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Spectroscopic and Photometric Studies of an X-ray–Selected Sample of Chromospherically Active Binary Stars [1]

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1. INTRODUCTION

Data from the Einstein X-Ray satellite continue to provide useful information for studies of x-ray emitting objects. The Einstein Medium Sensitivity Survey (EMSS), a tabulation of serendipitously discovered point sources from the Einstein database, included a number of objects which were identified, on the basis of spot sampling of optical spectra, as likely binary star systems (Fleming 1988, Silva *et al.* 1987; Takalo & Nousek 1988). Because the sample is limited primarily by X-ray flux, the physical characteristics of these stars are of considerable interest for understanding the origins of stellar activity among cool stars.

2. OBSERVATIONS

For four years we have been conducting a spectroscopic and photometric study of about four dozen of these stars to determine the orbital and physical characteristics of the individual members of the sample, to see if they represent a single population, and to discover objects of interest for the study of activity in late–type binary systems.

Our observations to date include the following:

1. Radial velocity observations have been obtained using the echelle spectrographs at Oak Ridge Observatory, and Fred L. Whipple Observatory. A few additional observations have been made using the MMT. Spectra are reduced at the Center for Astrophysics using standard CfA correlation reduction techniques, and orbital solutions are obtained using analysis programs written by Dr. Tzevi Mazeh. The stars we have best results on to

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date are those for which we have obtained good correlations using CfA templates, i.e. those with small to moderate Vsini (roughly <50 km/s). New reduction procedures using synthetic spectra matched to the rotationally broadened stellar spectra should make it possible to obtain reliable orbits for other stars for which we have numerous spectra, but whose solutions are not yet secure.

2. Photometric observations have been obtained using photoelectric photometers at Grundy Observatory, Gettysburg College, and the National Undergraduate Research Observatory, and CCD cameras at the Kitt Peak National Observatory. These observations have revealed several eclipsing binaries, and are also being used to study rotational starspot modulation of the light from the binary components. We have reported so far on two eclipsing binaries, 1E1247-0548, a detached system, and 1E2038-0046, a near contact binary. (Marschall *et al.* 1989; Marschall *et al.* 1991).
3. Additional high–resolution spectra have been obtained using the coudé feed at KPNO and the cassegrain spectrograph on the 72-inch reflector at Lowell Observatory to study the extent and variability of activity among these stars, and to detect secondaries that are unresolved in CfA spectra.

The status of our observations to date is summarized in Table 1. The first 5 columns list vital statistics on the stars. Values of Vsin i, when specified, are taken from Fleming's thesis (Fleming 1988). Column 6 lists the number of spectroscopic observations taken at CfA. Comments in column 7 include notes on whether the object is a confirmed or suspected single line (SB1) or double line (SB2) binary, whether the orbit is circular (-O), and what period has been determined, if any.

3. DISCUSSION

From our spectroscopic and photometric observations of several dozen X-ray selected stars from the Einstein Medium Sensitivity Survey we can report the following:

- We have derived new spectroscopic orbits for 12 stars.
- Most of the binary candidate stars selected from the EMSS by Fleming (1988), Silva *et al.* (1987), and Takalo & Nousek (1988), are in fact binary stars and will in time yield orbital solutions.
- Most orbits we have observed so far have periods between 1 and 10 days.
- The eccentricities of most of the orbits are very low or zero. The shortest period non-circular orbit is 7 days (1E08240, P=6.95d, e=0.4), but circular orbits with periods of 9.5 days (1E1937) and 11 days (1E15208) are also found.
- We have discovered two eclipsing binaries so far: 1E 1247-0548 (HD111487) and 1E2038-0046 (HD197010). The former appears to be a detached system, possibly an RS CVn binary, and the latter appears to be a near–contact binary system. We are looking for photometric variability in the other systems, both to detect eclipsing systems and to discover rotational modulation of the component stars, a phenomenon evident on 1E2038-0046 (Marschall *et al.* 1991).

TABLE 1. EMSS X-ray Binary Candidates Observed at CfA (as of 4/1/1992)

Name	R.A., Dec. (1950)	Mag	V sin *i*	SAO	N	Comments
1E00029	00:02:52+16:02:55	8.6	12	091699	39	SB2? SB1-O, P=295.66
1E00099	00:09:54+14:17:17	8.5	22	091772	36	SB1-O, triple?, P= 1.844 (Latham 1988)
1E00116	00:11:38+08:40:58	11.5	22	—	34	SB2, SB3?, P=25?
1E01053	01:05:16+31:44:54	6.3	68	054445	11	
1E01344	01:34:25+20:27:11	8.7	11	074827	49	SB2-O, P=25.34
1E02342	02:34:12−03:21:49	8.1	<10	130011	45	SB1-O, P=14.83
1E02417	02:41:40+10:45:05	11.1	28	—	15	SB?
1E02449	02:44:51−00:24:57	9.6	17	130113	40	SB1-O, P=2.63
1E03158	03:15:48−19:55:15	10.8	23	—	10	Constant?
1E03267	03:26:41−20:08:38	8.9	12	—	31	SB1-O, P=3.18
1E03482	03:48:13−14:04:20	10.7	<10	—	26	SB2, SB1-O, P=9.3
1E04294	04:29:22+17:55:11	12.1	<10	—	16	SB2, P=3.89, (Reipurth *et al.* 1990)
1E04386	04:38:33+02:13:05	10.7	—	—	29	SB?
1E05050	05:05:01−05:27:55	10.2	14	—	14	SB1-O, P=9.80, (Fleming 1988)
1E0657N	06:57:29+75:18:26	8.3	<10	006052	11	Constant velocity
1E0657S					9	SB1
1E07303	07:30:20+65:46:59	8.4	17	014241	21	SB1?
1E08240	08:24:01+29:44:39	8.6	<10	080190	48	SB1-O, P=6.95
1E08427	08:42:39+19:00:01	6.8	<10	098098	33	Constant velocity
1E09243	09:24:20+39:42:45	9.7	<10	—	39	SB2-O, P=8.49
1E09568	09:56:50−22:25:14	9.2	15	178272	31	SB2-O, P=1.84
1E10226	10:22:36+11:21:26	10.6	58	—	27	SB
1E10495	10:49:28−08:49:21	11.2	—	—	15	SB
1E10502	10:50:09−09:25:28	12.5	11	—	4	SB
1E11279	11:27:53−15:02:47	9.4	21	156720	41	SB2, P=2.3?
1E12086	12:08:37+39:24:47	8.0	var	062883	12	Velocity variable
1E12225	12:22:31+25:49:40	8.1	—	082295	62	SB2-O, P=0.96 (Kraft 1965)
1E12470	12:47:03−05:48:22	9.0	—	138983	42	SB1; sec res? eclipsing
1E14369	14:36:52−26:28:48	9.2	—	182743	16	SB1?
1E14404	14:40:24+52:13:25	7.5	70	029248	7	Velocity variable?
1E15208	15:20:47−06:25:48	7.3	35	140499	20	SB1-O, P=11.13 (Fekel *et al.* 1985)
1E15306	15:30:37+13:42:55	12.4	21	—	7	Velocity variable
1E15330	15:33:00+09:19:08	11.7	30	—	24	SB, P=2.5?
1E15488	15:48:45+11:25:16	12.8	30	—	9	Velocity Variable
1E16150	16:14:58+31:14:15	12.6	95	—	1	
1E16540	16:53:59+35:15:38	12.3	95	—	1	
1E17373	17:37:16+68:47:10	4.8	<10	017576	33	SB2-O, P=5.3 (Abt & Levy 1976)
1E17510	17:51:03+70:46:17	9.6	30	—	22	SB1
1E1806N	18:06:03+69:44:51	10.5	100	—	1	
1E1806S					1	
1E18481	18:48:10+33:05:30	10.0	24	—	62	SB2; P<2d?; triple?
1E19371	19:37:04+30:27:58	10.0	35	—	40	SB1; P=9.52 d
1E20383	20:38:20−00:46:26	9.4	100	144699	9	Near-contact, eclipsing
1E21134	21:13:24+05:17:09	12.8	<10	—	6	Velocity var, Low ampl
1E21167	21:16:40−10:42:17	12.1	60	—	5	Velocity variable
1E21197	21:19:44+16:55:32	11.7	100	—	2	
1E21483	21:48:16+14:20:43	14.4	<10	—	1	
1E2346A	23:46:53+18:42:27	12.1	21	—	5	Velocity variable
1E2346B					2	
1E23498	23:49:51−01:12:56	10.7	50	—	29	SB1?

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We are continuing observations of the stars in this sample to derive further orbits and to define the photometric and spectroscopic characteristics of the individual binaries.

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5. REFERENCES

Abt, H. & Levy, S.G. 1976, *ApJS*, **30**, 273
Fekel, F., Hall, D.S., Africano, J.L, Gillies, K., Quigley, R., & Fried, R. 1985, *AJ*, **90**, 2581
Fleming, T. 1988, Ph.D. thesis, University of Arizona
Kraft, R. 1965, *ApJ*, **142**, 695
Latham, D.W., Maseh, T., Carney, B.W., McCrosky, R.E., Stefanik, R.P., & Davis, R.J. 1988, *AJ*, **96**, 567
Marschall, L.A., Nations, H, & Witman, K. 1989, *BAAS*, **20**, 994
Marschall, L.A., Gauthier, C.P., Nations, H.L., Taylor, B.W., & Huard, T.L. 1991, *Inf. Bull. Var. Stars*, 3633
Reipurth, B., Lindgren, H., Nordstrom, B., & Mayor, M. 1990, *A&A*, **235**, 197
Silva, D.R., Gioia, I.M., Maccacaro, T., Mereghetti, S., & Stocke, J.T. 1987, *AJ*, **93**, 869
Stocke, J.T. 1987, *AJ*, **93**, 869
Takalo, L.O.& Nousek, J.A. 1988, *ApJ*, **326**, 779