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The role of underwater cultural heritage on dark matter searches: Ancient lead, a dual perspective

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A B S T R A C T

New generations of dark matter detection experiments require extreme low levels of background radiation in order to verify complex particle physics theories. Ancient lead ingots from shipwrecks provide the necessary shielding material to perform these experiments due to their low intrinsic radioactivity, difficult to achieve by modern materials or commercial means. This situation generates a debate between two different perspectives: The preservation of cultural heritage or its use in scientific fundamental research. In this Article we present the scientific implications of the use of salvaged Ancient lead for dark matter searches as well as the consideration on underwater cultural heritage management. We finally highlight the three main dilemmas on the issue and articulate their analysis using the three main cultural heritage mainstays: (1) benefit of the humankind, (2) scientific interest and (3) commercial exploitation of the underwater cultural heritage. We conclude that the use of Ancient lead in dark matter experiments does not contravene the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage, the foremost international legal reference for the protection of underwater cultural heritage. However, to prevent the uncontrolled utilization of the non-renewable Ancient lead we recommend the use of alternative shielding materials such as tungsten and a case-by-case benchmark against commercial ultra-low-alpha lead.

1. Introduction

The research on dark matter detection aims to underpin some of the most fundamental properties of the universe. It has been demonstrated experimentally that ordinary matter, i.e. elements of the periodic table, constitutes only 17% of the total matter of the universe whilst the remainder is attributed to dark matter (Komatsu et al., 2011). The understanding of the origin of the remaining 83% of the matter present in the universe remains one of the most fundamental open questions to humankind.

A 2000 year old shipwreck's cargo is planned to be used for these experiments (Nosengo, 2010). Italy's new neutrino detector, CUORE (Cryogenic Underground Observatory for Rare Events), at the Italian National Institute of Nuclear Physics, received from the National Archaeological Museum of Cagliari 120 archaeological lead ingots proceeding from a shipwreck recovered from the sea 20 years ago at the coast of Sardinia. The so-called "Ancient lead" (both Greek and Roman) will be used as a shield for the dark matter detectors because over the past 2000 years the lead has lost its intrinsic radioactivity due to natural radioactive decay to levels approximately 100,000 times lower than freshly mined lead.

"The use of these objects as stock for experimentation had never been an issue before, but now it is beginning to be deemed ethically questionable" (Perez-Alvaro, 2013a). Roman lead proceeding from a shipwreck under water for 2000 years is underwater cultural heritage and it is protected under the umbrella of the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage (2001 Convention hereinafter) for being traces of human existence having a historical character which have been under water for more than 100 years (UNESCO).

Underwater cultural heritage faces numerous menaces from natural deterioration (Manders, 2004), to destruction by construction of ports or illegal salvage (Dromgoole, 2013). Legislative efforts have been focused on preventing these menaces (2001 Convention) (Aznar-Gomez, 2013; O'Keefe, 2002). However, underwater cultural heritage also suffers other threats, legitimate

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threats. From the lying of submarine cables (Perez-Alvaro, 2013b), to fishing (Article 5, 2001 Convention) or the focus of this Article, its use for experimental physics (Perez-Alvaro, 2013a). Policy makers have largely neglected these issues.

However, it is not only the use of this heritage that presents a concern, but also its recovery and documentation. In the CUORE case the excavations and documentation of the underwater cultural heritage were done by archaeologists under archaeological standards (INFN, 2010). However, in the case of other laboratories the Ancient lead is bought from private companies whose end is a profitable recovery where the archaeological standards are unlikely to be accomplished (Throckmorton, 1998):

> The CDMS team – *Cryogenic Dark Matter Search* – had to find old lead […]. An Italian colleague mentioned that he had been using lead taken from two-thousand-year-old Roman ships that had sunk off the Italian coast. The CDMS team located a company that was selling lead salvaged from a ship that had sunk off the coast of France in the eighteenth century. Unaware that they were doing anything illegal, the researchers bought the lead. The company, however, got in trouble with French customs for selling archaeological material. Illegal or not, the lead worked (Ananthaswamy, 2010).

The issue introduces a new consideration on the treatment and the protection of underwater cultural heritage and its use for non-commercial/scientific experiments. The use of this material is also becoming popular in different scientific fields such as microelectronics (Ho-Ming Tong, 2013) and low background detectors (ORTEC). The dilemma, which was raised by Perez-Alvaro (2013a), has attracted the interest of different archaeological and physicist communities (Pringle, 2013b; Moskowitz, 2013, 2014; Gwynne, 2013).

The two different perspectives of the dilemma – experimental physics and cultural heritage – are the main concern of the following Article. In the first part, we present the analytical evaluation of dark matter searches: whether the use of this Ancient lead is indispensable for these experiments from the point of view of the dark matter physics, which other alternatives exist to Ancient lead and how much lead is necessary. The second part of this paper will be focused on analysing whether the use of Ancient lead on dark matter searches is legitimate from a cultural heritage rationale arising from three common principles:

- benefit of humanity
- scientific interest of the material
- concerns underlying commercial exploitation

These three mainstays of cultural heritage management have been subject to debate in similar cases:

Preservation for the benefit of humanity has been an issue in management of human remains in archaeology. A prime example of this is that of Kennewick Man, a 9300-year-old skeleton found in 1996 in a riverbank near the town of Kennewick in Washington state (Ackerman, 1997; Chatters, 2000). The finding of the skeleton triggered a nine-year legal clash between scientists, the US government and Native American tribes who claim Kennewick Man as an ancestor under the provisions of the Native American Graves Protection and Repatriation Act (NAGPRA). In February 2004, the United States Court of Appeals for the Ninth Circuit ruled that a cultural link between any of the Native American tribes and the Kennewick Man was not genetically justified, allowing scientific study of the remains to continue for the benefit of humanity (Bruning, 2006).

The scientific interest of pre-II World War steel from historical submarines and battleships has transcended its historical interest to be used in other domains, for example, medical research: 65 tons of steel from U.S.S. Indiana, scrapped in 1962, was used for shielding at an Illinois Veterans Administration hospital, and another 210 tons went into building a shielded room for in vivo radiation measurements at a Utah medical center (Lynch, 2007, 2011). Equally, steel salvaged from Scapa Flow shipwrecks has been used in low radiation detectors (Butler, 2006).

Commercial exploitation has been an issue in slave ship excavations. Between c1500 and 1860, European ships transported captive Africans from Europe to the Americans on what it has been called the "middle passage". Despite of the importance of the subject, the excavated shipwrecks relating to slave shipping is undeniable small (Webster, 2008). "Nautical archaeologists have placed their collective heads in the sand and have been tossing potshots at opportunistic treasure hunters who have funded slave ship excavations" (McGhee, 1997). This situation has promoted the proliferation of commercial agreements between private salvage companies and archaeologist that use these discoveries for scientific investigation.

The quandary is not the use of Ancient lead for dark matter experiments alone, it is the growing extended use of this material for other kinds of experiments, from medicine to microelectronics. The question raises the necessity to set boundaries and protocols in the use of the underwater cultural heritage.

2. The perspective from physics

Today we know that dark matter is present in the universe but we do not know what it is made of. Particle physicists have proposed tens of possible dark matter candidates and have suggested different strategies to detect them such as direct detection by interaction of dark matter particles with target detectors in underground laboratories (Bertone, 2010). Direct detection requires extremely low levels of background signals to distinguish a particular dark matter event from collisions produced by cosmic rays (fast-moving particles that continuously shower the Earth from deep space) or by the intrinsic radioactivity of the environmental materials.

The effect of cosmic ray radiation is efficiently mitigated by setting the detector in underground laboratories. However, low-intrinsic radioactivity materials are essential to provide additional shielding and reduce the effect of spurious signals.

Laboratories underground adopt a combination of shielding materials of which one must be a high density element (Lang and Seidel, 2009). Among high density elements that could provide a

Table 1
Evaluation of low-alpha lead sources. Radioactive emission per kilo in milli-Becquerels per kilogram and price per pound in U.S. Dollars per pound for different types of lead.

Type of lead	Radioactivity (mBq/kg)	Price ($/lb)
Hot ores	4×10^6–200×10^3	0.3–1.1 (Heusser, 1995)
Cold ores	200×10^3–5000	50 (Heusser, 1995)
Low-alpha lead	260	110 (Heusser, 1995)
Ultra low-alpha lead	60	310–500 (Lee, 2000)
Super ultra low-alpha lead	24	680–1150 (Lee, 2000)
Commercial salvaged lead	12	80–150 (Lee, 2000)
Silvia lead	<7	24 (Nosengo, 2010)
Oristano lead	<4	24 (Nosengo, 2010)
Greek lead	<0.2–0.9	–[a] (Danevich et al., 2009)
Gold	–[b]	18,010 (NASDAQ, 2014)

[a] Non-commercial ultrapure archaeological Greek lead.
[b] Pure gold is composed of a single non-radioactive isotope.