POSTER SESSION: first prize

Study of the Bloodstains in the Shroud of Turin: Chromatic Analysis and Interpretation

Gabriele Bedon, Matteo Linguanotto, Ivan Simionato, Francesco Zara http://sites.google.com/site/bloodstainsstudies/

Tutor: Prof. Giulio Fanti

Department of Mechanical Engineering, University of Padua
Via Venezia 1, 35137 Padua - Italy

Summary

This work shows the chromatic differences of the bloodstains of the Shroud of Turin according to the chromatic relations which distinguish them, to the histograms of the brightness, to their shapes and their positions; the results obtained consider also the geometry of the body and the position of the sheet. Six big macro-categories are so obtained, and in everyone of them most of the relations concerning the stains are gathered; these macro-categories allowed the formulation of the hypotheses on the dynamics of the formation and of blood expansion.

Keywords

Shroud of Turin – Chromatic analysis – Haematic analysis – Bloodstains – Comparison Chromatic

Premise

Wish to understand by the whole mankind the origins, the history and the authenticity of this find really unique involved any branch of sciences. The problem of dating it, the formation of the image and the identity of the Man of the Shroud (MS) are the issues which mostly emerge during this research which involves Science and Religion. Since the co-presence of these two large cultural areas, it is necessary to separate the religious aspects from the scientific ones: it is important to outline that this analysis is purely scientific. This study has analyzed the bloodstains which are largely distributed on the whole sheet, by the elaboration of high definition photographs.

Introduction

The first tests, conducted on 1973, did not reveled the presence of blood on the stains visible on the Shroud of Turin (ST). The following tests executed by Adam Adler since 1978 with more modern techniques gave, instead, a positive result, and showed that the blood is of human type: in particular the presence of haemoglobin and other blood specific substances were found.
The bloodstains are already the subject of high pitched discussions, not only concerning their peculiarities, but also their origins. This research focus the attention on the chromatic particulars, which it has been possible to study thanks to high definition images of the ST taken in 2000 and 2002. The aim of this work is the compilation of a "map" reproducing the chromatic compatibility areas: this map is useful to formulate hypotheses concerning the formation of the stains.
According to some researchers, in different points the blood pourings would be unreal;
this study has been made to help the comprehension in this field too.

Method Description

The blood stains analysis has been based on two high definition digital photographs taken in 2000 and 2002, elaborated with the software Gimp.
Different methods have been used, depending on the importance attributed to the stains, valuated in relation to dimension, position and clearness. For the stains considered localized, sample lines have been examined; for the stains considered diffused, the whole area has been examined. In order to check the validity of this method, “strange” stains

analysis has been conducted: these stains are supposed not to be blood and their ratios should be different from precedent zones ones.
With values so obtained, chromatic compatibility tables have been drawn.

Theoretical Model

In this section, the tools and mathematic models utilized in this study, are described.
The elaboration software provides the number of Red, Green and Blue pixels (RGB) for each chromatic level (8 bit image, 256 colors levels) of the selected zone, represented in a histogram. It also calculates the levels average for each color and the standard deviation.
The averages, then, have been adimensionalized, calculating the ratios q_{RG} of Red/Green (R/G) e q_{RB} of Red/Blue (R/B); unlike values RGB, these ratios are not related to particular positions of the stains in the background: the ratio remains the same (in a range) in the background zone and changes sensibly in stains zones.
Through the Kline-McClintock (KMC) formula, with the hypothesis of disconnected values:

$$i_q = \pm\sqrt{\sum \left(\Theta_i \cdot i_{xi}\right)^2} \tag{1}$$

where the sensibility rate has been considered as:

$$\Theta_i = \frac{\delta q}{\delta x_i} \tag{2}$$

The standard deviation values have been propagated to ratios.
The ratios, then, have been represented in graphs in order to point out the compatibility zones. For each of them, an average with the relative uncertainty was then calculated: the KMC values were divided by the square root of the number of the data; the results were multiplied by a K extension factor 2: considering the Student distribution, this value permits to obtain a confidence degree bigger than 90% in each case.

Experimental procedure

The digital photographs were processed using the program “GIMP”. As stated before, different procedures were used for localized, diffused and “strange” stains. The procedures for every kind of bloodstain are here mentioned.

1. Localized bloodstains

The bloodstains considered as localized are located in correspondence of arms, feet, face and side, both in the front and in the rear image.
The compatibility analysis was managed by comparing R/G and R/B ratios; the RGB values considered are the RGB average values of the pixels that compose lines taken as samples of various bloodstains zones.
The lines were picked where the flax tissue was thicker, generating a sort of bump: in fact the blood doesn't tend be uniform there, but it generates drops in order to lower its superficial energy. So it gathers in regions which can hold a big quantity of liquid, as result of tissue thickness. (Image 1)

Image 1: blood absorption in a wavy tissue

Considerations involving histogram trend, the brightness and the colors were instead held considering the whole area of the bloodstain.

2. Diffused bloodstains

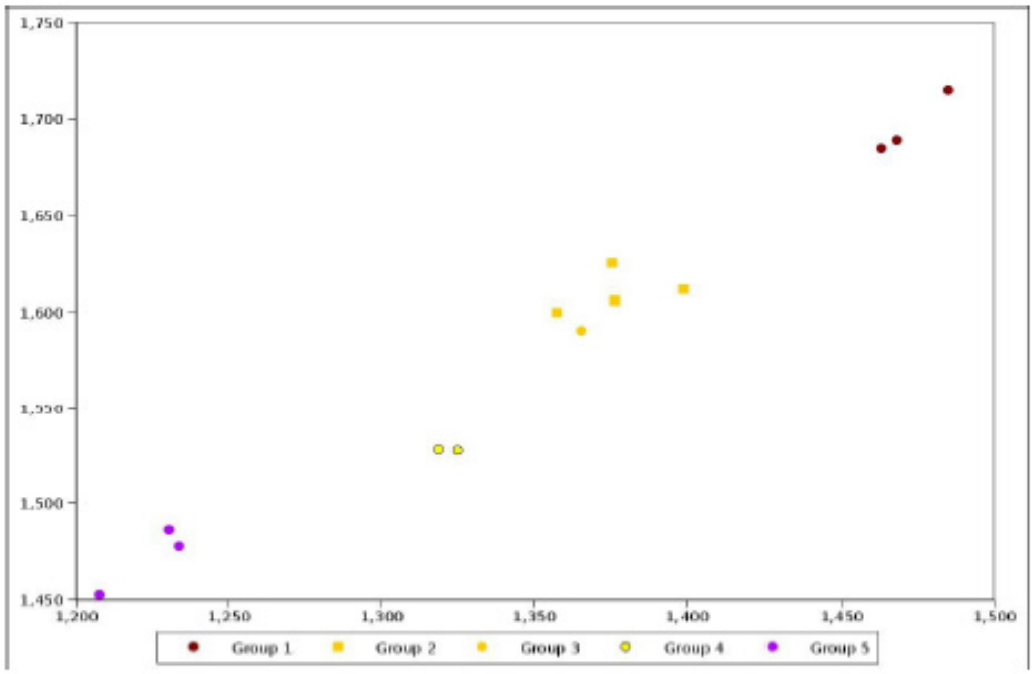
The diffused bloodstains, because of their number, position and dimension, allow an analysis based not on singular sample lines, but on the whole surface. We considered as diffused the bloodstains located in correspondence of the back and the buttocks (however it was better considering two different zones for them: one darker and more localized, the other lighter and diffused) and the rings near some localized bloodstains (for ex. Left arm): they're relatively small and homogeneous. The average RGB levels and the relative standard deviations were so gathered selecting a region wider than before. Low values of the standard deviation confirmed this procedure.

3. "Strange" stains

The experimental procedure adopted for the "strange" stains is the same applied to the diffused bloodstains, with the check of standard deviation. We considered as "strange" the stains located outside the image, near burned zones or the sheet edges.

Ratios values were plotted in graphs with spots, where the x-axis is represented by the R/G ratio, and the y-axis by the R/B one. These graphs allow to highlight compatibilities between different points, when they gather in the same area.

The graph concerning the blood stain on the hand of the Man of the Shroud (MS) is here related as example (graph 2).

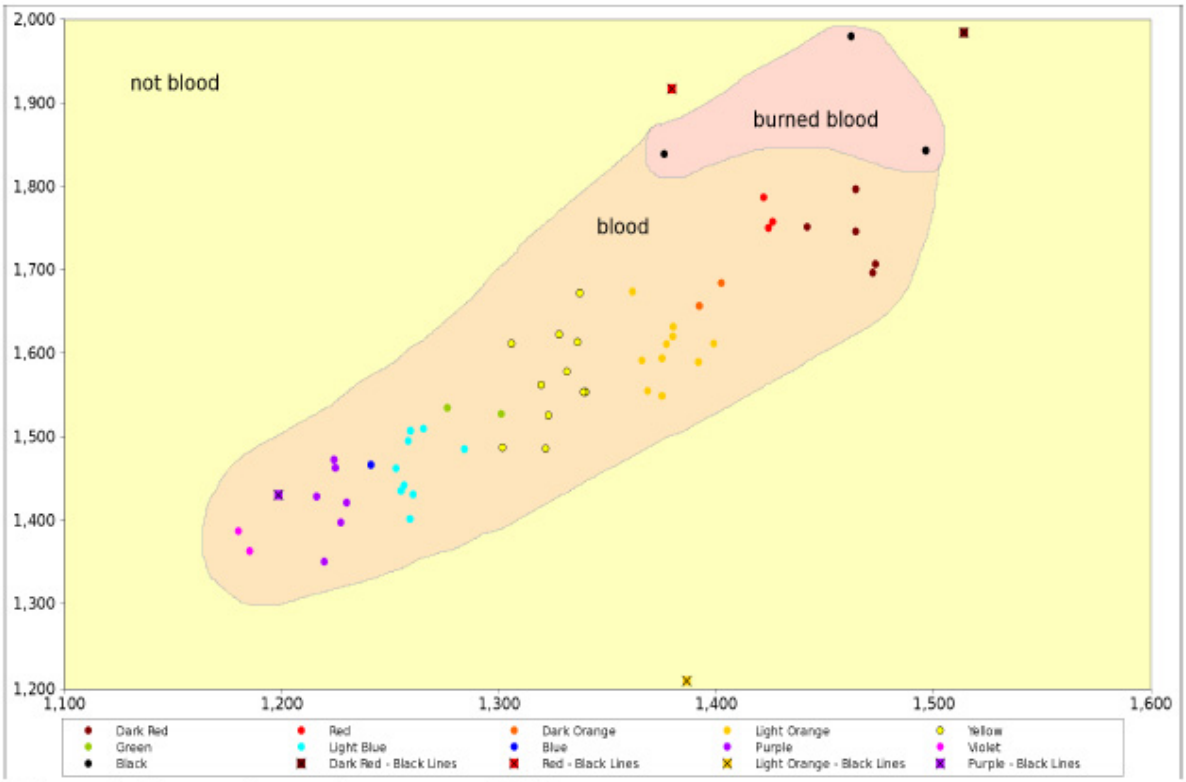


Graph 2: example; ratios graph concerning hand

It was then calculated the average of the ratios considered as compatible, in order to obtain two values directly comparable with the ones from the other areas. As above- mentioned, the uncertainty values of the ratios were propagated to the averages.
These values made possible to draw a compatibility "map" which allows to make hypotheses on bloodstains formation.

Results

Following the procedure explained above, 60 zones of compatibility were detected in various parts of the ST. Detailed data are reported in the attached spreadsheet and in the schemes. The ratios are reported in the graph 3, with the R/G ratios on x-axis, and the R/B ones on y-axis. The zones supposed belonging to bloodstains were then parted according on their ratios; a different color was assigned to each group, using the shades of the visible spectrum. Moreover, in the graph different ratios areas have been highlighted: the area whose ratios are supposed to belong to blood is highlighted in orange; in red, the area whose ratios are supposed to have been altered by the heat; in yellow, the area whose ratios are not relative to blood.



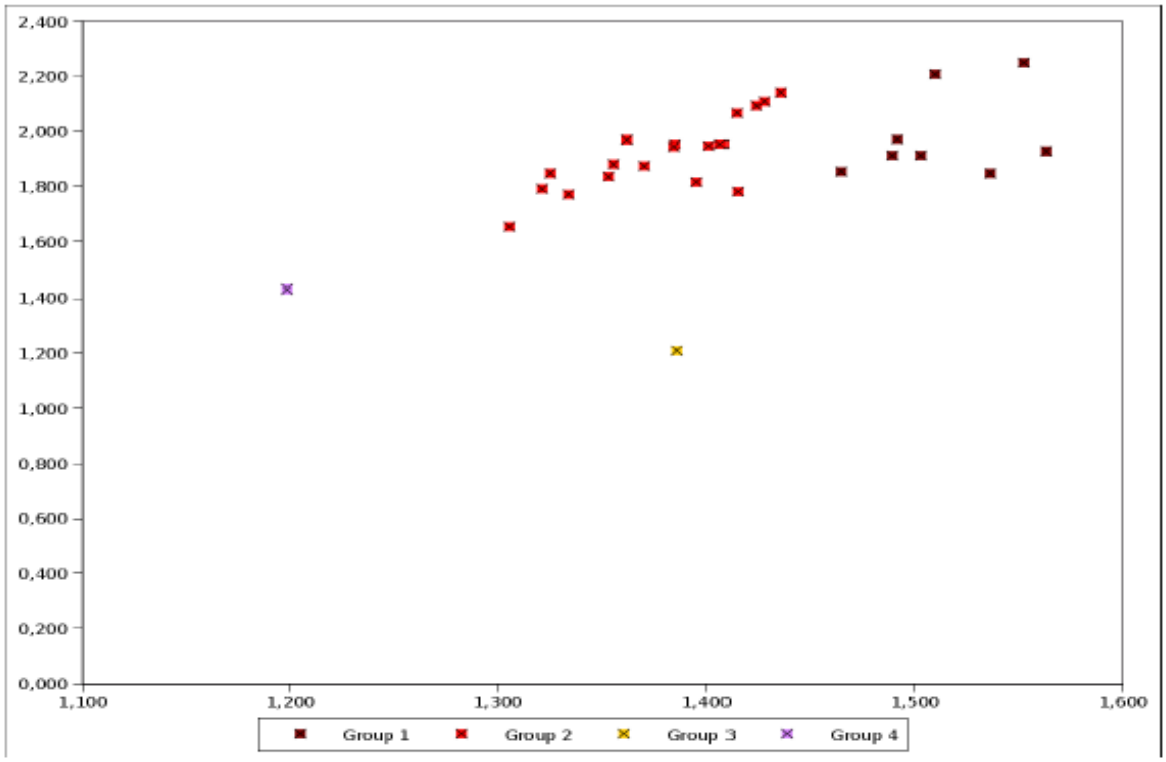
Graph 3: ratios of compatibility zones

In table 4, every color is associated to the maximum and minimum ratios of its group.

Color	*R/G min*	*R/G max*	*R/B min*	*R/B max*
Dark Red	1,442	1,473	1,696	1,796
Red	1,422	1,426	1,750	1,786
Dark Orange	1,392	1,402	1,656	1,684
Light Orange	1,361	1,399	1,548	1,673
Yellow	1,299	1,340	1,485	1,672
Green	1,276	1,301	1,527	1,534
Light Blue	1,252	1,284	1,401	1,509
Blue	1,241	1,241	1,466	1,466
Purple	1,216	1,230	1,350	1,472
Violet	1,180	1,185	1,363	1,386
Black	1,376	1,496	1,838	1,980

Table 4: correspondence colors - max and min ratios

In the graph colored squares with a black cross are present: these points are the averages of the "strange" zones groups; the graph 5 represents the detailed graph of these groups:

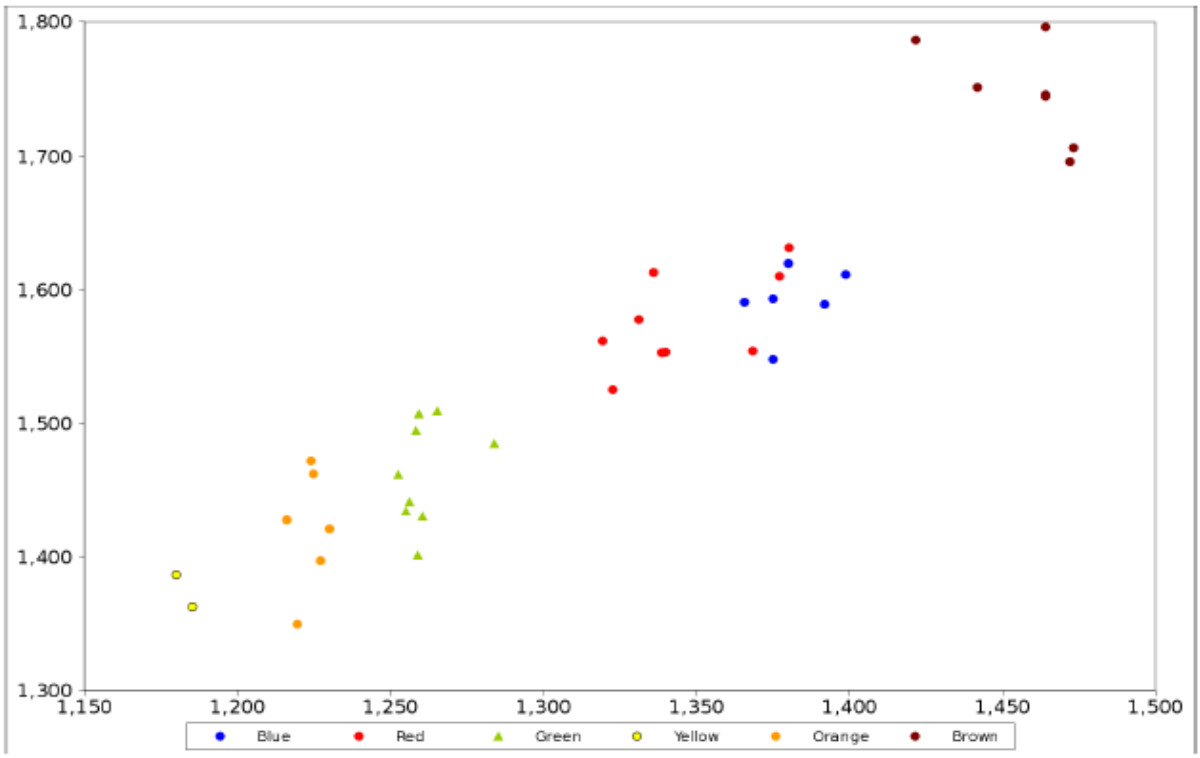


Graph 5: ratios derived from "strange" zones analysis

The ratios spotted as Group 1 and 2, respectively (R/G 1,514±0,058 – R/B 1,983±0,061) and (R/G 1,380±0,016 – R/B 1,916±0,026), are not compatible with the blood ratios above-mentioned: they are too high. The Group 3, whose ratios are (R/G 1,386±0,449 – R/B 1,210±0,339), presents instead too low values. Only one zone, denominated Group 4, with ratios (R/G 1,198±0,171 – R/B 1,430±0,274), is included in the range from minimum to maximum values of above-mentioned classes: for these reason, it could be a bloodstain, but this method doesn't allow to protract further the analysis. To know the position of these zones, the attached files can be consulted.

Considerations and comments

A correspondence between group ratios and stains formation has been hypothesized. Following this hypothesis, 6 big macro-categories have been individuated: for each of them, a complete description has been reported, with motivations that lend to these hypotheses.
In graph 6 the ratios of compatibility zones linked to the macro-categories are reported.
It is not possible, however, to attribute univocally each ratio with a macro-category: for this reason, for each group a detailed analysis has been reported, highlighting common aspects and differences from other zones.



Graph 6: compatibility zones ratios linked to macro-categories

Macro-categories

Table 7 can help to understand the association between macro-categories and related colors.

Color	*R/G min*	*R/G max*	*R/B min*	*R/B max*
Direct contact with wound	1,366	1,399	1,548	1,620
Contact with blood on the skin	1,319	1,380	1,525	1,632
Blood diffusion	1,253	1,284	1,401	1,509
Serum outside image	1,180	1,185	1,362	1,386
Serum inside image	1,216	1,230	1,350	1,472
Drops	1,422	1,473	1,696	1,796

Table 7: association between macro-categories – colors – max and min ratios

a. Direct contact with wound

Red ratios are very high; these zones are delimitated and localized. The red histogram presents a simil-Gaussian distribution: to a visual analysis, red distribution is, in fact, homogeneous. Considering the particularity of these stains, it is possible to suppose that these zones of the sheet came in direct contact with the wounds of the MS, absorbing big quantities of blood: they were covering the wounds. This hypothesis explains the homogeneity of the color: the big quantity of blood has been absorbed by thicker and thinner flax tissue.

b. Contact with blood on the skin

In the red histogram the distribution is similar to bi-modal, with an higher largeness

between maximum and minimum value: to a visual analysis, in fact, a separation between lines with a different shade of red can be noticed.
Red ratios are a bit lower than the previous category ones: these results permit to hypothesize that the blood was still liquid but in minor concentration; the blood doesn't tend to be uniform, but it generates drops in order to lower its superficial energy, gathering in zones that can hold bigger quantities of liquid.
These considerations lead to hypothesize that the blood of these zones was originally deposited on the skin of the MS; in a second time it was absorbed by the sheet.

c. Blood diffusion

Ratios are lower than the previous class ones and this leads to hypothesize that in these zones the sheet didn't cover wounds or blood deposits of the skin of the MS: the blood migrates by capillarity from zones where blood presence was bigger, to flax tissue thicker zones; this theory explains the bi-modal distribution of the red ratios.

d. Serum

Ratios values in these zones are absolutely lower than the other classes ones, and similar to background ones; anyway, because of their collocation near the precedent zones and their shape, it is possible to suppose that these stains weren't created by blood deposit, but by a part of it, that we name "Serum". Serum must have minor viscosity of blood, causing its major diffusion in the flax sheet. Its slight red coloring induces to assume a scarce presence of haemoglobin.
Ratios values are similar, but it is possible to highlight two principal groups of serum, linked to their position on the surface of the sheet:

1. Serum inside image: slightly higher ratios
2. Serum outside image: slightly lower ratios

Different ratios values can be explained by the theory "Body Image Formation Hypotheses Based on Corona Discharge" (IFCD), G. Fanti, F. Lattarulo, O. Scheuermann: energy from the inside of the body altered the blood composition of the nearer stains, of the stains inside the image.

e. Drops

Ratios typical of these macro-category are the highest of the whole sheet. Zones interested are very localized and their shape induces to hypothesize that their formation was linked to blood gathering caused by geometrical or physical factors: the blood can't slide in any directions and it stopped in a zone, forming a "sac" of coagulated blood, very dark.

Detailed Analysis

Hand

Thanks to the values of colors found in the zone of the hand, we could locate a circular zone presenting high ratios (R/G 1,366±0,245 – R/B 1,591±0,302): then we suppose that in that zone, highlighted in blue, the source of the blood was located. Histogram of luminance presents a Gaussian distribution: this shows that the blood spreads homogeneously, due to the big flux of it. In the surrounding zones, radially disposed and highlighted in red, ratios slightly lower can be individuated (R/G 1,377±0,047 – R/B 1,610±0,060), for which the luminance histogram presents bimodal distribution: the blood flux was less copious, probably coming from the main wound and gathered on the MS skin, then covered and absorbed by the sheet.
These zones are present only on the left side of the blood source: the blood flow, due to gravity,

probably followed only this direction. In fact, a little zone highlighted in brown, with high ratios (R/G 1,472±0,126 – R/B 1,696±0,129), can be individuated: it can represent a "drop". Following the blood spreading direction, a third group with even less ratios (R/G 1,224±0,037 – R/B 1,472±0,054), highlighted in orange, has been individuated; part of this zone can be noticed to the naked-eye, the other one is not easily identifiable: to individuate it, photographs taken with iridescent light were adopted. The position of the group and the light coloring induce to hypothesize that in this zone the component less viscose of the blood from the drop, that we call "serum", diffused by capillarity.

Right arm

The bloodstains concerning the right arm were parted in bloodstains located inside and outside the image of the MS.

The stains inside the image present mainly two zones: one in the top part, which values are the highest of the zone (R/G 1,336±0,014 – R/B 1,613±0,018), highlighted in red, and an underside part (R/G 1,259±0,029 – R/B 1,507±0,043), highlighted in green. Comparing those values with ones from other zones, it's possible to assume that the blood present on the skin of the MS entered in contact with the sheet; then this blood spreads thanks to capillarity, following the force of gravity, and creating the lower part. Values related, instead, to the stains outside the image are very interesting: a zone where ratios (R/G 1,258±0,078 – R/B 1,495±0,109) are compatible with the macro-category "Blood diffusion", highlighted in green, and two zones inter-compatible, highlighted in yellow, whose values are extremely low (R/G 1,180±0,054 – R/B 1,386±0,083) and (R/G 1,185±0,050 – R/B 1,362±0,069), can be individuated: these values can be associated to the ratios linked to blood-derived fluid named "serum". Anyway, these ratios have values lower than "serum" ratios in the zones inside the image; these results can bear out the IFCD theory: energy has hit principally the sheet zone where the image was formed: it is possible, then, that the blood deposited in these zones has been contaminated, varying its characteristics, its color; outside the image the phenomenon should be less intense, so the blood can have conserved the original ratios.

Left arm

The stains present in the right arm zone can be divided in three categories, according to the ratios values; the stains, in fact, are present homogeneously in the whole area but, analyzing the R/G and R/B ratios, it's possible to hypothesize a formation dynamic that explains this homogeneity.

The blood absorbed in this zone probably has its origin in the zones highlighted in blue, whose high ratios (R/G 1,399±0,045 – R/B 1,611±0,051) are compatible with those of the "Direct contact with wound" macro-category. In confirmation of this hypothesis, near these zones, stains whose ratios are lower (R/G 1,339±0,029 – R/B 1,553±0,036) are present; highlighted in red, their formation process is linked to the contact with deposits on the MS skin.

Thanks to the above-mentioned photographs where iridescent light was evidenced, it was possible to detect and obtain ratios relative to stains not clearly visible, present in this zone, highlighted in orange. Considering the particularity of this zone, the analysis was conducted with chromatic values obtained from the whole area evidenced by iridescence and not with discrete lines. The ratios (R/G 1,225±0,026 – R/B 1,462±0,039) are compatible with the "Serum" macro-category, nature attributed to this stain too.

Right foot, front image

The right foot zone in the front image is difficult to analyze; beyond the normal photographic difficulties, near this zone, in the HD photographs we were given, a violet stain is present, relative to an optical effect; the ST itself, moreover, presents a dark halo, probably related to some external liquid absorption.
In spite of these particular characteristics of the zone, the lines analysis gave some results. The stains inside and outside the image are divided as usual.
The stain inside the image was divided in four zones. The original wound, from which the blood is suppose to come, is highlighted in blue: high ratios values (R/G 1,380±0,140 – R/B 1,620±0,180), compatible with the other zones supposed blood sources, confirm this hypothesis. A wide zone is present around, highlighted in red, with lower ratios (R/G 1,368±0,033 – R/B 1,554±0,038): its formation is linked to blood absorption from deposits on the MS skin. Two particular zones can be individuated. The first one, highlighted in dark green, presents ratios compatible with the macro-category "Blood diffusion", (R/G 1,241±0,102 – R/B 1,466±0,137); inside this zone, however, a white vertical line is present: in this zone a folding on the ST surface is, or was, probably present: the blood went back up by capillarity from the surrounding zones. It was not considered prudent, then, to insert this zone in the compatibility table, because the photographic impression could have been altered by such an accentuated surface undulation. The last zone present inside the image, highlighted in azure-blue, doesn't have ratios compatible with any macro-category (R/G 1,322±0,077 – R/B 1,485±0,095): it is a peripheral zone of the stain and, to a visual analysis, it is collocated inside the halo linked to the external liquid absorption: ratios have been clearly altered.
Ratios compatible with this last zone, (R/G 1,302±0,086 – R/B 1,486±0,098), altered by the liquid too, are present in some zones outside the image, in a lower and nearer position to the presumed infiltration source, highlighted in azure-blue. A zone with ratios compatible with the "Direct contact with wound" was, moreover, highlighted in blue, (R/G 1,375±0,174 – R/B 1,593±0,194): the sheet bending has brought this zone in contact with the blood source (traditionally, the point where the nail was inserted). A zone compatible with the "Blood diffusion" macro-category was then highlighted in green; (R/G 1,259±0,320 – R/B 1,401±0,331).

Side area, frontal image

This area is near the holes caused by the fire which involved ST in 1532. Despite the fact this area could seem compromised, the chromatic analysis gave ratios that allowed the study of the stain formation dynamic. The hypothetical blood source is located in the central area, highlighted in blue; the ratios (R/G 1,375±0,066 – R/B 1,548±0,071), compatible with the macro-category, support this thesis. From this area, the blood diffused in a wide underlying area, because of gravity. This area is highlighted in red and is compatible with the macro-category ratios (R/G 1,319±0,063 – R/B 1,562±0,083). Higher than the blood origin area there is another one, highlighted in orange, whose ratios are compatible with "Serum" macro-category: the serum, considered as the less viscous component of the blood fluid, has gone up thanks to its characteristics in linen fibers, against gravity which dripped down most part of the blood. Compatible ratios have been revealed in the lowest stain area, still highlighted in orange: in this case the serum could seep in the tissue for a longer way. These two areas are characterized by ratios (R/G 1,230±0,019 – R/B 1,421±0,029). Unfortunately, the central area, highlighted in turquoise-blue, has ratios too scattered in the graph in order to obtain a certain classification: here, the damages suffered by ST have sensitively changed the colorations.

Face, front image

Before proceeding with the analysis of the blood stains in the front image of the face, particular characteristics of this zone should be considered. The utilized technique consists of comparing chromatic values detected in the rest of the sheet, but in this zone an independent analysis was seen fit to conduct: it has been hypothesized, in fact, that there was not only the ST, but also a facial-shroud. The blood on the face was first absorbed by the facial-shroud, and from this to the sheet. Following this hypothesis, it can be supposed that the absorbing modalities, the quantities and the "chromatic density" were in some way altered.

In spite of these particularities, macro-categories compatibilities has been found. Five categories can be individuated:

a) Direct contact with wound, brown color (R/G 1,464±0,051 - R/B 1,796±0,069)
   The wounds are present on the whole forehead, both in the sides and in the center, corresponding to the traditional "crown of thorns". According to the crown hypothesis, thorns caused bloody grazes exactly in these zones, with a massive blood pouring, pointed out by high ratios. High ratios are compatible with the "Drops" macro-category: the blood from the facial-shroud gathered on the sheet, forming drops with the typical ratios.
b) Near transit, black color (R/G 1,424±0,030 - R/B 1,750±0,040)
   Near the stains above described, stains with compatible values can be found, whose red ratios are lower than the precedent class ones. They can be found in a band around the principal wounds: the blood dripped both in the hair and in the eyebrows directions, because of the forehead geometry and the body position.
   The values of the lines analyzed in the left eyebrow, that are not in the nearness of the wound, are also members of this class. These zones are distant from the source wound: they are a deposit that, dripping down from the forehead, gathered in the eyebrows; this process gave it high red ratios.
c) Distant transit, gray color (R/G 1,402±0,038 - R/B 1,684±0,049)
   The red ratios are still lower than precedent class ones. These stains are located around the wound, but more distant than "near transit": the blood quantity is then lower.
   In particular, in the central zone of the forehead, it can be hypothesized that the blood dripped both upside and downside the wound, because of the lying position. From the wound zone, it diffused, then, by gravity and by capillarity.
d) Hair, white color (R/G 1,337±0,028 - R/B 1,672±0,042)
   The red ratios in these zones are clearly lower than precedent classes ones: the blood was, in fact, absorbed by the hair. This zone presents particular characteristics:
   The stains can be considered both internal and external from the image. They can be considered external because the hair are not "alive" and they are not part of the body; they can be considered internal, instead, if we considered a tri-dimensional view of the sheet around the body, with the hair in direct contact with the skin.
   The blood stains are not present in the whole zone of the hair, but almost only in a zone under the ears.
   There is a symmetry, because the hair is present both left and right side of the head. e)
   Stain images, purple color (R/G 1,276±0,030 - R/B 1,534±0,044)
   In this zone, the lowest head ratios values are present: considering these values, it is possible to hypothesize that the tracks are not blood stains, but "images" of the blood stains that were present on the body.

Face, rear image

The stains present on the rear part of the face have a particularity: the MS hair was interposed between the blood source and the sheet; the blood was first absorbed by the hair, then by the sheet.

In the image can be found 5 categories:

- Central wounds, brown color (R/G 1,464±0,046 - R/B 1,745±0,048)
  The highest ratios are present only in a central zone, where the most of the stains can be found. This zone coincides with the wound caused by the traditional "crown of thorns". The presence of high values can be explained considering that in this zone the head wields high pressure on the sheet, absorbing higher quantities of blood: the blood formed "drops", hypothesis confirmed by the presence of the typical ratios.
- Side wound, black color (R/G 1,426± 0,114 - R/B 1,757±0,153)
  The ratios values are lower than the precedent class ones, for the same reasons exposed in the front face analysis: they can be considered members of the same class.
- Near transit, gray color (R/G 1,392± 0,021 - R/B 1,656±0,026)
  Values are lower; these zones are localized principally around the wounds. On their nature, the same considerations elaborated for the front face are valid.
- Distant transit, white color (R/G 1,328± 0,055 - R/B 1,622±0,076)
  Values are lower; these zones are localized principally around the wounds, but more distant than the precedent category ones. On their nature, the same considerations elaborated for the front face are valid.
- Stains images, purple color (R/G 1,301±0,044 - R/B 1,527±0,071)
  The values are clearly lower than the rest of the group ones: this leads to suppose that these tracks can be stains images, similarly of front face tracks.

Right foot, rear image

The feet zone in the rear image is one of the most complex in the ST. The stains inside and outside the image are analyzed, as usually, independently; the affinities will be then pointed out.

In the zone inside the image, the blood source was individuated and highlighted in blue, agreeing with the traditional nail that went through the feet: the ratios confirm this hypothesis (R/G 1,392±0,075 - R/B 1,589±0,093). Zones compatible with "Contact with blood on the skin" were found, (R/G 1,323±0,038 - R/B 1,525±0,049) and (R/G 1,380±0,268 - R/B 1,632±0,366), highlighted in red, in various area of the foot, near and distant the principal wound: this can be explained considering the foot geometry; the blood, coming from the wound, strained on the whole skin surface, but the sheet entered in contact only with certain zones. Then, zones where the blood diffused by capillarity are present, highlighted in green, (R/G 1,256±0,013 - R/B 1,441±0,016) and (R/G 1,284±0,082 - R/B 1,485±0,0109); the wide extension of the blood diffusion can be noticed, probably linked to the sheet position. Finally, a zone compatible with the macro-category "Serum" has been highlighted in orange, (R/G 1,227±0,075 - R/B 1,397±0,093). The values analyzed in the heel zone are not useful: the ratios are, in fact, scattered in the graph and it's not possible to classify them univocally. To explain this fact, a presence of external material on the foot can be hypothesized, typically mold.

In the stains outside the image, only three zones can be highlighted: in the zones highlighted in red, blood entered in contact with deposits (R/G 1,331±0,024 - R/B 1,578±0,033); in green, the blood diffused (R/G 1,255±0,012 - R/B 1,434±0,016); in brown the blood formed drops (R/G 1,441±0,056 - R/B 1,751±0,069). The ratios of these zone are

compatible with the relative macro-categories: general considerations have been found valid for them.

Left foot, rear image

The stains in the left foot zone are less extended than the right foot ones, probably because of a superimposition of the MS right foot. There is no zone compatible with the blood source category: it is possible that this zone was covered by the right foot because, according to the tradition, the drilling axis was single. Instead, the zones where ratios permit to hypothesize that there was contact with blood deposit on the skin, (R/G 1,340±0,022 - R/B 1,553±0,029), have been highlighted in red; the zones where the blood is supposed to have diffused by capillarity, (R/G 1,261±0,024 - R/B 1,431±0,032) were also highlighted in green. The big extension of the zones where the blood diffused by capillarity can be noticed also in this case: similarly to the right foot case, the position of the left foot could have permitted a wider diffusion. A zone where ratios are compatible with "Serum" category, (R/G 1,220±0,079 - R/B 1,350±0,087), has been finally highlighted in orange: the zone is not in a peripheral zone, as in other cases, but near the blood deposit zones: it can be hypothesized that the foot geometry didn't permit the blood flux in some direction, unlike for the serum flux, possible because of its low viscosity.

Back and buttocks

The zone located in correspondence of the MS back and buttocks is particular: the tissue presents tracks that can't be clearly classified as blood; the coloring is very fine and the dimensions are small. A global area analysis, as above described, has been conducted. Three compatibility areas have been found:

a) wales: they are disposed uniformly on the whole back surface; every ratio is homogeneous: the average ratios are (R/G 1,216±0,010 - R/B 1,428±0,014). These zones, highlighted in violet, can be considered compatible with the macro-category "Serum inside image"; anyway, a different classification has been introduced because, differently to the stains belonging to that category, these tracks are not located near stains with higher ratios, where the blood came from. It is possible, then, to hypothesize that the blood came from healed wounds present on the US back, from which, because of unknown causes, probably linked to infective processes, the liquid has been purged.
b) little balls, lower back: near some wales, some tracks have been detected, highlighted in green, with ratios higher than the previous ones: (R/G 1,264±0,042 - R/B 1,506±0,063). Tradition explains the presence of these little balls with the flagellation of the MS. The ratios that characterize this zone permit to associate them to the category "Blood diffusion": even in this case, it is possible to hypothesize that, on the MS back, not completely healed wounds entered in contact with the sheet, leaving blood traces.
c) little balls, higher back: highlighted in purple, the same discussions of the lower back can be conducted; the ratios are, however, higher, (R/G 1,306±0,031 - R/B 1,611±0,049). The explanation of this anomaly is not simple: it can be linked to the IFCD theory. For the "Serum" category, an hypothetic energy altered the blood ratios inside the image, making them higher than the outside image ones; a similar process can have altered the ratios in these zones, but the reason why more energy was present in this zone than in the previous ones can't be easily explained, because the collocation of the energy source is unknown.

Blood belt zone, rear image

The blood belt zone in the back image collects stains for which it's difficult to establish a certain formation dynamic. The shape of the stains aggregate and the position induce to hypothesize that the blood source was the same of the side wound in the frontal image. However, this zone is characterized by a bigger deposit of blood, that interests not only a localized area but the whole back width. The chromatic analysis shows compatibilities with macro-categories only for certain zones; the process that conducted to the ratio variation of remaining zones is linked to the fire that involved the ST in 1532: it has damaged the sheet near this group.
These groups have been individuated:

a) Group 1, with ratios (R/G 1,376±0,021 - R/B 1,839±0,039), highlighted in red with black lines: these ratios, particularly high, are not compatible with any macro-category and with any group analyzed; the high R/B ratio induces to hypothesize the presence of external elements but, because of the distance from the burned zones, we can suppose that the color of this zone was influenced by the conservation environment of the ST.
b) Group 2, with ratios (R/G 1,361±0,005 - R/B 1,673±0,008), highlighted in purple with black lines: these ratios are not compatible with any macro-category, but the values are included in the range from minimum to maximum values of macro-categories: considering their positions, it is then possible to hypothesize that these zones weren't influenced by external factors. Incompatible ratios can be explained, in fact, observing the shape of these zones: the extended forms suggest a dripping process that, involving a smaller quantity of liquid than other zones, induced the formation of stains with different ratios; considering the geometry of the back, it is possible, moreover, that the body in these zone was not in direct contact with the sheet: it may have formed a "sac".
c) Group 3, with ratios (R/G 1,253±0,004 - R/B 1,462±0,006), highlighted in green: this group is compatible with macro-category "Blood diffusion": creation process described in the relative section was considered adapt for this zone.
d) Group 4, with ratios (R/G 1,462±0,027 - R/B 1,980±0,038), highlighted in light blue with black lines: this group is not compatible with any macro-category. As described above, considering the proximity with big holes in the sheet caused by the fire in 1532 and the high R/B value, the highest analyzed (130% comparing the other zones ones), it is possible to hypothesize that this zone was irremediably damaged by the flames: its analysis is not informative.
e) Group 5, with ratios (R/G 1,422±0,034 - R/B 1,786±0,050), and Group 7, with ratios (R/G 1,473±0,022 - R/B 1,707±0,022) highlighted in dark red: these groups are compatible with "Drops" macro-category. Their membership can be confirmed, besides the ratios, by the formation dynamic hypothesized previously: the blood in these zones was part of fluxes from the side wound: the formation of accumulation zones is then plausible.
f) Group 6, with ratios (R/G 1,496±0,039 - R/B 1,842±0,047), highlighted in yellow with black lines: this group is not compatible with any macro-category. Considering the nearness of burned zones and a R/B value among the highest ones, it is possible to suppose that the fire involved also this zone, as described for Group 4, even if ratios are different. The ratios difference can be explained considering the flame movement and the operations to put it out: water or the utilized technique may have contaminated this zone.
g) Group 8, with ratios (R/G 1,299±0,010 - R/B 1,577±0,015), highlighted in white with black lines: ratios are not compatible with any macro-category ones. Anyway, because they are in the range between maximum and minimum values of

macro-categories, for them it is possible to conduct the same hypothesis of Group 2.

Conclusion

The analysis through chromatic ratios compare revealed effective: it has provided coherent results and, from the analysis of stains considered not to be blood, the method has revealed their hypothesized nature. The compilation of the compatibility table provided datas suitable for the study of the formation dynamic, also by other researchers. Hypotheses about stains formation dynamic have been conducted, from objective analysis results. Six macro-categories have been created: for each one, a formation dynamic has been elaborated. The application of these macro-categories has been possible only in certain zones, where the ratios disposition permitted an easier theory elaboration. In the other zones, the groups compatible with the macro-categories have been evidenced; the reasons why ratios were different from expected ones are also reported.

∉ Thanks

We would like to thank in a special way:
Cristina Borgini, for the help in paper translation
Lucio Linguanotto, for printing our posters
Riccardo “Scave” Zampieri, for the help in paper translation and... for the icecream!

∉ License