Shedding ESRF-EBS light on artworks to get insight into their creation and to better preserve them

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In 2019, the European Synchrotron's core machine was completely dismantled to install a revolutionary machine producing a much brighter X-ray source. This upgrade has not only dramatically improved the properties of the X-ray beam, but also triggered several projects to improve the user experience, upstream and downstream data collection. As far as the cultural heritage community is concerned, the results are numerous[1].

For many beamlines, the increase in brightness translates into higher flux, smaller beams and faster acquisitions. This has motivated the implementation of a facilitated community access for structural analyses of historic materials (known as "BAG" access[2, 3]). Access is granted every six months to two X-ray powder diffraction (XRPD) beamlines (ID13 for μXRPD and ID22 for high angular resolution XRPD) and beamtime is shared by a network of more than 120 international collaborators (Fig. 1). Such analyses have led to major discoveries such as the identification of a very unusual lead carbonate (plumbonacrite) in *Mona Lisa*'s and in the *Last Supper*'s ground layers, giving insights into Leonardo da Vinci's painting techniques[4].

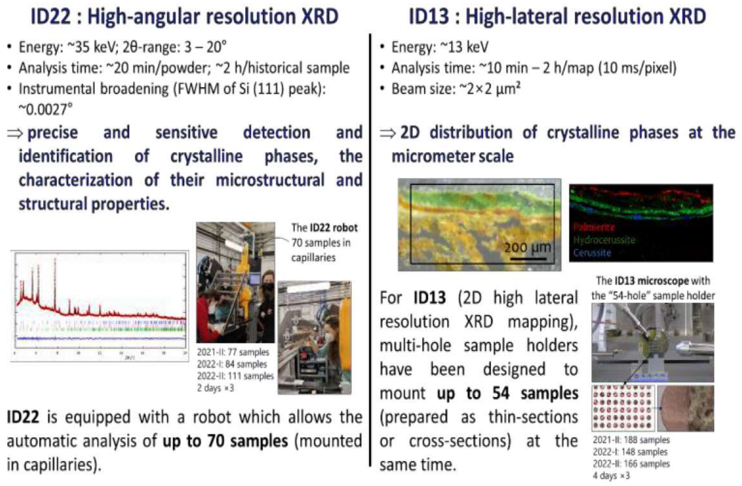

Figure 1. The two X-ray diffraction beamlines accessible through the "historical materials BAG" access: ID22 and ID13

The throughput of these beamlines (>200 samples analysed per experiment) is so high that this has motivated the creation of a dedicated database to make the data collected more FAIR and facilitate its re-use by anyone (project "SHARE", funded by the OSCARS European Call)[5] (Fig. 2).

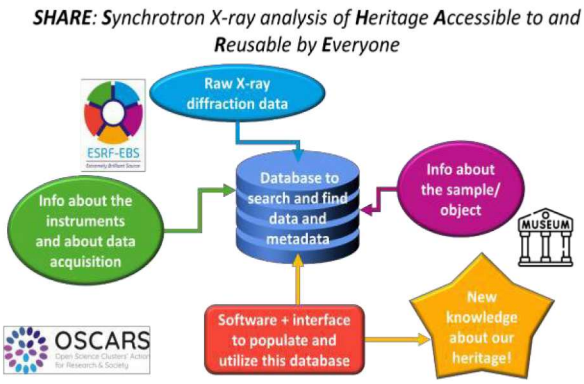

Figure 2. The many objectives of the OSCARS SHARE project:

In parallel, in the field of X-ray micro-spectroscopy, the ID21 beamline has just been refurbished and its new nanoscope provides unprecedented performance for 2D nano-XRF mapping and nano-XANES in the 2.1-10 keV energy range (Fig. 3). These two techniques can now be efficiently combined for hyper-spectral XRF mapping, to identify and locate species at the nano-scale, over millimetric regions. These assets are very important to tackle subtle chemical modifications related to artefact manufacturing (e.g. ceramics firing) or alteration (e.g. pigment degradations). Efforts are also being made to provide users with easy-to-use graphical interfaces for data acquisition and to automate data processing and analysis.

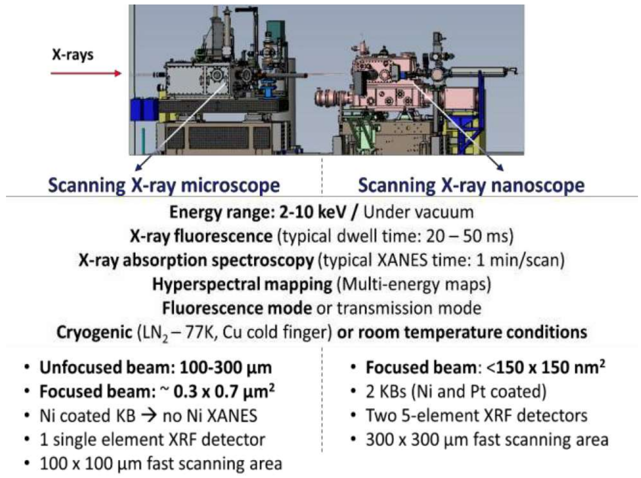

Figure 3. The scanning X-ray microscope and nanoscope at ID21: X- ray absorption spectroscopy at the sub- micrometric scale

Regarding X-ray computed tomography, a new flagship beamline, BM18, has been built and optimised for multiresolution phase-contrast imaging of large objects. Thanks to a wide beam of up to 30 cm horizontally and an energy of up to about 300 keV in filtered white beam, several large fossils and a dozen of music instruments have recently been successfully imaged.
In summary, the last five years have been instrumental in revolutionizing the user experience at the ESRF and, as recent examples will show, the benefits to the cultural heritage community are enormous.

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