

Machine Learning Analysis of PDS Mars Images to Improve Discoverability

Kiri L. Wagstaff¹, Steven Lu¹, Kevin Grimes¹,
Jesse Cai², Thamme Gowda³, Jake Lee⁴,
Alice Stanboli¹, and Jordan Padams¹

¹*Jet Propulsion Laboratory, California Institute of Technology*

²*California Institute of Technology*

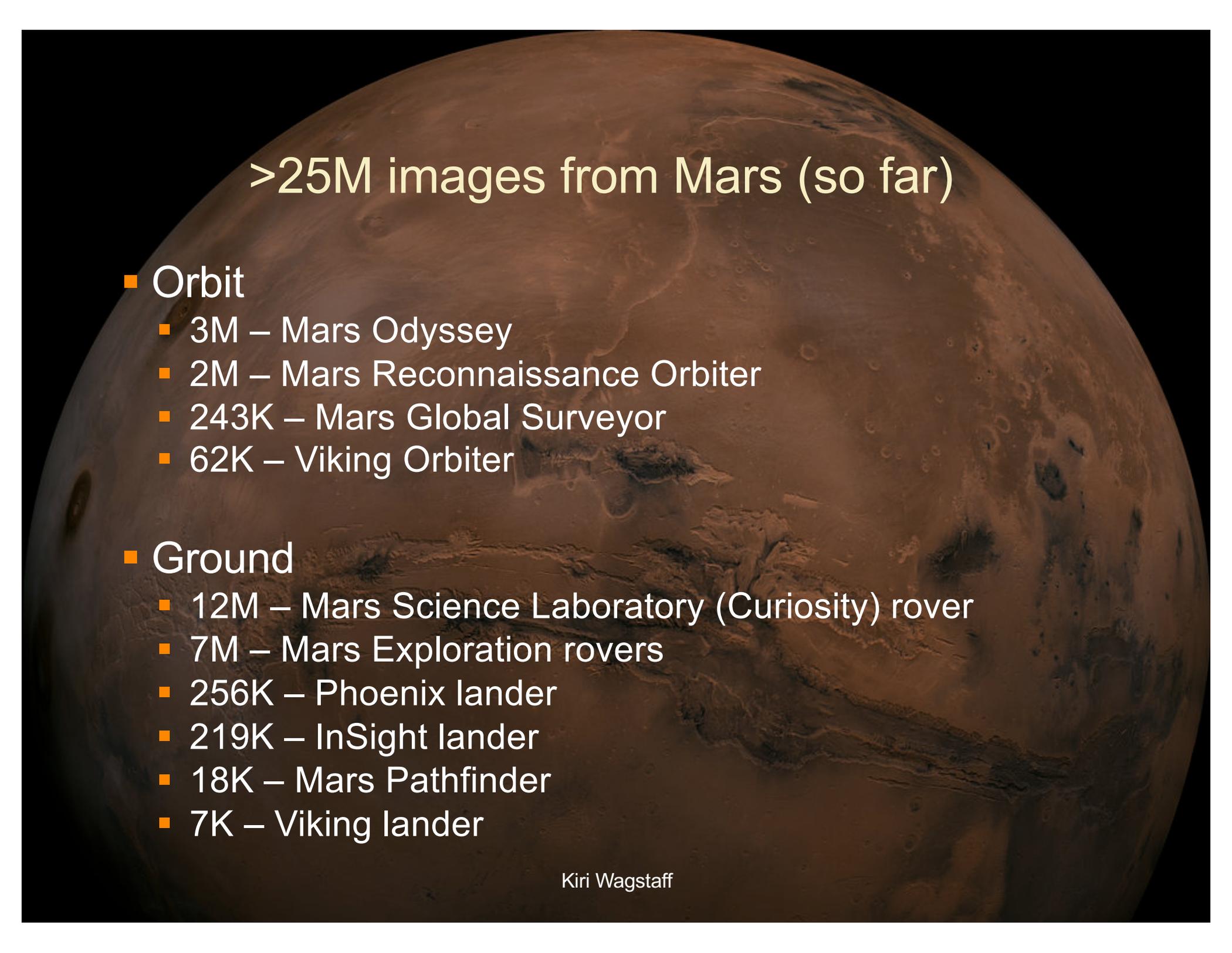
³*University of Southern California, Information Sciences Institute*

⁴*Columbia University*

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>25M images from Mars (so far)

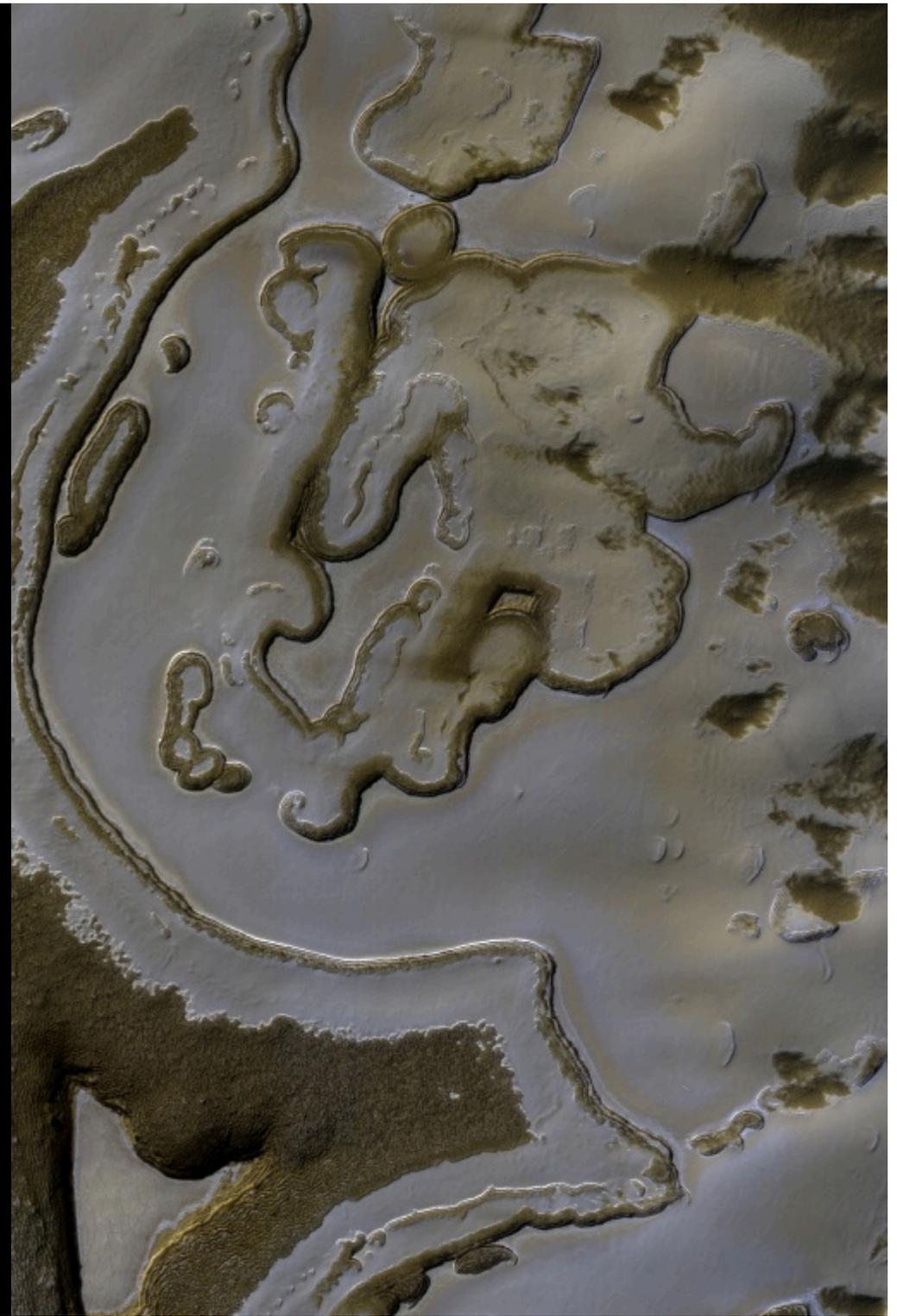
■ Orbit

- 3M – Mars Odyssey
- 2M – Mars Reconnaissance Orbiter
- 243K – Mars Global Surveyor
- 62K – Viking Orbiter

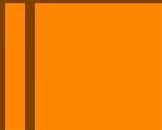
■ Ground

- 12M – Mars Science Laboratory (Curiosity) rover
- 7M – Mars Exploration rovers
- 256K – Phoenix lander
- 219K – InSight lander
- 18K – Mars Pathfinder
- 7K – Viking lander





Goal: Improve Discoverability



1. Content-based search

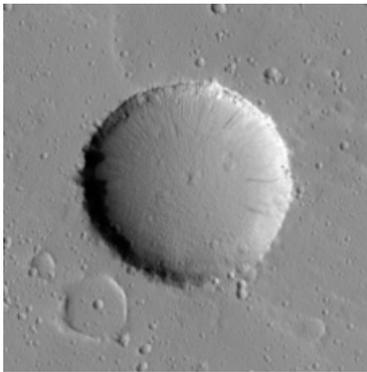
- Use machine learning to tag images with content of interest (e.g., craters, dark slope streaks)
- Integrate machine learning tags into the user-searchable PDS Image Atlas database

2. Novelty-based ranking

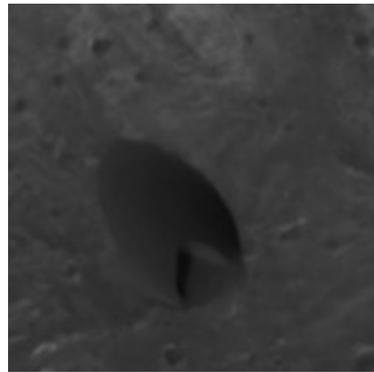
- Identify novel or unusual images to focus attention on observations that may lead to new scientific discoveries
- Integrate novelty ranking into the PDS Image Atlas with a browsable carousel

1. Content-based search

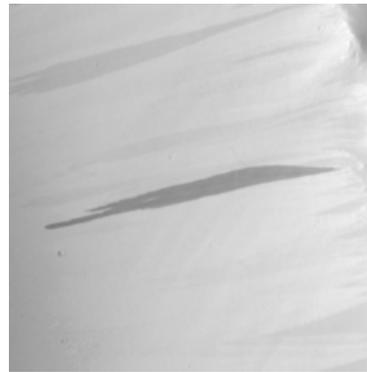
- HiRISE orbital images of Mars surface features



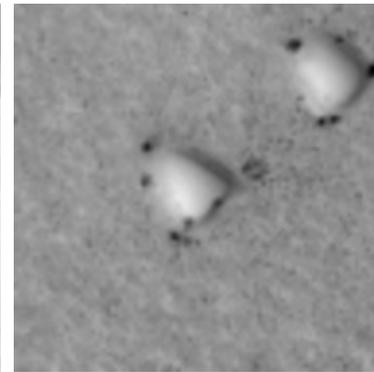
(a) Crater



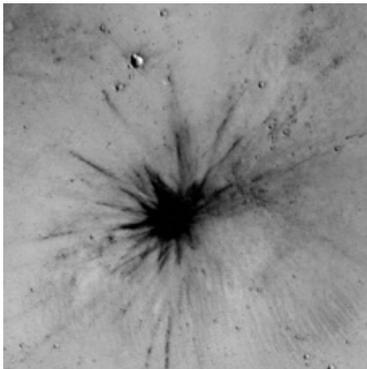
(b) Dark dune



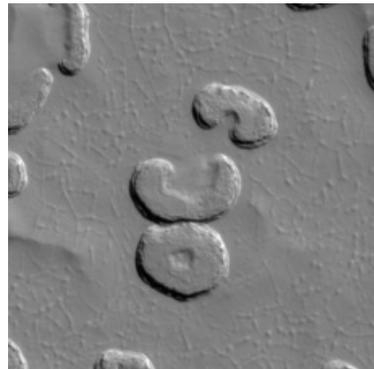
(c) Slope streak



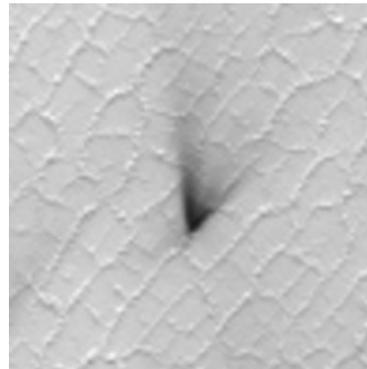
(d) Bright dune



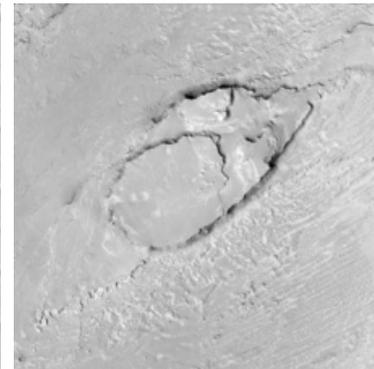
(e) Impact ejecta



(f) Swiss cheese



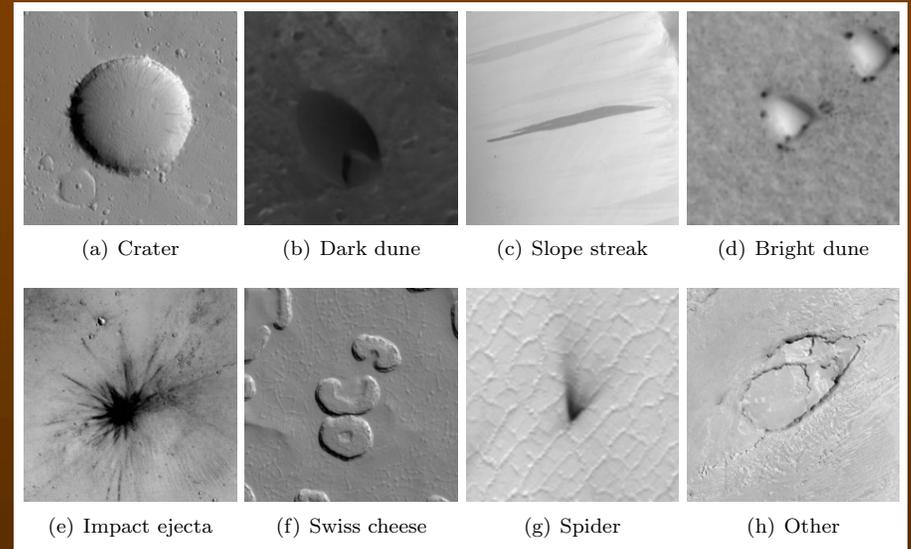
(g) Spider



(h) Other

1. Content-based search

- Detect and crop individual “landmarks”
- Train machine learning classifier to recognize each class
 - 10k labeled examples
 - Convolutional neural network (CNN)
- Predict class and retain if confidence ≥ 0.9
 - 15M in full HiRISE archive



http://pds-imaging.jpl.nasa.gov/search/

 **Jet Propulsion Laboratory**
California Institute of Technology

PDS Image Atlas

Begin searching the PDS image archive... **Search**

Results: 24 Page: < 1 2 3 ... 1278931 1278932 > displaying 1 to 24 of 30694365

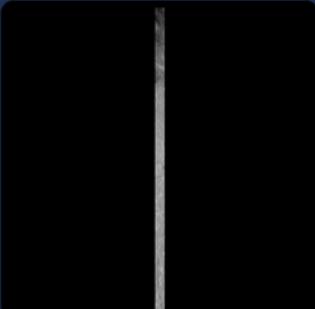
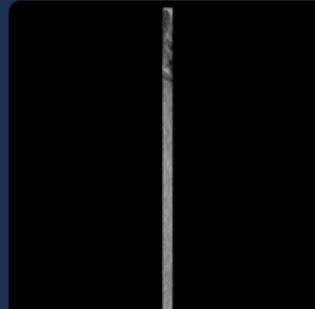
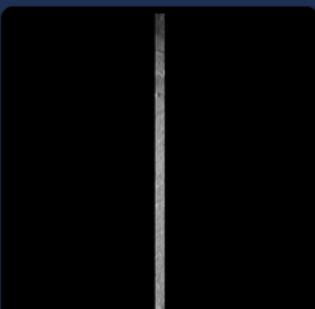
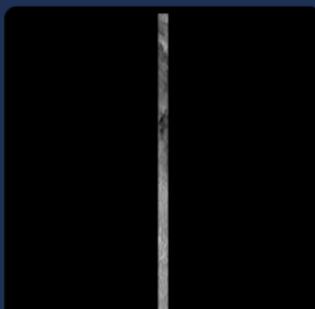
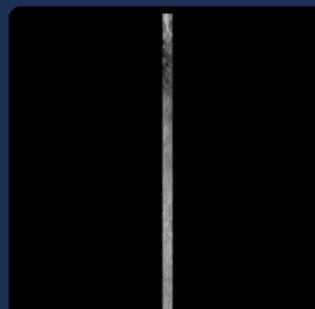
Grid View Sort View Add field to sort by: START_TIME Clear

Select All Images: On Page In Query

Show results for (click to remove filter) **Share**

Narrow your search by selecting a facet below

- ▶ Mission
- ▶ Spacecraft
- ▶ Instrument
- ▶ Target
- ▶ Product Type
- ▶ Lighting Geometry
- ▶ Filters
- ▶ Lat/Lon Bounding Box
- ▶ Time Constraints
- ▶ Orbital Mission Constraints
- ▶ Landed Mission Constraints
- ▶ PDS Archive Constraints
- ▶ Advanced Constraints
- ▶ MRO HiRISE Image Content 
- ▶ MSL Image Content 
- ▶ Cassini ISS Image Content 
- ▶ Galileo SSI Europa Image Content 
- ▶ Maps
- ▶ Reports
- ▶ Bulk File Download

 ESP_052799_2230_RED0_0    	 ESP_052799_2230_RED0_1    	 ESP_052799_2230_RED1_0    
 ESP_052799_2230_RED1_1    	 ESP_052799_2230_RED2_0    	 ESP_052799_2230_RED2_1    

Search for landmarks of interest

- E.g., search for images containing craters
- Landmarks are localized

PDS Image Atlas

▼ MRO HiRISE Image Content Beta

Image Class
(MRO HiRISE RDRs Only)

- bright dune (897)
- crater (20931) →
- dark dune (3277)
- impact ejecta (96)
- slope streak (2678)
- spider (98)
- swiss cheese (828)

“crater” search

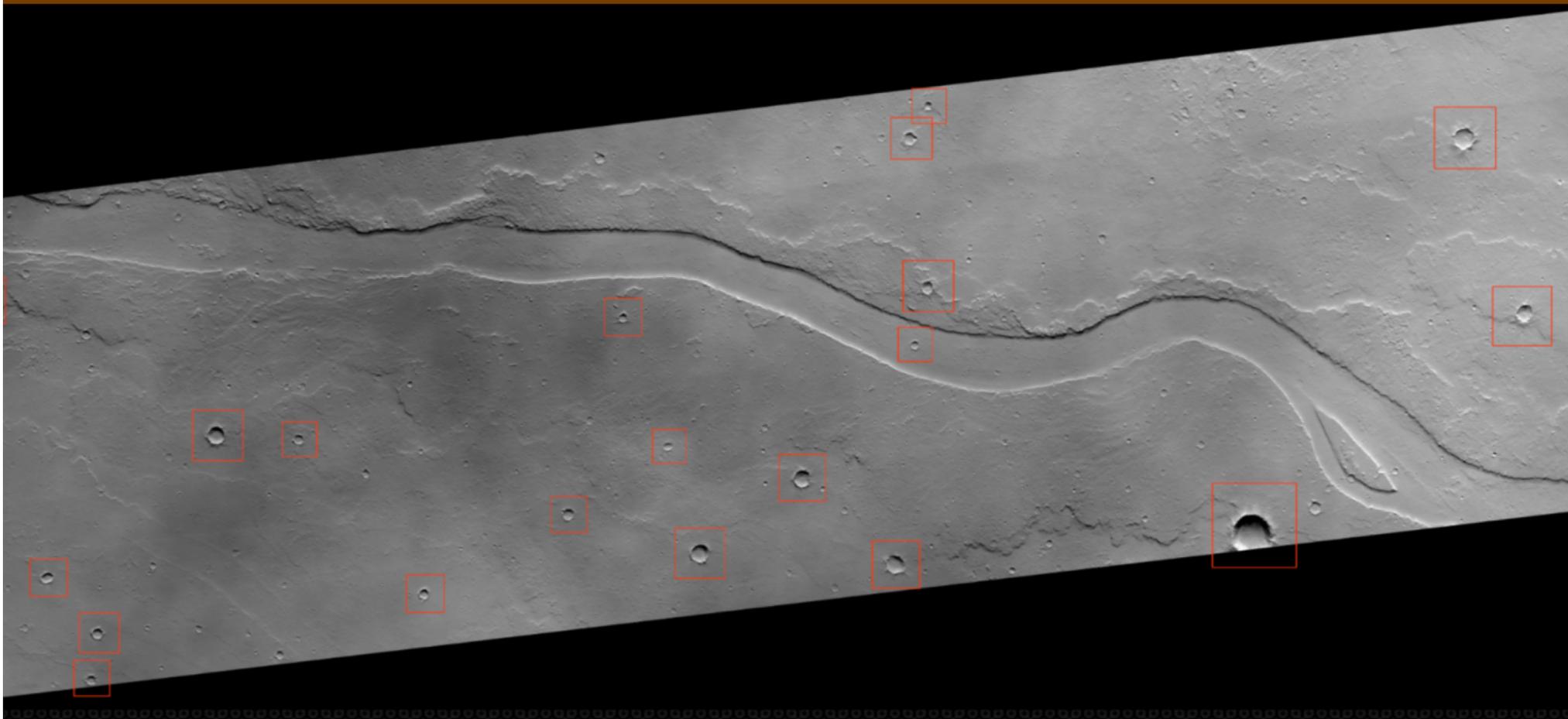
ESP_045368_2040_RED

ESP_045370_1930_RED

ESP_045373_1700_RED

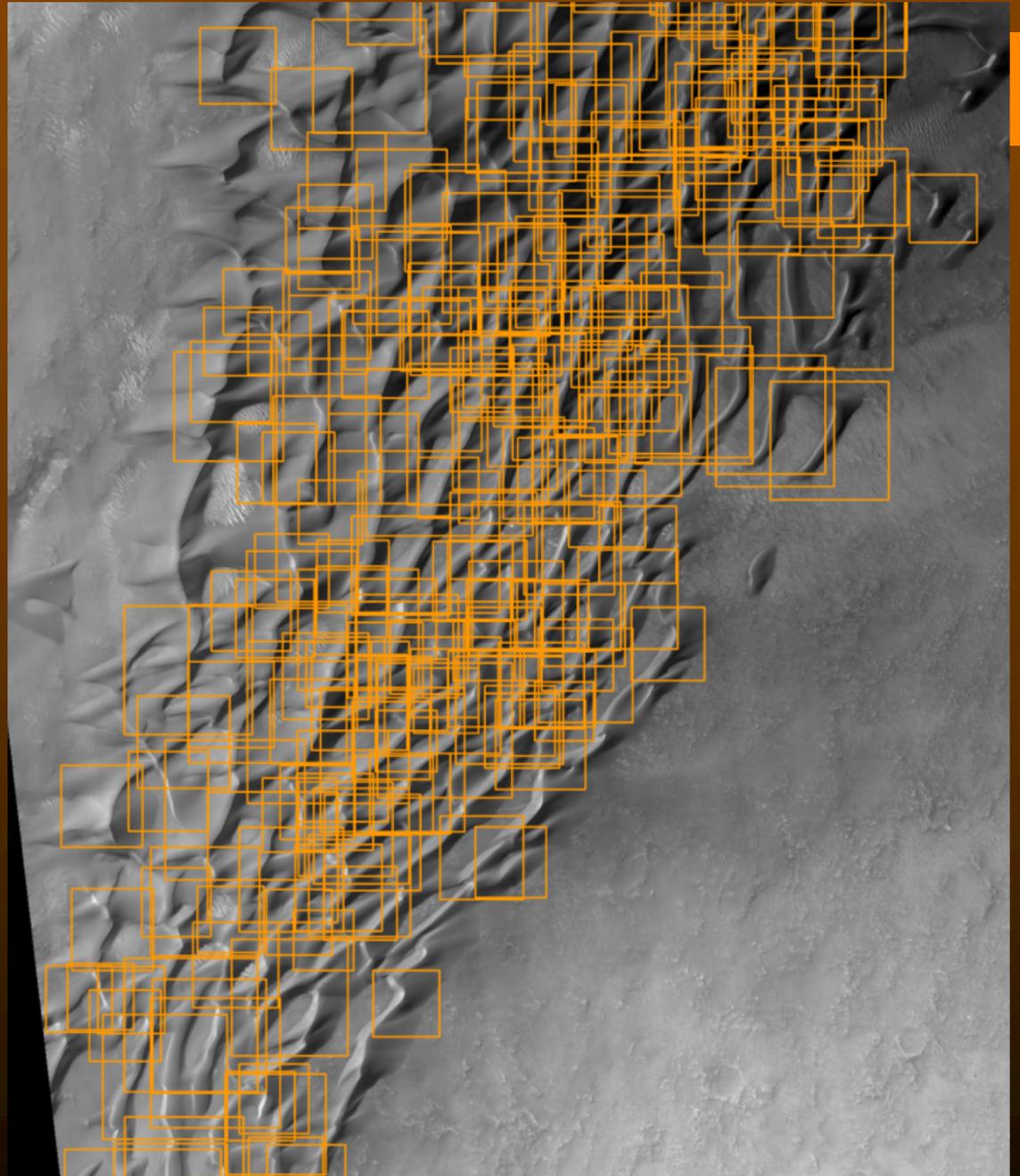
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Craters



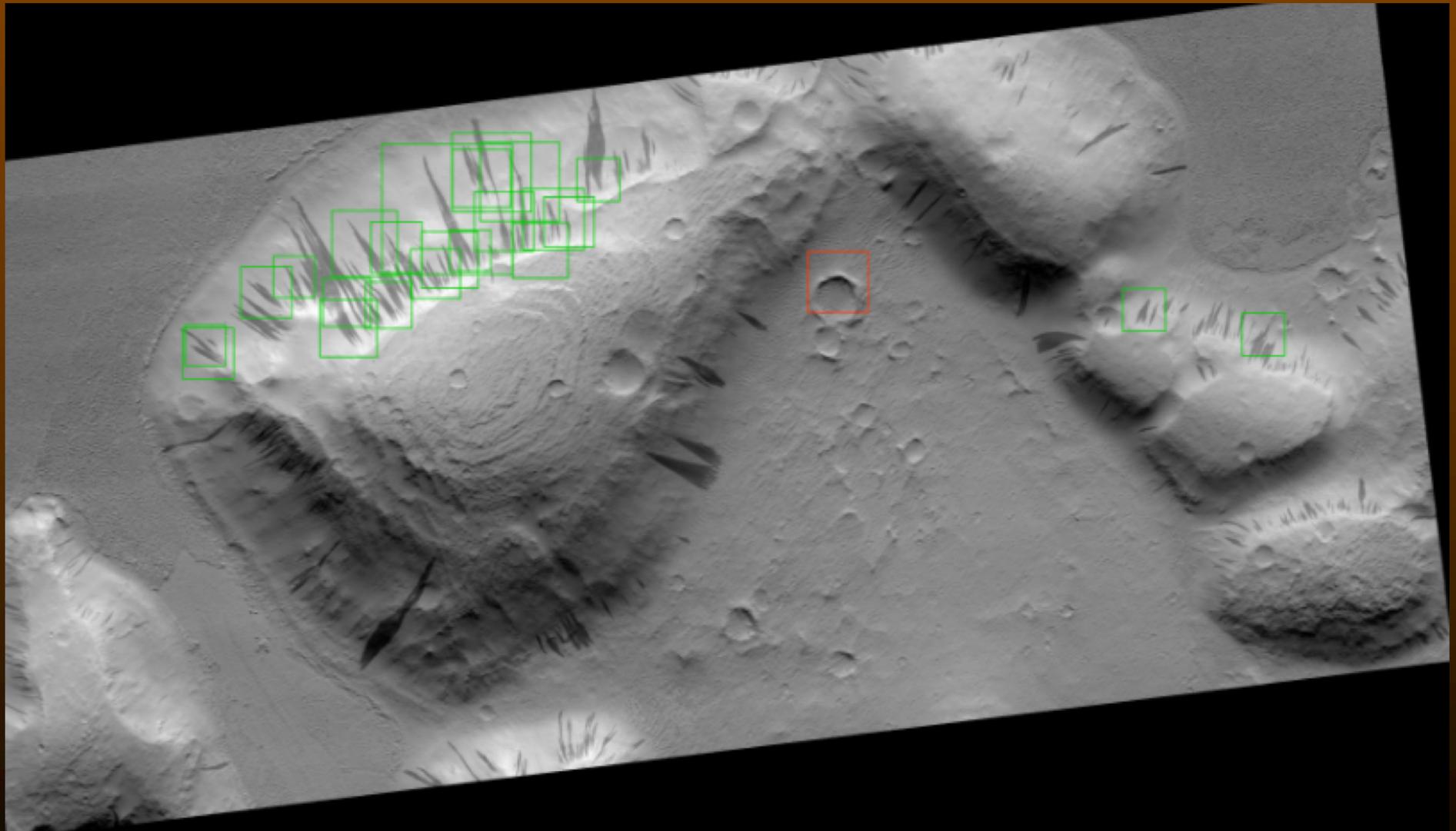
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Dark dunes



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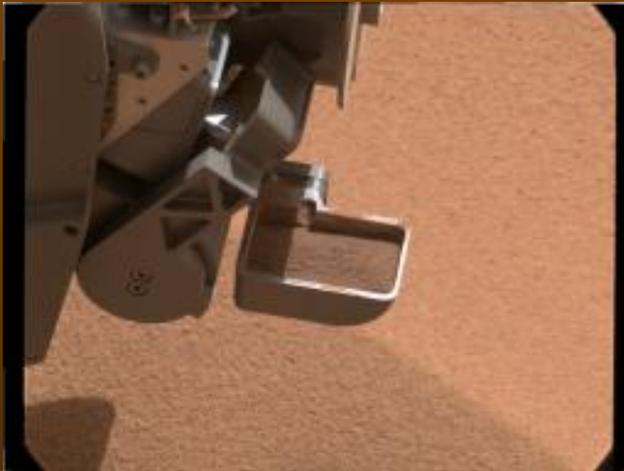
Dark slope streaks



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MSL rover images (25 classes)

Scoop



Wheel



MAHLI CT



Horizon



Mastcam CT



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Search for rover wheels

▶ PDS Archive Constraints

▶ Landmarks 

▼ MSL Image Classification 

Image Class

wheel (12555)

Confidence Level

73

to

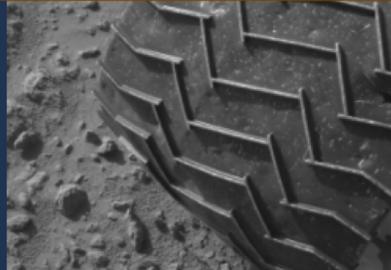
100



▶ Maps

▶ Report / Sort View Updates

▶ Bulk File Download



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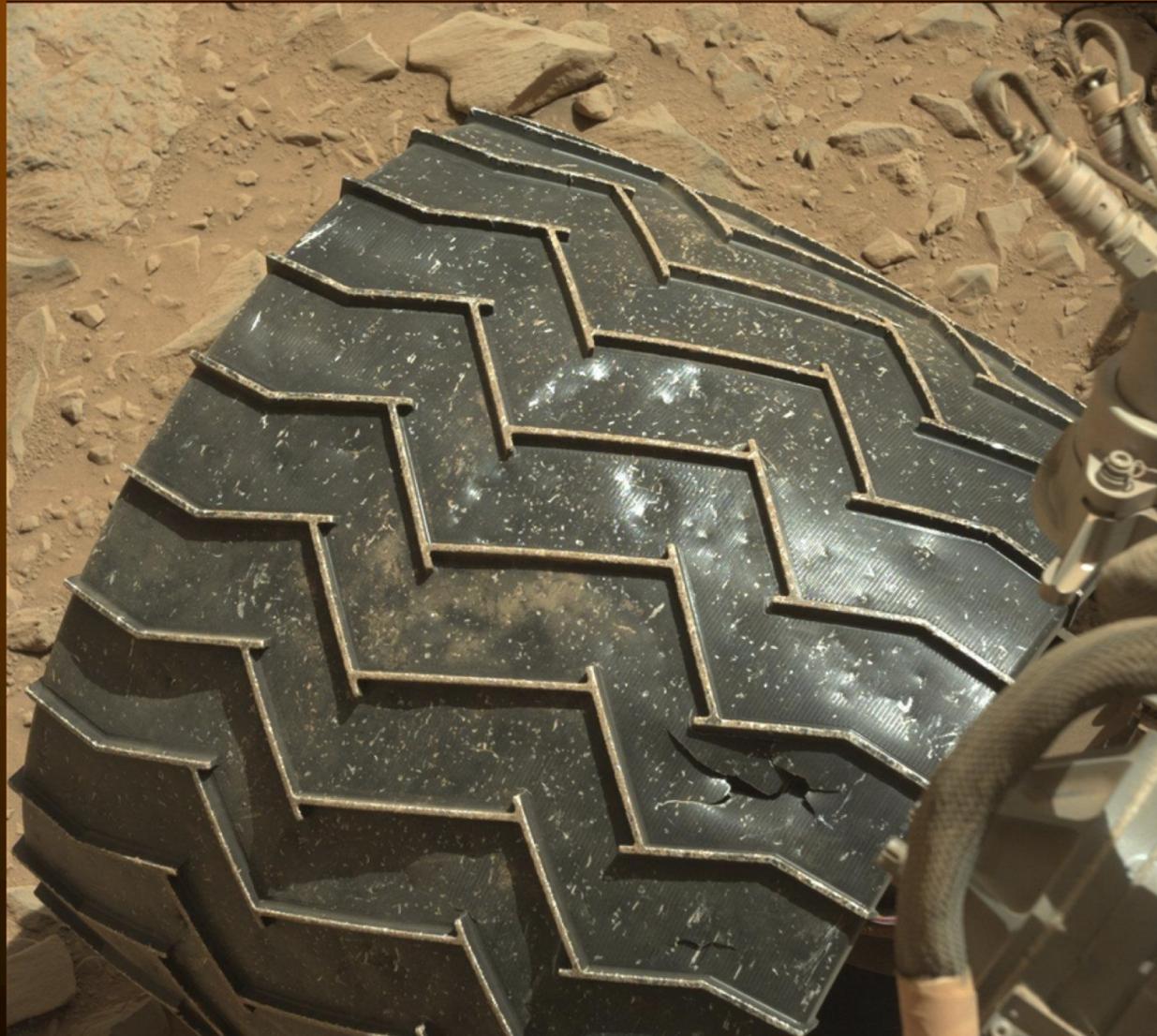


August 2012



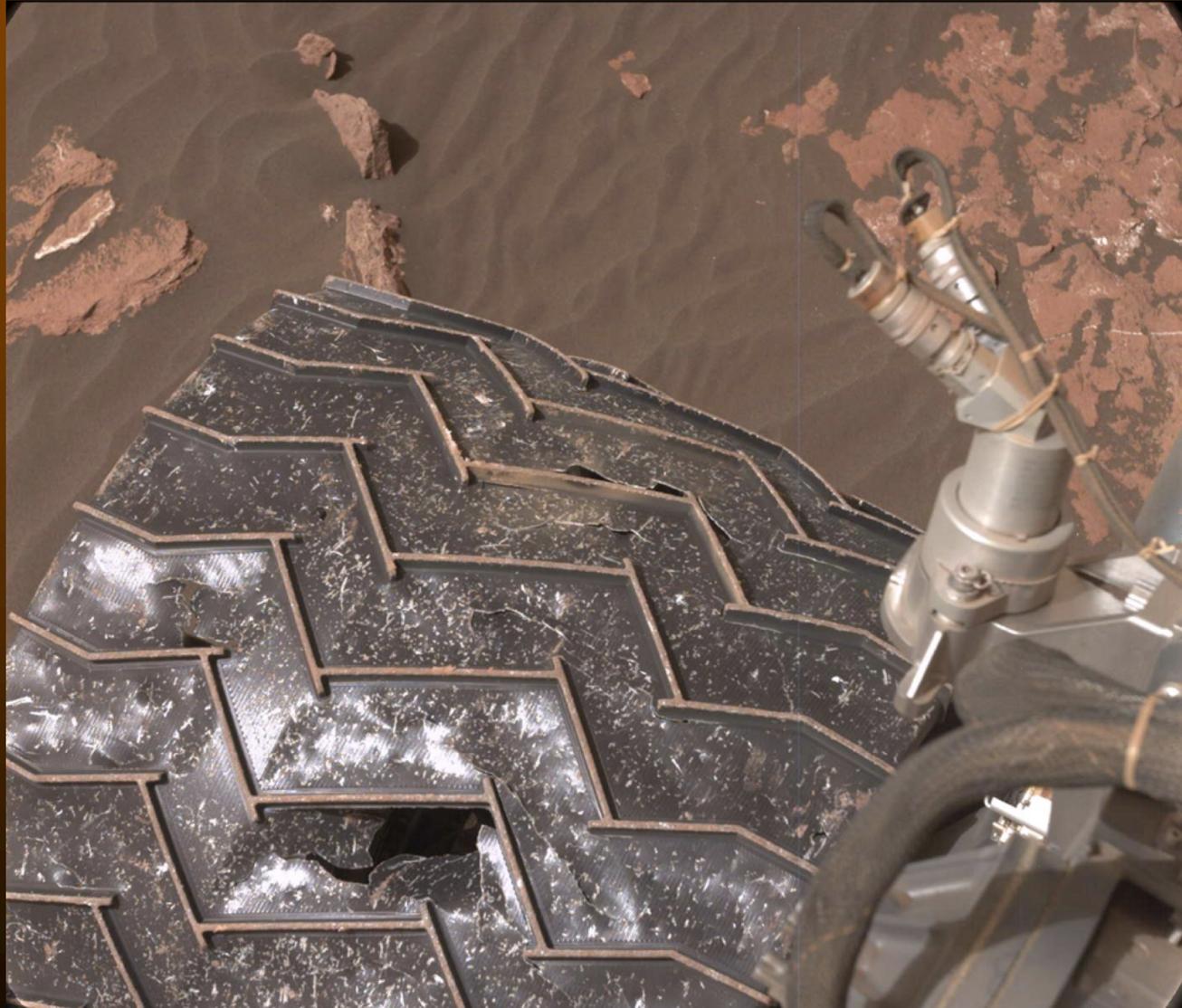
Kiri Wagstaff

December 2013



Kiri Wagstaff

November 2016



Kiri Wagstaff

January 2019



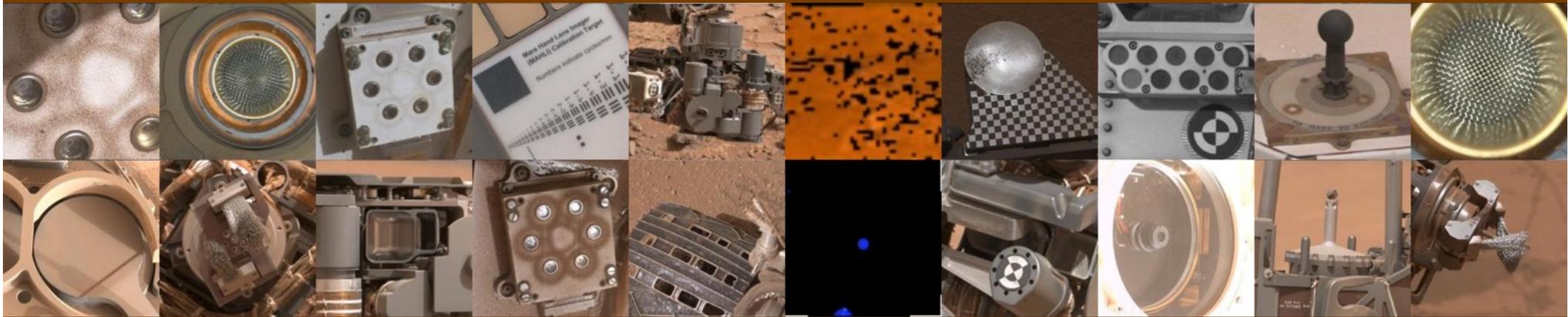
Kiri Wagstaff

2. Novelty-based ranking

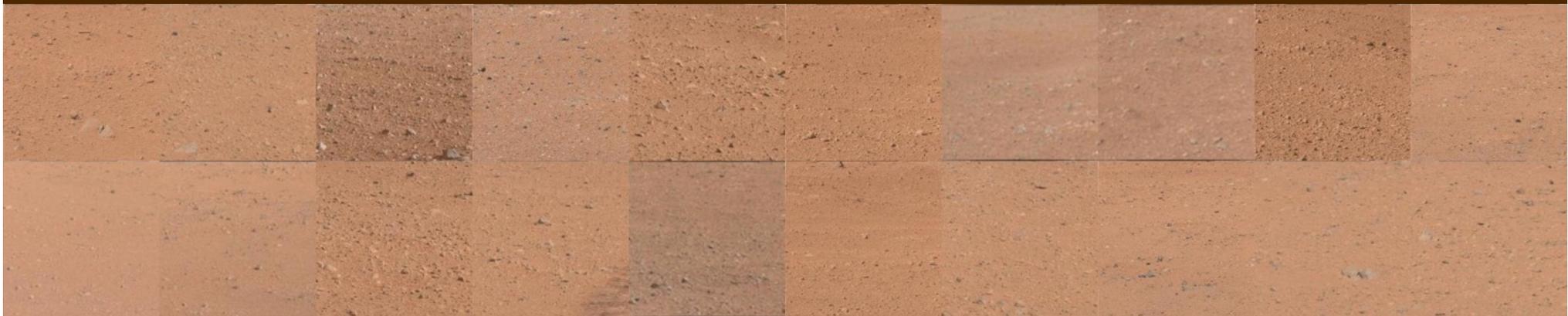
- Use DEMUD algorithm for novelty analysis
 - CNN to extract feature vector for each image
 - Singular value decomposition of feature vectors
 - Rank images by their reconstruction error (i.e., amount of novel content)

Novelty detection – MSL (6K images)

20 most novel

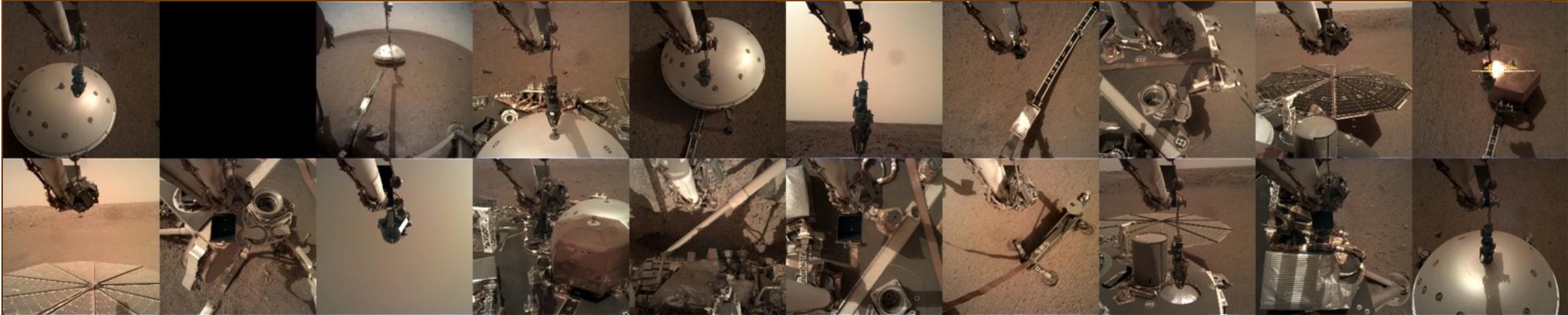


20 least novel



Novelty detection – InSight (2K images)

20 most novel



20 least novel



Novelty ranking – Atlas integration

- Default ordering is reverse chronological
- Show top-ranked images in browsable carousel

Show results for

(click to remove filter)

Share

(x) ATLAS_MISSION_NAME:insight

Mission

insight (89026)

Spacecraft

Instrument

Target

Product Type

PDS Archive Constraints

Advanced Constraints

Maps

Reports

Bulk File Download

Featured images



Results: 24

Page:

< 1 2 3 ... 3709 3710 > displaying 1 to 24 of 89026



Thumbnail View



List View

Add field to sort by:

START_TIME

Clear

Select All Images: On Page In Query



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Summary

- Machine learning to help users find images of interest
 - Content-based search for known classes
 - Novelty-based ranking to discover new phenomena
- Machine learning output -> image meta-data
 - Searchable with PDS Image Atlas web portal
- Current work
 - Final integration of novelty carousel into the Atlas
 - Add science-based classes to MSL rover data set
 - Use data augmentation and calibration to improve reliability

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