Catalogue of Stars measured in the Geneva Observatory Photometric system (fourth edition)

F. Rufener

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Observatoire de Genève - CH-1290 Sauverny - Switzerland

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Summary: A compilation of the photoelectric measurements in the Geneva Observatory seven colour system (U, B, V, $B1$, $B2$, $V1$, G) is presented for 29'400 stars. The catalogue, besides the coordinates and principal bibliographic references of each star, gives the colours (normalized magnitudes), the colour indices $B1 - B2$, $B2 - V1$ and $V1 - G$, the parameters d, Δ, g, m_2 and the V magnitude. The number of accurate measurements and the standard deviation of their mean value are given separately for the colours and the V magnitude. An estimation procedure of the uncertainties associated with the photometric parameters is described in the preface. The conversions to absolute fluxes in SI units have been described by Rufener and Nicolet (1988) in a recent paper.

Key words: Multicolour photometry - Geneva photometric system -
V magnitude scale - Geneva parameters d, Δ, g and m_2.

1 Introduction

This catalogue contains all the stars which have been measured with the seven colour Geneva photometric system (U, B, V, $B1$, $B2$, $V1$, G). Observations in the northern hemisphere started in 1960; they were made from the Jungfraujoch (3577m) and Gornergrat (3100m) observatories which both belong to the High Altitude Research Stations. Since 1964 we also observe from our station at St Michel l'Observatoire in the Haute-Provence Observatory (650m). Furthermore, some measurements have been made from the Spanish Observatories of Izania (Tenerife, 2400m) and Calar Alto (Almeria, 2160m). After 1971, observations have been extended to the southern hemisphere and are carried out at the ESO Observatory at La Silla (2400m). There, in 1975, Geneva Observatory installed a 40 cm telescope and in 1980 the magnitude limit as well as the precision of the measurements were improved through its replacement by a 70 cm telescope. Between 1960 and the summer of 1987 more than 200.000 measurements in seven colours have been gathered. Their percentages are distributed as follows: Jungfraujoch 5.3%, Gornergrat 5.6%, St Michel 8.9%, La Silla 79.4%, others 0.8%. This shows that the majority of the measurements are done from La Silla where the southern as well as the northern hemisphere are now observed for all declinations lower than $\sim 15^\circ$.

Since 1968 two photometers were used and since 1976 three photometers are available. Particular care was given to reproducing the system of instrumental passbands (same filters, same photocathodes for the photomultipliers). The use of a differential photometer (Burnet and Rufener, 1979) has increased rapidity, reliability and precision of the measurements. Also, systematic rapid sampling as well as the application of statistical criteria computed in real time (Bartholdi et al., 1984) ensure good control and efficient tests of the measurements' quality. They add to the signal measurements a signature which characterizes the observing conditions. Permanent vigilance and systematic procedures for reduction outside the atmosphere and correlation to the standard guarantee a homogeneous extension of the systems defined by the successive catalogues (Rufener 1970, 1976, 1981 and 1988).

The stars figuring in this catalogue result from the combination of various extensive programmes undertaken mainly by the astronomers of Geneva Observatory. Some were done by colleagues of Lausanne and Leuven Universities. Since all programmes are not yet completed, observations continue. The work for the present catalogue has involved many colleagues during the last twenty-eight years and it would be impossible to name all the persons who have contributed to it. I would like to mention, however, the exceptional and long-term cooperations with M. Burnet, B. Pernier, C. Richard and J.-J. Schwab. All the observatory staff has helped with the construction of the telescopes and photometers, the observations and reductions of the measurements and finally the compilation of the accumulated results. I should like to seize the opportunity to thank them all for their devotion and efficient help.

2 Passbands of the photometric system of Geneva Observatory

These passbands are experimentally delimited by absorbent glass filters and the function of chromatic sensitivity of the photomultipliers which all have $Sb\,Cs_3(S-11)$ photocathodes. The temperature of the filters and photocathodes are regulated so as to stabilize the instrumental response. Rufener and Maeder (1971) have derived a description of the pass-bands which define the system which is now revised and replaced by the version published by Rufener and Nicolet (1988). They can be used directly for calculating theoretical colours from models of stellar atmospheres.

Figure 1 shows the responses $T_i(\lambda)$ of these passbands to an equiphotonic flux. Table 1 summarizes some characteristics such as

$$\begin{aligned}
\lambda_{0,i} &= \frac{\int \lambda\, T_i(\lambda)\, d\lambda}{\int T_i(\lambda) d\lambda} \\
\mu_i^2 &= \frac{\int (\lambda - \lambda_{0,i})^2\, T_i\,(\lambda) d\lambda}{\int T_i\,(\lambda)\, d\lambda} \\
\Phi_i &= -2.5 \log \int T_i\,(\lambda) d\lambda - \Phi_B
\end{aligned}$$

These values can only be compared after transformation to those obtained with the responses to an equienergetic flux which we used in our preceding editions. The principal conversion formulae as well as the constants for the transformation of the colours and the V magnitude of the catalogue that are necessary to estimate each star's absolute fluxes are described in detail by Rufener and Nicolet (1988).

Figure 1: Responses for the seven colours of the Geneva photometric system to an equiphotonic flux. The determination of these profiles are from Rufener and Nicolet (1988).

Table 1: Pass-band characteristics

Filter	U	B	V	B1	B2	V1	G
λ_0 [Å]	3464	4227	5488	4015	4476	5395	5807
μ [Å]	159	282	296	188	163	202	200
$(\mu/\lambda_0)^2 \cdot 10^3$	2.11	4.45	2.91	2.19	1.33	1.40	1.19
Φ [mag]	0.534	0.000	0.564	0.869	1.499	1.297	1.638

These characteristics refer to the passband functions corresponding to an equiphotonic flux (Rufener and Nicolet, 1988).

3 Some definitions

Our weighting methods as well as the procedures for computing the deviations around the mean values are summarized hereafter.

a) To each observation in seven colours reduced to outside the atmosphere and correlated to our standard a weight p is assigned so that $0 \leq p \leq 4$. The actual value of this weight depends primarily on the photometric quality of the night (stability, homogeneity of the extinction). It is evaluated by examining the dispersion among the points in the correlation for each colour of the night's natural system with the corresponding colour of the standard. The number of points and thus also the usable duration of the night are factors in the evaluation. The attribution of this weight can be modified for each measurement individually, taking into account particular circumstances pertaining to the observation of a given star (passage of cirri, particular zenith distance, incorrect measurement of background illumination, etc.). Independently of the colour's weight but with the same kind of considerations (good distribution of V-magnitude standards during the night, smallness of dispersion between the night's and standard V-values, etc.) a weight q is assigned to the V-magnitude such that $0 \leq q \leq 4$. The choice of the weights p and q in the scale 0 to 4 results from the application of the following criteria:

4 for observations of exceptional quality whose correlation with standards is remarkably well assured.

3 normal weight for all the good measurements conveniently correlated with standards.

2 weight conferred as soon as the slightest doubt exists as to the transparency or correlation with standards.

1 weight conferred as soon as no certainty of good transparency and good correlation with standards can be obtained (case of partial night for instance).

0 this weight sanctions all measurements for which an objective risk of error exists.

The weighting of the $\sim$ 200.000 measurements which contribute to the establishment of the present catalogue has been such that the following proportions have been obtained:

$p = 0$ for 6.4%; $p = 1$ for 4.9%; $p = 2$ for 13.2%; $p = 3$ for 71.2% and $p = 4$ for 4.3% of the measurements. The obviously bad measurements are eliminated from our files.

b) When, for a given star, there are n determinations of the seven normalized magnitudes converted to the existing standard, we use the index k in order to number the independent determinations of the j colours (j = 1, 2, ... 7). We thus obtain a table of normalized magnitudes c_{kj} having n lines and seven columns. To each line corresponds a weight p_k. The mean colours could be

$$\overline{c}_j = \frac{\sum_{k=1}^{n} p_k\, c_{kj}}{\sum_{k=1}^{n} p_k} \tag{1}$$

with obviously $\overline{c}_2 = 0$, since our normalized magnitudes correspond to the magnitudes of the seven colours from which the magnitude of filter B (here numbered 2) has been subtracted. In fact, to preserve the reality of the fluxes we operate the mean on the flux estimators. We then prefer

$$\overline{c}_j = -2.5 \log \left(\frac{\sum_{k=1}^{n} p_k\, 10^{-0.4 c_{kj}}}{\sum_{k=1}^{n} p_k} \right) \tag{2}$$

This alternative has real importance when the c_{kj} show dispersed values but we do it systematically. Dispersed c_{kj} occur particularly for U fluxes of faint red stars. In general, the mean colour from (2) does not differ significantly from the one computed with (1). It is evident that for colour 2, set arbitrarily equal to 0, it is not possible to attribute accidental errors directly. Nevertheless, the following assumption allows an a posteriori estimation of the deviations for each colour. Let us consider that the sum of the observational errors per line, taken with their sign, is equal to zero. This allows us to state that the sums of normalized magnitudes per line must be equal. Then, using

$$C_k = \sum_{j=1}^{7} c_{kj}$$

and

$$\overline{C} = \frac{\sum_{k=1}^{n} p_k\, C_k}{\sum_{k=1}^{n} p_k}$$

we can establish a new table with

$$c^*_{kj} = c_{kj} + \frac{1}{7}\,(\overline{C} - C_k)$$

It is easy to see that we have, for the mean of the columns in this table, $\overline{c}^*_j \equiv \overline{c}_j$.

In our opinion, the deviations $\Delta_{kj} = c^*_{kj} - \overline{c}_j$ give a better representation of the true dispersion of the measurements. They are used to calculate the standard deviations σ_j

$$\sigma_j = \left[\sum_{k=1}^{n} p_k\, \Delta^2_{kj} / \sum_{k=1}^{n} p_k \right]^{1/2}$$

The mean standard deviation in the column σ (SIG for colours) of the catalogue is given by

$$\sigma = \frac{1}{7}\,\Sigma_{j=1}^{7}\;\sigma_j$$

The mean V magnitude and its standard deviation σ_V (SIG for V magnitude) are computed like the mean colours.

$$m_V = -2.5 \log \left(\frac{\sum_{k=1}^{n}\; q_k\; 10^{-0.4\, m_{V_k}}}{\sum_{k=1}^{n}\; q_k} \right)$$

$$\sigma_V = \left[\sum_{k=1}^{n}\; q_k\,(m_{V_k} - m_V)^2 / \sum_{k=1}^{n}\; q_k \right]^{1/2}$$

It is obvious that the values of σ_j, therefore σ and σ_V, do not have the statistical significance of a standard deviation as long as the number of measurements n is too small. Nevertheless for values of $n \leq 5$, these quantities allow us to find those stars for which one may suspect the dispersion of the first measurements to be abnormally large. When $n > 5$, the values of σ and σ_V become estimations of the true accuracy of the observations. We shall come back to this point later.

c) We have made use of three parameters to define the mean value of several measurements: their individual weights, p_k and q_k, and their total number n. When we have to compute a standard deviation for the mean value of several measurements, we need a number equivalent to the number of good measurements. We will use

$$P = \frac{1}{3}\sum_{k=1}^{n}\; p_k \quad \text{for the colours and} \qquad\qquad Q = \frac{1}{3}\sum_{k=1}^{n}\; q_k \quad \text{for the } V \text{ magnitude}$$

These numbers, rounded off to the nearest integer, are in the columns P and Q of the catalogue. The above definitions explain why we sometimes obtain a standard deviation for a star which has P or Q equal to 1.

4 Calculation of a confidence interval

Before we formulate and apply a method permitting an objective calculation of the "error bars" for the photometric quantities resulting from the use of the normalized magnitudes of the catalogue, we want to point out a fact observed for the majority of the deviation tables Δ_{kj} as defined in the preceding section. The deviations of one line are not independent and they are very often correlated to the mean wavelength of the colour j. This fact can be interpreted by considering that at least part of the deviation reflects a residual error in the value of the atmospheric extinction used for the reduction to outside the atmosphere. As a matter of fact, any error in the assumed instantaneous extinction will strongly depend upon the wavelength. This type of error is very frequent and affects all the stars. Another cause which could produce similar effects would be slight changes in the star's colour temperature. This second cause can only be invoked in the case of a few particular stars.

We calculate the variances of the deviations for each mean colour of subscript i, respectively j, as well as the covariances between them. We thus obtain a symmetric matrix s_{ij}. The calculation has been made for stars measured a great number of times. This matrix s_{ij} varies from star to star. A global matrix S_{ij} has been calculated for three samples of well measured stars having $\sigma \leq .010$ and $\sigma_V \leq .012$. For each sample, the matrix S_{ij} represents the variance and covariance of a large table of deviations composed from the association of the Δ_{kj} obtained with each of the sample stars. Sample 1 is composed of stars for which the sum of the weights p obtained for the third Catalogue (Rufener, 1981) was 50 or more and for which a sum of weights p superior or equal to 50 has been obtained in the meantime. Sample 2 has been selected in the same way but by limiting to 20 the sum of weights p obtained before and after the catalogue of 1981. As to sample 3 it is composed of all stars for which we have over 50 for the sum of weights, regardless of when they were gathered. Table 2 gives a description of these samples with their main properties. The S_{ij} matrices calculated for each sample are similar; we retain as characteristic example the matrix of sample 2 as it is based on a large number of measurements of stars from both hemispheres. This matrix is given in Table 3. The S_{ij} matrix shows the above-mentioned dependence of the deviations on the mean wavelength of the colours. This effect is essentially caused by differential extinction errors since stars suspected of variability have been eliminated from the sample used. The V magnitude variance and covariances prove that no significant correlation exists between the V magnitude and colour deviations.

For stars having V magnitude ≤ 11.0 we can now formulate the manner of calculating the confidence intervals with maximum objectivity. Let x be a photometric parameter defined by a linear combination of normalized magnitudes and calculated with values of known weight P,

$$x = \sum_j \lambda_j \, c_j$$

The variance, and consequently the standard deviation σ_x, will be obtained in the following manner

$$\sigma_x^2 = \frac{1}{P} \sum_i \sum_j \lambda_i \, \lambda_j \, S_{ij} = \frac{1}{P} \left[\sum_j \lambda_j^2 \, S_{jj} + 2 \sum_{i<j} \lambda_i \lambda_j \, S_{ij} \right]$$

For some particular cases standard deviations calculated in this manner figure in Table 4 where they are expressed in thousandths of a magnitude. Table 4 contains the standard deviations of the V magnitude, of some typical indices and of the main parameters used in the Geneva system as defined by Golay (1972).

¿From the diagonal terms of Table 3 we can compute the typical mean standard deviation of colours (σ). It can be compared to the one observed for the colour measurements, accumulated for each star of the catalogue and given in column 14. We obtain for this mean σ the rounded-off value of $\sigma = 0.005$.

For the stars weaker than $m_V = 11.0$ Figure 2 shows the variations of σ and σ_V as a function of the magnitude. One should take this variation into account, or, better, the real values per star shown in the catalogue. We might underline that the fast increase of σ is due to the fact that the majority of faint stars are also red and that the difficulty to measure U is therefore dominant for the estimation of σ.

Table 2: Characteristics for samples of well-measured stars

sample	1	2	3	4
sum of p before summer '79 sum of p after summer '79	≥ 50 ≥ 50	≥ 20 ≥ 20	$\left.\right\} \geq 50$	— ≥ 180
Total number of stars	166	278	607	198
Percentage of stars with $\delta > 0$	44	42	29	4
Percentage of stars with $\delta < 0$	56	58	71	96
Mean weight P per star	164	124	86	128
Colour mean sigma (σ)	$5.2\ 10^{-3}$	$5.1\ 10^{-3}$	$4.9\ 10^{-3}$	$3.6\ 10^{-3}$
V magnitude mean sigma (σ_V)	$6.1\ 10^{-3}$	$6.2\ 10^{-3}$	$6.2\ 10^{-3}$	$4.4\ 10^{-3}$
Estimation of the total number of measurements represented by the sample	$\sim$ 31.500	$\sim$ 40.000	$\sim$ 60.000	$\sim$ 28.000
Percentage of the total number of measurements represented by the sample	16%	20%	30%	22%

5 Comments concerning the conservation of the system

They are of two orders, firstly the stability of the photometric system has to be checked, secondly the evolution of the quality of the measurements must be accounted for.

One of our aims during the extension of our photometry to a large number of stars is the conservation of the system's passbands. This imposes, on the one hand, the conservation of the optical and photoelectric response curves within the narrowest possible limits and, on the other hand, the permanence of the correlation techniques while trying to avoid introducing any systematic drifts. We gain safety and confidence with the following controls:

a) For stars of samples 1 and 2 we have calculated the differences η_j between the mean colours in "Rufener's 1981 Catalogue" and those of the present one. We also compute the differences for both mean V magnitudes. The means of these differences ($\overline{\eta}_j$) taken with their sign should be equal to zero. For the two samples, we notice that these means are always such that

$$-0.0005 < \overline{\eta}_j < 0.0005$$

b) We have calculated two means for the colours of the stars in sample 2: the first for measurements leading to the 1981 Catalogue, the second for new measurements made since summer 1979. With the help of the matrix of variances and covariances, we have estimated the standard deviations $\sigma_{\varepsilon j}$ which the differences ε_j of these two means would present. In order to make this a global calculation applicable to all stars from the

Table 3: Covariance matrix (variances and covariances are multiplied by 10^6)

	j	1 U	2 B	3 V	4 B1	5 B2	6 V1	7 G	m_V
i									
1	U	60	2	-14	2	-10	-17	-21	2
2	B		17	-1	4	-5	-7	-11	-2
3	V			21	-7	-4	3	3	3
4	B1				21	0	-7	-12	0
5	B2					20	0	-1	-1
6	V1						20	8	-1
7	G							33	-1
	m_V								38

sample, the number of measurements adopted for each mean has been evaluated taking into account the selection criteria (sum of the weights $p \geq 20$). This corresponds to at least 6.7 good measurements done before and after the summer of 1979. For many of the means even more measurements have been obtained. In order to consider this at least partially and to keep the typical $\sigma_{\epsilon j}$ of each colour as a number expressed in entire thousandths, we adopted a compromise of 8.5 measurements for each mean of each star. As the differences ϵ_j should be equal to zero, we considered the statistics of cases for which

$$1) \quad \|\epsilon_j\| > \sigma_{\epsilon_j} \qquad\qquad 2) \quad \|\epsilon_j\| > 2\sigma_{\epsilon_j}$$

It is found that 1) holds for 30% and 2) for 6% of the 1668 cases represented by the six normalized magnitudes of 278 stars. These proportions are close to those predicted by theory for the ϵ_j, assuming a normal law and an exact appreciation of the variances and covariances. Considering the fact that some sample stars could present real physical drifts our results above seem too favorable. Very probably the six σ_{ϵ_j} adopted here are sometimes overestimated when the stars are measured frequently. Let us add that the ϵ_j present no significant correlation with the right ascension, the declination or the colour j of stars in the sample.

c) The root mean square values $\overline{\sigma}_j$ of the above differences ϵ_j calculated for all stars in samples 1 to 3 show that firstly they do not depend on the sample and that secondly they are comparable to or even lower than the ones obtained when testing Rufener's 1981 catalogue.

These three stability tests of the system are based on a large number of observations (as large as 60.000 according to the sample) distributed over all the nights. We can thus assert that our photometric system has not changed in any undesirable manner and that it conserves the same photometric significance throughout.

Table 4: Standard deviations of the main Geneva parameters (in thousandths of magnitude)

P	m_V	[U-B]	[B-V]	[B1-B2]	[B2-V1]	[V1-G]	d	Δ	g	m_2
1	6.2	8.5	6.3	6.4	6.3	6.1	13.7	14.4	9.9	7.8
2	4.4	6.0	4.5	4.5	4.5	4.3	9.7	10.2	7.0	5.5
3	3.6	4.9	3.7	3.7	3.7	3.5	7.9	8.3	5.7	4.5
5	2.8	3.8	2.8	2.9	2.8	2.7	6.1	6.4	4.4	3.5
10	2.0	2.7	2.0	2.0	2.0	1.9	4.3	4.5	3.1	2.5

$d =$ [U-B1] - 1.430 [B1-B2] $\qquad g =$ [B1-B2] - 1.357 [V1-G]

$\Delta =$ [U-B2] - 0.832 [B2-G] $\qquad m_2 =$ [B1-B2] - 0.457 [B2-V1]

The time-dependent evolution of the matrices S_{ij} shows an obvious tendency toward a variance decrease for the well measured star samples. For instance, sample 4 which was based on measurements done in Chile after the summer of 1979 with the differential photometer, selects the 198 stars for which a minimum of 60 and a mean of 128 good measurements have been carried out. Matrix S_{ij} which results from this sample is composed of 21% of the new measurements and displays very low variances. It gives for colours $\sigma = .0036$ and for V magnitude $\sigma_V = .0044$. These values represent the acquisition conditions of the actual measurements. The latter confirm estimations made by Waelkens and Rufener (1985) and Waelkens (1985) while analyzing measurements of variable stars gathered during one or two years which were in good correlation with the standard.

In conclusion we can say that the definiton of the colours was maintained and thus a good homogeneity of the catalogue achieved. Also, the internal precision of recent observations was improved. Therefore, the estimation of the confidence interval shown in section 4 is either slightly optimistic or pessimistic depending on whether it is applied to measurements done during the first or the last 10 years of the compilation.

6 Variable stars

Stars known as variables and designated in the fourth edition of the "General Catalogue of Variable Stars" (GCVS, Kholopov, 1985-7), are generally identified in our catalogue by the letters VR in the remarks column and, whenever possible, directly by their name or number. In the list of notes at the end of the catalogue we give the type of variability according to the GCVS categories. The stars detected as variables and identified by Rufener and Bartholdi (1982) are listed as well and marked with the same indications as used in the original article. In general the observations of variable stars are carried out at random with regard to their periods. As a result, the mean values of a few observations sometimes have little sense. The same occurs for eclipsing binaries

Figure 2: Histogram of the catalogue's stars in function of the magnitude m_V. Simultaneously, the variations of the mean σ and σ_V of these stars (see section 7 for comments).

for which we have recorded eclipses. We nevertheless give these means because the associated standard deviations tell us about the amplitude of the variations registered. When needed one can consult the individual measurements which are at disposal in the Geneva photometric data base. For stars having six or more good measurements (P or $Q \geq 6$) the computed standard deviation for the colours or for the V magnitude can indicate very slight variations (microvariable star). We have attempted a preliminary selection of such stars by using the criteria defined in Table 5. The limits of these criteria have been set empirically.

They were used with the 1981 catalogue and have allowed 333 identifications of suspected variables (Rufener and Bartholdi, 1982). A first application of the same criteria to the present edition of the catalogue leads to the following inventory: some 200 stars apply to criterion a, either variable or microvariable; about 100 satisfy criterion b and are possible microvariables; finally, about 300 stars are candidates for criterion c, they are suspected variables. Each case will need another close investigation as well as complementary observations.

7 Statistics and identification problems

The statistics which follow will give a general view on the acquisition, the contents and the quality of the material gathered for this catalogue. The acquisition of observations has developed quasi exponentially between 1960 and 1980, with a mean annual rate of increase around 20%. Since 1980 the situation has stabilized with an annual average close to 16.000 measurements. Each year the catalogue increases by roughly 1700 entries.

Table 5: Definition of the criteria of microvariability

Number of good measures Q	Standard deviation for the V magnitude $\cdot 10^3$		
	a	b	c
2			≥ 40
3			≥ 25
4 to 5			≥ 20
6 to 10	≥ 23	≥ 18	
11 to 20	≥ 18	≥ 14	
≥ 20	≥ 14		

The aim is to obtain three measurements per star correlated to a sufficient number of standard star observations. Many observations are devoted to short or long-term monitoring of variable stars of various types.

The distribution of the catalogue stars over the celestial sphere is not uniform. We count between 1000 to 1200 stars per right ascension hour, their frequency is 1.5 times larger between 5 and 9 hours. Due to the increasing preponderance of the chilean observations, 63% of the stars are in the southern hemisphere while 37% have positive declinations. Strong concentrations of stars can be observed around the galactic plain. Half of them are located between $\pm 15^\circ$ and one third between $\pm 6^\circ$ of galactic latitude. Cross-comparison with the Bright Star Catalogue reveals that 83% of its stars are now represented in our catalogue; the missing bright stars are mostly located in the northern sky. Also, approximately 10% of the HD catalogue are represented. The V magnitudes of stars in our catalogue are distributed rather evenly around a median value close to $m_V = 8.50$. Figure 2 illustrates this distribution. The frequency of known spectral types among the stars in our catalogue appears as follows:

O-B	25%			
A-F	30%	$A \simeq 20\%$	$F \simeq 10\%$	
G-K-M	35%	$G \simeq 15\%$	$K \simeq 15\%$	$M \simeq 5\%$

Without or other types 10%.

We have established statistics from the standard deviations observed for the colours (σ) and the V magnitude (σ_V). Fig. 2 shows the evolution, as a function of V magnitude, of the mean σ computed for stars with $P \geq 3$. A minimum can be observed for the most easily measurable stars. The growth of the mean σ from the 10^{th} magnitude onwards is correlated with the relative increase of photon noise. This is due to a particular circumstance. Such a rapid increase is essentially explained by the fact that the majority of faint stars are red and that their U flux is consequently extremely weak. The standard deviation σ defined in section 3 increases sharply in that case. For these stars the determination of the colours is less doubtful, except for U, whose colour is even more uncertain than indicated by σ which is an average over all colours. A higher dispersion is also visible for the brightest stars whose measurement presents certain difficulties (use of light-attenuators, possible saturation eff ects, higher dispersion of the air masses due to measuring conditions). Fig. 2 also shows the evolution, as a function of V magnitude, of the mean σ_V for stars with $Q \geq 3$. An increasing effect of photon noise from $m_V = 10$ onwards is also apparent. In both cases the estimates of σ and σ_V obtained in section 4 with the matrix of Table 3 are representative for all magnitudes $m_V < 11$. We have checked that σ and σ_V present mean values which are almost independent of the P or Q values as soon as these reach or exceed 6. This observation supports the statement made in section 3 and justifies the limits chosen for the criteria of microvariability in Table 5. The examination of the mean σ computed for each spectral type confirms a known and already published fact: O and B stars are frequently microvariable and M stars are often variable (Maeder and Rufener, 1972; Maeder, 1979).

We had to overcome some difficulties during the identification on sky atlases of stars selected from the NLTT (Luyten, 1979, 1980). Perhaps an undefined number of the proposed measurements might not concern the star with large proper motion we had searched for, but a neighbouring star. The probability of an identification error is, of course, higher for weak stars. The critical discussion of each case could not, at the present, be undertaken with all the security desired . The elimination of these errors will be a long process for which we ask for your cooperation by notifying us of any identification error you might notice.

8 Description of the catalogue

Columns 1 and 2	The Bayer or Flamsteed designations when these exist. The variable star designation is given secondary priority.
Column 3	The number in Hoffleit's 1977 "Catalogue of Bright Stars" (BS).
Column 4	The number in the "Henry Draper Catalogue" (HD). For components of multiple stars we added the suffix A, B, C... Usually when we know that two or more components are measured together a remark is made, D for optically double and B for spectroscopic binaries, in column 31.
Column 5	The number in the "Durchmusterung" (DM) according to the HD practice. For multiple stars we added the suffix A, B, C...
Columns 6 and 7	Right ascension for the year 1900.
Columns 8 and 9	Declination for the year 1900.
Column 10	Galactic longitude (ℓ^{II}).
Column 11	Galactic latitude (b^{II}).
Column 12	In this column we display explicitly the star's membership to a cluster or a group as well as the identification number defined in certain publications for which we give bibliographic references in Table 6.

Column 13	Weight P of the colours defined in section 3c.
Column 14	Mean standard deviation σ obtained for the colours as described in section 3b, in 0.001 of mag.
Columns 15 to 20	The normalized magnitudes or colours which correspond to our seven passbands. A normalized magnitude is a colour index formed in a particular manner. The first term is the magnitude of the colour considered and the second term is always the magnitude in colour B. The description of the reduction of observations to outside the atmosphere and the calculation of the normalized magnitudes is given by Rufener (1964, 1984).
Columns 21 to 23	Colour indices selected according to their frequency of use.
Columns 24 to 27	Photometric parameters defined as follows:

$$\begin{aligned} d &= [U-B1] - 1.430\,[B1-B2] \\ \Delta &= [U-B2] - 0.832\,[B2-G] \\ g &= [B1-B2] - 1.357\,[V1-G] \\ m_2 &= [B1-B2] - 0.457\,[B2-V1] \end{aligned}$$

Column 28	Weight Q of the V magnitude as defined in section 3c.
Column 29	Standard deviation σ_V obtained for V magnitude as described in section 3b, in 0.001 of mag.
Column 30	m_V magnitude of the star derived from our measurements alone. This m_V scale is very close to that of the UBV system (see Rufener and Maeder, 1973).
Column 31	Remarks according to the following code: D: Optical double star not separated during the measurement (information from various sources); B: Spectroscopic binary (information from various sources); V: Variable compiled in the "General Catalogue of Variable Stars" (GCVS) by Kukarkin et al. (1969-71) and Kholopov et al. (1985-7). Listed under the same remark are the microvariable stars selected by Rufener and Bartholdi (1982). R: Reference to a note at the end of the catalogue. These notes are ordered in the same manner as the catalogue, by increasing right ascension. The stars are identified by one of their numbers or by their membership to a cluster or group. In the absence of this information a contracted form of the equatorial coordinates gives the stars' identification.
Column 32	The MK spectral type when it figures in the BS, in Jaschek's (1964), Kennedy's (1974) or Buscombe's (1977) catalogue. In brackets we give the Harvard spectral type, in particular the one from the HD or from some other source.

Table 6 : Coded bibliographic references

Membership	**Bibliographic reference**
ALF PER	*Heckmann et al.* 1956
BPM	*Luyten* 1963
BR HOR	*Philip* 1967
CHI PER	*Oosterhoff* 1937
COMA TR	*Trumpler* 1938
COMA TA	*Trumpler, appendix A* 1938
COMA AR	*Argue* 1963
COMA G	*Internal numbering*
CYG II	*Schulte* 1958
G	*The Giclas numbered stars* 1971
GLIESE	*Gliese* 1969
GLO NGC	*Globular cluster with NGC number*
HYADES B	*van Bueren* 1952
HYADES A	*van Altena* 1966
HYADES J	*Johnson et al.* 1962
H PER	*Oosterhoff* 1937
IC 348	*Gingrich* 1922
IC 1805	*Vasilevskis* 1965
IC 2082	*Grenon* (to be published)
IC 2391	*Perry and Hill* 1969
IC 2602	*Braes* 1962
IC 2714	*Becker et al.* 1976
IC 4651	*Lindoff* 1972b
IC 4665	*Kopff* 1943
IC 4756	*Kopff* 1943
IC 4996	*van Schewick* 1967
LDS	*Luyten's double stars* 1972
LMC HV	*Leawitt* 1908
LS	*Luminous stars in North. Milky Way (Hamburg)*
LSS	*Stephenson and Sanduleak* 1971
LTT	*Luyten* 1957, 1961, 1962
MCORM	*Vyssotsky and Williams* 1948
MUR	*Murray et al.* 1987
NLTT	*Luyten* 1979, 1980
NPL	*Perek and Kohoutek* 1967
O-STARS	*Hiltner and Johnson* 1956
ORION CL	*Brun* 1935
OS	*Objective Prism Survey, Stock et al.* 1971
PHL	*Haro and Luyten* 1962
PLEI H	*Hertzsprung* 1947
PLEI T	*Trumpler* 1921
PRAE KW	*Klein-Wassink* 1927
PRAE VL	*Vanderlinden* 1933

ROBERTSON	*Robertson* 1978
SA 140	*Brueck* 1935
SA 141	*Brueck* 1935
SGP A ST	*Philip and Sanduleak* 1968
SMC AZZO	*Azzopardi and Vigneau* 1975
SP 025-02	*Reichen*
SP 206-02	*Rabattu*
SP 203+02	*Rabattu*
SP LLL $\pm$ BB	*Golay*
VYSSOTSKY	*Faint stars classed by Vyssotsky* 1943-1958
WD-STARS A	*Luyten* 1949
WD-STARS C	*Feige* 1959
WD-STARS D	*Giclas et al.* 1965, 1967, 1970
WR CAT MR	*Smith* 1968
NGC 104	*Grenon* (to be published)
NGC 129	*Arp et al.* 1959
NGC 457	*de Vegt* 1966
NGC 581	*Hoag et al.* 1961
NGC 654	*Müller* 1955
NGC 663	*Wallenquist* 1929
NGC 752	*Ebbighausen* 1939a; number $>$ 320: *Mermilliod* (to be published)
NGC 1039	*Bruggeman* 1935
NGC 1291	*Grenon* (to be published)
NGC 1313	*Grenon* (to be published)
NGC 1326	*Grenon* (to be published)
NGC 1502	*de Vegt* 1966
NGC 1543	*Grenon* (to be published)
NGC 1545	*Hoag et al.* 1961
NGC 1647	*Hoag et al.* 1961
NGC 1662	*Hoag et al.* 1961
NGC 1664	*Larsson-Leander* 1957
NGC 1778	*Hoag et al.* 1961
NGC 1912	*Cuffey* 1938
NGC 1960	*Boden* 1951
NGC 2168	*Hoag et al.* 1961
NGC 2169	*Hoag et al.* 1961
NGC 2217	*Grenon* (to be published)
NGC 2232	*Claria* 1972
NGC 2244	*Johnson* 1962
NGC 2251	*Hoag et al.* 1961
NGC 2264	*Walker* 1956
NGC 2281	*Vasilevskis and Balz* 1969
NGC 2287	*Cox* 1954
NGC 2301	*Grubissich and Purgathofer* 1962
NGC 2360	*Becker et al.* 1976
NGC 2362	*Johnson* 1950

NGC 2422	*van Schewick* 1966
NGC 2423	*Hassan* 1976
NGC 2447	*Becker et al.* 1976
NGC 2451	*Williams* 1967
NGC 2516	*Cox* 1955
NGC 2539	*Pesch* 1961
NGC 2547	*Fernie* 1959
NGC 2548	*Ebbinghausen* 1939b
NGC 2658	*Grenon* (to be published)
NGC 2682	*Fagerholm* 1906
NGC 3109	*Grenon* (to be published)
NGC 3114	*Jankowitz and Mac Cosh* 1963
NGC 3293	*Turner et al.* 1980
NGC 3532	*Koelbloed* 1959a
NGC 3680	*Eggen* 1969
NGC 4755	*Arp and van Sant* 1958
NGC 5101	*Grenon* (to be published)
NGC 5102	*Grenon* (to be published)
NGC 5139	*Grenon* (to be published)
NGC 5236	*Grenon* (to be published)
NGC 5460	*Claria* 1971
NGC 5466	*Cuffey* 1961
NGC 5822	*Bozkurt* 1974
NGC 6025	*Feinstein* 1971
NGC 6067	*Mermilliod numbering*
NGC 6121	*Alcaino* 1975
NGC 6205	*Grenon* (to be published)
NGC 6231	*Seggewiss* 1968
NGC 6254	*Arp* 1955, first digit is Roman
NGC 6281	*Feinstein and Forte* 1974
NGC 6341	*Grenon* (to be published)
NGC 6397	*Woolley et al.* 1961
NGC 6405	*Rohlfs et al.* 1959
NGC 6475	*Koelbloed* 1959b
NGC 6494	*Hoag et al.* 1961
NGC 6611	*Walker* 1961
NGC 6633	*Kopff* 1943
NGC 6752	*Alcaino* 1972
NGC 6791	*Grenon* (to be published)
NGC 6811	*Lindoff* 1972a
NGC 6871	*Hoag et al.* 1961
NGC 6910	*Tifft* 1958
NGC 6913	*Tifft* 1958
NGC 6940	*Vasilevskis and Rach* 1957
NGC 7092	*Weaver* 1953
NGC 7128 *)	*Hoag et al.* 1961
NGC 7160	*Hoag et al.* 1961

NGC 7209	*Mävers* 1940
NGC 7243	*Lengauer* 1937
NGC 7789	*Kuestner* 1923
NGC 7822	*Mac Connel* 1968

*) This reference contains two lists of stars for each cluster. We have used the numbers given by authors for designating stars belonging to the first list (i.e. stars measured photo-electrically). We have then numbered successively, and without exception, all stars belonging to the second list (i.e. stars measured photographically). This extension of the numbering has at times given a second number to stars figuring on both lists.

A version of this catalogue exists on magnetic tape and can be obtained from the Centre de Données Stellaires in Strasbourg (for more details, please consult the "Bulletin d'Information" of the Centre de Données Stellaires).

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