The VESPA Survey: 100 New Variable Stars Discovered in Two Years

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Abstract We describe the VESPA project made at IAU station 565, Astronomical Observatory in Bassano Bresciano (BS), Italy. It is one photometric survey of the northern hemisphere which has the aim of discovering and investigating new variable stars. In the first two years of activity we have discovered 100 new variable stars in the course of observations carried out from August 2014 to September 2016. The newly discovered stars comprise 80 eclipsing binary stars (66 of them classified as W Ursae Majoris, 11 as β Lyrae, and 3 β Persei), one rotating (ROT), one ellipsoidal variable (ELL), and 18 pulsating variables (5 of them classified as RRAB, 7 RRC, 3 HADS, 2 δ Scuti and one Cepheid). Variability classification is based on the properties of the optical light curves that we obtained using our 255 mm F/4.7 Newton robotic telescope.

1. Introduction

The VESPA project (Variable Star Search Project for Automated Telescope) is made at IAU station 565, Bassano Bresciano Observatory, Brescia, Italy (www.osservatoriobassano.org). It is a CCD photometric survey of the northern hemisphere, which has the aim of discovering and investigating new variable stars in the magnitude range $13.5 < V < 16.5$.

In the course of observations carried out from August 2014 to September 2016, we obtained 50,865 images with 120-second exposure on 253 nights (Table 1), and we have discovered 100 new variable stars (Tables 2 and 3; Figure 4). We have determined the type (Table 4), the period, the epoch, and the amplitude for all the discovered stars. A key to the sources of observations shown in Figure 4 is given in Table 5.

2. Instrumentation and methodology

Observations were obtained using our homemade 255-mm F/4.7 Newton telescope (Figure 1), equipped with Starlight Xpress Trius-SX9 CCD camera, with a sensor area of 1392 × 1040 pixels (Pixel size: 6.45 x 6.45 µm). This configuration results in a FOV (field of view) of 25.8' × 19.2'. We configured the camera in a 2 × 2 binning mode with angular resolution of 2.22 × 2.22 arcsec/pixel. The camera is equipped with a Sony ICX285A CCD and dual stage cooler. The observations were obtained with the CCD operating at the temperature of –10° C (in hot seasons) and –15° C (in cold seasons). Observations were made using a Johnson V filter or were unfiltered and reduced to a V zeropoint (CV).

Table 1. Summary of the observations.

Date	*Nights*	*Images*	*Hours/Month*
2014 Aug	15	2319	77
2014 Sep	15	2863	96
2014 Oct	17	2671	89
2014 Nov	8	1207	40
2014 Dec	6	1553	52
2015 Jan	15	3219	107
2015 Feb	8	1340	45
2015 Mar	1	254	9
2015 Apr	10	1689	56
2015 May	5	582	19
2015 Jun	5	678	23
2015 Jul	18	2468	82
2015 Aug	15	3044	102
2015 Sep	9	1750	58
2015 Oct	11	1814	61
2015 Nov	15	3383	113
2015 Dec	5	761	25
2016 Jan	10	2219	74
2016 Feb	4	845	28
2016 Mar	10	2827	94
2016 Apr	2	522	17
2016 May	5	1083	36
2016 Jun	2	241	8
2016 Jul	16	2733	91
2016 Aug	16	5225	174
2016 Sep	10	3575	119
Total 26	253	50865	1695

The telescope is located near the Bassano Bresciano Astronomical Observatory, at the coordinates 45° 19' 32" N, 10° 07' 49" E (WGS84) in a home-made dome that slides on rails and closes automatically at the end of the session or in bad weather.

Table 2. Main characteristics of discovered stars.

Name	*R.A. (J2000)*			*Dec. (J2000)*			*Type*	*Maximum Magnitude*	*Minimum Magnitude*	*Filter*	*Period (days)*	*Epoch (HJD)*
	h	*m*	*s*	°	'	"						
VESPA_V1	22	02	42.26	+27	56	11.9	EW	15.68	15.83	V	0.231335	2456884.49382
VESPA_V2	20	29	59.18	+16	13	24.8	EW	14.13	14.74	CV	0.410520	2456887.53907
VESPA_V3	20	30	57.66	+16	20	18.2	RRC	13.82	14.19	CV	0.269646	2456897.46106
VESPA_V4	20	33	27.57	+16	33	49.3	EW	14.20	14.49	CV	0.367287	2456900.41422
VESPA_V5	20	33	52.03	+16	37	16.2	EW	14.12	14.29	CV	0.251410	2456900.44974
VESPA_V6	20	33	31.01	+16	45	30.7	EW	15.30	15.57	CV	0.435868	2456902.43919
VESPA_V7	20	28	10.70	+15	57	48.4	EB	14.50	15.04	CV	0.515464	2456914.48392
VESPA_V8	20	29	04.95	+16	20	54.9	EW	12.68	13.20	V	0.689388	2454656.74000
VESPA_V9	22	14	34.94	+41	10	29.2	RRAB	15.20	16.14	CV	0.470367	2456923.47856
VESPA_V10	22	15	01.38	+40	55	41.6	EW	14.99	15.40	CV	0.301903	2456923.33854
VESPA_V11	22	15	32.47	+42	02	21.4	EW	14.56	15.35	CV	0.324274	2456929.59510
VESPA_V12	22	00	50.64	+43	28	05.5	EW	14.82	15.65	CV	0.308914	2456953.27595
VESPA_V13	22	16	11.34	+41	44	34.4	EB	13.17	13.78	CV	1.065884	2456956.26090
VESPA_V14	21	59	34.23	+43	44	20.1	EW	14.62	15.05	CV	0.307018	2456954.34605
VESPA_V15	22	01	56.59	+43	38	14.4	EW	14.36	14.91	CV	0.368932	2456953.31305
VESPA_V16	22	01	01.40	+43	07	47.5	HADS	14.61	14.80	CV	0.074446	2456958.42234
VESPA_V17	22	00	22.75	+42	47	16.3	EB	13.58	13.85	CV	0.612290	2456981.34566
VESPA_V18	21	59	21.72	+42	55	59.6	EW	13.42	13.83	V	0.707333	2456961.37362
VESPA_V19	01	21	57.75	+47	49	33.3	EW	11.66	11.92	CV	0.401534	2456963.48117
VESPA_V20	21	57	47.66	+43	12	52.1	RRAB	15.54	16.65	CV	0.500800	2456980.70800
VESPA_V21	01	55	59.74	+51	43	06.8	EW	12.74	12.87	CV	0.398786	2457021.33460
VESPA_V22	01	54	36.50	+51	40	25.7	EW	12.47	12.75	CV	0.331038	2457021.31500
VESPA_V23	01	56	15.56	+52	26	54.9	HADS	11.84	12.22	CV	0.097959	2457032.28910
VESPA_V24	01	56	01.71	+52	20	26.7	RRC	16.26	16.89	CV	0.255661	2457031.31195
VESPA_V25	05	29	11.37	+36	18	53.1	EW	12.88	13.02	CV	0.244124	2457046.42710
VESPA_V26	05	29	07.71	+37	07	19.0	EW	15.04	15.48	CV	0.350117	2457061.36990
VESPA_V27	15	03	17.13	+40	01	24.3	EW	14.10	14.22	CV	0.335815	2457094.54690
VESPA_V28	14	56	16.91	+42	20	08.7	RRC	14.83	15.20	CV	0.405029	2457128.47030
VESPA_V29	14	23	33.18	+40	28	42.5	DSCT	14.10	14.16	CV	0.244056	2457154.48110
VESPA_V30	20	28	04.41	+17	05	58.7	RRC	13.88	14.31	CV	0.297016	2457214.43030
VESPA_V31	20	28	22.41	+17	02	29.0	RRC	15.38	15.64	CV	0.226653	2457215.44521
VESPA_V32	20	28	35.95	+16	29	50.7	EB	12.80	13.01	V	0.324731	2457220.47750
VESPA_V33	20	28	10.72	+16	58	28.5	EW	13.55	13.70	CV	0.628050	2457218.42190
VESPA_V34	20	28	22.92	+17	25	25.9	RRC	15.68	16.06	CV	0.182098	2457221.50940
VESPA_V35	20	26	52.66	+16	07	38.5	HADS	14.23	14.53	CV	0.092075	2457226.48610
VESPA_V36	20	28	47.63	+17	27	52.1	EW	15.19	15.48	CV	0.426604	2457221.44360
VESPA_V37	20	25	52.43	+15	59	09.5	EW	15.47	15.85	CV	0.378992	2457226.41856
VESPA_V38	20	25	55.45	+15	55	03.5	EW	14.92	15.19	CV	0.539153	2457229.52320
VESPA_V39	20	26	26.08	+16	13	29.5	EW	13.64	14.31	V	0.531559	2457240.43710
VESPA_V40	20	25	29.70	+15	55	35.5	EB	13.97	14.52	CV	0.627498	2457242.46690
VESPA_V41	20	26	01.99	+17	16	05.5	EW	14.67	15.19	CV	0.415141	2457248.45400
VESPA_V42	20	25	55.36	+17	12	00.5	EW	16.00	16.55	CV	0.314593	2457255.36630
VESPA_V43	20	25	58.88	+16	04	59.7	EW	16.79	17.48	CV	0.337285	2457238.43280
VESPA_V44	20	25	45.96	+15	56	50.7	EW	17.30	18.20	CV	0.385902	2457238.46340
VESPA_V45	20	24	56.29	+16	34	20.8	EW	15.75	16.10	CV	0.354840	2457267.43020
VESPA_V46	20	25	26.75	+16	48	43.6	EW	16.13	16.90	CV	0.335819	2457260.39690
VESPA_V47	20	24	44.51	+16	48	59.5	EW	13.98	14.08	CV	0.287455	2457266.51978
VESPA_V48	21	57	23.21	+43	43	44.6	EW	12.98	13.22	V	0.382097	2457271.40468
VESPA_V49	21	55	09.40	+43	12	00.1	RRAB	15.64	16.85	CV	0.457989	2457271.40140
VESPA_V50	21	56	17.50	+43	06	30.1	ELL	14.40	14.51	CV	0.42497	2457272.51000
VESPA_V51	21	55	18.52	+43	43	50.4	EW	14.32	14.60	CV	0.429272	2457272.43140
VESPA_V52	21	55	33.79	+43	13	40.2	EW	15.63	16.15	CV	0.326901	2457272.46870
VESPA_V53	21	55	16.50	+43	38	24.7	EW	16.84	17.59	CV	0.352131	2457272.43590
VESPA_V54	21	55	59.08	+43	52	47.3	EW	14.63	15.15	CV	0.447872	2457287.55890
VESPA_V55	21	58	51.40	+44	03	14.4	EB	16.54	17.03	CV	0.378575	2457285.26930
VESPA_V56	21	58	28.30	+44	02	39.9	CEP:	16.70	17.60	CV	0.488907	2457286.33280
VESPA_V57	21	56	20.52	+44	00	50.6	EB	15.25	16.00	CV	0.49385	2457304.38380
VESPA_V58	23	06	00.72	+52	48	28.7	DSCT	14.09	14.26	CV	0.101393	2457317.27760
VESPA_V59	23	07	47.22	+53	08	32.6	EW	15.63	16.01	CV	0.346930	2457317.49470
VESPA_V60	23	07	05.97	+53	15	07.3	EW:	15.11	15.33	CV	0.258547	2457317.46000
VESPA_V61	23	06	54.85	+53	01	13.6	EB	14.40	14.88	V	0.521825	2457318.40000
VESPA_V62	21	57	32.58	+44	11	53.2	EW	15.76	16.42	V	0.437156	2457336.47790
VESPA_V63	22	15	36.03	+49	57	26.2	EA	14.75	15.57	CV	0.397447	2457328.36290
VESPA_V64	06	20	02.96	+24	31	00.5	EW	14.30	15.10	CV	0.483931	2457358.53500
VESPA_V65	05	26	25.66	+37	18	59.1	EW	14.75	15.25	CV	0.276202	2457334.64860
VESPA_V66	21	57	58.06	+44	14	25.4	EW	16.14	16.42	CV	0.377845	2457336.46710
VESPA_V67	04	42	39.24	+20	20	36.0	EW	13.75	13.89	CV	0.404445	2457404.3349

Table continued on next page

Table 2. Main characteristics of discovered stars, cont.

Name	*R.A. (J2000)* *h*	*m*	*s*	*Dec. (J2000)* °	'	"	*Type*	*Maximum Magnitude*	*Minimum Magnitude*	*Filter*	*Period (days)*	*Epoch (HJD)*
VESPA_V68	04	40	47.61	+20	38	58.9	EB	12.49	12.81	CV	1.867115	2457405.45456
VESPA_V69	05	55	32.35	+10	13	39.8	EB	15.03	15.60	V	0.406012	2457424.43617
VESPA_V70	05	56	09.59	+10	19	44.5	EW	15.86	16.51	CV	0.448186	2457424.4737
VESPA_V71	05	55	55.69	+10	25	40.1	EW	16.05	16.95	CV	0.282211	2457424.3464
VESPA_V72	05	55	35.92	+10	10	41.0	EW	17.20	17.90	CV	0.405469	2457424.4409
VESPA_V73	07	09	29.07	+24	02	15.3	EW	15.02	15.41	CV	0.425751	2457429.45313
VESPA_V74	07	09	46.41	+24	12	00.3	EW	17.34	17.76	CV	0.341853	2457429.48899
VESPA_V75	07	09	40.11	+24	13	03.1	EA	14.40	14.86	CV	1.105988	2457429.4171
VESPA_V76	15	01	27.29	+19	02	42.7	ROT	15.05	15.32	CV	0.446332	2457466.5402
VESPA_V77	19	29	55.23	+43	59	32.9	EW	17.36	18.14	CV	0.266673	2457577.4281
VESPA_V78	20	24	00.72	+16	05	13.6	EW	16.90	17.70	CV	0.429332	2457580.5226
VESPA_V79	20	22	19.15	+16	09	09.5	EW	14.90	15.23	CV	0.458647	2457587.543
VESPA_V80	20	22	26.51	+16	30	57.8	EW	17.10	17.95	CV	0.438596	2457596.3932
VESPA_V81	20	22	26.40	+16	36	00.6	RRC	14.37	14.76	CV	0.266504	2457600.5385
VESPA_V82	20	23	09.48	+16	43	21.4	EW	16.87	17.47	CV	0.304543	2457600.4959
VESPA_V83	20	22	58.03	+16	38	38.5	EW	16.70	17.50	CV	0.356628	2457596.4292
VESPA_V84	20	22	34.41	+16	30	39.4	EW	16.45	16.95	CV	0.370557	2457596.44
VESPA_V85	20	23	00.81	+17	17	18.4	RRAB	15.58	16.53	CV	0.590231	2457602.4502
VESPA_V86	20	22	28.61	+16	57	21.0	RRAB	15.65	16.52	CV	0.584052	2457602.4394
VESPA_V87	20	22	00.51	+17	00	59.1	EW	15.54	16.46	CV	0.390820	2457604.5495
VESPA_V88	20	21	59.18	+17	10	36.5	EW	15.07	15.51	CV	0.224842	2457602.559
VESPA_V89	20	24	51.91	+17	24	40.9	EW	16.26	16.98	CV	0.349912	2457608.3857
VESPA_V90	20	23	58.29	+17	44	30.4	EA/RS	15.05	15.75	CV	0.404912	2457613.4108
VESPA_V91	20	23	29.90	+17	34	56.5	EW	14.32	14.65	CV	0.320912	2457614.5985
VESPA_V92	20	23	16.71	+17	35	26.6	EW	15.13	15.53	CV	0.344223	2457614.5725
VESPA_V93	20	24	11.14	+17	36	57.9	EB	14.42	14.70	CV	0.819545	2457614.5751
VESPA_V94	20	19	57.74	+16	58	50.6	EW	14.72	15.12	CV	0.346042	2457632.3915
VESPA_V95	20	20	27.48	+16	48	48.2	EW	14.07	14.40	CV	0.36193	2457638.3591
VESPA_V96	20	20	32.03	+17	35	57.6	EW	16.40	17.10	CV	0.33209	2457623.3103
VESPA_V97	20	22	04.07	+16	40	44.2	EW	15.90	16.26	CV	0.302188	2457639.2871
VESPA_V98	20	21	42.04	+17	14	44.5	EW	16.01	16.48	CV	0.417834	2457624.2079
VESPA_V99	20	21	18.65	+17	41	37.2	EW	14.86	15.18	CV	0.403108	2457637.5187
VESPA_V100	20	20	26.39	+17	19	26.8	EW	14.76	14.98	CV	0.352926	2457624.5463

Figure 1. Observations were obtained using this homemade 255-mm F/4.7 Newton telescope, equipped with Starlight Xpress Trius-SX9 CCD camera, with a sensor area of 1392 × 1040 pixels (Pixel size: 6.45 x 6.45 µM).

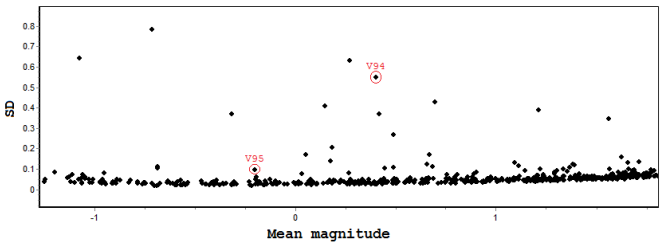

Figure 2. Magnitude-RMS scatter diagram. This a plot (SD Plot) of the Mean Magnitude (x-axis) and the standard deviation (y-axis) for each candidate, and is the discovery graph for VESPA_V94 and V95. The zero in the x-axis represents the mean of magnitudes. Values < zero are for the stars brighter than mean and the values > zero are for the stars fainter than the mean.

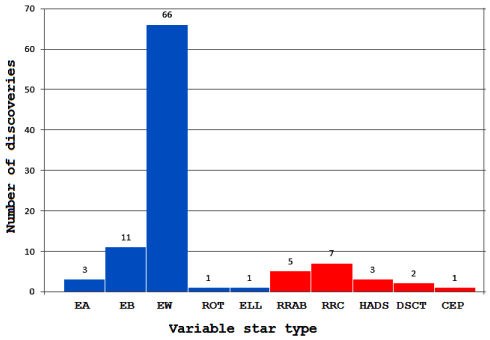

Figure 3. Variable stars discovered in this project, by type.

Table 3. Cross identification.

VESPA_V1 = 2MASS J22024225+2756117 = UCAC4 590-132222
VESPA_V2 = 2MASS J20295917+1613248 = UCAC4 532-128317
VESPA_V3 = 2MASS J20305765+1620182 = UCAC4 532-128620
VESPA_V4 = 2MASS J20332757+1633491 = UCAC4 533-132584
VESPA_V5 = 2MASS J20335203+1637161 = UCAC4 534-128918
VESPA_V6 = 2MASS J20333100+1645306 = UCAC4 534-128825
VESPA_V7 = 2MASS J20281070+1557483 = UCAC4 530-133575
VESPA_V8 = 2MASS J20290495+162054 = UCAC4 532-128061
VESPA_V9 = 2MASS J22143494+4110292 = UCAC4 656-106683
VESPA_V10 = 2MASS J22150137+4055416 = UCAC4 655-109319
VESPA_V11 = 2MASS J22153246+4202214 = UCAC4 661-108309
VESPA_V12 = 2MASS J22005064+4328054 = UCAC4 668-108654
VESPA_V13 = 2MASS J22161133+4144343 = UCAC4 659-105178
VESPA_V14 = 2MASS J21593423+4344200 = UCAC4 669-105250
VESPA_V15 = 2MASS J22015659+4338143 = UCAC4 669-105729
VESPA_V16 = 2MASS J22010139+4307474 = UCAC4 666-109206
VESPA_V17 = 2MASS J22002275+4247162 = UCAC4 664-106603
VESPA_V18 = 2MASS J21592172+4255596 = GSC 03193-01009
VESPA_V19 = 2MASS J01215775+4749332 = GSC 03269-00586
VESPA_V20 = 2MASS J21574764+4312521 = UCAC4 667-104920
VESPA_V21 = 2MASS J01555975+5143067 = GSC 03292-02057
VESPA_V22 = 2MASS J01543649+5140257 = GSC 03292-02037
VESPA_V23 = 2MASS J01561556+5226548 = GSC 03292-01328
VESPA_V24 = 2MASS J01560166+5220266 = USNO-B1.0 1423-0062011
VESPA_V25 = 2MASS J05291136+3618531 = GSC 02415-01387
VESPA_V26 = 2MASS J05290770+3707190 = UCAC4 636-026479
VESPA_V27 = GSC 03047-01108 = UCAC4 651-054439
VESPA_V28 = GSC 03047-00740 = UCAC4 662-058379
VESPA_V29 = GSC 03038-00203 = UCAC4 653-056492
VESPA_V30 = UCAC4 536-132799 = USNO-B1.0 1070-0618597
VESPA_V31 = UCAC4 536-132889 = USNO-B1.0 1070-0618935
VESPA_V32 = CMC15 J202835.9+162950 = UCAC4 533-131232
VESPA_V33 = CMC15 J202810.7+165828 = UCAC4 535-129895
VESPA_V34 = 2MASS J20282292+1725258 = CMC15 J202822.9+172525
VESPA_V35 = 2MASS J20265265+1607383 = CMC15 J202652.6+160738
VESPA_V36 = 2MASS J20284763+1727519 = CMC15 J202847.6+172751
VESPA_V37 = CMC15 J202552.4+155909 = UCAC4 530-132810
VESPA_V38 = 2MASS J20255544+1555036 = CMC15 J202555.4+155503
VESPA_V39 = 2MASS J20262608+1613294 = CMC15 J202626.0+161329
VESPA_V40 = 2MASS J20252969+1555353 = CMC15 J202529.7+155535
VESPA_V41 = 2MASS J20260198+1716055 = CMC15 J202601.9+171605
VESPA_V42 = 2MASS J20255536+1712004 = CMC15 J202555.3+171200
VESPA_V43 = 2MASS J20255886+1604597 = CMC15 J202558.8+160459
VESPA_V44 = 2MASS J20254596+1556505 = CMC15 J202545.9+155650
VESPA_V45 = 2MASS J20245629+1634209 = CMC15 J202456.2+163420
VESPA_V46 = 2MASS J20252674+1648434 = CMC15 J202526.7+164843
VESPA_V47 = 2MASS J20244451+1648594 = CMC15 J202444.5+164859
VESPA_V48 = 2MASS J21572320+4343446 = CMC15 J215723.2+434344
VESPA_V49 = 2MASS J21550937+4311599 = CMC15 J215509.3+431159
VESPA_V50 = 2MASS J21561748+4306299 = CMC15 J215617.4+430629
VESPA_V51 = 2MASS J21551852+4343504 = CMC15 J215518.5+434350
VESPA_V52 = 2MASS J21553378+4313402 = UCAC4 667-104506
VESPA_V53 = 2MASS J21551650+4338246 = CMC15 J215516.5+433824
VESPA_V54 = 2MASS J21555907+4352473 = CMC15 J215559.0+435247
VESPA_V55 = 2MASS J21585137+4403143 = CMC15 J215851.3+440314
VESPA_V56 = 2MASS J21582830+4402398 = CMC15 J215828.3+440239
VESPA_V57 = 2MASS J21562051+4400505 = CMC15 J215620.5+440050
VESPA_V58 = 2MASS J23060071+5248286 = UCAC4 715-107866
VESPA_V59 = 2MASS J23074721+5308326 = UCAC4 716-108199
VESPA_V60 = 2MASS J23070597+5315072 = UCAC4 717-106819
VESPA_V61 = 2MASS J23065483+5301137 = UCAC4 716-108055
VESPA_V62 = 2MASS J21573258+4411532 = CMC15 J215732.5+441153
VESPA_V63 = 2MASS J22153602+4957262 = CMC15 J221536.0+495726
VESPA_V64 = 2MASS J06200295+2431004 = CMC15 J062002.9+243100
VESPA_V65 = 2MASS J05262565+3718591 = CMC15 J052625.6+371859
VESPA_V66 = 2MASS J21575805+4414254 = CMC15 J215758.0+441425
VESPA_V67 = 2MASS J04423923+2020360 = CMC15 J044239.2+202035
VESPA_V68 = 2MASS J04404761+2038589 = CMC15 J044047.6+203858
VESPA_V69 = 2MASS J05553235+1013397 = CMC15 J055532.3+101339
VESPA_V70 = 2MASS J05560959+1019447 = CMC15 J055609.5+101944
VESPA_V71 = 2MASS J05555569+1025402 = CMC15 J055555.6+102540
VESPA_V72 = 2MASS J05553591+1010410 = CMC15 J055535.9+101041
VESPA_V73 = 2MASS J07092907+2402152 = CMC15 J070929.0+240215
VESPA_V74 = 2MASS J07094640+2412002 = CMC15 J070946.3+241200
VESPA_V75 = 2MASS J07094011+2413031 = CMC15 J070940.1+241303
VESPA_V76 = 2MASS J15012728+1902426 = CMC15 J150127.2+190242
VESPA_V77 = 2MASS J19295526+4359325 = CMC15 J192955.2+435932
VESPA_V78 = 2MASS J20240071+1605136 = CMC15 J202400.7+160513
VESPA_V79 = 2MASS J20221915+1609094 = CMC15 J202219.1+160909
VESPA_V80 = 2MASS J20222650+1630577 = CMC15 J202226.5+163057
VESPA_V81 = 2MASS J20222640+1636007 = CMC15 J202226.3+163600
VESPA_V82 = 2MASS J20230947+1643214 = CMC15 J202309.4+164321
VESPA_V83 = 2MASS J20225805+1638384 = CMC15 J202258.0+163838
VESPA_V84 = 2MASS J20223442+1630393 = CMC15 J202234.4+163039
VESPA_V85 = 2MASS J20230080+1717184 = CMC15 J202300.8+171718
VESPA_V86 = 2MASS J20222860+1657210 = CMC15 J202228.6+165721
VESPA_V87 = 2MASS J20220051+1700593 = CMC15 J202200.5+170059
VESPA_V88 = 2MASS J20215918+1710365 = CMC15 J202159.1+171036
VESPA_V89 = 2MASS J20245192+1724410 = CMC15 J202451.9+172441
VESPA_V90 = 2MASS J20235827+1744303 = CMC15 J202358.2+174430
VESPA_V91 = 2MASS J20232990+1734564 = CMC15 J202329.9+173456
VESPA_V92 = 2MASS J20231671+1735267 = CMC15 J202316.7+173526
VESPA_V93 = 2MASS J20241113+1736579 = CMC15 J202411.1+173657
VESPA_V94 = 2MASS J20195774+1658505 = CMC15 J201957.7+165850
VESPA_V95 = 2MASS J20202748+1648482 = CMC15 J202027.4+164848
VESPA_V96 = 2MASS J20203203+1735574 = CMC15 J202032.0+173557
VESPA_V97 = 2MASS J20220407+1640442 = CMC15 J202204.0+164044
VESPA_V98 = 2MASS J20214204+1714445 = CMC15 J202142.0+171444
VESPA_V99 = 2MASS J20211865+1741371 = CMC15 J202118.6+174137
VESPA_V100 = 2MASS J20202638+1719268 = CMC15 J202026.3+171926

We used POLYPUS software release 1.9 (Bassano Bresciano Observatory 2013) to control the robotic observations and astrometrical pointing system. We took exposures when the target's altitude was more than 30 degrees. Raw images were processed with flat field and dark frames.

We used the variable star search utility of MPO CANOPUS version 10.4.0.20 (Minor Planet Observer 2010) to search for new variable stars. This utility uses a magnitude-RMS scatter diagram. Figure 2 is a plot (SD Plot) of the Mean Magnitude (x-axis) and the standard deviation (y-axis) for each candidate, and is the discovery graph for VESPA_V94 and V95. The zero in the x-axis represents the mean of magnitudes. Values < zero are for the stars brighter than mean and the values > zero are for the stars fainter than the mean.

Usually, for our system, the discoveries are in the 0.05 < SD < 1 range. Other stars have SD in this range for other (non-variable) reasons.

We also used MPO CANOPUS to perform differential photometry on the reduced images. PERANSO software version 2.51 (Vanmunster 2013) was used for period analysis (using generally the ANOVA method) and to determine the epoch and the amplitude.

In a typical observing session, one or two fields in succession are imaged for the duration of the night, in order to have a continuous coverage of a 0.13 or 0.27 square degree area for each observing session, with a typical exposure time of 2 minutes. The exposure time was chosen in order to measure photometrically stars between magnitudes 13.5 and 16.5.

To increase the probability of finding new stars, the fields were chosen in the vicinity of the Milky Way in areas not yet covered by professional surveys to avoid discovering stars

already known. Generally, the fields were chosen from the +10 < declination < +60 range due to obstacles on the ground. In some cases, the fields were those crossed by some asteroids of which we studied photometrically the rotation period. For the choice of the fields we have used the AAVSO Variable Star Plotter (VSP; AAVSO 2016) service of the AAVSO.

The methodology involves a discovery phase in which we scanned the fields in search of new stars, and a followup phase in which we obtained the complete light curves.

We used comparison stars of similar color to that of the variable so as to minimize errors due to atmospheric refraction. To improve the parameters of these stars we have also used, if possible, data of the CRTS, SWASP, ASAS-3, APASS, and NSVS surveys. The coordinates of new variable stars (Table 2) were obtained from the UCAC4 catalogue (Zacharias *et al.* 2012).

3. Discussion

For every star we have proposed a type of variability based on the characteristics shown by its differential light curve, its amplitude, period, and spectral class (Tables 1 and 3; Figure 3).

We have determined the spectral class from the APASS, 2MASS, and CMC 15 catalogues, using tables contained in *A Stellar Spectral Flux Library: 1150–25000 A°* (Pickles 1998).

For the eclipsing stars we have also used *Binary Stars–A Pictorial Atlas* (Terrell *et al.* 1992). For pulsating stars we have used the text: "Variable Star Type Designations in VSX" (Watson *et al.* 2014), based on the *General Catalogue of Variable Stars* (GCVS; Samus *et al.* 2009) description of variable star type designations, and *Variable Star Classification and Light Curves* (AAVSO 2012).

We have submitted all stars to AAVSO/VSX, which has approved and registered these stars.

4. Co-discovery

In some cases the discoveries were made thanks to the collaboration of other people so we included them as discoverers, with us, in the VSX record: Sebastian Otero, co-discoverer of VESPA_V39 and VESPA_V76; Giorgio Bianciardi, co-discoverer of VESPA_V1 and VESPA_V2; and Bruce McMath, co-discoverer of VESPA_V20 and VESPA_V57.

5. Acknowledgements

Our thanks to Sebastian Otero (VSX Team) for his extremely valuable comments and help in resolving the intricate cases in variable star identification. Many of our discoveries have been resolved with the help of Sebastian's vast knowledge and his experience.

This research has made use of the follow sources and services: International Variable Star Index (VSX) database, operated at AAVSO,Cambridge, Massachusetts, USA; the AAVSO Photometric All-Sky Survey (APASS; Henden *et al.* 2015), funded by the Robert Martin Ayers Sciences Fund; VizieR catalogue access tool, CDS, Strasbourg, France; 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; the CMC15 Data Access Service at CAB (INTA-CSIC); the CSS survey funded by the National Aeronautics and Space Administration under Grant No. NNG05GF22G issued through the Science Mission Directorate Near-Earth Objects Observations Program; the CRTS survey is supported by the U.S. National Science Foundation under grants AST-0909182 and AST-1313422; The All Sky Automated Survey (Pojmański 1997); the Northern Sky Variability Survey created jointly by the Los Alamos National Laboratory and University of Michigan, funded by the U.S. Department of Energy, the National Aeronautics and Space Administration and the National Science Foundation; SuperWASP Public Archive operated by the WASP consortium; observations obtained with XMM-Newton, an ESA science mission with instruments and contributions directly funded by ESA Member States and the USA (NASA); U.S. Naval Observatory CCD Astrograph Catalog (UCAC4).

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Table 4. Variable stars by type.

Extrinsic		*Intrinsic*	
Type	*Number*	*Type*	*Number*
EA	3	RRAB	5
EB	11	RRC	7
EW	66	HADS	3
ELL	1	DSCT	2
ROT	1	CEP	1

Table 5. Key to the sources of observations shown in Figure 4 (from VSX, Watson *et al.* 2014).

Vespa	*Use of Colors in the Light Curves*	*Vespa*	*Use of Colors in the Light Curves*
V1	Green = UAI_Astra/Skylive 2014-08-16, all other VESPA at Bassano Observatory	V50	Yellow = SWASP, all other VESPA at Bassano Observatory
V2	Green = UAI_Astra/Skylive 2014-08-21, all other VESPA at Bassano Observatory	V51	Yellow = SWASP, all other VESPA at Bassano Observatory
V3	All VESPA at Bassano Observatory	V52	All VESPA at Bassano Observatory
V4	All VESPA at Bassano Observatory	V53	All VESPA at Bassano Observatory
V5	All VESPA at Bassano Observatory	V54	All VESPA at Bassano Observatory
V6	All VESPA at Bassano Observatory	V55	All VESPA at Bassano Observatory
V7	All VESPA at Bassano Observatory	V56	All VESPA at Bassano Observatory
V8	Black = VESPA, yellow = ASAS-3, pink = APASS	V57	Red = VESPA, blue = Bruce McMath
V9	All VESPA at Bassano Observatory	V58	Blue = VESPA, yellow = SWASP
V10	All VESPA at Bassano Observatory	V59	All VESPA at Bassano Observatory
V11	All VESPA at Bassano Observatory	V60	All VESPA at Bassano Observatory
V12	All VESPA at Bassano Observatory	V61	Yellow = SWASP, green = APASS, all other VESPA at Bassano Observatory
V13	All VESPA at Bassano Observatory	V62	Blue = VESPA, red = APASS
V14	All VESPA at Bassano Observatory	V63	All VESPA at Bassano Observatory
V15	All VESPA at Bassano Observatory	V64	Yellow = SWASP, all other VESPA at Bassano Observatory
V16	All VESPA at Bassano Observatory	V65	Blue = VESPA, yellow = SWASP
V17	All VESPA at Bassano Observatory	V66	All VESPA at Bassano Observatory
V18	Blue = VESPA, green = SWASP, black = APASS	V67	Blue = VESPA, green = CRTS
V19	Black = VESPA, green = SWASP	V68	Blue = VESPA, light grey = SWASP, grey = CRTS
V20	Blue = VESPA, black = Bruce McMath	V69	Blue = VESPA, red = APASS
V21	Grey = NSVS, all other VESPA at Bassano Observatory	V70	All VESPA at Bassano Observatory
V22	Grey = NSVS, all other VESPA at Bassano Observatory	V71	All VESPA at Bassano Observatory
V23	grey = NSVS, all other VESPA at Bassano Observatory	V72	All VESPA at Bassano Observatory
V24	All VESPA at Bassano Observatory	V73	Blue = VESPA, green = CRTS
V25	Black = VESPA, red = NSVS, green = SWASP	V74	Black = VESPA, red = CRTS
V26	All VESPA at Bassano Observatory	V75	Black = VESPA,grey = SWASP
V27	Grey = CRTS, all other VESPA at Bassano Observatory	V76	Grey = CRTS, all other VESPA at Bassano Observatory + Sebastian Otero
V28	Grey = CRTS, all other VESPA at Bassano Observatory	V77	All VESPA at Bassano Observatory
V29	Red = VESPA, grey = CRTS	V78	All VESPA at Bassano Observatory
V30	All VESPA at Bassano Observatory	V79	All VESPA at Bassano Observatory
V31	All VESPA at Bassano Observatory	V80	All VESPA at Bassano Observatory
V32	Yellow = ASAS-3, red = APASS, all other VESPA at Bassano Observatory	V81	All VESPA at Bassano Observatory
V33	All VESPA at Bassano Observatory	V82	All VESPA at Bassano Observatory
V34	All VESPA at Bassano Observatory	V83	All VESPA at Bassano Observatory
V35	All VESPA at Bassano Observatory	V84	All VESPA at Bassano Observatory
V36	All VESPA at Bassano Observatory	V85	All VESPA at Bassano Observatory
V37	All VESPA at Bassano Observatory	V86	All VESPA at Bassano Observatory
V38	All VESPA at Bassano Observatory	V87	All VESPA at Bassano Observatory
V39	Blue = VESPA, red = APASS, light green = NSVS, green = ASAS-3 + Sebastian Otero	V88	All VESPA at Bassano Observatory
V40	All VESPA at Bassano Observatory	V89	All VESPA at Bassano Observatory
V41	All VESPA at Bassano Observatory	V90	All VESPA at Bassano Observatory
V42	All VESPA at Bassano Observatory	V91	All VESPA at Bassano Observatory
V43	All VESPA at Bassano Observatory	V92	All VESPA at Bassano Observatory
V44	All VESPA at Bassano Observatory	V93	All VESPA at Bassano Observatory
V45	All VESPA at Bassano Observatory	V94	All VESPA at Bassano Observatory
V46	All VESPA at Bassano Observatory	V95	All VESPA at Bassano Observatory
V47	All VESPA at Bassano Observatory	V96	All VESPA at Bassano Observatory
V48	All VESPA at Bassano Observatory	V97	All VESPA at Bassano Observatory
V49	All VESPA at Bassano Observatory	V98	All VESPA at Bassano Observatory
		V99	All VESPA at Bassano Observatory
		V100	All VESPA at Bassano Observatory

Color versions of the plots shown in Figure 4 (published grayscale in print) may be viewed at https://www.aavso.org/apps/jaavso/article/3234/ .

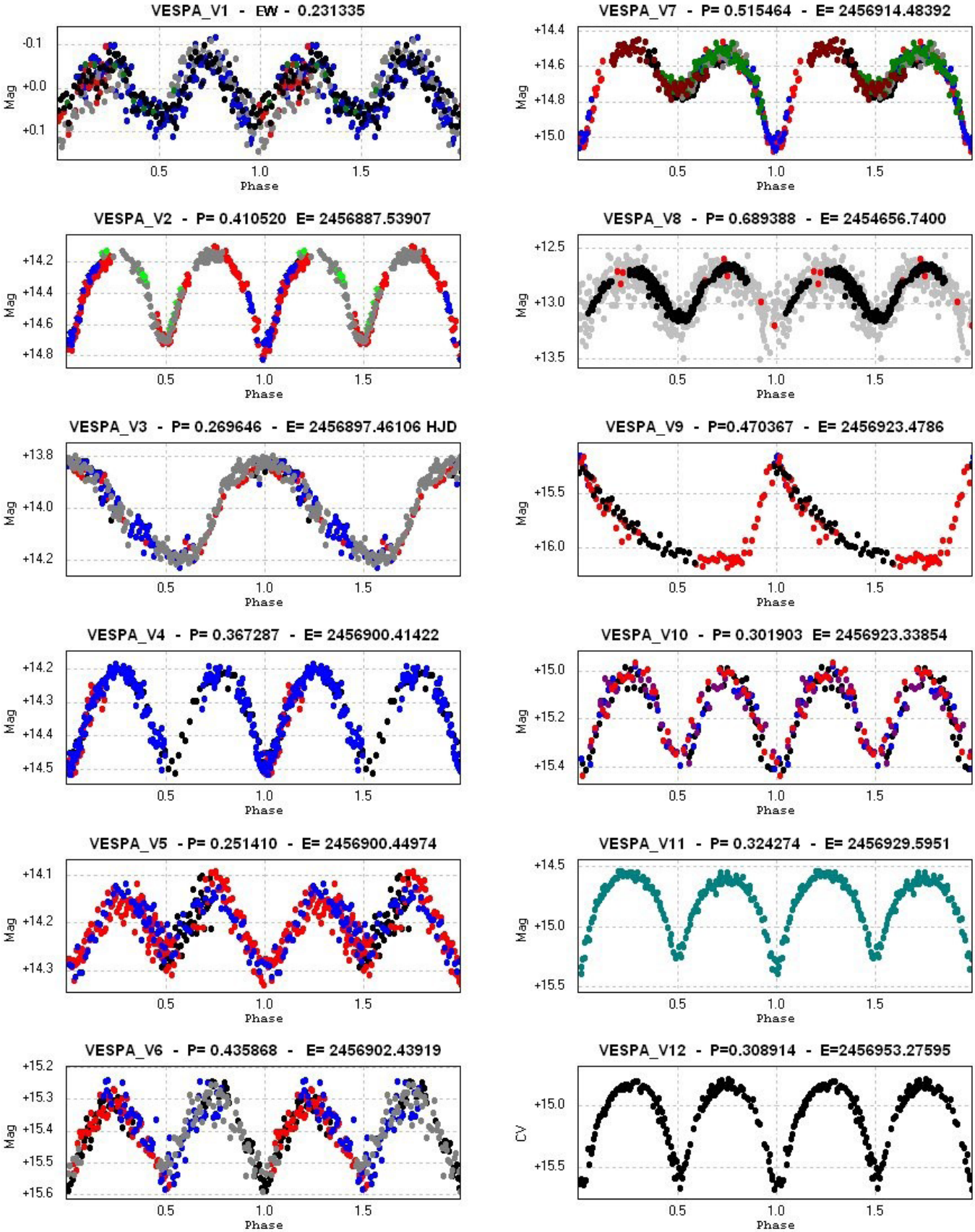

Figure 4. Light curves of the 100 discovered variable stars. In the following pages we present the light curves of all variable stars, presented in the order given in Table 2. Explanation of the colors used in the light curves: Generally each color represents an observing session. In some cases the different colors are used for the various survey (CRTS, SWASP, ASAS-3, APASS, NSVS, etc.) used to better determine the period of the variableas as described in Table 5. In the AAVSO-VSX, for each variable star there is a light curve with a legend that best explains the colors used.

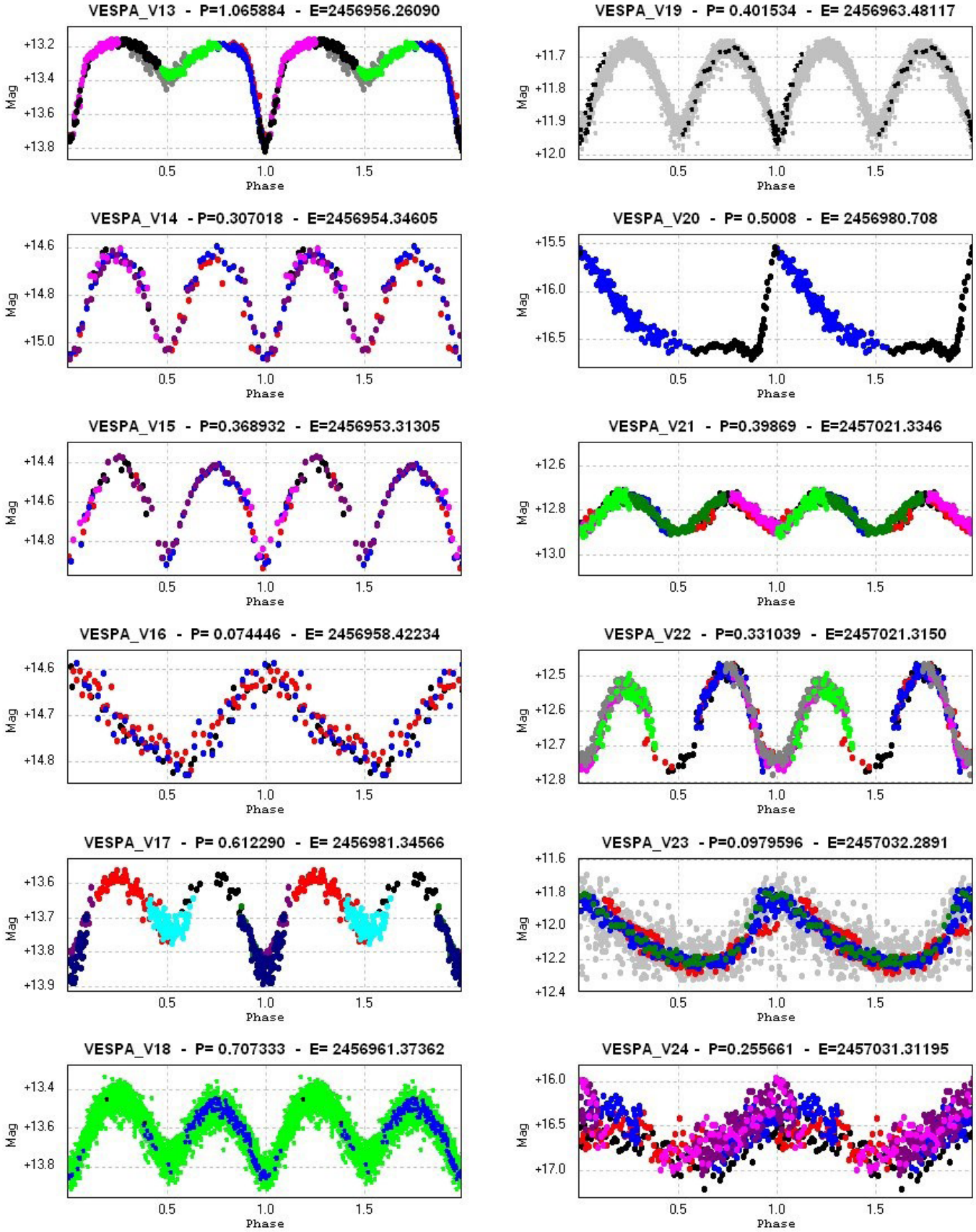

Figure 4. Light curves of the 100 discovered variable stars, cont.

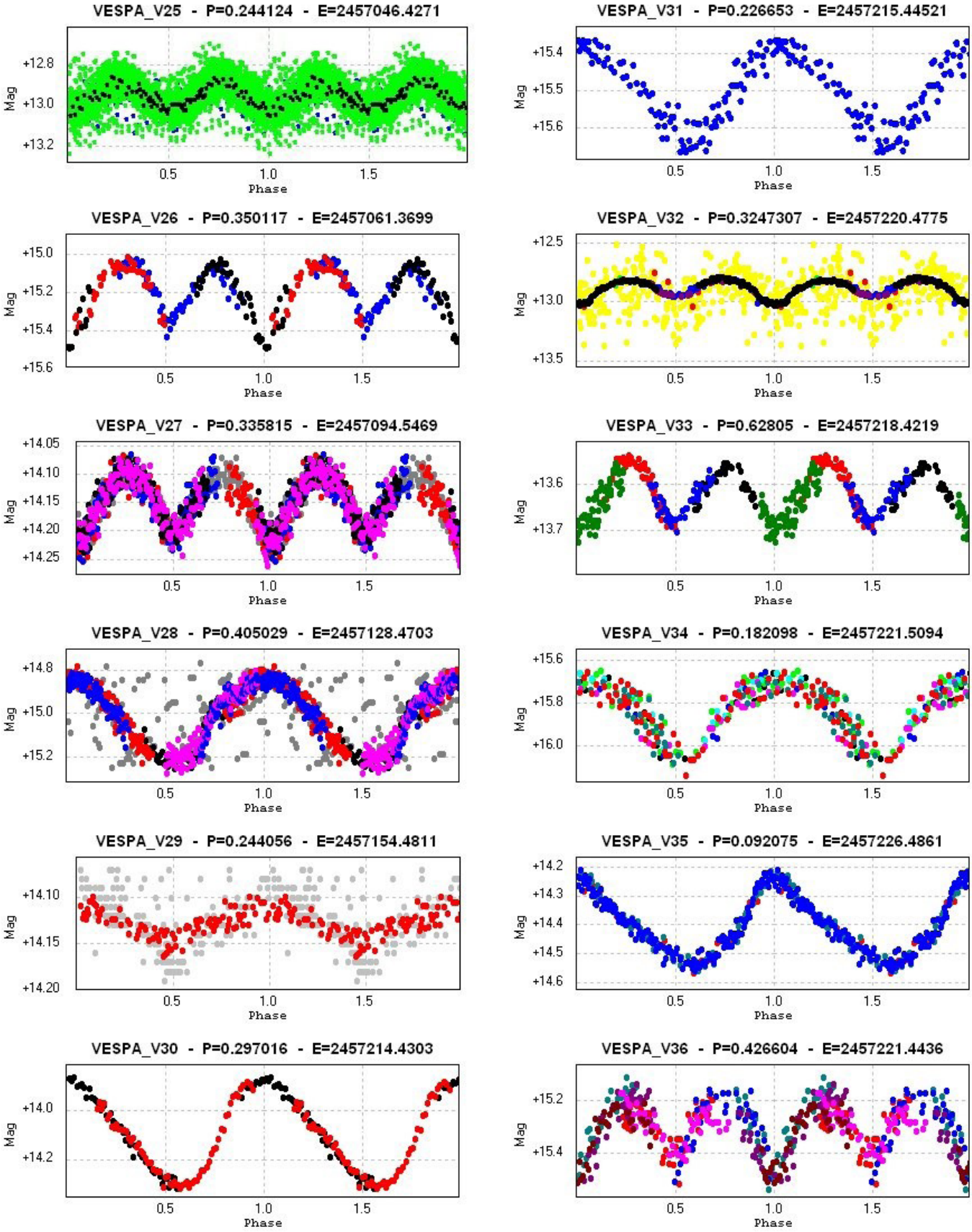

Figure 4. Light curves of the 100 discovered variable stars, cont.

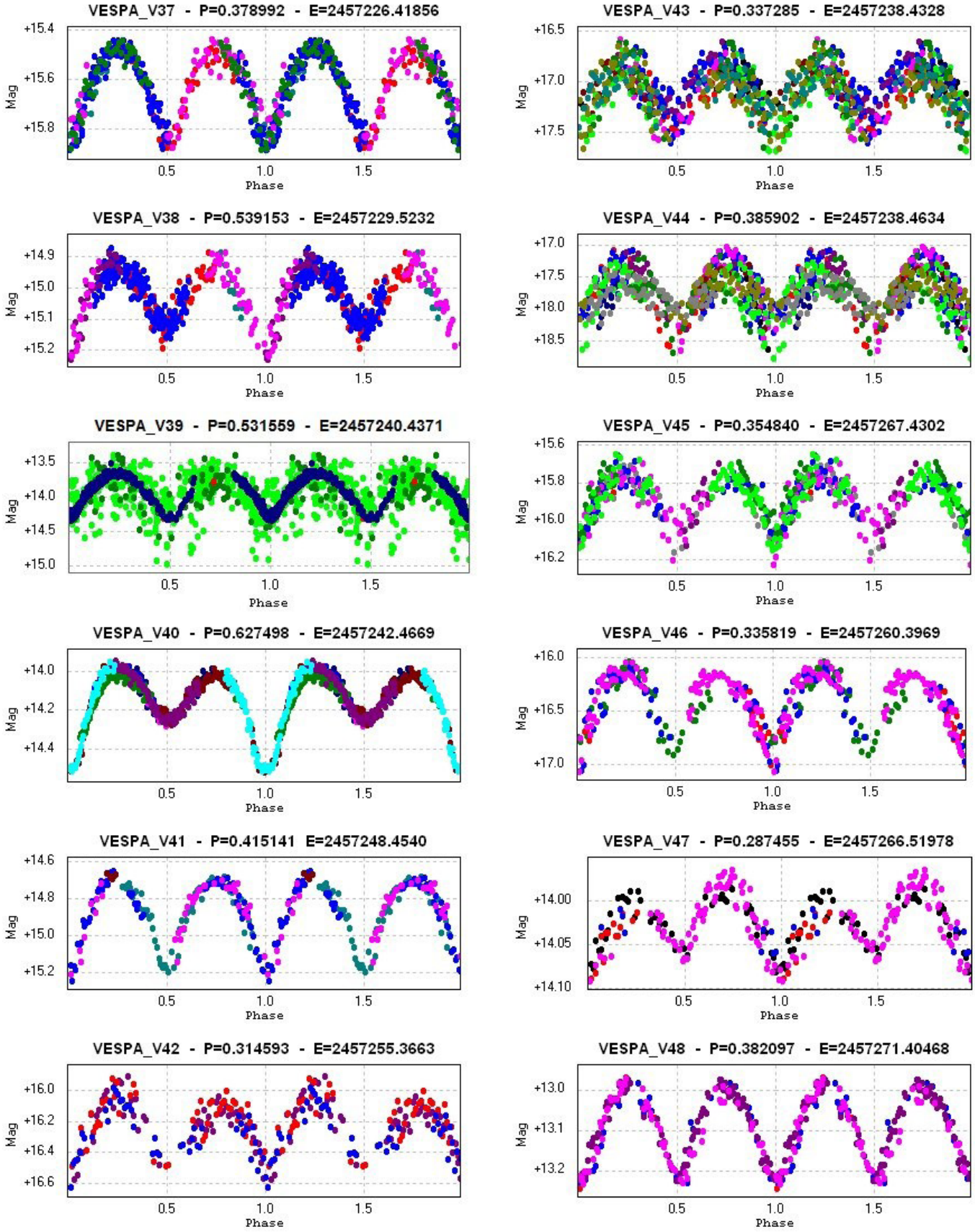

Figure 4. Light curves of the 100 discovered variable stars, cont.

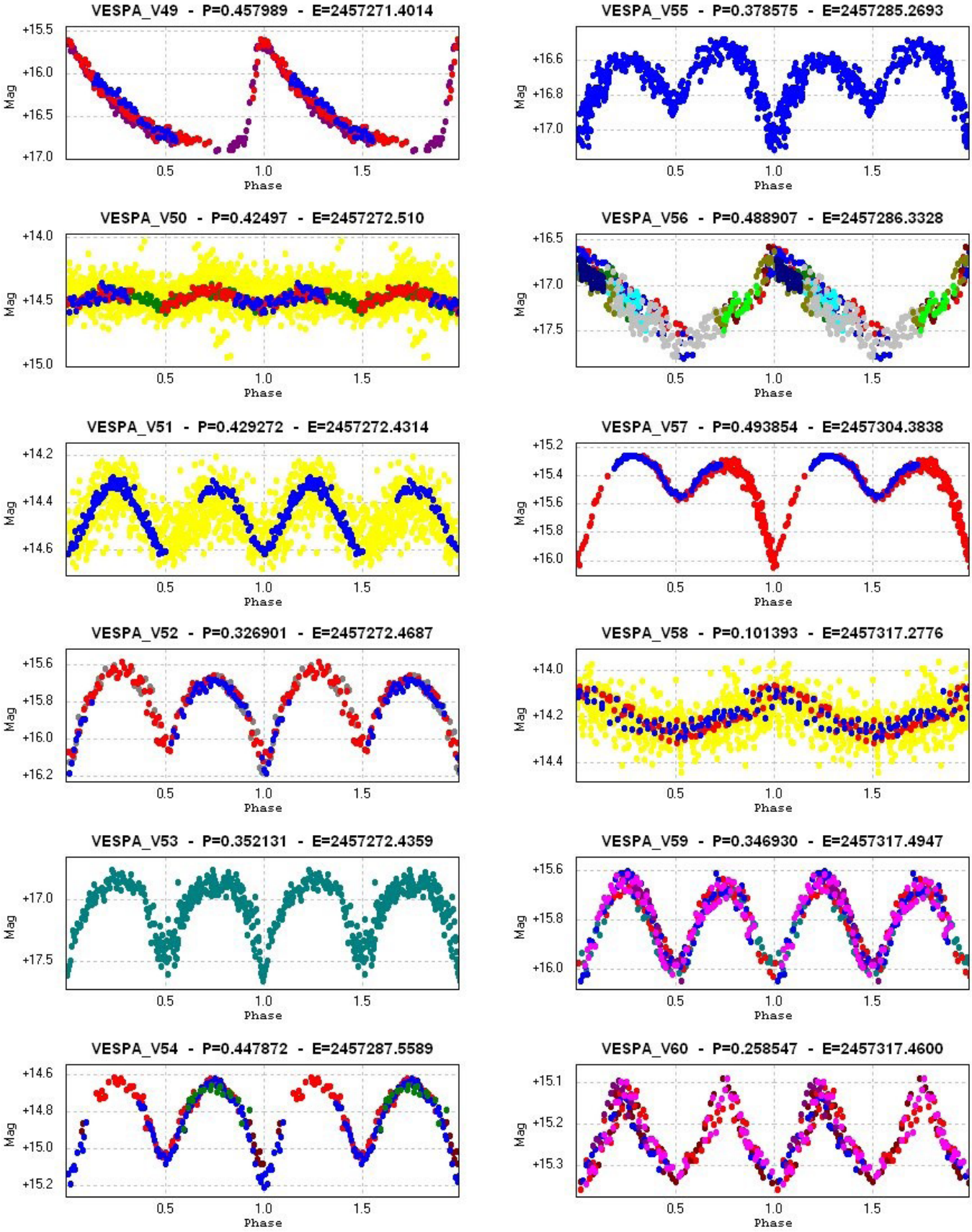

Figure 4. Light curves of the 100 discovered variable stars, cont.

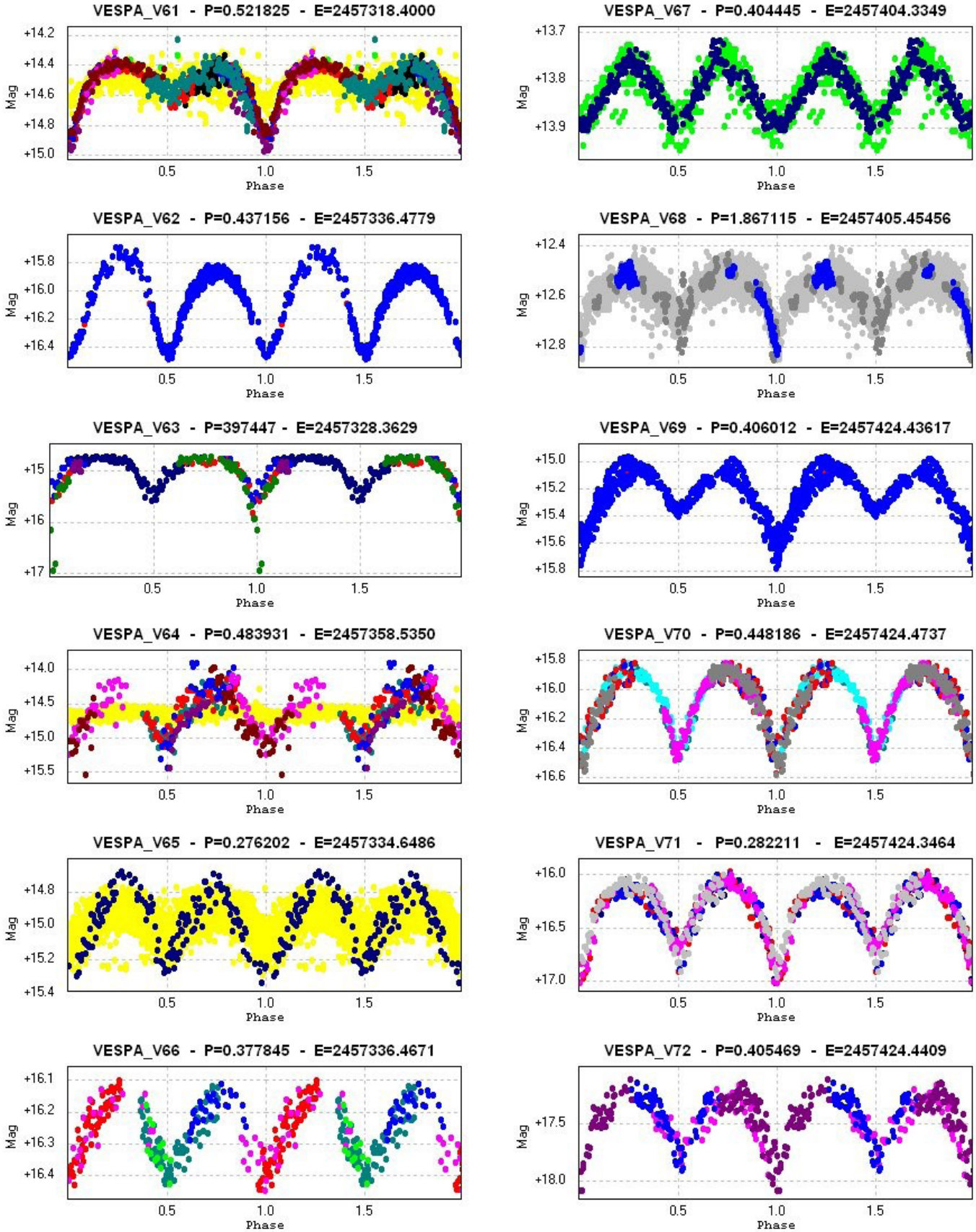

Figure 4. Light curves of the 100 discovered variable stars, cont.

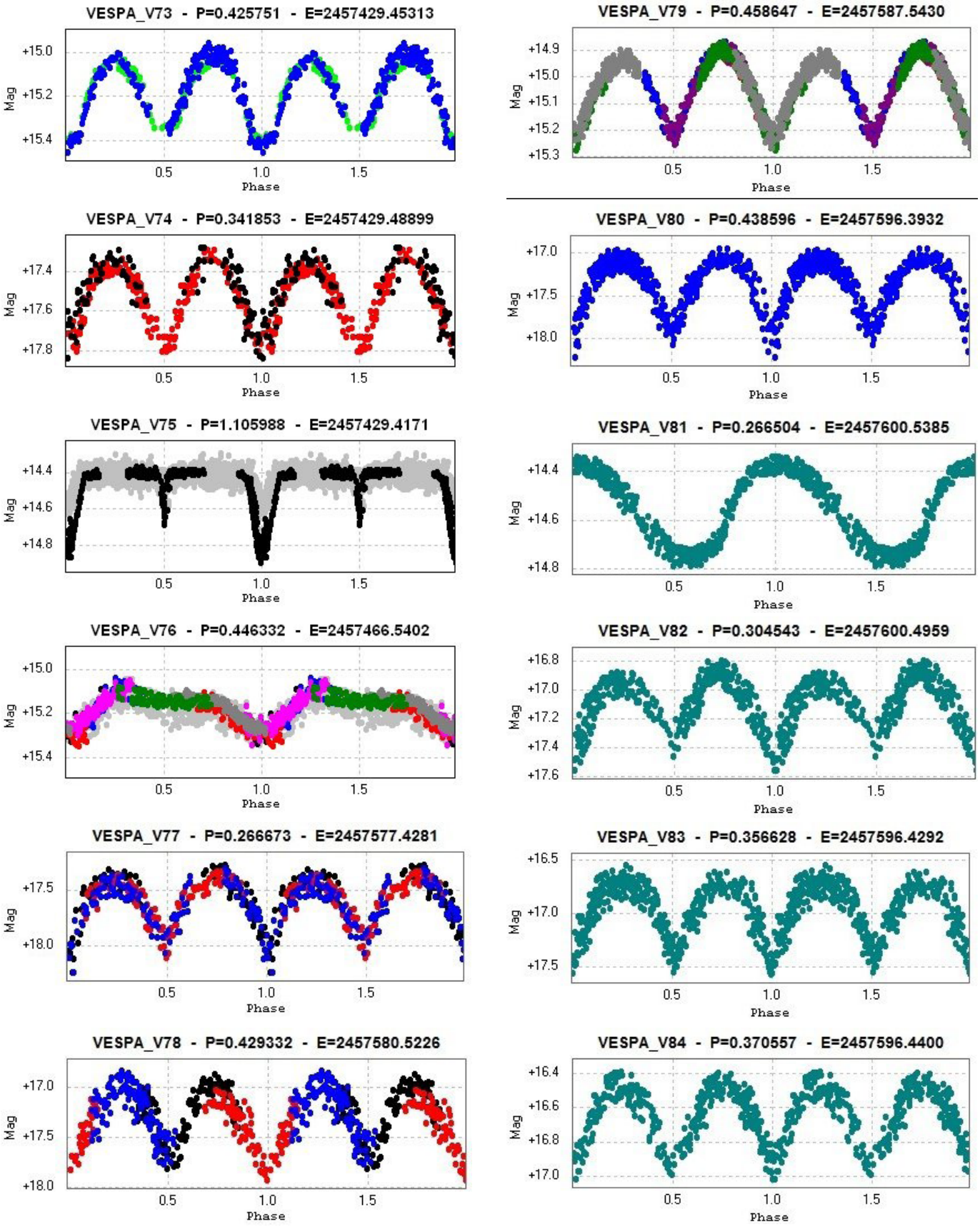

Figure 4. Light curves of the 100 discovered variable stars, cont.

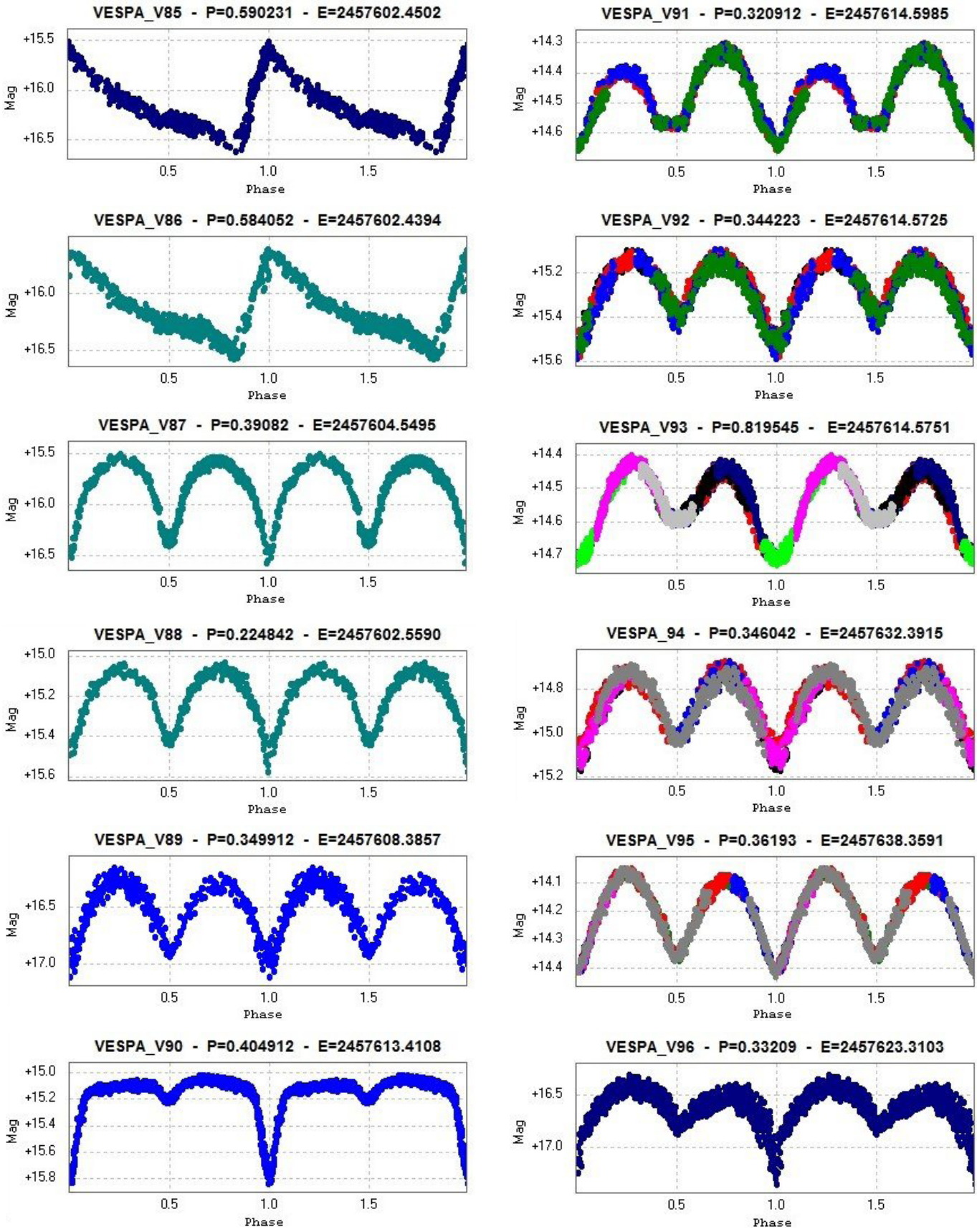

Figure 4. Light curves of the 100 discovered variable stars, cont.

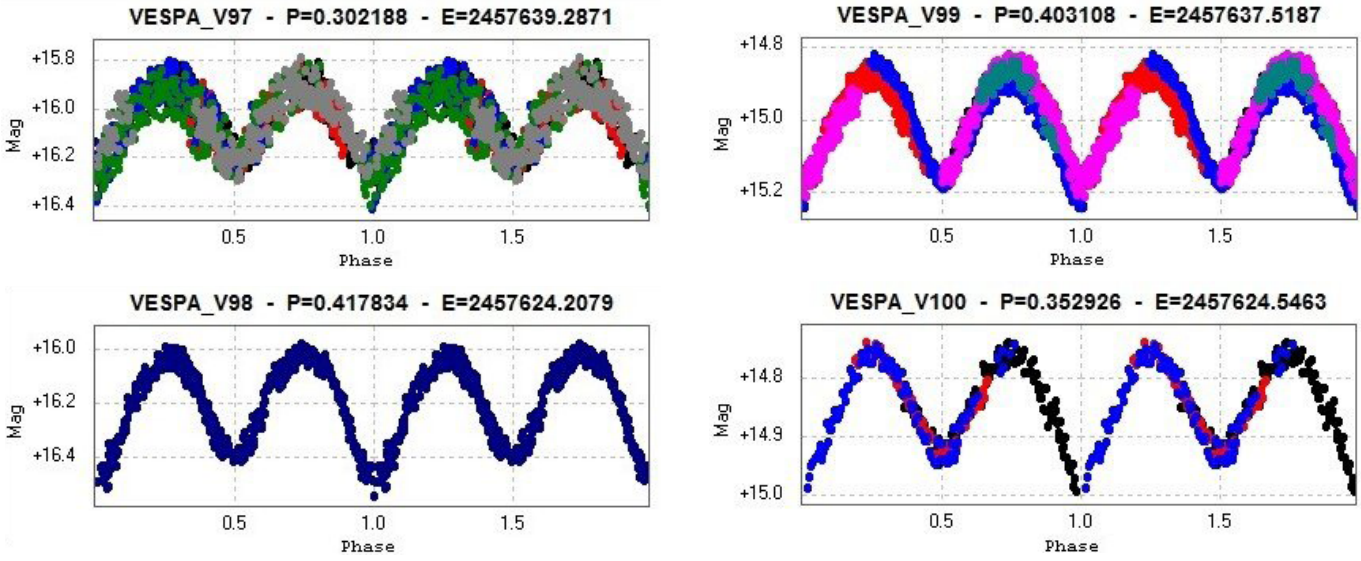

Figure 4. Light curves of the 100 discovered variable stars, cont.