Research Highlight

Muon Hunters: A Citizen Science Project

Why this is important

The VERITAS team received a phenomenal response from volunteers to the Muon Hunter project. The input from volunteers helped the collaboration gain insight into where the standard analysis is lacking, and train an updated machine learning model using convolutional neural networks. The Muon hunter project is an example of how citizen science is a great resource for both outreach and practical science, as well as an example of how advances in machine learning algorithms can be applied to astrophysics.

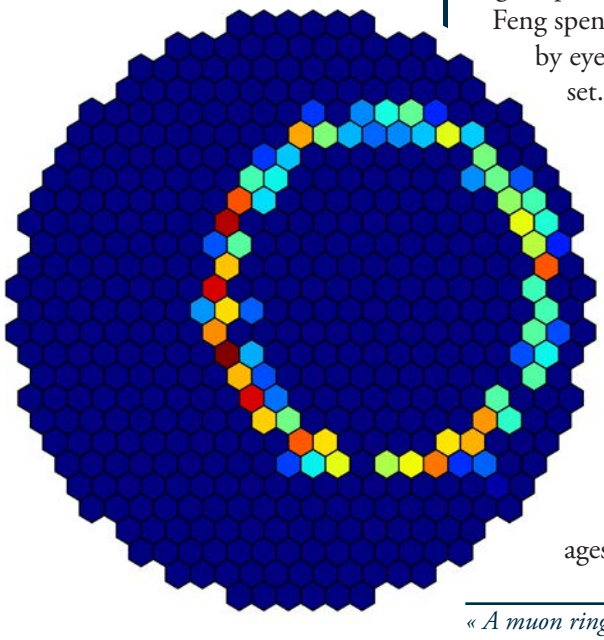
Dr. Qi Feng *was a postdoctoral fellow at the McGill Space Institute and a member of the VERITAS Collaboration. He is now a Postdoctoral Research Scientist at Columbia University.*

In southern Arizona, VERITAS (Very Energetic Radiation Imaging Telescope Array System) watches the nighttime desert sky for flashes of blue Cherenkov light with an array of four 12-meter telescopes.

When the high energy gamma-rays from astronomical objects hit the Earth's atmosphere, they make a shower of particles. Because these high-velocity particles move faster than the speed of light in air, but slower than the speed of light in a vacuum, they produce eerie blue light, called Cherenkov radiation, through a process similar to a sonic boom. VERITAS uses Cherenkov light to study the gamma-rays produced by some of the most extreme objects in the universe, including supernova remnants, active galactic nuclei and potentially even dark matter.

Unfortunately, cosmic rays — high energy particles from space, such as protons and electrons — also produce particle showers and Cherenkov light when they hit the Earth's atmosphere. One major challenge for the VERITAS team is to separate the Cherenkov light flashes made by Gamma-rays from the background events made by cosmic rays.

At a recent meeting of the VERITAS collaboration, MSI postdoc Qi Feng presented his work on the development of improved machine-learning algorithms to detect the signatures of one particular type of cosmic ray event, a shower of muons (the electron's fatter, shorter-lived cousin). Muons produce distinctive ring-shaped images in the VERITAS cameras. In order to train his algorithms, Feng spent a lot of time going through VERITAS data to pick out muon rings by eye, but had hard time finding enough images to make a proper data set.



« A muon ring as seen by the VERITAS telescope cameras.

Already on the lookout for a project using VERITAS data that would work on the Zooniverse citizen-science platform, collaborator Lucy Fortson wrote in a blog post that "it became immediately obvious that we should work with Qi to help him obtain the images he needed for his project."

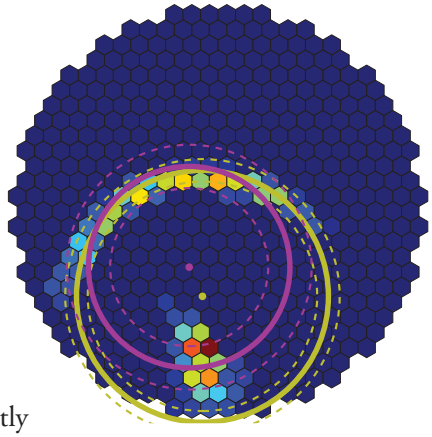
Several members of the VERITAS collaboration worked to build the Muon Hunter project on the Zooniverse, where volunteers without any specialised background, training, or expertise could identify muon rings by drawing circles on images from the VERITAS camera.

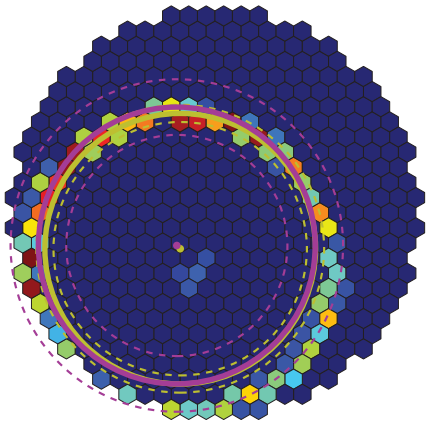
The project launched on 28th February, 2017 and ran out of images for volunteers to classify by April 20th. About 137,000

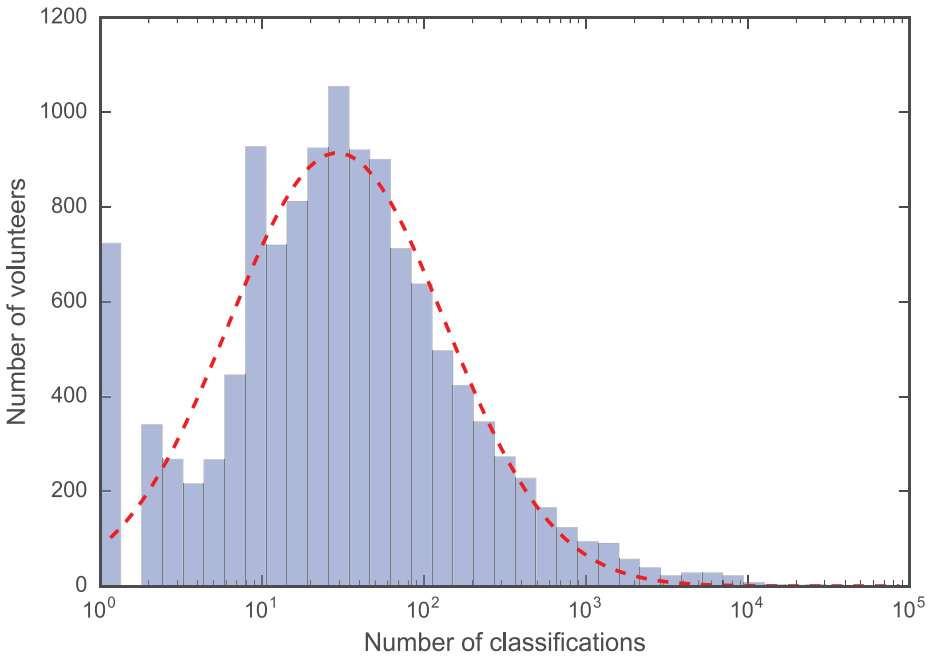
VERITAS single-telescope images were served on the Muon Hunter website. The project received about 2.1 million classifications, half within the first week after the official launch of the project, from 5,734 volunteers. While 724 volunteers only classified one image, 16 volunteers classified more than 10 thousand images each. Roughly 25 percent of the volunteers were under 18 years old.

Using the updated, larger data set provided by harnessing the pattern recognition power of the human brains of Muon Hunters volunteers, Feng was able to improve the accuracy of his model from ~95% to 97%. He was also able to demonstrate some flaws of the earlier model, which were due to the small number of images used in the original training.

Over 5,000 ordinary citizens were able to contribute meaningfully to cutting-edge research, as well as learn about the science behind the images that they classified. Thus, citizen science projects like Muon Hunters, are both a powerful way to sort through large data sets, and a unique outreach opportunity that allows the public to directly participate in the process of doing science.







Feng, Q. for the VERITAS Collaboration, Jarvis, J. 2017, *A citizen-science approach to muon events in imaging atmospheric Cherenkov telescope data: the Muon Hunter*, ArXiv e-prints, arXiv:1708.06393

» **Top:** *Muon rings identified by the older algorithm (magenta), and the Muon Hunter volunteers (yellow). solid lines and dashed lines show the mean and the standard deviation of the radius of the ring.*

» **Middle:** *Histogram showing the number of classifications each Muon Hunter volunteer made.*

» **Bottom:** *The VERITAS observatory in Arizona.*