THE POTASSIUM-ARGON LASER EXPERIMENT (KArLE): IN SITU GEOCHRONOLOGY FOR PLANETARY ROBOTIC MISSIONS.

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Introduction: Isotopic dating is an essential tool to establish an absolute chronology for geological events, including crystallization history, magmatic evolution, and alteration events. The capability for in situ geochronology will open up the ability for geochronology to be accomplished as part of lander or rover complement, on multiple samples rather than just those returned. An in situ geochronology package can also complement sample return missions by identifying the most interesting rocks to cache or return to Earth.

KArLE method: The K-Ar Laser Experiment (KArLE) brings together several flight-proven components to provide precise measurements of potassium (K) and argon (Ar) that enables accurate isochron dating of planetary rocks [1]. KArLE will ablate a rock sample, measure the K in the plasma state using laser-induced breakdown spectroscopy (LIBS), measure the liberated Ar using mass spectrometry (MS), and relate the two by measuring the volume of the ablated pit by optical imaging. Each component of the KArLE experiment (LIBS, MS, density, and volume) has been individually developed for application in a flight environment, yielding accurate measurements with 5-10% precision. Three separate laboratories have worked over the last several years to verify the measurement capabilities and performance of this approach [1-3] and the K-Ar approach to in situ dating has been validated by the Curiosity rover on Mars [4].

Results: We used breadboard component-level testing to demonstrate the viability of the individual KArLE analytical methods. We then conducted complete KArLE geochronologic studies of rock sample with known K-Ar age and potassium contents to demonstrate that KArLE can provide robust data with sufficiently high precision to represent major improvements in our understanding of planetary chronology. The KArLE breadboard testing on planetary analog samples yields good results, giving ages with 25% uncertainty on very young samples (<50Ma) and 10% uncertainties on older samples. These performance results predict that for planetary samples older than 2 Ga, precision will be on the order of ±100 Ma, in line with expectations set by NASA Space Technology Roadmaps. Our component-level proof-of-concept tests and our end-to-end KArLE experiments on analog samples bring the KArLE experiment to Technology Readiness Level (TRL) 4. We plan to further develop the KArLE concept into a well-characterized flight prototype that can be tested in relevant environments.

Many problems in geochronology require the resolution and sensitivity of a terrestrial laboratory and therefore cannot be solved by remote instrumentation. However, appropriate application of in situ dating can overcome such objections in specific situations and meet fundamentally important objectives on the Moon, Mars, asteroids, outer planetary satellites, and other bodies that contain rocky components.

References: [1] Cohen, B. A., et al. (2014) *Geostandards and Geoanalytical Research*, 38, 421-439. [2] Cho, Y., et al. (2015) *Spectrochimica Acta Part B: Atomic Spectroscopy*, 106, 28-35. [3] Devismes, D., et al. (2013) EPSC2013-71. [4] Farley, K. A., et al. (2014) *Science*, 343, 10.1126/science.1247166.