Non-Accelerator Experiments
Astro-particle Physics
Cosmology
Dark Matter

The 40th Anniversary Symposium of the US-Japan Science and Technology Cooperation Program in High Energy Physics

April 16, 2019 @ University of Hawaii

Akito Kusaka (Berkeley Lab. & University of Tokyo)

Disclaimer & Acknowledgement

- Blame me for mistakes and bias/unfairness.
  - And perhaps the organizer for selecting me. (but thanks!)

- Acknowledgement: inputs/lectures from colleagues.
  - Peter Sorensen (LBNL) for Dark Matter
  - Kohta Murase (Penn State) for Astroparticle
  - Hironao Miyatake (Nagoya), David Schlegel, Natalie Roe (LBNL) for Optical Surveys
  - Osamu Tajima (Kyoto); US-Japan Japan PI

Higgs

Light New Particle?

TeV

Yukawa

5^{th} force?

Dark Energy

ν

Dark Matter

Inflation

$\bar{B}/B$

My summary of "Snowmass Questions" 2014
(But I cannot trace citation path at this point)

What/Why do we learn from the Universe?

- ***Early Universe***: extreme and clean environment
  - Inflation
  - Relics: Baryogenesis, Dark Matter, Neutrinos, Unknown Unknown
- ***Gravity***: with other forces suppressed
  - Dark Matter and Dark Energy
  - Neutrinos
- ***Vacuum***:
  - Axions
  - Dark Energy
- ***Particle acceleration***

Cosmic Microwave Background

CMB: primordial gravitational waves

"Cosmic background is absolutely exciting – I've never expected it to be as exciting as it is now. I mean, finding the B modes is just unbelievably important."

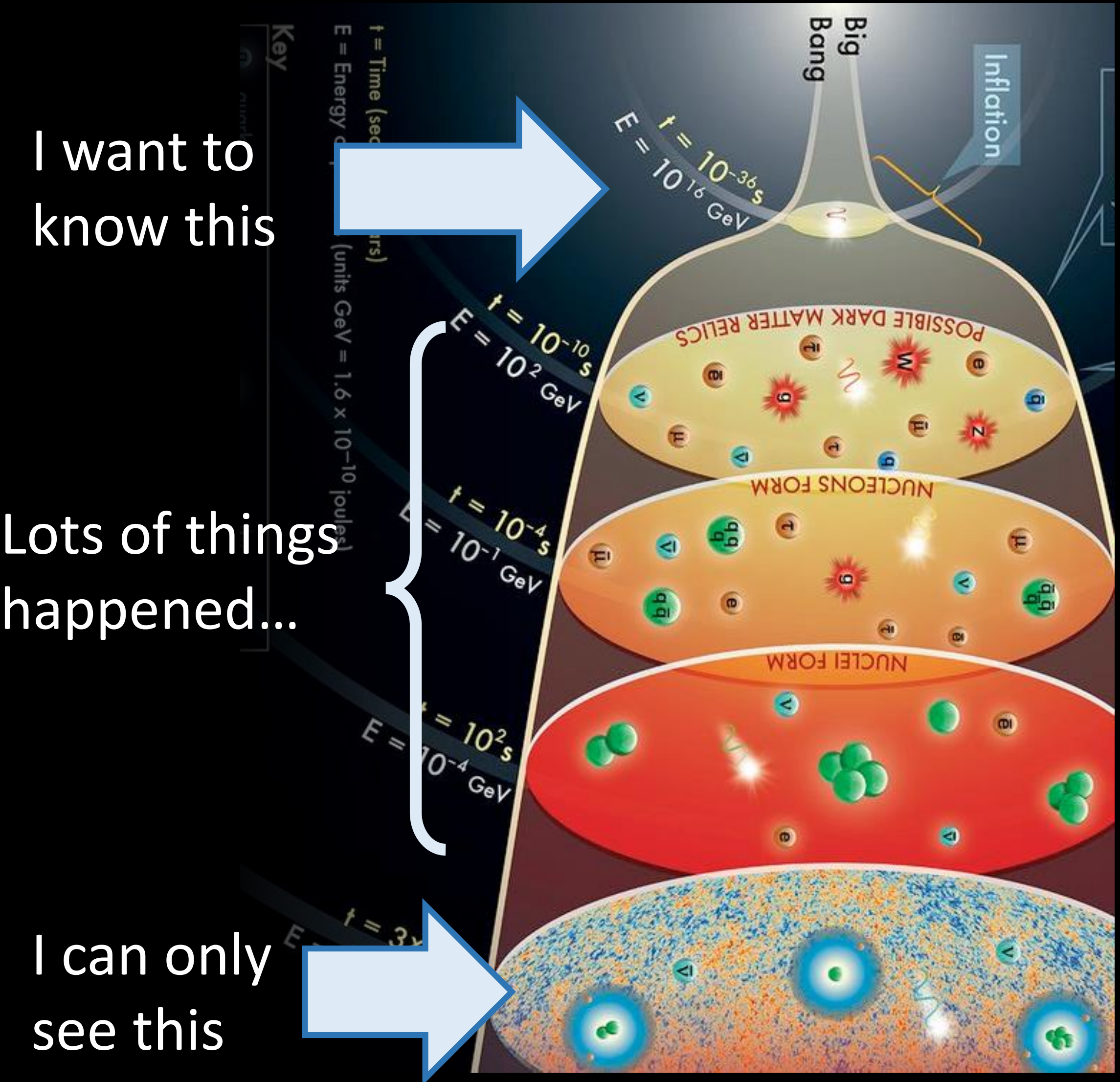
(Rainer Weiss, Segre lecture at UC Berkeley, 2016)

CMB: primordial gravitational waves

- We only observe t=380k yr.
- Really want to know: t≪1 sec.
- Things happened in between:
  - Bad: things get washed out.
  - Good: physics well understood.

Preserved “signal”?

- Gravitational Waves
  - Inflation, gravity quantization
- Sound waves
  - “Seed” of structure
  - Non-Gaussianity



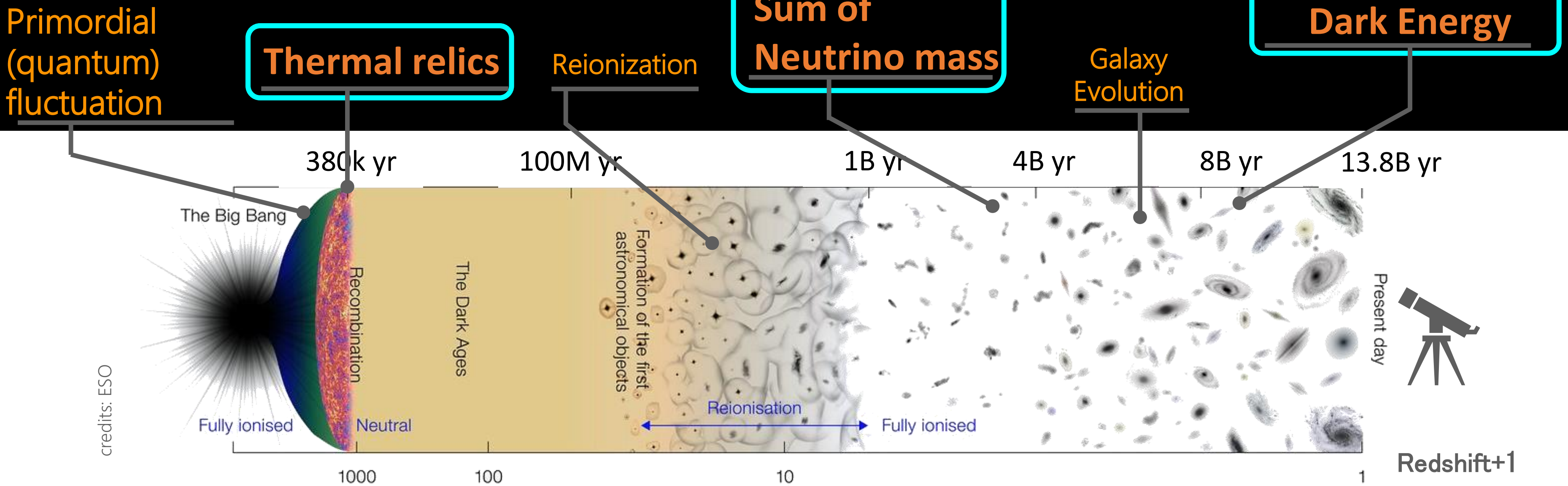
CMB: "backlight" shedding on cosmic evolution

A huge HEP laboratory

Axion?
Sterile ν?

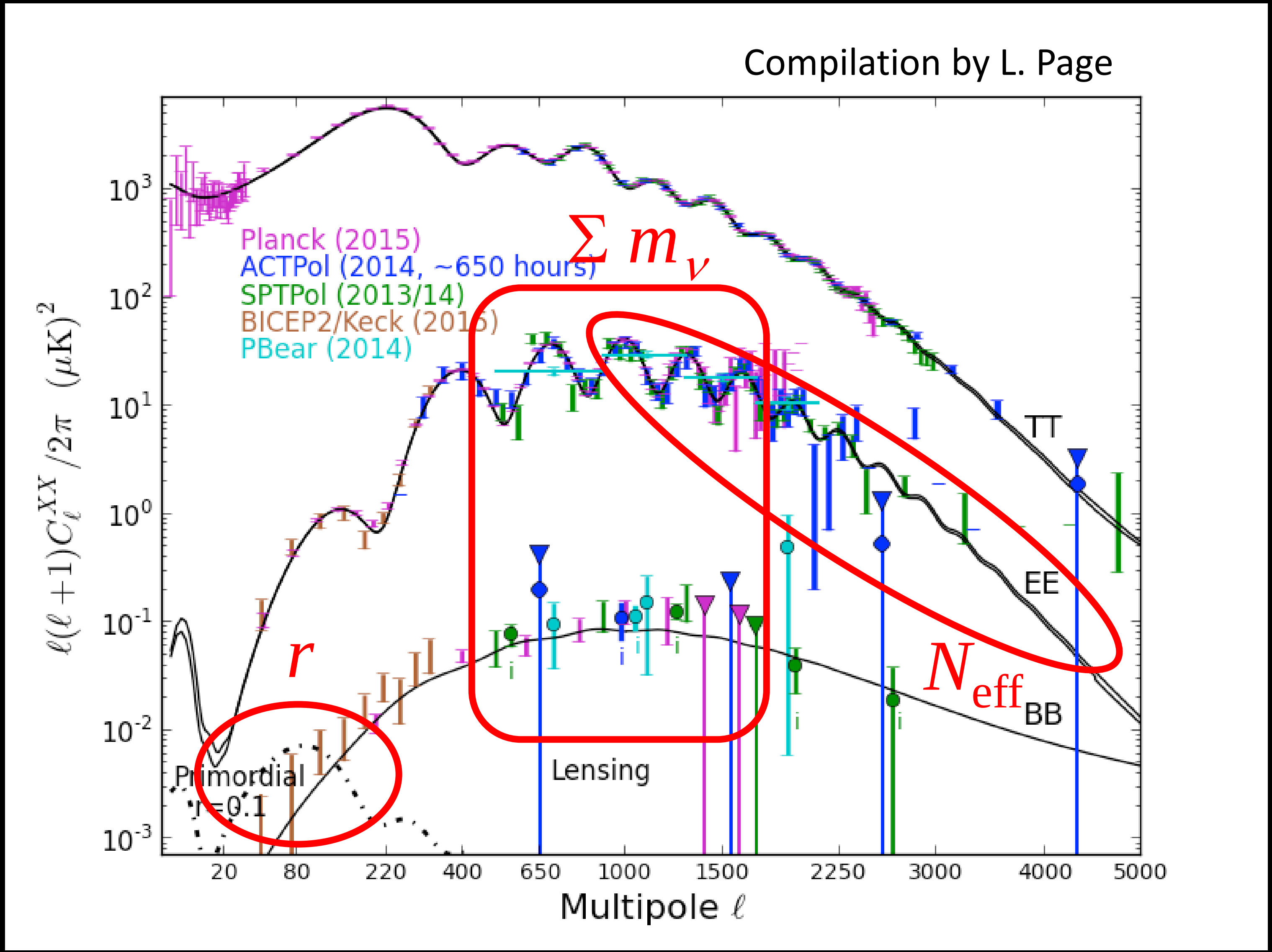
$\delta(\sum m_\nu)\sim 30\text{meV}$
Implication on hierarchy

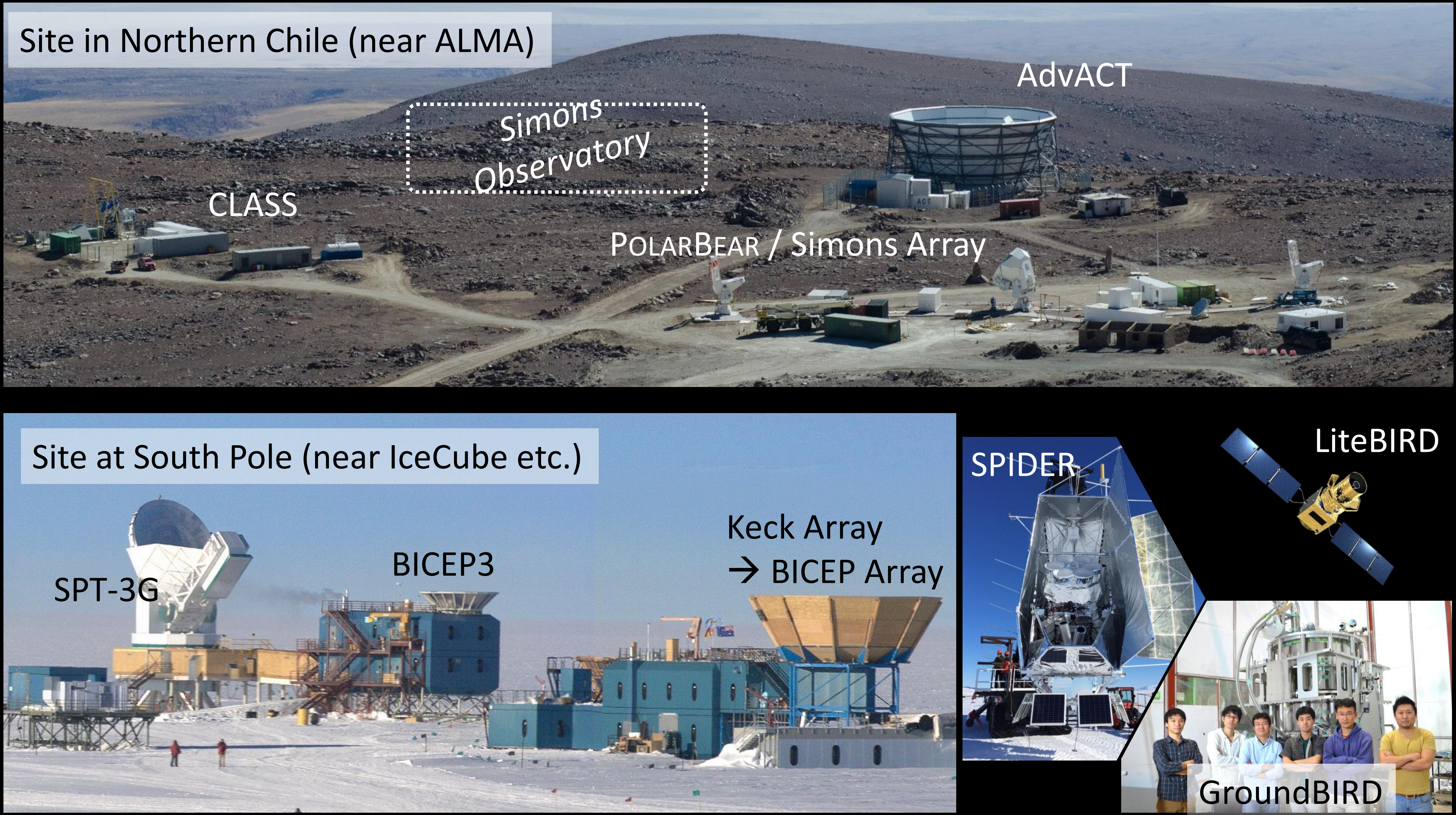
Understanding Vacuum



Order ~1 improvement by next-generation instruments → Leap in cosmology and HEP.

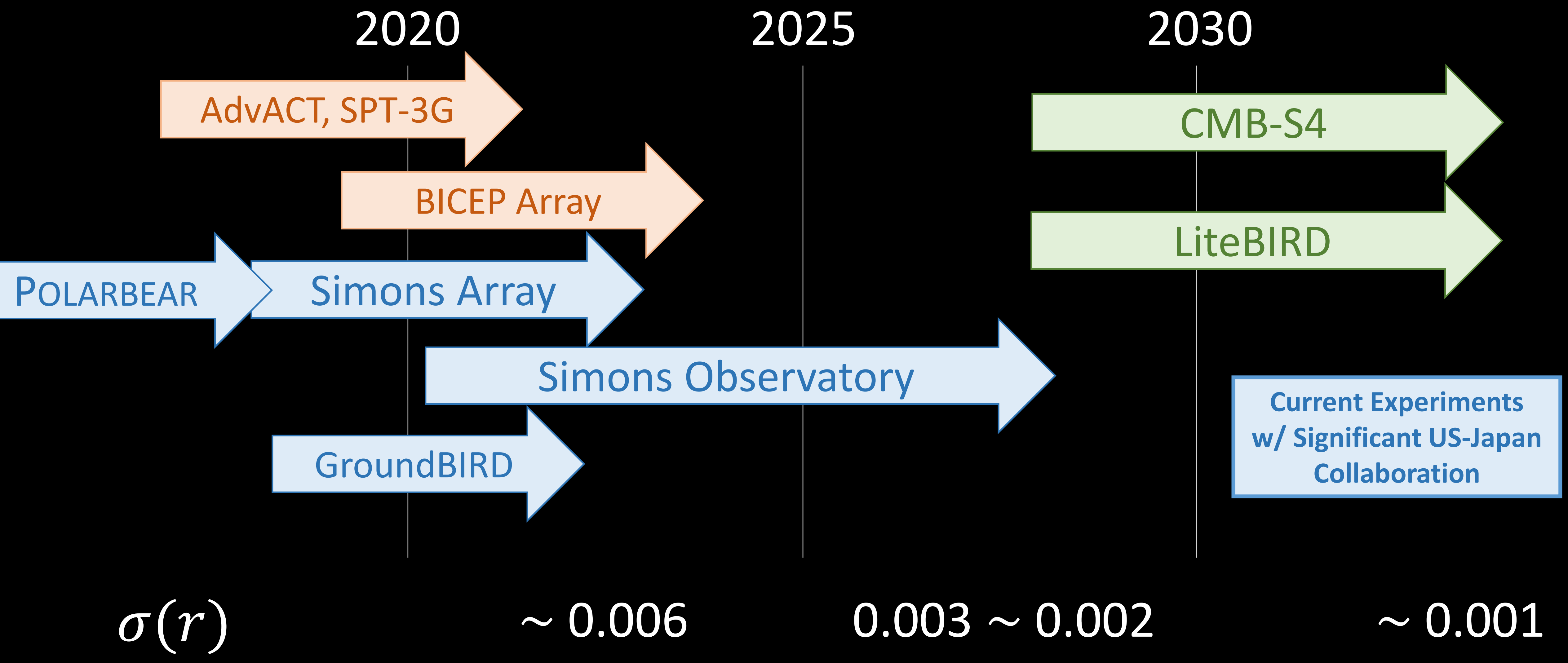
CMB Polarization: where do we stand now?





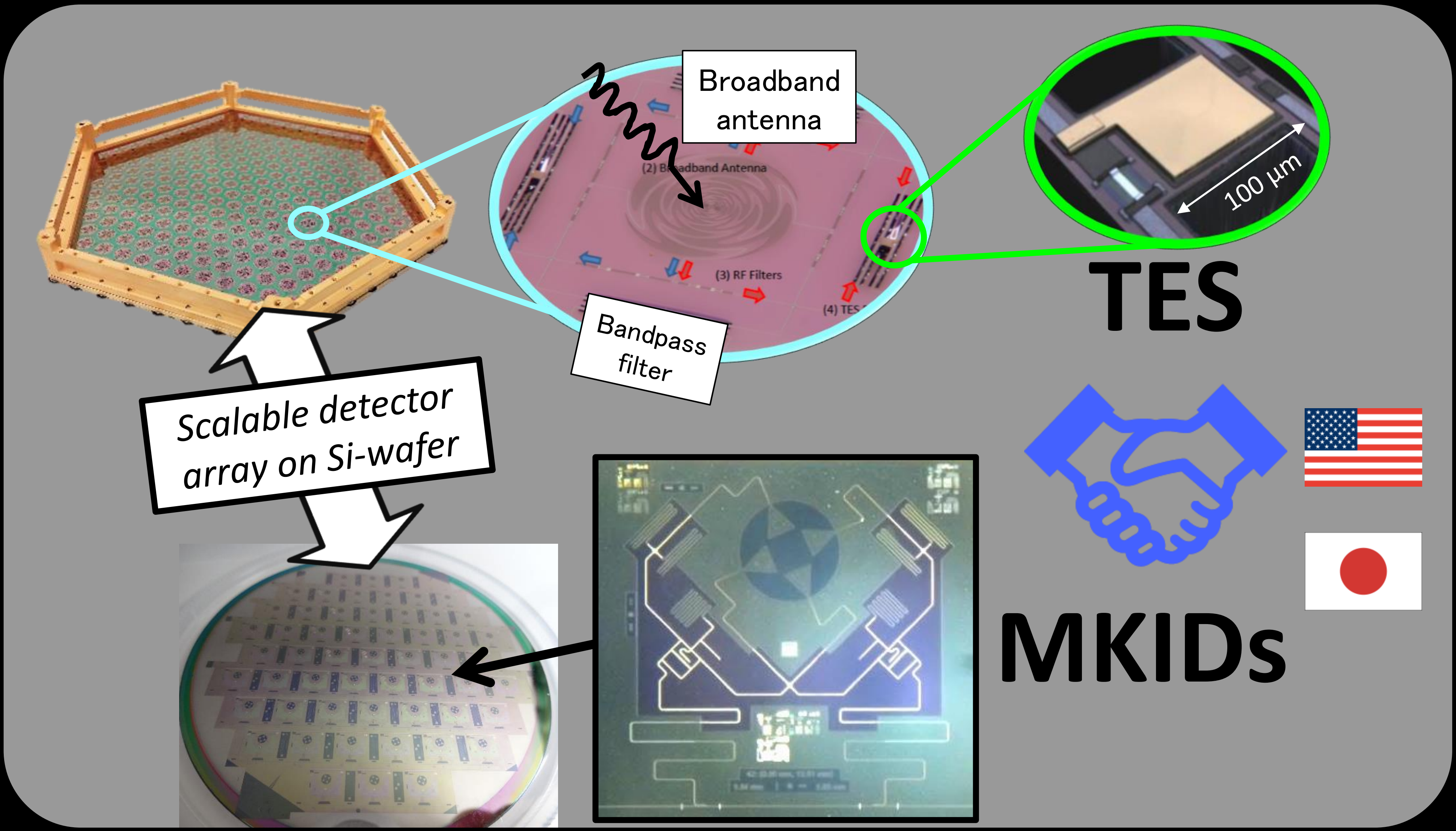
Site in Northern Chile (near ALMA)
AdvACT
Simons Observatory
CLASS
POLARBEAR / Simons Array
Site at South Pole (near IceCube etc.)
SPT-3G
BICEP3
Keck Array
→ BICEP Array
SPIDER
LiteBIRD
GroundBIRD

Timeline



2020
2025
2030
AdvACT, SPT-3G
BICEP Array
POLARBEAR
Simons Array
Simons Observatory
GroundBIRD
CMB-S4
LiteBIRD
Current Experiments w/ Significant US-Japan Collaboration
$\sigma(r)$
~ 0.006
$0.003 \sim 0.002$
~ 0.001

US-Japan: acknowledgement and shameless advertisement



Next Generation of ***Superconducting*** Devices for Photon and Particle Sensing: Universal Detector and ***Readout*** Systems for Large-Format Arrays

PIs: O. Tajima & A. Kusaka

Collaborators:
Kyoto, IPMU, Tohoku, KEK
LBNL, SLAC, UCB, NIST

Applications:
CMB
Dark Matter
0ν2β
Quantum Sensing

US-Japan: acknowledgement and shameless advertisement

高エネルギー加速器研究機構 KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

Top

平成３１年度日米科学技術協力事業(高エネルギー物理学分野)
Ozaki Exchange Program 募集案内
Application Guideline for the Ozaki Exchange Program for JFY2019

Final update: 2018/12/3

日米科学技術協力事業（高エネルギー物理）では、素核分野の研究とその日米間の協力の推進に多大な貢献をされた故・尾崎 敏 博士の功績をたたえ、同事業下での取組として、大学院生を対象とした若手人材交流プログラム"Ozaki Exchange Program"を開始することとなりました。

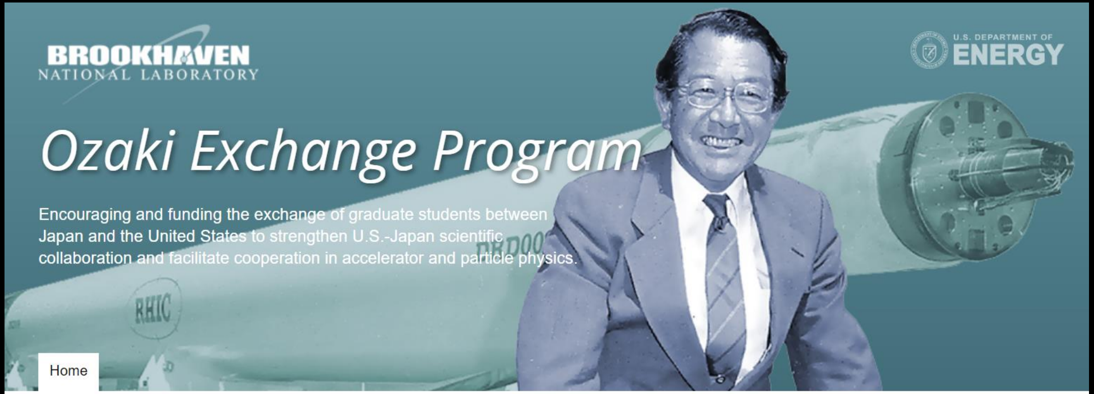
このプログラムは、日本国内で学ぶ高エネルギー分野の大学院生を米国の研究所に派遣し、研究を体験してもらおうというもので、渡航費と滞在費が支給されます。

ついては以下のとおり参加者を募集いたしますので、興味のある学生の方は奮ってご応募ください。

The Ozaki Exchange Program, in honor of the late Dr. Satoshi Ozaki, is a graduate student exchange program to strengthen the US-Japan scientific collaboration and in particular facilitate greater cooperation in the areas of accelerator and particle physics in projects of mutual ben…

This progra… in Japan to…

If you are i… this guideli…



Home

Mission

The goals of this program are to strengthen U.S.-Japan scientific collaboration and in particular facilitate greater cooperation in the areas of accelerator and particle physics in projects of mutual benefit to Japan and the United States. The program will encourage and fund the exchange of graduate students between Japan and the United States. This program has been established in honor of the late Dr. Satoshi Ozaki.

Eligibility and Terms

About Satoshi Ozaki

Satoshi Ozaki was a world-renowned physicist who helped design and build accelerators for scientific research across two continents.

After earning a master's degree in physics from Osaka University, Japan, and a Ph.D. in physics from the Massachusetts Institute of Technology, Ozaki came to …

Ozaki Exchange Program 2019 - Record for Evaluation (Japan-side

No.	Applicant Name	Affiliation	Grade	Dispatch Period	Host Laboratory	Mentor of Home Institution	Host Laboratory Partner
1	Tomofumi Abe	Graduate School of Science, Kyoto University	1st Grade of Master (M1)	Jun. 2019 - Sep. 2019 (4 months)	LBNL CMB	Osamu Tajima	Akito Kusaka
2	Sayuri Takatori	Graduate University for Advanced Studies (SOKENDAI),	1st Grade of Doctoral Course (D1)	Jun. 2019 - Nov. 2019 (6 months)	LBNL CMB	Masashi Hazumi	Adrian T. Lee

Cosmology: Optical Surveys

Cosmology: optical surveys

measuring gravity in a broad sense

Gravity acting on spacetime

- Type Ia Supernovae
- Baryon Acoustic Oscillation

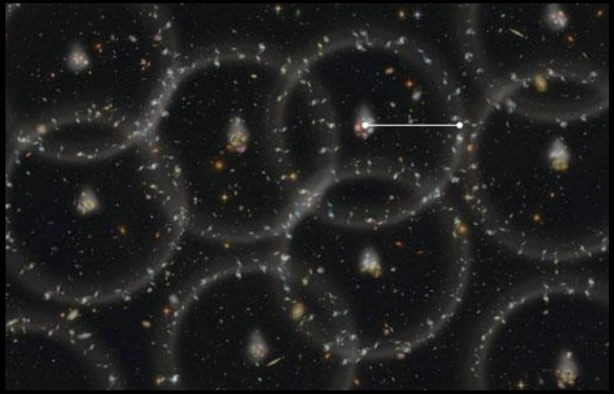


Image credit: BOSS/SDSS

Gravity acting on matter

- Cluster Number Count
- Weak Gravitational Lensing
- Redshift Space Distortion

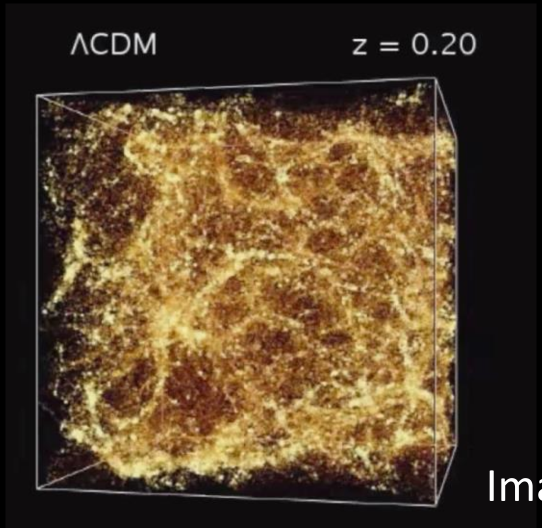
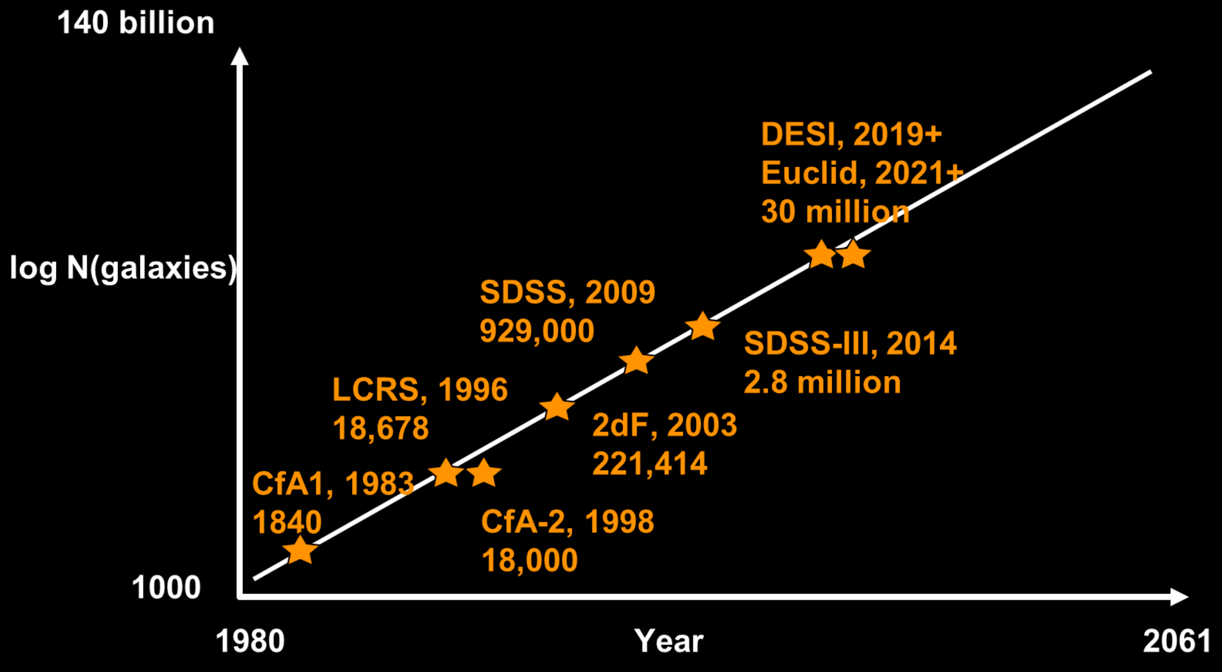
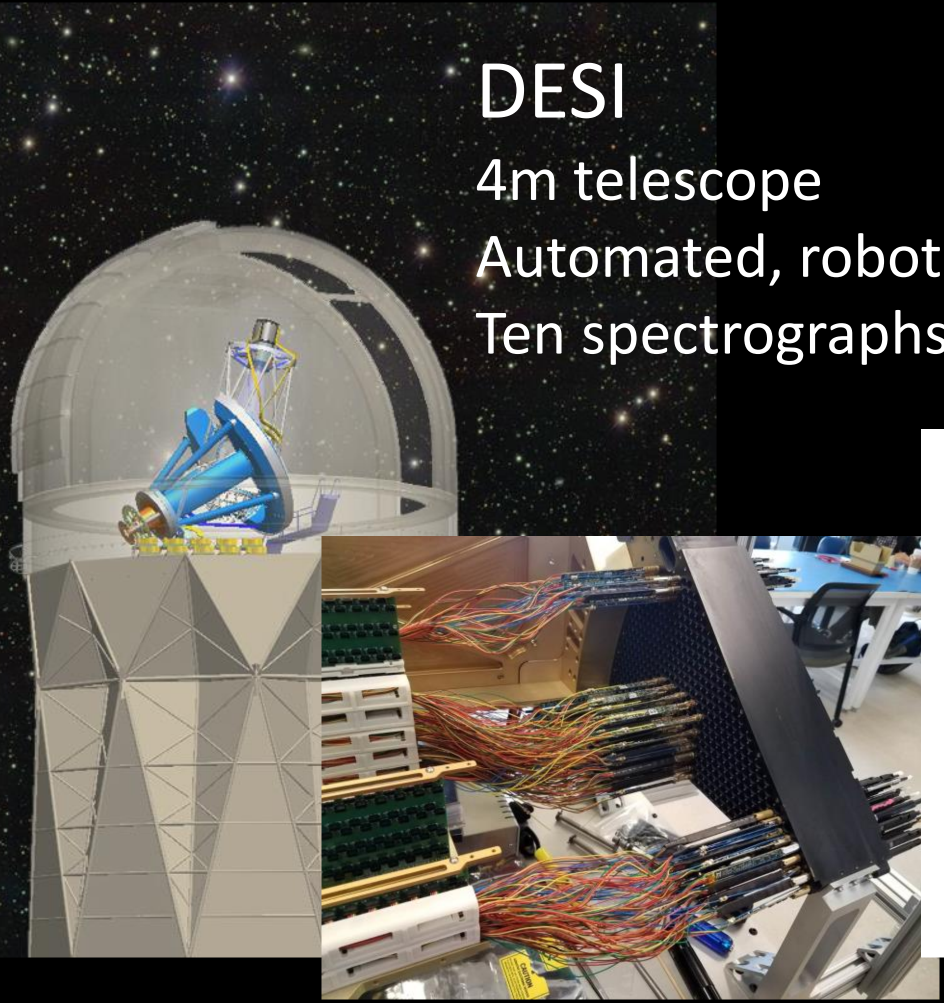


Image credit: ESA

Cosmology: spectroscopic surveys



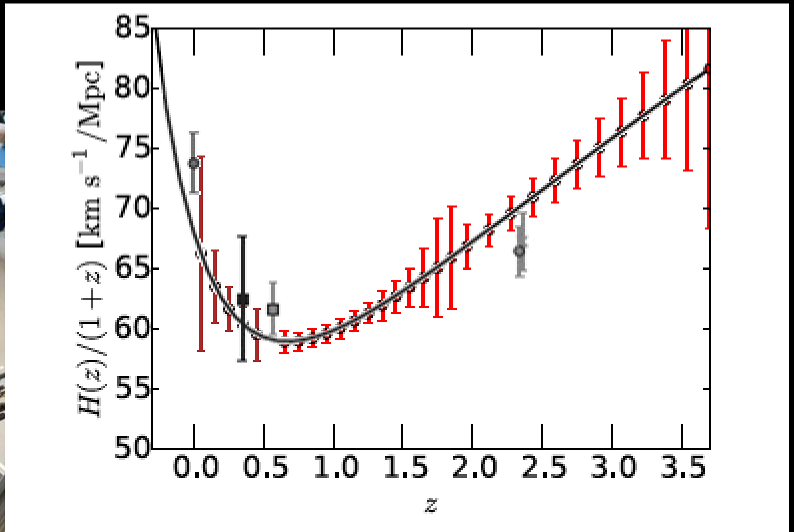


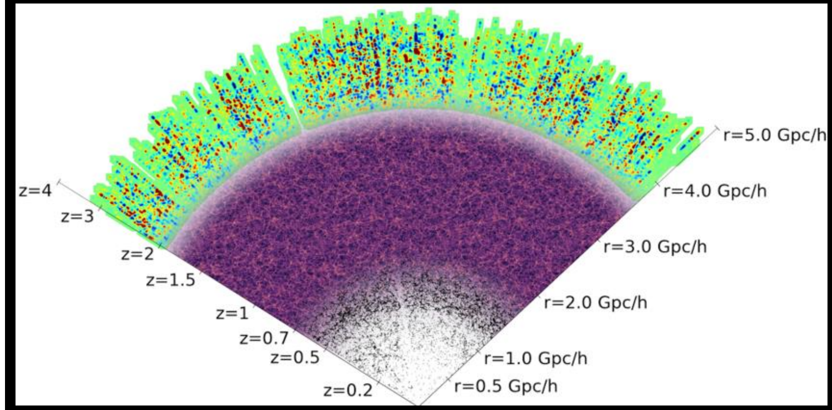
DESI

4m telescope

Automated, robotic, 5000 fibers

Ten spectrographs





3D map of 35M galaxies

Expansion history: z=0~3.5

Dark Energy Equation of State

Neutrinos mass and species, …

PFS and Euclid are also starting soon.

Cosmology: imaging surveys


Subaru/HSC

8.2m telescope
1B pixels
1.5 deg. FoV

- Dark Energy
- Matter fluctuation
- Growth of Structure
  - Neutrinos
  - Modified gravity

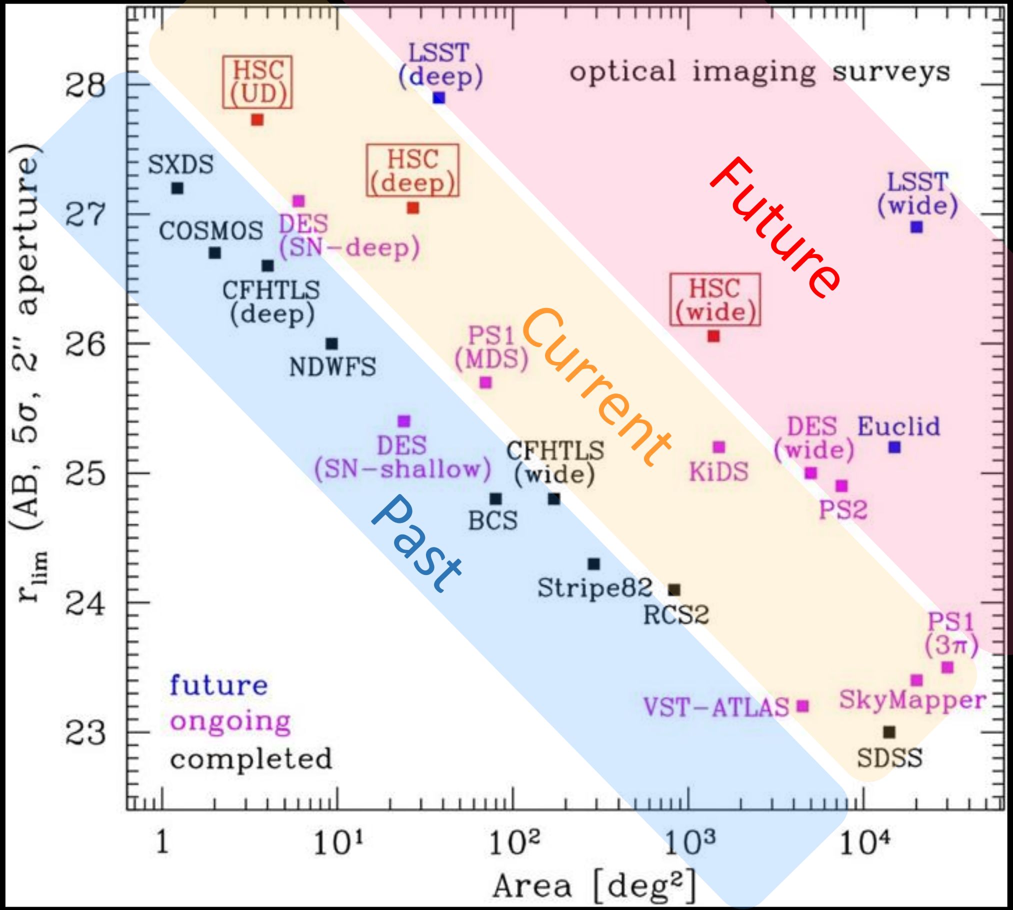


Image credit: M. Oguri

US-Japan: Yet another shameless advertisement

Evidence for the Cross-correlation between Cosmic Microwave Background Polarization Lensing from POLARBEAR and Cosmic Shear from Subaru Hyper Suprime-Cam

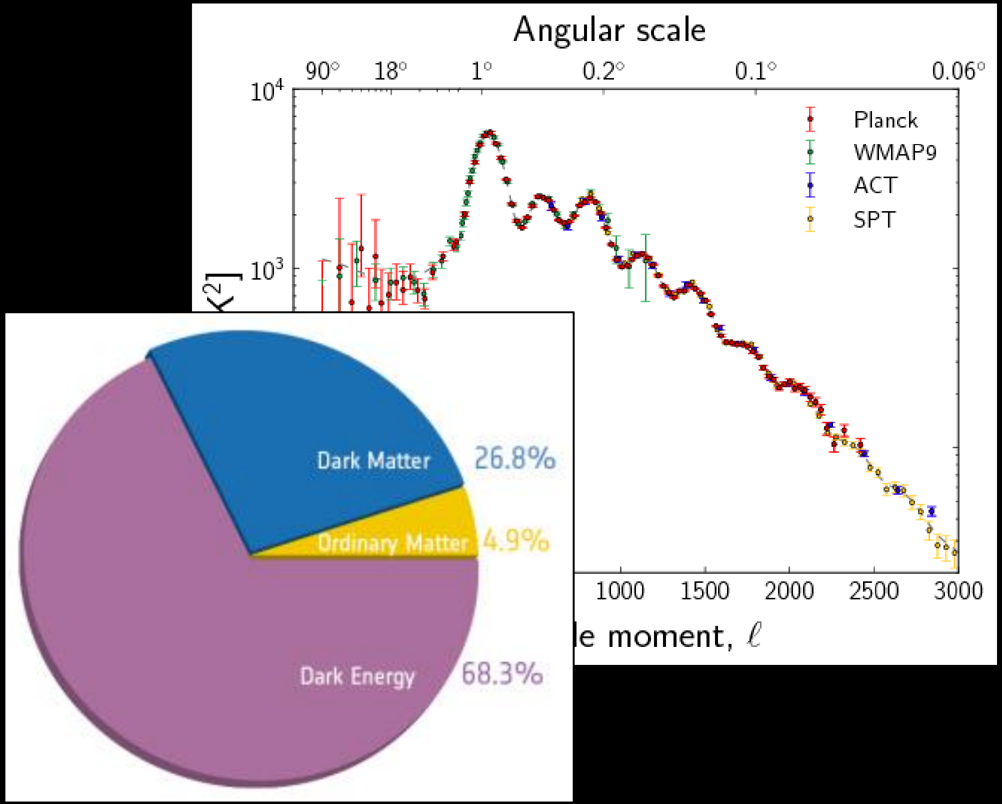
T. Namikawa,[1] Y. Chinone,[2,3,4] H. Miyatake,[5,6,3] M. Oguri,[7,3,8] R. Takahashi,[9] A. Kusaka,[10,7,4,8] N. Katayama,[3] S. Adachi,[11] M. Aguilar,[12,13] H. Aihara,[7,3] A. Ali,[2] R. Armstrong,[14] K. Arnold,[15] C. Baccigalupi,[16,17,18] D. Barron,[19] D. Beck,[20] S. Beckman,[2] F. Bianchini,[21] D. Boettger,[22] J. Borrill,[23,24] K. Cheung,[2] L. Corbett,[2] K. T. Crowley,[2] H. El Bouhargani,[20] T. Elleflot,[15] J. Errard,[20] G. Fabbian,[25] C. Feng,[26] N. Galitzki,[15] N. Goeckner-Wald,[2] J. Groh,[2] T. Hamada,[27,28] M. Hasegawa,[28,29] M. Hazumi,[28,3,29,30] C. A. Hill,[2,10] L. Howe,[15] O. Jeong,[2] D. Kaneko,[3] B. Keating,[15] A. T. Lee,[2,10,31] D. Leon,[15] E. Linder,[24,10] L. N. Lowry,[15] A. Mangu,[2,10] F. Matsuda,[3] Y. Minami,[28] S. Miyazaki,[32] H. Murayama,[3,2] M. Navaroli,[15] H. Nishino,[28] A. J. Nishizawa,[5] A. T. P. Pham,[21] D. Poletti,[16,17,33] G. Puglisi,[34] C. L. Reichardt,[21] B. D. Sherwin,[1,35] M. Silva-Feaver,[15] P. Siritanasak,[15] J. S. Speagle,[36] R. Stompor,[20] A. Suzuki,[10] P. J. Tait,[37] O. Tajima,[11,28] M. Takada,[3] S. Takakura,[3] S. Takatori,[29,28] D. Tanabe,[29] M. Tanaka,[32] G. P. Teply,[15] C. Tsai,[15] C. Vergés,[20] B. Westbrook,[31] and Y. Zhou[2]
The POLARBEAR Collaboration and the Subaru HSC SSP Collaboration

3 Apr 2019

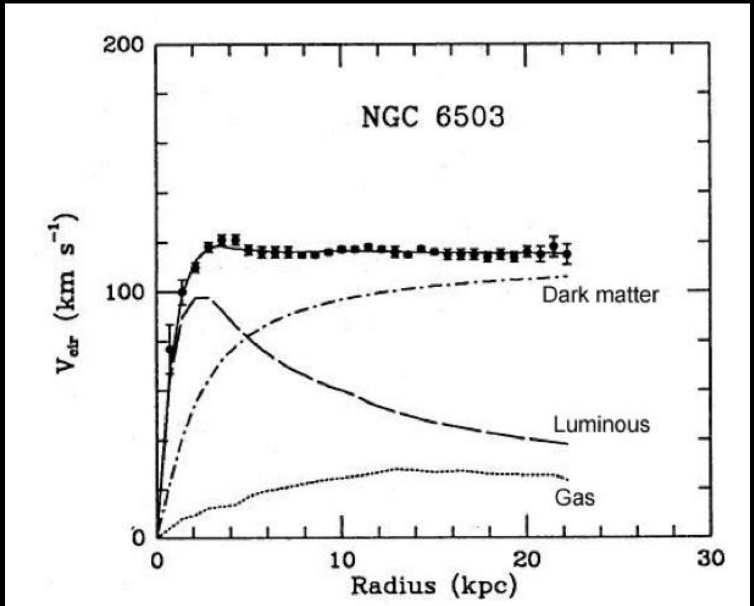
Current: HSC, DES, Pan-STARRS, KiDS
Upcoming: LSST, Euclid, WFIRST

Direct Dark Matter Search

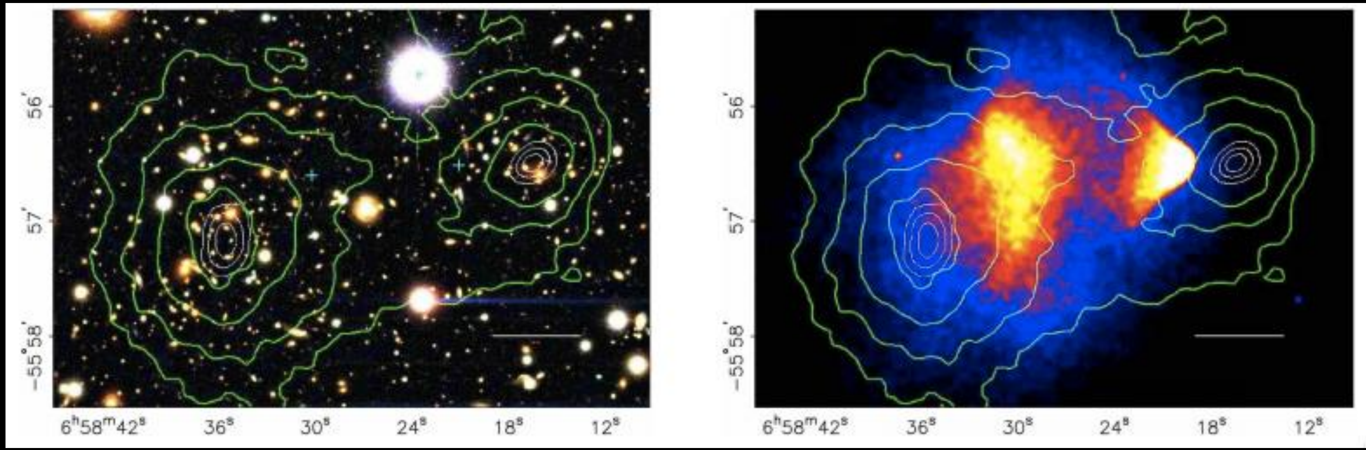
Evidence for "cold" dark matter



Planck Collaboration (2014 & 2015)



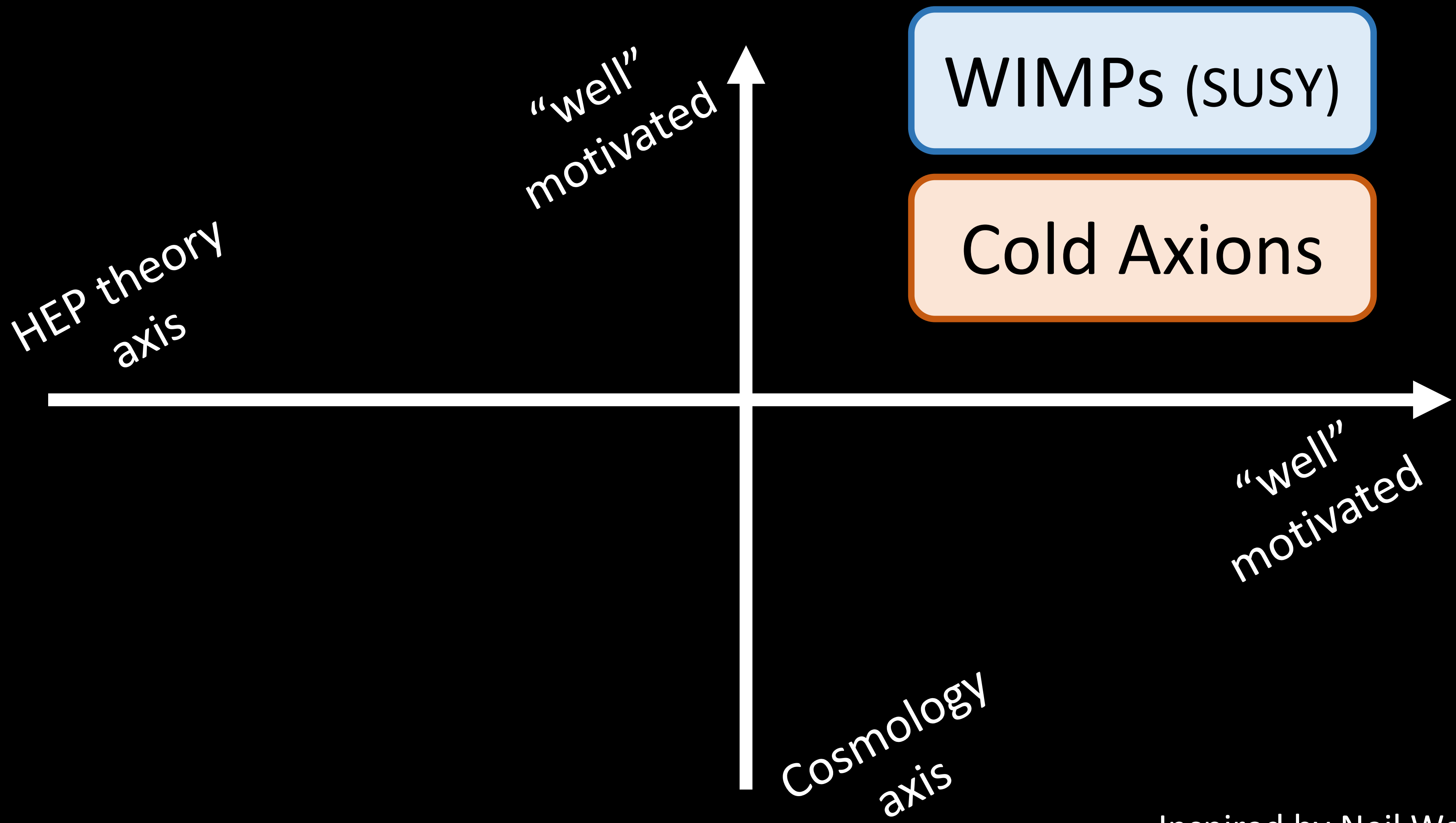
Begeman, Broels & Sanders (1991)



Clowe et al. (2006)

Cold = non relativistic (for a while)
Weak (or no) interaction other than gravity.
Energy density: 1/4 of the current universe.

Dark Matter model space

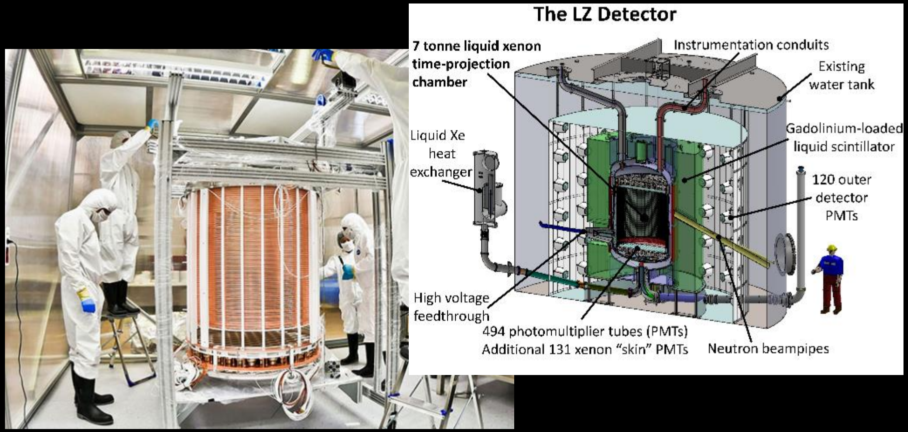


Inspired by Neil Weiner's slide (2017)

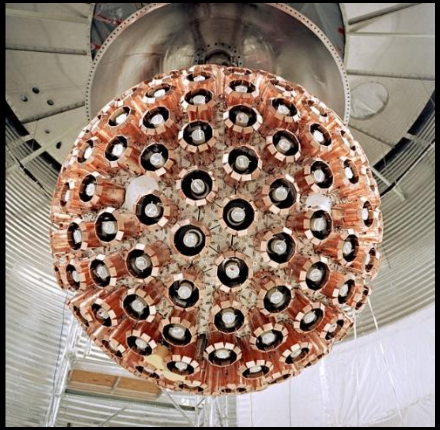
Dark Matter: Noble liquid detectors

XMASS (Xe 835kg)

PandaX
(Xe 580kg → 4t)



LUX/LZ (Xe 250kg → 7t)



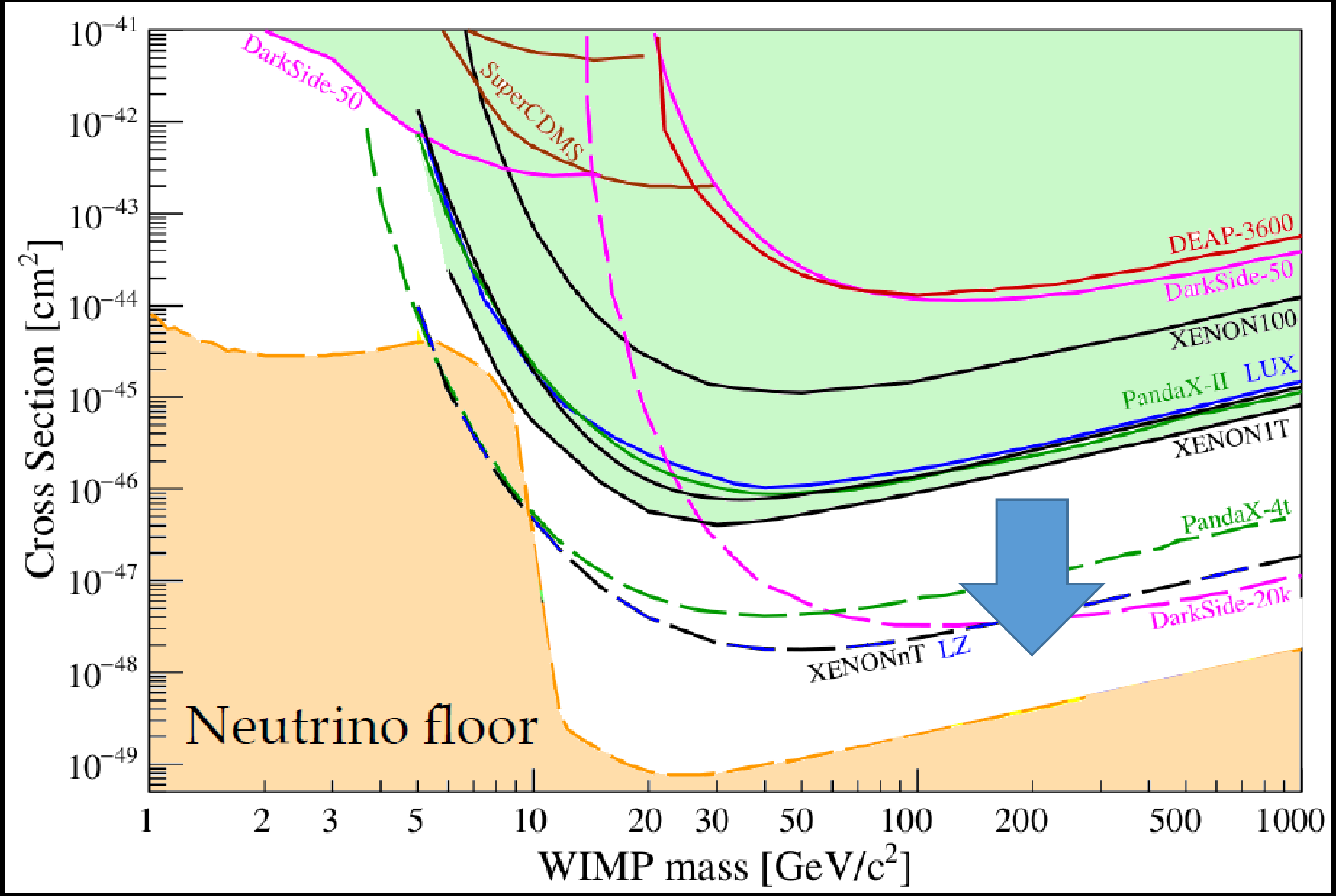
DEAP-3600 (Ar 3.2t)

DarkSide (Ar 46kg → 20t)

XENON (Xe 2t → 6t)

Dark Matter: Noble liquid detectors

Plot from A. Manalaysay's talk (2019)

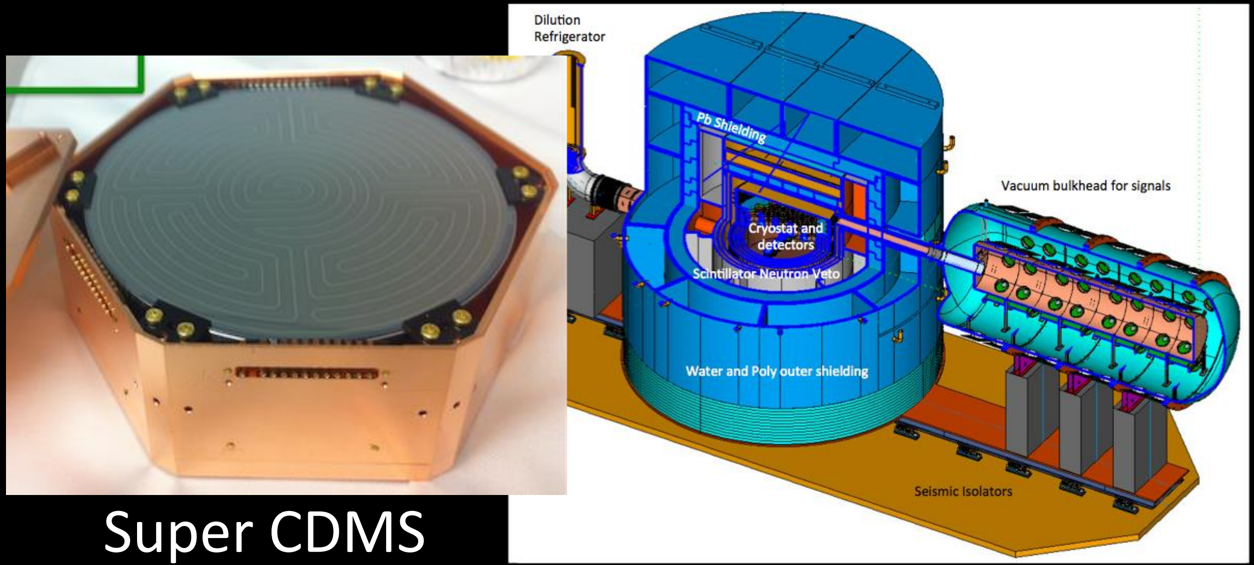


Reaching neutrino floor "soon."

Dark Matter: cryogenic detectors

CRESST

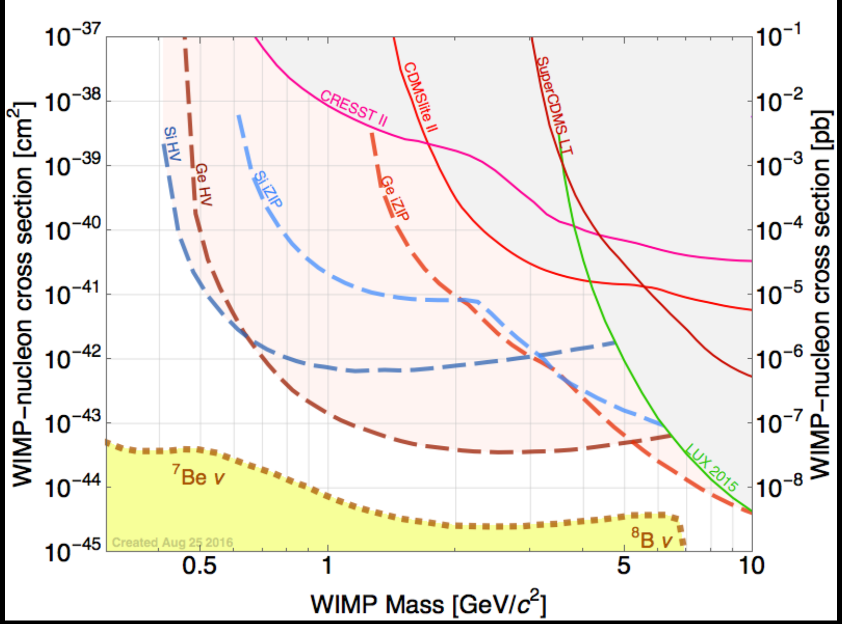
EDELWEISS

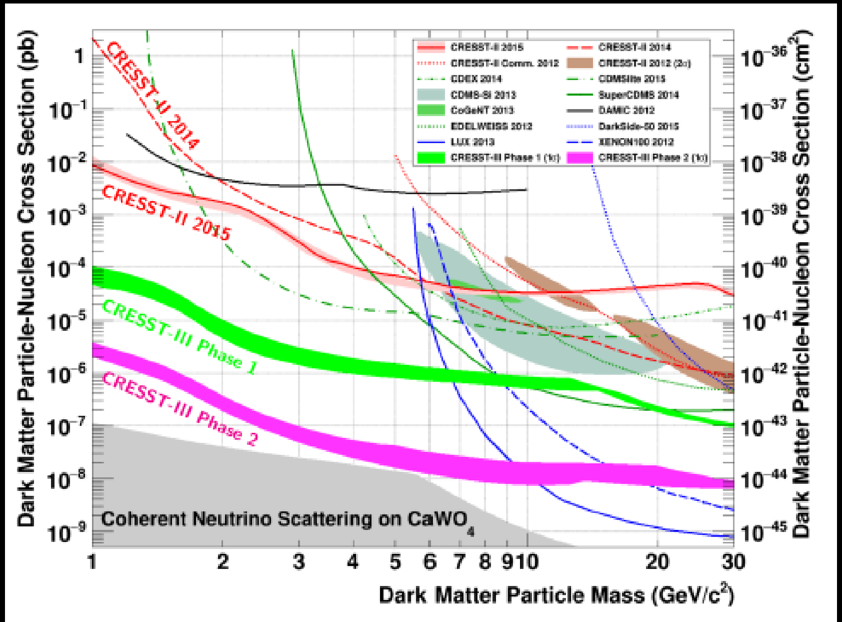


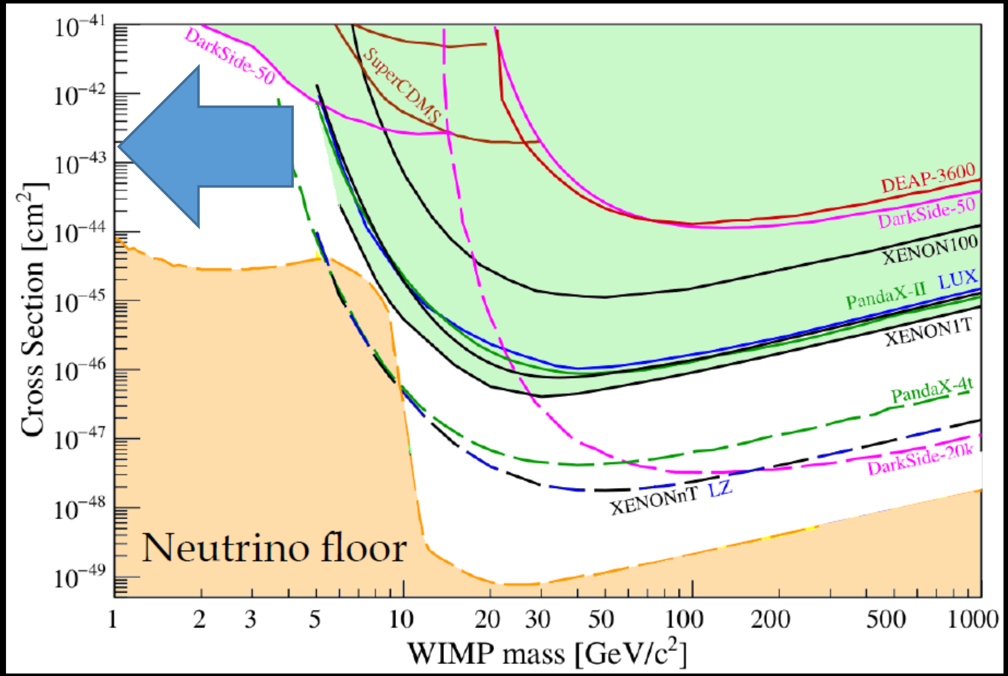
Super CDMS

And others
PICO, NEWS-G, DAMIC, SENSEI, …

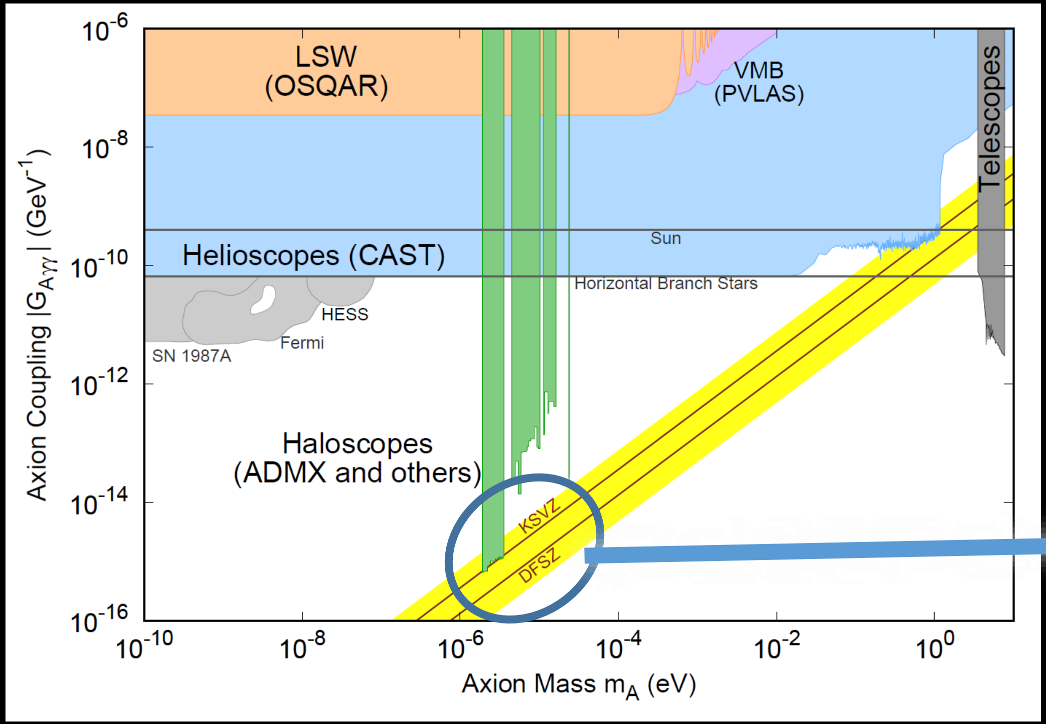
Dark Matter: cryogenic detectors



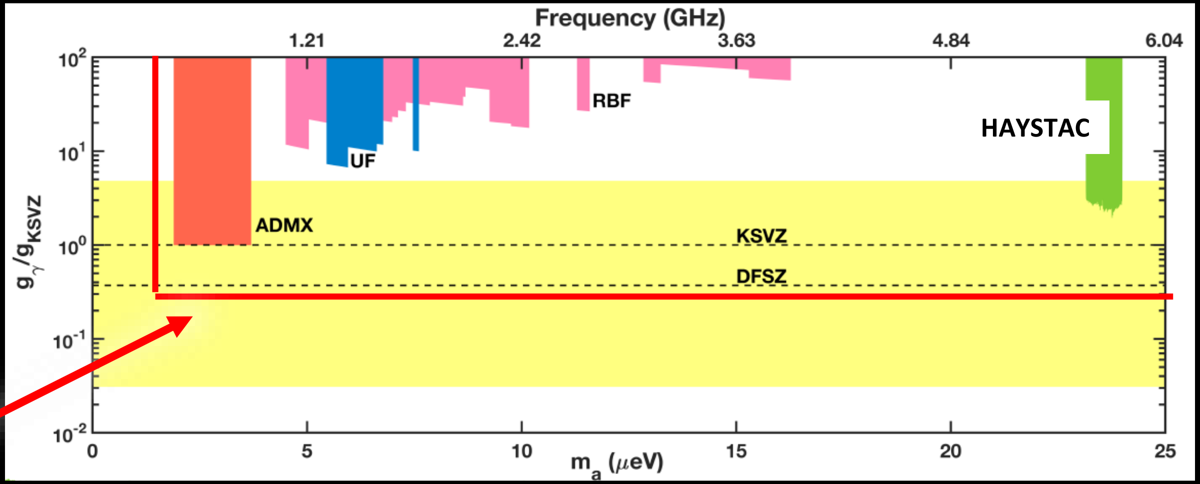




Dark Matter: Axion searches



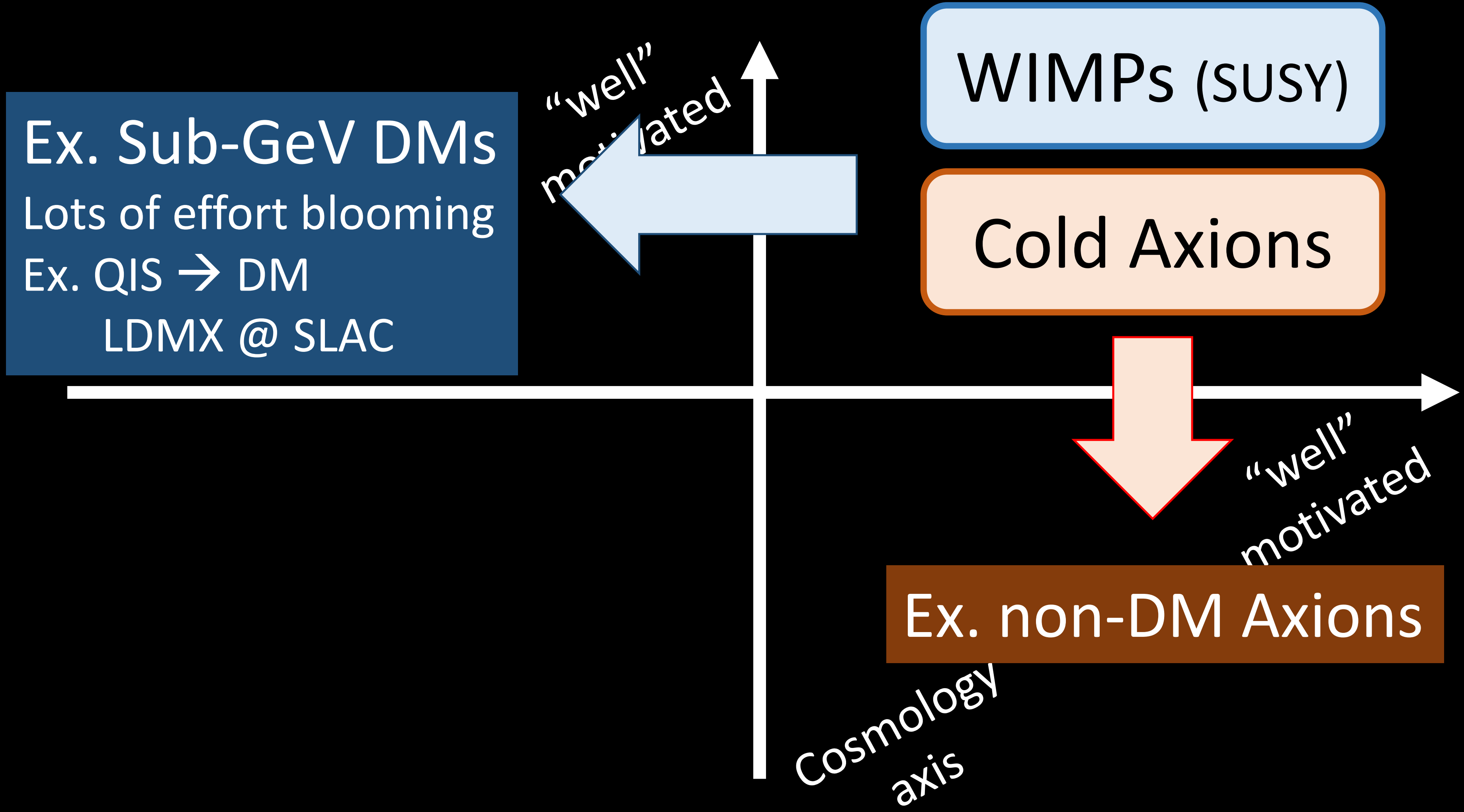
Plot from PDG (2017)



Plot from Zhong et al. (2018)

ADMX gen-2
(e.g., talk by Carosi 2019)

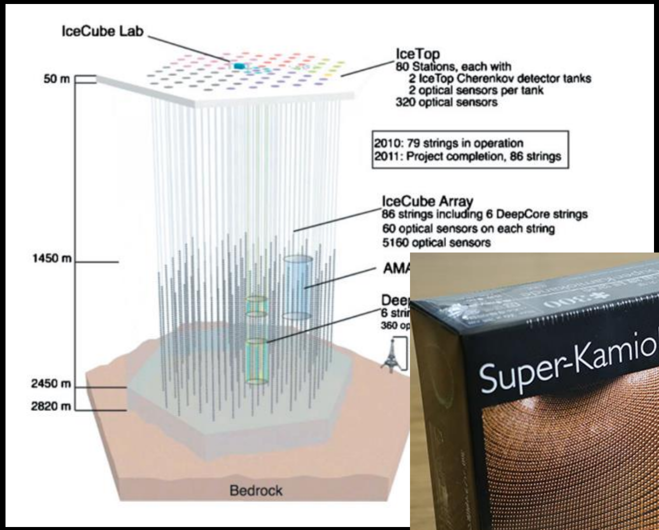
Dark Matter model space



Astroparticle

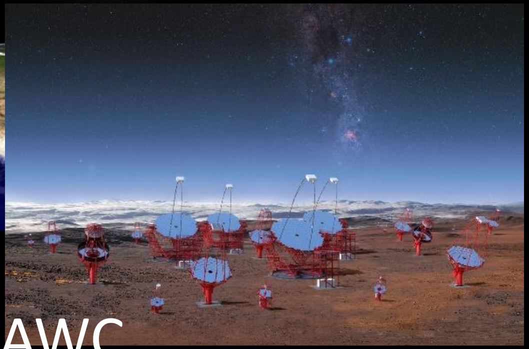
Astroparticle

Neutrinos



IceCube, Super-K, ANITA, KM3Net, …

Gamma Rays



Fermi, HAWC
HESS, MAGIC, VERITAS, CTA, …

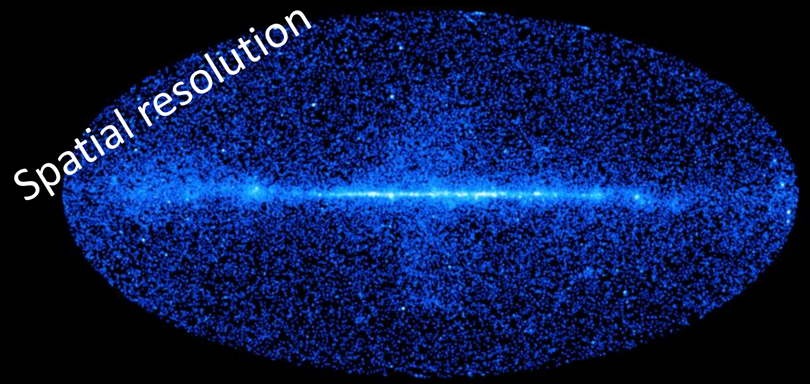
Cosmic Rays

PAMELA, AMS-02
Auger, Telescope Array, …

Gravitational Waves

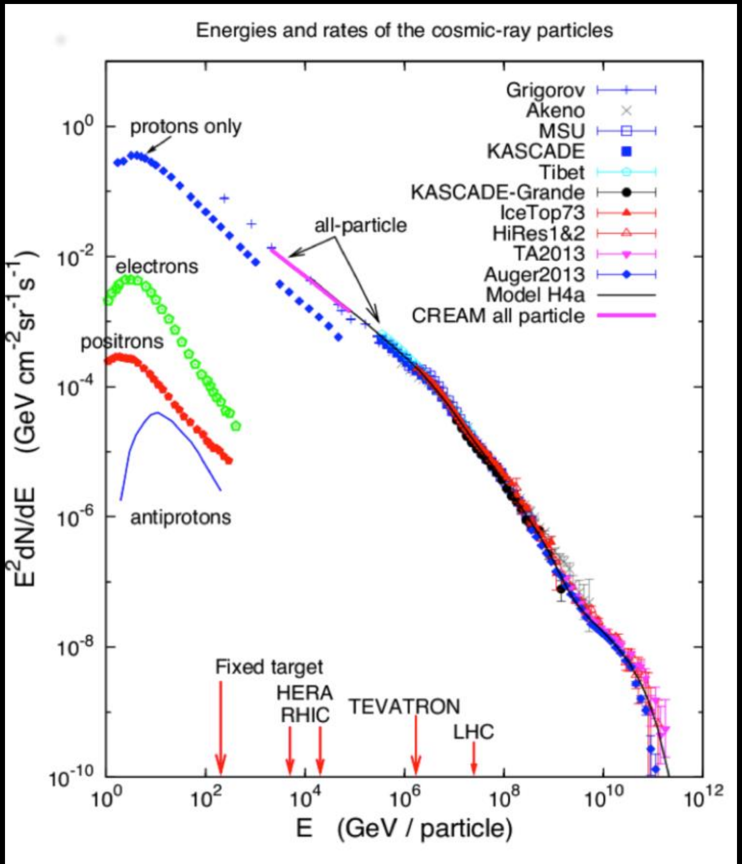
LIGO, Virgo, KAGURA

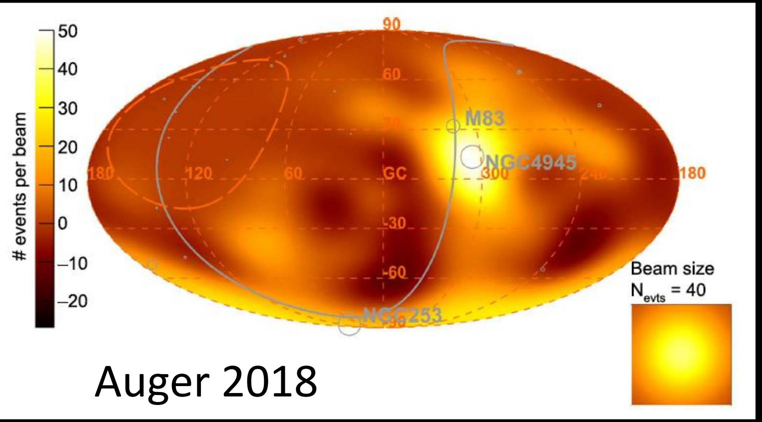
Astroparticle



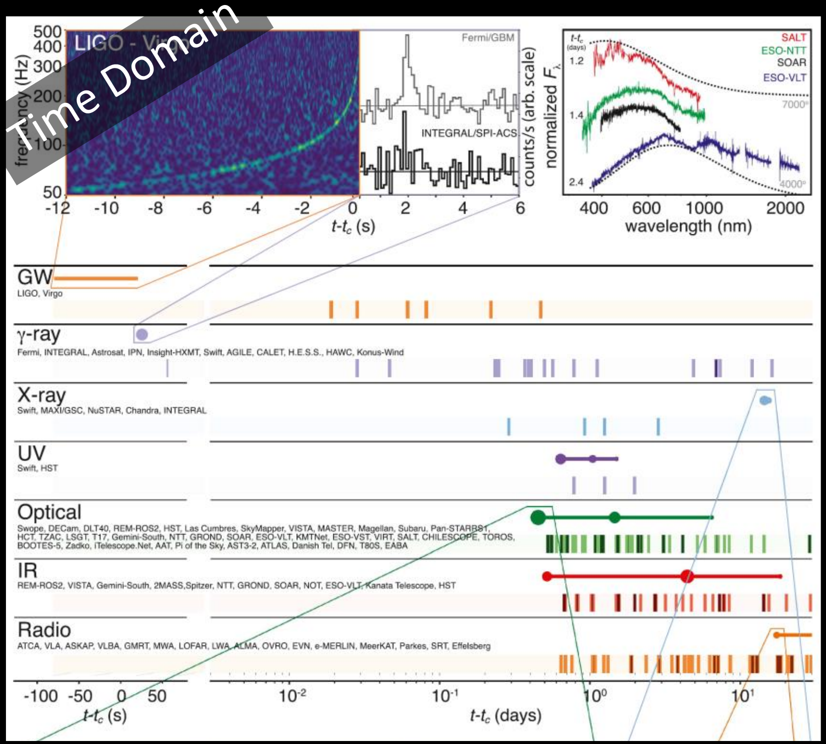
Fermi 2016

Energy Flux





Auger 2018



LIGO, Virgo, Fermi, INTEGRAL, … (2017)

Extremely rich astrophysics expected

- GWs, High energy ν, …
- Multi-purpose, multi-particle detector system

Particle physics implication?

- Ex.: $|c - c_{GW}|/c < O(10^{-15})$
- Exploration of unknowns: DM, Axion, Unknown unknowns
- History: early days of particle physics, ν oscillation, …

Summary

Tremendous progress in these area in the past decade, and expected in the next decade

- New CMB surveys coming online: Simons Observatory, CMB-S4, …
- New optical surveys coming online: DESI, PFS, LSST, Euclid, …
- Dark Matter: gen-2 (and gen-3) getting to neutrino floor, Axion searches cutting into plausible parameter region.
- Astroparticle: turning into “multi-purpose detector complex.”

Possibility of no new physics in next 10 years?

- Cosmology: no primordial gravitational waves.
- Cosmology: no BSM thermal relics.
- Cosmology: no deviation from w=-1.
- Cosmology: no detection of primordial non-Gaussianity.
- DM: no detection of WIMP.
- DM: no detection of Axion.
- Astroparticle: no detection of unknown unknown.
- No to all other possibilities of Unkown Unkowns.

Really ??

Possibility of no new physics in next 10 years?

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Really ??

And we are measuring very fundamental quantities.