IN-SITU LDRIMS GEOCHRONOMETRY FOR THE MOON AND MARS. F. S. Anderson[1] and K. Nowicki[1], [1]Southwest Research Institute, 1050 Walnut, Suite 300, Boulder, CO 80302 (anderson@boulder.swri.edu).

Introduction: We have developed and tested a bench-top version of a Laser Desorption Resonance Ionization Mass Spectrometer (LDRIMS) instrument for rubidium-strontium (Rb-Sr) geochronology. Current results are sufficient for radiometric dating (±0.1%), though we are working on increasing the precision of the measurement to a more optimal precision for geochronology of ±0.02%. Currently, a sample is placed in a miniature multi-bounce time of flight (MBTOF) mass spectrometer, and a spot on the surface is vaporized with a miniature 266 nm Nd:YAG laser. After removal and measurement of the prompt ions, we ionize just Rb or Sr in the remaining cloud of neutral atoms using resonance ionization (RI), enabling a measurement of sufficient precision for geochronology. Having demonstrated the concept in the laboratory, we are now ready to miniaturize components to prepare for using the instrument in the field in order to demonstrate real-time in-situ dating.

Background: In-situ LDRIMS will enable measurements of 1) isotope geochemistry relevant for chronology and igneous evolution, 2) light isotopes relevant for habitability, life, and climate history, as well as 3) elemental abundances relevant to understanding local and regional geology. Here we focus on chronology.

Deriving the size frequency distribution (SFD) of craters on a given planetary surface has enabled the derivation of relative dates for the Moon and Mars, however, this approach can have a significant error when trying to estimate absolute age. These errors have been mitigated for the Moon by the return and dating of lunar samples from locations of known relative age (**Fig. 1**). By extrapolating the cratering flux at the moon to Mars, and using the relationship between SFD and absolute age, researchers have derived surface ages for much of Mars (**Fig. 2**).

However, significant issues remain for geologic interpretation of these surfaces. For example, lunar cratering flux from 4.4-3.8 Ga [3-7], known as the late heavy bombardment (LHB), was much higher than the relatively constant rates following the LHB, however, it is unclear [7,8]: 1) whether cratering flux peaked at 3.8 Ga [9], 2) how the LHB effected other surfaces in the solar system, 3) whether cratering flux in the last 0.5 Ga has increased, and 4) if the currently disputed [8] hypothesis that the samples supporting a global LHB in fact are all derived from the Imbrium basin

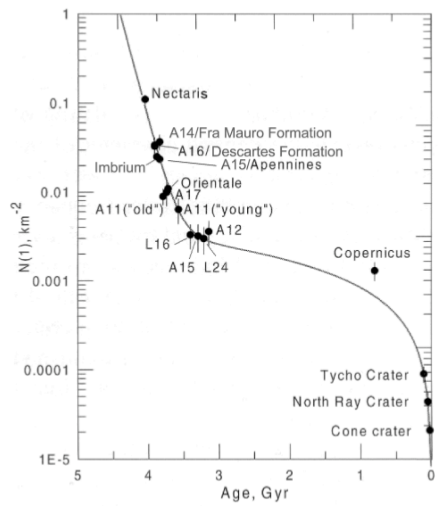

Figure 1: Lunar cratering chronology [adapted from 1].

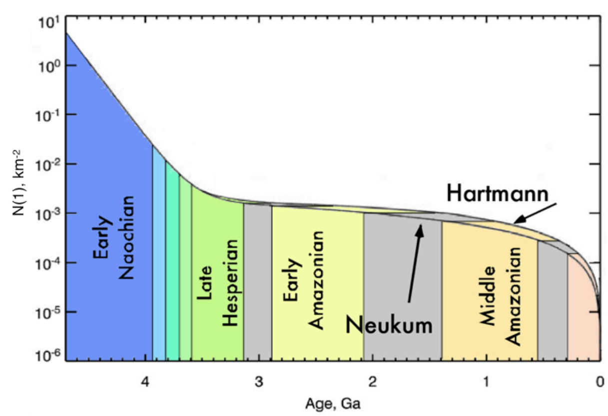

Figure 2: Impactor flux versus age for Mars [2].

[10]. Furthermore, there are significant assumptions built into the extrapolation of the lunar surface ages to other planets, in particular that the ratio of impact fluxes on the two bodies is known [8]. For Mars, uncertainties in these assumptions, result in two possible flux curves with differences of >1Ga (**Fig. 2**; [2]).

New in-situ radiometric measurements for the Moon and Mars would significantly improve geologic interpretation of these complex surfaces and constraining impactor flux throughout the solar system.

Initial Results: Advances in analytical chemistry have led to the development and commercial use of LDRIMS, which avoids the interference and mass resolution issues associated with geochronology measurements, and has miniaturization potential. In this method, laser desorption is used to vaporize a small sample of the target rock, generating >99.9% neutral atoms and <0.1% ions, and then tuned lasers are used to excite the resonances of neutral Sr or Rb, followed by photoionization of the excited atoms.

We have constructed a laboratory scale LDRIMS to assess the possibilities for using the RI technique in an in-situ flight environment. The instrument consists of a small laser desorption subsystem, a resonance ionization subsystem, a multi-bounce time of flight mass spectrometer developed for phase A of a flight proposal, and controlling electronics. Our prototype LDRIMS has had excellent success exciting Sr with small amounts of laser power (<50μJ for 461 &554), with a typical measurement precision of ±0.1% (see **Fig. 3 & 4**). A miniature RI laser system is possible for these low power requirements.

In order to achieve a precision of ±0.02%, two issues remain to be solved: 1) laser power jitter results in slight variations in measurement precision (**Fig. 4**). To overcome this issue, we are implementing power measurements on all lasers, in order to enable us deconvolve this effect. 2) LDRIMS can impart a broad energy distribution to individual isotopic masses, causing them to overlap, and influencing both precision & accuracy (causing accuracy offsets of up to 30% like those seen in **Fig. 4**). While these can be corrected by measurement of standards, our initial results show that we can resolve this issue by spreading the peaks using the bouncing mode of the MBTOF (**Fig. 5**). Measurements like these have shown improved precision and accuracy (error <0.04%). We anticipate that these modifications will allow us to achieve our target precision for geochronology.

Future Work: Because our current work suggests that a precision and accuracy sufficient for geochronology can be achieved, we are now focusing on miniaturizing the RI laser subsystem. The MBTOF and the LD subsystem are already small enough to be credible for space flight.

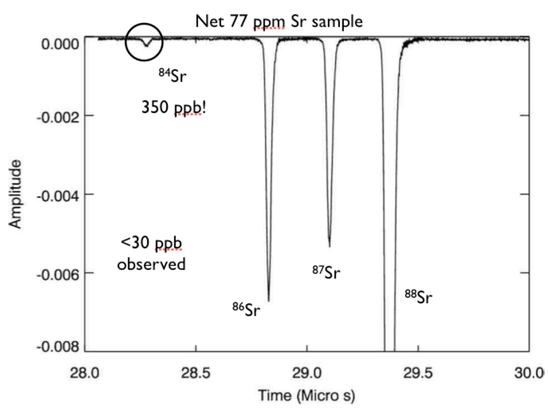

Figure 3: Example of LDRIMS spectrum of strontium for Shergotite plagioclase analog sample. Note sensitivity to well below 1 ppm, supporting age estimate better than predicted. Log plot of this data shows peaks overlap.

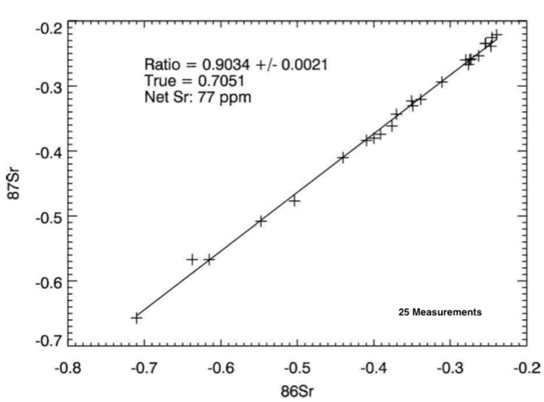

Figure 4: Example of LDRIMS precision; note that accuracy offset results from overlapping peaks, and will be mitigated by MBTOF and use of standards.

References:

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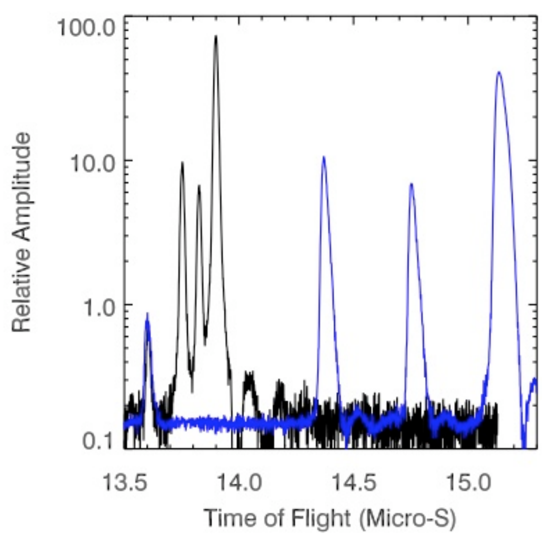

Figure 5: Initial MBTOF logarithmic data for Sr RI showing overlap in linear TOF mode (black), and clear mass separation after 3 bounce cycles (blue). Spectra arbitrarily moved to overlap ^{84}Sr peak.