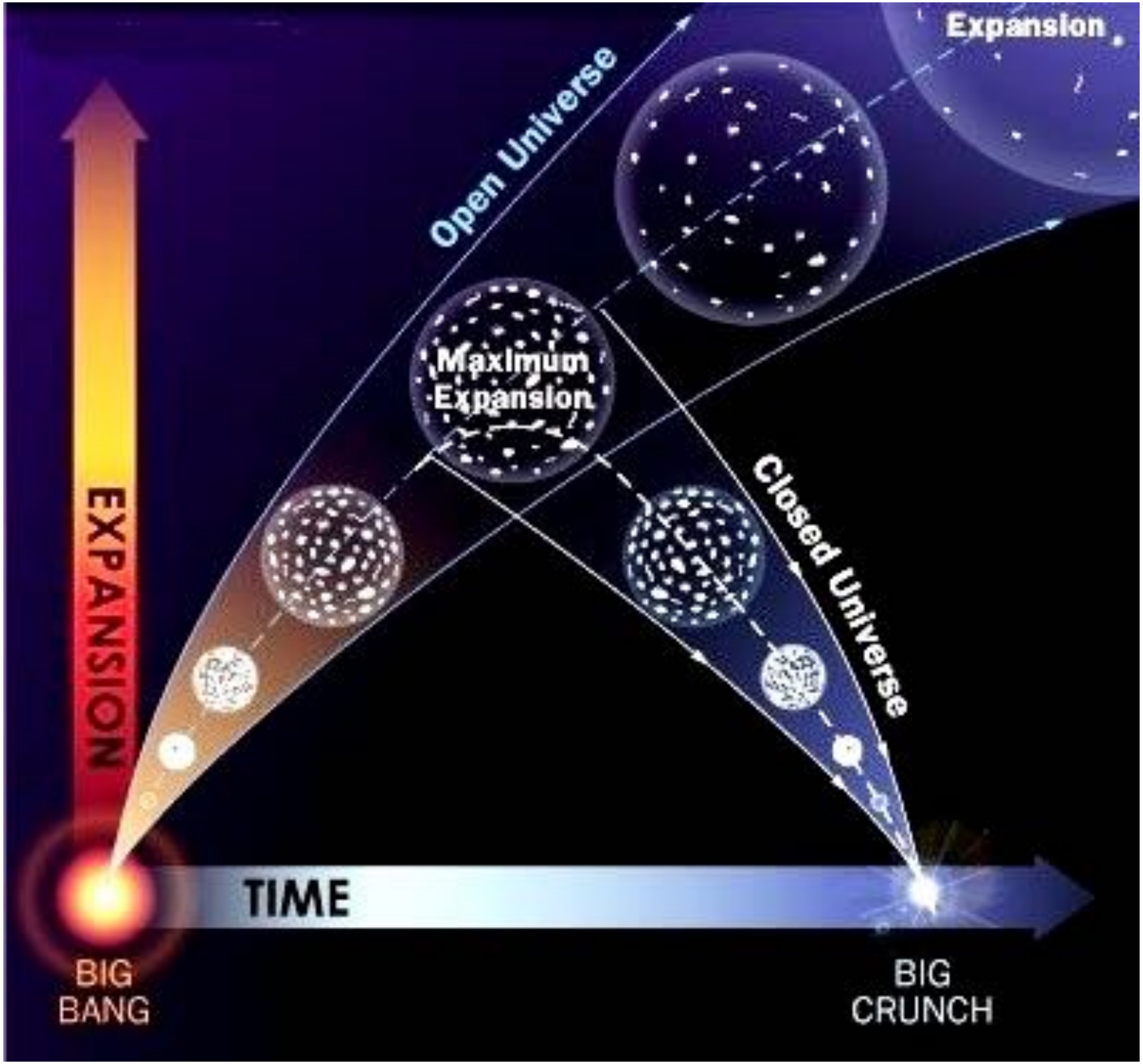
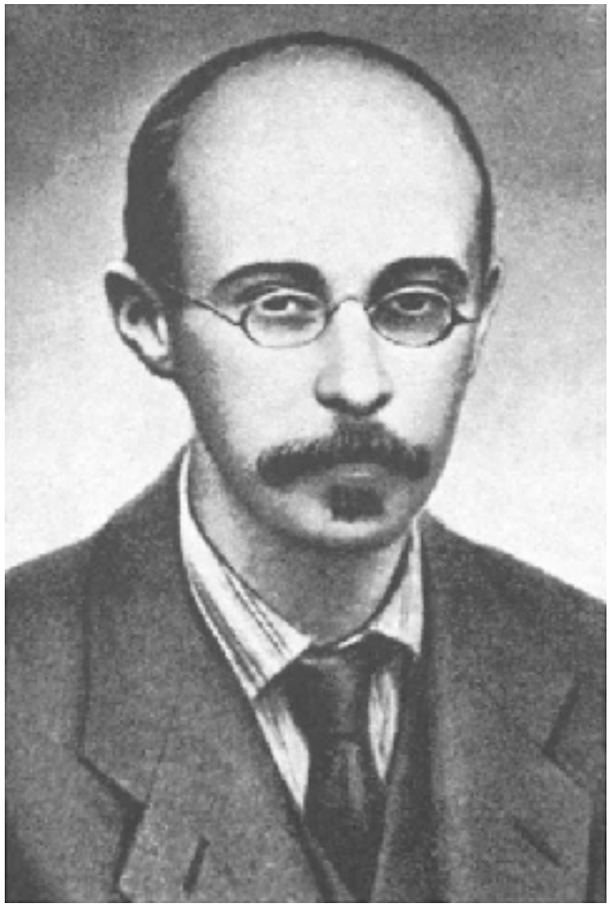

European Astroparticle
Physics Strategy
2017-2026
APPEC
Romain Gaïor (LPNHE)
Introduction astro / cosmo
JRJC2019

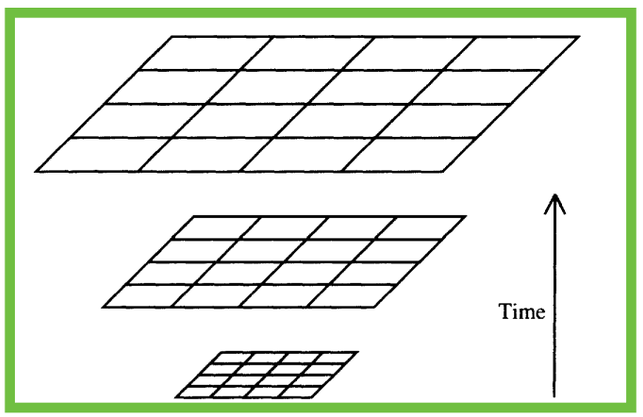

Expansion
Open Universe
Maximum Expansion
Closed Universe
EXPANSION
TIME
BIG BANG
BIG CRUNCH



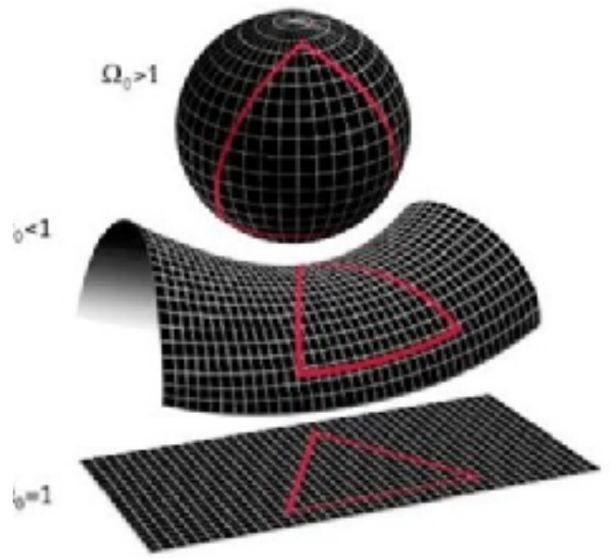
Alexandr Friedmann
(1922)

$$H^2 \equiv \left(\frac{\dot{a}}{a}\right)^2 \equiv \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$



$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) = 0$$



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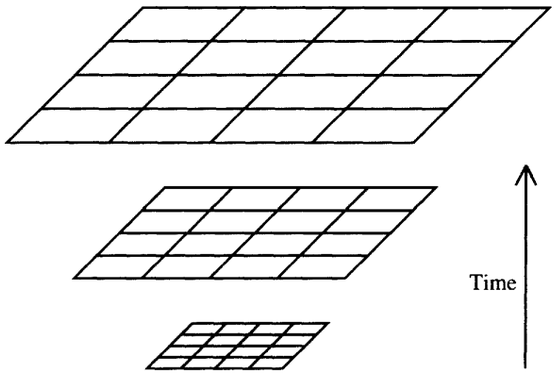
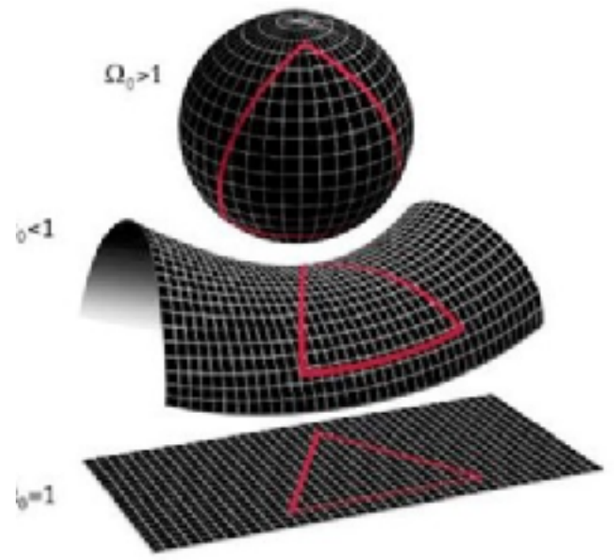


$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) = 0$$

$$\rho_{\text{mat}} \propto \frac{1}{a^3} \quad ; \quad \rho_{\text{rad}} \propto \frac{1}{a^4} \,.$$



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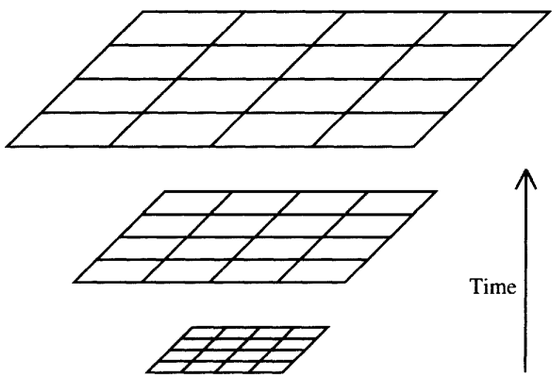

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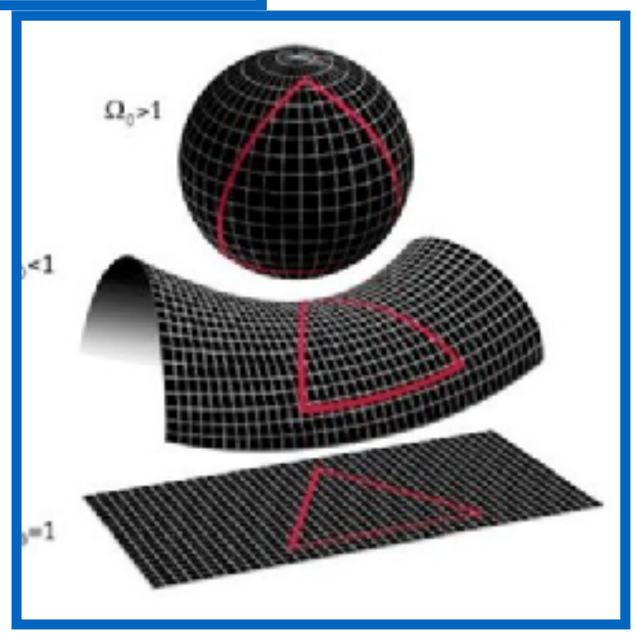

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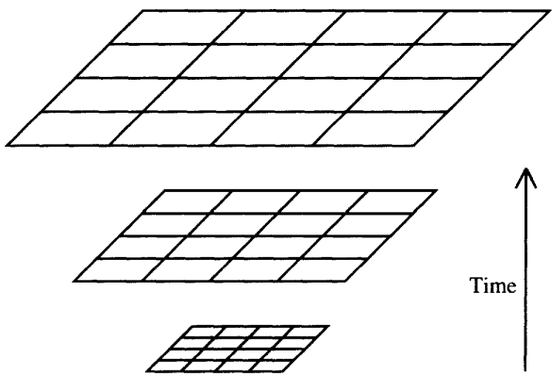
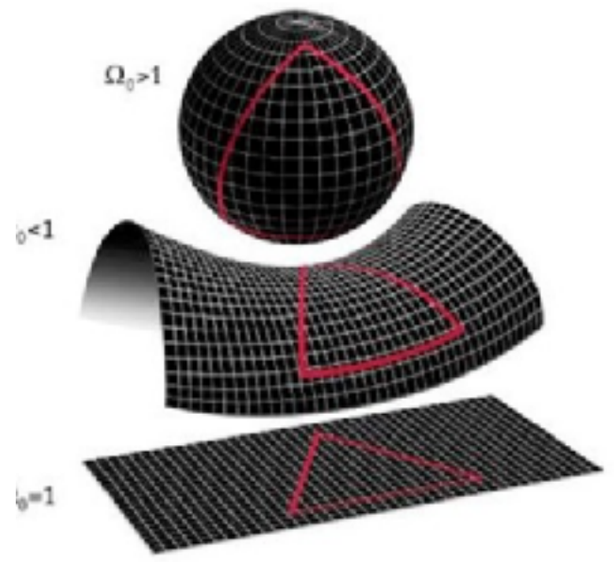


$$\dot{\rho} + 3\frac{\dot{a}}{a}\left(\rho + \frac{p}{c^2}\right) = 0$$



$$\Omega_\Lambda = \frac{\Lambda}{3H^2}$$

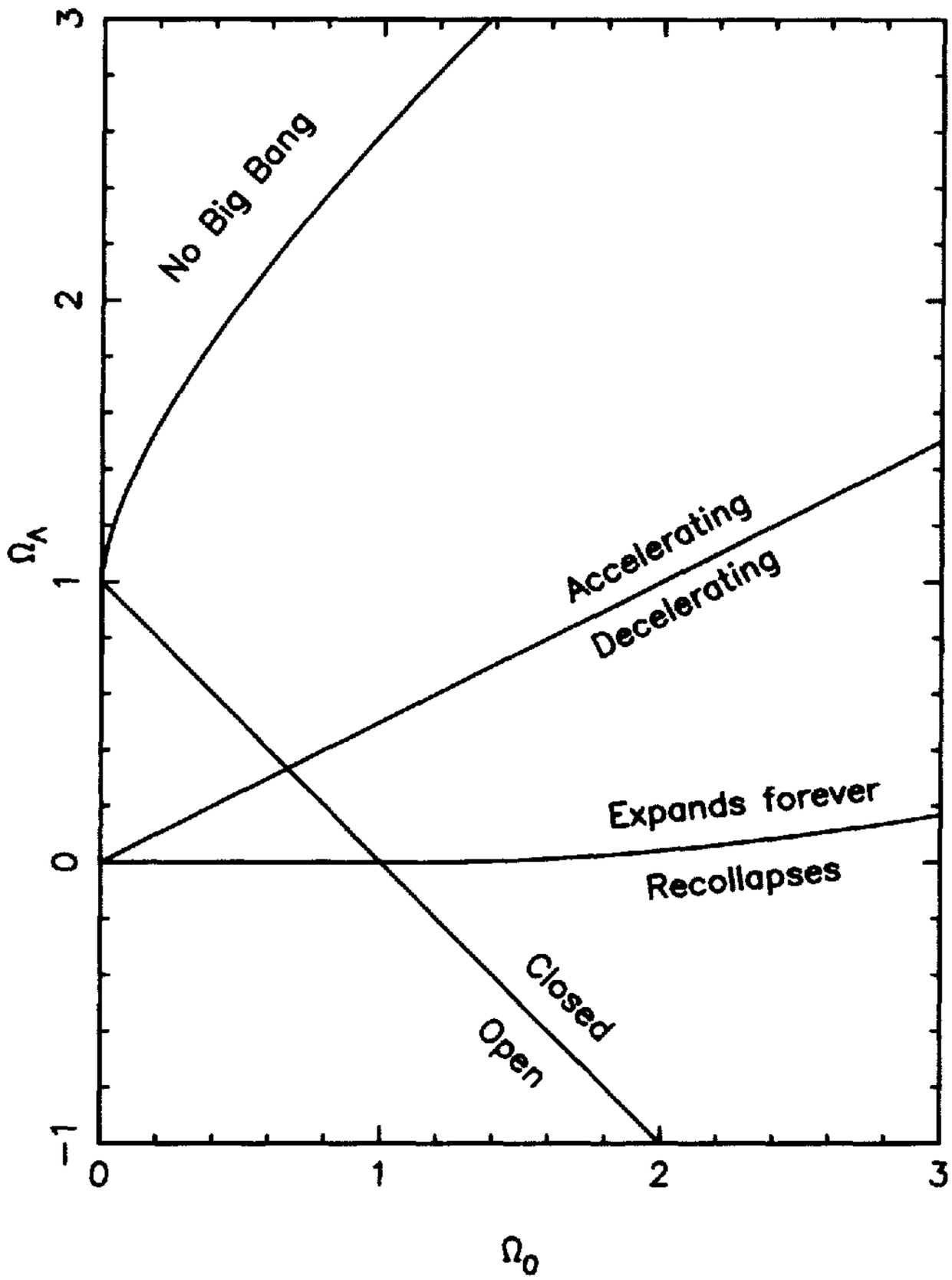
$$\Omega + \Omega_\Lambda - 1 = \frac{k}{a^2 H^2}$$

$$\Omega(t) \equiv \frac{\rho}{\rho_c} .$$

Open Universe: $0 < \Omega + \Omega_\Lambda < 1$.

Flat Universe: $\Omega + \Omega_\Lambda = 1$.

Closed Universe: $\Omega + \Omega_\Lambda > 1$.



Cosmological probes

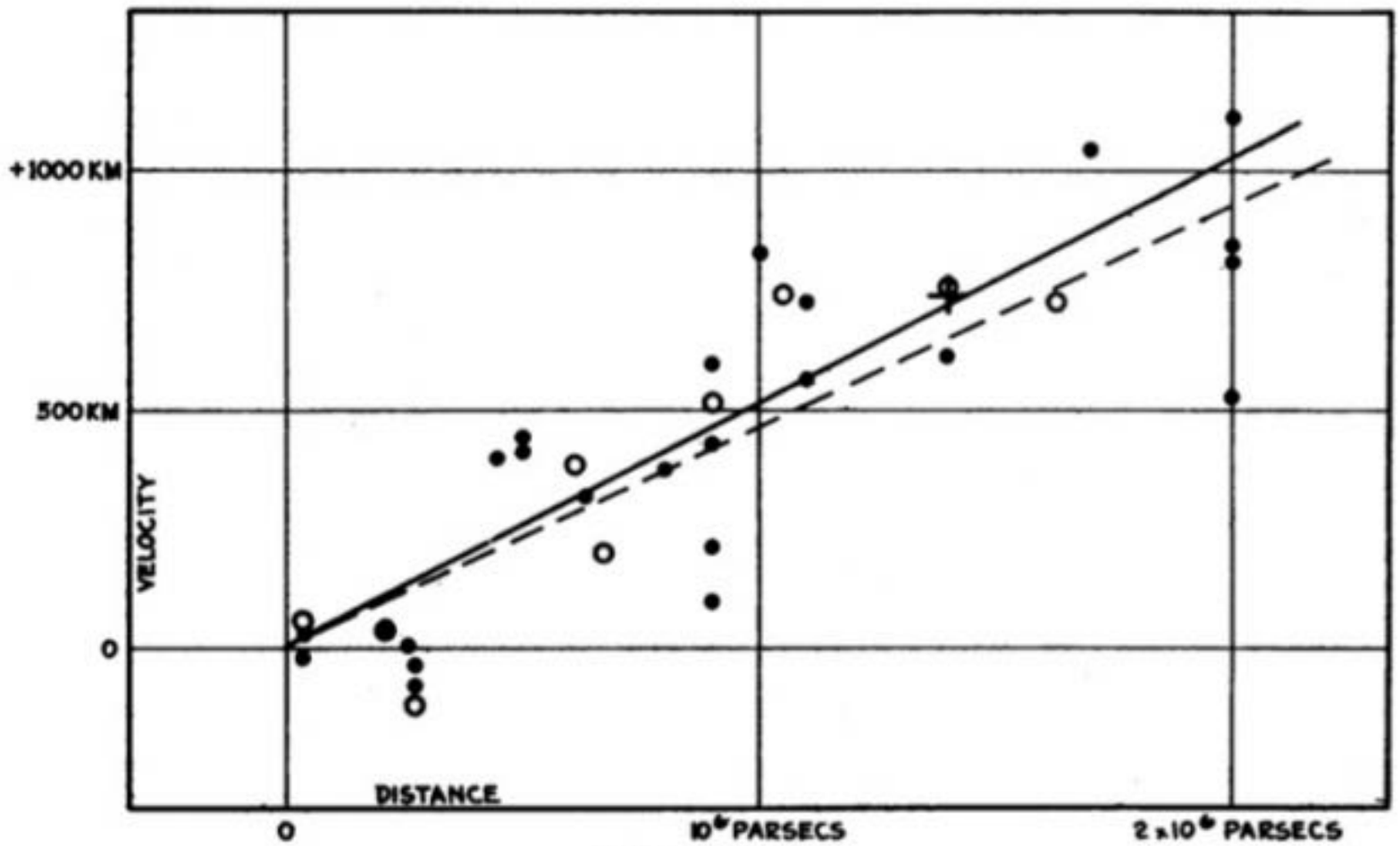


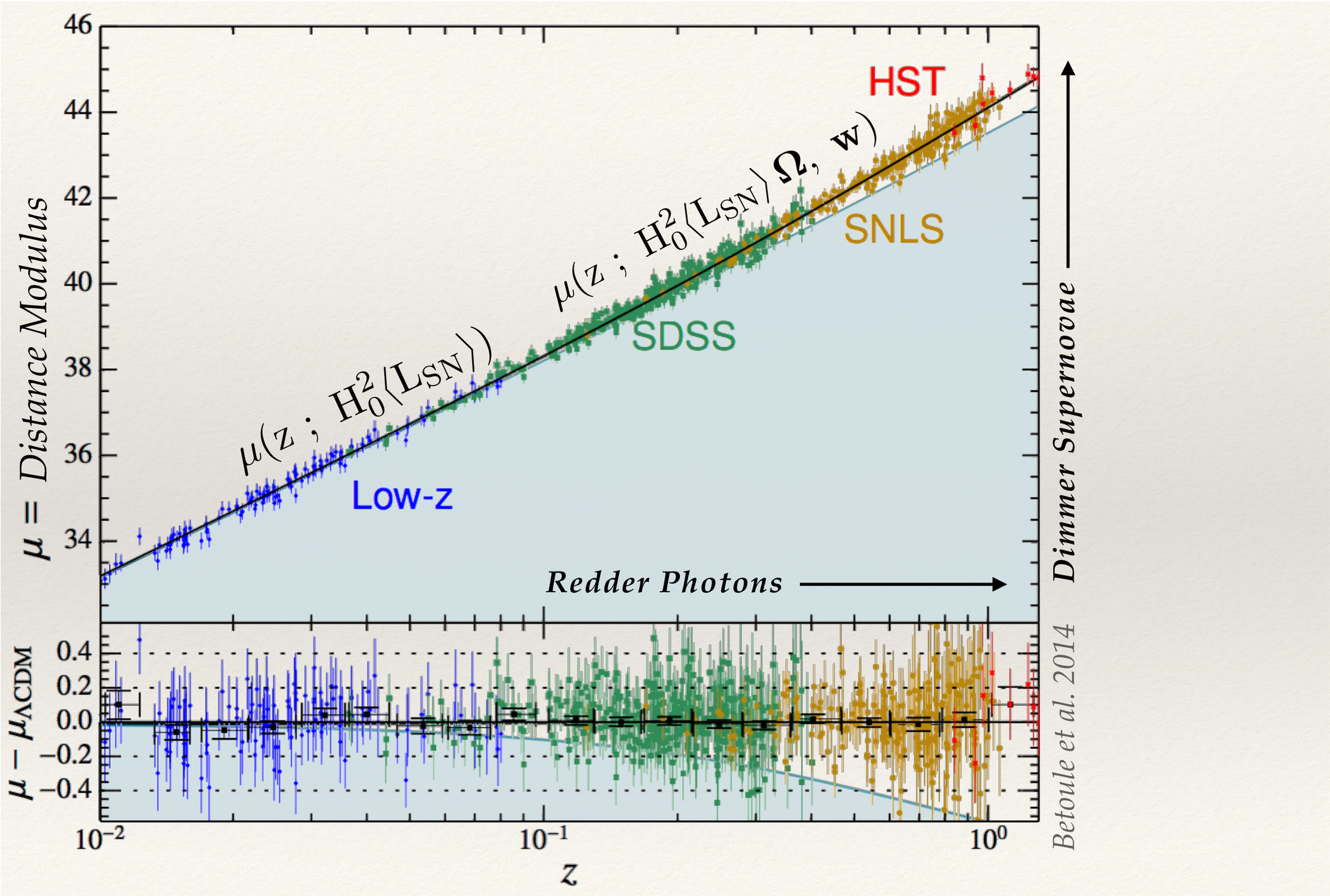
FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

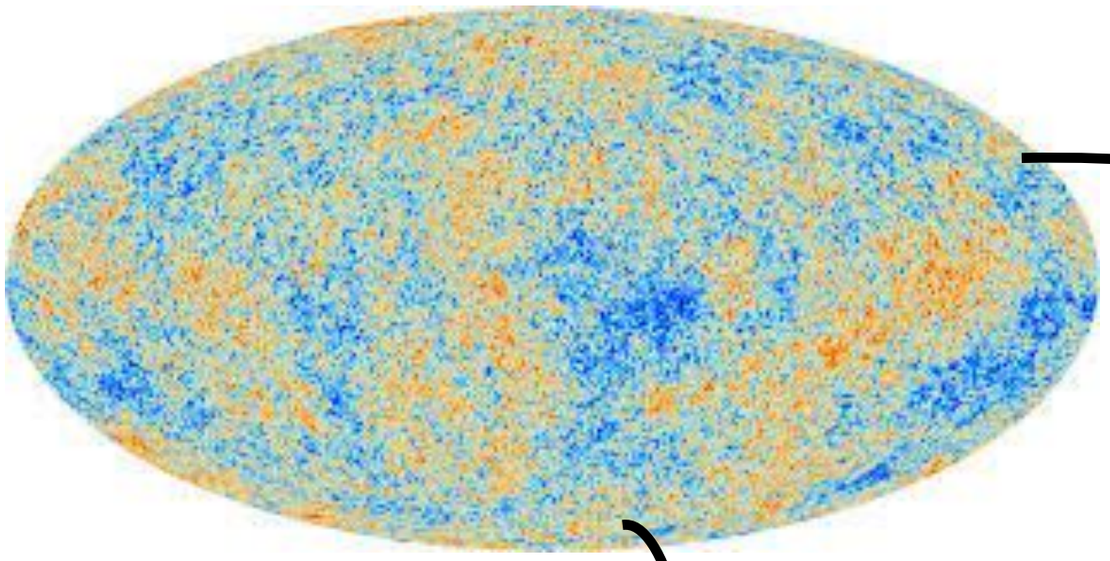
Velocity measurement: red shift

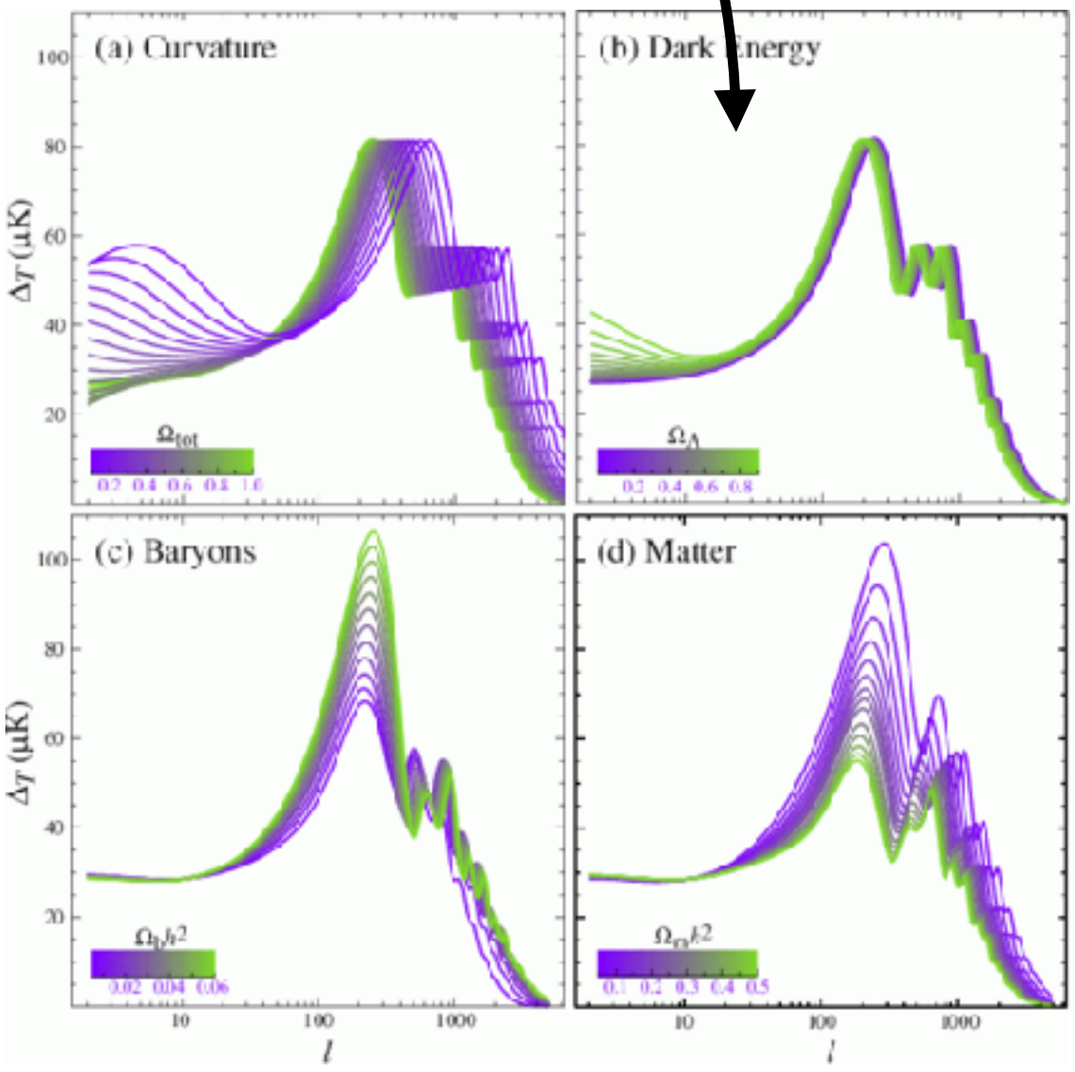
distance measurement: Luminosity + *standard candle*

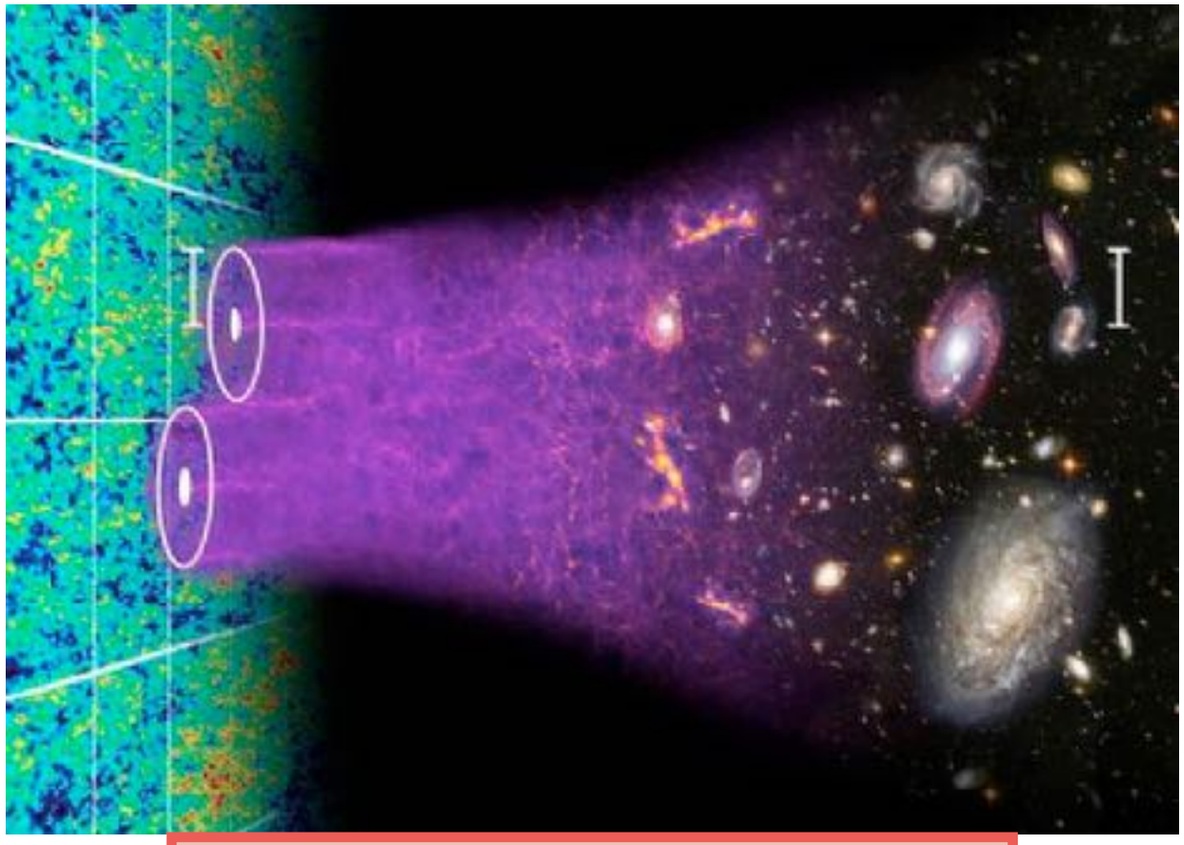
Cosmological probes: SNIa



CMB / BAO

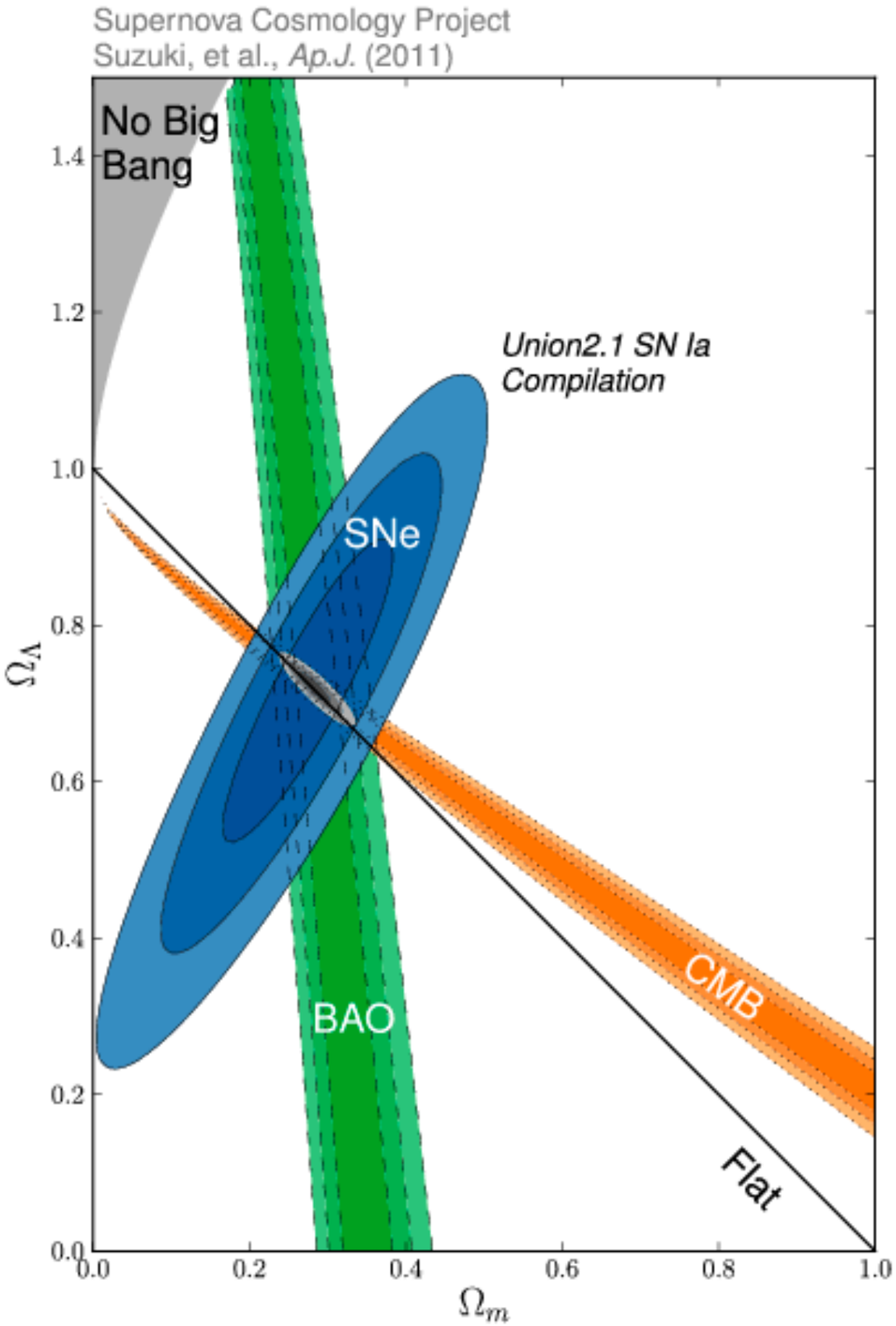


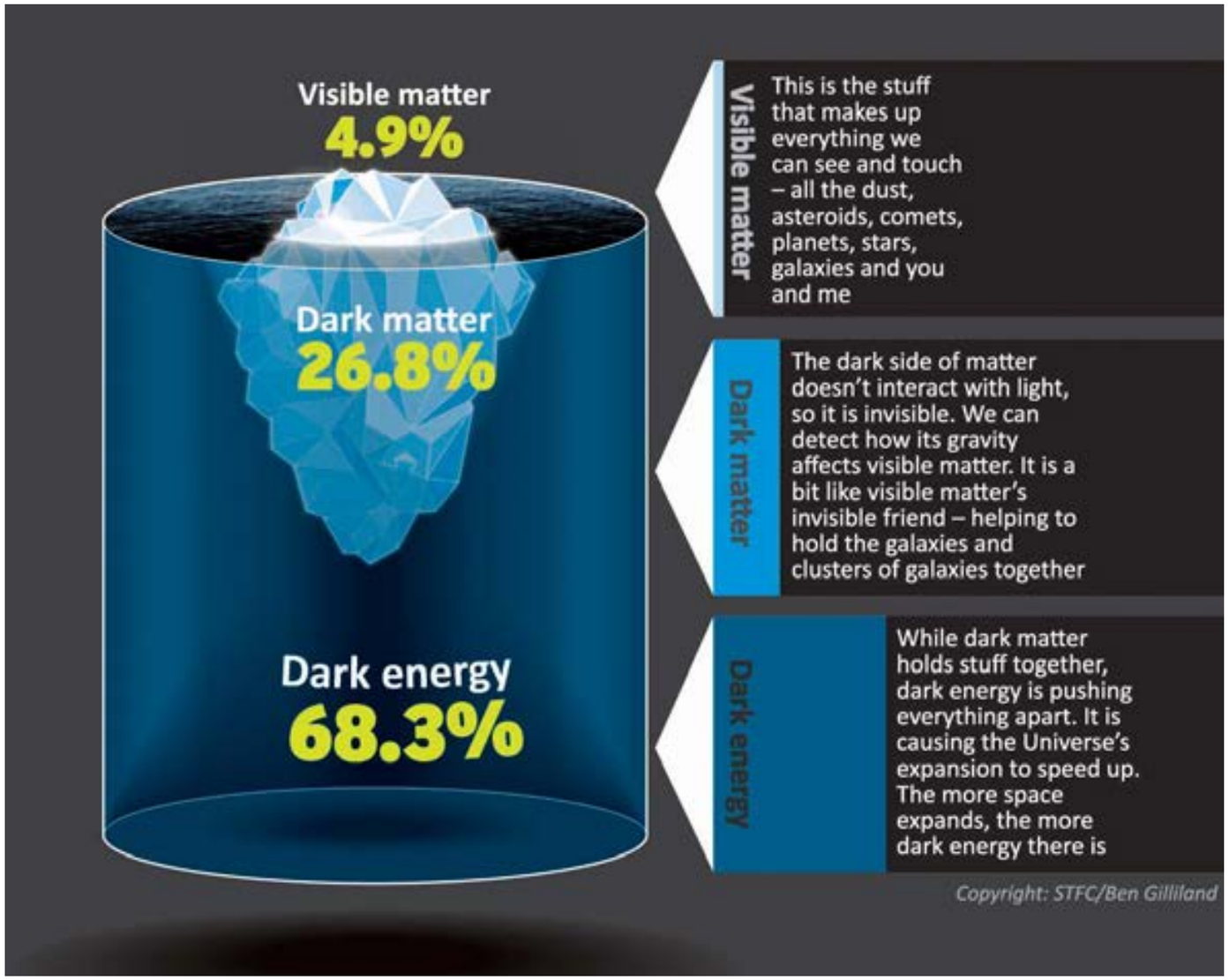




Julianna Stermer on BAO

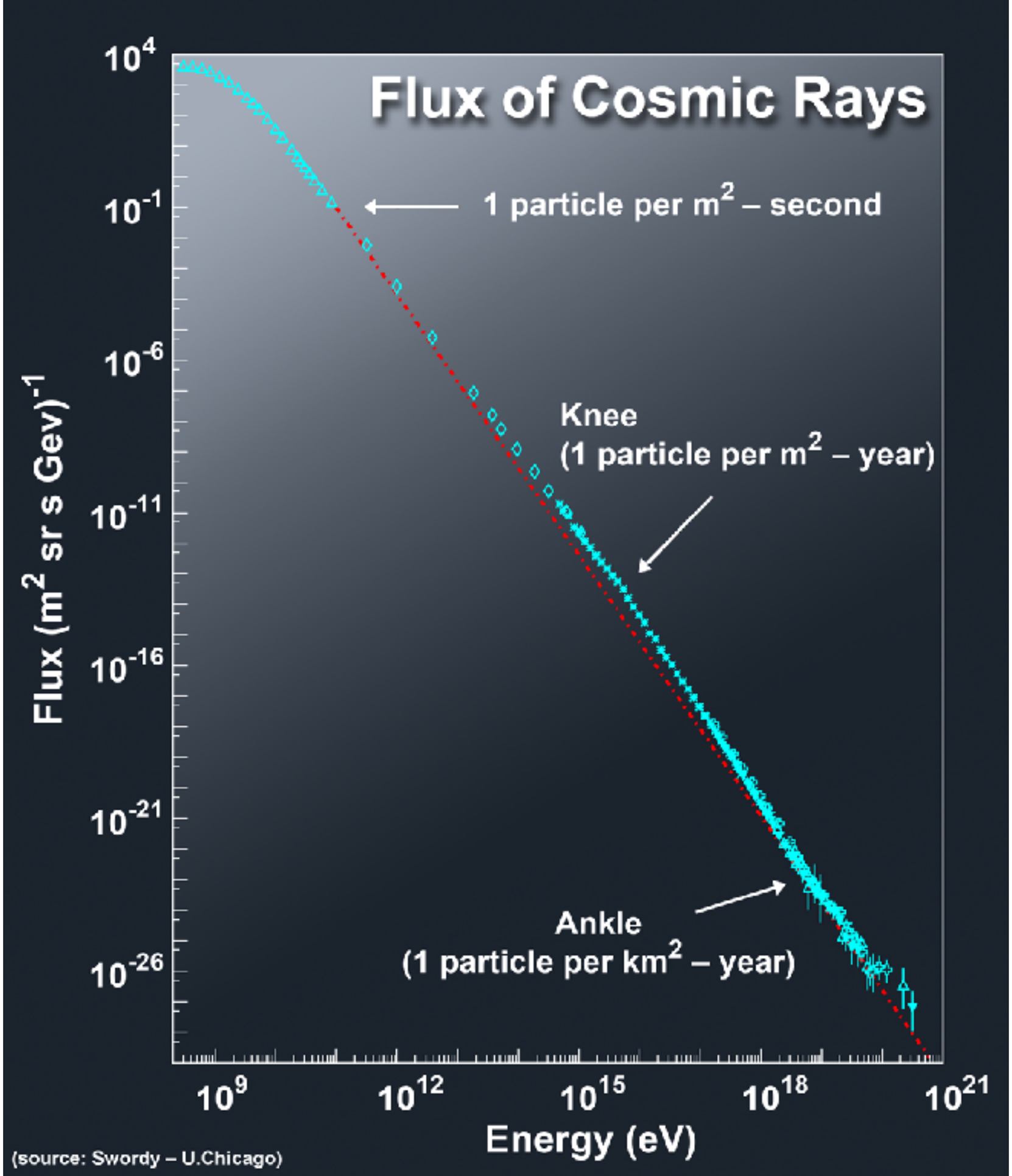
Current picture



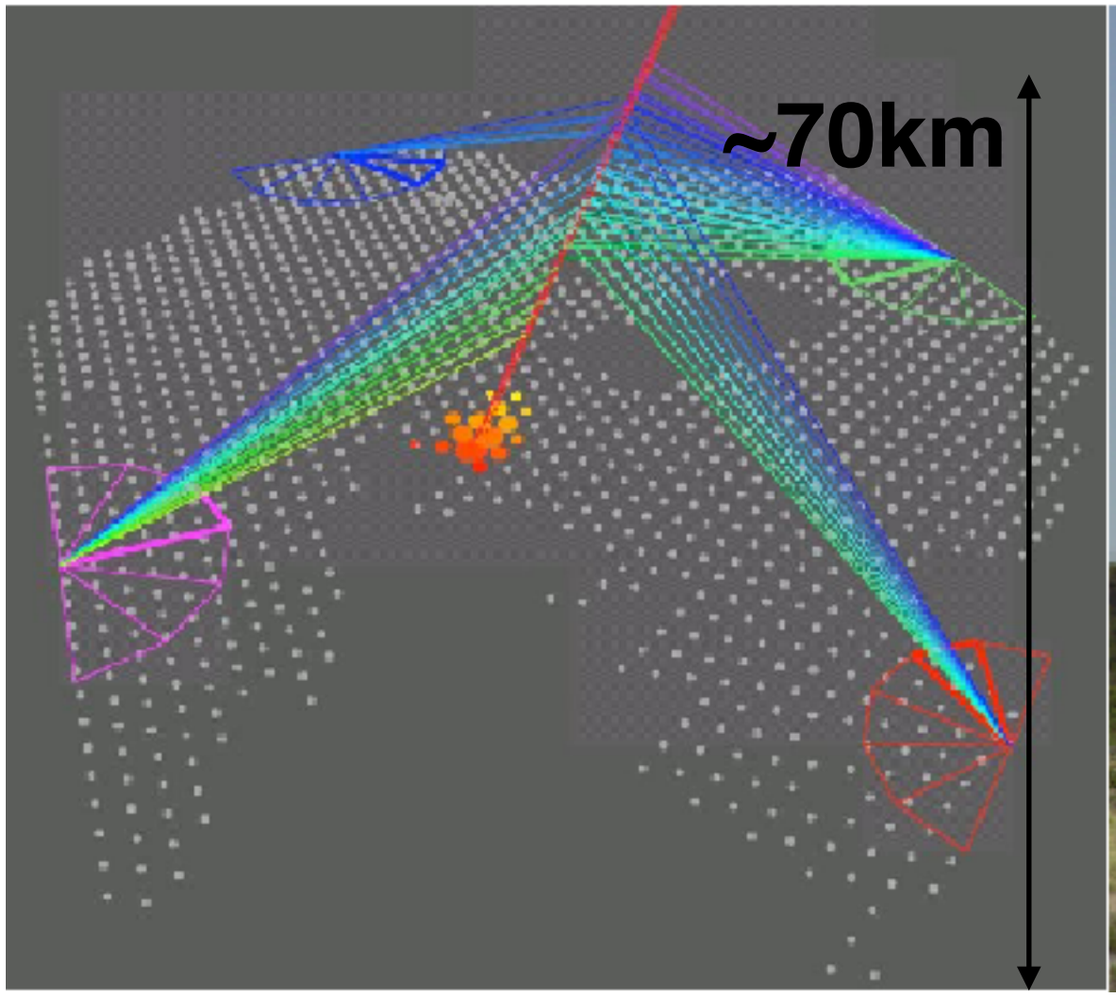


Astroparticules: les messagers de l'univers…

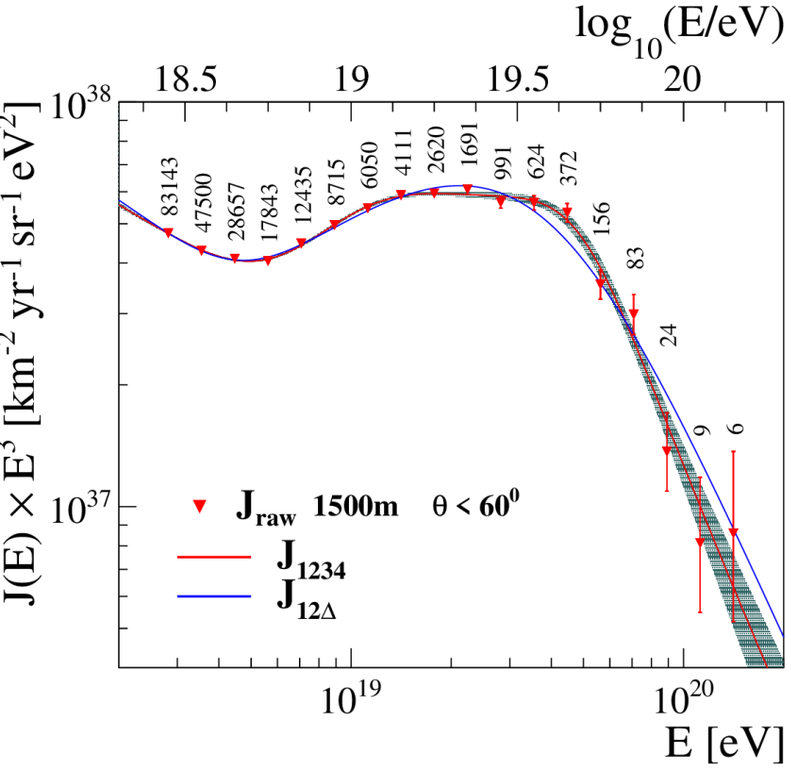
Astroparticules: les messagers de l’univers…

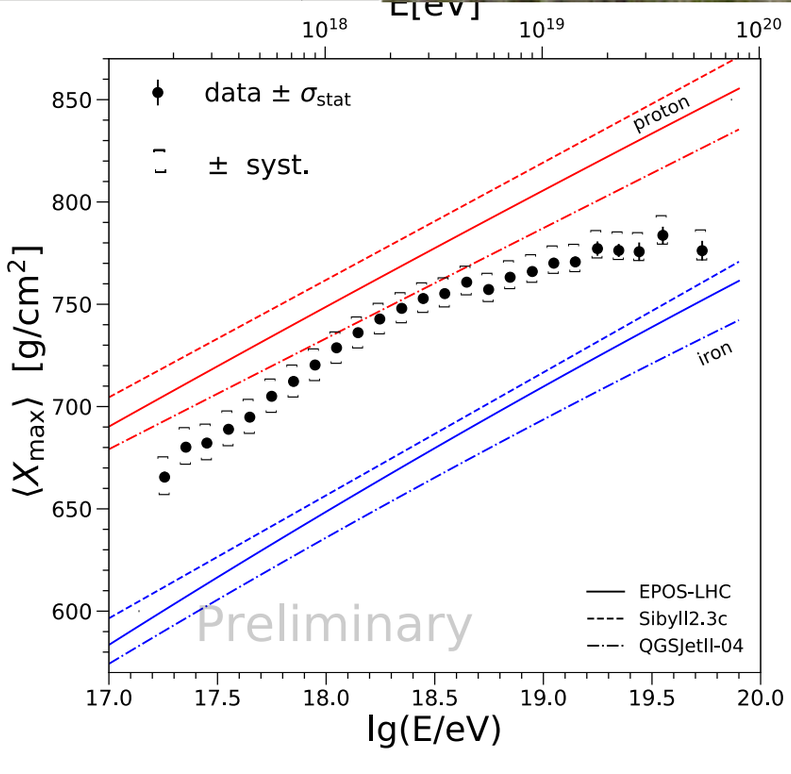

Flux of Cosmic Rays
1 particle per m2 – second
Knee
(1 particle per m2 – year)
Ankle
(1 particle per km2 – year)
Flux (m2 sr s Gev)-1
Energy (eV)
10^4
10^-1
10^-6
10^-11
10^-16
10^-21
10^-26
10^9
10^12
10^15
10^18
10^21
(source: Swordy – U.Chicago)

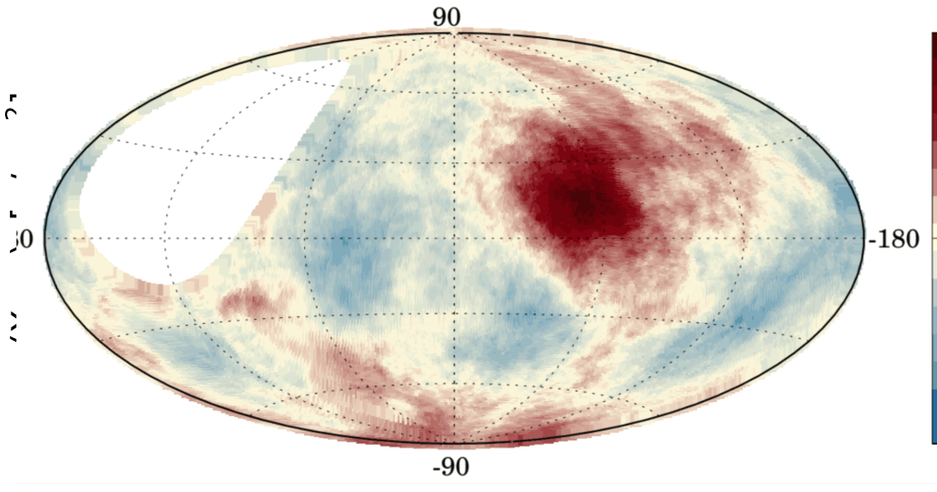
Cosmic rays


~70km

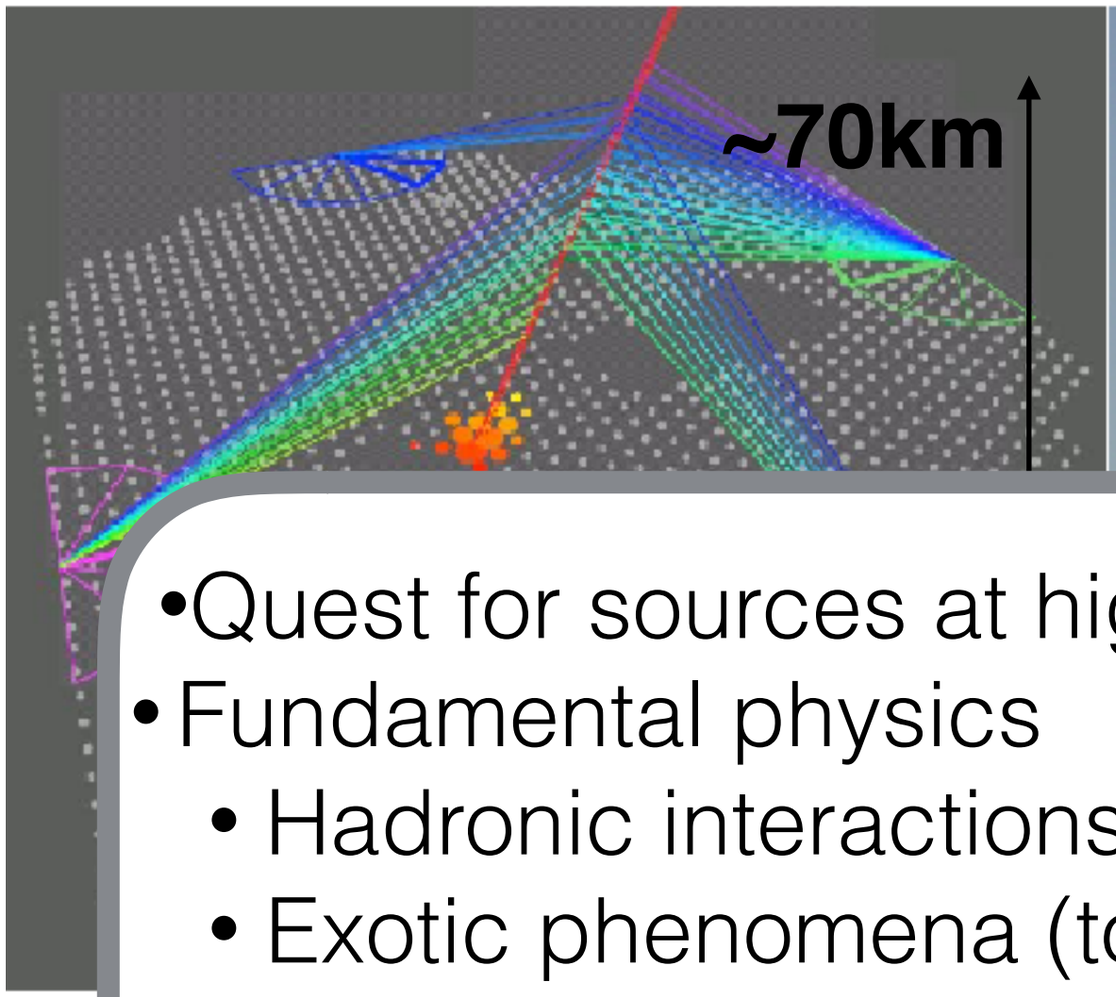

Observatoire Pierre Auger

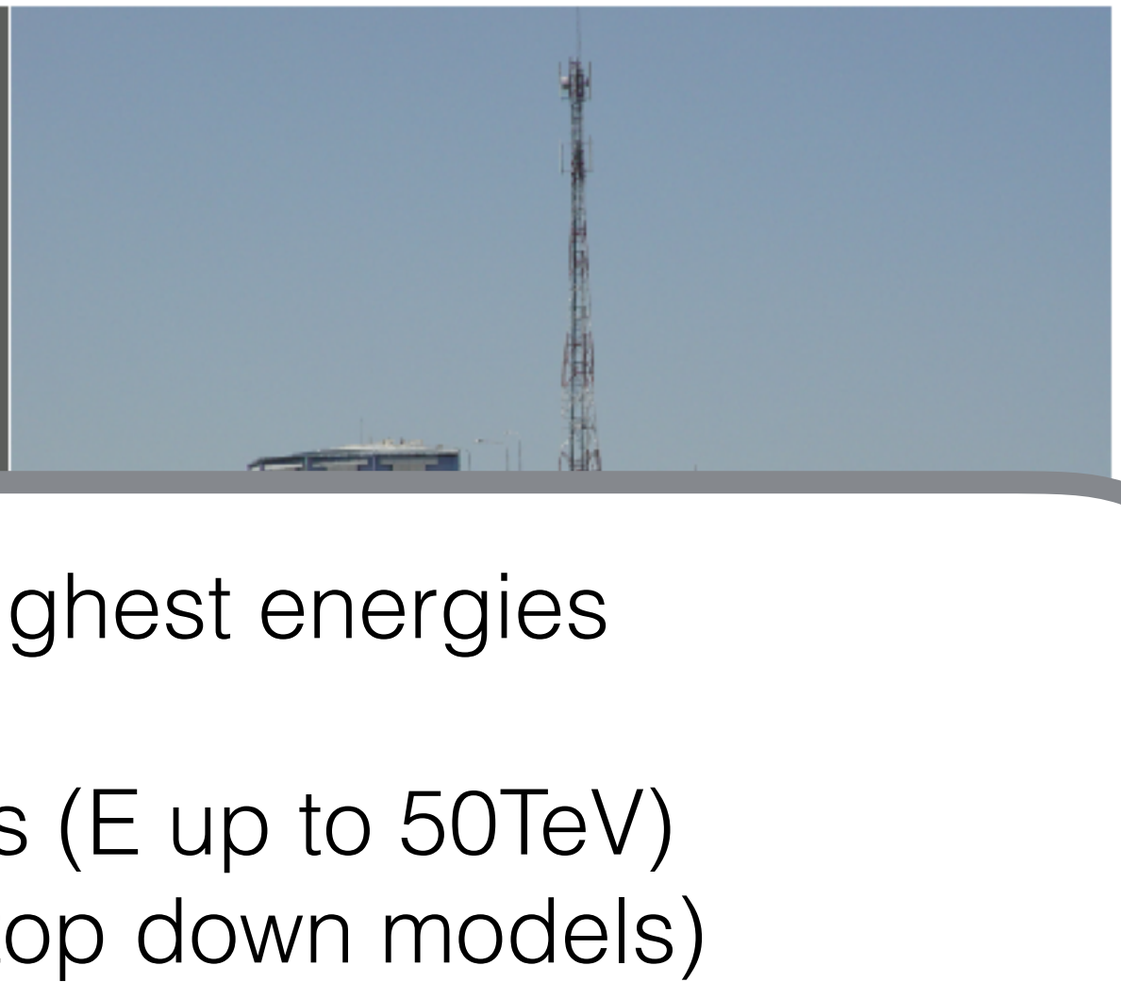

log10(E/eV)
18.5
19
19.5
20
10^38
10^37
J(E) × E^3 [km^-2 yr^-1 sr^-1 eV^2]
83143
47500
28657
17843
12435
8715
6050
4111
2620
1691
991
624
372
156
83
24
9
6
J_raw 1500m θ < 60^0
J_1234
J_12Δ
10^19
10^20
E [eV]


10^18
10^19
10^20
E[eV]
data ± σ_stat
± syst.
proton
iron
⟨X_max⟩ [g/cm^2]
850
800
750
700
650
600
Preliminary
EPOS-LHC
Sibyll2.3c
QGSJetII-04
17.0
17.5
18.0
18.5
19.0
19.5
20.0
lg(E/eV)

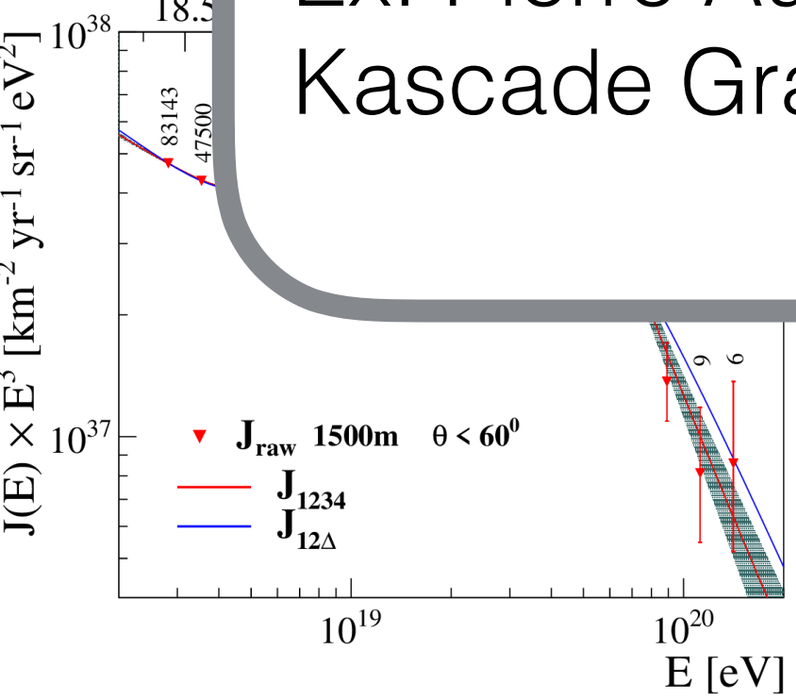

90
-90
-180

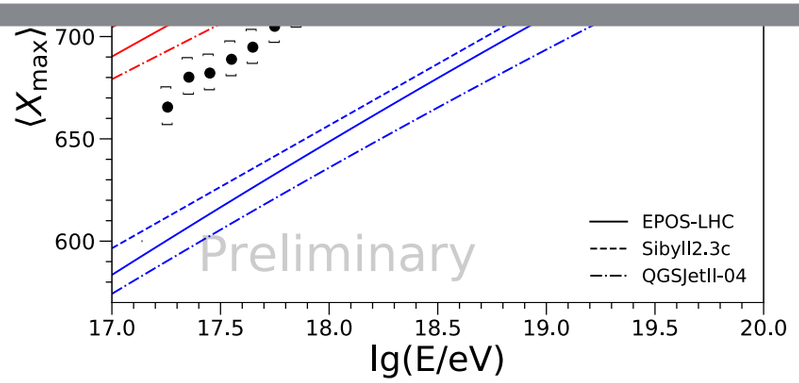
Cosmic rays

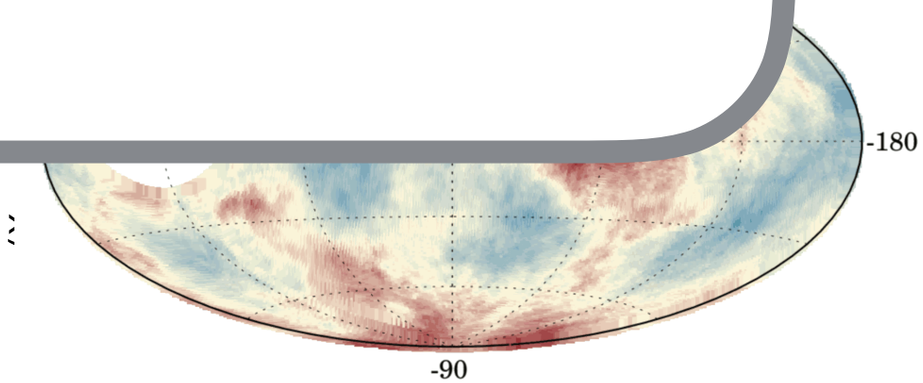




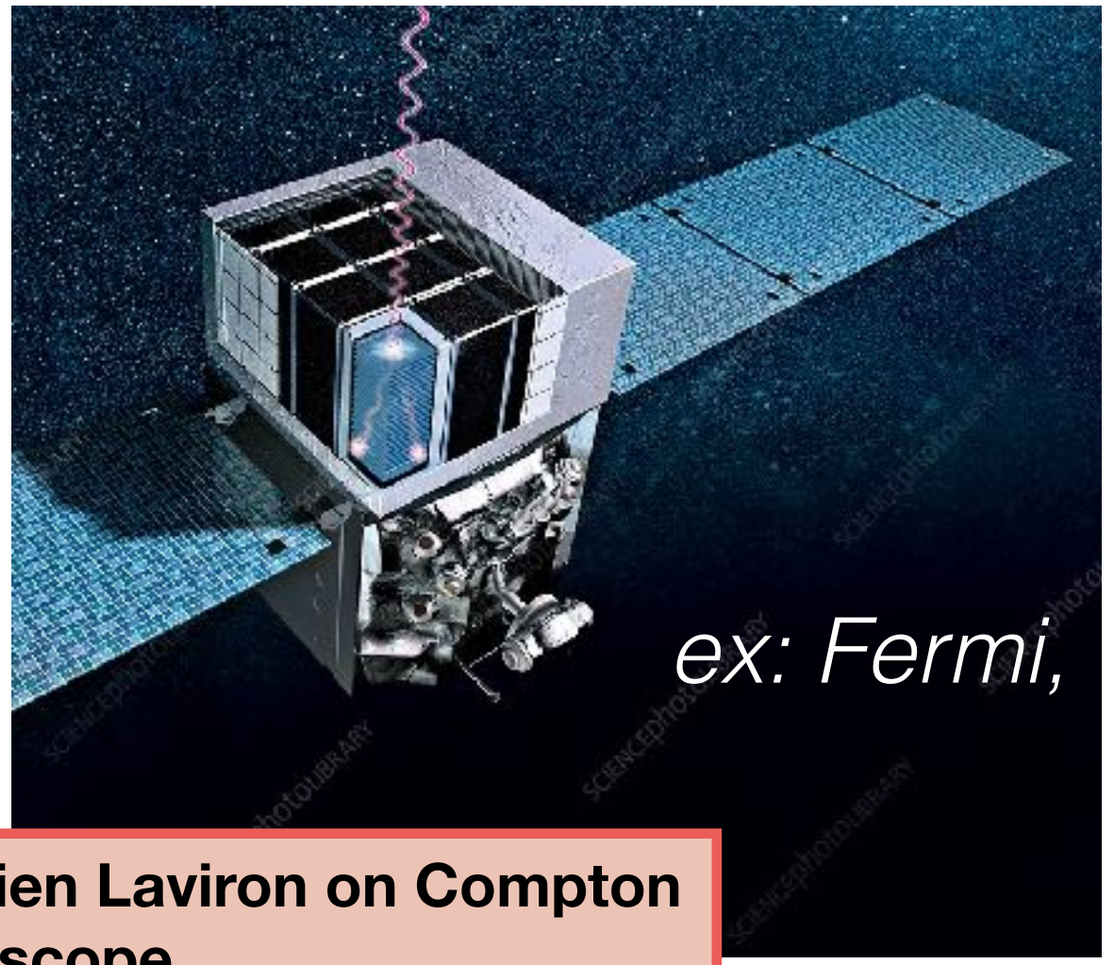
- Quest for sources at highest energies
- Fundamental physics
  - Hadronic interactions (E up to 50TeV)
  - Exotic phenomena (top down models)
- Ex: Pierre Auger Observatory, Telescope Array, Kascade Grande, LHASSO



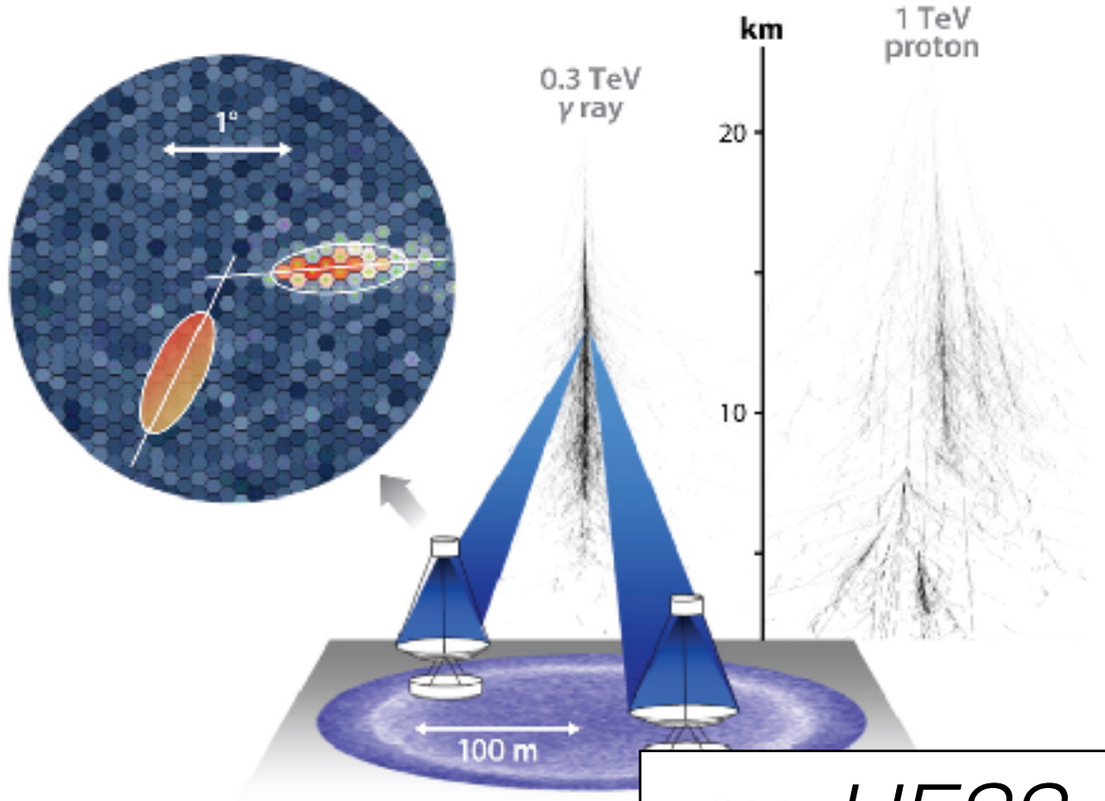




Gamma rays

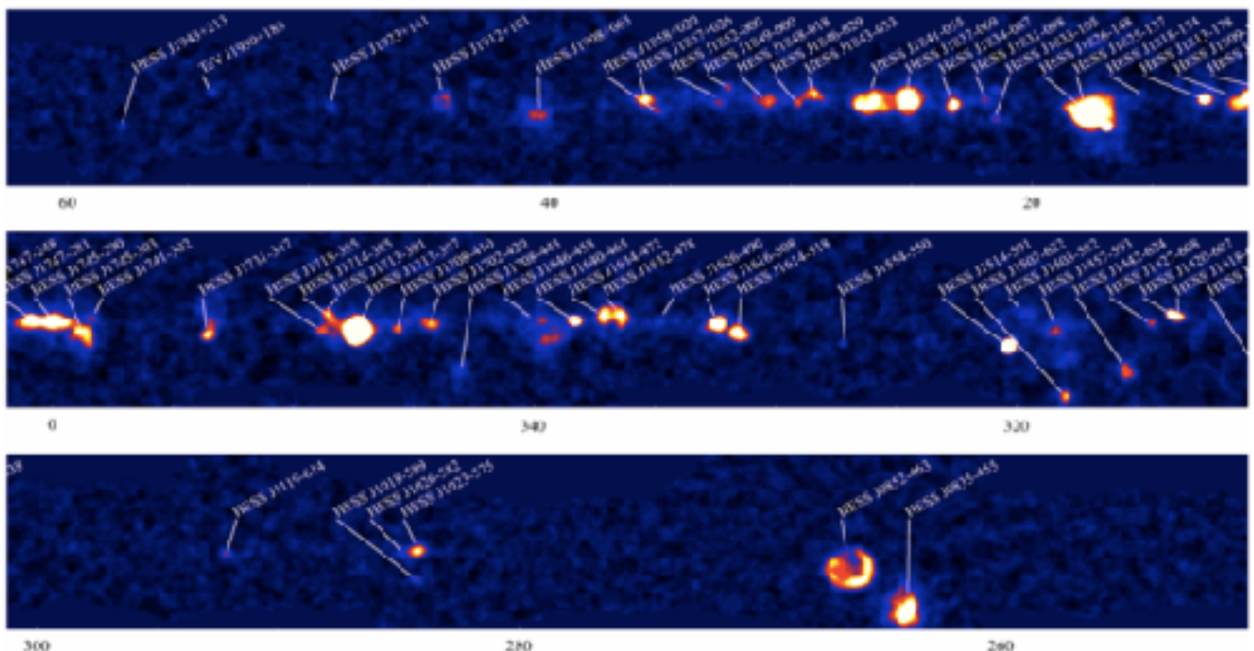


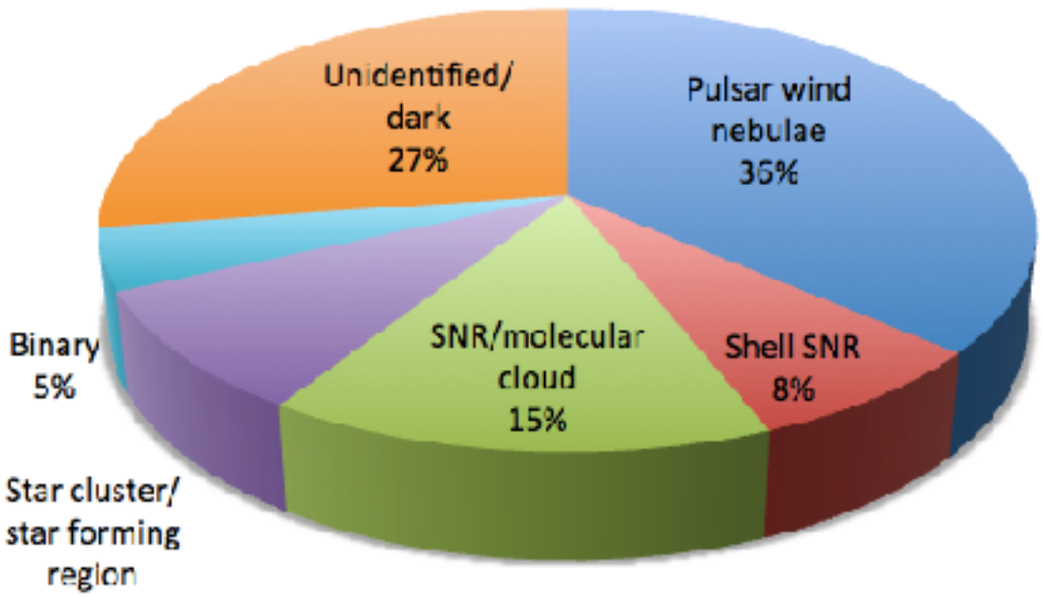
Adrien Laviron on Compton telescope



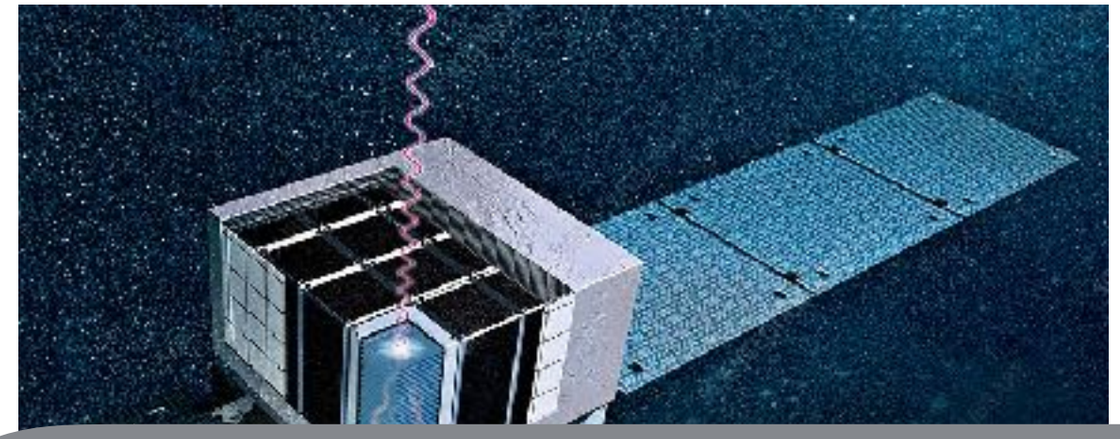
Hinton JA, Hofmann W. 2009. Annu. Rev. Astron. Astrophys.

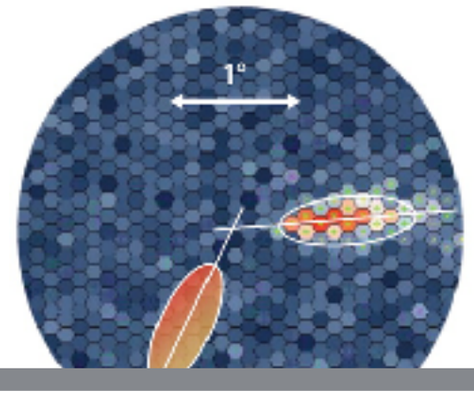
ex: HESS, Magic, CTA

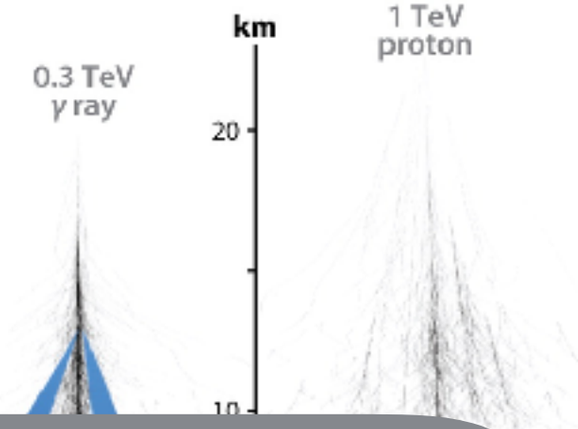




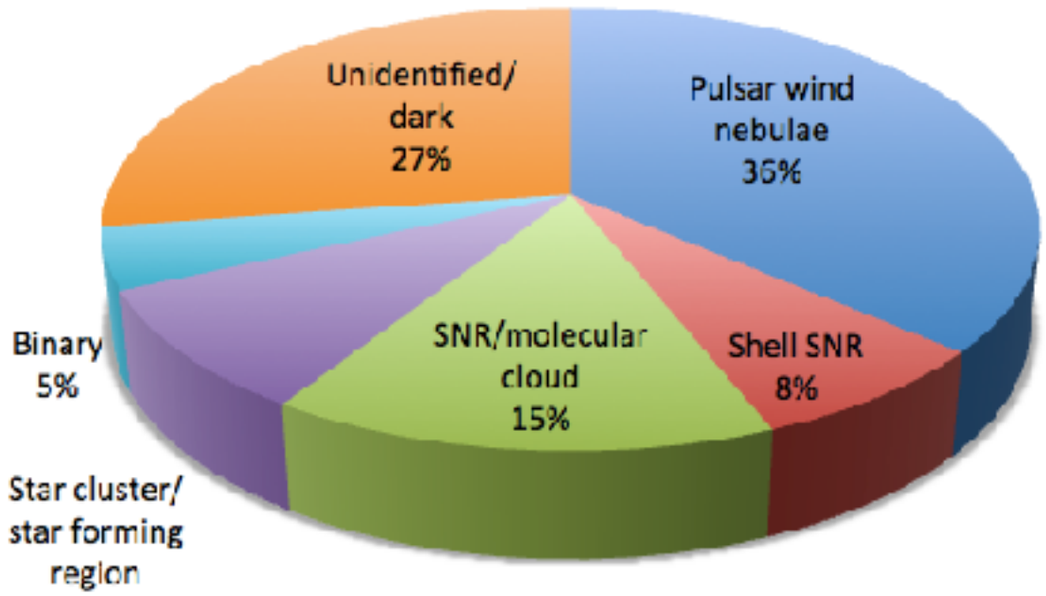
Gamma rays





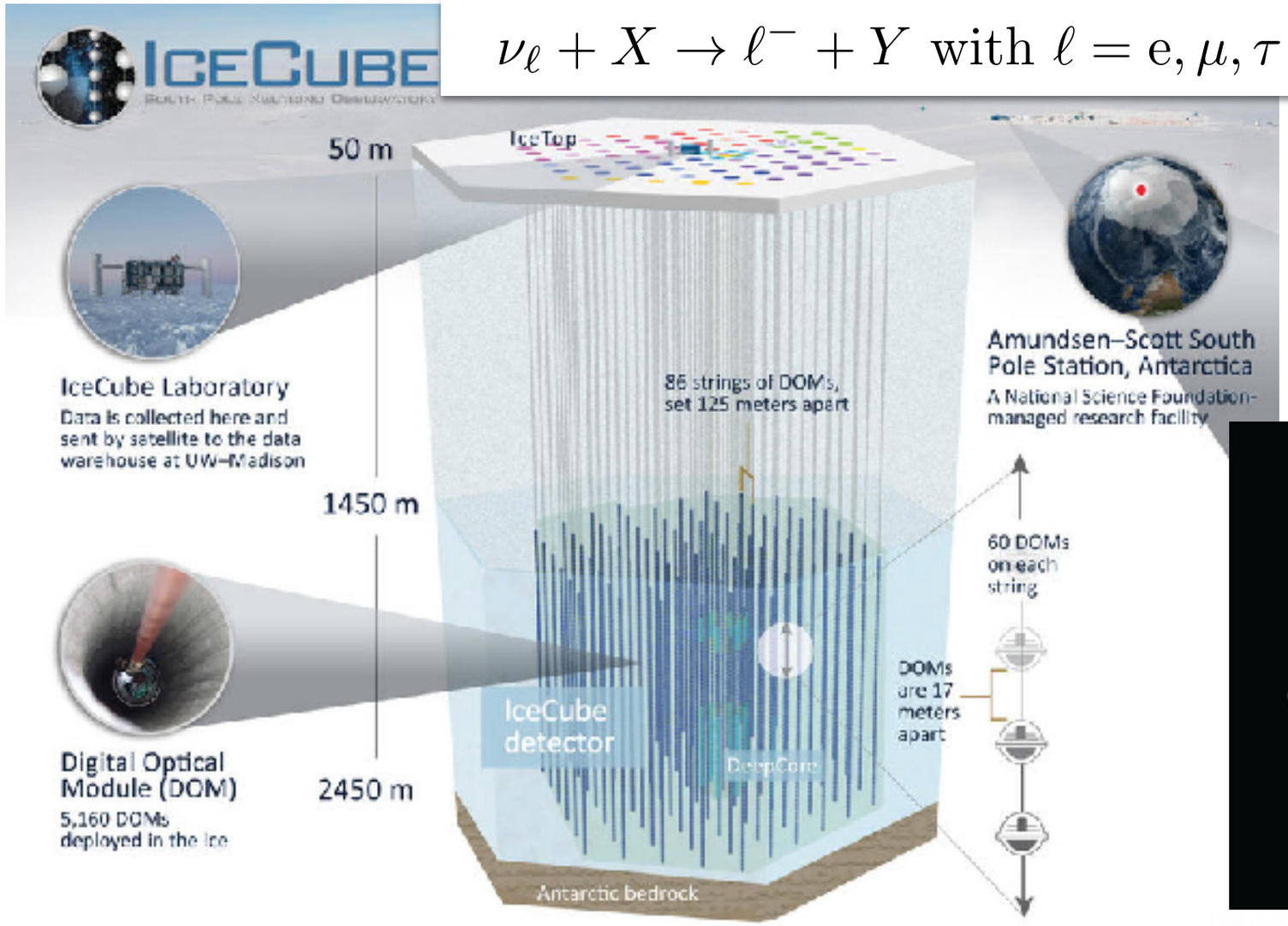


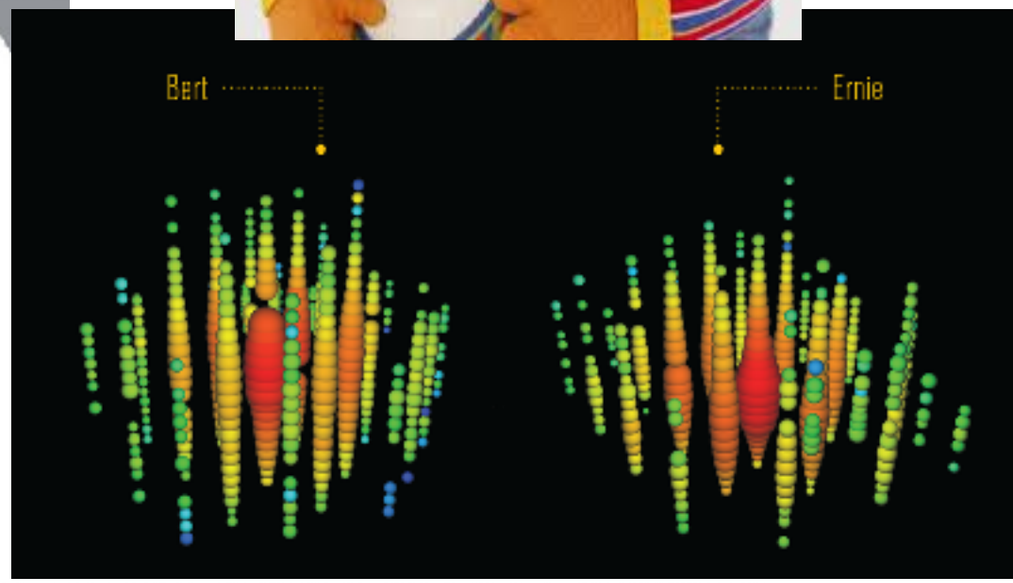
- Sources characterisation / Acceleration mechanism
- Diffuse spectrum of gammas
- Fondamental physics: dark matter, Lorentz invariance test
- Ex: HESS, MAGIC, FERMI, *CTA*

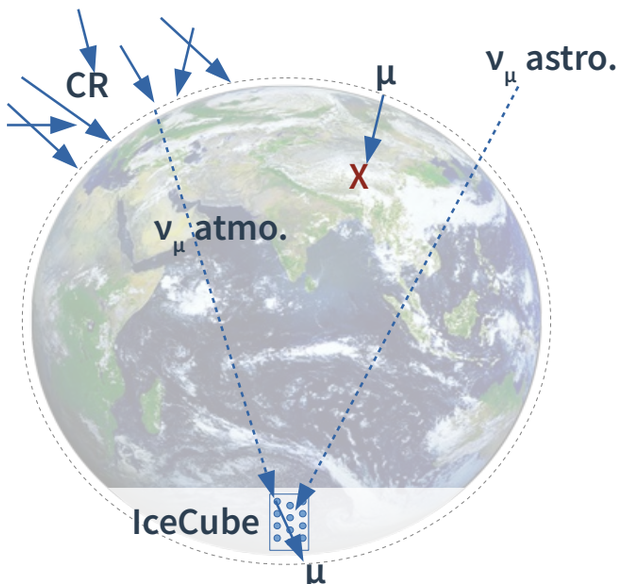


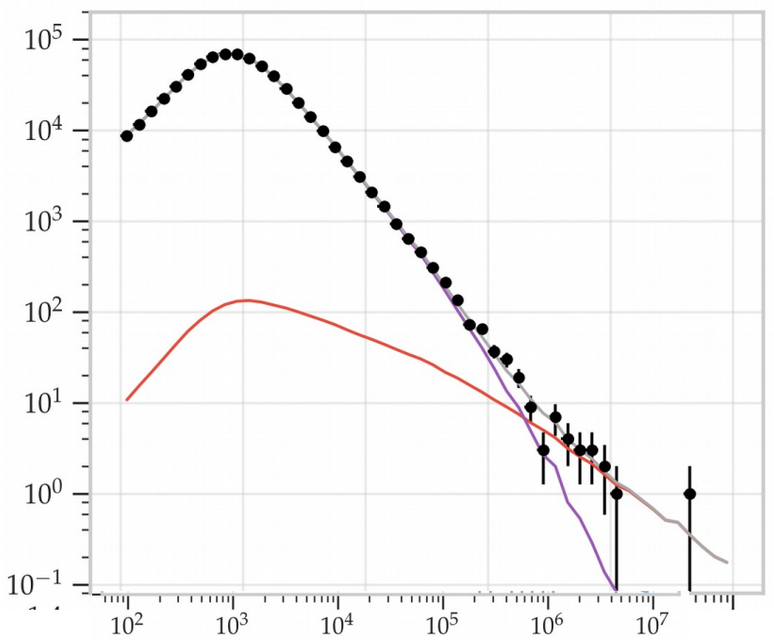
Neutrino

$$\nu_\ell + X \to \ell^- + Y \text{ with } \ell = \mathrm{e}, \mu, \tau$$

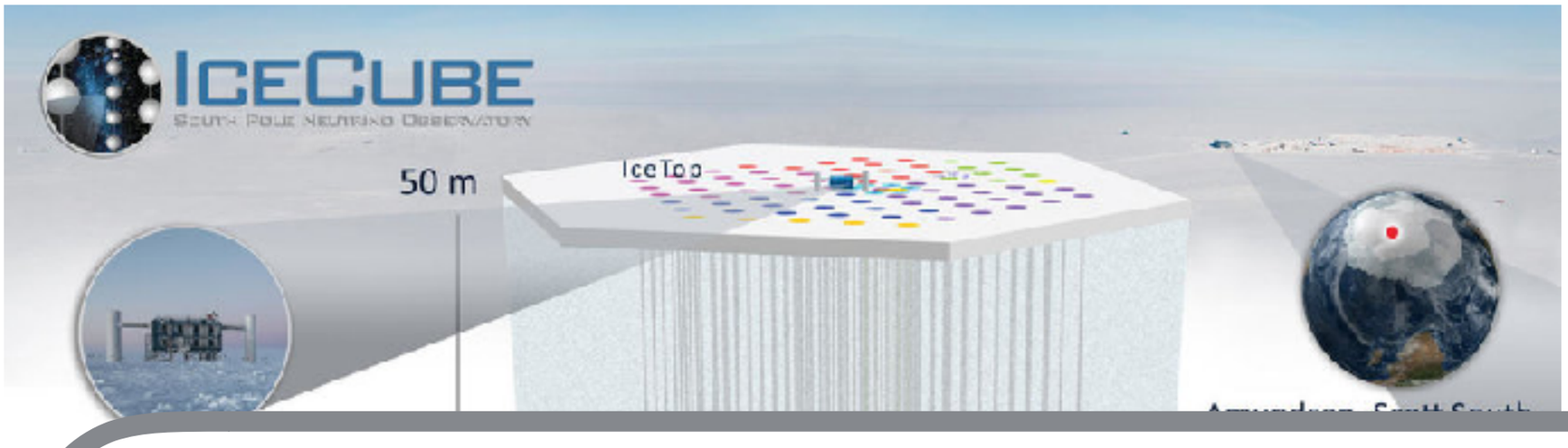




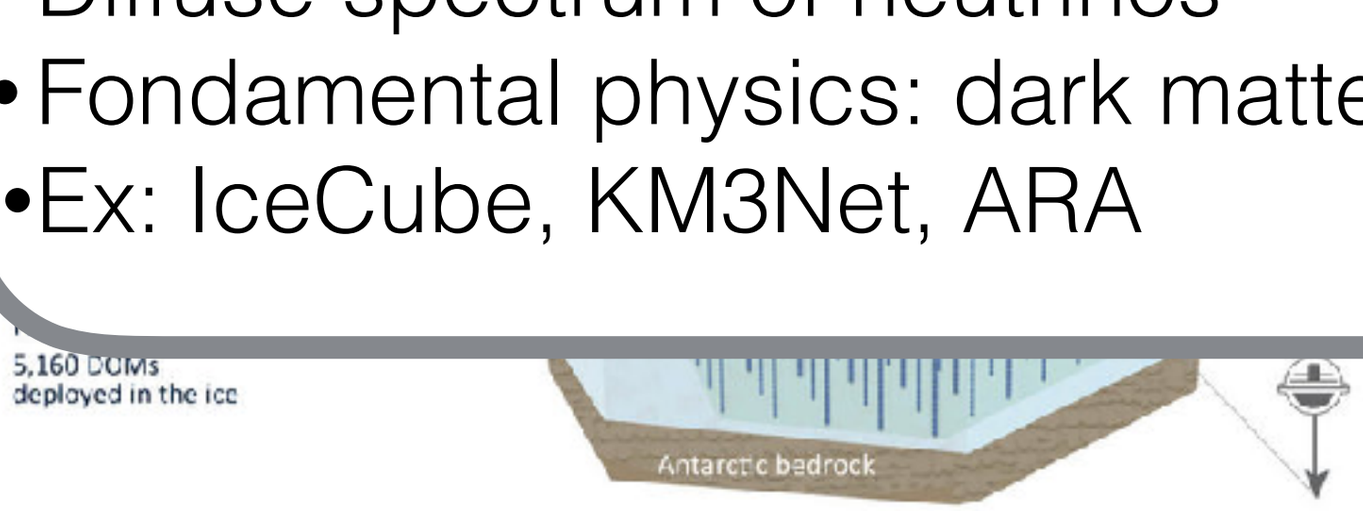


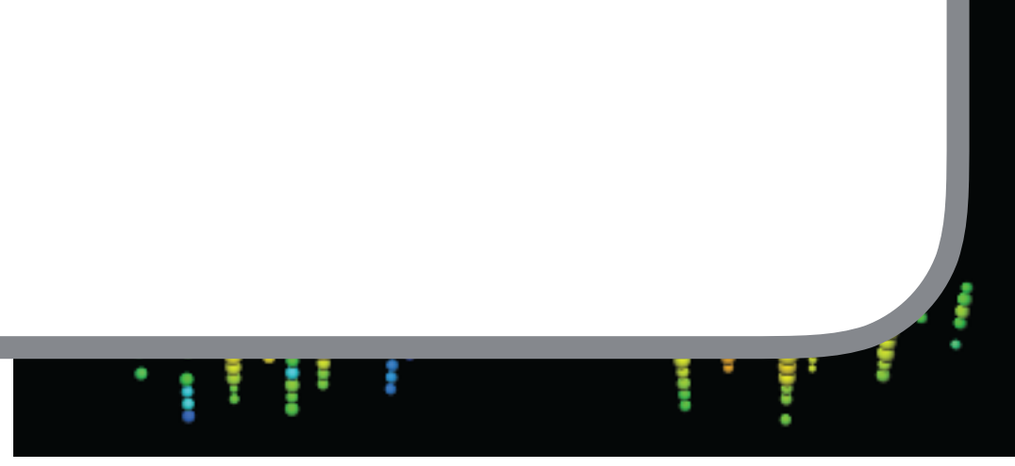


Neutrino



- Sources characterisation / Acceleration mechanism
- Diffuse spectrum of neutrinos
- Fondamental physics: dark matter
- Ex: IceCube, KM3Net, ARA

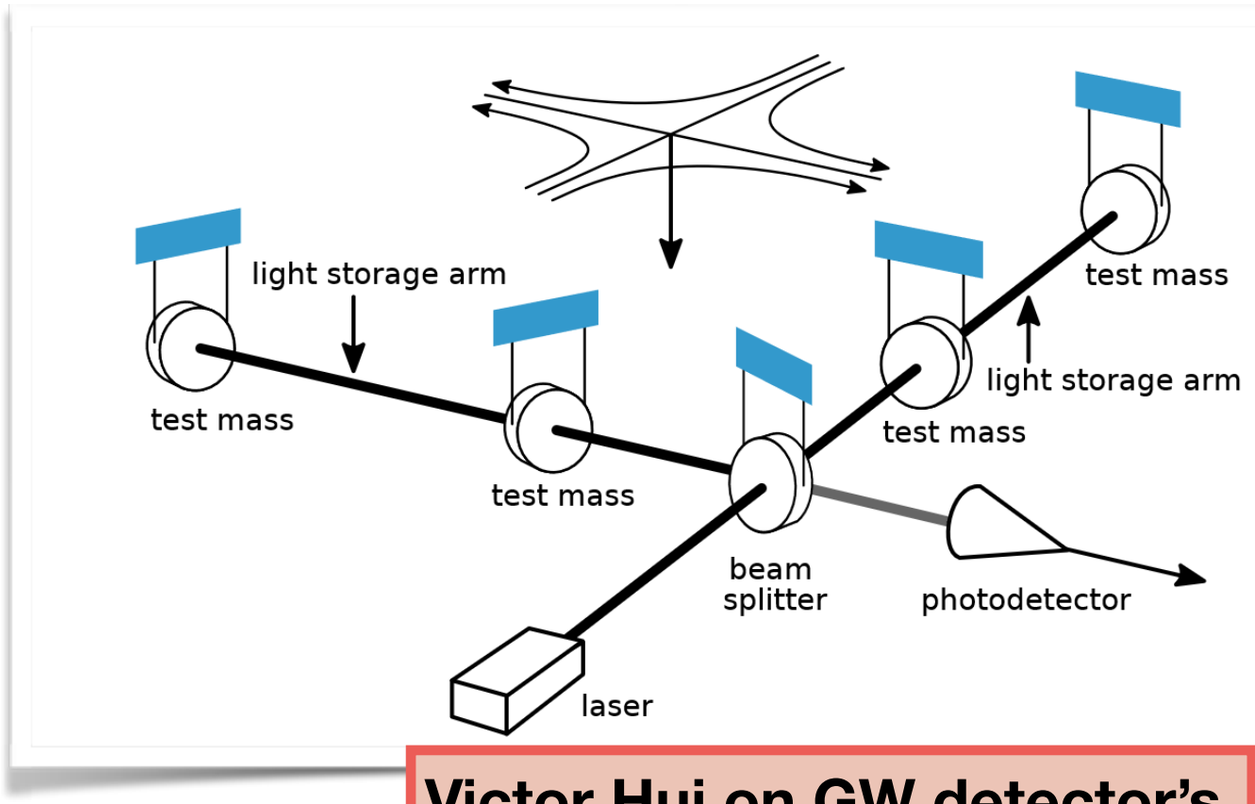




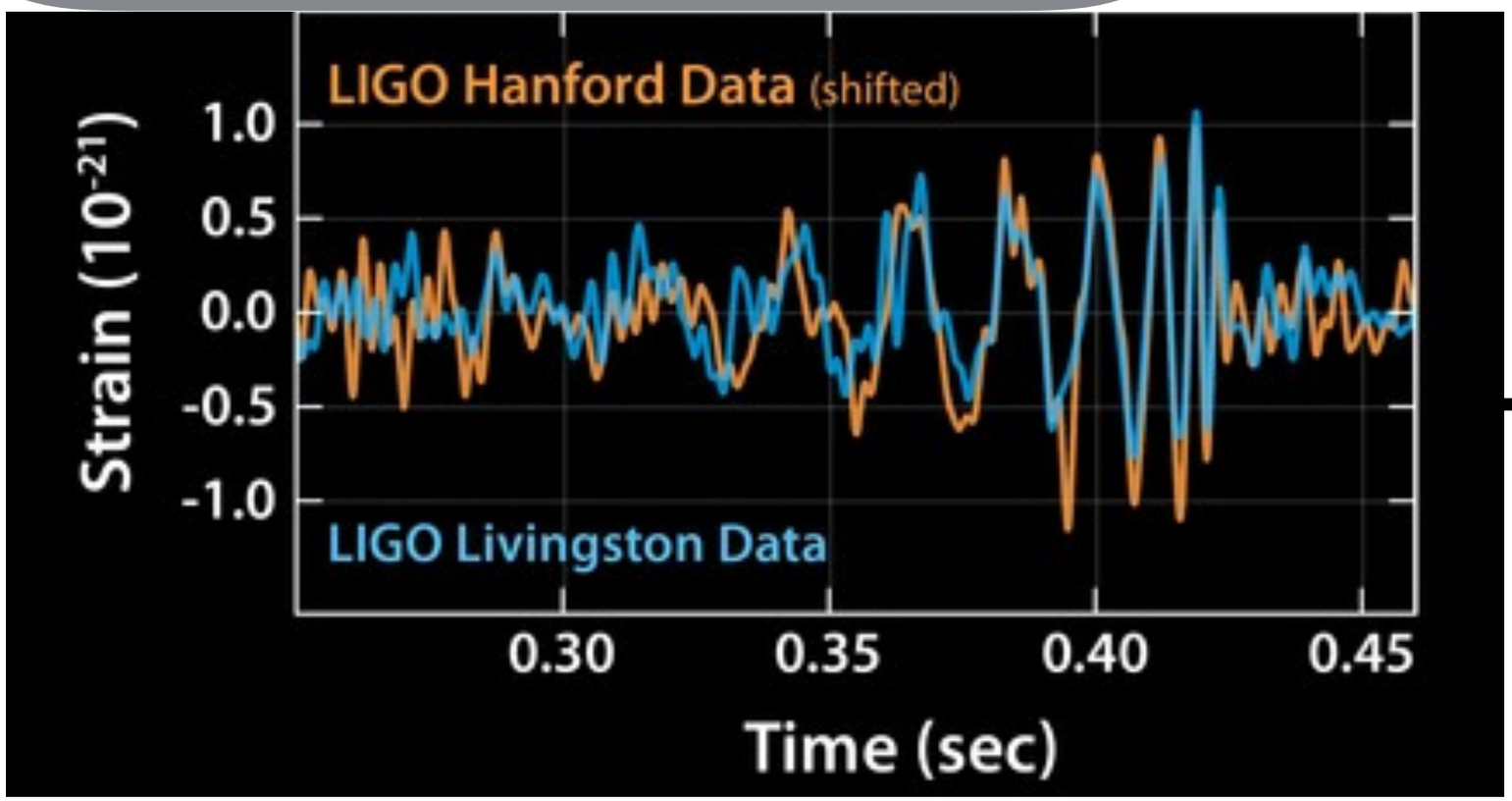
$$\nu_\ell + X \to \ell^- + Y \text{ with } \ell = \mathrm{e}, \mu, \tau$$

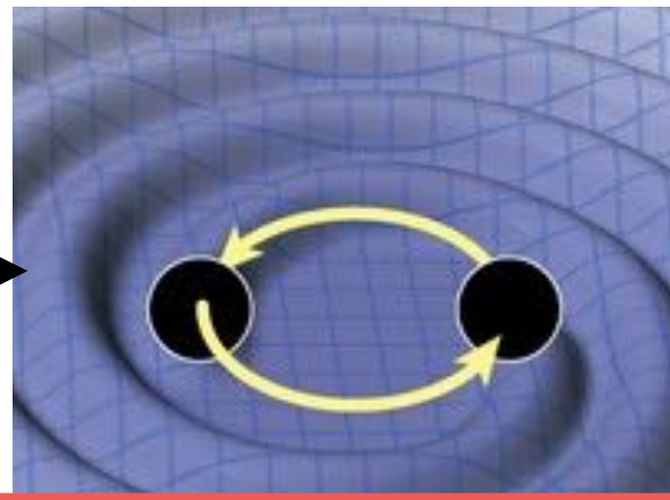
Gravitational waves

- Prevues par la GR
- Signal max pour des systèmes binaires
- Deplacements ~ 10^{-21}



Victor Hui on GW detector's mirror

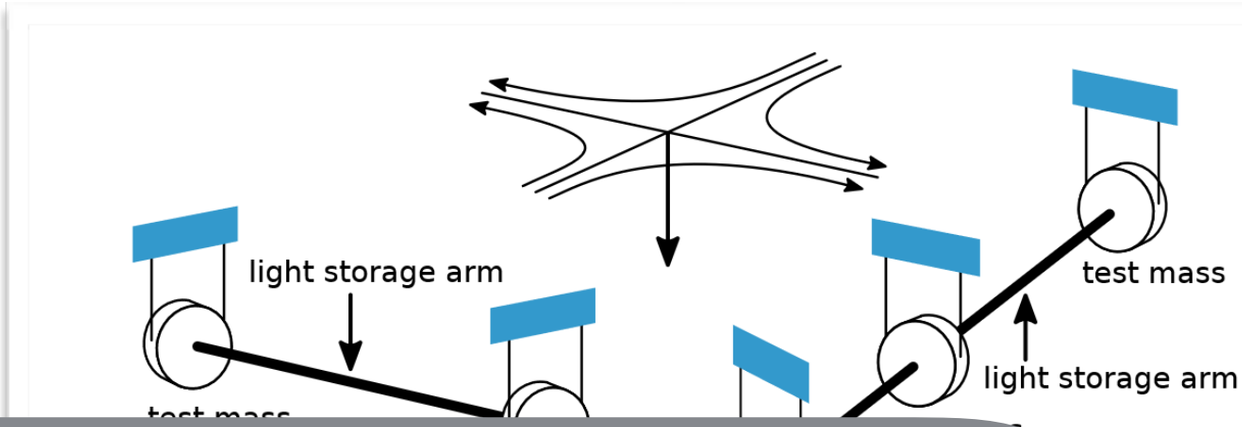




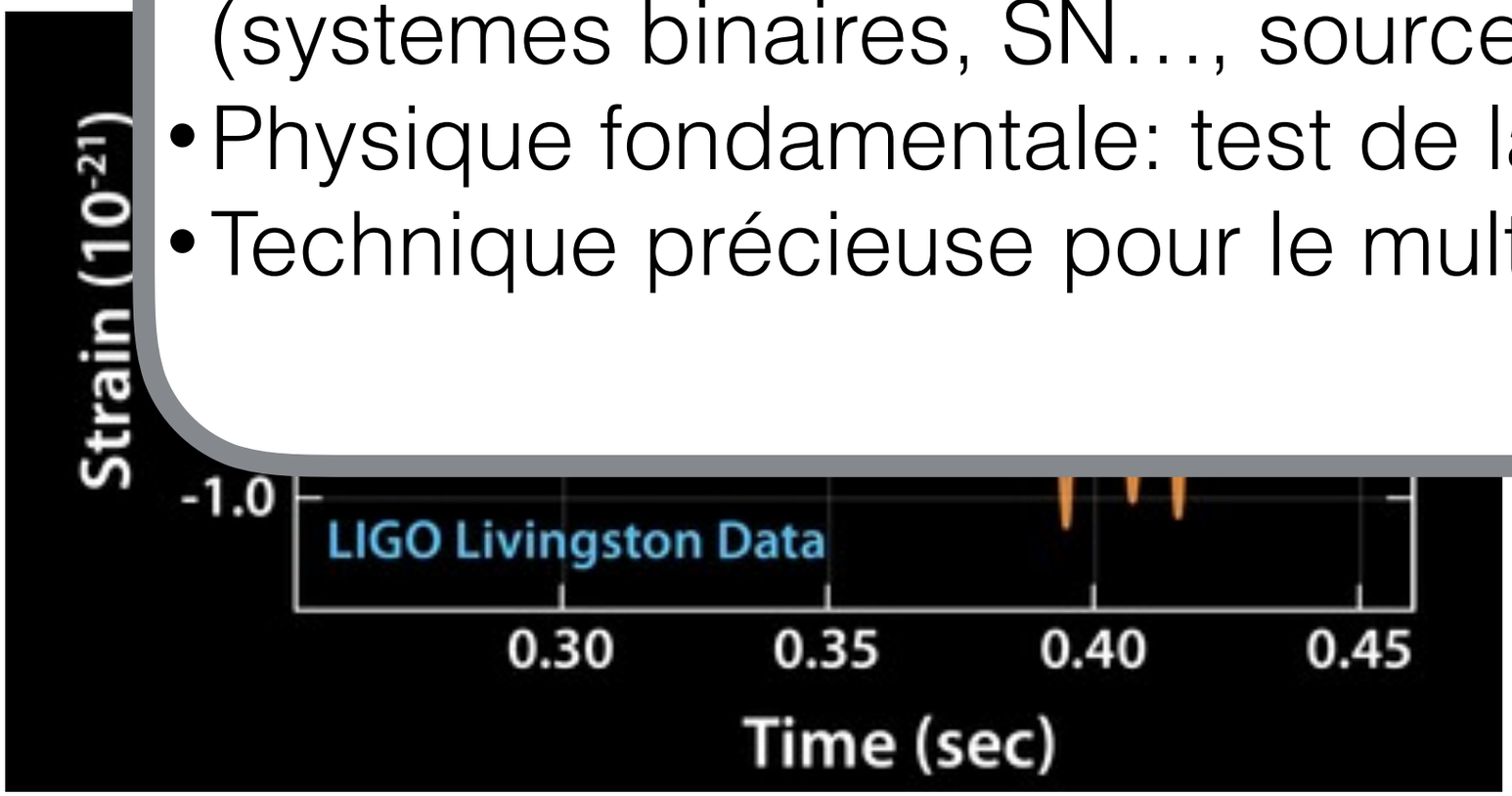
Carole Perigois on GW backgrounds

Gravitational waves

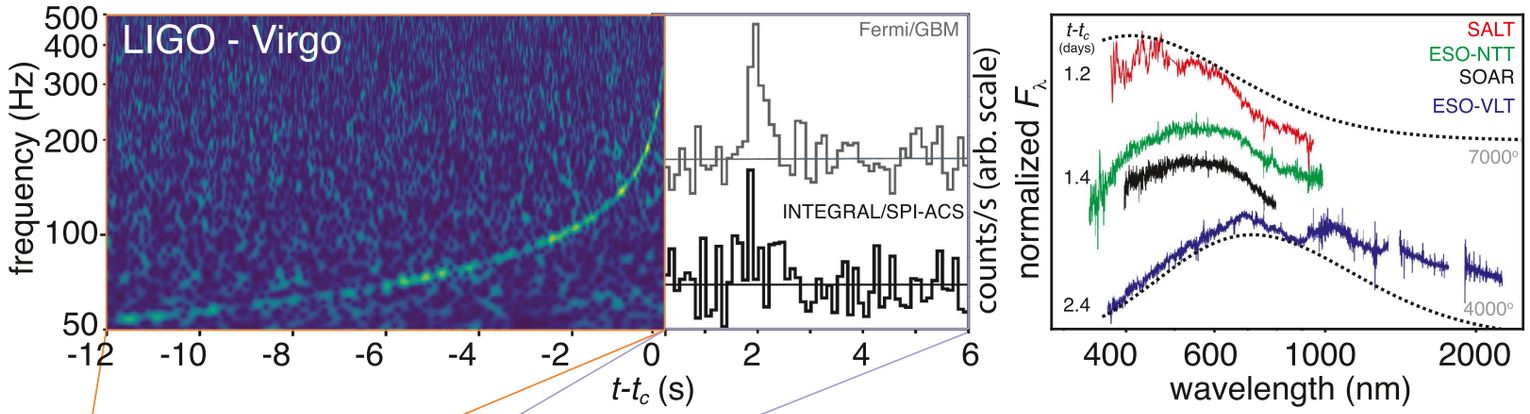
- Prevues par la GR
- Signal max pour des systè
- De

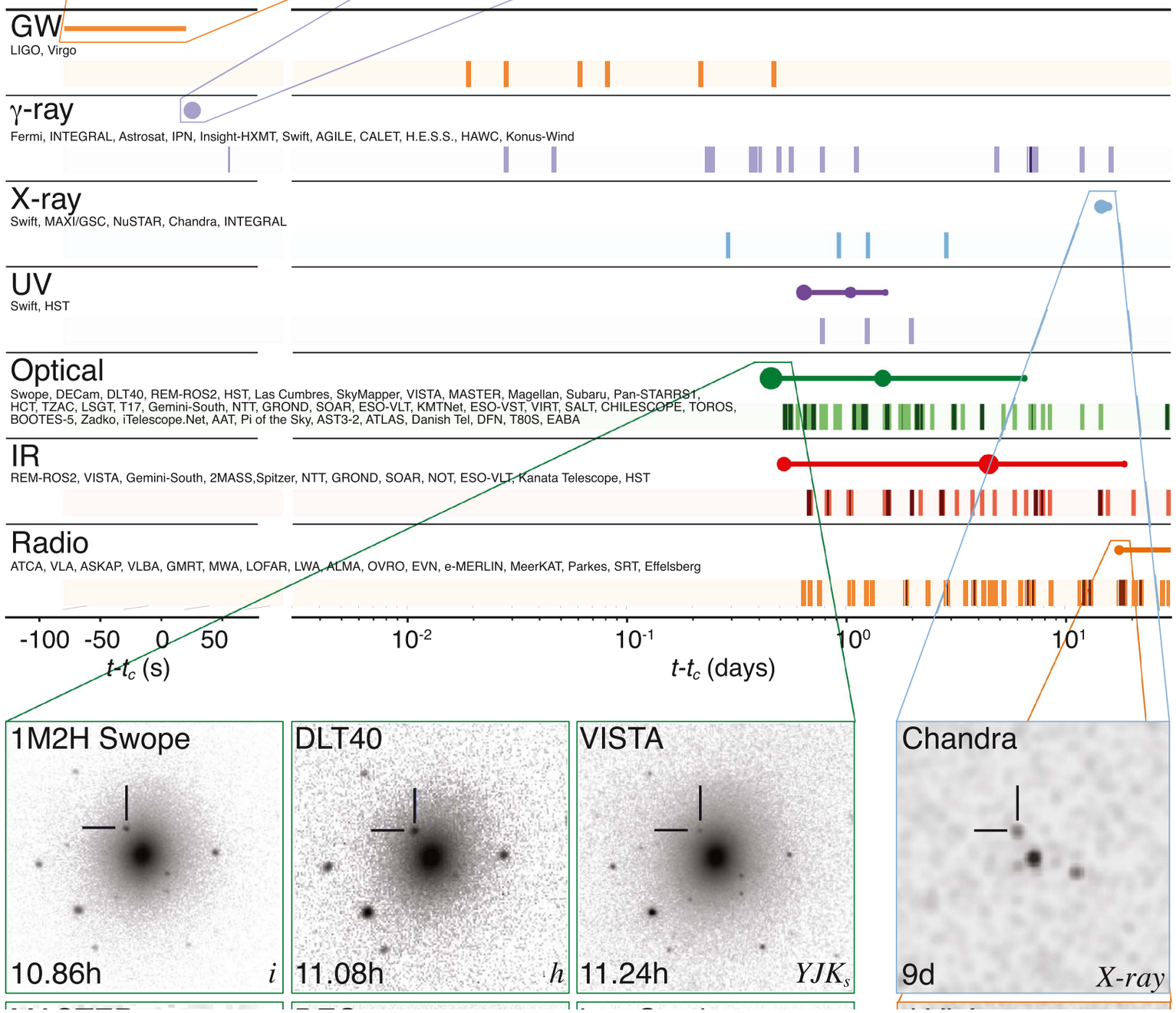


- Nouveau messager
- Caractérisation des phénomènes intenses (systemes binaires, SN…, sources inattendues)
- Physique fondamentale: test de la GR
- Technique précieuse pour le multimessager

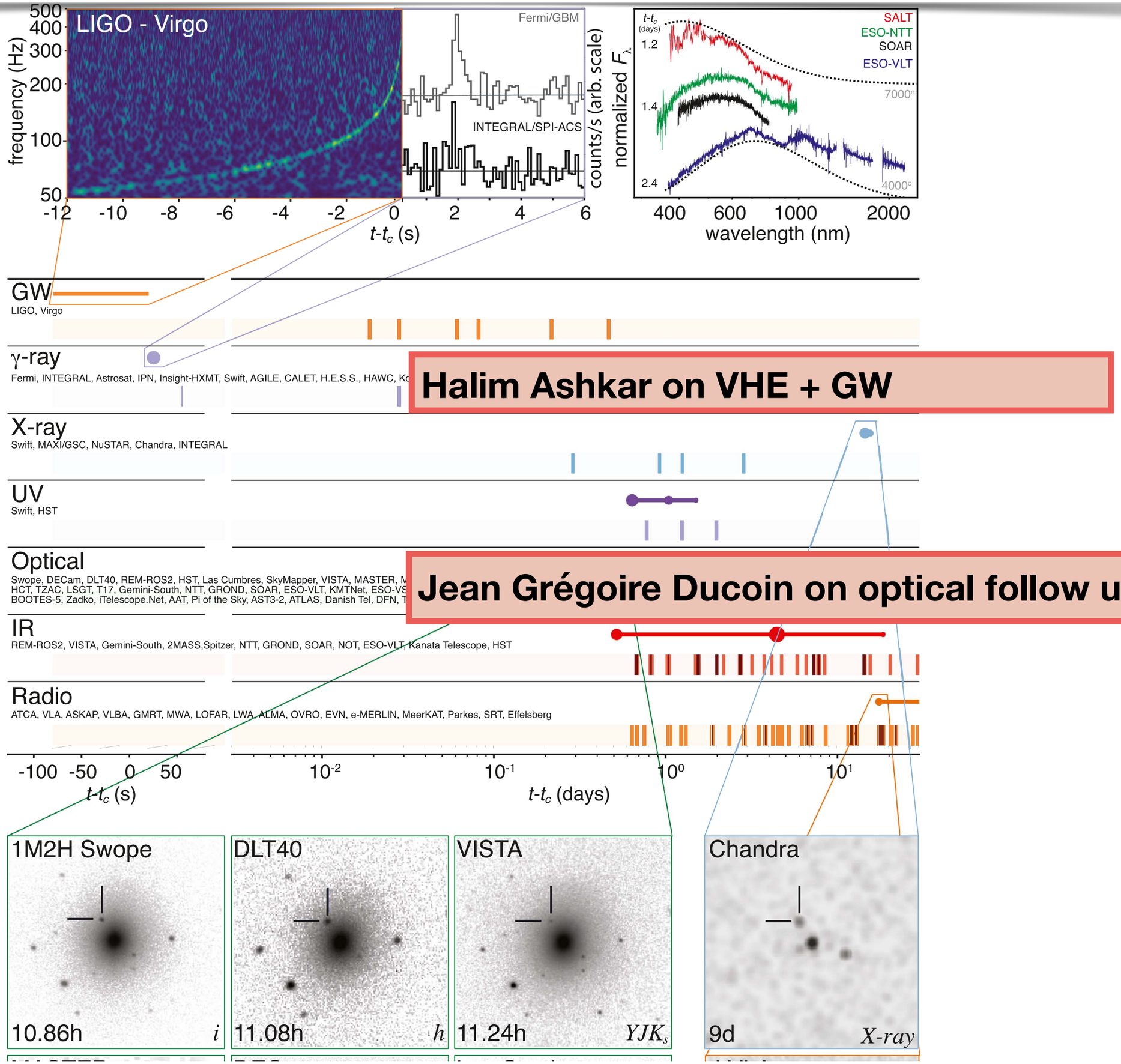


Multi-messenger Observations of a Binary Neutron Star Merger



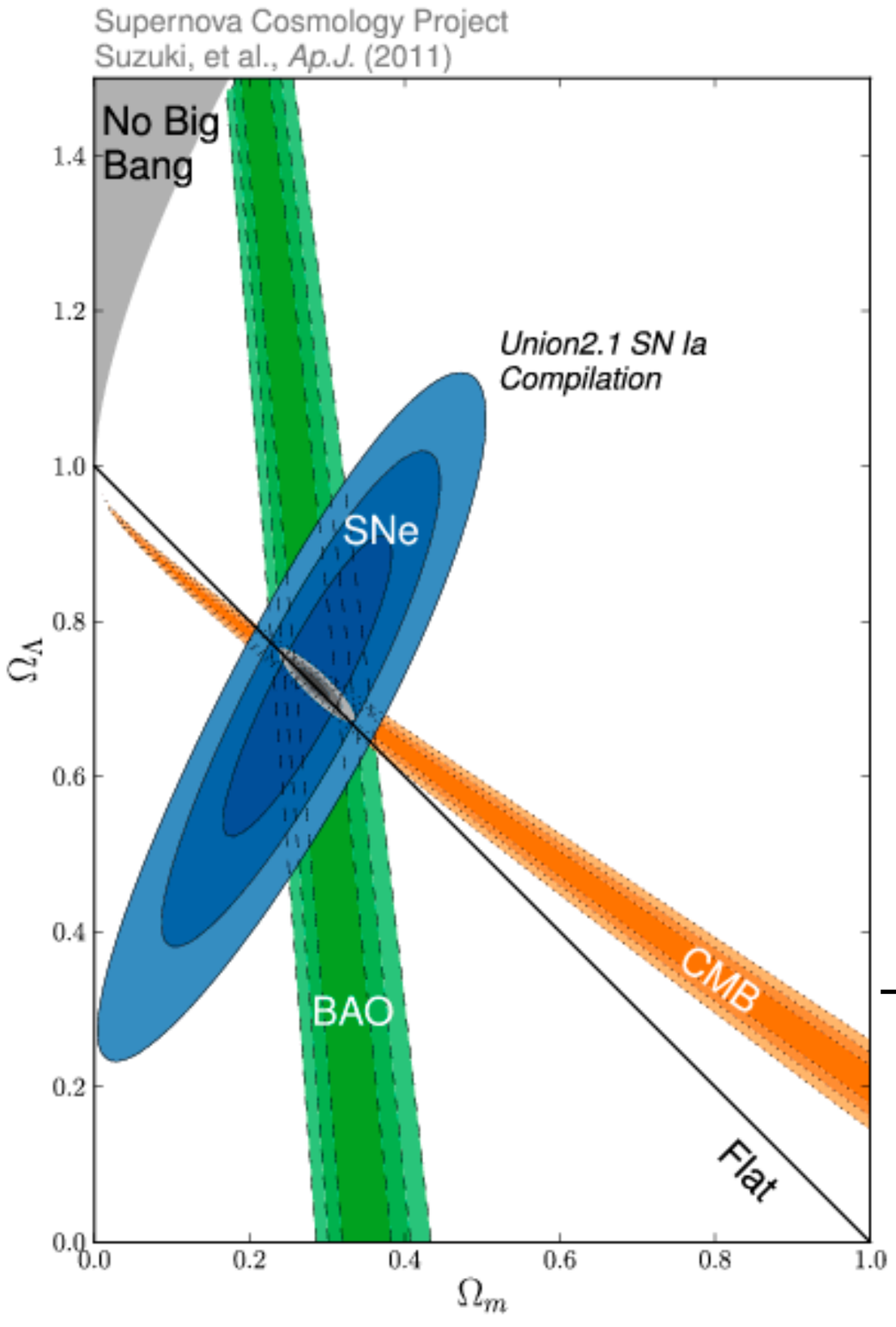


Multi-messenger Observations of a Binary Neutron Star Merger



Halim Ashkar on VHE + GW

Jean Grégoire Ducoin on optical follow up



Matter density ~ 0.3

Star density

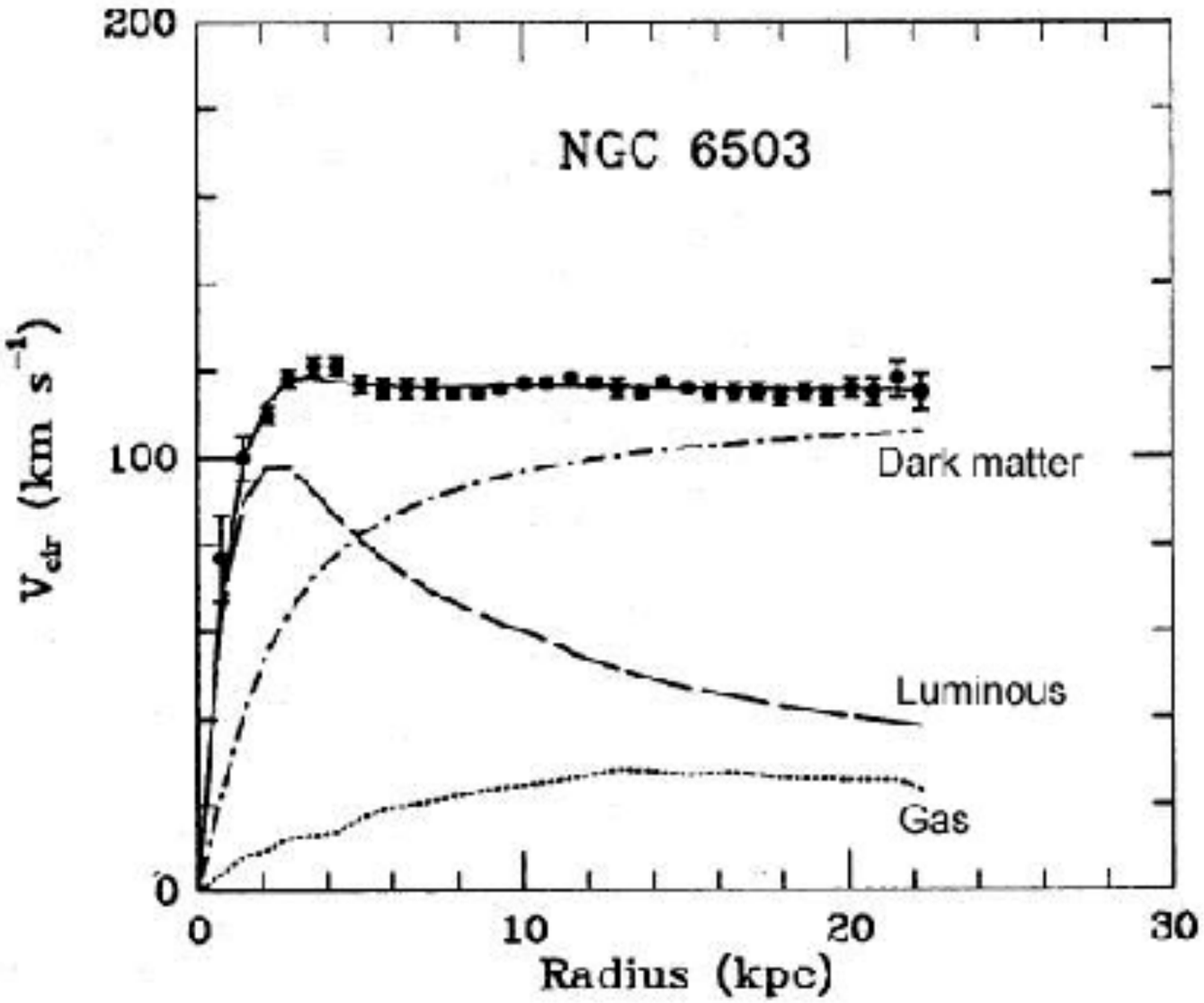
$$\Omega_{\mathbf{stars}} \equiv \frac{\rho_{\mathbf{stars}}}{\rho_{\mathbf{c}}} \simeq 0.005 \rightarrow 0.01$$

Big bang nucleosynthesis

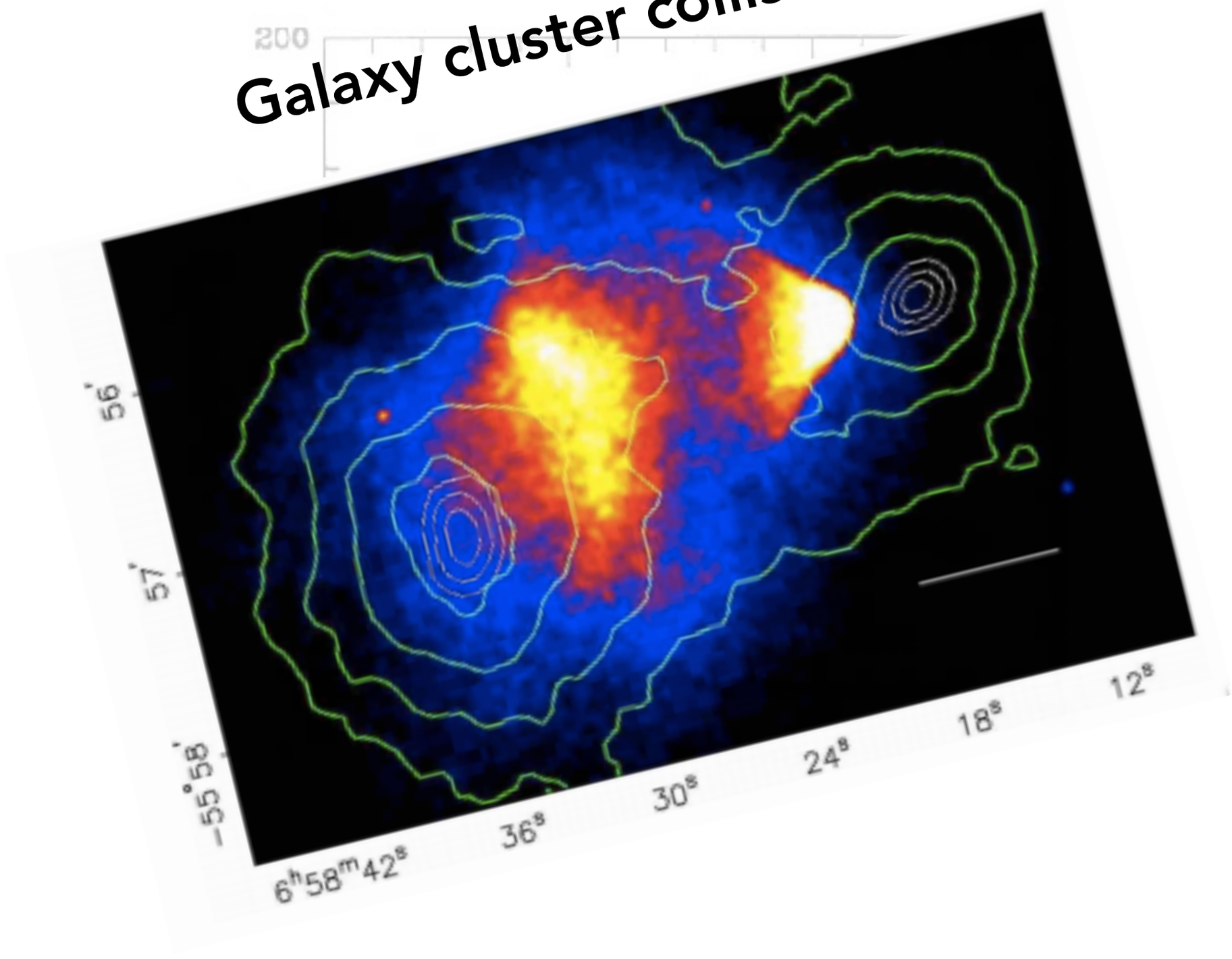
$$0.016 \leq \Omega_{\mathbf{B}} h^2 \leq 0.024\,.$$

→ Lack of baryonic matter

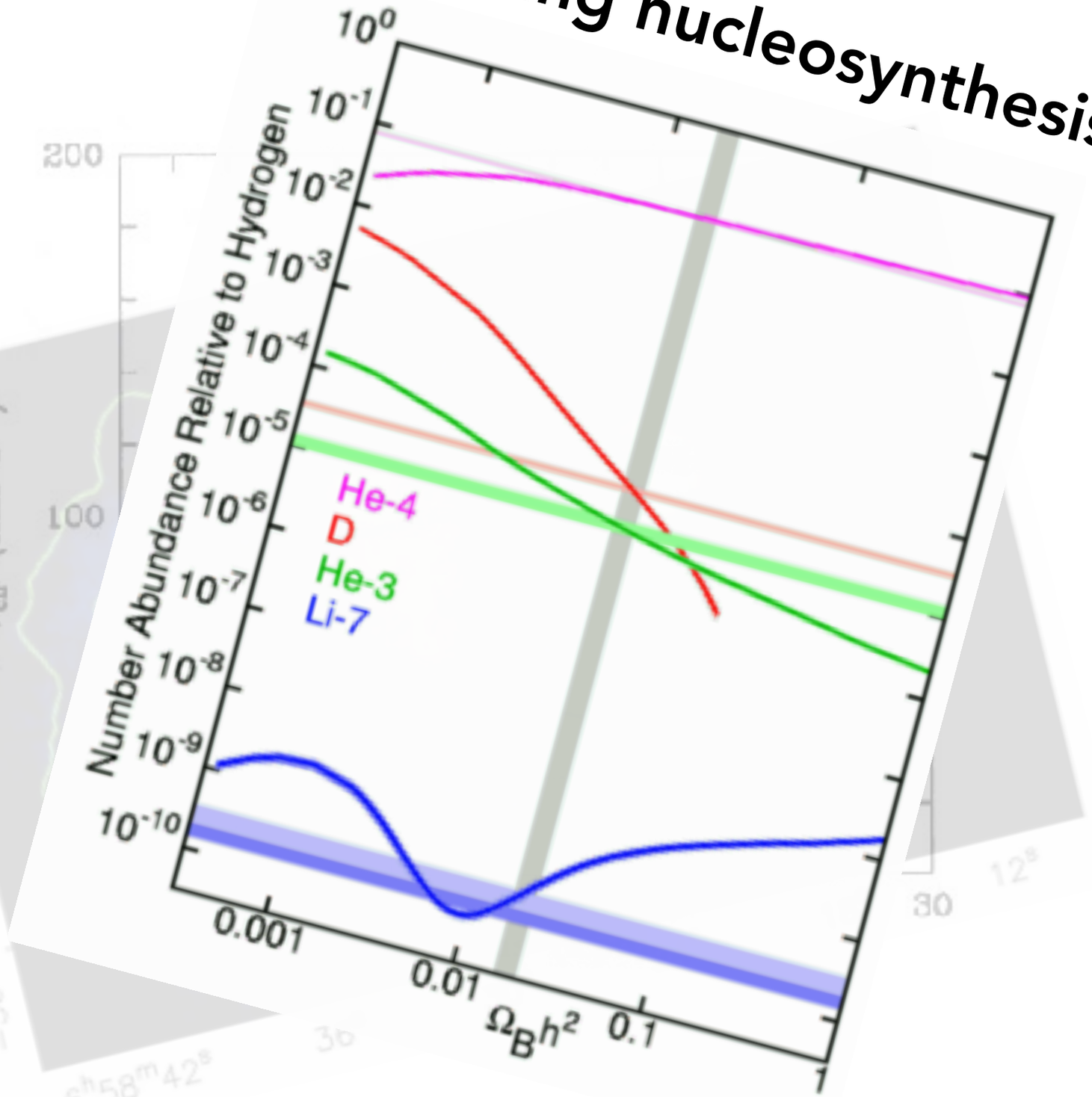
Galaxy rotation curve



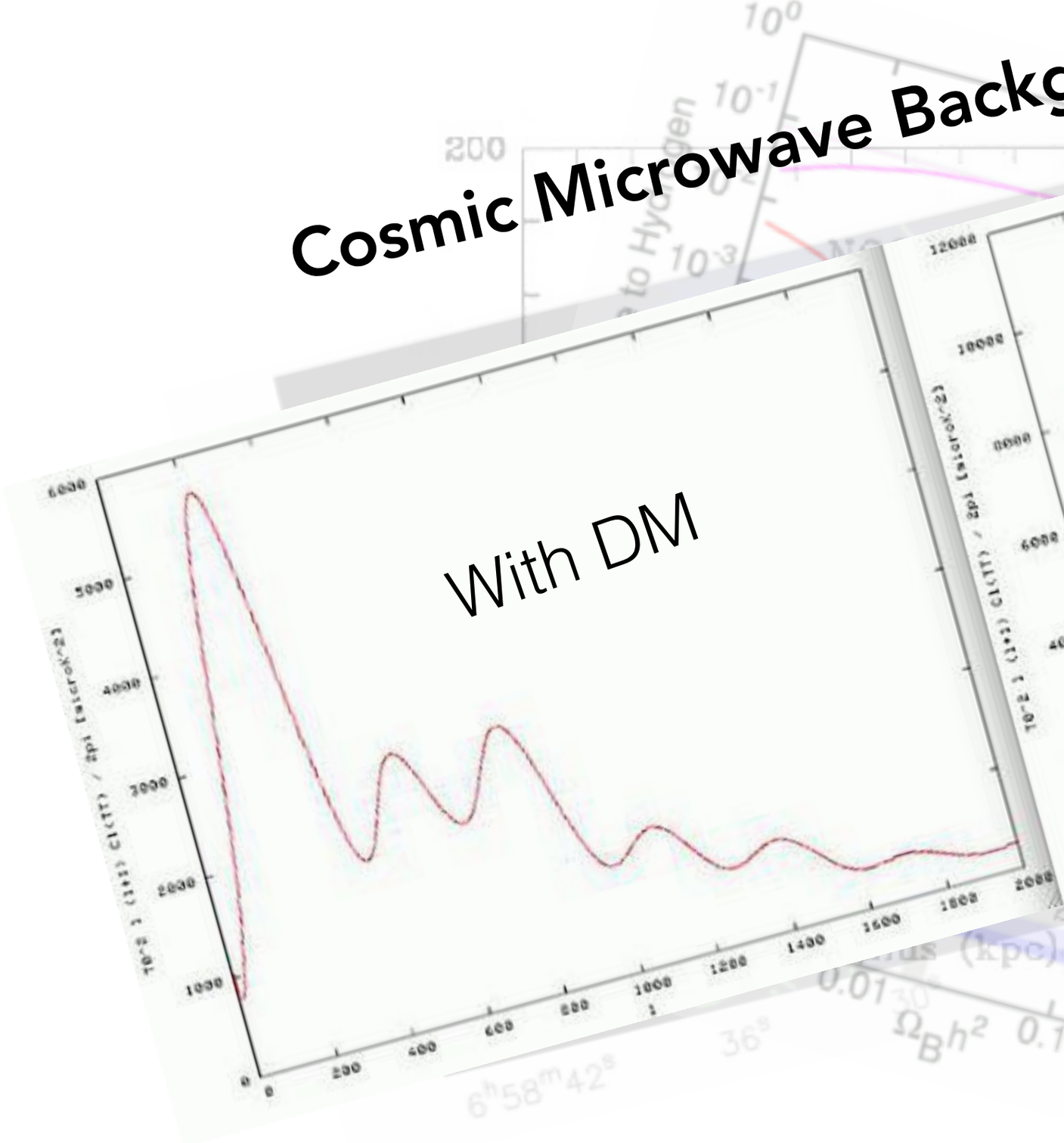
Galaxy cluster collision

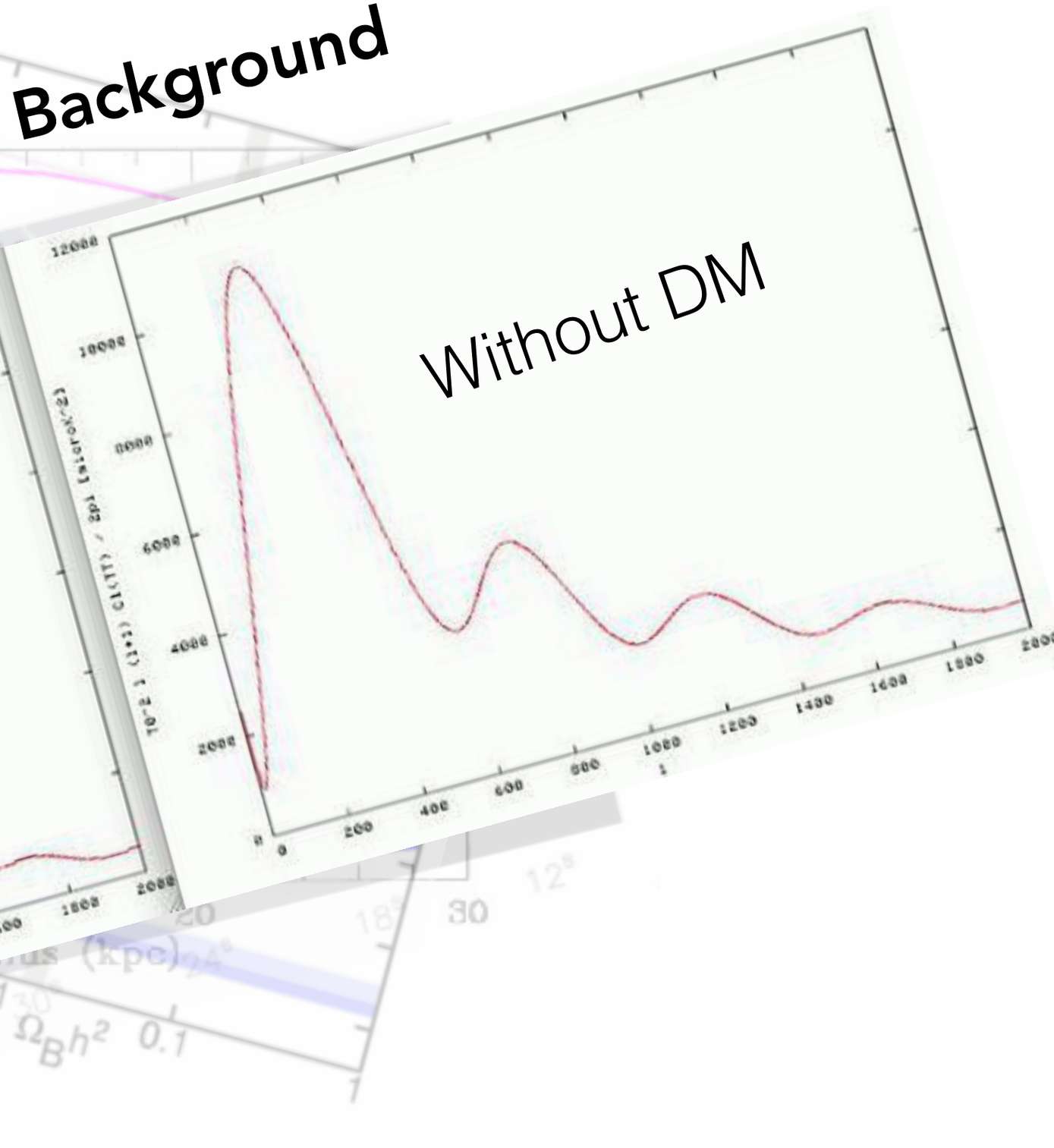


Big bang nucleosynthesis



Cosmic Microwave Background





DM requirements / models

Cold (not too relativistic)

neutral

feeble interaction

stable

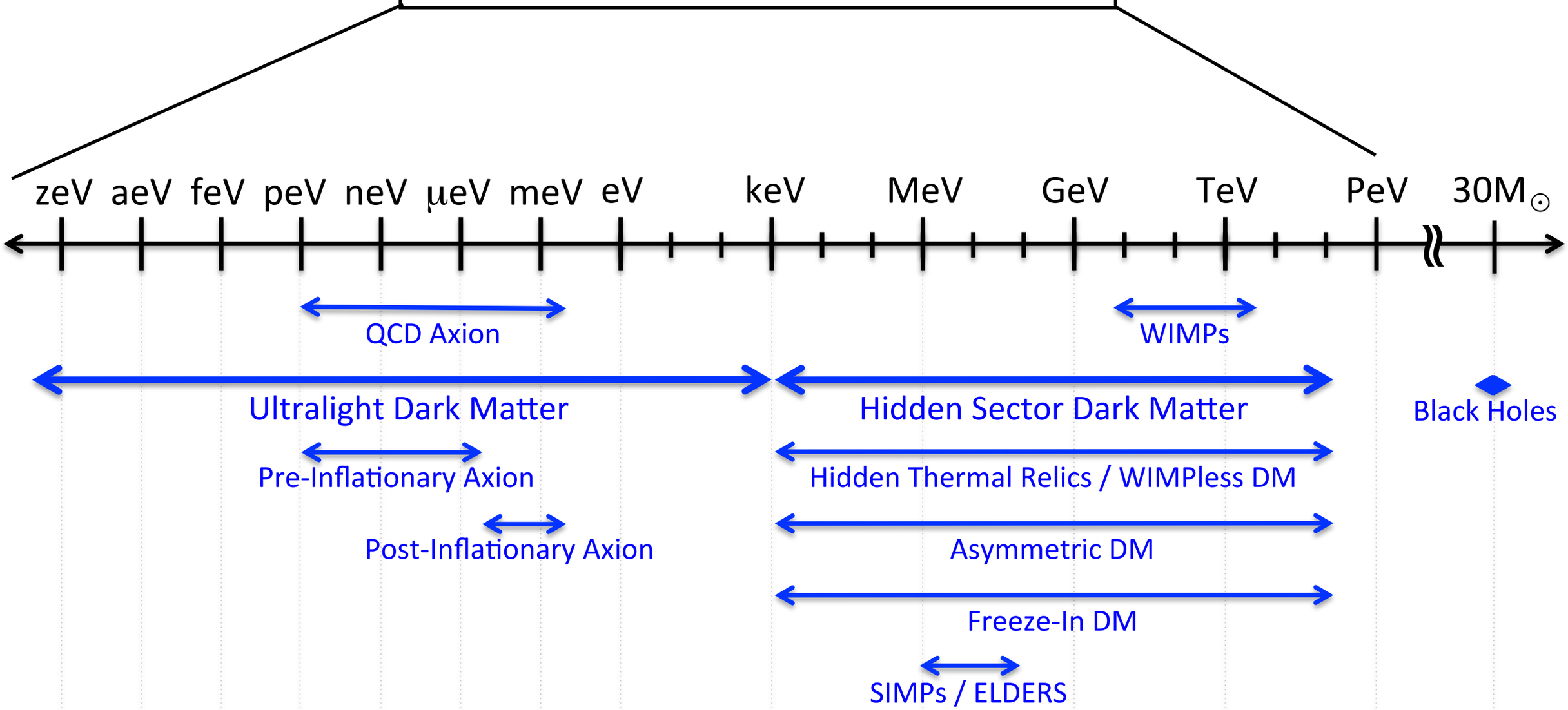
DM requirements / models

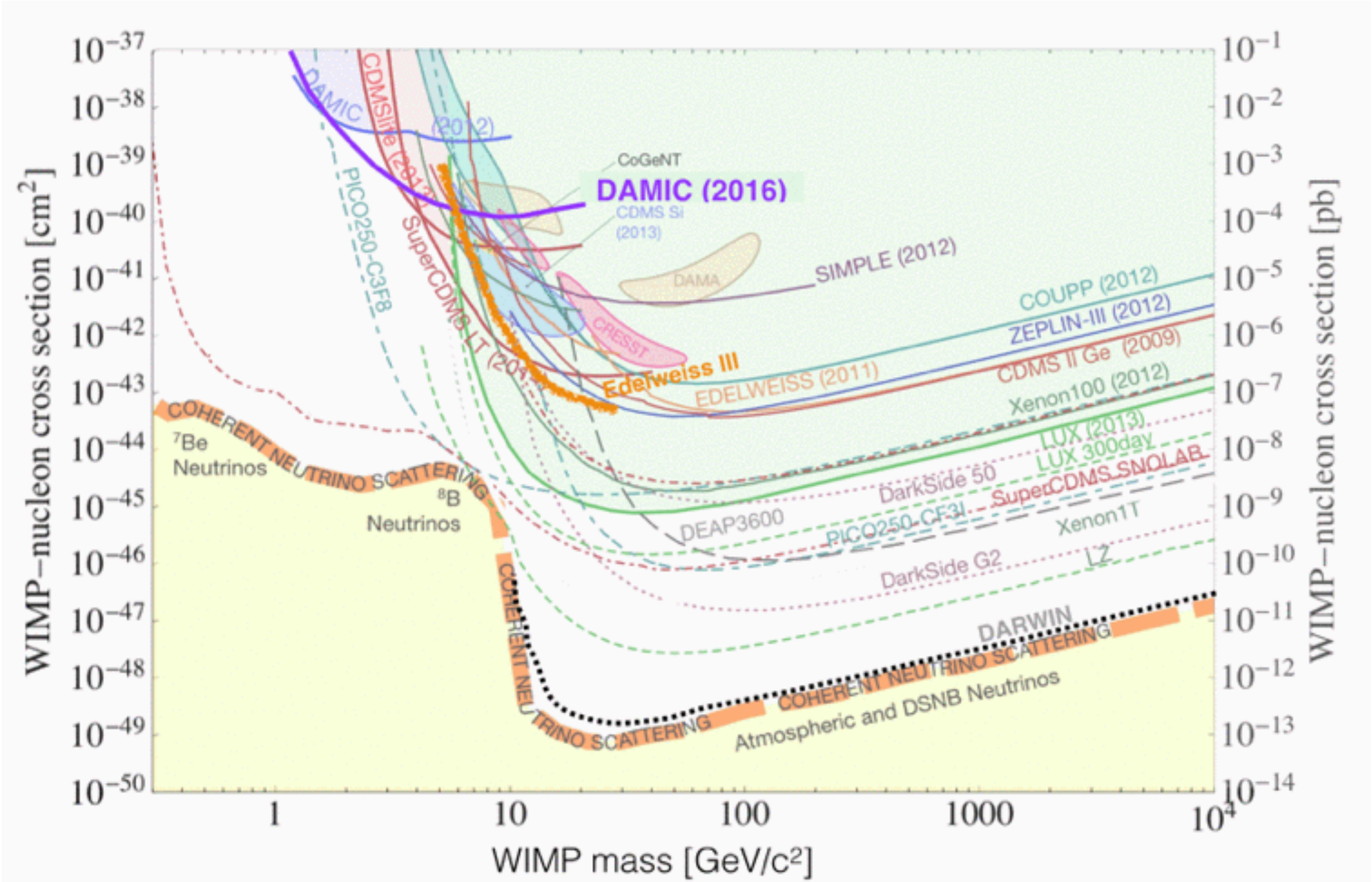
Cold (not too relativistic)

neutral

feeble interaction

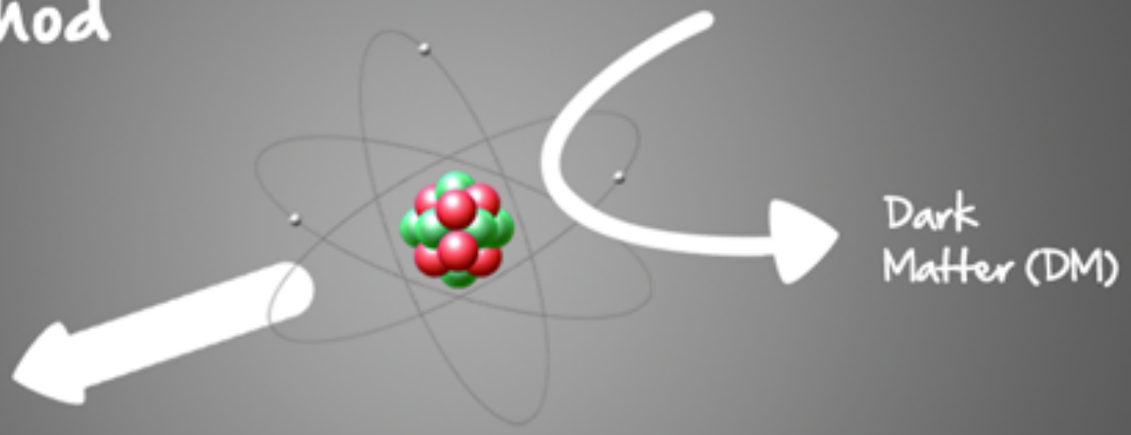
stable



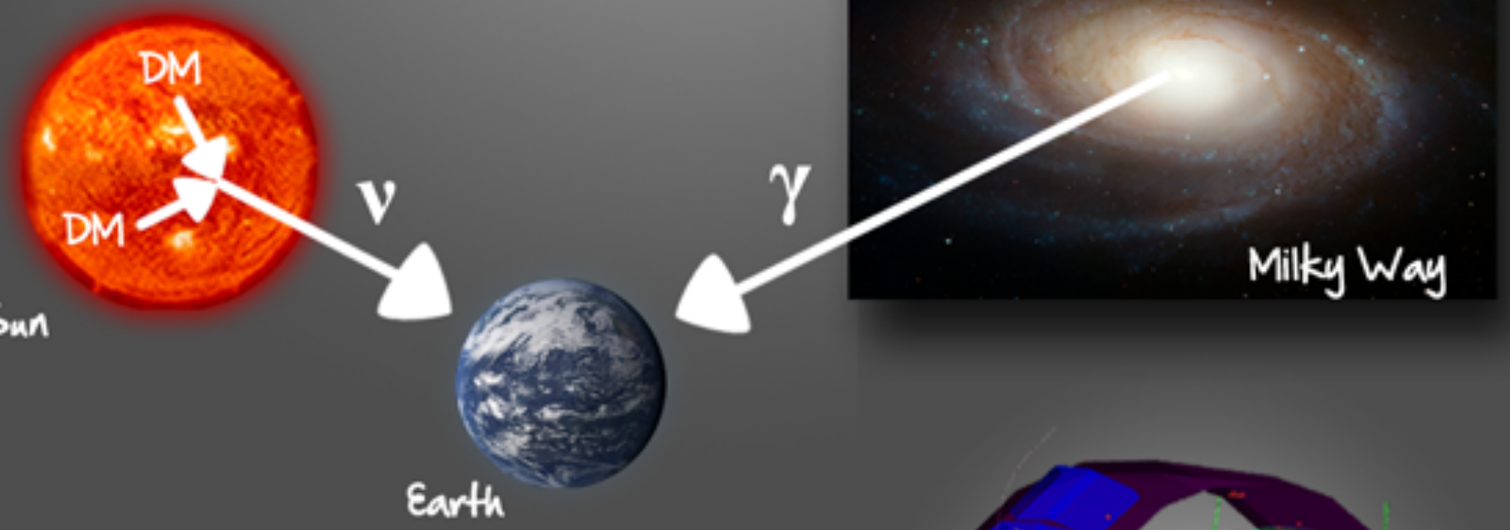

WIMP–nucleon cross section [cm²]
WIMP–nucleon cross section [pb]
WIMP mass [GeV/c²]
DAMIC (2012)
CDMSlite (2014)
PICO250-C3F8
SuperCDMS LT (2014)
CoGeNT
DAMIC (2016)
CDMS Si (2013)
DAMA
CRESST
EdeIweiss III
SIMPLE (2012)
COUPP (2012)
ZEPLIN-III (2012)
EDELWEISS (2011)
CDMS II Ge (2009)
Xenon100 (2012)
LUX (2013)
LUX 300day
DarkSide 50
SuperCDMS SNOLAB
PICO250-CF3I
DEAP3600
Xenon1T
DarkSide G2
LZ
DARWIN
COHERENT NEUTRINO SCATTERING
⁷Be Neutrinos
⁸B Neutrinos
COHERENT NEUTRINO SCATTERING
Atmospheric and DSNB Neutrinos

Dark Matter search strategies

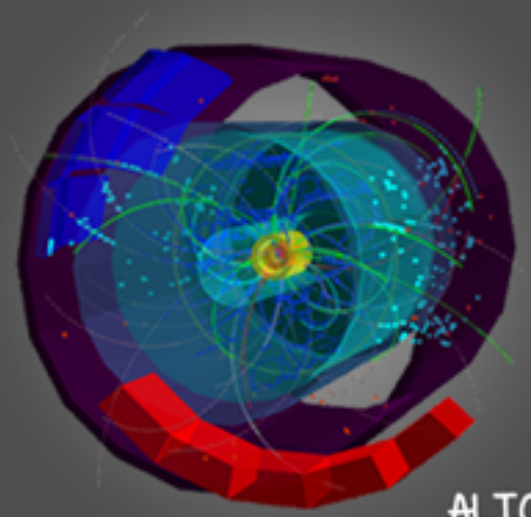
Direct Method



Indirect Method



Production at the Large Hadron Collider



(credit: HAP / A. Chantelauze)

Dark Matter search strategies

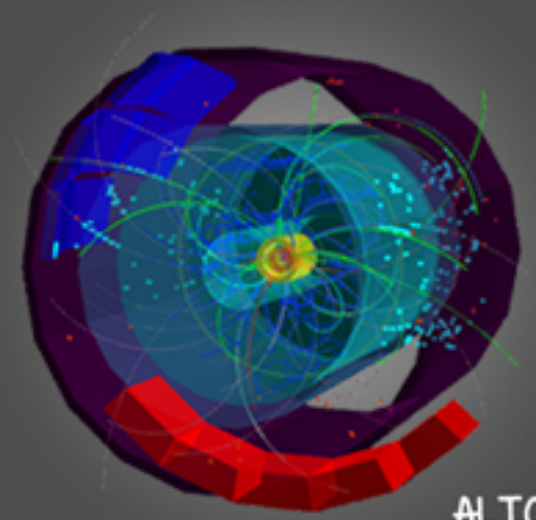
Direct Method

Ariel Matalon on DAMIC DM searches

Giorgos Papadopoulos on DAMIC-M electronics developemements

Indirect Method

Production at the Large Hadron Collider



(credit: HAP / A. Chantelauze)

Merci !

	The Search for Light Dark Matter with DAMIC *Ariel Matalon* *Centre Moulin Mer* 09:30 - 10:00
10:00	**Development and characterization of novel electronics for the search of dark matter for DAMIC-M** *Georgios PAPADOPOULOS* *Centre Moulin Mer* 10:00 - 10:30
11:00	**Reducing coating thermal noises in Gravitational wave detectors using AlGaAs crystalline mirrors** *Victor Hui* *Centre Moulin Mer* 11:00 - 11:30
	Optimisation of the optical follow up of gravitationnal waves events *Jean-Grégoire Ducoin* *Centre Moulin Mer* 11:30 - 12:00
12:00	**The hunt for VHE gamma-rays in the Gravitational Waves era.** *Halim Ashkar* *Centre Moulin Mer* 12:00 - 12:30

Lunch

14:00	**Development of an advanced Compton telescope prototype for MeV-range gamma-ray astronomy** *M. Adrien LAVIRON* *Centre Moulin Mer* 14:00 - 14:30
	StarTrack predictions of the stochastic gravitationnal-wave background from compact binary coalescences *Carole Perigois* *Centre Moulin Mer* 14:30 - 15:00
15:00	**Using simulated quasar catalogs for the BAO in lyman-α analysis of eBOSS and DESI** *Julianna Stermer* *Centre Moulin Mer* 15:00 - 15:30