

Application of Non-invasive Measurements in the Recent Studies of the Scrovegni Chapel: Results and Considerations

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Abstract. The Scrovegni Chapel is known all over the world for the famous frescoes made by Giotto that decorate its interior. The building stands on the remains of the Roman amphitheater of Padua, in a unique, highly scenic position. Many unsolved doubts about the origins of this building and its link with the Roman amphitheater affect the Chapel. The evident structural and decorative in-homogeneities visible between the various parts of the building (e.g., the nave, the apse, the sacristy, the hypogeum and the walls under the roof), pose numerous doubts about the transformations that must have affected it over the centuries, probably changing its original shape. This work reports some examples of recent applications of ground-penetrating radar (GPR), electrical resistivity tomography (ERT), IR thermography, and multispectral imaging to the study of the Scrovegni Chapel. The results of the multidisciplinary project, of which these measurements are part, demonstrate that the integrated approach represents the basic condition for the right interpretation and comprehension of the results of non-invasive approach, mostly in complex archaeological and historical context as well as that of the Scrovegni Chapel.

Keywords: Geophysical methods · Non-invasive measurements · Scrovegni Chapel

1 Introduction

The use of geophysical methods for non-invasive identification of buried targets and the determination of the extension of the archaeological sites before their excavation is well known for decades [1–5]. Many examples of case-histories, in the recent scientific literature, show the usefulness of the application of a single geophysical method or a combination of different techniques in Cultural Heritage studies [6, 7]. The most common geophysical measurements adopted for archaeological investigations are based on magnetic, ground-penetrating radar (GPR), electrical resistivity tomography (ERT), electro-magnetic induction (EMI), or frequency domain electro-magnetic (FDEM) techniques. However, the possibility of the application of this broad range of methods, in particular contexts, such as urban surveys or indoor measurements, due to the noise and logistical constraints, is drastically restricted, often reducing it to the use more or less only the GPR technique [8].

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Closely related to these restrictions, and relatively more recent, are the developments of micro-geophysics measurements as a part of non-invasive diagnostic methods, useful for the analysis of historic buildings and their decorative systems [9–13]. In this case, non-invasive measurements can provide information on the nature and condition of the inner parts of the buildings, or of their decorations. This information is essential to correctly design and implement all interventions aimed at safeguarding, protecting, monitoring, and conserving the historical-artistic and archaeological heritage. In general, the common feature of all these techniques, regardless of scale and context, is the possibility of identifying the presence of anomalies/targets of interest in a non-invasive manner. In this sense, an example of the potential and advantages deriving from combined use of non-invasive techniques is offered by the recent studies conducted on the Scrovegni Chapel and the area of the Roman amphitheater of Padua, hosting this famous building (Fig. 1). The application of non-invasive techniques, at different scales of investigation and for different purposes, provided, in fact, in this context new useful information about the transformations that must have affected the Chapel over the centuries.

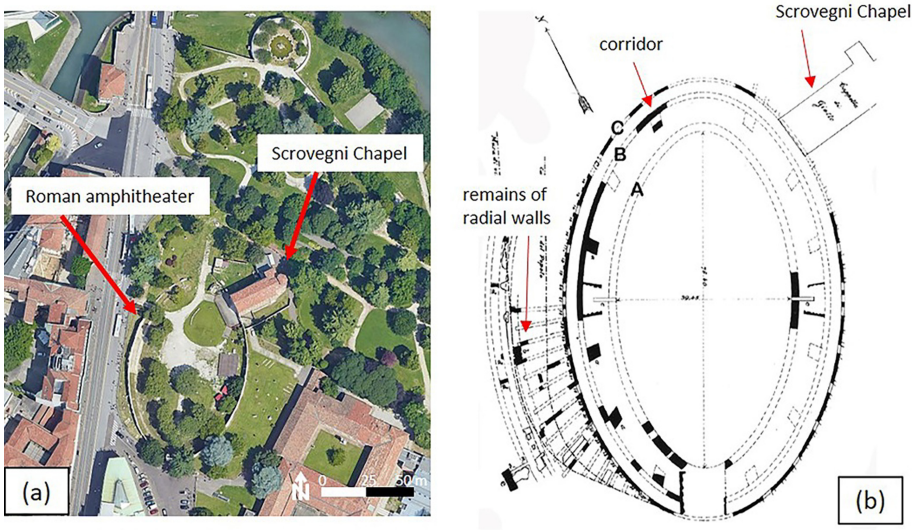


Fig. 1. (a) Location and link between the Scrovegni Chapel and Roman amphitheater of Padova (Google Earth modified); (b) Reconstruction of Roman amphitheater of Padova and distribution of its remains at the beginning of the nineteenth century (Brunelli Bonetti reconstruction modified)

The geophysical and, most in general, the non-invasive measurements carried out in this specific context, were a part of a multidisciplinary project, involving a number of experts in archaeology, history of art of the University of Padova, restorers of the Italian High Institute for Conservation and Restoration (ISCR), the local Superintendence (Soprintendenza archeologia, belle arti e paesaggio per l'area metropolitana di Venezia e le province di Belluno, Padova e Treviso) and the Municipality of Padova.

Thanks to this project, new integrated studies were made in synergy with the humanistic and technical-scientific support, aiming at the collection of new data about the Scrovegni Chapel [14]. The project demonstrated the importance of the contribution of non-invasive methods for the study of multi-layered historical sites. At the same time, it stressed that, especially in complex contexts, the contribution of archival documents and all the information available on the interventions carried out on the structure is necessary for a correct analysis and reading of the results of non-direct measurements.

The Scrovegni Chapel stands on the north-eastern sector of the Roman amphitheater of Padova (Fig. 1a). In particular, the building is not right-oriented E-W. Still, the south-western façade of the Chapel and the corresponding wall of the hypogeum, set on one elliptical wall of the amphitheater (Fig. 1b). The absence of documentation about the first centuries of the building's life has played and still plays a substantial role in understanding the events that have affected this location. Think, for example, of the particular position and orientation of the building, the role, and genesis of the hypogeum. Historical documents do not explicitly mention this underground space. Until today there is no agreement on the function of the so-called hypogeum of the Scrovegni Chapel and on the reasons that led to the construction of the Chapel only partially above it.

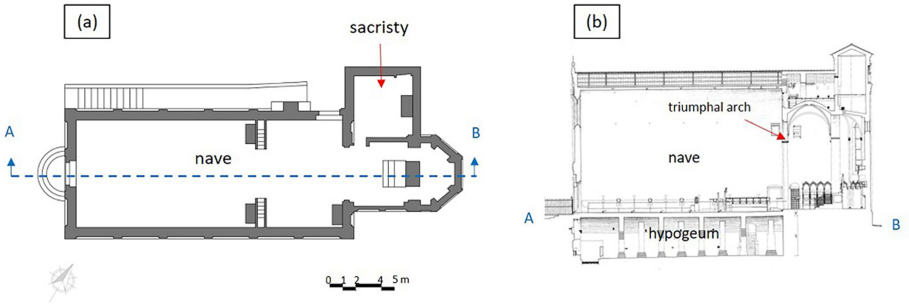


Fig. 2. (a) Plan of the Scrovegni Chapel, (b) Longitudinal section of the Scrovegni Chapel

The orientation of the building does not correspond with that of the radial walls of the Roman amphitheater (Fig. 1b), as documented by the archaeological excavations made between the end of the nineteenth century and the 2013 [15]. The current floor level of the hypogeum (Fig. 2b) would also presuppose that the radial walls of the Roman amphitheater and its foundations, found below in other parts of the Roman structure [15], have been demolished in this part, in 1300, to build the hypogeum. The asymmetric plan of the Chapel, by the presence of the sacristy on the northern side (Fig. 2a), also raises doubts about the possible demolition or non-realization of a southern part of a hypothetical transept of which the sacristy would represent one of the two parts.

2 Geophysical Measurements in the Roman Amphitheater

In order to analyze the link between the Scrovegni Chapel and the Roman amphitheater, also verifying the presence of buried remains of demolished parts of the Chapel, a series of GPR and ERT measurements were collected outside of the Chapel (Figs. 3, 4).

In particular, a GPR mapping was performed in the space in front of the SW facade of the Chapel (Fig. 3a), using an IDS RIS MF Hi-Mod GPR system with a dual-frequency 400–900 MHz antenna, making parallel lines every 0.3 m in the NW-SE direction. The collected data were post-processed using the ReflexW software, carrying out the start times correction, the mean-dewow filtering, the gain application, and the background removal for each GPR section.

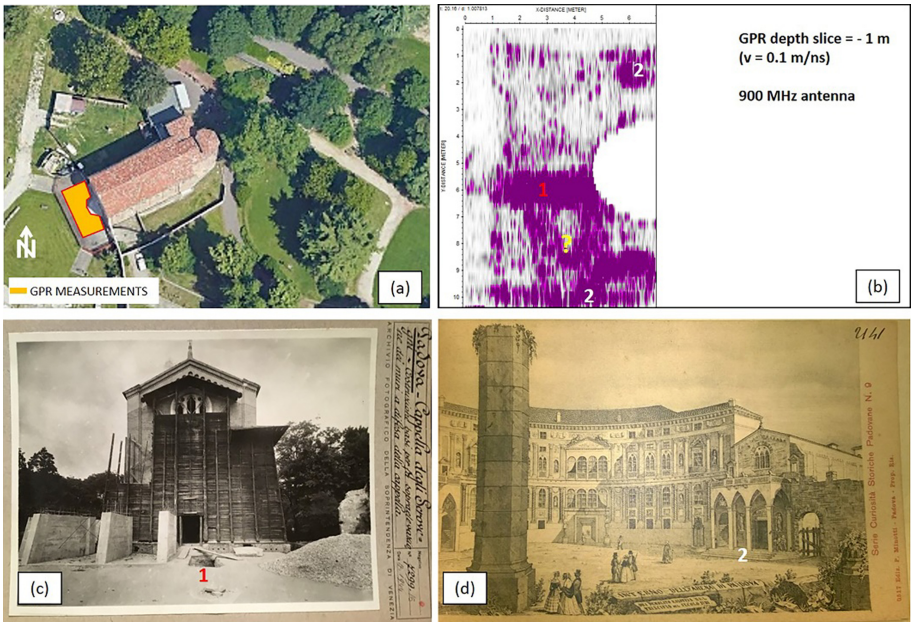


Fig. 3. (a) Location of GPR measurements (Google Earth modified), (b) Time slice of GPR iso-amplitude at −1 m depth, (c) Historical photo (1944) of the interventions to protect the Scrovegni Chapel during the II World War (SABAP VE-MET); (d) Old postal card showing the Scrovegni Chapel (before the collapse of its porch in 1817) and Foscari-Gradenigo Palace (Padua Municipal Archives)

GPR sections were after interpolated to obtain a pseudo-volume of the investigated area, extracting the maps of the iso-amplitudes of the reflected signal at different depths. Figure 3b shows, in particular, the map of the iso-amplitudes of the reflected GPR signal referring to the pseudo-depth of 1 m, obtained assuming an average signal of transit speed of 0.1 m/ns.

Two old images found in the historical archives (Fig. 3c and d) helped in the interpretation of some of the anomalies identified in the GPR time slice (Fig. 3b). The photo in Fig. 3c, found in the historical archives of the local Superintendence (Soprintendenza archeologia, belle arti e paesaggio per l'area metropolitana di Venezia e le province di Belluno, Padova e Treviso- SABAP), taken during the intervention for the protection of the Scrovegni Chapel in the II World War, shows a big trench in front of the SW façade of the building (Fig. 3c). Probably this trench, although filled, generated the GPR anomaly here detected, as the lateral anomalies probably due to the buried remains of the ancient porch, collapsed in the nineteenth century, showed in the old postal card found in the historical archives of the Municipality of Padova (Fig. 3d).

Also, two ERT lines (L1 and L2 in Fig. 4) were carried out in the space outside the Chapel, in the area of the Roman amphitheater, to study the link between the Scrovegni building with the Roman structure and to identify the presence of possible underground structures, as hypothesized by several scholars [16, 17]. Both ERT lines were made with the use of an IRIS Syscal pro-72 resistivity-meter using 48 stain steel electrodes.

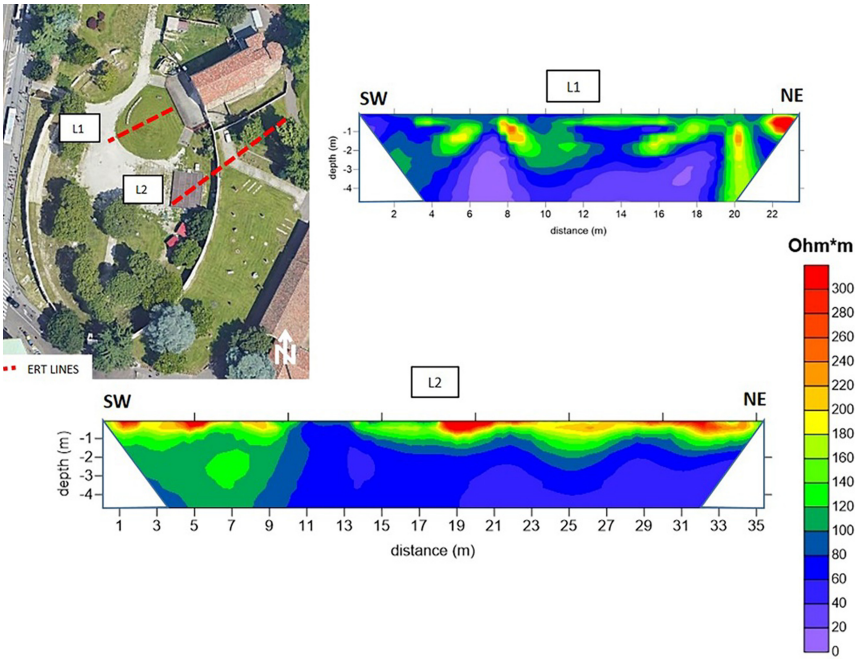


Fig. 4. Location and results of L1 and L2 ERT lines collected in the Roman amphitheater area

An electrode spacing of 0.5 m was adopted, for a total length of 23.5 m of a single line, and a corresponding investigation depth of about 5 m. The L2 tomography was carried out in roll-along mode, by performing two consecutive acquisitions, overlapping 24 channels, for a total length of 35.5 m, maintaining the same depth of investigation of about 5 m.

The results of the two ERT lines are shown in the images L1 and L2 in Fig. 4. The L1 line highlights the presence of some anomalies, which, due to their shape and type, could indicate the presence of buried structures related to the Roman amphitheater. The L2 line surely intercepts in the SW side, a part of the radial walls of the amphitheater and a known underground corridor. At the same time, it would seem to exclude in its NE side the presence of remains of foundations of a hypothetic demolished part of the Chapel transept.

3 Non-invasive Measurements Inside the Scrovegni Chapel

The large amount of data collected as part of the multidisciplinary project on the Scrovegni Chapel does not allow, given the limited purposes of this contribution, to account for the actual large number of non-invasive measurements realized to support this study also inside the building.

Therefore, only two examples of IR thermography and Multispectral Imaging for the analysis and understanding of the transformations of the internal structure of the Chapel during the centuries will be here discussed. The main feature of these two investigation methods lies in the possibility of acquiring data relating to the presence of anomalies in the structures without direct contact with the surfaces to be investigated. The absence of contact with the investigation surfaces represents the necessary condition for having the possibility of acquiring data on structures (e.g., walls) on which there is an extremely delicate and fragile decorative apparatus (e.g., frescoes) [18–24]. Although therefore these techniques do not allow in general to obtain detailed information on the deeper internal structure of the investigated system and in general arise with different purposes, the application in this context highlights some potential not yet fully exploited.

The use of IR thermography, inside the Scrovegni Chapel, has allowed us to discuss some of the hypotheses put forward by some scholars on its original distribution and partition of the space (Fig. 5).

Starting, for example, from what hypothesized by Laura Jacobus [25], about the existence of a partition and a pulpit necessarily clamped to the inner northern and southern walls of the nave, some thermographic IR measurements were made to verifying the actual existence of any anomalies of interest on the two walls. IR thermograms were acquired with a Flir T620BX/45° thermal imaging camera without artificial surface heating. The thermal measurements were repeated in different periods of the year, trying to identify the natural optimal seasonal thermal gradient to highlight possible anomalies in the walls.

Two thermal IR frames of the acquisitions made in January in the period of a maximum natural thermal gradient are shown in Figs. 5a and 5b. These thermal images evidencing other known hidden anomalies under the frescoes in the southern wall [26] made it possible to exclude the presence of any other anomaly compatible with traces of the presence of old structures. Even Multispectral Imaging, using a NIKON D800 FR modified camera by Profilocolore company, with an IR 850 nm band filter, confirmed the absence of structural interventions on the entire frescoed walls, except the traces of the insertion of the two small lateral wall screens in the nave (Fig. 6).

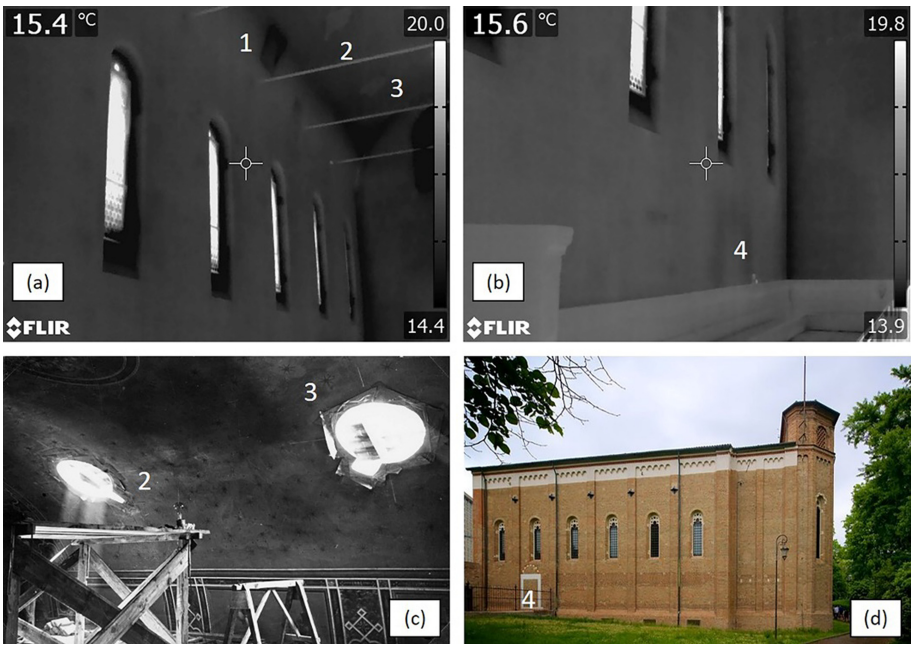


Fig. 5. (a) Thermal IR image of the upper part of the internal southern wall of the Scrovegni Chapel, (b) Thermal IR image of the lower part of the internal southern wall of the Scrovegni Chapel, (c) Historical photo of the interventions to protect the Scrovegni Chapel during the II World War (SABAP VE-MET); (d) Image of the external southern side of the Scrovegni Chapel with a visible walled door

Multispectral Imaging also allowed identifying the most likely original position of the wooden Cross painted by Giotto in the triumphal arch that connects the nave with the apse in the Chapel (Fig. 7e).

The wooden Cross was undoubtedly part of the Giotto's narration inside the Chapel. Multispectral images taken in the both opposite sides of the triumphal arch (Figs. 7a, b) show the presence of two specular anomalies (Figs. 7c, d).

These anomalies could apparently correspond to the positions of the holes for the insertion of a wooden beam supporting the Giotto's Cross, just between the two lateral funeral scenes (in Italian so-called "coretti") with funeral lanterns (Fig. 7e) and to face precisely the Cross painted in the opposite south side of the nave (Fig. 7f).

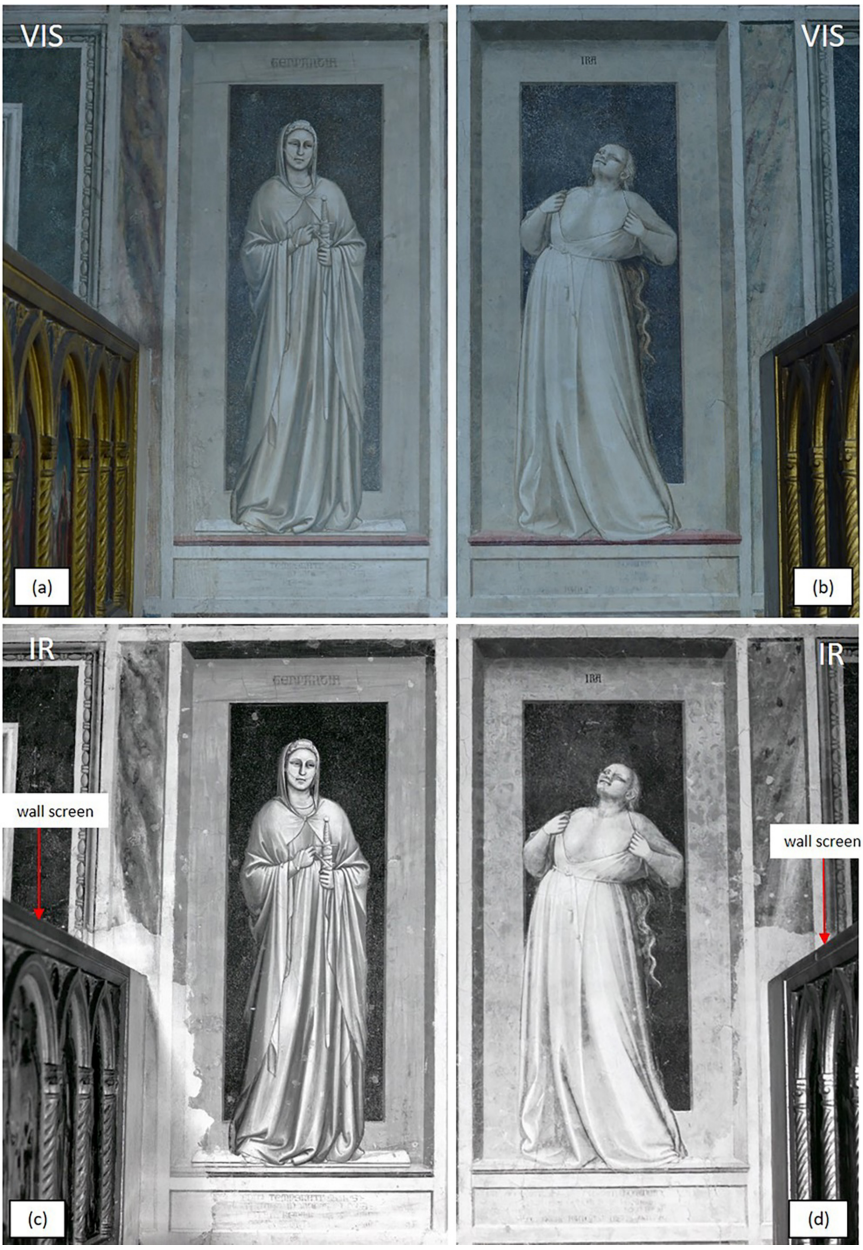


Fig. 6. (a) VIS and (c) IR filtered image (850 nm) of the wall screen insertion in the southern wall of the Scrovegni Chapel, (b) VIS and (d) IR filtered image (850 nm) of the wall screen insertion in the northern wall of the Scrovegni Chapel

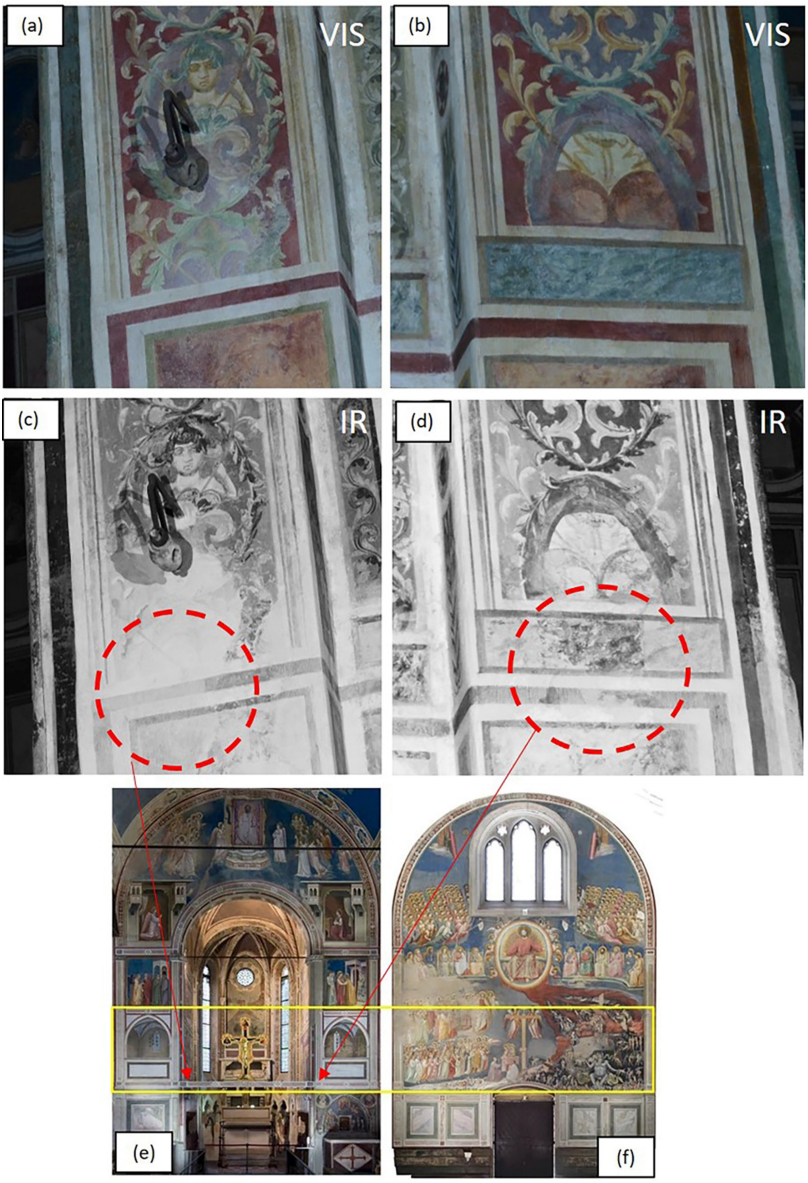


Fig. 7. (a) VIS and (c) IR filtered image (850 nm) showing an anomaly in the north side of the triumphal arch of the Scrovegni Chapel, (b) VIS (d) IR filtered image (850 nm) showing an anomaly in the south side of the triumphal arch of the Scrovegni Chapel; (e) hypothesis of the Giotto's Cross position in the triumphal arch; (f) position of the Cross in the Resurrection southern wall fresco

4 Conclusions

The results of the application of non-invasive methods from the field scale to the small one for the study of the Scrovegni Chapel in the Roman amphitheater of Padova demonstrated the high potential and additional value offered by these non-direct measurements. At the same time, these studies demonstrated that only by the synergy given by the multidisciplinary approach, involving humanistic and technical scientific worlds and only thanks to the dialogue between these experts from different disciplines, non-invasive data could be correctly interpreted, thus offering a real and useful contribution, fundamental in the complex field of Cultural Heritage studies.

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