STAR CLASSIFICATION THROUGH PHOTOGRAPHIC BROADBAND PHOTOMETRY WITH KODAK FINE-GRAIN EMULSIONS

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ABSTRACT

The recently developed Kodak emulsions IIIa-J and IIIa-F have been used as a new tool for deep-survey photometry. Among their most useful features are the following: (i) fine to very fine granularity; (ii) very high resolving power; (iii) high sensitivity over a large wavelength range in the optical part of the spectrum.

Some numerical results obtained from scanner data of a variety of normal star types, and from the spectral sensitivities of these Kodak plates combined with various optical filters are presented. We study the effects of these filters on the resulting synthetic colors with respect to the intrinsic potential of the colors to classify faint stars. In addition we briefly discuss the effects of interstellar reddening and the calibration of the photographic colors through photoelectric UBV photometry.

This synthetic approach to multicolor photometry is discussed in the more general context of the relations between spectral classification, stellar photometry, and model atmosphere calculations. This context is the natural basis for galactic astronomy.

1. SPECTRAL CLASSIFICATION AND PHOTOMETRY

The ultimate goal of spectral classification consists in preparing a suitable way to the understanding of the nature of the stars. What makes spectral types and luminosity classes (and chemical indices) really indispensible is that they are the basic constituents of the Hertzsprung Russell Diagram. If a star can be placed on the HR Diagram, it is, at the same time, placed within the fundamental physical context that has been intrinsically associated with this diagram.

https://doi.org/10.1017/S0252921100104464 Published online by Cambridge University Press

On the one hand spectral types are observable but not quantitative; on the other hand the physical parameters of stellar atmospheres are quantitative but not observable; whence derives the importance of photometry -- which is both observable and quantitative -- as the 'middle man' providing the support for spectral classification and theory to be quantitatively related.

This unique position of stellar photometry opens up another research area: the study of the space and luminosity distribution of the stars on a galactic scale. The technical vehicle for that purpose is a photographic broad-band system, which provides information for large numbers of faint stars. At the cost of losing detail and accuracy with the individual star it is thus possible to probe into the nature of galactic stellar populations by means of statistical photometric analyses.[1]

This task however requires the development of a photometric system that is especially designed for galactic structure work. Starting out from the present state of our knowledge relevant to stellar populations we choose a comprehensive sample of detailed spectral and spectrophotometric data of stars and stellar model atmospheres covering all major spectral and luminosity classes as well as various metallicities. The wavelength resolution of such data is good enough for broad-band colors to be synthesized from the spectra (Buser 1978a). The subsequent analysis of the synthetic colors and comparison with direct observations then allows us to define a photometric system whose application in galactic astronomy is both most effective and economical.

The next section summarizes -- in a condensed quasi-graphical form -- objectives and problems, and the pattern of their interrelations associated with this synthetic approach to multicolor photometry.[2] The following discussion of numerical results constitutes a piece of more concrete and detailed work specific to this approach in the context of galactic stellar populations.[3]

[1]At the present time the need for more, and more detailed, information about the stellar populations in our Galaxy is growing as theory and observation on the origin, structure, and evolution of extragalactic objects are progressing at an enormously fast rate.

[2]For more detailed accounts the reader is referred to Buser (1978a), Buser and Steinlin (1976), or Steinlin and Buser (1975).

[3]In sections II and III the same format as that of the paper presented in the Poster Session of the colloquium has been retained partially.

II. SYNTHETIC APPROACH TO MULTICOLOR PHOTOMETRY

1. Basic philosophy

Simultaneous study of		
Stars variety of types, classes, and populations	Interstellar matter effects of reddening	Photometric passbands variety of positions within a large wavelength range, variety of bandwidths
spectral scans objective prism spectra model atmospheres	reddening law(s)	response functions of existing and theoretical systems
Data		

↓

Synthetic colors

2. Applications and practical moments involved

Objectives	
Photographic reproduction of photoelectric systems	Study of observationally established systems

↓

Data

Photographic and/or Photoelectric

response functions

plate sensitivities — photomultiplier responses

filter transmissions

atmospheric extinction

(reflection(s) from mirror(s))

↓

Results

Basic parameters and calibrations of observed and synthetic systems

Transformations between observed and synthetic systems

Transformations between synthetic systems

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3. SEMITHEORETICAL EVALUATION OF THE APPLICATION OF KODAK EMULSIONS IIIa-J AND IIIa-F

In the following box we summarize the characteristics of the Kodak emulsions IIIa-J and IIIa-F, the most significant implications to be expected of their use in photometry, and some of the most attractive applications.

<u>Characteristics</u>

Granularity	Resolving power	Sensitivity
fine/very fine	very high	IIIa-J: 3000 to 5500 Å IIIa-F: 3000 to 7000 Å

<u>Implications</u>

Improved star and galaxy image structure

Improved iris and/or PDS determination of magnitudes and colors

High space-penetrating power: faintest limiting magnitudes

<u>Applications</u>

Stellar statistics and galactic structure work

Deep photometric surveys

Surface photometry of extragalactic objects

Since most of the experience in stellar statistics and galactic structure work has been obtained from RGU and UBV three-color photometry, we investigate alternative photographic realizations of these systems using the new Kodak emulsions instead of the older ones commonly employed for that purpose.

The variety of passbands obtained from the sensitivities of the Kodak emulsions and from the transmissions of Schott glass filters are shown in Fig. 1. These passbands were used to compute synthetic colors

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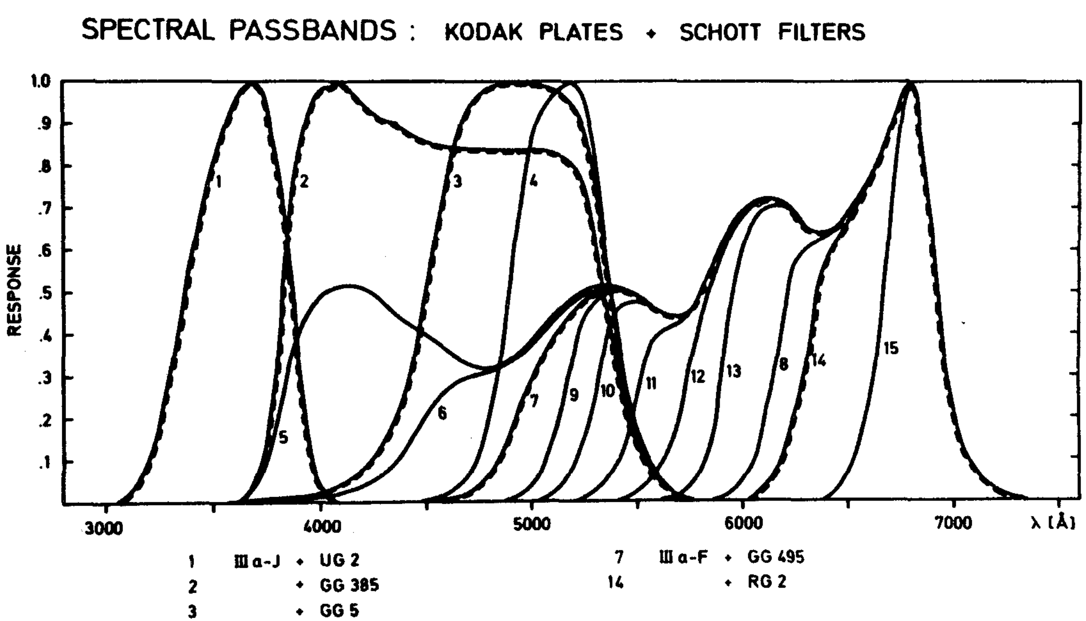

Fig. 1. The sensitivities of the Kodak IIIa-J and IIIa-F emulsions have been combined with a number of Schott glass filter transmissions to compute the response functions of various photographic systems (normalized to unity at maximum response). Double lines refer to the alternative photographic realizations of the UBV and RGU systems discussed in the text on the basis of two-color diagrams.

https://doi.org/10.1017/S0252921100104464 Published online by Cambridge University Press

from scanner data of Population I main-sequence (LC V) and giant (LC III) stars covering the spectral types O to M (Straižys and Sviderskienė 1972). Details of the numerical procedure have been described by Buser (1978a).

The two-color diagram of the (1-2-7)-system shown in Fig. 2 has been superimposed by the standard loci of main-sequence and late-type giant stars in the U-B, B-V plane (Johnson 1966). The (1-2-7)-system employs two passbands (2-7) that take full advantage of the large useful sensitivity ranges of the Kodak plates. The scales of the reresulting colors are considerably larger than for U-B and B-V in the standard UBV system. Better resolution in spectral and luminosity classification therefore can be expected.

In contrast to the photoelectric U-band, passband no. 1 of the photographic system is filter-defined and also slightly shifted to shorter wavelengths. Since passband no. 2 matches the photoelectric B-band fairly well, the scale of the color index (1-2) is about 10% larger than for U-B. On the other hand passband no. 7 extends to larger wavelengths than the V-filter and peaks around 6800 Å. As a result the scale of the (2-7) color index exceeds that of B-V by approximately 20%.

In view of the rather wide and irregularly shaped passbands the approximate linearity of the transformations of the photographic colors to the UBV system (Fig. 3) comes as a welcome surprise. This result enhances the usefulness of this photographic system, since the very existence of nonlinear transformations usually lowers the accuracy of the magnitude and color determinations and hence the intrinsic power of the system.

In Fig. 4 we plotted the two-color diagram of the (1-3-14)-system with standard loci in the U-G, G-R plane of the RGU system (Buser 1978a,b) superimposed for comparison of the color scales. The conventional G- and R-passbands have been replaced by the wider bands no. 3 and 14, respectively, which are both located at redder effective wavelengths. As a result the (1-3) color has a larger scale than U-G, which leads to the somewhat better separation of late-type dwarfs and giants shown in the diagram.

Furthermore the greater widths of the passbands involved in the new system allow one to penetrate to fainter stars than with the original RGU system. However the significance of getting at fainter stars is also determined by the way in which interstellar reddening affects the colors. For both the (1-2-7)- and (1-3-14)-systems the 'reddening lines' -- only a small linear segment of which has been plotted in Figs. 2 and 4 -- are equally or more strongly curved than the corresponding lines in their 'parent' UBV and RGU systems. While

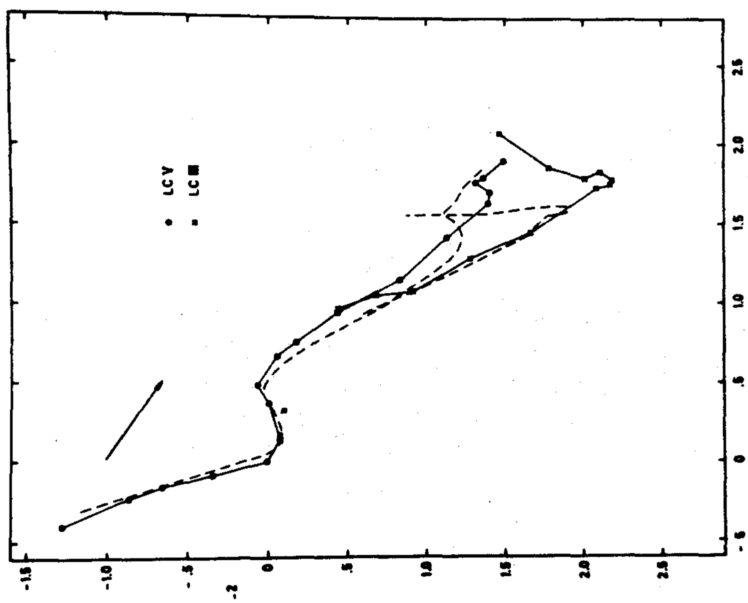

Fig. 2. The two-color diagram for population I main-sequence and giant stars in the (1-2-7)-system. Broken lines represent standard loci in the UBV system. Interstellar reddening is indicated by the arrow.

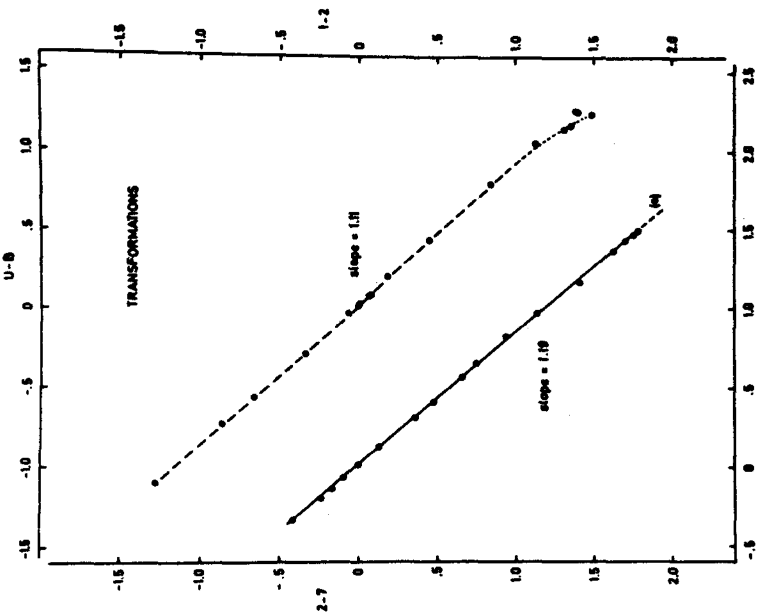

Fig. 3. The transformations of main-sequence star colors. Solid line: (2-7) vs. (B-V); broken line: (1-2) vs. (U-B). Note the approximate linearity of both relations.

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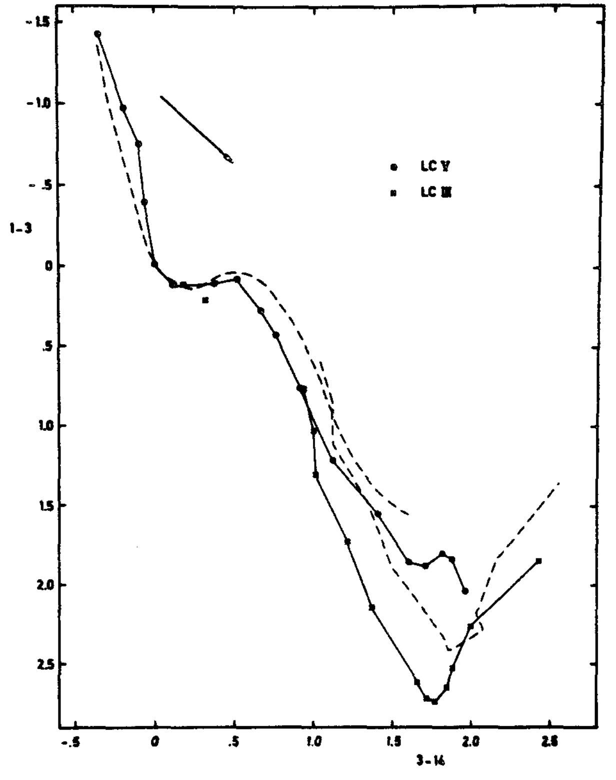

Fig. 4. The two-color diagram for population I main-sequence and giant stars in the (1-3-14)-system. Broken lines represent standard loci in the RGU system. Interstellar reddening is indicated by the arrow.

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this complicates the analysis of star fields where interstellar extinction is present, calculations show that the effects can be simulated with a fairly high degree of confidence (Buser 1978a,b). However observational studies will be necessary to estimate the limits beyond which the systems are no longer successful in stellar statistics.

The transformations of the (1-3) and (3-14) colors to UBV photometry are slightly nonlinear, which is also the case for U-G and G-R. This problem may be solved satisfactorily by using U-B and B-V in the actual transformations (Buser 1978b).

4. CONCLUSION

The numerical experiments reported in this paper show that the improved characteristics of the new Kodak emulsions can be fully exploited for photographic three-color photometry. It is possible to construct alternative photographic realizations of the widely used UBV and RGU systems. Calibration of these systems can be done via photoelectric UBV photometry, since the transformations between UBV and the photographic systems are linear or nearly linear over a large range of color. Improved spectral and luminosity classification for faint late-type stars of population I can be obtained.

A fuller account of the investigation of these systems, including results for other star types, will be published elsewhere.

ACKNOWLEDGEMENTS

I would like to thank Richard Kron and Professor U. W. Steinlin for valuable discussions, D. Cerrito for preparing the figures, and the Swiss National Science Foundation for financial support.

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DISCUSSION

Denoyelle: The new Kodak-emulsions have proved to be superior to the older ones in several domains. But I am a little worried as regards the measurements made with a hand-operated iris-photometer, because the diameter of the images plays an important role. The automatic measuring-machines like "Galaxy" or "COSMOS" scan the profile of the image, but many of us do not have access to such machines. Could you tell from your tests, if the precision of iris-photometer measurements has improved also, although the images are probably smaller, and also more difficult to measure.

Buser: The fine-grain emulsions give much neater, better-shaped images even for much fainter stars. The iris-photometer measures a mixture of the diameter and the density of the image. For the fainter stars,the grains of the emulsion become a critical factor. With the new emulsions this limit is shifted to fainter limits. The tests made so far did not consider this particular problem, but from experiences in astrometry and photometry of Schmidt plates, it can be concluded safely that these emulsions will give also better results for photographic photometry with a conventional iris-photometer.