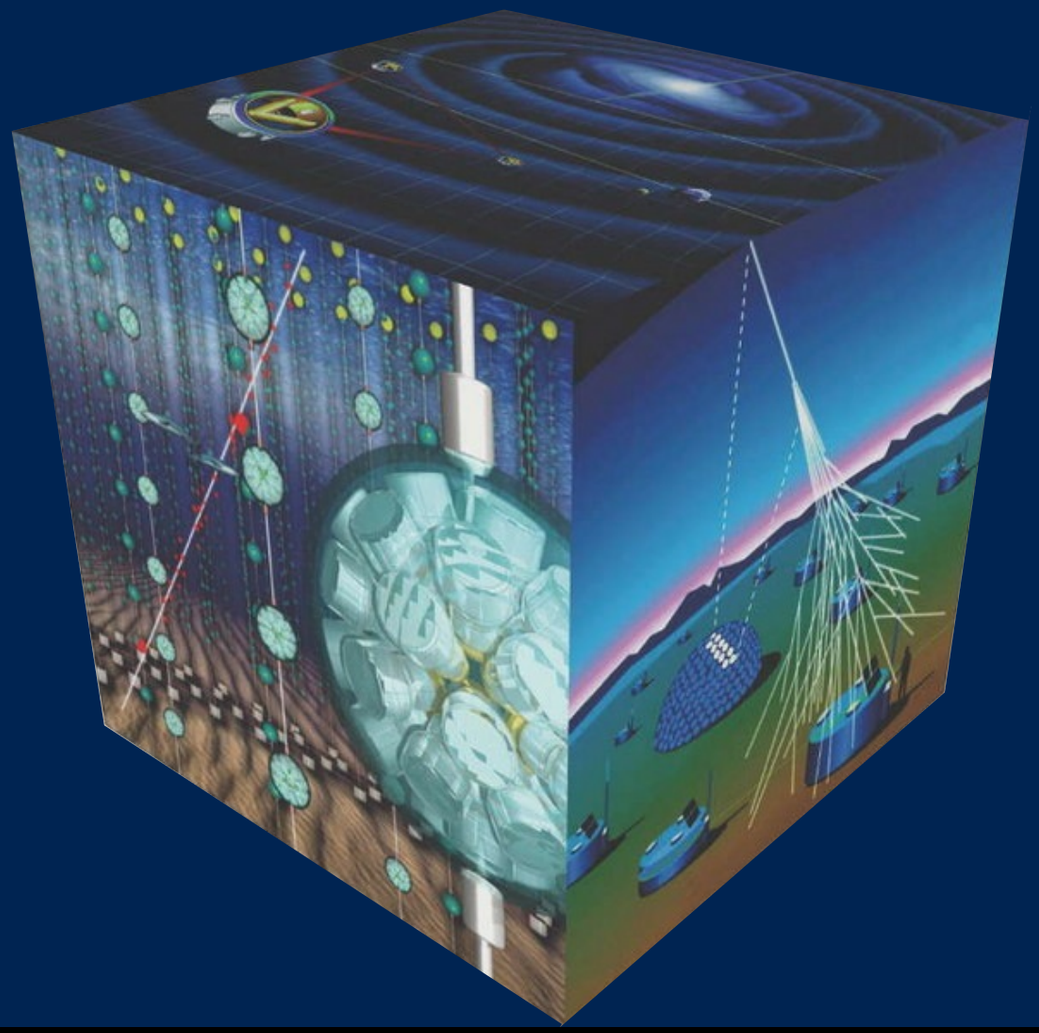
Centro Brasileiro de Pesquisas Físicas

MCTIC

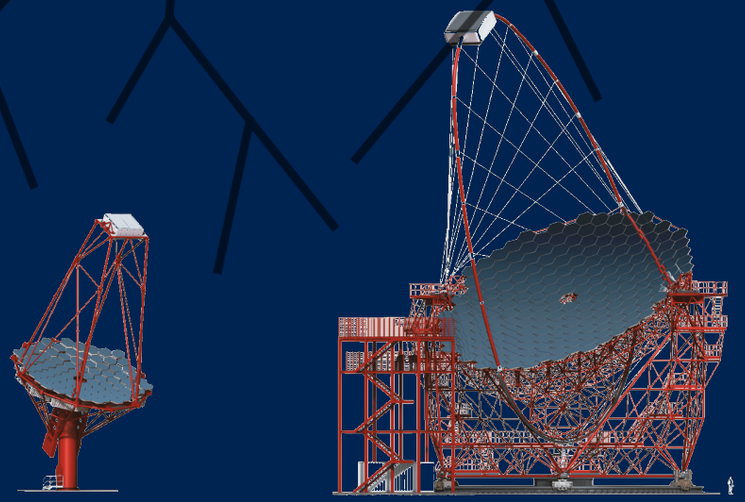
cherenkov telescope array

# Science with CTA

## The MWL & Multi-messenger scene



Ulisses Barres de Almeida
representing the CTA Consortium



# BASELINE DOCUMENT

**A complete outlook on the CTA science and potentials.**

Now available as a book by World Scientific.

Open access in astro-ph: arXiv:1709.07997

# THE CHERENKOV TELESCOPE ARRAY

Credit: CTA Consortium

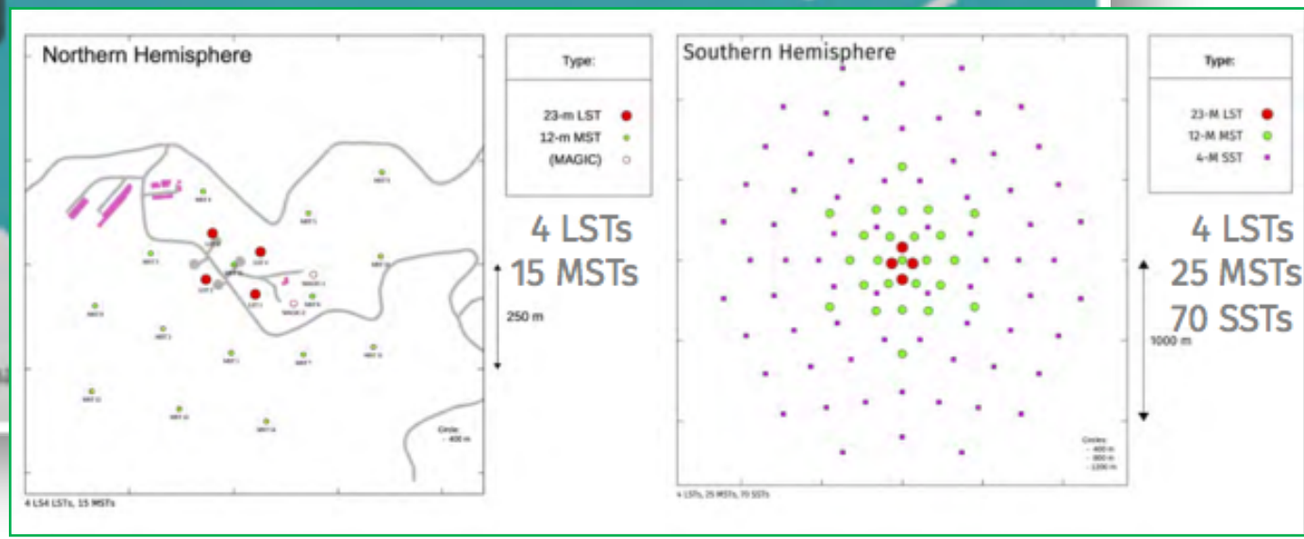




**1,350 scientists**
**from 210 institutes**
**In 32 countries**

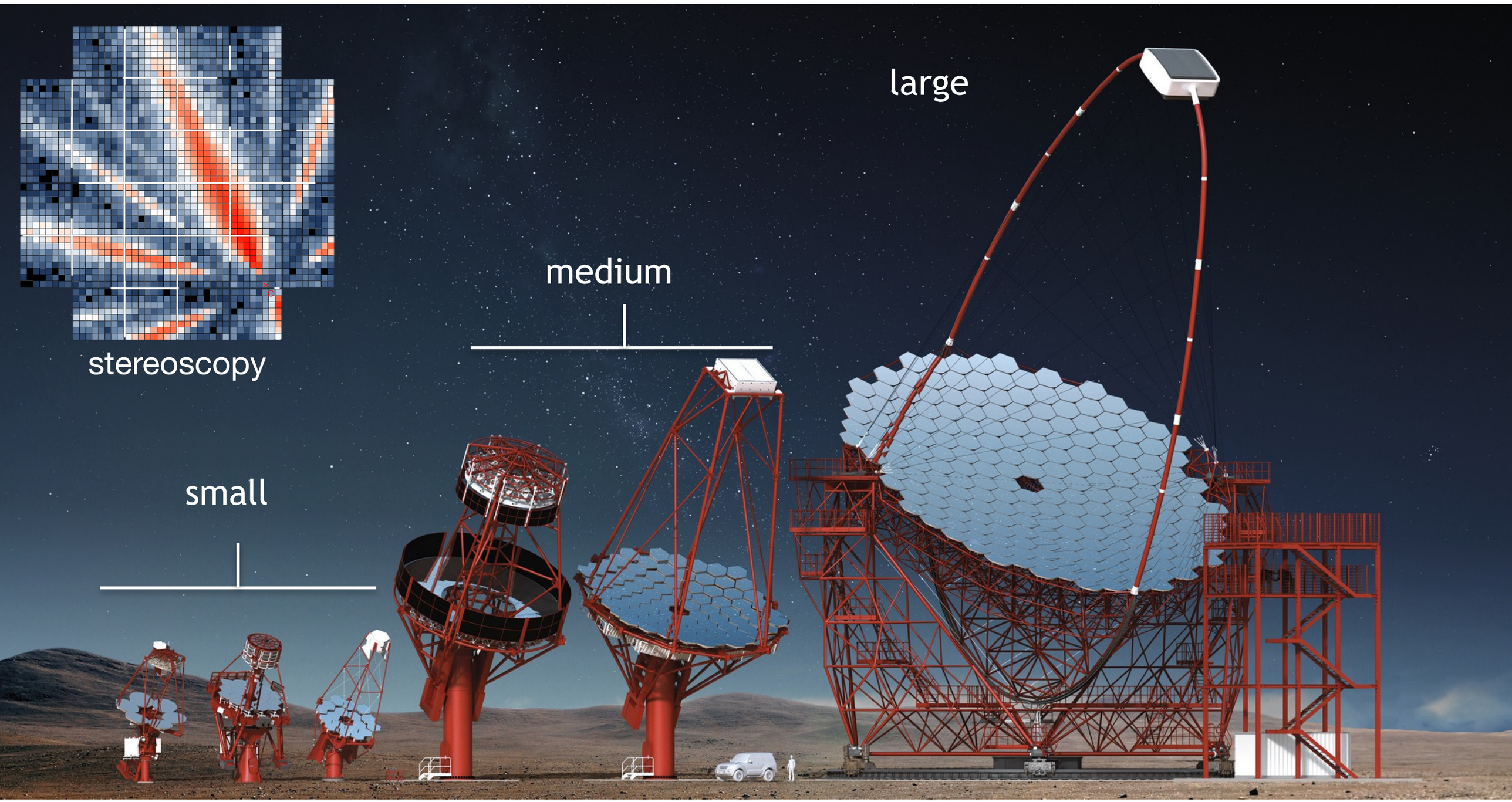
northern hemisphere
southern hemisphere

Array Sites



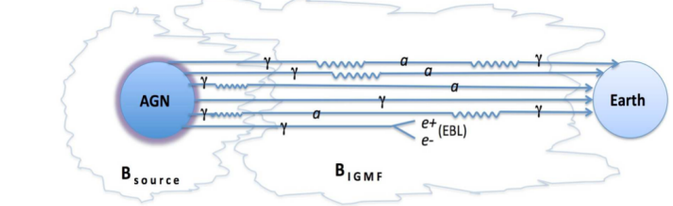
# THE CTA TELESCOPE PROTOTYPES

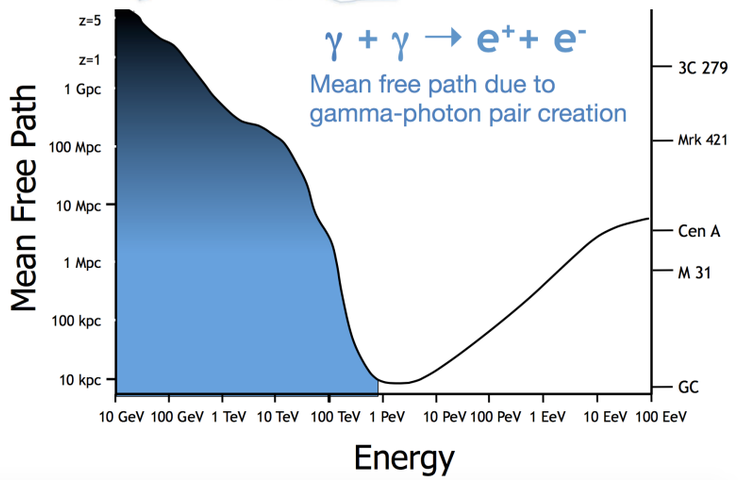
Credit: Gabriel Pérez Diaz, IAC

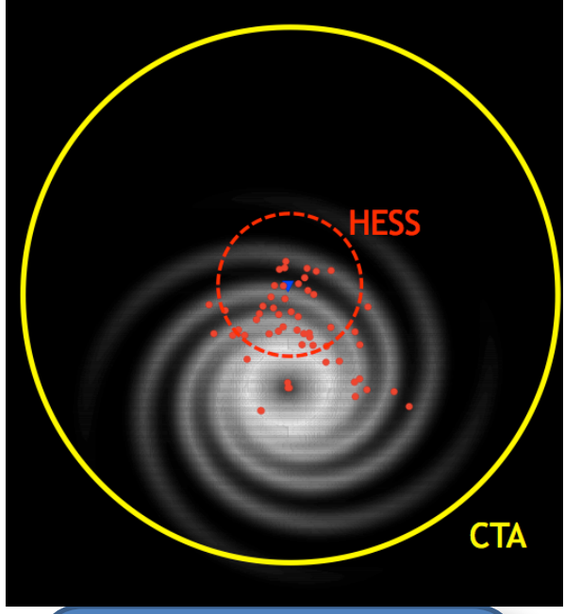


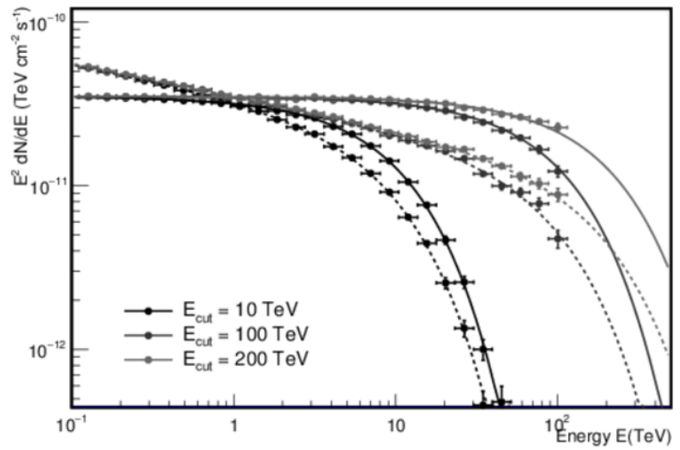
# THE THICK OF CTA SCIENCE

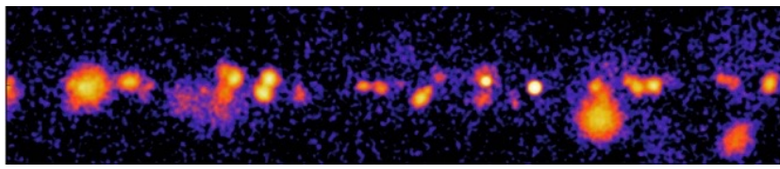
- Understanding the Origin and Role of Relativistic Cosmic Particles
  - What are the sites of **high-energy particle acceleration** in the universe?
  - What are the mechanisms for cosmic particle acceleration?
  - What role do accelerated particles play on star formation and galaxy evolution?
- Probing Extreme Environments
  - What physical processes are at work close to **neutron stars and black holes**?
  - What are the characteristics of **relativistic jets**, winds and explosions?
  - How intense are radiation fields and magnetic fields in cosmic voids?
- Exploring Frontier Physics
  - What is the **nature of dark matter**? How is it distributed?
  - Are there quantum gravity effects on photon propagation?
  - Do axion-like particles exist?

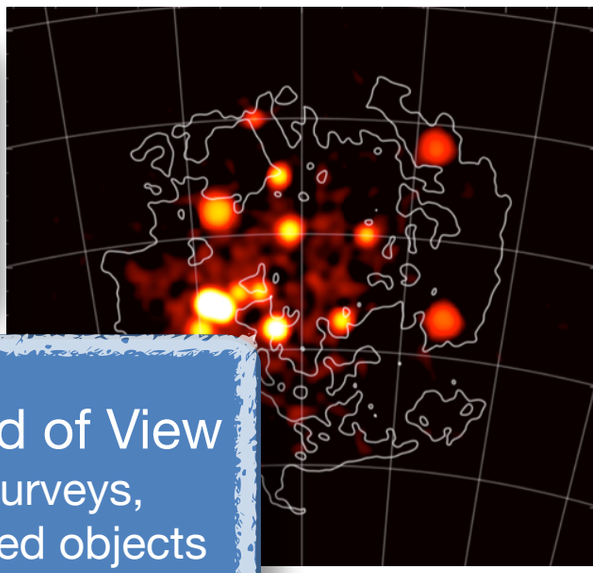


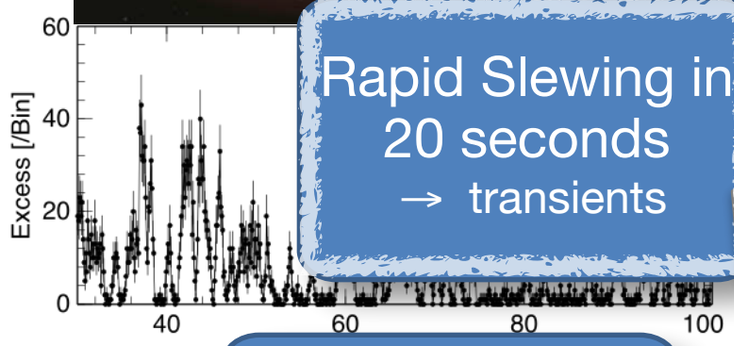





Energies down to 20 GeV
→ Cosmology++

10 x Sensitivity, Large Collection Area
→ all topics

Energies up to 300 TeV
→ Pevatrons

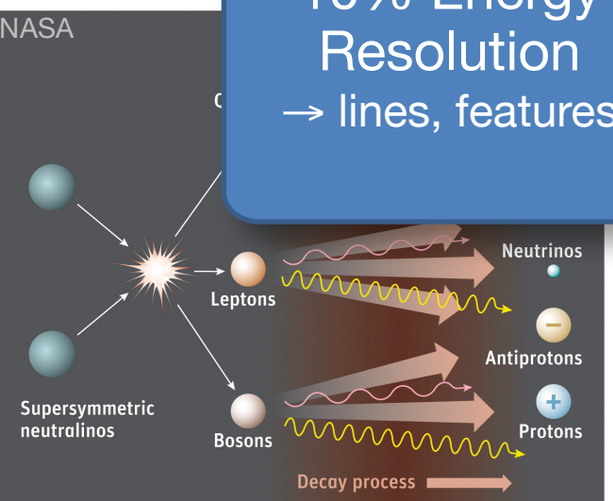



Rapid Slewing in 20 seconds
→ transients

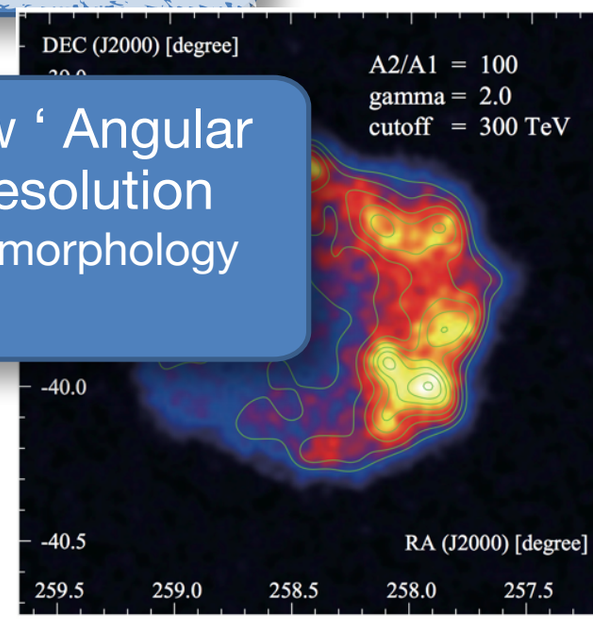
8º Field of View
→ surveys, extended objects

cta
cherenkov telescope array

10% Energy Resolution
→ lines, features

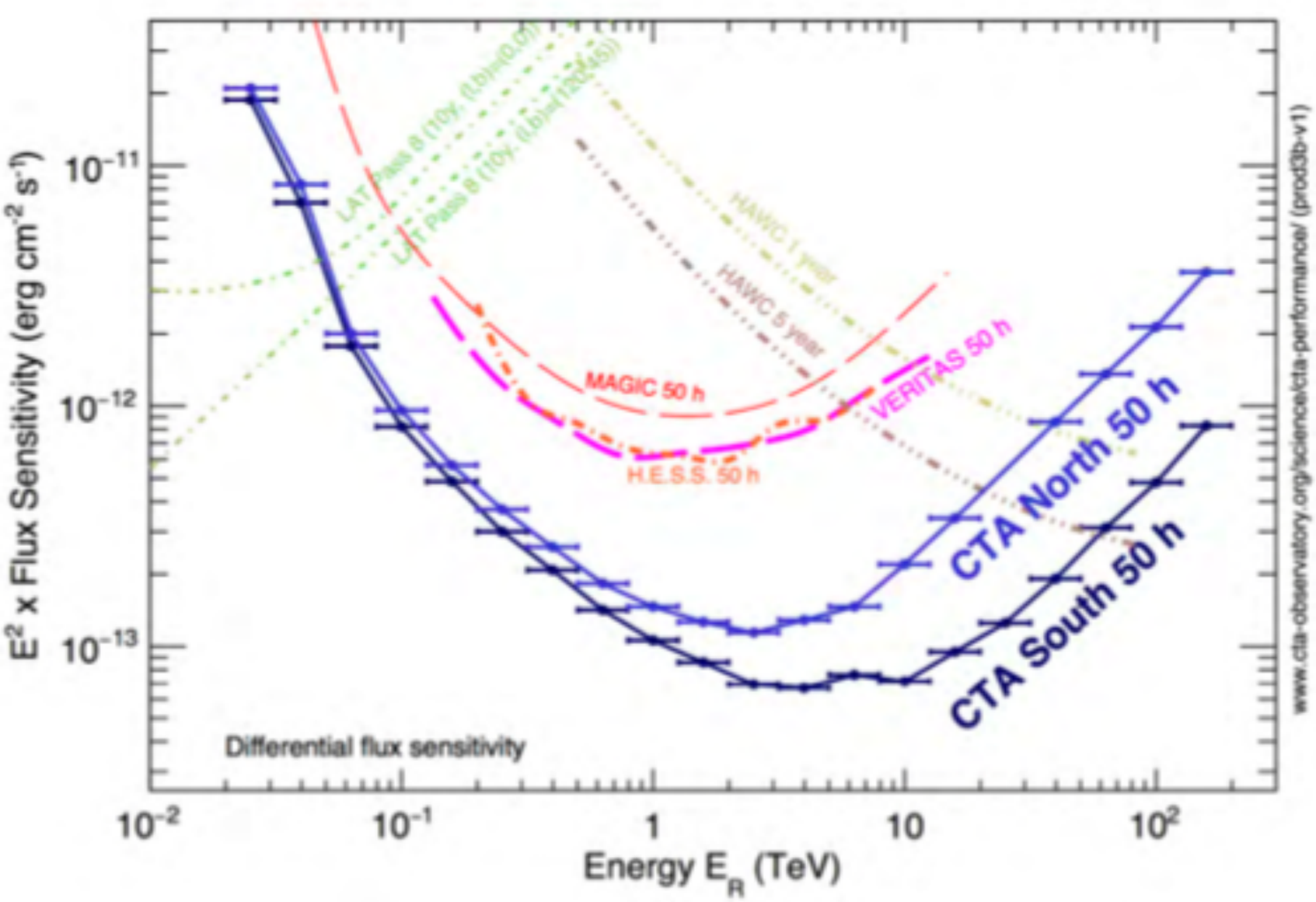



Few ‘ Angular Resolution
→ morphology




Credit: Werner Hofmann

# CTA PERFORMANCE IN CONTEXT I




A factor of **5-20x improvement** in differential sensitivity relative to current IACTS

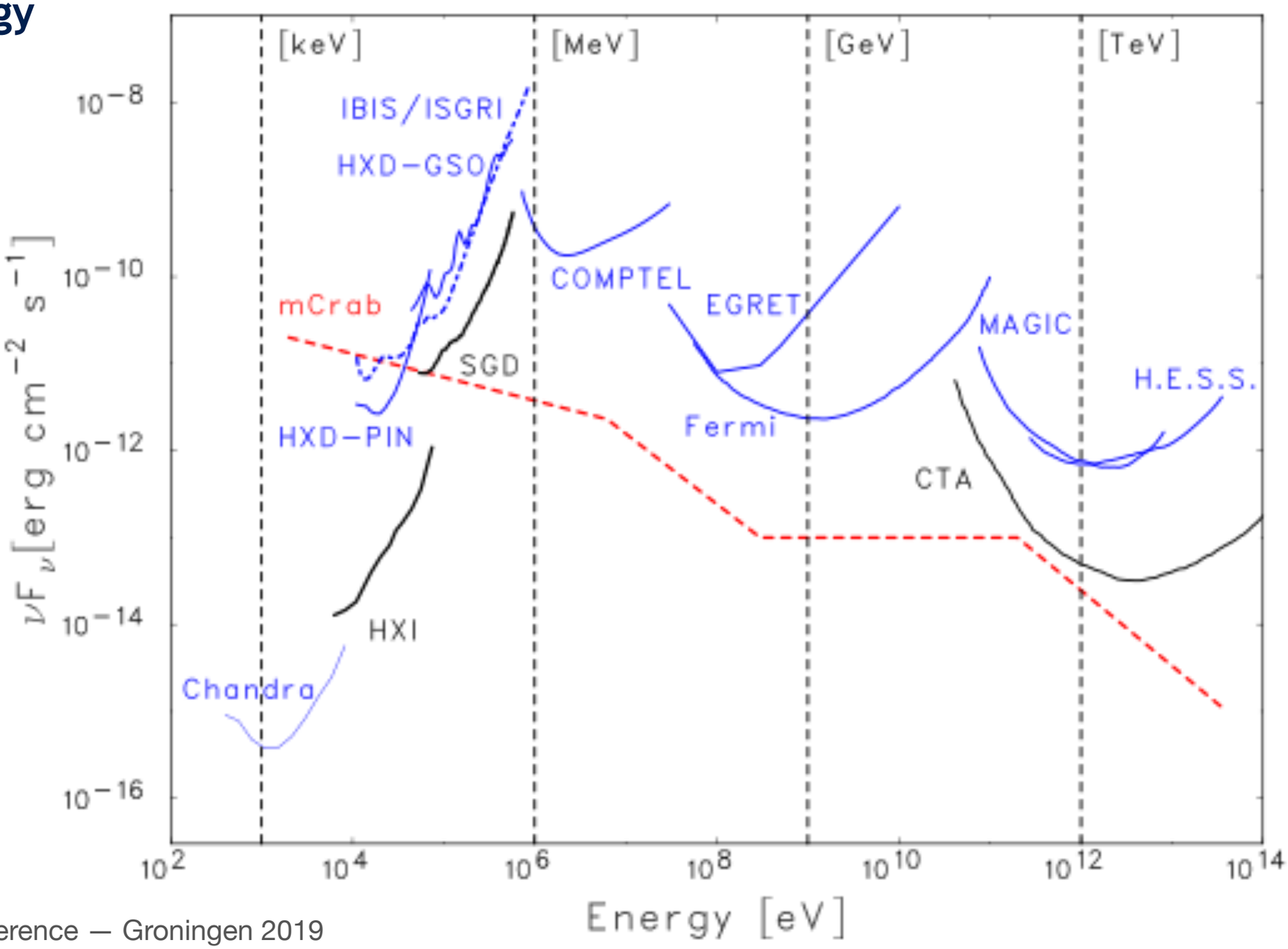
**Extension** of the accessible energy range **from below 100 GeV to above 100 TeV**

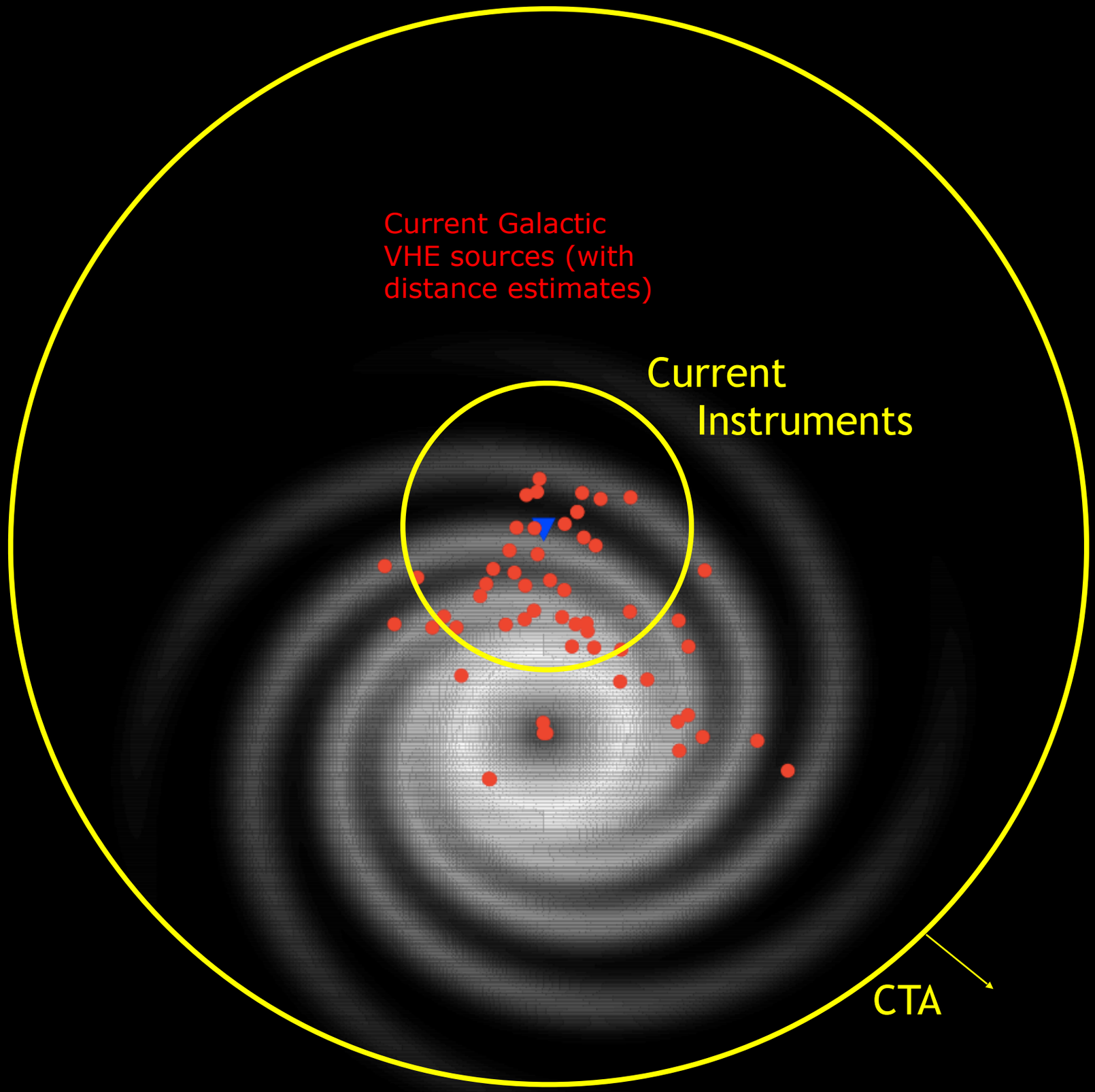
https://www.cta-observatory.org/science/cta-performance/

# CTA PERFORMANCE IN CONTEXT II

**Comparison with X-ray and other high-energy instruments**

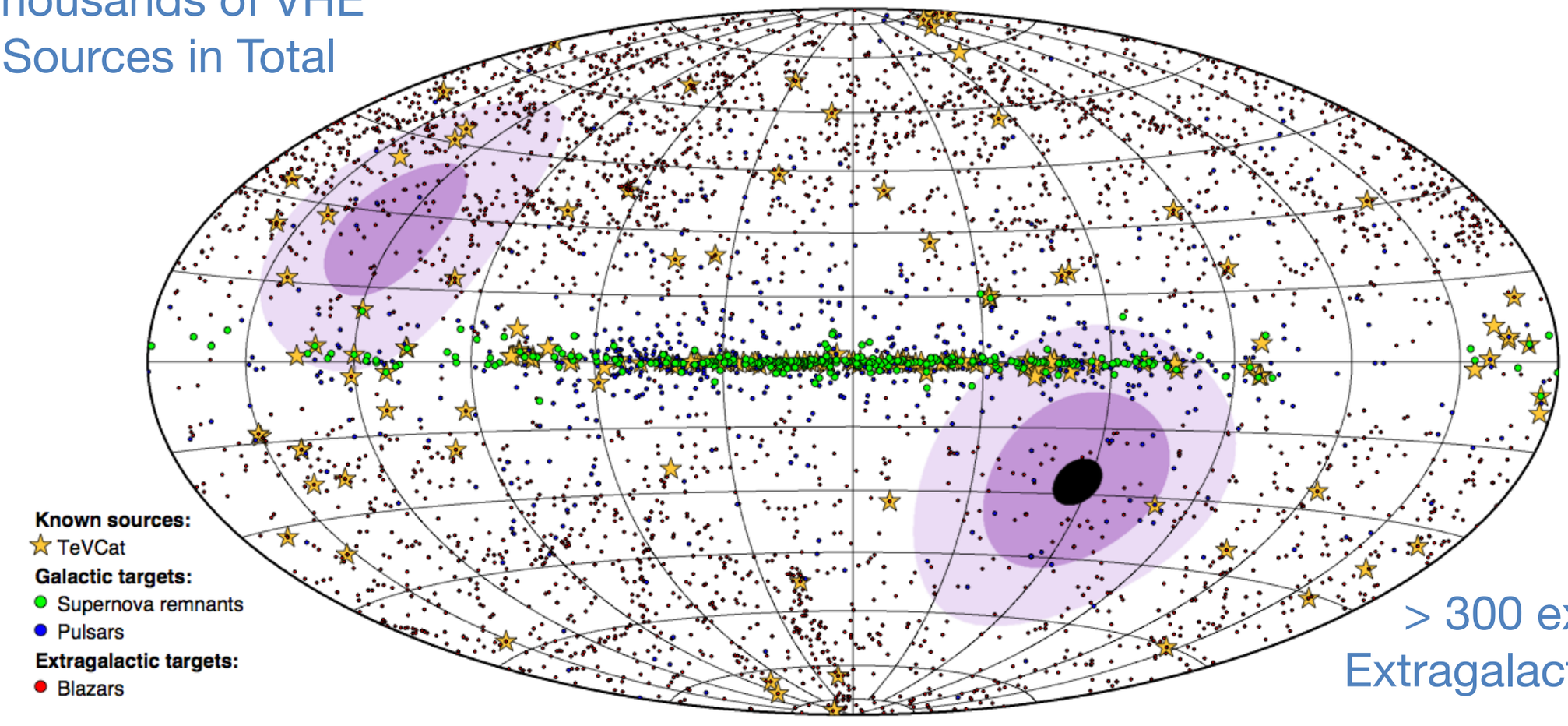
Takahashi et al. 2012



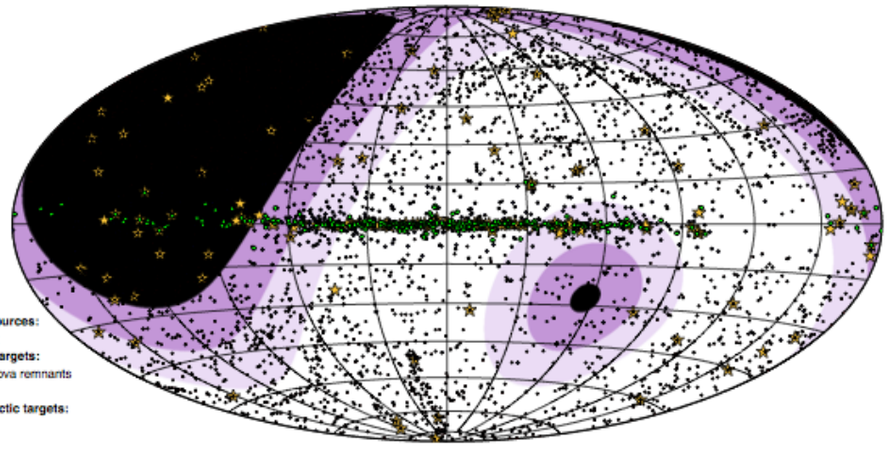

Current Galactic
VHE sources (with
distance estimates)
Current
Instruments
CTA

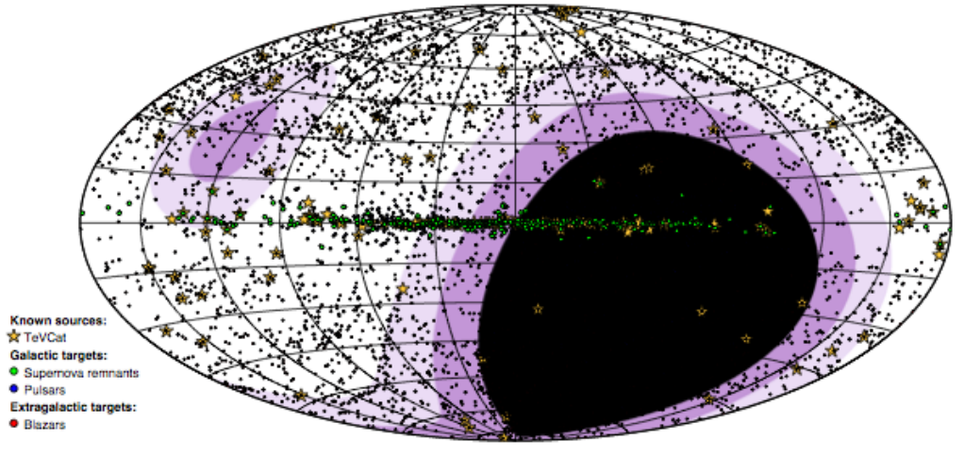
# THE EXPECTED CTA ALL SKY VIEW

Thousands of VHE Sources in Total



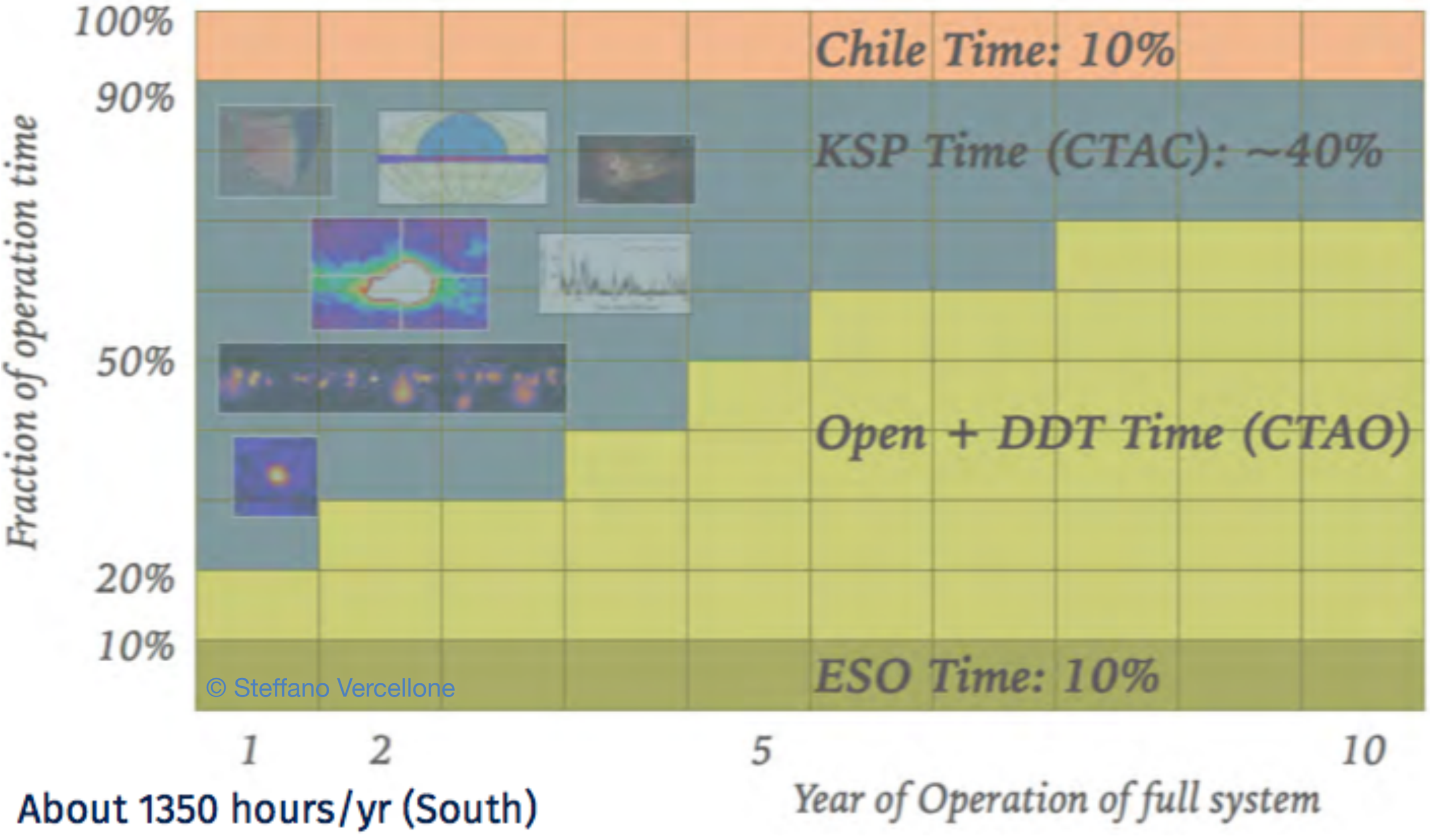

> 300 expected Extragalactic Objects




Credits: CTA Consortium

# POSSIBLE KSP VS G.O. TIME BUDGET




About 1350 hours/yr (South)

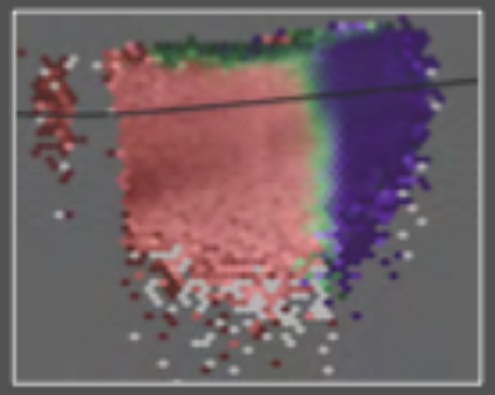
# THE THICK OF CTA SCIENCE

- Understanding the Origin and Role of Relativistic Cosmic Particles
- Probing Extreme Environments
- Exploring Frontier Physics

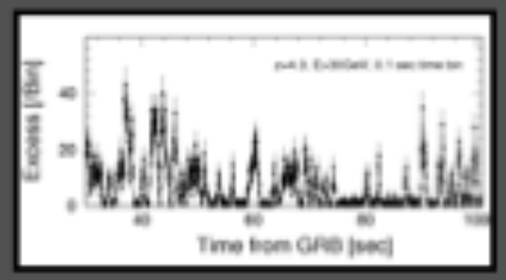
- 9 Key Science Projects (KSPs) and 1 DM Programme
  — KSPs are defined as a set of complex and time-demanding observations addressing multiple science questions within CTA themes

- Focuses on **major and legacy projects**
  — surveys and population studies for legacy catalogues and data sets
  — studies of sources as a class
  — plus focus on a few iconic objects

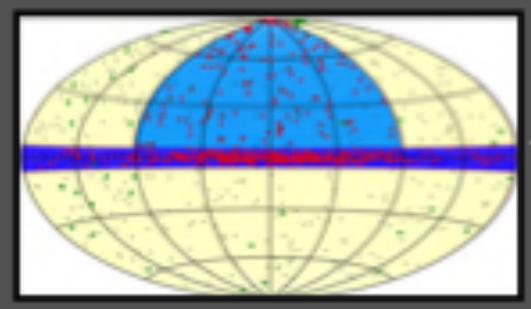
# THE CTA KEY SCIENCE PROJECTS



**Dark Matter Programme**



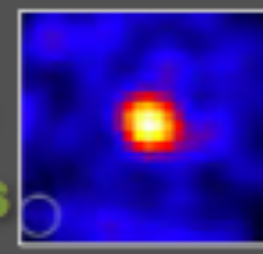

Transients



ExGal Survey

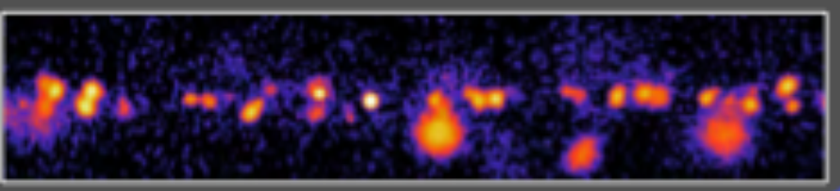
Extragalactic

Galaxy Clusters



Star Forming Systems

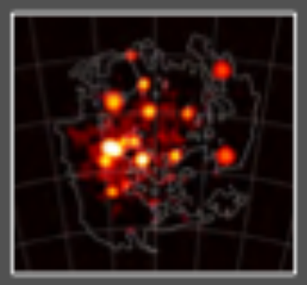
AGN



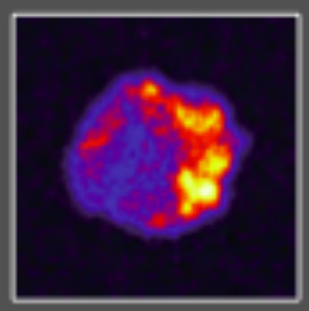
**Galactic Plane Survey**

Galactic

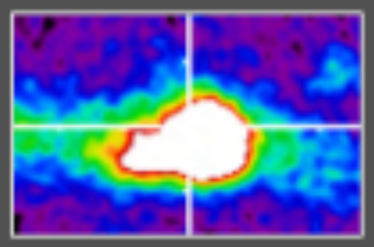
LMC Survey



PeVatrons

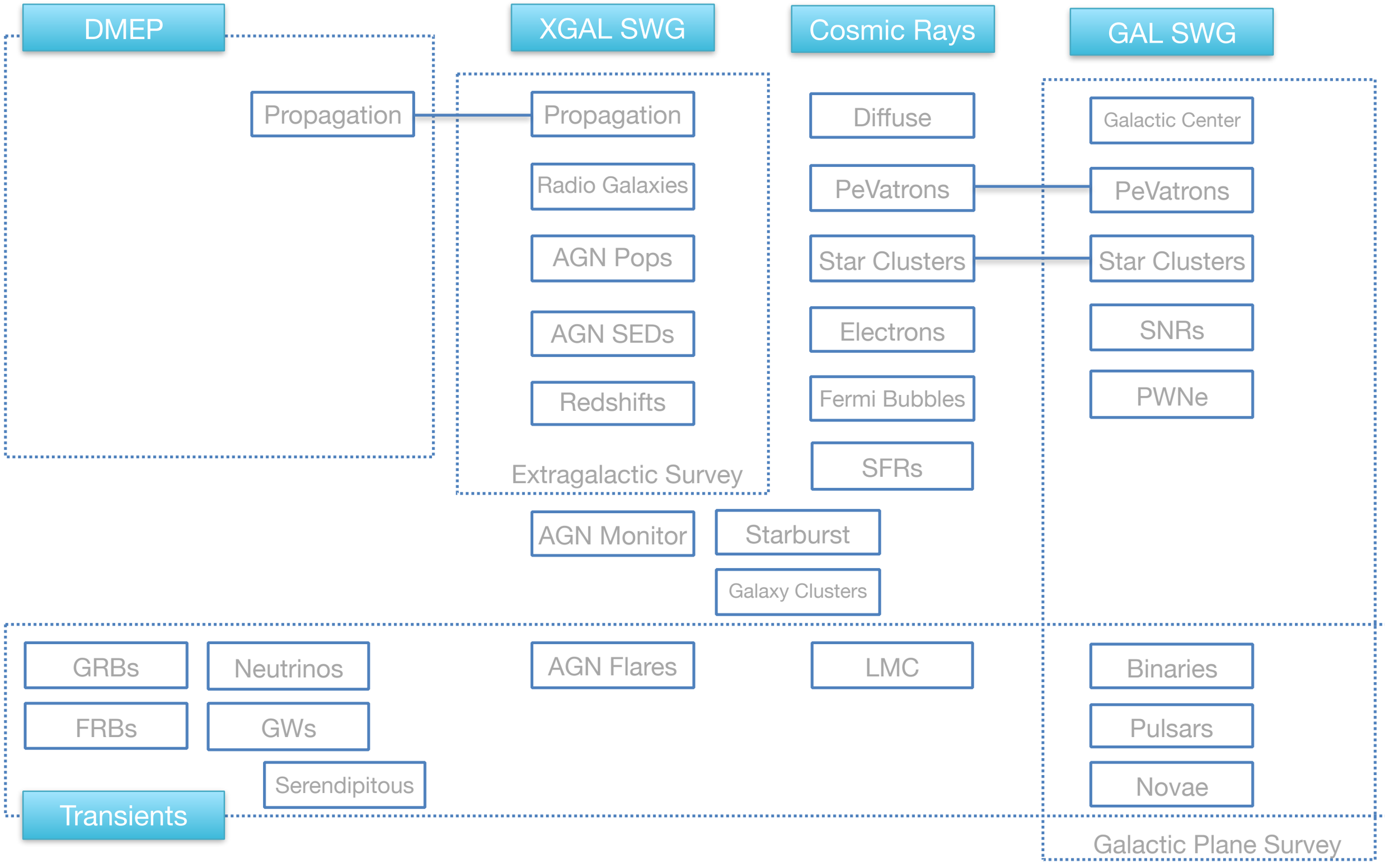


Galactic Centre Survey



cta
cherenkov telescope array

# SCIENTIFIC MAPPING



# THE NEW WINDOW OF MULTI-MESSENGER ASTROPHYSICS!


# THE NEW WINDOW OF MULTI-MESSENGER ASTROPHYSICS!


**First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C**

ATel #12390; ***Razmik Mirzoyan on behalf of the MAGIC Collaboration***
***on 15 Jan 2019; 01:03 UT***
*Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)*

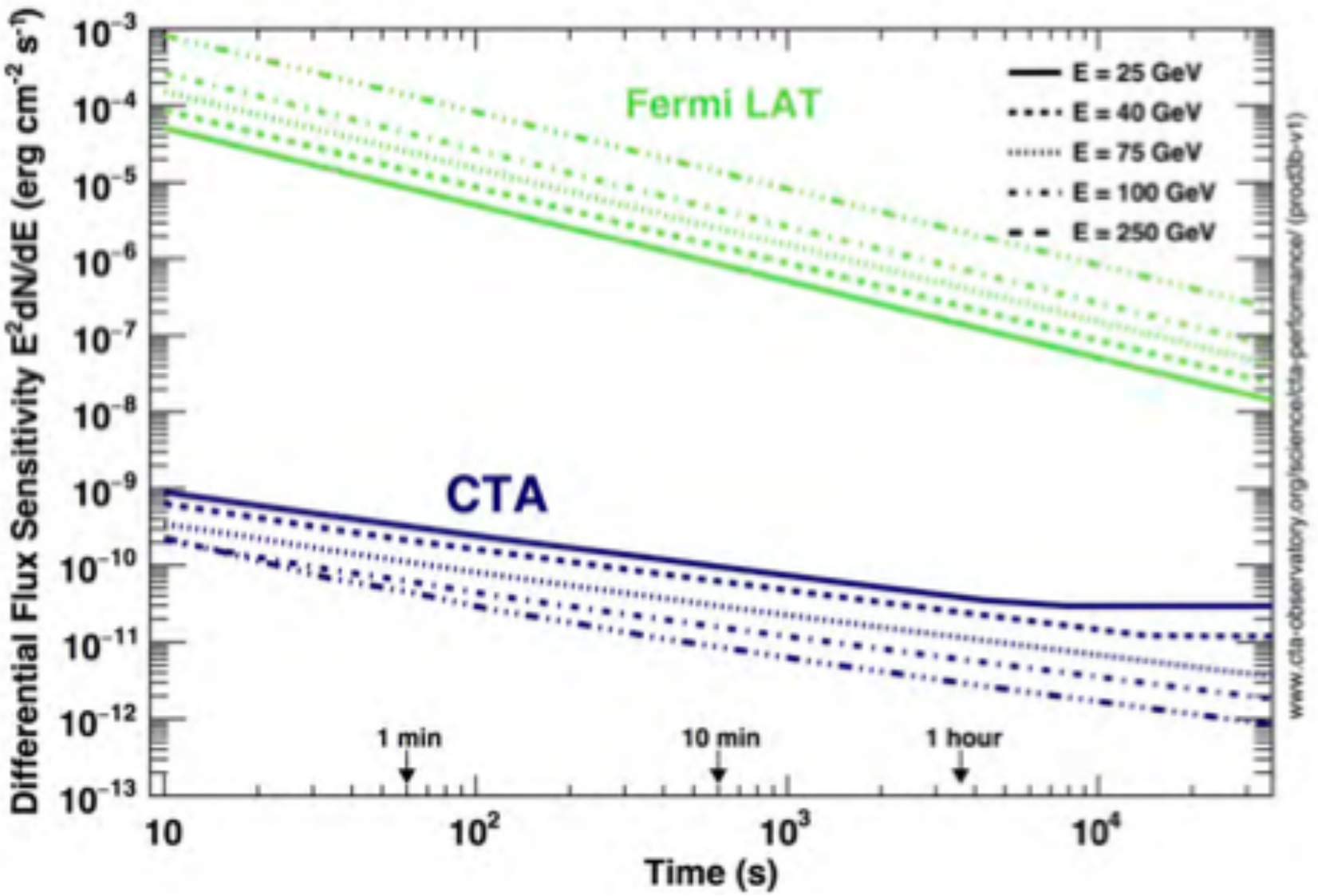
Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

# CTA PERFORMANCE IN CONTEXT III

CTA will be a high-energy **transient factory**

Orders of magnitude **advantage over Fermi-LAT** in intra-day timescales: GRBs, AGN flares, binaries.




© CTA Consortium, "Science with CTA Book"

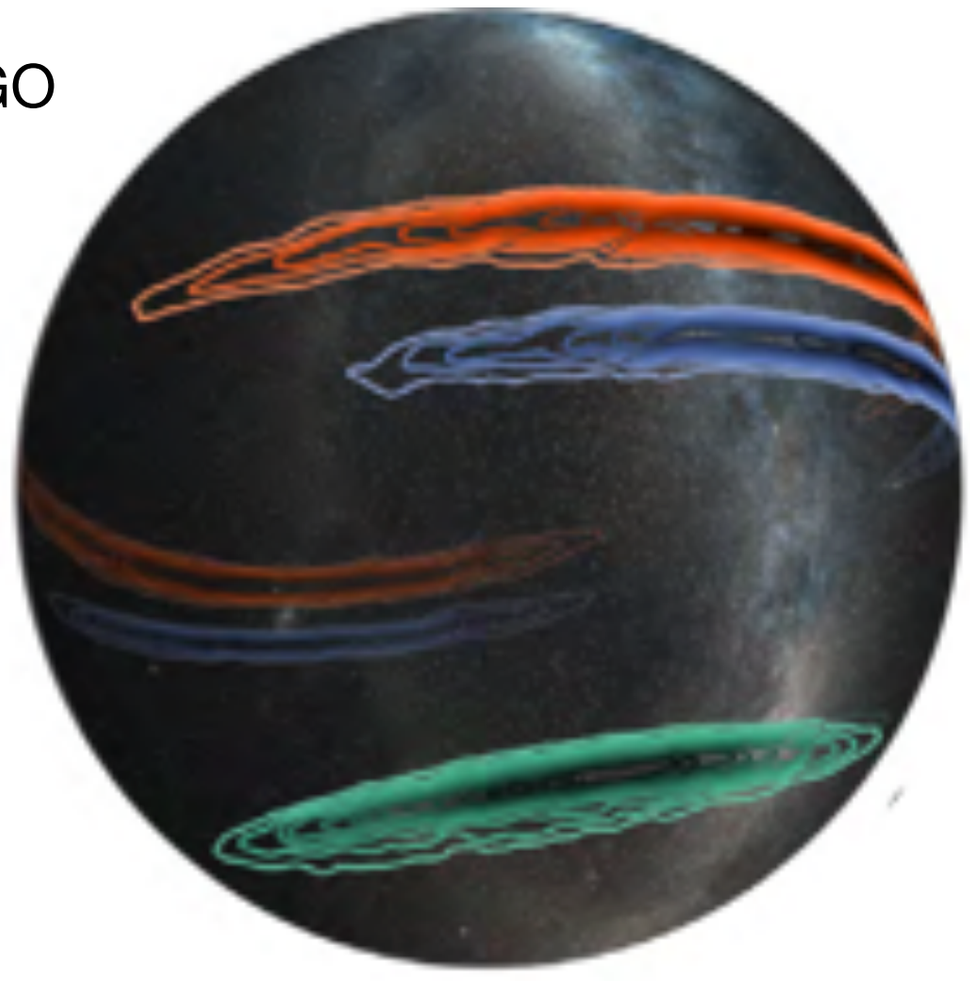
**Caveat & Synergies:** Limited FoV, depending on external triggers.

# TRANSIENT FACTORIES & CTA

**Transients:**

- several prominent gamma-ray emitters are variable sources in the TeV sky
- plus “dark sources” (multi-messenger emitters) may have VHE electromagnetic counterparts and prompt the discovery of new sources.

LIGO



**Optical and Radio Transient factories:** will be major sources of triggers to CTA follow-up. As well as the new class of GW and neutrino detectors.

Important to define the **response criteria and follow-up strategy** to these facilities, as well as for **multi-messenger event alerts** (VOEvents) to :

— manage providers of triggers,

— improve accurate source localisation,

— organise MWL follow-up campaigns, etc.

# THE NEW WINDOW OF MULTI-MESSENGER ASTROPHYSICS!

**Neutrinos:** recent association of an extragalactic flaring blazar with an IceCube neutrino event.

TITLE: GCN CIRCULAR
NUMBER: 21916
SUBJECT: IceCube-170922A - IceCube observation of a high-energy neutrino candidate event
DATE: 17/09/23 01:09:26 GMT
FROM: Erik Blaufuss at U. Maryland/IceCube <blaufuss@icecube.umd.edu>

**First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A**

ATel
Credential
Subjects: Optical, Gam

**Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.**

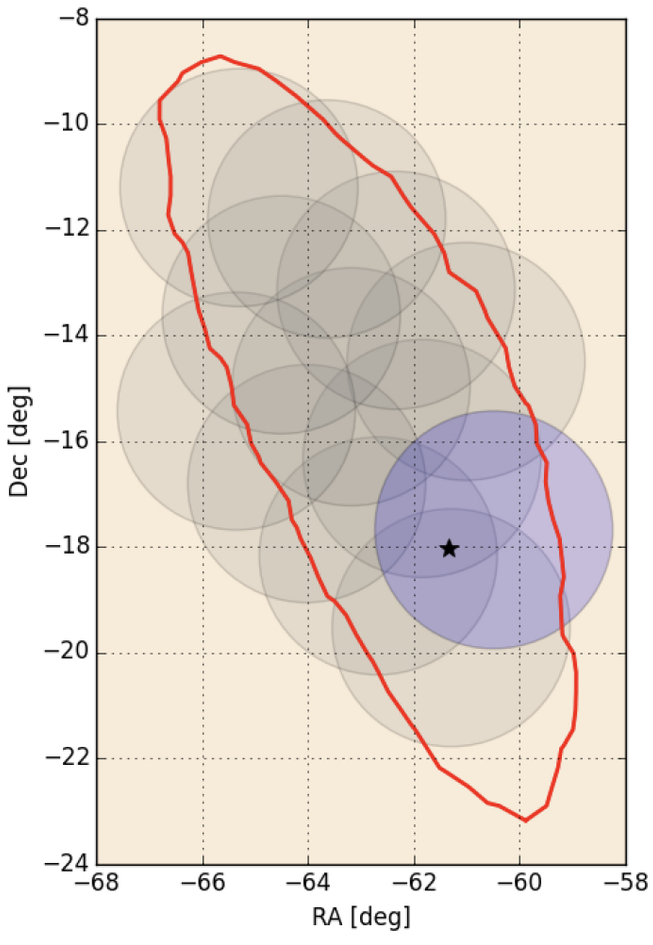
ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration*
*on 28 Sep 2017; 10:10 UT*
*Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)*

Subjects: Gamma Ray, Neutrinos, AGN

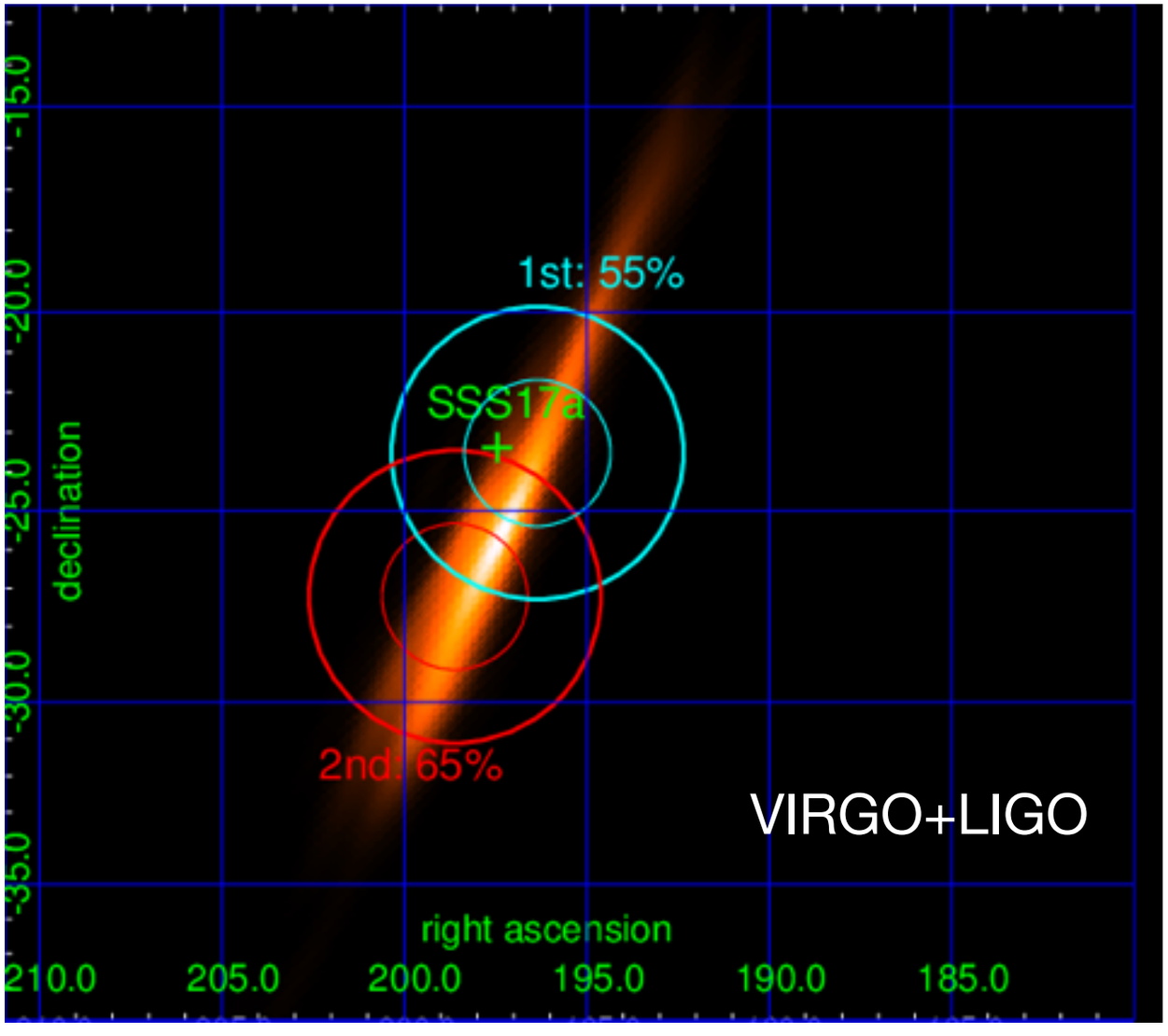

— fast slewing of the LST telescopes
— improved sensitivity at low timescales
— two-hemisphere coverage
— Blazars are more persistent sources, but…

# NEW WINDOW: GRAVITATIONAL WAVES FOLLOW-UP

CTA will provide excellent follow-up to GW events thanks to its large field-of-view



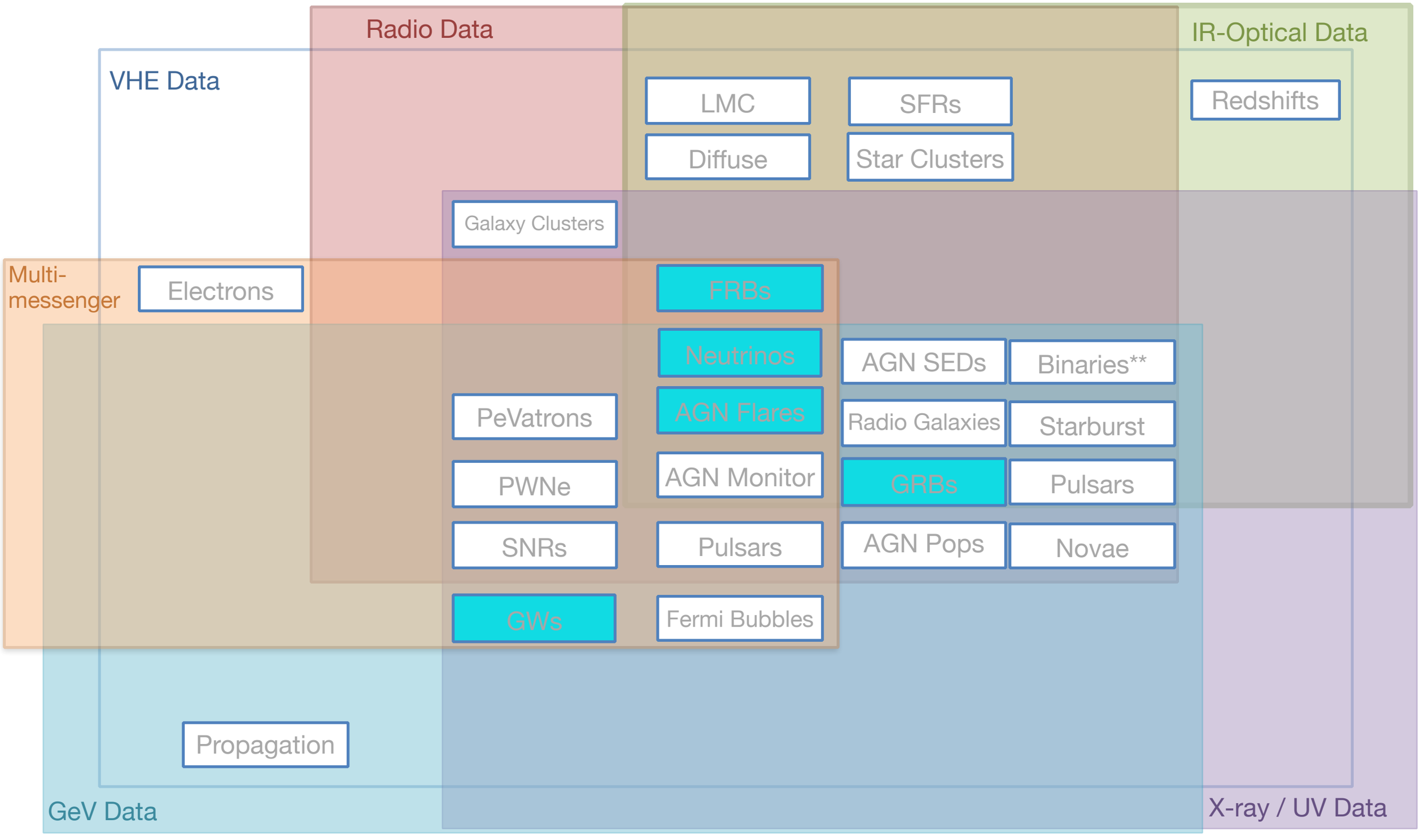

CTA Follow-up strategy of GW sky localisation region.
Patricelli et al 2018, arXiv: 1801.05167



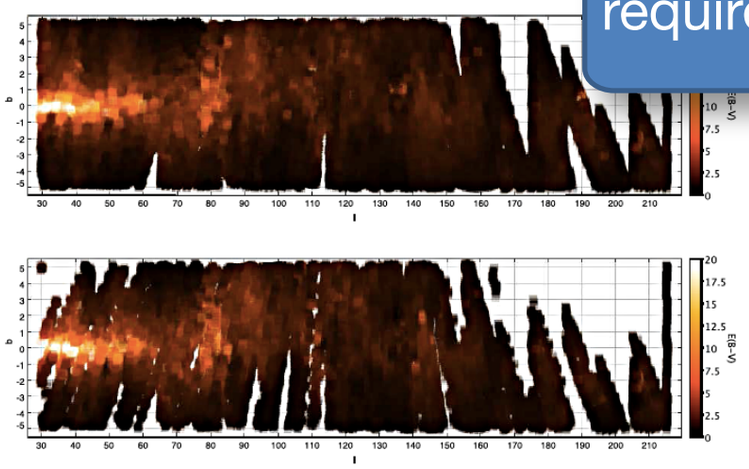

Credit: F. Schüssler, IRFU/CEA Paris-Saclay

Simulated response to the VIRGO +LIGO event GW170817 requires only two pointings.

# CTA MWL / MULTI-MESSENGER NEEDS

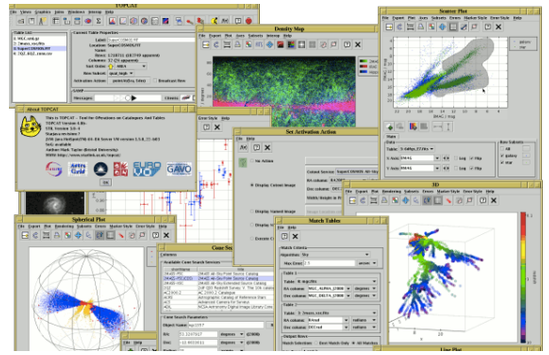


# CTA MWL / MULTI-MESSENGER NEEDS



Data quality requirements

mwl / multi-messenger requirements & strategy

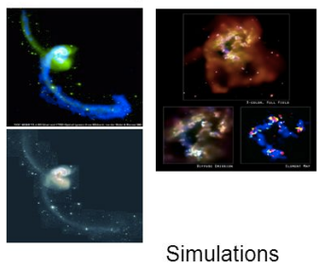


Data accessibility

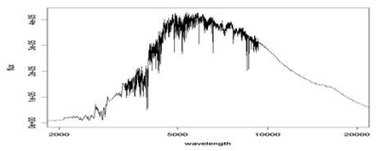
Observation time requirements

Some astronomical data products

Images

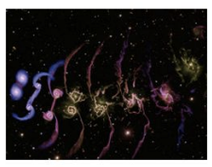


Spectra



Catalogues

Simulations

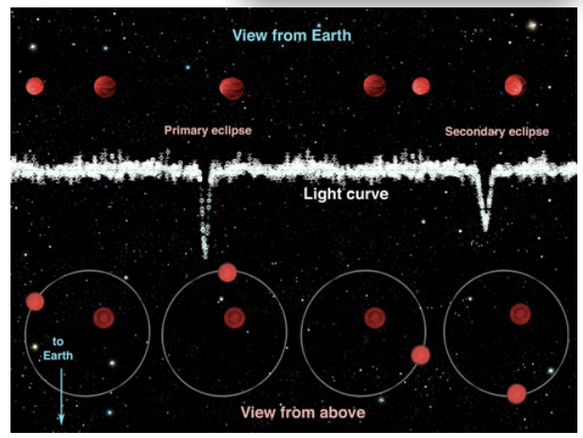


• John Hibbard http://www.cv.nrao.edu/~jhibbard/n4038/n4038.html
• NASA/CXC/SAO/G. Fabbiano et al.
• Di Matteo, Springel and Hernquist, 2005

GES 2007, 3.5.2007

Required data products

Observation Strategy



CBPF
Centro Brasileiro de Pesquisas Físicas

MCTIC

cta

# THANK YOU

ulisses@cbpf.br

www.cta-observatory.org