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Unlocking the history within Persian and Aksumite gold coins using negative muons

Muonic X-ray emission spectroscopy (μXES) is a powerful tool for generating important archaeological conclusions from high-value cultural heritage objects. We often want to fully understand the composition of hese monetarily, archaeologically or historically valuable objects. However,these are exactly the objects where aggressive or noticeably destructive sampling cannot be sanctioned, and we are frequently relegated to surface analyses. Muons solve this.

Negative muons are essentially 'heavy electrons'. By controlling the momentum of a muon we can control its implantation depth within our archaeological sample. Here it is captured by an atom at that specific depth, occupying an orbital like an electron would, but much closer to the nucleus. It then cascades down these various energy levels emitting high energy, characteristic muonic X-rays as it does this. By detecting these characteristic muonic X-rays we can determine the elemental composition of our sample at that specific depth, much in the same way as XRF works. Unlike XRF, however, our muonic X-rays can escape from deep within the sample. This means we can implant muons around a centimeter into gold and achieve analytical 'slices'in our gold objects of 10 to 25 microns. As such, we can determine sub-surface elemental composition in discrete 'slices'non-destructively even in precious metal objects.

Ancient gold coins present a particularly compelling use case for μXES. They are rare, valuable and arguably objets d'art in their own right, meaning destructive sectioning is almost impossible to sanction. However, they are fundamentally artefacts of monetary economies, meaning understanding their true composition can give us important insights into ancient state finances and supply chains, technological choices, and the economic consequences of political and historical events. These objects are documents, and negative muons help us to read the history, culture and archaeological narratives sealed within.

To articulate this point two case studies will be presented. One from Ancient Iran, showing a relatively unique manufacturing method; and the other from Ancient Ethiopia, showing how μXES can be used to support portable XRF surveying of a large series of objects.

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