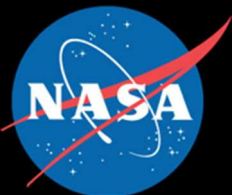


# Mars Rover In Situ X-ray Compositional Data Sets and Analysis Tools

Scott VanBommel

Planetary Data System Geosciences Node  
Payload Uplink/Downlink Lead, MER and MSL APXS

McDonnell Center for the Space Sciences  
Department of Earth and Planetary Sciences  
Washington University in St. Louis



To enter a tutorial session, click on “Let’s talk” at the **PDS Exhibitor Booth** at the DPS web site.

## Tutorials

### MRO CRISM Hyperspectral Data Sets and Analysis Tools

Monday, October 26  
2:30 to 3:30 PM EDT

### Mars Rover In Situ X-ray Compositional Data Sets and Analysis Tools

Tuesday, October 27  
3:00 to 4:00 PM EDT

### Content and Use of PDS Geosciences Node Orbital Data Explorers

Wednesday, October 28  
4:00 to 5:00 PM EDT

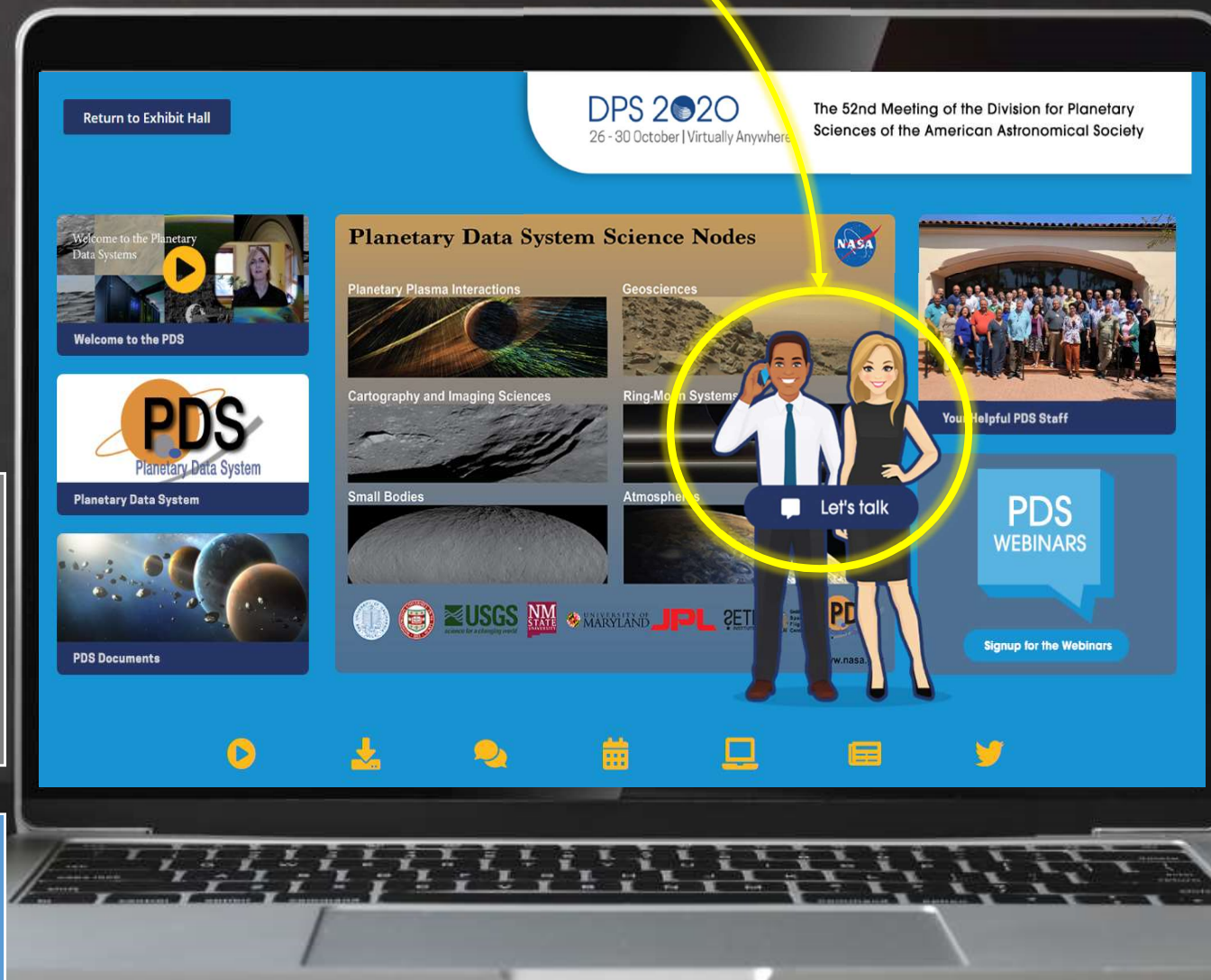
### Content and Use of PDS Geosciences Node Landed Mission Analyst Notebooks

Thursday, October 29  
3:00 to 4:00 PM EDT

## Webinars

Introduction to PDS Geosciences Node Data Sets and Analysis Tools  
Monday, October 26  
12:00 to 12:30 PM EDT

Introduction to PDS Geosciences Node Orbital Data Explorers and Landed Mission Analyst Notebooks  
Wednesday, October 28  
2:00 to 2:30 PM EDT



# Outline

Missions Overview

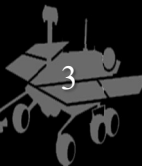
APXS Overview

APXS Data: Considerations

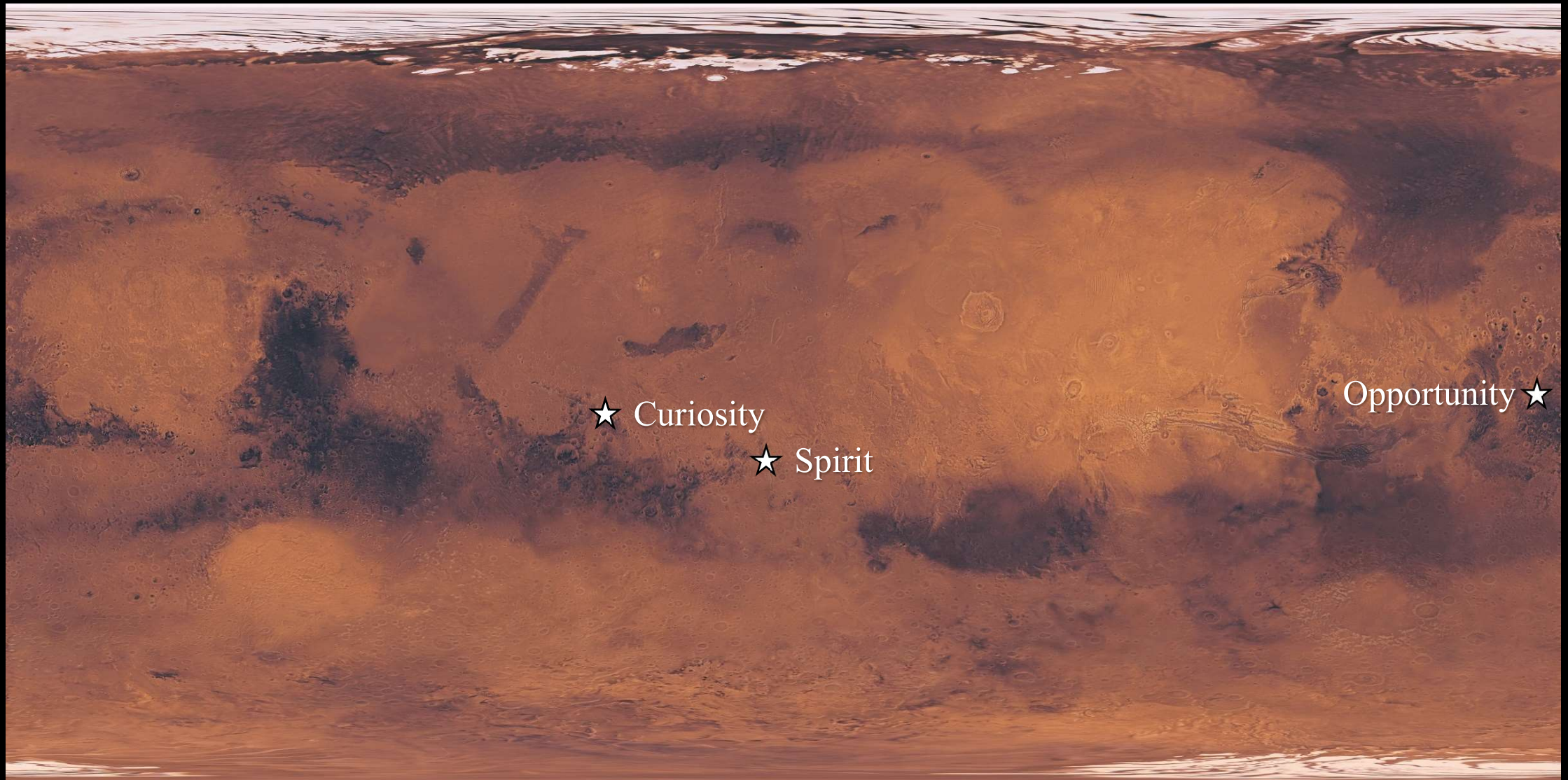
APXS Data: Availability

Analytical Techniques:  
Deconvolution & Emulation

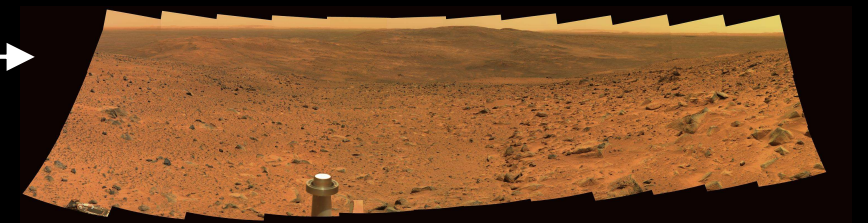
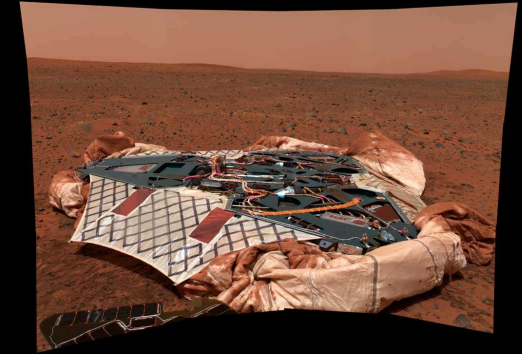
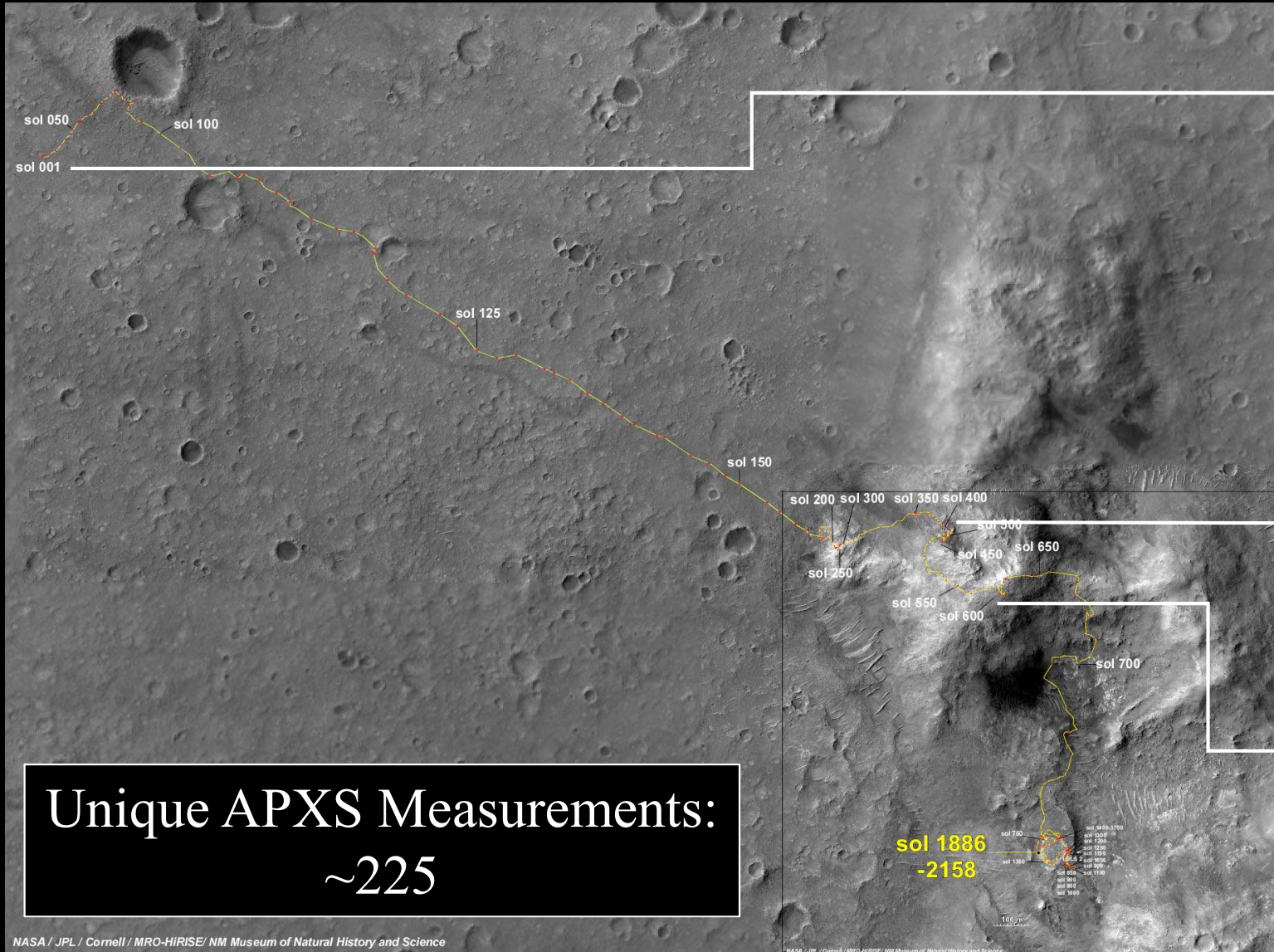
Analytical Techniques:  
PCA



# Missions Overview



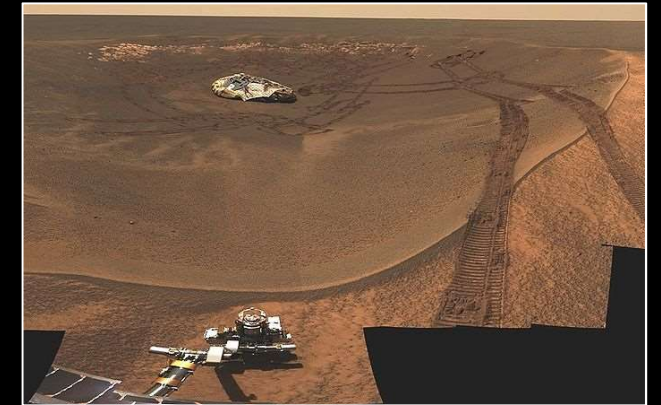
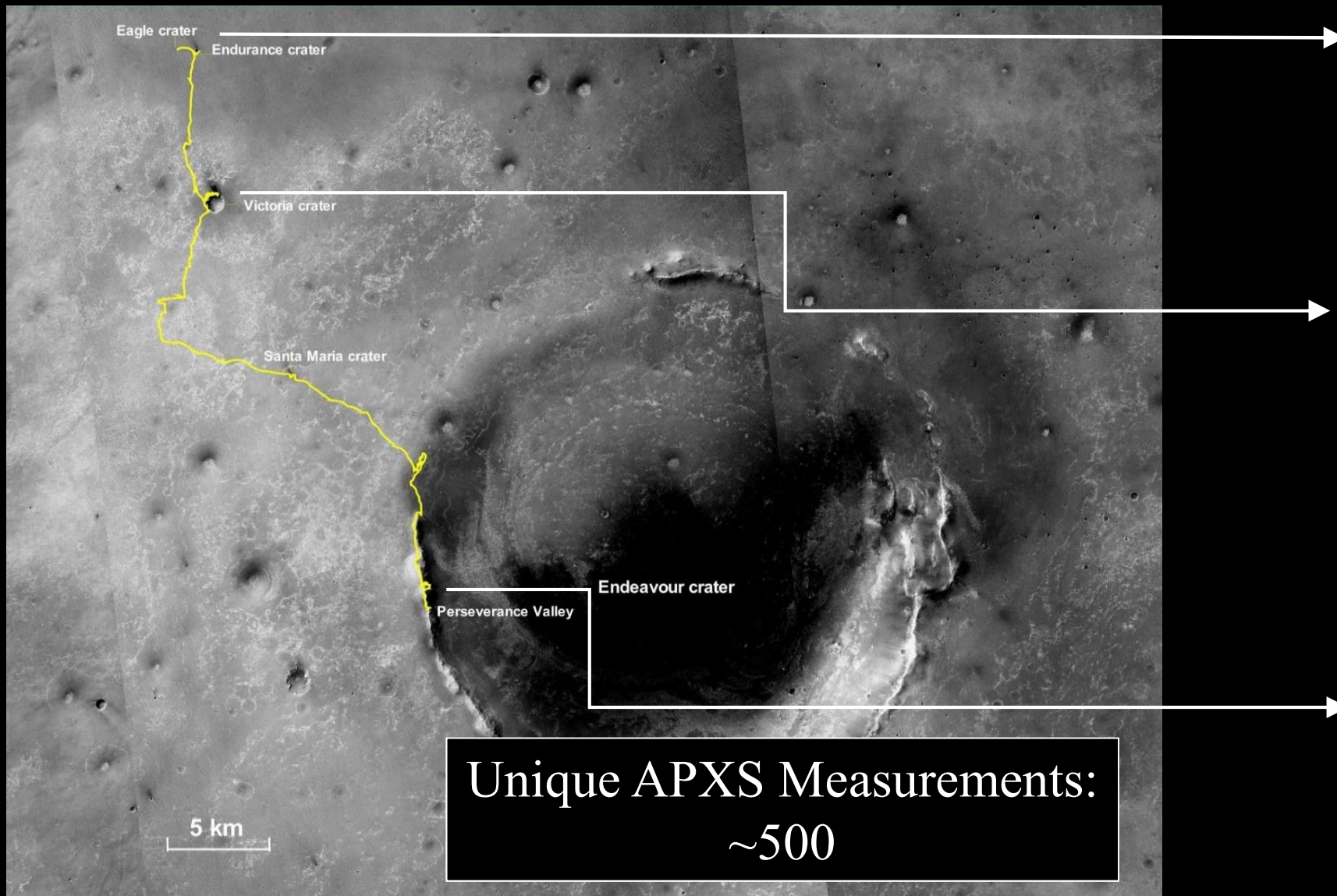
# Mission Overview: Spirit



MER Contact Science Target List: [https://pds-geosciences.wustl.edu/mer/urn-nasa-pds-mer\\_cs\\_target\\_list/](https://pds-geosciences.wustl.edu/mer/urn-nasa-pds-mer_cs_target_list/)



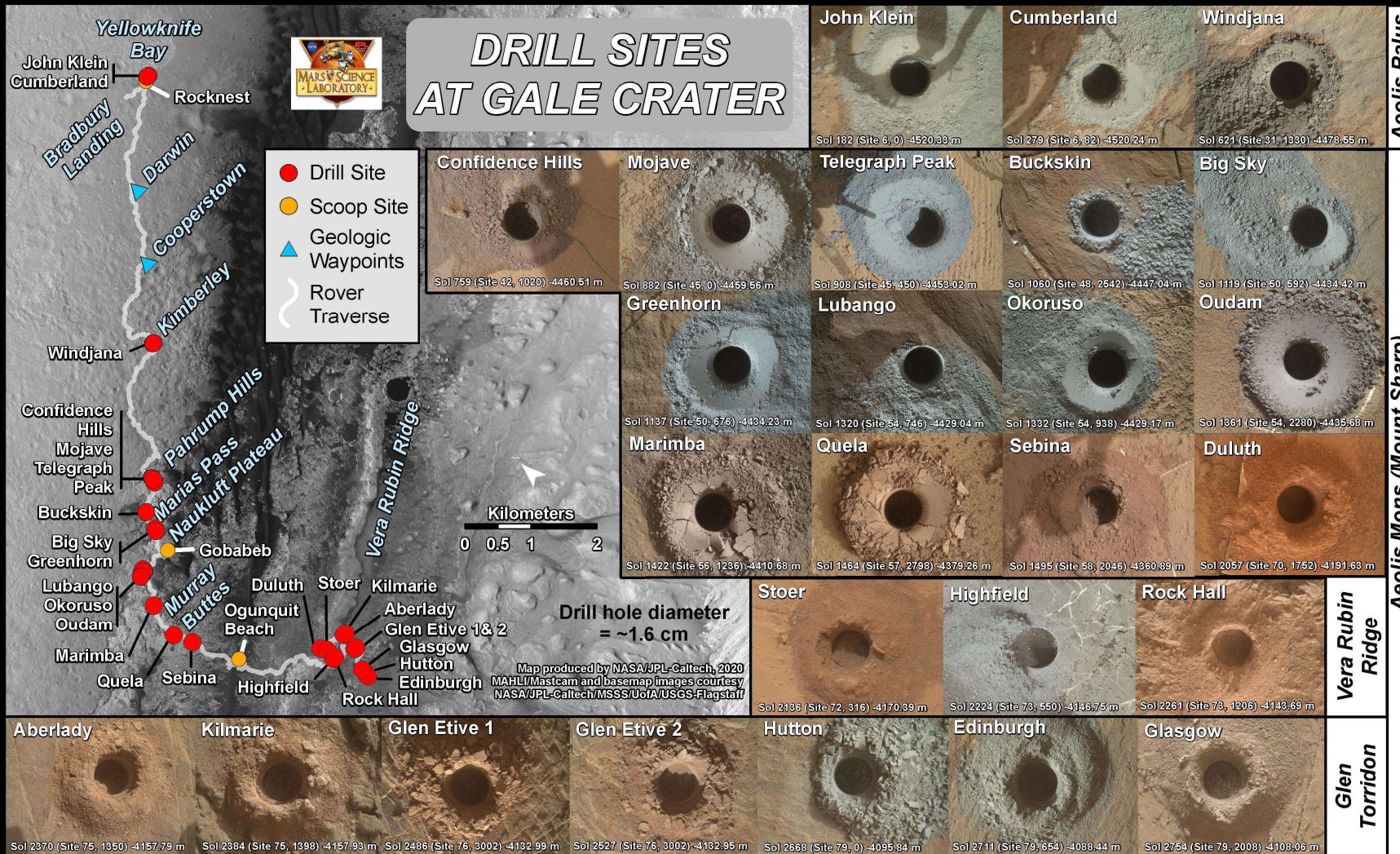
# Mission Overview: Opportunity



MER Contact Science Target List: [https://pds-geosciences.wustl.edu/mer/urn-nasa-pds-mer\\_cs\\_target\\_list/](https://pds-geosciences.wustl.edu/mer/urn-nasa-pds-mer_cs_target_list/)



# Mission Overview: Curiosity



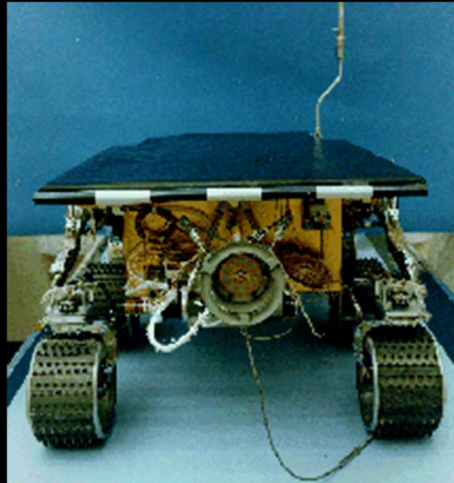
Unique APXS Measurements:  
~950

MSL APXS Data Supplement (to sol 2301): [https://pds-geosciences.wustl.edu/msl/urn-nasa-pds-msl\\_apxs\\_supplement\\_sols\\_0\\_2301/](https://pds-geosciences.wustl.edu/msl/urn-nasa-pds-msl_apxs_supplement_sols_0_2301/)

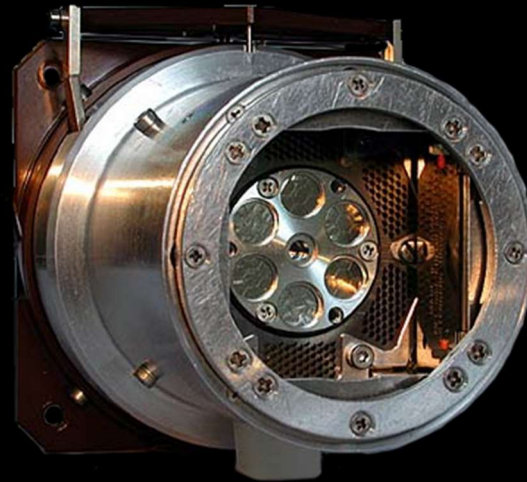


# APXS Overview

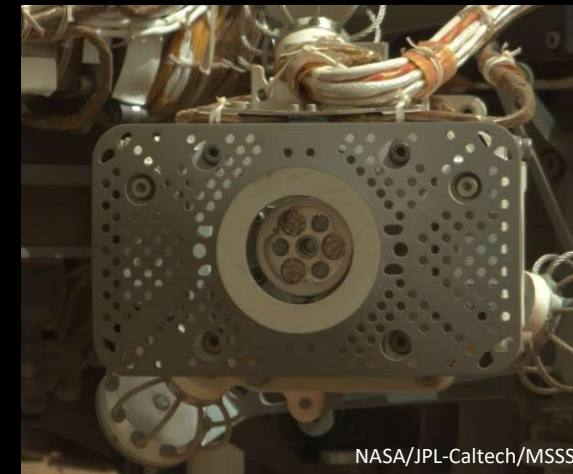
1997 – Mars Pathfinder  
(Sojourner)



2004 – MER  
(Spirit, Opportunity)

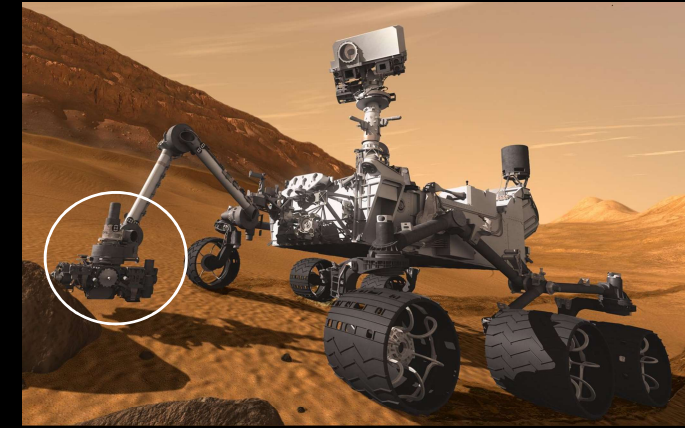
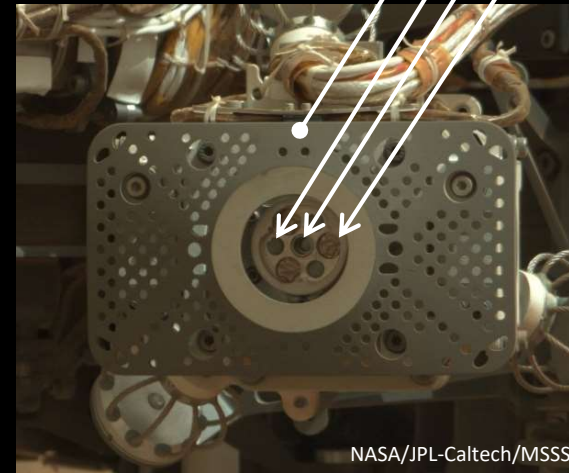
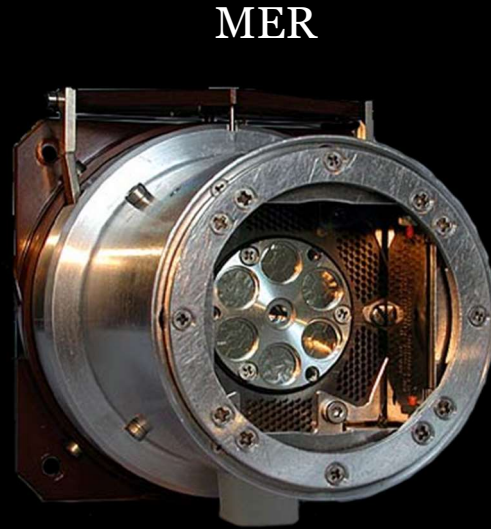
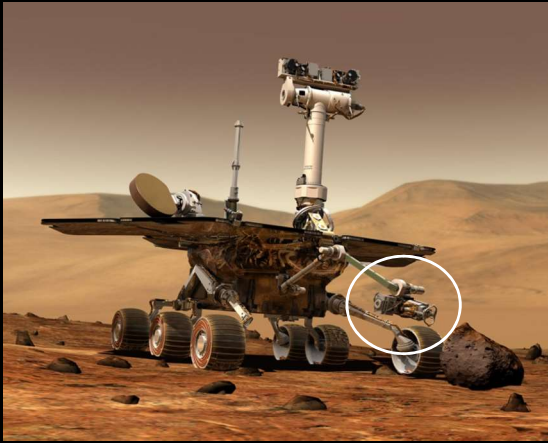


2012 – MSL  
(*Curiosity*)





# APXS Overview



- Contact Sensor Plate
- 10 mCi Beryllium-covered  $^{244}\text{Cm}$  (x3)
- SDD X-ray Detector
- 10 mCi Ti-foil-covered  $^{244}\text{Cm}$  (x3)

## Specifications

Sample Separation	30 mm (Contact)
In-Contact FOV	35 mm $\varnothing$
Energy Range	0.9 – 16 keV
Resolution	160 eV (FWHM)
Operating Temp	-130°C to -40°C
Power Dissipation	2.8 W

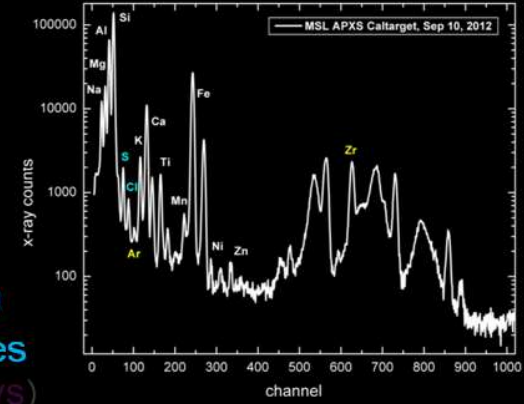
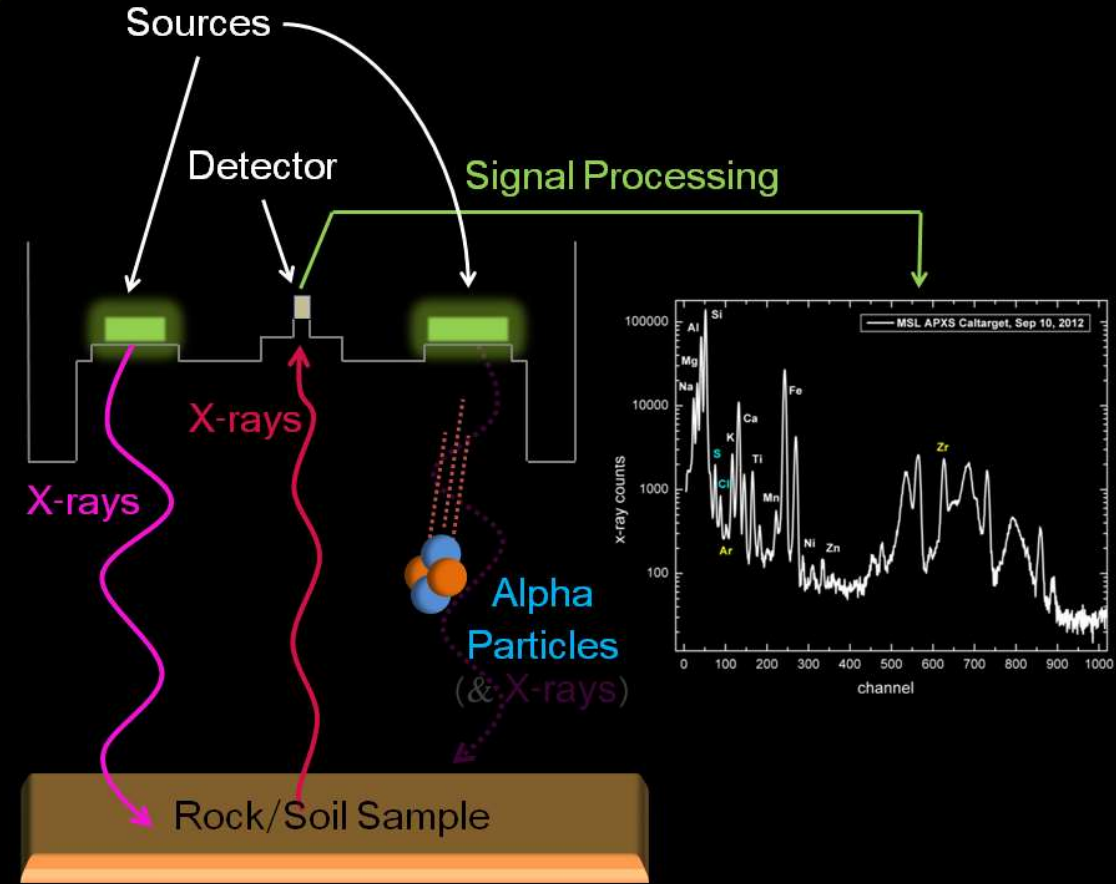
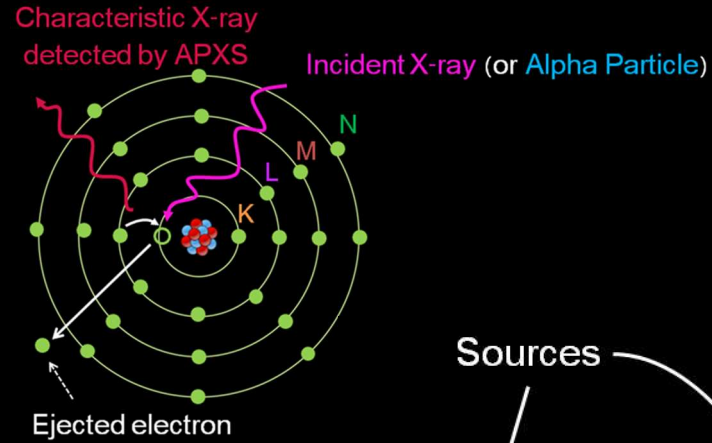
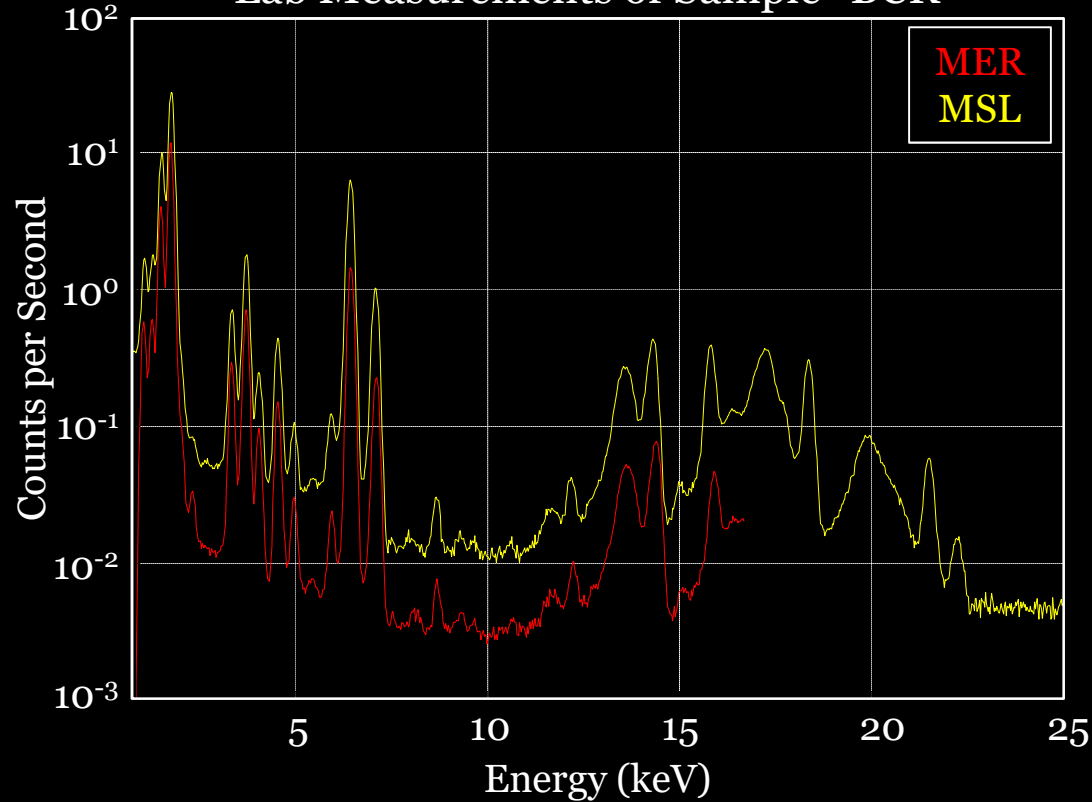
## Specifications

Sample Separation	18 mm (Contact)
In-Contact FOV	15 mm $\varnothing$
Energy Range	0.7 – 25 keV
Resolution	140 eV (FWHM)
Operating Temp	-130°C to -5°C
Power Dissipation	5 W (+3 w/Peltier)



# APXS Overview

Lab Measurements of Sample "BCR"

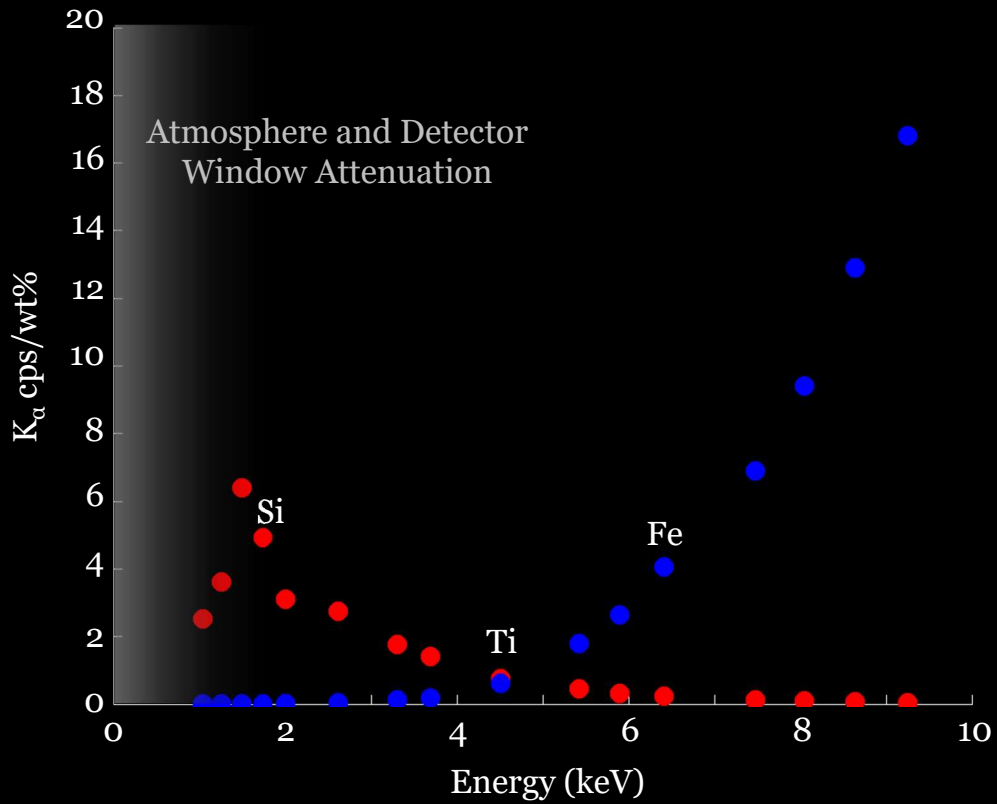


	MER	MSL
Sensitivity (Relative)	1	~3
Operable Peltier Cooler	No	$\Delta T=30^{\circ}C$
Meaningful APXS Calibration Target	No	Yes
Alpha Detectors (for RBS)	Yes	No
Proximity Mode	No	Yes

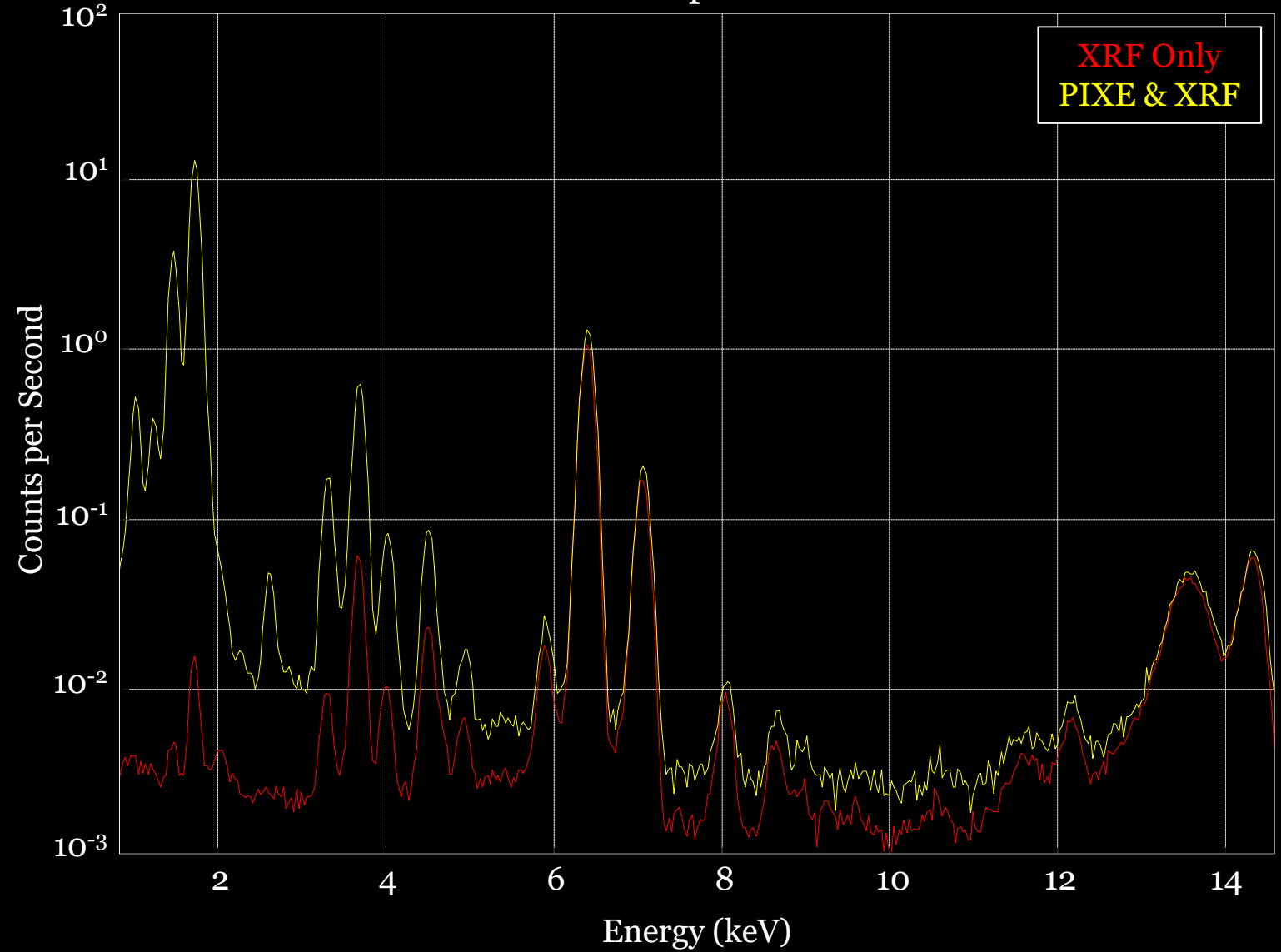


# APXS Overview

Excitation by **Alpha** and **X-rays** on APXS Target

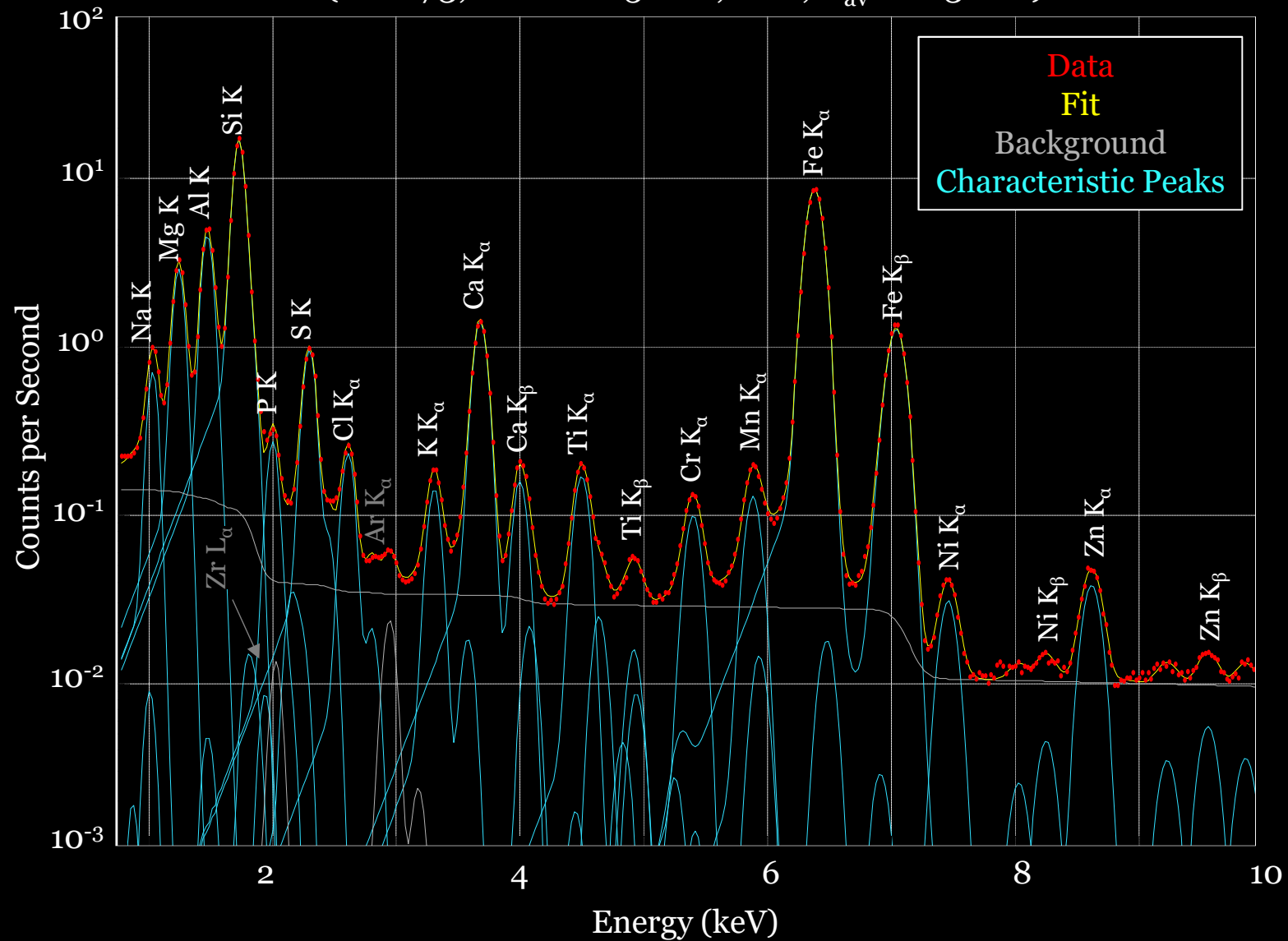


Lab Measurements of Sample "SSK1" with MER APXS



# APXS Overview

Fit of Mars Soil Sample “Sourdough”  
(Sol 673, FWHM 152 eV, ~8h,  $T_{av} = -63.2^{\circ}\text{C}$ )



# APXS Data Considerations

- Temperature
- Sample Proximity
- Measurement Duration
- Heterogeneities

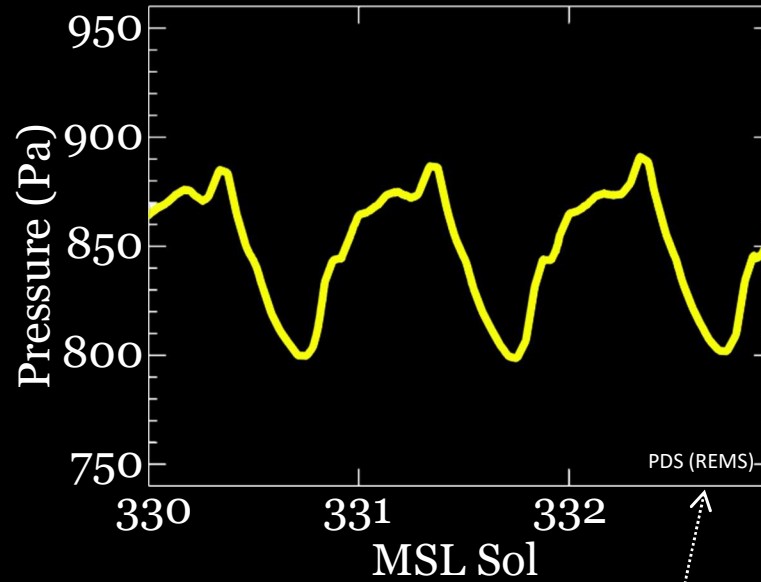


MSL APXS  
FOV

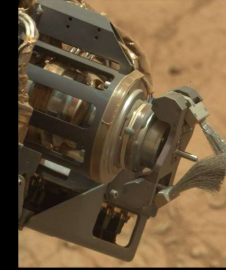
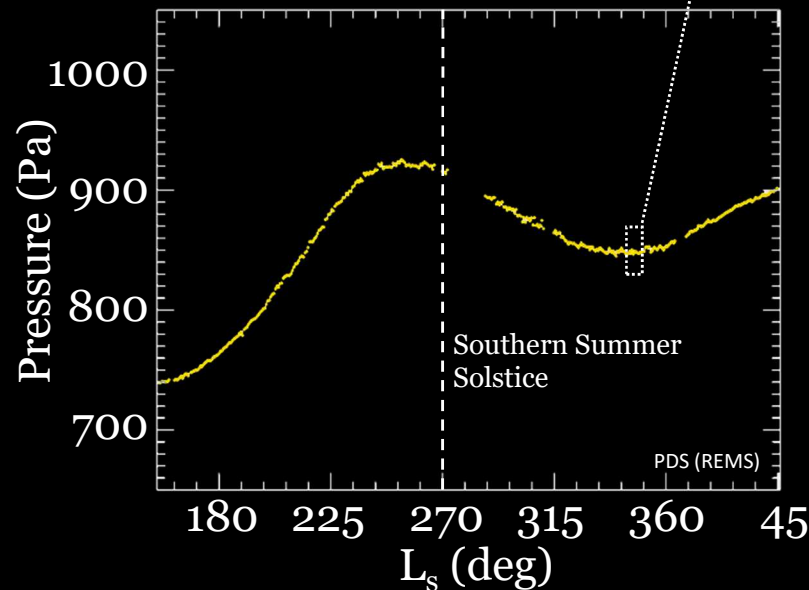
Image above captures an area approximately 3.5 cm x 5.0 cm in size

Credit: NASA/JPL-CalTech/MSSS

Diurnal Pressure Cycle



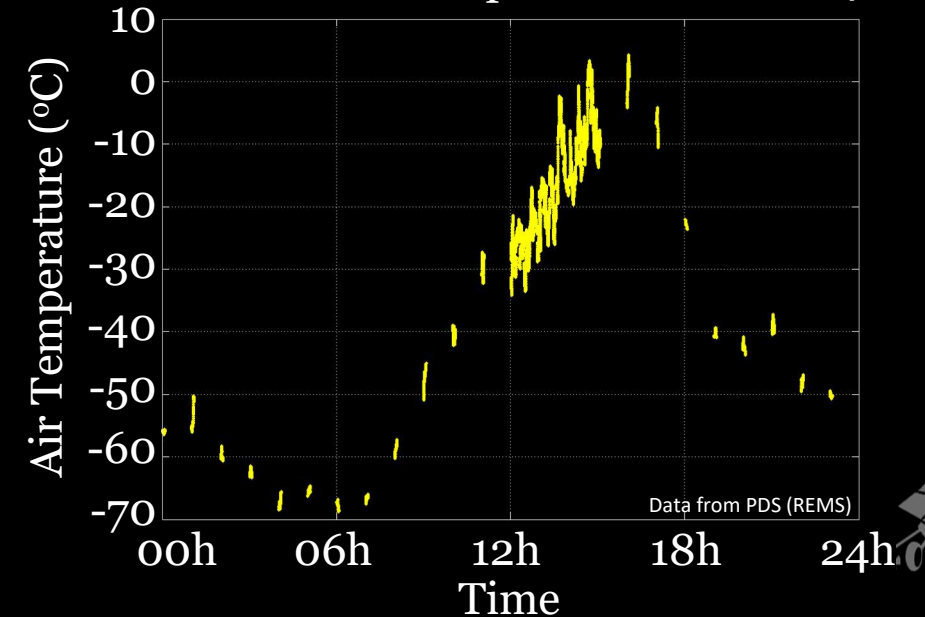
MSL Daily Averaged Pressure



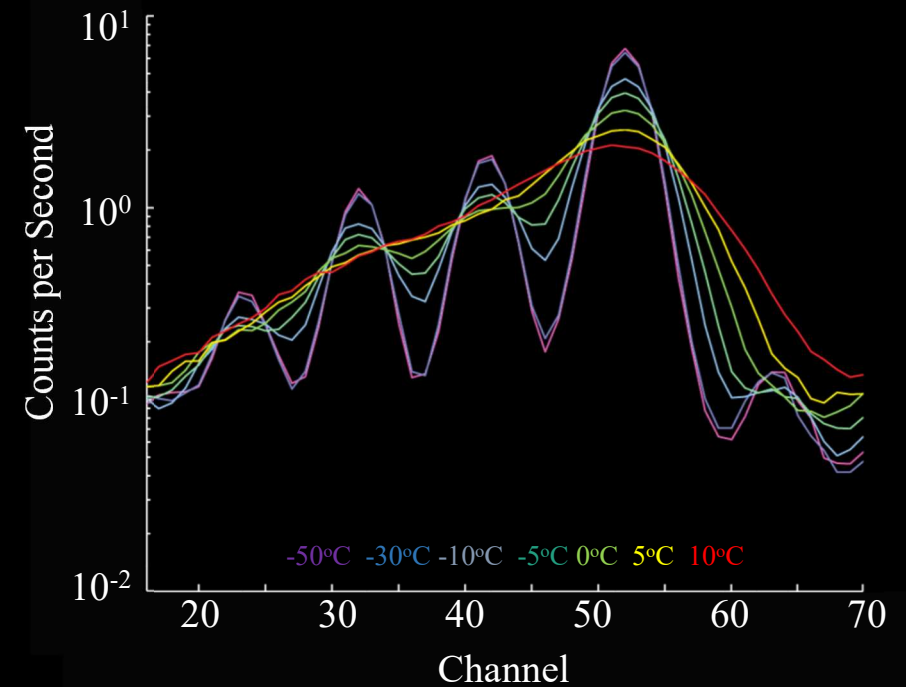
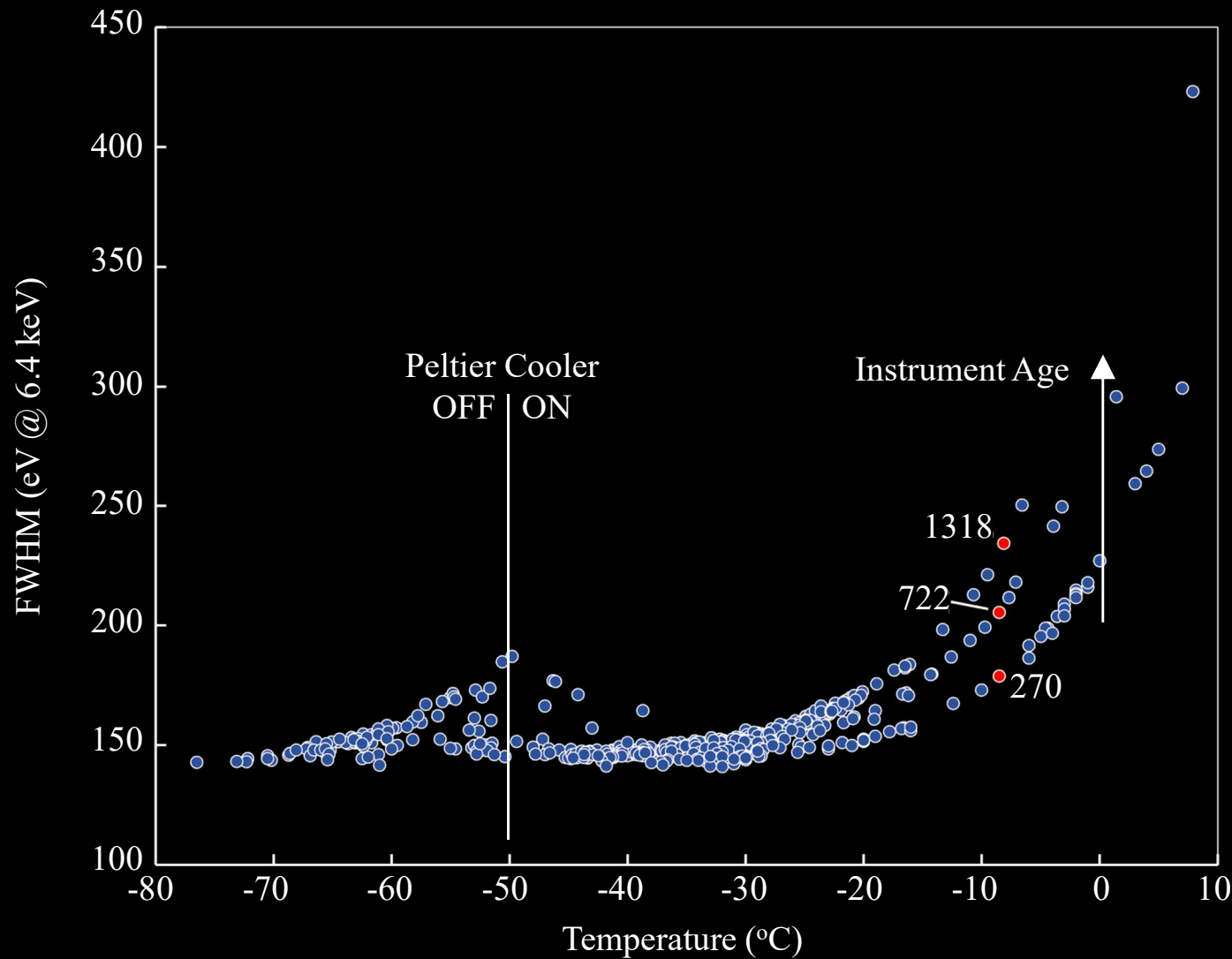
Dust



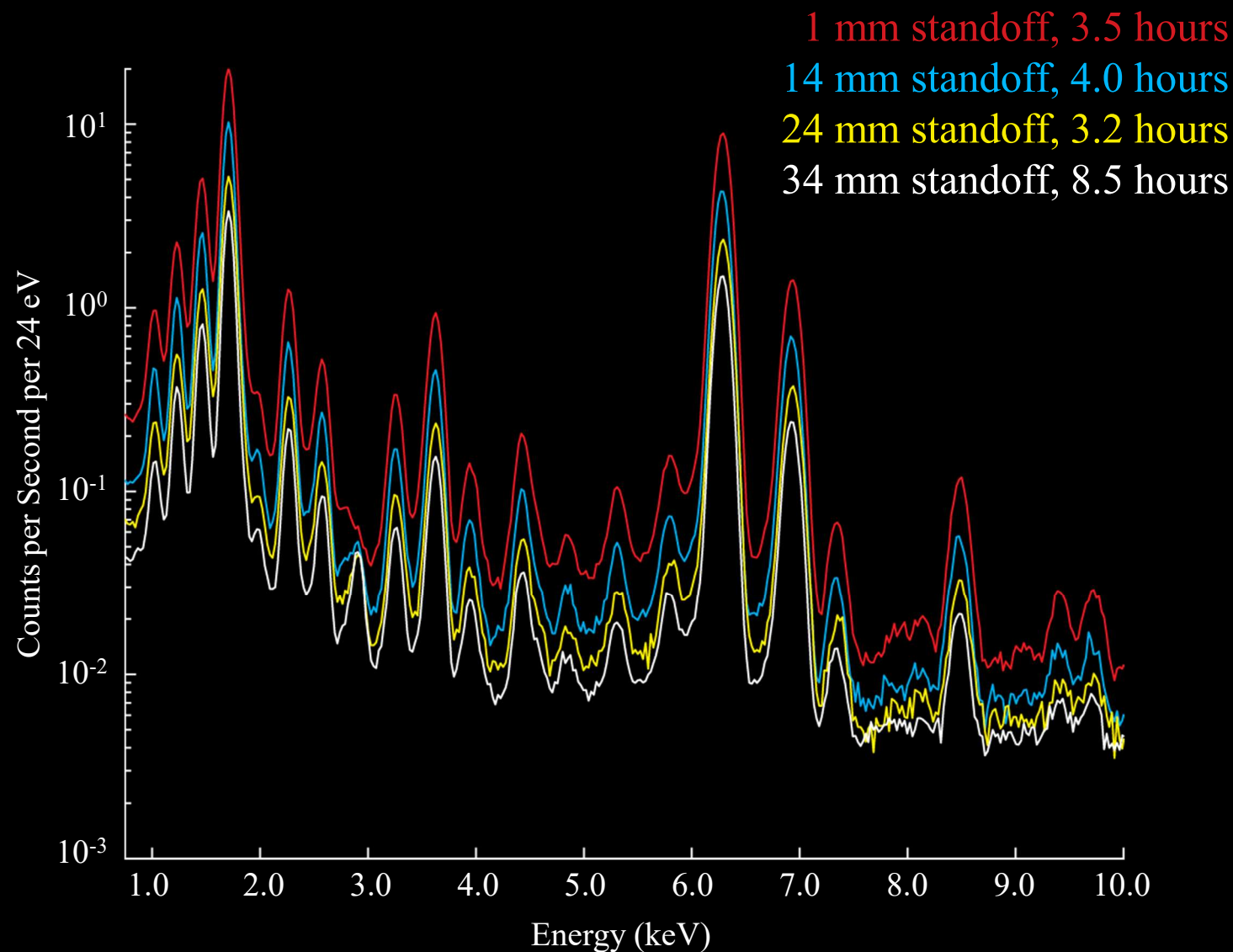
Ambient Air Temperature (Sol C224)



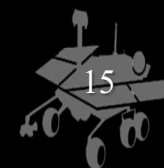
# APXS Data Considerations: Temperature



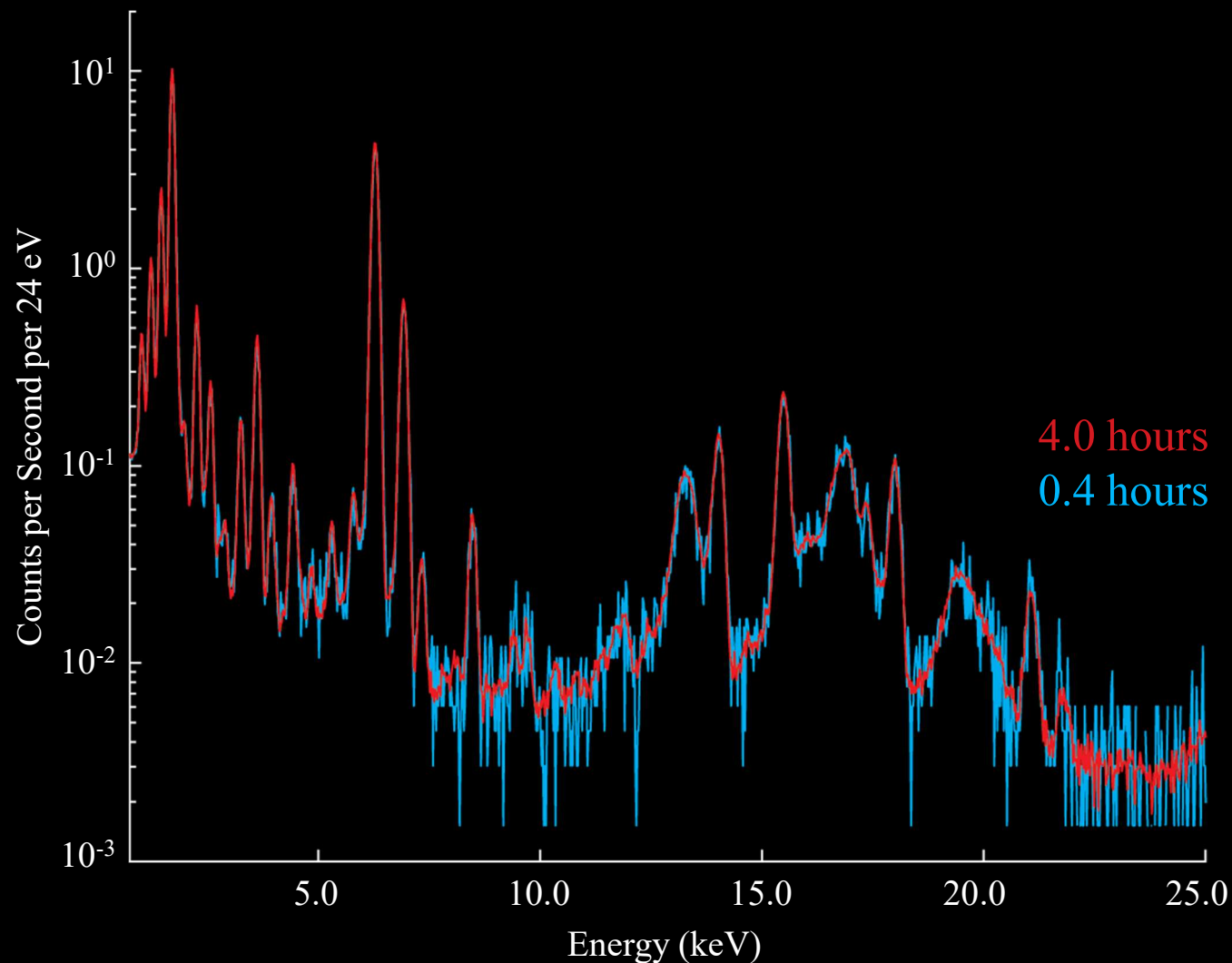
# APXS Data Considerations: Sample Proximity



- Standoff (sample proximity) primarily affects statistical count rates
- Some elements have a standoff-dependent background
- Higher standoff means more attenuation of low-Z X-rays by the atmosphere (e.g., Na, Mg)
- For every 1 cm further from the sample, count rates are approximately halved



# APXS Data Considerations: Measurement Duration

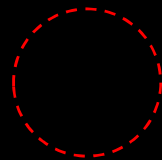
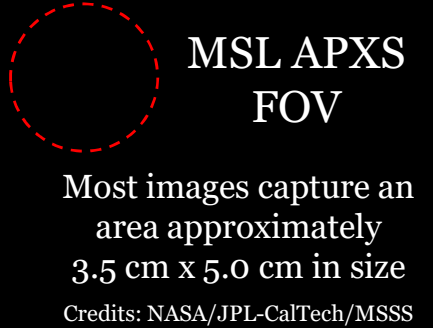


- Short-duration measurements are useful tactically in order to return geochemical data decisionally
- Short-duration measurements provide reliable results for major oxides
- Typical APXS measurements are 1-2 hours in length, or longer
- Overnight (4+ hour) measurements provide a high degree of confidence for trace elements





# APXS Data Considerations: Heterogeneities



MSL APXS  
FOV

Most images capture an  
area approximately  
3.5 cm x 5.0 cm in size  
Credits: NASA/JPL-CalTech/MSSS

- Targets are often interrogated with minimal sample preparation
- Chemical heterogeneities exist on a lateral scale smaller than a typical APXS field of view
- Vertical layering may also be present, affecting characteristic X-rays differently as a function of Z
- Surface dust is pervasive and skews low-Z compositions, as well as S and Cl, towards a known endmember composition



# APXS Data: Availability

- APXS data are available online through the PDS Geosciences node
- APXS data are reported in wt% oxides with a few exceptions (Cl, Ni, Zn, Br)
- Sixteen (16) elements and oxide concentrations are reported for each APXS measurement in wt% (unless otherwise noted): Na<sub>2</sub>O, MgO, Al<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, P<sub>2</sub>O<sub>5</sub>, SO<sub>3</sub>, Cl, K<sub>2</sub>O, CaO, TiO<sub>2</sub>, Cr<sub>2</sub>O<sub>3</sub>, MnO, FeO, Ni (μg/g), Zn (μg/g), Br (μg/g)
- Precision errors are reported, see data documentation for accuracy errors

## MER APXS Concentration Data Availability (PDS3, PDS4)

- Spirit & Opportunity:  
[https://pds-geosciences.wustl.edu/missions/mer/mer\\_apxs\\_oxide.htm](https://pds-geosciences.wustl.edu/missions/mer/mer_apxs_oxide.htm)

## MSL APXS Concentration Data Availability (PDS3)

- Curiosity:  
[https://pds-geosciences.wustl.edu/msl/msl-m-apxs-4\\_5-rdr-v1/mslapx\\_1xxx/extras/](https://pds-geosciences.wustl.edu/msl/msl-m-apxs-4_5-rdr-v1/mslapx_1xxx/extras/)



# APXS Data: Availability

MER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PDS Geosciences Node  
Washington University in St. Louis

HOME DATA AND SERVICES TOOLS ABOUT US CONTACT US SITE MAP

**Services**

- Analyst's Notebook
- Orbital Data Explorers
- Spectral Library
- Virtual Astronaut
- FTP Access
- Workshops

**Geosciences Node Data**

- Mars
- Venus
- Mercury
- Moon
- Earth
- Asteroids
- Radio Science
- Gravity Models
- All Geosciences DOIs
- All Geosciences Data Holdings

**Help**

- 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
- Email Us

**Scheduled Maintenance**

This site may be down on **Thursdays** between 7:00 and 9:30 pm Central Time for maintenance.

**Mars Exploration Rover Oxide Abundance Data**

**September 19, 2016.** PDS release 49 includes APXS Oxide Abundance data for Opportunity sols 1 through 4000, updating the previous delivery from 2012.

This data set contains oxide abundance data derived from the APXS Reduced Data Record (RDR) products acquired by the Alpha Particle X-ray Spectrometers on both MER rovers. The data were provided by Ralf Gellert, University of Guelph, and Rudolph Rieder, Max Planck Institute, and archived by the PDS Geosciences Node.

**Download the Archive**

mer\_apxs\_oxide.zip is a zip-compressed 315 KB file containing the complete archive.

**Direct Access to Archive Contents Online**

**Root Directory** - Start here for access to the entire volume.

- AAREADME.TXT - Introduction to the archive. Read this first.
- ERRATA.TXT - Release notes and errata concerning the archive.
- VOLDESC.CAT - Description of the volume contents as a PDS catalog object.

**DATA Directory** - This archive consists of two tables, one for each rover. Each table is accompanied by a PDS label that defines the table columns. The tables are in comma-separated-value (CSV) format, viewable in any text editor and suitable for loading into a spreadsheet program such as Microsoft Excel.

**CATALOG Directory** - Files in the CATALOG directory are text files containing documentation formatted for reading by humans and by software. The files contain information about the data set, the instrumentation, references, and personnel involved in archiving the data. See the file CATINFO.TXT for details. These files are called catalog files because they are entered into the PDS Catalog for online searching.

- APXS\_OXIDE\_DS.CAT - MER Oxide Abundance data set description.
- MER1\_APXS\_INST.CAT, MER2\_APXS\_INST.CAT - APXS Instrument descriptions.
- MER1\_INSTHST.CAT, MER2\_INSTHST.CAT - MER rover descriptions.
- MISSION.CAT - MER mission description.
- PERSON.CAT - Personnel associated with this archive volume.
- REF.CAT - References mentioned in the above catalog files.

**DOCUMENT Directory** - The DOCUMENT directory has notes from the APXS Payload Element Lead. **These notes contain important caveats regarding the use of the data. Read these notes carefully to avoid misinterpretation of the data.**

**EXTRAS Directory** - The EXTRAS directory in a PDS archive contains ancillary material that may be useful but is not required for the understanding of the archive. In this archive, the EXTRAS directory contains the original Excel spreadsheets as submitted to PDS, which became the basis for the tables in the DATA directory described above. The contents of this directory are described in EXTRINFO.TXT.

- APXS\_PDS\_540\_OXIDES\_MERAB.XLS - Excel spreadsheet
- APXS\_PDS\_541\_720\_OXIDES\_MERAB.XLS - Excel spreadsheet
- APXS\_PDS\_720\_1368\_OXIDES\_MERAB.XLS - Excel spreadsheet
- APXS\_OXIDES\_A\_1400\_2071\_B\_700\_2670.XLS - Excel spreadsheet
- APXS\_OXIDES\_MERB\_SOL4000.XLS - Excel spreadsheet

MSL

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**Geosciences Node Data**

- Mars
- Mars Exploration
- Mars 2020
- InSight
- MSL
- About MSL
- APXS
- ChemCam
- ChemMin
- DAN
- SAM
- MRO
- MER

**MSL: APXS (Alpha Particle X-ray Spectrometer)**

July 31, 2020. MSL Release 24 includes new APXS raw (EDR) and derived (RDR) data from sols 2580-2713. November 8, 2019 - March 25, 2020.

The Alpha Particle X-ray Spectrometer (APXS) measures the abundance of chemical elements in rocks and soils. The APXS is placed in contact with rock and soil samples on Mars and exposes the material to alpha particles and X-rays emitted during the radioactive decay of the element curium. APXS data sets are produced by the APXS Science Team at the University of Guelph, Ontario, Canada. The APXS is funded by the Canadian Space Agency.

**APXS Data Sets**

- Raw Data Products**
  - EDR - Experiment Data Records
- Derived Data Products**
  - RDR - Reduced Data Records
    - Product type APXS\_RSP - summed X-ray spectra (files named \*rsp\*.csv)
    - Product type APXS\_RWP - oxide abundance data (files named \*rwp\*.csv)

[To Parent Directory]

4/5/2017 10:27 AM	4942	aareadme.txt
4/9/2015 3:06 PM	<dir>	calib
8/28/2013 1:25 PM	<dir>	catalog
7/29/2020 7:21 AM	<dir>	data
2/19/2020 12:07 PM	<dir>	document
7/7/2020 11:02 AM	8832	errata.txt
7/29/2020 7:21 AM	<dir>	extrnas
7/7/2020 11:46 AM	<dir>	index
1/8/2013 11:35 AM	1642	voldesc.cat

3/11/2019 10:53 AM	2821	extrinfo.txt
2/25/2013 5:07 PM	2572	msl_apxs_activities_sol0000_0089.csv
5/31/2013 12:48 PM	2740	msl_apxs_activities_sol0090_0179.csv
8/9/2013 1:54 PM	1187	msl_apxs_activities_sol0180_0269.csv
12/6/2013 9:07 PM	1683	msl_apxs_activities_sol0270_0359.csv
2/27/2014 2:19 PM	1820	msl_apxs_activities_sol0360_0449.csv
6/12/2014 12:13 PM	2865	msl_apxs_activities_sol0450_0539.csv
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2/17/2015 2:39 PM	2301	msl_apxs_activities_sol0708_0804.csv
7/6/2015 2:24 PM	6974	msl_apxs_activities_sol0805_0938.csv
10/30/2015 12:30 PM	2214	msl_apxs_activities_sol0939_1062.csv
2/16/2016 12:37 PM	3650	msl_apxs_activities_sol1063_1159.csv
6/28/2016 2:21 PM	5572	msl_apxs_activities_sol1160_1293.csv

+ more (and new data every 90 days)



# APXS Data: Availability

- APXS compositional context is most easily gained through exploring APXS data and associated targets in the Analyst's Notebook (see **Zoom tutorial** here on **Thursday October 29<sup>th</sup>, 15:00 EDT**: Content and Use of PDS Geosciences Node Landed Mission Analyst Notebooks)
  - MER: <https://an.rsl.wustl.edu/mer/>
  - MSL: <https://an.rsl.wustl.edu/msl/>

sol	target	start_time	gnorm	sh_tavg	lifetime	Fe_FWHM	Na2O	Na2O_err	MgO	MgO_err	Al2O3	Al2O3_err	SiO2	SiO2_err	P2O5	P2O5_err	SO3	SO3_err	Cl	Cl_err	K2O	K2O_err	CaO	CaO_err	TiO2	TiO2_err	Cr2O3	Cr2O3_err	MnO	MnO_err	FeO	FeO_err	Ni	Ni_err	Zn	Zn_err	Br	Br_err
46	Jake_Matijevic	00046M11:43:31	101.8	-3	00:32:09	204.1	7.11	0.41	3.61	0.33	16.09	0.87	50.7	1.07	0.49	0.07	2.48	0.12	0.87	0.05	2.23	0.12	6.07	0.31	0.49	0.03	0.04	0.01	0.14	0.02	9.47	0.20	30	20	221	15	92	10
47	JM2_APXS_RP2	00047M11:53:23	96	-2	00:12:00	211.6	6.61	0.55	4.57	0.58	14.59	0.77	49.29	1.07	0.6	0.14	3.05	0.17	1.03	0.06	2.01	0.11	6.54	0.34	0.65	0.07	0.09	0.03	0.17	0.06	10.61	0.26	0	0	340	24	93	15
47	JM2_APXS_RP2_OVERNIGHT	00048M00:01:42	90.5	-55	00:30:00	148.6	6.59	0.20	4.60	0.17	14.65	0.38	48.87	0.54	0.85	0.05	2.81	0.08	0.95	0.03	1.89	0.06	6.78	0.08	0.73	0.03	0.04	0.01	0.23	0.02	10.94	0.13	60	20	318	15	93	5
54	Bathurst_Inlet_RP_For_Real	00054M11:51:54	113.1	-4	00:22:14	196.7	2.21	0.27	8.56	0.33	7.85	0.38	43.65	0.64	0.82	0.07	3.05	0.12	0.73	0.04	2.18	0.07	6.28	0.08	1.09	0.09	0.42	0.03	0.83	0.06	22.07	0.26	399	40	1359	44	13	10
54	Bathurst_Inlet_Top_RP	00054M12:42:20	132.3	-2	00:22:15	212.7	2.06	0.14	8.68	0.50	7.92	0.48	43.95	0.96	0.88	0.09	3.31	0.17	0.81	0.05	2.88	0.15	6.45	0.34	1.06	0.07	0.36	0.03	0.46	0.06	21.00	0.46	326	30	1221	65	40	10
58	Scuffed_E	00058M11:36:26	8.2	-1	01:04:19	217.9	1.99	0.41	7.90	1.67	9.02	0.48	43.94	0.96	0.65	0.14	5.97	0.30	0.84	0.08	0.55	0.12	7.45	0.38	0.97	0.21	0.39	0.06	0.39	0.08	19.13	0.39	436	115	544	70	0	5
58	Unscuffed_A	00058M12:48:47	8.2	4	00:19:01	264.9	2.14	1.64	7.79	1.58	8.84	1.25	43.54	1.82	0.00	0.82	6.93	1.23	1.05	0.23	0.76	0.16	7.11	0.71	0.44	0.47	0.30	0.17	0.5	0.18	19.58	1.44	649	299	649	179	0	0
86	Et_Then	00086M11:52:32	5.4	3	00:22:18	259.5	2.91	0.95	4.71	1.50	8.96	0.58	45.42	0.96	0.55	0.44	4.23	0.45	0.98	0.18	1.63	0.67	4.41	0.25	0.61	0.29	0.30	0.14	0.44	0.40	24.67	0.52	288	270	353	149	0	5
89	PortageRP	00089M05:23:06	27.2	-62	03:14:02	144.9	2.70	0.14	8.69	0.25	9.37	0.19	42.97	0.54	0.95	0.07	5.47	0.10	0.69	0.03	0.49	0.02	7.26	0.08	1.19	0.05	0.49	0.03	0.42	0.04	19.18	0.20	456	30	326	15	34	10
91	Et_Then_overnight	00091M01:03:40	6.7	-61	02:00:43	141.6	2.95	0.95	4.19	1.33	8.41	0.29	45.06	0.75	0.99	0.42	4.06	0.17	0.79	0.06	1.57	0.64	4.27	0.11	0.73	0.31	0.08	0.05	0.39	0.02	26.33	0.33	225	89	485	54	49	15
102	rocknest3_rp	00102M11:46:35	105.7	0	00:22:18	227.0	4.02	0.41	5.32	0.50	10.52	0.58	45.97	0.96	1.08	0.14	4.06	0.22	0.88	0.05	1.86	0.10	6.05	0.31	0.96	0.05	0.24	0.03	0.46	0.04	18.39	0.39	368	35	891	44	65	10
117	Bell_Island_target9_day	00117M12:00:02	84.6	-5	00:22:18	195.5	3.17	0.14	8.01	0.17	8.99	0.19	42.72	0.43	0.80	0.07	7.40	0.15	1.22	0.05	1.05	0.04	6.84	0.08	0.81	0.03	0.46	0.03	0.48	0.06	17.93	0.20	286	35	662	30	92	10
117	Bell_Island_target9_night	00117M21:01:49	81.8	-40	00:16:01	151.1	3.01	0.14	8.18	0.17	9.08	0.19	42.77	0.43	1.00	0.07	7.09	0.17	1.21	0.05	1.01	0.04	6.79	0.10	0.81	0.05	0.50	0.03	0.48	0.06	17.89	0.20	291	40	625	35	86	15
129	Costello	00129M12:39:12	113	5	00:44:19	273.8	2.19	0.48	8.72	0.50	8.35	0.48	42.28	0.86	0.51	0.33	6.25	0.65	1.36	0.14	0.46	0.05	6.58	0.67	1.04	0.12	0.48	0.06	0.41	0.06	21.12	1.50	505	60	828	85	168	20
129	Flaherty	00129M17:10:42	107.8	-23	06:01:01	149.6	2.59	0.14	8.67	0.25	8.20	0.19	41.36	0.43	0.93	0.07	6.42	0.08	1.18	0.02	0.42	0.02	6.63	0.07	0.95	0.03	0.49	0.01	0.36	0.02	21.60	0.26	441	24	795	24	324	10
132	Gillespie_Lake_1	00132M11:32:14	69.4	-2	00:44:18	213.3	2.58	0.34	9.18	0.50	9.11	0.48	45.60	0.96	0.88	0.12	2.88	0.15	1.10	0.06	0.51	0.04	6.45	0.34	1.12	0.07	0.52	0.03	0.35	0.06	19.59	0.46	320	35	590	30	93	10

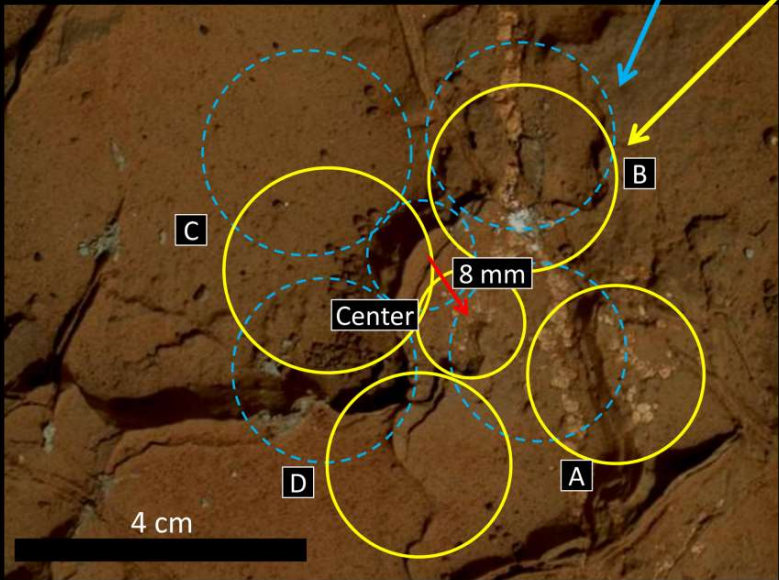
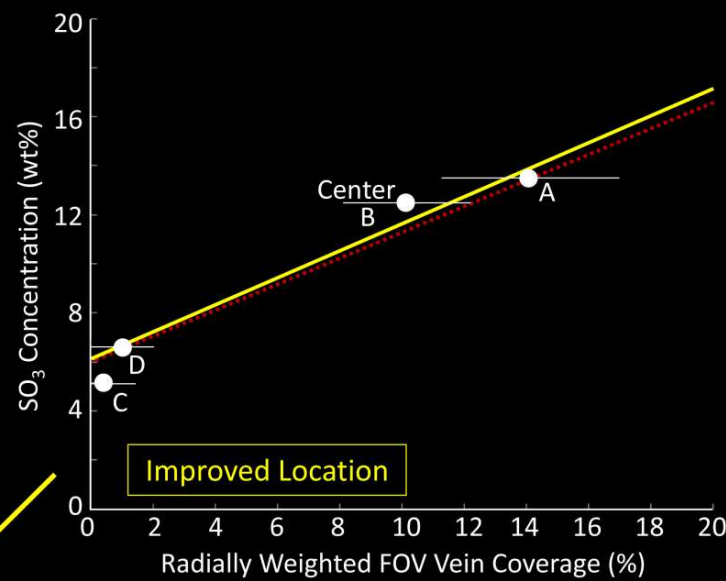
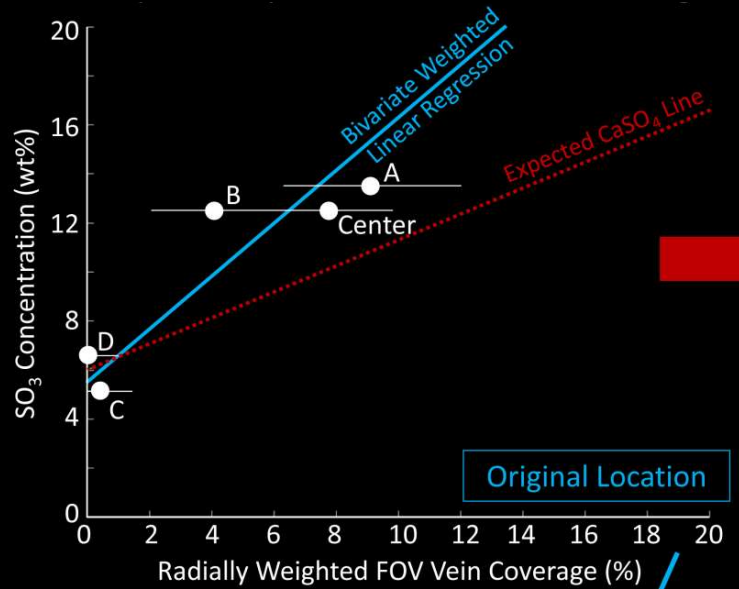


# APXS Analytical Techniques: Deconvolution & Emulation

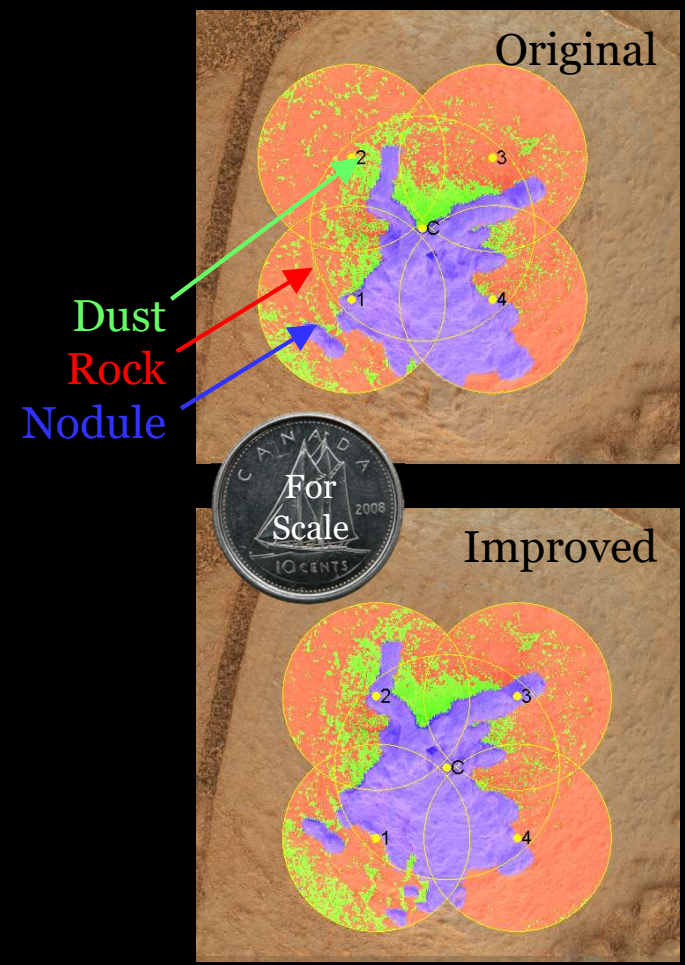
- APXS data is integral to elucidating geochemical trends on the surface of Mars
- The additional complement of data from other instruments on the rover enables one to assess whether past conditions on Mars were once habitable through a detailed characterization of Mars' paleoclimate
- New techniques are advancing the scientific return of data acquired by the APXS
  - Computational deconvolution techniques have increased the spatial resolution upon which the APXS can provide quantitative chemistry, essential for determining the chemical composition of diagenetic features
  - Artificial Intelligence has effectively created a “lab APXS” within a computer, enabling detailed studies of acquired and theoretical APXS data



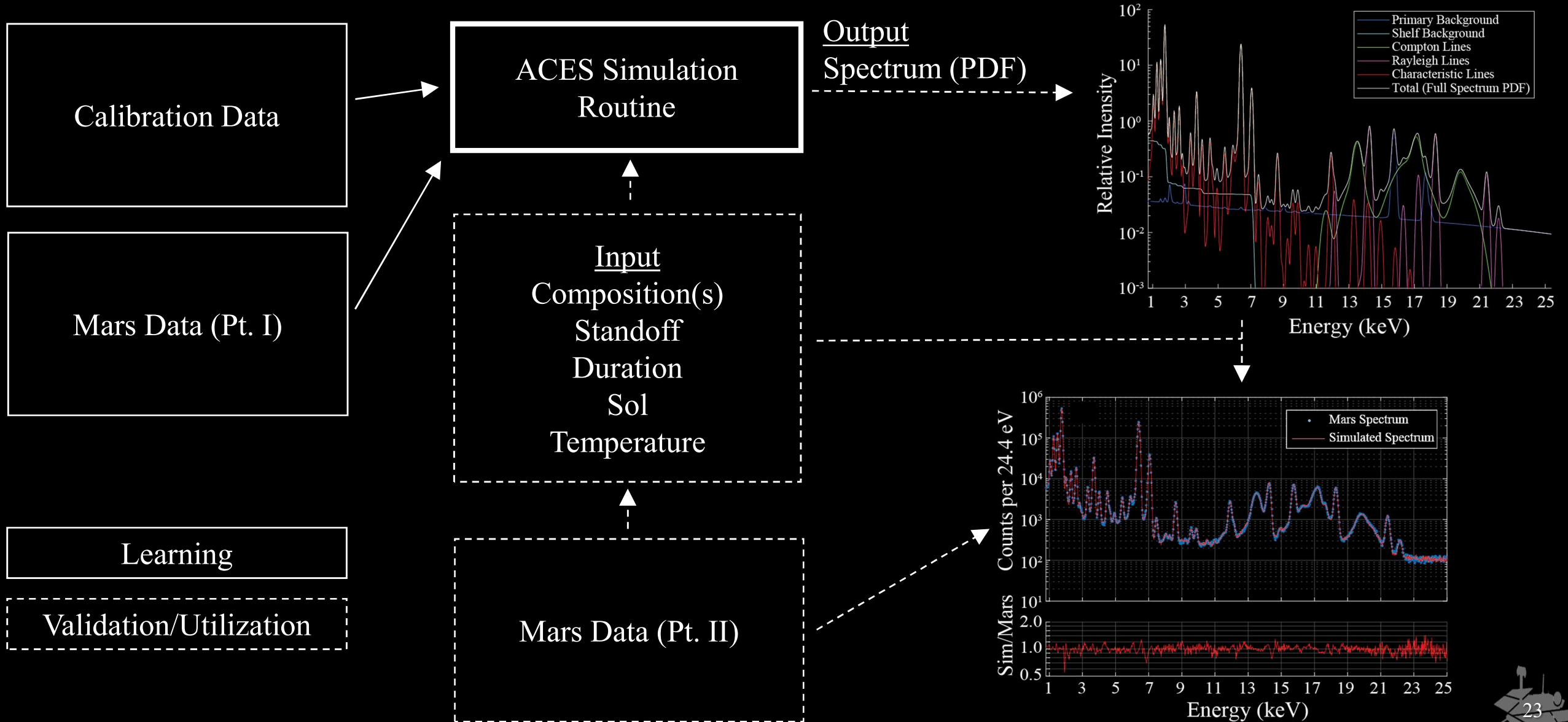
# APXS Analytical Techniques: Deconvolution



	Dusty Rock		Vein		R <sup>2</sup>
	Conc. (wt%)	Error (wt%)	Conc. (wt%)	Error (wt%)	
Na <sub>2</sub> O	2.75	0.10	0.00	0.07	0.47
MgO	9.58	0.12	0.00	0.06	0.24
Al <sub>2</sub> O <sub>3</sub>	8.65	0.12	0.00	0.07	0.58
SiO <sub>2</sub>	43.08	0.18	0.00	0.07	0.96
P <sub>2</sub> O <sub>5</sub>	1.01	0.04	0.00	0.07	0.52
SO <sub>3</sub>	5.38	0.11	<b>65.04</b>	0.61	1.00
Cl	1.54	0.02	0.00	0.01	0.10
K <sub>2</sub> O	0.55	0.01	0.00	0.01	0.44
CaO	5.54	0.07	<b>34.96</b>	0.61	0.94
TiO <sub>2</sub>	0.90	0.03	0.00	0.07	0.41
Cr <sub>2</sub> O <sub>3</sub>	0.40	0.01	0.00	0.13	0.00
MnO	0.31	0.01	0.00	0.01	0.95
FeO	20.12	0.11	0.00	0.06	0.59
Ni (ppm)	817	30	0	40	0.07
Zn (ppm)	827	20	0	15	0.82
Br (ppm)	240	5	0	5	0.02



# APXS Analytical Techniques: Emulation

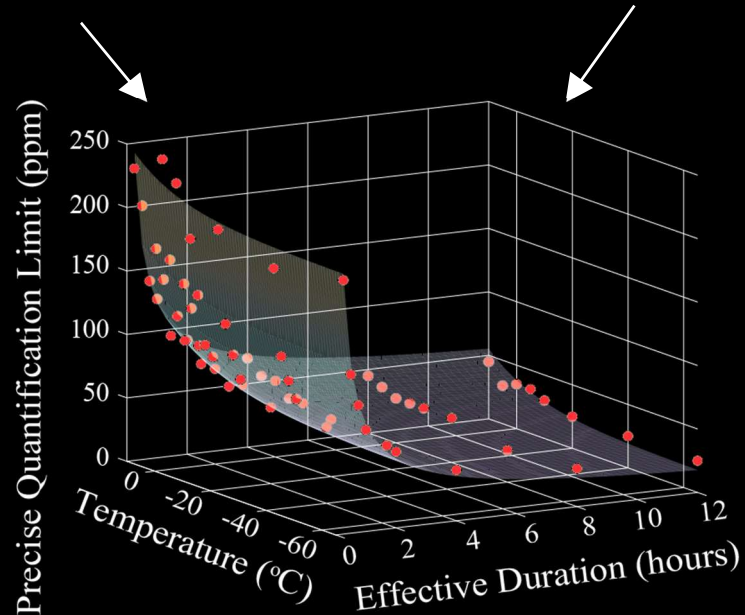
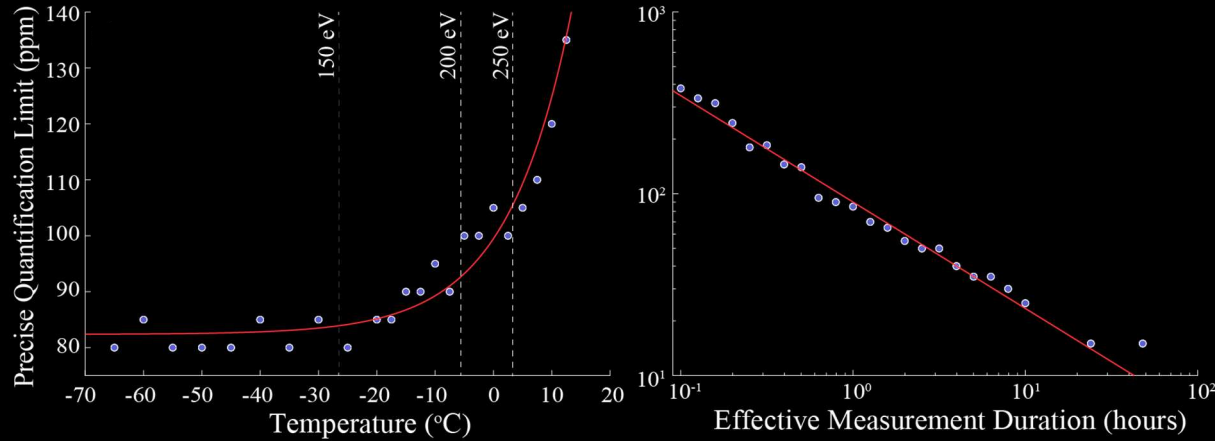


# APXS Analytical Techniques: Emulation

APXS Situational Sensitivity (PQL): Zn

Effective Duration: 1 hour

Temperature: Ideal



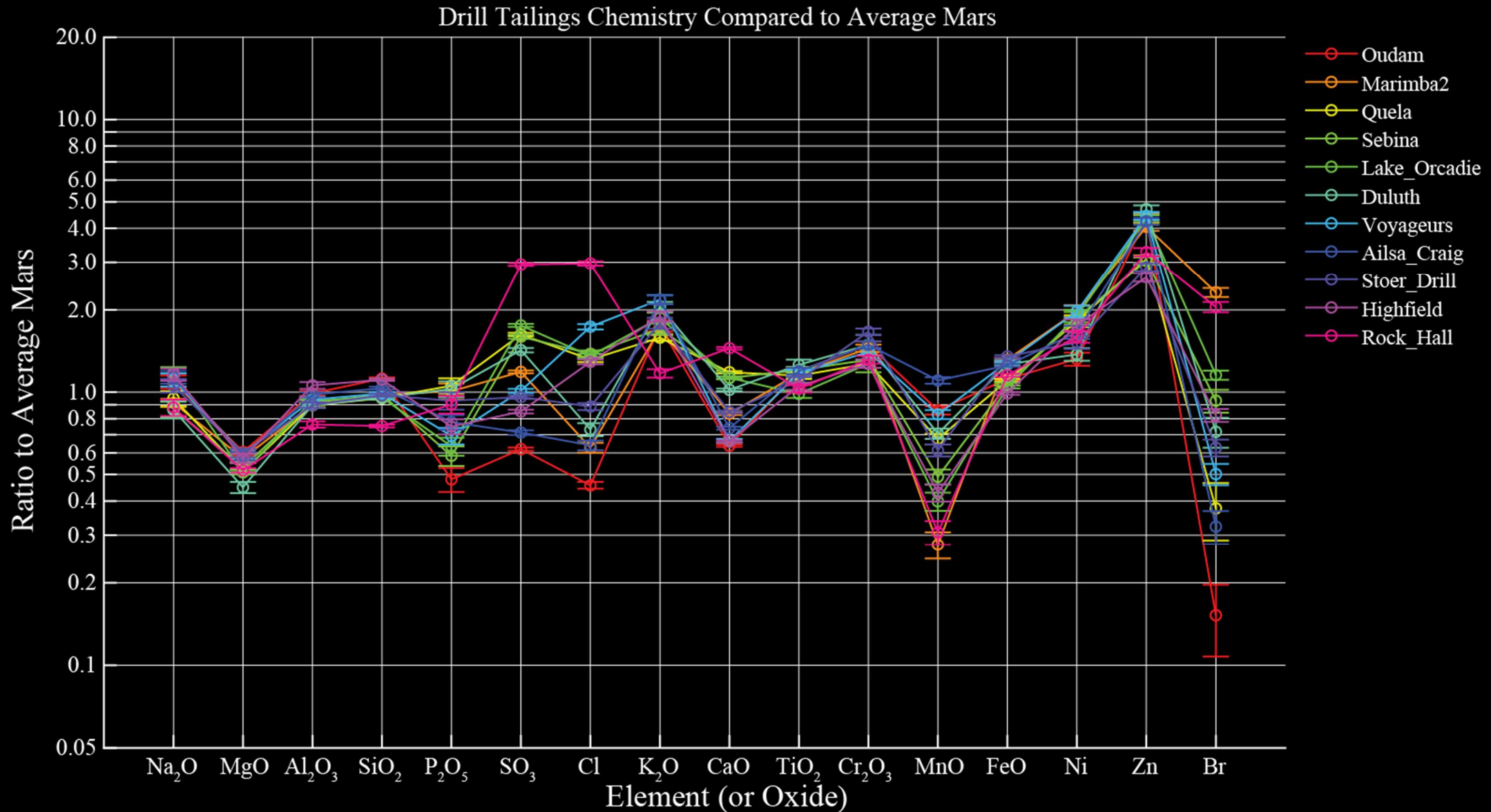
Element	PQL (ppm) by Measurement Condition		
	Touch-and-Go	Evening	Overnight
Ni	365	115	55
Cu	220	75	30
Zn	190	55	30
Ga	135	45	25
Ge	150	45	25
Br	85	25	15

- APXS emulation is also being used to conduct performance testing for possible application on lunar missions, without the need for special laboratory equipment and lunar samples



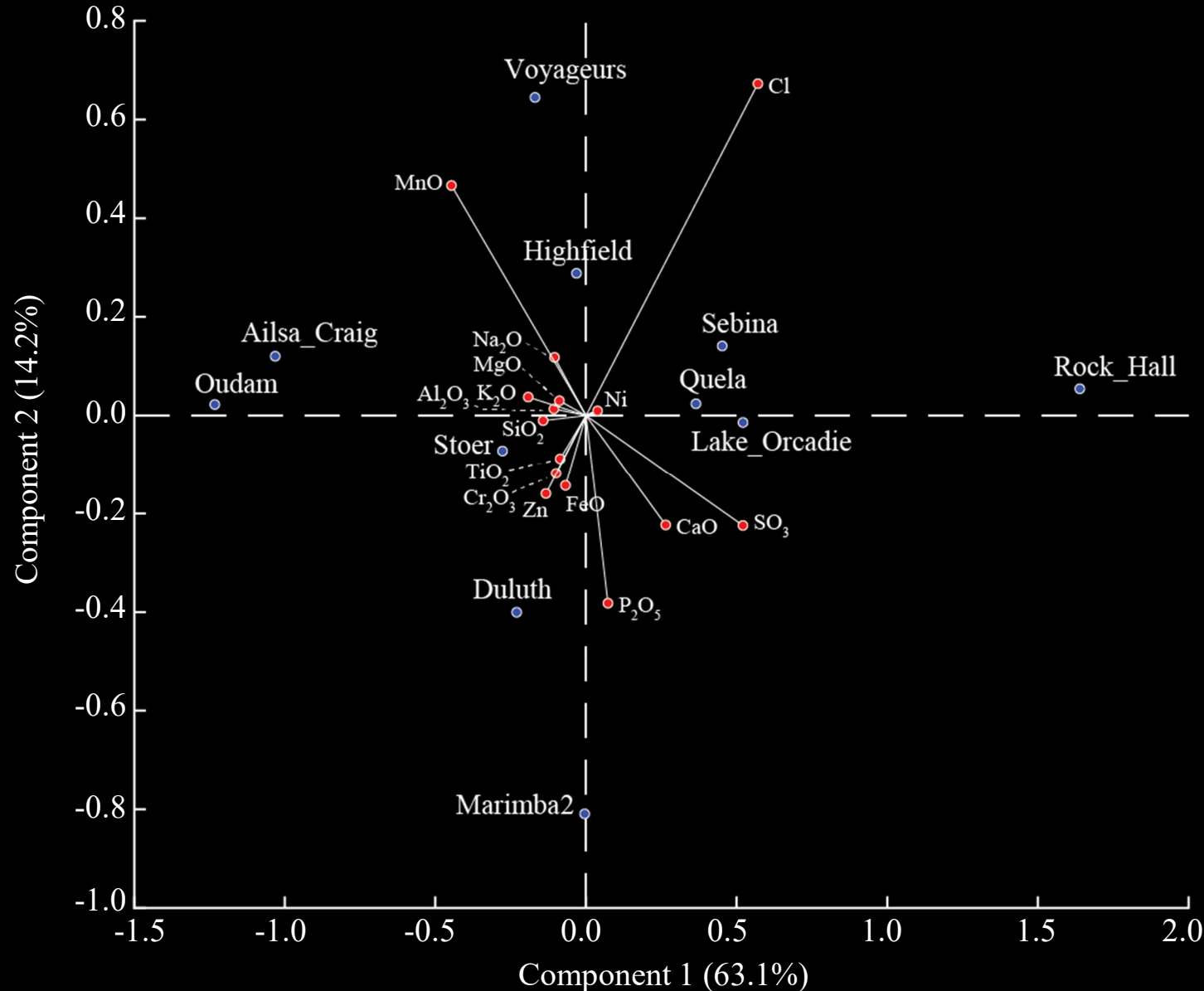


# APXS Analytical Techniques: PCA



# APXS Analytical Techniques: PCA

Total Explained Variance in Bi-Plot: 77.3%



- PCA analysis follows work by J. Aitchison and corrects for closed-number artifacts
- Quick and convenient way to review multivariate data



To enter a tutorial session, click on “Let’s talk” at the **PDS Exhibitor Booth** at the DPS web site.

## Tutorials

### MRO CRISM Hyperspectral Data Sets and Analysis Tools

Monday, October 26  
2:30 to 3:30 PM EDT

### Mars Rover In Situ X-ray Compositional Data Sets and Analysis Tools

Tuesday, October 27  
3:00 to 4:00 PM EDT

### Content and Use of PDS Geosciences Node Orbital Data Explorers

Wednesday, October 28  
4:00 to 5:00 PM EDT

### Content and Use of PDS Geosciences Node Landed Mission Analyst Notebooks

Thursday, October 29  
3:00 to 4:00 PM EDT

## Webinars

Introduction to PDS Geosciences Node Data Sets and Analysis Tools  
Monday, October 26  
12:00 to 12:30 PM EDT

Introduction to PDS Geosciences Node Orbital Data Explorers and Landed Mission Analyst Notebooks  
Wednesday, October 28  
2:00 to 2:30 PM EDT

