MEGARA-GTC stellar spectral library – II. MEGASTAR first release

E. Carrasco,1,2 E. Carrasco,1,2 M. Mollá,2,3 M. L. García-Vargas,1,2 A. Gil de Paz,4,5 N. Cardiel,4,5 P. Gómez-Alvarez3 and S. R. Berlanas6

1Instituto Nacional de Astrofísica, Óptica y Electrónica, INAOE, Calle Luis Enrique Erro 1, C.P. 72840 Santa María Tonantzintla, Puebla, Mexico
2Dpto. de Investigación Básica, CIEMAT, Aida. Complutense 40, E-28040 Madrid, Spain
3FRACTAL SLNE, Calle Tulipán 2, portal 13, 1A, E-28231 Las Rojas of Madrid, Spain
4Dpto. de Física de la Tierra y Astrofísica, Fac. CC. Físicas, Universidad Complutense de Madrid, Plaza de las Ciencias 1, E-28040 Madrid, Spain
5Instituto de Física de Partículas y del Cosmos, IPARCOS, Fac. CC. Físicas, Universidad Complutense de Madrid, Plaza de las Ciencias 1, E-28040 Madrid, Spain
6Departamento de Física Aplicada, Universidad de Alicante, E-03690 San Vicente del Raspeig, Alicante, Spain

ABSTRACT
MEGARA is an optical integral field and multi-object fibre-based spectrograph for the 10.4 m Gran Telescopio CANARIAS that offers medium-to-high spectral resolutions (FWHM) of \( R \approx 6000, 12 000, 20 000 \). Commissioned at the telescope in 2017, it started operation as a common-user instrument in 2018. We are creating an instrument-oriented empirical spectral library from MEGARA-GTC stars observations, MEGASTAR, crucial for the correct interpretation of MEGARA data. This piece of work describes the content of the first release of MEGASTAR, formed by the spectra of 414 stars observed with \( R \approx 20 000 \) in the spectral intervals 6420–6790 Å and 8370–8885 Å, and obtained with a continuum average signal-to-noise ratio around 260. We describe the release sample, the observations, the data reduction procedure and the MEGASTAR data base. Additionally, we include in Appendix A an atlas with the complete set of 838 spectra of this first release of the MEGASTAR catalogue.

Key words: astronomical data bases: atlases – astronomical data bases: catalogues – stars: abundance – stars: fundamental parameters.

1 INTRODUCTION
MEGARA, an acronym of Multi Espectrógrafo en GTC de Alta Resolución para Astronomía, is an optical integral field and multi-object spectrograph (MOS) for the Gran Telescopio CANARIAS (GTC). The MEGARA project was carried out by a consortium formed by the Universidad Complutense de Madrid (Spain) as the leading institution, the Instituto Nacional de Astrofísica, Óptica y Electrónica (Mexico), the Instituto de Astrofísica de Andalucía (Spain), and the Universidad Politécnica de Madrid (Spain), with the participation of European, Mexican, and US companies. In particular, the Spanish company FRACTAL SLNE played a key role by taking responsibility for the project management and system engineering, among other work packages. MEGARA accomplished its mission successfully: it finished fulfilling all the requirements within budget and schedule. The instrument combines versatility and performance offering both bidimensional and MOS high-efficiency spectroscopy with three spectral resolutions. MEGARA commissioning at GTC concluded on 2017 August 31 and was offered to the community in the second observing semester of 2018.

For a detailed description of the instrument and its scientific validation, see Carrasco et al. (2018), Gil de Paz et al. (2018, 2020), and Dullo et al. (2019). Here, we present a summary for completeness. Its main characteristics are shown in Table 1. In the bidimensional mode, an integral field unit (IFU) called a large compact bundle (LCB) provides a field of view (FoV) of 12.5 × 11.3 arcsec, plus eight additional seven-fibre minibundles for sky subtraction, located in the external part of the MOS field. In the MOS mode, 92 robotic positioners, each with a seven-fibre minibundle, cover an area on sky of 3.5 × 3.5 arcmin. The spatial sampling in both modes is 0.62 arcsec per fibre. Each spaxel size is a combination of a 100 μm core fibre coupled to a microlens that converts the f/17 entrance telescope beam to f/3 to minimize focal ratio degradation.

MEGARA provides low resolution, LR, \( R(\text{FWHM}) = 6000 \); medium resolution, MR, \( R(\text{FWHM}) = 12 000 \); and high resolution, HR, \( R(\text{FWHM}) = 20 000 \). In LR and MR with 6 and 10 volume phase holographic (VPH) gratings, respectively, the wavelength interval coverage is 3650–9750 Å. In HR, using two gratings, the wavelength range is 6405–6797 Å for HR-R and 8360–8890 Å for HR-I.

The MEGASTAR library is an ambitious long-term project with the goal of having stellar spectra in as many as spectral configurations as shown in Table 1, although the priority is now to create a large enough library in the HR set-ups. This is the second of a series of papers relating to the MEGARA-GTC library. In the first one (García-Vargas et al. 2020, hereafter Paper I), the authors comprehensively described this MEGARA-GTC spectral library and the rationale behind the 2988 star catalogue. It was created from libraries whose spectral resolutions are similar to that of MEGARA at LR, MR, and HR, covering a wide interval in \( T_{\text{eff}} \), \( \log g \), and abundance [M/H], generally as [Fe/H], and that could be observed from...
the Observatorio del Roque de los Muchachos with geographical coordinates 28°45′25″N latitude, 17°53′33″W longitude.

A discussion of the fundamental role of spectral libraries in single stellar population (SSP) models and the advantages and constraints introduced by theoretical and empirical libraries in these models is presented in Paper I. The main motivation of the MEGASTAR library is to produce a spectral atlas to be used as input spectra for POPSTAR models (see e.g. Mollá, García-Vargas & Bressan 2009; Martín-Manjón et al. 2010; García-Vargas, Mollá & Martín-Manjón 2013) to create synthetic templates required to interpret the observations taken with the same instrument set-up. To delimit the goal we have concentrated on HR- and HR-I spectral configurations with \( R \) \( \geq 20\,000 \), centred in the rest frame at H\( \alpha \) and the brightest line of the Ca II triplet, respectively, as there are no published theoretical or empirical catalogues with these resolution and spectral intervals. Moreover, such resolution with the combination of efficiency and telescope collecting area has not been provided by any other integral field instrument.

In this paper we present the first release of the MEGASTAR library formed by 838 spectra obtained in the two high-resolution spectral configurations: HR- and HR-I. This is the result of 152.25 h of filler-type observing time of 414 stars, covering different spectral types, effective temperature, surface gravity and abundances. The complete atlas with fully reduced and calibrated spectra will be available to the community at the time of the acceptance of this publication (https://www.fractal-es.com/megara/egalitestellarlibrary). In Section 2, we describe the main characteristics of the stars in this release. The observations and the data reduction pipeline are summarized in Sections 3 and 4, respectively. The data base produced to manage the star catalogue, the observation proposal preparation, the resulting observations, and the release itself are presented in Section 5. Some examples of our spectra are given in Section 6 and in Section 7 a summary and final remarks are included. We present in Appendix A an atlas with 838 spectra, corresponding to the 414 stars of this first release. Appendix B is the release summary table and Appendix C contains a table with Gaia DR2 data for the 388 stars of the release for which Gaia data exist. These three appendices will be published in the online version only.

2 SAMPLE

The distribution of the stellar types, retrieved from the SIMBAD astronomical data base, CDS\(^1\), or from published papers in the literature is shown in the left-hand panel of Fig. 1. The red dashed-line region represents the parameters for the whole MEGASTAR library while the solid blue bars indicate the present data release (1.0), DR-1 stars. The dominant spectral types in this release are G (113) and B (107), followed by F (77), K (39), A (29), O (27), M (13), W (7), S (1), and Flat (1). In the right-hand panel we present the \( \log g \) versus \( \Theta = 5040/T_{\text{eff}} \) diagram, over which we have plotted as cyan dots the values of the stars of the whole MEGARA library with estimated stellar parameters from the literature and those from DR-1 plotted as blue circles, green squares, and red triangles according to the three metallicity ranges as indicated in the plot. Finally, we have overprinted the Padova isochrones (Bertelli et al. 1994; Girardi et al. 2000; Marigo et al. 2008) since these are the ones used in the evolutionary synthesis POPSTAR models (see Mollá et al. 2009), which will be used in combination with MEGASTAR to provide a MEGARA-oriented set of spectra. The continuous update of this plot allows us to identify which areas of the physical parameter space must be completed to prioritize the future observations of the corresponding library stars, within the limitations of the filler-type program.

These stars cover the values of \( T_{\text{eff}} \), \( \log g \), and abundance \((M/H)\) presented in Fig. 2, where \( N_{\text{tot}} \) indicates the number of points used for each histogram, since for some stars one or more stellar parameters were not reported in the literature when we created the MEGASTAR catalogue. One of the goals of our project is to develop a method to homogeneously derive the stellar parameters for all the stars in the library. In particular, in Paper I we proposed a technique to estimate these parameters by using the best-fitting theoretical models to the combined spectrum of HR- and HR-I of 97 stars. We plan to apply this method to the 414 stars of this release in a forthcoming paper.

To juxtapose our sample with Gaia\(^2\) data, we found DR2 measurements for 388 MEGARA library stars. In the top panel of Fig. 3 we present a Hertzsprung–Russell diagram (HRD) showing the density of 65,921,112 Gaia stars in DR2 with good-quality parallax and photometry measurements, i.e. \( \Delta \sigma/\sigma < 0.1 \), \( \sigma_G < 0.02 \text{ mag} \), and \( \sigma_{GX} < 0.054 \text{ mag} \) (see Fig. 1 in Babusiaux et al. 2018, from the Gaia Collaboration). A Gaussian kernel-density estimate has been applied to the stellar density map. The units in this map are normalized to the maximum star density and the colour map is shown in a logarithmic scale; a lower threshold of \( 10^{-6} \) for the stellar density has been set. In the bottom panel of the same figure we show the HRD of Gaia DR2 stars with identical maximum parallax and photometry uncertainties as panel (a) but selecting only those 132,033 solar neighbourhood stars with parallaxes \( \sigma > 5 \text{ mas} \), that is, heliocentric distances below 200 pc. The MEGARA library stars with Gaia DR2 measurements are shown as light-blue filled circles. There is a lack of late-type stars due to the low fraction of main-sequence K and M stars in this release sample, around 13 per cent, particularly those with reliable Gaia DR2 measurements. Note that the Gaia DR2 saturation limit is at \( G = 3 \) but at \( G < 6 \) the quality of the astrometry starts to worsen (Lindegren et al. 2018). In Appendix B we include an extract of the Gaia DR2 measurements for 388 out of the 414 stars of MEGARA release 1.0. The details are described in Section 6.3.

3 OBSERVATIONS

Observations of the library are in progress and GTC open time has been awarded in four consecutive semesters. The observations included in this release 1.0 of MEGASTAR are from programmes

---

1http://simbad.u-strasbg.fr/

2https://gea.esac.esa.int/archive/documentation/GDR/
Figure 1. Properties of the release stars compared with the whole MEGASTAR library. Left: Distribution of spectral types retrieved from SIMBAD. The complete library MEGASTAR is shown in red, that corresponding to this data release (1.0) DR-1 in blue. The y-axis is in logarithmic scale. Right: Surface gravity log $g$ versus $\theta = 5040/T_{\text{eff}}$ diagram. We show (1) the values given by the Padova isochrones, which we would need for a synthesis code such as POPSTAR, in grey-scale (more intense in regions where there are more points); (2) the stars from the MEGASTAR library, with stellar parameters (w.s.p.) available in the literature, as cyan dots, and (3) the stars of this release shown with three metallicity intervals, indicated by different colours as labelled.

Figure 2. Histogram of the number of stars in this release as a function of $T_{\text{eff}}$ (a), log $g$ (b), and $[\text{M}/\text{H}]$ (c). Ntot indicates the number of points in each graph.

GTC22/18B, GTC37/19A, and GTC33/19B, with a total of 152.24 h of observed filler-type GTC open time. Table 2 shows the time requested, awarded, and observed through the three semesters whose observations are included in this release. 414 stars were observed were but five of them were observed twice; therefore we are reporting 419 observations carried out in the HR-$R$ and HR-$I$ spectral configurations, producing a total of 838 spectra. Additionally, the project was awarded another 75 h in 2020A.

The MEGASTAR library observations have been carried out as a filler-type program that, according to GTC rules, must accept the following values: seeing generally larger than 1.5 arcsec, any night type, especially bright and any kind of sky quality, in particular spectroscopic (non-photometric) time, with the possibility of having bad seeing being the most important criterion. The seeing distribution, as reported in GTC log files, is shown in Fig. 4 with first-quartile, median, and third-quartile values of 1, 1.8, and 2 arcsec, respectively. Nevertheless, the great advantage of creating a stellar library with an IFU instrument is that the spectral resolution is conserved as the slit width is constant as long as the stop is at the micro lens + fibre. In fact, to ensure that the flux was recovered in all the cases, we always added the individual spectra from 37 spaxels centred in the highest-flux fibre in the reconstructed LCB images. Most stars were observed in bright conditions. The telescope delivers a standard star per observing block (OB) for flux calibration and instrument response correction.

Thanks to the optimization of the observational strategy, the priority given to bright stars, and, overall, the manoeuvring and GTC overhead time saving to observe HR-$R$ and HR-$I$ in the same OB, in the three already fully observed semesters, the charged time per OB ranges from 850–1600 s for $V$-magnitude stars brighter than 12.5 with an average value of 1100 s star$^{-1}$ with the two set-ups, so that we have increased the originally expected efficiency by a factor of 1.6.

The limiting $V$ magnitude of the observed stars is 12.4. So far we have observed 80 stars with $T_{\text{eff}} > 20000$ K, seven of them being WR stars. This will allow us to produce an initial version of our $R = 20000$ SSP models for young populations. The targets proposed for the complete library are available through the MEGARA-GTC-library data base described in Section 5. The data base supports the working team for preparing and uploading the OBs to the GTC Phase 2 tool. To prepare a new OB set, we search unobserved stars in the MEGARA-GTC library filtered by a certain magnitude range in both the $R$ and $I$ bands and/or by spectral type or any stellar parameter, considering that all stars within that group and for a given set-up will have a similar signal-to-noise (S/N) ratio when choosing the appropriate exposure time in each set-up. The exposure times were
Figure 3. a) HRD showing the density of 65,921 Gaia stars in DR2; b) HRD of Gaia DR2 stars with identical maximum parallax and photometry uncertainties as in panel (a) but selecting only those 1322 solar neighbourhood stars. The 388 MEGARA-GTC spectral library with Gaia DR2 measurements are shown as light-blue filled circles.

Table 2. MEGARA-GTC spectral library observing time.

| Semester | Requested h | Granted h | Observed h | Stars observed |
|----------|-------------|-----------|------------|----------------|
| 2018B    | 50          | 50        | 63.85      | 176            |
| 2019A    | 50          | 50        | 11.66      | 32             |
| 2019B    | 75          | 75        | 76.73      | 206            |
| Total    | 175         | 175       | 152.24     | 414            |

estimated using the MEGARA exposure time calculator (ETC) tool⁵ to obtain S/N ratio values between 20 and 300. When the exposure time resulting from the ETC was longer than 30 s, we preferred to divide it into three exposures to be able to calculate the median of the three images to eliminate cosmic rays. Calibration images of halogen and ThNe lamps were obtained during the daytime.

4 DATA REDUCTION

The data reduction procedure was carried out using the MEGARA data reduction pipeline (DRP),² publicly available and open source under GPLv3 (GNU Public License, version 3 or later). It is a custom-made user-friendly tool formed by a set of processing recipes developed in PYTHON (Cardiel & Pascual 2018; Pascual et al. 2018, 2019). The recipes used for obtaining all the calibration images were MegaraBiasImage, MegaraTraceMap, MegaraModelMap, MegaraArcCalibration, MegaraFiberFlatImage, and MegaraLcbStdStar. Each recipe generates a product: a master bias image for bias subtraction; a trace map for fibre tracing; a model map for spectra extraction, as a result of a simultaneous fit to all the fibre profiles; a wavelength map for wavelength calibration; a fibre flat-field map for pixel-to-pixel relative sensitivity; and a master sensitivity function for flux calibration and instrument response correction. Each product has to be copied to a specific directory, previously defined by a calibration file tree structure (see Castillo-Morales, Pascual & Gil de Paz 2018).

Additionally, each routine generates a quality-control file allowing full tracking of the process. Halogen and ThNe lamp exposures are required for tracing flat-field and wavelength calibration. MEGARA DRP uses a general configuration file with the information necessary for data reduction like data directories, the polynomial degree, and the number of spectral lines required for wavelength calibration and the observatory extinction curve, among others. It operates in a sequential mode, i.e. each recipe requires products generated in the previous ones. An individual routine has its own input .yaml file that includes the images to be processed and the specific parameters required for that particular recipe. For example, when the temperature of the halogen lamp observations differs more than one degree from that of the source, a global offset must be applied for fibre tracing, which is done by giving a value to the extraction_offset parameter.

The last step is to apply the recipe MegaraLcbImage to the star image. This produces a row-stacked-spectra file with the individual fibre spectra corrected for atmospheric extinction and instrument response and flux calibrated. The sky subtraction is carried out automatically by calculating the median of the signal of the eight sky minibundles located outside the LCB FoV. The top panel of Fig 5 shows the reconstructed image of the star HD 048682, generated by the quick look analysis (QLA) tool (Gómez-Alvarez et al. 2018). The rectangular shape is the reconstruction of the LCB such that the dimensions are equivalent to 12.5 × 11.3 arcsec and the eight sky-minibundle projections are shown in the external part of the LCB.

The view of these sky minibundles has been collapsed for visualization purposes but they are located between 1.75 and 2.5 arcmin from the centre of the IFU. To extract the 1D spectrum we integrated three rings formed by 37 spaxels, shown in red, each

⁵http://gtc-phase2.gtc.iac.es/mect/etc/form
⁶https://github.com/guaix-ucm/megaradrp
Figure 5. Layout of the QLA tool. Top: reconstructed image of the star HD048682 on the LCB; the eight minibundles in the external part, collapsed for visualization, are used for sky subtraction. Bottom: final HR-I spectrum corresponding to the 37 selected spaxels marked in red in the LCB. The seeing during this observation was reported to be 2.5 arcsec.

equivalent to 0.62 arcsec on the sky. In the bottom panel the final HR-I spectrum corresponding to these 37 spaxels, after flux calibration and instrument response correction, is displayed. All the spectra were extracted in the same wavelength range: 6420–6790 Å in HR-R and 8370–8885 Å in HR-I. The flux is given in Jy.

We note that at the extreme wavelengths of the spectrum, shown in Fig. 5, the flux tends to rise. This effect, present in most of the spectra, is due to the coarse reciprocal dispersion and spectral resolution of the tabulated spectra of most spectrophotometric standard stars. During the determination of the system sensitivity function we had to degrade the MEGARA HR-R and HR-I observations of our standard stars. This coarse resolution implies that the tabulated fluxes at the edges of the wavelength range covered by these VPHs are affected by fluxes that correspond to wavelengths that are not explored by our data. Therefore, we ought to degrade the MEGARA observations of these standards using (null) fluxes that would come from wavelengths beyond each specific observed interval. This leads the degraded reference spectrum and the corresponding master sensitivity curve to drop faster at these extreme wavelengths, \( \sim 50 \) Å at each size, than the actual system sensitivity. As a consequence of this edge effect, the flux-calibrated spectra tend to rise at the very extremes of each specific wavelength range.

In order to obtain a first-order correction to this effect we have divided every spectrum by a normalized continuum obtained from the fitting to the rather flat HR-R and HR-I spectra of BD+083095. The corresponding fits were performed following the same approach described in Paper I. Fig. 9 shows the result for BD+083095. All the stars of the release have been corrected with this normalized continuum. It is important to remark that this is not producing spectra normalized to the continuum. In Paper III a specific continuum fitting for each star will be carry out as part of the procedure for determining the physical stellar parameters. Accordingly, in the next release we will also include all normalized spectra.

To assess the quality of the spectra, we report in Fig. 6 the distribution of the measured continuum S/N ratio averaged over the whole spectrum, following the recipe by Stoehr et al. (2008), for the HR-R and HR-I spectral configurations in the top and bottom panels, respectively. In both cases the average S/N ratio is around 260. The plots are similar since most of the star observations included the two spectroscopy set-ups in the same OB to be executed in sequence. The S/N ratio distribution spreading over a wide range of values is a consequence of the nature of the GTC filler-type program itself that does not guarantee any specific observing conditions. On the contrary, these observations are conducted randomly and out of the standard scheduling, normally done whenever other programmed observations cannot be executed. This is due mostly to bad observing conditions but filler observations can be carried out just to complete the night time or during twilight, and sometimes the conditions can be good.

Additionally, any single observation has to be executed with the exposure time pre-defined in the GTC Phase 2 tool. In other standard programs the observing conditions are guaranted and the exposure time is estimated accordingly. In MEGASTAR observations, the integration time has to be pre-defined no matter what the observing conditions are, increasing the uncertainty to the observation quality.
Our decision of extracting 37 spaxels for all spectra, regardless of the seeing value, guarantees that all the flux is integrated, and generally improves the S/N ratio for bad seeing observations but might degrade it for very good seeing conditions since in these cases we are mostly adding noise when extracting all 37 spaxels.

Fig. 7 shows the S/N ratio as a function of the total exposure time for the HR-R and HR-I spectra in the top and bottom panels, respectively. The size of each filled circle is proportional to the apparent brightness of the star in the J band for the HR-R (top) and the HR-I (bottom) spectra. As a reference, we include the S/N ratio predictions of the MEGARA ETC for different R-band and I-band magnitudes as indicated, considering average observing conditions. For more details see Section 4.

5 MEGARA-GTC LIBRARY DATA BASE
Our goal in this project has been twofold, to assemble input spectra for POPSTAR models for the interpretation of stellar populations in a broad range of observations with MEGARA, and to generate a public data base of reduced and calibrated spectra for other MEGARA users. We developed a data base in MYSQL and a web-based tool to manage the stellar data and the observed spectra that will be available to the community as part of this MEGASTAR release 1.0. Via a scheme of permission levels, different actions are allowed. The public user will be able to retrieve the information compiled for each star and observations and to download the individual reduced spectrum or the full release as described in this section.

The data base resides on https://www.fractal-es.com/megaragtc-stellarlibrary/ and offers different menus: source, observations, library completion, download, utilities, project description, and papers. The left-hand panel of Fig. 8 shows the menus available. The source functionality allows the user to list the sources of the complete library; to search sources when filtering by different parameters such as source name, RA, Dec., and spectral type, among others, and to browse observations of a source. The filtering parameters are those created in the source form where the complete star information resides. In the top right-hand panel of Fig. 8 the layout of the source form is shown for the star BD+083095: its RA and Dec. coordinates, the corresponding ∆RA and ∆Dec. proper motions, the spectral type and luminosity class, and the U, B, V, R, I & J Johnson–Cousins magnitudes retrieved from the SIMBAD data base are displayed. This star was observed in the GTC observing semester 2018B. In this example, the stellar parameters Teff, log g, and [Fe/H] were extracted from the HARP catalogue. In the Teff-L, log g-L, and [Fe/H]-L windows the ‘L’ stands for our own library determination of the stellar physical parameters that will be provided in the near future. The comments section shows that the star was observed in both HR-R and HR-I set-ups. In other comments is the reference to the HARPS project publication from which the star and the values of the physical parameters Teff, log g, and [Fe/H] were compiled.

The observations menu allows listing and searching of observations, filtering them by source name, RA, Dec., VPH, and instrument mode, among other parameters, as seen in the bottom left-hand panel of Fig. 8. An observation form is created for each spectral set-up observation, as shown in the bottom right-hand panel of the same figure for an HR-I observation. The first window has the name and coordinates of the star retrieved from the source form. In the observation data window the following information is provided: BD+083095_27487_HR-I id is a unique code used internally to identify the observation; the star was observed in the HR-I set-up with three exposures of 60 s each, under 1.5 arcsec seeing, while the temperature at the MEGARA spectrograph bench was 15.7 °C, the HR-I spectrum is public. In the comments window GTC22-18B_0154 indicates that MEGARA library observing program has assigned the code GTC22, the OB number is 0154, and the observation was carried out on 2019 February 22. The data products available are the HR-I spectra in two formats, with BD+083095_27487_HR-I_waveJ.fits and BD+083095_27487_HR-I_waveJ.asc being their filenames; the ‘J’ in the filenames indicates that the flux-calibrated spectra are provided in Jy. The calibration comments window shows the DRP recipes used in the data reduction process described in Section 4: in summary, that the spectrum was obtained after bias subtraction, fibre tracing, wavelength calibration, flat-field, extraction, extinction, and spectral response correction and flux calibration. The individual spectrum can be visualized by clicking the HR-I or HR-R buttons in the observation list menu. In this case, the spectra that would be displayed for the star BD+083095 are shown in Fig. 9. All the lists created in the source and observations menus can be exported to PDF, MSEXCEL, or ASCII files.

In the library completion menu the full library button paints a graph of all the stars of the library grouped by three ranges of metallicity: [Fe/H] < −0.7, −0.7 ≤ [Fe/H] ≤ −0.2, and [Fe/H] > −0.2, while the observed stars button paints a plot with all the stars observed.
in the same defined [Fe/H] intervals. Furthermore, in case the user wishes to upload her/his own stars, she/he can choose to overlay the graph with one of these two graphics: full library or observed stars. In the utilities menu the user can download the spectra plot application to plot the data product files. The useful links menu includes links to ING Object Visibility--STARALT, to the SIMBAD astronomical data base, and to the MEGARA exposure time calculator.

The download menu leads to the link ‘click here to download the latest release’. The current release 1.0 presented in this paper contains observed and calibrated spectra from the MEGASTAR library stars after a basic quality-control check. All spectra were reduced with MEGARA DRP passing through all standard reduction steps described in Section 4. The release download includes: (i) a readme.txt file with the description and the content of the release; (ii) a list of the stars with a description of the observations (release summary 1.0) in MSE XCEL and ASCII formats; (iii) a main directory and three sub-directories with the release spectra in ASCII, FITS, and JPG formats; and (iv) a JAVA application for the display of the observations.

The star information in the release files is mainly that displayed in the sources and observations forms. The column headers of the release summary 1.0 (.xls and .txt) files, shown in Table 3, are as follows: name, main star name; right ascension (RA) and declination (Dec.) in equatorial coordinates J2000.0, spectral type and luminosity class; and referenced available Johnson–Cousins magnitudes U, B, V, R, I, and J; all these parameters are obtained from the SIMBAD data base, updated to 2020 July 8. The other name column is for any alternative names for the star. The next one shows the VPH grating used in the observation; the values for effective temperature, surface gravity (log), and iron abundance (log) $T_{\text{eff}}, \log g$, and [Fe/H] are displayed in the next three columns, respectively, for those stars whose values have been extracted from other libraries. In the reference column is the name of the original catalogue from which the star was selected; other comments are those relating to the star. The next two columns indicate the name of the ASCII/FITS spectrum file provided by the release and the GTC observing semester, obs. period. The observation parameters of each star are presented in the next three columns: the number of exposures, No. exp., and the exposure time, exp. time (s), from the images headers and the seeing (arcsec) as reported by GTC in the observation log file. The last one, obs-GTC, displays comments relating to the observations including the OB number and the observation date. The release_summary_1.0 files (.xls and .txt) are included in Appendix B.

The main directory observations_release_1.0 has the ASCII, FITS, and JPG sub-directories with the release spectra in the corresponding formats and three files with the spectra lists. An example of the JPG spectra is shown in Fig. 9 for the star BD+083095 in HR-R; the header of the plot includes the spectrum filename. The JAVA application spectraplot.jar allows further visualization and basic analysis of the ASCII or FITS spectra. The JAVA plots includes the star name, the spectrograph set-up, the spectral type, and the values of $T_{\text{eff}}, \log g$, and [Fe/H] from the literature whenever available.

6 MEGASTAR LIBRARY FIRST-RELEASE STARS

6.1 MEGARA stellar atlas

In Appendix A, available online, we present an atlas of the 838 spectra of this first MEGASTAR release, ordered alphabetically by star name. In Table 5 we list the names of the stars in the same way as their spectra are displayed in the corresponding page of that appendix. To illustrate the content of the atlas, Fig. 10 shows an extract of 28 spectra of 14 stars. For each star the atlas displays the HR-$R$,
from 6400–6800 Å, on the left, followed by the HR-I set-up, from 6400–8850 Å, on the right. The star name, the spectral type, and the stellar parameters compiled from the literature (if they exist) are labelled inside each HR-I plot. The colour of the spectrum has been associated with the star spectral type in the literature as follows: purple, WR; blue, O; cyan, B; green, A; orange, F; red, G; magenta, K; maroon, M; grey, S; and black, flat. Spectra shown in Fig. 10 are therefore from stars of different spectral type and luminosity class, in particular, from left to right and from top to bottom, F3 (BD+083095), sdF8 (BD+191730), G0 (G234–28), A1V (HD014191), O5e (HD015558), WC6 (HD016523), B9IV (HD027295), O9.5Ia (HD030614), M1.5Ia (HD035601), B9V (HD037269), A2II (HD039866), K0 (HD042983), S4.5 (HD064332) and G8V (HD101501).

Fig. 11 shows a spectral-type sequence of HR-I set-ups. All the spectra of the release were normalized dividing by the flux at λ = 6650 Å in HR-R and at λ = 8780 Å in HR-I, and shifted vertically. On the left-hand side of the figure the HR-R set-up spectra are shown, while on the right-hand side the corresponding HR-I set-up spectra are presented. Each stellar spectrum has the name of the star in the HR-R panel and the corresponding spectral type in the HR-I panel.

6.2 Examples of hot stars

The first release of the MEGARA-GTC library also includes a representative sample of hot stars, i.e., there are 51 OB stars earlier than B3 and seven Wolf–Rayet stars. As an example, in Fig. 12 we show the spectra obtained for three of them: HD 000108 (or WR#2), HD 000108, and HD 058343.

HD 000108 is an Of?p star (Walborn et al. 2010) that shows line profiles in our HR-R spectrum with those reported by Schultz & Wade (2017) (for the 2015 period) and Martins et al. (2010) (for the period 2007–2009) suggests that HD 000108 might be moving towards a high-emission state, since it is much stronger than in both observations.

Finally, HD 058343 is a runaway Be star (Hoogerwerf, de Bruijne & de Zeeuw 2001; Tetzlaff, Neuhauser & Hohle 2011) for which the SIMBAD data base provides a spectral classification of B2 Vne, although in the literature we can find spectral types that vary between
Figure 10. Extract from the MEGASTAR first-release atlas. Each row shows the HR-\(R\) (left) and HR-\(I\) (right) spectra for two observed stars. Thus, columns 1 and 3 are HR-\(R\) spectra while columns 2 and 4 contains HR-\(I\) spectra. Columns 1 and 2, or columns 3 and 4, refer to the same observation. The colour indicates the published spectral type of the star: purple, WR; blue, O; cyan, B; green, A; orange, F; red, G; magenta, K; maroon, M; and grey, S. The complete atlas is presented in Appendix A, available online only.
Figure 11. Sequence of some spectra from stars of the first release with different spectral types. The left-hand panels show the HR-R set-up spectra while the right-hand ones display the corresponding HR-I set-up spectra. Each spectrum has the name of the star in the left-hand panel, while the corresponding spectral type is labelled in the right-hand one.

B2 and B4 (e.g. Indo–US library, Silaj et al. 2010; Ahmed & Sigut 2017; Cochetti et al. 2020). Stellar parameters and Hα line profile variability has been investigated by Arcos et al. (2018) and Ahmed & Sigut (2017) within the BeSOS and MiMeS surveys, respectively. Our spectrum clearly shows strong emission in the Hα line profile. We highlight that all Paschen lines appear in emission with absorption wings.

These examples show the variety of line profiles that can be found in the spectra of massive hot stars. They are strongly affected by different factors that play an important role in their evolutionary...
Figure 12. Normalized spectra of three hot stars of this first release: HD 058343 (cyan), HD 000108 (blue), and HD 006327 (purple) in the two spectral configurations: HR-R (left) and HR-I (right). The star names and spectral types are indicated in black while the main hydrogen and helium lines are shown with the identification labelled in red.

behaviour, such as rotation, binarity, magnetic fields, or strong stellar winds (Langer 2012). Therefore, the inclusion of high-quality OB star spectra in the MEGASTAR data base, which will increase in future releases, can help to study their physics, providing empirical data to constrain the complex theoretical evolutionary models of young stellar populations.

6.3 Additional data: Gaia DR2

As complementary information to the first release, in Appendix C we include Gaia DR2 measurements for 388 stars of the MEGASTAR library and additional useful information. In Table 4 the columns headers of Appendix C are described. The Gaia DR2 data included were retrieved using the PYTHON interface for querying the VizieR web service provided by ASTROQUERY,5 and an affiliated package of ASTROPY.6 The table incorporates the default columns that are pre-selected when accessing the catalogue I/345/gaia2 (Gaia Collaboration et al. 2018). For completeness, the table includes, when available, the Hipparcos (Høg et al. 2000) and Tycho (van Leeuwen 2007) identifications, as well as the specific designation when the objects are recognized as known variable stars in the SIMBAD data base.

5https://astroquery.readthedocs.io/en/latest/vizier/vizier.html
6http://www.astropy.org, (Astropy Collaboration et al. 2018).

7 SUMMARY

In this paper we present the first release (1.0) of the MEGARA-GTC stellar spectral (MEGASTAR) library composed of 838 spectra from 414 different stars of a wide range of spectral types and hence physical parameters. All the spectra are given reduced and calibrated with MEGARA DRP, which has been proved to be robust and reliable. The data have passed through all standard reduction steps: bias subtraction, fibre tracing and extraction, flat-field and wavelength calibration, instrument response correction, and flux calibration (Jy). The spectra were all taken as filler-type GTC open-time observations and were observed under different seeing conditions. Nevertheless, as we extracted 37 spaxels around the star’s centroid position, most of the flux is guaranteed for seeing better than 2.5 arcsec. The spectra were extracted in the same wavelength intervals: 6420–6790 Å in HR-R and 8370–8885 Å in HR-I.

We have compiled an atlas with all 838 spectra (Appendix A), the main characteristics of the stars in the release sample (Appendix B), and the Gaia DR2 data for 388 stars, from the 414 observed, shared with our release 1.0 sample (Appendix C). We have described in this work the atlas and table contents but the three appendices will be published online only.

We have developed a data base that has allowed us to handle the complete stellar library (2988 stars), to select and update the stars to be observed in the different semesters, and to generate complex files
Table 4. Column description of the Appendix C file, available online only. Includes data from Gaia DR2 for 388 stars of the MEGASTAR library.

| Column       | Description                                                                 |
|--------------|-----------------------------------------------------------------------------|
| Name         | Star name (n)                                                               |
| RA           | Right ascension (2000.0) hh:mm:ss (n)                                        |
| Dec.         | Declination (2000.0) dd:mm:ss (n)                                           |
| Sp. type     | Spectral type (n)                                                           |
| RV_VALUE     | Radial velocity (km s\(^{-1}\)) (n)                                          |
| U            | Johnson–Cousins U magnitude (n)                                             |
| B            | Johnson–Cousins B magnitude (n)                                             |
| V            | Johnson–Cousins V magnitude (n)                                             |
| R            | Johnson–Cousins R magnitude (n)                                             |
| I            | Johnson–Cousins I magnitude (n)                                             |
| J            | Johnson–Cousins J magnitude (n)                                             |
| H            | Johnson–Cousins H magnitude (n)                                             |
| K            | Johnson–Cousins K magnitude (n)                                             |
| Other name   | Alternative name of the star (n)                                            |
| T\(_{\text{eff}}\) | Effective temperature from the literature (K) (n)               |
| log g        | Surface gravity (log) from the literature (n)                             |
| [Fe/H]       | Iron abundance from the literature (log) (n)                                |
| Reference    | Original catalogue from which it was inherited (n) |  |
| Other comments | Comments relating to the star (n)                                     |
| MAIN_ID      | Default name in the SIMBAD data base (n)                                   |
| id_variable  | ID if the star is identified as a known variable (n)                       |
| id_hipparccos| Star name in the Hipparcos catalogue (n)                                   |
| id_tycho     | Star name in the Tycho catalogue (n)                                        |
| id_gaiaid2   | Star name in the Gaia DR2 catalogue (n)                                     |
| RA,ICRS      | Barycentric right ascension (ICRS) at Ep = 2015.5 (n)                      |
| e_RA,ICRS    | Standard error of right ascension (mas)                                     |
| DE,ICRS      | Barycentric declination (ICRS) at Ep = 2015.5 (n)                          |
| e_DE,ICRS    | Standard error of declination (mas)                                         |
| Source       | Unique source identifier (unique within a particular data release)          |
| Plx          | Absolute stellar parallax (mas) (n)                                        |
| e_Plx        | Standard error of parallax (mas) (n)                                        |
| pmRA         | Proper motion in RA direction (mas yr\(^{-1}\)) (n)                       |
| e_pmRA       | Standard error of proper motion in RA (mas yr\(^{-1}\)) (n)                |
| pmDE         | Proper motion in Dec. direction (mas yr\(^{-1}\)) (n)                      |
| e_pmDE       | Standard error of proper motion in Dec. (mas yr\(^{-1}\)) (n)              |
| Dup          | [0/1] Source with duplicate sources                                         |
| FG           | G-band mean flux (n)                                                        |
| e_FG         | Error on G-band mean flux (n)                                               |
| Gmag         | G-band mean magnitude (Vega)                                                |
| e_Gmag       | Standard error of G-band mean magnitude (Vega)                             |
| FBP          | Mean flux in the integrated BP band (n)                                     |
| e_FBP        | Error on the integrated BP mean flux (n)                                    |
| Bpmag        | Integrated BP mean magnitude (Vega)                                        |
| e_Bpmag      | Standard error of BP mean magnitude (Vega)                                  |
| FRP          | Mean flux in the integrated RP band (n)                                     |
| e_FRP        | Error on the integrated RP mean flux (n)                                    |
| Rpmag        | Integrated RP mean magnitude (Vega)                                        |
| e_Rpmag      | Standard error of RP mean magnitude (Vega)                                  |
| BP-RP        | BP – RP colour                                                             |
| RV           | Spectroscopic radial velocity in the solar barycentric reference frame (n) |
| e_RV         | Radial velocity error (km s\(^{-1}\)) (n)                                 |
| Teff_2       | Stellar effective temperature from A–P (K)                                 |
| AG           | Estimate of extinction in the G band from (n)                             |
| E(BP-RP)     | Estimate of reddening from A–P (n)                                         |
| Rad          | Estimate of radius from A-FLAME (solRad) (n)                              |
| Lum          | Estimate of luminosity from A-FLAME (solLum)                               |

Notes. (n) Source: SIMBAD. (n) indicates a possible blank or null column.

Acknowledgements

This work has been supported by MINECO-FEDER grants AYA2016-75808-R, AYA2016-79724-C4-3-P, RTI2018-096188-B-100, AYA2017-80589-REDT and has been partially funded by FRACTAL, INAOE, and CIEMAT. This work is based on observations made with the Gran Telescopio Canarias (GTC), installed in the Spanish Observatorio del Roque de los Muchachos, on the island of La Palma. This work is based on data obtained with the MEGARA instrument, funded by European Regional Development Funds (ERDF), through the Programa Operativo Canarias FEDER 2014–2020. The authors thank the support given by Dr Antonio Cabrera and Dr Daniel Reverte, GTC Operations Group staff, during the preparation and execution of the observations at the GTC. This research has made use of ASTROPY, a community-developed core PYTHON package for astronomy. This research has made use of the SIMBAD data base and the VizieR catalogue access tool, CDS, Strasbourg, France (doi: 10.26093/cds/vizier). The original description of the VizieR service was published in Ochsenbein, Bauer & Marcout (2000). This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the Gaia has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

Data Availability

The fully reduced and calibrated spectra of MEGASTAR first release are available at https://www.fractal-es.com/megaragtc-stellarlibrary. The access username is public and the password is Q50ybAZm.

Appendix A is an atlas of the 838 spectra of the 414 stars of this data release, i.e. the plots of all the spectra are shown. The information in the appendix is described by a table to find the page where the spectra for each star are located. This table is in the main manuscript as Table 5. The atlas is available as a PDF format file.

Appendix B is a table with the information associated with this data release. The columns description is given in Table 3 of the
Table 5. Summary of the stars of the MEGASTAR first release whose spectra are shown in Appendix A, available online only. The first column is the page number of Appendix A where the spectra can be found. The stars are listed in the same order that they are displayed in each page of this atlas.

| Page | Stars |
|------|-------|
| A3   | BD−32525 BD−122669 BD+083095 BD+092190 BD+130013 BD+191730 BD+195116B |
| A4   | BD+203603 BD+241676 BD+262606 BD+351484 BD+381670 BD+511696 BD+541399 |
| A5   | G171−010 G197−45 G202−65 G234−28 HD000108 HD000358 |
| A6   | HD00560 HD00886 HD03360 HD03369 HD03628 HD03644 HD04004 |
| A7   | HD03269 HD034191 HD034194 HD034597 HD034911 HD034914 HD034979 |
| A8   | HD020804 HD020512 HD021742 HD022484 HD023862 HD024341 HD024451 |
| A9   | HD024534 HD024912 HD025173 HD025825 HD026756 HD027126 HD027282 |
| A9   | HD030649 HD030676 HD031219 HD031293 HD031374 HD031996 HD032537 |
| A10  | HD03632 HD033904 HD034078 HD034255 HD034797 HD034816 HD035468 |
| A11  | HD035497 HD035601 HD035961 HD036066 HD036130 HD036165 HD036395 |
| A12  | HD037742 HD037958 HD038230 HD038529 HD038650 HD038899 |
| A13  | HD035987 HD039773 HD039801 HD039866 HD040801 HD040964 HD041117 |
| A14  | HD041330 HD041357 HD041501 HD041692 HD041808 HD042035 HD042250 |
| A15  | HD042553 HD042543 HD042597 HD042807 HD042983 HD043042 HD043153 |
| A16  | HD043264 HD043285 HD043286 HD043526 HD044109 HD044274 HD044537 |
| A17  | HD044614 HD045321 HD045391 HD045410 HD045829 HD045910 HD046223 |
| A18  | HD025637 HD043680 HD046480 HD046588 HD046703 HD047127 HD047302 |
| A19  | HD047839 HD048279 HD048682 HD049330 HD049409 HD049732 HD050522 |
| A20  | HD050696 HD051219 HD051309 HD051530 HD052711 HD053929 HD054371 |
| A21  | HD054717 HD055280 HD055575 HD055606 HD056925 HD056925 HD058343 |
| A22  | HD037747 HD039320 HD039594 HD040730 HD040900 HD040900 HD040900 |
| A23  | HD041178 HD041715 HD041715 HD041715 HD041715 HD041715 HD041715 |
| A24  | HD076943 HD078175 HD078209 HD078249 HD078362 HD078418 HD078712 |
| A25  | HD079028 HD079210 HD079452 HD079765 HD080081 HD080218 HD080536 |
| A26  | HD082106 HD083425 HD084737 HD086133 HD086560 HD086728 HD086986 |
| A27  | HD088446 HD088609 HD088725 HD088737 HD089010 HD089125 HD089269 |
| A28  | HD089307 HD089744 HD08995 HD090537 HD090839 HD090839 HD090839 |
| A29  | HD095128 HD095241 HD096094 HD096436 HD097560 HD097855 HD097916 |
| A30  | HD099028 HD099747 HD100030 HD100446 HD100563 HD100696 HD101107 |
| A31  | HD101177 HD101177B HD10227 HD101501 HD101606 HD101690 HD102870 |
| A32  | HD104556 HD104979 HD104985 HD105087 HD106038 HD106156 HD107213 |
| A33  | HD107328 HD107582 HD108177 HD10958 HD109995 HD110897 HD112735 |
| A34  | HD113002 HD113606 HD114710 HD114762 HD115136 HD115393 HD116316 |
| A35  | HD117176 HD117243 HD118244 HD119291 HD120136 HD123299 HD124570 |
| A36  | HD125560 HD126271 HD126511 HD126660 HD128167 HD128987 |
| A37  | HD129174 HD129336 HD131111 HD131156 HD131156B HD131507 HD132756 |
| A38  | HD134083 HD134113 HD135101 HD137391 HD138573 HD138749 HD138764 |
| A39  | HD139457 HD14004 HD141272 HD142091 HD142860 HD142860 HD143807 |
| A40  | HD144206 HD144284 HD145148 HD145389 HD147394 HD148816 |
| A41  | HD149121 HD149161 HD153558 HD155763 HD160762 HD163433 HD165029 |
| A42  | HD165358 HD165670 HD166046 HD169822 HD173524 HD174912 HD175535 |
| A43  | HD176437 HD180554 HD183144 HD185396 HD187123 HD187879 HD188001 |
| A44  | HD188209 HD190887 HD190229 HD190603 HD192639 HD192907 HD193432 |
| A45  | HD193793 HD194453 HD195198 HD195592 HD196426 HD196610 HD198183 |
| A46  | HD198478 HD199478 HD199579 HD200580 HD206165 HD208374 HD208501 |
| A47  | HD209459 HD209975 HD210809 HD211472 HD212076 HD212422 HD212454 |
| A48  | HD215560 HD215420 HD214080 HD214167 HD214168 HD214689 HD215512 |
| A49  | HD215704 HD216831 HD216916 HD217086 HD217833 HD217891 HD218045 |
| A50  | HD218059 HD218376 HD220182 HD220876 HD220876 HD220933 HD221585 |
| A51  | HD221830 HD224544 HD224559 HD224801 HD224926 HD225160 |
| A52  | HD233345 HD235511 HD237846 HD241253 LHS10 Ross−889 |
main manuscript. This appendix is provided in ASCII and MSEXCEL formats.

Appendix C is a table with the available information in Gaia DR2 for the 388 stars it has in common with the MEGASTAR library. The column description is given as Table 4 in the main manuscript. This appendix is provided in ASCII and MSEXCEL formats.

REFERENCES

Ahmed A., Sigut T. A. A., 2017, MNRAS, 471, 3398
Arcos C., Kanaan S., Chávez J., Vanzi L., Araya I., Curé M., 2018, MNRAS, 474, 5287
Astropy Collaboration et al., 2018, AJ, 156, 123
Babusiaux C. et al., 2018, A&A, 616, A10
Bertelli G., Bressan A., Chiosi C., Fagotto F., Nasi E., 1994, A&AS, 106, 275
Cardiel N., Pascual S., 2018, guaix-ucm/megaradrp-calibrations: release 2018.1
Carrasco E. et al., 2018, Proc. SPIE, 10702, 1070216
Castillo-Morales Á., Pascual S., Gil de Paz A., 2018, MEGARA Data Reduction Cookbook
Chené A.-N. et al., 2019, MNRAS, 484, 5834
Cochetti Y. R., Zorec J., Cidale L. S., Arias M. L., Aidelman Y., Torres A. F., Frémat Y., Granada A., 2020, A&A, 634, A18
Conti P. S., Massey P., Vreux J.-M., 1990, ApJ, 354, 359
Crowther P. A., 1993, PhD thesis, University of London
Dullo B. T. et al., 2019, ApJ, 871, 1
Gaia Collaboration et al., 2018, A&A, 616, A1
García-Vargas M. L., Mollá M., Martín-Manjón M. L., 2013, MNRAS, 432, 2746
García-Vargas M. L. et al., 2020, MNRAS, 493, 871 (Paper I)
Gil de Paz A. et al., 2018, Proc. SPIE, 10702, 1070217
Gil de Paz A. et al., 2020, submitted to A&A
Girardi L., Bressan A., Bertelli G., Chiosi C., 2000, A&AS, 141, 371
Gómez-Alvarez P. et al., 2018, Proc. SPIE, 10707, 107071L
Hamann W.-R., Gräfener G., Liermann A., 2006, A&A, 457, 1015
Hamann W.-R. et al., 2019, A&A, 625, A57
Hiltner W. A., Schild R. E., 1966, ApJ, 143, 770
Hoogerwerf R., de Bruijne J. H. J., de Zeeuw P. T., 2001, A&A, 365, 49
Hog E. et al., 2000, A&A, 355, L27
Lindegren L. et al., 2018, A&A, 616, A2
Langer N., 2012, ARA&A, 50, 107
Maíz Apellániz J. et al., 2019, A&A, 626, A20
Marigo P., Girardi L., Bressan A., Groenewegen M. A. T., Silva L., Granato G. L., 2008, A&A, 482, 3
Martín-Manjón M. L., García-Vargas M. L., Mollá M., Díaz A. I., 2010, MNRAS, 403, 2012
Martins F. et al., 2010, MNRAS, 407, 1423
Mollá M., García-Vargas M. L., Bressan A., 2009, MNRAS, 398, 451
Nazé Y., Walborn N. R., Martins F., 2008, Rev. Mex. Astron. Astrofis., 44, 331
Nazé Y., Ud-Doula A., Soman M., Rauw G., De Becker M., Walborn N. R., 2010, A&A, 520, A59
Ochsenbein F., Bauer P., Marcout J., 2000, A&AS, 143, 9
Pascual S., Cardiel N., Picaço-Sánchez P., Castillo-Morales A., Gil de Paz A., 2018, guaix-ucm/megaradrp:v0.8
Pascual S., Cardiel N., Gil de Paz A. et al., 2019, in Montesinos B., Asensio Ramos A., Buitrago F., Schödel R., Villaver E., Pérez-Hoyos S., Ordóñez-Endezbarria I., eds, Proc. of the XIII Scientific Meeting of the Spanish Astronomical Society, Highlights on Spanish Astrophysics X, Spain, p. 227
Sander A., Hamann W.-R., Todi H., 2012, A&A, 540, A144
Shultz M., Wade G. A., 2017, MNRAS, 468, 3985
Silaj J., Jones C. E., Tycner C., Sigut T. A. A., Smith A. D., 2010, ApJS, 187, 228
Stoehr F. et al., 2008, in Lewis J., Argyle R., Bunclark P., Evans D., Gonzales-Solares E., eds, Astronomical Data Analysis Software and Systems XVII. ASP Conference Series, San Francisco, p. 54
Tetzlaff N., Neuhäuser R., Hohle M. M., 2011, MNRAS, 410, 190
van Leeuwen F., 2007, A&A, 474, 653
Walborn N. R., Sota A., Maíz Apellániz J., Alfaro E. J., Morrell N. I., Barbuy R. H., Arias J. I., Gamen R. C., 2010, ApJ, 711, L143

SUPPORTING INFORMATION

Supplementary data are available at MNRAS online.

Table S1. Summary of the stars of the MEGASTAR first release whose spectra are shown in this appendix.

Figure S1. Stellar spectra ordered by name, given in each plot, for this release I catalogue.

Please note: Oxford University Press is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the article.

This paper has been typeset from a TEX/LATEX file prepared by the author.