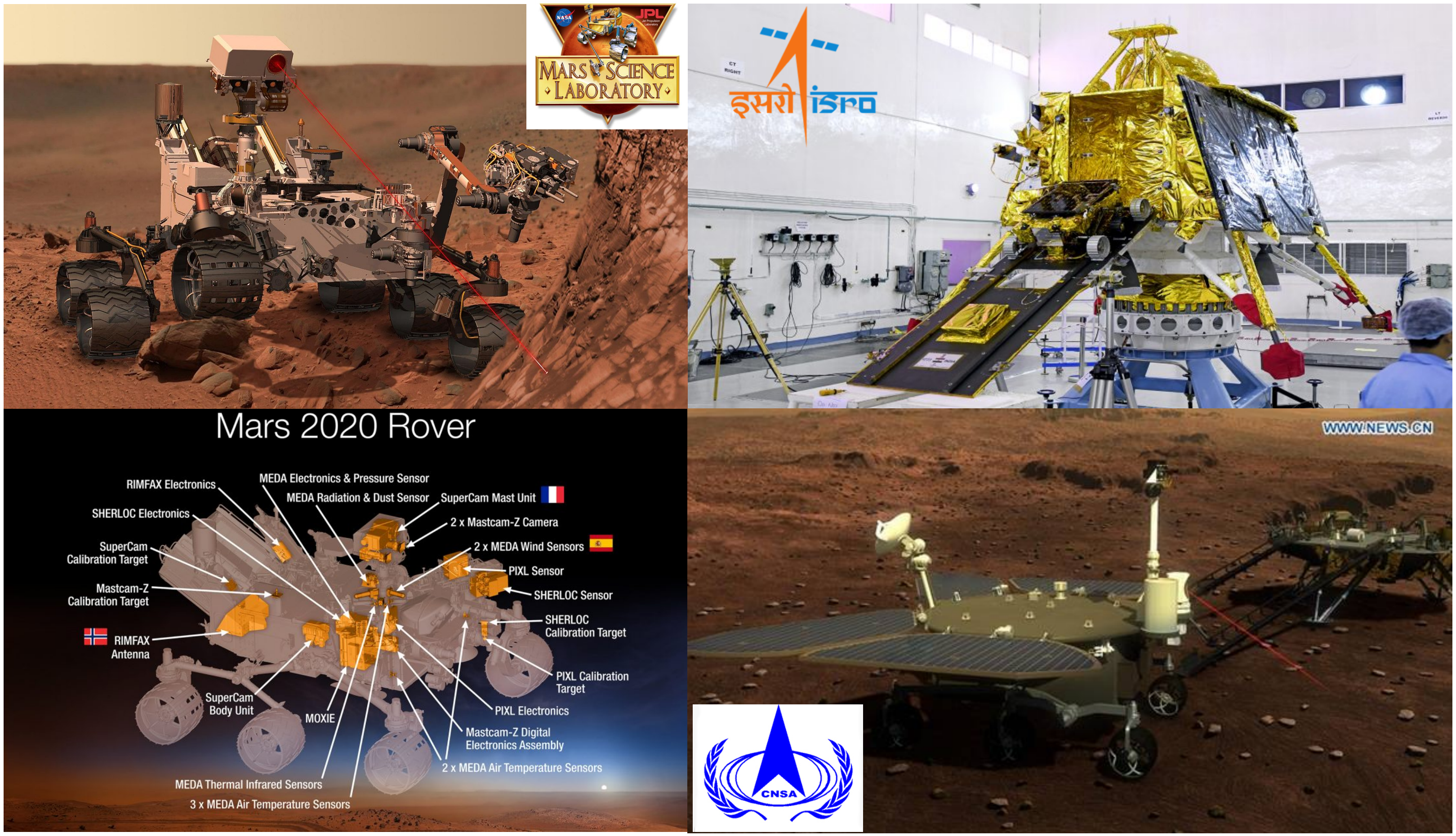
Science enabled by LIBS exploration of planetary surfaces



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Cross-calibration of Laser-Induced Breakdown Spectroscopy (LIBS) instruments for planetary exploration

ISSI Team led by Jeremie Lasue (FR) & Roger Wiens (USA)

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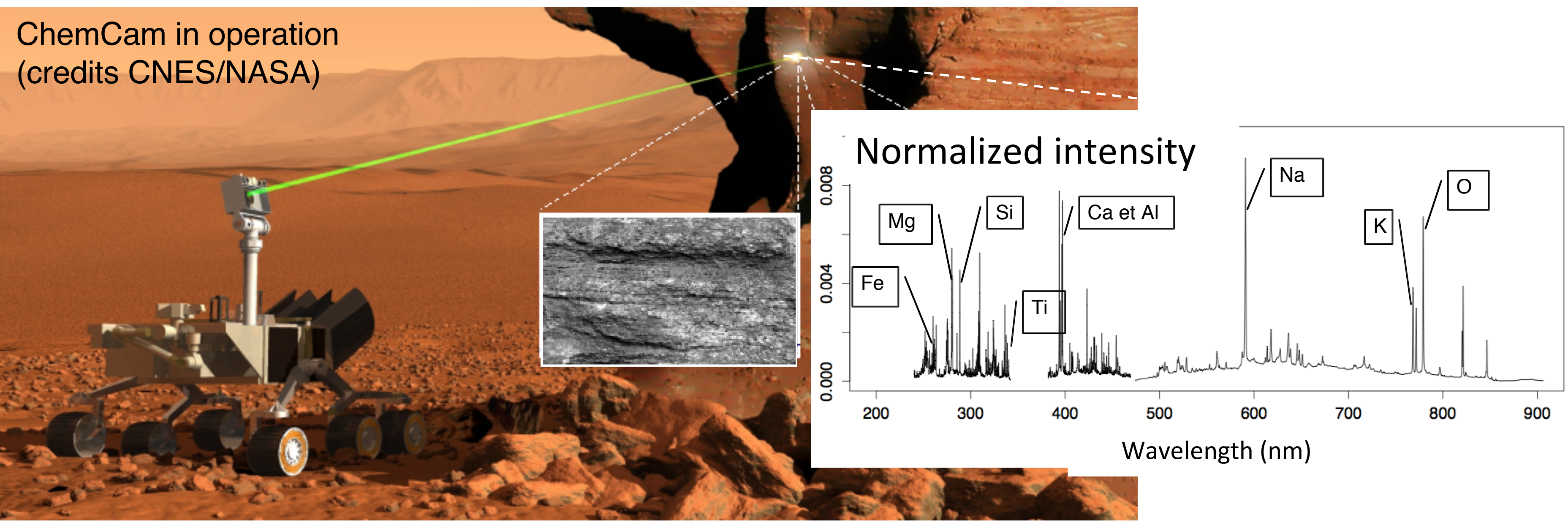
Laser-Induced Breakdown spectroscopy

1) **No** sample **preparation**
2) Fast analysis (**5-20 min; rep. rate 1-3 Hz**)
3) Measurements at a **distance possible** (up to ~10m)
4) Fine scale analysis (~0.5 mm); smaller if in-situ
5) Ablate the surface dust
6) Assess composition variation at different depths to ~1 mm
7) Sensitive to many chemical elements, notably all **major and the light elements** (H, Li, Be, B, C, N, O, etc.)



ChemCam in operation (credits CNES/NASA)

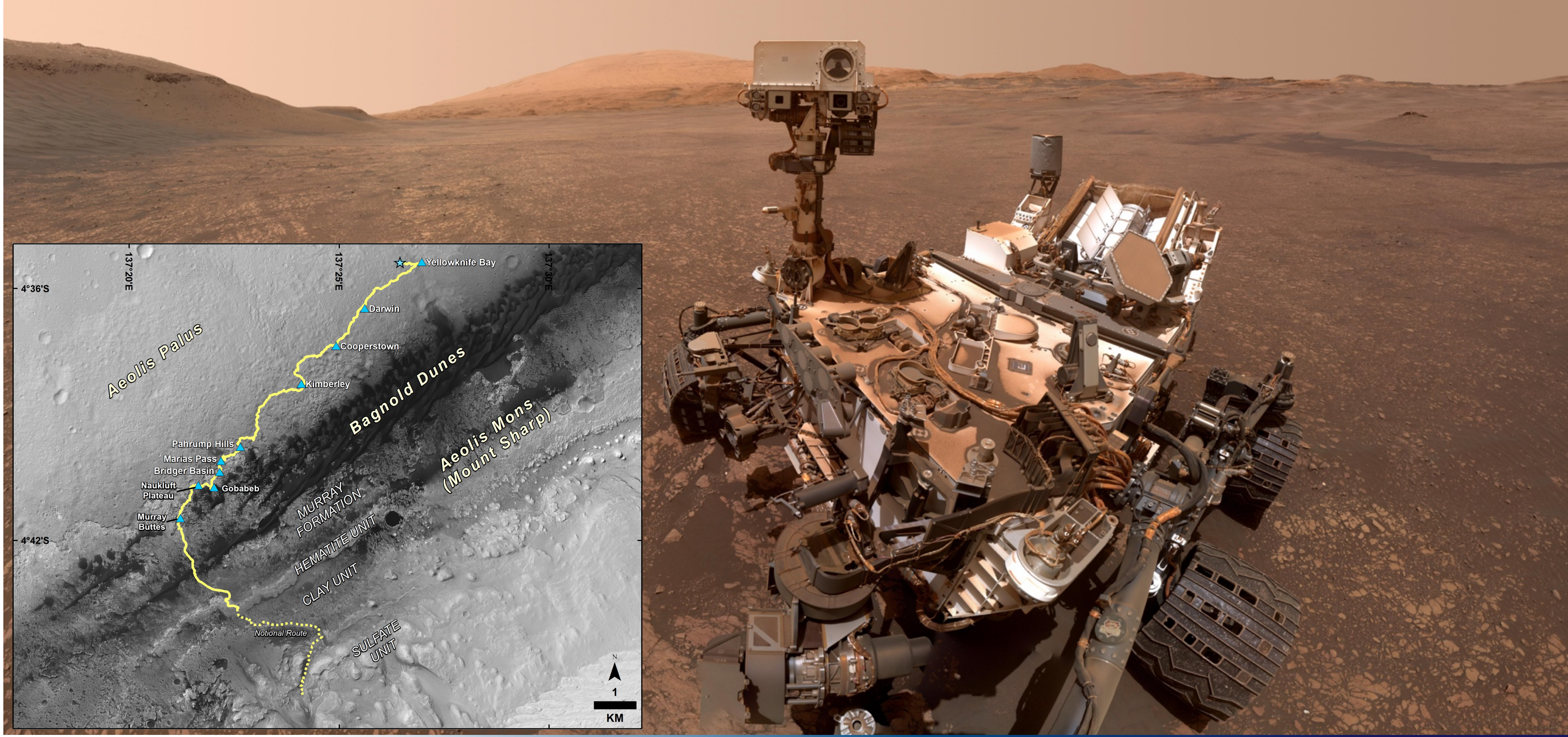
The ChemCam experience

ChemCam on-board MSL has been exploring Gale Crater for the past 7 years, over a 21 km distance (MSL session on Monday).

MSL at the Kilmarie and Aberlady drill site (credit NASA)

Reviews: Wiens et al. Elements 2015; Maurice et al. JAAS 2016

LPSC workshop: https://pds-geosciences.wustl.edu/workshops/ChemCam_Workshop_Mar15.htm



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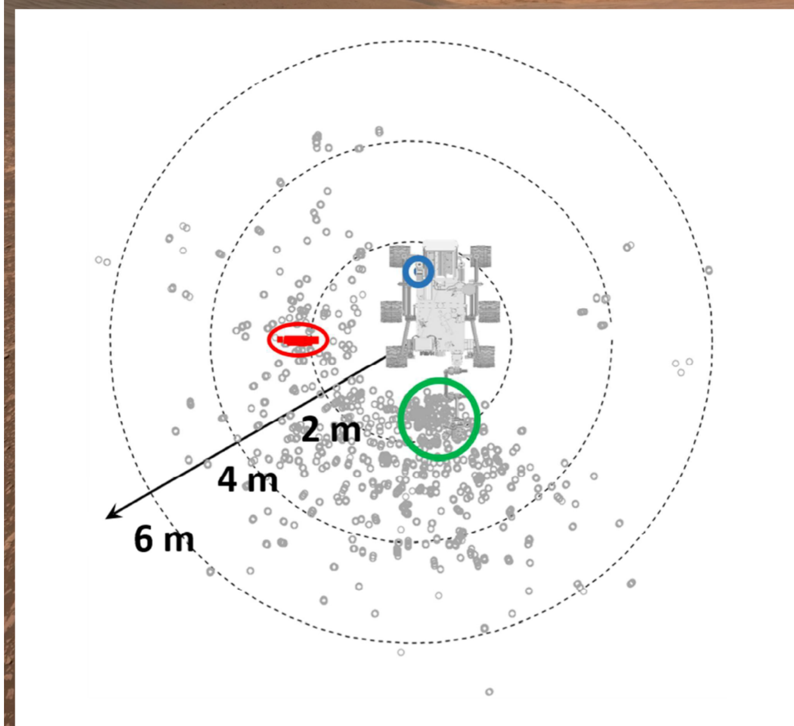
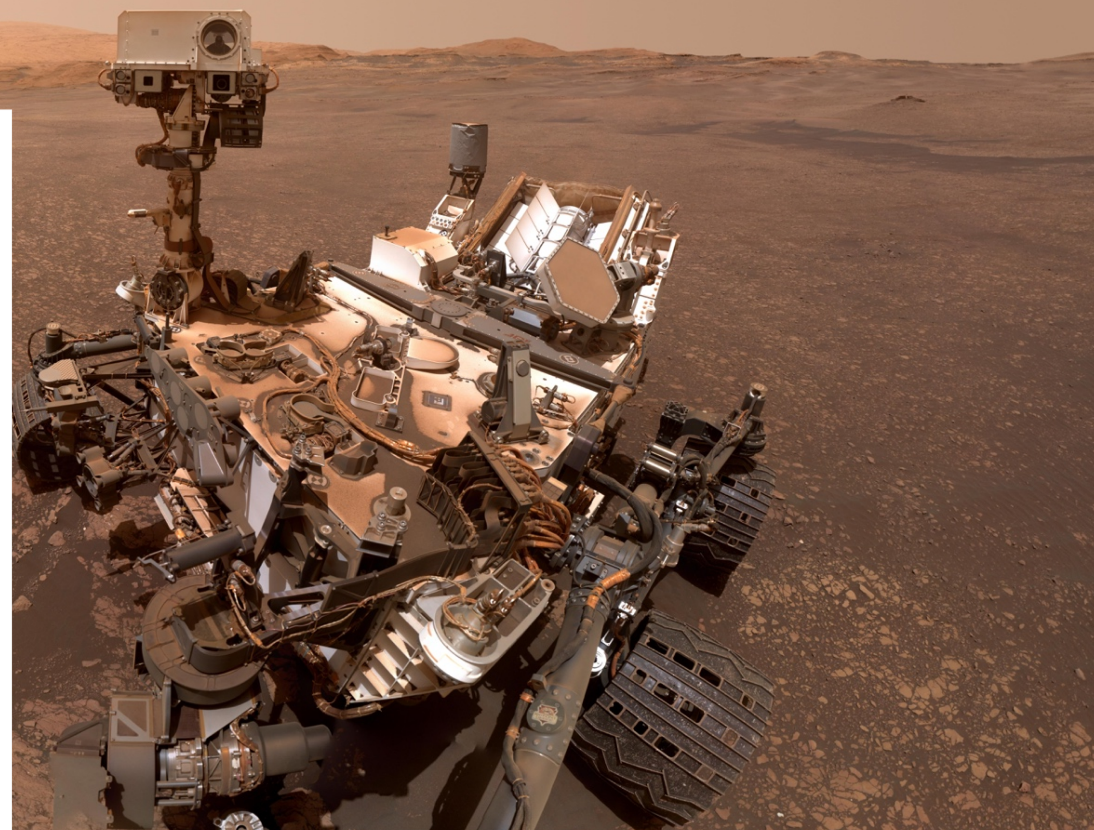
Distribution of targets around the rover

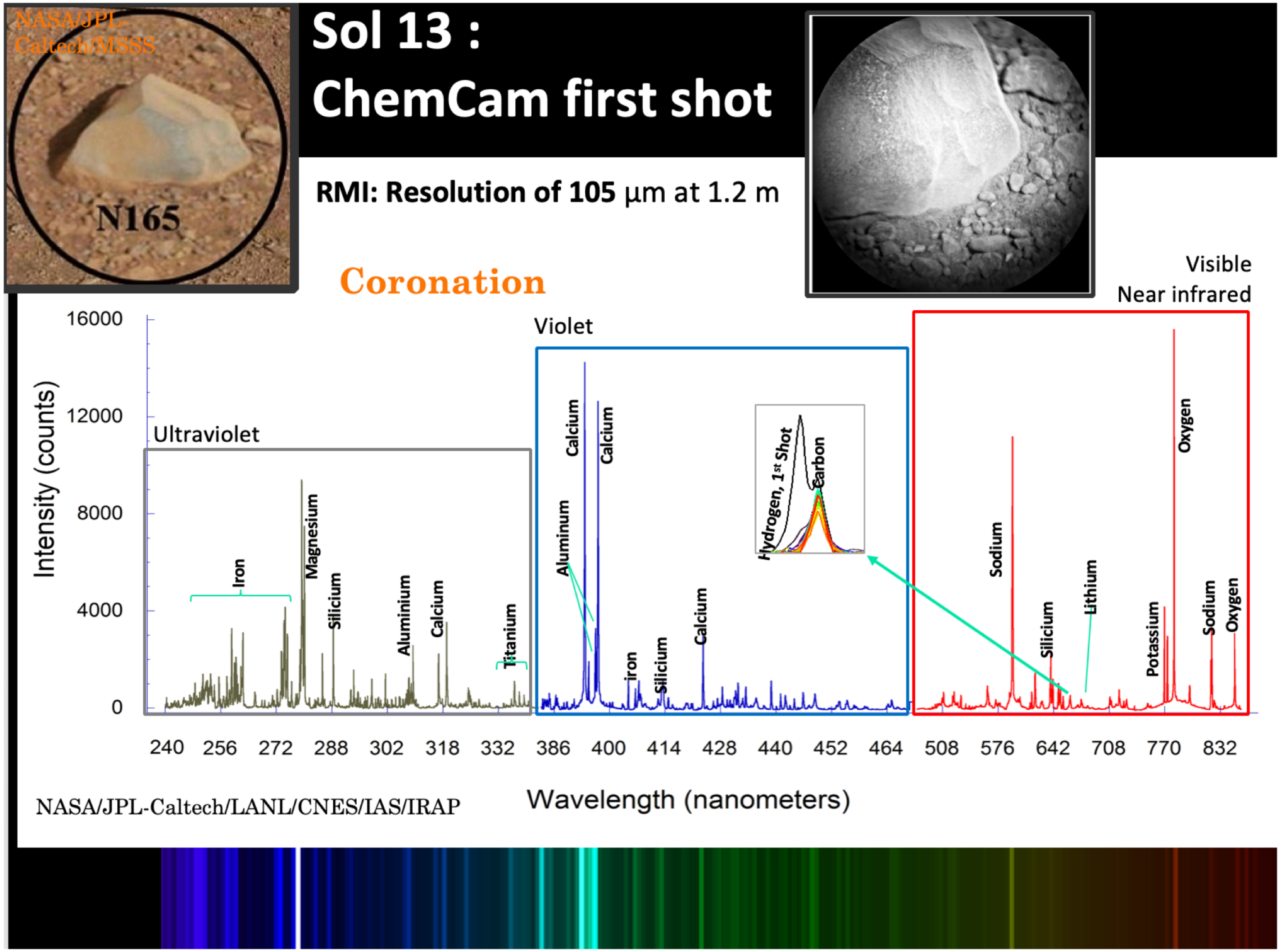




The ChemCam experience

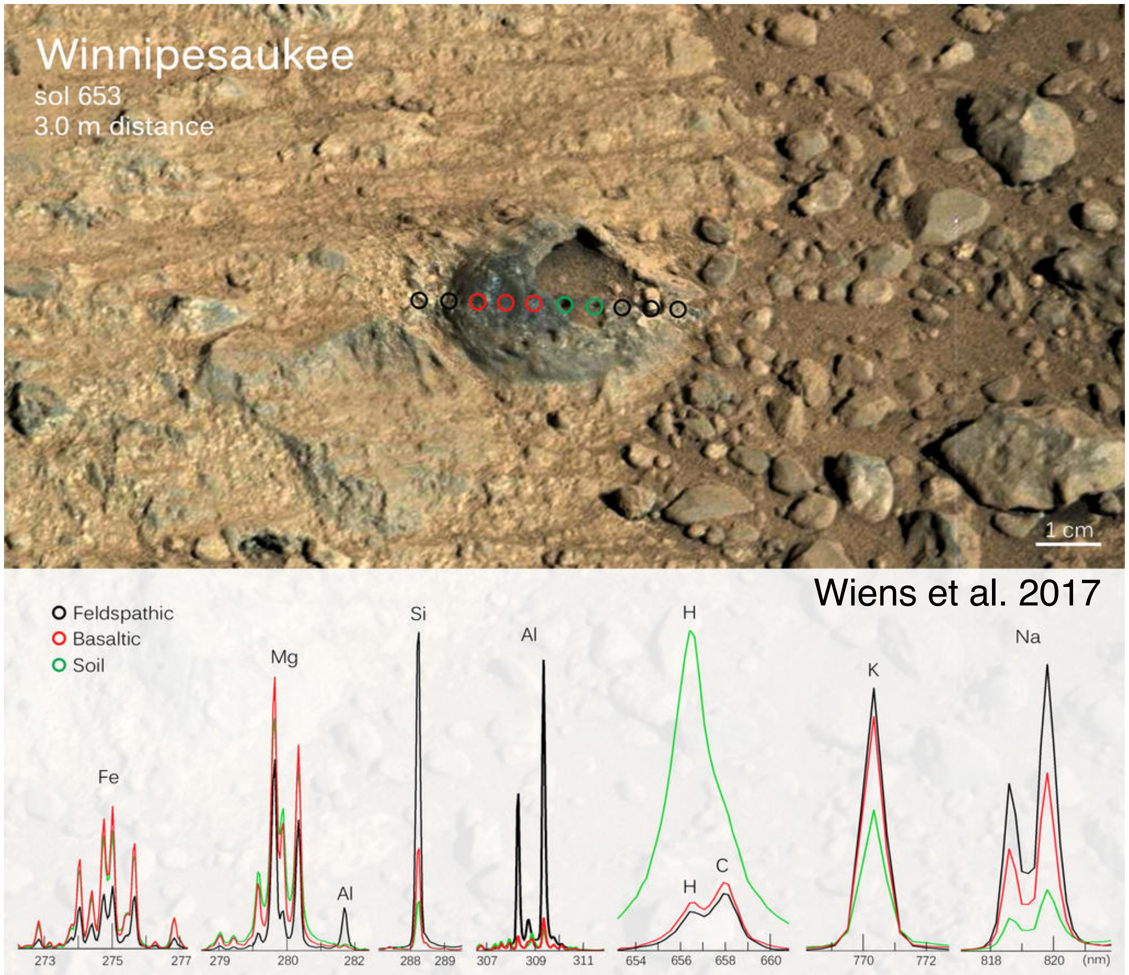
Quantification of the major elements constituting a target (O, Na, Mg, Al, Si, K, Ca, Ti, and Fe);

detection of non-metallic elements especially volatile ones (H, C, O, P, S, Cl);

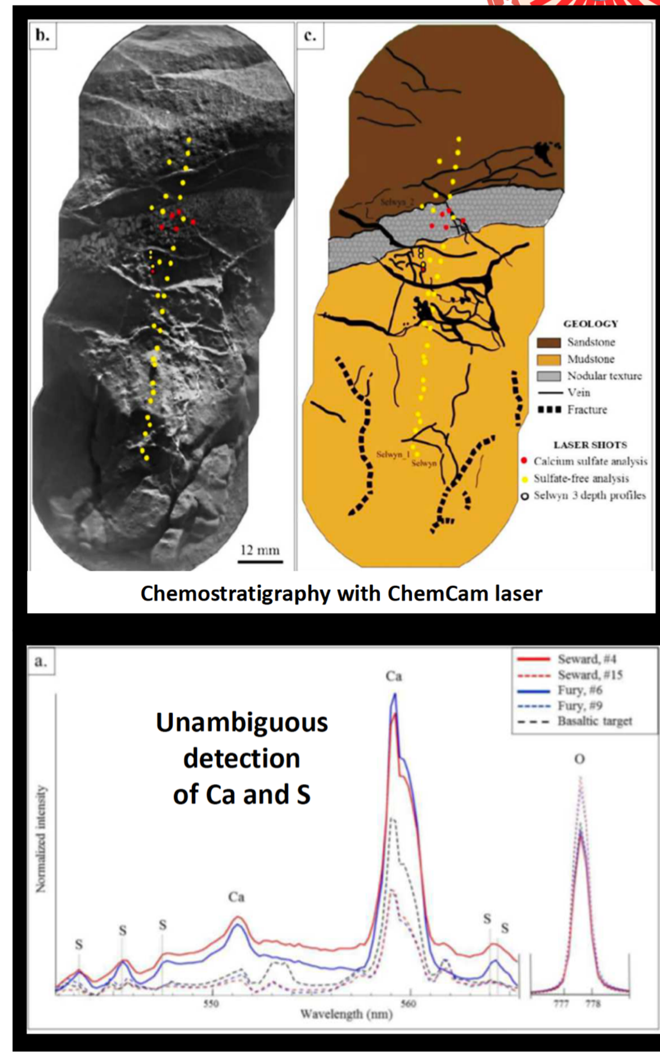


The ChemCam experience

ChemCam fine scale analysis of composition variation of Gale crater rocks



Wiens et al. 2017

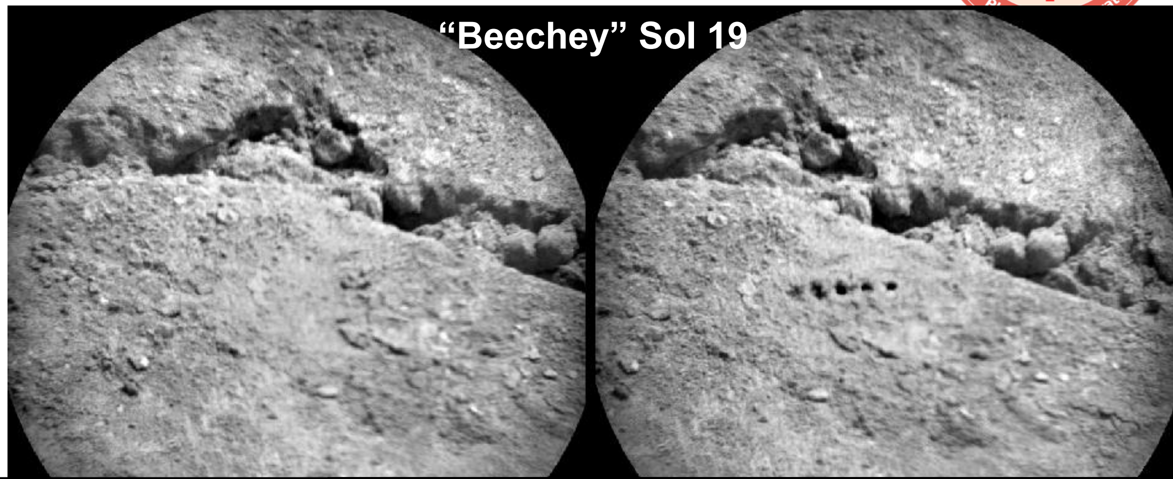


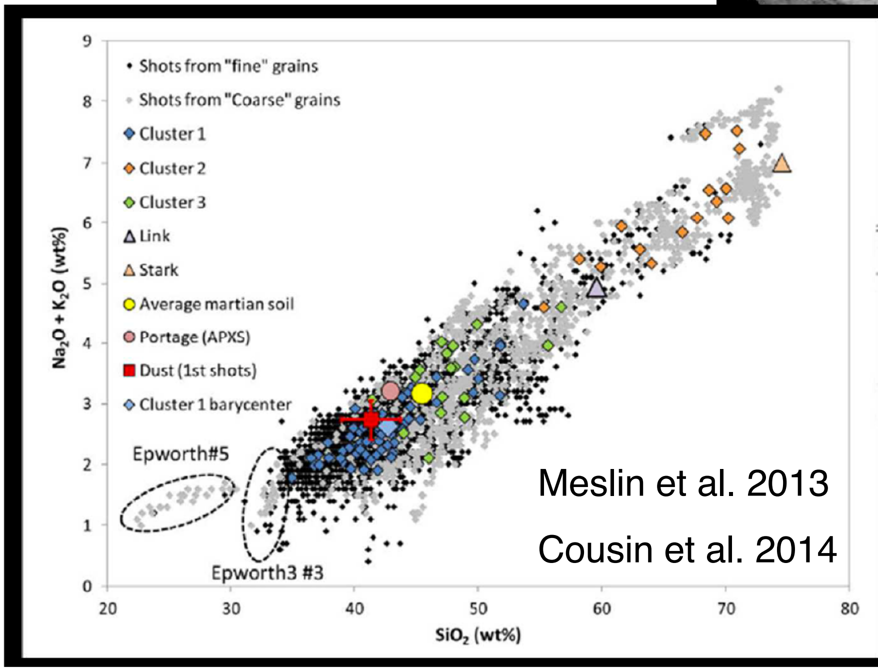
Nachon et al. 2016

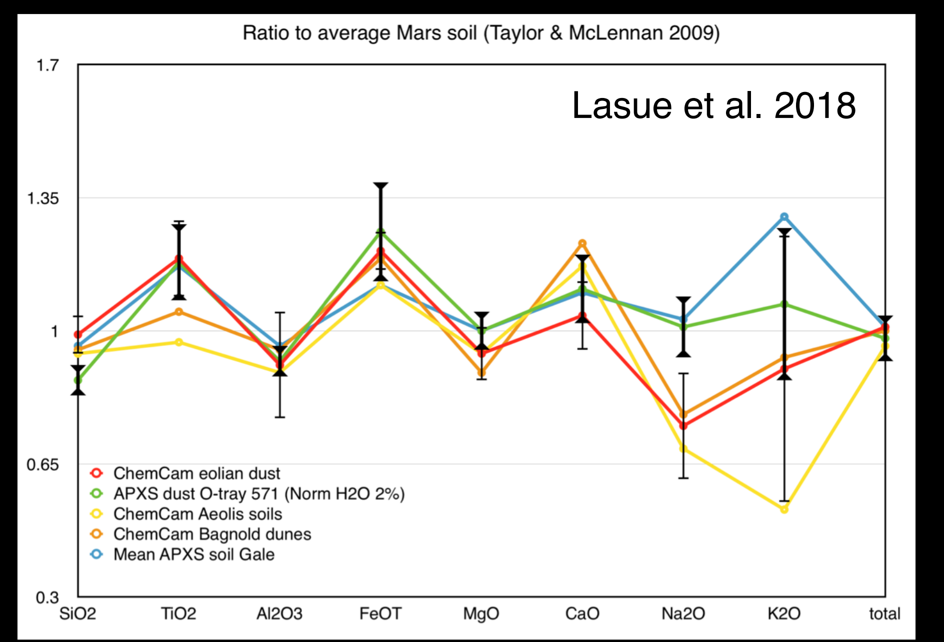
The ChemCam experience

ChemCam analyses the composition of the different fractions of soils and dust.

- Hydrated fraction of eolian dust
- Local alkali enrichment in soils



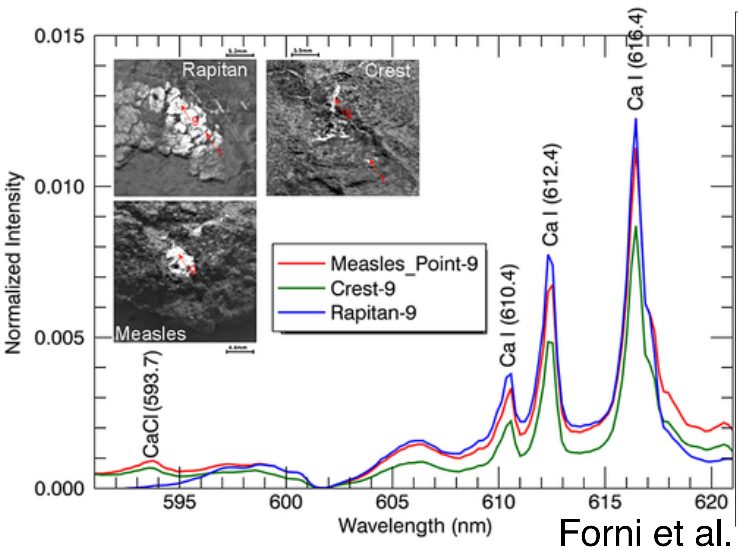


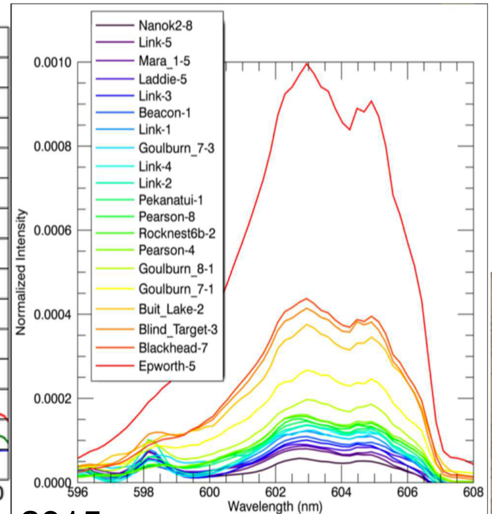


The ChemCam experience

First analyses of F, B, Li, Rb, Sr, and Ba on Mars
Detection of Mn, Cu and Zn enriched minerals

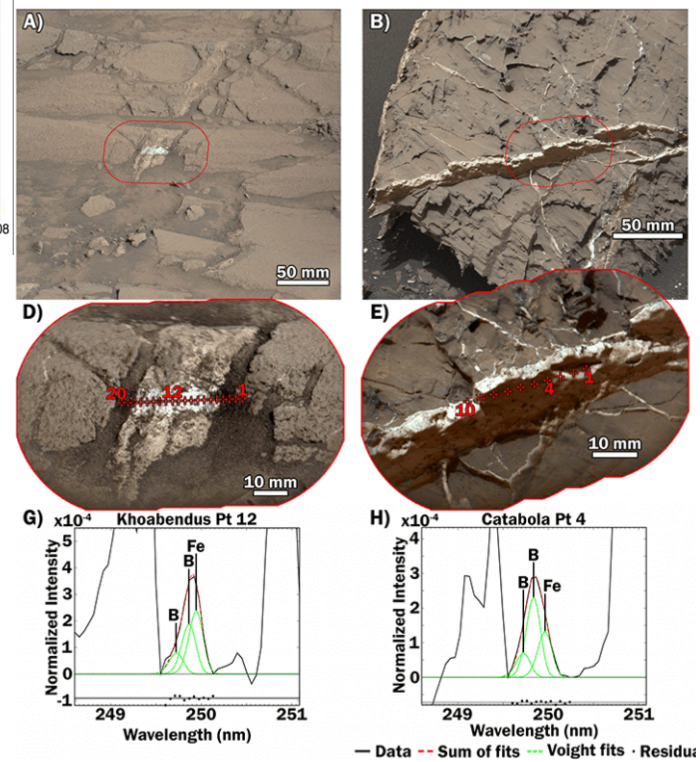
(Lanza et al. 2014; Lasue et al. 2016; Payré et al. 2019).



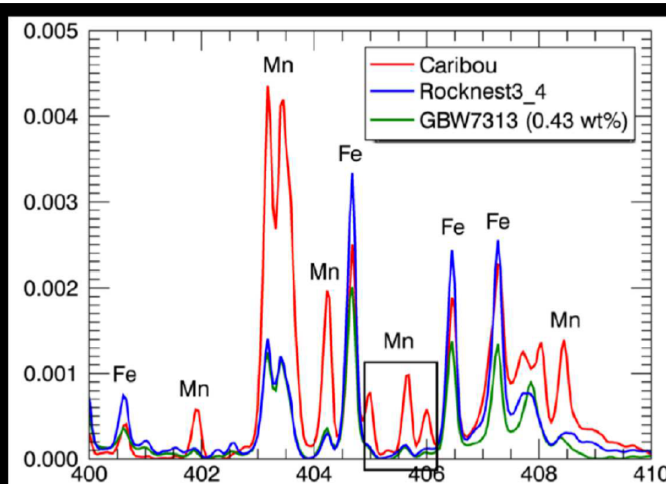


Forni et al. 2015

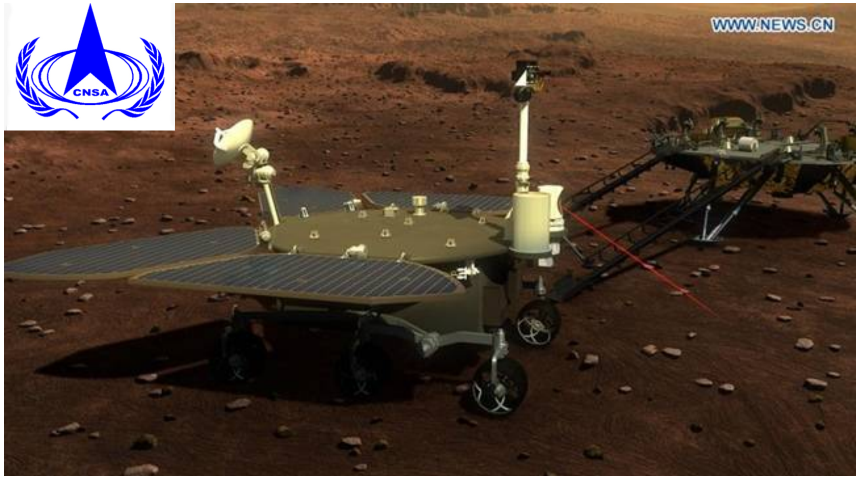
Gasda et al. 2017



Caribou Sandstone with High-Mn Mineral

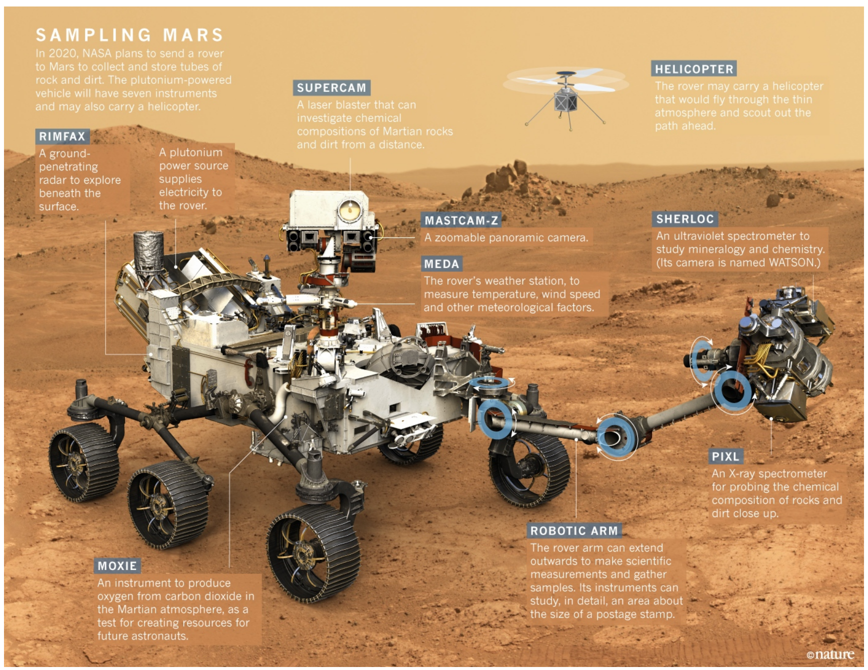


The next space missions

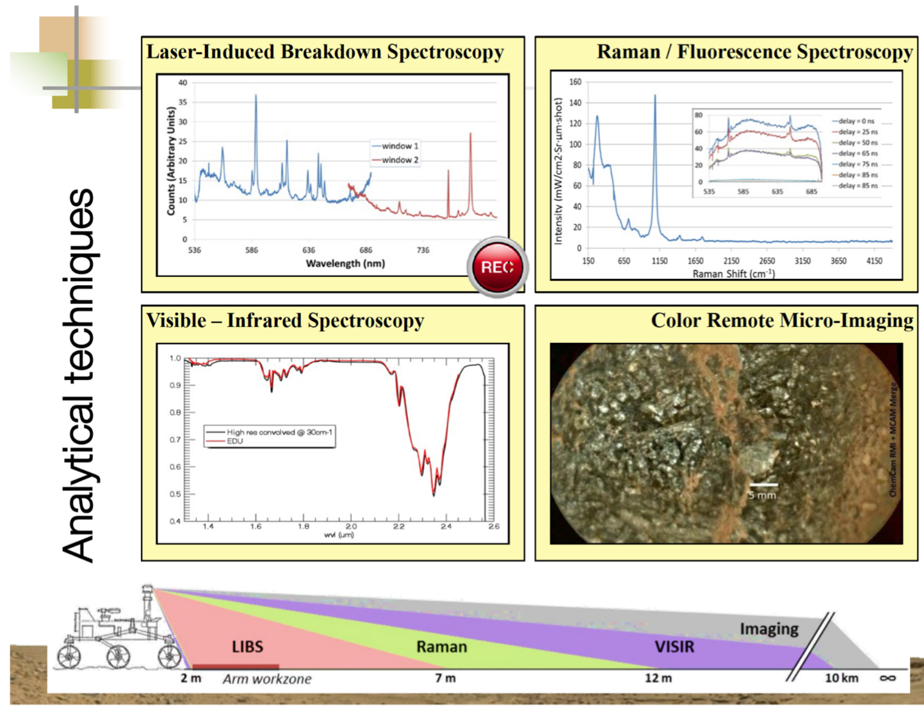


MarsCoDE on HX-1 1064nm, 21mJ, 4.5ns, 2-5m distance with adjustable mirror.

SuperCam combines 4 measurement types with LIBS.



Wiens et al. 2017

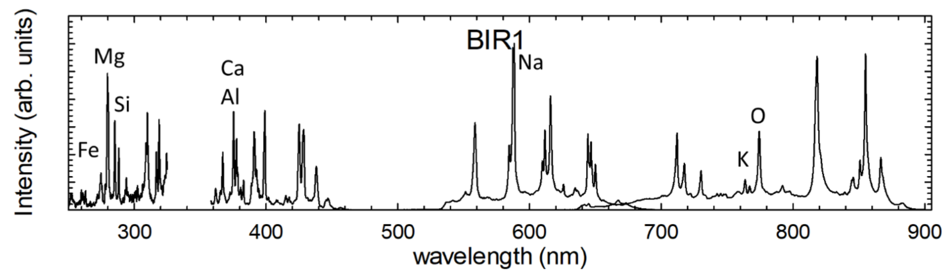


Possible use on Venus: VEMCam

Venera 13 and 14 experience:

- carried x-ray fluorescence experiments, both successful.
- Sources = ^{238}Pu (50 mCi), ^{55}Fe (250 mCi)
- Detector energy range = 1.1-8 keV
- MCA = 256 channels
- Mg to Fe detected

Surkov et al. 1983, 1984



Advantages of LIBS + Raman

- No need to be in contact with surface.
- Can identify relevant minerals (olivine etc.)
- Most major and some minor elements detected in a 240nm - 900nm range.

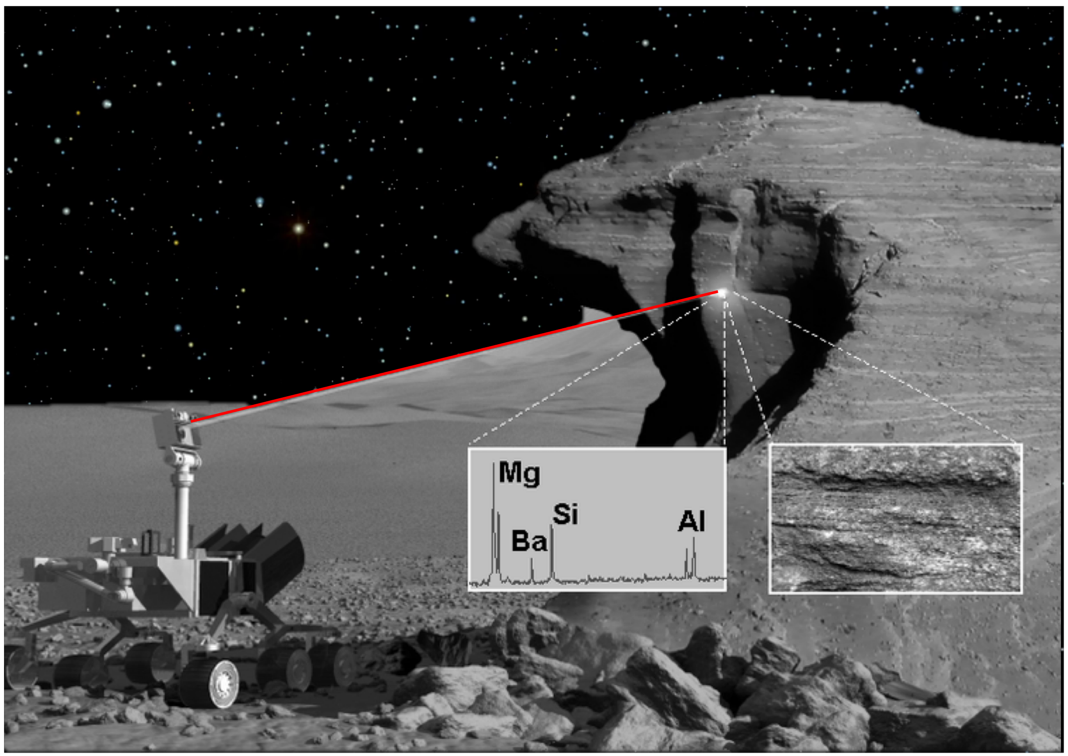
Clegg et al. 2014; Clegg et al. EPSC 2019

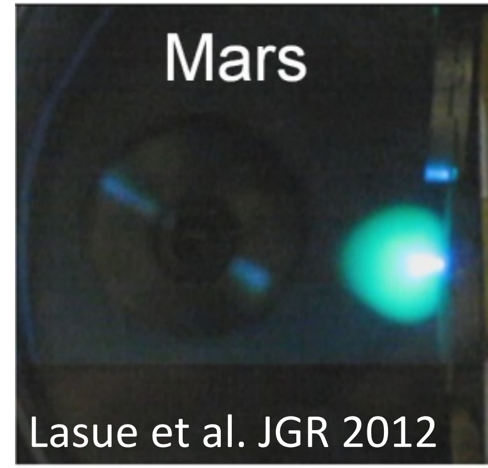
LIBS applications for the Moon

Validation of a proto-ChemCam instrument for use on airless bodies (Moon, asteroids, comets:

- Nd:Yag laser (17 mJ @ 1064 nm, 10 ns)
- 3 spectrometers [220-835] nm

LIBS on the Moon





~5 Torr

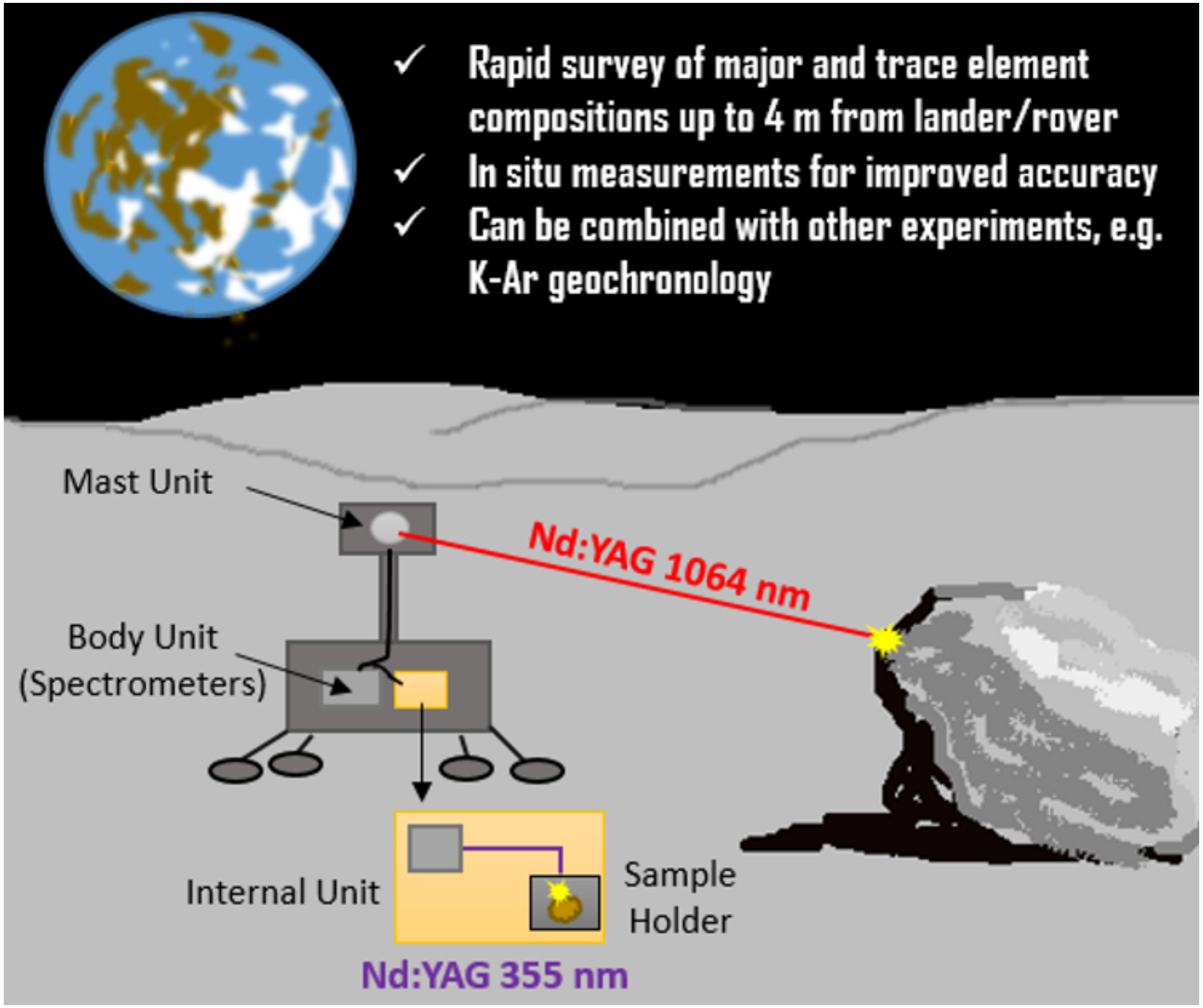
~4e-4 Torr

LIBS applications for the Moon

Can separate basalts from feldspatic rocks of lunar highlands (Al, Fe, Ti, Mg).

Sensitive to volatile elements

K sensitivity sufficient to detect KREEP. Can be combined with isotopic measurements for age dating.



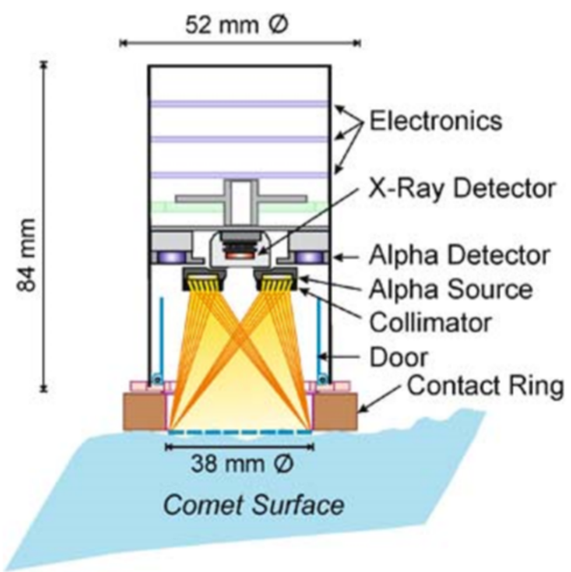
LunaLIBS

Laser-Induced Breakdown Spectroscopy for Rapid Remote and In-Situ Geochemical and Geochronological Analysis of Lunar Materials

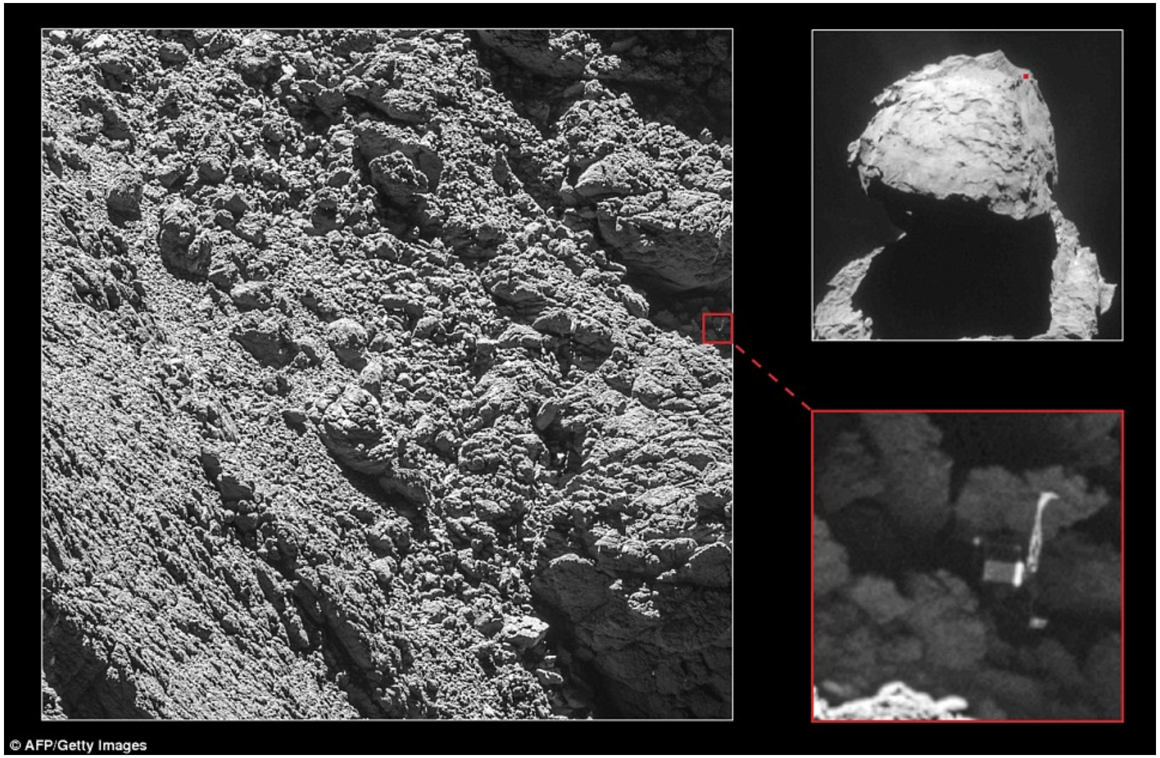
Ollila et al. LPSC 2019

LIBS for asteroids, comets, icy satellites

- Avoid the need to be in contact with the surface (unlike Philae's APXS).
- Sensitive to the major elements (O, Na, Mg, Al, Si, K, Ca, Ti, and Fe)
- detection of non-metallic elements especially volatile ones (H, C, O, P, S, Cl)
- Interest in comparison with meteorites collections on Earth (constrain origins).
- Rapid survey of potential sample return areas.



Klingelhöfer et al. 2007

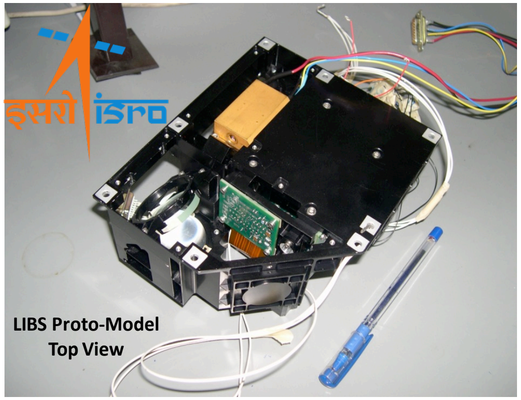


Miniaturization – Extreme environments

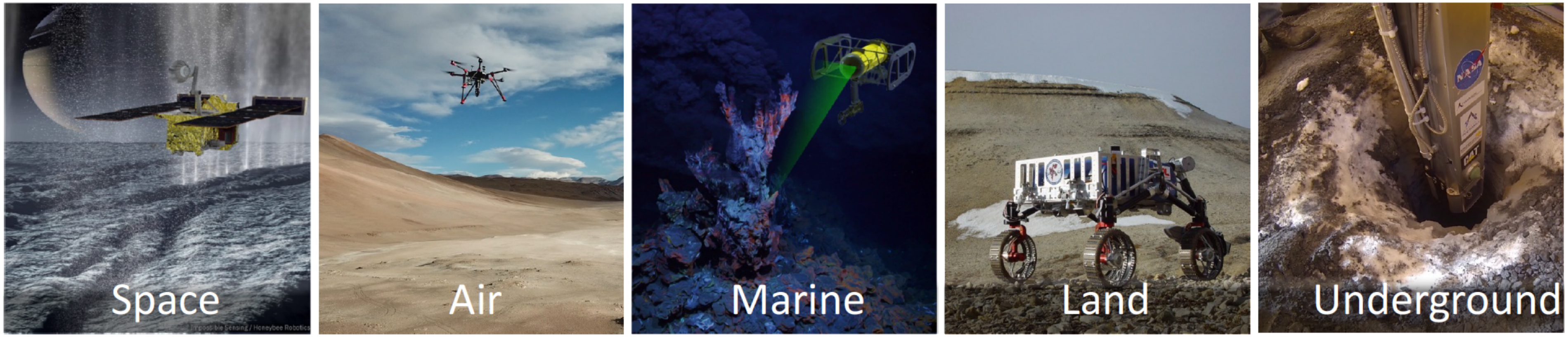
Chandrayaan 2 rover LIBS

Specification	Value
Volume	180 × 150 × 80 mm
Power	<5 W
Mass	< 1.2 kg

Laxmiprasad et al. 2011; 2013



Impossible Sensing



e.g. Sobron et al. 2012; 2018

Perspectives on LIBS

- Tactical and versatile instrument with many different designs (low to high mass).
- Detects most major and volatile chemical elements at distance and with a sub-mm scale
- Interesting science for any planetary surface.