RB-SR DATING WITH ACCURACY OF < ±150 MA USING A PORTABLE LDRIMS FOR THE 2020 MARS ROVER

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Goals

We propose a Mars in situ geochronology mission that will triage and validate samples for Mars Sample Return (MSR). This mission will address:

1. The National Research Council Decadal Survey call for: "long-term development of instruments … focusing on the most important future in situ measurements… [including] … in situ geochronology experiments" [1];
2. MEPAG Goals III.A.3-10, but especially 3, specifically call for "Constrain[ing] the absolute ages of major Martian crustal geologic processes… with both in situ and returned sample analysis…";
3. NASA's integrated technology roadmap for Science Instruments, Observatories, and Sensor Systems [2] specifically calls for "Surface Chronology" and "Age Dating [to] ±200 Myr on surface";
4. And from the Mars 2020 SDT charter: ""Explore an astrobiologically … ancient environment … to decipher … geological … history, including … past habitability…" and "Demonstrate… progress towards… return of… well-documented samples…"

The Science: Dating Processes

$$^{87}_{37}Rb \rightarrow {}^{87}_{38}Sr + \beta^- + \bar{\nu} + Q$$

$$^{87}Sr = {}^{87}Sr_i + {}^{87}Rb\left(e^{\lambda t} - 1\right)$$

$$\frac{^{87}Sr}{^{86}Sr} = \left(\frac{^{87}Sr}{^{86}Sr}\right)_i + \frac{^{87}Rb}{^{86}Sr}\left(e^{\lambda t} - 1\right)$$

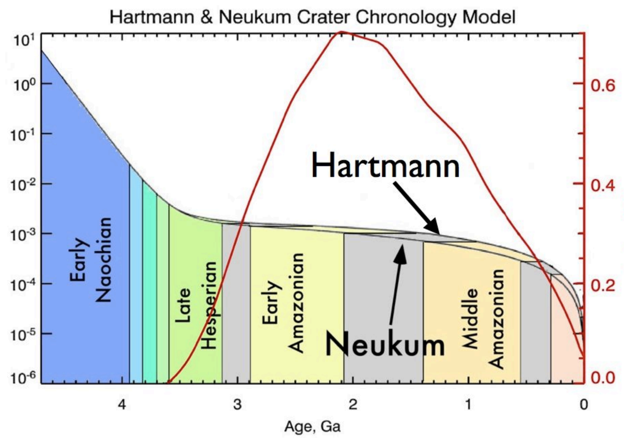
$$\lambda = 1.42 \times 10^{-11} y^{-1}$$

Why Rb-Sr?

- Rb-Sr widely used
- More dependable than K-Ar for SNCs
- Used for igneous, metamorphic, & sedimentary rocks [3]
- Relatively immobile [3]

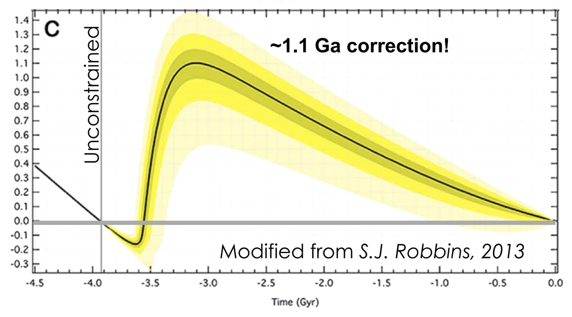
Understand Mars Chronology [4]

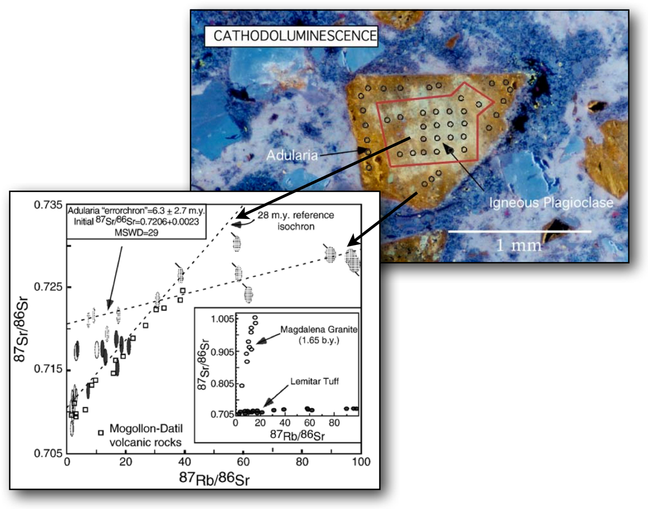
- Current assumptions: Flux similar to Moon & ratio between Moon & Mars fluxes known
- Results in model dependent differences ~700 Ma



However, New Estimates of Moon & Mars Flux Highlight Discrepancies

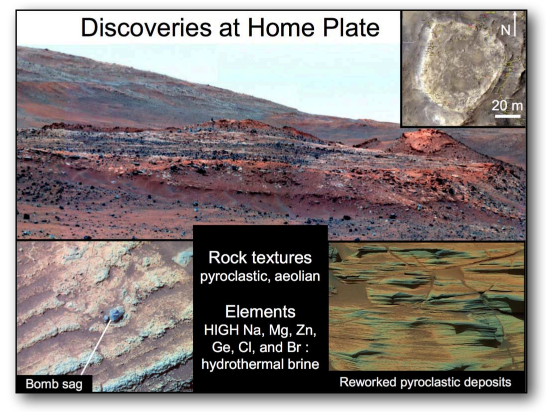
- LROC data suggests that previous flux curves may be wrong
- Provides constraints for identifying regions for isotopic dating





Date alteration by H_2O

- Rb-Sr used to date primary formation and secondary alteration
- Lemitar Tuff, NM, 28 Ma [5]
- Metasomatism & cementation 6 Ma

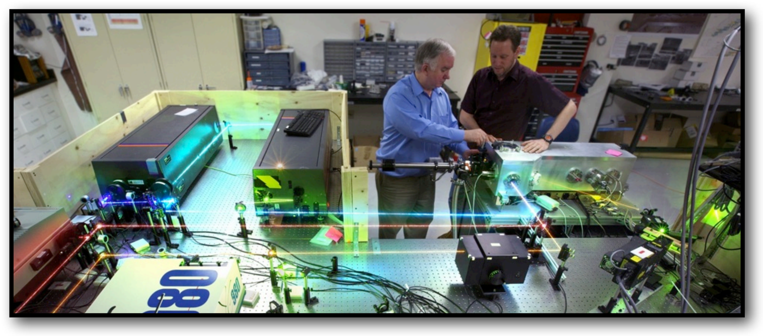


Date Life on Mars?

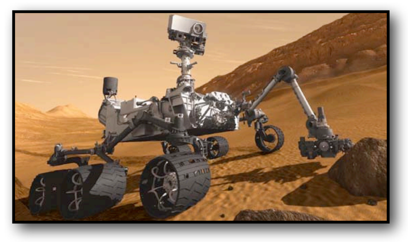
- Aqueous alteration abundant
- Hydrothermal sites ideal for ID'ing life [6]

Laboratory Prototype Demonstrates Repeatability, Accuracy, & Precision of 60-90 Ma

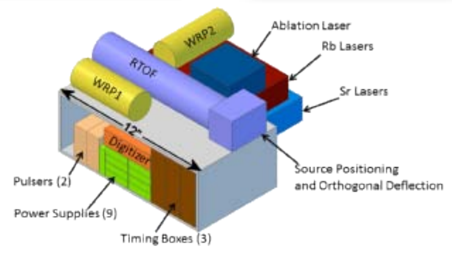
Benchtop LDRIMS: Proof of principle



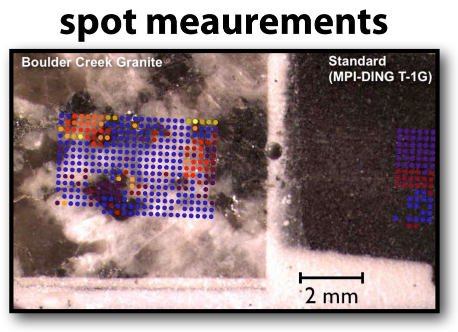
Designs show these systems could fit in a 1³-foot box, compatible with MSL)



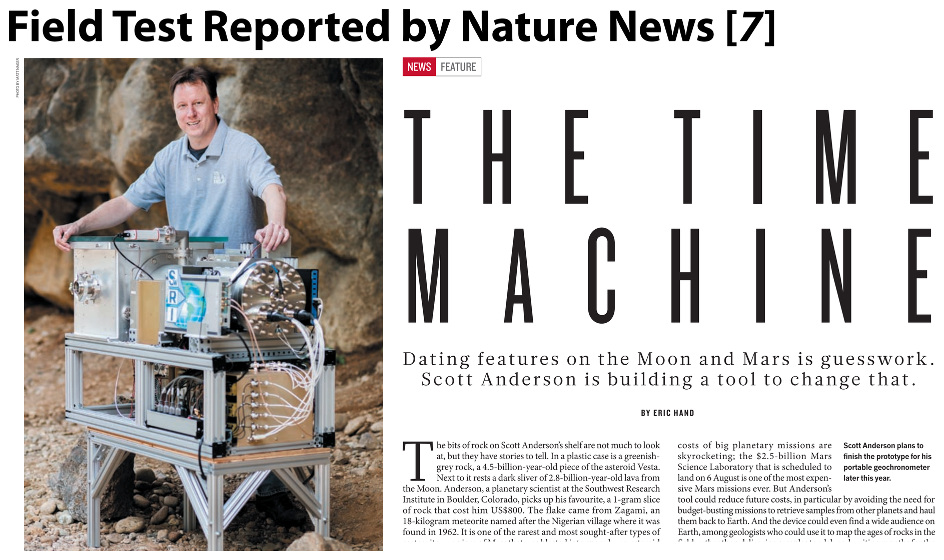
Courtesy K. Zacny, 2011



LDRIMS makes ~300 spot meaurements

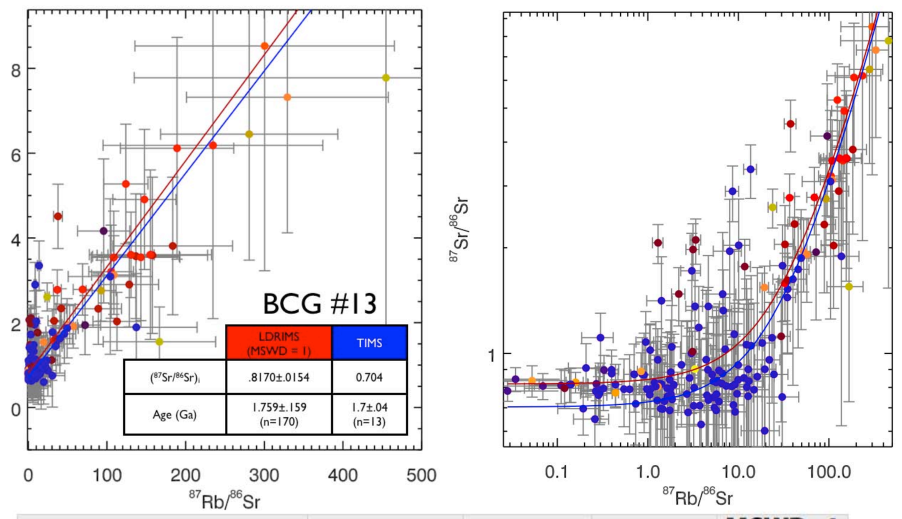


Field Test Reported by Nature News [7]



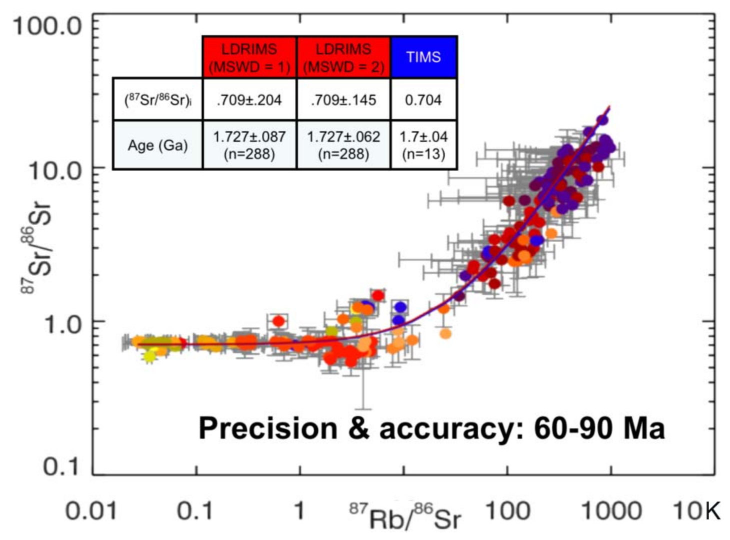
Isochron of the Boulder Creek Granite:

Colorized points correlate with spatial position. A linear fit to the data and error is shown in red; the blue line the is the TIMS result.



Files	Age	MSWD=1 Age Error	$^{87}Sr/^{86}Sr_i$	MSWD=1 $^{87}Sr/^{86}Sr_i$ Error
20120222 BCG #7	1.624	0.138	0.707	0.012
20120514 BCG#10	1.753	0.116	0.602	0.005
20120608-09 BCG#12	1.927	0.176	0.813	0.016
20120821 BCG#13	1.760	0.159	0.817	0.015
Average	1.766	0.147	0.735	0.012

Multiple measurements show repeatable dates.

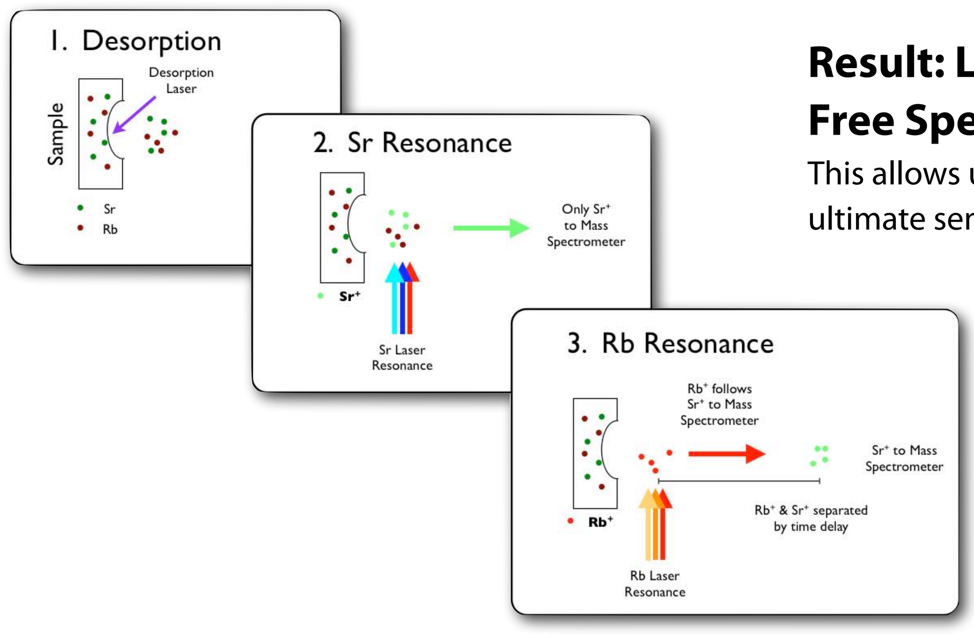


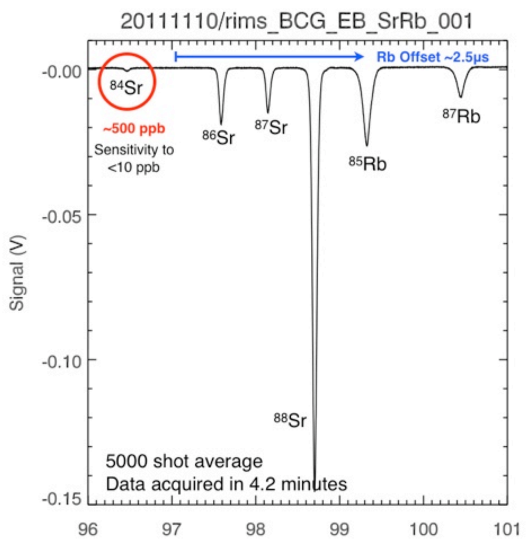
Log-log isochron of BCG #10 using the average of measurement runs as a calibration: A linear fit to the data in log-log appears as a curved line (red); the blue line overprinting the red line is the TIMS result. Error bars exceeding 100% are not shown, but do not strongly influence the fit.

How LDRIMS Works

Laser Desorption Resonance Ionization Mass Spectrometry

1. UV Laser desorption releases neutral atoms from surface
2. Resonance ionization of Sr, and measurement by mass spectrometer
3. After slight delay, resonance ionization of Rb and measurement by mass spectrometer

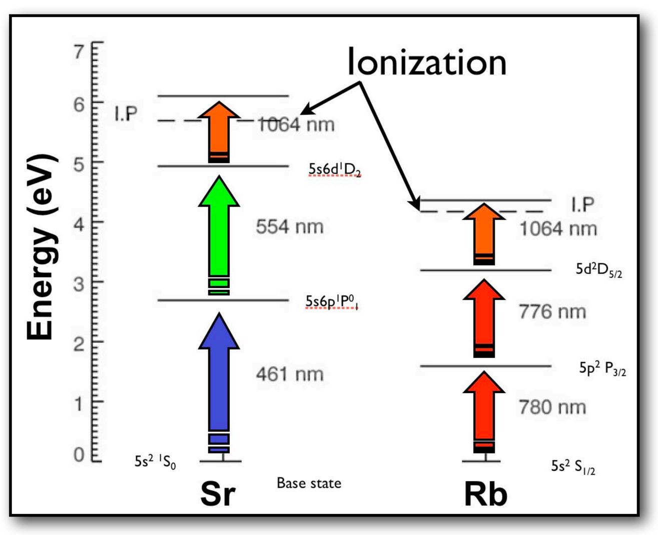




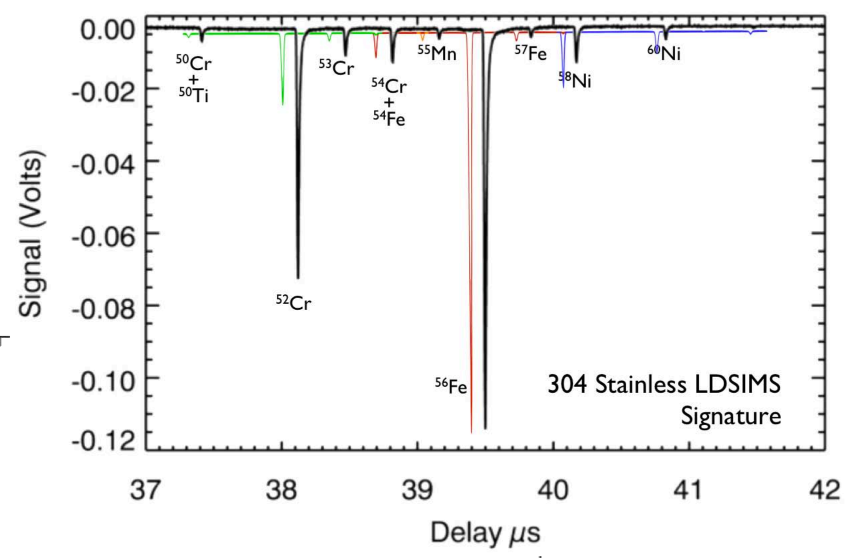
Result: LDRIMS Produces Interference Free Spectra

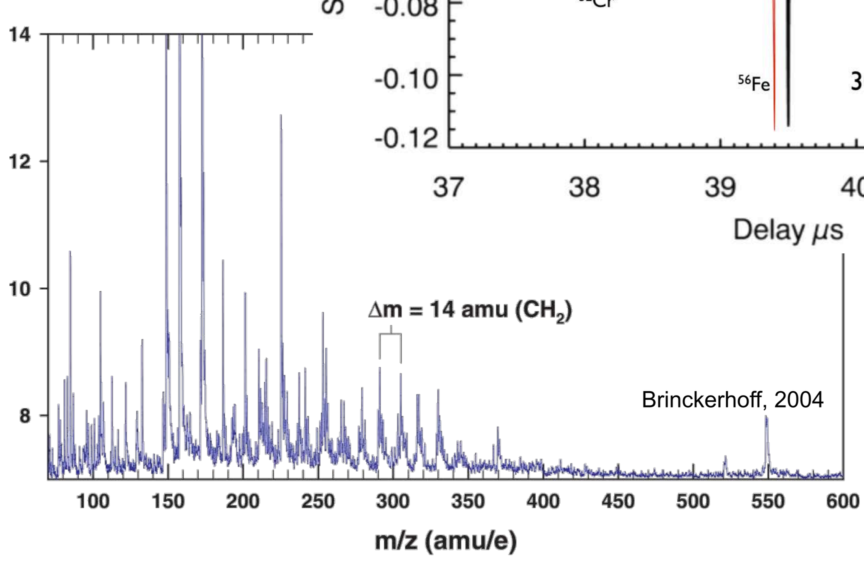
This allows us to easily measure Rb-Sr isotopes with an ultimate sensitivity of ~300 ppt

How Does LDRIMS Avoid Isobaric Interferences?



L2MS Mode: Geochemistry & Organics





Summary & Flight Implementation

1. State of the art in-situ dating has significantly advanced
   - Accuracy and precision ±60-90 Ma
   - Speed < 24 hours
2. Precursor/Triage for MSR; does NOT replace MSR
3. Is important for triage, both scientific and political:
   - Reduces risk of caching by pre-assessing rocks
   - Reduces risk of later mission loss
   - Addresses long fiscal commitment/initial low science return

Payload Component	Our TRL	Flight Analog TRL	Mass (kg)	Power (W)	Total Power (W-hrs)/Date	Volume (cm^3)
Low Voltage Power Supplies (LV PS)	6	9	0.5	0.5	5.0	1000
Computer (SPARC architecture)	6	9	0.5	2.5	25.0	750
XYZ Sample Handling	4	9	0.8	5	0.4	2113
Timing Control (FPGA)	6	9	0.5	0.5	5.0	1000
Dating Source			0.3	0.5	6.25	250
Rb Laser	3	2	2.1	5	63	1170
Ablation Laser	4	6	1	3	38	306
Sr Laser	4	4	2.5	6	75	1418
RTOF & (Pumps, HVPS, ADC, Pulsers)	6	6+	13.0	10	100.0	9767
Proposed LDRIMS-3 Totals			**21**	**33**	**317**	**$1.7x10^4$**
Comparisons						
Portable LDRIMS-2 (Approximate)	4	-	170	500	8000	$5x10^5$
Bench-top LDRIMS-1 (Approximate)	-	-	2000	7000	112000	$8x10^6$
Additional Suggested Science Payload Outside the Scope of this Proposal						
uRaman & electronics		5	2.3	5	4	2400
Probe		5	0.2	-	-	299
Spectrograph		5	-	-	-	950
Arm (IDD)		9	2.5	-	-	-
Drill/Coring/Abrading/scoop		5	1.5	45	8	168
Cameras x3		9	0.795	2	12	94
Camera electronics x3		9				472
Grand Totals			28.5		340	22156

References

1. National Research Council, *Vision And Voyages For Planetary Science In The Decade 2013-2022*, ed. C.o.t.P.S.D. Survey2012: National Academies Press; 2. Barney, R.D., et al., *Draft technology area 08 input: Science Instruments, Observatories, and Sensor Systems*, 2010: NASA; 3. Faure, G., *Principles of Isotope Geology*. 2nd ed1986, New York: John Wiley and Sons. 589; 4. Hartmann, W.K. and G. Neukum, *Cratering Chronology and the Evolution of Mars*. Space Science Reviews, 2001. **96**: p. 165-194; 5. Fritz, D.E., G.L. Farmer, and E.P. Verplanck, *Application of Sr isotopes in secondary silicate minerals to paleogroundwater hydrology: An example from K-metasomatized rocks in the western U.S.* Chemical Geology, 2006. **235**(3–4): p. 276-285; 6. Walter, M. and D.J. Des Marais, *Preservation of biological information in thermal spring deposits: developing a strategy for the search for fossil life on Mars*. ICARUS-NEW YORK-, 1993. **101**: p. 129-129; 7. Hand, E., *Planetary science: The time machine*. Nature, 2012. **487**: p. 422-425.

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