VSOP: the variable star one-shot project

I. Project presentation and first data release


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ABSTRACT

Context. About 500 new variable stars enter the General Catalogue of Variable Stars (GCVS) every year. Most of them however lack spectroscopic observations, which remains critical for a correct assignment of the variability type and for the understanding of the object.

Aims. The Variable Star One-shot Project (VSOP) is aimed at (1) providing the variability type and spectral type of all unstudied variable stars, (2) process, publish, and make the data available as automatically as possible, and (3) generate serendipitous discoveries. This first paper describes the project itself, the acquisition of the data, the dataflow, the spectroscopic analysis and the on-line availability of the fully calibrated and reduced data. We also present the results on the 221 stars observed during the first semester of the project.

Methods. We used the high-resolution echelle spectrographs HARPS and FEROS in the ESO La Silla Observatory (Chile) to survey known variable stars. Once reduced by the dedicated pipelines, the radial velocities are determined from cross correlation with synthetic template spectra, and the spectral types are determined by a new automatic classifier, currently being developed by members of the VSOP team, based on these spectroscopic data and on the photometric classifier developed for the COROT and Gaia space missions, will be used.

Results. We confirm or revise spectral types of 221 variable stars from the GCVS. We identify 26 previously unknown multiple systems, among them several visual binaries with spectroscopic binary individual components. We present new individual results for the multiple systems V349 Vel and BC Gru, for the composite spectrum star V4385 Sgr, for the T Tauri star V1045 Sco, and for DM Boo which we re-classify as a BY Draconis variable. The complete data release can be accessed via the VSOP web site.

Key words. stars: variables: general – stars: fundamental parameters – methods: observational – astronomical data bases: miscellaneous

1. Introduction

There are more than 38,000 known variable stars listed in the latest edition of the General Catalog of Variable Stars (GCVS; Kholopov et al. 1998). Almost 4000 of these have no spectral type assigned and nearly 2000 are listed with an uncertain variability type, often because of lack of spectroscopic characterisation. The rate of inclusion of new variables is currently around 500 per year; actually 1700 between the Namelists 77 (Kazarovets et al. 2003) and 78 (Kazarovets et al. 2006). The true number of new variables is higher though, and this incompleteness of the GCVS will likely increase in the coming decade due to the large surveys that will be performed with both ground-based and space-based telescopes. About half of the newly identified GCVS variables have unknown variability type and most of them have no published spectral type. Moreover, many (even “firm”) variables have disagreeing designations between different authors and even between different catalogs.
e.g. there are frequent disagreements between the SIMBAD database and GCVS. In addition, binarity is rarely detectable unquestionably by photometric data alone. Finally, many designations are taken at face value without questioning the reliability. This unreliability is a major obstruction to many individual studies, and would often require only one "snapshot" spectrum to achieve a major improvement. Of course, single shot spectra would not always be able to reveal binarity or transient phenomena.

Recent examples of the misidentification of variables, where the designation was based solely on photometric light curve appearance, and subsequently corrected by taking one single snapshot spectrum, include:

FH Leo, that was long thought to be the only known cataclysmic variable (CV) to form part of a binary system, being designated as a nova-like variable by Kazarovets et al. (2003) based on an outburst observed by the Hipparcos satellite. High-resolution FEROS spectroscopy allowed us to refute the classification and show that the stars are normal F8 and G0 dwarfs (Dall et al. 2005), and that the outburst cannot possibly be due to an accretion disk, but rather to a superflare or to erroneous Hipparcos measurements, or due to a CV "hidden" in the light of the two normal stars (Vogt 2006).

XY Pic was included in a study of statistical properties of W UMa type variables (active, very fast rotating contact binaries) by Selam (2004), who concluded that it was among the most active stars of the sample, based on a fit of its Hipparcos light curve, using synthetic light curves based on physical parameters. FEROS spectra of XY Pic allowed us to show that the star is a rather slowly rotating F3 giant, with no measurable chromospheric activity (Dall et al. 2005), and is likely a δ Scuti pulsator. This example shows, that even a high-quality light curve analysis can result in wrong conclusions about the nature of an object without spectroscopic confirmation.

TV Ret was long thought to be a CV due to an outburst observed photometrically in 1977. A single low resolution spectrum, revealed the object to be a compact emission line galaxy at z ~ 0.1, possibly hosting an extremely bright supernova as the cause of the outburst (Schmidtobreick et al. 2007).

The above examples illustrate the need for snapshot spectra, and shows that the vast collection of poorly studied variable stars contains many errors in terms of variability type designation, which may in many cases "cover up" some potentially interesting physical phenomena under a wrong and seemingly dull label. In this paper we describe a new large project, the Variable Stars One-shot Project (VSOP), undertaken to provide the required "snapshots". We present the motivation and scope of VSOP in Sect. 2, the instrumentation and data handling in Sect. 3, and present results from the first observing semester from the European Southern Observatory’s La Silla site in Sect. 4, listing the revised spectral and variability types for 221 stars. The results and the reduced data are freely accessible from our website. We conclude the paper with plans for the future of VSOP in Sect. 5, where we also address the problem of automatic variability classification.

2. The project

Motivated by the situation outlined above, the goals of VSOP are:

1. to obtain the first spectroscopy of all unstudied variable stars, revising spectral and variability types;
2. to process, publish, and make the data available as automatically as possible, facilitating additional science;
3. to generate serendipitous discoveries that will fuel future research.

In addition, due to its beginnings as a proposal for an observatory project, VSOP has been designed with a view to both science and observatory efficiency.

2.1. Science efficiency

A stellar spectrum is a rich source of information. Often, however, only certain aspects of the object under study is of interest to the scientist conducting the study. One main goal of VSOP is to revise spectral and variability types, but there are certainly many other scientifically interesting studies one could perform using our data. We choose, rather than to sit on the data until we may find time for additional studies, to make the data easily available to the general community, in the hope that somebody else will be able to do additional science with the data. This way, the science output is maximised.

Another aspect that contributes to the science efficiency, is serendipity. The VSOP observations are targeting poorly studied variable stars, many of which are exhibiting poorly studied phenomena. We thus expect to obtain by chance data that either merit follow-up in-depth studies, or sheds light on some hitherto obscured phenomenon. Much of this work may naturally be done by groups not affiliated with VSOP.

2.2. Observatory efficiency

VSOP was originally conceived as an ESO observatory project, aimed at providing observations with loose weather and pointing constraints, with the aim of increasing observing efficiency during periods when other programmes with stronger constraints on airmass, seeing, and/or transparency cannot be carried out. Given the all-sky coverage, the loose constraints, and the large scope of the project, VSOP is an excellent example of a perfect filler programme, which will be extended to other observatories in the near future.

2.3. VSOP vs. other surveys

The most extensive spectroscopic survey to date, is the Sloan Digital Sky survey (SDSS; York et al. 2000). As of the fifth data release, the SDSS provides more than 800 000 spectra of galaxies, quasars and stars over nearly 7000 square degrees, mostly in the Northern hemisphere. The spectroscopy is carried out with multi-object fiber spectrographs, providing spectral resolution of $R = 2000$ and spectral coverage from 3900–9100 Å. The fiber aperture on the sky is 3”, so some contamination from fainter nearby objects is possible.

We cross-correlated the GCVS with the SDSS spectroscopic list to estimate the possible contribution of the SDSS towards accurate spectroscopic classification of the variable stars. The overlap consists of 80 objects (less than 0.3% of the GCVS) and given the degree of SDSS completeness we expect some additional objects, on order of 10, leading us to conclude that less than 0.5% of the GCVS have been covered by SDSS. The low number of stars in common is a consequence both of the faint brightness limit of the SDSS ($g > 14$), and of the science goals of the SDSS, which dictated selection for spectroscopic follow

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1 "Chance favors the prepared mind" – L. Pasteur.
up primarily for the extragalactic targets, obtaining spectra of stars only if some fibers remained unused.

However, spectra of a significant number of stars will be obtained under the Sloan Extension for Galactic Understanding and Exploration (SEGUE; Newberg & Sloan Digital Sky Survey Collaboration 2003; Rockosi 2006) which plans to obtain spectra of 240,000 Milky Way stars over 3500 square degrees with the same spectrograph. The goal of this survey is to provide radial velocities and metallicities with typical accuracies of 10 km s\(^{-1}\) and 0.3 dex respectively. SEGUE would thus complement VSOP. However, VSOP provides superior spectral resolution and \(S/N\) at any given magnitude, since we use 2–4 m-class telescopes. Plus, VSOP is already producing and releasing data.

Another large survey is the RAVelocity Experiment (RAVE; Steinmetz et al. 2006), aimed at kinematic studies of the local Milky Way environment. While this survey targets a large number of stars (24,748 in the first data release), the spectral coverage is limited to the IR Ca triplet region, and only at a moderate resolution of 7500. Thus, RAVE is likely not very useful as a general classification and discovery study.

Of existing surveys, the GAUDI (Solano et al. 2005) is the one most similar to VSOP. GAUDI is a photometric and spectroscopic database of objects that may be observed by the COROT mission, covering all targets down to \(V = 9.5\) inside the COROT accessibility zone – an area on the sky of \(10^\circ\) radius. While GAUDI covers a small area of the sky, looking for stellar variability in all available objects, VSOP is targeting known variables all over the sky. Thus, while complimentary, our scope is different.

Furthermore, a number of spectroscopic surveys have been performed in recent years, targeting the variability of individual types or classes of stars. Examples include surveys for \(\beta\) Cep stars (Teltjeng et al. 2006), Hipparcos-selected O-B supergiants (Lefever et al. 2007), \(\gamma\) Dor stars (de Cat et al. 2006), and studies of Ap star oscillations (Kurtz et al. 2006). While these are all high-resolution spectroscopic studies, they target a limited subset of stellar types, while the scope of VSOP is all of stellar variability, spanning the complete HR diagram, including all phenomena. In this respect, VSOP is a unique project, and it is our hope that VSOP will also turn out to be a unique resource for researchers of any stellar variability phenomena.

3. Observations and data handling

We present here the results of the first semester of VSOP observations, collected between April and October 2006 with the two high-resolution Echelle spectrographs FEROS and HARPS, of the ESO La Silla Observatory in Chile.

3.1. Target selection

Our target list is constructed based on a magnitude limited sample of spectroscopically unstudied southern variables drawn from the GCVS composed of stars with unknown or uncertain variability types (designations ending in “:”), in addition to the irregular or “unsolved” variables (GCVS types *, I, L, S and subclasses). This was complemented with stars having disagreeing designations according to SIMBAD, or according to recent literature. Stars were chosen to have a magnitude generally brighter than \(m_V = 10\) to be easily observable with high-resolution spectrographs on middle-sized telescopes.

The 221 stars reported here, belong to the bright end of the unstudied variables of the GCVS, which is now \(\sim 40\%\) complete (i.e., having reliable, wide wavelength coverage spectroscopy) down to \(m_V = 10\). The rate of discovery of new variables has been relatively constant in recent years, and is very low at the bright end of the distribution. Assuming similar number of observations for the coming semesters, we can expect to complete the bright end of the unstudied variables of the Southern hemisphere in 1–2 additional observing seasons. Going to fainter magnitudes, the completeness decreases rapidly, reaching a plateau of around 20–25% fainter than \(m_V = 13\), not including as yet unrecognized variables.

3.2. FEROS

FEROS (Fibre-fed Extended Range Optical Spectrograph, Kaufer et al. 1999), is ESO’s high resolution, high efficiency versatile spectrograph. It is a bench-mounted, thermally controlled, prism-cross-dispersed Echelle spectrograph. It provides in a single spectrogram spread over 39 orders almost complete\(^2\) spectral coverage from \(\sim 350–920\) nm at a resolving power of \(\sim 40,000\).

The spectrograph is fed by two fibres providing simultaneous spectra of object plus, in the case of VSOP observations, an empty sky region for background subtraction. The fibres are illuminated via apertures of \(2.0'\) on the sky separated by \(2.9'\). A dedicated pipeline implemented as a MIDAS context provides, in almost real-time, extracted 1-dimensional, wavelength calibrated spectra.

FEROS Period-77 VSOP observations have been obtained with exposure times ranging from 180 to 1200 s. Given the relaxed observing constraints, signal-to-noise \((S/N)\) ranges from \(\sim 10\) to \(\sim 370\) at \(V\). The standard calibration plan, which provides bias, flat-field, wavelength calibration and spectrophotometric standard star observations, has been used for this programme.

3.3. HARPS

HARPS (High Accuracy Radial velocity Planet Searcher; Mayor et al. 2003) is the ESO instrument dedicated to extrasolar planet searches through the radial velocity method. Moreover, it has proved to be very efficient as well as a general purpose high resolution spectrograph. HARPS is a fibre fed, \(\text{Échelle}\) cross-dispersed spectrograph, achieving a resolution of \(110,000\), while covering the spectral range from 390 nm to 690 nm in 72 spectroscopic orders. The spectrograph is kept under vacuum and under strict temperature control to increase stability. The light is fed to the spectrograph through a fibre with a \(1''\) aperture on the sky. Like FEROS, the fibre link includes two fibres, one for the scientific target and the other for sky subtraction. The efficiency of the spectrograph peaks at \(\sim 8\%\) (Blaze maximum) at 520 nm and is quite flat between 450 nm and 690 nm.

The standard calibration set executed prior to each observing night included bias, flat-fields and wavelength calibration. The HARPS data are automatically processed upon acquisition by a dedicated pipeline developed by the HARPS consortium and which provides bias subtraction, order localization, flat fielding, cosmic filtering, order extraction (using the Horne technique, Horne 1986, assigning lower weights to the pixels away from the peak in the spatial profile at any given wavelength) and radial velocity determination through cross correlation of each spectral order with a predefined stellar mask (synthetic spectrum).

\(^2\) The two spectral ranges 853.4–854.1 nm and 886.2–887.5 nm are lost due to non overlap of the spectral orders.
HARPS Period-77 VSOP observations have been obtained with exposure times ranging from 90 s to 1200 s, resulting in \( S/N \) between 30 and 150, averaging to \(-100 \) at 550 nm.

### 3.4. The VSOP wiki database and data policy

All the data and basic information about the stars are stored in a wiki-wiki website located at [http://vsop.sc.eso.org](http://vsop.sc.eso.org), from where the reduced data of this First Data Release can be freely accessed. We expect to make incoming data freely available through subsequent data releases, with only a few months delay to allow for our initial data analysis. Research work benefiting from VSOP data should reference this paper, and include the following acknowledgement:

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Based on data provided by the VSOP collaboration, through the VSOP wiki database operated at ESO Chile and ESO Garching.
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For the organization of information, we have chosen the MediaWiki software, developed for the open and free on-line encyclopedia Wikipedia. This ensure a reliable and extendable website where all VSOP members can contribute easily from their own daily workplace. This is of growing importance given the distribution of VSOP members around the world, as evidenced by the list of affiliations for this paper.

The MediaWiki software is based on the article/discussion wiki philosophy, which means that to each article page there is an associated discussion page. For VSOP we have extended the software to make the discussion pages restricted to VSOP members only, while the article pages are reserved for already published results, freely accessible to anybody. Thus, each star has a dedicated article page, where basic informations (coordinates, magnitude, link to SIMBAD, finding charts, old variability and spectral types – when available) are provided. Also, the observation details are described as well as the analysis, its results, a list of references, catalogues and download links to plots of the spectra as well as to all the reduced data products: Cross-Correlation Function (CCF) and wavelength calibrated one-dimensional spectrum, all of which are publicly available.

Finally, the MediaWiki software allows the wiki website to be scriptable. We have thus developed a VSOP-dedicated software module written in Python which makes the development of scripts dedicated to VSOP pages much easier. These robot scripts can then update a large amount of repetitive information, or collect the results of given subcategories of stars. Table 2 of this paper, for instance, is automatically produced by one of these scripts.

### 3.5. The VSOP dataflow

The VSOP dataflow comprises a collection of different steps that are developed in order to make it as automatic as possible. The following is an outline:

1. a list of targets is build, as described in Sect. 3.1;
2. when observing time is granted, we automatically generate one wiki-page per target;
3. observations for each target are defined and submitted to the observatory database;
4. observations are carried out through the observing semester, and data is automatically reduced by the instrument pipelines (Sects. 3.2 and 3.3);
5. raw and reduced data are automatically transferred to the VSOP machine at ESO Vitacura (Sect. 3.4) and the wiki star page is updated;
6. automatically generated plots of spectra and CCF are included in the star page (Sect. 4.1);
7. VSOP members receive an email alert that new VSOP observations have been obtained;
8. analysis is undertaken, and the wiki-pages are updated if needed.

The dataflow has proved very smooth and efficient throughout the first observing season. For the following seasons, we have in addition implemented automatic spectral analysis (Sect. 4.2). However, in order to make it completely automatic, one needs to develop an automatic variability classifier, incorporating both spectroscopy and the available photometry. As already mentioned, this is an area where VSOP will play an active future role (Sect. 5).

### 4. Results

Table 2 lists the 221 stars observed during ESO Period 77: 90 of these were observed with HARPS, 131 with FEROS.

#### 4.1. Radial velocities and binary status

Radial velocities (RVs) are computed via the Cross Correlation Function (CCF) method, in which a template synthetic spectrum with box shaped lines is correlated with the star spectrum to measure the Doppler line shift. Details can be found in Baranne et al. (1996). The HARPS online pipeline provides accurate radial velocities \( (\pm 1 \text{ m s}^{-1}) \) for slowly rotating late-F, G, K and early M dwarfs. Similarly, FEROS demonstrated a RV accuracy of \( \pm 20 \text{ m s}^{-1} \), the difference with HARPS being mainly due to the mechanical stability of the latter and the different choice of light injection in the two instruments. Correlation with mid to late M type stars is problematic due to the amount of wide molecular features in their spectra and to the paucity of narrow metal lines. Earlier type stars often have higher rotational velocities and weaker metallic lines, limiting the accuracy of the radial velocity determination but, at least for stars with metal lines, still allowing the computation of a CCF and therefore the estimation of the RV. In the presence of only few metal lines in the early type stars, the correlation with the G2 template (the “earliest” available for HARPS) will return a CCF with a small contrast (few \%). Due to the scarcity of narrow metal lines, early-type templates will necessarily include strong lines which naturally suffer from asymmetries, which in turn will lower the RV precision. For the time being, the RV of earlier spectral types is estimated by automatic fitting of the core of H\( \beta \) with a second-order polynomial as part of the VASP analysis (cf. Sect. 4.2). While techniques such as the cross correlation in Fourier space with template spectra obtained from observations allows relative accuracies of \( \pm 10 \text{ m s}^{-1} \) in RVs on early type stars (Galland et al. 2005), we use the faster CCF method, as such an accurate RV determination is not our primary concern.

We designate SB2 and SB3 binarity status from the presence of multiple peaks in the CCF, or via a careful analysis of the spectrum, identifying spectral features belonging to stars of different spectral types. The latter case is when the stars have widely different spectral types, and the CCF mask only “sees” one of the components (see e.g. V4385 Sgr, Sect. 4.3.3). Since we have only one epoch, the SB1 designation is not used.
Table 1. A sample of results from the automatic analyses. We list the names, HD numbers and spectral types from the manual spectral typing. We give the \( T_{\text{eff}} \), \( \log g \) and [Fe/H] and estimated uncertainties determined by VASP and VWA. \( v \sin i \) values are calculated with VWA and have uncertainties of 10–20\%. The first four targets are not VSOP targets, but high S/N HARPS spectra taken from Dall et al. (2006), which we have used to calibrate our tools. Full detailed results for all VSOP stars can be found online (see text).

<table>
<thead>
<tr>
<th>Star</th>
<th>HD</th>
<th>Spectral type</th>
<th>( v \sin i ) [km s(^{-1})]</th>
<th>( T_{\text{eff}} ) [K]</th>
<th>VASP ( \log g )</th>
<th>VASP [Fe/H]</th>
<th>VWA ( T_{\text{eff}} ) [K]</th>
<th>VWA ( \log g )</th>
<th>VWA [Fe/H]</th>
</tr>
</thead>
<tbody>
<tr>
<td>α Hor</td>
<td>26967</td>
<td>K1III</td>
<td>2</td>
<td>4675(143)</td>
<td>2.0(4)</td>
<td>+0.22(13)</td>
<td>4550(80)</td>
<td>2.2(2)</td>
<td>−0.02(5)</td>
</tr>
<tr>
<td>τ Cet</td>
<td>10700</td>
<td>G8V</td>
<td>3</td>
<td>5292(157)</td>
<td>4.6(4)</td>
<td>−0.45(15)</td>
<td>5320(50)</td>
<td>4.5(1)</td>
<td>−0.47(5)</td>
</tr>
<tr>
<td>Sun</td>
<td></td>
<td>G2V</td>
<td>2</td>
<td>5842(168)</td>
<td>4.5(4)</td>
<td>−0.16(16)</td>
<td>5810(40)</td>
<td>4.5(1)</td>
<td>−0.07(3)</td>
</tr>
<tr>
<td>γ Ser</td>
<td>142860</td>
<td>F6IV</td>
<td>11</td>
<td>6322(191)</td>
<td>4.1(7)</td>
<td>−0.18(20)</td>
<td>6250(80)</td>
<td>4.1(1)</td>
<td>−0.24(5)</td>
</tr>
<tr>
<td>ZZ Pyx</td>
<td></td>
<td>K3V</td>
<td>5</td>
<td>4228(223)</td>
<td>4.1(4)</td>
<td>−0.31(13)</td>
<td>3900(150)</td>
<td>1.4(3)</td>
<td>−1.3(2)</td>
</tr>
<tr>
<td>V349 Vel</td>
<td>91021</td>
<td>F2+2</td>
<td>16</td>
<td>7314(241)</td>
<td>5.2(9)</td>
<td>−0.89(54)</td>
<td>7200(150)</td>
<td>4.0(2)</td>
<td>−0.43(5)</td>
</tr>
<tr>
<td>LP Vir</td>
<td>115466</td>
<td>F1IV</td>
<td>40</td>
<td>7031(194)</td>
<td>3.4(8)</td>
<td>−0.32(29)</td>
<td>7030(80)</td>
<td>3.7(1)</td>
<td>−0.13(5)</td>
</tr>
<tr>
<td>V976 Cen</td>
<td>118551</td>
<td>F0III</td>
<td>40</td>
<td>7048(203)</td>
<td>2.0(7)</td>
<td>−0.16(23)</td>
<td>8400(100)</td>
<td>2.4(2)</td>
<td>−0.78(5)</td>
</tr>
<tr>
<td>PP Hya</td>
<td>87130</td>
<td>A5V</td>
<td>80</td>
<td>7924(219)</td>
<td>4.0(8)</td>
<td>−1.35(73)</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>

Out of the 221 observed targets, we identify 22 new SB2 binaries, several of these as components of wide visual binaries. In addition we find four new SB3 binaries. However, the binarity of most of our targets remains undetermined due to our single-epoch approach. For many of the stars we could not compute a CCF, due to the difficulty to build reliable templates for such peculiar objects. We postpone accurate determination of the binary status of such stars to a later work.

4.2. Spectral classification

The first set of atmospheric parameters (\( T_{\text{eff}}, \log g, \text{[Fe/H]} \)) listed in Table 1 have been obtained automatically by comparison of the observed spectra with theoretical spectra in a region around H\(\beta\) (486 nm). This spectral window can be used to uniquely constrain the atmospheric parameters for stars with spectral types A to K (Allende Prieto 2003). This automated software (VASP: VSOP Automatic Stellar Parameters) and the synthetic spectra are very similar to those used for the STELLA robotic telescopes (Strassmeier et al. 2007, in preparation).

The search for the optimal solution is carried out using the Nelder-Mead algorithm and third order interpolation in a grid of synthetic spectra based on Kurucz (2006) model atmospheres and modern line and continuous opacities\(^{1}\) (Allende Prieto et al. 2003a,b). The grid currently in use covers 4500 < \( T_{\text{eff}} \) < 7500 K. To overcome problems with fast rotation, the grid has been constructed with a resolution of 38 km s\(^{-1}\), corresponding to a spectral resolving power of 7700. For faster rotational velocities, the accuracy of the fits decrease significantly as rotation increases.

The solar reference abundances are from the photospheric abundances compiled by Asplund et al. (2005). Known spectroscopic binaries (cf. Sect. 4.1), as well as stars clearly outside the grid boundaries, are not run through VASP.

Future upgrades to VASP will include wider temperature range grids, as currently only about one third of our targets fall within the limits of the grid. Other upgrades will be parameter estimation using other spectral intervals besides H\(\beta\), and the ability to handle rotational broadening.

For comparison, we have included results from a classical abundance analysis obtained with the VWA\(^{2}\) package (Bruntt et al. 2004). VWA works with the original (full resolution) spectra and determines the abundance of each individual line. It relies on the lines of Fe, Cr and Ti to automatically adjust the microturbulence, \( T_{\text{eff}} \) and \( \log g \) of the applied atmospheric models (Heiter et al. 2002). VWA is a semi-automatic procedure and to obtain optimal results the user needs to make (1) a careful correction of the continuum and (2) inspect the fit of individual lines. The abundances found with VWA are based on corrected \( \log g \) values, which are derived from the HARPS spectrum of the Sun.

We did not analyse PP Hya due to its high \( v \sin i \), which is known to cause problems for VWA’s automatic procedures. While VWA seems to produce more robust results, the process involves a lot of manual intervention and is not at this point suited for an automated analysis.

We have in addition performed manual spectral classifications, by comparison with standard stars of the MK spectral classification as defined by Morgan et al. (1978) and Keenan & McNeil (1976). The practical comparison has been done with the help of the Digital Spectral Classification Atlas by Gray\(^{3}\), using high resolution spectra of spectral standards obtained with HARPS, FEROS and UVES. Whenever the emission cores of the Ca II H&K lines have been present, we have determined the luminosity type from the Wilson-Bappu effect (Wilson & Vainu Bappu 1957), using the calibration by Pace et al. (2003). Since many older classifications are done in this way, it is instructive to investigate the differences between this traditional human skill driven task, and a modern automatic classification.

We have identified several causes for problems in the spectral classifications, the most common one associated with binarity. Spectroscopic and very close visual binaries (separations <1.5") often show multiple peaks in the CCF, and are thus easy to filter out of the VASP analysis. One such example is V349 Vel (Sect. 4.3.1). We also found that early-type and very metal-rich stars limit the precision of the VASP fit, and of course influences the manual classification. In many cases, apparent low metallicity may be due to a binary companion contributing light to the spectrum, causing the metallic lines to appear weaker. One clear example of this can be seen in V4385 Sgr (Sect. 4.3.3). In a few cases we have found disagreement between the VASP-computed \( \log g \) and the absolute magnitude derived from the Wilson-Bappu relation, in most cases caused by being near the lower temperature limit of the grid.

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\(^{1}\) Also Kurucz (1993) and http://kurucz.harvard.edu/, the odnew grid.

\(^{2}\) VWA is available here: http://www.hans.bruntt.dk/vwa/

\(^{3}\) http://nedwww.ipac.caltech.edu/level5/Gray/frames.html
Table 2. The VSOP stars of the first observing season.

<table>
<thead>
<tr>
<th>GCVS name</th>
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<td>ACV F3I1-V1</td>
<td>? OS: A4m</td>
<td></td>
<td></td>
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<tr>
<td>OT Hya</td>
<td>GSC 05489-01121</td>
<td>2006-06-12</td>
<td>F 8.04</td>
<td>? M2I1</td>
<td>? OS: M0</td>
<td></td>
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<tr>
<td>OU Hya</td>
<td>GSC 05486-00657</td>
<td>2006-06-14</td>
<td>F 8.81</td>
<td>? M4I1</td>
<td>? OS: M3I1</td>
<td></td>
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<td></td>
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<tr>
<td>OW Hya</td>
<td>GSC 05456-00152</td>
<td>2006-08-10</td>
<td>F 8.61</td>
<td>LB M1I1</td>
<td>? OS: K5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>OX Ser</td>
<td>GSC 00379-00580</td>
<td>2006-04-12</td>
<td>F 9.33</td>
<td>LB K2V+K5(?)</td>
<td>SB2 OS: K2; OB: ?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OX Ser</td>
<td>GSC 01157-00471</td>
<td>2006-08-10</td>
<td>F 9.65</td>
<td>LB K0</td>
<td>? OS: M0</td>
<td></td>
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<tr>
<td>OQ Hya</td>
<td>GSC 07186-00100</td>
<td>2006-06-14</td>
<td>F 6.97</td>
<td>? M2I1-V3I1</td>
<td>? OS: M2I1</td>
<td></td>
<td></td>
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<tr>
<td>OQ Ser</td>
<td>GSC 05063-01296</td>
<td>2006-05-24</td>
<td>F 7.66</td>
<td>? M3I1</td>
<td>? OS: M2I1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OQ Hya</td>
<td>GSC 01585-01116</td>
<td>2006-08-10</td>
<td>F 7.96</td>
<td>LB M0I1</td>
<td>? OS: K5</td>
<td></td>
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<td></td>
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<tr>
<td>OQ Ser</td>
<td>GSC 07221-00698</td>
<td>2006-04-09</td>
<td>F 9.05</td>
<td>LB M0I1-V1I1</td>
<td>? OS: M1I1I;</td>
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<tr>
<td>OQ Hya</td>
<td>GSC 00320-00214</td>
<td>2006-06-16</td>
<td>F 8.86</td>
<td>M1I1-V1I1 VIS</td>
<td>OS: K5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. continued.

Properties of the stars in our sample

| Star Name | Catalogue | MJD | Filter | V | B | R | I | J | H | K | M_0 | Spectral Type | Orbital Type | Secondary Spectral Type | Orbital Period |
|-----------|-----------|-----|--------|---|---|---|---|---|---|---|---|-----|--------------|--------------|---------------------|---------------|
| TW Sex GSC 04896-01383 | 2006-06-13 | F | 7.93 | ? | M4III | ? | OS: M4 |
| TYC 7798-500-1 | 2006-05-21 | F | ? | F5III | ? | OS: ? |
| UV Crt GSC 06108-00927 | 2006-04-01 | H | 9.38 | BY | K3IV+? SB3 | OS: K1V, OB: VIS |
| UV Crt GSC 06090-01429 | 2006-04-09 | F | 8.24 | LB | K5/7V+IV | OS: K5/M0III |
| UV Crt GSC 05495-00576 | 2006-04-09 | F | 9.17 | LB | M3III | VIS | OS: M0 |
| V1001 Cen GSC 09862-01015 | 2006-04-02 | H | 7.24 | IA | B4 | SB2 | OS: B4IV/V, OB: ? |
| V1003 Sco GSC 14971 | 2006-05-04 | H | 5.83 | ELL | B3III | VIS | OS: B2.5IV |
| V1026 Sco GSC 06199-00618 | 2006-04-02 | F | 8.85 | IA | F0IV-III | ? | OS: A8Ve |
| V1045 Sco GSC 05624-00995 | 2006-08-11 | F | 8.08 | LB | K7III | ? | OS: K5III |
| V1052 Sco GSC 05613-00357 | 2006-09-13 | F | 8.62 | LB | M4IV-III | ? | OS: M4III |
| V1053 Sco GSC 05625-00721 | 2006-04-12 | F | 8.03 | LB | M3IV-III | ? | OS: M3IV |
| V1066 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1080 Sco GSC 07883-00697 | 2006-08-15 | F | 7.56 | LB | M3III | ? | OS: M |
| V1094 Sco GSC 06090-01429 | 2006-04-09 | F | 8.24 | LB | K5/7V+IV | OS: K5/M0III |
| V1095 Sco GSC 05495-00576 | 2006-04-09 | F | 9.17 | LB | M3III | VIS | OS: M0 |
| V1096 Sco GSC 09862-01015 | 2006-04-02 | H | 7.24 | IA | B4 | SB2 | OS: B4IV/V, OB: ? |
| V1097 Sco GSC 14971 | 2006-05-04 | H | 5.83 | ELL | B3III | VIS | OS: B2.5IV |
| V1126 Sco GSC 06199-00618 | 2006-04-02 | F | 8.85 | IA | F0IV-III | ? | OS: A8Ve |
| V1145 Sco GSC 05624-00995 | 2006-08-11 | F | 8.08 | LB | K7III | ? | OS: K5III |
| V1152 Sco GSC 05613-00357 | 2006-09-13 | F | 8.62 | LB | M3III+M | SB2 | OS: M2, OB: ? |
| V1153 Sco GSC 05625-00721 | 2006-04-12 | F | 8.03 | LB | M4IV-III | ? | OS: M4III |
| V1166 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1204 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1206 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1207 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1208 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1209 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1210 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1211 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1212 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1213 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |
| V1214 Sco GSC 07358-00675 | 2006-06-11 | F | 7.65 | IA | A0V | M2III | OS: B9.5IV, OB: VIS |

4.3. Selected individual cases

In this section, we give a few examples of different kinds of objects we have encountered. These examples include both “typical cases” and “special cases”, in order to give an impression of the wide range of phenomena we have to deal with, and which our automated procedures will have to be able to handle. Subsequent publications will deal in depth with interesting special cases, be devoted to resolving binaries, deal with various classes of stars, and will address the general problem of variability classification.

4.3.1. V349 Vel – visual and spectroscopic binary

V349 Vel is a close visual binary, separated by 1.1′′. The CCDM (Dommanget & Nys 1994) lists spectral type F5 for the A component (m_v = 9.8), while the B component must be a later type at m_v = 11.1. Our HARPS spectrum, obtained on 2006-04-01, reveals a complex CCF with at least four well defined components, the dominant one being a F2 type. Due to their proximity, the fiber entrance (1.0 ′′) includes light from both visual components. Thus, the A and B components both split up into SB2...
spectroscopic binaries. Based on the line strengths and the rotational broadening, which is expected to be higher for F type stars than for later spectral types, we identify the lines of each of the four components as shown in Fig. 1. While new epoch spectroscopy would be needed to determine the orbital parameters, we consider it beyond doubt that V349 Vel is a four component multiple system composed of two SB2 binaries orbiting each other.

The GCVS variability type is \( \alpha \) Canum Venaticorum (ACV), which is reserved for magnetic B-A stars with peculiar spectra. We suspect that the SB4 appearance of V349 Vel may have been misinterpreted as spectral peculiarities. We do not see evidence of magnetic activity in the spectrum, hence we also consider BY Dra type variability unlikely. From our spectral analysis (Sect. 4.2) we find that the parameters of the primary component is consistent with an early F type star near the main sequence. Thus, the primary component of V349 Vel could well belong to the \( \delta \) Scuti or \( \gamma \) Dor variables. Alternatively, one or both of the SB2 components could show eclipses. Otero (2003) listed V349 Vel as an EA-type eclipsing binary, with \( P = 3.02 \) d, and notes that additional shorter periods may be present as well. More detailed photometric or spectroscopic

\begin{table}[h]
\centering
\begin{tabular}{llll}
\hline
V371 Nor & GSC 08715-01929 & 2006-04-02 & H 9.35 BY K3V ? OS: K2V \\
V389 Pav & GSC 09321-01375 & 2006-04-30 & F 7.61 LB M0IV ? OS: M1/M2III \\
V390 Pav & GSC 09114-01109 & 2006-05-04 & H 9.03 BY K3V VIS OS: K2Vp \\
V412 Pup & GSC 07569-03359 & 2006-04-09 & F 8.74 LB M4III ? OS: K5 \\
V414 Pup & GSC 05420-08844 & 2006-04-01 & H 8.80 ACV A0I+A SB2 OS: A0p, OB: Y \\
V424 Pup & GSC 06564-02968 & 2006-04-09 & F 8.93 LB K7IV-III ? OS: K5 \\
V4422 Sgr & GSC 06312-00760 & 2006-04-30 & F 8.01 LB M2IV ? OS: M2III \\
V841 Ara & GSC 08720-01374 & 2006-05-04 & H 8.73 BY K0V VIS \\
V856 Ara & GSC 08739-02203 & 2006-08-31 & F 8.34 LB K3III ? OS: K4III \\
V915 Her & GSC 01524-00660 & 2006-08-23 & F 8.32 LB M2III ? OS: M \\
V940 Cen & GSC 08257-01308 & 2006-04-02 & H 9.95 BY K0III ? OS: G8/K0V \\
V981 Her & GSC 01554-01928 & 2006-08-15 & F 7.24 LB M2III ? OS: M \\
V982 Cen & GSC 07794-00857 & 2006-04-02 & H 9.6 BY K4V+K SB2 OS: K2V, OB: VIS \\
V990 Her & GSC 02800-01100 & 2006-04-02 & H 9.77 BY K0+K+ SB3 OS: K0V, OB: ? \\
V999 Her & GSC 01574-01900 & 2006-06-12 & F 8.90 ? M2 ? OS: M0 \\
WX PsA & GSC 07511-00060 & 2006-08-09 & F 8.71 LB M3IV-III ? OS: M \\
\hline
\end{tabular}
\end{table}
4.3.3. V4385 Sgr – composite spectrum

V4385 Sgr is a known composite spectrum star, classified as an ellipsoidal variable, and hence a close early-type binary system with geometrically distorted components (Kazarovets et al. 1999a). Its variability was detected by Hipparcos, which found a period of 2.62 d with peak-to-peak variations of 0.08 mag. It was observed during lunar occultations (Dunham 1974; Schmidtke et al. 1989) and recorded as double in the University of Texas Special Double Star list (Schmidtke 1979). Previous prism observations (typically 39/91 Å mm⁻¹) were obtained by several authors (see, e.g., Houk & Cowley 1975; Reed & Beatty 1995; Garrison et al. 1977; Abt et al. 1979; Kennedy 1983; Kawabata et al. 2000). The composite spectrum is usually classified combining an early B to late A star component, plus an early F. In particular, Garrison et al. (1977) classified V 4385 Sgr as a shell star having Mg, He, and Si like a B5 star but with very broad H and CaII and the rest of the spectrum like an F2 star. SIMBAD however, classifies it as a A2/A3V primary and unknown secondary, which is clearly incorrect.

Our high quality VSOP spectrum of V4385 Sgr (S/N = 130 at 550 nm) was obtained on 2006-05-04 using HARPS, and is the first full optical range high resolution spectrum of the source. The HARPS CCF is single-peaked at high contrast (11%) but asymmetric, as expected due to geometric distortion. The CCF is constructed using a G2 mask, and hence represents the average line profile of the F-component only at a radial velocity of 14.5 km s⁻¹. The $FWHM$ of the CCF is 13 km s⁻¹, which is a safe upper limit for $v \sin i$. Thus the rotation is significantly slower than for the average early F-star, which is surprising given the short variability period, and the fact that binary evolution tends to increase rotation rates as the orbit shrinks.

The spectrum (Fig. 3) shows the typical He I lines of the B component superimposed on the metallic-line spectrum. Note that the RV of the two components seem compatible within the uncertainties.

The VSOP spectrum shows Balmer emission lines, strongest at Hα ($FWHM = 132$ km s⁻¹), core fill-in at Hβ and Hγ (see also Merrill & Burwell 1950). Weak P Cyg profiles can be seen in several lines, however not in the Balmer lines. Note that the lines of both components, including the strong Hα emission, are compatible with $RV = 14.5$ km s⁻¹. The interstellar Na doublet is saturated and presents also a P Cyg profile from the underlying stellar spectrum.

Based on the observed emission properties, and on the undisputable two-component nature, we can safely rule out that the 2.62 d period can be due to γ-Dor like pulsations in a single F star. Rather, due to the slow rotation of the F-star and the apparent same RV of the two components, we propose that V4385 Sgr could be a near pole-on viewed close binary system, showing only slight eclipses. We propose that the orbital period is equal to the photometric period, caused either by a partial eclipse of the smaller component, or by variations in the wind structure over the orbit. Unfortunately, only scattered photometric data exists, as summarized by Reed (1998), making it difficult at this point to test the hypothesis. Given its brightness, the star would be an easy target for small telescopes.

4.3.4. V1045 Sco – strong lithium absorption

V1045 Sco (HD 144377, $V = 8.06$) is classified as K5III in SIMBAD, with only one bibliographic reference (Kazarovets et al. 1999b). It is an IRAS source with a flux of 2 Jy in the 12 µm channel, and decreasing fluxes towards the longer wavelength.
The mid-IR flux is therefore well above the expected photospheric level, and indicates circumstellar, dusty, material.

We have secured two FEROS spectra of this object, on 2006-08-11 and 2006-09-16. Our spectral typing procedure (Sect. 4.2) yields consistently a somewhat later spectral type, K7, compatible with a giant (or sub-giant). A radial velocity of 25.77 km s\(^{-1}\) is determined. A striking feature is the H\(\beta\) magnitude and (\(H\alpha\) is, however, inconsistent with the bulk according to the commonly accepted \(H\) and \(K\) emission cores, which, \(-\), \(\approx T\). H. Dall et al.: VSOP I. First data release 1211

4.3.5. DM Boo – reclassification

DM Boo (HD 120447, HIP 67499, BD+11 2604) has been classified as an irregular variable star of spectral type G5 (Simbad) and a Johnson \(V\) magnitude and \((B - V)\) color of 8.68 and 0.67 respectively. The only photometric monitoring found in the literature is the one carried out by the Northern Sky Variability Survey (NSVS; Wozniak et al. 2004). The average brightness of the star in their no-filter observations (ROTSE) gives a value of 8.59 mag, with a scatter of less than 0.08 mag (and precision of 0.01 mag). Hipparcos gives a parallax for the star of \(\Delta d = 1.25\) mas, corresponding to a distance of \(d = 172\) pc.

There are also \(uvby\) observations (one set, from 1993) and the \(V\) and \(B\) values from Tycho. The Tycho-2 Spectral Type Catalog (Wright et al. 2003) converts the G5 spectral class into a temperature of \(T_{\text{eff}} = 5150\) K. The GCVS lists the star as a IB type, i.e., a poorly studied irregular variable of intermediate to late spectral type.

The VSOP FEROS spectrum was taken on 2006-08-12 with an integration time of 600 s. From the CCF we derive a \(v \sin i\) of \(=65\) km s\(^{-1}\) and a radial velocity of \(-42\) km s\(^{-1}\). The most prominent features are strong Ca II H&K emission cores, which, together with the fast rotation, points to a young active star. Analysis of the lithium line region reveals higher than solar photospheric lithium abundance, confirming the notion of a relatively young, active star. We thus feel confident classifying DM Boo as a BY Draconis star, noting the low photometric amplitude typical of such stars.

4.4. Evaluation in terms of spectral type and binarity

To compute some statistics of the VSOP observations, we must rely on “old” values as they were before VSOP observations. This concerns mostly the spectral type and the binary status. The old spectral type is determined automatically by querying SIMBAD. To determine the binary status of a target, we query VizieR catalogues with the Multiple and Double stars, Spectroscopic, Cataclysmic and Eclipsing binary keywords to see if the star belongs to one of these classes. If the star belongs to a catalogue of spectroscopic binaries, or one providing orbits
of stars, the star is said to be a binary. If the star belongs to some
visual binaries or multiple and double stars catalogs, the star is
suspected to be a visual binary. Finally, if it only belongs to the
Tycho’s and Hipparcos catalogues, the suspected binary status
is inferred from the MultiFlag parameter of the catalogue.
The procedure is quite complex, and is described in the wiki website
(Binary Status page). We have tested various combination of cri-
teria, which seems to converge to a relatively stable results. Our
statistics are based on these tests.

The main points of the VSOP observations can be summa-
rized as follows:

– VSOP observations allow to revise more than two third of
the spectral types;
– among these revisions about 4% had no previous spectral
type, about 25% of the revisions implies a complete change
of spectral class (say from F to G), about 30% are changes
by more than one subclass (say from F3 to F5), and about
20% are changes of one subclass. The remaining approxi-
mately 20% are assignment or re-assignment of luminosity
class.
– there are no clear trends or systematic biases toward revis-
ions of any given spectral class, spectral subtype, or lumi-
nosity class.
– 40 of our targets (about 20%) appear to be spectroscopic bi-
naries. Of these, 22 are previously unknown SB2 systems,
while we have identified four new SB3 systems.

5. The future of VSOP

This paper has presented the first data release from VSOP, cov-
ering ESO Period 77. Observations are ongoing in Periods 78
and 79, and data from these periods will be released as soon as the
periods end.

5.1. Next steps

Future space missions like COROT and GAIA will provide a
wealth of data for variable stars that will be observed with
unprecedented precision and sampling of their light curves.
Nevertheless, situations of ambiguity in the determination of the
variability type can arise. Also, as in the case of Hipparcos, it is
expected that these data will lead to the discovery of a number
of new classes of variables. For all of them, it will be necessary
to refine their variability type and position in the HR diagram
with spectroscopic data. This is what VSOP has been doing with
objects of the GCVS, but the sheer number of stars provided by
these missions would deem this classification impossible to be
determined by hand.

For the next steps, the main aim of VSOP is to acquire and
develop the necessary tools to provide good and reliable spec-
tral and variability classification of stars automatically from the
available data, either the spectrum, the light curve, color informa-
tion, or combinations of these.

5.2. Automatic variability classification

There have been in the past several attempts to mine large
archives of variable objects data, mainly based on photomet-
ric time series and, sometimes, on photometric colours as well.
Good examples in the field of classification, are the series of pa-
pers on MACHO, OGLE and ASAS data (for RR Lyrae stars,
for example, see Alcock et al. (2003), Soszynski et al. (2003)
and Wils et al. (2006), for MACHO, OGLE and the NSVS re-
spectively), where catalogues of distinct variability classes are
compiled according to several selection criteria (rules) and, in
some occasions, with human intervention. Basically, the prob-
lem of supervised classification of variable objects can be de-
scribed as that of defining general boundaries (hard or fuzzy)
in the hyperspace of the features that describe the classes, based on
a set of examples of each class.

The field of Machine Learning and Pattern Recognition of-
fers a wealth of alternatives for defining more complex, flexible,
and general boundaries than the hyperboxes used in the com-
pilation of catalogues, minimizing at the same time the human
intervention in the classification process. In this sense, the VSOP
automatic variability classifier will build upon a previous effort
(Sarro et al. 2006; Debusscher et al. 2006, 2007) carried out dur-
ing the past few years to i) create a well defined training set of
bona fide variable objects belonging to the most important and
numerous classes, ii) analyse the most relevant and informative
features that describe these classes and iii) to study and compare
different approaches to the task of classification, from Bayesian
Networks (Pearl 1988) to Bayesian averages of artificial neural
networks (Neal 1996) or SVMs (Support Vector Machines,
Vapnik 1995). The development of this classifier was motivated
by the wealth of data expected from the COROT space mission
(Baglin et al. 2000) and was thus designed to facilitate the in-
depth analysis of representative samples of these classes as ob-
served by COROT. It produces probabilistic class assignments
based on photometric time series parameters (harmonic ampli-
tudes of component frequencies, phase differences, amplitude
ratios, etc.). The objective is twofold: i) to generate class specific
object lists for further analysis by COROT’s Additional Program
scientists and ii) to detect objects lying outside the known den-
sity distribution of objects/classes in the parameter space; these
objects can possibly represent new astrophysical scenarios for
variability. The classifier presented in Debusscher et al. (2007)
has now been extended by the same authors to incorporate the
photometric colours $B – V$, $V – I$, $J – H$, $H – K$ and, for a re-
duced number of classes, also Strömgren indices (Sarro et al.
2007).

The effort described in the previous paragraphs is now be-
ing continued and adapted as part of the GAIA Data Processing
and Analysis Consortium (Gilmore et al. 2000) to incorporate at-
tributes that will be provided by GAIA instruments such as Blue
and Red spectrophotometry or spectroscopy near the Calcium
infrared triplet (Eyer 2006).

The VSOP automatic classifier is designed as a Virtual
Observatory compliant service capable of producing proba-
bilistic class assignments for objects with a wide variety
of attributes available (from time series photometry to multi-
wavelength spectra or photometric colours) and will thus rep-
resent the culmination of all the efforts on which it is based.

The development plan necessarily includes a first stage
where spectra of at least a representative sample of the COROT
training set objects have to be obtained in order to allow for
the incorporation of spectral information to the classifier. Here
is where VSOP initially will play a major part by collecting this
dataset. Subsequent to this, a study will be conducted in order to
determine an optimal subset of features providing the best clas-
sification performance. Obvious candidate features will be line
or band fluxes, equivalent widths, ratios, and/or combinations
thereof, line asymmetry measures, and derived physical parame-
ters ($T_{eff}$, $log g$, [Fe/H]). All these will be subject to the statistical
feature analysis classical in Machine Learning applications.
One obvious requisite of the classifier will be its capability for prediction based on incomplete data. This can happen if the spectral information only covers a fraction of the wavelength range used for training or if the resolution is too poor to separate several lines. Based on these specifications, several state-of-the-art machine learning algorithms will be applied to the training set and the performance assessed according to standard figures of merit like overall classification rates or the area under the receiver operating curve (Fawcett 2003).

While these efforts are already undergoing in the context of the space missions, the VSOP team is actively taking part in these new developments towards complete automatic classification.

5.3. Long-term vision

While it is growing rapidly, VSOP is flexible enough to allow us to imagine a long-term future. VSOP is a project implemented only by astronomers, using the MediaWiki software. With a simple, though large, collection of scripts developed over the year of operation, in addition to the already implemented spectrograph’s pipelines, VSOP is a quasi-automatic spectrum production machine whose results are automatically available through a wiki website. As emphasized before, the spectral and variability analysis will also become automatic in the future. The wiki provides a scriptable and clean interface which requires minimum human intervention, while centralizing all the work done by the team.

In this sense, it combines both the advantages of an automatically generated content website (homogeneity, reliability, cleanliness), with the total flexibility for the contributors to customize a specific point, and for the public to have access to the data, the information and the history. In that perspective, we could imagine an all-automatic wiki-database accepting pipeline-reduced spectra from any observatories in the world, not necessarily dedicated to variable stars.

This larger vision of complete automation while retaining absolute flexibility, is at the core of the VSOP future. As a first step in this direction, we have included the released data in Wikimbad (http://wikimbad.org) as well as directly on our own VSOP server.

5.4. An open community

We would like to stress that VSOP is an open community of scientists. We obtain, process, publish, and provide data at a growing rate, and to be able to keep up with that, we welcome any scientist from any background, who wants to contribute to the growth of the project. By joining the VSOP Team, first access rights to the data is granted, which has already spurred several follow-up projects, and will continue to do so. A major commitment of VSOP is the fast release of data, including fully calibrated reduced spectra. Once released, the data will of course be available to the entire community.

We believe in open sharing of information on all levels, and we believe this can be accomplished without sacrificing individual scientific ambitions by basing our collaboration on teamwork and the drive for fast scientific turnover. We would like to conclude with an open invitation to participate in VSOP and its mission, either as part of the VSOP team, or independently through the freely accessible data releases.

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