HIGH ENERGY GAMMA RAY ASTRONOMY WITH MAGIC TELESCOPES

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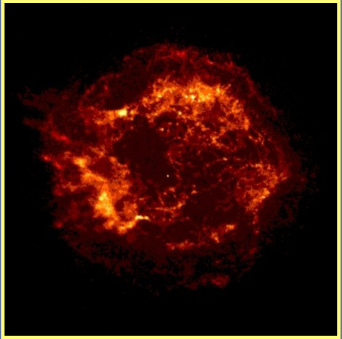
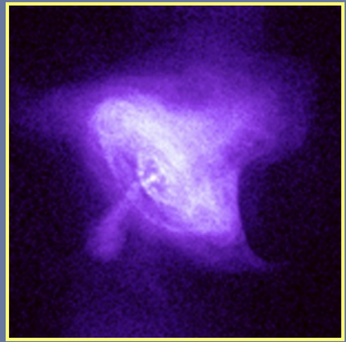
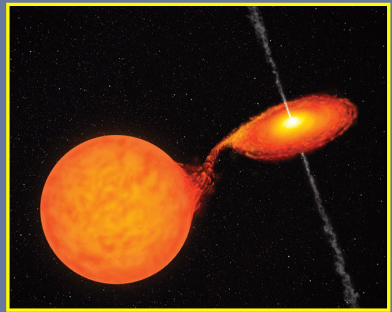
Scientific Objectives



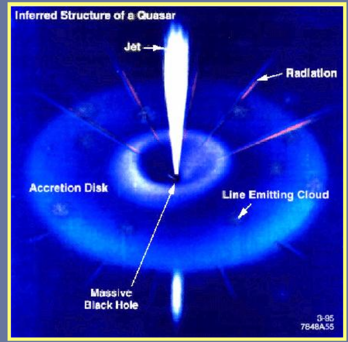
SNRs



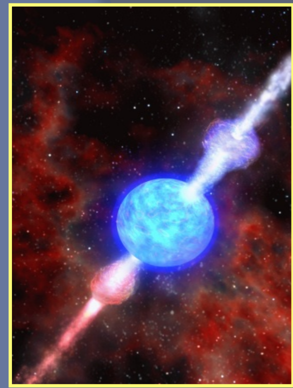
Pulsars
PWNe



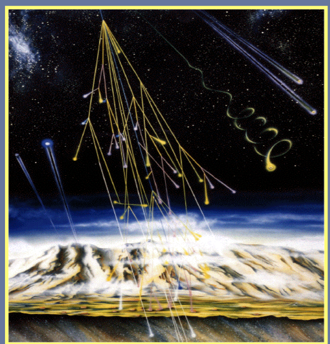
Micro quasars
X-ray binaries



AGNs

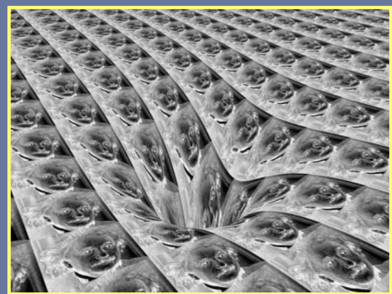


GRBs

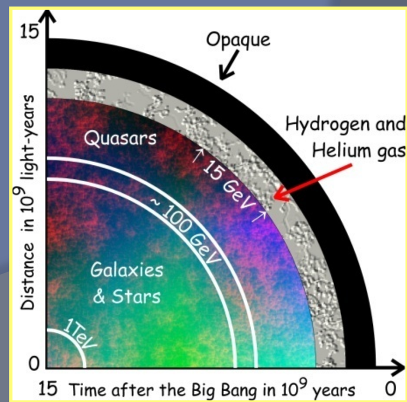


Origin of
cosmic rays

Dark matter



Space-time
& relativity



Cosmology

Big International Collaboration
~150 Scientists from 8 countries

Bulgaria Sofia

Croatia Consortium

Finland Tuorla Observatory

Germany DESY, Dortmund
MPI Munich, Wuerzburg

Italy INFN Padova, INFN Siena
INFN Udine, INFN Como,
INAF Rome

Poland INRNE Lodz

Spain U. Barcelona, UAB Barcelona
IEEC-CSIC Barcelona
IFAE Barcelona, IAA Granada
IAC Tenerife
U Compultense Madrid

Switzerland ETH

MAGIC Telescopes

New technologies
to lower the threshold energy

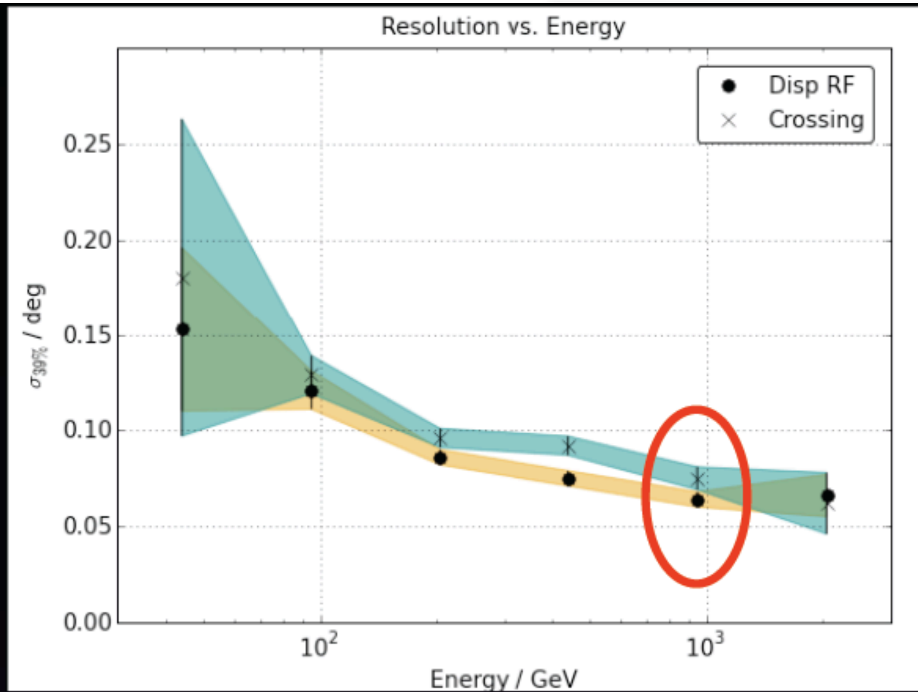
17m diameter world largest Cherenkov tel.
0.1°High resolution camera
Hemispherical High QE PMT
Optical fibre analogue signal transmission
2GS/sec Ultra Fast FADCs
Fast rotation for GRB ~20secs/180deg.
Trigger threshold ~50GeV ➔ ~25GeV

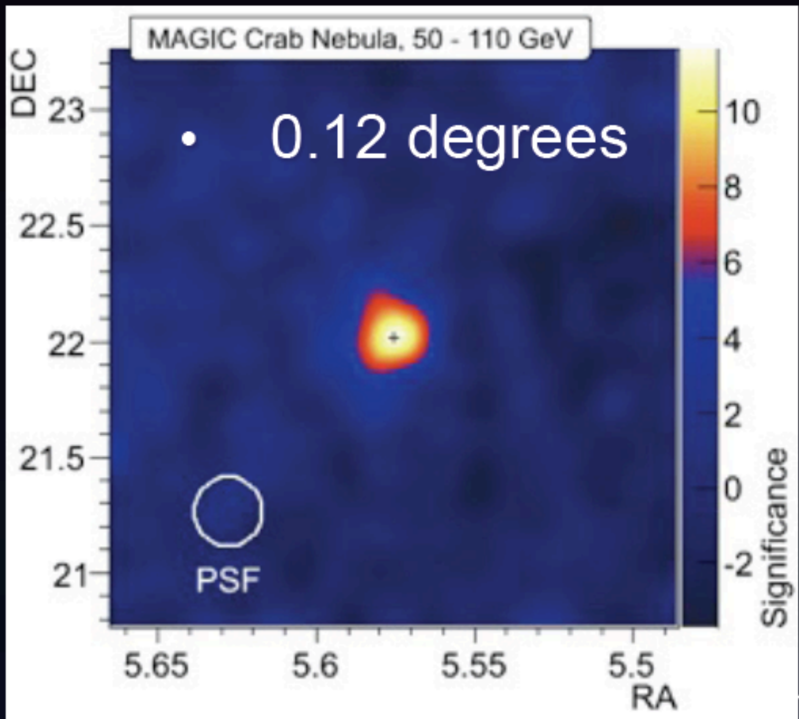
Upgrade from MAGIC to MAGIC Stereo
Regular operation since September 2009

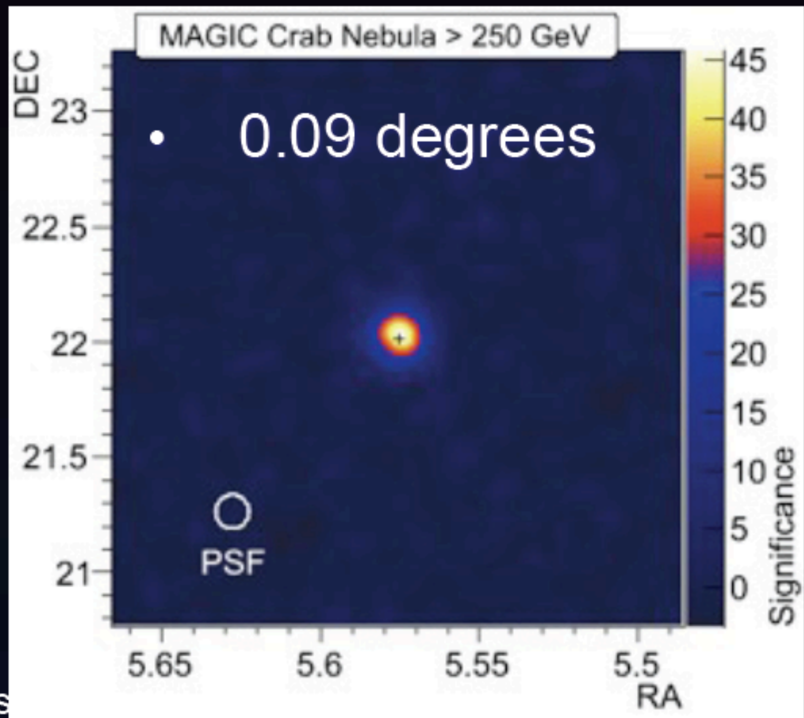
Sensitivity 1.6% Crab ➔ ~0.8% Crab (50hrs)
Angular resolution 1.0 deg ➔ 0.6 deg
Energy resolution 25% ➔ 15%

Angular resolution (39% containment) on Crab

- Well below 0.1 degrees above 200 GeV
- We reach 0.06 degrees at 1 TeV.

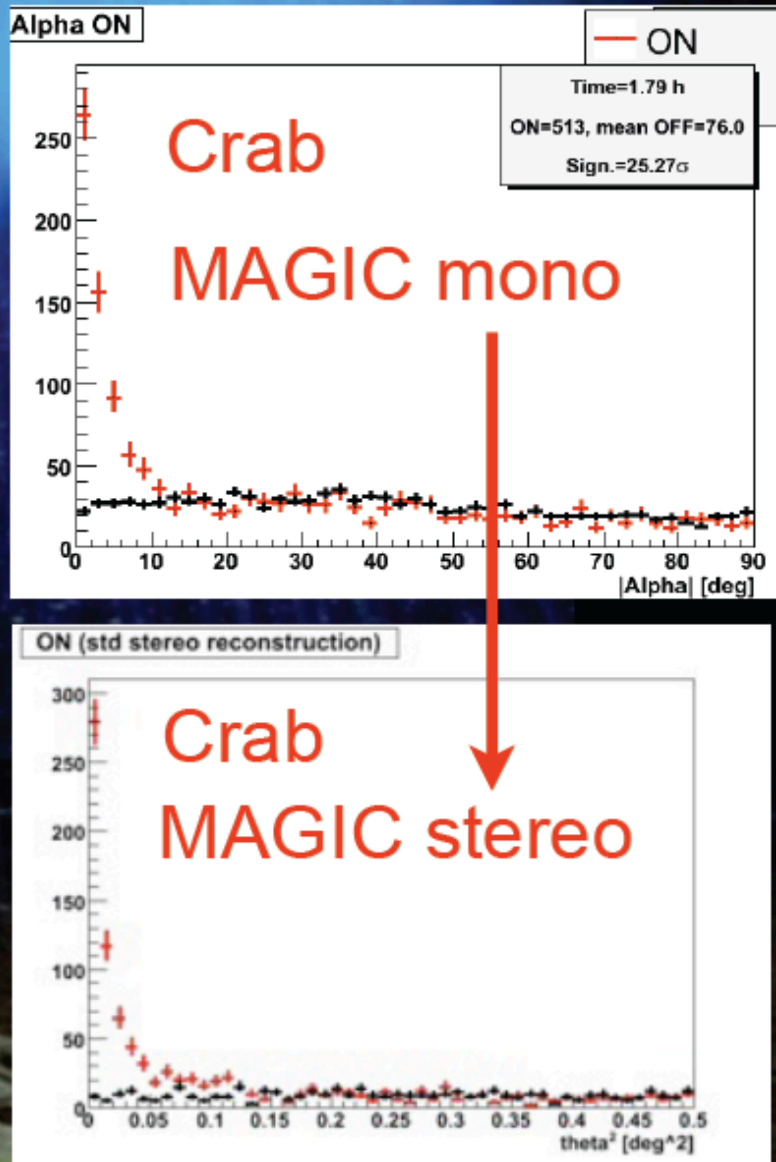


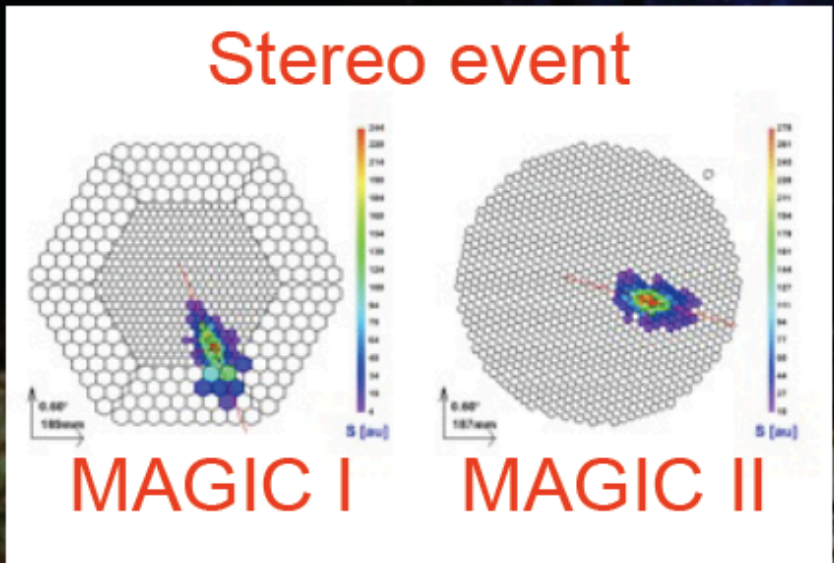




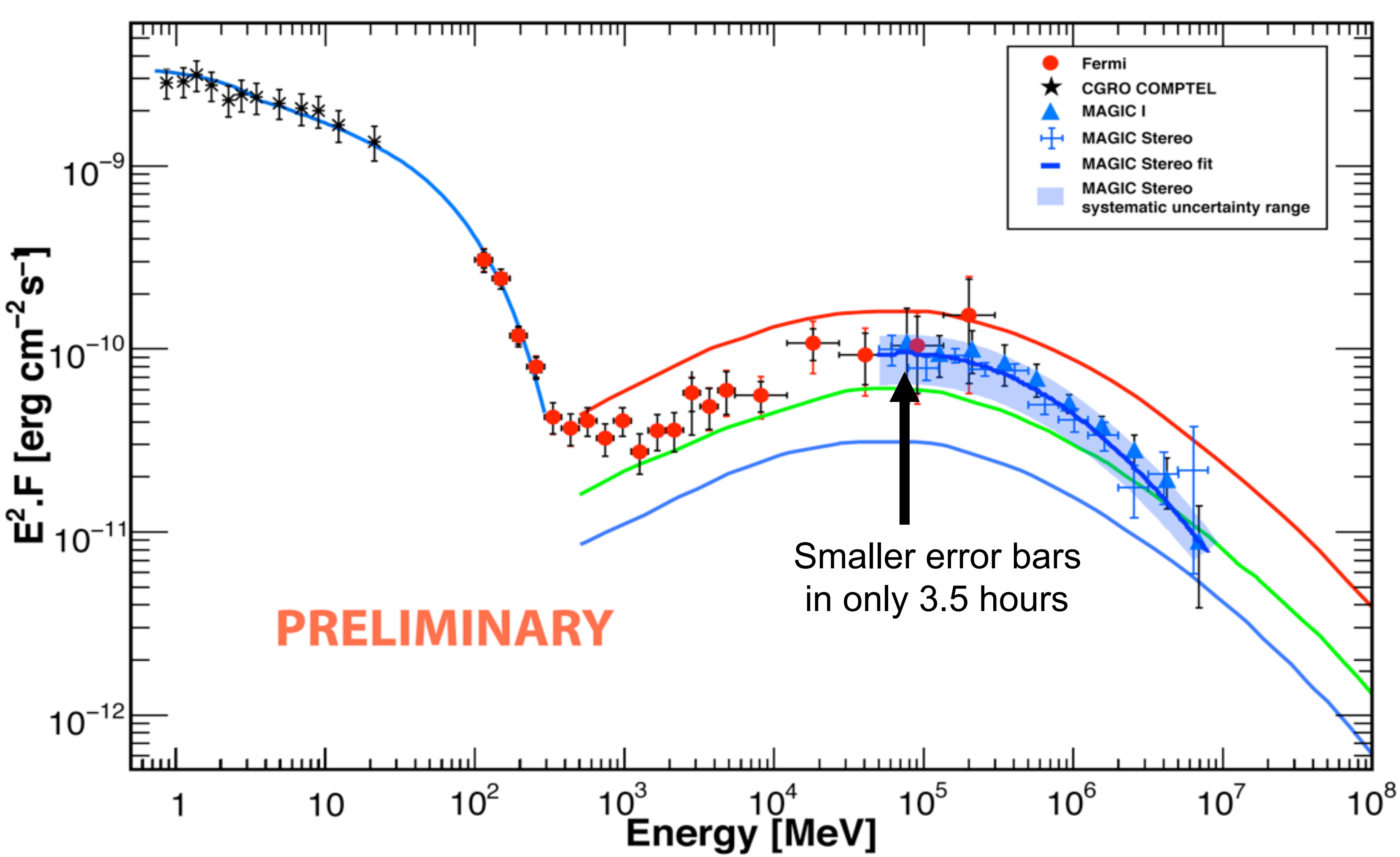
Started regular observations from October 2009

- ☑ Better hadron rejection
- ☑ Better angular resolution (0.06 degrees)
- ☑ Better energy resolution (25%-15%)
- ☑ Enhance the sensitivity over the whole energy range

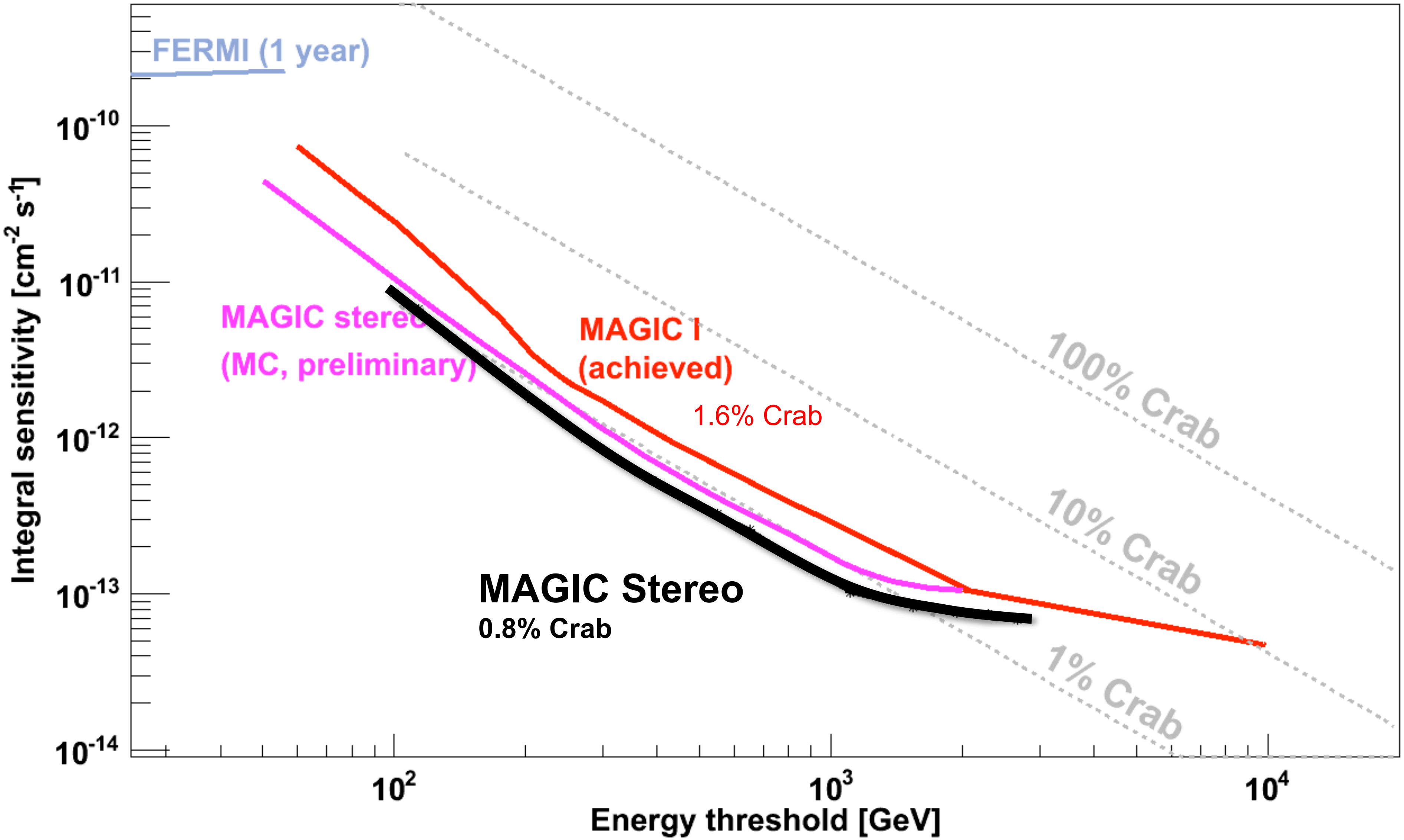




Crab Nebula 3.5hr observation with MAGIC-Stereo



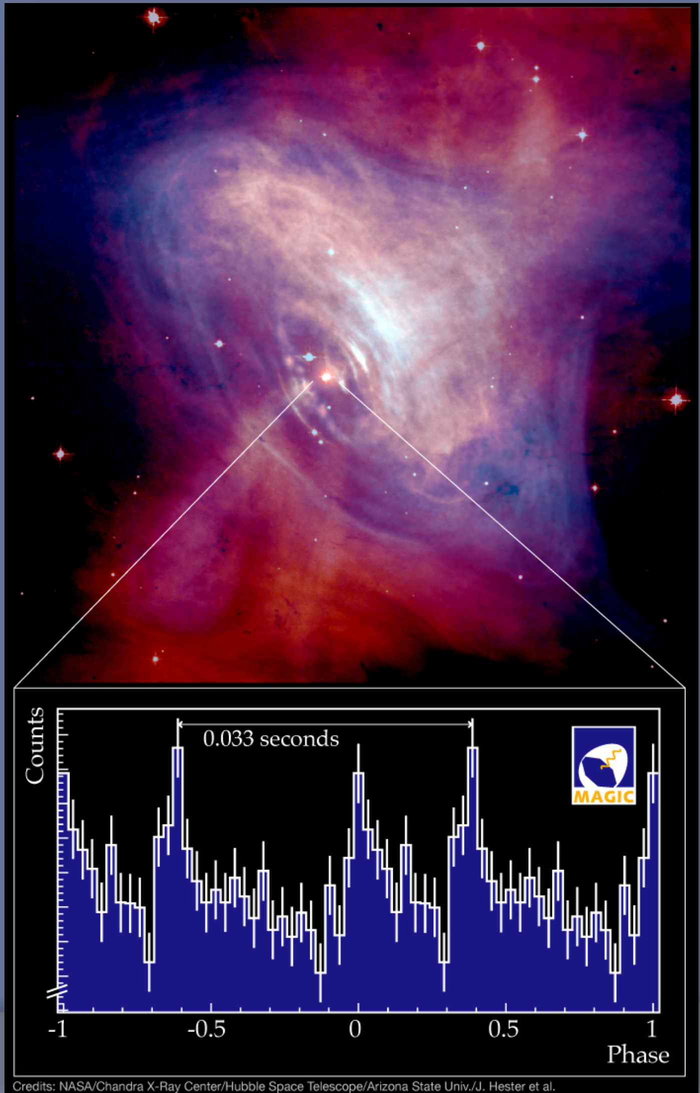
Sensitivity of MAGIC Stereo achieved (~0.8% Crab)

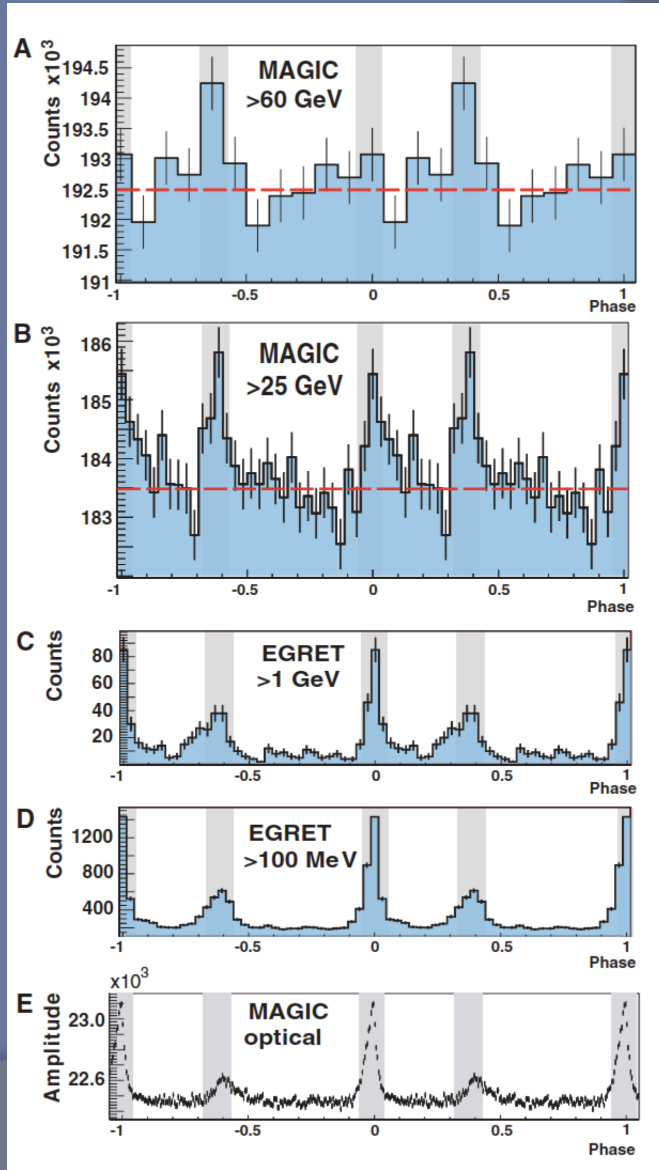



MAGIC results

Detection of Crab Pulsar after 20 years' long effort

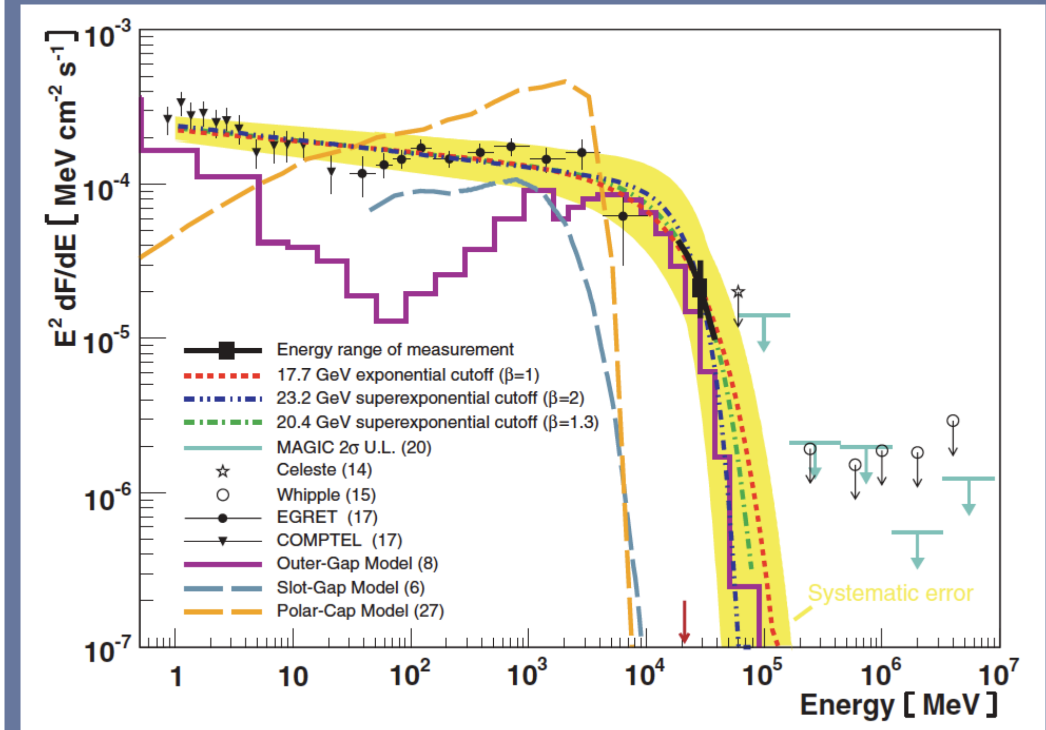
Published in Science in 2008

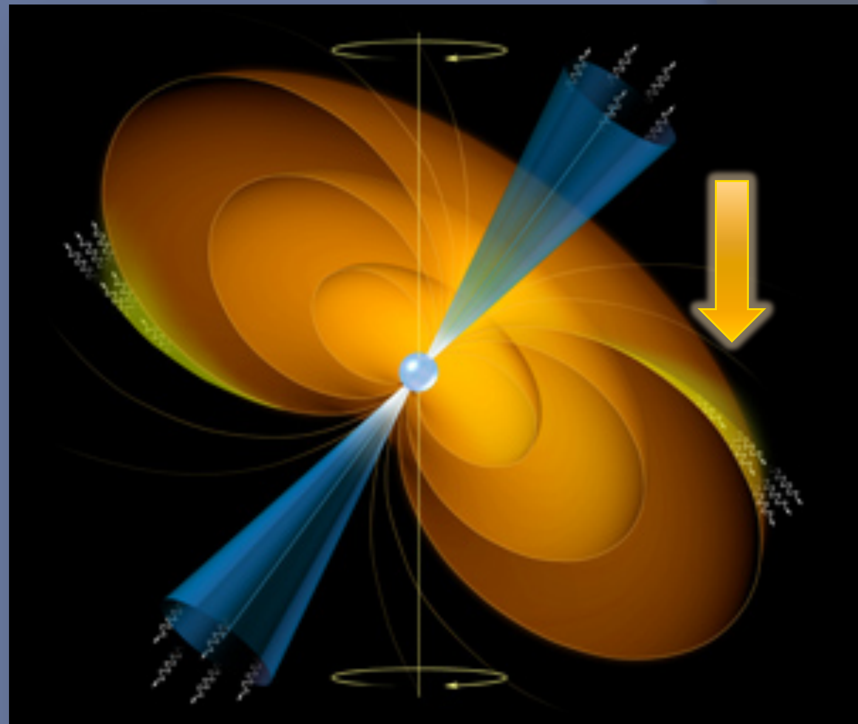




The MAGIC measurement clarified the emission mechanism

Outer gap /Polar cap

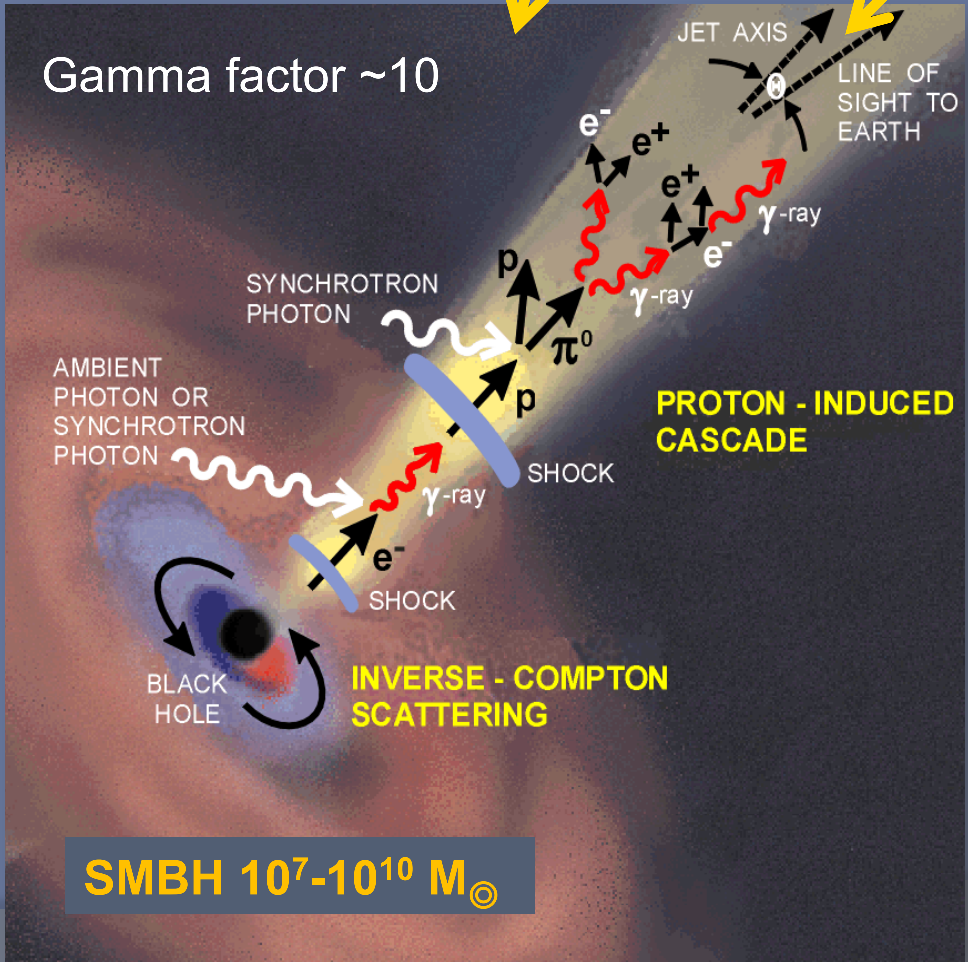


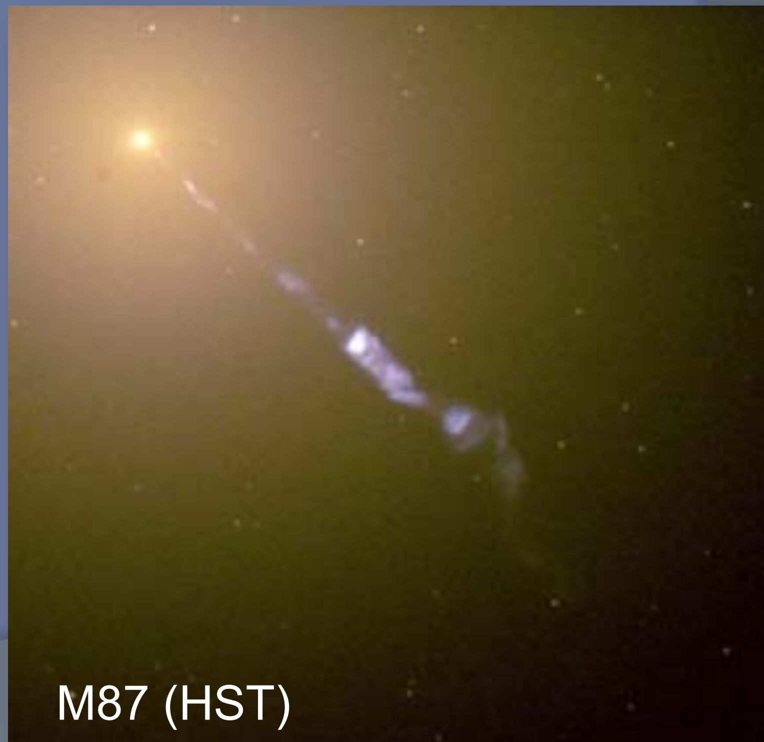


Published in Science 2008

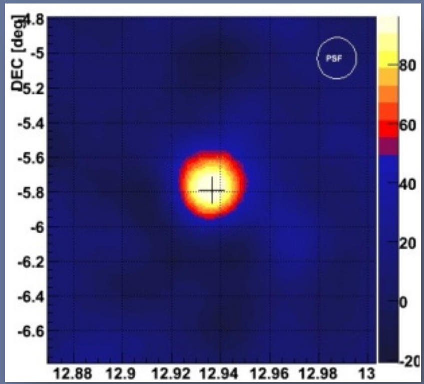
Cosmic Ray accelerator
Active Galactic Nuclei

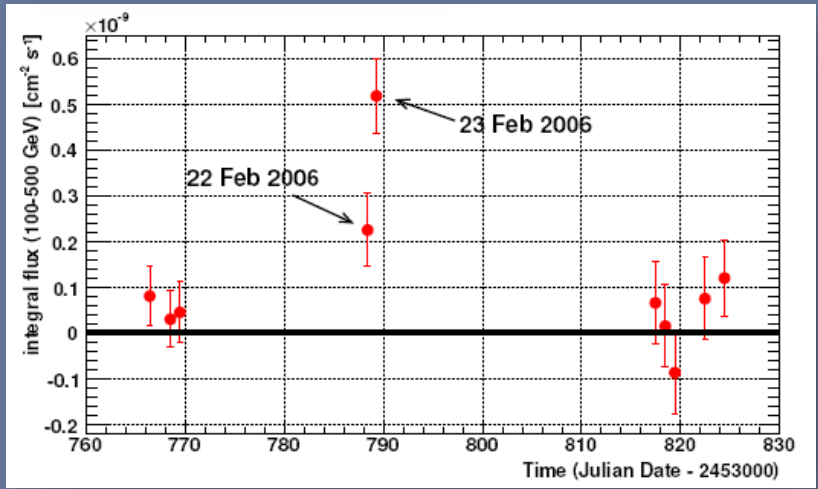
FRI, FRII   Blazars

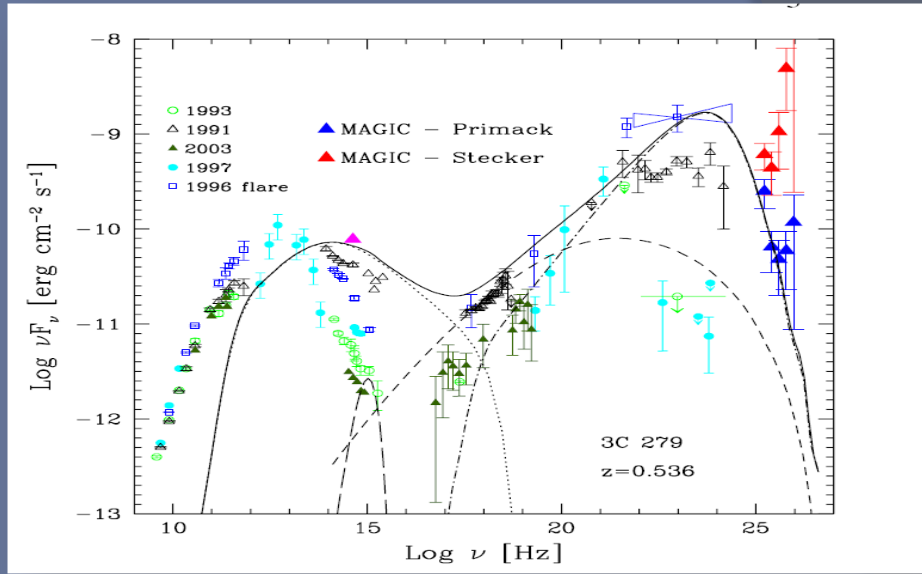


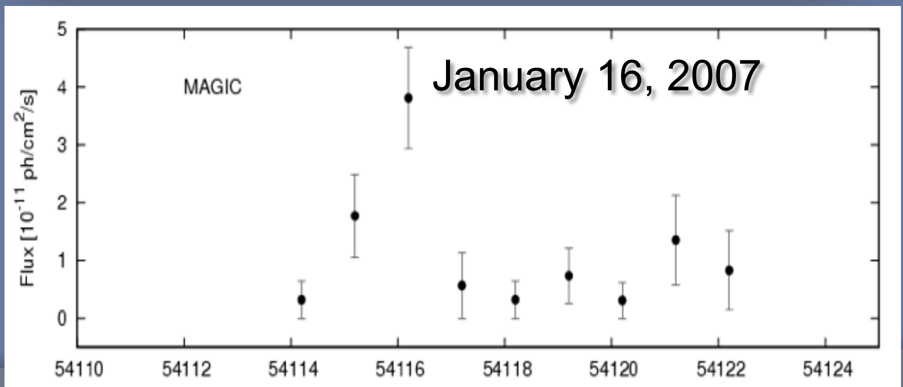


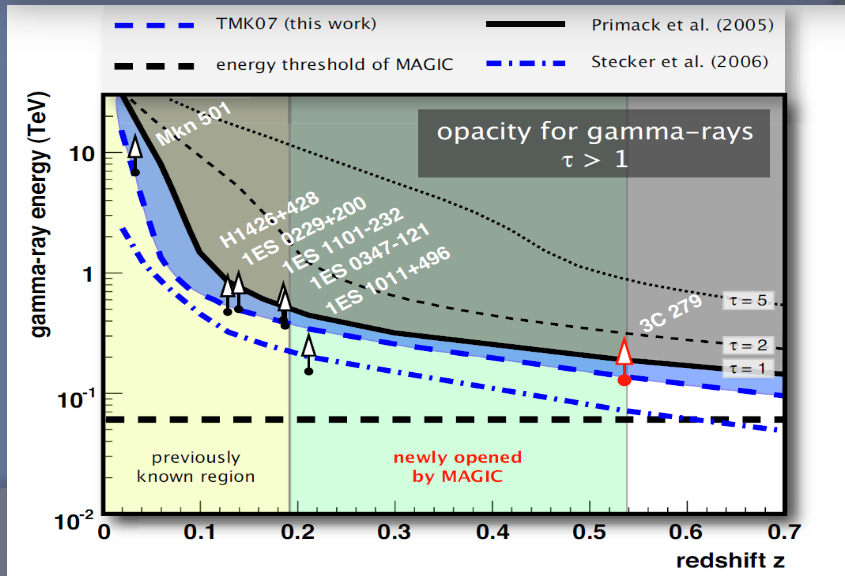
FSRQ 3C279 (z=0.536) MAGIC Most distant 100GeV AGN



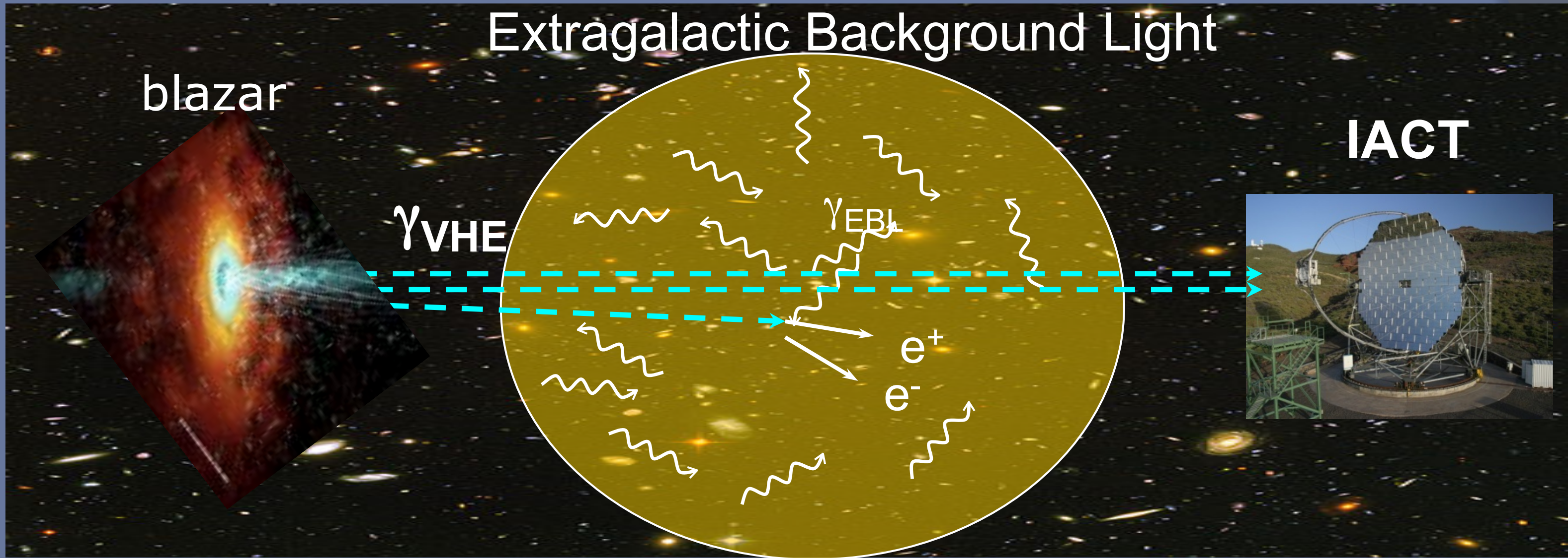




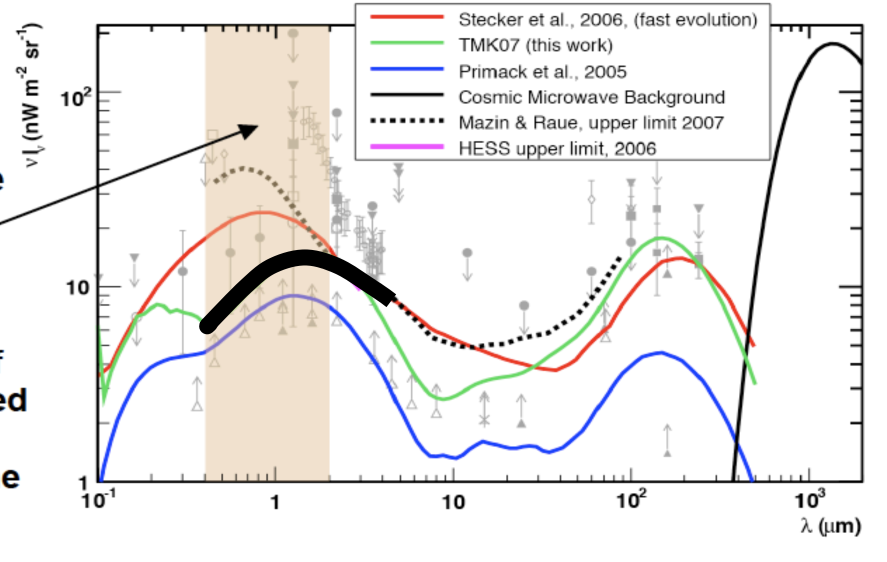




EBL upper limit by MAGIC and HESS observations

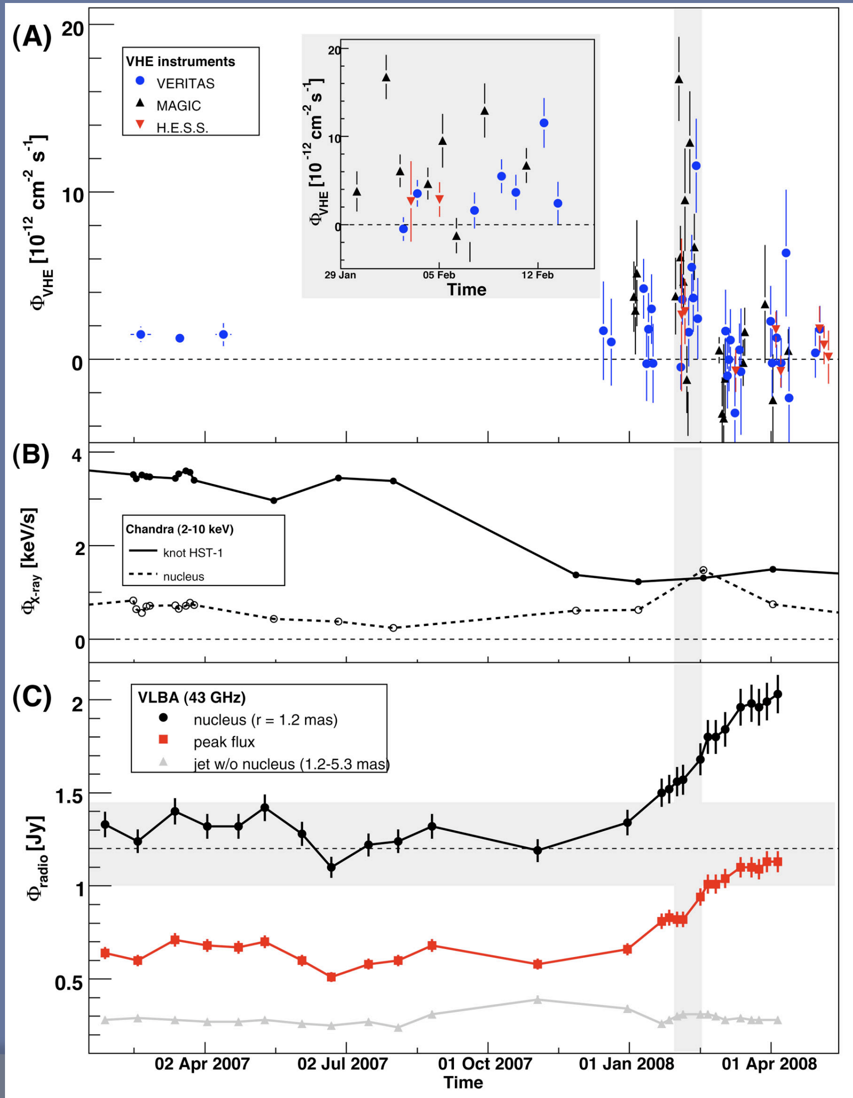


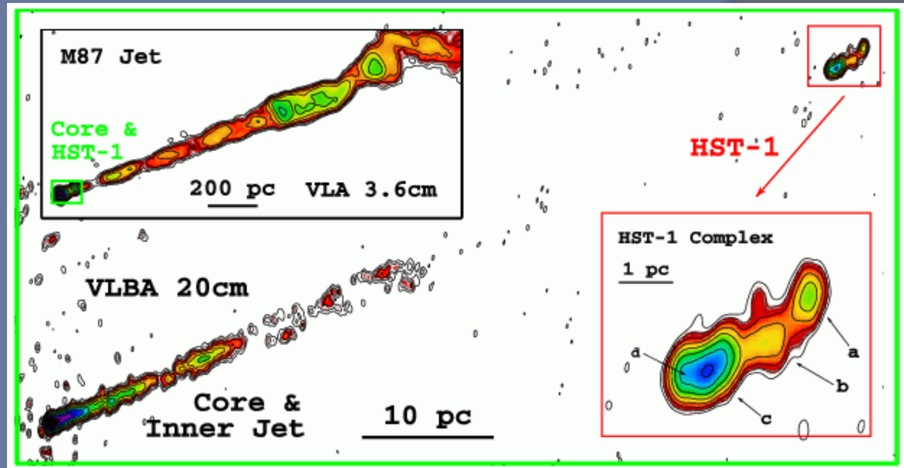
Probing new range of the EBL



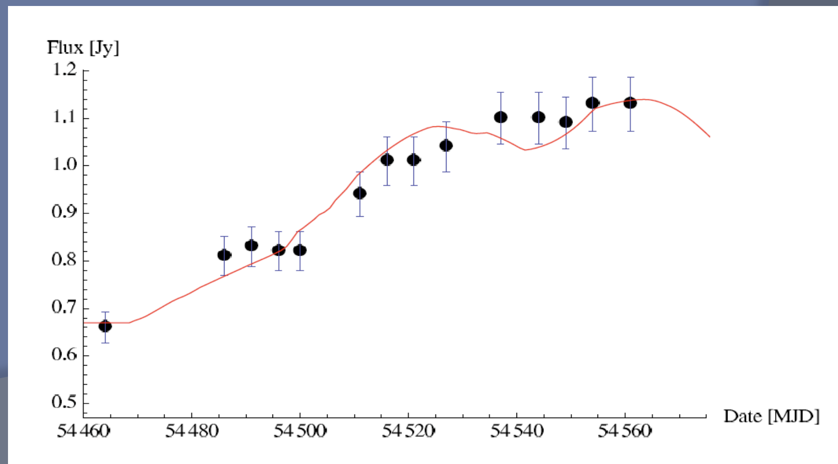
Green line: model of Kneiske et al., tuned to the 3C 279 spectrum using the Γ=1.5 criterion

M87 (FR-I off-axis blazar) flare in 2008: MAGIC, VERITAS, HESS, VLBA

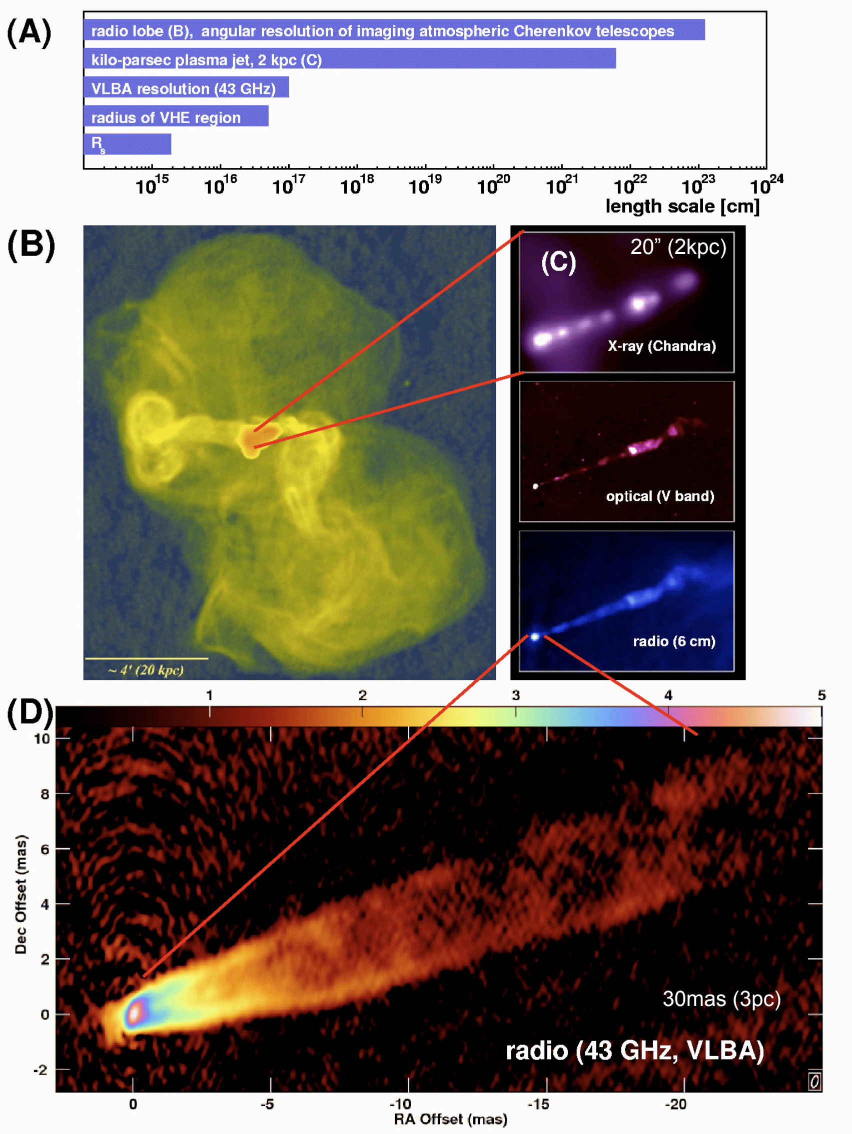


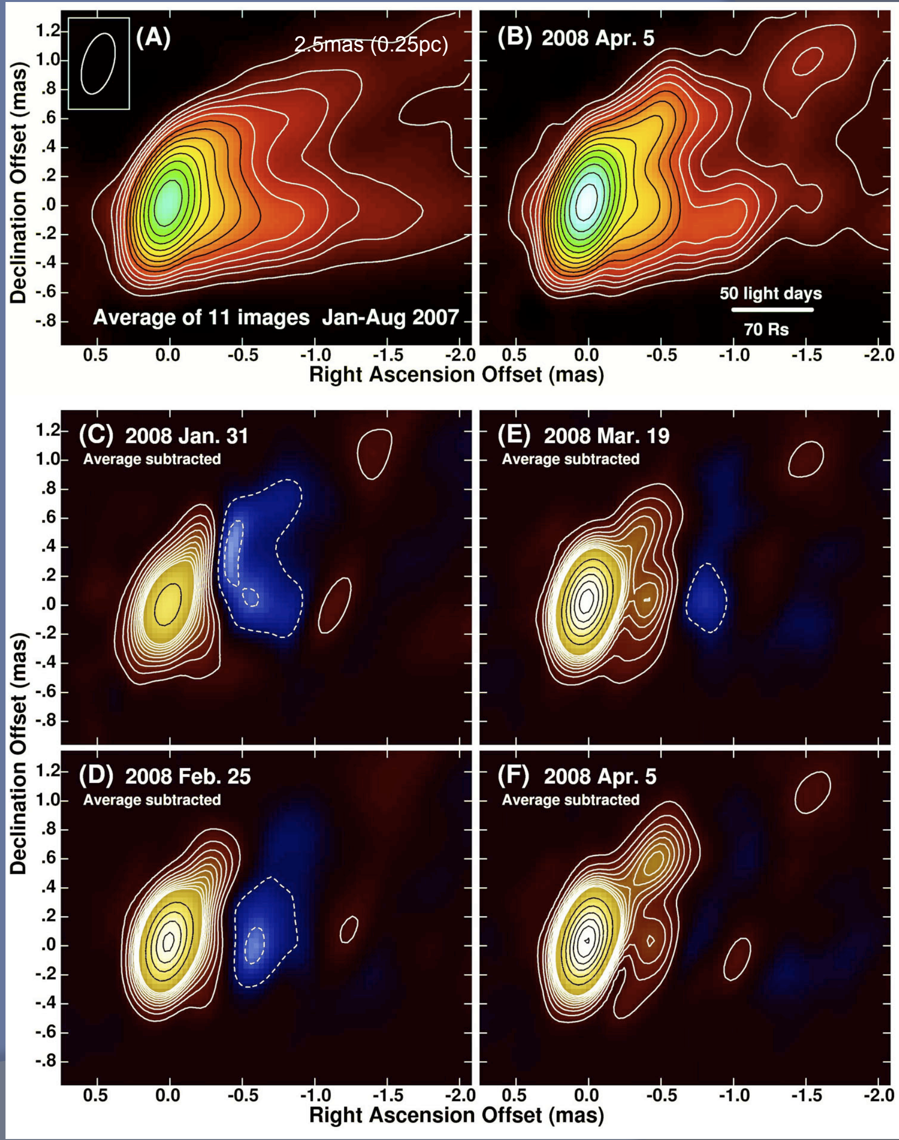


Model of 43GHz Radio flux
using the measured VHE gamma flux



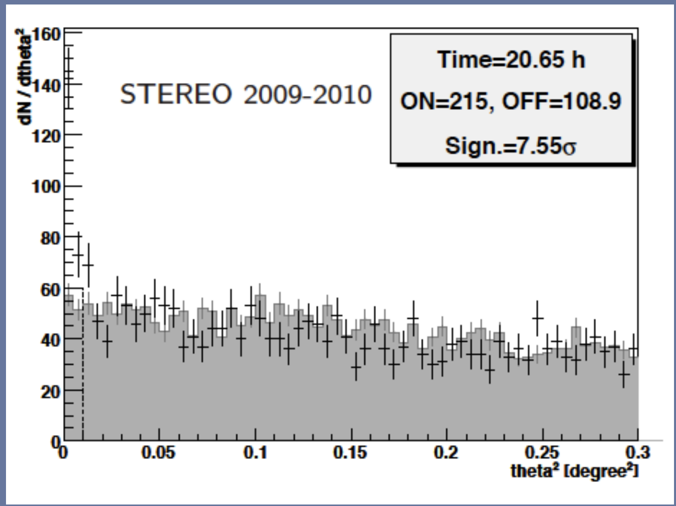
M87 flare in 2008:
MAGIC, VERITA, HESS, and VLBA

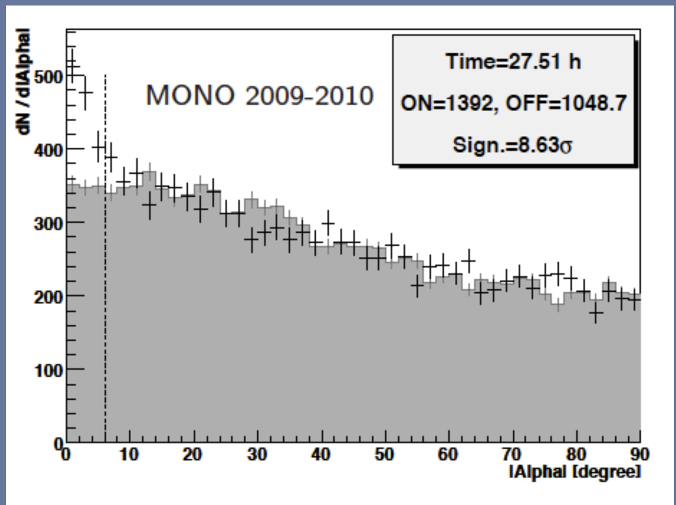


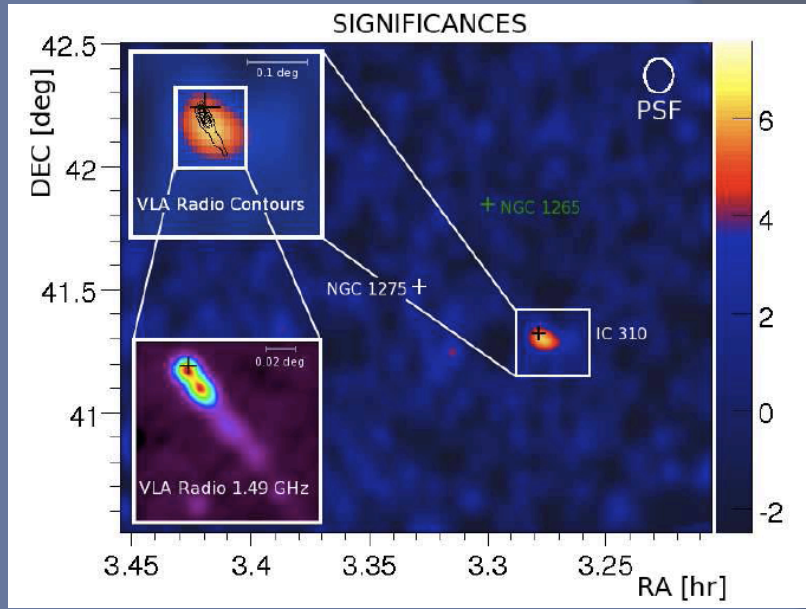


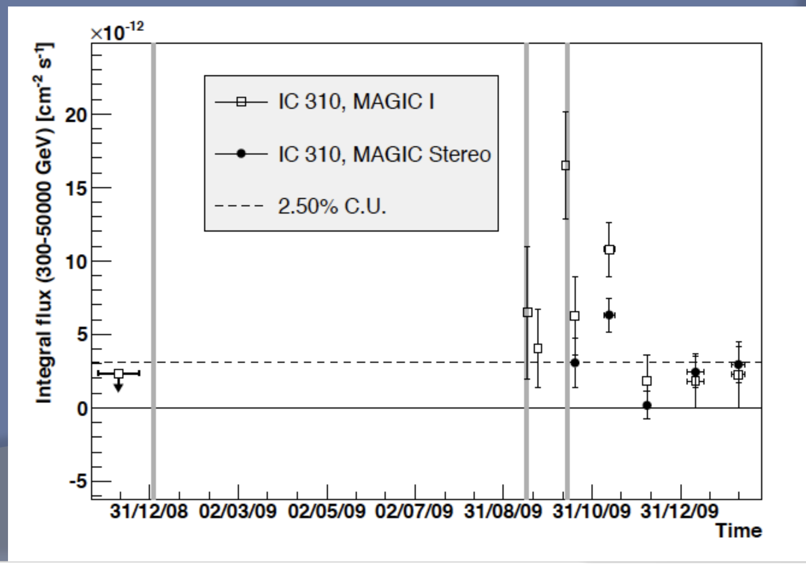
MAGIC STEREO RESULTS

IC310 (FR-I Radio galaxy) is discovered, when observing Perseus cluster / NGC1275





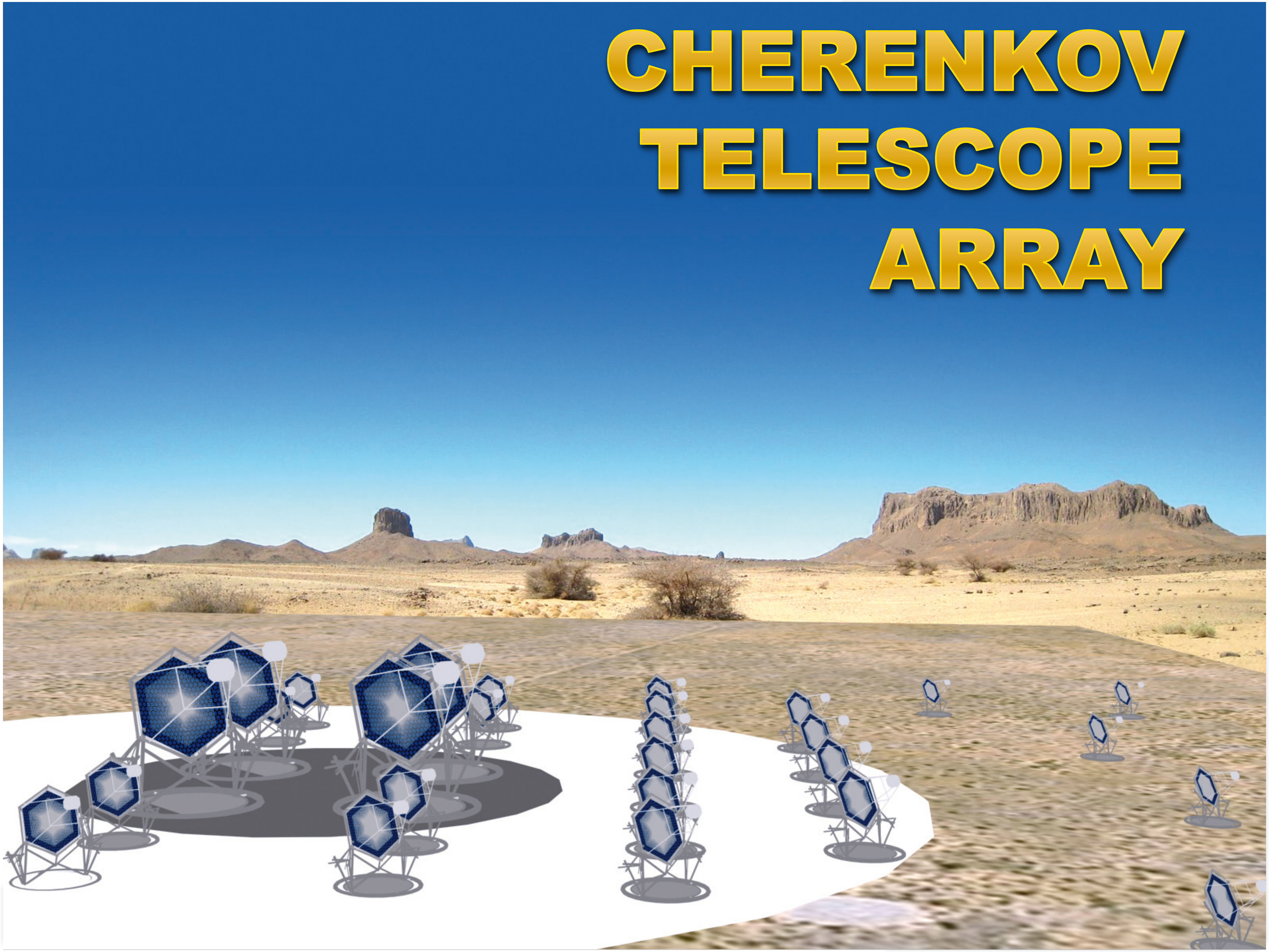


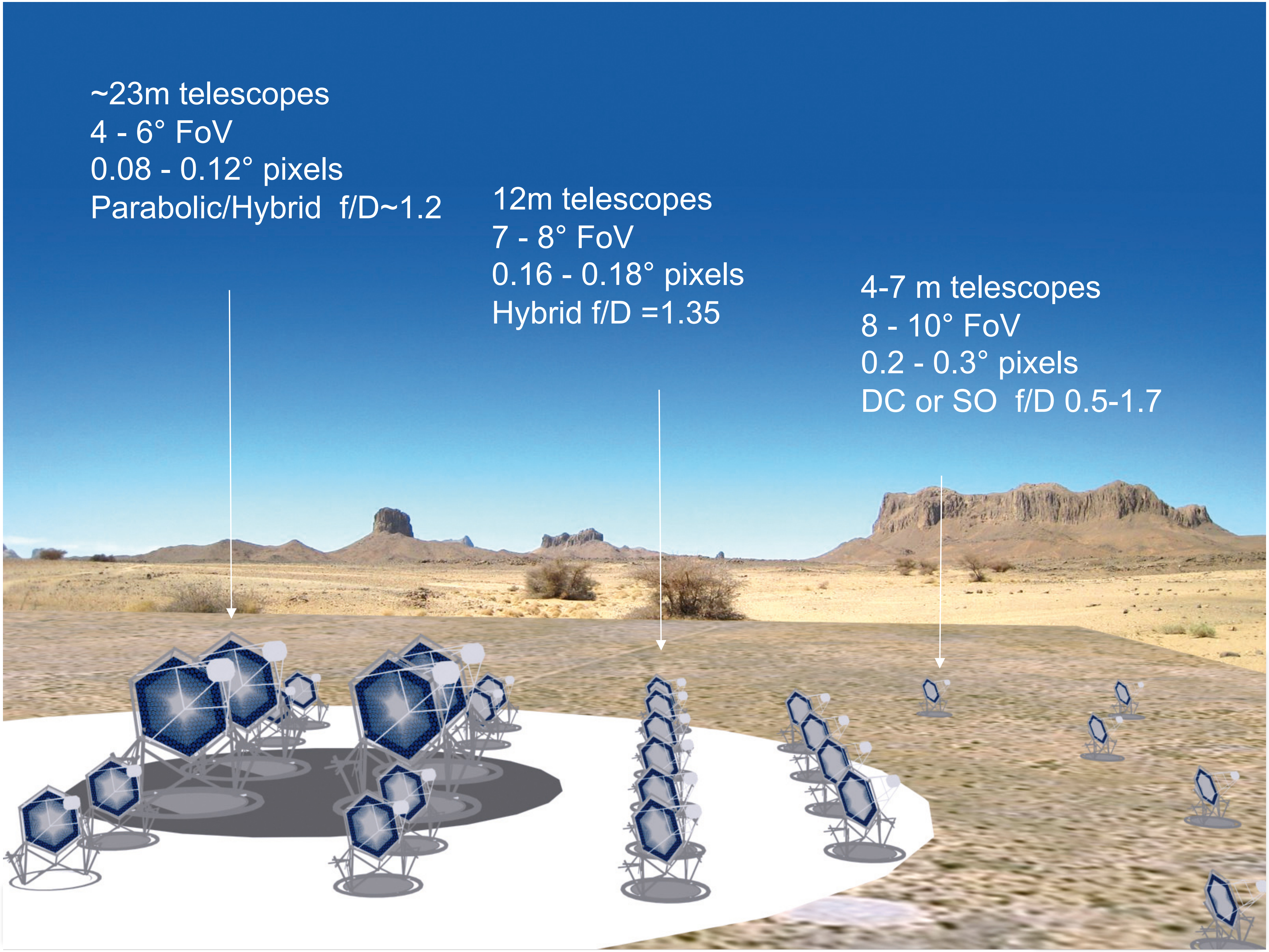


Too bright as an off-axis blazar

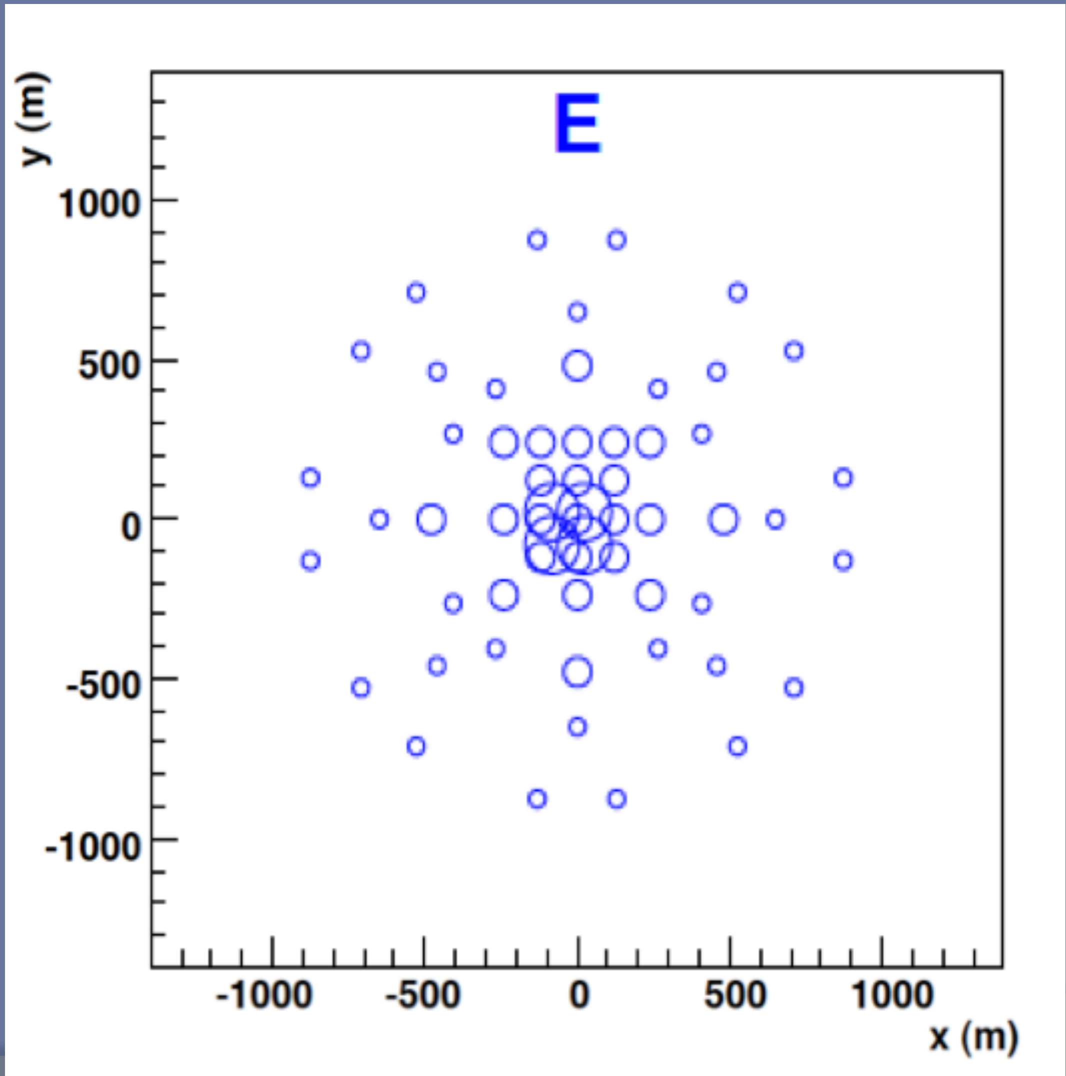
Summary of MAGIC

- MAGIC Stereo is working as expected or even better
- Highly productive
  - Many source detections, many source discoveries
    - 66 publications last 5years (4 publications in Science)
      - 3C279 detection, M87 big flare
      - Crab Pulsar, Gamma Ray Binary LSI +61 303
    - Most of distant sources are discovered by MAGIC
      - ➔ 3C279(z=0.536), PKS1222(z=0.436)
    - Last several months, 5 ATels are submitted


CHERENKOV
TELESCOPE
ARRAY


~23m telescopes
4 - 6° FoV
0.08 - 0.12° pixels
Parabolic/Hybrid f/D~1.2
12m telescopes
7 - 8° FoV
0.16 - 0.18° pixels
Hybrid f/D =1.35
4-7 m telescopes
8 - 10° FoV
0.2 - 0.3° pixels
DC or SO f/D 0.5-1.7

Possible array configuration

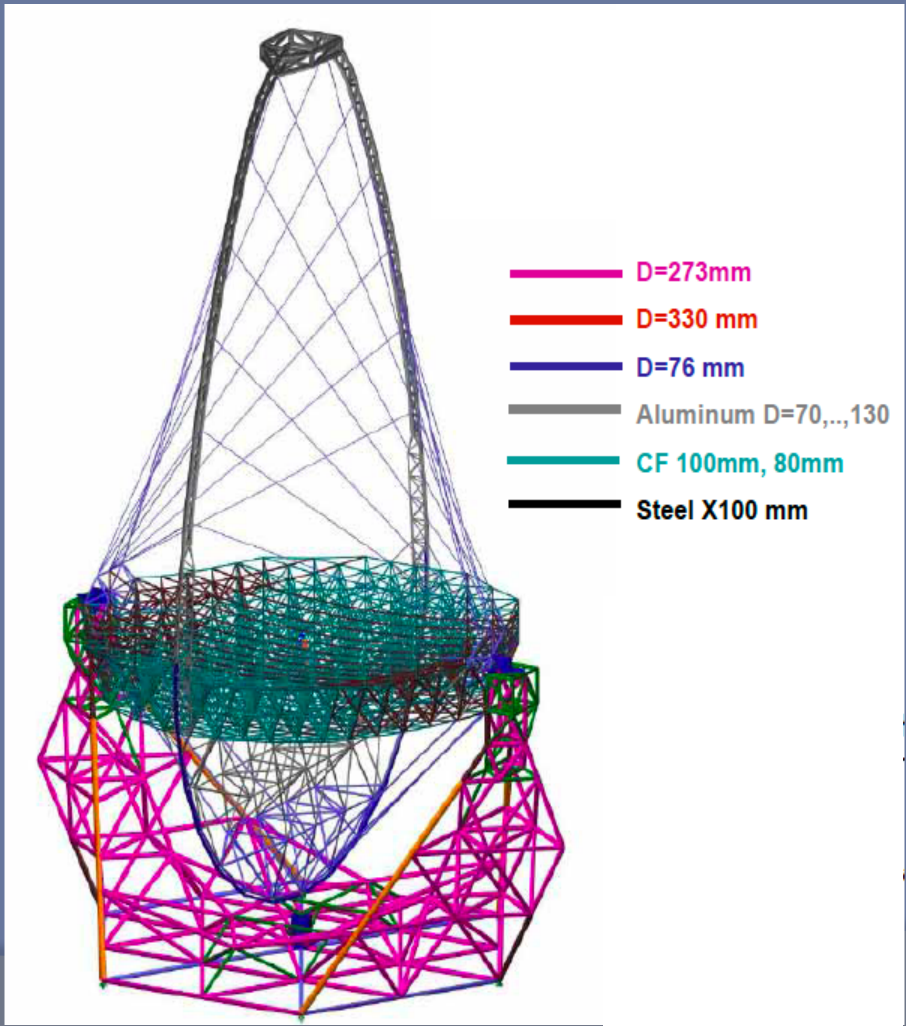


Configuration E:
LST x 4, MST x 23, SST x 32

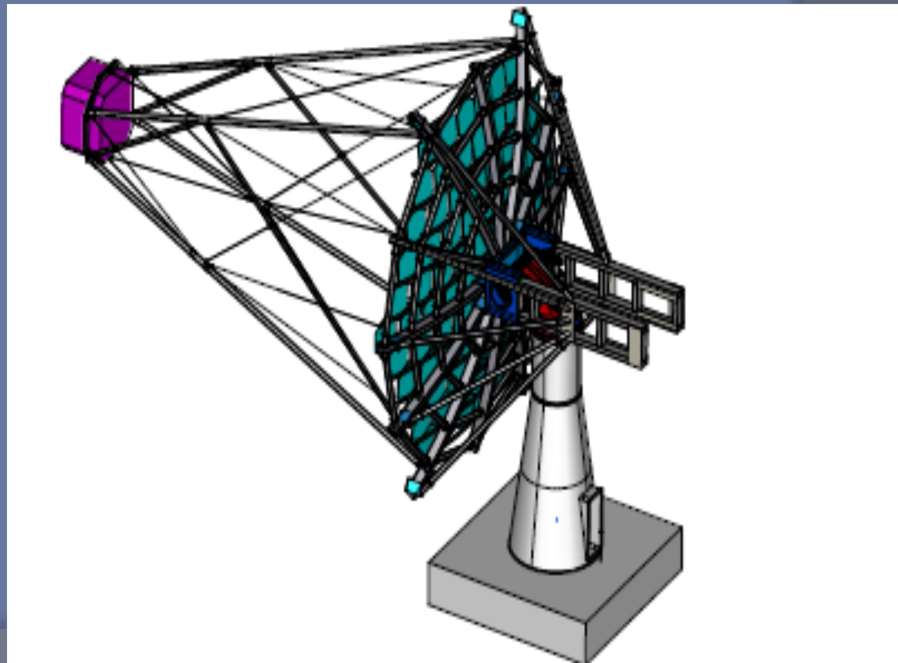
Acceptance 3km2

23m Large size telescope and 12m Middle size telescope

23m LST designed by MPI group

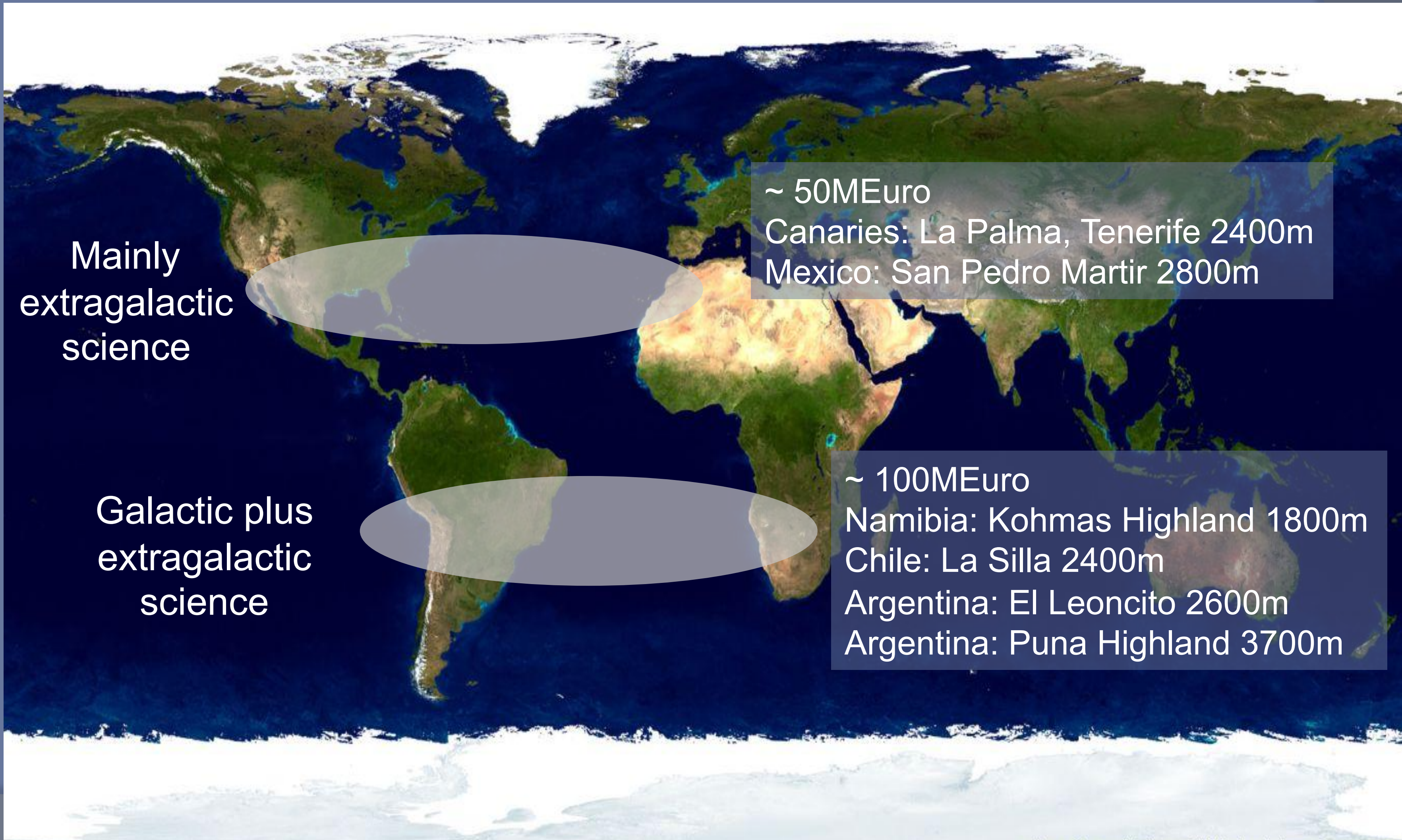


12m MST designed by DESY group

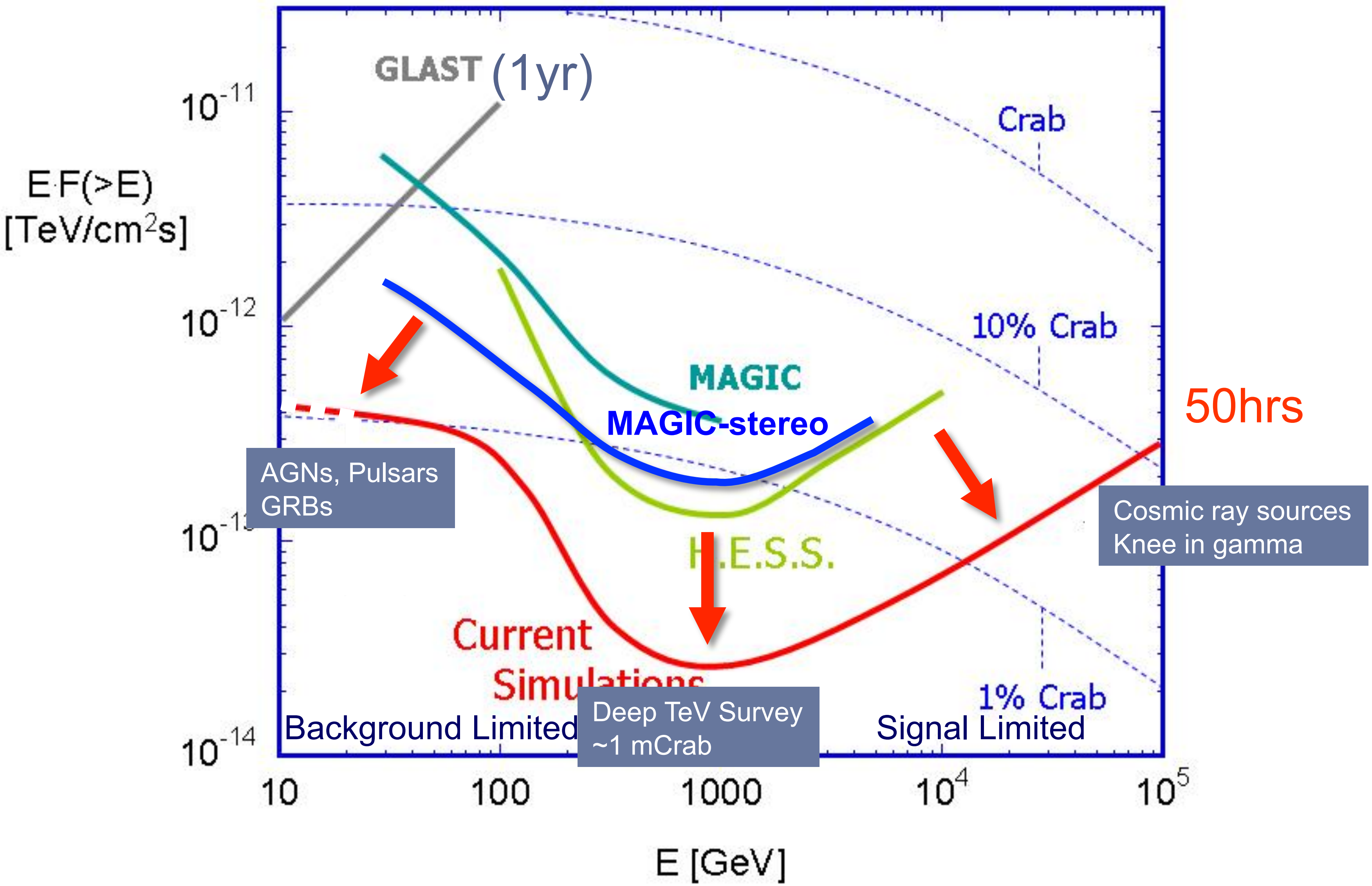


All sky observatory (2 stations in North and South)

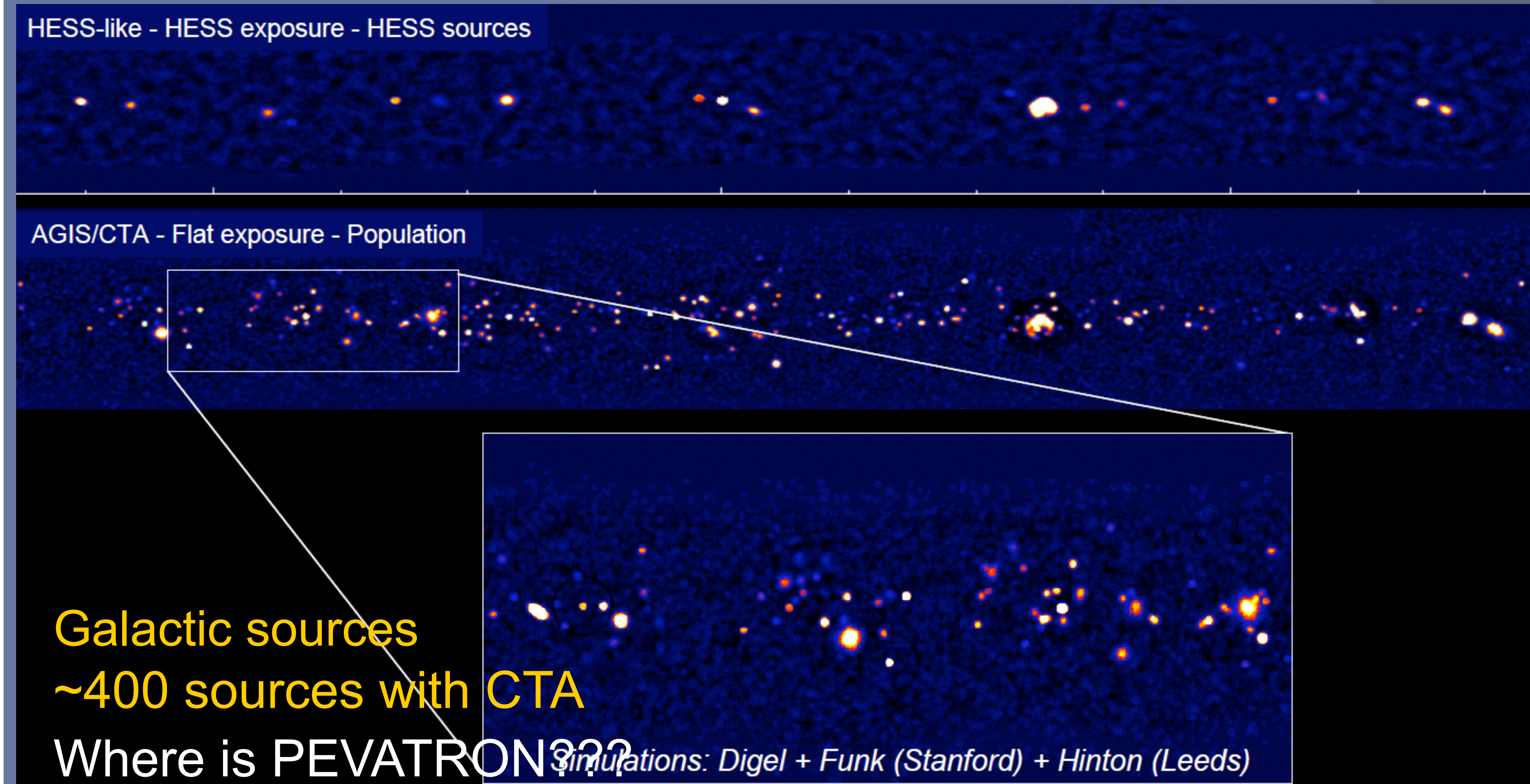
One observatory with two sites operated by one consortium



Aiming sensitivity



Galactic sources

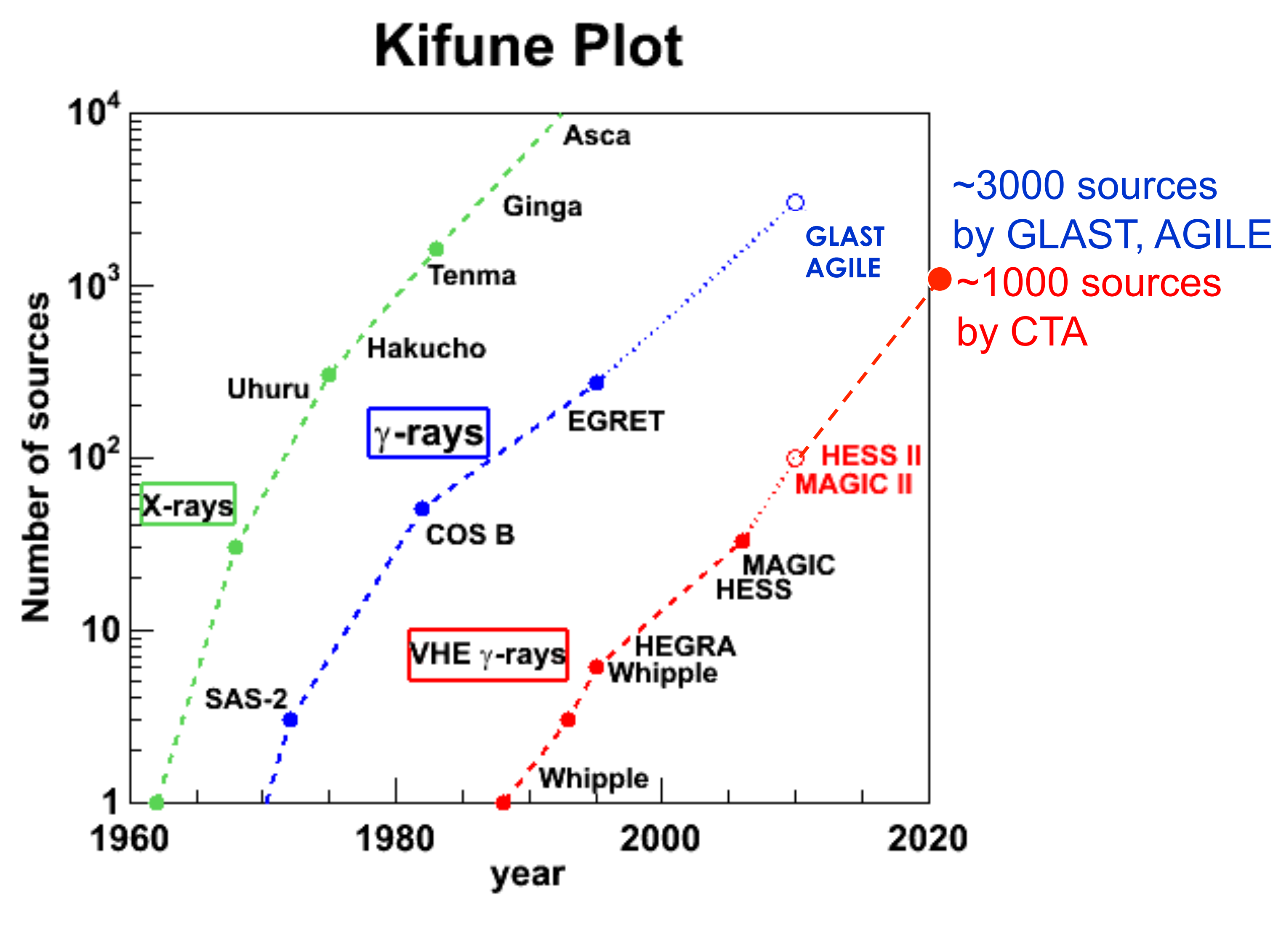


Galactic sources

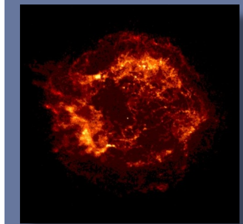
~400 sources with CTA

Where is PEVATRON???

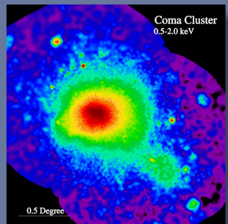
Kifune Plot (expectation from log S - log N)



CTA Specification and Physics



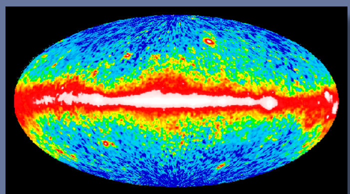
SNRs



New sources

Morphology

Origin of CR



TeV - All sky map
Galactic diffuse

Sensitivity x10
(10^{-14}erg cm^{-2}s^{-1})

Energy Res. x2
(10% @ 1TeV)

Angular Res. x3
(2 arcmin @1TeV)

Low Threshold E
x2 (20GeV)

Large Accept. x30
(3x 10^6m^2 >1TeV)

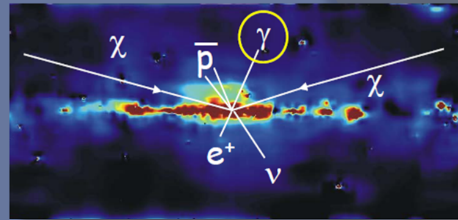
Fast rotation
20 sec/180°

Better S/N x3
>99.9%

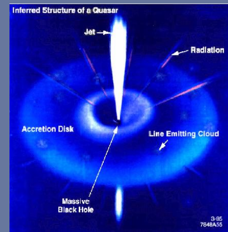
High Time Res.
x10 (~1sec)

All Sky
Observatory

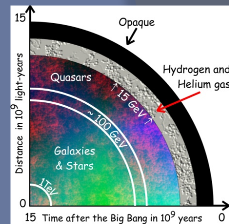
Flexible modes
Scan / Monitor



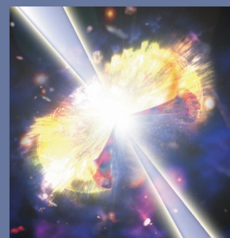
DM



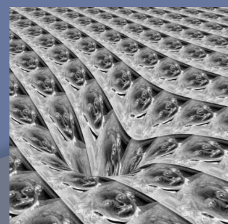
Distant AGNs



cosmology

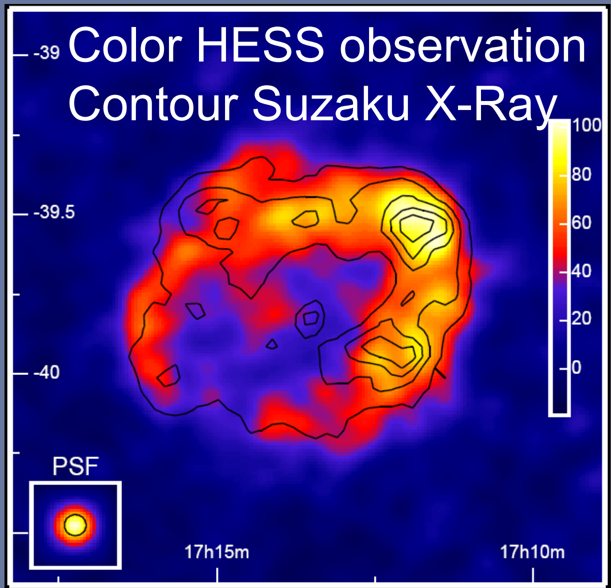


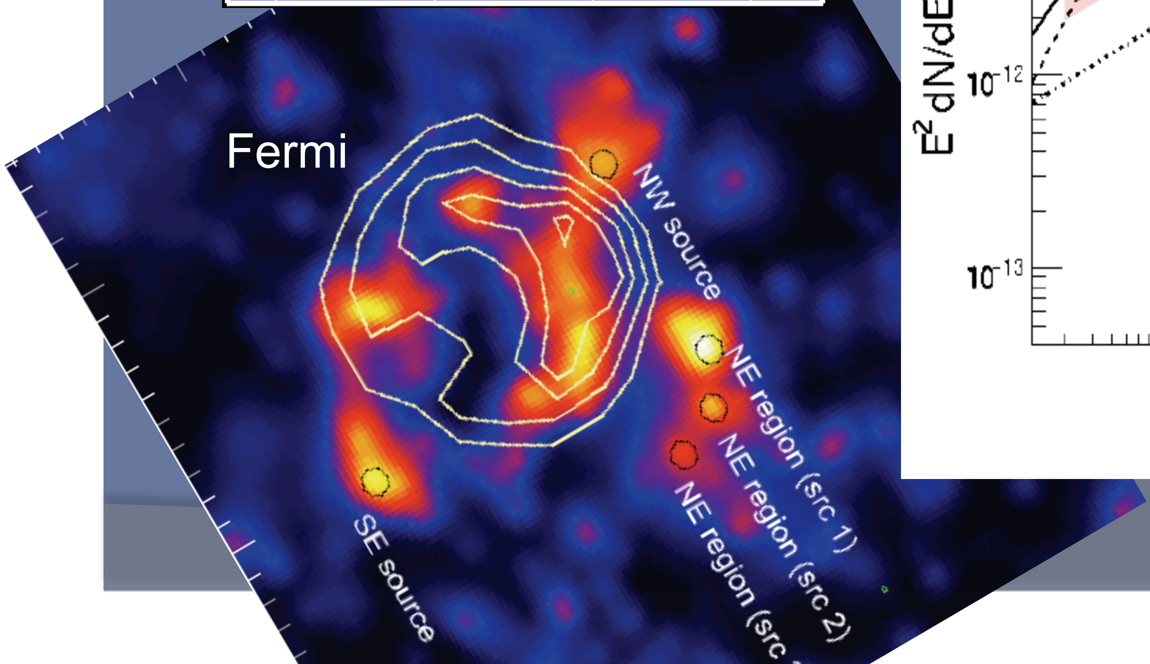
GRBs



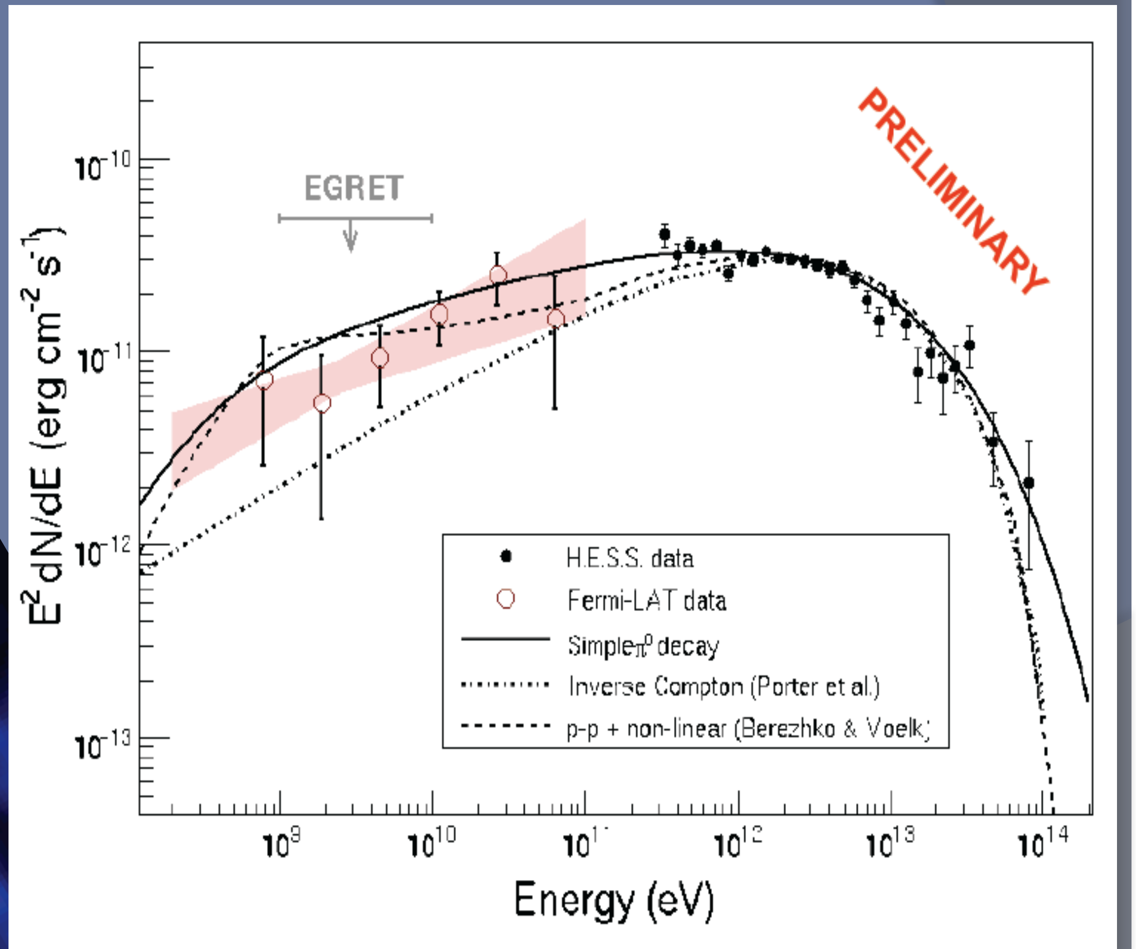
Space and Time

SNR Study
RX J1713 HESS + Fermi

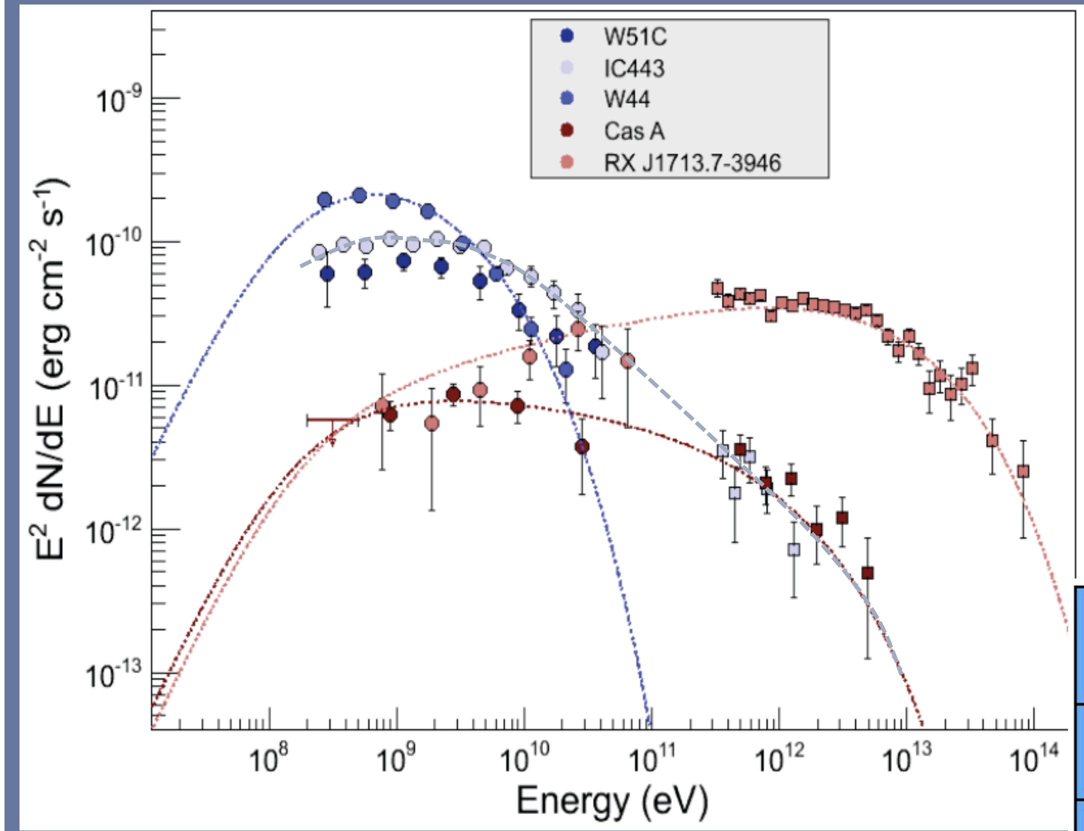




Concaved spectrum (non-linear effect)??



SNRs in different evolutionary stages



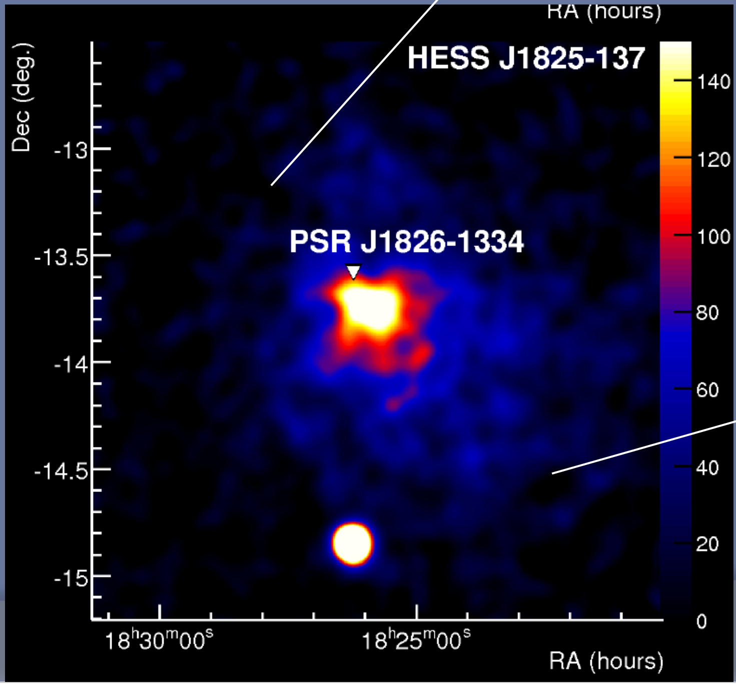
We can study SNRs in different evolutionary stages

	Cas A	RX J1713.7 -3946	IC443	W44	W51C
Age (kyears)	0.3	2	10	20	30
$n_{average}$ (cm-3)	10	0.1	10	100	10
$CR_{fraction}$	2%	50%	25%	5%	10%

Courtesy of S.Funk

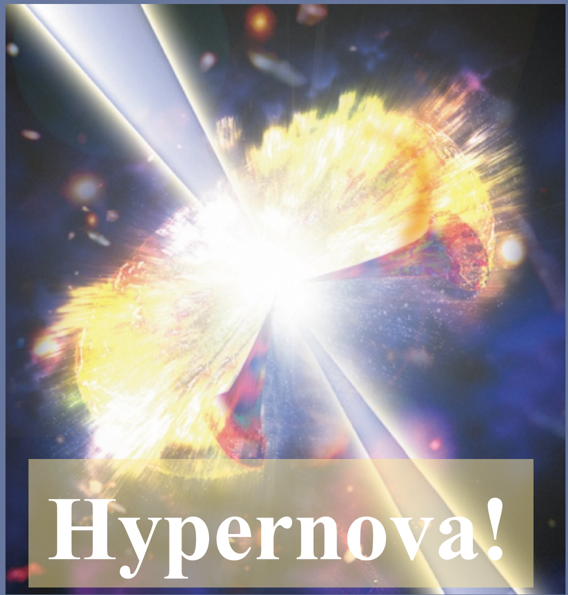
Pulsar Wind Nebula HESS J1825-137 Energy Dependent Morphology

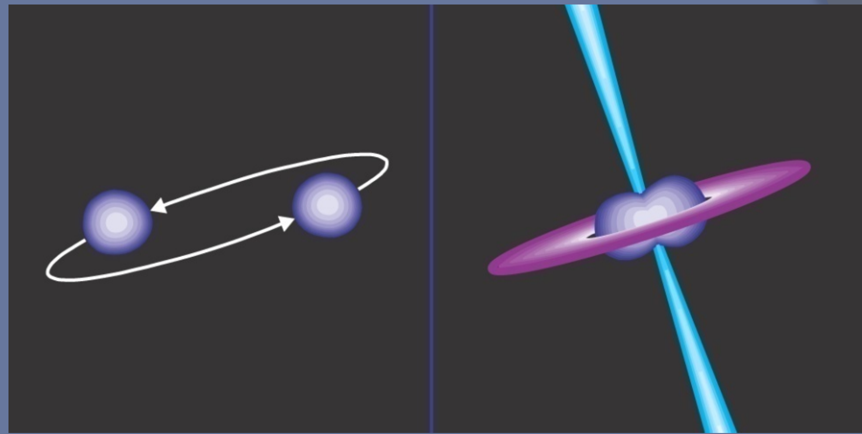
- Major galactic TeV source population
  - Associated with relatively young (<10^5 year old) and energetic pulsars
- Generally believed that we see inverse Compton emission of 1-100 TeV electrons
- 1% of Spin-down energy goes to VHE gamma rays



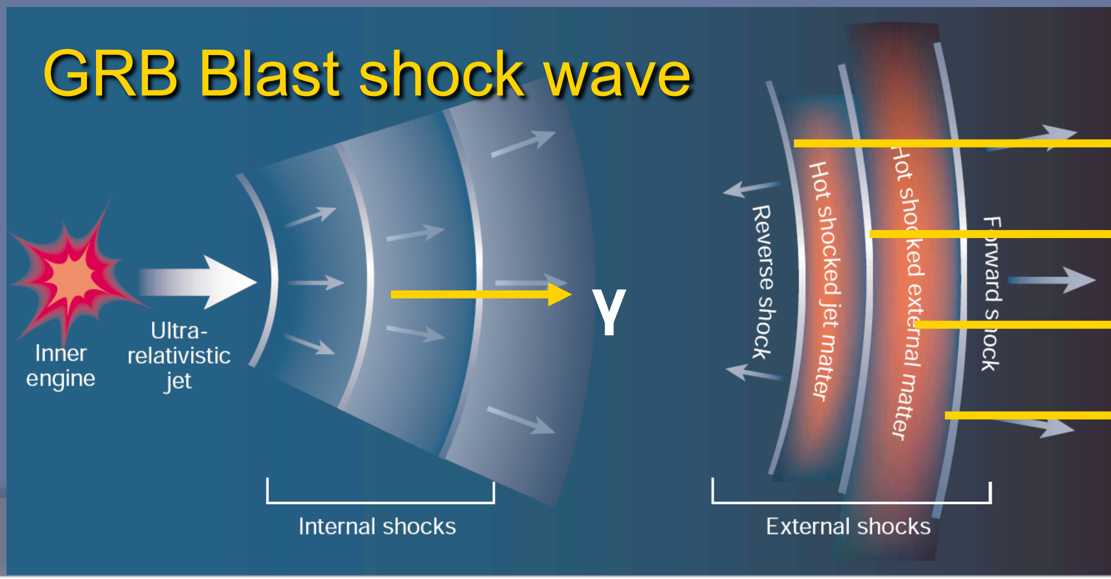
- Clear evidence for cooling of electrons in the Nebula

Gamma ray bursts UHECR source?





Binary neutron stars



After glow

γ

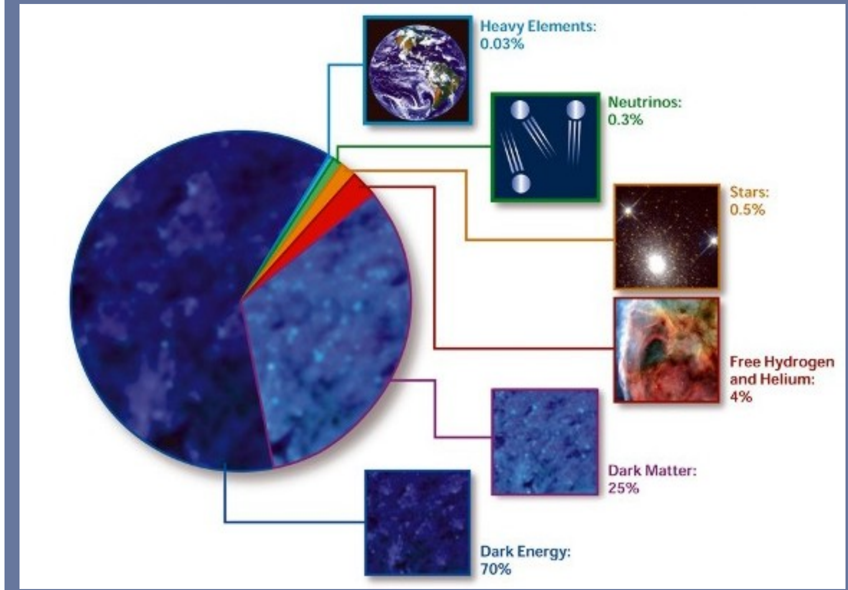
X

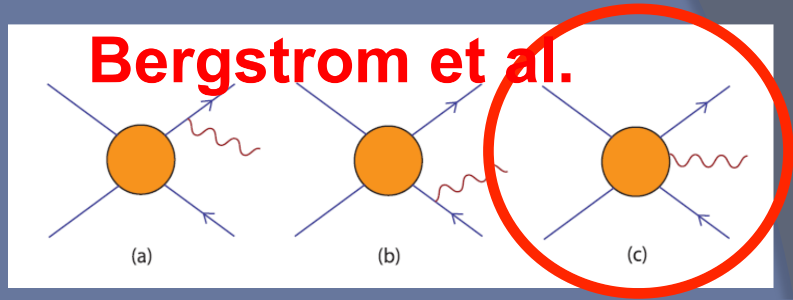
Optical

Radio

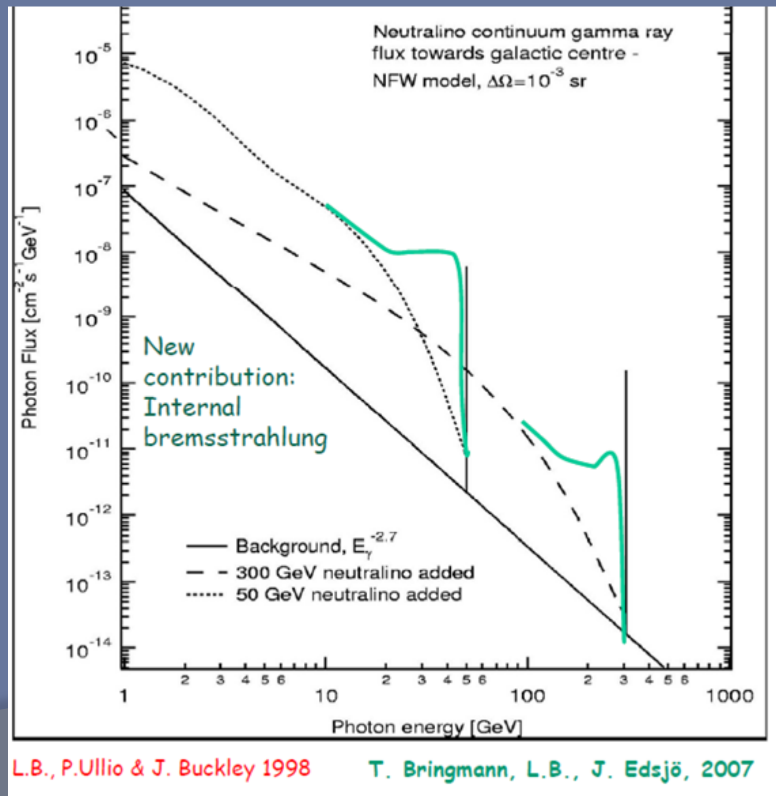
Dark Matter
Gamma ray from DM Annihilation

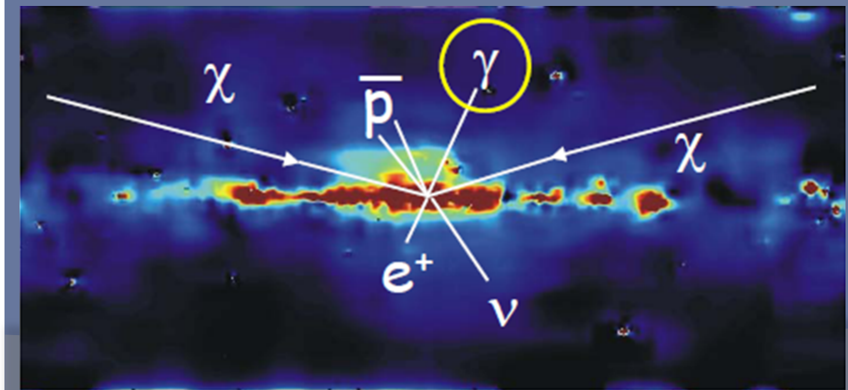
Dark Matter Annihilations



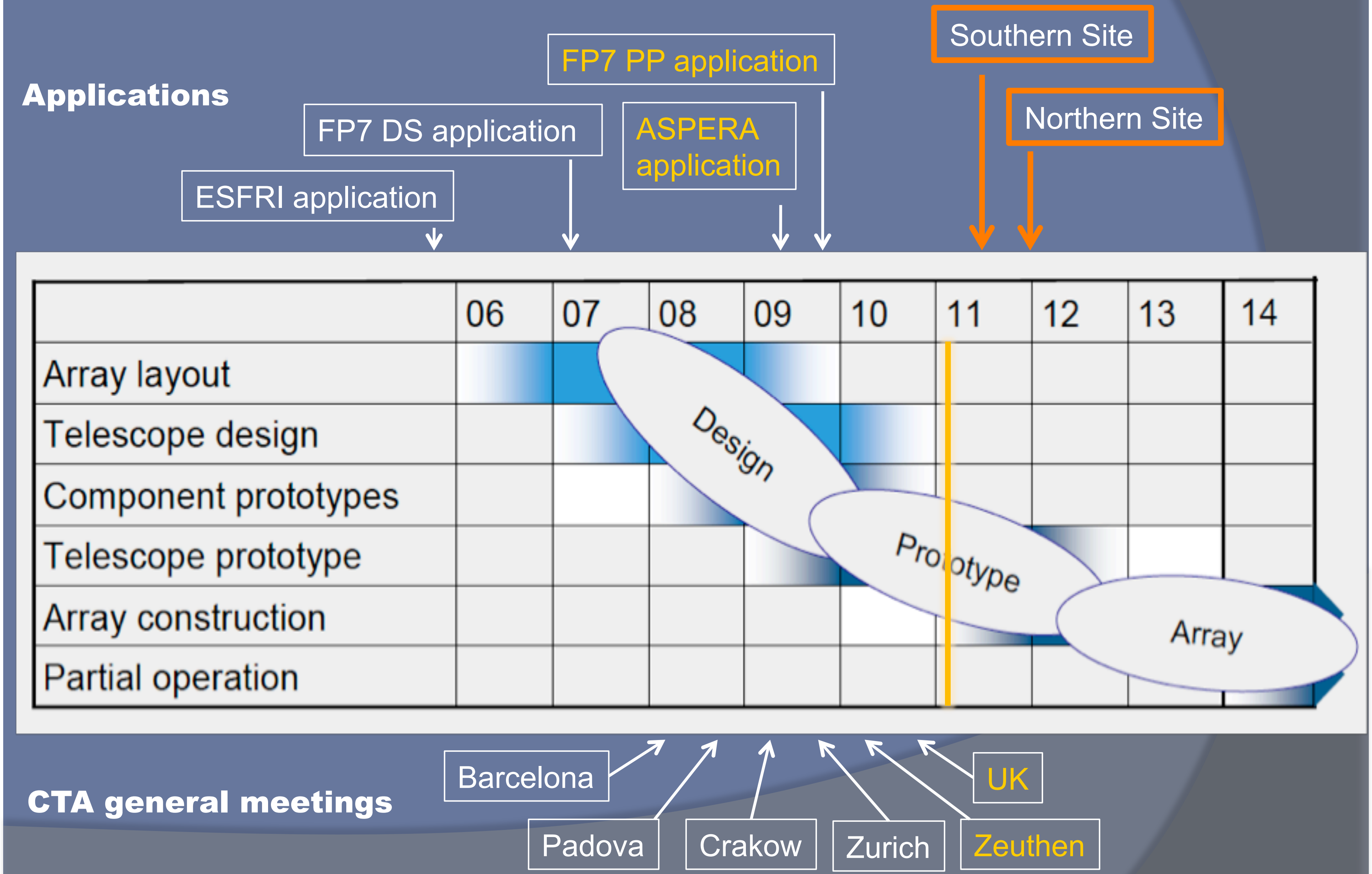


Looks like a step function with a small bump





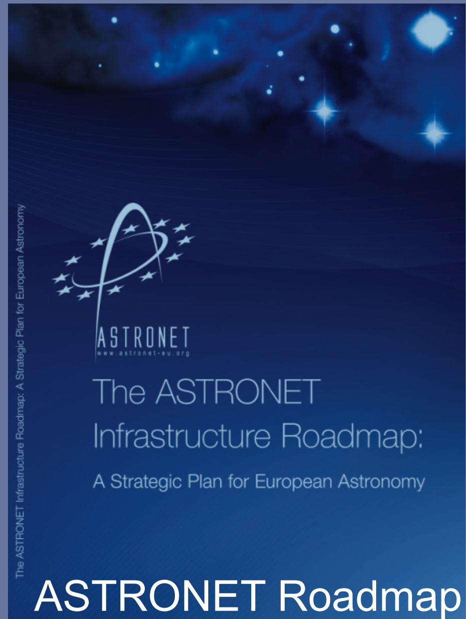
Tentative time schedule



Recommendations and supports

ASPERA Roadmap

Magnificent Seven



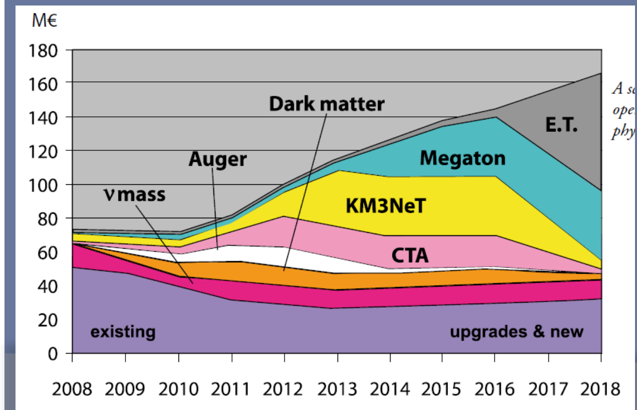
ASTRONET Roadmap

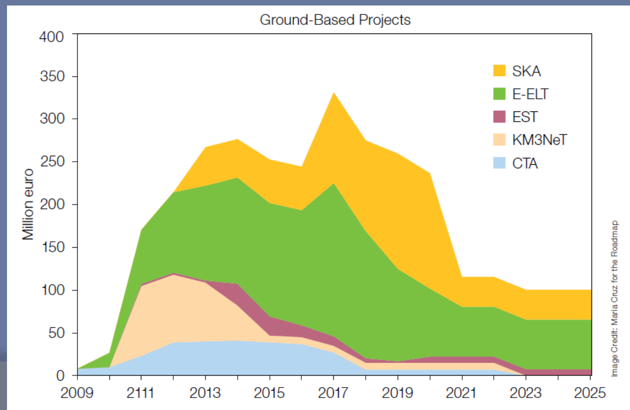
High Priority project

Ground based projects

8 Infrastructures

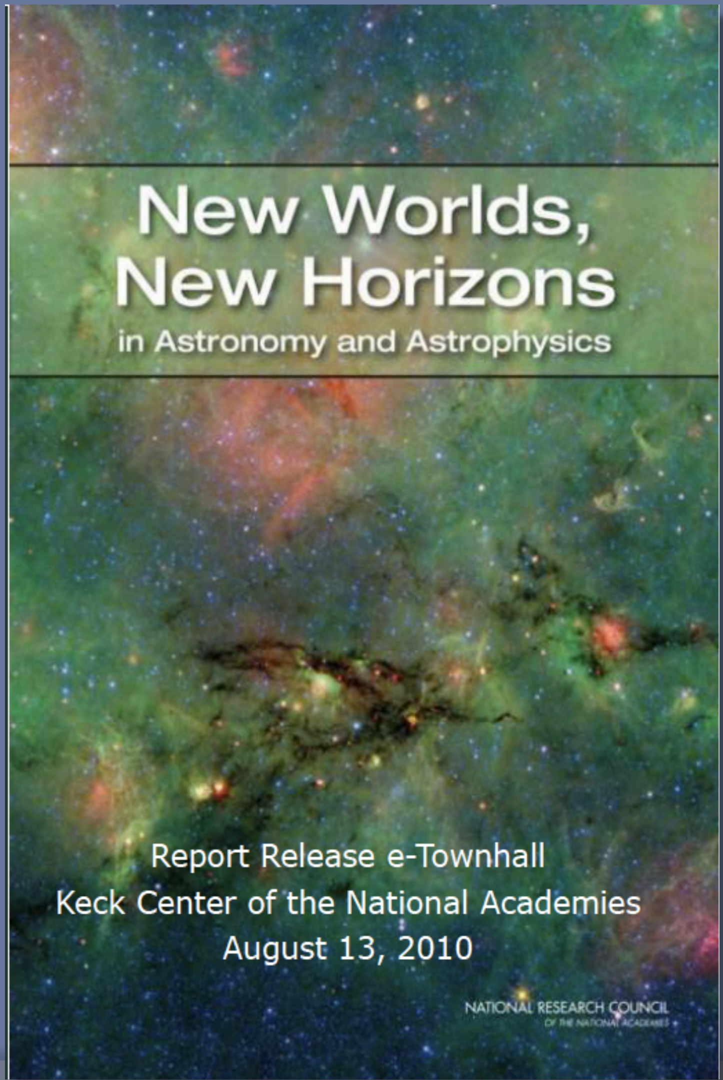
from Physics and eng





CTA	150
E-ELT	950
ELI	400
FAIR	1187
KM3NeT	200
PRINS	1400
SKA (GLOBAL)	1500
SPIRAL2	196

Decadal Survey in Astronomy and Astrophysics in US



Ground-based projects ranked in order:
Large-scale

- Large Synoptic Survey Telescope (LSST)
- Innovations Program
- Giant Segmented Mirror Telescope (GSMT)
- Atmospheric Čerenkov Telescope Array (CTA)

Summary of CTA

- VHE gamma ray astronomy is now blooming!!
  - H.E.S.S., MAGIC and VERITAS are producing a lot of physics results.
  - There are still many open questions about High Energy Universe.
  - We need the next generation instrument → CTA
- CTA will achieve excellent sensitivity, higher resolutions and wider energy coverage
  - CTA is now a big international project (700 scientists from 100 institutes)
  - It will be a unique facility for high energy gamma ray astronomy next 20 years
  - Observation will reach to the very deep universe
    - Distant AGNs($z<2.5$), GRBs($z<6$)
    - History of Universe: Structure formation, Star formation
  - Challenges
    - Search for DM
    - Test the special relativity using long flying high energy photons