

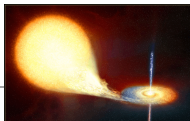
AstroParticle(s) & Observational Cosmology

Presentation

Thierry Pradier

[pradier@in2p3.fr]

Université de Strasbourg & IPHC/DRS (IN2P3)

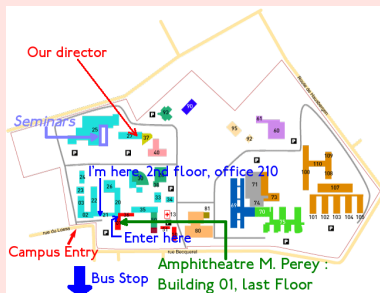


Some informations...

Lectures site

<https://sites.google.com/site/astrom2psa/>

Where to find me



- Or elsewhere, see the agenda on my page
 - <http://physiquepourtous.unistra.fr/thierrypradier>

An important bias...

...the lecturer !

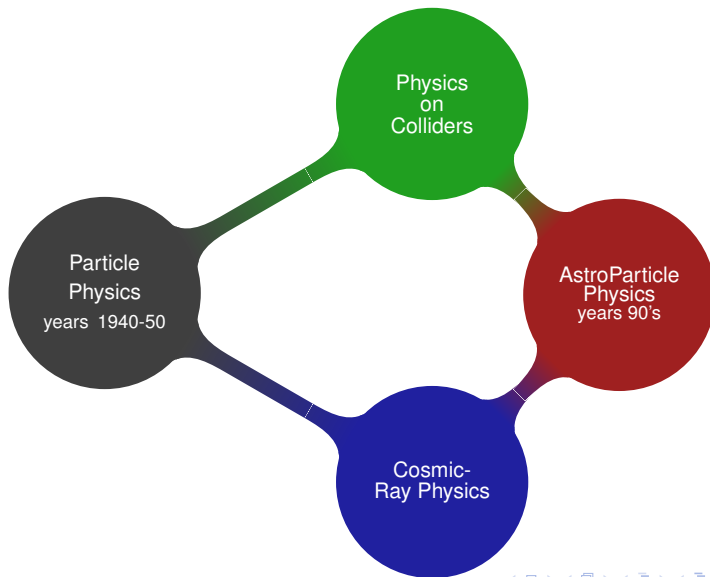
- Before PhD :
 - *Survey* IR with satellite ISO (ultra-luminous galaxies)
 - **Detection of Dark Matter** (EROS, gravitational lensing)
 - **Cosmic Rays UHE** (Auger)
 - **TeV Gamma-Ray Astronomy** (Celeste)
- PhD Thesis : **Gravitational Waves** (Virgo)
- After PhD : (High Energy) Neutrino Telescopes
 - ↪ **Antares** (ν at TeV) : coincidences **Antares/Virgo/Ligo**
Search for ν from Black Hole mergers (GW150914, LIGO)
Search for ν for Neutron Star Binary (GW170817, LIGO-Virgo)
 - ↪ **KM3NeT** : ν at GeV → PeV - Astronomy/physics
 - ↪ Since 08/2019 also in **Virgo** : **Gravitational Astronomy**
- ⇒ **Multi-Messenger Astronomy**
- ⇒ **More Cosmic messenger-related than Cosmologist**

A double-meaning definition

« AstroParticle Physics » $\Rightarrow$ AstroParticle(s) ambiguous in French !

- 1- Cosmic messengers, from astrophysical sources
- 2- Interface between Particle Physics and Astrophysics/Cosmology

A double-meaning definition



A double-meaning definition

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-1- Cosmic messengers, from astrophysical sources

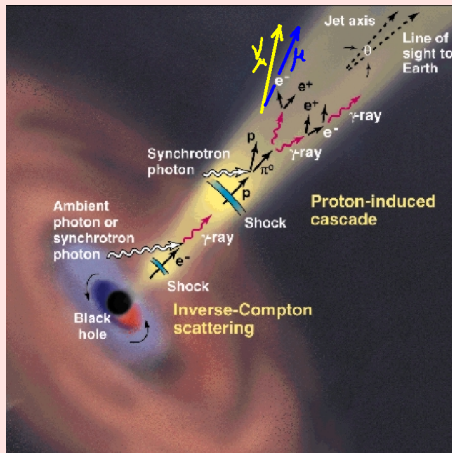
- Photons at GeV - TeV (non-astrophysical techniques) : HESS, CTA
- Cosmic Rays charged or not : protons, nuclei etc, GeV - ZeV : AUGER
- Neutrinos from MeV to PeV : SuperK, Borexino, ANTARES, IceCube
- Gravitational Waves : Virgo/LIGO

- $\Rightarrow$ Theory : Sources models, process of accréton, ejection, process of acceleration
- $\Rightarrow$ Exp. : Definition/construction of detectors, signal processing/detection, data analysis
- $\Rightarrow$ Analysis/Pheno : Constraints on source models

$\Rightarrow$ Particle Physics detection techniques

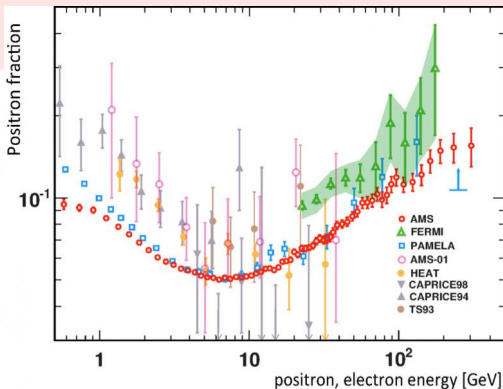
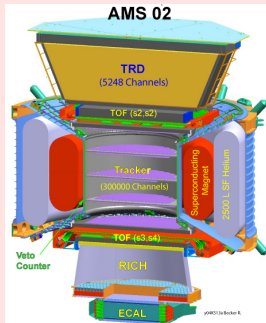
High Energies : Sources

Compact astrophysical sources

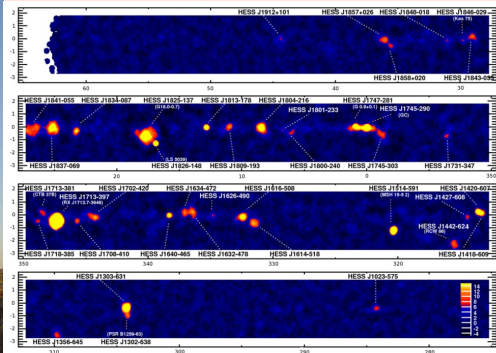
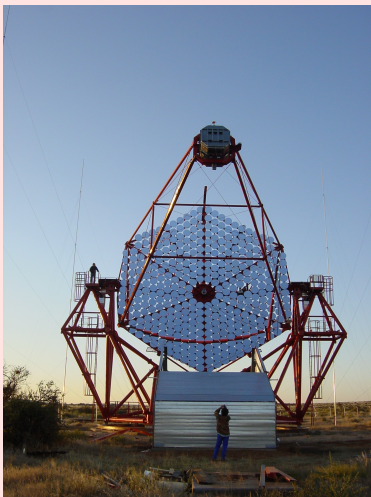


High Energies : Detection Techniques

Particle Physics techniques : AMS

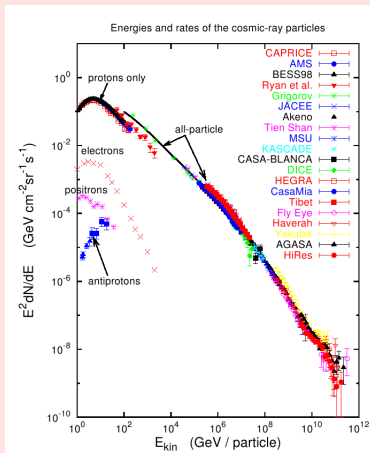


Particle Physics techniques : HESS



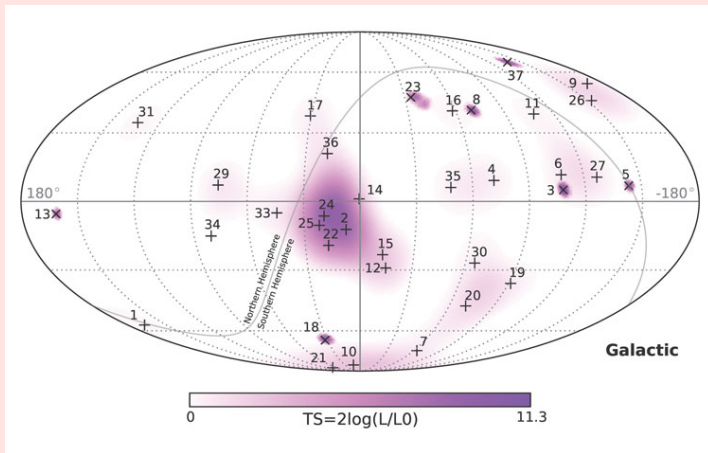
High Energies : Detection Techniques

Particle Physics techniques : RC au sol



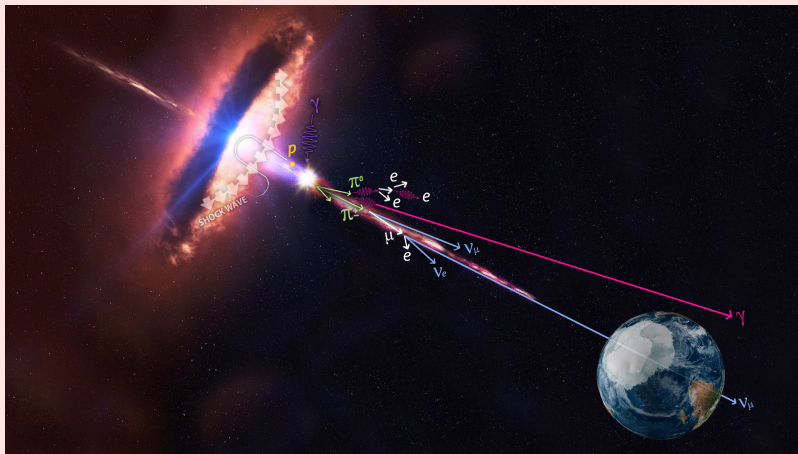
High Energies : Detection Techniques

Particle Physics techniques : IceCube ($\nu > 30$ TeV)



High Energies : Detection Techniques

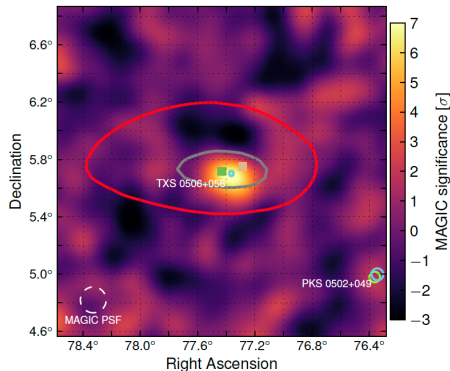
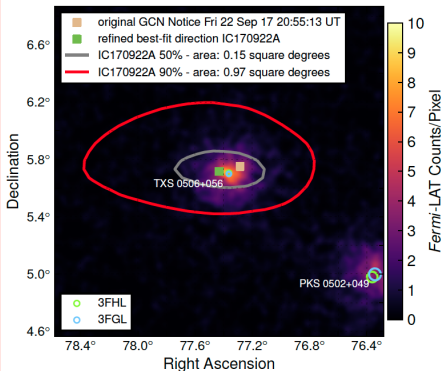
Particle Physics techniques : IceCube ($\nu > 30$ TeV)



Multi-Messenger Astronomy !

High Energies : Detection Techniques

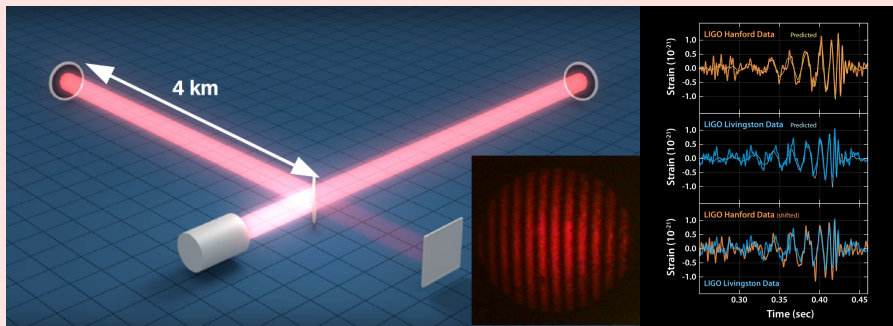
Particle Physics techniques : IceCube ($\nu > 30$ TeV)



Multi-Messenger Astronomy !

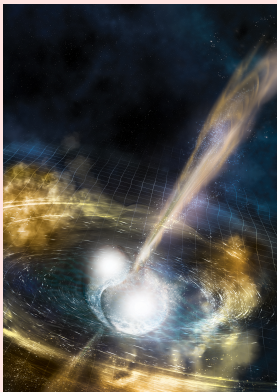
High Energies : Detection Techniques

Particle Physics techniques : Virgo/LIGO (Grav. Waves)



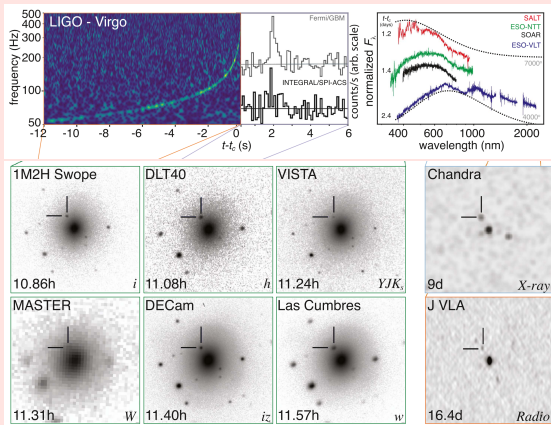
High Energies : Detection Techniques

Particle Physics techniques : Virgo/LIGO (Grav. Waves)



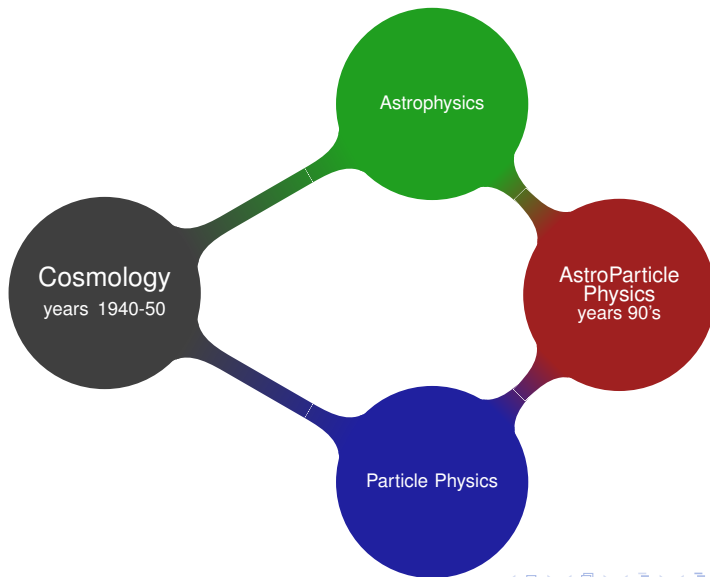
High Energies : Detection Techniques

Particle Physics techniques : Virgo/LIGO (Grav. Waves)



Multi-Messenger Astronomy !

A double-meaning definition : cosmology



A double-meaning definition : cosmology

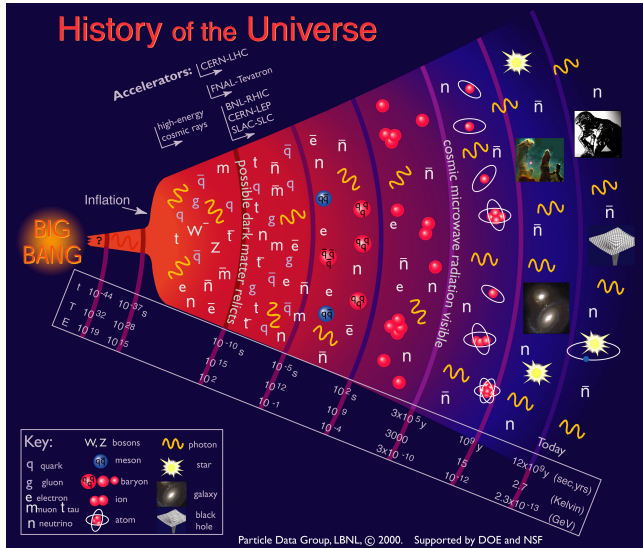
« AstroParticle Physics » more accurate ! $\Rightarrow$ AstroParticle(s)

-2- Interface Particle Physics / AstroPhysics+Cosmology

- **History and content** (matter, energy) of the Universe
 - $\Rightarrow$ **History** : Big-Bang, Inflation, Matter-AntiMatter asymmetry, formation of structures...
 - $\Rightarrow$ **Content** : **Dark Matter, Dark Energy**...
- $\Rightarrow$ **Theory** : **Models of Universe, nature of Dark Matter, Dark Energy**
- $\Rightarrow$ **Exp.** : **Definition/construction** of detectors, signal processing/detection, data analysis
- $\Rightarrow$ **Analysis/Pheno** : **Constraints** on models

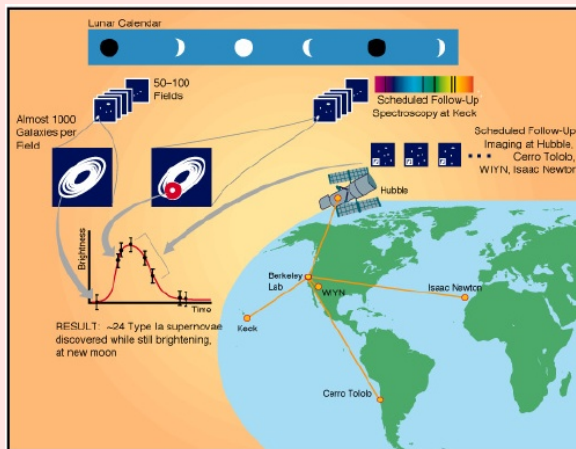
$\Rightarrow$ **Astrophysical detection techniques**

A double-meaning definition : cosmology



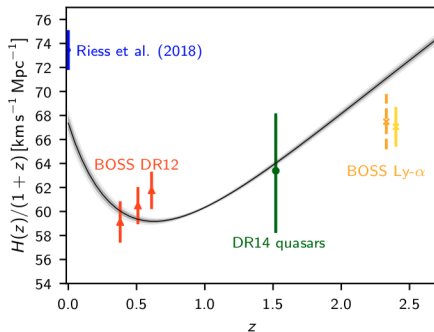
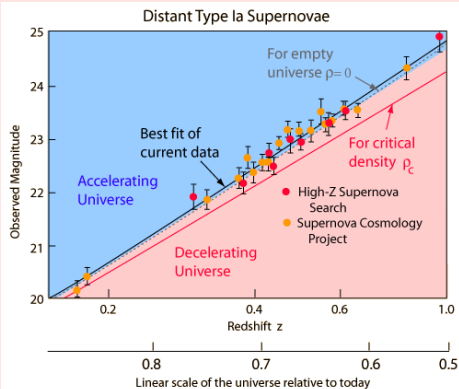
A double-meaning definition : cosmology

Methods : Astrophysics from ground/space



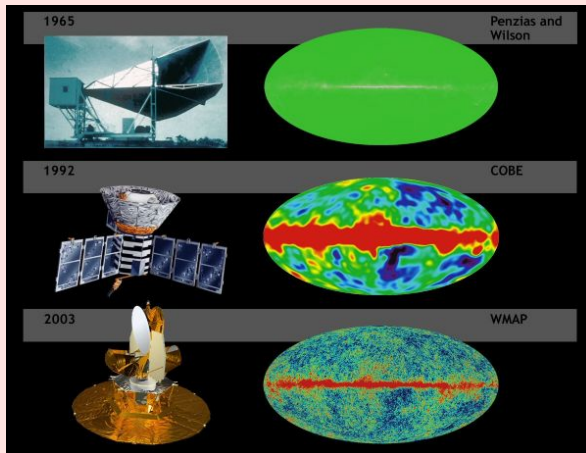
A double-meaning definition : cosmology

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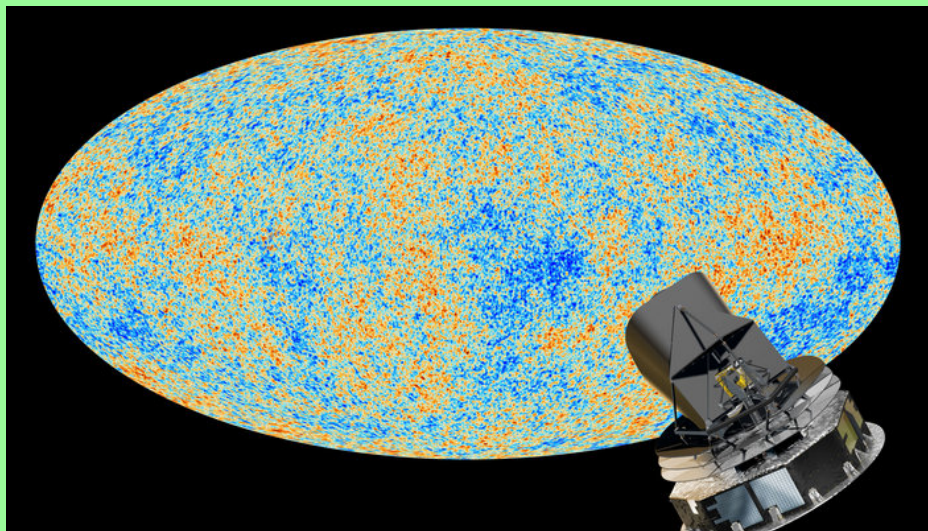
A double-meaning definition : cosmology

Methods : Astrophysics from ground/space



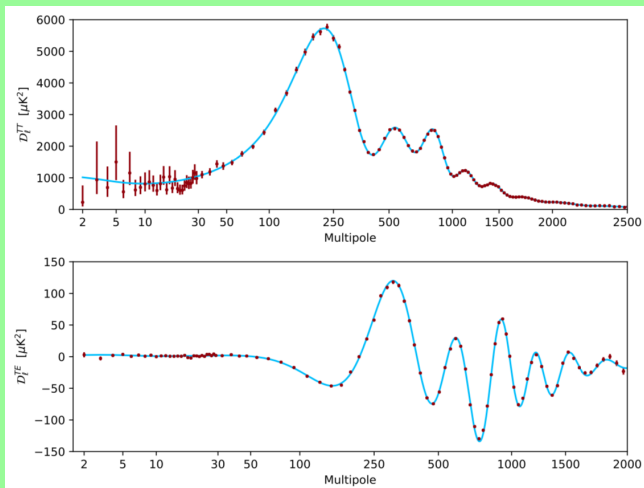
A double-meaning definition : cosmology

Planck Results



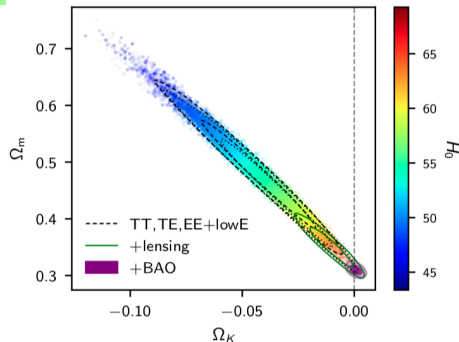
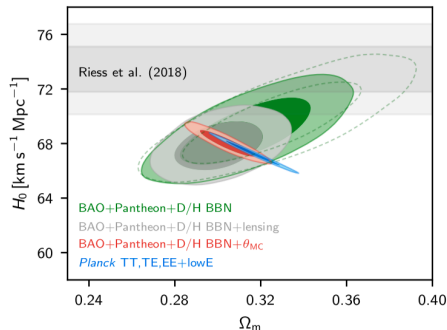
A double-meaning definition : cosmology

Planck Results - 2018 !



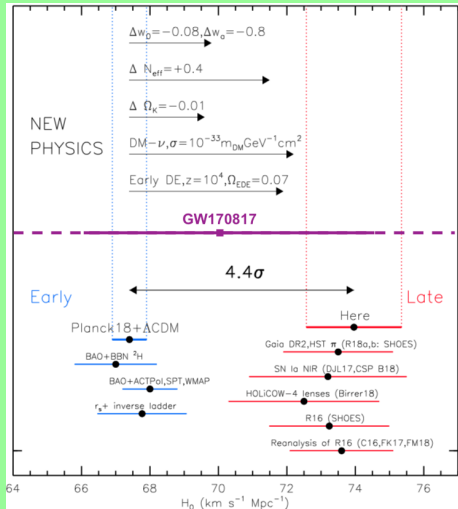
A double-meaning definition : cosmology

Planck Results - 2018 !



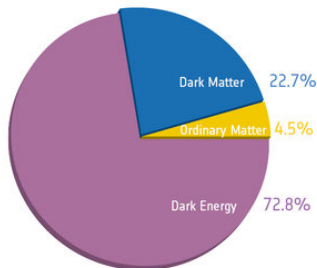
A double-meaning definition : cosmology

A problem with Hubble Constant ?

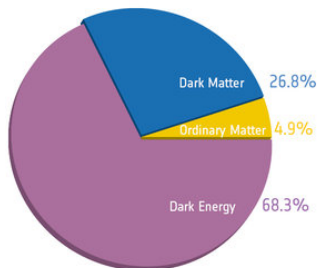


A double-meaning definition : cosmology

Before/After Planck...



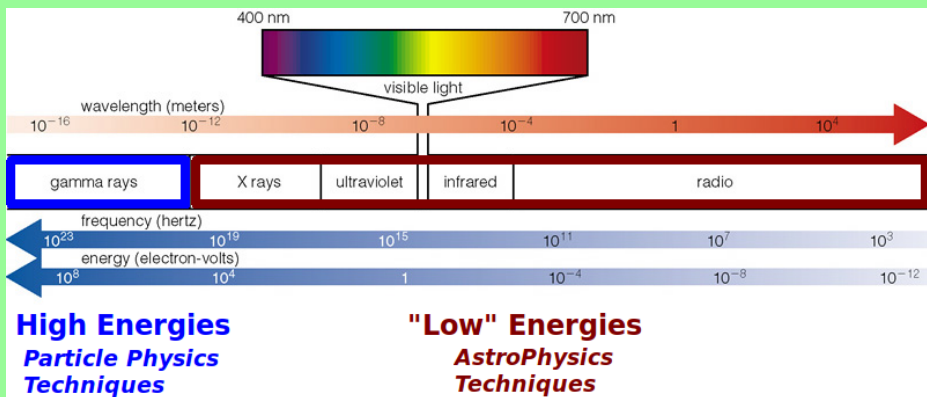
Before Planck



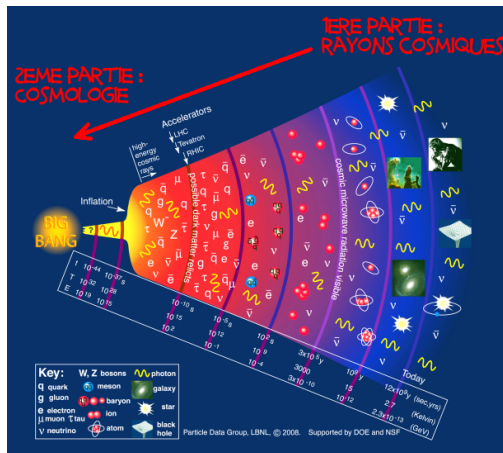
After Planck

A double-meaning definition : High/Low Energies

Distinction AstroParticles/Cosmology



Structure of the lectures



- Cosmology at the end for better interaction with « General Relativity & Cosmology »

Structure of the lectures

A touch of "theory" :

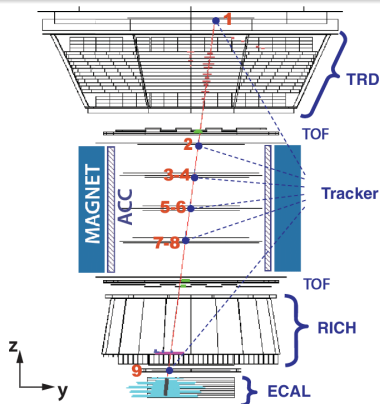
- Acceleration, propagation of Cosmic Rays
- Space-time metrics, distances in cosmology

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3} (\rho_{\text{matter}} + \rho_{\text{rad}} + \dots)$$
$$\frac{\ddot{a}}{a} = -4\pi G \left(p_{\text{matter}} + \frac{1}{3} \rho_{\text{matter}} + p_{\text{rad}} + \frac{1}{3} \rho_{\text{rad}} + \dots \right)$$

Structure of the lectures

A pinch of "experimental" :

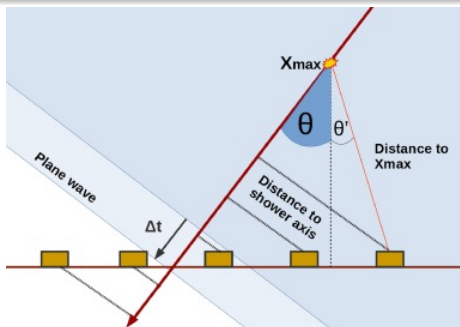
- Detection of cosmic-rays, from space and ground
- Detection of Cosmic-Microwave Background

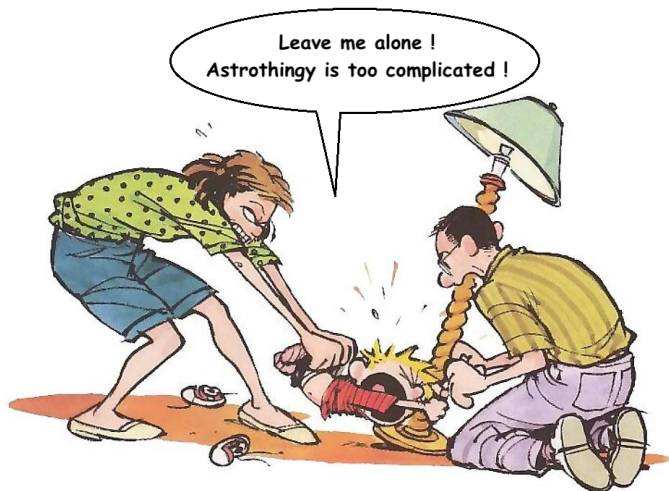


Structure of the lectures

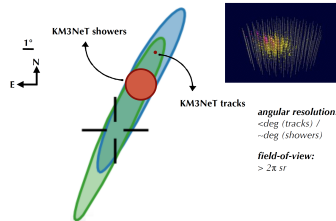
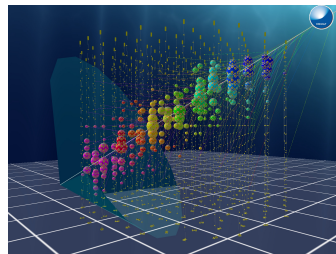
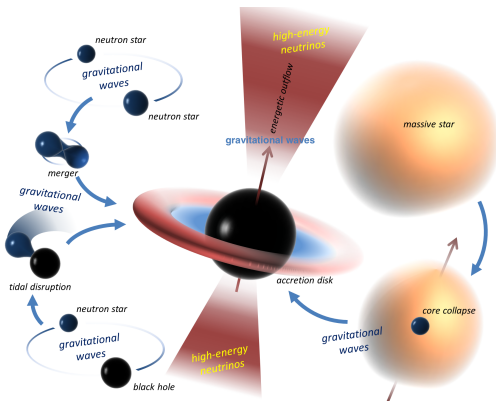
A hint of "Analysis" :

- Reconstruct the direction of an atmospheric shower, the energy of the primary...
- Build a CMB map, structure formation...





Master Project on Neutrinos + Gravitational Waves

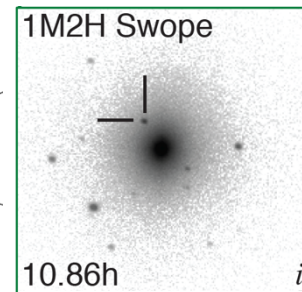
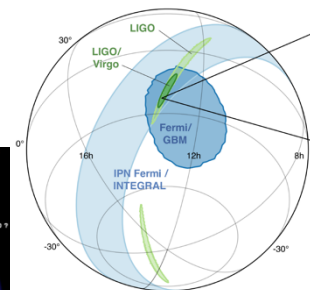
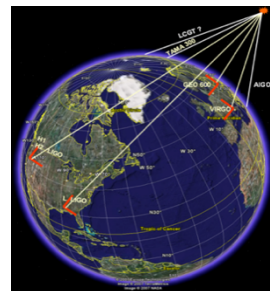


- KM3NET : future GeV-PeV neutrino Telescope
- Coincidences Neutrino - GW (Virgo/LIGO)

thierry.pradier@inps.cnrs.fr

GW physics and GW detector calibration

- Find weak optical counterparts
 - GW events are visible by multiple GW detectors
 - Sky maps built using times of flight + relative amplitudes
 - Need a accurately calibrated signal
 - Or accurate cross calibration between detectors



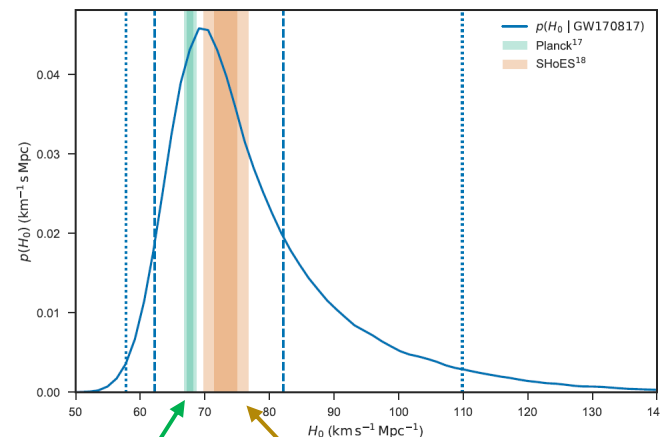
Measuring the Hubble Constant with GW:

Velocity from host
galaxy NGC4993

$$v_H = H_0 d$$

Distance
from GW

- GW170817 – AT2017gfo
 - $H_0 = 70.0 +12.0 -8.0$ km/s/Mpc
 - Could be improved with radio counterpart info:
 - $H_0 = 72.4 +7.9 -7.3$ km/s/Mpc
- Error on $h(t)$ calibration directly translate to H_0 error



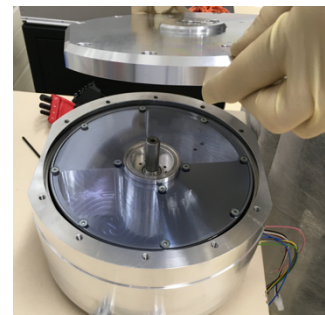
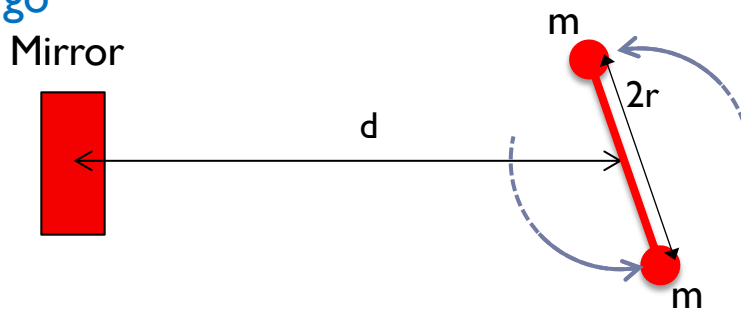
CMB/BAO
measurements

Measurements with
distance ladder

Contact : benoit.mours@iphc.cnrs.fr

GW activity at IPHC

- ▶ Neutron Star/Black Hole mergers search in LIGO-Virgo data
 - Low latency analysis + offline analysis
- ▶ Development of a new calibration technique: Newtonian Calibrator (NCal)
 - Creation of a variable gravitational field
 - Promising tests performed at Virgo



- ▶ Internship: contribution to the NCal development
 - Instrumental and data analysis work like:
 - ▶ Participate to first metrology tests, deduce the impact on the calibration error
 - ▶ Study the LIGO/Virgo cross calibration with observed GW events

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