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Research Article

Information in the Shroud of Turin About Its Variable Molecular Properties

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Abstract

Three earlier papers on the Shroud of Turin showed that ultraviolet induced fluorescence (UVIF) intensity is non-uniform over the surface of the Shroud. These intensity results were based on an analysis of UVIF photographic images taken in 1978 as part of a scientific investigation of the Shroud. In this paper the statistical technique, principal component analysis (PCA), is used to analyze the information present in the UVIF images. It is shown that the vast majority of information in the UVIF Shroud images is contained in their International Commission on Illumination (CIE Lab) image intensity. Differences in UVIF intensity indicate differences in the Shroud's molecular properties. Such differences can be due to differences in molecular structure, contamination, and burned regions. Fluorescence spectral results published as part of the same 1978 scientific study confirm the intensity variation with position of the UVIF images. These spectral fluorescence results are discussed in detail. The combined photographs and spectral results demonstrate that color contributes relatively little to the information in the UVIF images. One possible cause of the variation of UVIF intensity, namely neutron radiation, is briefly discussed. Charred Shroud material, collected during its cleaning in 2002, can be used to assess whether the Shroud was exposed to neutron radiation. Such testing would be completely non-destructive to the Shroud. New UVIF photographs need to be taken to validate the results discussed in this paper.

Keywords

Shroud, Ultraviolet, Fluorescence Intensity, Information, Molecular Properties

1. Introduction

The Shroud of Turin is a unique linen cloth with an image of a crucified man on it. Many people believe that this cloth was Christ's burial shroud. The Shroud of Turin has been studied more than any other ancient relic in history. In 1976 scientists put a photograph of the Shroud of Turin into a VP-8 analyzer and they found that amazingly the Shroud photo displayed 3 dimensional properties. Intrigued by this interesting result two of the scientists established a scientific research project (Shroud of Turin Research Project, STURP) to investigate the Shroud. Two years later with 31 US scientists joining the project the team traveled to Turin to carry out a scientific analysis of the Shroud. STURP had a technical photography team that took approximately one thousand high quality images of the Shroud. In April 2019, 199 images including 44 UVIF images taken by Vern Miller as a member of STURP were published on the web [1]. In this paper twenty-one of Miller's UVIF images are analyzed for their information content.

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In 1981 Miller and Pellicori published 7 of the UVIF images that were taken down the center of the Shroud [2]. In an earlier paper McAvoy analyzed 21 of Miller's UVIF web images published by Gil Lavoie and Tom D'Muhala [3]. The 21 images were analyzed for their color and information content. A detailed discussion of how the web UVIF images were produced is given by McAvoy [3]. Unfortunately, Miller's original UVIF images have been lost. The published web images have an orange coloration which does not agree with either the color of the images published in 1981 or the comments made in that paper [2]. McAvoy demonstrated that the web UVIF images were produced using color correction filters and these filters altered their characteristics [3]. This earlier research is briefly reviewed below. In this paper an additional analysis of the information content in the UVIF Shroud images is presented. It is shown that the main information content in the UVIF images is contained in their fluorescence intensity. How the intensity of the UVIF images could relate to differences in the Shroud's molecular properties with position is also discussed.

2. Earlier Research on UV Induced Fluorescence Images of the Shroud

Figure 1 below shows three of the same three UVIF images given in Figure 1 in [3]. The three UVIF images show the same section of the Shroud.

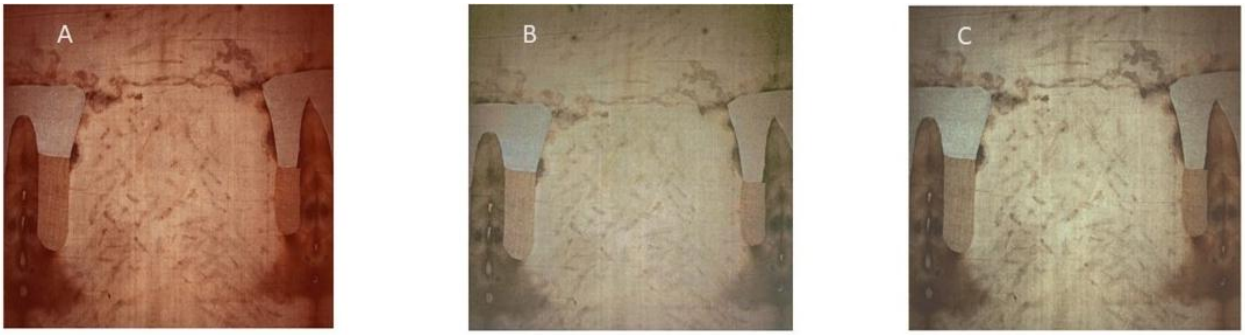

Figure 1. *A Miller web image [8-Misc.-UV-D-8_0508 (D8#188)] [1]. B Image of D8 region cropped from Fig. 6 [2]. C Filter reconstructed web D8 image [3]. A and C copyright Vernon Miller, 1978.*

Figure 1A is taken from the UVIF images available on shroudphotos.com [1]. McAvoy demonstrated that the orange coloration of all the UVIF images on shroudphotos.com was the result of their being created by photographing the original UVIF Shroud images using combined magenta and yellow color correction filters [3]. These filters repressed the blue and green colors in the original UVIF images and enhanced the images' red color. Figure 1B is copied from Miller and Pellicori's 1981 paper [2] which gave seven UVIF images taken down the center of the Shroud. Since the original UVIF images were lost, the Miller and Pellicori's images were the only ones to which the web UVIF images could be compared. Figure 1C shows the results of using a mathematical model of the color correction filters applied to the image shown in Figure 1A. The agreement between the color of Figures 1B and 1C is excellent. Figure 1C has more detail than Figure 1B. McAvoy was able to use his filter model to restore the color of the orange web images to closely match the color of Miller and Pellicori's center images [3]. He also applied the filter model to restore the color of UVIF images taken along the top and bottom of the Shroud. Details of the color matching are given in [3].

In analyzing Miller's uv photos, McAvoy used the CIE L*a*b color space [4], which is designed to approximate human vision [3]. Figure 2 shows a schematic of this color space.

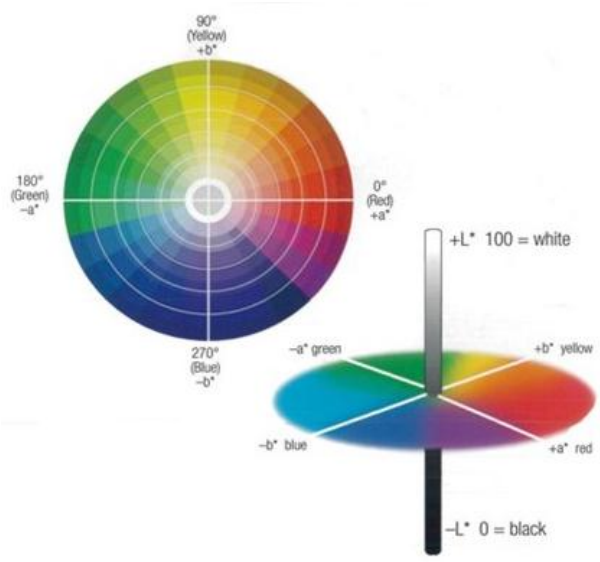

Figure 2. *CIE L*a*b Color Space.*

The vertical axis in the CIE L*a*b space gives image intensity, L, and the horizontal axes, a and b, give color

information. Note that the vertical axis is perpendicular to the a and b axes and therefore L is independent of color. Each of the images in Figure 1 is made up of red (R), green (G), and blue (B) pixels of varying intensity, so they are called RGB images. For each pixel in Miller's UVIF images, L was calculated using the MATLAB function rgb2lab, which converts an RGB image to a CIE L*a*b image.

An important result, that emerged from the earlier research on the UVIF Shroud images, involves the change of UVIF intensity, L, with location on the Shroud. Miller used a rail system to move his UV camera down the Shroud [2]. He stopped at various locations along the Shroud and photographed UVIF images of the top, center, and bottom sections of the Shroud. The rail system had an arm that kept Miller's camera at the same distance from the Shroud for each image. Miller photographed both the frontal (front) and dorsal (back) images on the Shroud. Thus, each part of the body appears on two images, the frontal and the dorsal.

Unfortunately, the UV lighting system Miller used did not evenly illuminate the Shroud section being photographed. As a result, the only way to compare the fluorescence intensity of Miller's UVIF images to one another is to compare the average UVIF intensity for each image [5]. A pointwise comparison of the images cannot be done without modeling the UV lighting source. McAvoy calculated the average UVIF intensity, L, for 21 of the images that were reconstructed from the orange web images [1] using his model of the color correction filters [3]. Figure 3 below shows these intensity results.

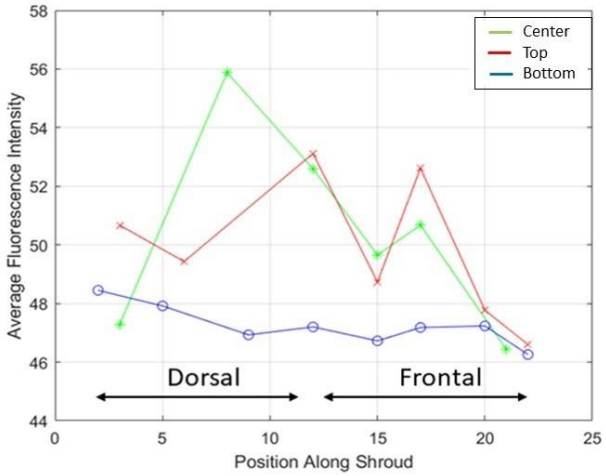

Figure 3. *Average UVIF intensity of filter reconstructed web images taken from [3].*

A priori, one would expect that the average UVIF intensity would be relatively constant with position on the Shroud. However, as Figure 3 demonstrates this is not the case. As can be seen the average UVIF intensity ranges from roughly 46 to 56 depending on the UVIF image analyzed.

McAvoy found some very interesting trends in these average intensity results [3]. The following is a summary of the unique spatial average UV fluorescence intensity properties of the Shroud:

1. Average UV fluorescence is highest in the mid-section of the dorsal image on the Shroud (Green 8 location).
2. Except for the left side blue (Blue 9 Blue17 locations) comparison the other nine comparisons show that at the same body location the dorsal side of the Shroud fluoresces more (has higher average intensity) than the frontal side.
3. All of the top sections of the Shroud (red curve) fluoresce more (have higher average fluorescence intensity) than the corresponding bottom sections (blue curve).
4. Along the center green images average UV fluorescence intensity goes through two maxima at points 8 and 17.

The question of how these interesting UVIF intensity trends could relate to the Shroud's molecular properties is discussed next.

3. Assessing Information Content in Shroud UVIF Images

When a material absorbs UV radiation, electrons in the material are temporarily raised to a higher energy state. Then when the electrons settle back, energy in the form of fluorescence is emitted in the visible light range. Molecular structure differences, burn marks, and contamination associated with position on an object UVIF photographed can cause differences in UV induced fluorescence. These fluorescence differences can show up as color and intensity differences in the UVIF images. Differences in UVIF results give information about the underlying nature on the object being photographed. This information is relative in the sense that it simply indicates whether one region of the object differs from another. The information does not necessarily indicate what the molecular differences, such as molecular bonds are or what the object might be contaminated with. UVIF images therefore contain property information at the molecular level for the object being photographed.

One well established method of assessing information in a data set is principal component analysis (PCA), which is a statistical technique [6]. McAvoy used PCA to assess the information content of all Miller's web UVIF Shroud images, and the UVIF images published by Miller and Pellicori [3]. The mathematical details of PCA and results of the PCA analysis for these two sets of UVIF images are given in [3]. Here a different approach is taken to demonstrate that UVIF image intensity is the key variable in terms of demonstrating that the Shroud's underlying molecular properties change with location being photographed. A PCA analysis of one filter reconstructed web UVIF image is used for illustration. A complete PCA analysis of all the filter reconstructed UVIF web images is given in Appendix 1, since this analysis was not

given in [3]. In Appendix 1 it is shown that all the filter reconstructed UVIF images exhibit similar PCA results as the UVIF images analyzed in [3].

Consider the UVIF image in Figure 1C. All of the UVIF images are composed of RGB pixels with various intensities for each color. Thus, the UVIF images have three independent variables, the intensity of their R, G, and B pixels values. If PCA is applied to the image in Figure 1C, three principal components result. Each PCA component (PCi) is a linear combination of the R, G, and B pixel intensity values. If the images determined from the three PC's are added, one gets the original image. Figure 4 below illustrates the PCA decomposition of the filter reconstructed UVIF image in Figure 1C.

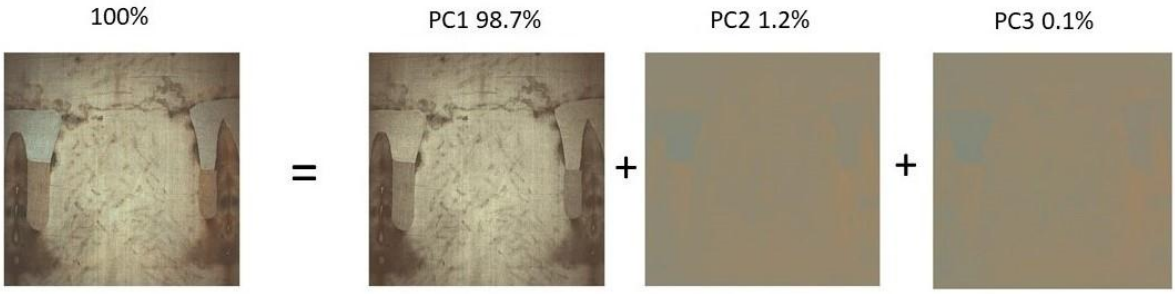

Figure 4. *Principal component reconstruction of UVIF image in figure 1C.*

The percents shown in Figure 4 for each PCi indicate the amount of information captured by that PC. As can be seen PC1 contains the vast majority of the information present in the UVIF image in Figure 1C. McAvoy demonstrated that PC1 explains greater than 96% of the information in both the web UVIF images and the UVIF images published by Miller and Pellicori [3]. Appendix 1 shows that for the filter reconstructed images PC1 also explains greater than 96% of their information content.

To demonstrate the difference between the UVIF images and a typical photographic image, consider the image of the bird feeder shown in Figure 5 below.

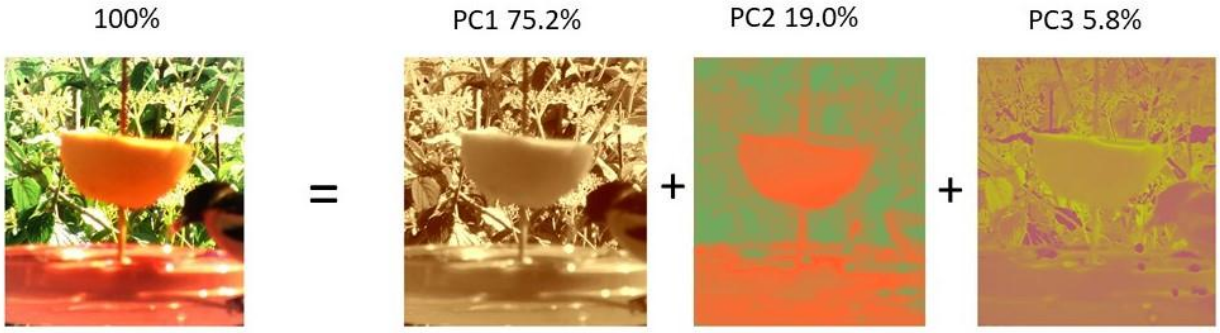

Figure 5. *Bird feeder image.*

In this case PC1 only explains 75.2% of the information in the original image. PC1 and PC2 combined still do not account for 5.8% of the information in the original image. This result sharply contrasts with the PC results for all of the UVIF Shroud images.

Importantly, McAvoy also demonstrated that PC1 for both Miller's web images and Miller and Pellicori's published UVIF images had correlation coefficients with the CIE L*a*b image intensity, L, that are .997 or greater [3]. In Appendix 1, Table A1 for the filter reconstructed UVIF images shows their correlation coefficients between L and PC1 is .998 or greater. These results mean that PC1 is essentially equivalent to the CIE L*a*b intensity, L, for all the UVIF images. Further, since L is perpendicular to the a and b color dimensions, color contributes very little information in the UVIF images (< 4%). It can be concluded that UVIF image intensity is the most important variable showing whether there are differences in molecular structure or contamination throughout the Shroud.

One might argue that the differences in intensity shown in Figure 3 could be caused by differences in burn marks in the images, or possibility to a difference in contamination levels. However, the images from which the red and blue intensity curves in Figure 3 were calculated have almost identical burn marks in them, no doubt due to the way the Shroud was folded

when it was exposed to fire in 1532. So, the comparison between the top red and bottom blue curves shown in Figure 3 should not be affected by burn marks. For the center green curve, McAvoy presented intensity results for the case where the burn marks were cropped off the center images [5]. These results demonstrate that eliminating the burn marks still results in UVIF center images with a varying intensity pattern. While there is no doubt some contamination is on the Shroud, it can be questioned whether the patterns shown in Figure 3 would be caused by different amounts of a contaminant spread throughout the Shroud. Thus, it is likely that part of the intensity differences shown in Figure 3 can be attributed to differences in molecular structure with location on the Shroud.

4. Corroborating Evidence for Variation of UVIF Intensity of the Shroud

As part of their STURP research Gilbert and Gilbert measured fluorescence spectra from 16 regions of the Shroud [7]. The size of each region studied was 6mm by 3mm, which is 3.71×10^{-6} times smaller than the size of each region photographed by Miller. Given their small size these scans give fluorescence information that is comparable to a very small number of pixels in the UVIF Shroud images. For the fluorescence spectral scans, a 200-W mercury arc lamp was used. The source monochromator was set at 365 nm. A UV transmitting, visible absorbing filter (Oriel G-77 4-3300) was inserted after the source monochromator to reduce the visible stray light. A long pass filter with 50% transmission at 390 nm was placed before the detector monochromator. The monochromator was continuously scanned from 390 to 700 nm using an effective instrument bandwidth of 8 nm.

Gilbert and Gilbert also studied relative spectral absorbance at locations on the Shroud. All the points on the Shroud studied by Gilbert and Gilbert are shown in Figure 6 below. Spectral fluorescence measurements were only made for some of the points shown on Figure 6.

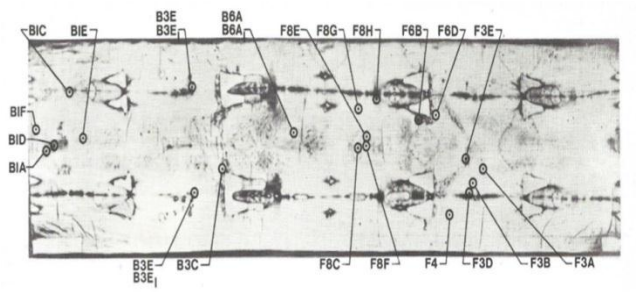

***Figure 6**. Shroud showing location of data points. Taken from [7].*

Fluorescence spectra were measured at four clear, four image, five burn, and three blood points. These points are shown in Table 1, which gives the locations where fluorescence spectra were measured and the location type.

***Table 1**. Fluorescence spectral data from references [7, 8].*

Location	Type	x	y	Y*	R	G	B	L
F4	Clear	0.2390	0.2675	0.1831	63.7648	124.1343	177.8783	49.8700
F3B	Clear	0.2393	0.2763	0.1727	57.0353	122.0091	168.986	48.5985
F6D	Clear	0.2424	0.2741	0.1496	58.6645	113.2755	158.8717	45.5794
B1F	Clear	0.2362	0.2687	0.1325	49.2426	107.3519	153.5600	43.1375
B1E	Image	0.2424	0.2769	0.1556	58.3187	115.7576	160.4579	46.3918
B6A	Image	0.2493	0.2902	0.1465	58.8218	113.0574	149.3706	45.151
F8F	Image	0.2563	0.2957	0.1244	59.3925	104.2505	135.4702	41.9071
B1D	Image	0.2386	0.2712	0.0882	41.1891	88.3474	126.2172	35.6354
B3E	Scorch	0.2593	0.3000	0.165	69.9933	119.0631	151.8011	47.6238
F8H	Scorch	0.2615	0.2982	0.1327	65.7022	106.9663	137.7927	43.1673
F3C	Scorch	0.2697	0.3072	0.1055	62.1469	95.7598	119.6635	38.812
B1C	Scorch	0.284	0.3236	0.083	59.6677	85.1219	100.0855	34.600
F3D	Scorch	0.3126	0.3472	0.0558	56.6239	69.0383	73.5648	28.3271
F8C	Blood	0.2529	0.2787	0.1021	57.1171	93.5017	130.3196	38.2167
F3E	Blood	0.2528	0.2809	0.0828	50.2654	84.7626	117.5088	34.5593

Location	Type	x	y	Y*	R	G	B	L
F6B	Blood	0.2545	0.2795	0.0727	48.7649	79.1877	110.8306	32.4138
F4#	Clear	0.2362	0.2927	0.1927	42.4375	131.1194	170.1753	51.0016

Unfortunately, the original spectral data that was measured by Gilbert and Gilbert has been lost.

In 2023 Schwalbe and Pellicori, both of whom were STURP members, published a paper in which they estimated the fluorescence spectral data from plots given by Gilbert and Gilbert [8]. The fluorescence spectra were reduced to equivalent chromaticity values and visual intensities, by digitizing the graphs given in [7]. Schwalbe and Pellicori used a delta frequency value of 5 nm and interpolated between frequencies of 380 and 780 nm. They reconstructed the fluorescence spectra by summing the discrete values using a modified version of equation 1 in their paper. Their results are shown under columns x, y, and Y* in Table 1. The xyY color space is known as the CIE 1932 color space in which x and y give chromaticity and Y is the luminance which is orthogonal to the chromaticity plane, xy. This color space is very similar to the CIE L*a*b color space. Schwalbe and Pellicori give a reference to an online calculator that can be used to convert between the two CIE color spaces, xyY and L*a*b [9]. The calculator can also be used to determine the RGB values that correspond to each spectral scan. Schwalbe and Pellicori denoted their color space results as xyY*, where the asterisk indicated the quantity Y relative to the arbitrary units that Gilbert and Gilbert used in their paper. Table 1 gives the xyY* values given by Schwalbe and Pellicori, plus their corresponding RGB and CIE L*a* intensity, L, values.

Figure 7 below gives a plot of the L values in Table 1 versus location on the Shroud.

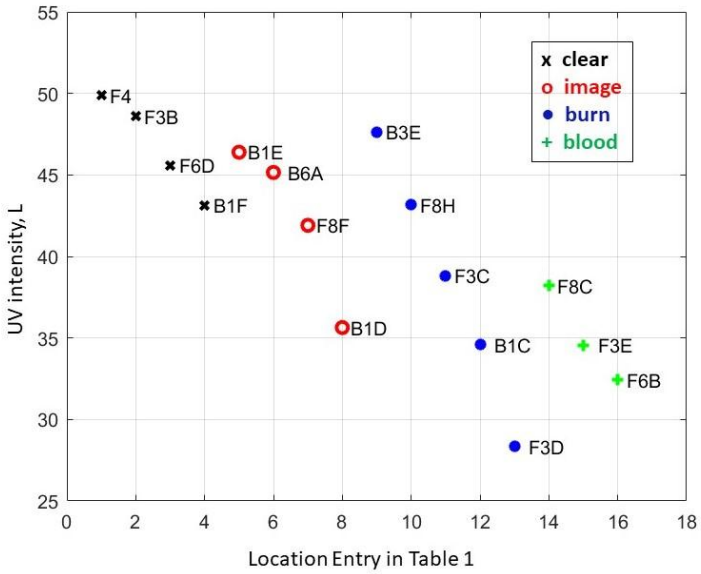

Figure 7. *UV intensity, L, versus position on the Shroud.*

As can be seen the UV intensity, L, determined from the Gilbert and Gilbert data shows a significant variation with location. These differences occur for all four types of points that Gilbert and Gilbert considered in their study. These results corroborate the results obtained from the analysis of the UVIF Shroud images, namely that UV fluorescence intensity varies with location on the Shroud. They further indicate that that the molecular structure of the Shroud could vary by location, since contamination alone should not account for all the variation seen in Figures 3 and 7. An important question that should be answered is: what caused the change in the Shroud's UVIF fluorescence properties? Before addressing this question, the color of the Shroud UVIF images is addressed.

5. Color of UVIF Images of the Shroud

In Miller and Pellicori's paper they state: that the background of the Shroud fluoresces with a "generally green-yellow" color, and the image itself has "no color" [2]. Clearly the image shown in Figure 1A does not have these properties, since color correction magenta and yellow filters were used to create the

image. Another color space, the HSV space, can be used to assess the color in the UVIF images in Figures 1B and 1C [10]. In the HSV space H gives the hue which reflects the color, S the saturation (amount of gray) and V the value (the brightness). If an RGB image is converted to the HSV space, then a color histogram that reflects the hue, H, for the RGB images' colors can be calculated [11]. Figure 8 below shows the color histogram for the UVIF images in Figure 1B and 1C.

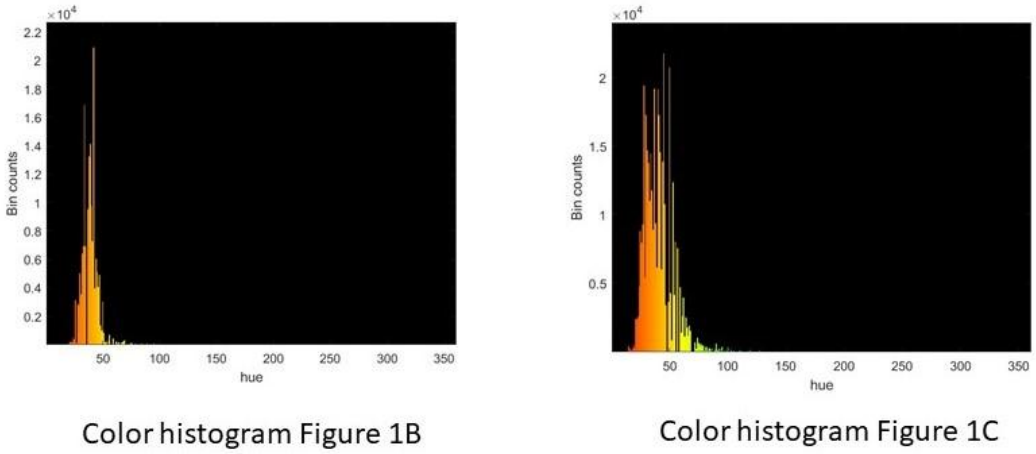

Figure 8. *Color histograms for UVIF images shown in Figures 1B and 1C.*

As can be seen the histogram for the UVIF image in Figure 1C does have some yellow and a small amount of green hue, but it is dominated by the orange hue. The histogram for the UVIF image in Figure 1B has even less yellow and almost no green hue.

The results given by Schwalbe and Pellicori can be converted to RGB space and displayed [8]. Each result in Table 1 corresponds to an individual RGB value. The results for the four clear and four image locations are shown above the dotted line in Figure 9 below.

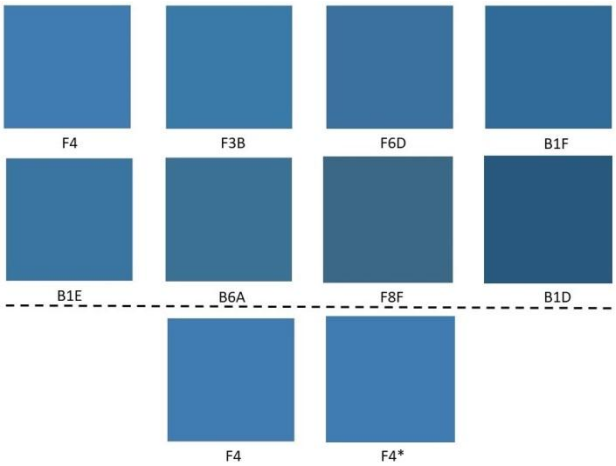

Figure 9. *RGB Color of xxY* values given in [9].*

As can be seen all eight of these colors are distinctly blue. Pellicori studied a modification of the spectra for location F4 and this result is shown below the dotted line and labeled F4* [8]. The modification accounts for the difference between the UV filtering used by Gilbert and Gilbert [7] and that used by Miller [2]. Pellicori noted that his modeling shows a shift toward the green region which occurs as the result of the difference in the UV filters used in each case. Clearly the colors shown in Figure 9 differ from those shown in Figures 1B and 1C. Further, neither the colors shown in Figure 9 nor those in Figures 1B and 1C seem to agree with the comments made about color of the UVIF images by Miller and Pellicori [2]. Unless the original UVIF images can be found, it does not appear that these disagreements can be explained. Fortunately, as the previous section shows UVIF image intensity is much more important in assessing information in the UVIF images than color is.

If a PCA analysis of the clear and image data in Table 1 is carried out, 88% of the information in these 8 images is contained in their PC1 values. Further the correlation coefficient between CIE L*a*b intensities, L, and PC1 is .994. These PCA results indicate that L is approximately 9 times more important than color in terms of the information in these 8 results. Interestingly, as Table 1 shows the xy chromaticity values for the data for the 3 blood points, shown in boldface, are very close to one another. However, the intensity plot shown in Figure 7 shows that there is a difference in CIE L*a*b intensity, L, for these 3 points. So, something appears to be different about them, either contamination or a change in blood properties, or molecular structure. Fanti has recently published a paper in which he discusses three different types of blood found on the Shroud [12]. These types are: A (post-mortem), B, (pre-mortem), and C which was difficult to categorize. So perhaps the blood intensity differences shown in Figure 7 reflect that there are different types of blood on the Shroud.

McAvoy gave a comparison between the UVIF intensity results in Figure 3 and Rucker's simulation results [13] of the

hypothesis that neutrons were released from the body of the crucified man shown on the Shroud [14]. There was a remarkable agreement between Rucker's simulation and the four unique spatial average UV fluorescence intensity properties of the Shroud discussed in Section 2 above. This agreement led to a study about whether UV induced fluorescence intensity could be affected by neutron radiation for modern linen. In that study the modern linen was not contaminated. Indeed, it was found that UVIF intensity increases with increasing neutron flux. After reference [14] was published it was found that the neutron radiation used for the study contained both slow thermal neutrons, as well as fast neutrons. In addition, there was some gamma radiation exposure as well [15]. All three types of radiation can potentially affect UV induced fluorescence. Exposure to thermal neutrons would affect the radiocarbon dating of the Shroud that was determined by measuring its ^{14}C content. It is also likely that additional types of radiation can affect the fluorescence properties of linen. Fanti [12] has recently presented preliminary results that indicate that one of the blood samples from the Shroud appears to show beta radiation activity. Such activity would result from among other things the decay of radiocarbon, ^{14}C.

Tom D'Muhala was a founding member of STURP and was President of the organization from 1978 to 1996. Before his passing in 2023, Tom discovered 2 UVIF images of the Shroud in his files. These two images have colors that appear to agree with the colors in Figure 9. These two new images have PCA and intensity properties that agree with those given in this paper. The two new images are discussed in the Appendix 2.

6. Recommendations

One recommendation that can be made is that new UVIF photography of the Shroud should be commissioned. The photography should be done with uniform UV lighting. Such lighting would give information about the Shroud's fluorescence properties over much smaller regions than those obtained by averaging results from Miller's UVIF images [3]. These new UVIF images would allow for a point wise UVIF intensity map to be developed over the entire Shroud surface.

There is a simple, and straightforward non-destructive test of the Shroud that could answer the question of whether the Shroud was exposed to thermal neutron radiation. In 2002 the Shroud was cleaned [16] and the cleaners scraped away the charred edges of all the burned areas and collected the scrapings into small containers. Radiocarbon dating can be done on this charred material, since the charring would not destroy any radiocarbon that had not burned completely and been converted into gaseous carbon monoxide or dioxide. Since the burned areas occur throughout the Shroud, a number of different locations could be tested using a small amount of the charred material from each. The goal would be to detect differences in radiocarbon age as a function of location on the Shroud. Obviously, such use of the charred material would not detract at all for the Shroud itself, and it would help settle the question of whether the Shroud dated from medieval times, or was exposed to thermal neutron radiation.

7. Conclusions

This paper has demonstrated that the UVIF fluorescence intensity varies with position on the Shroud of Turin. This result was initially demonstrated by analyzing UVIF images of the Shroud taken during STURP's 1978 scientific study. New, independent results obtained from fluorescence spectroscopy, also done by STURP, are presented that corroborate the intensity variation. The variation in fluorescence intensity could be caused by differences in molecular structure and as well by contamination. However, it is unlikely that contamination would be such that the patterns shown in Figures 3 and 7 would be the result of contamination alone. Thus, it can be concluded that the molecular structure of the Shroud probably varies with location. New UVIF photographs of the Shroud, taken with uniform UV lighting, would contribute to a better understanding of the UVIF intensity variation. An important question that should be addressed is what caused the Shroud's variation in its fluorescence properties? Additional scientific testing needs to be done to answer this question.

Abbreviations

^{14}C	Radioactive Carbon 14
CIE Lab	International Commission on Illumination Lab Color Space
PCA	Principal Component Analysis
PCi	Principal Component i
RGB	Red, Green, Blue Pixels
STURP	Shroud of Turin Research Project
UVIF	Ultraviolet Induced Fluorescence

Author Contributions

Thomas McAvoy is the sole author. The author read and approved the final manuscript.

Acknowledgments

The author acknowledges the many useful discussions he has had about the Shroud UVIF images with Gilbert Lavoie, M.D. His help was invaluable in conducting the research presented. Images in Figures 1A, 1C, and A1 are copyrighted (Vernon Miller, 1978), and the author has received written permission from the copyright holder, shroudphotos.com, to use them in this paper.

Conflicts of Interest

The author declares no conflicts of interest.

Appendix

Appendix I. Principal Component Analysis of Filter Reconstructed UVIF Shroud Images

Table A1 gives the PCA analysis for the filter reconstructed UVIF Shroud images. Figure 3 plots the CIE L*a*b average intensity for these images.

Table A1. *Calculated Results for Filter Reconstructed UVIF Images.*

Image Name	% Information Explained First PC	Correlation Coefficient between First PC & L	Image Name	% Information Explained First PC	Correlation Coefficient between First PC & L
B2	97.07	0.999	E12	97.54	0.999
B5	98.03	0.999	E15	96.01	0.998
B9	97.02	0.998	E17	98.28	0.999
B12	98.30	0.999	E20	96.53	0.999
B15	96.08	0.998	E22	96.13	0.998
B17	98.64	0.999	D3	98.98	0.999
B20	97.07	0.999	D8	98.69	0.999
B22	97.18	0.999	D12	98.43	0.999
E3	97.68	0.999	D15	98.32	0.999
E6	98.32	0.999	D17	98.75	0.999
			D21	96.61	0.998

As can be seen the percent information captured by PC1 is greater than 96%, and the correlation coefficient between image intensity, L, and PC1 is .998 or greater. These results agree with those given by McAvoy and discussed in Section 3 above [3].

Appendix II. Two New UVIF Shroud Images

The 2 new UVIF Shroud discovered by Tom D'Mulah are shown in Figure A1 below.

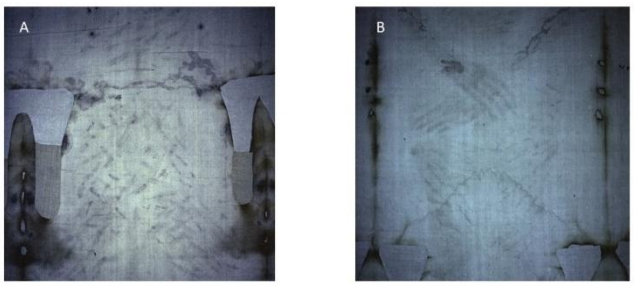

Figure A1. *(A) New UVIF image of Shroud section D8. (B) New UVIF image of Shroud section D17.*

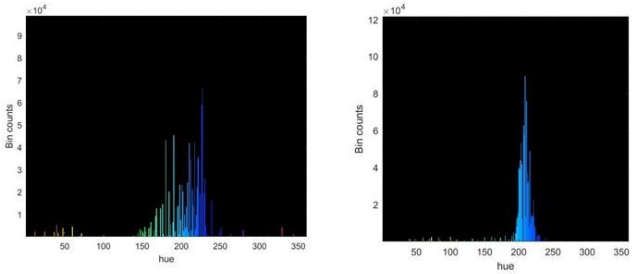

Figure A2. *Color histograms for UVIF images shown in Figures A1 calculated with code in [11].*

As can be seen the coloration of these two images is different from the coloration of all the images shown in Figure 1. The coloration of these two new UVIF images is closer to that shown in Figure 9. The color histogram calculated for the two new images is shown below in Figure 2A.

Figure A2 shows that the new D8 UVIF image has some green and some yellow coloration in its histogram, and that the new D17 image has a small amount of green and almost no yellow coloration in its histogram. Both new UVIF images have blue coloration that is similar to the results shown in Figure 9 above. The intensity, L, for the new D8 image is

48.31 and its correlation coefficient with PC1 is .999. The intensity, L, for the new D17 image is 44.76 and its correlation coefficient with PC1 is also .999. For new image D8 PC1 explains 99.38% of the information in the image and for new image D17 PC1 explains 99.68% of the information in the image. The fact that L for new image D17 is lower than L for new image D8 agrees with the results shown in Figure 3 above. These two new images may be correct in terms of their coloration, but with only two of them it would be difficult to reconstruct the coloration of the web Miller images [1]. However, as shown above coloration is relatively unimportant in terms of the information constant in all the UVIF images.

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