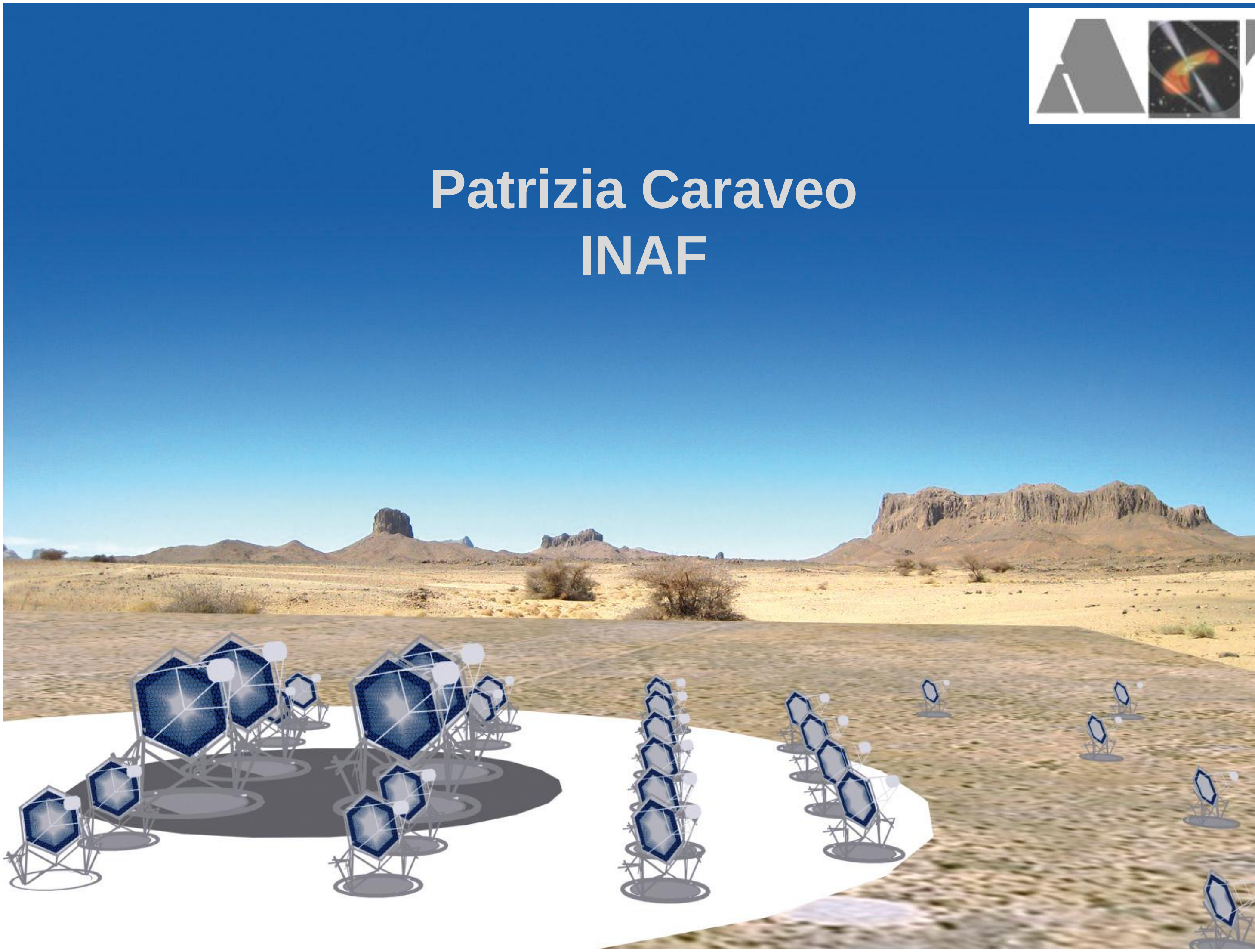
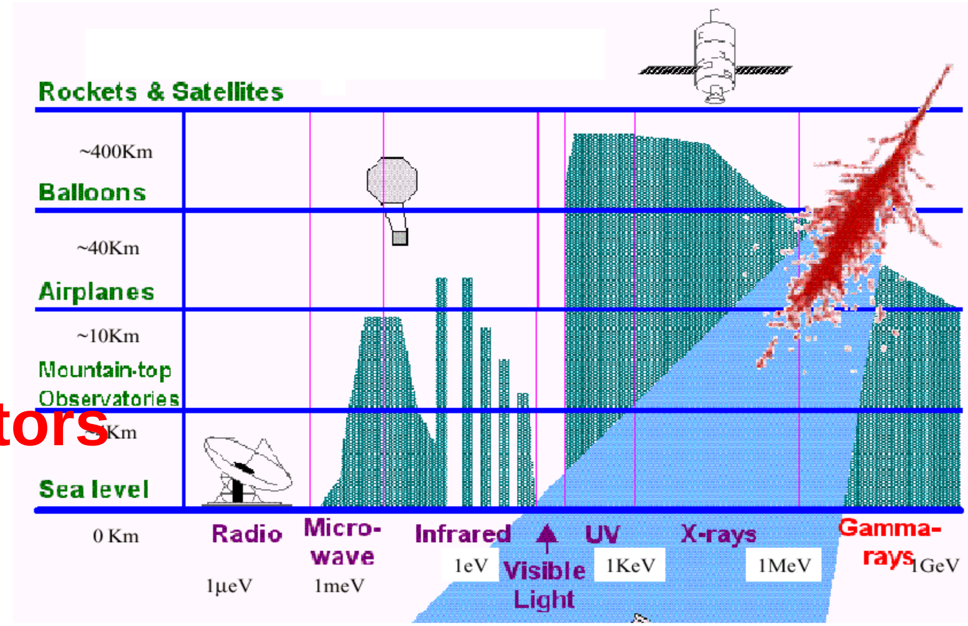
The Cherenkov Telescope Array Observatory: project status and Italian participation



Consequences on the techniques



- The earth atmosphere is opaque to gammas => **only sat-based detectors can detect primary gammas**

- The fluxes of h.e. gammas are low and decrease rapidly with energy
  - a perfect 1m^2 detector would detect only 1 gamma-photon/2h above 10 GeV from the strongest sources

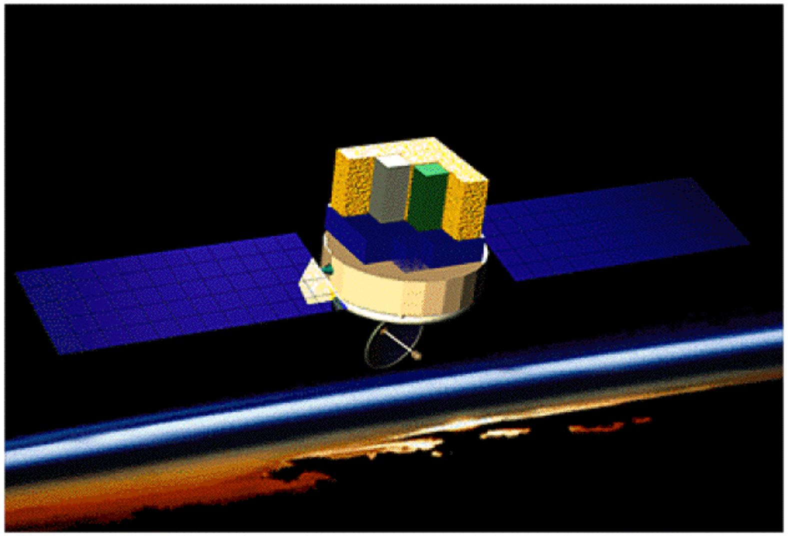
=> **with the present space technology, VHE and UHE gammas can be detected only from atmospheric showers**

  - Earth-based detectors, atmospheric shower satellites

- The flux from high energy charged cosmic rays is much larger

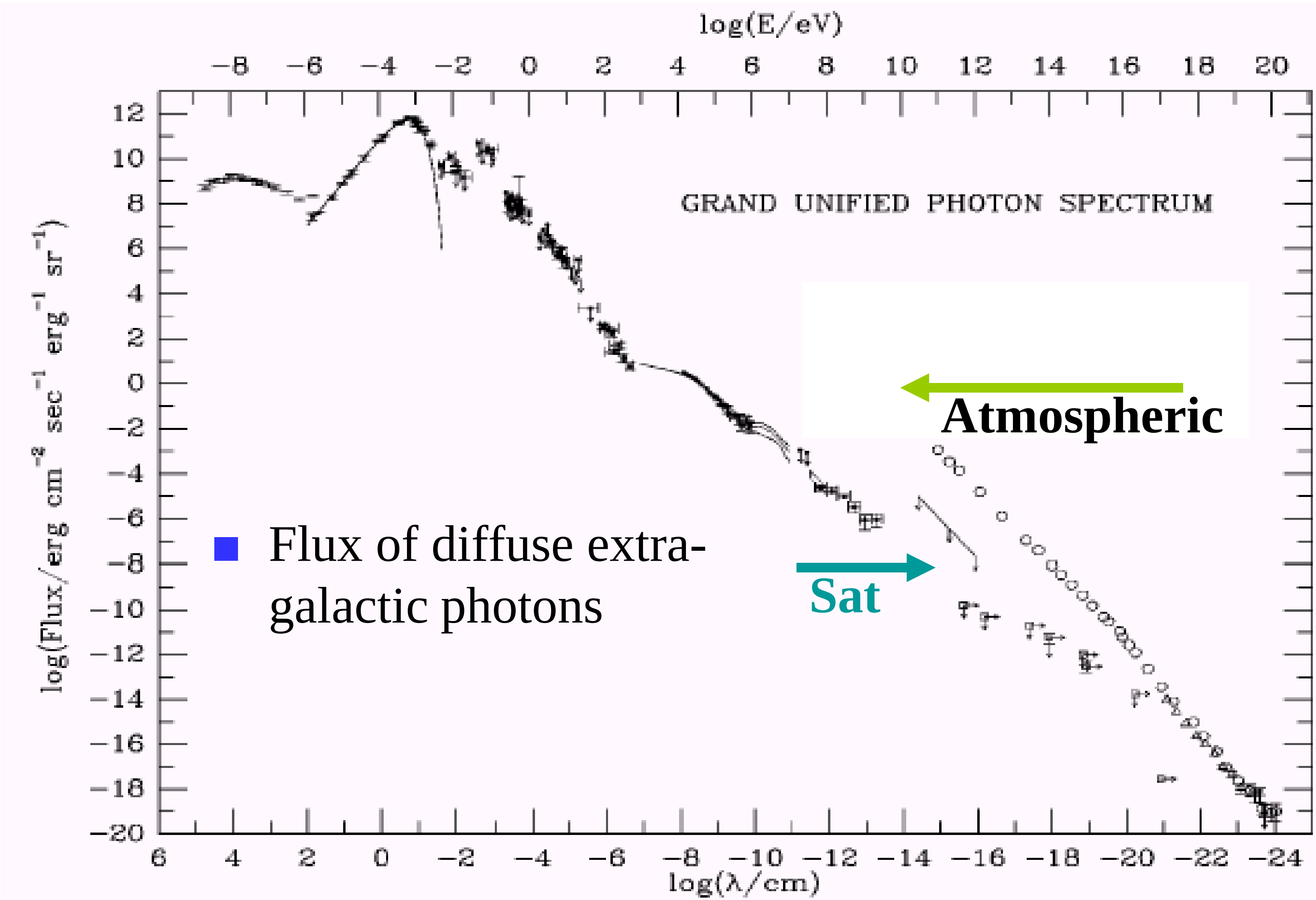
Ground-based vs Satellite

- **Satellite :**
  - small effective area ~1m^2
    - lower sensitivity
  - large FoV
  - large duty-cycle
  - large cost
  - low energy
  - low bkg



- **Ground based**
  - huge effective area ~10^4 m^2
    - Higher sensitivity
  - small FoV (IACT)
  - small duty-cycle
  - low cost
  - higher energy
  - high bkg

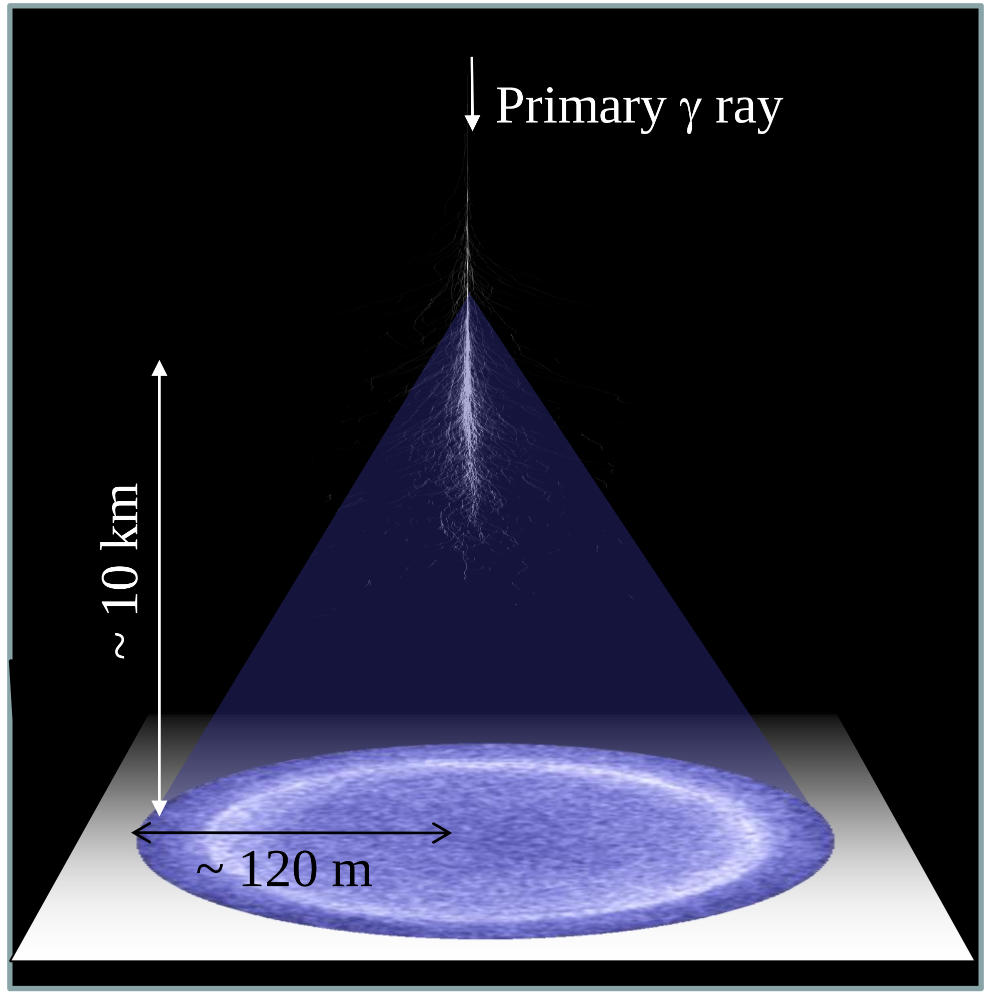
Satellite-based and atmospheric: complementary, w/ moving boundaries

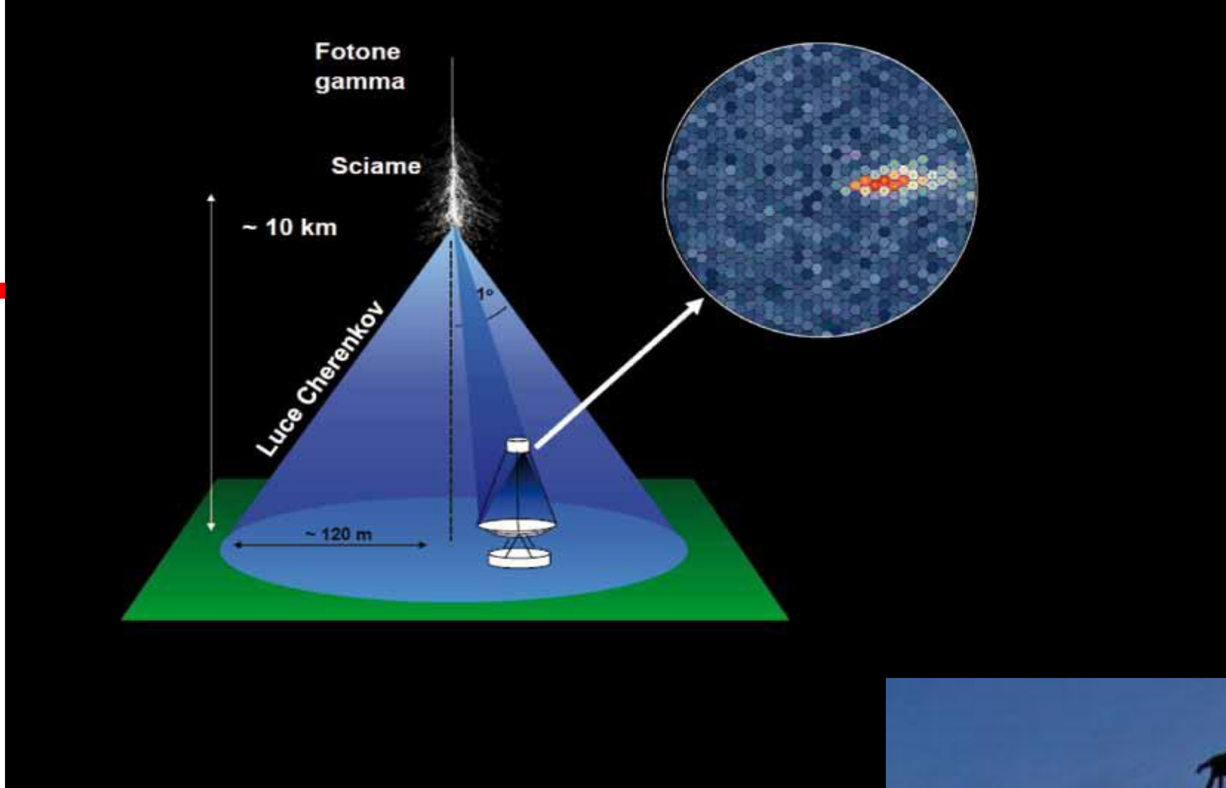


- Flux of diffuse extra-galactic photons

Detecting Cherenkov radiation from EM showers

- Air at STP, rad. length $X_0 \sim 330$ m, refractive index $n \sim 1.0003$, Moliere radius $r_M \sim 65$ m.
- VHE gamma causes shower with max. at height ~ 10 km.
- Cherenkov light production threshold for $e^{\pm}$ is $E_c \sim 20$ MeV (STP).
- Total $e^{\pm}$ path length above E_c $\sim 10^4$ km for 1 TeV photon.
- Get ~ 20 Cherenkov photons/m in wavelength range l = 300...400 nm.
- Cherenkov angle ~ 1°: at low shower particle energy, multiple scattering causes further spreading.
- Light pool radius ~ 120 m.

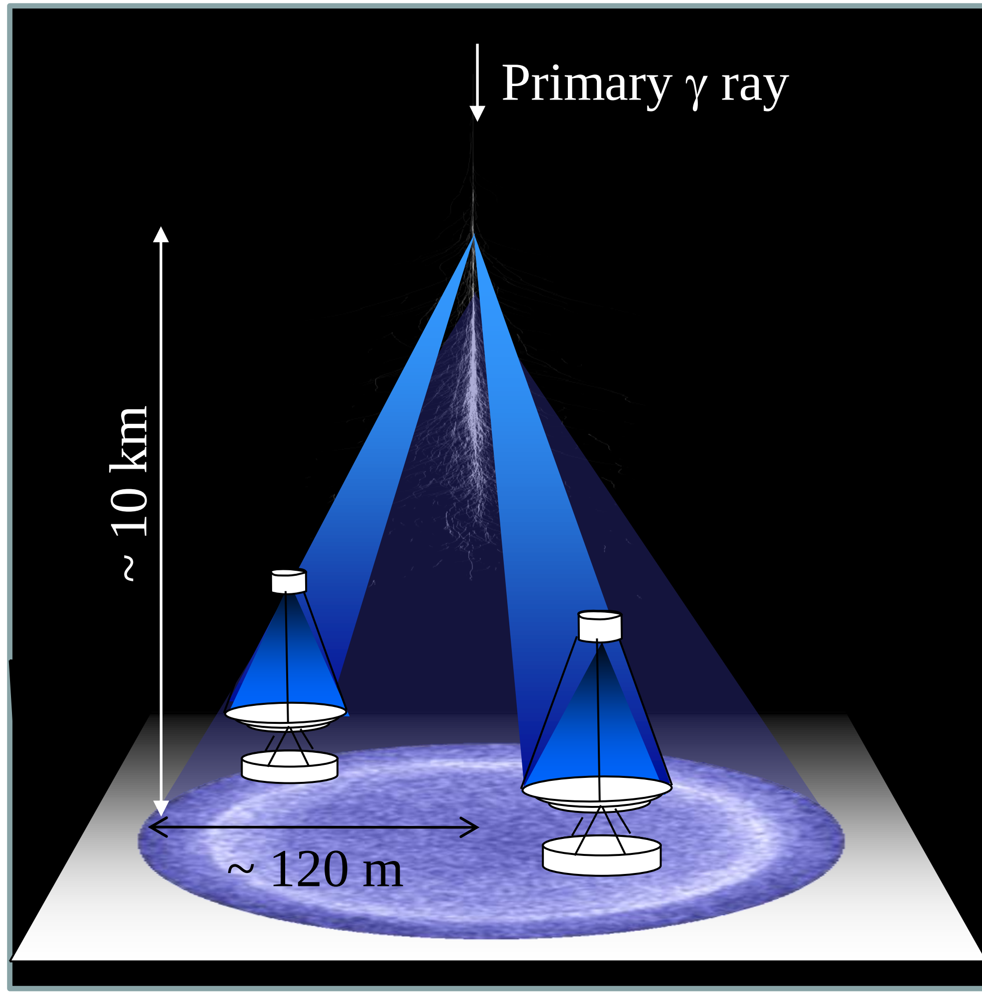




Whipple

Detecting Cherenkov radiation from EM showers

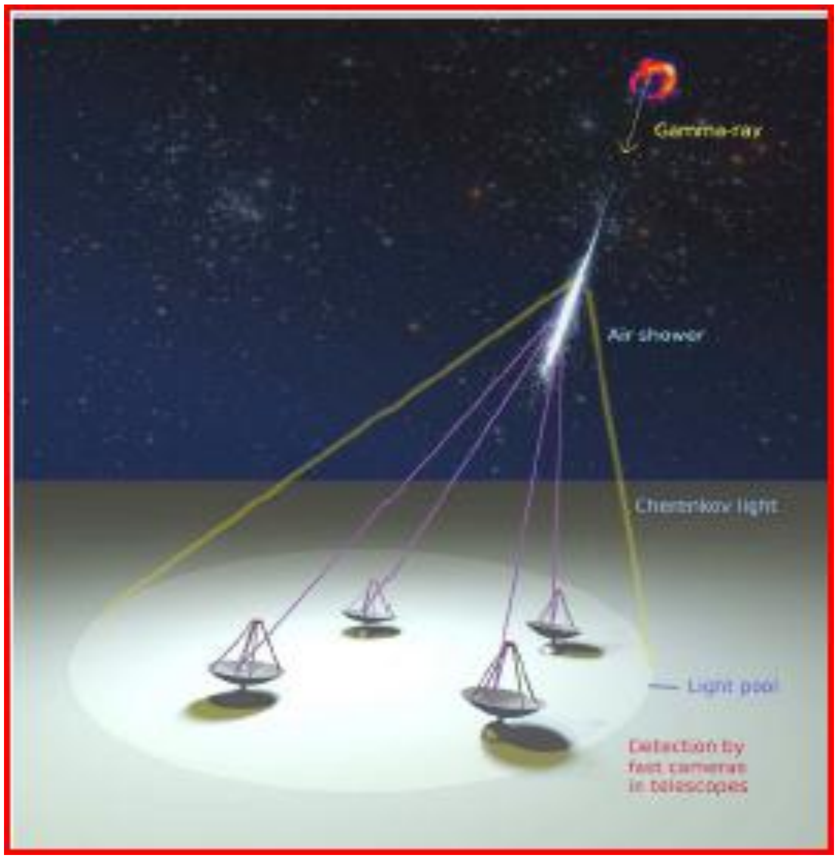
- Attenuation length of order km (strong function of λ).
- Quantum efficiency of PM ~ 20%, net result:
  - About 1 p.e./m^2 in few ns for (frequent) 100 GeV g-ray.
  - About 10^3 p.e./m^2 in few 10 to 100 ns for (infreq.) 10 TeV g-ray.
- **Limitations:**
  - **E < 100 GeV, night sky background.**
  - **E = 0.1...5 TeV, cosmic ray background (gamma/particles separation).**
  - **E > 5 TeV, rate.**
- **Need array of different telescopes.**

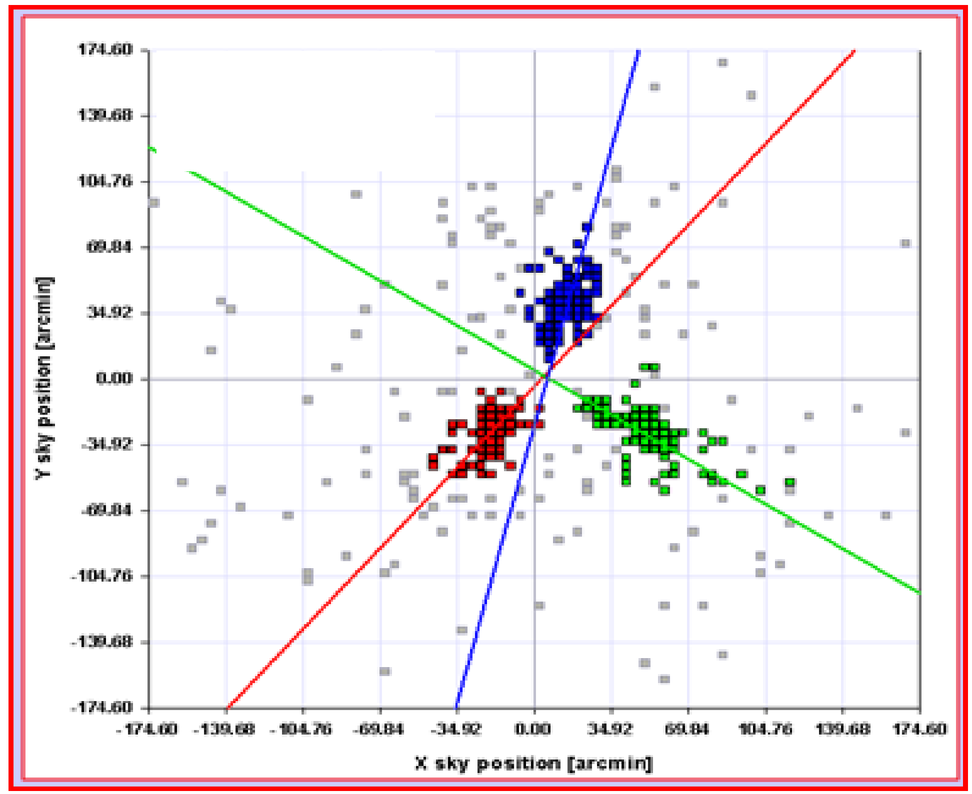


telescope arrays

Increase of the fiducial area → better sensitivity

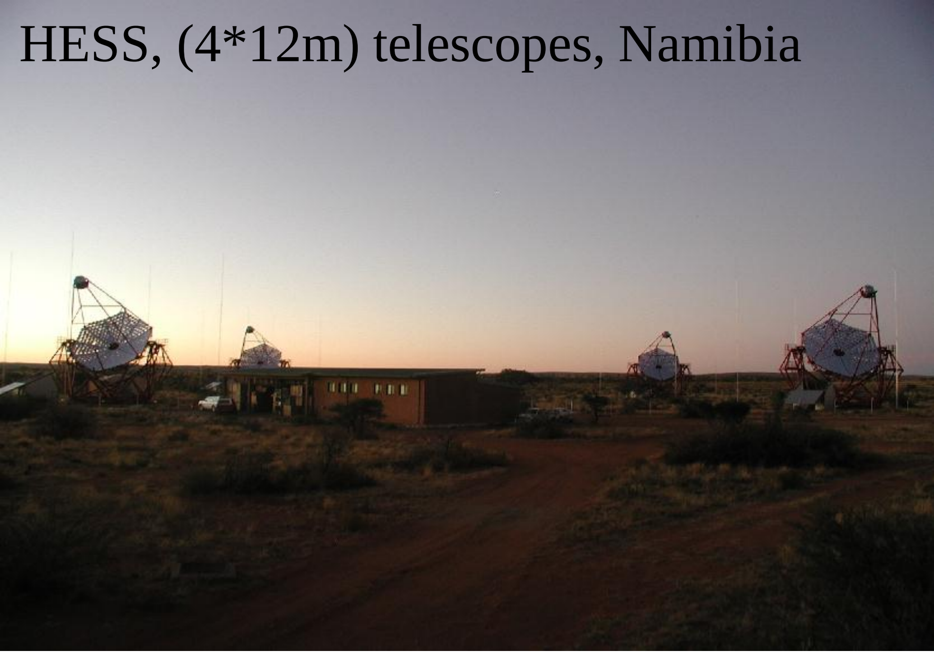
Cherenkov Telescopes in Stereo Vision





Arc minute angular resolution

HESS, (4*12m) telescopes, Namibia

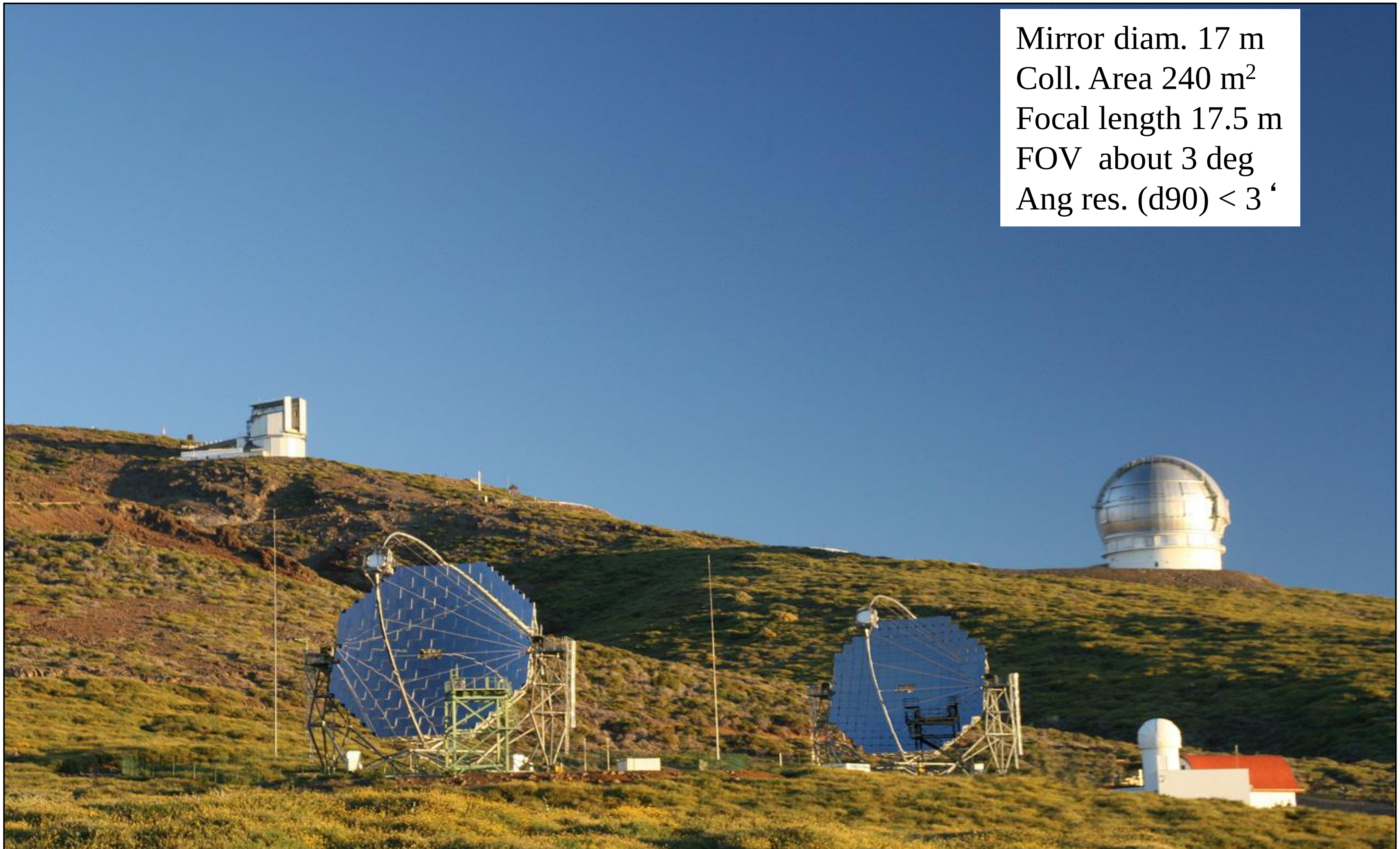


VERITAS, Arizona

MAGIC (2*17m) telescopes , La Palma
Canary Islands

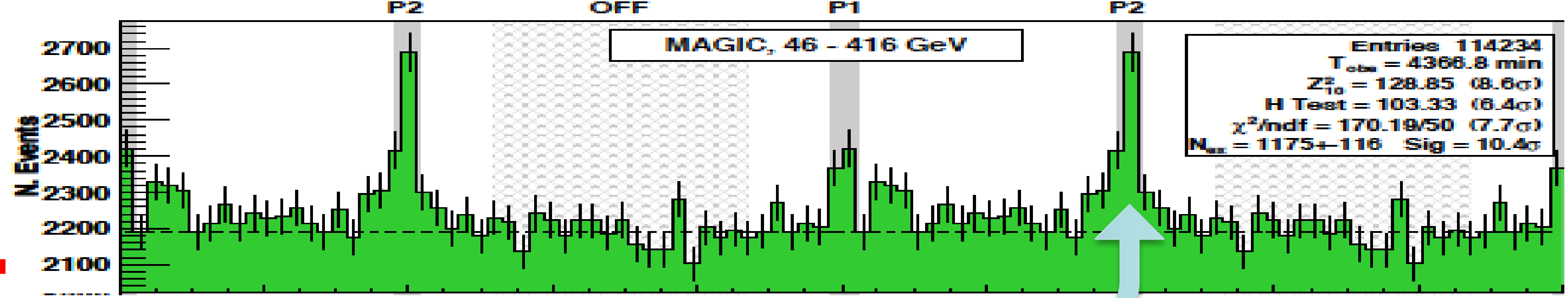
	WIPPLE	HESS	MAGIC	VERITAS
Site	Arizona	Namibia	Canary Island	Arizona
Lat (°)	32	-25	29	32
Alt (km)	1.3	1.8	2.2	1.3
Tel. Ǿ (m)	10	12	17	12
N. Tel.	1	4	2	4
FoV Ǿ (°)	2.3	5	3	3.5
Thresh. (GeV)	300	100	50	100
Sensitivity (mCrab)	150	7	20	10

The MAGIC telescopes

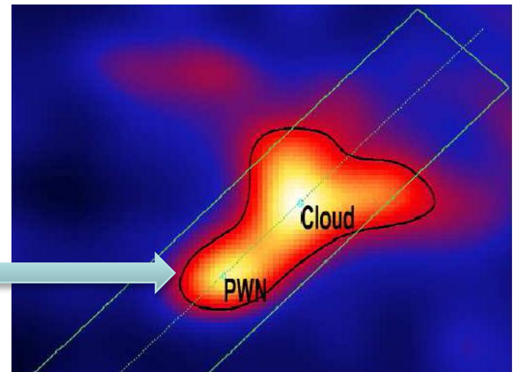


Mirror diam. 17 m
Coll. Area 240 m^2
Focal length 17.5 m
FOV about 3 deg
Ang res. (d90) < 3 ‘

Scientific highlights in the last 12 months

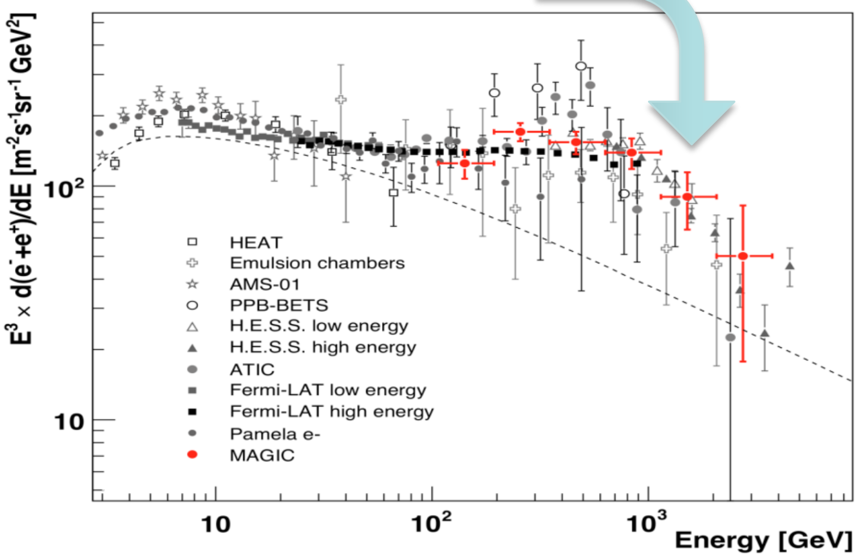


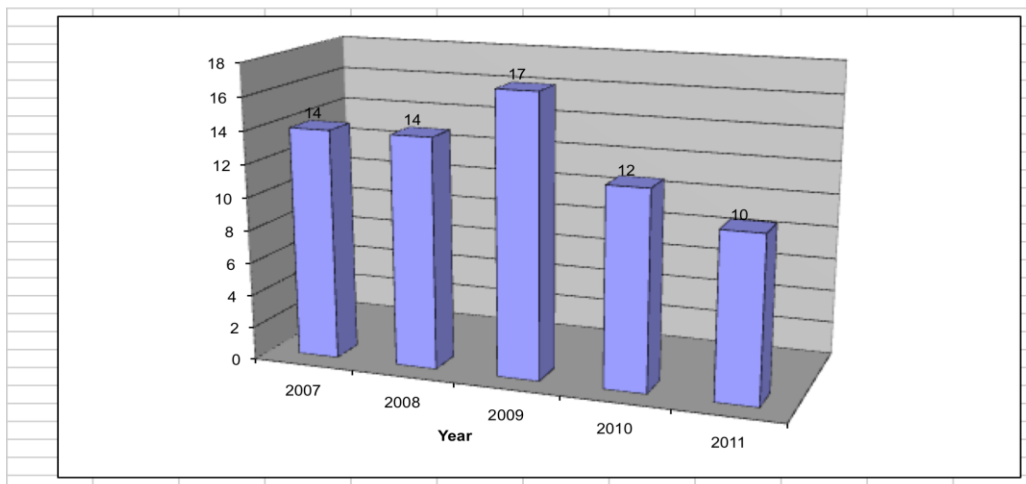
- Pulsed (~ 30 Hz) Crab signal from 25 to 420 GeV
- AGN: most relevant new case is PKS1222 (rapid flare; constraints on Extragalactic Background Light)



W51: gamma rays come from a molecular cloud separated from the pulsar

- Galactic sources: highlight is W51 (one more hint of acceleration of hadrons)
- Electrons+positrons 130 GeV-2 TeV

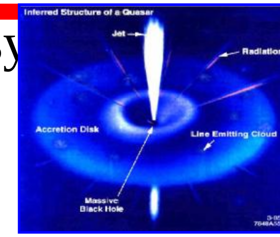




> 1 article/month since 2006

> 35, Active Galactic Nuclei (Blazars)

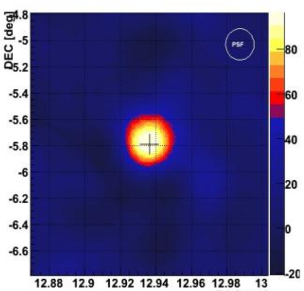
AGN ➔ TeV by electrons (strong correlation between x-ray and TeV flux variability, clearly suggests a unique parent population i.e. Electrons emitting X by sy



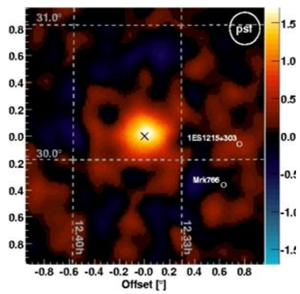
l Gamma by Inverse Compton).

AGN ➔ Mechanisms in jets and particles acceleration in the jets
(Tavecchio F. , Maraschi L., Ghisellini G. 1998. AP. J. 509:608-19)

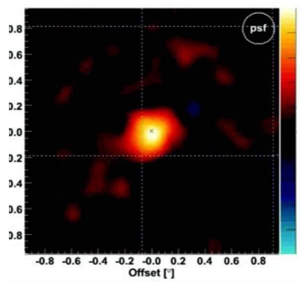
Some MAGIC discoveries of extra-galactic sources (MAGIC courtesy)



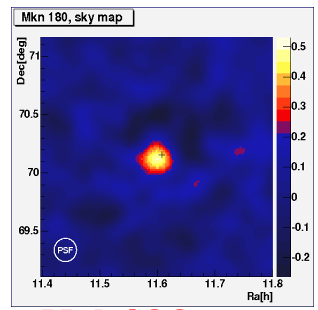
3C279
(z = 0.536)



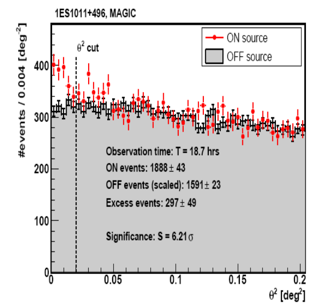
1ES1218
(z= 0.18)



PG 1553
(Z>0.25)



Mrk180
(z=0.045)



1ES1011
(Z=0.212

AGN ➔ spectra shape distribution ➔ Constraint on the EBL (Extragalactic Background Light) intensity can be derived by the AGN spectral cut-off assuming an average AGN emission spectrum; Correlation luminosity /spectral index can affect the result!

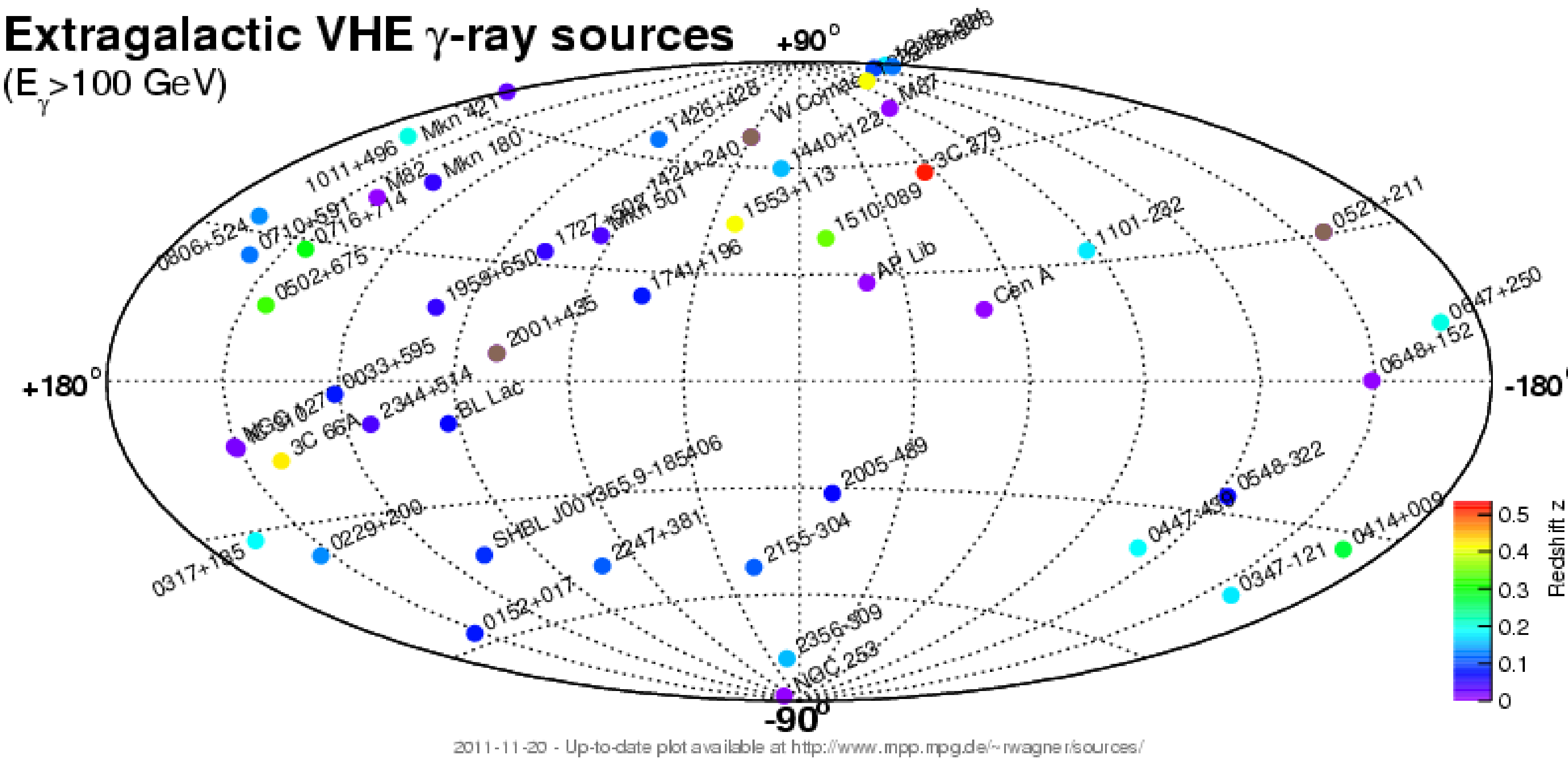
Far extragalactic sources: leadership by MAGIC

>40 Sources

…

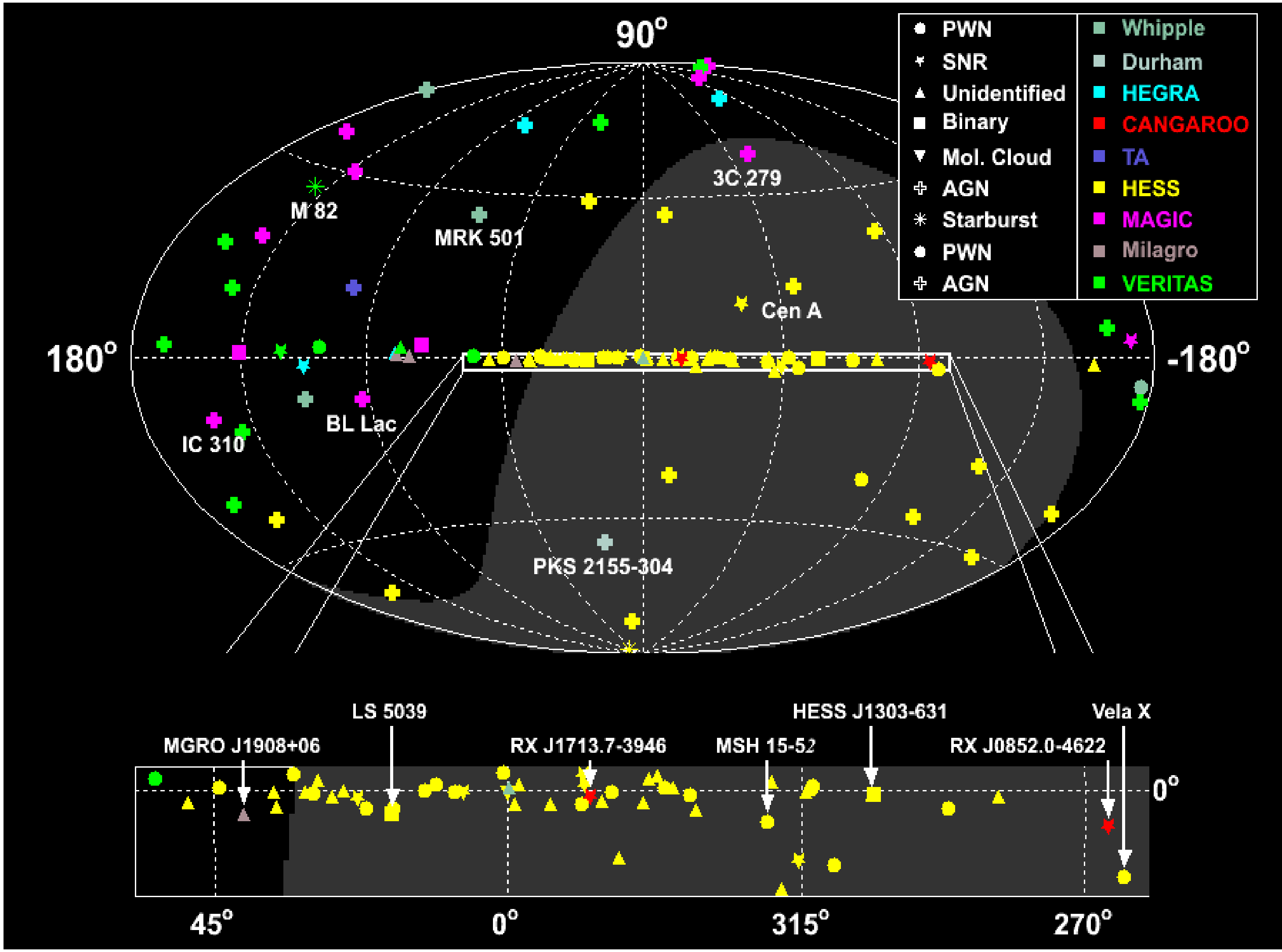
1ES 1011+496	z=0.21	MAGIC 2007
1ES 0414+009	z=0.29	HESS/Fermi 2009
S5 0716+71	z=0.31±0.08	MAGIC 2009
1ES 0502+675	z=0.34	VERITAS 2009
PKS 1510-089	z=0.36	HESS 2010
PKS 1222	z=0.43	MAGIC 2010
3C 66A	z=0.44	VERITAS 2009
3C 279	z=0.54	MAGIC 2008

(Red: discovered by MAGIC. Orange: detected by MAGIC)

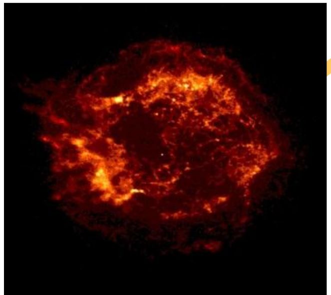


TeV Astronomy today

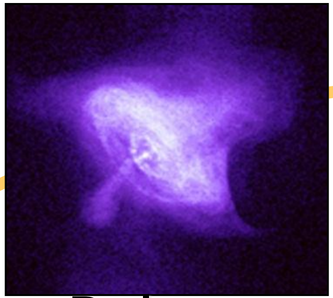
- April 2012.
- 136 TeV gamma-ray sources.
  - 89 galactic.
  - 47 extra-galactic.
- Further progress requires improved sensitivity, better E/angular resolution, larger area...



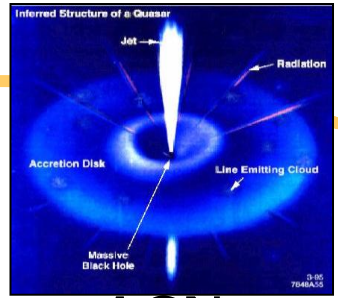
The Physics Program and the first results



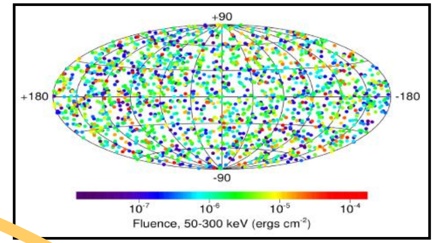
SNRs



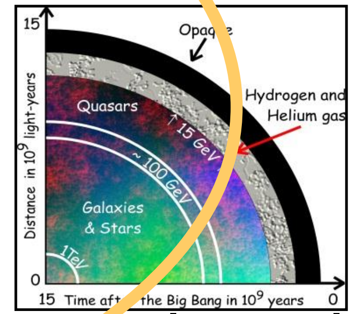
Pulsars



AGNs

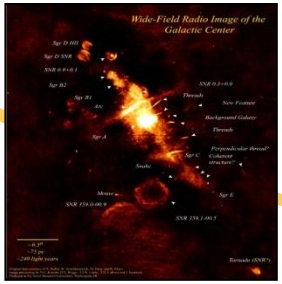


GRBs

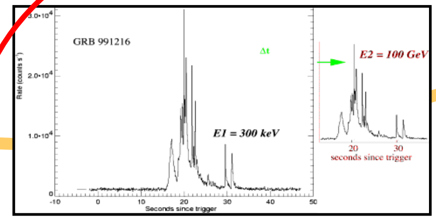


cosmological
γ-Ray Horizon

Origin of
Cosmic Rays

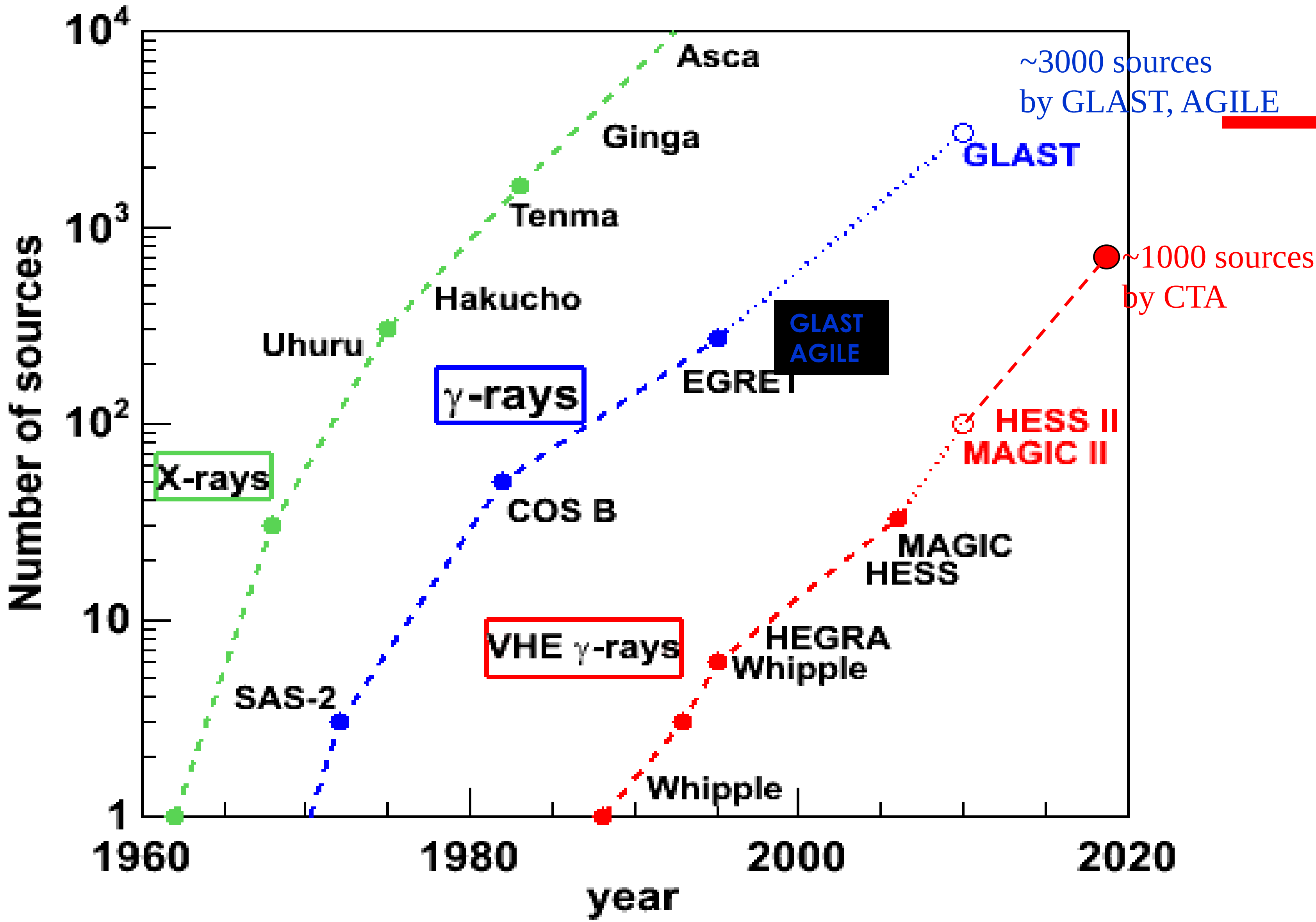


Cold Dark
Matter

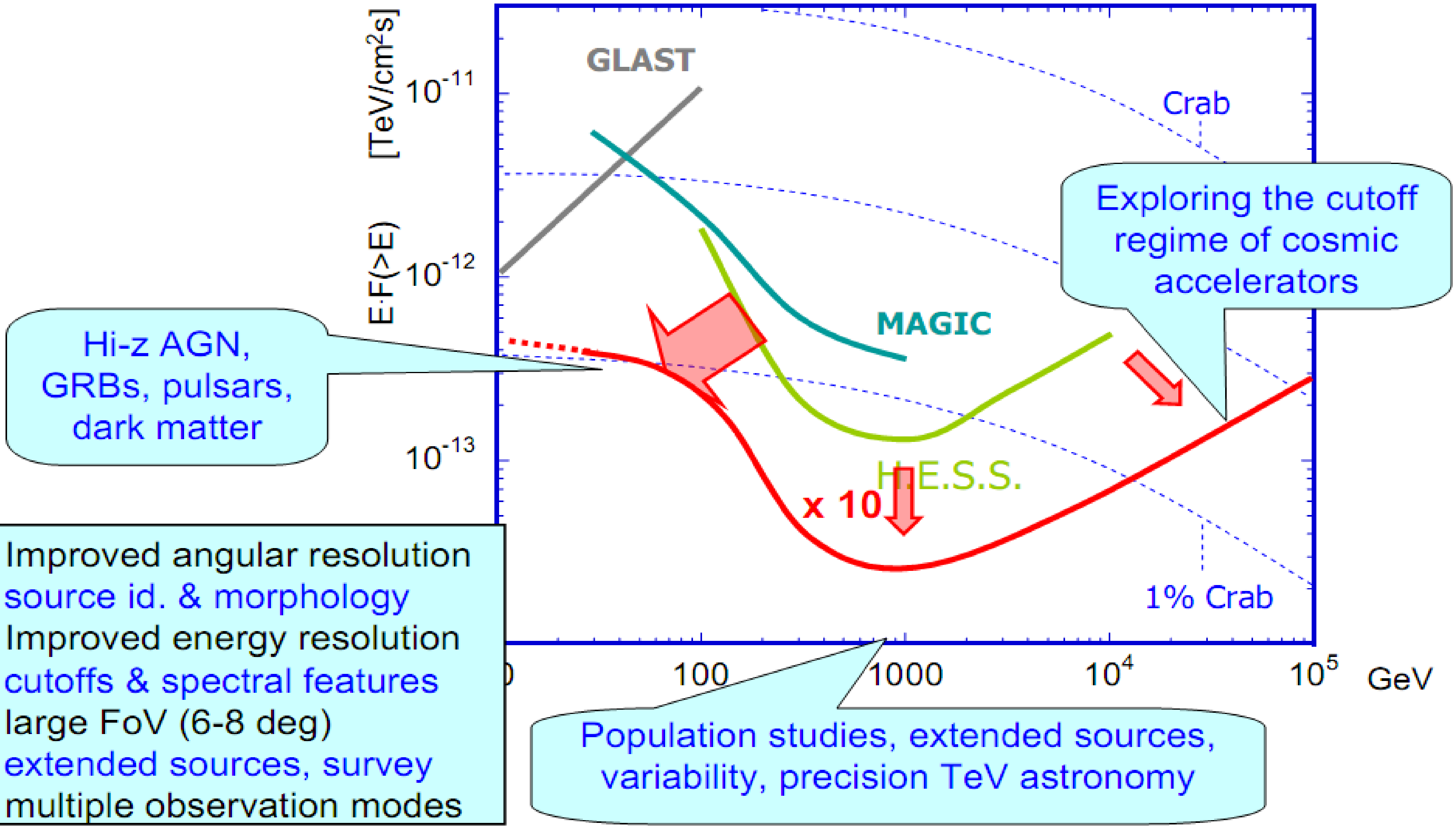


Quantum Gravity effects

Kifune Plot

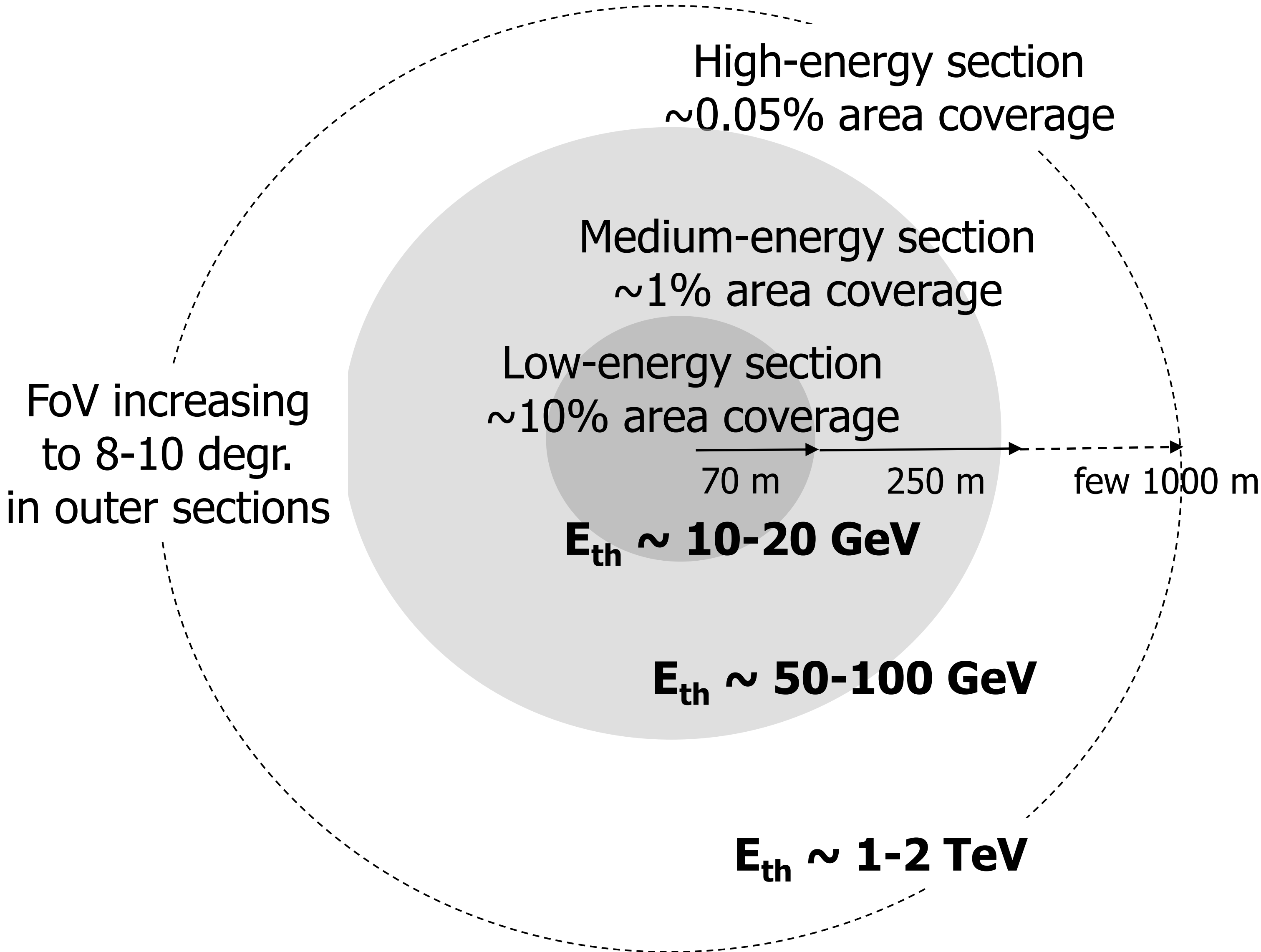

Number of sources
year
1960
1980
2000
2020
1
10
10^2
10^3
10^4
Asca
Ginga
Tenma
Hakucho
Uhuru
X-rays
γ-rays
GLAST
AGILE
EGRET
COS B
SAS-2
VHE γ-rays
HEGRA
Whipple
Whipple
MAGIC
HESS
HESS II
MAGIC II
GLAST
~3000 sources
by GLAST, AGILE
~1000 sources
by CTA

CTA: the Array sensitivity curve



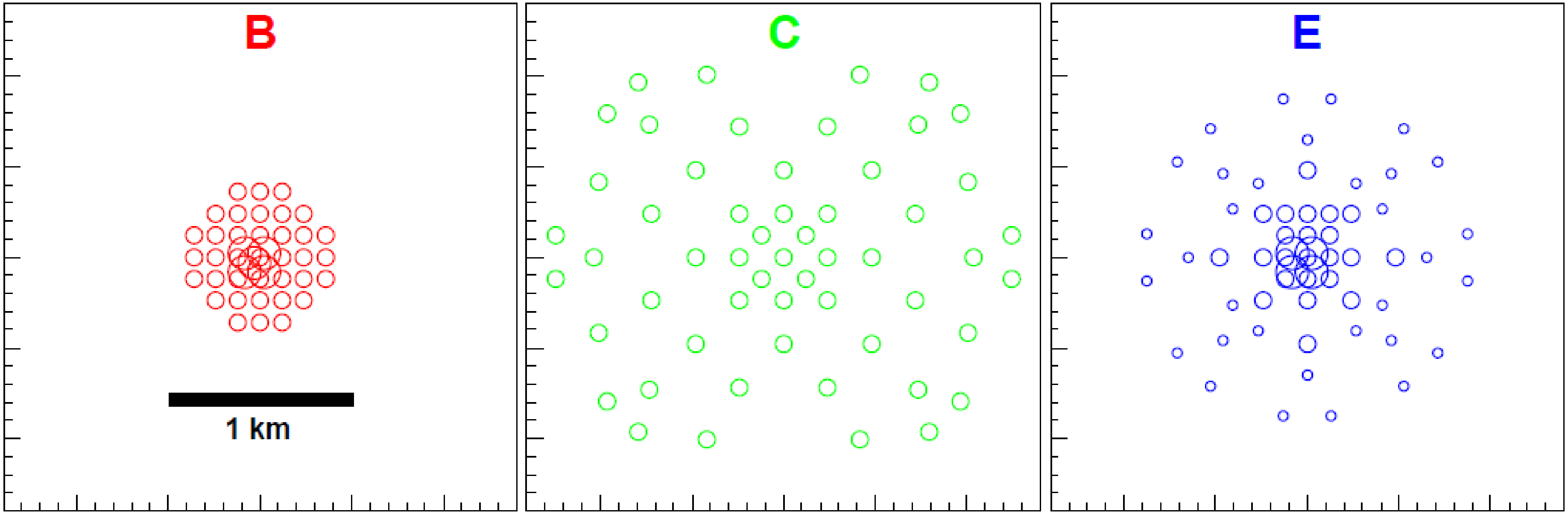
- + Improved angular resolution
  source id. & morphology
- + Improved energy resolution
  cutoffs & spectral features
- + large FoV (6-8 deg)
  extended sources, survey
- + multiple observation modes

Array layout: 2-3 Zones



Performance of multi-telescope arrays

- Examples of sub-arrays:

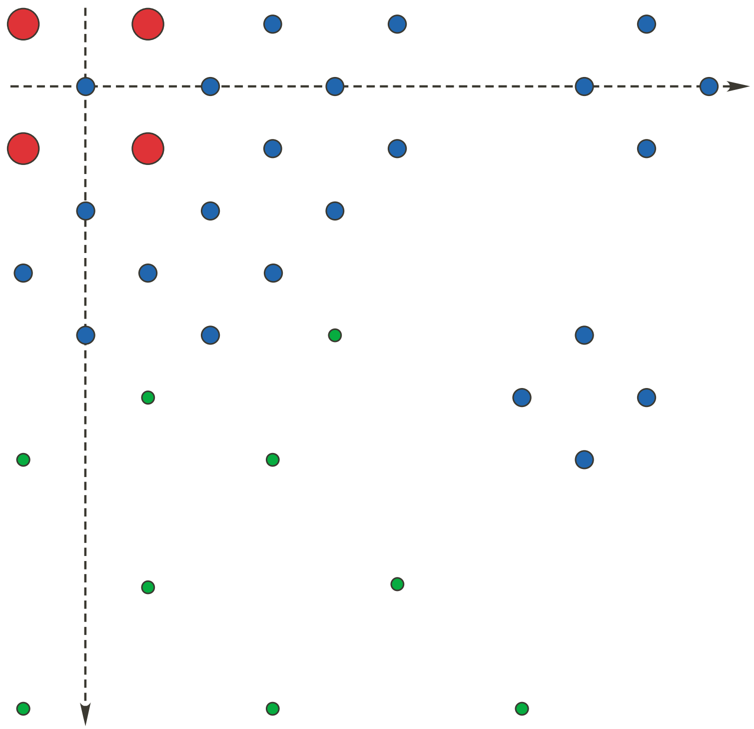


- Dense array of 12 and 24 m telescopes.
- Good low E, but poor high E performance?

- Low density array of 12 m telescopes.
- Good high/medium E, but poor low E performance?

- Array of 7, 12 and 24 m telescopes.
- Provides sensitivity across complete energy range?

CTA Array scheme



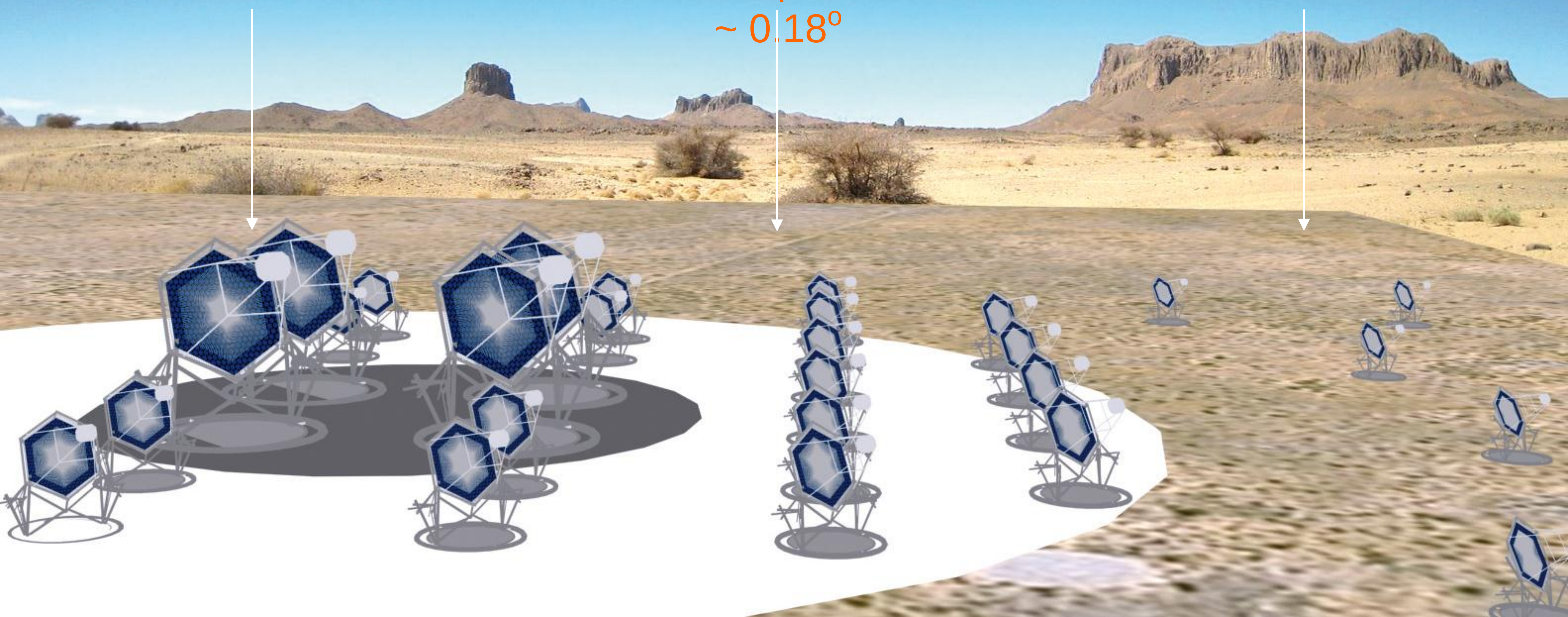
- The centre of the installation is near the upper left corner.
- In the upper right part, clusters of telescopes of the 12-m class are shown at the perimeter
- In the lower left part an option with wide-angle telescopes of the 3–4 m class is shown

The Cherenkov Telescope Array concept

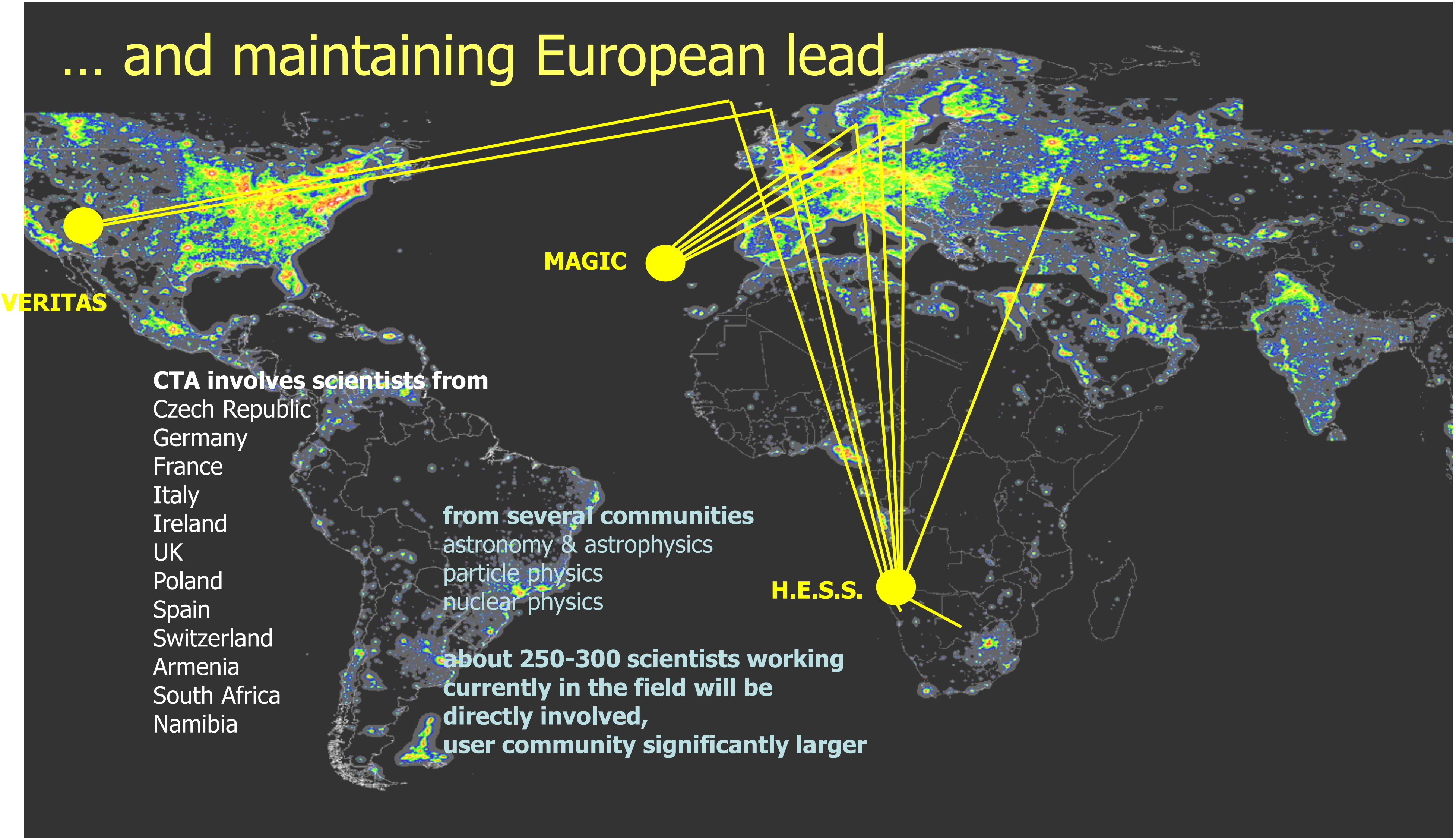
Low energy
Few 24 m telescopes
4…5^{o} FoV
2000…3000 pixels
~ 0.1^{o}

Medium energy
About twenty 12 m telescopes
6…8^{o} FoV
2000 pixels
~ 0.18^{o}

High energy
Fifty + 4…7 m telescopes
8…10^{o} FoV
1000…2000 pixels
~ 0.2^{o}…0.3^{o}



CTA: Unifying European efforts



CTA for the European Union: the Preparatory Phase

Extracts from W. Hofmann, CTA general meeting, 2010
and from M. Martinez, CTA general meeting, 2010

Unambiguously strong European support:

Project listed as priority in roadmaps of

- **ASTRONET (Astrophysics)**
- **ASPERA (Astroparticles)**

-> Targeted DS Common Call -> Up to €2.7M

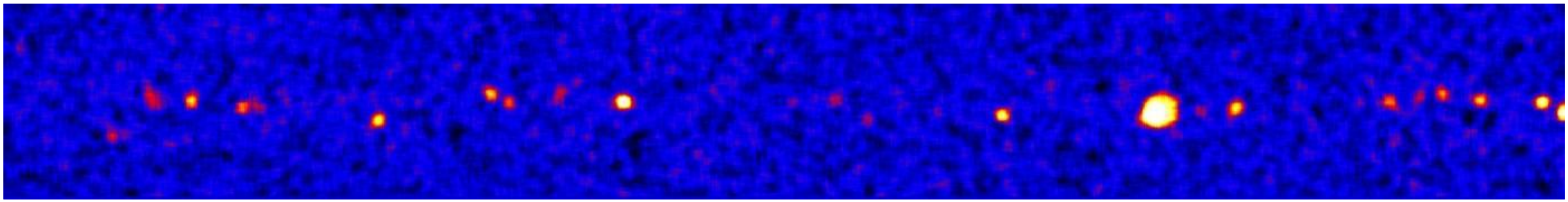
- **ESFRI (European Strategic Forum for Research Infrastructures)**

-> FP7 Preparatory Phase approved -> Up to €5.2M

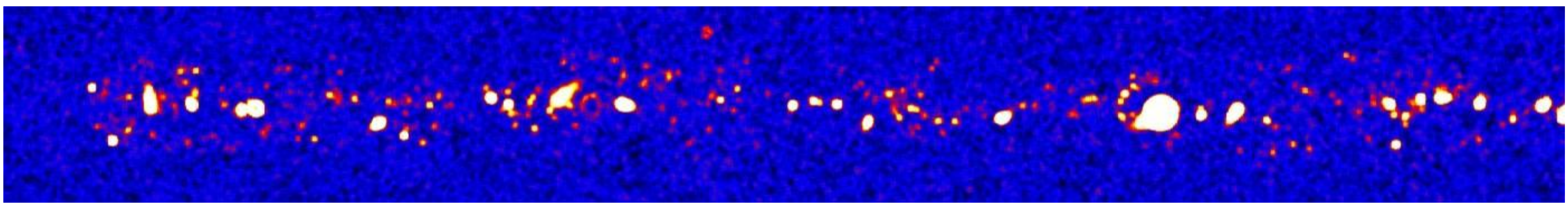
	Construction cost [M€]	Operations cost [M€]	Timescale
CTA	150	10	2013
E-ELT	950	30	2018
ELI	400	50	2015
FAIR	1187	120	2016
KM3NeT	200	5	2016
PRINS	1400	300	2009-2015
SKA (GLOBAL)	1500	100-150	2016
SPIRAL2	196	6.6	2014

CTA performance goals

- Aim for factor of 10 improvement in sensitivity.
- Compare simulated HESS ~ 500 hour image of galactic plane...



- ...with expectation with increased sensitivity, same exposure.



- Expect to observe around 1000 sources (galactic and extra-galactic).

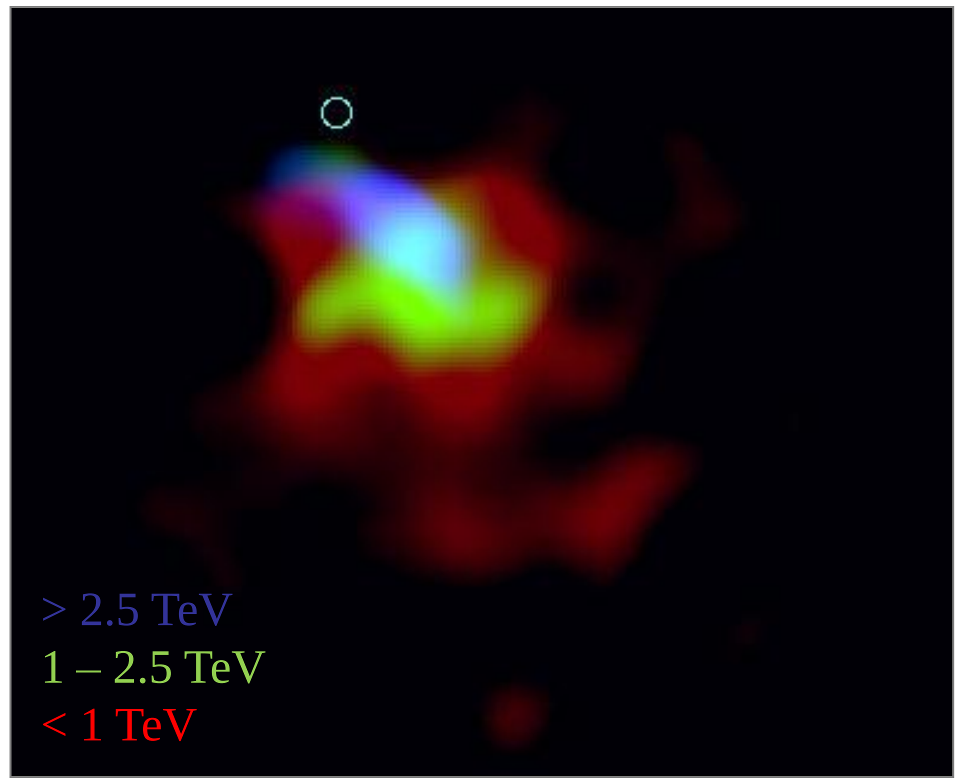
CTA performance goals

- Improve angular resolution by factor ~ 5.
- Substructure of SNR shock fronts can then be resolved:

- Better understand energy dependent morphology of pulsar wind nebulae.
- HESS J 1825-137, PWN size decreases with energy:

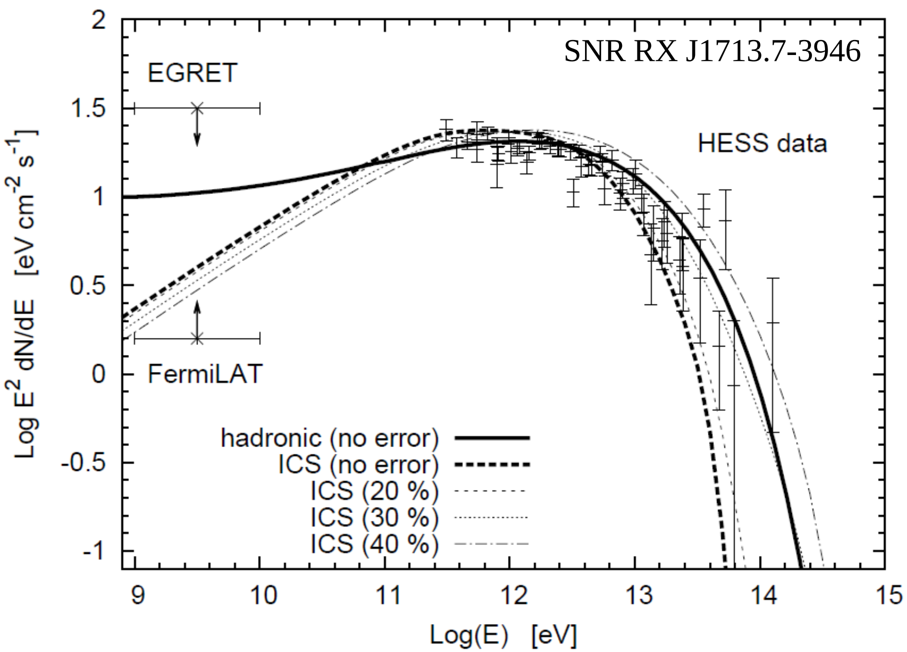
Resolution 0.02 °.

Resolution 0.1°.



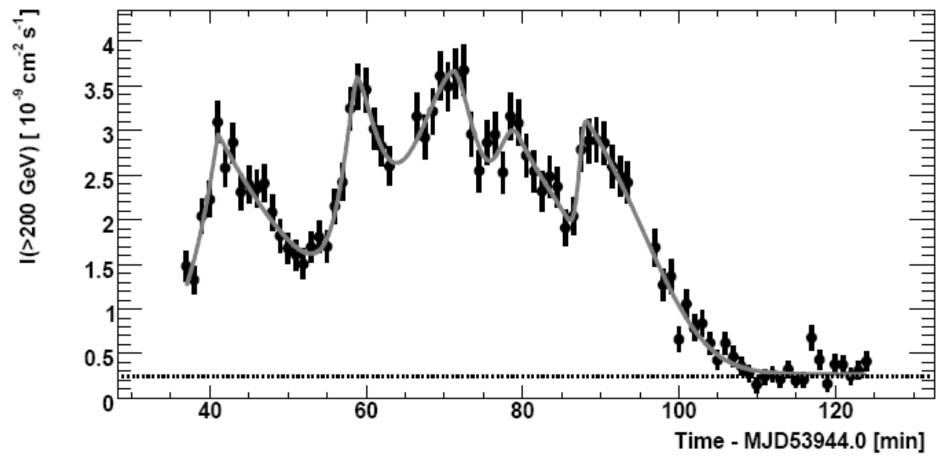
CTA performance goals

- Extend energy coverage to higher and lower energies:



- Understand processes in sources: hadronic showers or inverse Compton scattering?

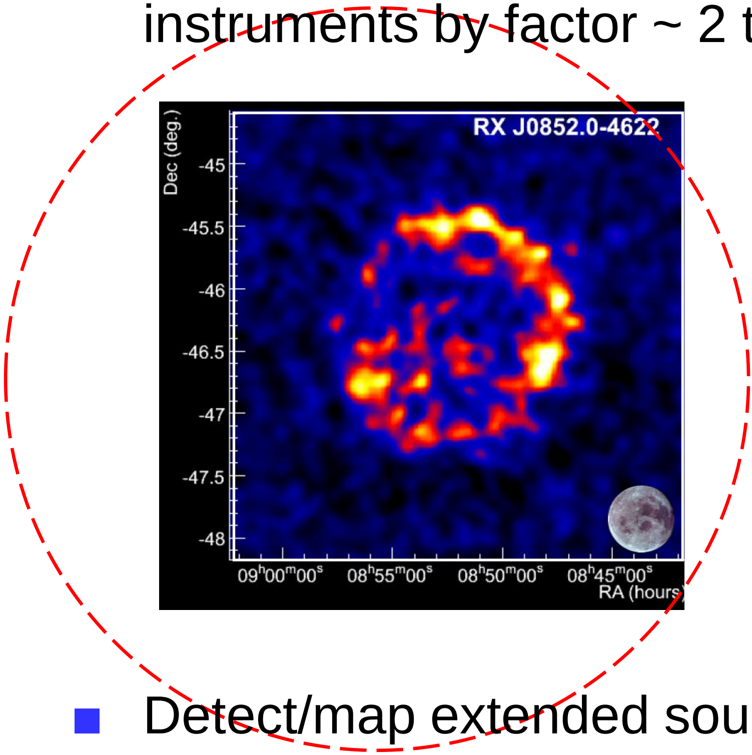
- Increase detection rate, map activity on sub-minute timescales.
- E.g. blazar PKS 2155-304 (HESS):



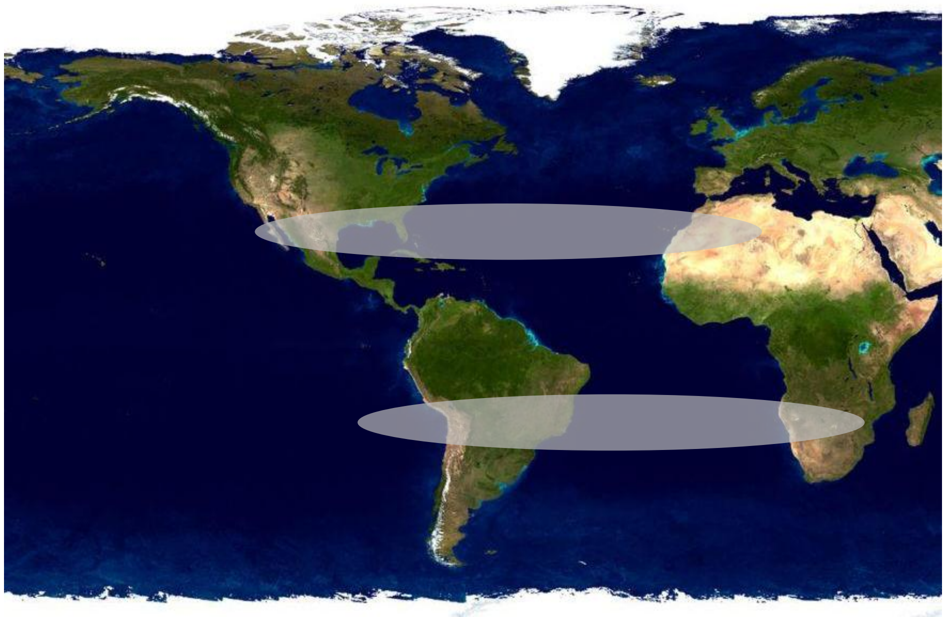
- Determine size of emission regions around active galactic nuclei.
- Study quantum gravity.
- Fast slewing, large FoV (fastest burst notification from Fermi g-ray burst monitor precision ~ 10°).

CTA performance goals

- Increase field of view w.r.t. current instruments by factor ~ 2 to 6...8°.

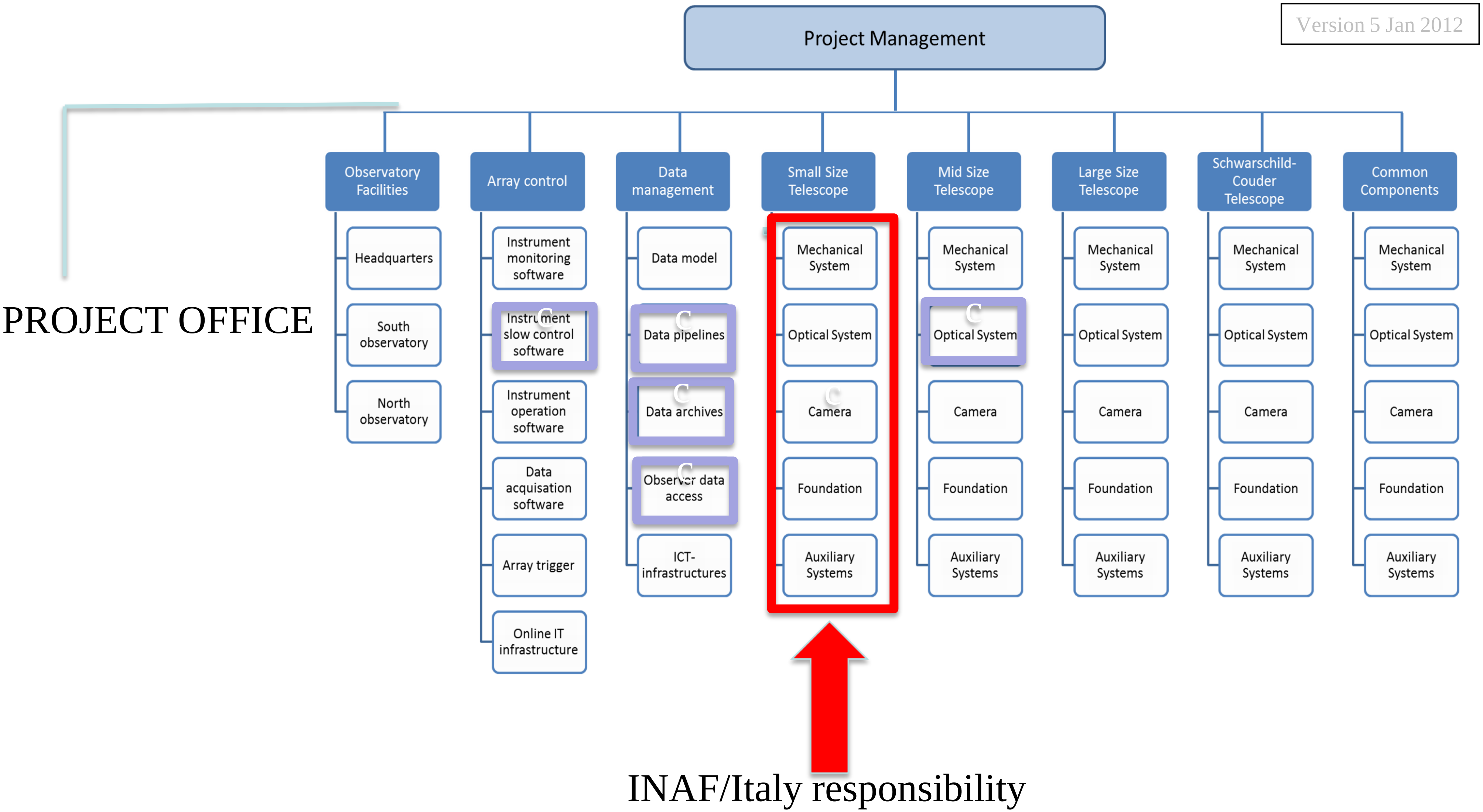


- Detect/map extended sources.
- Improve survey capability: galactic plane at ~ 0.001 Crab in 250 hours, full sky at ~ 0.01 Crab in 1 year.



- Southern array:
  - Galactic and extragalactic sources.
  - 10 GeV...100 TeV.
  - Angular resolution 0.02...0.2°.
- Northern array:
  - Mainly extragalactic sources.
  - 10 GeV...1 TeV.
  - Smaller field of view.

CTA PBS


Version 5 Jan 2012
Project Management
PROJECT OFFICE
Observatory Facilities
Headquarters
South observatory
North observatory
Array control
Instrument monitoring software
Instrument slow control software
Instrument operation software
Data acquisation software
Array trigger
Online IT infrastructure
Data management
Data model
Data pipelines
Data archives
Observer data access
ICT-infrastructures
Small Size Telescope
Mechanical System
Optical System
Camera
Foundation
Auxiliary Systems
Mid Size Telescope
Mechanical System
Optical System
Camera
Foundation
Auxiliary Systems
Large Size Telescope
Mechanical System
Optical System
Camera
Foundation
Auxiliary Systems
Schwarschild-Couder Telescope
Mechanical System
Optical System
Camera
Foundation
Auxiliary Systems
Common Components
Mechanical System
Optical System
Camera
Foundation
Auxiliary Systems
INAF/Italy responsibility

Small size telescope design – take one

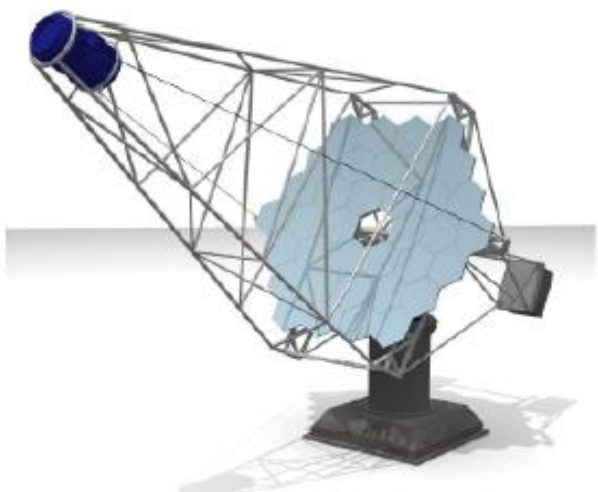


Fig. 5 The Davies-Cotton design.

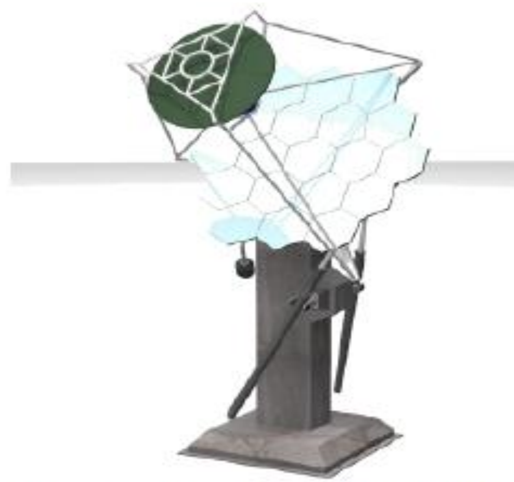


Fig. 6 The Schwarzschild-Couder design.

- Single mirror DC is the optical model of the present Cherenkov telescopes
- Single mirror DC is the baseline for LST and MST of CTA.

The INAF ASTRI Program

(in a nutshell...)

The INAF ASTRI SST prototype

The ASTRI Program is an **Italian "Progetto Bandiera"** funded by the Ministry of Education, University and Research (MIUR) for a total amount of **8 MEuro** to develop the **"replica" technology for mirrors and new sensors for VHE astrophysics.**

The main goal is the realization, within the CTA framework, of an **end-to-end prototype** of the CTA SST to be tested under field conditions.

INAF is in charge of the design of the mirrors and the camera, development of the software and other related activities. The telescope structure is designed by external firms.

INAF contributes with about **24 FTE/year** to the project, and received **3 MEuro** to cover the costs for the **2011**. Annual reviews are foreseen by MIUR in order to allocate, on an annual basis, the rest of the budget according to the following scheme: **2012 (2 MEuro), 2013 (2 MEuro), and 2014 (1 MEuro)**.

A detailed description of the ASTRI Program has been given to the CTA Project Committee Meeting on 2011 July 5th and it is available at the PO INDICO repository.