Spitzer 3.6 and 5.8 micron Monitoring of the Seyfert 1 NGC 4051

Varoujan Gorjian (JPL/Caltech), Babs Sepulveda, Taylor Bennett, Daniel Keen, Samuel Meyer, Brian Remlinger, Amanda Taylor, Nidhi Tiyyagura, Daniel Wu (Lincoln High School), Jeff Adkins, Ame Bartlebaugh (Deer Valley High School), Kareen Borders (Key Peninsula Middle School), Bryan Mendez (Space Sciences Laboratory), Susan Kelly, Cornel David, Miles Konstantin, Doug Streat (Blind Brook High School), Chris Martin, Brandon Wood (Howenstine High Magnet School), Jeff Paradis, Jay Amin, Sam Becker, Joe Ciminelli, Brian Dana, Taylor Dennison, Meghan Dorn, Chris Fallon, LeighAnn Larkin, Chris Tasber, Marlena Vera-Schockner, Rebecca Yuhas (Rush-Henrietta Senior High School), Vincent Pereira, Tomasz Sadowski, Paula Santos-Shevett, Redwan Saleh, Thomas Stolarski, John Tkaczuk, Alanna Weissman (New Explorations into Science, Technology, and Math), Peter Pitman, Anders Larson, Bryant Richardson (White Bear Lake High School), Greg Schultz (Space Sciences Laboratory)

ABSTRACT

We used the *Spitzer* Space Telescope Infrared Array Camera (IRAC) to monitor the Seyfert 1 active galactic nucleus NGC 4051. We took data at 3.6 and 5.8 microns every day for 10 days in June 2008. We also observed in the optical at B, V, and R bands starting a month before the IRAC observations with various ground based observatories, though we were unable to achieve daily coverage. We present the IR and optical light curves and search for correlated variability that may be evidence of dust reverberation. For the education and public outreach component of this program please see Sepulveda et al. 463.02 on Wednesday, 1/6/09

Spitzer and Optical Monitoring of NGC 4051

As part of the *Spitzer* Education and Public Outreach program in collaboration with the National Optical Astronomy Observatories (NOAO) and the Wide-Field Infrared Survey Explorer (WISE) we obtained one hour of Director's Discretionary Time on the *Spitzer Space Telescope* to monitor the infrared (3.6 and 5.8 μm) variability of the Seyfert 1 NGC 4051.

NGC 4051 had previously shown correlated optical (V band) and near-infrared (2.2 μm) variability by Suganuma et al (2006 ApJ 639, 46). The interpretation of that variability is dust reverberation where the optical outburst from the accretion disk is followed by an infrared outburst from the dust surrounding the nucleus, presumed to be in the shape of a torus, which absorbs the optical light and re-emits in the IR. The 2.2 μm emission is then expected to be from the hottest dust at the edge of the torus while infrared emission at longer wavelength are presumably from cooler dust located within the torus and thus carry information about the overall structure of the dust. Figure 1

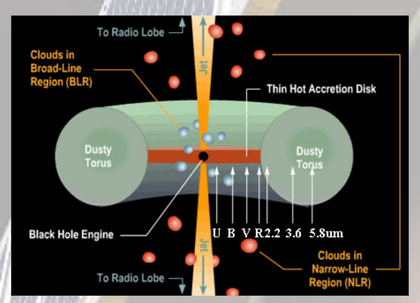


Figure 1. Schematic representation of an active galactic nucleus (AGN) accretion disk and dusty torus, not to scale.The regions of optical emission from the accretion disk are noted based on their optical emission bands: U, B, V, R. The expected IR emission regions are noted based on their wavelengths: 2.2 - 5.8 μm. Note that the 2.2 μm emission is expected to come from the edge of the dusty torus which is at the dust sublimation radius while the longer wavelengths detectable by *Spitzer* come from within the torus. Original Image credit: Brooks/Cole Thomson Learning.

Suganuma et al's finding was that the inner edge of the dust was approximately 10 light days from the accretion disk. So we started a ground based optical monitoring campaing to see if we might be able, in addition to seeing variability in the IR, to catch an optical outburst that might be correleated with the longer wavelngth IR observations. The ground based observatories that were used were: New Mexico Skies, Grainger Observatory telescopes at Exeter Academy, the Faulkes telescope in Hawaii, and the 0.9m telescope at Kitt Peak.

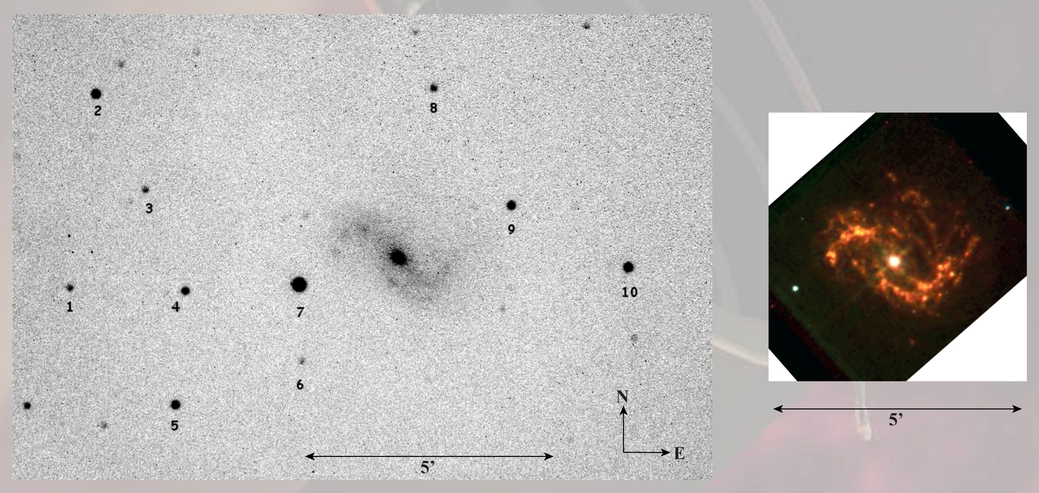
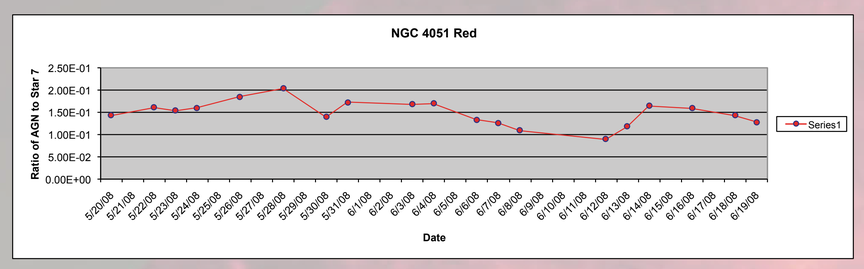


Figure 2. Left: Optical V band image of NGC 4051 obtained by the New Mexico Skies telescope. Right: *Spitzer* image of NGC 4051 with 4.5 (blue), 5.8 (green) and 8.0 (red) microns. The stars that are numbered were the ones that were used as references to compare to the AGN. The individual and median flux density values of the stars that appeared in the most images were used as a baseline to compare the flux density of the AGN in the optical and IR bands..



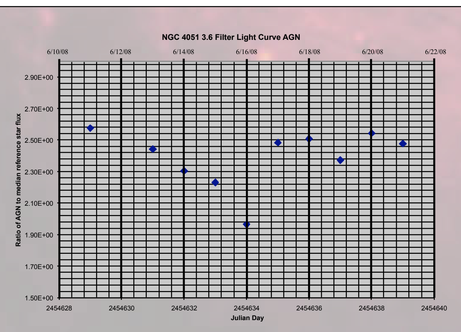


Figure 3. Top: Optical R band photomtery comparing the AGN flux density to the nearest star (Star 7) from May 20th to June 19th, 2008 using the ground based observatories noted earlier. Bottom: 3.6 μm photometry comparing the AGN flux density to the median of the stars in the field of view from June 10th to June 20th, 2008.

Conclusions

NGC 4051 shows evidence of some variability at both the optical and the IR, but, to first order, there does not seem to be correlated variability between the optical and the IR in these observations. This is partly due to the sparse coverage in the optical, particularly at the critical 10 day separation, because of frequent bad weather. More careful analysis of the data combined with archival optical imaging may show some correlation in the future.