COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5891

Konkoly Observatory
Budapest
29 June 2009

HU ISSN 0374 – 0676

A PERIOD ANALYSIS OF THE δ SCUTI VARIABLE GSC 03973-01698

HINTZ, E. G.[1]; BUGNO, J. L.[1]; JONER, M. D.[1]

[1] Brigham Young University, Dept. of Physics and Astronomy, Provo, UT 84602, USA

e-mail: doctor@tardis.byu.edu; batgirl3220@aim.com; jonerm@forty-two.byu.edu

As part of an undergraduate summer research program, we examined the High Mass X-ray Binary system (HMXB) 4U 2206+543. On a finder chart for this system provided by the American Association of Variable Star Observers (AAVSO), they identify one of the comparison stars, GSC 3973-1698, as a δ Scuti variable with a period of 0.06 d. GSC 3973-1698 was present in our field of view on all nights of observations during our campaign; therefore we present an analysis of its light curves.

Our data consists of 20 nights of photometric observations on the field near 4U 2206+543. A finder chart is given in Fig. 1 which includes the δ Scuti, 4U 2206+543, and the five comparison stars. A total of 19 nights were obtained with the 0.41-m David Derrick Telescope of the Orson Pratt Observatory (OPO), which is located in the center of the BYU campus. Observations were made with an unbinned ST-10XME CCD. Six nights of data were obtained with the 0.31-m telescope of the BYU West Mountain Observatory (WMO) using another ST-10XME CCD which was binned 2×2. These six nights overlapped with six of the nights secured on the OPO system. Finally we obtained two nights of data with the 0.51-m telescope at the BYU West Mountain Observatory using a SBIG STL-1001 CCD. One of these nights was in common with the OPO data, while the other provided our 20th night of data. All observations were made with a standard V filter (Bessell, 1990) and yielded an error per observation on the order of 0.004 mag. The observational dara are available on the IBVS website as `5891-t3.txt`.

Differential magnitudes were determined relative to an ensemble of four comparison stars (Star 2 was not used since it is an eclipsing binary system). Apparent magnitudes were determined using GSC 3973-1066 (Star 3, $V = 11.946 \pm 0.013$) and GSC 3973-1906 (Star 4, $V = 11.837 \pm 0.008$). The magnitudes given were taken from the calibration of the field obtained by A. Henden[†]. In Fig. 2 we show simultaneous light curves from data taken at both observatory facilities. The light curves for all nights are presented in Fig. 3. The denser portions of the light curves indicate when simultaneous data were obtained.

Both a Fourier analysis using the `Period04` (Lenz & Breger, 2005) program and a traditional time of maximum light argument were utilized to determine a period for GSC 3973-1698. We note that a time of maximum light analysis is not always reliable for low amplitude, multiperiodic stars. In Table 1 we present the 19 times of maximum light found for GSC 3973-1698. From this we find an ephemeris of

$$\mathrm{HJD} = 2454630.942(\pm 0.003) + 0.06501(\pm 0.00001)\mathrm{E}. \quad (1)$$

[†] `http://homepage.usask.ca/~ges125/Astronomy/LPH128_aavso.pdf ftp://ftp.aavso.org/public/calib/3a2206.dat`

From the Fourier analysis we find four frequencies that have detection signal-to-noise values higher than four (Breger et al., 1993, 2007). The four main frequencies are reported in Table 2 and the power spectrum is shown in Fig. 4. Overlaid in Fig. 3 we show the four-frequency model generated from our Fourier solution. From the final panel in Fig. 4, and the fit in Fig. 3, it is clear that additional frequencies exist in GSC 3973-1698, but their detection level is too low from this data set. Our primary frequency of 15.3843 cycles/day corresponds to a period of 0.06500 days and is consistent with the value and errors found in Equation 1.

GSC 3973-1698 is a typical low amplitude δ Scuti variable with a complex frequency content. The thing that makes this star so interesting is that it is in the field of 4U 2206+543, which means that a great deal of data will be obtained in many filters as observations are taken of the HMXB.

Acknowledgements We would like to acknowledge the Brigham Young University Department of Physics and Astronomy for their continued support. We acknowledge a grant for the Theodore Dunham, Jr. Grant for Research in Astronomy. We finally acknowledge NSF grant PHY-0552795.

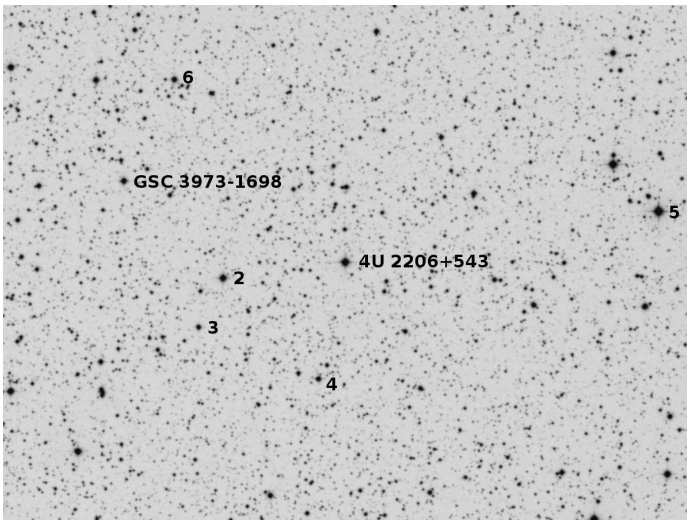

Figure 1. Finder chart for GSC 3973-1698 with 4U 2206+543 and comparison stars marked. The field is 20' wide and 15' high with North being up and East to the left.

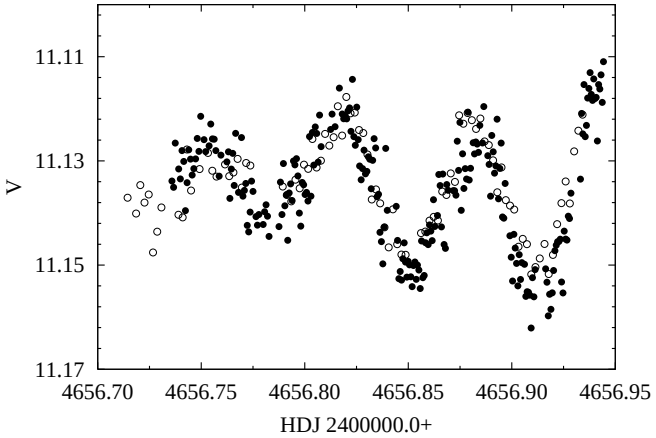

Figure 2. Simultaneous light curves from the OPO (solid) and WMO (open) facilities.

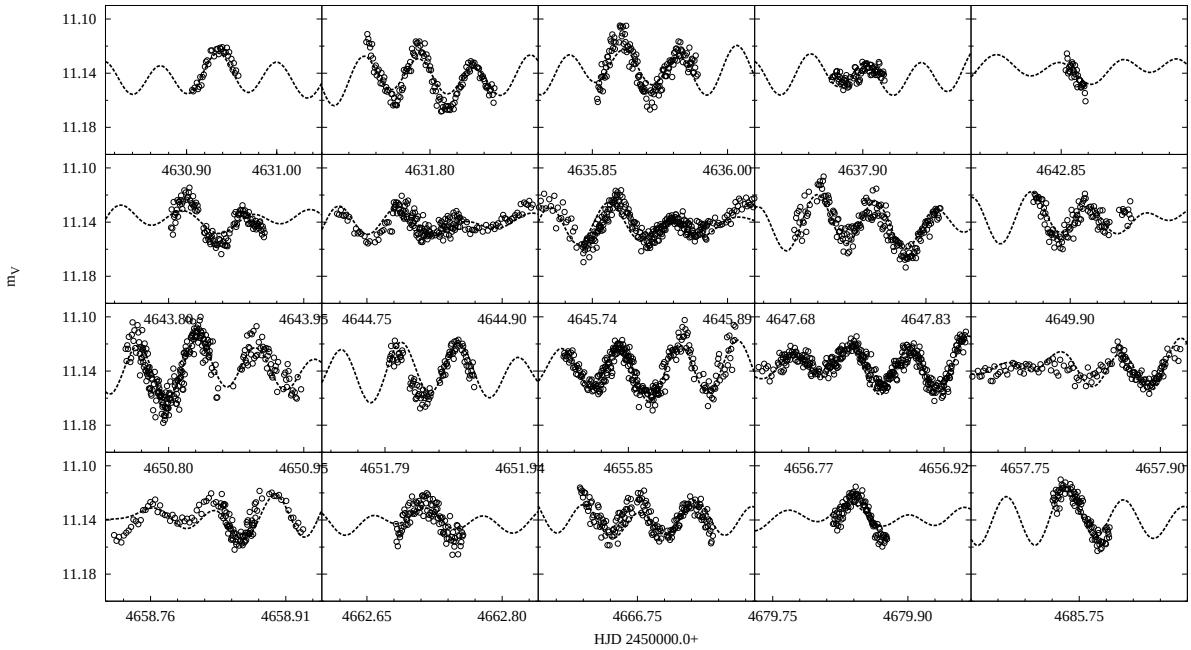

Figure 3. All 20 nights of V photometry are presented on the same magnitude and time scales. The data from WMO and OPO are plotted together.

Table 1. Times of Maximum Light for GSC 3973-1698

Cycle	HJD	Cycle	HJD	Cycle	HJD
0	2454630.9375	228	2454645.7687	398	2454656.8164
13	2454631.7871	229	2454645.8370	399	2454656.8795
14	2454631.8481	258	2454647.7103	551	2454666.7485
76	2454635.8808	259	2454647.7693	552	2454666.8103
77	2454635.9492	306	2454650.8319	752	2454679.8403
198	2454643.8204	322	2454651.8699		
199	2454643.8853	383	2454655.8394		

Table 2. Frequency Content of GSC 3973-1698

ID	Frequency (cycles/day)	Amplitude (mag)	Detection S/N
f_1	15.3843	0.010	12.5
f_2	16.3310	0.006	7.3
f_3	13.4091	0.005	6.2
f_4	6.0763	0.004	5.0

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Lenz, P. & Breger, M., 2005, *Commun. Asteroseismol.*, **146**, 53

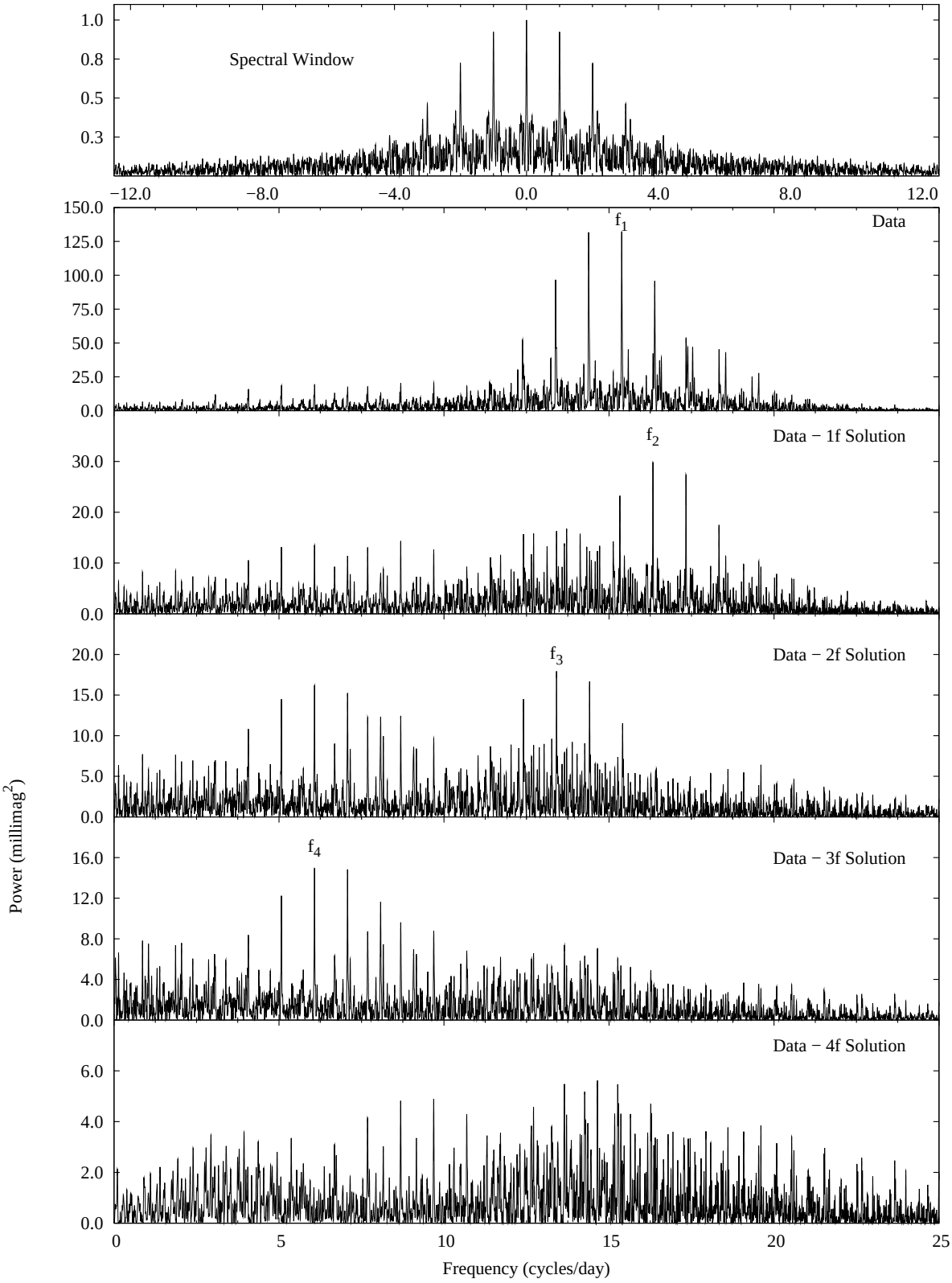

Figure 4. Power spectra of GSC 3973-1698. The spectral window in the top panel is scaled to the same frequency range as the individual power spectra.