heritage

Article

The Tartan Ribbon or Further Experiments of Maxwell's Disappointment/Sutton's Accident

Susanne Klein [1,*] and **Paul Elter** [2,*]

[1] Center for Print Research, University of the West of England, Bristol BS16 1QY, UK
[2] Elter Studios, Chelsea, QC J9B 1K8, Canada
* Correspondence: susanne.klein@uwe.ac.uk (S.K.); paul@elter.ca (P.E.)

Abstract: On 17 May 1861, James Clerk Maxwell delivered a lecture at the Royal Society where he demonstrated, using a lantern slide projection, his theory for colour perception in the human eye via the additive colour process known today as RGB. Three images from three separate lantern slide projectors were projected onto a surface. The same colour filters with which the object had been photographed where then placed in front of each projection lens, carefully realigned, and what has been called "the first colour photograph" was supposed to have been created. It was a series of happy accidents, during capture and exposure, and a misinterpretation of the results—mostly long after the event itself—that has invented this commonly referred to fictional "First Ever" title. In the following retelling of the historical details in their chronological order and through a series of experiments with historically correct emulsions, we will clearly outline the errors and where they occurred.

Keywords: Maxwell's colour theory; wet collodion; 19th century photography and optics; RGB; tricolour photography; UV light; Thomas Sutton; James Clerk Maxwell

Citation: Klein, S.; Elter, P. The Tartan Ribbon or Further Experiments of Maxwell's Disappointment/Sutton's Accident. *Heritage* **2023**, *6*, 968–978. https://doi.org/10.3390/heritage6020054

Academic Editors: Marcello Picollo and Barbara Cattaneo

Received: 22 December 2022
Revised: 11 January 2023
Accepted: 19 January 2023
Published: 24 January 2023

1. Introduction: Historical Context

In 1852, James Clerk Maxwell, while still in University Cambridge, Trinity College studying Mathematics, developed an interest in Thomas Young's theory of colour and perception and, influenced by the experiments of his Professor J.D. Forbes, began his famous experiments using a top fitted with various colour patterns. It was not until 1855, after Maxwell had graduated, that the results of these experiments were delivered in his first paper on the subject entitled *Experiments on Colour, as Perceived by the Eye, with Remarks on Colour Blindness* [1] for the Royal Society of Edinburgh and would become the grounds for all future experiments and the beginning of humanity's relationship with RGB. It was another five years until Maxwell presented another crucial paper: *On the Theory of Compound Colours & Relations of the Colours of the Spectrum* [2] in which Maxwell expands on the subject of colour and perception, giving us the complete formulations on RGB and the human eye's perception of the visible colour spectrum. Sometime in 1860, it became clear that Maxwell was desirous of a way to demonstrate, physically in a more visual manner, his thought experiment that had started ten years prior, and he first theorized the following [1]:

"This theory of colour may be illustrated by a supposed case taken from the art of photography. Let it be required to ascertain the colours of a landscape, by means of impressions taken on a preparation equally sensitive to rays of every colour.

Let a plate of red glass be placed before the camera, and an impression taken. The positive of this will be transparent wherever the red light has been abundant in the landscape, and opaque where it has been wanting. Let it now be put in a magic lantern, along with the red glass, and a red picture will be thrown on the screen.

> *Let this operation be repeated with a green and a violet glass, and, by means of three magic lanterns, let the three images be superimposed on the screen. The colour of any point on the screen will then depend on that of the corresponding point of the landscape; and, by properly adjusting the intensities of the lights, &c., a complete copy of the landscape, as far as visible colour is concerned, will be thrown on the screen. The only apparent difference will be, that the copy will be more subdued, or less pure in'tint, than the original. Here, however, we have the process performed twice-first on the screen, and then on the retina."*

Maxwell then contracted Thomas Sutton—the eminent and distinguished photographer; editor in chief of the publication *Photographic Notes* (1856–1867); and inventor of the panoramic/wide angle lens and camera and the first SLR camera—to physically manifest his colour theory and create the B&W slides necessary to demonstrate his theory (Figure 1). There is no documentation regarding how the contact between Maxwell and Sutton came about; but, as we stated before [3], Maxwell was not a photographer, and these were not his photographs. This is a present-day common source of confusion. It was these three glass plate lanternslides, which on that evening on 17 May 1861, Thomas Sutton had created using the fastest photographic emulsion of the time, wet collodion or wet-plate, that became legend. Or so the story goes…

Figure 1. Sutton's original lantern slides for Maxwell's lecture at the Royal Institution; images provided by the Cavendish Laboratory in Cambridge where the lantern slides reside.

One would expect that a breakthrough of this magnitude being demonstrated publicly for the first time in history would attract the attention of every contemporary scholarly publication, and that even some of the daily newspapers would have written about such a great discovery: a way of capturing and representing the world in full colour. Contrarily, there was virtually nothing written about it in the academic or popular press. One would also expect Maxwell to have written about the event himself; again, there is oddly little mention; it is relegated to a footnote in his collected writings. We can surmise that the results of Maxwell's "first colour photograph" demonstration were lacklustre and compounded, when in the subsequent decades, tricolour photography and its associated technology were perfected and became relatively easy to use. The few sentences about the experiment that Maxwell committed to paper, summarizing his projection experiment, speak to this disappointment. "…By finding photographic materials more sensitive to the less refrangible rays, the representation of the colours of objects might be greatly improved." [4].

This lack of interest is what we refer to as Maxwell's disappointment [3] and perhaps it is why the event was not spoken of again until 33 years later, when in 1896, Fredrick E. Ives revives interest in Maxwell and the events of May 1861 to reference his own new invention, the Photochromoscope [5]. Additionally, it is here that the cult of the "first ever colour photograph" has its beginnings.

The three images that constitute the original three separations are still in existence and reside at the Cavendish Laboratory of the University of Cambridge; they are seen here (Figure 2) mounted and ready for projection on a singular fabric bow, *The Tartan Ribbon*. As anyone old enough to remember filling a slide carousel with transparencies knows, the slides must be upside down and backwards in order to be projected the right way up out of the lens and onto the projection surface, just as in your eye, another lens which is poignant to mention here, because Maxwell's paper on colour theory has more to do with how the eye perceives colour than it does with photography itself, but the two are joined here through this singular experiment.

On 15 June 1861, a few months after the demonstration, Sutton published a very short explanation of how he created the transparencies used by Maxwell for his interested followers in the *Photographic Notes*. "*A bow made of ribbon, striped with various colours, was pinned upon a background of black velvet, and copied by photography by means of a portrait lens of full aperture, having various coloured fluids placed immediately in front of it and through which the light from the object had to pass before it reached the lens. The experiments were made out-of-doors in good light, and the results were as follows:-…* " [6].

What did Thomas Sutton create sometime in the early summer of 1861? Was it a real tricolour separation of that tartan ribbon? The prevailing theory is that Sutton captured a sort of tricolour separation using wet collodion—a colour-blind photographic emulsion—and, accidentally, luckily captured the ultra-violet reflectance of the red portions of the ribbon on the red slide [7]. This is a reference to the *Scientific American* article from 1961 authored by Ralph Evans, in which he suggested that the reason for Sutton's supposed success was the result of various pigments in the tartan ribbon having increased levels of UV reflectance in the red and other pigments. (Figure 2). He argues that when red pigments not only reflect red light but also UV radiation, and this radiation is recorded on wet collodion, a false red image is created.

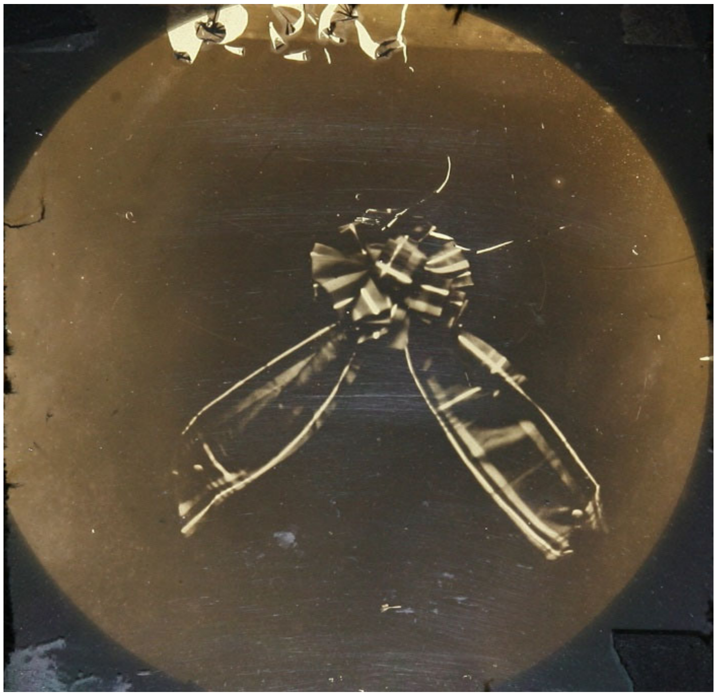


Figure 2. Detail of the red slide from Sutton's original lantern slides for Maxwell's lecture at the Royal Institution; images provided by the Cavendish Laboratory in Cambridge, where the lantern slides reside.

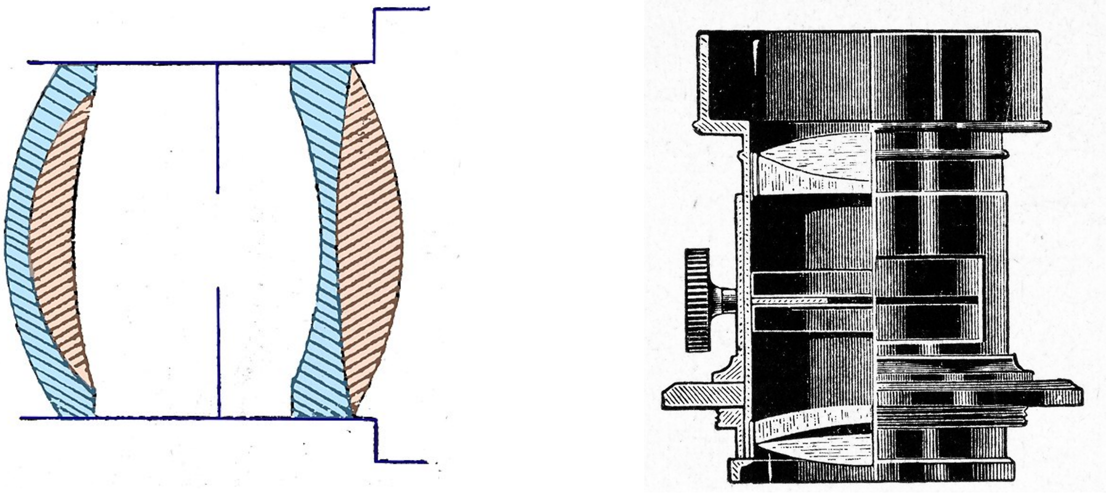
2. Experiments to Determine the UV Throughput through Lens Systems

Ralph Evans's explanation has become a kind of standard. We do not doubt that some red dyes reflect in UV and that the red filter Sutton used could have transmitted UV, but *was there enough UV to excite the bromide particles in the colloidal silver of the sensitised plate in order to record a permanent image on the glass plate?*

We do not know the exact type of lens that Sutton used, but twenty years hence, technical advancement in optics by Joseph Petzval had revolutionized photography; therefore, it is most likely he used a version of Petzval's optic. This two-air-spaced doublet optic, at f 3.7 and a focal length of 143 mm [8], had an aperture that was remarkably fast when compared to all other optics of the time, when f8 was standard.

The lenses were made from crown and flint glass (Figure 3a,b) and the total thickness of the glass that the UV radiation had to travel through was about 13 mm [8]. In [3] we discussed whether it is possible to generate a colour picture based on recording through density filters, but did not discuss the influence of a camera lens system on the transmitted electromagnetic radiation. A lens system consists of glass lenses and an iris which transform the incoming light into an image in the plane of the recording device, either plate, film, or detector. This is easier said than done. The different wavelengths or colours of visible light have a different optical path through glass which, in the extreme case of a prism, splits white light into the colours of the rainbow. This effect is called dispersion. When a lens is not correct for dispersion, images of different sizes are generated in the plane of the recording plate. Even with modern corrected lens systems, this effect is visible when we follow Maxwell's principle and record through red, green, and blue filters. Apertures of less than f4 lead to different image sizes, and the RGB images can only be registered in the middle of the image and diverge towards the edges.

Glass is transparent in the visible spectrum but absorbs UV radiation in different amounts depending on the type of glass and its impurities [9]. The aperture reduces the amount of UV reaching the plate further, and it is important to note that the amount of bellows draw or length further compound a decrease in the intensity of the UV. We do not know what lenses Sutton used. We therefore tried to gauge the influence of the lens system on UV radiation by measuring the transmission of UV through a set of modern, and one historic, systems.



(**a**) (**b**)

Figure 3. (**a**) A portrait lens design by Joseph Petzval, 1841, demonstrating the positions of the crown and flint glass, crown in pink and flint in blue, and the space between, and (**b**) a later version mounted with focusing screw. Wiki Commons and Public Domain.

At an aperture of f3.7 and a 143 mm focal length, the Petzval lens provides a diameter for the effective aperture of 38.6 mm comparable to the effective aperture of the ROKKOR-QD 1:3.5 f = 135 mm lens, as a first attempt to gauge the throughput of UV radiation through a lens system. Measuring the UV throughput in the range of 340 to 400 nm shows only 0.13% percent of the incoming radiation, maybe too little to be recorded on the glass plate within Sutton's recorded 8 min time window for the red plate [6].

To investigate how much UV radiation will reach the recording plate and to estimate exposure times in the visible and the UV light, we performed 4 sets of experiments:

1. UV transmittance through 10 different apertures with diameters ranging from 2 mm to 20 mm in 2 mm steps without any lens system. The light source was a Philips TL-D 18 W BLB fluorescent tube.
2. UV transmittance through 10 different apertures with diameters ranging from 2 mm to 20 mm in 2 mm steps and through crown glass of 9 and 19 mm thicknesses. The light source was a Philips TL-D 18 W BLB fluorescent tube.
3. UV transmittance through the lens systems ROKOR-QD, Soligor 1:2.8 and Rodenstock Reomar (see Table 1). The light source was a Philips TL-D 18 W BLB fluorescent tube.
4. UV and visible light transmittance through 7 different lens systems (see Table 2). The light source was the sun.

Table 1. Normalized UV transmission through different lens system when the UV source is emitting between 340 and 400 nm.

Lens	ROKKOR-QD 1:3.5 f = 135 mm	Soligor 1:2.8 f = 28 mm	Rodenstock Reomar 1:2.8 f = 45 mm
Effective aperture	38.6 mm	7 mm	11.25 mm
Normalised UV transmission (340 to 400 nm)	0.13%	0.77%	6.6%

Table 2. Normalized transmission of visible and UV light through different lens systems when the light source is the sun and the lens system was directed at the sun.

Lens	Normalized Transmission by the Sun in the Visible Range, 380 to 700 nm in the Focal Plane	Normalized Transmission by the Sun of UVA and UVB, 280 to 400 nm in the Focal Plane	Calculated Minimum Exposure Time for an Ipagsa ECO 88S Plate in the Focal Plane of the Lens System for an Incident UV AB Radiation of 2000 µW/cm²
ROKKOR-QD 1:3.5 f = 135 mm, aperture 3.5	157%	44%	57 s
Soligor 1:2.8 f = 28 mm, aperture 4	17%	20%	125 s = 2 min 5 sec
Rodenstock Reomar 1:2.8 f = 45 mm, aperture 4	8%	50%	50 s
Kodak box camera No. 3	0.02%	0.03%	About 24 h
Polaroid 110 A with Rodenstock 1:4.7 f = 127 mm	0.93%	0	No UV is transmitted through the lens
8 × 10 Kodak 2D with Voigtländer & Son no. 8454, circa 1858	130%	0.035%	About 24 h
Halina Achromat in Halina 6-4	11%	25%	100 s = 1 min 40 sec

To measure the UV radiation, we used an RS Pro IM-213 UVAB meter with an aperture of 20 mm, which records between 280 and 400 nm. Visible light was measured with a digital Lux meter, model LX1330B, with a light level range from 0 to 200,000 Lux and an accuracy of 0.1 Lux. In the experiments 1 to 3, the light source was as set of blacklight fluorescent tubes (Philips TL-D 18 W BLB) emitting between 340 and 400 nm. The distance between the detector and light source was 40 cm. The intensity of the UV radiation at 40 cm from the source was, on average, 950 µW/cm². In experiment 4, we used the sun as a light source because it was Sutton's light source. We measured visible and UV radiation during several days in summer, autumn, and winter. The light and UV levels varied according to season and location.

Wet collodion can record the visible and the UV ranges of sunlight. To investigate the influence of UV only on image formation, we used Ipagsa ECO 88S positive lithographic plates mounted in the Halina 6-4 camera, which has a spectral sensitivity between 350 and 450 nm, with a peak sensitivity at 400 nm and a required energy of 45–55 mJ/cm² for image formation. Ipagsa ECO 88S is a commercially available plate. It can be easily cut to any size.

2.1. Experiments 1 and 2

The variable iris sat directly on the detector. The maximal diameter of the iris was the same size as the detector of the UV meter. Soda lime glass was mounted directly under the fluorescent tubes.

Figure 4 shows the increase in transmission with the increase in the diameter of the aperture. Note that for apertures smaller than 6 mm in diameter, the transmission through glass has minimal influence on the final transmission. The diameter plays the major role.

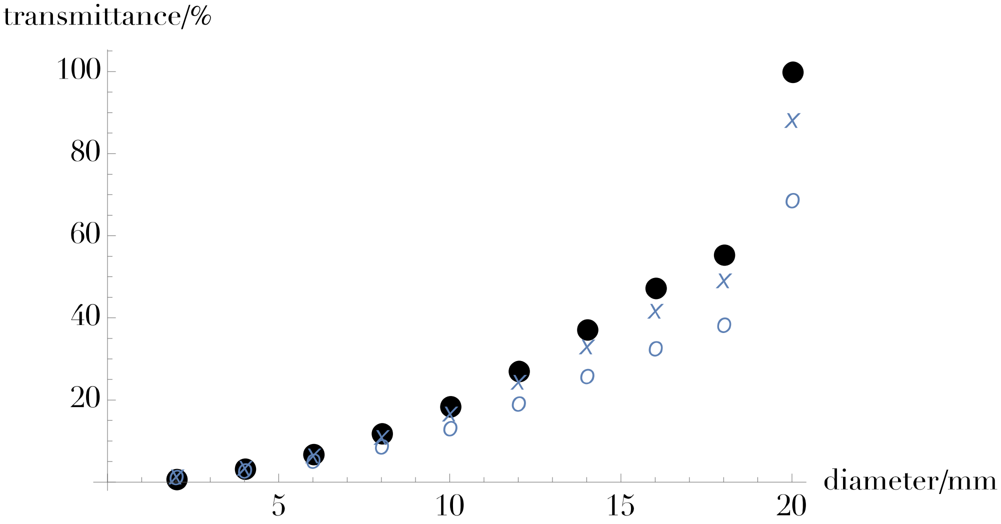


Figure 4. The aperture increases from a 2 mm to 20 mm diameter. The black dots mark the transmission through air, X through 9 mm and O through 19 mm soda lime glass and air.

2.2. Experiment 3

We do not know which lens or camera Sutton used for his experiment. To show how variable transmission of UV radiation through different lens system is, we measured the transmission of 340 to 400 nm UV light through three lens systems. The lenses sat directly on the detector.

The Soligor 1:2.8 f = 28 mm is a compact wide-angle lens of unknown optical design. The Rodenstock Reomar 1:2.8 f = 45 mm consists of two lenses and is part of the Kodak Retinette IB. Table 1 shows that all three lens systems transmit very little UV radiation in the range of 340 to 400 nm.

In Table 1, the UV transmission for different lenses is listed.

2.3. Experiment 4

Philips TL-D 18 W BLB fluorescent tubes only emit between 340 and 400 nm. Sunlight reaching the surface of the earth contains UV radiation from 280 to 400 nm, the range of UVAB detectors and the sensitivity range of AgI wet collodion [10]. UVC, from 100 to 280 nm, is absorbed by the earth's atmosphere. The transmittance of visible light and UV radiation was measured in the focal plane of the lens system, i.e., the film or plate plane, when the lens was directed towards the sun. We also calculated the exposure times for the Ipagsa ECO 88S lithographic plate based on the UV light intensity in the focal plane when we assume 2000 μW/cm^2 of incoming UV radiation.

We put an Ipagsa plate and a halftone screen into the Halina 6-4 and oriented it so that the sky covered half of the image. UV reading in the direction of the sky, not directly at the sun, was 1000 μW/cm^2. The intensity measured in the plane of the plate was 10 μW/cm^2. We exposed plates for 2 min, 10 min, 20 min, 40 min, 60 min, and 90 min. It took 90 min for an image to form, which is only a little bit longer than the calculated time of 83 min for an energy of 50 mJ/cm^2 to accumulate on the plate.

We can safely assume that the Ipagsa lithographic plates are more sensitive to UV radiation than wet collodion because they are optimized for UV exposure. We can also safely assume that the reflectance from the red tartan ribbon based-illumination of about 2000 μW/cm^2 was in the range of 400 μW/cm^2 to 700 μW/cm^2 (in [7] Evans provides a reflectance curve for the red cloth with a UV maximum of 20% at 380 nm). According to Evans, the red filter used by Sutton transmitted 10% of the incoming UV radiation, and then about 40 μW/cm^2 to 70 μW/cm^2 reached the lens system. Looking at the lens systems in Table 2, we can expect between 0.012 (Kodak box) and 35 μW/cm^2 (Rodenstock Reomar) to reach the focal plane of the lens system. For an Ipagsa plate, we would be looking at exposure times of 23 min for 35 μW/cm^2 and 48 days for 0.012 μW/cm^2, all outside the feasible processing time for wet collodion. Even if Sutton had diluted the red filter to a homeopathic level, and he has diluted the solutions [6], i.e., not reduced the amount of UV reaching the plate any further. Our conclusions reveal that he would not have been able to capture enough UV in his own prescribed time of 8 min or even before the collodion dried out, in around 15 min.

3. Recreating Sutton's Experiment and Conclusions

What were Sutton's own thoughts on the experiment? In the summation of his paper in the *Photographic Notes* he states, "…and when these different coloured images were superimposed upon the screen a sort of photograph of the striped ribbon was produced in the natural colours." [6]. This is not exactly a glowing statement of success and by no means a clear affirmation of creating distinct RGB separations.

What if instead of actually filtering differing wavelengths of colour, Sutton merely created neutral density filters generating differences in exposure, not colour, such that that they could be separated into three distinct colour slides, forming a fake tricolour image?

After receiving digital images of the original glass slides from the Cavendish Laboratory, upon closer inspection, this seems to be exactly what happened.

It is probably best to begin with the details of the experiment that we do know based on how Sutton described them in No. 125 of the *Photographic Notes*, 15 June 1861 [6].

"1st. A plate-glass bath, containing the ammoniacal sulphate of copper which chemists use for the bottles in their windows, was placed immediately in front of the lens. With an exposure of six seconds a perfect negative was obtained. This exposure was about double that required when the coloured solution was removed.

2nd. A similar bath was used, containing a green solution of chloride of copper. With an exposure of twelve minutes not the slightest trace of a negative was obtained, although the image was clearly visible on the ground glass. It was therefore found advisable to dilute the solution considerably and by doing this, and making the green tinge of the water very much paler, a tolerable negative was obtained in twelve minutes.

3rd. A sheet of lemon-coloured glass was next placed in front of the lens, and a good negative was obtained with an exposure of two minutes. [This glass plate has been lost.]

4th. A plate-glass bath, similar to the others and containing a strong solution of sulphocyanide of iron was next used and a good negative was obtained with an exposure of eight minutes.

…The thickness of fluid through which the light had to pass was about three quarters of an inch…the negatives…were printed by the Tannin process upon glass and exhibited as transparencies…

Upon first reading this, the statement regarding it taking 12 min of exposure for the green filter immediately raised doubts. As stated earlier [3], fifteen minutes is essentially the longest exposure one could achieve in the heat of a spring day out of doors. Taking into consideration all the handling prior to and after exposure, if the plate had not completely dried out, a good portion of it would have begun to dry inward from the edges, yet the plate exists? Again, as you read, the difference in exposure times between that of the blue plate at six seconds and every other exposure is measured in minutes, with the extreme example of green, an exposure of 120 times that of blue.

We can take an example of a true tricolour separation of the period for reference. We will use the Leon Vidal flower arrangement circa 1877 to demonstrate that when comparing the red, blue, and green channels, portions of the image completely disappear. We understand that this is by no means a fair comparison due to the advances of technologies, but it does illustrate what should, to some degree, be happening in the Sutton ribbon images (Figure 5).

Figure 5. Vidal, Leon "La photographie au charbon" Paris, Gauthier-Villars imprimeur-libraire 1877.

If we do the same with Sutton's transparencies, this is barely noticeable, but what we can clearly see is that they become darker or lighter globally as opposed to specifically. In fact, in the blue transparency, there are highlights from the change in sunlight creating noticeable increased exposure or "hotspots" (not because of colour filtration) which are still noticeable in the red slide, although considerably lighter. If Sutton had managed to isolate colour, these would not be apparent.

We can almost definitively say that the recurring "overexposed" lines of the ribbon, which are repeated in each of the transparencies, are either blue or white, because this is exactly how a very saturated ultramarine type blue or white presents itself. "Haloing" is very common and consistent with wet collodion. (Figure 6).

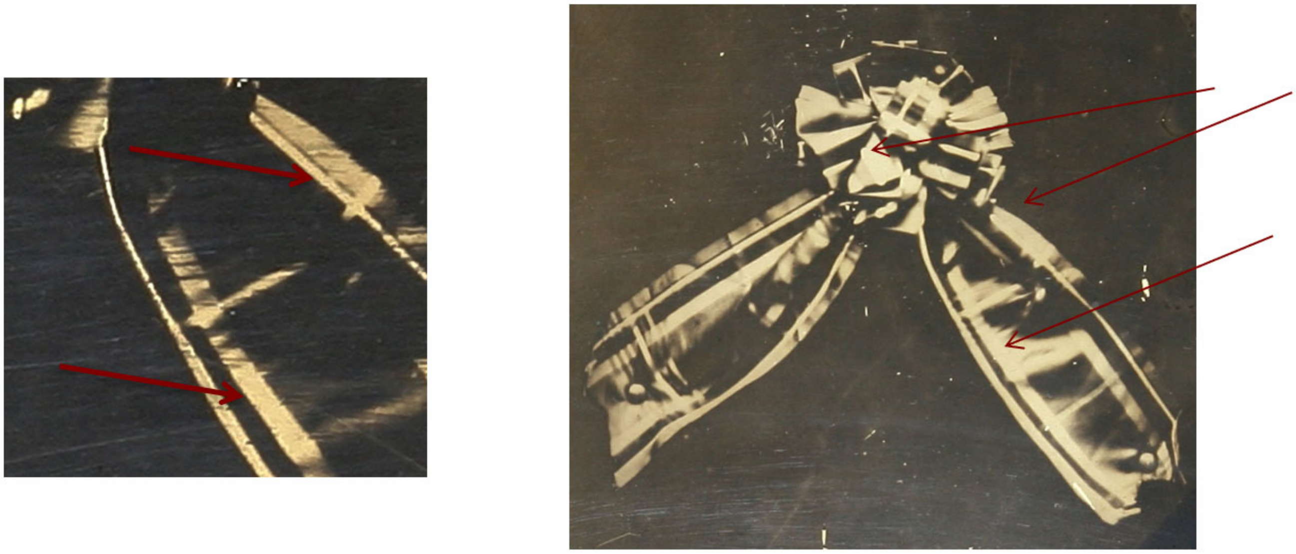


Figure 6. Detail of the green and blue slides demonstrating "haloing", a type of extreme overexposure that happens in areas of high concentration of blue or white.

Keeping this theory of Sutton creating neutral density filters, not tricolour filters, in mind, this was exactly what we set out to demonstrate in replicating Sutton's experiments using the original wet collodion emulsions, first trying the colour separation model and then secondly using neutral density filters to test this hypothesis. We decided on several key factors and necessary controls that would help clearly demonstrate the theory of neutral density filters in reference to the tartan ribbon: colour, printed colour, how wet collodion sees colour, and measurements during exposure that would provide points of reference and facilitate a more linear and scientific approach and thereby create a measurable/repeatable defined colour reference [3].

In [3], we demonstrated that a colour effect can be achieved when using neutral density filters instead of colour filters when photographing with wet collodion (Figure 7). The transmission spectra of the different filter sets used for the experiments justify the assumption that UV reflection by red filters, as stated in [7], is not possible to create a colour effect in the prescribed time stated by Sutton. These are not the colours present in any object which contains reds and greens. In [3], we did not consider the UV transmission of the lens system. Table 2 shows extreme variations in the transmission of different lens systems. The lens system created by Voigtländer & Son no.8454, manufactured in Germany circa 1858, and mounted to an 8 × 10 Kodak 2D, shows us a clear example of what the recording times may well have been outside the process time for wet collodion, even if we propose that the red in the tartan ribbon was a perfect UV mirror.

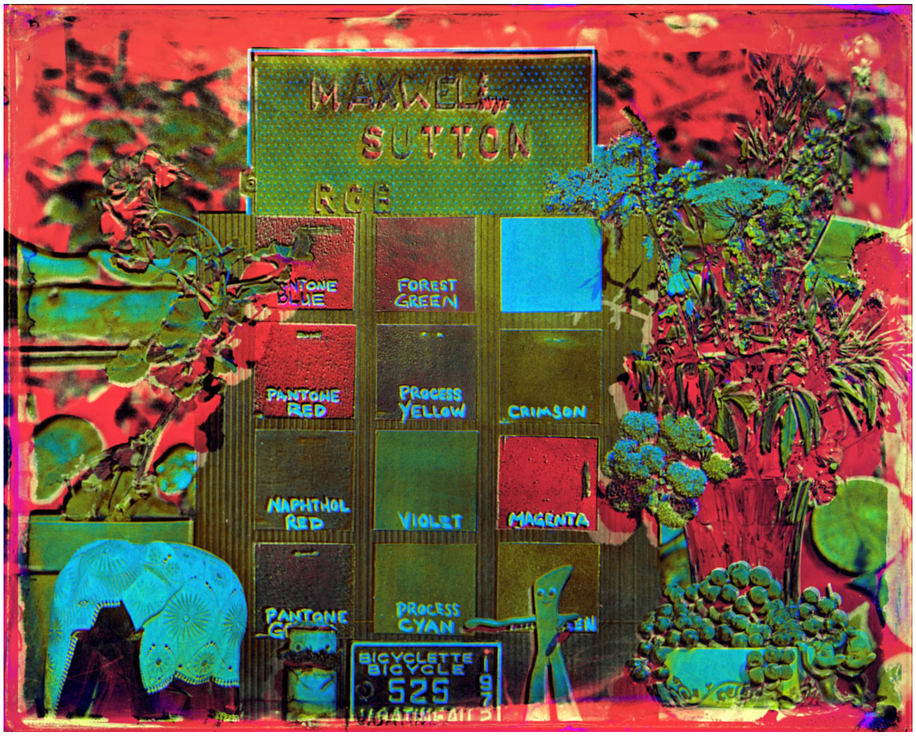


Figure 7. Tricolour wet-plate photograph—digitally scanned and coloured from three wet collodion glass plate photographs—creating a false tricolour image. Image copyright: Paul Elter.

In conclusion, even if, in Maxwell's own words, the experiment was a failure, his theory most definitely was not, and was one of major breakthroughs in optics and engineering. Perhaps, therefore, our take-away should be, and what we should remember and work together to correct the spin in current photographic circles, that this moment in history definitely was not the origin of "The First Colour Photograph" but the "The First Attempt at Tri-Colour Separation". Maxwell's principals of colour photography hold true even though the famous "Tartan Ribbon" is currently celebrated for the wrong reasons.

Author Contributions: Conceptualization, S.K. and P.E.; methodology, S.K. and P.E.; validation, S.K. and P.E.; formal analysis, S.K. and P.E.; investigation, S.K. and P.E.; resources, S.K. and P.E.; data curation, S.K.; writing—original draft preparation, S.K. and P.E.; writing—review and editing, S.K. and P.E.; visualization, S.K. and P.E.; funding acquisition, S.K. All authors have read and agreed to the published version of the manuscript.

Funding: The research was partly (S.K.) funded by the EPSRC grant EP/R011761/1.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: https://iopscience.iop.org/article/10.1088/1751-8121/aca8db.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Maxwell, J.C. 1. Experiments on Colour as perceived by the Eye, with Remarks on Colour-Blindness. *Proc. R. Soc. Edinb.* **1857**, *3*, 299–301. https://doi.org/10.1017/S0370164600028224.
2. Maxwell, J.C. On the Theory of Compound Colours and the Relations, of the Colours of the Spectrum. In *The Scientific Papers of James Clerk Maxwell*; Maxwell, J.C., Niven, W.D., Eds.; Cambridge Library Collection—Physical Sciences; Cambridge University Press: Cambridge, UK, 2011; Volume 1, pp. 410–444.
3. Klein, S.; Elter, P.; Vazquez, A.T. Maxwell's disappointment and Sutton's accident. *J. Phys. A Math. Theor.* **2022**, *55*, 491002. https://doi.org/10.1088/1751-8121/aca8db.
4. Maxwell, J.C.; Niven, W.D. (Eds.) On the Theory of Three Primary Colours. In *The Scientific Papers of James Clerk Maxwell*; Cambridge Library Collection—Physical Sciences; Cambridge University Press: Cambridge, UK, 2011; Volume 1, pp. 445–450.
5. Ives, F.E.; Parry, J.W. The Perfected Photochromoscope and its Colour Photographs. *J. Soc. Arts* **1896**, *44*, 517–528.
6. Sutton, T. *Photographic Notes*; Sampson Low, Son & Company: London, UK, 1861; pp. 169–170.
7. Evans, R.M. Maxwell's Color Photograph. *Sci. Am.* **1961**, *205*, 118–131.
8. Ray, S.F. *Applied Photographic Optics*, 3rd ed. Focal Press: Oxford, UK, 2002.
9. Ehrt, D. UV-absorption and radiation effects in different glasses doped with iron and tin in the ppm range. *Comptes Rendus Chim.* **2002**, *5*, 679–692. https://doi.org/10.1016/S1631-0748(02)01432-7.
10. Skladnikiewitz, P.; Hertel, D.; Schmidt, I. The wet collodion process—A scientific approach. *J. Imaging Sci.* **1998**, *42*, 450–458.