Contribution ID: **39** Type: **ORAL**

A non-invasive protocol based on Ion Beam Analysis for the study of lapis lazuli provenance in antiquity

Monday 13 June 2022 14:20 (20 minutes)

Lapis lazuli is a semi-precious blue stone, used since the VII millennium BCE for the manufacturing of small carved artifacts (e.g. jewels, seals, amulets) in the Ancient Middle East and in part of Central and Southern Asia. The Badakhshan mines in Afghanistan are generally considered the most plausible hypothesis for the origin of the lapis lazuli used in antiquity[1]; however, the limited number of reference samples from well-documented geological sources, the records in ancient written evidence and the results of scientific provenance studies conducted since the 1960s have shown that the question of the provenance is still unsolved.

Despite the useful and interesting results obtained, most of these previous studies exploited invasive or destructive techniques, as for example IRMS[2,3] or AAS[1,4]. This approach is not always applicable in the case of precious archeological artifacts, where micro- or no sampling for the analysis is required. Driven by the growing interest in adopting conservative methods when analyzing such valuable objects and by the lack of a systematic and exhaustive study of the origin of the raw material of lapis lazuli artworks, the Solid State Physics group at the University of Torino started in 2008 a project involving different departments and institutions, still ongoing, with the aim of creating a provenance protocol based on Ion Beam Analysis[5]. In fact, the use of μ-PIXE and μ-IBIL has proved effective in finding markers within reference geological rocks able to distinguish among five provenances (Afghanistan, Tajikistan, Siberia, Chile and Myanmar, this last one recently added and under study[6]). The markers can be then exploited to relate the raw material used for artifacts production to a specific geological source. The possibility of applying these techniques both in vacuum and in air (in this case without any sample preparation) ensures at the same time a non-invasive and high-sensitive approach, also in the case of archeological samples. Due to the lapis lazuli heterogeneity, minero-chemical markers are searched inside single mineral phases, exploiting the IBA capability to investigate matter down to the single crystal scale with a microprobe. The sample provenance can be investigated by scanning micrometric areas of its surface, and the target crystals are usually pre-identified with cold-Cathode Luminescence maps (when allowed by the sample dimensions) and SEM-EDX analysis, avoiding unnecessary irradiation of the sample and minimizing the analysis time.

The realized protocol has been so far applied to different archeological artifacts of various museum collection[5-7], successfully obtaining results regarding the provenance of the lapis lazuli material. μ-PIXE and μ-IBIL have been performed at the in-vacuum microbeam line of the National Laboratories of Legnaro of the Italian National Institute of Nuclear Physics and at the external microbeam lines at INFN-LABEC (Florence) and also, within the CHARISMA, IPERION CH and IPERION HS European programs, at the NewAGLAE facility (C2RMF, Paris).

An overview of the non-invasive methodologies selected and adopted in the protocol for approaching the provenance problem of lapis lazuli will be presented and discussed, together with some examples of case studies involving archaeological artifacts and future prospects.

Author: Ms MAGALINI, Marta (Università degli Studi di Torino, Italy)

Co-authors: Dr GUIDORZI , Laura (Istituto Nazionale di Fisica Nucleare (INFN) –Torino section); Dr RE, Alessandro (Physics Department, Università degli Studi di Torino, Italy); Prof. LO GIUDICE, Alessandro (Physics Department, Università degli Studi di Torino, Italy)

Presenter: Ms MAGALINI, Marta (Università degli Studi di Torino, Italy)

Session Classification: Interpretation, presentation and dissemination of the scientific results. Case studies and success stories

Track Classification: Track 2: Interpretation, presentation and dissemination of the scientific results