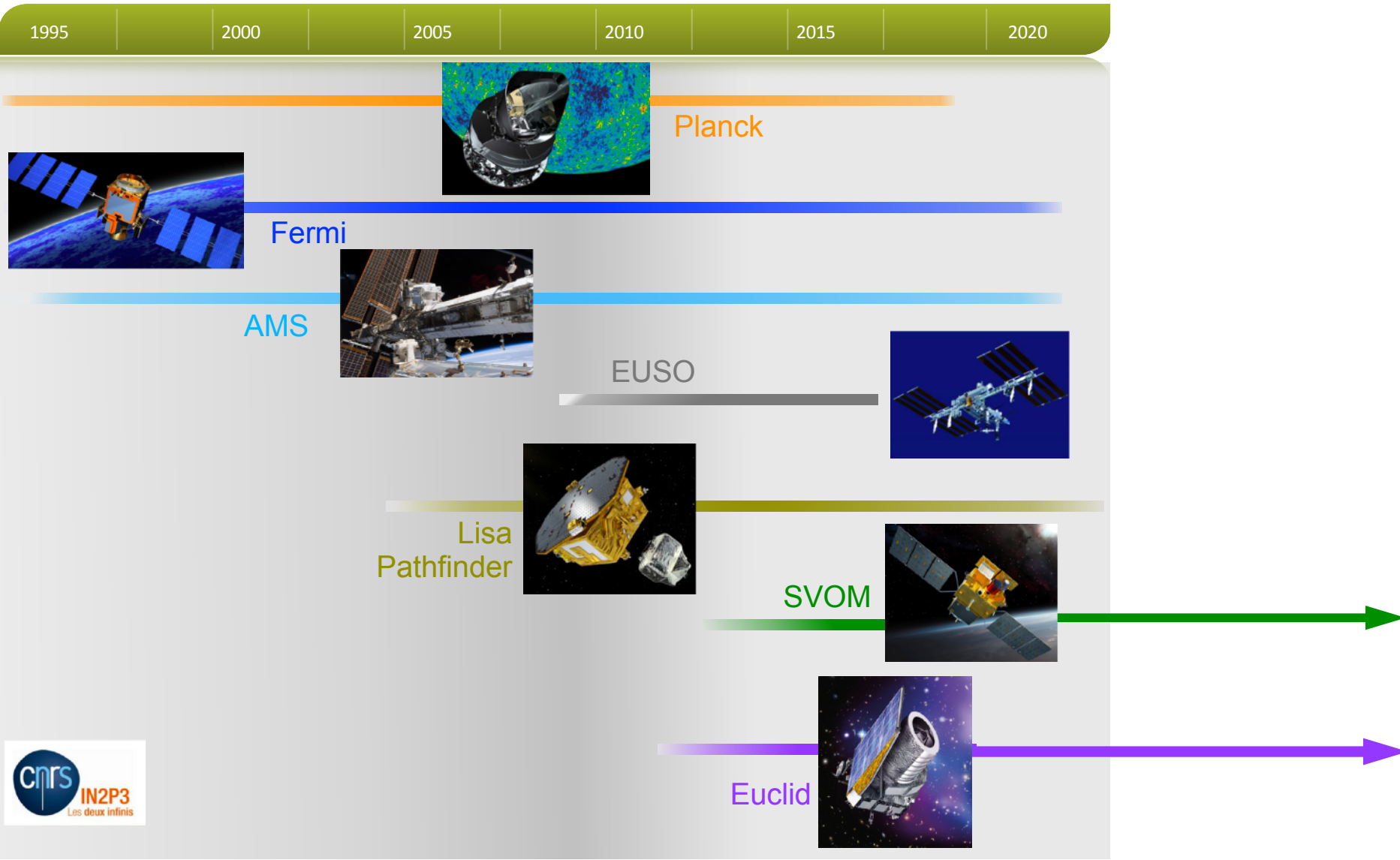


# IN2P3 in Space Part I

## « Summary » and next steps

June 2020 IN2P3 scientific council

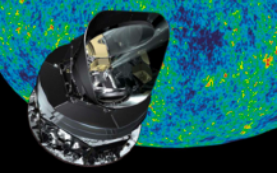
# IN2P3 in space: past and present (discussed today)



# Complementary balloon adventures



Archeops



Planck

Fermi



AMS

EUSO



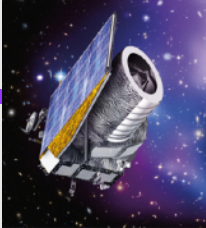
Lisa Pathfinder



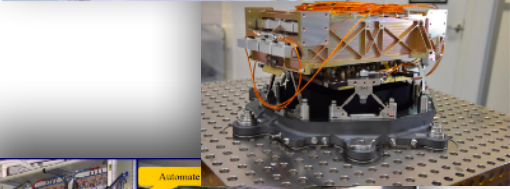
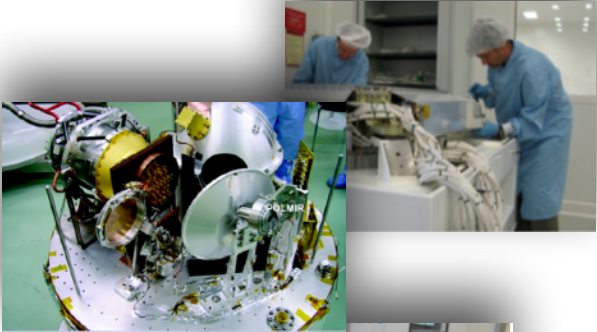
SVOM



Euclid



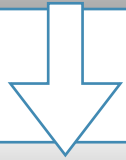
# Involvement of IN2P3 teams at each step



Instrumental deliveries



Integration, calibration

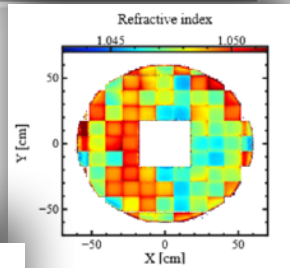
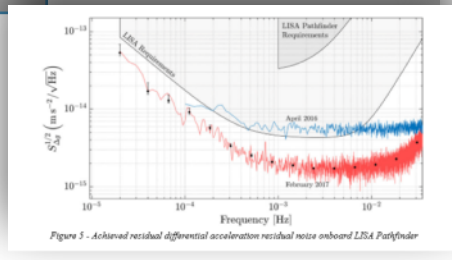
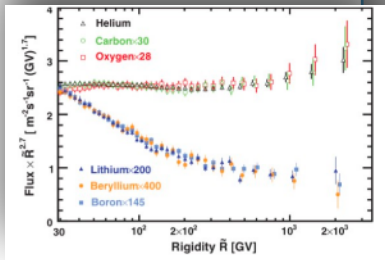
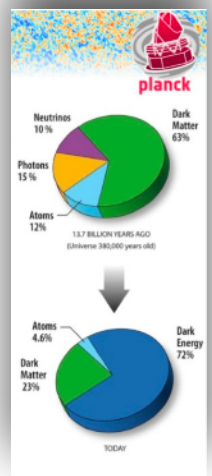
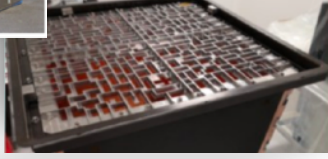
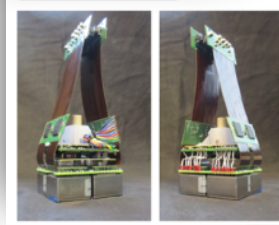
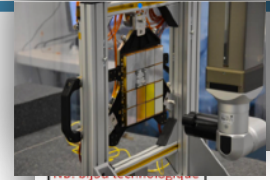
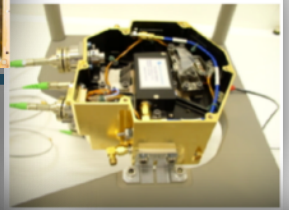
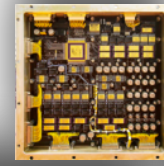


Data analysis and simulations



Scientific results

- astroparticles
- cosmology



# Space instruments instrumental deliveries

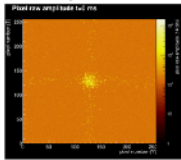
Contributions in various technical domains for space instruments construction:

- conception, realisation and delivery of detection systems
- mechanics for flight models: design and fabrication
- electronics & computing for on-board processing unit
- electronics for on-board cryogenic systems
- ...

## LABORATORIES DEVELOPMENT

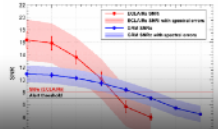
IJCLab is responsible for the on-board scientific partition of the *MXT* instrument. The group also develops the pipeline using the VHF data from the *MXT* instrument. It has been leading the activities around the program for *Target of Opportunity* on multi-messengers alerts. IJCLab works at the interface with *LIGO/Virgo* and *LSST*. Finally, it proposed the *Virtual Data Infrastructure* as an integration center for the French Scientific Center.

Simulation of a GRB in *MXT* camera



LUPM is in charge (with IAP/INSU) of the *ECLAIRS* and *GRM* data analysis pipelines (VHF and X-band) for the Core Program at the French Science Center. For this purpose, LUPM is also coordinating the Sino-French *ECLAIRS/GRM* analysis group. LUPM works also on the synergy with *CTA* (and *Fermi*), making the link with the *Transient Working Group* of the *CTA* Consortium.

Simulation of *ECLAIRS* and *GRM* response to GRB170817A



## Contribution Française (construction)

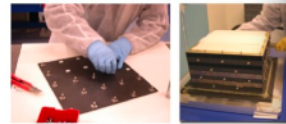
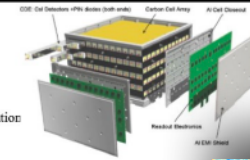
~ 20 ingénieurs et techniciens durant la phase de construction (plus de 10 ans)

- LUPM Montpellier
- LPSG Grenoble
- RICH
- ECAL

- PMT Front Electronic & integration
- Radiator plane Characterization
- Light collection system and Front End Electronics readout

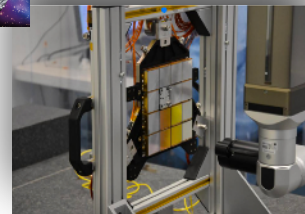
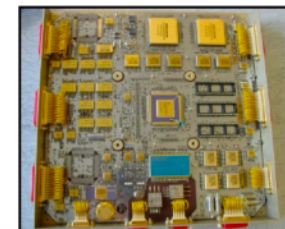
## LAT calorimeter

- IN2P3 contribution to the instrument construction
- Design phase
  - Carbon fiber structure (LLR, from CMS)
  - Crystal wrapping (LLR)
  - Photodiode size and bonding (C. Chapron, PCC)
- Structure fabrication (O. Ferreira, LLR)
  - Purchase of an autoclave (180 k€) to improve polymerization clean room
  - Metrology (LLR) + vibration tests (externalized)
  - 24 structures delivered to NRL (~2 per month)
- Quality/system engineering:
  - Standard in spatial activities
  - A kind of revolution for IN2P3
  - 2 engineers were hired
    - P. Prat (PCC)
    - S. Couturier (LLR)



## Planck @ IN2P3 inflight hardware

- **Data Processing Unit (DPU)**
  - development and construction of the Planck-HFI DPU
- **Electronics for cryogeny**
  - electronic for the sorption cooler (SCE-20K)
  - electronic for 100mK dilution valve control (DCE)
  - control command (SCE-20K) (soft & validation tests)
  - cryo-harness (SCE-50K)



# Space instruments AIT/AIV/Calibration

- Large involvements of IN2P3 teams in characterisation and calibration of instruments
- from component level characterisation
- to integrated level calibration operations in cold environment (in dedicated cryostats)
- design, fabrication and deliveries of Ground Segment Equipment for such activities
- till in-flight calibration operations

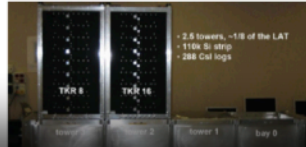
## Beam tests and calibration



Several beam tests (SLAC, CERN) during design phase (LLR, PCC)

For calibration and performance validation (IN2P3 lead):

- GANIL, GSI (CENBG) :
  - MIP peak of cosmic ions useful for on-orbit calibration
  - Beam tests found anti-quenching for light ions (alpha, C, O) in relativistic domain
- CERN PS+SPS (CENBG, LLR, LUPM)
  - Test of the Calibration unit (2.5 towers)
  - Photons and electrons
  - Check direction and energy measurement



Software for the in-flight calibration (LUPM)

- Selection of MIP cosmic ions that are used for the inter-calibration of the 2 crystal ends

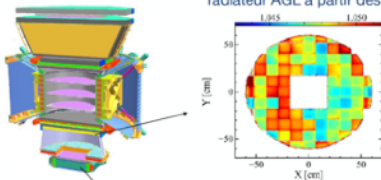
Verification of the GPS timing (CENBG)

- Bug fix thanks to a cross-check with

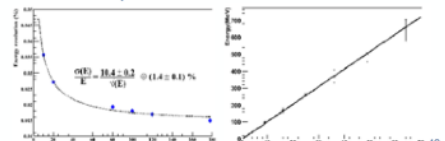
## Contribution Française (Performances)

Nombreuses contributions à l'étude et à l'optimisation des performances des détecteurs. Quelques exemples :

- Reconstruction de la carte d'indice des tuiles du radiateur AGL à partir des données de vol :



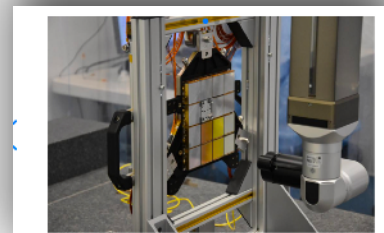
- Calibration et performances ECAL à l'aide données TB et ISS :



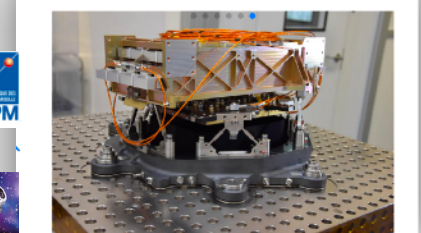
### Planck @ IN2P3 ground segment hardware

planck

- Participation to the ground pre-flight HFI calibration
  - construction of the polarisation wheel and source
  - calibration sources
  - control command of the calibration setup cryogenics
  - measurement of time constants, non-linearity, cross-talk
  - FTS measurements
  - impact of cosmic rays on detector (using particle beam)
- Data taking
  - participation to calibration phases (2004 & 2006 & 2008)
  - participation to the Daily Tele-Communication Period



Intégration des détecteurs infra-rouges du plan focal du satellite Euclid




Intégration des détecteurs infra-rouges du plan focal du satellite Euclid

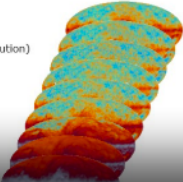
# Data Analysis & simulations

- Data analysis activities in close link with instrumental developments
- Simulations, production, data processing,
- Instrumental systematics & the end of the statistics dominated error bars
- Close interactions between scientific and technical teams
- Key role of CC-IN2P3 data center for some missions
- (not to mention shifts, participation in IOT...)

## Planck @ IN2P3 data analysis #1



- **Simulations**
  - pipeline construction and support
  - development of simulation modules for instrumental effects
- **Data processing and systematics studies**
  - study of **glitch** impact on data and method for removal
  - model for **non-linearity** of the detector response (from ADC)
  - studies of systematics for polarisation (including impact of NL ADC)
  - time constant models
- **responsible for Timeline processing**
  - development of **time processing pipeline** and algorithms (demodulation, detector non-linearity, temperature variation deconvolution)
  - Data validation, cleaned timeline production
- **responsible for Map-Making and calibration**
  - development of **map-making** algorithm (destripping)
  - upgrades to include identified systematics (as templates)
  - Inflight calibration in temperature and polarization
  - map production (for public release)



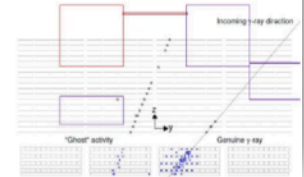
## Event reconstruction/selection

Energy reconstruction (the calorimeter is only 8.6 X0 but longitudinally segmented)

- Development of several algorithms (PCC,LLR) to cover the full energy range ( $\rightarrow 2$  TeV)

Data version timeline

- Pass 6: developed before launch
  - o Meets performance requirements
  - o First data: effective area loss (10-30%) due to off-time pile-up of cosmic protons
- Simulation changed to include pile-up
  - o Correction of the Instrument Response Functions
- Pass 7: same reconstruction, optimized selection
  - o Public release in 2011
  - o Reprocessing with improved calibration (2013)
- Pass 8: full reworking of the reconstruction (2015)
  - o New tracking + clustering in calorimeter
  - o Increased energy range
  - o  $>+25\%$  of effective area
  - o Data partition according to direction quality
- Strong IN2P3 contribution to these developments



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## Software

- The IN2P3 is responsible for the coordination of the deployment, integration and production of Euclid simulations at the French part of the Euclid Data Center (SDC-Fr – CC) - CPPM
- The IN2P3 is responsible for the deployment, integration & production of simulations (SC3, SC456, SC7 et SC8) - CPPM/CCIN2P3/APC
- The IN2P3 develops two of the major Euclid simulators:
  - o EXT (LSST, KIDS, DES) - APC
  - o TIPS - NISP Spectroscopy - CPPM

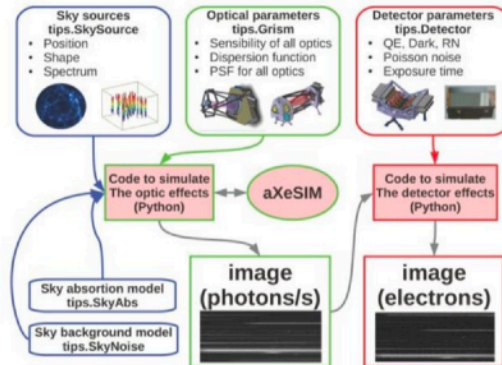
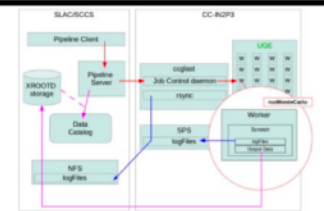


Figure 6: Schematic view of TIPS.

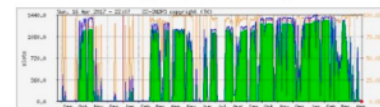
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## Simulation at CC-IN2P3

- LAT pipeline branch at CC-IN2P3 (LUPM): development, exploitation & maintenance
  - o 1300 to 1600 cores at any time
  - o Virtualization (Singularity containers) in 2017-2018
- All MC simulations performed at CC-IN2P3 since launch:
  - o Event reconstruction optimization, IRFs production, backgrounds
  - o 380 millions of CPU hours (HS06 units)
- CNES support: 4 engineering contractors at LUPM in 10 years
- IN2P3 in-kind contribution to the LAT common funds:  $\sim 1.9$  M€ since 2009



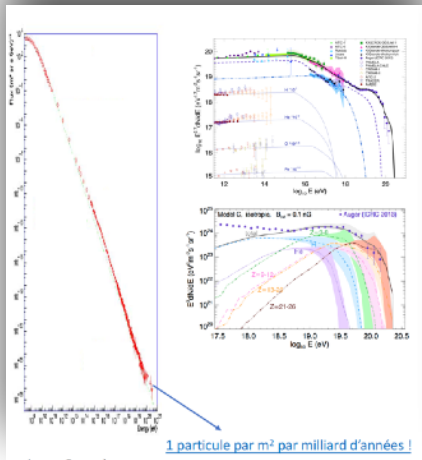
Number of running jobs (09/2015-04/2017):



15

# Astroparticles physics: results ! and prospects

- Better characterise and hence understand the physical processes at the origin of the cosmic messengers: gamma rays, neutrinos, cosmic rays, gravitational waves...
- constrain the models of SN, Pulsars, AGN/Blazars, ...
- hopefully get insiders to the nature of Dark Matter.



## Multi-messengers

**Burst Advocates:**

- monitor LIGO-Virgo alerts and check the automatic analyses by the LAT GW pipelines
- 11 LAT GCN circulars (flux upper limits) during LIGO-Virgo O3 run

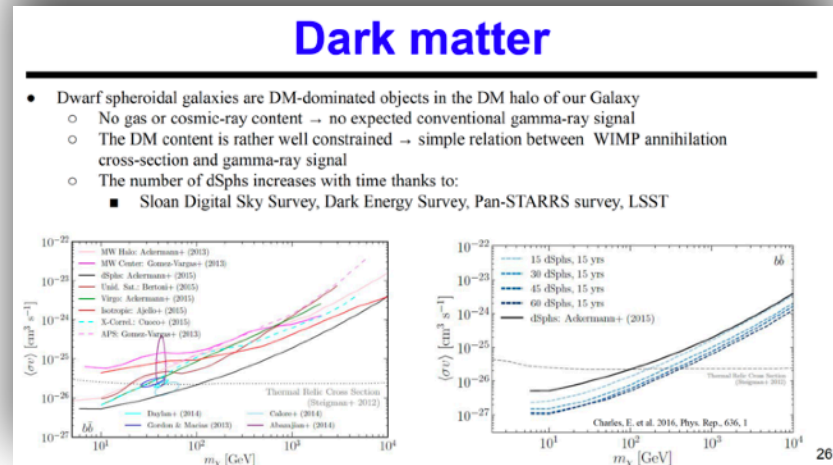
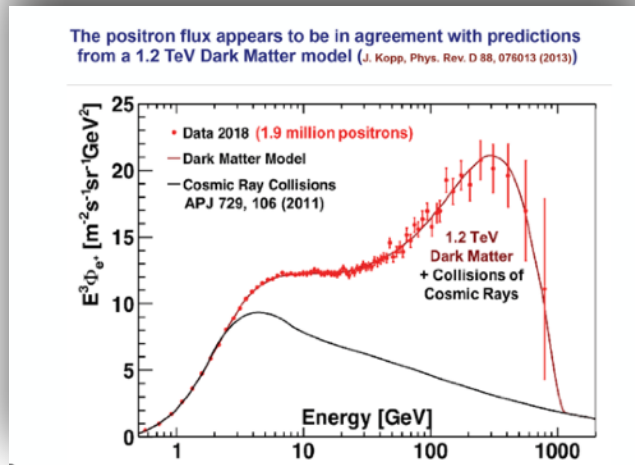
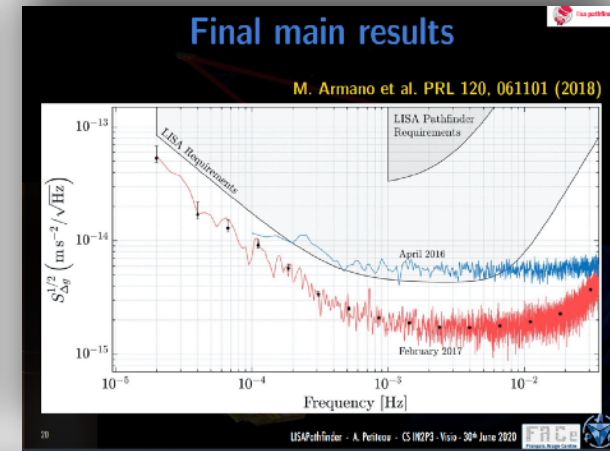
**Flare Advocates:**

- monitor IceCube neutrino alerts, look for possible LAT counterparts in the error region
- run dedicated analyses on the candidates (over various timescales) and issue ATels or GCNs

LAT scan (in ~5 ks) of the error localization contour (~14700 deg<sup>2</sup>) of S190901ap (86% Binary Neutron Star merger, 240±80 Mpc) detected by LIGO-Virgo

**Fermi-LAT detection of enhanced gamma-ray activity and hard spectrum of TXS 0506+056, located inside the IceCube-170922A error region**

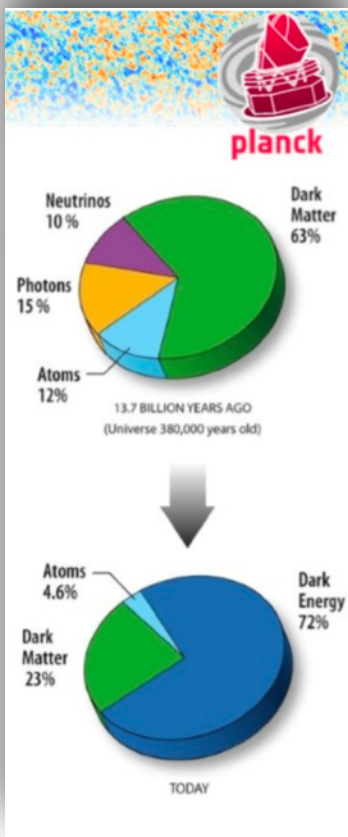
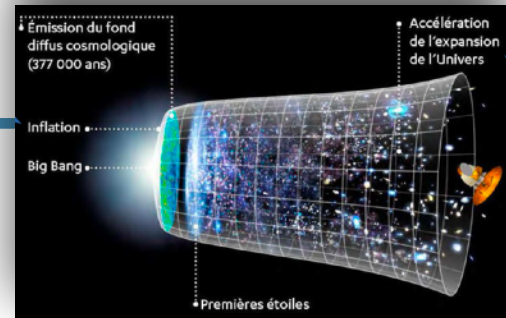
ATel #11410; *Roopesh Ojha (NASA/GSFC/UMBC), and Janeth Valverde (LLR/Ecole Polytechnique) on behalf of the Fermi Large Area Telescope Collaboration on 14 Mar 2018; 20:16 UT*





# Cosmology: results ! and prospects

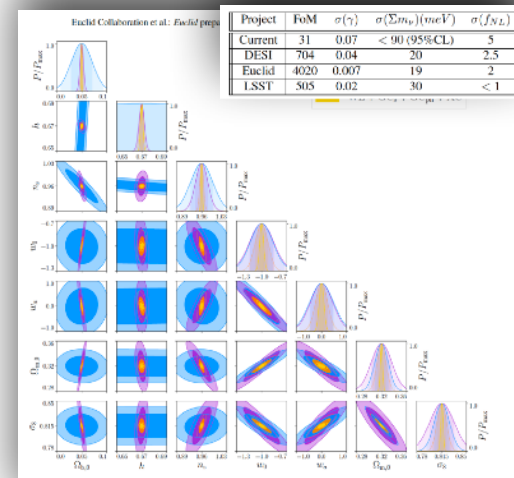
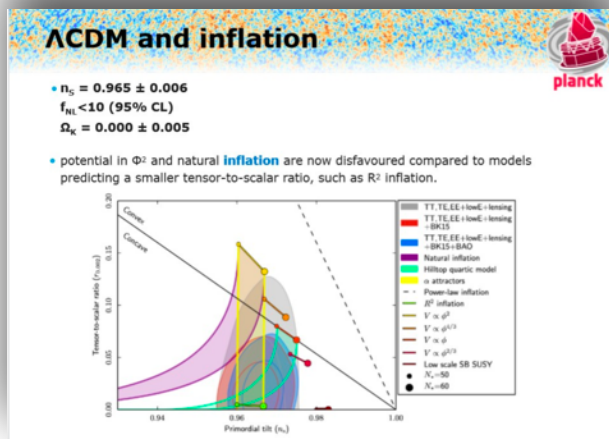
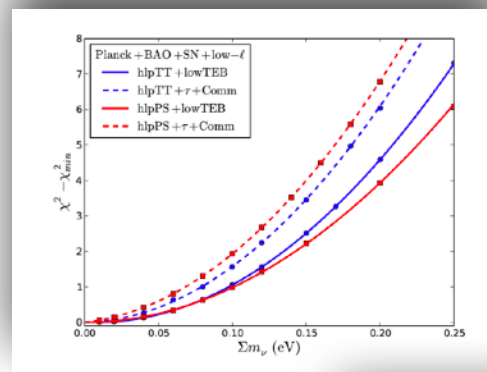
- $\Lambda$ CDM and precision cosmological physics
- Tests of robustness of the concordance model
- Dark Matter and Neutrino sector constraints through cosmo
- Further constrain inflation and reheating physics (coupled with hep physics)
- Understand the accelerated expansion: a new energy component with a repulsive action, or a modification of general relativity



**$\Lambda$ CDM results with time**

	WMAP	Planck 2013	Planck 2015	Planck 2018
$\Omega_b h^2$	$0.02264 \pm 0.00050$	$0.02205 \pm 0.00028$	$0.02225 \pm 0.00016$	$0.02236 \pm 0.00015$
$\Omega_c h^2$	$0.1136 \pm 0.0045$	$0.1199 \pm 0.0027$	$0.1198 \pm 0.0015$	$0.1202 \pm 0.0014$
$H_0$	$70.0 \pm 2.2$	$67.3 \pm 1.2$	$67.27 \pm 0.66$	$67.27 \pm 0.60$
$n_s$	$0.972 \pm 0.013$	$0.960 \pm 0.007$	$0.964 \pm 0.005$	$0.965 \pm 0.004$
$10^9 A_s$	$2.189 \pm 0.090$	$2.196 \pm 0.090$	$2.207 \pm 0.074$	$2.101 \pm 0.033$
$\tau$	$0.089 \pm 0.014$	$0.089 \pm 0.014$	$0.079 \pm 0.017$	$0.054 \pm 0.007$
$\Omega_m$	$0.721 \pm 0.025$	$0.685 \pm 0.018$	$0.684 \pm 0.009$	$0.685 \pm 0.007$
$\Omega_\nu$	$0.279 \pm 0.023$	$0.315 \pm 0.018$	$0.316 \pm 0.008$	$0.315 \pm 0.007$

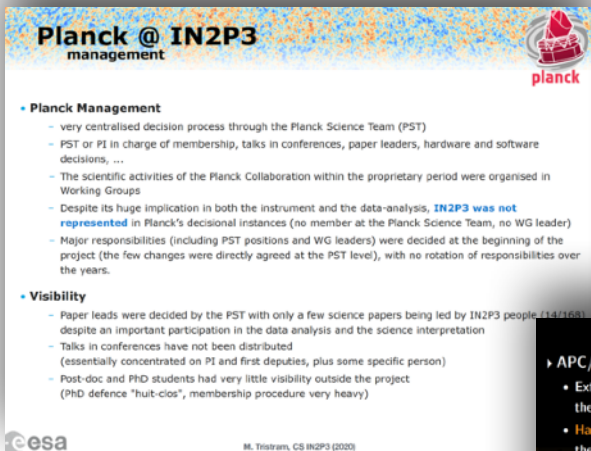
- more than a factor 2 on errors for basic  $\Lambda$ CDM parameters wrt WMAP
- Very stable with time
- Precision cosmology (below 1% error bar for most of them)



2x Fisher Matrix marginalised contours for the Euclid specification for a  $m_\nu$  flat cosmology, for CC, (purple), WL (blue), their combination (orange) and with the addition of  $GC_{\text{gal}}$  and its cross-correlation with WL (yellow). All combinations correspond to an optimistic

# Return of Experience

- Learn from past experience to build the future
  - Space methodology in instrumental work (quality, new procedures...)
  - Confidence of space agencies in IN2P3 labs / CNES Space label for IN2P3 labs ?
  - The PI/consortium wrt Spokesman/collaboration model
  - Importance of hardware delivery to be part of core teams
  - The pressure of open data and scientific results deadlines
  - Data: properties of PI at the end of the mission ?
  - The relation with other partners in France and its evolution with time
- ..... A lot to be digested and thought further ...



**Planck @ IN2P3 management**

- **Planck Management**
  - very centralised decision process through the Planck Science Team (PST)
  - PST or PI in charge of membership, talks in conferences, paper leaders, hardware and software decisions, ...
  - The scientific activities of the Planck Collaboration within the proprietary period were organised in Working Groups
  - Despite its huge implication in both the instrument and the data-analysis, **IN2P3 was not represented** in Planck's decisional instances (no member at the Planck Science Team, no WG leader)
  - Major responsibilities (including PST positions and WG leaders) were decided at the beginning of the project (the few changes were directly agreed at the PST level), with no rotation of responsibilities over the years.
- **Visibility**
  - Paper leads were decided by the PST with only a few science papers being led by IN2P3 people
  - despite an important participation in the data analysis and the science interpretation
  - Talks in conferences have not been distributed (essentially concentrated on PI and first deputies, plus some specific person)
  - Post-doc and PhD students had very little visibility outside the project (PhD defence "huit-clos", membership procedure very heavy)

## Retrospective SWOT analysis

	1998	A posteriori assessment
Strengths	Expertise in particle physics (detector design to event analysis).	It worked very well in all aspects and contributed much to our successful integration in the collaboration.
Weaknesses	No spatial label for instrument construction nor data exploitation.	The starting phase has been difficult but we were able to remain in the project, allowing us to gain the spatial label both on the i
Opportunities	Moving from first generations Cherenkov telescopes (small number of sources) to a success-guaranteed mission (thousands of sources, x20 better than	It actually seems to Fermi.
	EA, CNES)	Yes, but IN2P3/CN Yes, but now it has It turned out not to

### Return of experiences

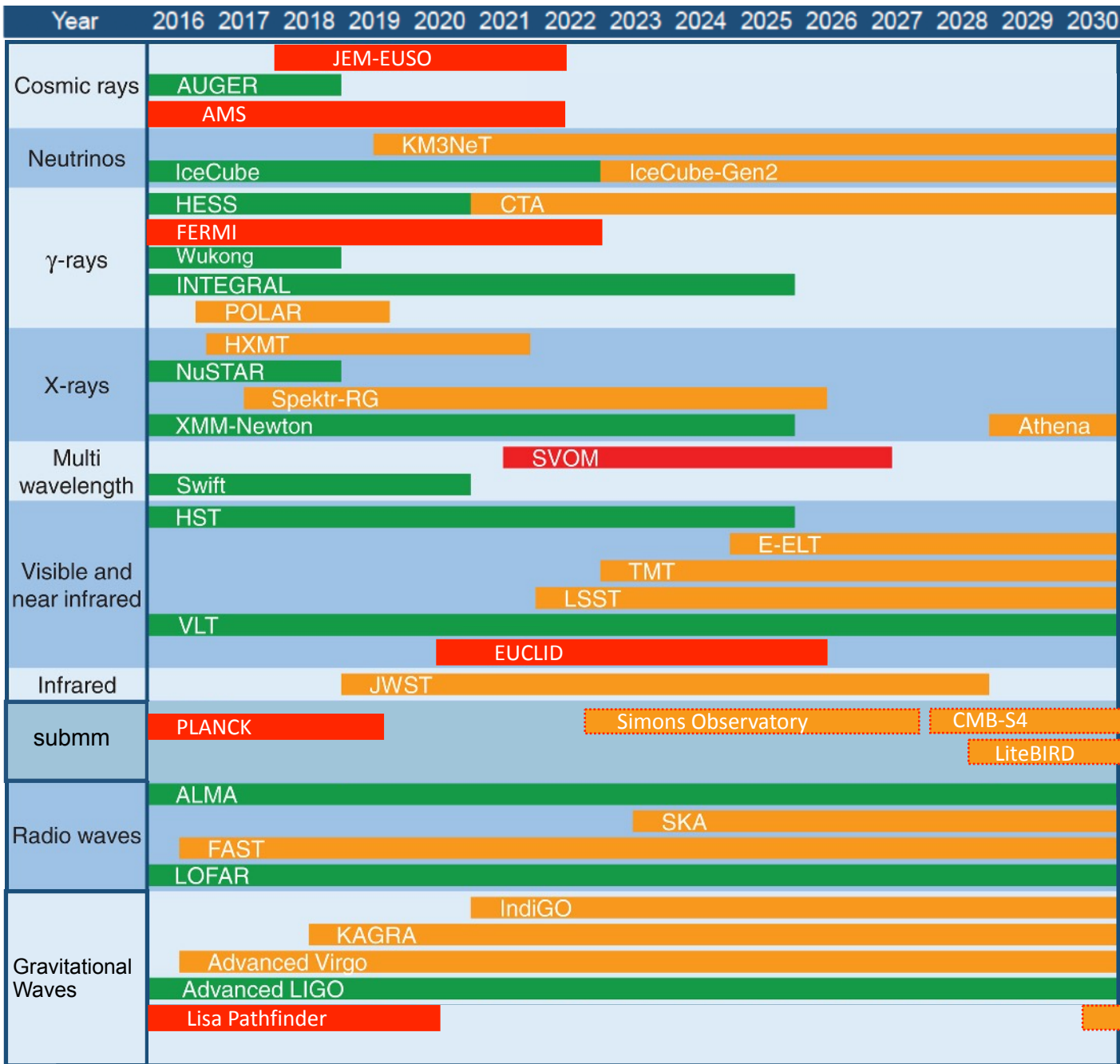
- **APC/IN2P3 level:**
  - Extreme level of precision + complexity => a **global understanding** of the instrument and the mission is necessary
  - **Hardware contribution:** crucial to be part of the core team developing the instrument & an access to the relevant information
  - Importance of an **'agile' collaboration infrastructure** (as FAcE), in particular for in-flight preparation and operations
  - Active participation to the **Operation & Data Analysis** preparation effort and exercises
  - **Human resource** support to capitalise on acquired experience and 'stabilise' skills (instrumentation, simulations, data analysis, etc.)
    - CNES: 'equipments' & **short term** contracts for technical assistance,
    - CNRS/IN2P3 to ensure a **long-term** support & workforce visibility

## AMS : retour d'expérience (1/2)

AMS projet spatial unique:

- Projet construit autour d'une communauté avec une expertise forte de l'instrumentation HE mais sans expérience spatiale.
- Partage du financement et des responsabilités entre la NASA et la DOE : la collaboration responsable de la réalisation de l'instrument et son opération, le retour scientifique.
- Rôle majeure du précurseur AMS-01 pour le projet, bien au delà de la validation des concepts instrumentaux :
  - Crédibilité de la collaboration auprès des agences
  - Préparation de l'analyse.
  - Premiers retours scientifiques, nombreuses publications.
  - Renforce la visibilité et l'attractivité du projet, essentiel pour la formation des étudiants.
- Rôle clé pour consolider une collaboration malgré les délais et un futur qui a été longtemps compromis.

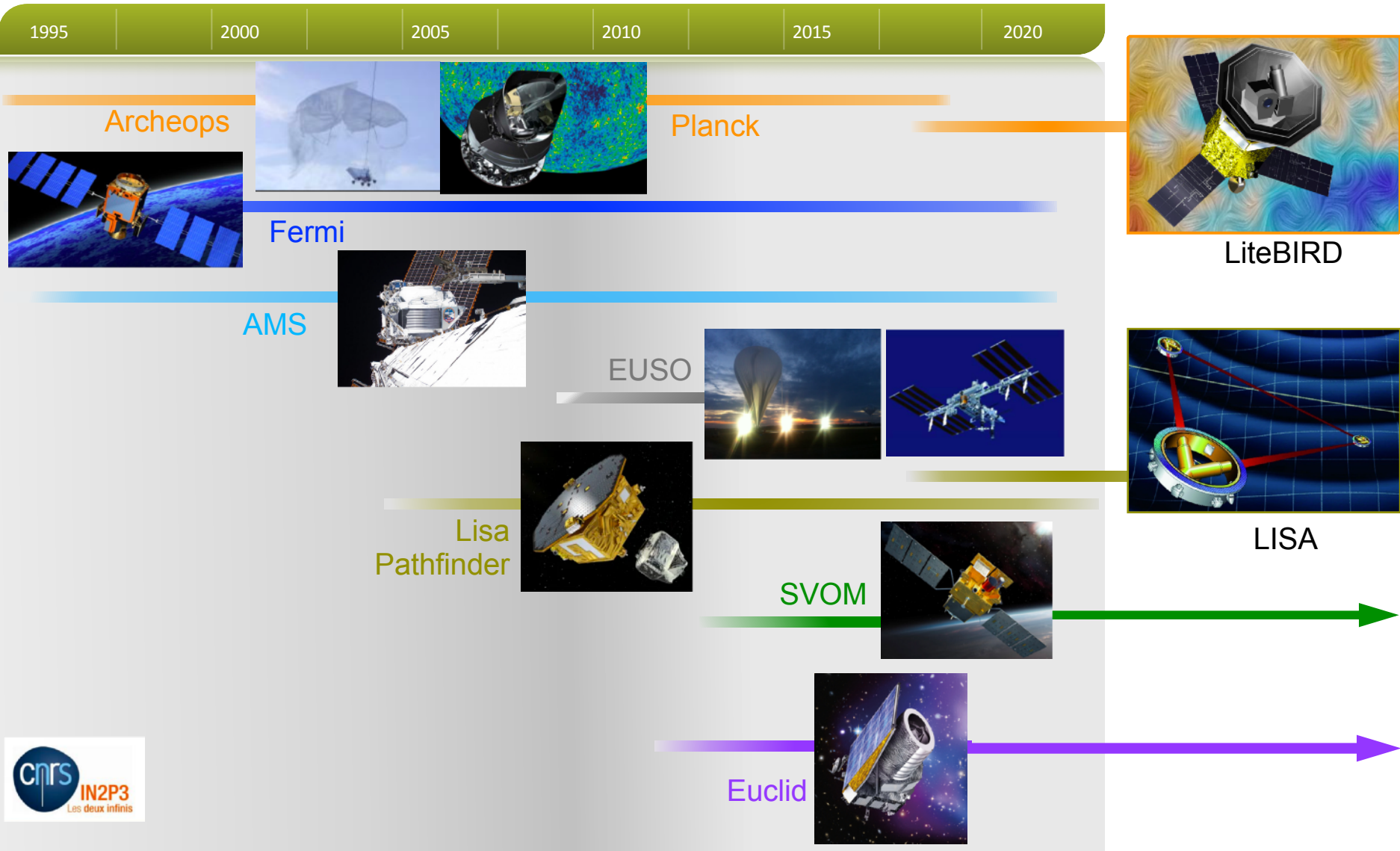
adapted from Astronomische Nachrichten, Volume: 338, Issue: 9-10, Pages: 978-983, First published: 28 November 2017, DOI: (10.1002/asna.201713415)



- Coherent scientific program combining ground and space (and balloon) experiments  
 > astroparticles  
 > cosmology

Einstein Telescope  
 LISA

# For next Scientific Council ..... More Space @ IN2P3 ...

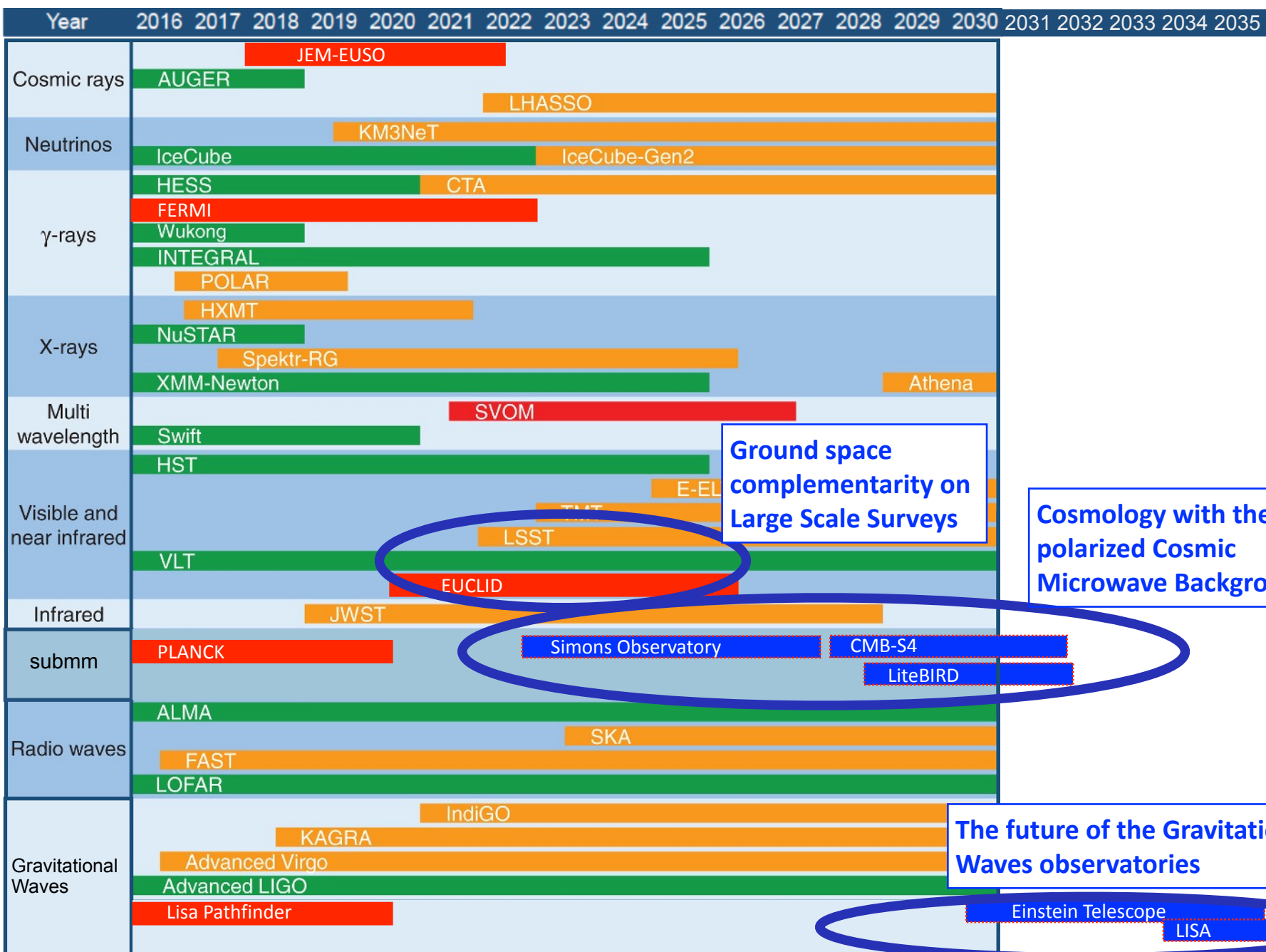


discussed today

for next CS

# More Space @ IN2P3 ...and beyond !

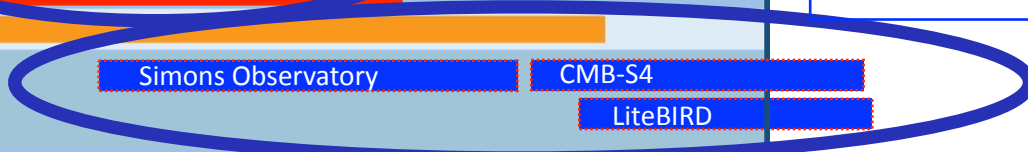
adapted from Astronomische Nachrichten, Volume: 338, Issue: 9-10, Pages: 978-983, First published: 28 November 2017, DOI: (10.1002/asna.201713415)



Ground space complementarity on Large Scale Surveys

Cosmology with the polarized Cosmic Microwave Background

The future of the Gravitational Waves observatories



Thanks a lot to all the speakers and referees

....Not yet finished: private session of the CS tomorrow

And let's keep in touch in autumn !

The scientific council members