The Status of CTA and CTA-LST Project

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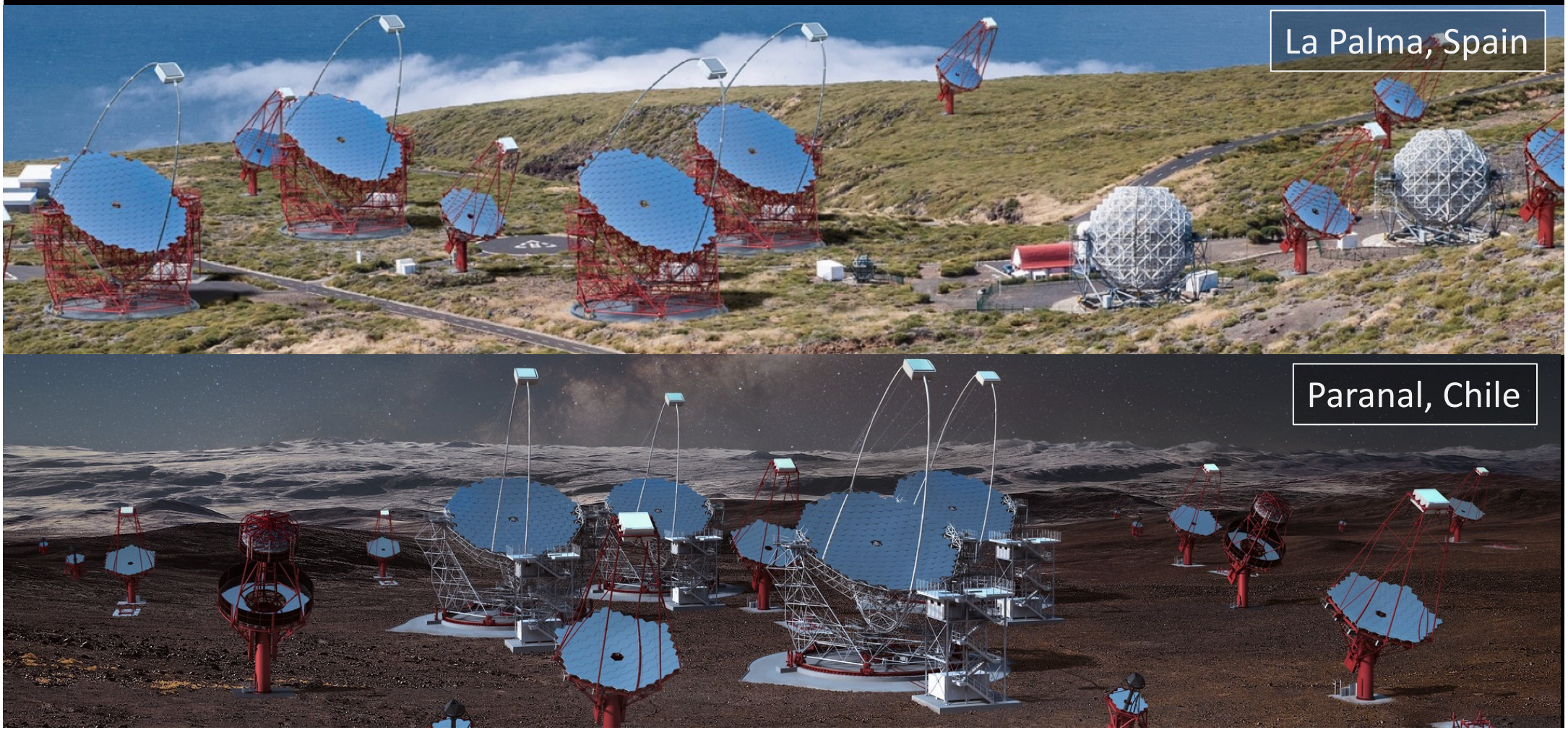
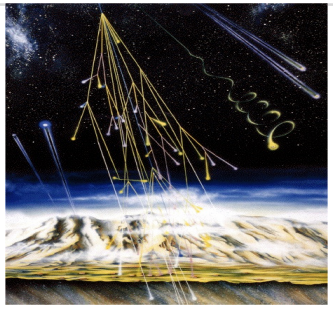
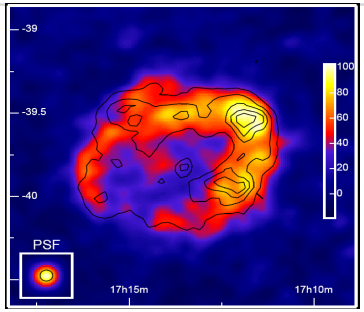


Science of CTA is very wide

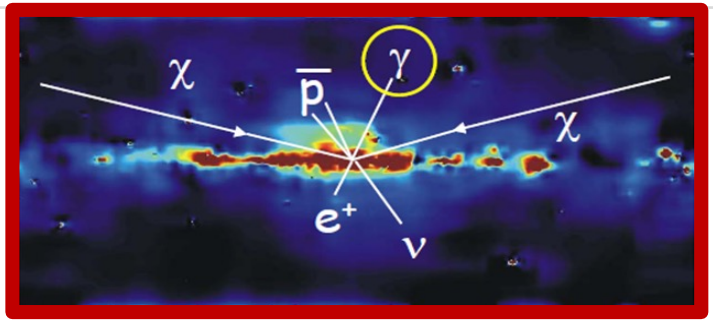
SNRs, PWNe, AGNs, GRBs, Dark Matter





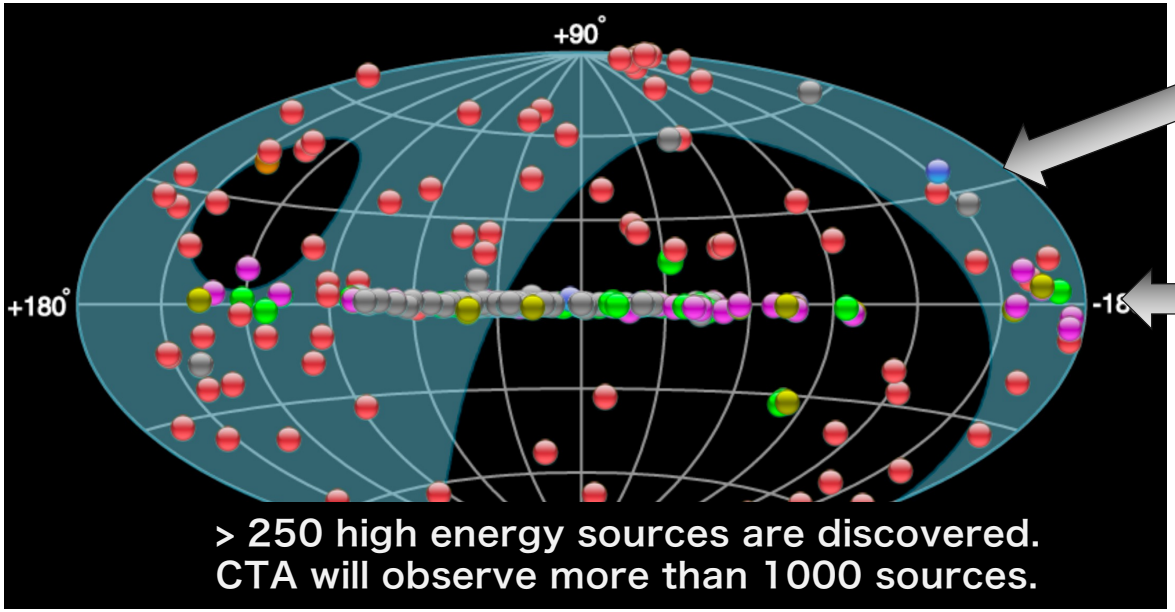
Cosmic Ray Origin

Super Massive Black Holes



Dark Matter Search (Discovery)

- Origin of Cosmic Rays (Big accelerators)
- Black Hole and S.M.B.H.
- Dark Matter Search

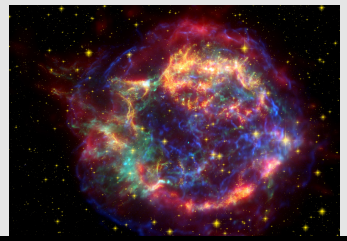


Extragalactic Sources

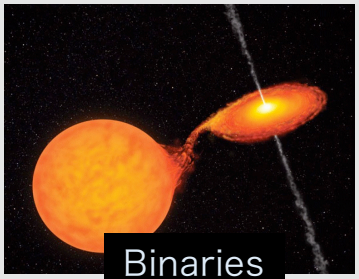
Active Galactic Nuclei

Gamma Ray Bursts

Galactic Sources



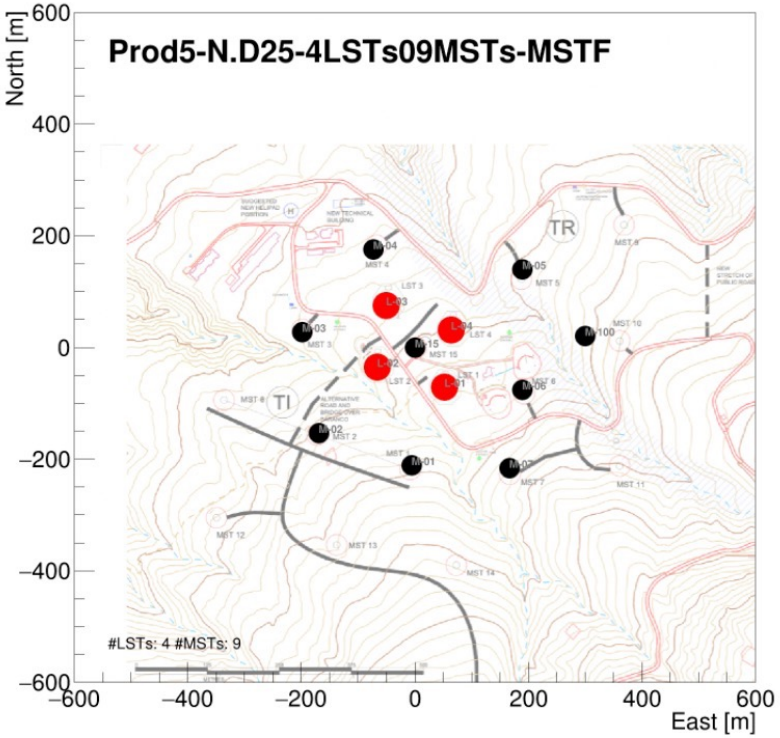
Super Nova Remnants



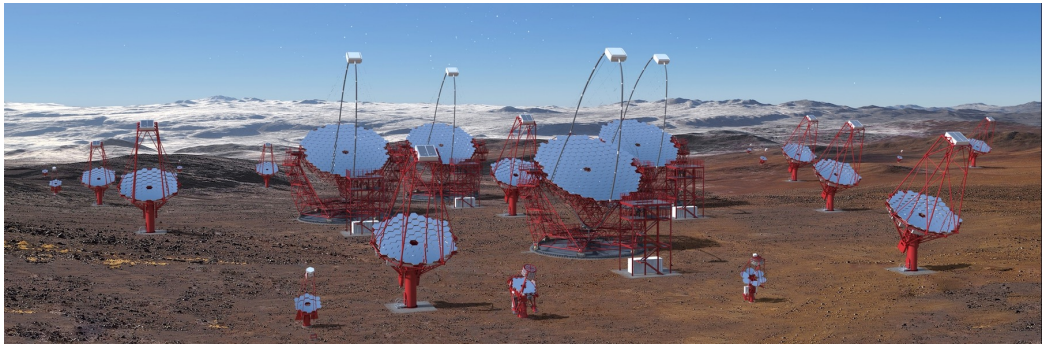
Binaries

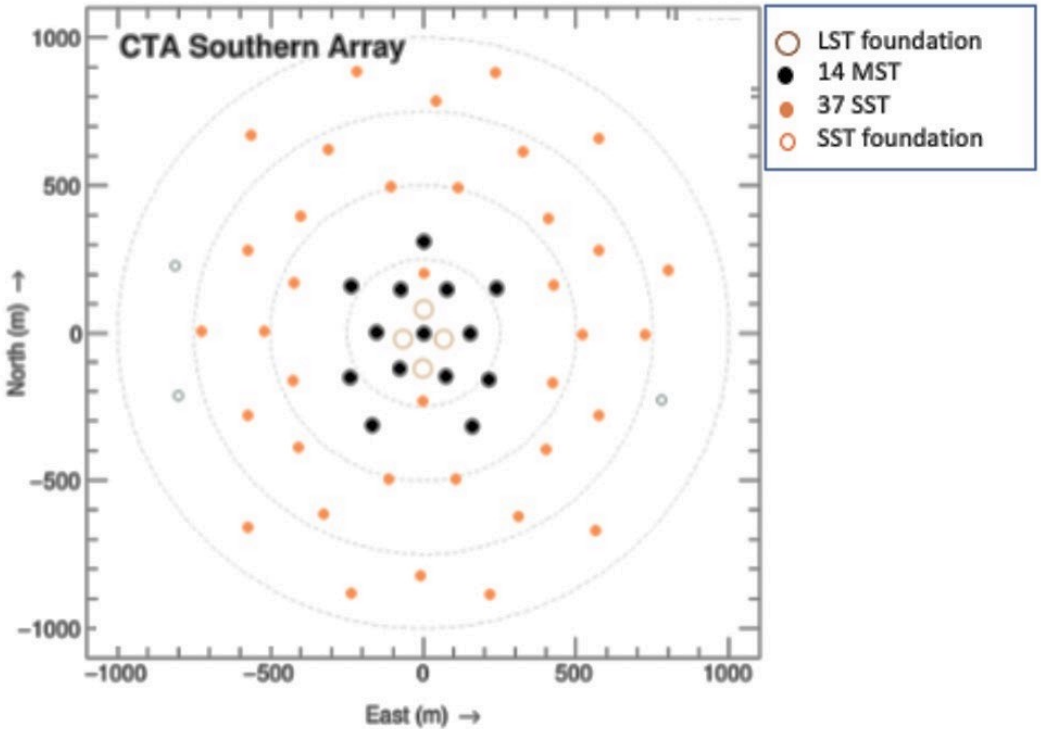
Alpha Configuration is decided with the financial constraints

Roque de los Muchachos Observatory
La Palma, Spain

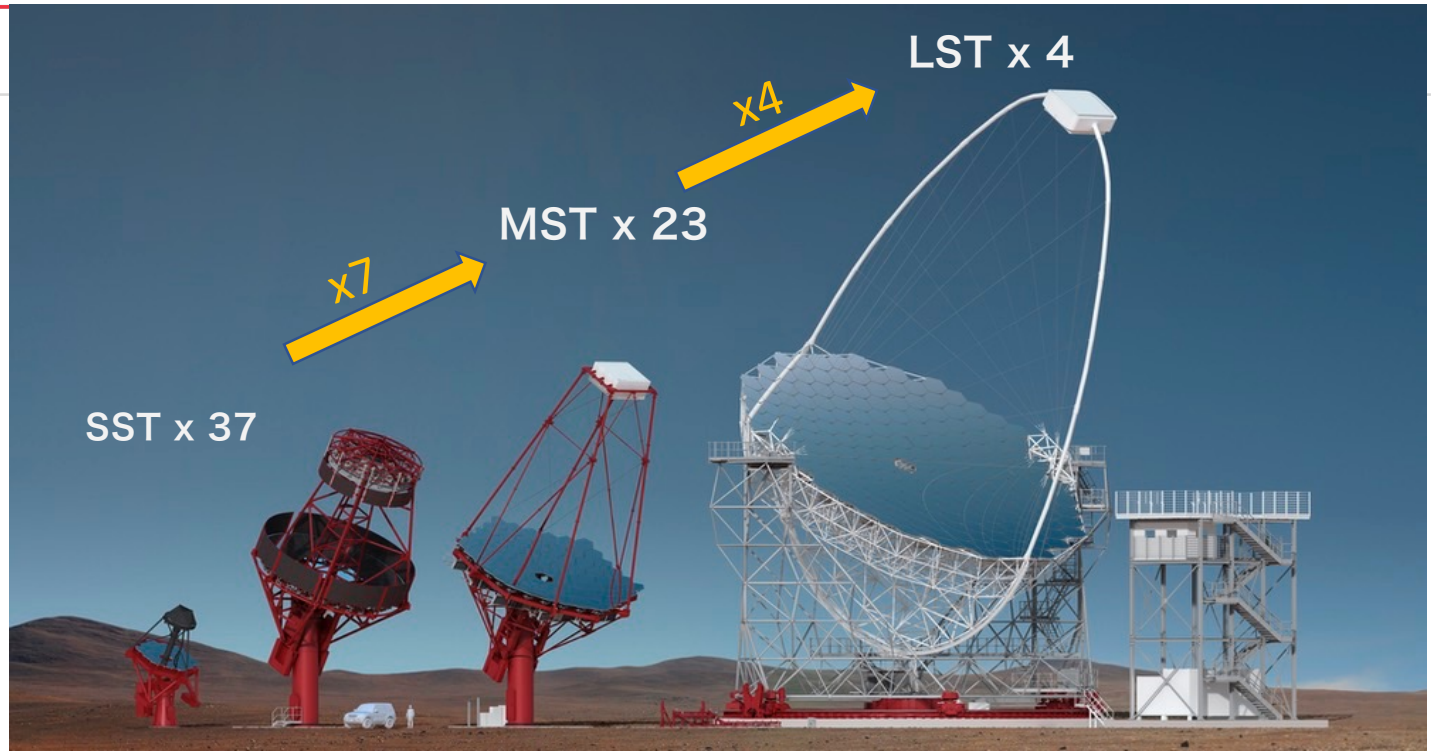


Paranal, Chile





Telescope Design



Telescope Types	SST	MST	LST
Optics	Schwarzschild-Couder	Davies-Cotton	Parabolic (Isochronous)
FoV and Camera	10.5 deg SiPM	7.5 deg PMT	4.3 deg PMT
Mirror Diameter	4.3m	11.5m	23m
Energy Range	3 TeV - 200 TeV	100GeV - 10TeV	20GeV – 2000GeV
Science Targets	Galactic Sources PeVatron (UHE CR)	Galactic Sources Nearby AGNs (z<0.5) Dark Matter	Transient Sources AGNs(z<2), GRBs(z <4) Dark Matter

Cost Book for Alpha Configuration 4 LSTs, 23 MSTs and 37 SSTs

CTAO Cost Book Executive Summary	Cash [M€]	IKC [M€]	Total cost [M€]
Company Related	**8.1**	**0.3**	**8.4**
001 - Director's Office	2.4	-	2.4
002 - Administration	5.8	0.3	6.0
Construction Project	**78.7**	**244.2**	**322.9**
P01 - Project Management	2.4	-	2.4
P02 - Science & Science Ops. Preparation	2.3	6.3	8.6
P03 - Systems Engineering & Integration	3.2	0.1	3.3
P04 - On-Site Construction	53.4	16.3	69.6
Northern site	3.5	15.7	19.2
Southern site	49.9	0.6	50.5
P05 - Site/Infrastructure Design & Planning	2.1	3.6	5.7
P06 - Computing	13.1	39.4	52.5
P07 - Telescopes	1.6	171.6	173.3
Large-Sized Telescopes	-	60.1	60.1
Medium-Sized Telescopes	-	72.8	72.8
Small-Sized Telescopes	-	38.7	38.7
P08 - Array Common Elements	0.7	6.8	7.5
Grand Total	**86.9**	**244.4**	**331.3**

Table 2: CTAO Cost Book Executive Summary

Contributions to the construction costs of CTAO (MEur), from the last version of statutes, 5 Nov

Member/ Observer/ Strategic Partner/ Third Party	Construction					Pre-construction	Grand Total	
	Materials and Services (M&S)	FTEs	Other (non-cash)	Direct cash	Total	Contribution to the gGmbH	Contribution to construction costs	
Australia	1.340	0.108	0	0.450	1.898	0.219	2.117	
Austria	1.695	0.080	0	0.600	2.375	0.625	3.000	
Czech Republic	0.734	1.775	0	2.500	5.009	1.696	6.705	
France	26.196	14.000	0	18.280	58.476	1.609	60.085	17.4%
Germany	36.926	24.680	0	26.718	88.324	8.440	96.764	28.1%
Italy	26.010	12.560	0	26.000	64.570	4.681	69.251	20.1%
Japan	19.200	3.950	5.850	3.400	32.400	0.375	32.775	9.5%
Poland	9.143	1.339	0	6.096	16.578	0	16.578	
Slovenia	0.080	0.077	0	0.350	0.507	0.209	0.716	
Spain	21.397	9.814	14.932	1.000	47.143	1.350	48.493	14.1%
Switzerland	1.550	5.082	0	0.620	7.252	0.440	7.692	
Total	144.271	73.465	20.782	86.014	324.532	19.644	344.176	

WBS_v4 (but still in progress)

CTA+: A proposal for enhancing CTA's performances (Telescopes, Science & Technologies)

Proposal CTA+ editorial board
M. Cappi (Coord.), A. Antonelli, A. Comastri, G. Pareschi, G. Tagliaferri (INAF) R. Zanin (CTAO)N. Giglietto, G. Marsella, R. Paoletti (INFN)

PNRR Program INAF
Budget: ~ 80MEur
Period: 2023 – 2025

Application: Feb 2022
Negotiation: June 2022

CTA+ Program Office
(Science&Tech Coordination, Management, Finances & Administration)

- Program Coordination Office — Sci Coord+All WP leads
- Program Management Office — Manager of IR/Program + Financial Officer + Admin resp.

+ 3LSTs 49MEur

+ 9SSTs

- **Science and HQ enhancement Project Office** — Lead: A. Comastri WP1000
  - CTAO HQ Enhancement Lead.: A. Comastri WP1100
  - Science & Outreach/communication Enhancement Lead.: R. Zanin (CTAO/INAF) WP1200
- **LSTs South Project Office** — Lead: A. Antonelli/G. Pareschi (INAF)+ co-lead:D.R. Paoletti/N. Giglietto (INFN) WP2000
  - Mechanical structures Resp.:INAF+ INFN WP2200
  - Mirrors & Actuators Resp.:INAF+INFN WP2300
  - Camera and raw Processing Resp.:INFN+ INAF+ Partners WP2400
  - AIV+CAL+Data Processing HL Rep.: INAF+ INFN+Partners WP2500
- **SSTs+ Project Office** — Lead: G. Tagliaferri/P. Attinà (INAF) WP3000
  - Mechanical structures Resp.:INAF WP3200
  - Mirrors Resp.:INAF WP3300
  - Cameras Resp.:Partners+ INAF WP3400
  - AIV+CAL+Data Processing HL Rep.: INAF+ INFN+Partners WP3500
- **CTA+ Optical/radio follow-up Project Office** — Lead: E. Capellaro WP4000
  - TNG FP enhancement (DOX+POL+Fast PoI) Resp.:INAF WP4100
  - Intensity Interferometry for SSTs prototyped on ASTRI Resp.:INAF WP4200
  - VST Spectroplarimeter Resp.:INAF WP4300
  - RadioFast VLBI Resp.: INAF WP4400
- **R&D (CTA Technologies enhancements) Project office** — Lead: G. Marsella WP5000
  - Water Cherenkov + RPC (SWGO ehancement) Resp.:INFN WP5100
  - SiPM (R&D for future CTA) Resp.:INFN WP5200
  - Muon Tomography (CTA spin-off Tech) Resp.:INAF WP5300

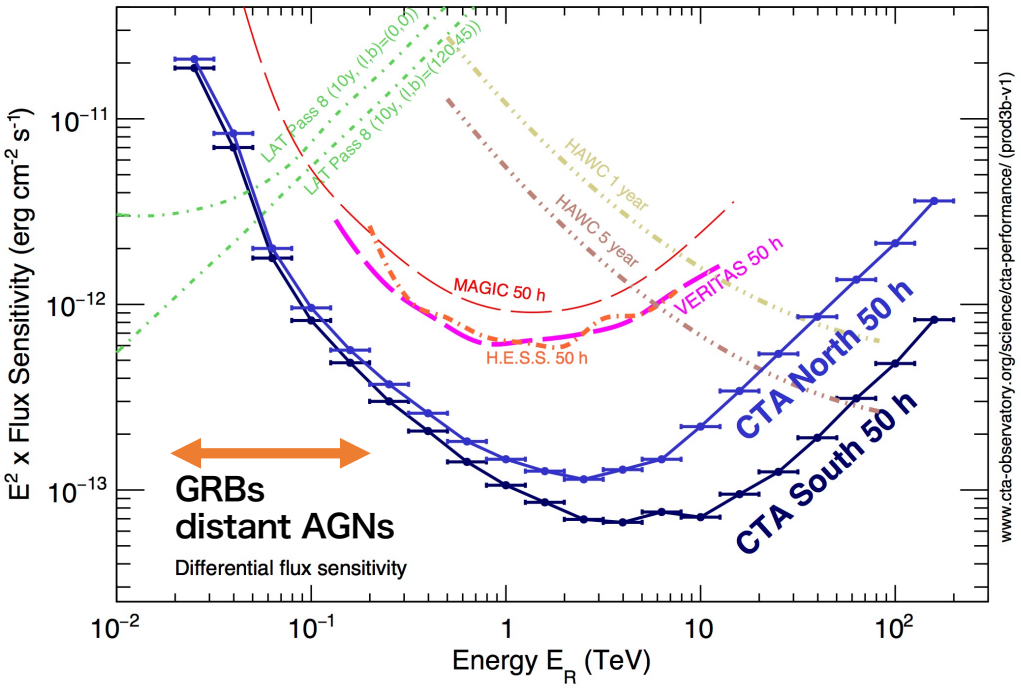
A slide by M. Cappi at PC

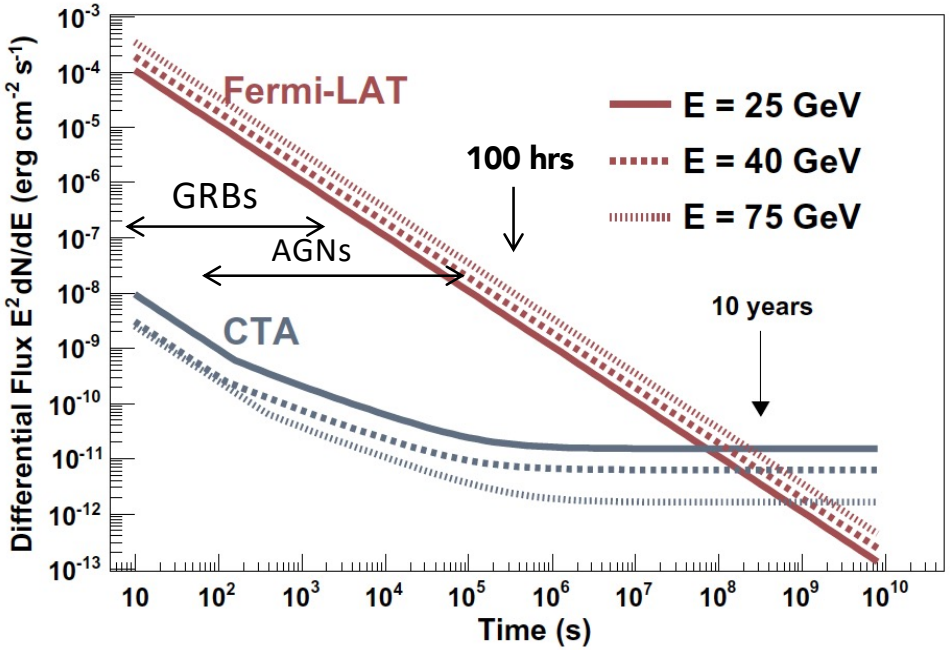
CTA and LST Timeline

- 2016-2018 LST1 was constructed
- 2018-2021 LST1 in commissioning phase
- 2022-2024 LST2-4 will be constructed, and we need to take care operation and maintenance of LSTs
  LST1 can be defined in Science-Engineering Phase after commissioning
- 2022 CTAO ERIC will be founded
- 2026-2027 The final Acceptance of LST1-LST4 and IKC process
- 2023-2025 LST5-8 construction?

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Organization	CTAO gGmbH (Heidelberg)										
			CTAO ERIC (European Research Infrastructure Consortium)								
Alpha Config	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LST North	Comissioning and Operation of LST1					Operation as 4 LST Array				Observatory Operation	
	CDR		Deployment of LST2-4								
MST North	Design and Finance		INFRA	Construction of 9MSTs							
CTA South	Array config, Finance and CDR		INFRA		Construction and Deplyment of 14 MSTs						
					Construction and Deployment of 37 SSTs						
Extension	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LST South		Finance / CDR		Construction of 4 LSTs ???			Operation ???				

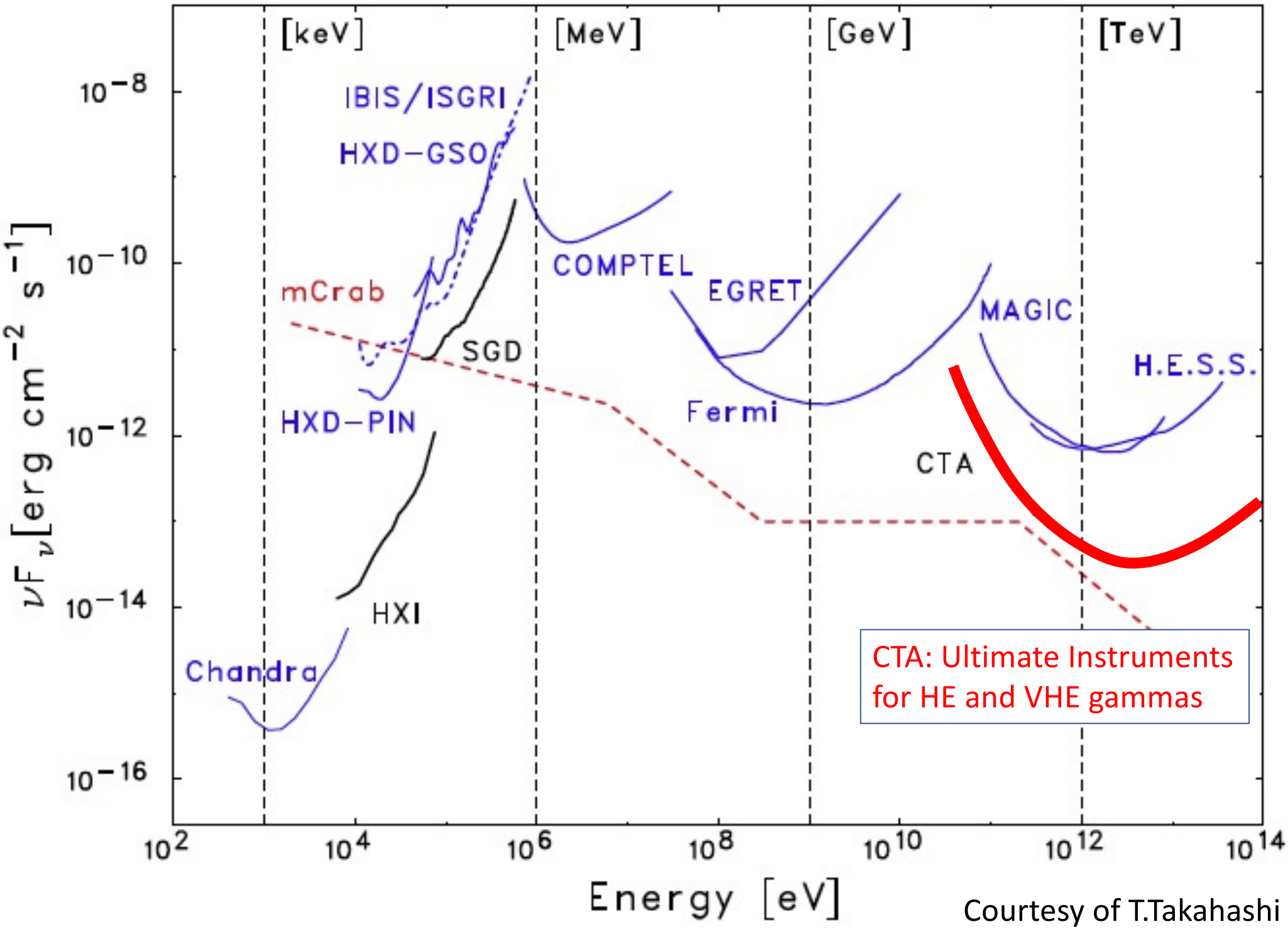
10 times better sensitivity
Wide Energy coverage 20GeV~200TeV





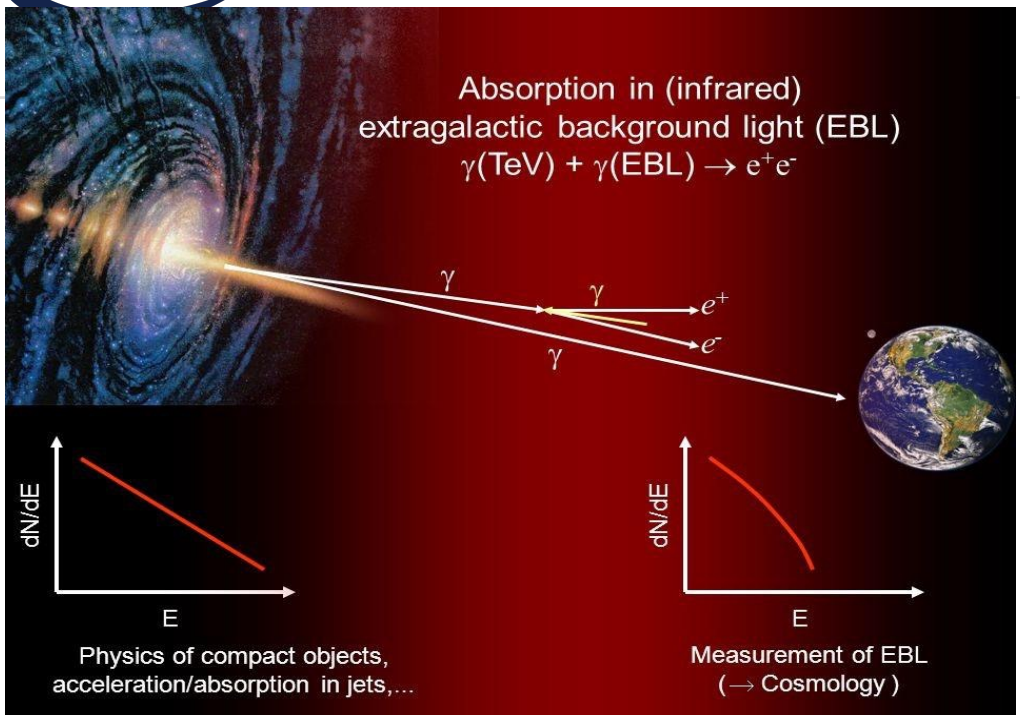
- CTA array has a 10 times better sensitivity than HESS, MAGIC, and VERITAS
- CTA covers wide energy range from 20GeV to 200TeV (4 orders of magnitude)

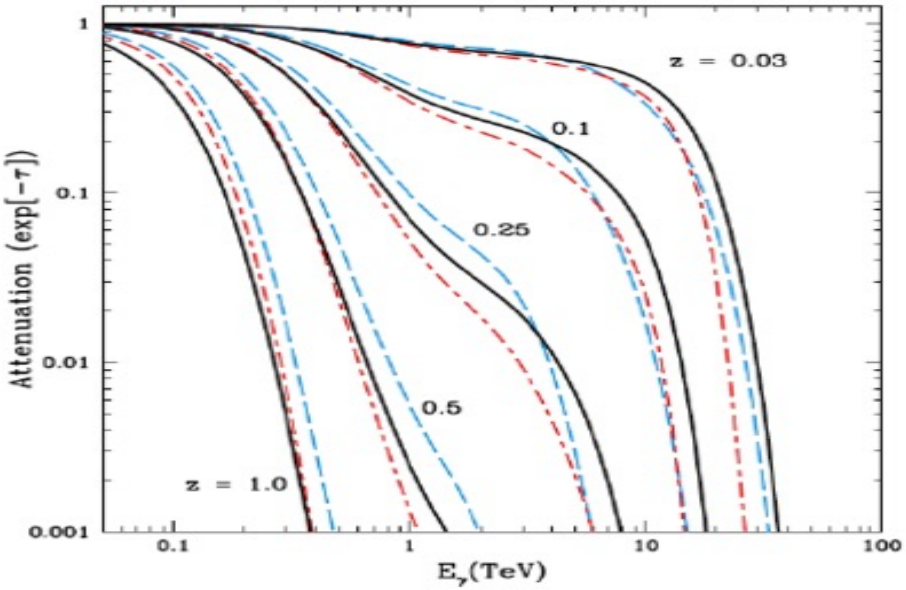
- LSTs will offer
  - Distant AGNs up to z = 2 and GRBs up to z = 4 are observable with LSTs
  - X10000 sensitivity for GRBs and AGN flares than Fermi
  - The fast rotation (20 sec) offers the observation of GRBs even in prompt phase

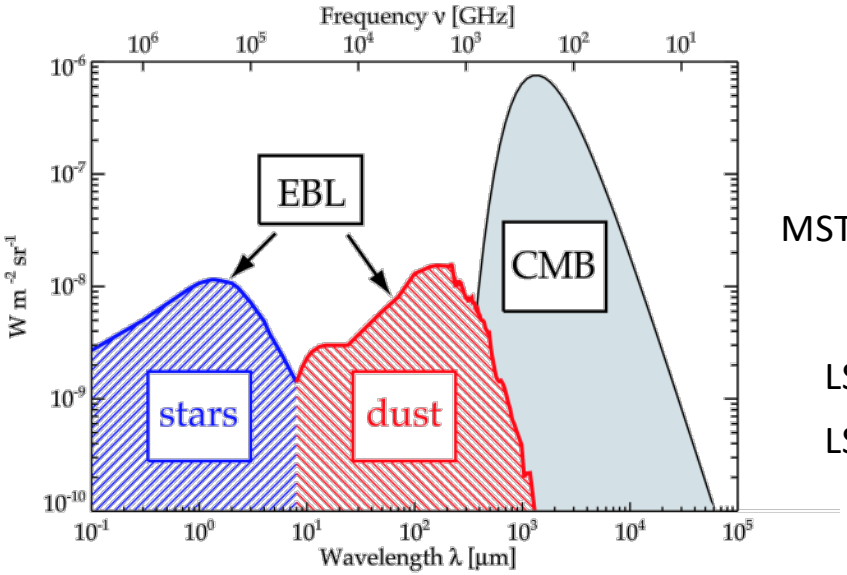


Courtesy of T.Takahashi

Gamma Ray Horizon
20GeV Low Threshold Energy → z~4



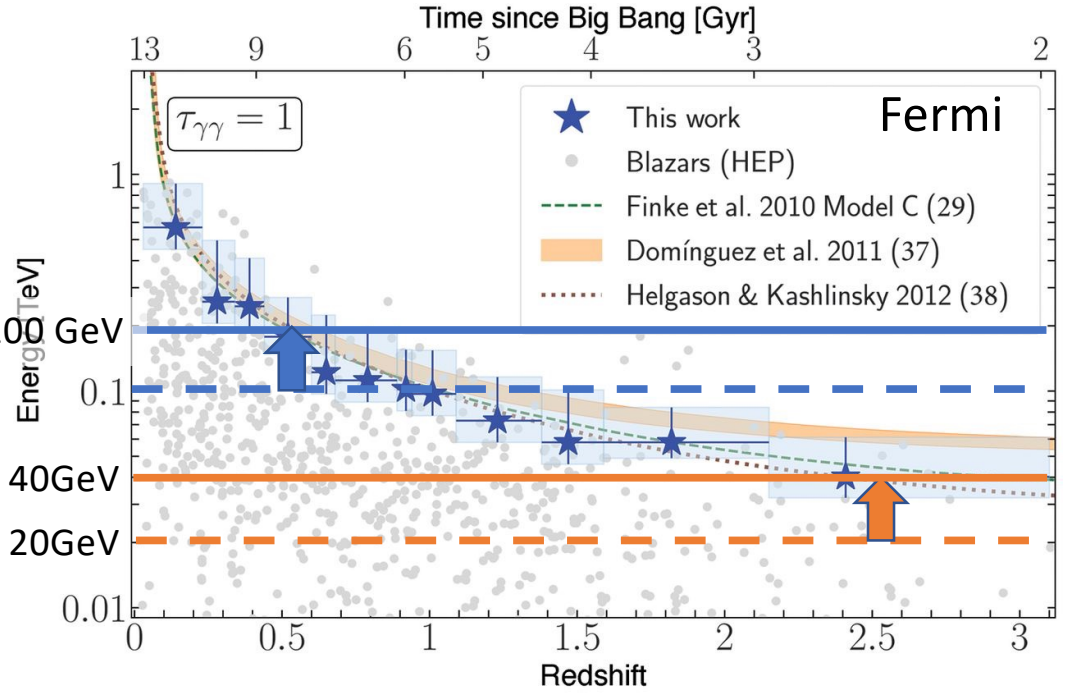




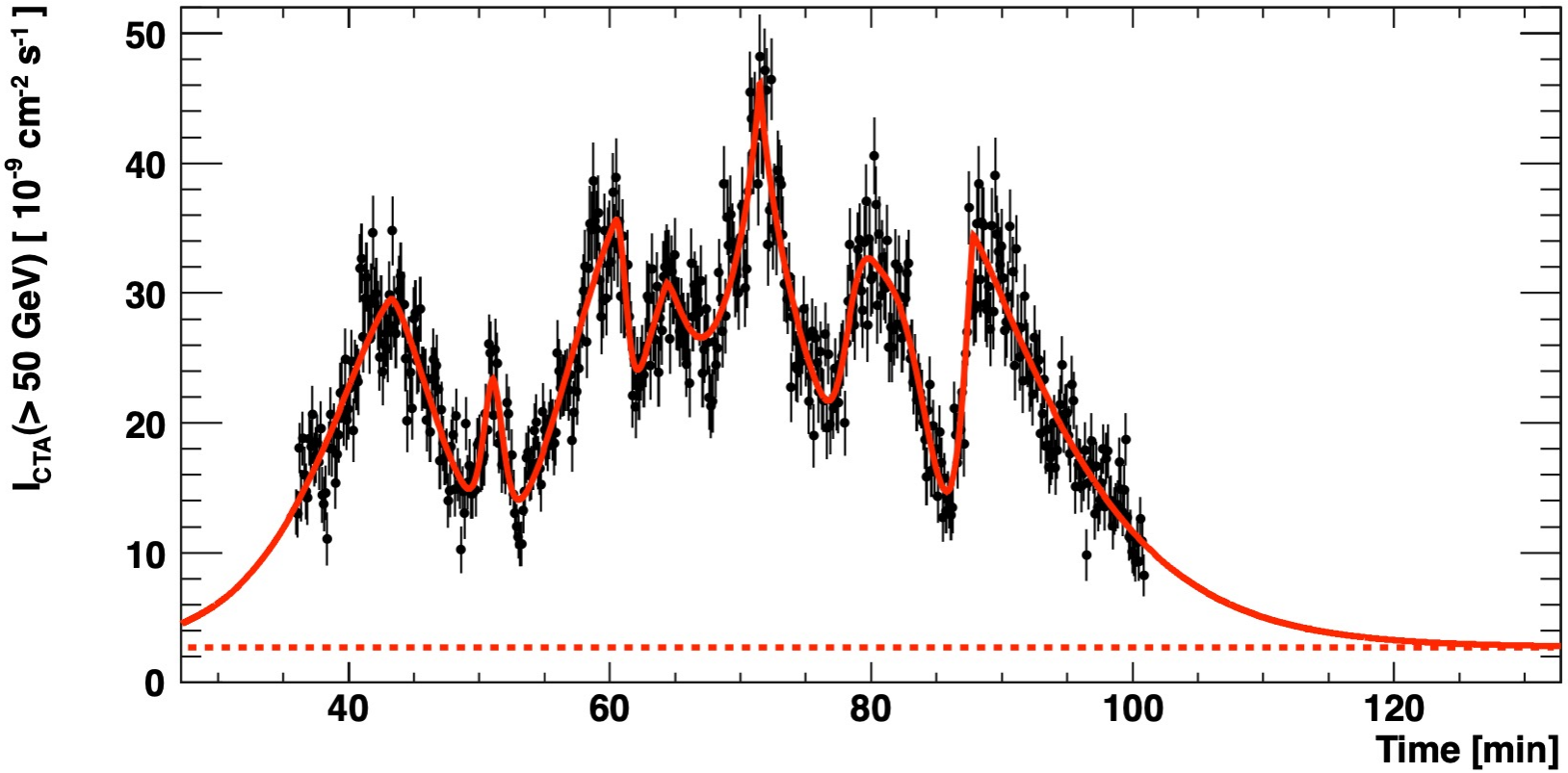
MST@45° Eth 200 GeV

LST@45° Eth 40GeV

LST@25° Eth 20GeV

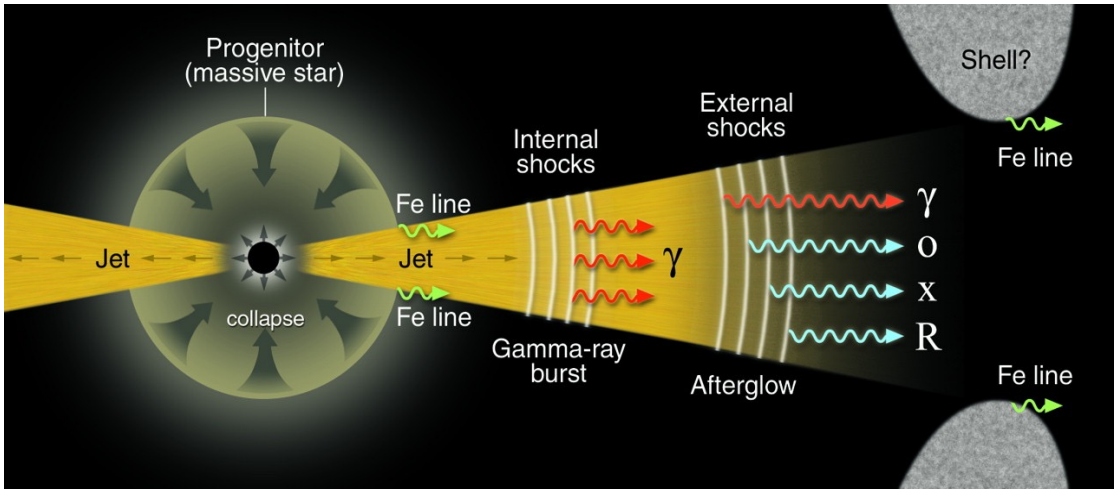


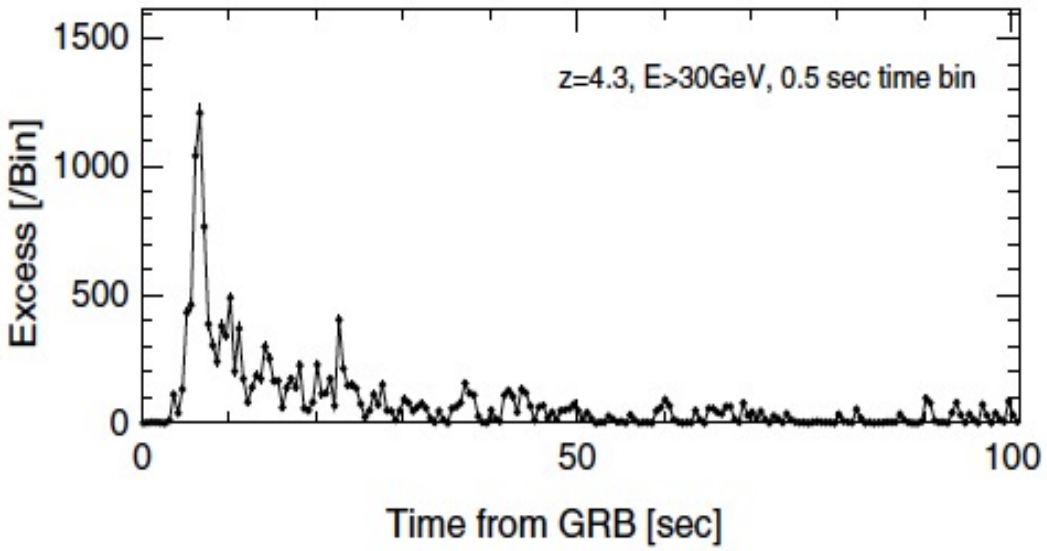
Simulated AGN Flares
Template: the 2006 flare of PKS2155-304
Low Threshold Energy ➔ High Precision Light curve

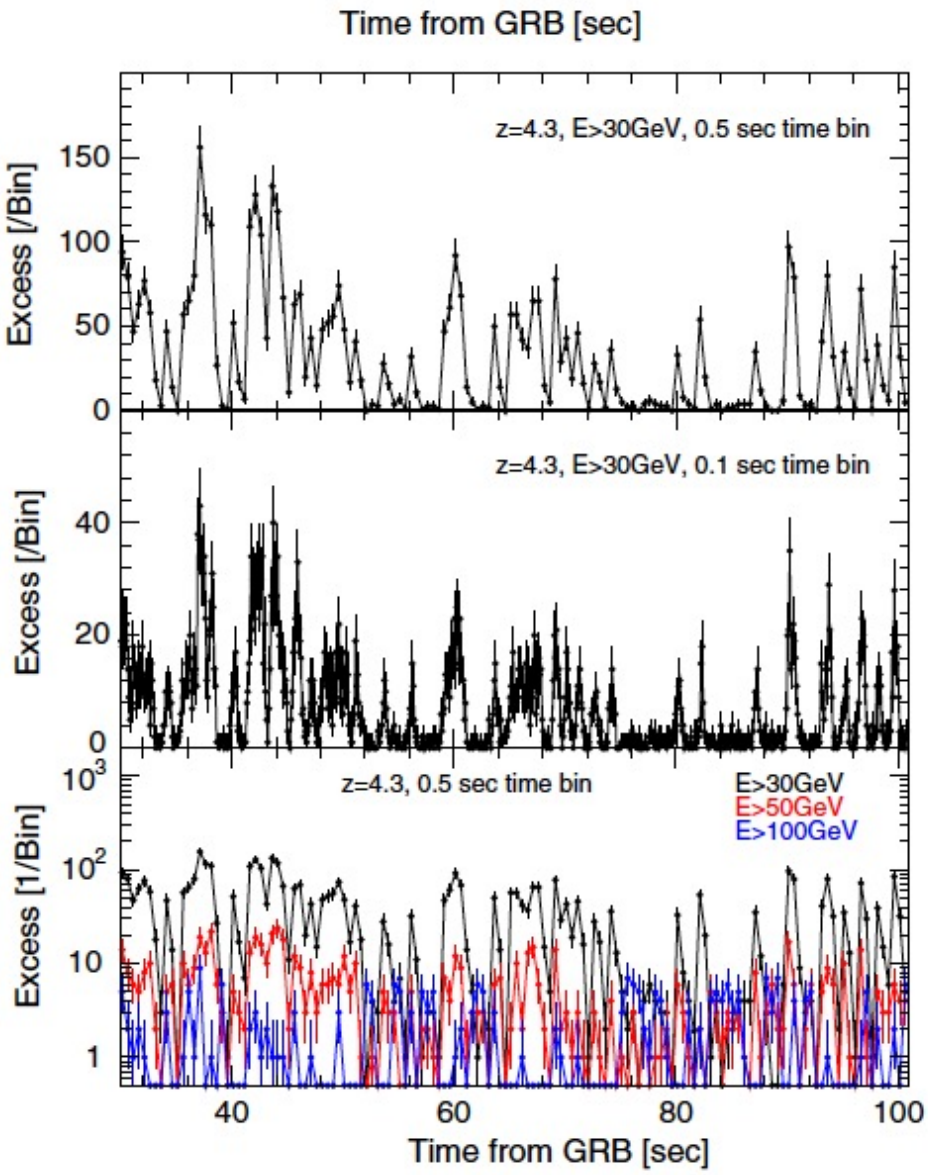


- Light curve can be examined, a few minutes scale structure ➔ a few 10s of seconds
  - Particle acceleration mechanism, Cooling process
  - Light curve vs. Energy dependence ➔ Q.G. Energy scale > Planck Mass scale

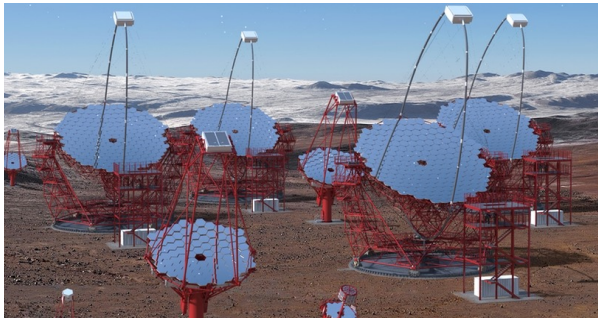
GRB: Simulated light curve (template: GRB080916C)

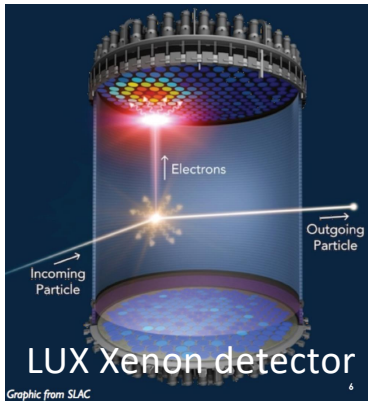


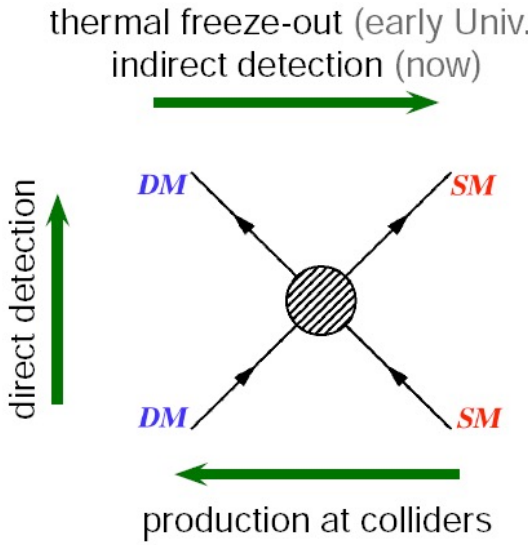


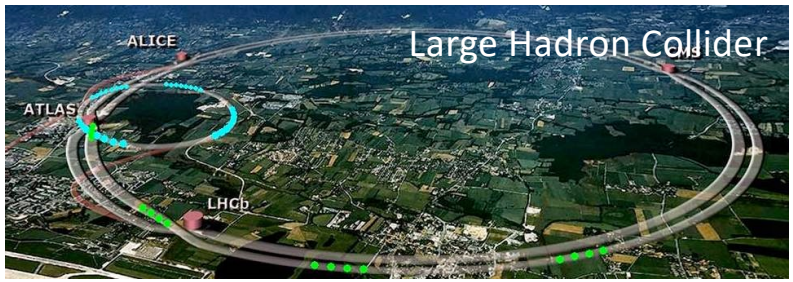


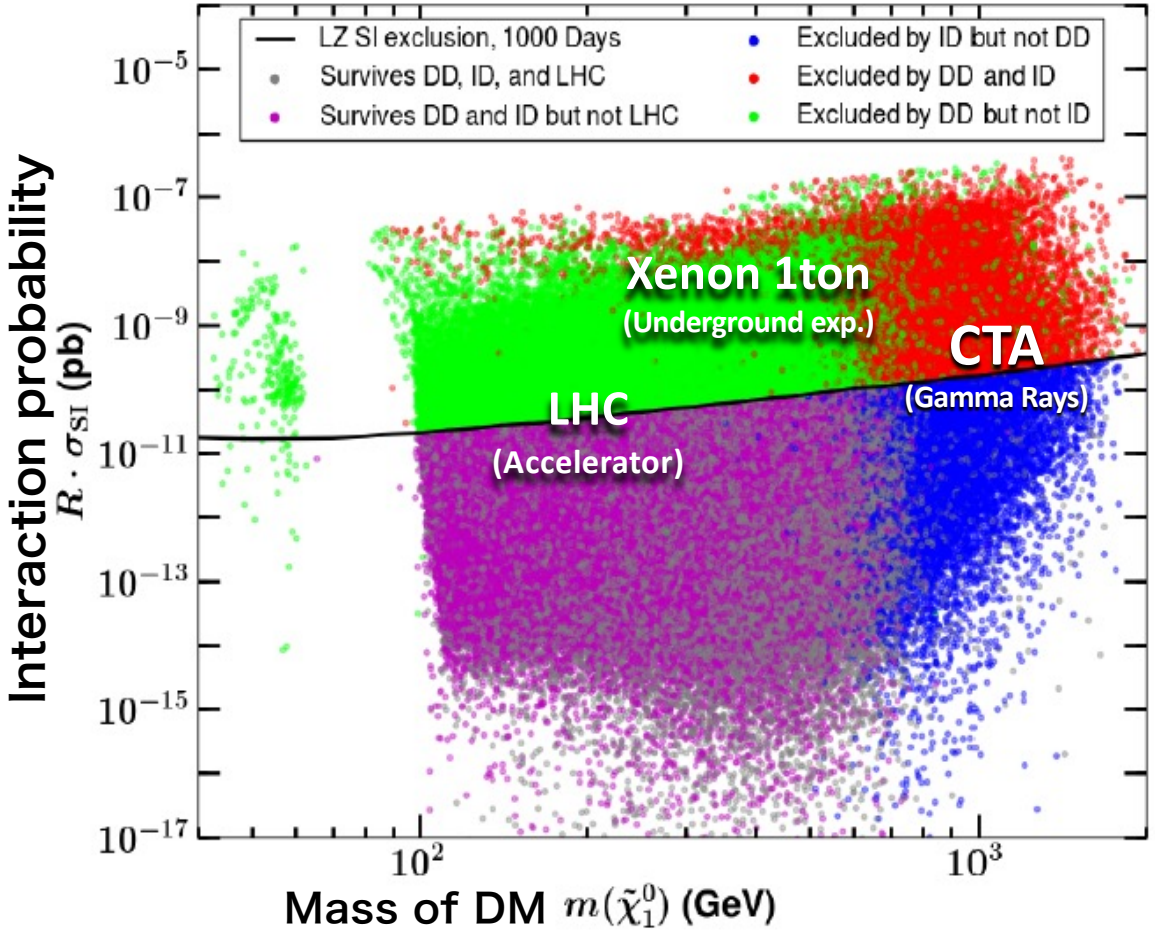
Complementarity of different approaches Direct, Indirect, and Collider Experiment







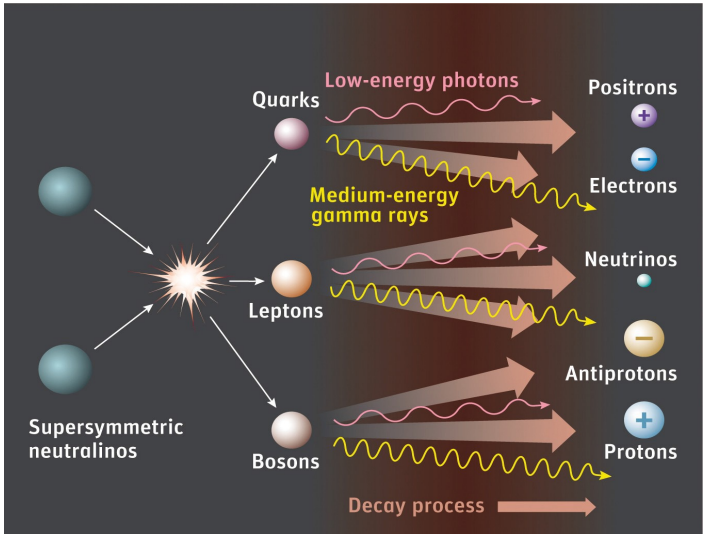




- Explore Dark Matter in the Galactic Center and Dwarf Sph. Galaxies
- CTA has the best sensitivity above 700GeV

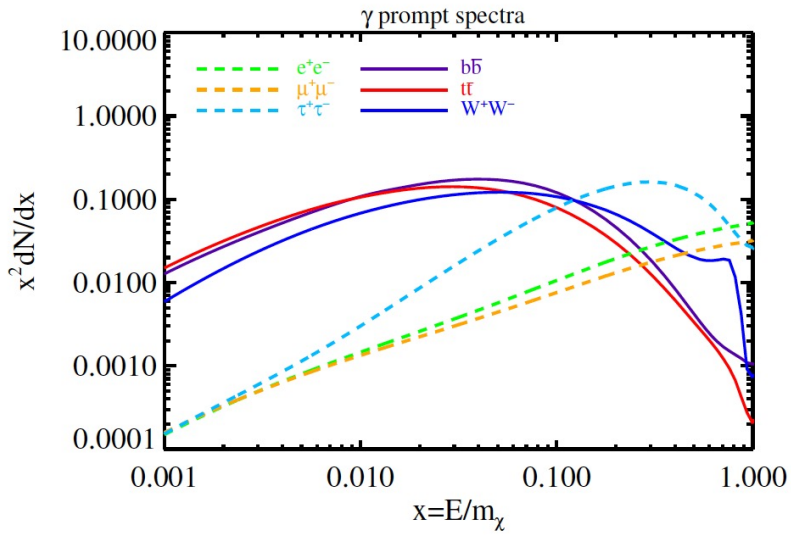
Dark Matter Search

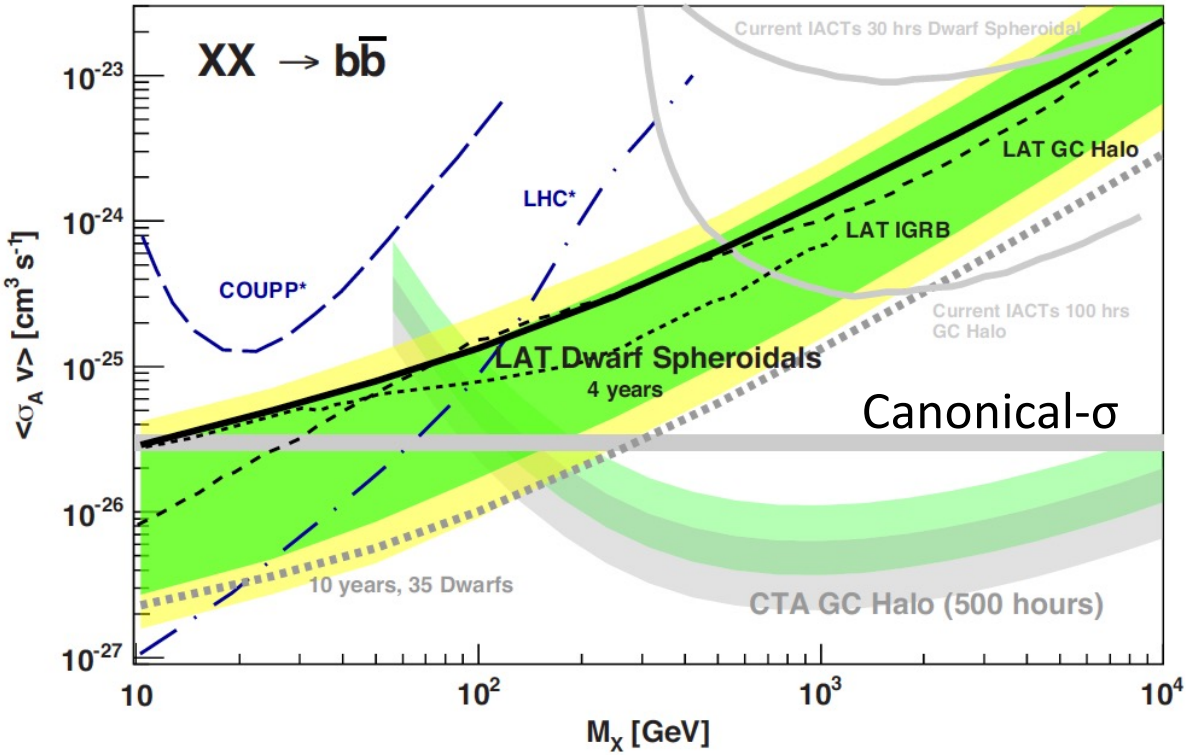
Sensitive M_χ: 200GeV - 10TeV



$$\frac{d\Phi_\gamma}{dE_\gamma} = \frac{1}{4\pi} \underbrace{\frac{<\sigma_{ann} v>}{2m^2_{WIMP}} \sum_f \frac{dN^f_\gamma}{dE_\gamma} B_f}_{\text{'Particle Physics'}} \times \underbrace{\int_{\Delta\Omega} d\Omega' \int_{los} \rho^2 dl(r,\theta')}_{\text{'Astrophysics' or } J(E)}$$

Particle Physics Astrophysics





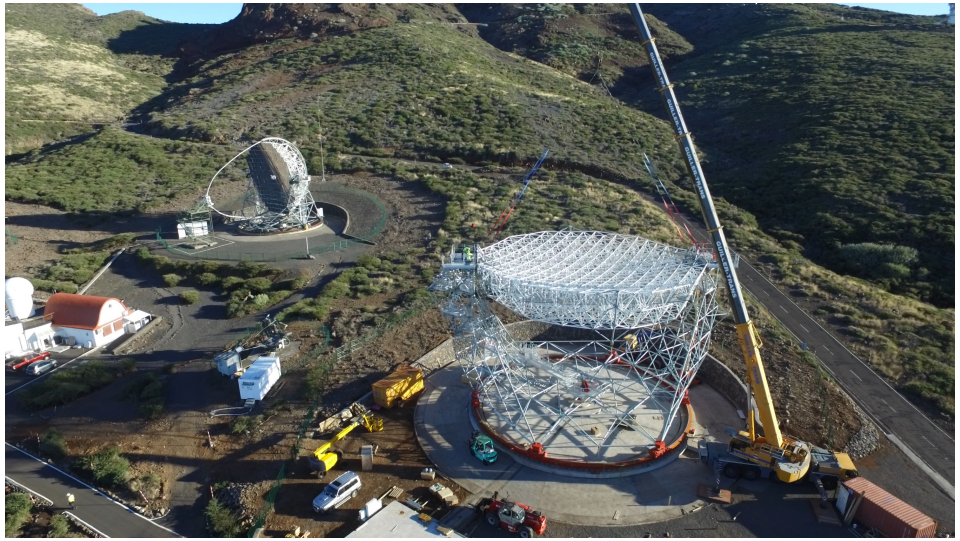
Gamma rays from Annihilation produce the bump around 1/10 -1/20 Mχ ➔ 20GeV-1TeV gamma

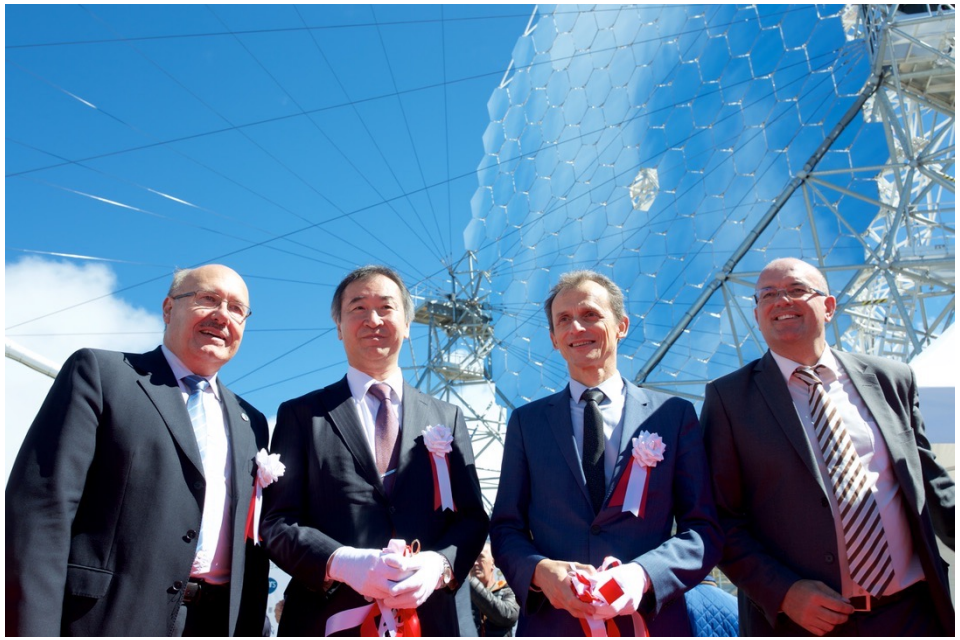
CTA gives the stringent upper limit.
Stefan Funk 2015

cherenkov telescope array

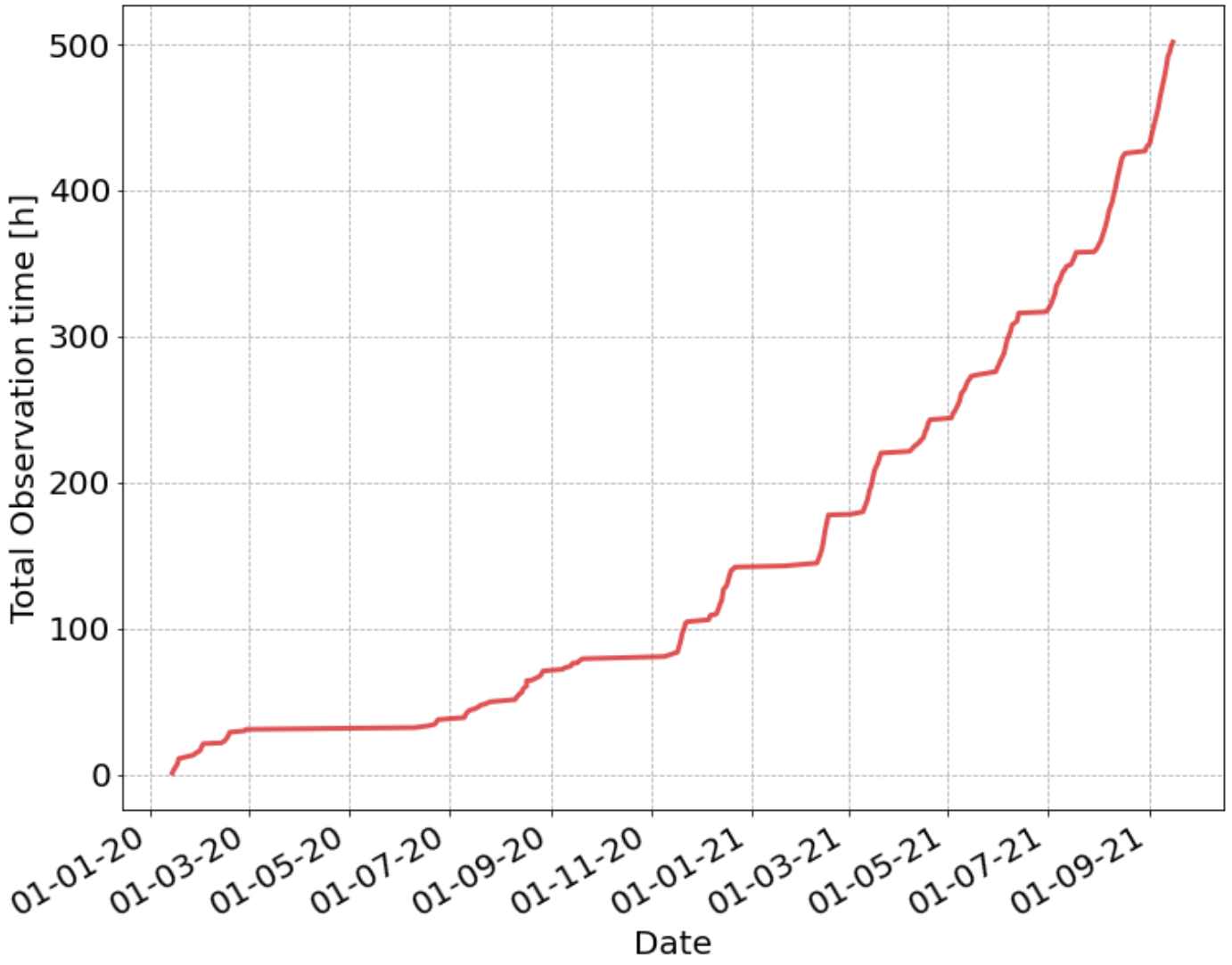
Commissioning of LST1 scientific observations

LST1 construction and Inauguration (Oct.2018)





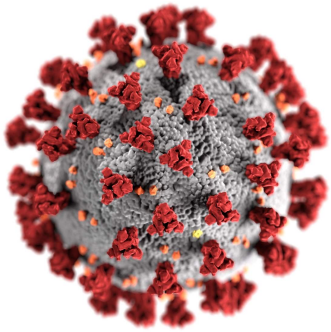
LST1 commissioning
500hrs of Scientific Observation

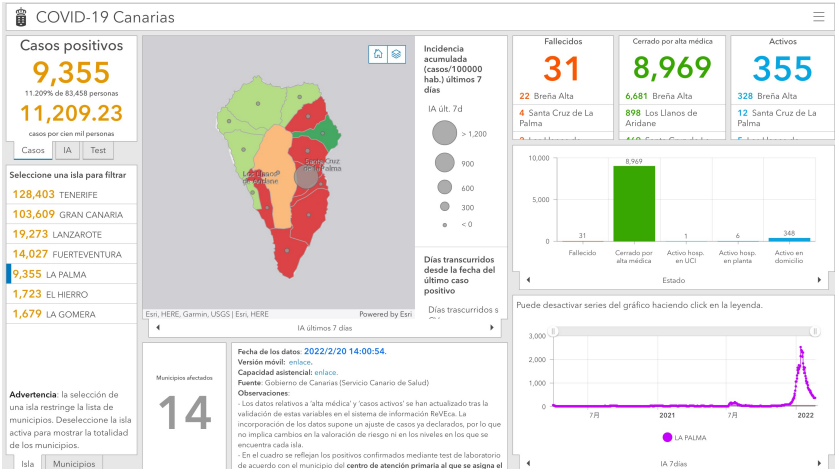


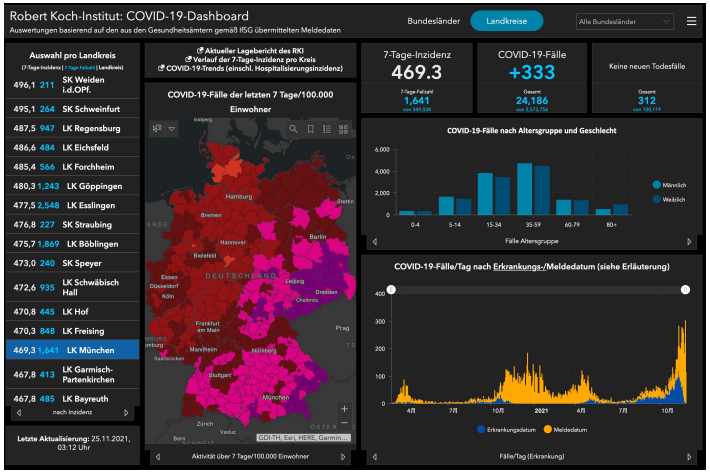
Last two years we suffered very much from Nature

Our status: Oh, my God!!

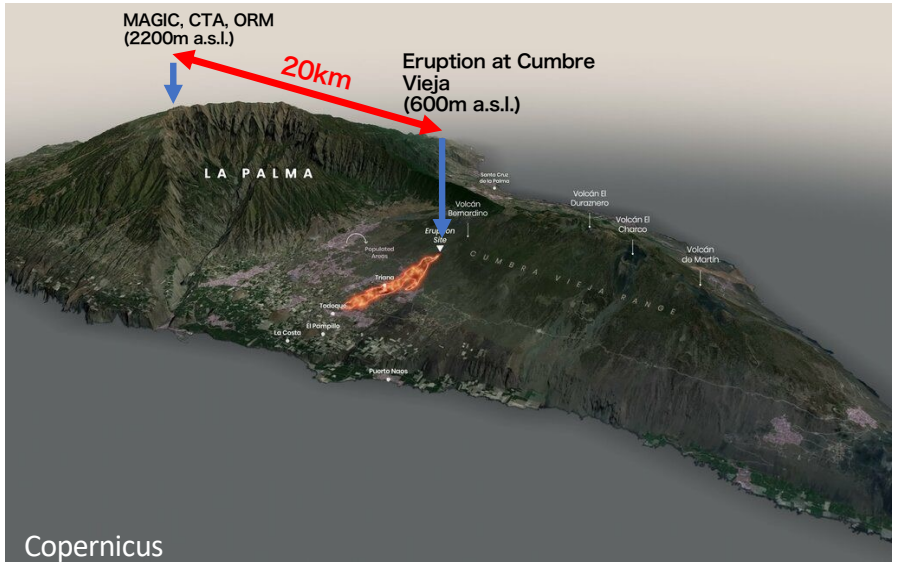
- Covid-19







- Volcano Eruption (19.Sep-14.Dec)



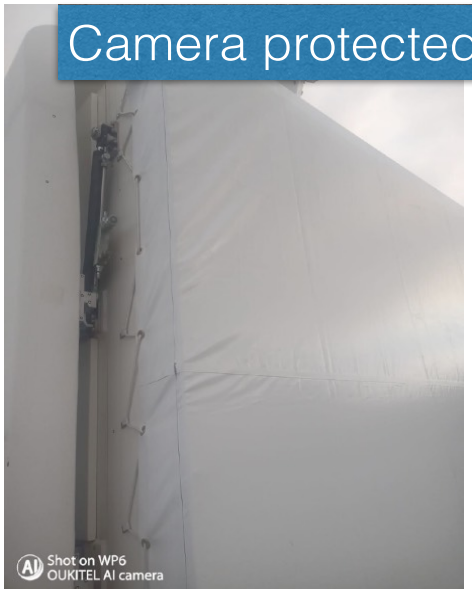
Erupciones históricas en La Palma			
#	Erupción	Año	Días erupción
1	nombre?	2021	85?
2	Teneguía	1971	24
3	San Juan	1949	47
4	Charco	1712	56
5	San Antonio	1667/1678	66
6	Tigalate	1646	82
7	Tehuya	1585	84
8	Tacande	1430/1440	?

We are very sorry for the local people who evacuated from their living places and lost heir properties. Fortunately the ORM is located 20km from the volcano, so far there is no damage to MAGIC and CTA LST.

Volcano Eruption,
from time to time, ash fell at LST Site

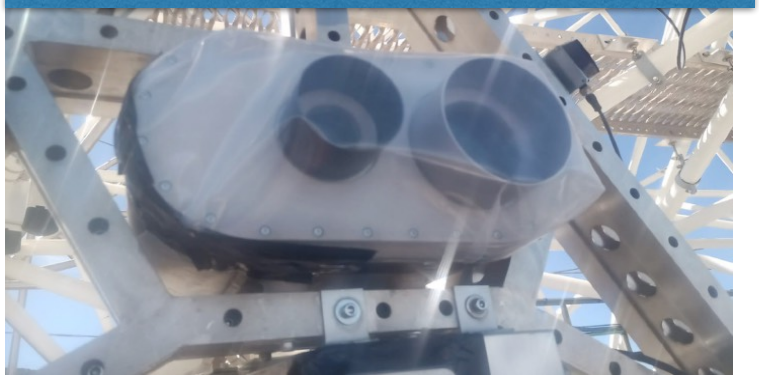
We could not find any major damages last weeks

Camera protected



Rail protected

devices in dish center protected



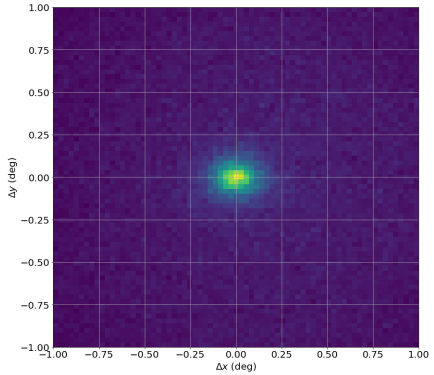
A/C and IT working

A lot of ash

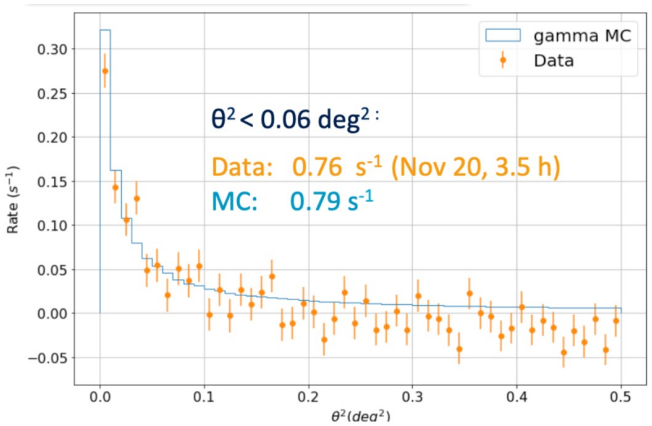
Regular Cleaning by CaSana

Crab Nebula and Pulsar

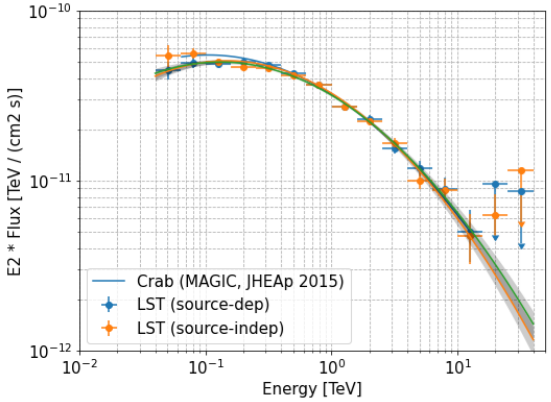
- Crab Nebula
- Crab Pulsar
- LST-MAGIC Joint Observations

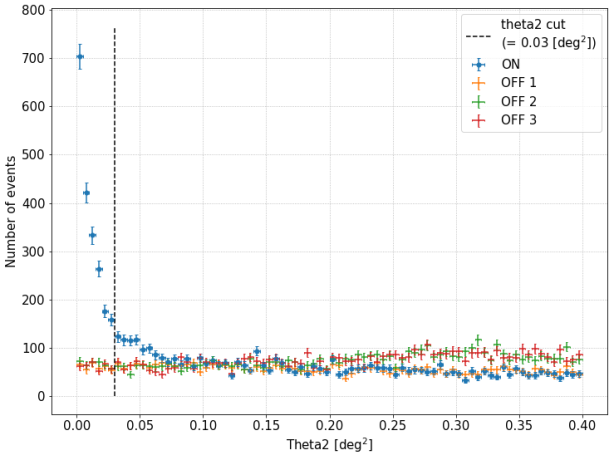


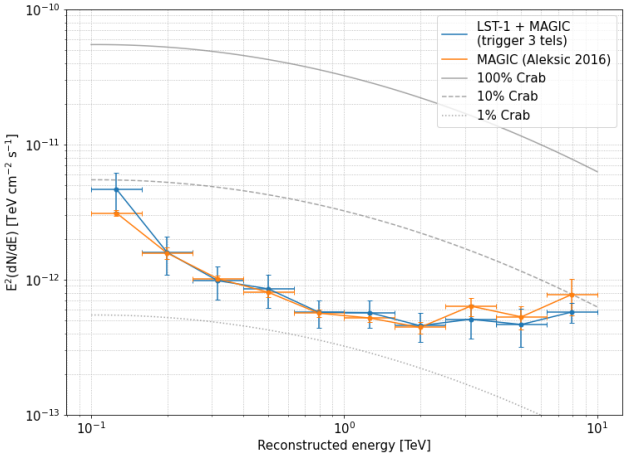
Crab theta2 by Abelardo

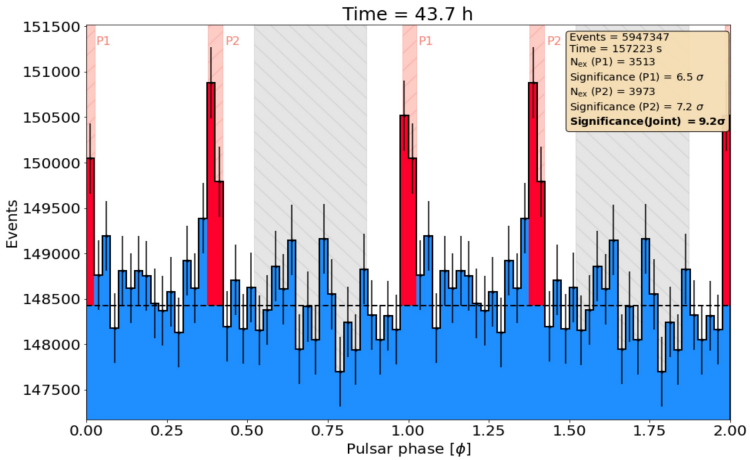


Crab Nebula by Dr. **Nozaki**







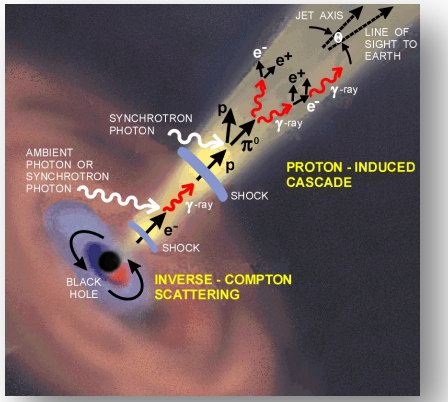


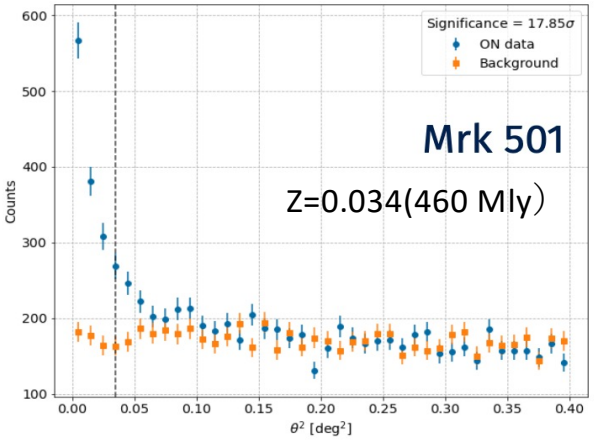
Crab LST-MAGIC joint analysis by **Yoshiki Ohotani**

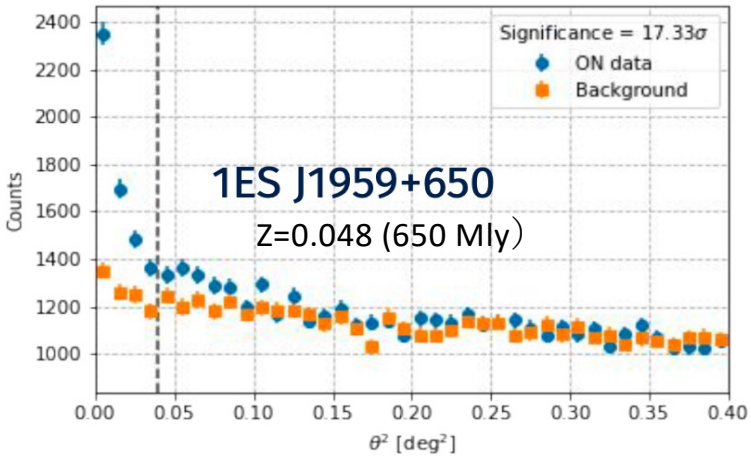
Crab Pulsar by Dr. R.L.Coto

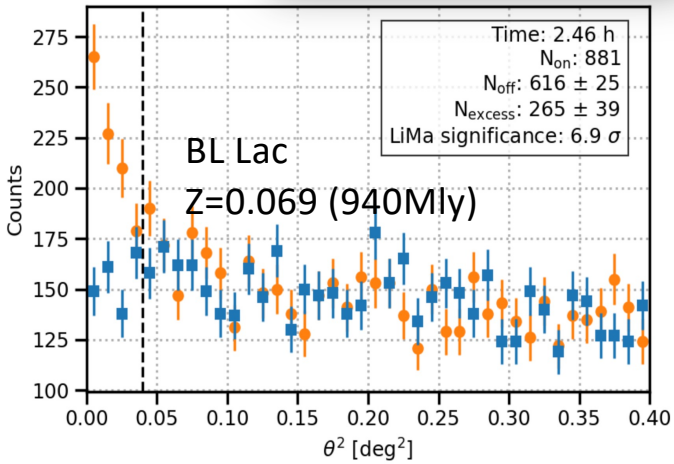
AGN observation with LST1 during 2020-2021Q1

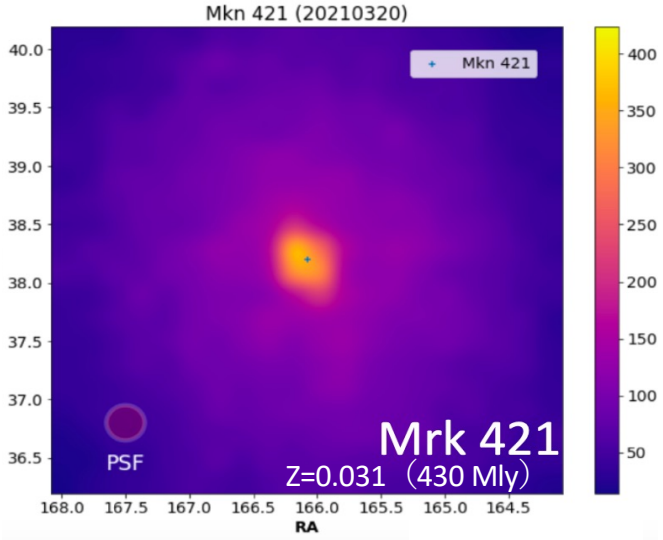
- ❑ Nearby AGNs, Mrk501, Mrk421, 1ES 1959+650, BL Lac
- ❑ Distant AGNs, 1ES0647+250, PG1553+113

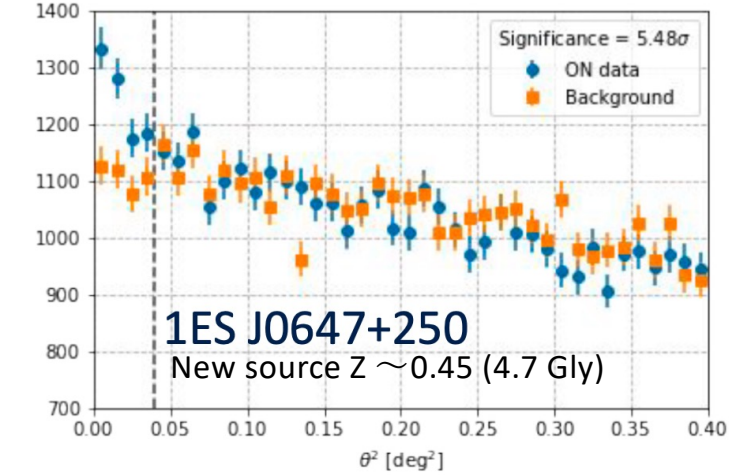


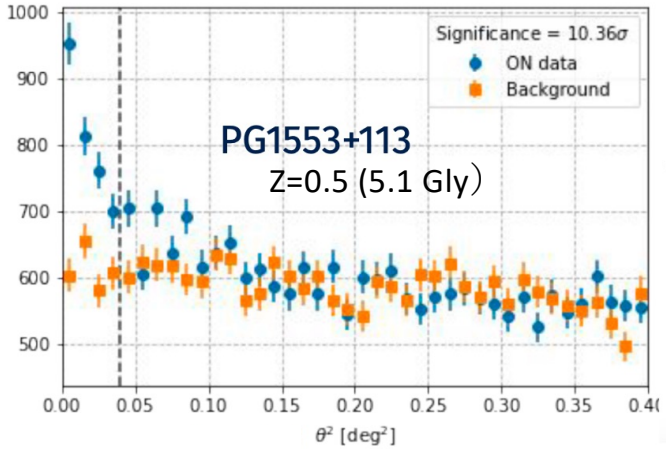






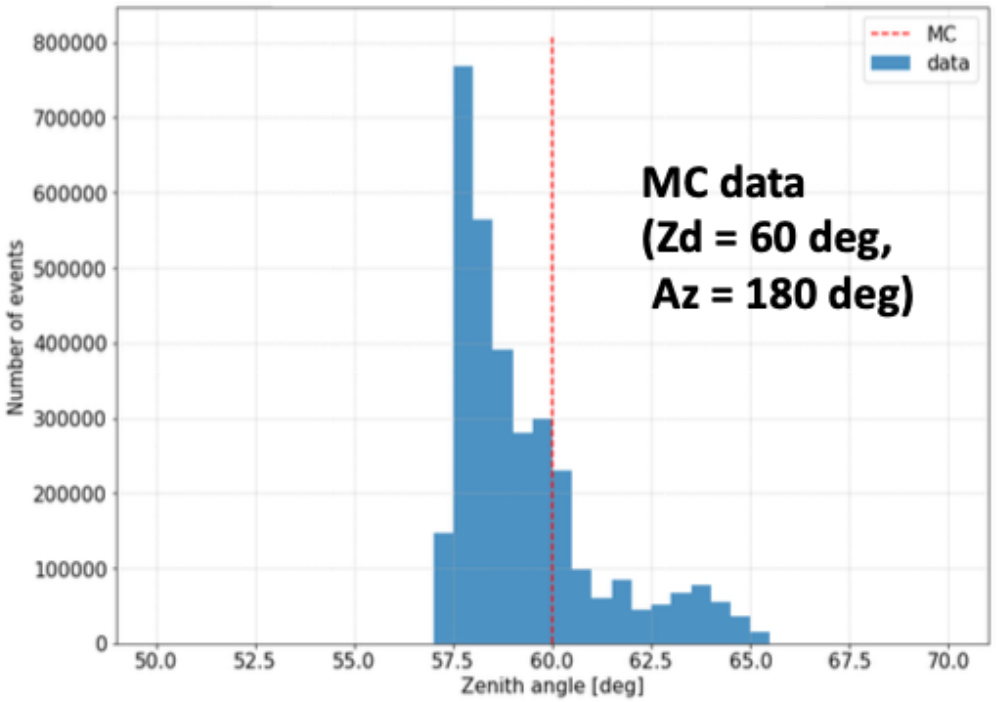


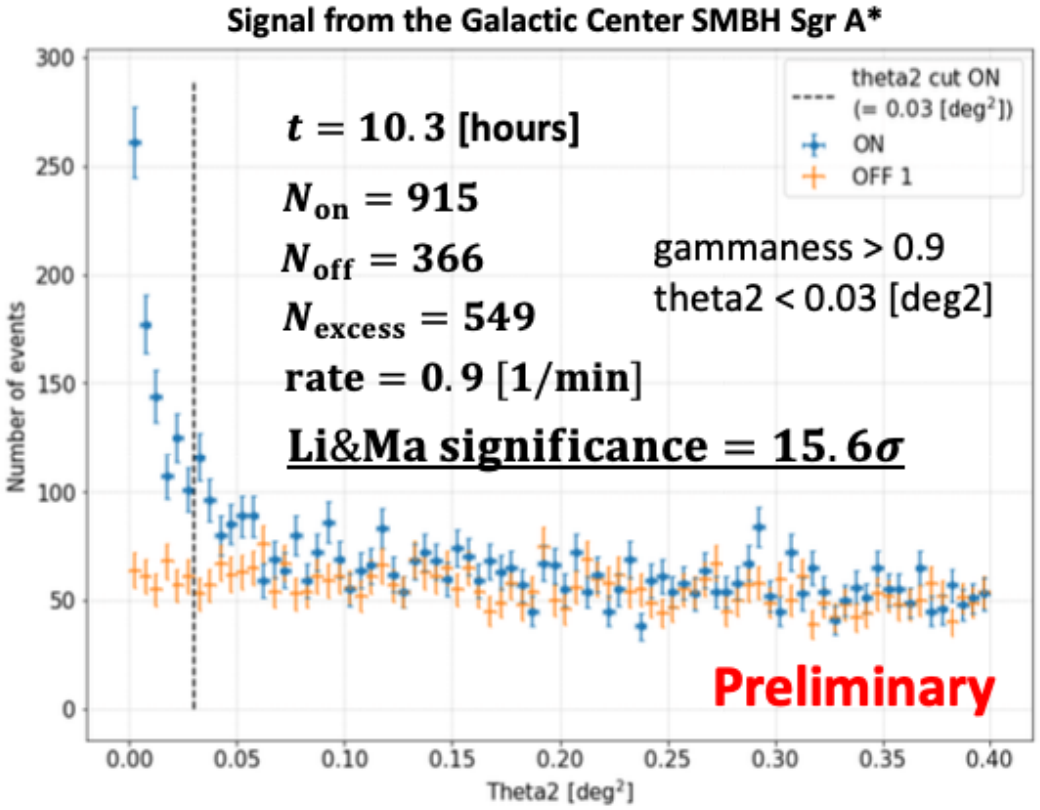




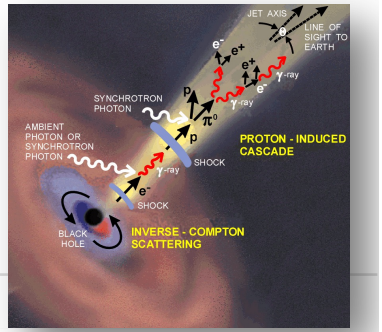
Galactic Center
with MAGIC+LST1 stereo by Yoshiki Ohtani

- The joint observations were performed not only the Crab Nebula, **but also other interesting sources such as Galactic Center**
- The Galactic Center is not only scientifically interesting region, containing SMBH SgrA*, SNRs, DM, etc., but also a stable source in VHE region, which could be used for calibration
- The application of the combined analysis pipeline to the data shows that **the Galactic Center has been clearly detected with 15.6σ in 10.3 hours observation time**

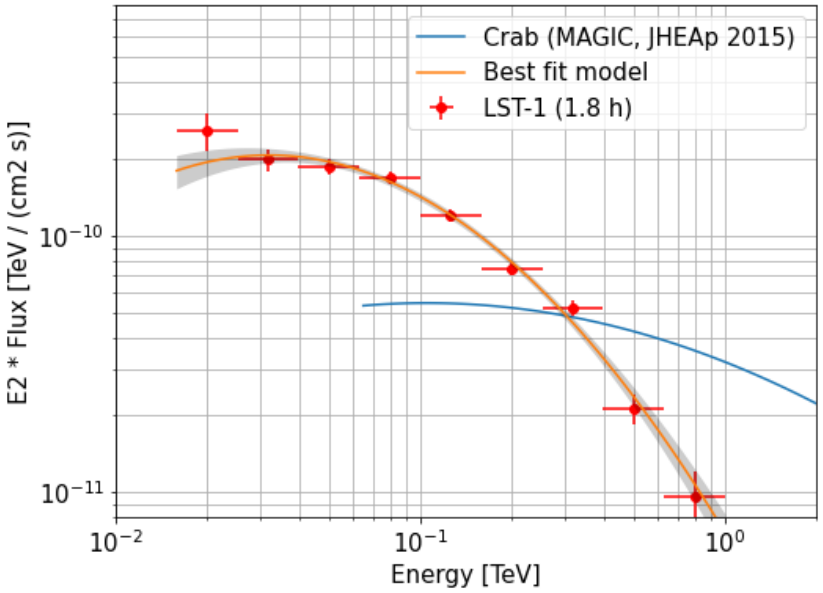


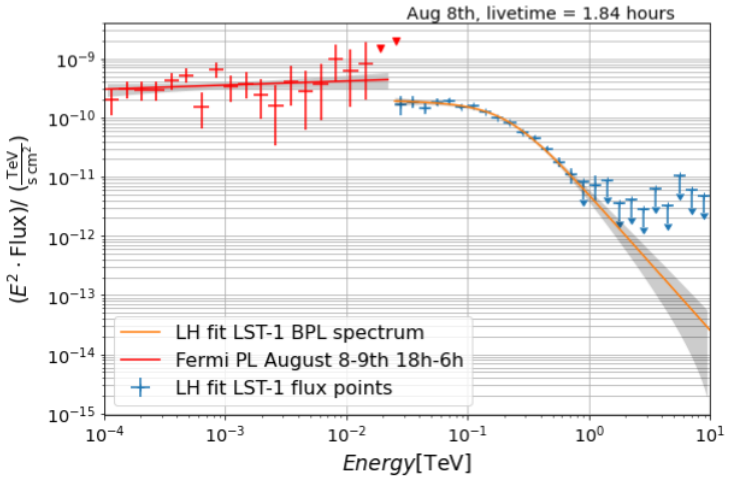


BL Lac Flare observed with LST1
by Dr. Seiya Nozaki

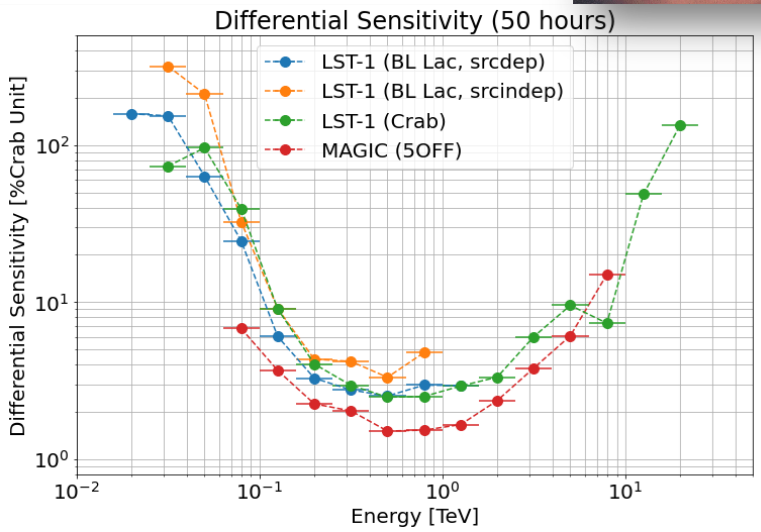


SED measured down to 20GeV

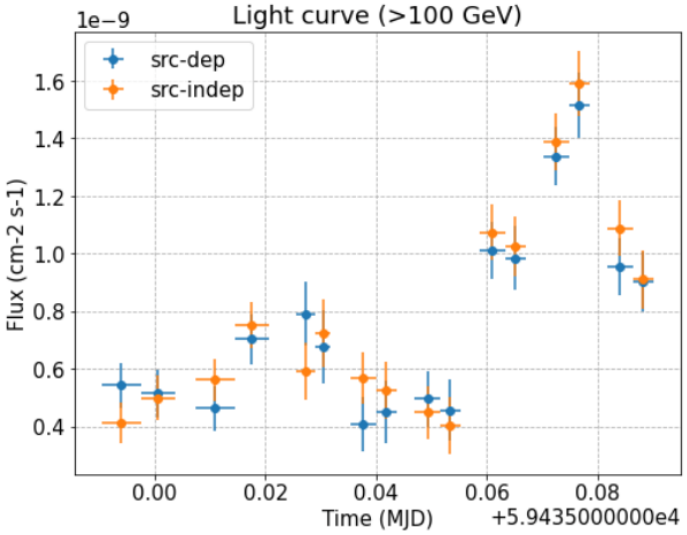




LH Analysis
by Gabriel



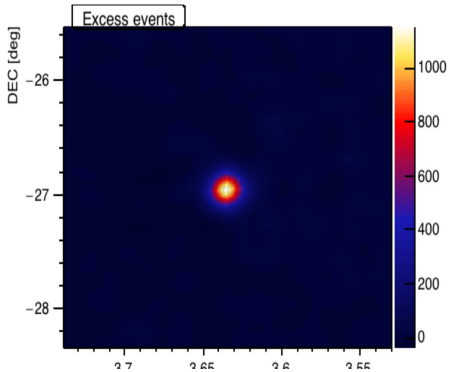
Intranight Variability

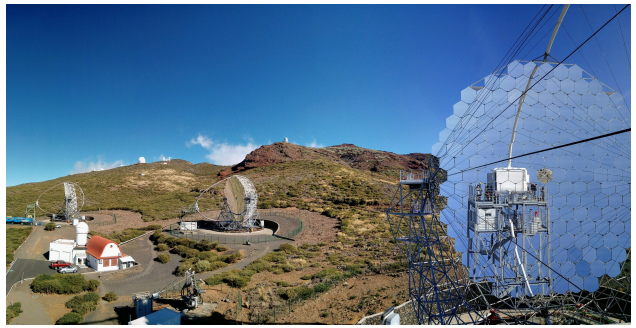


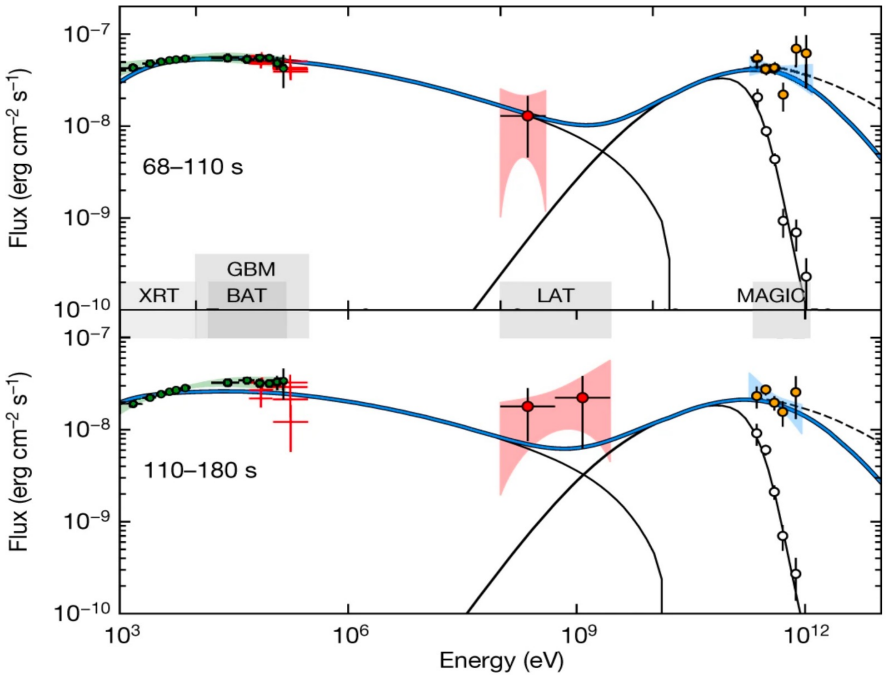
MAGIC Highlight, Gamma Ray Burst GRB190114C (z=0.42)

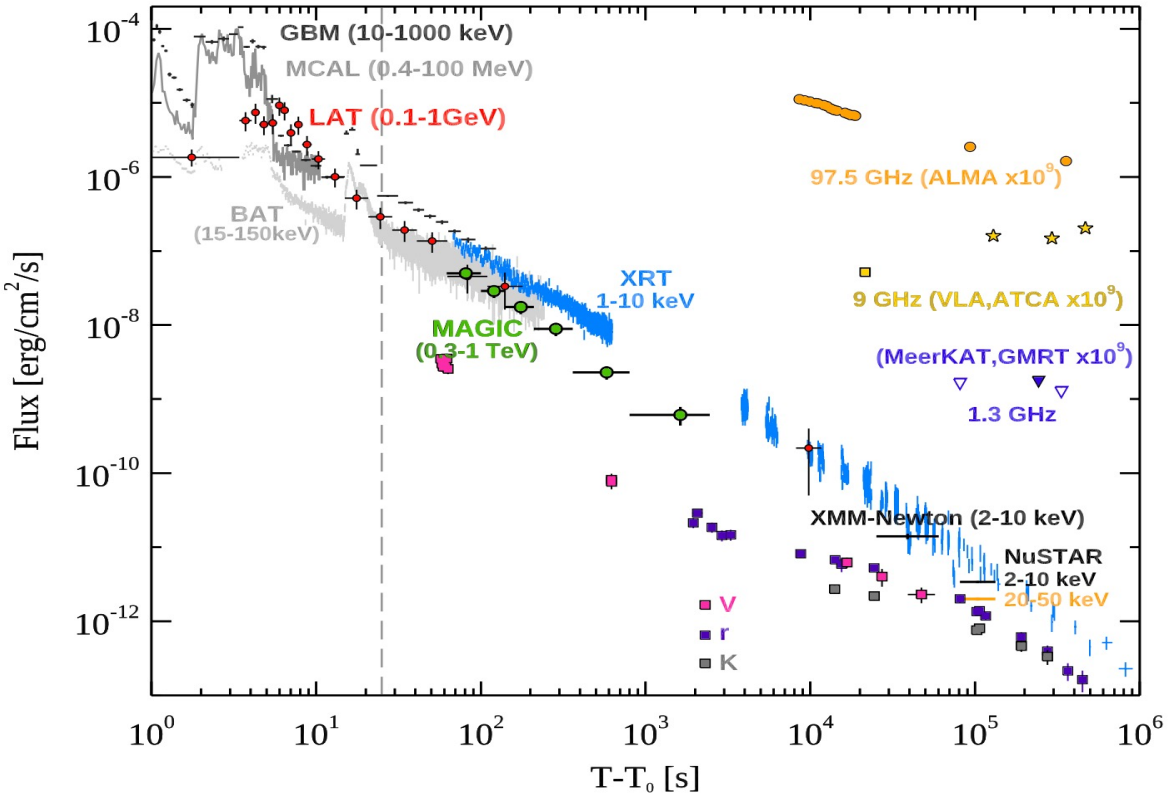
Historical achievement

- ❑ First Detection of the GRB from ground.
- ❑ ~100 Crab flux in the first minutes.
- ❑ TeV bump has a similar energetics with KeV-GeV bump





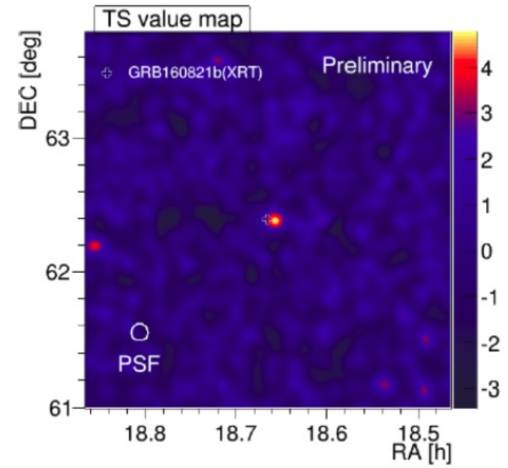


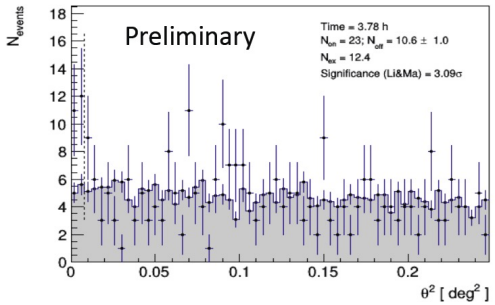


MAGIC Highlights
Other GRB observations with MAGIC

GRB 160821B

Short GRB under moon
E > 600GeV
Z = 0.162
3.1 σ (PostTrial)
Published in APJ 2021

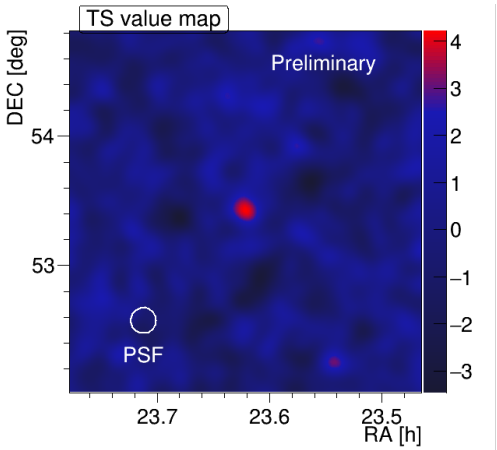


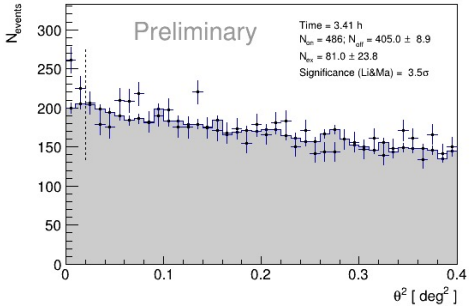


GRB 201015A

Long GRB in Dark

Z = 0.426
3.5 σ (PostTrial)
Published, ICRC 2021_797
Y. Suda et al.

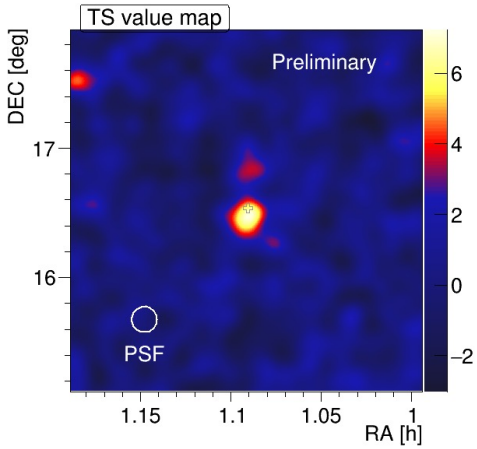


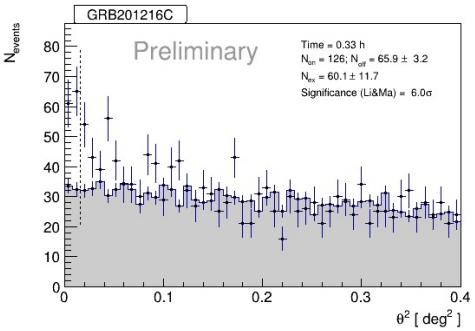


GRB 201216C

Long GRB in Dark

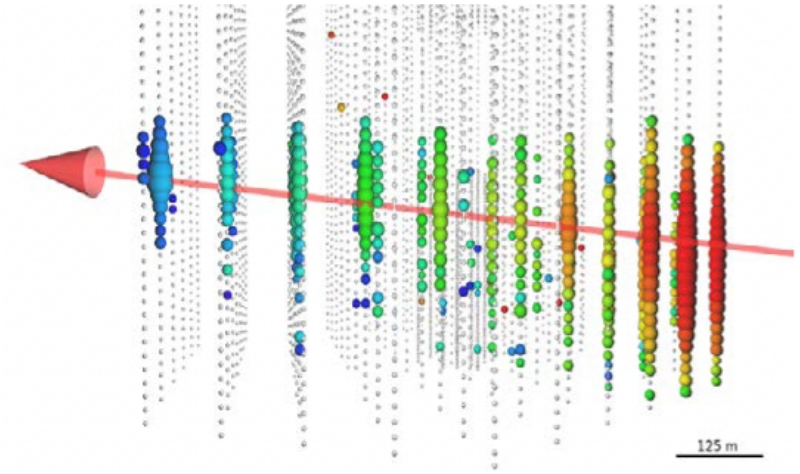
Z = 1.10
6σ (PostTrial)
Published, ICRC 2021_788
S. Fukami et al.



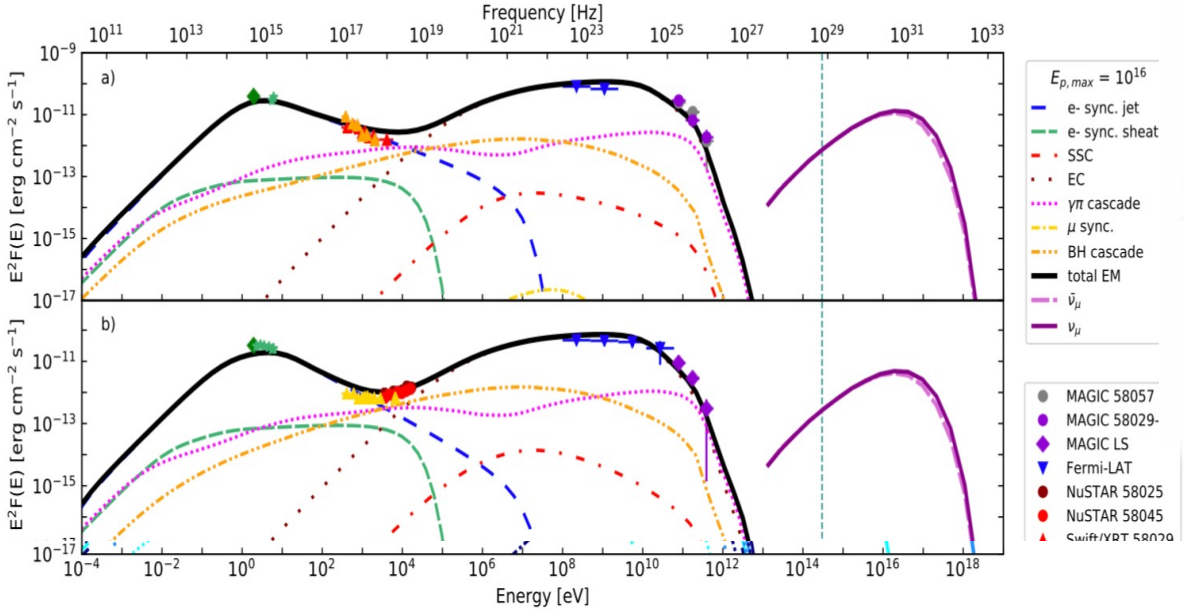


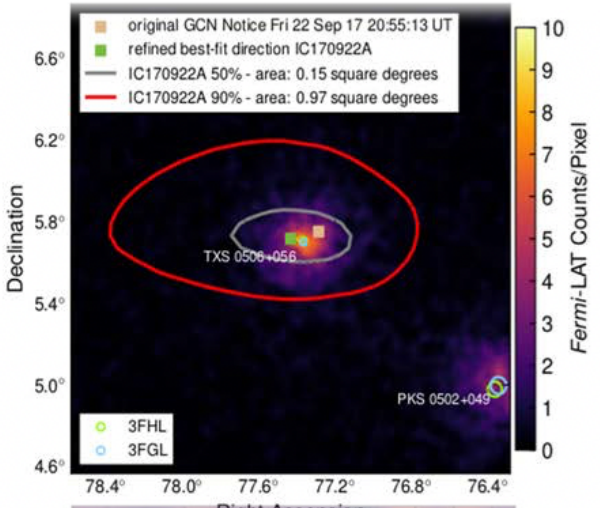
Multi Messenger Astronomy IC170922A / TXS 0506+056

Ice Cube Observation (~300TeV)

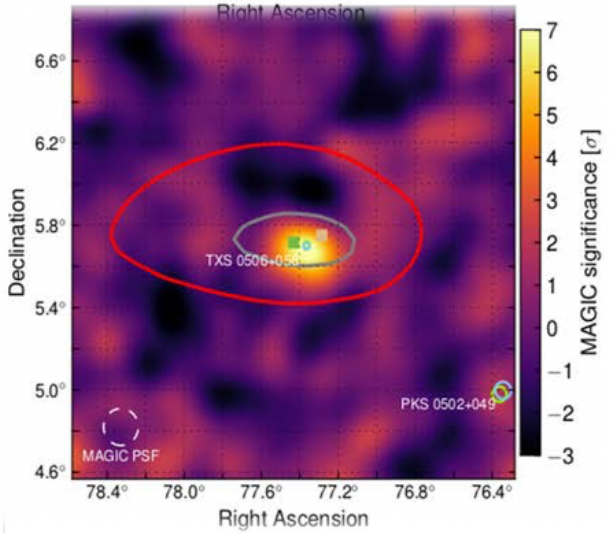


Lepto-Hadronic Scenario





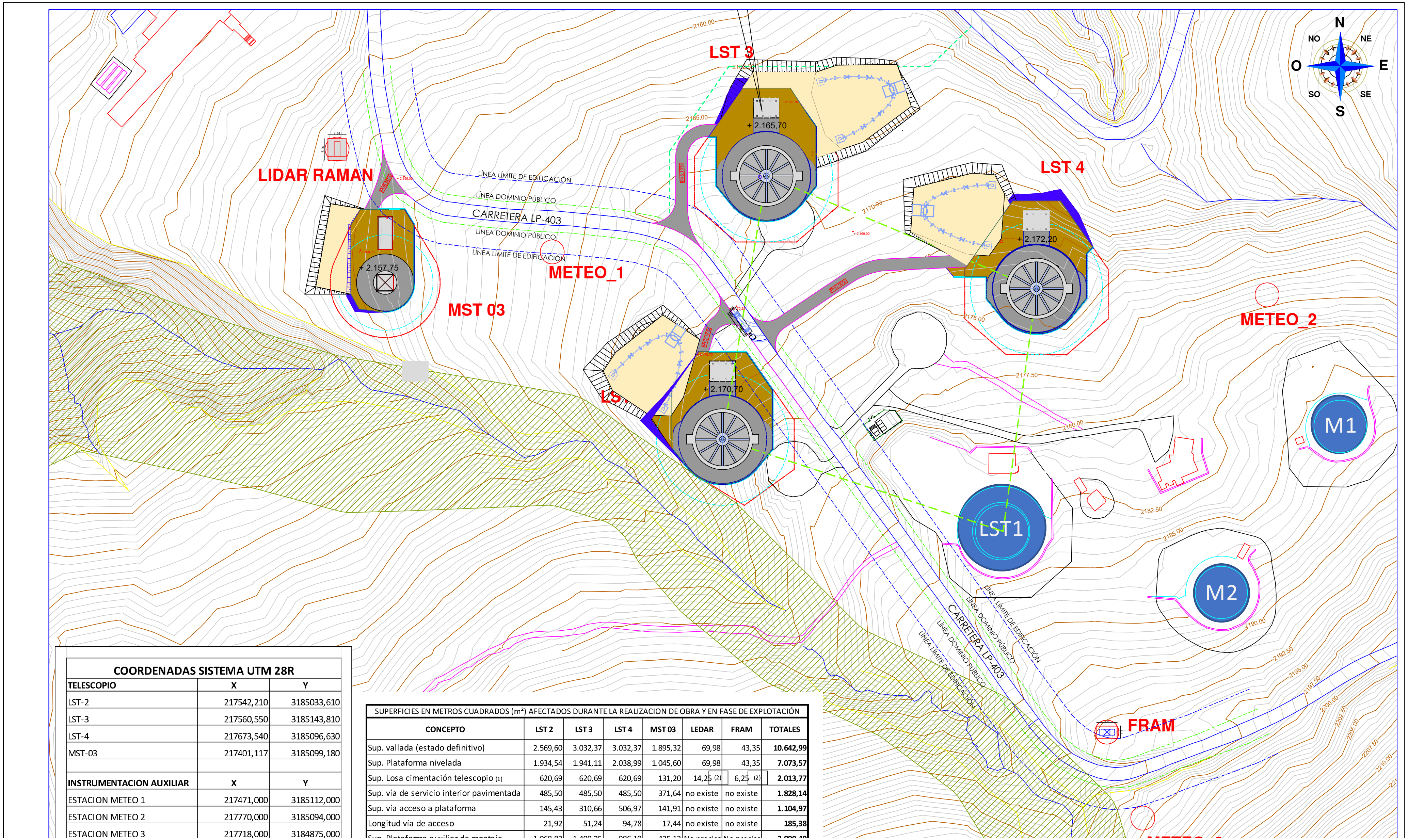
Fermi LAT
(>100 MeV)



MAGIC
(>100GeV)

GTC Observation z = 0.3365
S. Paiano et. al 2018

CTA North Phase I Installation Plan
LST1-4 location



COORDENADAS SISTEMA UTM 28R		
TELESCOPIO	**X**	**Y**
LST-2	217542,210	3185033,610
LST-3	217560,550	3185143,810
LST-4	217673,540	3185096,630
MST-03	217401,117	3185099,180
INSTRUMENTACION AUXILIAR	**X**	**Y**
ESTACION METEO 1	217471,000	3185112,000
ESTACION METEO 2	217770,000	3185094,000
ESTACION METEO 3	217718,000	3184875,000

SUPERFICIES EN METROS CUADRADOS (m²) AFECTADOS DURANTE LA REALIZACION DE OBRA Y EN FASE DE EXPLOTACIÓN

CONCEPTO	LST 2	LST 3	LST 4	MST 03	LEDAR	FRAM	TOTALES
Sup. vallada (estado definitivo)	2.569,60	3.032,37	3.032,37	1.895,32	69,98	43,35	**10.642,99**
Sup. Plataforma nivelada	1.934,54	1.941,11	2.038,99	1.045,60	69,98	43,35	**7.073,57**
Sup. Losa cimentación telescopio (1)	620,69	620,69	620,69	131,20	14,25 (2)	6,25 (2)	**2.013,77**
Sup. vía de servicio interior pavimentada	485,50	485,50	485,50	371,64	no existe	no existe	**1.828,14**
Sup. vía acceso a plataforma	145,43	310,66	506,97	141,91	no existe	no existe	**1.104,97**
Longitud vía de acceso	21,92	51,24	94,78	17,44	no existe	no existe	**185,38**
Sup. Plataforma auxiliar de montaje	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Large Size Telescope

Mirrors: JP
Interface plates: JP, DE, BR
Actuators: JP, CH
CMOS: JP

Tension cables: IT

Camera Support Structure: FR

calibration: IT, HR, IN, DE

Camera electronics: JP, IT, ES
Camera mechanics: ES
Camera safety: FR

Telescope structure: DE

Rail: DE

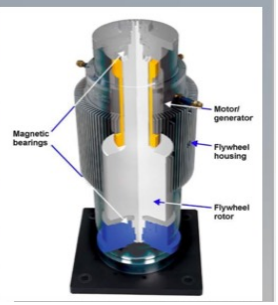
Camera Access Tower: DE, ES

Bogies: ES

Foundation: ES

Drive and main el. cabinet: FR

FlyWheels (2x300kW) energy storage and UPS: JP



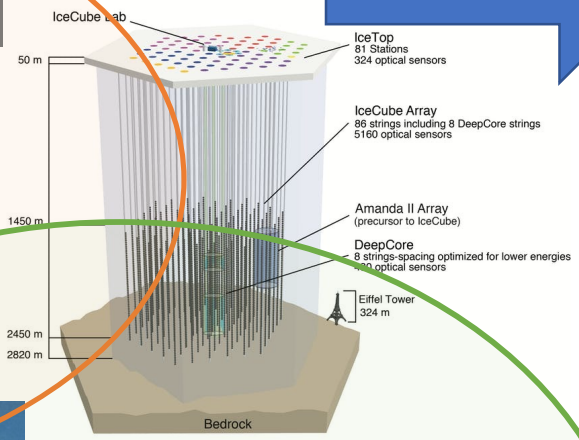
Multi-messenger and Multi-wavelength Astrophysics

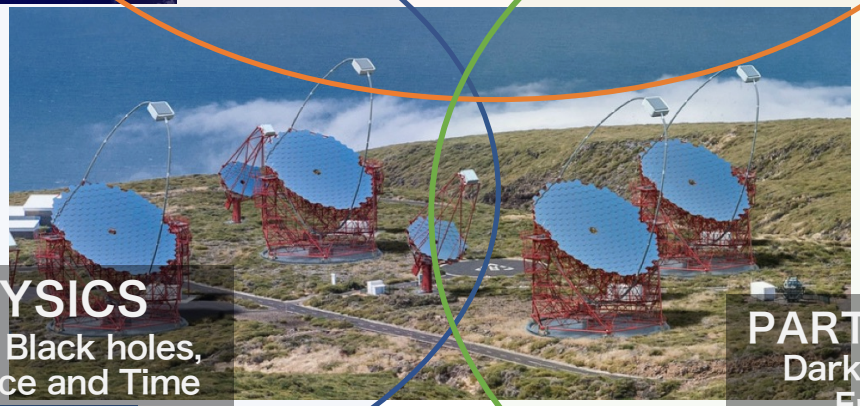
cherenkov telescope array

Wave AstroPhysics

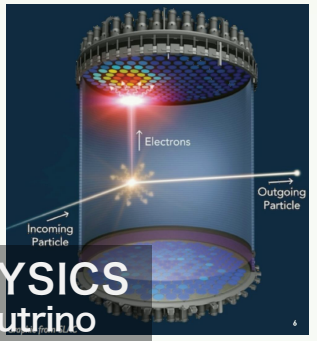
Particle Physics

ASTRO-PARTICLE PHYSICS
Cosmic Ray Physics
High Energy Astrophysics





ASTRO-PHYSICS
Gamma Ray Bursts, Black holes,
Neutron Stars, Space and Time



PARTICLE PHYSICS
Dark Matter, Neutrino
Energy Frontier

Summary

- CTA is a big and ambitious project and plays an important role in the MM and MWL astronomy in the next decades
- CTA South construction will start in 2023
- CTA North construction, LST2-4 and MST start in summer 2022 and completed in 2024
- LST5-8 construction in South is on Discussion to enhance the performance of CTA Observatory
- CTA-Japan should also contribute.

- LST1 commissioning ➔ Science and Engineering operation
- We confirmed LST1 satisfies the design performance
- GRBs with the redshift up to z = 4 can be seen with LST
- ~10 sources are detected with LST1. Some results, Crab Pulsar, BL Lac flare, G.C., RS Oph are very interesting

Breaking News !!

Merger of giant black holes predicted

Science 1 Feb 2022, Astro-ph 2201.11633 (N.Jiang et al)

Tick ··· tick ··· boom?

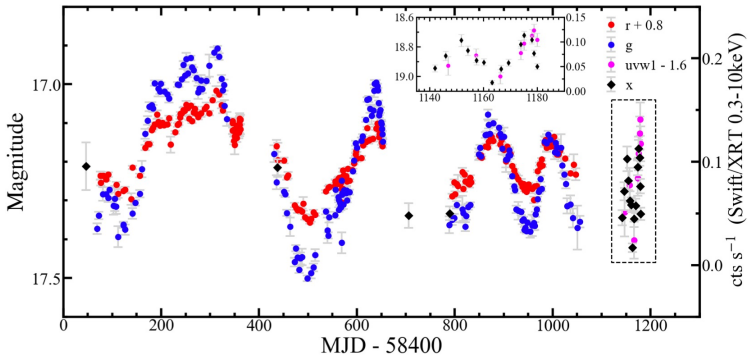
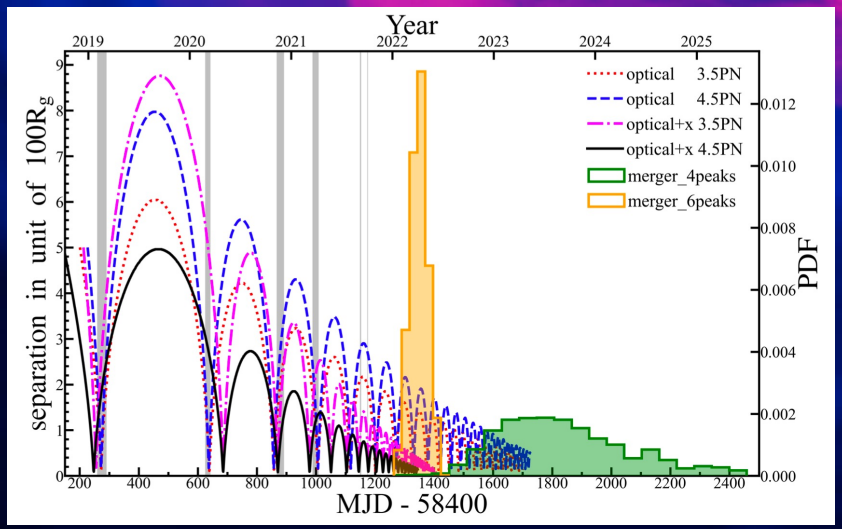


Figure 1: **The optical, UV and X-ray light curves of SDSSJ1430+2303.** The ZTF g and r band photometric data are shown in blue and red solid circles, with error bars in grey. The black solid diamonds and magenta solid circles represent the XRT count rate in 0.3-10 keV and UVW1 magnitudes from our Swift monitoring, respectively. We have zoomed in the Swift data (the region encircled by dashed box) in the inset for clarity.



SDSS J1430+2303
z = 0.081

Close supermassive black hole binaries with the separation below parsec??

Credit: NASA

cherenkov telescope array

Thank you very much


cta
cherenkov
telescope
array