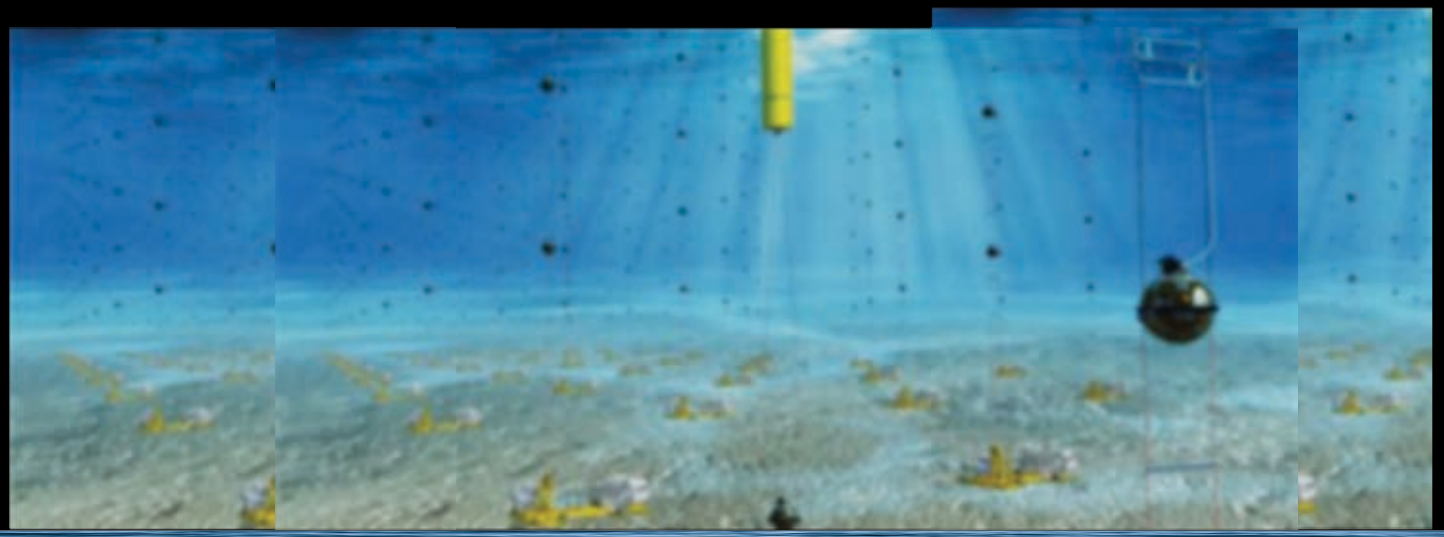
MARCH 4-5, 2024
EGO, CASCINA (ITALY)
AND ONLINE

# Workshop on the synergies between astrophysics and geoscience

EGO EUROPEAN GRAVITATIONAL OBSERVATORY

AHEAD 2020

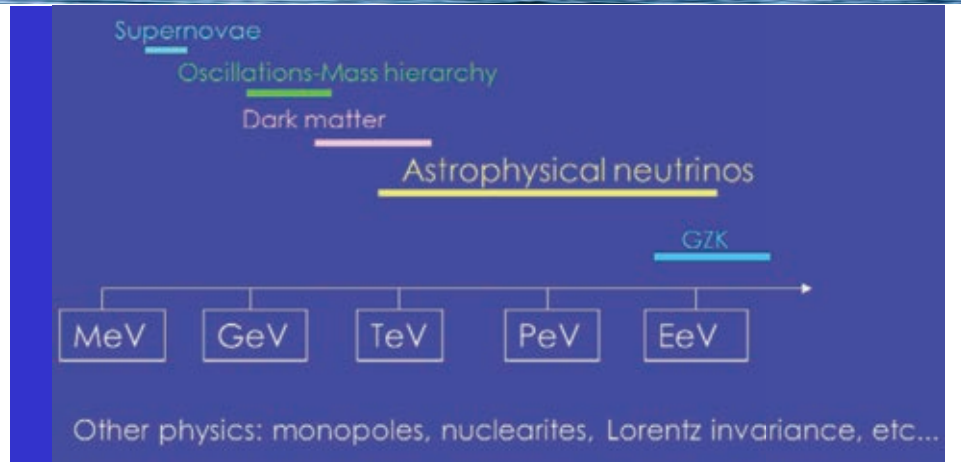
## The KM3NeT detector and infrastructure: an unprecedented tool for the exploration of deep sea

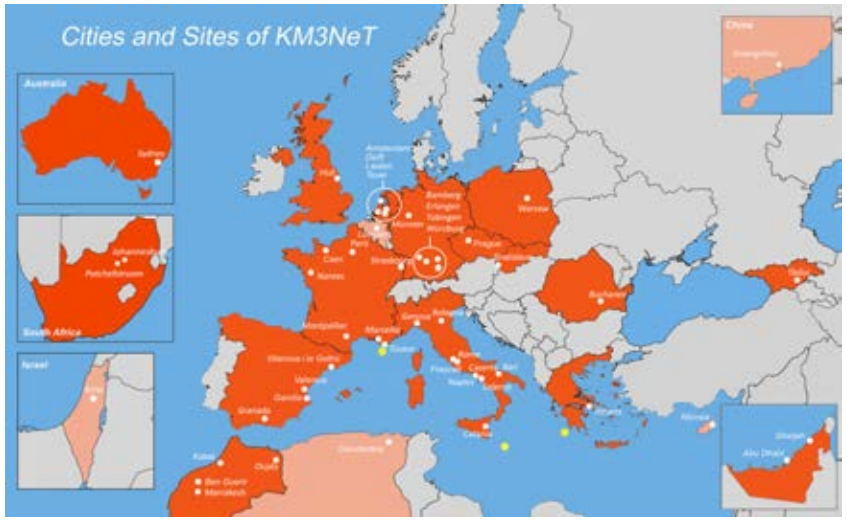


# KM3NeT: the giant underwater HE ν telescope

Large volume of transparent medium surveyed by photodetectors
- Deep Sea water
- Long light absorption length (70 m)
- Very small light scattering (good angular resolution)
- Natural backgrounds ($^{40}$K and bioluminescence) can be handled

Northern terrestrial hemisphere:
- Complementary to IceCube
- Upgoing tracks from Southern sky sources. Milky-Way optimised



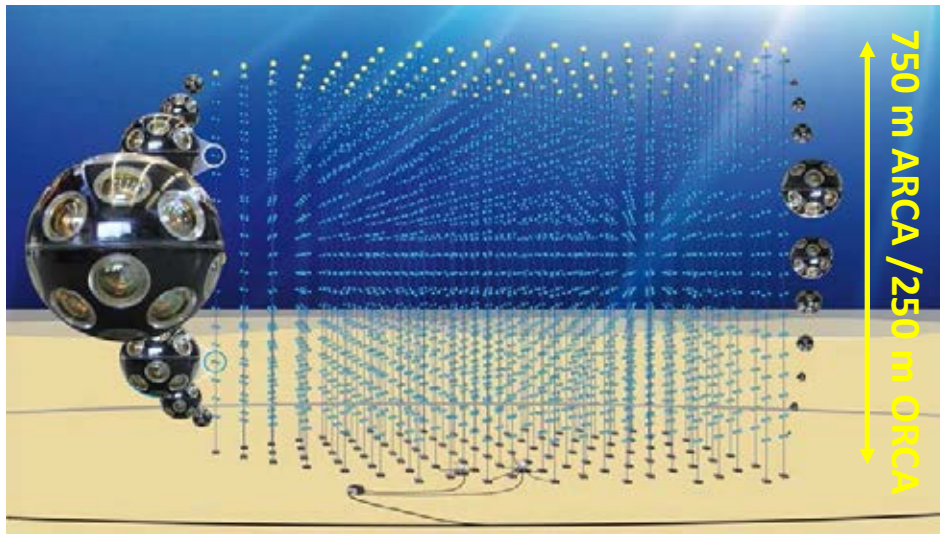

Volume (ARCA + ORCA) ≈ 1 km$^3$
more sensors (circa 180000) more photocathode area than IC
better optical properties in sea than in the ice
→ improved sensitivity
→ identification of neutrino sources and study of neutrino properties

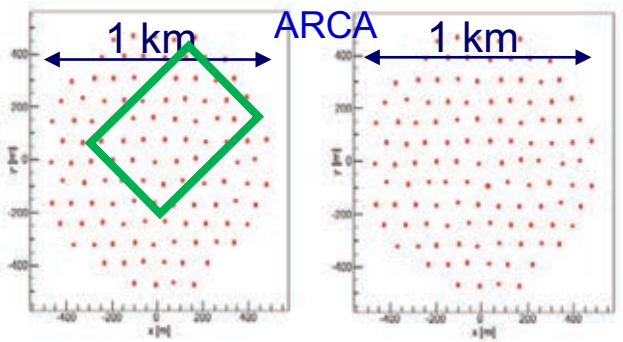
Still growing!

See P. Coyle's Talk

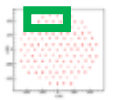
# KM3NeT: the giant underwater HE ν telescope

Astronomy: ARCA @ Capo Passero 3500 m wd
2 building blocks (few km among the blocks)
115 Detection Units(DU) / block
18 DOMs (36 m inter-DOM), 90 m inter-DU distance
1 $km^3$ volume
Oscillations and Mass Hierarchy: ORCA @ Toulon 2500 m wd
1 building block
115 detection Units
18 DOMs (9 m inter-DOM), 23 m inter-DU distance
8 Mton volume



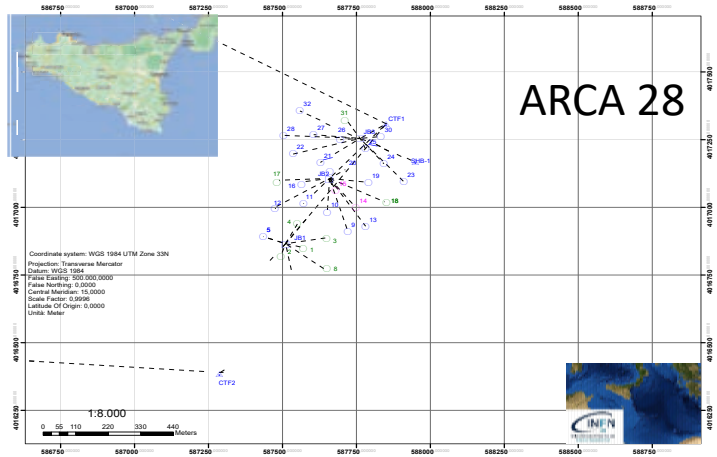



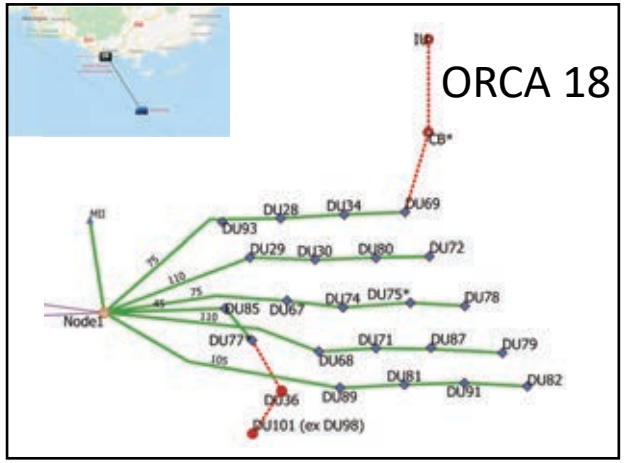

ORCA
200 m



Phase 1: COMPLETE !

KM3NeT 2.0



# KM3NeT: detector elements

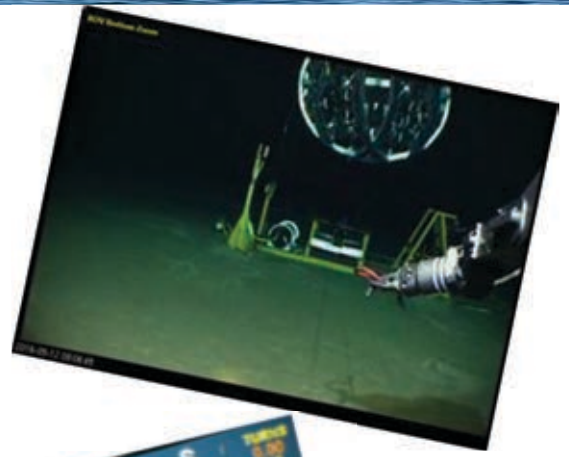
Digital Optical Module (DOM)
A fly's eye light detector Inside a 17'' glass sphere

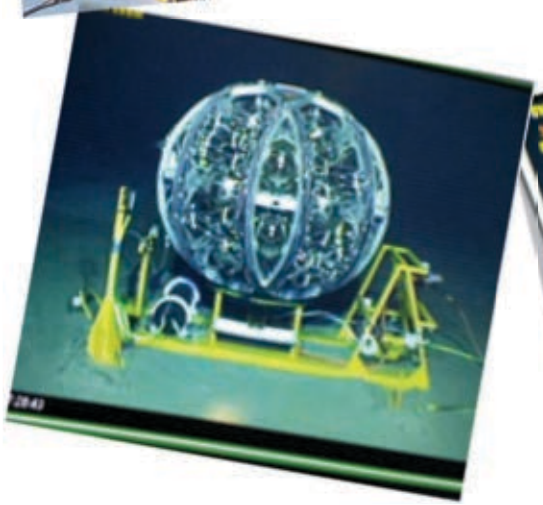
Plus:
compass, acoustic sensor, front-end and data transmission electronics

1 hydrophone at each Detection Unit base

Detection Unit
a vertical string with 18 DOMs

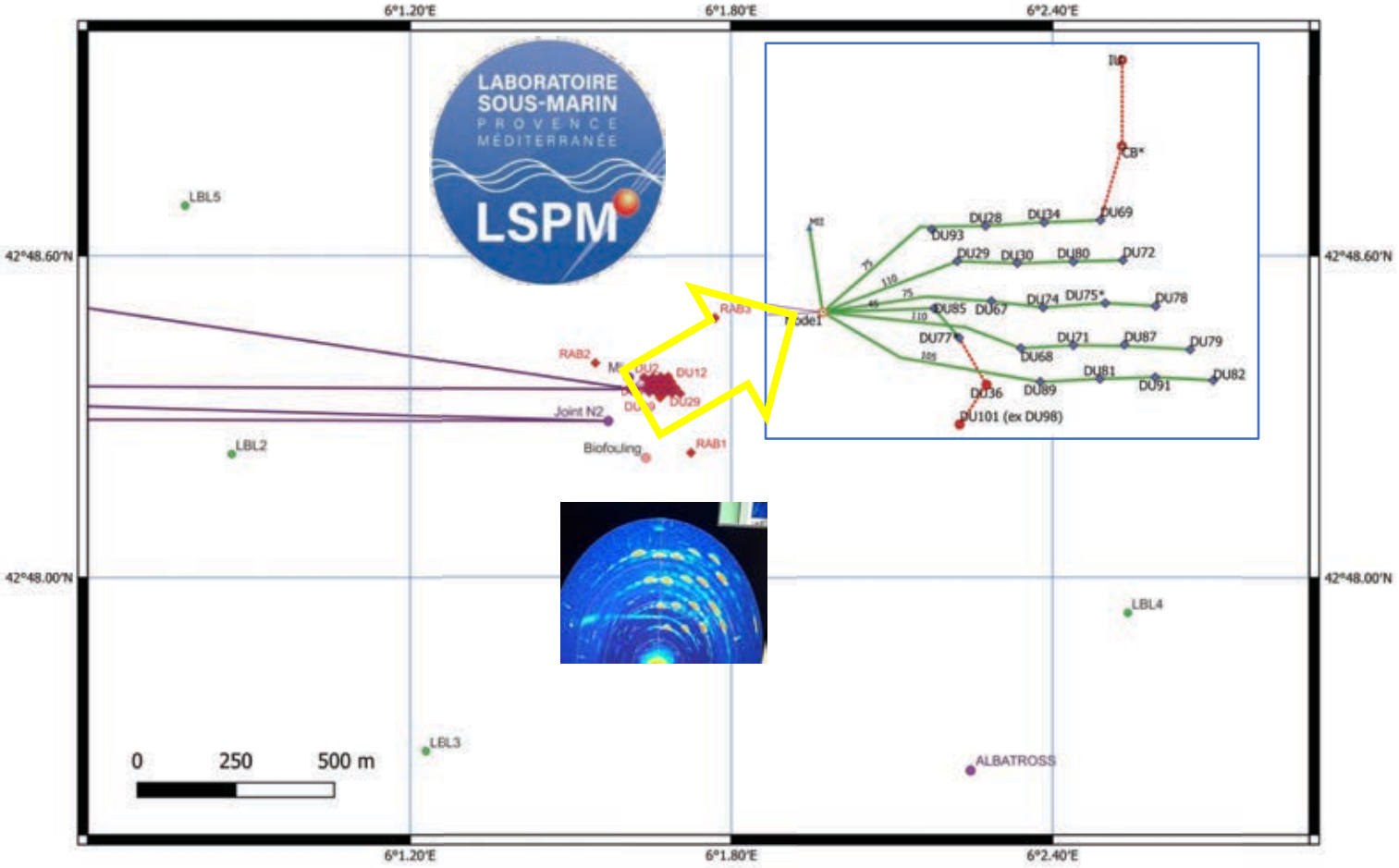
power: 260 W

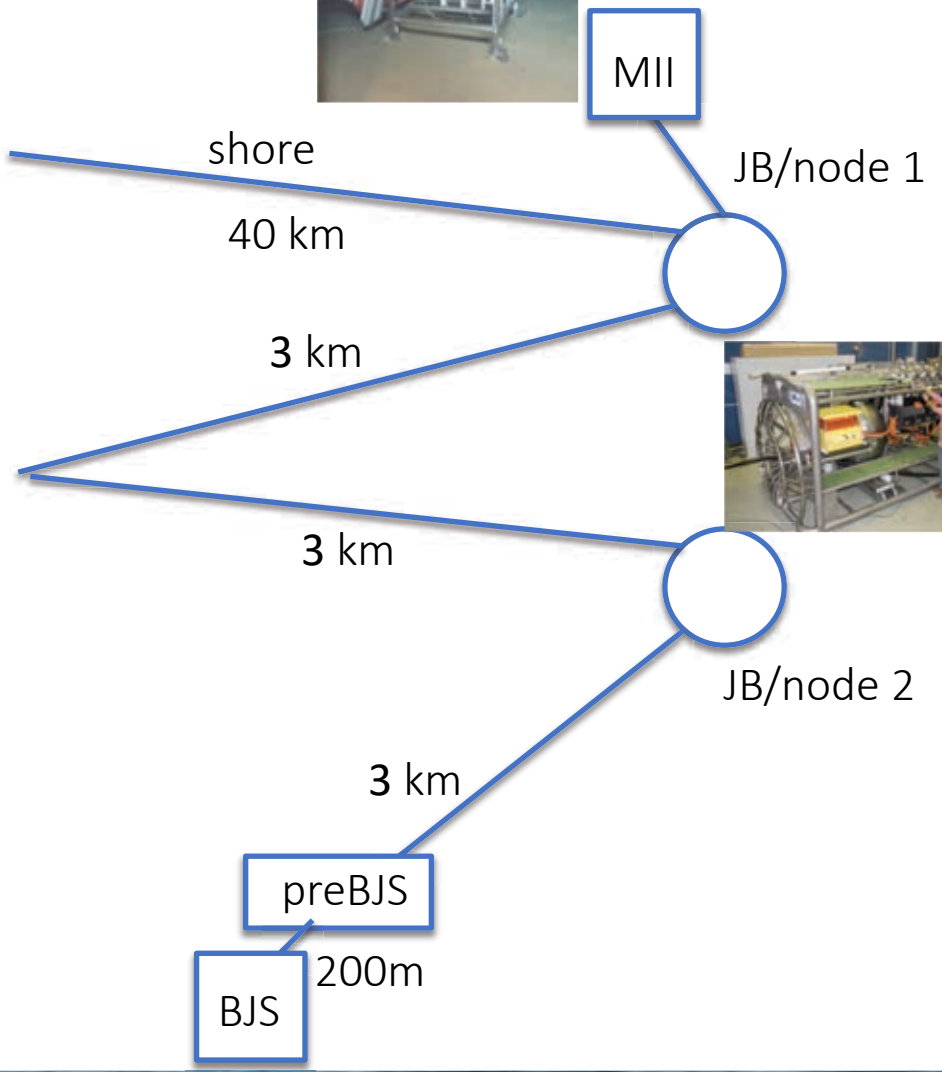




Plus: special units for monitoring of water column oceanographic properties

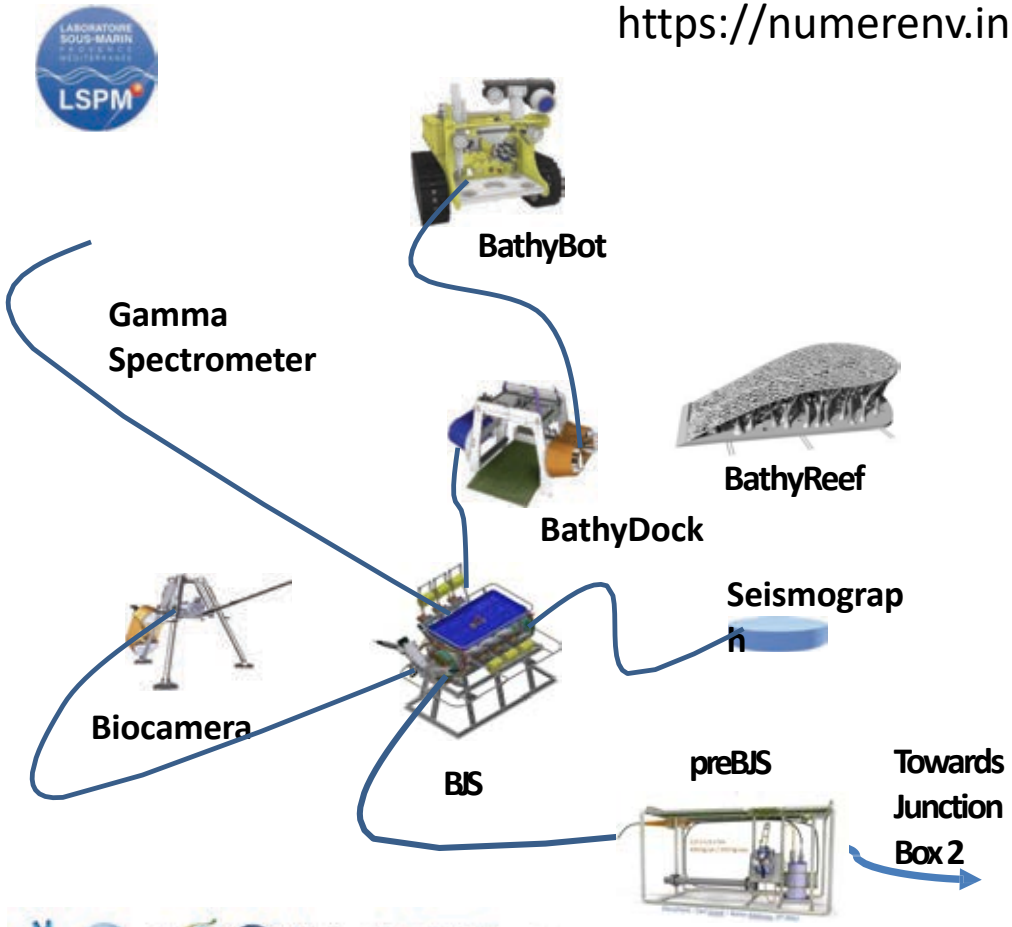
# ORCA Infrastructure: the LSPM

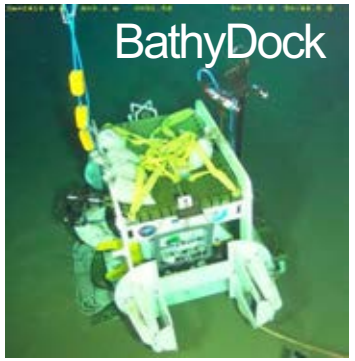


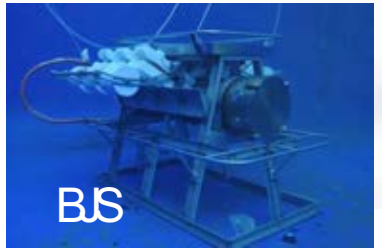


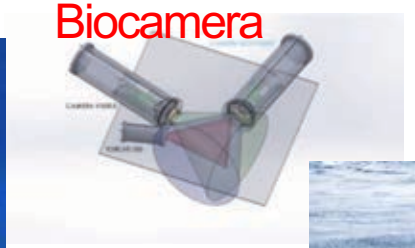
# ORCA Infrastructure: the LSPM

https://numerenv.in2p3.fr/



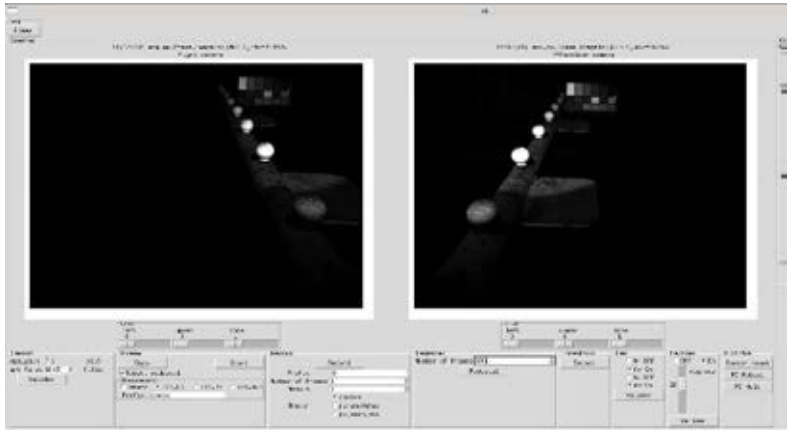


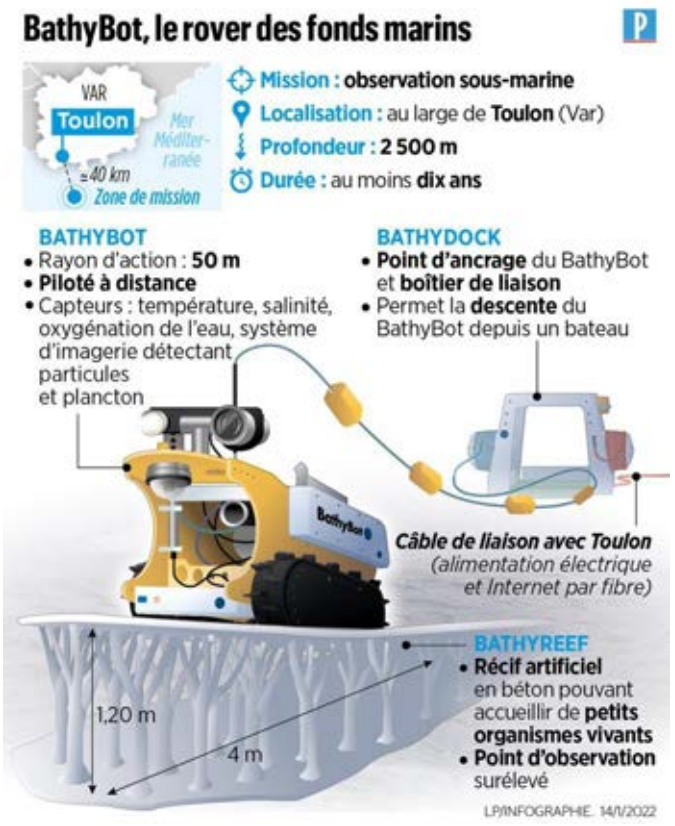



# ORCA Infrastructure: the LSPM

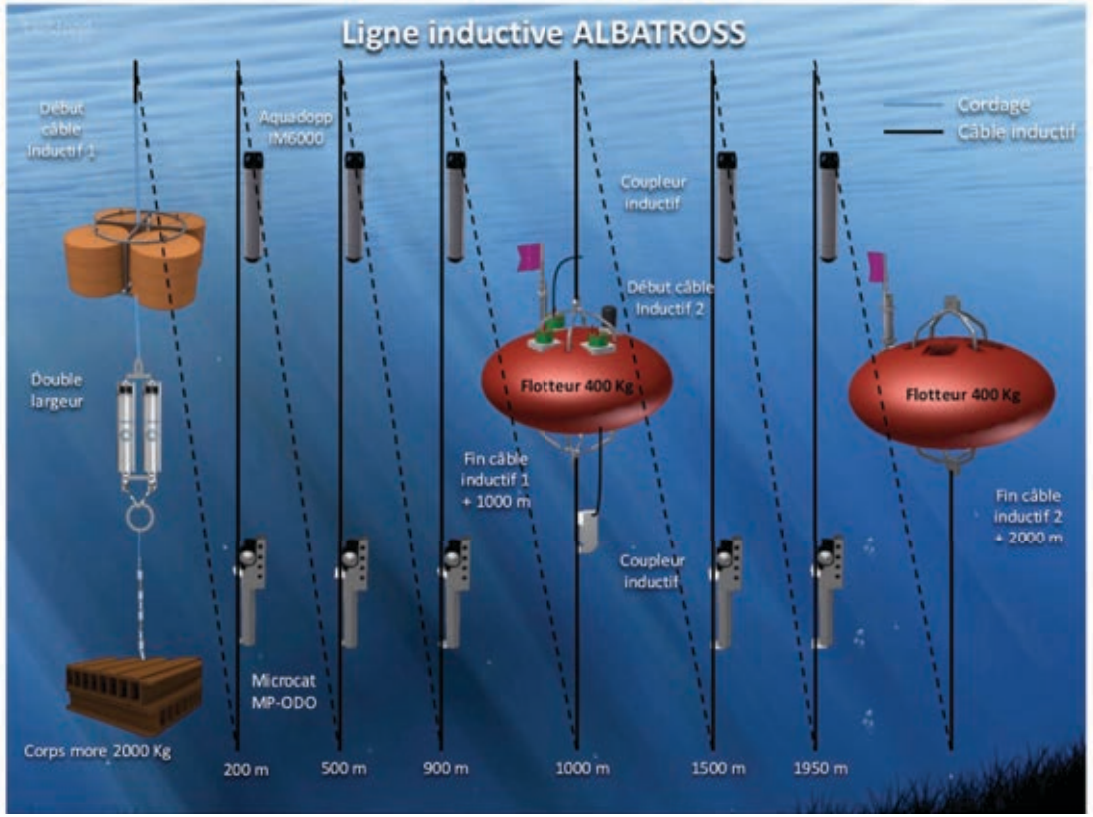
Bioacamera



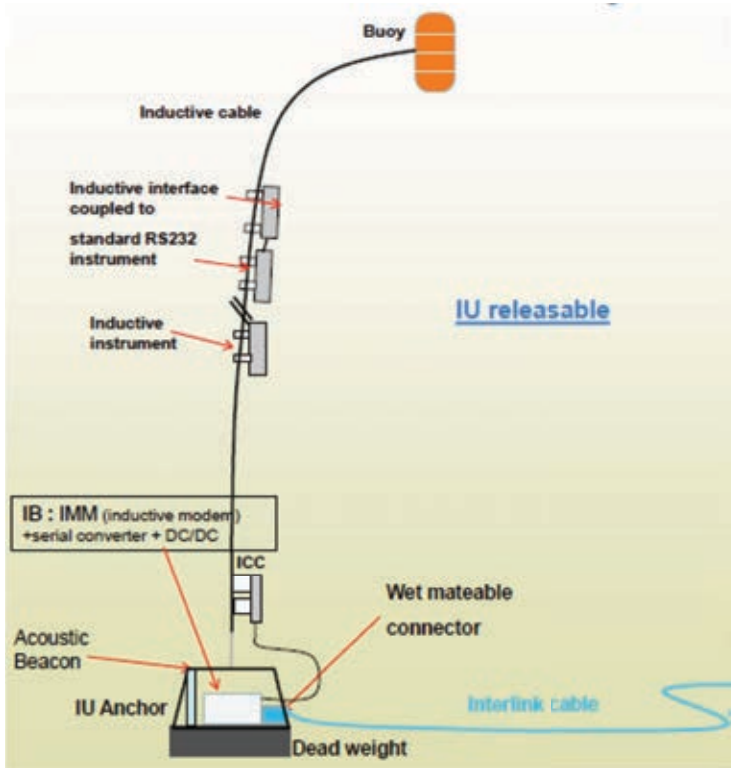
BathyBot



# ORCA Infrastructure: the LSPM

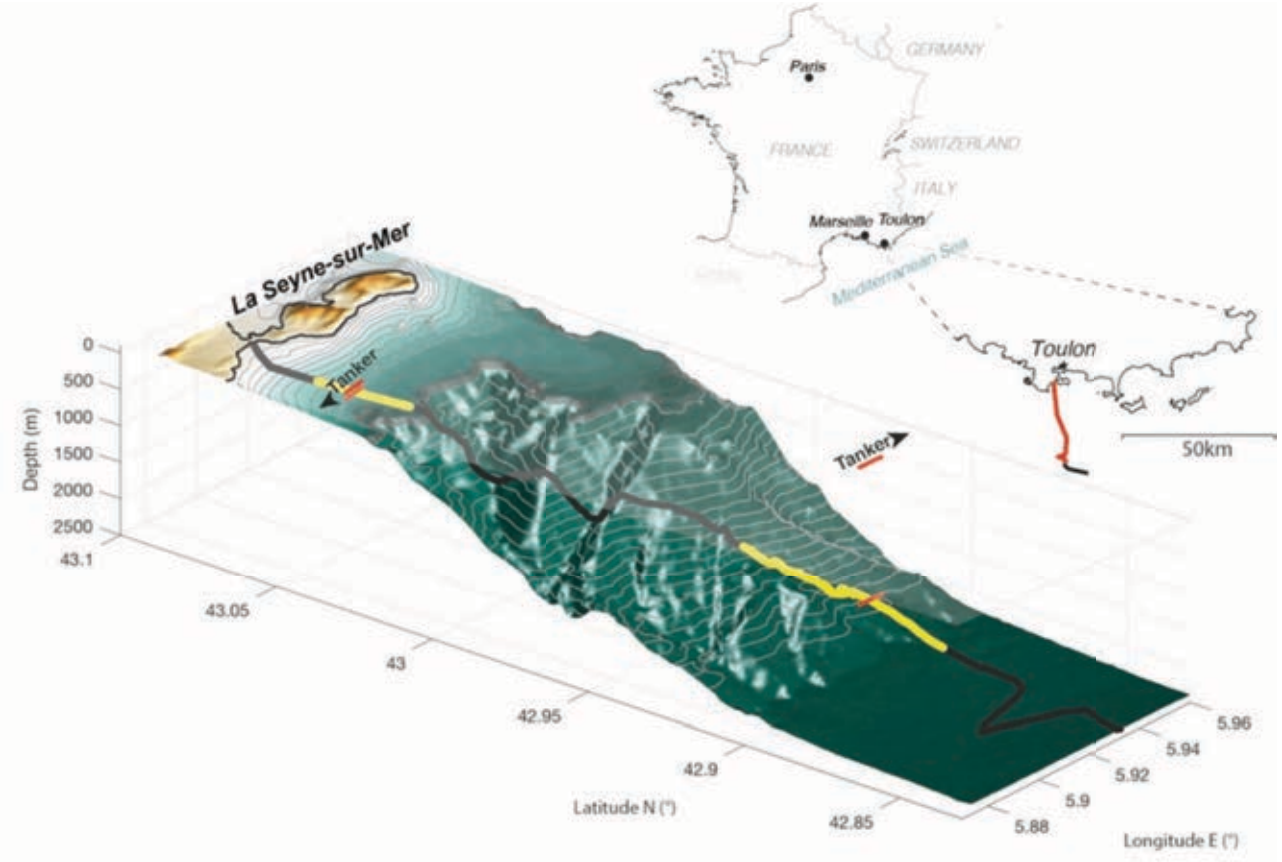


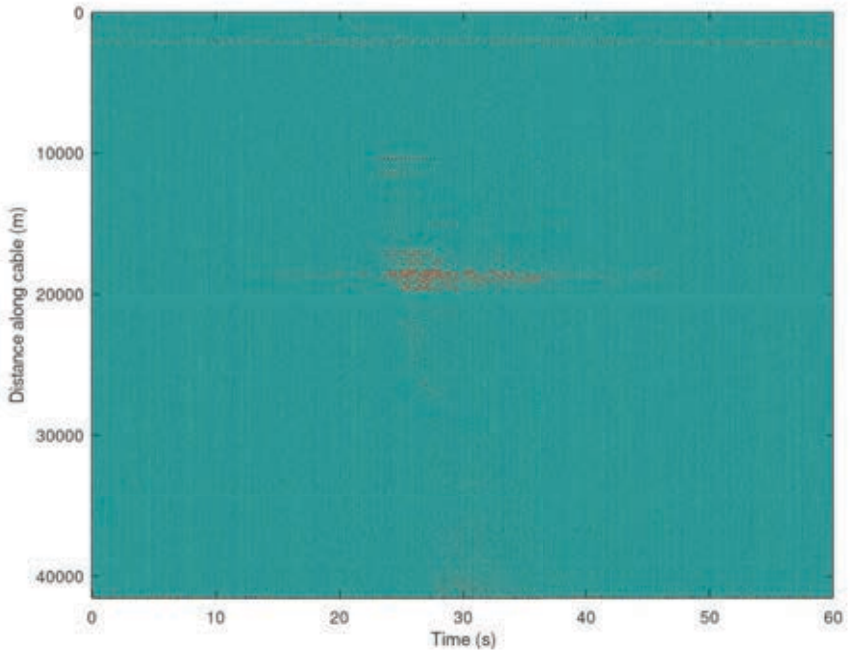

Albatross Line




Calibration Base

# The ORCA case: Distributed Acoustic Sensing

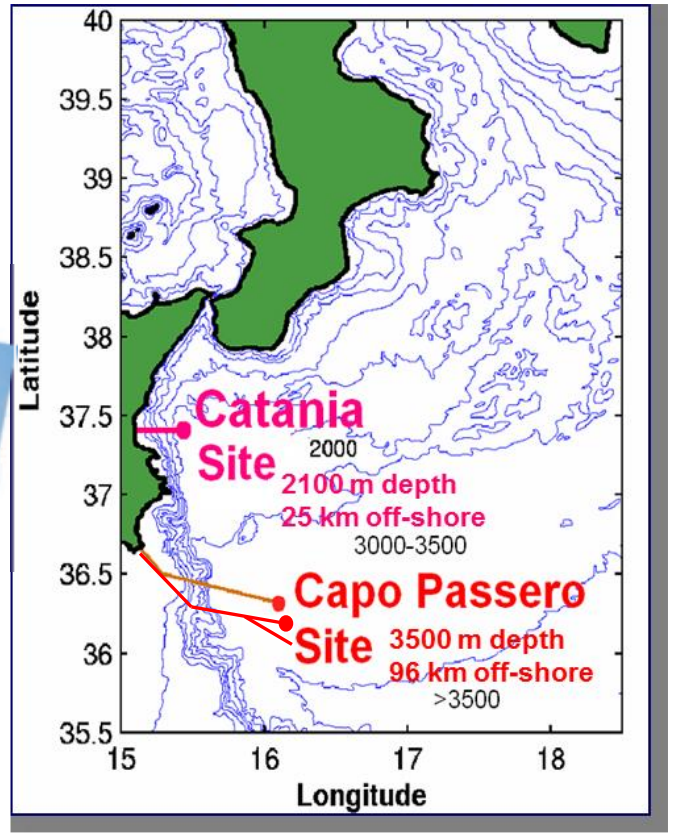



[MEUST-NUMerEnv/KM3NeT DAS experiment Feb. 2018]
**Earthquake_1p9_Var_BP_2p5_15Hz.gif**

# INFN-LNS: Marine infrastructure in Eastern Sicily

Both shore labs have direct 10Gbit connection to the EU optical network infrastructure for research



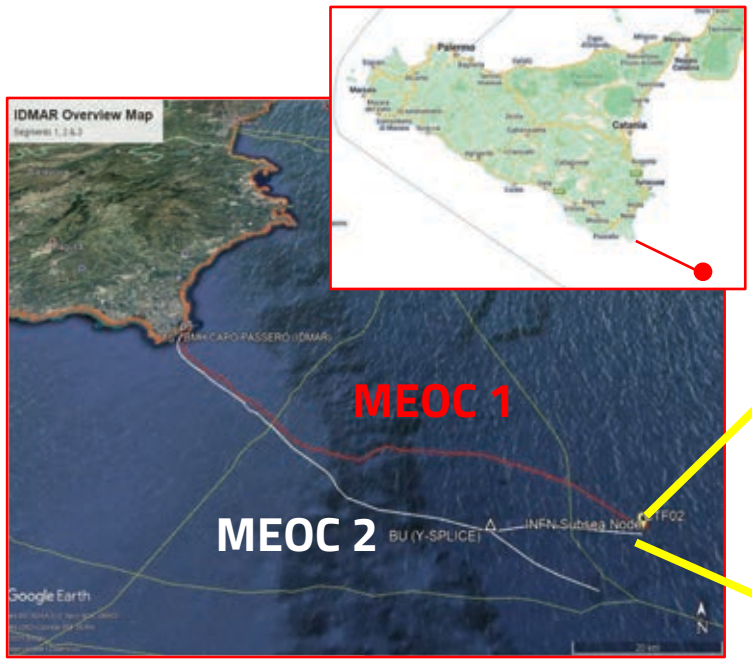

**Catania (2100 m water depth)**
**Multipurpose (including EMSO-ERIC)**

25 km-long electro-optical cable 10 fibers, 6 conductors divided among 2 CTFs (4 independent e.o. outputs)

**Capo Passero (3500 m water depth)**
**Multipurpose (including KM3NeT and EMSO-ERIC)**

100 km-long electro-optical cable 20 fibers, 1 conductor (DC)
Cable Termination (5 independent e.o. outputs)
100 km-long electro-optical cable 48 fibers, 2 conductors (DC)
Cable Termination (16 independent optical and electrical outputs)

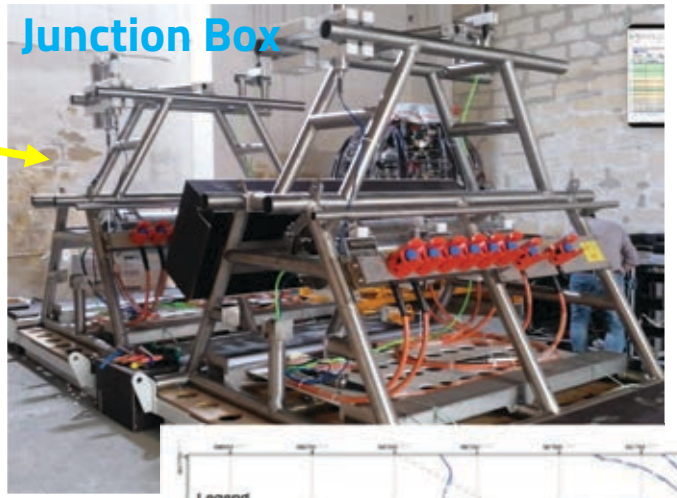
# KM3NeT ARCA Subsea Network

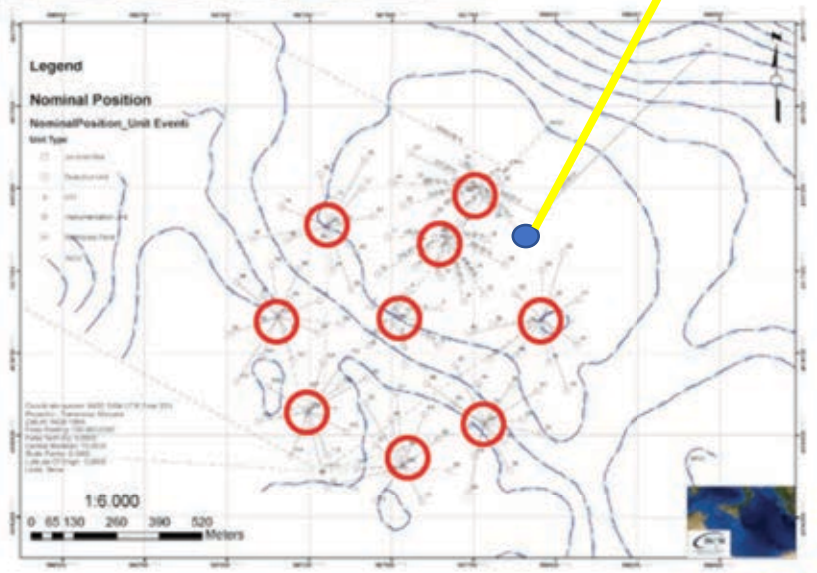


5 electro-optical ports in CTF 1

16 electro-optical ports in CTF 2

9 JBs: 12/14 electro-optical ports per JB






## The Capo Passero site

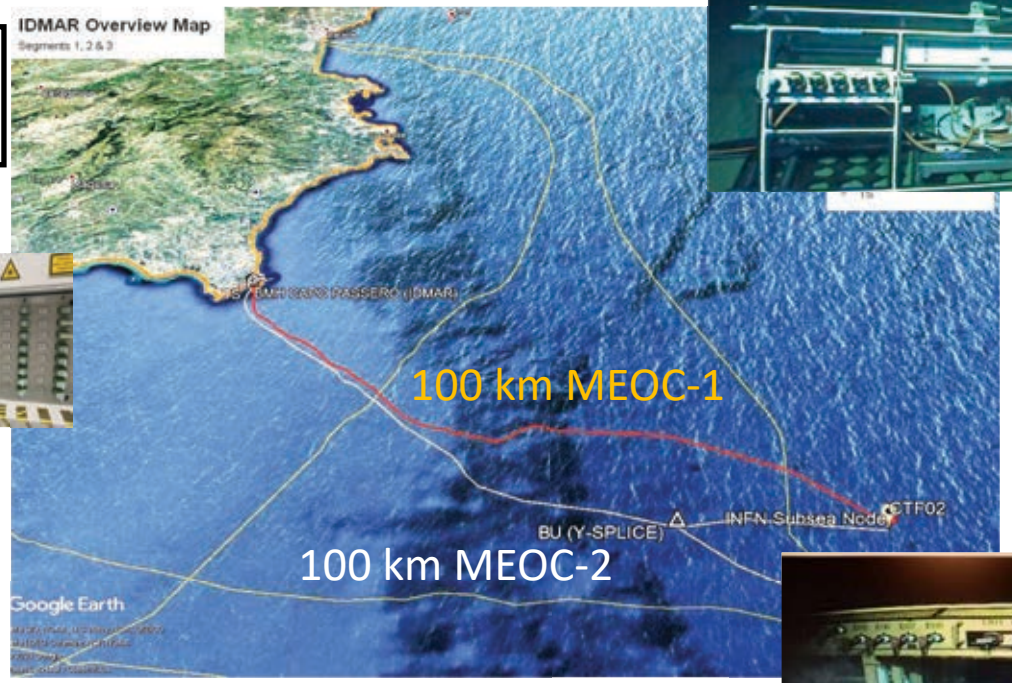
deep-sea infrastructures and observatories offer unprecedented tools to

- develop and test novel marine technologies and detectors
- monitor geophysics and biological phenomena and anthropic footprint

# KM3NeT: sub-nanosecond synchronisation

White Rabbit: An enhanced ptp (IEEE1588) protocol to synchornise all devices offshore with sub-ns accuracy

Phase 1:3 JBs, 28 DUs



Junction Box

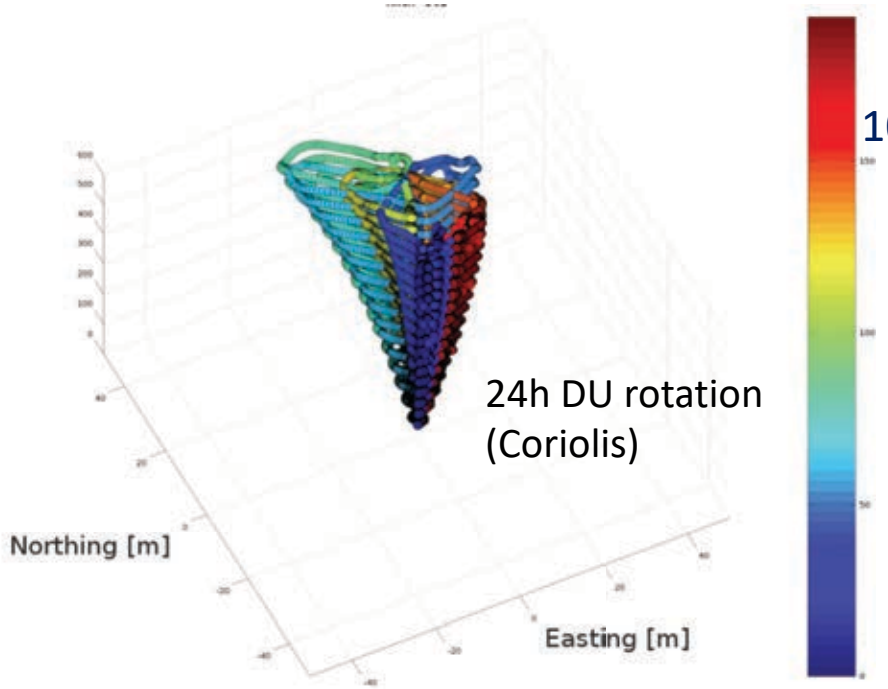
Phase 2: 6 JBs, 85 DUs (x 2→block 2)

Detection Unit

# KM3NeT: Custom Acoustic Positioning System

Digital acoustic receivers (192 kHz/24 bits) synchronised with detector master clock (<1 μs)
All data to shore in real time

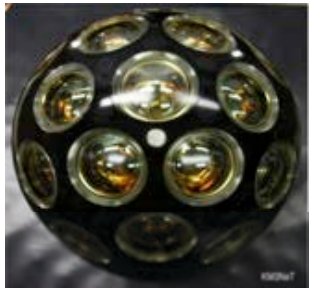
→ the largest (scientific) phased array of acoustic receivers subsea

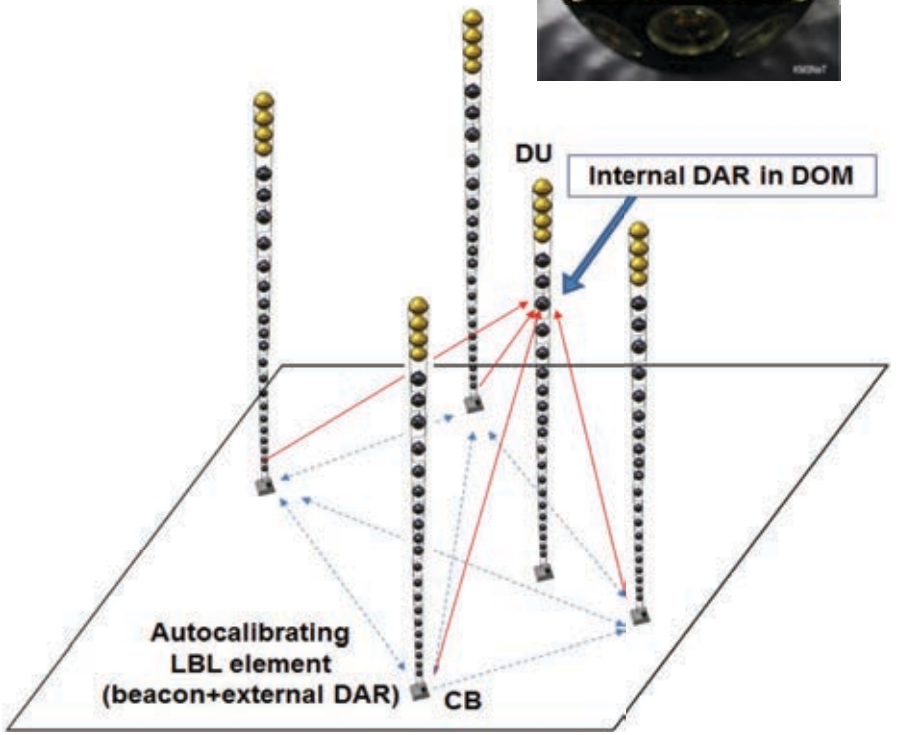



24h DU rotation
(Coriolis)



10 minutes integration

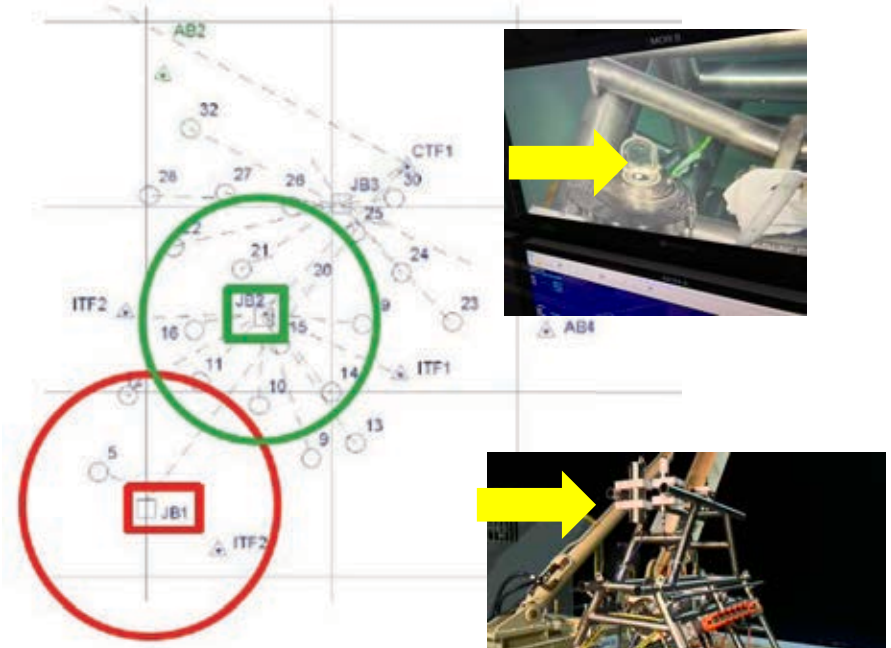




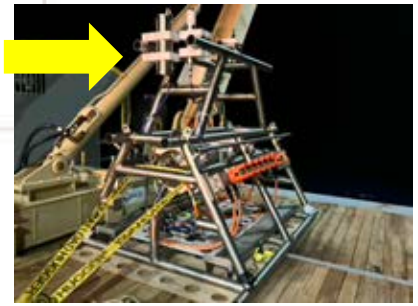

Goal 20 cm accuracy (1ns == DOM radius)

# Study of optics in water: laser and led beacons

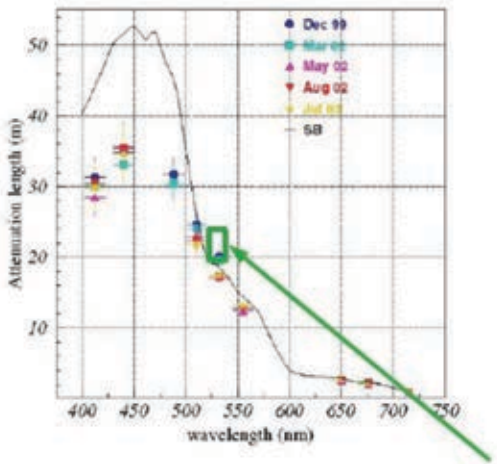
measurement of seawater optical properties
timing
simulation of showers in situ



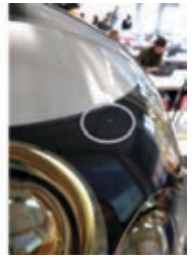


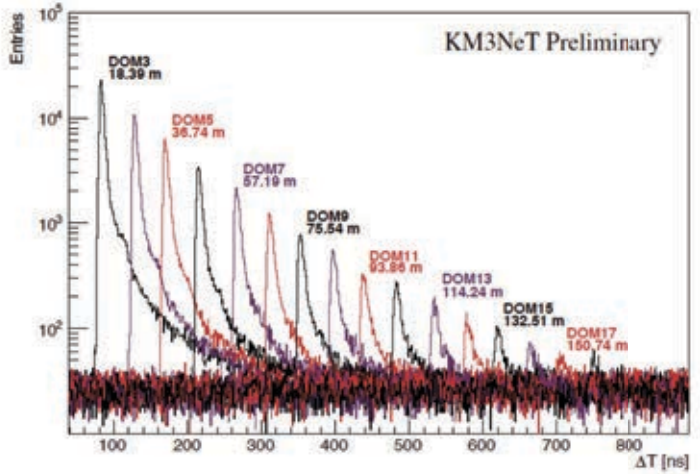



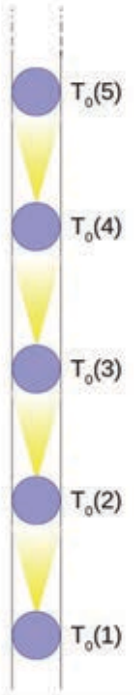
laser beacons in JB




nanobeacon in each DOM





# KM3NeT: the calibration unit



Allow streaming of water column oceanographic properties

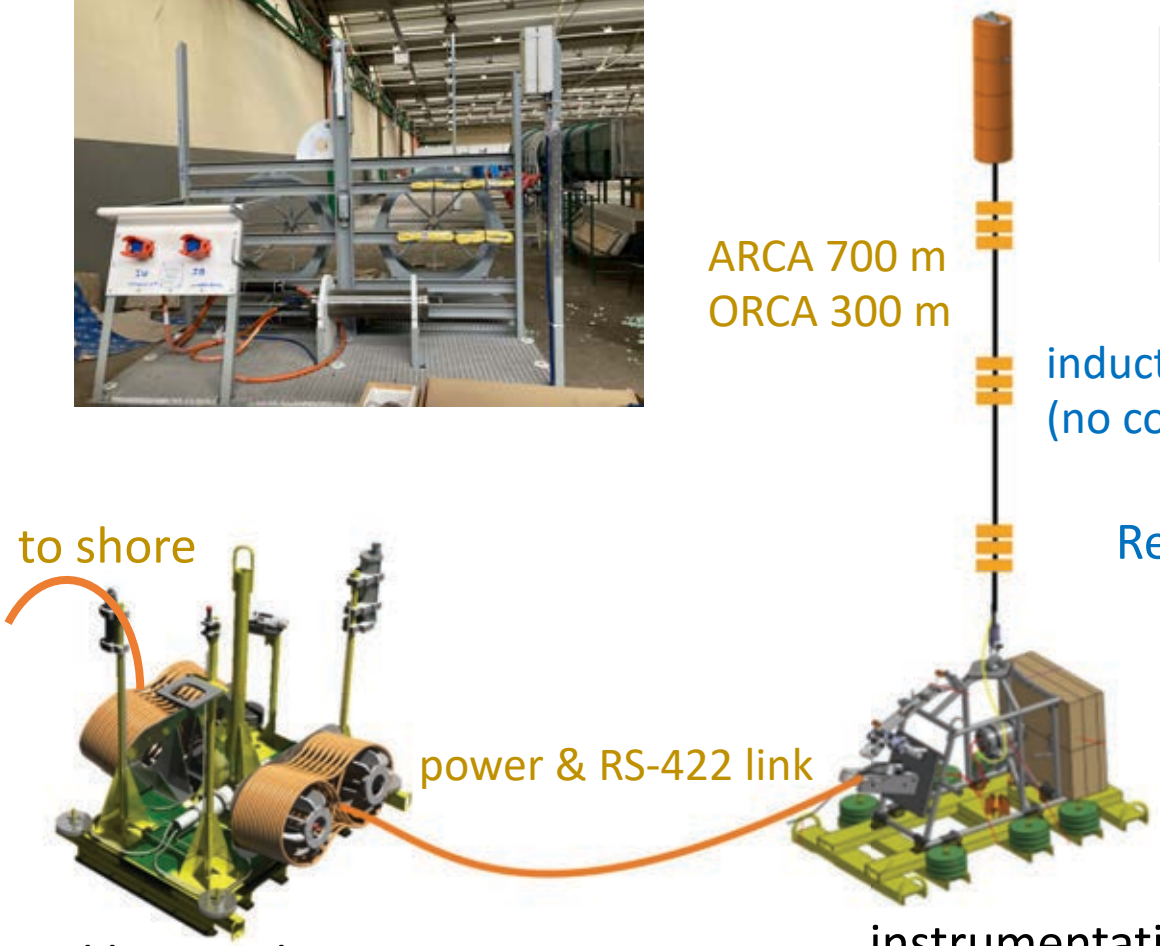
- Sound Velocity
- Water Current (Doppler acoustic sensor)
- Conductivity, Temperature, Depth, Oxygen Probe (CTD)
- Absolute Pressure (bottom)

ARCA 700 m
ORCA 300 m

inductive cable technology
(no connectors, up to 100 instruments)

Retrievable unit: re-calibration/re-configuration of instruments

Installed far at the rim of the detector footprint
for safe multiple recovery/deployment




R. Le Breton JINST 16-C09004, 2021

# Real-time marine data harvesting

Deep sea current monitoring

ARTICLE

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DOI: 10.1038/ncomms1836

## Abyssal undular vortices in the Eastern Mediterranean basin

Currents in deep sea

## Integrating Diel Vertical Migrations of Bioluminescent Deep Scattering Layers Into Monitoring Programs

*Damianos Chatzievangelou[1]*, Nixon Bahamon[2], Séverine Martini[3], Joaquin del Rio[4], Giorgio Riccobene[5], Michael Tangherlini[6], Roberto Danovaro[6,7], Fabio C. De Leo[8,9], Benoit Pirenne[8] and Jacopo Aguzzi[2,6]**

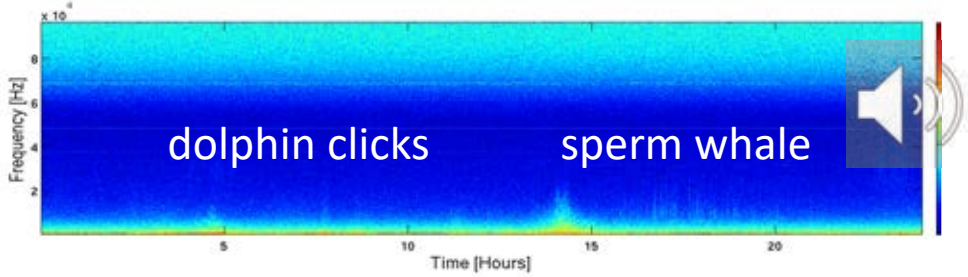
[1] Ocean Lab, Department of Physics and Earth Sciences, Jacobs University, Bremen, Germany, [2] Functional

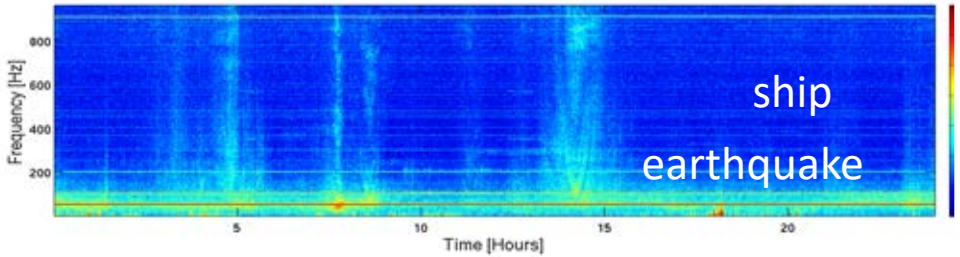
Study of Bioluminescence

# INFN-LNS: Catania Site - subsea acoustic detectors

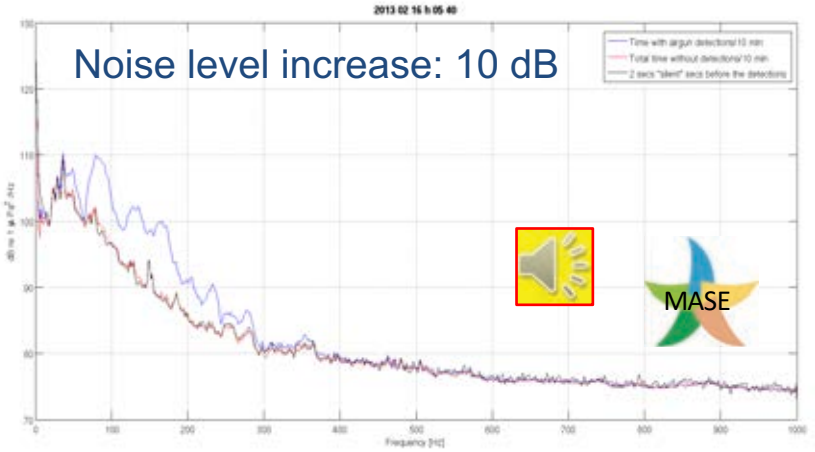
Marine spatial planning

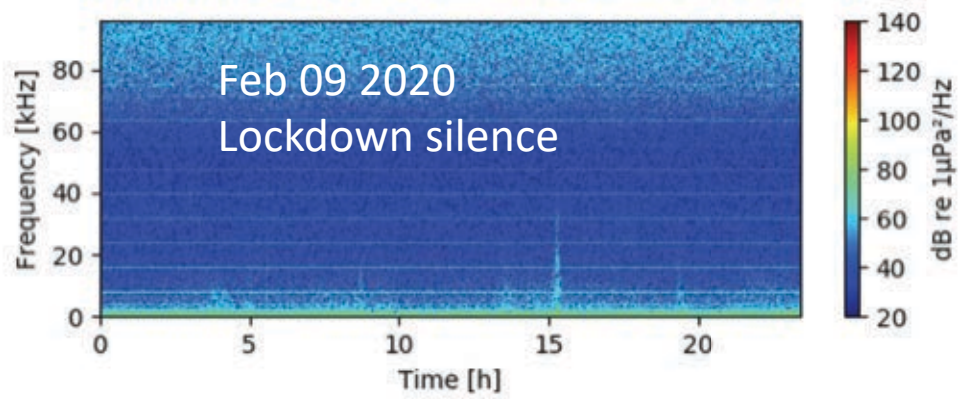
- Anthropogenic (shipping, airguns, …) noise monitoring
- Presence of Cetaceans
- Geophysical Noise monitoring
- Wind/rain (noise) monitoring offshore





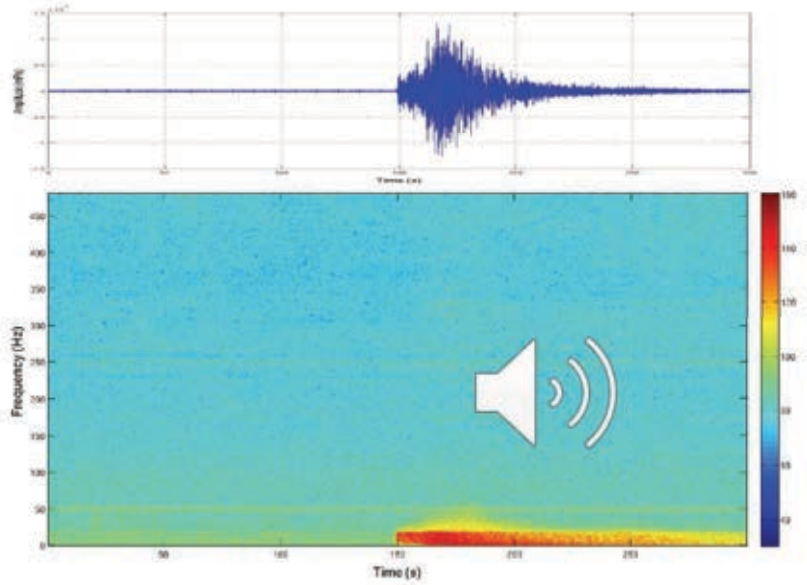

Airgun operated off Cyprus
Detection in the Gulf of Catania



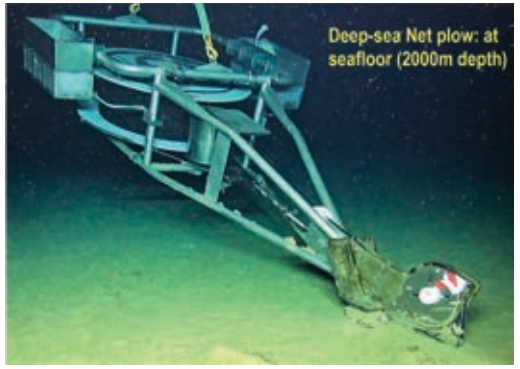
# Seismology and volcanology

The area is prone to numerous natural hazard issues due to high seismicity and the presence of Mount Etna, one of the biggest and active volcanoes in Europe, whose roots possibly sink down to seafloor. Seismicity is linked to the collision between African and European plates and the region experienced large historical earthquakes and some of these strongest earthquakes (the most recent in 1908) caused also very intense tsunami wave.



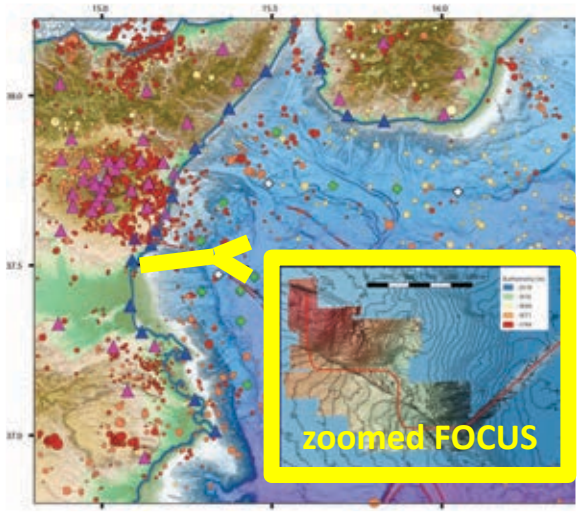
# Optical Time Reflectometry: DAS and BOTDR at INFN

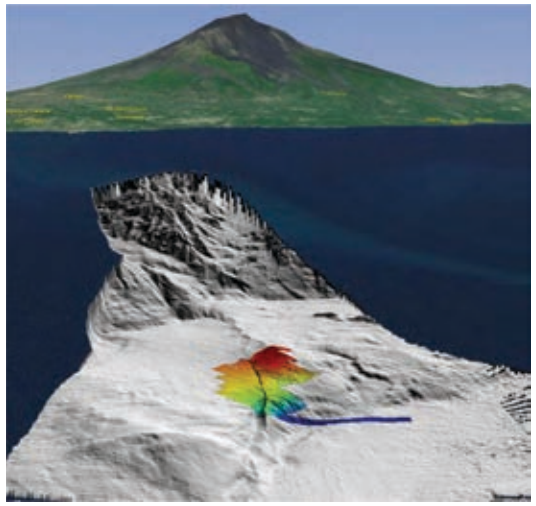
BOTDR (FOCUS) and iDAS acquisition using optical fibres of the Catania Infrastructure plus 6 km extension (looped)
Correlation with acoustics (SMO-OnDE/ EMSO-SN1) and seismic data (EMSO-SN1) and geodetic stations, OBS

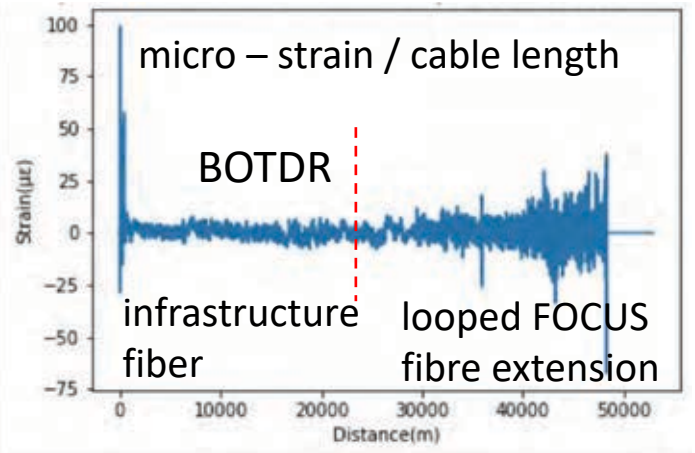


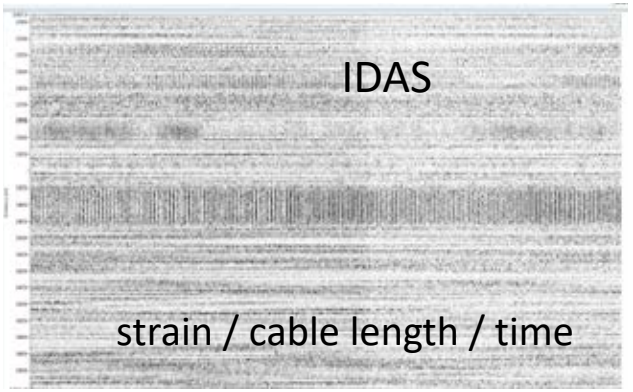

https://www-iuem.univ-brest.fr/lgo/les-chantiers/erc-focus/

Geophysics and Volcanology, studies and real time alert
Surveillance and Marine Planning



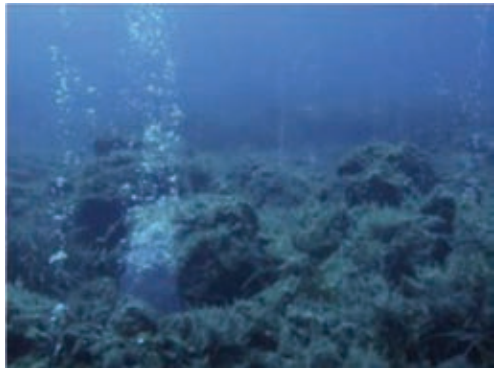



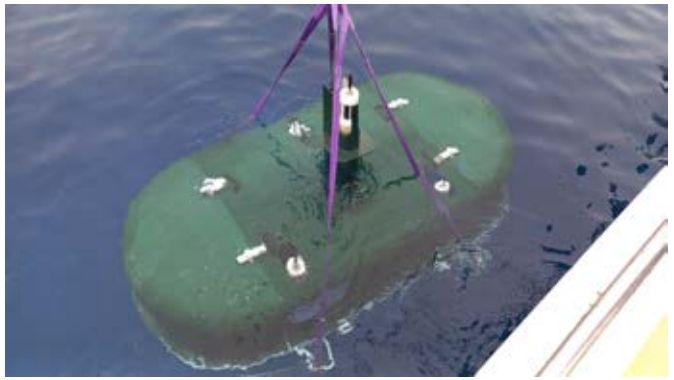


# Carbon dioxide subsea emission and storage studies

IPANEMA



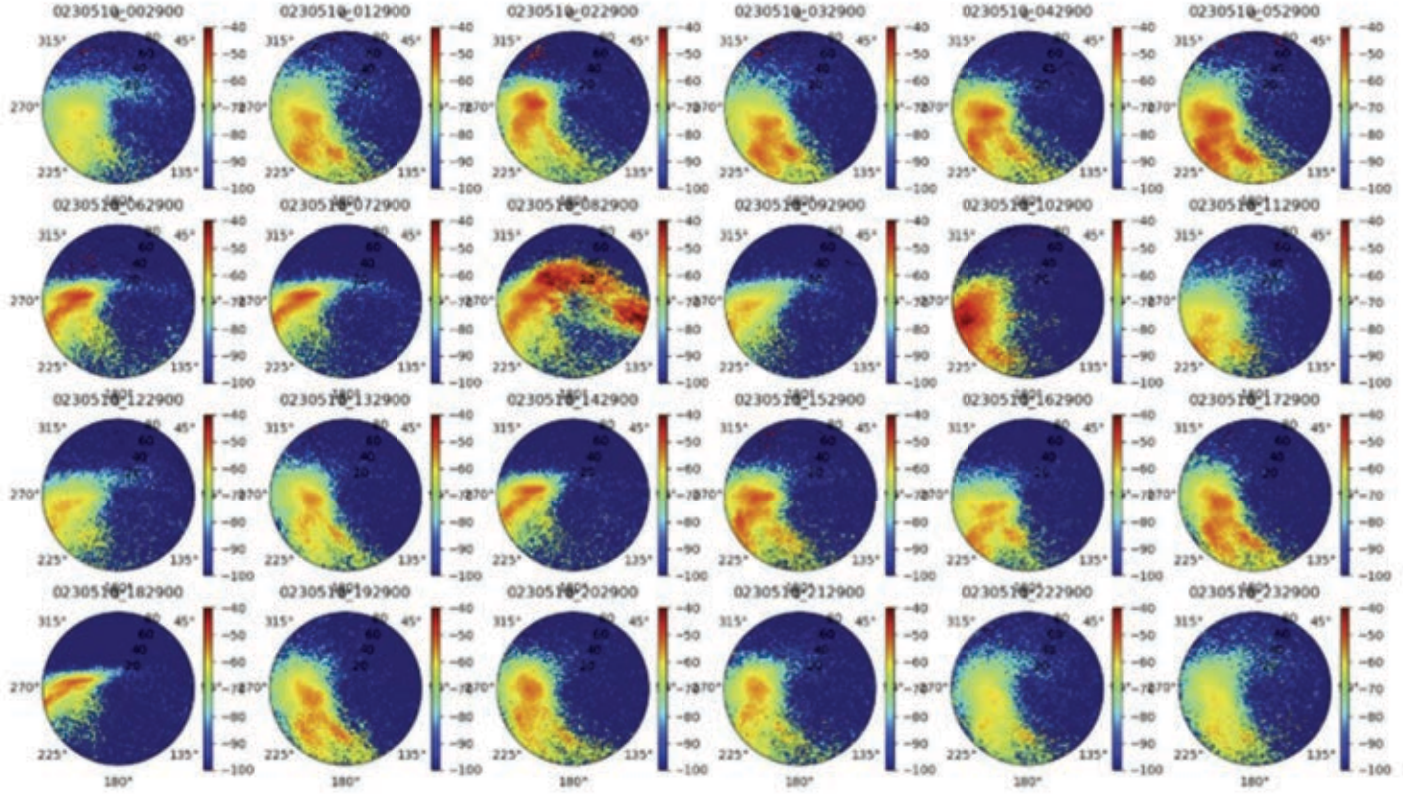


Carbon dioxide emission from subsea floor
Monitoring for possible subsea storage

Autonomous Hydrophone array: CO2 bubbling noise, noise montitoring
Standardised design: easy deployment recovery

# Carbon dioxide subsea emission and storage studies

IPANEMA



Carbon dioxide emission from subsea floor
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Standardised design: easy deployment recovery

# Access to data and infrastructures

KM3NeT

INFRADEV 2

https://www.km3net.org/km3net-eu-projects/km3net-infradev2/data-management-and-open-science/

**Coming soon: Astrophysics Center** for **Multimessenger studies in Europe** (**ACME**)

emso ERIC

https://emso.eu/physical-access/

Geo-iNQUIRE

**Geosphere INfrastructures for QUestions into Integrated REsearch**

https://www.geo-inquire.eu/transnational-access/how-to-apply-for-access

ITINERIS

**Italian Integrated Environmental Research Infrastructures System**

Italiadomani

Finanziato dall'Unione europea NextGenerationEU

# Summary and Outlook

Upon completion, the KM3NeT detector will be one of the largest tracker and calorimeter ever designed

Cross fertilization with Earth and Sea Science is well established:

Many common areas of interest on development and testing of sensors/technique

Many joint projects for environmental monitoring

Particle Geophysics is at the corner

Thanks Stavros!

https://egu-galileo.eu/gc12-fibreoptic/