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New Variable Stars in the NSVS database

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Abstract: A search in the NSVS database resulted in the discovery of new variable stars. The aim of this paper is to present and classify the stars found.

Methodology: An SQL search has been applied on the Northern Sky Variability Survey (NSVS; Wozniak et al., 2004) catalog via Skydot website (http://skydot.lanl.gov/nsvs/nsvs.php). The search methodology applied was to browse objects sorted by their respective NSVS identification number and filtering out objects with high measurement errors and small amount of observation records. Stars were selected with at least 100 observational records and flagged data, including the APINCOMPL flag, was not included in the analysis. None of the stars presented appear in SIMBAD and AAVSO VSX databases as an identified variable star. All stars show obvious visual variability and in many cases periodicity.

Periods were found with the period analysis software Peranso 2.2 (Vanmunster, 2006). The first method used employs periodic orthogonal polynomials to fit observations, and the analysis of variance (ANOVA) statistic to evaluate the quality of the fit. This method was proposed by (Schwarzenberg-Czerny, 1996). For those stars showing multiple peaks of near the same significancy in the ANOVA periodogram, a CLEANest method (Foster, 1995) was further applied to determine the true dominant period or light variation timescale. It is shown to be an effective technique for detecting and describing multiperiodic signals, and at least in some cases is capable of divining the true nature of a multiperiodic signal, even when the single strongest peak in a periodogram occurs at a spurious frequency, as it happened with ANOVA in some cases. If CLEANest spectrum confirms ANOVA periodogram, ANOVA result is left by default. The Table 2 indicates which method was applied to derive the indicated period per each star.

A Fisher randomization method was used to calculate two complimentary False Alarm Probabilities (FAP) for determining the significance of the indicated dominant period. Randomization is done by shuffling the mangitude measurements to form a new, randomized time-series. A period calculation is then made. Randomization and calculation are repeated for 200 permutations for each star. The first FAP represents the portion of permutations with peaks power higher than the power of a found period at any frequency. It is the probability that there is no periodic component in the synthetic data. The second FAP represents the proportion of permutations that contained a period with power higher than the power of period exactly at the frequency of the indicated period. It is the probability that the original data contains a period that is different from the one indicated. The lower the FAP, the more likely the indicated period is significant. FAP values are between 0 and 1.

An epoch is determined by fitting a polynomial curve to the actual observations data and finding an extremum. Rough approximate B-V index converted from USNO-B1.0 catalog is provided for some stars for a comparative purpose only: B-V≈0.556*(B1-R1), with B1 and R1 values from USNO-B1.0 catalog.

Acknowledgements:

This research has made use of the SIMBAD and VizieR databases operated at the Centre operated at the Centre de Données Astronomiques (Strasbourg) and also of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. Additionally, all variable stars were checked through the Variable Star Index of AAVSO (http://www.aavso.org/vsx/) and General Catalogue of Variable Stars operated by Sternberg Astronomical Insitute of Moscow, Russia (http://www.sai.msu.su/groups/cluster/gcvs/).

Special thanks to Luboš Brát, Anton Paschke and the OEJV editorial board for supporting me on the first stages of this paper; and Ivan Sergey for thoroughly describing the opportunity and methodology of variable star search in the NSVS database.

Results: Table 1 specifies position and cross-identificators for all the variables.

#	NSVS Object ID	Known Cross-identificators	B-V	JHK (2MASS)	Position (J2000)	Type
1	NSVS 2002156	USNO-B1.0 1509-0102483 2MASS 03231208+6054446	1.11 (GSC2.3)	J-H=1.467 J-K=2.11	03:23:12.09 +60:54:44.7 USNO-B1.0	SRD:
2	NSVS 3261775	USNO-B1.0 1438-0346729 USNO-A2.0 1425-11406270 2MASS 20591538+5350454	1.65 (GSC2.3)	J-H=0.831 J-K=1.109	20:59:15.43 +53:50:45.6 USNO-B1.0	SRA
3	NSVS 3509188	USNO-B1.0 1541-0287546 USNO-A2.0 1500-09216800 2MASS 22391552+6406360	1.42 (GSC2.3)	J-H=1.238 J-K=1.656	22:39:15.51 +64:06:36.1 USNO-B1.0	SRA
4	NSVS 3272998	USNO-B1.0 1445-0352511 2MASS 21131840+5431583	-	J-H=1.515 J-K=2.255	21:13:18.40 +54:31:58.4 USNO-B1.0	SRA:
5	NSVS 357907	2MASS 01485038+6757437	-	J-H=1.951 J-K=3.406	01:48:50.39 +67:57:43.8 2MASS	SRA:
6	NSVS 2113215	USNO-A2.0 1425-05258645, GSC 0373600025, 2MASS 04300599+5603165	1.66 (GSC2.3)	J-H=1.067 J-K=1.463	4:30:05.982 +56:03:16.87 USNO-A2.0	LB
7	NSVS 8773367	USNO-A2.0 1125-18619564, GSC 0219701336, USNO-B1.0 1173-0658578, 2UCAC 41459082, 2MASS 21383086+2722088	1.24 (GSC2.3)	J-H=0.867 J-K=1.22	21:38:30.885 +27:22:08.83 USNO-A2.0	SRB:
8	NSVS 11509052	USNO-A2.0 0975-19106140, GSC 0108701012, USNO-B1.0 0991-0553048, 2MASS 20310639+0909036	1.38 (GSC2.3), 1.30 (FONAC)	J-H=0.907 J-K=1.286	20:31:06.406 +09:09:04.7 USNO-A2.0	SRB:
9	NSVS 424463	USNO-A2.0 1650-00555686, GSC 0450800996, USNO-B1.0 1655-0027736, 2MASS 02505771+7533599	1.72 (GSC2.3), 1.95 (FONAC)	J-H=1.036 J-K=1.367	02:50:57.714 +75:34:00.22 USNO-A2.0	LB
10	NSVS 2424121	USNO-A2.0 1425-07032818, GSC 0378300086, USNO-B1.0 1439-0186845, 2MASS 07520399+5356535, CGCS 1889, NC 64	1.91 (GSC2.3)	J-H=1.008 J-K=1.557	07:52:04.016 +53:56:53.33 USNO-A2.0	LB
11	NSVS 3138146	USNO-A2.0 1500-07111604 GSC 0423900846 2MASS 19552864+6517330	1.59 (GSC2.3)	J-H=0.96 J-K=1.326	19:55:28 +65:17:33.47 USNO-A2.0	LB:
12	NSVS 3912518	USNO-A2.0 1350-01683813 GSC 0328300953 2MASS 01472997+4806481	1.16 (GSC2.3)	J-H=1.022 J-K=1.335	01:47:30 +48:06:48.37 USNO-A2.0	LB:
13	NSVS 3991874	USNO-A2.0 1275-01492759 GSC 0283101629 TYC 2831 01629 1 2MASS 02272239+3911287	1.47 (FONAC)	J-H=0.854 J-K=1.087	02:27:22.430 +39:11:28.49 USNO-A2.0	LB:
14	NSVS 1367728	USNO-A2.0 1575-04862771 GSC 0447001662 2MASS 21573499+7118285	1.71 (YB6)	J-H=1.066 J-K=1.572	21:57:35.057 +71:18:28.73 USNO-A2.0	LB:
15	NSVS 4899159	TYC 2999 784 1 USNO-A2.0 1275-07609586 GSC 0299900784 2MASS 09541151+4239013	1.154 (Tycho2 B_T-V_T)	J-H=0.497 J-K=0.676	09:54:11.515 +42:39:01.43 TYC	LB:

#	NSVS Object ID	Known Cross-identificators	B-V	JHK (2MASS)	Position (J2000)	Type
16	NSVS 509251	USNO-A2.0 1500-03443029 GSC 0407500339 2MASS 03545612+6724118	2.02 (GSC2.3)	J-H=1.055 J-K=1.477	03:54:56.074 +67:24:11.99 USNO-A2.0	SRB:
17	NSVS 2263698	USNO-A2.0 1425-06208857 GSC 0374900919 2MASS 05435595+5257308	1.41 (GSC2.3)	J-H=0.974 J-K=1.361	05:43:55.953 +52:57:31.03 USNO-A2.0	SRB:
18	NSVS 2035937	TYC 4073 263 1 USNO-A2.0 1500-03738515 GSC 0407300263 2MASS 04284531+6517082	0.56 (TYC), 0.54 (Lick NPM2 Catalog)	J-H=0.081 J-K=0.124	04:28:45.327 +65:17:08.24 TYC	SRD
19	NSVS 2087512	USNO-A2.0 1425-04706112 GSC 0372100035 2MASS 03583771+5514269	1.78 (YB6)	J-H=1.143 J-K=1.568	03:58:37.744 +55:14:27.36 USNO-A2.0	SRB:
20	NSVS 3074041	USNO-A2.0 1425-09697449 GSC 0392501735 2MASS 19264668+5427097	-	J-H=0.96 J-K=1.244	19:26:46.688 +54:27:09.64 USNO-A2.0	LB
21	NSVS 4150468	USNO-A2.0 1275-02147552 GSC 0285600868 2MASS 03161038+4119321	0.92 (The GPM catalog (Rybka+, 1997-2001))	J-H=0.915 J-K=1.242	03:16:10.402 +41:19:31.96 USNO-A2.0	LB
22	NSVS 10016609	USNO-A2.0 0975-05318851 GSC 0077300614 2MASS 07371689+1139534	-	J-H=0.875 J-K=1.208	07:37:16.902 +11:39:53.69 USNO-A2.0	SRB:
23	NSVS 1231827	USNO-A2.0 1575-04362850 GSC 0445001779 2MASS 20093268+6955215	1.7 (GSC2.3)	J-H=1.012 J-K=1.387	20:09:32.703 +69:55:21.18 USNO-A2.0	LB
24	NSVS 1352814	USNO-A2.0 1575-04648021 GSC 0447301135 2MASS 21191212+7355574	1.7 (YB6)	J-H=1.099 J-K=1.542	21:19:12.188 +73:55:57.51 USNO-A2.0	SRB:
25	NSVS 2260602	USNO-A2.0 1425-06157042 GSC 0374901043 2MASS 05384444+5356313	1.43 (YB6)	J-H=0.962 J-K=1.28	05:38:44.46 +53:56:32.1 USNO-A2.0	SRB:
26	NSVS 3037592	USNO-A2.0 1425-09199634 GSC 0391701274 2MASS 18340583+5855569	1.08 (YB6)	J-H=0.862 J-K=1.197	18:34:05.926 +58:55:57.40 USNO-A2.0	LB
27	NSVS 4160974	USNO-A2.0 1275-02298343 GSC 0287300011 TYC 2873 11 1 2MASS 03255287+4314571	0.91 (Tycho2 B_T-V_T)	J-H=0.604 J-K=0.781	03:25:52.877 +43:14:57.21 TYC	SRD

Elements: Table 2 specifies elements and data for all discovered stars. For irregular and SRB type variables, period indicates apparent timescale of the light variability.

#	Max. Mag (R)	Min Mag (R)	Period, d	Method	FAP #1	FAP #2	Epoch, Max (JD)	Number Obs.
1	12.5	15.8	>172	-	-	-	2451588.6±6.5	206
2	13.4	14.4	123±5	CLEANest	<0.005	<0.005	2451279.6±1.7	225
3	13.7	15.1	140±26	ANOVA	<0.005	<0.005	2451325.7±3.1	226
4	13.6	15.1	>235	-	-	-	2451381.7±7.8	227
5	13.8	15.6	>189	-	-	-	2451597.9±5.0	201
6	10.6	11.0	119±9	ANOVA	<0.005	<0.005	2451567.3±1.6	280
7	10.4	10.9	33±1	CLEANest	<0.005	<0.005	2451302.4±0.5	296
8	10.7	11.1	45±2	ANOVA	<0.005	<0.005	2451284.7±0.7	208
9	10.6	10.9	58±9	CLEANest	<0.005	<0.005	2451508.7±1.9	240
10	10.1	10.4	130±11	CLEANest	<0.005	<0.005	2451342.8±2.5	254
11	10.6	11.0	-	-	-	-	2451428.4±2.0	202

#	Max. Mag (R)	Min Mag (R)	Period, d	Method	FAP #1	FAP #2	Epoch, Max (JD)	Number Obs.
12	10.7	11.1	56±3	CLEANest	<0.005	<0.005	2451512.4±5.6	212
13	10.0	10.3	>250	-	-	-	2451604.3±2.3	242
14	10.1	10.7	>237	-	-	-	2451274.3	258
15	10.1	10.4	77±5	CLEANest	<0.005	<0.005	2451279.0±1.6	266
16	10.7	11.1	56±4	CLEANest	<0.005	<0.005	2451609.8±2.5	306
17	10.0	11.0	92±14	CLEANest	<0.005	<0.005	2451450.4±1.6	221
18	10.7	11.0	82±20	CLEANest	<0.005	<0.005	2451527.0±3.0	215
19	10.8	11.2	50±3	CLEANest	<0.005	<0.005	2451478.8±1.6	287
20	10.5	10.9	87±9	CLEANest	<0.005	<0.005	2451599.4	287
21	10.6	11.1	86±8	CLEANest	<0.005	<0.005	2451607.2±3.2	283
22	10.4	10.7	57±2	CLEANest	<0.005	<0.005	2451629.3	219
23	10.4	11.0	125±10	CLEANest	<0.005	<0.005	2451452.1±3.3	248
24	10.8	11.1	45±6	CLEANest	<0.005	<0.005	2451486.4±1.1	301
25	10.5	10.9	47±2	CLEANest	<0.005	<0.005	2451433.0±1.4	300
26	10.3	10.6	114±15	CLEANest	<0.005	<0.005	2451480.2±3.3	301
27	10.9	11.1	20±1	CLEANest	<0.005	<0.005	2451543.6±0.9	299

Remarks:

#1 There is no enough observational data to determine upper period margin.
#3 Periodogram shows two peaks, one at 267 days. As the time span of NSVS observational data is 261 days only, the longer period has been excluded from the analysis, however it is quite possible that light variability exists beyond the indicated 140 day period.
#4 There is no enough observational data to determine upper period margin.
#5 There is no enough observational data to determine upper period margin.
#6 =IRAS 04260+5556 (04 30 05.5 +56 03 14), =TASS4 6388486, Welch-Stetson variability index 2.74 (Welch and Stetson, 1993), B-V≈1.957 (converted B1-R1 in USNO-B1.0)
#7 =TASS4 3113065, =MSX6C G078.6379-18.4736 (21 38 30.9 +27 22 06). Additional light variation is possible with apparent timescale greater than the observational data time span.
#8 =TASS4 260862, #9 =TASS4 5526968
#10 =DO 31906, =NC 64 (Catalogue of Stellar Spectral Classifications (Skiff, 2007)), =C* 3283, = =IRAS 07481+5404, =[TI98] 0748+5404. This star appears in the “The APM Survey for Cool Carbon Stars in the Galactic Halo - II The Search for Dwarf Carbon Stars” (E. J. Totten+, 2007), however authors specifically mention that this particular object is brighter than APM survey limit thus it is impossible to measure it’s proper motion correctly. Authors finally conclude that it is probably not a dwarf. Assuming it is a late type carbon giant perfectly correlates with the LB classification. Both ANOVA and CLEANest methods show questionable spectrum with second most significant period at 271 days (appears as most significant in ANOVA.)
#11 =TASS4 2701686, CLEANest spectrum shows peak at frequency close to observational data time span.
#12 =IRAS 01443+4751 (01 47 30.0 +48 06 48), =TASS4 4717208
#13 =TASS4 4729013, There is no enough observational data to determine upper period margin.
#14 NSVS data contains no evident maximum, single epoch for brightest magnitude within the data is indicated.
#15 =MSX A104705 (09 54 11.51 +42 39 01.4), T_{eff}=4420K, spectral type K2 (The Tycho-2 Spectral Type Catalog (Wright+, 2003)), ANOVA periodogram shows peak at 196 days, however Lomb-Scargle periodogram confirms period found by CLEANest. Additional long period light variation is possible.
#16 =TASS4 6369984, #17 =IRAS 05399+5256 (05 43 58.5 +52 57 31)
#19 =IRAS 03546+5505 (03 58 35.8 +55 14 21) =MSX6C G147.4983+01.5614
#20 B-V≈1.7 (converted B1-R1 in USNO-B1.0), NSVS data contains no evident maximum, single epoch for brightest magnitude within the data is indicated.
#21 CLEANest shows strongest period beyond data time span. Within time span, 86d peak is the most significant.
#22 B-V≈1.54 (converted B1-R1 in USNO-B1.0). NSVS data contains no evident maximum, single epoch for brightest magnitude within the data is indicated.
#23 =IRAS 20095+6946 (20 09 33.3 +69 55 20)
#24 =IRAS 21191+7343 (21 19 13.2 +73 55 50), B-V≈2.31 (converted B1-R1 in USNO-B1.0)
#25 =TASS4 7238652, B-V≈2.096 (converted B1-R1 in USNO-B1.0)
#26 CLEANest shows strongest period beyond data span. Within time span, 114d peak is the most significant.
#27 =TASS4 5907656, Welch-Stetson variability index 2.99

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Additional Data: Figures below represent light curves, ANOVA periodograms or CLEANest spectrums and phased curves for the variable stars and indicted periods presented in this paper. For irregular and SRB-type variables or stars with no exact period identified, no phased curve is plotted.

Fig L1 - Data for #1:

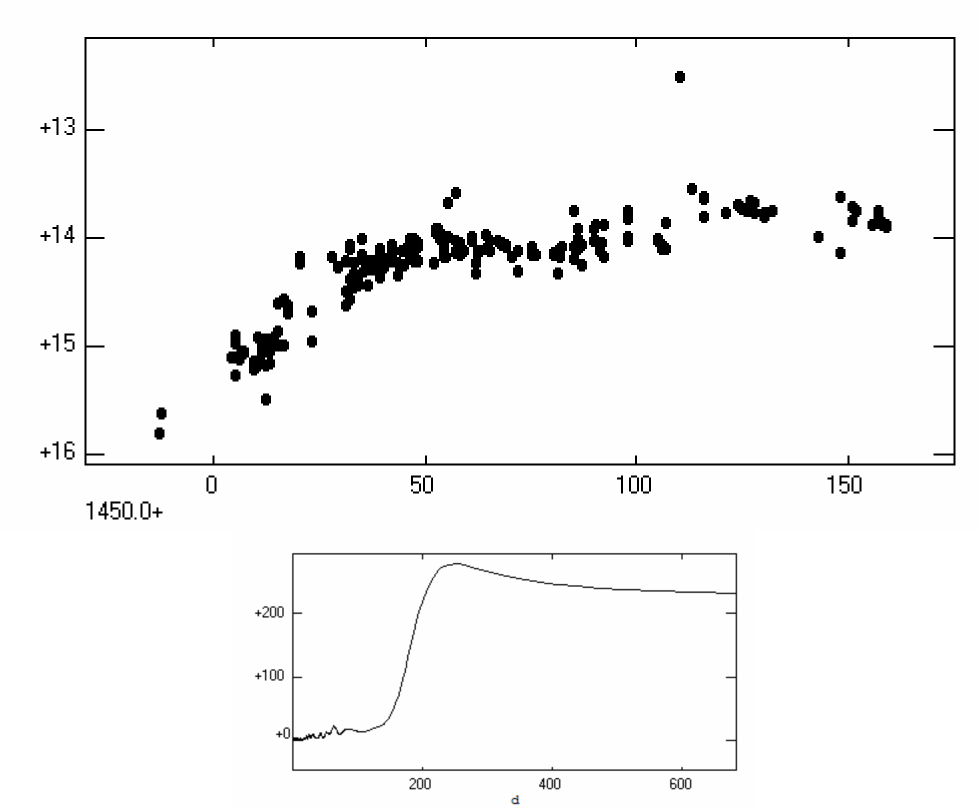


Fig L2 - Data for #2:

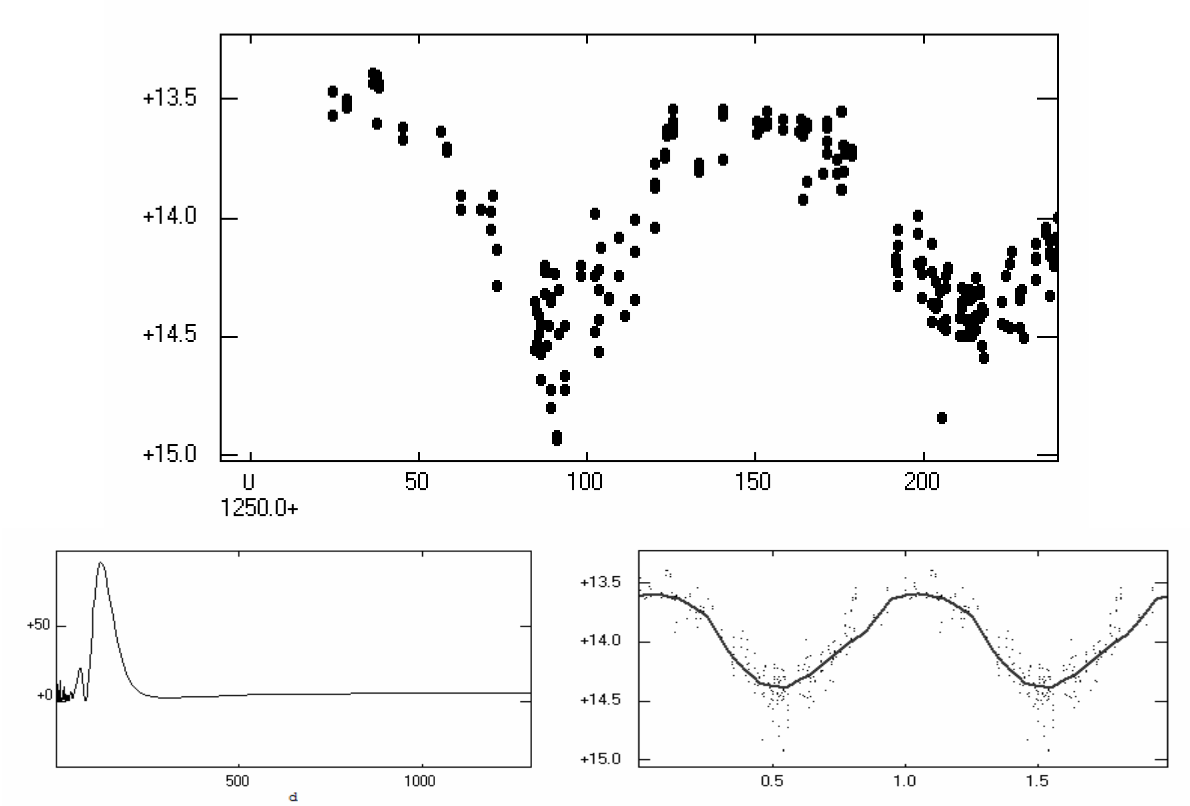
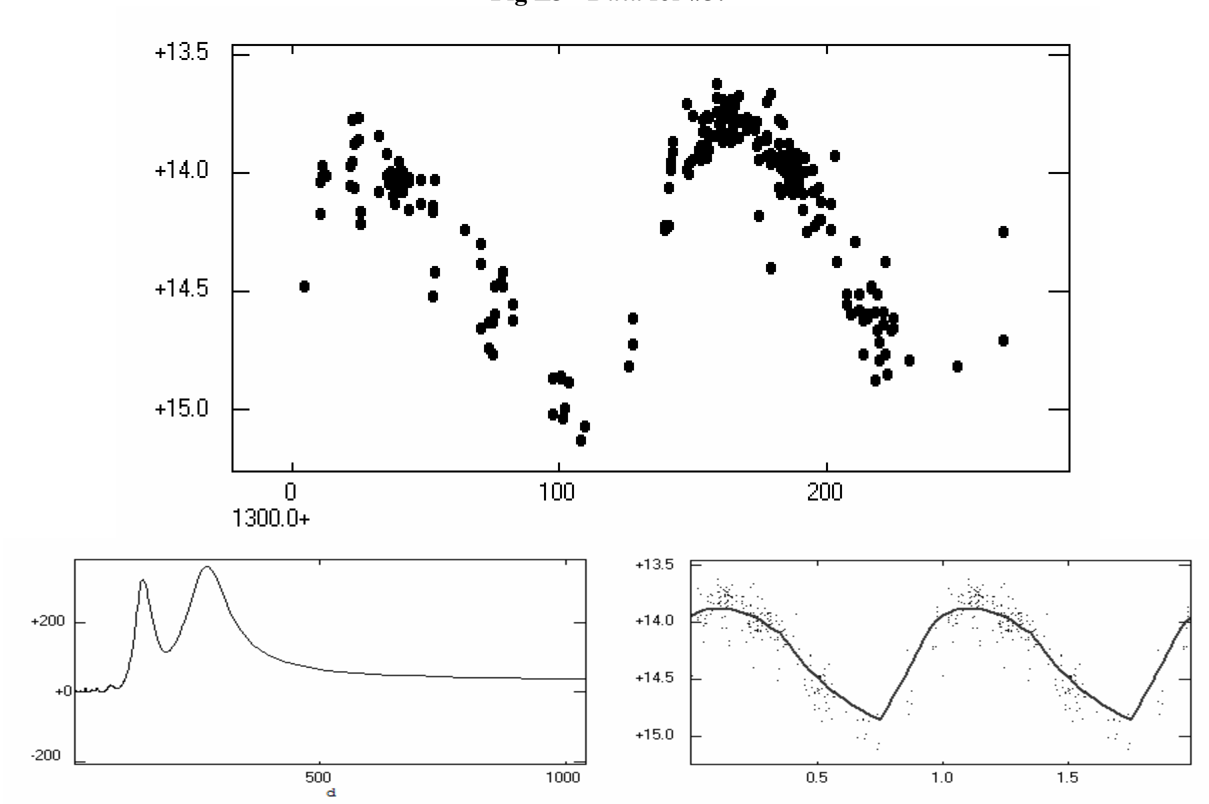


Fig L3 - Data for #3:



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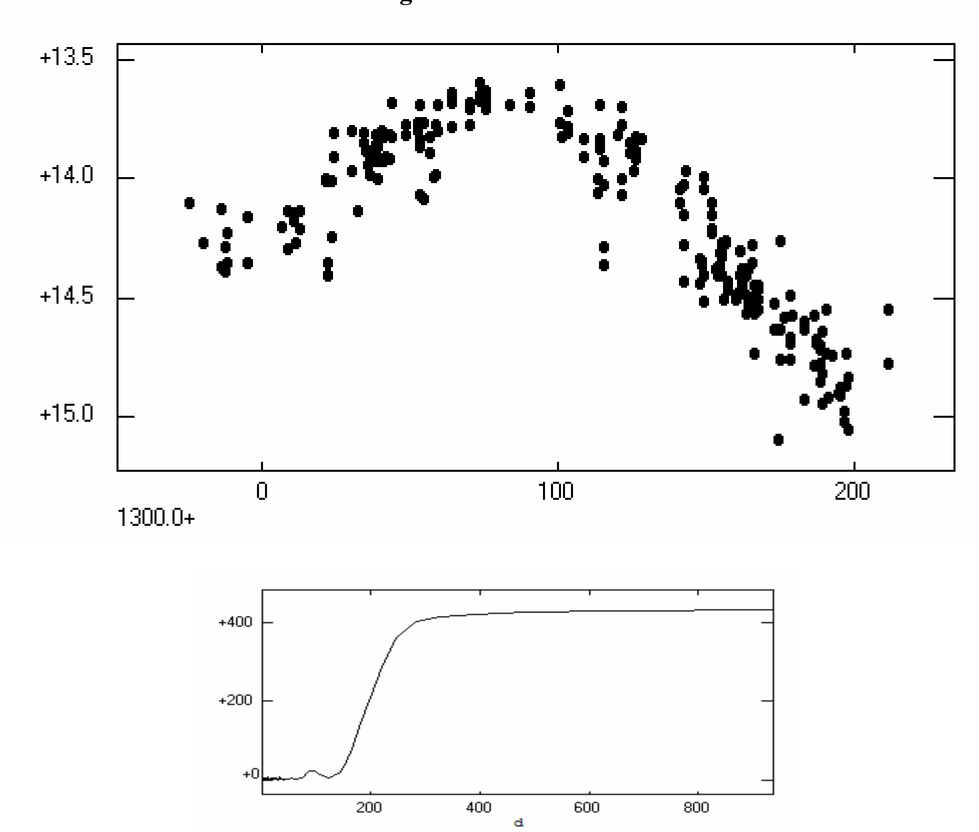
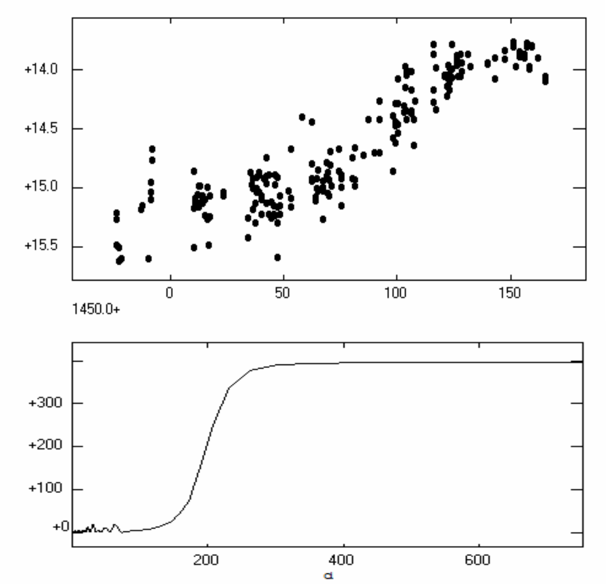


Fig L5 – Data for #5



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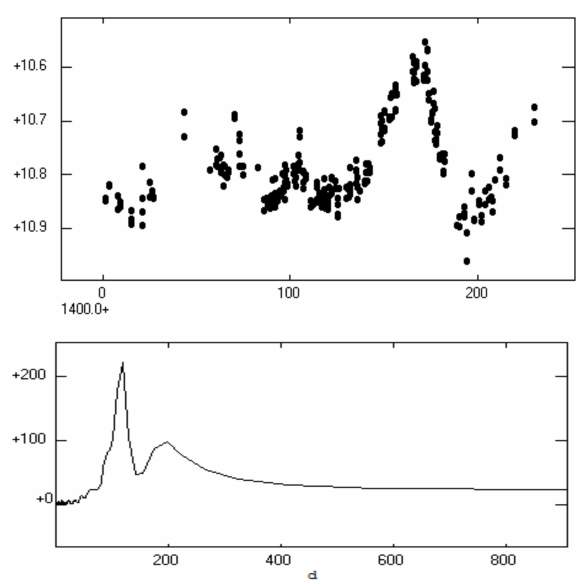

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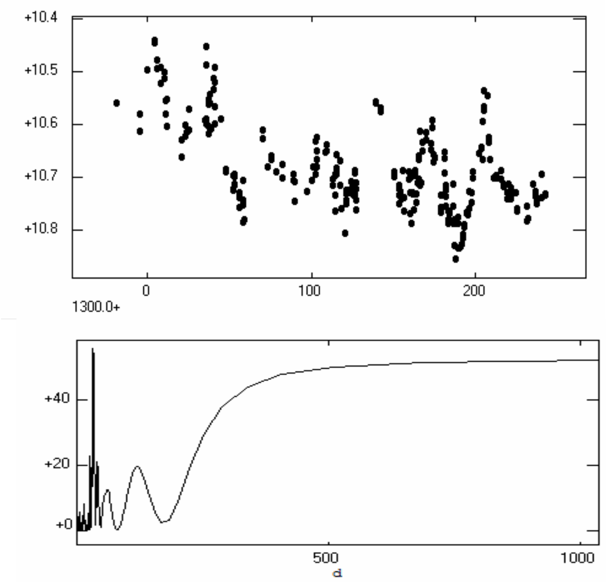
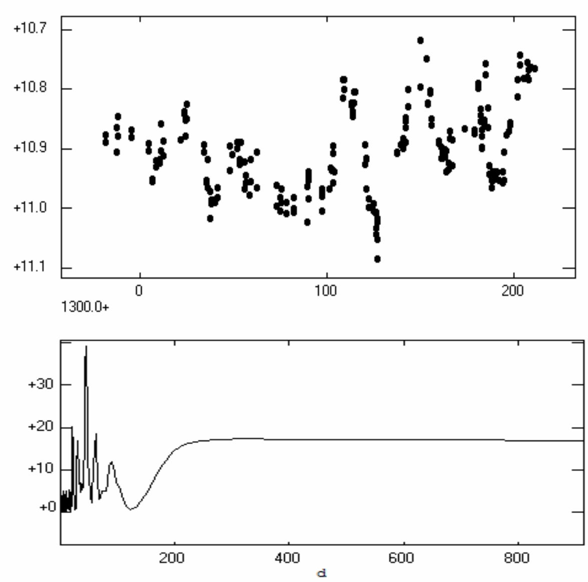


Fig L8 – Data for #8



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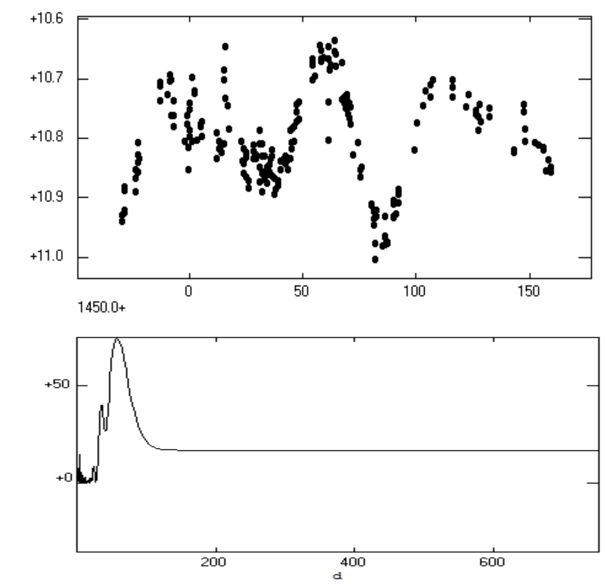


Fig L10 – Data for #10

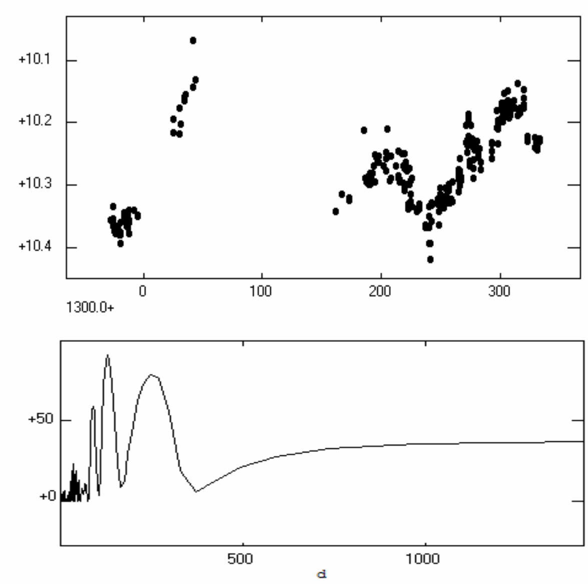
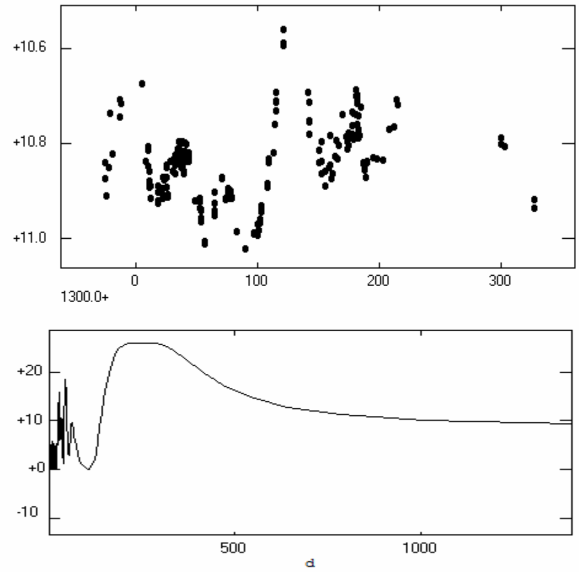


Fig L11 – Data for #11



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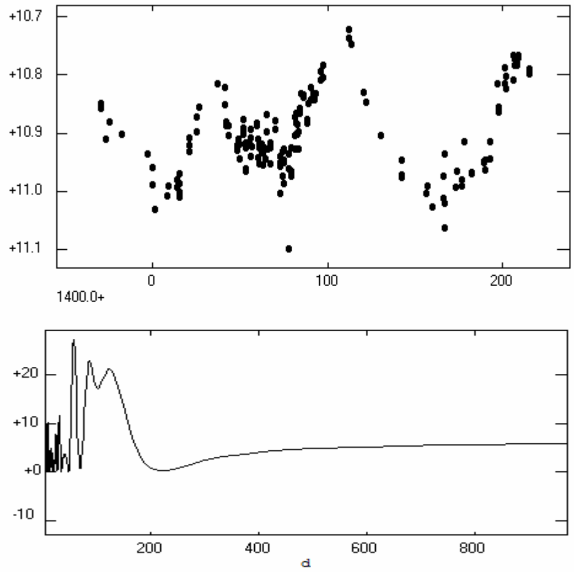

Fig L13 – Data for #13

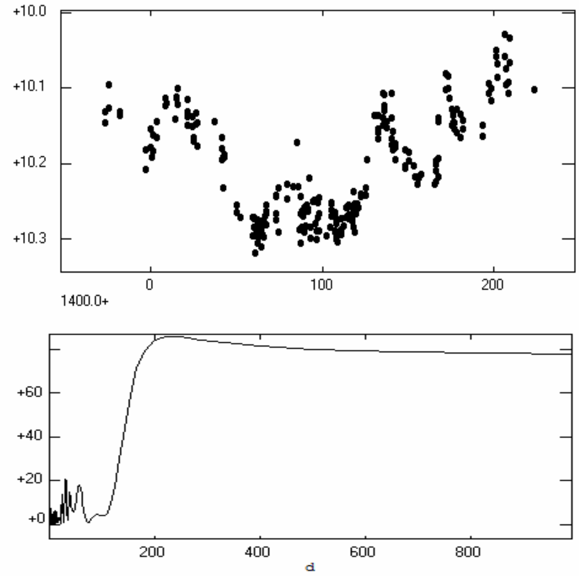

Fig L14 – Data for #14

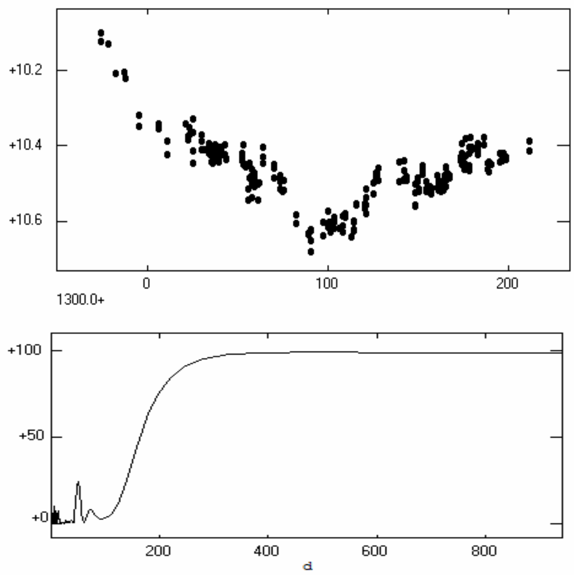

Fig L15 – Data for #15

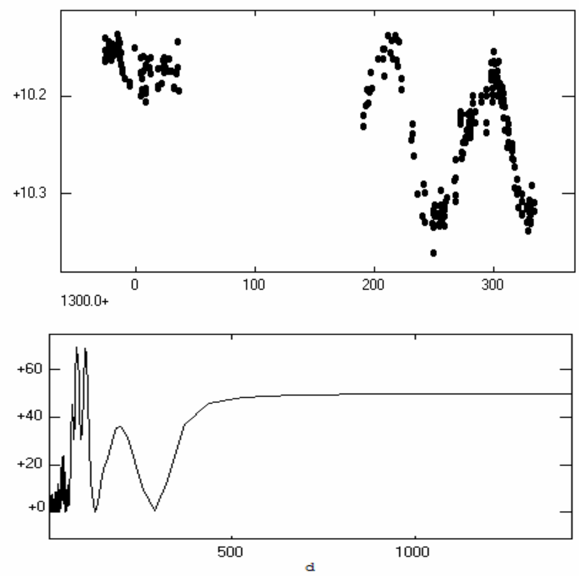

Fig L16 – Data for #16

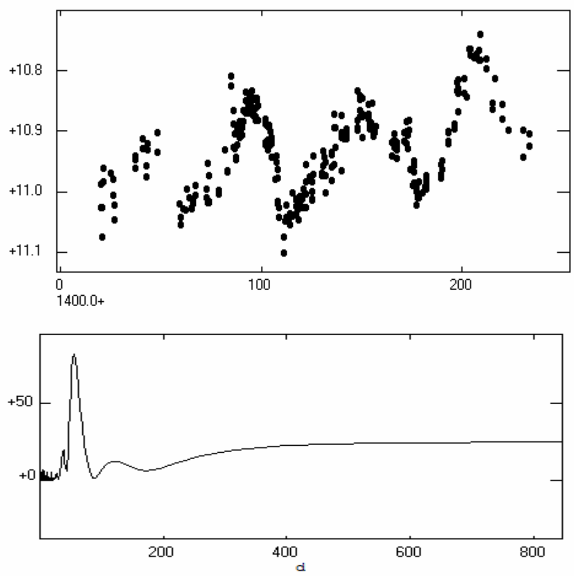

Fig L17 – Data for #17

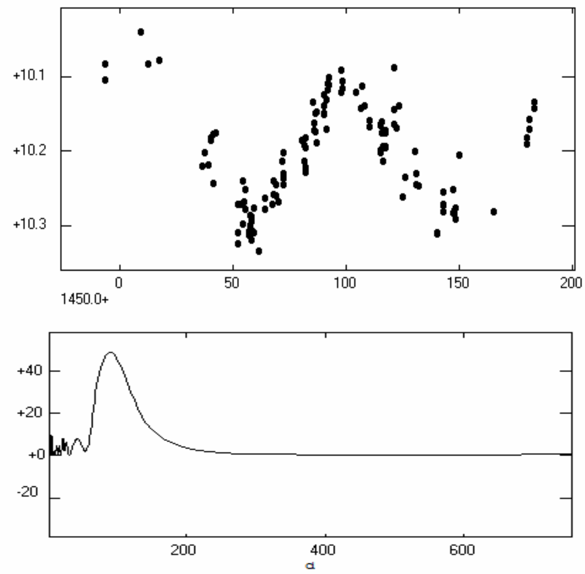

Fig L18 – Data for #18

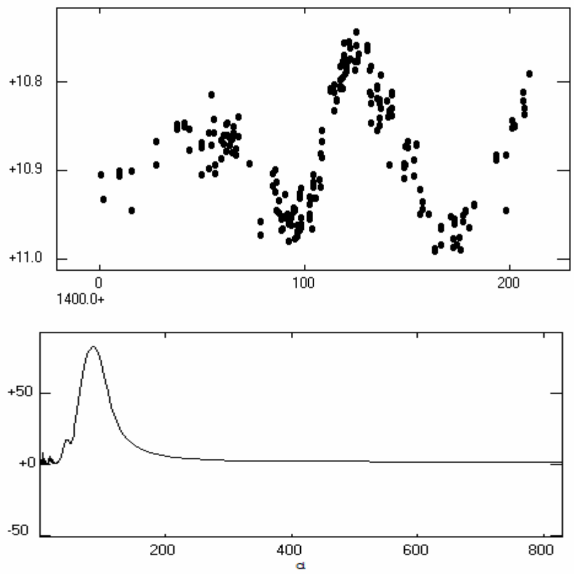

Fig L19 – Data for #19

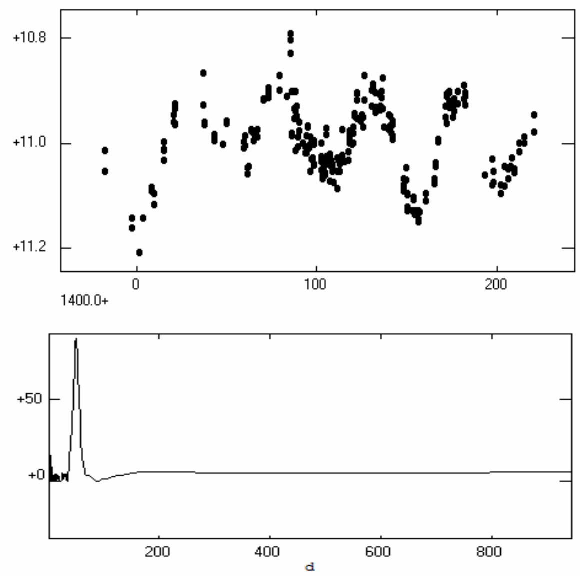

Fig L20 – Data for #20

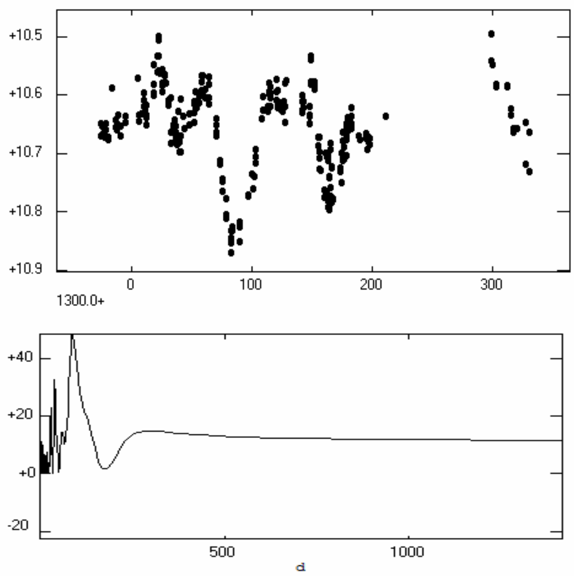

Fig L21 – Data for #21

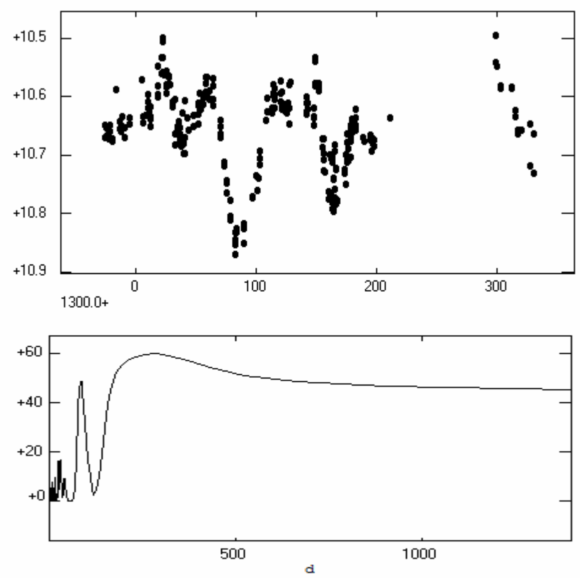

Fig L22 – Data for #22

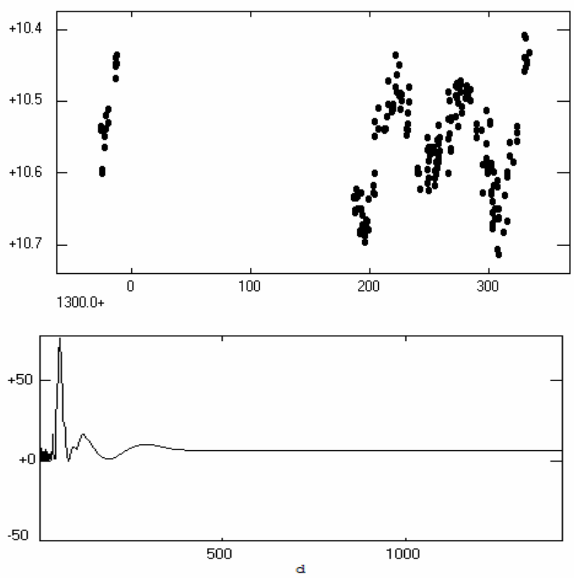

Fig L23 – Data for #23

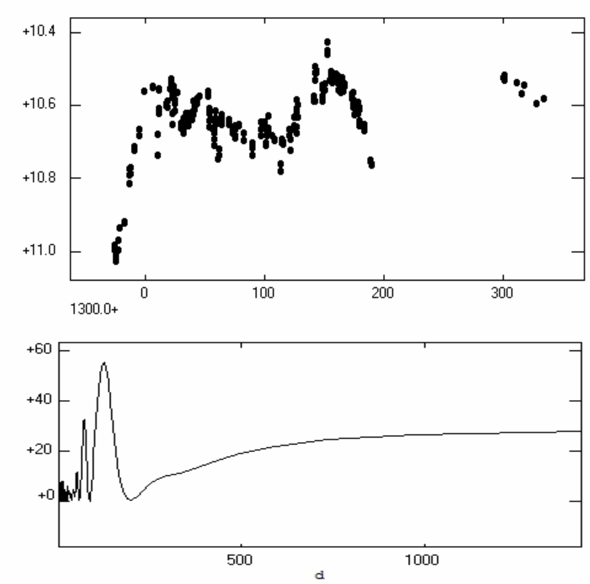

Fig L24 – Data for #24

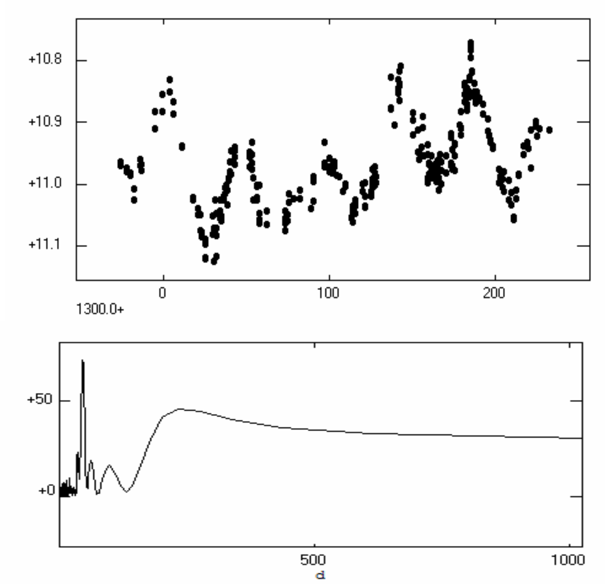

Fig L25 – Data for #25

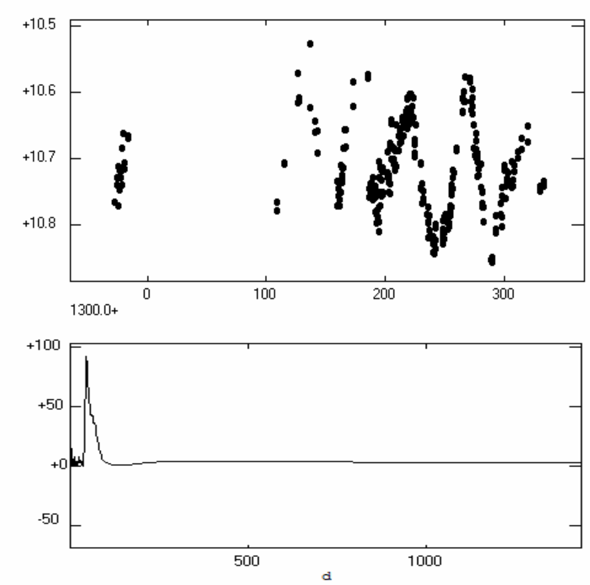

Fig L26 – Data for #26

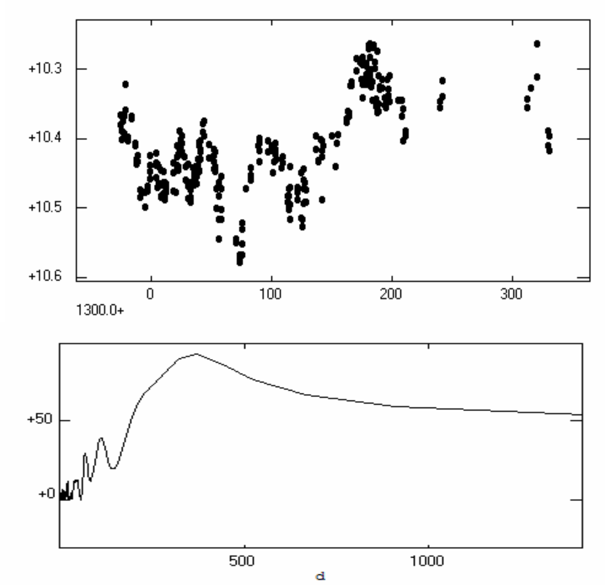

Fig L27 – Data for #27