AGN Spectral Energy Distributions
of GLAST Telescope Network Program Objects
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Participants:
Lead: Jeff Adkins, Deer Valley High School, Antioch, CA
astronomyteacher@mac.com

Linda Stefaniak, Allentown High School, Allentown, NJ
stefanl@optonline.net

Dr. Steve Rapp, Linwood Holton Governor's School, Abingdon, VA
srapp@hgs.k12.va.us

Dr. Mark Lacy, Spitzer Science Center
mlacy@ipac.caltech.edu

Abstract:
The Gamma-Ray Large Area Space Telescope (GLAST) has a proposed observing list that includes AGNs and Polars bright enough to be observed optically by amateurs and students. This observing list is maintained by the "GLAST Telescope Network" (GTN) and includes a number of objects that have yet to be observed by the Spitzer Space Telescope. Our project will observe one of these objects with the Spitzer MIPS and the IRAC instruments to determine their Spectral Energy Distribution (SED), which will be compared to a computer model of disk emission in order to determine what component of the SED is due to the disk and what component is due to synchrotron radiation induced by the jets. In addition we will observe our program objects prior to, simultaneously with, and after Spitzer observes them. This gives a direct connection from Spitzer research to student activities in the classroom.

Background:
Toroidal accretion models such as Pier and Krolik (1992, 1993) show that a pronounced infrared peak does not occur for active galaxies "close to face on." New research presented at the 205th AAS meeting announces the discovery of an infrared synchrotron jet (Floyd 2004). We would like to see if such synchrotron-driven infrared emissions are present in our program objects.

Target List criteria:
Our targeting list was derived from the GTN Program list (Spears, 2004) which targets selected AGN for long term ground based observing. We narrowed the list (which has dozens of targets) using these criteria:
Targets previously observed by Spitzer were removed. Searches were done using Leopard and the remaining list was screened using ROC.
Extreme z values were discarded. This eliminates extremely dim targets as well.
Objects close to the plane of the ecliptic and the plane of the galaxy were eliminated to reduce the interference from interplanetary and ISM dust.
Objects with extremely low declinations were eliminated as they are not easily visible from the northern hemisphere.

This left 4 candidate objects (Table 1), one of which is above 75 degrees galactic latitude, (#7) and another is above 70 degrees declination (#3). We have 2 other objects (GTN 19 and 23) prepared in the case of unanticipated problems with the primary target.

GTN #	Object name	V mag	RA h:m:s	Decl d:m:s	Object type	Approximate gal. latitude2	z
7	4C 29.45	15.6	11:59:31.8	29:14:44	QUASAR	+78 deg	0.729
3	S5 0716+714	14.17	07:21:53.4	71:20:36	BL LAC	+28 deg	0.300
19	OS 319	17.5	16:13:41.1	34:12:47.9	QUASAR	+46 deg	1.401
23	PKS 1229-021	16.75	12:32:00.0	-02:24:05.8	QUASAR	+60 deg	1.045

Table 1. Proposed target list. Primary target list was derived from the GTN network program list. Items previously observed by Spitzer have been eliminated from this list after consulting Leopard and the ROC. [1]Targets within 20 degrees of the ecliptic have been eliminated. [2]Galactic Latitudes via SIMBAD. This table shows our targets in order of priority, highest priority at the top of the table.

Spitzer Observing:

We propose to observe each object with MIPS at 24, 70, and 160 microns (Photometry mode). In addition, we will observe each object using all 4 channels of IRAC. This will generate 7 measurements for the SED.

A search was done using the NASA Extragalactic Database (NED) and 2MASS data to get information that would guide our planning for instruments and exposures. We used the PET tools at the Spitzer web site to make estimates of exposure times for our four target objects using both MIPS in SED mode and IRAC, to give us the widest possible SED for each target. In several cases integration times were approaching an hour on MIPS in SED mode, so we used MIPS in Photometry mode instead. Dr. Mark Lacy assisted us with preparing every observation in our AOR.

As we set up the AOR using SPOT, we made adjustments as necessary to the number of cycles and the exposure times in order to bring the signal to noise ratio up to 5 (and down in some cases to conserve observing minutes.) In each case we selected dithering using a 5-position Gaussian model.

IRAC and MIPS observations cannot be taken simultaneously. There may be a gap of several days to a few weeks between them. Since the target object can vary over time, we will need to use ground-based observations to match the IRAC and MIPS observations so the results are comparable. This means that the ground based observations described in the next section are not merely an educational tie-in; they are essential to complete the science proposed for this project. With both the Spitzer observations and the ground based observations we will construct SEDS over a broad range of wavelengths to seek synchrotron emission distinguishable from disk emission in the infrared. The ground based observations will help us connect the IRAC and MIPS observations since the object may vary between the Spitzer observations. If identical ground based measurements are made simultaneously with both IRAC and MIPS

7	4C 29.45	11:59:31.8	14 May 05- 27 Jun 05	Beg. window: 81º at 8:30 PM End window: culminates before sunset: altitude 66 º at 7:30 PM
		29:14:44	16 Dec 05- 28 Jan 06	Beg. window: 81 º at 6:41 AM End window: 81º at 3:40 AM

observations, and the ground based observations are found to be comparable, then the Spitzer observations can be used to construct a more valid, typical SED for the target.

Target	Instrument	Exposure Time wavelength in microns (u) – time in seconds	Cycles	Integration Time	Total Resource Time needed	Comments
GTN 7 4c 29.45	MIPS Photometry	24 u = 3 70 u = 3 160 u = 10	24 u=1 70 u=1 160u=3	24u=42s 70u=30 s 160u=60s	1110 s	24,70 u predicted to have large signal/noise; reduced cycles to save time
	IRAC Mapping	3.6 u = 10 s 5.8 u = 10 s 4.5 u = 10 s 8.0 u = 10 s			378.1 s	Gaussian 5 dithering, Large Scale.

Table 2. AOR Summary of GTN 7.

Because the Spitzer Teacher Observing Program has only a limited amount of time available, we expect that we will be able to observe at best one of the four targets in our list. The others are still in the list to be treated as alternates in case of unforeseen problems, or in case extra time becomes available.

Origin of the Project and connection to GTN

The origin of this proposal began with the primary author (Adkins). NASA's GLAST E/PO office selected him and a group of other teachers including W. Glogowski to be Education Ambassadors for a variety of Structure and Evolution of the Universe (SEU) missions, including GLAST. During a workshop in summer 2004, teachers were introduced to the GTN as a possible ongoing student involvement project, where students maintain time-based observations of AGN to look for variances on a variety of time scales. When the opportunity for the Spitzer Teacher Observing Program was announced, and knowing that the infrared characteristics of AGN tell us many things about the structure of accretion disks surrounding them, Adkins saw an important opportunity for leverage in order to maximize student involvement.

Since we need ground based observations to help compare the Spitzer observations which are not taken simultaneously, targeting with Spitzer must be timed to allow simultaneous ground-based observing. Therefore we have selected observing windows with Spitzer for the target objects that allow the object to be observed at night from North America, where most of the GTN telescopes are located. The director of the GTN, Dr. Gordon Spear, has experience with simultaneous ground based observing coupled to space observatories and "guarantees" the GTN can respond with multiple telescopes given minimal warning on the order of a few days.

Visibility from Earth telescopes

GTN 7 is visible in the early evening (Pacific time, 9:00 PM) near zenith during its first visibility window starting in mid-May 2005. This means simultaneous observations with students are possible—even convenient, if the Spitzer observation takes place from 10:00 PM or later Pacific Time. (A later start time allows for setup and calibration of the ground based telescopes.)

The table that follows shows estimated times of culmination generated with Starry Night desktop planetarium software, accessing an extended table of quasars. The time of culmination gives an indication of the window of opportunity for good ground based observing. The ephemerides generated by the program were made assuming the observer was in San Francisco, California, and all times are Pacific Standard time. Windows are evaluated for all 4 potential targets, although our principal target remains GTN 7. Only GTN 7 is presented below.

Considering that student observers will be participating, for practical reasons favorable times are those when the target is near culmination just after sunset. Spitzer telescope schedulers should note these observing windows carefully, and schedule the observations during early evening hours. Observations in the pre-dawn sky are possible but will reduce participation in the project from student observers.

GTN #	Object name[1]	RA h:m:s dec d:m:s	Spitzer Observing Windows[1]	Culmination or maximum altitude in degrees followed by approximate time of culmination (PST)

Table 3. Earth-based Visibility Windows for target GTN 7. [1]Windows generated by SPOT. If the windows are different for the two instruments for each target, the later starting window and the earlier ending window are listed here. Ephemerides generated by Starry Night 5.0 using a quasar catalog by Teras (2005).

These constraints mean that when Spitzer observations are scheduled, they should be done so mindful of the fact that our objective is to observe them simultaneously with the GTN, and that two of the observatories participating (among others) will be in California and in New Mexico. Therefore not every date or time in the window is acceptable, but only those which are also during nighttime in these locations as described in the example above. GTN 19 and 23 are visible from these locations during the Spitzer observing windows, but their placement in the sky is not quite as advantageous as the primary target GTN 7.

Educational Applications and Outreach

A copy of this proposal will be posted at the ESPACE Academy web site at this address: http://homepage.mac.com/dvhscience/SpaceAcademy/Projects/Spitzer/index.html. At the time of this writing there is simply a placeholder page at this address with no downloads available. This page will be the home page for this project and will eventually contain the measurements, reports, and data obtained for this proposal (if approved), plus notice of scheduled Spitzer observations for project participants. Copies of the ephemerides used to judge visibility windows for ground-based observers will be posted there.

<u>Jeff Adkins, Deer Valley High School:</u>
I teach Astronomy and Physics to mostly 11th and 12th grade students in a suburban school. I have 120 astronomy students, 20 Physics AP students, and 10 Planetarium Production and Research students. Our school has a dedicated academy for earth science (Earth, Space, and Astronomy Center for Education) and I am the director.

Students will learn about the MIPS and IRAC instruments on board the Spitzer Space Telescope. They will use planetarium software in our school's planetarium to understand why Spitzer cannot point at a target at an arbitrary time but must use carefully selected observing windows. Planetarium Production students will construct a model of the earth, sun, and Spitzer similar to that seen at Flandreau Planetarium's infrared astronomy exhibit to explain how Spitzer operates to the public. They will also create static and interactive exhibits based on the infrared teaching kit we will be receiving. We will set up an exhibit with a video camera, infared emitter such as a remote control, and a TV monitor to illustrate how infrared light works.

To introduce the topic of AGNs and the analysis of their SEDs, we will do the "AGN Spectroscopy" project provided by TLRBSE. Students in all of my classes will analyze AGN data provided by the TLRBSE project. My research students will use this as an introduction for the analysis of the Spitzer data. Students will use Graphical Analysis software and a classroom LAN to access sample data files from TLRBSE and from the Spitzer data archive.

Students will learn to access Spitzer archived data and extract the kind of SEDS data which will be provided by this project. Students will use SPOT to visualize the planned observation and see how the MIPS and IRAC instrument will be used to create images. Students will be asked to review selected portions of the IRAC and MIPS Data handbooks, learn about the concept of a data pipeline, and review the Data Analysis Demos posted at the Spitzer web site to understand the process of how observations are converted into data.

When the Spitzer data from this proposal becomes available, students will construct Spectral Energy Diagrams (SEDs) from the flux data obtained by Spitzer for each IRAC and MIPS channel (seven different fluxes ranging from 3.6 microns to 160 microns) and include wavelengths which are observed by ground based observers to get the widest possible spectrum for the target. They will construct these diagrams using the programs Excel and Graphical Analysis.

Students will then compare the SEDs they have constructed of these objects with models of emission for AGNs to see if there is additional emission (due to synchrotron radiation) beyond that predicted for blackbody emission from the torus. Modeling will be done with a statistical analysis program called Fathom made by Key Curriculum Press.

Student observers involved in the Spitzer AGN project from Deer Valley High School include Robert Johnson, Barry Parker, Kyle Hornbeck, Tri Nguyen, Brielle Hinckley, and Jamie Laird. These students are enrolled in Adkins' Astronomy or Research classes, and results will be used for them to conduct a major project for completion in the class. Nguyen (2005) and several other students have experience reducing data from astronomical images already. Laird and Hinckley have already begun work on a light curve project and have taken their first image of GTN 7 in V.

Each of these students is expected to adopt an AGN from this proposal and make luminosity measurements using a variety of filters to construct SEDS using their observations in combination with the Spitzer observations. Students will use networked computers to share data and collaborate on results. They will use remote control telescopes, locally controlled telescopes with CCD cameras, spreadsheets and computer modeling software to create the magnitude measurements and the SEDS. Hinckley and Laird are juniors and will extend research into the senior year. All students in these classes next year are expected to present or enter at the following events:

- the Bay Area Science Fair
- the Northern California-Nevada Junior Science and Humanities Sympoium
- the Westinghouse national science competition
- the Northern California American Association of Physics Teachers annual conference

Each student must make a public presentation about the results of their research at the DVHS planetarium. Each week the planetarium features a student researcher plus a planetarium show. Students will use animation software, digital projectors, posters, and models to create a presentation about the Spitzer space telescope and infrared astronomy.

In addition, student presenters enrolled in the Planetarium Production class will develop a program about infrared astronomy using Spitzer results for elementary schools. These students will take advantage of the infrared teaching kit provided by the Spitzer Teacher Observing Program. Students in this class will also create a permanent exhibit of Spitzer images and infrared science for the school's planetarium lobby.

Adkins will present sessions related to this project as follows:
"Spitzer Space Telescope Observing Proposal," Deer Valley High School Planetarium, Antioch, California, March 8, 2005.
"Connecting Space-Based Astronomy to the Classroom," Nashville, TN Regional NSTA meeting, December 2005.
"Infrared Science and the California Science Standards," Antioch Unified School District, Deer Valley High School, May 10, 2005.
"Spitzer Teacher Observing Program," Stockton Astronomical Society, Stockton, California, February 10, 2005.

<u>Dr. Steve Rapp: Linwood Holton Governor's School:</u>
Students from Dr. Rapp's physics and astronomy classes will conduct observations of the Spitzer AGN targets using remotely controlled telescopes from the New Mexico Skies site and the Harvard Micro-Observatory sites. Using this data in conjunction with the Spitzer Telescope data, the students will use Excel and computer programs to plot the variation of spectral irradiance with wavelength of AGN targets. Students will also learn about the MIPS and IRAC instruments on board the Spitzer Space Telescope. To

introduce the topic of AGNs and the analysis of their Spectral Energy Diagrams (SEDs), students will be guided through the "AGN Spectroscopy" project provided by TLRBSE. Students in astronomy and physics classes will analyze AGN data provided by the TLRBSE project. They will use this as an introduction for the analysis of the Spitzer data. Students will use Graphical Analysis software and the Internet to access sample data files from TLRBSE and from the Spitzer data archive.

Students will learn to access archived Spitzer data and extract the kind of SEDS data that will be provided by this project. Students will construct SEDs from the Spitzer flux data from IRAC and MIPS. They will use Excel and Graphical Analysis software programs to construct these diagrams. The diagrams will be used to compare to published SEDS of AGN which may exhibit IR emissions coming from synchrotron radiation in the jet.

Students will create Power Point Presentations about the Spitzer telescope and infrared astronomy and present it to other class members via the Internet. The presentations will be available on our website: http://hgs.k12.va.us. It is also expected that some of these students will be entering infrared astronomy projects in the Blue Ridge Regional Science Fair.

Since Dr. Rapp teaches all of his students via the Internet, students will learn about infrared astronomy, hands on, using the infrared teaching kits provided by the Spitzer Teacher Observing Program (STOP), during a field trip to the National Radio Astronomy Observatory in Green Bank, WV, April 1-3, 2005.

Rapp will give a local professional development workshop for Washington County, Virginia teachers utilizing the STOP infrared teaching kits April 23, 2005. He is presently working on some possible summer regional workshops for teachers in other counties. Other presentations to be given are as follows:

“Utilizing Infrared Astronomy in the Science Classroom,” Virginia Association of Science Teachers Meeting, Roanoke, VA, November 17-19, 2005;
“The Spitzer Telescope and Infrared Astronomy,” Regional NSTA meeting, Baltimore, MD, November 2-4, 2006;
“Teaching Infrared Astronomy in Your Classroom,” National NSTA meeting, Anaheim, CA, April 6-9, 2006.

Linda Stefaniak, Allentown High School
My students include 22 sophomores in honors level chemistry I and 20 juniors and seniors in an astronomy class. All students are introduced to atomic structure through a series of lessons that include a demonstration of the production of emission lines in tubes of excited gases. As an extension, they learn to classify active galactic nuclei from visible light spectra and determine the Doppler shift of these objects from the relative positions of emission lines of the elements in their spectra. My students are encouraged to develop original questions in this, and other areas of study, and work in teams or individually to answer their questions, culminating in a paper for publication in the current year’s RBSE journal of student work. The students perform a search of research papers in the ADS Abstract Service similar to the work they propose and are encouraged to write to the authors of these papers. I plan to have my students interpret data of the

AGNs listed in this proposal as well as find targets common to our existing RBSE visible light AGN list and infrared targets included in the Spitzer data archive. I will have the students develop project ideas for papers from the greater range of wavelengths this will make available to them. I am an active member of the National Science Teacher's Association as well as my state association and am presenting workshops this summer through Brookdale Community College's office of Community Education on using solar and infrared astronomy in the middle and high school science class, a workshop on multi-wavelength astronomy and a second on infrared astronomy for the October 2005 New Jersey Science Teacher's Convention.

References:

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