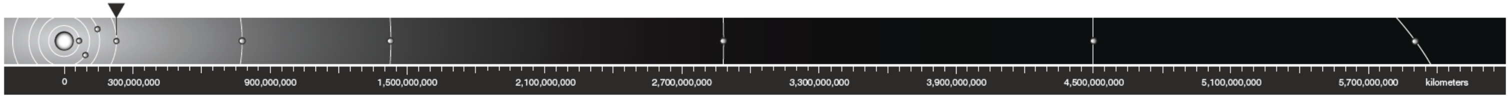
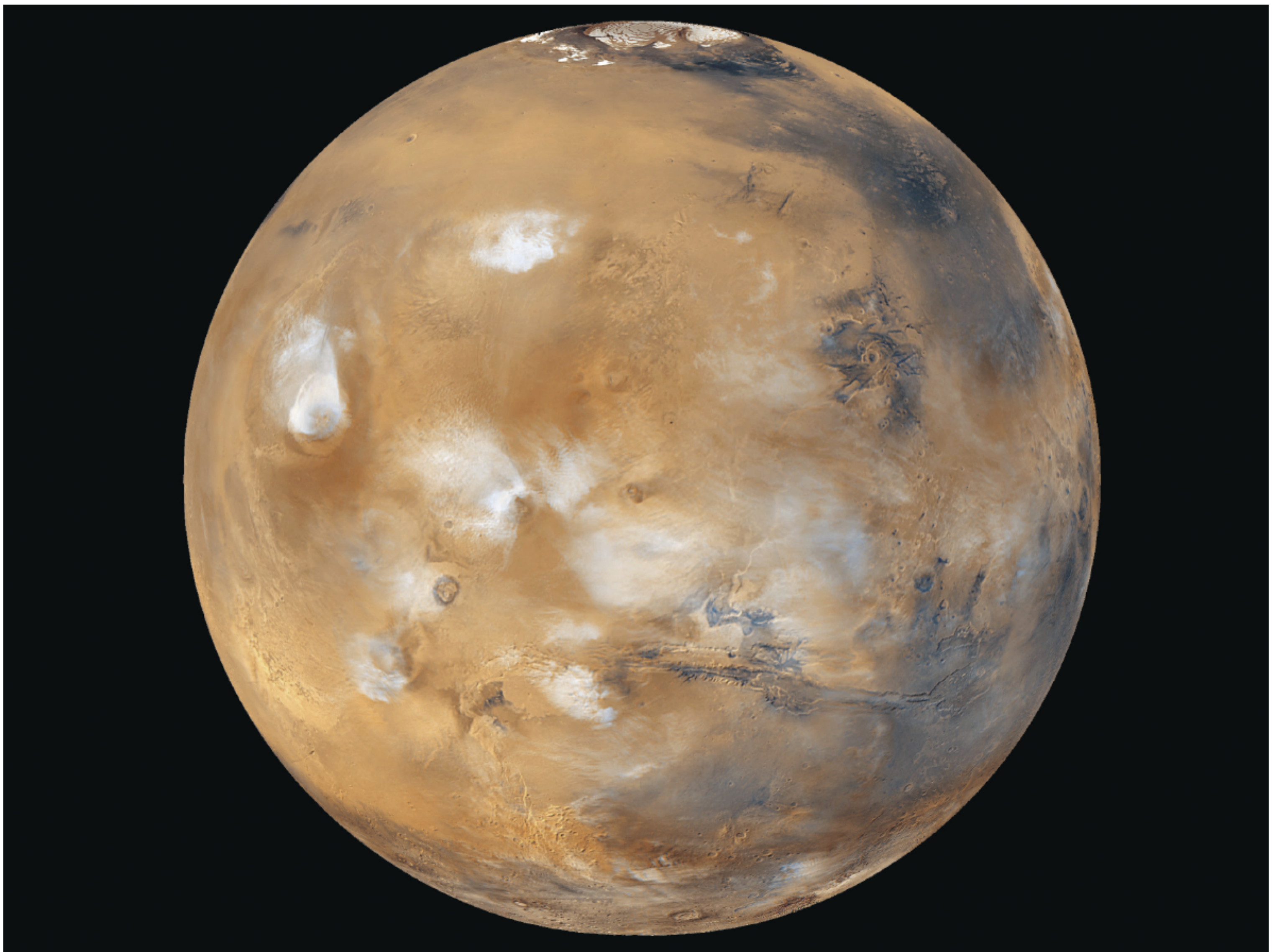
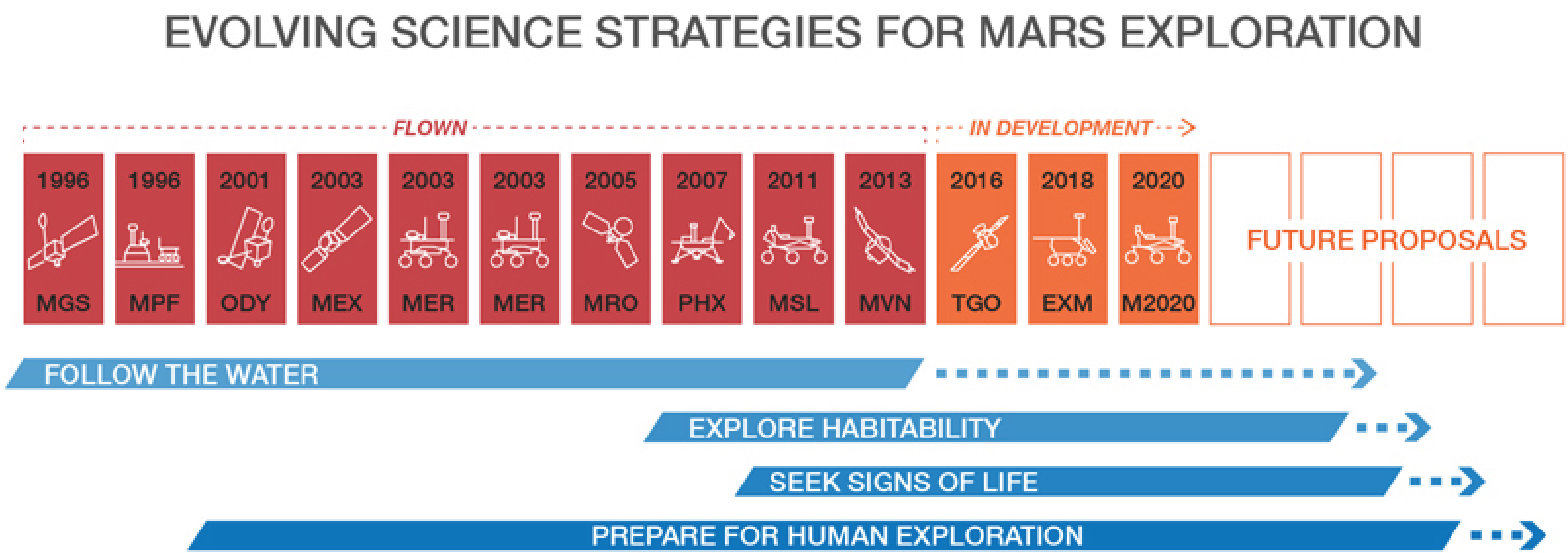


Le Raman pour l'exploration de Mars



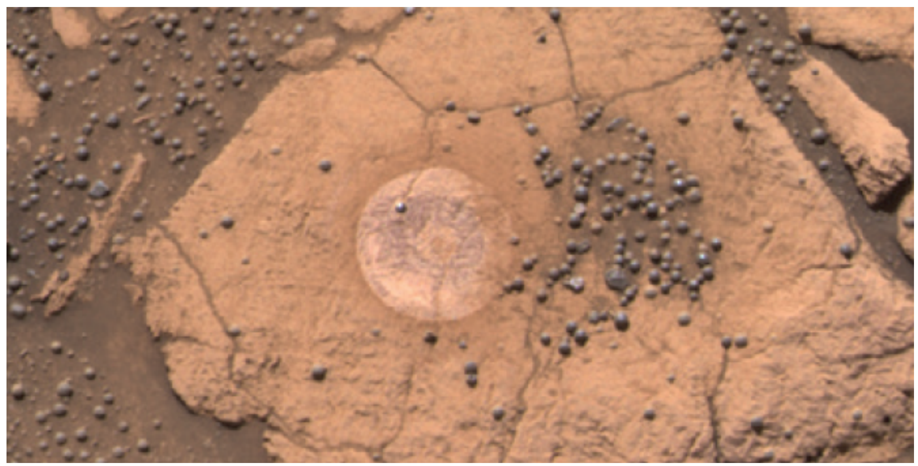
Thèmes du débat

- Que nous apprend la mission Mars science laboratory et Curiosity ?
- Faire de la géologie sur Mars avec la spectroscopie Raman ?
- La spectroscopie Raman comme outil d'astro-biologie dans l'environnement de Mars ?
- La mission Mars 2020 et SuperCam...



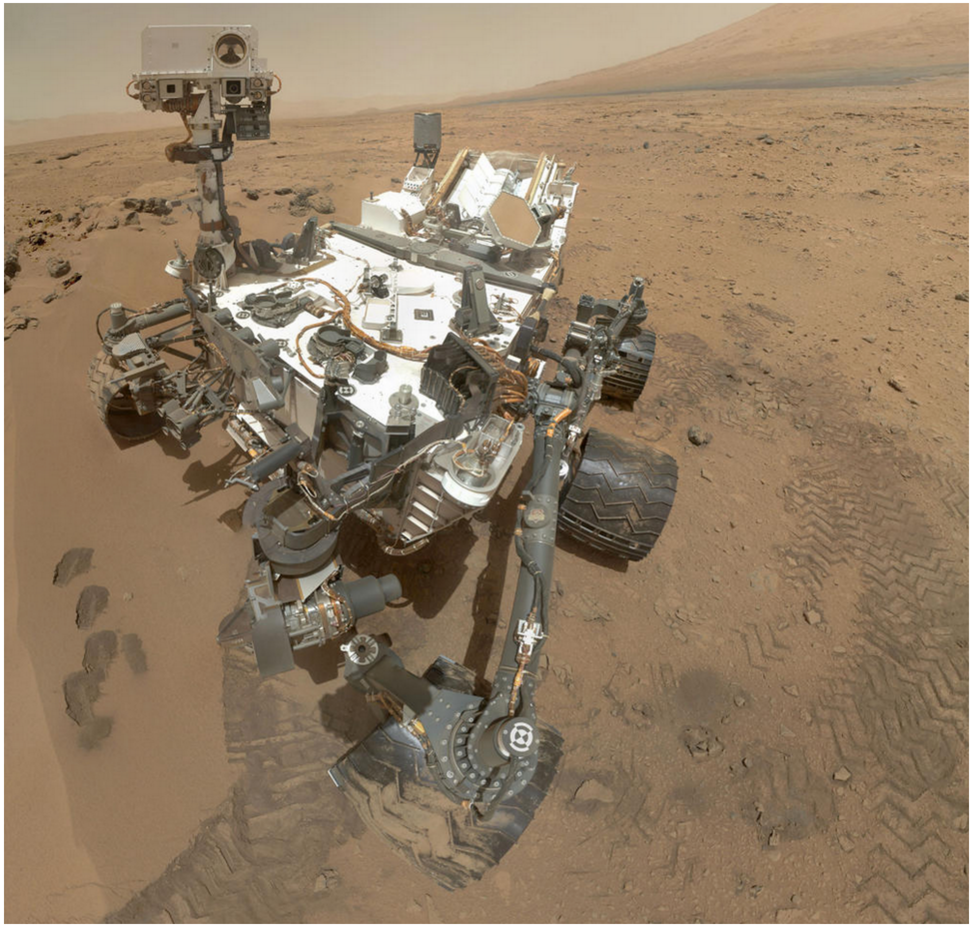
« time-line » des missions de la NASA.
rovers : Mars Pathfinder, Beagle2 (échec), Spirit et Opportunity (Mars exploration rovers), **Mars science laboratory (Curiosity)**, **ExoMars** et **Mars 2020**.

géologie et astro-biologie



Crédit NASA/JPL (2003)

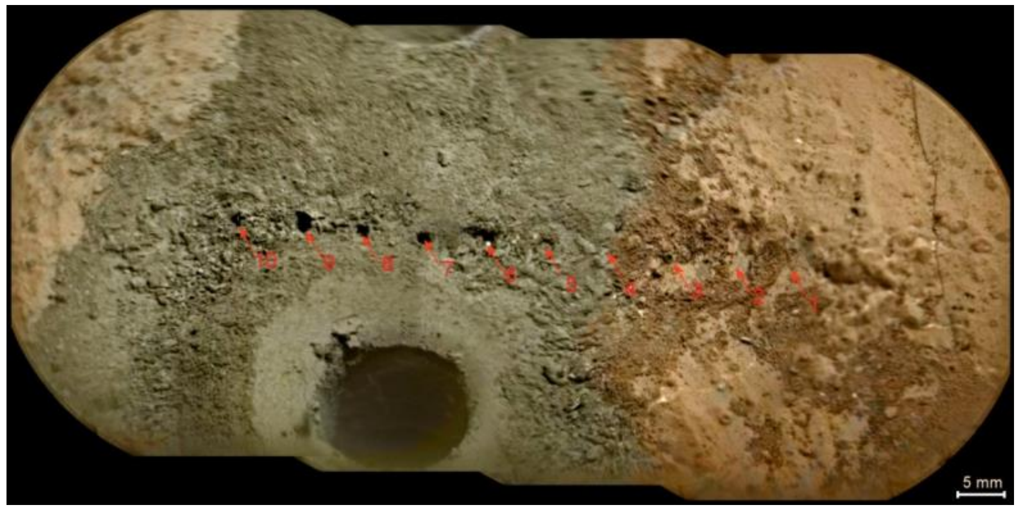
Mission Mars science laboratory



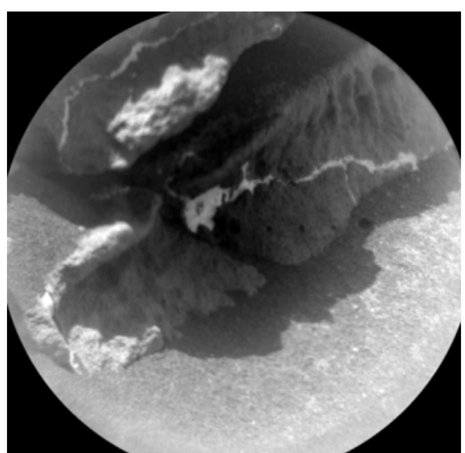
Crédit: NASA/JPL-Caltech/Malin Space Science Systems (2012)

Heritage

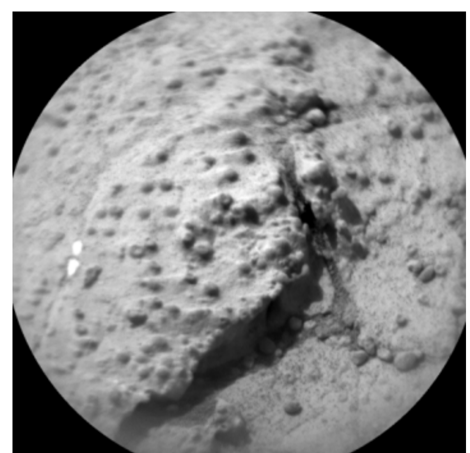
ChemCam RMI + MastCam (colors)



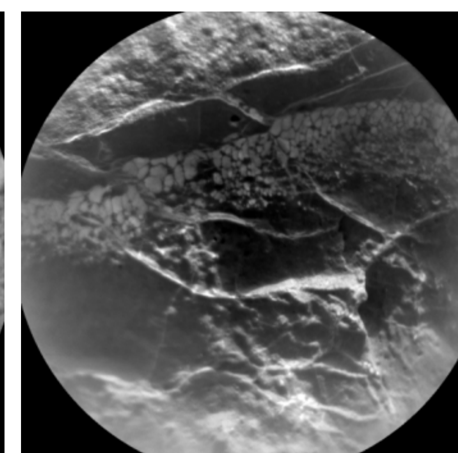
Denham (sol 326)



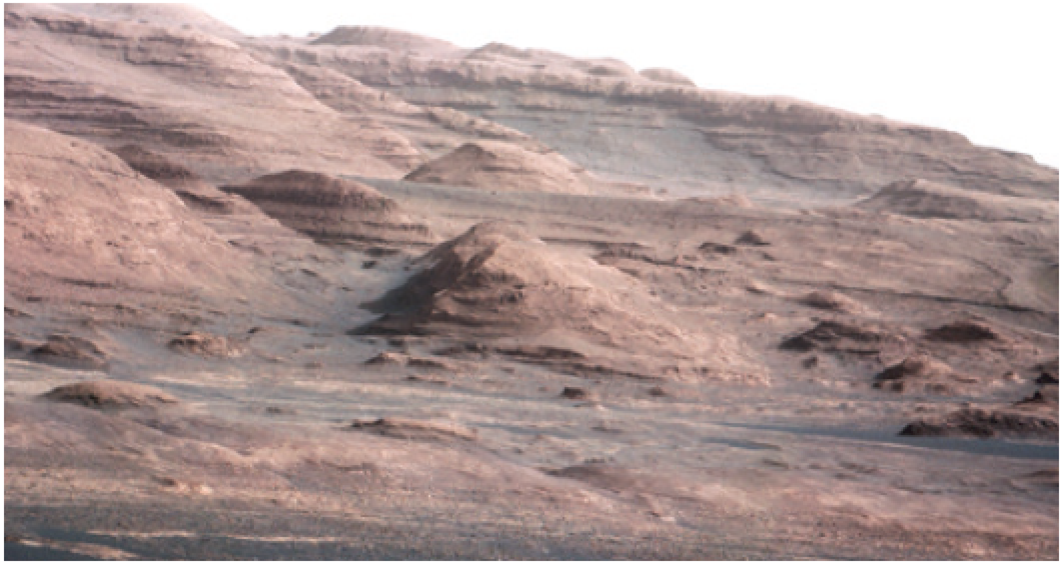
Fabricius_Cliffs (sol 322)



Cumberland (sol 187)



Selwyn (sol 157)



Crédit : NASA /JPL. Curiosity picture of layered rocks of Mount Sharp in Gale Crater (2014)

Avancées technologiques

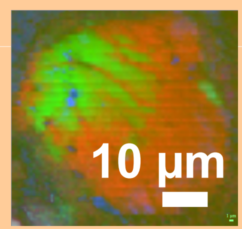
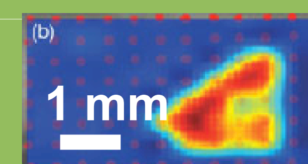
Caméra iCCD et SPAD array
Réseau VPHG (1999)
Spectromètres échelle (2009)**
**** utilisant un échelle commercial**
2010

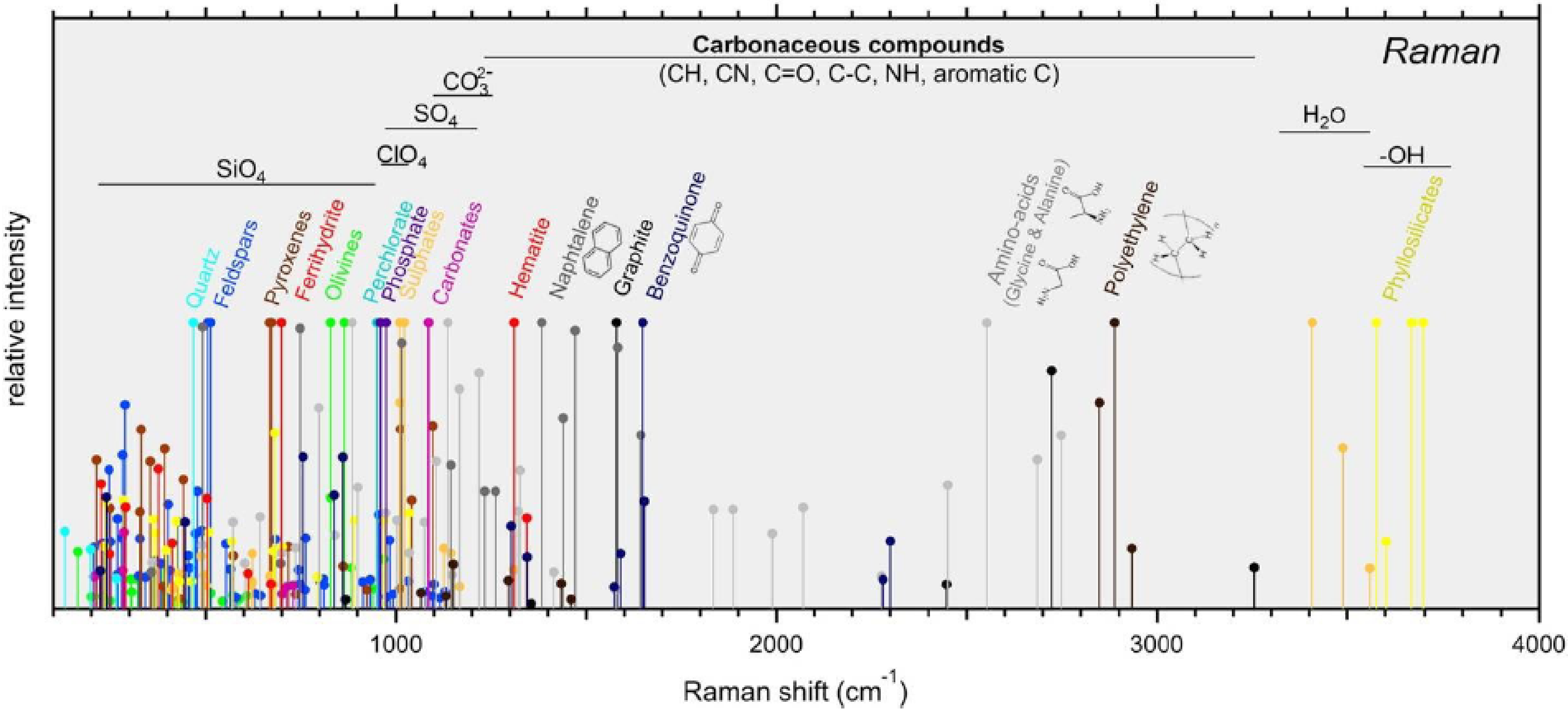
Caméra CCD (1989)
Filtres holographiques (1991)
Micro Raman confocal (1996*)
*** le principe datant de 1966**
1990

Laser
Spectroscope à réseau
Photo détecteurs
1950

Lampe Hg
Spectroscope à prisme
Plaque image
1930

Le Raman hors du labo

	Instrument de laboratoire 	Instrument sur le terrain 
Résolution spatiale et spectrale	< 1 µm, < 1 cm-1	qq mm, 5-10 cm-1
Cartographie	LGL, ENS-Lyon 	Porter et al, 2011, JRS 
In situ	Pression, température, atmosphère contrôlée	De fait !



Raman
Carbonaceous compounds
(CH, CN, C=O, C-C, NH, aromatic C)
CO_3^{2-}
SO_4
ClO_4
SiO_4
H_2O
-OH
Quartz
Feldspars
Pyroxenes
Ferrihydrite
Olivines
Perchlorate
Phosphate
Sulphates
Carbonates
Hematite
Naphtalene
Graphite
Benzoquinone
Amino-acids
(Glycine & Alanine)
Polyethylene
Phyllosilicates
relative intensity
Raman shift (cm^{-1})
1000
2000
3000
4000

Les SNC, des météorites martiennes

Shock-induced compaction, melting, and entrapment of atmospheric gases in Martian meteorites.
P. Beck, T. Ferroir and P. Gillet. GEOPHYSICAL RESEARCH LETTERS, VOL. 34, 2007

Crédit : NASA /JPL. Curiosity drilled this hole and fired its laser several times (2013)

MATIERE ORGANIQUE SUR MARS

Matière organique dans météorites martiennes:

- contamination terrestre?
- apport météoritique?
- décomposition thermique de carbonates?
- précipitation à partir de fluides aqueux?
- préservation de molécules d'origine biologique?

[Meteorite accumulation on Mars. Bland and Smith (2000) *Icarus* 144, 21]

We have modeled single-body meteoroid atmospheric entry speeds at Mars and the effect of drag and ablation, and identify a narrow range of small masses (10–50 g) that should impact Mars at survivable speeds. The rate of oxidative weathering is much lower than that on Earth, so this small flux of meteorites could give rise to significant accumulations: ca. 5×10^2 to 5×10^5 meteorites greater than 10 g in mass per square kilometer. Given that extremely large numbers of meteorites may be present on Mars, future sample-return missions should consider the real possibility that they may recover meteoritic material. Due to the low weathering rate, meteorites may survive on the surface of Mars for more than 10^9 years, preserving a record of the temporal variability of the meteoroid flux and the compositional evolution of the meteoroid complex. Intact carbonaceous chondrites may also preserve organic compounds from degradation by ultraviolet radiation. Terrestrial meteorites may be present, but would probably be sterile.

[UV degradation of accreted organics on Mars... Moores et Schuerger (2012) *JGR 117, E08008*]

[1] Reanalysis of the Viking Lander results on Mars has suggested a surface reservoir of organic carbon at the ppm level. The size of this putative reservoir could be explained if the source of carbon on Mars is meteoritic in origin and is destroyed primarily by UV irradiation, yielding methane. By combining a numerical UV model for the surface of Mars with published laboratory measurements of organic UV photolysis, the times required to completely convert the carbon within individual particles to methane may be calculated. For interplanetary dust particles (IDPs) initially containing 10 wt% carbon, lifetimes of organics range from 3.9 years for a 0.2 μm diameter particle at equatorial latitudes to 4900 years for a 200 μm diameter particle at polar latitudes, and implies a median time for IDP organics by UV photolysis of 320 years at equatorial latitudes and 1500 years at polar latitudes. Assuming no redistribution of organics over the surface, the IDP organic reservoir at the surface would range from 1.1×10^{-6} kg m^{-2} at equatorial latitudes to 6.6×10^{-6} kg m^{-2} at polar latitudes. If accreted carbon is evenly mixed with the soil, up to 3.4 ppm of organic carbon at the VL1 landing site can be explained from a meteoritic origin and up to 4.9 ppm at the VL2 landing site. Derived from the IDP organic reservoir, small fluctuations in methane would exist due to variations in UV irradiation with latitude and L_S. Production of methane is expected to range up to 0.35 pptv sol^{-1}.

MOLECULES ORGANIQUES DANS LES METEORITES MARTIENNES: origine abiotique

[Steele et al. (2012) *Science* 337, 212]

→ Mesure par spectro. Raman dans 11 météorites martiennes (cristallisation datée de 4.2 milliards à 190 millions d'années)

→ 10 contiennent un "matériel carboné complexe" encagé dans des minéraux ignés: C ~ 20 ppm; $\delta^{13}C$ ~-20 ‰

spectres Raman caractéristiques

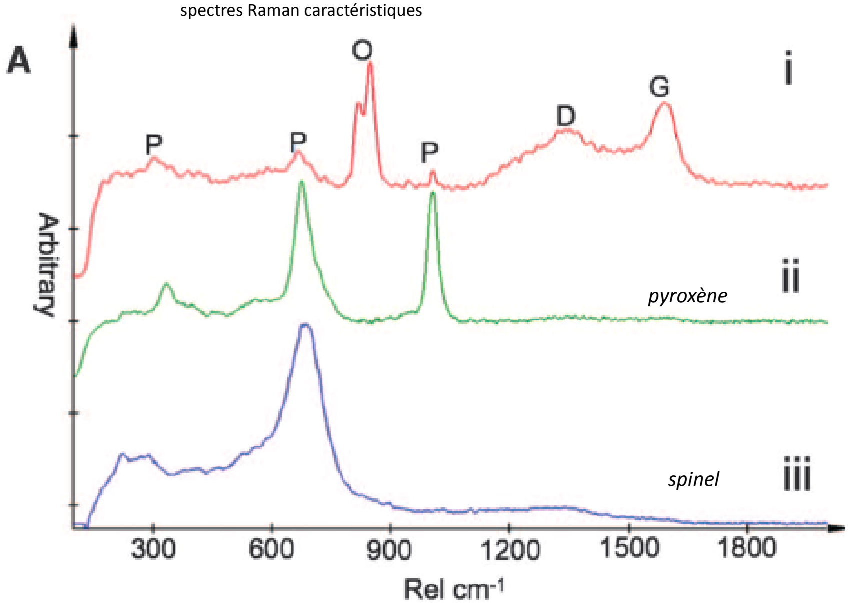
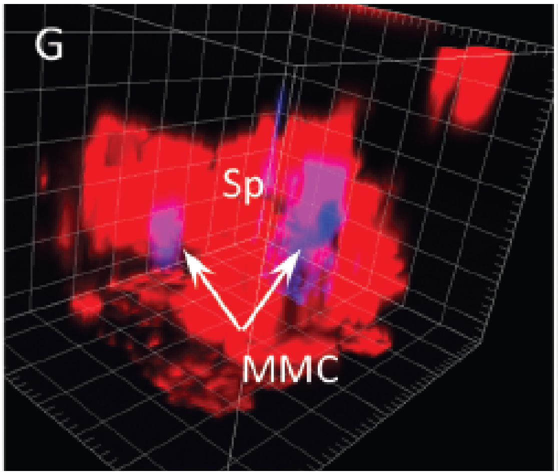
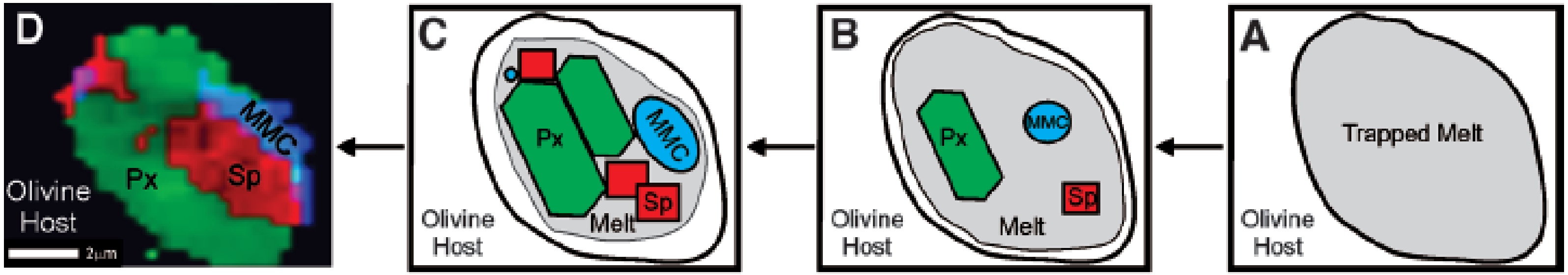
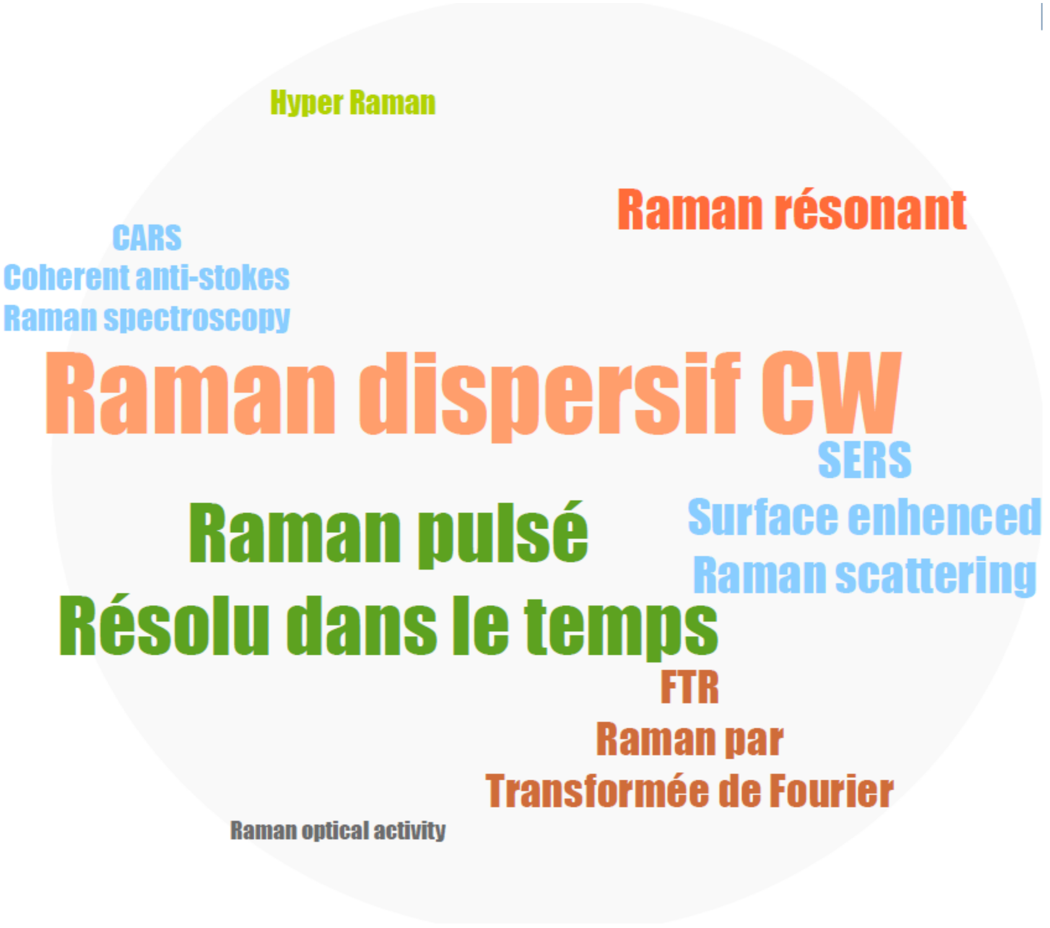


image Raman d'une inclusion de matière carbonée dans du spinel (grille = 2µm)

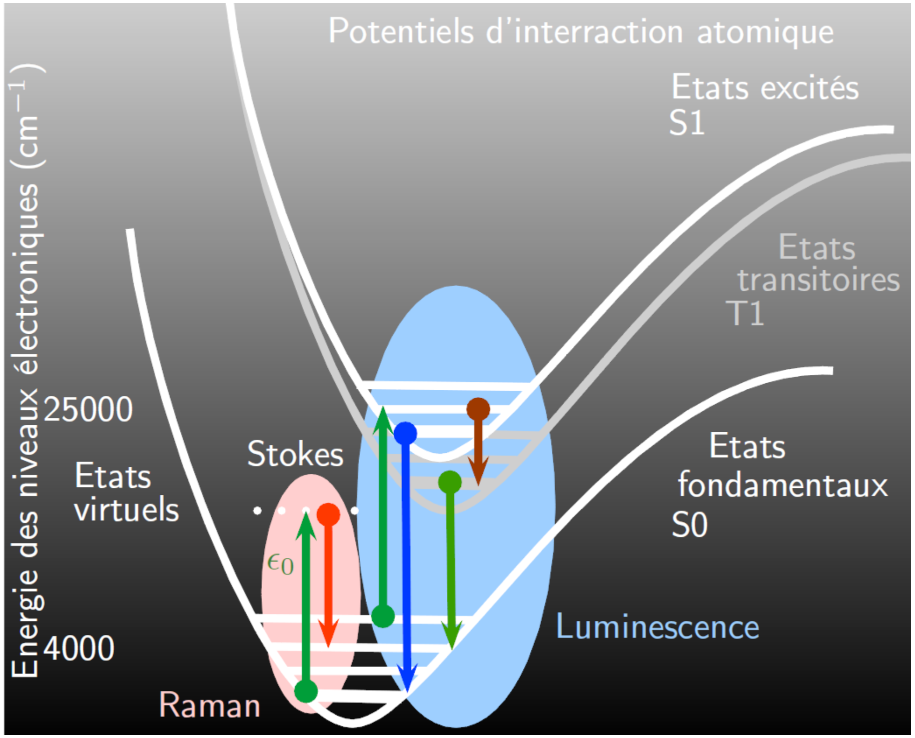


→ scénario proposé: car encagée dans minéraux ignés, matière organique probablement formée lors de la cristallisation du magma → donc d'origine abiotique



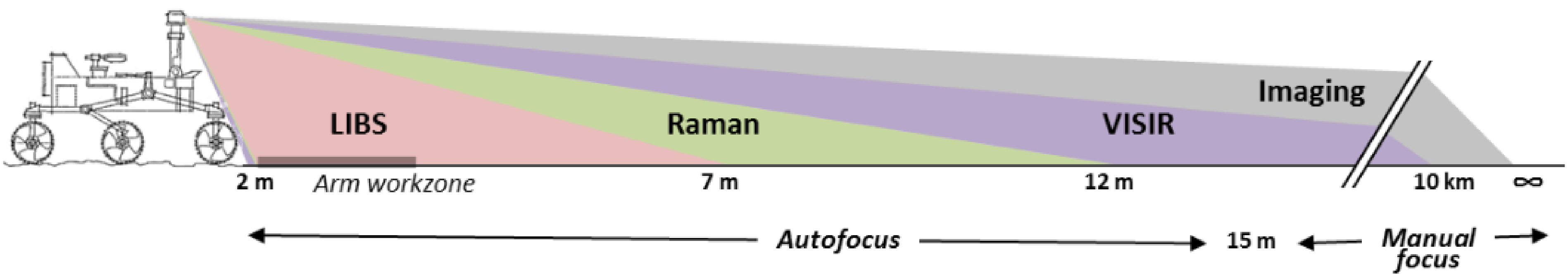

Hyper Raman
Raman résonant
CARS
Coherent anti-stokes
Raman spectroscopy
Raman dispersif CW
SERS
Surface enhenced
Raman scattering
Raman pulsé
Résolu dans le temps
FTR
Raman par
Transformée de Fourier
Raman optical activity

Raman vs luminescence



	Luminescence	Raman
Intensité I/I0	$10^{-2} - 10^{-4}$	$10^{-7} - 10^{-14}$
Temps caractéristique	~ 1 µs (inorganiques) ~ qq ns (organiques)	< 1ps !

Distances d'opération de SuperCam



SuperCam proposal for Mars 2020.

Objectifs scientifiques de SuperCam

1) Identification des roches.

2) Stratigraphie sédimentaire et caractérisation des faciès hydrothermaux.

3) Détection et identification d'organiques et de bio-marqueurs.

4) Volatiles (H et halogènes).

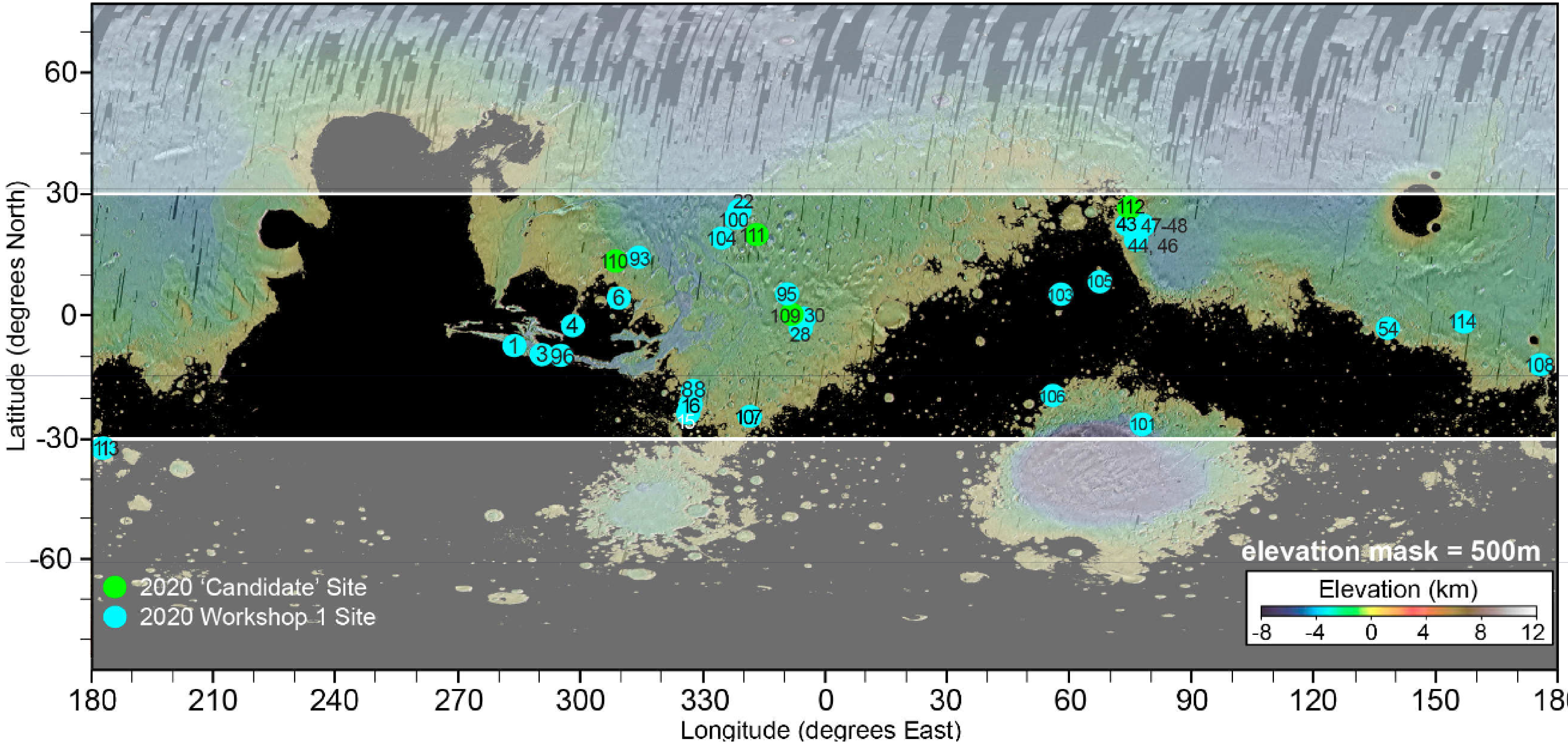
5) Morphologie et texture.

6) Vernis et revêtements.

7) Caractérisation du régolite.

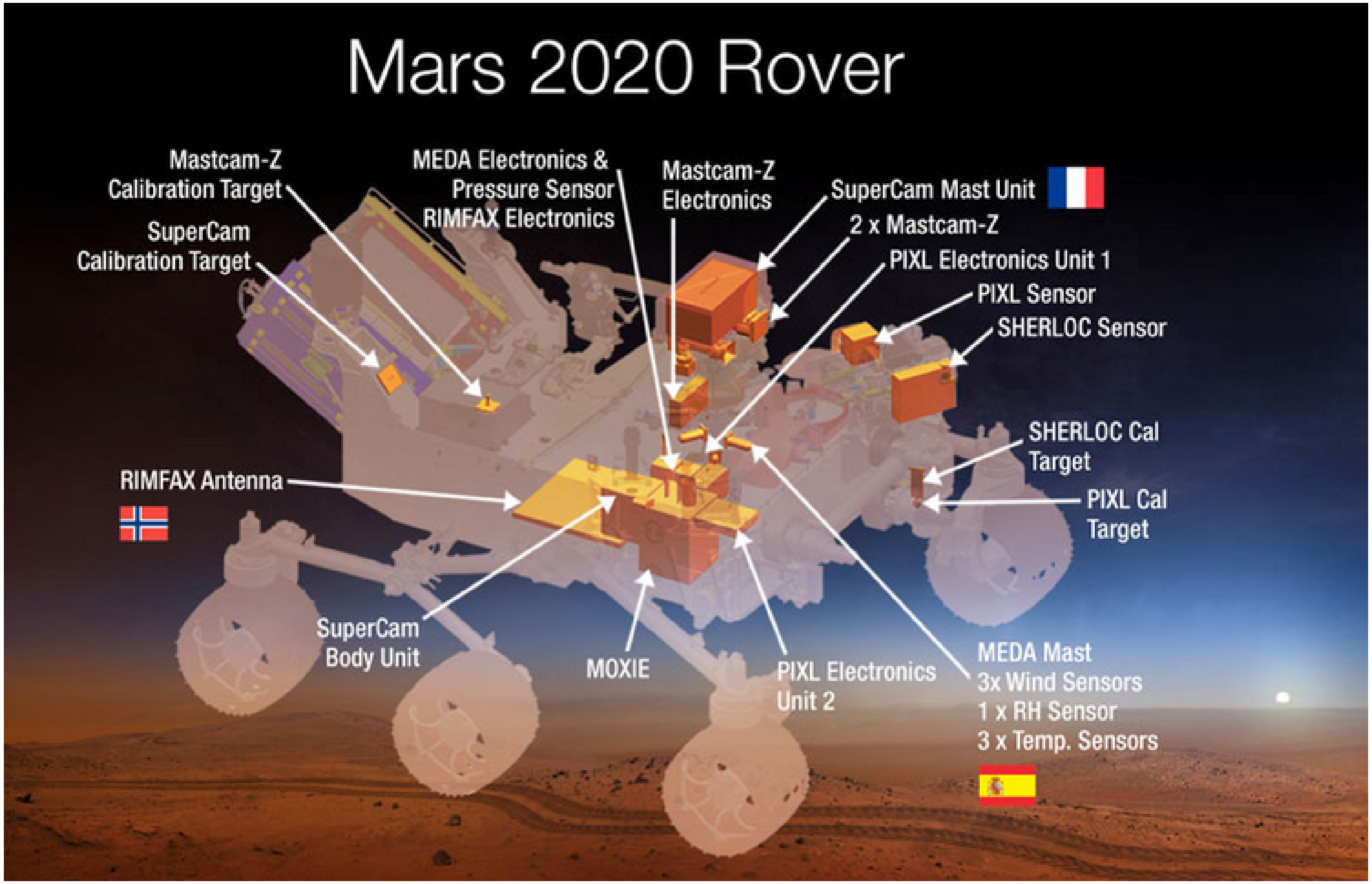
8) Caractérisation de l'atmosphère.

Sites pour la mission



Grant & Golombeck, Mars 2020 landing site selection workshop, May 2014

Instruments

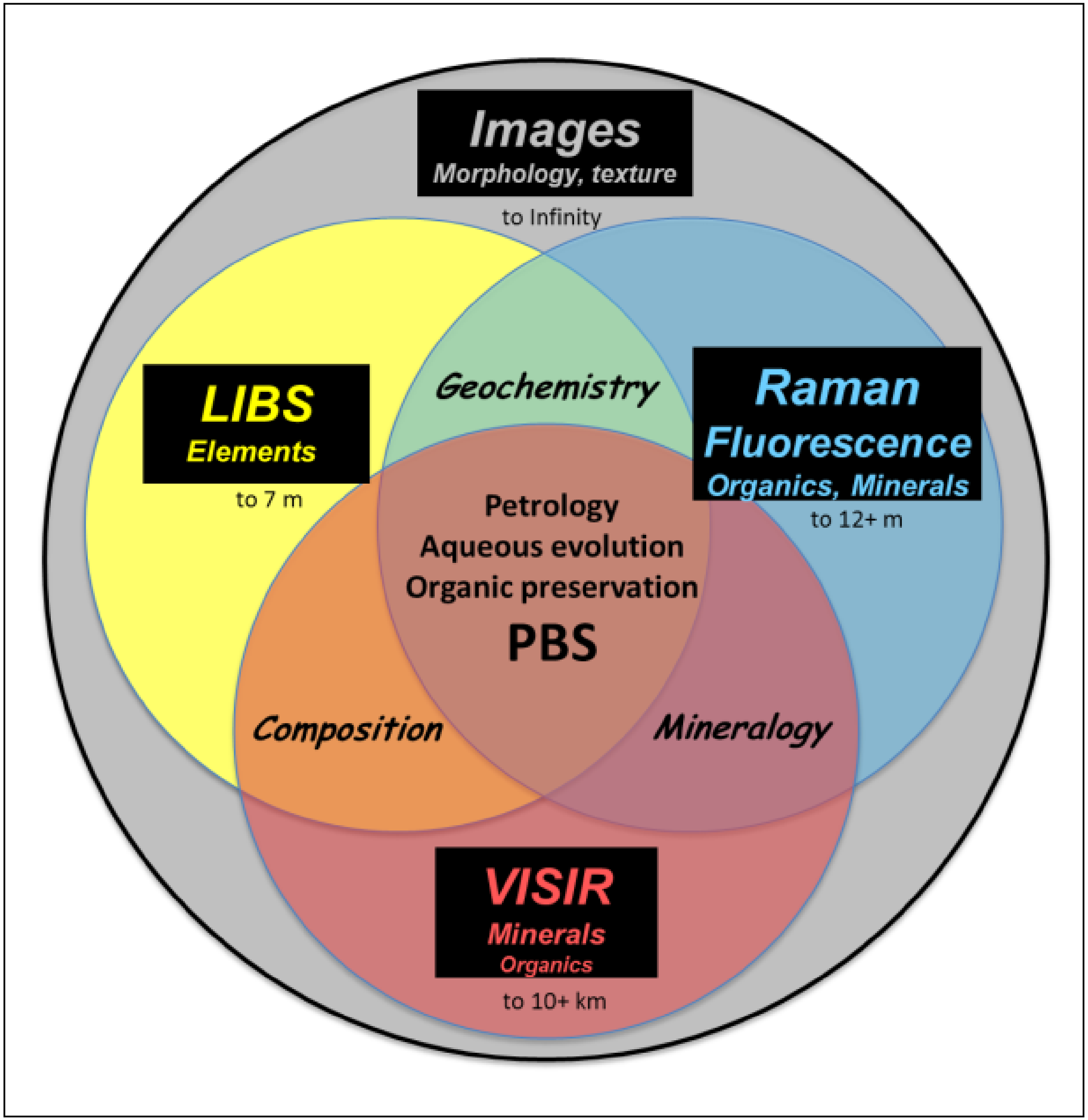


Strengths

SuperCam provides rapid, synergistic, **fine-scale** *mineralogy*, *chemistry*, and *color imaging* after removing obscuring surface dust.

Using color imaging for context, SuperCam combines *co-aligned* Raman-fluorescence, visible/infrared reflectance, and laser-induced breakdown spectroscopy covering broad areas at **remote distances**.

Synergy



Images
Morphology, texture
to Infinity
LIBS
Elements
to 7 m
Geochemistry
Raman
Fluorescence
Organics, Minerals
to 12+ m
Petrology
Aqueous evolution
Organic preservation
PBS
Composition
Mineralogy
VISIR
Minerals
Organics
to 10+ km