High Energy Astrophysics APC

A. Lemière

On behalf of the HEA group

HCERES, 29 November 2017

The HEA group

34 Group Members :

- 21 permanent researchers :
  - 10 CNRS
  - 7 EC *(6 Paris Diderot, 1 Paris Sud)*
  - 4 CEA
- 2 EMERITES, 1 scientific associate (CEA)
- 3 Post-docs
- 7 PhDs
- 14 APC members as secondary group
- 9 associated researchers *(CNRS,CEA, Observatoire, ect…)*

Group evolution

	2013	2014	2015	2016	2017
Staff researchers	23	23	23	23	21
Post-docs	7	7	7	5	3
Phds	8	7	7	8	7

	2017	2018	2019	2020	2021	2022
Staff researchers	21	22	22	22	22	21
Post-docs	3					
Phds	7					

- 2016 : F. Lebrun & V. Beckmann's leave.
  X-gamma space missions

- 2016-2017: End of several post-docs :
  End of CNES Integral post-docs
  End of CNES Hitomi, Taranis post-docs

- End 2017 : 2 years post-doc for CTA (founded by in2p3)

- Within next years: 2 emerites + 1 more retirement
- 2018 : arrival of a new MCF P7
- New CDD CNES for TARANIS and SVOM in 2018/2019

High Energy Astrophysics

Theory

Model

Simulations

Physical processes

Acceleration & Propagation
Accretion & ejection
Stellar Explosion
ISM physics & chemistry

Astrophysical objects

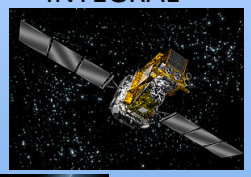
Supernova remnants & Shocks
Pulsars & isolated NS
Active Galactic Nuclei & SMBH
Gamma-ray burst & Supernovae
Compact binary systems

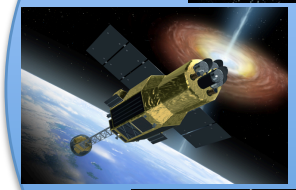
Messenger	Experiments
Photons	**X-rays:** Athena **hard X-rays:** INTEGRAL, SVOM, Astro-H, Taranis **Space Gamma-ray Telescopes:** ASTROGAM, Gamma-Cube **Tcherenkov Telescopes:** HESS-I & -II, CTA
UHE CRs	JEM-EUSO,
VHE neutrinos	ANTARES, KM3NeT

Teams & Projets

10^3eV 10^6eV 10^9 eV 10^{12} eV 10^{15} eV 10^{18} eV 10^{21}eV

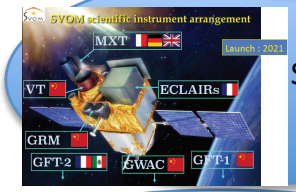
INTEGRAL





ASTRO-H

TARANIS
microsat

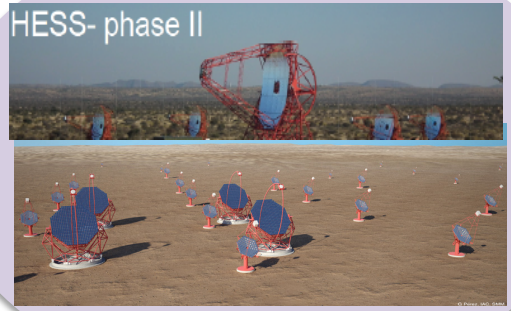


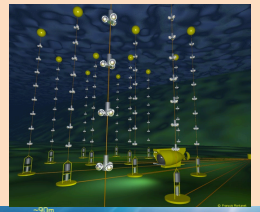
SVOM Eclairs
GRB trigger

ATHENA

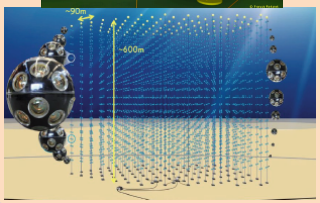
R&D Compton
R&D Gamma Cube

HESS & CTA

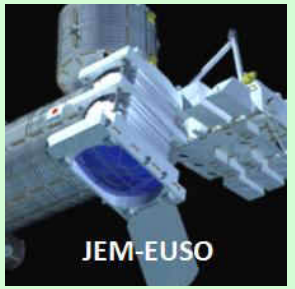




Antares
& KM3Net



EUSO-ballon &
JEM-EUSO



Group strategy

- Balance between projects :
  - By type:
    - Spatial projects (X-rays & soft gamma-rays & UHECRs)
    - Ground projects (VHE gamma-rays & neutrinos)
  - In time:
    - Integral --> SVOM, ATHENA, Compton telescope (?)
    - HESS --> CTA
    - ANTARES --> KM3NeT
    - Auger --> EUSO
- Balance between activities :
  - Data analysis (Integral, HESS, ANTARES, EUSO-Ballon/SPB)
  - Construction and development (TARANIS,SVOM, ATHENA, CTA, KM3NeT, EUSO)

- Develop complementary activities on tranverse topics :
  - Theory (CRs, UHECRs, GRBs, SNRS, Pulsars, MC)
  - Numerical simulation (AGN, compact objects, GRBs)
  - Multi-wavelength and multi-messengers (SMBH, AGNS, GRBs, GW, etc..)

Internal Organization

- Group leader-2014: Etienne Parizot
- Group leader since 2015 : Anne Lemière

- HEA group meeting every week :
  - Informations, administration, news of the group, news from the direction
  - Informal scientific presentation by a group member or seminar
  - Scientific discussions /prospective /meet other groups

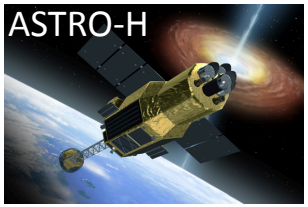
- Frequent individual Projects-Teams meetings (2 to 4 per month depending of the project)

- HEA meetings statistics :

	Total	Discussions	Seminar	Talk Staff	Talk Post-doc	Talk Phd
2015	23	4	4	14	1	0
2016	24	4	6	5	3	6
2017	29	8	8	5	6	2

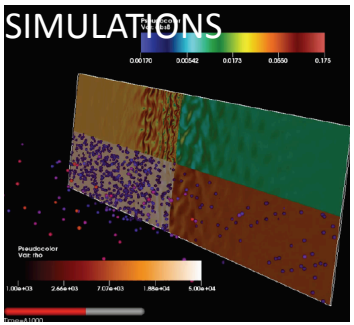
Scientific activities & results (2012-2017)

-**ISGRI camera**, calibration, S/W maintenance
-**Data analysis**: Crab polarization, Nova V404, GRBs, Binaries, SMBH, ect..
~ **30 journal papers** (1 NATURE paper)



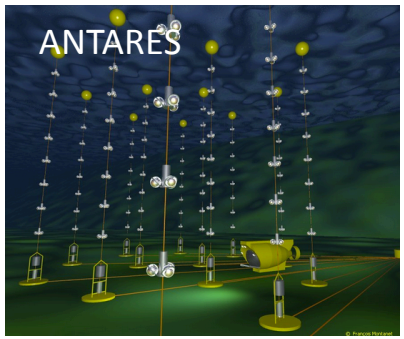
-**Limited technical participation** : BGO detectors for anticoincidence & in-flight calibration sources
- **8 journal paper**s(2 NATURE papers)

More than **3000 hrs of Guest Observer X-ray Observation and survey** of the GC since 2010.
~ 15 journal papers

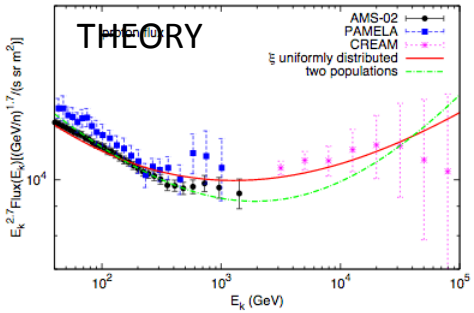


-**Temporal variability of compact objects**(multi-messengers predictions)
- **hybrid code (RMHD +PiC)** : RC acceleration in shocks
- **~30 journal papers**

-**Software developments**: (reco,discri, high level tools)
-**Data anlysis:HGPS**, pop studies, GC, Pulsars, AGNs (redshift determination)
~**60 journal papers** (20 as direct contributors including 1 NATURE paper)
HESS LEGACY 2017: 7/14 papers, 3 as corresponding authors



- **Hardware :** Front-End electronics calibration, Data Quality, monitoring, Optical sensor measurements
- **Analysis :** Search for Galactic netrinos, GRBs, multi-messengers & GW follow-up.
~ 30 journal papers

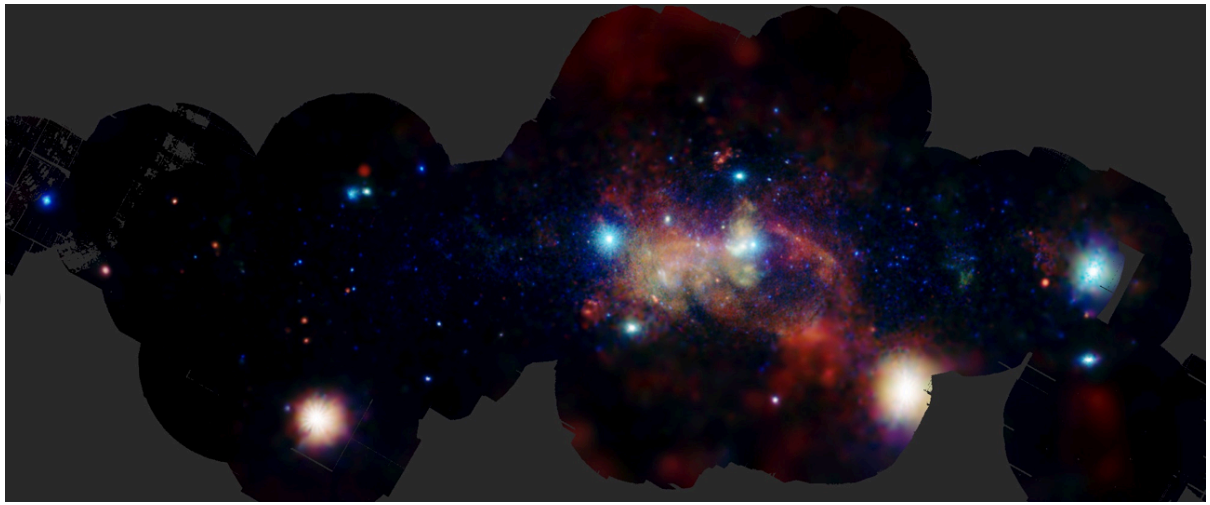


-**UHECR** acceleration and propagation (GRBs,Gal/extraGal transition, ect..)
-**Galactic CRs** acceleration & propagation (SNRs,MCs, GC…)
~ 40 journal papers

Highlights (I) : X-ray observations of the GC

More than 3000 hrs of survey and monitoring of the GC with since 2010

- XMM : (640 ks (PI) + 1700 ks (Co-I)
- Chandra 740 ks (480 ks PI + 104 ks Co-I)
- XMM+VLT (10hrs) on SgrA* (PI)
- CARMA: 10h (PI)



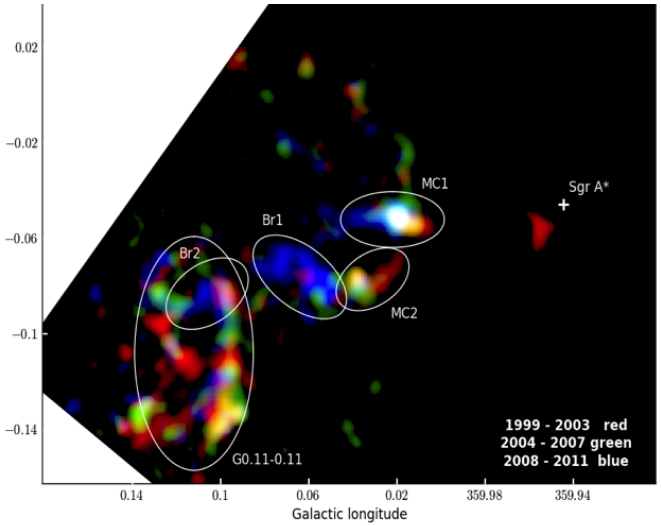
Diffuse variable X-ray reflection emission from Molecular Clouds reveals SMBH activity

- Propagation of Fe K line emission at 6.4 keV in the GC
- Reflection by Molecular Clouds of past Sgr A* outbursts

possibility to reconstruct the SMBH light curve of recent past.

Crucial science linking local SMBH to AGN and galaxy evolution

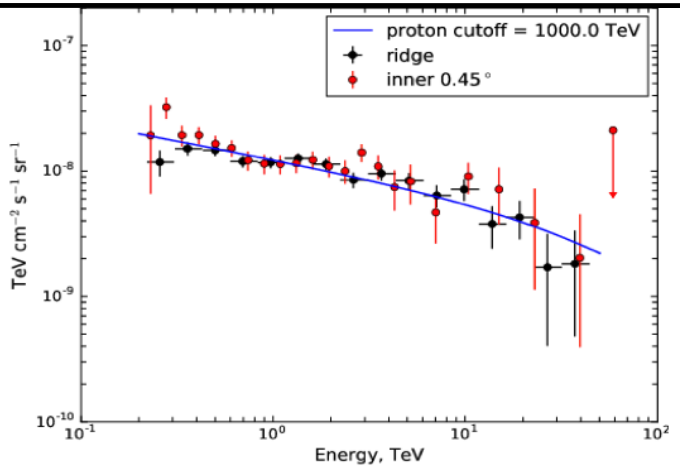
M. Clavel PhD 2014, Clavel et al 2013, Terrier et al 2017, M. Walls et al 2016, D. Chuard et al 2017, …

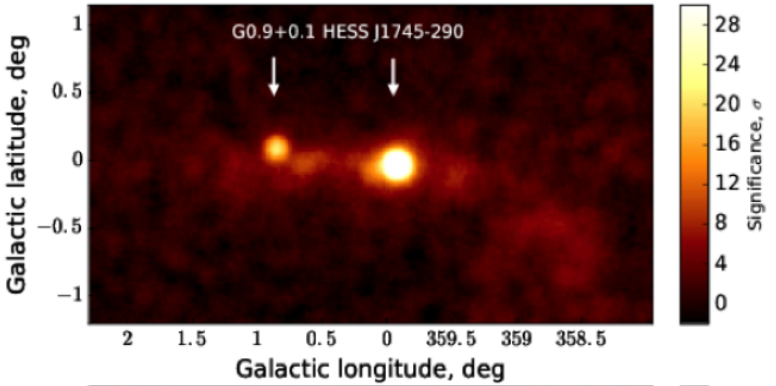


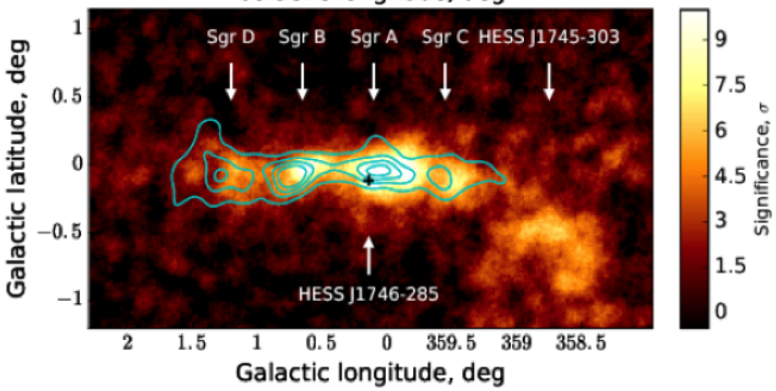
Highlights (II) : GC at VHE

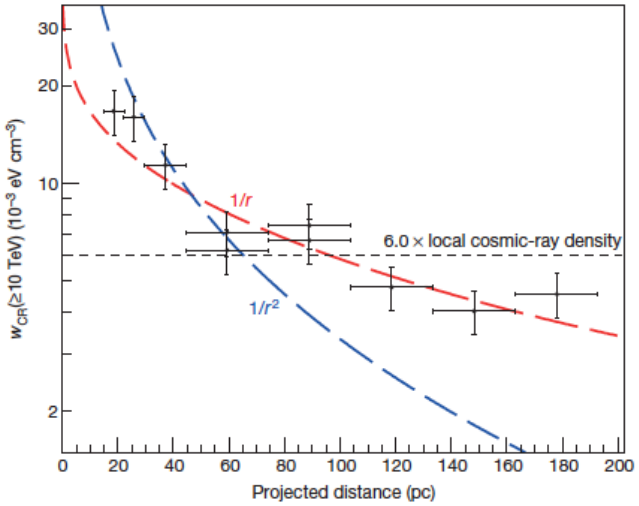
Galactic center observations with HESS reveals the presence of PeV protons in the Galaxy

- Diffuse emission spectrum compatible with a proton spectrum of index 2.4 up to 1 PeV : Pevatron
- CRs excess in the central parts compatible with a stationnary source. Possibly the SMBH itself !
- High latitude emission beyond dense CMZ matter
- Detection of a new source close the radio Arc









Acceleration of Petaelectronvolt protons in the Galactic Centre. ***Nature 531, 2016***

Characterising the VHE diffuse emission in the central 200 pc of our Galaxy with HESS. Accepted A&A 2017

Highlights (III)
Cobalt emission lines from the type Ia SN2014J

Type Ia supernova 2014J in the nearby galaxy M82

INTEGRAL detection 50 - 100 days after explosion

Observations :

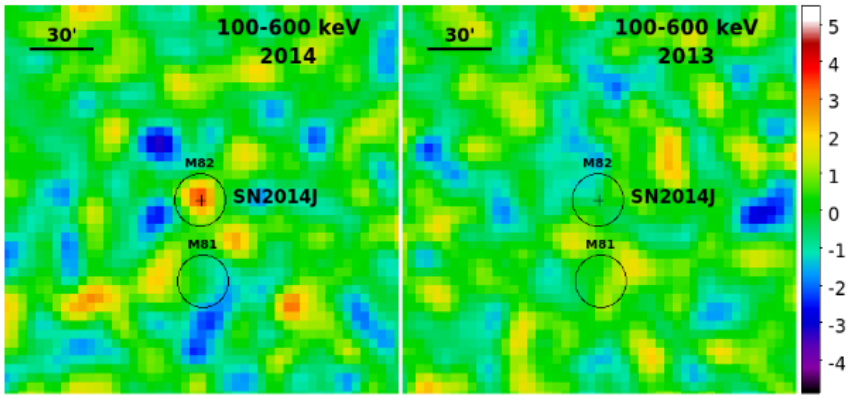
- gamma-ray continuum in the 200–400 keV band
- ^{56}Co lines at energies of 847keV and 1238 keV

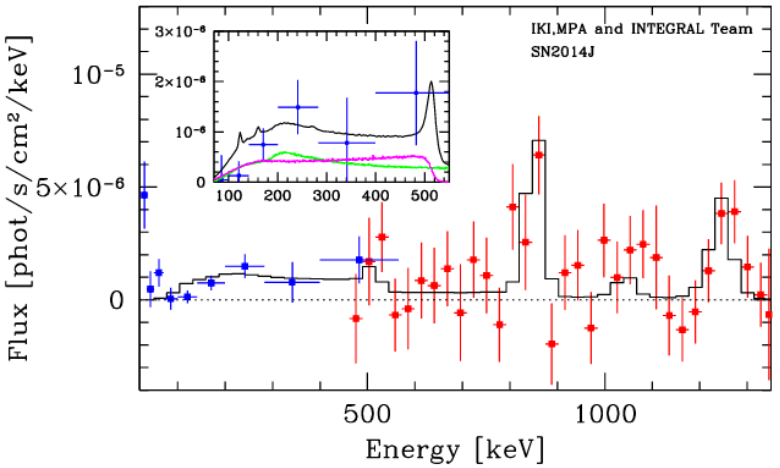
Direct proof that ^{56}Ni were synthesized during the explosion.

First test of the models of nucleosynthesis in SN1a !

0.6±0.1 solar masses of radioactive ^{56}Ni synthesized:
In broad agreement with canonical model of an explosion of a massive white dwarf (gravitational collapse).

ISGRI images



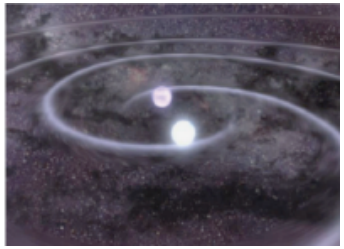


Churazov et al., 2014, ***Nature, 512,406***

Highlights (IV): Multi-messengers & GW

August 2017 : Paper co-signed by 4 experiments at APC !
LIGO-VIRGO, INTEGRAL, ANTARES, HESS

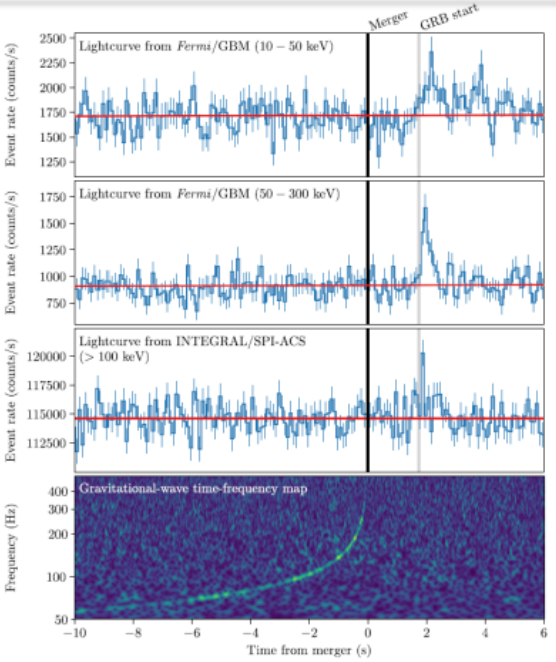
Multi-messenger Observations of a Binary Neutron Star Merger. Abbott et al., The Astrophysical Journal Letters, Volume 848



INTEGRAL

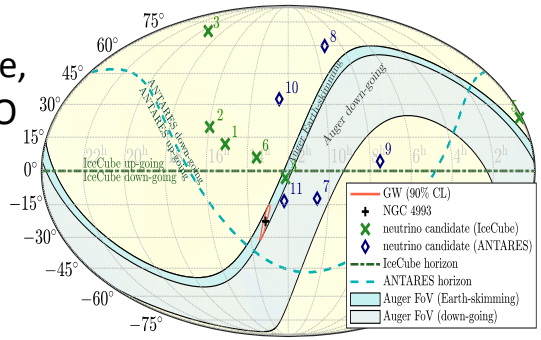
Detection of the gamma-ray counterpart of GW170817 together with the Fermi GBM (GRB 170817a, short GRB).

(Savchenko, Laurent et al 2017)



ANTARES:

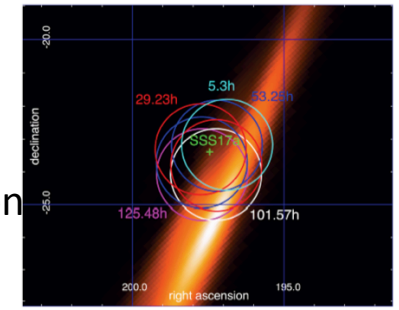
Dedicated neutrino paper ANTARES, IceCube, Pierre Auger, LIGO Scientific and Virgo Collaborations, *accepted ApJL(2017)*

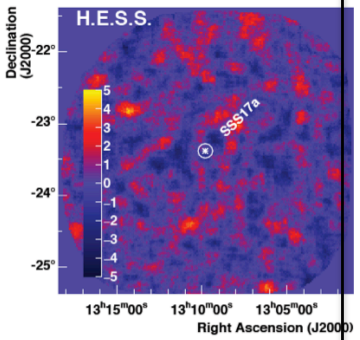


HESS :

First ground telescope to point GW170817. 5hrs observation

HESS Collab , accepted 2017



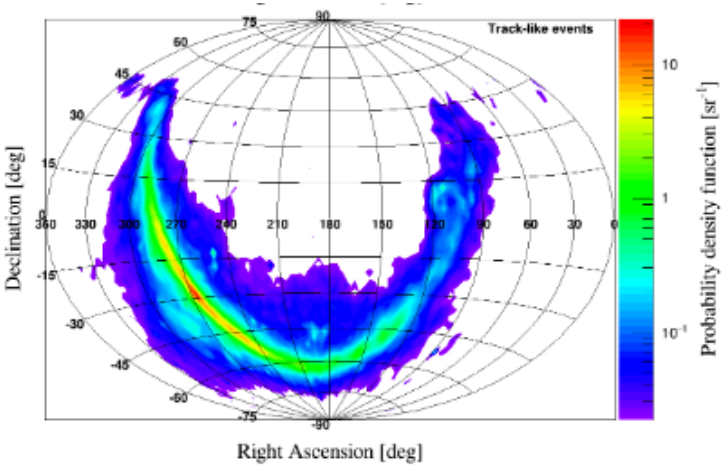


Highlights (V): Neutrinos from the Galactic ridge

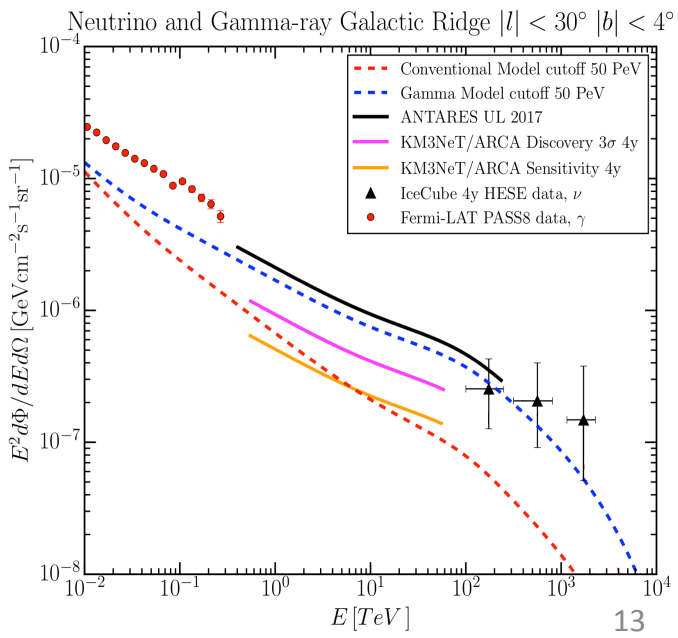
Can Galactic Ridge emission explain the spectral anomaly (North/South) in IceCube excess ?

ANTARES has good exposure towards GC, and good angulare resolution.

- Diffuse neutrino flux (tracks+ showers): 9 years of data analysed
- No significant excess but compatible with IceCube signal.
- Galactic emission contributes max 18% of IceCube HESE flux



Probability density function of the reconstructed direction of signal events from tracks, along the Galactic Plane



New Constraints on all flavour Galactic di use neutrino emission with the ANTARES telescope. A. Albert et al. (ANTARES Collab)
Phys. Rev. D 96, 062001, 2017

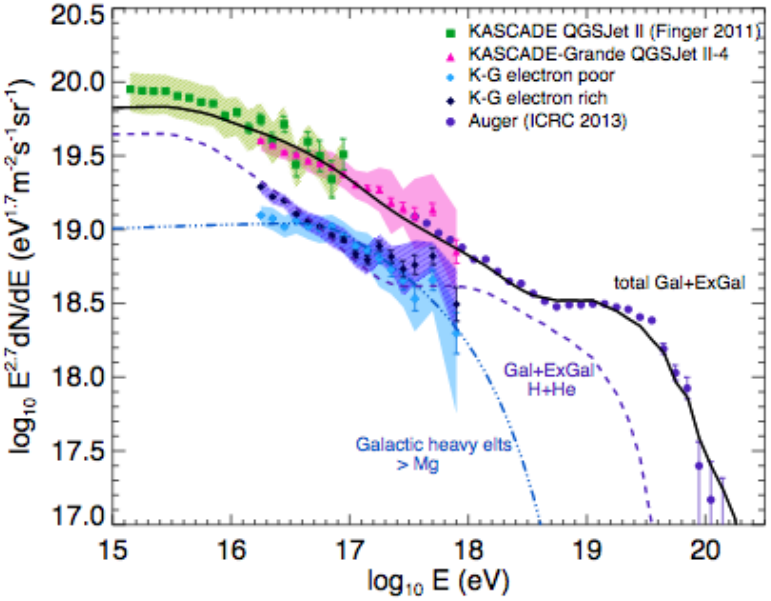
Highlights (VI): CRs Galactic/ExtraGalactic transition

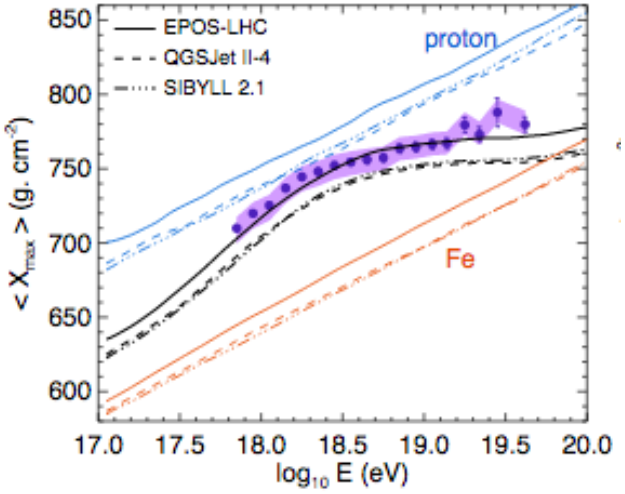
Phenomenological model accounting for the evolution of the cosmic-ray spectrum and composition with energy, including :

- Rigidity dependent Galactic component
- Generic ExtraGalactic component based on numerical model for the acceleration of UHECRs in GRB + propagation.

Results :

- Reproduce key region of the GCR/EGCR transition,
- Transition from a light-dominated to a heavy-dominated composition interpreted as a consequence of a low-energy cut-off of the protons in the sources.





A complete model of the CR spectrum and composition across the Galactic to Extragalactic transition. Globus, Allard & Parizot. Phys. Rev. D 92, 021302 (2015)

Highlights(VII) : CR acceleration near parallel shocks

Development of a hybrid code (RMHD +PiC) for ultra-relativistic jets *(funded by ANR : 2015-2017)*
Designed for GRB observations in future X/γ missions

mPIC-AMRVAC: first-ever code linking an Adaptative Mesh Refinement MHD code to a Particle-In-Cells approach: particle acceleration near astrophysical shocks

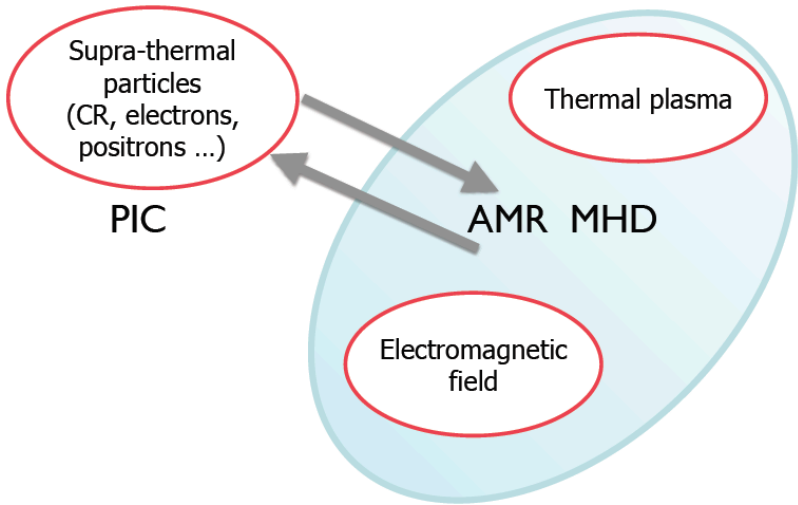
CR acceleration near parallel shocks:

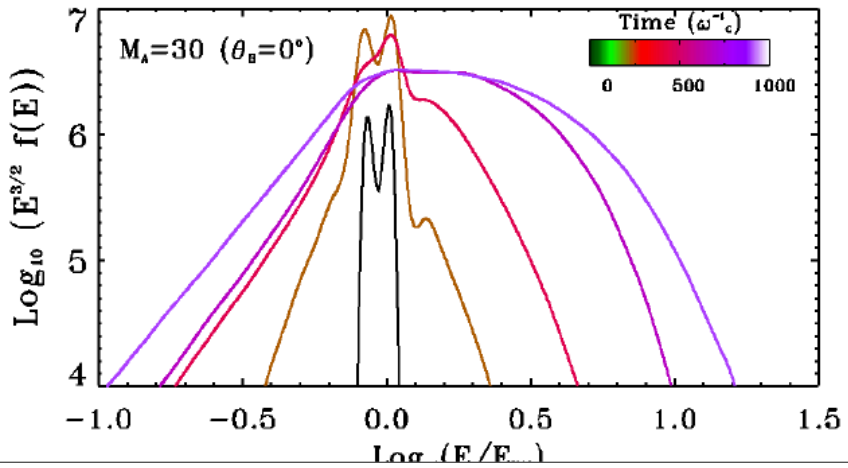
- CR spectrum is consistent with Diffusive Shock Acceleration prediction.

- The DSA process does not produce higher energy particle as the shock gets rapidly disrupted.

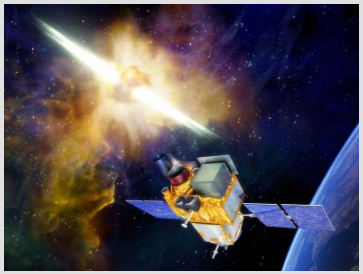
- Full 3D simulations in progress

Van Marle, Casse & Marcowith. Accepted for publication in MNRAS (2017)

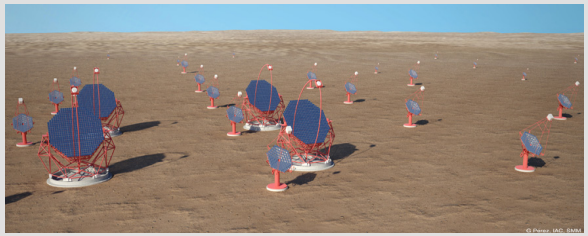




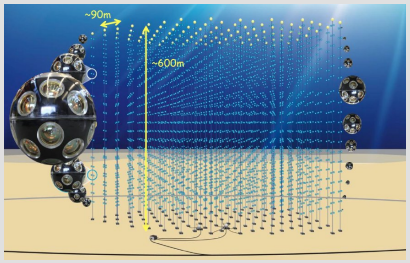
Preparing the Future



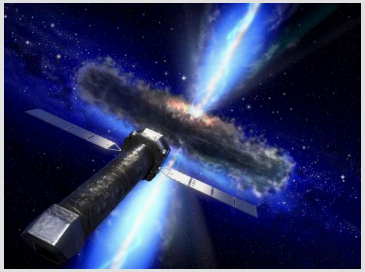
SVOM +5 years



CTA +5 years



KM3neT +5 years

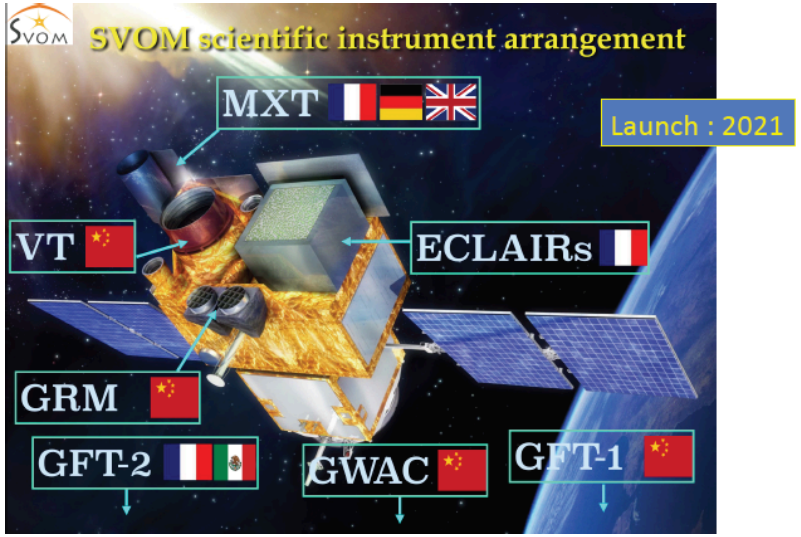


ATHENA (+10 years)

EUSO +10 years

Future GRB mission: SVOM (+5 years)

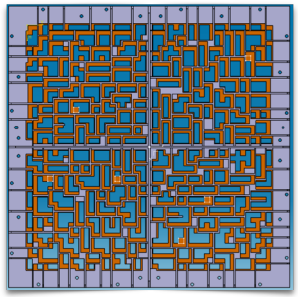
- GRBs in the distant Universe
- Tight schedule for a launch in 2021
  - 2015-2016 : preparation
  - 2017-2020 : development
  - 2021- : operation

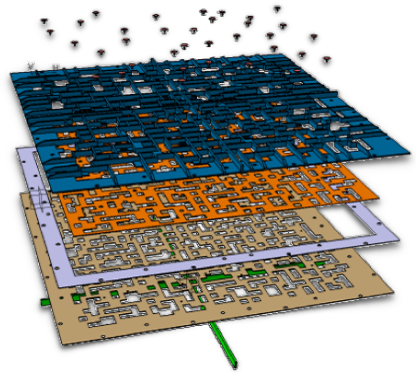


Science fits well within APC perimeter :

- Non-GRB science group (resp A.Goldwurm) : GP
- Multi-messenger science group (resp C.Lachaud) : ToO

Large involvement of APC technical teams:



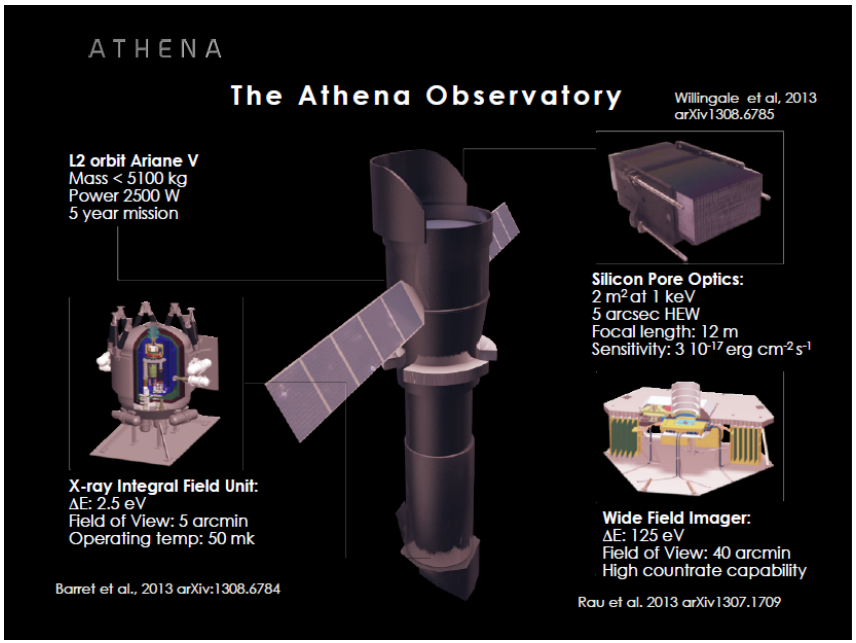


- Coded Mask of ECLAIRs (Givaudan – Lachaud)
  - Flight model to be delivered in 2019

- Ground Segment: ECLAIRs analysis pipeline (Colley - Goldwurm)
  - 2017-2020: Development (arrival of 6 years post-docs CNES in 2018)
  - 2021: Delivery

Future X-rays mission: Athena (+10 years)

- ESA Cosmic Vision Large (L2) Space Mission
- **Large X-ray (0.1 – 12 keV) Observatory :**
  ~ 2 m² effective area, angular res. of 5",
  FoV up to 30' , exceptional energy resolution of 2.5 eV



- **Science with ATHENA:**
  - Unprecedent resolution on Fe lines from MC of the GC
  - Detail of the accretion flow and SgrA* flares
  - Spectral-timing studies of Black Hole binaries
  - Search for GW events counterparts

- **Timeline :**
  - APC joined Athena consortium in Feb-Mar 2014
  - Phase A extension up to 2019
  - Launch 2028 -> 2030

- **APC Participation :** (A. Goldwurm "Referent Physicist", R.Terrier , S. Gabici , P.Laurent, P. Varniere)
  - 2/10 X-IFU French Co-I at APC
  - X-IFU (Spectrometer) Warm Front End Electronics (part of readout electronic chain)
  - X-IFU background Simulation
  - Possible future implication : Athena Science Ground Segment with the FACe

It exploits the H/W & S/W Expertise and Facilities of APC

Hard X-rays- Soft gamma Instrument Science

• **TARANIS :**

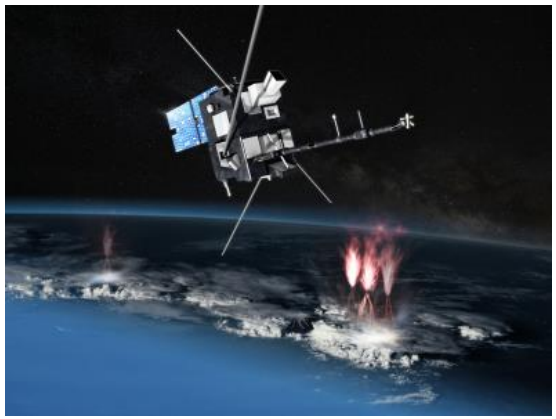
CNES microsatellite dedicated to the study of the transient phenomena in the atmosphere above storm regions. Fastest space gamma-ray detector (10 times faster than Fermi/GBM), important for pulsars and GRB studies

APC responsible for the development of XGRE: first complete space instrument developped in APC

Timeline :

July 2018: Delivery to CNES.

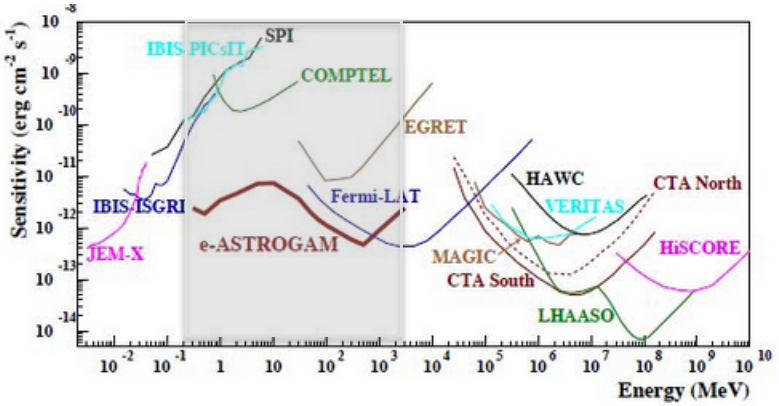
Sept 2019: launch.



• **R&D: preparing the future of spatial gamma-ray astronomy**

- Si DSSDs (Double Side Stripped Slilicon Detectors) tracker
  Possibly used in eASTROGAM if selected
- Gamma Cube :3D imaging scintillating tracks thanks to microlens array

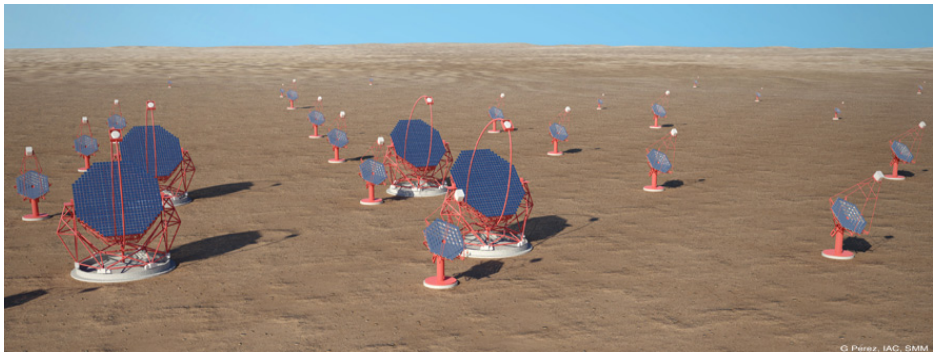
2017: project stopped in 2017



Future VHE gamma-ray Observatory: CTA (+5 years)

- **Next generation high sensitivity Cerenkov telescope array :**

- **Timeline:**
  - 2016: CDR CTA International/ TGIR CTA /
    « Founding agreement »
  - 2019: production phase
  - 2023 : ~ full array



- **APC implications :**

Central Trigger/Clock distribution (TDC)**: Simulation and design optimization**
- MUTIN system developed at APC (P2I & GATE (IN2P3+region) funding)
- CTA choice defaulted: "White Rabbit" (WR) protocol from CERN (open hardware)
- Successfull reorientation MUTIN ⟶ WhiteRabbit

  Competition with WhiteRabbit ZEN (GRAPPA): more flexibility but more expensive

Quality of NectarCAM RAM

Future VHE gamma-ray Observatory: CTA (+5 years)

- **Data WP:**
  - Conception (contribution to the Use Cases)
  - Former participation to reconstruction
  - Now strong participation to the high level data analysis :
    First 3D analysis with bkg model within gammaPy (L.Jouvin Phd)
    Participation to the data challenge, development of physics simulation tools
    Taking responsabilities on high level analysis for CTA (gammaPy)

  - Proposal handling platform accessible via the CTA web portail (resp B.Khelifi)
    Contribution in-kind from APC to CTA**.** Most of the effort in IT (~65%)

- **Science WP:**
  - Co-coordination of the preparatory phase, contribution to the key science projects: done
  - Task Leader for the group "Cosmic rays,supernova remnants and molecular clouds"(SG)
  - Convenor of the Galactic Physics Working Group (SG))
  - Continue science and analysis preparation :
    - Catalog Gal/Extra-Gal (BK,PG,RT,AL,AD,SP)
    - GC (RT, AL)
    - Pulsars (AD)
    - Galactic physics, Diffuse Emission, SNRS, PWNe, Pevatrons (BK,RT,AL,DS)
    - AGN : Pop, Redshift détermination, EBL (S.Pita, P.Goldoni, D. Semikoz)

Future of VHE neutrinos: KM3NeT (+5 years)

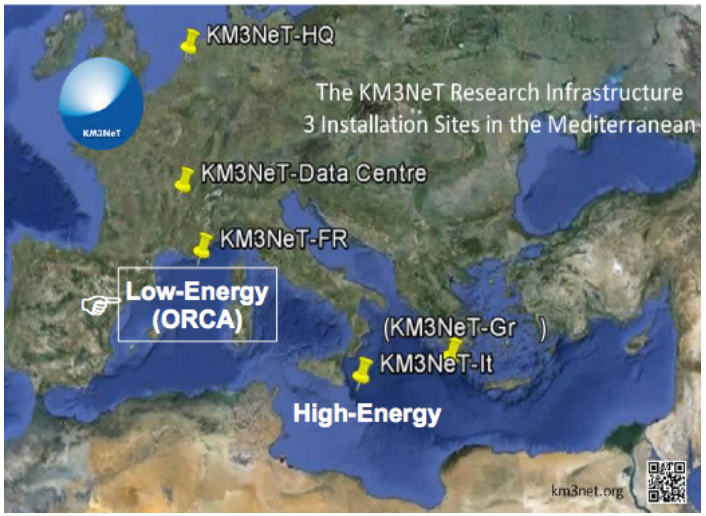
- KM3NeT : infrastructure with 2 main physics topics :
  Low -Energy studies of atmospheric neutrinos : **ORCA**
  High-Energy search for cosmic neutrinos: **ARCA**

- **Timeline :**
  2017 : First ORCA line, first neutrino seen.
  2020 : ORCA & ARCA full detectors.

- **Future and perspectives :**
  Keep an activity on both ARCA / ORCA

- **Technical implication in ORCA:**
  - Design and construction of the first calibration unit
  - Test benches for characterization of Digital Optical modules
  - Possible involvement in container assembly

- **Data analysis ARCA/ORCA**
  - Galactic Plane, GC, Fermi Bubles
  - Sensitivity to supernovae detection
  - Multi-messengers analysis and GW and GRBs follow-up
  - Neutrino oscillation tomography of the Earth
    (*see A.Kouchner talk*)



September: Development of first ORCA line @ Toulon
Data taking ongoing… first neutrinos seen

The Future of UHECRs: JEM-EUSO (+10years)

- **Definition and goal of the mission:**
  - Wide field UV telescope operating from the ISS
  - Space based detection of UHECRs, through the fluorescence light of the induced showers

- **Main highlight :**
  - successful flight of the **EUSO-Balloon** pathfinder, funded by CNES (Aug. 2014): 1 PDM on stratospheric balloon
  - **EUSO SPB** : APC responsible for the development, integration tests and calibration of the instrument focal surface
    Launched in April 2017, data analysis in progress.

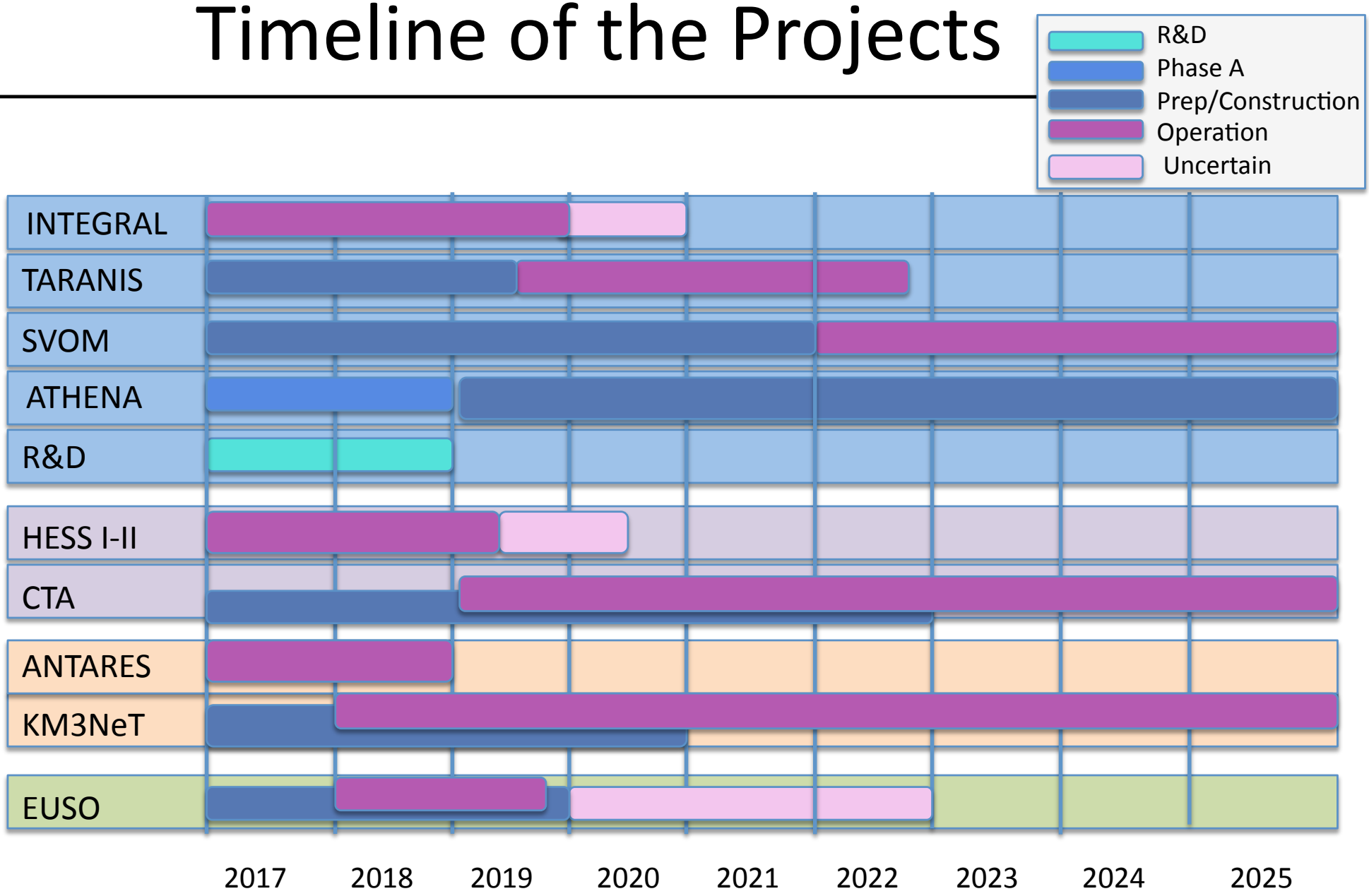
- **Future and perspectives :**

  - mini EUSO (ASI +ROSCOSMOS): Prep/construction until end 2018.
  Operation 2018-2020.

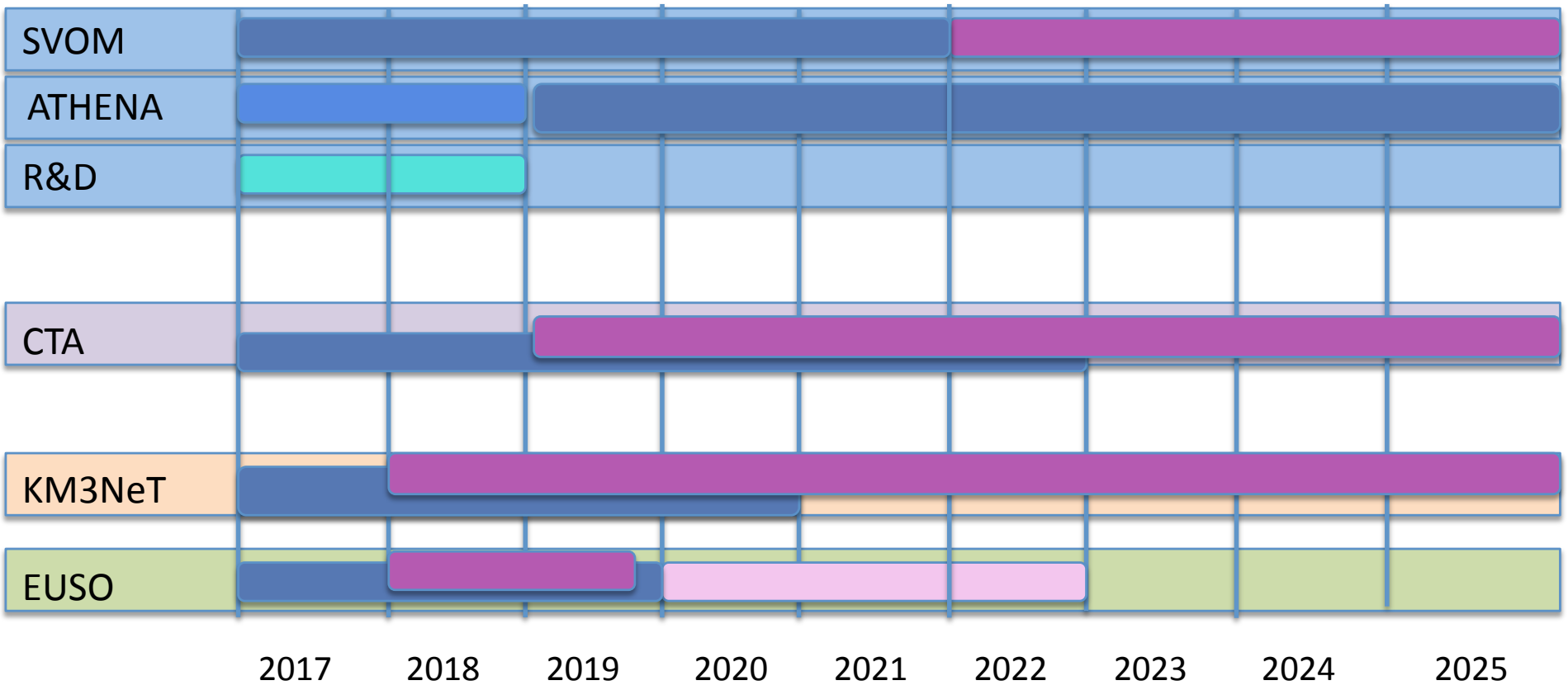
  - **EUSO-SPB2** (NASA) : - R&D 2018.
    - Phase A 2019.
    - Prep/construction 2021/2022.
    - Operation 2022.

  - **K-EUSO/ POEMMA (NASA):** Phase A until 2018. Beyond 2018 uncertain.

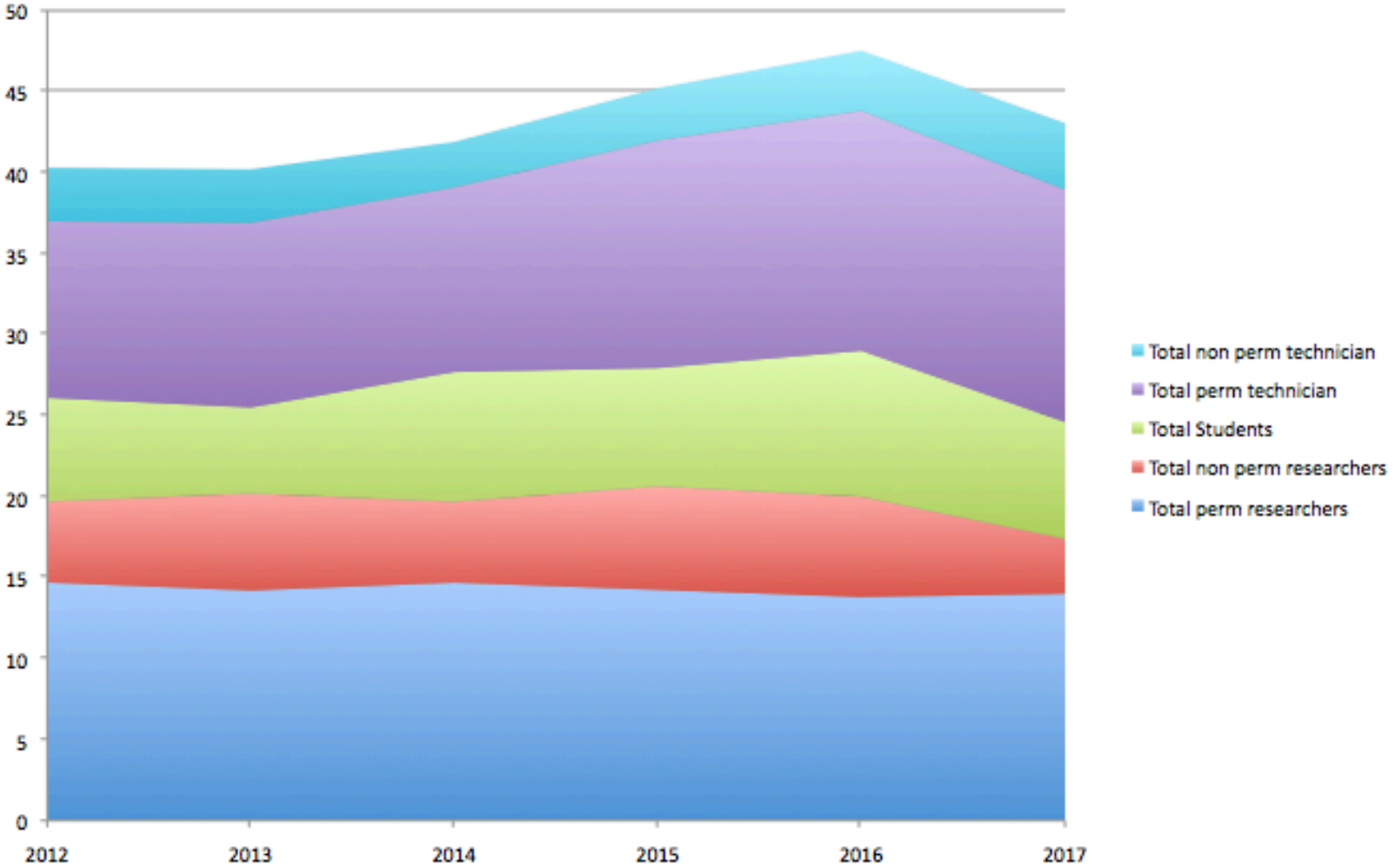
Timeline of the Projects



Timeline of the Projects



HEA Projects Workload



Responsibilities and indices of recognition

- **Publications, seminars, conferences :**
  - 250 publications in refereed journals (3 NATURE papers, 1 Science paper), 180 as primary authors
  - 100 proceedings of conferences
  - 70 talks or posters presented
  - 50 invited talks and seminars

- **27 strategical responsibilities in main projects :**
  INTEGRAL, HESS/CTA, ANTARES/KM3NeT, SVOM, ATHENA, EUSO, TARANIS

- **Main national responsibilities:** CNU (section 29,section 34), CNRS (section 17,section 01), PNHE

- **More than 15 participations to scientific evaluations:**
  ANR, HCERES, Chandra & INTEGRAL proposal evaluation, European commission,
  referee for journals etc…)

- **Strong responsibilities in University life:**
  - responsabilities of departments (L,M2)
  - Members of Scientiifc council, pedagogical council, UFR council (9 members)

Scientific animation, teaching & outreach

- **Teaching :**
  - More than 700 hrs of teaching each year
  - Responsabilities of HE lectures in 2 major M2 in the field
  - Nanosatellite IGOSAT @P7

- **Outreach:**
  -Organization and participation of more than 50 events:
  public seminars, public events, journal papers, High-school programs,
  movies, high school teachers formations and website, etc…

- **Scientific animation :**
  - Organization of ~20 events : workshops, Ateliers, collaboration meetings, etc…
  - Organization of the APC colloquium (2012-2016)
  - Organization of joint Gravitational/HEA meetings and seminars

SWOT analysis

SWOT analysis

Strengths	Weaknesses
• Unique multi-wavelength and multi-messenger environment • Strategic experimental know-how (photo-detection, space missions, R&D compton) • Guaranted funding of most of the future projects in which the group is involved (CTA, KM3NeT, SVOM, ATHENA, TARANIS)	• Limited technical ressources compared to the number of projects. • Given the limited ressources, it is difficult to conciliate a strong participation in key experiments and a significative involvement in multi-messenger programs at the same time.
Opportunities	**Threats**
• The large discovery potential of the new generation of large observatories (KM3NeT, CTA) and space projects (SVOM, ATHENA, EUSO) in which the group is involved. • The advent of gravitationnal waves astronomy and its intrinsic connection with multi-messenger and multi-wavelength observations	• Recent departure of several group members involved in the field of X-ray and MeV photons have not been replaced yet. • The prevalence of Astrophysical questions in our field places the HEA team in a marginal position within the IN2P3, while we are neither sufficiently recognized within INSU.

Conclusion

- **Strong implication in projects in operation: large visibility and recognition**
  - HESS: software developments & strong implication in data analysis.
  - ANTARES: technical and software developments & strong implication in data analysis**.**
  - INTEGRAL : technical and software developments & strong implication in data analysis**.**
  - ASTRO-H : clear contribution, few months of operation in 2016.
  - EUSO-Balloon, EUSO-SPB : development, construction and data analysis

- **Importance of transverse activities:**
  - Numerical simulations: strong link with multi-messenger data
  - Theorical and phenomenological activities in connection with projects
  - Multi-wavelength data analysis : Large program of GC X-ray data analysis with perspectives linked to the futur of X-ray missions, GRB, AGN monitoring, Blazar redshift measures, etc…
  - Multi-messenger joint studies : GWEN, GRBs, diffuse cosmological bkg, etc ..
  - Monitoring of transient events & GW events

- **Implication in main future projects :**

  +5 years : CTA, KM3NeT, SVOM

  +10 years : ATHENA, EUSO, Prep future MeV telescope missions

HE Astro questions: Answers have been distributed in the presentation

1	What is the evolution of FTE researcher/technicians/students over the last 5 years?	Slide 26
2	What is the group's internal organization and what are the processes for communication (regular meetings, interactions between the experimentalists and phenomenologists (e.g., publications co-authored), "transverse" interactions (i.e., publications co-authored by people from different projects?), nteractions with the Gravitation team and with the Neutrino team)?	Slide 7
3	There is mention throughout the document of interactions with geosciences but no details are given on these activities in the HEA part. Is it relevant to this team or presented somewhere else?	Slide 22 : Interdisciplinary talk by A. Kouchner
4	Concerning X-rays studies:	
	• We find it difficult to evaluate the recognition of the studies based on data from outside observatories. Of course we can check papers and their impact but could you help quantifying, letting us know for example if the studies carried out were approved by some (Chandra, XMM-Newton, VLT, VLA...) scientific committee or if observation time was requested and approved?	Slide 9
	• Were there technical developments invested in the late HITOMI-ASTRO-H mission or is that (only) data analysis?	Annex : Slide 39
	• At first look, this sub-team seems very much under-critical, the ratio human resource / number of projects being probably one of the lowest at APC. How do you see its evolution?	Slides 7,29,30
	Concerning VHE gamma astro:	
	• Evolution of researcher/technicians/student FTEs over the last 5 years?	Annex: Slide 47
	• Internal organization? Regular meetings?	
	• CTA: What are the implications for the APC team if the TiCKs cards will not be chosen by the international collaboration?	Slides 19, 20
	Concerning neutrinos:	
	• clearly this axis is 50/50 in the HEA team (ARCA) and in the Neutrino team (ORCA). How do both teams coordinate their actions? It seems that there are regular HEA-Gravitation meetings. Is it also the case with Neutrinos?	Slide 22
	Concerning UHECR:	
	• Overall (Mini-EUSO apart, flight in 2018) all the other future projects (EUSO-SPB2, K-EUSO, POEMMA) are uncertain as for the moment they are all at the level of discussion/proposal/study. What are the backup plans?	Slide 23, Annex Slide 50

Annex

Summary (II)

- **VHE γ-rays:**
  Strong involvmnet in software developments and data analysis of HESS data
  CTA major high-energy observatory in the next decade
  Hardware :APC proposal within White Rabbit: successful reorientation GATE->WR
  Software : Proposal handling : large visibility for moderate effort
  First test of the platform March 2018. Tight schedule
  Analysis : Strong involvement in high level tools (gamma-Py)
  Physics *:* strong involvement in Galactic and extra-Galatic groups

- **VHE cosmic neutrinos :**
  Technical and software developments of ANTARES & strong implication in data analysis.
  KM3NeT major neutrino detector in the next decade
  Hardware : implication in ORCA (calibration units, characterization of DOM)
  Analysis : strong implication in ORCA/ARCA data analysis
  Physics : Supernovae detection, GC, Diffuse emission, multi-messengers and GW.

Summary (I)

- **X-rays :**
  - **Large program of GC data analysis: perspectives linked to the futur of X-ray missions.**
  - Involvement in ATHENA (since spring 2014) : launch ~ 2028-2030
    Strong H/w and S/w involvement
  - ASTRO-H : Small contribution, few months of operation in 2016.
  - TARANIS : PI-ship involvement, launch in 2019, data analysis 2019-2012

- **γ-rays:**
  - SVOM mission start operation in 2021
    Strong technical involvement at APC : hardware & software (strategic responsabilities)
    Physics preparation : responsability of multi-messengers and GP programs
    Involvement in data analysis and exploitation will be strategic for the group

  - Preparation of a future MeV telescope mission (>2025)
    R&D on Si DSSDs and scintillation trackers
    Effort to gather community on a common proposal/design (AstroMeV)

Summary (III)

- **UHECR: JEM-Euso for >10^{19} eV CR**

  Strong APC technical involvement

  - Successful flight of the EUSO-Balloon pathfinder in 2014
  - flight of EUSO SPD in spring 2017 : data analysis in progress
  - Two new flight: SPB2 and mini-EUSO onboard ISS in 2018-2019
  - Future incertain after 2019 for the field of UHECRs, balance with theoritical activities

- **Transverse activities reinforced**

  - Numerical simulations: strong link with multi-messenger data
  - Theorical and phenomenological activities in connection with projects
  - Multi-wavelength and multi-messenger analysis and monitoring of transient events

The AHE theoretical activities

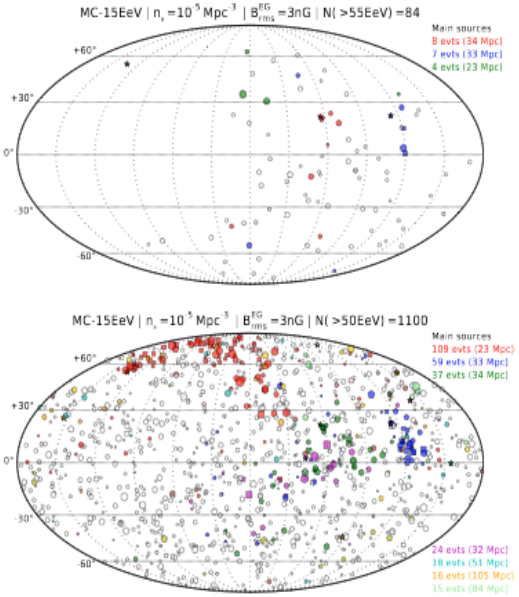
• **Modeling of UHECR acceleration and propagation :**

– UHECR acceleration at GRB internal shocks

Including secondary gamma-rays and neutrinos

– Preparation of JEM-EUSO science case

Collab. with ANTARES groups in APC and within Paris-Oxford-Hamburg research training network.



Examples of sky maps corresponding to a given model simulated for the current statistics of Auger and for the expected statistics that JEM-EUSO (Eth=50EeV)would gather with a total exposure of 300000 km2 sr yr.

• **Galactic sources of cosmic rays.**

Time dependent acceleration and escape, propagation of CR in both turbulent and regular galactic magnetic Field.

– Calculations of secondary gamma-ray and neutrino fluxes.

– Molecular clouds illuminations. Comparison with HESS/CTA obs.

– Low energy cosmic-ray including H3+ results

• **Theoretical modeling of gamma-ray sources**, using Fermi and HESS data at the same time.

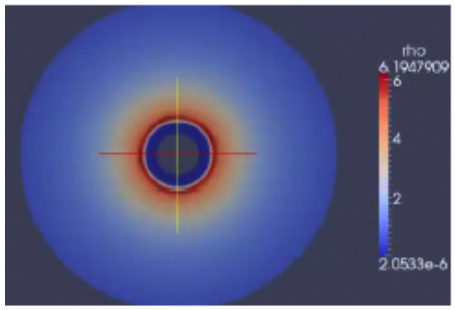
– Study of the intergalactic magnetic fields and infrared background with gamma-ray data.

– PWN time-dependant modeling

AHE numerical simulation activities

- **Temporal variability from compact objects**

Development of a toolkit to study compact objects multi-wavelength emission



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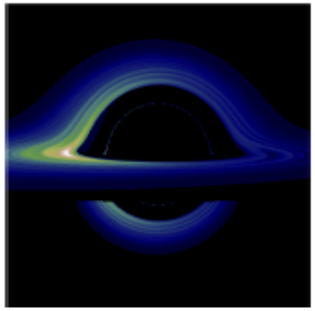


+ General Relativistic MHD & metrics

3D simulation of RWI

GR Ray tracing calculations

microquasars, galactic center, AGN and the iron lines...

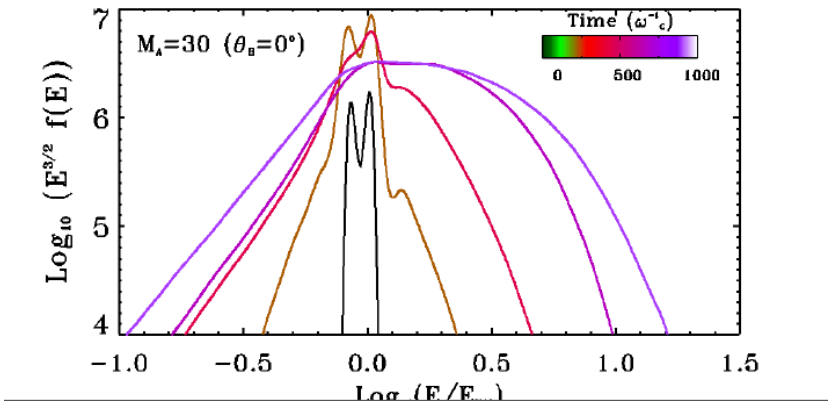
- **GRBs, Cosmic-Rays and HE emission**

Development of a hybrid code (RMHD +PiC) for ultra-relativistic jets *(funded by ANR : 2015-2017)*

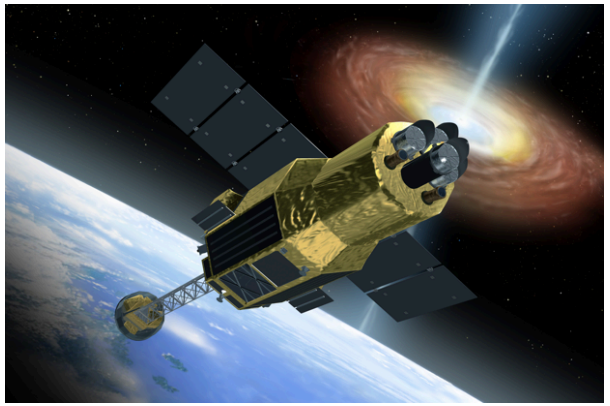
- including description of micro-turbulence in the shocks
- Designed for GRB observations in future X/γ missions

First step archived : particle acceleration and magnetic amplification around parallel chocs at 1D

Next step : Full 3D simulation



Hard X-rays: ASTRO-H



- Japanese satellite
- Focusing hard X-ray telescope (0.3 to 600 keV)
- 4 French Co-Is : O. Limousin (AIM), F. Lebrun (APC), P. Laurent, A. Goldwurm (APC).
- **Successfully launched the 17 Feb 2016.**
- BUT : Joint Space Operations Center reported that telescope separated into multiple pieces on Saturday 26 March.
  Since then:satellite lost, project stopped

APC participation :

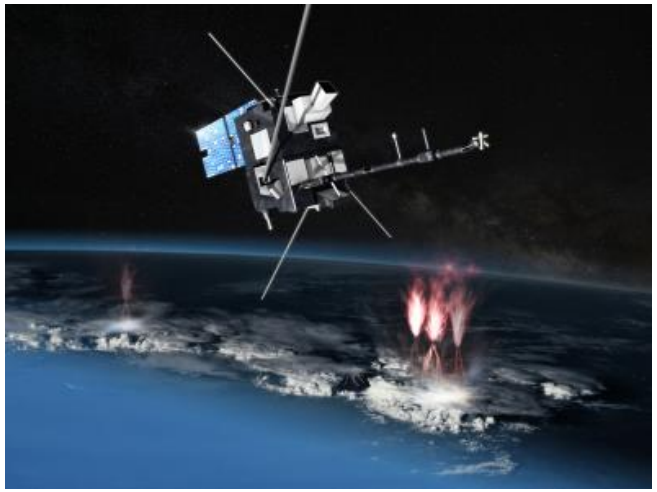
Procurement, test and delivery to JAXA of BGO detectors for the anticoincidence system of the HXI and SGD instruments of Hitomi

- Supplied the in-flight calibration sources of the ASTRO-H high energy telescopes (HXI and SGD) (jointly with CEA). *Allow to continuously calibrate these detectors.*

- **Data analysis :** (P. Laurent + D.Maier (post-doc 2015-2017)
  Calibration and Gamma-ray polarization analysis on existing Crab data

Hard X-rays- Soft gamma: TARANIS

CNES microsatellite dedicated to the study of the transient phenomena in the atmosphere above stormy regions



XGRE: X, Gamma-ray and Relativistic Electrons detector

APC responsible for the development of XGRE

- first complete space instrument developped in APC
- fastest space gamma-ray detector (350 ns dead time; 10 times faster than Fermi/GBM)

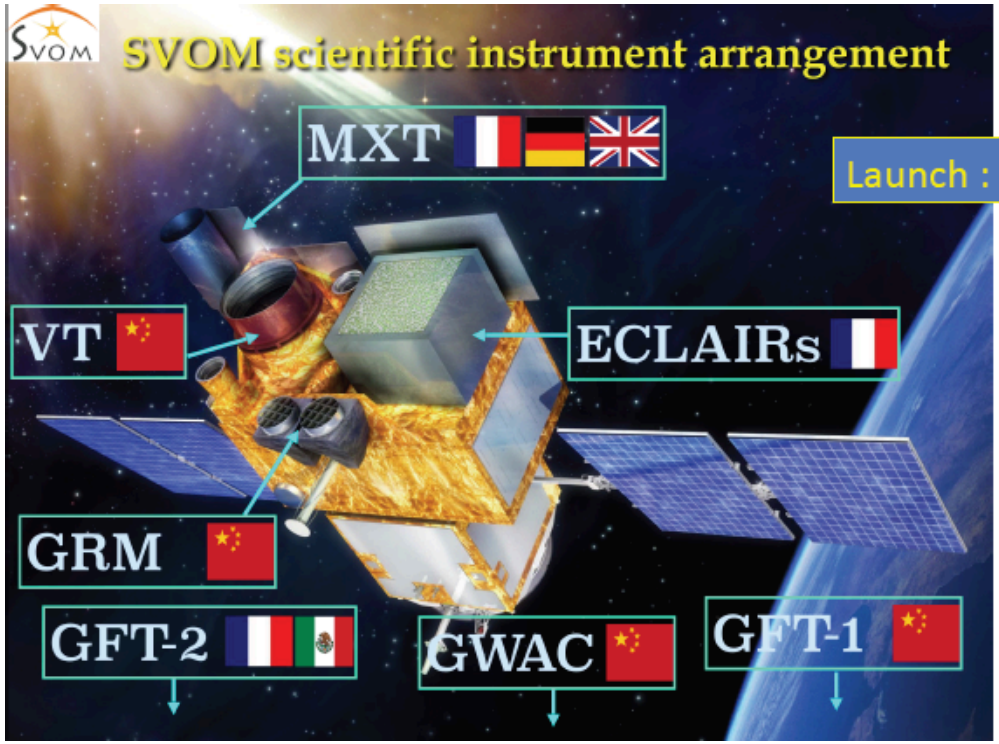
- **Timeline :**

2018 : Fabrication of the UD FM and three XGRE FM sensors.
April 2018 : XGRE sensors calibration
July 2018: Delivery to CNES.
Sept 2019 :launch.

SVOM: a GRB mission

- GRBs in the distant Universe
- Wide field imager in X/hard X-rays
- Mission approved by CNES/CNSA in summer 2014.

- Tight schedule for a launch in 2021
  - 2015-2016 : preparation
  - 2017-2020 : development
  - 2021- : operation



Science fits well within APC perimeter :

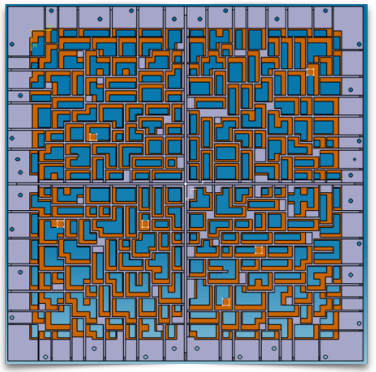
- Non-GRB science group (resp A.Goldwurm) : General Program
  AGNs, Ultra Luminous X-ray sources, Tidal Events, Magnetars, X-ray Binaries

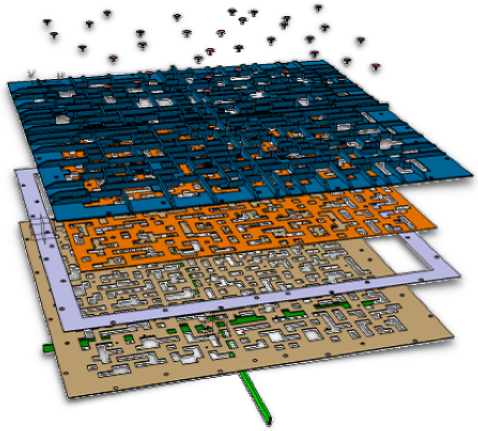
- Multi-messenger science group (resp C.Lachaud) : ToO Program
  GW, neutrinos, gamma HE

SVOM @ APC

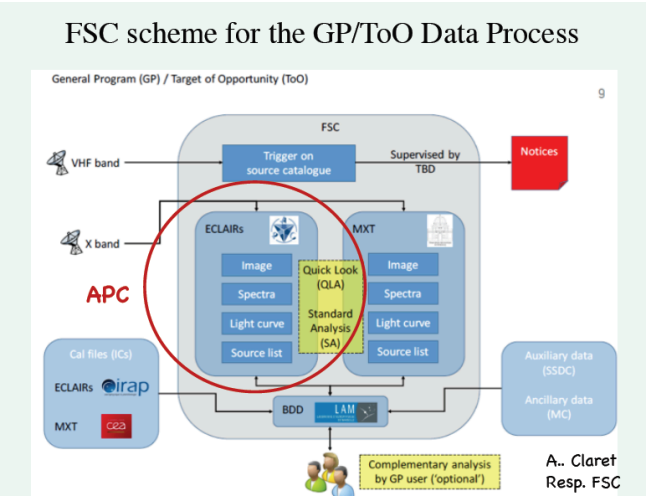
Large involvement of APC technical teams:

- Coded Mask (Givaudan - Lachaud)
  - Responsibility for the development of the Coded mask of the ECLAIR instrument technically challenging
  - Flight model to be delivered in 2019





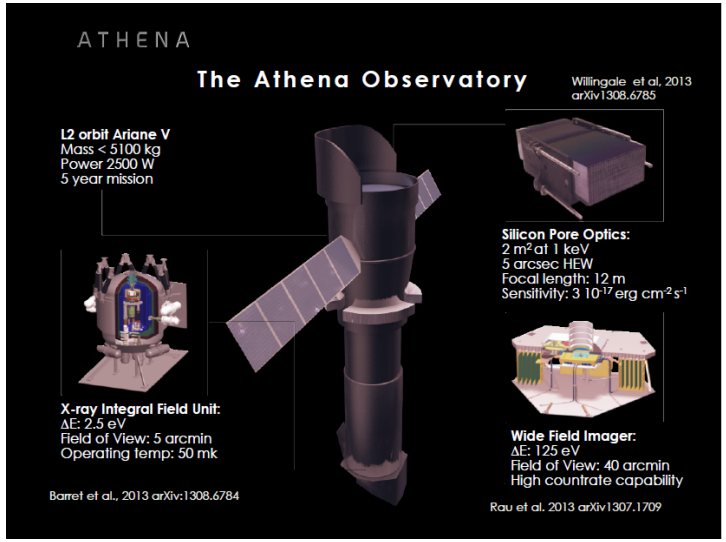
- Ground Segment (Colley - Goldwurm)
  - Responsibility of the ECLAIRs analysis pipeline :
    (A. Goldwurm, C.Lachaud, J.M.Colley, C. Cavet+ 2 CNES FTE)
    2017-2019 : Development
    2020 :Delivery
  - Responsible for Mission documents for the SIR (System and Interface Review)



Future X-rays mission: Athena

- ESA Cosmic Vision Large (L2) Space Mission
- **Large X-ray (0.1 – 12 keV) Observatory :**

~ 2 m² effective area, angular res. of 5", FoV up to 30' and exceptional energy resolution of 2.5 eV,



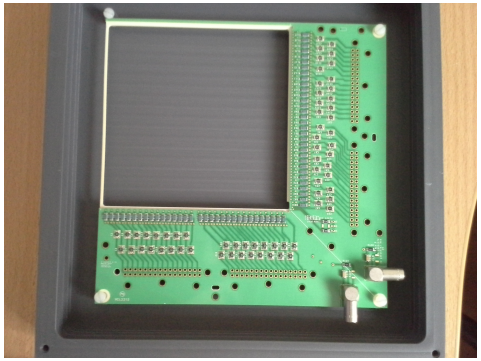
- **Timeline :**
  - APC joined Athena consortium in Feb-Mar 2014
  - Athena Phase A started in July 2015
  - Phase A extension up to 2019
  - Launch 2028 -> 2030

- **APC Participation :** (A. Goldwurm "Referent Physicist", R.Terrier , S. Gabici , P.Laurent, P. Varniere)
  - X-IFU (Spectrometer) Warm Front End Electronics (part of readout electronic chain): provision of the whole system : ASIC realization and tests and interfaces definition in good progress
  - X-IFU background Simulation
  - Possible futur implication : Athena Science Ground Segment with the FACe

It exploits the H/W & S/W Expertise and Facilities of APC

Space Gamma-ray Telescopes (1-100 MeV)

R&D :



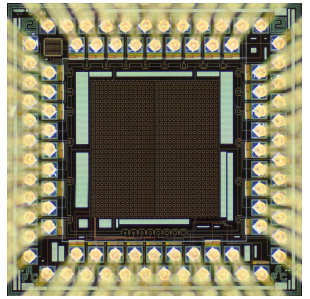
- Si DSSDs (Double Side Stripped Slilicon Detectors) tracker
  (funded by CNES and Labex UnivEarthS)

  2015 :

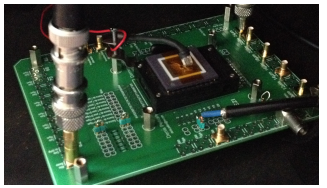
  - Development of test bench MUSETT at APC
  - DSSD integration into hybrid PCB
  - Development of numerical readout card for ASIC IDefX

  2016 :

  - Validation of the DSSDs spectroscopic performances with the ASIC IDefX
  - Design and test of first COMPTON mini camera (COCOTE)



- Gamma Cube: 3D imaging scintillating tracks thanks to microlens array readout on SPAD arrays
  - GEANT4 model and reconstruction methods
    Estimations of localisation performances Lebrun et al. 2014
  - Design of a prototype imager in CMOS



  2016 :SATT supports the « prematuration program» : (50 k€/ 6 months)
  application to a medical gamma camera (convince industrial partners)

  2017 : stop of the project because no technical forces available

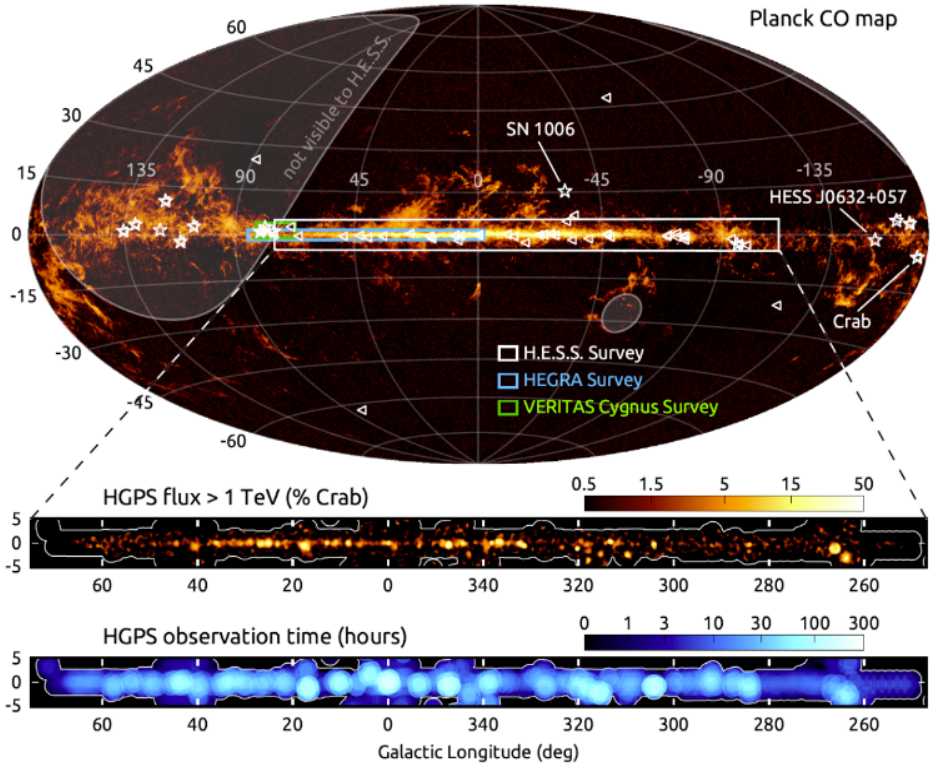
VHE gamma-rays : HESS-I

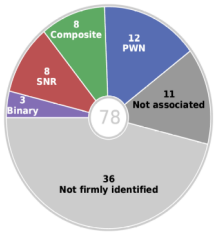
APC activities on HESS I :

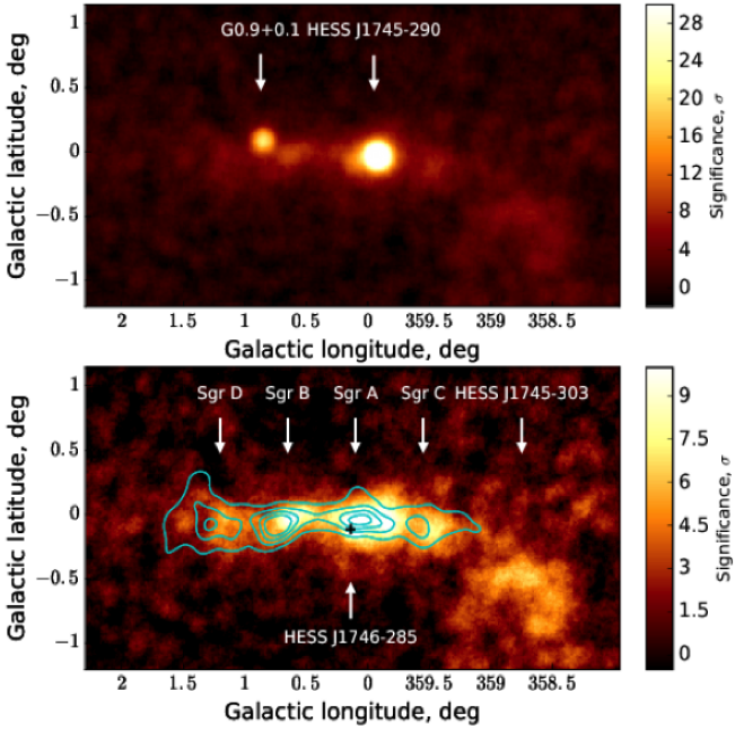
Préparation of the HESSLegacy :

- HESS-I Legacy Survey : 3000 h of data, 78 sources + diffuse emission
- SNR pop studies, PWN pop studies
- Galactic center

Special Edition A&A End 2017 (14 articles submitted, 10 accepted, 4 en review, Public Data Release in prep)



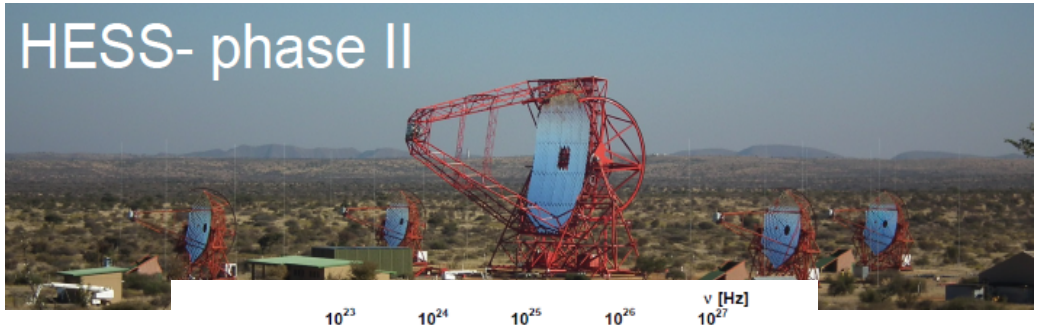




VHE gamma-rays : HESS-II

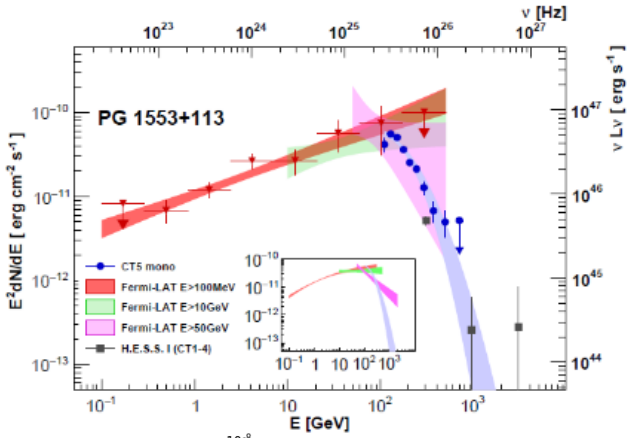
HESS-II : add 5th telescope
(28 m diameter, camera 2000 pixels)

- Reduce E threshold : 100GeV → 30 GeV
- In operation since 09/2012



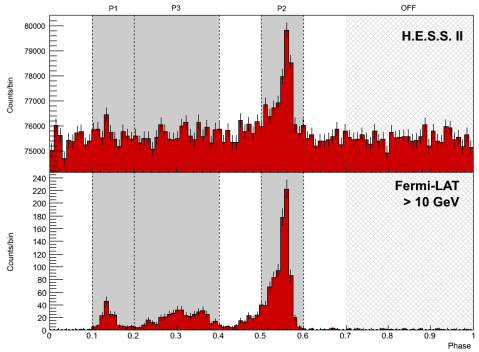
APC implication in HESS II : Data analysis on mono-telescope mode and stereo-telescopes mode :

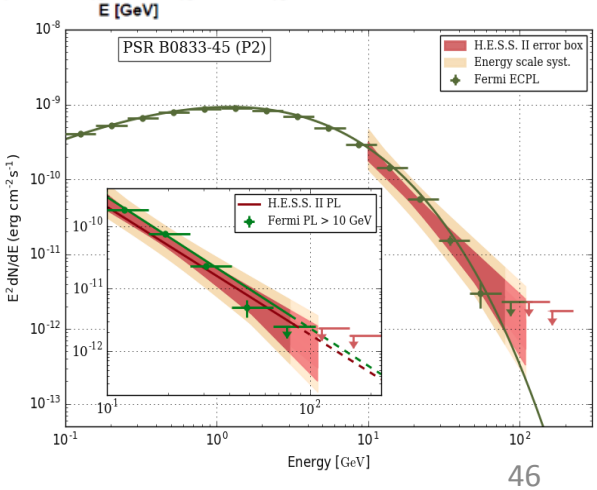
- Spectral analysis of AGNs:
  First Analysis of HE-VHE Blazar Spectra with H.E.S.S. II: PKS 2155-304 and PG 1553+113 *(published)*



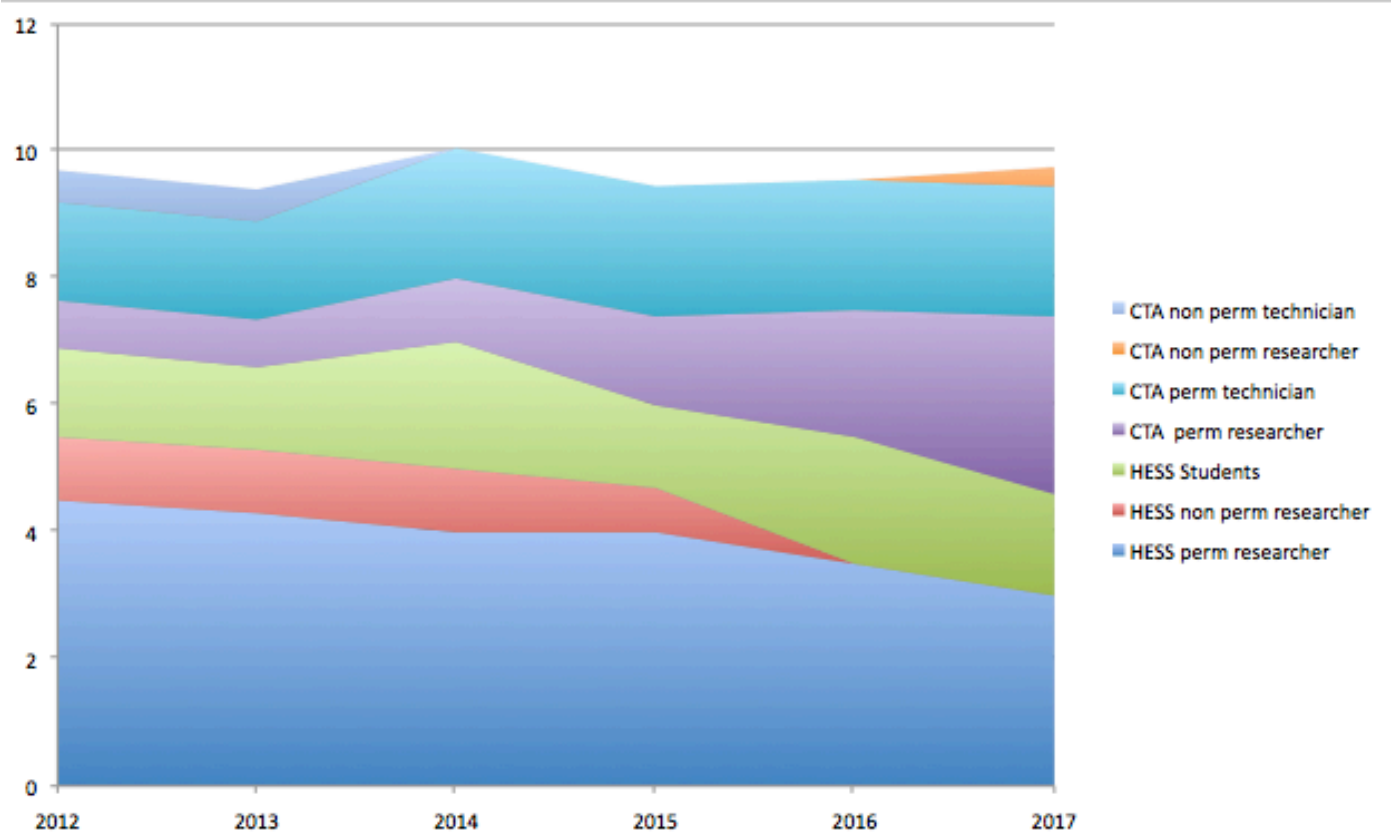
- Discovery of the pulsed HE emission of the Vela pulsar:

First Ground-based Measurement of Sub-20 GeV gamma-rays from the Vela Pulsar with H.E.S.S. II (*submitted)*





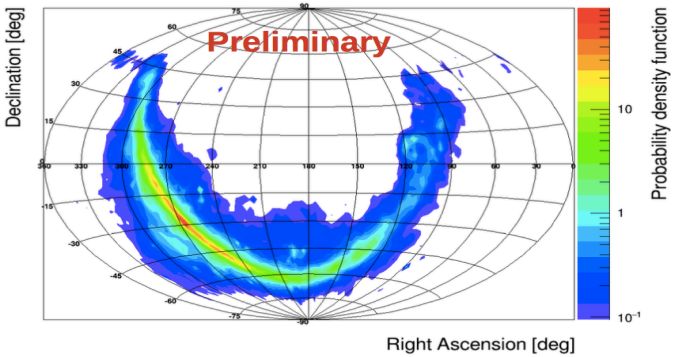
Workload HESS & CTA



AHE neutrinos : Antares

- Deep-sea VHE neutrino telescope
- Timeline: Complete since 2008, running until end 2018

- APC Activities : *(A.K spokesman since 2014)*



Hardware :

– Front-End electronics calibration, Data Quality monitoring,

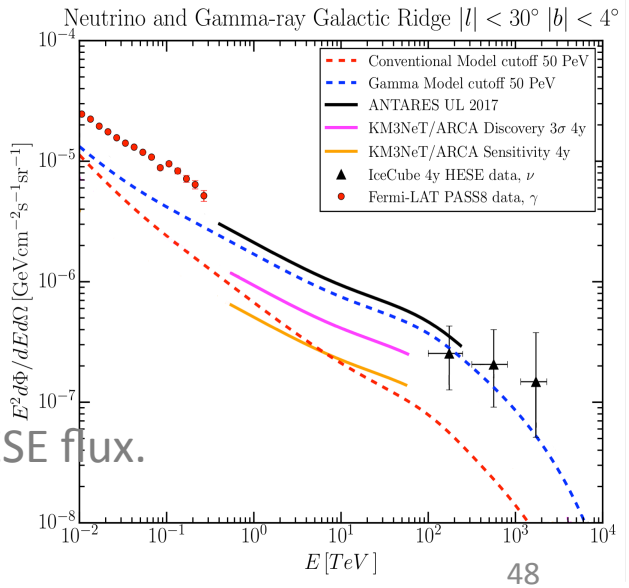
- Optical sensor measurements :

(responsabilities : Data quality(V.VE),CalibrationB.B)

Analysis : (B. Baret,T. Grégoire, A. Kouchner, V. Van Elewyck)

- Search for Cosmic neutrinos in the Galaxy :
  - Limit on Fermi Bublles and Galactic center signal
  - Emission from the Galactic Plane Ridge:

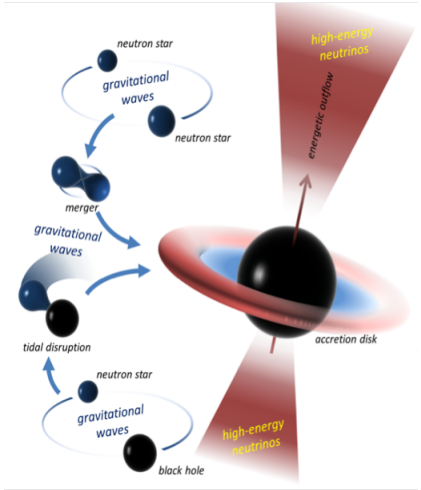
    Galactic emission contributes max 18% of IceCube HESE flux.

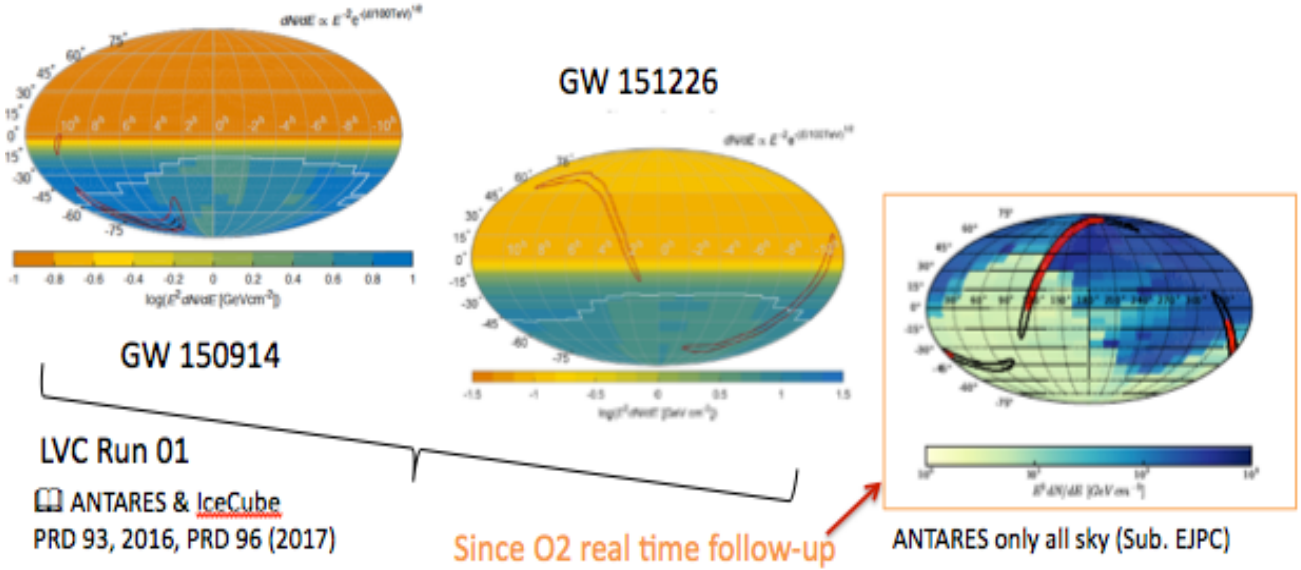


AHE neutrinos : Antares

Search for Cosmic neutrinos outside of the Galaxy : mulit-messengers studies

- GWHEN : *first joint search for HE neutrinos and gravitational waves(LIGO/VIRGO*)
- Search for *neutrinos and UHERCs from GRBs*
- *Gravitational lenses,time/space correlations.*
- Follow-up observations of Gravitational waves Events recently seen by LIGO/VIRGO





UHECR: Euso-Ballon & X-EUSO

- **Definition and goal of the mission:**
  - Wide field UV telescope operating from the ISS
  - Space based detection of UHECRs, through the fluorescence light of the induced showers

- **Main highlight :**
  - successful flight of the EUSO-Balloon pathfinder, funded by CNES (Aug. 2014): 1 PDM (photo-detection module) on a stratospheric balloon
  - EUSO SPB : APC responsible for the development, integration tests and calibration of the instrument focal surface
    Launched in April 2017, data analysis in progress

- **APC activities :**
  - R&D Photodetection, calibration
  - Science case preparation, modelling
  - Simulations & data analysis
  - French PI at APC & EUSO-balloon project manager at APC/ Member of the speaker's bureau

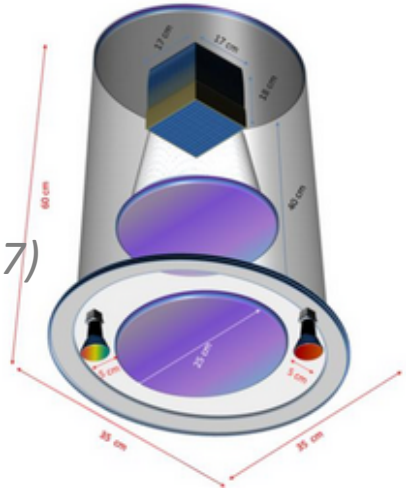
UHECR: Euso-Ballon & X-EUSO

- **Future Timeline:**

  - mini EUSO (ASI +ROSCOSMOS):

  Launch end 2018/ data in 2019

  1 PDM onboard the ISS *(approved by ROSCOSMOS and ASI, 2017)*



- **SPB2** (NASA) (POEMMA & K-EUSO pathfinder) :

  August 2017 : sélection & funding by NASA (2018-2022)

  2021/2022 : long flight

- **K-EUSO : Russian project on ISS** (~ 4 X AUGER)

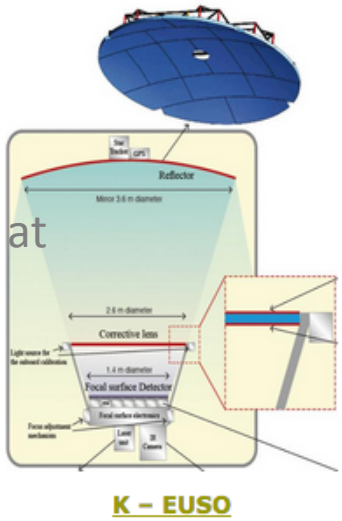
  Launch 2022 (electronic similar to mini EUSO but with ASICs integration at at APC)

- **POEMMA (NASA):**

  2017: selection as « Probe study »for the next NASA decadal survey

  Extending science case to multi-messenger

  2017-2030 if final selection



K – EUSO

The HEA group

- 24 staff researchers

Allard Denis (CR1)
Baret Bruny (CR1)
Djannati-Atai Arache (DR) (HDR)
Gabici Stefano (CR1) (HDR)
Khélifi Bruno (CR1)
Lemière Anne (CR1)
Pita Santiago (CR1)
Punch Michael (CR1)
Terrier Régis (CR1) (HDR en cours)
Varniere Peggy (CR1)
Capdevielle Jean-Noel (EMERIT)
Gorodetzky Philippe(EMERIT)

Casse Fabien (MCF)(HDR)
Creusot Alexandre (MCF)
Donzaud Corinne (MCF P11)
Kouchner Antoine (PR) (HDR)
Lachaud Cyril (MCF)
Parizot Etienne (PR) (HDR)
Van Elewick Véronique (MCF)

Goldoni Paolo (CEA)
Goldwurm Andrea (CEA) (HDR)
Laurent Philippe (CEA) (HDR)
Loucatos Sotiris (CEA) (HDR)
Lebrun Francois (CEA, retired, associated to APC)

- 3-6 Post-doc

Maier Daniel (CDD CNES jusqu'en Avril 2017)
Sarria David (CDD CNES jusqu'en nov 2016)
Volodymyr Savchenko (CDD CNES jusque fin 2016)
Van Marie Allard (ANR)
Reccia Sarah (CDD DIM ACAV)
Atreyee Sinha (CDD in2p3, depuis 10/2017)

- 7-9 phd

Jung Aera (defended in 2017)
Jouvin Léa (defended in 2017)
Chuard Dimitri (end in 2018)
Grégoire Timothée (end in 2018)
Si Chen (end in 2018)
Phan Thanh-Hien (end in 2019)
Demidem Camilia (end in 2019)
Jacob Marion (end in 2019)
Phan Vo Hong Minh (end in 2020)

Scientific responsabilities

ANTARES, KM3Net

- Spokesperson (A. Kouchner) ANTARES
- Responsible of the Astronomy working group (~60 people, largest of the collaboration, divided into 4 subgroups): since 2008 (A. Kouchner)
- Responsible of the data quality (V. van Elewyck)
- Responsible of the working groups “Charge and Energy Calibration” and “Point-like sources” (up to 2008) (A. Kouchner)
- Coordination of the DAQ Front End Electronics Calibration group (since 2006) (A. Kouchner, then B. Baret)
- Member of the Steering Committee of the collaboration (since 2008) (A. Kouchner, B. Barret)
- Member of the collaboration’s Publication Committee (since 2011) (A. Kouchner, B. Barret)

HESS, HESS-2, CTA

- Deputy-spokesman of the HESS collaboration (M. Punch)
- Coordination of the HESS AGN working group (M. Punch)
- Responsibility of the Quality workpackage of CTA (HEA team, M. Punch)
- Participation to the CTA Science workpackage:

Responsibility of the SNR and Molecular Clouds working group (S. Gabici)
Responsibility of the reconstruction in the Data working group (A. Djannati-Ataï)
Co-responsibility of the advanced analysis methods working group (A. Djannati-Ataï)

INTEGRAL

- Co-PI of the IBIS instrument and permanent member of the INTEGRAL User Group (P. Laurent)
- Participation to the INTEGRAL User Group (→ 2009) (A. Goldwurm)
- Member of the Time Allocation Committee (2009-2010) (R. Terrier, A. Goldwurm)

JEM-EUSO and EUSO-Balloon

- Initiator of the French participation to the mission and National PI of JEM-EUSO (E. Parizot)
- Member of the Executive Committee of JEM-EUSO (E. Parizot)
- Deputy European Coordinator of JEM-EUSO (E. Parizot)
- International Project manager of the EUSO-Balloon mission (funded by CNES) (G. Prévôt, physicien référent: E. Parizot)
- Responsible of the calibration workpackage for JEM-EUSO and EUSO-Ballon (P. Gorodetzky)

SVOM/ECLAIRs

- Responsibility of the coded mask of the main instrument (ECLAIRs) (C. Lachaud)
- Responsibility of the General program (A. Goldwurm)
- Responsibility of the Too program and multi-messengers (C. Lachaud)

TARANIS/XGRE

- Co-PI of the XGRE instrument (F. Lebrun, P. Laurent)
- Project manager (M.Lindsey Clark)

ATHENA

- Responsibility of the WFEE of the X-IFU instrument (A. Goldwurm, Prêle)
- Referent scientist (A. Goldwurm)