

## CHAPTER

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## CHAPTER

# 2 Selection, Processing and Presentation of the Spectra

## 2.1 Selection of Spectra

The main criteria for the selection of the spectra have been the documentation of the spectral characteristics and the demonstration of certain effects, for example due to the different luminosity classes. The consideration of bright “common knowledge stars” was of secondary importance. The ordinary spectral classes are presented here at least with an early and a rather late subtype to show the development of characteristic features in the profile. Further spectra are commented on in separate chapters such as extraordinary star types, emission nebulae, composite spectra of extragalactic objects, star clusters, reflectance spectra of solar system bodies, absorption bands generated by the Earth’s atmosphere and finally some profiles of terrestrial and calibration light sources.

## 2.2 Recording and Resolution of the Spectra

Except of a few clearly declared exceptions all spectra have been recorded by the author with the DADOS spectrograph, equipped with reflection gratings of 200 or 900 lines  $\text{mm}^{-1}$  [4]. Unless otherwise noted, the recording was made by an 8 inch Schmidt–Cassegrain Celestron C8, applying the 25  $\mu\text{m}$  slit of the DADOS spectrograph. Similar results could surely be achieved by applying other spectrographs, for example from Shelyak Instruments or other suppliers. To display some highly resolved spectral details, the SQUES echelle spectrograph was used, applying slit widths of 25–85  $\mu\text{m}$  [5]. Finally, most of the spectra have been recorded by the cooled monochrome camera ATIK 314L+, equipped with the Sony chip ICX285AL. A few spectra have been

recorded, in cooperation with Martin Huwiler, by the CEDES 36 inch telescope of the Mirasteilas Observatory in Falera. However, applying longer exposure times, these objects are also within the reach of average amateur equipment!

The processing of the profiles with Vspec software yields about the following dispersion values [ $\text{\AA}/\text{pixel}$ ]: DADOS 200  $\text{L mm}^{-1}$ : 2.55, DADOS 900  $\text{L mm}^{-1}$ : 0.65 and SQUES echelle: 0.18. Data of the Sony chip ICX285AL: 1.4 megapixel, 2/3” monochrome CCD, pixel size 6.45  $\mu\text{m} \times 6.45 \mu\text{m}$ .

## 2.3 Processing of the Spectra

The monochrome fits-images have been processed with the standard procedure of IRIS [6]. In most cases, about 2–5 spectral profiles have been stacked, to achieve a reasonable noise reduction. The generating and analyzing of the final profile was subsequently performed with Vspec [7]. For longer exposure times a dark frame was subtracted, if necessary also the separately recorded light pollution (by IRIS or fitswork). The processing of “flat fields” was omitted.

For profiles recorded by the echelle spectrograph SQUES, each order was processed and calibrated separately, analogously to the DADOS spectra. Further in rare cases with a significantly increased noise level (recording of very faint objects), the profile was sometimes smoothed, using filters such as “Spline” provided by the Vspec software. The goal of this process here was exclusively to improve the recognizability of the documented lines. A reduction of the telluric  $\text{H}_2\text{O}/\text{O}_2$  absorptions in the yellow/red range of the spectral profile was omitted. Correspondingly, the



documentation of lines of lower resolved profiles has been cautious and rather restrained.

## 2.4 Calibration of the Wavelength

Most of the spectra have been calibrated, based on rest wavelengths of known lines and not absolutely with the calibration lamp. This prevents the profile, as a result of possibly higher radial velocities, appearing to be shifted on the wavelength axis. The focus here is on the presentation of the spectral class and not on the documentation of the individual star. The calibration with the light source was restricted to higher resolved spectra of very late spectral classes, extraordinary stars and of course applied to extragalactic objects. Generally the applied unit for the wavelength is ångstrom [ $\text{\AA}$ ]. According to convention such values are indicated with the prefix  $\lambda$  [2]. For instance 5000  $\text{\AA}$  corresponds to  $\lambda 5000$ . The values are mostly taken from the Vspec database “lineident,” according to the catalog of lines in stellar objects, ILLSS Catalog (Coluzzi 1993–1999, VI/71A). As usual in the optical spectral domain, the wavelength  $\lambda$  is based on “standard air.”

## 2.5 Display of the Intensity Scale and Normalization of the Profiles

With minor exceptions in all spectra the pseudo-continuum was removed. The according process is outlined in [3]. The profiles have been rectified, divided by the course of their own continuum. Thus, the intensity of the spectral lines becomes visually comparable over the entire range. Otherwise in a raw profile of a pseudo-continuum strong lines at the blue or red end of the spectrum appear to be optically as too weak and vice versa, weak lines in the middle part as too high. But just this reasonable correction may confuse beginners, if they try to find spectral lines of their uncorrected pseudo-continuum in the according flat and rectified atlas profile. This effect is demonstrated in [3].

An absolute flux calibration of the intensity profile would be extremely time consuming and demanding and is not necessary for the purpose of this atlas. However, with minor exceptions, the intensity of the rectified profiles was normalized to unity, so the medium continuum level yields about  $I_c = 1$ . Hence, for space saving reasons, the displayed wavelength axis is normally shifted upwards, recognizable on the according level of the intensity axis ( $I > 0$ ). In some cases only the intensity value of the shifted wavelength axis is labeled (Figure 2.1). In case of montages, showing several

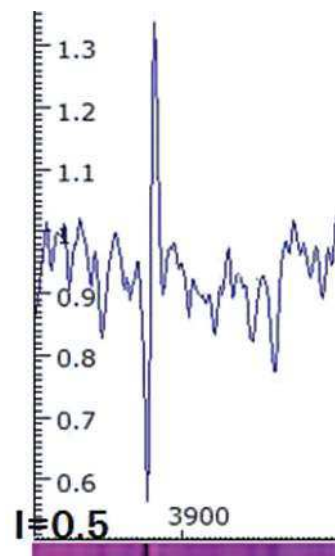


Figure 2.1 Labeling of the intensity scale, located here on the level  $I = 0.5$

spectra in one chart, the individual profiles have been normalized to unity, based on the same continuum section, to enable a rough comparison of the line intensities.

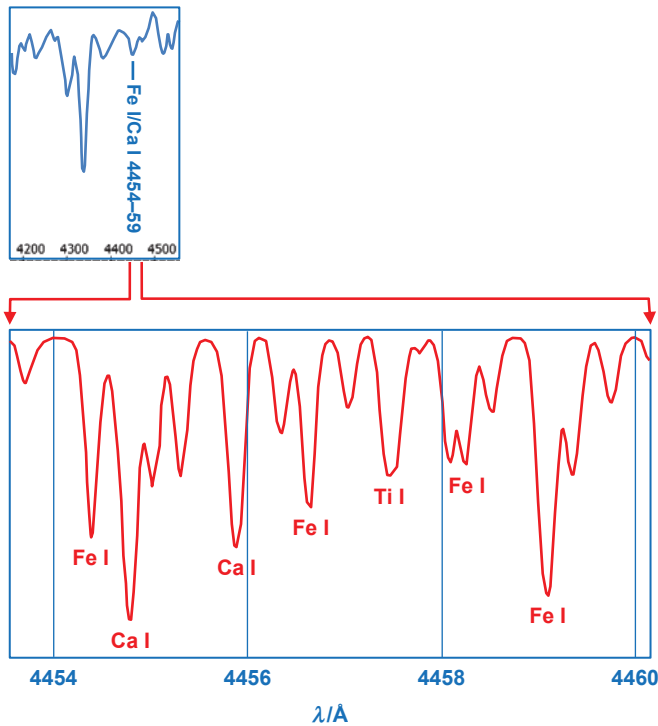
## 2.6 Identification and Labeling of the Spectral Lines

For line identification spectra commented on from the literature were used. In many cases, the sources are referenced accordingly. The aim was to specify two decimal places. If required some positions have been supplemented by the according Vspec databases, based on the ILLSS Catalog, Coluzzi 1993. In some cases NIST has also been consulted [8]. This way, a few intensive but undocumented lines have also been identified. However, this procedure was applied very restrictively, i.e. in few cases with a clear profile and a high line-intensity as well as missing plausible alternative elements in the immediate neighborhood. The labeling of such items is declared with a red “V.”

If appropriate in highly resolved SQUES echelle profiles, the lines are labeled with an accuracy of three decimal places – mostly based on SpectroWeb [9], or other referenced sources.

Blends of several spectral lines, appearing especially frequently in the mid to late stellar spectral classes, are usually labeled without decimal places. The most intense of the metal lines involved were mostly determined by SpectroWeb based on a comparable spectral class and in a few special cases even counter-checked by the *Bonner Spektralatlas* (BSA) [10].






**Figure 2.2** Procyon,  $\alpha$  CMi, DADOS profile  $R \sim 900$  (above), compared to a corresponding resolution of  $R \sim 80,000$  (cut-out, schematically after SpectroWeb [9])

If the intensity of a blended line is clearly dominated by a certain element or ion, it is also used to label the whole blend.

Figure 2.2 shows using the example of Procyon how complexly composed even an inconspicuous small absorption can be, if displayed in a high-resolution profile. What in Plate 12 is roughly summarized as “Fe I/Ca I 4454–59,” turns out in SpectroWeb to be a highly complex blend of numerous metal lines.

## 2.7 Presentation

All spectra are at least documented by a broadband profile ( $200 \text{ L mm}^{-1}$ ). In the presence of interesting lines or according information, higher resolved spectra are attached, recorded with the  $900 \text{ L mm}^{-1}$  or in some special cases even with the SQUES echelle spectrograph. The line profiles are supplemented on the wavelength axis by synthetically generated 1D-spectra (by Vspec). Their color gradient is chiefly intended as a rough visual reference for the wavelength domain. Molecular absorption bands are marked with this icon, indicating the direction of fading intensity: .

## 2.8 Object Coordinates

With exception of the quasar list in Appendix H, this atlas contains no coordinates for the individual objects. Today the corresponding data for different epochs can easily be found online, either in the CDS [11] or NED database [12], and for brighter objects also in the numerous existing planetarium programs. Many such objects are further implemented even in the control software of today’s standard amateur telescopes and can be directly approached this way (Goto).

## 2.9 Distances

Distance information is given in light years [ly] or parsec [pc], where  $1 \text{ pc} \approx 3.26 \text{ ly}$ . For extragalactic objects often the  $z$ -value is applied, directly depending on the measured red- or blueshift in the spectrum (Section 26.10).