



APC High-Energy Astrophysics group

*These slides reflect discussions with project leads **and not final decisions**. Their purpose is to open a debate that the group will pursue collectively in the coming months.*

Scientific objectives of the AHE group

Origin of cosmic rays and acceleration mechanisms

- Identify Galactic PeVatrons and high-energy neutrino sources
- Probe particle acceleration at different scales (pulsars, AGNs, ...)
- Measure flux of EeV cosmic rays

Physics of compact objects and transient phenomena

- Understand accretion/ejection processes at different scales
- Cartography of the population of high-energy transients (GRBs, TDEs, supernovae, ...)

Evolution of the Universe

- Use high-redshift transients to probe early Universe
- Formation and evolution of black holes and their environments

Nature of dark matter & fundamental physics

- Constrain dark matter through indirect detection methods
- Test fundamental physics with extreme Universe (SQM, LIV, ...)
- Search for axion-like particles in AGNs & Galactic sources spectra

Identity of the AHE group: multi-wavelength and multi-messenger approach

From objectives to current activities

Four modes of action to meet these objectives

1

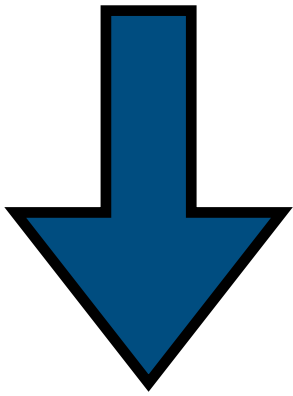
We build instruments

2

We develop data analysis tools



With expertise of APC technical services



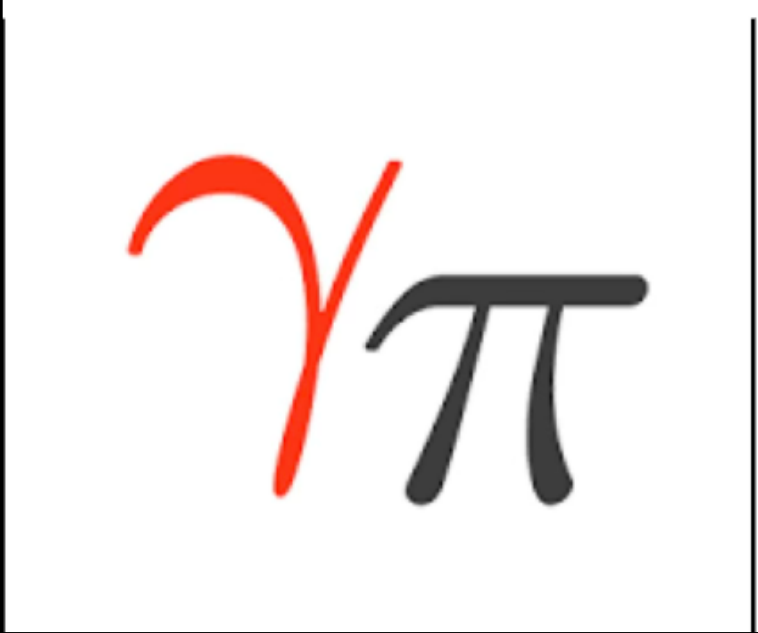
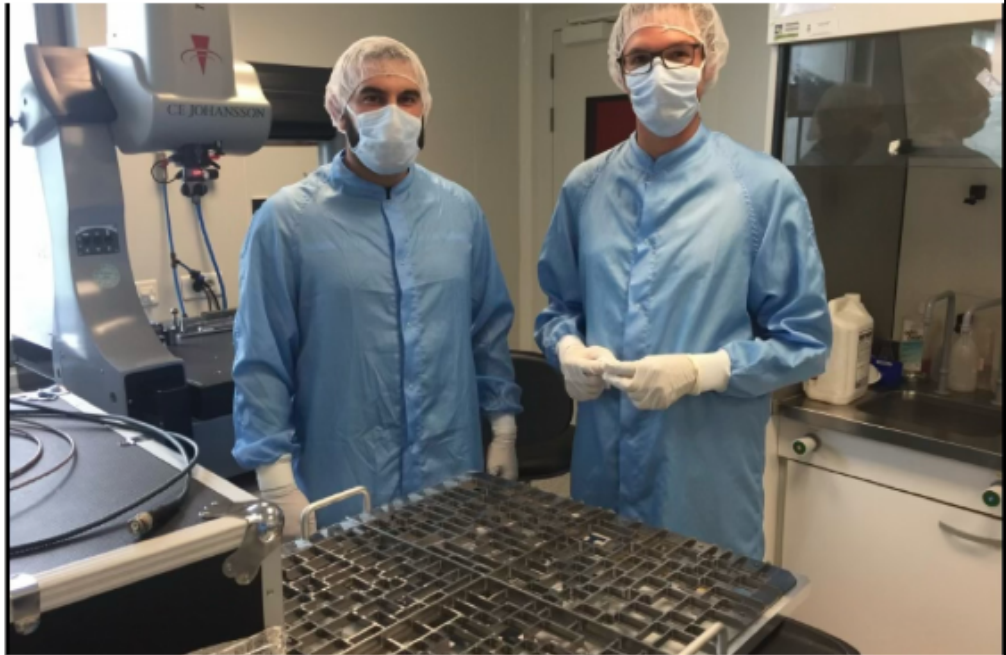
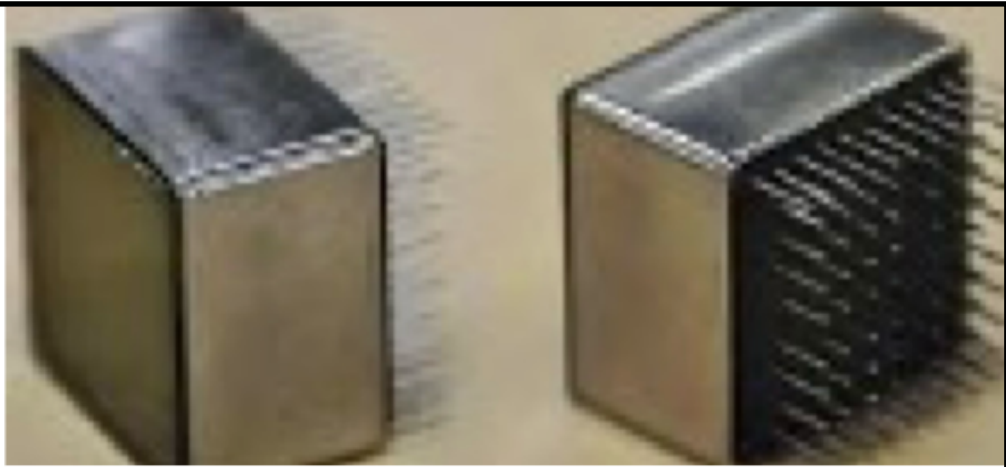
Building instruments and pipelines guarantees access to data and leadership on scientific programs

3

We operate instruments and analyse their data

4

We interpret data (numerical simulations + phenomenology)



From objectives to current activities

- ● ● Strong contribution
- ● Medium contribution
- Small contribution

Photons

Cosmic rays

Neutrinos

Exotic matter

Numerical tools

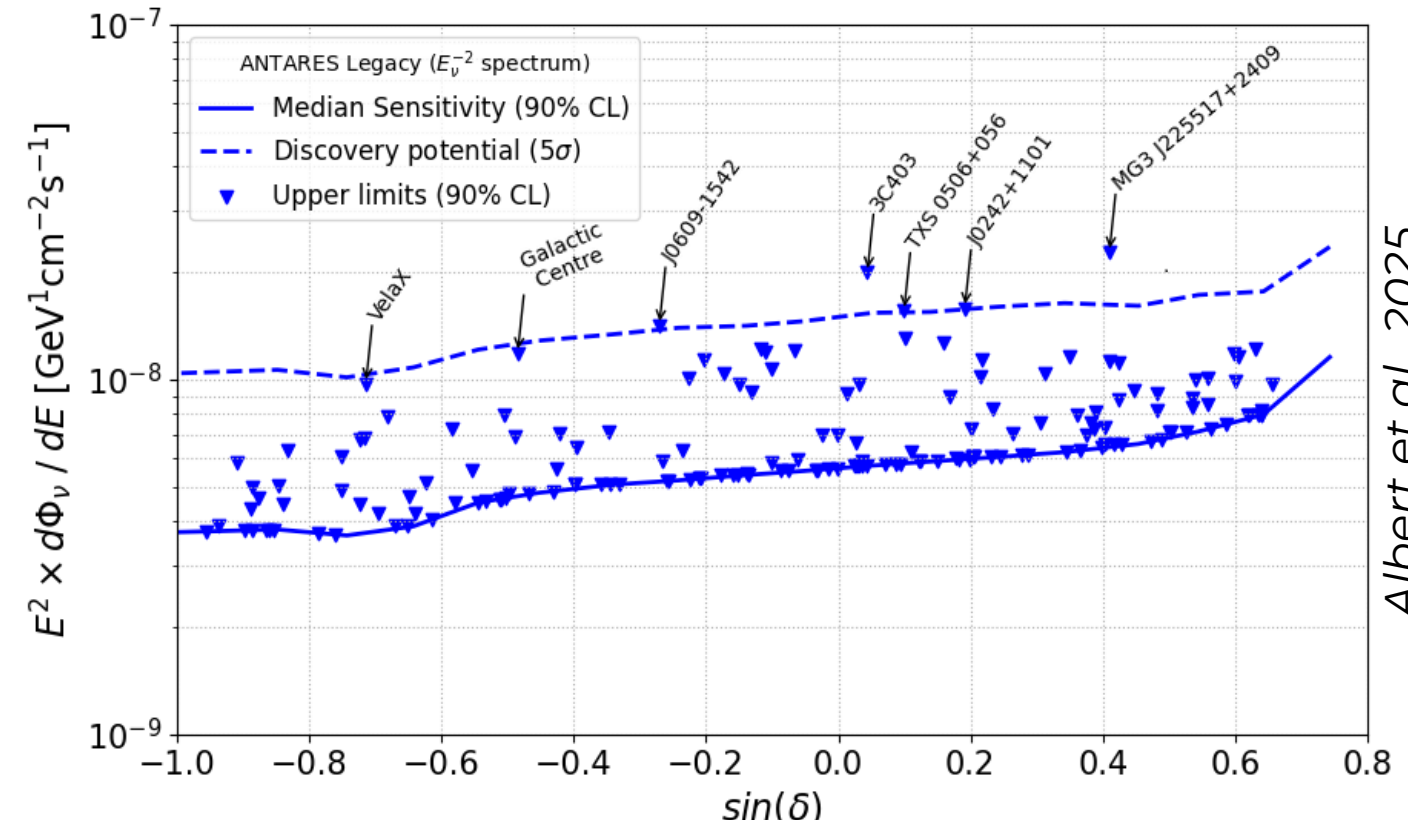
	Origin of cosmic rays and particle acceleration	Compact objects & transients	Evolution of the Universe	Fundamental physics and dark matter
NewAthena	● ●	● ● ●	● ● ●	●
SVOM / CATCH		● ● ●	● ● ●	●
HESS / CTAO	● ● ●	● ● ●	● ●	●
IGOSAT	● ●			● ●
LHAASO / SWGO	● ● ●	● ●		
JEM-EUSO	● ● ●			●
KM3NeT	● ● ●	●		●
SQM-ISS			●	● ● ●

Gammapy	● ● ●	● ●	● ● ●	● ●
e-NOVAs	● ● ●		● ● ●	●
IVOA	● ● ●	● ● ●	● ● ●	● ● ●

Recent milestones

2 decades of neutrino astronomy in the Mediterranean Sea: from ANTARES to the highest-energy neutrino ever detected

- **ANTARES dismantled in 2022** after 16 years of data taking, leaving a rich legacy
- Legacy papers with strong contribution from APC (diffuse Galactic neutrino flux, ...)

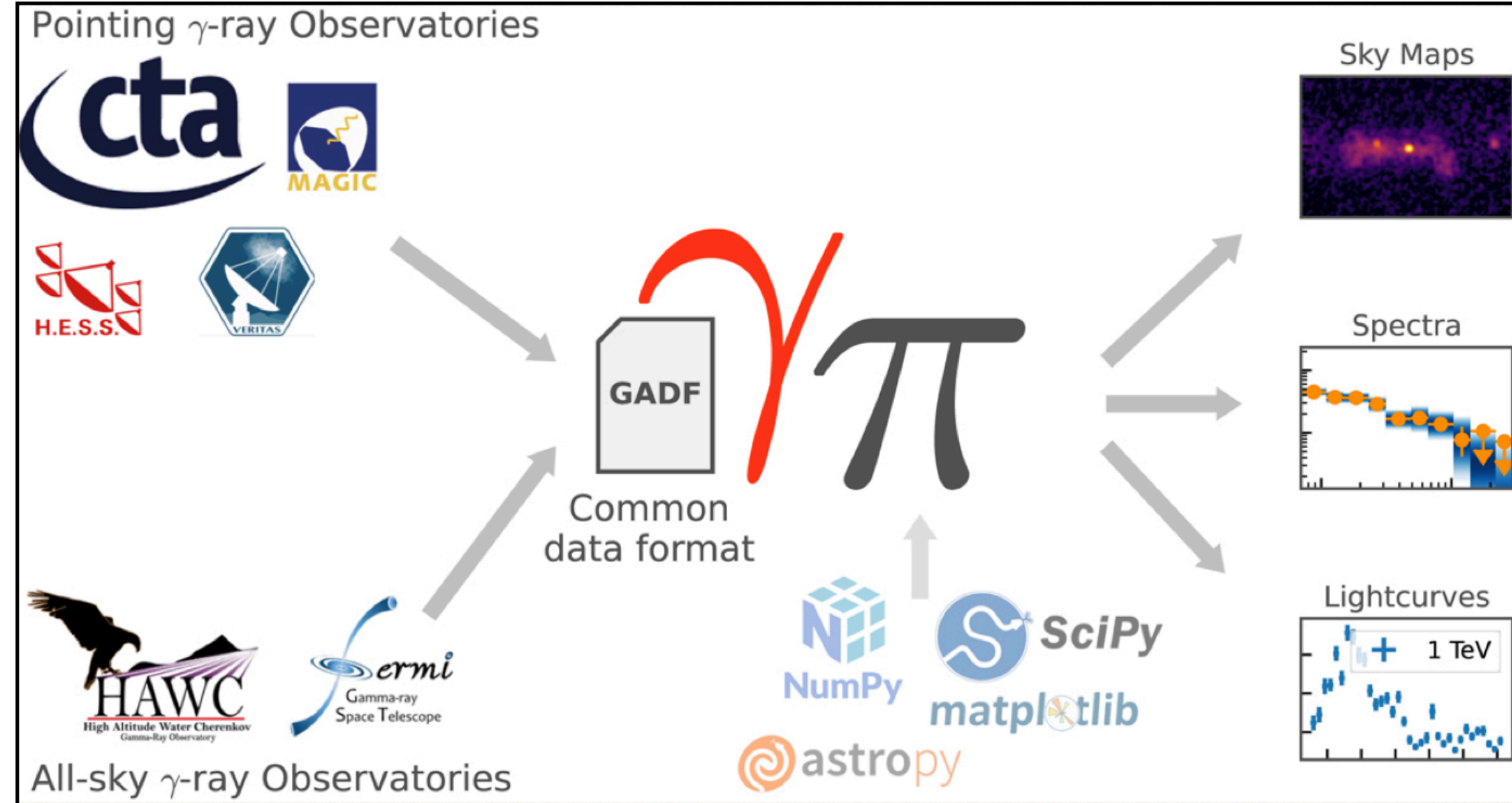


- **KM3NeT currently under deployment** (ARCA 51 since July 2025)
- **KM3-230213A** (~220 PeV, Nature 2025) **opens a new window on PeV neutrino sources**
- AHE group involvement on direction uncertainty estimate + physical origin
- Future of neutrino astronomy is bright!



KM3NeT collab., 2025

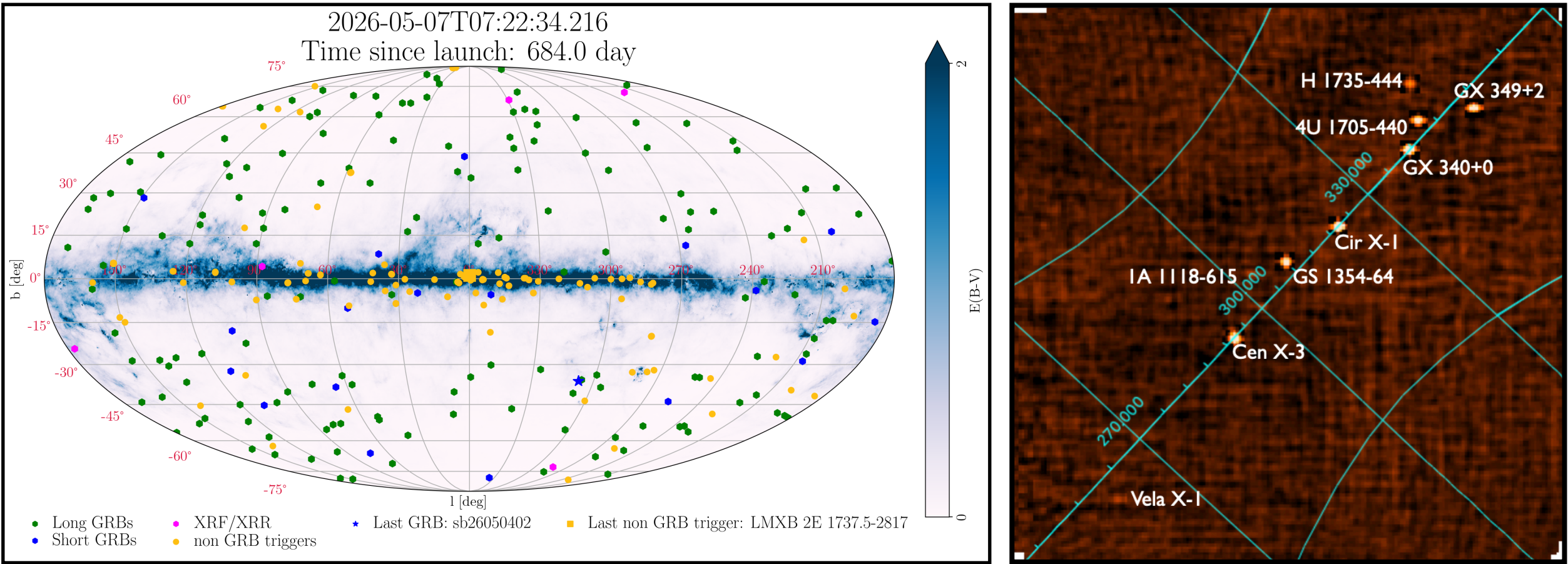
APC-led Gammapy becomes the standard analysis tool for the next decade of gamma-ray astronomy



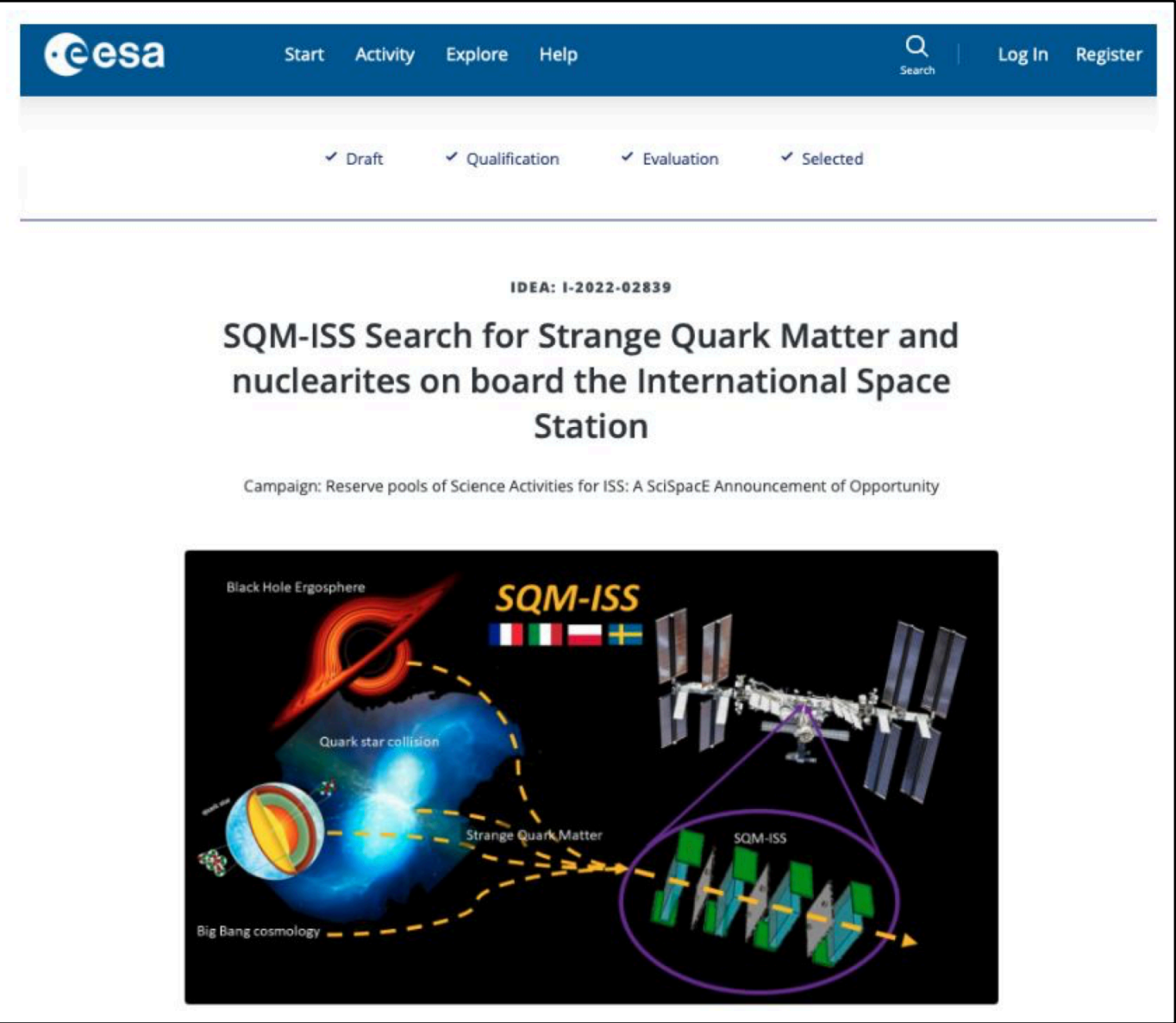
- APC: main contributor
- **Adopted by CTAO**, H.E.S.S., MAGIC, VERITAS, HAWC, LST-1, SWGO
- Now **extending to neutrino** (KM3NeT/ACME) and **X-ray** data
- Becoming the **multi-messenger analysis platform** of reference

Recent milestones

SVOM detects its first astrophysical transients



SQM-ISS selected by ESA to search for Strange Quark Matter



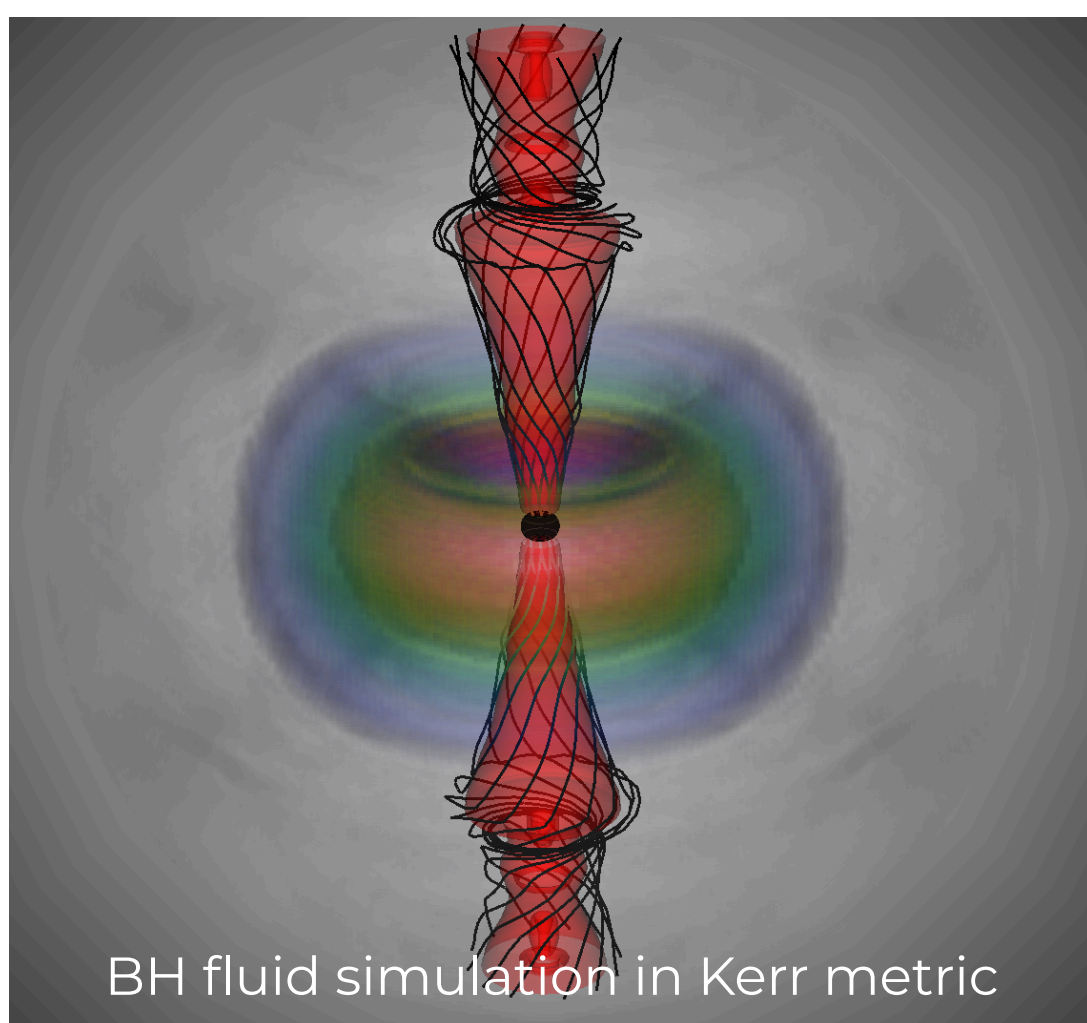
- **~300 GRBs detected since 2024** (~100 by ECLAIRs). GRB250314A at $z=7.3 \Rightarrow$ discovery of the most distant supernova by JWST
- **Strong involvement of AHE group:**
 - ECLAIRs X-band pipeline
 - Leadership on Observatory Science + ToO programs
 - Constrain X-ray flash population: GRB251122A (led by APC - Z. Lin et al.)
- **SVOM special issue** (3 papers led by APC researchers)

- **Open a new observational window on exotic dark matter candidates**
- Detailed design and tests ongoing
- To be deployed on the International Space Station in 2028/2029 (TBC)
- **APC responsible for the development of the front-end detector** (scintillators, SiPM + readout chain)

Synergies with other groups

AHE x Theory: HENBoS project (PI: M. Lemoine)

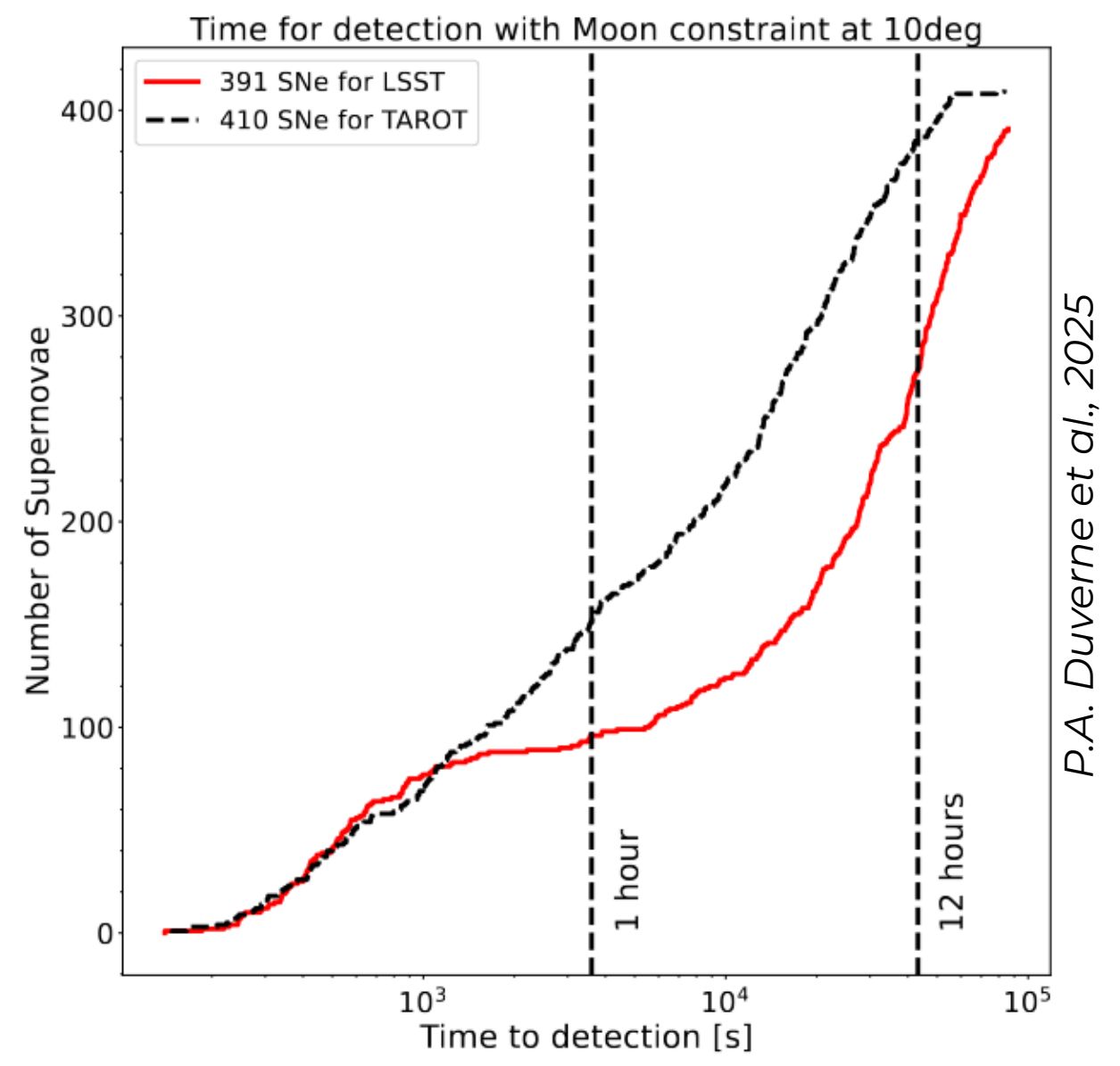
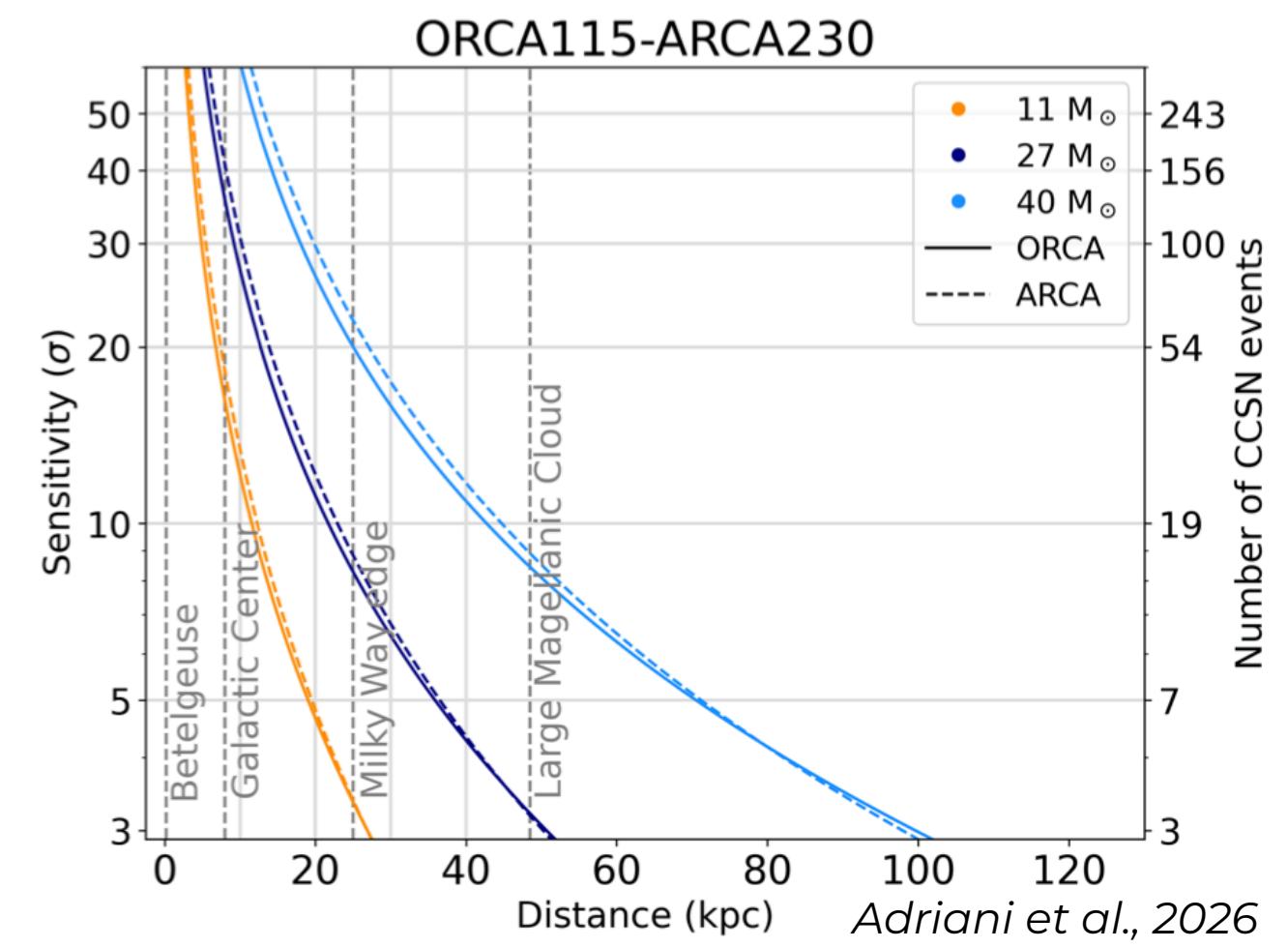
- **Where and how are particles accelerated to very high energies around supermassive black holes?**
- High-performance **GRMHD-PIC simulations** to track high-energy ions across all relevant sites (jet, corona, turbulent flow, ...)



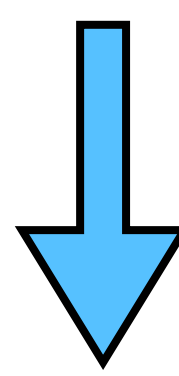
BH fluid simulation in Kerr metric

- **Multi-messenger flux predictions** for upcoming detectors (KM3NeT, CTAO, ...)

AHE x Particles: neutrinos from Galactic supernovae



- **LEAK project since 2018** (funded by LabEx UnivEarthS): **assess CCSN neutrino detectability with KM3NeT, DarkSide and DUNE**
- Detection of neutrino burst would help to locate the source through triangulation

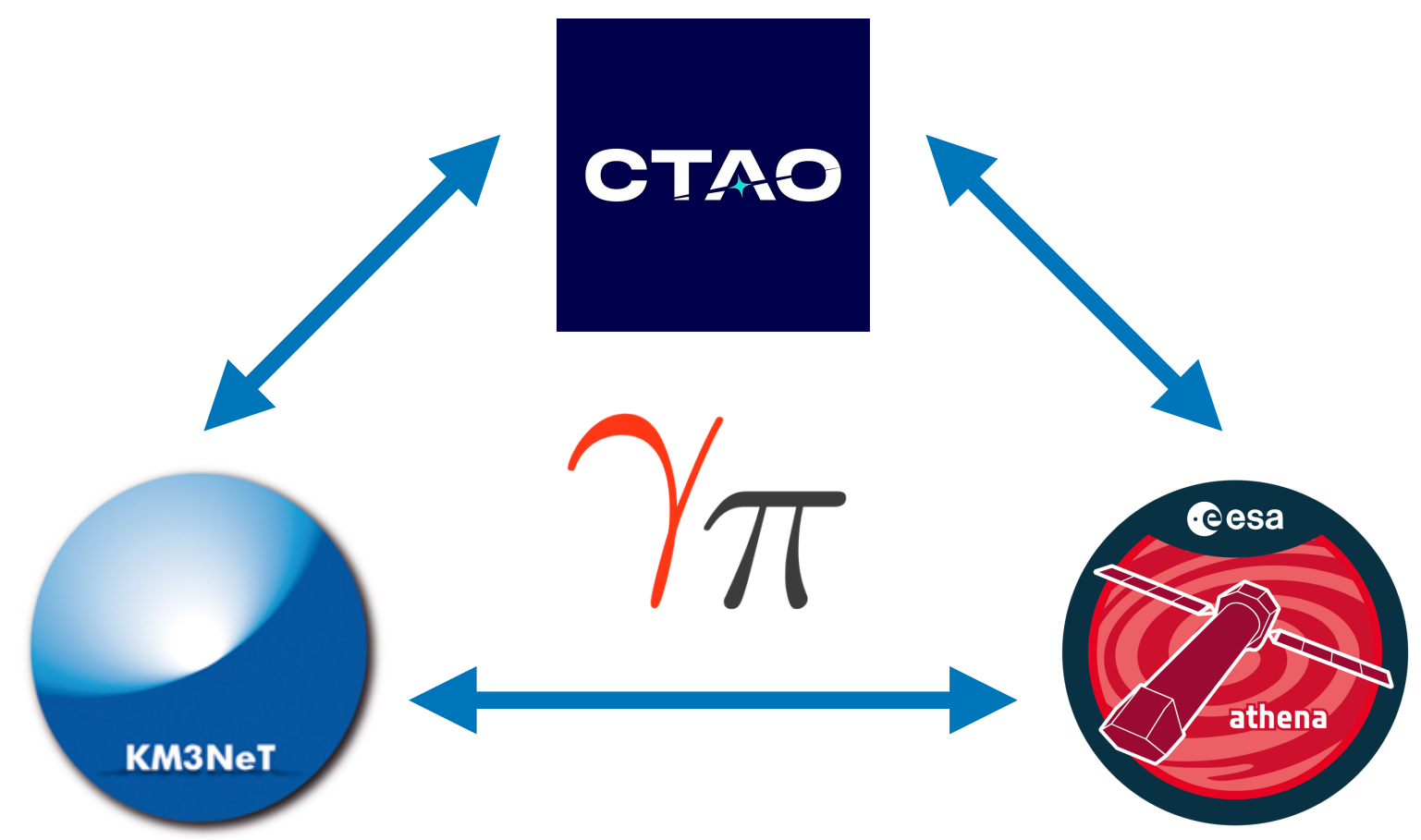


- Optimisation of the **electromagnetic follow-up strategy** with space and on-ground facilities to quickly identify the source

Scientific and technical opportunities

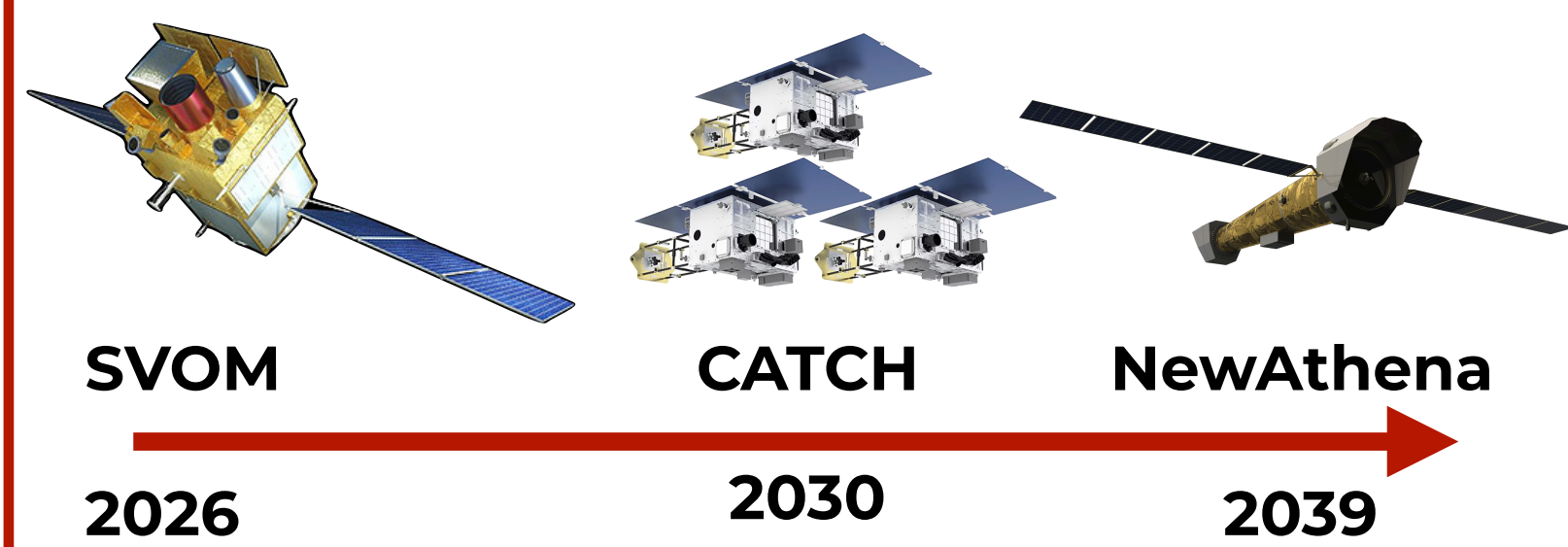
Constrain the origin of (Galactic) cosmic rays

- Start of CTAO operations + ramp-up of KM3NeT/ARCA
- ⇒ **AHE group could be a key player** in the joint exploitation of CTAO & KM3NeT data
- One common tool to perform the analyses: **Gammapy**
- NewAthena to probe conditions of particle acceleration on longer term

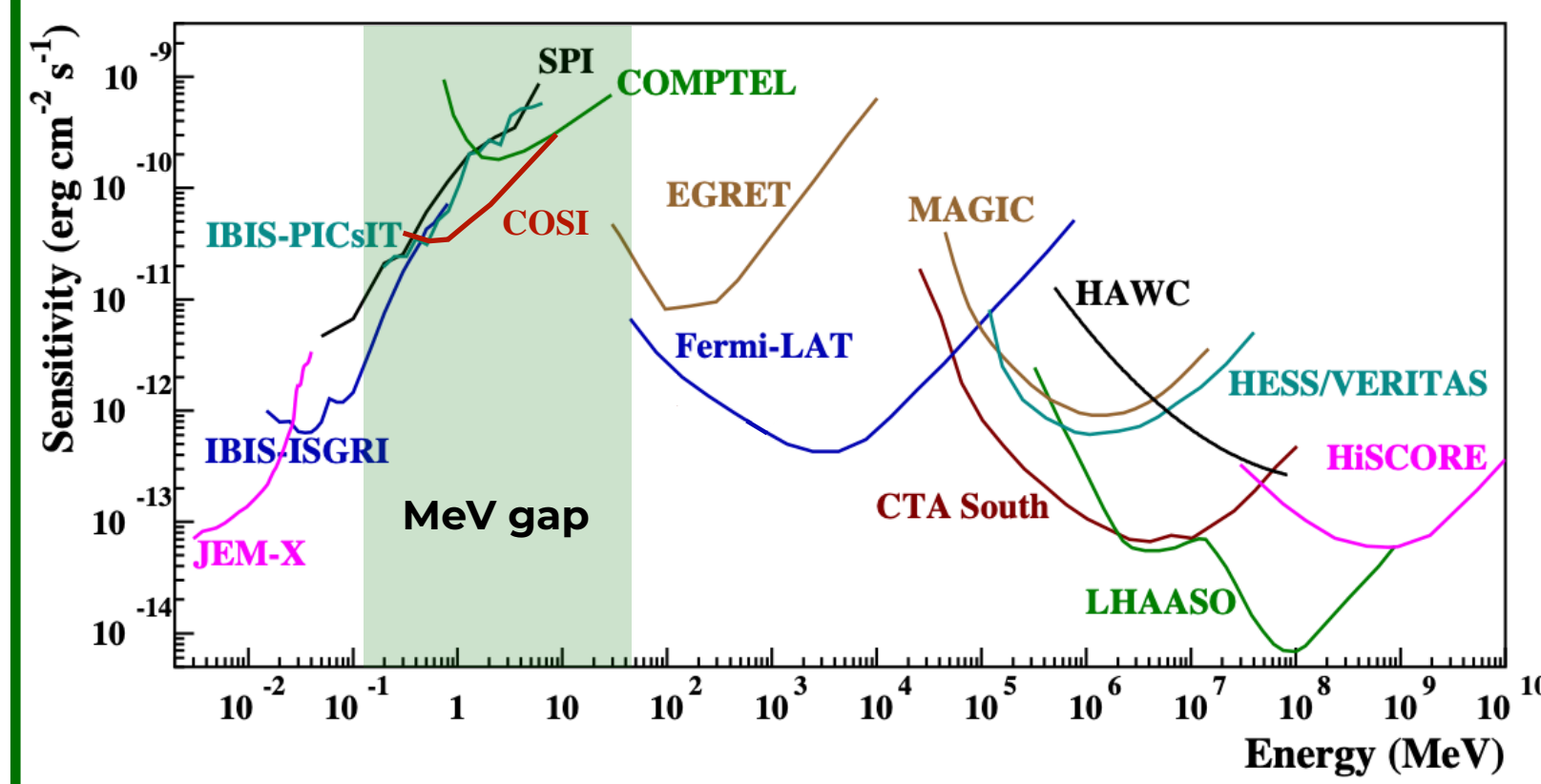


From SVOM to NewAthena: a 15-year transient science program

- AHE group developed strong expertise on time-domain astronomy thanks to SVOM
- Leadership to be confirmed with **CATCH & CTAO**
- Pave the way to **NewAthena** - need to take advantage of APC strong involvement on X-IFU hardware
- Build a long-term scientific program on transients and their use as probes of the early Universe



Filling the MeV gap: a new observational window for APC?






- **0.1-100 MeV:** key to probe non-thermal Universe
- **ASTROGAM proposal not selected** by ESA for M7 mission
- **LArTPC technology** proposed as alternative for MeV astronomy
- Build on **APC (Particles group) expertise** on LArTPC detection method ⇒ **long-term R&D opportunity for APC / Ile-de-France laboratories ?**

Challenges to overcome

Objectives

Challenges

Motivations

	Objectives	Challenges	Motivations
 Short term	To make real use of multi-messenger datasets \Rightarrow need to interpret them together using joint fits	<ul style="list-style-type: none">• Implement self-consistent (lepto-hadronic) astrophysical models into Gammapy (synergies with Theory group ?)	<ul style="list-style-type: none">• Separate fits leave too many physical parameters unconstrained• Gammapy has the potential to become the next standard tool for high-energy astronomy analyses
 Mid term	Sustained leadership in transient science with SVOM, CATCH and secure strong scientific position in NewAthena	<ul style="list-style-type: none">• Maintain human resources on SVOM operations and CATCH development• Engage in NewAthena science working groups now (interface Cosmology, Gravitation groups ?)	Unique time window for APC to maintain leadership on transient activities and take advantage of APC strong involvement in X-IFU development
 Long term	Define a coherent long-term (space) instrument strategy	<ul style="list-style-type: none">• Make collective decisions on future commitments (MeV R&D, ...)	Several options but funding strategies and APC contributions to be clarified

Priorities for the next 5 years

Anticipate our involvement in CTAO early science and Key Science Projects

- Will determine our scientific visibility for the next decade.
- Define priority targets we want to study (Galactic PeVatrons, AGNs, ...) jointly with KM3NeT/ARCA.

Consolidate APC as a national leader in time-domain astronomy

- Build on SVOM/ECLAIRs expertise to maintain leadership on transients.
- Prepare the scientific transition to CATCH and NewAthena

Invest in Gammapy as a common multi-messenger analysis framework

- Extend it to neutrino and X-ray astronomy
- Strategic infrastructure that benefits all activities of the group
- Secure long-term development



Future of ACME ?

Other open questions:

- SWGO/LHAASO involvement \Leftrightarrow future of HESS (public archives)
- Impact of AI on our activities (pipeline development, ...)