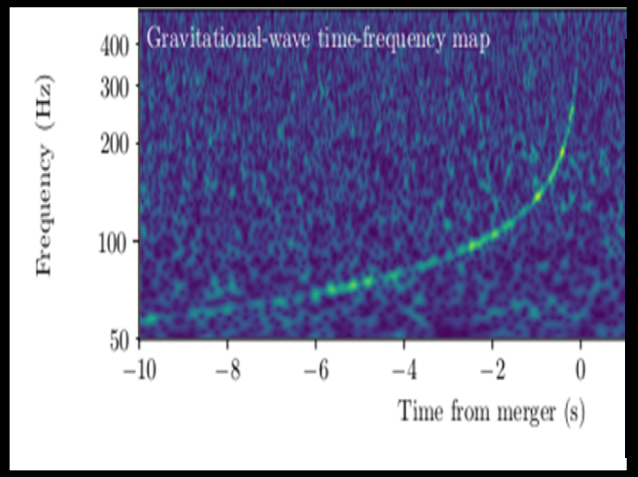
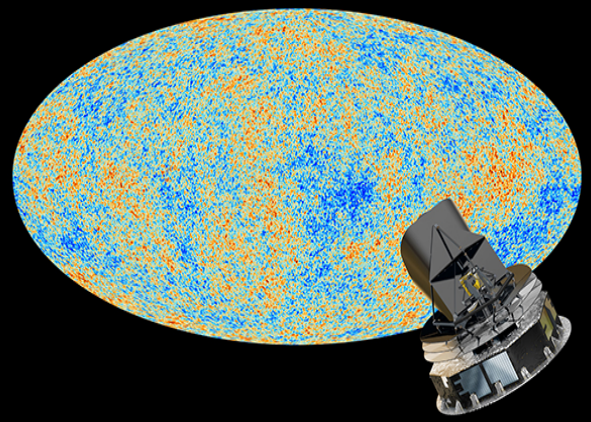
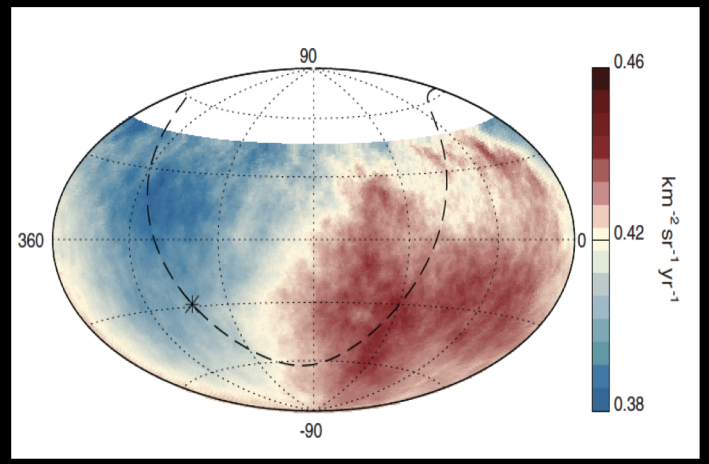
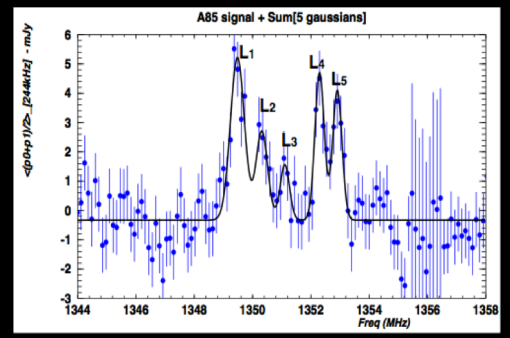
HCERES evaluation of Laboratoires de la vallée d'Orsay

- CSNSM
- IMNC
- IPNO
- LAL
- LPT









HICluster

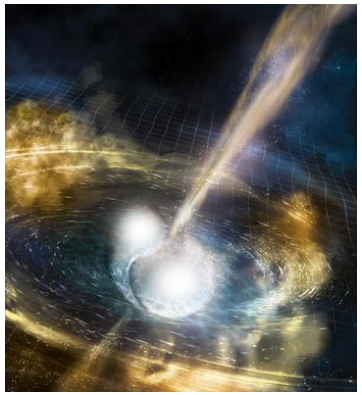
Astroparticule and cosmology

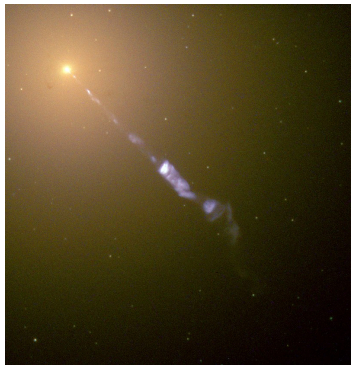
Speaker : N. Leroy on behalf of GW (Virgo), High Energy (SVOM, eASTROGAM, CTA, Auger, EUSO Balloon), Dark Energy (21 cm, LSST) and CMB (Planck, QUBIC, Simons Obs., LiteBIRD) groups - ~37 members

14-17 january 2019

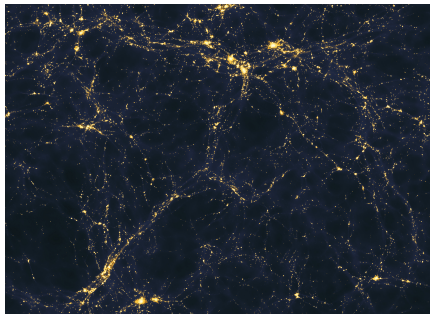
Astroparticles to cosmology

From most energetic astrophysical phenomena
(from galactic sources to extragalactic ones)

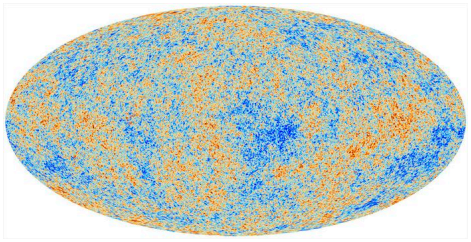




To Large Scale Structures and first instants of the Universe



Population studies, particles propagation



List of experiments/activities and laboratories

Solid state physics

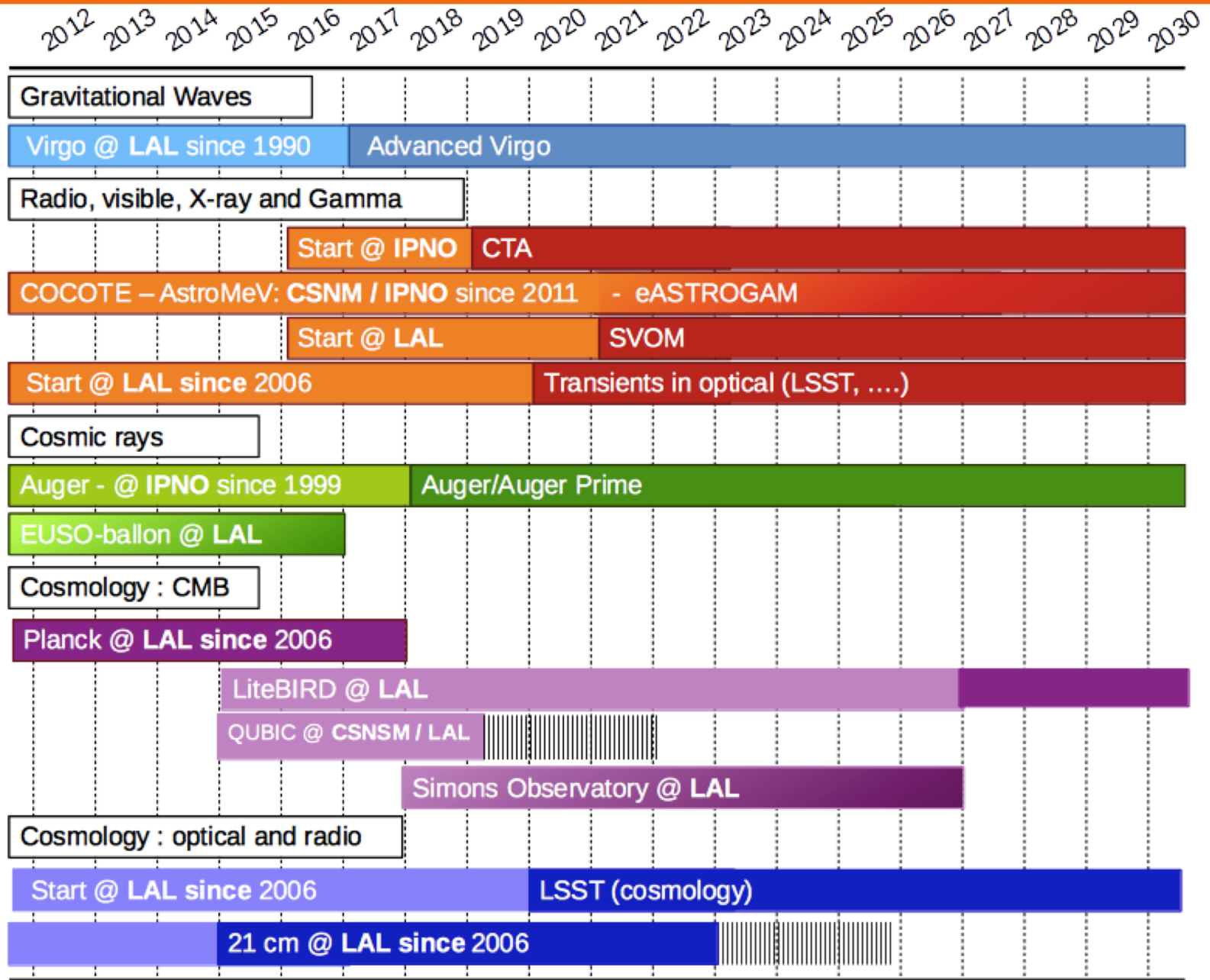
Neutrinos and Particles Physics

Detector R&D

Theory

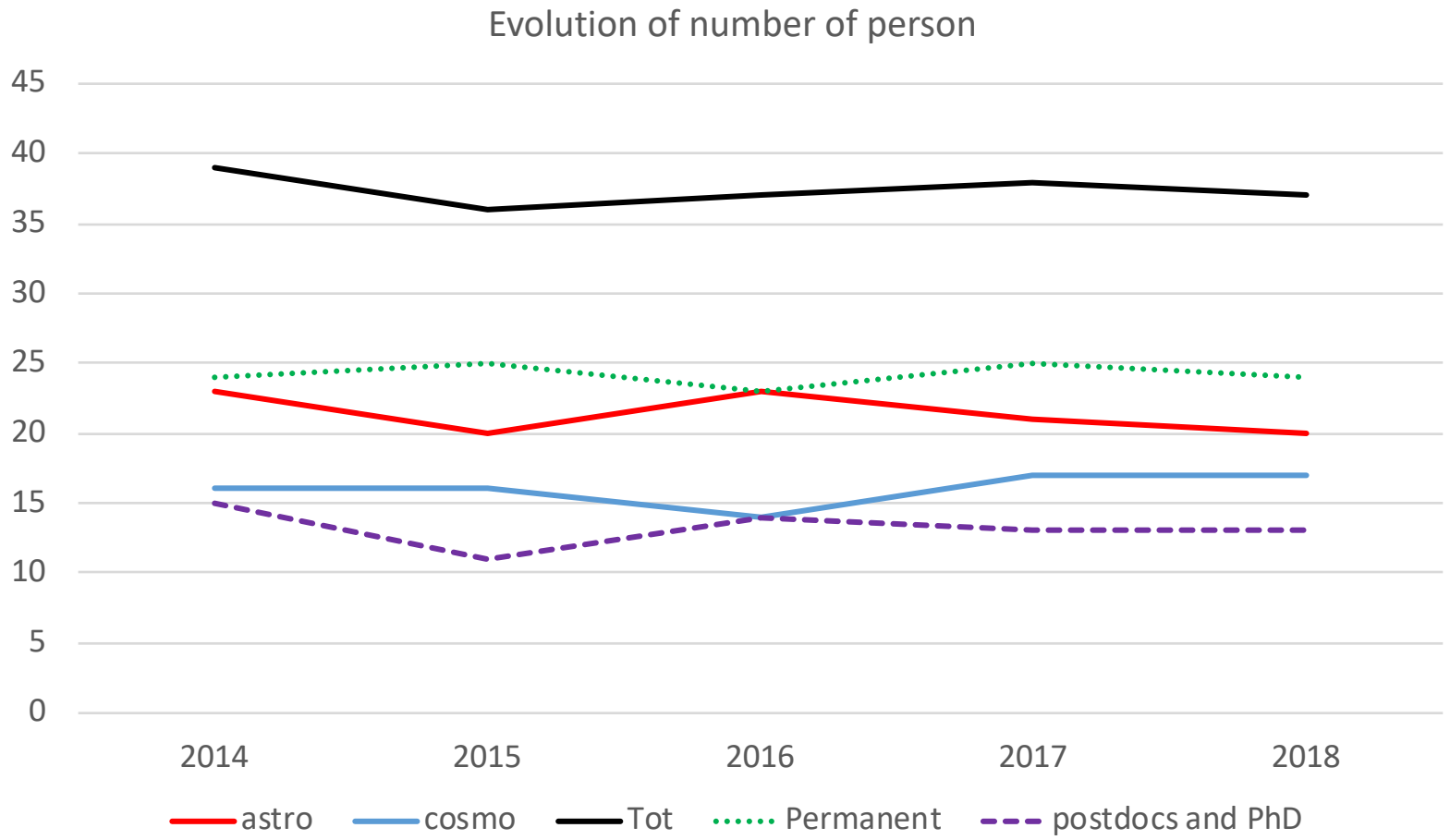
Dark Matter

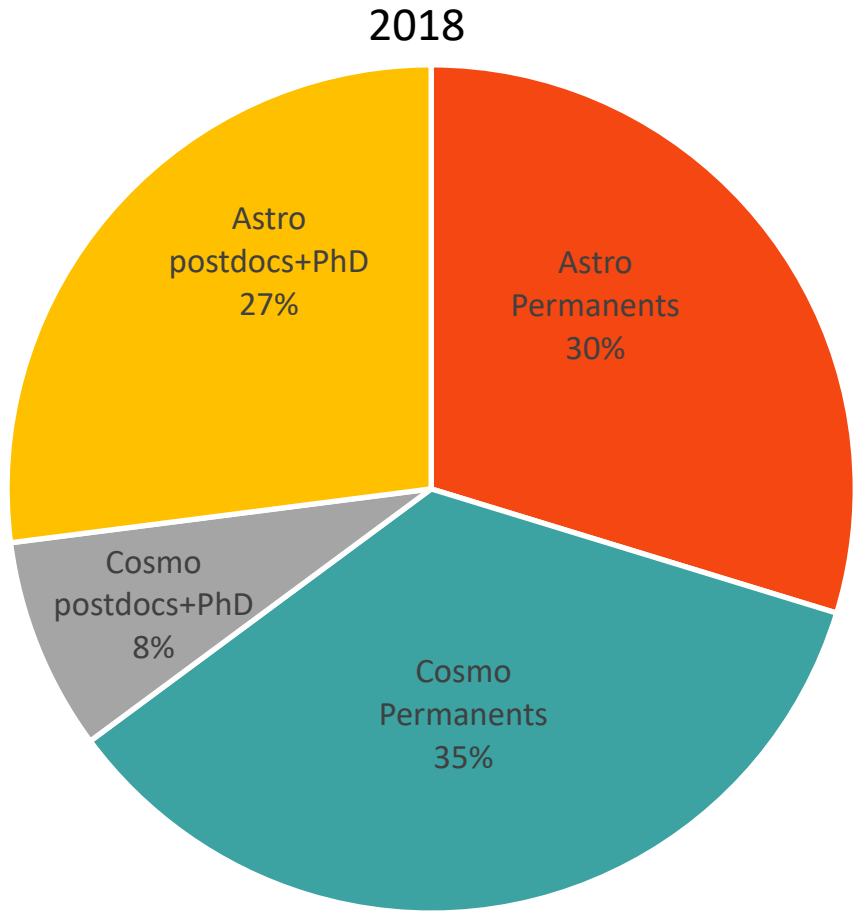
Nuclear astrophysics



Human resources

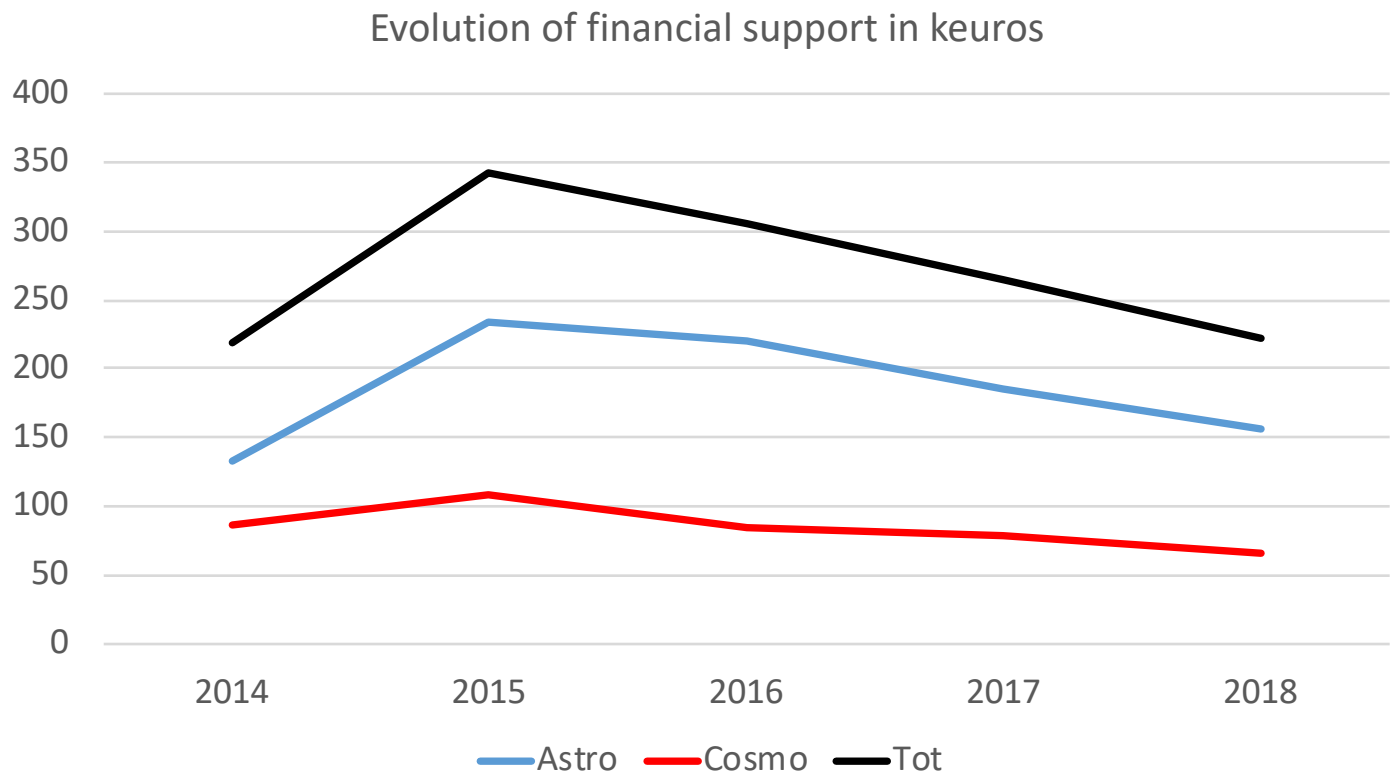
- permanent positions: 2/3 CNRS – 1/3 University
- ~37 members: 2/3 permanents for 1/3 PhD + postdocs





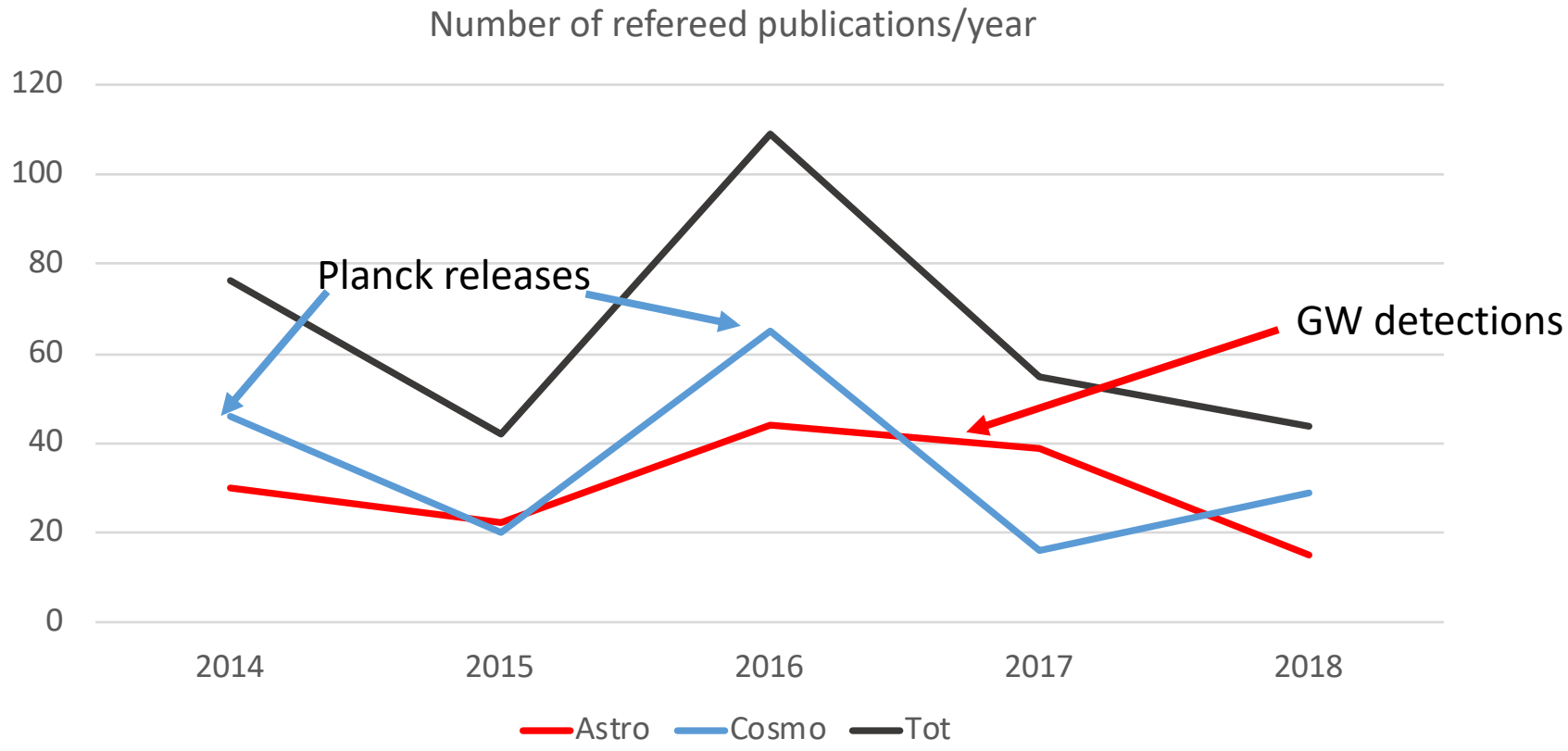
Financial support

- Large diversity of supports: IN2P3, CNRS-TGIR, ANRs, Labex P2IO, Idex Paris-Saclay, Ile-De-France with DIM-ACAV+, EGO, LAL, CNES, ESA, etc
- R&D, construction, missions
- ANR and Prix de l'académie des sciences received between 2015 and 2016



Publications

- Publications are strongly coupled to data release or extraordinary events



Prizes

- Prix de la Fondation Del Ducca – Académie des sciences 2015, P. Hello
- Breakthrough prize in Physics 2016 to LIGO-Virgo collaborations
- Springer Thesis Prize 2017, J. Casanueva
- Gruber Prize in Cosmology 2018 to Planck consortium
- UK Royal society Group Award 2018 to Planck consortium
- Prix Fondation L'Oréal- UNESCO « Pour les femmes et la science » 2018, S. Antier

Involvement in committees (in the last 5 years)

- Members of (at least) one of the 5 laboratories councils
- Members of (at least) one of the 5 laboratories scientific councils
- LAL deputy director and then director
- Directors of the Physics of the 2 Infinites Research Department, Paris-Saclay University
- University Paris-Sud Physics department Vice President
- Members of selection committee in DIM-ACAV+ (Ile de France)
- Members of selection committee for University positions (Paris-Sud, Grenoble, Marseille, Paris Denis-Diderot, Paris-Sorbonne, etc)
- Members of external scientific councils: Observatoire de Paris, LPSC
- Members of Conseil National des Universités commission 29
- Members of CNRS National commission 01
- Members of the boards of the PNCG or GDR OG
- Member of editorial board : classical and quantum gravity
- Member of ESO evaluation and time allocation committees

Teaching activities

- **7 professors or assistant professors**
- Lectures in Licence, Master and Engineering School
- **Responsibilities Bachelor, 1st year Master level of General Physics and NPAC Master (2nd year)**
- **Co-chair and chair of the Doctoral School « PHENIICS »**
- Lectures in International schools
- Supervisions of internships (bachelor and master) and PhD students
- Main organizer of French or international schools
- Many more pedagogical responsibilities not reported here

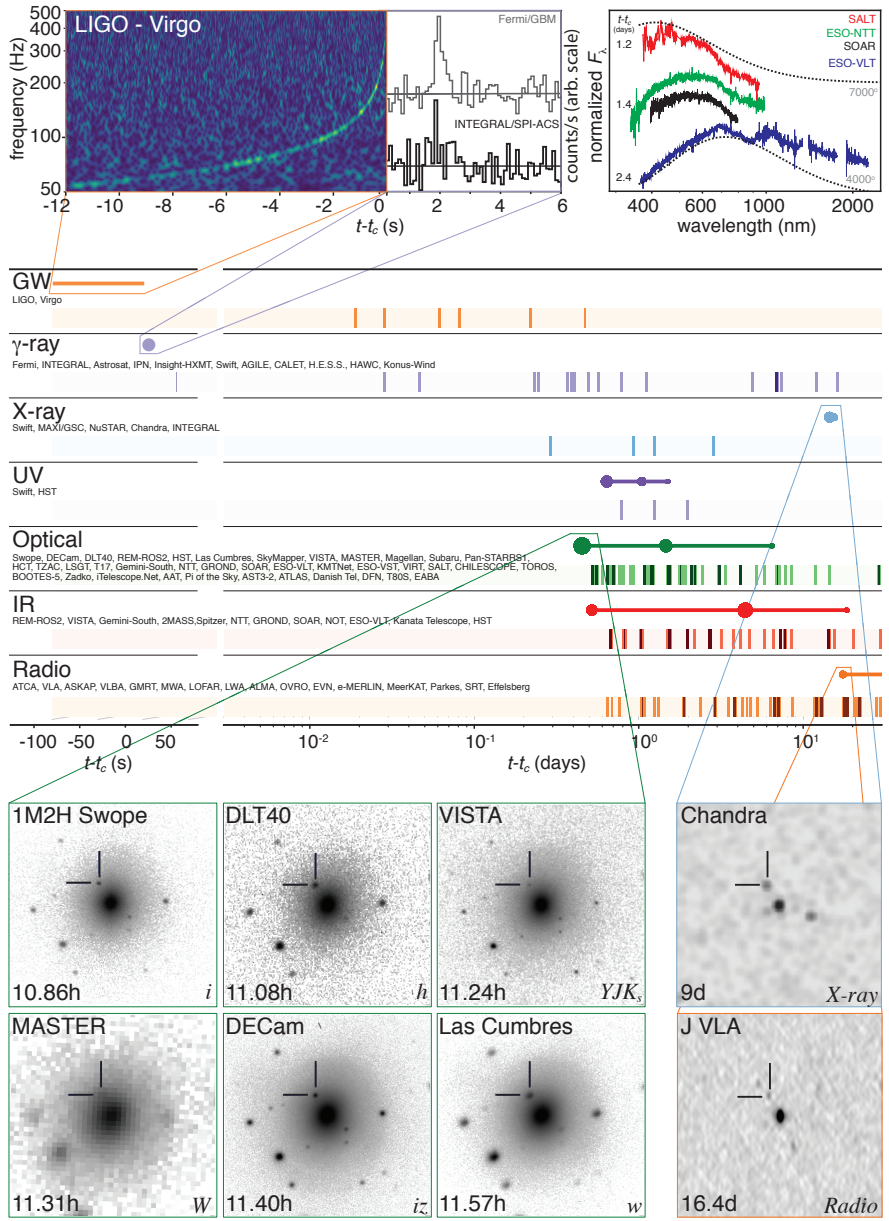
Outreach/Valorisation

- Large contributions with the main results published in the last years: Planck results and gravitational wave detections.
- Presentations to students, public, media, participation to MOOCs , etc
- Outreach coordinator in Virgo
- Coordination of IN2P3 outreach and educational activities
- Nuits des Ondes gravitationnelles: event with 2000 persons in Paris and satellites meetings in several places in France
- Fête de la Science (exposition LSST, etc)

- Scientific animation:
  - Transient Sky 2020, Orsay, mai 2017
  - Auger Collaboration meeting , Paris, June 2017
  - CTA collaboration meeting, Orsay mai 2018
  - UHECR 2018 , Paris , October 2018
  - Permanent member of the Scientific Advisory Committee of the European ISAPP Summer School
  - IPA conference, one in Orsay in 2017
  - Autumn lecture on CMB in LAL 2018
  - Dark Energy 2017 in LAL
  - QUBIC collaboration meeting in 2016
  - Paris 21cm intensity mapping workshop in 2014
  - Members of Moriond and Vietnam conference series organizing committee

Scientific achievements (2013 - 2018)

Multimessenger astronomy (@IPNO, LAL, CSNSM)



« Multi-messenger observations of a binary neutron star merger », Abbott et al., ApJ, 2017

- Combining efforts is rewarding, as for GW170817 !

GW:
spacetime disturbance
mass acceleration
Probe densest parts

neutrinos:
acceleration mechanisms (Tev)
Nuclear reactions, (MeV)
Probe densest parts

HE photons kev->TeV:
acceleration mechanisms
Nuclear reactions
Probes few Gpc distance

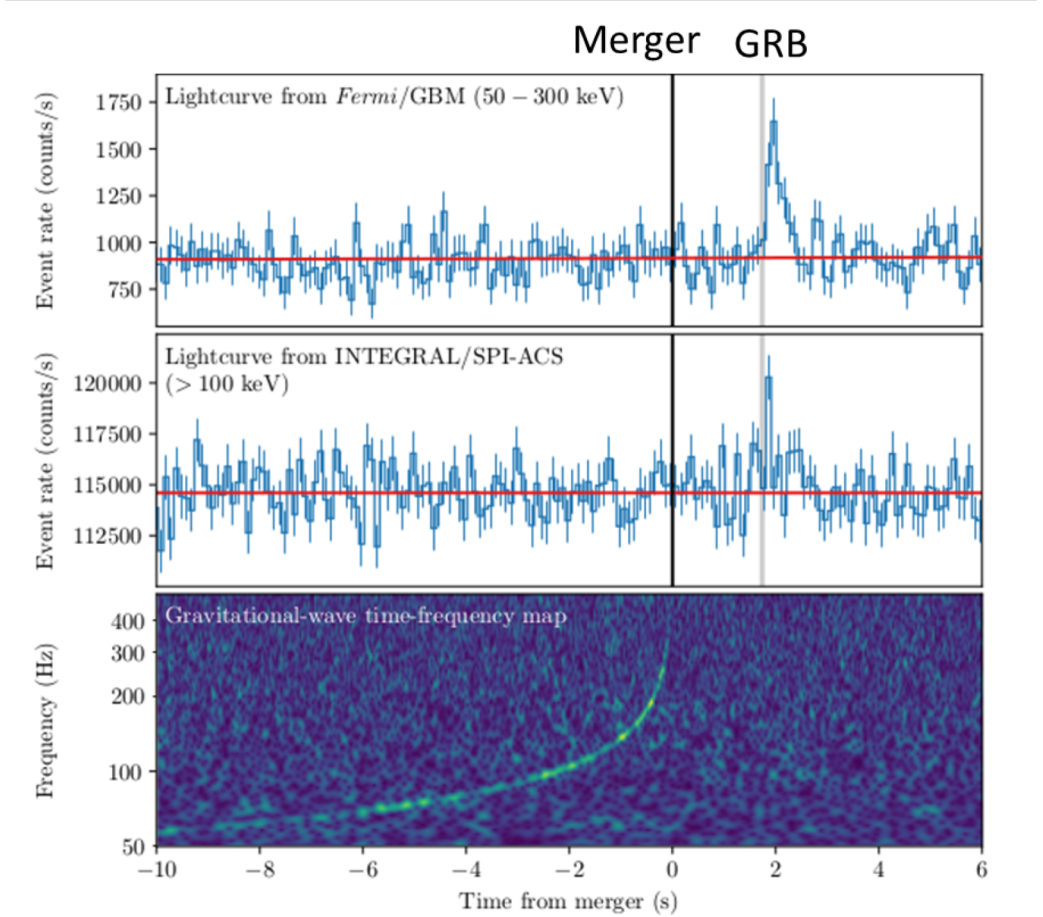
UHECR 10^{18} to 10^{21} ev :
acceleration mechanisms
Max distance ~ Gpc

Detections/constraints from
keV, MeV, UHE neutrinos or CR, visible, … + GW – all available here !

Can also be used to constrain cosmology

First direct detection of gravitational wave events (@LAL)

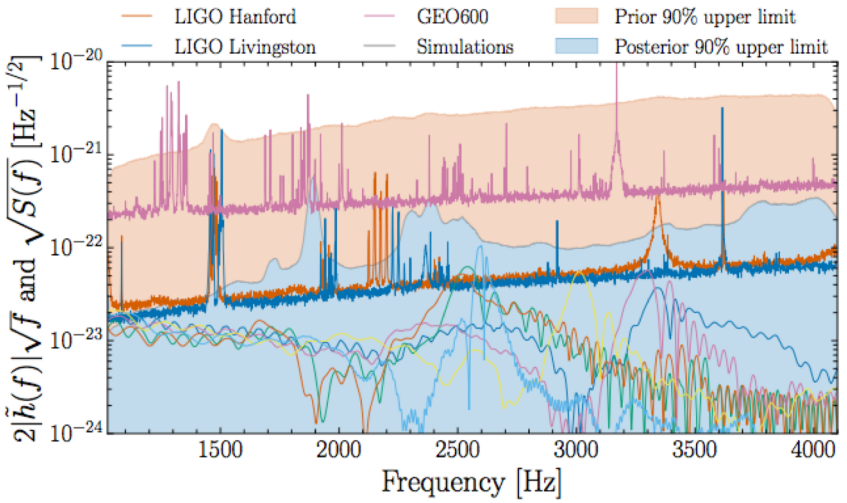
- 10 Binary Black holes and 1 binary neutron star (with electromagnetic counterpart!)
  - Main result in physics/astrophysics of the last years, large recognition (Nobel prize, etc)
  - Implication in different fields : tests of General Relativity, constraints on speed of gravitation, astrophysical impact, etc
  - Importance of a 3 detectors network
  - Large involvement of the Virgo group in different steps:
    - Commissioning of the Virgo detector
    - Analysis for the post merger signal of the BNS
    - Characterization and validation of the events for Virgo – rapid response team
    - Publications and internal validations



LIGO-Virgo Burst and Data Analysis co chair
Virgo detector characterization co-chairs
Virgo run coordination

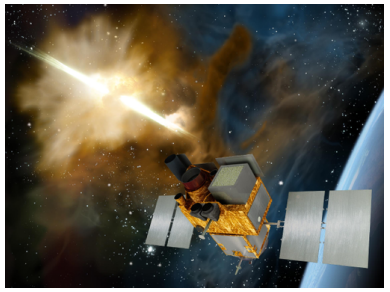
Gravitational waves – other activities (@LAL)

- Different analyses done in the group (with development of associated pipelines):
  - Searching for transients with duration ~100s – 2 thesis defended
  - Search for cosmic string signals – 1 thesis on going
  - Search for signals associated to gamma-ray bursts – 1 thesis on going
  - Close links with detector characterization
  - Electromagnetic follow-up of GW alerts

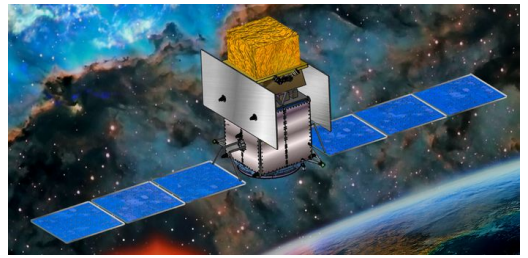


- Program on commissioning and R&D for detector
  - Thermally deformable mirrors to reduce thermal optical defects – 1 thesis defended + 1 on-going
  - Frequency dependent squeezing – using CALVA facility – 1 thesis on-going
  - Parametric instabilities – 1 thesis on-going
  - Commissioning of the Virgo interferometer – 1 thesis defended + 1 on-going
  - Vacuum control command for the interferometer

Photons kev to MeV: space missions (@CSNSM, LAL)



- Implication in different aspects on the SVOM Sino-French mission to be launched in 2021 – instruments in IR, visible, kev to MeV
  - Scientific on board software for the X-ray telescope (MXT) and associated ground segment
  - Automatic follow-up scenario of Multi-messenger alerts with all instruments available in the consortium
  - Link with LSST
- eASTROGAM covers the MeV range, currently least (under!) explored electromagnetic band – to be proposed in 2019 for launch in 2028
  - Development of the concept since several years



Photons TeV: Cerenkov Telescope Array (@IPNO)

- Observation from 30 GeV to 300 TeV
- Start first installation in 2019-2021 before full production
- Preparation of first CTA observations:
  - Extragalactic science, including gamma-ray propagation on cosmic scales – *responsible of the extragalactic science working group*
  - Modelisation of spectral emission of galactic CR source, search for PeVatrons (ongoing thesis)
- Implication in French project of camera for middle size telescope
  - *Responsible for calibration devices*
  - Realization of a movable flashing screen

UHECR: Major results from Auger Observatory (@IPNO)

- Anisotropy studies (mostly leaded by IPNO group members): one step forward the origin of the Ultra energy cosmic rays !

Low energies ie above 8EeV

Discovery of an anisotropy (5.4 σ) in the arrival directions of UHECR supporting an **extragalactic origin.**

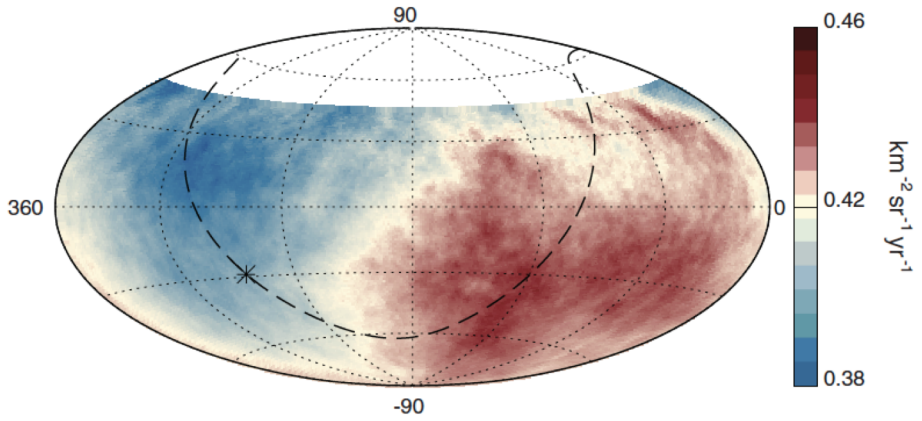
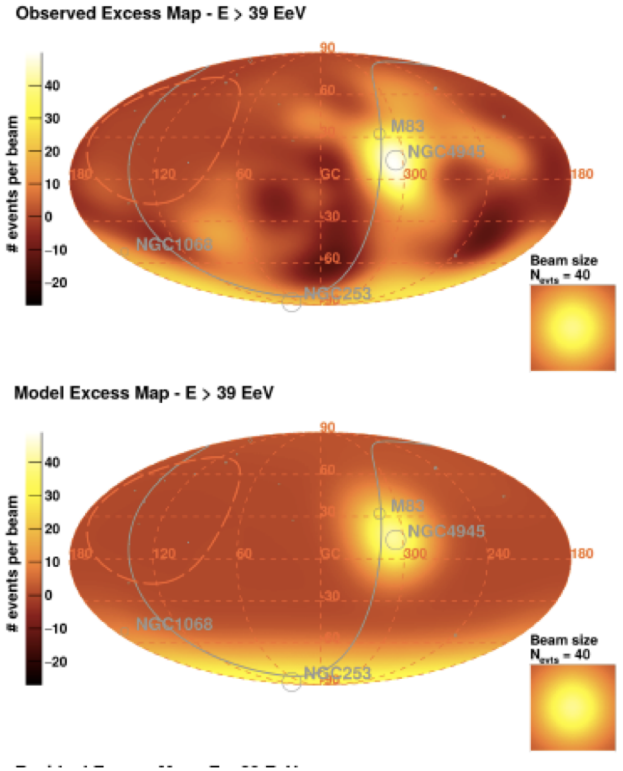


Fig. 2. Map showing the fluxes of particles in equatorial coordinates. Sky map in equatorial coordinates, using a Hammer projection, showing the cosmic-ray flux above 8 EeV smoothed with a 45° top-hat function. The galactic center is marked with an asterisk; the galactic plane is shown by a dashed line.

Highest energies ie above 40 EeV

An Indication of Anisotropy in Arrival Directions of UHECR through Comparison to the Flux Pattern of Extragalactic Gamma-Ray Sources

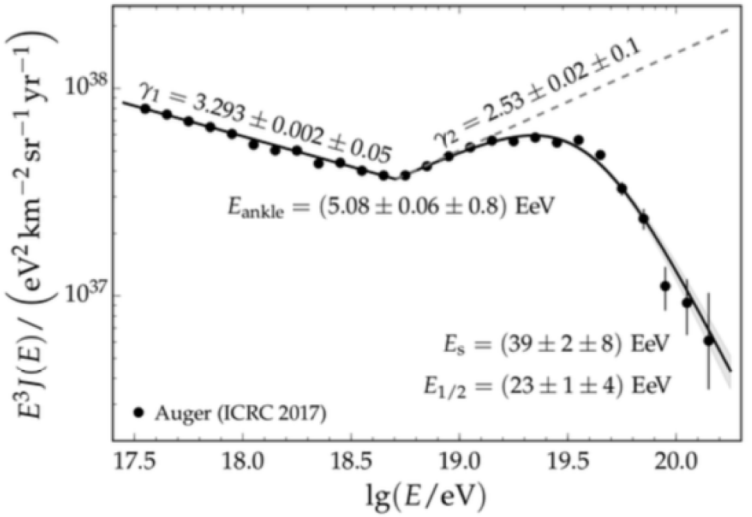


Model based on SBGs in better agreement with data than isotropy hypothesis (4σ).

- *Science Coordinator*
- *Performance coordinator*
- *Anisotropy task leader*
- *Responsibility of the SD electronic (including upgrade)*

UHECR: other studies (@IPNO, LAL)

- Auger produces a spectrum with unsurpassed statistics thanks to its huge surface and 14 years of stat.
- -> 2 majors papers providing detailed methods & phase-I legacy results:

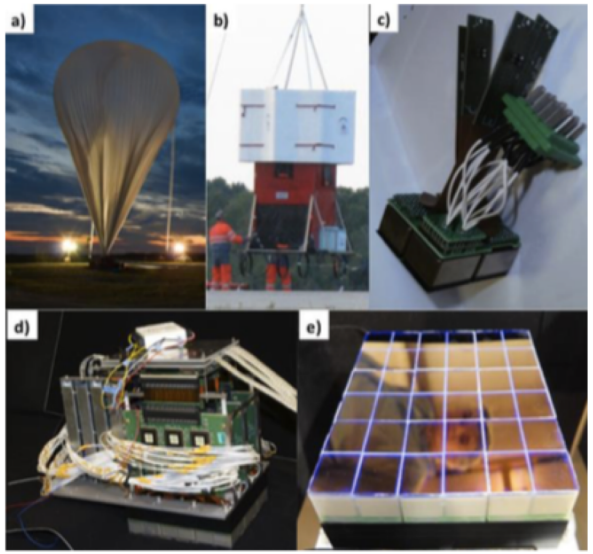


- Surface Detector Reconstruction
- Energy Spectrum

→ Expected early2019

- Common work with Telescope Array within working groups (spectrum and anisotropies) – common publication and presentations
- Interpretation of spectrum/composition : Combined fit Spectrum (1 thesis)
- Radio studies : estimation and limits on the MBR within ANR GIGAS

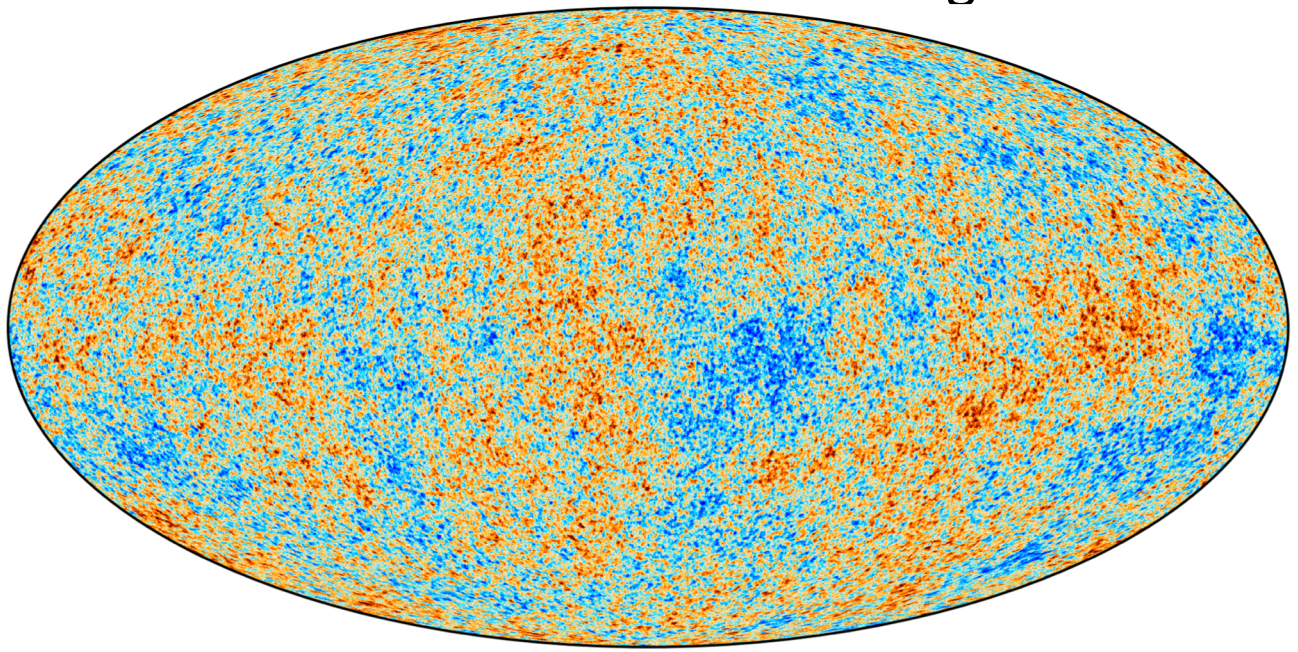
- Participation in EUSO-ballon (LAL) – pathfinder to observe UHECR from above atmosphere
  - Group involved in the UV camera (in particular electronics with an ASIC developed)
  - 2 balloon flights in 2014 and 2017 : conception, realization, integration and data analysis



Cosmic Microwave Background (@LAL)

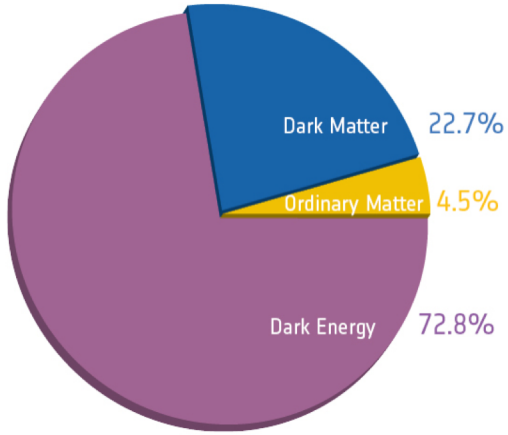
Assessment of the ΛCDM cosmological model

Planck

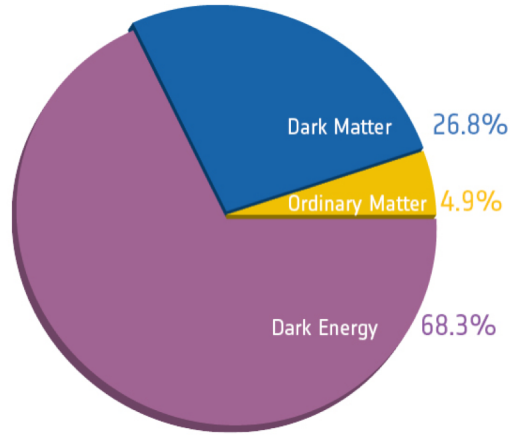


data releases in 2013, 2015 and 2018

- Confirm the standard cosmological model (flat, adiabatic with dark energy component)
- Measure the cosmological parameters at the % level or better
- No need for extension to the model
- connection to lower-redshift probes of structure formation
- stringent constraints on our models of the early Universe (hints for the inflation, initial perturbations)



Before Planck

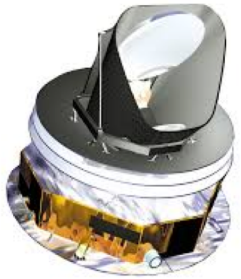


After Planck

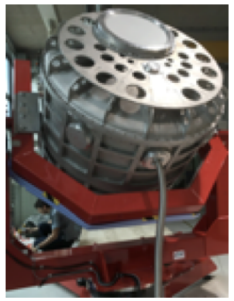
Cosmic Microwave Background (@LAL, CSNSM)

Constraints on the cosmological models using the measurement of the CMB

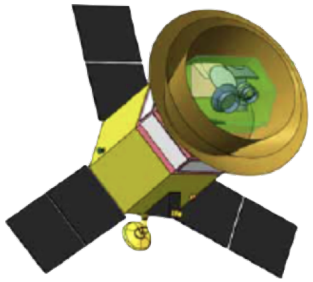
- **The LAL group has been / is involved in CMB experiment collaborations**
  - Planck
  - QUBIC
  - LiteBIRD
  - ACTpol / Simons Observatory



Planck



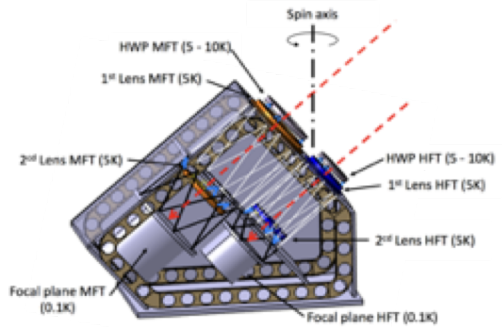
QUBIC



LiteBIRD

Simons Observatory

- **Hardware involvement**
  - **QUBIC**: responsible for the Technological Demonstrator integration (LAL), development and construction of the TES detectors (CSNSM), build the calibration mount (LAL including control-command), build internal calibration sources (LAL), participation to the mechanics (LAL)
  - **LiteBIRD**: participation to the mechanical design and thermal modeling

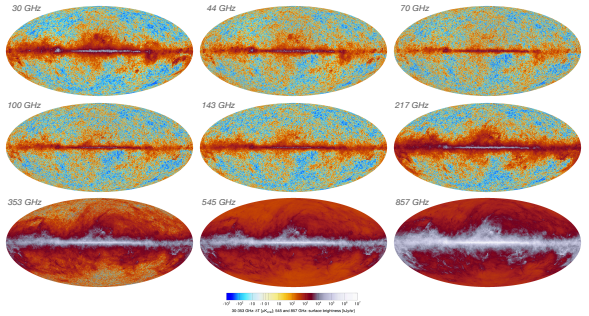


- **Responsibilities (@ LAL)**
  - **Planck**: responsible for map production
  - **QUBIC**: project direction for the TD, member of the Collaboration Board, member of the Editorial Board, responsible of the calibration WP for the TD
  - **LiteBIRD**: member of the collaboration board of LiteBIRD-France, responsible for the French data analysis, co-convener of the ground calibration working group
  - **Simons Observatory**: responsible for spectra analysis
  - **CMB roadmap**: member of the board

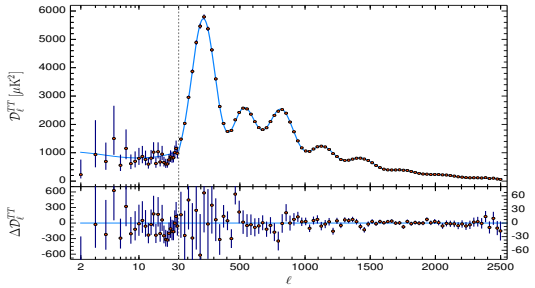
Cosmic Microwave Background (@LAL)

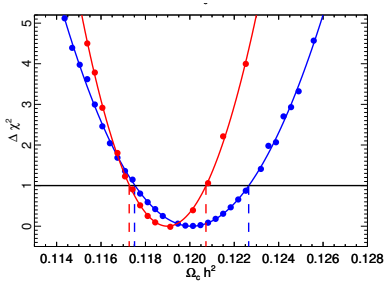
From low-level data analysis to theoretical constraints

- **Study of CMB detector response**
  - impact of cosmic rays
  - Measure of non-linearity response (ADC correction for Planck)
  - Measure of time response
- **Map-making & photometric calibration**
  - Code development
  - Responsible for Planck-HFI map production
  - Study of impact of systematics in map-making
  - Polarization systematics and leakages
- **Power spectrum estimators**
  - statistics on low-multipole spectra
  - development of codes for estimating sky power spectra (Xpol, Xpure, xQML)
- **Likelihood for cosmological constraints**
  - development of Planck likelihoods at high- and low-multipoles
- **CMB lensing**
  - development of CMB lensing spectrum reconstruction code on sky patches
- **Cosmology**
  - development of a toolbox including frequentist and bayesian statistics (CAMEL)
  - study of internal consistency of Planck likelihoods (through A_L measurement)
  - constraints on reionization history
  - constraints on inflation (through ns, r)
  - cosmological constraints on the neutrino sector (Mnu, Neff)
  - external constraints on SUSY models and on the gravitational stochastic background density *(in collaboration with Atlas and Virgo groups)*

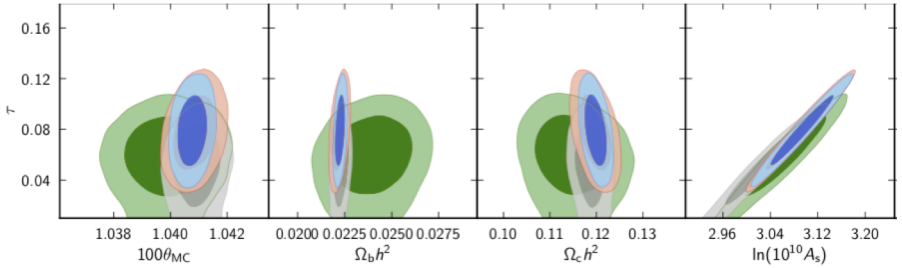


[Planck 2013 results]
[Planck 2015 results]
[Planck 2018 results]





[Planck intermediate results. XVI. (2014) A&A 566 A54]
[Mangilli et al. (2015) MNRAS, 453, 3, 3174]
[Couchot at al. (2017) A&A 602 A41]

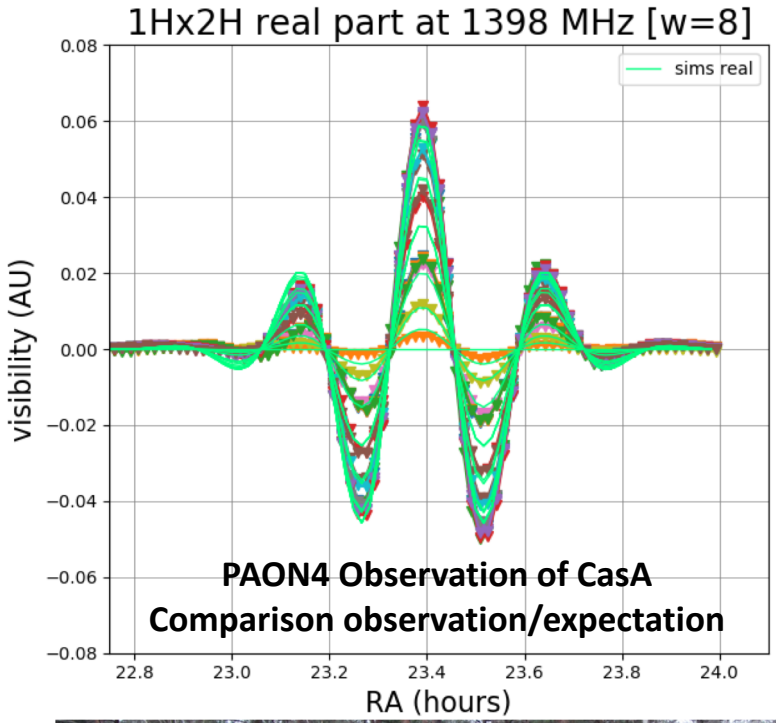


[Couchot at al. (2017) A&A 597 A126]
[Couchot et al. (2017) A&A 606 A104]

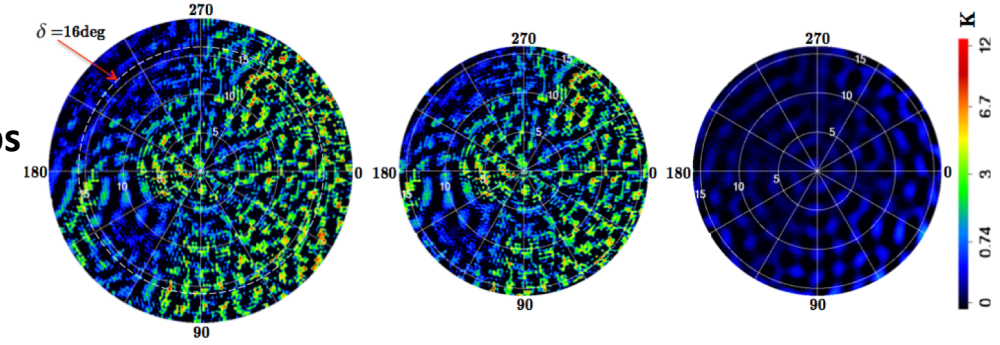
21 cm / BAORadio (@LAL)

- Mapping cosmic matter distribution using HI emission@21 cm

- **HICluster**: Observation on NRT Nançay using BAO-radio electronic chain – search for 21cm in nearby galaxy clusters (*Exp. Ast. 2015*)
- **PAON4**: Construction and operation of 4-dish prototype radio interferometer in Nançay
- **NEBuLA/IDROGEN**: Development of a new generation digitizer/signal processing board, with Paris Observatory – white rabbit technology
- **Tianlai**: Collaboration (China and USA) on a Chinese interferometer for intensity mapping
- **Map making**: m-mode sky reconstruction for transient interferometer – 2 PhDs with NAOC (China) (*MNRAS 2016*)

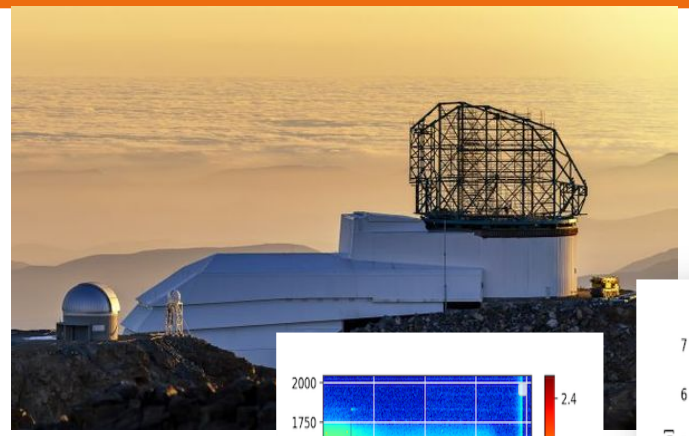


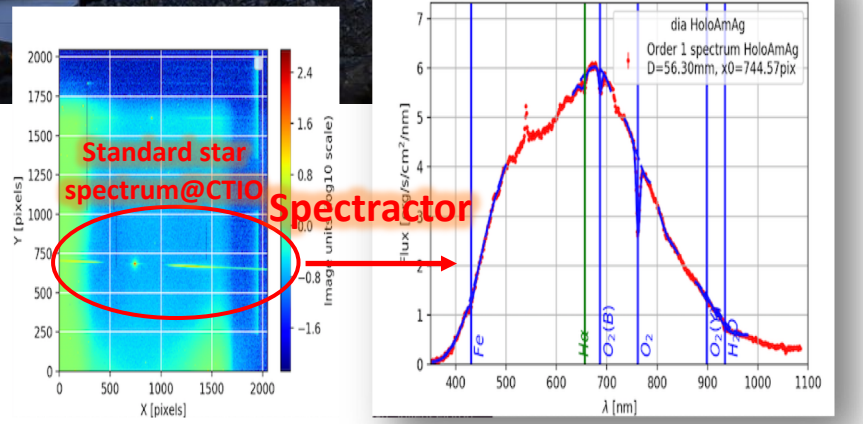
Polar cap m-mode reconstructed maps for Tianlai



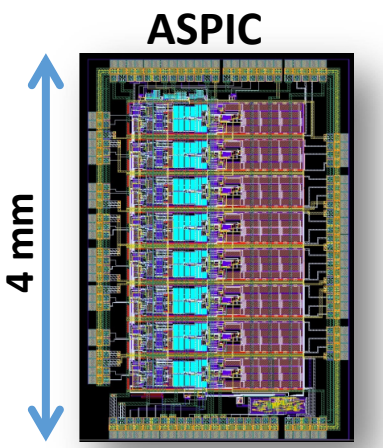
Large Synoptic Survey Telescope, LSST (@LAL)

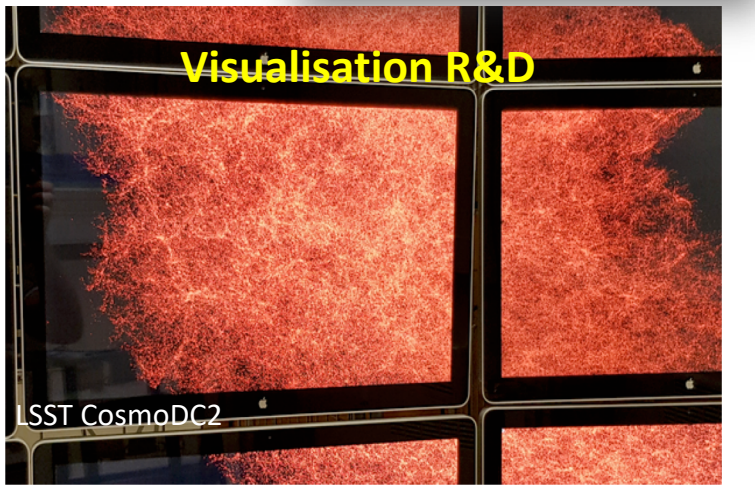
- Deep 6 band photometric survey with large field-of-view (3.5°) 8.4m telescope
- LAL is one of the 3 founding labs of the french LSST consortium (since 2007)





- **Electronics/ASPIC** : analog amplifier for the camera readout system – *1500 chips delivered*
- **Calibration/Atmosphere** : transmission models & measurement - impact on photo-Z
- **Calibration/HOLOSpec** : Development of hologram as disperser for the LSST auxiliary telescope
- **Calibration/Spectractor :** Pipeline to perform spectral analysis with the auxiliary telescope
- **LSST-Computing** : Contribution to the implementation of SRDP (1/2 of catalog production at CC-IN2P3)
- **Computing R&D** : Spark (distributed computing), visualisation, contribution to PetaSky (CNRS MASTODONS)(*AstroLab, ArXiV:1804.07501*)





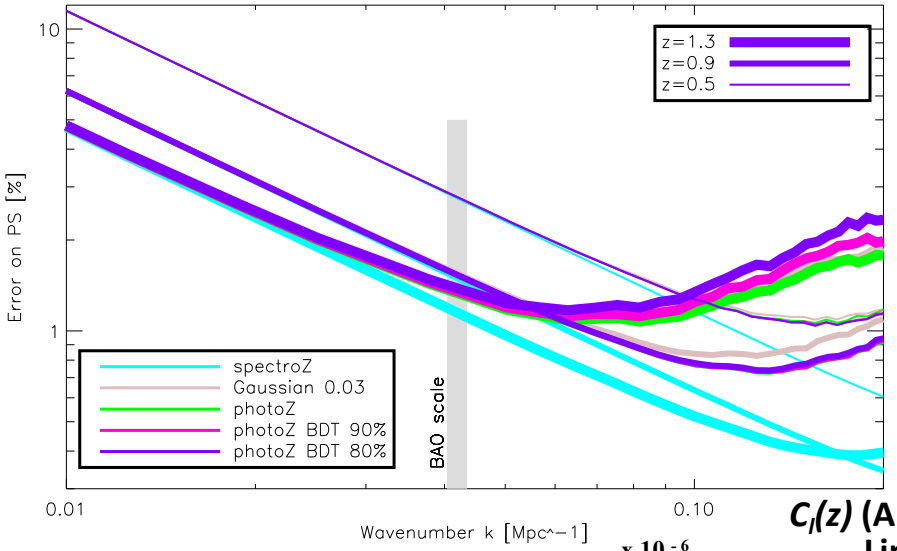
Science with LSST data (@LAL)

Dark Energy Science collaboration (DESC)

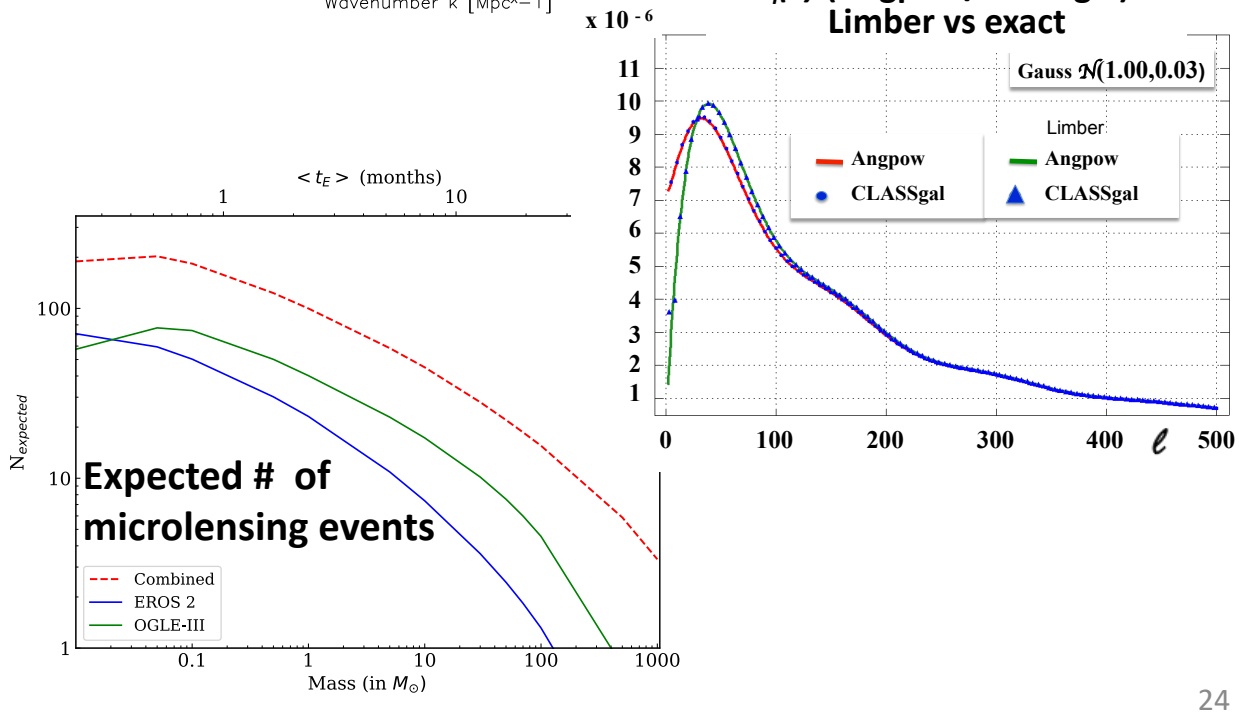
- **DESC/PhotoZ :** Photometric redshift studies : reconstruction, systematics, classifications (*A&A 2014*)
- **LSS/PhotoZ :** Impact of photo-z on Large scale structures and BAO scale reconstruction (*A&A 2019*)
- **DESC/LSS : Angpow** software for efficient computation of LSS power spectrum in spherical geometry $C_l(z1,z2)$ and angular correlation function (*A&A 2017, ApJ 2017*)
- **DESC/TJP :** Angpow software interfaced with CLASS and DESC **CCL** (Core Cosmology Library) (*ApJS 2018*)

Dark Matter / microlensing / transient sky

- **DM/Scintillation :** Search for cold molecular clouds as dark baryon using scintillation (*A&A 2013*)
- **DM/Black holes :** Search for massive black holes ($> 10.M_\odot$) through microlensing – on-going PhD with current available data sets (*A&A 2018*)



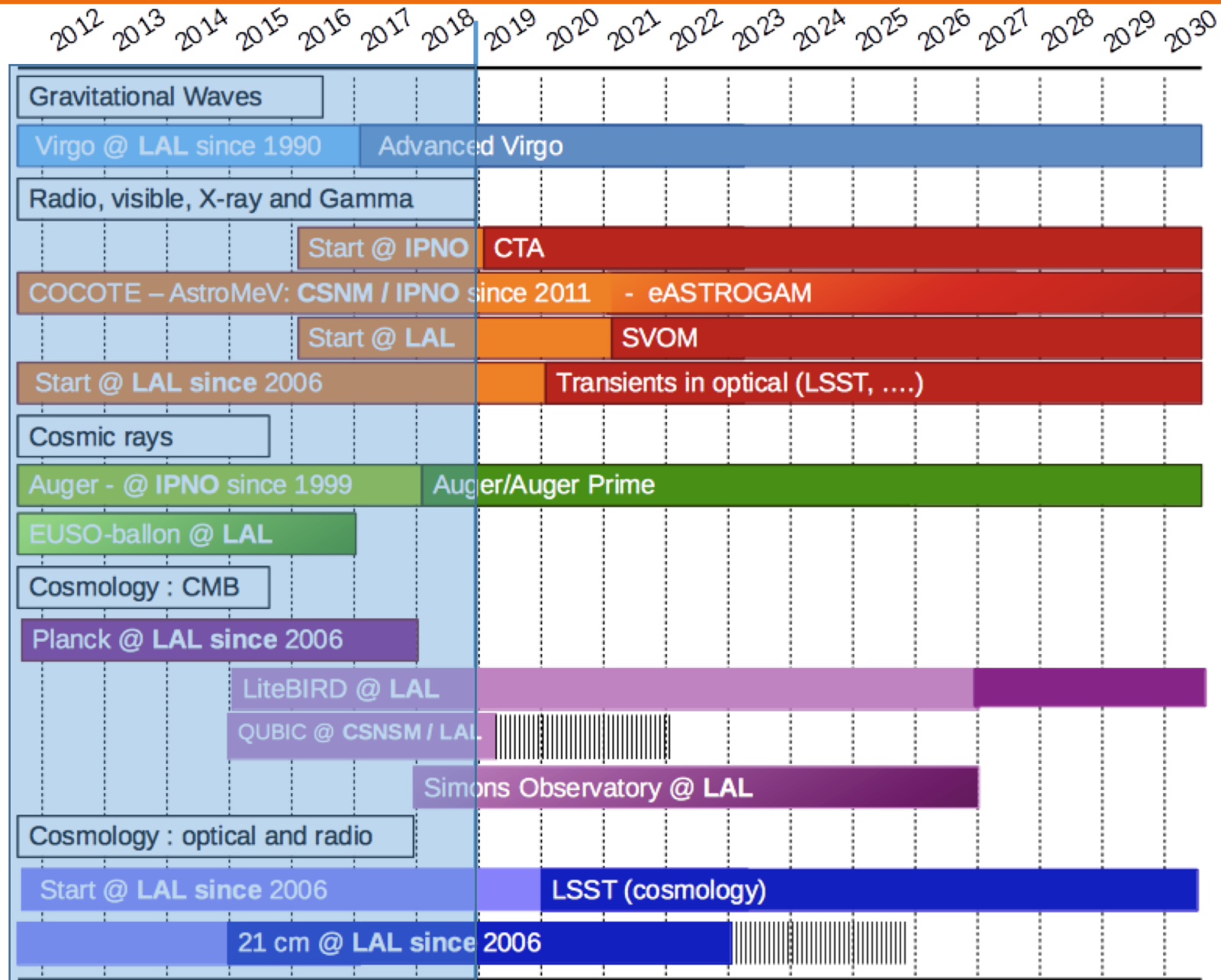
Impact of photo-Z on LSS P(k) fractionnal error (%)



$C_l(z)$ (Angpow/CLASSgal): Limber vs exact

Project (2018 – 2023 and longer term future)

Evolution in the next years



GW

- New observation run including LIGO and Virgo instruments will start in few months (run O3)
  - Implication in several analyses (cosmic strings, GRB), in low latency event validation and in commissioning of the instrument
  - Detector characterization will continue to be central
  - Follow of the GW alerts with a network of optical telescopes and find the EM counterpart for such event
- Preparation of the next series of upgrades between O3 and O4 – 18 months starting in March 2020
  - We are currently leading the activity around the installation of the last suspended mirror in the interferometer, the Signal recycling mirror
  - We are also part of R&D activity around frequency dependent squeezing and its installation on the Virgo interferometer
- Discussion on-going for participation in LISA (GW space detector) and/or Einstein Telescope (ground GW-3G detector) projects
- GW also require skill in optics and associated instrumentation - could be mutualize with other needs in the new laboratory

HE Space projects

- SVOM is currently under construction, current schedule is December 2021 for launch
  - Several months of commissioning before moving to science data taking
  - Involvement in the Burst Advocate activities
  - Interest to look to event close to threshold, à la GRB170817A/GW170817
- eASTROGAM, selection to be done in the next months, see Nuclear astrophysics presentation for more details

CTA

- Few milestones in the next years for the French camera project
  - Critical design review including calibration system
  - Production of 15 (more?) full calibration systems
  - New technical involvement under discussion
  - First data from Large Size Telescope soon available
- Preparation of data taking will continue before transition to full exploitation of the network
  - Full-scale development of MWL MM synergies
  - Expected early science with CTA in 2022

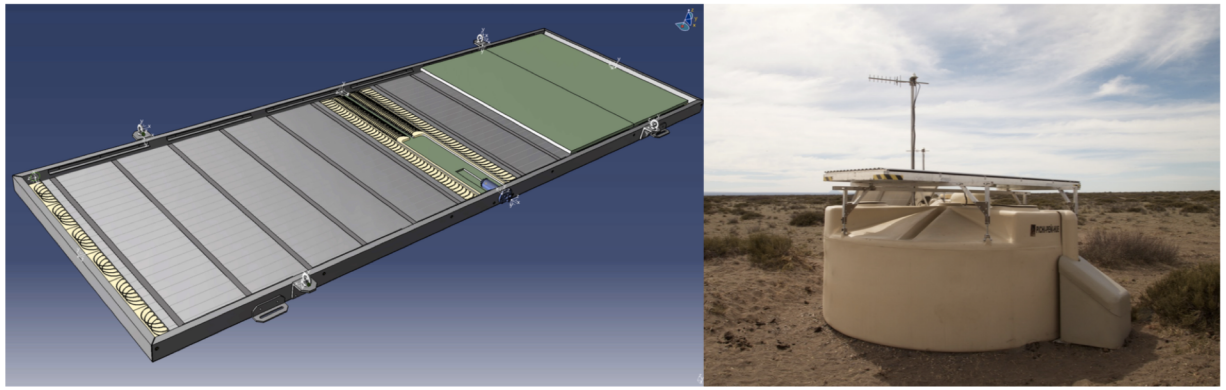
LST1 in Canari Islands

Auger Prime: upgrade on Surface detector

Auger Prime : upgrade to get a composition-dependant observable event by event with the Surface Detector

- Origin of the flux suppression?
- Proton fraction at UHE?
- Rigidity-dependence of anisotropies?
- Hadronic physics above $\sqrt{s} = 140$ TeV?

- 3.8 m^2 scintillators (SSD) on each 1500-m array station
- upgrade of station electronics
- additional small PMT to increase dynamic range
- buried muon counters in 750-m array (AMIGA)
- increased FD uptime



Engineering Array was deployed already in October 2016.
Production and full deployment 2019-20
Data until 2025

Anisotropies and spectrum studies will be strongly enriched from composition

CMB: toward CMB B modes

2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028

LiteBIRD

- The down-selection of the mission by the JAXA will occur in March 2019
- CNES is considering taking the lead of one of the two instruments (the High Frequency Telescope)
- Our hardware involvement will depend on the decisions from the space agencies...

Simons Observatory → **CMB-S4**

- Responsibilities in the preparation to the data analysis
- First discussions within IN2P3 for an hardware contribution

QUBIC

- The Technological demonstrator is currently under calibration at APC
- Data will be taken and analysed up to an IN2P3/INFN review before the summer 2019

SPACE ↕ GROUND

TECHNO

- **Preparation of the data analysis for B-modes**
  - Continue to development software tools for B-modes analysis (Map-Making, Spectra, likelihoods)
- **Cosmology constraints**
  - Papers in preparation with the last Planck data release
  - Study of SUSY models of inflation

21 cm / BAORadio : perspectives

- **PAON4** : Finalise PAON4 analysis and papers (-> 2021)
- **IDROGEN** : Deploy NEBuLA/IDROGEN on PAON4 and qualify the digitisation/signal processing board on sky
- **Tianlai** : Continue the collaboration with NAOC & TAC (Tianlai Analysis Center , US) on data analysis (-> 2024)
- **PolarCap** survey with Tianlai + spectroscopic optical survey LAMOST
- 21cm Cosmology: explore SKA, large 2<z<7 intensity mapping surveys proposed for US decadal survey… (-> 2035)

LSST: commissioning and early science

AuxTel in 2019, ComCam in 2020 (9 CCDs), Mini Surveys in 2021

- **LSST Commissioning** , specifically AuxTel, Spectractor and HOLOSpec
- **Spark** know-how for image/catalog production with LSST first light data & large data set analysis
- DESC/Data Analysis : Correlation function and power spectra (3x2pts) analysis (LSS+WL) - Cosmological parameters determination - **Angpow**/CCL and **CAMEL**
- DESC/Data Analysis : Exploring **modified gravity** theory (MG) parameters space (know-how on galileon)
- **Transient sky** science: **microlensing** ; synergy with local projects (VIRGO …)

Link with local/national/international communities

- All our teams are integrated in international and large collaborations : Europe, North and South Americas, China, Japan, India, Australia, South Africa and Iran
- International laboratories : with USA (UMI-Berkley) and China
- Most of our projects are also coordinated on national level with IN2P3/CNRS and CNES and collaborations with several labs in France
- Local connections with IAS, CEA, APC and LPNHE

- Important involvement in space missions (Planck, LiteBIRD, SVOM, eASTROGAM) with relation with CNES and ESA
- Link with ESO for ground based telescopes
- Opportunity to develop a « space department » within the new laboratory and reinforce partnership with CNES and ESA

Perspectives on teaching/outreach/valorisation

- We will remain involved in teaching at different levels
- Paris-Saclay may also be an opportunity to attract new high skills students
- Redefinition of Paris-Saclay program structure and contents (Bachelor+Master) in 2020
  - Improve our visibility in the students cursus
- Need to be more attractive for PhD student: reinforce our visibility in cosmology and to offer a better alternative to Parisian labs (LPNHE+APC)

RH evolution in the next five years

- All experiments will have data during the same period:
  - CTA: only professors as permanent scientists, lack CNRS staff research member
  - Dark energy lack of young permanent researcher
  - To support leading role in LiteBIRD and SO will require a new position
  - GW astronomy is rapidly growing
- A new CNRS position is currently open to stabilize the GW group (one person leaving in 2018)
- We need to keep technical skills in construction, not only R&D
- With the start of the science in almost all the instruments a support for post-docs and PhD will be important
- Some technical profiles are needed for future developments:
  - Instrumentalist with skills in optics, control, mechanics, cryogenics, computing scientist, etc
- Organization in the future structure ?

Expectation on financial support

- Onset of CTA and LSST and part of the Virgo upgrades are already been accepted and funded through TGIR CNRS
- Space projects as eASTROGAM and LiteBIRD have not yet been accepted, decision to be taken in 2019
  - CNES started Phase A for LiteBIRD and will fund it for 2 years
- Our needs for a potential hardware participation to Simons Observatory are under study

SWOT analysis

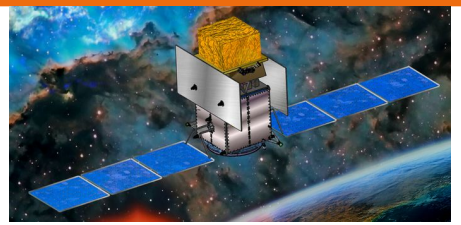
- Participation in leading experiments in their fields
- Pioneer teams
- Recognized experts in our fields
- Large coverage in wavelength and messengers
- Implication on all the steps : from R&D to theoretical physics
- Teams including researchers and engineering
- Links with theoretician and astrophysicist
- University formations in one of the top university on the subjects

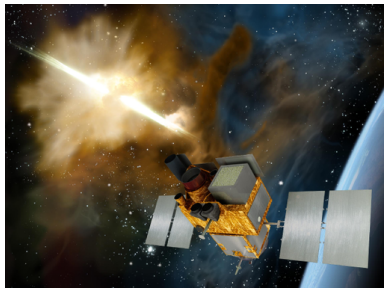
- Lack of exchange between the different teams
- Large number of funding agencies, time to write proposals
- Attractivity to PhD student not always optimal

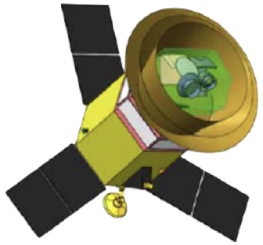
- New projects approaching maturity
- Possibility to have important contributions in new projects
- Obtain new leading roles in the different fields
- Correlations between different probes or messengers
- Attractivity to young researchers

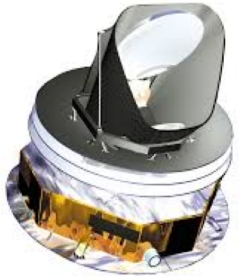
- Lost some technical skills
- Quite complicate to protect large infrastructures
- one team lack younger permanent researcher

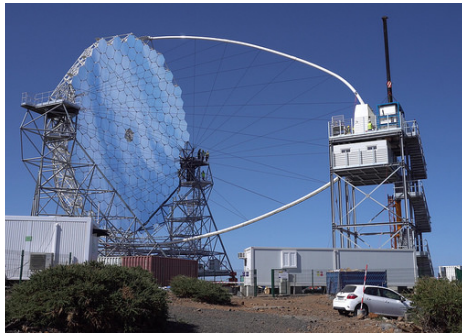
Last 5 years were very dense as the next 5 years

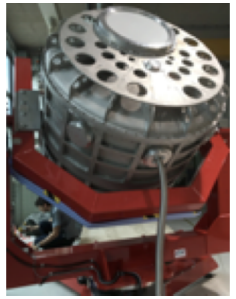












Backup

Composition in 2018

- B. Biasuzzi
- J. Biteau
- O. Deligny
- P.-L. Ghia
- I. Lhenry Yvon
- Q. Luce
- Z. Ou
- T. Suomijarvi
- S. Antier
- N. Arnaud
- I. Belhacene
- M.A. Bizouard
- F. Cavalier
- D. Cohen
- D. Corre
- J.G. Ducoin
- P. Gruning
- P. Hello
- A. Lartaux
- N. Leroy
- F. Robinet
- F. Couchot
- X. Garrido
- S. Henrot-Versille
- H. Imada
- T. Louis
- M. Tristram
- S. Vanneste
- R. Ansari
- T. Blaineau
- G. Blanc
- J.E. Campagne
- S. Dagoret-Campagne
- M. Moniez
- J. Neveu
- O. Perdereau
- S. Plaszczynski
- N. Theodore

Astroparticules FTE in 2018/19

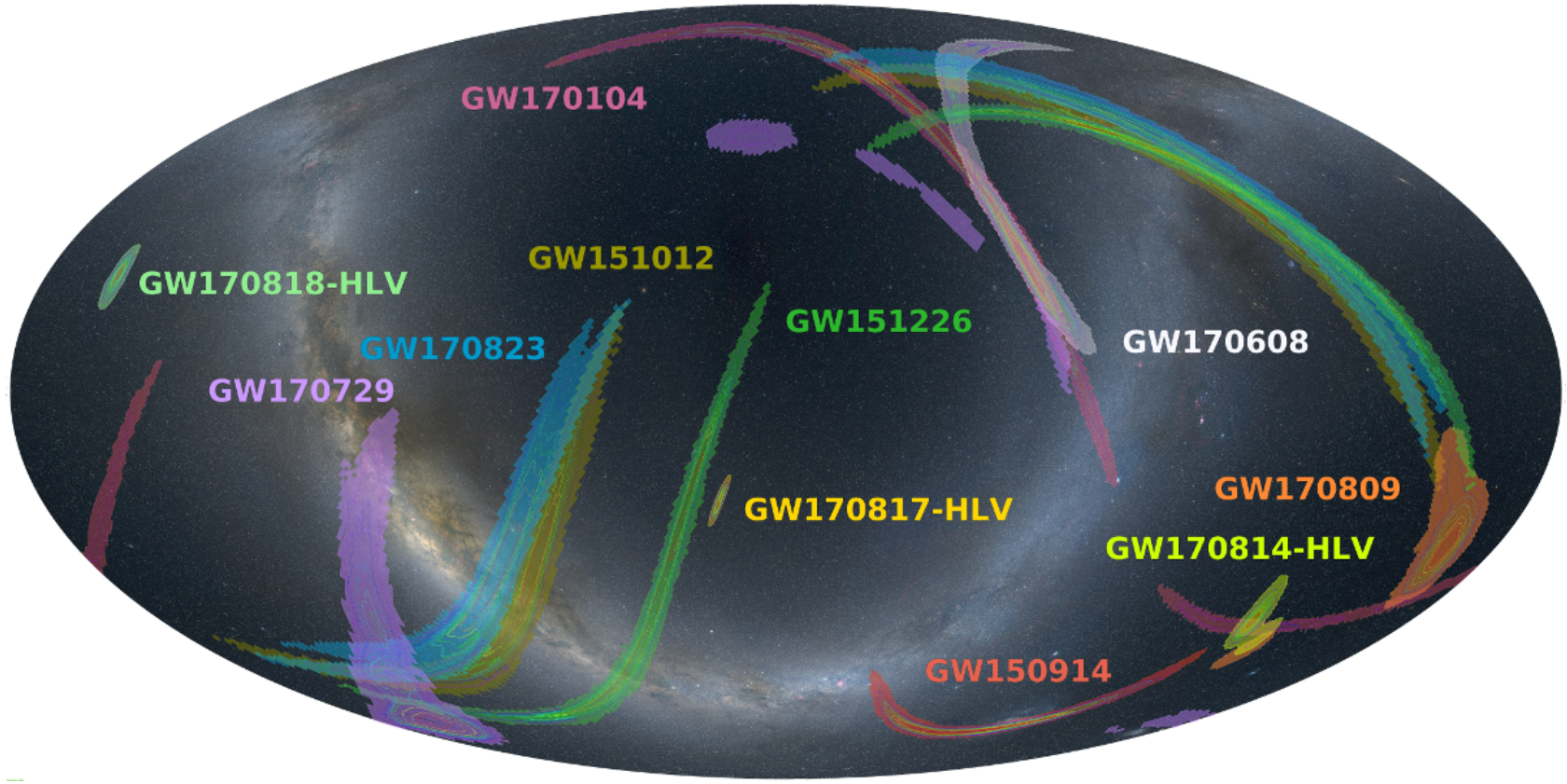
		research time FTE	Comment
CTA			
Tiina Suomijarvi	professor	0,5	
Jonathan Biteau	assistant prof.	0,4	
Barbara Biasuzzi	post-doc	1	
Ziwei Ou	PhD	1	
Kevin Pressard	engineer	0,85	
Giulia Hull	engineer	0,1	
Julien Bettane	engineer	0,1	
Thi NGuyen Trung	technician	0,2	
Miktat Imre	technician	0,2	
Michael Josselin	technician	0,35	
Lucien Seminor	technician	0,1	
Auger			
Tiina Suomijarvi	professor	0,5	
Jonathan Biteau	assistant prof.	0,6	
Quentin Luce	PhD	0,7	defended in 2018
Olivier Deligny	CNRS	0,8	
Isabelle Lhenry-Yvon	CNRS	1	
Piera Ghia	CNRS	1	
Thi NGuyen Trung	technician	0,05	
Virgo			
Patrice Hello	professor	1	
Nicolas Arnaud	CNRS	1	
Amrie-Anne Bizouard	CNRS	0,7	left in October 2018
Fabien Cavalier	CNRS	0,1	
Nicolas Leroy	CNRS	0,6	
Florent Robinet	CNRS	0,6	
Sarah Antier	postdoc	0,5	left in December 2018
David Corre	postdoc	0,5	arrived in December 2018
Pierre Gruning	postdoc	1	
Imene Belhacene	PhD	1	
David Cohen	PhD	1	
Jean-Grégoire Ducoin	PhD	0,5	arrived in October 2018
Angélique Lartaux	PhD	1	
Valentin Frey	PhD	0,7	defended in 2018
Michel Gaspard	engineer	0,5	
Patrick Cornebise	technician	0,05	
Eric Jules	technician	0,1	
Christopher Magueur	technician	0,35	
Rodolphe Marie	technician	0,05	
SVOM			
Nicolas Leroy	CNRS	0,4	
Florent Robinet	CNRS	0,4	
Sarah Antier	postdoc	0,5	left in December 2018
David Corre	postdoc	0,5	arrived in December 2018
Jean-Grégoire Ducoin	PhD	0,5	arrived in October 2018
Serge Du	engineer	0,5	
Marc Nicolas	engineer	0,8	
Antoine Perus	engineer	0,2	

Cosmology FTE in 2018/19

Dark energy		
Réza Ansari	professor	1
Guillaume Blanc	assistant prof.	1
Jérémy Neveu	assistant prof.	1
Jean-Eric Campagne	CNRS	1
Sylvie Dagoret	CNRS	1
Marc Moniez	CNRS	1
Olivier Perdereau	CNRS	1
Stéphane Plaszcynski	CNRS	1
Tristan Blaineau	PhD	1
Thédorore Nicolas	PhD	0,5
Chrisitian Arnault	engineer	0,75
Guy Barrand	engineer	0,25
Thierry Caceres	engineer	0,05
Daniel Charlet	engineer	0,15
Julien Peloton	engineer	0,75
Monique Taurigna	engineer	0,2
Cheik-Ali Chafik	technician	0,1

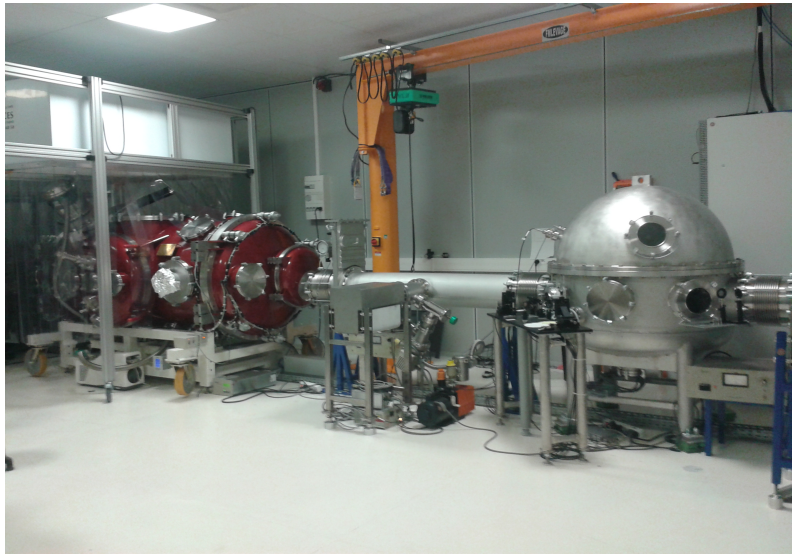
CMB		
Planck		
Xavier Garrido	assistant prof.	0,2
Francois Couchot	CNRS	0,2
Matthieu Tristram	CNRS	0,2
Sylvain Vanneste	PhD	0,2
QUBIC		
Sophie Enrot-Versille	CNRS	0,3
Thibault Louis	CNRS	0,3
Julien Bonis	engineer	0,1
François Wicek	engineer	0,05
Didier Auguste	technician	0,1
Michel Baltazar	technician	0,1
LiteBIRD		
Xavier Garrido	assistant prof.	0,3
Sophie Enrot-Versille	CNRS	0,6
Thibault Louis	CNRS	0,3
Matthieu Tristram	CNRS	0,7
Imada	postdoc	1
Sylvain Vanneste	PhD	0,8
Julien Bonis	engineer	0,3
Didier Auguste	technician	0,1
Eric Guerard	technician	0,1
Simons Observatory		
Xavier Garrido	assistant prof.	0,3
Sophie Enrot-Versille	CNRS	0,1
Thibault Louis	CNRS	0,4
Matthieu Tristram	CNRS	0,1

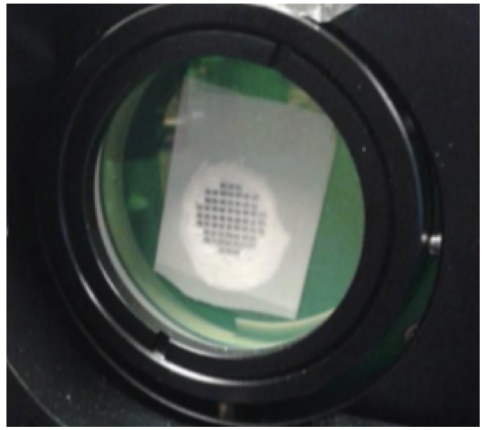
GW

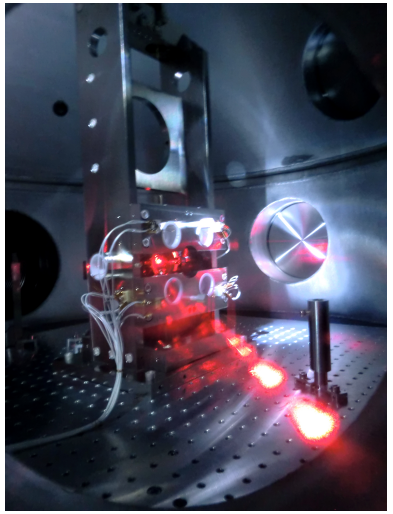

GW170104
GW151012
GW170818-HLV
GW151226
GW170823
GW170608
GW170729
GW170809
GW170817-HLV
GW170814-HLV
GW150914

CALVA : CAvité pour le Lock de Virgo Avancé

- Having suspended optical cavity similar to the ones used in Gravitational Wave (GW) detectors to work on control strategy
  - shorter distance : 50 m vs 3 km
  - smaller mirrors
  - similar dynamics for the mirrors
  - similar radiation pressure effects
- Long suspended cavities are also used to perform frequency dependent squeezing – reduce quantum noise in GW detectors
- 2 ANRs on-going on the latter subject with LKB, LMA and LAPP
- Also work on Thermally Deformable Mirror system :
  - Reducing losses
  - Low noise actuators
- Perfect tools for training – more than 10 internships in the last 8 years

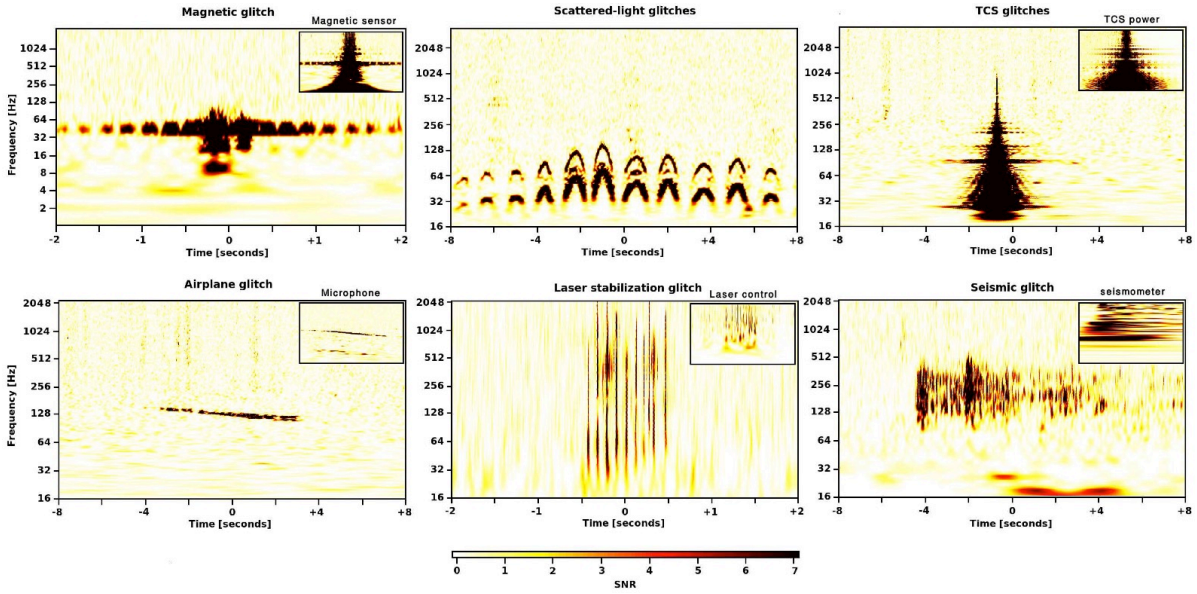


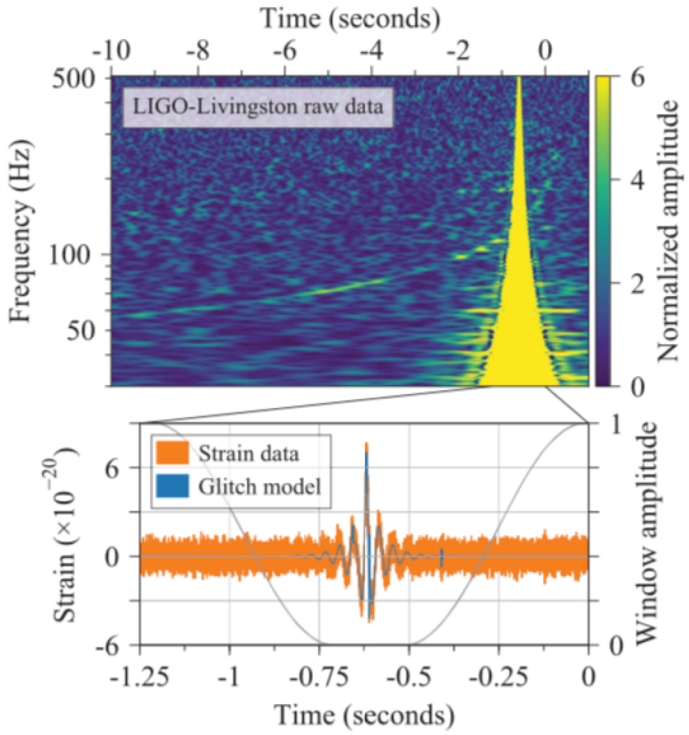




GW vs artefacts

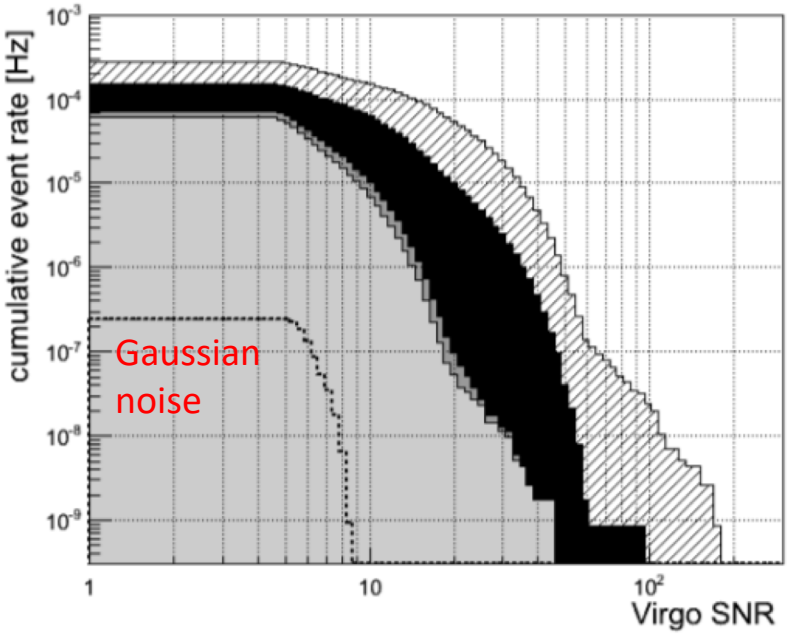
- Different types of pipelines depending on nature of the signals searched for
- Not always easy to distinguish between artefacts and real signals
- Artefacts can also pollute detection





GW vs artefacts

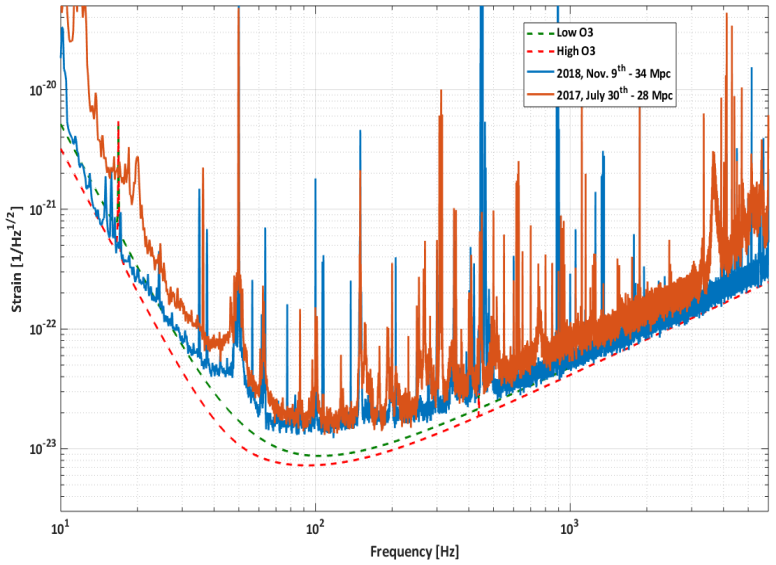
- Lot of non stationarities in the pipelines output – highly non gaussian
- Non possible to model all the noises
- Reducing the tails with:
  - Network analysis
  - Understanding of limiting noises, remove them when possible
- Need to have accurate and rapid follow-up of transient noises during data taking
- Need also to validate or exclude a GW candidate

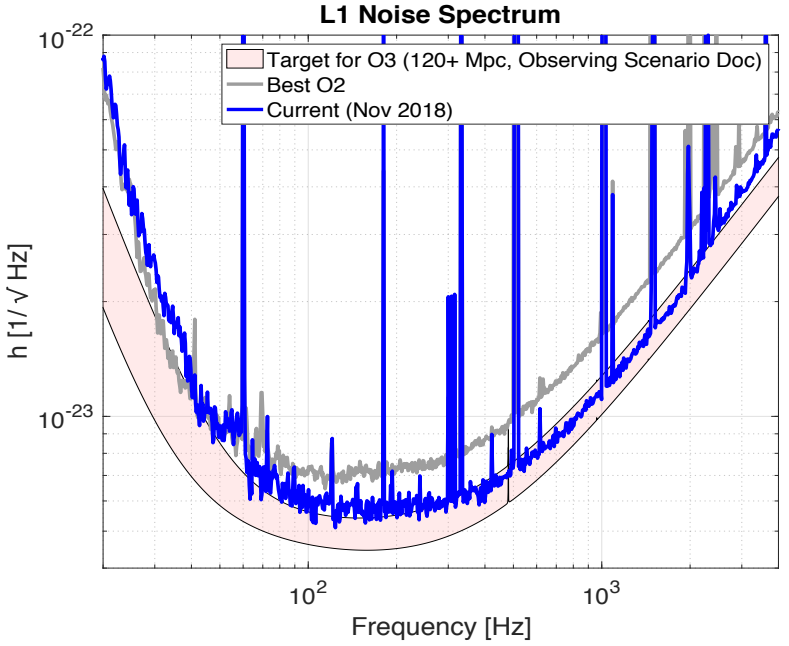


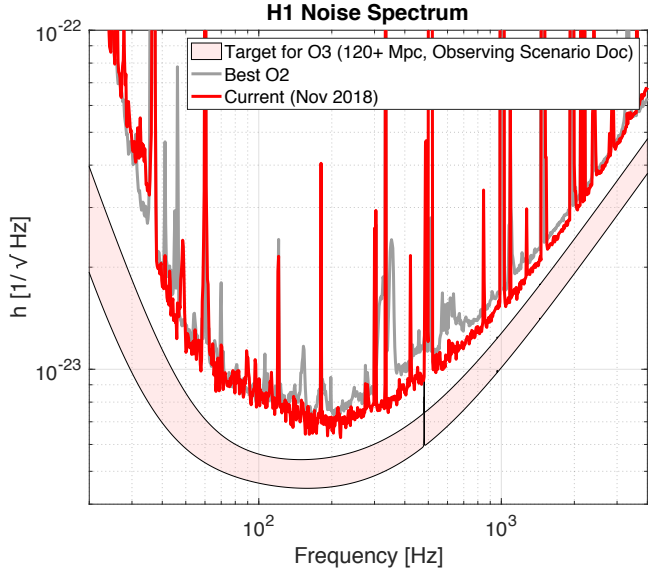
Double coincidence triggers, including Virgo

Observation Run 3 (O3)

- Suspension wires on Virgo is now in silicate (lower thermal noise)
- Work is on-going to reduce the different noise and achieve at least 60 Mpc on BNS range in Virgo
- Plan to run for one calendar vear with LIGO (@120 Mpc)



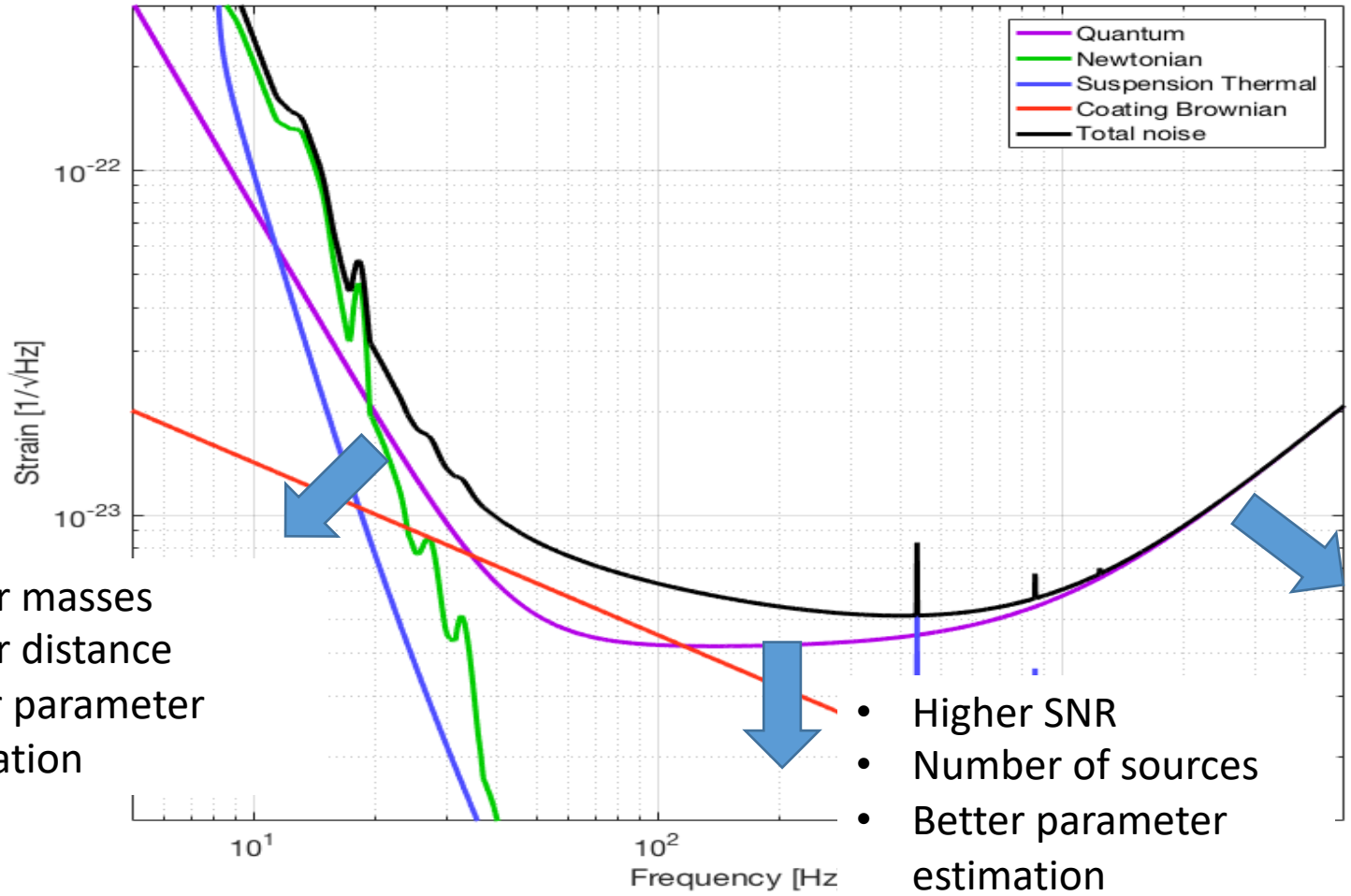




Improving sensitivity

- What can be done with a better sensitivity?

Virgo design sensitivity with SR installed



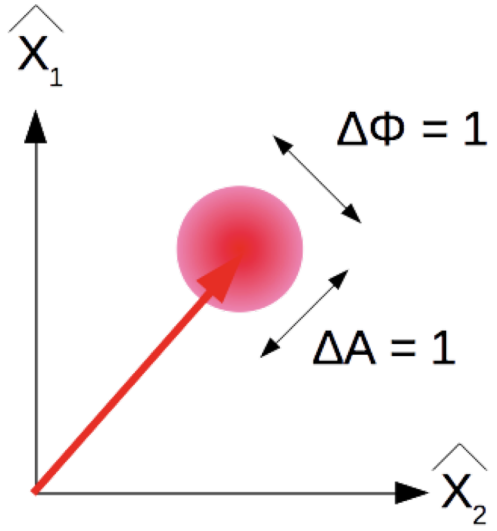
- Higher masses
- Higher distance
- Better parameter estimation

- Higher SNR
- Number of sources
- Better parameter estimation

- BNS merger physics
- Localization

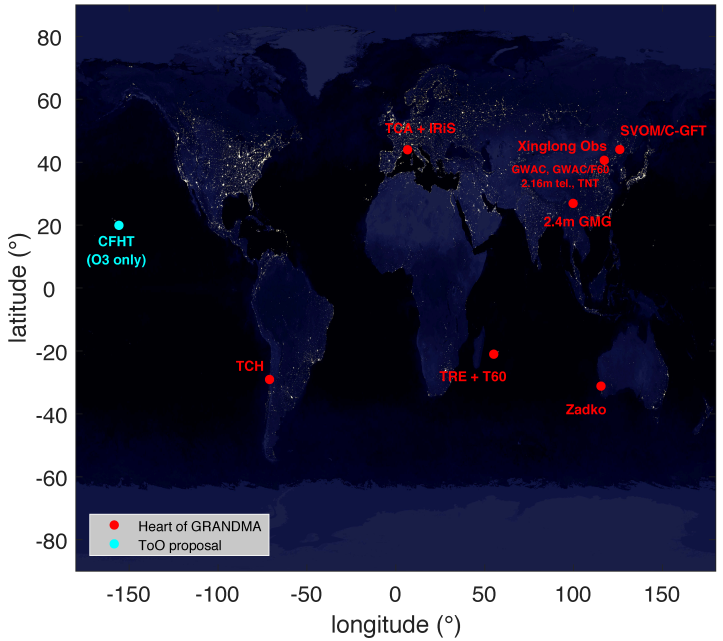
Advanced Virgo+ (2021)

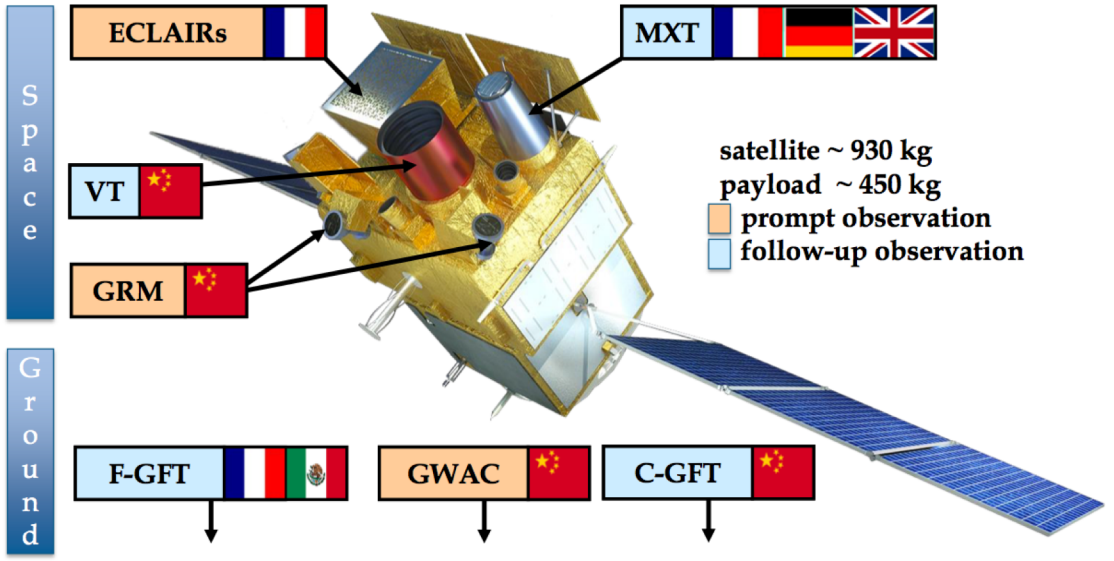
- Improve Newtonian noise cancellation with an array of seismometers
- Improve the quantum noise with squeezing technics (ANRs Exsqueez + Quantum filters)
- Under test with LKB, LMA and LAPP using CALVA infrastructure @ LAL



Multi-messenger astronomy

- SVOM mission @ LAL (to be launched in 2021):
  - Perform detection of GRB – LAL in charge of the photon reconstruction in MXT
  - Responsible for follow-up of multi-messengers alerts (from GW or neutrinos detectors)
- Already working on follow-up with ground based telescopes (for O2 and now GRANDMA project for O3)

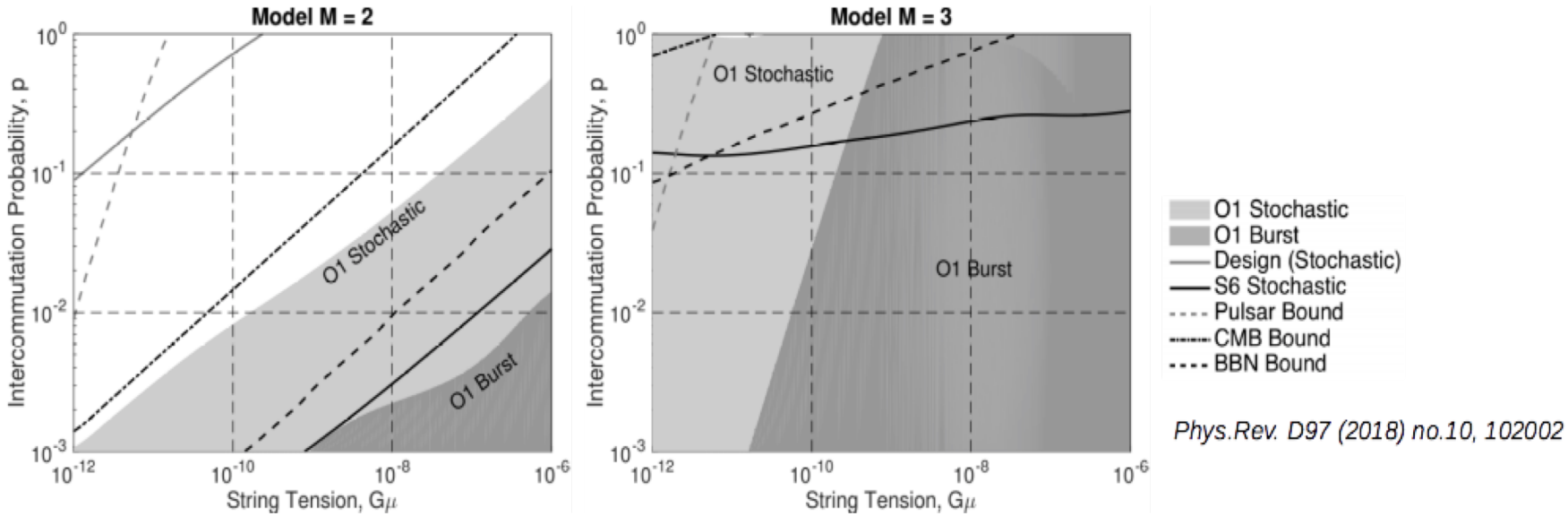




Search for cosmic strings

- Cosmic strings are topological defects which could result from phase transitions in the early universe
- Bursts of gravitational waves are expected to be produced by oscillating loops of cosmic strings
- The waveform of these bursts is well-modeled and are searched in LIGO-Virgo data
  → constraints on the energy of the cosmic string network → constraints on loop formation models
  → constraints on string theory

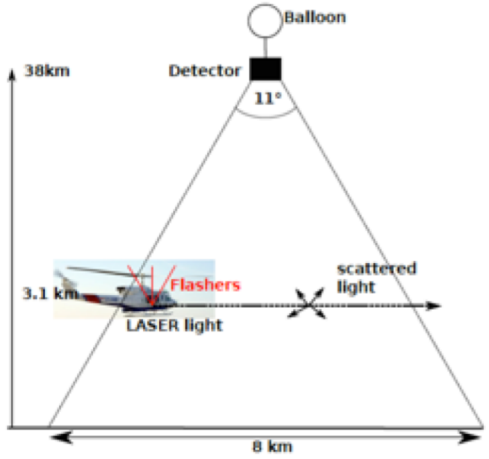
- Publications:
  → multiple papers using data from LIGO-Virgo runs (S4, S5-S6/VSR1-2-3, O1, O2 in prep.)
  → joint paper with the Planck group including CMB/BAO data (2015)

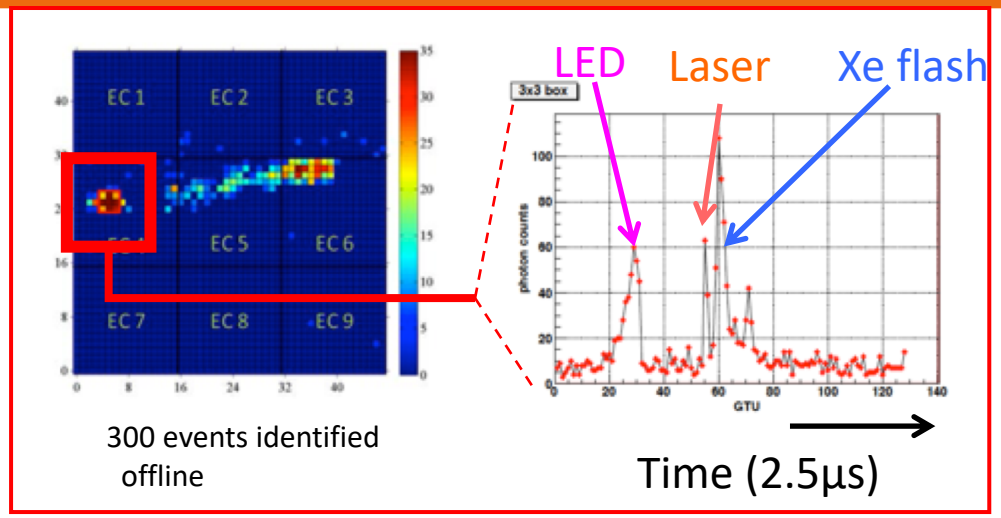


Phys.Rev. D97 (2018) no.10, 102002

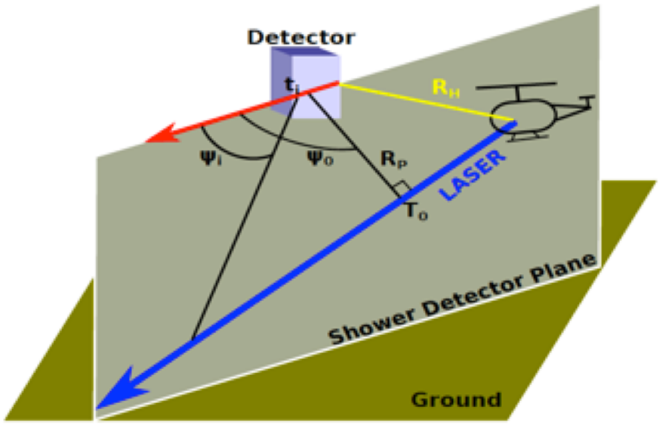
UHECR

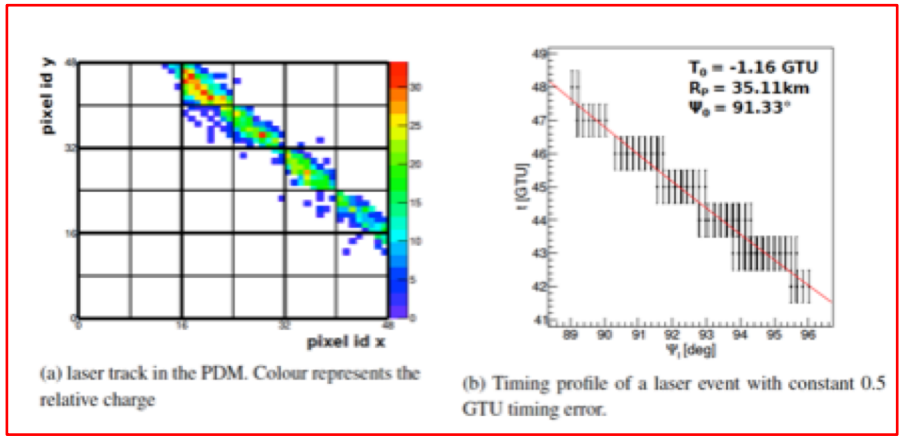
EUSO- Balloon Scientific result 1 : on light source detection





Example of laser track reconstruction :





(a) laser track in the PDM. Colour represents the relative charge

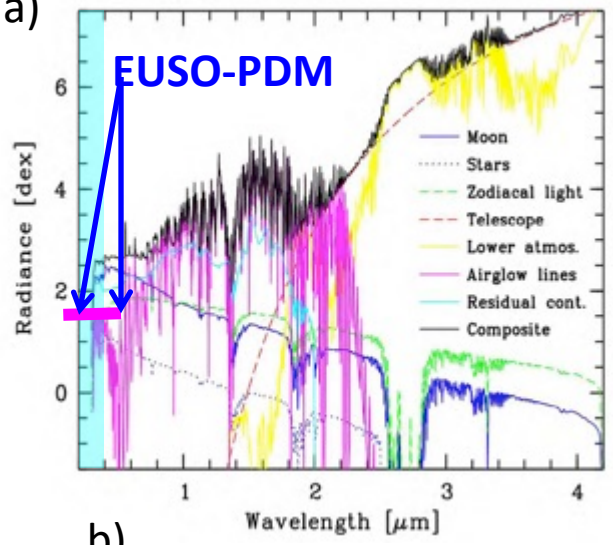
(b) Timing profile of a laser event with constant 0.5 GTU timing error.

$$t_{i,expected} = T_0 + \frac{R_P}{c}\tan\left(\frac{\pi}{4} + \frac{\psi_0 - \psi_i}{2}\right)$$

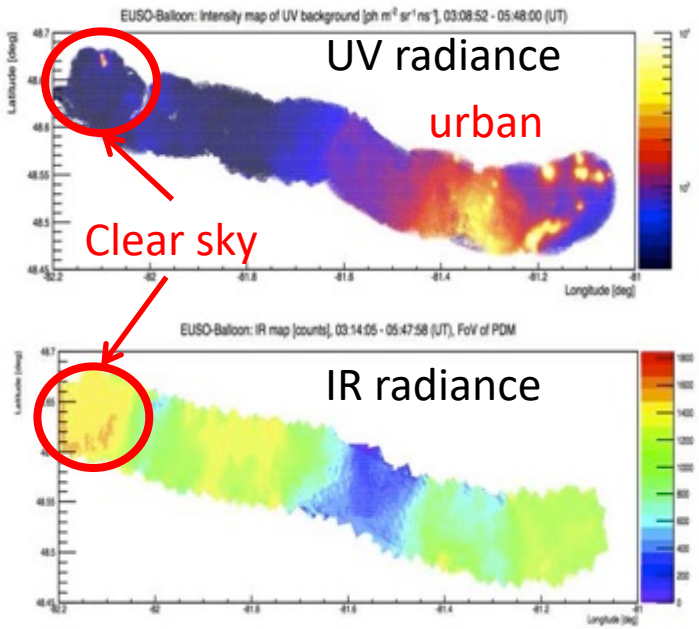
ICRC2015

EUSO-Balloon Scientific result 2 : on Airglow UV component

a)

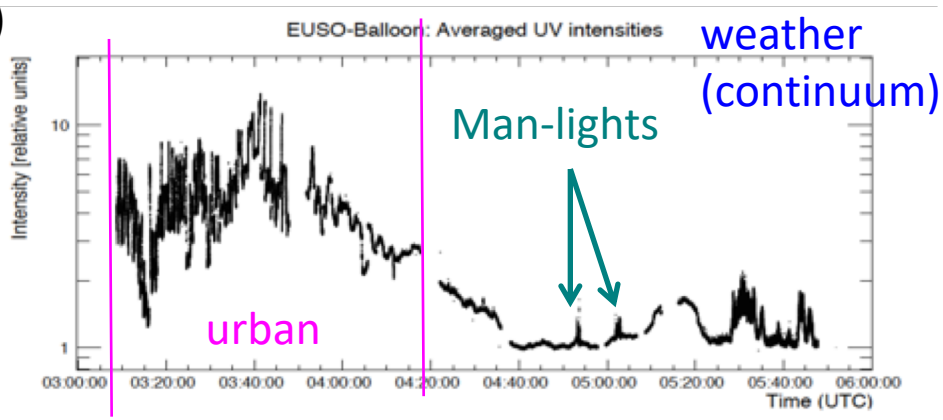


b)



Airglow estimated in C. Moretto's thesis

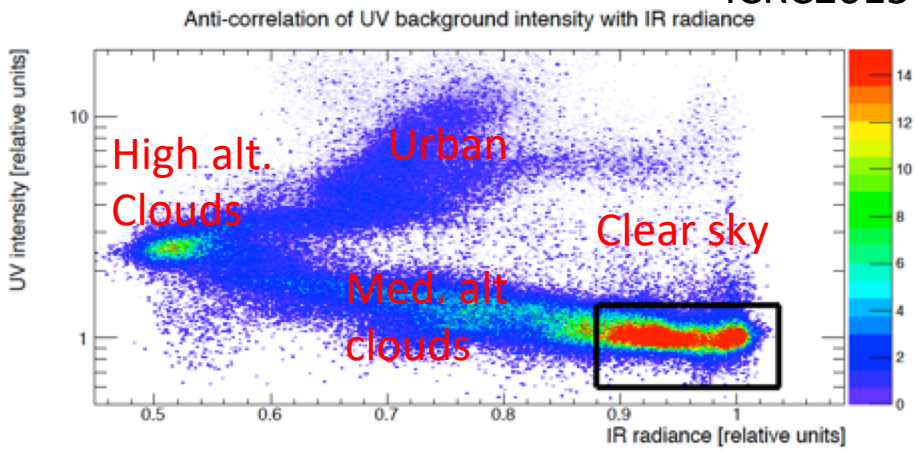
c)



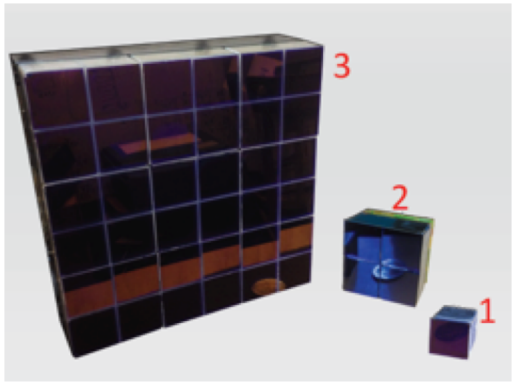
$$I_{BG} \equiv \frac{N_{pe}}{A_0 \int_\varphi \int_\vartheta \int_\lambda \kappa_i(\lambda,\vartheta,\varphi)\, f(\lambda)\, d\lambda \cos\vartheta\, d\vartheta\, d\varphi\, \Delta t_{int}},$$

K_i : optical throughput and electronic efficiency

ICRC2015



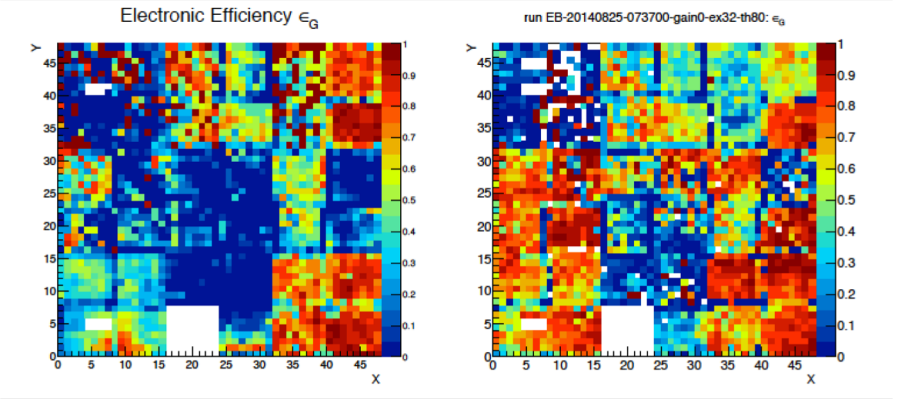
LAL team work in EUSO-BALLOON data : the PDM calibration



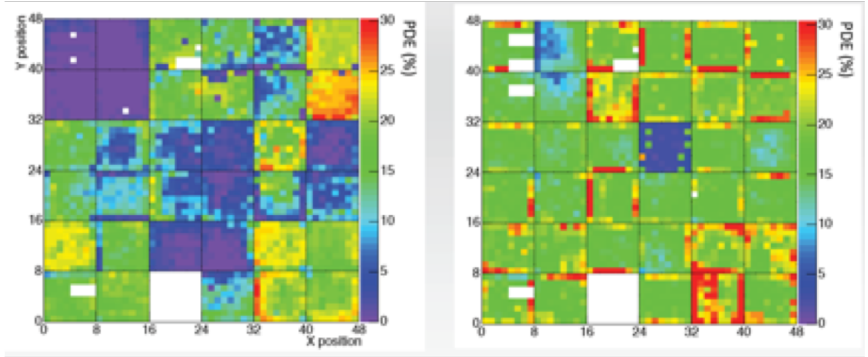
ICRC2015

In-Flight **relative calibration**
Dagoret- Rabanal et al. (Thesis sept 2016)

Relative efficiency from August 2014's fligth

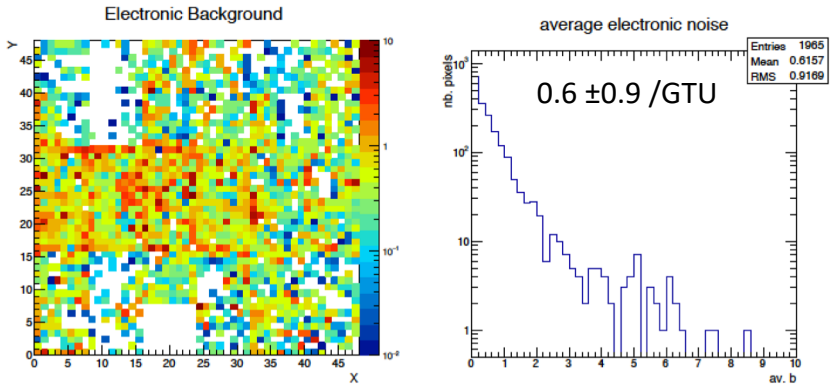


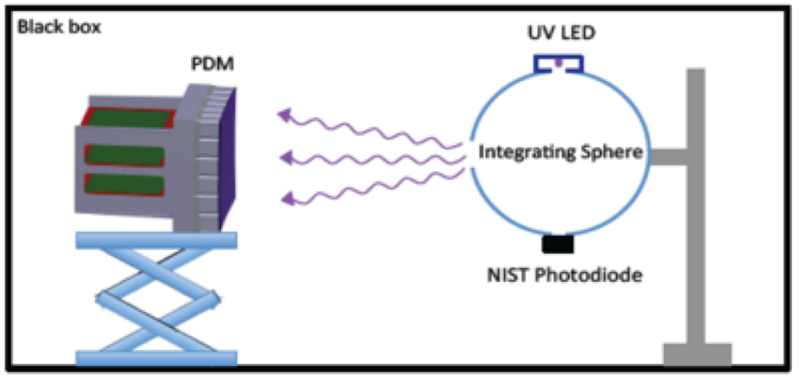
Post-Flight (lab) **absolute calibration**
Moretto et al. (Thesis Oct 2nd 2015)



HV = 950 V HV =1100 V

Electronic noise

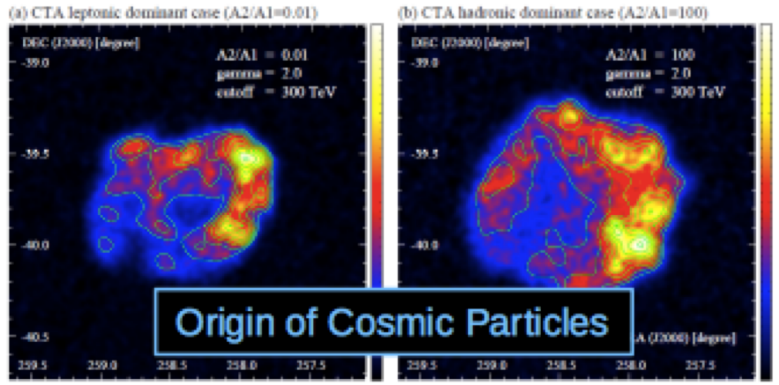


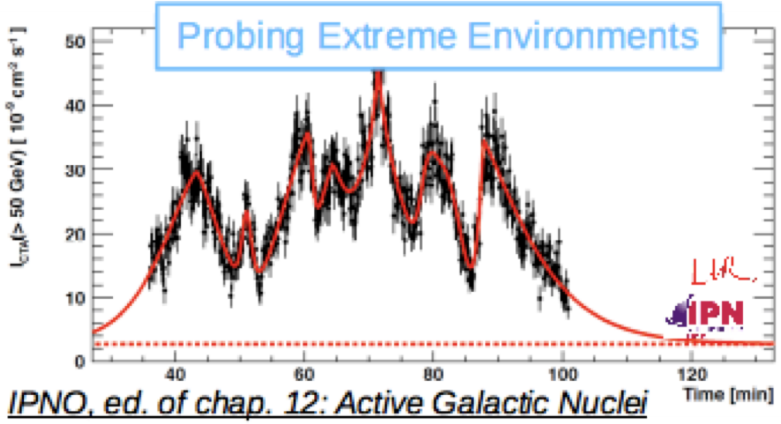


CTA

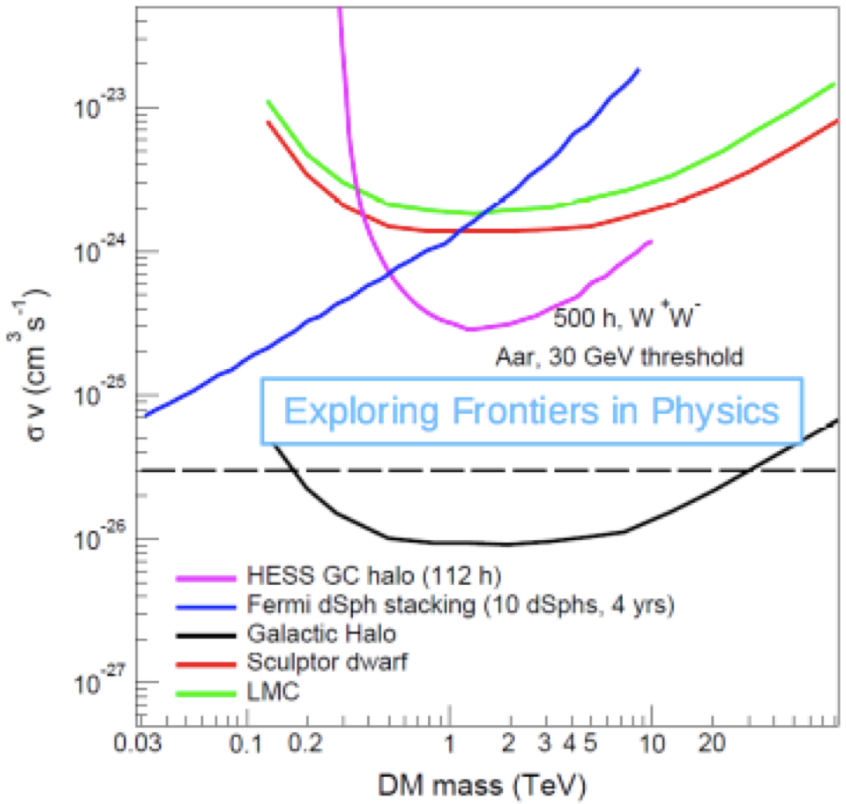
CTA Science

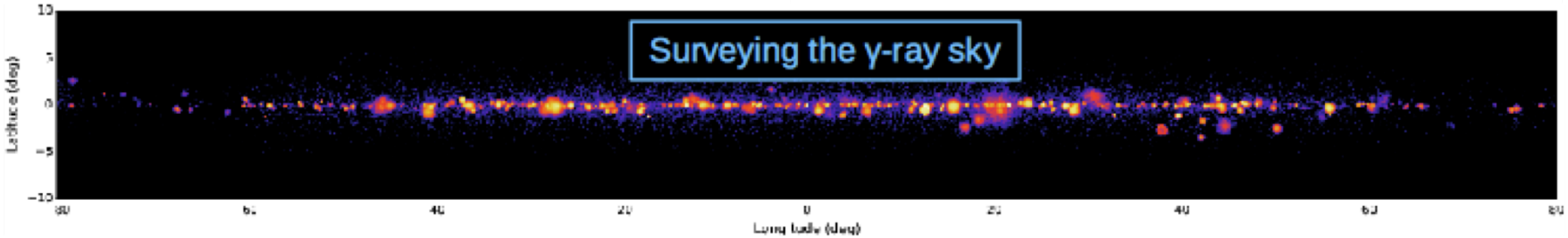
Credits: *Science with CTA*, World Scientific (2018)





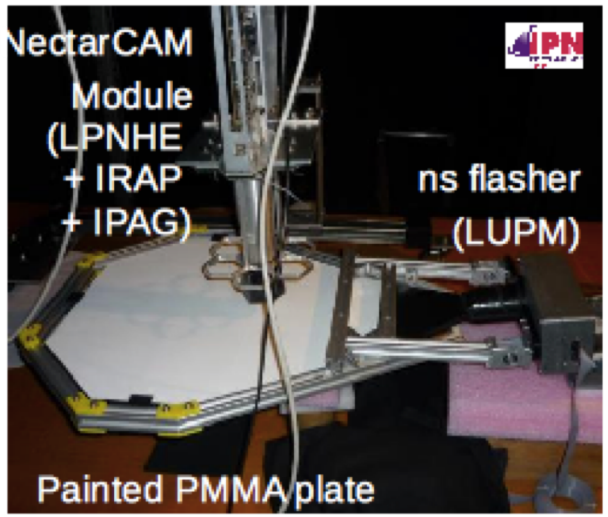
IPNO, ed. of chap. 12: Active Galactic Nuclei





Technical activities

Single p.e. & reflective target: instrumentation

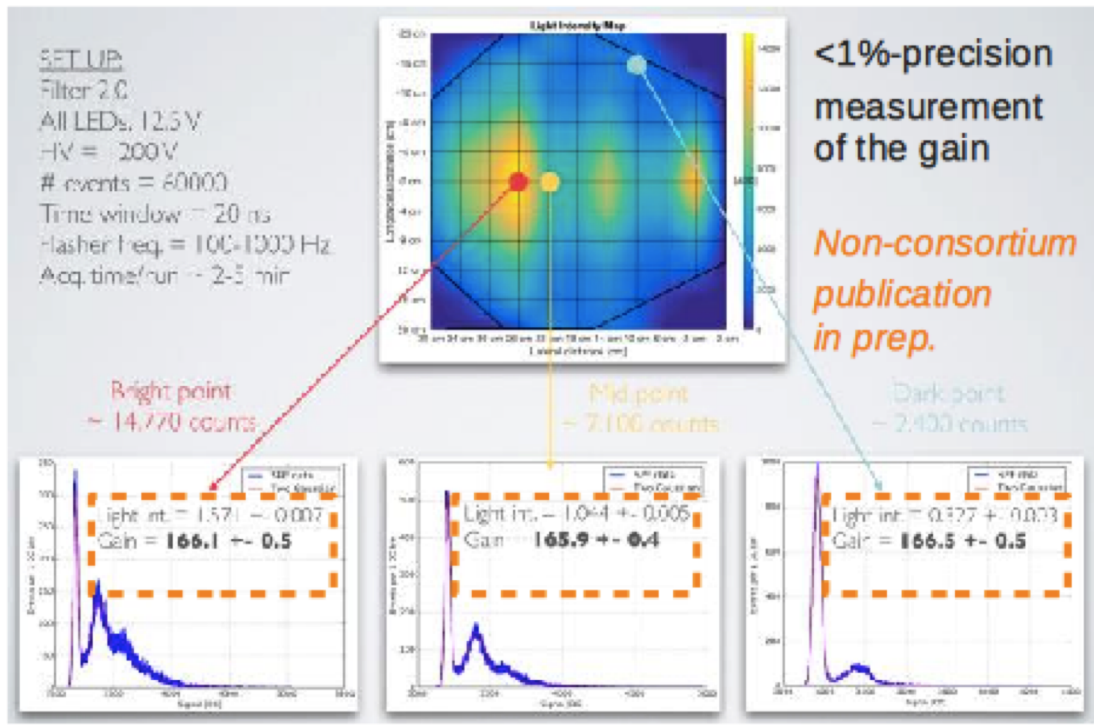


Realization: movable flashing screen

Light injection from ns-flasher in PMMA plate through fishtail

Internal reflections on tailored paint pattern (dip coating)

Low emissivity (p.e. level), fast (few ns), homogeneous (1:5)



CTA project at IPNO

Wrap up

The Cherenkov Telescope Array

Major astroparticle project for the next two decades

→ cosmic accelerators, extreme environments (+BSM physics!)

IPNO activities in CTA

Involvement in the flagship French project: NectarCAM

→ cameras probing the core energy range of CTA

Development of the SPE calibration sys. & reflective target

→ original concept validated in the lab

⇨ eager to perform tests in a real environment!

Active participation to Science working groups & Consortium

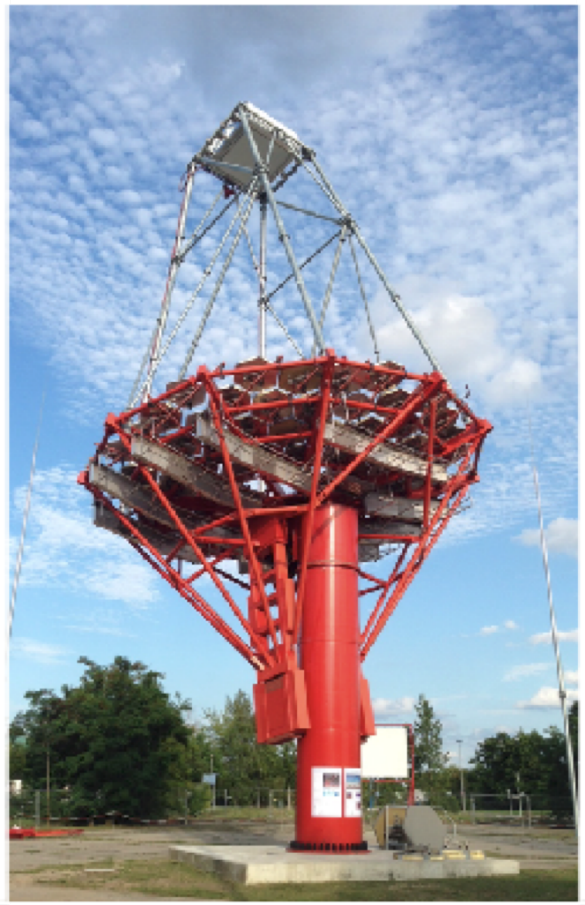
Looking ahead

Expected growth of technical activities

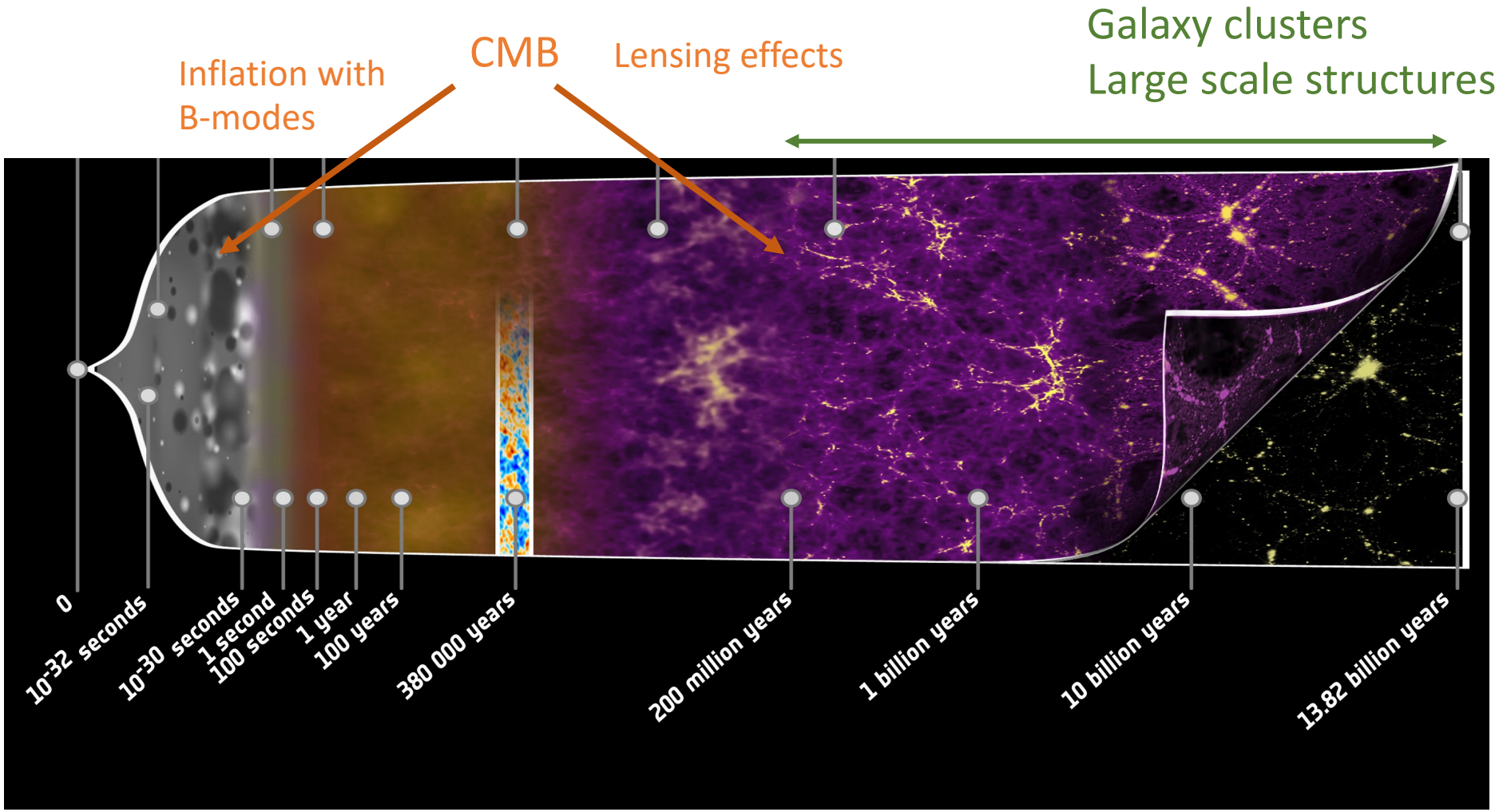
→ SPE system production (+ Maintenance tools?)

Analysis of the first CTA data

Nice opportunities for involving new-comers in CTA science



Intro Cosmo



Radiation dominated

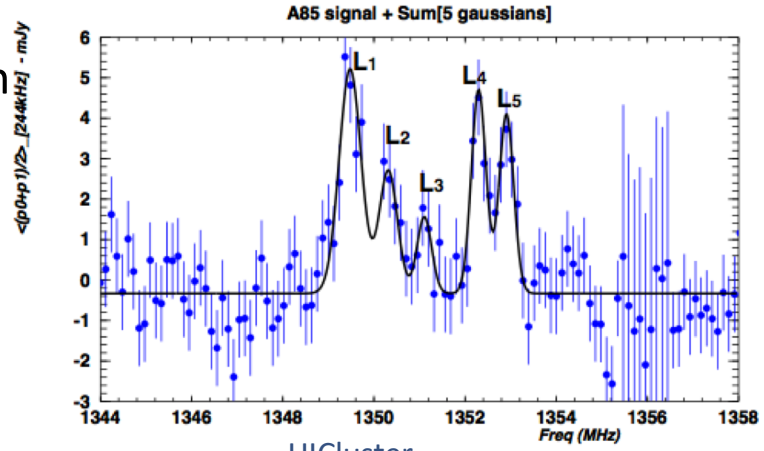
Matter dominated

Dark Energy dominated

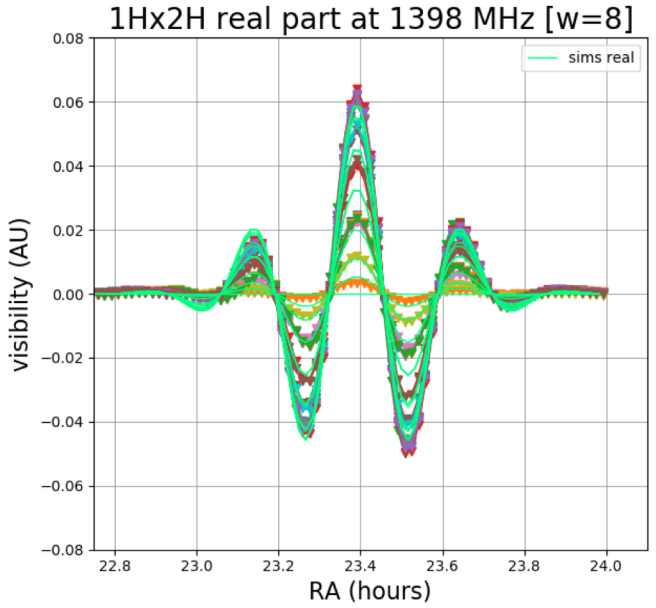
Dark Energy

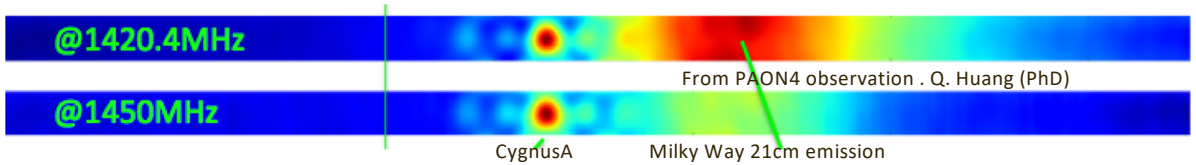
BAORadio (1)

- **HICluster** program : Wide band observations at the Nançay Large Radio Telescope (NRT), equipped with BAORadio electronic chain - Search for 21 cm emission from nearby galaxy clusters
- **PAON4** : construction & deployment of a 4-dish prototype radio interferometer array, operating in transit mode, in collaboration with Obs. de Paris & Irfu/DPhP - 21cm Intensity Mapping instrument concept validation



HICluster



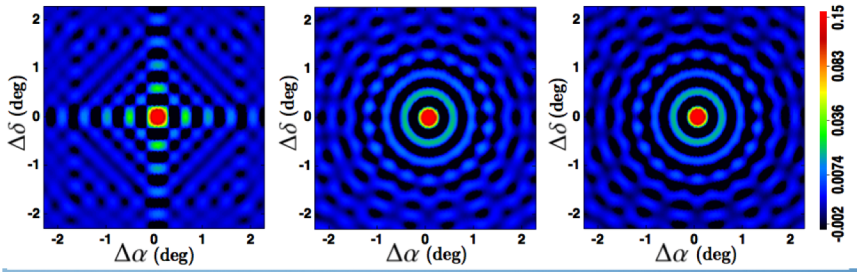


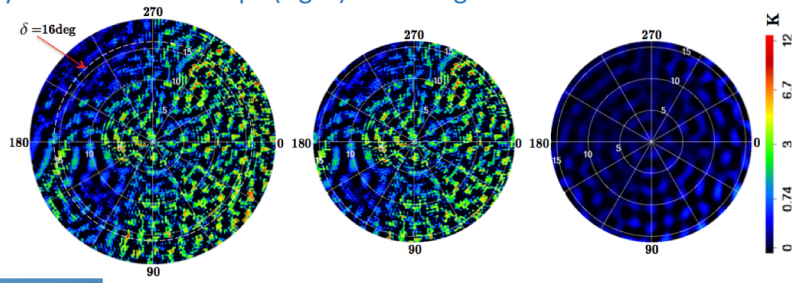
PAON4 Obs. on CasA
Comparison of observation with expected signal, after gain/phase calibration

BAORadio (2)

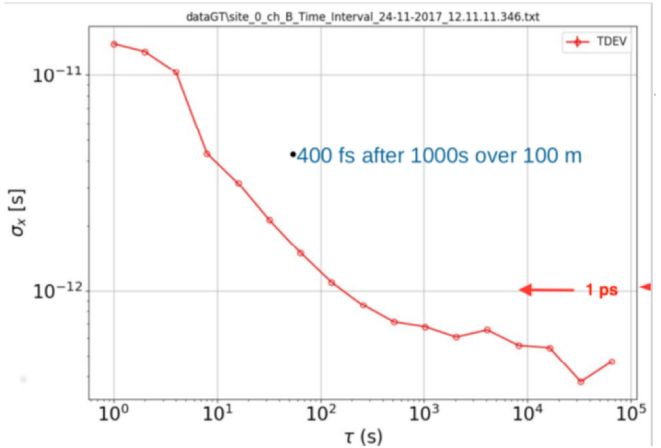
- **NEBuLA/IDROGEN** : Development of a new generation digitiser / signal processing board, using the White Rabbit technology (clock synchronisation), suitable for deployment over a large area (large interferometers). Collaboration with Nançay (Obs. de Paris) - Continued in the framework of DAQGEN IN2P3 program
- **Map making :** m-mode map making for transit interferometers, foreground separation, instrument configuration optimisation (J. Zhang PhD, Q. Huang PhD)
- **Tianlai** : Collaboration with the NAOC group in China & US (Wisconsin/Fermilab) on Tianlai (Intensity Mapping path finder experiment) design and data analysis

Tianlai instrument configuration optmisation : Beams (left) , polar cap survey reconstructed maps (right) - J. Zhang PhD



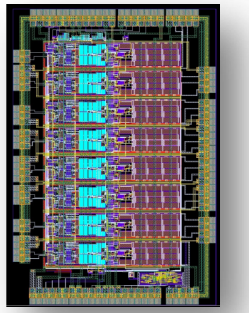


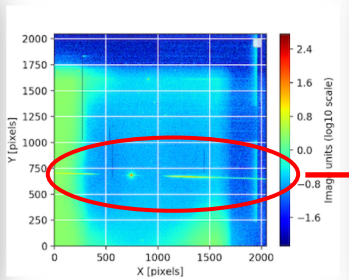
White Rabbit synchronisation on NEBuLA

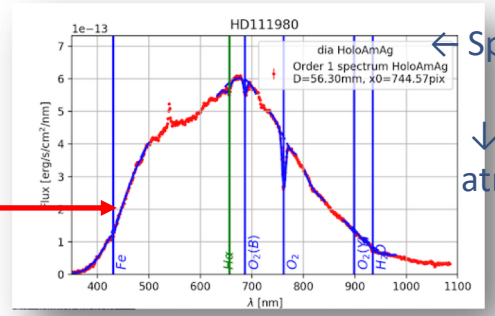


LSST (1)

- **Electronics/ASPIC** : LSST camera readout system FE ASPIC/CABAC chips - 1500 ASPIC chips delivered in 2015 (in collaboration with LPNHE/Paris)
- **Calibration/Atmosphere** : Atmospheric transmission models and impact on LSST effective passbands & PhotoZ
- **Calibration/HOLOSpec** : Development of holograms as dispersers for the LSST Auxiliary Telescope (AuxTel , atmospheric monitoring) - work in progress in collaboration with LPNHE/Paris
- **Calibration/Spectrator** : Development of spectral analysis pipeline for AuxTel

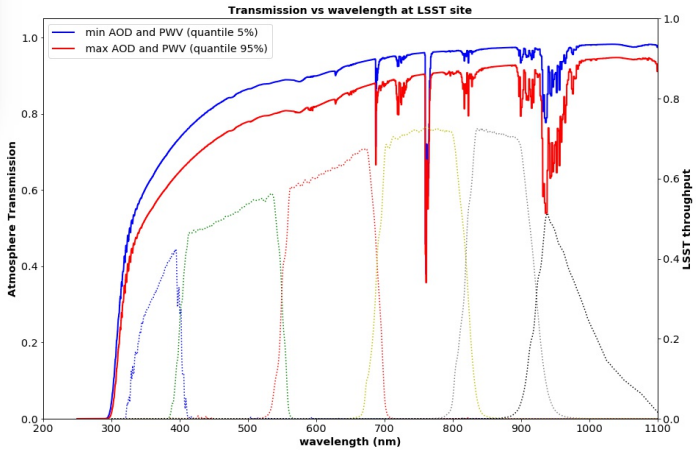


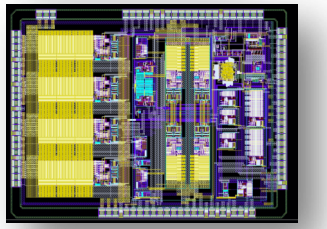


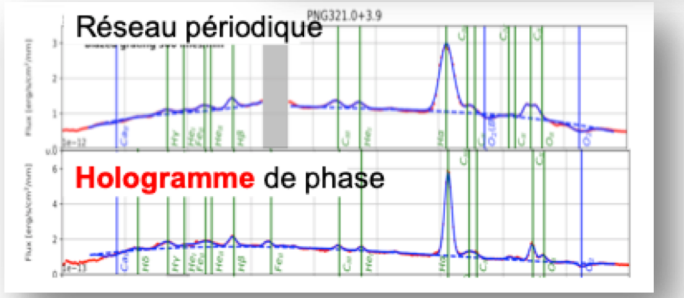


← Spectrator software pipeline / HOLOSpec

↓ Atmospheric transmission with different atmospheric parameters



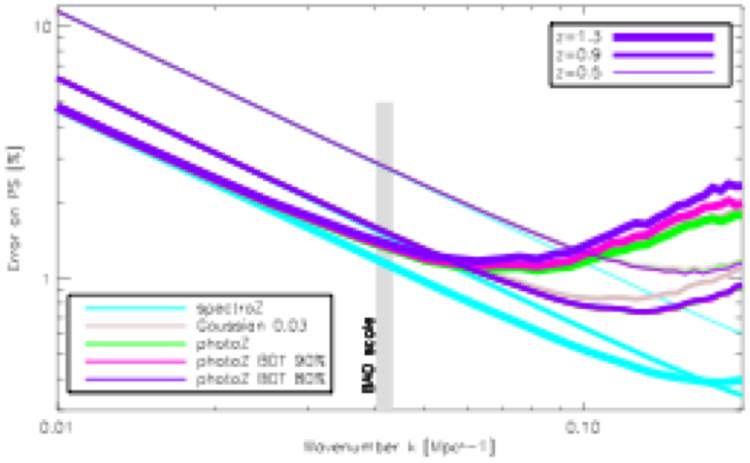




ASPIC/CABAC

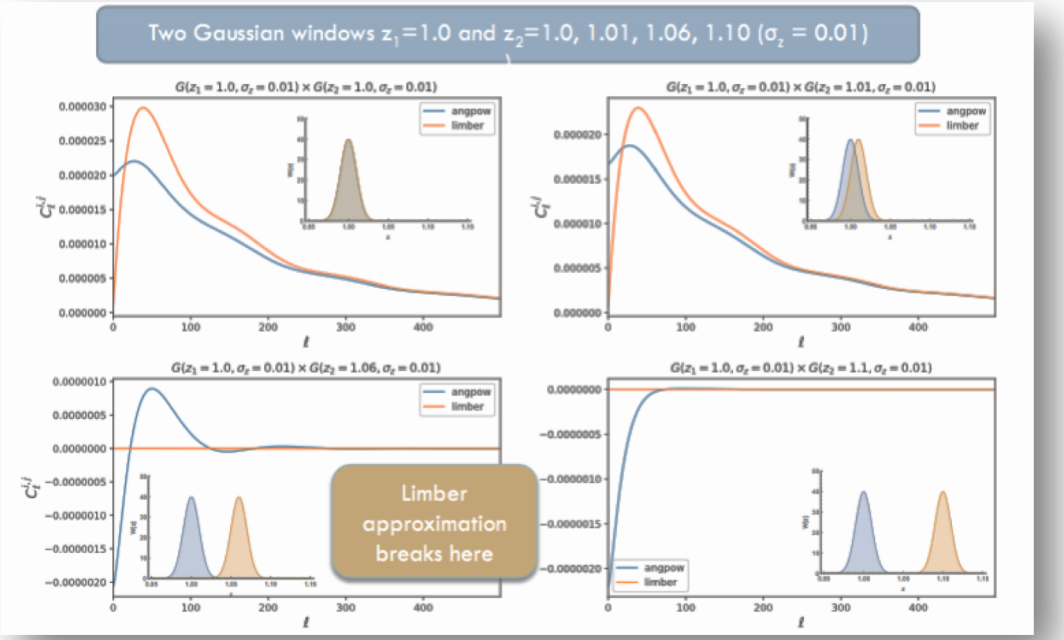
LSST (2)

- **DESC/PhotoZ** : PhotoZ systematics , use of Machine Learning methods for classification (star/galaxy/quasar separation)
- **LSS/PhotoZ** : Study of photometric redshifts in LSST, development of a complete, but simplified simulation and reconstruction pipeline to study PhotoZ impact of LSS & BAO scale reconstruction (collaboration with LPSC/Grenoble)
- **DESC/LSS** : Method (**Angpow** software) for efficient computation of LSS power spectrum in spherical geometry $C_l(z1,z2)$ and angular correlation function computation
- **DESC/TJP** : Angpow software interfaced with CLASS and DESC **CCL** (Core Cosmology Library)



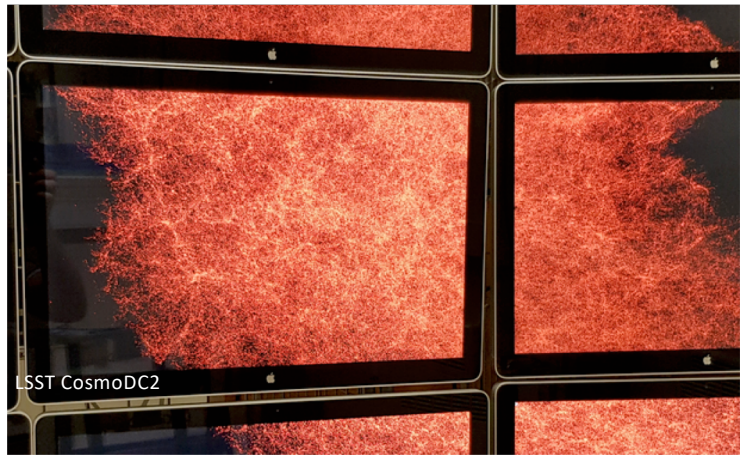
Fractional error on LSS power spectrum measurement by LSST - PhotoZ impact (A&A 2018)

Angpow



LSST (3)

- **LSST/Computing** : Preparation for SDRP (Satellite Release Data Processing) and major contribution to the deployment of LSST DC-2013 at IN2P3
- **Computing R&D** : Participation to the PetaSky big data project (CNRS MASTODONS) with contributions on PhotoZ & Visualisation (collaboration with LPC/Clermont) …
- **Computing R&D** :
  - Development on the Apache **Spark** distributed computing framework , Evaluation of Spark for use in the astro/cosmo community
  - Development of the **AstroLab** software suit, with **spark-fits** (efficient connector to FITS format data) , **spark3D** (3D catalog handling),
  - Large data set **visualisation**



Dark Matter / Microlensing

- **DM/Scintillation** : Search for cold molecular clouds as dark baryons on the Milky Way : nano survey of LMC during one night
- **DM/Black holes** : Search for massive black (~10 Msol) holes through long duration microlensing events - **MEMO** project : Combining EROS/MACHO/OGLE data sets to perform long duration (> year) microlening events - T. Blaineau PhD (started Oct 2018)

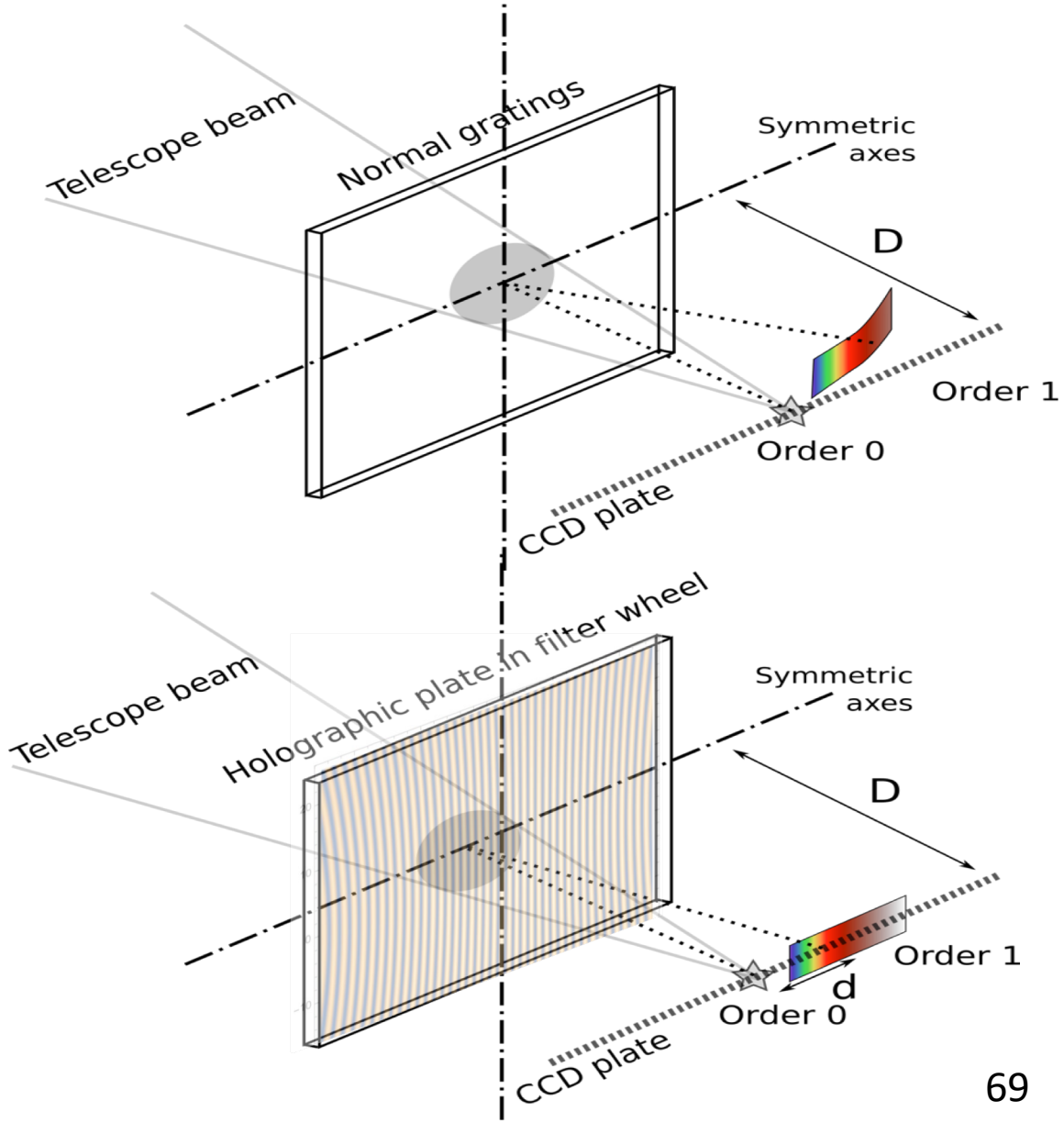
+ Une figure du Papier Mirhosseini & Moniez

Holograms for AuxTel

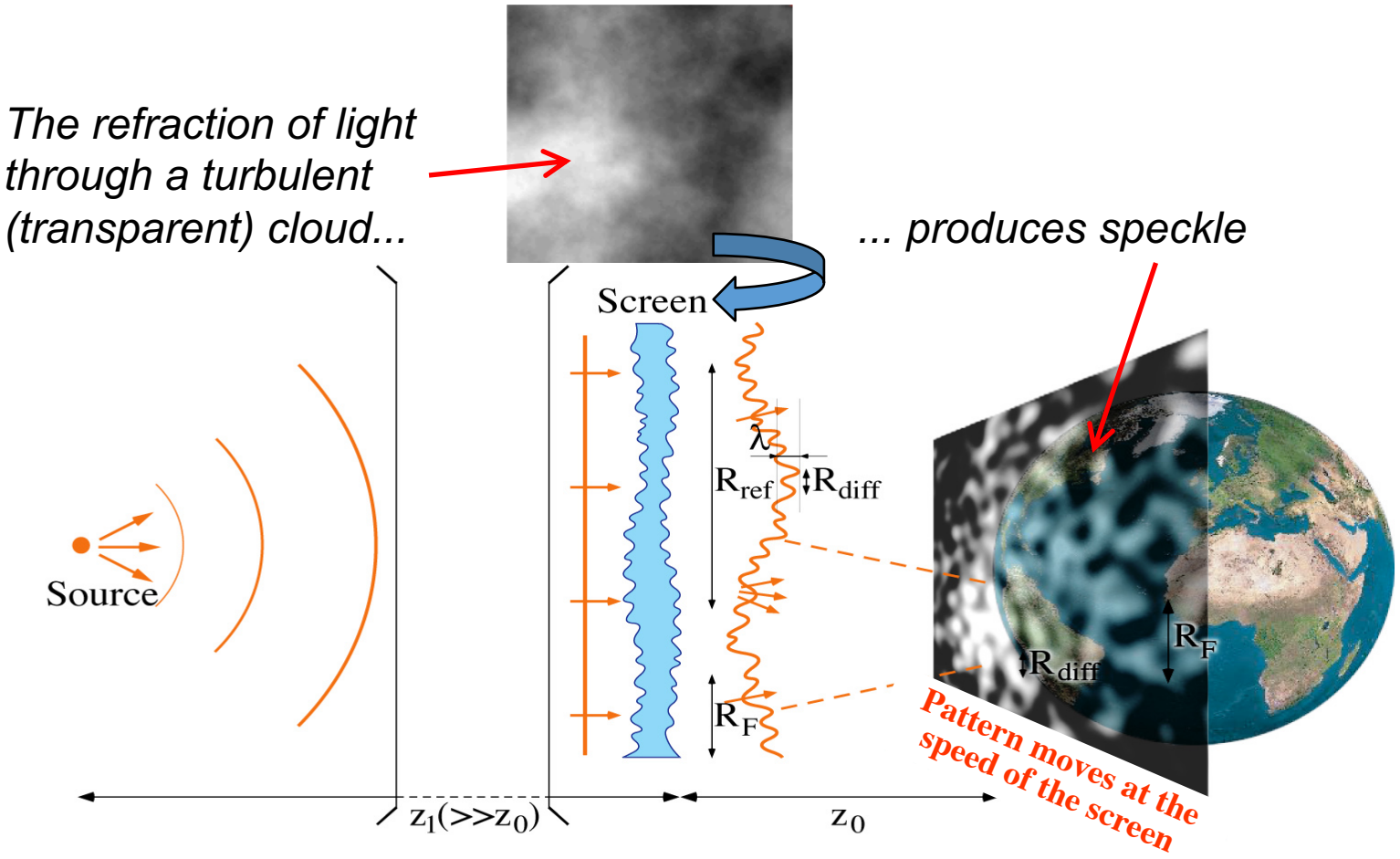
- **Goal :** constrain atmospheric parameters by extracting spectrum of standards

- **Constraints**
  - Easilly switch imager / spectro.
  - Incident beam perpendicular to CCD-plane
- **Usual gratings:**
  - Defocus due to optical path variations with the diffraction angle
  - Distorsion when used with a converging beam

- **Holographic grating:**
  - forced focus on the focal plane at all wavelengths: **0th and 1rst order at same focus**
  - No distorsion by design of hologram



Search for transparent missing H_2 gas through Scintillation



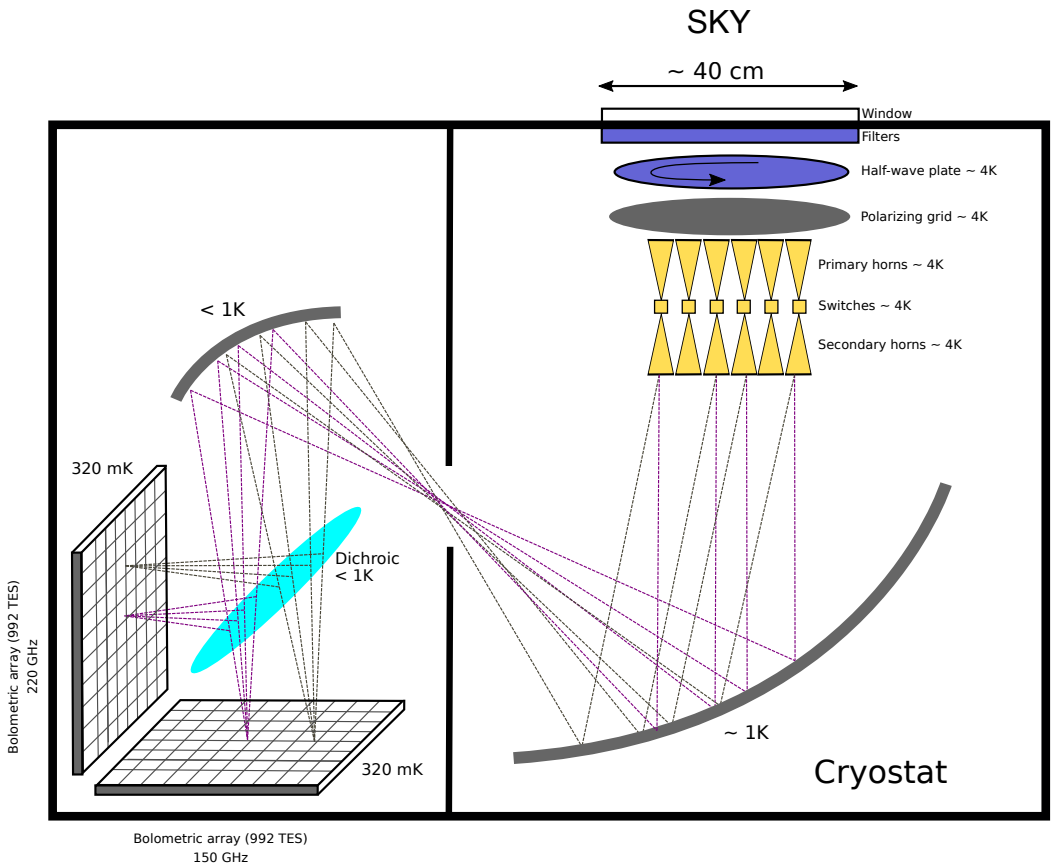
The light that enters a telescope varies with ***timescale ~10 min*** *due to the relative speed of the cloud;* ***modulation*** *can reach* ***a few %****, depending on* ***distances / turbulence parameters / source extension***

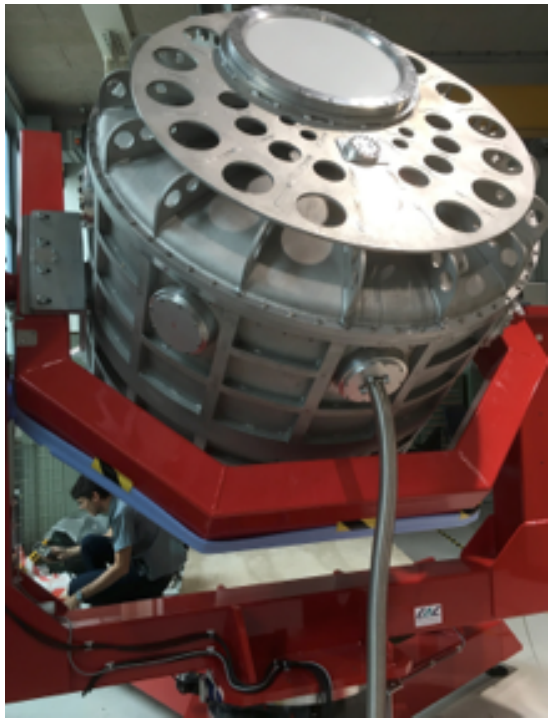
CMB

QUBIC

Explore the b-mode polarisation anisotropies of the CMB

Ground based bolometric interferometer (T=350mK).
Very high accuracy on systematic effects and foregrounds control.
The technological demonstrator instrument is realised.





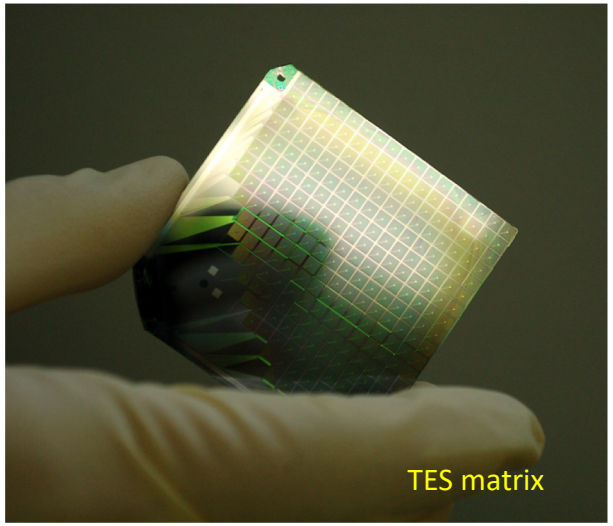
QUBIC experiment @ CSNSM

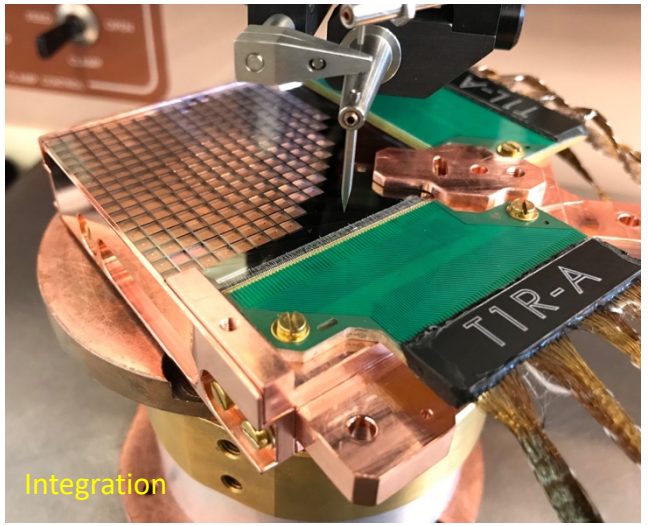
QUBIC instrument combines the sensitivity of TES bolometric detectors with the systematic effects and foreground control provided by its interferometric design.

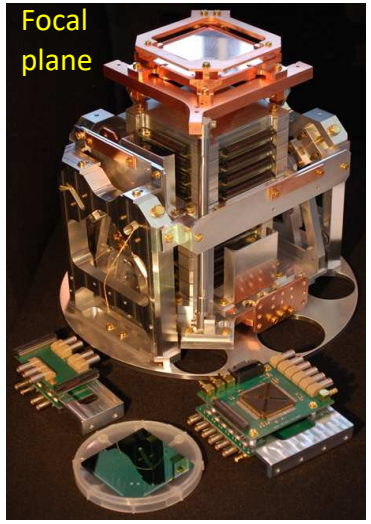
TES detectors developed at CSNSM:

Two focal planes : 150 GHz & 220 GHz spectral band

Each focal plane to be equipped with an assembly of 4 bolometer matrixes (total of 1000 pixels)



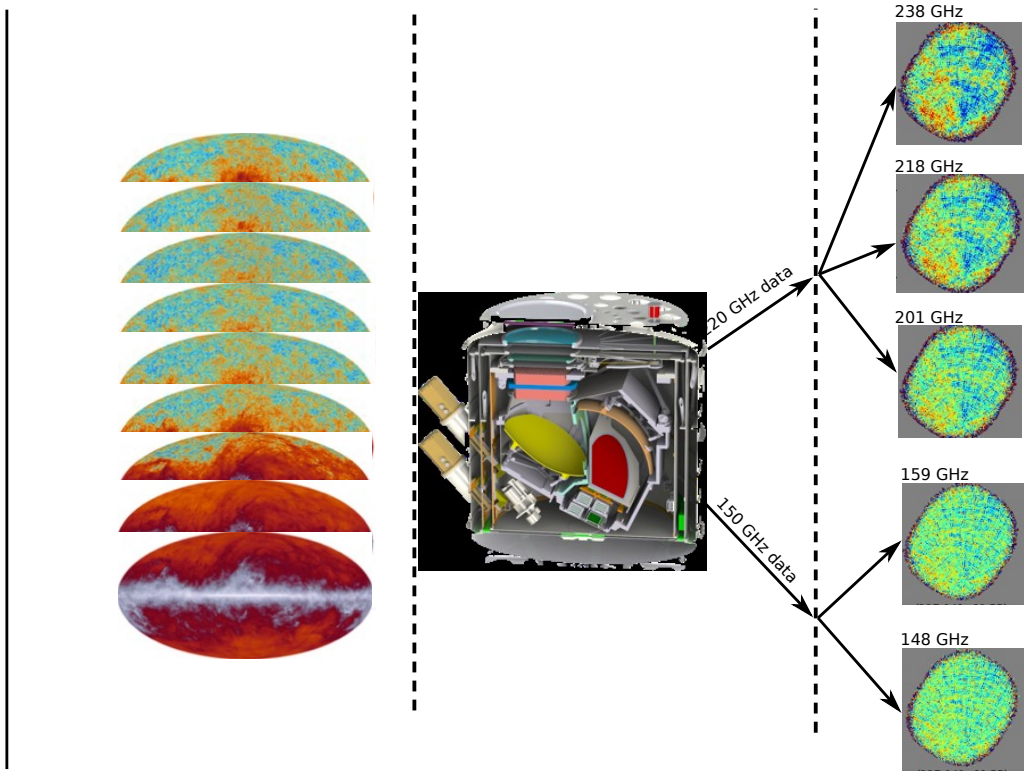


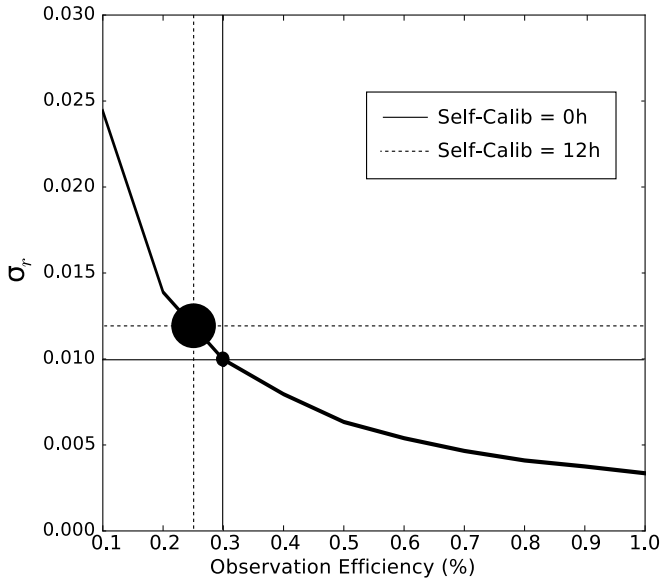


Instrument will be limited by the photon noise of the sky. Detector noise NEP = 5 10^{-17} W/sqrt(Hz)

QUBIC technical demonstrator commissioning

The Technological Demonstrator instrument is currently under testing at APC-IN2P3. It will be installed at Argentina (Salta province.





Self calibration mode and ability to resolve spectral sub-bands of the synthetized beam will allow to reach tensor-to-scalar ratio $r=10^{-2}$ after two years of operation.