
CREDIT: GILLES GERBIER
Welcome to the
Theory meeting experiment:
Particle astrophysics
and Cosmology
2020
QUY NHON

# When Theory Meets Experiments

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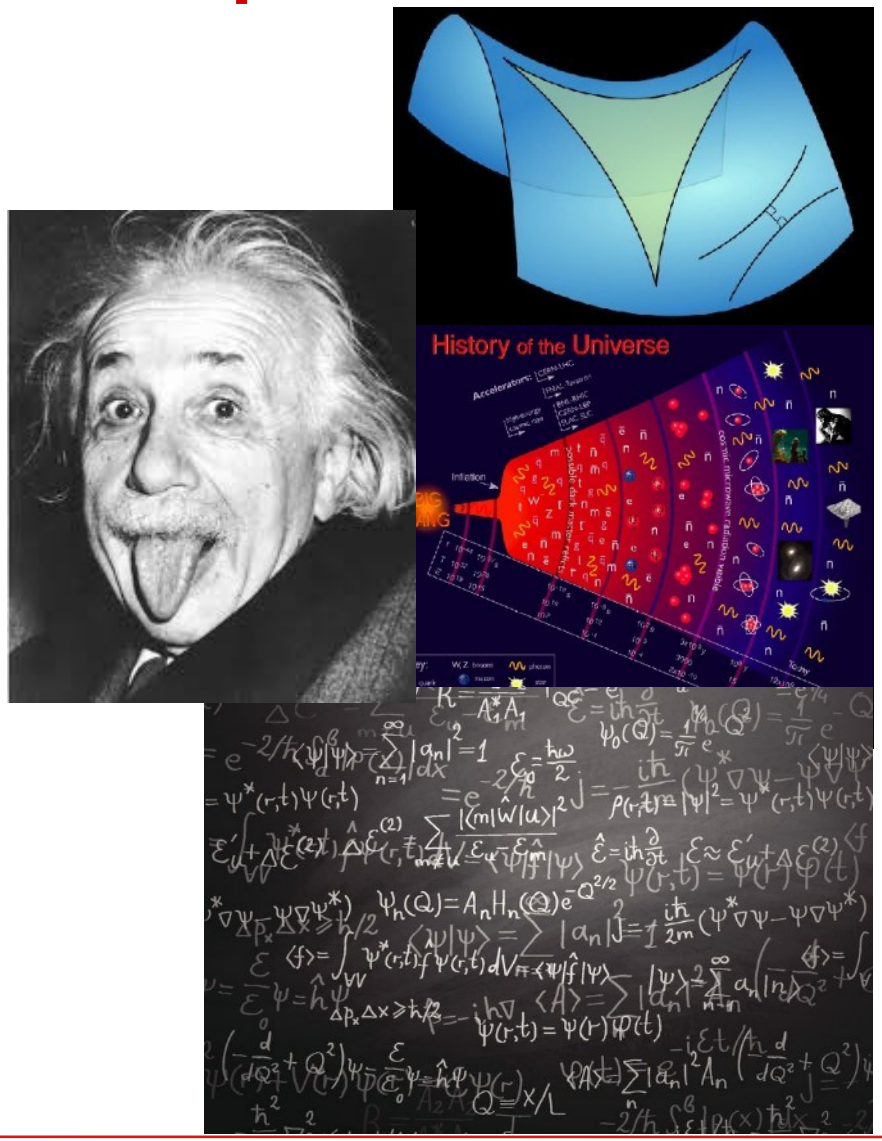
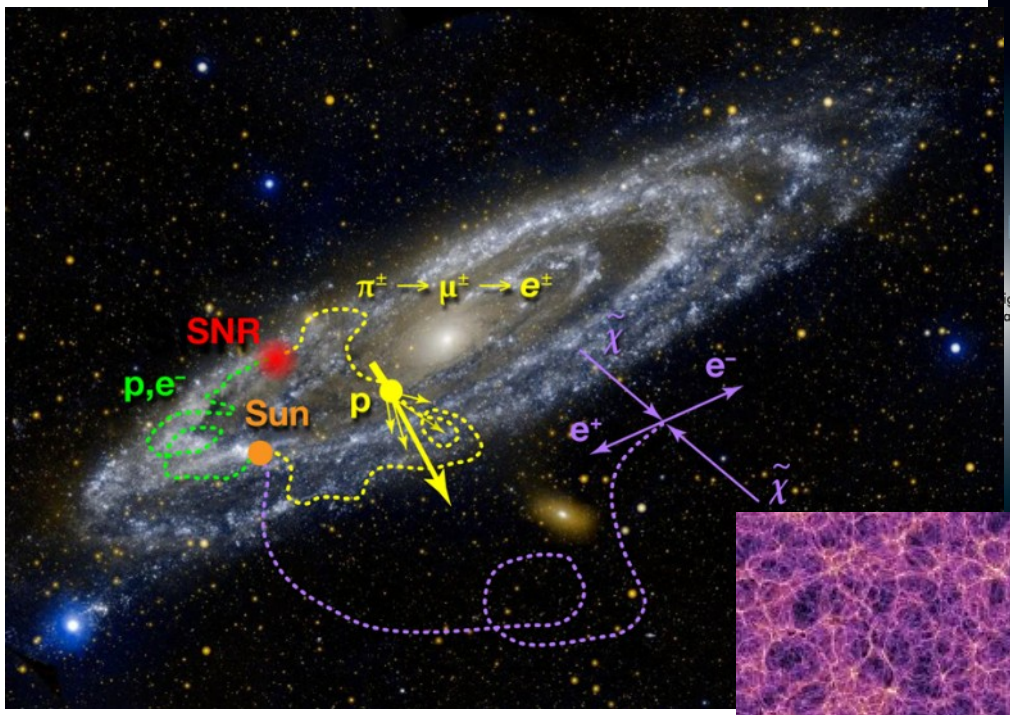
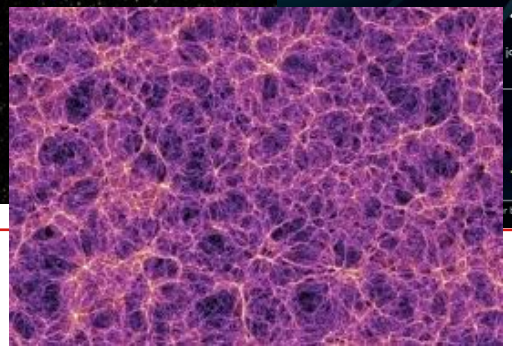


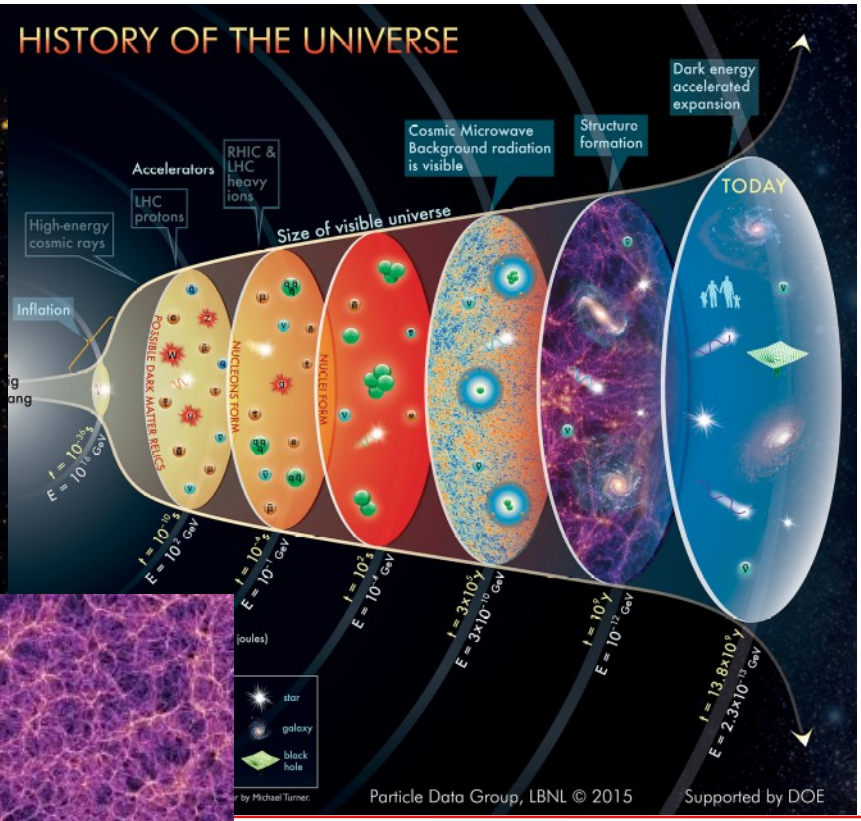
# When Theory Meets Experiments

# Particle astrophysics & cosmology

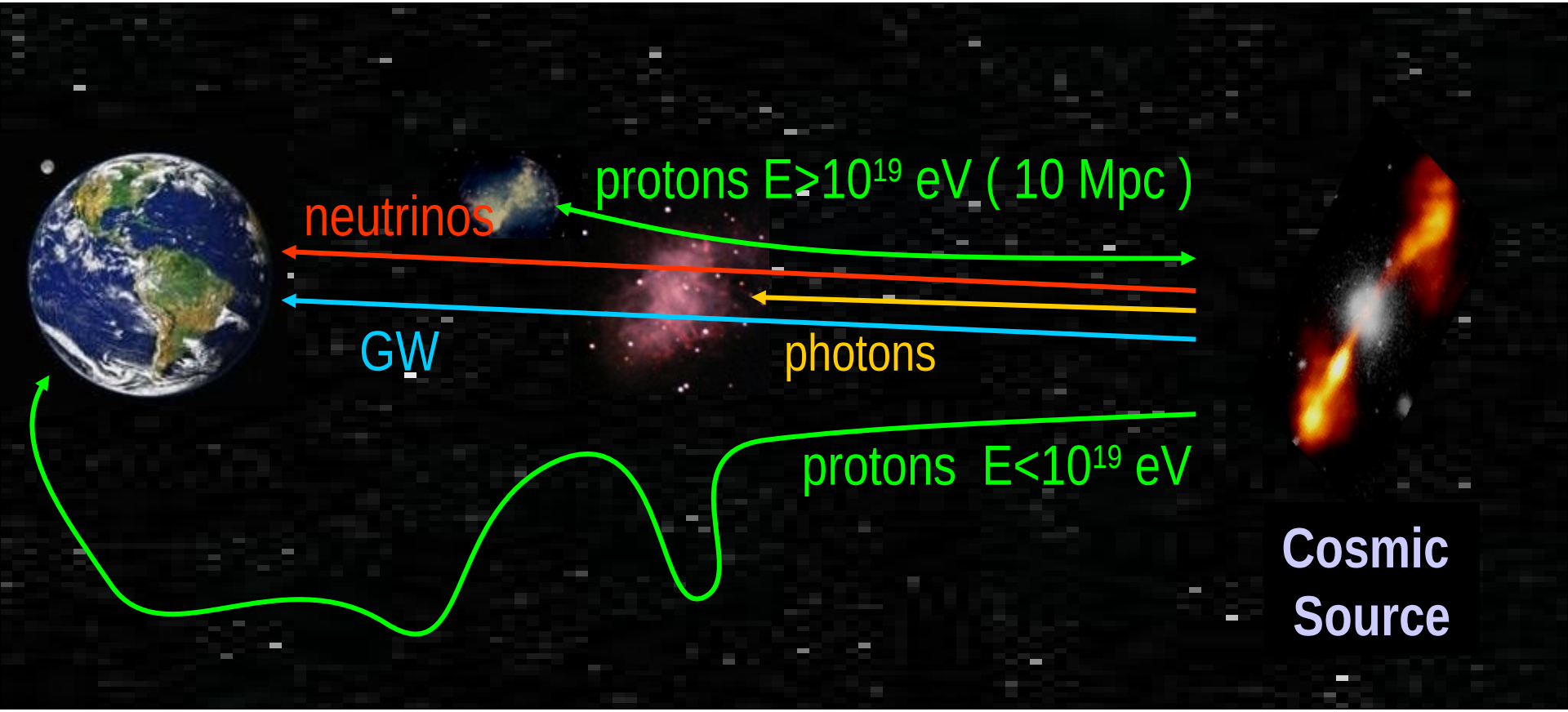
- Where the infinitely small meets the infinitely large…
- Interplay between production, acceleration, propagation of particles (SM & DM) on one side, and the overall structure of the Universe and its evolution on the other side (cosmology)
- Not limited to big bang era...





# Astrophysical Messengers




| | |
|---|---|
| **photons:** | Interacts with plasma, dust and radiation (pair creation, ...) |
| **protons/nuclei:** | Deviated by B field, absorbed by CMB (GZK effect) |
| GW: | Scales as 1/R, not deviated, not absorbed, difficult to detect |
| neutrinos: | Not deviated, not absorbed, difficult to detect |

# Being more specific

## Experiments

- Cosmological Probes
  - CMB
  - SN Ia
  - Lensing
  - Rot. Curves
  - BAO
  - Abundances
- Cosmic Rays
  - GeV
  - PeV
  - UHECRs
- γ
  - GeV
  - TeV
- ν
  - MeV
  - TeV
- GW
- Direct DM

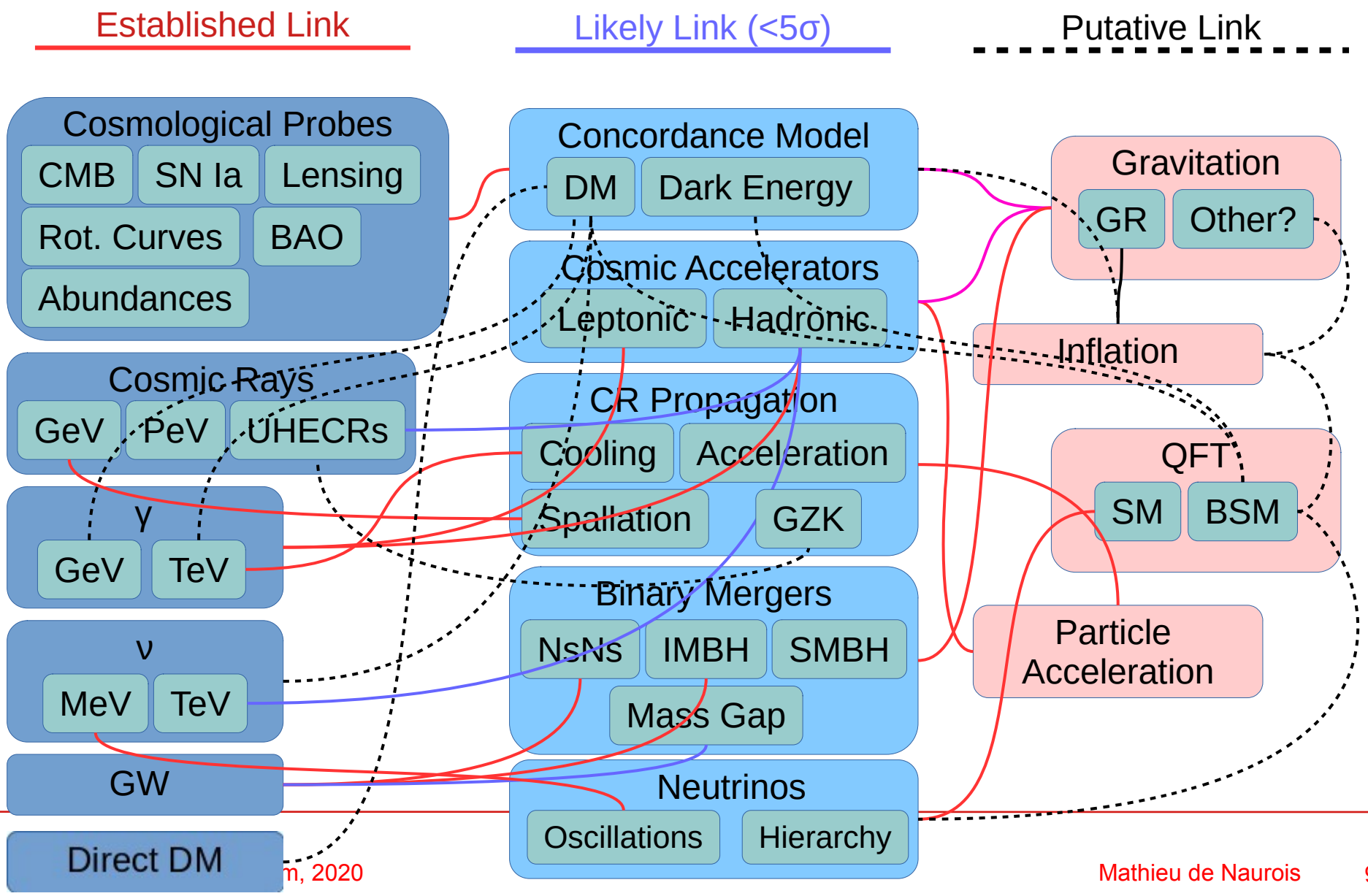
## Models

- Concordance Model
  - DM
  - Dark Energy
- Cosmic Accelerators
  - Leptonic
  - Hadronic
- CR Propagation
  - Cooling
  - Acceleration
  - Spallation
  - GZK
- Binary Mergers
  - NsNs
  - IMBH
  - SMBH
  - Mass Gap
- Neutrinos
  - Oscillations
  - Hierarchy

## Theories

- Gravitation
  - GR
  - Other?
- Inflation
- QFT
  - SM
  - BSM
- Particle Acceleration

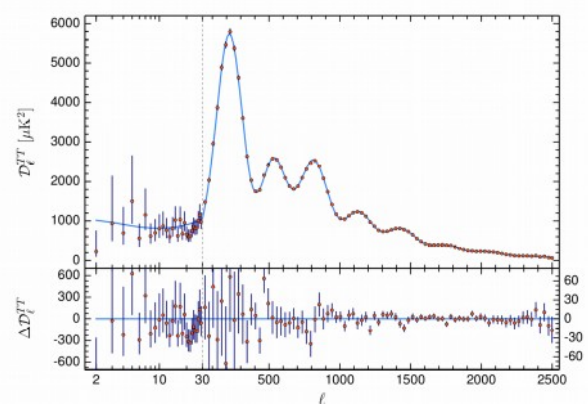
# Overall picture (2020)

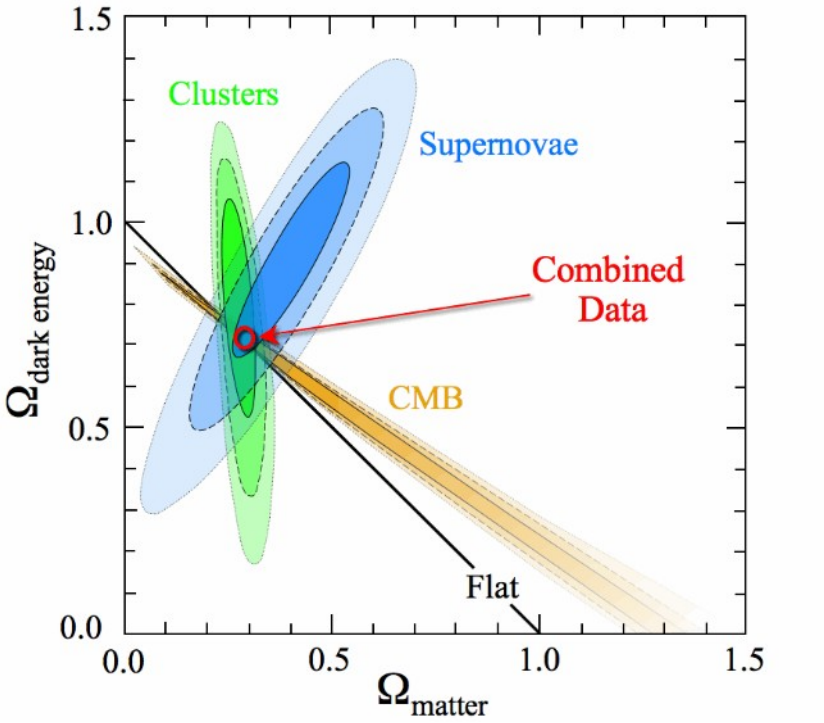


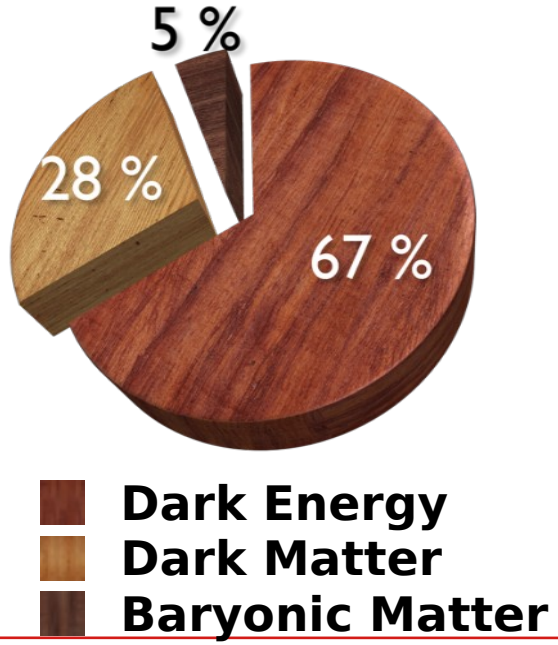
# Cosmology – Condorcance Model

- Global fit combining several (many) probes
- Excellent description of our Universe in the so-called Λ-CDM Model (dominated by dark energy and dark matter)

Planck 2018 CMB spectrum

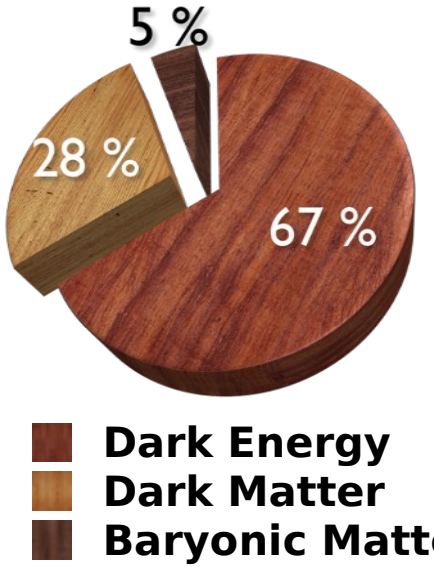


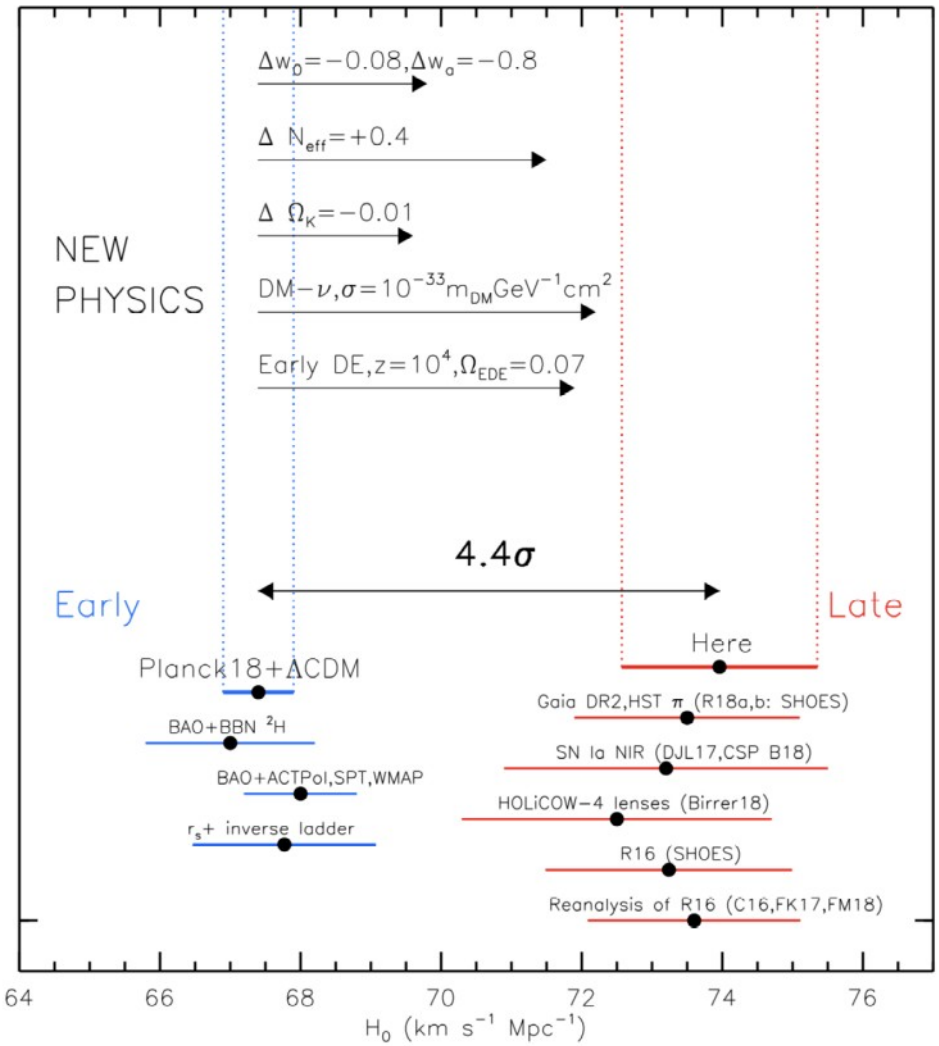



# Concordance Model – in tension?

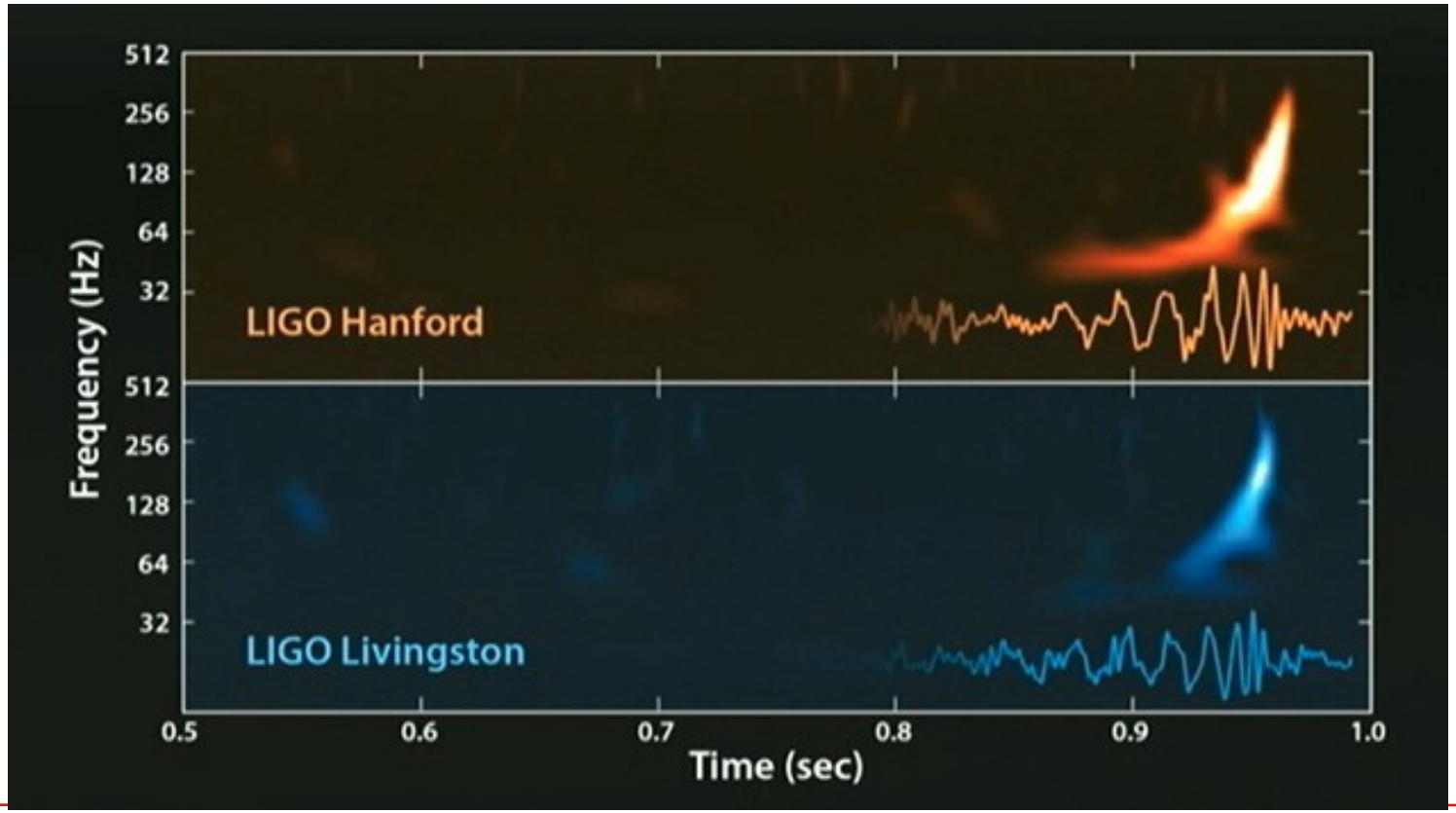
- Origin of Dark Matter & Dark Energy not solved
- Tension in Hubble Constant (expansion speed of the Universe)
- Food for though for future experiments? (LSST, Euclid, ...)



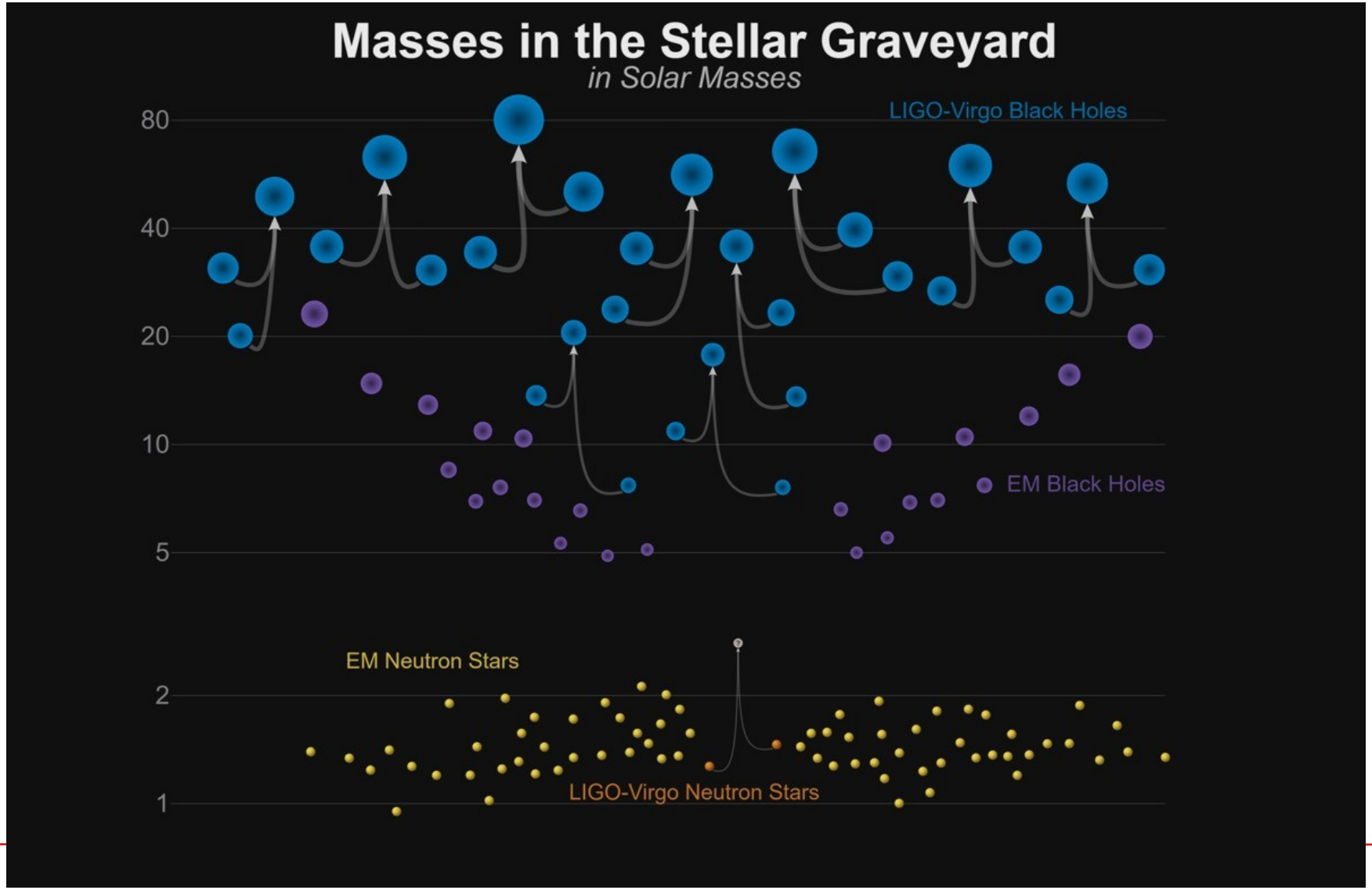



# Birth of GW Astronomy

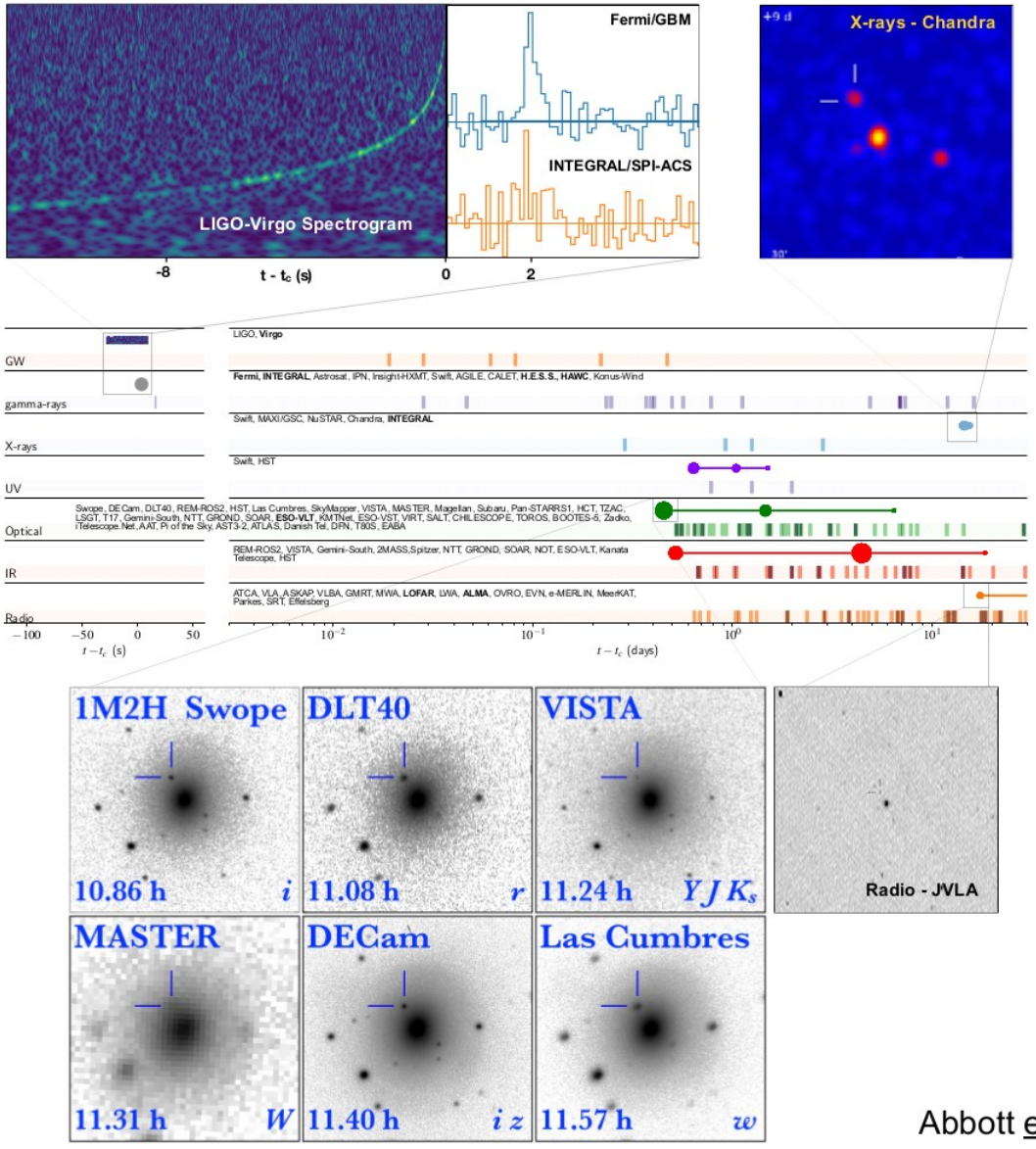
- Ripples of space-time propagating in straight lines
- First detection: September 14th 2015 (LIGO)
- Coalescence of intermediate mass black holes (somewhat unexpected)



# Second Science Run – Final Mass chart



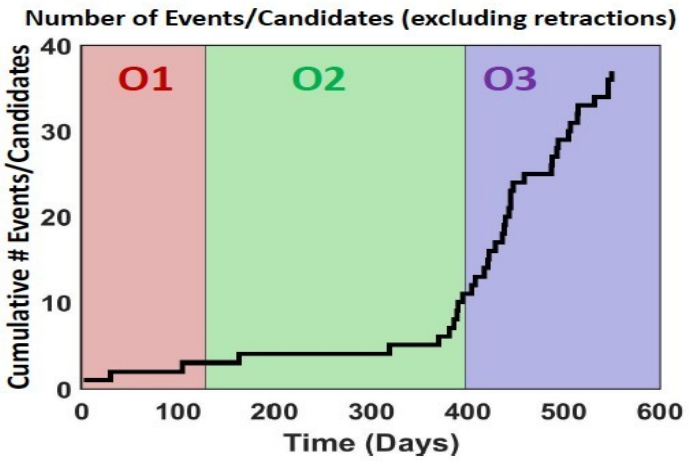
# Into the multimessenger era

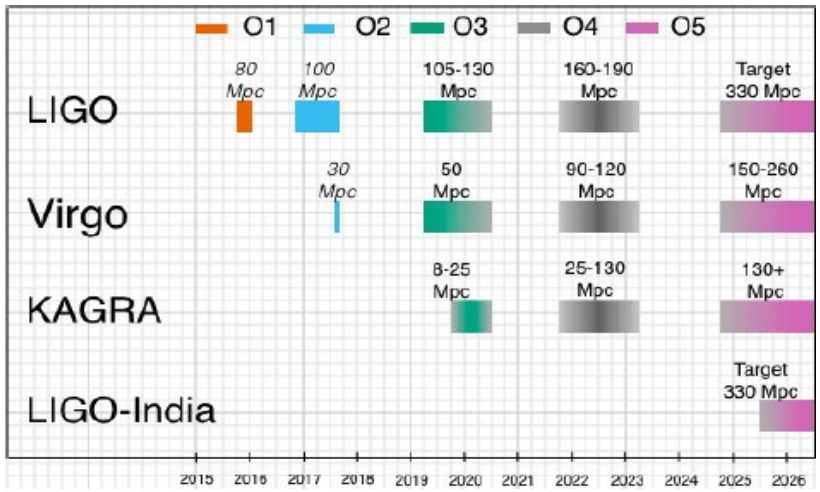



- Binary neutron star merger at 40 Mpc
- Tests of general relativity ($\Delta t \sim 1.7$s)
- Independant measurement of Hubble constant

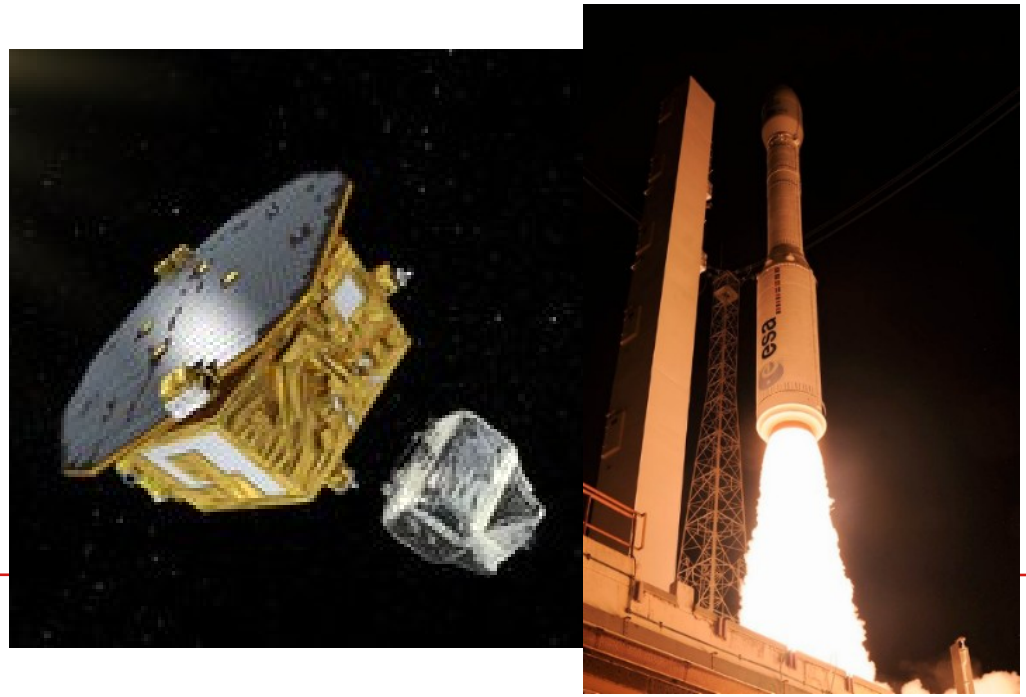
Abbott et al., ApJL 2017

# Entering a new era



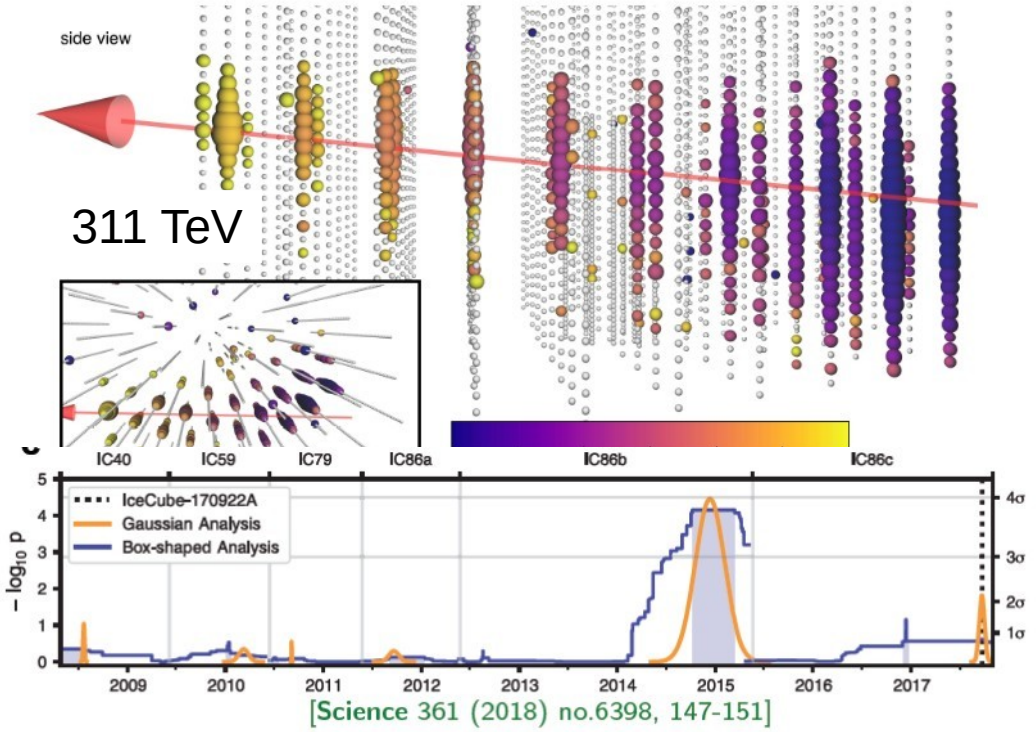



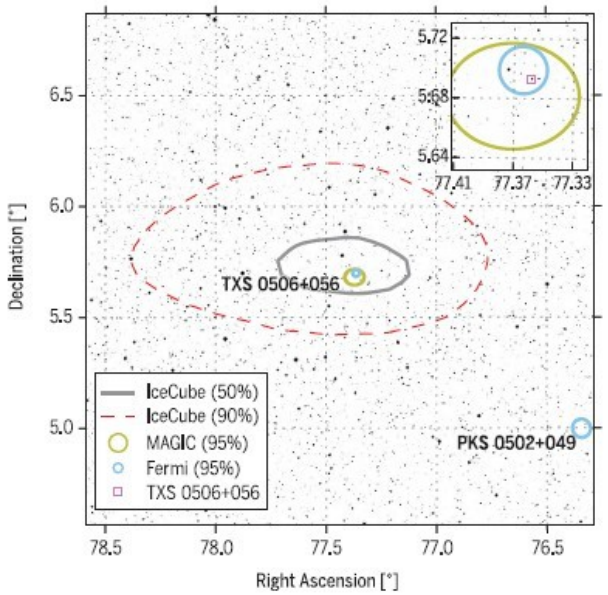

- Detection rate ~ 1/weak
- Next major step: LISA
  - Huge level arm
    → Lower frequencies
- LISA pathfinder sucessfull



# Birth of Neutrino Astronomy


# IC-170922A – First Neutrino from a blazar?



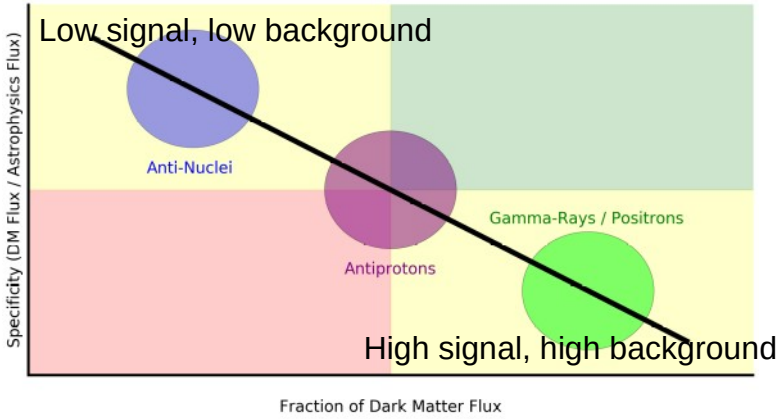



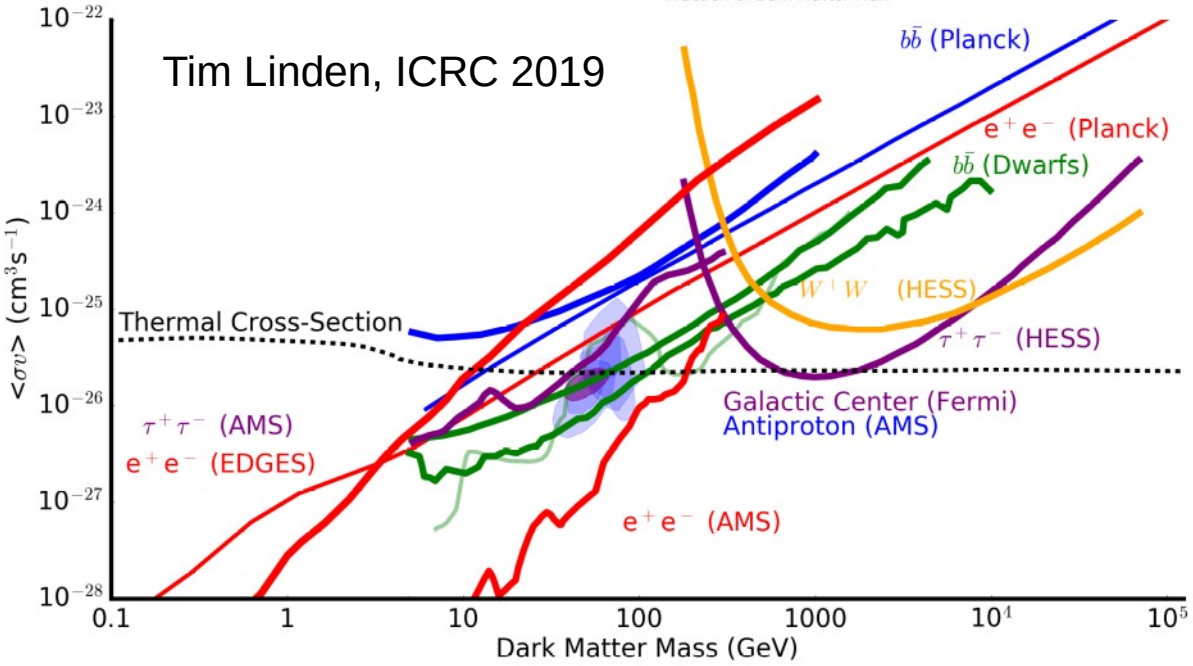

First identification of neutrino high-energy source (~3σ + ~3.5σ)

- IceCube EHE (“extremely-high energy”) alert IC-170922A, Up-going muon track (5.7° below horizon)
- Coincident with blazar TXS0506+056 (MAGIC + Fermi-LAT) + archival data
- Fermi-LAT: Brightest Fermi source in the region of interest at energies above 1GeV during the IceCube-170922A event but only above 2−5 GeV during the neutrino flare

# Indirect Search for Dark Matter

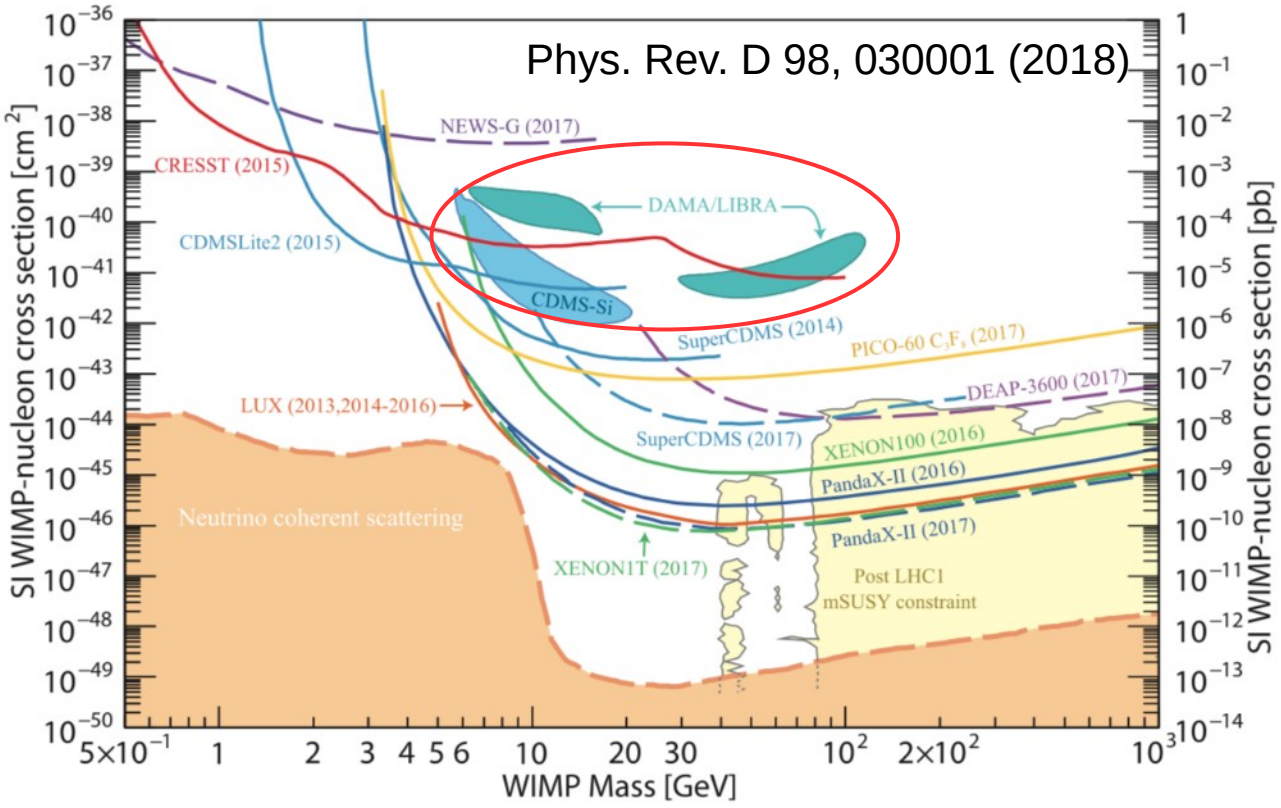
- Indirect search for WIMPs (most natural candidate) with many astrophysical probes/targets:
  - Gal. Center (γ+radio)
  - Dwarf Spheroidals (γ)
  - Positron excess, antiprotons
  - Antinuclei
  - ...
- Now reaching relic densities on large mass range
- Room for other type of DM



# Direct Search for Dark Matter

- Direct searches showed not evidence so far
- Some experiments (e.g. DM-Ice + KIMS → Cosine100) trying to reproduce Dama result
- The hunt continues (XENON, ...)



# Other hot topics

- Alternatives to WIMPs: Axions, primordial BH, …. & searches at accelerators (LHC)
- γ-ray astronomy: very large structures (Fermi Bubbles), VHE emission from pulsars & from GRBs deep in the afterglow phase
- UHCRs & Particle Physics: connection between accelerator physics & cosmic rays (again): proton-air cross section, etc.
- Survey γ-ray instrument (HAWC, LHAASO, ...)
- How to efficiently improve synergies between instruments, sub-threshold alterts, network, etc…
- Primordial Anti-Helium nuclei with AMS
- ….

# Welcome to the multimessenger Era!