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NEW ECLIPSING VARIABLES IN THE FIELD OF M67

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The old open cluster M67 has been extensively studied photometrically, but its variable star content has not been completely surveyed due in part to its large angular diameter. We have discovered 4 new eclipsing variable stars in our photometric data for the cluster taken using the 1 m telescope at Mount Laguna Observatory. The newly discovered variables are listed in Table 1. The identification numbers are from Fan et al. (1996; abbreviated FBC) and Sanders (1977). The photometry and period estimate comes from the current study (with the tabulated magnitudes being estimates of maximum light). Proper motion membership probabilities come from Sanders (1977; labelled S), Girard et al. (1989; labelled G), and Zhao et al. (1993; labelled Z). The color-magnitude diagram (CMD) positions for the stars are shown in Figure 1.

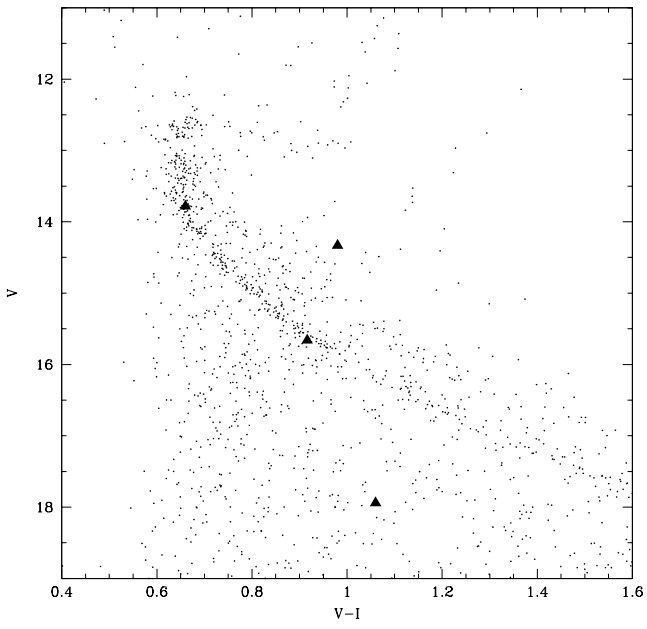

Figure 1. VI color-magnitude diagram for M67 stars, with the identified variables indicated.

Two of the new systems have positions in the CMD near the main sequence for M67 members, but have small ($< 20\%$) proper motion membership probabilities. Because M67 has a relatively small distance from the Sun, a velocity of 1 km s^{-1} relative to the cluster

Table 1. New Eclipsing Variables in the Field of M67.

FBC ID	S ID	max(V)	max(I)	V amp.	I amp.	P (d)	P_μ		Type
2404	743	15.66	14.74	0.10			16 (S)		EA
5018	1601	14.32	13.33	0.13	0.11	0.54	91 (S)	48 (G)	EW
5774		17.94	16.88	0.31	0.30	0.28			EW
5986	1849	13.78	13.12	0.15	0.12	0.445	0 (S)	0 (Z)	EW

motion in the plane of the sky would produce an apparent proper motion of 0.25 mas y^{-1}. Dynamical interactions between stars appear to play a significant role in M67 thanks to a high binary star content and low velocity dispersion (e.g. Sandquist 2005), so we need to bear in mind that a relatively small kick velocity ($\sim$ 10 km s^{-1}) resulting from a 3- or 4-body interaction could give a cluster member a membership probability of less than 20% in proper motion studies. The possibility of kicks can be examined by looking at the magnitude of the measured proper motions (which are generally measured relative to high-probability cluster members) and the position of the star in the vector point diagram. If a star falls near the center of the field star proper motion distribution, a kick would be a less likely explanation.

The calibrated VI photometric data for the variables are provided in Tables 2 - 5, available on the IBVS website as `5679-t2.txt - 5679-t5.txt` The columns are heliocentric Julian date − 2450000.0, magnitude, magnitude error, and filter band.

FBC 2404 (S743): The one proper motion study (Sanders 1977) that covered this detached eclipsing system gave it a low, but nonzero, membership probability. Its position close to the cluster main sequence in the CMD, however, hints that the binary might be a cluster member. The system was just outside of the Chandra field observed by van den Berg et al. (2004), and it was not detected by Belloni et al. (1998). The nondetection would not be surprising because of the faintness of the system, especially if the orbital period is more than a few days.

We observed a single partial eclipse, and see no sign of significant variation outside of eclipse. The eclipse is depicted in Figure 2.

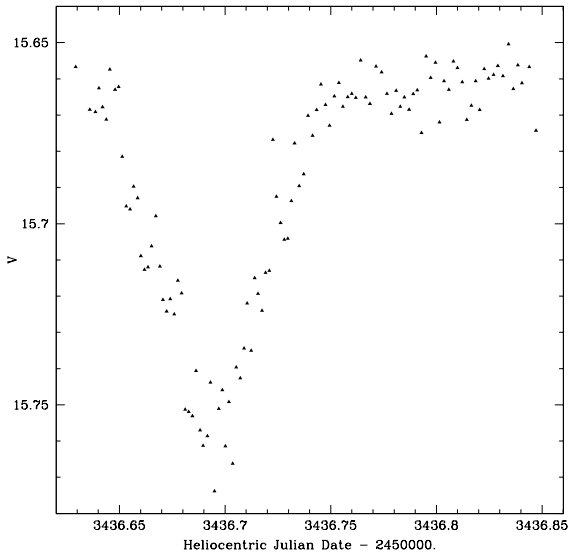

Figure 2. Eclipse observed for the star FBC 2404.

FBC 5018 (S1601): The proper motion membership probabilities for this system identify it as a possible cluster member. Girard et al. (1989) measured a larger proper motion (3.2 mas y^{-1}), which is responsible for their lower membership probability. The color-magnitude diagram position is unusual, however: the system is bluer than the locus for equal-mass binaries. If the system is truly part of the cluster, there must be at least one other star contributing significantly to the system light. If it is not a cluster member, it is unusually bright for its properties: the M_I-period-color relation (Rucinski 1997) for W UMa binaries returns a distance modulus that is about 0.7 mag *larger* than those of cluster member systems in contradiction to its position brighter than M67's main sequence. van den Berg et al. (2004) identified this star in Chandra X-ray observations (CX7), and they found a count rate that was more than twice as large as any of the previously known cluster W UMa variables. The contradictions among the methods we have used to check on membership leads us to recommend that this system be studied further to clarify its unusual nature.

Although we have not observed the binary through an entire orbital cycle, we did observe two maxima in I-band, allowing us to estimate the period (see Figure 3). The first maximum we observed appeared to be slightly fainter than the second, which could indicate the presence of starspots.

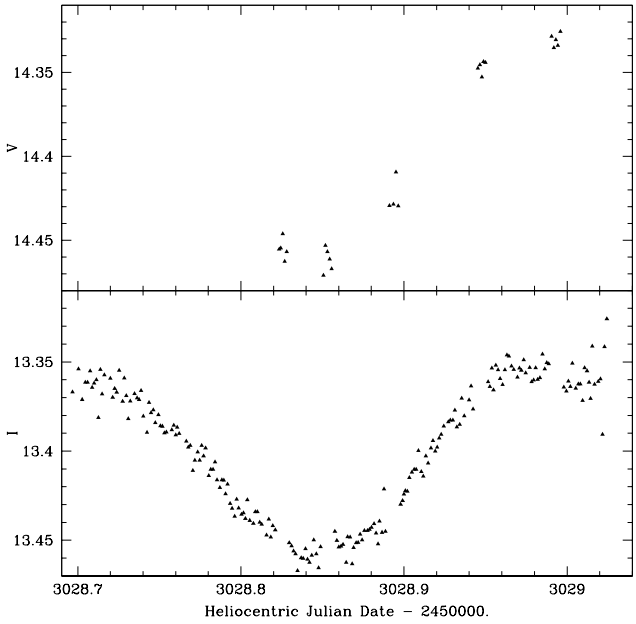

Figure 3. Observations for the W UMa-type variable star FBC 5018.

FBC 5774: No proper motion information is available, but the system falls far to the red of the cluster main sequence, so that it is very unlikely to be a member. Use of the M_I-period-color relation (Rucinski 1997) indicates that the system has a distance modulus more than 2.5 magnitudes larger than the 4 previously known cluster W UMa stars. The amplitude of the variable is fairly large ($\sim$ 0.3 mag), and one of the photometric minima is definitely deeper than the other (See Figure 4).

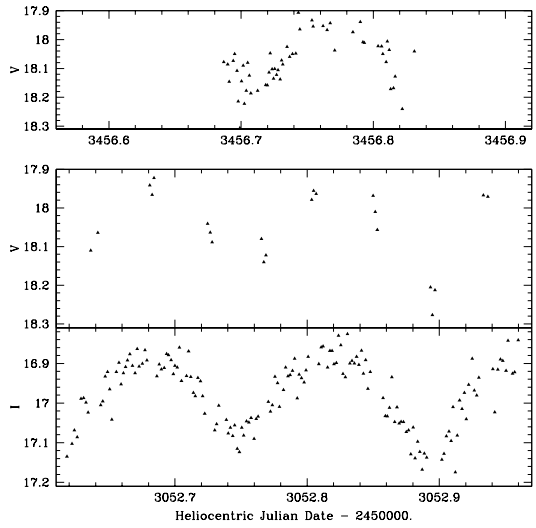

Figure 4. Observations for the W UMa-type variable star FBC 5774.

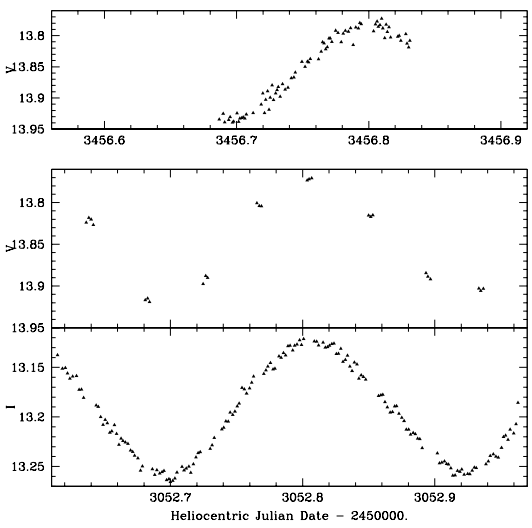

Figure 5. Observations for the W UMa-type variable star FBC 5986.

FBC 5986 (S1849): This contact system happens to lie very close to the cluster main sequence in the CMD. However, two proper motion studies give the system a 0% probability of membership, thanks to measured relative proper motions of 6.8 (Sanders 1977) and 9.1 mas y^{-1} (Zhao et al. 1993). Based on this, the system is unlikely even to be a member in the process of ejection. Use of the M_I-period-color relation also indicates that its distance modulus is about 0.8 mag larger than the cluster W UMa stars. This system was not in the field observed in X-rays by van den Berg et al. (2004) or Belloni et al. (1998). The light curve is fairly symmetrical (see Figure 5).

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References:

Belloni, T., Verbunt, F., & Mathieu, R.D. 1998, *A&A*, **339**, 431.
Fan, X., et al. 1996, *AJ*, **112**, 628.
Girard, T.M., Grundy, W.M., Lopez, C.E., & van Altena, W.F. 1989, *AJ*, **98**, 227.
Rucinski, S.M. 1997, *AJ*, **113**, 407.
Sanders, W.L. 1977, *A&AS*, **27**, 89.
Sandquist, E.L. 2005, *ApJL*, **635**, L73.
van den Berg, M., Tagliaferri, G., Belloni, T., & Verbunt, F. 2004, *A&A*, **418**, 509.
Zhao, J.L., Tian, K.P., Pan, R.S., He, Y.P., & Shi, H.M. 1993, *A&AS*, **100**, 243.