CBPF
Centro Brasileiro de Pesquisas Físicas

MCTIC

cta
cherenkov telescope array

CTA POTENTIAL TO PROBE THE EXTREME EXTRAGALACTIC SKY

Ulisses Barres de Almeida, for the CTA Consortium
Centro Brasileiro de Pesquisas Físicas

(with E. Prandini, L. Foffano, B. Fraga and B. Arsioli)

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

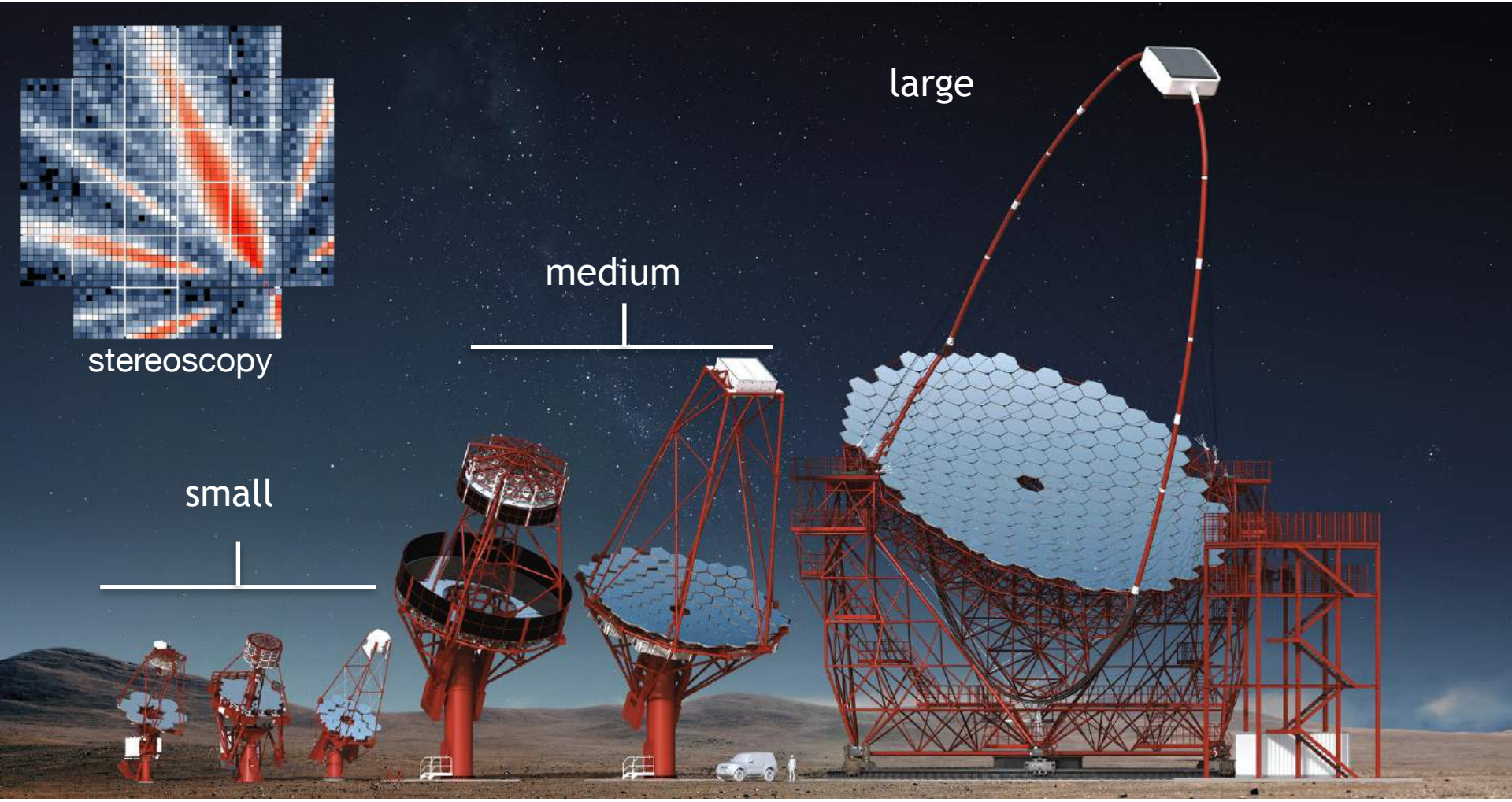
OUTLINE OF THIS TALK

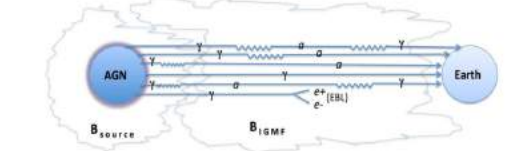
- **Few words about CTA**
- **The CTA Extragalactic and AGN Science Programme**
- **CTA probes of the extreme extragalactic sky**
- **Extreme blazars with CTA**

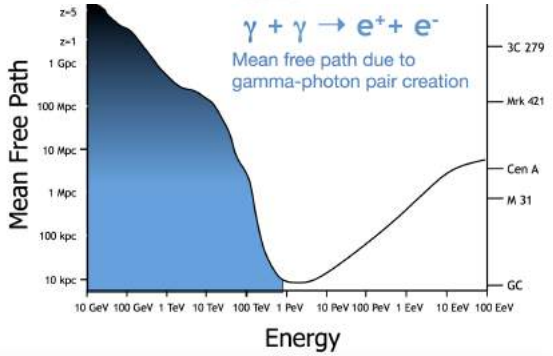
THE CHERENKOV TELESCOPE ARRAY

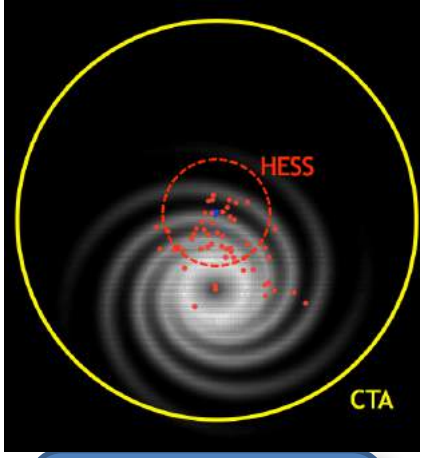
THE CTA TELESCOPE PROTOTYPES

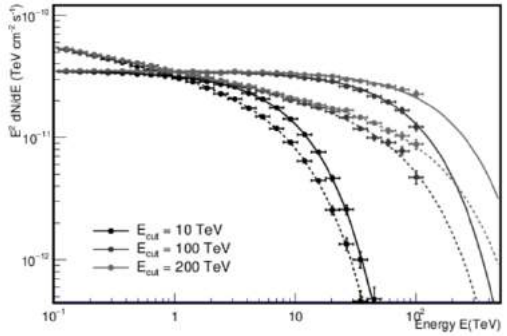
Credit: Gabriel Pérez Diaz, IAC

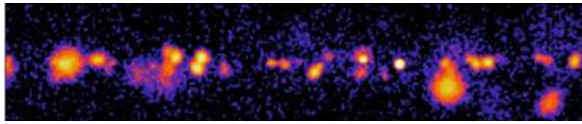


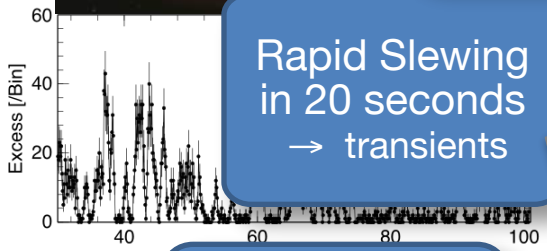


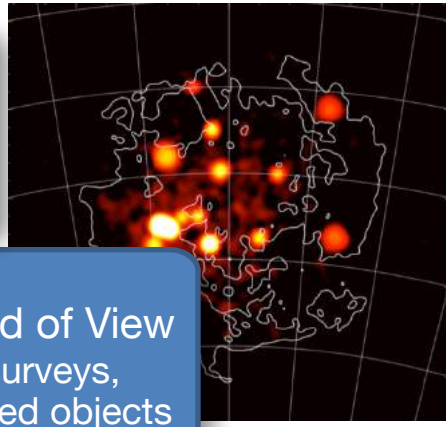












Energies down to 20 GeV
→ Cosmology++

10 x Sensitivity, Large Collection Area
→ all topics

Energies up to 300 TeV
→ Pevatrons

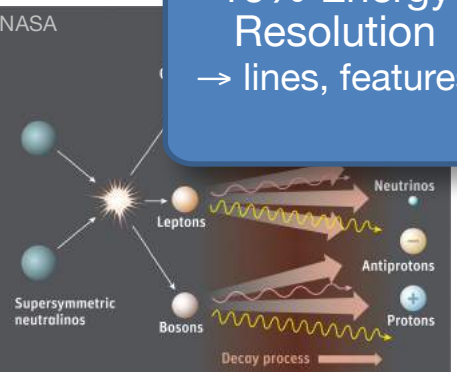
Rapid Slewing in 20 seconds
→ transients

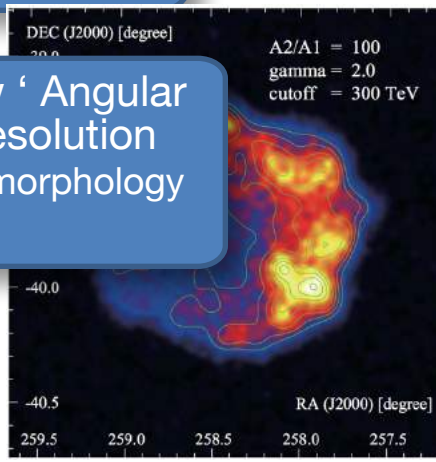
8° Field of View
→ surveys, extended objects

cta
cherenkov telescope array

10% Energy Resolution
→ lines, features

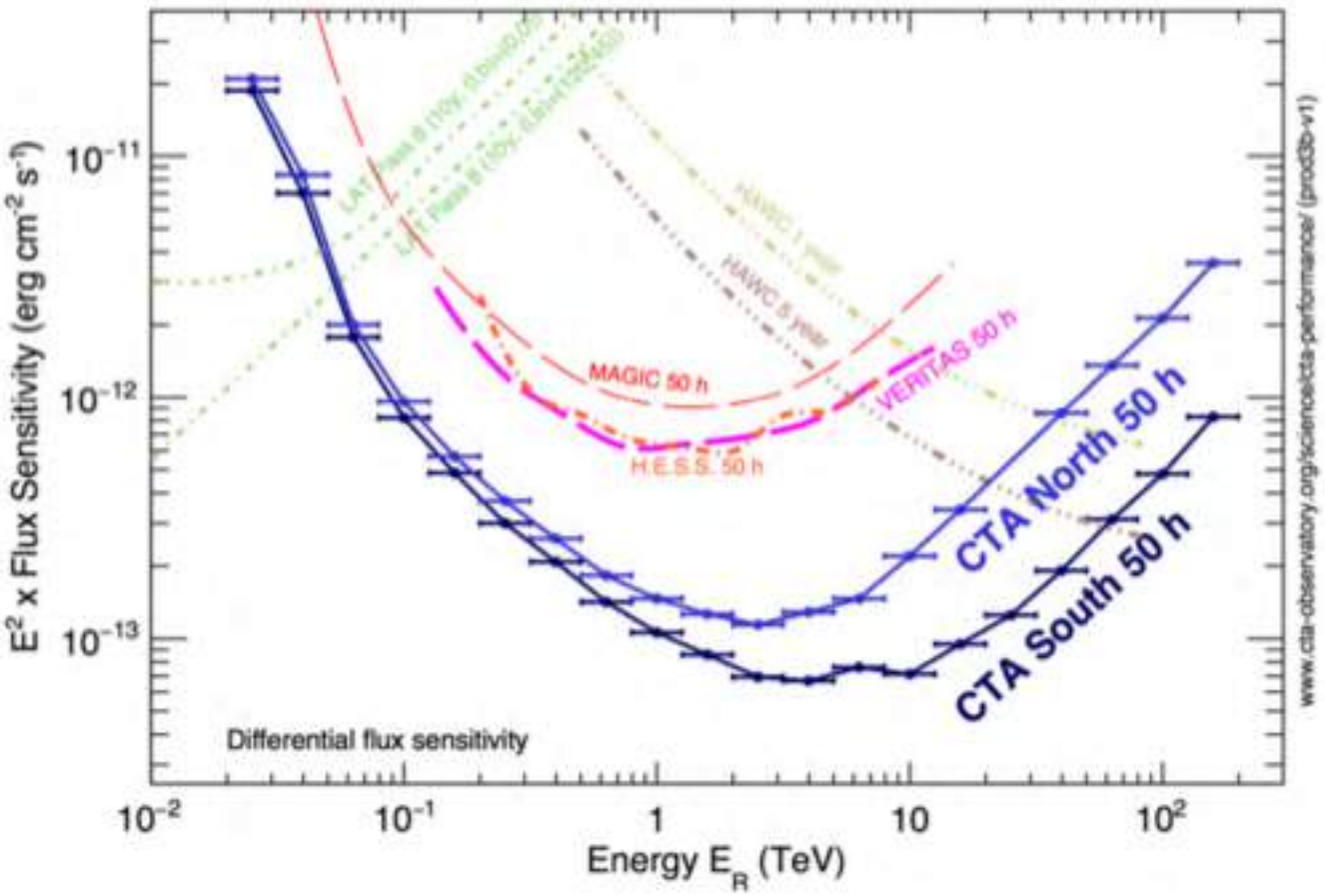
Few ' Angular Resolution
→ morphology





Credit: Werner Hofmann

CTA PERFORMANCE IN CONTEXT I



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

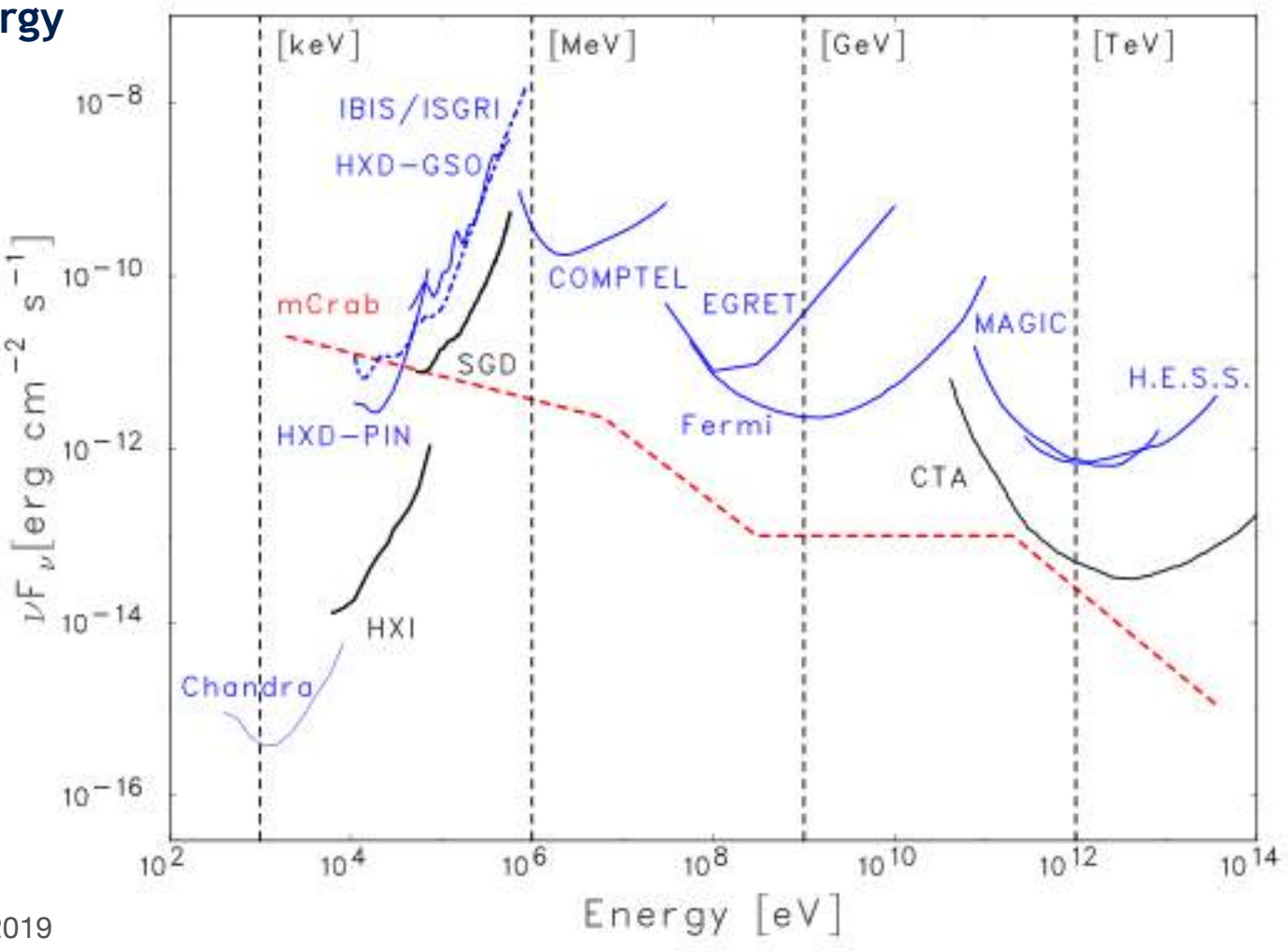
Extension of the accessible energy range **from below 100 GeV to above 100 TeV**

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

CTA PERFORMANCE IN CONTEXT II

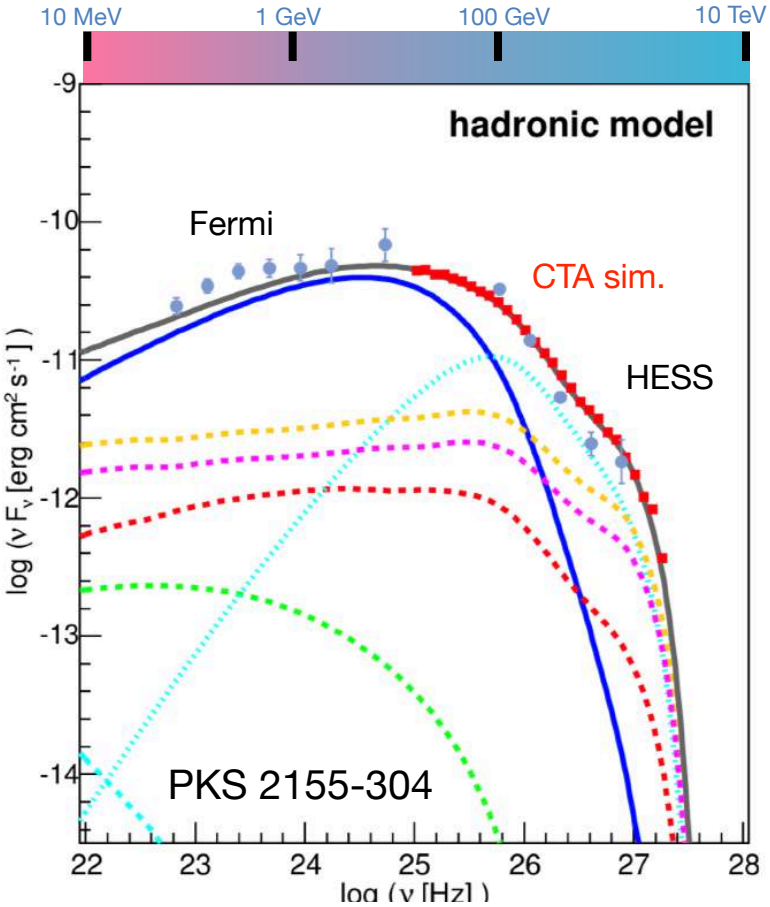
Comparison with X-ray and other high-energy instruments

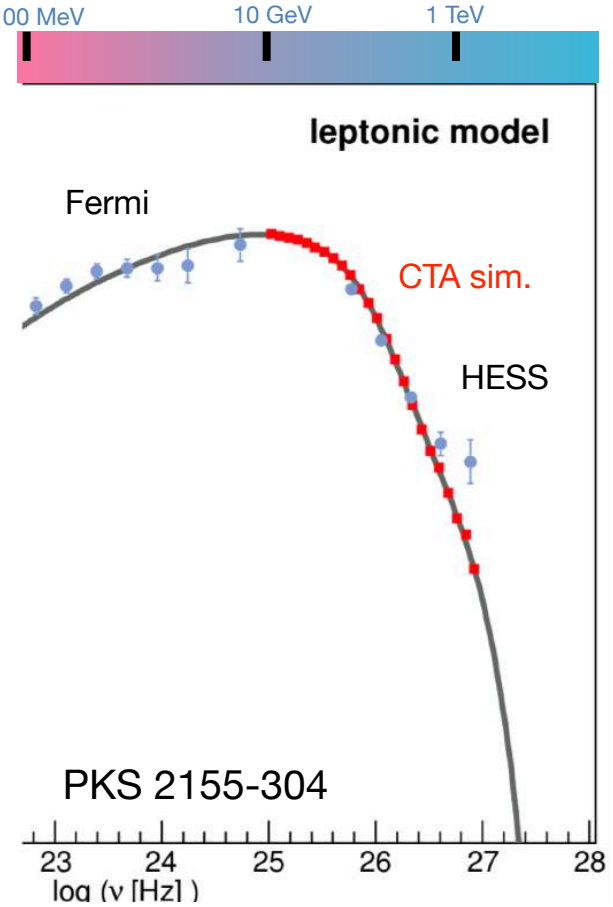
Takahashi et al. 2012



PRECISION HIGH-ENERGY SPECTRA

Disentangling hadronic from leptonic scenarios for AGNs



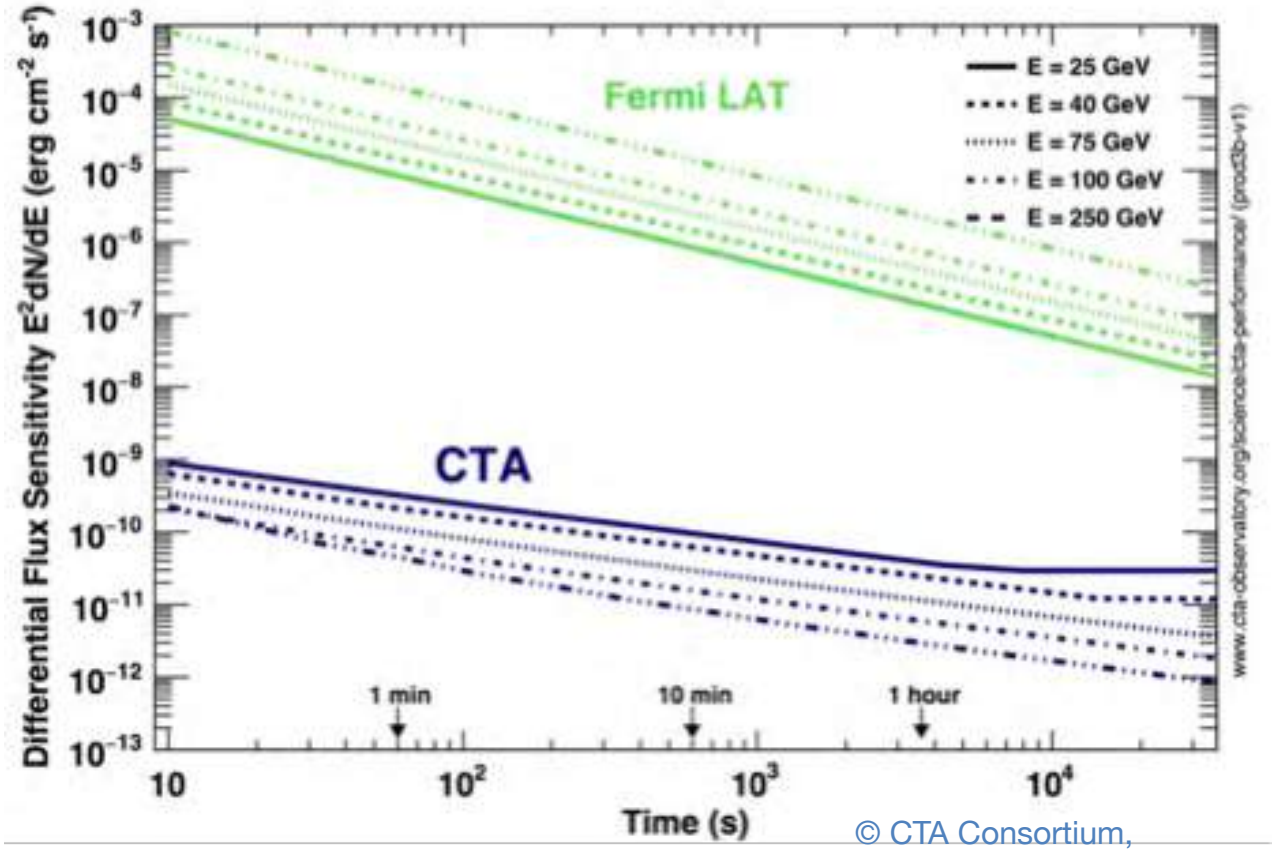


Zech, Cerruti et al. 2017
Acharya et al. 2017

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.

THE NEW WINDOW OF MULTI-MESSENGER ASTROPHYSICS!

Detection of a gravitational wave event following a GRB onset and MWL follow-up

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

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

THE THICK OF CTA SCIENCE

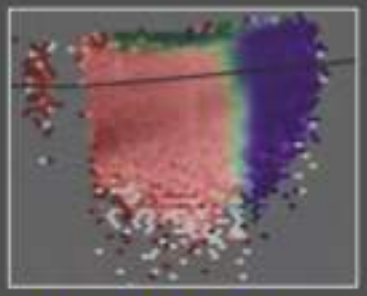
- Understanding the Origin and Role of Relativistic Cosmic Particles
  - What are the sites of **high-energy particle acceleration** in the universe?
  - What are the mechanisms for cosmic particle acceleration?
  - What role do accelerated particles play on star formation and galaxy evolution?
- Probing 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?

THE THICK OF CTA SCIENCE

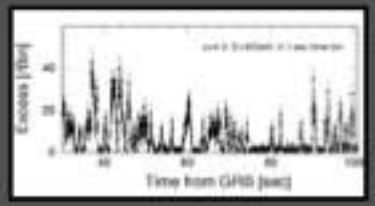
- Understanding the Origin and Role of Relativistic Cosmic Particles
- Probing Extreme Environments
- Exploring Frontier Physics

- 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

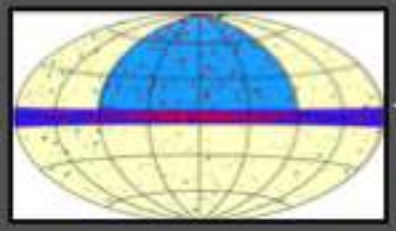
- Focuses on **major and legacy projects**
  — surveys and population studies for legacy catalogues and data sets
  — studies of sources as a class
  — plus focus on a few iconic objects



Dark Matter Programme



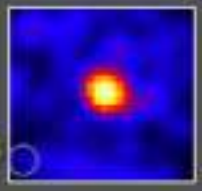
Transients



ExGal Survey

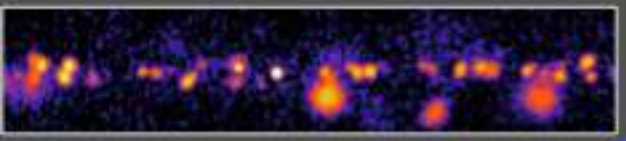
Extragalactic

Galaxy Clusters



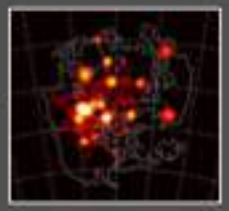
Star Forming Systems

AGN



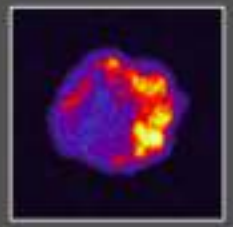
Galactic

LMC Survey

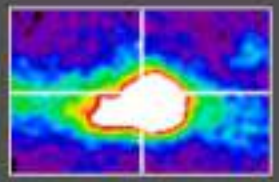


Galactic Plane Survey

PeVatrons

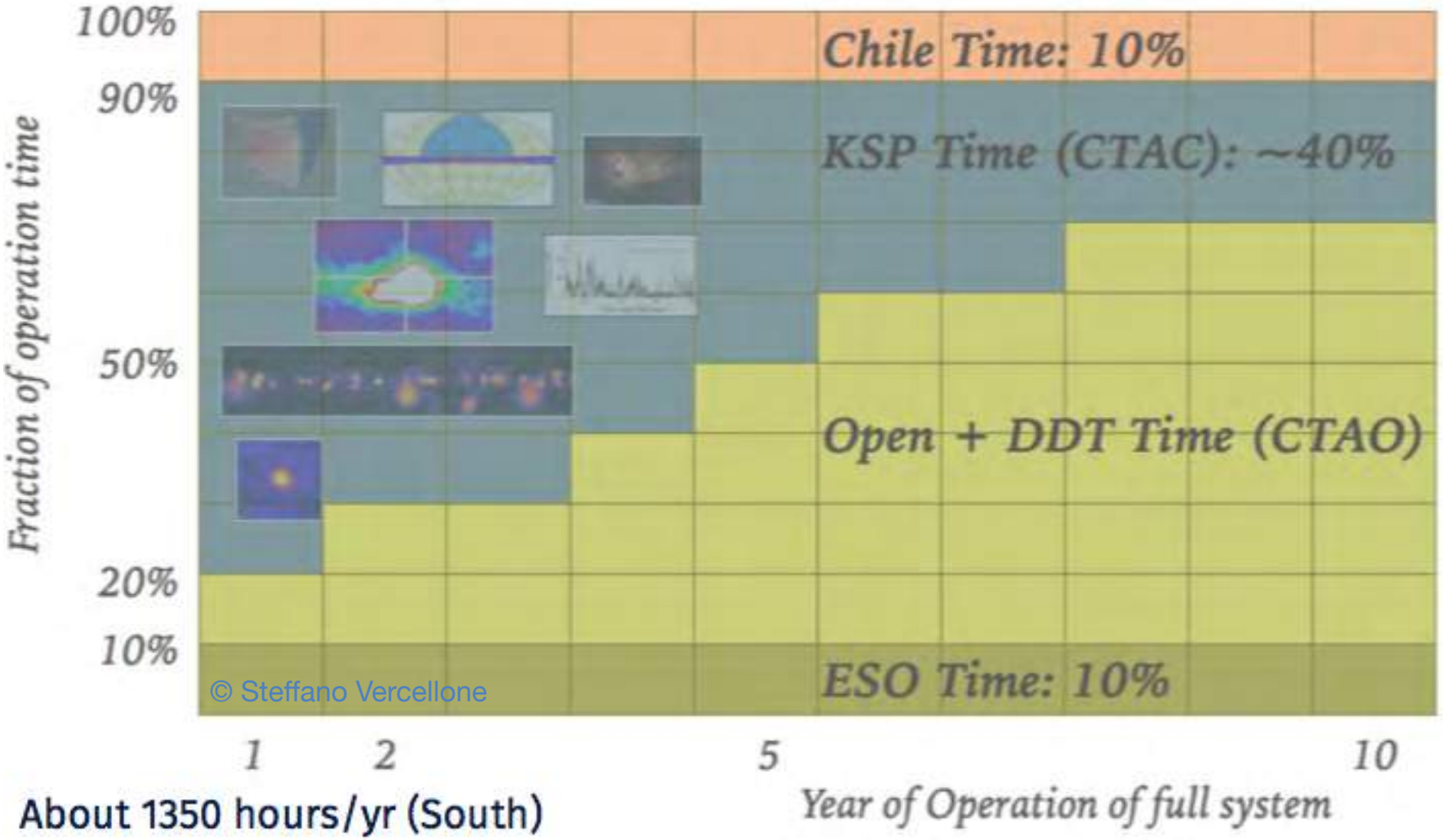


Galactic Centre Survey



cta
cherenkov telescope array

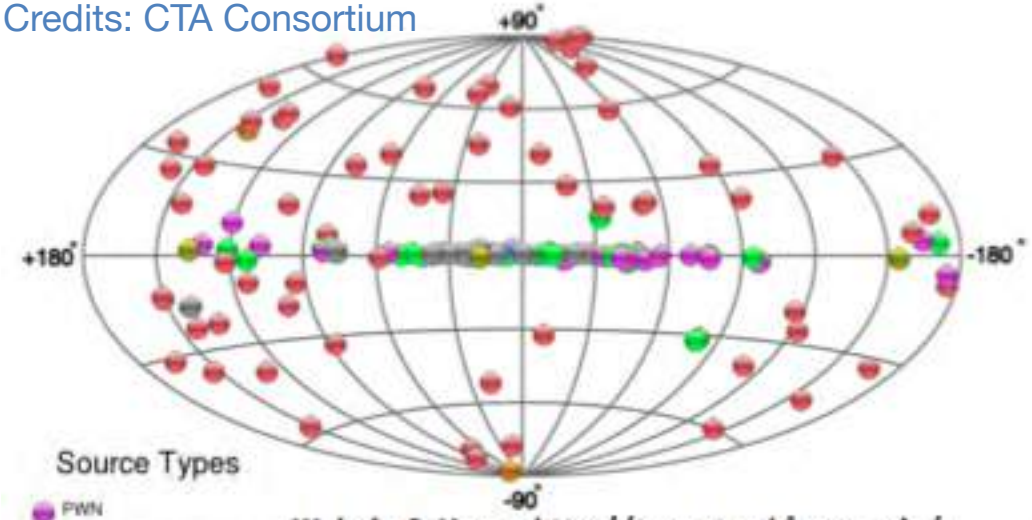
POSSIBLE KSP VS G.O. TIME BUDGET



About 1350 hours/yr (South)

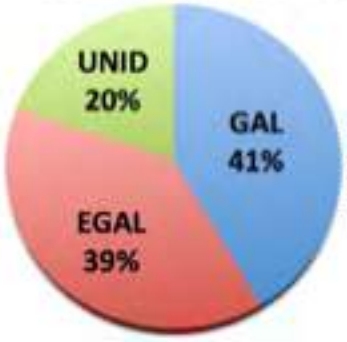
THE VHE SKY TODAY

Credits: CTA Consortium



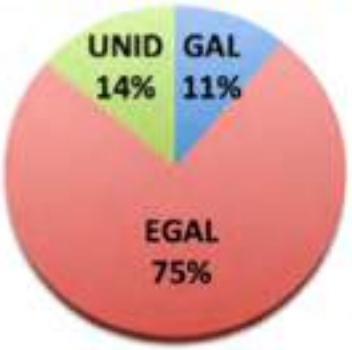
Wakely & Horan http://tevcat.uchicago.edu/

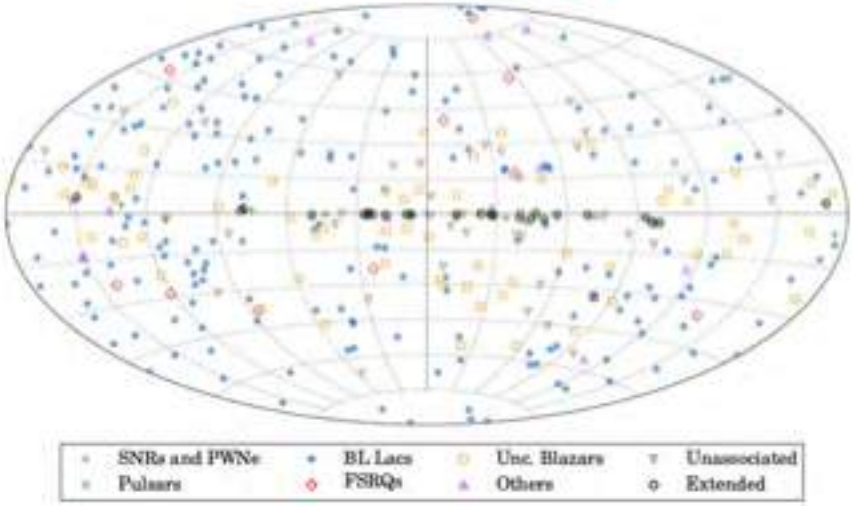
~180 TeVCat sources



H.E.S.S.
MAGIC
VERITAS

360 *Fermi*-LAT sources E>50 GeV



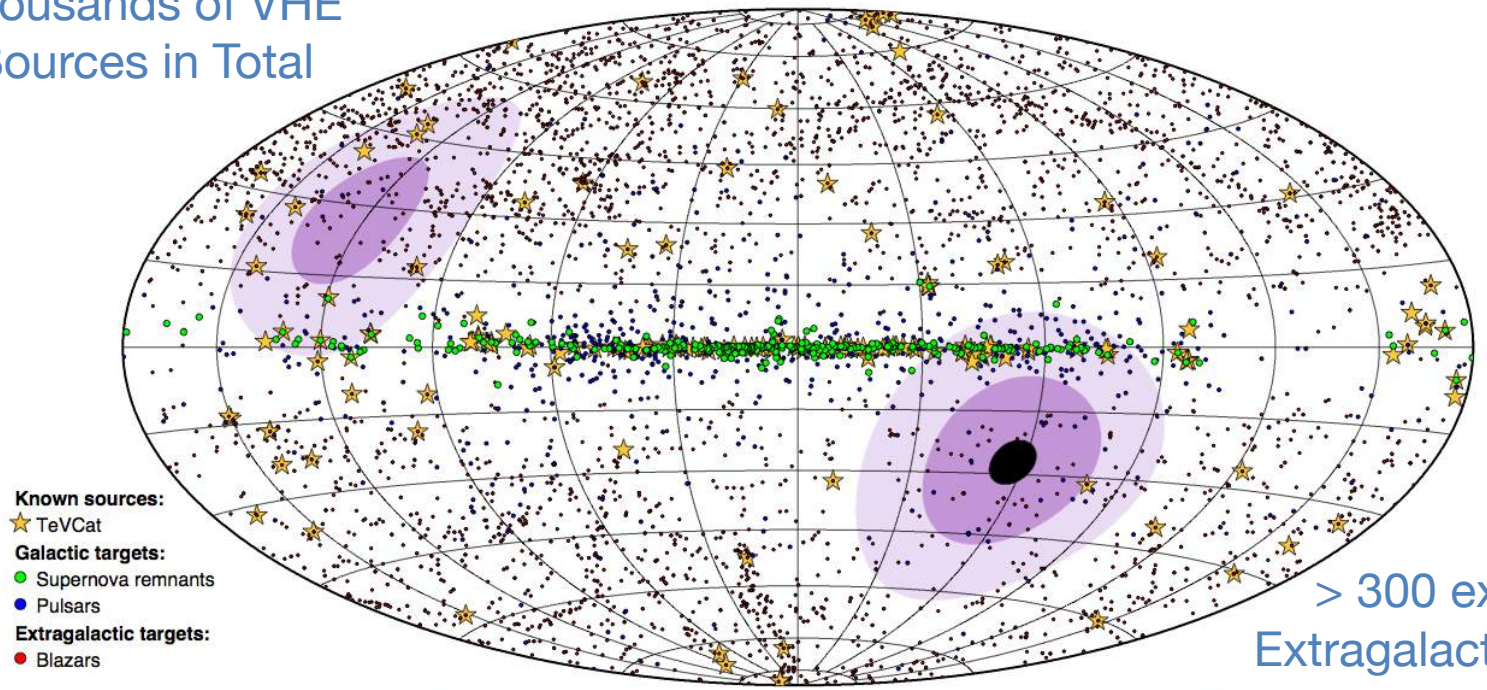


2FHL Ackermann+16

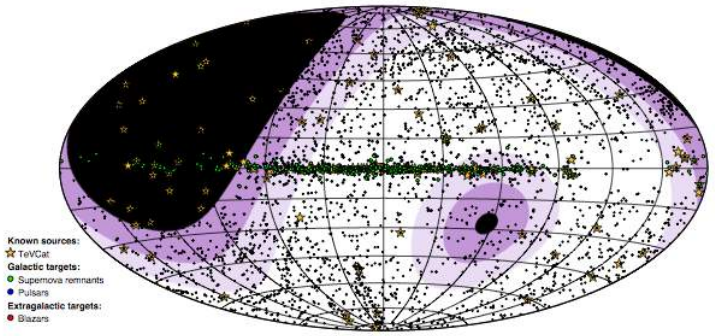
Only ~25% of the 2FHL sources have been previously detected by Cherenkov telescopes.
2FHL provides a reservoir of candidates to be followed up at very high energies.

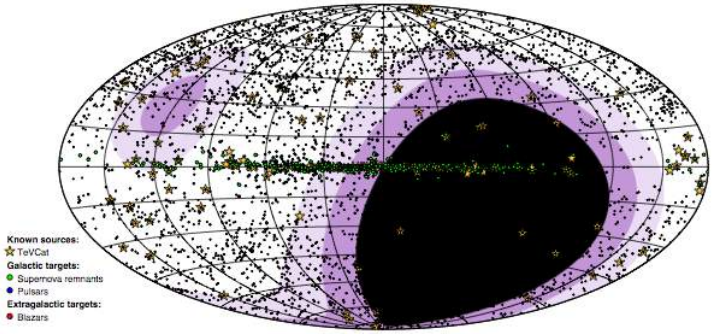
THE EXPECTED CTA ALL SKY VIEW

Thousands of VHE Sources in Total



> 300 expected Extragalactic Objects





Credits: CTA Consortium

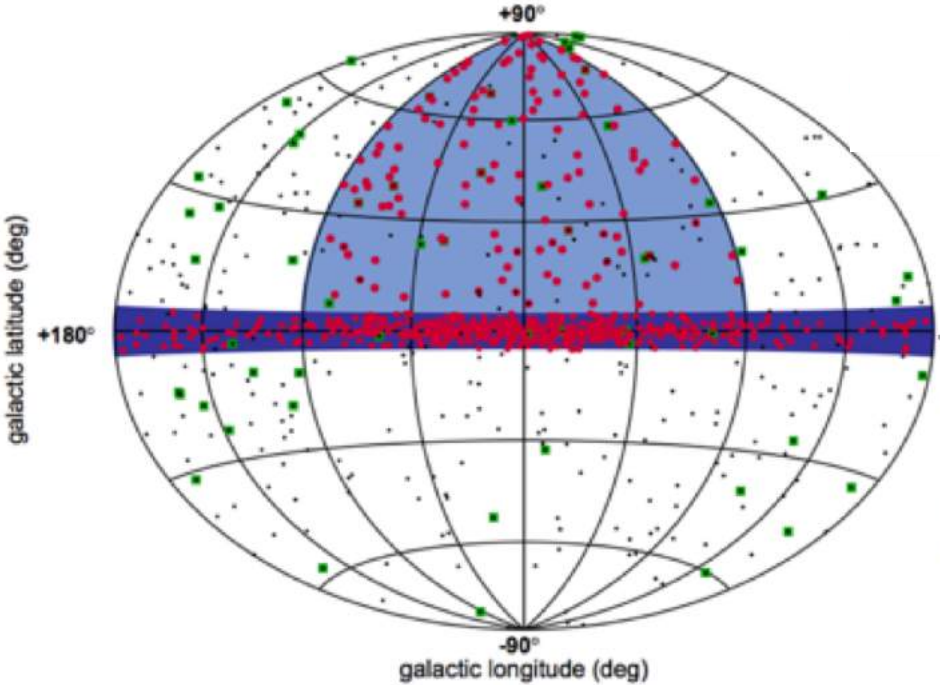
CTA EXTRAGALACTIC SURVEY

Unbiased survey of 1/4 sky to 6 mCrab

- performed above b > 5°, over galactic longitudes -90° < l < 90°
- region includes Virgo & Coma clusters, Fermi bubbles, and Cen A

— VHE population studies and their duty cycle;

— total time of about 1000 hours over 10 years;



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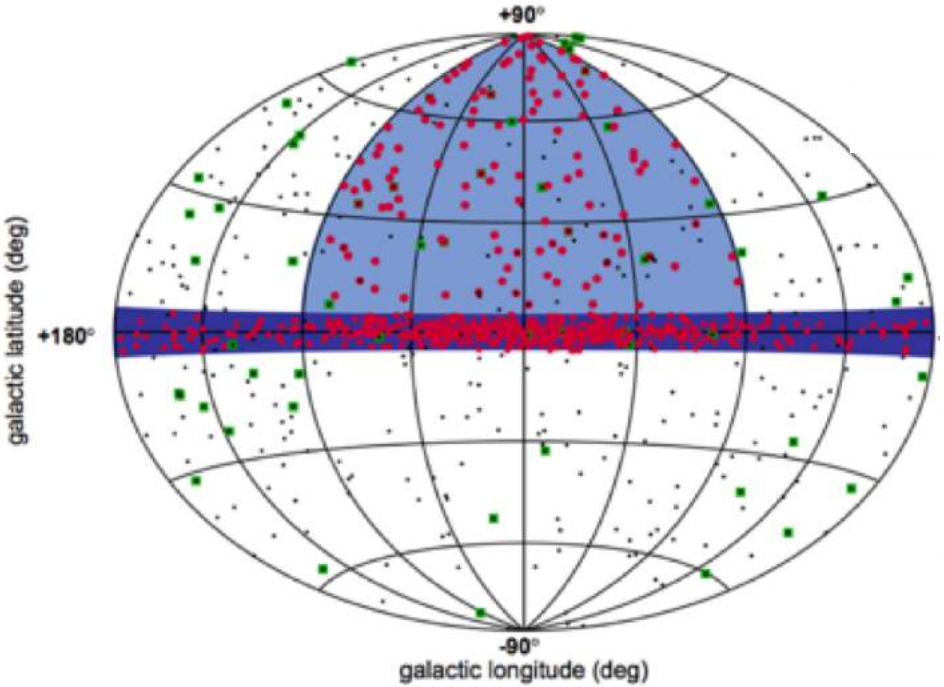

Aims:

- **unbiased determination of logN-logS of gamma-ray AGN (BL LACs + FSRQ)**
- **discovery of extreme blazars peaking in the 100 GeV - 1 TeV region**
- serendipitous detection of fast flares (hours) unseen by Fermi-LAT and HAWC
- discovery of gamma-ray emission from new classes like Seyferts and ULIRGs
- discovery of dark sources with no astrophysical counterparts
- detection of gamma-ray bursts (GRBs) in prompt phase at VHEs (a hard one!)
- study of large scale anisotropies in the electron spectrum beyond 100 GeV

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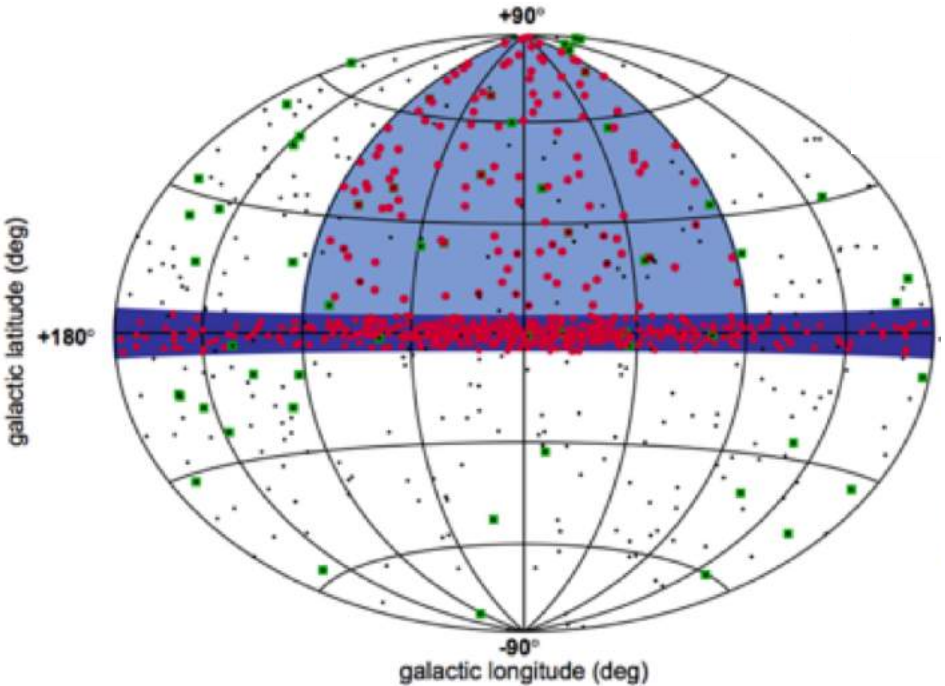
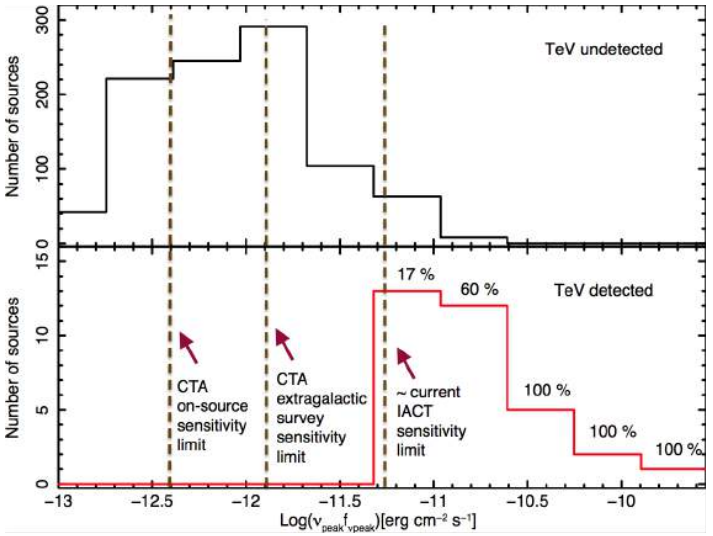
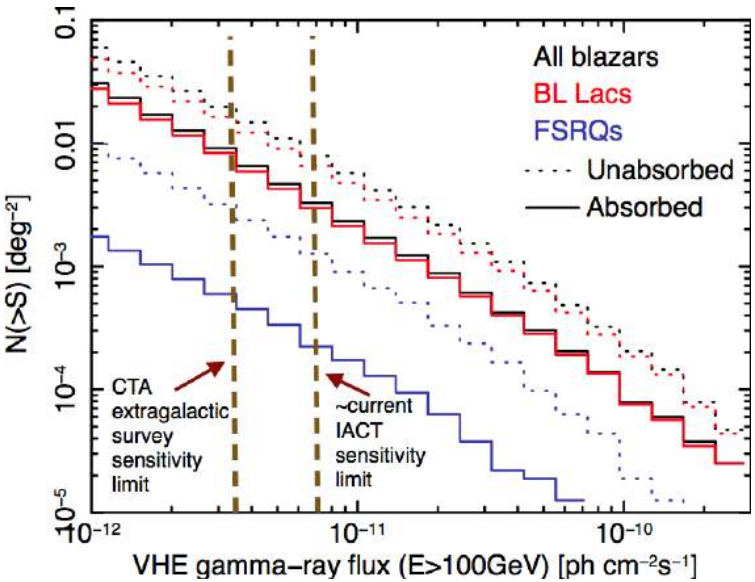
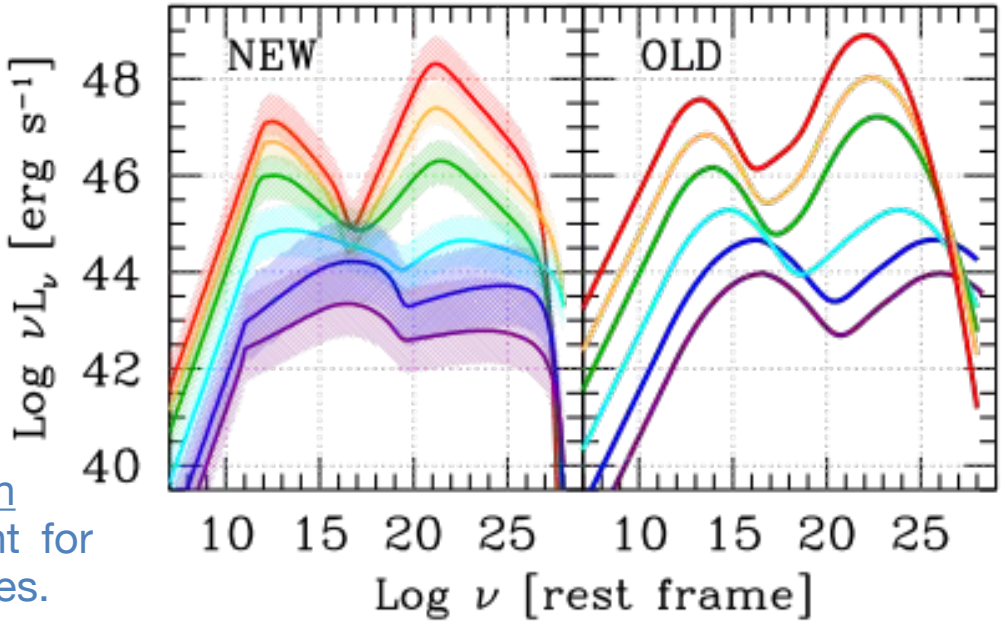






QUEST FOR EXTREME BLAZARS

Discovery of extreme blazars peaking in the 100 GeV - 10 TeV region



The Fermi blazer sequence
Ghisellini et al. 2017

Definition: Sy peak in excess of 1E17 Hz (Costamante 2001)

These are prime sources in terms of population studies for CTA, as they would be important for EBL and IGMF studies, peaking at VHE energies.

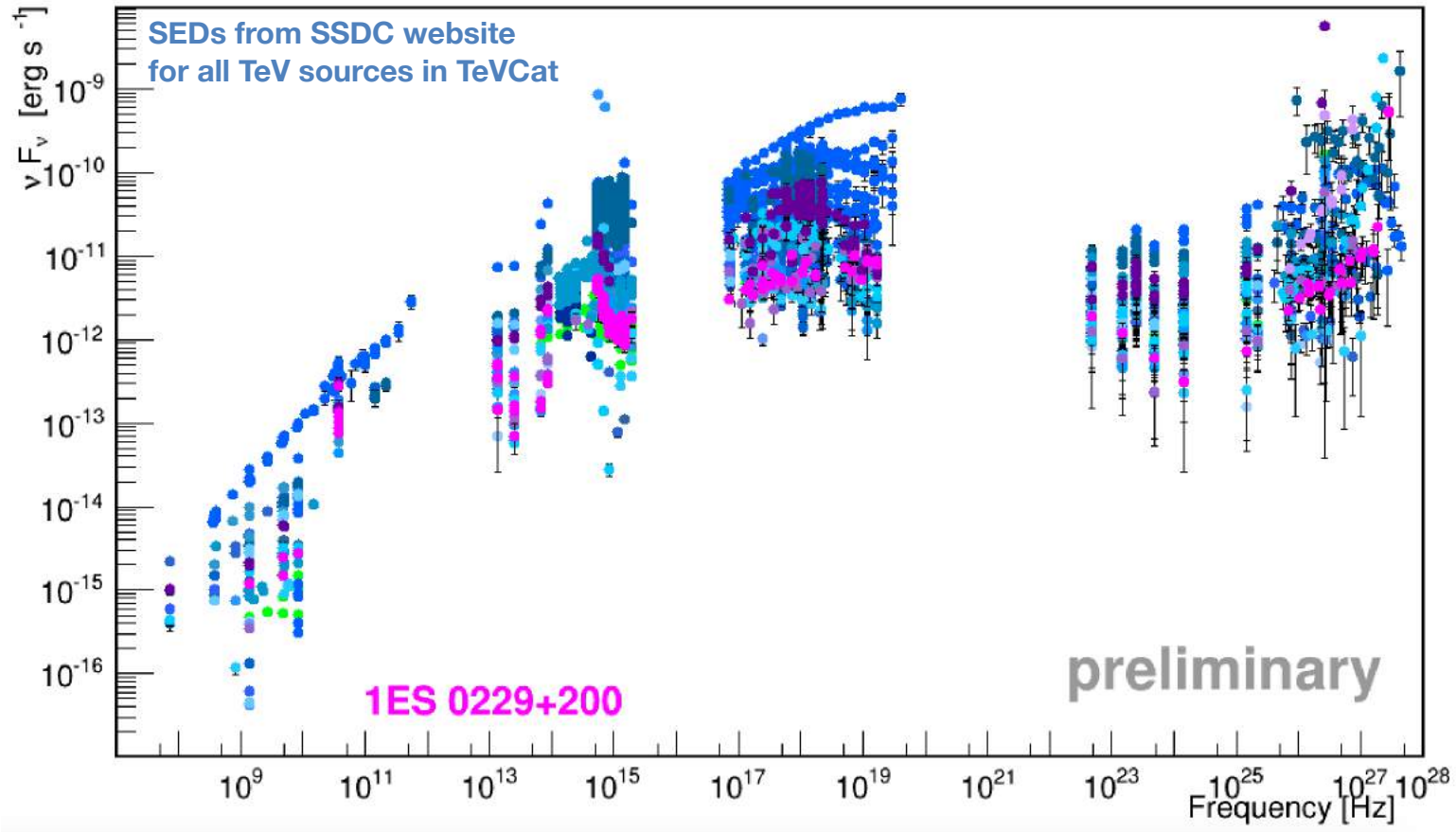
Concerning AGN science, EHBLs must either have strong **hadronic component** or operate under unusual **deep Klein-Nishina regime**.

Examples: Mkns 421 and 501, 1ES 0229+200 all of which have quiescent fluxes ~ 200 mCrab >> 6 mCrab sensitivity of CTA
=> 200x larger volume space for searches.

QUEST FOR EXTREME BLAZARS

Can appear as hard TeV sources, but also as weak HBLs in the Fermi bands, which makes them a population at the edge of detectability, from which is hard to extrapolate predictions.

25 sources classified as EHBLS seem at VHE



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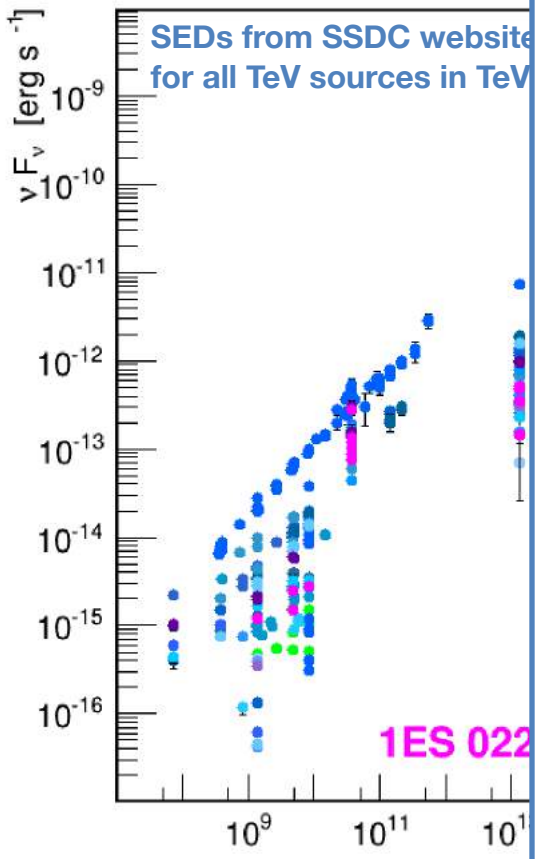


MAGIC detects an unprecedented activity from the blazar 1ES 1218+304 at very high energy gamma rays

ATel #12354; **Razmik Mirzoyan on behalf of the MAGIC Collaboration**

on **3 Jan 2019; 22:11 UT**

Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Blazar

Referred to by ATel #: 12360, 12365

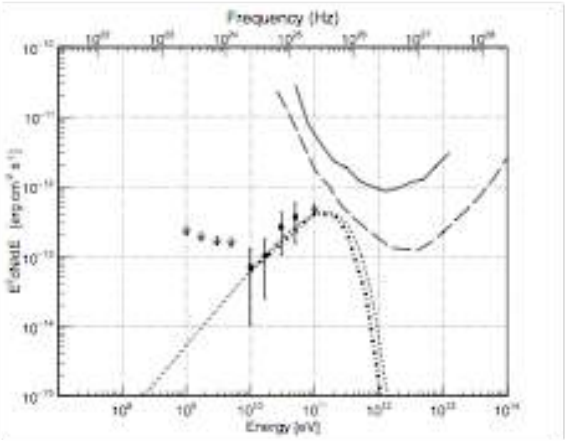
The MAGIC telescopes have observed unprecedented level of very-high-energy (VHE; >100 GeV) gamma-ray flux from 1ES 1218+304 (12h21m21.941s, +30d10m37.11s, J2000.0). The preliminary analysis of the data from 2018/12/31 to 2019/01/02 indicates a VHE gamma-ray flux reaching the level of ~25 % of the flux from the Crab nebula above 100 GeV. Compared to the quiescent state reported by VERITAS, this implies an increase by a factor of ~4. The previous record of VHE gamma-ray flux of this source was ~20% of the flux from the Crab nebula above 100 GeV. It was measured by VERITAS on the night of 30 January 2009 (2010ApJ,709L, 163A). 1ES 1218+304 is a high-synchrotron-peaked BL Lac object located at redshift z=0.182. It was first recognized as a

QUEST FOR EXTREME BLAZARS

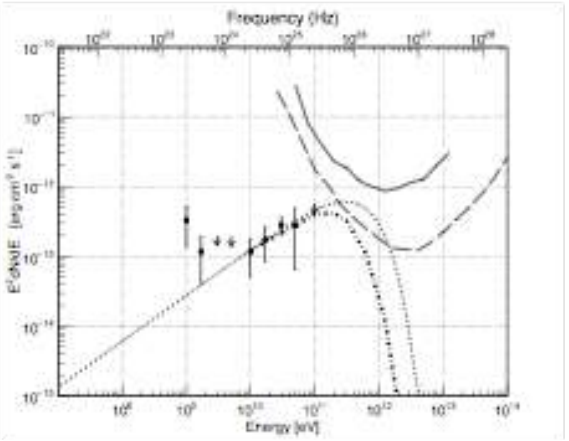
Catalogues such as the 1BIGB (Arsioli et al. 2017, 2018) contain 150 extragalactic EHSP candidate sources, at the limit of Fermi-LAT detectability and provide a guide for targeted searches with CTA.

Arsioli et al. 2018

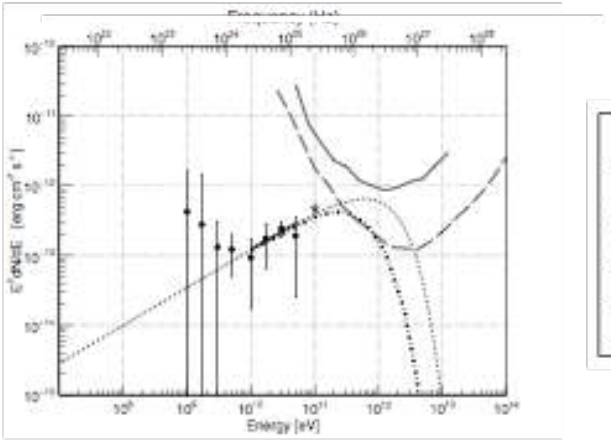
Fermi plays an important role in selecting candidate targets, specially faint objects



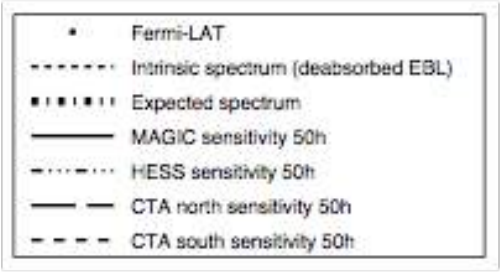
(c) 1BIGB J220155.8−170700 extrapolated with power-law and cut-off at 150 GeV.



(d) 1BIGB J151041.0−333503 extrapolated with power-law and cut-off at 300 GeV.



(e) 1BIGB J090802.2−095936 extrapolated with power-law and cut-off at 600 GeV.

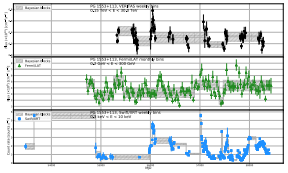


(f) Legend.

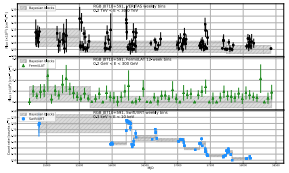
CURRENT VHE LIST & VIEW

Systematic view provided by MAGIC and VERITAS, which have been observing EHBLs systematically for almost a decade.

PG 1553+113



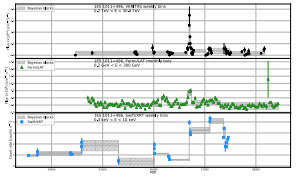
RGB J0710+591



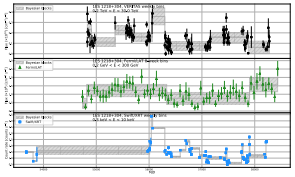
VERITAS EHBL Monitoring List

See Gueta's talk on Tuesday!

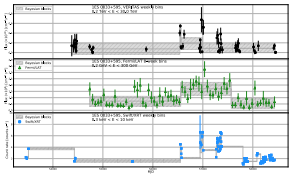
1ES 1011+496



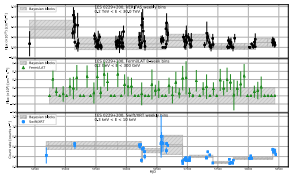
1ES 1218+200



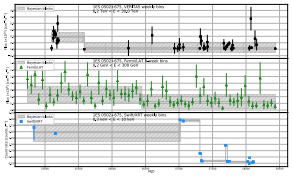
1ES 0033+595



1ES 0229+200



1ES 0502+675



Source	z	FoM	
TXS 0210+515	0.049	1.3	a
1ES 0229+200	0.139	2.0	
PGC 2402248	0.065	1.0	a,b
TXS 0637-128	---	2.5	
BZB J0809+3455	0.083	0.3	
RBS 0723	0.198	1.3	a
1ES 0927+500	0.187	1.0	
RBS 0921	0.236	0.6	
1ES 1426+428	0.129	4.0	
1ES 2037+521	0.053	0.5	a
RGB J2042+244	0.104	0.8	
RGB J2313+147	0.163	0.3	

a) New TeV emitter

b) Not included in population study

MAGIC EHBL Observation Log!

See Vandad's talk on Tuesday!

CURRENT VHE LIST & VIEW

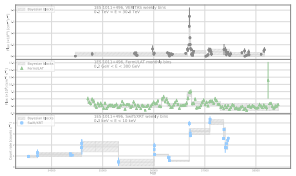
Systematic view provided by MAGIC and VERITAS, which have been observing EHBLs systematically for almost a decade.

NOTE 1: CTA extragalactic survey will provide an unbiased population search, but a good source-candidate list is fundamental to establish the class up start once CTA becomes operational

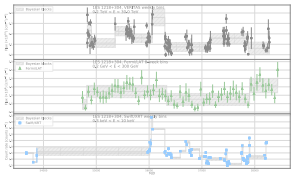
Source	z	FoM	
TXS 0210+515	0.049	1.3	a
1ES 0229+200	0.139	2.0	
PGC 2402248	0.065	1.0	a,b
TXS 0637-128	---	2.5	
BZB J0809+3455	0.083	0.3	
RBS 0723	0.198	1.3	a
1ES 0927+500	0.187	1.0	
RBS 0921	0.236	0.6	

Tuesday!

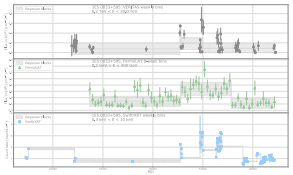
1ES 1011+496



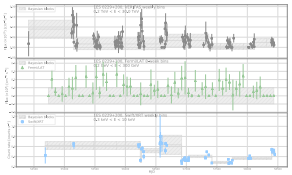
1ES 1218+200

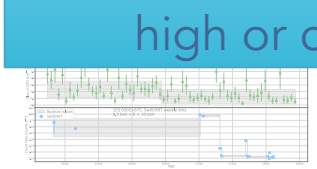


1ES 0033+595



1ES 0229+200





NOTE 2: Follow-up and monitoring of the candidate sources is essential to nail down the class and, e.g. if the EHBL character is a permanent "state" of the these sources, or a transient property associated to high or certain transient states of activity.

b) Not included in population study

MAGIC EHBL Observation Log!

See Vandad's talk on Tuesday!

THANK YOU

ulisses@cbpf.br

www.cta-observatory.org