# Preparation of a u.v Spectrophotometric Catalogue of Bright Stars

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# Preparation of a u.v. spectrophotometric catalogue of bright stars

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After a short review of the scanning characteristics of the S2/S68 experiment, the forthcoming bright star spectrophotometric catalogue is discussed, as well as the repartition in ecliptic longitude and spectral classes of the 1500–2000 stellar objects that will be selected.

The reproducibility of the data from one observation to the next is demonstrated and the sensitivity degradation rate is shown to be lower than 8% per year over the whole spectral range. The low noise and high absolute precision (± 10%) of the laboratory calibration finally complete the high precision of the data that will be included in the catalogue.

## 1. The S2/S68 Sky-Survey telescope

TD1, the first and, up to the present time, the only fully stabilized E.S.R.O. satellite, was launched on 12 March, 1972. Among the seven experiments aboard, S2/S68 occupies the full height of the instrumental part. It consists mainly of a 27.5 cm diameter off-axis paraboloid telescope feeding a spectrophotometric device. Four detectors are delivering simultaneously signals in the spectral range 1350–2900 Å. (See Boksenberg *et al.* 1973.) Three of them (the spectrophotometric channels) correspond respectively to bandpasses of 1350–1750, 1750–2150 and 2150–2550 Å, scanned with a resolution of 35–40 Å. The fourth channel is photometric with a bandpass width of 310 Å centred on 2750 Å.

The orbit of the satellite is nearly circular in shape, of period 95.5 min and is inclined at 98° to the Earth's equator to produce a precession of 360° per year. Thus, the orbit is Sun-synchronous and maintains its initial inclination approximately perpendicular to the Sun–Earth direction. The stabilization of the spacecraft is based on ecliptic coordinates. One axis points to the centre of the Sun with an accuracy of 1′. Another axis, parallel to the optical axis, is kept alined in a direction close to the zenith. Consequently, due to the Earth's motion around the Sun, the celestial sphere is scanned along ecliptic meridians, each displaced by about 4′. Thus, a complete scanning of the sky is achieved in 6 months and, because of the inclination of the Earth's equator to the ecliptic, the satellite enters into the Earth's shadow about 7 months after launch. Subsequently, the stabilization is lost until the satellite is again continuously in sunlight.

Because of this scanning, star images move, at the focal plane, across the two slits (figure 1). The wide slit corresponds to the three spectrophotometric channels and the spectral scanning is simply due to the motion of the stellar image. The narrow one corresponds to the photometric channel. In each spectral element the photons are integrated during 0.148 s so that 3.3 s are required to fulfill the complete spectral range.

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## 2. Publication of the data

The first edition of the S2/S68 catalogue of bright stars will contain the spectra obtained during the first scanning of the sky performed by the TD1A satellite. Only stars giving spectra with a 5 % statistical precision will be included in the catalogue. Taking into account that about 80 % of the sky has been covered in 1972, approximately 1500–2000 spectra will be published. Unfortunately, the missing stars are not evenly distributed over the sky. Two regions are only very partially covered, as is shown in figure 2. They correspond to the observation period following the breakdown of the second tape-recorder.

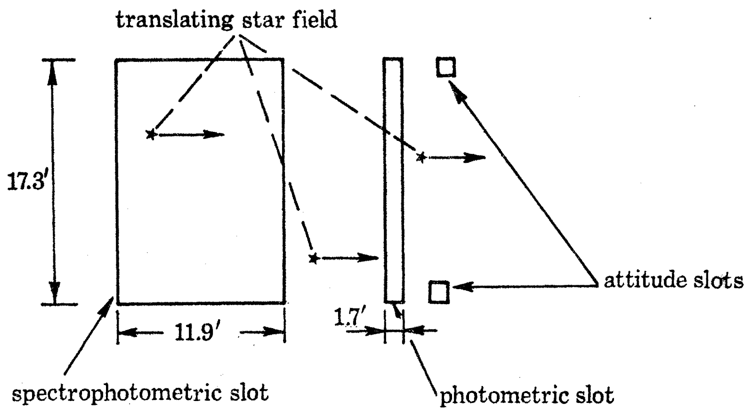


Figure 1. Focal plane of the telescope. The two main slits can be seen, as well as a stellar image passing across them.

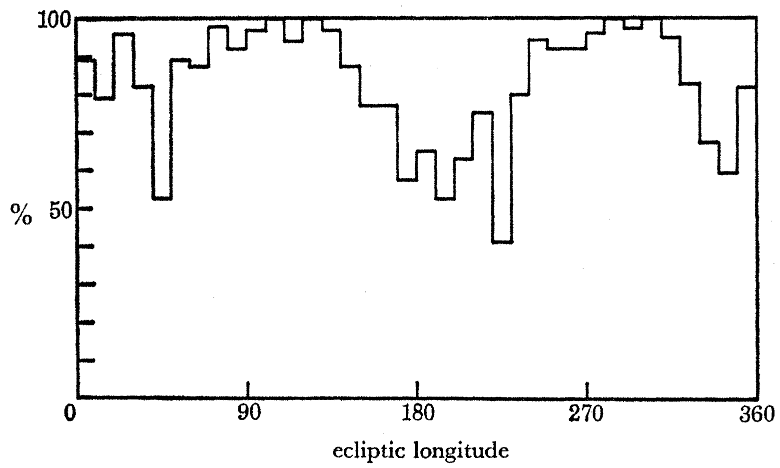


Figure 2. Sky coverage of the catalogue as a function of ecliptic longitude on 29 October 1972.

The spectral type distribution can be found in table 1, where it is shown that the limiting magnitudes decrease from 7 for O–B3 stars to only 2 for $G_0$–$G_2$ stars. The number of stars in each line of the table falls down from a few hundreds per category for the early type stars to a few units for the G-types.

Figure 3 shows a standard page of the catalogue. The upper part is occupied by general information about the star, as well as the corresponding references. The next line is devoted to the radiant flux density for the photometric channel (expressed in $10^{-7}$ J cm$^{-2}$ s$^{-1}$ Å$^{-1}$), followed by $S$, the maximum deviation between the average values and the observations, $\sigma$, the photometric statistical error for each data and ($N$) the number of observations.

The main part of the upper half of the page is then devoted to the data corresponding to the three spectrophotometric channels. For each of them can be found the wavelength of the centre of the spectral band, the radiant flux density per $A$ ($10^{-7}\,J\,s^{-1}\,cm^{-2}\,Å^{-1}$), the deviation $S$ between different spectra and the statistical error. The absolute flux intensity of 64 spectral elements are given for each star.

Table 1

| MK | $V$ |
|---|---|
| 0–B3 | 7.0 |
| B4–B5 | 6.5 |
| B6–B9 | 6.0 |
| A0–A1 | 5.5 |
| A2–A4 | 5.0 |
| A5–A9 | 4.5 |
| F0–F4 | 4.0 |
| F5–F7 | 3.0 |
| F8–F9 | 2.5 |
| G0–G2 | 2.0 |

On the lower part of the page can be seen an average spectrum, drawn in logarithmic ordinate against linear wavelength (in nm). The radiant flux densities are given in absolute values as a result of a complete laboratory calibration operation. This was carried out completely independently in Liège and Edinburgh. In each laboratory, the flight model was calibrated against a secondary standard, the latter having been calibrated on an absolute basis. The methods used were different and are described elsewhere (Marette 1973).

The overall agreement between the two procedures (in absolute sensitivities) is better than 20 % in the whole spectral range:

| | | | | | |
|---|---|---|---|---|---|
| it varies from | 0 to 13 % | between | 1350 | and | 1750 Å |
| | 10 to 17 % | between | 1750 | and | 2150 Å |
| | 10 to 19 % | between | 2150 | and | 2550 Å |
| | 4 to 14 % | between | 2600 | and | 2900 Å |

The arithmetic average of the results has been finally adopted for the catalogue and is consequently within 10 % of the Liège and Edinburgh initial calibrations.

## 3. General comments on the quality of the data

The reproducibility of the observations is perfectly illustrated on figure 4 which shows, for several successive orbits, spectra of the same star. On the other hand, the same star may be observed at six month intervals, when the scanning grand circle has rotated 180°.

In figure 5, the average decrease of sensitivity has been shown for three successive sets of observations over a period of one year. It is to be seen that the overall change, expressed in magnitude, is everywhere less than 8 %. The corresponding correction will be introduced in the calibration programme, although it is smaller than the overall absolute precision.

The noise might have been a source of imprecision. It has not been included in the table as, apart from perturbed regions or periods (South Atlantic Anomalies, auroral precipitations),

| σ Sco | | | | | | | | HD 147165 |
|---|---|---|---|---|---|---|---|---|
| R.A. (2000) | DEC. | Sp-L | V | B-V | U-B | $v \sin i$ | rem. | ref. |
| 16 21 12 | −25 35 | B1 III | 2.88 | 0.13 | −0.69 | 53 | — | S1, P1, V1 |

photom. $E = 7.26E\text{-}13$ $S = 3\%$ $\sigma = 4\%$ $N = 4$

| λ/nm | $\bar{E}(\lambda)$ | $S$ (%) | σ (%) | λ/nm | $\bar{E}(\lambda)$ | $S$ (%) | σ (%) | λ/nm | $\bar{E}(\lambda)$ | $S$ (%) | σ (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 136.0 | 3.81 *E*-12 | 3 | 5 | 175.8 | 1.94 *E*-12 | 5 | 7 | 215.6 | 5.32 *E*-13 | 6 | 7 |
| 138.0 | 3.04 | 4 | 5 | 177.8 | 1.84 | 4 | 6 | 217.6 | 5.35 | 6 | 6 |
| 140.0 | 2.89 | 3 | 6 | 179.9 | 1.82 | 5 | 6 | 219.7 | 4.96 | 5 | 6 |
| 142.1 | 3.04 | 5 | 3 | 181.9 | 1.80 | 4 | 6 | 221.7 | 5.18 | 5 | 5 |
| 144.1 | 3.16 | 4 | 4 | 183.9 | 1.55 | 5 | 5 | 223.7 | 5.23 | 6 | 5 |
| 146.1 | 2.98 | 5 | 3 | 186.0 | 1.53 | 5 | 5 | 225.8 | 5.68 | 4 | 5 |
| 148.2 | 2.82 | 6 | 4 | 188.0 | 1.44 | 3 | 5 | 227.8 | 5.82 | 4 | 6 |
| 150.2 | 2.49 | 4 | 5 | 190.1 | 1.25 | 3 | 5 | 229.9 | 5.78 | 5 | 6 |
| 152.2 | 2.03 | 4 | 4 | 192.1 | 1.18 | 3 | 4 | 231.9 | 6.37 | 5 | 5 |
| 154.3 | 1.84 | 5 | 3 | 194.2 | 1.13 | 2 | 5 | 234.0 | 6.66 | 4 | 6 |
| 156.3 | 2.06 | 5 | 3 | 196.2 | 1.01 | 2 | 4 | 236.0 | 6.98 | 4 | 5 |
| 158.3 | 2.13 | 4 | 3 | 198.2 | 9.98 *E*-13 | 2 | 4 | 238.0 | 7.25 | 5 | 6 |
| 160.4 | 2.10 | 3 | 4 | 200.3 | 9.00 | 3 | 5 | 240.1 | 7.73 | 5 | 4 |
| 162.4 | 2.21 | 3 | 4 | 202.3 | 8.63 | 4 | 4 | 242.1 | 7.71 | 4 | 5 |
| 164.4 | 2.31 | 4 | 5 | 204.4 | 7.69 | 4 | 5 | 244.2 | 7.89 | 3 | 3 |
| 166.5 | 2.47 | 4 | 3 | 206.4 | 7.04 | 5 | 6 | 246.2 | 8.35 | 3 | 3 |
| 168.5 | 2.47 | 5 | 6 | 208.4 | 6.69 | 5 | 6 | 248.2 | 8.73 | 3 | 4 |
| 170.5 | 2.25 | 5 | 6 | 210.5 | 5.99 | 5 | 6 | 250.3 | 8.46 | 3 | 5 |
| 172.6 | 2.10 | 5 | 4 | 212.5 | 6.04 | 5 | 5 | 252.3 | 8.85 | 4 | 6 |
| 174.6 | 2.01 | 3 | 5 | 214.6 | 5.36 | 6 | 6 | 254.4 | 8.44 | 5 | 7 |
| 176.6 | 1.83 | 3 | 7 | 216.6 | 5.05 | 7 | 7 | 256.4 | 8.06 | 6 | 7 |

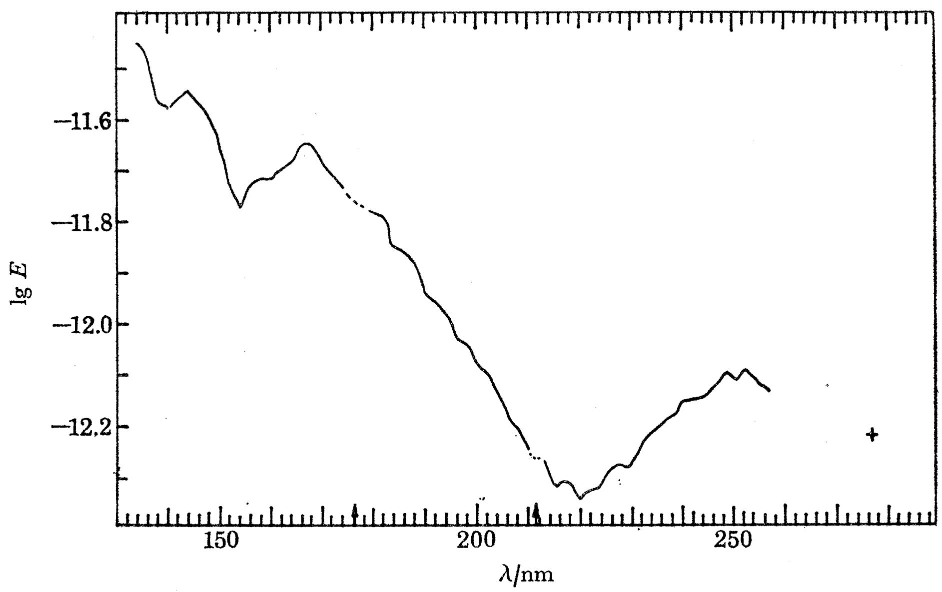


FIGURE 3. Standard page of the catalogue.

the noise linked with the background is negligible. This is shown in table 2 in the case of a B2 star of magnitude $m_V = 6.96$, which, as can be seen from table 1, is one of the faintest to be included in the catalogue. The background itself is obviously subtracted as it may amount to a 10% error or more.

It has already been pointed out that the spectrum of a star presented in the catalogue is the average of all spectra recorded for the same object. The number of these may often be three or

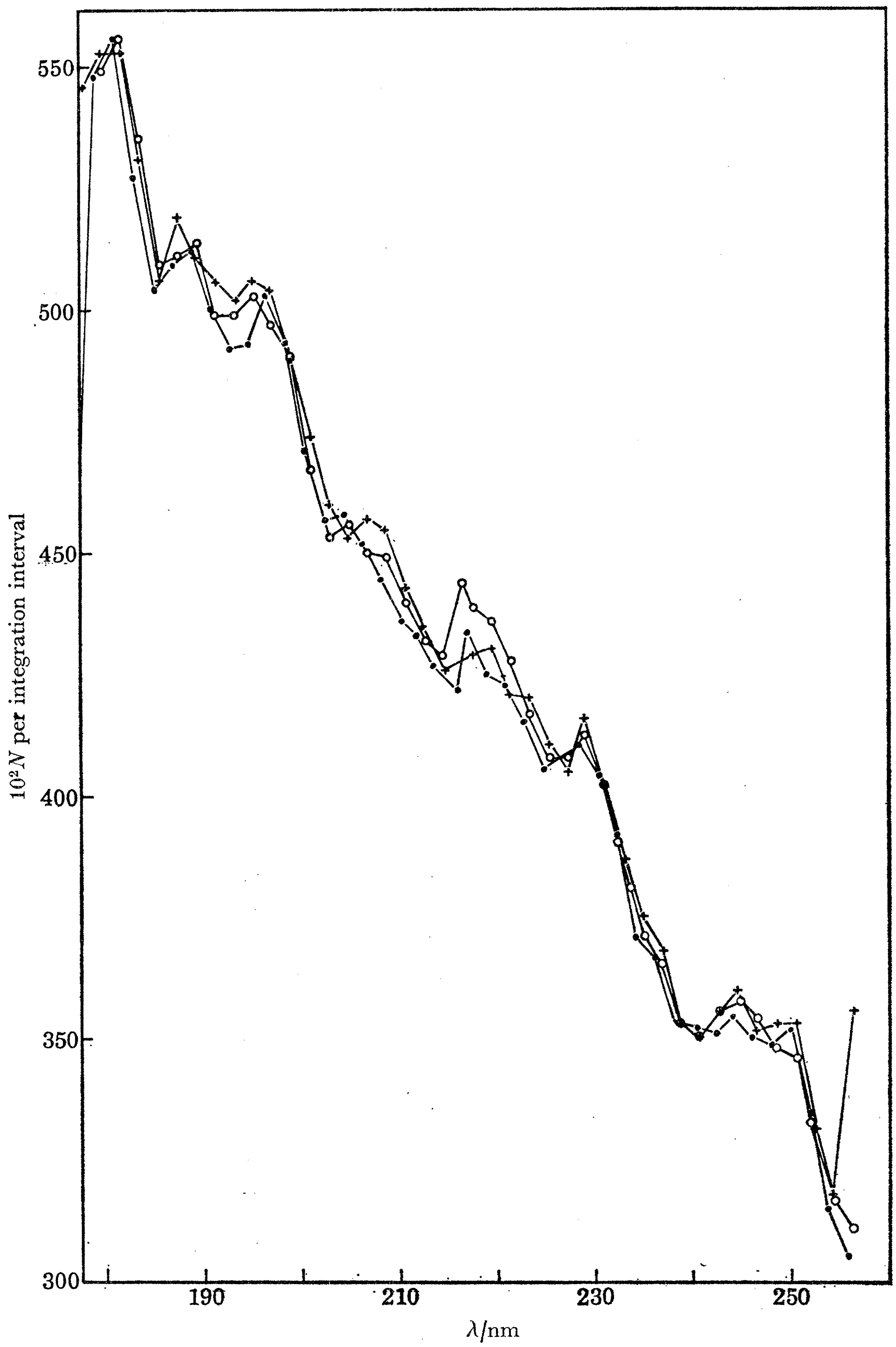


FIGURE 4. Successive recordings of the spectrum of α Lyrae.

four. For objects at high ecliptic latitudes, it may be ten or more. The statistical error has been simply decreased by a factor equal to $N^{\frac{1}{2}}$ if $N$ is the number of spectra. The criterion for the limiting magnitude has not, however, taken the multiplicity of the observations into account.

Within two years, when all the observations have been processed (corresponding to 1972, 1973 and the beginning of 1974), a second edition of the bright star catalogue will be issued.



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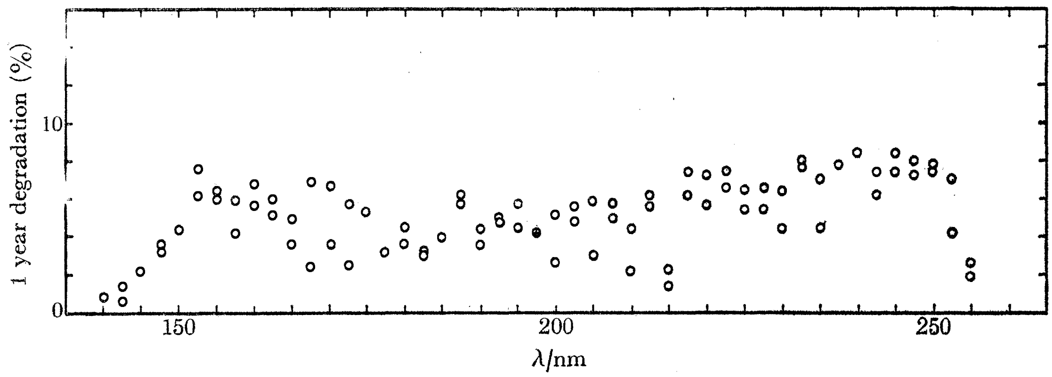


FIGURE 5. Average decrease of sensitivity for channels 2, 3 and 4 over a period of 1 year.

TABLE 2. RECORDED PULSE NUMBERS OF A B2 STAR OF MAGNITUDE $m_v = 696$. THE NOISE CORRESPONDING TO THE BACKGROUND IS SEEN TO BE NEGLIGIBLE

(Orbit 802. Segment 2. Ecliptic coordinates, λ-133 46 53. β-60 6 43.)

| A2 | A3 | A4 | A1 |
|---|---|---|---|
| 28 | 61 | 32 | 32 |
| 46 | 36 | 15 | 23 |
| 34 | 44 | 14 | 20 |
| 32 | 36 | 28 | 16 |
| 24 | 45 | 28 | 25 |
| 25 | 27 | 30 | 20 |
| 35 | 42 | 17 | 44 |
| 33 | 28 | 25 | 75 |
| 130 | 72 | 12 | 36 |
| 820 | 338 | 0 | 12 |
| 812 | 316 | 244 | 10 |
| 672 | 314 | 239 | 8 |
| 696 | 282 | 242 | 19 |
| 668 | 352 | 215 | 25 |
| 668 | 278 | 223 | 19 |
| 584 | 308 | 246 | 14 |
| 560 | 264 | 245 | 23 |
| 484 | 258 | 300 | 19 |
| 424 | 302 | 200 | 17 |
| 360 | 240 | 227 | 19 |
| 328 | 284 | 235 | 8 |
| 334 | 280 | 240 | 4 |
| 296 | 274 | 183 | 20 |
| 276 | 300 | 194 | 13 |
| 304 | 312 | 223 | 32 |
| 254 | 264 | 222 | 23 |
| 253 | 256 | 201 | 15 |
| 181 | 308 | 197 | 28 |
| 182 | 290 | 175 | 55 |
| 107 | 190 | 108 | 65 |
| 30 | 30 | 27 | 70 |
| 31 | 30 | 23 | 98 |
| 27 | 19 | 18 | 82 |
| 32 | 32 | 13 | 24 |
| 34 | 30 | 18 | 19 |
| 23 | 47 | 7 | 18 |
| 30 | 28 | 13 | 37 |
| 27 | 49 | 10 | 44 |
| 28 | 26 | 11 | 23 |
| 23 | 41 | 12 | 8 |
| 32 | 26 | 12 | 8 |
| 26 | 50 | 6 | 9 |

It will cover more than 95 % of the sky and will, consequently, contain new objects. For the stars already included in the first edition, an improvement in the statistical precision will be reached. This, however, does not provide much new information for the bright objects. It has been considered preferable to take advantage of the fact that the phase of the observations with respect to the integration intervals being statistically variable, the number of experimental points per resolved interval will no longer be 2, as was necessary for a single observation, but many more. Certain redundant information therefore does exist which may be used in order to increase the effective resolution by some deconvolution method.

It is well known that these methods are very sensitive to noise and can never, in practice, increase a resolution by a factor notably higher than 3 or 2. This problem has been considered at length, taking into account the fact that, due to the structure of the S2/S68 experiment, each measuring point corresponds to a double integration (Malaise & Beeckmans 1973). The use of the inversion of the Fredholm integral is being considered, which appears to minimize the influence of noise, of the stability and the calibration error on the shapes of the final spectra.

Another catalogue devoted to faint objects will be published after the first bright star catalogue. The detailed specifications and the date of issue have not yet been defined. The bright star catalogue (first edition) should appear in the course of 1975.

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