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On the theoretical interpretation of SCHWARZSCHILD's law of blackening

with a recognition of the founder of Scientific Photography

Karl Schwarzschild

(Lecture, given on May 16th, 1966 at the Astrophysical Observatory Potsdam
on a colloquium in memory of the 50th anniversary of KARL SCHWARZSCHILD's death)

by Ewald Gerth

Abstract

The article starts with a commemoration of the famous astrophysicist KARL SCHWARZSCHILD (1873-1916), who is regarded as the founder of the discipline *Scientific Photography*. SCHWARZSCHILD remarked by means of long-time exposures of stellar objects, that the effciency of the exposure declines with exposure time. That means: the product of light intensity E and time t, the so-called *reciprocity law* $E \cdot t$ = const, established by BUNSEN and ROSCOE generally for allphotochemical reactions, has to be replaced in the case of photography with a law in the form $E \cdot t^{\,p}$ = const, where p is an exponent within the limits $0.7 < p < 1$.

SCHWARZSCHILD's law is an analytical formulation of an empirically found result – without interpretation of the underlying physics. Similar attempts with a broader range of validity were made by ABNEY, MIETHE, MICHALKE, SCHEINER, KRON, and others. The author shows, that the physics of crystals, by accounting for the photoelectric effect and the creation of inter-lattice free electrons and defectelectrons, can give a reasonable interpretation and even an analytical derivation of SCHWARZSCHILD's and KRON's formulae.

The new concept: The build-up process of development specks in crystals of silver bromide of a photographic emulsion is regarded as a chain of equilibrium reactions which are characterized in that the forward reactions are determined by the concentration of free electrons in the crystal lattice, whereas the back reactions take place due to thermal and chemical decay as well as the photoelectric effect acting directly onto the already created specks. If the intensity is low, the saturation concentration of electrons is proportional to the light intensity of the exposure. In the case of high light intensity, however, the electron concentration is proportional to the square root of the intensity. On the assumption that specks of the first degree are extremely unstable and distinguished by a high power of absorption for light of special wavelengths, saturation occurs already in the first reaction step, resulting in the reduction of the order of the exposure time by one degree. The specks grow from step to step by recharging with free electrons – up until having accumulated at least four silver atoms, which are necessary for relasing the development of the whole silver bromide grains.

SCHWARZSCHILD's well-known photographic blackening law

$$E\, t^{\,p} = \text{const}, \qquad (p \text{ Schwarzschild-exponent})$$

describes only the long-term exposure effect. After the new concept, the validity of this law is extended to long and short exposure times with a transition region expressed by a formula

$$\left(\sqrt{1 + \varepsilon E} - 1\right) t^{\,p} = \text{const}. \quad (\varepsilon \text{ sensitivity coeffcient})$$

The new blackening formula will be proved using the *historical* measurements made by KRON.

Comment of the author in April 2016:
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The article in German (www.ewald-gerth.de/22.pdf) is an excerpt of the author's thesis, which was defended at the *Pädagogische Hochschule Potsdam* on November 19th, 1965:
www.ewald-gerth.de/19verteidigung.pdf
A first explanation of the SCHWARZSCHILD-effect was given in 1965: www.ewald-gerth.de/16.pdf.
The theoretical interpretation of the SCHWARZSCHILD-effect is contained in the postdoctoral thesis of the author:
www.ewald-gerth.de/germanus/dissertation-b.pdf **Book: ISBN 978-3816-4299-1**