Spitzer Observations of Stellar Variability in the Mid-Infrared Sky

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- ABSTRACT -

We used archival mid-infrared data from the Spitzer Space Telescope to search three Infrared Array Camera (IRAC) fields containing exoplanet host stars (TrES-2, HAT-P-1, and TrES-4) for additional stars that vary in the mid-infrared. We used the Image Reduction and Analysis Facility (IRAF) software to determine photometry for all field stars detected by 2MASS, plus a number of manually selected stars in each field that were not contained in the 2MASS Point Source Catalog. In total, 242 stars in 6447 images were surveyed (62 stars in 1073 4.5-micron images of the TrES-2 field spanning 3.5 hr, 49 stars in 1605 3.6-micron and 4.5-micron images of the HAT-P-1 field spanning 6.0 hr, and 131 stars in 2164 4.5-micron images of the TrES-4 field spanning 8.0 hr). We created light curves for each of the stars and visually inspected these light curves for variability above the level of the noise. We found one star in the TrES-4 field that displayed periodic variability (P = 0.084 days) when phase-folded. We designated this star NITARP-V1. Thus, we found that approximately 0.4% of stars observed in the mid-infrared, down to our sensitivity level (approximately 0.15 mJy at 4.5 microns for a S/N = 5 detection), exhibit variability. This research was conducted within the NASA/IPAC Teacher Archive Research Project (NITARP). Also see the education results from this project in poster 248.10 M. Piper, et al.

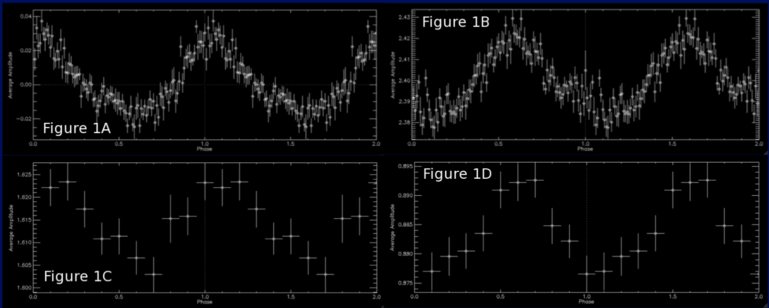
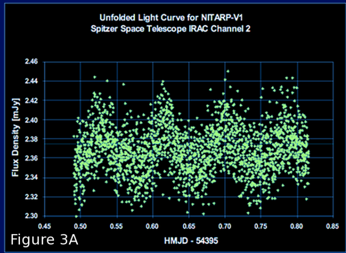
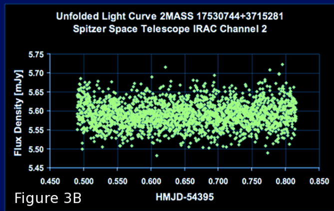


Figure 1: Plots of NITARP-V1 Flux Density [mJy] folded on the period P in days found from the periodogram and power spectrum analyses, binned into phase bins of width 0.01 or 0.05 (the ordinate error bars are the standard deviation of the mean in each phase bin; the abscissa "error" bars show the width of the phase bin). The phase offset between channel pair 1 and 3 and channel pair 2 and 4 is due to the fact that these data were obtained at a different time.

[1A] 3.6 microns, P = 0.085 +/-0.013; [1B] 4.5 microns, P = 0.084 +/- 0.012;
[1C] 5.8 microns,0.089 +/- 0.015 and [1D] 8.0 microns, P = 0.088 +/- 0.010 d]





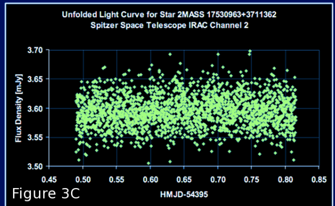
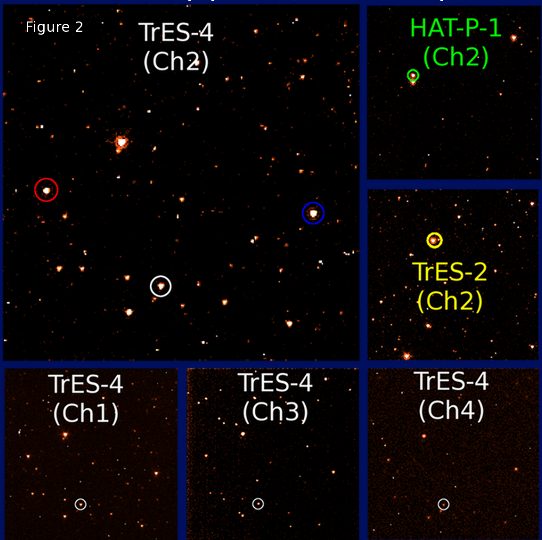


Figure 3: Plots of three unfolded light curves [Flux density mJy vs. HMJD-54395]. We used IRAF to obtain the photometry for these graphs. Figure 3A is our variable NITARP-V1 with its average flux density of 2.3755 mJy and period of 0.084 day clearly visible. Figure 3B and 3C are light curves of stars of comparable brightness from the same TrES-4 field that show no detectable variation. These stars are indicated by the blue [3B] and red [3C] circles on the TrES-4 field, Figure 2a.

Figure 2: The three IRAC fields that we examined for the presence of variable stars. The 5.12' X 5.12' images for channel 2 at 4.5 microns are shown for all three fields. The variable star that we identified is in the TrES-4 field, which is shown for all four IRAC channels. [3.6, 4.5, 5.8 and 8.0 microns]. NITARP-V1 is indicated by the white circle. Its 2MASS identification is 17530247+3713134.



The Spitzer Science Center is aware of an effect that produces a variation in photometry for long staring observations such as we are using. The cyclic pointing wobble and the response variations across a given detector pixel (the pixel-phase effect) for the IRAC arrays combine to produce a period of 0.044 days. Since NITARP-V1's period of 0.084 days is about twice this period, we have taken additional care to be sure that this variation is real and not related to the known artifactual variation.

We performed additional power spectrum analyses on a star of brightness similar to our candidate variable, but which shows no apparent variation. Its light curve is shown in Figure 3c. The analysis [plots not shown here] has been applied to both the normalized pixel-phase corrected photometry and the normalized raw photometry with no such correction. As expected, the power spectrum for the raw time-series photometry for this comparison star clearly shows a peak at frequency corresponding to the known effect period of 0.044 days. There is no peak corresponding to the frequency peak observed for NITARP-V1. And the corresponding analysis for the comparison star, after the effect has been removed, shows no significant peak at 22.9/day [period = 0.044 day].

This is strong evidence that the variation that we observe for NITARP-V1 is real. Also we point out that the variation for NITARP-V1 is observed in two independent data sets obtained at different times as shown by the plot 1[a] and 1[b] for channels 1 and 2 respectively.

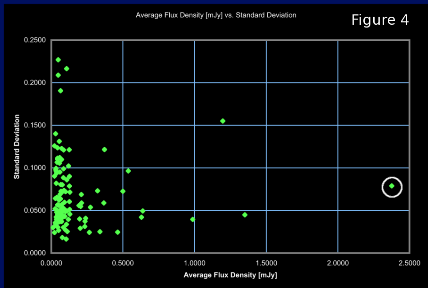


Figure 4: Plot of Standard Deviation vs. Flux Density for the 131 stars we observed in the TrES-4 field. Of these 131 stars only 45 were previously identified by 2MASS. After eliminating cosmic rays and other artifacts, we identified 86 additional stars within this field. In order to focus our search for variation, we gave light curves for stars with larger standard deviations at higher flux densities especially critical scrutiny. NITARP-V1 is shown by the white circle. From these curves we determined our sensitivity at 4.5 microns to be ~ 0.15 mJy at an S/N of 5.

Summary

The period of NITARP-V1 of 0.084 days and the general shape of its light curve suggest that this variable is of the delta Scuti type. These short period variables have individual periods of 0.03 to 0.3 days and reside where the instability strip crosses the main sequence in the HR diagram.