

Finding the most variable stars in the Orion Belt with the All Sky Automated Survey

José A. Caballero*, M. Cornide, and E. de Castro

Departamento de Astrofísica y Ciencias de la Atmósfera, Facultad de Física, Universidad Complutense de Madrid, E-28040 Madrid, Spain

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We look for high-amplitude variable young stars in the open clusters and associations of the Orion Belt. We use public data from the ASAS-3 Photometric V -band Catalogue of the All Sky Automated Survey, infrared photometry from the 2MASS and *IRAS* catalogues, proper motions, and the Aladin sky atlas to obtain a list of the most variable stars in a survey area of side 5 deg centred on the bright star Alnilam (ϵ Ori) in the centre of the Orion Belt. We identify 32 highly-variable stars, of which 16 had not been reported to vary before. They are mostly variable young stars and candidates (16) and background giants (8), but there are also field cataclysmic variables, contact binaries, and eclipsing binary candidates. Of the young stars, which typically are active Herbig Ae/Be and T Tauri stars with $H\alpha$ emission and infrared flux excess, we discover four new variables and confirm the variability status of another two. Some of them belong to the well known σ Orionis cluster. Besides, six of the eight giants are new variables, and three are new periodic variables.

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1 Introduction

The Ori OB1 b subgroup association, mostly coincident with the asterism of the Orion Belt, contains a rich population of very young stars (e.g. Haro & Moreno 1953; Walker 1969; Warren & Hesser 1978; Brown et al. 1994; Sterzik et al. 1995; de Zeeuw et al. 1999; Briceño et al. 2001). The youngest regions, including Alnitak (ζ Ori), which illuminates the Flame Nebula (NGC 2024), and σ Ori, which illuminates the Horsehead Nebula (Barnard 33 and IC 434), are to the east of the Belt and have ages of 1 to 5 Ma. Here lies the σ Orionis cluster, one of the most suitable sites for discovering and characterising substellar objects (Béjar et al. 1999; Zapatero Osorio et al. 2002; Sherry et al. 2004; Caballero et al. 2007). The population of stars surrounding Alnilam (ϵ Ori) and Mintaka (δ Ori), to the west of the Belt, are older (5–10 Ma) and spread over a wider area than the much denser σ Orionis cluster (Caballero & Solano 2008). Surrounding the Belt, there is another dispersed population of 10–20 Ma-old stars, mostly associated to the Ori OB1 a subgroup association (Jeffries et al. 2006; Caballero 2007) and its agglomerates, such as the 25 Orionis group or the η Orionis overdensity (Briceño et al. 2007; Caballero & Dinis 2008).

$H\alpha$ and X-ray emission and infrared excess are the primary features for the identification of very young stars as those in the Orion Belt. Optical and near-infrared variability, cosmic lithium abundances, surrounding jets, or forbid-

den emission lines are other signposts used to confirm very young ages in stars. Photometric variability in young stars is mostly due to dark (cool) and bright (hot) spots and flare activity, which are related to the strengthened magnetic activity due to fast rotation, and interactions with circumstellar discs, such as intense, variable accretion episodes or occultations (e.g. classical works: Joy 1945; Walker 1956; Herbig 1977 – theoretical works: Koenigl 1991; Collier Cameron & Campbell 1993; Shu et al. 1994 – modern observational works: Bouvier et al. 1993; Herbst et al. 1994; Thé et al. 1994; Hartmann & Kenyon 1996; Hamilton et al. 2001; Eiroa et al. 2002).

The Orion Nebula Cluster in the Ori OB1 d subgroup association has been a traditional target for studying the photometric variability of young stars (Jones & Walker 1988; Carpenter et al. 2001; Herbst et al. 2002; Stassun et al. 2006; Parihar et al. 2009), but the surveys for variability in the Orion Belt are relatively scarce. The most thorough variability surveys in the Ori OB1 b association have been aimed at the low-mass pre-main sequence stars and brown dwarfs (Bailer-Jones & Mundt 2001; Zapatero Osorio et al. 2003; Caballero et al. 2004, 2006; Scholz & Eislöffel 2004, 2005; Briceño et al. 2005; Scholz et al. 2009), while the brightest variable stars were first recognised as early as the beginning of the 20th century and have not received quite attention. Only a few (multiple) young stars of important astrophysical interest had been extensively monitored, such as VV Ori (Miller Barr 1904; Struve & Luyten 1949; Terrell et al. 2007), σ Ori E (Walborn & Hesser 1976; Landstreet & Borra 1978), or Mintaka AE–D (Stebbins 1915; Koch

* Corresponding author: e-mail: caballero@astrax.fis.ucm.es

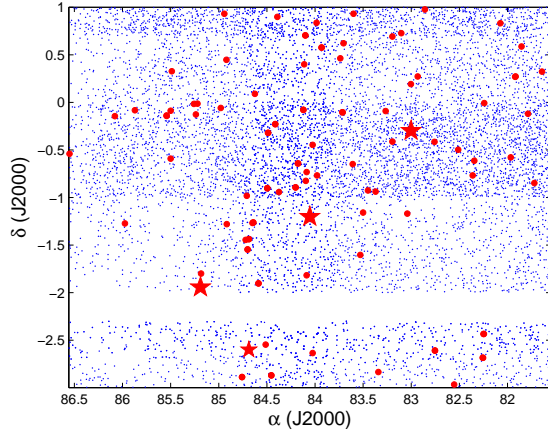


Fig. 1 Spatial location of the 10 029 ASAS sources in the studied area with light curves with more than 40 data points, marked with (blue) small dots. North is up, east is to the left. The 100 ASAS sources with possible variable light curves, the three Orion Belt supergiant stars (Alnitak, Alnilam, and Mintaka, from east to west), and σ Ori are marked with (red) filled circles, big stars, and a small star, respectively. Note the blank strip where ASAS did not survey (between Alnitak and σ Orionis’ declinations) and the overlapping between different ASAS pointings (at about the Mintaka’s declination).

& Hrivnak 1981). Many of the intermediate-mass T Tauri stars in the Orion Belt with variability denominations (e.g. BG Ori, V505 Ori) were compiled by Fedorovich (1960) and have never been monitored again. After a century of photometric searches in the region, there are still serendipitous discoveries of bright, UX Orionis-, A-type, variable stars (Caballero et al. 2008).

Our aim is to find the most variable stars in the Orion Belt, giving especial emphasis to the young Herbig Ae/Be (HAeBe) and T Tauri stars. To accomplish that, we have used the ASAS-3 Photometric V -band Catalogue of the All Sky Automated Survey (ASAS)¹, which is “a low cost project dedicated to constant photometric monitoring of the whole available sky” (Pojmański 1997, 2002).

2 Analysis

First, we compiled 63 276 ASAS light curves of objects in a square of side 5.0 deg centred on Alnilam; see Fig. 1. We used the default parameters $N > 4$ data points and $r < 15$ arcsec (N is the number of data points within a circle of radius r centred on the coordinates of an ASAS source). If not for certain blank strip, the surveyed area would have been 25 deg². To maximise the scientific return and minimise possible further troubles with light curves of poor quality, we discarded all ASAS light curves with $N \leq 40$ data points. It left 10 029 light curves (16 %) with $N > 40$

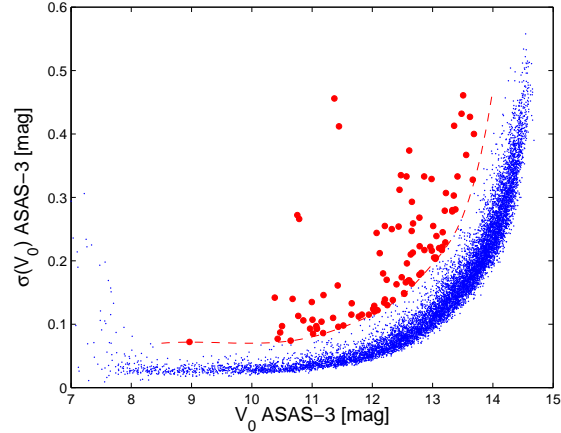


Fig. 2 Diagram showing $\sigma(V_0)$ vs. $\overline{V_0}$. ASAS sources above the dashed line are variable star candidates in this work. X Ori is out of limits ($\overline{V_0} \sim 12.7$ mag, $\sigma(V_0) \sim 1.4$ mag).

for next phases of the analysis. The ASAS data covered almost six years during the first decade of the 21st century.

Of the five available apertures (0, 1, 2, 3, 4), the “0” aperture photometry seemed to provide better data (i.e. less dispersion and number of grade “C” and “D” data points – probably useless data or without photometric value at all due to bad pixels, frame-edge and bright star/planet proximity, or excessive faintness). According to Pojmański (2002), the five apertures correspond to diameter sizes of the aperture photometry from 2 to 6 pixels; the “0” aperture corresponds to the narrower photometry (Pojmański, priv. comm.). From this point on, we used only the Johnson V magnitude with the ASAS “0” aperture photometry, which we indicate with the symbol V_0 .

Fig. 2 illustrates the selection of variable stars. It is a $\sigma(V_0)$ vs. $\overline{V_0}$ diagram in which the variable star candidates have larger values of standard deviation $\sigma(V_0)$ with respect to non-variable stars of the same average magnitude $\overline{V_0}$. ASAS stars brighter than $\overline{V_0} \approx 8.5$ mag are affected by saturation in the detector and were not considered. The lower envelope at the non-saturated, brightest end of the cloud of data points in the diagram indicates the best photometric accuracy of the system, which is of about 0.02 mag. The obvious rise of the lower envelope at faint magnitudes is a combination of the standard deviations (root-mean-squares) from Poisson noise in the targets and from sky noise in the photometric aperture (e.g. Irwin et al. 2007). The line used as the selection criterion is the lower envelope shifted to larger $\sigma(V_0)$ s by magnitude-dependent amounts (roughly 0.06 mag at $\overline{V_0} \sim 8.5$ –11.5 mag, 0.12 mag at $\overline{V_0} \sim 12.5$ mag, and 0.18 mag at $\overline{V_0} \sim 13.5$ mag). This choice was relatively arbitrary: more or less restrictive selection criteria would have given significantly less or more variable star candidates, respectively. Thus, the used selection criterion was a compromise to minimise the number of false positives (variable star candidates that actually do not vary) and maximise

¹ <http://www.astrouw.edu.pl/asas/>.

Table 1 Identified variables in the Orion Belt.

No.	$\alpha^{2\text{MASS}}$ (J2000)	$\delta^{2\text{MASS}}$ (J2000)	\bar{V}_0 [mag]	$\sigma(V_0)$ [mag]	$\bar{\delta V}_0$ [mag]	N_{obs}^*	Spectral type	Name	Class	Variable
01	05 28 59.57	-03 33 52.3	13.621	0.412	0.055	190	...	V1159 Ori	Dwarf nova	Known
03	05 31 01.46	-03 23 24.3	12.492	0.341	0.056	294	...	IRAS 05285-0325	Giant	New
06	05 33 22.45	-03 09 55.7	11.185	0.085	0.032	207	...	No. 06	Unknown	New
07	05 37 48.79	-03 07 48.7	10.780	0.101	0.021	286	...	IRAS 05353-0309	Giant	New
11	05 32 09.94	-02 49 46.8	11.581	0.524	0.032	191	F5-8Vpe	RY Ori	HAeBe	Known
12	05 38 33.68	-02 44 14.2	12.885	0.368	0.054	187	K4e	TX Ori	T Tauri	Known
13	05 38 25.87	-02 43 51.2	13.059	0.356	0.054	142	K3e	TY Ori	T Tauri	Known
14	05 43 54.26	-02 43 35.4	11.628	0.135	0.032	222	...	2M054354-0243.6	Contact binary	Known
15	05 39 39.99	-02 43 09.7	13.246	0.246	0.054	197	...	RW Ori	T Tauri	Known
18	05 38 48.04	-02 27 14.2	13.340	0.295	0.053	224	K7e+M:	Mayrit 528005 AB	T Tauri	New
21	05 36 20.91	-02 10 57.6	12.607	0.192	0.056	252	F3e	PQ Ori	HAeBe	Known
29	05 37 38.67	-01 46 16.6	12.752	1.441	0.054	179	M8-9III:	X Ori	Giant	Known
30	05 37 56.59	-01 40 50.3	10.734	0.250	0.021	273	...	IRAS 05354-0142	Giant	New
33	05 30 02.89	-01 30 05.3	12.786	0.263	0.056	176	...	No. 33	Unknown	New
36	05 34 25.82	-01 21 06.5	12.667	0.325	0.055	170	...	V469 Ori	T Tauri	Known
41	05 26 53.53	-01 09 02.3	13.478	0.480	0.057	144	...	Kiso A-0903 135	T Tauri?	New
43	05 37 59.04	-01 05 52.8	13.554	0.371	0.054	200	...	V993 Ori	T Tauri?	Known
46	05 31 26.41	-00 58 33.1	10.454	0.076	0.021	192	F0	HD 290509	Unknown	New
48	05 39 45.65	-00 55 50.9	10.934	0.075	0.021	203	...	GSC 04767-00071	T Tauri?	Known
51	05 36 24.29	-00 42 12.0	13.399	0.388	0.056	227	K3e	PU Ori	T Tauri	Known
53	05 34 48.91	-00 37 16.7	13.384	0.298	0.056	178	...	V472 Ori	T Tauri?	Known
54	05 27 24.67	-00 35 11.2	11.031	0.134	0.033	184	...	IRAS 05248-0037	Giant	New
55	05 35 43.27	-00 34 36.7	12.411	0.278	0.057	246	K4e	StHA 48	T Tauri	New
60	05 26 34.28	-00 19 27.2	12.353	0.137	0.056	181	...	No. 60	Giant	New
65	05 36 28.55	+00 04 45.7	11.987	0.131	0.056	257	...	No. 65	Unknown	New
66	05 43 29.25	+00 04 58.9	11.459	0.513	0.032	202	F0?	GT Ori	Giant	Known
70	05 44 18.80	+00 08 40.4	8.906	0.061	0.019	204	A7IIIe	V351 Ori	HAeBe	Known
72	05 46 11.86	+00 32 25.9	13.390	0.439	0.053	167	...	VSS VI-32	Unknown	New
73	05 41 59.81	+00 35 27.1	12.698	0.435	0.053	185	...	No. 73	Unknown	New
74	05 36 42.64	+00 38 34.3	11.010	0.101	0.033	254	A2	HD 290625	HAeBe	New
75	05 33 47.85	+00 55 36.3	10.433	0.166	0.021	181	...	IRAS 05312+0053	Giant	New
78	05 28 17.85	+01 10 06.1	11.219	0.165	0.033	173	F8-K0e	StHA 40	T Tauri	Known

the number of actual variable stars, but always keeping a manageable number of objects to be followed up.

There were 100 ASAS light curves above the selection criterion in Fig. 2. We were able to identify the 2MASS (Skrutskie et al. 2006) and USNO-B1 (Monet et al. 2003) possible stellar counterparts of 99 of them. The unidentified ASAS source was 054200-0154.7 ($V_0 = 13.167$ mag, $\sigma(V_0) = 0.245$ mag, $N_{\text{obs}} = 49$), which is actually a bright spot in NGC 2024. For the visual identification, we used the Aladin interactive sky atlas (Bonnarel et al. 2000). The actual number of stars with light curves was 78, because there were 21 variable star candidates with two corresponding light curves. The separated datasets (with identical associated coordinates and magnitudes within error bars) correspond to the same star in different observed fields (Pojmański 2002).

We revisited the ASAS data for the 78 stars by retrieving all data points with quality grades “A” and “B” in a circle of radius $r = 15$ arcsec centred on the stars, and merging them into a unique light curve. “A” and “B” quality grades, which are tabulated by the ASAS catalogue and derived from the average photometric quality of the frame for each aperture,

correspond to the best and mean data, respectively². Because of the large ASAS pixel size (of about $15 \mu\text{m}$) and typical full width at half maximum, of no less than 1.4 pixels (Pojmański 2002), we discarded all visual binaries of roughly the same brightness separated by less than about 20 arcsec. Besides, we also discarded relatively faint variable candidates at less than 1 arcmin to very bright stars, including Alnilam, Mintaka, and σ Ori, which are seen by the naked eye and lead to a high sky background. After these removals, we kept 32 variable stars whose light curves were likely not contaminated by other stars. The 32 light curves are shown in Figs. A1 to A4.

The identification number, 2MASS coordinates, average \bar{V}_0 magnitude, standard deviation $\sigma(V_0)$, mean error of magnitude $\bar{\delta V}_0$, and number of finally used light curve data points, N_{obs}^* , of the 32 identified variable stars are listed in Table 1. The ratios between the standard deviations and mean errors vary between ~ 2.5 and 27; the expected ratio

² The quality grades “A” and “B” of a new ASAS frame depends on the average dispersion between ‘old’ and ‘new’ magnitudes for stars in the range 8–11 mag (Pojmański, priv. comm.).

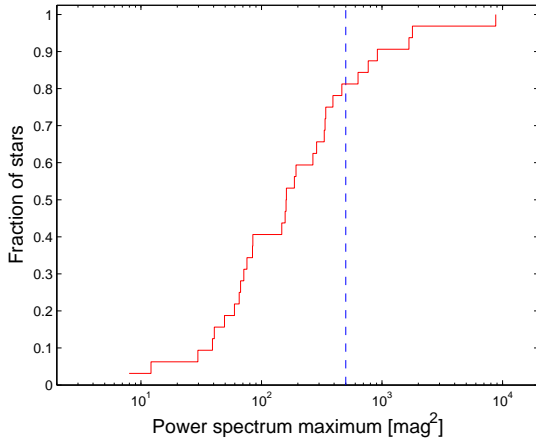


Fig. 3 Cumulative distribution function of power spectrum maxima of the light curves of the 32 identified variables in the Orion Belt. Stars to the right of the dashed vertical line at power spectrum of 500 mag^2 are classified here as probable periodic variable stars.

for a non-variable star should be lower than 2 (e.g. Bailer-Jones & Mundt 2001). In Table 1, we also provide the spectral type from the literature (if it has ever been given), name, variability class (see Section 3), and if the variability status was known or not. For those stars that have never been mentioned in the literature, we use the nomenclature “No. X”, where X is the identification number.

For a typical number of light curve data points of $N_{\text{obs}}^* \sim 200$ and a temporal coverage of almost six years, one may derive that there was an ASAS visit every $\sim 11 \text{ d}$ for each of the 32 stars. Actually, the typical time interval between consecutive ASAS visits was shorter because there were long non-observing gaps without data. The median time interval between consecutive ASAS visits was $2.0\text{--}3.0 \text{ d}$, depending on the star. Approximately 15–20, 20–33, 65–85, and 85–95 % of the time intervals were shorter than 1, 2, 5, and 10 d, respectively, and only in four cases, coincident with the four Austral summers, the time intervals were longer than 100 d.

We performed a rutinary time-series analysis on the 32 light curves by applying the Scargle (1982) procedure. Fig. 3 shows the cumulative distribution function of the measured maxima of power spectrum. Roughly 85 % of the stars have power spectrum maxima lower than 500 mag^2 , where there seems to be an inflection point in the cumulative distribution function. The other 15 % (6) of the stars with larger power spectrum maxima are given in Table 2 and were classified by us as probable periodic variable stars. We provide periods for two previously known periodic variable stars (V1159 Ori and X Ori) consistent with those in the literature, and found probable periods for two previously unknown variable giant stars (with *IRAS* denomination), but failed to find any reliable periodicity for RY Ori and GT Ori. The six of them will be studied in detail in Section 3.

We performed a compilation of additional infrared data by collecting JHK_s magnitudes from 2MASS and *IRAS*

Table 2 Identified variables with power spectrum maxima larger than 500 mag^2 .

No.	Power [mag^2]	P [d]	Name	Remarks
01	767.19	44.345	V1159 Ori	$P = 44.2\text{--}46.8 \text{ d}$
03	1785.4	78.226	IRAS 05285–0325	New periodic
11	632.39	600.38	RY Ori	No clear peak
29	8779.7	416.05	X Ori	$P = 424.2 \pm 1.8 \text{ d}$
30	913.68	373.31	IRAS 05354–0142	New periodic
66	1671.2	920.32	GT Ori	Pulsating

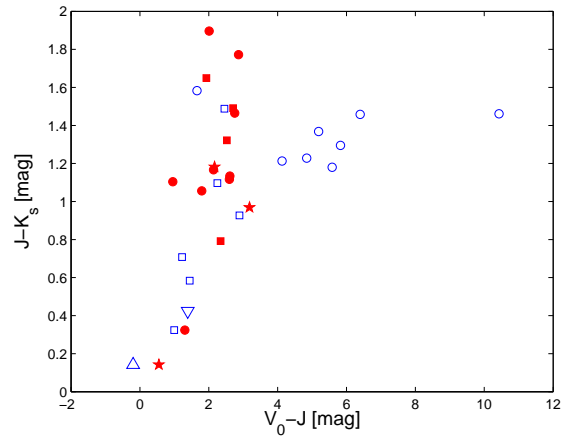


Fig. 4 Optical-infrared colour-colour diagram ($J - K_s$ vs. $V_0 - J$). Filled (red) stars: new variable young stars; filled (red) circles: previously known variable young stars; filled (red) squares: variable young star candidates; open (blue) circles: variable giants; open (blue) up-triangle: dwarf nova (V1159 Ori); open (blue) down-triangle: contact binary (2M054354–0243.6); open (blue) squares: other new variable stars.

average non-colour corrected flux densities with qualities “3” or “2” (high and moderate qualities, respectively). While all the 32 stars have a near-infrared counterpart in the 2MASS catalogue, only 12 stars were identified in the *IRAS* catalogues (e.g. *IRAS* catalogue of point sources, version 2.0; IPAC 1986). Furthermore, only one star, the A7IIIe Herbig Ae/Be star V351 Ori, has high/moderate quality measurements at the four *IRAS* passbands at 12, 25, 60, and $100 \mu\text{m}$. A colour-colour diagram combining ASAS optical and 2MASS near-infrared magnitudes is shown in Fig. 4.

Besides, we also collected proper motions from Tycho-2 (Høg et al. 2000), PPMX (Röser et al. 2008), and USNO-B1 for the 32 stars. Given that only a few of them have appreciable proper motions, we do not list them, but are mentioned in Section 3 when appropriated.

Finally, only 13 stars have variable star designations, and there were suspects of variability for other three stars. Besides, an important fraction of the targets have also been tabulated as variable stars of the Southern Hemisphere by Pojmański (2002), to which our work complements. Next,

Table 3 Infrared photometry of identified variables.

No.	J [mag]	H [mag]	K_s [mag]	F_{12} [Jy]	F_{25} [Jy]	F_{60} [Jy]	F_{100} [Jy]
01	13.817 ± 0.027	13.781 ± 0.046	13.675 ± 0.050	...	...	...	...
03	6.097 ± 0.019	5.083 ± 0.027	4.639 ± 0.021	1.08 ± 0.08	0.39 ± 0.04	< 3	< 20
06	8.295 ± 0.034	7.552 ± 0.024	7.368 ± 0.026	...	...	...	...
07	5.590 ± 0.021	4.665 ± 0.076	4.222 ± 0.033	1.09 ± 0.07	0.47 ± 0.08	< 0.9	< 30
11	9.444 ± 0.023	8.885 ± 0.055	8.277 ± 0.031	0.75 ± 0.09	0.71 ± 0.09	< 2	< 20
12	10.131 ± 0.026	9.280 ± 0.024	8.666 ± 0.024	0.38 ± 0.04	0.50 ± 0.07	< 0.7	< 40
13	10.445 ± 0.027	9.726 ± 0.024	9.311 ± 0.028	...	...	...	...
14	10.240 ± 0.026	9.943 ± 0.026	9.816 ± 0.021	...	...	...	...
15	10.647 ± 0.027	9.920 ± 0.023	9.530 ± 0.019	...	...	...	...
18	10.156 ± 0.023	9.463 ± 0.026	9.187 ± 0.019	...	...	...	...
21	11.303 ± 0.022	11.065 ± 0.028	10.979 ± 0.023	...	...	...	...
29	2.322 ± 0.292	1.379 ± 0.306	0.861 ± 0.346	96 ± 4	49 ± 7	6.0 ± 0.9	< 20
30	5.152 ± 0.018	4.608 ± 0.076	3.972 ± 0.320	2.0 ± 0.2	0.63 ± 0.07	< 2	< 40
33	11.340 ± 0.024	10.878 ± 0.025	10.756 ± 0.021	...	...	...	...
36	10.655 ± 0.023	9.647 ± 0.030	8.759 ± 0.021	...	...	...	...
41	11.547 ± 0.027	10.652 ± 0.027	9.898 ± 0.019	...	...	...	...
43	10.846 ± 0.027	9.955 ± 0.024	9.355 ± 0.027	...	...	...	...
46	9.457 ± 0.023	9.247 ± 0.023	9.133 ± 0.021	...	...	...	...
48	8.589 ± 0.023	7.933 ± 0.055	7.797 ± 0.027	...	...	...	...
51	10.536 ± 0.023	9.551 ± 0.033	8.764 ± 0.019	< 0.4	0.38 ± 0.05	< 3	< 20
53	10.860 ± 0.022	10.043 ± 0.026	9.538 ± 0.019	...	...	...	...
54	5.206 ± 0.017	4.225 ± 0.202	3.911 ± 0.258	1.48 ± 0.09	0.49 ± 0.04	< 5	1.7 ± 0.3
55	10.243 ± 0.021	9.509 ± 0.033	9.061 ± 0.019	...	...	...	...
60	7.508 ± 0.023	6.596 ± 0.029	6.280 ± 0.021	...	...	...	...
65	10.762 ± 0.024	10.447 ± 0.025	10.054 ± 0.019	...	...	...	...
66	9.802 ± 0.027	9.043 ± 0.025	8.219 ± 0.026	0.87 ± 0.13	1.02 ± 0.17	< 5	< 40
70	7.950 ± 0.020	7.504 ± 0.040	6.846 ± 0.026	1.16 ± 0.07	4.1 ± 0.2	26 ± 3	21 ± 3
72	10.936 ± 0.024	10.046 ± 0.023	9.448 ± 0.019	...	...	...	...
73	10.448 ± 0.023	9.818 ± 0.023	9.351 ± 0.019	...	...	...	...
74	10.459 ± 0.024	10.342 ± 0.024	10.317 ± 0.023	...	...	...	...
75	6.304 ± 0.026	5.375 ± 0.027	5.091 ± 0.020	0.47 ± 0.03	< 0.2	< 0.4	< 20
78	9.422 ± 0.023	8.825 ± 0.040	8.366 ± 0.018	0.41 ± 0.06	0.67 ± 0.06	0.47 ± 0.05	< 1.1

we classify the 32 variable stars based on spectroscopic, astrometric, and photometric criteria.

3 Identified variable stars

3.1 H AeBe and T Tauri variable stars

3.1.1 Previously known variable young stars and candidates

This class is mostly made of probable accreting T Tauri stars with intense $H\alpha$ emission. Of the nine $H\alpha$ emitter stars, three belong to the σ Orionis cluster (TX Ori, TY Ori, RW Ori), three have been associated to the Alnilam and Mintaka young star populations (V469 Ori, PU Ori, V472 Ori), and three have not been linked to any young region in particular but are bright stars at the boundary between H AeBe and T Tauri stars (RY Ori, V351 Ori, StHa 40 – two of them may have edge-on discs). The true nature of the other three non- $H\alpha$ emitter stars (PQ Ori, V993 Ori, GSC 04767–00071) should be investigated with further spectroscopic analyses.

Besides, six of the stars in this class display X-ray emission, and other six, infrared flux excess. Only the three σ Orionis members are known to simultaneously display $H\alpha$ and X-ray emissions and infrared flux excess.

RY Ori (No. 11). It is a well investigated, emission-line star of the Orion population at the boundary between H AeBe and T Tauri stars (e.g. Haro & Moreno 1953; Herbig & Bell 1988; Yudin & Evans 1998; Eiroa et al. 2001; Mora et al. 2001; Hernández et al. 2004; Acke & van den Ancker 2006). Its photometric variability was detected very early (Pickering 1904). According to Bibó & Thé (1991), it is a UX Ori-type star with a colour reversal in the colour-magnitude diagram, indicative of an edge-on disc. The disc of RY Ori is also detected because of its long-time-known infrared excess (Cohen 1973; Glass & Penston 1974; Weintraub 1990; Weaver & Gordon 1992). Its photometric variability in the ASAS lightcurve is obvious, with small mean photometric errors with respect to the peak-to-peak amplitude from 10.8 to 13.0 mag ($\overline{\delta V_0} = 0.032$ mag). RY Ori is one of the six identified variable stars with power spectra maxima larger

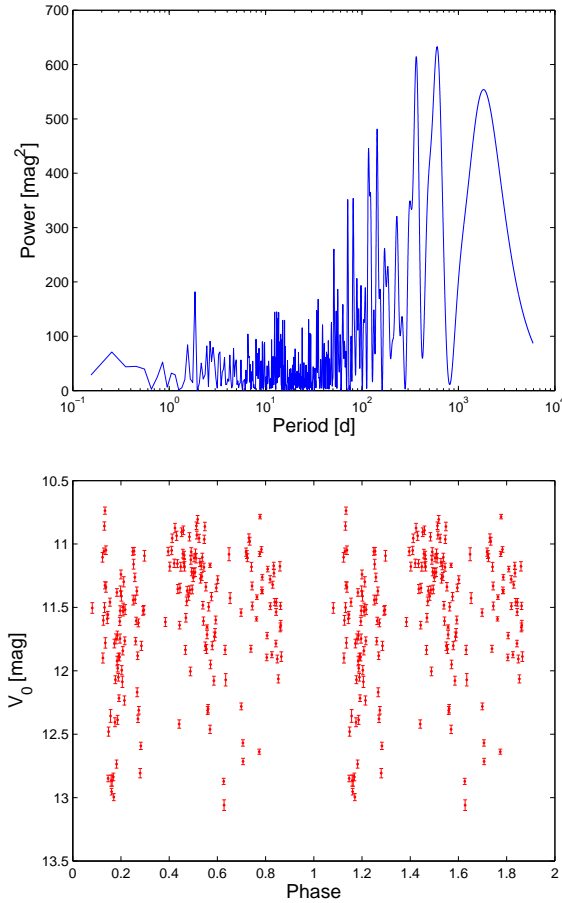


Fig. 5 Periodogram of the ASAS light curve (*top*) and phase-folded light curve of RY Ori to the period $P = 600.38$ d (*bottom*).

than 500 mag^2 (Table 2 – actually, it is the star with the lowest power spectrum maximum). The periodogram of the ASAS light curve, displayed in Fig. 5, shows no clear peak, with a number of power maxima increasing towards longer periods. The phase-folded light curve at the period of the highest peak, at $P \sim 600$ d, does not show any evidence of real periodicity. Actually, from the full-length light curve in Fig. A1, the time scale of the irregular variability of RY Ori is of the order of a few days, just like many confirmed young stars in this work.

TX Ori (Mayrit 521199, No. 12) and TY Ori (Mayrit 489196, No. 13).

They are two close ($\rho \sim 40$ arcsec) pre-main sequence stars in the σ Orionis cluster that have appeared in a number of young and emission-line star catalogues (Herbig & Kameswara Rao 1972; Cohen & Kuhl 1979; Herbig & Bell 1988; Ducourant et al. 2005). As in the case of many variable stars in this work, they were discovered as variable stars by Pickering (1904). Both TX Ori and TY Ori have been subject of comprehensive studies and data compilations by Oliveira & van Loon (2004) and Caballero (2008). Their light curves are quite similar, with minima and max-

ima at about $V_0 \sim 12.5$ and 14.0 mag. Remarkably, the TX Ori light curve displayed an apparent dimming for heliocentric Julian day³ $\text{HJD} > 3500$.

RW Ori (Mayrit 931117, No. 15). It is another member in the σ Orionis cluster, but it is much less known than the stars above. Its photometric variability and $\text{H}\alpha$ emission were first detected by Pickering (1906) and Haro & Moreno (1953), respectively. Afterwards, it has been only investigated by Franciosini et al. (2006 – with *XMM-Newton*, Hernández et al. (2007 – with *Spitzer*), and Caballero (2008). Its ASAS light curve varied between $V_0 \sim 12.8$ and 14.0 mag (the outlier data point is probably unreliable).

PQ Ori (No. 21). In the discovery paper, McKnelly (1949) classified the star as a rapid, irregular variable with an observed range of variability of 12.5 – 13.5 mag (photographic magnitude). Although its light curve displayed many maxima and minima, he was unable to determine “any semblance of periodicity”. Herbig & Kameswara Rao (1975), Cohen & Kuhl (1979), and Hernández et al. (2004) measured F0, F5:, and $F3.0 \pm 1.5$ spectral types and observed no emission lines. However, while the first authors classified it as a star in the Orion population, Hernández et al. (2004) did not find significant differences from F3 main-sequence stars nor near infrared excess, and categorized it as an object with uncertain evolutionary status. The variability patterns in the ASAS light curve of PQ Ori, although ranging between $V_0 \sim 12.3$ and 13.3 mag, do not resemble those of other young stars in this work, and its $J - K_s$ colour is quite blue with respect to other early F stars in Ori OB1 b. As a result, its field dwarf nature seems to us more plausible.

V469 Ori (No. 36). It is an emission-line star with X-ray emission (Haro & Moreno 1953; Wiramihardja et al. 1989; Nakano et al. 1999). According to Caballero & Solano (2008), the star is a member in the young Ori OB1 b stellar population surrounding Alnilam, and is probably associated to the [OS98] 29J, [OS98] 29H, and [OS98] 29K remnant molecular clouds (Ogura & Sugitani 1998). Based on its $V_0 - K_s$ colour and the empirical scale of effective temperatures of main-sequence stars of Alonso et al. (1996), and extrapolating it to the pre-main sequence, V469 Ori is likely a late Ge or early Ke star. Its ASAS light curve looks like those of other T Tauri stars.

V993 Ori (No. 43). It is a long-time-known variable star discovered by Luyten (1932). Caballero & Solano (2008) classified it as a probable member of the Ori OB1 b young stellar population surrounding Alnilam. It has a very red colour $J - K_s = 1.26 \pm 0.04$ mag for its brightness ($H =$

³ The values of heliocentric Julian day used in the Figures are those tabulated by the ASAS catalogue. Actually, they are not heliocentric Julian days HJD, but the HJD minus the constant 2450 000.0 (do not confuse with the constant used to transform the Julian day into the modified Julian day MJD, which is 2 400 000.5).

9.82 ± 0.02 mag), which may indicate the presence of a circumstellar disc or, alternatively, that it is a background giant star. It may be the optical/near infrared counterpart of IRAS Z05354–0107, a source in the *IRAS* Faint Source Reject Catalog (Moshir 1992). There is no spectroscopy available to confirm or discard its possible T Tauri status. The large peak-to-peak amplitude of its light curve of $V_0 \sim 13.0$ to fainter than 14.5 mag, although sheds light on the photometric variability of V993 Ori, is not conclusive.

GSC 04767–00071 (No. 48). Schirmer et al. (2009) classified it as a chromospherically active star suspected of variability in the *ROTSE-1* database. The star GSC 04767–00071 is probably associated to the X-ray source 1RXS J053944.7–005612 (Voges et al. 1999) and has a very low PPMX proper motion, of $(\mu_\alpha \cos \delta, \mu_\delta) = (-6 \pm 2, -9 \pm 2)$ mas a^{-1} . The optical and near-infrared photometry supports membership in Ori OB1 b. It may be a very young solar analog. The amplitude of photometric variability of its ASAS lightcurve, of $V_0 \sim 10.8$ to 11.1 mag, is relatively small.

PU Ori (No. 51). It is a pre-main sequence star near the Alnilam supergiant with $H\alpha$ in strong two-lobe emission (Haro & Moreno 1953; Herbig & Kameswara Rao 1972; Cohen & Kuhi 1979; Wiramihardja et al. 1989), photometric variability (Fedorovich 1960; Briceño et al. 2005), mid-infrared flux excess at the *IRAS* passbands (Weintraub 1990; Weaver & Jones 1992), and forbidden emission lines ([O I] $\lambda 6300.3$ Å; Hirth et al. 1997). It has a very red colour of $J - K_s = 1.77 \pm 0.03$ mag (Caballero & Solano 2008). From our light curve, PU Ori is an irregular variable with minimum and maximum magnitudes $V_0 \sim 12.5$ and 14.5 mag.

V472 Ori (No. 53). It is an $H\alpha$ emitter star (Haro & Moreno 1953; Wiramihardja et al. 1989) of known photometric variability (Fedorovich 1960; Cieslinski et al. 1997). It may be the optical/near infrared counterpart of IRAS Z05322–0039. V472 Ori is a probable member in the Mintaka cluster (Caballero & Solano 2008). Its ASAS light curve has a peak-to-magnitude larger than 1 mag.

V351 Ori (No. 70). It is a HAeBe A7IIIe variable star of δ Scuti type discovered by Hoffmeister (1934). It has been investigated in detail, especially after Kovalchuk (1984) observed a flare-like event on its light curve at the *UBVR* bands (Wouterloot & Walmsley 1986; Sterken et al. 1993; Rosenbush 1995; Marconi et al. 2000; Balona et al. 2002; Vieria et al. 2003). It has been proposed that a temporarily strong accretion of matter onto the star or extinction by circumstellar dust clouds takes place to explain the remarkable V351 Ori change of behaviour from “that of a [HAeBe] star with strong photometric variations [...] to that of an almost non-variable star” (van den Ancker et al. 1996). The main period of pulsations of V351 Ori is only of the order of 0.06 d with a peak-to-peak amplitude of about 0.1 mag

(van den Ancker et al. 1998; Marconi et al. 2001; Ripepi et al. 2003). The pre-main sequence nature of the star is supported by the presence of $H\alpha$ in emission, a pronounced inverse P Cygni profile, S I $\lambda 1296$ Å and O I $\lambda 1304$ Å lines in emission, and infrared excess (Valenti et al. 2000 and references above). With $V_0 \approx 8.91$ mag and 20–30 Jy at the 60 and 100 μ m *IRAS* passbands, it is by far the brightest star in our sample at all wavelengths, but also the less variable one. However, the amplitude of variability, between $V_0 \sim 8.80$ and 9.15 mag, is slightly larger than previously measured. It may be due to our long (ASAS) temporal coverage, probably longer than any other previous monitoring.

StHa 40 (No. 78). It was first listed in the $H\alpha$ -emission star catalogues of MacConnell (1982) and Stephenson (1986) and followed-up afterwards by Downes & Keyes (1988), Torres et al. (1995), Gregorio-Hetem & Hetem (2002), and Maheswar et al. (2003). StHa 40 is a T Tauri star with variable spectral type (from F8, through G2 and G5, to K0), variable $H\alpha$ emission (from $pEW(H\alpha) = -14.5$ Å to a faint absorption), lithium absorption (from $pEW(Li I) = +0.13$ to $+0.33$ Å), and radial velocity (indicative of possible spectral binarity). Besides, Gregorio-Hetem & Hetem (2002) associated StHa 40 to a *ROSAT* X-ray source and derived basic stellar and circumstellar parameters. Maheswar et al. (2003) estimated a magnitude difference $\Delta V \sim 1.6$ mag between two optical spectra taken almost three years apart and after comparison with spectro-photometric standards. The $H\alpha$ line was in emission [absorption] when the star was brighter, $V \sim 10.9$ mag [fainter, $V \sim 12.5$ mag]. However, while the brightest Maheswar et al. (2003)’s estimation for V agrees very well with our light curve (from where we measure $V_{0,bright} \approx 11.0$ mag), none of the 173 StHa 40 data points covering almost six years were fainter than $V_{0,faint} \approx 11.8$ mag.

3.1.2 Previously unknown variable young stars

Of the four stars in this class, only two (Mayrit 528005 AB and StHa 48) have uncontroversible signposts of youth. The other two stars (Kiso A–0903 135 and HD 290625) have not been well investigated yet and may not belong to the young Orion Belt stellar population.

Mayrit 528005 AB (No. 18). It is a hierarchical triple system in the σ Orionis cluster, made of a close binary ($\rho_{A-B} = 0.40 \pm 0.08$ arcsec) resolved with adaptive optics at $\rho_{AB-C} \sim 7.6$ arcsec to the low-mass star Mayrit 530005 (S Ori J053847.5–022711; Caballero 2005, 2009). The binary primary has a cosmic lithium abundance (Zapatero Osorio et al. 2002), double-peak $H\alpha$ (Caballero 2006), and strong X-ray emissions (Wolk 1996; Fraciosini et al. 2006; Caballero et al. 2009), and an spectral energy distribution typical of class II objects (Hernández et al. 2007). The ASAS light curve shows variability between $V_0 \sim 13$ and 14 mag, and an apparent series of brightenings at HJD ~ 3000 .

Kiso A-0903 135 (No. 41). It is an emission-line star only referenced once by Kogure et al. (1989), who measured a weak $H\alpha$ emission intensity and placed it in the Orion region. Its optical (DENIS; Epchtein et al. 1997) and near-infrared (2MASS) photometry and null proper motion (within error bars; USNO-B1) are consistent with membership in the Ori OB1 b association. With $\sigma_{V_0} = 0.480$ mag, it is one of the most variable stars in the study. While its brightest magnitude is $V_0 \sim 12.8$ mag, the faintest one is $V_0 \sim 15.0$ mag or fainter.

StHa 48 (No. 55). It is a K4-type T Tauri star with $H\alpha$ in emission and Li I in absorption (Stephenson 1986; Maheswar et al. 2003; Caballero & Solano 2008). The star, which is located in the surroundings of Alnilam, has a wide amplitude of variability, with maximum and minimum brightness at $V_0 \approx 11.9$ and 13.3 mag, respectively, and time scales of variation of a few days.

HD 290625 (No. 74). It is an A2 star classified as a probable member in the young stellar population of Ori OB1 b (Guetter 1979; Nesterov et al. 1995). The ASAS light curve displayed variations between $V_0 \approx 10.8$ and 11.3 mag, approximately. The Tycho-2 and 2MASS photometry and the low proper motion, of less than 4 mas a^{-1} (Tycho-2, PPMX, USNO-B1), are consistent with the spectral type and a long heliocentric distance. Besides, lives of A2 stars are relatively short, which confirm the HD 290625 youth. However, the star is a couple of magnitudes fainter than expected for “normal” A2 Orion stars at $d \sim 0.4$ kpc. Instead of resorting to another young population in the far background of Orion, of which there is no evidence, we propose that HD 290625 is a variable HAeBe star with a scattering edge-on disc in the Orion complex, just like UX Ori or the σ Orionis star StHa 50 (Mayrit 459340 – Thé et al. 1994; Caballero et al. 2008) or, alternatively, a bright, blue, subdwarf (there have been previous detections of such objects in the area: Caballero & Solano 2007; Vennes et al. 2007).

3.2 Variable background giants

Unfortunately, because of the relative resemblance between the spectral energy distributions of distant giant stars with extended cool envelopes and of young stars with developed discs (due to the common strong infrared flux excess), giant stars sometimes contaminate lists of member candidates in star-forming regions. For example, the bright (in the infrared) giant star IRAS 05358–0238 was once classified as a Class I object in the σ Orionis cluster (Oliveira & van Loon 2004; Hernández et al. 2007; Caballero 2008). Since the surveyed area in this work is rich in star-forming regions (including σ Orionis), we had to be careful with disentangling both pre-main sequence and giant star populations.

Of the eight identified variable background giants, only one (No. 60) has no *IRAS* excesses or were not detected with the Spatial Infrared Imaging Telescope onboard the

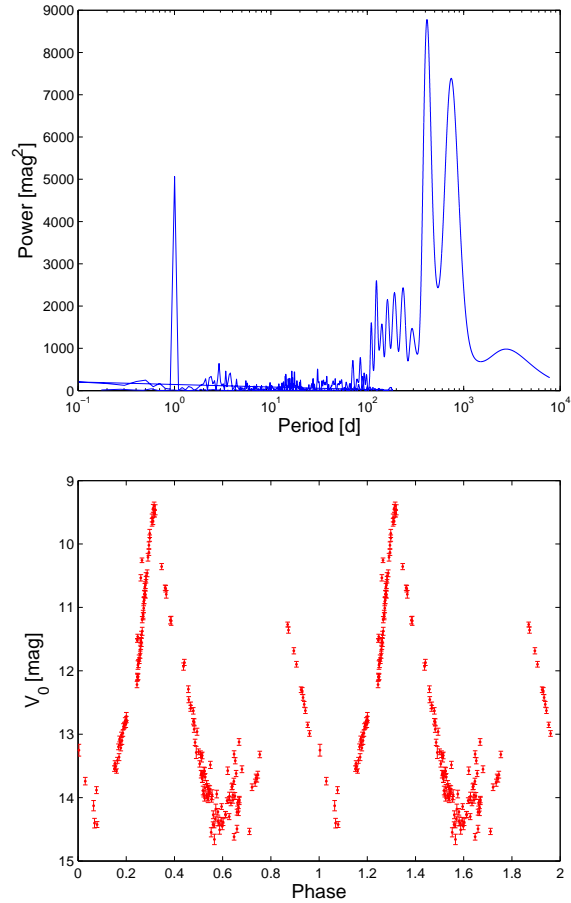


Fig. 6 Same as Fig. 5, but for X Ori and a period $P = 416.05$ d.

Midcourse Space Experiment ($8.3\text{--}21.3 \mu\text{m}$; Kraemer et al. 2003). There were also only three stars previously classified as giants: X Ori, GT Ori, and IRAS 05354–0142 (for which variability had not ever been proposed). Therefore, in this work we present six new variable giants. Besides, we measure periods of photometric variability (with maxima of the power spectrum above 500 mag^2) between 78 and 920 d for four of the eight giants, while only one, X Ori, had been reported before to display periodicity.

3.2.1 Known background giants

X Ori (No. 29). This giant or supergiant star was the reddest object in the Alnilam-Mintaka area studied by Caballero & Solano (2008), but is located at about twice the heliocentric distance to the Ori OB1 association (Jura et al. 1993). It is an M8–9-type Mira Ceti variable found by Wolf (1904) with $P = 424.75 \pm 1.77$ d (Templeton et al. 2005) and silicate dust emission (Sloan & Price 1998; Speck et al. 2000). In particular, the 9.7 and $18 \mu\text{m}$ silicate dust feature originates from the circumstellar envelopes of oxygen-rich asymptotic giant branch stars (Kwok et al. 1997). From our periodogram (Fig. 6), there are two clear peaks at $P \approx$

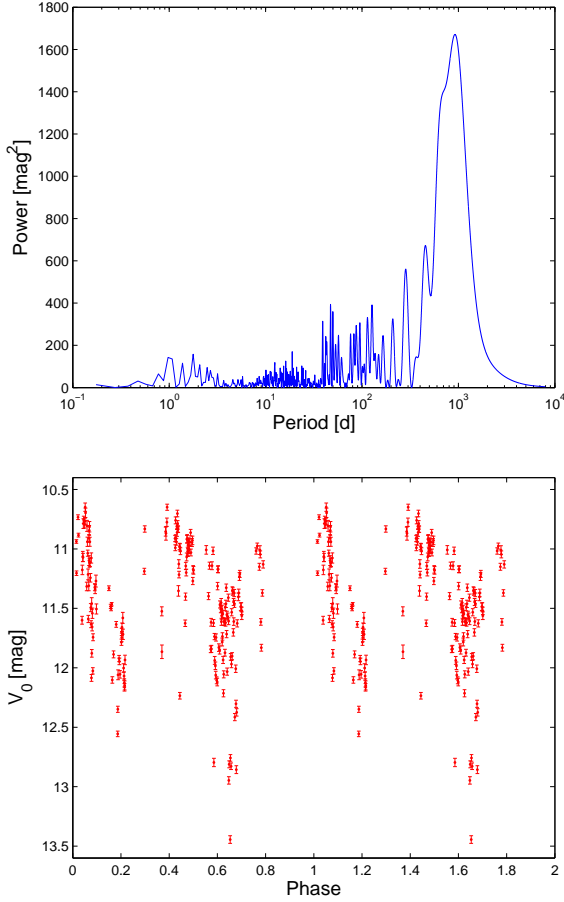


Fig. 7 Same as Fig. 5, but for GT Ori and a period $P = 920.32$ d.

416 d, consistent with literature values assuming a reasonable error of 2 %, and its harmonic at $P \approx 832$ d. There is also a spurious (systematic) peak at $P = 1$ d. The triangular shape of minima and maxima in the phase-folded light curve may be useful for modelling the astrophysical properties of the Mira star.

GT Ori (No. 66). It is a semi-regular pulsating star, originally proposed to be a likely Mira star with variations between 11.5 and 12.5 mag by Hoffmeister (1934). Afterwards, it has been monitored by several authors (e.g. Kurochkin 1949; Braune 2001). The F0 spectral type determined by Nesterov et al. (1995) is in contradiction with the red optical and near-infrared colours, the detection of GT Ori by *IRAS* at the 12 and 25 μm , and its low proper motion, of less than 3 mas a^{-1} . The photometric and astrometric information and the strong periodogram peak at $P \sim 920$ d and the phase-folded light curve in Fig. 7 are more consistent with the semi-regular pulsating status and a probable K-type, giant nature of GT Ori. The large amplitude of variability of the star, of almost 3 mag ($V_0 \approx 10.6\text{--}13.5$ mag), and the overlapping of different (shorter) periods in the light curve

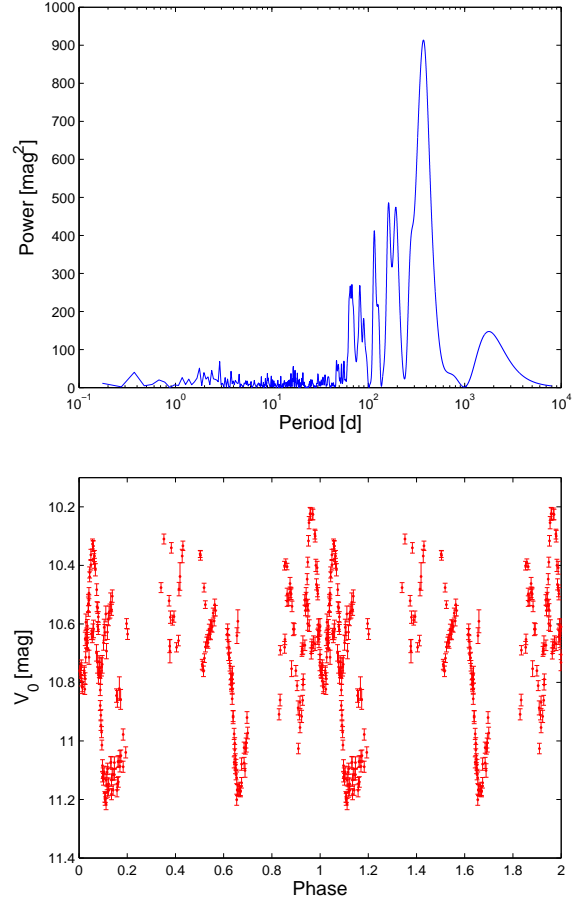


Fig. 8 Same as Fig. 5, but for IRAS 05354–0142 and a period $P = 373.31$ d.

are remarkable, as well as its abnormally blue $V_0 - J$ colour for its red $J - K_s$ and *IRAS* flux excess emission.

3.2.2 New variable giant candidates

IRAS 05354–0142 (No. 30). With $V_T - K_s = 7.1 \pm 0.3$ mag, it had the reddest optical-infrared colour among the ~ 1500 Tycho-2/2MASS stars investigated by Caballero & Solano (2008). According to them, “the closeness of IRAS 0534–0142 to the Ori I–2 globule may explain part of its reddening, but not all. It might be an S-type or a C-type giant with a very late spectral type and very low effective temperature”. From our ASAS data, IRAS 05354–0142 is the brightest star in Table 2 ($V_0 \approx 10.2\text{--}11.2$ mag) and has the fourth largest power spectrum. Besides, it is one of the four most clearly variable stars in this study, together with X Ori, RY Ori, and GT Ori. The light curve power spectrum peaks at $P = 373.31$ d, but there are also secondary maxima at shorter periods (Fig. 8). The multi-pattern, phase-folded light curve indicates that a harmonic study is necessary to disentangle the different oscillation modes of the giant. At about 3 arcmin to the north lies the irregular variable star V1299 Ori, found by Kaiser (1992). It was the only

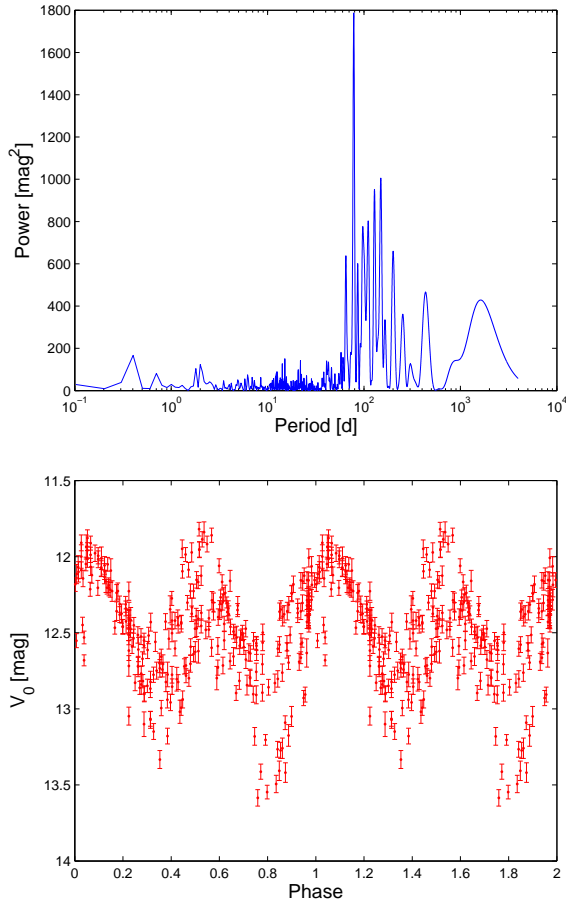


Fig. 9 Same as Fig. 5, but for IRAS 05285–0325 and a period $P = 78.226$ d.

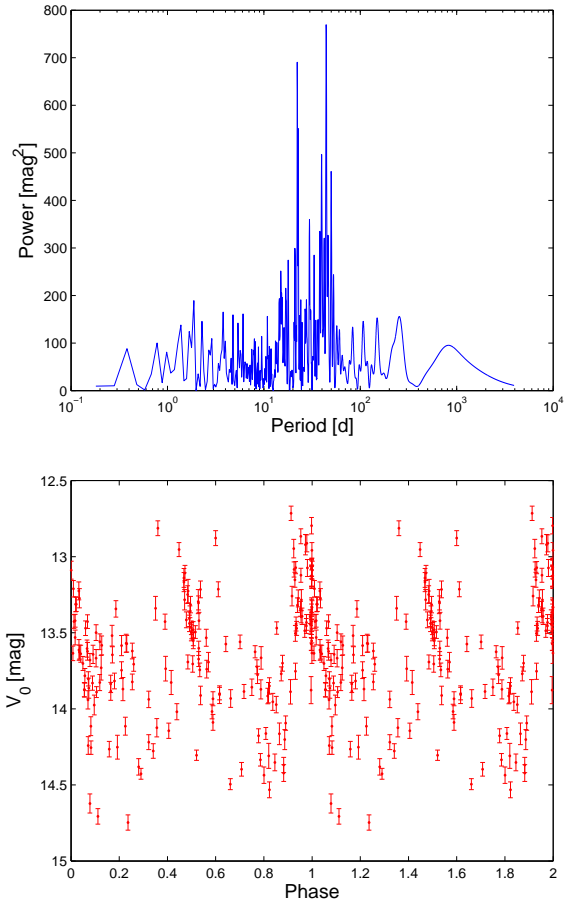


Fig. 10 Same as Fig. 5, but for V1159 Ori and a period $P = 44.345$ d.

SIMBAD object unidentified by Caballero & Solano (2008) in the Alnilam/Mintaka region. Tabulated coordinates are likely incorrect. IRAS 05354–0142 and V1299 Ori might be the same star, but the variability type and amplitude given by Kaiser (1992) are inconsistent with the data presented here.

IRAS 05285–0325 (No. 03), IRAS 05353–0309 (No. 07), IRAS 05248–0037 (No. 54), and IRAS 05312+0053 (No. 75).

They had been only reported by Kraemer et al. (2003) as “infrared” sources and have “high quality” flux densities at the *IRAS* 12 μm (and 25 μm) pass-bands and proper motion absolute values of a few milliarcseconds per year. Of them, only one had a power spectra peak larger than 500 mag^2 (Table 2). The periodogram of IRAS 05285–0325 shows a forest of peaks associated to the different pulsation modes of the giant. The main mode, which is quite clear in Fig. 9, corresponds to a period $P = 78.3 \pm 0.1$ d.

No. 60. It is reported here for the first time and has not a measured *IRAS* flux density. However, its very red optical and near-infrared colours, which puts the star in the giant

locus in Fig. 4 ($V_0 - J \sim 4.8$ mag), and very low proper motions make No. 60 to be a fair giant candidate.

3.3 Miscellaneous

In this class, we include variable objects that are neither young stars nor background giants. Of the eight objects in this class, only two (the dwarf nova cataclysmic variable V1159 Ori and the contact binary 2M054354–0243.6) were known to vary. At least three of the other six stars, including the nearby early F-type star HD 290509, might be eclipsing or interacting binaries.

V1159 Ori (No. 01). It is a well-known dwarf nova cataclysmic variable of ER UMa (or RZ LMi) type, which is a subgroup of SU UMa-type dwarf novae⁴ with short recurrence time of super-outburst ($\tau \leq 45$ d). Their super-

⁴ A dwarf nova is a close binary star system in which one of the components is a white dwarf, which accretes matter from its companion. In contrast to classical novae, outbursts and super-outbursts in dwarf novae result from instabilities in the accretion disc. SU UMa dwarf novae are characterised by two distinct types of outbursts in time scales of days (more frequent) and weeks (less frequent and with larger amplitude).

cycles are stable both in length and outburst pattern (Osaki 1996; Patterson 1998; Downes et al. 2001). V1159 Ori was discovered by Wolf & Wolf (1906), who gave it the name “Var.,Orionis 36.1906”, and first investigated by Kippenhahn (1953) and Jablonski & Cieslinski (1992). Afterwards, its very short outburst cycle, superhumps, orbital periods, and high energy (X-ray, ultraviolet) emission have been studied by a number of authors (Nogami et al. 1995; Robertson et al. 1995; Patterson et al. 1995; Thorstensen et al. 1997; Szkody et al. 1999). We can add little to the knowledge on V1159 Ori except for its supercycle period. In our periodogram (Fig. 10), we detect a clear peak (and its harmonics) at $P = 44.3 \pm 0.1$ d, which is agreement with, or may improve or complement, previous determinations at 44.2–46.8 d (Robertson et al. 1995; Richter 1995; Kato 2001; Pitts et al. 2002).

2M054354–0243.6 ([GGM2006] 12390250, No. 14). It is a contact binary discovered by Gettel et al. (2006), who measured an heliocentric distance of $d = 288 \pm 5$ pc. Given the appreciable proper motion tabulated in the USNO-B1 and PPMX catalogues, $\mu = 46$ mas a^{−1}, one can measure a transversal velocity of about 63 km s^{−1}, which is typical of Galactic disc stars. In our periodogram (not shown here), there are two faint peaks at 0.29 and 2.3 d, but nothing at the 0.438118 d measured by Gettel et al. (2006). Besides, the phase-folded light curve of 2M054354–0243.6 at this period does not show any clear periodic behaviour.

No. 33 and No. 65. They are reported here for the first time. The stars display optical and near-infrared colours typical of early K dwarfs and have no infrared excess. The light curve magnitudes varied between $V_0 \approx 12.4$ and 13.4–13.6 mag (No. 33) and $V_0 \approx 11.7$ and 12.4 mag (No. 65), with most of the data points concentrated towards the brightest limits. This fact may be an indication that the stars are possibly new eclipsing or interacting binaries, but the possibility of being stars with magnetic spots should not be ruled out. That the periodograms (not shown here) do not display any strong peak puts a limit on the maximum periods, which are possibly shorter than a few days.

HD 290509 (No. 46). It is an anodyne F0-type Tycho-2 star with only one entry in SIMBAD (Nesterov et al. 1995). The appreciable proper motion tabulated by PPMX, of $(30.6 \pm 1.3, -8.8 \pm 1.3)$ mas a^{−1}, indicates that it is a field star and not a young star in Orion. Its optical and red colours match those of dwarfs of the same spectral type. The ASAS light curve of HD 290509 resembles that of the star No. 33, but with a shorter range of variation, between $V_0 \approx 10.35$ and 10.60 mag. It might be another short-period eclipsing binary.

VSS VI–32 (No. 72). It is an unpolarised star in the background of the Messier 78 star-forming complex, only reported by Vrba et al. (1976). Its very red colours, of $V_0 -$

$J \sim 2.5$ mag and $J - K_s = 1.49 \pm 0.03$ mag, may not be intrinsic, but due to the high extinction in the area. Its variability class is unknown to us.

No. 06, No. 73. They are also reported here for the first time and none of them have a measured *IRAS* flux density. They have very low proper motions and are the reddest (in $J - K_s$) stars in this section except for VSS VI–32, but do not seem to be red enough to be classified as giant star candidates. Their light curves are quite different, with No. 06’s one varying only between 11.05 and 11.45 mag, and No. 73’s one between 12.0 and 14.0 mag. Neither the power spectrum analysis nor the light curve shapes provide any clear indication of the nature of the two stars.

4 Summary

With the aim of discovering and confirming variable Herbig Ae/Be and T Tauri stars among the young stellar population of the Orion Belt, we have analysed over 60 000 light curves from the ASAS-3 Photometric *V*-band Catalogue of the All Sky Automated Survey in a squared area of side 5 deg centred on the supergiant star Alnilam (ϵ Ori, the middle star of the Orion Belt).

After consecutive filterings, visual inspections with the virtual observatory tool Aladin, and cross-matches with infrared and astrometric catalogues, we kept 32 variable stars with average magnitudes $\bar{V}_0 = 8.5$ –13.5 mag for a detailed analysis and data compilation. They are *the most variable stars in the Orion Belt* and complement the results in Pojmański (2002). Based on spectroscopic, photometric, and astrometric information from catalogues and the literature, we classified the 32 stars into:

- previously known variable young stars and candidates (12 stars). The list includes well-investigated Herbig Ae/Be and T Tauri stars surrounding the early-type stars σ Ori, Alnilam, and Mintaka in the Ori OB1 b association. We confirm the variable status of two active stars suspected of variability (GSC 04767–00071 and StHa 40) and measure a peak of the power spectrum larger than 500 mag² in the light curve of the emission-line, UX Ori-type variable, disc-host star RY Ori. However, the corresponding period of photometric variability seems unreliable. Thus, the 12 stars appear to be irregular variables;
- previously unknown variable young stars (4 stars). They are two T Tauri stars with Li I in absorption and H α in emission (Mayrit 528005 AB and SHa 48) and two stars earlier classified as probable members in the Ori OB1 b association. Besides, one of them, Mayrit 528005 AB, displays infrared flux excess and strong X-ray emission, and is a close binary within a hierarchical triple system in the σ Orionis cluster. Again, we do not find periodic trends among these young stars;
- known background giants (2 stars). The two giants (or supergiants) are X Ori, for which our period determination is consistent with those provided in the literature,

and GT Ori, for which we firstly provide a period of photometric variability at about 920 d and determine abnormal optical-near infrared colours;

- new variable giant candidates (6 stars). Of them, we remark the new, extremely red, periodic variables IRAS 05354-0142 ($P \sim 370$ d – with a lot of shorter periods) and IRAS 05285–0325 ($P \sim 78$ d);
- miscellanea objects (8 stars). This class contains the cataclysmic variable V1159 Ori, for which we measure a period $P = 44.3 \pm 0.1$ d, in agreement with previous determinations, the contact binary 2M054354–0243.6, and six poorly investigated, new variable stars.

Some of these targets, including variable active Herbig Ae/Be and T Tauri stars in the Ori OB1 association and background giants, merit next spectroscopic analyses and photometric monitoring.

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A The most variable ASAS stars in the Orion Belt

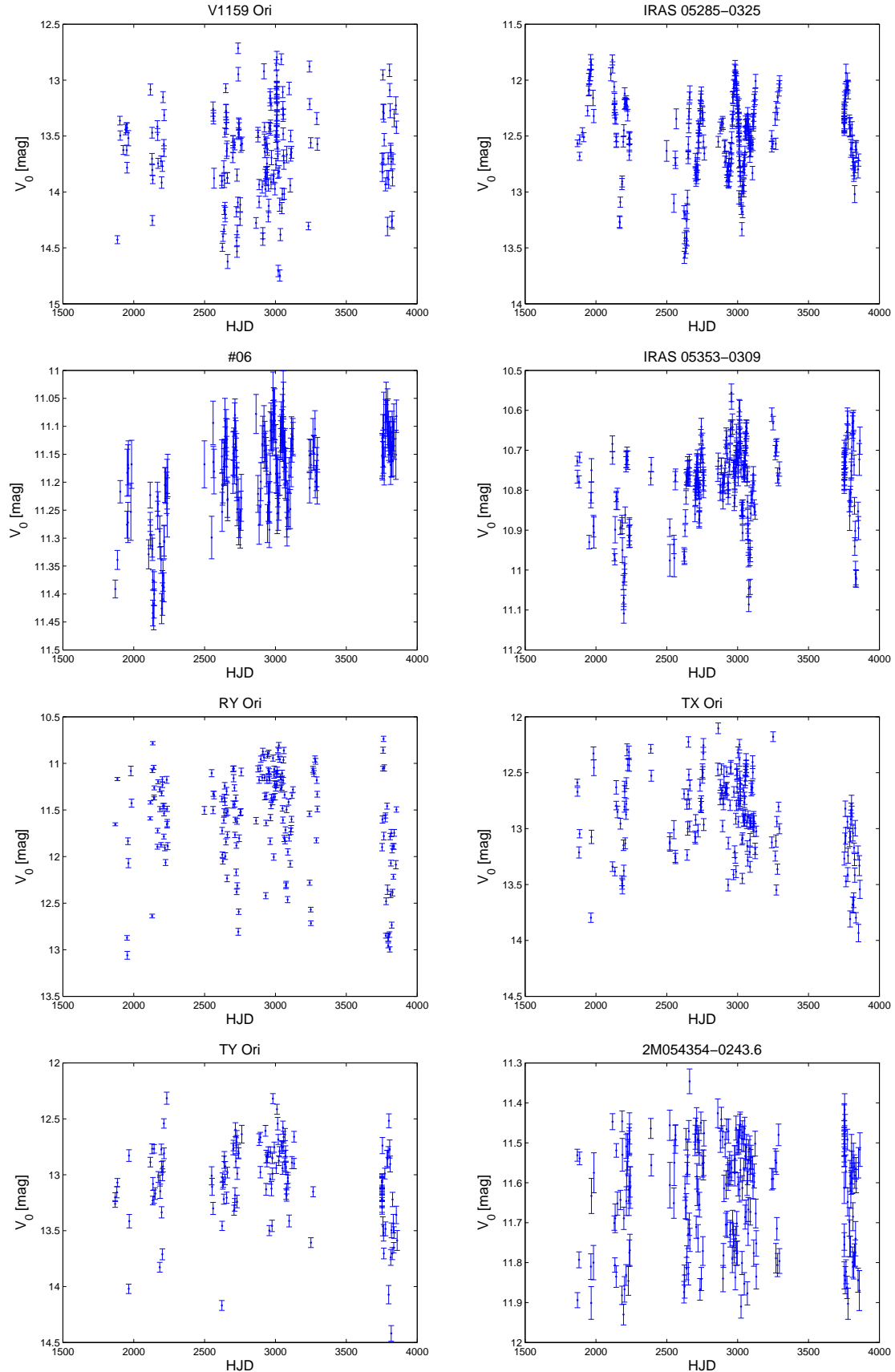


Fig. A1 ASAS (V_0) light curves of the identified variables No. 01 to 14 (labeled).

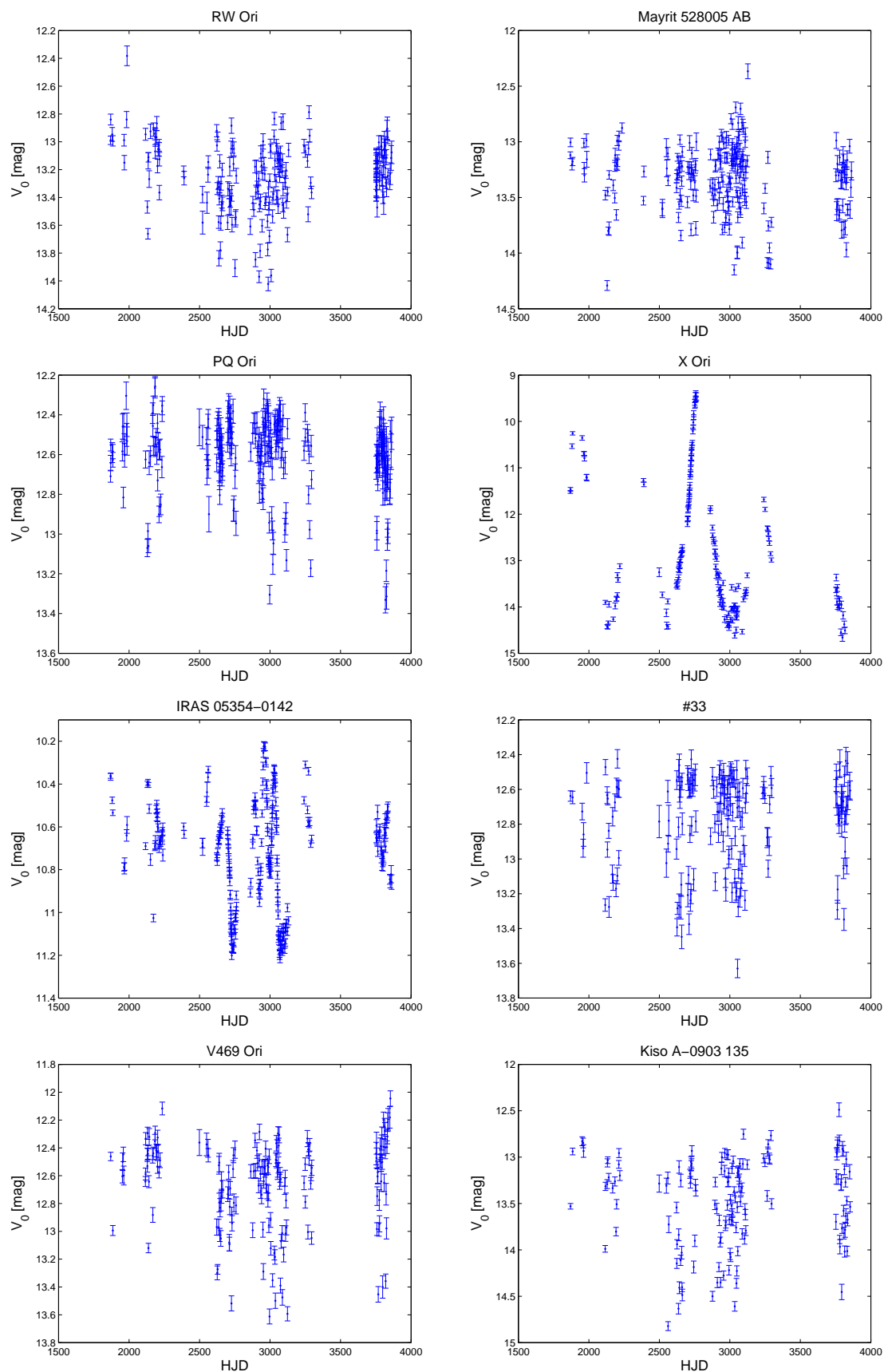


Fig. A2 Same as Fig. A1 but for identified variables No. 15 to 41.

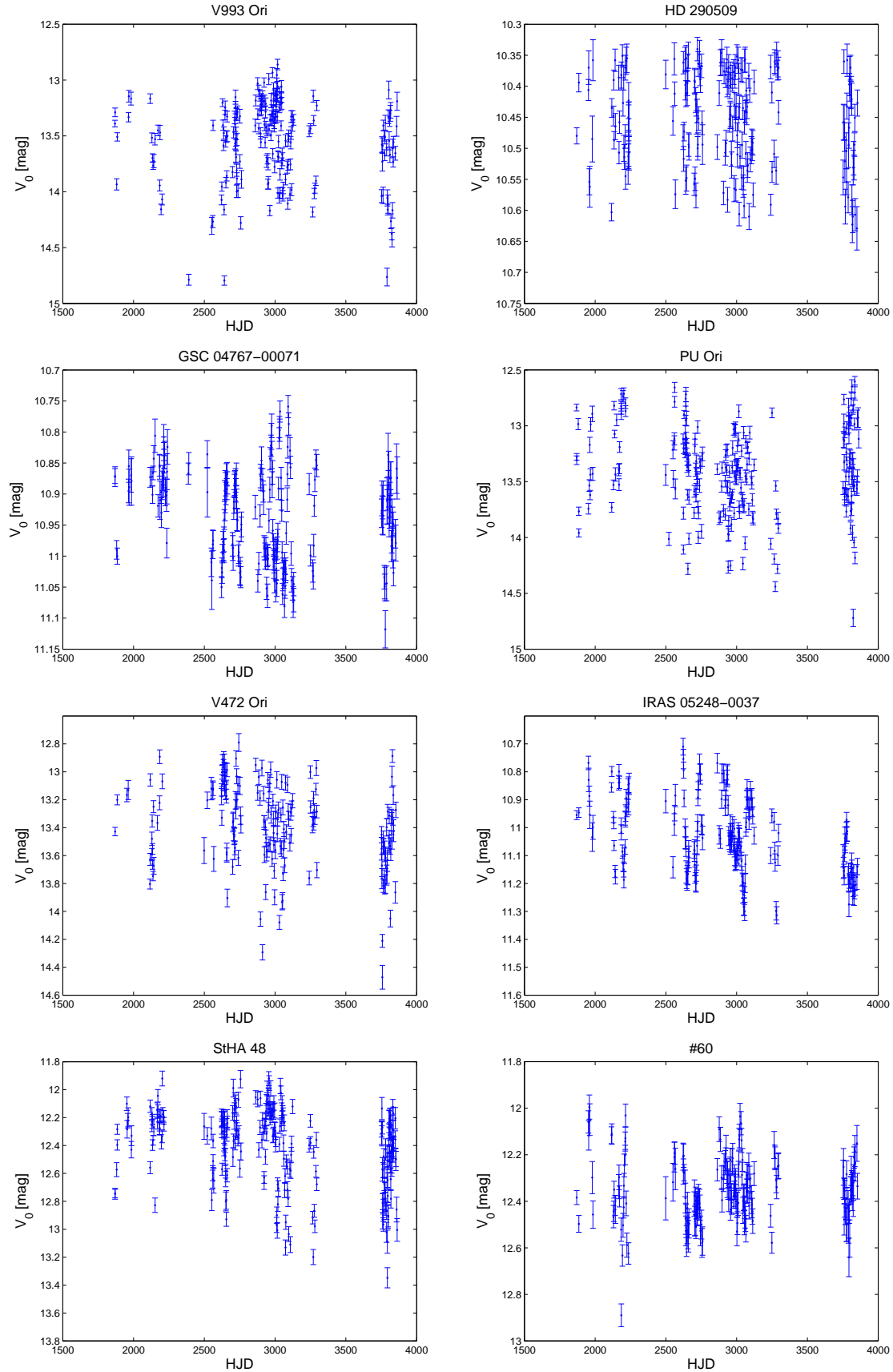


Fig. A3 Same as Fig. A1 but for identified variables No. 43 to 60.

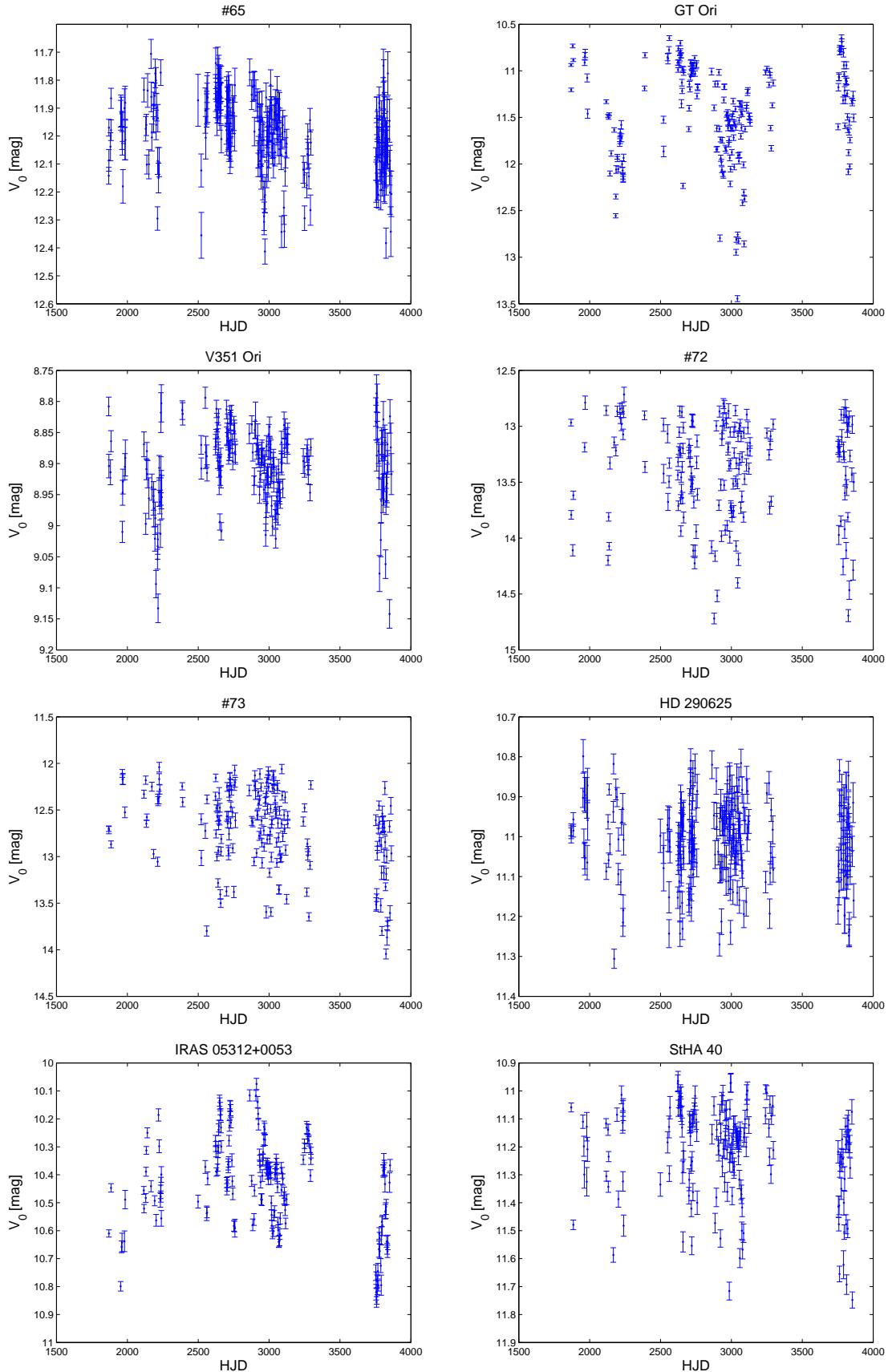


Fig. A4 Same as Fig. A1 but for identified variables No. 65 to 78.