OBSERVATIONS OF S5 0716+714 WITH THE SPITZER SPACE TELESCOPE AND GROUND BASED TELESCOPES

ABSTRACT

The Gamma-Ray Large Area Space Telescope (GLAST) to be launched in 2007 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 Global Telescope Network (GTN). One of our targets, S5 0716+714, was observed with the Spitzer Space Telescope MIPS and IRAC instruments and also using ground based telescopes. Observations were made in seven infrared bands with Spitzer. Additional observations made from the ground by students, amateur astronomers, and college observatories in R,V, and I were nearly simultaneous with the Spitzer observations. This data were used to construct light curves over the course of the observation and the Spectral Energy Distribution (SED) of the target using all the sources. These data were compared to models of the dust emission from the torus, synchrotron emission from the radio core, and thermal emission from the accretion disk to determine the relative importance of the different emission mechanisms in this object as a function of wavelength. Results were compared to observations of 4C 29.45 made last year.

BACKGROUND

Our project is sponsored by the Spitzer Science Center (SSC) and the National Optical Astronomy Observatory's Teacher Leaders in Research-Based Science Education as part of a teacher-based observing program. Using time contributed from the Our project examined two aspects of a S5 0716+714 AGN and recorded a Spectral Energy Diagram (SED) and light curves. An SED is based on all of the typical forms of electromagnetic radiation. Our observations were through the Spitzer Infrared Telescope and the New Mexico Skies ground-based telescopes, and a radio telescope in Green Bank, West Virginia. The ground-based telescopes observed the target using luminous filters while the infrared telescope observed the infrared radiation from the target.

John Michael Santiago, Thomas Travagli, Dr. Mark Lacy, and Alekzandir Morton work on Spitzer data reduction at the Spitzer Science Center.

The term "blazar" is a more detailed classification of AGN. The primary high-energy emissions come out in a large relativistic jet that is of intense energy and magnitude, which includes all types of radiation from the entire range of the electromagnetic spectrum. The jet is typically perpendicular to the plane of the accretion disk, which is the main collection of galactic matter as it falls into the AGN.

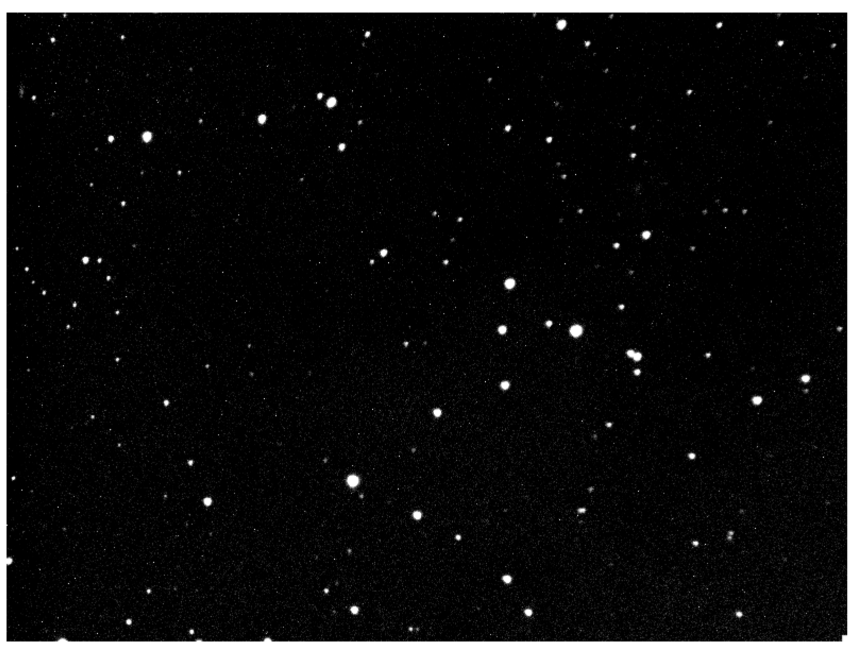
There have been previous observations of the synchrotron radiation emitted from the Active Galactic Nucleus of S5 0716+714, however it is a rare occurrence for a flare to increase the synchrotron peak and create a 'bump' in the SED graph. A collection of observations about blazers showed that "no strong shift in the synchrotron peak frequency are reported." (Krichbaum 2005). The BeppoSax X-ray observatory observed wavelengths in the X-ray region and the authors noted that little variance was seen in optical or infrared when X-ray flares were occuring (Krichbaum 2005).

The relationship between the time-scales and variability is crucial to understanding the light curves of the target. The range of time-scales of the variability is broad. "On inter-night time scales, a bluer when brighter correlation was found when the object was in an active or flaring state, but this trend was absent during the quiescent time." (Stalin 2005).

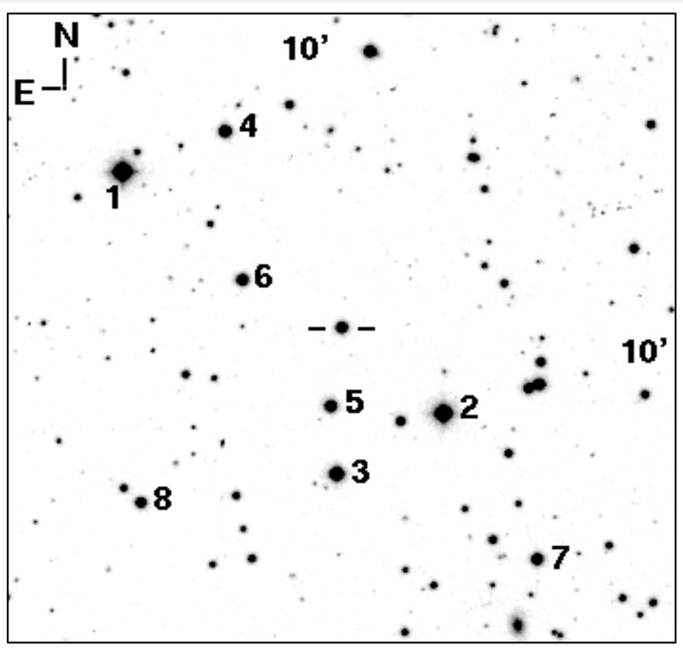
In our project, the SED yielded a bump centered around 70 microns. Such emissions are characteristic of thermal radiation from the torus. Superimposed on the radiations from other areas at a variety of temperatures, the thermal "bump" stands out and enables us to estimate the temperature of the material surrounding the AGN.

Sarah Short, Kristan McCullum, James McCullum, and Justin Smith of Linwood Holton Governor's school discuss the calibration and conversion of radio data taken from the target.

GROUND-BASED OPTICAL OBSERVATIONS



A typical ground-based observation of the target. Taken with the New Mexico Skies remote control 14" telescope by Morton.



Finder chart for the target from the Sonoma State GTN target web site. Numbered stars were our standards.

Observations of the target were made before, between, and after the Spitzer observations. Since these objects are known to fluctuate over short time periods, and the Spitzer observations with MIPS and IRAC were not simultaneous, we wanted to ensure that any significant changes were accounted for. Observations were contributed from a variety of sources including amateur astronomers. The images were reduced by making a model of the magnitude v. log(brightness). This is given by the equation magnitude=-2.5log(brightness). While small variations were seen, within the limits of measurement errors we judged the changes to be insignificant. Data were contributed by Vivian Hoette, Mike Harms, FrP, and JrH. Most observations were through the New Mexico Skies remote telescope system and were conducted by Morton, Travagli, and Santiago. This data contributed to the SED as well.

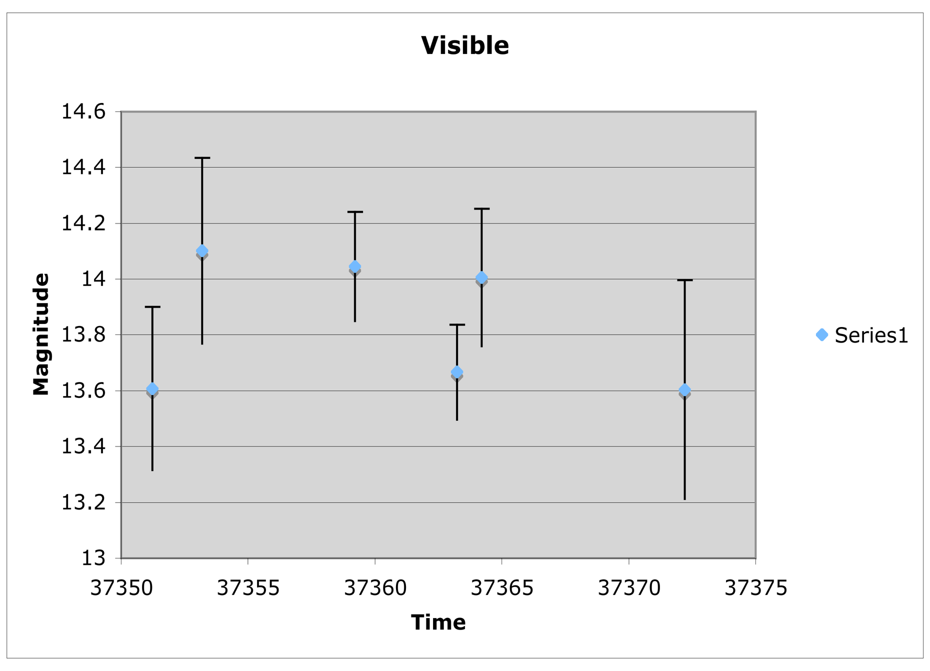
RADIO DATA

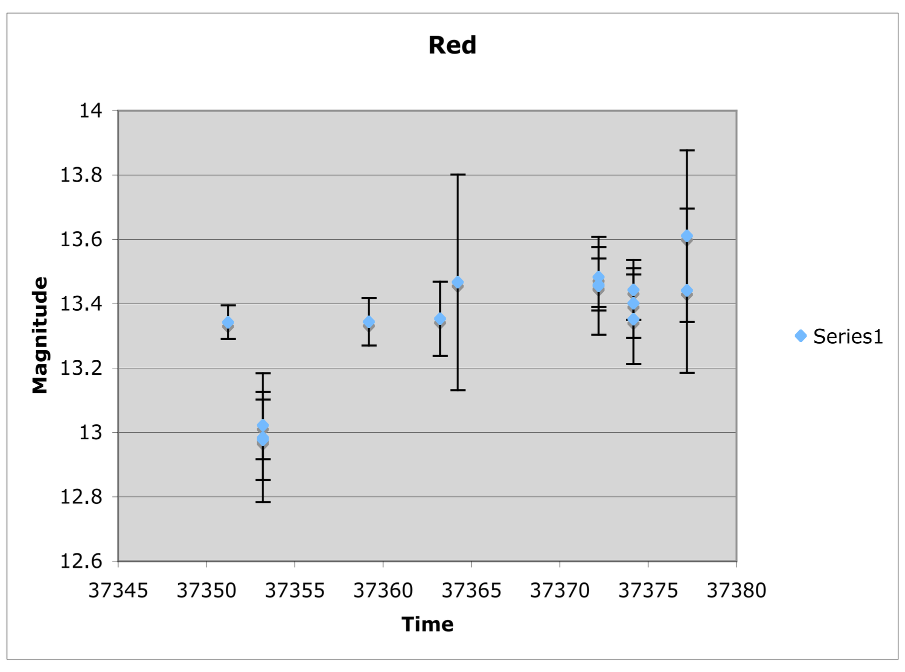
Observations of several AGN including the target for this project were made by Dr. Steve Rapp and students at Linwood Holton Governor's School in Green Bank, West Virginia using an 11 meter antenna. We used the equation: $S = 2kt/A_e$ where S is radio intensity, k is Boltzman's constant (1.38×10^{-23} J/K), t is the temperature in Kelvins, and A_e is the effective area of the telescope dish.

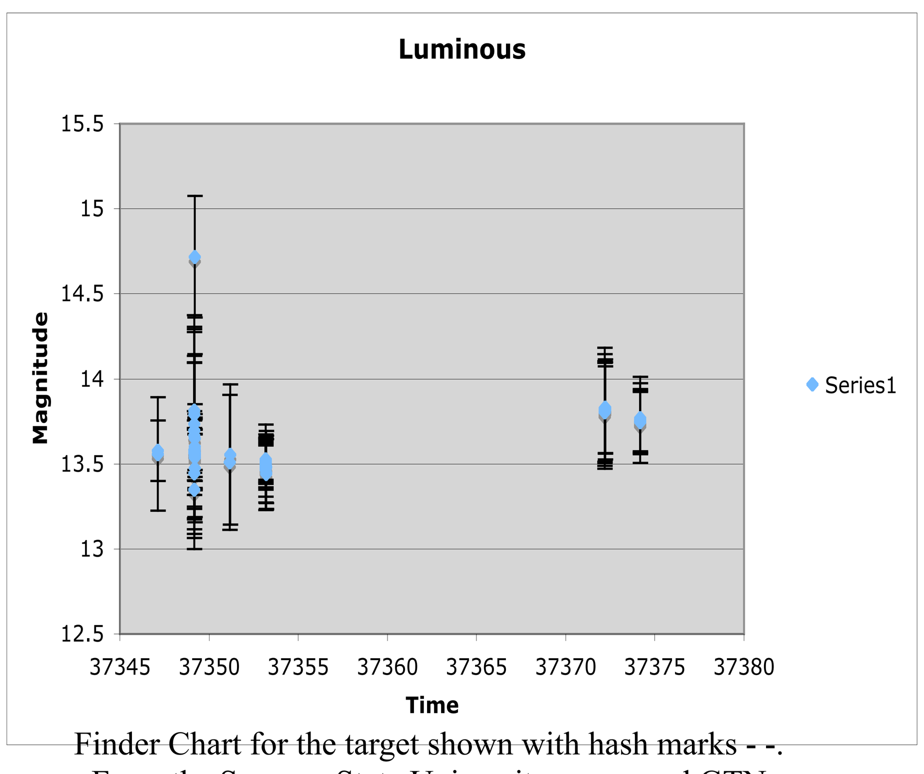
Since the telescope is only 30% efficient the $A_e = .30\ (117\ m^2) = 35.1\ m^2$.

After calibrating the instrument our measurement of the target's flux at 21 cm wavelength was $1.73\ x10^3$Jy.

LIGHT CURVES







Finder Chart for the target shown with hash marks - -. From the Sonoma State University sponsored GTN catalog, listed as GTN 3. Numbered stars are standards used for ground based differential photometry.

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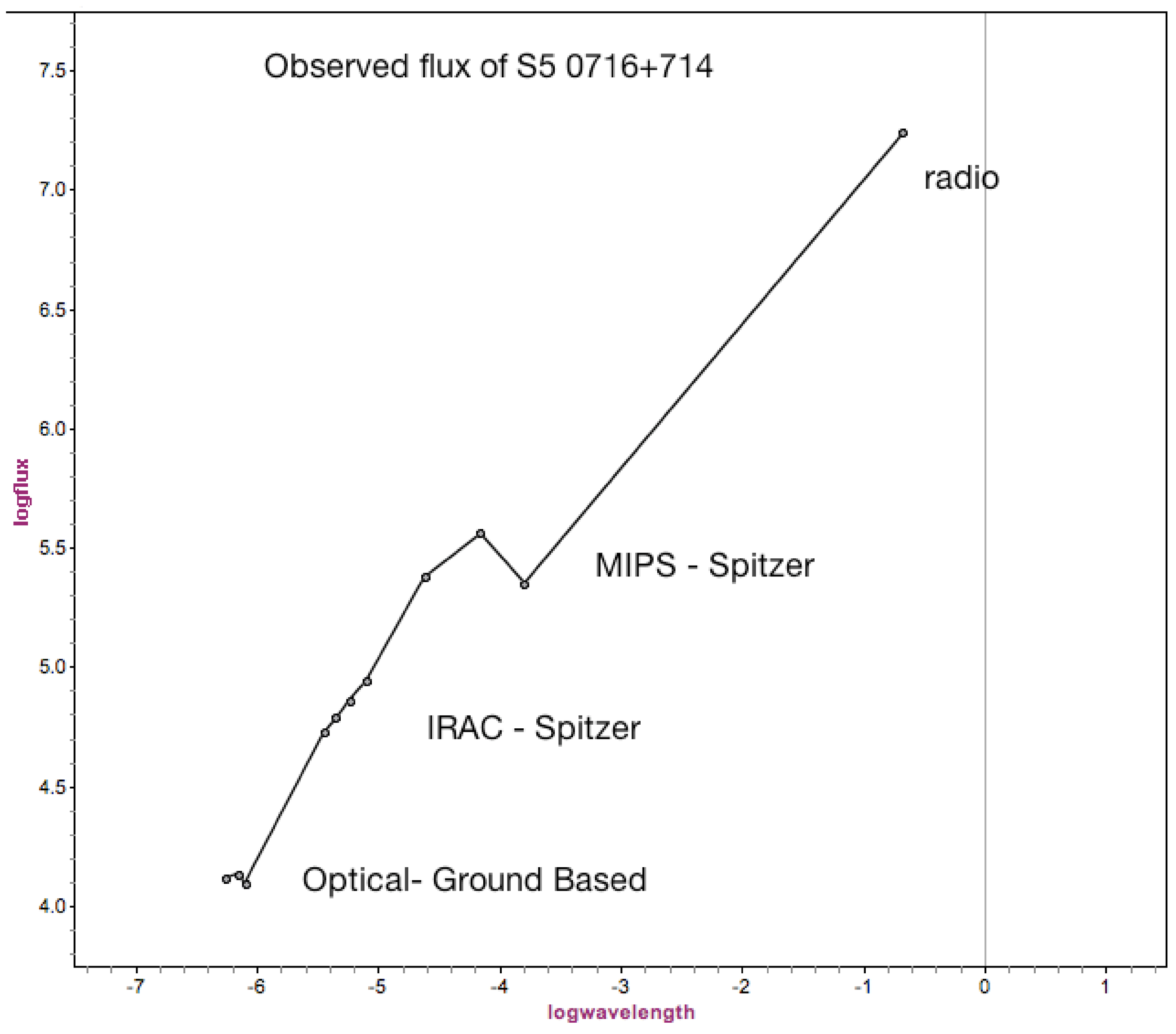
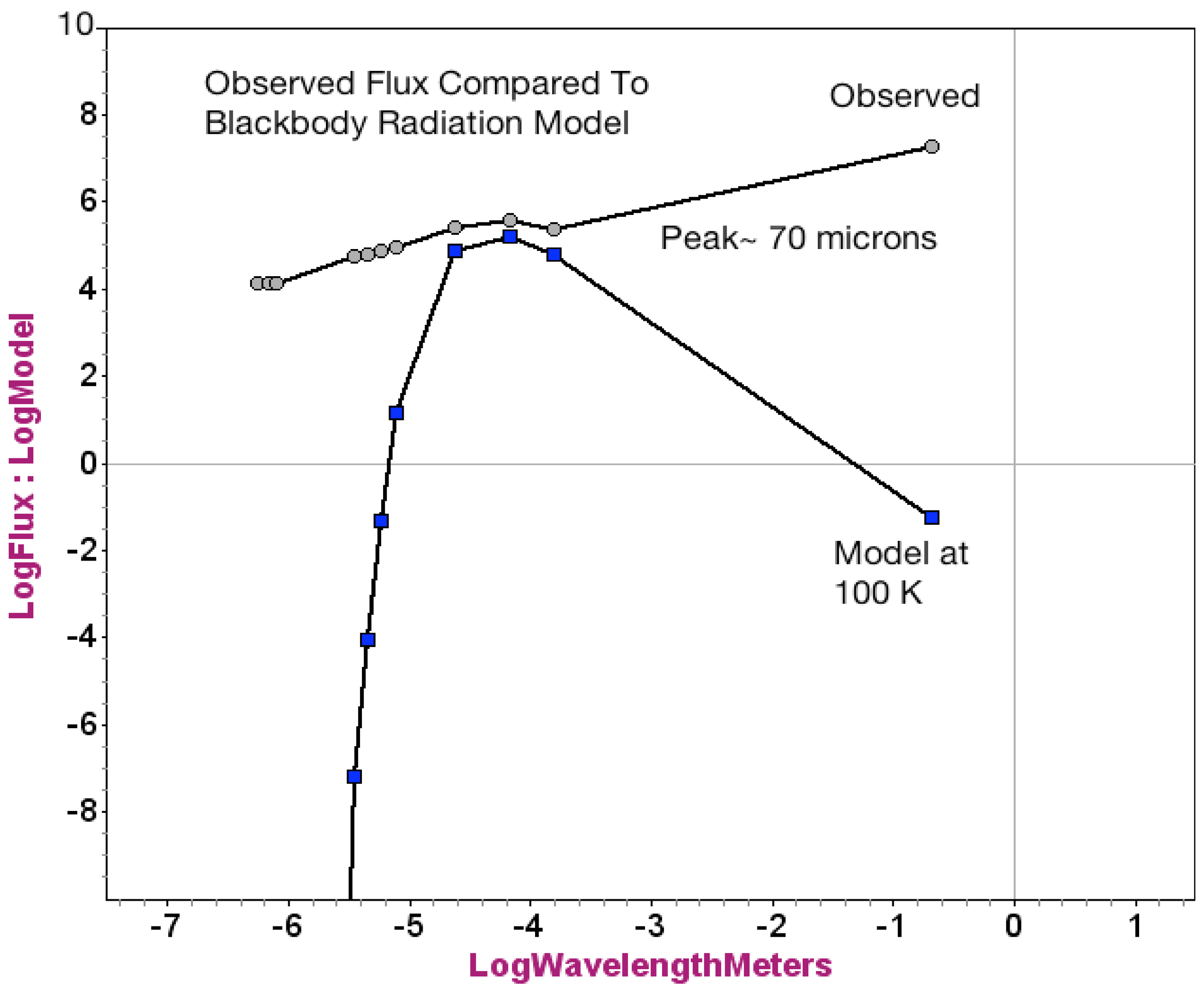
SPITZER OBSERVATIONS & SED

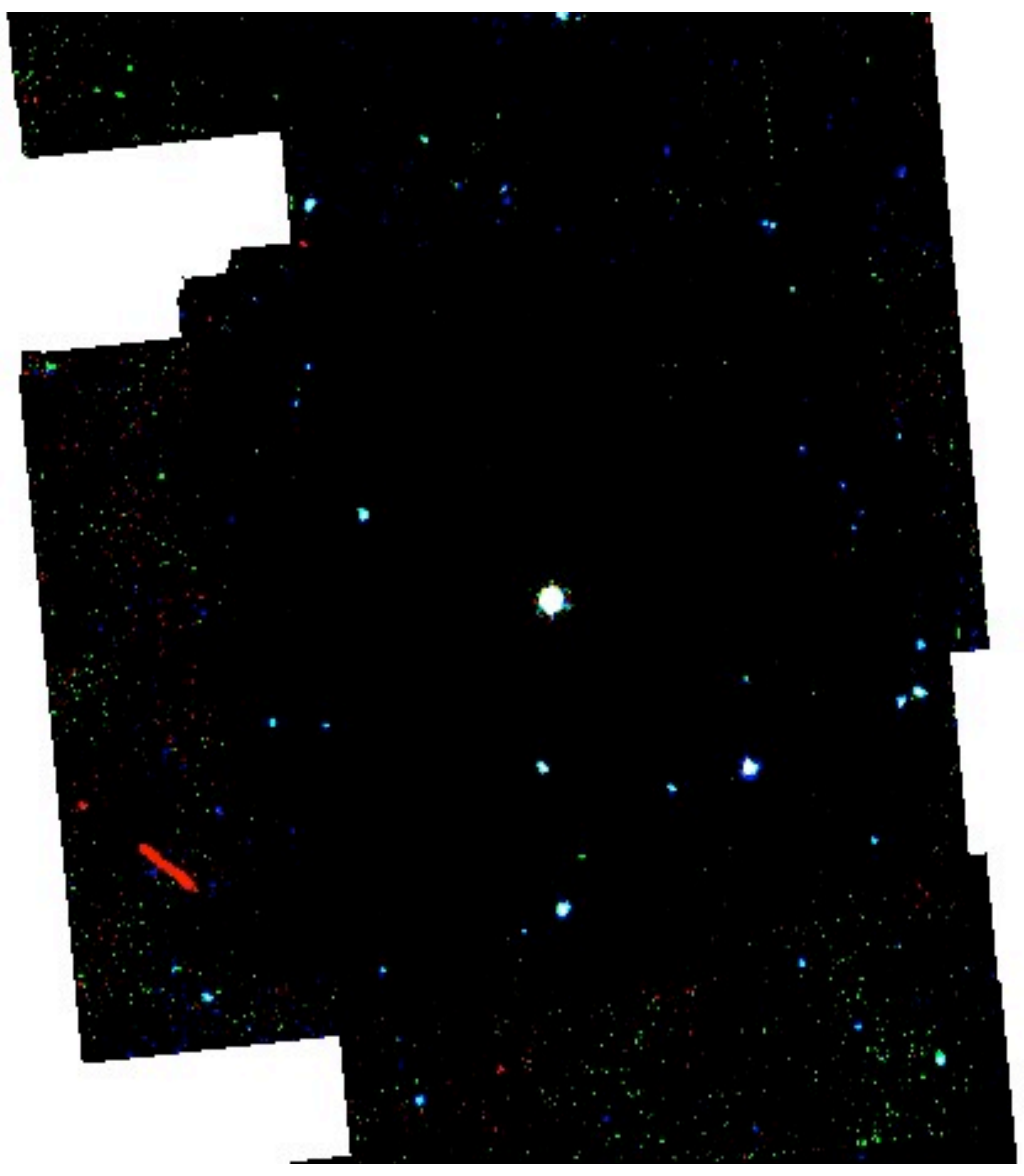
Our target, S5 0716+714, was observed by the Spitzer Infrared Space Telescope on April 8, 2006 (MIPS) and April 28, 2006 (IRAC). A total of seven different channels were observed. Data were reduced by Morton, Travagli, Santiago, and Mulaveesala under the direction of Dr. Lacy using IRAF at the Spitzer Science Center in Pasadena. The wavelengths of each channel and the flux detected by Spitzer is included in the data table and graphs of the SED below. Dr. Steve Rapp and students measured the target and contributed the radio data using the Green Bank radio telescope facility.



Spectra Energy Diagram of S5 0716+714 based on optical, infared and radio data collected by the authors and contributing amateur astronomers.



The observations of S5 0716+714 (top curve) compared to a blackbody radiation model at ~100 K (bottom curve). Units are log (microJanskys) vs. log(meters).



False color image of the target by the authors. It should be noted that in infrared the object is much brighter than surrounding stars (which can be seen by comparing this photo to the optical ground-based image.)

MODELING AND ANALYSIS

Planck's Law was used to graphically model the curve characteristic of radiation from black bodies.

$$I(v,T) = \frac{2hv^3}{c^2} \cdot \frac{1}{e^{(\frac{hv}{kT})} - 1}$$

T is the temperature of the black body in Kelvins.
The flux (as determined through Planck's Law) was plotted on the y-axis against the wavelength (in meters) on the x-axis (both axes were scaled logarithmically) to generate a Spectral Energy Distributions (SED) diagram. Temperature was made an adjustable parameter to visually depict the effects on the model as T varied. Our measured fluxes from observations of the target were then graphed with the model and compared to it.

The peak wavlength was adjusted from a redshifted value to the rest wavelength using a redshift of 0.3, the best value we could find in the literature (Stalin 2005).

It was determined that the peak temperature of the "bump" should be approximately 100 Kelvins, which is somewhat higher than our Wien's Law temperature of 53.816 Kelvins.

Channel	Flux (μJy)	Wavelength (μm)	Wavelength (m)	Model (arbitrary units)	Log (model)	Log (flux)	Log (λ)
Blue	13100	0.556	5.56E-07	3.58E-120	-119.447	4.11727	-6.25493
Red	13500	0.7	7.00E-07	1.64E-95	-94.785	4.13033	-6.1549
Ifr	12400	0.8	8.00E-07	1.23E-83	-82.9115	4.09342	-6.09691
Irac ch. 1	53100	3.6	3.60E-06	5.26E-20	-19.2793	4.72509	-5.4437
Irac ch. 2	61000	4.5	4.50E-06	1.51E-16	-15.8219	4.78533	-5.34679
Irac ch.3	72300	5.8	5.80E-06	1.61E-13	-12.7922	4.85914	-5.23657
Irac ch.4	86900	8	8.00E-06	9.72E-11	-10.0124	4.93902	-5.09691
Mips ch.1	237000	24	2.40E-05	1.51E-06	-5.82091	5.37475	-4.61979
Mips ch. 2	363000	70	7.00E-05	4.80E-06	-5.31899	5.55991	-4.1549
Mips ch.3	224000	160	0.00016	2.01E-06	-5.69716	5.35025	-3.79588
21 cm radio	17300000	210000	0.21	1.97E-12	-11.7058	7.23805	-0.677781

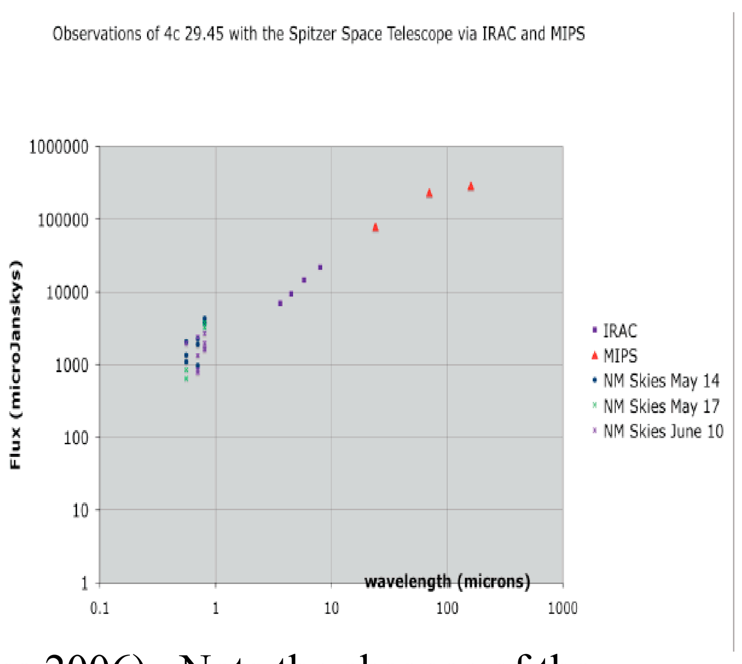
Table 1. Data from a variety of sources used to generate SEDs.

CONCLUSION

Our observations show that while minor time-based variations occured during the observing window in optical wavelengths, no significant changes happened during the interval where the Spitzer Infared Space Telescope was used. The SED shows a bump characteristic of thermal emission from the torus of an AGN, at a temperature of approximately 54 K, as determined by Wien's law. Our math model requires a temperature of approximately 100 K. This is on the cool end of a typical AGN torus (100-300K). Either an unusual mechanism is at work or the estimated redshift is inaccurate. We suggest a followup project to more accurately measure the object's redshift.
These effects were not observed in a similar project done by the authors while observing 4C 29.45 last year.

COMPARISON TO 4C 29.45

This is the second in a series of observations of the GTN targets proposed for observation by the Gamma Ray Large Area Space Telescope. These targets are cataloged by the Global Telescope Network by Sonoma State University, which provided finder charts and standards for our differential photometry. Our target for this poster, GTN 3 (S5 0716+714) has a different SED than the one we observed for the previous target, GTN 3 (4C 29.45).



The SED for GTN 3 is reproduced at right (Adkins 2006). Note the absence of the pronounced infrared bump seen in our current target.

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