

CaLIBSow

Chemical Analysis with LIBS for Ocean Worlds

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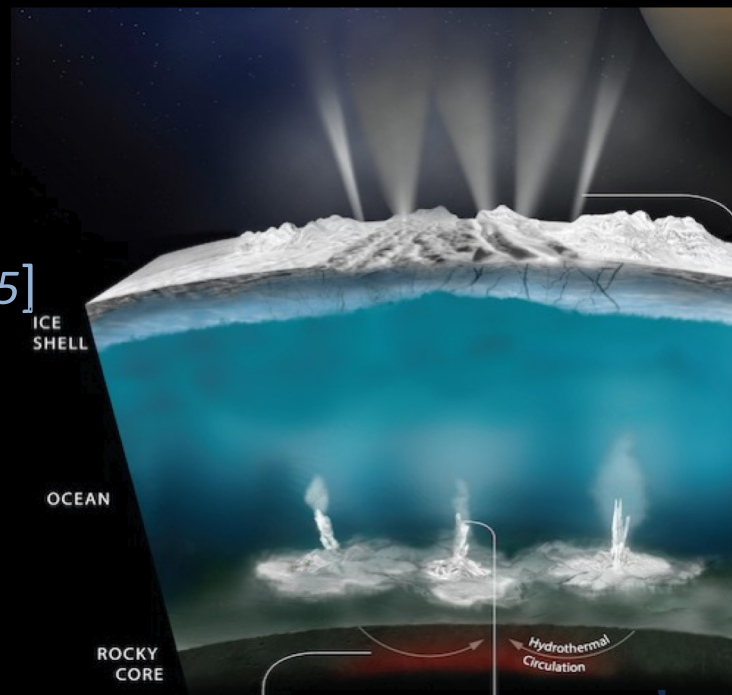
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Ocean Worlds

Europa, Enceladus and Titan **major targets** for the search of habitability and extent life [*see N. André talk*]

- Liquid subsurface ocean [*less et al. 2014, Khurana et al. 1998*]
- Hydrothermal activity [*Hsu et al. 2015*]
- Water-rock interactions
- Organic species
- Salty water, enriched in Na, Cl, CO₃ [*Glein et al. 2015*].

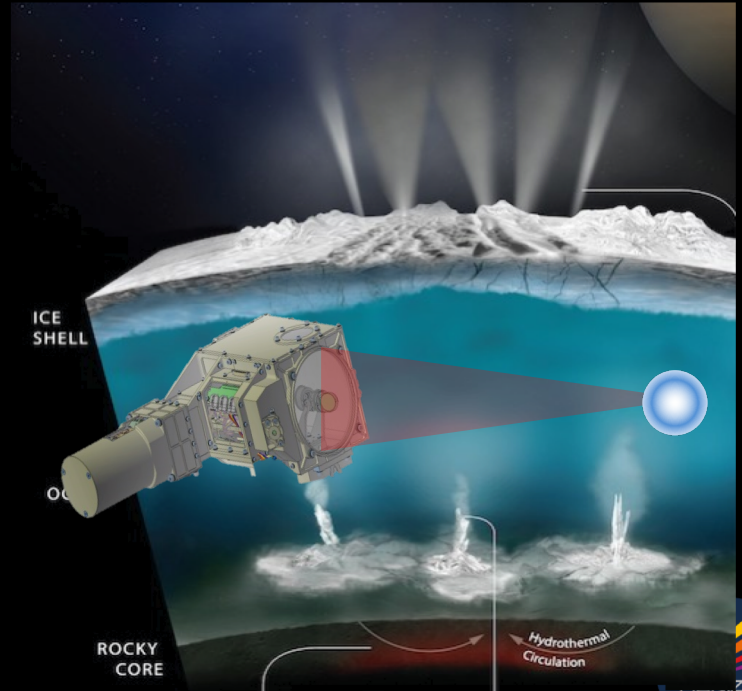


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Chemical Analysis with LIBS for Ocean Worlds

- Chemical composition of the ocean [see *J. Antonio Rodriguez Manfredi talk*]
- Quantification of major elements and alkali
- Detection of CHNOPS

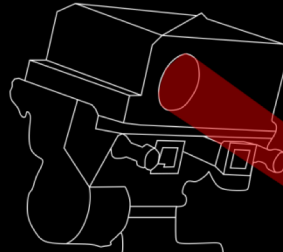
Based on Laser-Induced Breakdown Spectroscopy Experiment with one spectrometer ranging from UV to VNIR



The Laser-Induced Breakdown Spectroscopy (LIBS)

Analytical technique to measure abundance of chemical elements

- Rapid analysis
- No sample preparation
- In-situ and remote capabilities
- Ideal for harsh environments [*Fichet et al. 2019*] and fragile targets [*Serifaki et al. 2009*]

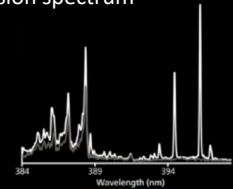


Focused Pulsed Laser

More than 10 GW/cm² released on target

Laser-Induced Plasma

LIBS emission spectrum

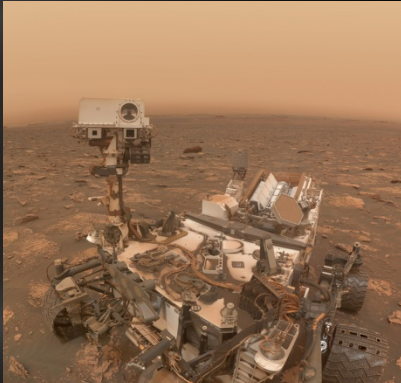


Analyzed by spectrometers

Sample (solid, gas or liquid)

LIBS for Planetary Exploration

MARS



- ChemCam instrument onboard MSL/Curiosity [Maurice et al. 2012]. More than 700.000 spectra acquired since 2012
- Mars2020/SuperCam suite launched next year [Wiens et al. 2017]

MOON



- LunaLIBS, proposed instrument [Ollila et al. 2019] to fly on the Moon with commercial partners for surface regolith analysis

VENUS

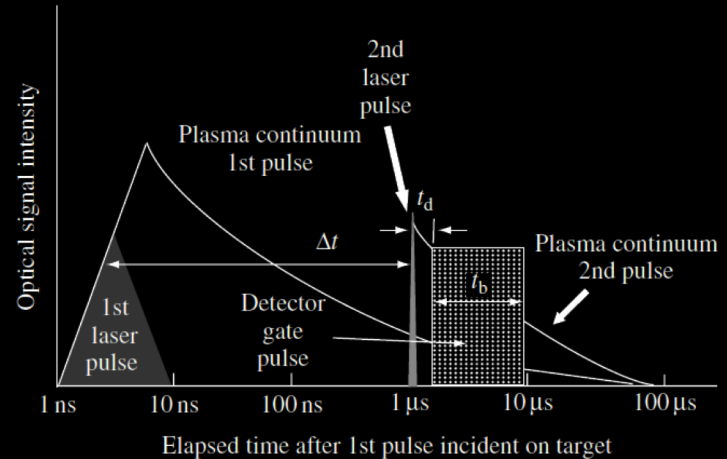


- Feasibility demonstrated for Venus surface [Clegg et al. 2012]
- Proposed LIBS instrument for VICI mission to Venus [New Frontier 2017 call, Glaze et al. 2017]

Double pulse LIBS underwater

Double-Pulse LIBS

- Plasma strongly confined due to surrounding water and cools/decays too fast
- First pulse inducing the breakdown of the water and used to create a bubble
- Second pulse will expand inside this vapor cavity
- More energy available for plasma excitation thanks to the 2nd pulse, leading to an enhanced signal [De Giacomo et al. 2005]

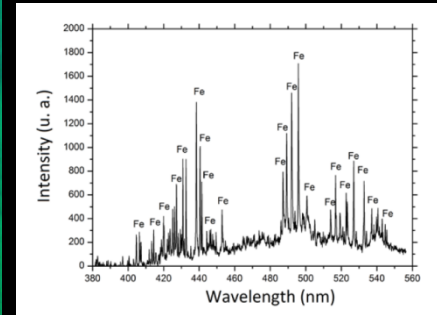


The temporal history of a LIBS plasma when two laser pulses are used. Modified from *Cremers and Radziemski, 2006*

Double pulse LIBS underwater

Applications in Deep Sea Ocean on Earth

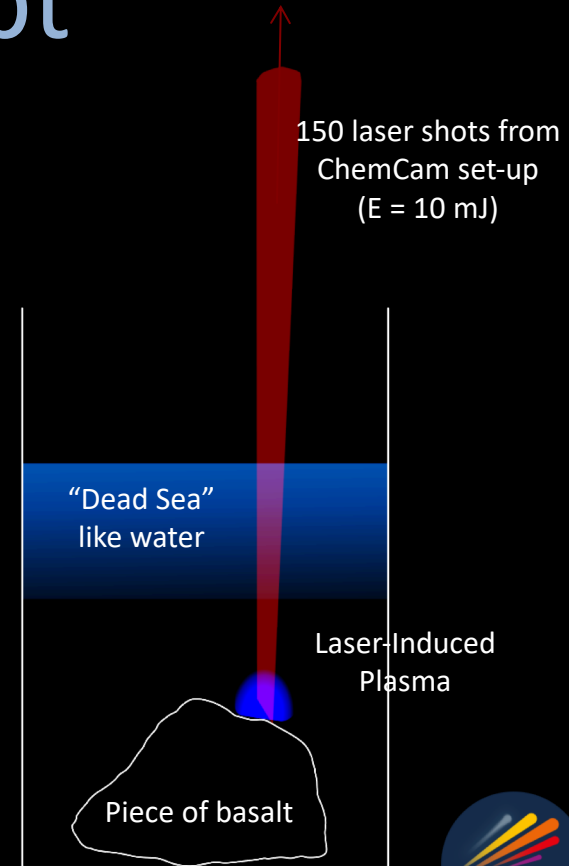
- Feasibility proved with submerged metallic samples [*De Giacomo et al. 2004*]
- Used for archeological underwater shipwrecks [*Fortes et al. 2016*]
- Application in oceanography for bulk water analysis in mid-ridge ocean hydrothermal vents.



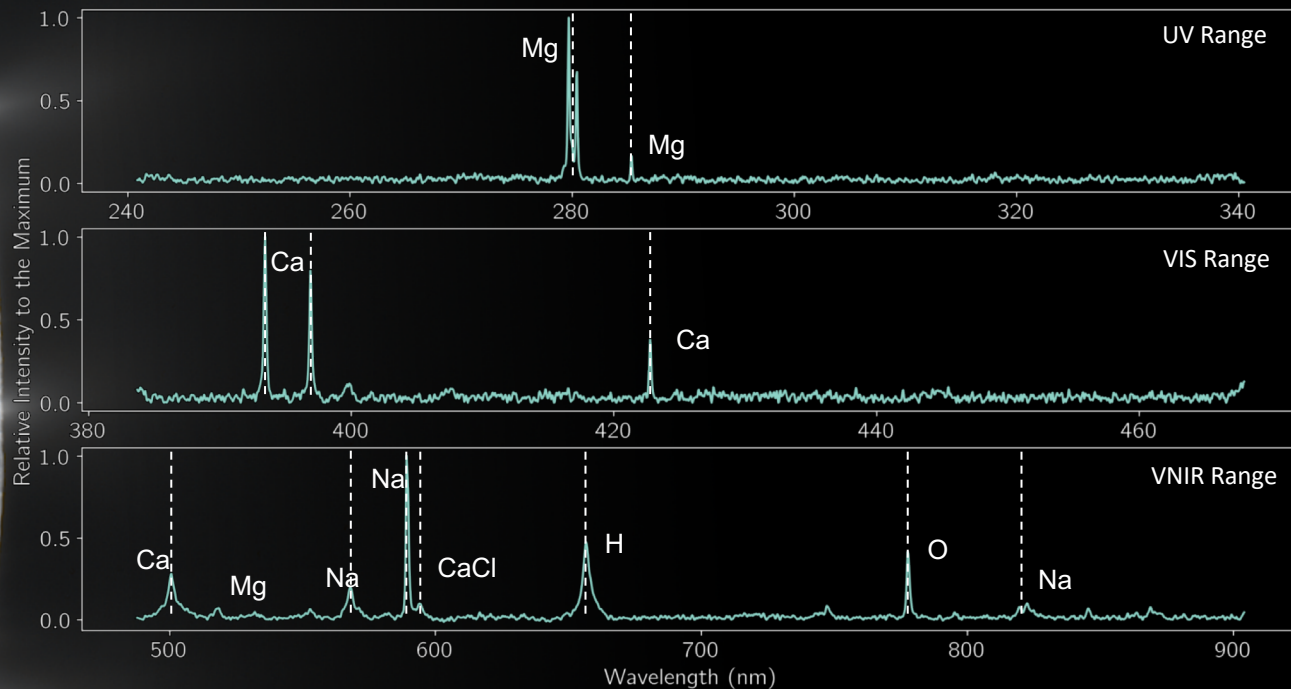
LIBS spectrum of an iron cannon recorded underwater From Fortes et al. 2016, LIBS in cultural heritage: exploration and identification of objects at underwater archaeological sites

Proof of concept

- Experiments conducted at IRAP, Toulouse with the ChemCam instrument replica
- Piece of basalt immersed in a simulated Dead Sea water:
 - 125 g/L of MgCl_2
 - 75 g/L of NaCl
 - 37.5 g/L of CaCl_2
- 150 laser shots at 10 mJ per shot
- Start simple with a single pulse laser



Proof of concept



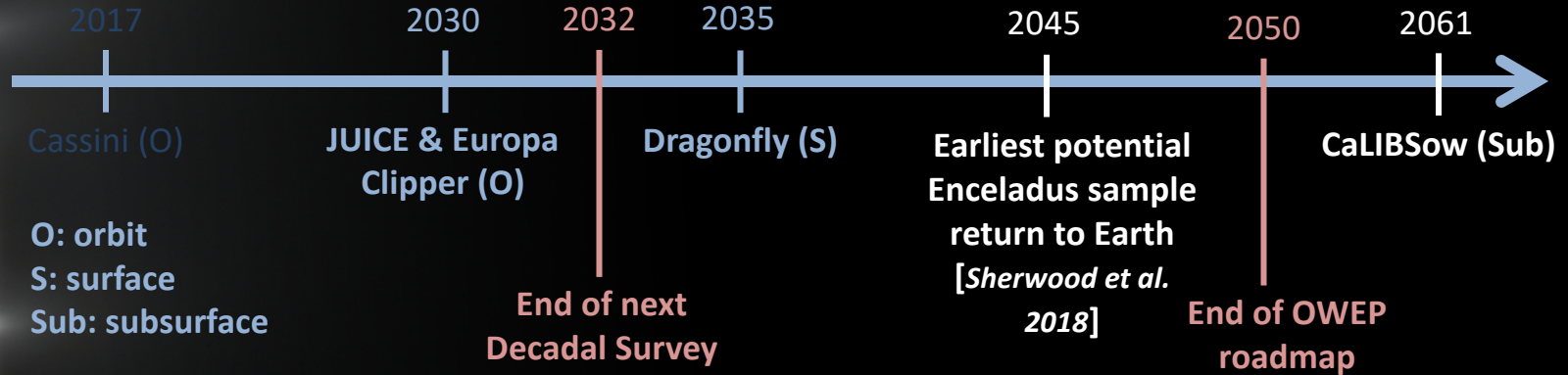
- All the elements in the solution are visible in the spectrum
- No peak emissions from the basalt due to confinement of the sample ablated matter

150 shots averaged spectrum for the three ChemCam spectrometers for an ablation point underwater focused on the basalt. The main elements line emissions detected are highlighted

Instrument Future

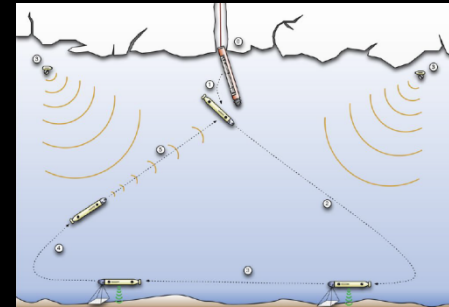
- Spreading the idea
- Increase the laser energy
- Try with double-pulse
- Try with micro-LIBS
- Be ready for being part of a 2061 mission

Future missions



Ambition mission concepts already exist to go through the ice shell:

- Ice melting with heated probe [Swenson et al. 2015]
- In-situ submarine exploration probe [Hilderbrandt et al. 2013]



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