On the Employment of Copies in Astrophotography [1]

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ABSTRACT. Diverse aspects of the use of copies of photographs in astrophysical measuring techniques are considered, emphasizing the necessity of the preservation of the originals as irretrievable documents carrying the primary information of the astrophysical observation.

Astrophysical photographs – i.e., star field plates as well as spectrograms – are primary carriers of information about the physical conditions of stars at a definite time; they represent unique, nonrepeatable, indispensable and, in the case of loss, irretrievable o r i g i n a l s.

We do not assume the unfavorable, but nevertheless possible case that such a precious original could be spoiled, destroyed or simply lost at the observatory itself, where it has been taken; however, the lending of astrophotographs to other companies for measuring and evaluation treatments is a practise that is much more dangerous for the plates as it involves transports (with all accompanying risks) and leaving the observatory without its original documents usually for a long time.
Thus, the archives of astrophotos at an observatory will never be complete. Gathering a set of plates not available at the observatory mostly turns out to be a cumbersome problem.

A lot of further arguments could be advanced emphasizing the urgency of taking c o p i e s from the original photographs, but the most important reason for doing this is the protection and preservation of the documentarily stored information on the original plates, transferring the information to secondary carriers and thus making it available to a great number of users simultaneously and permanently.

Let us first clarify the term c o p y.
Here under a copy we will understand a s e c o n d a r y carrier of information being similar to the original one in a controllable and repeatable manner. The ideal would be full congruence between the original and the copy, then called a d u p l i c a t e, which naturally can only be reached more or less approximately. But there could occur cases in which it would be desirable to replace and to redistribute the information contained on the original at the reproduction process such as in image transformation, amplification or superposing of several images. In this paper we restrict the term "copy" to 1 to 1 magnification preserving in the reproduction the coordinate arrangement of the information unchanged.
Therefore, the normal means of carrying out the reproduction is a c o n t a c t printing device, which is all we refer to – not excluding other possibilities.

[1] ASTROPHOTOGRAPHY. Proceedings of the IAU Workshop, Jena, GDR, April 21-24, 1987, p. 121-124. Ed. S. Marx, Springer-Verlag Berlin Heidelberg New York London Paris Tokyo. Scanned from the original publication by the author in 2010.

In the following we will discuss the different aspects that are essential in doubling astrophotographs regardless of having been considered in special contexts already elsewhere.

The q u a l i t y of the copies must not be appreciably inferior to the originals, that means that the inevitable loss of information bound up with image processing generally has to be kept within narrow, controllable and tolerable limits.

The m a t e r i a l of the copies need not to be the same as that of the originals, because the photographic reproduction process is governed by other exposure conditions than the original exposure during the observation. As is well known to any astronomer engaged in astrophotography, one has to cope with the dilemma that high sensitivity of the photographic plate as desired at the original observation is strictly connected with coarse graininess of the photographic emulsion.
In the reproduction exposure sufficient light is available, so that less sensitive photographic emulsions may be used which have more advantageous image printing properties. This is fulfilled by fine-grained emulsions, which, regardless of their low sensitivity, cause practically no more distortions of the image than contained on the grainy original plate, so that the information from the original is transferred to the print with a minimal loss.

The properties of the i m a g e t r a n s f o r m a t i o n are represented by the modulation transfer function giving an overview of the spatial spectrum of a photographic material.
A fine-grained photolayer gives a modulation transfer function with higher spatial frequency than a coarse-grained one. Therefore, in all stages of image transformation, considerations of the image quality should rely on the image transfer function.

As c a r r i e r s for the photographic layer used in astrophysical measurements, only materials with a high degree of coordinate stability against all possible deforming influences come into question. Under special physical conditions of temperature, pressure and humidity the relative positions of all picture elements must be unchangeable, which is fulfilled best by glass. But other materials with satisfactory measure-stabilizing properties should not be excluded. A copy on synthetic materials as, e.g., polyester film may keep the measures as well as on glass. In any case, however, the aptitude of the special material used has to be proved. The advantage of synthetic materials over glass obviously consists in better resistance to fracture and in easier cutting into parts like stripes for spectrograms.

The use of c o m m e r c i a l photographic m a t e r i a l s is possible, in principle, especially resorting to ones with a high production rate as, for instance, applied to offset printing. Diapositive plates could also be be taken into account. As outlined below, the properties of such available materials can be varied by special treatments to accommodate them to the application purpose. Nevertheless, we want to propose here to apply the best-suited material, including a new development of a special copy material by the industry.

The c o n t r a s t of the copy primarily is determined by the properties of the reproducing material; but in the case of a steep material like printing film the contrast and the exposure range are variable within wide boundaries.

Therefore, the gradient of the characteristic curve must be sufficient steep, supplying reserves for regulating the contrast.

The amplification of the contrast in copies in many cases may even improve the availability of the astrophoto. This is related to the fact that what we measure as the effect of the exposure is the transparency of the developed photolayer and not the density. However, the higher the density the less the light being transmitted through the layer, which thus offers an awkward dilemma: The blackening rate is the response to the light quantity, that means, the number of incident photons. Therefore, the higher the photon number, the higher the significance but also the density barring the transmission of the light for the measuring detector. A compromise is found at average densities of both the original and the printing material. In reproduction processing the variation of the contrast may be shifted intentionally to ranges of the transparency favorable for the measurement.
The contrast can also be increased by the application of chemical amplifiers supplying an additional means of regulating the contrast.

The diminuation of the contrast is achievable by special developing methods, the application of chemical reducers and dyeing the emulsion before the exposure The last-mentioned method deserves some more attention.

By the method of dyeing as described by Lau and Krug [1,2] the density is not merely diminished proportionally, compressing the characteristic curve in the direction of the ordinate, but the characteristic curve is deformed in the sense that it is stretched to a straight line covering an increased range of exposure. The dyeing dose can be chosen arbitrarily, giving thus the possibility of regulation and adjustment of the contrast.
The dyeing, of course, diminishes the sensitivity of the photographic layer because of the absorption of light passing through during the exposure. But this is only a virtual disadvantage, for in the reduction process enough light is available. Only in order to secure the primary information at observation do we need the highest possible speed of the photographic material, avoiding stingily any loss of light.
One might now assume that the absorption caused by the dye lowers the transparency of the copy appreciably, making it quite black, or whatever the color may be. However, the dyes are only needed for steering the light transfer process during the exposure, afterwards they are redundant and unwanted; therefore, they may be washed out of the layer either during or after the development. Thus, there does not remain any fog on account of the dyes, so that at the threshold of the characteristic curve the full transparency is warranted.

The two properties – linearity and regulation – are very important if faithfulness to the original is demanded from the copy. All graduations have to be transferred from the original to the copy without distortion at any part of the characteristic curve. To give the correct contrast the rule of Goldberg holds, whereafter the product of the gradients (γ-values) of all materials used in a sequence of reproductions has to be unity ($\prod_i \gamma_i = 1$).

A negative print from a simple reproduction may be sufficient for a lot of astrophysical measuring purposes.

Sometimes it could even be advantageous, in comparison to the original. The integral light of the star dots on the plates, for instance, can be better measured by the transparency than by the density. The same as one may say concerning the emission lines in a spectrum. Beside all this, in spectrograms the negative copy is superior to the original because it transforms the light distribution emerging from the source into a transparency distribution. In most cases to be expected, however, positive p r i n t s will be desired, especially if the plates are to be compared visually, or photoelectrical registrations are to be carried out. Such positive prints can be obtained by two successively performed reproductions or by reverse development. The first method requires an intermediate print, which could be useful if a lot of second prints are required. However, if the number of copies is small, the reversal development should bc preferred, as it economizes on material and avoids the second reproduction. Undoubtedly, every reproduction contributes to the distortion of the image by scattering of light, inaccuracies of projection, and displacements of the layer by washing, drying and shrinking, so that in any case the number of successive reproductions should be kept as small as possible.

The c a l i b r a t i o n contained in astrophotos is not injured by the reproduction process. This is quite obvious in the case of the copy material having been linearized by dyes. This statement, however, is valid for nonlinear characteristic curves, too. In the reproduction process the characteristic curve of the original material is combined with that of the printing material, resulting in a characteristic curve of both materials which contains all the calibration steps with an unambiguous coordination in the range of the modulation interval.

However, the g o a l of the r e p r o d u c t i o n of an astrophoto is not in every case the true resurrection of the original. The properties of the i m a g e may be c h a n g e d anyhow in the copy compared to the original. Thus, for the measurements of spectrograms it could be desirable to have an enhanced contrast on the plates, so that the shallow lines are more conspicuous on visual inspection. In other cases the contours have to be more pronounced, which could be achieved by a d e t a i l f i l t e r i n g method after LAU [3]. The modulation transfer function for this method exhibits characteristic peaks. Photometric evaluation of luminosity distributions – for example at galaxies, comets – may be performed by means of equidensites (LAU [1,2]).

All such procedures should not be applied to originals because they operate on the content of information which has to be preserved inviolably in any case.

E x p e r i m e n t s on i m a g e t r a n s f o r m a t i o n s have to be referred to copies, which might be spoiled or distorted anyhow, but could be drawn from the originals so often as wanted.

References

[1] LAU, E., KRUG, W.: Die Aquidensitometrie. Akademie-Verlag, Berlin 1957

[2] LAU, E., KRUG, W.: The Focal Press, London and New York 1968

[3] LAU, E.: Anwendung des Entwicklungsdetailfilterverfahrens (EDFV) für alle normalen Schwarzweiß-Fotoschichten durch Belichtungsmultiplikations- und additionseffekte. BILD UND TON **25** (1972) 149-152.
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