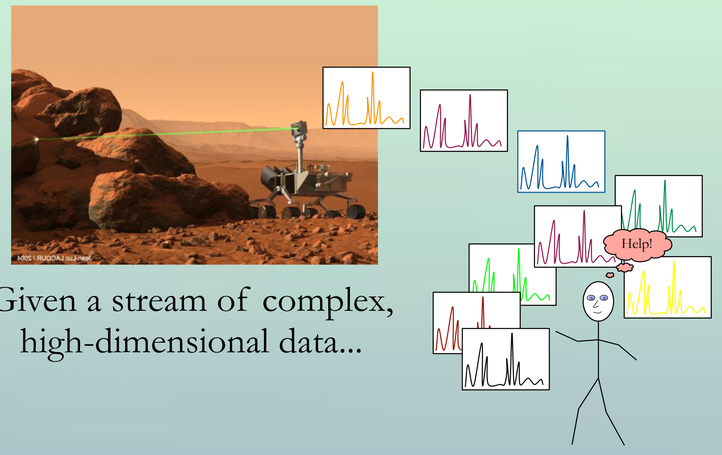
Unusual ChemCam targets discovered automatically in Curiosity's first ninety sols in Gale Crater, Mars

Kiri L. Wagstaff (kiri.l.wagstaff@jpl.nasa.gov), Jet Propulsion Laboratory, California Institute of Technology
Nina L. Lanza and Roger C. Wiens, Los Alamos National Laboratory

Motivation



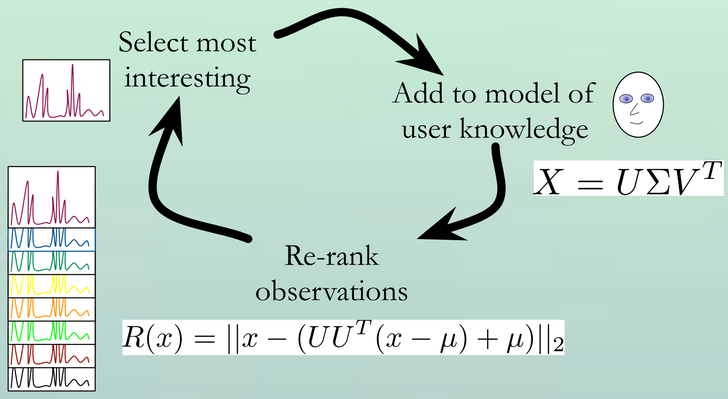
Given a stream of complex, high-dimensional data...

Which spectrum should we look at first?
What's most interesting?

Desired:
(1) Automatic prioritization of data
(2) Explanations for prioritization decisions

Method

DEMUD:
Discovery through Eigenbasis Modeling of Uninteresting Data [1]



DEMUD uses a truncated (low-dimensional) singular value decomposition (SVD) to model the observations that have already been seen by the user (X).

All remaining observations in D are ranked by their reconstruction error using that model (U), which consists of the principal components of X. Observations that cannot be accurately captured by the model have a high error, or "interestingness."

DEMUD selects the most interesting item (highest reconstruction error), presents it to the user, adds it to X, and updates the model U.

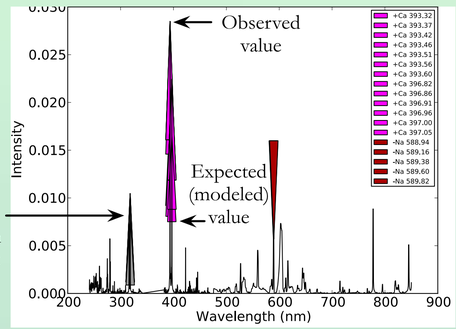
DEMUD also produces **explanations** for its decisions. Triangles point from modeled to observed values. Peaks are auto-mapped to elements via an element database.

Results

Five of DEMUD's top selections, with automatically assigned element annotations, from 11,750 ChemCam [2] Mars spectra

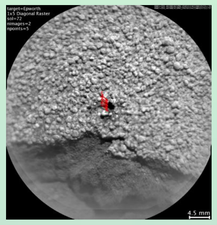
Observation point:

2



Gray triangles have no match in the element database. Artifacts?

Epworth: (5)
Higher Ca; Lower Na (versus Kilian, Rocknest)



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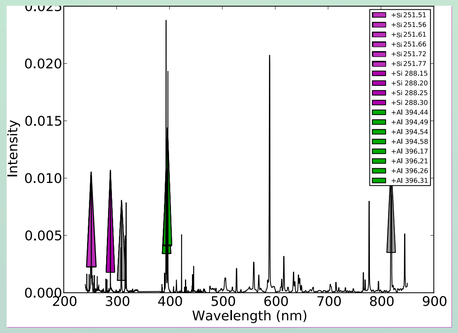
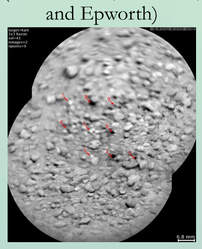


Kam: (7)
Higher Si, Al (versus Kilian, Rocknest, and Epworth)



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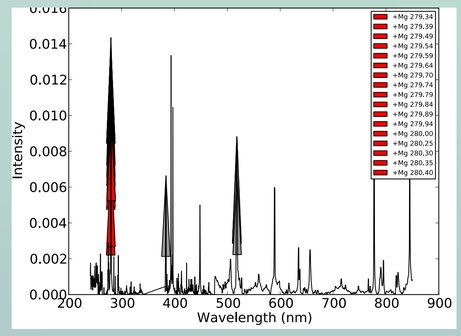
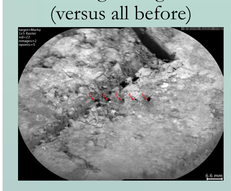


Murky: (5)
Higher Mg (versus all before)



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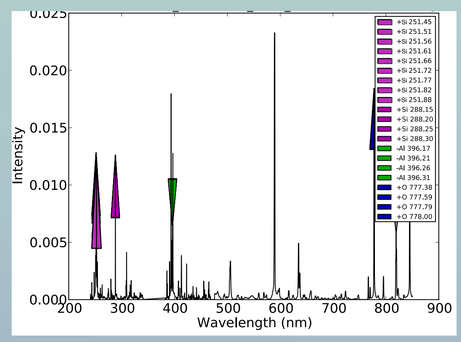
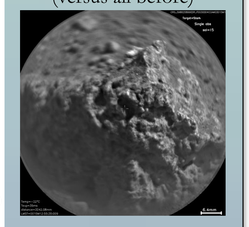


Stark: (1)
Higher Si, O; Lower Al (versus all before)



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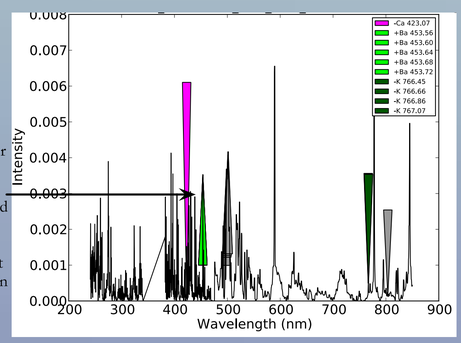
453 nm peak looks like Ba (455 nm); further investigation found Ti [6]. DEMUD pointed to a feature of interest even if the element isn't correct (Ti isn't in our element database).



Thor Lake: (5)
Higher Ba (Ti); Lower Ca, K (versus all before)

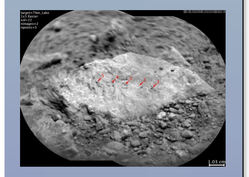


Table 1. First ten ChemCam targets selected by DEMUD from 11,750 spectra collected during MSL's first 90 sols on Mars.

Sel	Target	Sol	Observation	Shot	Explanation (automatically generated by DEMUD)
1	Rocknest3_3	88	19 (of 25)	2	Reduced Ca, Na, and O
2	Epworth	72	5 (of 5)	8	Elevated Ca; reduced Na
3	Kam	43	7 (of 9)	18	Elevated Si and Al
4	Rocknest3_3	88	25 (of 25)	22	Reduced Ca and O
5	Kenyon	82	3 (of 9)	25	Elevated O; reduced Ca and Na
6	Murky	22	5 (of 5)	19	Elevated Mg
7	Rocknest3_3	88	17 (of 25)	28	Elevated Ca
8	Stark	15	1 (of 1)	48	Elevated Si, and O; reduced Al
9	Kilian	72	4 (of 10)	10	Reduced Ca
10	Thor_Lake	22	5 (of 5)	34	Elevated Ba (Ti) [6]; reduced Ca and K

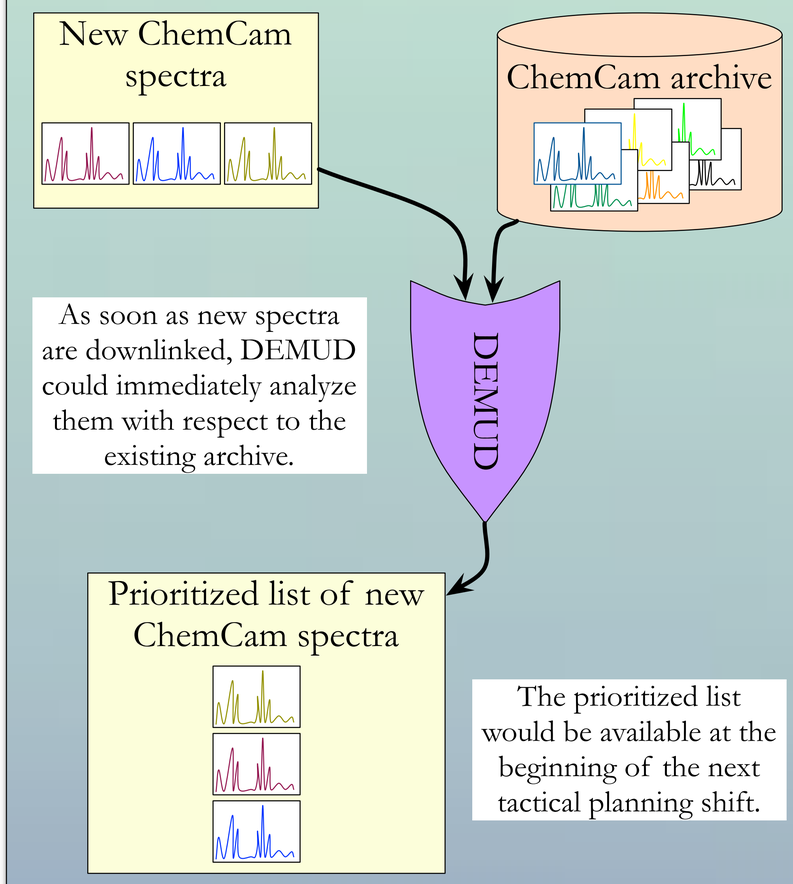
Discussion

DEMUD complements other data analysis methods such as trend analysis and a search for known items of interest. It provides a ranked list of observations likely to be of individual interest, with explanations for each one.

The DEMUD results at left are consistent with summary observations for this data set:
* Epworth has elevated Ca [3,4,5]
* Stark has elevated Si and low Al [5,7]

However, DEMUD focuses on individual observations rather than summary statements about entire targets. This reveals that some targets are more heterogeneous than expected (e.g., shots from Rocknest3_3 appear three times in DEMUD's top 10, with different explanations each time).

Operational Use



As soon as new spectra are downlinked, DEMUD could immediately analyze them with respect to the existing archive.

The prioritized list would be available at the beginning of the next tactical planning shift.

References and Acknowledgments

[1] Wagstaff K. L. et al. (2013) AAAI Conf. on Artificial Intelligence.
[2] Wiens R. et al. (2012) Space Sci. Rev., 170.
[3] Forni, O. et al (2014) LPS XLV, Abstract #1328.
[4] Gasnault O. et al. (2013) LPS XLIV, Abstract #1994.
[5] Clegg S. M. et al. (2013) LPS XLIV, Abstract #2097.
[6] Ollila, A.M. et al. (2014) JGR-Planets MSL special issue 119.
[7] Sautter, V. et al. (2014) JGR-Planets MSL special issue 119.

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