# Black hole Astrophysics with CTA LST

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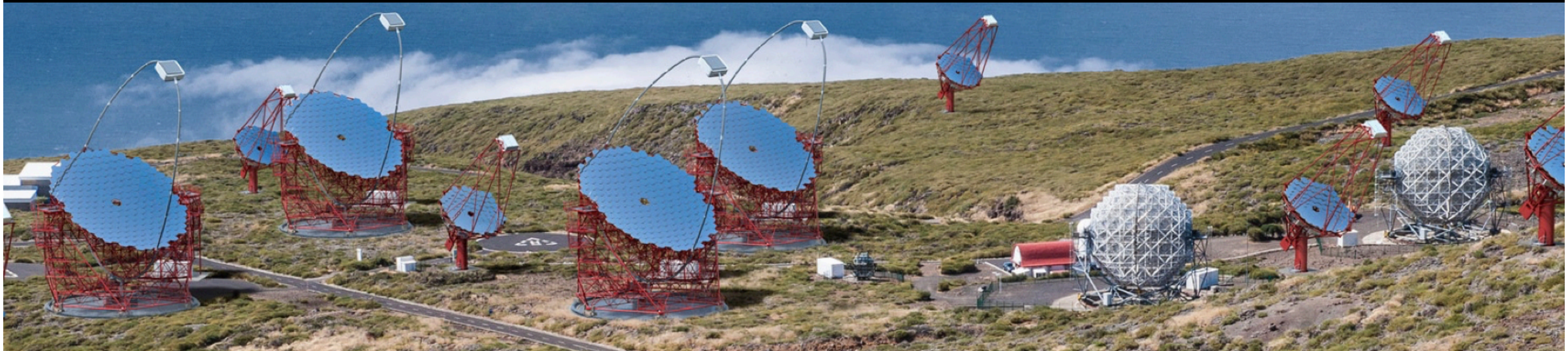
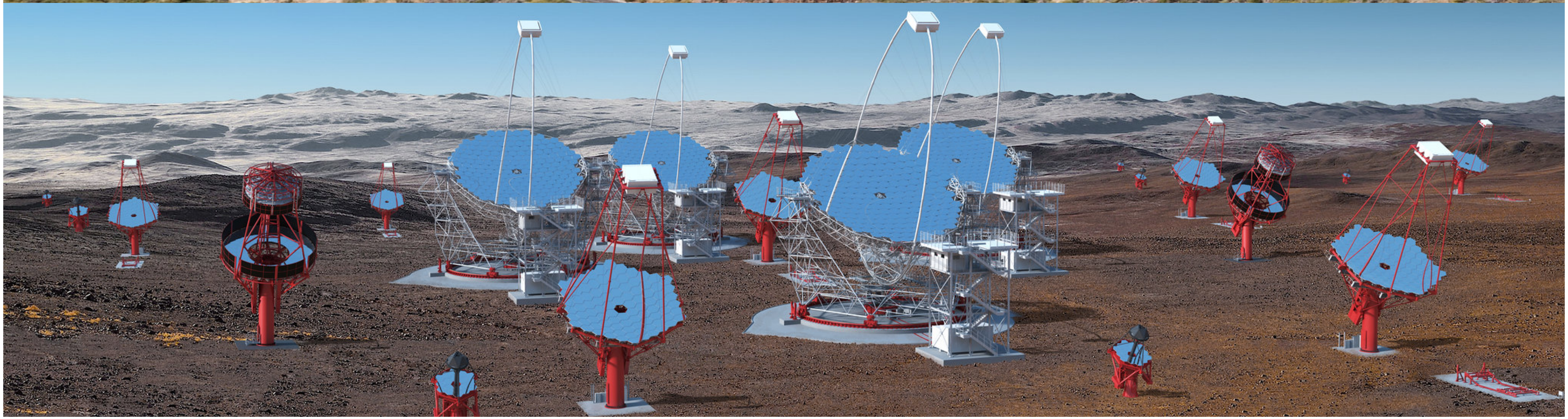
*ICRR, The University of Tokyo*



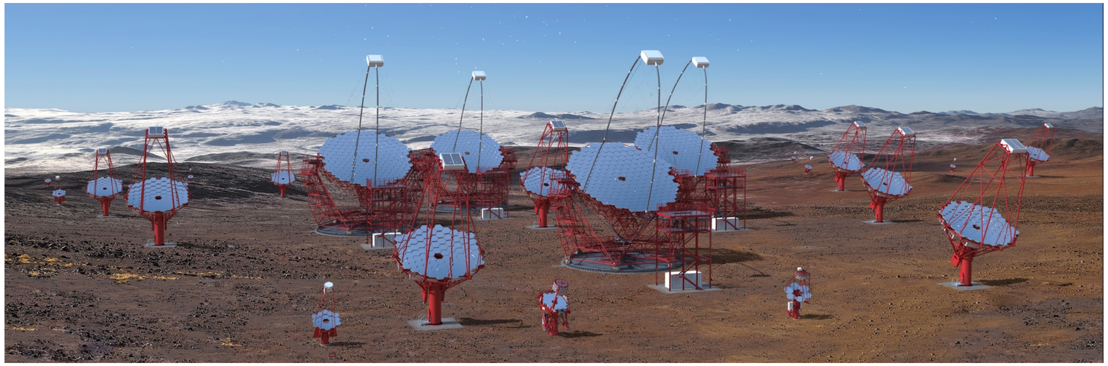


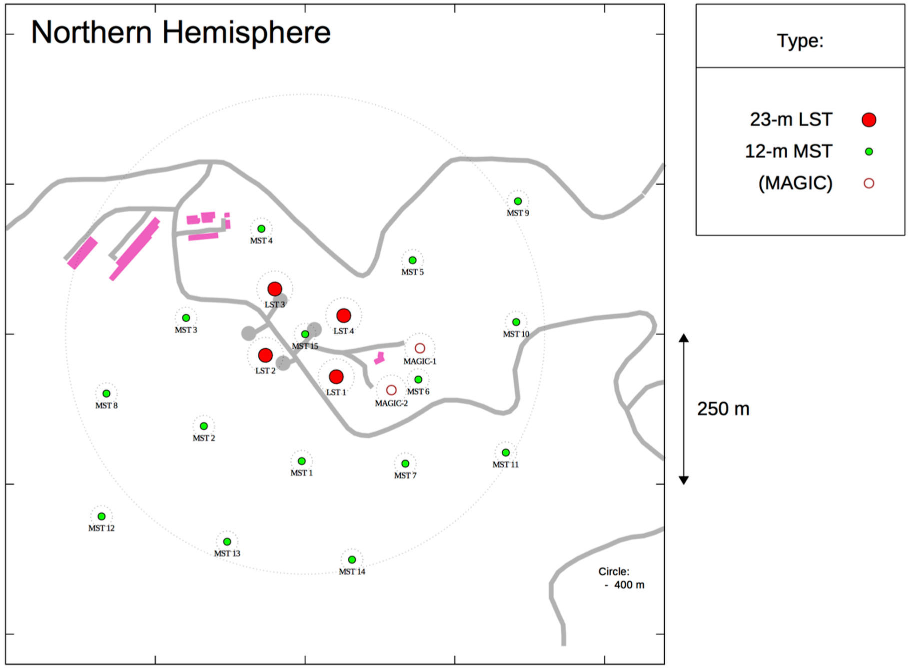
cta cherenkov telescope array

# Two sites for all sky observatory

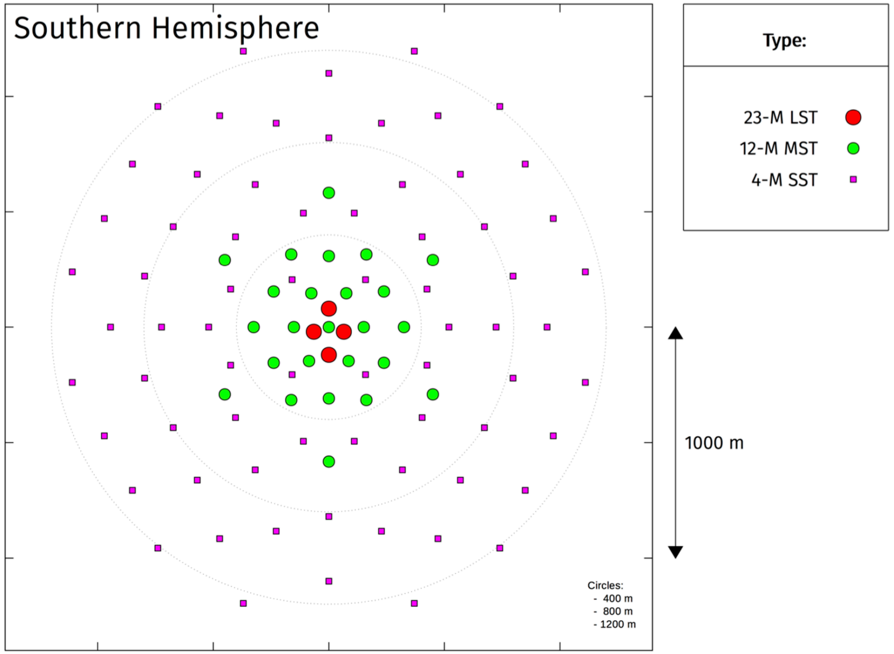
## ORM, La Palma, Spain

## Paranal, Chile





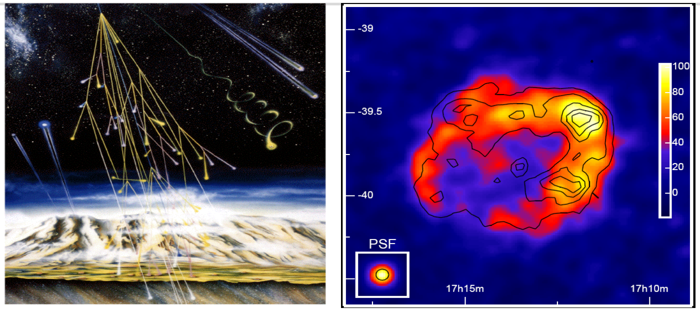

4 LS4 LSTs, 15 MSTs




4 LSTs, 25 MSTs, 70 SSTs

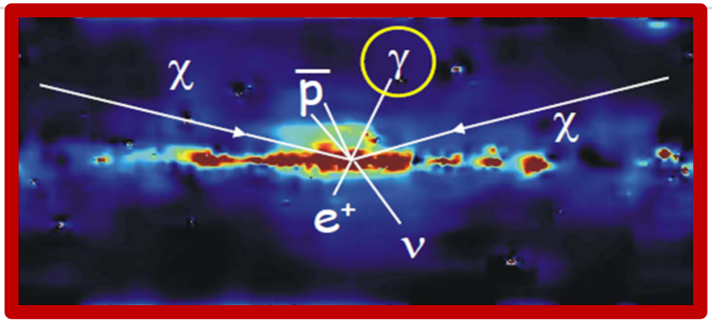
# Science of CTA-LST is very wide

## LST will cover S.M.B.H., Dark Matter, AGNs, GRBs



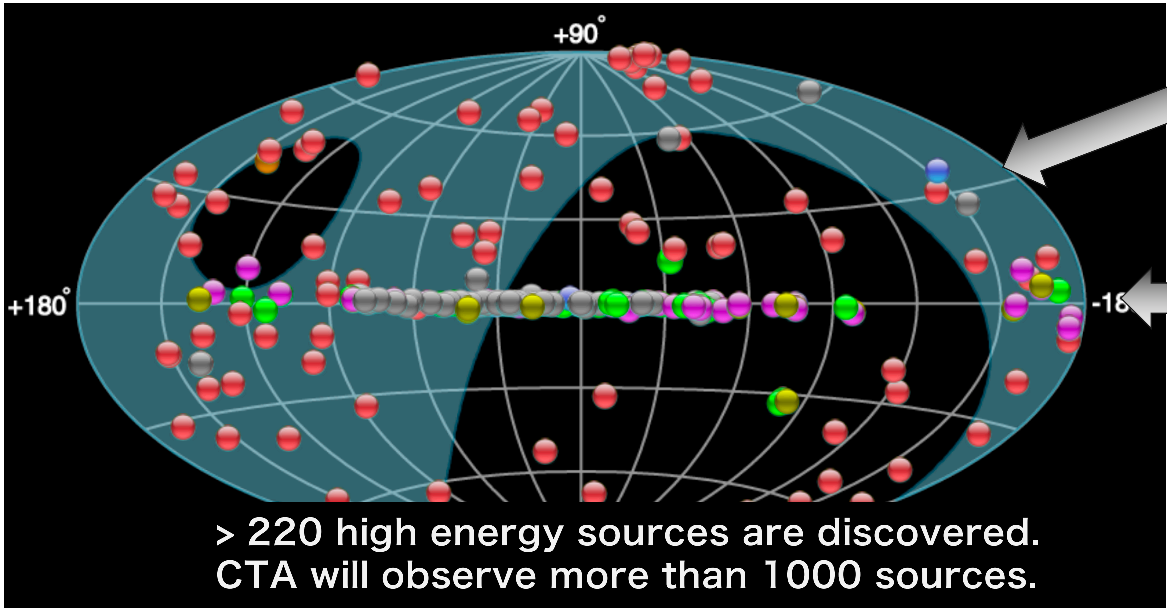

Cosmic Ray Origin

Super Massive Black Holes




Dark Matter Search (Discovery)

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

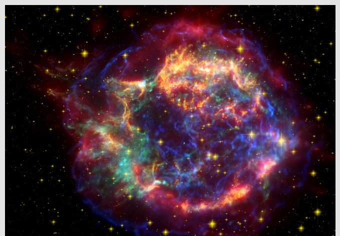



### Extragalactic Sources

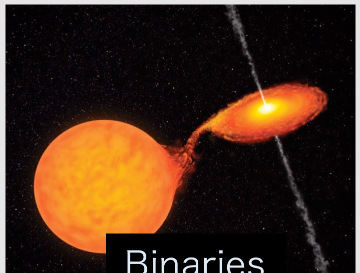
Active Galactic Nuclei

Gamma Ray Bursts

### Galactic Sources

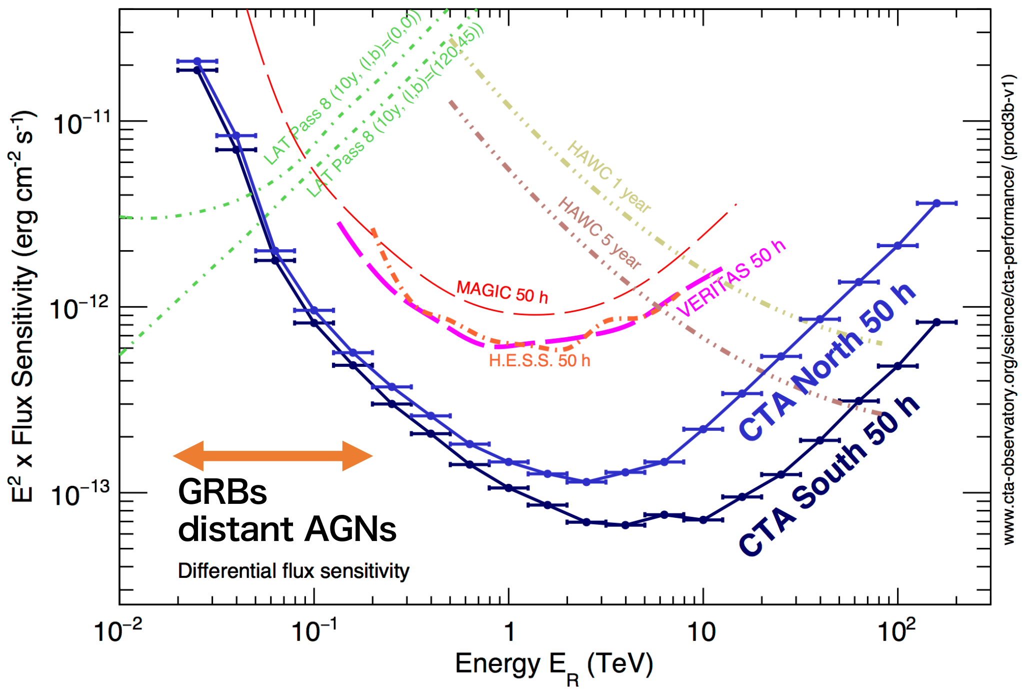


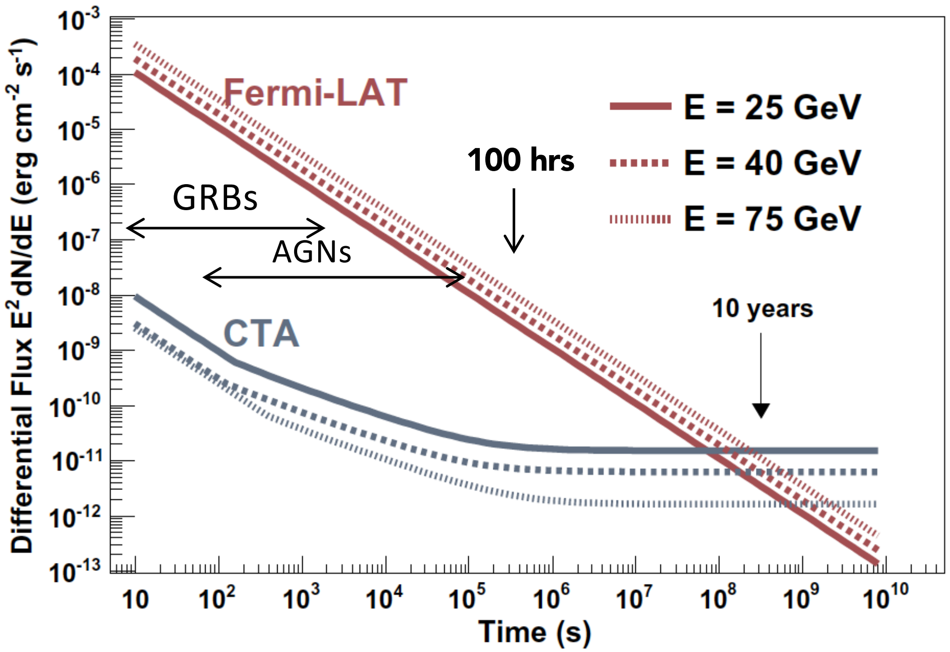
Super Nova Remnants



Binaries

# Sensitivity x10, Angular Resolution x2 Energy Range 20GeV~200TeV




- LST sub consortium focuses on the CTA-LST Array on La Palma

- The CTA-LST array has a good sensitivity from 20 GeV to 1000 GeV
- Distant AGNs up to z = 2, and GRBs up to z = 4 are observable
- X10000 sensitivity for GRBs and AGN flares than Fermi
- The fast rotation (20 sec) offers the observation of prompt emission of GRBs

# AGN Detectability

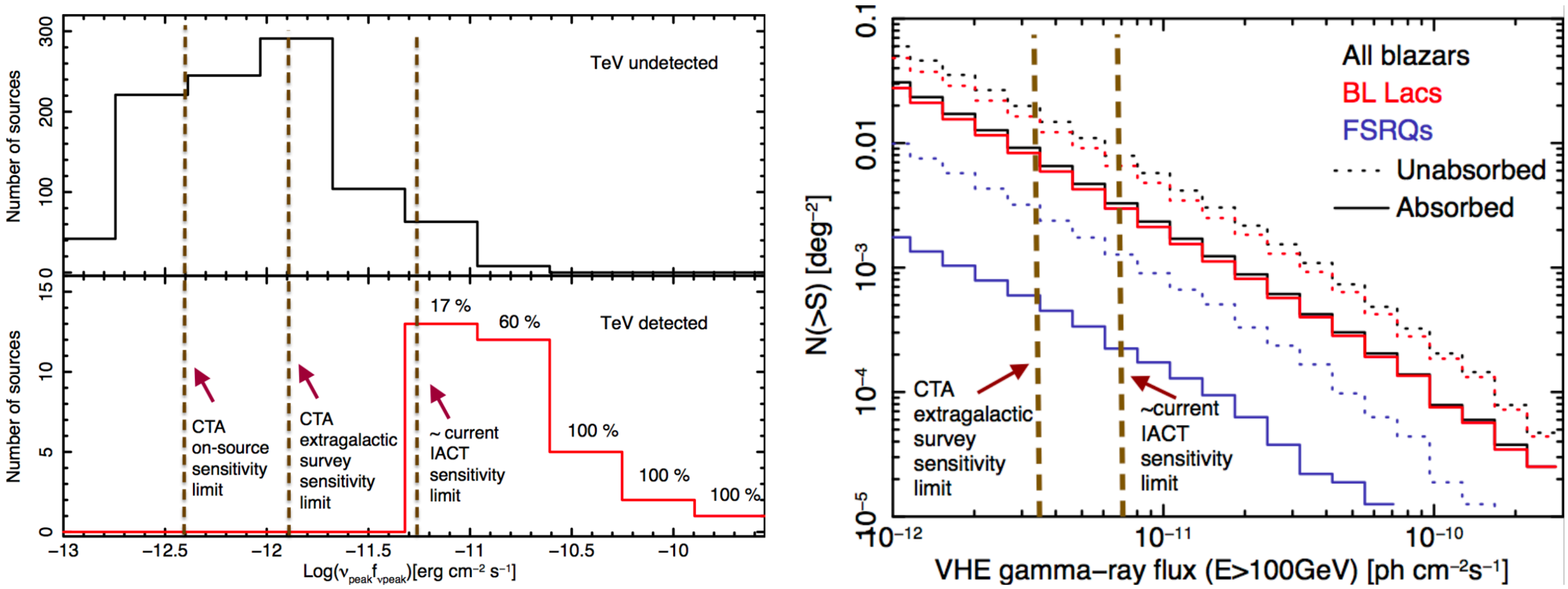



**Figure 1.3** – Predictions for the number of blazars on the sky in the GeV–TeV domain. Left: Source counts versus peak synchrotron flux. The upper panel shows predictions by [8] together with the current and envisioned sensitivity limits of IACTs. The lower panel shows detected AGN with current instruments. Right: Expected source counts as a function of the integral gamma-ray flux above 100 GeV, from [9].

# High-Res light curve for AGN Flares

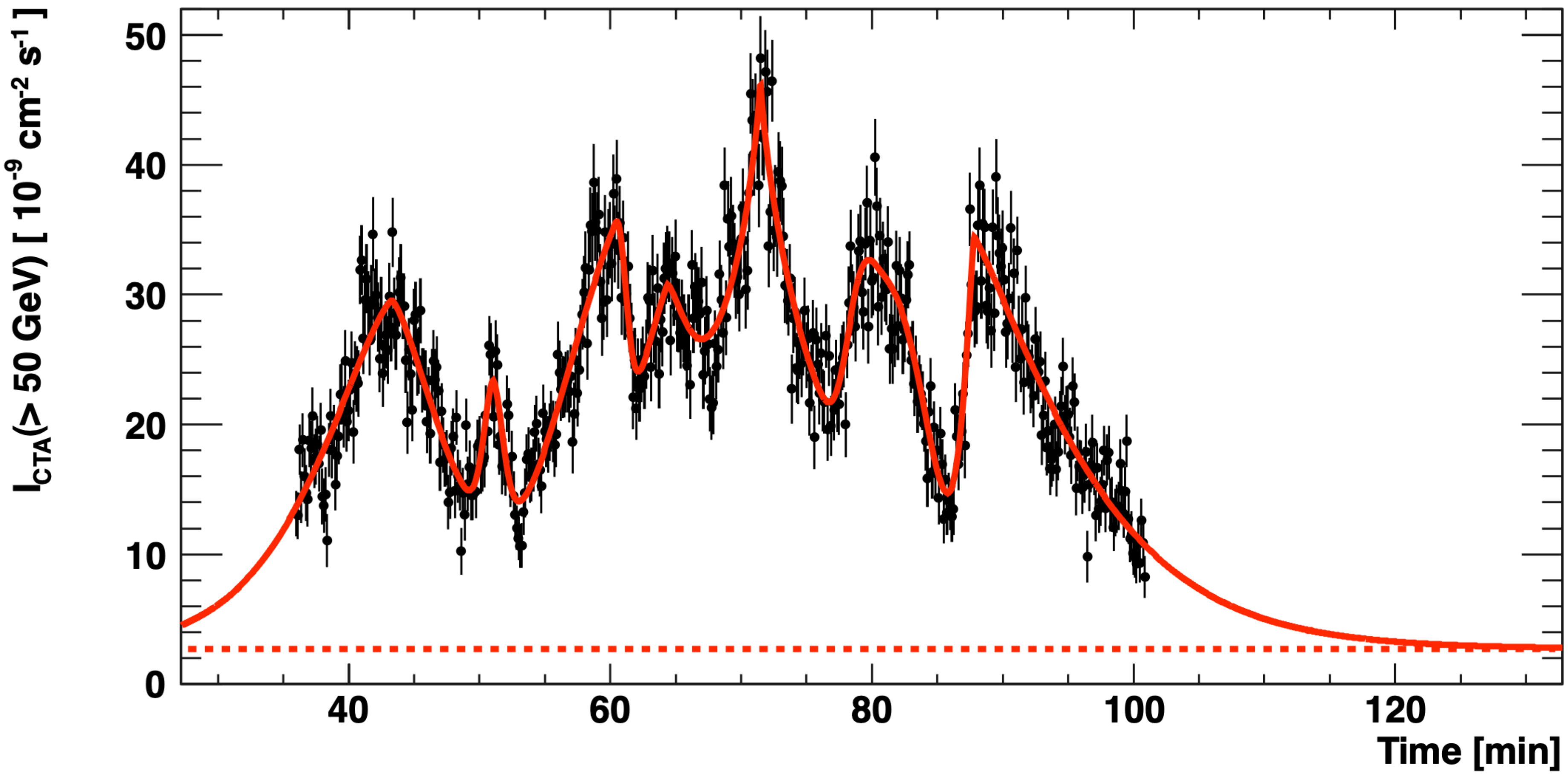



**Figure 1.7** – Probing ultra-fast variability in the inner jet of an active galaxy: simulated CTA light curve for the 2006 flare of PKS 2155−304 (see [26] for details). Such observations provide access to timescales much shorter than the light-crossing time of the supermassive black hole.

# CTA Phase I and the enhancement in CTA CB and BP

| COST Book 2020 | | CTA Construction | CTA Enhancement |
|---|---|---|---|
| Northern Array | Number of LSTs | 4 | 0 |
| | Number of MSTs | 5 | 10 |
| Southern Array | Number of LSTs | 0 | 4 |
| | Number of MSTs | 15 | 10 |
| | Number of SSTs | 50 | 20 |
| **Total** | | **74** | **44** |

**Business Plan 2016**

| Site | Telescope | Baseline Number | Threshold Scenario | Priorities Beyond Threshold |
|---|---|---|---|---|
| CTA-South | LST | 4 | | 4 |
| | MST | 25 | 15 | |
| | SST | 70 | 50 | |
| CTA-North | LST | 4 | 4 | |
| | MST | 15 | 5 | +5 |

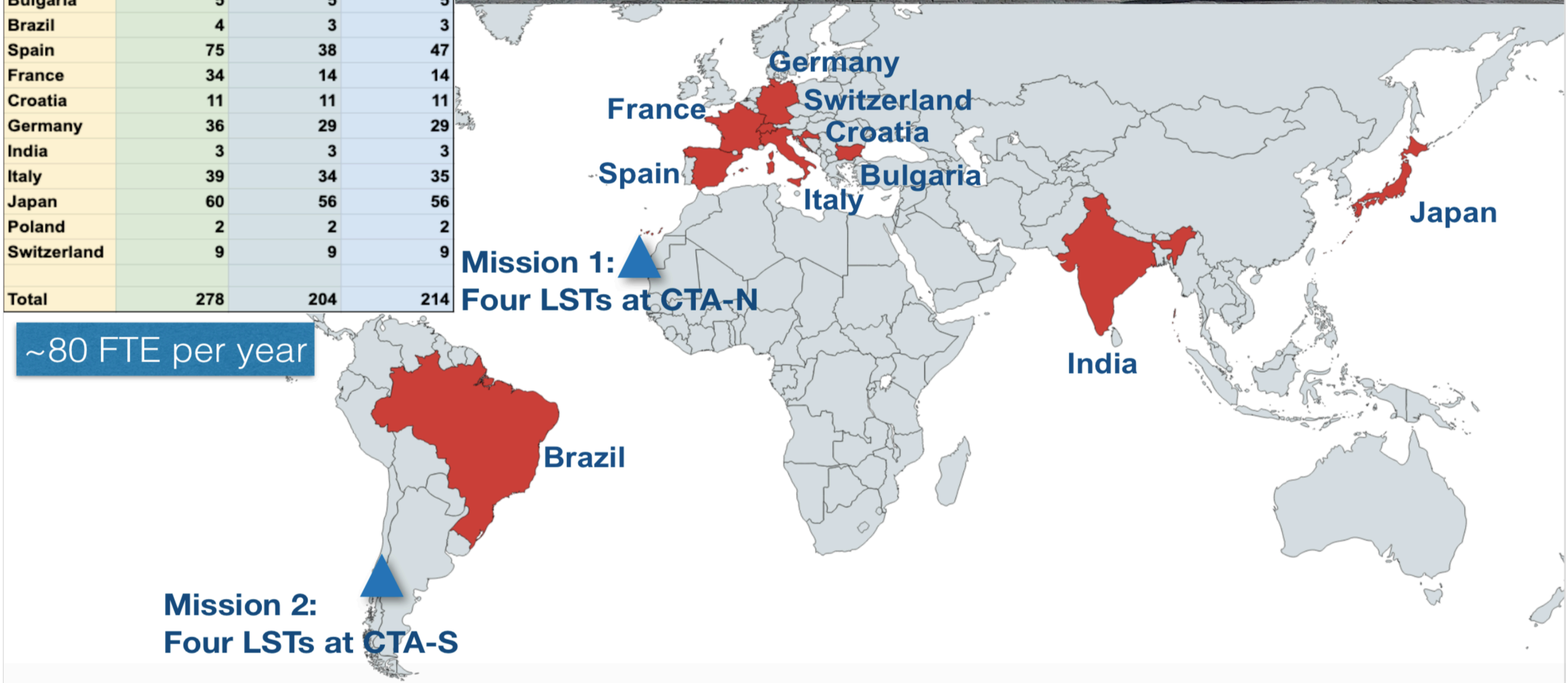
Picture from LST meeting, 2018

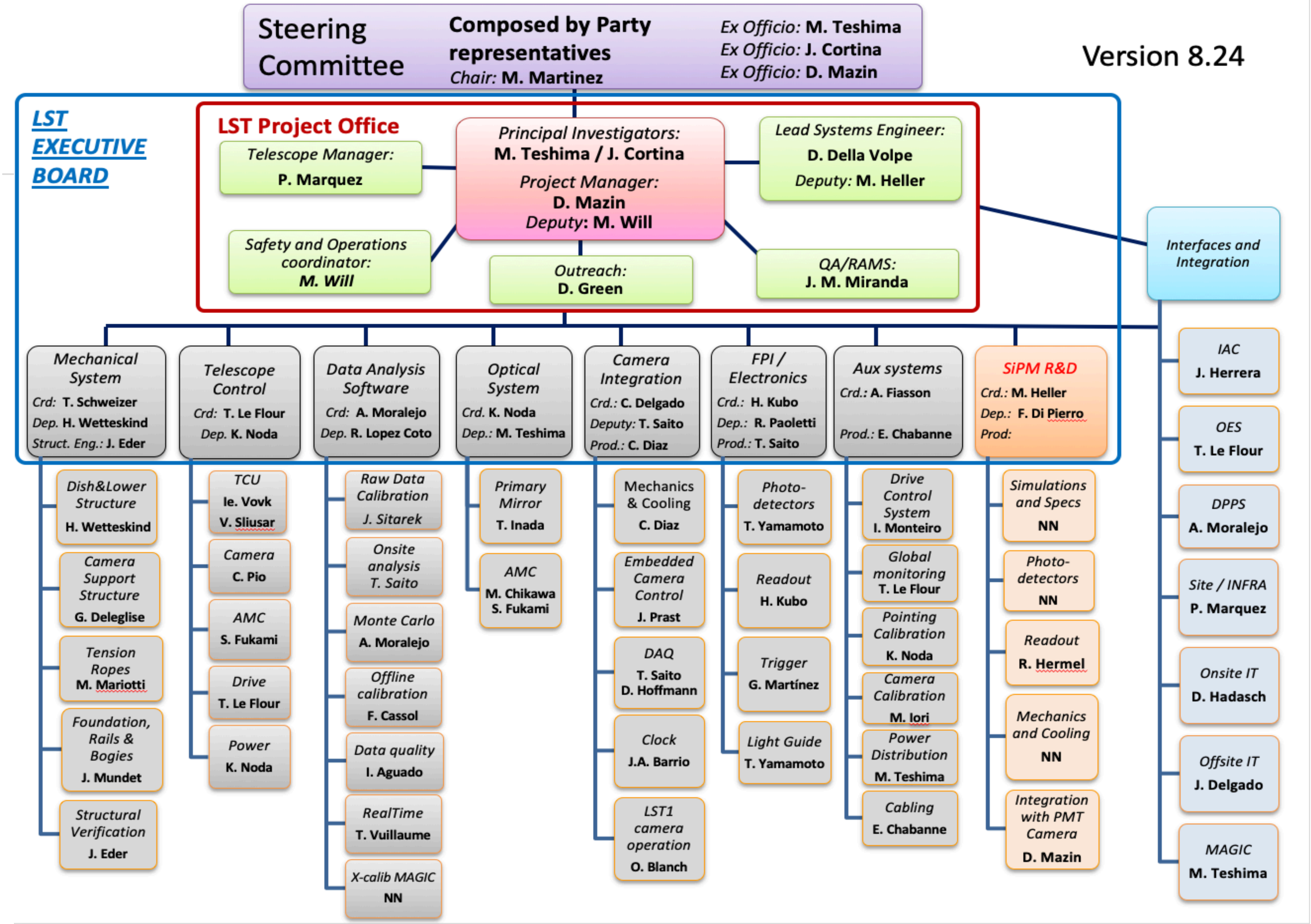
# LST sub-consortium

## LST statistics

| | Members | Scientist + Students | Authors |
|---|---|---|---|
| Bulgaria | 5 | 5 | 5 |
| Brazil | 4 | 3 | 3 |
| Spain | 75 | 38 | 47 |
| France | 34 | 14 | 14 |
| Croatia | 11 | 11 | 11 |
| Germany | 36 | 29 | 29 |
| India | 3 | 3 | 3 |
| Italy | 39 | 34 | 35 |
| Japan | 60 | 56 | 56 |
| Poland | 2 | 2 | 2 |
| Switzerland | 9 | 9 | 9 |
| | | | |
| Total | 278 | 204 | 214 |

~80 FTE per year





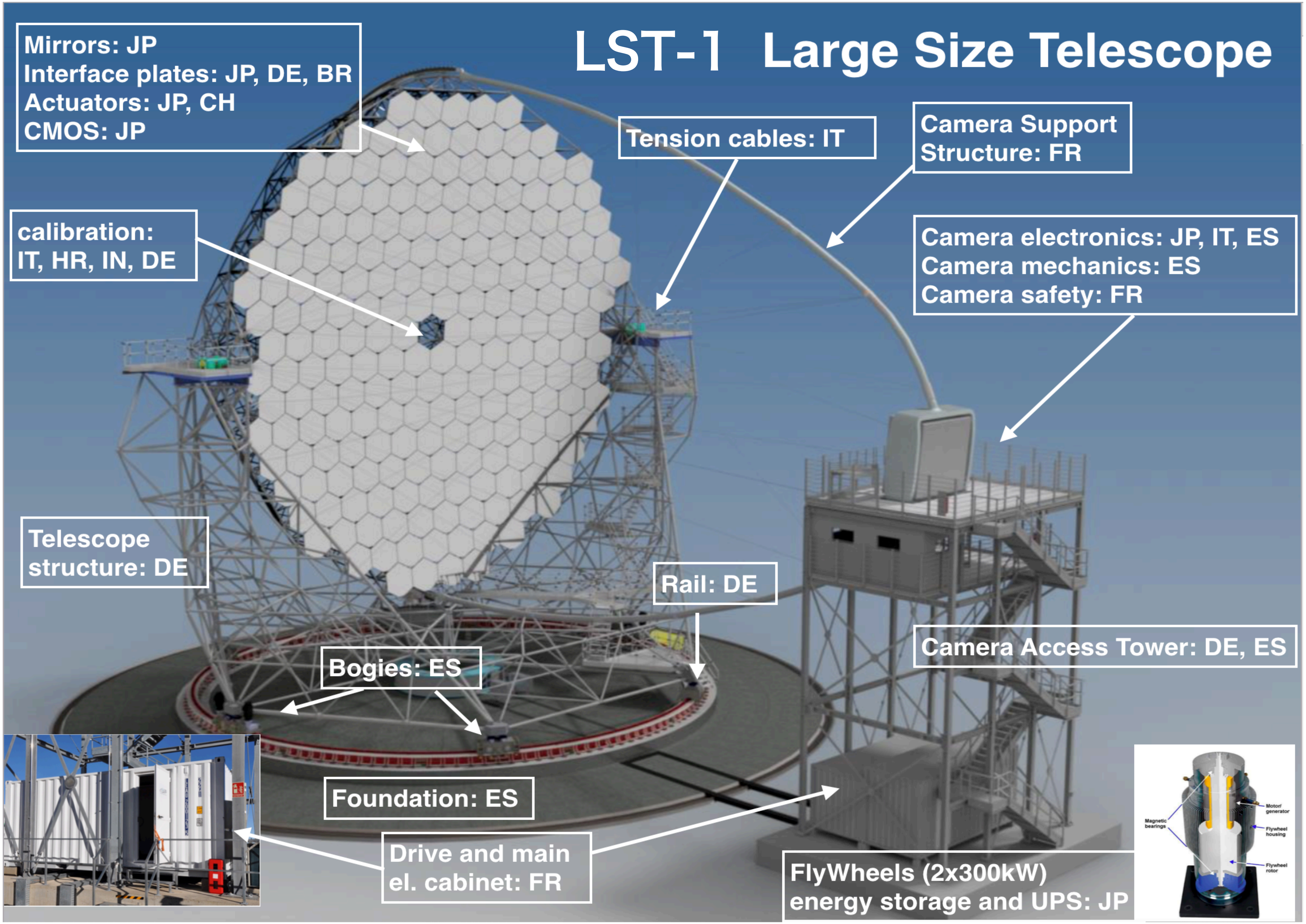
Steering Committee
Composed by Party representatives
Chair: M. Martinez
Ex Officio: M. Teshima
Ex Officio: J. Cortina
Ex Officio: D. Mazin
Version 8.24
LST EXECUTIVE BOARD
LST Project Office
Telescope Manager: P. Marquez
Principal Investigators: M. Teshima / J. Cortina
Project Manager: D. Mazin
Deputy: M. Will
Lead Systems Engineer: D. Della Volpe
Deputy: M. Heller
Safety and Operations coordinator: M. Will
Outreach: D. Green
QA/RAMS: J. M. Miranda
Interfaces and Integration
Mechanical System
Crd: T. Schweizer
Dep. H. Wetteskind
Struct. Eng.: J. Eder
Telescope Control
Crd: T. Le Flour
Dep. K. Noda
Data Analysis Software
Crd: A. Moralejo
Dep. R. Lopez Coto
Optical System
Crd. K. Noda
Dep.: M. Teshima
Camera Integration
Crd.: C. Delgado
Deputy: T. Saito
Prod.: C. Diaz
FPI / Electronics
Crd.: H. Kubo
Dep.: R. Paoletti
Prod.: T. Saito
Aux systems
Crd.: A. Fiasson
Prod.: E. Chabanne
SiPM R&D
Crd.: M. Heller
Dep.: F. Di Pierro
Prod:
Dish&Lower Structure
H. Wetteskind
Camera Support Structure
G. Deleglise
Tension Ropes
M. Mariotti
Foundation, Rails & Bogies
J. Mundet
Structural Verification
J. Eder
TCU
Ie. Vovk
V. Sliusar
Camera
C. Pio
AMC
S. Fukami
Drive
T. Le Flour
Power
K. Noda
Raw Data Calibration
J. Sitarek
Onsite analysis
T. Saito
Monte Carlo
A. Moralejo
Offline calibration
F. Cassol
Data quality
I. Aguado
RealTime
T. Vuillaume
X-calib MAGIC
NN
Primary Mirror
T. Inada
AMC
M. Chikawa
S. Fukami
Mechanics & Cooling
C. Diaz
Embedded Camera Control
J. Prast
DAQ
T. Saito
D. Hoffmann
Clock
J.A. Barrio
LST1 camera operation
O. Blanch
Photo-detectors
T. Yamamoto
Readout
H. Kubo
Trigger
G. Martínez
Light Guide
T. Yamamoto
Drive Control System
I. Monteiro
Global monitoring
T. Le Flour
Pointing Calibration
K. Noda
Camera Calibration
M. Iori
Power Distribution
M. Teshima
Cabling
E. Chabanne
Simulations and Specs
NN
Photo-detectors
NN
Readout
R. Hermel
Mechanics and Cooling
NN
Integration with PMT Camera
D. Mazin
IAC
J. Herrera
OES
T. Le Flour
DPPS
A. Moralejo
Site / INFRA
P. Marquez
Onsite IT
D. Hadasch
Offsite IT
J. Delgado
MAGIC
M. Teshima

# CTA-LST Project

## LST1 is Inaugurated on 10 October 2018

- 2017-2018 LST1 (15MEur)
- 2020-2023 LST2-4 (45MEur)
- Budget are almost secured

In Feb 2019 LST1 is awarded with 21st Cent. Technology 2019

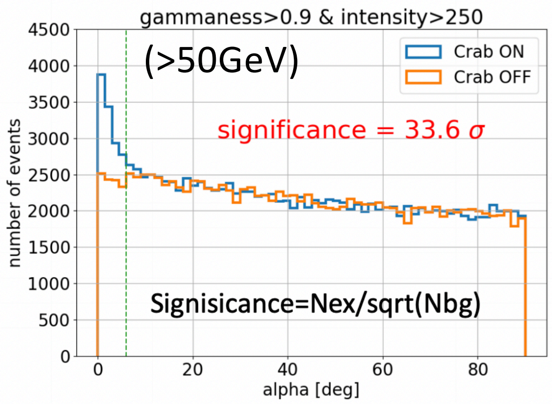

LST-1 Large Size Telescope
Mirrors: JP
Interface plates: JP, DE, BR
Actuators: JP, CH
CMOS: JP
Tension cables: IT
Camera Support
Structure: FR
calibration:
IT, HR, IN, DE
Camera electronics: JP, IT, ES
Camera mechanics: ES
Camera safety: FR
Telescope
structure: DE
Rail: DE
Camera Access Tower: DE, ES
Bogies: ES
Foundation: ES
Drive and main
el. cabinet: FR
FlyWheels (2x300kW)
energy storage and UPS: JP


LST-1 in commissioning and engineering operation

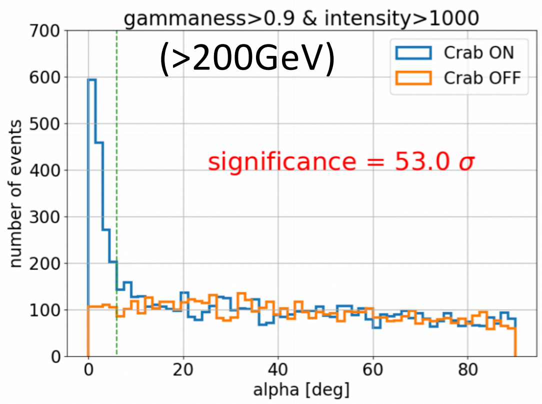
# Commissioning of LST1 Crab Nebula and Pulsar

## 2hrs of Crab observation in Nov. 2019

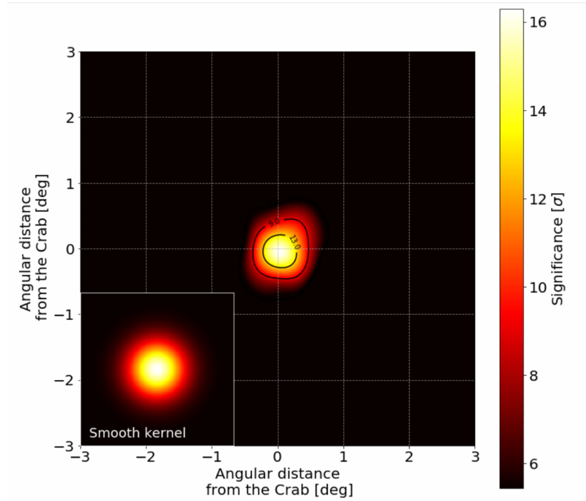
alpha cut = 6deg




Excess = 29.0/min




Excess = 9.6/min

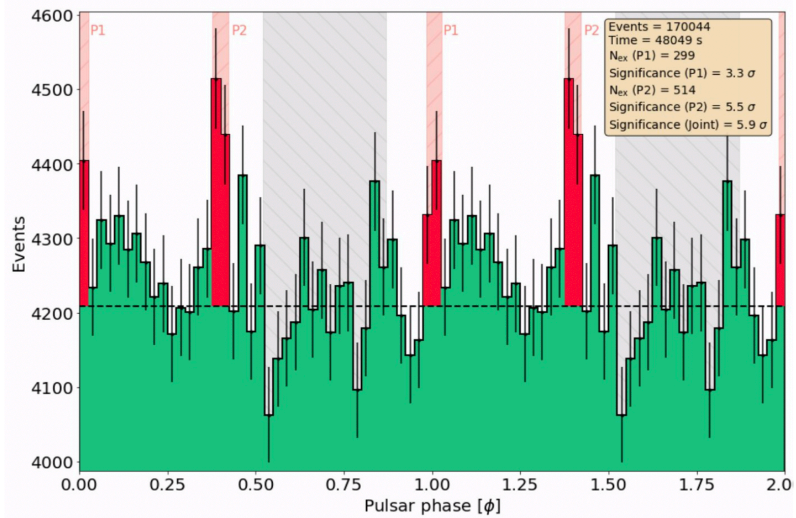



## 16hrs of Crab Pulsar Observation, January/February 2020

Threshold energy is estimated as 40-50GeV

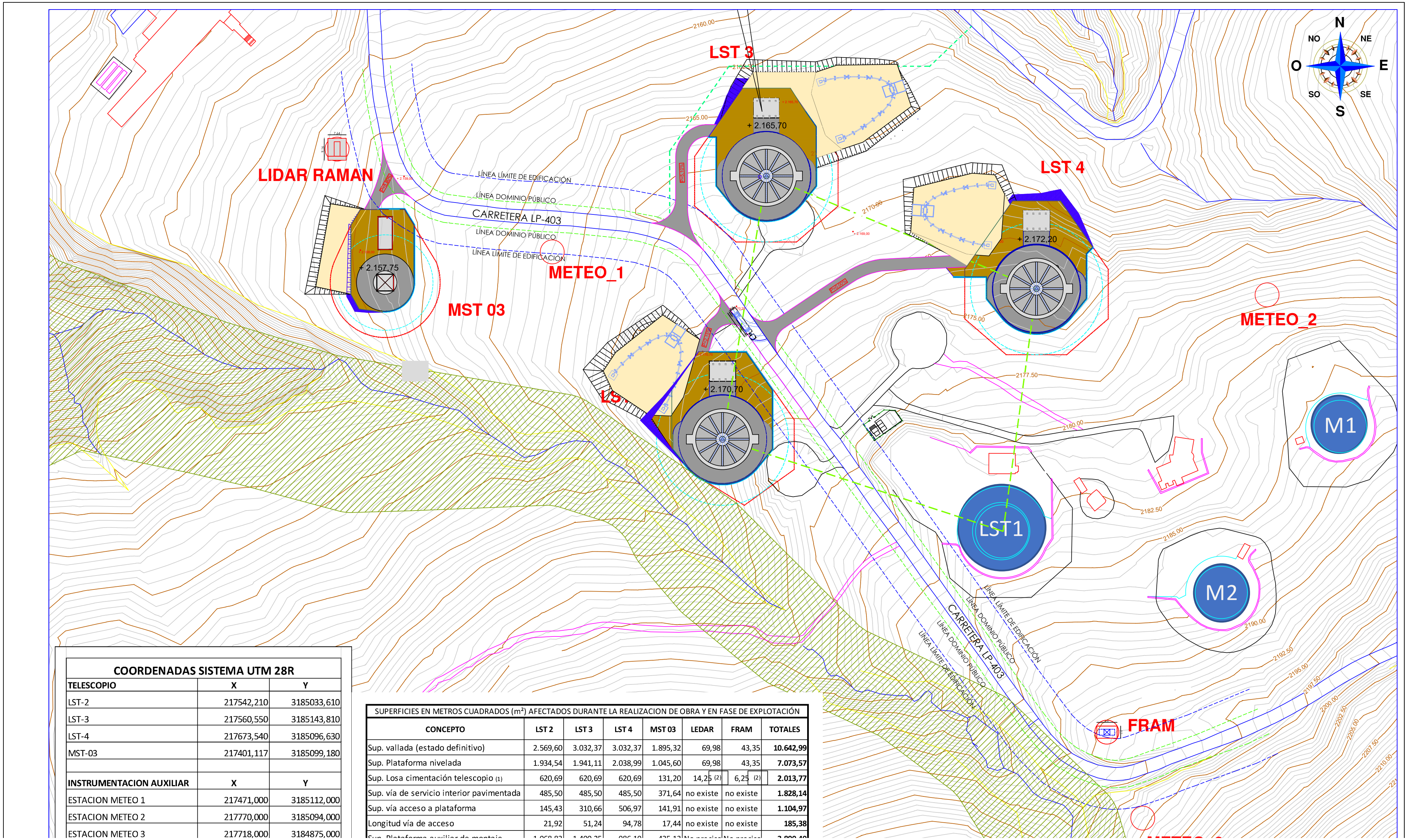
Confirmed the accurate time stamp

**Extragalactic Sources**
**Mrk421, Mrk501, 1ES1959 !!**
**GRB 2101XX?? and more**




In three years, we will get an Instrument with a 10-20 times better sensitivity !!

# 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 | 1.068,83 | 1.400,35 | 986,10 | 435,13 | No precisa | No precisa | **3.890,40** |

# LST Timeline

- 2021-2023
  - Deployment of 3 more LSTs, and 5 MSTs in CTA North
  - Study the Advanced Design and Prototyping, and create budgets for LST South
- 2024-
  - Operation of CTA North will start
  - Construction of LST South (by Switzerland, Japan, Italy-INAF, Germany-MPP,,,)

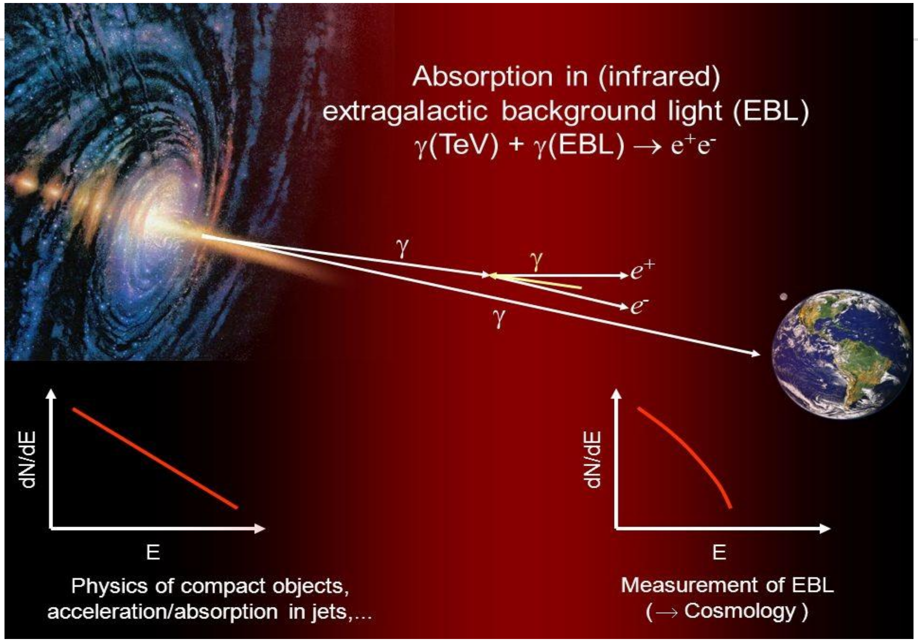
| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
|---|---|---|---|---|---|---|---|---|---|
| LST North | Comissioning and Operation of LST1 | | | | CTA North starts the operation with 4 LSTs and 5 MSTs | | | | |
| | CDR | Deployment of LST2-4 | | | | | | | |
| *MST North* | *Design and Finance* | | *Construction of 5MSTs* | | | | | | |

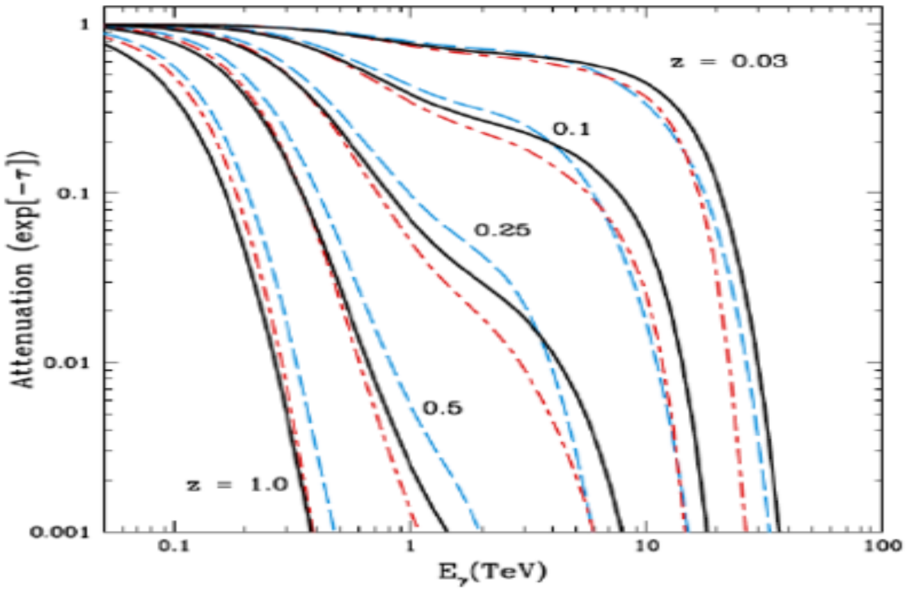
| | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
|---|---|---|---|---|---|---|---|---|---|
| LST South | | Advanced Design and Proto / Finance / CDR | | | Construction of 4LSTs | | | Operation | |

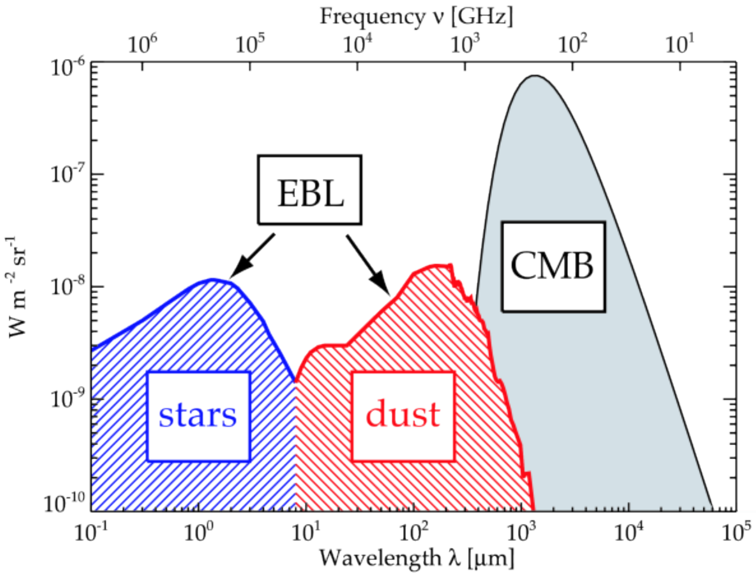
| | *2020* | *2021* | *2022* | *2023* | *2024* | *2025* | *2026* | *2027* | *2028* |
|---|---|---|---|---|---|---|---|---|---|
| *Organization* | *CTAO gGmbH* | | | | | | | | |
| | | *CTAO ERIC (European Research Infrastructure Consortium)* | | | | | | | |

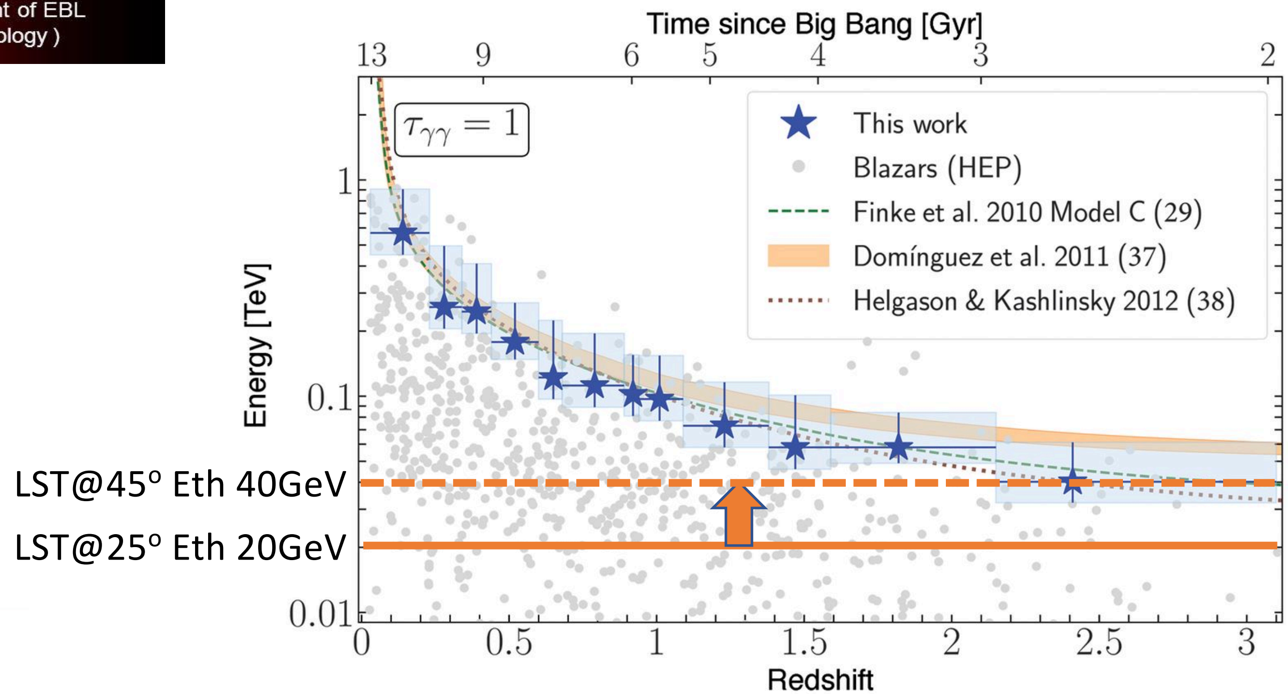
| | *2020* | *2021* | *2022* | *2023* | *2024* | *2025* | *2026* | *2027* | *2028* |
|---|---|---|---|---|---|---|---|---|---|
| *CTA South* | *Design and Finance* | *INFRA* | | *Construction and Deplyment of 15 MSTs* | | | *Operation of 15 MSTs* | | |
| | | | | *Construction and Deployment of 50 SSTs* | | | *Operation of 50 SSTs* | | |

# Expand Gamma Ray Horizon with LSTs
# Zmax = 1.0 → Zmax = 3.0



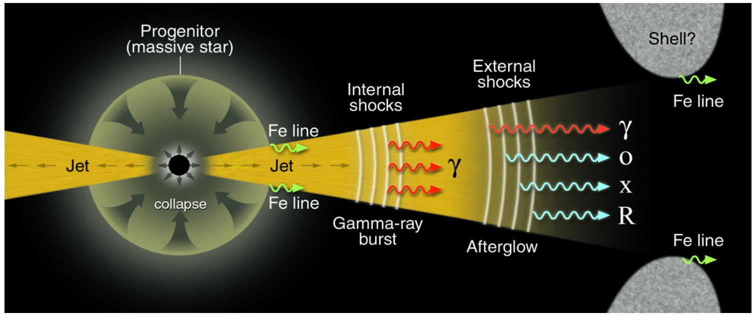



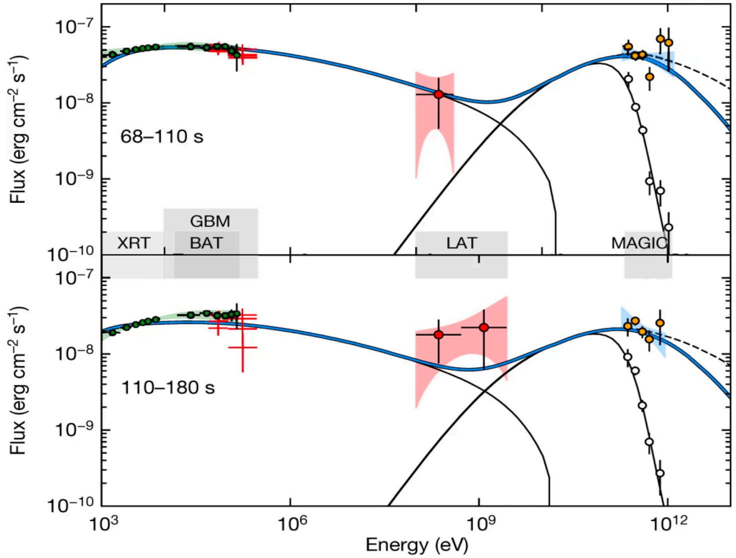



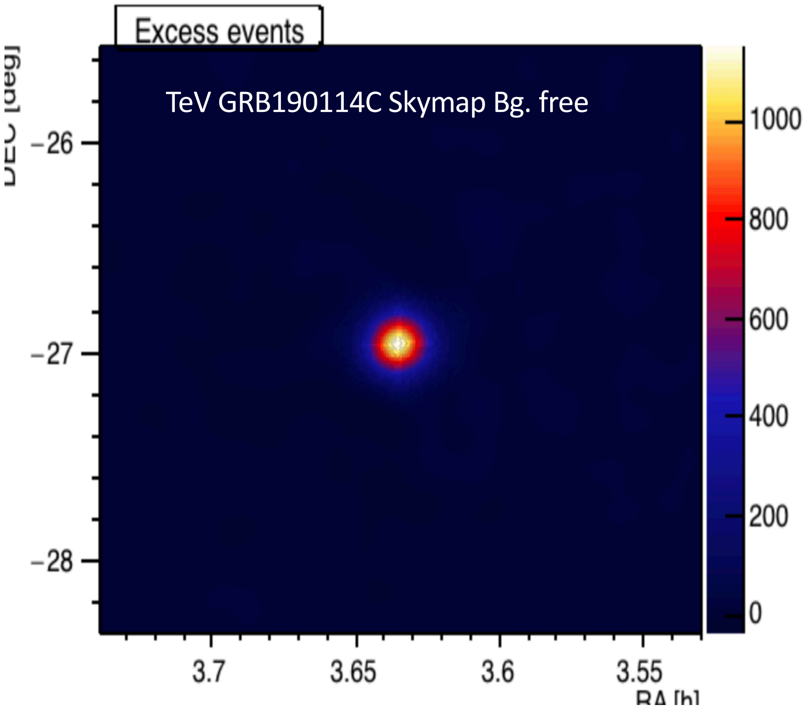
# TeV-GRB 190114C observation with MAGIC

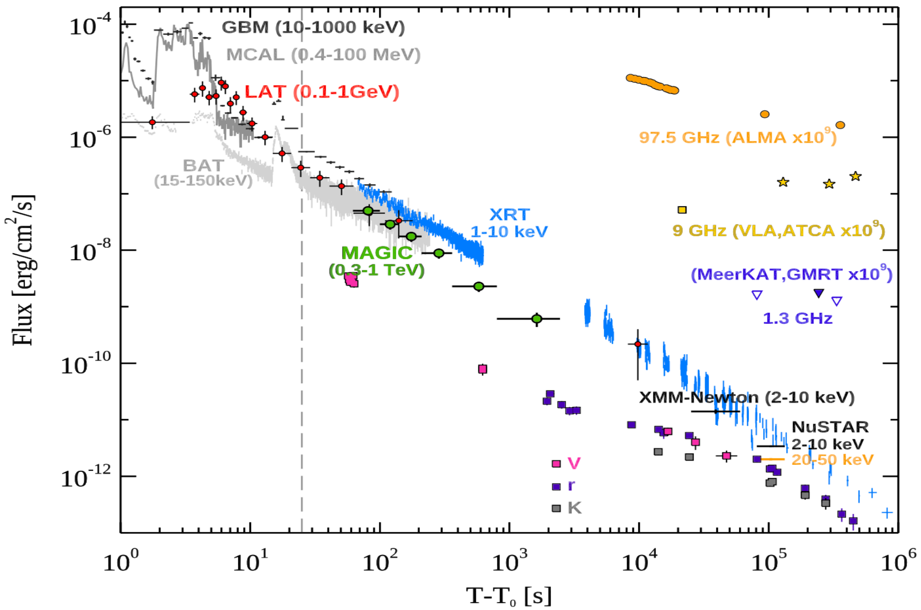
## Two Nature Papers 21. Nov. 2019



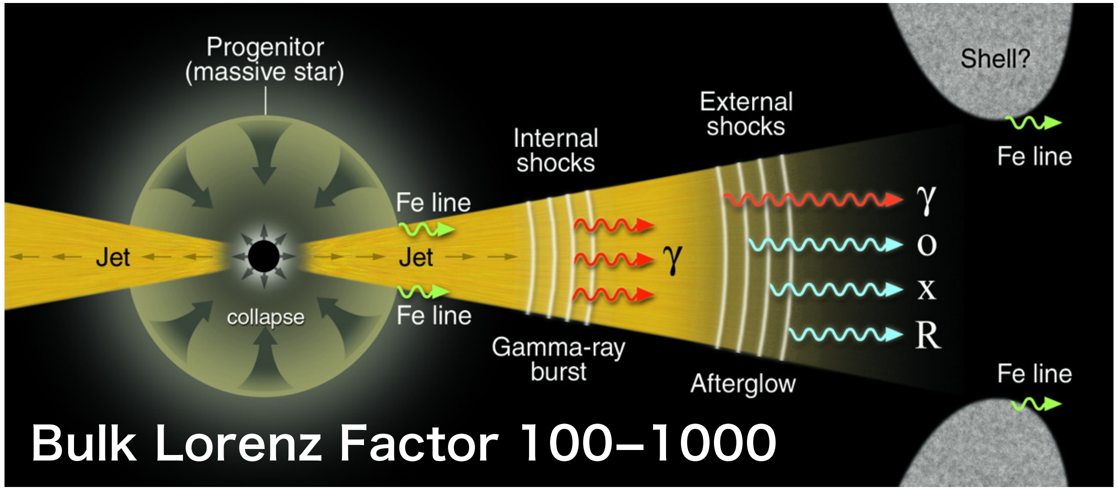



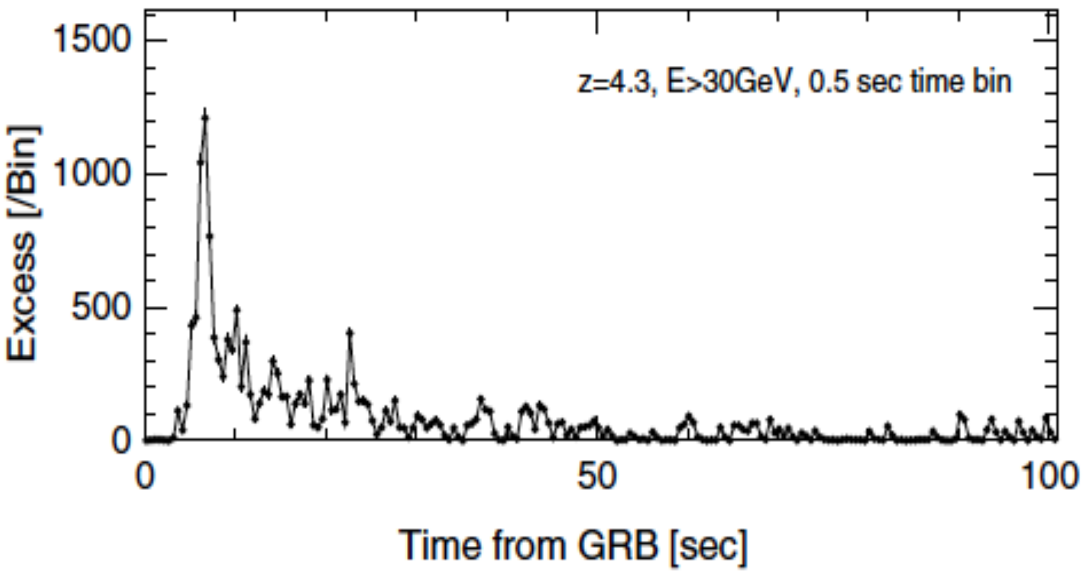

- Energy spectrum is extending to TeV energies
- Significant energy released in TeV domain
- Afterglow curve is parallel to X-Ray afterglow
- LST will detect 10 times more events than MAGIC and HESS



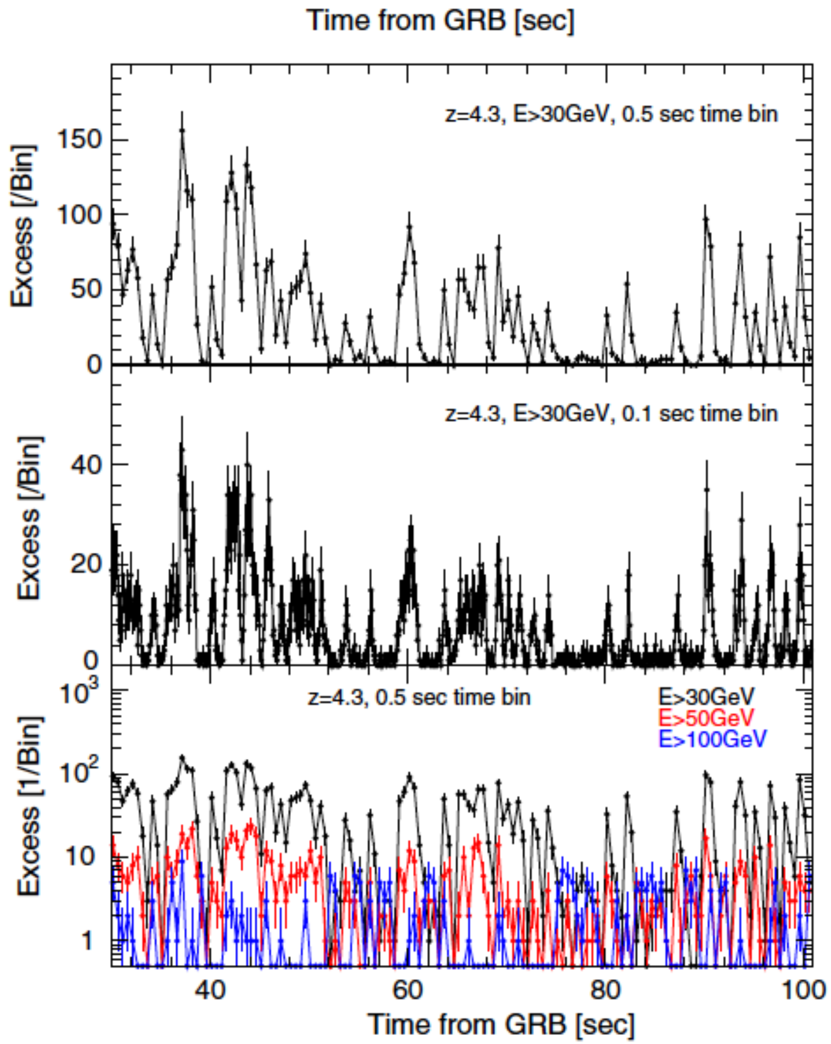



# GRBs: good targets for CTA-LSTs
# Study the newborn baby black holes



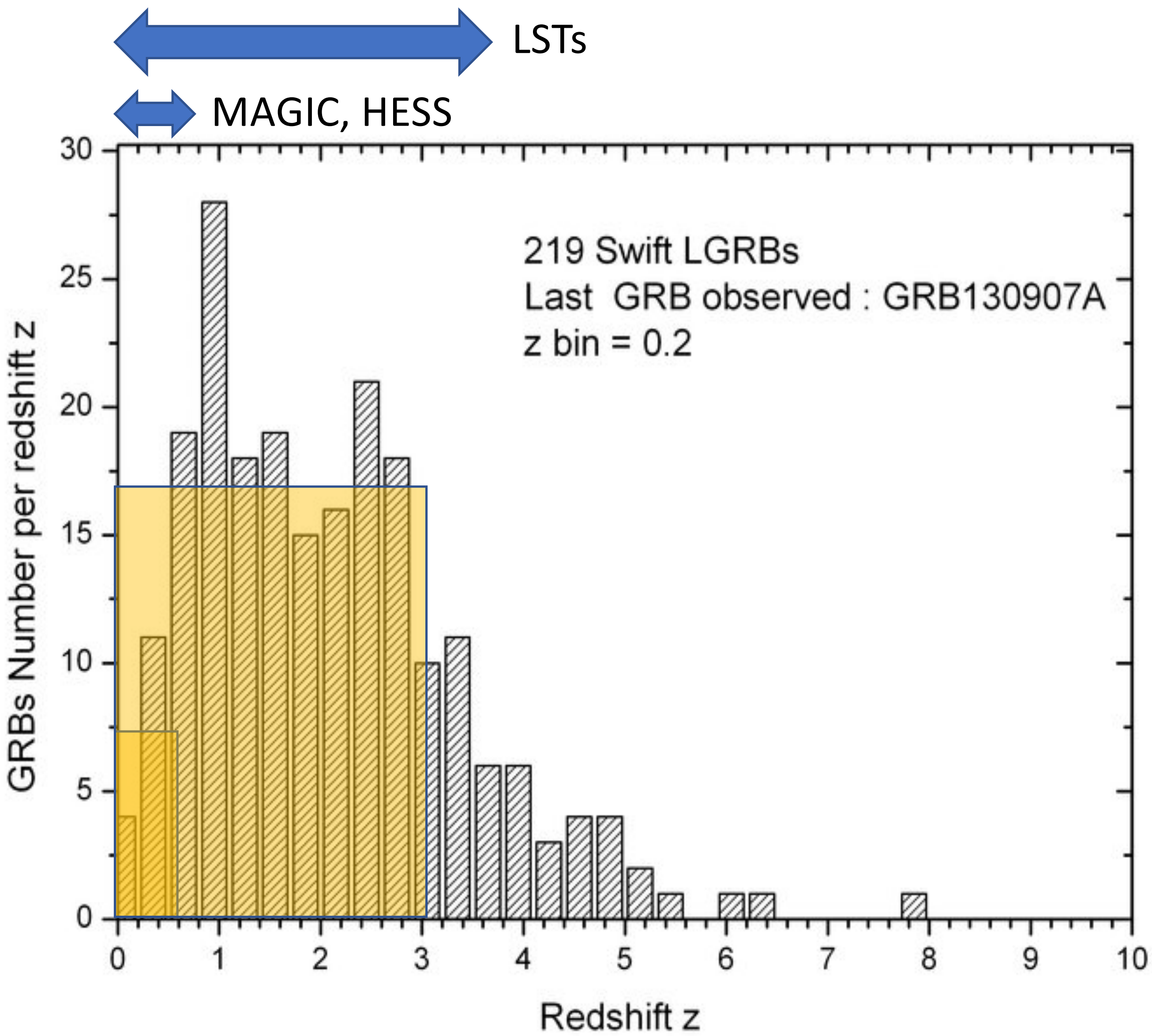




CTA Simulation
(Template GRB080916C)



# Redshift Distribution from SWIFT GRBs

## W. J. Azzam et al. 2014




15 GRBs in z < 0.5
112 GRBs in z < 2.0
164 GRBs in z < 3.0

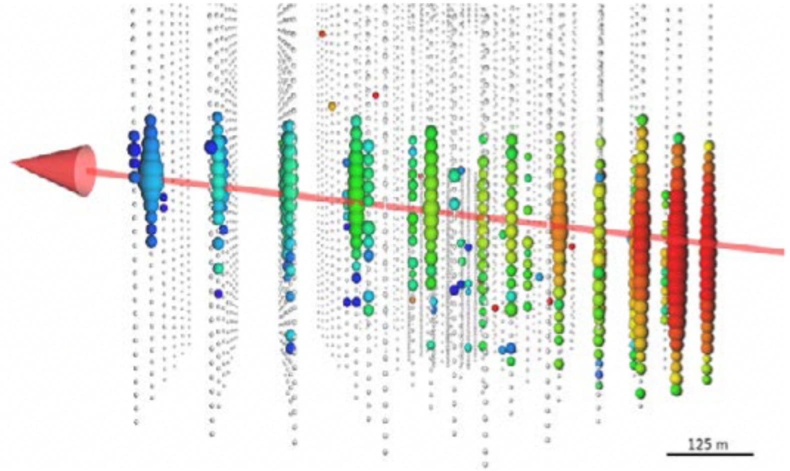
LST will increase
the detection probability x10

cherenkov telescope array

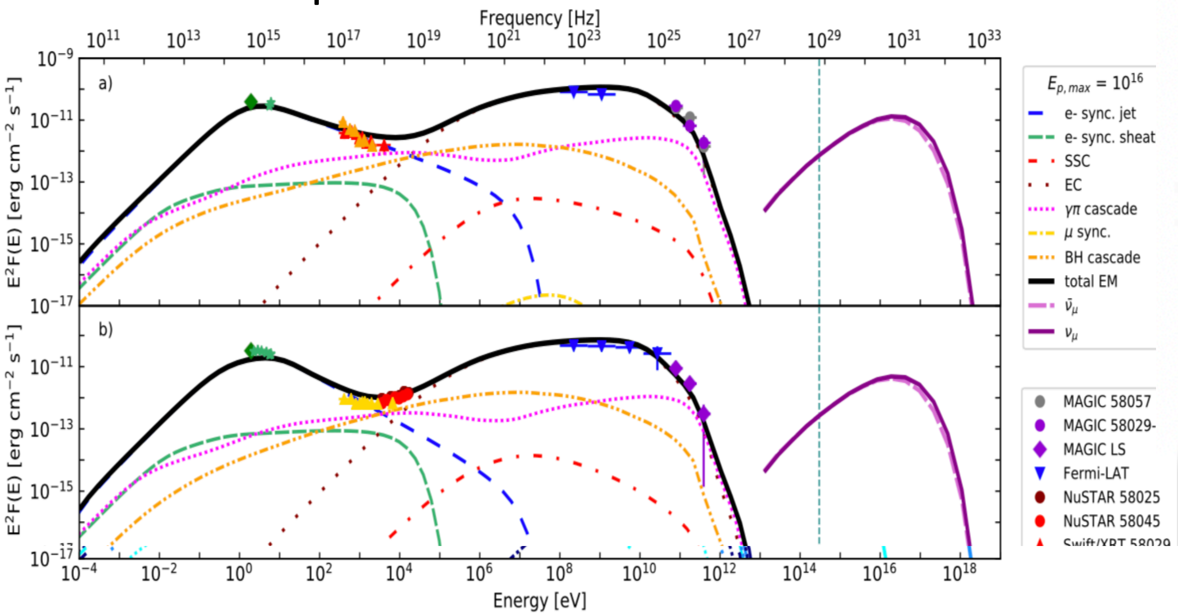
# IC170922A / TXS 0506+056

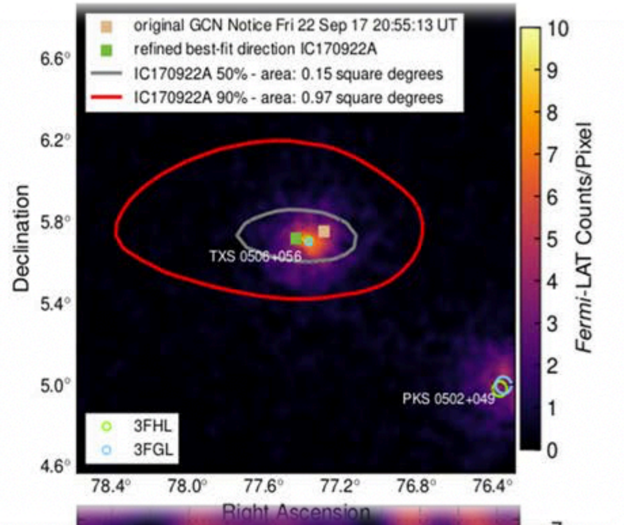
## PeV Neutrinos may come from distant UHECR sources
## The source density relates with the Star formation rate

### Ice Cube Observation (~300TeV)

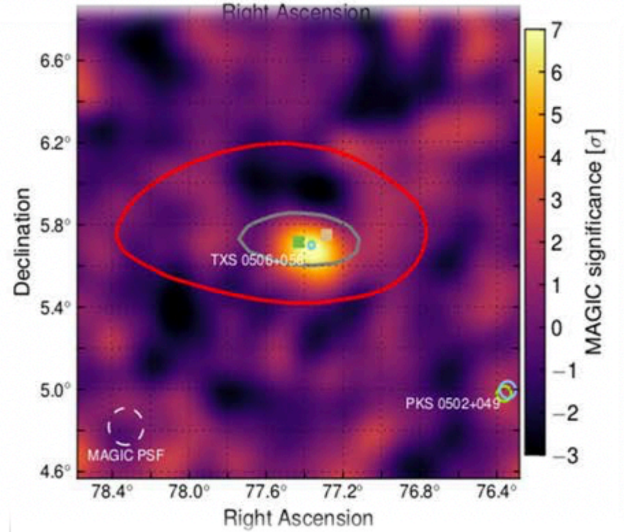



### Lepto-Hadronic Scenario




Fermi LAT (>100 MeV)

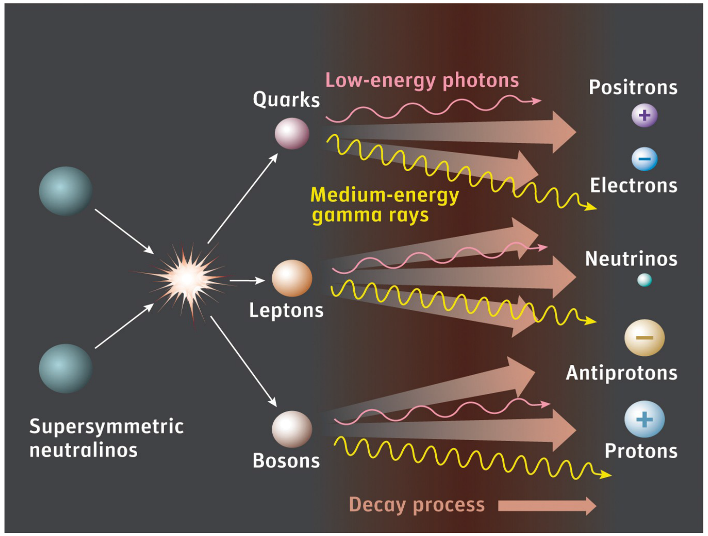



MAGIC (>100GeV)

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

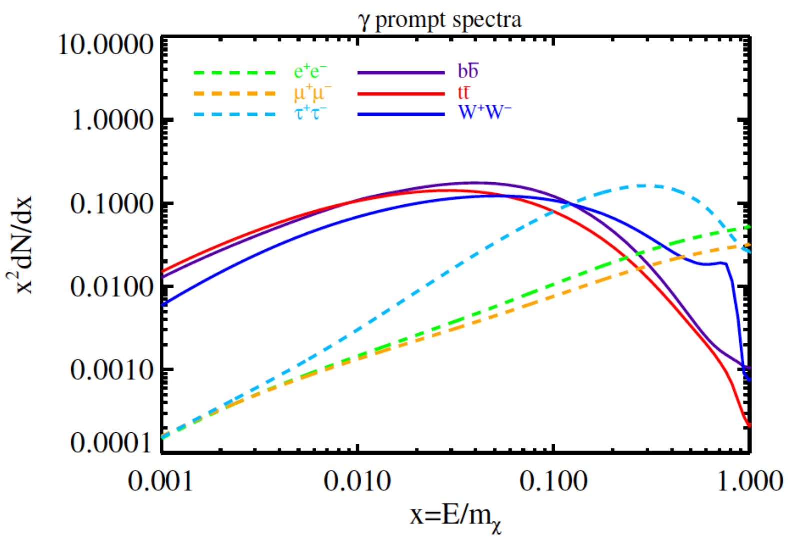
# Dark Matter Search

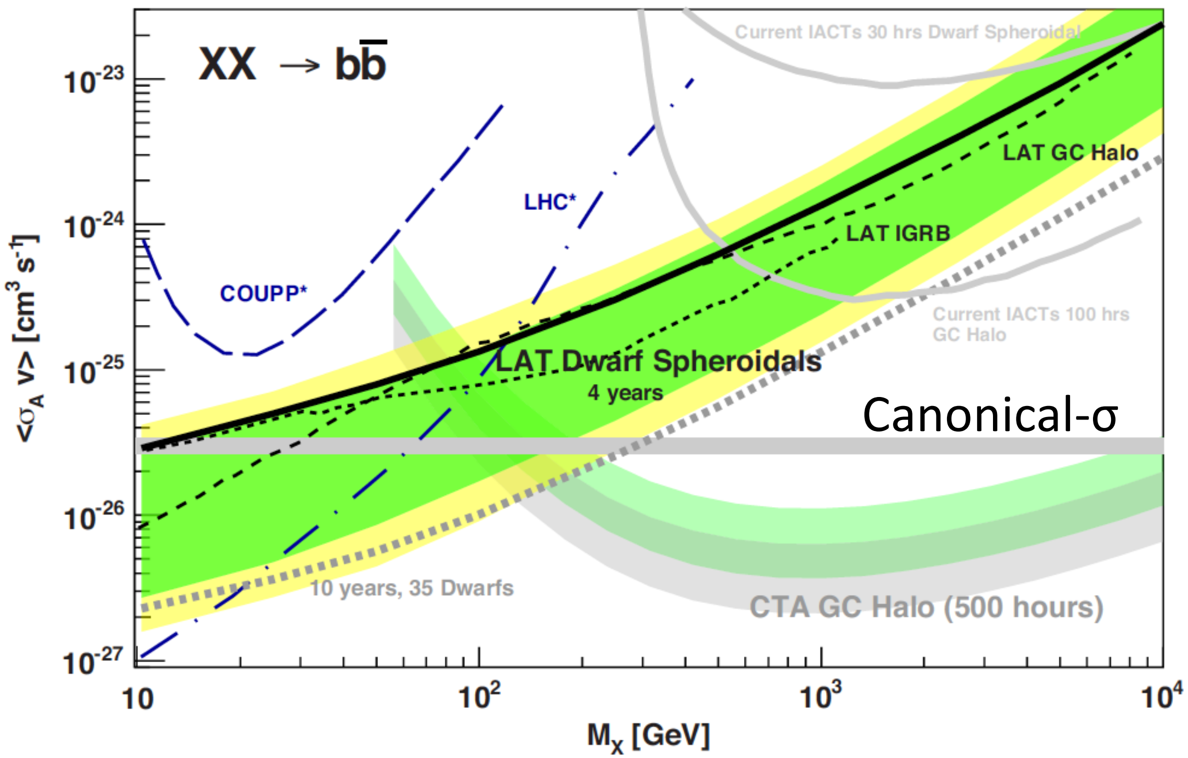
## Sensitive $M_\chi$: 200GeV - 10TeV




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

Particle Physics Astrophysics



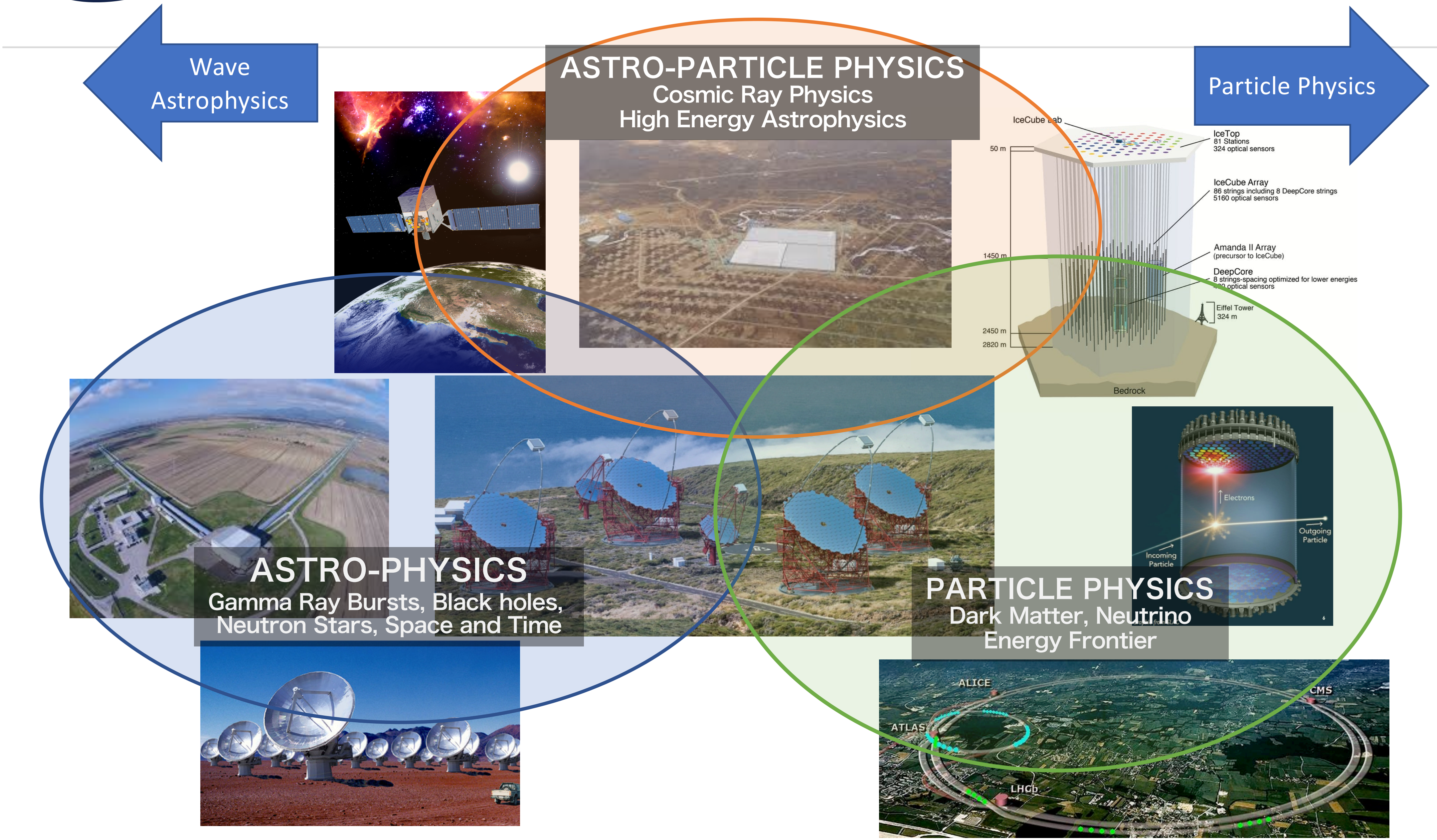



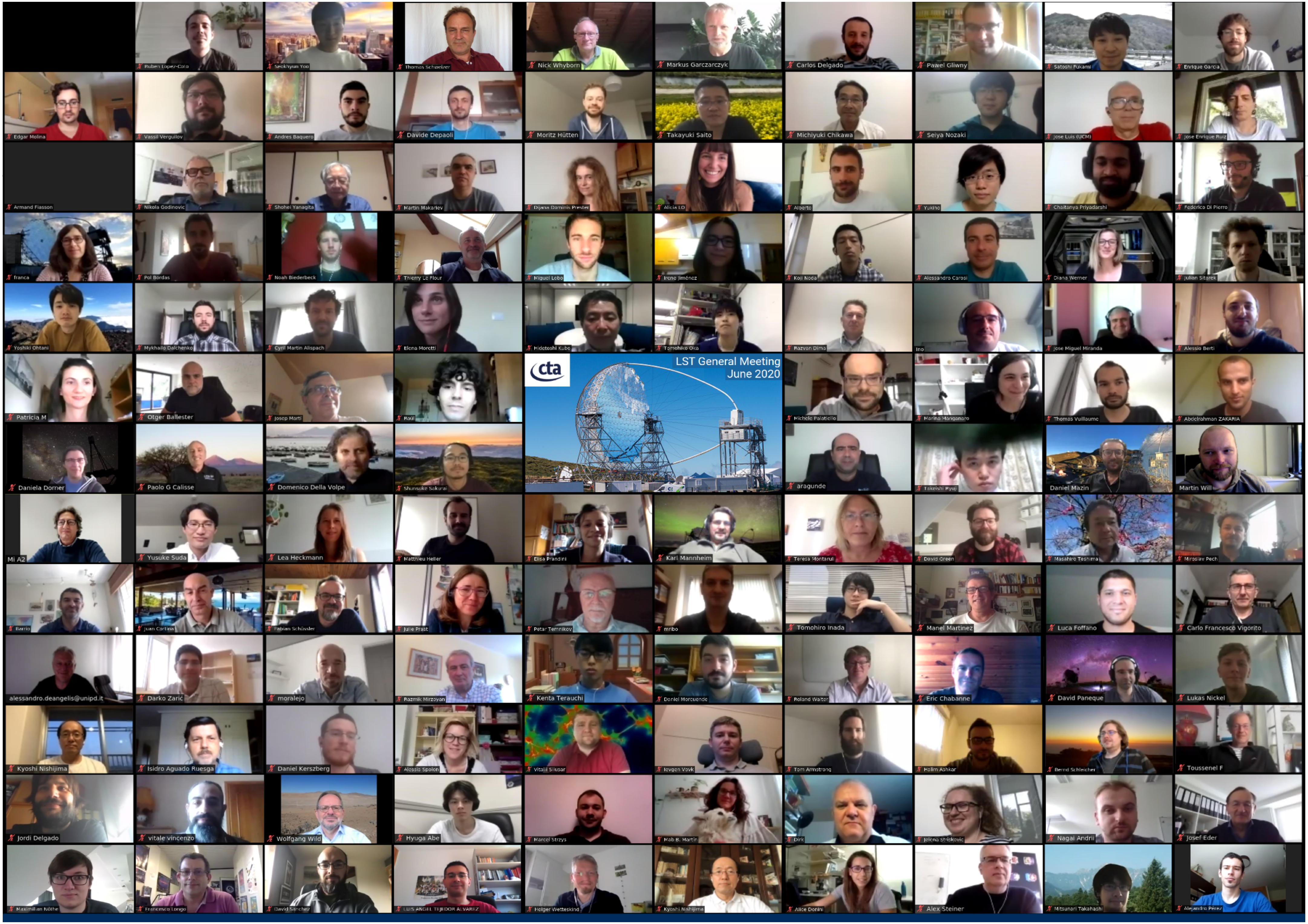

Gamma rays from Annihilation produce the bump around 1/10 -1/20 $M_\chi$ ➔ 20GeV-1TeV domain

CTA gives the stringent upper limit.
Stefan Funk 2015

cta cherenkov telescope array

# Multi-messenger and Multi-wavelength Astrophysics




LST General Meeting
June 2020