65th Compton Lectures
Special Assignment
You Be the TAC

A TAC is a Time Allocation Committee used to select a program of scientific observations for a telescope. A TAC is made up of experts that review proposals submitted by other scientists and decide which observations are most important and how to divide up the available time among them.

As an attendee of this series, you are now familiar with many of the celestial objects that a gamma-ray telescope observes and the scientific questions that can be investigated. Therefore, you are qualified to be an auxiliary TAC member for VERITAS, a very high energy gamma-ray telescope array located in Arizona.

Key Science Projects

Your first job as part of our informal Compton Lecture TAC is to define a core science program for VERITAS. A telescope facility may pick several science areas that have a broad scope or a high level of importance to be key science programs. These programs are given priority for observations and help to provide focus. By defining key science programs, we make sure to set aside devoted observation time for the science topics that we think are the most important. A large fraction of the available observation time for a telescope may be assigned to one or more key science programs.

For Part I, simply select two source classes from the list that you feel deserve a high priority for VERITAS observations and should be key projects.

Observations at Large

Key science programs use a large fraction of available time on a telescope, but not all of it. The remaining time goes to general proposals, to special opportunities that we may not know about ahead of time like GRBs, or even to the telescope director.[1]

For Part II, you get to review 8 general proposals and select a couple that you think are worthy. All of these are real objects that can be viewed by VERITAS around this time of the year. In fact, a small committee made up of members of the VERITAS collaboration had to make a very similar decision a few months ago. To make things more challenging the observations must also fit into this month's schedule. VERITAS gets something like 100 hours of observation time in a month. For this scenario you get a total of 60 hrs to assign. However, a celestial object doesn't remain overhead all night long for a telescope on the Earth. Half of the observation time you assign must be spent on sources that are

[1] A great example from the Hubble Space Telescope is the director's discretionary time that was used to create the Hubble Deep Field image. The telescope was pointed at a small and typical patch of the sky for a series of exposures to make the most sensitive optical image ever taken. This is like taking a core sample of the Universe and resulted in a stunning view of the oldest and faintest galaxies ever seen by any optical telescope. What is now one of the most spectacular astronomy images would never have been taken if not for the director's choice to spend a large amount of time on an observation without a more specific science goal.

above the horizon early in the night and the remainder on sources above horizon later in the night. Sources that are above the horizon during the same portion of the night cannot be observed simultaneously and have to share time. For example, we may view Source A one night and Source B the next, but if we split our time up too much, then we will not accumulate enough total hours on a source. You may find, as the the real VERITAS TAC does, that the proposals you think are most deserving may compete for the same observation period. The good news is that we get a chance to observe this part of the sky every year. The sources that we don't have time to observe this year, will be up again next year.

Example: I think Source A and Source B should be observed. They are both early-night sources with requests for 20 hrs. I could give each source 15 hrs, or I could decide that source A really needs the time, and the measurement for source B could be done with less. I give Source A the full 20 hrs and Source B 10 hrs to use up the full 30 hr allotment. One of my fellow TAC members may decide that the science of faint, but compelling Source C is so important that it deserves the entire 30 hrs. Like a jury, we have to discuss the merit of each proposal and come to an agreement on how the time should be spent.

Useful things to know:

- The VERITAS telescopes point at one source at a time.
- VERITAS needs to observe most targets for at least 10 hrs to make an interesting measurement. An exception to this are a couple very bright blazars that can be detected in a minute or two during a strong flare.
- A detailed measurement of a spectrum may require longer observations than a detection. This could take about 20 hrs or even longer depending on the brightness of the source and how high in energy we want to extend the measurement.

Observation Proposal Summaries

1. **Markarian 421** - Type: Active Galactic Nuclei, Blazar
   Requested Time: 20 hrs
   Goal: Measure a strong flare in coordination with optical and X-ray telescopes

   Markarian 421 is a well-known TeV gamma-ray blazar that in several recent years has flared to very bright levels over periods of weeks. We should monitor the gamma-ray brightness and observe this source at the same time as X-ray and optical telescopes so that we can catch a flare and make a multiwavelength measurement of it. If we happen to see a flare, then we can test models of the jet from this galaxy against the optical, X-ray, and gamma-ray brightness over time. Markarian 421 is nearby and not strongly affected by absorption of gamma rays by starlight.

2. **H 1426+428** - Type: Active Galactic Nuclei, Blazar
   Requested Time: 20 hrs
   Goal: Measure the spectrum of a distant blazar

   H 1426+428 is a blazar that has already been detected at gamma-ray wavelengths. It is further away and fainter than Markarian 421, and it has not been seen to flare as frequently or strongly. We should observe it and measure the gamma-ray spectrum to better understand how gamma rays are produced by a blazar when it is not flaring. Additionally, a detailed measurement of the gamma-ray spectrum may tell us about how strongly gamma rays traveling this distance have been absorbed by starlight.

3. **RGB 1725+118** - Type: Active Galactic Nuclei, Blazar
   Requested Time: 10 hrs
   Goal: Discover a new TeV blazar

   RGB 1725+118 is a nearby blazar that shows strong flaring activity at X-ray wavelengths. This makes it one of the the best candidates for a new discovery among the blazars that have not been detected by gamma-ray telescopes. Models using inverse Compton scattering to produce gamma rays indicate that this galaxy should be bright enough to be detected by new gamma-ray telescopes like VERITAS.

4. **Draco** - Type: Dwarf Galaxy
   Requested Time: 10 hrs
   Goal: Discover gamma rays from dark matter

   Draco, as a small nearby galaxy, is a candidate for discovering a gamma-ray signal from dark matter annihilation. Although the dark matter signal from a small galaxy is likely to be weaker than in larger galaxies or galaxy clusters, Draco has the advantage of containing no sources of gamma rays to drown out a possible dark matter signal.

5. **PSR 1951+32** - Type: Pulsar
   Requested Time: 10 hrs
   Goal: Discover the first TeV pulsar

PSR 1951+32 is a famous high energy gamma-ray pulsar detected by the EGRET instrument on the Compton Gamma Ray Observatory. Ground-based gamma-ray telescopes have not yet detected a pulsed signal from any pulsars. The detection of a pulse of very high energy photons from this source would be a new and exciting discovery. If it is not detected, then we still learn that certain models for how pulsars produce gamma rays do not work.

6. **PSR 2021+3651** - Type: Pulsar Wind Nebula
   Requested Time: 20 hrs
   Goal: Discover a new TeV pulsar wind nebula

   PSR 2021+3651 is a recently discovered pulsar with an x-ray emitting pulsar wind nebula around it (featured in Lecture 3.) Observations indicate that the pulsar is young and very energetic, the right type for producing a gamm-ray nebula. The EGRET space-based gamma-ray telescope also detected GeV gamma rays from this location making it one of the top candidates in the Northern Hemisphere for detecting TeV gamma rays from a pulsar wind nebula. This object is close enough that it may appear extended for VERITAS and is in a gamma-ray bright region of the sky. For this reason, we request 20 hours of observations to offset a possible loss in the efficiency for collecting gamma rays.

7. **W44** - Type: Supernova Remnant and Pulsar Wind Nebula
   Requested Time: 10 hrs
   Goal: Discover a new TeV supernova remnant and measure the presence and acceleration of cosmic rays or discover a new TeV pulsar wind nebula and measure the structure and development.

   W44 is a large nearby supernova remnant that has not been detected in TeV gamma rays. It is a complex object and offers several potential gamma ray sources. If we detect gamma rays from the expanding shell of the supernova blastwave, then we learn about cosmic ray acceleration. There is also a possiblity of finding regions where the blastwave interacts with clouds of gas near the remnant. W44 contains a pulsar. If we detect a pulsar wind nebula here, then we learn about the pulsar, how it accelerates particles, and how the remnant may have changed over time. There is some possibility that we might see gamma rays from both the shell and the nebula, which would make this a very valuable source for studying the ways in which supernova remnants develop after the initial blast.

8. **TeV 2032+413** - Type: Unidentified
   Requested Time: 20 hrs
   Goal: Measure the location, size, and spectrum of a gamma-ray object that defies explanation

   TeV 2032+413 was discovered in TeV gamma rays by an array of small Čerenkov telescopes called HEGRA in 2002 and still does not have a lower energy counterpart identified. Observations with VERITAS are needed to improve our knowledge of the location and extent of this gamma-ray source. These measurements and the gamma-ray spectrum are important for interpreting what kind of object this may be.

TAC Ballot

Instructions: Hand in this form before the beginning of the last lecture on June 2nd to participate in our own informal experiment. No penalties here for asking questions and working in groups. Results will be announced at the end of the last lecture.

PART I: Select two gamma-ray source classes that you think should get the highest priority for observations.

_____ Supernova Remnant Shells
_____ Pulsars
_____ Pulsar Wind Nebulae
_____ Wolf Rayet Stars/Star forming regions
_____ Pulsar/Black Hole Binaries
_____ Our Galactic Center
_____ Potential Sources of a Dark Matter Signal
_____ Blazar Galaxies
_____ Non-blazar Galaxies (active galactic nuclei with jets not directed toward us.)
_____ Gamma Ray Bursts
_____ Our Galactic Plane
_____ Unidentified Sources (for example, detections by other gamma-ray telescopes that have not been identified with optical, radio, or X-ray objects.)

PART II: (Bonus round) Select the amount of time you think VERITAS should observe the proposed targets. You don't have to observe all the sources. Assume that 30 hrs is the maximum time available for sources in each portion of the night during this cycle of observations.

Early Night Sources (Enter number of hours)

_______ Markarian 421
_______ H 1426+428
_______ RGB 1725+118
_______ Draco
_______ **Total Hours** (should add to 30)

Late Night Sources (Enter number of hours)

_______ PSR 1951+32
_______ PSR 2021+3651
_______ W44
_______ TeV 2032
_______ **Total Hours** (should add to 30)