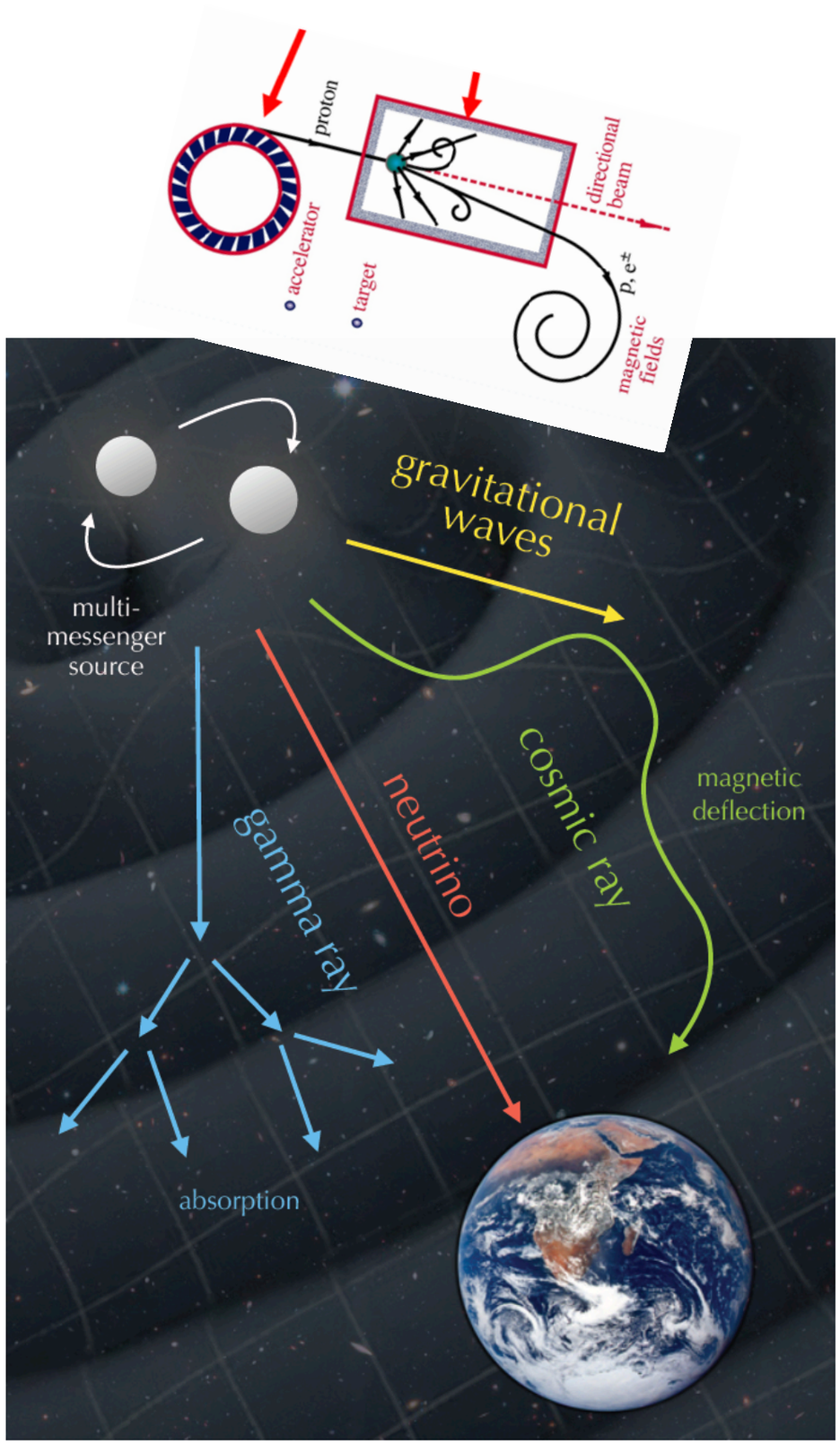
# NEXCOS

**NE**utrinos and **X**-ray follow-up for **Co**smic-ray **S**ource studies

**D. Dornic - D. Porquet - IPhU day - 20/01/2023**

# Context: multi-messenger astronomy




**Multi-messenger: use of at least 2 of the 4 messengers to study extreme astrophysical phenomena. Each one bring one piece of the puzzle.**

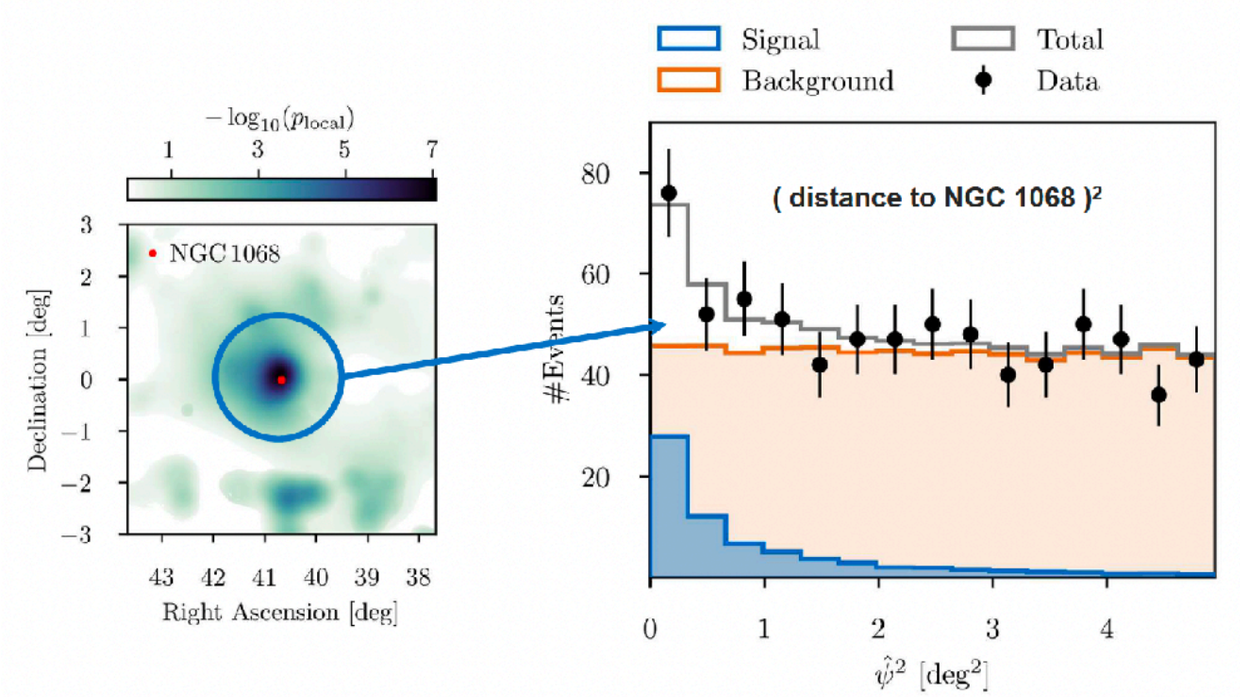
**Neutrinos are neutral, weakly-interacting, elementary particles.**

**⟹ Smocking gun of the cosmic-ray sources.**
**⟹ However, finding neutrino sources is still challenging [large background contamination and tiny fluxes].**
**⟹ Need the coincidence with other messengers i.e. multi wavelength emission) to improve drastically the detection sensitivity.**

# Context: astronomy neutrino

- Detection of the cosmic neutrino diffuse flux by IC/GVD/ANTARES
- One source is particularly interesting, NGC1068, with a 4.2 $\sigma$ detection (~79 HE neutrinos in correlation)
- Several hints have also been observed with flaring blazars (TXS 0506+056, PKS1502+106, PKSB1424-418,PKS0735+178, J0242+1101, etc.) at ~2-3 σ.

$\Longrightarrow$ We are reaching the top of the iceberg of the individual source detections.




NGC1068 (M77), nearby active galaxy nuclei (not jetted)
Distance:~14.4 Mpc
$\Longrightarrow$ neutrino production in obscured core of the AGN (not by the star formation)

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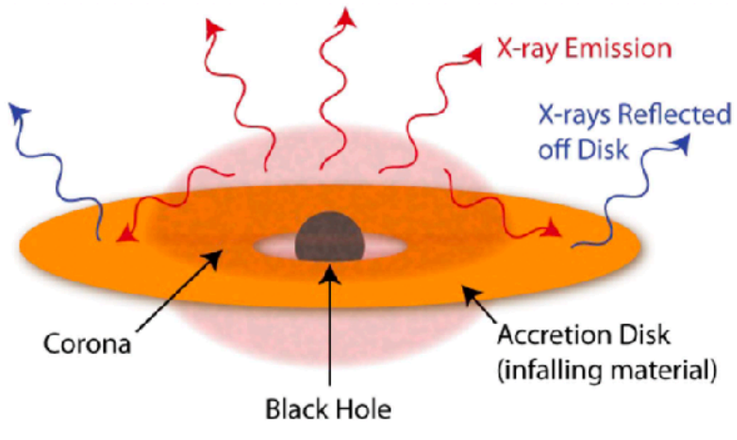
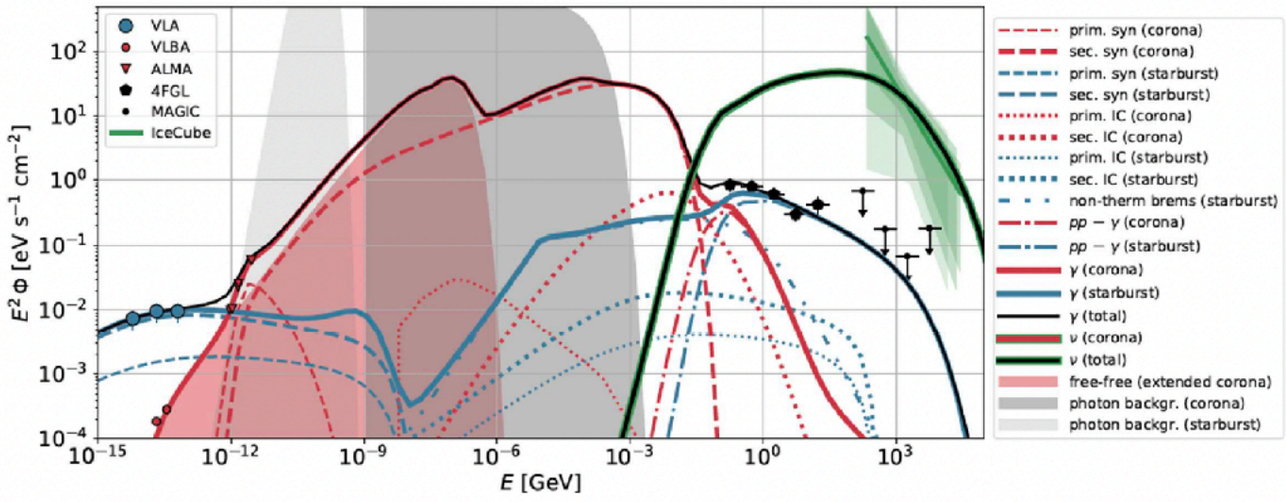
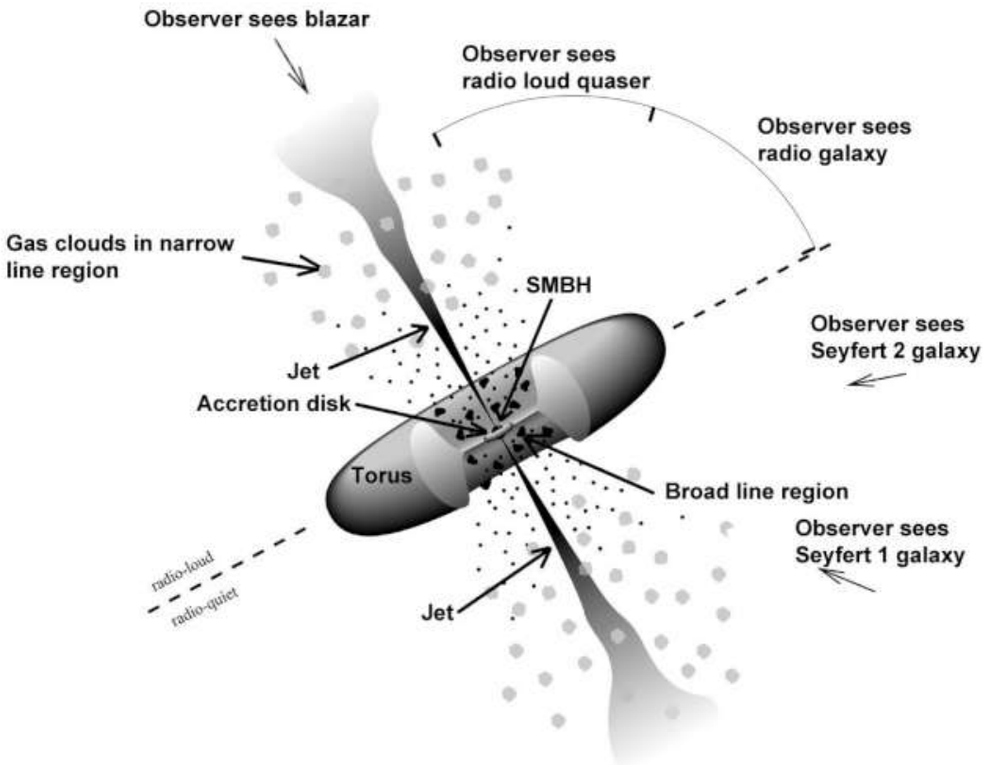
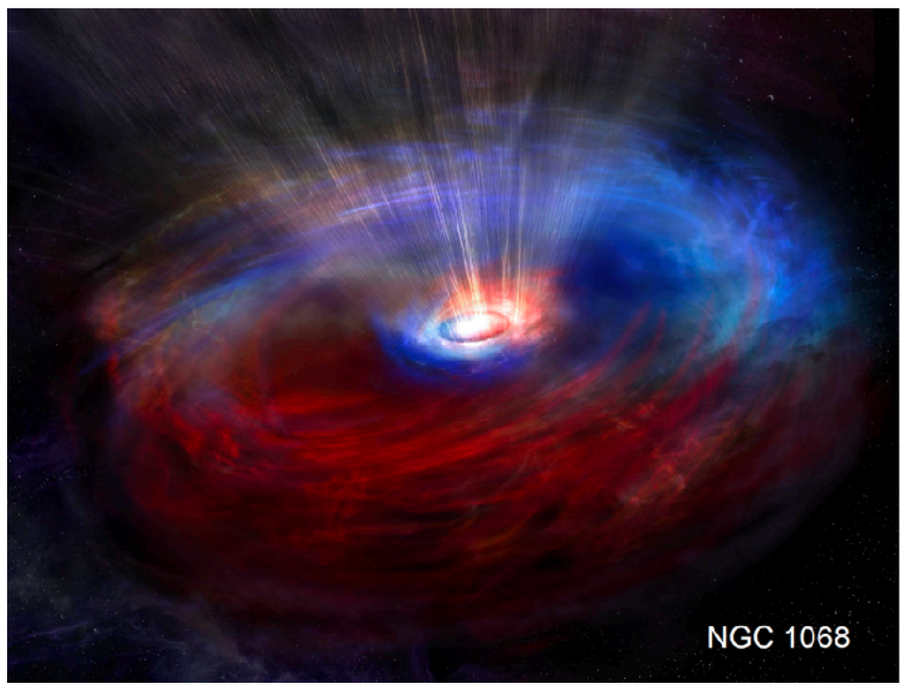


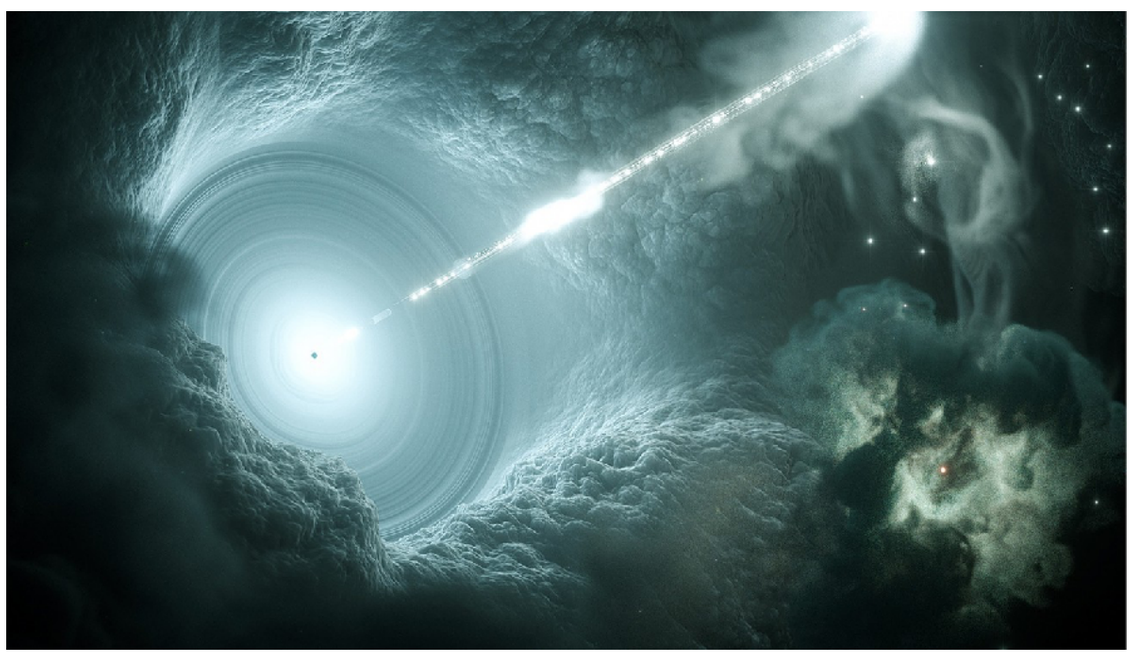



# Context: Active Galaxy Nuclei

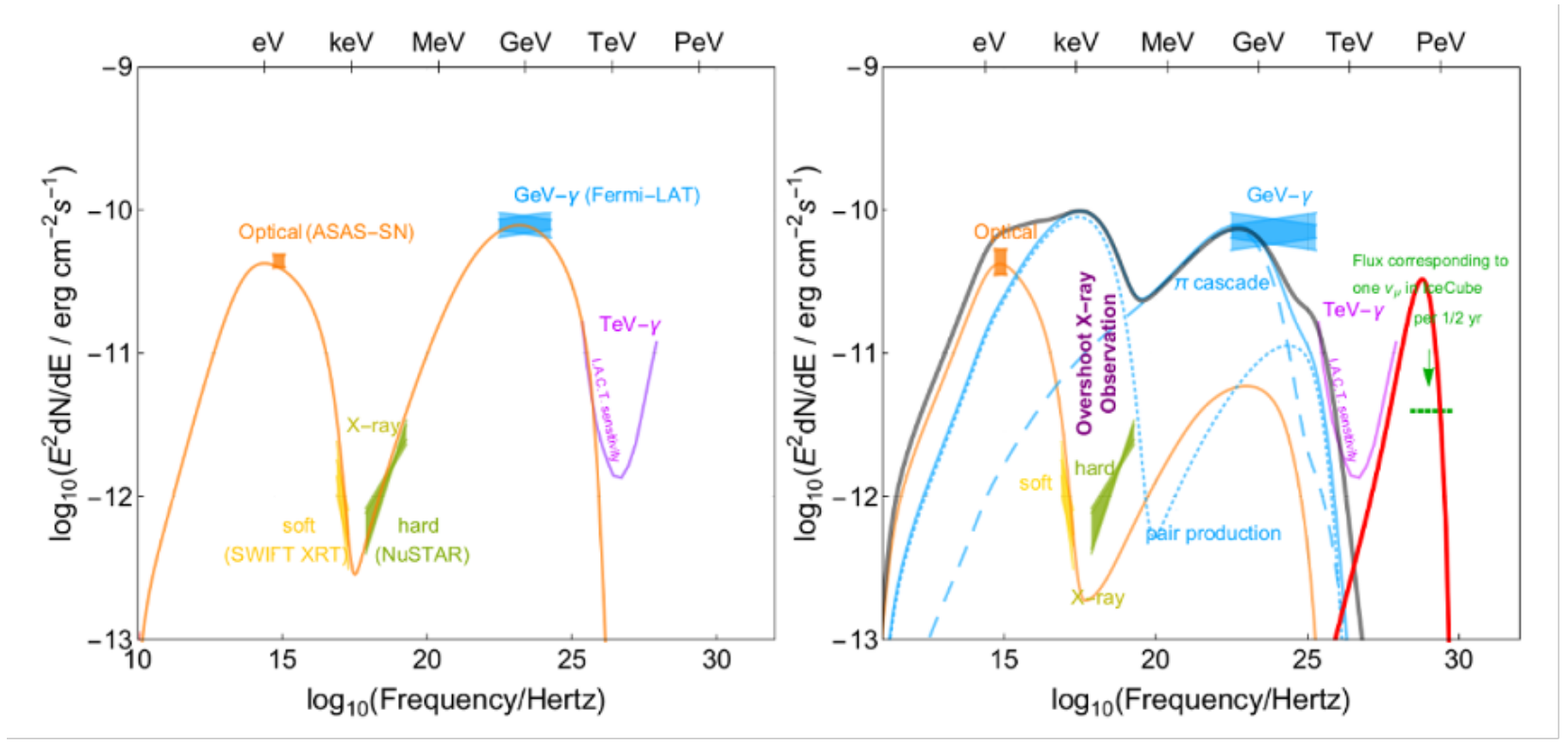



- Active Galaxy Nuclei (AGN): are among the most powerful emitters of electromagnetic radiation in the Universe.
- Supermassive black holes ($10^6$ - $10^9$ $M_{Sun}$) are located at the center of almost all galaxies and are called AGN when a very significant amount of matter is accreted and/or ejected by them
- Amongst AGN, blazars and Seyfert galaxies have been proposed to be powerful cosmic accelerators and thus prominent candidates of high-energy astrophysical neutrinos.



# Context: importance of the X-ray follow-up




Broadband SED of TXS 0506+056 with a purely leptonic model (left panel) and a purely hadronic model (right panel)(Gao + 2019).

**X-rays are the most crucial wavelength to constrain particle acceleration processes in those sources and to understanding neutrino production :**

- PeV protons will interact mainly with keV photons (X-ray flux determines the neutrino production efficiency).
- Proton interaction may lead to a significant secondary gamma-ray emission either directly or after re-processing in the magnetic fields in this keV energy ranges.
- Seyfert galaxy (NGC1068, Cen A…) emission is dominated by the X-ray emission from the hot corona. Important to monitor the X-ray spectral and timing behavior
- Thanks to XRISM (2023-24), the very fine X-ray spectroscopy will allow us to trace high-energy protons (accelerated protons may interact with iron nuclei that are very abundant in AGN accretion disc, inducing nuclear spallation that will enhance Mn, Cr, V, Ti emission lines)

# NEXCOS project

**The goal of the project is to study the link between AGNs ans cosmic ray/ neutrino production, i.e. perform in particular a X-ray follow-up to study each association between AGNs (X-ray/$\gamma$-ray) and neutrinos detected by the neutrino telescope KM3NeT:**

- WP1: define and implement event selections for all-flavor astrophysical neutrinos at low and high energies detected by KM3NeT using advanced data analysis tools

- WP2: study the **multi-wavelength electromagnetic emission** and the **neutrino production** in AGN - Define a list of AGN potentially bright in neutrinos.

- WP3: perform the optimum multi-wavelength electromagnetic follow-up of the AGN-neutrino associations.

- WP4: perform the **multi-messenger analyses** of each neutrino-AGN associations: estimation of the joint significance, construction of the hybrid SED function of the studied AGN and extraction of the microphysics parameters based on the fit of the SED.

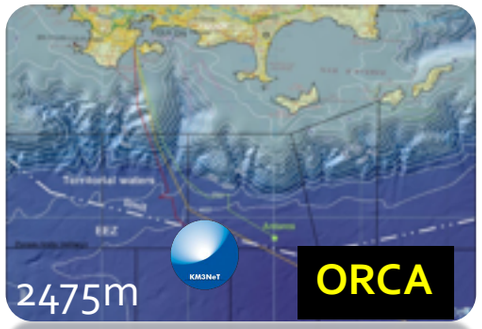
$\Longrightarrow$ 1 young postdoc starting Spring-Summer 2023

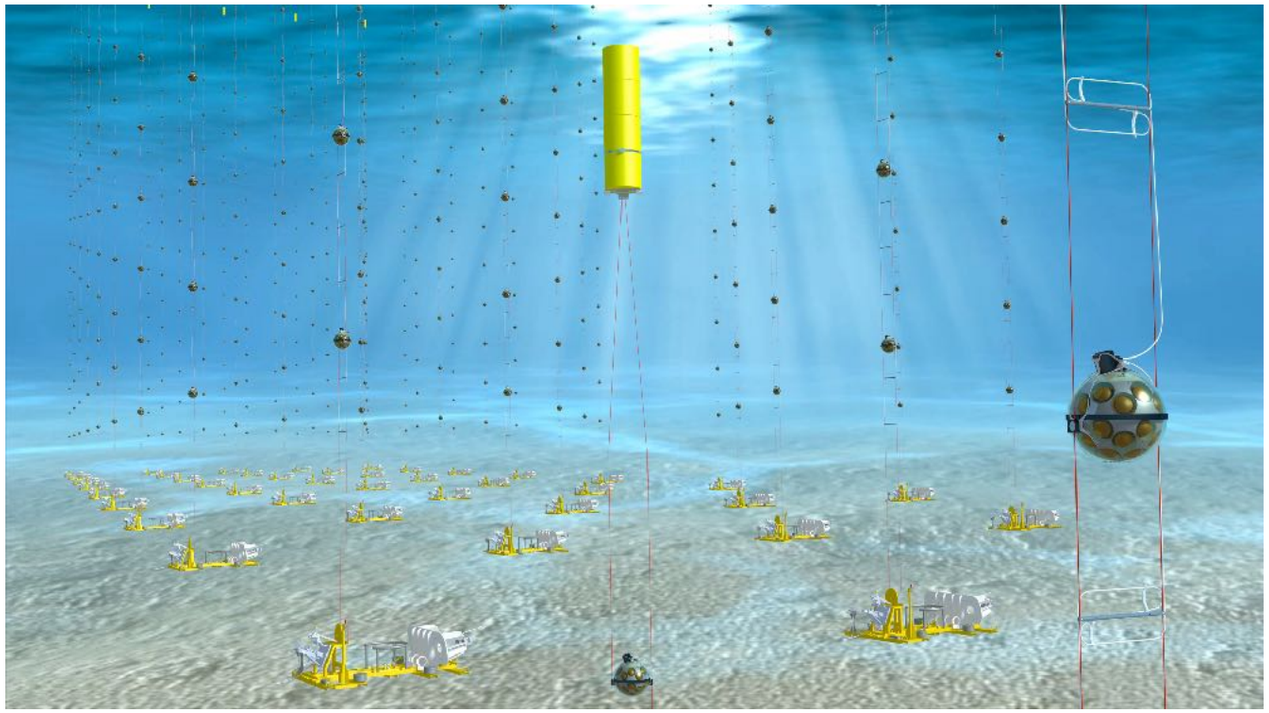
# KM3NeT

**KM3NeT** is the neutrino research infrastructure in the deep Mediterranean Sea

**O**scillation **R**esearch with **C**osmics In the **A**byss

ORCA: off shore Toulon, France



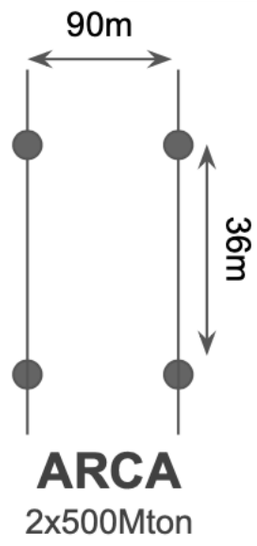
**A**stroparticle **R**esearch with **C**osmics In the **A**byss

ARCA: off shore Capo Passero, Italy

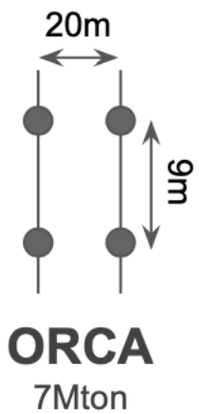

## Main characteristics:

- Extended energy range: 1 GeV → 10 PeV (+ 10-40 MeV)
- Full sky coverage with the best sensitivity for the galactic sources
- High duty cycle (> 95%)
- All-flavor neutrino detection
- Good angular resolutions

⟹ 15/21 lines already in operation (+~20 in 2023)




**230 DUs, 128340 PMTs**



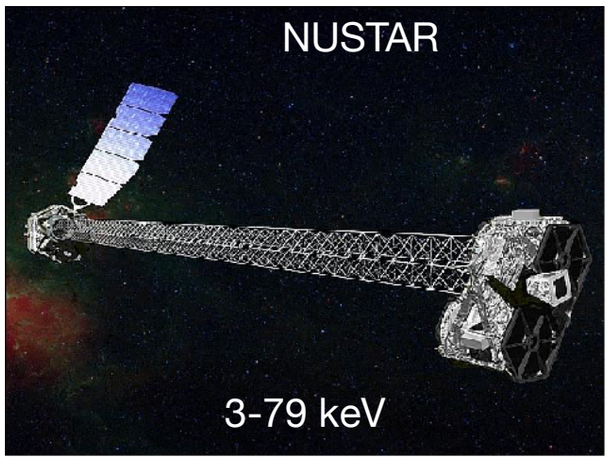

**115 DUs, 64170 PMTs**

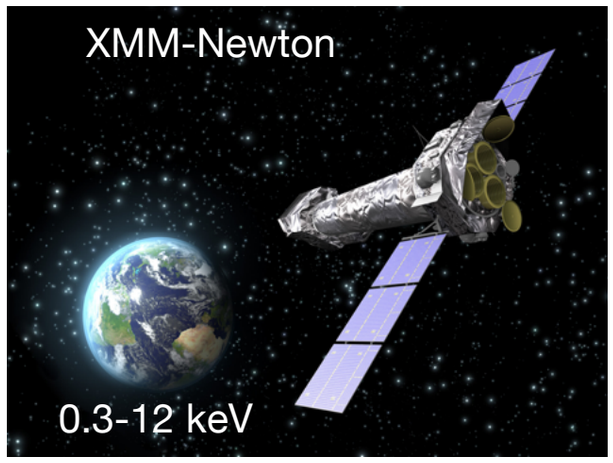
# Follow-up instruments

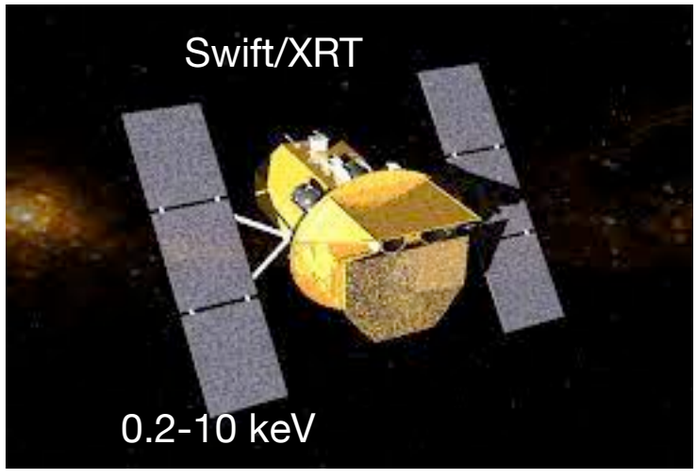
- SVOM: franco-chinese satellite (4 instruments) + ground telescopes
- COLIBRI: 1.3m diameter robotic telescope equipped with 2 instruments (2 visible arms + 1 NIR channel CAGIRE)

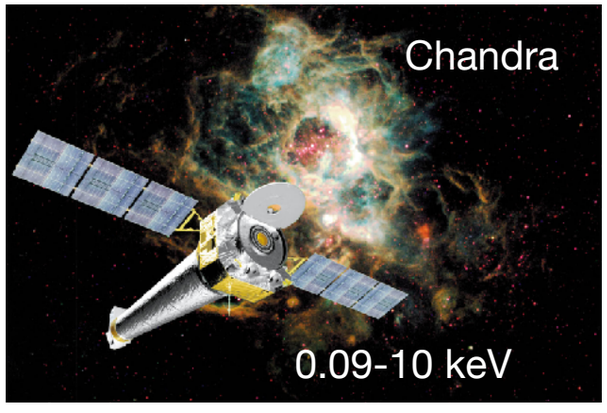
⟹ Launch of SVOM end 2023 + installation of COLIBRI at OAN mid 2023.

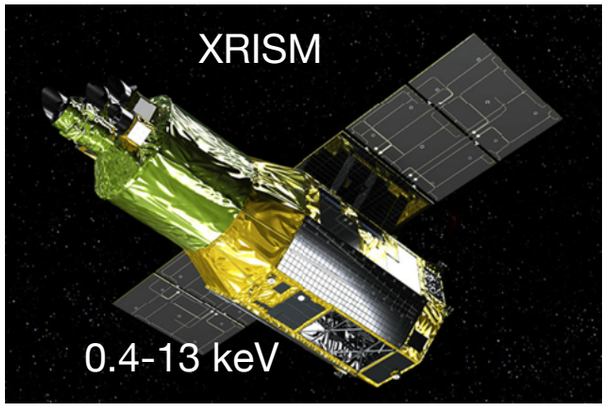
⟹ ToO with MXT/VT/COLIBRI + proposal TAC




X-ray follow-up instruments for the characterization of the AGN in coincidence with the neutrinos: NUSTAR, Swift, XMM-Newton or Chandra, XRISM

⟹ ToO/DDT + proposal TAC