Mediterranean Archaeology and Archaeometry, Vol. 14, No 2, pp. 55-65

THE MYSTERIOUS COEXISTENCE OF BLOODSTAINS AND BODY IMAGE ON THE SHROUD OF TURIN EXPLAINED BY A STOCHASTIC PROCESS

G. Fazio[1], Y. Clement[2], G. Mandaglio[1,3]

[1]Istituto Nazionale di Fisica Nucleare, Sezione di Catania, I-95123 Catania and Dipartimento di Fisica e di Scienze della Terra, dell'Università di Messina, I-98166 Messina, Italy
[2]Independent Shroud Researcher, Louiseville, Québec, Canada
[3]Centro Siciliano di Fisica Nucleare e Struttura della Materia, I-95125 Catania, Italy

Received: 27/10/2013
Accepted: 24/02/2014
Corresponding author: Giovanni Fazio (gfazio@unime.it)

ABSTRACT

The presence of bloodstains certifies that a wounded human body has been enveloped in the Shroud of Turin and that most parts of this corpse came in direct contact with the cloth during the burial procedure. On the contrary, the ventral body image, by correlation between image intensity and cloth-body distance, shows codified information regarding the distance from which the cloth was versus the body at the time of the image formation. At first sight, this last statement seems to be impossible for a human corpse. Therefore, the coexistence of the bloodstains and the body imprints on both sides of the Shroud could be seen as unnatural, especially when we consider that a deterministic process as the UV radiation or the action of an electrostatic field (corona discharge), as well as manmade chemical and thermal treatment. These processes do not explain all the known characteristics of the body images (ventral and dorsal) because they do not distinguish the fibrils that must be yellowed from the ones that must retain the background colour. In this paper we prove that a natural stochastic process can offer a rational and scientific explanation that can account for all the known properties of these bloodstains and body images. However, another possible explanation that must be taken into account is a natural process involving the production of oxygen that yields a latent image.

KEYWORDS: Shroud of Turin, bloodstains characteristics, body image characteristics, stochastic process, fibrils

1. INTRODUCTION

In the Royal Chapel of the Turin Cathedral, there is a rectangular linen cloth (4.36 m x 1.10 m about) known as the Shroud of Turin. This ancient cloth has a history confirmed from the middle of the 14th Century when it was in possession of the French knight Geoffrey I de Charney. Before this date, its history is uncertain. Nowadays, for many people, the ventral and dorsal images of the beaten, scourged and crucified man that appears on the Shroud of Turin are the ones of the historical Jesus as he appeared after his death and burial (see Fig.1). On the contrary, others denounce it as a forgery created by a mediaeval forger/artist. In every case, over the years and especially since the end of the 19th Century, the Shroud has generated a wide debate involving scientists, technicians, historians, religious men, professional sceptics and other people, with considerable controversies (Wilson, 1977; Humbert, 1977; Culliton, 1978; Zaccone, 1997).

The above debate was born when Secondo Pia, an amateur photographer, took the first official photograph of the Shroud in 1898, showing the negative photographic characteristics of both ventral and dorsal body images. It increased in the first half of the 20th Century, after the work done by some European scientists, and became world known, in 1977, when John Jackson, an American physicist who was working for the Air Force Academy in Colorado Springs, scientifically confirmed the 3-D properties of the frontal image that had been already studied and described by some European researchers like Antoine Legrand and Paul Gastineau. Nowadays, there is a clash between the supporters of the forgery hypothesis and the ones who see in the formation of the body images (ventral and dorsal) something miraculous. In our opinion, this state of affairs is due to the fact that this cloth could be the authentic burial shroud of Jesus of Nazareth. On the contrary to these two points of view, we believe that it is necessary to try an explanation of all the known characteristics of the Shroud, which includes both the bloodstains and the body images (ventral and dorsal), by natural sciences, while leaving aside the question of the potential identity of the Shroud man

In 1988, radiocarbon dating by AMS done at Arizona, Oxford and Zurich laboratories furnished conclusive evidence that the Shroud of Turin is medieval (Damon et al., 1989). Successively the pyrolysis-mass-spectrometry showed that the radiocarbon sample was not an original part of the Shroud (Rogers, 2005). In our opinion, it is necessary a new run of measurements, by radiocarbon dating, with an original sample.

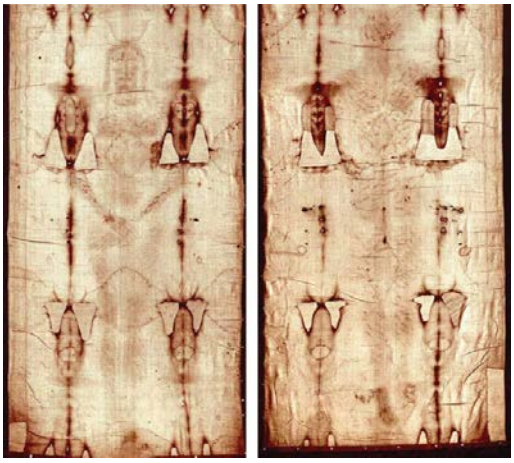

Figure 1. The Linen of Turin: (left) full ventral image and (right) full dorsal image.

In more than a Century, all the mechanisms that were proposed to explain the body image formation have failed. On the contrary, we are certain that the analysis of the results obtained by the STURP (Shroud of Turin Research Project) team (Jumper et al., 1984) is useful to extract the mechanism that is responsible for the formation of the body images (ventral and dorsal) on the Shroud. We will demonstrate that the known physical and chemical characteristics of the body images and the bloodstains that have been found and/or confirmed by the scientific study of the cloth done by the STURP team in the late 1970s and early 1980s are sufficient to reject the radiative hypotheses (ultraviolet radiation, corona discharge, etc.) and those involving an artistic forgery. Indeed, the physics and the

chemistry of the ventral and dorsal images agree with a natural mechanism able to eliminate the apparent discrepancy between the characteristics of the body images and those of the bloodstains. For us, on the Shroud, there are latent body images (ventral and dorsal), yielded by the action of a stochastic process that is triggered by a little quantity of energy, without threshold to appear, with effects that have a time of latency of the order of many years. These effects are absent just when the energy is zero. Therefore, the hypothesis involving an artistic forgery or a miraculous event must be discarded. In every case, the scientific study of the Shroud of Turin must not be influenced by religious or anti-religious feelings. Unfortunately, these kinds of biased studies have already been done many times since 1898 and will certainly occur again in the future, which is something that has contributed to stopping, or at least restraining, the collaboration among many Shroud researchers. Actually, we see many scientists who are involved in Shroud research who are not inclined to the possibility of changing some of their ideas or even just seriously taking account of other points of view about the Shroud. These researchers appear motionless in their convictions and are unable to consider other possible solutions for the problems they study. Finally, in this paper, we will leave aside all the burned and scorched areas, as well as all the water stains, because they do not furnish pertinent information about the subjects we will analyse in this current study.

2. BLOODSTAINS AND BODY IMAGES ANALYSIS

2.1 Bloodstains characteristics

The bloodstain characteristics that have been determined by the contribution of spectroscopy, micro chemical analysis, microscopy and photomicrography, radiography and X-ray fluorescence, photoelectric spectrophotometry, photoelectric and photographic fluorescence and analysis of forensic pathologists (Jumper et al., 1984; Heller and Adler, 1981; Bucklin, 1982; Mills, 1995), can be summarized in the following manner:

i) The bloodstains are made up of real blood and serum.

ii) There is serum surrounding the proteins (albumin and hemoglobin).

iii) The iron concentration (20-40 $\mu g/cm^2$) is in line with the presence of bloodstains.

iv) The distribution of bloodstains and serum stains on the cloth confirms that the Shroud has been used to enfold a wounded and crucified human body.

v) The hemoglobin is present as "perturbed acid methaemoglobin", due to oxidation, from Fe^{+2} to Fe^{+3}, of the iron in the protoporphirin IX.

vi) Microscopic examinations have shown that the methaemoglobin particles bound to the fibres, by proteinaceous film derived from serum, have protected the linen underneath against the yellowing process.

vii) Bile pigments are also present in the blood.

viii) There are bloodstains located everywhere in the image areas but especially in the regions of the legs and torso (in both the ventral and dorsal images) and they appear somewhat different (dumbbell-shaped) from the others. In these particular areas, there are a lot of scourge marks that show the spectral characteristics of iron porphyrin compounds and they are visible in the UV fluorescence photographs, especially when it comes to the clear serum stains that surround these bloody wounds.

ix) The bloodstains were on the linen cloth before the body image.

x) There are pre-mortem blood flows on the Shroud (for example, on both the forearms and in the hair) as well as post-mortem blood flows (for example, under the side wounds and in the lower back and the feet areas).

xi) Most bloodstains are the result of exudates of moistened blood clots that stained the cloth by direct-contact with the dead body, while a few others (like some bloodstains in the feet area and the trans-

versal bloodstains in the lower back area) came from post-mortem blood flows that had not enough time to clot completely when they came in contact with the Shroud (some of those were still probably in their initial liquid form).

xii) There are no smudges of blood on the Shroud, which strongly suggest that all the bloodstains (including the few bloodstains resulting from liquid post-mortem bleeding) have been transferred to the Shroud by direct-contacts between the corpse and the cloth and that the enshrouding of the corpse was done very gently with great caution.

xiii) At the exception of some scourge marks and maybe a few other minor bloodstains, the vast majority of the bloodstains (whether they came from exudates of blood clots, including the scourge marks, or from blood that was still not completely clotted) have penetrated through all the thickness of the cloth and are visible on the backside of the Shroud, especially in the dorsal part where there was a high pressure on the cloth due to the body weight.

xiv) The immunochemical tests suggest that it is human blood on the basis of positive results involving human antiglobulin. This result has been confirmed using human anti-albumin and anti-whole serum.

xv) There are also bloodstains off-register with respect to the anatomical details of the body images (for example, the one located outside the image of the right foot, as it appears in the dorsal image). The correlation between these locations and the specific types of injuries has been already studied and described by many forensic experts, even though some questions are still debated to this day.

The bloodstains characteristics analysis certifies an ancient event (Item v) related to a wounded human body (Item xiv) that has been violently tortured (Items vii and viii), who eventually died of crucifixion (Item x) and who was finally enfolded in the Shroud of Turin some times later (Items i through iv and items xi through xiii). In reason of those particular characteristics and especially because the bloodstains formed on the cloth before the body image (Item ix), the hypothesis of an artistic forgery should be, already, discarded. Indeed, in all logic, a mediaeval forger/artist would have created first the body image on the cloth and, only thereafter, the bloodstains. Such a scenario is completely the opposite of what really happened on the Shroud of Turin. In fact, the presence of blood, serum and bile pigments are the result of a direct-contact mechanism between a real wounded human body who died by crucifixion and the linen cloth, which had been used to cover it (see Items xi through xiii). It's important to understand that some of these biological stains could have been formed on the cloth by temporary contacts during the burial procedure (for example, during the probable moving of the enshrouded body from a central place inside the tomb to his final resting place on a stone bench carved in a wall of the tomb), while others (representing certainly the major part of the bloodstains) are the result of a permanent contact between the corpse and the cloth (e.g. direct-contacts that were maintained after the end of the burial procedure). And it should be noted that the very probable fact that some bloodstains were formed by temporary contacts during the burial procedure could explain why some bloodstains on the Shroud are off-register with respect to the anatomical details of the body images (Item xv). Here, it is necessary to add a comment: in spite of the vast amount of solid data obtained by different experiments and analysis done by blood chemists and medical or forensic experts, there are still self-styled scientists who denied such a fact, which is incredible, especially when we consider that this is one of the most unquestionable facts regarding the Shroud! These people should know that science has nothing to do with personal opinions.

Recently, one of us has analysed the question of Shroud authenticity related to the bloodstains present on the cloth (Clément, 2012). This work is relevant because it concerns an open question that, nowadays, is still the object of an intense

debate: Is the Shroud of Turin a fake or is it really the authentic burial cloth of Jesus Christ? In the end, even if various scientists as well as non scientists believe that the relic is a medieval forgery, this study, based on the evidence coming from the bloodstains, shows that it is an authentic burial cloth that certainly contained for less than 72 hours the dead body of a man who was beaten, scourged and crucified in the same way as Jesus of Nazareth, as reported in the Gospels. It's important to emphasize the fact that such a conclusion doesn't prove the Shroud is the authentic burial cloth of Jesus of Nazareth, but it indicates that it is a real burial cloth that was used to cover the dead body of a man who had the same wounds as Jesus of the Gospels.

2.2 Body image characteristics

The body image characteristics have been obtained with direct microscopic observation, X-ray fluorescence spectrometry, low-energy X-radiography, infrared, visible and ultraviolet reflectance spectra, photoelectric and photographic fluorescence, macroscopic visual observation, thermal emission images and VP-8 images analysis (Jumper et al., 1984; Heller and Adler, 1981; Schwalbe and Rogers, 1982). The most important ones can be described in the following manner:

1) The hypothesis that the Shroud body images (ventral and dorsal) are simply the result of a clever painting is totally inconsistent with the chemical properties of the linen cloth.

2) Both body images (ventral and dorsal) are the result of some uneven cellulose dehydration and/or oxidation processes with generation of a chromophoric group.

3) Both body images (ventral and dorsal) have negative photographic properties. Indeed, the linen appears darkness on the points close to the skin and lighter tones when the cloth-body distance increases.

4) Both body images (ventral and dorsal) have good resolution and the intensity of the ventral image is correlated to the cloth-body distance expected by enfolding volunteer human subjects in a full-scale model of the Shroud. This correlation is well represented by a linear regression. For the dorsal body image, the VP-8 analysis shows a general flat image due to the compression of the body on the cloth, which has kept the backside of the body generally much closer to the Shroud. Therefore, it was difficult for STURP to know whether such a correlation is present in this dorsal image. For this reason, we made a theoretical analysis of the dorsal image and showed that there really is a correlation, but the distance value that makes the body image intensity equal to the background intensity is certainly lower but still undetermined (Fazio, and Mandaglio, 2008). In other words, both images on the Shroud are showing 3D properties, but such properties are much more evident in the ventral image, because the image formation process (which was the same for both images) seem to have been able to yellow fibrils that were located farther from the ventral side of the corpse than the dorsal.

5) The 3-D ventral body image, originally obtained by VP-8 analysis, appears without major distortions, confirming the existence of a correlation between the image intensity and the cloth-body distance.

6) In the regions where both body images lies, there are fibrils with the same background colour as the ones located in non-image areas mixed with others that all have the same higher optical density value in comparison with those who have kept their background colour. That means that there are only two types of fibrils in image areas: a) Fibrils that possessed the same background colour as the ones located in non-image areas. b) Others that possessed a higher optical density value, which are responsible for the body images (ventral and dorsal) that we see on the cloth.

7) These last fibrils that produced both body images (ventral and dorsal) have penetrated the linen for a very short depth of about 20-30 μm (which represent the thickness of only two or three fibrils) and none of those seem to be present deeper inside the cloth or on its backside surface.

8) No body image formed under the blood or the serum stains (meaning that the

blood was on the cloth before the image formed) and the image formation mechanism was sufficiently mild that it did not damage, denature, or char the blood.

9) In the regions where there is no body image, every fibril show the same background colour due to natural interaction with the electromagnetic radiation (which have caused a normal aging of the cloth) and they are present throughout the whole thickness of the cloth (about 345 μm).

10) The abrupt changes in the image intensity that appear at the sides of the face (two stripes of approximately 2.5 cm wide that can be seen running the length of the Shroud) are due to threads of different manufacture. This indicates that the cloth was made with non-homogeneous threads (especially when it comes to their degree of bleaching), which strongly support the hypothesis of an antique method of manufacture instead of a medieval one.

Relative to Item 4, we have demonstrated that for the dorsal body image, there is also a correlation that exists between the intensity of the image and the cloth-body distance, with a different slope than what has been measured on the ventral (Fazio and Mandaglio, 2008). Moreover, in the same dorsal body image (Item 10), there are rapid changes in the colour intensity. The areas were these kind of rapid changes are the most obvious are the ones at the base of the shoulders and the buttocks. Indeed, in these zones were direct-contact occurred between the corpse and the cloth, the wounds left by a Roman flagrum are visible while the body image intensity values are much lower than the other ones that are located in the same kind of contact areas. We explained the above changes with the possible presence of aromas and/or burial ointments (Curciarello et al., 2012). However, both Shroud body images (ventral and dorsal) are not the result of a simple direct-contact mechanism.

2.3 Analysis

In the introduction, we have affirmed that both radiative and artistic forgery hypotheses must be discarded. Indeed, it is theoretically impossible for these mechanisms to produce a subtle body image on linen like we see on the Shroud with an unpredictable mix of fibrils (10-15 μm each) that would be yellowed, along with some others that would preserve their background colour in a same region (Pellicori and Evans, 1981). In fact, UV radiation (Di Lazzaro et al., 2010 and 2012) or the action of an electrostatic field (Fanti, 2010 and 2011), as well as manmade chemical and thermal treatment (Garlaschelli, 2010) always affect, without distinction, all the linen fibrils. On the contrary, in order to reproduce the Shroud body images (ventral and dorsal) correctly, the fibrils must be yellowed with respect to the trend (linear regression) of the correlation between the image intensity and the cloth-body distance. For the three mechanisms mentioned above, it is possible to yellow fibrils of linen, but without respecting the fact that on the Shroud, there are fibrils with background colour mixed with others that have been yellowed by the image formation process, which all show the same greater value of optical density. In other words, the action of these mechanisms can yellow or colour all the fibrils in the areas they affect with the correct image intensity values, but without being able, at the same time, to respect the discontinuous distribution of yellowed fibrils that has been noted, at microscopic level, on the Shroud of Turin by the STURP team (Pellicori and Evans, 1981). Nevertheless, we can acknowledge the fact that the radiative hypothesis can reproduce the very small thickness of the Shroud image (Mottern et al., 1980; Weaver, 1980), but without being able, at the same time, to reproduce the discontinuous aspect of the yellowed fibrils in the image area. On the other hand, the hypothesis of an artistic forgery is not able to account for the fact that the formation of the bloodstains on the cloth has preceded the body image formation. Indeed, in this case, the predisposed bloodstains would have been damaged by both chemical and thermal treatments. It should be noted that, in the case of Garlaschelli's work, he created false bloodstains on the cloth after the creation

of the body images (ventral and dorsal), without any respect for the reality of what really occurred on the Shroud.

In our opinion, a non-stochastic process is unable to explain the formation of both body images (ventral and dorsal) that have the same physical and chemical characteristics as the ones that appear on the Shroud. Indeed, for a deterministic process (like the ones that have been considered in more than a Century of Shroud research), it is not possible to satisfy the particular characteristics of the body images described in the Item 6. The above mechanisms do not agree with the following data coming from the Shroud: the energy received by the cloth per unit of surface during the cloth-human body interaction did not have the same effects on all the fibrils that lie in both body images (ventral and dorsal). It produced a yellowing only for a portion of these fibrils, even though these coloured fibrils have all reached the same optical density value, independently from the cloth-body distances.

Now, contrarily of the bloodstains, the characteristics of the body images (ventral and dorsal) do not agree with some kind of transfer between the cloth and a human body that would have operated solely by direct contact. At first sight, it does not appear possible for a human body to produce an image of itself naturally on a cloth that contains spatial information codified about the cloth-body distance. Such a correlation was scientifically confirmed on the Shroud when, with the help of a VP-8 Image Analyzer, STURP scientists were able to transform the shading of the Shroud ventral image in relief: the result is a 3-D image without important distortions (Jackson et al., 1984). Those who have conducted this 3-D study have suggested a linear regression to correlate the intensity of the ventral body image and the estimated cloth-body distance. Here, we want to underline that already, in 1902, a scientist (Vignon, 1902) thought the linen cloth had been used to cover a human body and noted that the density of both body images (ventral and dorsal) appeared to vary inversely to the cloth-body distance he estimated. In the end, this result obtained by STURP certifies that the bloodstains and the body images that are on the Shroud contain very different characteristics that really seem to be irreconcilable with each other. Therefore, the mechanism that could explain the Shroud body image formation must be capable to overcome this apparent problem of coexistence between the bloodstains and the body images on the Shroud of Turin.

The intensity of the image (or yellowed fibrils density) is maximal in the contact areas and decreases, with a linear curve, when the cloth-body distance increase. It reaches the background colour when the frontal part of the cloth was located at 3.7 cm of distance or more from the corpse (Jackson et al., 1984). We have also demonstrated that, in the case of the dorsal image, a correlation (still undetermined) does exist between this image and the cloth-body distance (see Item 4). Therefore, in the direct-contact areas, there is a greater density of yellowed fibrils (all with the same optical density value) that decreases when the above distance increases, and this is true not only for the ventral image but also for the dorsal. Consequently, the energy transferred to the linen cloth, per unit area, followed the same tendency as the intensity of the body images (ventral and dorsal). In sum, on the Shroud of Turin, the density of the yellowed fibrils is proportional to the received energy (e.g. in areas where the energy transfer was the strongest (direct-contact zones), more fibrils became yellowed, thus creating a darker image, like in the nose area for example).

Such an uneven, discontinuous and unpredictable distribution of yellowed fibrils in the image area strongly suggests a stochastic phenomenon that involves yellowing in random manner of a number of fibrils proportionally to the received energy. Indeed, it is easy to hypothesize that before the cloth-body interaction occurred, all the fibrils had the same original background colour. Taking into account the ones that we see on the Shroud of Turin, we can state that the probability that a fibril became yel-

lowed was a direct function of the energy it received; on the contrary, the optical density value of every yellowed fibril (which is the same in every part of the body image) was not a function of the energy (Fazio and Mandaglio, 2011 and 2012).

Today, we know the characteristics of the stochastic processes, which are triggered by a little quantity of energy that produce noticeable effects only after a time of latency of the order of many years. It should be noted that such an effect doesn't need a minimum threshold to appear (e.g. there is no noticeable effect only when the energy is equal to zero). It is this kind of process that occurs when many persons absorb small doses of radiation. Such an emission of a little quantity of energy triggers a mechanism with chemical modification that only appear after decades. These modifications, that always affect only an unpredictable portion of the sample, consist in tumours for some of the persons exposed to small doses of radiation and in yellow fibrils for some of them located in the areas of the fabric that were exposed to a small dose of energy (still undetermined). The same stochastic result can also happen when a group of persons is exposed to a faint pollution due to chemical substances. Now, taking into account the works about the Shroud that appear in literature (Tyrer, 1981; Little, 1997; Di Lazzaro, 2011), it is reasonable to think that for 1 cm^2 of fabric, there are about 2000-2200 fibrils. Moreover, considering roughly that both body images occupies a space of around 1/3 of the entire linen cloth, we can state that the number of fibrils that are present in the body image area are in the range of 30 million, which is the kind of large number that is ideal for a stochastic process.

In this case, what was the source of energy? This question is and will remain open because for a stochastic process, if two or more sources of energy are involved (which can well be the case for the Shroud images), it is not possible to know which one has triggered it. For example, this can happen when a numerous group of persons is weakly irradiated in an environment where a little quantity of chemical polluting is present. Indeed, for a particular person of that hypothetical group, it would be impossible to know if the modification (in this case, a tumour) has physics or chemical origin. In the case of the Shroud, we have suggested that a release of thermic radiation could have been the source of the body images (Fazio and Mandaglio, 2011), which is possible for a fresh corpse, while others authors (Rogers and Arnoldi, 2002 and 2003) have proposed some low temperature chemical processes (Maillard reactions) between reducing sugars (which are polysaccharides that would have been left on the cloth's surface by the use, in ancient times, of starch to protect the threads during the weaving of the cloth (Rogers and Arnoldi, 2002 and 2003) and *Saponaria Officinalis* to wash it (Pliny the Elder, 1992) and post-mortem gases, including ammonia and heavy amines, coming from the first stage of the corpse decomposition (which happened before the appearance of the first liquids of putrefaction between 36 to 72 hours after death, depending on various factors). However, we underline the fact that these authors did not think about stochastic processes when they proposed their image formation hypothesis.

2.4 The reactive oxygen intermediate hypothesis

A Shroud body image formation mechanism based on an increased build-up of lactic acid by superficial cells of the body enveloped in the Linen of Turin (Mills, 1995) has to be also taken into account. This process should occur because the man of the Shroud has suffered a tremendous physical trauma. Therefore, the lactic acid would have reacted with the oxygen in the air yielding free radical singlet oxygen that releases their excess energy into the fibres of the linen and turning back into ordinary molecular oxygen The oxidative effects initiated whenever the varying concentration of singlet oxygen was carried upwards until to contact the Linen of Turin. The yellowing fibril process was more intense (statistically more probable) in the fabric re-

gion where the oxygen concentration was higher.

The reactive oxygen hypothesis yields a latent image with a probability to yellow a fibril that changes with the concentration, in agreement with our stochastic hypothesis. In our model the yellowing fibril process, able to produce the image on the Shroud, was generated by fibril damages produced by an unknown energy source. Such damage on the fibrils, which depends on the intensity of the energy sources and their macroscopic effect (yellowing of fibrils), is purely probabilistic. In our hypothesis, the dependence of yellowing fibril density versus the distance is linear, while in the Mills hypothesis, such dependence versus the distance and time presents an exponentially trend.

3. CONCLUSIONS

Today, in the present state of our knowledge about the Shroud of Turin, we can categorically state that this long piece of fabric has been used to enfold the corpse of a wounded human body who was beaten, scourged and crucified. There, the dead body left stains of blood, serum and bile pigments on the cloth by a transfer process involving only direct-contacts. During this transfer, all the fibrils had the same chemistry with an optical density value equal to the original background colour, which was without a doubt much whiter than the actual non-image area that surrounded the body images on the Shroud now.

In our opinion, the bloodstains formation was followed shortly thereafter by a transfer of a little quantity of energy that was released by the dead body in direction of both parts of the cloth (ventral and dorsal parts), which triggered a stochastic process that produced, after some time (e.g. a few decades), a yellowing of some fibrils on the cloth's surface. On the Shroud of Turin, the result of this process concerns a number of coloured fibrils proportional to the received energy per unit of surface (e.g. the more the cloth was located near the body, the more it received energy per unit of surface and consequently, the more fibrils were yellowed).

This yellowed fibrils distribution has codified information on the cloth-body distance, yielding an image that possessed very particular properties such as having some three dimensional and photographic negative qualities. Besides, in line with the action of a stochastic process, the fibrils that composed both body images (ventral and dorsal), independently of the cloth-body distance, have all the same optical density value. Therefore, all the yellowed fibrils that composed the body images we see on the Shroud of Turin are the result of the same natural event. Consequently, all the image formation hypotheses involving an artistic forgery of some sort or a release of energetic radiation from the dead body must be discarded.

In conclusion, we can state that the above stochastic process is able to explain the body image formation on the Shroud and to resolve the apparent discrepancy that seems to exist between the formation of the bloodstains (which only happened through direct-contact transfers) and both body images (which happened through direct-contact and short distance types of transfers) on the cloth.

AKNOWLEDGEMENTS

The authors wish to thank both Mr. Andy Weiss, Webmaster of shroudnm.com, for his great help in the revision of the English text and the anonymous referee that has suggested a natural process to Shroud body image formation involving the production of oxygen.

REFERENCES

Bucklin, R. (1982) The Shroud of Turin: A Patholigist's Viewpoint. *Legal Medicine Annual*, 33- 39.

Clement, Y. (2012) Concerning the question of the authenticity of the Shroud of Turin: don't forget the evidence of the bloodstain! *BSTS Newsletter*, vol. 76, 32-56.

Culliton,B. J.(1978) The mystery of the Shroud of Turin. Challenges 20th Century science. *Science*, vol. 201, pp. 235-239.

Curciarello, F., De Leo, V., Fazio, G. and Mandaglio, G. (2012) The abrupt changes in the yellowed fibrils density in the Linen of Turin. *Radiation Effects and Defects in Solids,* vol. 167, 224-228.

Damon, P. E., Donahue, D. J., Gore, B. H., Hatheway, A. L., Jull, A. J. T., Linick, T. W., Sercel, P. J., Toolin, L. J., Bronk, C. R., Hall, E. T., Hedges, R. E. M., Housley, R., Law, I. A., Perry, C., Bonani, G., Trumbore, S., Woelfli, W., Ambers, J. C., Bowman, S. G. E., Leese, M. N., Tite, M.S. (1989) Radiocarbon dating of the Shroud of Turin. *Nature*, vol. 337, 611-615

Di Lazzaro, P., Murra, D., Santoni, A., Fanti, G., Nichelatti, E. and Baldacchini. (2010) G., Deep ultraviolet radiation simulate the Turin Shroud image. *Journal of Imaging Science and Technology*, vol. 54, 040302-1-6.

Di Lazzaro, P. (2011) Un approccio scientifico alla formazione dell'immagine della Sindone di Torino,http//www.uccronline.it/2011/10/30/un-approccio-scientifico-alla-formazione-dell%E2%80%99immagine-della-sindone-ii%C2%B0-parte/, 1-9 (*in Italian*).

Di Lazzaro, P., Murra, D., Nichelatti, E., Santoni, A. and Baldacchini. G. (2012) Superficial and Shroud-like coloration of linen by short laser pulses in the vacuum ultraviolet. *Applied Optics,* vol. 51, 8567-8578.

Fanti, G. (2010) Can a corona discharge explain the body image of the Turin Shroud? *Journal of Imaging Science and Technology*, vol. 54, 020508-1-11.

Fanti, G. (2011) Hypotheses regarding the formation of the body image on the Turin Shroud. *Journal of Imaging Science and Technology*, vol. 55, 060507-1-14.

Fazio, G. and Mandaglio, G. (2008) Does an I(z) correlation exist for the back-part of the Shroud body image? *Accademia Peloritana dei Pericolanti,* vol. LXXXVI, CIA0802005-1-5.

Fazio, G. and Mandaglio, G. (2011) Stochastic distribution of the fibrils that yielded the Shroud of Turin body image. *Radiation Effects and Defects in Solids*, vol. 166, 476-479.

Fazio, G. and Mandaglio, G. (2012) Can a latent image explain the characteristic of the Shroud body Image? *Radiation Effects and Defects in Solids*, vol. 167, 220-223.

Garlaschelli, L. (2010) Life-size reproduction of the Shroud of Turin and its image. *Journal of Imaging Science and Technology*, vol.54, 040301-1-14.

Heller, J.H. and Adler. A.D. (1981) A chemical investigation of the Shroud of Turin. *Canadian Society Forensic Scientific Journal*, vol. 14, 81-103.

Humbert, T. (1977) *The Sacred Shroud*. Pocket Books, New York.

Jackson, J.P., Jumper, E.J. and Ercoline, W.R. (1984) Correlation of image intensity of the Turin Shroud with the 3-D structure of a human body shape. *Applied Optics*, vol.23, 2244-2270.

Jumper, E.J., Adler, A.D., Jackson, J.P., Pellicori, S.F., Heller, J.H. and Druzik, J.R. (1984) A comprehensive examination of the various stains and images on the Shroud of Turin. *Archaeological Chemistry III*, vol. 205, 447-476 (*and references therein*).

Little, K. (1997). The formation of the Shroud's body image. *BSTS Newsletter* , vol.46, https://www.shroud.com/pdfs/n46part7.pdf.

Mills, A.A. (1995) Image formation on the Shroud of Turin. The reactive oxygen intermediates hypothesis. *Interdisciplinary Science Reviews*, vol. 20, 319-326.

Mottern, R.W., London, J.R. and Morris R.A. (1980) Radiographic examination of the Shroud of Turin. A preliminary report. *Material Evaluation*, vol. 38(12), 39-44.

Pellicori, S.F. and Evans, M.S. (1981). The Shroud of Turin through the microscope. *Archaeology*. 34 (1), 34-43.

Pliny the Elder (AD 77). *Natural History*. (Reprinted by Harward University Press, 1992, *Latin text and English translation*).

Rogers, R. N. and Arnoldi, A. (2002) A., Scientific method applied to the Shroud of Turin. A review. http://www.shroud.com/pdfs/rogers2.pdf, 1-38.

Rogers, R. N. and Arnoldi, A. (2003) The Shroud of Turin: an amino-carbonyl reaction (Maillard reaction) may explain the image formation. *Melanoidins Publication of the European Communities*, vol. 4, 106-113.

Rogers, R.N. (2005) Studies on the radiocarbon sample from the shroud of turin. *Thermocimica Acta*, vol. 425, 189-194.

Schwalbe, L.A. and Rogers, R.N. (1982) Physics and chemistry of the Shroud of Turin. A summary of the 1978 investigation. *Analytica Chimica Acta*, vol. 135, 3-49.

Tyrer, J. (1981) Looking at the Shroud of Turin as a textile. *Textile Horizons*. December, 20-23.

Vignon, P. (1902) *The Shroud of Christ*, Paris. (Reprinted by University Books,1970, New Hyde Park, New York).

Weaver, K.F. (1980) Science seeks to solve the mystery of the Shroud. *National Geographic*, vol. 157, 730-753.

Wilson, I. (1977) *The Shroud of Turin*. Doubleday, New York.

Zaccone, G.M. (1997) Sulle tracce della Sindone. Storia antica e recente. Elle Di Ci, Torino, (in Italian).