





# LIBS Spectroscopy - Elemental Chemistry -

Agnes Cousin on behalf of the LIBS WG

# SuperCam Data Workshop

LPSC, The Woodlands, Texas, USA Tuesday, March 11, 2025



Outline



- LIBS technique overview
- SuperCam LIBS instrument details
- LIBS processing
- Major Element Oxide (MOC): Quantification
- Next Steps
- PDS release process
- List of papers and useful tools





### LIBS technique overview





Maurice et al., SSR, 2021 Wiens et al., SSR, 2021

- Remote sensing technique: >10 m
- Spot size: 100-450 microns (between 1.5 7m)
- From UV to near Infrared (243.5 853 nm)
- Different raster types (see introduction)
- Depth profiles are possible (up to 500 shots)
- Advantages:
  - Quick, no sample preparation
  - Remote sensing (no arm placement)
  - Acquires ample of data



### SuperCam LIBS instrument details





- Three spectrometers (range, resolution):
  - UV: 243.5 341.7 nm, 0.05 nm/pixel
  - VIO: 382.1 467.5 nm, 0.04 nm/pixel
  - Transmission spectrometer 0.06 0.09 nm/pixel
    - Green: 535 620 nm
    - Orange: 620 712 nm
    - Red: 712 853 nm
- Major elements that are quantified:
  - Si, Ti, Al, Fe, Mg, Ca, Na and K
- Minor elements that can be observed:
  - Rb, Ba, Sr, Mn, Cr, Li, Ni, Cl => quantification in progress
  - $\circ \qquad \mathsf{Cu},\,\mathsf{S},\,\mathsf{F},\,\mathsf{P},\,\mathsf{N},\,\mathsf{C},\,\mathsf{H},\,\ldots$



## LIBS processing



- Raw data need to be processed (noise & background removal, radiance correction,..)
  - These steps are presented in Wiens et al., 2021 and in Anderson et al., 2022
- LIBS Quantification is challenging
  - Distance is varying
  - The physics of the plasma are challenging and cannot be modeled well enough for an accurate "first principles" quantification
    - Rapidly changing plasma (temp, density, opacity, shot to shot interactions, .. )
    - Atoms and molecules in the plasma interact with each other "Matrix effects"
      - Intensity of emission from one element can change due to concentrations of other elements
  - Empirical calibration based on laboratory data for which we have independent compositions (our "LIBS database")
  - Use of average spectra for a better SNR
- Multivariate vs Univariate approach:
  - Univariate:
    - Single variable
    - Simple and easy to interpret
    - Do not perform as well as multivariate tools for major elements
    - Matrix effects are not accounted for
  - Multivariate:
    - Use several variables (whole spectra, or many spectral channels)
    - Mitigate better than univariate approach the matrix effects
    - Can be difficult to interpret

We have developed multivariate models for our quantifications



# Major Element Oxides (MOC) - Anderson et al., 2022

- Details about setup, database (334 samples) pre-processing are in Anderson et al., 2022
- 11 regression algorithms have been tested
- For some elements, the combination of different models were giving the best results, as well as some blended models
- Accuracy is determined by Root Mean Square Error of Prediction (RMSEP)

Element	RMSEP wt%	Model				
SiO <sub>2</sub>	6.1	Average (GBR, PLS)				
TiO <sub>2</sub>	0.3	RF				
Al <sub>2</sub> O <sub>3</sub>	1.8	Average				
FeOT	3.1	GBR				
MgO	1.1	GBR				
CaO	1.3	Blend RF + PLS				
Na <sub>2</sub> O	0.5	Blend GBR + LASSO				
K <sub>2</sub> O	0.6	LASSO				

• Precision (shot-to-shot standard deviation) is always better than accuracy

	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	FeO <sub>T</sub>	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O
3 m Test Set (Laboratory)	0.8	0.06	0.4	0.5	0.2	0.2	0.1	0.1
SCCTs (Mars)	1.6	0.02	0.7	1.3	0.5 (0.3)	0.5	0.3 (0.2)	0.3

• This is the first quantification effort was made a few months only after the landing, with known idiosyncrasies





# Major Element Oxides (MOC) - Anderson et al., 2022



### Some idiosyncrasies about the MOC

- SiO2:
  - Overestimated for olivine mineralogies
  - Poor discrimination for some minerals between 40-60 wt%
- TiO2:
  - Model (Random Forest) not able to extrapolate outside the training range (i-e 3.4 wt%) => high contents are underestimated
- Al2O3:
  - Suffers some matrix effects overpredicted when Ti is elevated
  - Overpredicted at low contents
- FeOT:
  - Underpredicted for mars dust
  - Seems to be underestimated in olivine mineralogies
- MgO:
  - Bimodality/Quantized predictions, not always related to mineralogies
  - Highest predictions are related to sum of oxides >100 %.
- CaO:
  - Bimodality in the predictions
- Na2O:
  - No issues that we are aware of !
- K2O:
  - LIBS is very sensitive to K lines.



# Major Element Oxides (MOC) - Anderson et al., 2022



- Even though our actual LIBS quantification has known caveats, MOC is actually very good.
- Very good precision: easy to compare data all together



Mars 2020 Project

SUPERCAM

NASA

### What's Next ? New quantification effort (Anderson et al., #2273 this meeting)

Mars 2020 Project SUPERCAM

- New database has been acquired
  - Wider range of compositions to better match Mars observations
  - Over twice the number of targets (793 targets)
  - Varying distances, z-stacks



- New pipeline effort
  - Enabling to optimise the pre-processing steps
  - Improving consistency between models
  - Enabling apples to apples comparisons between model candidates
    - RMSE from test set (including shift in wavelength)
    - RMSE on SCCTs
    - RMSE on some targets at different distances
    - Shot to shot stability
    - Z-stack focus check
  - Use of superlearners, along with blended submodels
  - Several models to compare:
    - ElasticNet, ExtraTrees, Support Vector Machines, Gaussian Process



### PDS release process

- Some quality-checks are done before delivering the data to PDS (keep in mind that all EDR are released)
- CDR spectra (point to point) can be removed from the release if: low signal (total intensity <  $1.10^{14}$ ) ٠

  - Focus not optimum:
    - By checking the focus curves and their spacing
  - Distance > 6.5m
- MOC are removed for same filters, and when: ٠
  - TiO2 is > 2.4 wt%
  - Sum of Oxides > 121 wt% (>3sigma)
  - Sum of oxides > 107 % (1sigma) are released but there is a note in the masterlist
- Mosaics for data out of focus (for LIBS activity only) are not delivered ٠ either
- LIBS fit files contain several data (see intro. slides for CDR structure): ٠
  - "statistics": mean, median, and standard deviation (first 5 shots removed)
  - "spectra": all shots

NATIONAL AERO AND SPACE ADN	AUTICS + NASA Homepage + NASA en Español + Contact NASA									
210 00	PDS Geosciences Node Washington University in St. Louis	A DE A DE A								
HOME DATA AND	ERVICES TOOLS ABOUT US CONTACT US SITE N	IAP								
Services Analyst's Notebooks Orbital Data Explorers Spectral Library FTP Access Workshops	Mars 2020: SuperCam (LIBS, Raman, Time-Resolved Fluorescence, VIS/IR, RMI) Dec. 3, 2024. Mars 2020 Release 11 includes new SuperCam data from sols 1140									
Geosciences Node Data	The Mars 2020 SuberCam instrument identifies the chemical composition of rocks and soils usi	na a								
Mars Mars Exploration Mars 2020 About Mars 2020	camera, lasers, and spectrometers. From more than 7 meters away, it can determine the atomic molecular makeup of targets as small as a pencil point. SuperCam is located on the head of the rover's long-necked mast.	an								
PIXL Returned Sample Science RIMFAX SHERLOC	SuperCam Release Notes SuperCam Release Notes contain information about the archive and errata, if any.									
SuperCam InSight	Collections in the SuperCam Archive Bundle									
MRO	Introduction to the SuperCam Archive Bundle (readme.txt)									
MER Mars Express	SuperCam Bundle Root Directory									
Odyssey	SuperCam Document collection									
MGS	SuperCam Calibrated Audio data collection									
Pathfinder Prototype Rovers	SuperCam Calibrated Spectra data collection									
Viking Orbiter Viking Lander	SuperCam Derived Spectra data collection									
Mariner	SuperCam Data Observation Log data collection									
Venus	SuperCam Calibrated RMI Image data collection									
Mercury Moon	SuperCam Raw Audio data collection									
Earth	SuperCam Raw Spectra data collection									
Radio Science	SuperCam Raw RMI data collection (at the CIS Node)									
Gravity Models All Geosciences DOIs	SuperCam Annotated RMI Mosaic data collection									
All Geosciences Data Holdings	SuperCam Calibration data collection									
Help	Mars 2020 Mission Camera Document collection (secondary member)									
Frequently Asked Questions Geosciences Node Forums	Mars 2020 Mission Camera Calibration collection (secondary member)									
Help for Data Users Help for Data Reviewers	Mars 2020 Mission Miscellaneous collection (secondary member)									
About PDS4										
About Checksums Cite PDS On Your Poster	Readme.txt gives a high-level overview of the SuperCam Bundle.									
Email Us	The SuperCam Bundle Software Interface Specification (SIS) describes the contents format and structure of the bundle. Lears who are unfamiliar with PDS									
Scheduled Maintenance	archives should read this first.									
This site may be down on Thursdays between 7:00 and 9:30 pm Central Time for maintenance.	The SuperCam PDS User Guide summarizes information from other documents that is likely to be most useful to the science user. The SuperCam EDR and RDR SIS describes the data products generated by the									
	Operation and when states, including from single is processes and labeled. The one is a detailed document intended for use in mission operations as well as by science users of the archive.									

Mars 2020 Analyst's Notebook - This PDS Geosciences Node tool provides access to Perseverance data in the context of mission operations -- by so ocation, instrument, and other criteria.

PDS4 Viewer - This standalone tool displays PDS4-labeled images and tables, Available for Windows, Mac, and Linux platforms. Source code and Python library also available

### PDS release process

- MOC (compositions) can be found here:
  - <u>https://pds-geosciences.wustl.edu/m2020/urn-nasa-pd</u>
     <u>s-mars2020\_supercam/data\_derived\_spectra/</u>

Training set Quartiles		SIUZ		TIOZ		ALZOS		Feor		MgO		Cau		Nazu		N20				
Min		0.02		0.01		0.01		0.04		0.03		0.01		0.01		0.01				
1st		48.07		0.41		10.1		4.25		1.695		0.4		0.4		0.53				
Med		55.03		0.685		15.41		6.185		2.93		1.76		1.75		1.9				
3rd		61.75		0.9		18.1		9.3225		5.12		8.73		3.38		3.65				
Max		88.38		3.39		38.79		74.96		49.18		35.67		6.72		8.88				
RMSEP		6.1		0.3		1.8		3.1		1.1		1.3		0.5		0.6	1			
Precision		1.6		0.02		0.74		0.93		0.47		0.6		0.2		0.2				
cdr_fname		SiO2	SiO2_stdev	TiO2	TiO2_stdev	Al2O3	Al2O3_stdev	FeOT	FeOT_stdev	MgO	MgO_stdev	CaO	CaO_stdev	Na2O	Na2O_stdev	K2O	K2O_stdev	Total	distance_mm	Tot.Em.
scam_0012_0668002890_477_cl1_scam15210_maaz	_01p	43.74	1.28	0.68	0.02	9.15	1.45	12.91	1.56	5.73	0.49	4.79	0.3	1.52	0.32	0.72	0.33	79.24	3126	7.04E+14
scam_0015_0668272463_966_cl1_scam15218_tselchee	_01p	55.81	2.17	0.62	0.02	10.89	1.28	7.59	2.14	1.66	0.6	3.52	0.52	3.45	0.41	2.46	0.38	86	3192	4.09E+14
scam_0015_0668272508_963_cl1_scam15218_tselchee	02p	61.21	3.1	0.48	0.03	10.38	1.47	9.26	2.55	0.78	0.49	1.99	0.63	3.37	0.36	2	0.45	89.47	3192	5.34E+14
scam_0015_0668272553_991_cl1_scam15218_tselchee	03p	50.96	1.43	0.74	0.06	8.92	1.64	21.78	5.8	2.1	0.75	7.54	0.79	2.22	0.24	0.88	0.26	95.14	3192	8.00E+14
scam_0015_0668272816_977_cl1_scam15218_tselchee	05p	49.73	9.3	0.52	0.06	7.69	1.5	13.03	2.22	5.83	6.53	3.28	0.4	2.64	0.51	1.82	0.54	84.54	3187	6.84E+14
scam_0015_0668272861_983_cl1_scam15218_tselchee	06p	47.95	2.33	0.69	0.01	7.03	1.27	12.41	2.08	5.48	1.38	3.75	0.35	3.11	0.23	0.9	0.42	81.32	3187	6.95E+14
scam_0015_0668272906_994_cl1_scam15218_tselchee	_07p	59.73	3.25	0.37	0.19	14.67	1.06	5.44	2.72	1.57	0.79	4.5	0.14	3.65	0.15	1.74	0.42	91.67	3189	4.84E+14
scam_0015_0668272951_964_cl1_scam15218_tselchee	08p	39.61	2.33	0.65	0.06	6.15	1.42	11.01	1.71	10.9	2.51	9.93	2.93	2.24	0.24	0.76	0.41	81.25	3189	9.08E+14
scam_0015_0668272996_966_cl1_scam15218_tselchee	_09p	45.86	1.94	0.65	0.07	3.36	0.75	46.82	3.98	1.31	0.33	3.49	0.41	1.05	0.15	0.42	0.33	102.96	3189	1.54E+15
scam_0015_0668273137_969_cl1_scam15218_tselchee	10p	45.79	2.1	0.54	0.08	10.92	2.06	13.99	2.06	3.64	1.14	5.13	0.89	3.25	0.57	1.45	0.67	84.71	3192	5.03E+14
scam_0027_0669344001_357_cl1_scam01027_scct_pmian0106	15p	41.19	1.19	0.2	0.01	25.03	1.01	3.52	2	1.49	0.53	5.86	0.19	5.96	0.34	1.44	0.21	84.69	1556	2.66E+14
scam_0027_0669344412_399_cl1_scam02027_scct_pmian0106	15p	45.1	1.3	0.04	0	25.66	0.64	3.3	0.05	1.39	0.3	6.19	0.29	5.32	0.12	1.64	0.17	88.64	1556	2.10E+14
scam_0028_0669424371_181_cl1_scam01028_iina	01p	58.31	1.62	0.31	0.03	7.54	0.53	9.6	8.1	0.95	0.2	0.88	0.2	1.84	0.21	4.03	0.43	83.46	3177	1.23E+15
scam_0028_0669424511_056_cl1_scam01028_lina	02p	67.62	1.37	0.41	0.07	13.35	0.96	3.66	1.61	1.23	0.21	3.64	0.51	4.37	0.2	2.27	0.42	96.55	3177	6.01E+14
scam_0028_0669424650_124_cl1_scam01028_iina	03p	59.15	1.67	0.35	0.03	6.3	1.08	42.16	10.07	0.74	0.14	1.55	0.46	2.64	0.18	2.03	0.39	114.92	3177	1.45E+15
scam_0028_0669424790_046_cl1_scam01028_iina	_04p	60.12	3.3	0.45	0.11	7.41	1.29	29.8	5.17	1.9	0.45	2	0.74	3.1	0.59	1.72	0.48	106.5	3180	1.43E+15
scam_0028_0669424927_993_cl1_scam01028_iina	_05p	56.38	2.99	0.68	0.12	7.03	1.41	36.96	3.84	1.6	0.51	3.21	0.65	3.31	0.3	1.19	0.44	110.36	3180	1.64E+15
scam_0028_0669425240_031_cl1_scam01028_iina	_06p	48.4	1.52	0.33	0.14	17.77	1.01	12.54	1.18	1.85	0.29	6.74	0.51	3.85	0.22	0.24	0.3	91.72	3172	8.65E+14
scam_0028_0669425379_071_cl1_scam01028_iina_	07p	62.9	3.51	0.61	0.05	10.9	1.11	5.29	4.05	0.92	0.25	2.16	0.58	3.93	0.28	2.96	0.47	89.67	3172	1.21E+15
scam_0028_0669425518_039_cl1_scam01028_lina	08p	60.45	8.36	0.49	0.13	5.3	1.21	13.49	2.38	2.13	0.77	3.03	0.57	1.92	0.33	1.59	0.42	88.4	3174	1.27E+15
scam_0028_0669425657_056_cl1_scam01028_iina	_09p	53.73	2.85	0.34	0.16	15.3	1.15	11.99	1.73	1.56	0.37	4.18	0.24	4.4	0.27	1.61	0.39	93.11	3174	7.87E+14
scam_0028_0669425885_040_cl1_scam01028_iina	_10p	55.42	1.83	0.59	0.05	20.67	1.54	6.36	1.02	1.74	0.22	4.73	0.16	4.78	0.22	1	0.28	95.29	3171	9.74E+14
scam_0034_0669954315_530_cl1_scam01034_scct_pmifs0505	10p	40.51	2.22	0.02	0.01	2.67	0.72	40.62	1.56	4.49	1.01	4.2	0.07	0.58	0.12	0	0 0	93.09	1560	4.95E+14
scam 0034 0669954755 560 cl1 scam02034 scct tsrich0404	07p	31.38	5	1.45	0.24	7.46	0.96	5.16	2.88	2.6	0.23	4.56	0.34	1.57	0.07	34.87	2.01	89.05	1559	2 55E+14



The Mars 2020 SuperCam instrument identifies the chemical composition of rocks and soils using a camera, lasers, and spectrometers. From more than 7 meters away, it can determine the atomic and molecular makeup of targets as small as a pencil point. SuperCam is located on the head of the rover's long-necked mast.

#### SuperCam Release Notes

Mars

Mars Exploration

SHERI OC

SuperCam InSight

About Mars 2020

Returned Sample Science RIMFAX

Mars 2020

MSL MRO MER Mars Express Odyssey Phoenix MGS Pathfinder Prototype Rovers Viking Orbiter Viking Lander Mariner Earth Based Data Venus Mercury Moon Earth Asteroids Radio Science Gravity Models All Geosciences DOIs All Geosciences Data Holdings

Hein

Frequently Asked Questions Geosciences Node Forums Help for Data Users Help for Data Reviewers

Help for Proposers About PDS4

About Checksums Cite PDS On Your Poster

Scheduled Maintenance

This site may be down on Thursdays between 7:00 and

9:30 pm Central Time for

Email Us

maintenance

SuperCam Release Notes contain information about the archive and errata, if any. They are updated with each release.

#### Collections in the SuperCam Archive Bundle

SuperCam Bundle Ro	ot Directory
Supercarri Dunule No	or Directory
SuperCam Document	collection
SuperCam Calibrated	Audio data collection
SuperCam Calibrated	Spectra data collection
SuperCam Derived Sp	pectra data collection
SuperCam Data Obse	rvation Log data collection
SuperCam Calibrated	RMI Image data collection
SuperCam Raw Audio	data collection
SuperCam Raw Spect	tra data collection
SuperCam Raw RMI o	data collection (at the CIS Node)
SuperCam Annotated	RMI Mosaic data collection
SuperCam Calibration	data collection
Mars 2020 Mission Ca	amera Document collection (secondary member)
Mars 2020 Mission Ca	amera Calibration collection (secondary member)
Mars 2020 Mission Mi	scellaneous collection (secondary member)

#### Documentation

Readme.txt gives a high-level overview of the SuperCam Bundle.

The SuperCam Bundle Software Interface Specification (SIS) describes the contents, format, and structure of the bundle. Users who are unfamiliar with PDS archives should read this first.

The SuperCam PDS User Guide summarizes information from other documents that is likely to be most useful to the science user.

The SuperCam EDR and RDR SIS describes the data products generated by the SuperCam instrument suite, including how they are processed and labeled. The SIS is a detailed document intended for use in mission operations as well as by science users of the archive.

#### Tools

Mars 2020 Analyst's Notebook - This PDS Geosciences Node tool provides access to Perseverance data in the context of mission operations -- by sol, location, instrument, and other criteria.

PDS4 Viewer - This standalone tool displays PDS4-labeled images and tables. Available for Windows, Mac, and Linux platforms. Source code and Python library also available.

## List of papers and links to useful LIBS tools



### Instrument and calibration targets:

- Wiens et al., 2021 (Body Unit); https://doi.org/10.1007/s11214-020-00777-5
- Maurice et al., 2021 (Mast Unit); https://doi.org/10.1007/s11214-021-00807-w
- Manrique et al., 2020 (Calibration targets, design); https://doi.org/10.1007/s11214-020-00764-w
- Madariaga et al., 2021 (Calibration targets, homogeneity); https://doi.org/10.1016/j.aca.2022.339837
- Cousin et al., 2021 (Calibration targets, characterization); https://doi.org/10.1016/j.sab.2021.106341.
- Legett et al. 2022 (Instrument response function); https://doi.org/10.1364/AO.447680

### SuperCam LIBS papers:

- Anderson et al., 2022 (MOC): https://doi.org/10.1016/j.sab.2021.106347
- Manelski et al., 2024 (plasma density): https://10.1016/j.sab.2024.107061
- Manelski et al., in prep (Ni quantification)
- Gabriel et al., in prep (Minors quantification)
- Wolf et al., in prep (Cl quantification)

### Team papers using LIBS data:

- Wiens et al., 2022 (crater floor, perchlorate detection); https://doi.org/10.1126/sciadv.abo3399
- Clavé et al., 2023 (crater floor, carbonate detection); https://doi.org/10.1029/2022JE007463
- Beyssac et al., 2023 (Seitah, olivine detection); https://doi.org/10.1029/2022JE007638
- Udry et al., 2022 (Màaz, lava flows): https://doi.org/10.1029/2022JE007440
- Beck et al., accepted (silica and quartz, hydrothermalism)
- Hausrath et al., 2022 & 2024 (regolith): https://doi.org/10.1029/2023JE008046 & https://doi.org/10.1029/2022JE007433
- Cousin et al., 2024 (regolith diversity): https://doi.org/10.1016/j.icarus.2024.116299

### RSS papers (samples)

- Simon et al., 2023 (Crater floor samples); https://doi.org/10.1029/2022JE007474
- Bosak et al., 2024 (Fan Front samples); https://doi.org/10.1029/2024AV001241

### Useful links:

- NIST dedicated to LIBS: https://physics.nist.gov/PhysRefData/ASD/LIBS/libs-form.ht ml
- NIST Atomic Spectra lines database: https://physics.nist.gov/PhysRefData/ASD/lines\_form.html
- CQUEST:
  - Presentation:
    - https://pds-geosciences.wustl.edu/workshops/chemcamworkshop-2014/4. CQUEST Mars LIBS Emission Line \_Tool\_Cousin.pdf
  - Tool:
- Ternary Diagram tool:
  - Poster #2033, Essunfeld Ari.
- Python Hyperspectral Analysis Tool (PyHAT)
  - <u>https://code.usgs.gov/astrogeology/pyhat</u>

Don't hesitate to reach out to SuperCam team members if you have any questions or need help with LIBS data !







# **Backup Slides**



Raman shift (cm 1)

## LIBS Data Processing



- Remove spikes (cosmic rays)
- Subtract "dark" spectra (collected when there is no LIBS pulse, to correct for thermal noise)
- Denoise spectra
- Convert to photons using instrument response
- Stitch the Green, Orange and Red ranges together
- Wavelength calibration
- Subtract continuum
- Convert to radiance



### **LIBS** Quantification







### SuperCam calibration targets - LIBS dedicated



Mars 2020 Project

SUPERCAM

ASA

### SuperCam calibration targets - LIBS dedicated



Cousin et al., 2021 (Calibration targets, characterization); https://doi.org/10.1016/j.sab.2021.106341.

Position	Target #	TargetName	Description	Science Intent				
2.1	7	TSRICH0404	BHVO-2 basalt and K sulfate mixture	Sulfur detection				
2.2 8		LCMB0006	Chert	Past acqueous environment and astrobiology interest				
2.3	9	LCA530106	Calcite	Carbonate calibration				
2.4	10	PMIFS0505	Ferrosilite	Stoichiometric reference				
2.5	11 TAPAG0206 Fluoro-Chloro- Hydro Apatite		Fluoro-Chloro- Hydro Apatite	Volatile detection, phosphate				
3.1	12 PMIOR0507 Orthoclase 13 PMIDN0302 Diopside		Stoichiometric reference					
3.2			Diopside	Stoichiometric reference				
3.3         14           3.4         15		PMIFA0306	Olivine	Stoichiometric reference Stoichiometric reference				
		PMIAN0106	Andesine					
3.5	16	PMIEN0602	Enstatite	Stoichiometric reference				
3.6	17	TSERP0102	Serpentine/Talc	Hydrated silicate, alteration product				
4.1	18	LBHVO20406	BHVO-2 standard basalt	Mars analog, basaltic composition				
4.2	19	LJSC10304	JSC-1 standard	Mars soil analog				
4.3	20	LANKE0101	Ankerite	Carbonate calibration				
4.4	21	LSIDE0101	Siderite	Carbonate calibration				
4.5	22	LJMN10106	JMN-1 standard Mn nodule	Mn enrichment, coating detection				
5.1	23 NTE010301 В п		Basalt dopped in minor elements	Calibration and quantification of Cu, Zn				
5.2	24	4 NTE020106 Basalt dopped in minor elements		Calibration and quantification of Mn, Ba, Cr				
5.3	25	NTE030106	Basalt dopped in minor elements	Calibration and quantification of Zn				
5.4	26	NTE040106	Basalt dopped in minor elements	Calibration and quantification of Li, Sr				
5.5	27	NTE050301	Basalt dopped in minor elements	Calibration and quantification of Ni				
5.6	28	SHERG02	Shergottite	ChemCam cal. Target replicate, cross calibration				
/ 33		TITANIUM	Titanium	calibration Wavelength calibration				









- Raw (EDR) files can be found here:
  - <u>https://pds-geosciences.wustl.edu/m2020/urn-nasa-pds-mars2020\_supercam/data\_raw\_s</u>
     <u>pectra/sol\_00214/</u>
- CDR can be found here:
  - <u>https://pds-geosciences.wustl.edu/m2020/urn-nasa-pds-mars2020\_supercam/data\_calibra</u> ted\_spectra/
- MOC (compositions) can be found here:
  - <u>https://pds-geosciences.wustl.edu/m2020/urn-nasa-pds-mars2020\_supercam/data\_derive\_d\_spectra/</u>
- Masterlist can be found here:
  - <u>https://pds-geosciences.wustl.edu/m2020/urn-nasa-pds-mars2020\_supercam/data\_observ</u> ation\_log/

