

Remote optical sensing of electronic-free sensors
(motion, strain, pressure,...) for real-time high-precision
monitoring of difficult environments



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Mathieu Feuilloy³, Guy Plantier³

7th of November 2025 - Transform² 1st Forum

Summary

- Good reasons to be there
- Starting with a strong heritage
- Develop further and cross-fertilize
- Expand the scope with more sensors
- and more locations !

MAAGM origin

LOKI from ESEO

6 new use-cases...

...and more dimensions to explore

...up to the Moon!

Why MAAGM ?



Metrology



High-grade



Ångstrom



Optic



Solutions

River



Discoveries



Geosciences



Metrology



High-grade



Ångstrom



Optic



Solutions



Magnifying discoveries

River



Geosciences



Discoveries

MAAGM's associates

➤ **Paul-Eric Pottie, PhD**



SYRTE Observatoire de Paris PSL
Systèmes de Référence Temps-Espace

➤ **Damien Ponceau**



iXblue



➤ **Hervé Lefevre, PhD**



EOS
European Optical Society

iXblue
Société Française d'Optique

➤ **Hervé Arditty, PhD**



iXblue

➤ **Arnaud Gaillot**



iXblue

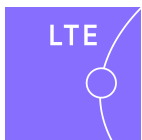
➤ **Frédéric Guattari**



iXblue

Former

Current



iXcore



MAAGM 's team

Executive & Scientific CEO&CSO

> Frédéric Guattari



R&D engineer
Anthony Bercy, PhD

Technologic CTO

> Olivier Robert, PhD



PhD @ IPGP
Alban Leleux

Operation COO

> Vincent Leray



Financial CFO

> Hugo Hajaali



PhD @ ESEO
Ilyes Daddy

Technological innovations

Supplier of leading
scientific instrumentation



Optical
readout
expertise

Innovative
Geophysics
Sensors

MAAGM

R&D , indust°, and production



Partnered research
Services and solutions for dedicated sensing

Sensor requirements for innovative science

=> Dual partnership strategy

Academic partnerships

- 2 CIFRE PhD
- 4 subcontractors
- 4 research partners
- 4 technological transfer
- 1 joint laboratory
- 4 MoUs / Coop Contracts



And strong supports :



Commercial activities

> NJORD



Station orientation tools

- Optical gyrocompass
- Tripod+laser alignment kit
- True North finder



> LOKI



Remote geoscientific optical sensors

- Optical interrogator
- Special cables
- Electronic-free sensors
 - Geophone
 - Seismometer
 - Strainmeter 1C
 - Strainmeter 6C
 - Inclinator
 - Pressiometer
 - Hydrophone
 - Rotational seismometer
- ...more to come!

Technology transfer



Developer

Co-developer NG



Specifier



User



Manufacturer
Supplier

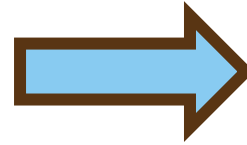
Co-developer NG

Optical remote interrogator

Inteferometric digitizer

Local Electronic-less Sensor
Internal Displacement:

- Motion
- Tilt
- Strain
- Pressure
- Rotation
- ...



High-precision Time-stamped
miniSEED geoscientific data



Down to 7 W
Up to 8 channels
>30km away!



Front panel



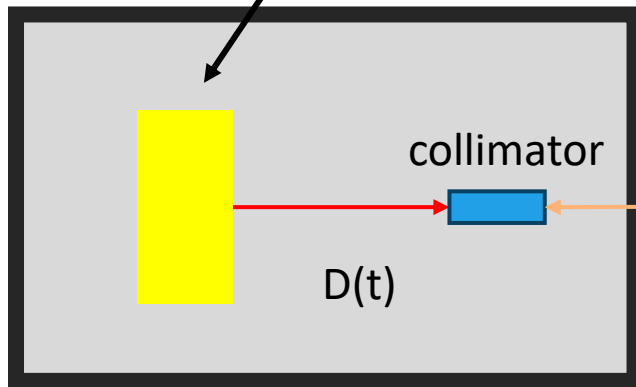
Rear panel

Optical remote interrogator

Local Electronic-less Sensor

- Motion
- Tilt
- Strain
- Pressure
- Rotation
- ...

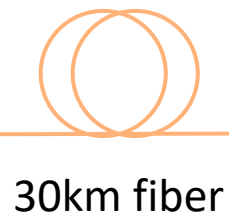
Internal Mirror Displacement



Electronic-less sensor

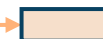


High-precision Time-stamped
miniSEED geoscientific data



30km fiber

coupler



Laser

Modulation

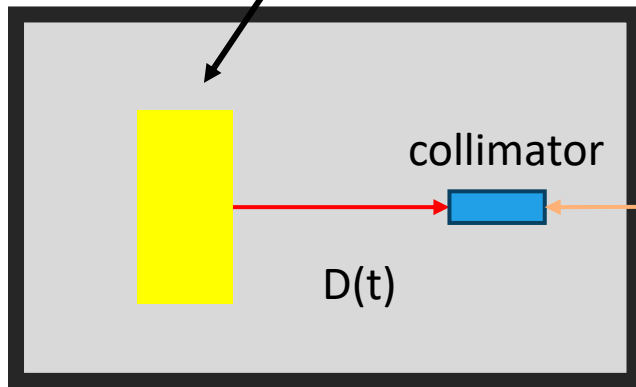
GNSS
disci-
plined
clock

Optical remote interrogator

Local Electronic-less Sensor

- Motion
- Tilt
- Strain
- Pressure
- Rotation
- ...

Internal Mirror Displacement



OBU



30km fiber

coupler

Detector

Synchronous
demodulation

GNSS
disci-
plined
clock

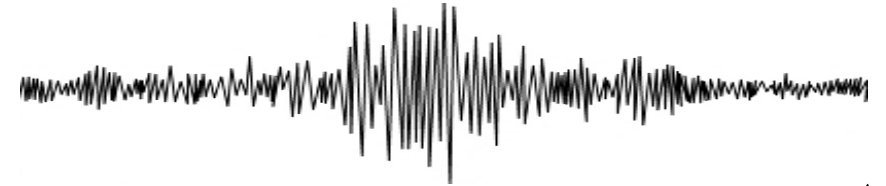
Laser

Modulation

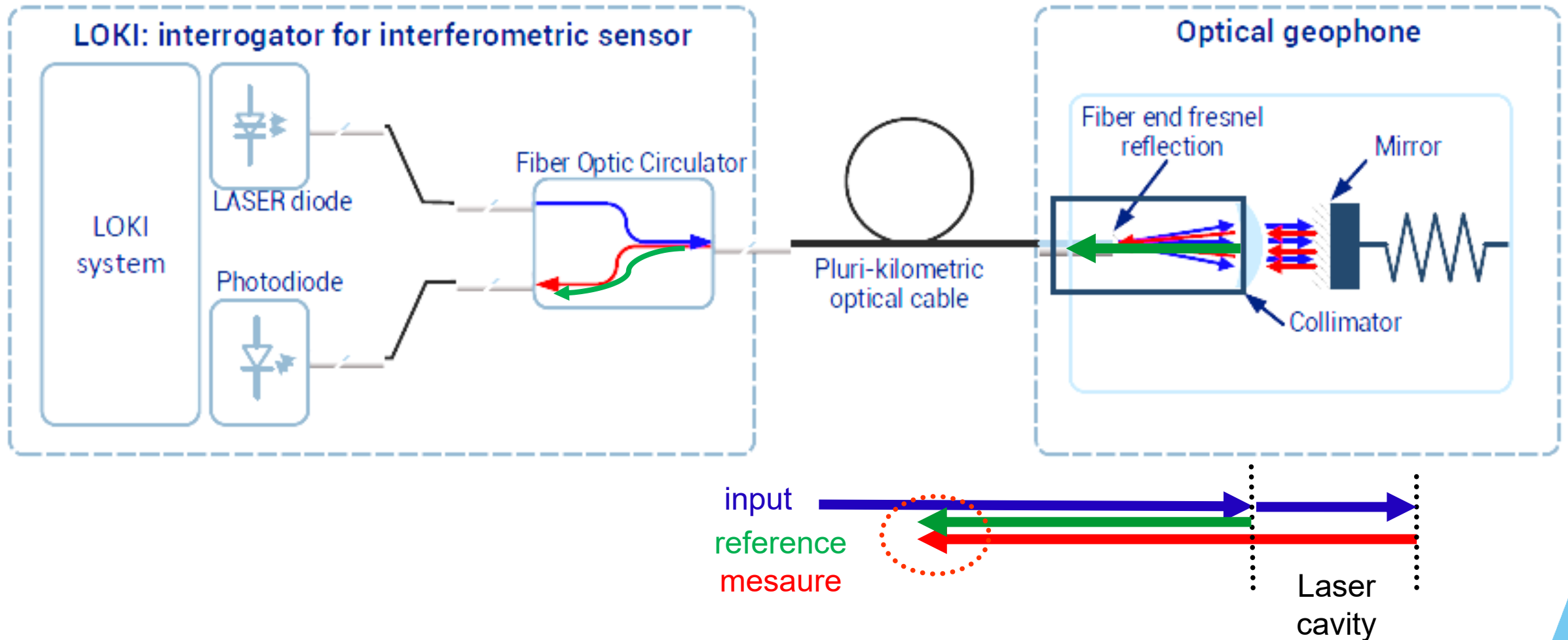
Phase estimation

Kalman Filter

High-precision Time-stamped
miniSEED geoscientific data

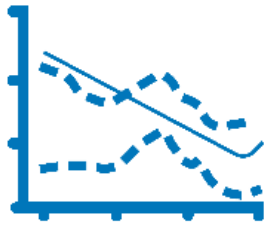


Optical remote interrogator

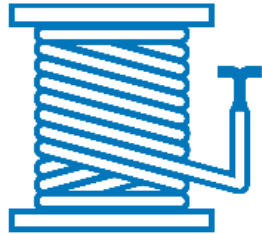


Optical remote interrogator

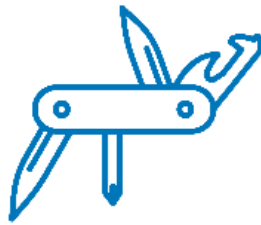
HighRes



50km



Versatile



SeedLink



Low power



GNSS Disciplined



Front panel



Rear panel



Fully passive



Omni-tilt



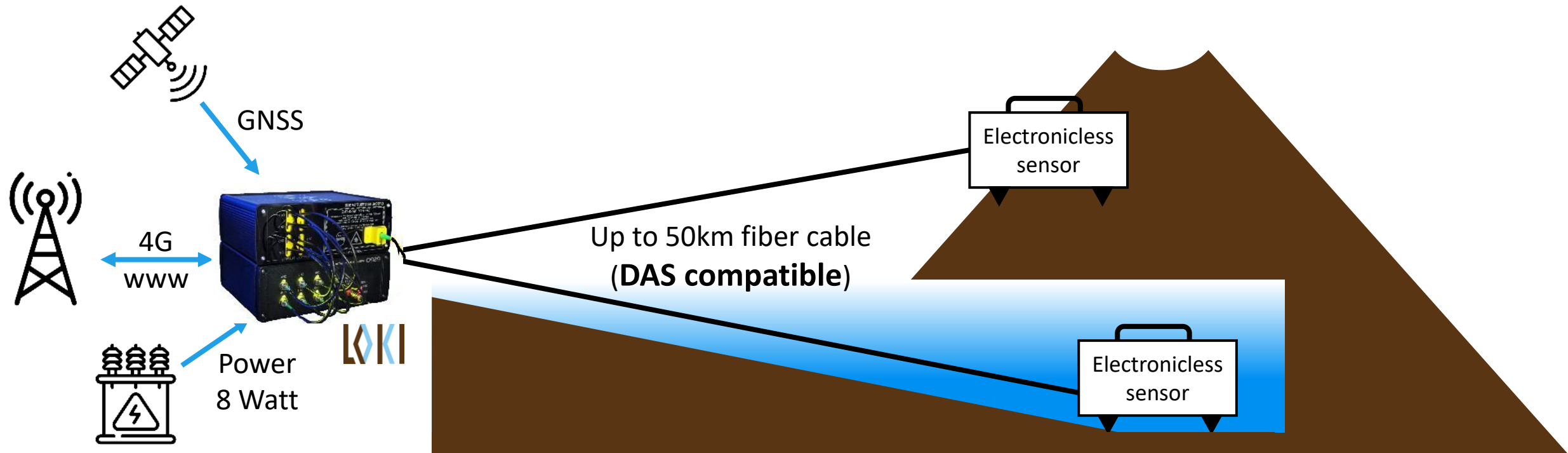
Expendable



Heat resistant



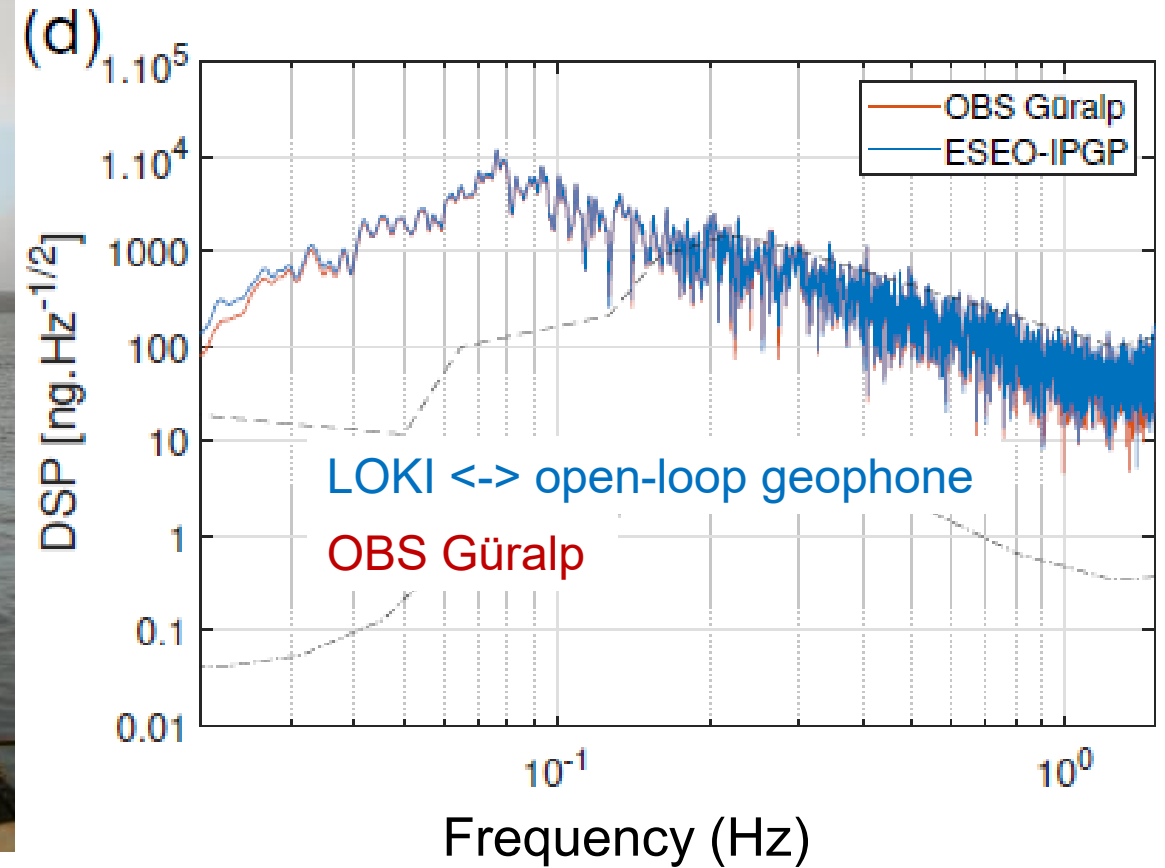
Optical remote interrogator



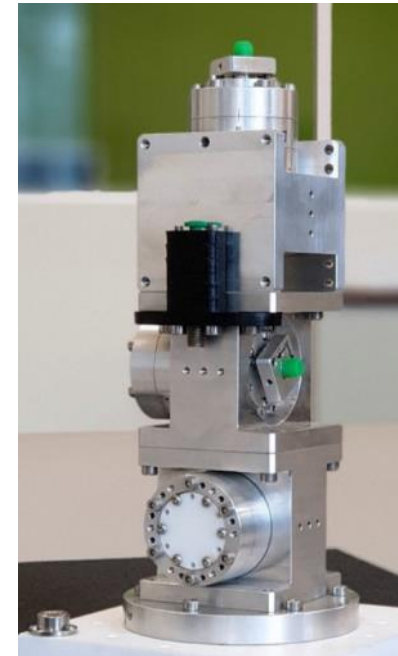
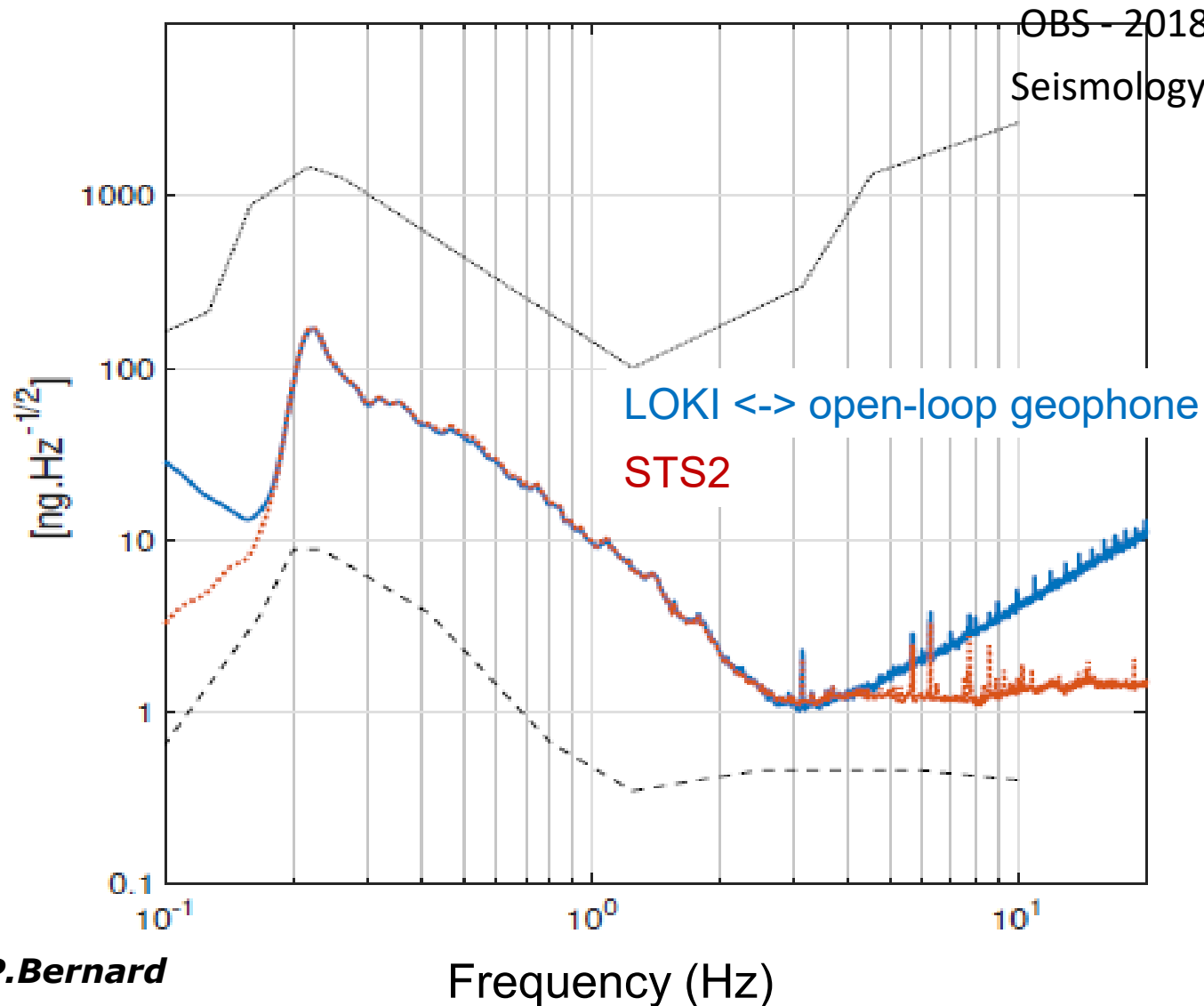
Strong heritage

OBS - 2018 - Open-loop Geophone – Brest (France)

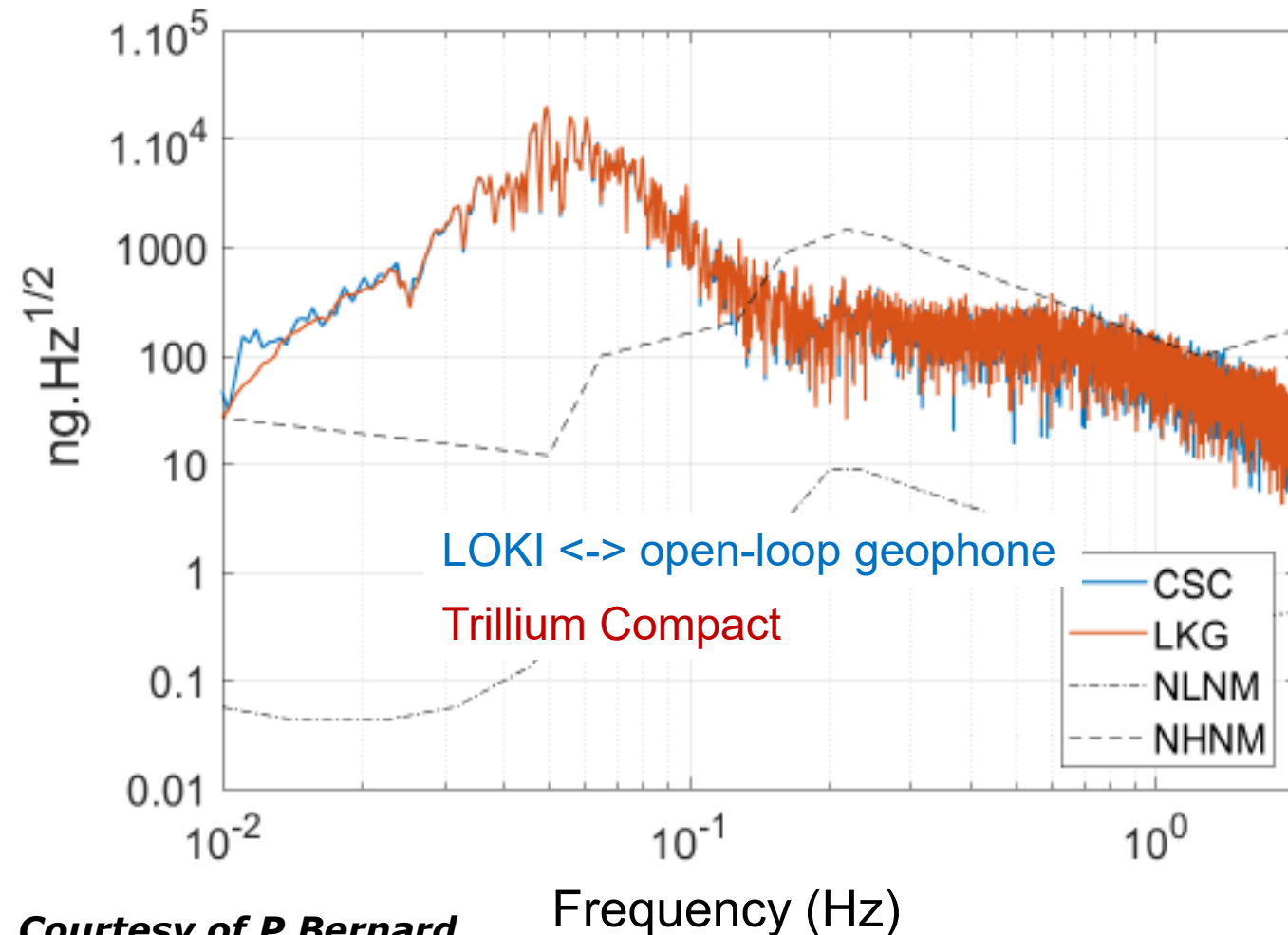
LOKI standalone on the buoy



Strong heritage



Strong heritage



Courtesy of P. Bernard

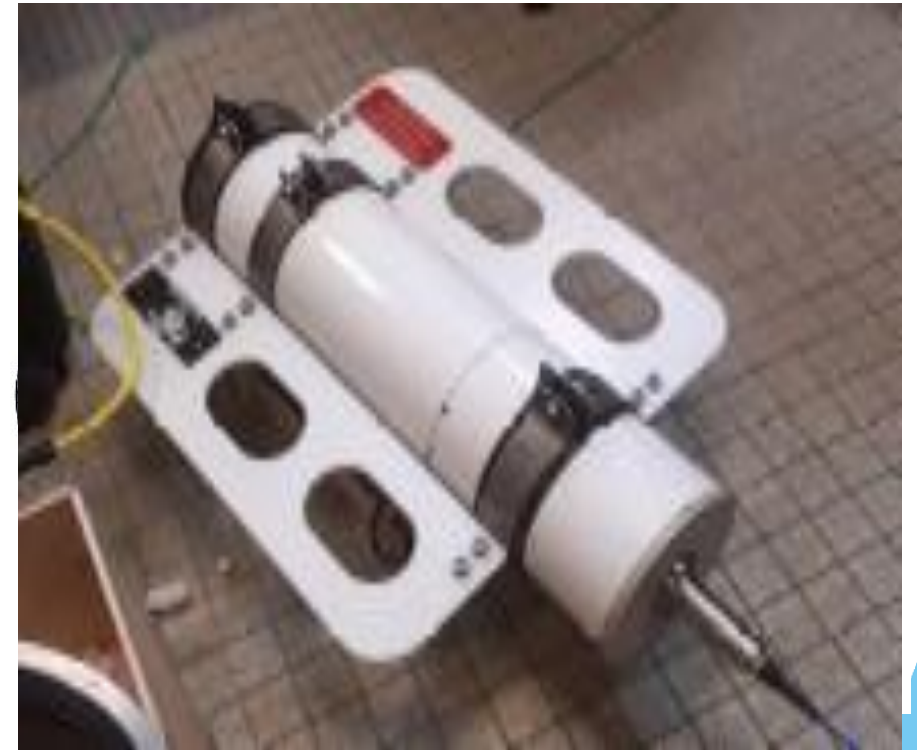
OBS - 2018 - Open-loop Geophone – Brest (France)
Seismology - 2019 Open-loop Geophone – LSBB (France)
Volcanology - 2020 Open-loop Geophone – La Souffrière



Strong heritage



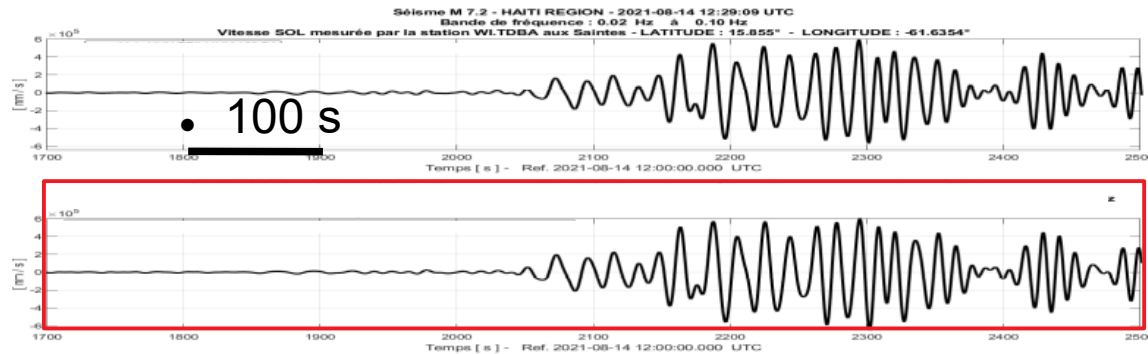
OBS - 2018 - Open-loop Geophone – Brest (France)
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Volcanology - 2020 Open-loop Geophone – La Souffrière
OBS – 2022 Open-loop Geophone – Les Saintes



- Haiti 2021 M7.2 - Velocity - N26°, filter 0.02-0.1 Hz

Trilium 120s
TDBA

Optical
TDBSM

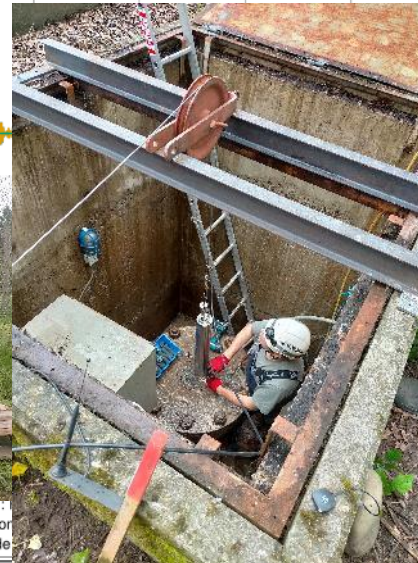
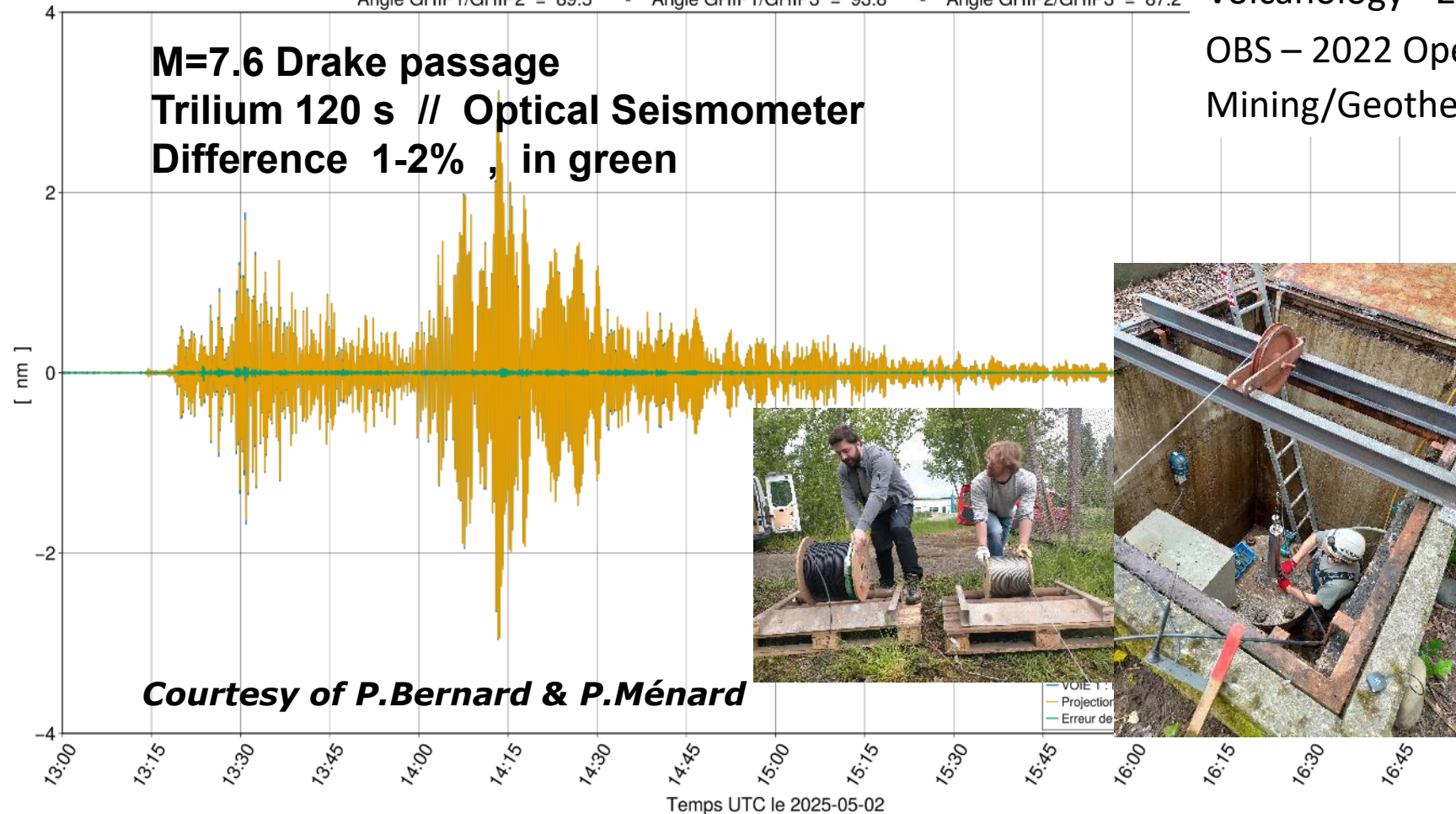


Strong heritage

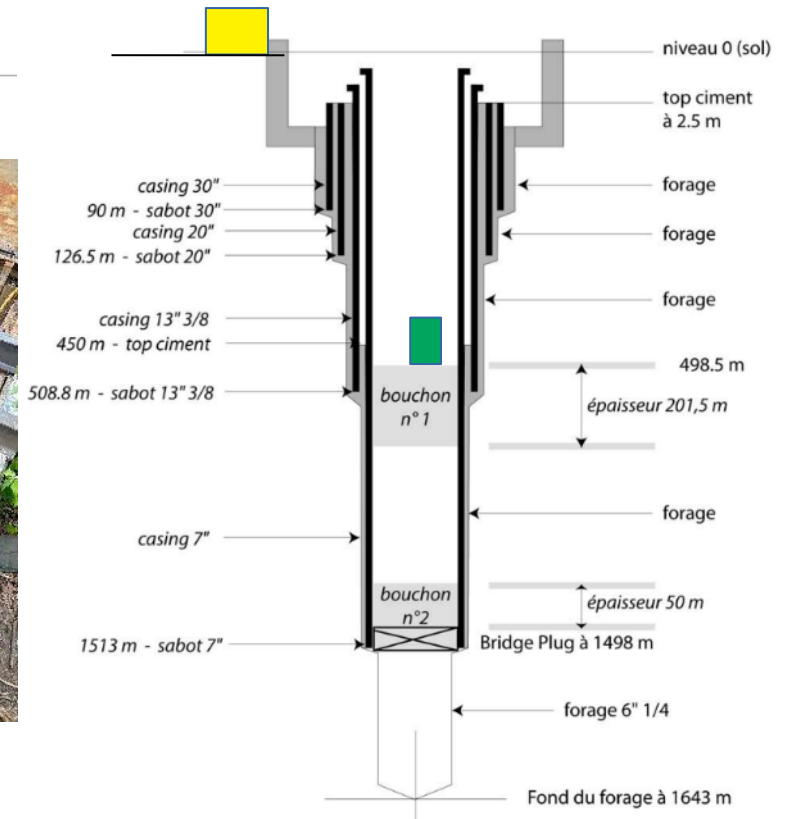
M 7.4 - DRAKE PASSAGE - 225 km SSE of Ushuaia, Argentina - 2025-05-02 12:58:27.5 UTC

Projection de la vitesse TRILLIUM 120QA traduite en déplacement de masse mobile sur la voie 1 du BOS en forage
Passe-haut : 0.04 Hz - Passe-bas : 0.09 Hz - Longitude GHIP1 : $\phi = 56.3^\circ$ - Latitude GHIP1 : $\pi/2 - \theta = 2.7^\circ$ - F
Angle GHIP1/GHIP2 = 89.5° - Angle GHIP1/GHIP3 = 93.8° - Angle GHIP2/GHIP3 = 87.2°

M=7.6 Drake passage
Trilium 120 s // Optical Seismometer
Difference 1-2% , in green



- OBS - 2018 - Open-loop Geophone – Brest (France)
- Seismology - 2019 Open-loop Geophone – LSBB (France)
- Volcanology - 2020 Open-loop Geophone – La Souffrière
- OBS – 2022 Open-loop Geophone – Les Saintes
- Mining/Geothermal – 2025 – Strasbourg (France)



Fit the need of borehole optic-only sensors for borehole

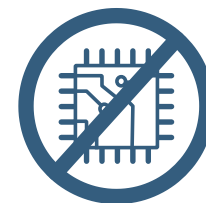


- Housing **10cm** diameter
- 3 components
- 60cm Height

Heat resistant

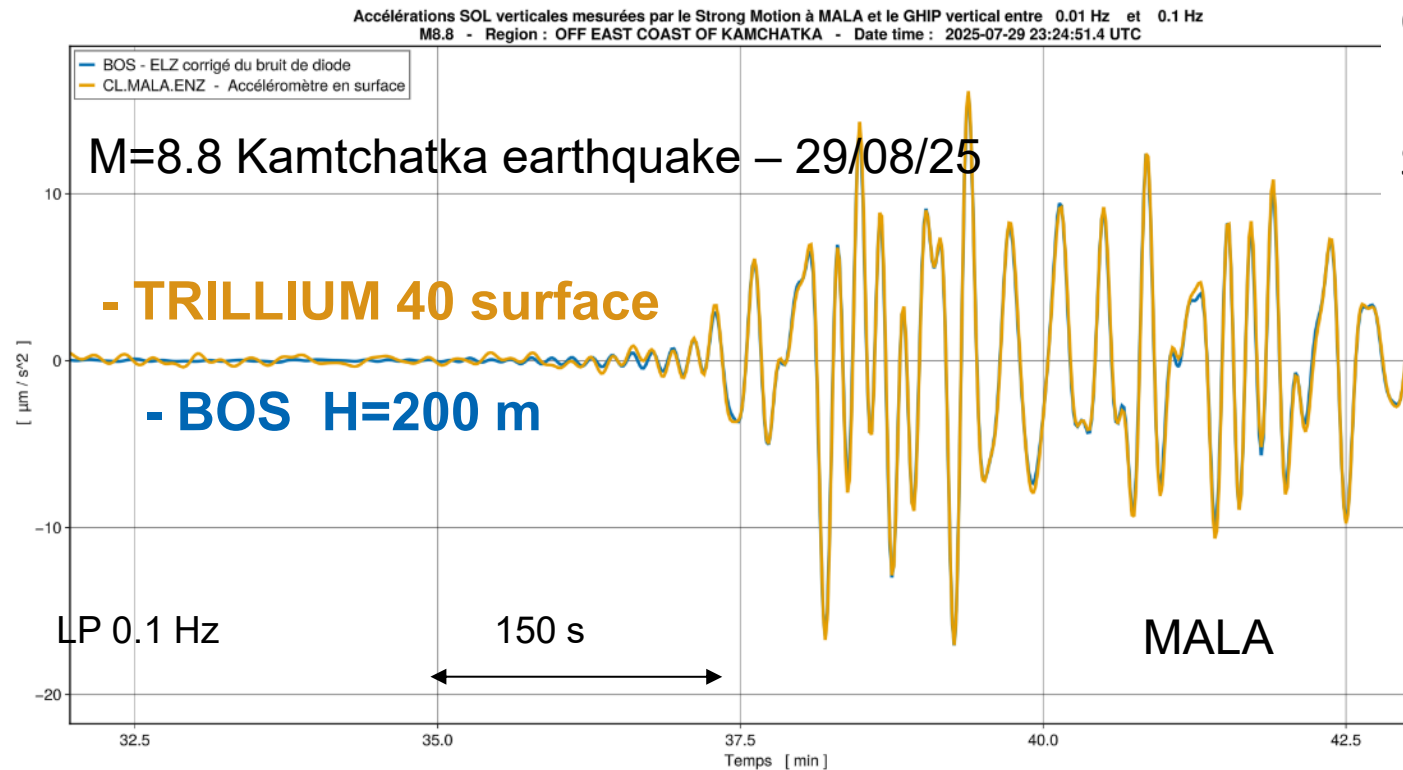


Fully passive



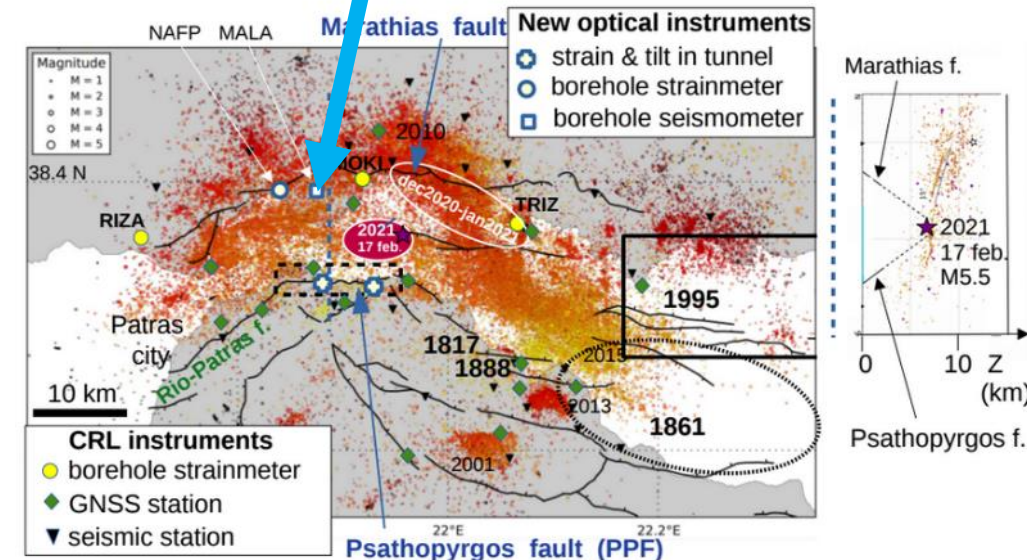
Strong heritage

Borehole optical seismometer (“BOS”) in the Corinth Rift Near Fault Observatory (NFO)



Courtesy of P.Bernard & P.Ménard

OBS - 2018 - Open-loop Geophone – Brest (France)
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Mining/Geothermal – 2025 – Strasbourg (France)
Seismology – 2025 – Corinth Rift (Greece)



Strong heritage

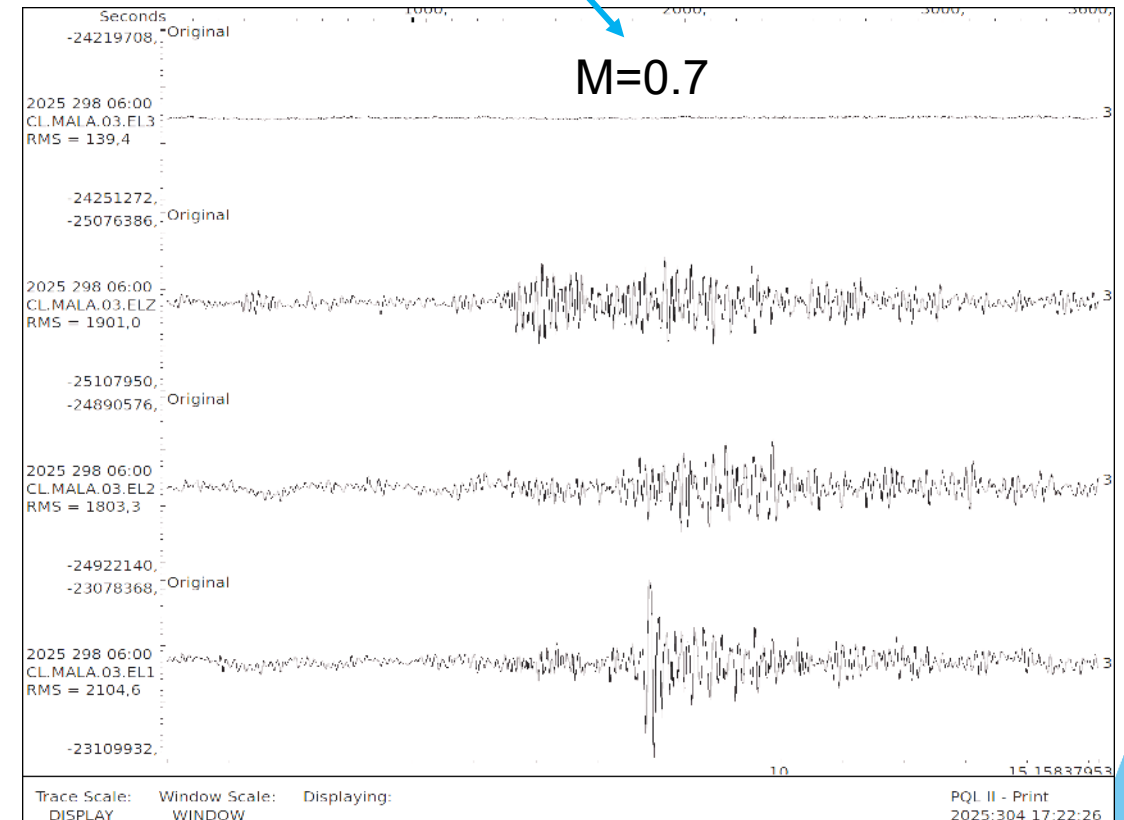
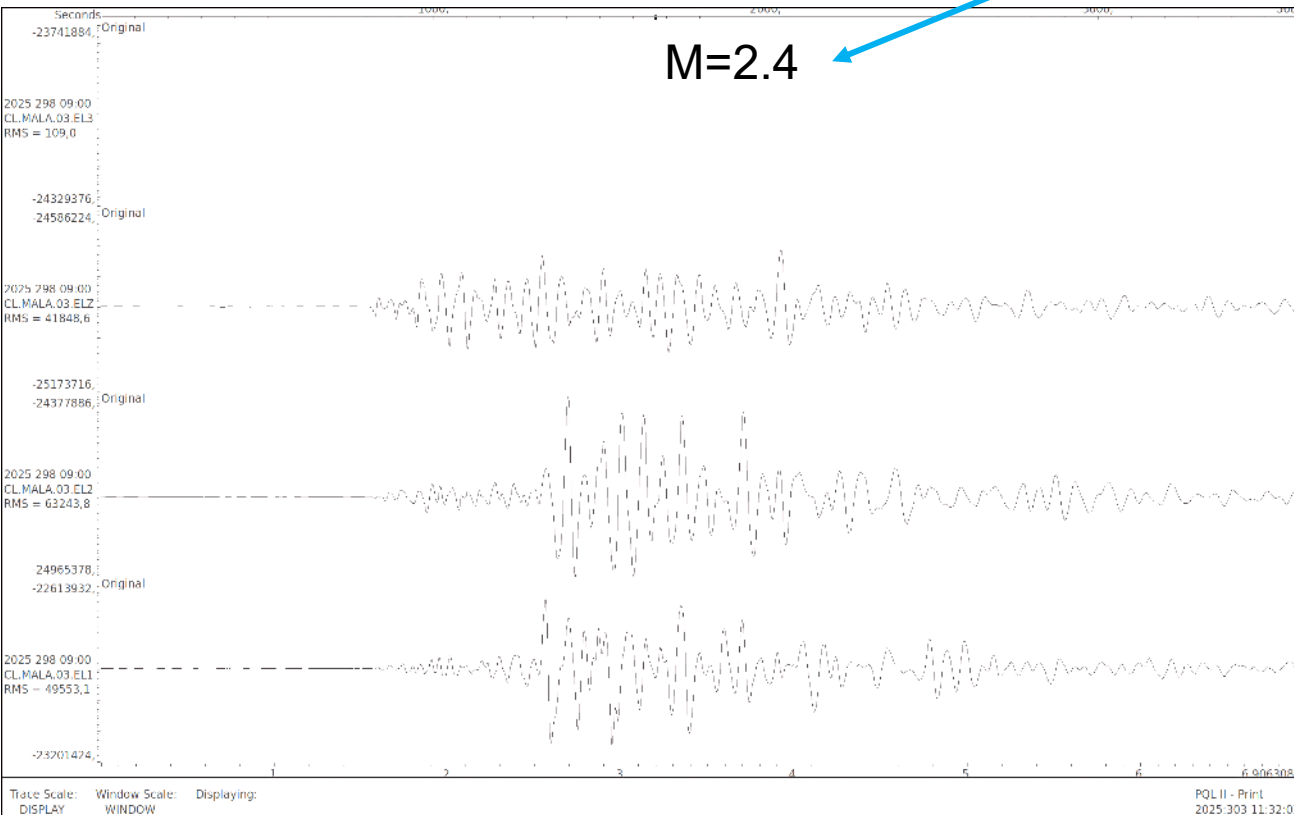
Borehole optical seismometer (“BOS”)
in the Corinth Rift Near Fault Observatory (NFO)



Optical geophone
Acts as
Broadband seismometer

M=2.4

M=0.7



Courtesy of P.Bernard & P.Ménard

Strong heritage

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C
Ocean Bottom System	• BREST 2018 • LES SAINTES (CARIBBEAN) 2022		
Volcanology	• SOUFRIERE 2019	• STROMBOLI 2021 • STROMBOLI 2023	
GeoThermal	• STRASBOURG 2025 Borehole 500m		
Seismology	• LSBB 2019		
Mining Monitoring		• SWEDEN 2023-2025	

Bernard et .al (2019) *Onland and offshore extrinsic Fabry-Pérot optical seismometer at the end of a long fiber*. SRL

Bernard and al. (2024). *High resolution seismometers and strainmeters at the termination of plurikilometric fibers: a new brand of fiber optic sensors for harsh environment*

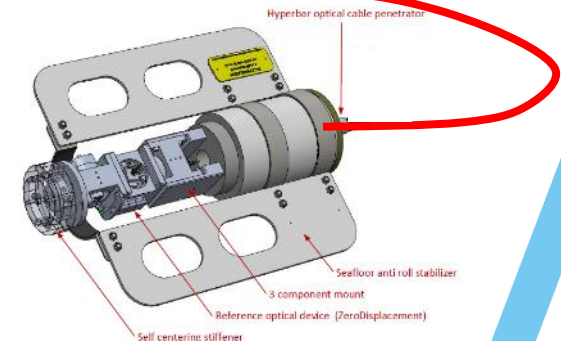
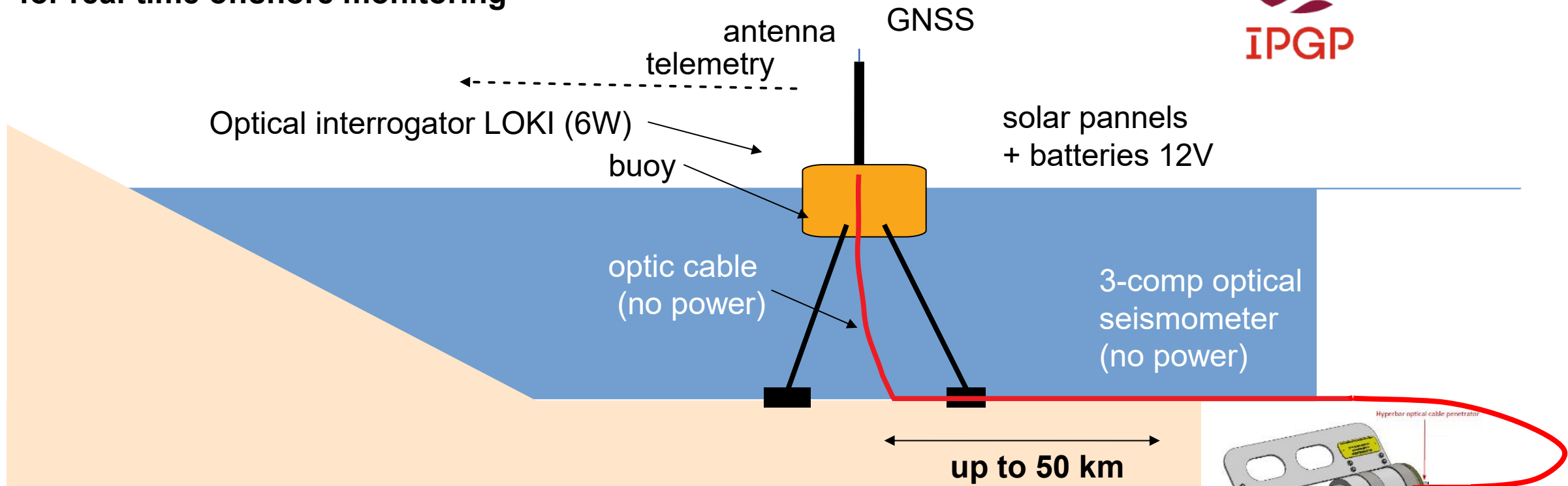
Develop new use-cases of LOKI

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C
Ocean Bottom System	• BREST 2018 • LES SAINTES (CARIBBEAN) 2022 • PATRAS 2026 offshore buoy		
Volcanology	• SOUFRIERE 2019	• STROMBOLI 2021 • STROMBOLI 2023	
GeoThermal	• STRASBOURG 2025 Borehole 500m		
Seismology	• LSBB 2019		
Mining Monitoring		• SWEDEN 2023-2025	

- Permanent real-time OBS with LOKI on a buoy (IPGP)

Permanent real-time OBS with LOKI on a buoy

**ocean bottom optical seismometer on a moored buoy
for real-time offshore monitoring**



Develop new use-cases of LOKI

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C
Ocean Bottom System	• BREST 2018 • LES SAINTES (CARIBBEAN) 2022 • PATRAS 2026 offshore buoy		
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Volcanology	• SOUFRIERE 2019	• STROMBOLI 2021 • STROMBOLI 2023	
GeoThermal	• STRASBOURG 2025 Borehole 500m		
Seismology	• LSBB 2019 • CORINTH RIFT 2026 borehole 200m	• CORINTH RIFT 2026 borehole 200m	
MiningMonitoring		• SWEDEN 2023-2025	

- Permanent real-time OBS with LOKI on a buoy (IPGP)
- Address the need for optic-only borehole sensors (IPGP)

Develop new use-cases of LOKI

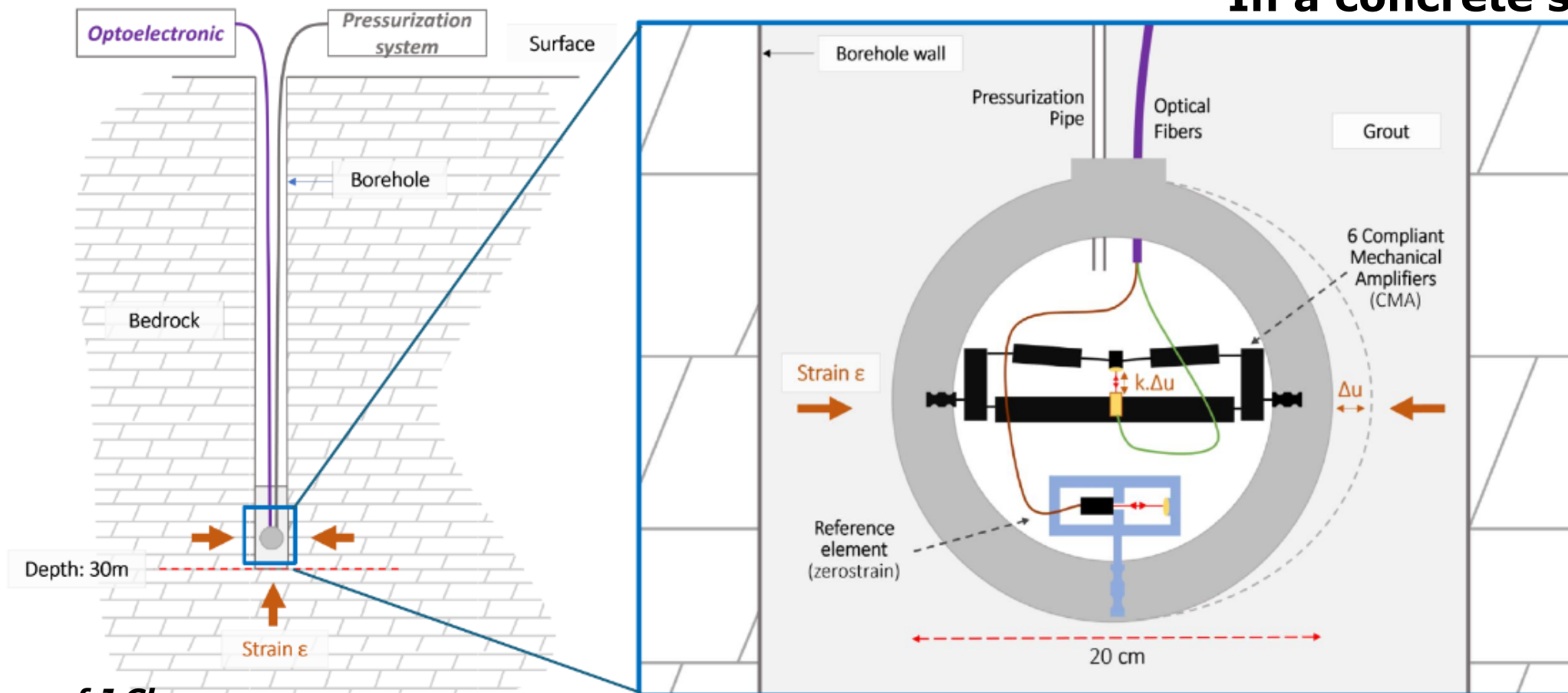
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Seismology	• LSBB 2019 • CORINTH RIFT 2026 borehole 200m	• CORINTH RIFT 2026 borehole 200m	
MiningMonitoring		• SWEDEN 2023-2025	

- Permanent real-time OBS with LOKI on a buoy (IPGP)
- Address the need for optic-only borehole sensors (IPGP)
- 6C borehole strainmeter with compact scale (Géosciences Montpellier)

6C borehole strainmeter with compact scale

Full tensor borehole strainmeter CNRS 13039-01

**Tetrahedral 6C
In a concrete sphere**



Courtesy of J.Chery

Develop new use-cases of LOKI

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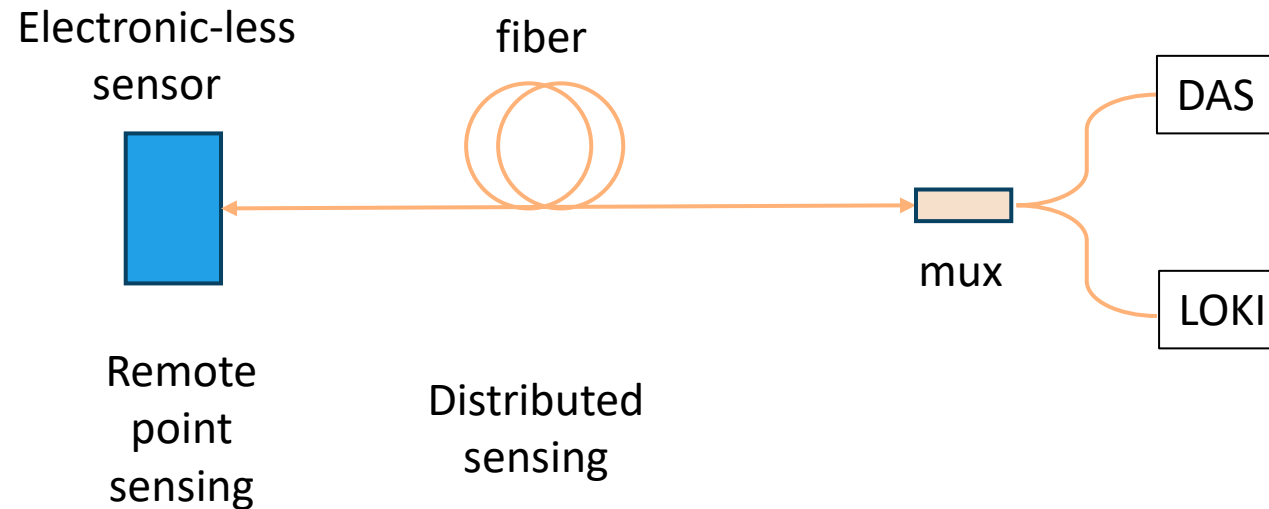
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- Permanent real-time OBS with LOKI on a buoy (IPGP)
- Address the need for optic-only borehole sensors (IPGP)
- 6C borehole strainmeter with compact scale (Géosciences Montpellier)
- Complement Distributed (=DAS) and Local (=LOKI) measurements

Develop new use-cases of LOKI

Complement Distributed (=DAS) and Local (=LOKI) measurements



Develop new use-cases of LOKI

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C
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Seismology	• LSBB 2019 • CORINTHE RIFT 2025 borehole 200m	• CORINTHE RIFT 2025 borehole 200m	
MiningMonitoring		• SWEDEN 2023-2025	

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- Address the need for optic-only borehole sensors (IPGP)
- 6C borehole strainmeter with compact scale (Géosciences Montpellier)
- Complement Distributed (=DAS) and Local (=LOKI) measurements (**call for interest in a joint project**)

Offer new dimensions to explore

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C	Rotational seismometer
Ocean Bottom System	• BREST 2018 • LES SAINTES (CARIBEAN) 2022 • PATRAS 2026 offshore buoy			→
Volcanology	• SOUFRIERE 2019	• STROMBOLI 2021 • STROMBOLI 2023		→
GeoThermal	• STRASBOURG 2025 Borehole 500m		• LSBB 2025 Borehole 30m	
Seismology	• LSBB 2019 • CORINTHE RIFT 2025 borehole 200m	• CORINTHE RIFT 2025 borehole 200m		→
MiningMonitoring		• SWEDEN 2023-2025		

Offer new dimensions to explore

	Open-loop geophone	Fiber Strainmeter high-resolution	Strainmeter 6C	Pressiometer	Inclinometer	Rotational seismometer
Ocean Bottom System	• BREST 2018 • LES SAINTES (CARIBBEAN) 2022 • PATRAS 2026 offshore buoy			→	→	→
Volcanology	• SOUFRIERE 2019	• STROMBOLI 2021 • STROMBOLI 2023		→	→	→
GeoThermal	• STRASBOURG 2025 Borehole 500m		• LSBB 2025 Borehole 30m			
Seismology	• LSBB 2019 • CORINTHE RIFT 2025 borehole 200m	• CORINTHE RIFT 2025 borehole 200m		→	→	→
MiningMonitoring		• SWEDEN 2023-2025				



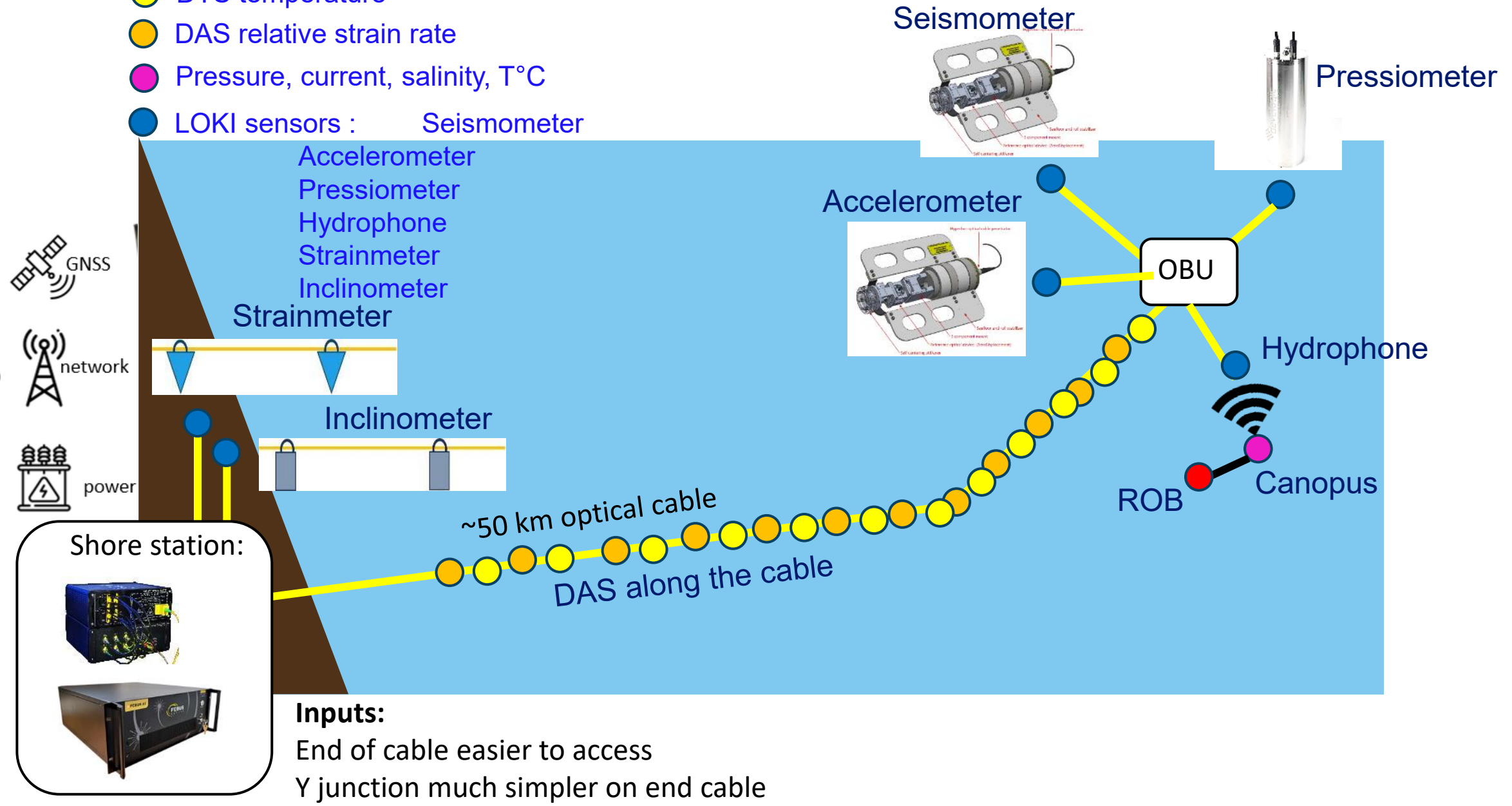
Objectives

Evaluate an innovative **real-time remote instruments panel**
building a **Proof of Concept of Tsunami Early Warning System**



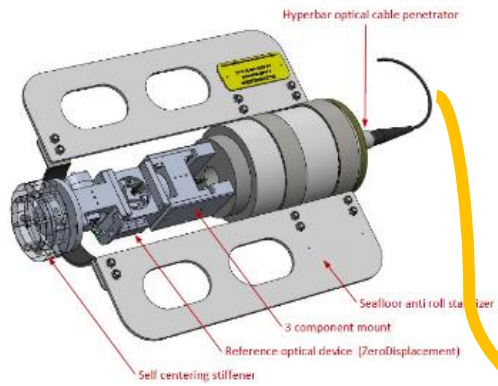
SAMUDRA instrument pannel

- DTS temperature
- DAS relative strain rate
- Pressure, current, salinity, T°C
- LOKI sensors : Seismometer



SAMUDRA : LOKI instrument pannel

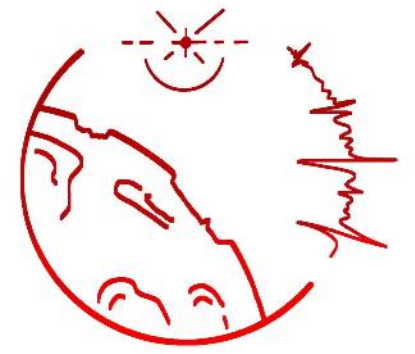
Broadband seismometer



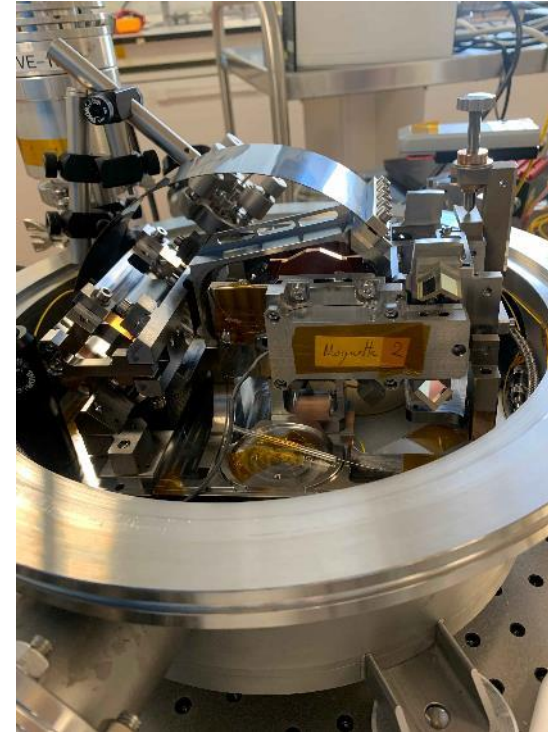
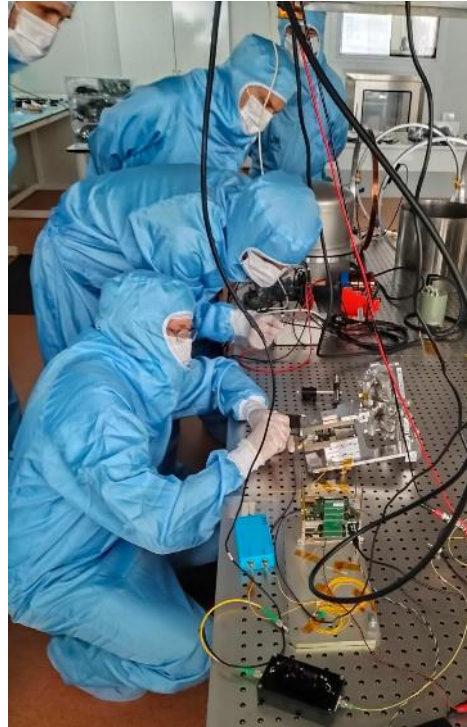
Canopus + ROB

LOVBB project

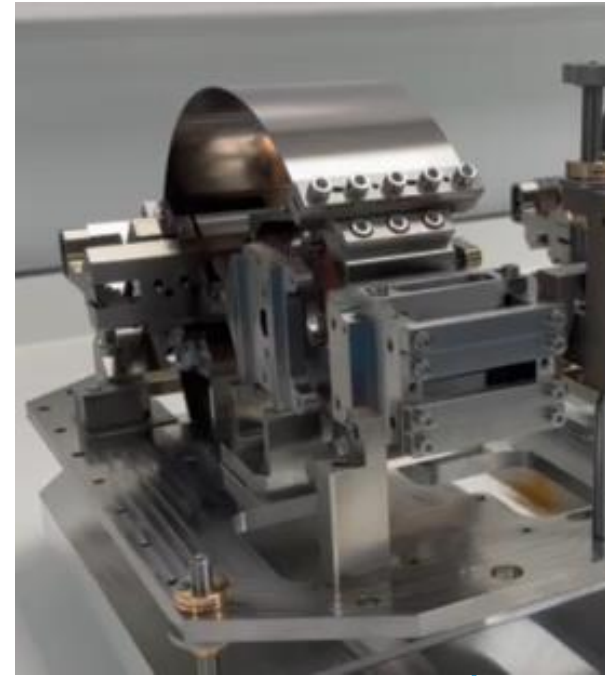
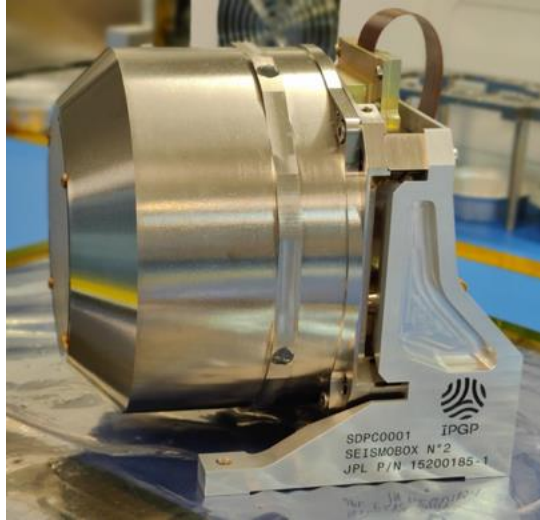
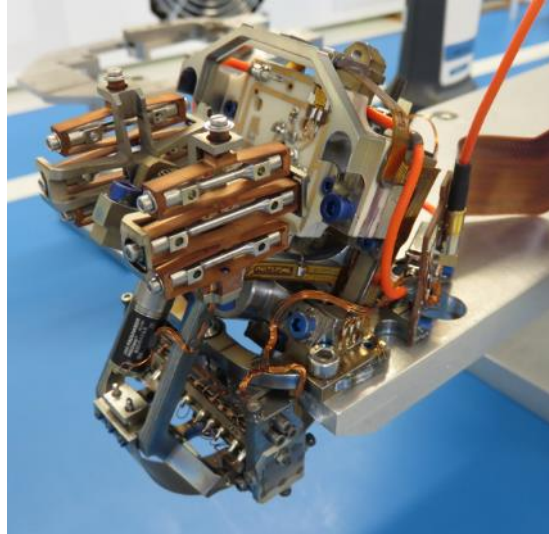
Lunar Optical Very Broad Band



LOVBB



Context: Planetology



Apollo
1972-1977
➔ Moon

Capacitive readout

  **SEIS**
2018-2022
➔ Mars

Capacitive readout

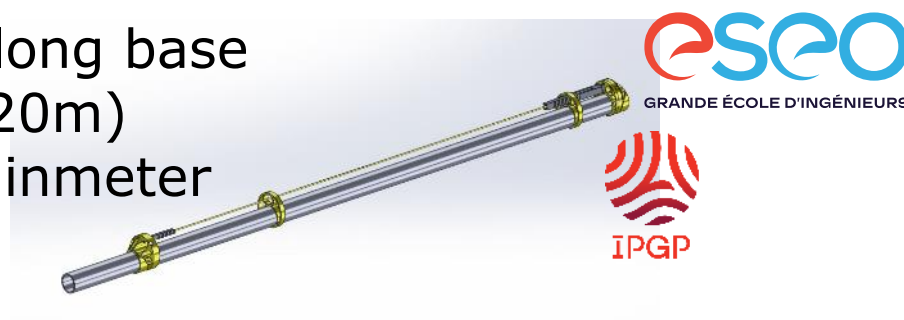
FSS - CLPS
2026
➔ Moon

Capacitive readout

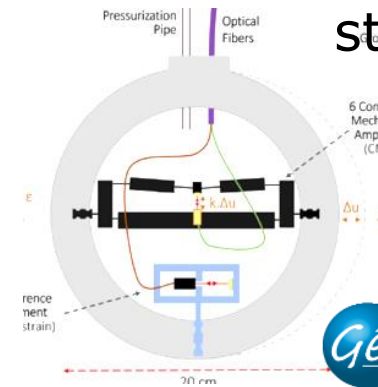
LOVBB
2030
➔ Moon

Optical readout

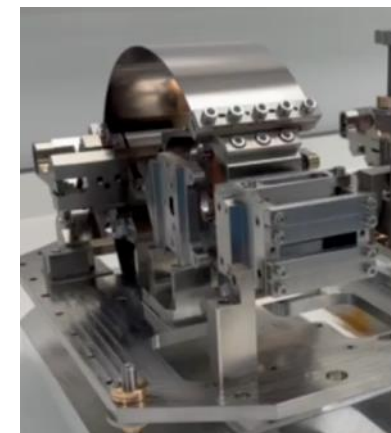
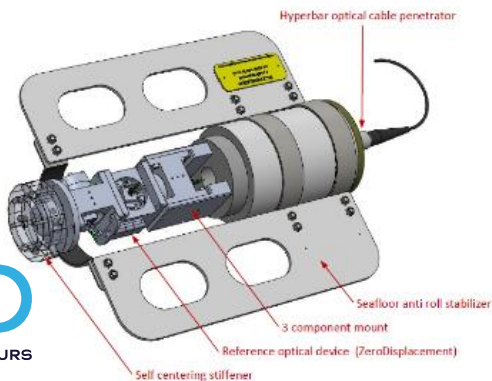
1C long base
(2-20m)
strainmeter



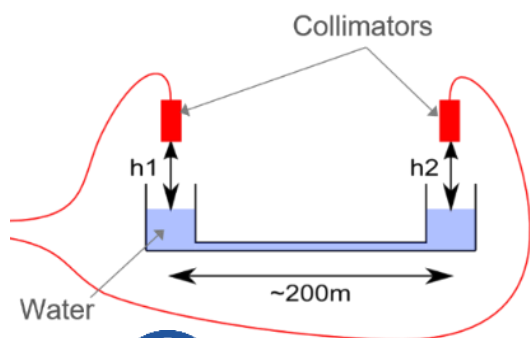
6C local
strainmeter



Broadband seismometer



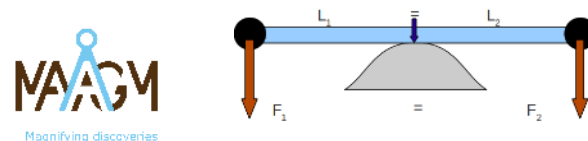
Planetary
seismometer



Pressiometer



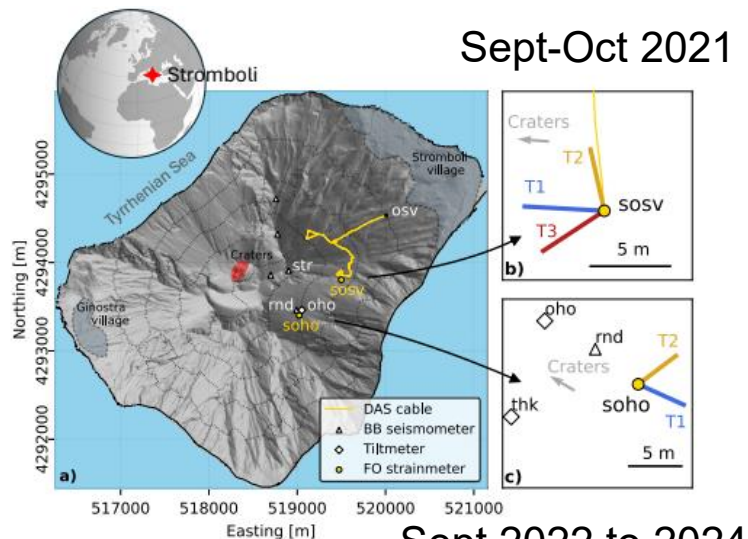
Hydrophone



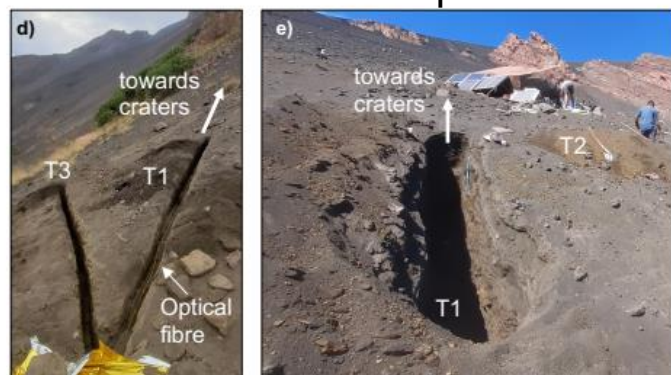
Rotational seismometer

Inclinometer

LOKI looking at precursors on the Stromboli volcano



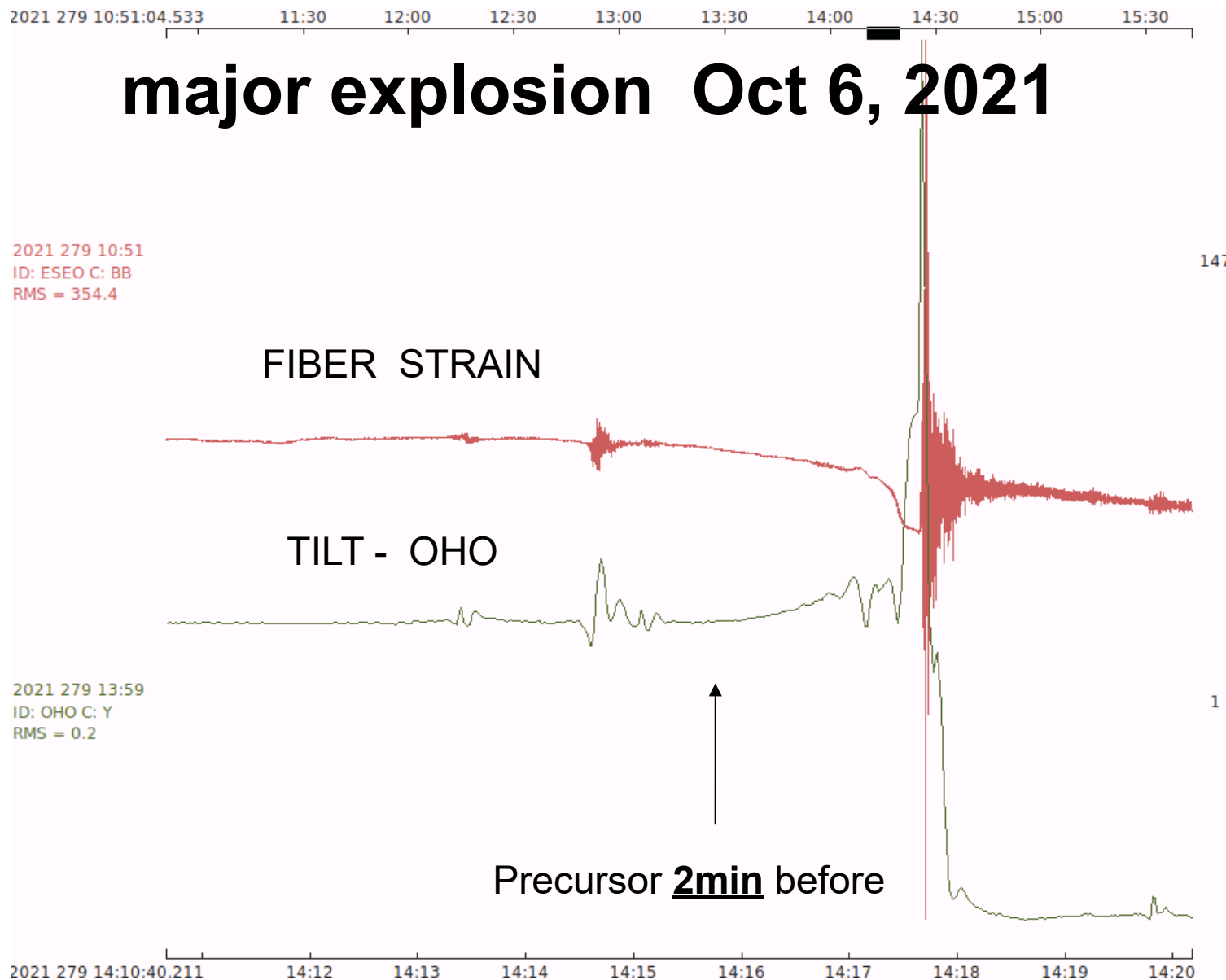
Sept 2022 to 2024



Sept-Oct
2021

Sept 2022 to
2024

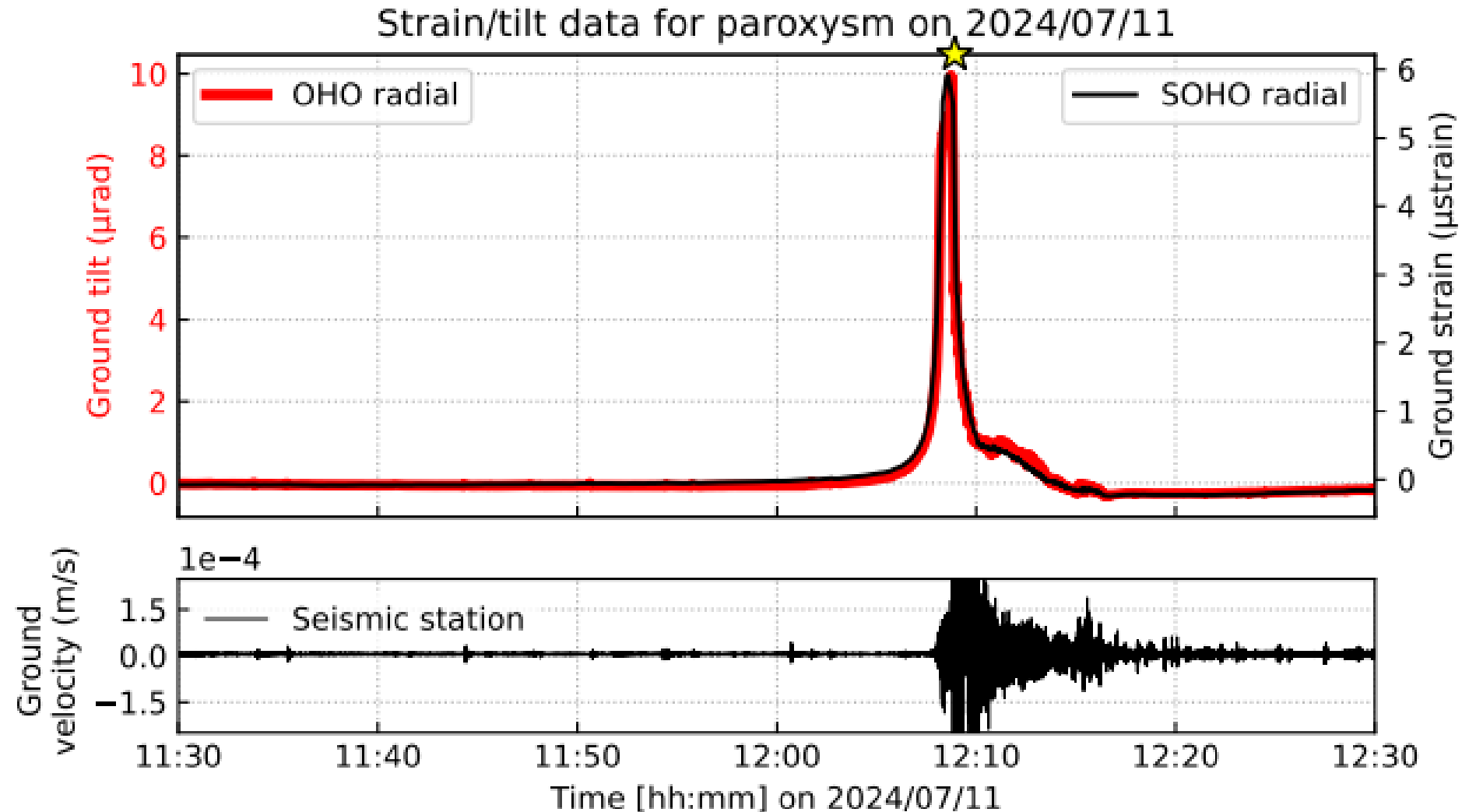
Bernard et al.



LOKI looking at precursors on the Stromboli volcano

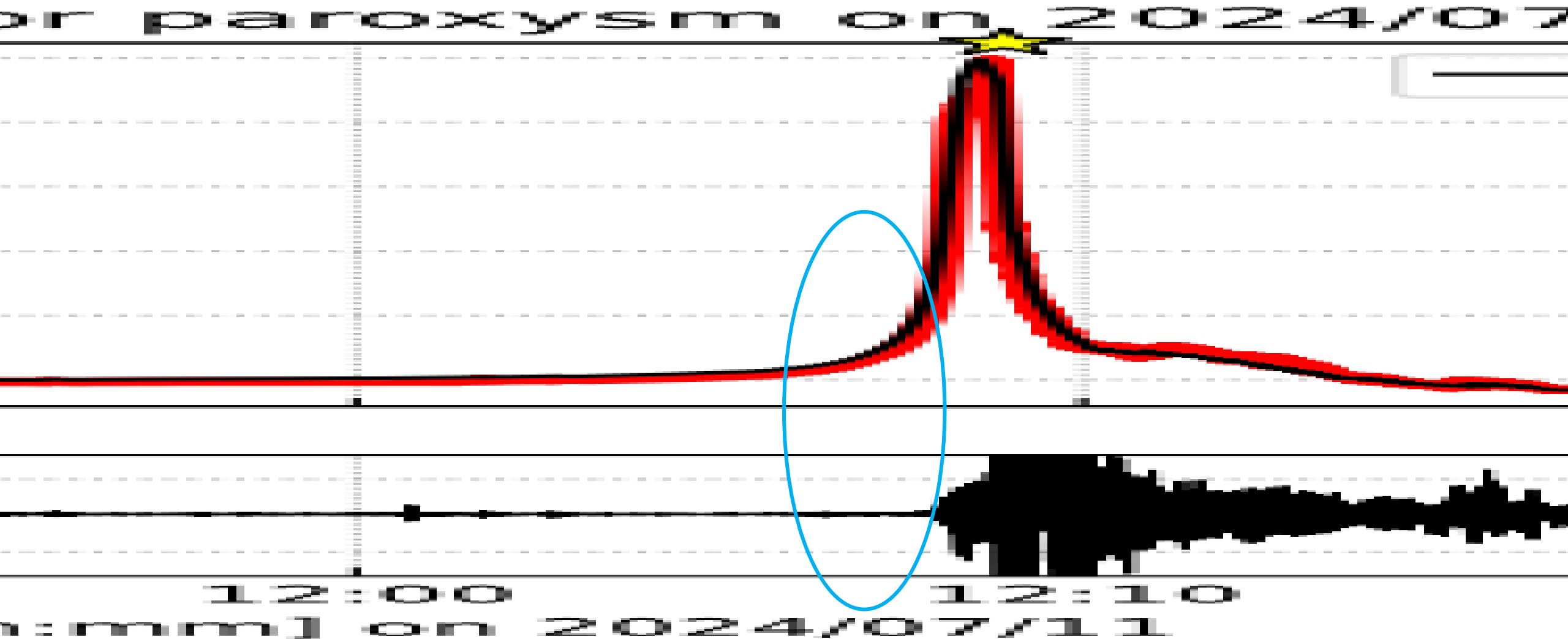
th

Paroxysmal explosion , July 11th , 2024, Stromboli



LOKI looking at precursors on the Stromboli volcano

Paroxysmal explosion , July 11th , 2024, Stromboli





Curious about what we've done with LOKI, and what we could achieve together? Happy to discuss with you !
frederic.guattari@maagm.com



➤ Only if needed

LOKI specification

	4-Channels		8-channels	
Collimator to target distance	Short base (0-1cm)	Long base (1-5m)	Short base (0-1cm)	Long base (1-5m)
Reference	LOKI-4S	LOKI-4L	LOKI-8S	LOKI-8L
Power consumption	8 Watts		12 Watts	
Optical source	1310 nm	1550 nm	1310 nm	1550 nm
Max Datarate	2 kHz		1 kHz	
Max sensor distance	30 km	10 km	15 km	5 km

LOKI specification

Physical characteristics

Dimensions: Electronic box	250x160x60mm	2kg
Dimensions: Optic box	250x160x130mm	2kg
Flight case integrating the full system	475mmx607mmx275mm	15 kg

Operational features

Power supply	11 – 36 V (external fuse 2A)
Configuration user	Web interface TCP/IP - Signal viewer included
Configuration admin	USB – Serial 115200 Baud or SSH
Environment monitoring	T°C 4 channels (24bit @ 1Hz) – Pressure + T°C (24bit @ 1Hz)
Internal monitoring	V & I supplied (12bit @ 1Hz) – PPS status – Memory Free Space%
Pannel checking	LED laser status – 1 LED per channel
Data storage and access	31 Go internal – SEED link server embedded – STEIM 2 - miniSEED
Data retrieval	USB – SSH – SEEDlink request – Real-time Streaming
Remote configuration	VPN access allowing full configuration and maintenance remote
Time stamping	Internal GNSS antenna and receiver & TCXO 0.5ppm & NTP
Datarate	GNSS Disciplined – Configurable : 1Hz – 1kHz