

Investigating particle fluxes with an imaging detector

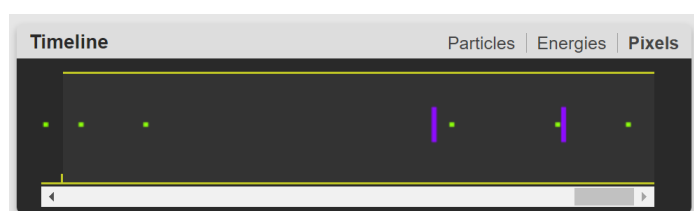
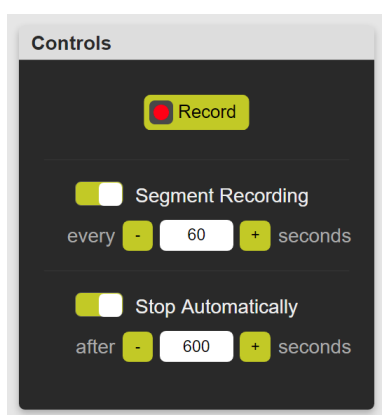
Instructions for Activity C.42 Task (d)

1. You have previously looked at the two Particle Cameras and determined *qualitatively* (by eye) which had the higher count rate. You now know that one detector is only detecting background (from cosmic rays for example) and that the other has a “uranium marble” in front of it. The detector with the uranium marble will also be detecting background as well as any alphas, betas, gammas and muons coming from the marble.

You may have noted that the particle interactions happen randomly in time, sometimes with many particle hits in a short space of time and sometimes with a longer period between hits. We will now look *quantitatively* at the count rates (in events per minute) to determine the count rate of events from the uranium marble alone by subtracting the background count rate. This is similar in many ways to what you would need to do in a space mission to determine the signal from a star or galaxy, i.e. remove the background counts that are not from the star or galaxy but are instead from cosmic rays or a diffuse optical background.

We will start by collecting data from the Particle Camera *without* the uranium marble, i.e. finding the background count rate.

We can do this using the “Record” function. In the “Controls” panel (top right), turn on “Segment Recording” and set it to “every 60 seconds”. Also turn on “Stop Automatically” and set this to “after 600 seconds”. Now hit the “Record” button. You will see your 10 images or segments (each with 60 seconds of integration) build up in the “Timeline” panel. Wait for your 10 images to finish before moving on to step 2. Note that it will take 600 seconds (10 minutes) to record your images, so while the events are being recording, you may wish to revise what you have studied already about uncertainties in Activity C.40 task (a), specifically in section 1.8.2 and 1.8.3 of *An Introduction to Astrophysics and Cosmology by Andrew Norton (2016)* which you have studied within that activity.



Note that there is a scroll-bar at the bottom of the Timeline panel so that you can scroll through and select any of your segments.

2. Making sure that “Show Particles” is turned on, in the “Timeline” panel click on the first segment. This will show the related image in the “Particle Data” panel. Count the number of each particle-type and record them in a spreadsheet. You may find the “Analysis” panel useful to give the number of each particle-type in each segment. Add rows to your table for the remaining nine images.

Analysis		
	Particles	Energies
Particle	Segment	Total
Alpha	0	0
Beta	2	38
Gamma	5	60
Muon	0	0
Unknown	0	14

3. Calculate the mean rate (in counts per minute) for detection of each particle-type.
4. Now calculate the standard deviation (the “random uncertainty”) for each particle-type, either using equations 1.12 to 1.14 in the document *An Introduction to Astrophysics and Cosmology by Andrew Norton (2016)* or using the built-in features of your spreadsheet software. As the number of images used to calculate the standard deviation increases, the standard deviation will tend towards the square root of the mean number of particle counts per image. This is because you are observing randomly occurring events, as described in *An Introduction to Astrophysics and Cosmology by Andrew Norton (2016)*. You might be able to see this effect by calculating the standard deviation with a larger or smaller number of images (but do not worry if your specific data set contains too few images to demonstrate this trend).
5. Switch to the other Particle Camera and repeat steps 1 to 4 such that you have mean count rates and uncertainties for each particle type with the two detectors independently.
6. Calculate the count rate for each particle type in **counts per second** for particles that are being emitted by the uranium marble only. To do this, you will need to subtract the background count rate from the detector without the uranium marble from the count rate of the detector with the uranium marble, as well as converting the rate to *counts per second* from *counts per minute*. What is the uncertainty on the count rate from the uranium marble alone for each particle type? Notes that may help with this calculation can be found at the end of this document. For which particle types can you say that there is a significant (3-sigma) increase in the count rate (i.e. for which particle types does the count rate increase by more than 3 times the uncertainty) and for which particle types can you see no significant change?
7. We have used this example as an analogy to detecting signal from a star or galaxy and needing to subtract the background signal. In the experiment, our background count rate is quite small compared to that from the uranium marble. For the case of a space mission such as *Gaia*, think about what would happen if the background count rate (and the related uncertainty) was higher. How would this affect the uncertainty in the measurements that you would make of the signal from any stars or galaxies? Can you see why the design of a space telescope would include methods to minimise the background signal getting to the detectors?

Notes

We will use the notation from section 1.8.5 of *An Introduction to Astrophysics and Cosmology* by Andrew Norton (2016).

To calculate the count rate from the uranium marble only in **counts per second** we can take the first part of equation 1.19, with X being the number of counts per second from the uranium marble (the number we are trying to calculate), A being the number of counts per minute from one detector (with background and the uranium marble), B being the number of counts per second from the other detector (with background only), and with j and k being $1/60$ (to convert from “per minute” to “per second”).

We can then take the second equation in 1.19 to calculate the uncertainty δX in the number of counts from the uranium marble in counts per second, where δA and δB are the uncertainties that you calculated in steps 1 to 5 and with j and k again being $1/60$.

Reference

An Introduction to Astrophysics and Cosmology by Andrew Norton (2016). (Note that this is available under the Resources tab of the S818 website.)