

# gr8stars – I. A homogeneous spectroscopic study of bright FGKM dwarfs and a public library of their high-resolution spectra

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## ABSTRACT

As the fields of stellar and exoplanetary study grow and revolutionary new detection instruments are created, it is imperative that a homogeneous, precise source of stellar parameters is available. This first work of the gr8stars collaboration presents the all-sky magnitude limited sample of 5645 bright F,G,K, and M type dwarfs, along with homogeneously derived spectroscopic parameters of a subset of 1716 targets visible from the Northern hemisphere. We have collected high-resolution archival and new spectra from several instruments. Spectroscopic parameters are determined using the PAWS pipeline, employing both the curve-of-growth equivalent width method, and the spectral synthesis method. We achieve median uncertainties of 106 K in stellar effective temperature, 0.08 dex in surface gravity, and 0.03 dex in metallicity. This paper also presents photometric stellar parameters for these dwarfs, determined using spectral energy distribution fitting. The full gr8stars sample selection, including derived spectroscopic and photometric parameters, is made available through an interactive online data base. We also perform a kinematic analysis to classify these stars according to their Galactic component.

**Key words:** techniques: spectroscopic – stars: atmospheres – stars: solar-type.

## 1 INTRODUCTION

Our desire to understand our Solar system drives us to observe stars and planets with configurations similar to our own. Observations of solar-like stars, here defined as FGK main-sequence stars, open the way to understanding the Solar system's formation and evolution, with investigations into orbiting planets solidifying and expanding such knowledge. In particular, observations of an ‘Earth twin’ – that

is, an Earth-like planet orbiting a Sun-like star with an orbital period similar to Earth's – would be a crucial cornerstone in this study. The search for these long period, small exoplanets will rely on the next generation of transit (e.g. PLATO; Rauer et al. 2014) and extreme precision radial velocity (EPRV) surveys [e.g. the Terra Hunting Experiment (Hall et al. 2018), the NEID Earth Twin Survey (Gupta et al. 2021, 2025)].

A homogeneously characterized input sample for EPRV surveys is crucial for target selection (e.g. Hojjatpanah et al. 2019; Crass et al. 2021). Target selection for such a survey is rather complex, with many potential selection criteria depending on information that can be obtained from high-resolution stellar spectra. Impactful stellar

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properties gained from these spectra such as metallicity, magnitude, spectral type, and rotational broadening will affect the intrinsic radial velocity (RV) information from the star, so learning these properties will allow us to gauge detection limits for exoplanetary searches. High-resolution spectra additionally allow the investigation of binarity and stellar activity, which further complicate the extraction of planetary signals.

Stellar activity is a particularly difficult obstacle in its obscuration of planetary RV signals: an Earth twin will produce RV amplitudes on the order of  $10 \text{ cm s}^{-1}$ , which are readily overwhelmed by the amplitude of stellar activity signals (e.g. Robertson et al. 2014; Meunier et al. 2015; Fischer et al. 2016; Suárez Mascareño et al. 2017; Zicher et al. 2022; Al Moulla et al. 2023). It is therefore understandable why no such Earth twin has yet been observed.

The challenges presented to the search for an Earth twin have led to the creation of the Terra-Hunting Experiment (THE) (Hall et al. 2018), which will draw upon the upcoming High Accuracy Radial velocity Planet Searcher (HARPS-3) instrument on the Isaac Newton Telescope (INT)<sup>1</sup> (Thompson et al. 2016). The orbital periods of Earth twins require a long survey to repeatedly observe the RV signal produced. The THE will therefore require a select few stars for repeat observations across a period of many years. Such targets must be solar-like stars, bright enough to achieve high signal-to-noise ratio (SNR) observations, and observable from the INT site in La Palma. In this paper, we introduce the gr8stars catalogue, a key foundation in the target selection of the THE, and other long-term RV surveys.

gr8stars was created as a collaborative effort to ensure the preparedness of the exoplanetary field for upcoming EPRV missions and studies. The main products of gr8stars are the library of homogeneously derived stellar parameters for the included stars, in addition to the data base of uniformly formatted spectra in both one-dimensional, and order-by-order formats. Aside from the primary aim of EPRV preparations, the collaboration and resulting catalogue will benefit many other science cases. For example, exoplanet occurrence rates and properties can be studied as a function of stellar properties occurrence using gr8stars as a homogeneous source of stellar parameters to investigate planet formation (e.g. Mortier et al. 2013; Buchhave et al. 2014; Adibekyan et al. 2021). Target selection using gr8stars additionally does not have to be limited to EPRV surveys; direct imaging missions and planetary atmosphere studies, among many others, will be able to draw upon the information provided by the catalogue. The catalogue will also aid in the identification of solar twin stars, which are crucial to the understanding of stellar evolution and development of stellar atmospheric models.

Looking to the future, it is anticipated that many of the bright, solar-like stars in gr8stars will benefit from asteroseismology observations with PLATO (PLANetary Transits and Oscillations of stars - Rauer et al. 2014). The homogeneous stellar effective temperatures and metallicities from gr8stars will benefit the homogeneity of asteroseismic masses, radii, and ages for such stars. Additionally, the high-resolution, high SNR spectra used as part of gr8stars provide an excellent data set for stellar abundance studies. Such investigations are crucial for not only the understanding of Galactic chemical evolution (e.g. McWilliam 1997), but also benefit studies of lithium enrichment (e.g. Tsantaki et al. 2023) and planetary composition (e.g. Santos et al. 2017).

In Section 2, we describe the gr8stars catalogue and its context in the fields of stellar and exoplanetary physics. The target selection

for the catalogue is described in terms of the selection criteria used, in addition to plans for the expansion of the catalogue. The structure of the catalogue and the spectra it contains are also detailed. Section 3 describes the observations used to create the catalogue and the instruments used to conduct them. The methods used to determine stellar parameters for the targets within the catalogue are described in Section 4. Section 5 then displays the results achieved, with a concluding discussion of these in Section 6.

## 2 THE GR8STARS CATALOGUE

The gr8stars catalogue provides an easy-to-access source of homogeneously prepared one-dimensional spectra in the lab frame, in addition to the full complement of Echelle order-by-order spectra available for RV studies. Once completed using facilities from both hemispheres, the catalogue will include 5645 FGKM main-sequence stars. Homogenous stellar atmospheric parameters – namely effective temperature ( $T_{\text{eff}}$ ), surface gravity ( $\log g$ ), metallicity ( $[\text{Fe}/\text{H}]$ ), microturbulent velocity ( $v_{\text{mic}}$ ), macroturbulent velocity ( $v_{\text{mac}}$ ), and projected rotational velocity ( $v \sin i_*$ ) – are provided for all targets with available spectra, as described throughout this paper. With the combination of stellar parameters and downloadable high-resolution spectra, the gr8stars catalogue provides a robust, reliable, and extensive source of materials and information for future studies. Amongst undoubtedly many others, the areas of exoplanet characterization, precision stellar abundances, and ultimately direct imaging of exoplanetary systems can benefit from the resources provided by this catalogue.

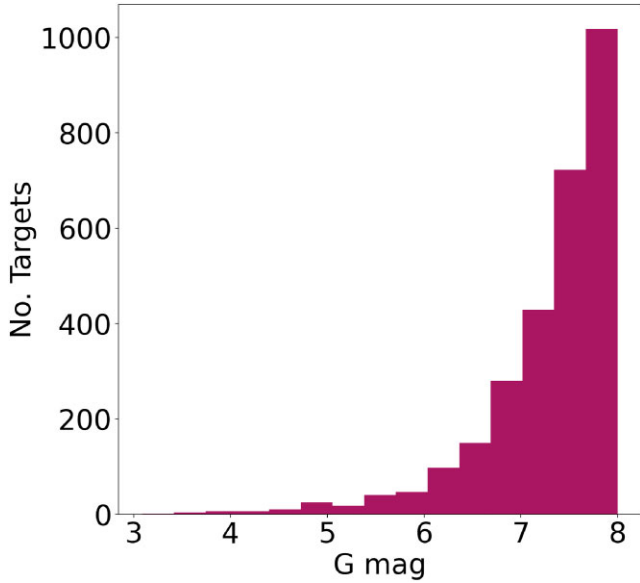
The gr8stars catalogue focuses on bright FGKM stars. We have begun with stars observable from the Northern hemisphere, with plans to expand this to the Southern hemisphere in the future. Target selection was based on the *Gaia* DR3 catalogue (Gaia Collaboration 2016, 2021), which provides crucial measurements for 1.8 billion sources including their colour, brightness, and parallax.

Broadly, the selected targets for the catalogue were determined by four main requirements. First, stars must be brighter than an apparent *Gaia* G-band magnitude of 8, ensuring that high SNR observations (ideally  $\text{SNR} \geq 200$ ; Sousa et al. 2008) could be available for all targets. Photometric and astrometric *Gaia* measurements were used to calculate the absolute G magnitudes and extract the BP–RP colours. Given the focus of the catalogue on bright, nearby stars, extinction was assumed to be small here, hence parallax-corrected G magnitude could be used as a proxy for absolute G magnitude. The distribution of the magnitudes of the gr8stars targets is shown in Fig. 1. It is worth noting that there is a slight lack of completeness for extremely bright targets in *Gaia* eDR3 due to saturation ( $\approx 20$  per cent of  $G \leq 3$  targets do not have entries; Gaia Collaboration 2016; Fabricius et al. 2021; Riello et al. 2021). However, in addition to the majority of these being unsuitable for gr8stars due to their nature as giant stars, we anticipate that future work within the gr8stars collaboration will require solutions from *Gaia* DR3, hence ensuring we only use targets with complete *Gaia* information helps to preserve completeness for future papers.

Focusing on FGKM main-sequence stars required us to cut all earlier type main-sequence stars, in addition to giants and subgiants. The majority of such sources were removed by the implementation of the minimum *Gaia* BP–RP colour  $\geq 0.6$ , where the lack of lower limit allows for the inclusion of bright M dwarfs.

Evolved stars were removed from the sample by the use of isochrones. Fig. 2 displays the isochronal cuts made on the sample, using the Dartmouth isochrones and evolutionary tracks (Dotter et al. 2008). An iron-poor ( $[\text{Fe}/\text{H}] = -0.5$ ) mass track of  $1.05 M_{\odot}$  ensured

<sup>1</sup><https://www.ing.iac.es/astrometry/telescopes/int/>



**Figure 1.** Histogram of apparent G magnitudes for the `gr8stars` targets.

the inclusion of metal-poor G dwarfs, and a 13 Gyr isochrone for iron-rich ( $[\text{Fe}/\text{H}] = 0.5$ ) sources was used to define the upper edge of the main sequence.

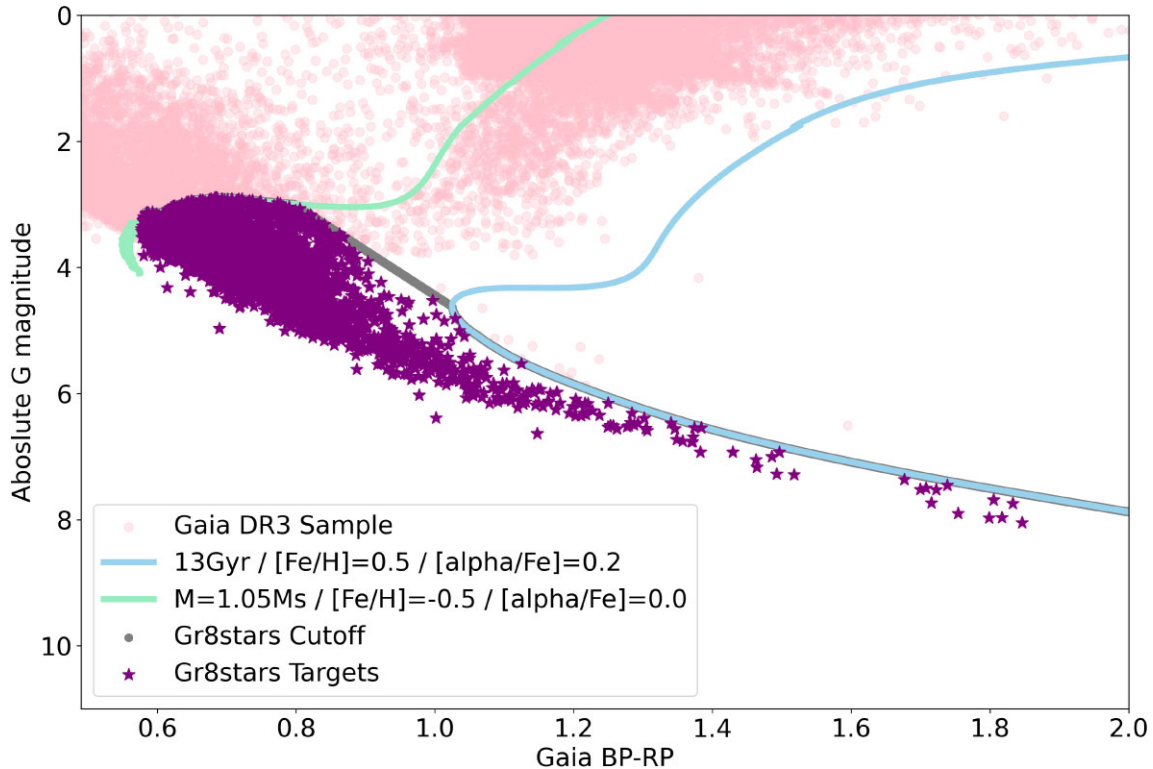
Observability from Northern hemisphere instruments was desired for all targets. To ensure high-quality observations with minimal airmass, we selected only targets with a declination larger than or equal to  $-15^\circ$ .

The diversity of the targets within the `gr8stars` sample is displayed as a series of histograms in Fig. 3 according to their SIMBAD object types (The SIMBAD astronomical database - Wenger et al. 2000). Unsurprisingly, the vast majority of targets belong to either the HighPM\* (High Proper Motion Star) or Star categories, with these being ‘regular’ single stars, however many also fit into other regimes. Many types of variable stars are seen within the sample, with the majority being BY Dra and RS CVn variables, in addition to both spectroscopic and eclipsing binaries. In the case where the main SIMBAD object type is listed as an Eruptive Variable, we use the classification in this work as UV Cet. As the term Eruptive Variable encompasses a broad definition of stars, with many mechanisms of stellar variability, we have traced all of our targets under this classification to be specifically UV Ceti Variables, classified by Gershberg et al. (1999). As the `gr8stars` catalogue is intended to be a foundation for a variety of studies, targets of all object types are kept in the sample, to attempt to minimize the degree of bias present in the sample.

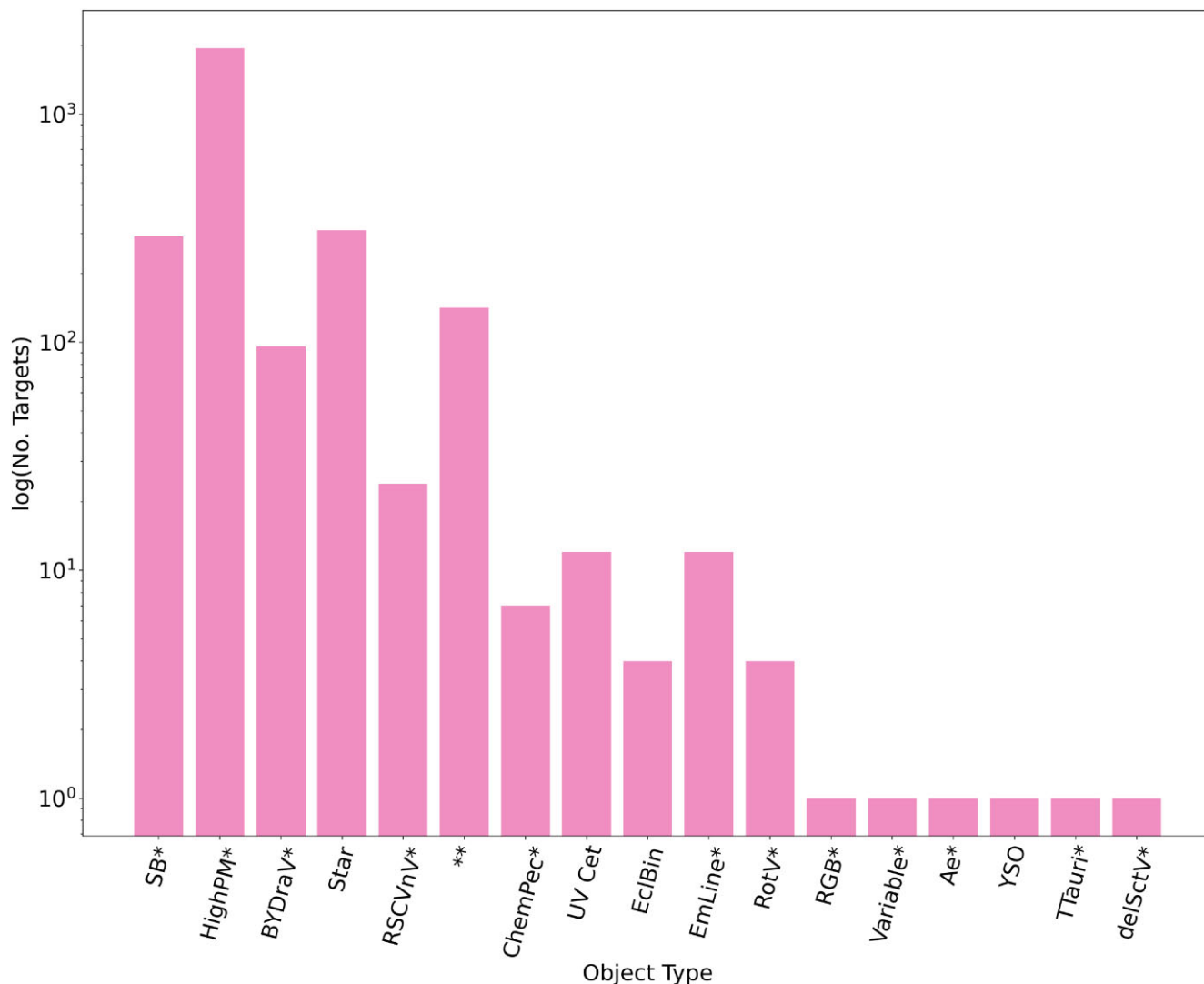
After selection criteria were enforced, the final sample size for Northern hemisphere observable targets is 2858 targets. Of these, we have obtained either archival or new observations for 1716 targets. Considering a brighter subsample of  $G < 7.5$ , which may be more desirable for EPRV surveys, the completeness of `gr8stars` is 986 of 1418 targets.

### 3 DATA

Spectra used to form the `gr8stars` catalogue were taken using the Fiber-fed Extended Range Optical Spectrograph (FEROS), Fibre-fed Echelle Spectrograph (FIES), High Accuracy Radial velocity



**Figure 2.** The isochronal and mass track cuts used in the target selection. The 13 Gyr, metal-rich ( $[\text{Fe}/\text{H}] = 0.5$ ) isochrone, and the metal-poor ( $[\text{Fe}/\text{H}] = -0.5$ ), 1.05 solar mass ( $M_\odot$ ) mass-track used in selection are shown bordering the sample. Targets meeting these two cuts are shown as stars, with targets not selected shown as circles.



**Figure 3.** A histogram representing the number of targets belonging to each SIMBAD object type within the gr8stars catalogue. Table C1 contains definitions for the SIMBAD object types.

Planet Searcher (HARPS), High-Efficiency and high-Resolution Mercator Echelle Spectrograph (HERMES), Spectrographe pour l’Observation des Phénomènes des Intérieurs stellaires et des Exoplanètes (SOPHIE), and Ultraviolet and Visual Echelle Spectrograph (UVES) high-resolution, optical spectrographs. The statistics of the observations made are shown in Table 1, where resolution and wavelength coverage for the observation modes used in gr8stars are also specified. A total of 36 019 spectra were used to create the final gr8stars products, with the bulk of observations conducted using the SOPHIE spectrograph.

A blend of both archival observations and new observing programmes were used to create the gr8stars catalogue. The varying properties of each instrument, described in the following sections, results in systematic differences in the spectra available. To minimize the effects of these, the spectra are all processed homogeneously after the respective instrumental reduction pipelines to produce the combined spectra available as part of the gr8stars catalogue.

### 3.1 FEROS

22 archival spectra were used from the FEROS spectrograph (Kaufer et al. 1999) as part of the gr8stars catalogue. These spectra were taken between 2004 and 2022, with the programme IDs listed in Appendix A. Located at the La Silla Observatory, FEROS is mounted on the MPG/ESO 2.2 m telescope and achieves a resolving power of  $R \approx 48000$ , with a wavelength range of 350–920 nm. The archival spectra were accessed as pre-processed science spectra, having been reduced by the FEROS data reduction software (DRS), implemented in ESO-MIDAS (Munich Image Data Analysis System - European Southern Observatory 2013). The FEROS DRS is applied in real-time as observations are taken.

### 3.2 FIES

The FIES spectrograph (Telting et al. 2014) is located on the Nordic Optical Telescope (NOT) in La Palma, with a wavelength coverage

**Table 1.** Observation statistics from the instruments used in the `gr8stars` catalogue, with spectral resolution and wavelength coverage specified for the instrumental set-ups used as part of `gr8stars`, rather than representing all possible configurations. The number of overlapping targets that have been observed by multiple spectrographs is also displayed here.

| Spectrograph | No. of targets | Overlap                                      | Mean SNR | Resolving power | Wavelength coverage |
|--------------|----------------|--|----------|-----------------|---------------------|
| FEROS        | 18             | UVES 6, HARPS 1, SOPHIE 1                    | 299      | 48 000          | 350–920 nm          |
| FIES         | 139            | HERMES 8, SOPHIE 1                           | 89       | 67 000          | 365–730 nm          |
| HARPS        | 375            | SOPHIE 161, FEROS 1, HERMES 1, UVES 8        | 278      | 115 000         | 378–691 nm          |
| HERMES       | 54             | FIES 8, HARPS 1, SOPHIE 3                    | 165      | 85 000          | 377–900 nm          |
| SOPHIE HR    | 1286           | FIES 1, HARPS 161, FEROS 1, HERMES 3, UVES 2 | 196      | 75 000          | 387.2–694.3 nm      |
| UVES         | 42             | FEROS 6, HARPS 8, SOPHIE 2                   | 244      | 80 000          | 320–1050 nm         |

of 365–730 nm, and a resolving power of  $R \approx 67000$  using the high-res fibre. A combination of archival observations and new observations from 2017 to 2023 were used for 139 targets, supplied as pre-merged SID spectra using FIEStool<sup>2</sup> New observations were conducted under Proposal ID 66–010 (Gr8stars: A survey of the brightest Northern FGKM dwarf stars; PI: Buchhave); Proposal IDs for the archival spectra are shown in Appendix A.

### 3.3 HARPS

Mounted on the ESO 3.6m telescope at La Silla Observatory, the HARPS (High Accuracy Radial velocity Planet Searcher) spectrograph (Mayor et al. 2003) has a wavelength range of 378–691 nm and resolving power of  $R \approx 115000$ . 375 targets were observed using HARPS between 2003 and 2019, totalling 12 526 individual spectra, all reduced by the HARPS DRS (Lovis & Pepe 2007). The programme IDs for the observations can be found in Appendix A.

### 3.4 HERMES

The HERMES spectrograph (Raskin et al. 2011) operates on the 1.2m Mercator telescope in La Palma, having a spectral range of 377 to 900 nm, and a resolving power of  $R \approx 85000$ . 54 targets were observed using HERMES, with spectra supplied as a single combined spectrum for each target by the HERMES DRS (Raskin et al. 2011). Observations were taken as part of the new programme 123-Mercator4-A/20B (PI: Mortier) in 2021.

### 3.5 SOPHIE

Owing to their northern observability, the majority of the `gr8stars` targets were observed using the SOPHIE spectrograph (Perruchot et al. 2008; Bouchy et al. 2009), mounted on the 1.93 m reflector telescope at the Haute-Provence Observatory. Two observation modes are available using SOPHIE – for the `gr8stars` targets, we used only HR (high resolution) mode observations, achieving a resolving power of  $R \approx 75000$  across the wavelength range of 387.2 to 694.3 nm. 1286 targets were observed using SOPHIE between 2006 and 2020, totalling 22 720 individual spectra with programme IDs specified in Appendix A. The spectra were all processed by the SOPHIE DRS (Bouchy et al. 2009).

### 3.6 UVES

Archival spectra for 42 `gr8stars` targets were obtained from the UVES spectrograph (Dekker et al. 2000) on the VLT (Very Large

Telescope) Kueyen telescope at Paranal. UVES has a wavelength range of 320 to 1050 nm, able to achieve resolving powers of  $R \approx 80000$  and  $R \approx 110000$  dependent on observation mode. UVES observations were used for 27 targets, with a total of 130 spectra reduced by the UVES DRS (Ballester et al. 2000) between 2020 and 2022. A mix of red and blue arm observations were available, hence varying resolutions of UVES spectra are used in this analysis, and made available as part of the `gr8stars` catalogue.

The programme IDs for the observations can be found in Appendix A.

### 3.7 Spectral format

A uniform, non-continuum-normalized format is applied to all spectra in the catalogue, allowing for ease of use and automation of analysis. Spectra are named according to the form ‘X\_INST\_SYD.fits’, where X is the target’s primary name (selected as the SIMBAD main identifier), INST refers to the instrument from which the spectrum originates, and Y is either 1 or 2, depending on whether the spectrum is one- or two-dimensional, respectively. The SID spectra, which are formatted from the SID product produced by each instrument’s reduction pipeline, contain two FITS extensions. The first extension (i.e. index 0) contains the flux values as a data product, and the header contains the start wavelength and fixed wavelength step, allowing the spectrum to be built solely from this extension. In the case that the original SID spectrum is not sampled uniformly, it was resampled uniformly to form the `gr8stars` SID product. The header for this extension also contains the target information displayed in Table B1. The second extension (index 1) contains a table of the wavelength, flux, and flux errors, again allowing the spectrum to be built from this. Having both formats of information available allows for a versatile array of methods to be used for spectral analysis. Where available, SID spectra from the same instrument are combined for each target to produce a higher SNR final product, with the individual spectra files used specified in the index 0 header. In cases where wavelength gaps are present in the spectra, flux values are set to NaN. By nature of being combined from multiple exposures, the SID spectra have all been RV corrected to the lab frame, where the RV was determined using a cross-correlation function (CCF) and G2 mask.

The order-by-order S2D spectra for all exposures are also individually available to allow for customized reduction pipelines and analysis methods, following the same naming convention. The files comprise of three FITS extensions, the first (index 0) containing the fluxes, the second (index 1) containing the blaze corrections, and the third (index 2) being the wavelengths, with all three extensions containing arrays for the separate orders.

<sup>2</sup><https://www.not.iac.es/instruments/fies/fiestool/FIEStool.html>

## 4 STELLAR PARAMETER DETERMINATION

As part of the *gr8stars* catalogue, we make available stellar parameters homogeneously derived from both spectroscopic and photometric methods. The parameters derived by these methods complement each other well, with common parameters allowing for direct comparison, and those exclusive to each method adding to the completeness of our knowledge of each star.

### 4.1 Spectroscopic methods

To determine the atmospheric parameters for the *gr8stars* targets using their spectra, we made use of the PAWS pipeline as described by Freckelton et al. (2024), which employs the functionalities of *iSpec* (Blanco-Cuaresma et al. 2014; Blanco-Cuaresma 2019). The pipeline is presented as an easy-to-use GUI (Graphical User Interface), combining two methods, both using the ATLAS9 set of model atmospheres (Kurucz 2005), to produce reliable atmospheric stellar parameters. The *gr8stars* spectra are supplied as coadded spectra in the lab frame, hence many of the spectral preparation steps in the pipeline were omitted. The spectra were normalized by modelling the continuum using a B-spline of 2° fitted every 5 nm, and then dividing the flux at each point in the spectrum by the fitted continuum flux.

Once spectra were prepared as described above, the equivalent width (EW) method was employed to generate a set of initial stellar parameters ( $T_{\text{eff}}$ ,  $\log g$ ,  $[\text{Fe}/\text{H}]$ , and  $v_{\text{mic}}$ ) using the WIDTH (Sbordone et al. 2004) radiative transfer code to ensure ionization and excitation balance in the Fe I and Fe II lines. These parameters were then fed as inputs to the spectral synthesis method [using the SPECTRUM (Gray & Corbally 1994) radiative transfer code], which derived the final parameters –  $T_{\text{eff}}$ ,  $\log g$ ,  $[\text{Fe}/\text{H}]$ ,  $v_{\text{mic}}$ ,  $v_{\text{mac}}$ , and  $v \sin i_*$ . The spectral synthesis method is applied in the wavelength region 480–680 nm, using the SPECTRUM line list based on the NIST (National Institute of Standards and Technology) atomic data base (Ralchenko 2005). Each of the parameters, aside from macroturbulent velocity ( $v_{\text{mac}}$  which was derived from the  $T_{\text{eff}}$ ,  $\log g$ , and  $[\text{Fe}/\text{H}]$  using an empirical relation from the results of the *Gaia*–ESO survey; Blanco-Cuaresma et al. 2014; Jofré et al. 2014), is a free parameter in at least one stage of the pipeline, allowing for as little model dependence as possible. As described by Blanco-Cuaresma et al. (2014), errors on the determined parameters are derived from the covariance matrix resulting from least-squares fitting. As these uncertainties reflect precision only, we account for model accuracies by adding uncertainties on  $T_{\text{eff}}$  by 100 K in quadrature, as is standard for PAWS (Parameters Approximated With Synthesis - Freckelton et al. 2024). Additionally, we follow Sousa et al. (2011), adding accuracy uncertainties on  $[\text{Fe}/\text{H}]$  and  $\log g$  of 0.04 and 0.1 dex in quadrature respectively. PAWS can be applied to all FGKM main-sequence stars with high-resolution, high SNR spectra, hence was used for the whole *gr8stars* data set.

### 4.2 Spectral energy distribution fitting

In addition to the spectroscopic analysis, we computed the stellar radius  $R_*$  and effective temperature  $T_{\text{SED}}$  (to differentiate it from spectroscopically derived measures of temperature) using a spectral energy distribution (SED) fitting method. We first applied this method to low-mass stars in Morrell & Naylor (2019, 2020), with Morrell et al. (submitted) demonstrating that the technique generalizes to solar-like exoplanet hosts.

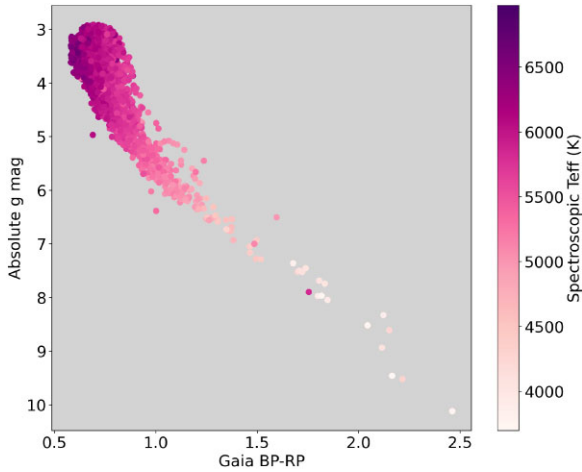
In contrast to spectroscopic analyses, which measure the characteristic of temperature dependent spectral features, our SED fitting method compares broad-band, multicolour photometry with synthetic photometry. Synthetic photometry were generated from the BT-SETTL Cosmological Impact of the First Stars (CIFIST) (Allard, Homeier & Freytag 2012) stellar atmosphere grid, diluted using the geometric distances of Bailer-Jones et al. (2021). By best matching the integrated area beneath and the overall shape of the SED, we determined the luminosity  $L_{\text{SED}}$  and temperature  $T_{\text{SED}}$ , respectively. Both parameters together unambiguously define  $R_*$ . Note that unlike the other analyses in this paper, this method self-consistently measures both  $T_{\text{SED}}$  and  $R_*$  using only photometry and distances, providing an alternate, orthogonal measure of temperature to spectroscopic methods.

The photometric fitting was performed using the  $G_{\text{BP}}$  and  $G_{\text{RP}}$  bands from *Gaia* DR3 (Gaia Collaboration 2016, 2023), the  $J$ ,  $H$ , and  $K$  bands from 2MASS (Two Micron All-Sky Survey - Skrutskie et al. 2006), and the  $W1$ ,  $W2$ , and  $W3$  bands from ALLWISE (Wide-field Infrared Survey Explorer - Wright et al. 2010). For inclusion in the final catalogue we required that targets were fitted with five or more photometric bands, and the fit had  $\chi^2 < 10$ . We calculated our statistical uncertainties following the methods described in Morrell & Naylor (2019, 2020) and Morrell et al. (submitted), adopting a floor value for the uncertainty in each photometric band of 0.01 mag, corresponding to an uncertainty of about 1 per cent. We imposed this floor to both avoid the systematics present in *Gaia* photometry at below this level, and to down-weight the *Gaia* bands during the fitting process.

Although nearby, the target stars are still subjected to some extinction, which makes the observed SED appear cooler and less luminous than the star actually is. We compensated for this by fitting each target with a grid of atmosphere models reddened with the Fitzpatrick et al. (2019) extinction law. The amount of reddening applied to each target was determined by using the *Gaia* positions and parallaxes to place it within the 10 pc resolution dust maps of Vergely, Lallement & Cox (2022). We then integrated along the line of sight from the Sun to the target star to determine an extinction at 550 nm ( $A_{55}$ ). Combining this with the mean Milky Way total-to-selective extinction ( $R(55) = 3.02$ ), allows us to determine the nominal colour excess ( $E(44 - 55)$ ) to which we should redden the models. As the extinctions to these targets are so low, errors in its determination will have little impact on our results. All the stars in our sample have  $E(44 - 55) < 0.03$ , compared with the error of  $E(44 - 55) = 0.01$  required to introduce an error of 1 per cent in radius or  $T_{\text{SED}}$  (Morrell et al., submitted). Hence it would require an error of 30 per cent in the determination of the extinction to significantly affect our results, whereas the uncertainties in  $E(44 - 55)$  given by Vergely et al. (2022) are always less than 0.001 mag within 100 pc of the Sun for their 50 pc resolution maps.

### 4.3 Galactic velocities

We determined the galactic velocities –  $U$ ,  $V$ ,  $W$  – in order to classify the galactic components of the *gr8stars* targets, with  $U$  being the velocity towards the galactic centre,  $V$  the velocity in the direction of the galactic rotation, and  $W$  the velocity towards the galactic North Pole. These velocities were obtained following the matrix equations outlined by Johnson & Soderblom (1987), using the right ascension, declination, proper motions, parallax, and radial velocity from *Gaia* DR3 (Gaia Collaboration 2023). Of the sample, 250 did not have an available radial velocity from *Gaia* DR3, hence were not included in this analysis.



**Figure 4.** Colour–magnitude diagram of the *gr8stars* targets, with the colour-bar representing the effective temperature derived via spectroscopy in this work.

## 5 RESULTS

### 5.1 Validation of parameters

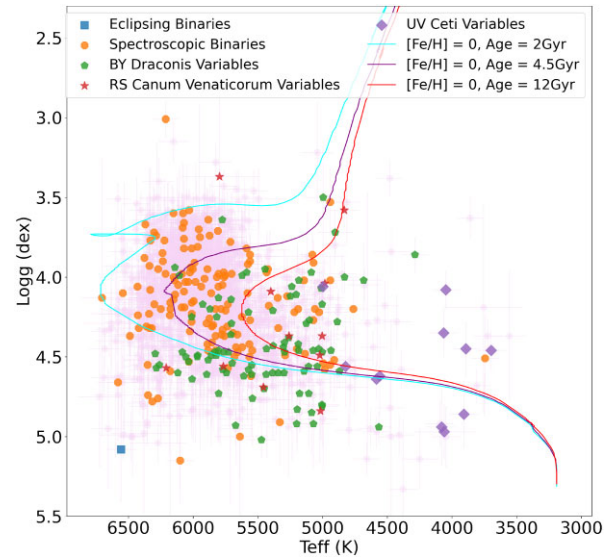
#### 5.1.1 Atmospheric parameters

Given the breadth of the catalogue, results were expected to follow the trend of main-sequence stars in the solar neighbourhood with the exception of a small number of outliers. Fig. 4 displays a *Gaia* colour–magnitude diagram of the targets, with a colour scale representing the spectroscopic  $T_{\text{eff}}$  derived in this work. Overall, the targets follow the expectation of bluer, brighter stars being the hottest. A few outliers to this are present within the diagram, which we further investigate within this section.

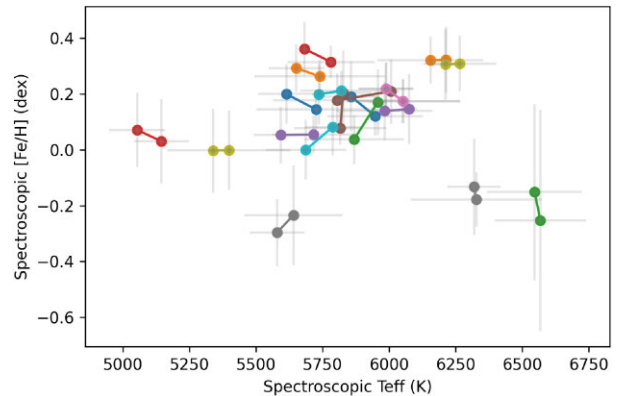
By cross-matching the *gr8stars* targets with the SIMBAD astronomical data base<sup>3</sup> (Wenger et al. 2000), all targets were classified into the five categories shown in Fig. 5. Each of these categories bring about challenges in the determination of atmospheric parameters from their stellar spectra, which may provide explanation for outliers in our results. Eclipsing binaries (EBs), spectroscopic binaries (SBs), and RS Canum Venaticorum variables (RS CVns) all consist of two stars, meaning the spectra from both stars can be ‘entangled’ (e.g. Rawls et al. 2016; Czekala et al. 2017; Sairam et al. 2024), in which the two spectra are blended.

UV Ceti variables are typically M dwarfs that undergo stellar variability processes mainly characterized by short flares, causing brightness increases between 1 to 6 mag (Gershberg et al. 1999). RS CVn and BY Draconis (BY Dra) variables have prevalent chromospheric activity, resulting in large numbers of stellar spots. These spots may produce adverse effects in the stellar spectra from these stars, potentially resulting in inaccuracies in the atmospheric parameters derived. Additionally, in the context of the use of the *gr8stars* catalogue in selecting optimal targets for planet-searching surveys, high-activity stars may increase difficulty as outlined in Section 1, hence it was important that we identify and highlight these within this work.

Fig. 5 displays the *gr8stars* target spectroscopic results from this work in a  $\log g$  versus  $T_{\text{eff}}$  diagram, with the outliers coloured according to the plot legend. With almost all targets being FGK



**Figure 5.** Spectroscopic surface gravity ( $\log g$ ) and spectroscopic effective temperature ( $T_{\text{eff}}$ ) results from this work plotted against each other, with the legend identifying outliers of different categories. Dartmouth isochrones are overlotted as solid lines (Dotter et al. 2008).

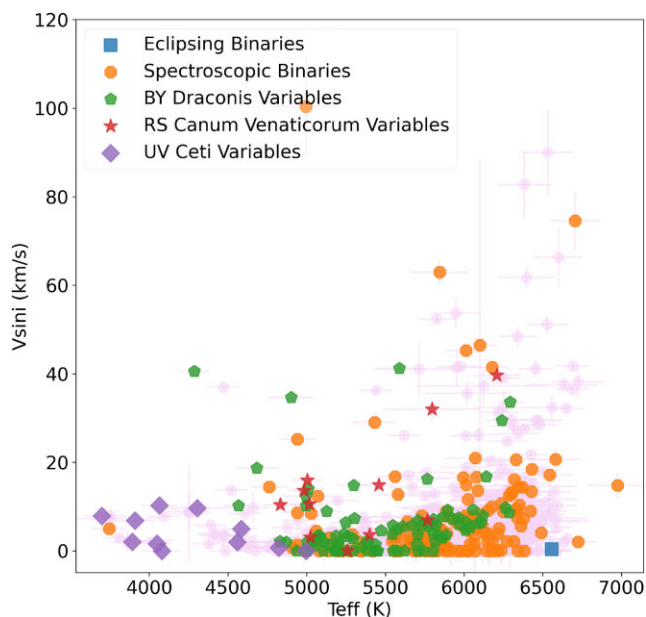


**Figure 6.**  $[\text{Fe}/\text{H}]$  versus  $T_{\text{eff}}$ , both derived in this work, for 20 randomly selected targets in the *gr8stars* catalogue. All 20 targets have spectra available from two different instruments, wherein which results for the same target from separate instruments are plotted in the same colour and joined by a line.

main-sequence stars, the majority of points occupy the region  $3.5 \text{ dex} < \log g < 5.0 \text{ dex}$ ,  $4500 \text{ K} < T_{\text{eff}} < 6500 \text{ K}$ . Several targets are cooler or hotter than this temperature range, however still show a derived  $\log g$  appropriate for a main-sequence star, hence represent the extreme ranges of F and K type targets, extending into three M dwarfs present in the sample. More problematic, however, are those targets found to have  $\log g < 3.5 \text{ dex}$ . Such values are much lower than expectations for these stars, indicating that the spectra observed from these stars posed inherent difficulties for determining  $\log g$ , suggesting the value determined from SED fitting may be more suitable.

To investigate the effects of any systematics introduced by the use of different instruments, 20 targets with observations from multiple spectrographs were selected for comparison. Fig. 6 displays the effective temperatures ( $T_{\text{eff}}$ ) and metallicities ( $[\text{Fe}/\text{H}]$ ) determined for the 20 randomly selected targets. From this, it is clear that the results from different instruments overall agree within uncertainties.

<sup>3</sup><https://simbad.u-strasbg.fr/simbad/sim-fid>



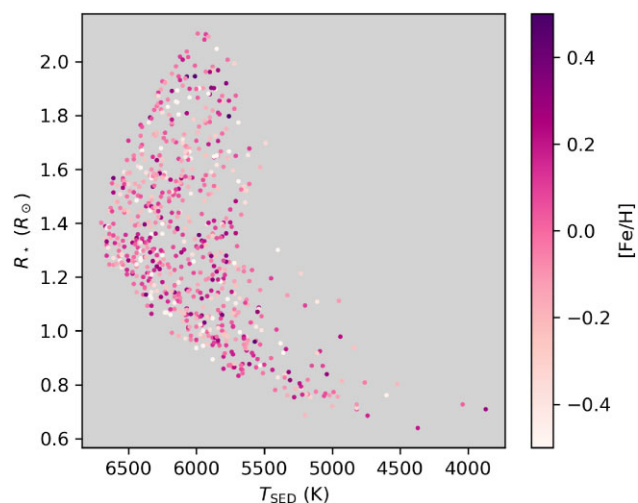
**Figure 7.** Spectroscopic projected rotational velocity ( $v \sin i_*$ ) plotted against the spectroscopic effective temperature ( $T_{\text{eff}}$ ) for the gr8stars targets, with outliers marked again as in Fig. 5.

Additionally, we note that Fig. 6 does not appear to show any correlations between  $[\text{Fe}/\text{H}]$  and  $T_{\text{eff}}$ . Of the 20 targets plotted, 7 show  $[\text{Fe}/\text{H}]$  to be increased for an increase in  $T_{\text{eff}}$ , 8 show a decrease in  $[\text{Fe}/\text{H}]$  for an increase in  $T_{\text{eff}}$ , and 5 show no change in  $[\text{Fe}/\text{H}]$ . The mean difference between  $T_{\text{eff}}$  measurements for the same target is 78 K, with a standard deviation of 45 K; for the measured  $[\text{Fe}/\text{H}]$ , the mean difference is 0.05 dex, having a standard deviation of 0.04 dex.

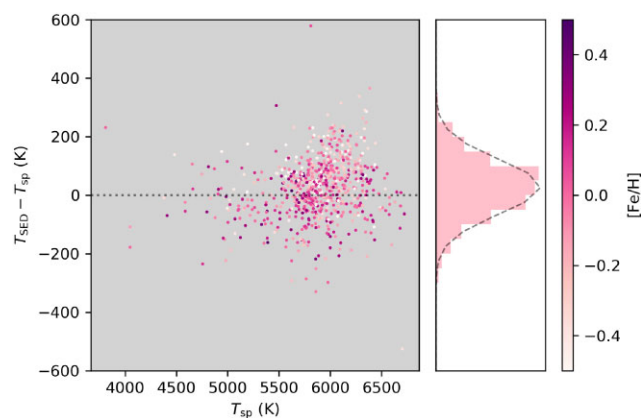
Using spectra from varying instruments is therefore not a concern with regard to the homogeneity of the gr8stars catalogue. However, we keep in mind that observations are all subject to environmental effects, and therefore low SNR observations may cause discrepancies in results from different instruments. In cases where multiple sources of spectra are available for a target, an inverse variance-weighted mean is taken for all parameters, with uncertainties on the final parameters taken from the variance of the input parameters. However, if observations from one instrument are deemed low quality (i.e.  $\text{SNR} < 50$ ), results from only the higher quality spectra are taken.

Outliers are further explored in Fig. 7, in which the  $v \sin i_*$  is plotted against the spectroscopic  $T_{\text{eff}}$ , both results from this work. Many of the higher  $v \sin i_*$  targets can be classified according to the outlier categories, indicating that the  $v \sin i_*$  measurement may have been inflated by broadening due to blended spectra.

The resulting  $T_{\text{SED}}$  and  $R_*$  measured using the SED fitting method are plotted for the gr8stars catalogue in Fig. 8. We achieved a median statistical uncertainty of 1.0 per cent and 1.9 per cent in  $T_{\text{SED}}$  and  $R_*$ , respectively. However, there will be systematic effects due to using only solar metallicity atmospheres. Using results of Morrell et al. (submitted) we find that for  $4000 \text{ K} < T_{\text{SED}} < 7000 \text{ K}$  we can expect such a systematic to lie below our statistical uncertainties for  $-0.25 < [\text{Fe}/\text{H}] < 0.25$ . This metallicity range covers 70 per cent of our spectroscopic sample, and presumably a similar fraction of the sample which have photometrically determined parameters.



**Figure 8.** Our sample with the  $T_{\text{SED}}$  and  $R_*$  derived from SED fitting along with their uncertainties. The colour-bar indicates spectroscopically determined metallicity. To avoid comparing objects whose observed flux may vary, we omitted objects flagged as double or multiple systems (\*\*), Herbig Ae/Be (Ae\*), BY Dra Variables (BYDraV\*), Eclipsing Binaries (EclBin), Eruptive Variables (Eruptive\*), Red-giant branch stars (RGB\*), RS CVn Variables (RSCVnV\*), spectroscopic binaries (SB\*), variable stars (Variable\*), young stellar objects (YSO) or Delta Scuti variables (delSctV\*).



**Figure 9.** The residuals between the  $T_{\text{SED}}$  and  $T_{\text{sp}}$ , plotted as a function of  $T_{\text{sp}}$ . The distribution of these residuals, overlaid with a Gaussian fit, are shown in the right-hand pane. We omitted from this plot the same targets as specified in Fig. 8.

With the SED-based methods we have achieved a second, orthogonal measurement of temperature. A comparison of the temperatures determined from both methods is shown in Fig. 9. The median difference between the temperatures from both methods is 34 K, with the Gaussian fit to the residuals yielding a  $\sigma = 98 \text{ K}$ . Although there is some evidence for a systematic with temperature, the scatter is consistent with our cited uncertainties for both methods.

### 5.1.2 Comparison to PASTEL catalogue

To further investigate the reliability of our spectroscopic atmospheric parameters, we compared the effective temperature and metallicities determined in this to those from the PASTEL catalogue (Soubiran et al. 2016). From the 1716 targets for which we have determined

atmospheric parameters, 1638 have effective temperature results in the PASTEL catalogue, and 1171 have metallicity results. As the PASTEL catalogue is a compilation of literature results from various sources and thus not homogeneous, we chose to take the median of these results for use in our comparison, along with a weighted standard deviation to represent uncertainties. In the cases where the PASTEL catalogue does not quote an uncertainty for a measurement, it was omitted from our comparison.

Fig. 10 shows the comparison of our results to the effective temperatures and metallicities from the PASTEL catalogue. Overall, the results agree in both parameter spaces. The root-mean-square (RMS) difference between results from this work and those from the PASTEL catalogue are 101 K and 0.11 dex for  $T_{\text{eff}}$  and [Fe/H], respectively. This matches with our median error of effective temperature and their median error of metallicity. The majority of significant outliers in  $T_{\text{eff}}$  lie in the cooler regime ( $\leq 4500$  K), with their relatively large uncertainties reflecting the lower SNR of their spectra. HD234677 presents the most prominent outlier in  $T_{\text{eff}}$ , having a  $T_{\text{eff}}$  determined in this work to be  $4887 \pm 101$  K, and  $4200 \pm 13$  K from PASTEL. The low uncertainty in the PASTEL value suggests high confidence in the result. As the SNR of the spectrum used in this work is relatively low, at  $\text{SNR} = 32$ , this target will be prioritized in future efforts to complete the `gr8stars` sample so new spectra can be obtained.

## 5.2 Exoplanet host stars

Of the `gr8stars` targets, 147 were found to be hosts of confirmed exoplanets by cross-matching with the `exoplanet.eu`<sup>4</sup> data base. These host stars were found across a range of metallicities, as shown in Fig. 11. As well-established in the literature, it is expected that higher metallicity stars are more likely to host giant planets than those that are metal-poor (e.g. Santos, Israelian & Mayor 2004; Fischer & Valenti 2005; Udry & Santos 2007; Buchhave et al. 2012; Mortier et al. 2012; Buchhave et al. 2014). Evidence of this trend influencing that is seen for all planet hosts is apparent in Fig. 11.

## 5.3 Galactic classification

Once obtained using the method outlined in Section 4.3, the galactic velocities were used to determine whether the targets were most likely to be thin disc, thick disc, or halo stars. The most likely membership, along with its probability, for each target was obtained following Reddy, Lambert & Allende Prieto (2006). Although all targets are included here, when considering multiple star systems the kinematics may be affected by additional motion (Dehnen & Binney 1998), therefore reducing the reliability of the membership probability. Within the `gr8stars` sample, 75.1 per cent of targets have a Renormalized Unit Weight Error (RUWE) between 0.8 and 1.2, indicating that a single star solution fits well to the astrometric data. Fig. 12 shows the resulting Toomre diagram of the `gr8stars` sample, including targets for which we have not yet obtained spectroscopic observations, with the targets marked by their most likely Galactic membership.

Within the entire Northern-observable sample, regardless of whether spectra have been acquired, 2526 targets (96.86 per cent) are likely to belong to the thin disc, 79 (3.03 per cent) to the thick disc, and 3 (0.11 per cent) are likely to be halo stars. A majority thin-disc sample was expected for `gr8stars`, as all stars are within

103 pc, hence belonging to the solar neighbourhood. Of perhaps the most interest here are the three possible halo stars; HD103095 (Deliyannis et al. 1994; King 1997; Creevey et al. 2012), HD140283 (Bond et al. 2013; VandenBerg et al. 2014; Creevey et al. 2015; Siqueira-Mello et al. 2015), and HD148816 (Meléndez & Barbuy 2009).

The distribution of metallicity in all three galactic component groups is displayed in Fig. 13 as a stacked histogram. Main-sequence stars in the solar neighbourhood are expected to follow a Gaussian distribution, as shown by Haywood (2001), peaking just below solar metallicity. Observing Fig. 13, the distribution of [Fe/H] does indeed follow the expected Gaussian shape for the thin disc stars, centred close to solar metallicity with a mean of  $-0.04$  dex. When considering the thick disc, Fig. 13 shows the population is far more metal poor than the thin disc, as expected due to the older age of the stars; the mean [Fe/H] for `gr8stars` thick disc stars is  $-0.33$  dex. We see this again extending to the halo stars; being the oldest stellar components of the galaxy, they are the most metal poor, with a mean [Fe/H] of  $-1.47$  dex.

## 6 CONCLUSIONS

The `gr8stars` catalogue presents a unique data base tailored to the purpose of supporting future exoplanet searches in the Northern hemisphere. This work collates spectroscopic and photometric parameters for the targets, made publicly available to allow the easy identification and classification of stars. The `gr8stars` catalogue itself is a library of thousands of spectra for the targets available in both S1D and S2D format, allowing for users to perform their own spectroscopic and radial velocity analyses. Observations from multiple instruments are made available in the catalogue for targets where they are present, with their homogeneity in terms of atmospheric parameters derived explored in Fig. 6. As no systematic trends were present in this testing, the final spectroscopic parameters presented in this work are an inverse-variance-weighted mean for targets with multiple instrument observations.

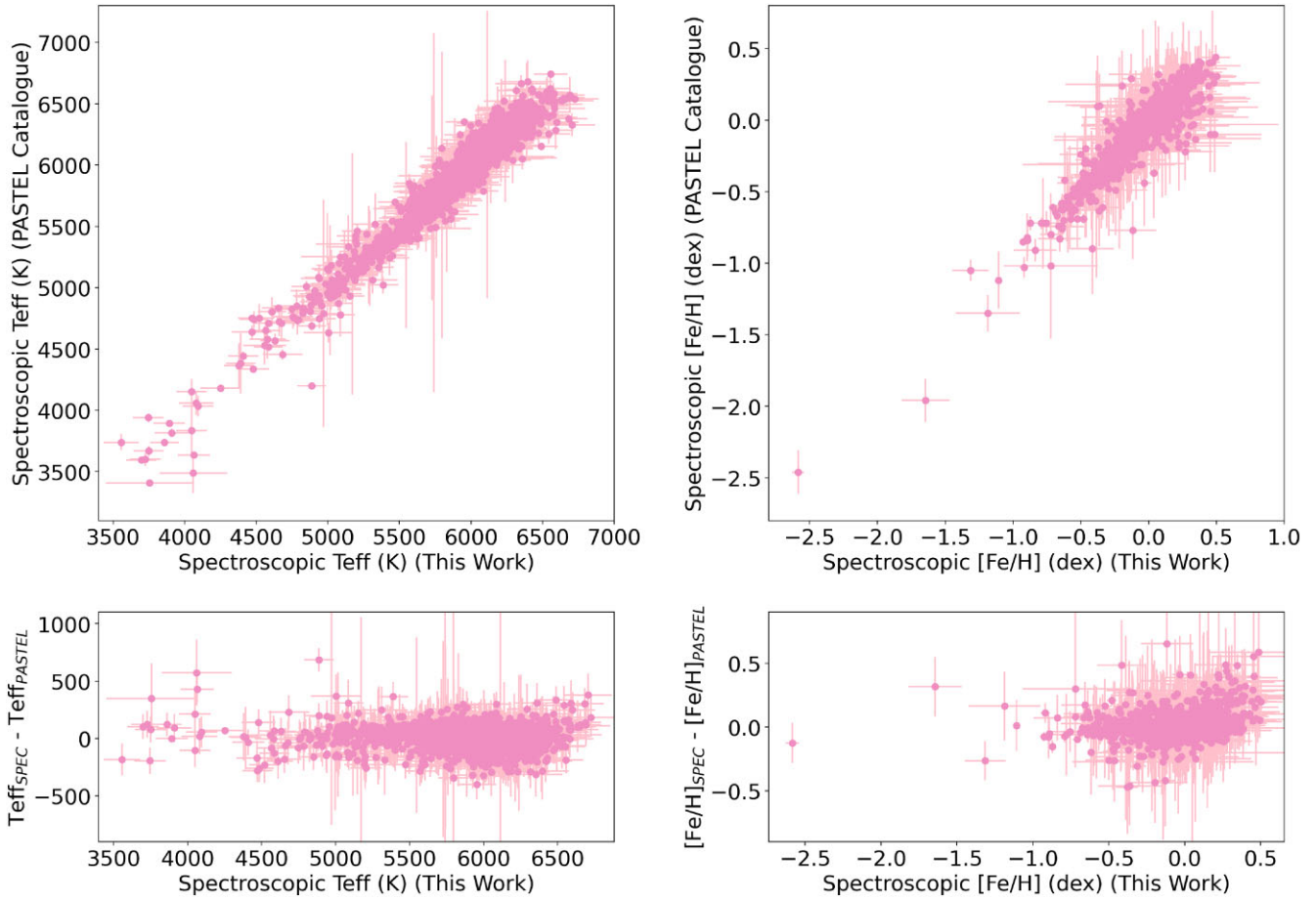
While the majority of the Northern-observable targets have available spectra, we will expand the catalogue to include observations for all targets in the sample in the future.

To both explain any outliers in terms of spectroscopic parameters derived, and make users aware of targets deviating from the standard solar-like stars, the special cases identified and first displaying in Fig. 5 are noted within the table of final parameters for the catalogue in the ‘OTYPE’ column. The majority of these targets would be less suitable for exoplanet searches than a solar-like star in terms of searching for exoplanets in RV space, hence it is important that they are identified here.

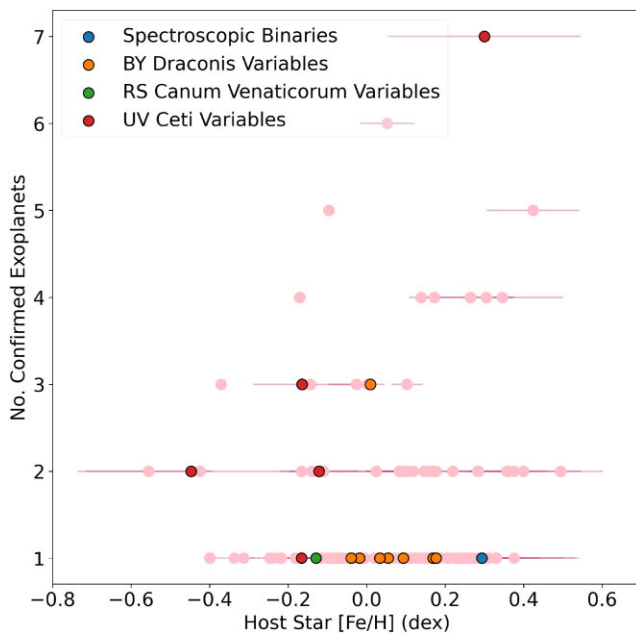
Anticipating future work on targets observable from Southern hemisphere facilities such as the Second Earth Spectrograph (2ES) under construction for the MPG/ESO 2.2 m telescope (Stürmer et al. 2024), the target selection process was repeated with the declination constraint replaced with  $\delta \leq +15^\circ$ . This produced a list of 2788 targets that will be suitable for such work. Combining this with the previous target list tailored to Northern hemisphere facilities, and accounting for overlap between the two, the total `gr8stars` sample encompasses 5645 stars.

Future papers within the `gr8stars` collaboration will benefit from a wide range of expertise, covering stellar activity, precision stellar abundances, mass and radius analyses, method comparison and benchmarking, plus many more possible science cases. To facilitate achieving a complete sample for `gr8stars`, periodic archive searches will be performed for new publicly available spectra.

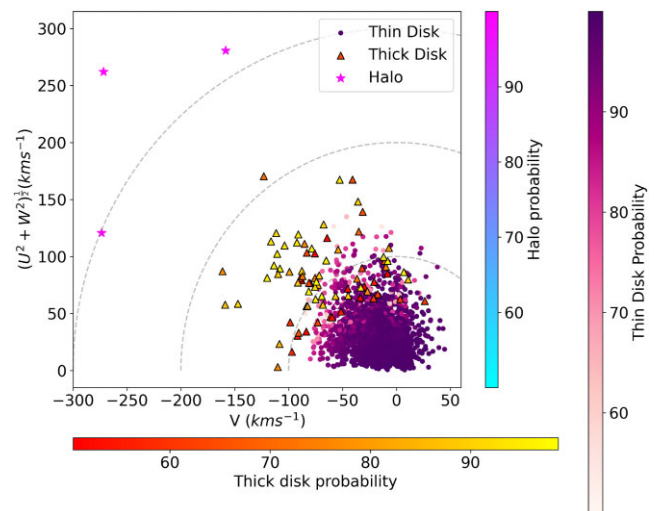
<sup>4</sup><https://exoplanet.eu/home/>



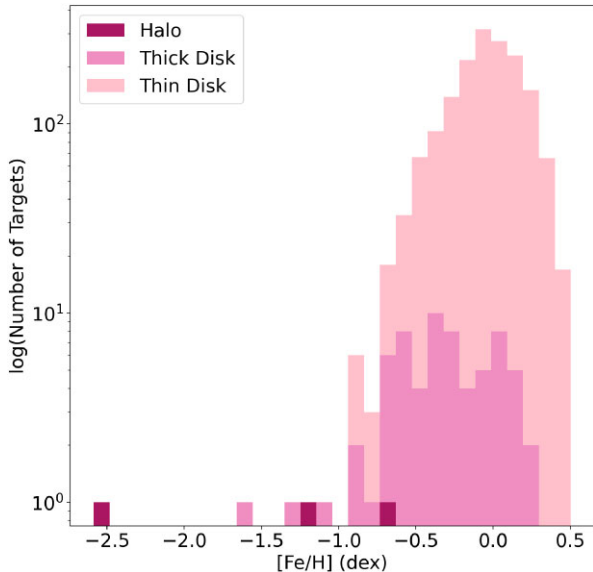
**Figure 10.** Comparison of spectroscopic effective temperatures (a) and metallicities (b) derived in this work to those from the PASTEL catalogue (Soubiran et al. 2016). The differences between results from this work and those from the PASTEL catalogue are shown in the subplots below.



**Figure 11.** Exoplanet hosts in the gr8stars sample as found from the exoplanet.eu data base, plotted as number of confirmed exoplanets versus metallicity of the host star. Special cases are highlighted as in Fig. 5.



**Figure 12.** The Toomre diagram of the Northern-observable gr8stars sample, with circles representing thin disc stars, triangles representing thick disc stars, and stars representing halo stars. The respective membership groups have individual colour scales representing the probability that each target belongs to that group. Dashed lines show the total velocity ( $V_T^2 = U^2 + W^2 + V^2$ ) constants of 100, 200, and 300  $\text{kms}^{-1}$ .



**Figure 13.** Distribution of metallicities derived from this work spectroscopically in each galactic component group, plotted as a stacked histogram in log scale.

Additionally, current proposals on FIES (PI: Buchhave) and UVES (PI: Freckelton) are currently underway taking observations for both the Northern and Southern samples, and proposals will continue to be submitted as part of the *gr8stars* collaboration.

Looking to the future, it is vital to consider the importance of *gr8stars* in the context of revolutionary upcoming missions such as the proposed Habitable Worlds Observatory (HWO) (National Academies of Sciences, Engineering, and Medicine 2023). Cross-matching our list of 5645 targets with the current proposed star list for HWO (Mamajek & Stapelfeldt 2024), we find that 137 of the 164 stars are present in the *gr8stars* sample. This overlap highlights the significant role that *gr8stars* could play in the characterization of host stars for upcoming Earth twin searches.

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SGS acknowledges the support from FCT through Investigador FCT contract nr. CEECIND/00826/2018 and POPH/FSE (EC).the update to *pyaneti* to do model comparison for different multidimensional GPs – is that included in the live version? As we may benefit for our system here.

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## DATA AVAILABILITY

All stellar parameters determined and uniformly formatted spectra used within this work can be accessed via Zenodo.<sup>5</sup> The table of stellar parameters will additionally be uploaded to Vizier CDS. Spectra are available upon request to the authors.

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## APPENDIX A: PROGRAMME IDS

### A1 FEROS

082.A-9007, 078.A-9059, 088.C-0892, 0108.A-9029, 0102.A-9008, 074.A-9002, 082.C-0446, 0100.A-9022, 0108.A-9032, 0103.A-0910, 095.A-9029.

### A2 FIES

64–302, 55–006, 59–802, 58–901, 61–510, 54–413, 61–605, 59–901, 61–803, 58–199, 63–901, 55–901, 64–201, 55–019, 50–410, 66–010

### A3 HARPS

183.C-0972(A), 072.C-0488(E), 099.D-0717(A), 091.C-0034(A), 099.C-0458(A), 0101.C-0379(A), 089.C-0732(A), 0103.C-0432(A), 0100.C-0097(A), 094.D-0596(A), 085.C-0019(A), 093.C-0409(A), 090.C-0421(A), 087.C-0831(A), 097.C-0561(A), 075.C-0332(A),

076.C-0279(A), 080.C-0712(A), 082.C-0412(A), 184.C-0815(F), 080.C-0664(A), 184.C-0815(B), 077.C-0295(A), 081.C-0774(A), 184.C-0815(E), 077.C-0295(B), 076.C-0279(B), 184.C-0815(C), 076.C-0279(C), 198.C-0836(A), 192.C-0852(A), 074.C-0364(A), 188.C-0265(M), 188.C-0265(I), 188.C-0265(R), 188.C-0265(A), 188.C-0265(P), 188.C-0265(G), 188.C-0265(D), 188.C-0265(O), 188.C-0265(L), 188.C-0265(K), 188.C-0265(H), 0100.D-0444(A), 096.D-0402(A), 096.C-0499(A), 183.D-0729(A), 077.C-0101(A), 188.C-0265(C), 087.C-0012(B), 089.C-0415(B), 087.C-0012(A), 089.C-0415(A), 0101.C-0232(A), 097.C-0090(A), 0103.C-0548(A), 0100.C-0414(B), 0102.C-0338(A), 101.C-0232(B), 60.A-9700(G), 0102.C-0584(A), 091.C-0936(A), 196.C-0042(E), 190.C-0027(A), 196.C-0042, 196.C-0042(D), 192.C-0224(C), 192.C-0224(B), 082.C-0212(B), 60.A-9036(A), 191.C-0873, 183.C-0437(A), 191.C-0873(A), 188.C-0265(J), 188.C-0265(N), 188.C-0265(E), 188.C-0265(B), 188.C-0265(F), 075.C-0689(B), 184.C-0815(A), 077.C-0295(C), 102.D-0717(A), 077.C-0364(E), 0102.C-0558(A), 092.C-0721(A), 196.C-1006(A), 188.C-0265(Q), 0103.C-0785, 0101.C-0275, 0104.C-0090(A), 0103.C-0206(A), 0102.C-0338(C), 0100.C-0414(A), 0102.C-0338(B), 080.D-0347(A), 082.C-0390(A), 185.D-0056(D), 183.D-0729(B), 0102.D-0119(A), 0101.C-0275(A), 0101.C-0232(C), 103.C-0548(A), 083.C-0794(A), 083.C-0794(C), 192.C-0224(H), 083.C-0794(B), 192.C-0224(G), 192.C-0224, 185.D-0056(H), 188.C-0779(A), 185.D-0056(B), 076.C-0155(A), 078.D-0071(C), 079.D-0075(D), 075.D-0194(A), 081.D-0065(D), 076.D-0130(A), 076.D-0130(C), 078.D-0071(B), 072.C-0096(C), 079.D-0075(E), 078.D-0071(A), 072.C-0096(B), 076.D-0130(B), 073.D-0038(D), 079.D-0075(C), 081.D-0065(E), 074.D-0131(C), 078.D-0071(D), 072.C-0096(A), 074.D-0131(A), 079.C-0927(C), 089.C-0497(B), 091.C-0866(C), 098.C-0739(A), 0104.C-0090(B), 288.C-5010(A), 086.C-0284(A), 085.C-0063(A), 078.C-0209(B), 078.C-0209(A), 098.C-0366(A), 192.C-0852(M), 082.C-0212(A), 083.C-0794(D), 0100.C-0474(A), 100.D-0717(A), 0103.D-0445(A), 073.D-0578(A), 075.C-0689(A), 185.D-0056(F), 081.C-0779(A), 086.C-0145(C), 092.C-0427(A), 094.C-0322(A), 094.C-0322(B), 084.C-0228(A), 082.C-0357(A), 086.C-0145(A), 088.C-0513(B), 075.C-0202(A), 078.C-0044(A), 096.D-0717(A), 095.C-0551(A), 096.C-0460(A), 0100.C-0487(A), 079.D-0075(A), 074.D-0131(E), 081.D-0065(B), 081.D-0065(A), 081.D-0065(C), 072.C-0096(E), 080.D-0086(E), 078.D-0071(E), 079.D-0075(B), 073.D-0038(C), 073.D-0038(B), 072.C-0096(D), 076.D-0130(E), 074.D-0131(B), 080.D-0086(B), 089.C-0739(A), 099.C-0205(A), 098.C-0518(A), 097.C-0571(B), 074.C-0012(A), 0101.C-0106(A), 073.C-0733(C), 185.D-0056(E), 185.D-0056(K), 074.C-0037(A), 078.D-0245(C), 079.C-0127(A), 079.C-0828(A), 081.C-0388(A), 074.D-0131(D), 080.D-0086(C), 080.D-0086(A), 080.D-0086(D), 0103.C-0759(A), 079.C-0046(A), 077.C-0012(A), 075.D-0760(A), 098.C-0269(A), 098.C-0269(B), 096.C-0876(A), 080.D-0408(A), 0104.C-0418(A), 1101.C-0557(A), 183.C-0792, 072.C-0488, 081.C-0148, 089.C-0479, 091.C-0866, 086.D-0082, 106.21DB, 090.C-0395, 088.C-0662, 106.21TJ, 108.22CE, 109.2392, 110.242T, 106.21TJ, 0102.D-0119

#### A4 SOPHIE

08A.PNP.CONNS, 07A.PNP.CONNS, 11A.PNP.CONNS,  
07B.PNP.CONNS, 17B.PNPS.AREN, 12B.PNPS.HALB,  
16A.PNPS.HALB, 18B.PNPS.HALB, 17B.PNPS.HALB,  
17A.PNPS.HALB, 06B.PNP.CONNS, 11A.PNCG.SOUB,

08A.PNG.SOUB, 15B.PNCG.SOUB, 06B.PNG.SOUB,  
17A.PNCG.SOUB, 09A.PNG.SOUB, 12B.PNP.CONNS,  
06B.PNP.SANT, 13B.PNP.DIFO, 09B.PNCG.SOUB,  
08B.PNG.SOUB, 19A.PNPS.LOPE, 14A.PNP.LAGR,  
13A.PNP.LAGR, 17B.PNPS.KIEF, 09B.PNP.CONNS,  
16B.PNCG.SOUB, 10A.PNCG.SOUB, 18B.PNPS.KIEF,  
07A.PNP.FBOU, 14B.PNCG.KATZ, 17A.PNP.CONNS,  
16B.OPT.HASW, 15B.DISC.HASW, 07B.PNG.SOUB,  
10B.PNCG.SOUB, 13B.PNCG.HAYW, 16A.PNCG.SOUB,  
14A.TECH.BOU, 12A.PNPS.HALB, 15A.PNPS.HALB,  
10B.PNPS.HALB, 15B.PNPS.HALB, 13A.PNPS.HALB,  
10A.PNPS.HALB, 11A.PNPS.HALB, 14A.PNPS.HALB,  
13B.PNPS.HALB, 14B.PNPS.HALB, 18A.PNPS.HALB,  
19B.PNPS.HALB, 18A.PNPS.KIEF, 15B.PNPS.FORV,  
07A.PNG.SOUB, 15B.PNCG.KATZ, 06B.PNPS.SOUB,  
13A.PNP.DELF, 13B.PNP.DELF, 16B.PNPS.SOUB,  
11A.TECH.BOU, 15A.PNP.BOIS, 09B.PNP.BOUV,  
11B.PNPS.HALB2, 08A.PNP.EGG2, 18A.PNP.HEBR,  
16A.PNP.COUR, 17B.PNP.HEBR, 06B.PNPS.DELF,  
11B.DISC.SOUS, 13B.PNPS.MONI, 07A.PNPS.ROYE,  
12B.PNP.DELF, 14B.PNPS.HAL1, 07B.PNP.EGG2,  
18B.PNP.LOPE, 19B.PNP.LOPE, 19A.PNPS.HALB,  
09B.PNP.BPOUV, 06B.PNPS.FBOU, 10A.PNPS.VAUC,  
11B.PNPS.HALB, 06B.PNG.BIEN, 15B.PNP.COUR,  
13A.OPT.RATA, 10B.PNCG.SOUB, 07A.PNP.CONNS,  
12B.PNPS.CREE, 15A.OPT.HASW, 12B.PNPS.HALB,  
17A.PNP.CONNS, 08A.PNP.CONNS, 22A.PNP.PHIL,  
07B.PNP.CONNS, 06B.PNP.CONNS, 16B.PNCG.SOUB,  
20B.PNP.HOYE, 06B.PNG.BIEN, 11B.PNPS.BOUV,  
15B.PNCG.KATZ, 17B.PNPS.AREN, 11B.PNPS.BOUV,  
18A.PNPS.CREE, 11B.PNPS.BOUV, 13A.PNP.LAGR

#### A5 UVES

086.D-0062, 076.B-0055, 072.B-0585, 0104.D-0550, 089.C-0207, 70.D-0356, 094.D-0596, 078.D-0760, 093.A-0373, 089.D-0202, 087.D-0724, 077.B-0507, 108.221X, 087.D-0010, 165.L-0263, 65.L-0507, 109.22VP

#### APPENDIX B: FITS HEADER KEYS

Table B1 displays the keywords used in the `gr8stars` FITS file headers.

**Table B1.** The keys contained within the headers of the `gr8stars` SID spectra.

| Header key | Information contained                   |
|------------|---|
| OBJECT     | Primary name of target                  |
| INSTRUME   | Instrument used to observe the spectrum |
| RA         | Right ascension of the target           |
| DEC        | Declination of the target               |
| EQUINOX    | Target equinox                          |
| CRPIX1     | Reference pixel                         |
| CRVAL1     | Wavelength at reference pixel           |
| CDEL1      | Wavelength step                         |
| GR8        | Date and author of merging              |
| ESTSNR     | Estimated SNR of the spectrum           |

## APPENDIX C: SIMBAD OBJECT TYPES

Table C1 displays the definitions of the SIMBAD object classifications used throughout this work.

**Table C1.** Definition of the SIMBAD object types used to classify the `gr8stars` targets.

| OTYPE     | Description              |
|-----------|--------------------------|
| SB*       | Spectroscopic binary     |
| HighPM*   | High proper motion star  |
| BYDraV*   | BY Dra Variable          |
| Star      | Star                     |
| RSCVnV*   | RS CVn Variable          |
| **        | Double or multiple star  |
| ChemPec*  | Chemically peculiar star |
| UV Cet    | UV Ceti Variable Star    |
| EclBin    | Eclipsing binary         |
| EmLine*   | Emission line star       |
| RotV*     | Rotating Variable        |
| RGB*      | Red giant branch star    |
| Variable* | Variable star            |
| Ae*       | Herbig Ae/Be star        |
| YSO       | Young stellar object     |
| TTauri*   | T Tauri star             |
| delSctV*  | Delta Sct Variable       |

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