



Jet Propulsion Laboratory  
California Institute of Technology

# The Challenges of Landing a Car-Sized Rover on Mars

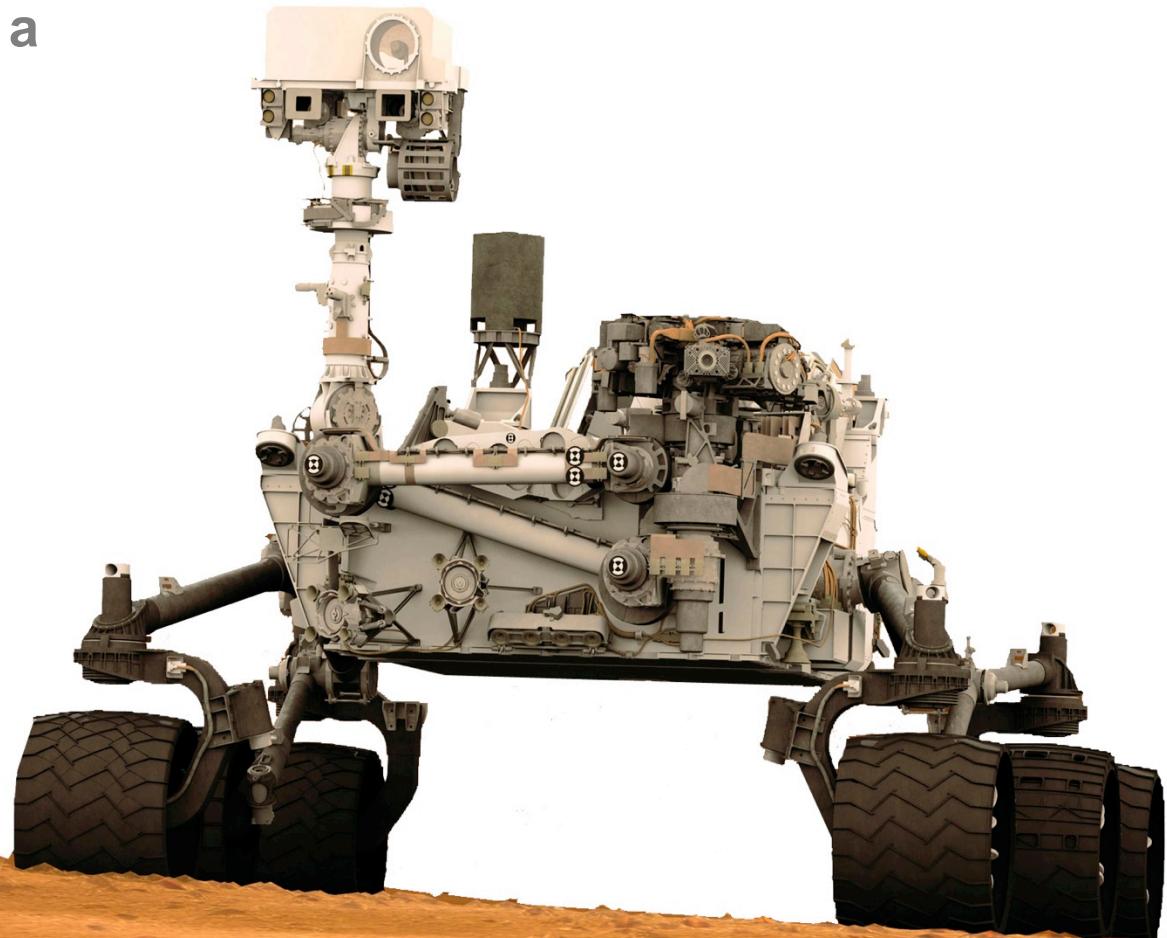
a presentation for the

**ICALEPCS**

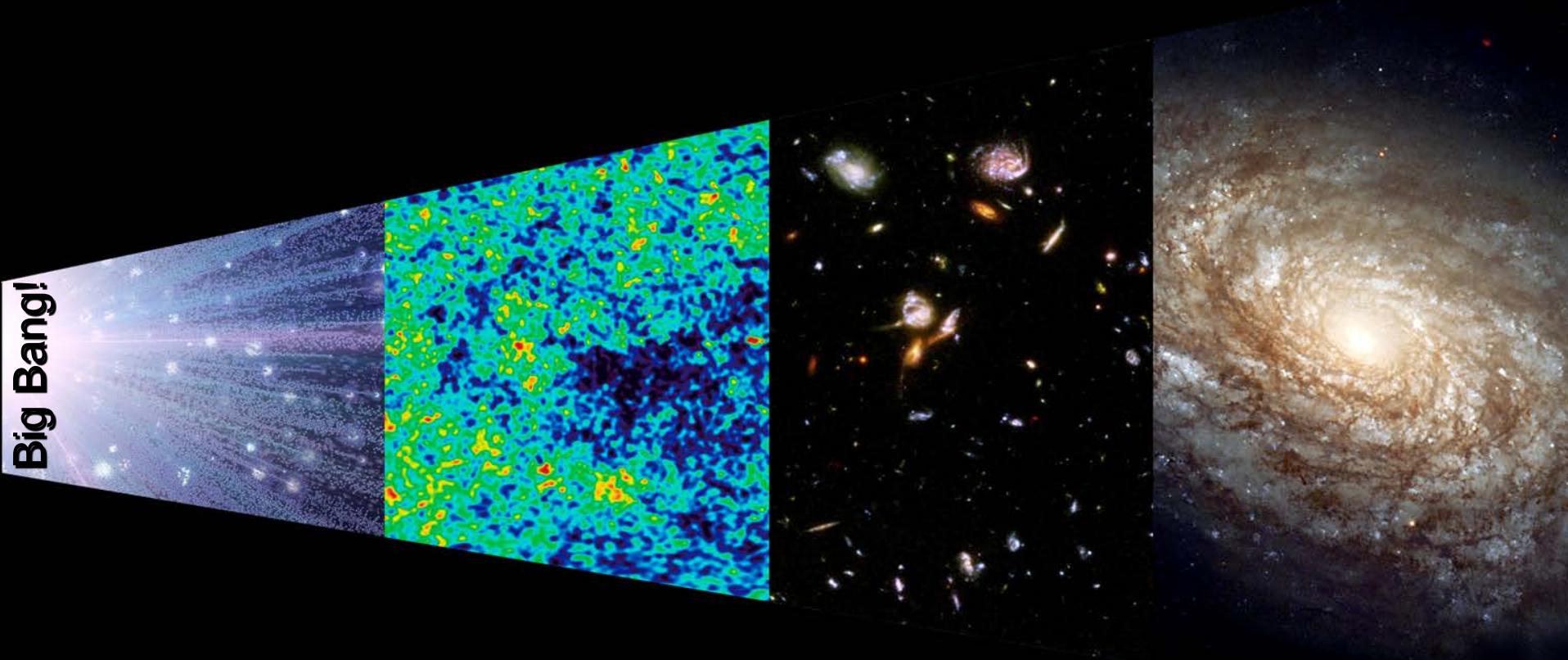
9 October 2013

**Charles Elachi, Director**

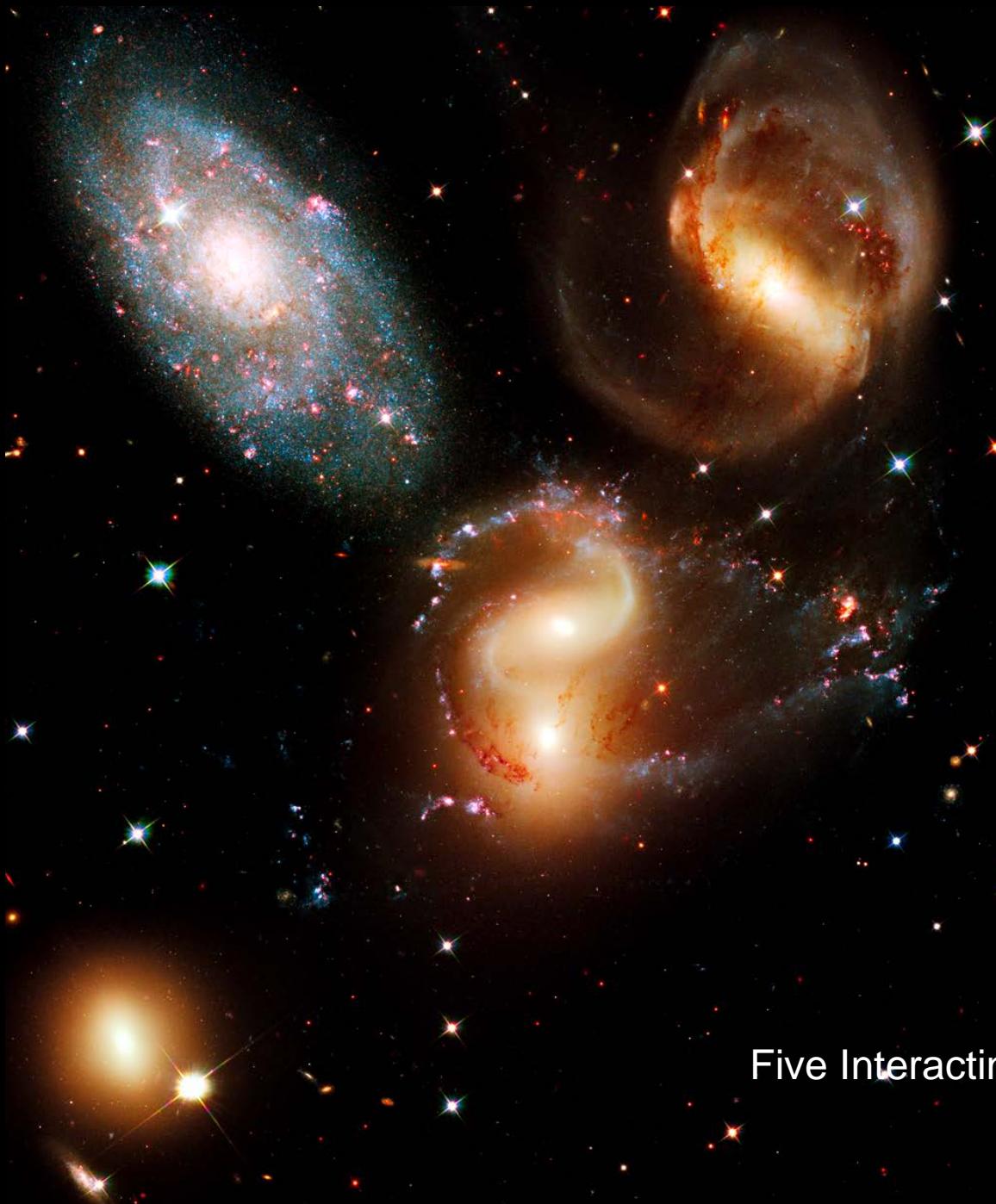
NASA Jet Propulsion Laboratory  
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**Big Bang!**



History of the Universe



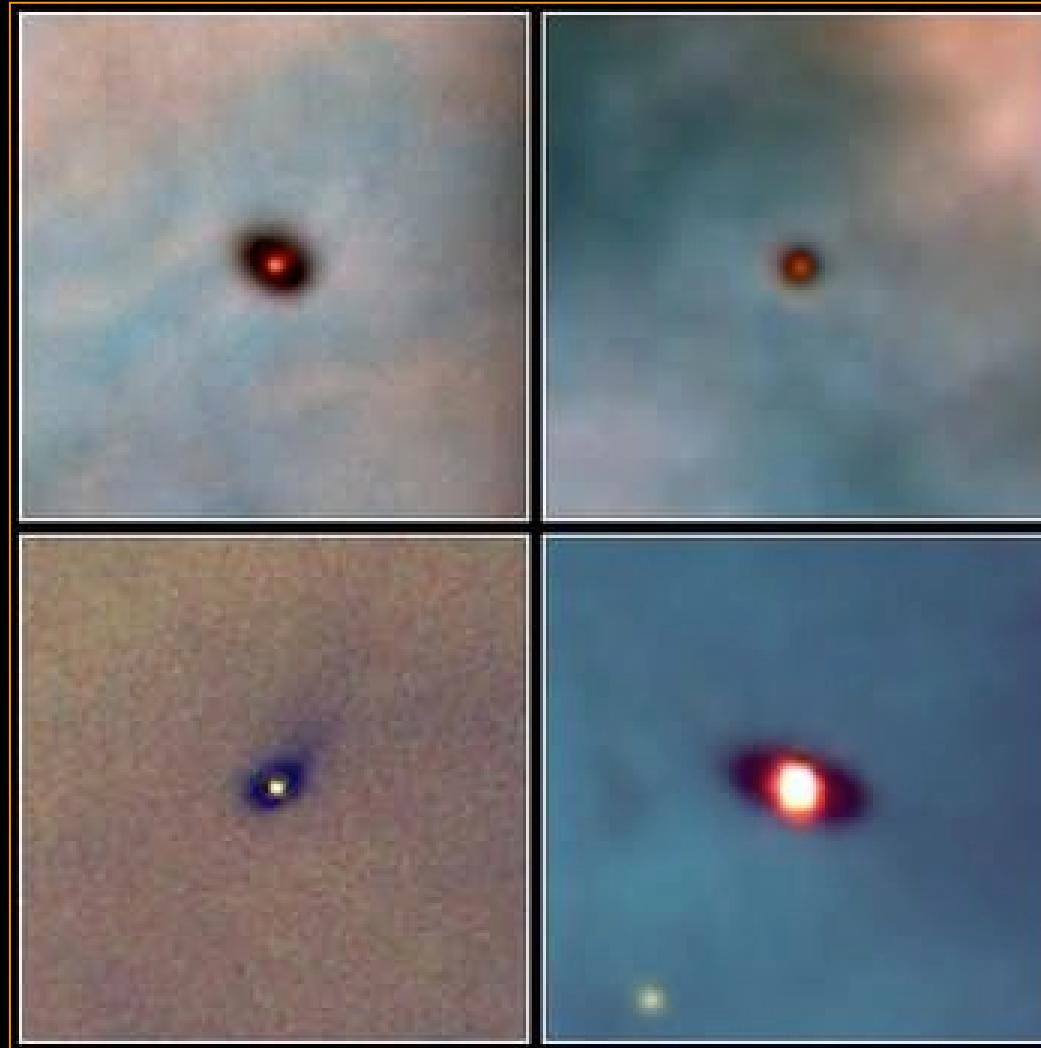
Five Interacting Galaxies

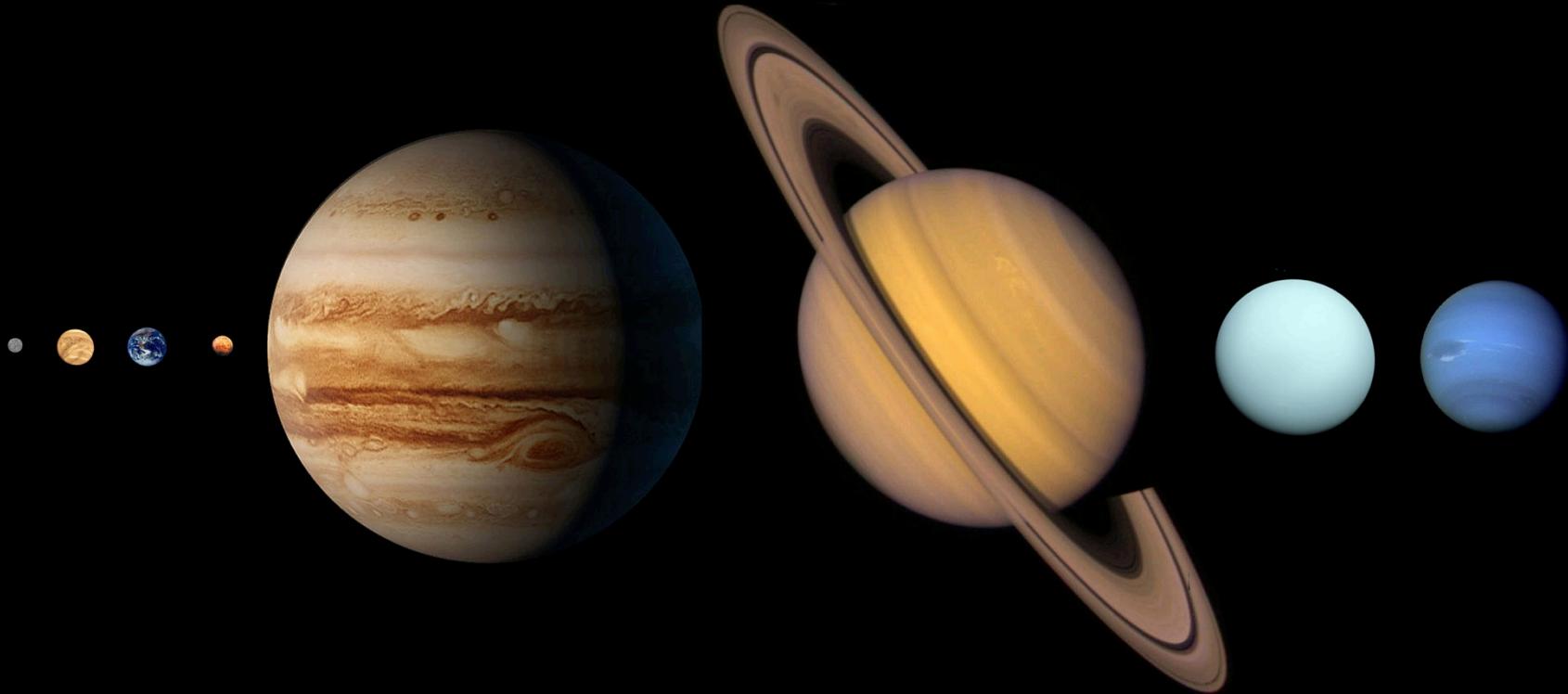


Spiral Galaxy  
*Composite: Spitzer, Hubble, Chandra*

# Formation of Extra-Solar Disks

Hubble Space Telescope

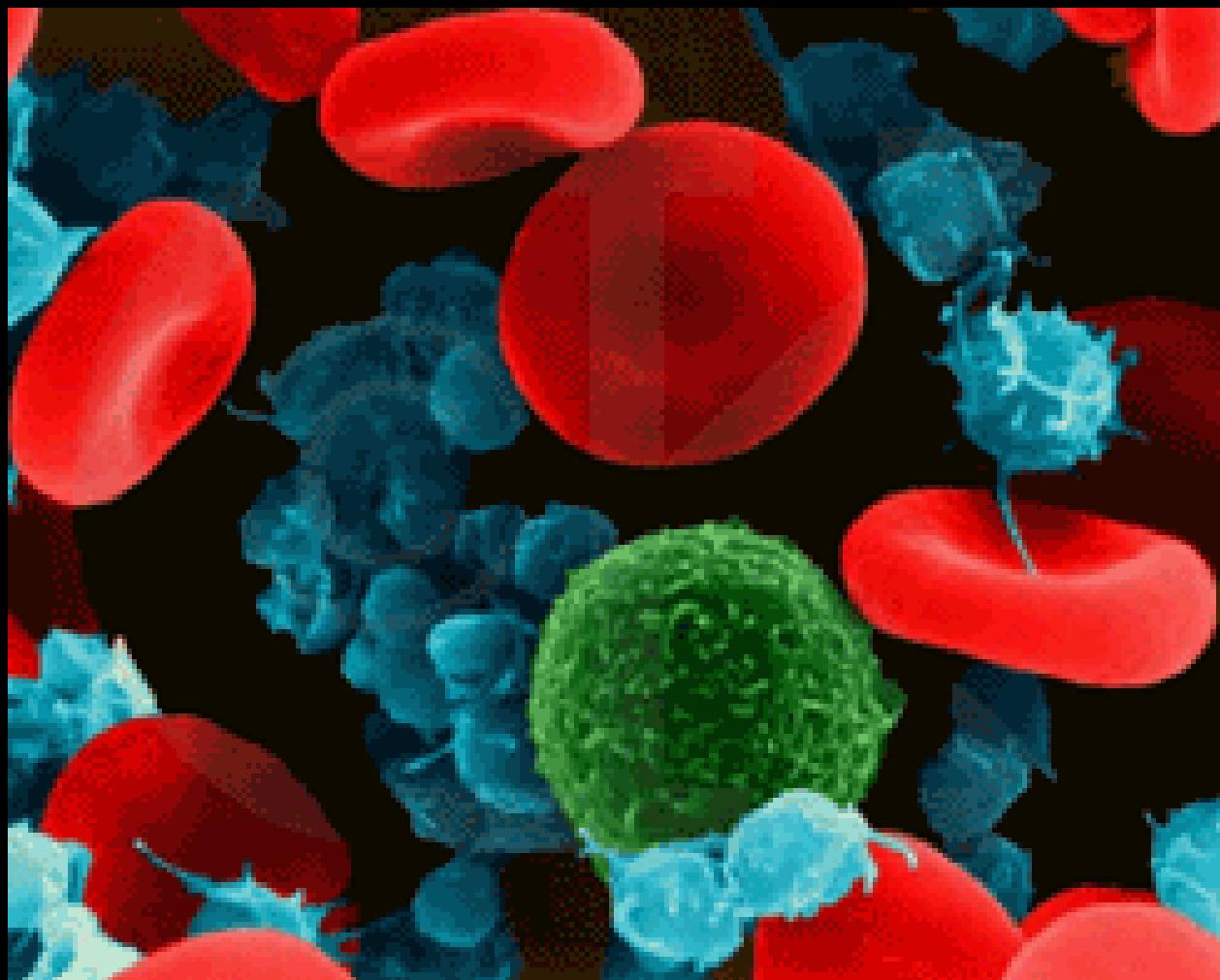




Our Solar System



A Planet Friendly to Life



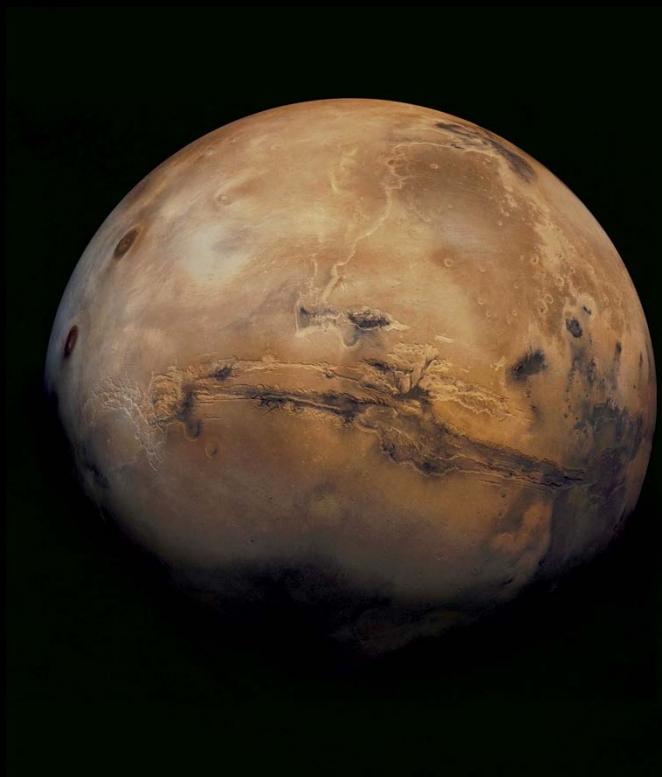
Self-replicating Molecules Lead to Cells and Life



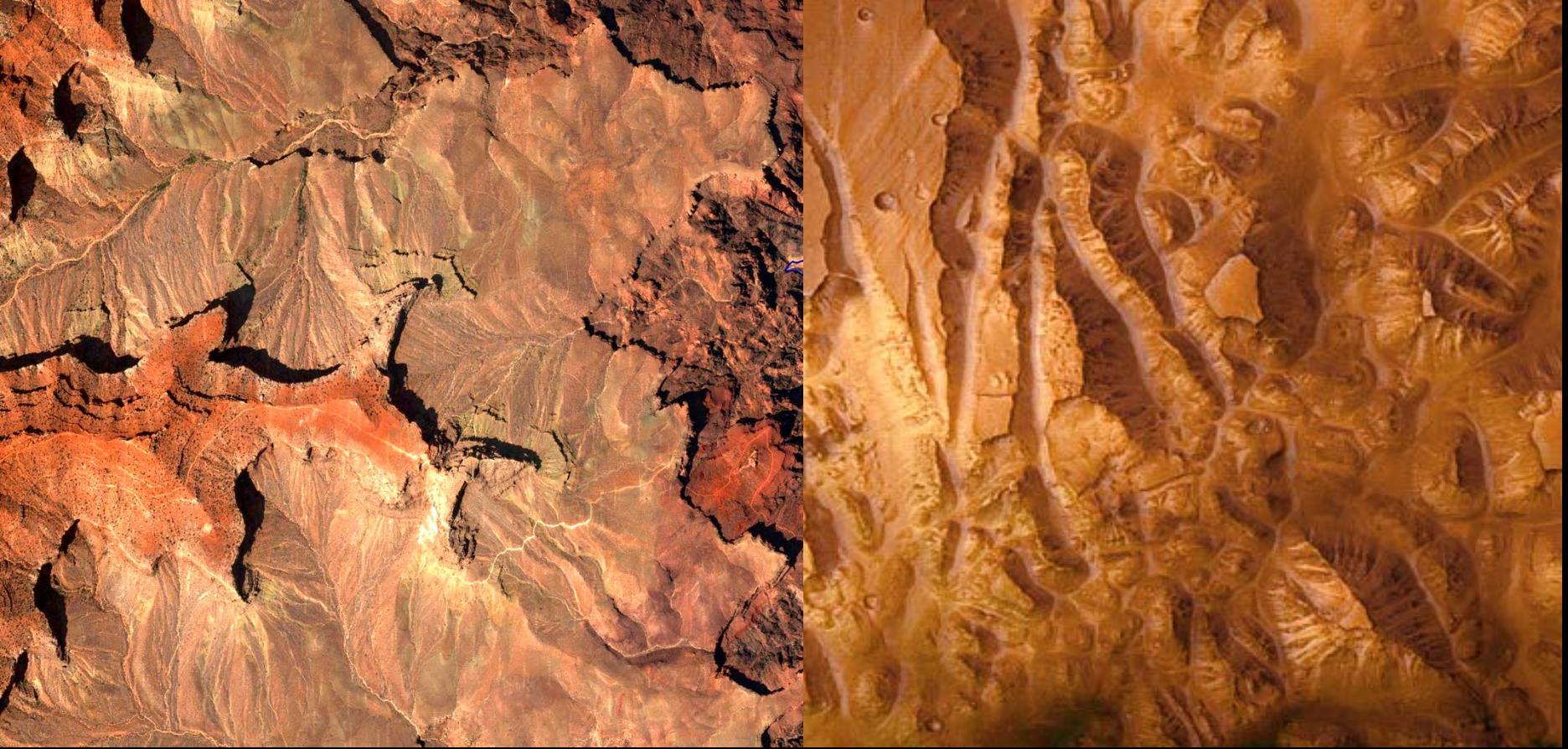
3.8 Billion Years of Evolution Produced...



...the Lawrence Livermore National Laboratory!



Earth and Mars share several features



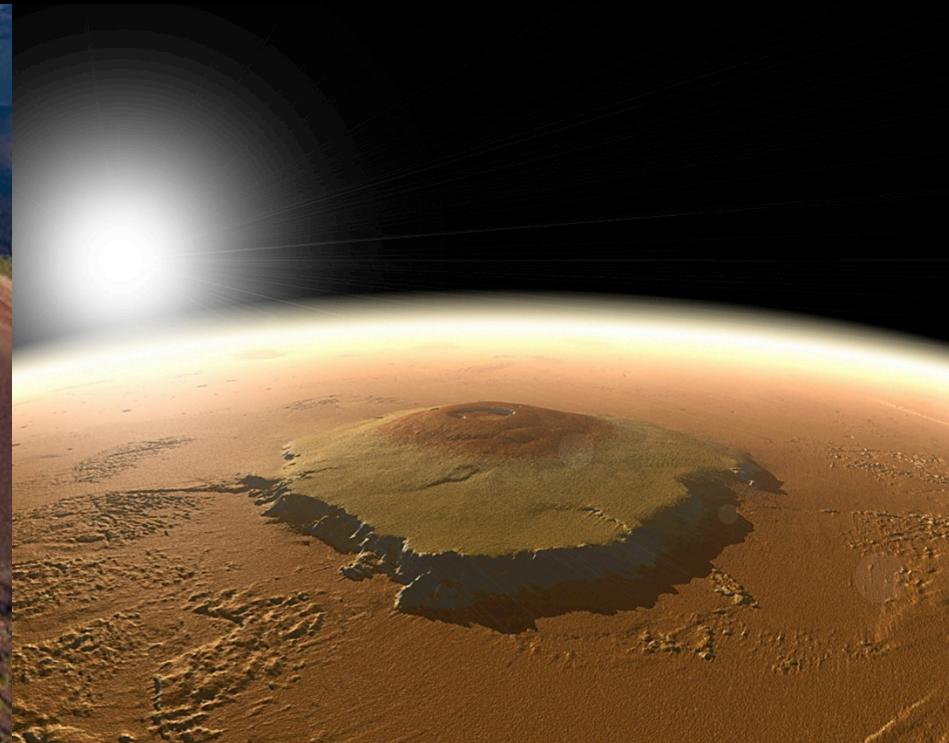
Grand Canyons



Arizona's Grand Canyon



Mars' Victoria Crater from *Opportunity*



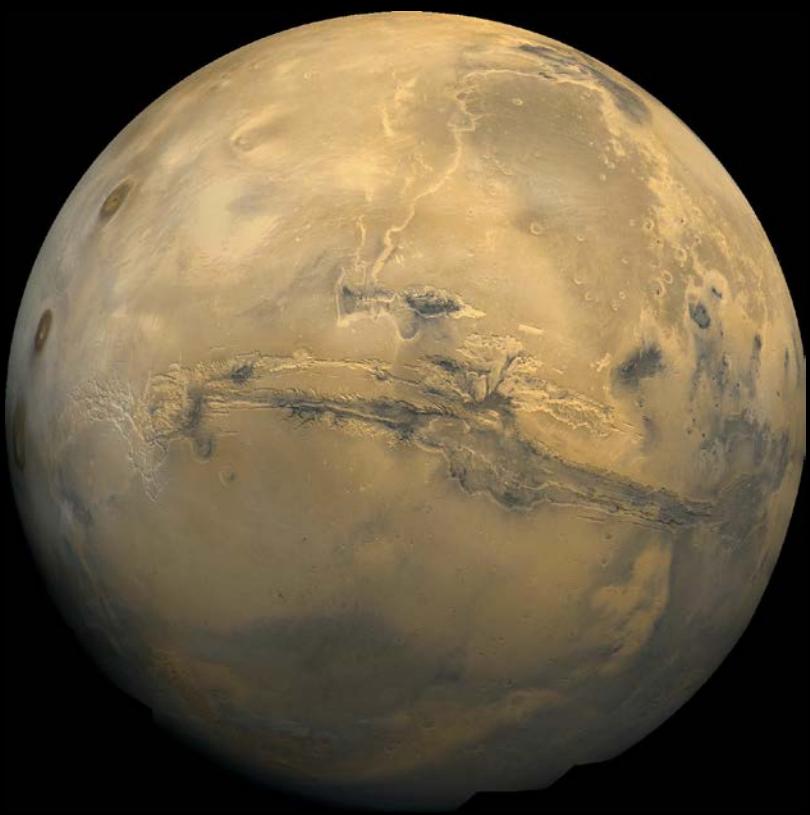
Great Volcanoes



Geology

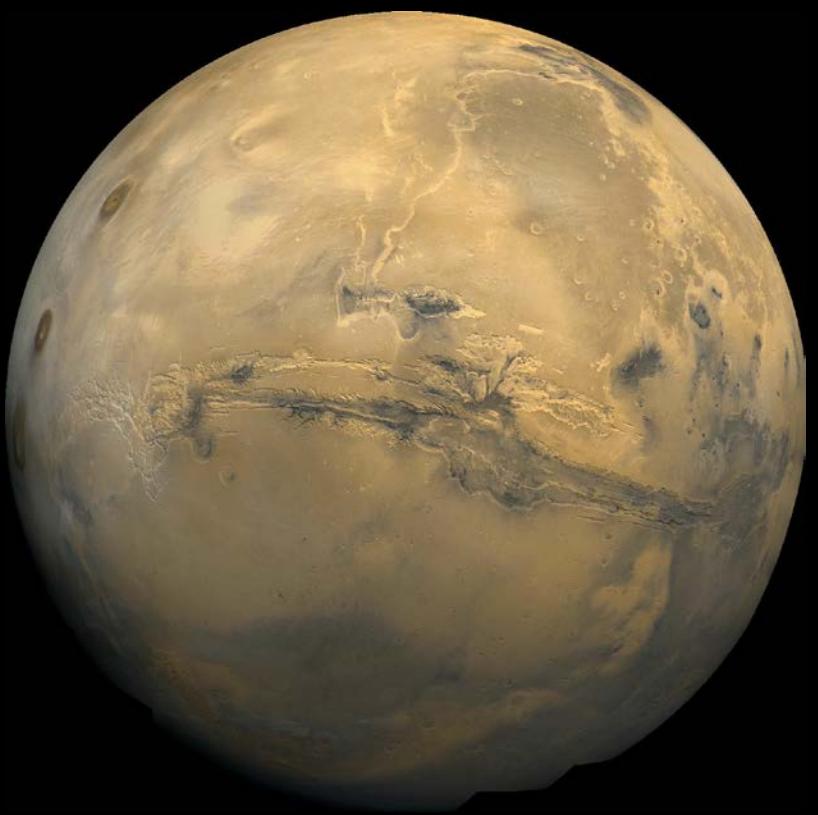
# Traveling 100 Million Miles to Mars





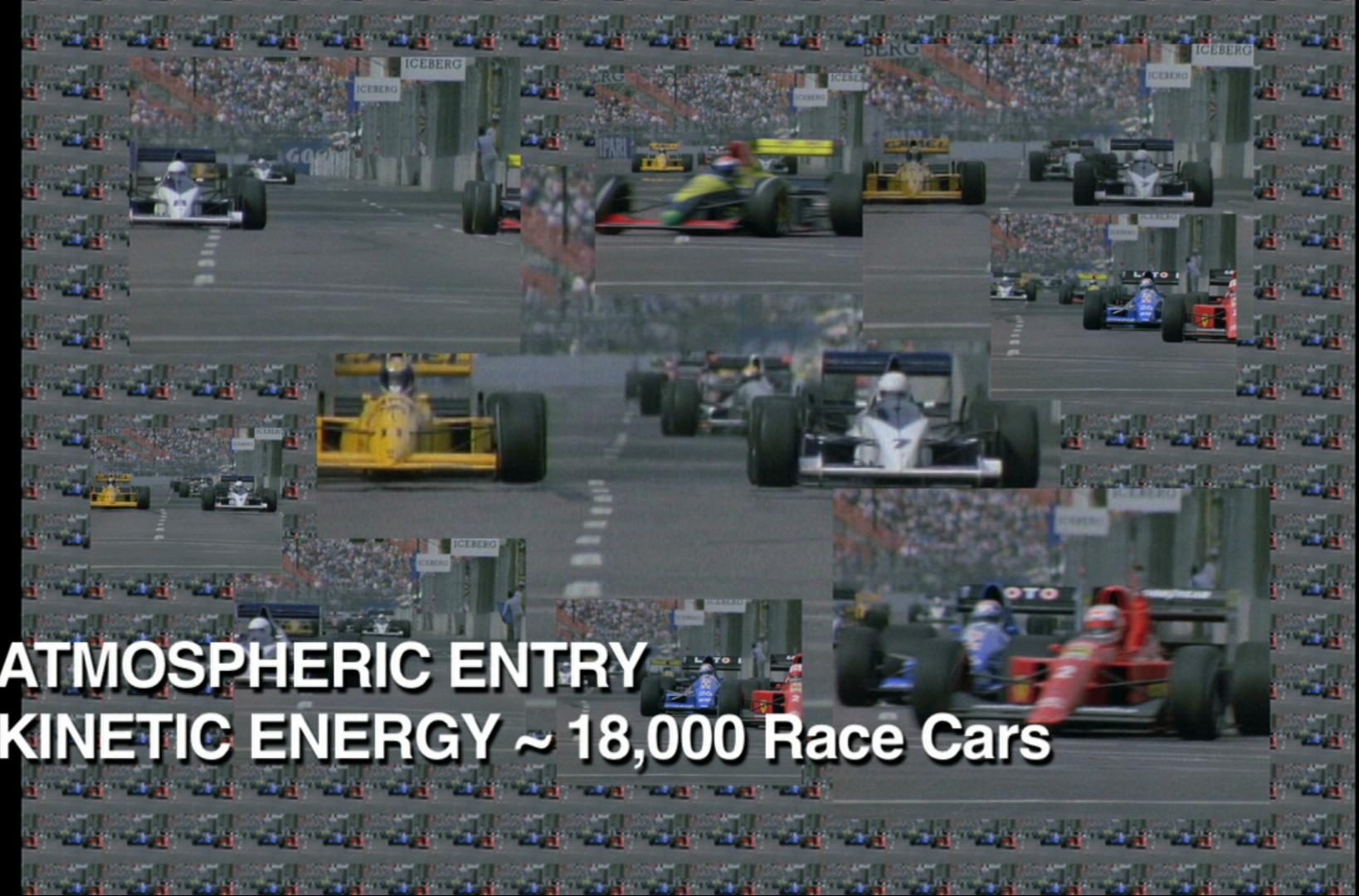
## Navigation

After traveling 450 million kilometers, the rover *Curiosity* arrived at Mars within 2 kilometers of its intended landing site...



## Navigation

...the equivalent of teeing off in Los Angeles and sinking a hole in one in St Andrews Scotland. And the hole on Mars was moving at 60,000 mph!



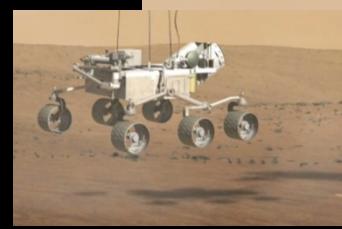
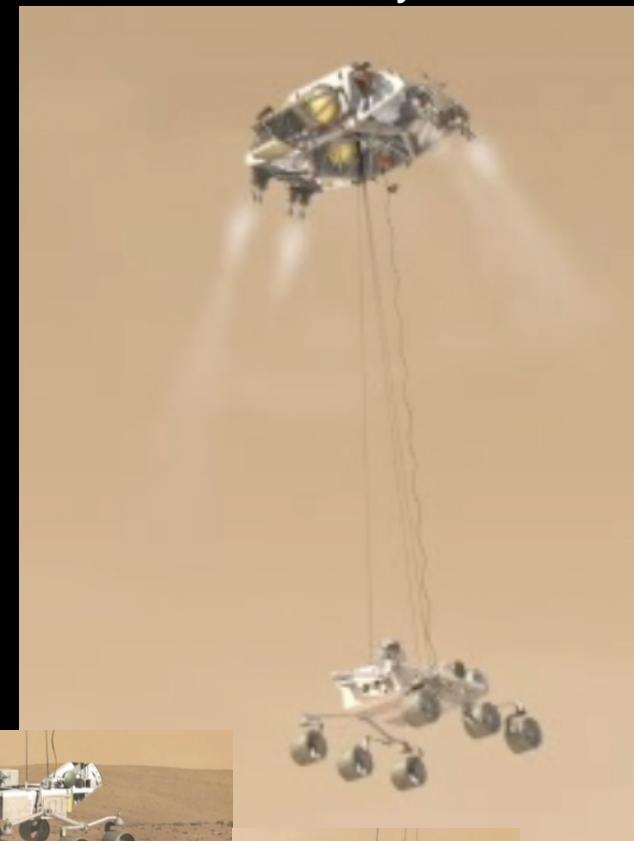
**ATMOSPHERIC ENTRY  
KINETIC ENERGY ~18,000 Race Cars**

# Entry, Descent, and Landing

Spirit & Opportunity

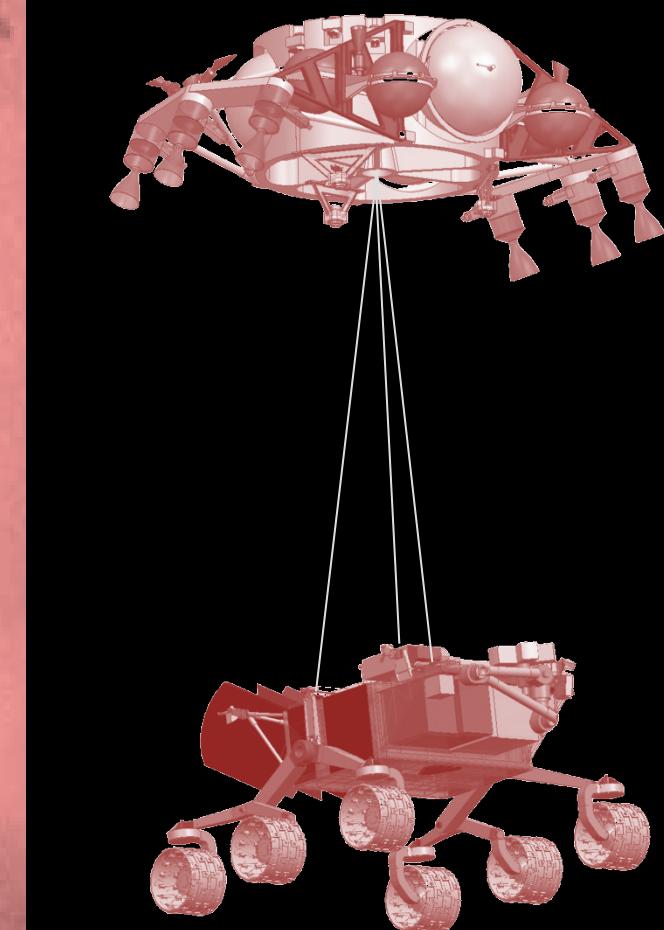


Curiosity





# 2003: The Skycrane maneuver is born



**ChemCam**  
(Chemistry)

**Mastcam**  
(Imaging)

**REMS**  
(Weather)

**DAN**  
(Hydrogen)

**SAM**  
(Isotopes)

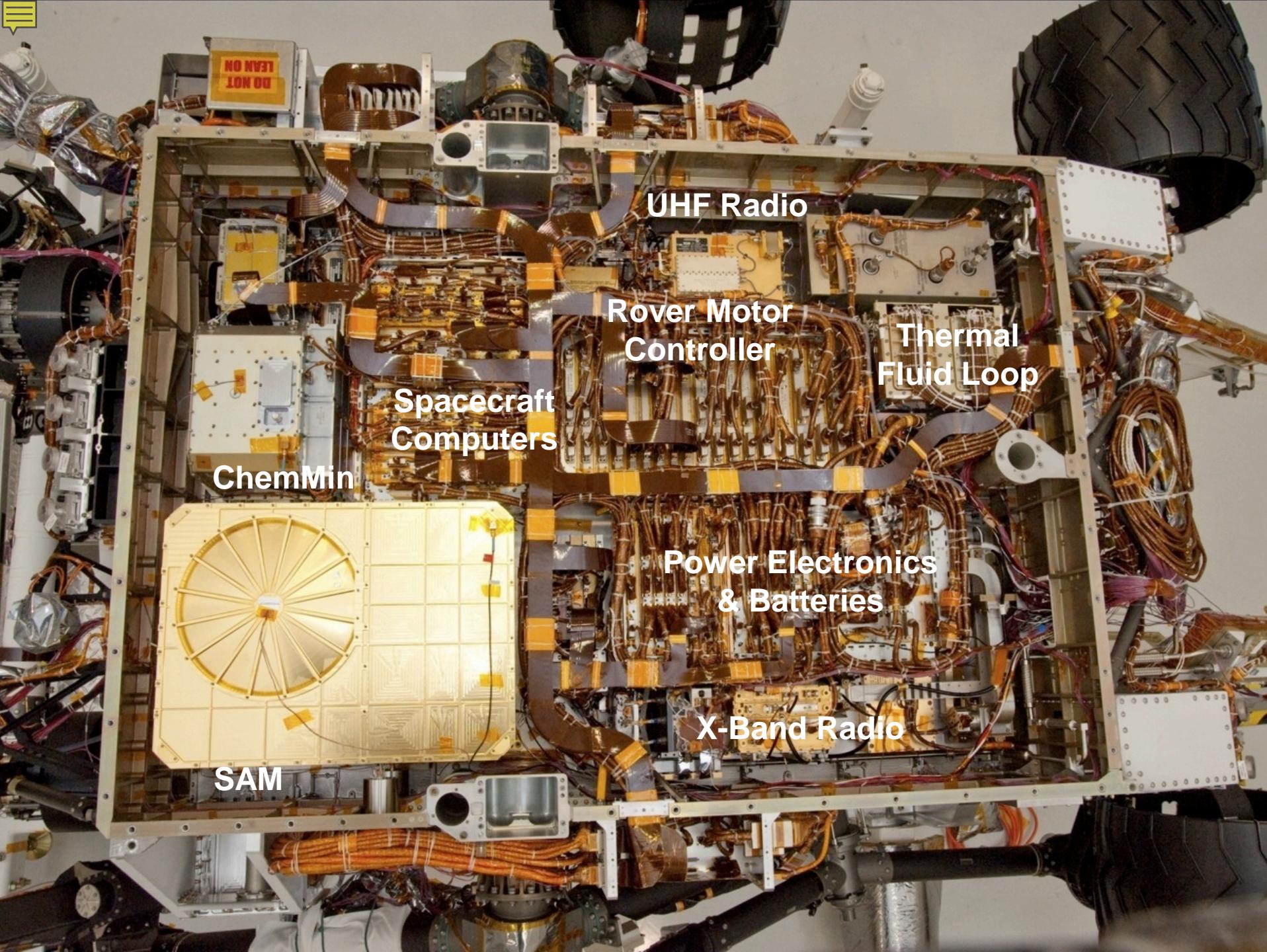
**CheMin**  
(Mineralogy)

**RAD**  
(Radiation)

**MAHLI**  
(Imaging)

**APXS**  
(Chemistry)

**MARDI**  
(Imaging)



DO NOT  
LEAN ON

ChemMin

SAM

Spacecraft  
Computers

UHF Radio

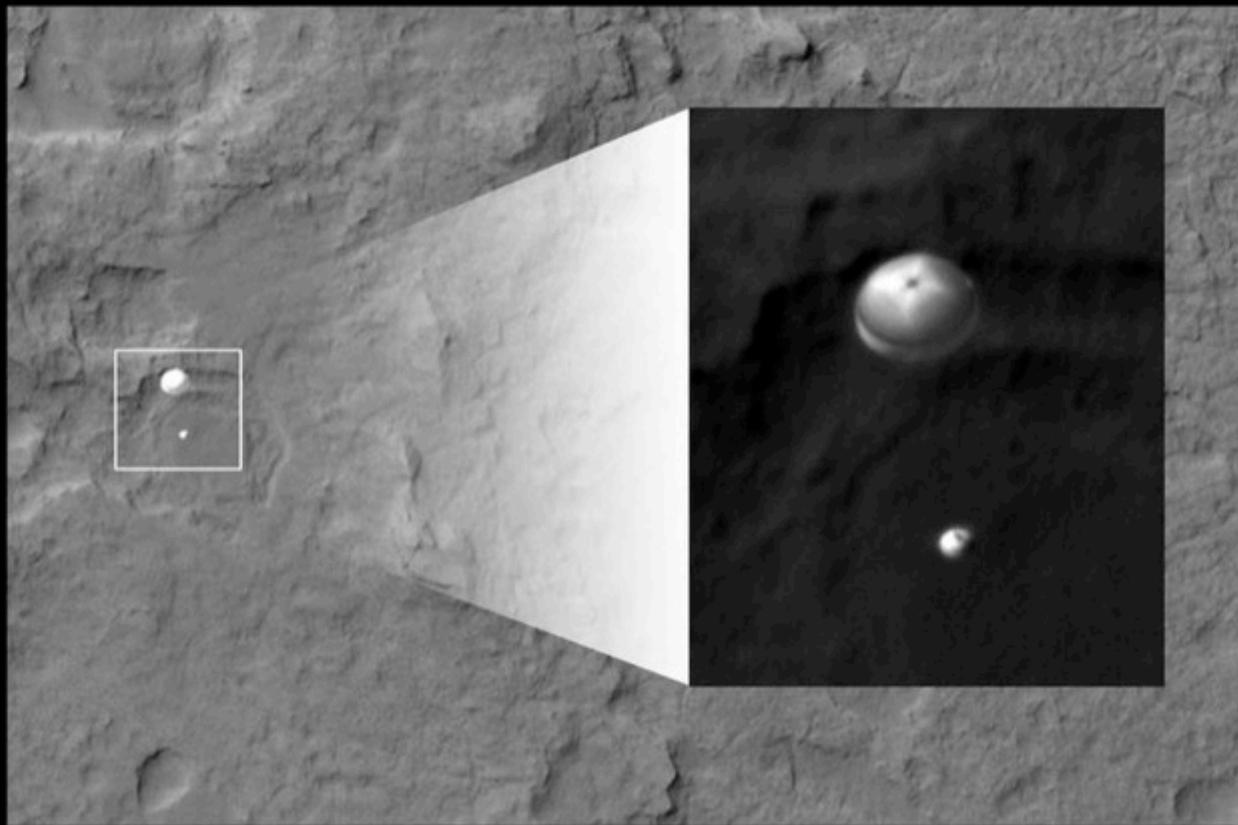
Rover Motor  
Controller

Thermal  
Fluid Loop

Power Electronics  
& Batteries

X-Band Radio

Where were you?



*Parachute Deployed*  
MRO HiRISE camera



# Designing the World's Largest Parachute



Parachute Test

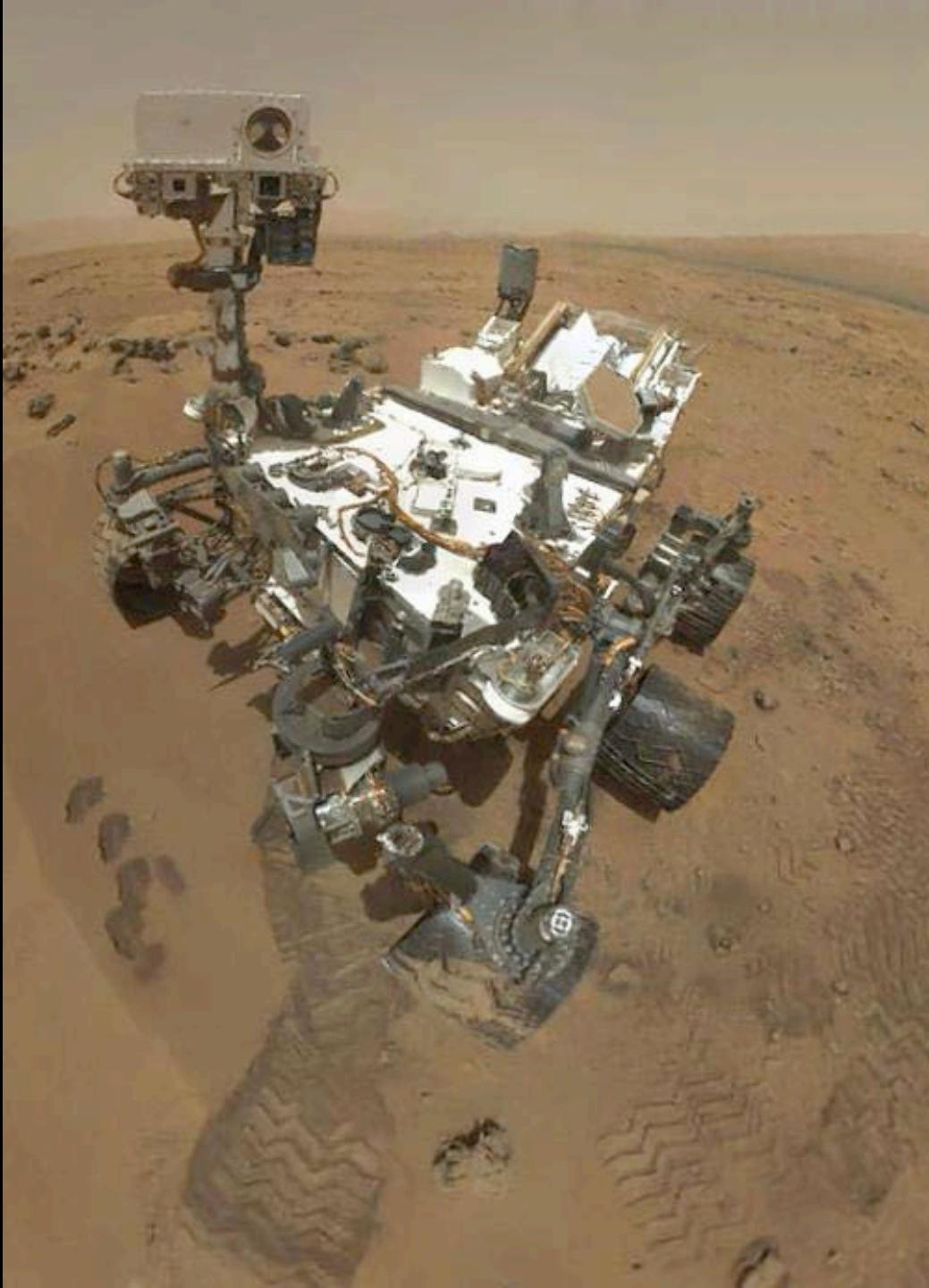
Parachute Test

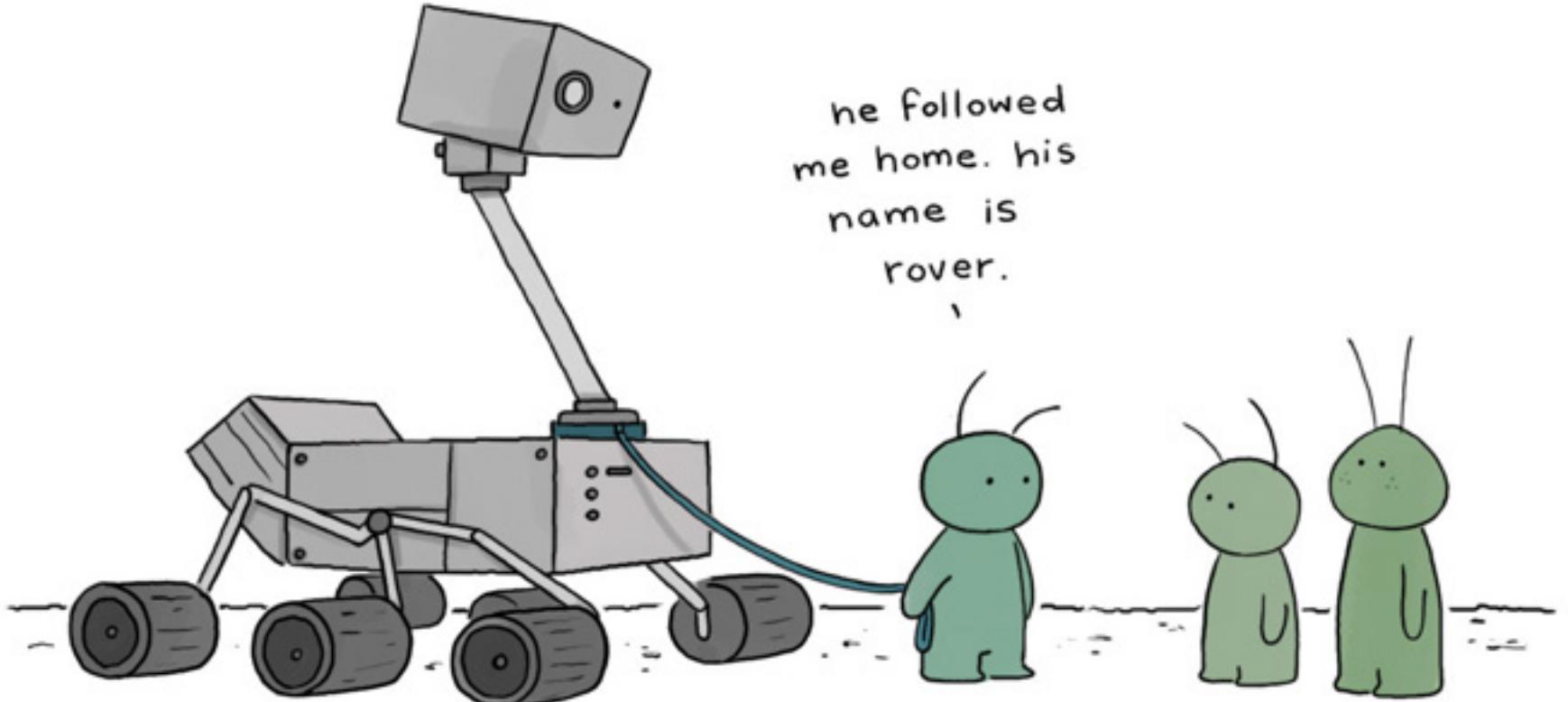
Parachute Test

Parachute Test



Parachute Test





he followed  
me home. his  
name is  
rover.

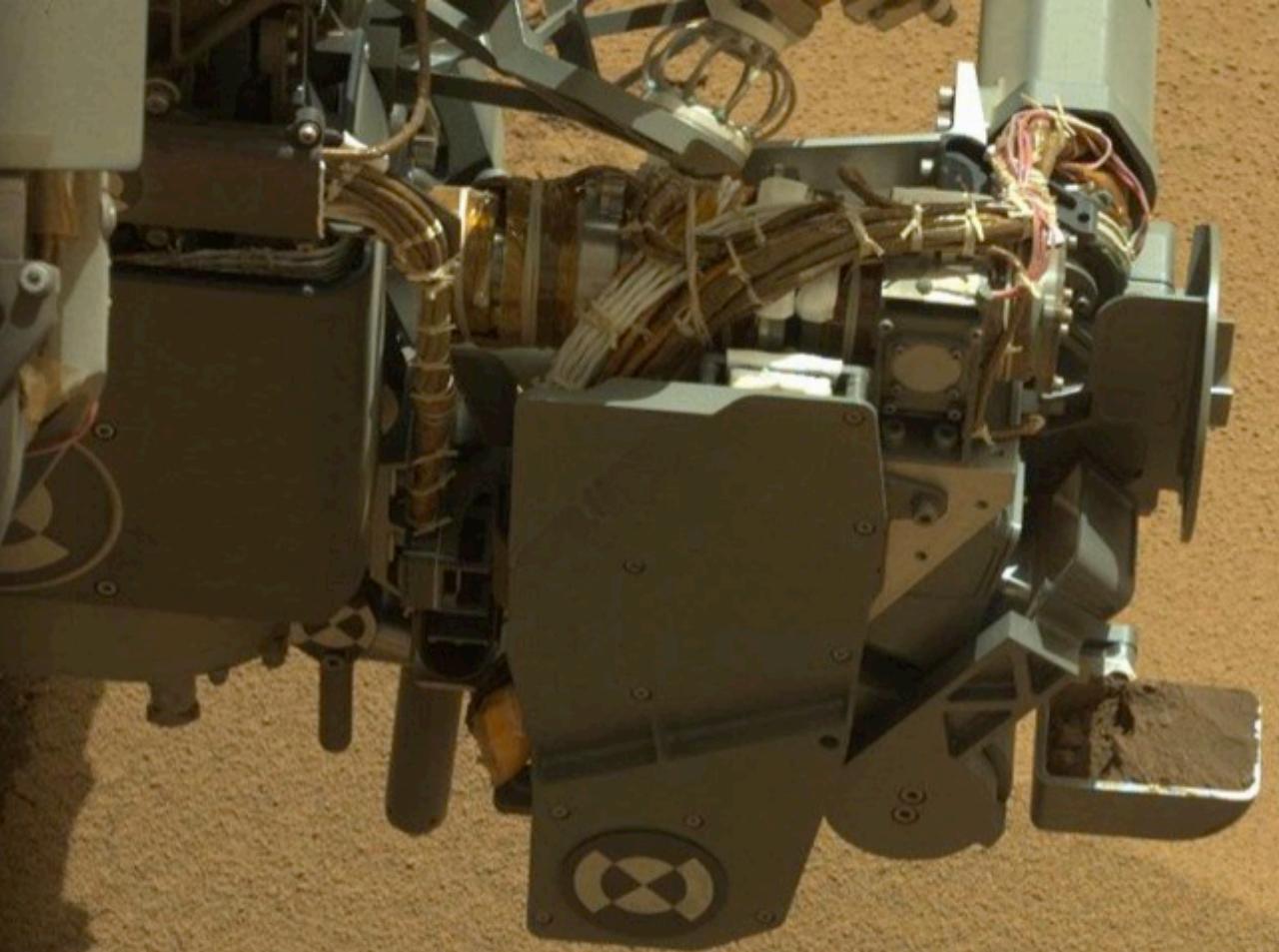


Mars

NASA/JPL-Caltech/MSSS



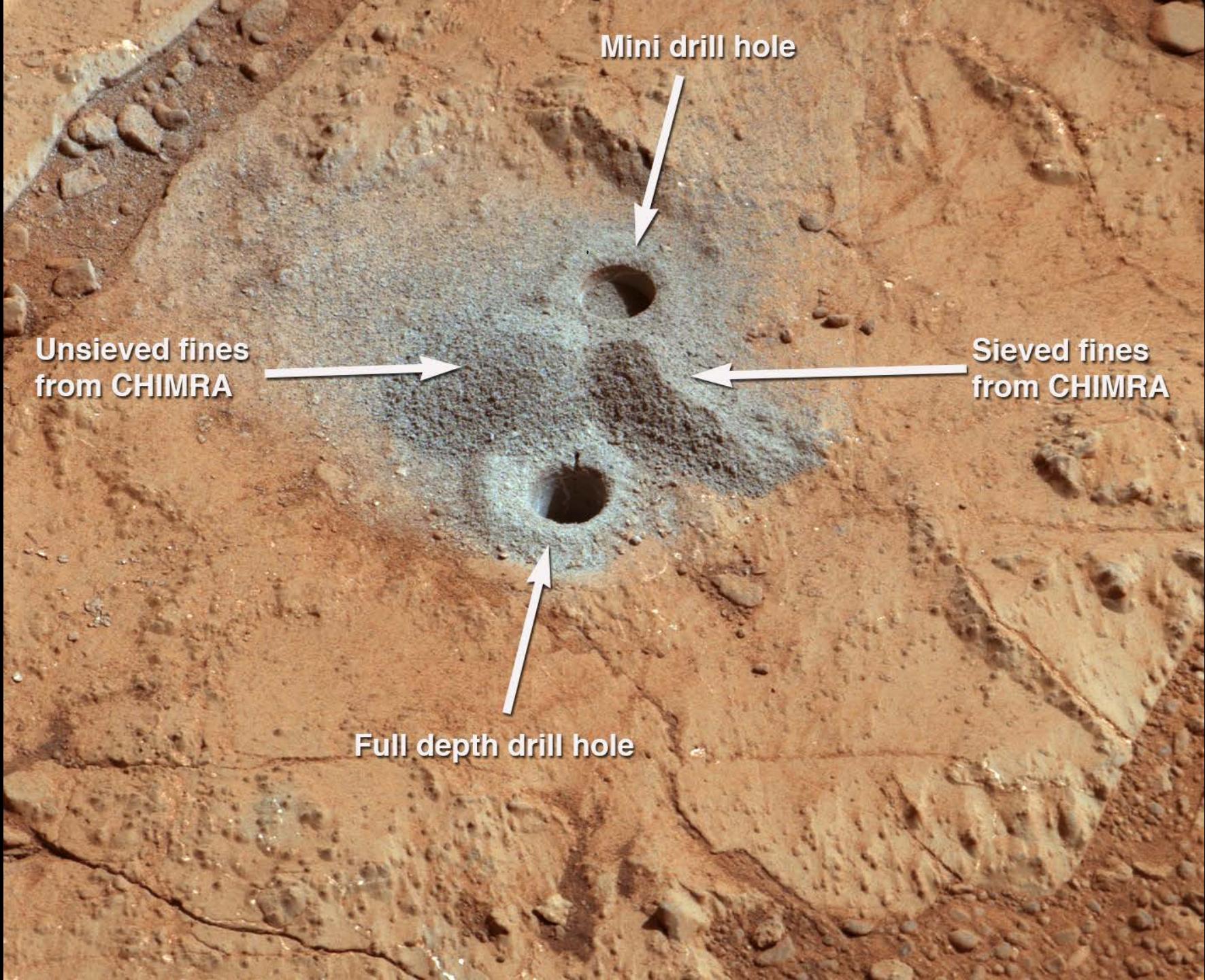
Earth





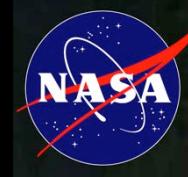


Cumberland Drill Hole

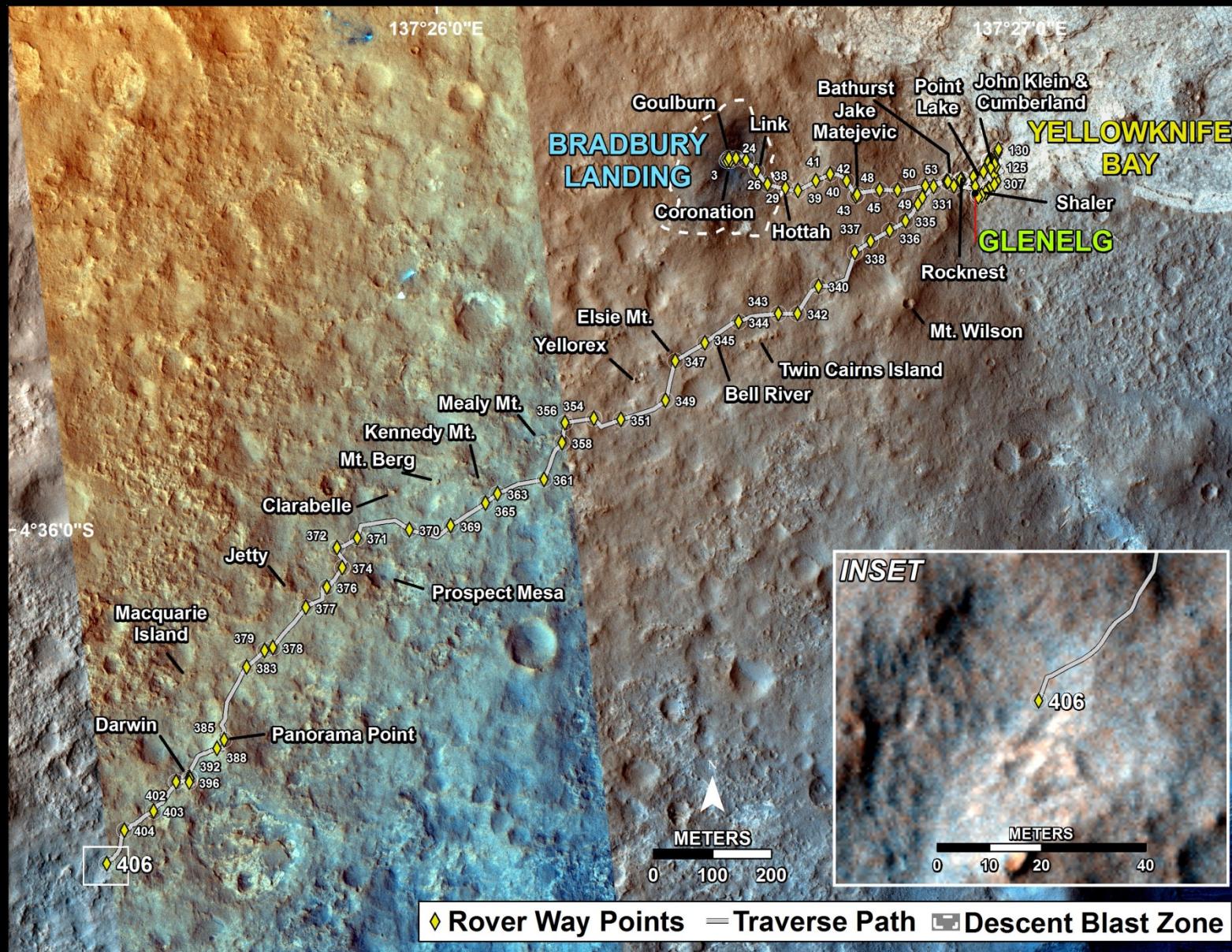




# Curiosity's Location on Sol 406

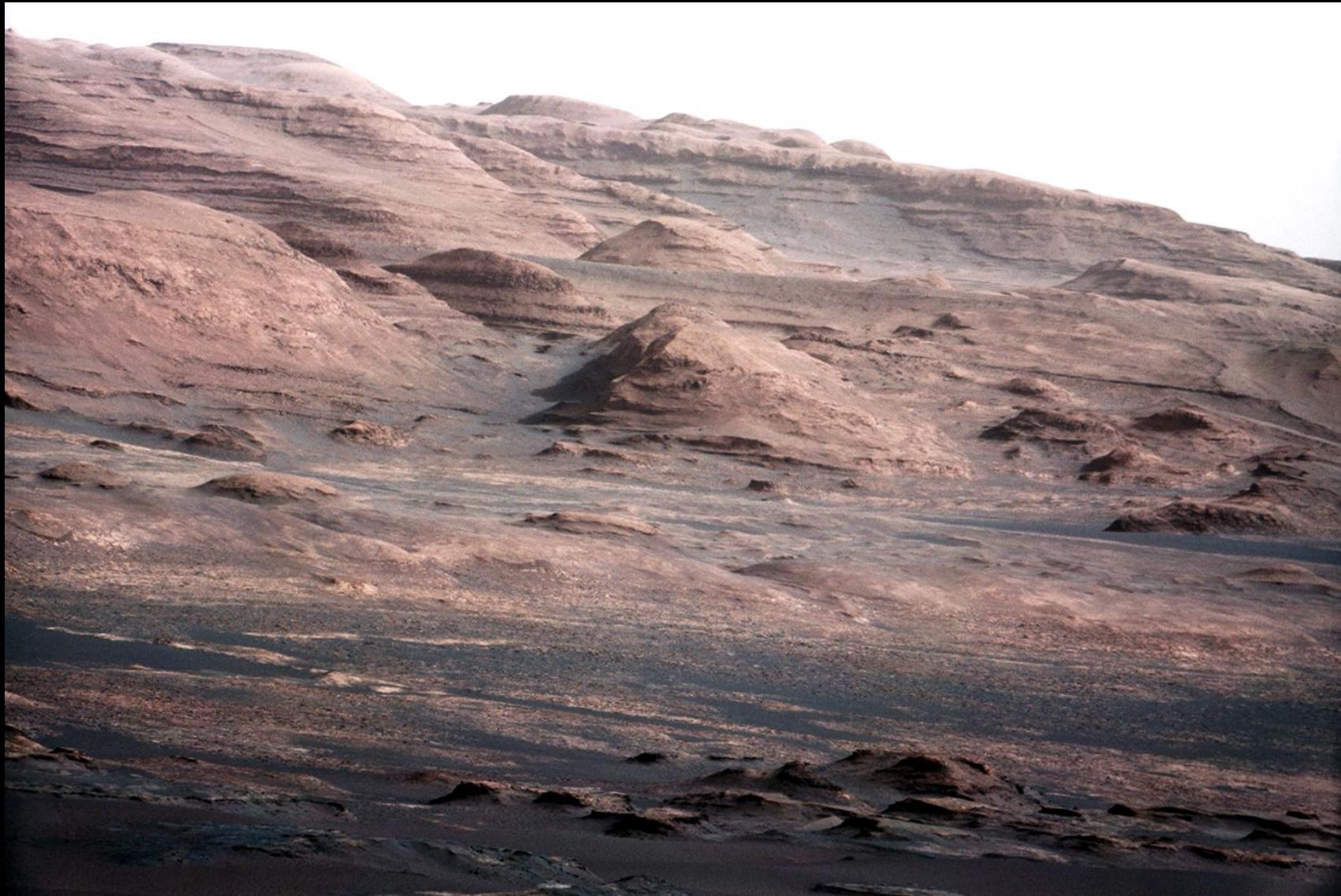


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Vista With 'Twin Cairns' on Route to Mount Sharp

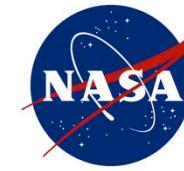


Destination: Mount Sharp

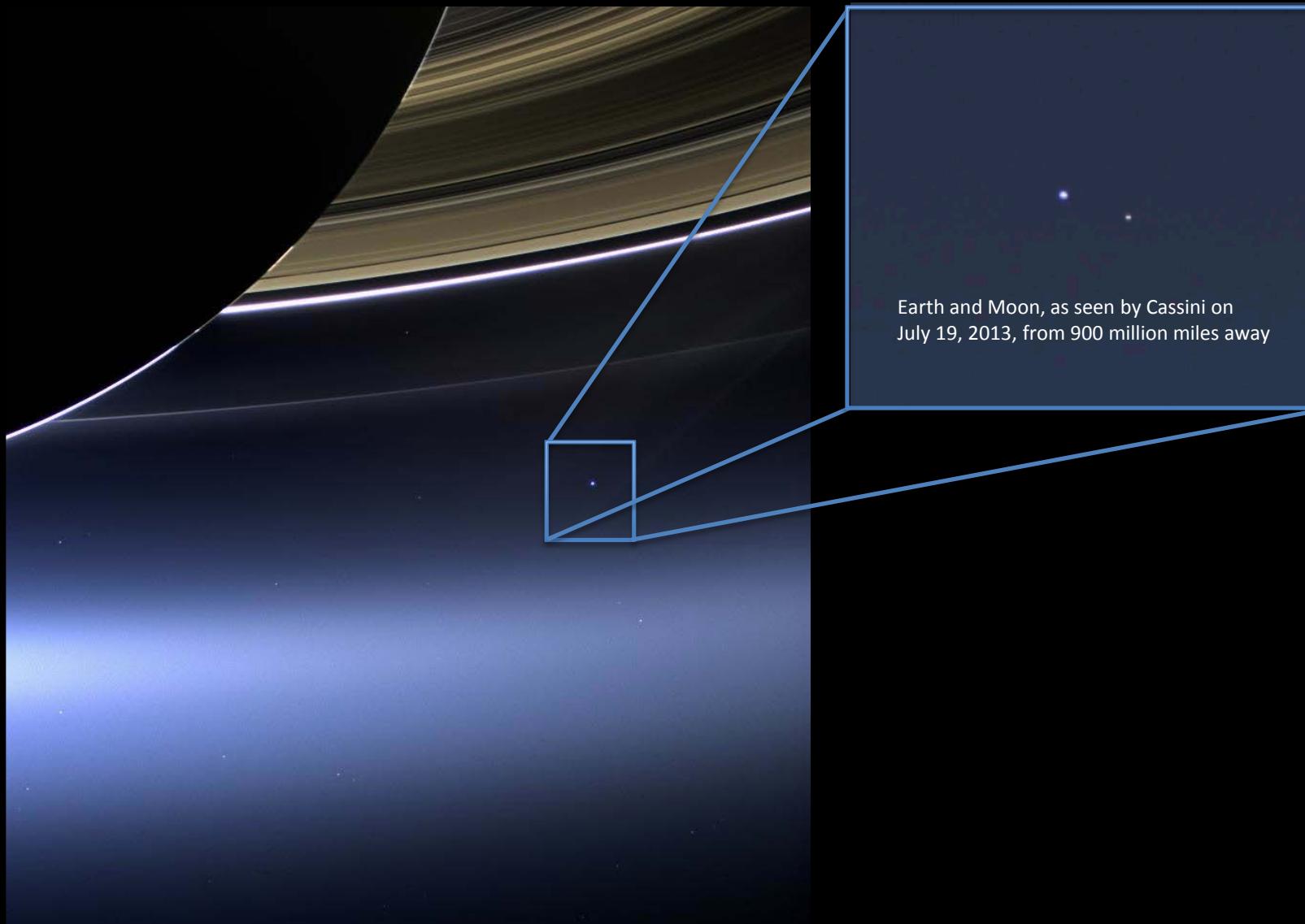


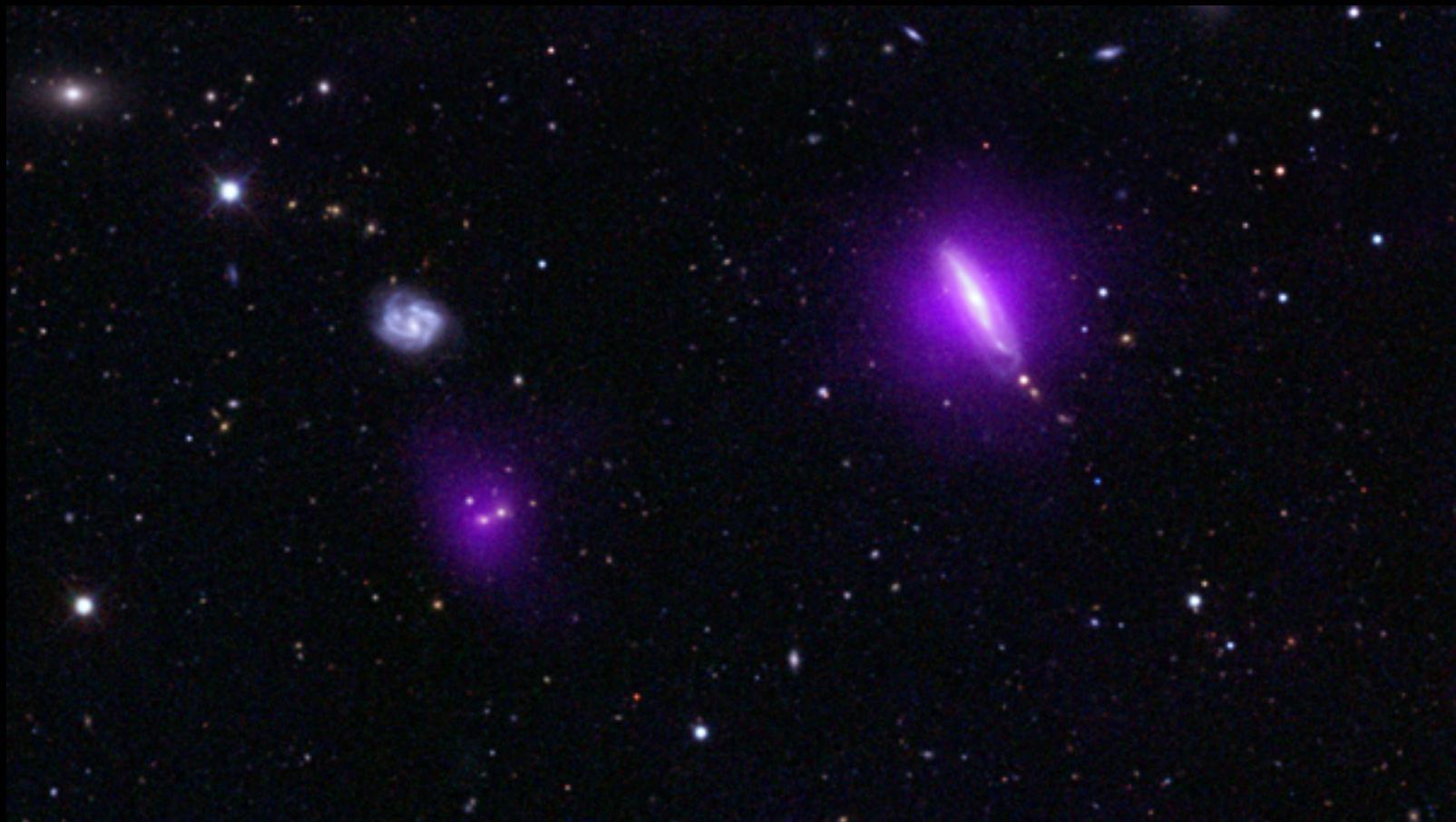
# Image of Earth taken by Cassini

July 19, 2013



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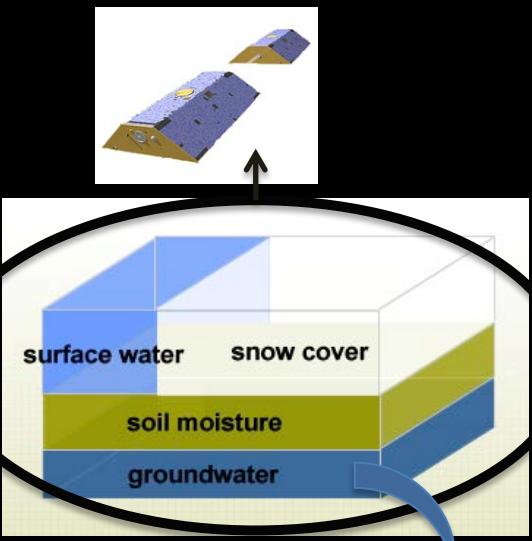
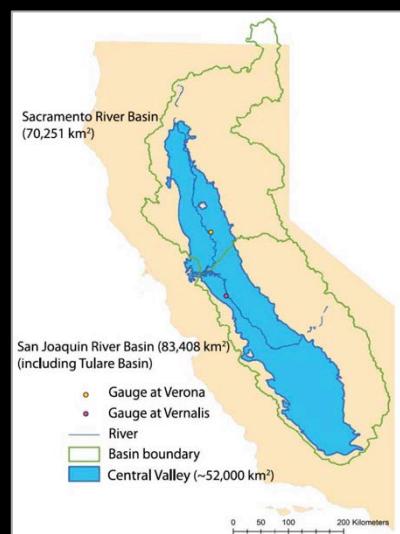
Black Holes shine for NuSTAR



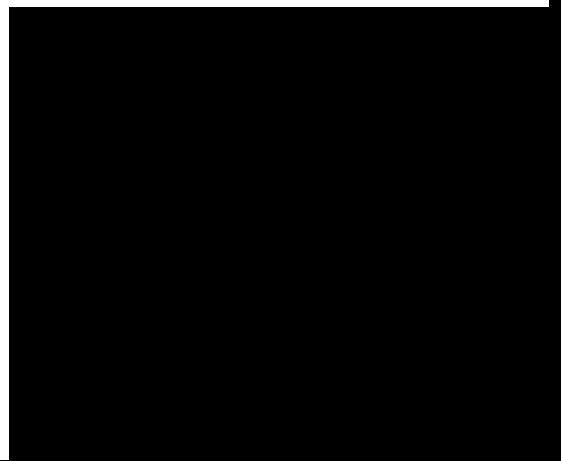
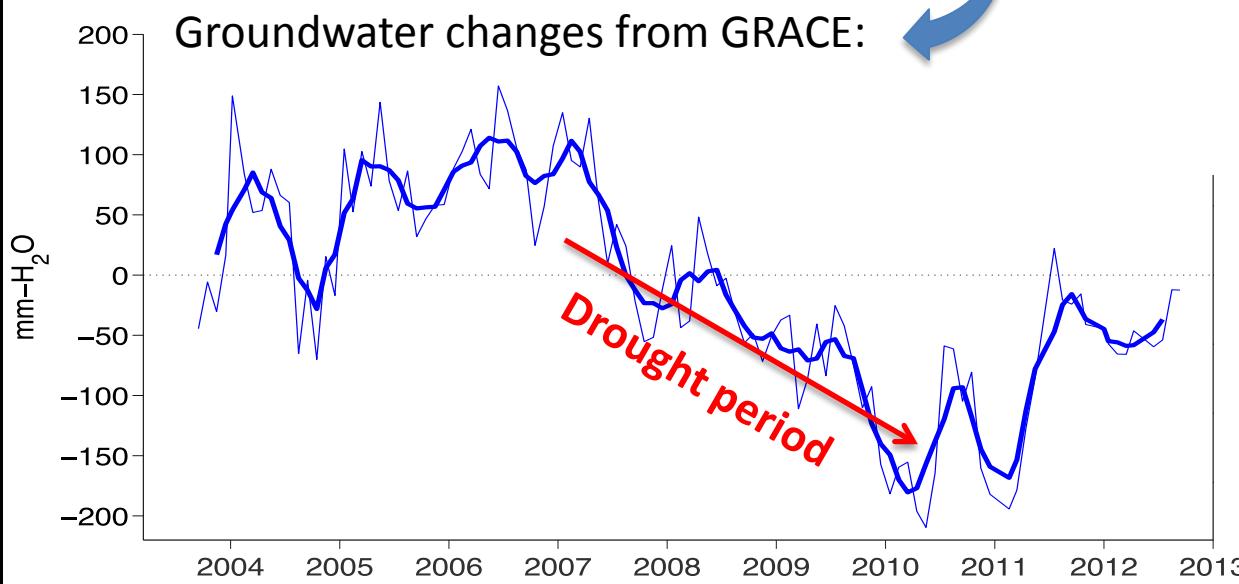
# California's Central Valley 2003 - 2012: Groundwater changes from GRACE



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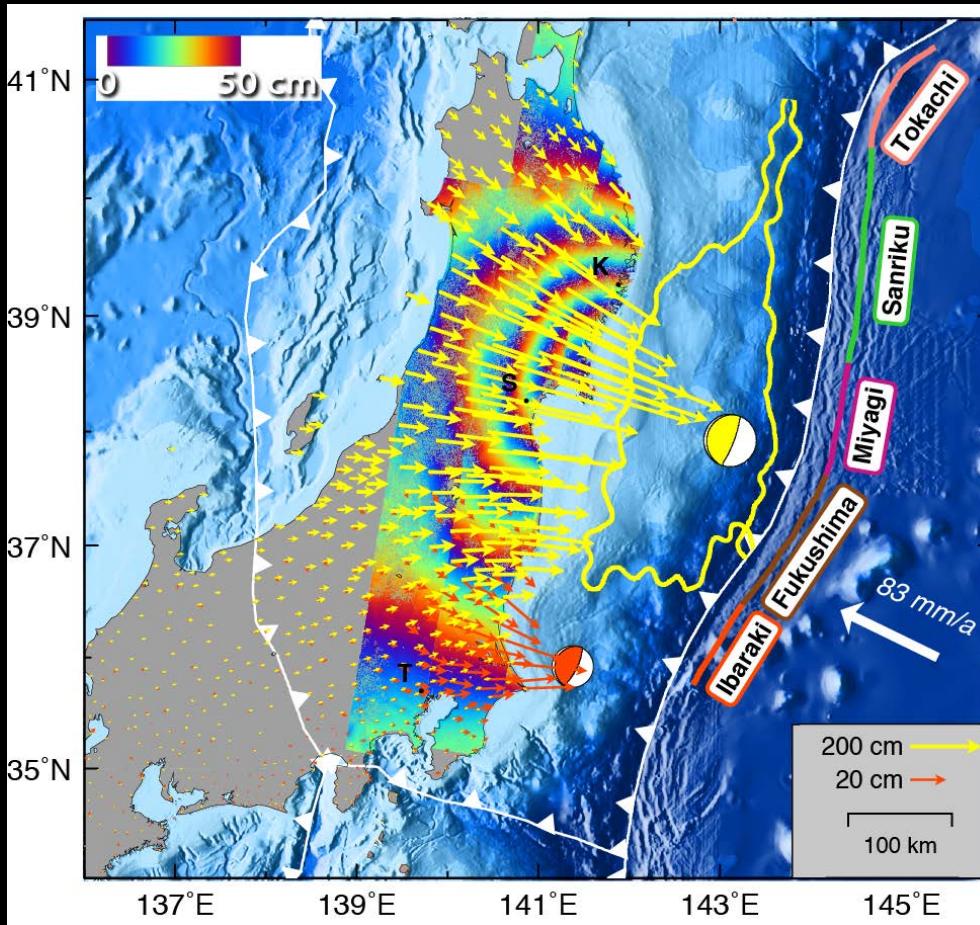
- GRACE measures all the water storage changes on land
- To estimate groundwater, the snow, surface water and soil moisture changes must be subtracted
- **Result:** even after official drought ended in 2010, GRACE detects that Central Valley groundwater still remains *below* pre-drought levels



# Science and the Environment: Natural Hazards



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Coseismic interferogram (Envisat), coseismic GPS offsets (mainshock in yellow, aftershock in orange), and 8 m contour of mainshock fault slip model from 2011 Magnitude 9.0 Tohoku-Oki Earthquake (Simons et al, Science, 2011)



# Apollo 11 & Curiosity Rover



*“Do not go where the path may lead. Go instead where there is no path and leave a trail.”*

- Ralph Waldo Emerson

