Observations of S5 0716+714 using
Spitzer's Infrared Spectrograph
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This proposal was written by Thomas Travagli and Alekzandir Morton, who both attend Deer Valley High School. Jeff Adkins helped direct the research, and Dr. Mark Lacy of the Spitzer Science Center assisted with the technical areas and understanding of the project.

Abstract

Our research on this target left a number of questions concerning the causes and nature of the 'bump' seen in the SED. We propose to target S5 0716+714 for a consecutive observation to extend this data. Spitzer's Infrared Spectrograph (IRS) could provide detailed information, which would primarily be used to deliver a closer value of the object's redshift.

Summary of Previous Work

Targeted AGN

The highly variable AGN S5 0716+714 (fig. 1) was selected from GLAST's (Gamma-ray Large Area Space Telescope) proposed list of targets to be observed. The list was compiled and is updated by the GLAST Telescope Network (GTN). Candidates for observation within 20° of the ecliptic were eliminated, as were objects with high z values, and those that had already been observed with Spitzer in the past (according to the Leopard database).

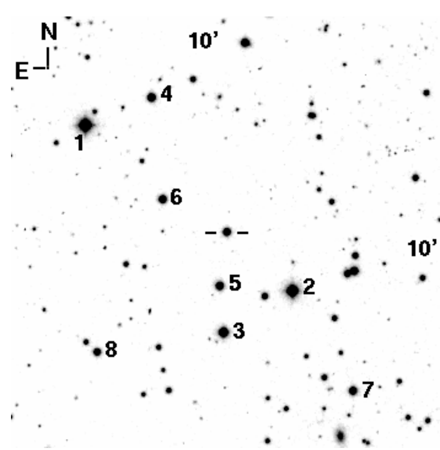


Fig. 1

Ground-based Observations
and Light Curves

Images taken with Spitzer's MIPS and IRAC cameras were bracketed with observations from ground-based telescopes. 91 images were taken with a remote controlled telescope at the New Mexico Skies Observatory (fig. 3), and were coupled with pictures from amateur and professional astronomers to construct light curves (fig. 4,5,6). These graphs were made to ensure that the target's magnitude did not alter significantly between times of Spitzer observations in reference to several standard stars. No considerable changes were seen.

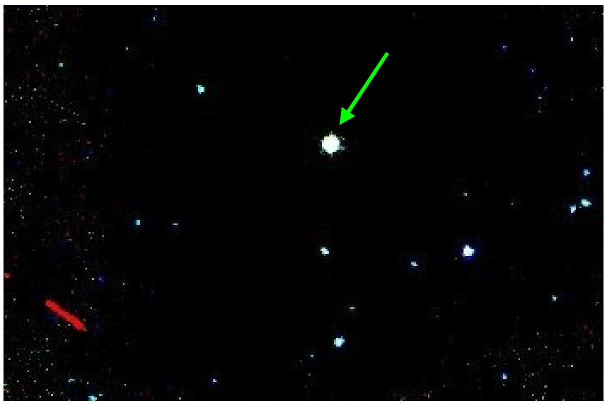


Fig. 2 Image from Spitzer – The target is much clearer in infrared

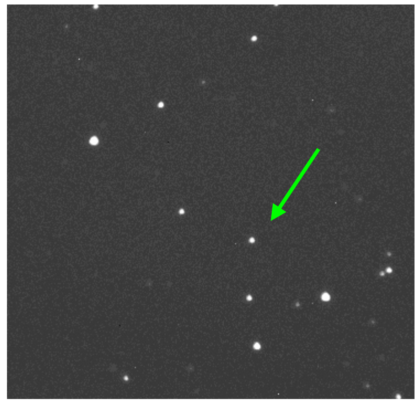


Fig. 3 Ground-based image from New Mexico Skies

Light Curves

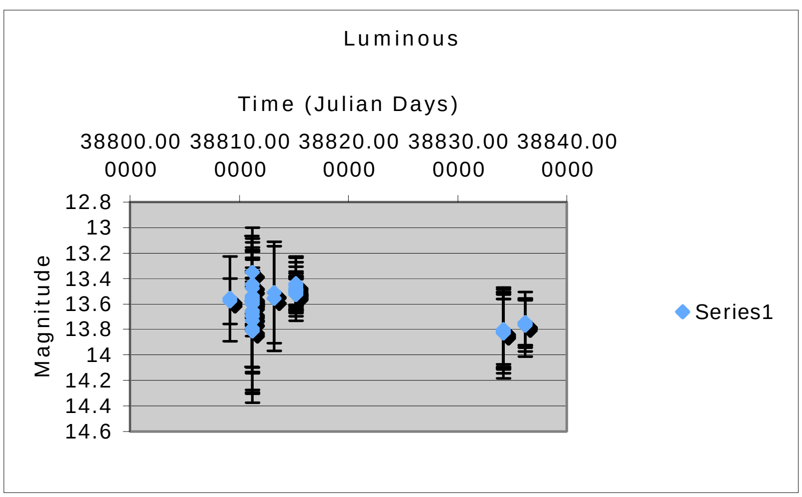


Fig. 4

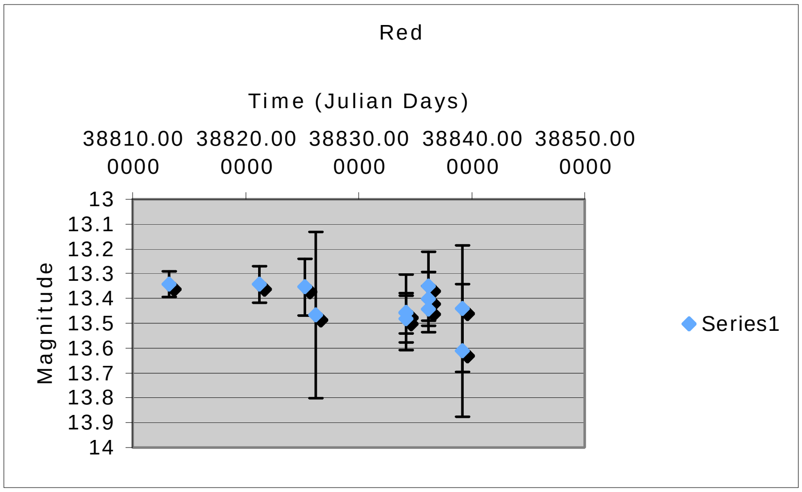


Fig. 5

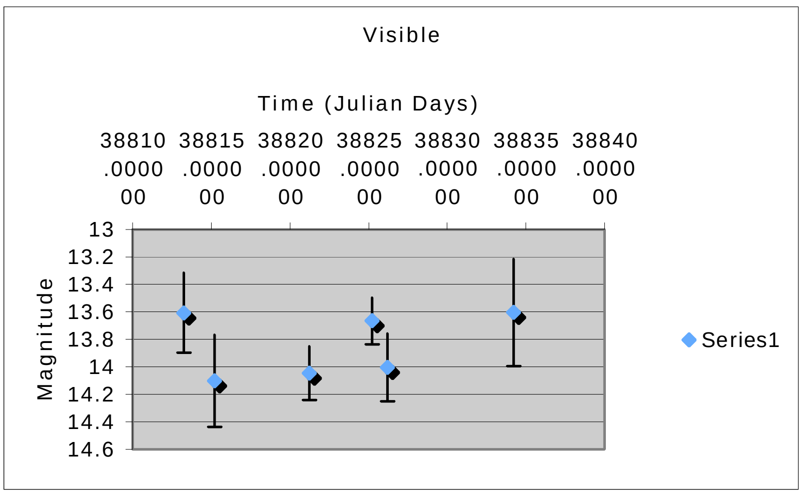


Fig. 6

Spectral Energy Distribution (SED) diagram

The flux of the AGN in each image from Spitzer was then computed to build a graph of the Spectral Energy Distribution (SED). Wavelength (x-axis) and Flux (y-axis) were plotted on logarithmic scales to show the spread of intensity at wavelengths across the electromagnetic spectrum. This graph (fig. 7) included ground-based optical data from New Mexico Skies, data from the seven Spitzer images, and a contributed radio point from Dr. Steve Rapp in Green Bank, West Virginia. This bump in the SED is unexpected in such a highly variable AGN, and suggests that an amount of excess infrared is being added to the synchrotron radiation emitted primarily from the jet.

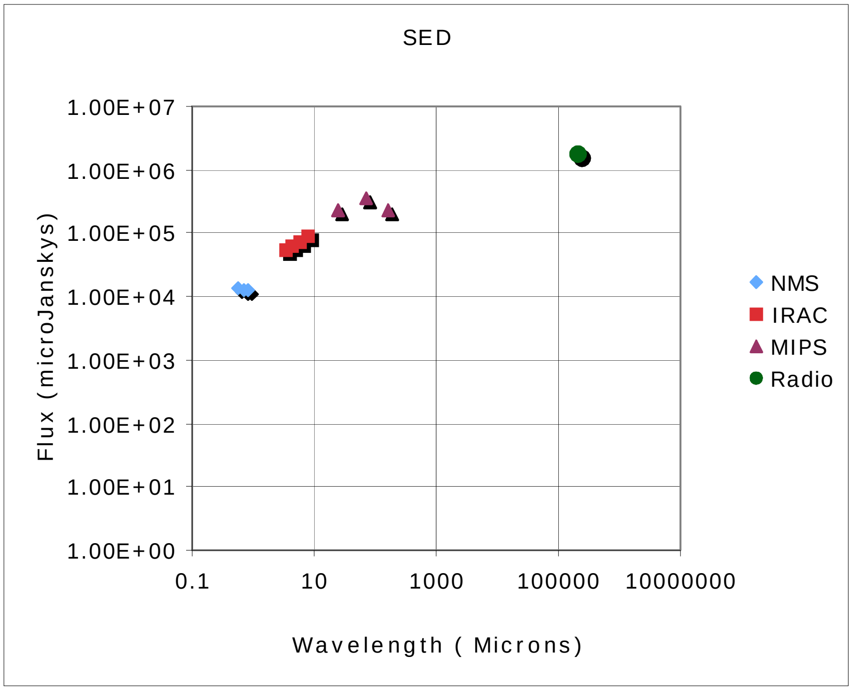


Fig. 7 The SED of the target

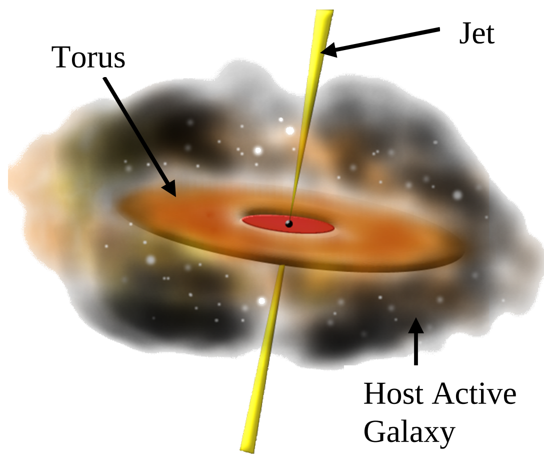
Possible Explanations for the Bump

Three main explanations exist, which were most likely to induce the bump seen in the SED:

a.) Infrared in the galaxy and the stars within it, through star formation.

b.) Infrared emission from material in the torus, heated by the AGN.

c.) Emission from an inner part of the jet not seen in the radio.



Modeling

The SED yielded results that were uncommon for this AGN, and they were explored in further detail with the creation of a mathematical model. The model was based on Planck's Law of Blackbody radiation, which is capable of accurately predicting the spectral intensity of blackbody objects at all wavelengths. The model correctly displayed the behaviors that characterize a blackbody curve, as described through the Stefan-Boltzmann Law and Wien's Law, which demonstrates its credibility as a functioning model and increases the likelihood that it is working properly.

The model was superimposed on a graph, which also contained the SED from our measured data, and was vertically scaled for purposes of comparison (flux scaling is arbitrary, so this does not present a problem). The temperature, *T*, was used as a parameter and adjusted to fit the curve exhibited in the SED. It matched the general shape of the bump at approximately 100 Kelvin, which is considered to be relatively cool for an object of this type.

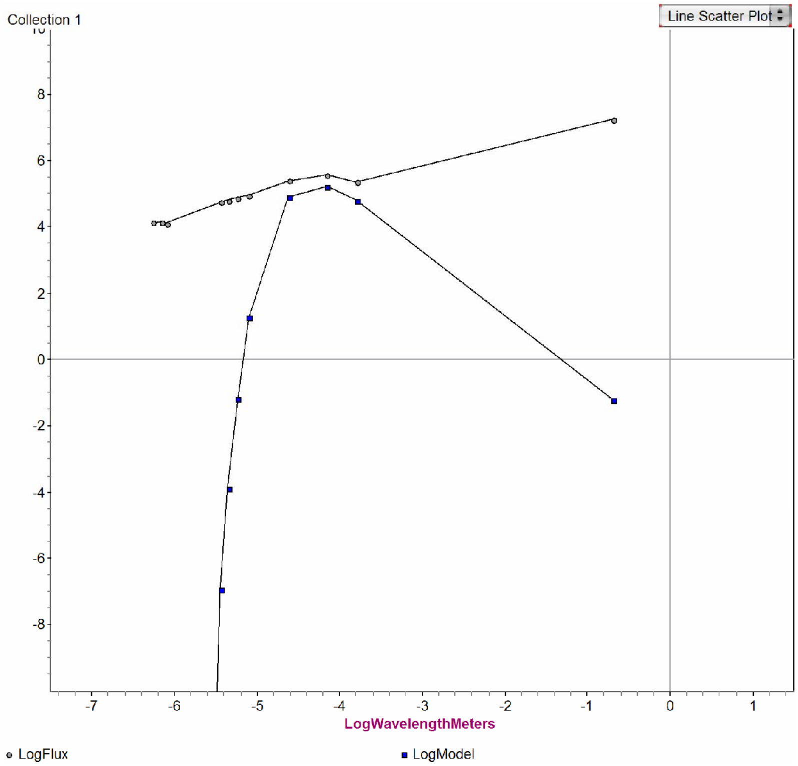


Fig. 8 The model (bottom curve) on a graph also containing the SED of our target (top curve)

Temperature was also calculated through Wien's Law, but temperatures ranged from 53K to 108K due to inconsistent rest wavelengths from two different redshifts (z = .3 and z = 1.5). Travis Rector of the University of Alaska suggested that we use this second redshift value.

Proposed Follow-up Project

Our follow-up project would use Spitzer's Infrared Spectrograph to refine this work. IRS could reveal a spectrum with emission lines (which are expected to be present in this target rather than absorption lines) that could be employed for a closer representation of the target's redshift. Some PAHS (Polycyclic Aromatic Hydrocarbons) have emission lines in the mid-infrared.

Although this target is one of the brightest and most variable BL Lac objects, and many attempts have been made to observe its redshift (the most recent by Rector & Stocke in 2001, with the Keck telescope), only a lower limit $z > 0.3$ has been estimated by Schalinski et al. (1992) and Wagner et al. (1996) because of the lack of detection of a host galaxy in deep images (Tagliaferri et al. 2002). Therefore, the redshift has not been accurately measured for this object (Giommi et al. 1999). Emission lines in the IRS spectrum would permit the calculation of a redshift. This would then allow the SED to be matched to a galaxy model (Granato et al. 2007), and the origin of the bump could be determined.

This information would be very useful and could enhance our understanding of the irregularity, as IRS (5.2-38 μm) covers a fraction of the wavelengths in the bump (24-160 μm). S5 0716+714 is classified as a blazar, and the IRS spectrum may also be used to test this classification, since we detect that it has quasar-like characteristics (the bump). In addition, the object's variability (Giommi et al. 1999) suggests that a repeated observation might be necessary, and silicate dust also emits strongly in the spectra of many AGN.

Mode	Ramp Duration (sec)	Number of Cycles	Point Source Flux Density at Fiducial Wavelength (mJy)	Wavelength (microns)
SL 2	6	2	72	5.8
SL 1	6	2	87	8 (avg)
LL 2	6	2	160	16
LL 1	6	2	237	24 (avg)

The signal-to-noise ratios generated using the data above are shown here:

Mode	S/N
SL 2	72
SL 1	69
LL 2	100
LL 1	74

Observing Time Required

Approximately 13 minutes of telescope time will be required to complete the observation (this includes overhead). The signal-to-noise ratio received using these times should be adequate for finding a redshift.

Participation of Amateur Astronomers and Students

Since the target varies over time, as in our previous two AGN projects we propose to coordinate amateur and student observations of the target using the New Mexico Skies remote telescope system, amateur contributions, and contributions from other Spitzer teacher participants such as Dr. Steve Rapp. Observations will, at a minimum, be made in optical UVBRI filters and calibrated by student participants. These observations will indicate if the object is undergoing any unusual changes during the Spitzer observing period, and, if necessary, be used for interpreting the flux seen in the SED.

Publication of Results

The students involved plan to enter local and regional science fairs and submit their work to the RBSE journal. In addition, they will present the results as a poster session at an AAS meeting and make presentations to several local astronomical societies, the school board, and to workshop participants sponsored by the Deer Valley High School space academy.

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