise how this Spectrum can be explained in terms of both wavelength and energy, which will naturally lead on to understanding how astronomical objects which are more energetic (such as neutron stars) emit higher energy light in the form of X or even gamma-rays. We will then move on to looking at how this light is detected, explaining how the Earth's atmosphere affects our ability to see certain radiation. From this we will look at how this leads to observatories being sited on very specific points across the globe, or even in space. Once this concept is fully understood we will then explore how the light from astronomical objects differs. This will lead to students building a full picture of basic astronomical analysis and a greater understanding of why astronomers think they can classify what they see. Finally, we will look to the future. Exploring missions and telescopes which the next generation of astronomers will work with and why these represent great leaps forward for astronomy.

Course Map

How do Astronomical objects look across the electromagnetic spectrum?
How can we use all the information to identify what an object is?
How do we detect all forms of light?
Twinkle, Twinkle little star, how can we work out what you are?
How does the light from astronomical objects change over time?
What do Energy Spectra look like for different objects?

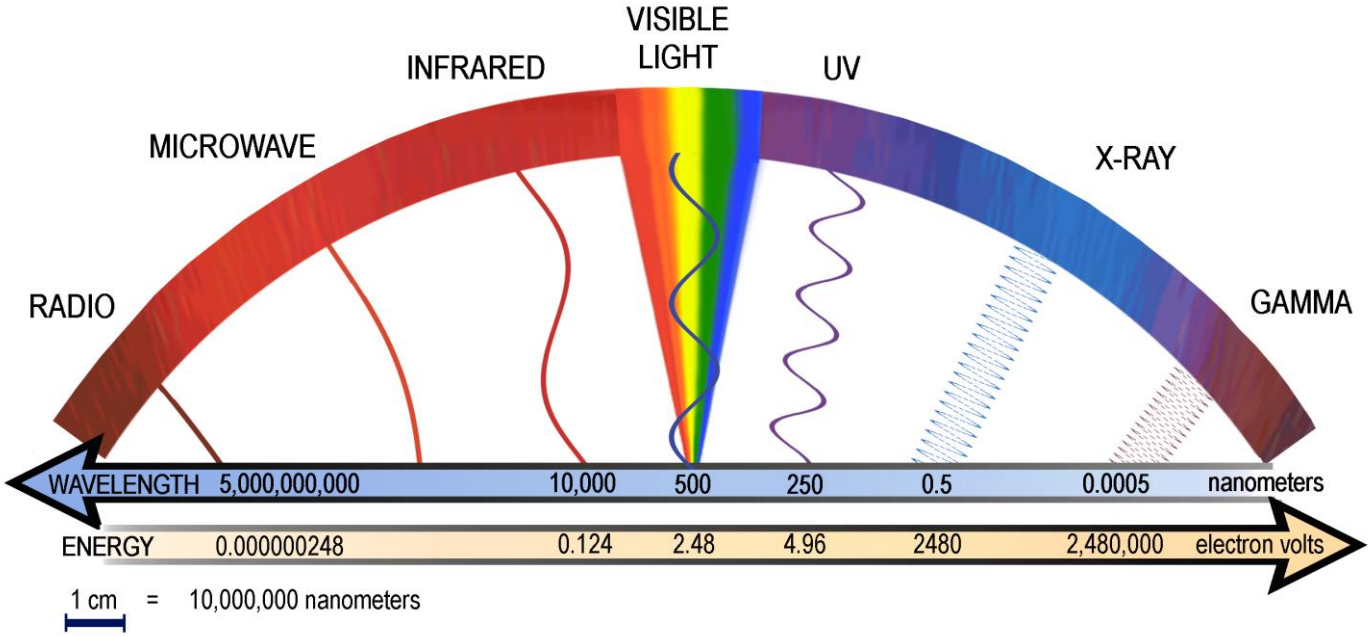
Mark Scheme

Key Skill	1st	2.2
Communication	☐ Well structured essay which flows well ☐ Excellent use of scientific terminology ☐ Consistent and confident use of language ☐ Points clearly defined and well made ☐ Essay is referenced with suitable sources	☐ Essay shows some attempt at structure ☐ Some use of scientific terminology correctly ☐ Clear use of language ☐ Some points made in a clear and concise manner ☐ Some references included
Research	☐ Careful research into new telescopes, astronomical objects and astronomical processes has been done with good use of a number of suitable sources ☐ New concepts have been identified, understood and an attempt has been made to explain them ☐ Images and plots have been included with good attempts made to explain their significance ☐ A clear explanation of the scientific advantages of the new telescope is given, with reference to previous science	☐ Some new research into the new telescope is included from a few sources ☐ An attempt has been made to explain new concepts ☐ Images are included with some explanation given ☐ Some advantages of the new telescope are given
Logic and Reasoning	☐ A good attempt has been made to support all conclusions using valid scientific reasoning ☐ Links are made between the characteristics of varied pieces of data ☐ Decisions have been made which draw on a range of background knowledge, including their own research into astronomical objects and processes	☐ Some attempt has been made to provide supporting evidence for reasoning ☐ Some links are made between pieces of information ☐ Some new background knowledge of astronomical objects has been used appropriately

Glossary of Keywords

Word	Definition	In a sentence…
Photon	A single particle of light, it can have different energies depending on how it is created.	Using a detector we can measure photons coming from the astronomical object.
Absorption	When a photon is absorbed by an atom it is called absorption.	A solar spectrum contains absorption lines.

Tutorial 1 – How does light have different energy?



Reference: NASA

Today's Key Question(s):

- Question 1 - What is a photon and how does its energy place it within the electromagnetic spectrum?
- Question 2 - Why are some astronomical objects more energetic than others?

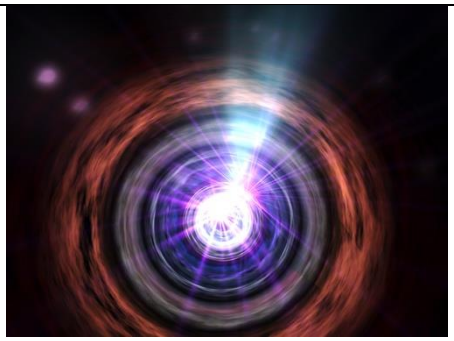
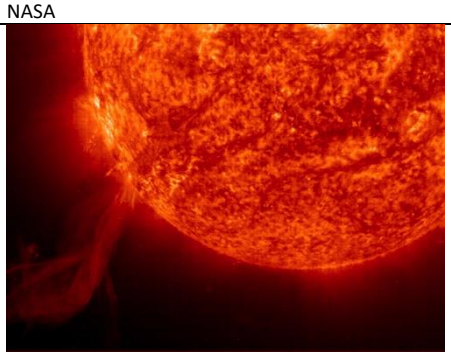
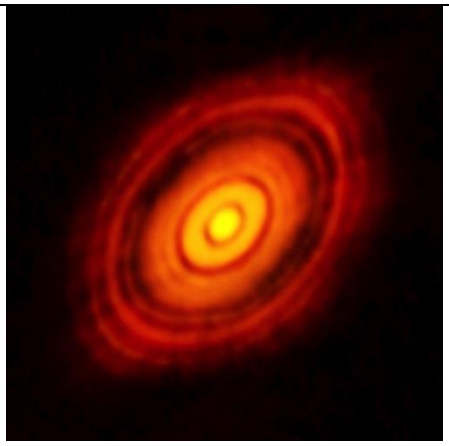
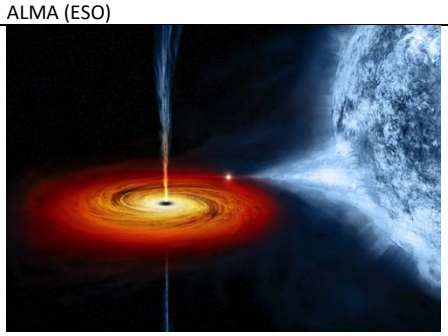
What is the Purpose of Tutorial 1?

- Objective 1 - Light is electromagnetic radiation
- Objective 2 - Photons have both a wavelength and an energy
- Objective 3 - Astronomical Objects emit light from across the electromagnetic spectrum
- Objective 4 - Learning about some common Astronomical Objects

Astronomical Objects:

Here are 5 astronomical objects. From reading the short paragraph about each object identify which part of the electromagnetic spectrum they emit the most light in and give a short explanation for your answer. You might like to start by placing them in order of how energetic the light they emit is. Draw on our discussion about the images on: http://www.chromoscope.net

Object Name	Object Image	Description	Order Of Heat	Main electromagnetic emission
Emission Nebula	Hubble Space Telescope (NASA)	Emission nebulae are large regions of gas in space. They can be the birthplace of hot, massive stars which then release high energy photons, continually heating up the gas in the nebulae. They are constantly energised by light from the stars, but are still only around 3000 Kelvin and can also contain denser clouds of dust.		

Blazar	 NASA	Blazars are a type of supermassive black hole. In these objects we are looking directly down a jet of extremely hot, energetic gas which is being propelled directly in our direction. Due to an effect called relativistic beaming, these appear to be some of the most energetic objects we ever observe in the sky.		
The Sun	 SOHO (NASA)	Stars like our sun are dense balls of hot gas and dust undergoing nuclear fusion. The Sun is a fairly average star, which will remain stable for up to 9 million years. It has a 22 year magnetic cycle due to strong magnetic fields running through the core. It is fairly cool with a peak temperature of around 5777 Kelvin		
Proto-planetary Disc	 ALMA (ESO)	Proto-planetary discs form around young stars. They are made of gas and dust and are relatively cool, only their inner parts have temperatures up to 1000 Kelvin. These are the discs from which planets are formed.		
Stellar-Mass Black Hole	 NASA/CSC/M.Weiss	Stellar-mass black holes are the remnants of massive dead stars. They are regions of space where gravity is so strong that nothing, not even light, can escape. We can see them when they are eating, stealing material from a nearby star which forms an accretion disc around the black hole. The centre of this disc, closest to the black hole, is extremely hot losing lots of radiation into the surrounding space.		

Homework 1 – Baseline Test

The homework assignment for the first tutorial is a baseline test to see your initial level of attainment in this subject area. The assignment will test for some or all of the subject specific skills that are required later in the final assignment. However, it is shorter than the final assignment and is will be an introduction to the subject as well as a challenge!

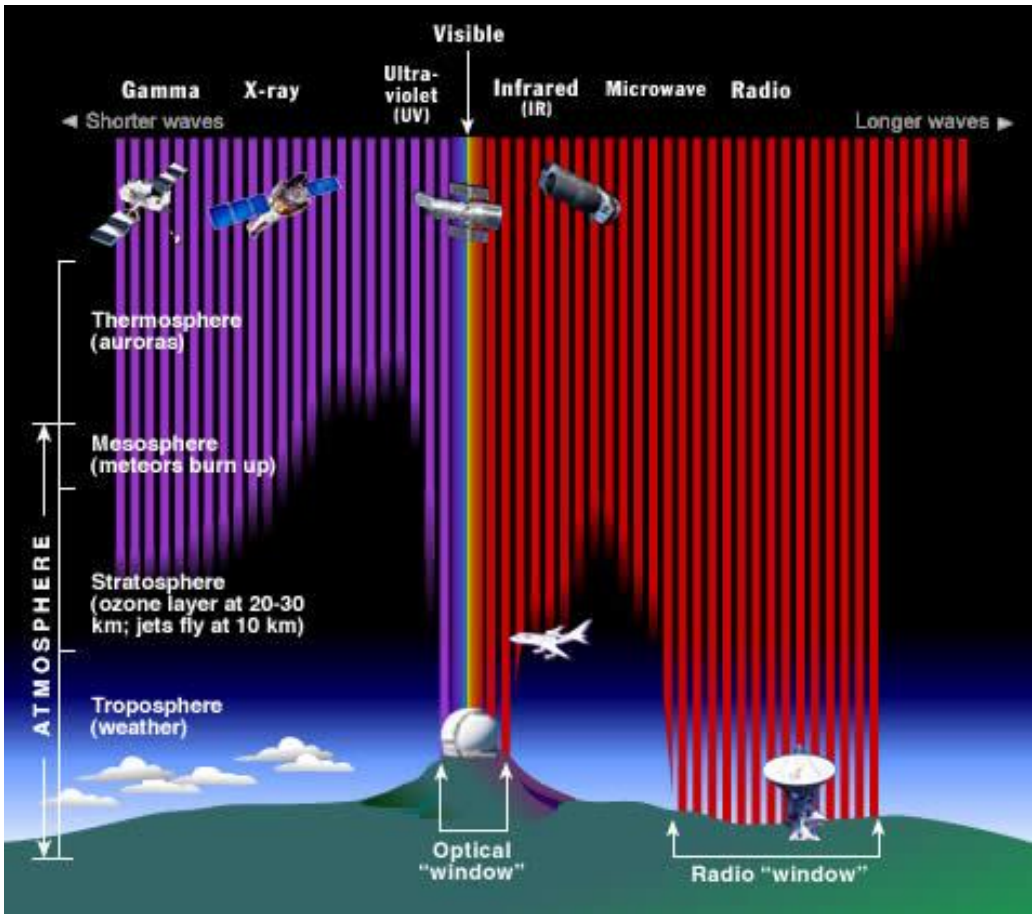
Do not worry too much about doing 'well' or 'badly' on the baseline test, it takes into account the fact that you may not be familiar with the subject area. It is designed to help you and your PhD tutor identify where you are at the start of the programme and to help you measure your progress along the way.

Question 1. Here is an electromagnetic spectrum with some parts missing, label the missing parts and for all sections give an example wavelength **and energy** range. Then give an example of how the radiation from each part of the spectrum is used (not necessarily in astronomy). Give references where necessary.

Question 2. We have discussed how different astronomical objects emit light at different wavelengths/energies. Take these four objects and say where in the electromagnetic spectrum most of their light is emitted. Think about how **energetic** the object is and what sort of telescope is used to detect it. Add these objects to your Electromagnetic Spectrum. Give references where you have used them.

Object List: Active Galactic Nuclei, Massive B-type Star, Brown Dwarf Star, Pulsar

Tutorial 2 – Different Telescopes in Different Places



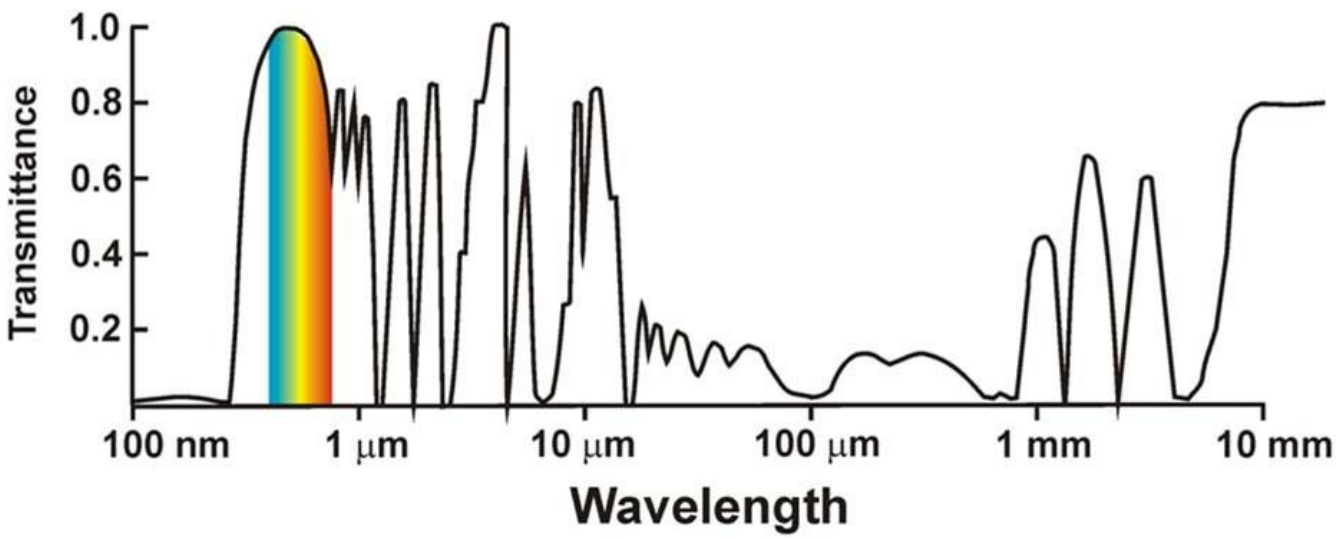
NASA

Today's Key Question(s):

- Question 1 - How can we detect different types of electromagnetic radiation?
- Question 2 - What do different telescopes look like?
- Question 3 - Why are different telescopes in different places?

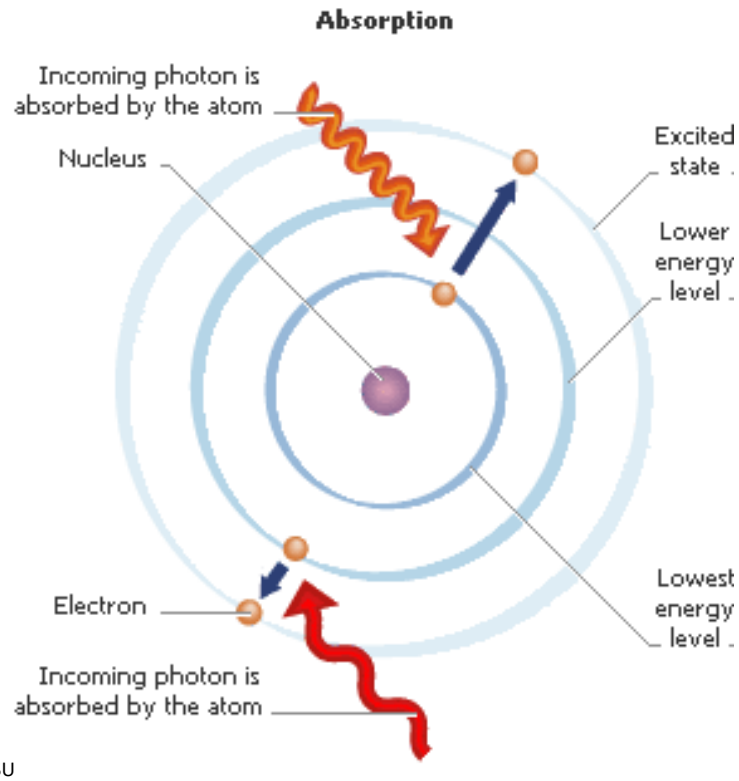
What is the Purpose of Tutorial 2?

- Objective 1 - To understand that we have to use different types of telescope to detect different types of astronomical object
- Objective 2 - That the distance photons with different energies penetrate into the atmosphere differs
- Objective 3 - That the Earth's atmosphere can both help and hinder astronomy at different wavelengths



Humboldt

Photon Absorption:



Credit: MSU

Photons with particular energies can be **absorbed** by atoms.

When a photon is absorbed the energy goes into the electrons in the atom, **exciting** them to **higher energy levels**.

The Earth's atmosphere contains the following gases:

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

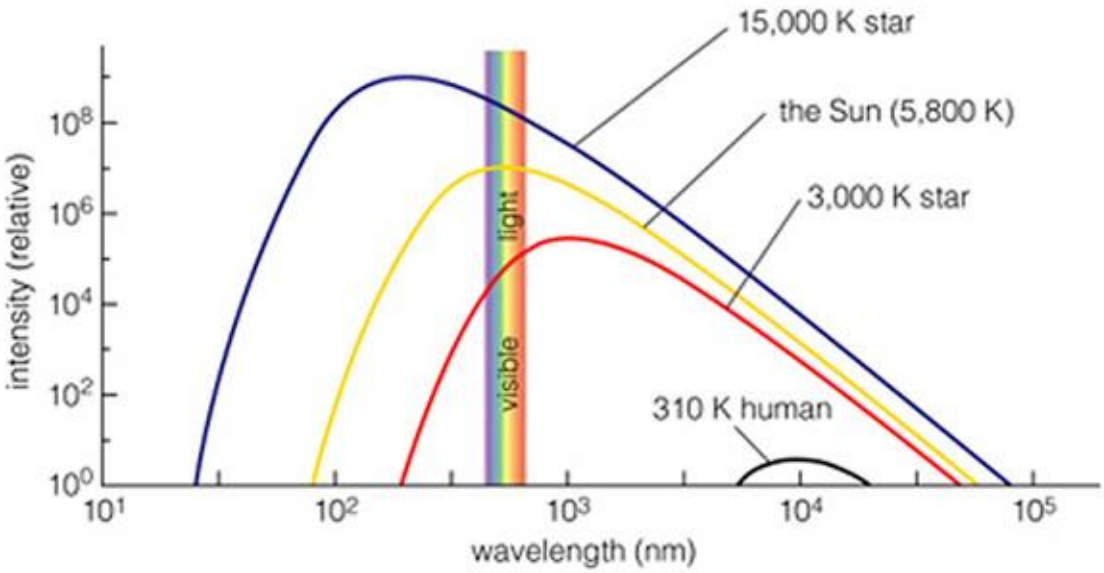
Along with: _____

These different gases absorb photons at a range of different wavelengths/energies. As a result not all electromagnetic radiation at all wavelengths reaches the surface of the Earth. For this reason we have to put telescopes in different positions depending on what wavelength or energy of electromagnetic radiation we want to observe.

Today's Homework is:

- Pick five different telescopes in a range of wavebands (radio to gamma-ray). Investigate where they are sited – either where on the earth or where in space. Write a short paragraph on each telescope explaining the reasoning behind their location.
- Is there are part of the electromagnetic spectrum which astronomers find it very difficult to observe in? Investigate this and write a brief paragraph explaining some problems faced by astronomers and where they originate

Tutorial 3 – What is an Energy Spectrum



Today's Key Question(s):

- Question 1 - What is an Energy spectrum?
- Question 2 - Why does it look different for different objects?
- Question 3 - What are some common energy spectral shapes and why do they look like that?

What is the Purpose of Tutorial 3?

- Objective 1 - To understand what an energy spectrum is and how it is calculated
- Objective 2 - To understand what a Black Body is; what its energy spectrum looks like; and what objects emit light like a black body
- Objective 3 - To understand what a power-law is; what the energy spectrum looks like; and what objects emit light like a power-law
- Objective 4 - To gain a basic understanding of emission and absorption lines

What is an Energy Spectra?

An Energy Spectra shows how many photons of each energy are arriving at the detector from the astronomical object. By building up a histogram of the number of photons, astronomers can create a spectrum of light from the source.

Some Typical Spectral Shapes

We see a range of different shapes of energy spectra from astronomical objects, but there are a few typical ones which we see repeatedly, and sometimes in combination, from many different objects. We will look at two if these in this tutorial and then discuss some features of energy spectra in more detail.

Blackbody Spectra

If something absorbs all of the radiation that falls on it and then re-emits it, then the object is called a black body. There is a rule called Wien's displacement law which links what photon energy or wavelength the black body energy spectrum peaks at to the temperature of the black body, this is shown below:

$$T = \frac{2.9 \times 10^{-3}}{\lambda_{max}}$$

If you average all of the electromagnetic radiation from a human being and make a spectrum out of it then the spectrum will approximately look like a black body. Some astronomical objects which look like black bodies include Stars and Black Holes.

Task:

Calculate the peak wavelength for these objects which emit as black bodies:

1. A Human

_____

_____

2. A Toaster

_____

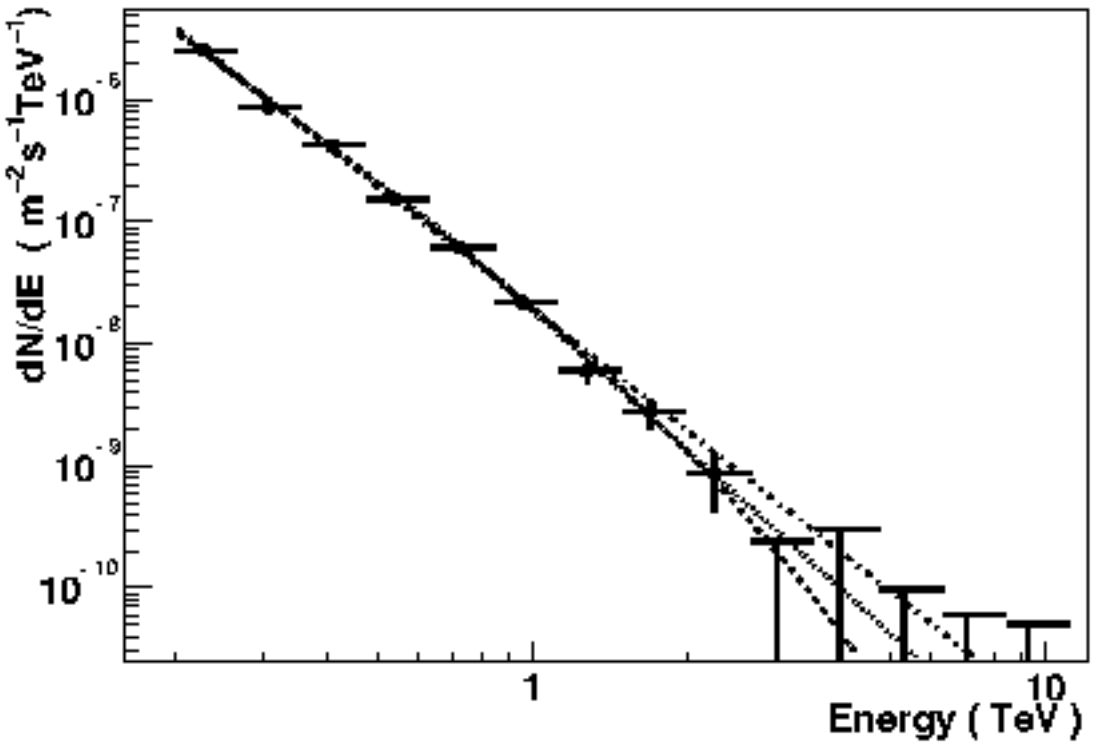
_____

3. An iPad

_____

_____

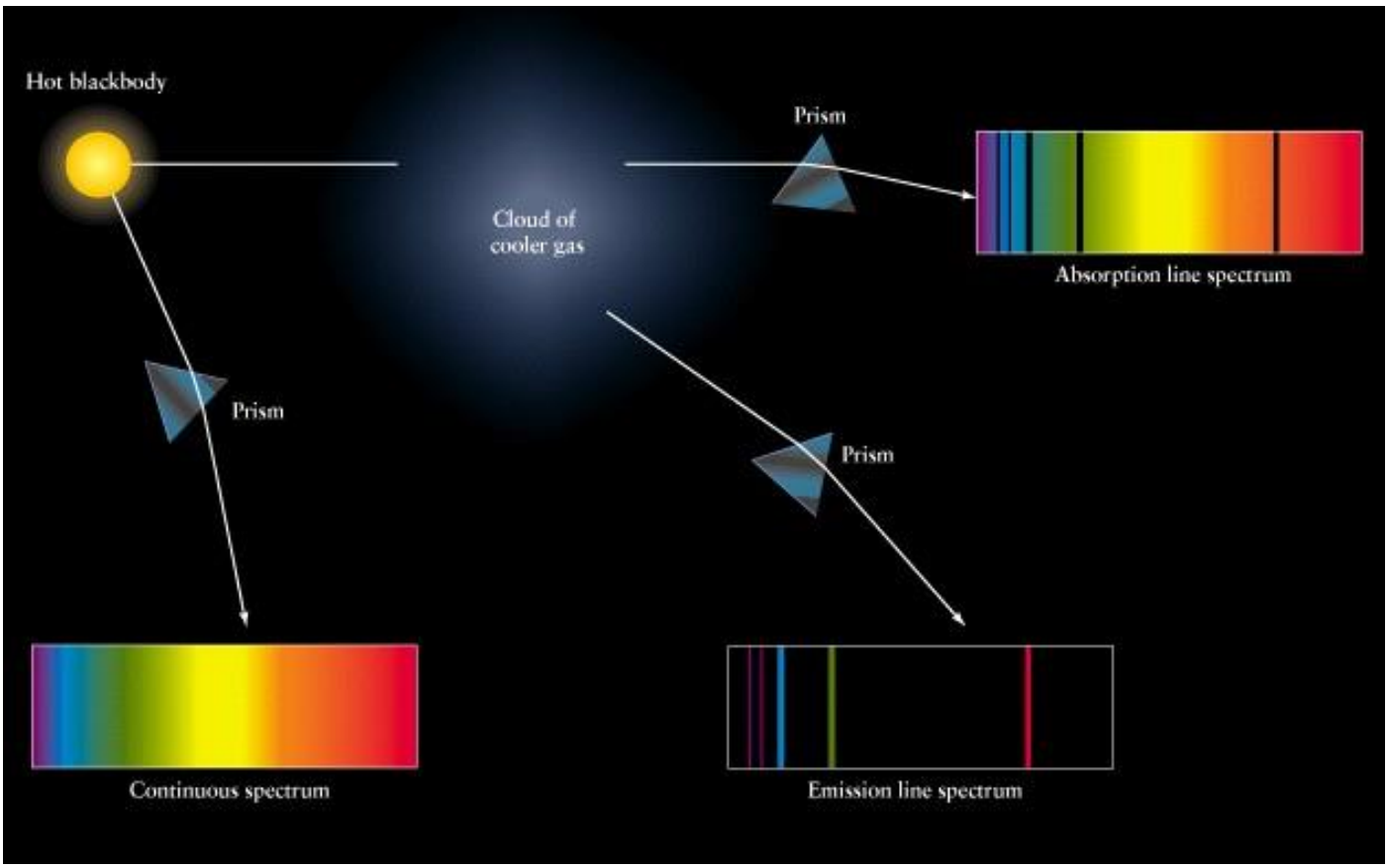
Power Law Spectra



HESS – PKS 2155-310

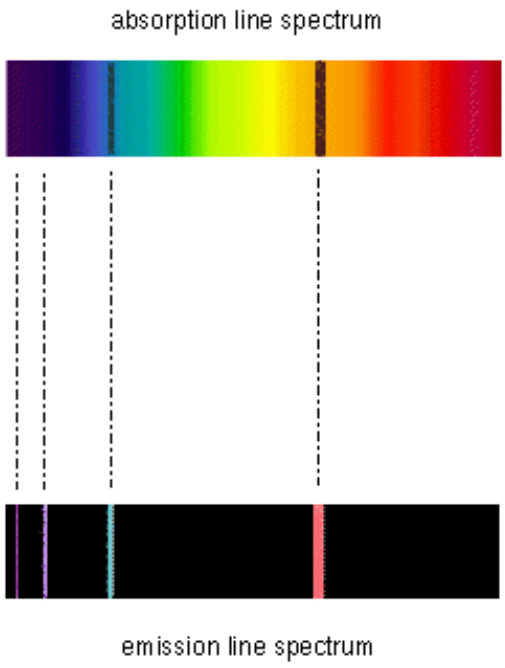
If an object emits radiation in one line when you plot the spectrum on a logarithmic scale then the object emits as a power law. Astronomical objects which emit like power laws include pulsars, and Active Galactic Nuclei (AGN).

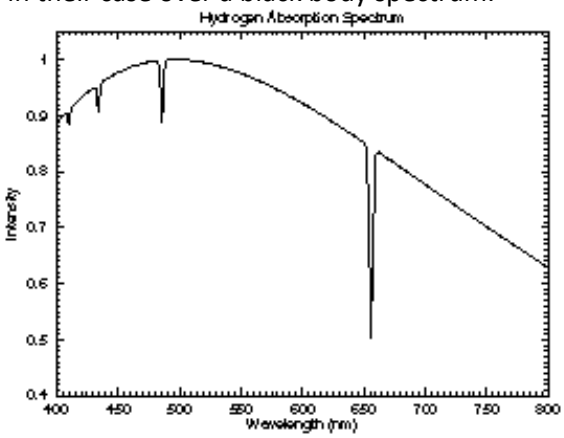
Absorption and Emission Lines

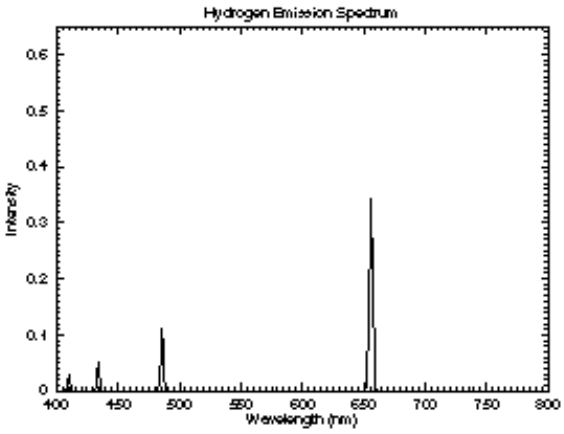


psu.edu

Just like in the Earth's atmosphere, clouds of cold gas in space, or even in the astronomical object itself can absorb some radiation and stop it reaching us at Earth. Particular atoms absorb specific energies of light, this makes lines called absorption lines in the energy spectra of the star. If the gas is hotter, the atoms will emit the energy they absorb, creating a strong line in the energy spectra where a lot of light is present in a small area. Stars in particular feature many absorption and emission lines, in their case over a black body spectrum.







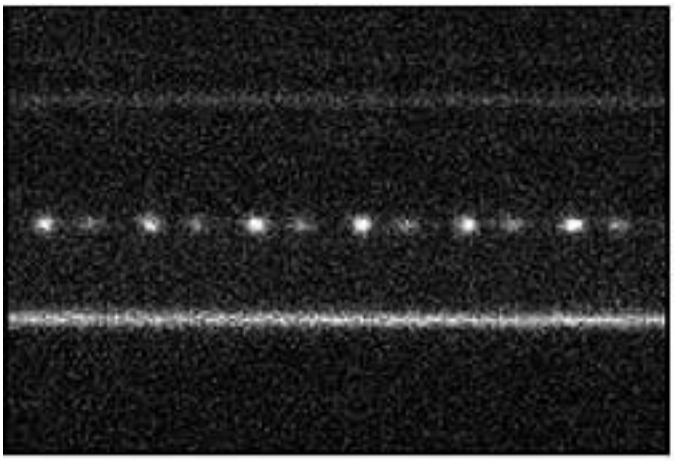
This image is courtesy of Nick Strobel at www.astronomynotes.com

Today's Homework is:

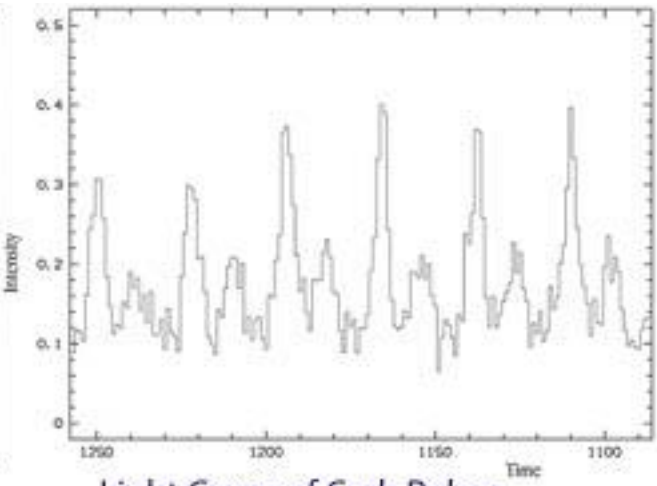
- Investigate the energy spectra of the following objects. Use your newfound knowledge of some basic energy spectra to explain why they look how they do.
- Look up the term synchrotron radiation. Write a paragraph explaining how it occurs and what its spectra looks like. Which of these objects include some synchrotron radiation?

The objects are: Protoplanetary disc, G-type star, Black hole X-ray Binary and Emission Nebula.

Tutorial 4 – How and why do Astronomical Objects Vary?



Time Sequence of Crab Pulsar



Light Curve of Crab Pulsar

(VLT KUEYEN + FORS2 + FIERA) © ESO

Today's Key Question(s):

- Question 1 - Why does electromagnetic radiation from astronomical objects change over time?
- Question 2 - Why does it look different for different objects?
- Question 3 - What are some common types of variability and what do they look like?

What is the Purpose of Tutorial 3?

- Objective 1 - To explore the three main types of variability we observe from astronomical objects
- Objective 2 - To understand what extrinsic variability is and what causes it
- Objective 3 – To understand what intrinsic deterministic variability is and what causes it
- Objective 4 - To understand what stochastic variability is and what it looks like

How does light from astronomical objects vary?

The electromagnetic radiation from some astronomical objects changes over time. Why and how they change depends on the type of object it is. We look at variability using a light curve. This is just a plot of the amount of electromagnetic radiation from the object against the time the observation was taken. There are three main types of variability and part of our job as astronomers is to figure out which is present in our astronomical source. These types of variability are:

Extrinsic: Something outside the source is causing it to vary

Intrinsic and deterministic: Something inside the source is causing it to vary in a predictable or at least understandable way

Intrinsic and stochastic: The source itself is varying randomly but with some sort of pattern (this is a very difficult idea to understand!).

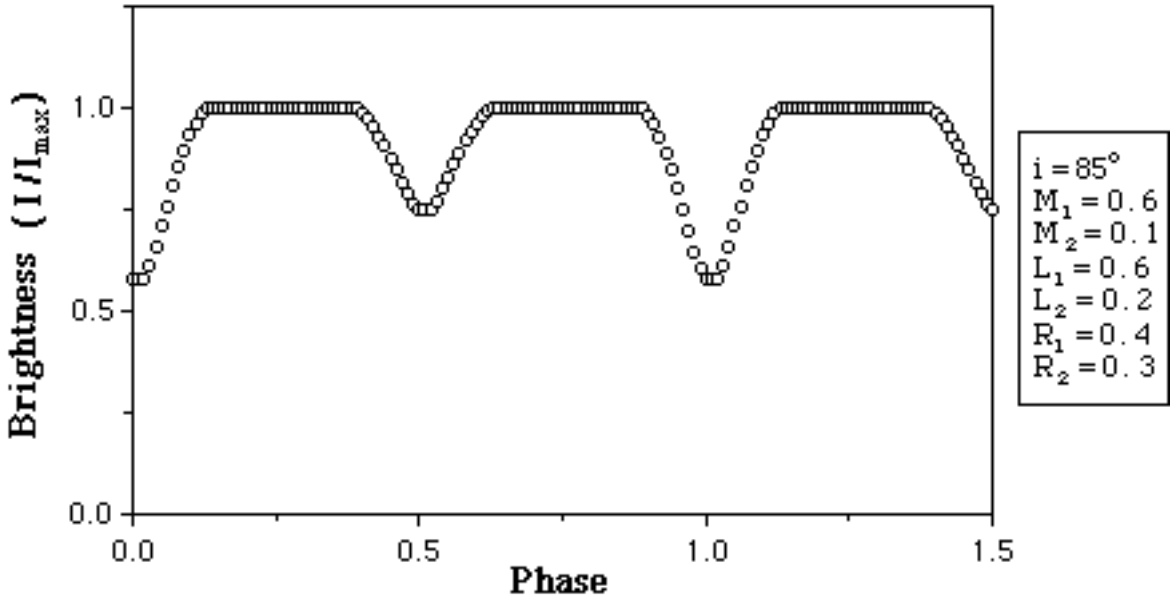
Extrinsic Variability

Extrinsic variability can be caused by a range of different things, from clouds of gas close to the object to something along our line of sight unrelated to the object we are observing, to a planet which is orbiting the star. In order to figure out what is going on, astronomers create complex simulations and then try to reproduce the light curves we see, often they use additional information from energy spectra or from other objects near the source.

In the example below we see a simulated light curve of a planet passing in front of a star. Think about why the brightness does not drop all the way to zero. Write an answer below:

_____

_____

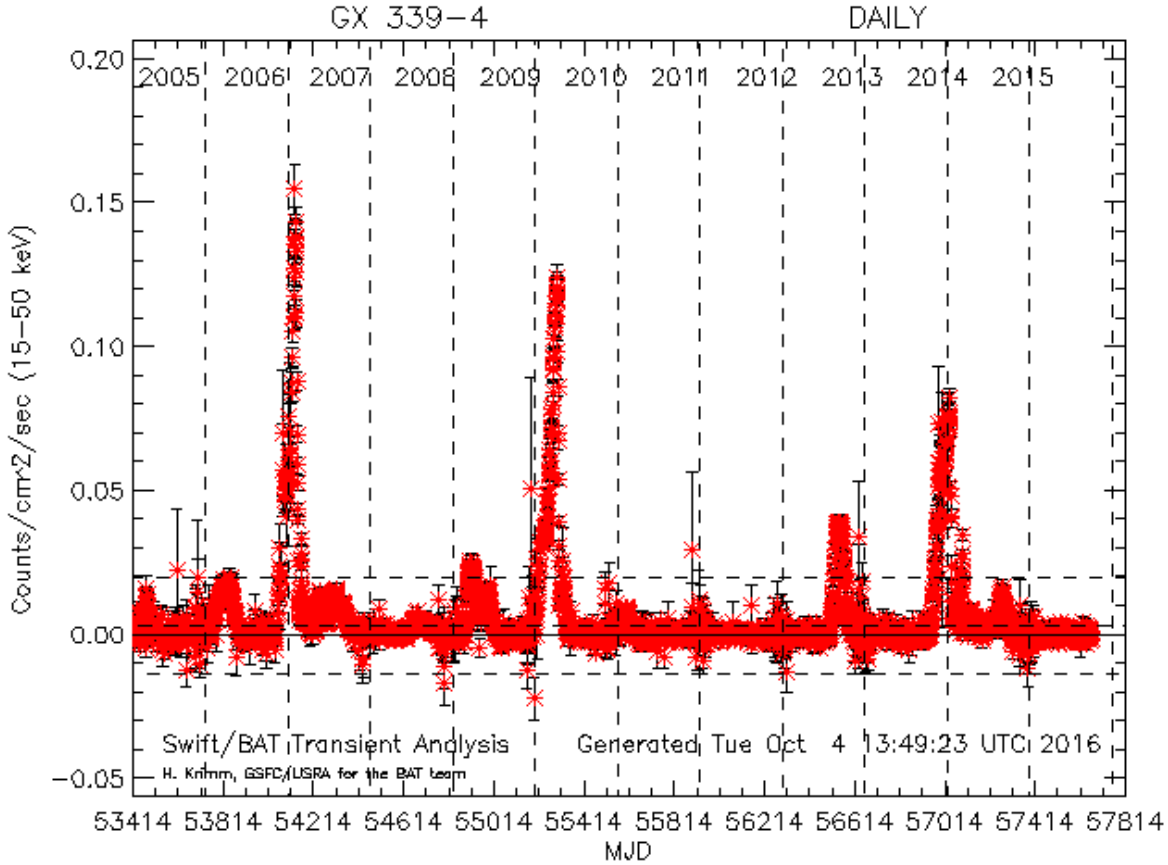


BASIC simulation

Intrinsic Deterministic Variability

This variability is intrinsic to the source, but is typically predictable in some way. One example would be pulsations from a pulsar. Pulsars are rotating very fast and often their magnetic poles do not match up with the axis they rotate around (this is similar to the earth) their magnetic poles glow and as they rotate we see them very briefly as a flash of light before they disappear again. Because of the rotation this flash of light appears in the sky very regularly and so we get a periodic light curve. Look at the light curve of the crab pulsar at the start of this section, can you see how it relates to the change in brightness?

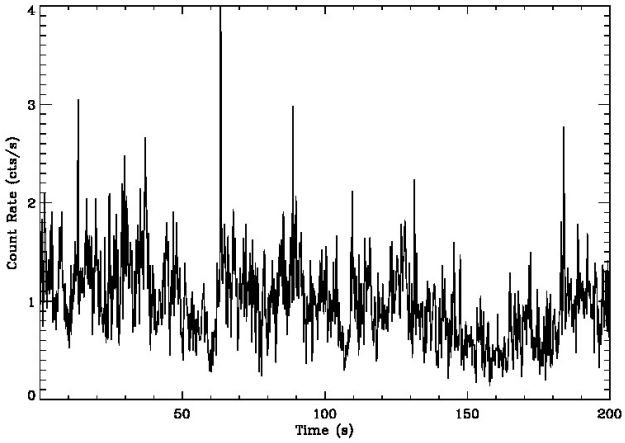
SWIFT/BAT
mission lightcurve
GX 339-4

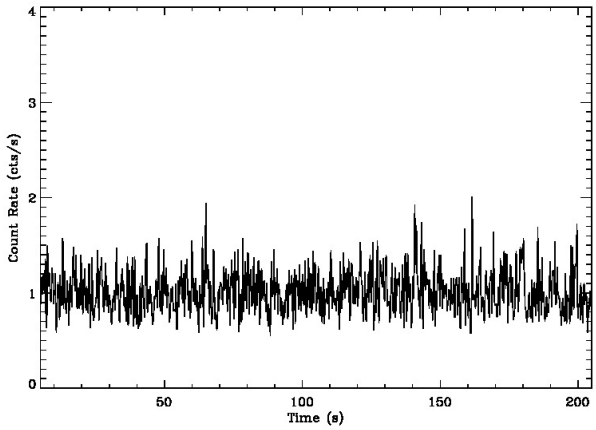


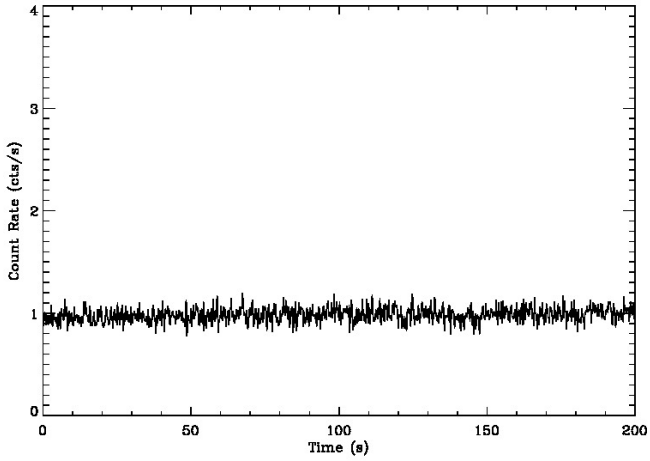
We can also have types of deterministic variability which are harder to predict. One example would be looking at lightcurves from black hole X-ray binaries which have been taken over many years. In these lightcurves we see that there are points when they get much brighter, astronomers call this going into outburst. This sort of variability is considered deterministic as the rise and fall is fairly predictable and caused by major events close to the black hole, although the exact length of the outburst changes over time.

Intrinsic Stochastic Variability

The final type of variability we need to consider is complex and hard to understand. It is random variability and looks just like what many scientists would call noise, lots of flickering with no apparent purpose. However, different formation processes can make this noise look very different, so even though it is random there is an underlying pattern. This sort of variability can be seen in all sorts of places both in and outside astronomy. In astronomy it can be found in the light from stars; supermassive and stellar mass black holes; and in pulsars and other neutron stars. It can look very different when you observe the same object at different times.







These three images show random stochastic variability with three different underlying causes. All three of them are different observations of the same black hole X-ray binary GX 339-4. Understanding why this light changes so much is a very difficult, complicated problem and astronomers are only just beginning to grasp why it occurs.
Write down the 3 main differences you can see between these stochastic lightcurves. Think about the amount of variability and also what time scale it is happening on.

1. _____

_____

2. _____

_____

3. _____

_____

Today's Homework is:

Draft Final Assignment:

Choose a telescope which will either be built or launched in the next 20 years to be the subject of your final essay. Pick one which interests you as you will need to write a 1000 word essay on it.

You will need to identify what types of object it is expected to look at and what sort of astronomical analysis this telescope will do. Be clear on which parts of the electromagnetic spectrum it will be observing in.

When you have chosen your telescope and done some research on it write a draft structure for your essay, we will discuss this structure in the next tutorial so try to write a good draft. Remember that it will need to consist of an Introduction, a central Discussion and a Conclusion.

Tutorial 5 – Fitting Everything Together

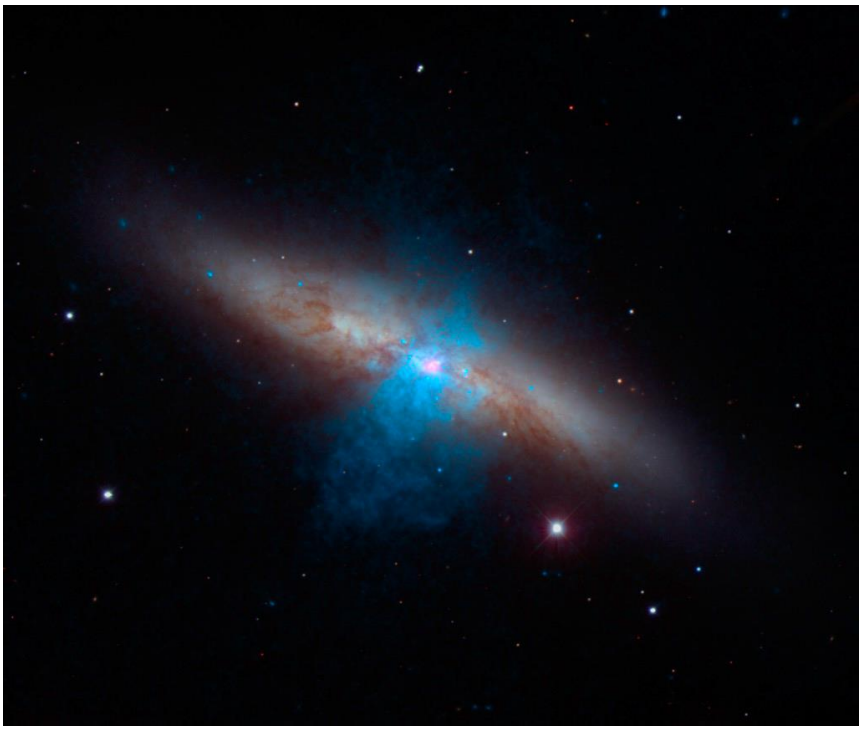
Today's Key Question(s):

- Question 1 - How do astronomers fit everything together to figure out what an object is?
- Question 2 - What information can we use to strengthen our object identification?
- Question 3 - What is the future for this type of astronomy?

What is the Purpose of Tutorial 5?

- Objective 1 - To look at a case study for one particular object
- Objective 2 - To understand that we need lots of different types of evidence to correctly identify an object
- Objective 3 – To explain that we still do not understand all of the emission from some objects.

How can we identify an object? – The strange case of M82 X-2

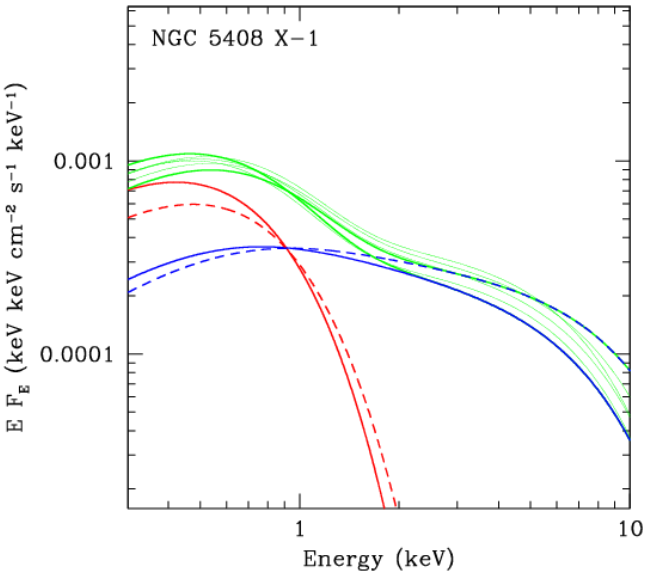


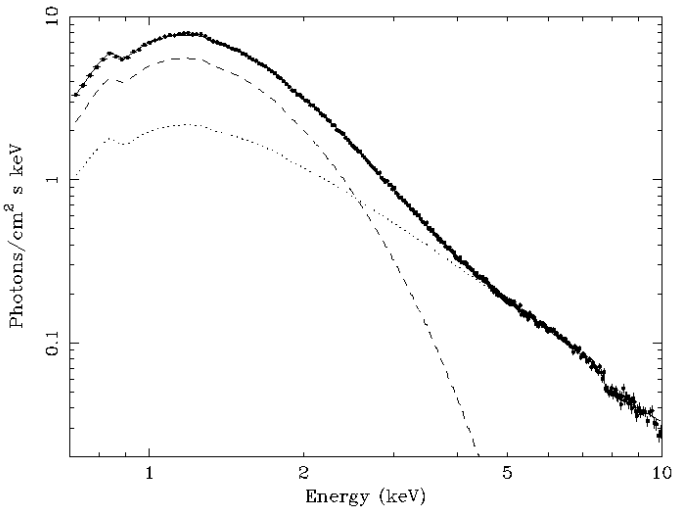
M82, seen here in optical and X-ray emission, is a starburst galaxy. Where new stars are being made continually. As a result, it is very bright in the X-ray part of the electromagnetic spectrum with a lot of emission from hot gas across the centre of the galaxy. We do see some individual sources however and two of these belong to a group of objects which are known to be very strange.

Ultraluminous X-ray Sources

Ultraluminous X-ray Sources (or ULXs) are astronomical objects which have mystified astronomers for twenty years. They look a lot like stellar mass black holes, the energy spectra seemed to change in a similar way and the light curves also look like they might be the same. Unfortunately, they are all found in other galaxies, so to telescopes here on Earth they look very faint. When we might get thousands of photons landing on the telescope

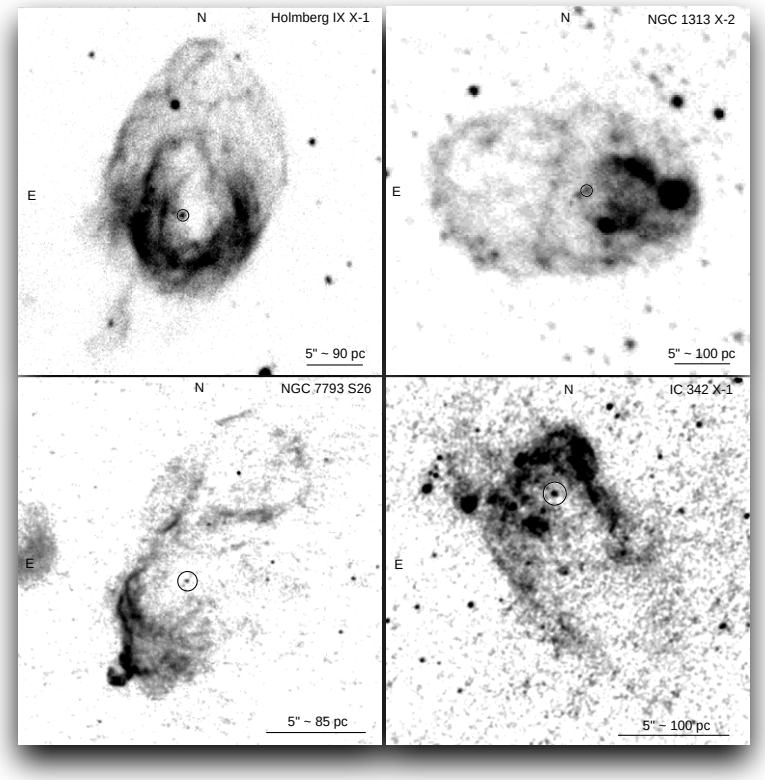
detector in one second for black holes in our own Galaxy, we might only get one every second from a ULX. Even though we do not see many photons from these objects, what we do know is that if there was one in our own Galaxy it would be much brighter or more luminous than any stellar mass black holes. For this reason, astronomers originally thought that ULXs were bigger black holes than usual. There were some hints from the energy spectra that this might be the case.





The blackbody from the ULX spectra peaked at lower energies than the blackbody from stellar mass black holes, making it look cooler and therefore suggesting that the black hole was bigger. The problem was two-fold: no-one was sure how these big black holes would form, but they also did not know how normal black holes could shine so brightly. Astronomers needed more information to tell what these strange objects really were.

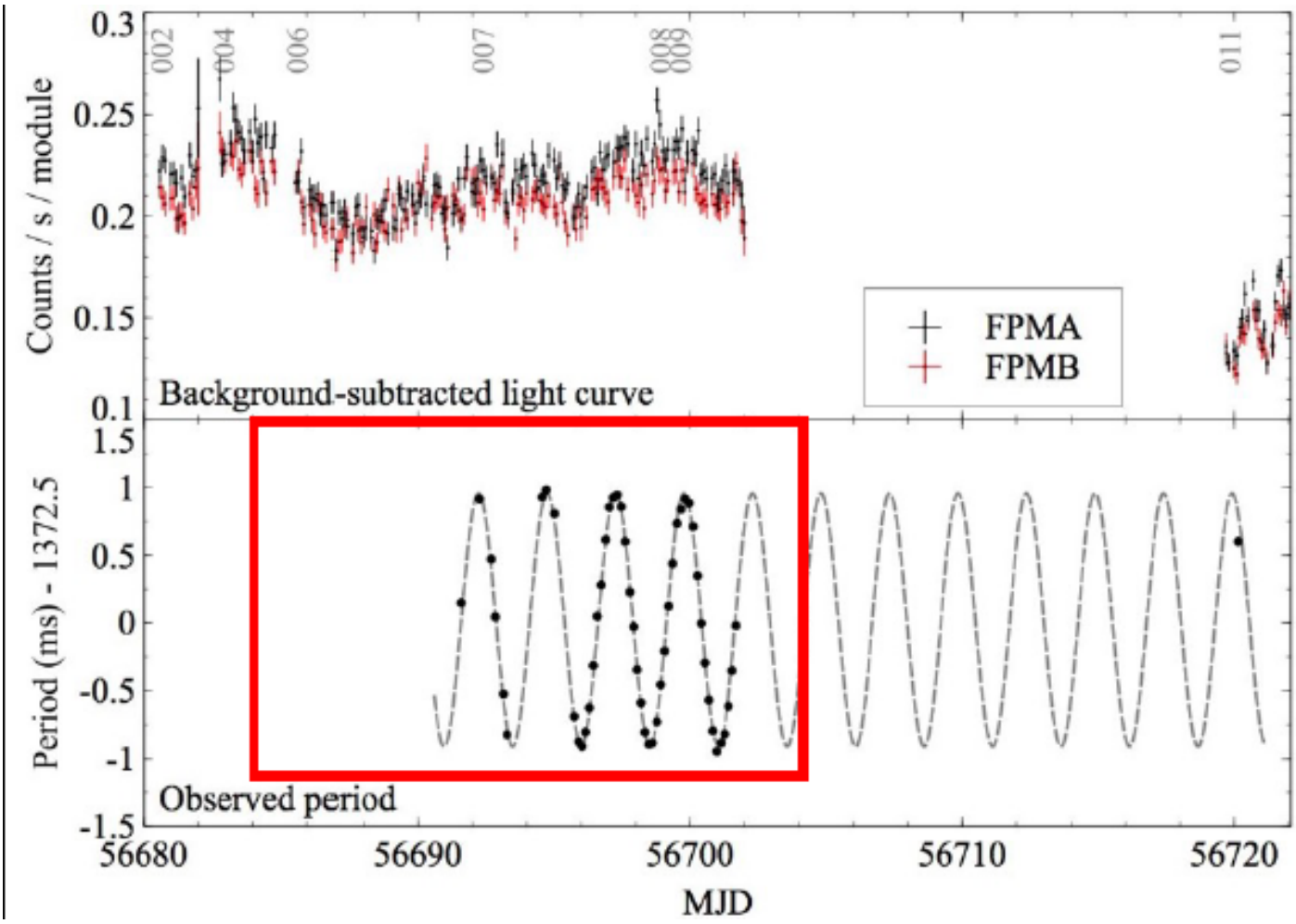
From looking at other energy ranges, such as the optical, astronomers saw that these objects often formed in areas where new stars were rapidly forming and in spiral galaxies. They also found that ULXs sometimes sat in the centre of bubbles of gas, which could be seen in the Radio, Optical and UV. These bubbles suggested that the objects at the centre were pushing out a large amount of energy into the surroundings.



Radio emission from the same position as the X-ray object, also indicated that there were strong jets being emitted by the central source. These are commonly seen from black holes and neutron stars.

Astronomers also looked at the variability from these objects. As they are in distant galaxies, so the number of photons we receive is quite low, it was hard to get much information from the variability. But some people suggested that it did look like intrinsic stochastic variability, again similar to that seen from black holes or neutron stars.

It was assumed that little further could be found out about these mysterious objects until bigger telescopes were built which could collect more electromagnetic radiation. This was until one relatively new telescope (NuSTAR) happened to look at the galaxy M82, not to study the ULXs but to look at a new supernova which had recently exploded. The two brightest ULXs in M82 also happened to be in the telescope's field of view (the part of the sky that the telescope can see at any one time) so the astrophysicists decided to study these objects too. When they looked at the variability in the light curve from the ULXs, they found something very unexpected: a strict periodic signal – this meant that one of these objects could not be a black hole but had to be a neutron star, an astronomical object which was even lighter than any stellar-mass black hole.



Astrophysicists are now trying to work out how ULXs appear to be so bright to us here on earth as the object is much smaller than they first thought. This case study is a really interesting look into how astronomers steadily gather information about a mysterious object in order to finally figure out what it is.

Today's Homework is: Final Assignment

- Choose a telescope which is either under construction or will be built/launched in the next few years. Write a mini essay (at least 1000 words) on this new telescope explaining why it is a big leap forward for astronomy. Explain what it is built to observe and how it will observe these objects. Make sure to explain any challenges involved in building it and why its final location is important for the science the telescope will carry out. This essay should include images and plots which are referred in the text

The Deadline is:

Tutorial 6 – Feedback

What is the Purpose of Tutorial 6?

- Reflect on skills learned on the programme with a view to encouraging resilience
- Receive feedback on final assignment

What are the key questions?

- What strengths have I demonstrated in my work and what areas of development are there left for me to address?
- What steps do I need to take to improve my academic output?

Activity 1 – Marking your own

Using the mark scheme, identify three things you did well and three things you could improve.

What went well?

1.

2.

3.

What could be improved?

1.

2.

3.

Activity 2 – Responding to feedback

Read through your feedback sheet and highlight on your assignment where you received positive feedback (one colour) and areas for improvement (different colour). You might find it helpful to annotate this with a brief comment or two.

Activity 3 – Looking Forwards: Think, Pair Share

1. Think about how you can use this feedback in your future school work.
2. Talk to your partner about how you both plan to make changes to your school work in the future as result of this feedback
3. Share your ideas as a group.

Appendix 1 – Referencing correctly

When you get to university, you will need to include references in the assignments that you write, so we would like you to start getting into the habit of referencing in your Brilliant Club assignment. This is really important, because it will help you to avoid plagiarism. Plagiarism is when you take someone else's work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. In order to avoid losing marks in your final assignment, or even failing, you must be careful to reference your sources correctly.

What is a reference?

A reference is just a note in your assignment which says if you have referred to or been influenced by another source such as book, website or article. For example, if you use the internet to research a particular subject, and you want to include a specific piece of information from this website, you will need to reference it.

Why should I reference?

Referencing is important in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps to prevent you losing marks, or failing, due to plagiarism.

When should I use a reference?

You should use a reference when you:

- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

How do I reference?

There are a number of different ways of referencing, and these often vary depending on what subject you are studying. The most important to thing is to be consistent. This means that you need to stick to the same system throughout your whole assignment. Here is a basic system of referencing that you can use, which consists of the following two parts:

A marker in your assignment: After you have used a reference in your assignment (you have read something and included it in your work as a quote, or re-written it your own words) you should mark this is in your text with a number, e.g. [1]. The next time you use a reference you should use the next number, e.g. [2].

Bibliography: This is just a list of the references you have used in your assignment. In the bibliography, you list your references by the numbers you have used, and include as much information as you have about the reference. The list below gives what should be included for different sources.

Websites – Author (if possible), title of the web page, website address, [date you accessed it, in square brackets].

E.g. Dan Snow, 'How did so many soldiers survive the trenches?', http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [11 July 2014].

Books – Author, date published, title of book (in italics), pages where the information came from.

E.g. S. Dubner and S. Levitt, (2006) *Freakonomics*, 7-9.

Articles – Author, 'title of the article' (with quotation marks), *where the article comes from* (newspaper, journal etc.), date of the article.

E.g. Maev Kennedy, 'The lights to go out across the UK to mark First World War's centenary', *Guardian*, 10 July 2014.

Appendix 2 – University Applications Guidance

For course choices and careers information:	www.brightknowledge.org.uk
For information and statistics on universities and course:	www.unistats.direct.gov.uk
For comprehensive information on universities, including rankings:	www.thecompleteuniversityguide.co.uk

PLEASE NOTE – The Researchers in Schools programme is designed to support the university applications process at your school. The work you complete for the programme should add to your schoolwork rather than detract from it. Please be aware of deadlines and try to manage your workload appropriately. If you are worried about the programme interfering with your schoolwork then please speak to your teacher.

Subject Specific Top Tips for Strengthening an application?

The best tip I can give students who want to study Physics or Astrophysics at university is to take Physics **and** Maths at A-level. It would also be an advantage to do some form of computer programming.

You might also like to consider applying for a Nuffield bursary in the summer before applying for university: http://www.nuffieldfoundation.org/nuffield-research-placements