AGN Spectral Energy Distributions
of GLAST Telescope Network Program Objects II
Version 1.0, 10 January 2006

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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. In the first year of the Spitzer Teacher Observing Program, our project observed one of these objects (4C 29.45) with the Spitzer MIPS and the IRAC instruments as well as ground based instruments. These observations were used to determine its Spectral Energy Distribution (SED), which was compared to a model of disk emission in order to determine if there was a component of the SED due to synchrotron radiation induced by the jets. In this proposal we will observe another target from the list and expand our efforts to create simultaneous observations through radio telescopes, optical telescopes (large and small), and other instruments as the opportunity arises.

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. 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 observed GTN 7, 4C 29.45 last spring and hope to observe target #3 in the upcoming cycle of observations.

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 in this cycle to observe GTN 3 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.

As was done last time, we also plan to observe the target with ground-based telescopes in the optical with a variety of filters (at least V, R, and I as was done before, and U and B if a large enough telescope can observe). In addition we plan to add radio observations to this year's proposal. We should have access to one or more radio telescopes at Green Bank in West Virginia, arranged and "in the pipeline" already by Dr. Steve Rapp. Deer Valley High School is installing a small radio telescope on campus, and it should be able to target GTN 3 as well if it is installed and running in time.

Because GTN 3 is very similar to GTN 7, our previous target, the same Sptizer settings should suffice to create AORs for the observation. These are reproduced here.

Target	Instrument	Exposure Time wavelength in microns (u) – time in seconds	Cycles	Integration Time	Total Resource Time needed	Comments
GTN 3 S5 0716+714	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 3.

Origin of the Project and connection to GTN
This is a continuation of the proposal we carried out last year. The background about the origin of the project is therefore documented and not repeated here.

Visibility from Earth telescopes
GTN 3 is visible during the following windows generated by SPOT. From Antioch, California, GTN 3 is circumpolar although during the lower meridian crossing it is quite close to the horizon.

Spitzer window	Ground based window
27 February 2006 to 28 April 2006	Culminates at midnight at beginning of window—best opportunity is near beginning of the window
10 October 2006 to 12 December 2006	Stays near horizon at nighttime- limited observing window

Either of these windows will be usable for the educational and scientific goals of the project if ground-based observations are taken the day before and the day after Spitzer observes, as happened last time. Simultaneous observations by ground based telescopes, while desirable, are not entirely necessary. However, we do need to be able to see the object sometime during the nights surrounding the observation. That means the first window is best for the purposes of this project.

Educational Applications and Outreach
A copy of this proposal will be posted at the ESPACE Academy web site at this address: http://www.astronomyteacher.com.
Click on the "Spitzer Project" icon to find documentation related to this project.

Since our first proposal, participating students and teachers have conducted workshops for the public in a variety of settings. In addition amateur astronomers and other facilities were invited to participate in the simultaneous observation, although primarily due to bad weather at other sites, very little imaging of the target was done by anyone other than students at Deer Valley High School.

Observations

What has been done
Observers were recruited through the GTN, the American Association of Variable Star Observers, the Hands-On Universe observing program at Yerkes Observatory, and others. A considerable amount of data was collected. At this point in the project two of Adkins' students, Brielle Hinckley and Crystal Ewen, photographed the target before and after the Spitzer observations using a remotely controlled observatory called New Mexico Skies and sponsored by NOAO. A web page was developed giving observing tips, coordinates, filtering instructions, and links to background reading (see www.AstronomyTeacher.com).

Some of the data collected was unusable because of a lack of identifiable standard stars in the field, and other images were not correctly calibrated.

Observations

Spitzer IRAC	4 images
Spitzer MIPS	3 images
HOU (Yerkes)	15 images
New Mexico Skies	20 images (over VBR and I filters)
AAVSO	pending analysis
Amateur observers	2 images (many attempts were clouded out)
GTN (GORT)	unknown number of images lost due to computer malfunction

The HOU images were completed, but the field was so small none of our standard stars were in the field. Crystal Ewen attempted to calibrate based on the stars in the field, using other images to establish new standards, but we judged the measurement errors so large that the data was not useful. Observers with the AAVSO did make observations, but at this writing those observations remain unvalidated and therefore could not be used for publication.

The usable observations were compiled into a poster presented at the January 2006 AAS meeting in Washington, DC. (Adkins 2006)

<u>What will be done</u>

If this proposal is approved, we will again send word to various communities that an observing program for this object is under way and solicit data and images. We will rewrite the instructions on the project web site to give better criteria for observers to help ensure a successful imaging session.

In addition, we believe we will be able to add our own radio data to the project from a contact at NRAO (Green Bank) through Dr. Steve Rapp, and the pending installation of a small radio telescope at Deer Valley High School. We can also make a more extensive search of available data through NED and the online National Virtual Observatory to provide images and data as sub-projects for a larger number of students.

At Deer Valley High, the venue for the science fair has changed and now we are allowed to enter group projects. It is much more likely that a small team of students will participate in a new round of observations.

Presentations

<u>What has been done</u>

The teacher team members have made a number of presentations about the project in a variety of venues. A list appears below.

Presenter	Audience	Date	Topic
Steve Rapp	Teachers, NSTA Dallas	April 2005	Infrared science
Jeff Adkins	Teachers	April 2005	Infrared science

Jeff Adkins	Teachers, IISEF	May 2005	Space Probes in the Classroom
Jeff Adkins	Amateur astronomers	June 2005	Spitzer project
Linda Stefaniak	Teachers	July 2005	Teaching Multiwave Astronomy
Linda Stefaniak	Teachers, state science convention	October 2005	DASLed by the Sun; Teaching Multiwave Astronomy; Infrared Astronomy
Jeff Adkins and Brielle Hinckley	Teachers Regional SSP Conference	October 2005	Space Probes in the Classroom
Steve Rapp	Teachers Virginia Association of Science Teachers	November 2005	Infrared Astronomy Presentation and Workshop
Steve Rapp	Regional Workshop	December 2005	Understanding infrared radiation

In addition, we developed a written guide to the installation of IRAF on a school computer. This will be posted on the Astronomyteacher.com web site. Brielle Hinckley entered the Junior Science and Humanities Symposium and will enter the Contra Costa County Science and Engineering Fair. Other students such as Crystal Ewen and Jennifer Becker used techniques learned from this project on other objects not observed with Spitzer.

Jeff Adkins published several articles related to these experiences in his irregular column published at Low End Mac, a web site dedicated to older Macintosh computers. Among other articles he published a review of software used to generate the posters presented at AAS, detailed descriptions of how to download the images from this project via Leopard, and others. Articles published on this site typically have several hundred to a few thousand hits.

<u>What will be done</u>

Jeff Adkins, Deer Valley High School:
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, 30 Physics 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 participating in any research must make presentations about it to the school board, the local amateur astronomy society, enter the Contra Costa County Science and

Engineering Fair, and display results at the Contra Costa County Fair. Other venues such as the Junior Science and Humanities Symposium are optional, but many of the students participate. We are diligently trying to get our radio telescope installed in time to make this observing window.

We will continue to make public presentations about our research projects, send press releases to the local press, and communicate what we have learned. Upcoming events include:

- Spring Specialized Secondary Program Demo Day at Deer Valley HS (regional)
- California Partnership Academies Conference (statewide)
- May “What’s up” at Mt. Diablo Astronomical Society
- Summer training for NASA Education and Public Outreach Office for GLAST mission

In addition, an article written with Dr. Steve Rapp describing research opportunities for high school students will be written for a broad audience and offered to Sky and Telescope, Astronomy, and similar venues. The research sponsored by the Spitzer Science Center and NOAO will be a portion of this article.

One other project we are considering is adapting our data and making it part of a downloadable classroom project that teachers can use to make their own SEDs and light curves. We will release all ground-based raw images for analysis following this year’s science fair. In the next cycle, if we are approved, we will again solicit observations from amateurs, schools, and other observatories.

Adkins is also the author of an introductory astronomy textbook, *Conceptual Astronomy*, which is published by TeachingPoint. Volume 1 is completed and for sale. Volume 2, which deals with stars, cosmology, and instrumentation, will have references to Spitzer in general and this project in particular, and activities for the student workbook will be developed which exploit the knowledge gained in this project.

One anecdotal story related to our project has to do with the young lady who did the majority of the data reduction. Brielle Hinckley entered this project professing “I hate math,” and indeed has struggled to complete basic math requirements during her senior year in high school. Since becoming involved in this project she has had an epiphany of sorts, and has enrolled in night classes to make up poor grades. She has since been accepted to Embry-Riddle University and intends to investigate a major in aeronautical engineering.

<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://www.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 (NRAO) in Green Bank, WV, March 24-26, 2006. Students will also attempt to make some radioscans of GTN 3 while at NRAO. They will then calculate the intensity of the emissions in Janskys.

Rapp will give a local professional development workshop for Washington County, Virginia teachers utilizing the STOP infrared teaching kits March 30, 2006. 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

Co-Investigator (Linda Stefaniak): Each year I teach a minimum of two astronomy classes, one per semester, into which I incorporate a research project representing approximately 20% of class time. My students learn to use a variety of image processing programs, learn to interpret data by graphing it a number of different ways and choose the graphing technique that best represents the data, giving arguments for and against all other approaches. As a component of the class I also stress the importance of the scientific method as a problem solving technique. They learn the necessity of a logical approach to a question, how to gather evidence with which they will support their interpretation and the importance of the peer review of these interpretations so that alternative conclusions might be considered. My students also provide volunteer services as astronomy ambassadors to the PTA's Science Night Live program where they teach simple concepts in astronomy from lessons they develop in class.

Professional Development:

Co-Investigator (Linda Stefaniak): I am an active member of the National Science Teacher's Association as well as my state association and am a New Jersey Department of Education certified instructor for professional development. I presented half a dozen programs and workshops at state and local levels in 2005 and will provide three astronomy workshops at the New Jersey Science Teachers' Association Convention in October 2006. I am the astronomy and earth science content provider to the third grade classes at Upper Freehold Regional Elementary School where I work in close contact with more than 150 students, their parents and teachers.

Summary of Education and Outreach Activities

We will expand the number of workshops and the audience served from last year, and involve more students directly in the next cycle of observations. We also plan to prepare more released materials and data for other schools to use. In combination with other projects, this will become a long-term observing program for several schools directly and indirectly involved with this project.

References:

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Floyd, D. et. al. 2004. Infrared to ultraviolet HST imaging of nearby 3C Radio Galaxies, AAS 205 #144.02.

Krolik, Julian H. 1999. Active Galactic Nuclei: From the Central Black Hole to the Galactic Environment. Princeton, page 441.

Lacy, Mark. 2005. Personal communication.

Nguyen, Tri. 2005. "Microvariability in BL Lac," submitted to Junior Science and Humanities Symposium in Berkeley, CA. A copy will be available at www.ESPACEAcademy.com. A copy is also included with our proposal as an ancillary document.

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Spear, Gordon. 2004. GTN Program Object Catalog. http://gtn.sonoma.edu/participants/catalog/

Spear, Gordon, 2005. Personal communication.

Teras, Ulf. 2005. Quasars and Active Galaxies Catalog for Starry Night. http://home.swipnet.se/teras/starrynight/index.html

AORs

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HEADER: FILE_VERSION=11.0, STATUS = PROPOSAL

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     AOR_LABEL:  GTN 3-IRAC
    AOR_STATUS:  new

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      POSITION:  RA_LON=7h21m53.45000s,
DEC_LAT=+71d20m36.4000s, PM_RA=0.0", PM_DEC=0.0",
EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

          READOUT_MODE: FULL_ARRAY
                 ARRAY: 3.6_5.8u=YES, 4.5_8.0u=YES
            HI_DYNAMIC: NO
            STELLAR_MODE: NO
            FRAME_TIME: 2.0
        DITHER_PATTERN: TYPE=Gaussian5
          DITHER_SCALE: large
 N_FRAMES_PER_POINTING: 1
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO,SECOND_LOOK =
NO
RESOURCE_EST: TOTAL_DURATION=378.1, SLEW_TIME=51.5,
SETTLE_TIME=0.0, SLEW_OVERHEAD=215.0, SPECIAL_OVERHEAD=0.0,
UPLINK_VOLUME=855, DOWNLINK_VOLUME=2812640, VERSION=S11.0.3
INTEGRATION_TIME:
IRAC_3_6=10.0,IRAC_4_5=10.0,IRAC_5_8=10.0,IRAC_8_0=10.0

COMMENT_START:
This project proposes simultaneous observation by Spitzer
and
ground-based observatories, some of which involve high
school
students.  Several observatories are involved but the two
primary
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the
timing of the Spitzer observations should be done when it
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astronomical twilight, up to and including the hours before
dawn if
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necessary. The written proposal accompanying this AOR provides
more details about this special scheduling condition.
COMMENT_END:

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AOT_TYPE:  MIPS Photometry
     AOR_LABEL:  GTN 3- MIPSP
    AOR_STATUS:  new

 MOVING_TARGET:  NO
   TARGET_TYPE:  FIXED SINGLE
   TARGET_NAME:  S5 0716+714
  COORD_SYSTEM:  Equatorial J2000
      POSITION:  RA_LON=7h21m53.45000s,
DEC_LAT=+71d20m36.4000s, PM_RA=0.0", PM_DEC=0.0",
EPOCH=2000.0
OBJECT_AVOIDANCE:  EARTH = YES, OTHERS = YES

    MICRON_24: FIELD_SIZE = SMALL, EXPOSURE_TIME = 3,
N_CYCLES = 1
    MICRON_70: IMAGE_SCALE = DEFAULT, FIELD_SIZE = SMALL,
EXPOSURE_TIME = 3, N_CYCLES = 1
   MICRON_160: FIELD_SIZE = SMALL, EXPOSURE_TIME = 10,
N_CYCLES = 3
SPECIAL: IMPACT = none, LATE_EPHEMERIS = NO,SECOND_LOOK =
NO
RESOURCE_EST: TOTAL_DURATION=1110.1674, SLEW_TIME=39.4,
SETTLE_TIME=41.867405, SLEW_OVERHEAD=215.0,
SPECIAL_OVERHEAD=0.0, UPLINK_VOLUME=1354,
DOWNLINK_VOLUME=13325584, VERSION=S11.0.3
INTEGRATION_TIME:
MIPS_24=48.234497,MIPS_70=37.748737,MIPS_160=62.91456
```

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```