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ISAGE – in situ dating of planetary surfaces

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Abstract

We propose a concept for an in situ dating experiment for a planetary mission, based on ^{40}Ar-^{39}Ar dating and cosmogenic noble gas nuclides.

^{40}Ar-^{39}Ar dating

Radioisotopic dating is an essential tool to decipher planetary differentiation and impact cratering histories. Particularly ^{40}Ar-^{39}Ar dating is a highly successful technique, and was widely applied to date extraterrestrial rocks, either Apollo samples or lunar, Martian and asteroidal meteorites, or to decipher the terrestrial cratering record [e.g. 1-4]. This dating technique is based on the classical K-Ar dating method, which uses the decay of ^{40}K to ^{40}Ar, and exploits the diffusivity of argon in order to identify primary (e.g. crystallization) as well as secondary events (e.g. reheating during impact cratering). However, this technique needs a neutron source, which complicates a mission based experimental design [5].

Mission concept

Recent efforts to study the realization potential of ISAGE focused on neutron sources and irradiation geometry, and mass spectrometric capabilities. Though disadvantages concerning radiation protection, a 10 mg ^{252}Cf source seems to be more promising than alternatives like e.g. portable sources based on deuterium and tritium fusion. Appropriate irradiation geometries were checked using MCNP calculations at FRM II, e.g. a sample irradiated by Cf distributed in a spherical geometry of a few cm radius. An important gain in neutron dose can be achieved by the use of a few cm neutron reflector. ^{39}Ar produced from an (n,p) reaction from ^{39}K could be measured mass spectrometrically, though the expected amount of 10^{-12} cm³ STP would be technically challenging for current miniaturized instruments. The amount of the critical isotope ^{39}Ar, of course, depends on further mission details such as duration of neutron irradiation.

Synergies

Our concept allows to simultaneously measure cosmogenic nuclides produced by interaction of the upper meter surface of a solid body with cosmic rays. This will produce noble gas nuclides such as ^{3}He, ^{21}Ne, or ^{38}Ar which allows to determine the time of surface exposure. Solar wind implanted ions (also helium and neon isotopes with specific characteristic isotopic compositions) can also be measured in order to e.g. estimate regolith mixing processes. Typical lunar samples have concentrations of these nuclides allowing safe detection. Moreover, the neutron activated samples also offer the possibility of instrumental neutron activation analyses of certain chemical elements, allowing important characterization of dated samples.

References

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