Gamma-Ray Astronomy

Gamma rays are the most energetic radiation in the universe and we study them to explore the most exotic and extreme processes and physical conditions. Objects that emit gamma rays include supernova remnants (the remains of stars that exploded at the end of their life), active galactic nuclei (supermassive black holes at the centers of galaxies that are accreting matter to produce jets thousands of light years long) and potentially even dark matter (an unidentified type of matter comprising approximately 27% of the mass and energy in the observable universe). In fact, this emission offers the only direct probe of the extreme conditions in these exciting phenomena.

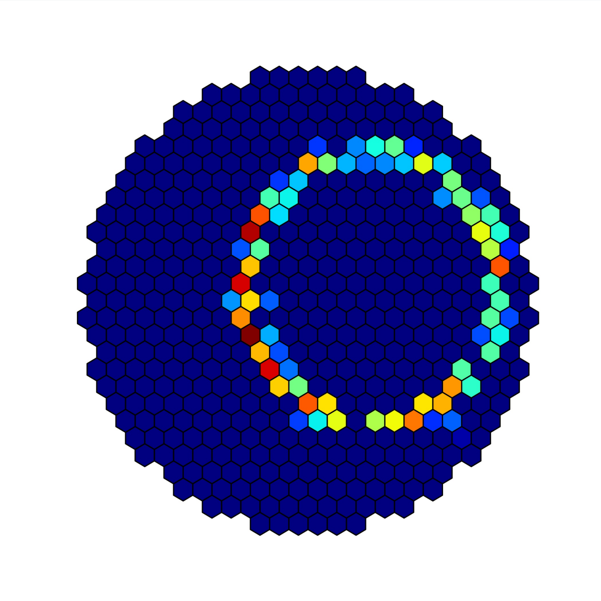
VERITAS is an array of telescopes designed to detect the very highest energy gamma-rays (>1×10^{11} eV (that is 100,000,000,000 eV), roughly equivalent to the energy of a small fly in flight carried by a single photon!) through their interaction with the Earth's atmosphere. The gamma-rays produce a shower of particles that travel through the atmosphere, emitting Cherenkov light which is then detected by our large (12-m diameter) telescopes.

For more about VERITAS and the science we do see our website or follow us on facebook or twitter @veritasgammaray.

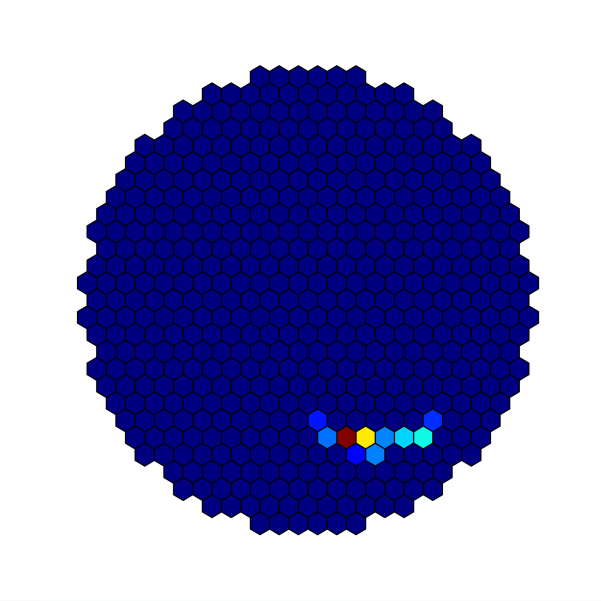
About this project

As well as showers produced by gamma-rays we also have showers produced by cosmic rays, high energy particles such as protons and electrons. These provide a background of showers that we have to detect the gamma-rays above (think of trying to pick out the light of a candle at 500m on a bright day - not easy!). Fortunately they look different in our cameras and we can tell them apart, allowing us to only select showers that look like they were produced by gamma-rays (this makes the problem more like picking out the light from a candle at 500m at night - this is still not easy, but it is possible).

Sometimes these cosmic ray showers produce muons (think of them as the electron's heavier cousin) as they pass through the Earth's atmosphere. Muons produce distinctive ring shaped images in our cameras. If we get a good image of a ring it can be very useful for us, the diameter of the ring and how bright it appears is related, so by detecting lots of rings we can can use them to check that our telescopes are working properly. If one day the muon rings all appear brighter or dimmer than they should for their diameter then something is wrong!



Unfortunately these rings are not all good. If we only get the edge of a ring in the camera then it looks like an ellipse. Unfortunately this is the shape that we are looking for to detect gamma-ray showers. The computer finds this very difficult to tell the difference between a small part of a ring and a complete ellipse. This is where you come in, by identifying these partial rings you help us to reduce our background and also provide us with more images to check that our telescopes are working properly. In the future we can use the images that you have identified to better train our algorithms and improve our ability to tell the different image types apart.



How does VERITAS work?

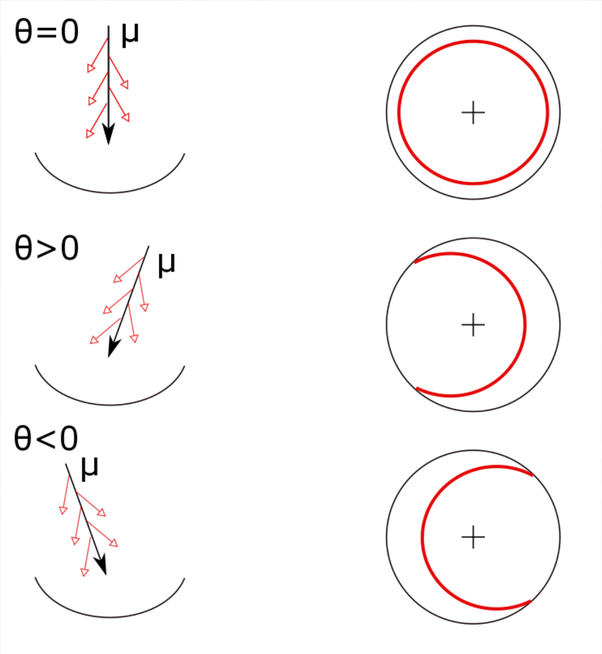
VERITAS is an array of imaging atmospheric Cherenkov telescopes that detects the light induced by showers as they pass through the Earth's atmosphere (the particles in the shower are moving faster than the speed of light in air (but slower than the speed of light in a vacuum so Einstein is still right!) and, a bit like a sonic boom, they induce blue/UV light (named Cherenkov light after Pavel Cherenkov who was the first to detect it experimentally)). Each telescope uses large mirrors to collect this faint, short flash of light and focus it onto a camera made up of 499 photo-multiplier tubes (these form the pixels that you see in the images). We use a very fast camera and electronics to record this light whilst minimizing the other light (from stars, the moon, air glow, nearby light sources, ...) that gets recorded. What we are showing in the images in the color scale is how much light we are detecting from the shower relative to the background light from other sources, with reds indicating a strong signal and blues a weak one. If the level of signal light to background light is small, then we have set the scale to zero so it is easier to analyze (both for you and for the computer).

What causes the differences in the muon images

Three parameters dictate the differences between the different muon images you see.

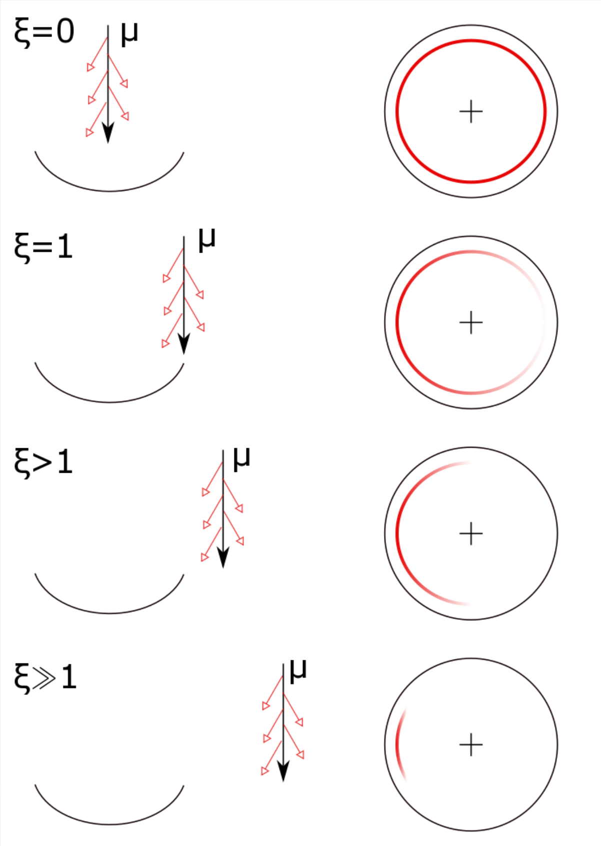
1. Direction of the muon relative to the telescope pointing.

If a muon impacts at an angle relative to the pointing of the telescope then the position of the ring in the camera moves. This is how truncated rings form when the edge of the ring moves outside the field of view of the VERITAS cameras.



2. Position of the impact position relative to the telescope centerline.

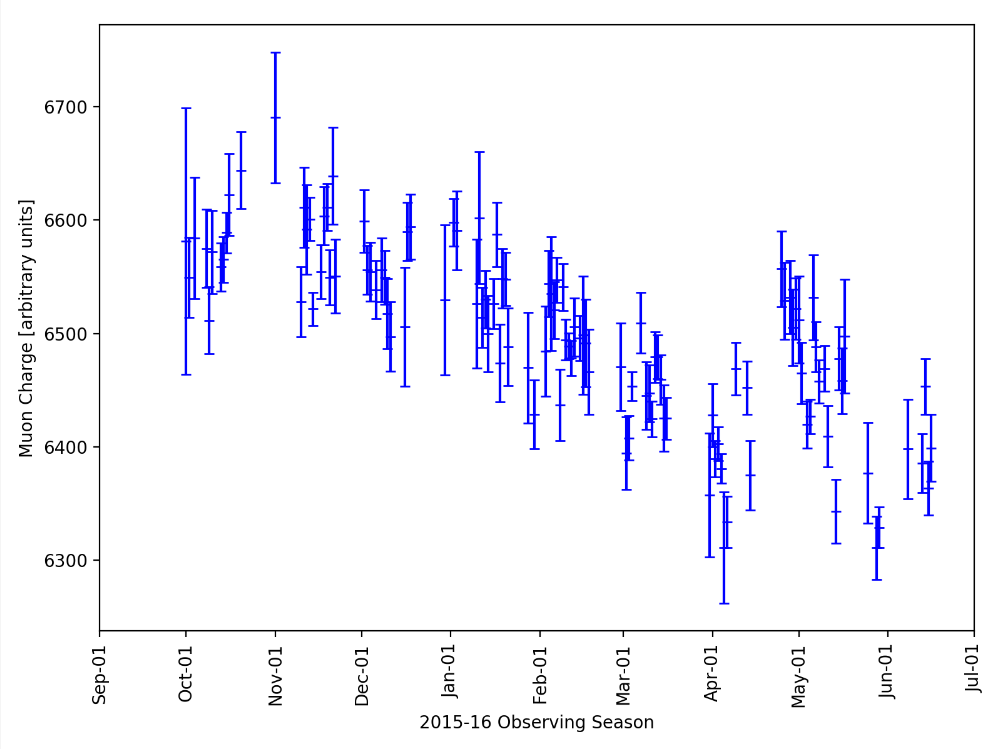
Muons impacting at a distance offset from the telescopes centerline result in images that are brighter on one side than on the other. This is how partial rings form when the fainter side is too weak to be seen by the VERITAS cameras.



3. Energy of the muon.

More energetic muons produce brighter images with larger radii. The relationship between the total signal measured in the ring (the brightness) and the size of the ring well understood.

By using all three of these relationships we can look at any changes in the relationship between image brightness and ring size. This is what we use to check that the telescopes are operating as we would expect. The following figure shows how the average charge of the muons (how bright they are) varies over an observing season for one of our telescopes. As you can see, over time the average charge drops, we expect this to happen and account for it in our work. The jump in the charge that you see in April is because we replaced some mirrors, these new mirrors reflect more light (the mirrors are in the open in the desert - this gives them a gentle sand blasted over time and degrades their performance) and give us a stronger signal. Understanding these changes is where your work comes in. With more muons we can see more detail, this allows us to better study what is going on in our telescopes.


Muon Charge [arbitrary units]
6700
6600
6500
6400
6300
Sep-01
Oct-01
Nov-01
Dec-01
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
2015-16 Observing Season