Enigmass

The enigma of mass

astro-particule & cosmology

state of the art in Enigmass labs

June 2014

With inputs from LAPP, LAPTh, LPSC teams

Cécile Renault (LPSC) - astro-particle coordinator

comité de pilotage ENIGMASS - 18 juin 2014

The Universe is our lab

- LAPP, LAPTh, LPSC, LSM largely implied *(almost half of the proposed PhD subjects for instance)*
- some projects are closed to the end while others will really start at the horizon 2020
- focus on subjects with large involvement of our lab teams
- focus on results obtained by multi-lab team, Enigmass post-doc or Enigmass PhD students
- for each subject **experiments** & **phenomenology/theory**

Summary

- Reminder about the Enigmass astro/cosmo experiments (just what do they do)
- Results from Galactic, extragalactic and cosmological observations
- Dark matter hunt
- Calendar
- Collaborations between Enigmass labs: current and possible future ones

AMS, CREAM

AMS is an international long duration (10-20 years) experiment on the International Space Station. May 19, 2011: AMS installation.
The detectors function as designed and is routinely collecting events at a rate of 16 billions of events/year.
Is providing data on the fluxes and composition of the Galactic Cosmic Rays in the large range of energy between GeV and TeV with unprecedented precision.

CREAM is a long-duration balloon-borne experiment. Measurement of CR from fraction of TeV to few hundreds of TeVs.
The CREAM instrument has had 6 successful balloon flights over Antarctica during the local summer time from 2004 to 2010, accumulating 161 days of exposure.
Will be installed on ISS for at least 3 years.

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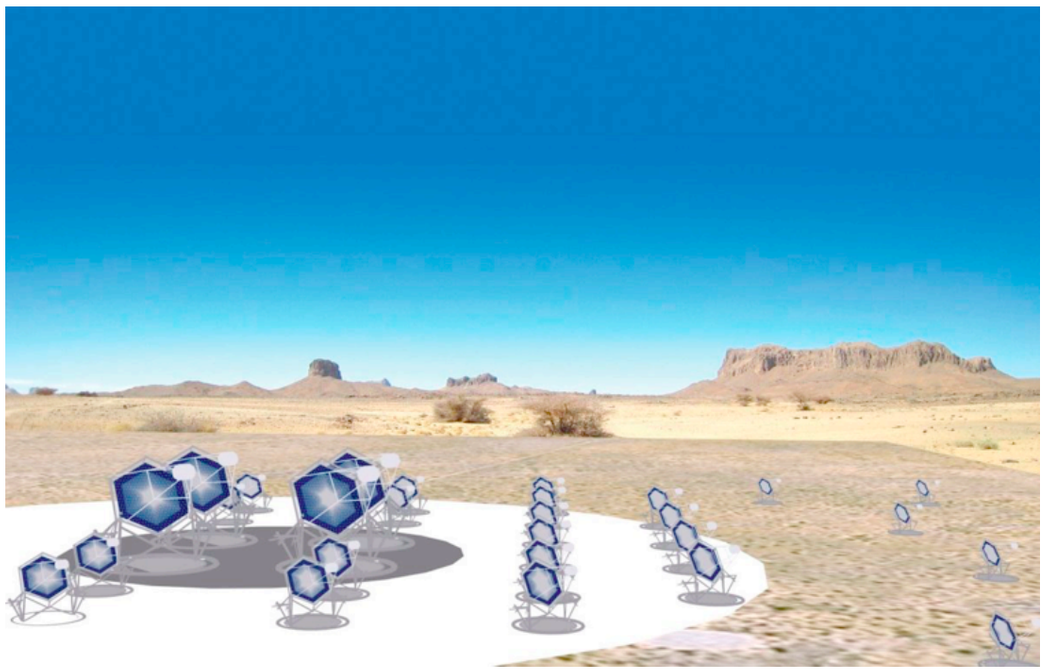
HESS, CTA

H.E.S.S. is a system of Imaging Atmospheric Cherenkov Telescopes that investigates cosmic gamma rays in the energy range from tens of GeV to tens of TeV.
The four telescopes of Phase I of the H.E.S.S. were operational in December 2003. A much larger fifth telescope - H.E.S.S. II - is operational since July 2012, extending the energy coverage towards lower energies and further improving sensitivity.



CTA is the next generation of gamma-ray observatory. Combine 3 sizes of telescope to achieve a sensitivity to events of tens of GeVs to more than 100 TeV with both improved angular resolution and better suppression of cosmic-ray background events.

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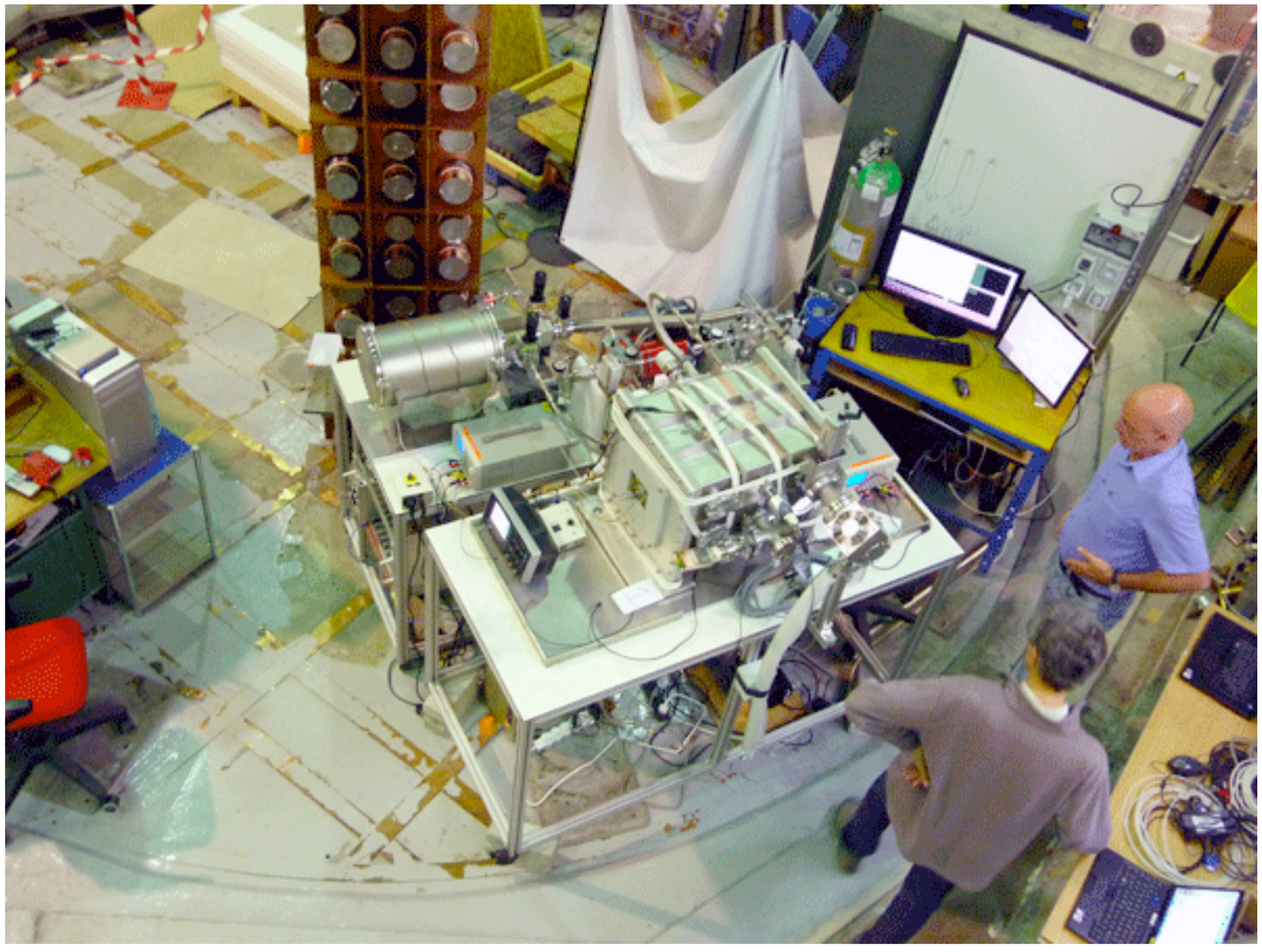
LSST

LSST will be a large aperture, wide field survey telescope with a 3200 Megapixel camera to image faint astronomical objects across the sky.
LSST will rapidly scan the sky, charting objects that change or move. Its deep images will trace billions of remote galaxies.

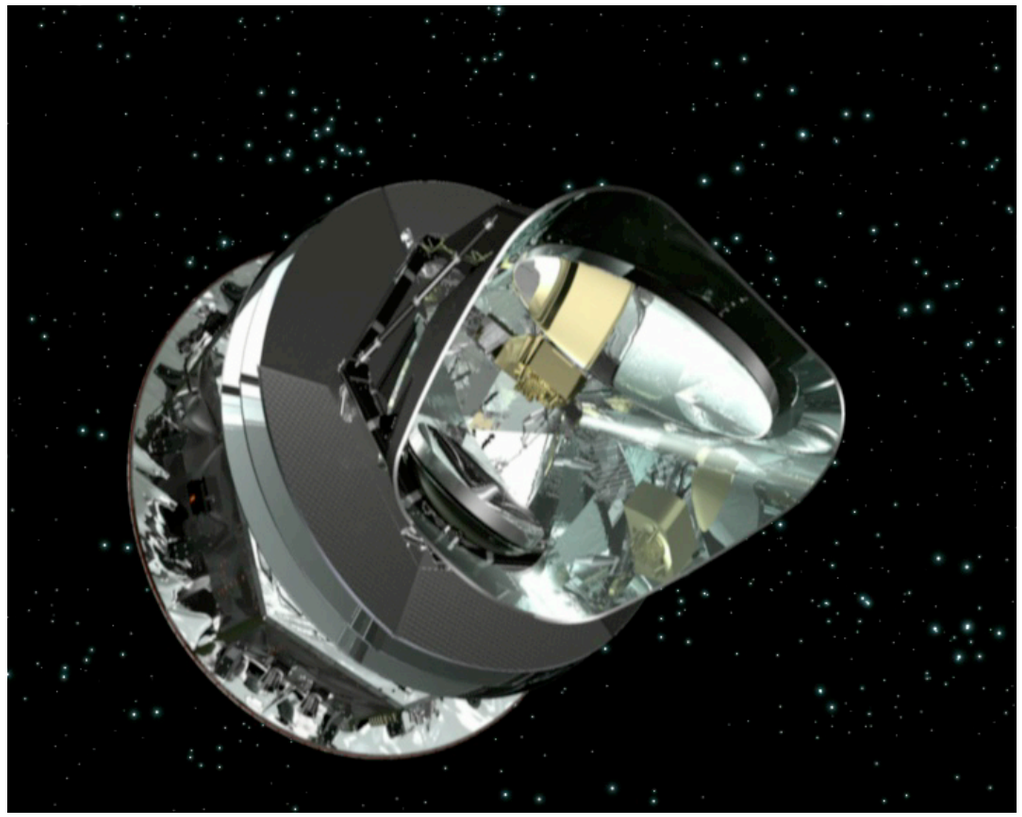
MIMAC



MIMAC is a Large TPC for directional non baryonic Dark Matter detection. This strategy requires both a precise measurement of the energy down to a few keV and 3D reconstruction of tracks down to a few mm.

MIMAC bi-chamber module prototype is working at 50 mbar since June 22nd, 2012 at Modane Underground Laboratory.

Planck, NIKA



Planck is a satellite from the European Space Agency designed to map the whole sky from 30 to 857 GHz with unpreceedented sensitivity and angular resolution.
The scientific operations started the August 13th, 2009. The High frequency instrument (cooled down to 0.1 K) was operating up to January 14th, 2012, the Low frequency instrument (cooled down to 20 K) was operating up to October 3rd, 2013.

NIKA is a camera made of two array of hundreds of KIDs. This instrument is installed at the focal plane of the 30m IRAM dish in Spain. It produces map of very high resolution at 1mm and 2mm.
NIKA2 will consist of 2 cameras of thousands of KIDs.
This technology has been developped also for the after-Planck satellite.

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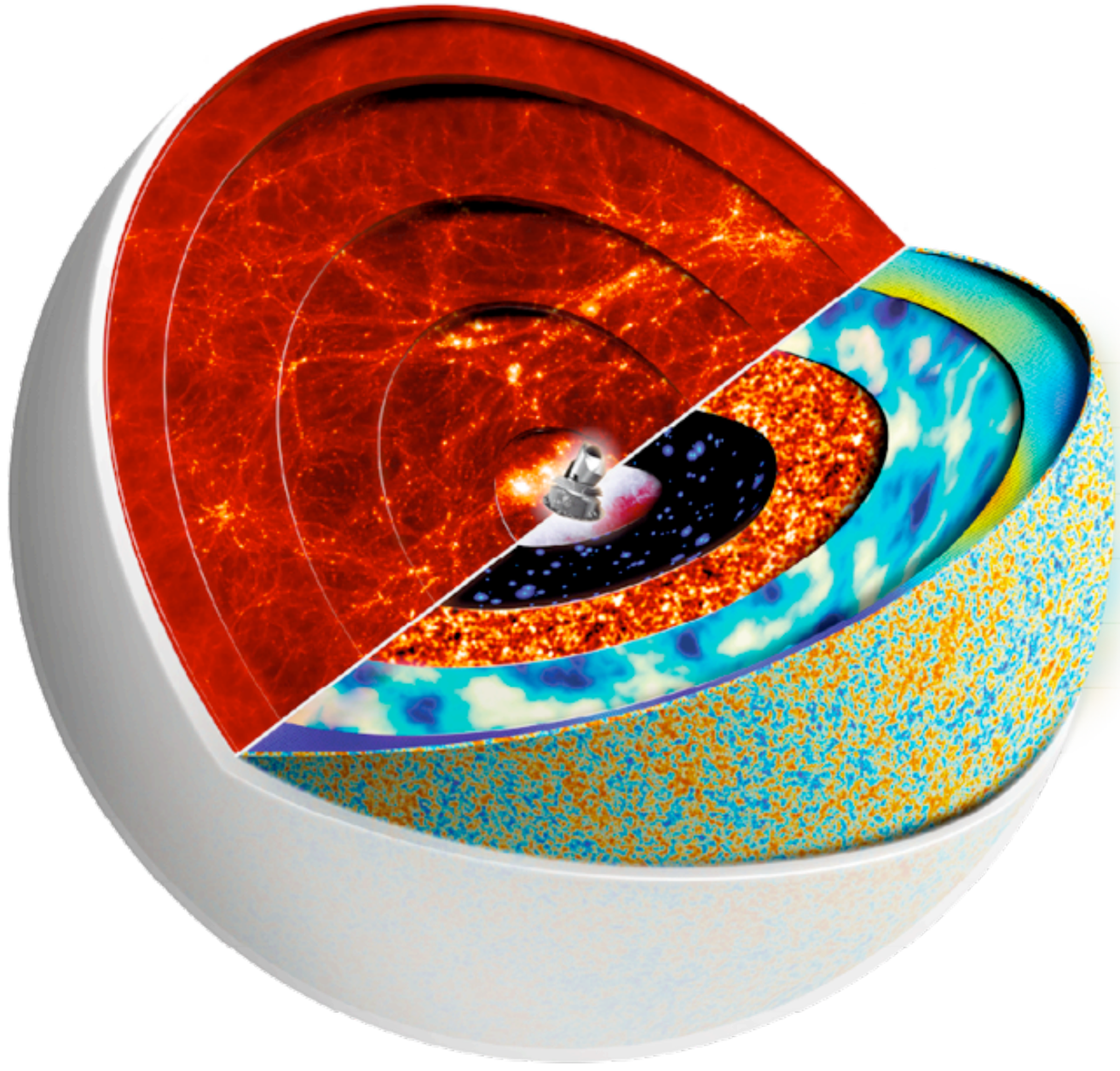
VIRGO

VIRGO is a gravitational wave detector in Italy, which started operating in 2007.
It is a massive Michelson laser interferometer made of two orthogonal arms, each three kilometers long.
Due to the multiple reflections between mirrors located at the extremities of each arm, the effective optical length of each arm is extended up to 100 kilometers.
The gravitational wave frequency range sensitivity of VIRGO extends from 10 Hz to 10 kHz.

Observing the sky

We can just "look" around us.

But we can use light from radio to gamma, particules and gravitationnal waves



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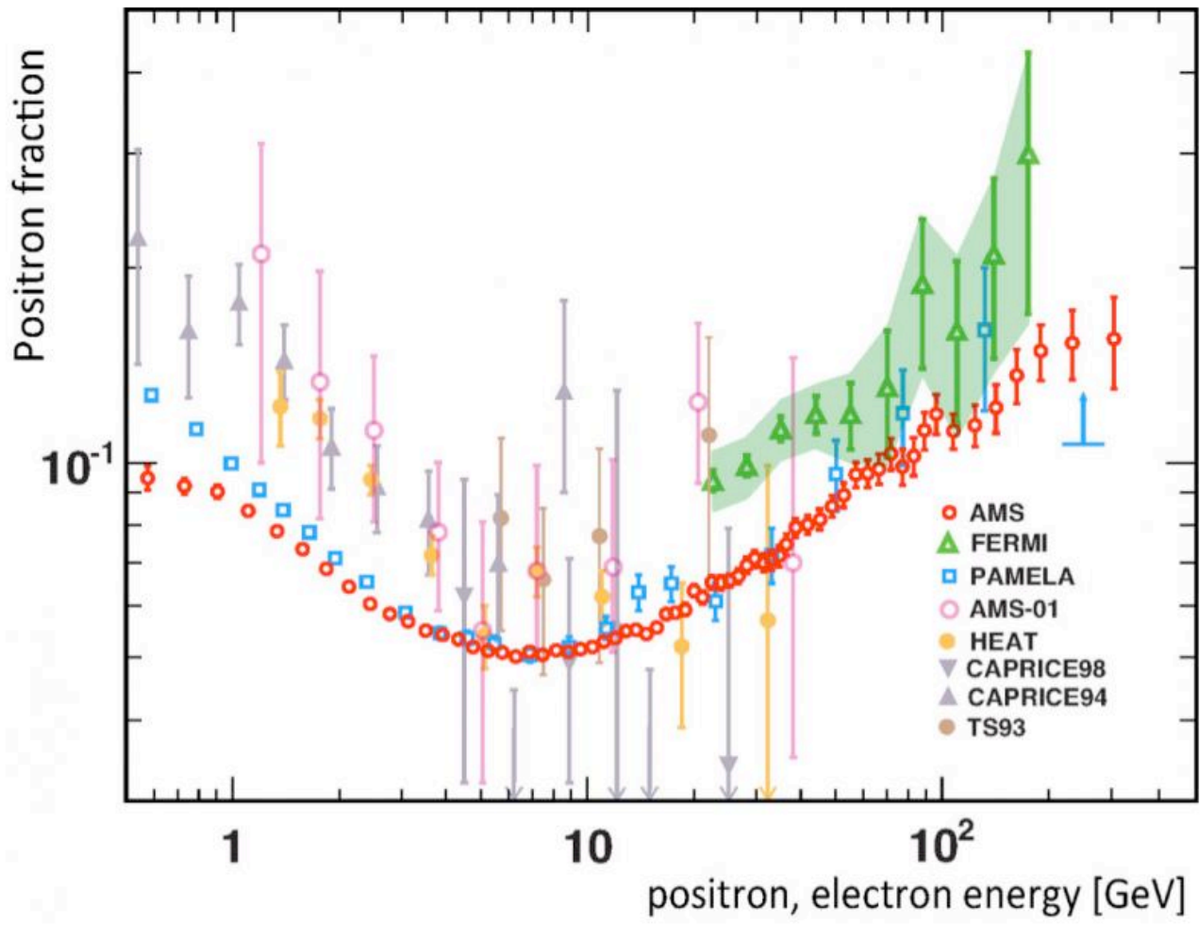
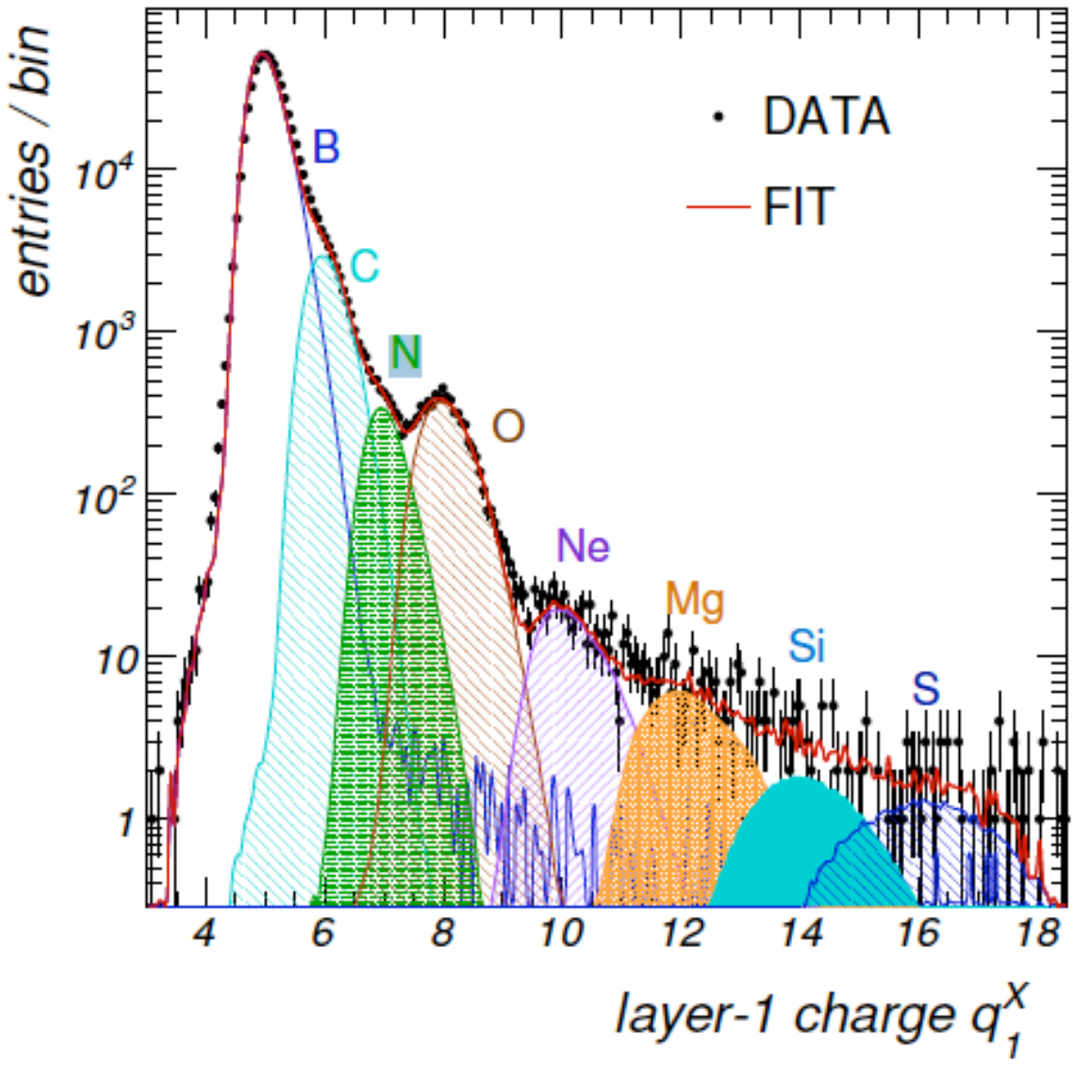
Galatic sky with charged particules

- **AMS & CREAM** (LAPP, LPSC)
- **cosmic rays propagation** (LPAPP, LAPTh, LPSC)
- **origin of the cosmic-rays** (LAPP, LAPTh)



Phys. Rev. Lett. 110, 141102
A comparison of AMS results with recent published measurements. AMS collaboration



ICRC-2013 Nicola Tomassetti
(Enigmass Post-doc)

Galatic sky with charged particules

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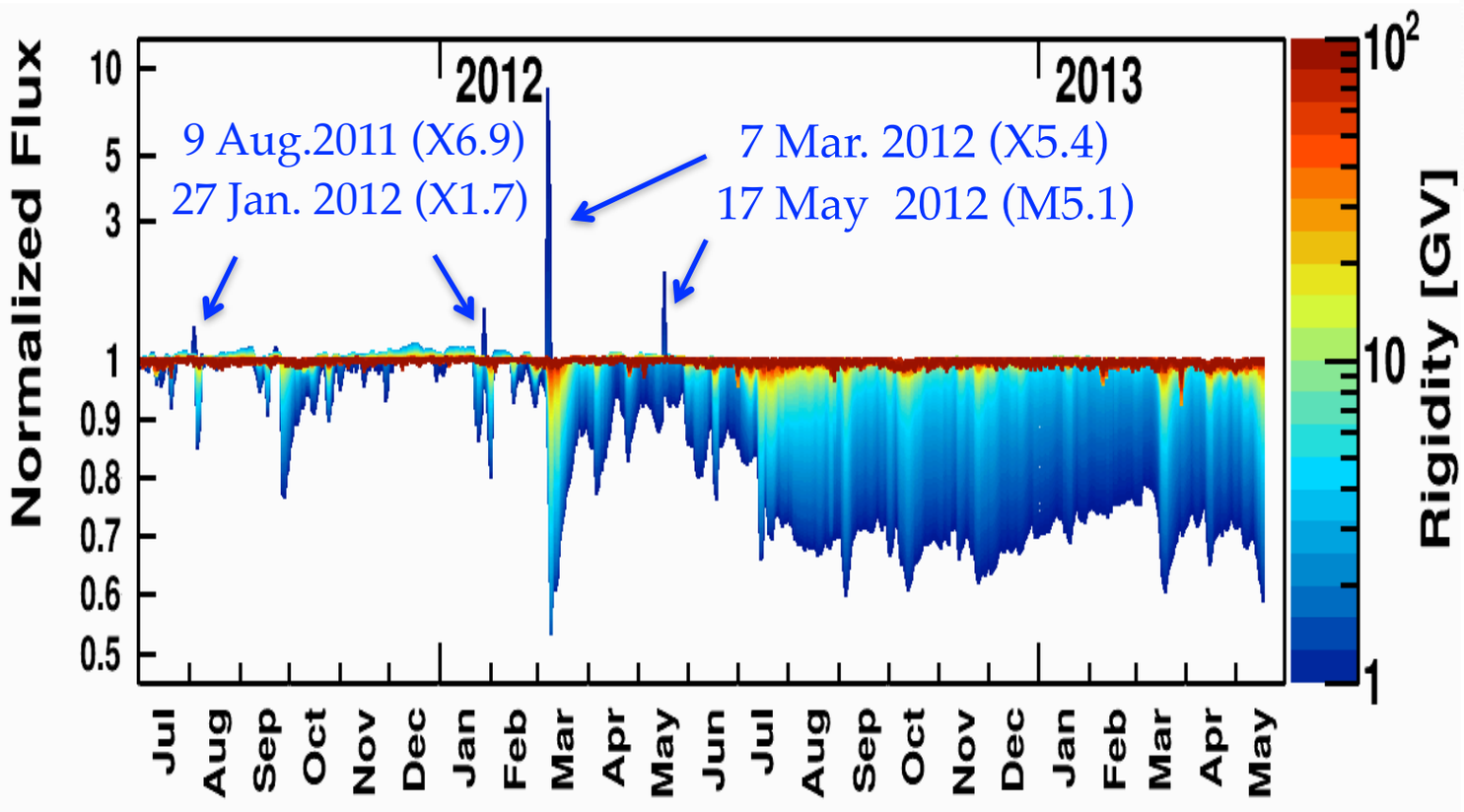
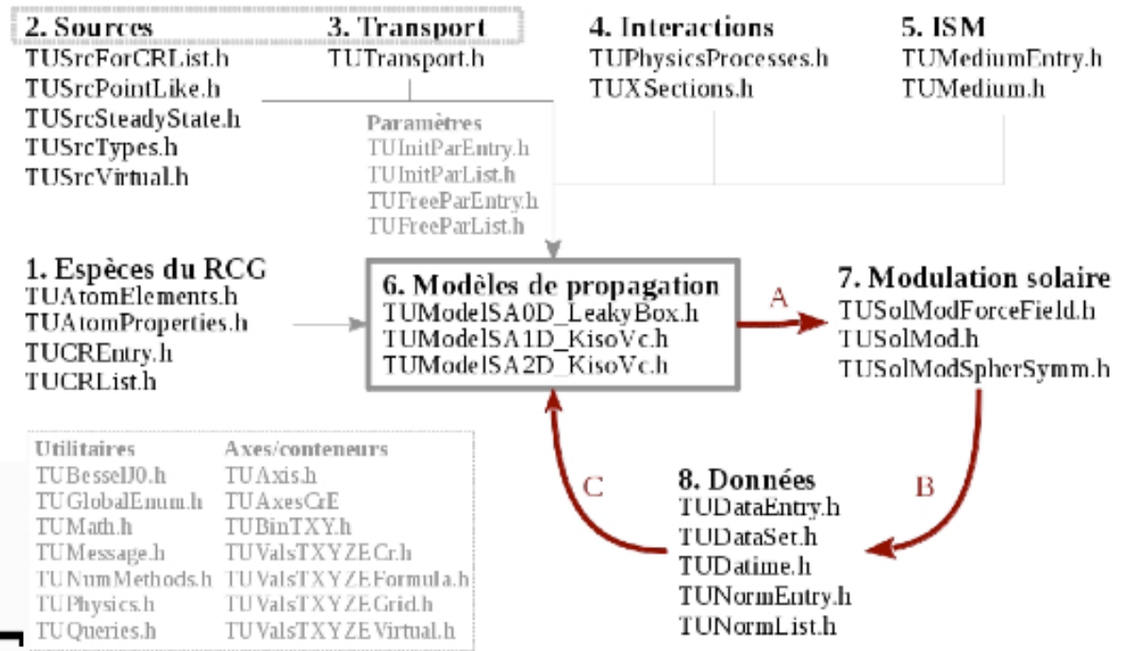


ICRC-2013

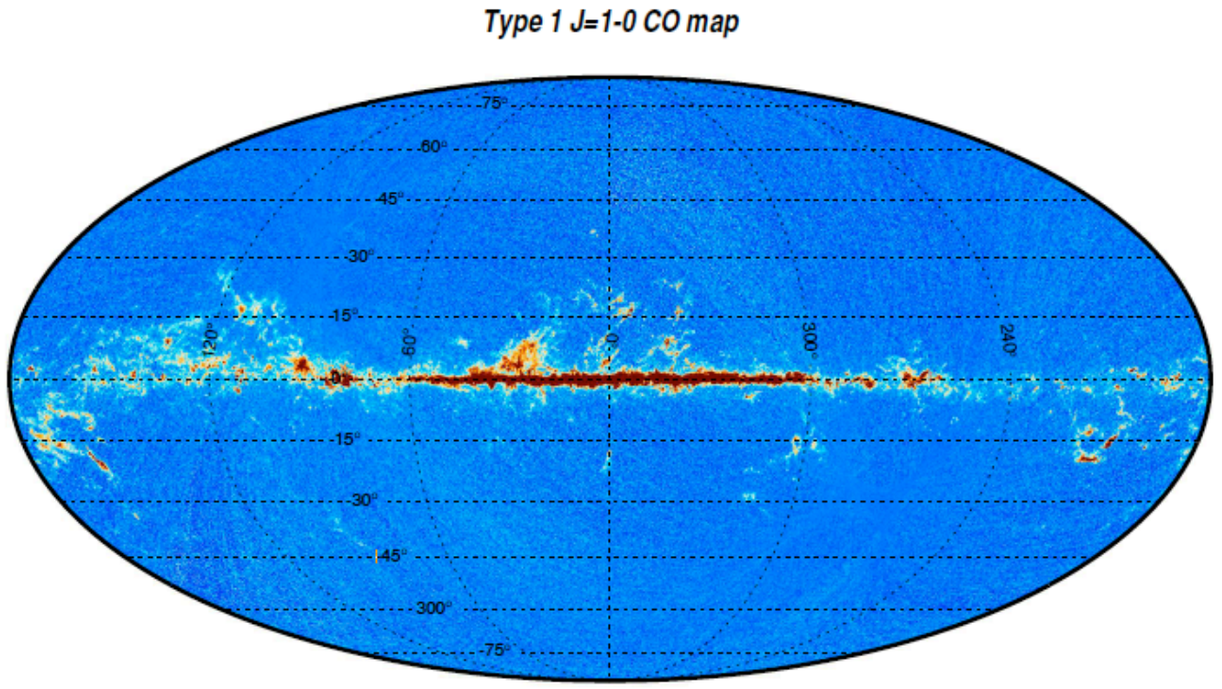
solar flares and solar activity from protons in AMS



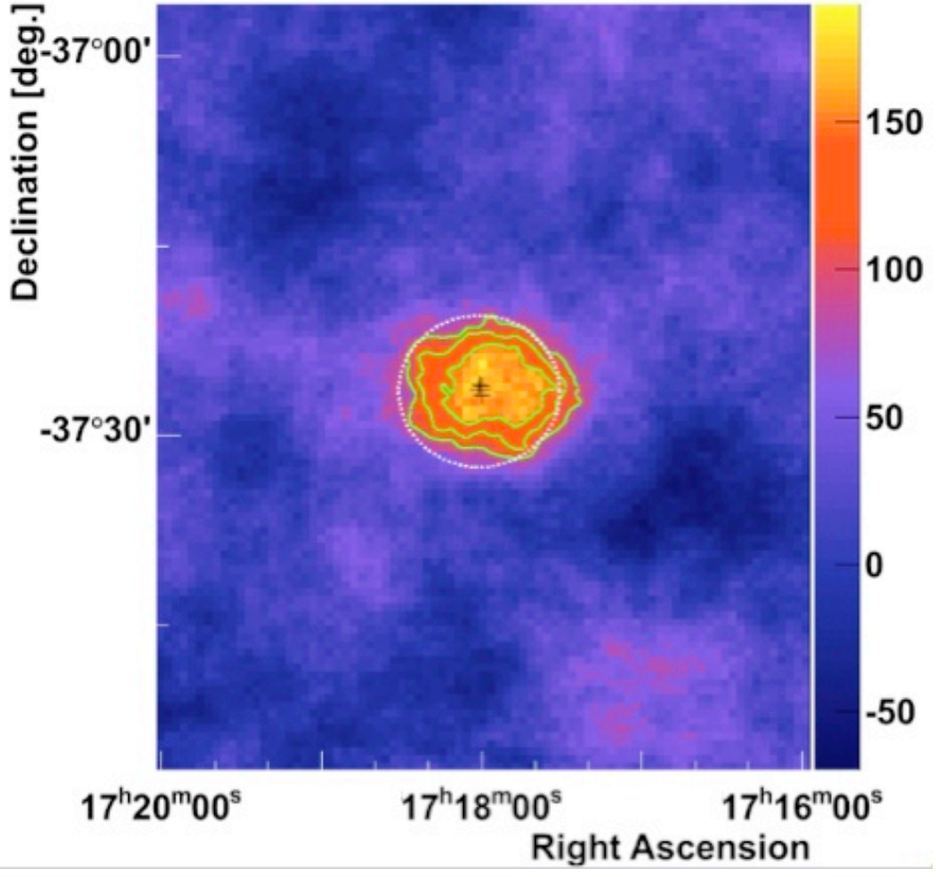
USINE: a package for cosmic-ray propagation studies
LAPP/LAPTh/LPSC

Galatic sky with photons

- **submm photons** with **Planck** (LPSC)
  polarized or CO foregrounds, Galactic magnetic field
- **VHE photons** with **HESS / CTA** (LAPP)
- **origin of the cosmic-rays** (LAPP, LAPTh)



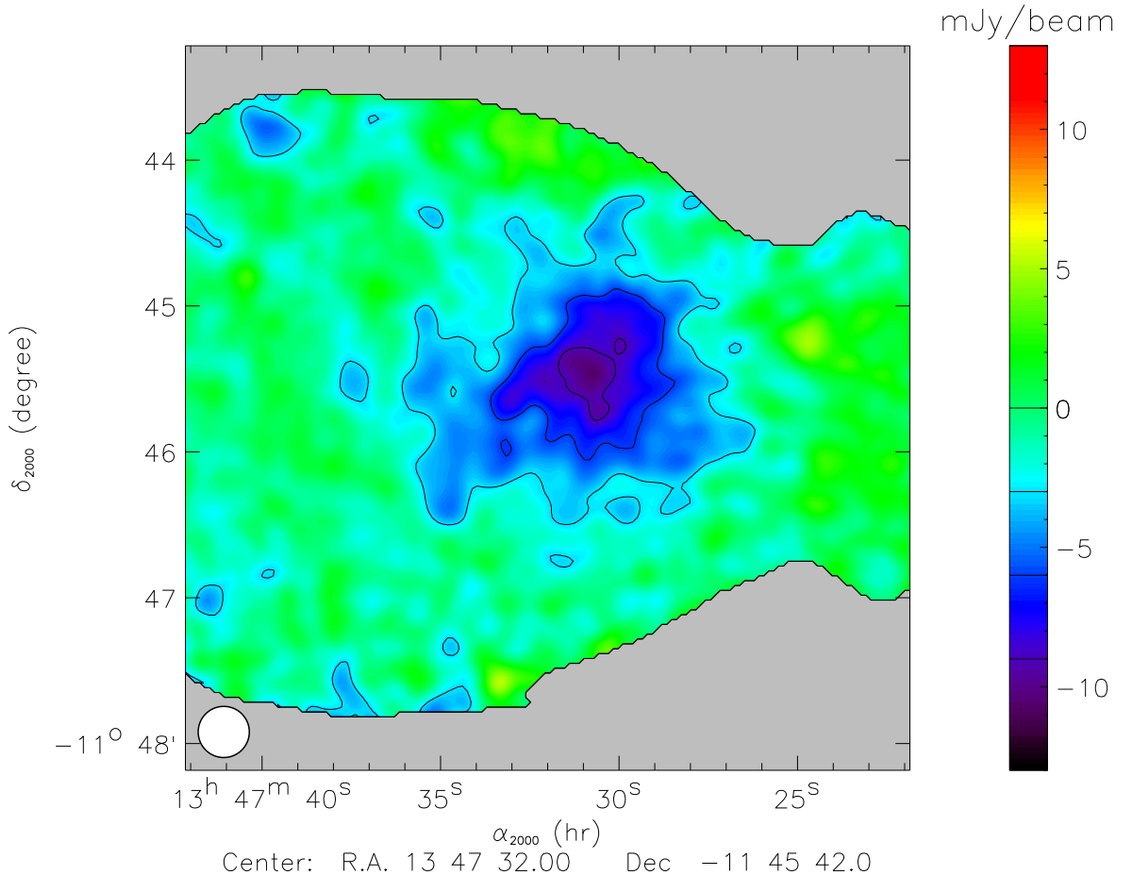
astro-ph 1303.5073
Céline Combet **(Enigmass Post-doc)**



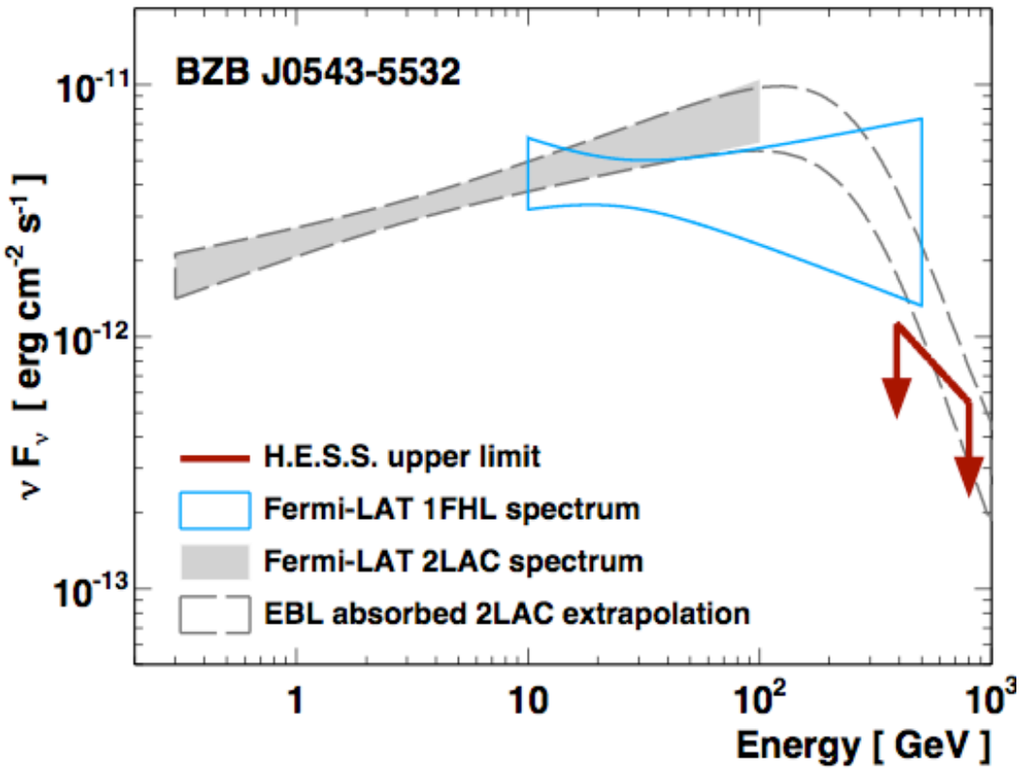
H.E.S.S. very high energy gamma ray image of G349.7+0.2, a young (~2800 years old) and distant (~22 kpc) SNR.

Extragalatic sky with photons

- **submm photons** with **Planck, NIKA** (LPSC)
  galaxy clusters from SZ effect
- **gamma photons** with **HESS** (LAPP) *AGN*
- **diffuse gamma emission** (LAPP, LAPTh)



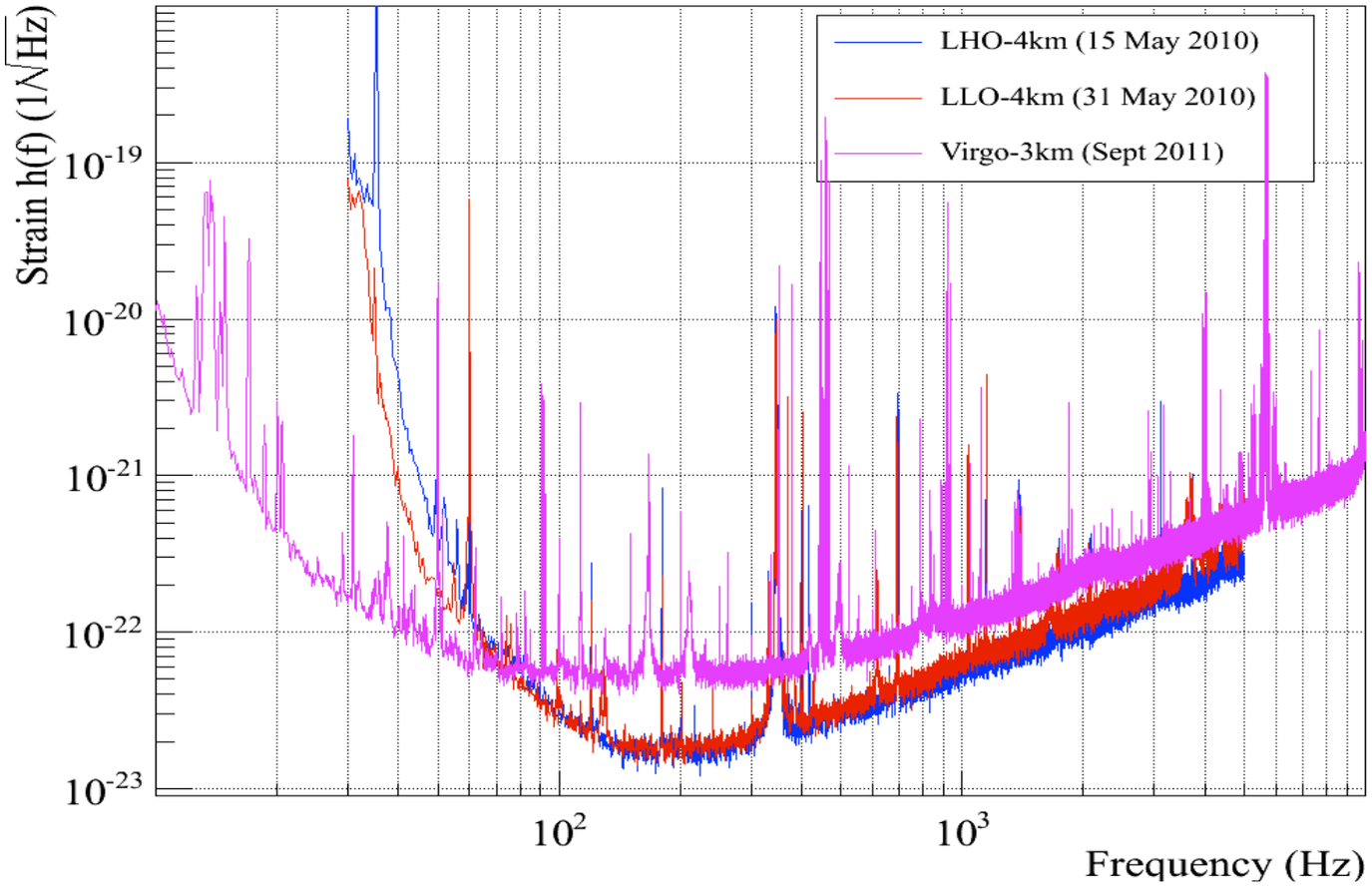
astro-ph 1310.6237
NIKA map of RX J1347.5-1145 at 140 GHz
Remi Adam **(Enigmass PhD student)**



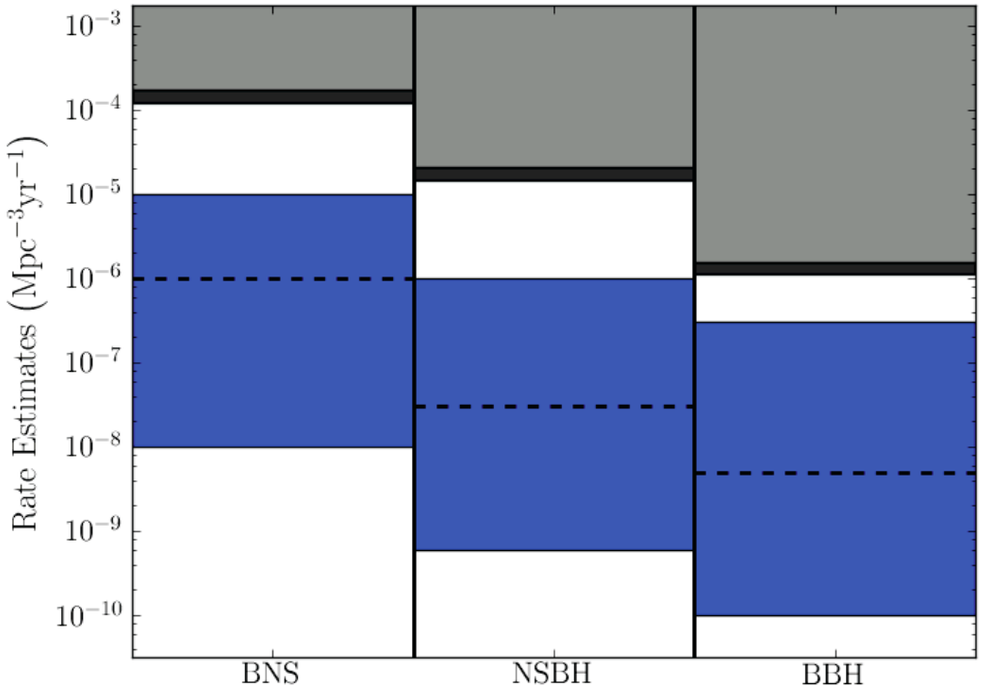
astro-ph 1402.2332
HE γ-ray spectrum, VHE upper limit and
EBL extrapolation (z~ 0.3)
David Sanchez **(Enigmass Post-doc)**

Whole sky with gravitationnal waves

- **VIRGO** (LAPP)



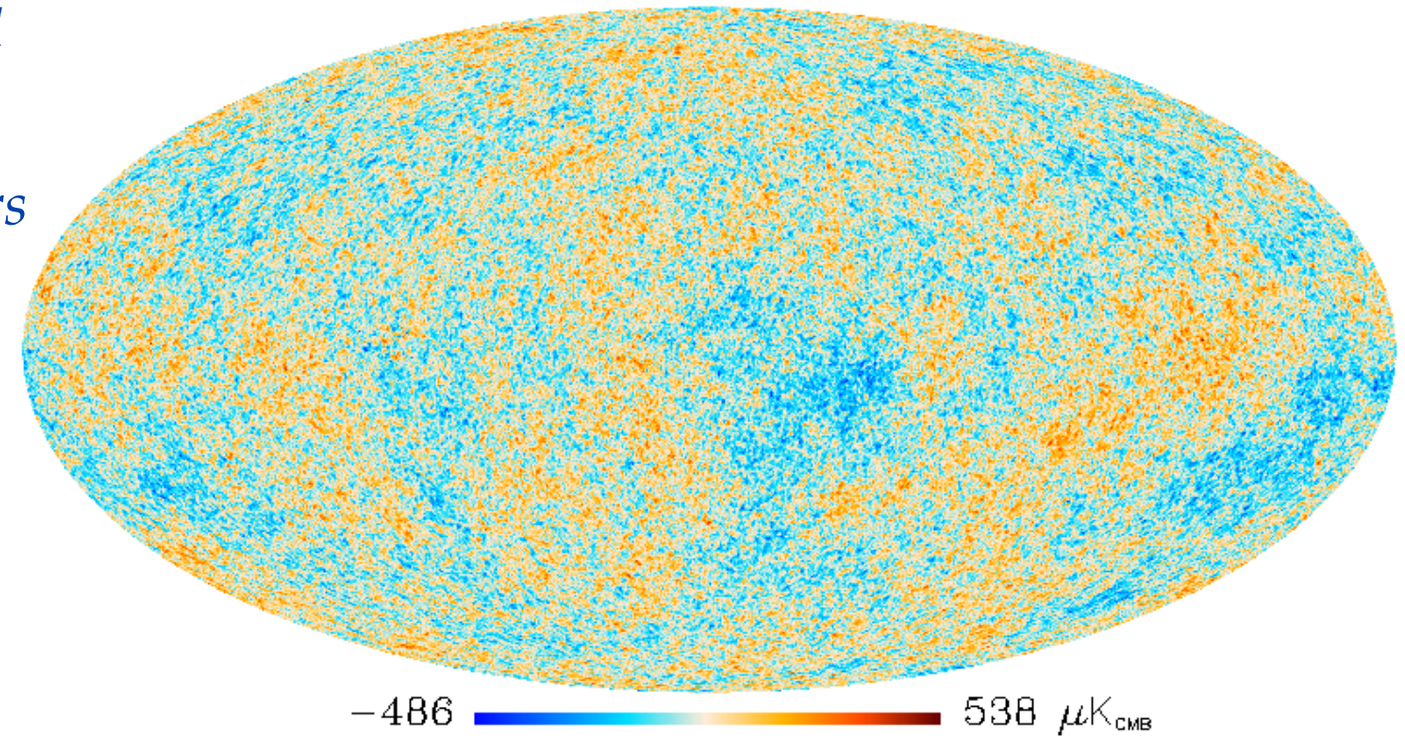
Comparison of **LIGO** & **VIRGO** sensitivities
VSR4 results VIRGO collaboration
Nominal sensitivities achieved



The cumulative 90%-confidence rate upper limits of the binary coalescence of binary neutron star, neutron star-black hole.

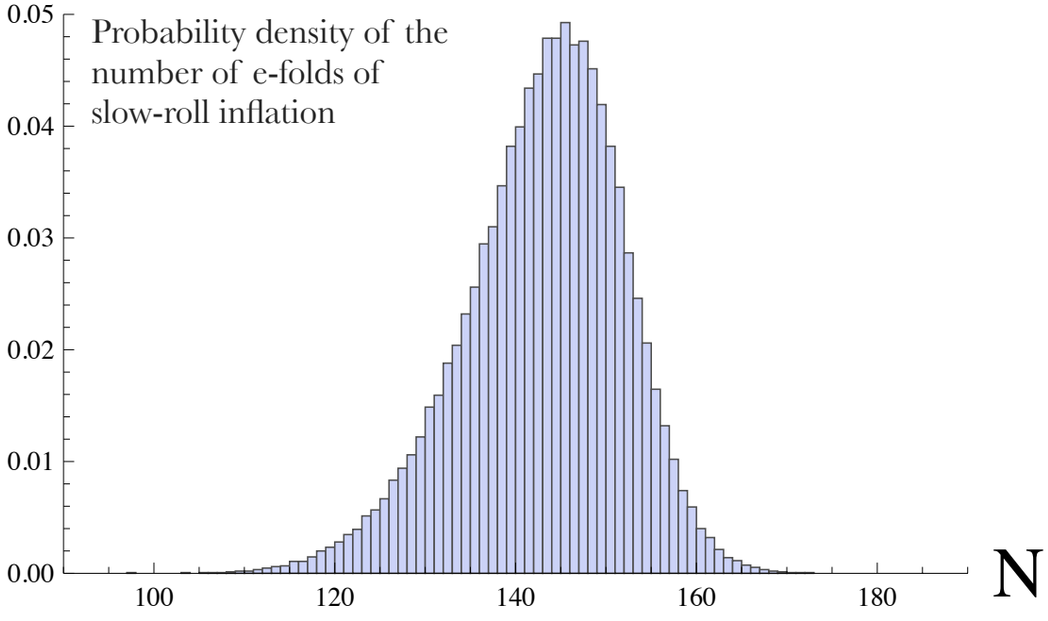
The Universe as a whole

- **Planck** (LPSC, LAPTh) *cosmological parameters from CMB anisotropies*
- **LSST** (LPSC) *cosmological parameters from BAO*
- **primordial fluctations** (LAPTh / LPSC) *inflation, public code CLASS*
- **loop quantum cosmology** (LPSC)



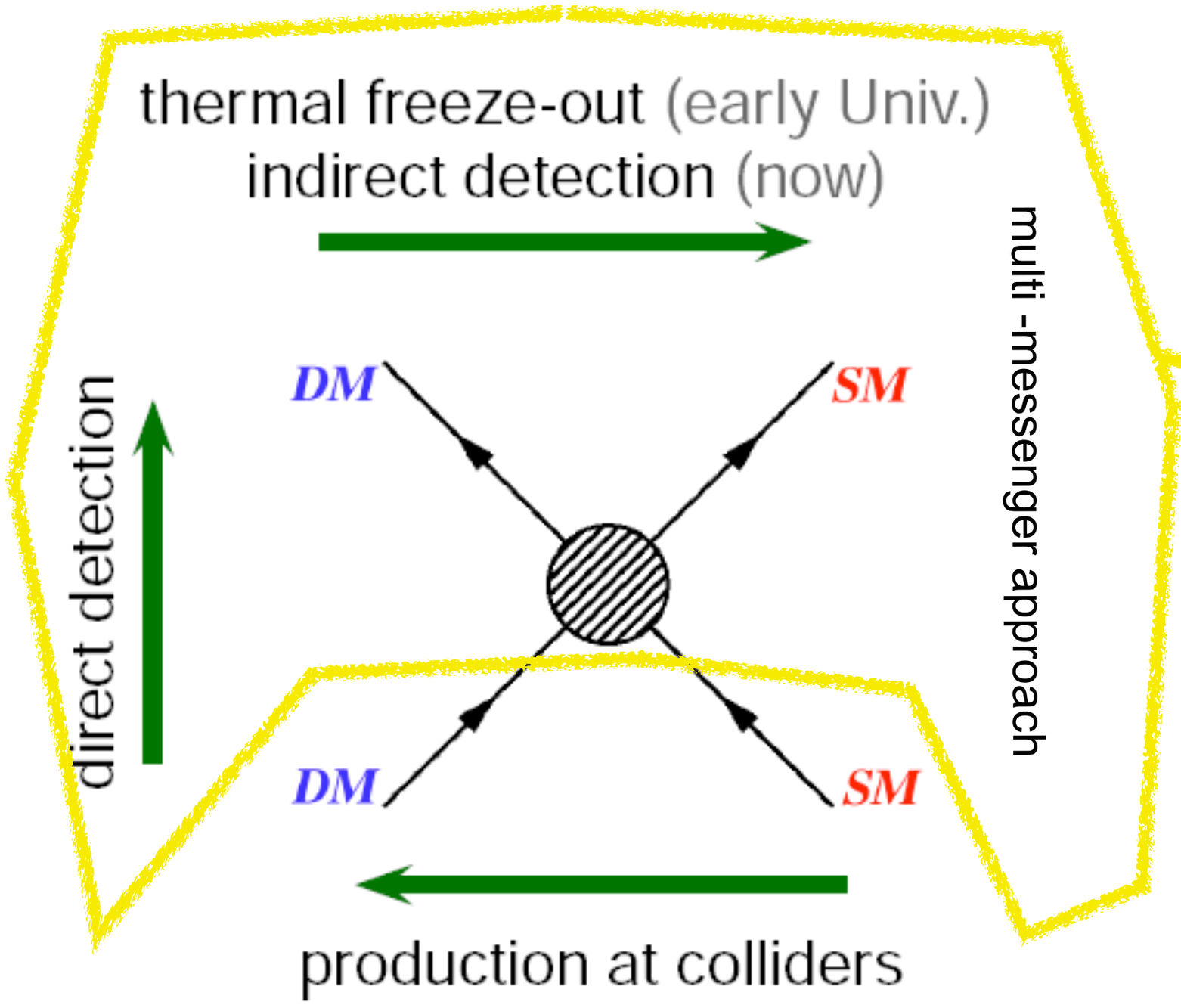
astro-ph 1303.5076
data analysis, lensing (LPSC)
cosmological parameters (LAPTh)
cited by 1949 papers (14/06/17)

pdf

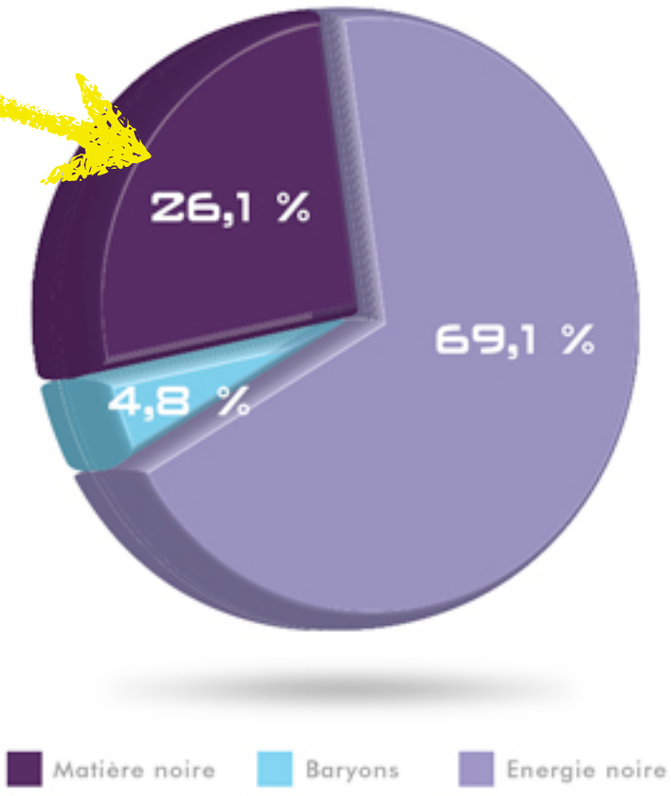


astro-ph 1301.1264
Linda Linsefors (**Enigmass PhD student**)

Dark matter

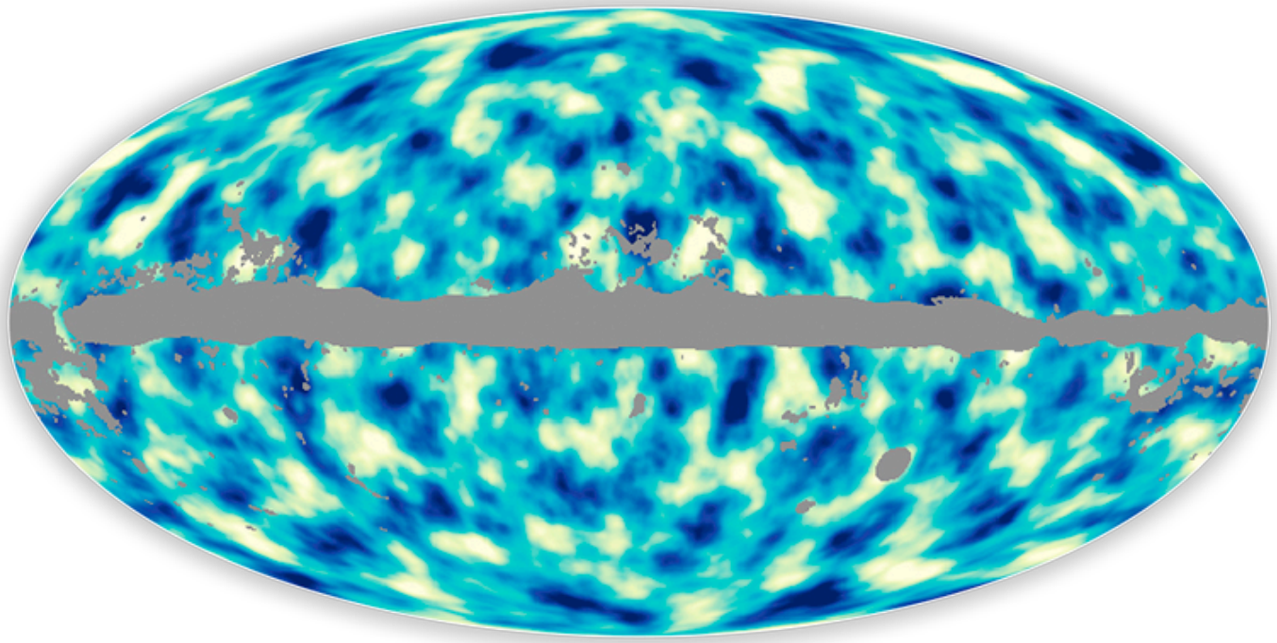


All Enigmass experiments have something to say about the puzzeling DM problem.

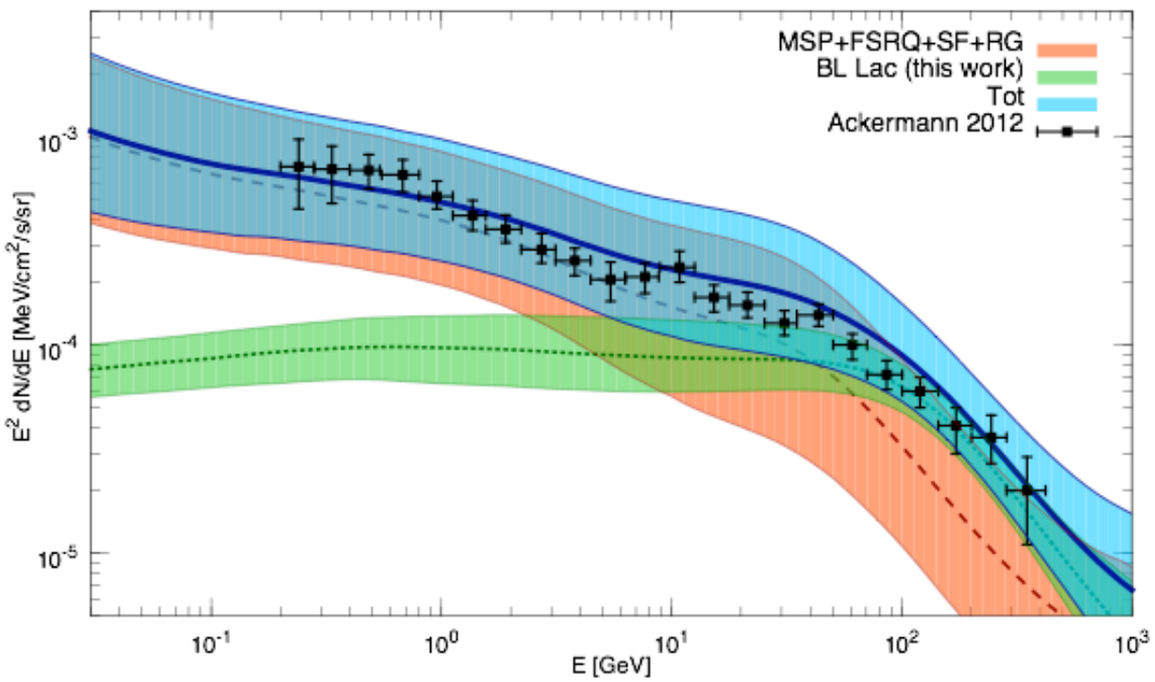


Dark matter: where is it ?

- **lensing + Ω_CDM** with **Planck** (LPSC / LAPth)
- **clusters of galaxies** with **NIKA** (LPSC)
- **indirect detection with charged particles** with **AMS** (LAPP/LPSC)
- **gamma and cosmic-rays background understanding (LAPP/LAPTh/LPSC)**



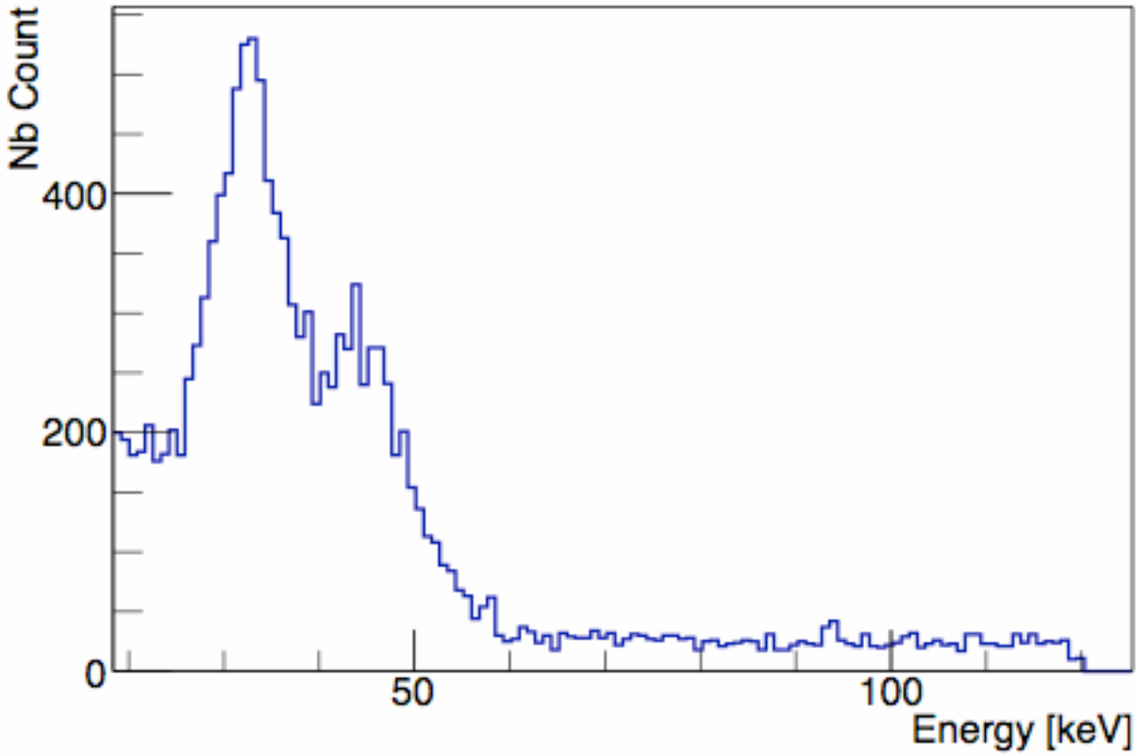
astro-ph 1303.5077
Integrated measure of the mass distribution back to the CMB last-scattering surface



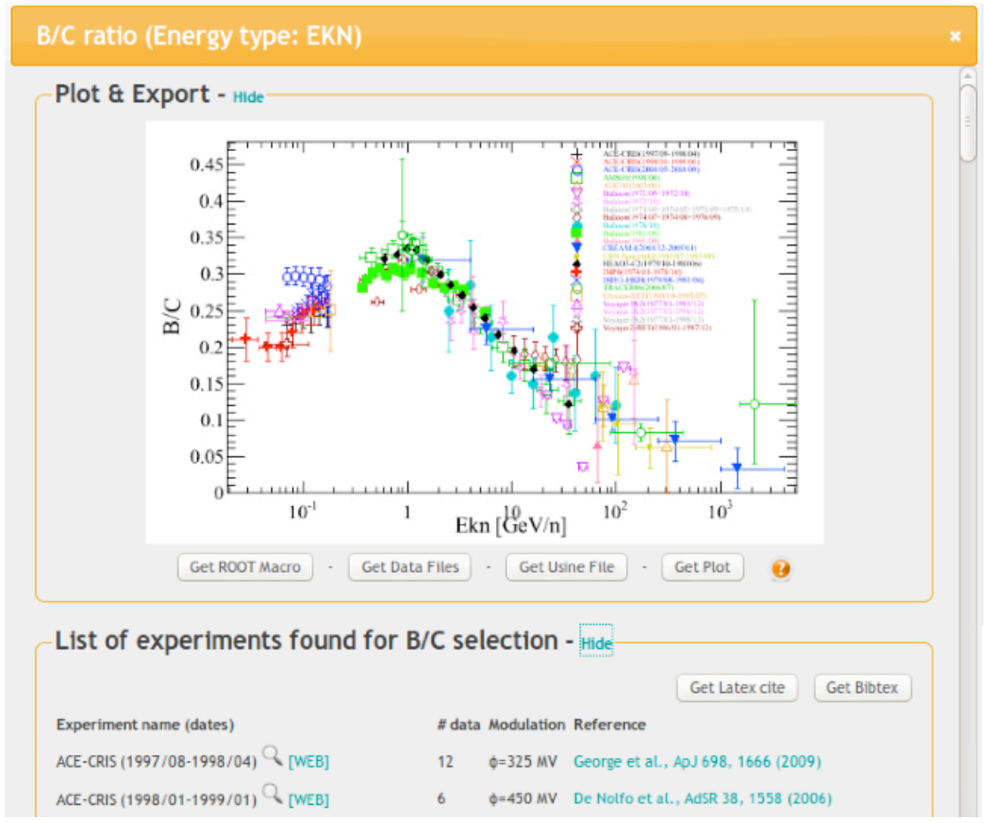
astro-ph 1311.5708
global view of the diffuse γ-ray predictions
(best fit models and relevant uncertainty band)
David Sanchez **(Enigmass Post-doc)**

Dark matter: what is it ?

- **direct detection** with **MIMAC** (LPSC / LSM)
- **indirect detection with photons** with **HESS / CTA** (LAPP)
- **indirect detection with charged particles** with **AMS** (LAPP/LPSC)
- **links with particle physics**



astro-ph 1311.0616
MIMAC prototype @ LSM
1 CDD ingeneer Enigmass



database of charged cosmic-rays (LAPTh, LPSC)

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Calendar

- Planck: up to 2015
- MIMAC proto: up to 1m^3
- NIKA2: proprietary period up to 2020
- AMS: up to ~2018 (for DM)
- HESS: up to CTA

scheduled end

- ISSCream: on ISS in 2015
- advVIRGO: starts in 2015
- LSST: first light in 2020/22
- CTA: first light in 2020

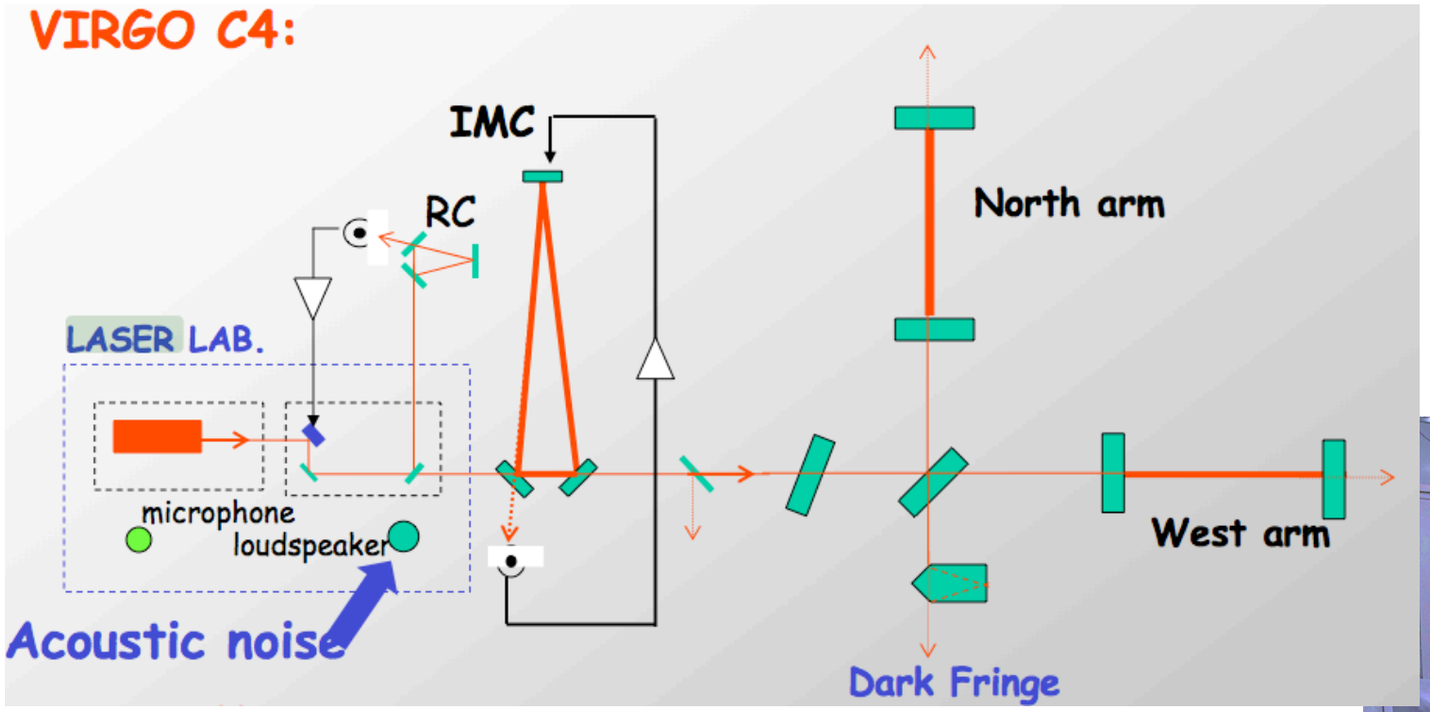
scheduled start

?
- MIMAC 1m^3 could start in 2016 (if ANR in 2014 to build it)
- Planck successor (M4, launch in ~2025, answer to the call in progress)

The future in progress

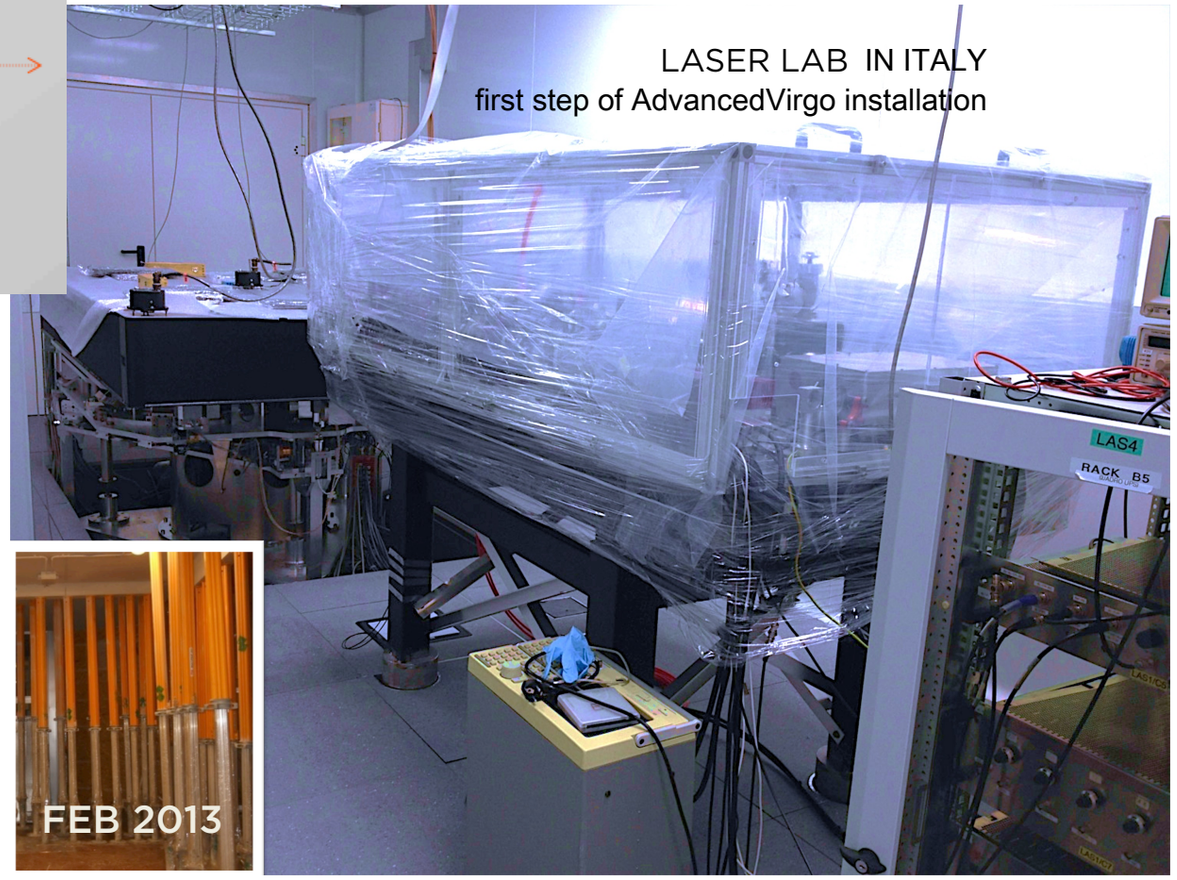
The NIKA2 cryostat
has arrived in February.
Now working.

The future in progress



2014/2015:
very important years

End of the construction + installation



Current collaborations

- AMS
  - **Meetings each month between LPSC and LAPP teams.**
  - **Invited researcher Fernando Barrao working in both places**
  - **Teams work together for the analysis in CCIN2P3. Not exactly same analysis but really strong interactions.**
- MIMAC
  - **First prototype mainly made by LPSC installed in LSM since June of 2012, improved bi-chamber prototype installed last autumn.**
  - **If calendars (and funding) match, MIMAC 1m3 in the LSM extansion**
- Planck
  - **"Historical" links between some LAPTh/LPSC people**
  - **Common work in progress with CLASS/CLIK public codes**

Current collaborations

- Phenomenology on cosmic-rays propagation
  - **"Historical" links between some LAPTh/LPSC people**
  - **Common works to be continued (USINE public code, database ...)**
- Phenomenology on dark matter
  - **Public code CLUMPY available (compute gamma signal from DM**
  - **annhilation). Useful for CTA as well as for theoreticians**
  - **Combining astro/cosmo constraints with LHC constraints on Higgs,**
  - **SUSY (ANR project DMAstroLHC)**
  - **probably not exhaustive list !**

New collaborations ?

- **LSST** Potential interest from LAPP (+LAPTh ?) people to be confirmed

  ➢ 1 day mini-colloquium on cosmology + discussion in Annecy: **tomorrow**

  Significant advantage to appear as "Alpes" labs in the LSST collaboration as LPSC+IPAG+Neel were "Grenoble" labs in Planck: efficient way to really exist beside IdF labs...

- **Phenomelogy of quantum gravity** LPSC /LAPP/LAPTh: from CMB to gamma through quantum gravity. Might be a post-doc proposal in 2014.

- Use of the **NIKA2** camera to participate to the follow-up of binary seen by **VIRGO** (calendars reasonnably match, contacts established, NIKA should answer to the next call.)