

**On a sample of the Turin Shroud (TS), we applied a new method for dating ancient linen threads by inspecting their structural degradation by means of Wide-Angle X-ray Scattering (WAXS).**

The X-ray dating method was applied to a sample of the TS consisting of a thread taken in proximity of the 1988/radiocarbon area (corner of the TS corresponding to the feet area of the frontal image, near the so-called Raes sample). The size of the linen sample was about 0.5 mm × 1 mm. We obtained one-dimensional integrated WAXS data profiles for the TS sample, which were fully compatible with the analogous measurements obtained on a linen sample whose dating, according to historical records, is 55–74 AD, Siege of Masada (Israel). The degree of natural aging of the cellulose that constitutes the linen of the investigated sample, obtained by X-ray analysis, showed that the TS fabric is much older than the seven centuries proposed by the 1988 radiocarbon dating. The experimental results are compatible with the hypothesis that the TS is a 2000-year-old relic, as supposed by Christian tradition, under the condition that it was kept at suitable levels of average secular temperature—20.0–22.5 °C— and correlated relative humidity—75–55%—for 13 centuries of unknown history, in addition to the seven centuries of known history in Europe. To make the present result compatible with that of

the 1988 radiocarbon test, the TS should have been conserved during its hypothetical seven centuries of life at a secular room temperature very close to the maximum values registered on the earth.

Reference: <https://www.mdpi.com/2571-9408/5/2/47>

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<https://shroudofturin.uk/research-evidence/dating-evidence/x-ray-dating>

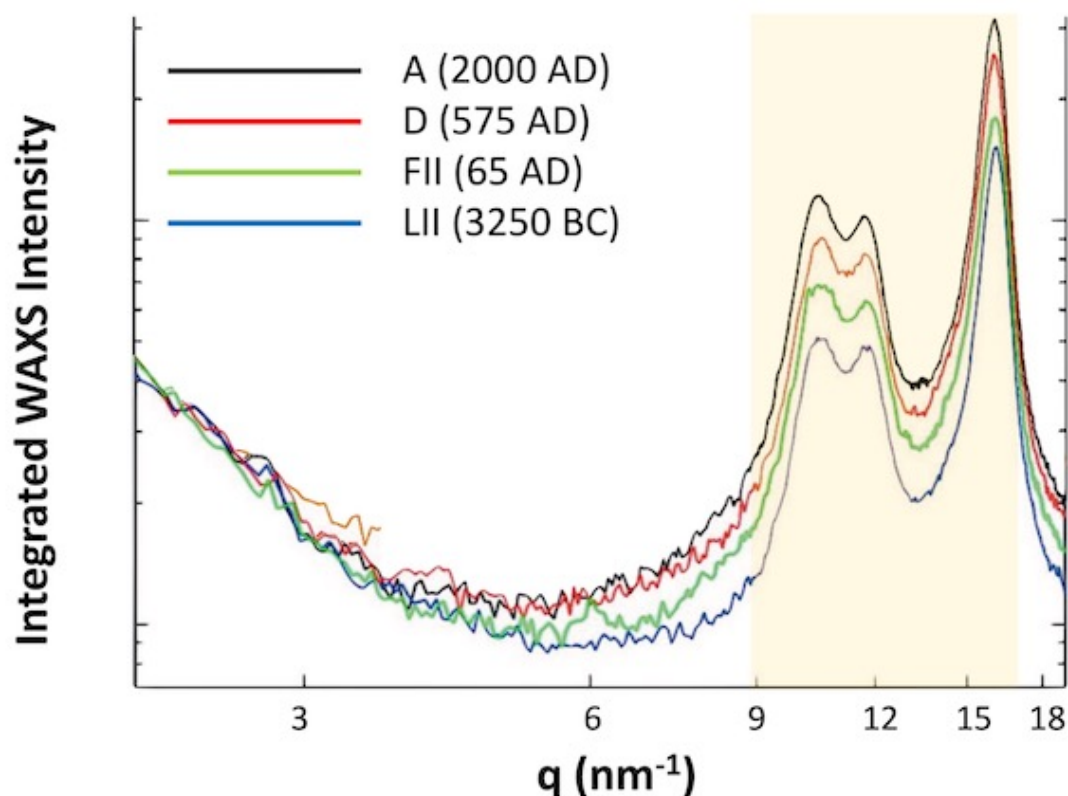
## X-Ray Dating

In 2019, a team of scientists from the Institute of Crystallography in Bari led by Liberato De Caro performed research into the potential use of Wide Angle X-Ray scattering as way of measuring the age of linen threads. At certain wavelengths, X-rays are reflected and scattered by the lattice planes of crystalline material, producing a scatter pattern with peaks in intensity that reveal details of the material's crystalline structure.

As we've already seen, the [crystalline cellulose zones](#) become more and more unstructured or amorphous with increasing age due to chain breaks occurring in the long cellulose molecules. This reduces the amount of crystalline cellulose on linen over time which causes measurable changes to the intensity of the peaks in the X-ray scatter profile.



Liberato De Caro



*WAXS profiles produced by four linen samples of varying age. The height of WAXS signal peaks in the highlighted area produced by these samples decreases with increasing age.*

*From X-ray Dating of a Turin Shroud's Linen Sample by Liberato De Caro et al., Heritage 2022, 5, 860–870.*

De Caro utilised some of the known age linen samples that had been used for the previous dating research under the leadership of Giulio Fanti. Each of these thread samples produced a scatter pattern which was then analysed to create a chart that showed how the signal intensity varied with the angle of scatter. These tests revealed that where the cellulose degradation is entirely due to natural ageing effects, the relationship between the WAXS measurements and the age of the sample is almost linear up to an age of between 2,500 and 3,000 years.

The chemical process that causes chain breaks in cellulose molecules has reaction a reaction rate that increases with rising temperature and humidity. This means that some historical linen samples degrade faster than others as a result of different environmental conditions and so samples of the same age from different locations could give different WAXS measurements. However, it is possible to make assessments of the average storage temperature and humidity over a sample's history from knowledge of where they had been kept and this allows a reaction rate adjustment factor to be introduced into the calculation that compensates for the effect of different environmental conditions

WAXS profiles were taken from two of the nine linen samples, one from Masada known to date from 55 to 74AD and an Egyptian fabric that dated from 544 to 605AD. These were used to calibrate an equation that could calculate the age of linen threads

from their WAXS measurements, average temperature and relative humidity and this equation was then used to determine the age of threads removed from another four of the linen fabrics. This gave impressive results and a regression analysis confirmed that the formula used was reliable for samples that were less than 3,000 years old.

The team also checked to see what effect the 1532 fire might have by obtaining WAXS profiles for a piece of modern linen before and after exposure to similar levels of heat but found that these conditions made no noticeable difference.

They then obtained a WAXS scatter profile for a thread taken from the fabric retained when the radiocarbon sample was removed from the Shroud. Move your mouse over (or click) the image opposite and the profile produced by the Shroud thread will be added to the chart. The relevant parts of the scatter profiles are the peaks seen in the highlighted area. If you look closely you will see that the signal peaks of the brown line representing the Turin Shroud are closest to the peaks of the green line indicating that the ages are similar. Indeed the peak furthest to the right exactly matches and obscures the green line.

The green line is the profile produced by a sample of linen from Masada in Judea which is known to date from the period 55 to 74AD. This clearly indicates that the thread removed from the Shroud also originated in the first century.

<https://shroudofturin.uk/research-evidence/dating-evidence/x-ray-dating>

The following links provide further information on this research

**A remarkable, new Shroud dating measurement.** An article by Michael Kowalski published in BSTS Newsletter No. 95, June 2022

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**X-ray Dating of Ancient Linen Fabrics.** Research paper by Liberto De Caro et al, published in the Heritage Journal, Volume 2 Issue 4 (2019)

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**X-ray Dating of a Turin Shroud's Linen Sample.** Research paper by Liberto De Caro et al, published in the Heritage Journal, Volume 5 Issue 2 (2022)

<https://www.mdpi.com/2571-9408/5/2/47>

# X-ray Dating of a Turin Shroud's Linen Sample

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