

**The Potassium-Argon
Laser Experiment
(KArLE): *In Situ*
Geochronology for
Planetary Robotic
Missions**


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Image created under contract to Cohen

KArLE **Geochronology: More than just rock ages** 

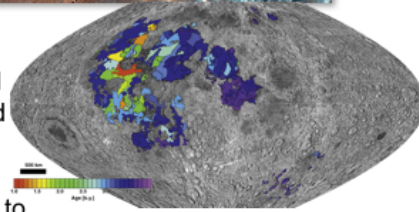
- What are the constraints on the **time evolution** of the dynamic solar system? **When** did the outer planets migrate and the asteroid belt lose mass? How did it affect other bodies **at that time**?
- **When** was Mars warm and wet? **How much time** did organisms have to thrive in this environment? What was going on elsewhere in the solar system **at this time**?
- **How long** were planetary heat engines active? What are the differences in heat dissipation and magma formation between the Moon, Mars, and large asteroids?
- **How long** have current surfaces been exposed to (and possibly changed by) the space environment?



Rheasilvia basin, Vesta



Ancient Martian Crust, Syrtis Major



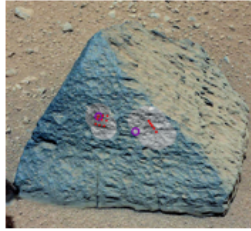
Heat map of Vesta showing age distribution with a color scale from 0 to 4.5 billion years.

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http://dawn.jpl.nasa.gov/multimedia/vesta_south_pole.asp

Syrtis Major is from Ehlmann, B. L., et al. (2009), Identification of hydrated silicate minerals on Mars using MRO-CRISM: Geologic context near Nili Fossae and implications for aqueous alteration, *J. Geophys. Res. Planets*, 114. – Fair use

Lunar volcanism is from Hiesinger, H., R. Jaumann, G. Neukum, and J. W. Head (2000), Ages of mare basalts on the lunar nearside, *J. Geophys. Res.*, 105, 29239-29276. – Fair use

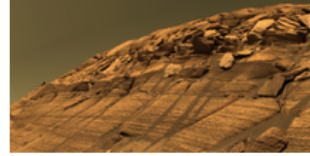


Igneous rocks

- Crustal base of every rocky body
- K-rich accessory minerals to give wide spread of parent/daughter
- Well-studied ^{40}Ar - ^{39}Ar ages and diffusion characteristics (based on meteorites)

Phyllosilicates (clays)


- Identified on Mars and asteroids
- Indicator of neutral, habitable environment
- May hold biosignatures
- K-rich illite common in basalt-derived phyllosilicate assemblages




Sulfates

- Widespread identification on Mars
- Indicator of acidic, generally uninhabitable environment
- K-rich jarosite common in terrestrial sulfate assemblages
- Well-studied ^{40}Ar - ^{39}Ar ages and diffusion characteristics

<http://mars.nasa.gov/mer/gallery/press/opportunity/20041213a.html>
<http://www.nasa.gov/topics/solarsystem/features/life-components.html>
https://www.nasa.gov/mission_pages/msl/multimedia/pia16192.html



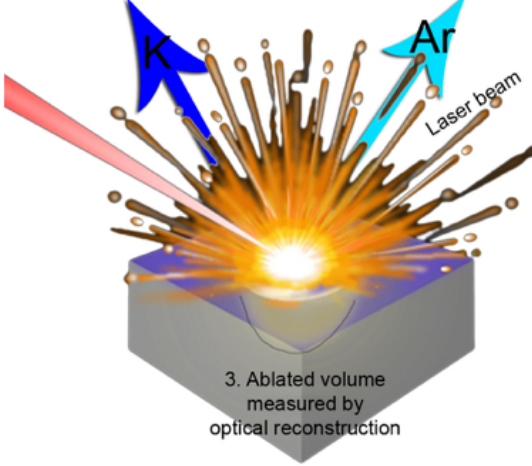
KArLE concept



- Use TRL 9 components to achieve new science
 - payload synergy
 - reasonable cost
 - low risk
 - real conops
 - near-term implementation
- K measured using laser-induced breakdown spectroscopy (e.g. Chemcam), also ablates the rock
- Liberated Ar measured using mass spectrometry (e.g. SAM)
- K and Ar related by volume of the ablated pit using optical measurement (e.g. MAHLI)

1. K excited by laser energy, emission measured by spectrometry

2. Liberated Ar measured in gaseous state by mass spectrometry



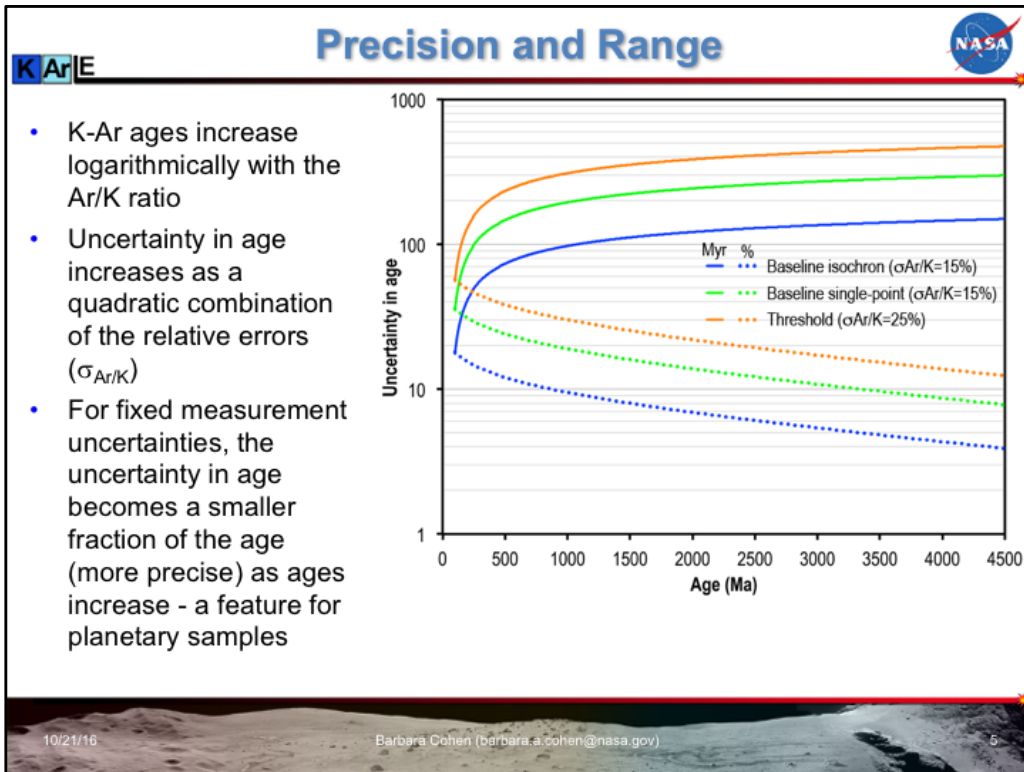
3. Ablated volume measured by optical reconstruction

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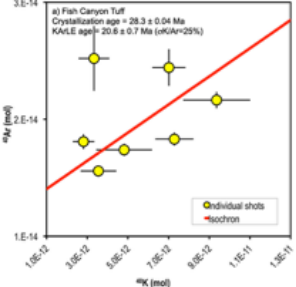
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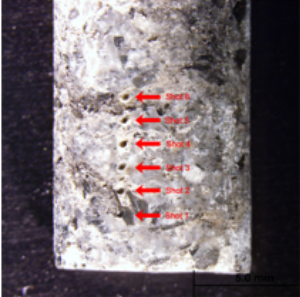


Measurements & uncertainties



- LIBS measures K ($\sigma_L=10\%$), also breaks sample matrix and releases noble gases
- ^{40}Ar and noble gases measured by mass spectrometry ($\sigma_A=3\text{-}5\%$)
- Density from bulk composition ($\sigma_p=5\%$)
- Volume from optical reconstruction ($\sigma_V=10\text{-}15\%$)
- Actual magnitude of uncertainties set by calibration, element abundances, blanks, and backgrounds
- **Results yield whole-rock ages within error of accepted ages and precision close to theoretical = TRL 4 (validation in the laboratory)**

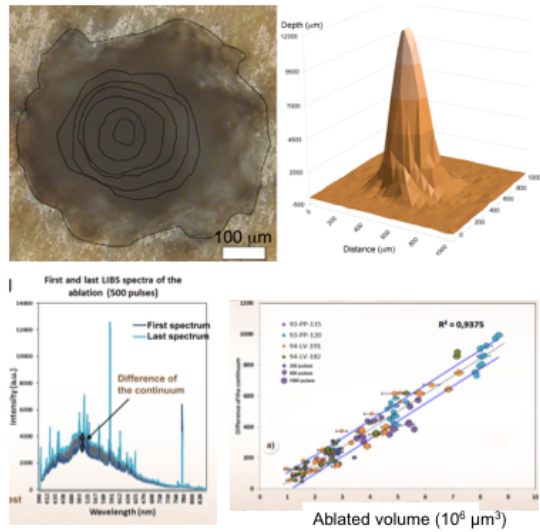




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- Volume from optical reconstruction (French et al. 2014) LIBS continuum (Devismes et al. 2014), QMB (Devismes et al. 2015) ($\sigma_v=10-15\%$)

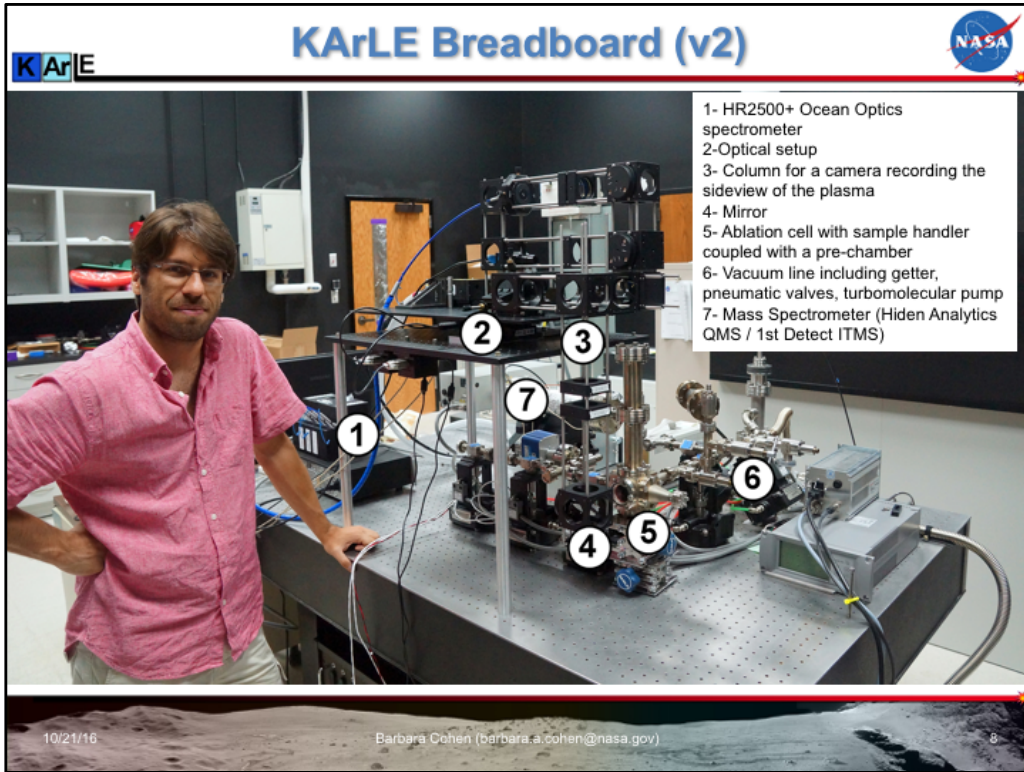


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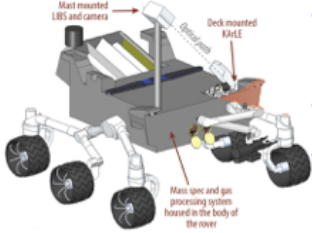
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KArLE flight concept (example)



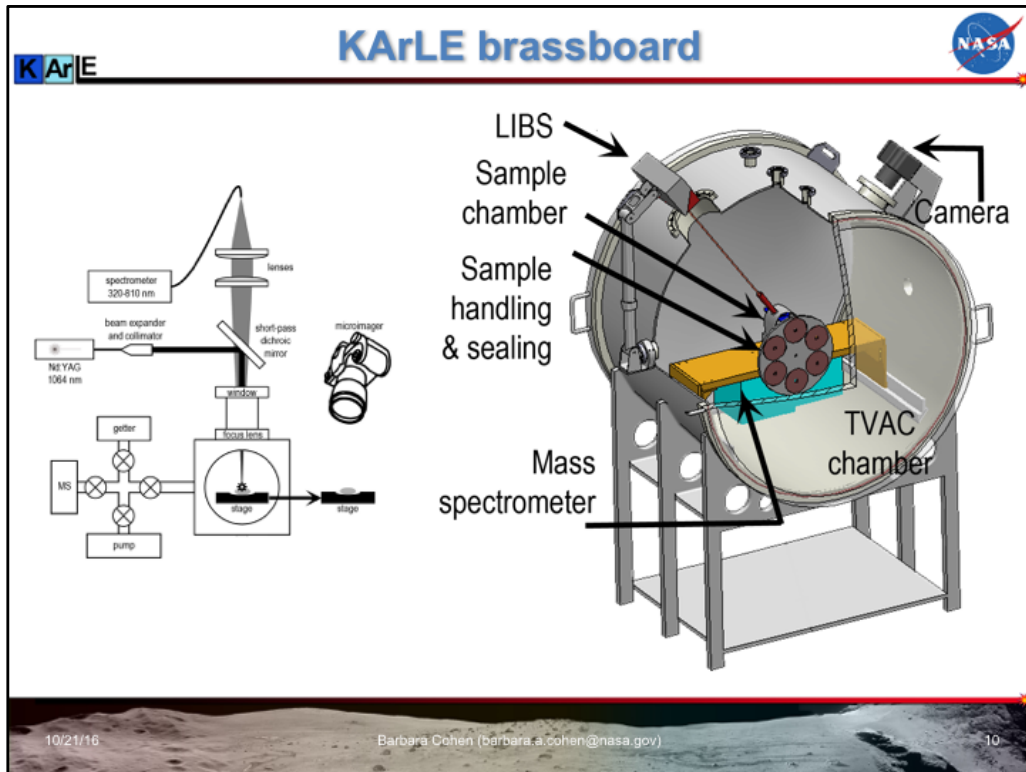
- Partner-provided instrument suite; agnostic to specific analysis providers
- KArLE-specific hardware is mechanically simple
- Flexible implementation with multiple sample delivery systems – core, scoop, etc.
- Internal and external calibration targets monitor dust and vapor buildup
- KArLE chamber & hardware ~3 kg; dimensions 35 x 40 cm; power = 0W
- Complete payload ~20 kg; distributed volume; power = 10 – 66 W

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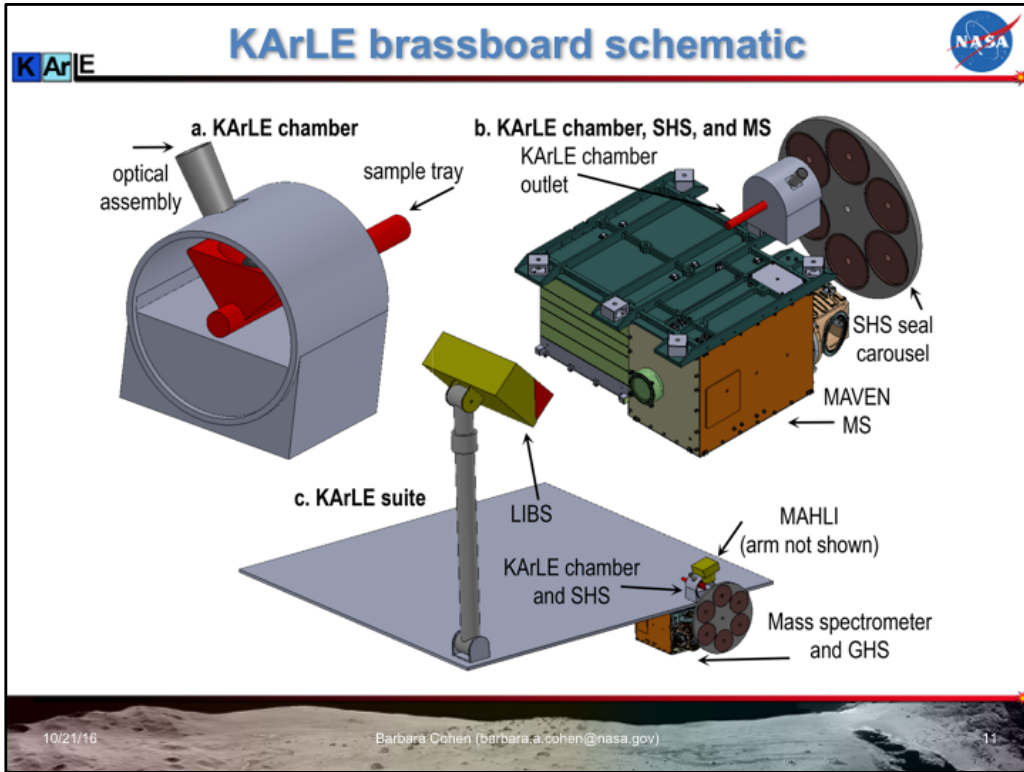
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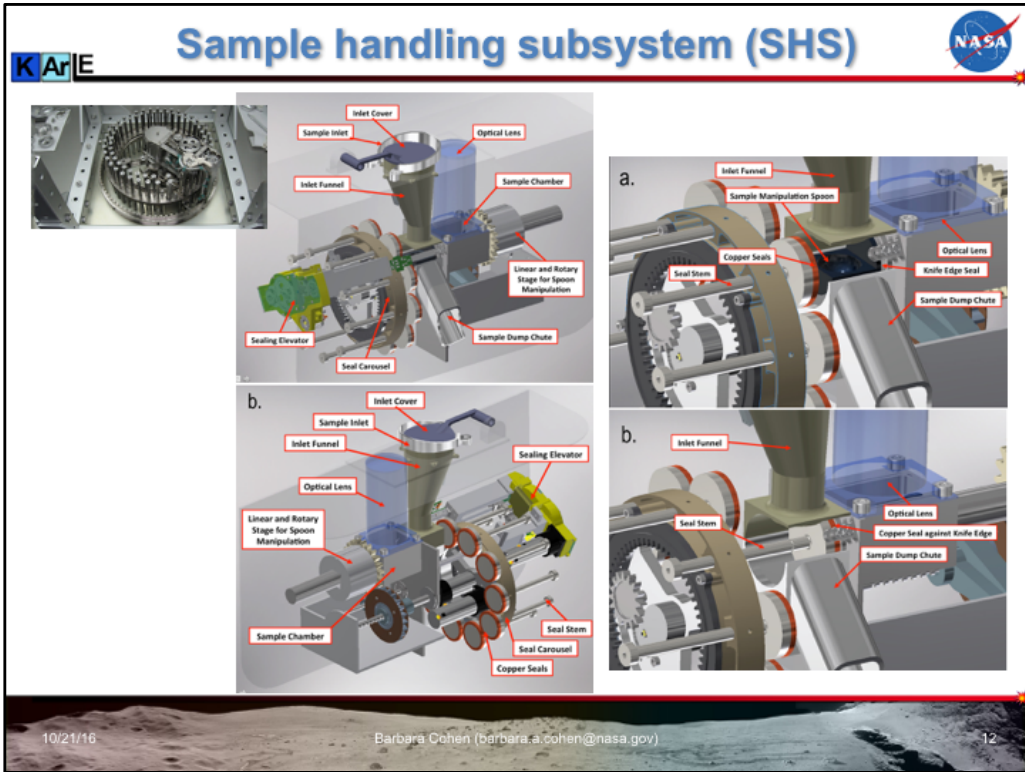
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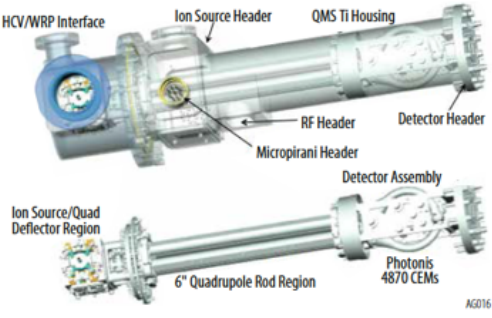


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Gas handling subsystem (GHS)

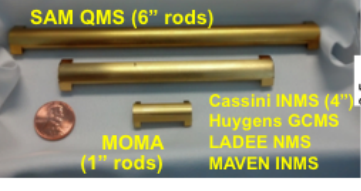




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KArLE QMS sensor assembly comprising the three main hardware elements (ion source, rod assembly, and detector) within a custom Ti housing with multi-pin headers. Total length ~ 30 cm.

The KArLE QMS leverages the flight design of (left) the Sample Analysis at Mars microvalves; and (right) the hyperbolic rods for SAM, Cassini-Huygens, MSL, LADEE, MAVEN, and ExoMars.

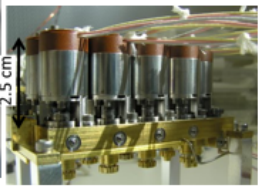


MOMA (1\" data-bbox="250 380 305 400"/>

Cassini INMS (4\" data-bbox="325 355 425 375"/>

LADEE NMS

MAVEN INMS



2.5 cm

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- *In situ* dating **does not replace** sample return - however, we can't get samples from everywhere in the solar system
- KArLE can determine the age of geologic samples with 10-15% precision, sufficient to address a **wide range of fundamental questions** in planetary science
- We achieve this using **flight-proven components** with no consumables or inherently limiting steps, enabling thousands of measurements
- KArLE-specific hardware is a simple, low-cost, value-added addition to a **synergistic payload** that achieves analyses common to most planetary surface missions (elemental and volatile analysis, microimaging)
- Flight heritage of components ensures they will fit (mass, volume, power) on future landers or rovers to the **Moon, Mars, Asteroids** (Phobos, Vesta, Ganymede)

