Ground Based Gamma Ray Astronomy and future

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HE/VHE Gamma-Ray detectors

VERITAS

MAGIC-II

Fermi Gamma-Ray Satellite

HAWC

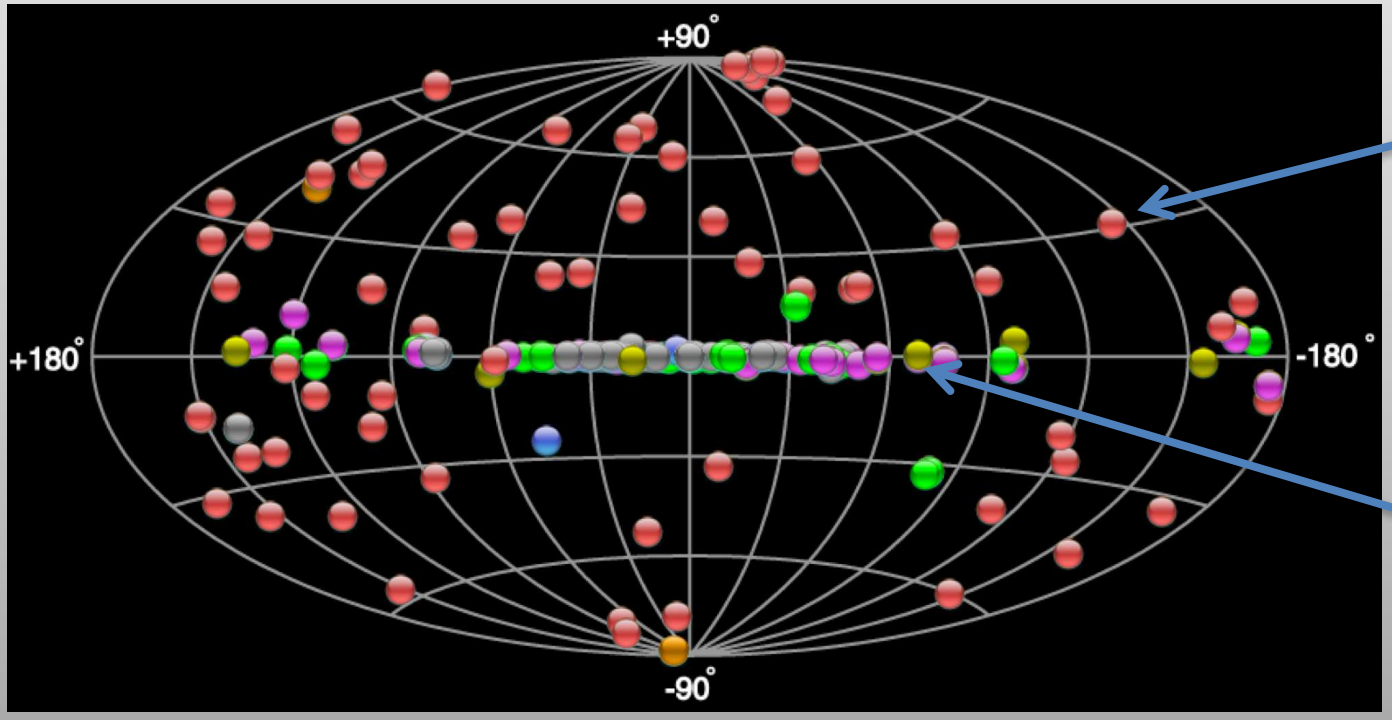
HESS-II

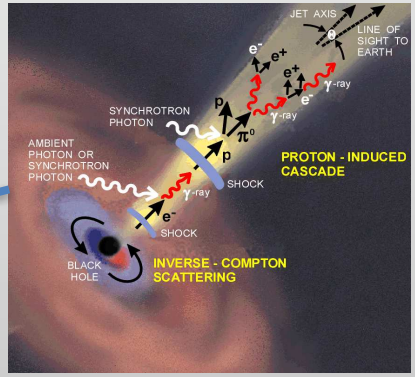
VHE Gamma Ray Astronomy

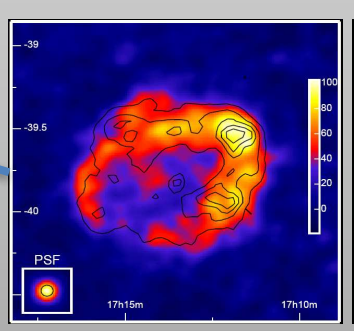
A New Window to the Universe and Energy Frontier in Astrophysics

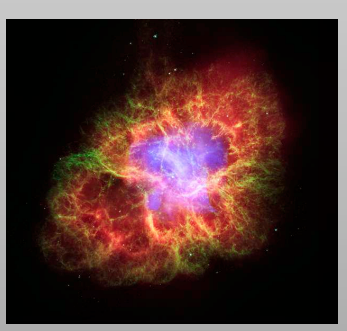
- HESS, MAGIC, VERITAS observed about 200 sources

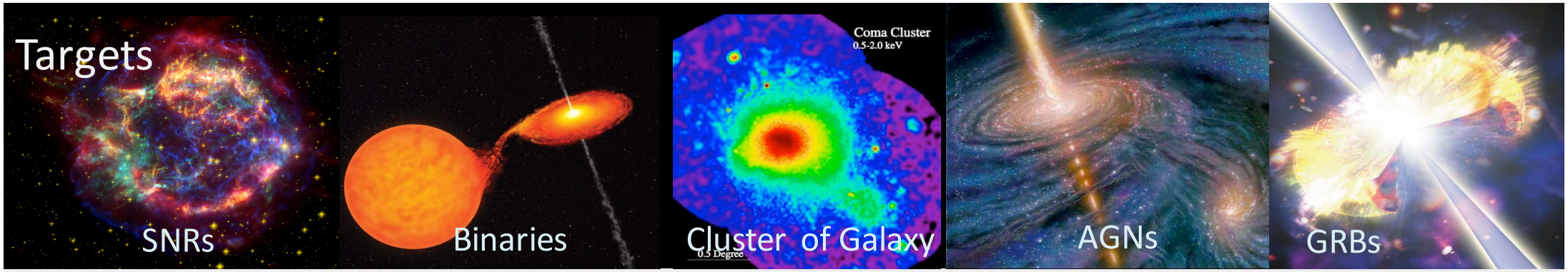
- CTA will expand the visible universe up to z = 2 with the superior sensitivity, and broad band energy coverage, and will observe >1000 sources
- CTA will have 10^4 times higher sensitivity for the transient/flaring sources than Fermi, for example, gamma ray bursts and AGN flares.





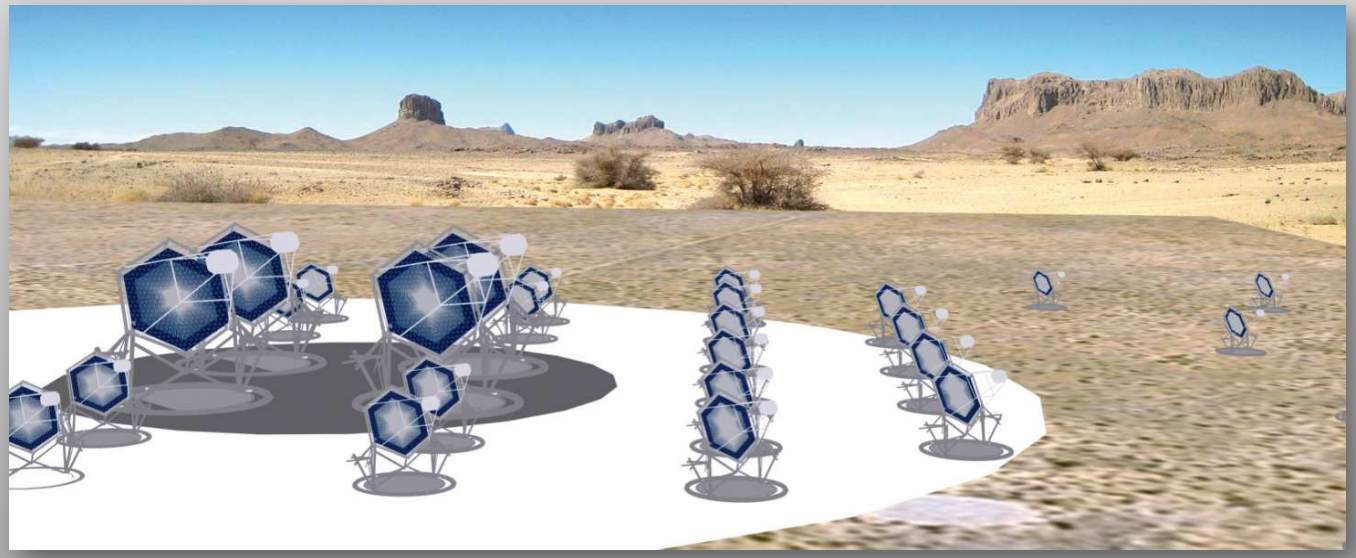




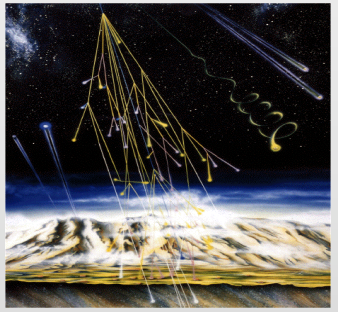


Cherenkov Telescope Array
High Energy Gamma Ray Astronomy

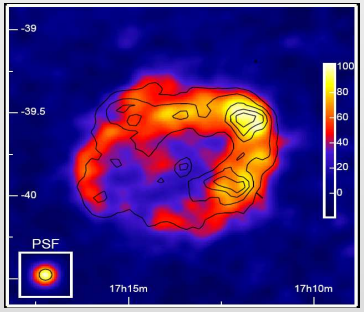
- Origin of Cosmic Rays
- High Energy Astronomical Objects
- Super Massive Black Holes
- EBL Study ➔ Cosmology (Star formation rate)
- Search for Dark Matter



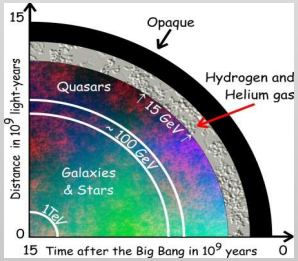
Science Objectives



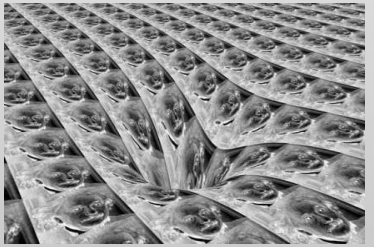
Cosmic Ray Origin



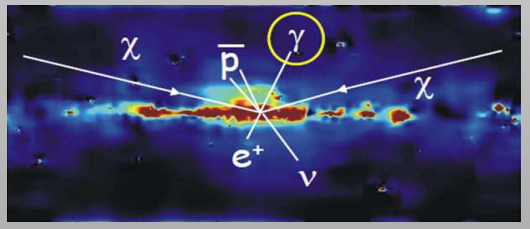
High Energy Objects



Cosmology



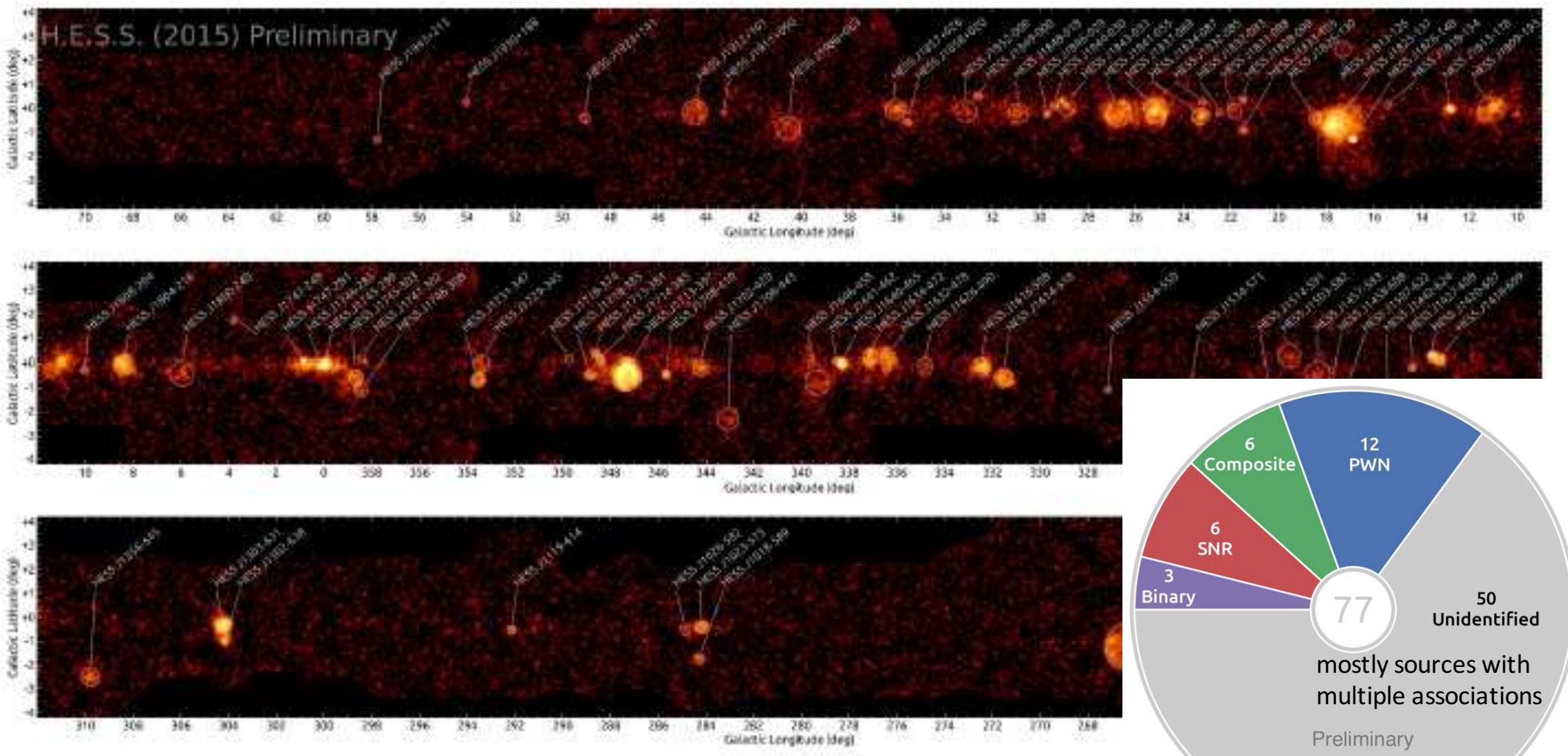
Space & Time



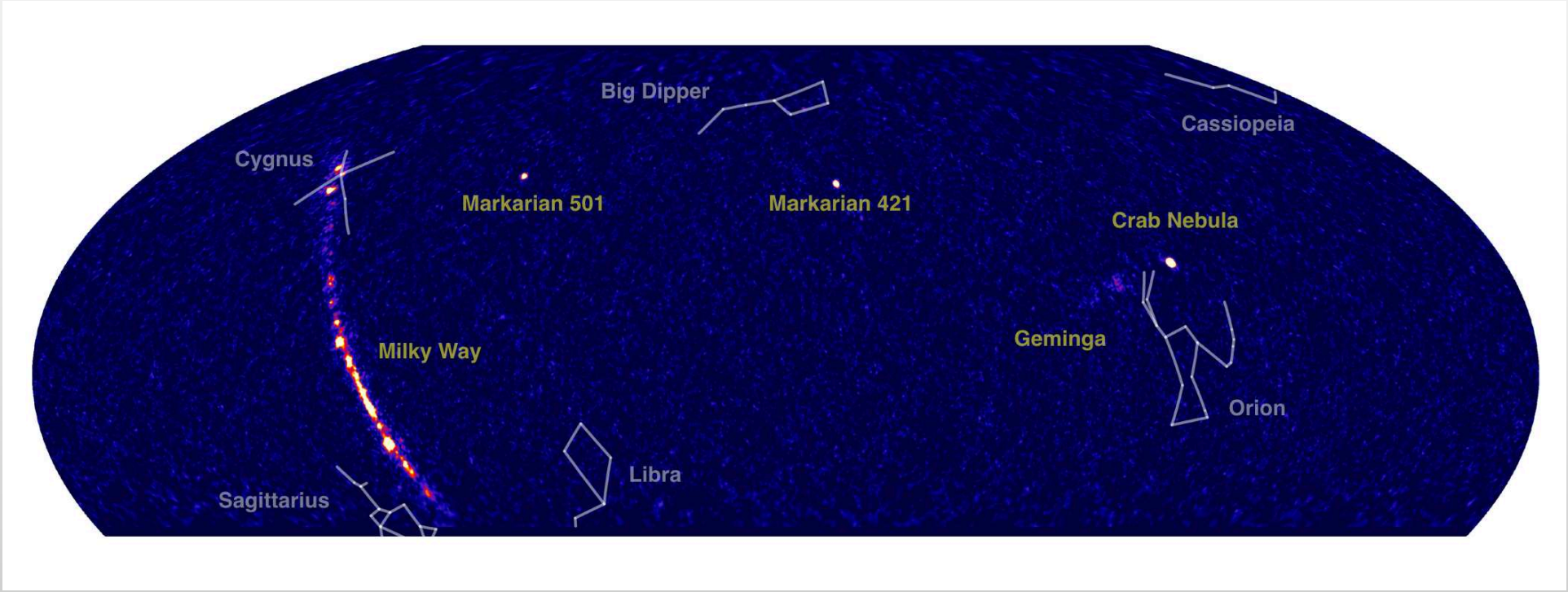
Dark Matter

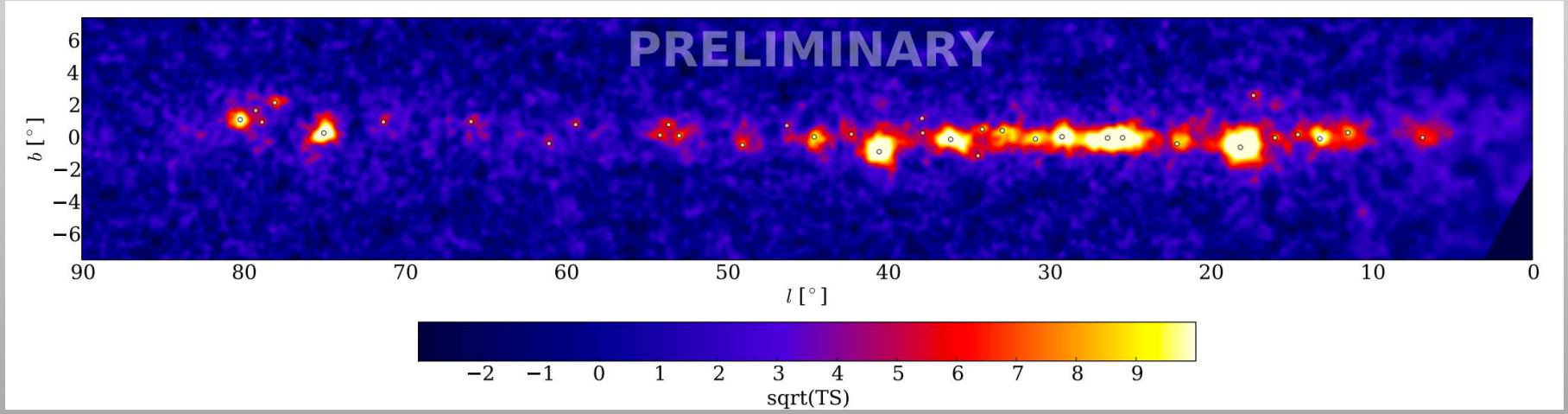
HESS Galactic Plane Survey

Deil et al. ICRC 2015 and Chaves TeVPA 2015

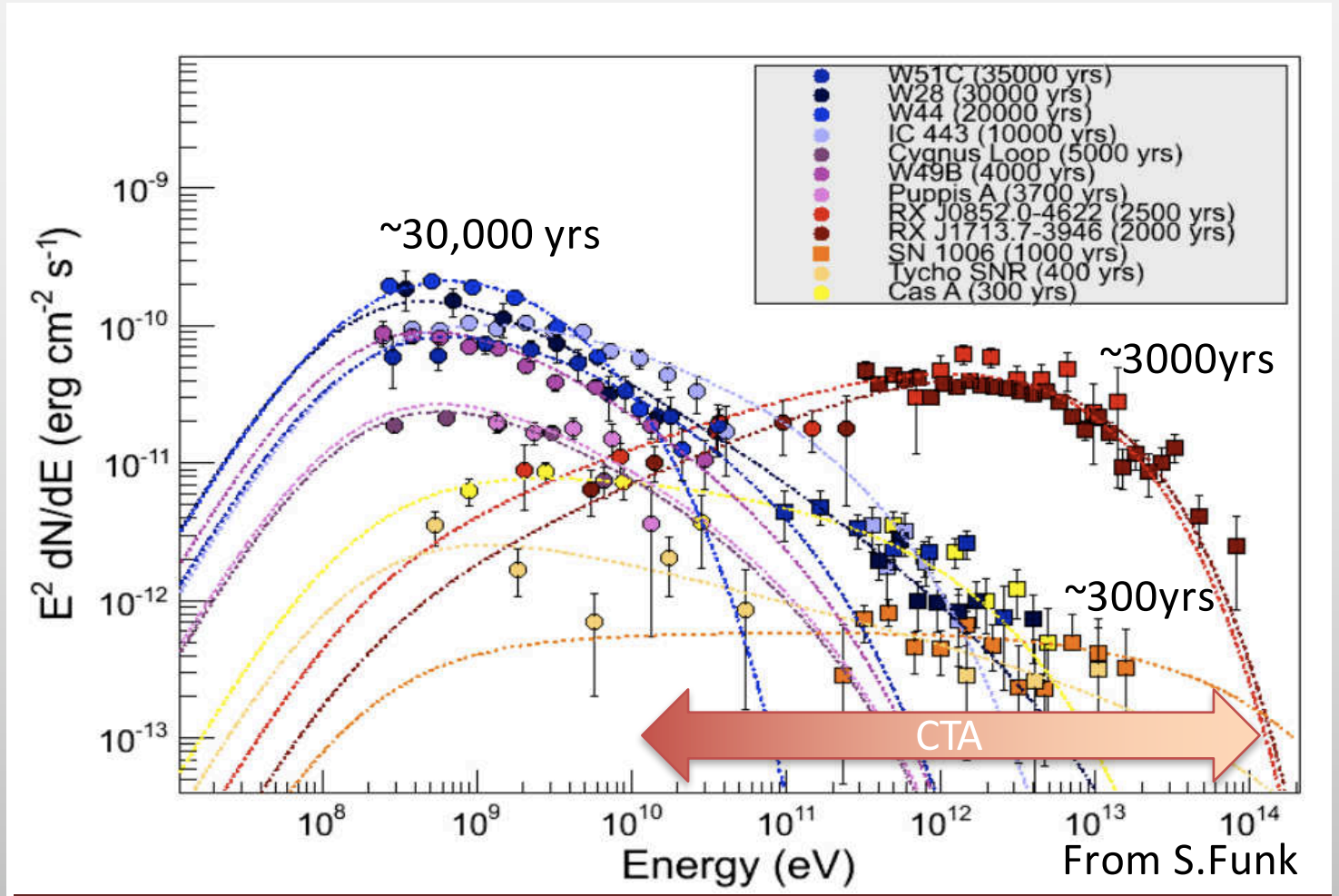


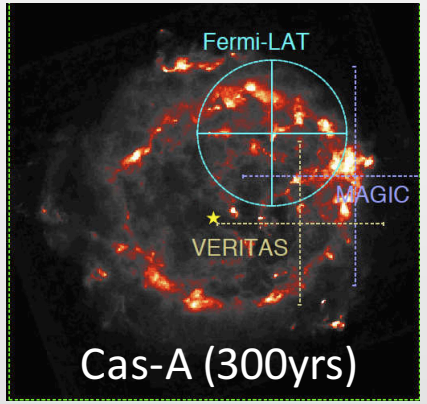
HAWK shows the first results
in APS meeting 2016 → Miguel Mostafa

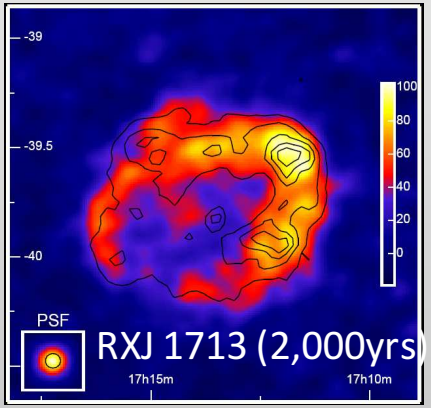


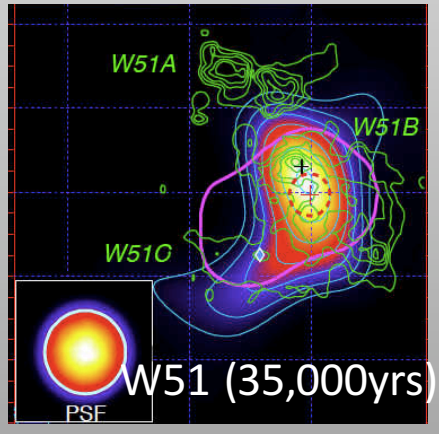


E<10^{15}eV Cosmic Rays ←→ Shell type SNRs









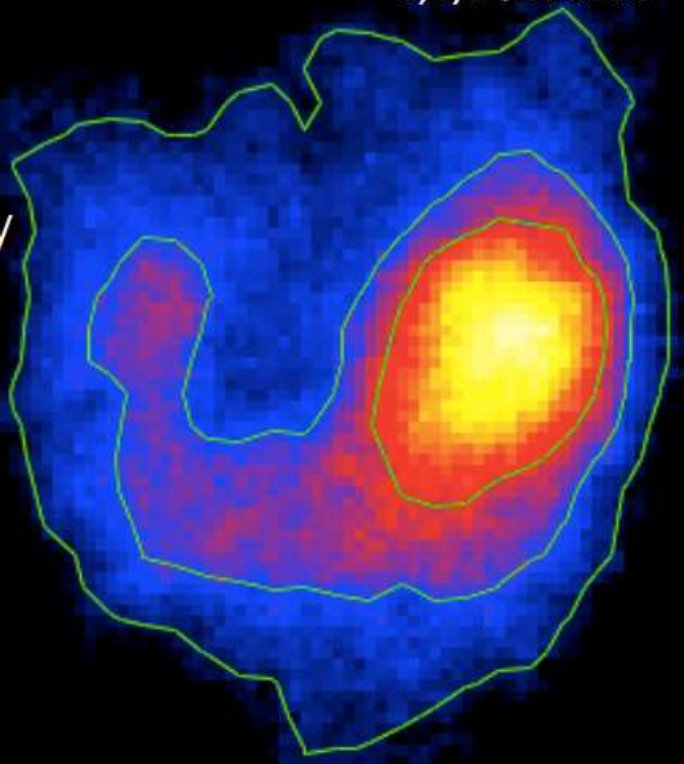
- Different stages of SNRs as cosmic ray accelerator
- CTA will deliver more information on SNRs as cosmic ray accelerators
- We can survey most of SNRs in our galaxy ➔ C.R. energetics

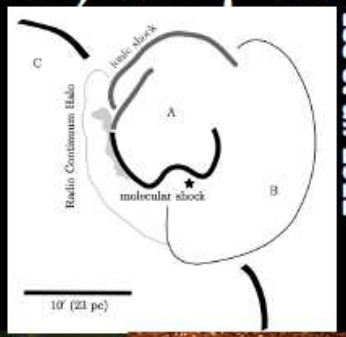
VERITAS IC443

Humensky ICRC2015 & Mukherjee TeVPA

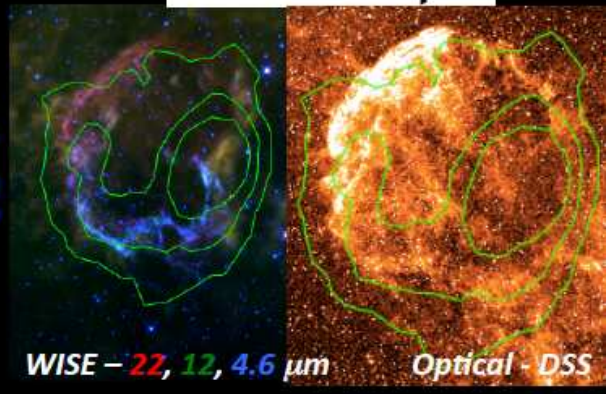
Summary: Resolving the Jellyfish Nebula (IC 443) in γ-rays

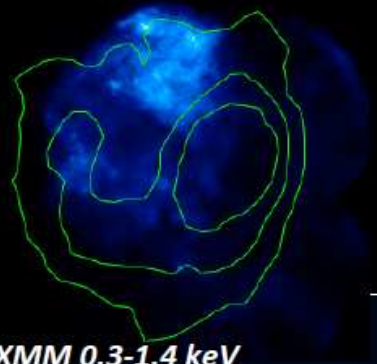
- A deep observation of IC 443 with VERITAS has resolved significant VHE emission from the entire northeast lobe.
- Pass-8 Fermi-LAT data reveals very similar morphology above 5 GeV.
- The γ-ray emission spans multiple, very different, environmental conditions.
  - *Can extract spectra from different regions to probe the environmental dependence of cosmic-ray diffusion.*





Lee *et al.* 2012



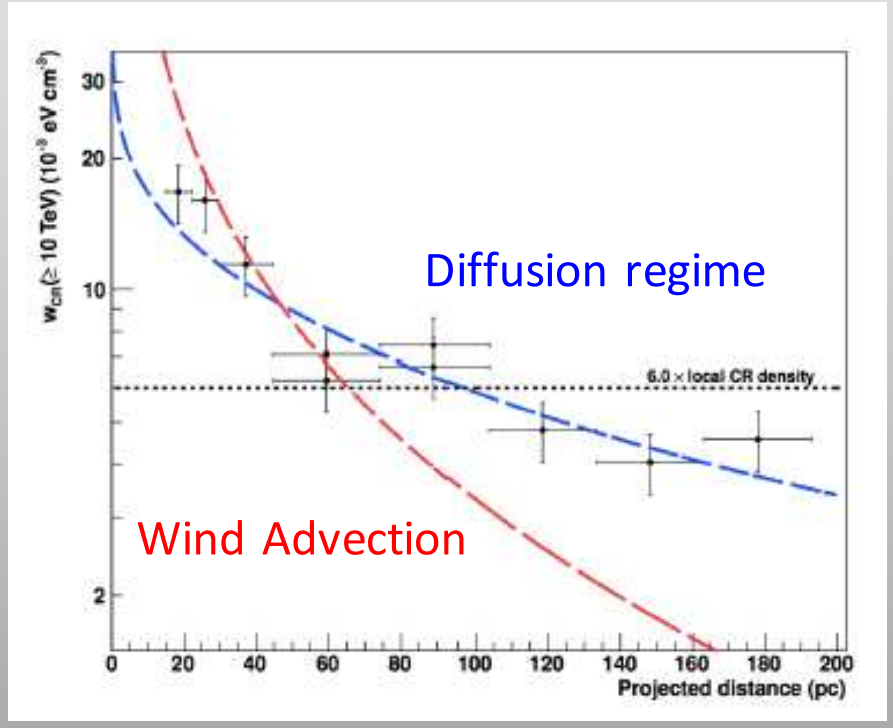


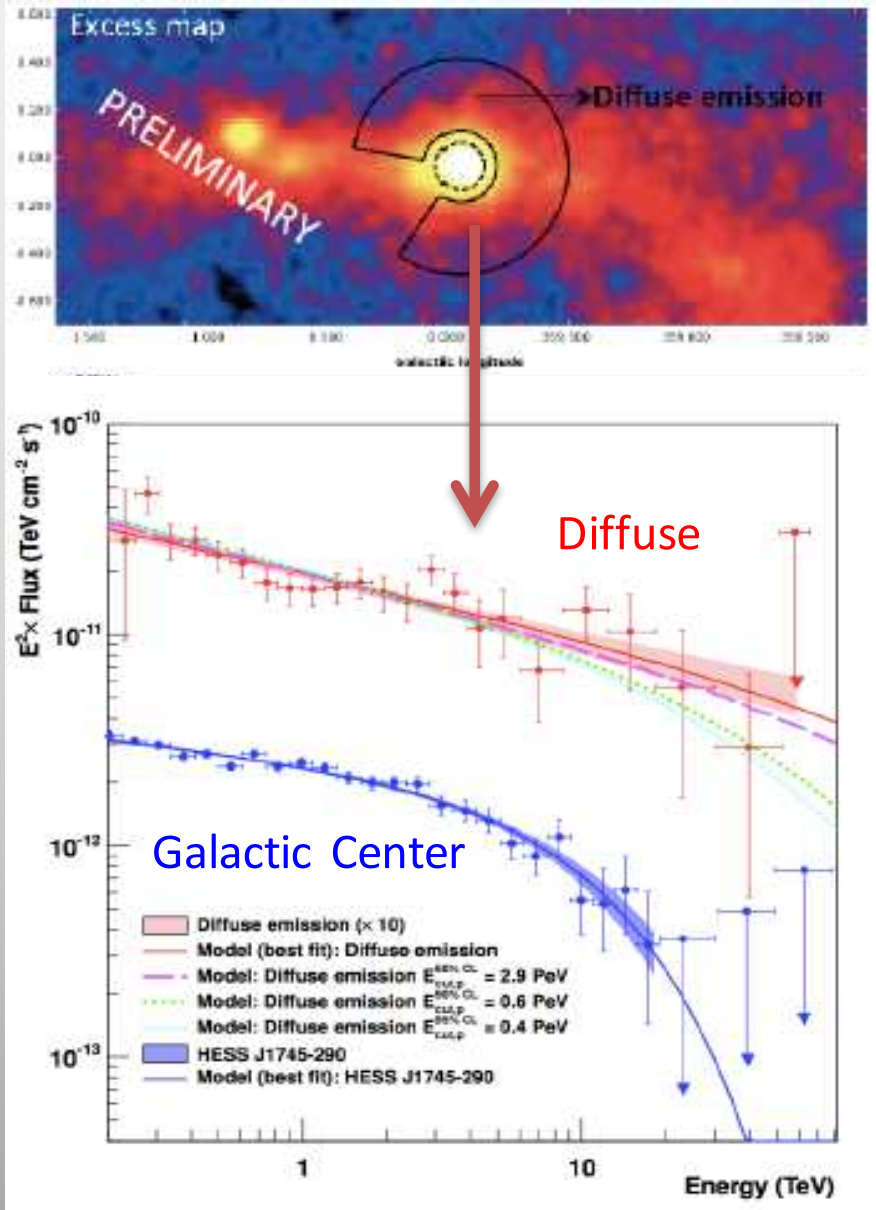
Galactic Center Diffuse with HESS PeVATRON?

HESS Deep Observation of 250hrs

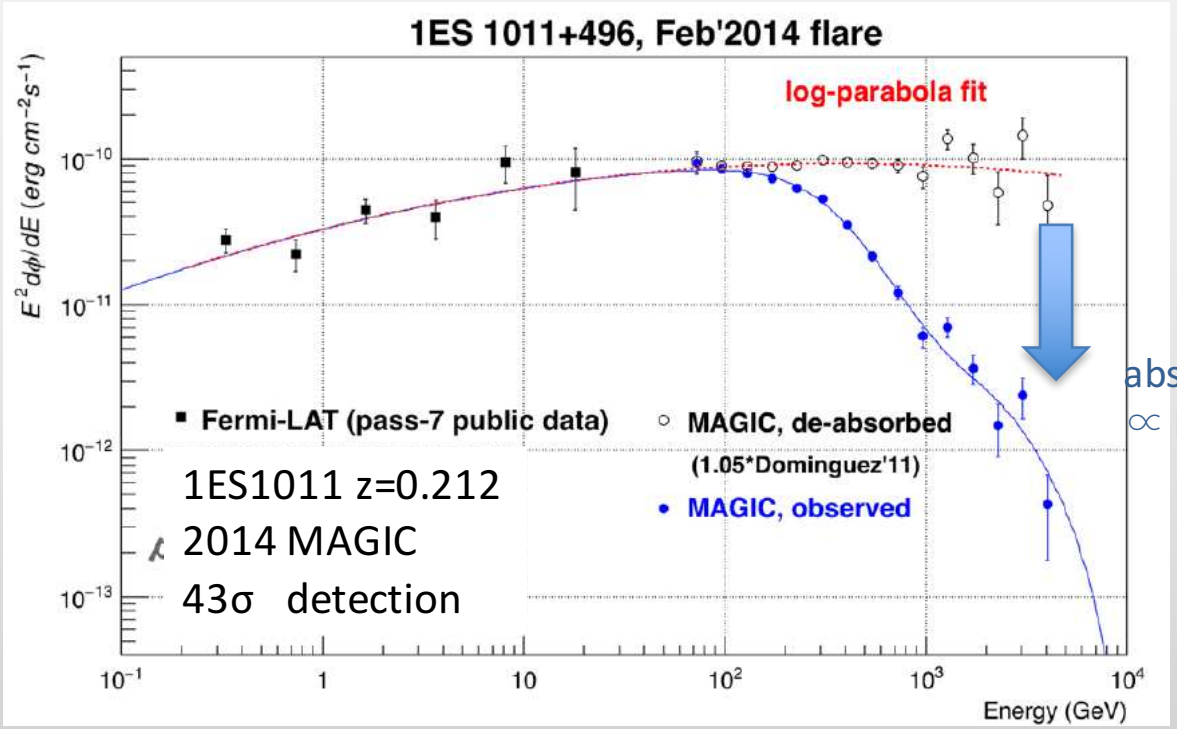
Spectrum:
Parent proton could be 1PeV ➔ PeVATRON?

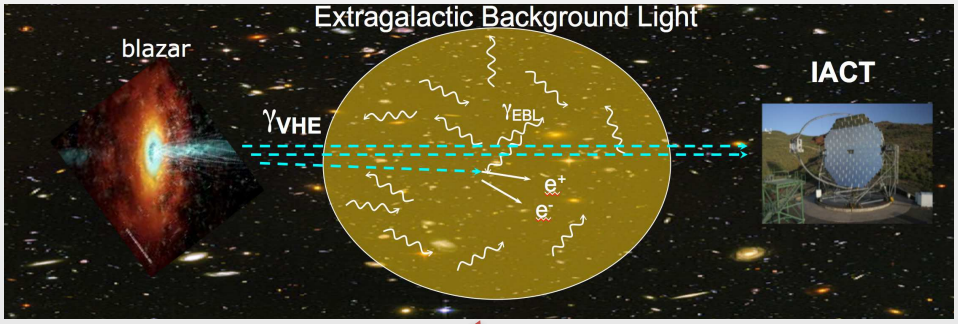
Radial distribution 1/r:
Consistent with the diffusion from the central BH



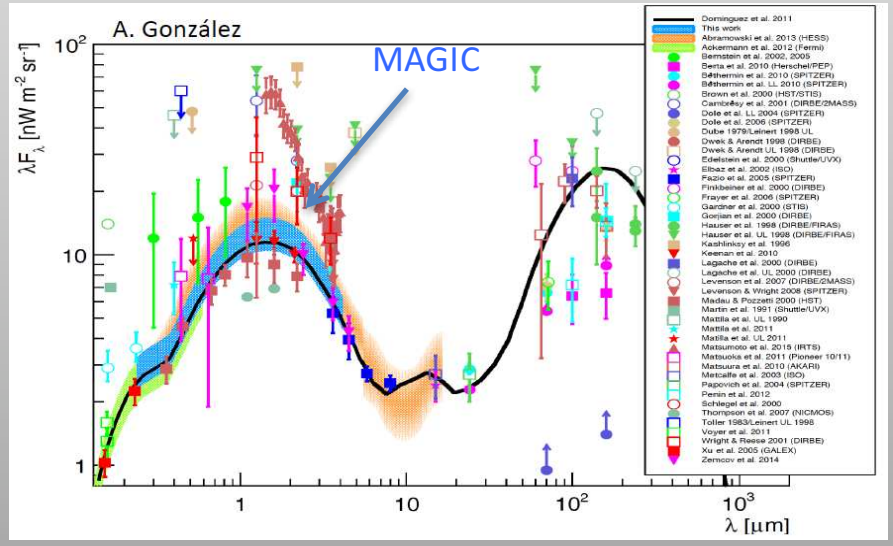


Study of Extragalactic Background Light 1ES1011+496 observed with MAGIC in 2014





absorption
$\propto$ EBL Density



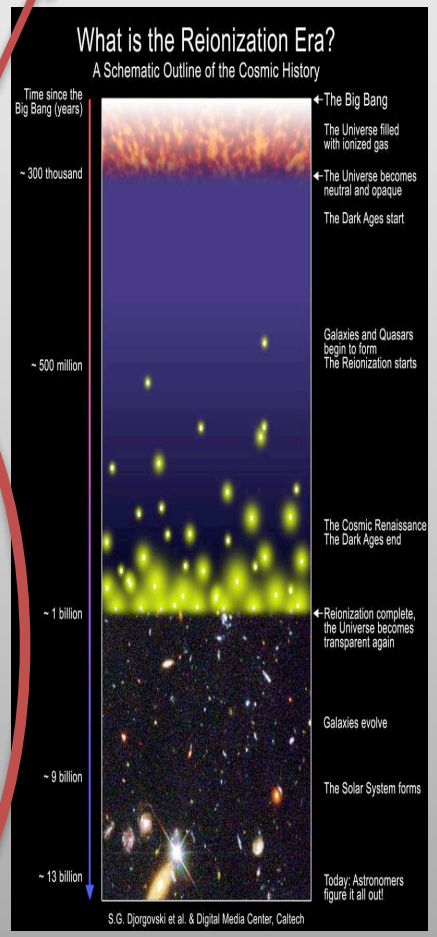
z ~ 1000, WMAP

z = 15~30 First star Pop-III

z = 6~15, Reionization

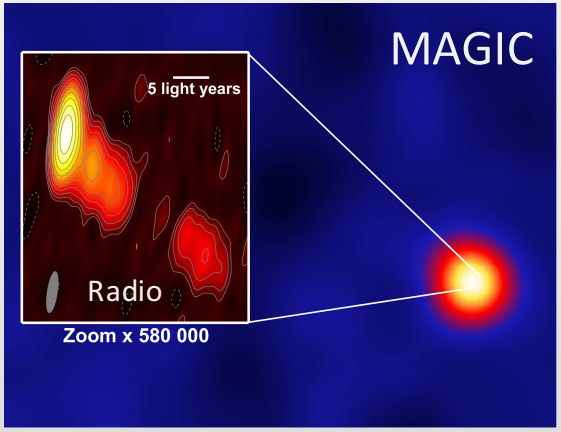
z = 3,Galaxies

z = 0, Present



IC310 Radio Galaxy / Blazar

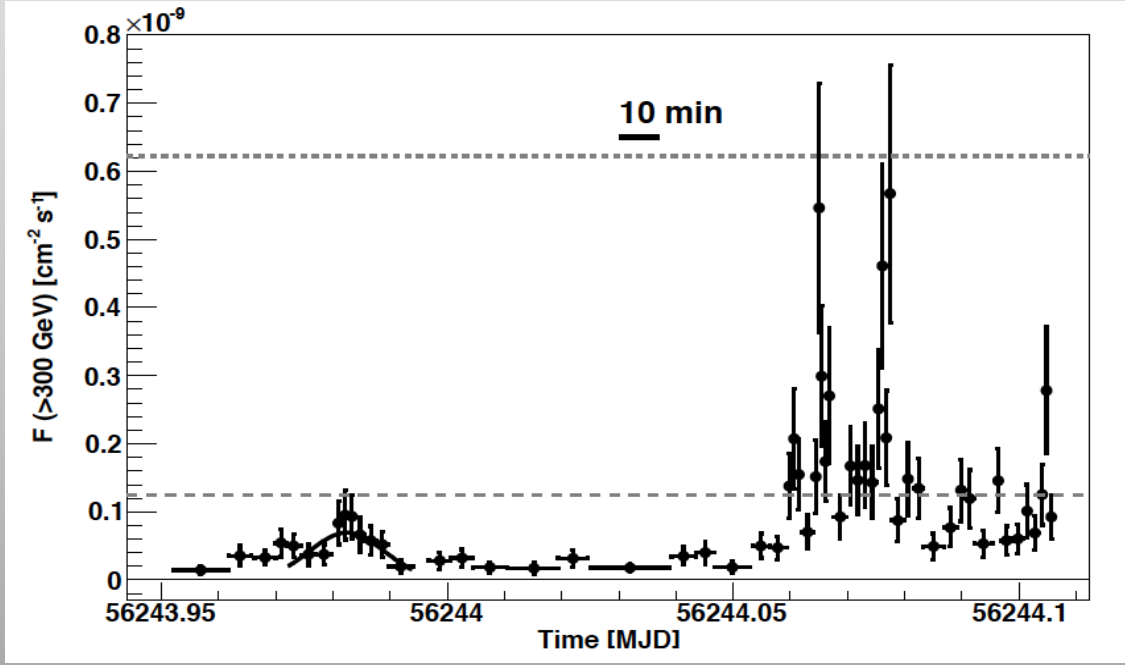
MAGIC Observation published in Science



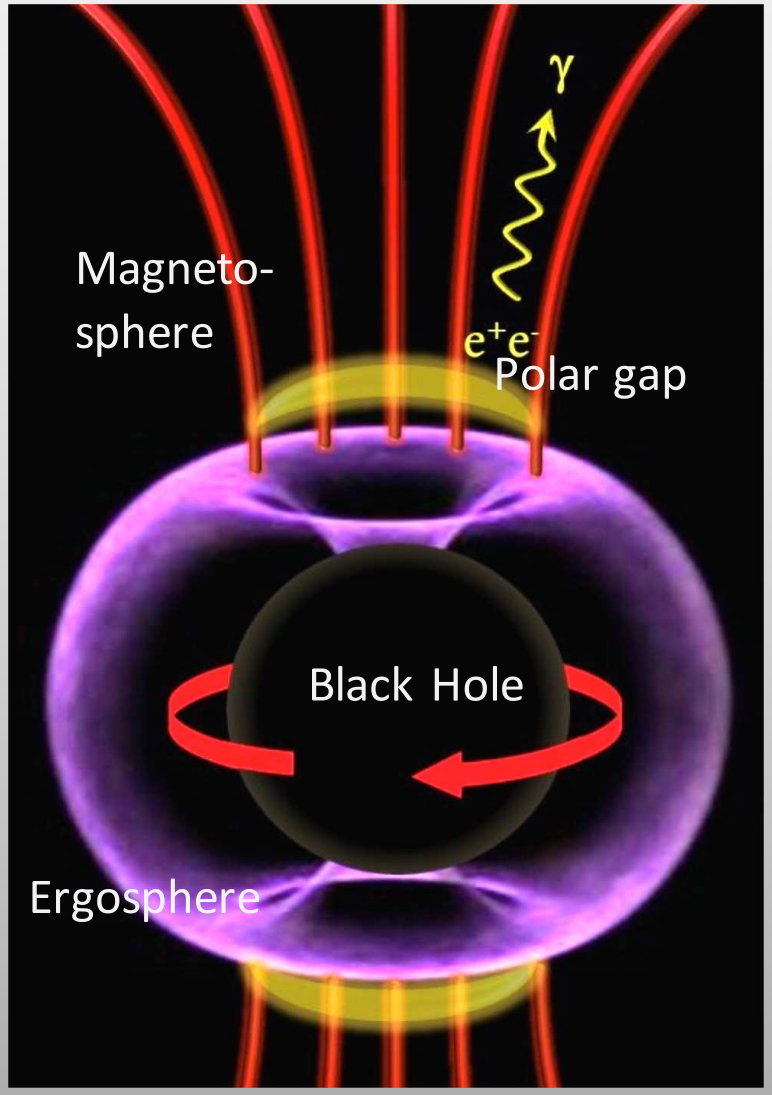
- Nov.12 2012 MAGIC obs.
- Flare ~ 100 x Low State
- Time variation ~ 1 min

- B.H. mass 3 x $10^8 M_\odot$
  - Crossing Time ~ 25mins
  - Γ-factor of jet ~ 5

IC310 Light curve

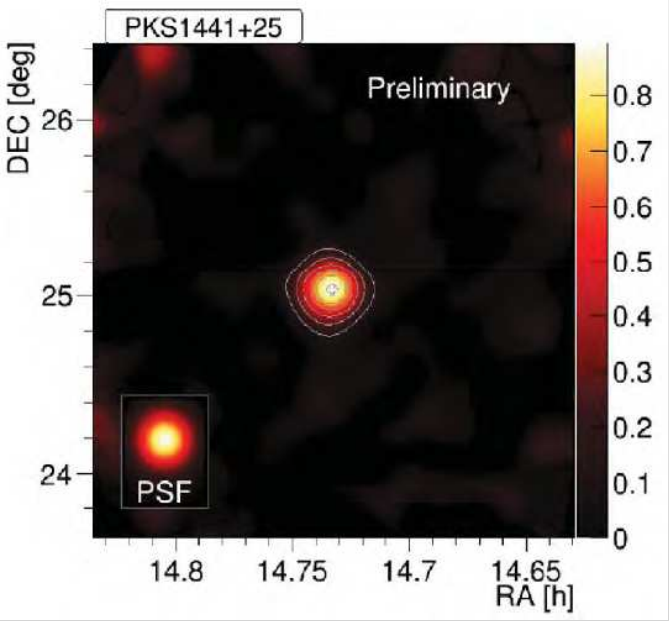


Possible Model



Discovery of Very High Energy Gamma-Ray Emission from the distant FSRQ PKS 1441+25 with the MAGIC telescopes

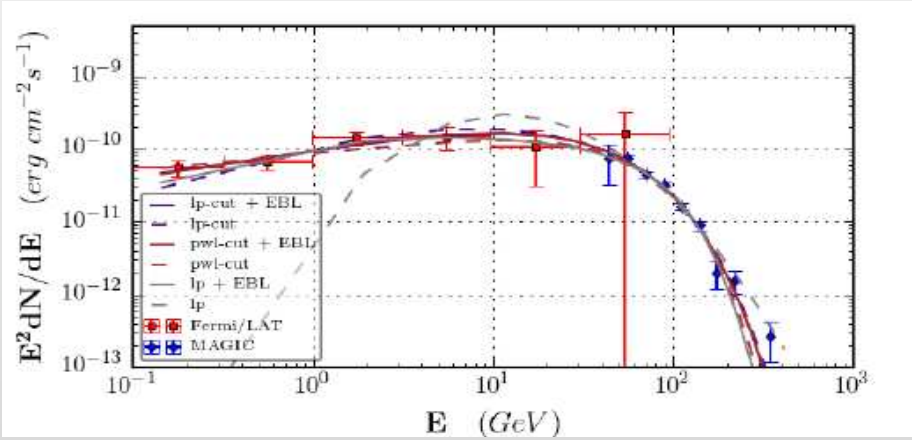
ATel #7416; ***R. Mirzoyan (Max-Planck-Institute for Physics)***
on 20 Apr 2015; 02:09 UT
Credential Certification: Masahiro Teshima (mteshima@mppmu.mpg.de)

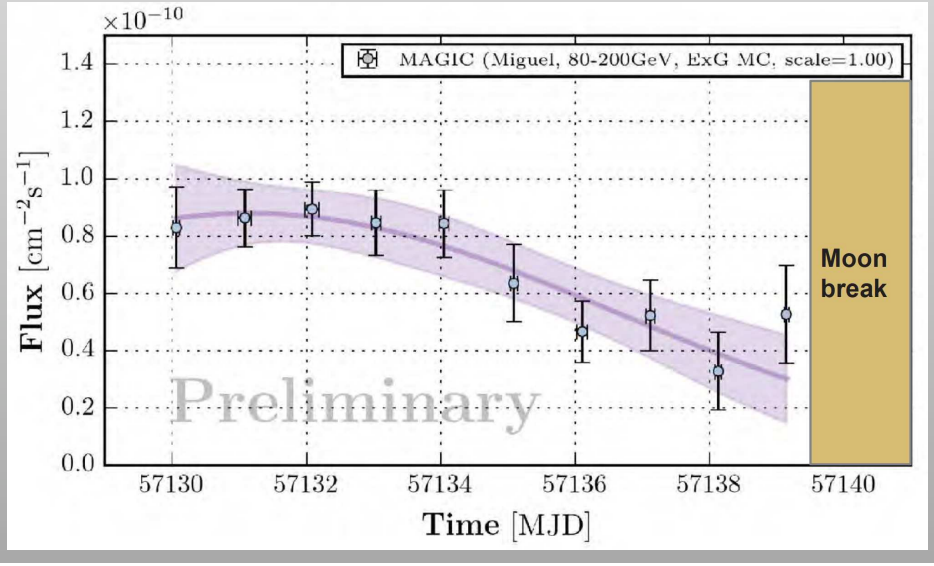


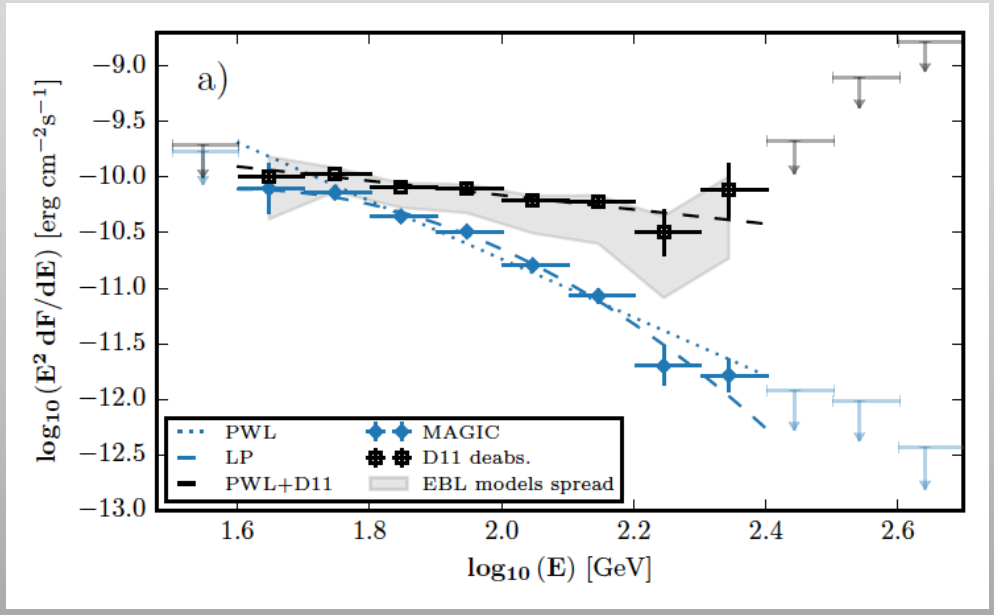
PKS1441+25
Flat Spectrum
Radio Quasar

z = 0.940

MAGIC detection
Significance～25 σ







Dark Matter Global Limits with Fermi and MAGIC

Left

Fermi-LAT: 15 dwarfs

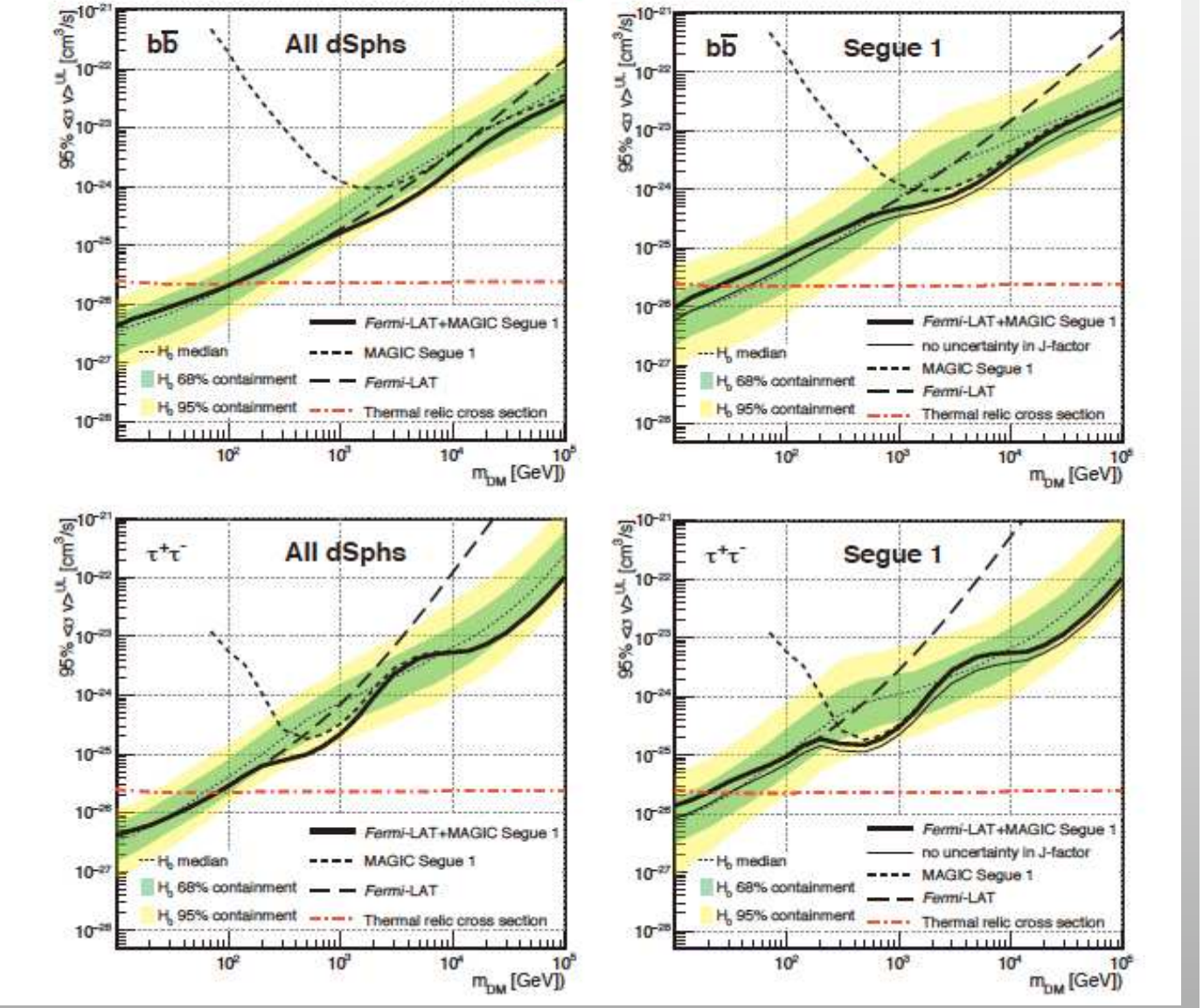
MAGIC: Segue 1

Right

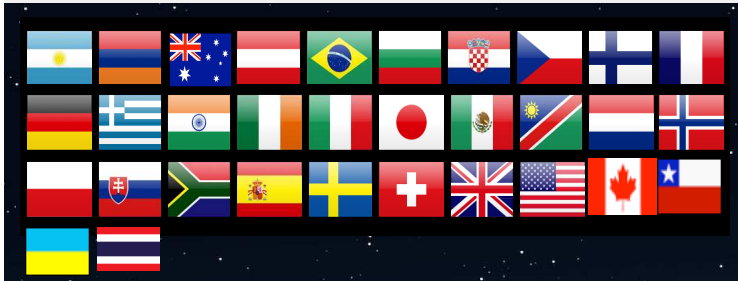
Fermi-LAT: Segue1

MAGIC: Segue1

- Fermi-LAT+MAGIC Segue 1
- no J uncertainty
- MAGIC Segue 1
- Fermi-LAT
- Thermal relic cross section
- H_0 median
- H_0 68% containment
- H_0 95% containment



CTA: Big International Project



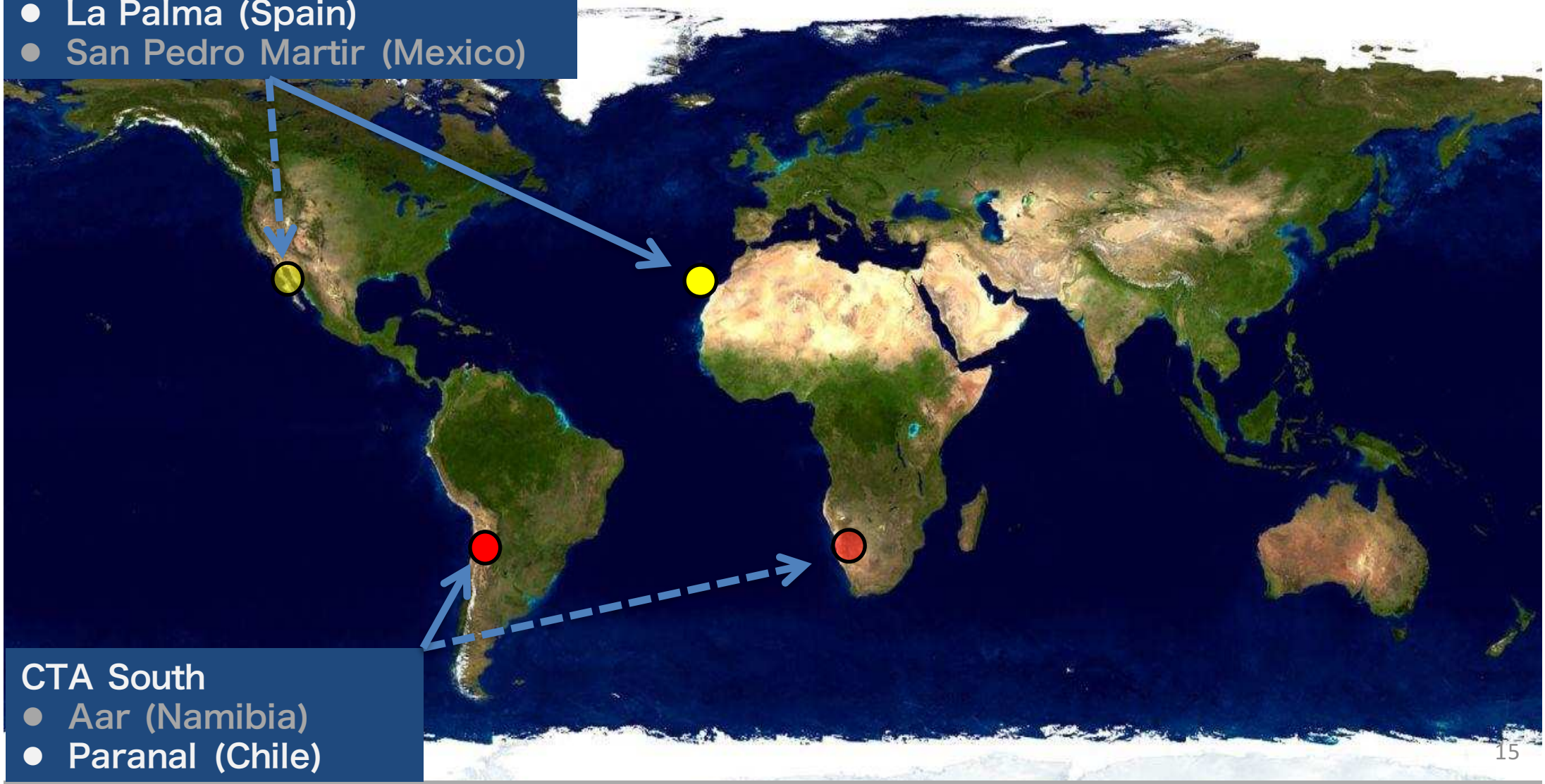
- 1200 scientists from 32 countries

In comparison with current instruments, HESS, MAGIC and VERITAS

- Sensitivity x 10
- Angular resolutions x 3
- Energy band x 10
- Gamma ray horizon (z<4)
- Objects x 10

Two CTA primary Sites in South and North decided in July 2015

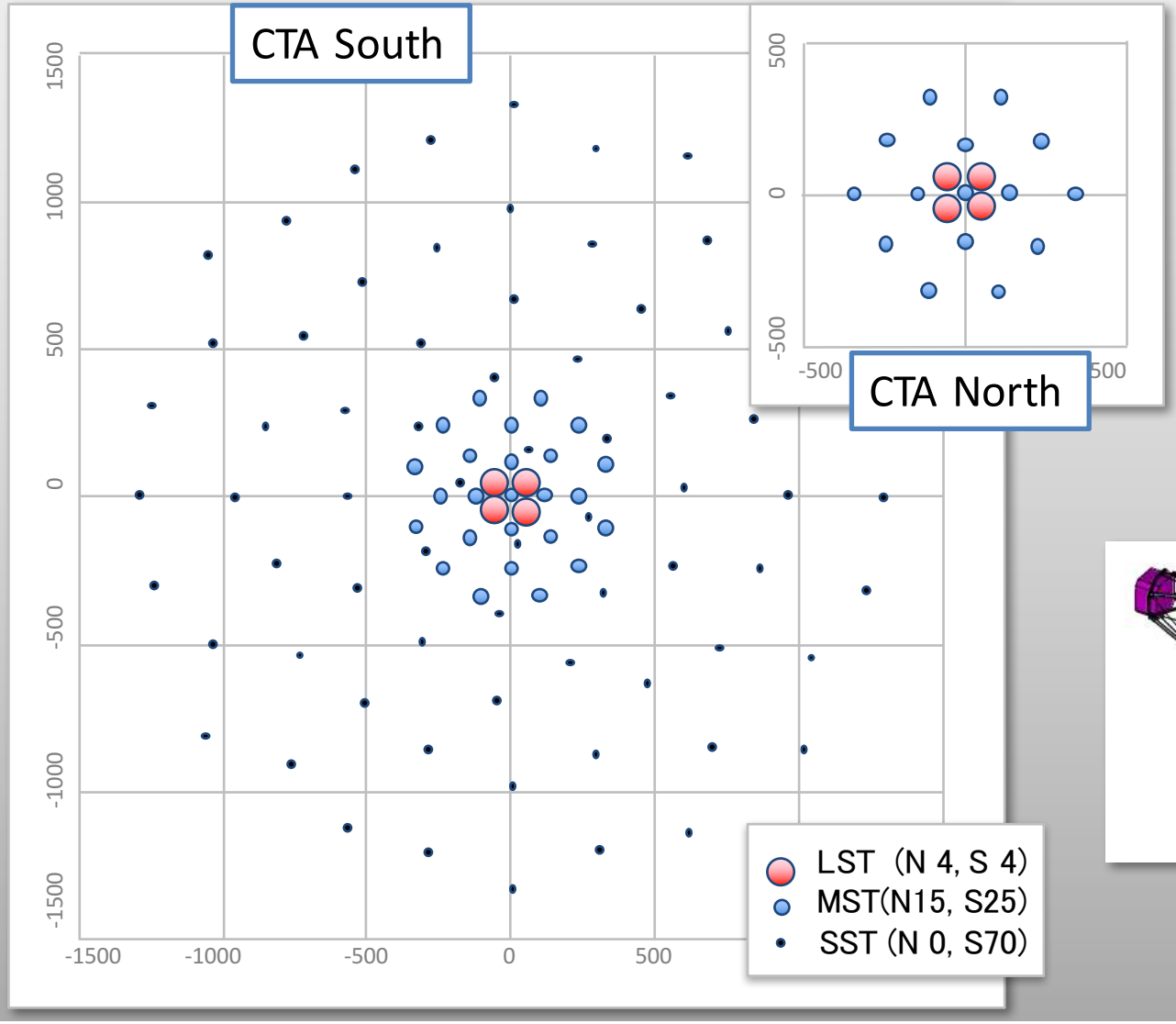
CTA North
- La Palma (Spain)
- San Pedro Martir (Mexico)



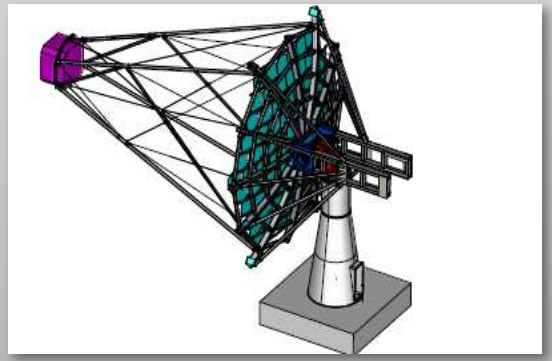
CTA South
- Aar (Namibia)
- Paranal (Chile)

CTA Array Configuration
(Cherenkov Telescope Array)

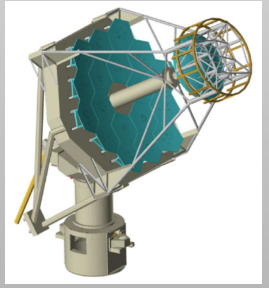
CTA is all sky observatory consisting of two stations in South and North



LST 23m



MST 12m

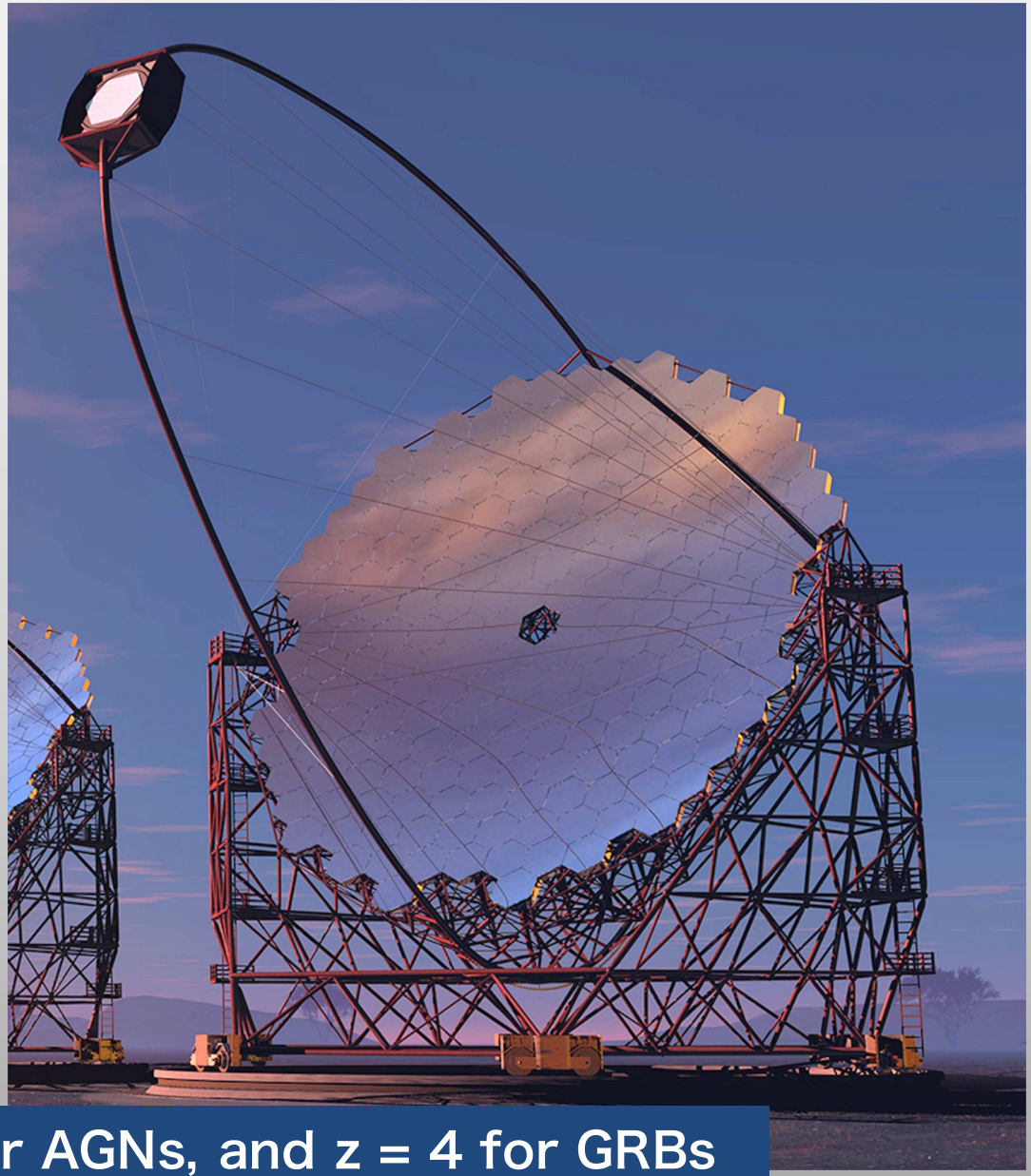


SST 4.3m

CTA Large Size Telescope

Major specifications

- Threshold energy **>20GeV**
- Telescope Structure
  - Diameter of dish 23 m
  - Parabolic optics 389 m^2
  - focal length 28 m
  - Weight 100 tons
  - CFRP mirror supp. structure
  - Fast rotation 180°/20sec
  - Tracking accuracy 14arcsec



Expands visible Universe to z = 2 for AGNs, and z = 4 for GRBs

MEDIUM-SIZED 12 M TELESCOPE

OPTIMIZED FOR THE 100 GEV TO ~10 TEV RANGE

cta
cherenkov telescope array

100 m^2 dish area
16 m focal length
1.2 m mirror facets

7-8° field of view
~2000 x 0.18° pixels

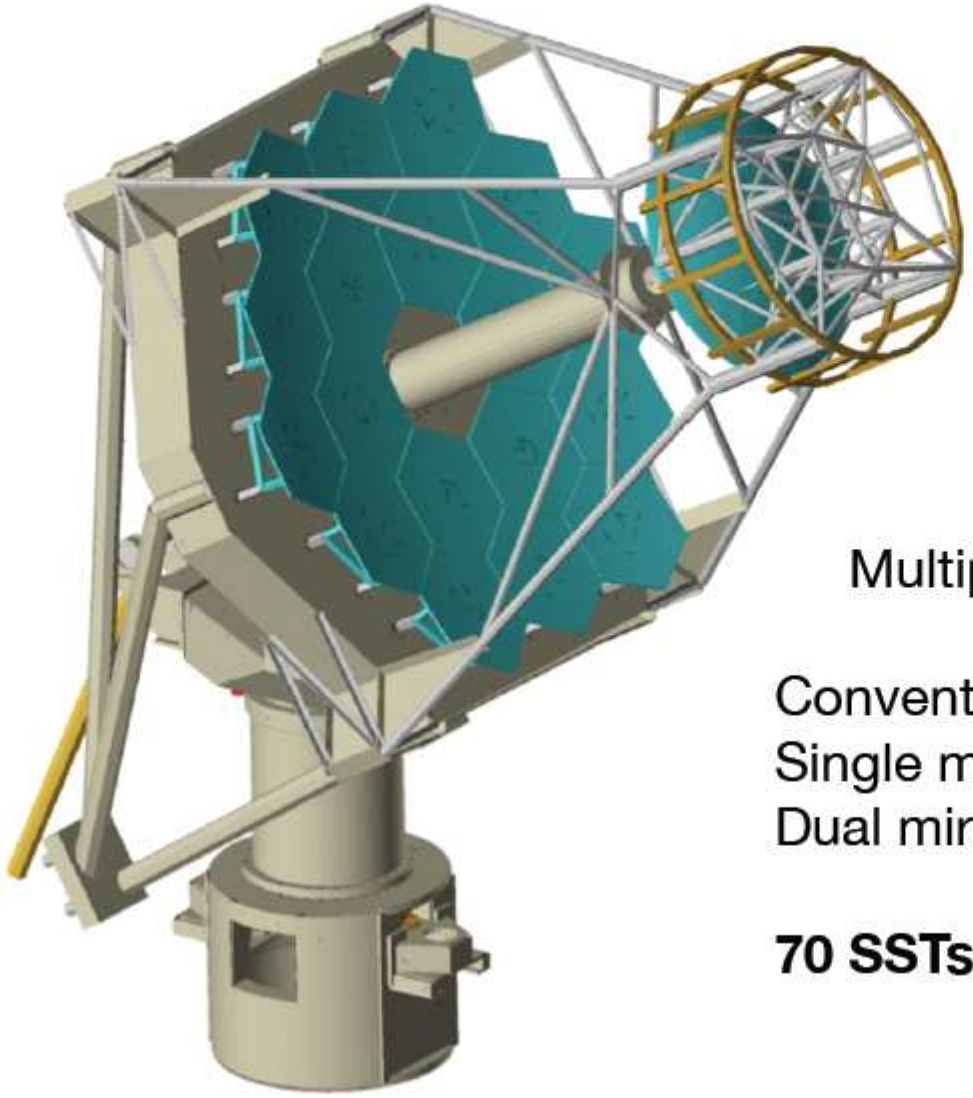
25 MSTs on South site
15 MSTs on North site

Achieve the best sensitivity of 1mCrab at 1TeV and survey our galaxy

SMALL TELESCOPE

OPTIMIZED FOR THE RANGE ABOVE 10 TEV

cta
cherenkov telescope array



ASTRI Design
4.3 m mirror
9.6° foV
0.25° pixels

Multiple options under study:

Conventional single mirror, PMT camera
Single mirror, silicon sensor camera
Dual mirror optics, silicon & MAPMT camera

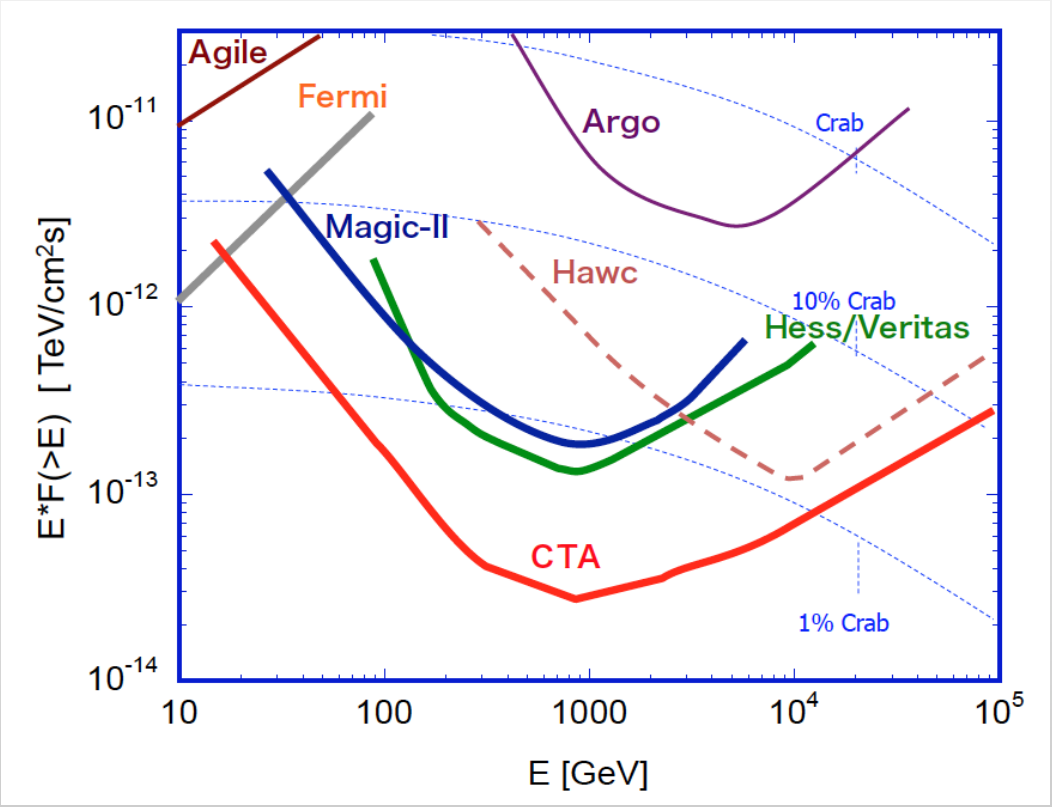
70 SSTs on Southern site

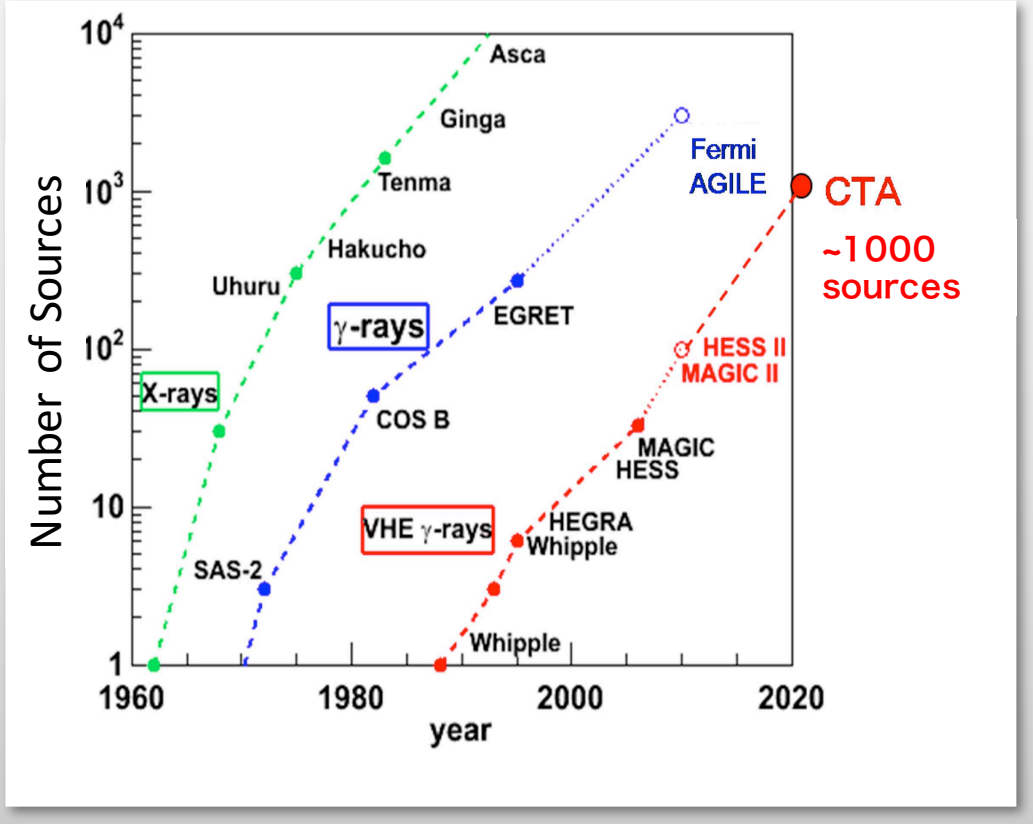
Look for PeVatron in our galaxy

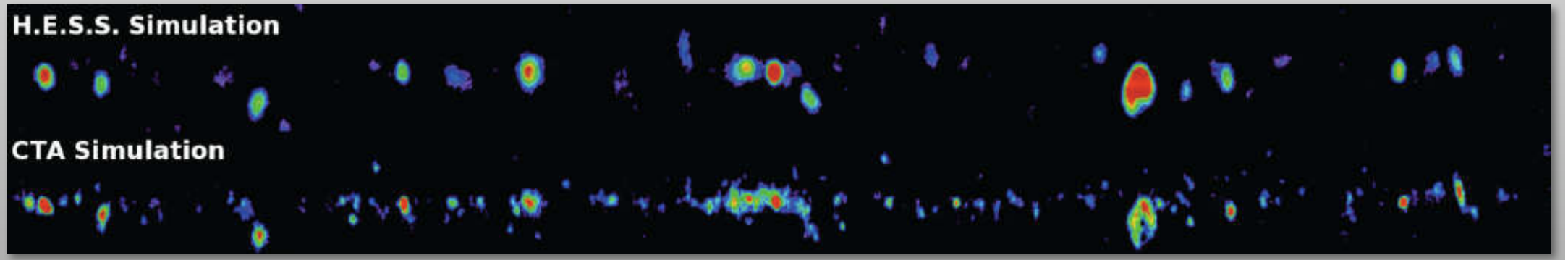
CTA（Cherenkov Telescope Array）covering 20GeV-100TeV

An order of magnitude better sensitivity
Wide energy coverage

More than 1000 sources will be discovered







Simulation Galactic Plane scan（HESS and CTA）

CTA : Ultimate Survey instrument

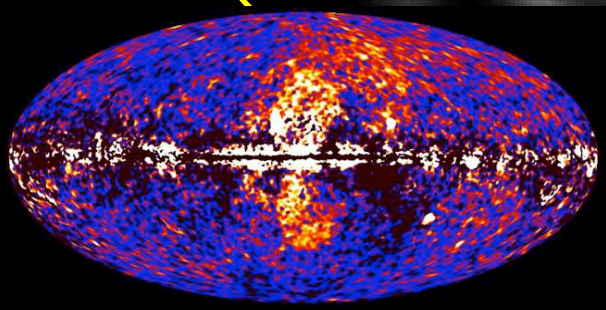
- All sky survey with two stations in south and north

Red dots: Galactic sources observed by HESS

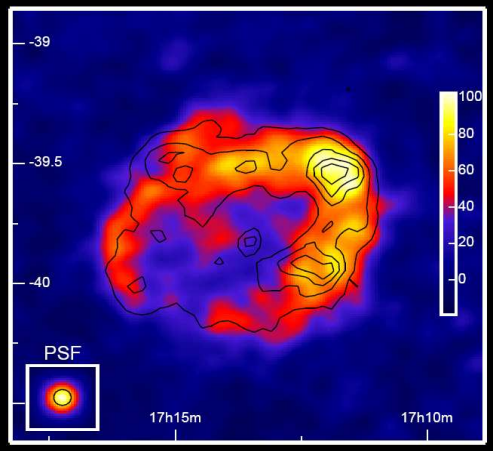
HESS

CTA

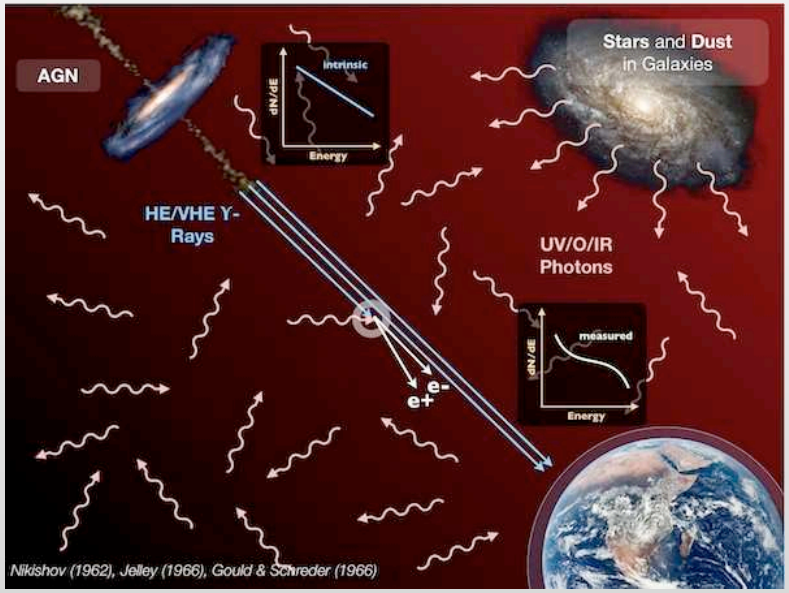
Fermi Bubble

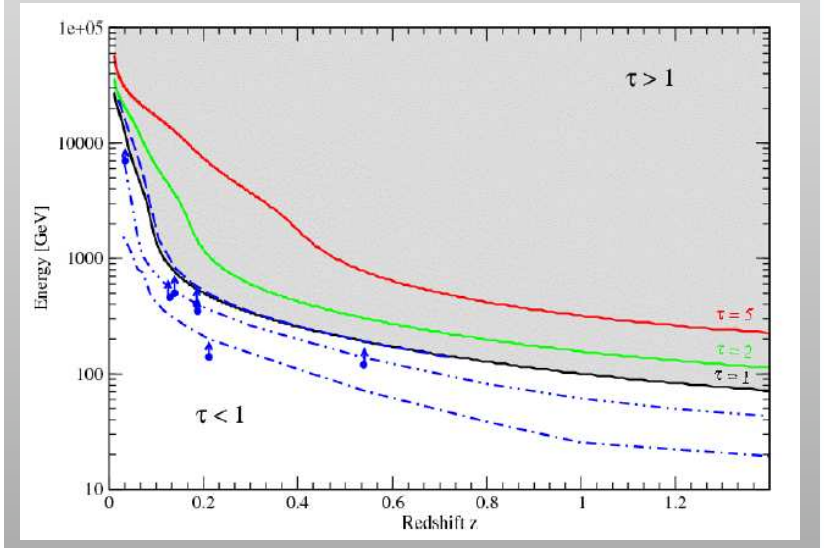


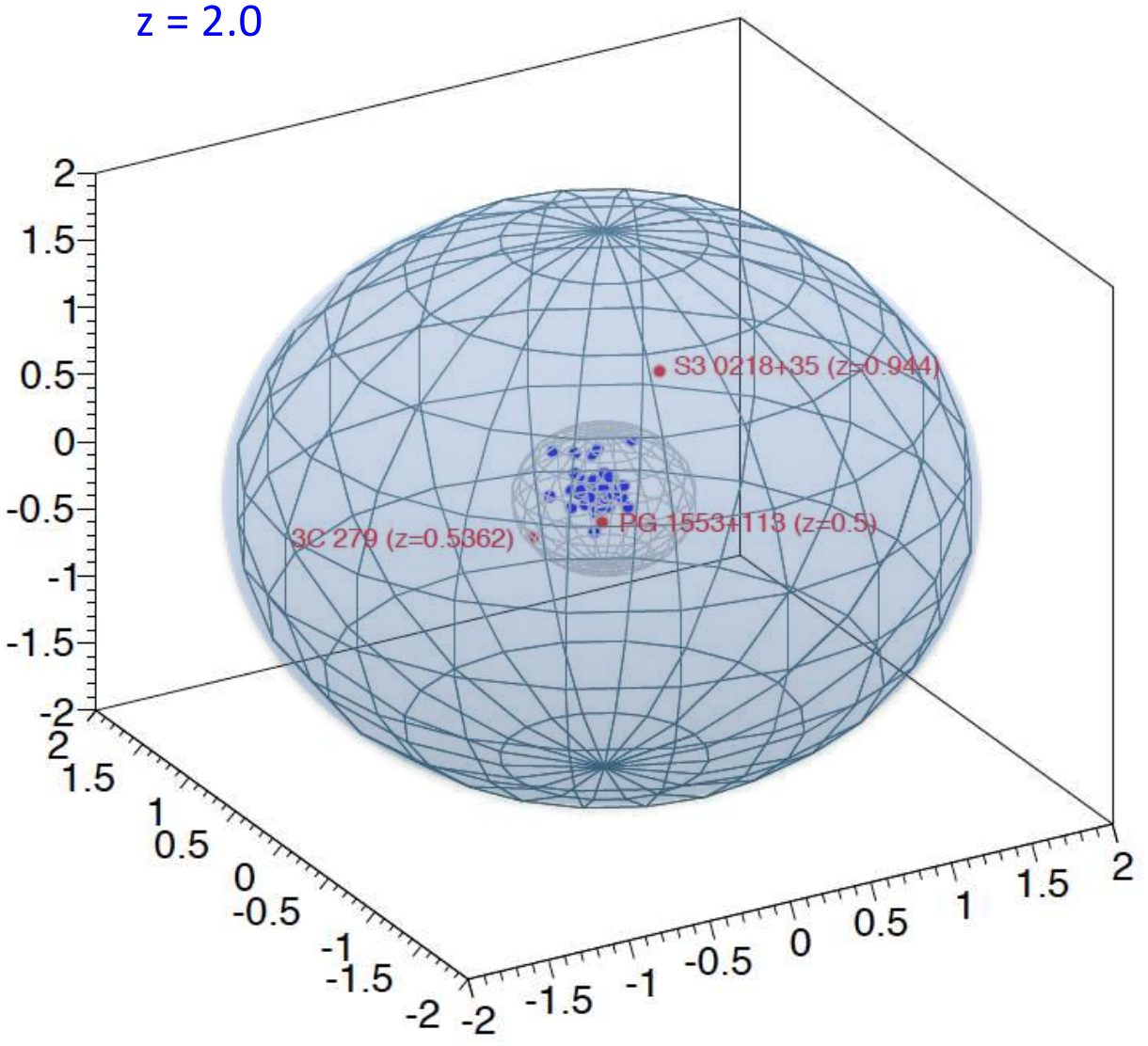
Supernova remnants



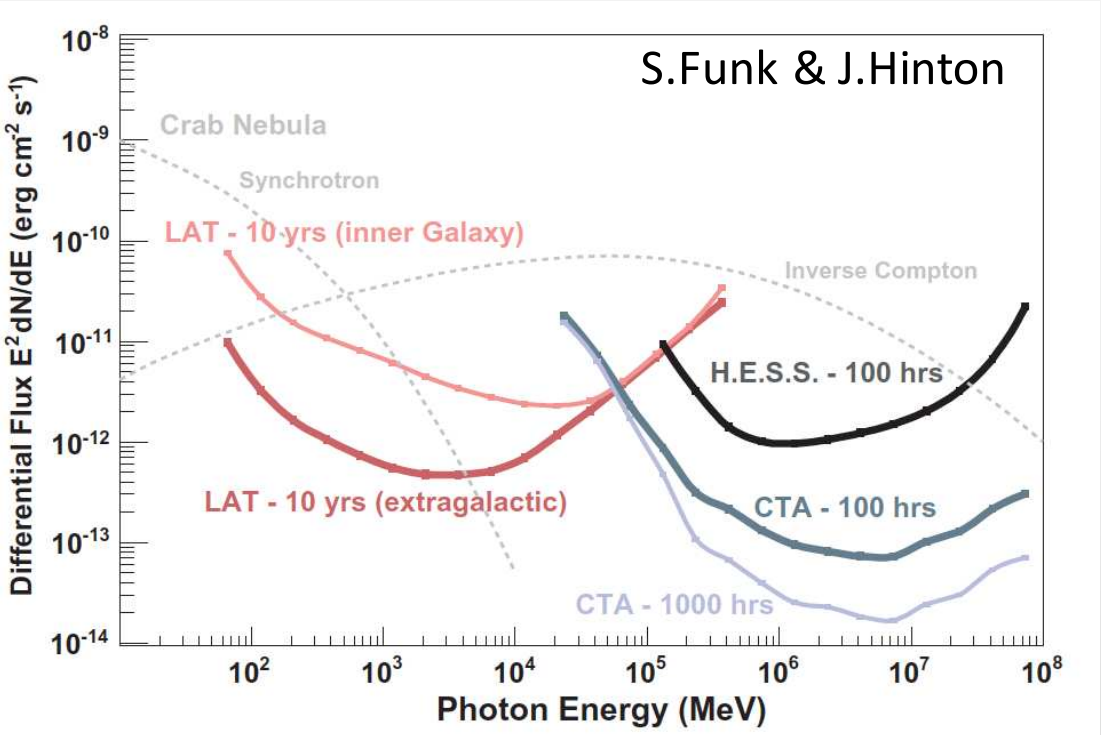
Ultimate Survey Instrument for the extragalactic sources, AGN Survey (z < 2.0)





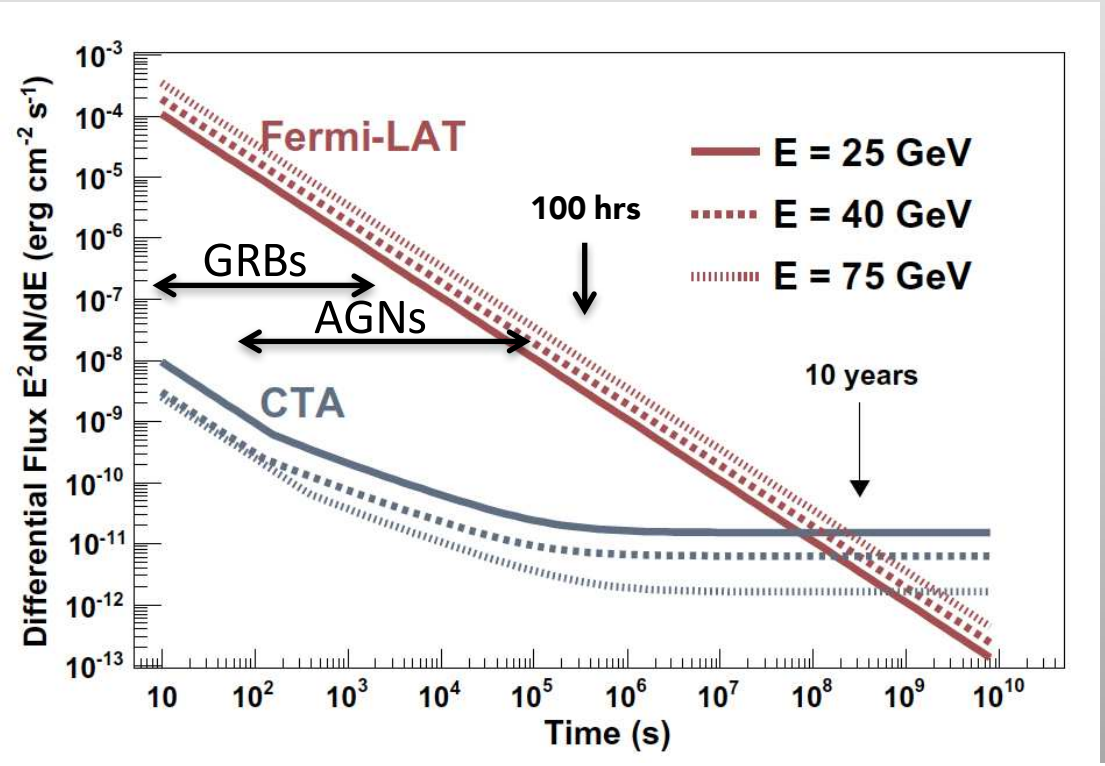


Comparison and Complementarity with Fermi



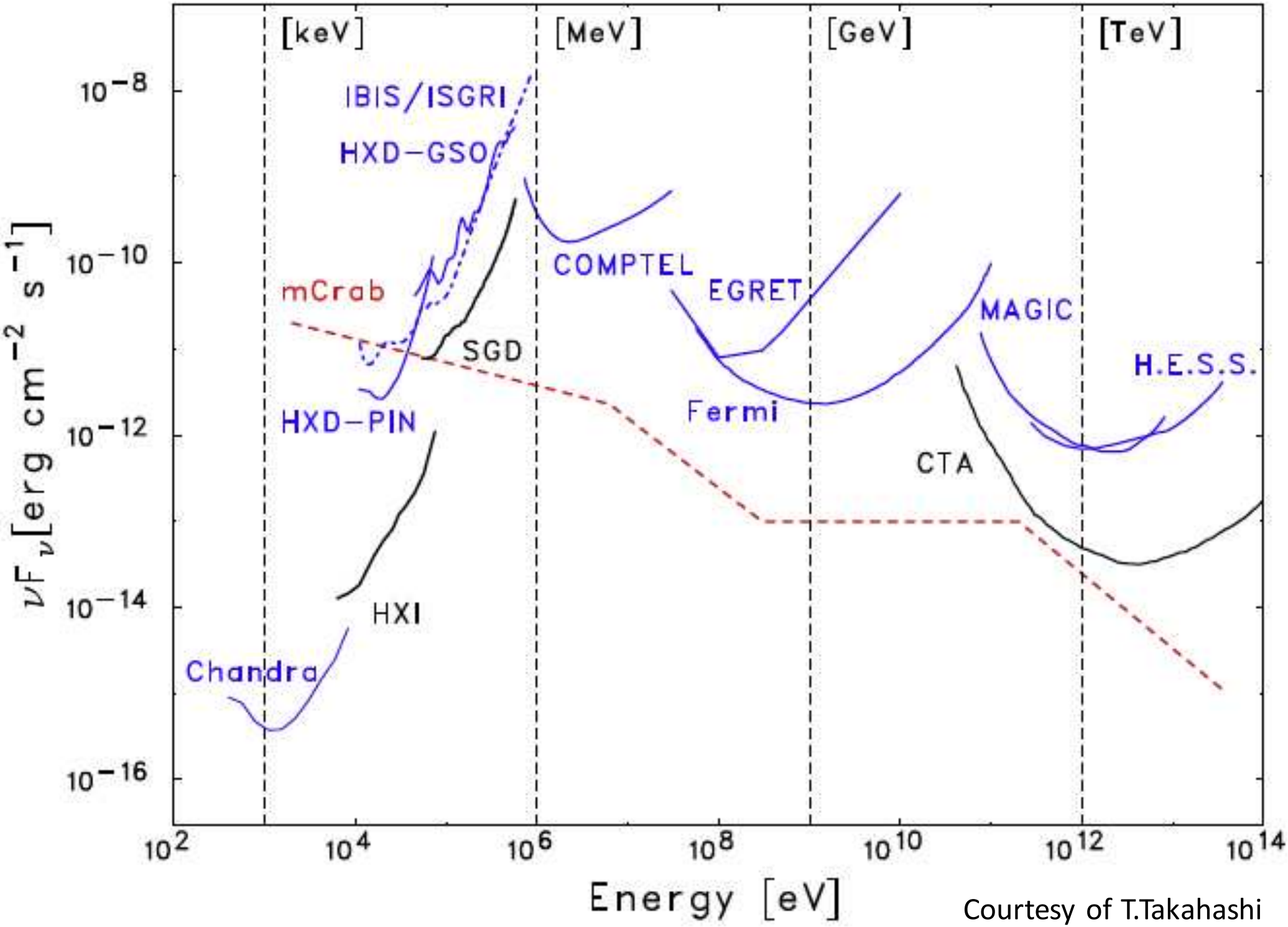
Cover 6 decades of Energy!!

After long observation, Crossing Energy is ~40GeV



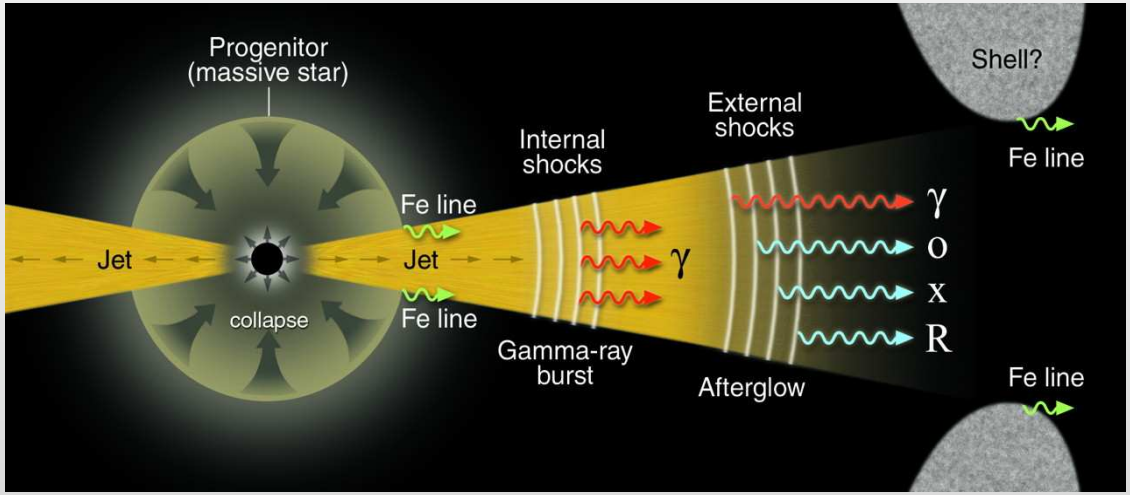
CTA-LSTs give a significant sensitivity for transient sources,

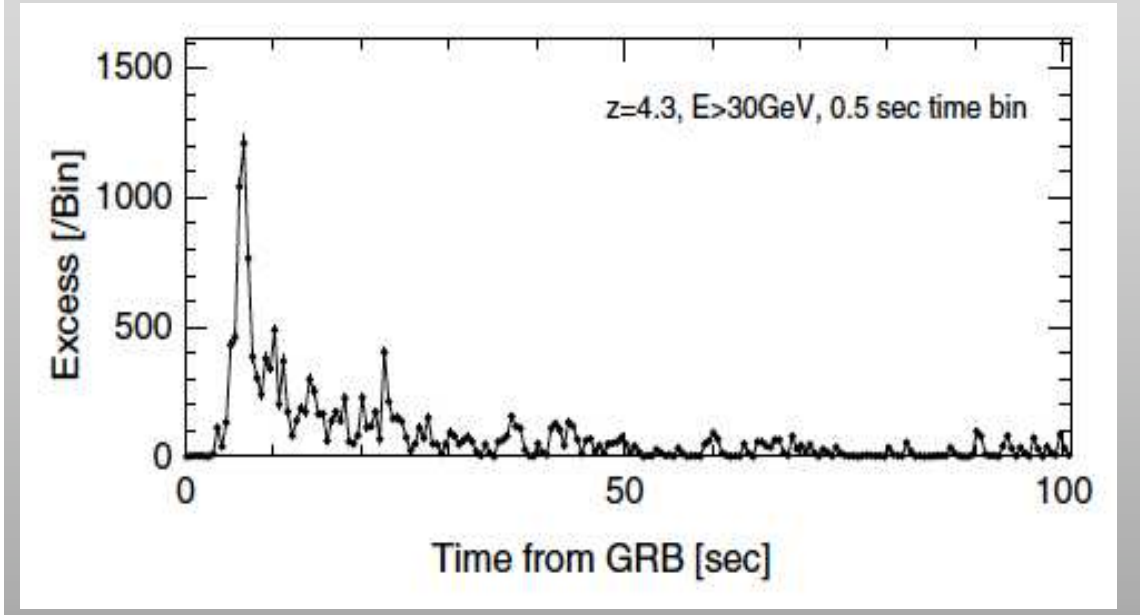
GRBs, AGNs, and Galactic Transients

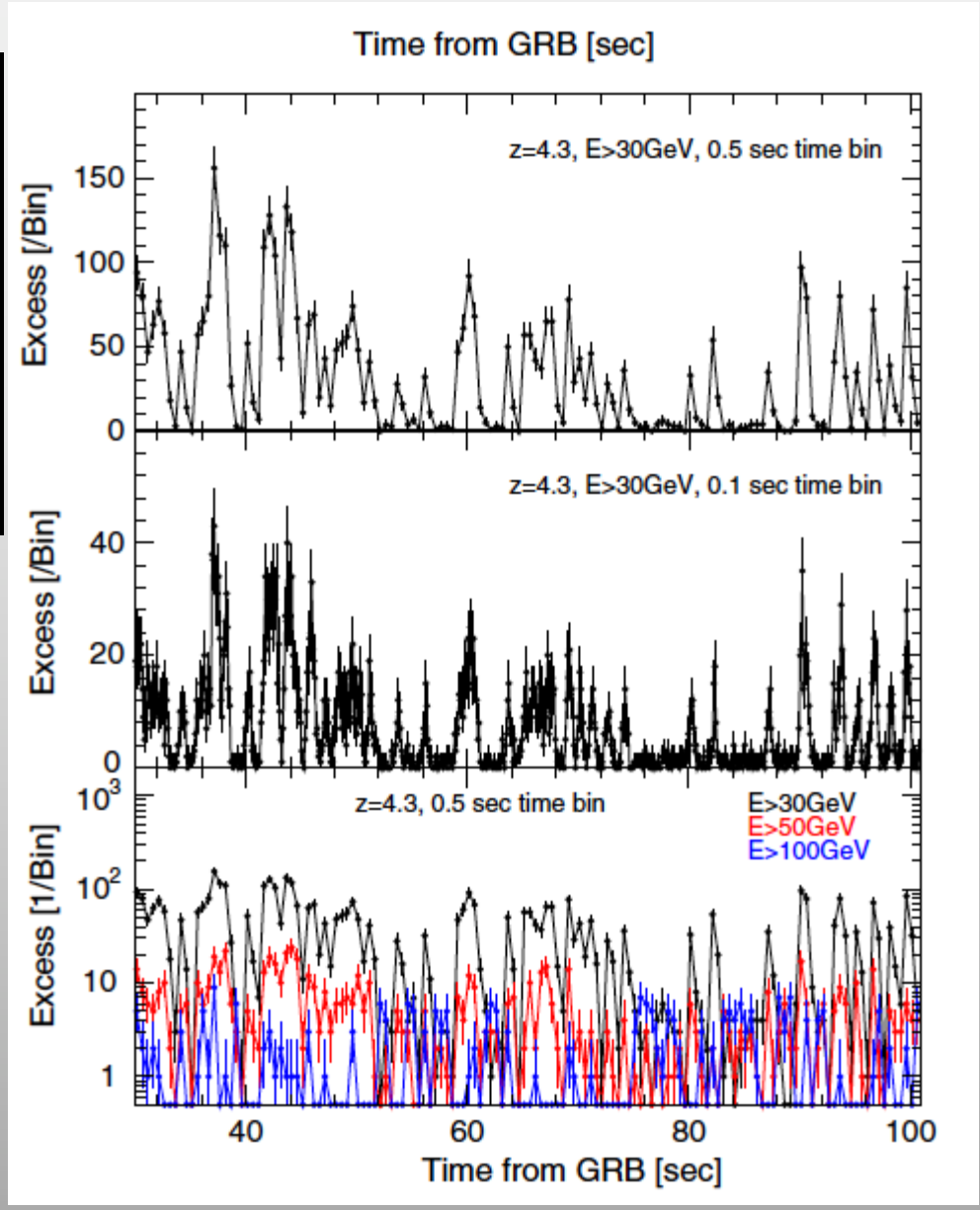


Courtesy of T.Takahashi

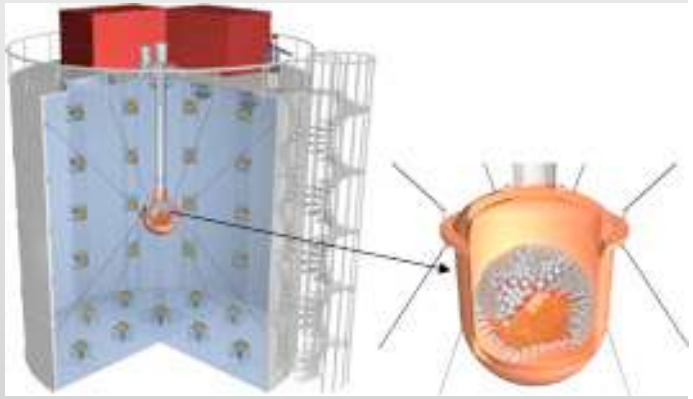
GRB: Simulated light curve
(template: GRB080916C)

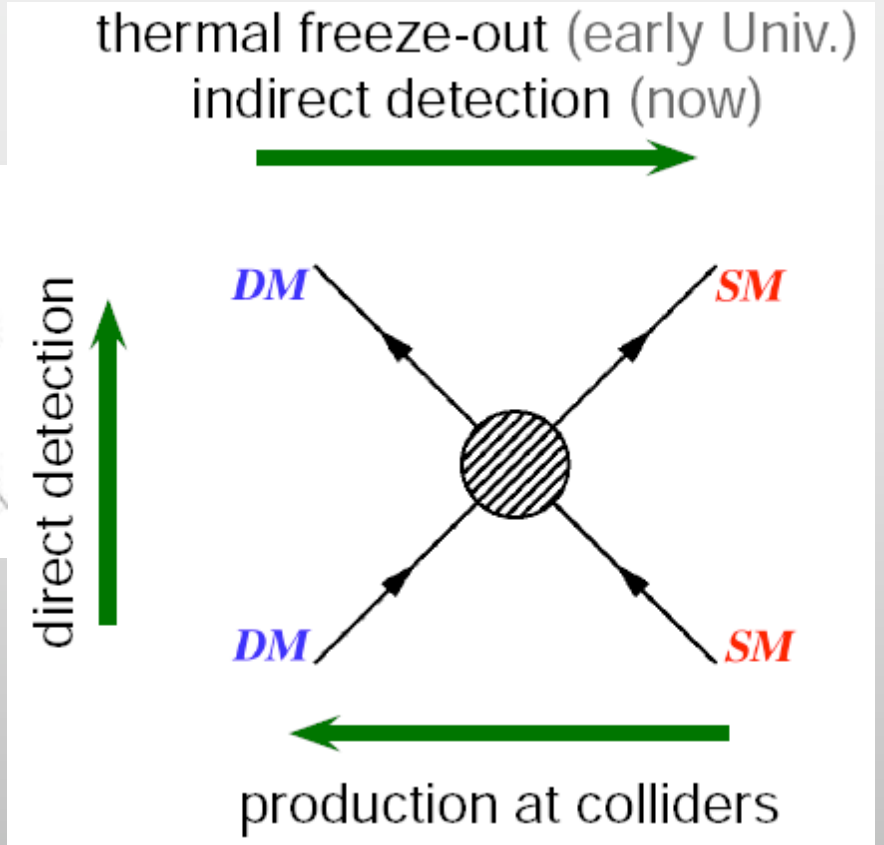


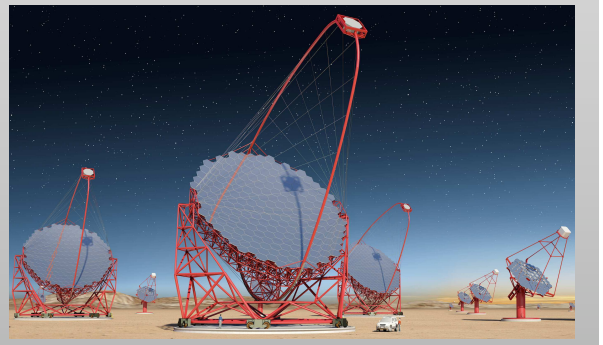


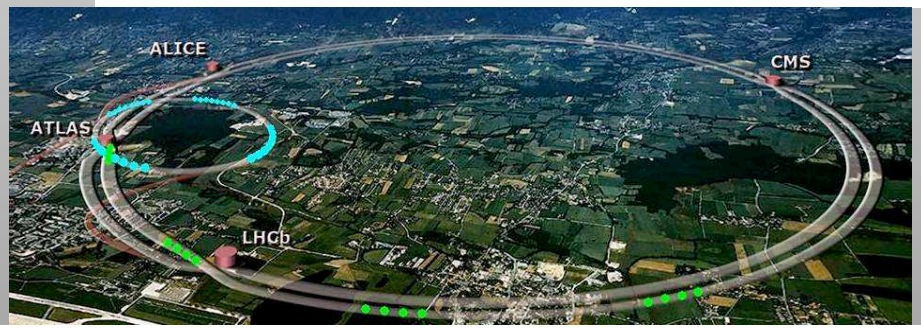


Search for DM
m_x~ 50-2000GeV

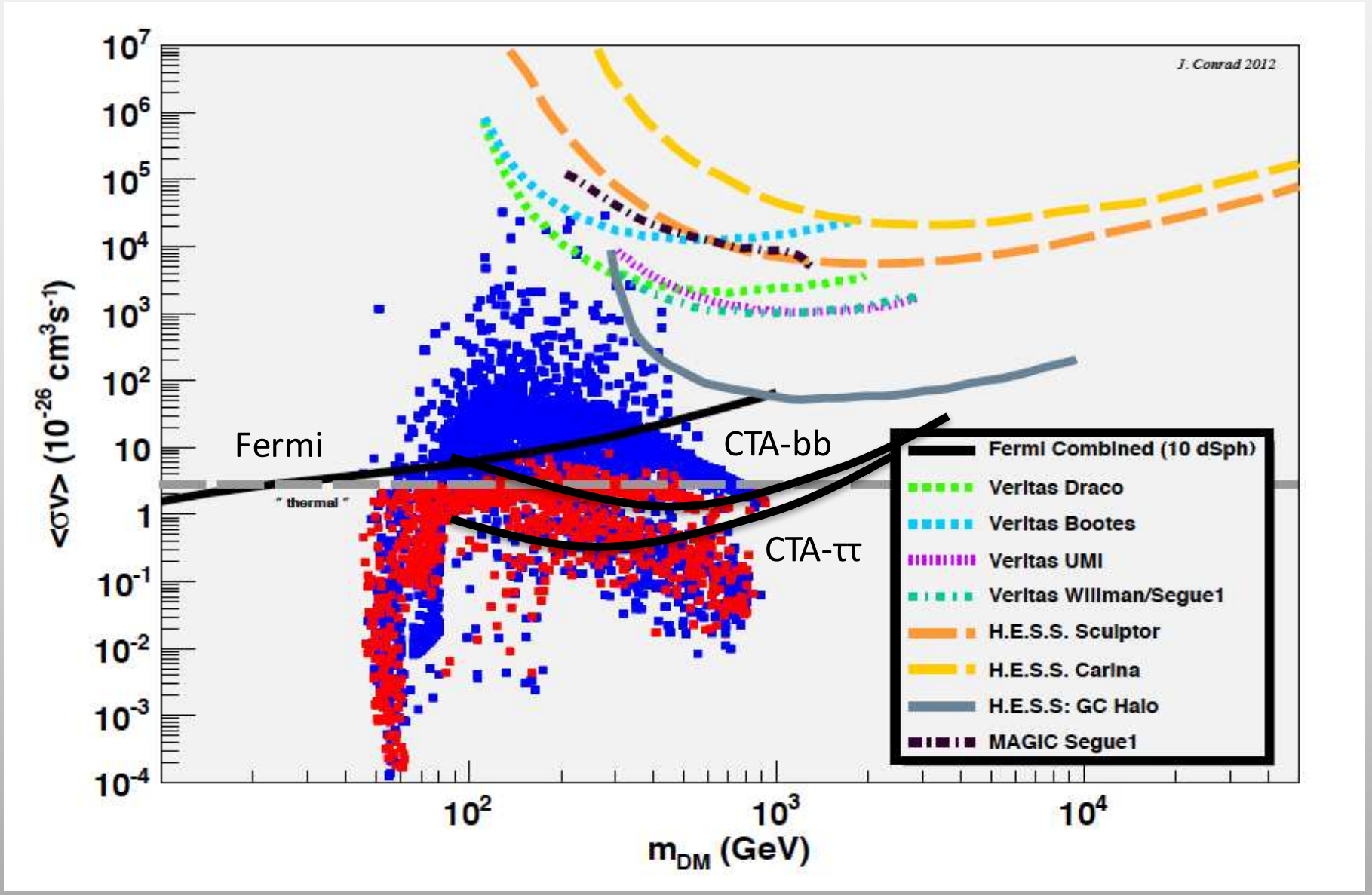








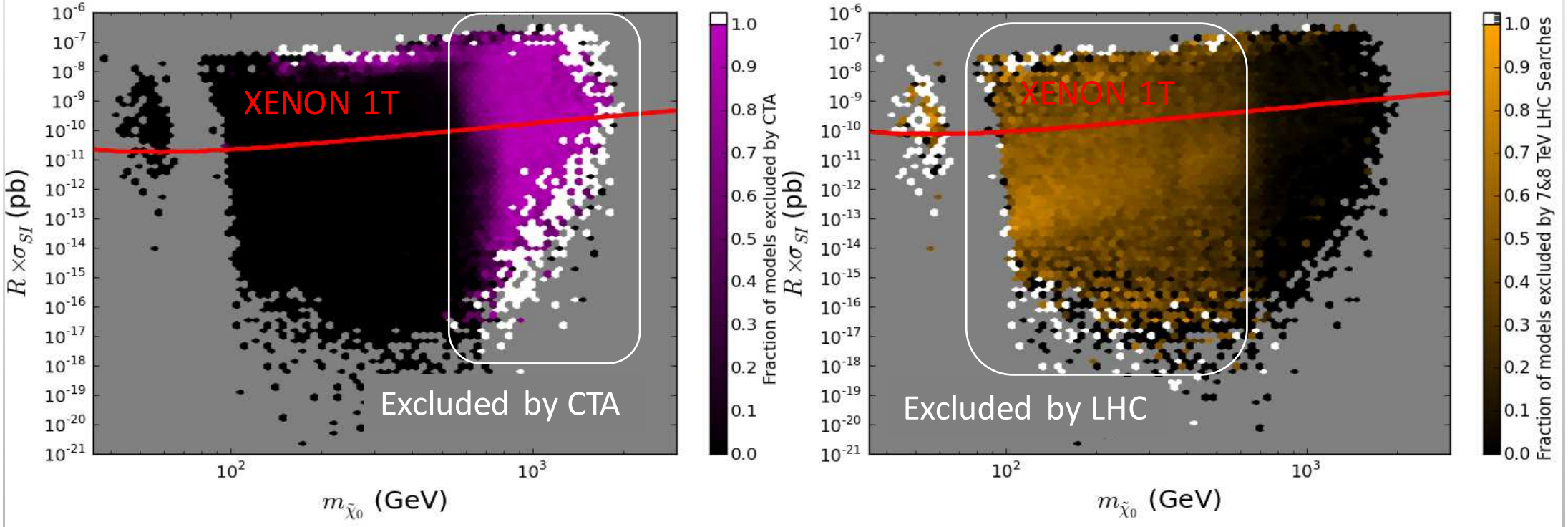
CTA Sensitivities for G.C. Halo in 100 h (J. Conrad)



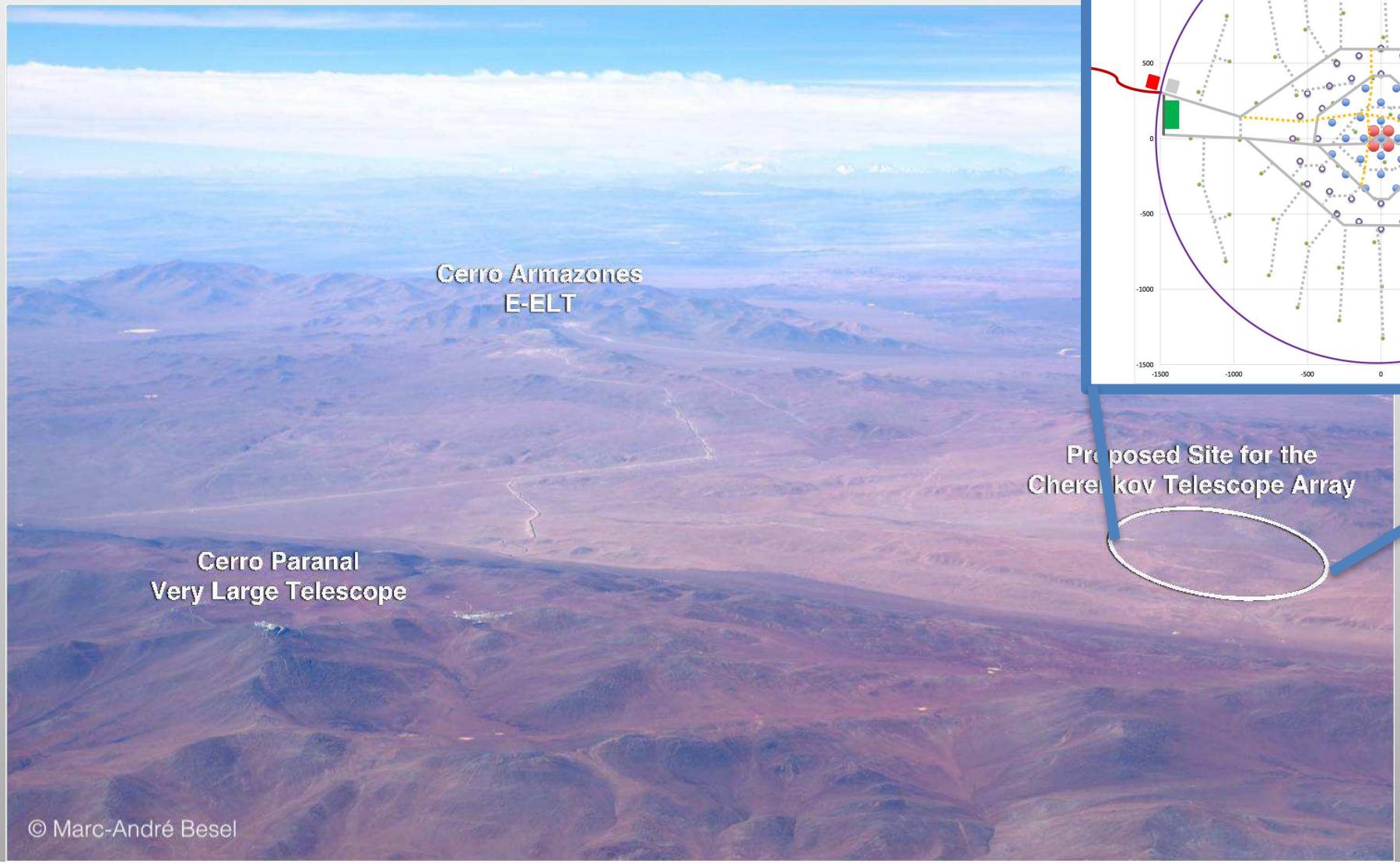
Complementarity with Direct Search, Indirect Search, and accelerators

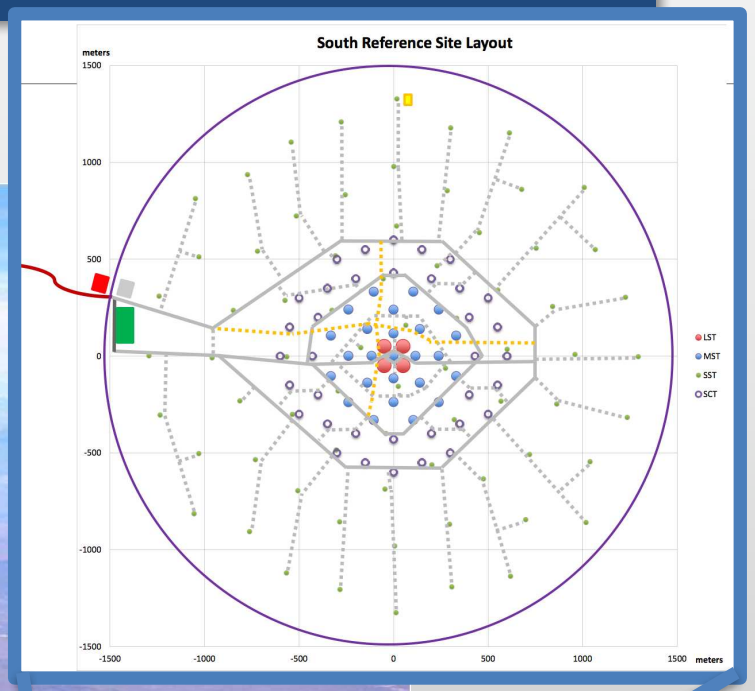
Red : XENON 1T Sensitivity
Purple : CTA Sensitivity
Brown : LHC Sensitivity

Cahill-Rowley+ hep-ph/1305.6921

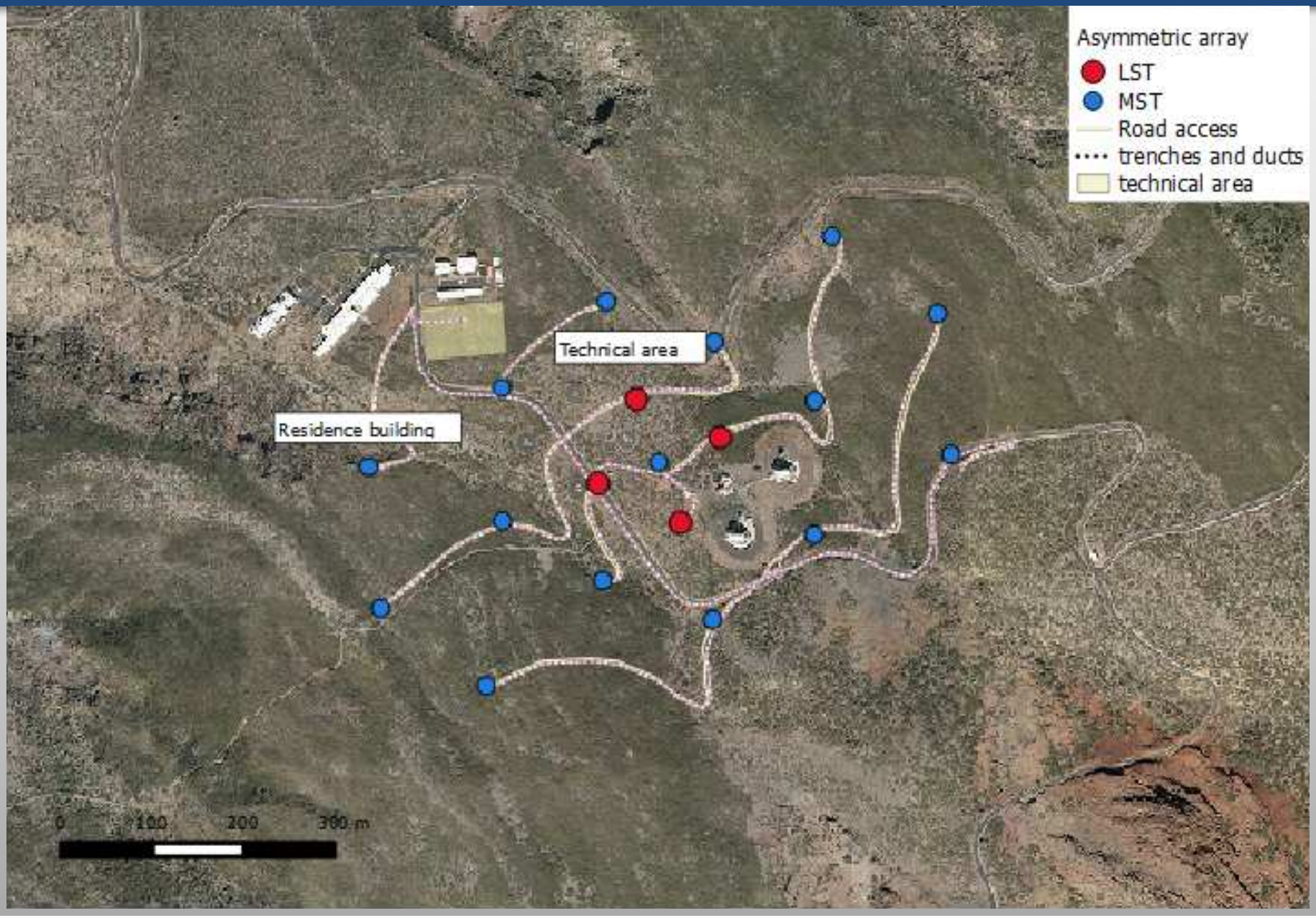


Chile Paranal Site

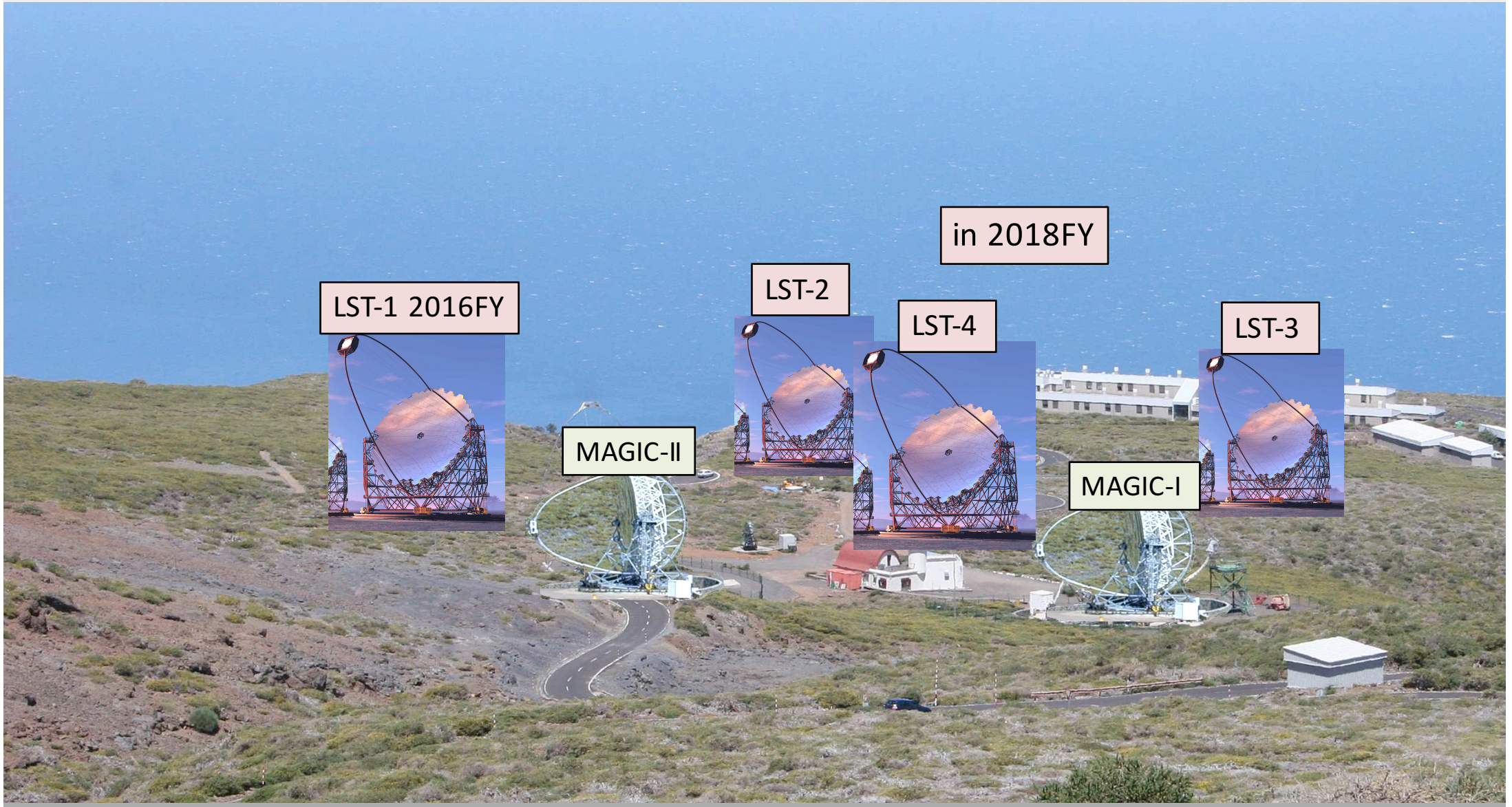




Spain La Palma Site

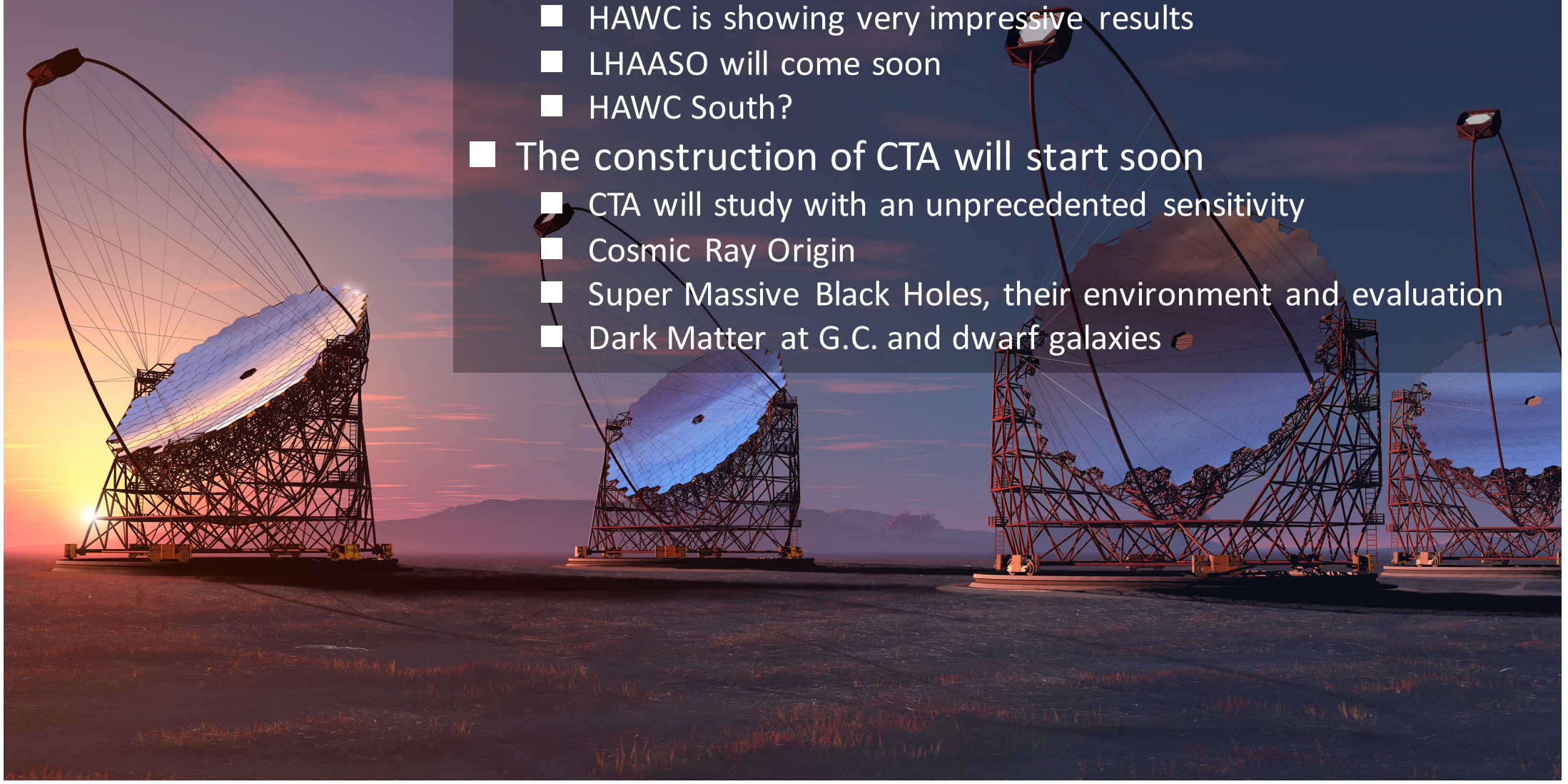


Spain La Palma site in 2018FY

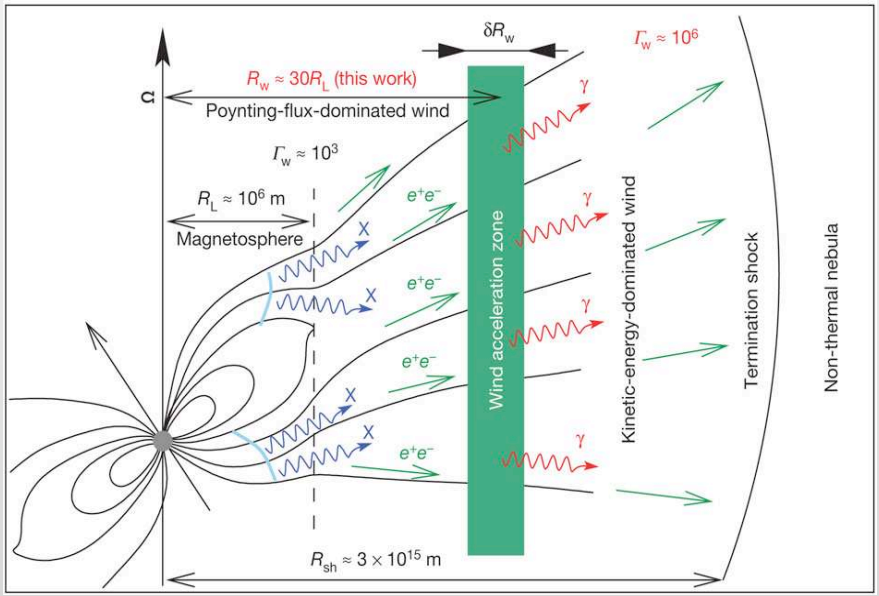


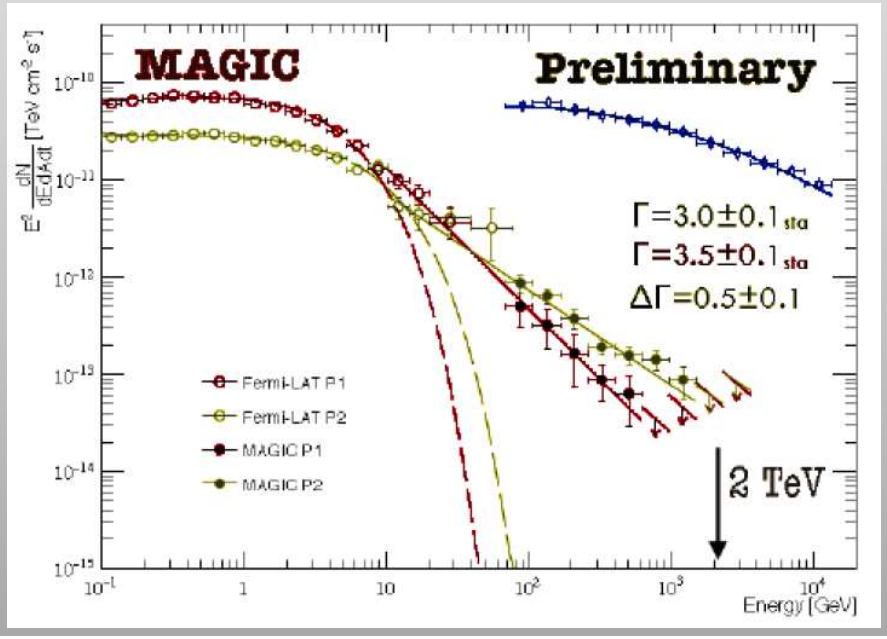
Summary

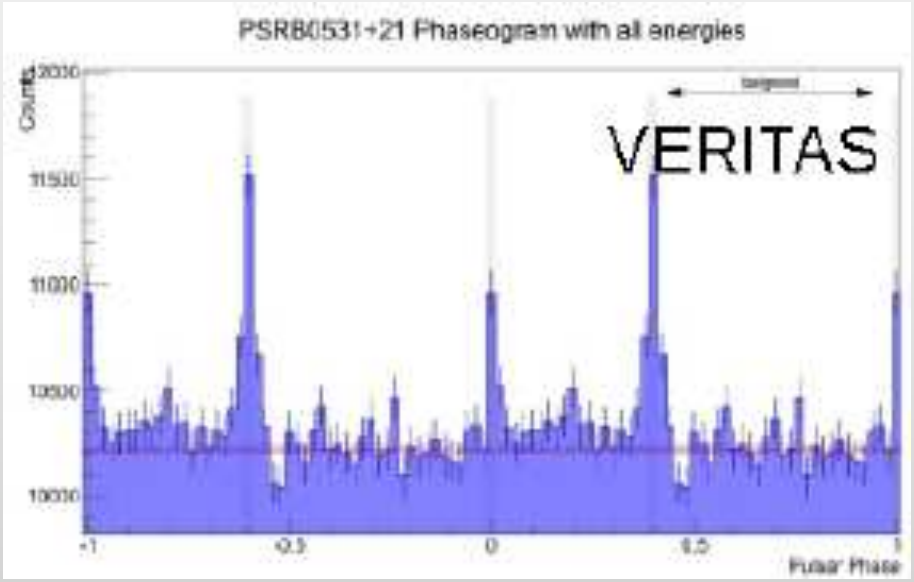
- VHE Gamma ray astronomy moves to the key science with the deep observation ➔ matured phase
  - The discovery of new physics/phenomena and deep observation of the interesting source are now more important rather than the hunting of new sources
- Wide Angle Telescopes
  - HAWC is showing very impressive results
  - LHAASO will come soon
  - HAWC South?
- The construction of CTA will start soon
  - CTA will study with an unprecedented sensitivity
  - Cosmic Ray Origin
  - Super Massive Black Holes, their environment and evaluation
  - Dark Matter at G.C. and dwarf galaxies

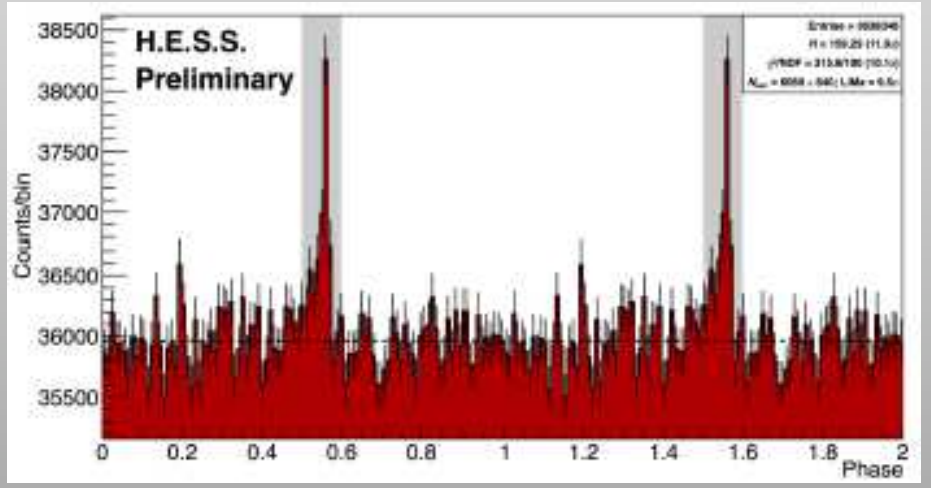


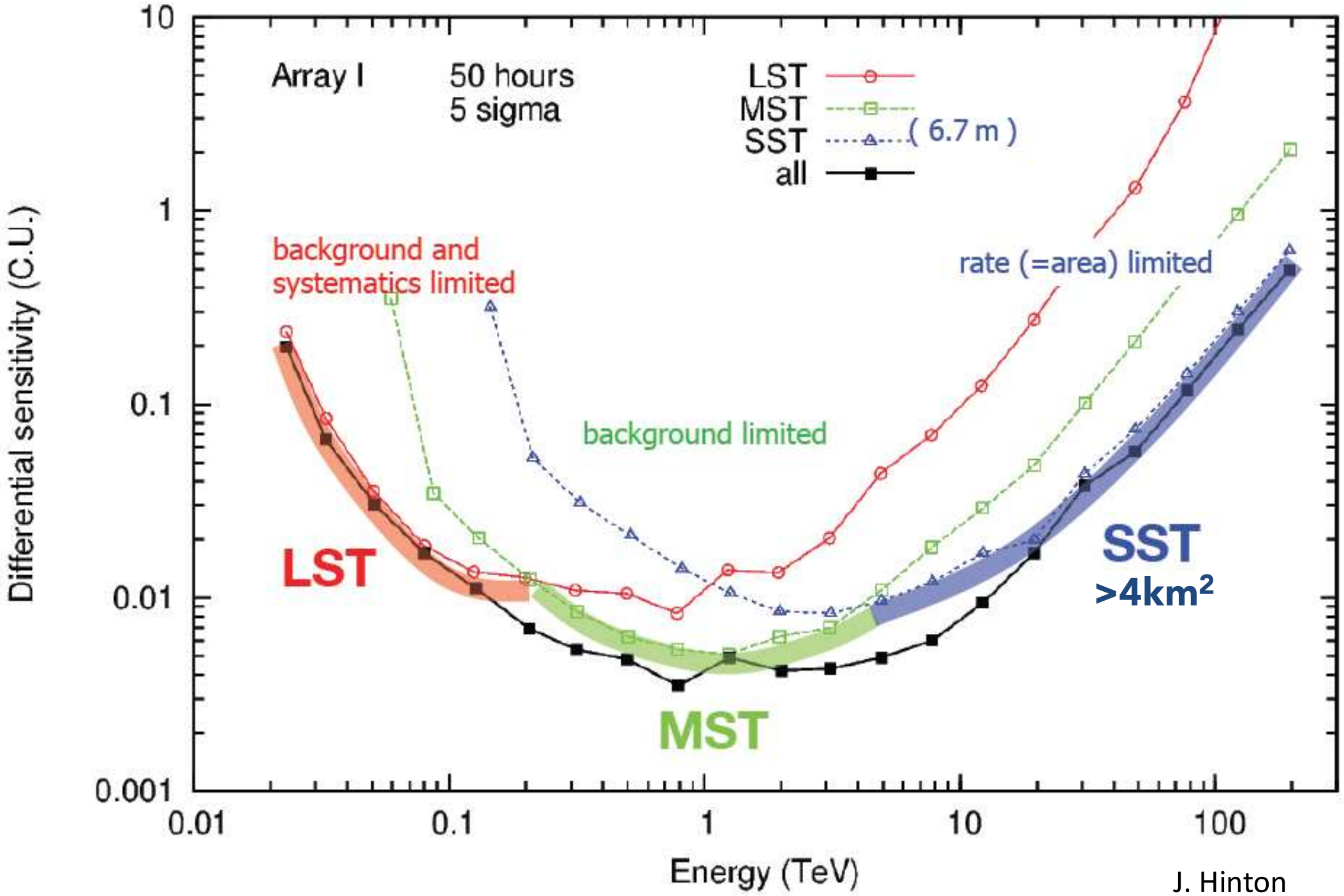
Crab Pulsar & VELA Pulsar ICRC 2015







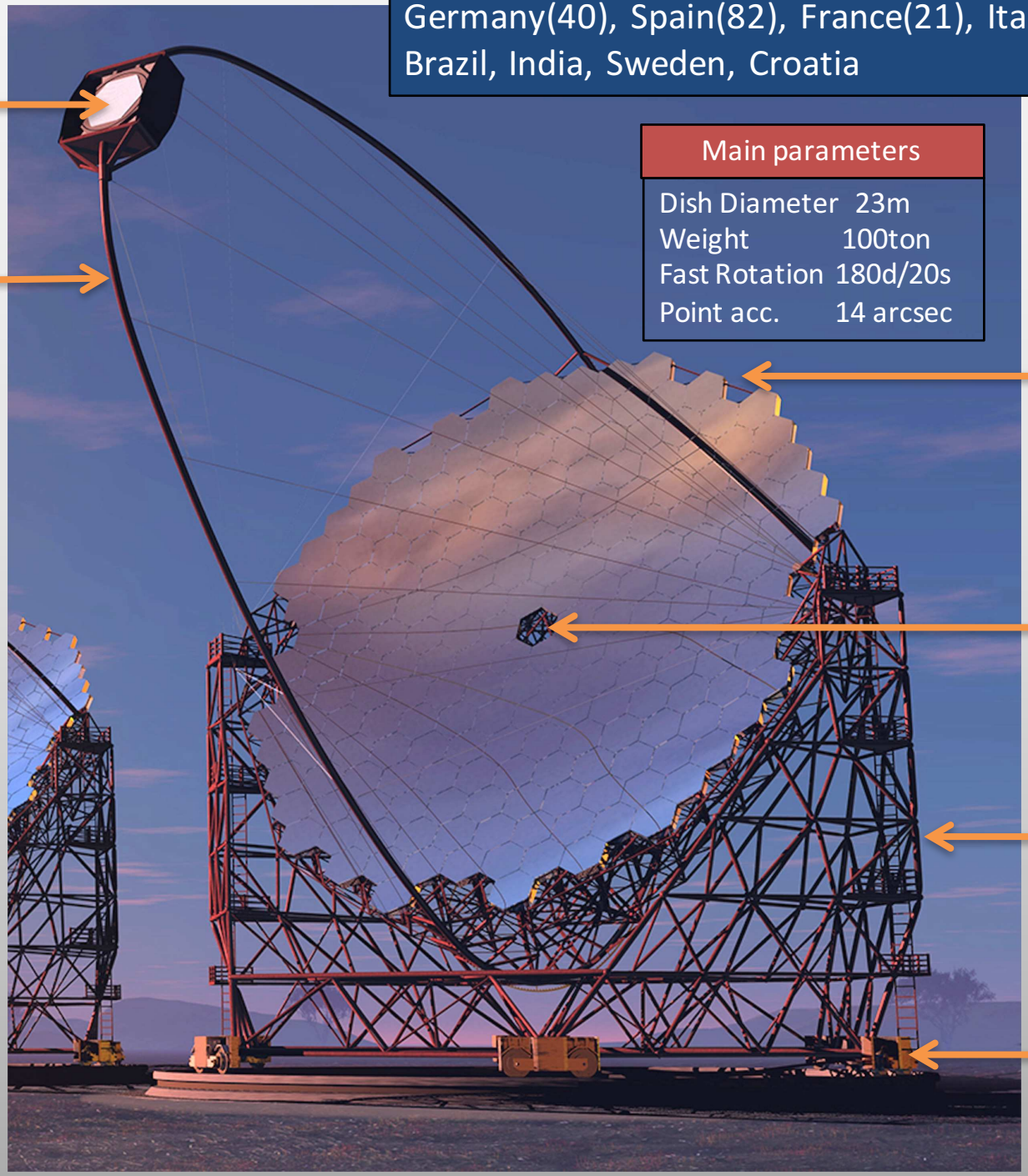



Array I
50 hours
5 sigma
LST
MST
SST
all
(6.7 m)
background and
systematics limited
background limited
rate (=area) limited
LST
MST
SST
>4km²
Differential sensitivity (C.U.)
Energy (TeV)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100

J. Hinton

Large Size Telescope : International effort

Germany(40), Spain(82), France(21), Italy(28), Japan(60),
Brazil, India, Sweden, Croatia



Main parameters	
Dish Diameter	23m
Weight	100ton
Fast Rotation	180d/20s
Point acc.	14 arcsec

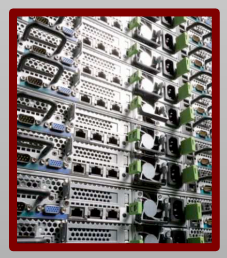
FPI/Elec (日、伊)
Camera body (西)

CSS (仏、伊)

MIR (日)
Interface PL (独、伯、日)
Actuator (日、瑞)
CMOS-Cam (独、日)

StarGuider (瑞典)
CalibBox (印、伊)

Flywheel, UPS (日、西)
Comp. (独、伊)



Structure (独)
Access Tower (独)

Drive (独/仏/西)
Bogie (独/西)
Rail (独/西)
Found. (独/西)