The Spitzer 24μm Photometric Light Curve of the Eclipsing M-dwarf Binary GU Boötis

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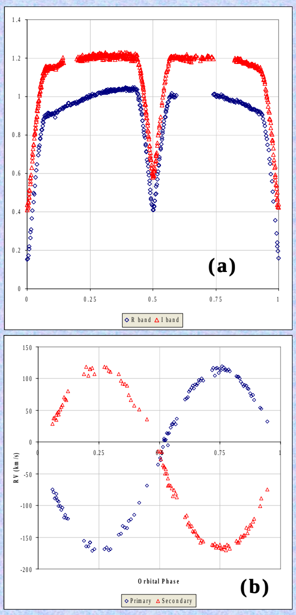
Abstract: We present a carefully controlled set of Spitzer 24 μm MIPS time series observations of the low mass eclipsing binary star GU Boötis. These observations serve to characterize the MIPS-24 observing techniques of the spacecraft, precisely establishing the photometric repeatability of this instrument at the tens of μJy level. The data aim to substantiate the previously announced observations of extrasolar planet transits at similar levels of precision. A further science return is the first-ever long wavelength characterization of such an object's light curve, allowing for improved characterization of the components' linear radii, in addition to other aspects of their surface morphology. Here, we show GU Boo's 24 μm light curve and give our estimates on astrophysical parameters of the binary system.

What is GU Boötis?

- GU Boötis is a nearby, low-mass eclipsing binary system, consisting of two M-dwarfs (López-Morales & Ribas 2005).
- The nearly equal mass binary system was only recently discovered in 2005.

Why is GU Boötis important?

- Very few (<10 pairs) double-lined, detached eclipsing low-mass binaries are known.
- Eclipsing binaries can be used to ascertain fundamental stellar properties such as mass, linear radius, and effective temperature
- Over 70% of the stars in the Milky Way are low-mass objects with M< 1 $M_{\odot}$.
- There is still considerable uncertainty over the mass-radius relation for low-mass stars.



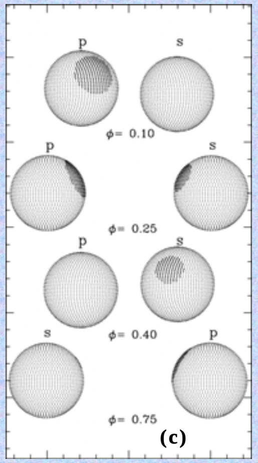


Fig. 1 a, b, c: *R*-band and *I*-band differential photometry curves (**a**), radial velocity curves (**b**), and visualization of star spot geometry (**c**) from López-Morales & Ribas (2005).

Table 1: GU Boo System Parameters

Parameter	Value
Orbital Period (*days*) [a]	0.488728 ± 0.000002
Orbital Eccentricity[a]	0.0
Component radii (solar units) [a]	0.623 / 0.620
Component masses (solar units) [a]	0.610 / 0.599
Secondary Eclipse duration (*sec*)	5665
Combined 24 μm flux (μJy)	502 ± 30
Secondary eclipse minimum 24 μm flux (μJy)	253 ± 80

[a] From López-Morales & Ribas (2005)

Table 2: Spitzer MIPS-24 Observations of GU Boötis

Date	MIPS Campaign	AORs	Exposures[a]
2006 Feb 20	29	16103424 16103680 16103936	860
2006 Feb 21	29	16104192 1610448 16104704	860
2006 Apr 01	30	16104960 16105216 16105472	860

[a] 10 seconds per exposure

Observations / Data Reduction

- 24 μm MIPS data were obtained as described in *Table 2*.
- Two secondary eclipse events were recorded in MIPS campaign 29, a third was observed during MIPS campaign 30 to test MIPS repeatability from event to event, over the short- and long-term.
- 24 μm observations were selected as being minimally affected by limb darkening and/or spots for M-dwarfs.
- BCD frames were mosaiced together in sets of 17.
- The Spitzer *mopex/apex* package was utilized to extract the point-source aperture photometry.

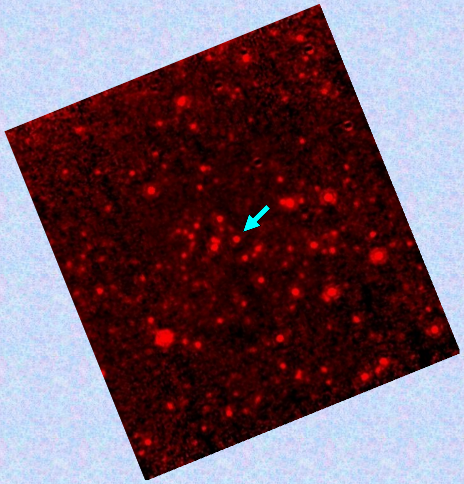


Figure 2: A mosaic of 272 MIPS-24 images from Spitzer. At the center of this mosaic is GU Boötis (marked by arrow). North is up and east is left. The size of the image is about 5 arcmin on the side.

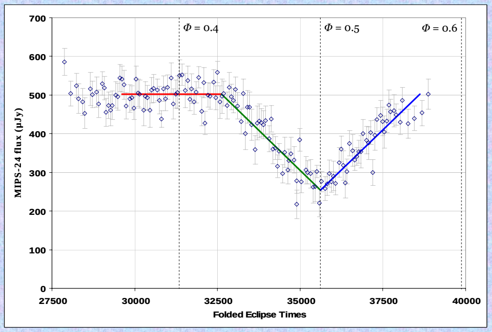


Figure 4: Folded 24 micron light curve for all 3 observed secondary eclipses of GU Boötis. Constant flux level prior to the eclipse is 502±31 μJy; minimum flux level is 253±80 μJy during the eclipse, consistent with a nearly total eclipse of a secondary star with equal surface brightness. Phase angles shown for comparison with Fig. 1.

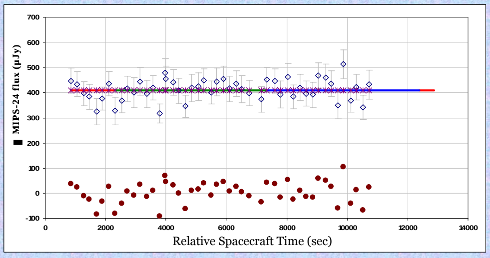


Figure 5: Light curve for arbitrary non-variable star (observing campaign #1). Colors of fit-line segments correspond to the ones in Figs. 3 & 4. Diamonds represent actual data, brown dots residuals about the fit. Flux levels are 409±34 μJy (campaign #29.1); 415±34 μJy (campaign #29.2); 430±33 μJy (campaign #30).

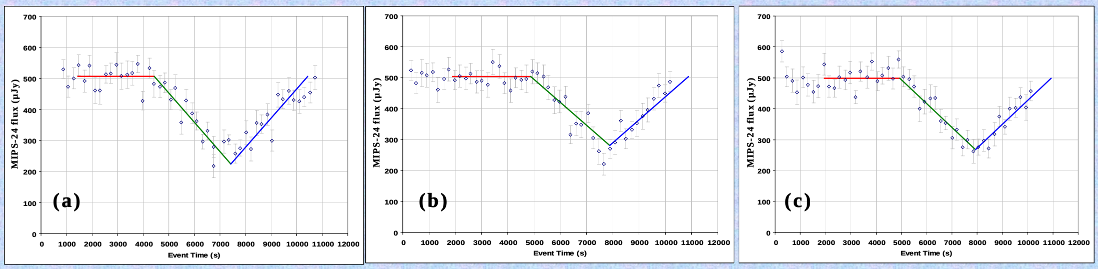
Conclusions (thus far)

- Spitzer's photometric repeatability from observing campaign to campaign is statistically consistent with intra-campaign levels.
- At 500 μJy (max. GU Boo flux level), the rms is 30μJy.
- For comparison, the 24 μm flux decrement during the secondary eclipse for HD 209458 is 55 μJy (stellar flux ~ 22,000 μJy).
- We find that the scatter in the *apex* aperture photometry is smaller than in its point-response function fitting routine.
- 24 μm light curves for GU Boötis appear to be uncontaminated by surface morphology compared to their optical counterparts.

References

- Berger et al. 2006, ApJ, 644, 475
- Deming et al. 2005, Nature, 434, 740
- López-Morales & Ribas 2005, ApJ, 631, 1120
- Torres et al. 2006, ApJ, 640, 1018

Figure 3 a, b, c: Individual observed secondary eclipse events for of GU Boötis. Constant flux level for (**a,b,c**) are 506±30, 504±31, 498±30 μJy; ingress egress slopes are 0.094±0.028, 0.074±0.034, 0.077±0.032 μJy/sec; minimum flux during maximum eclipse is 224±72, 282±87, 268±83 μJy. Reduced χ2 for each fit was 1.98, 0.91, 1.62, respectively.



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