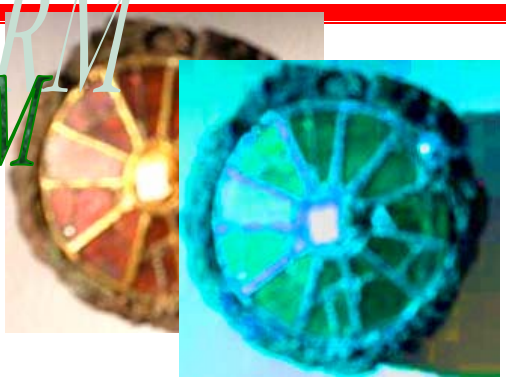
ANCIENT CHARM



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Report on cultural heritage motivations of neutron-based imaging techniques

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Integrating and Strengthening the European Research Area
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Look into the objects – why?

D2: Report on cultural heritage motivations of neutron-based imaging techniques

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Introduction

Archaeologists, as a rule, are a curious set of people. They are trying to fathom the objects and features, i.e., artefacts made and utilised by our ancestors. As the matter stands now, we typically look into the surface only unless we destroy the evidence, and that is what archaeologists usually do when excavating. It is often said that an archaeological excavation is an unrepeatable experiment – while we are opening up the evidence, we are destroying it at the same time (hence the need for a very minute documentation of this process).

The possibility to look inside, i.e., by the assessment of physical qualities, and visualise the contents of archaeological sites is manifested in different prospection techniques, that are now applied as routine in archaeological geophysics: magnetometer surveys, electromagnetic measurements, ground penetrating radar, resistivity measurements etc. (Herz--Garrison 1998). Archaeological excavations, especially large surface projects, are today not feasible or at least tediously long and ineffective without the application of these methods.

The question we are addressing here is: is there a similar need for „looking inside" on the level of the object?

The advance of physical techniques of archaeometry made this question topical and 'Ancient Charm' project made it feasible.

The Ancient Charm project

Ancient Charm (**A**nalysis by **N**eutron resonant **C**apture **I**maging and other **E**merging **N**eutron **T**echniques: new **C**ultural **H**eritage and **A**rchaeological **R**esearch **M**ethods)

is an ADVENTURE project, an action line of NEST (New and Emerging Science and Technology) in the Sixth Framework Programme (FP6) of the European Union. Its aim is to develop methods of neutron imaging techniques, penetrating solid and non-transparent inorganic objects, and test their applicability in the field of cultural heritage. Detailed information on the project can be found at the project website (http://ancient-charm.neutron-eu.net/ach). The initiative has been reported on in a number of meetings and scientific communications (***See References***).

In parallel with the methodological development, we are interested in the possible use of these techniques: will they be in demand? is there a justification, on the "consumers' side", for the obviously large input of work and development?

The techniques covered by Ancient Charm include elemental analysis techniques based on nuclear reactions, by capturing or scattering neutrons: prompt gamma activation; neutron resonance capture analysis and imaging; neutron radiography and tomography; and time-of-flight neutron diffraction studies. An overview of these techniques was given in Kockelmann-Kirfel 2006, esp. Table 1.

These techniques may provide different images of the interior, normally invisible parts of the objects: 3D contrast images, structural information on the (mineral) phases included, and elemental distribution. The application of these methods individually may provide important new information concerning the objects; their joint application offers a unique compound view . Theoretically, all aspects of the objects can be studied - practically, we have to see if the results justify the effort.

Possible reasons on behalf of neutron physics

- testing methodology

The study of archaeological and other (historical, artistic) objects belonging to the cultural heritage (=CH objects) can be considered an ideal field for testing the potential of new advances in the field of applied sciences. CH objects are interesting, attractive even, for the wide public and are 'patient' in their own way. Even in the case of failure, nothing 'tragic' happens – a bridge does not collapse, a patient does not die, contracts do not fail. On the other hand, leading edge technologies preferentially 'tested' on CH objects will not typically become part of the routine applications of archaeological / art historical methodology and have little or no impact on the mainstream research of humanities. To be considered essential for the art, large programmes of examinations are needed, involving fast and possibly cheap methodologies.

- publications

The main purpose of having CH objects analysed by neutron physicists is beyond doubt having quality publications in high-impact factor journals. For that, objects of high artistic quality and great historical importance would be preferred by the analysts. The problem with such objects is that they are more difficult to move, from the collection and even more across boundaries; they are considered as having exceptional cultural value. A lot of effort is needed to convince curators and museum management of the benefits of the analysis and in any case, the objects must be heavily insured.

Possible reasons on behalf of CH

- conservation

The most compelling need for looking inside objects emerges prior to conservation/restoration of the objects. The conservator and the curator would like to know what is inside, in case the object deserves special treatment. Some chemicals used for fixing metal parts may be harmful for organic components, for example, and the other way round, and any chemical interference (necessary for preservation) can unfavourably influence the possibilities of later analysis. It would be ideal to check 'suspect' objects (that is, objects of possible high complexity and aesthetic/historical value) as soon as they are found and stabilised. The problem with this approach is, partly, methodological: in

routine archaeological practice there is no time to play with the individual objects, and also there are too many candidates for detailed 'look inside' studies with uncertain outcome.

For the time being I see little chance of applying neutron imaging techniques as a routine means for masses of archaeological objects coming fresh from excavation contexts. This can be, though, a future prospect if the availability of the method and the suitable equipment become widely accessible.

The most important routine application of neutron imaging techniques could be the fast and effective study of "fresh" archaeological finds to optimise treatment . X-ray radiography, in fact, has for a long time been applied to conservation science and can be regarded as a routine means for assessing different (hidden, or not visible) qualities of the object. Given the large number of fresh archaeological finds, the biggest problem here is selecting the really appropriate pieces and getting them in a stable enough state to undergo the analytical process without damage to the objects, their possible further conservation treatment, and the analytical equipment itself[1].

- presentations

The most successful applications of visualising the interiors of CH objects is that of digital (?) presentations in the context of an exhibition or a wide range of public media. It can add up to the understanding and visualisation of the archaeological objects in a modern context that is required by the current audience. Exhibits are supposed to be not only "beautiful", "valuable" and "meaningful" in a historical sense but also attractive in the modern IT world. This appeals most to the young generation whose visual (and non-visual) culture develops in the context of sophisticated (e.g., 3D) imaging techniques where most of the information is derived from the image, much less the text.

- technology studies

Neutron imaging techniques can support the scientific study of objects in the field of humanities. The most plausible field is that of ancient technology, its recognition and analysis. Differentiating authentic pieces from fakes might be one of the marketable benefits. With a library of ancient technological fingerprints, modern fakes could be easily sorted out. It can also support experimental archaeology studies in reviving and reconstructing former technological knowledge.

Suggestions for a 'best practice'

Start with excavation-fresh material

[1] Excavation-fresh materials, especially unconsolidated, might be harmful: they have to be stabilized, desinfectionalised first.

- careful documentation

- preliminary conservation in view of possible later needs of analytical treatment (minimal interference)

- assessment of composition / complexity

- measurement of weight, specific gravity (dimensions in this state may be misleading)

- fast and high resolution imaging techniques (radiography, maybe tomography)

- decision on further steps

Conserved/Complete objects from museum stores

- try to trace history of object: recovery, conservation, previous treatment and/or analyses

- simple tests: measurements of dimensions, weight, specific gravity

- is there a question concerning interiors?

(hollow objects, complex objects, technology)

- information on bulk chemical composition

assessment of significance:

- of the object (in respect of possible publication/presentation)

- of the question, in view of historical/artistic added value to the already known information

- planning possible optimal sequence of analysis

assessment of difficulties:

- transport of objects including administration and insurance

- analytical requirements and limitations:

activation/cooling time

sample size - analytical equipment sample holders and individual support

Conclusions

Neutron imaging techniques can be widely applicable in 3D of mapping archaeological and other CH objects. These methods can be applied individually or as a package, providing both visual information on whereabouts of high/low contrast parts (NR/NT), phase composition of hidden "inclusions" and different phases inside the object (TOF-ND, SANS) or pinpointing parts of different chemical composition inside the objects (=PGAA/PGAI, NRCA/NRCI).

Knowing simple physical parameters like dimensions, weight and specific gravity, archaeologists/conservators may find it necessary to investigate the internal parts of an object. Depending on the actual find circumstances, investigations can be carried out both on 'excavation fresh' or 'gem of collection' pieces, typically to define

a, best treatment

b, visualisation (for presentation)

c, increase scientific information available on the object

It is suggested to start with the visualisation techniques first, which are fast and offer high resolution. They might be adequate for deciding if further neutron-imaging techniques for the determination of phase composition (=minerals) or elemental composition might be necessary, and if so, on which part of the objects. The next step is an assessment of bulk chemical composition (to be able to predict the behaviour of the object during the further steps of analysis). The continuation of the process may turn towards the identification of the spatial ordering of atoms (crystalline structure, orientation) and suspected different elemental composition of hidden parts. It is important to note that the resolution of neutron radiography/tomography is in the order of 100 microns, whereas the resolution of neutron diffraction and elemental analysis is a minimum of 1 millimetre, so their visualisation possibilities are widely different.

All observations should be carefully recorded in an unambiguously defined 3D coordinate system within the object. The interpretation of the data should involve both analysts and experts from the CH field. It is necessary to construct reference libraries for typical ancient techniques, even on simple objects.

The most likely candidates for in-depth analysis will be composite objects of elaborate workmanship, typically made, at least partly, of metal(s). Organic composite objects will probably give poor contrast for elemental mapping, as hydrogen is a strong neutron-scatterer.

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Internet resources:

Ancient Charm central homepage: http://ancient-charm.neutron-eu.net/ach

Ancient Charm-WP1 homepage: http://www.ace.hu/acharm/

Geophysical methods homepage: http://www.geosphereinc.com/main_geo-methods.html