Searching for Mid-IR AGN Variability in the IRAC-CF

Lauren B. Hund[1], Matthew L. N. Ashby[1], Joseph L. Hora[1], Jason Surace[2]

[1]Harvard-Smithsonian Center for Astrophysics, [2]Spitzer Science Center, Caltech

Abstract

We report on a new, extremely sensitive search for mid-IR (3.6 μm) variability in the calibration field for Spitzer's IRAC telescope (the IRAC-CF). We developed a sorting algorithm to search the database of 15,000+ distinct 3.6 μm sources for those with clear intrinsic variations in brightness. We found four such objects; all exhibited variations on timescales of approximately one year. We found no sources that appeared to be varying on shorter timescales.

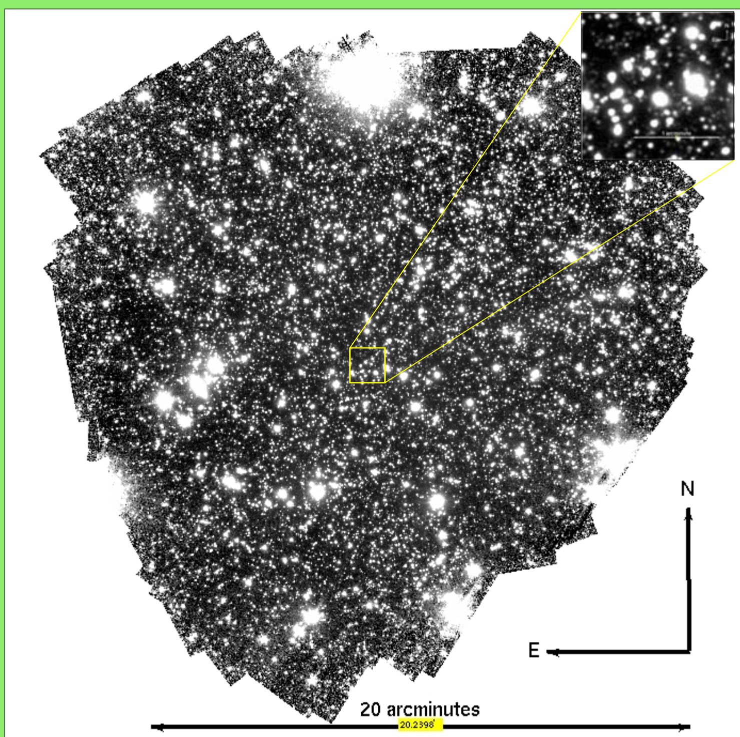


Figure 1 – Total coadd of 128 epochs from the IRAC-CF at 3.6 μm. Image inset illustrates the source density.

The IRAC Calibration Field

An Unparalleled IR Deep Field

Searching for mid-IR variability necessitates having an extremely sensitive IR field, which is now available through the *Spitzer Space Telescope* (Werner et al., 2004) and IRAC. The advantages to observing with *Spitzer* (due to its Earth-trailing orbit) include the stability of the platform, constant focus of the instrument, low background, and absence of thermal instability. *Spitzer*'s Infrared Array Camera (IRAC) is calibrated by repeatedly observing a low-background field with few bright sources in it near the North Ecliptic Pole at 17h40m +69d (Fazio et al. 2004).

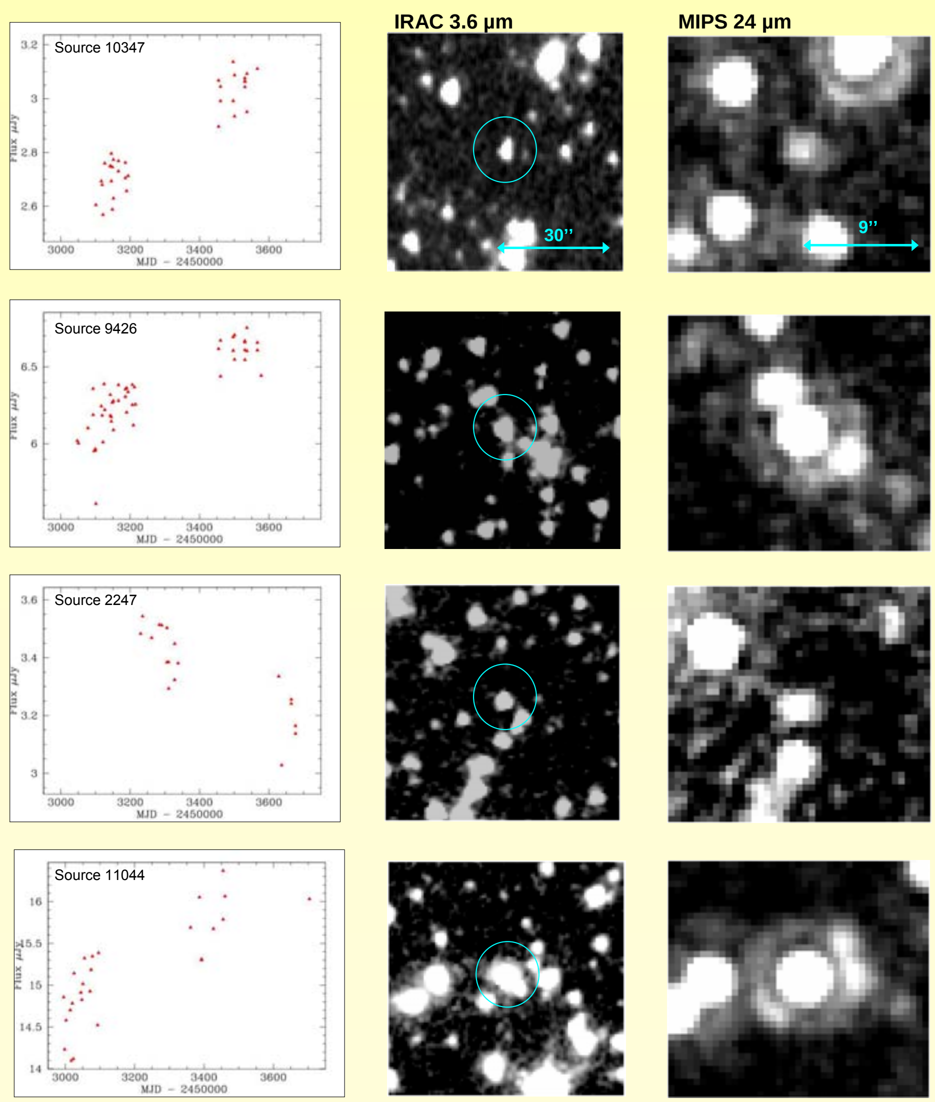
There are 3 main advantages to using the IRAC-CF in our search: frequency of observation, size of the field, and sensitivity of the images. This field is observed 2-5 times every 1-4 weeks when IRAC is turned on. The IRAC-CF is altogether approximately 20' in diameter. Sources in this field are detected at up to a 5 σ sensitivity of 0.8 μJy. The depth, size, frequency of observation, and low background of the IRAC-CF, coupled with the benefits of observing with a space-based telescope, make the IRAC-CF arguably the best resource in existence for finding AGN variability in the mid-IR. We perform our search using 123 epochs at 3.6 μm.

We found four sources displaying strong evidence for long-term variability.

We are confident that these sources are galaxies, as they are red in the IRAC bands. Additionally, all four sources meet the Stern et al. (2004) color criteria for active galaxies. The table below displays data about the four sources.

Source	RA, DEC (J2000)	Average (μJy)	σ (μJy)	Range (μJy)	% Increase	# Epochs	Comments
10347	17:39:24.21, 69:03:17.89	2.85	0.172	0.532	20.5	34	Increasing
9426	17:39:30.38, 69:01:59.23	6.33	0.221	0.801	13.5	50	Increasing
2247	17:40:24.55, 68:53:05.24	3.36	0.122	0.515	-17.0	18	Decreasing
11044	17:40:31.08, 69:03:32.23	15.2	0.546	2.28	16.2	26	Increasing

Figure 4 – Four AGN candidates; (left) flux vs. time graphs of candidates. (center) 3.6 μm IRAC images of the sources (right) MIPS 24 μm images of four candidates. All four sources are bright in the MIPS images, providing further evidence that these sources are AGN.



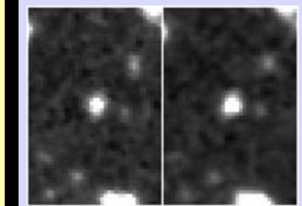


Figure 2. IRAC 3.6 μm images of source 10347 when faint (left) and bright (right).

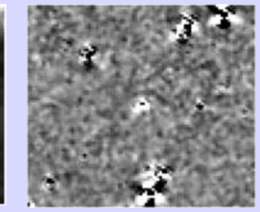


Figure 3. Difference image of source 10347 at 3.6 μm made from images at left .

Variable Source Search

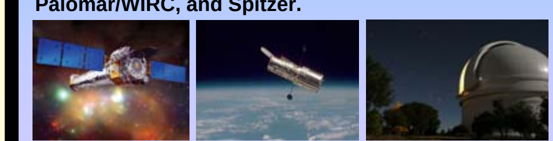
The data from the Spitzer calibration field were mosaicked using the SWIRE Legacy Programs pipeline. Individual epochs were created from data collected on the same dates and large coadd mosaics of the entire field were compiled combining all images. We used Source Extractor (Bertin & Arnouts 1996) to photometer the approximately 15,000 sources and were consistent with our photometry in each epoch. We coded a variability detection algorithm, designed to detect and quantify significant deviations in the fluctuation of a source's apparent brightness from normal patterns that occur due to random noise. We used photometric trends for neighboring sources to verify the photometry of all the variability candidates. Trends between neighbors typically denote errors in the background estimation, misalignment of images, or rotating diffraction spikes. Using this process, we were able to attribute many candidates' variation to extrinsic factors and find intrinsic variability in several sources.

Results

Our method for detecting mid-IR AGN variability in the IRAC-CF successfully isolated variable sources and found four strong candidates for intrinsically varying AGN on long-term timescales (see Figure 4). The frequency of the data sets precludes detection of intra-day variability. Furthermore, we found no evidence for *intrinsic* intra-month variability in any of the approximately 15,000 sources we analyzed. We did an additional search for variability candidates among sources that were within the AGN wedge in the IRAC color-color plot as defined by Stern et al. (2004), and aside from the four long-term candidates, none of the sources meeting these criteria appeared to show any intrinsic variability. We conclude that either our methods for image alignment and source photometry left too many artifacts in the data, precluding detection of intrinsic intra-month variability, or intra-month variability in sources in the IRAC-CF at 3.6 μm is too faint for detection. However, our algorithm is useful in detecting long-term (over one year timescale) intrinsically varying sources.

We have received observing time at the MMT this June and will observe redshifts and emission line intensities for these sources in visible wavelengths.

Furthermore, we plan to follow up these sources with Chandra/ACIS, Hubble/ACS, Akari/IRC, Palomar/WIRC, and Spitzer.



Acknowledgments

This work is based on observations made with the *Spitzer Space Telescope*, operated by JPL/Caltech under NASA contract 1407. Support for this work was provided through the SAO REU Summer Intern Program. This research was made possible by NSF grant 9731923.

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