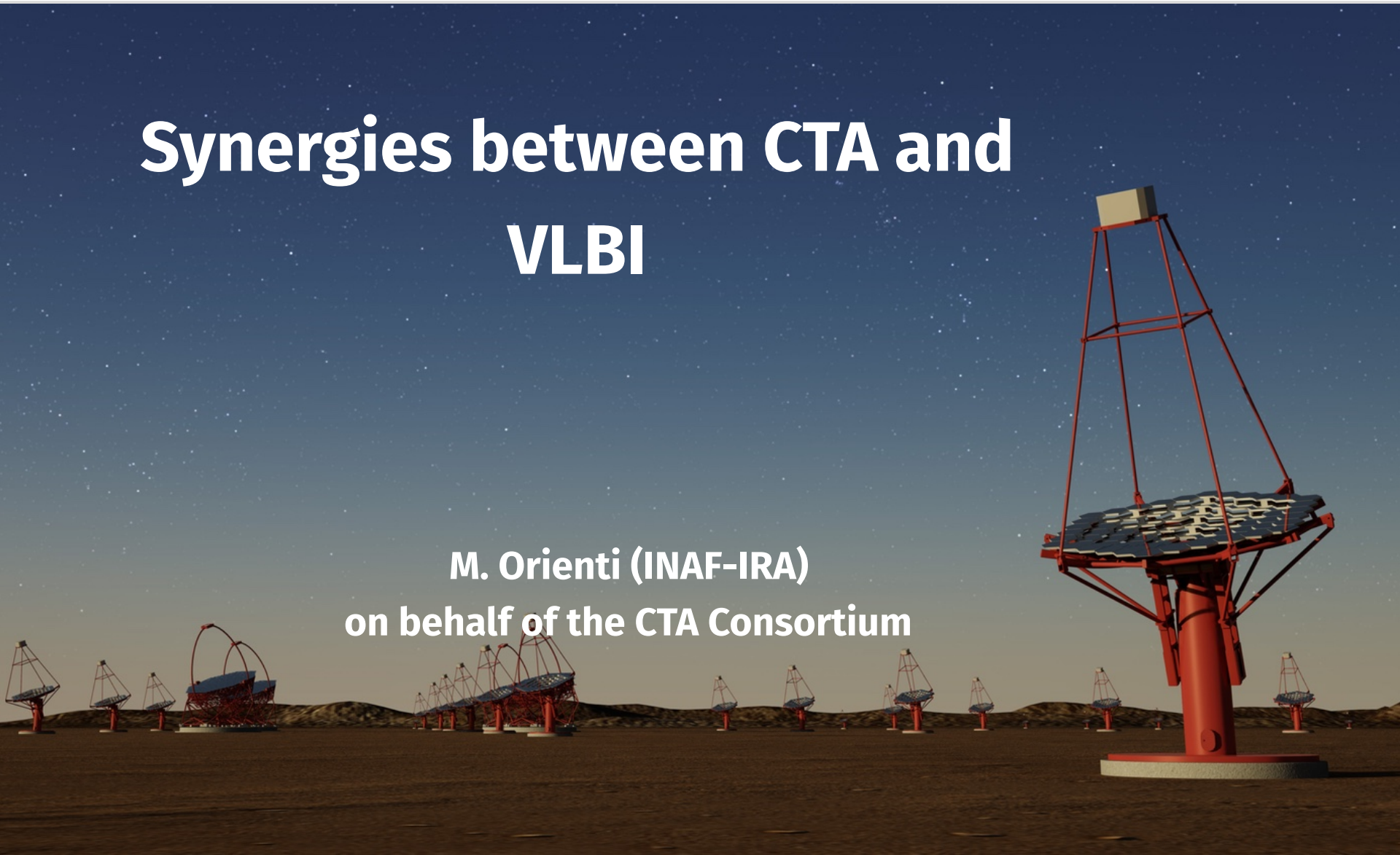
cherenkov telescope array

RadioNet

Synergies between CTA and VLBI

M. Orienti (INAF-IRA)
on behalf of the CTA Consortium



Outline

- The Cherenkov Telescope Array
- Science with CTA
- Synergies between CTA and VLBI

Background

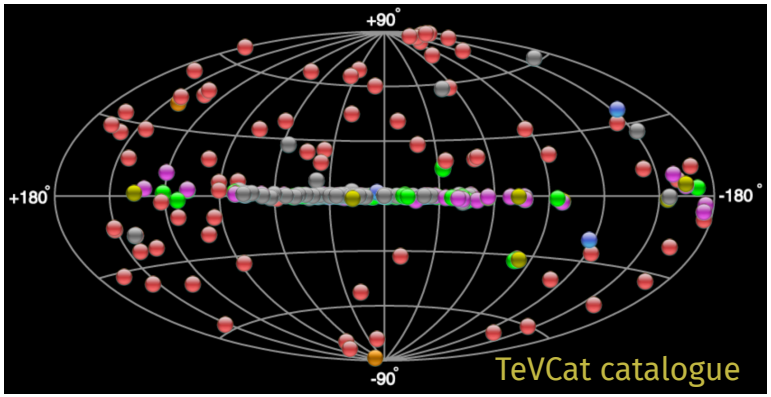
The gamma-ray sky provides a look into the most energetic and violent processes of the universe.

About 215 objects are in the TeVCat (~30% unidentified)

Ground-based gamma-ray astronomy is a young field with enormous scientific potential.

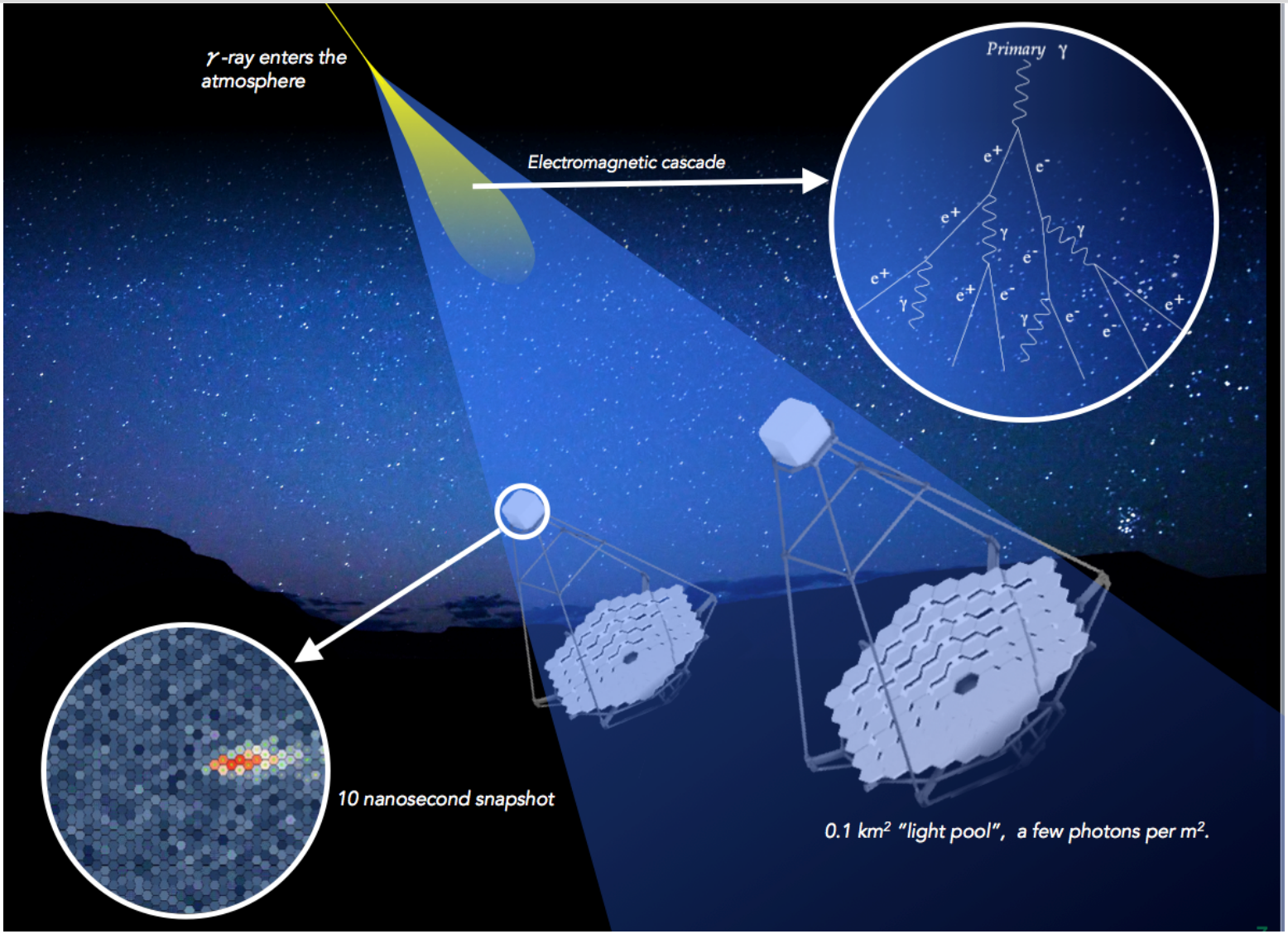
CTA will represent the next generation ground-based gamma-ray observatory and, in combination with multi wavelength and multi messenger studies, will address many of the open questions concerning non-thermal phenomena.

CTA will be the first **open, proposal-driven** ground-based gamma-ray observatory



http://tevcat.uchicago.edu/

How CTA works



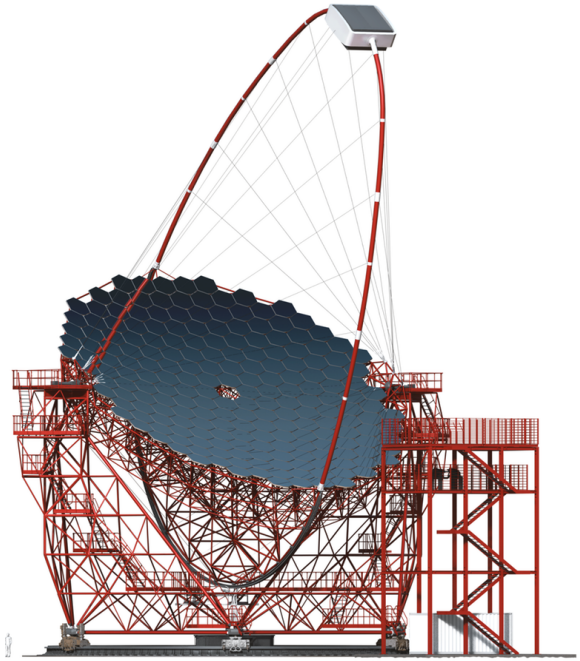
CTA Consortium

CTA Consortium is currently responsible for directing the science goals of the observatory and is involved in the array design and supplying components.

~1420 members, >200 institutes, 31 countries.

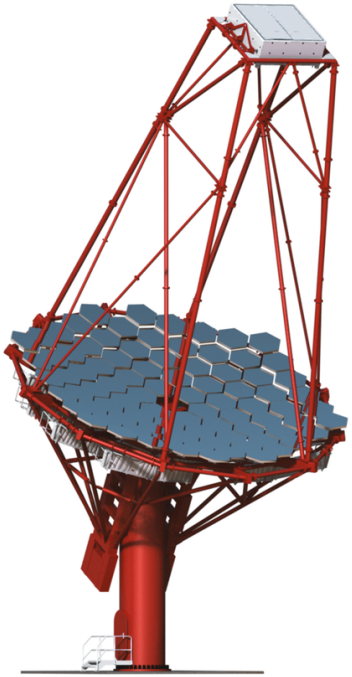
CTA Telescopes

LST



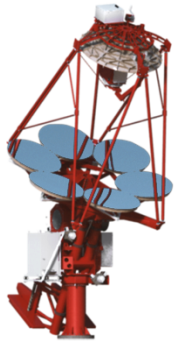
E: 20 GeV - 150 GeV
D: 23.0m
FoV: 4.3 deg
Pointing: 30s

MST

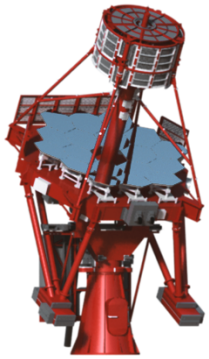


E: 150 GeV - 5 TeV
D: 11.5m
FoV: ~7.5 deg
Pointing: 60s

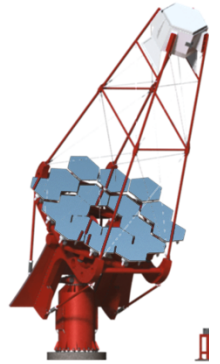
SST



SST-2M GCT



SST-2M ASTRI



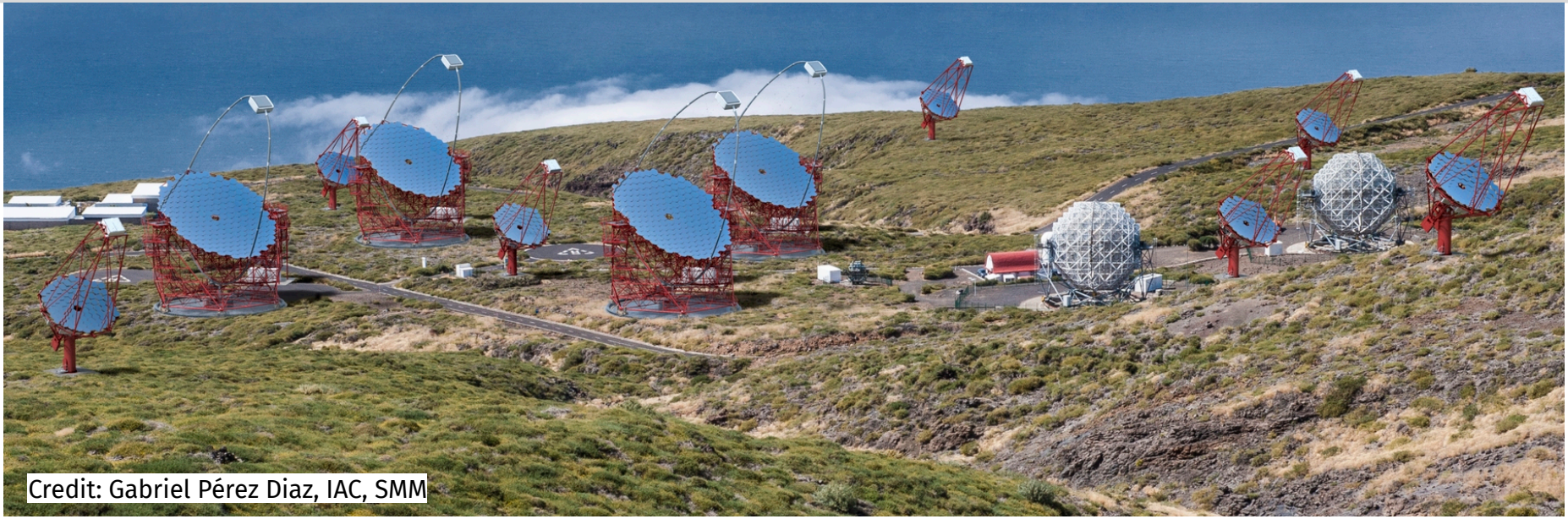
SST-1M

E: 5 TeV - 300 TeV
D: 4m
FoV: ~9 deg
Pointing: 60s

CTA sites


Heidelberg
MPIK
Zeuthen
DESY
Spain
La Palma
CTA North
Bologna
INAF
northern hemisphere
southern hemisphere
CTA South
Chile
Paranal
La Palma Map: ©2015 Google, Inst. Geogr. Nacional
Paranal Map: ©2015 Google
Array Sites
CTAO Offices
Science Data Management Centre

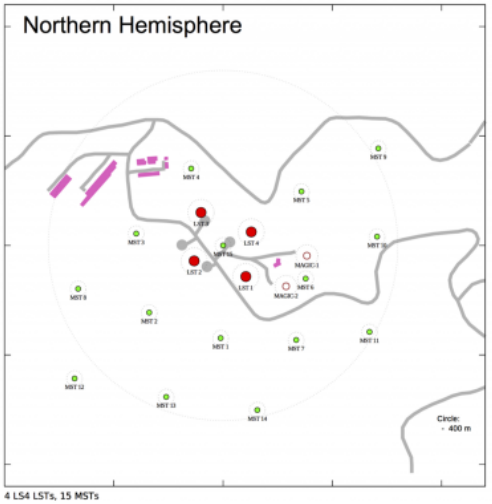
CTA North - La Palma


Credit: Gabriel Pérez Diaz, IAC, SMM

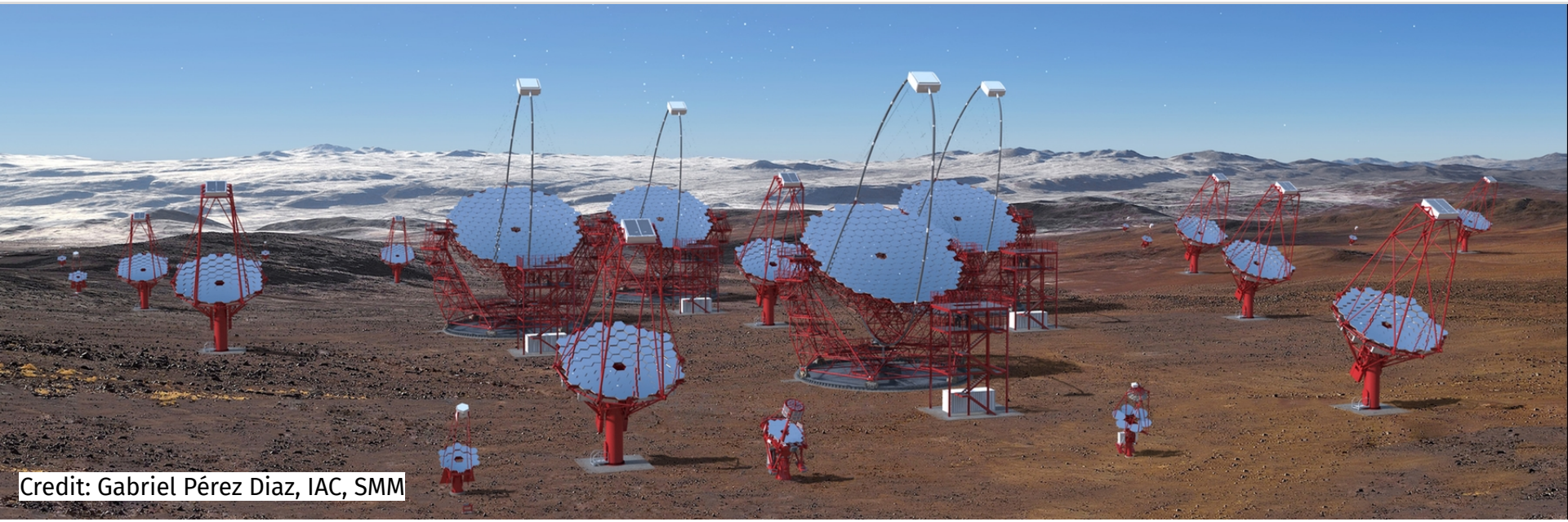
Energy range: 20 GeV - 20 TeV

4 LST; 15 MST spread over ~1 km^2

Galactic and Extragalactic science



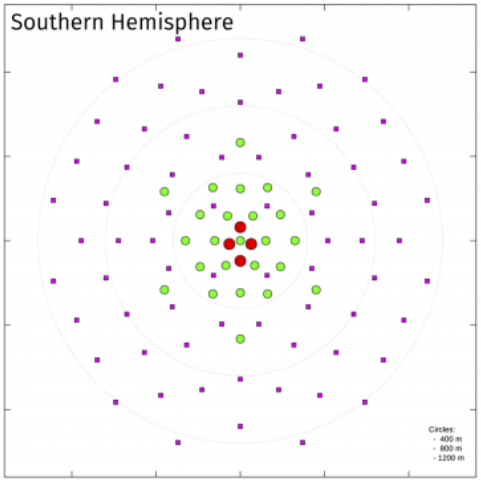
CTA South - Chile



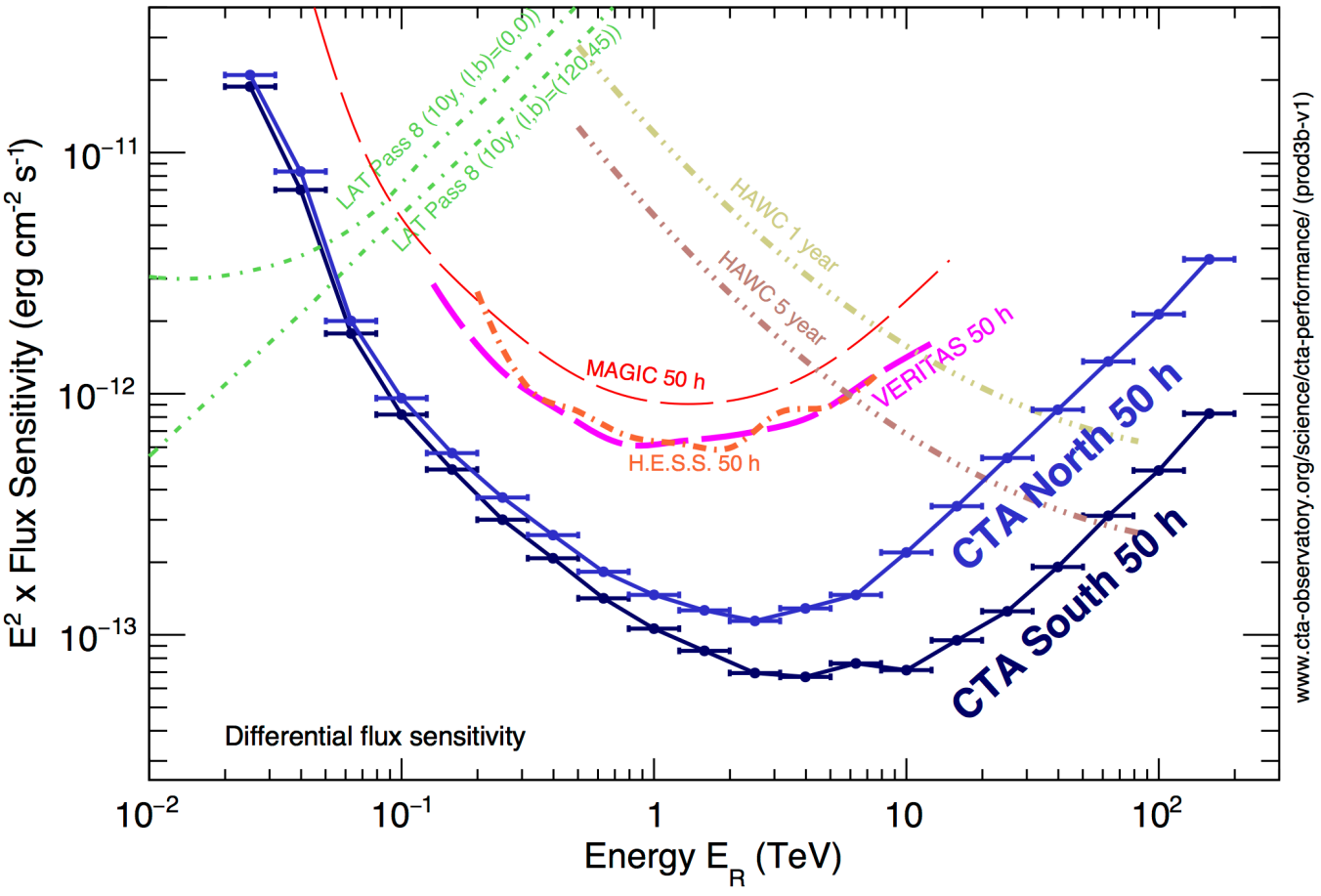
Energy range: 20 GeV - 300 TeV

4 LST; 25 MST; 70 SST spread over ~ 4 km^2

Galactic and Extragalactic science

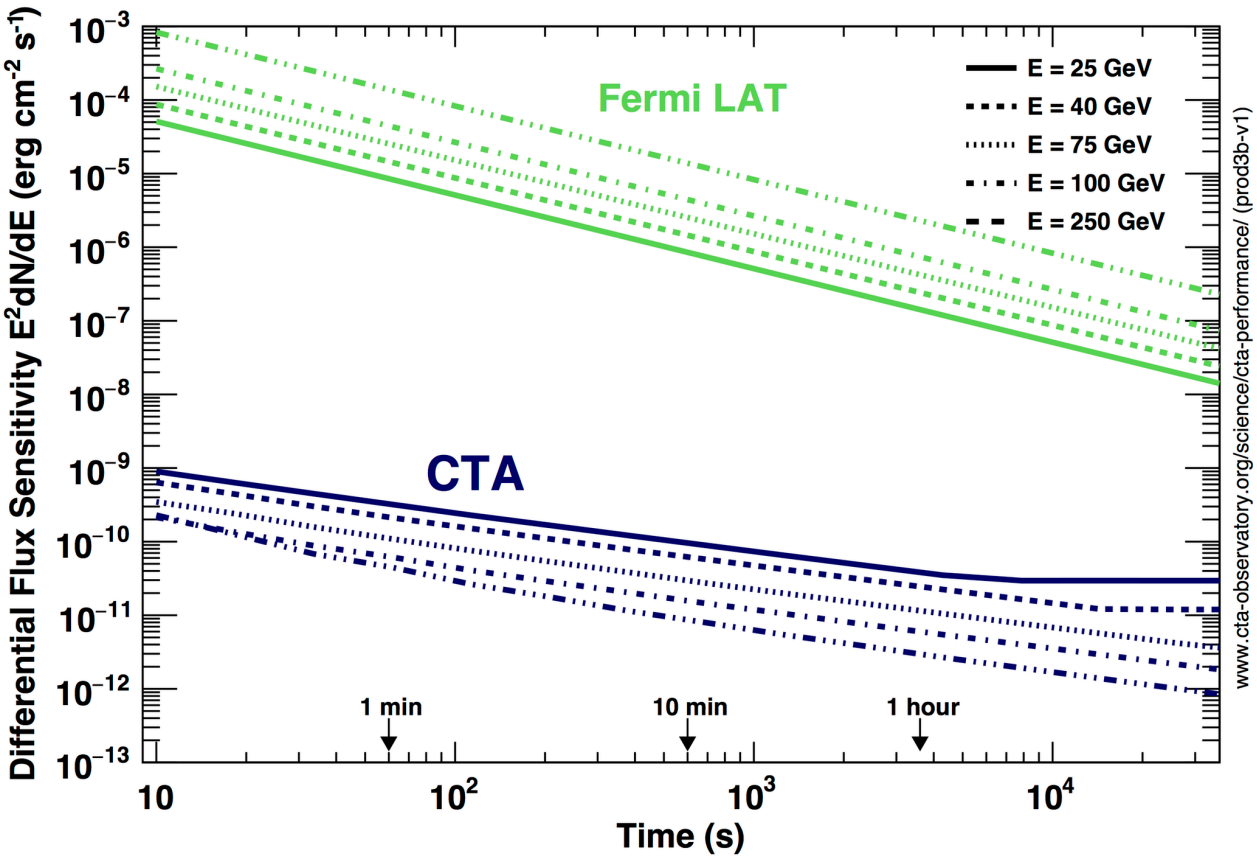


CTA Performance - Flux Sensitivity



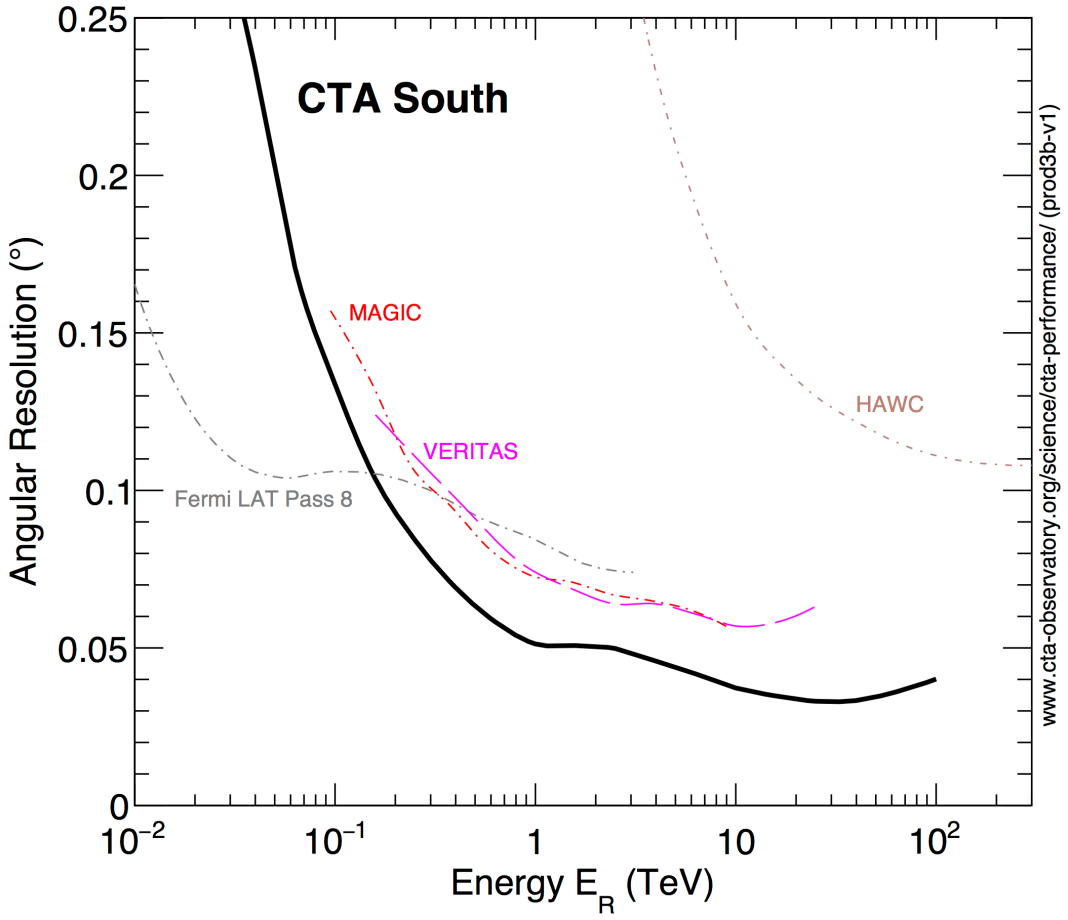
Significant sensitivity improvement and wider energy range

CTA Performance - Sensitivity vs Time



Huge sensitivity improvement for short timescale phenomena

CTA Performance - Angular resolution



Substantial angular resolution and field of view improvements

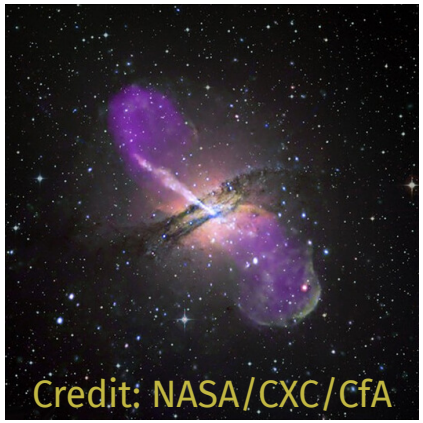
Science with CTA

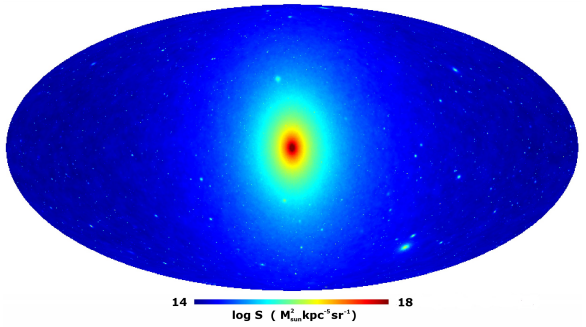
arXiv:1709.07997v2

https://arxiv.org/abs/1709.07997

CTA Science Themes

- **Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles**
  - How and where are particles accelerated?
  - How do they propagate?
  - What is their role on star formation and galaxy evolution?
- **Theme 2: Probing extreme environments**
  - Physical processes close to neutron stars and black holes
  - Characteristics of relativistic jets, winds and explosions
  - Radiation fields and magnetic fields in cosmic voids and their evolution
- **Theme 3: Exploring frontiers in Physics**
  - Nature and distribution of dark matter
  - Quantum gravitational effects on photon propagation
  - Do axion-like particles exist?

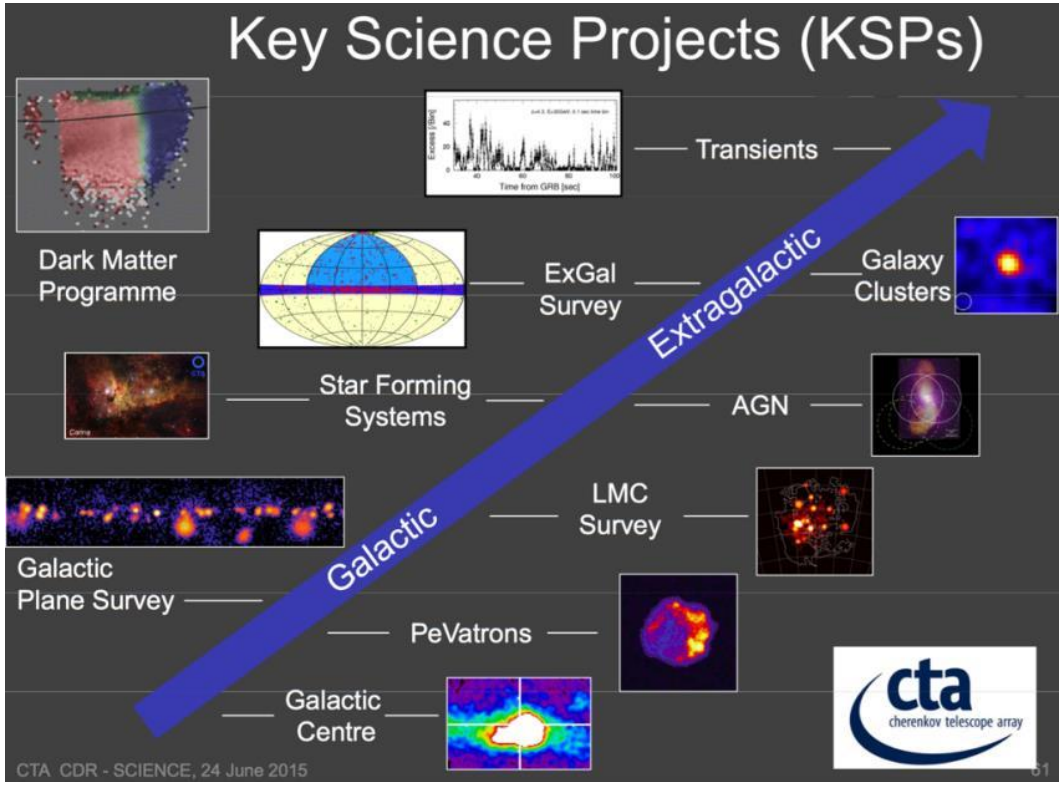




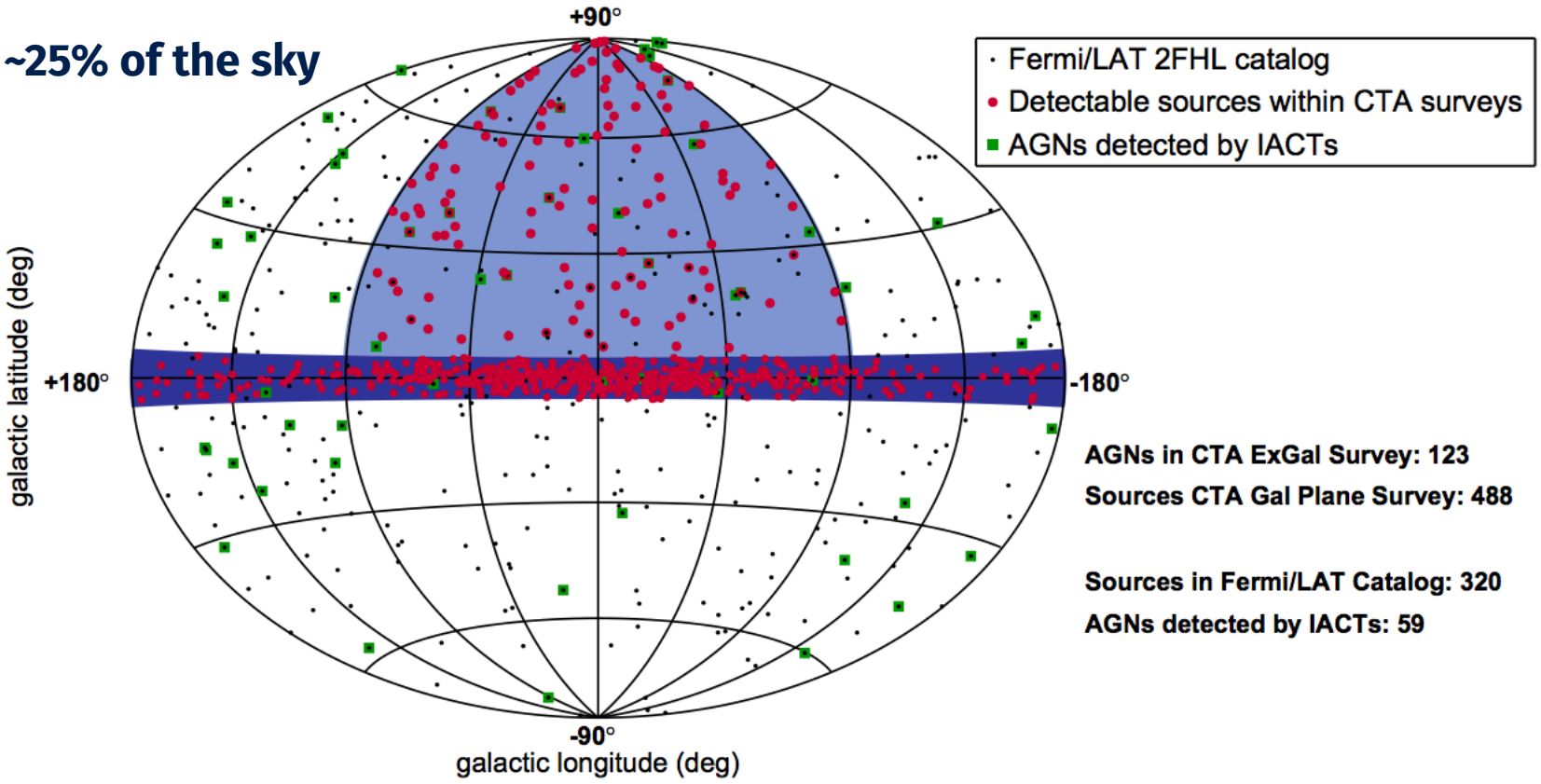
Credit: Aquarius Project of Virgo Consortium

Key Science Projects

- Galactic centre
- Galactic Plane
- Large Magellanic Cloud
- Cosmic Ray PeVatrons
- Star forming systems
- **Extragalactic Survey**
- Galaxy clusters
- **Active Galactic Nuclei**
- **Transient Phenomena**
- Dark Matter programme

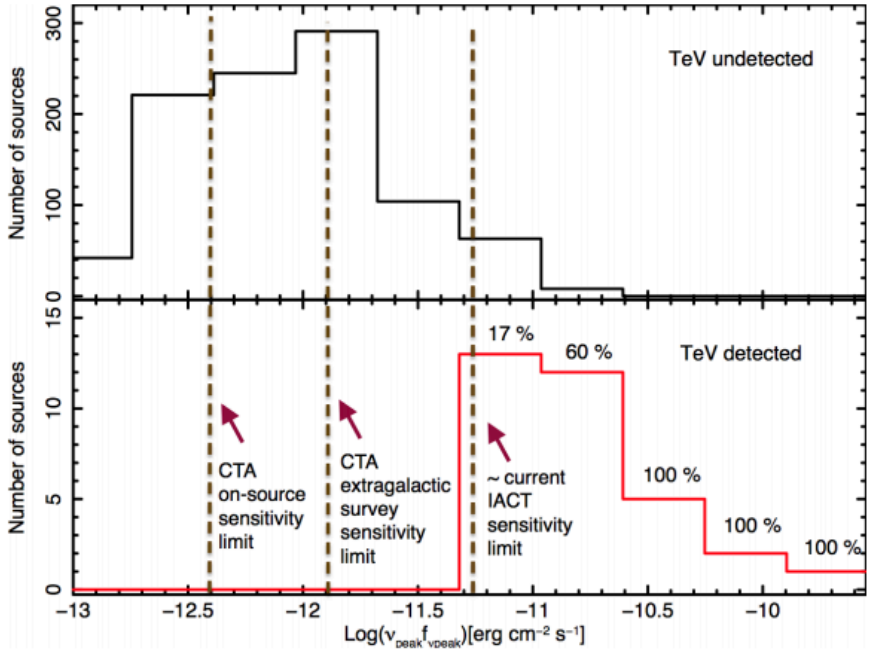


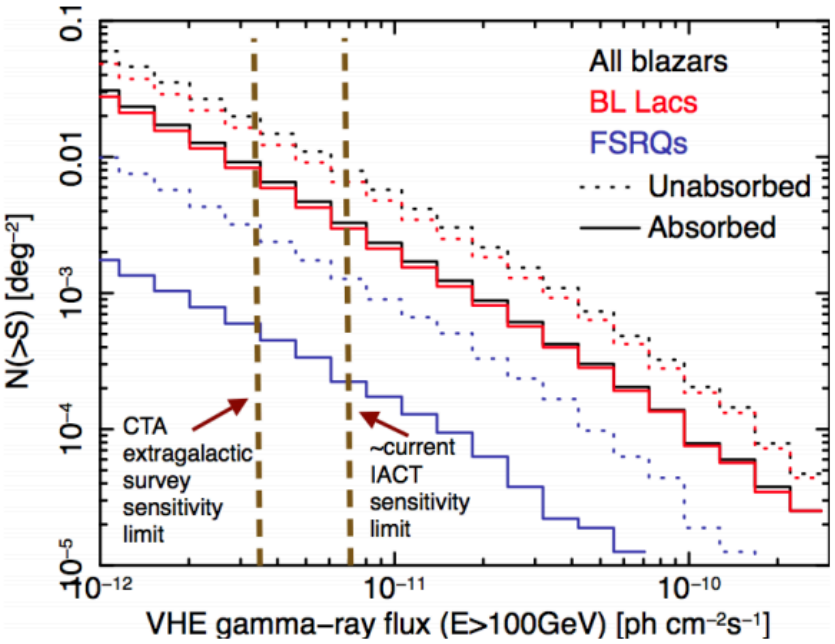
Extragalactic Survey



Uniform sensitivity limit of **6 mCrab** at E>125 GeV in 1000 hr of observations

Extragalactic survey - goals



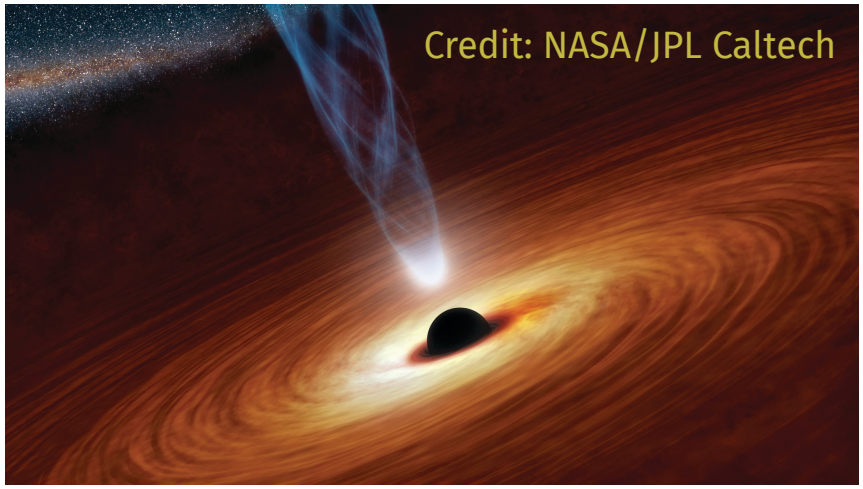


- Source population study of the local universe (z<0.2)
- Extreme blazar population
- Discovery of new source classes
- Fast flaring sources

Active Galactic Nuclei

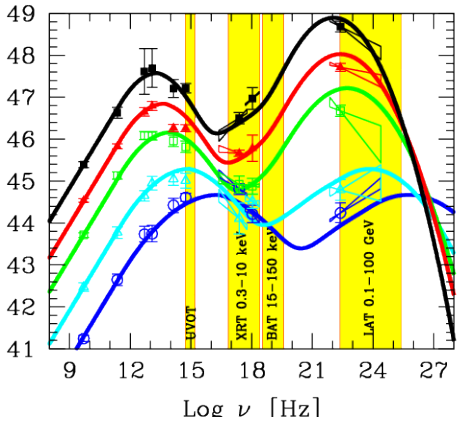
Radio-loud AGN represent a high fraction of gamma-ray emitting objects detected by Fermi-LAT and Cherenkov Telescopes.

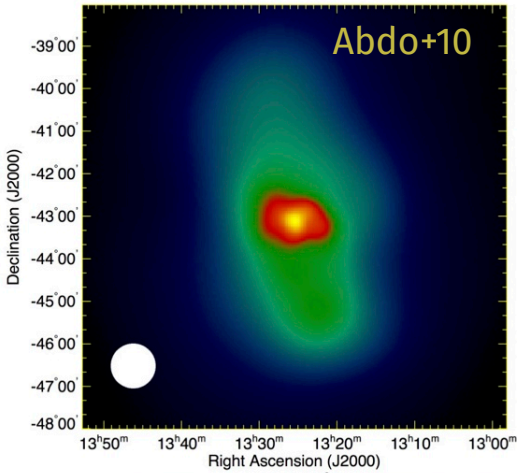
Their non-thermal emission is observed at all wavelengths and shows pronounced variability.



Open questions:

- Jet-disk coupling
- Gamma-ray emitting processes
- Gamma-ray emitting region
- Seed photon fields
- Extreme blazars





Active Galactic Nuclei

- **Long-term monitoring**

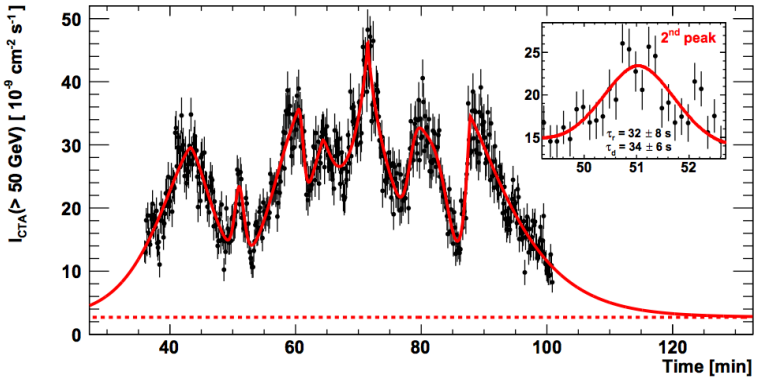
Long-term light curve and time-resolved spectra for ~15 sources representative of gamma-loud AGN population

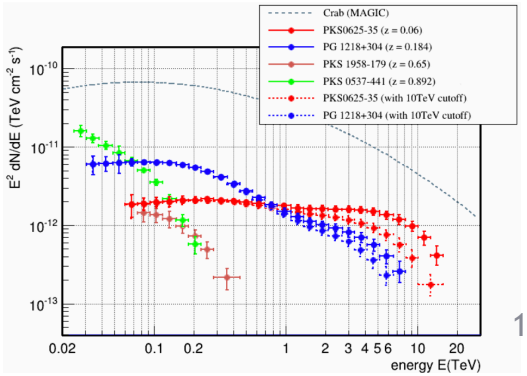
- **High-quality spectra**

High-quality spectra for ~40 sources with different redshift and AGN class and deep observations of Cen A and M87.

- **AGN flare programme**

Follow-up observations of AGN detected during a flare (external and self-triggered alerts) of a list of potential targets.





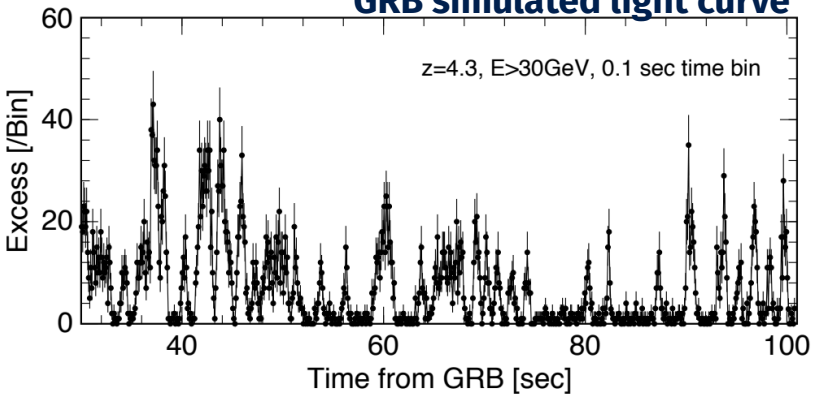
Transients

One of the most violent and energetic phenomena in the universe is represented by transients.

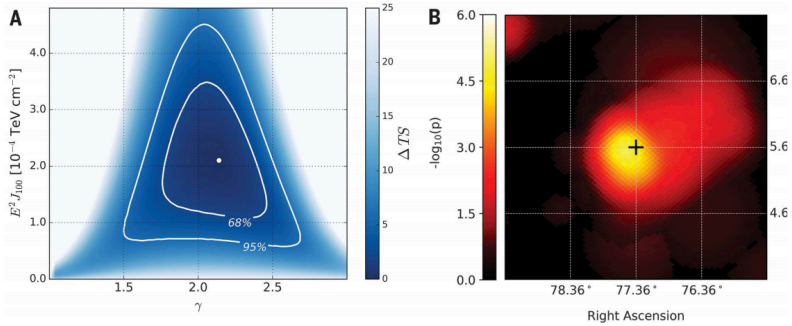
Thanks to its unprecedented sensitivity and large field of view CTA will open a new window on transients events. The main targets are:

- **GRBs**
- **Galactic transients** (binary systems, microquasars, novae, ..)
- **Radio, optical, X-ray transients** (FRB, TDE,..)
- **High-energy neutrino transients**
- **GW transients**
- **Serendipitous VHE transients** (via CTA real time analysis)
- **VHE transient survey** (divergent pointing and in conjunction with Extragalactic survey)

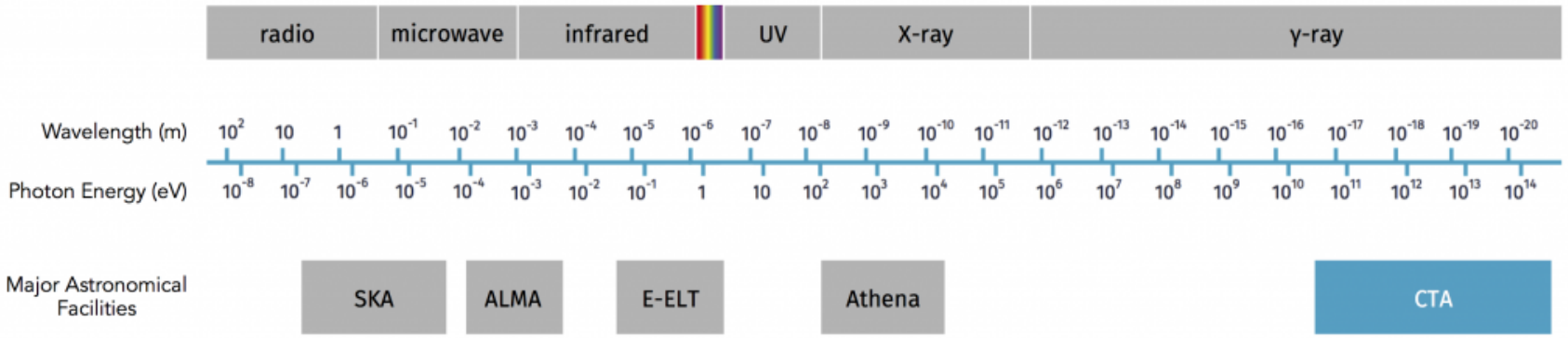
GRB simulated light curve



IceCube Collaboration+18



Synergies with VLBI

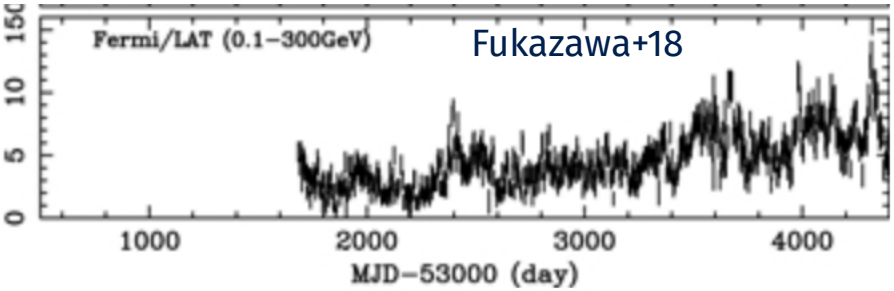


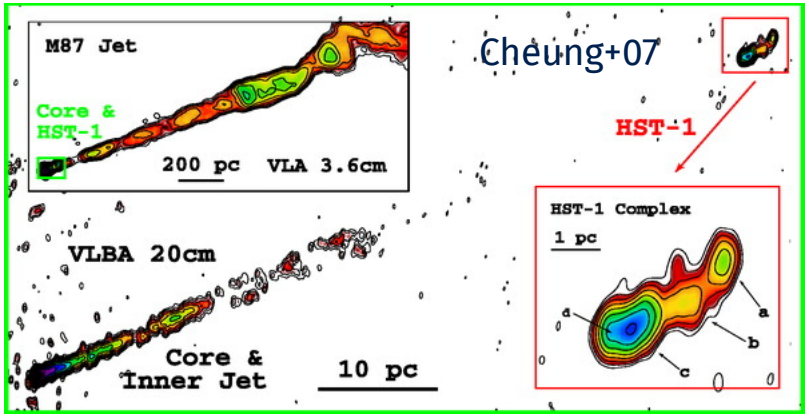
Two windows on the non-thermal universe

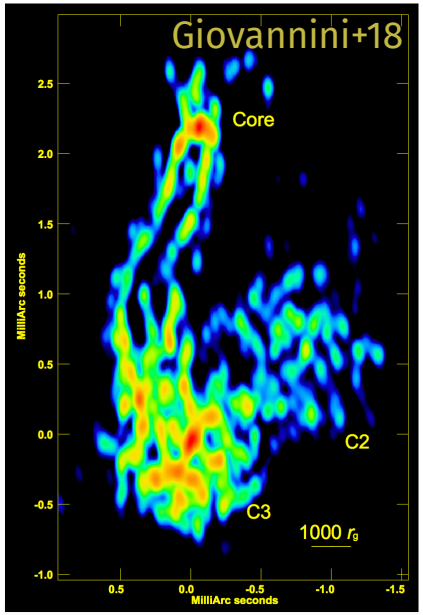
Radio VLBI: deep look into the innermost region of relativistic jet and radio outflows. Information on the magnetic field structure, shock propagation...

VHE observations: particle acceleration, seed photons for IC scattering, hadronic/leptonic processes, EBL, ...

Synergies with VLBI - AGN

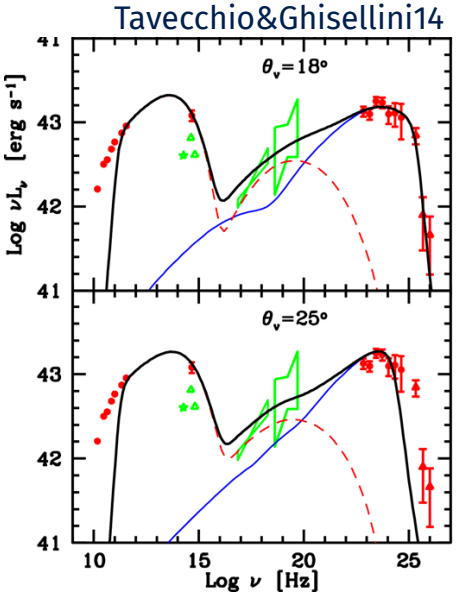






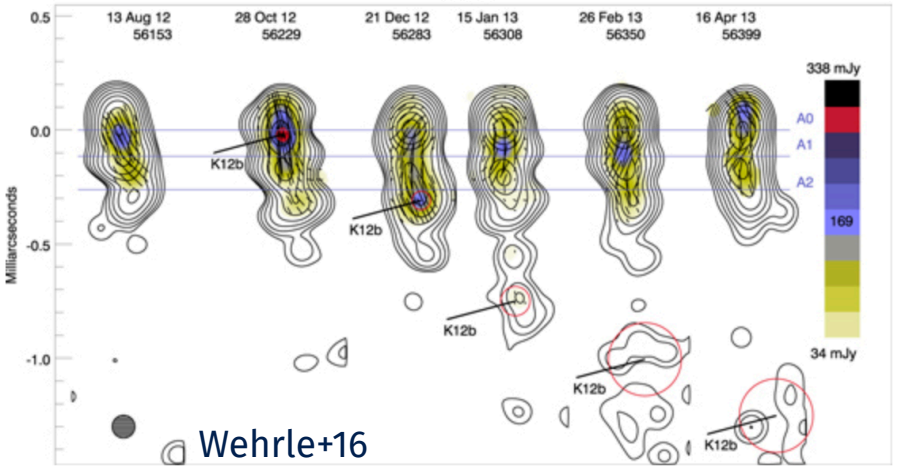
Long-term monitoring: Locating the high-energy emitting region in radio-loud AGN

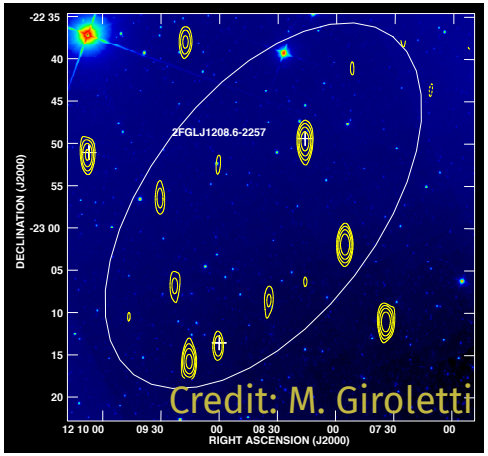
High-quality spectra: A deep look into the high-energy emitting processes

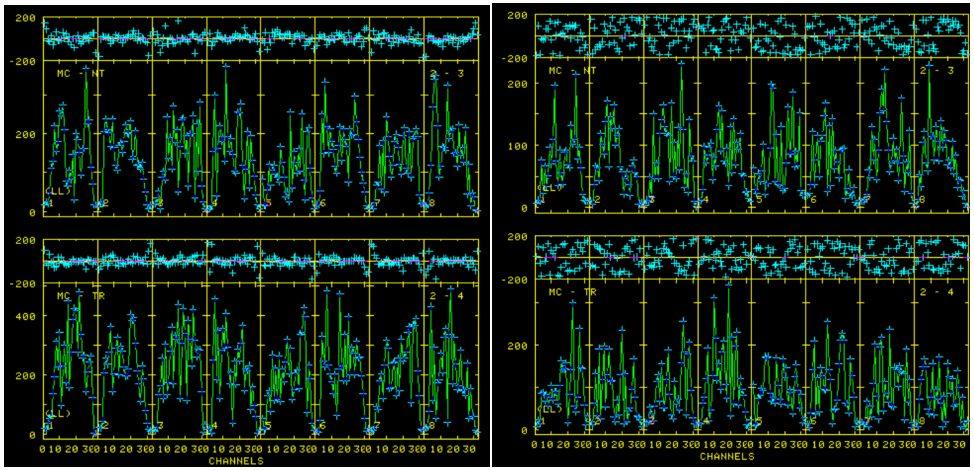


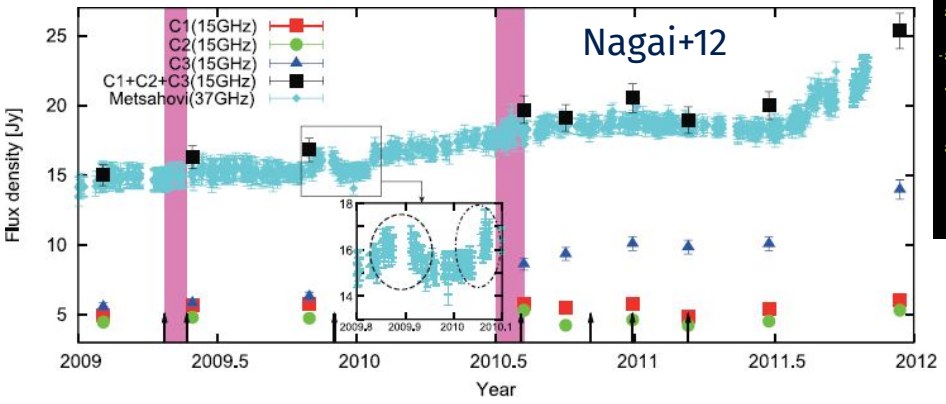
Synergies with VLBI - AGN

AGN flare programme: Gamma-ray flares and superluminal components









Extragalactic survey: Association of gamma-ray counterparts

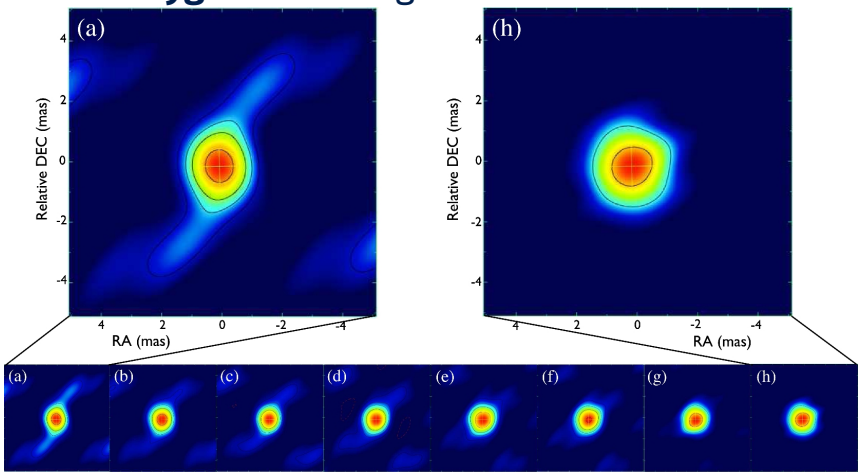
Synergies with VLBI - Transients

Novae: study of the ejecta and identification of the non-thermal emitting region

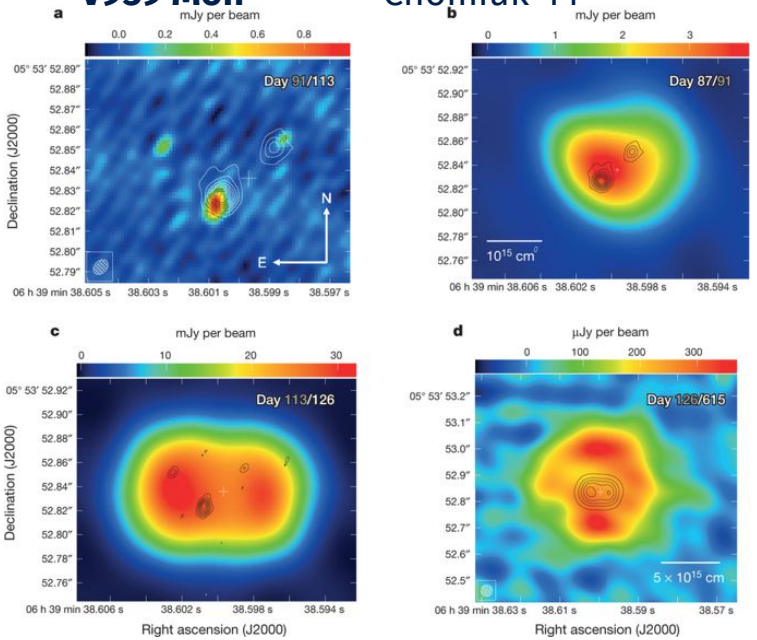
Gamma-ray binary pulsars: pulsar winds and binary pulsar evolution

Microquasars: emission models and jet formation in accreting objects

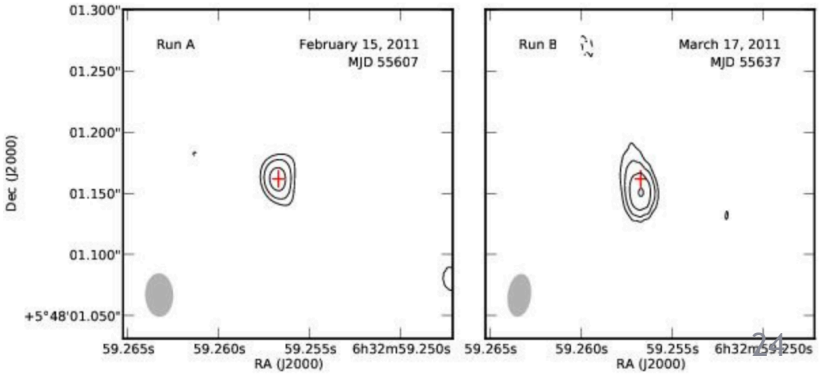
Cygnus X-3 Egron+17



V959 Mon Chomiuk+14



HESS J0632+057 Moldon+11



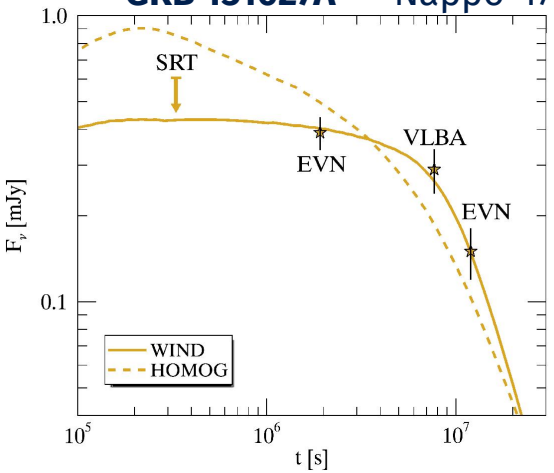
Synergies with VLBI - Transients

GRB: jet formation, particle acceleration and emission site

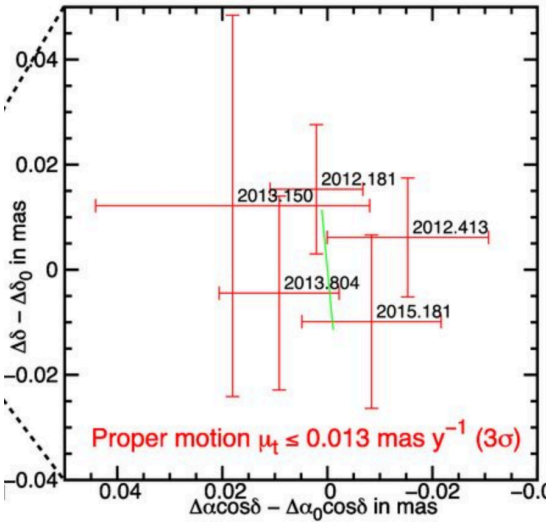
GW: Relativistic jet or isotropic outflow

Unidentified VHE transients: new types of VHE transients (FRB, TDE, Magnetars, ...)

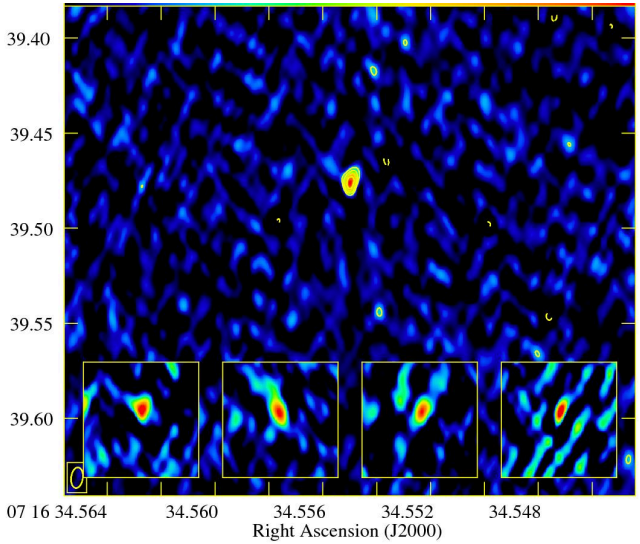
GRB 151027A Nappo+17



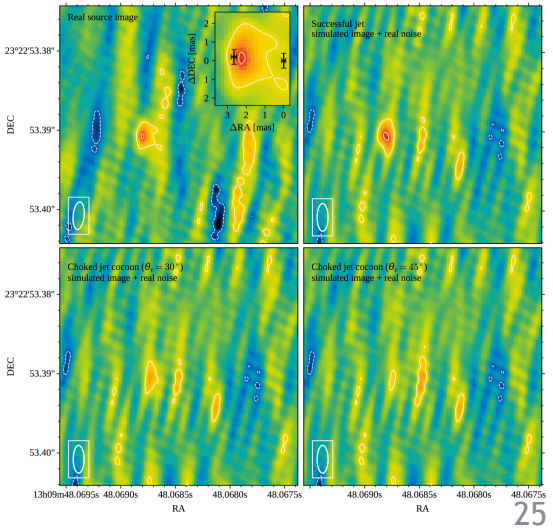
TDE *Swift* J1644+5734 Yang+16



FRB 150418 Giroletti+16



GW170817 Ghirlanda+18



Synergies with VLBI - Galactic Centre

Complete em study of SgrA* by confirming its VHE emission

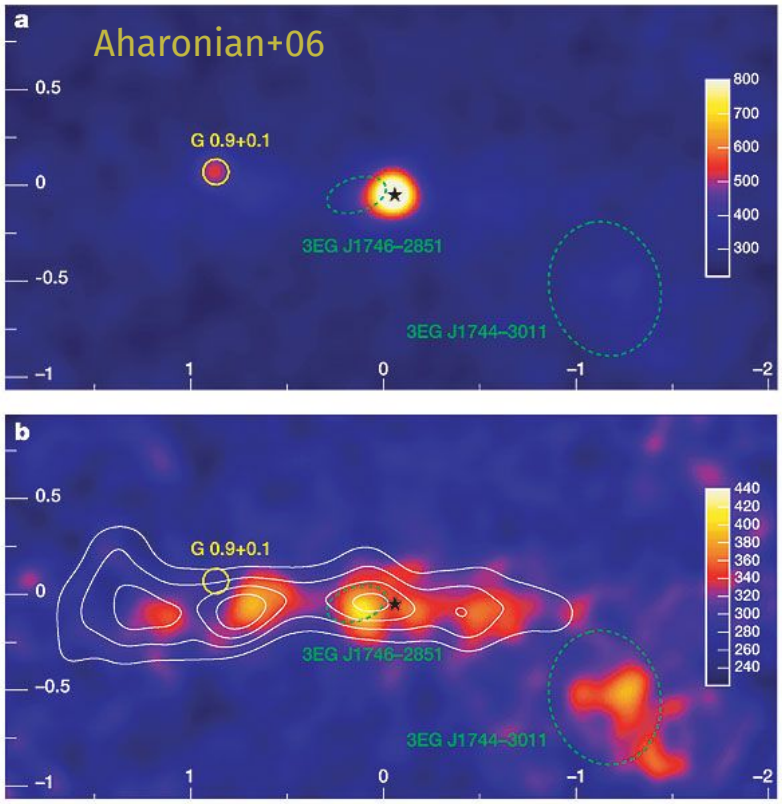
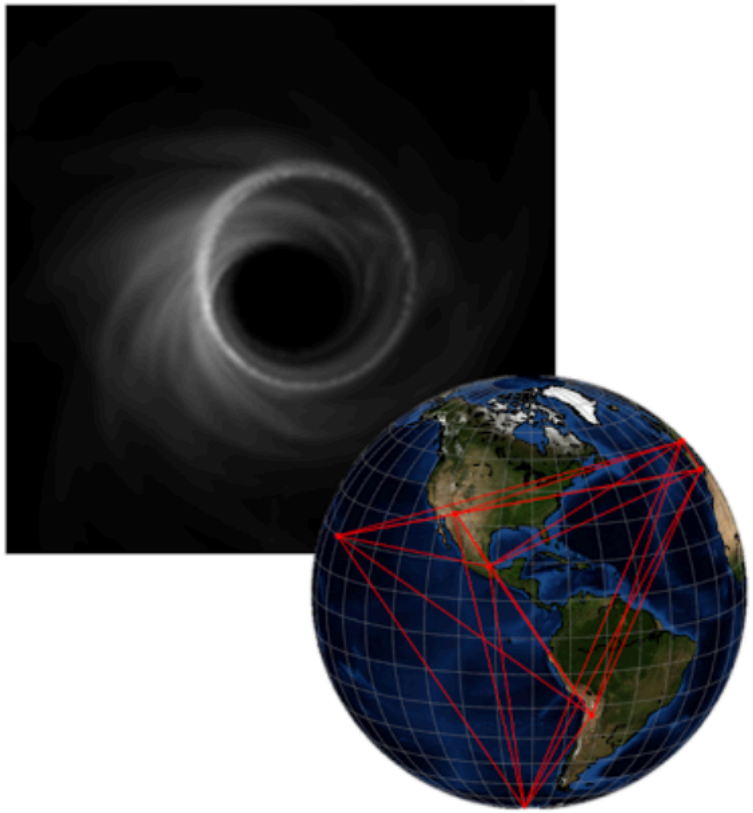


Image credit: Katie Bouman



EHT: Imaging SMBH, accretion, jet formation and collimation

Summary

- CTA will be the ground-based gamma-ray observatory in the near future
- CTA will be open, proposal-driven observatory, but in the first years a large fraction of time will be devoted to KSP
- CTA has broad scientific potential: from particle acceleration to dark matter and is an explorer of the extreme universe
- CTA will have important synergies with many present and future MW and MM observatories. The combined strength among different facilities will be crucial for new discoveries.
- https://www.cta-observatory.org/
- https://www.cta-observatory.org/science/cta-performance/cta-performance-archive1/
- https://www.cta-observatory.org/project/technology/

Thank you

This presentation has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562 [RadioNet]