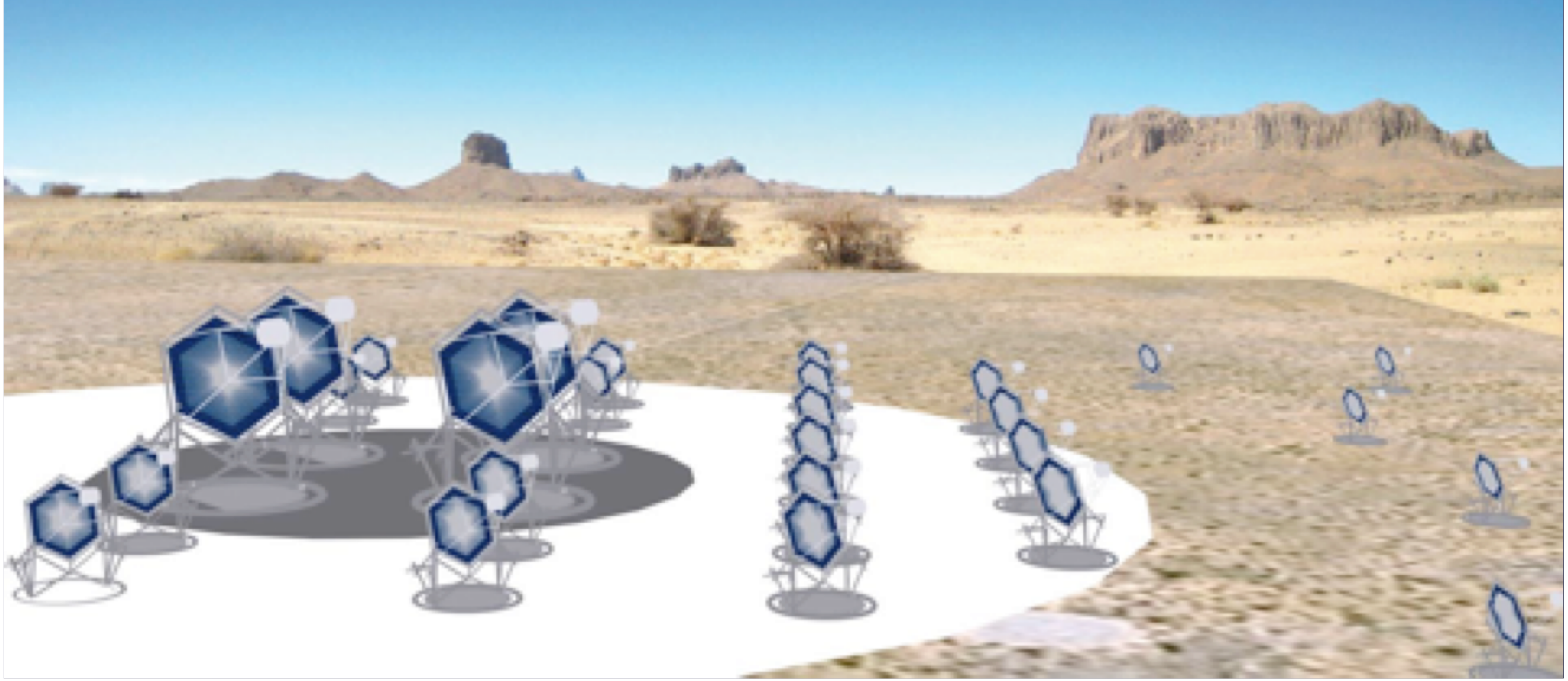
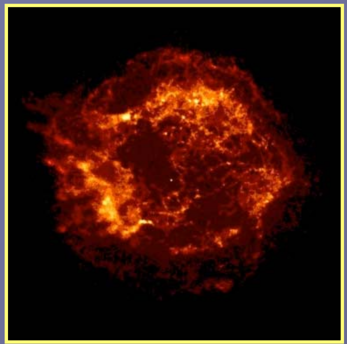
Cherenkov Telescope Array (CTA) Project

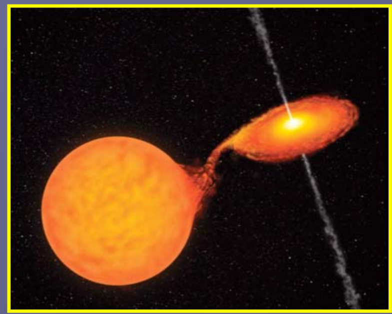


観測対象 & 物理目的

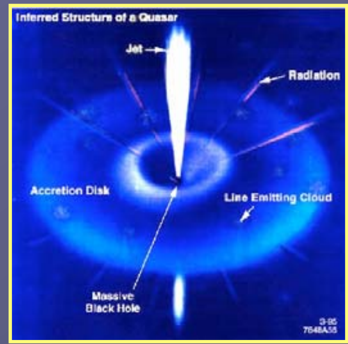


SNRs

Pulsars
and PWNe



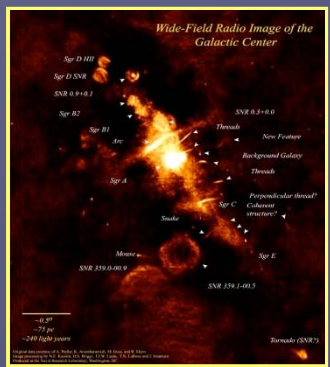
Micro quasars
X-ray binaries



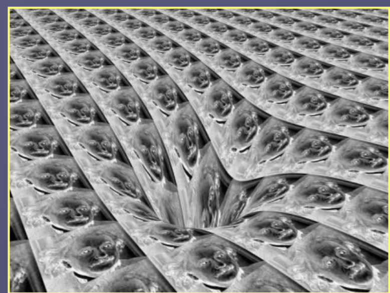
AGNs

GRBs

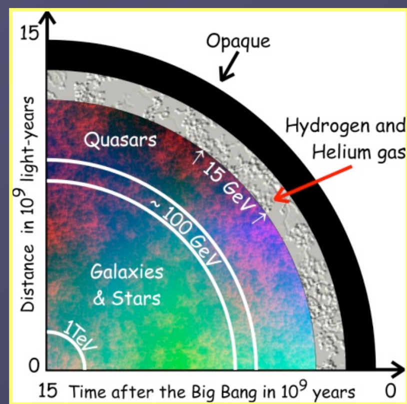
Origin of
cosmic rays



Dark matter



Space-time
& relativity

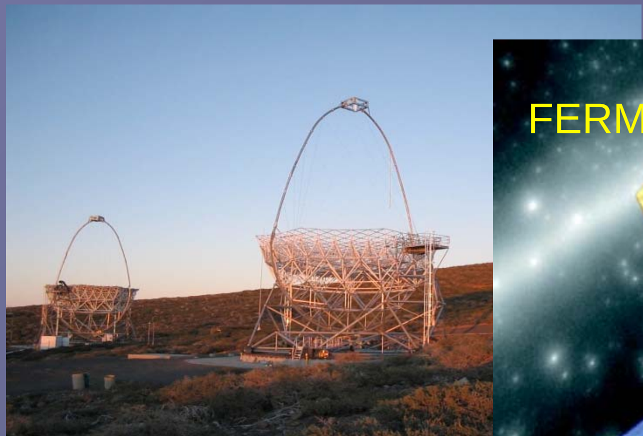


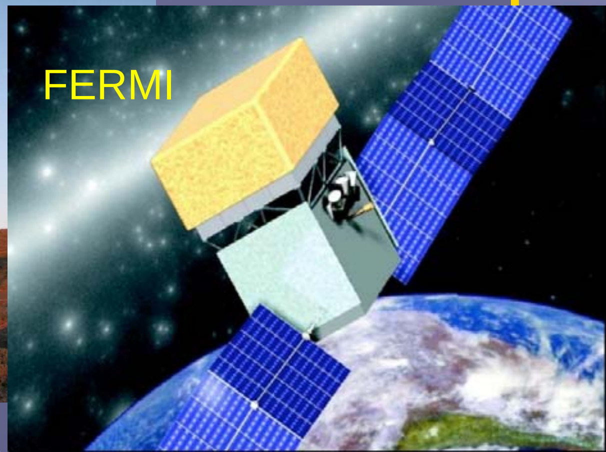
Cosmology

CTAに向けて

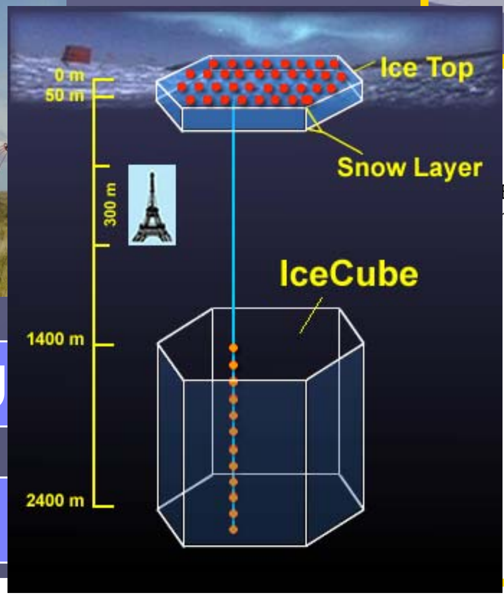
次世代　高エネルギーガンマ線観測施設

MAGIC Phase II (MAGIC-I + MAGIC-II) in 2009

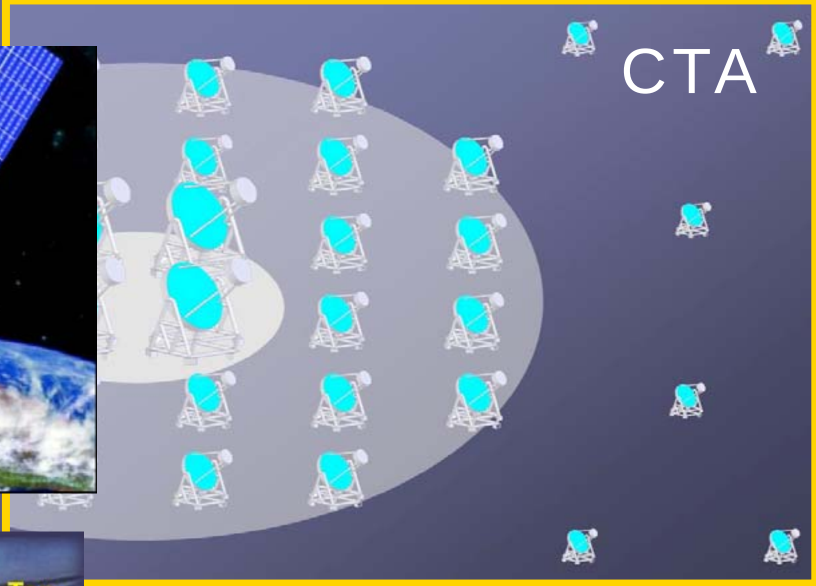


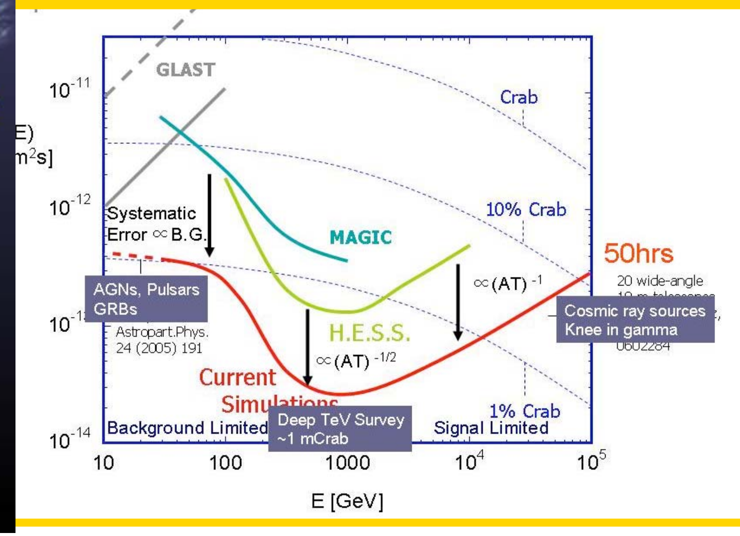


HESS Phase II (HESS + 28m Telescope) in 2010



>1000 sources will be discovered

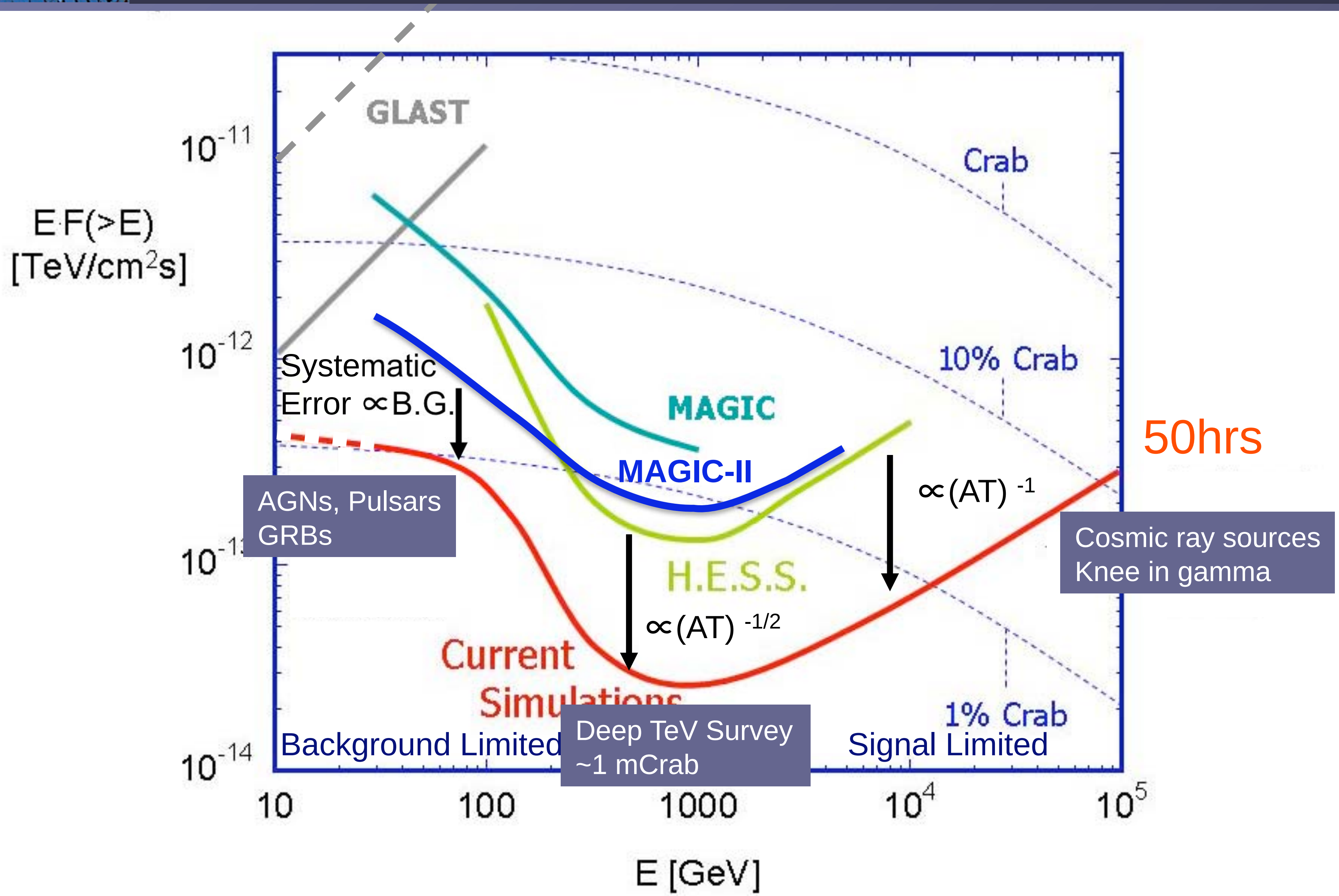




Astronomers in EU

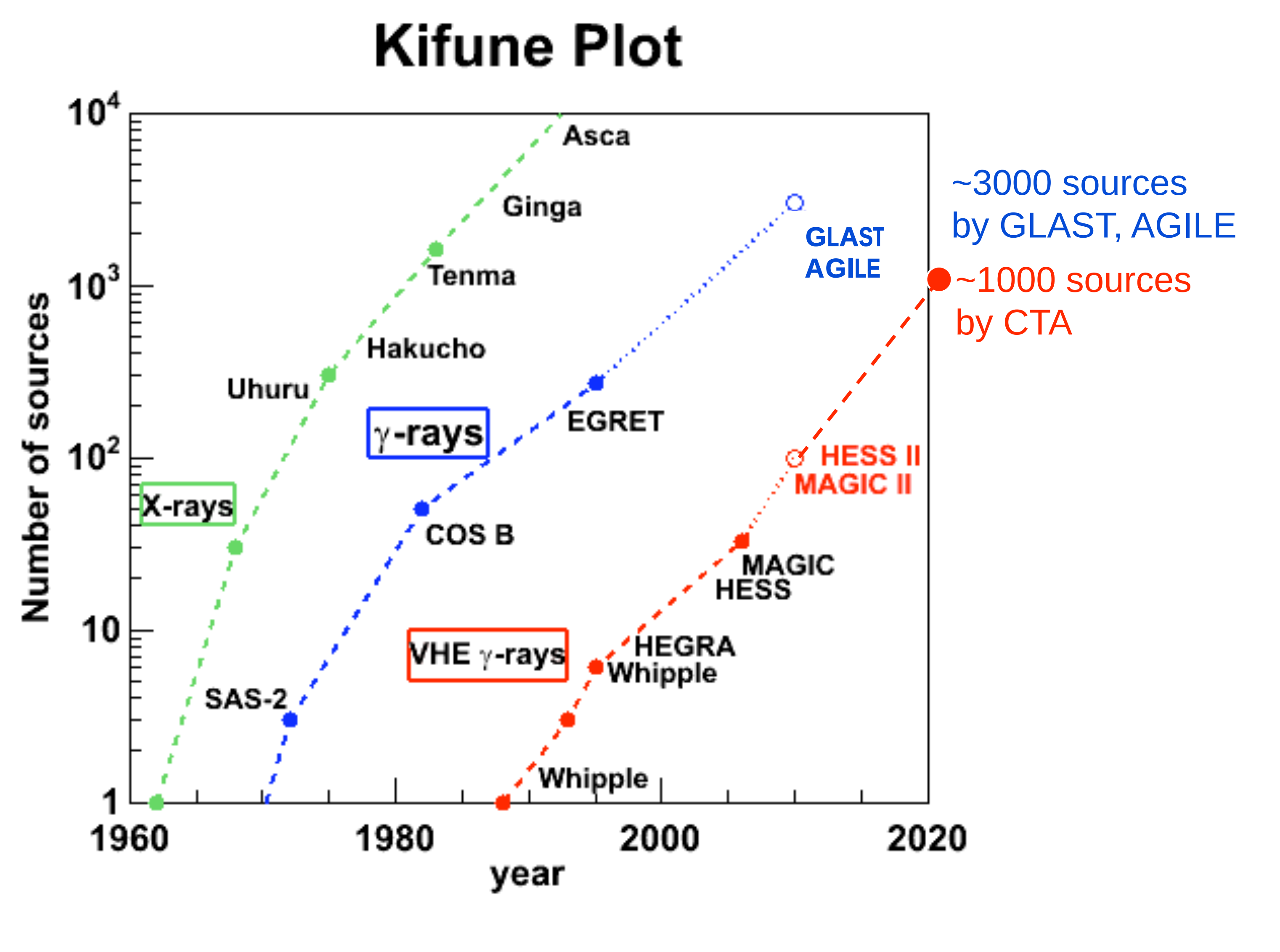
JAPAN(EoI), US

目標達成感度



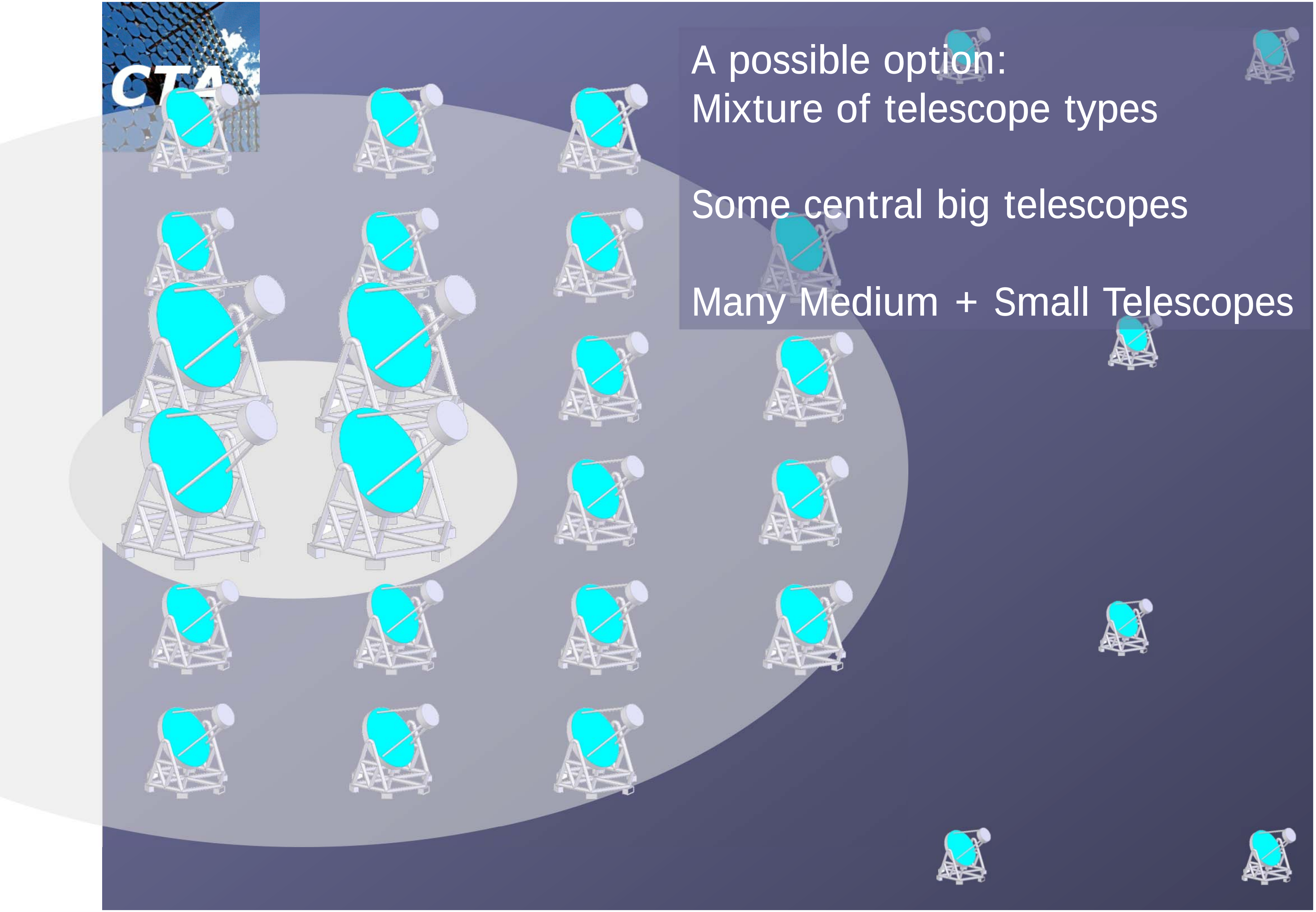
GLAST
Crab
10% Crab
1% Crab
MAGIC
MAGIC-II
H.E.S.S.
Current Simulations
50hrs
E·F(>E) [TeV/cm²s]
E [GeV]
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10
100
1000
10^4
10^5
Systematic Error ∝B.G.
$\propto (AT)^{-1/2}$
$\propto (AT)^{-1}$
AGNs, Pulsars GRBs
Cosmic ray sources Knee in gamma
Deep TeV Survey ~1 mCrab
Background Limited
Signal Limited

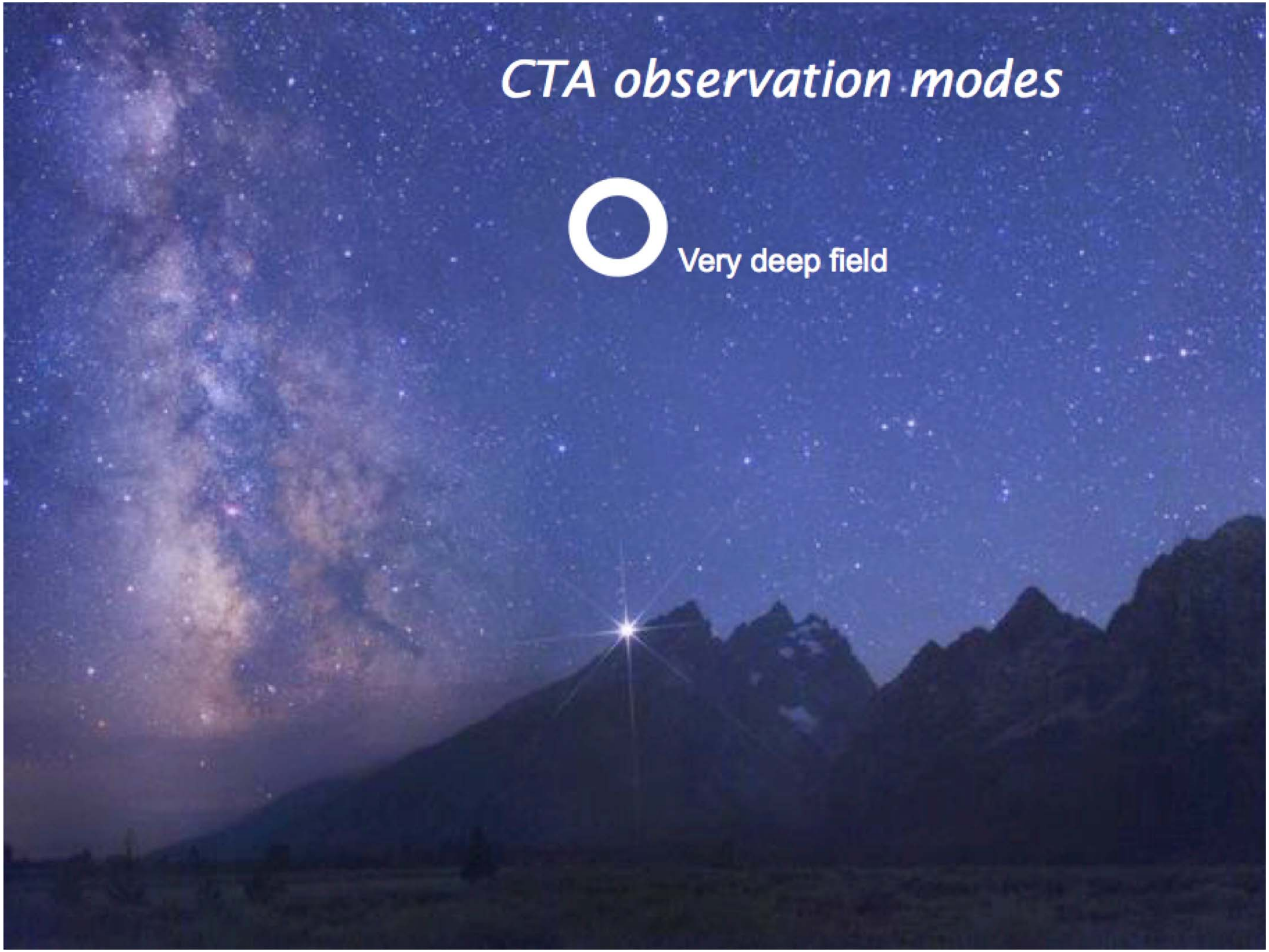
Kifune Plot
(expectation from log S - log N)

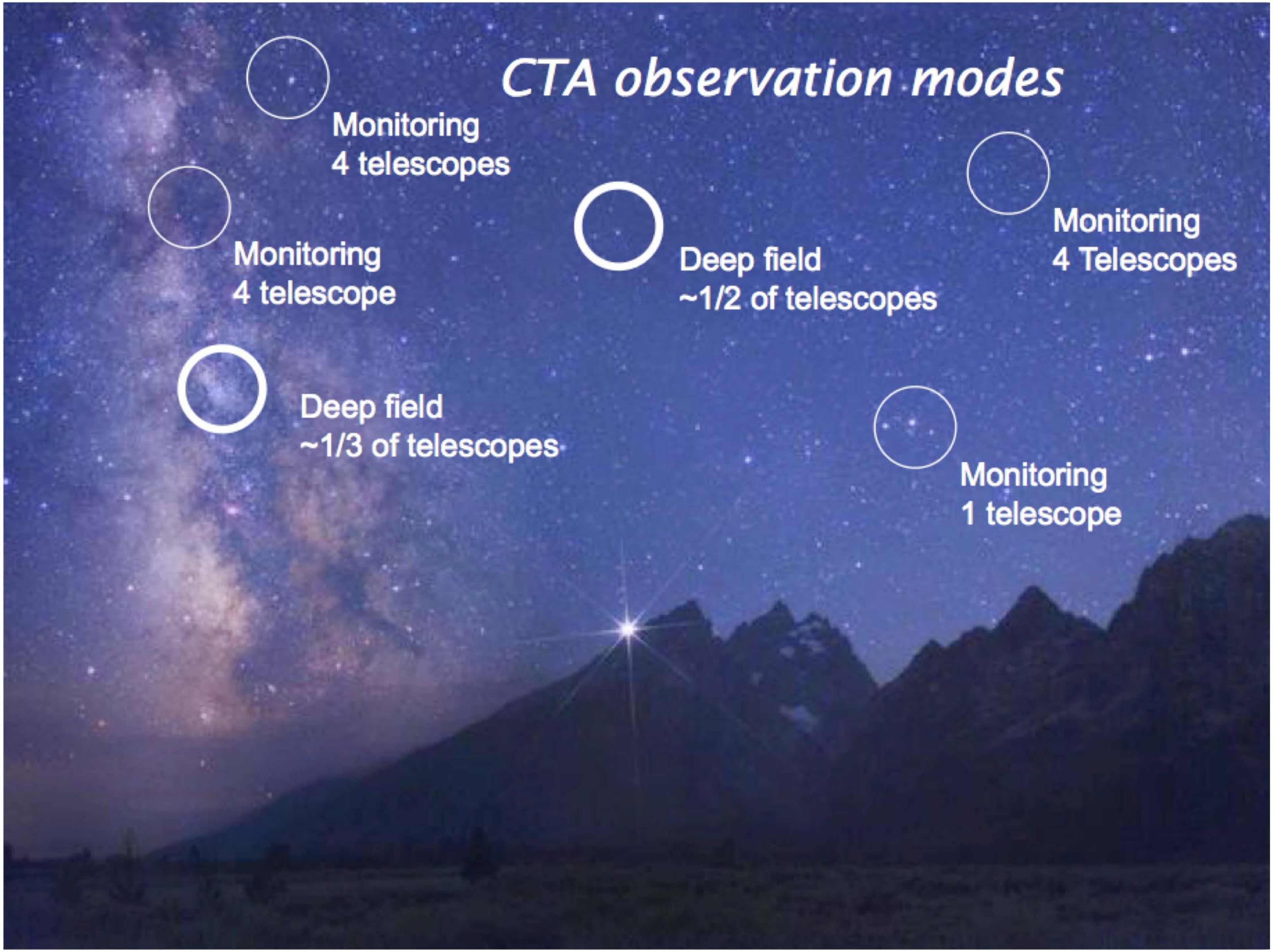


CTA　仕様・パラメーター

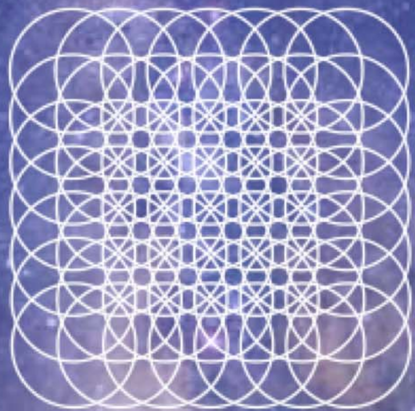
- 観測エネルギー領域: 20-30GeV ~ 100TeV
  - 20-30GeV ➔ 遠方の活動銀河核(z<2)の研究、系外宇宙線起源、EBL 背景放射光密度の測定(星形成史)
  - 100TeV ➔ 銀河宇宙線源の研究
- 10倍の感度向上 （HESS, MAGICから）
  - 観測される天体数30倍(1000-2000)
  - 感度 ~1mCrab
- 3倍の角度分解能
  - Better morphological study
- 全天観測
  - 北半球：20-30GeV ~ 1TeV (mainly extragalactic science)
    - Several 23m class telescopes + some 12m class telescopes
  - 南半球：20-30GeV ~ 100TeV (galactic + extragalactic science)
    - Several 23m class telescopes + many 12m class telescopes + some 6m telescopes


CTA
A possible option:
Mixture of telescope types
Some central big telescopes
Many Medium + Small Telescopes


CTA observation modes
Very deep field


CTA observation modes
Monitoring
4 telescopes
Monitoring
4 telescope
Deep field
~1/2 of telescopes
Monitoring
4 Telescopes
Deep field
~1/3 of telescopes
Monitoring
1 telescope

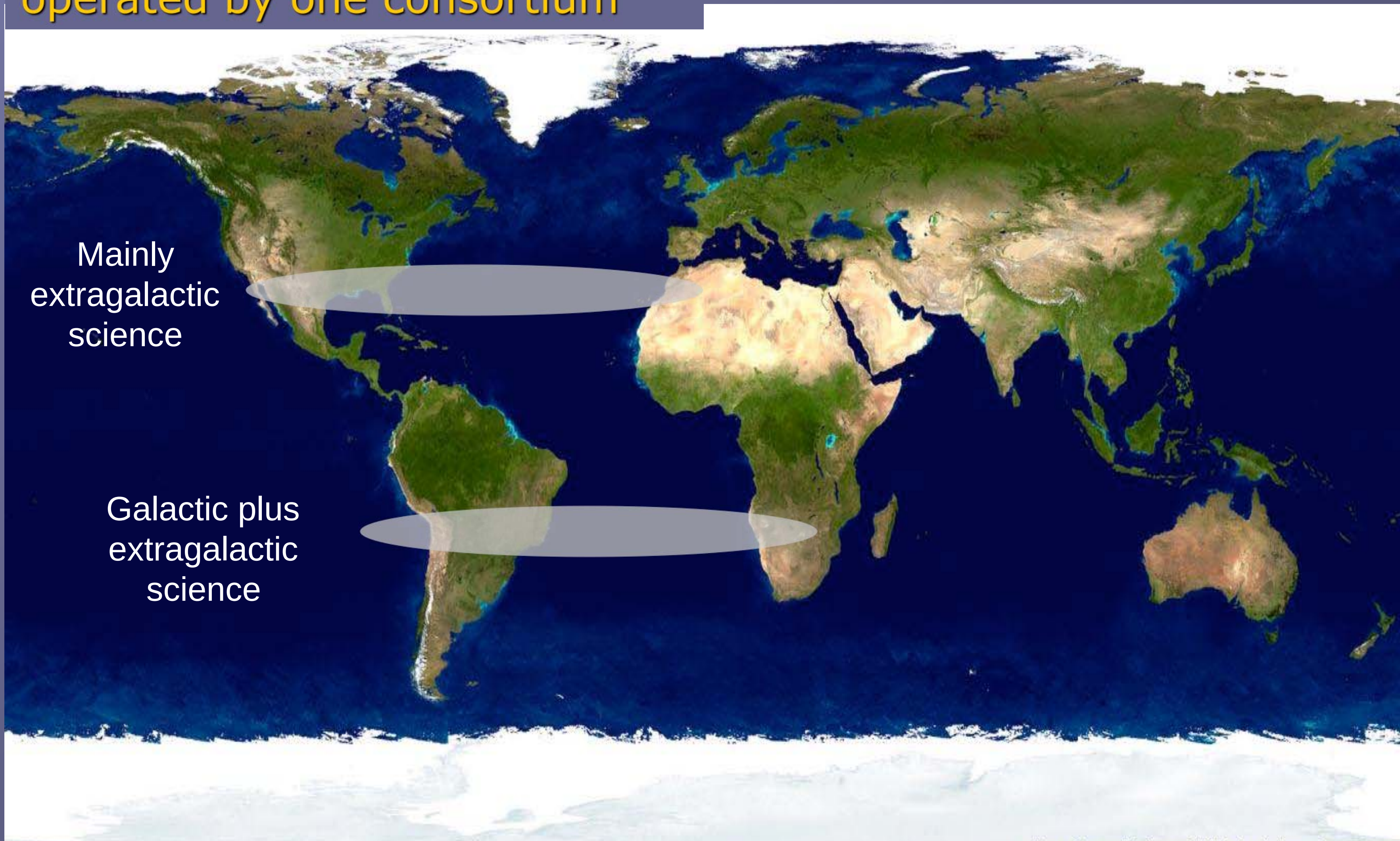
CTA observation modes



Survey mode:
Full sky at current
sensitivity in ~1 year

CTA候補地（北、南　2 stations）

One observatory with two sites
operated by one consortium

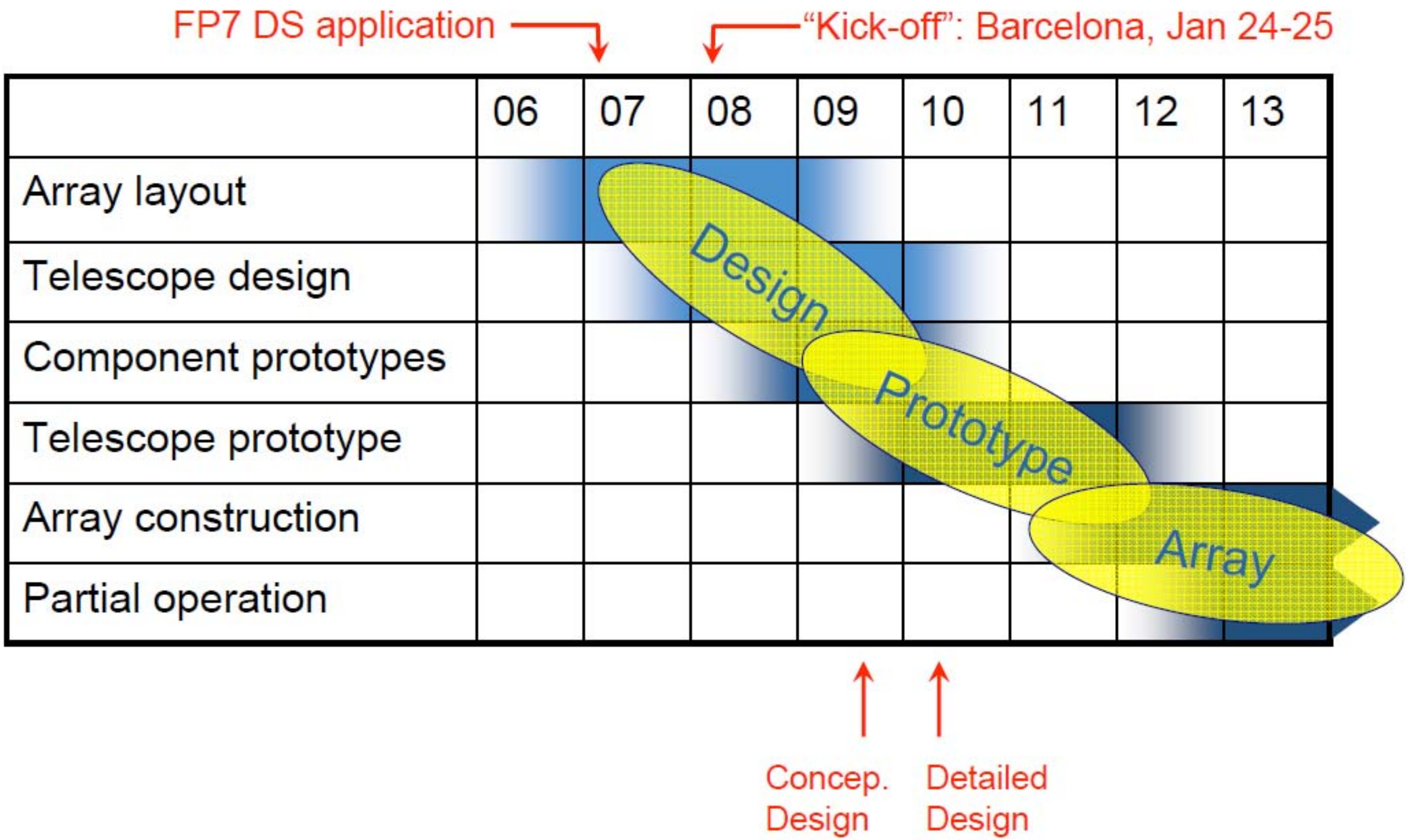


Design Study started in Jan. 2008

Milestones, tasks are defined in each WP

WP1	**MNG**	Management of the design study
WP2	**PHYS**	Astrophysics and astroparticle physics
WP3	**MC**	Optimization of array layout, performance studies and analysis algorithms
WP4	**SITE**	Site evaluation and site infrastructure
WP5	**MIR**	Telescope optics and mirror
WP6	**TEL**	Telescope structure, drive, control
WP7	**FPI**	Focal plane instrumentation, mechanics and photo detectors
WP8	**ELEC**	Readout electronics and trigger
WP9	**ATAC**	Atmospheric monitoring, associated science & instrument calib.
WP10	**OBS**	Observatory operation and access
WP11	**DATA**	Data handling, data processing, data management and access
WP12	**QA**	Risk assessment and quality assurance, production planning

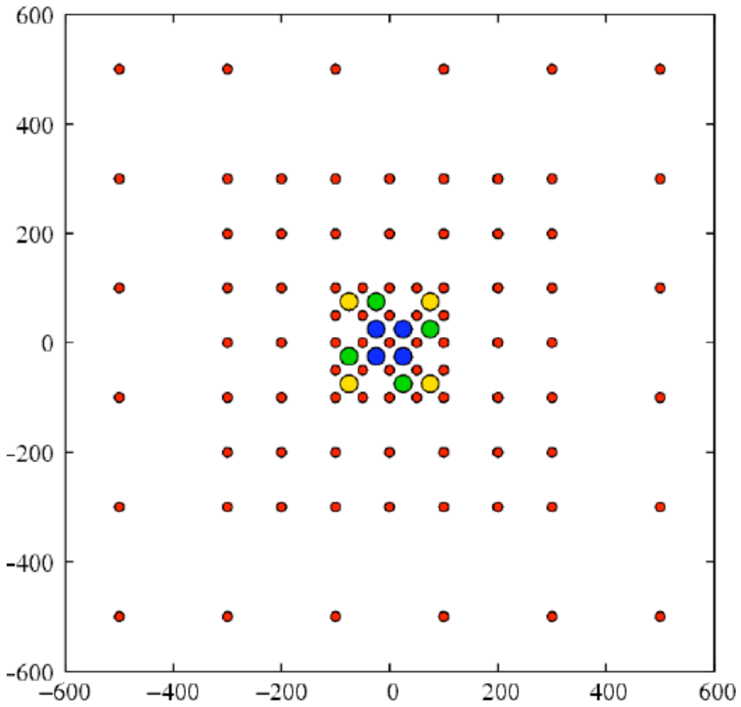
タイムスケジュール



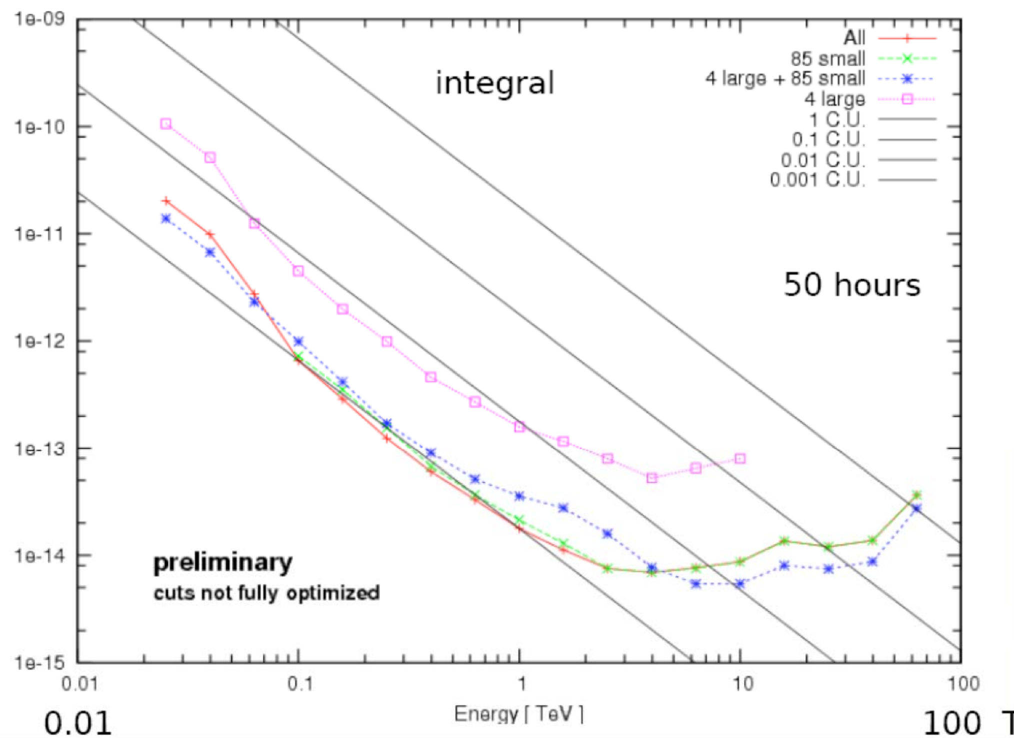
FP7 DS application
"Kick-off": Barcelona, Jan 24-25
06
07
08
09
10
11
12
13
Array layout
Telescope design
Component prototypes
Telescope prototype
Array construction
Partial operation
Design
Prototype
Array
Concep.
Design
Detailed
Design

CTA preliminary M.C. Study

Configurations: 97 tel. hybrid system

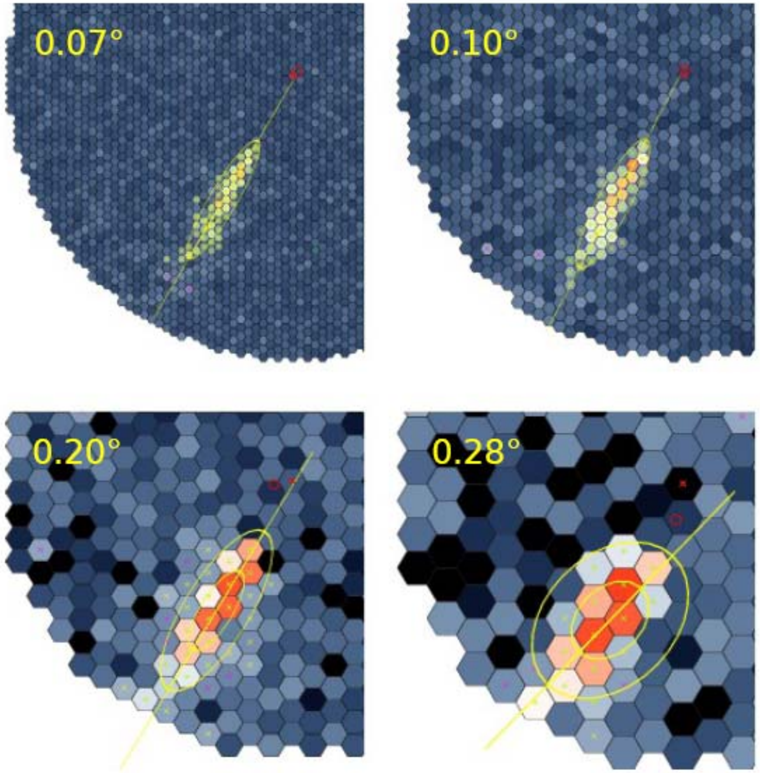


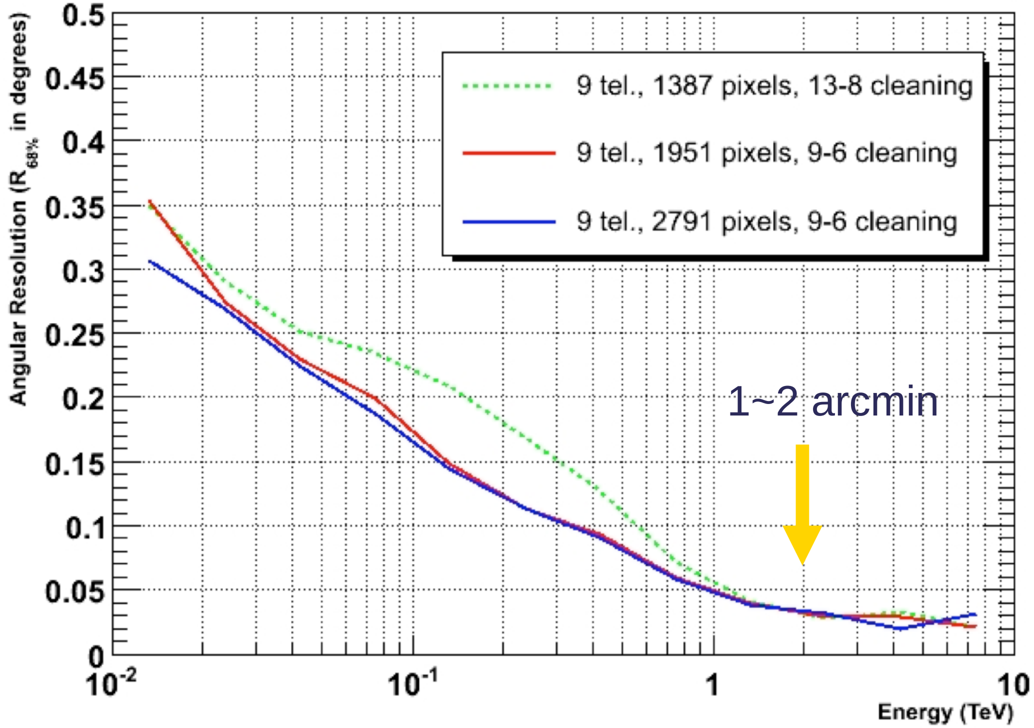
Hybrid system of
- 12 600 m² class tel.
- 85 100 m² class tel.
with 1.4* larger f.o.v.
a
c



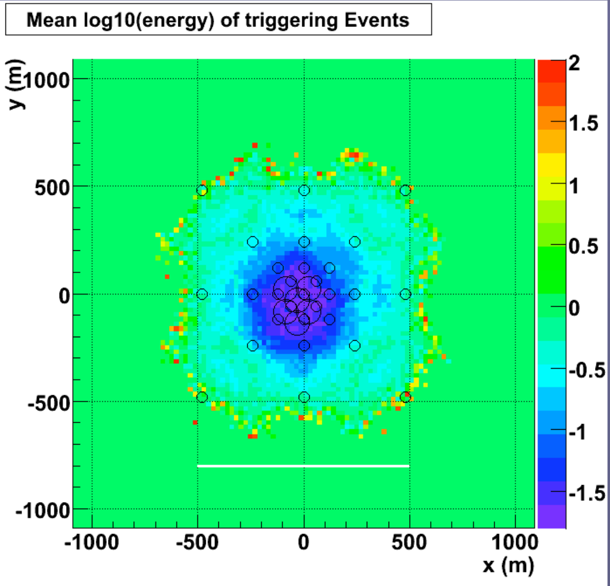
0.01 100 T

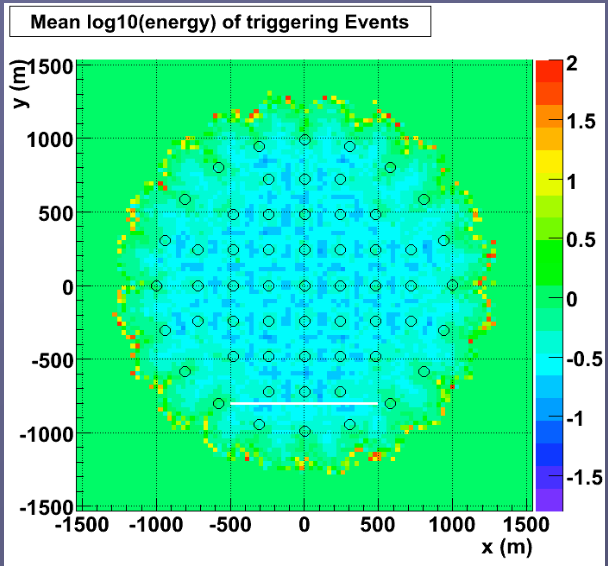
Impact of Pixel size to the Angular resolution

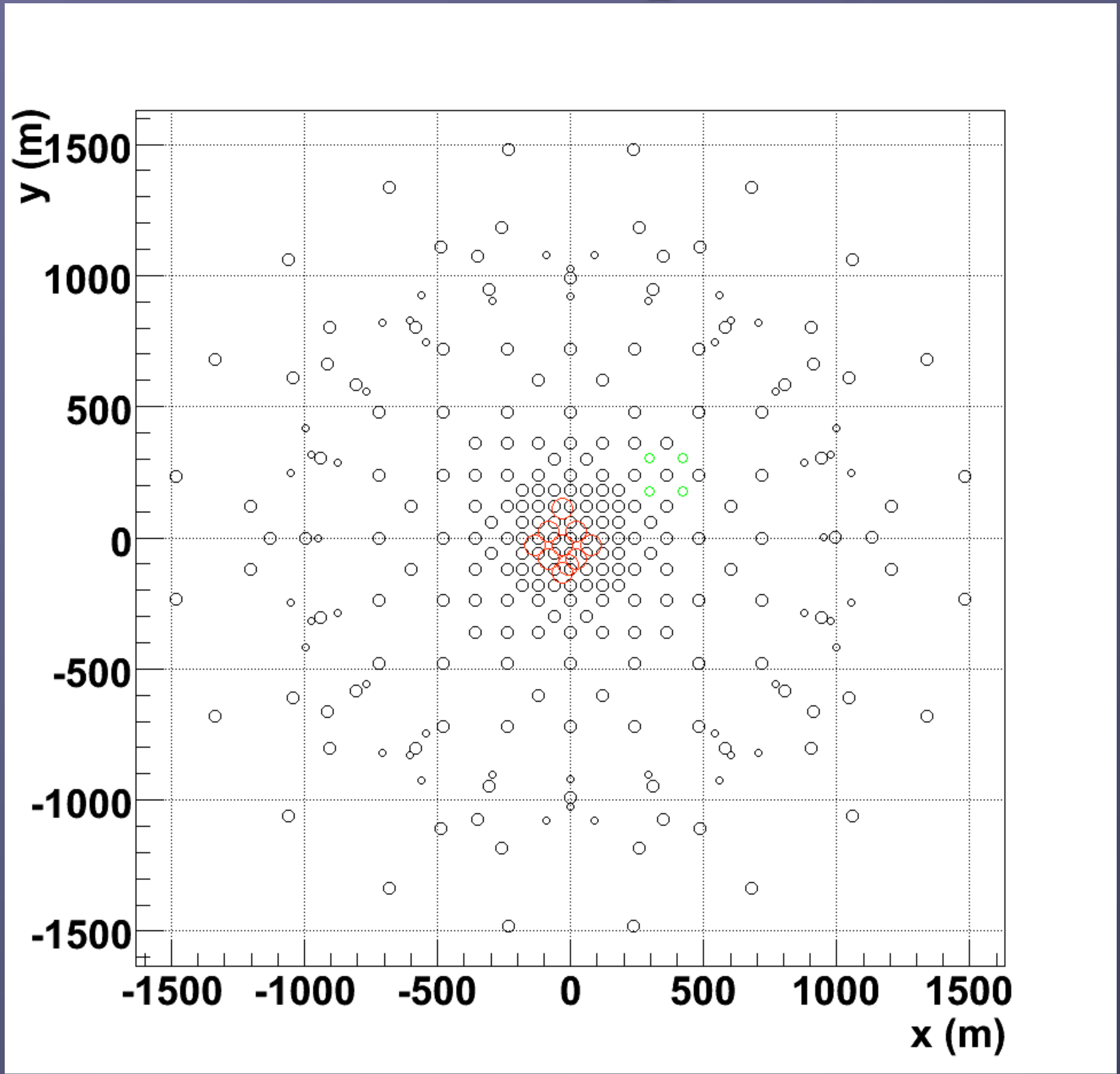




Optimization is on-going
275 telescopes



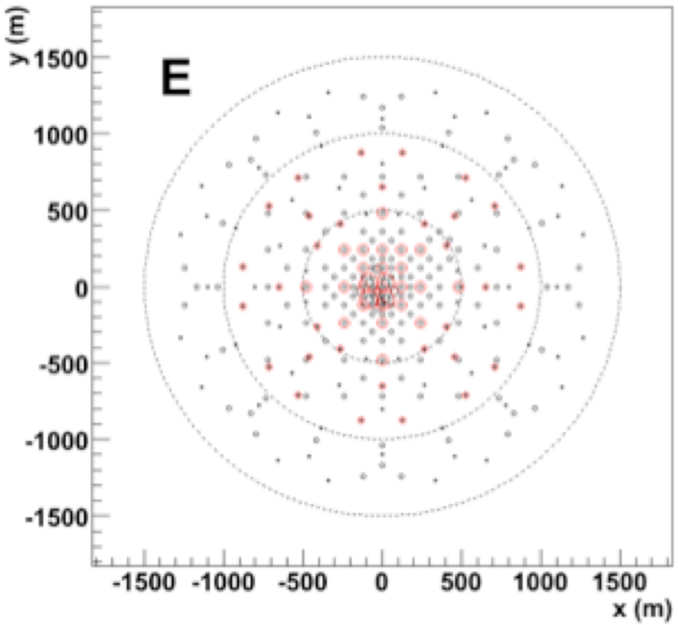


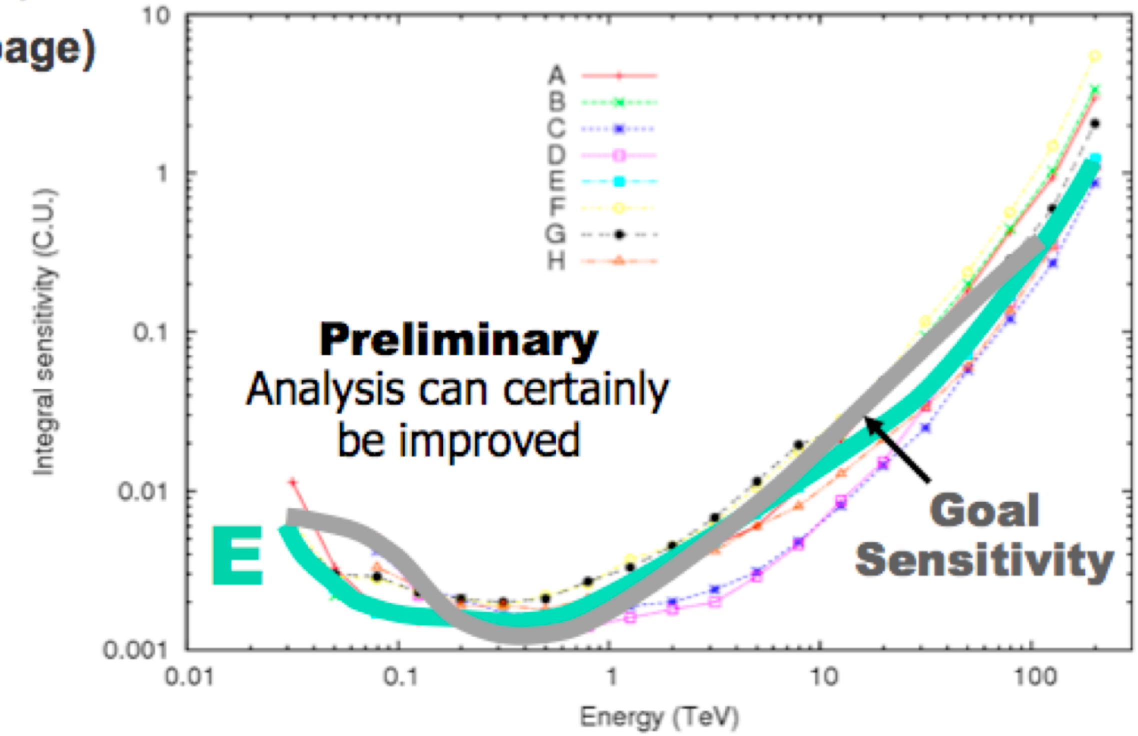


Report from M.C. group

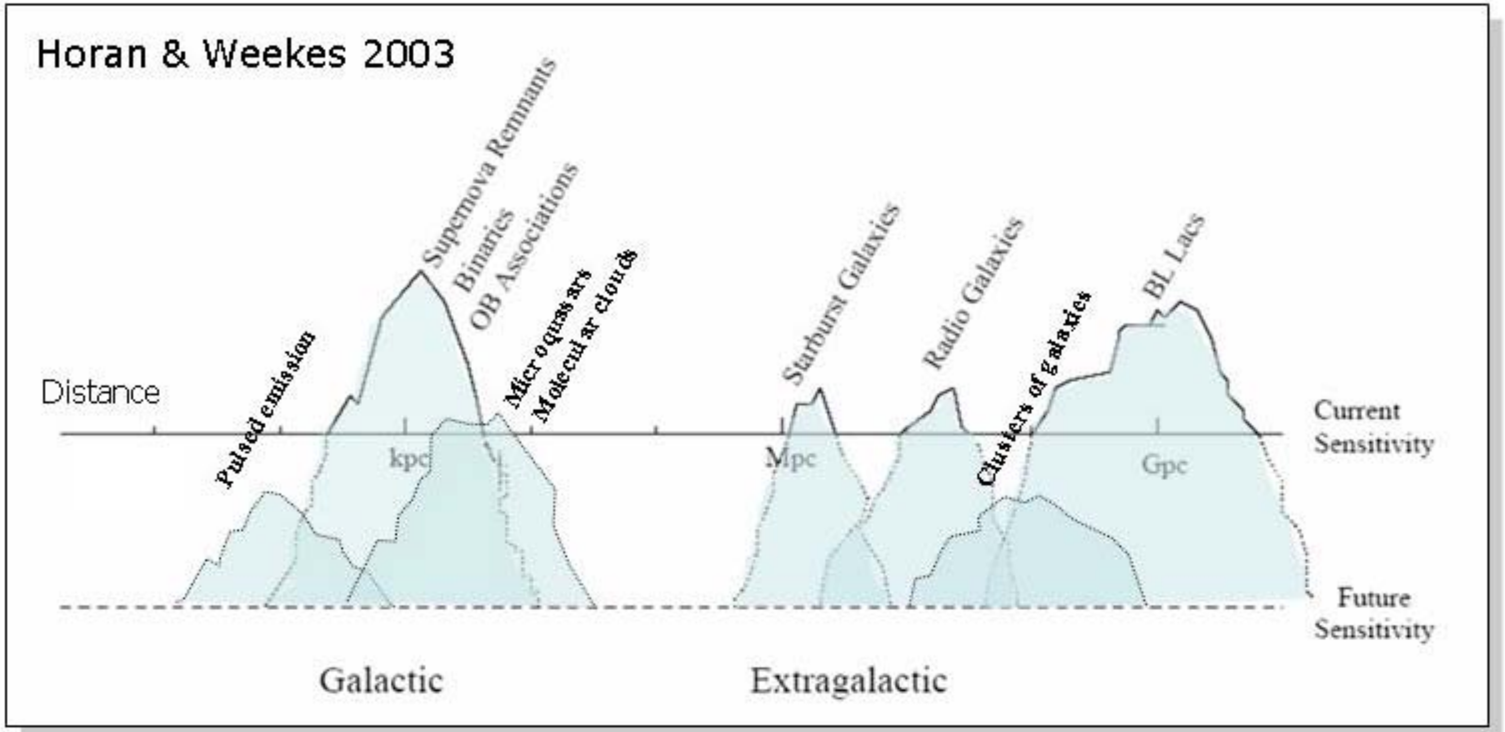
How many telescope sizes?

- Current studies show that we can get close to the goal sensitivity curve within budget for an array with 3 telescope sizes
  - 24 m, 12 m, 7 m (L, M, S)
  - e.g. array E (see Wiki page)



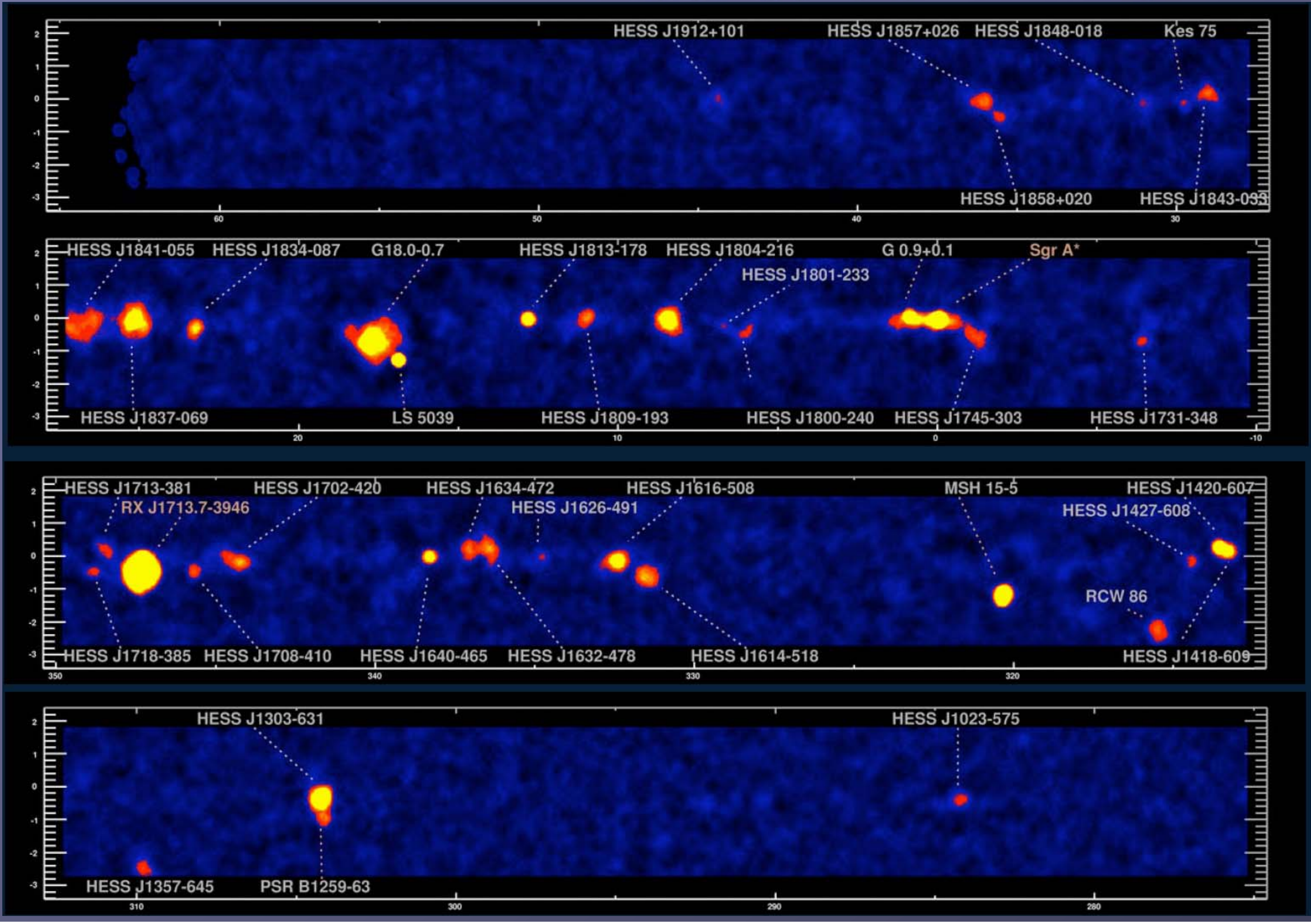


Scientific potential of CTA

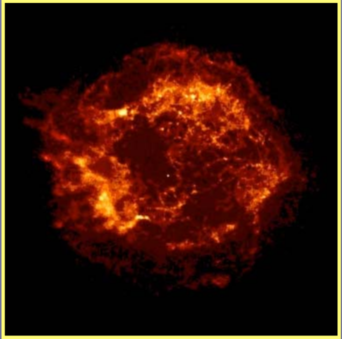


- Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, but this is clearly only the tip of the iceberg
- Broad and diverse program ahead, combining guaranteed astrophysics with significant discovery potential

Great success!!
HESS の銀河面サーベイ

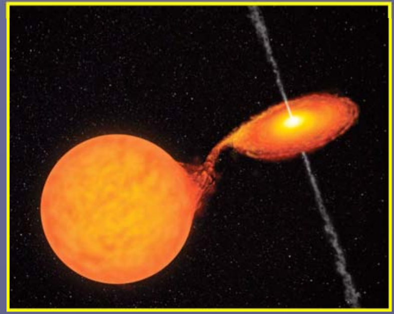


Guaranteed sources
Galactic sources



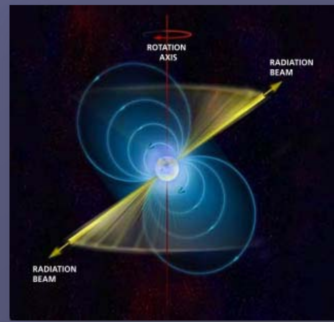
SNRs

PWNe

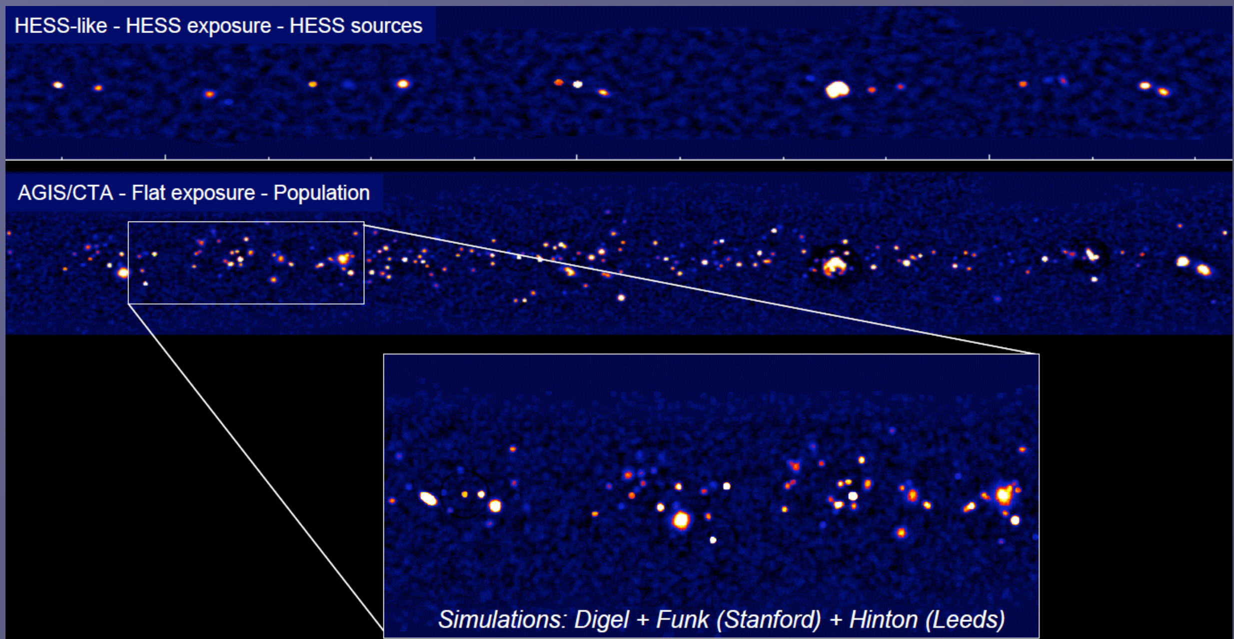


Micro quasars
X-ray binaries

Un-ID sources
Dark Sources



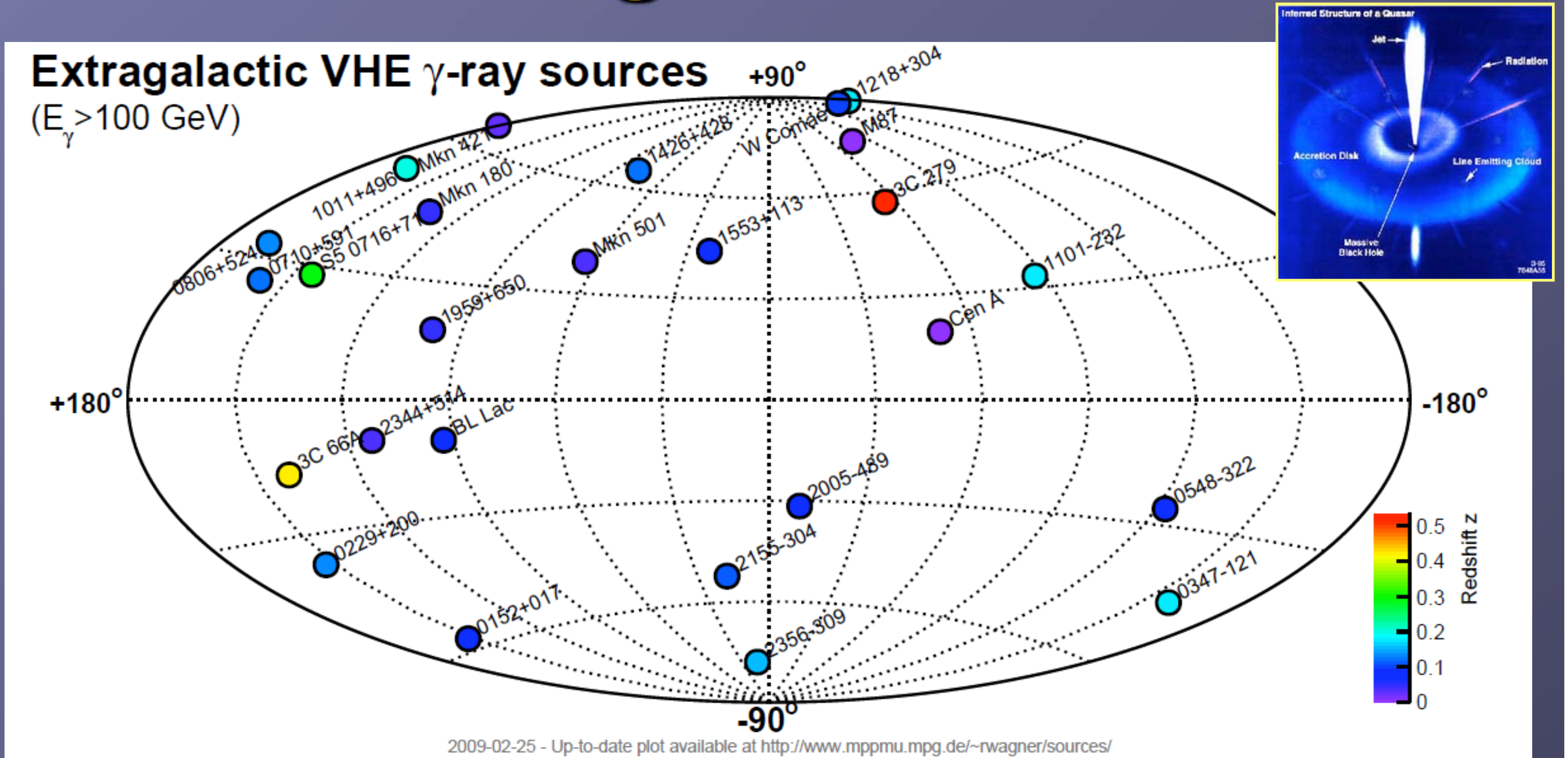
Pulsars



Galactic sources
200~400 sources with CTA

Where is PEVATRON???

Guaranteed sources
Extragalactic sources



27 sources (2 x FR-I, 24 BL Lac(HBL, IBL, LBL), 1 x FSRQ)

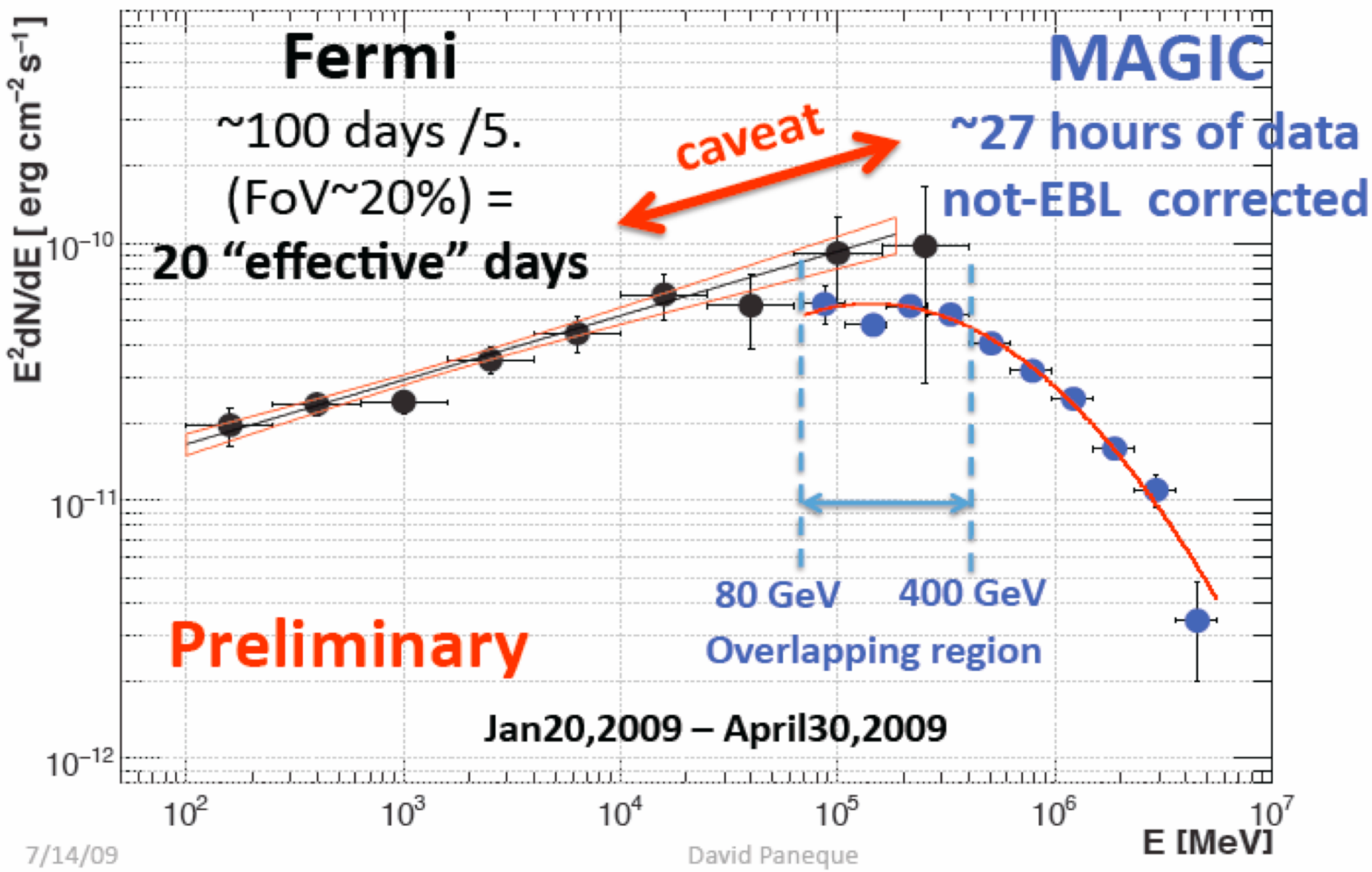
~800 sources with CTA

First "simultaneous" GeV-TeV spectrum of Mrk421

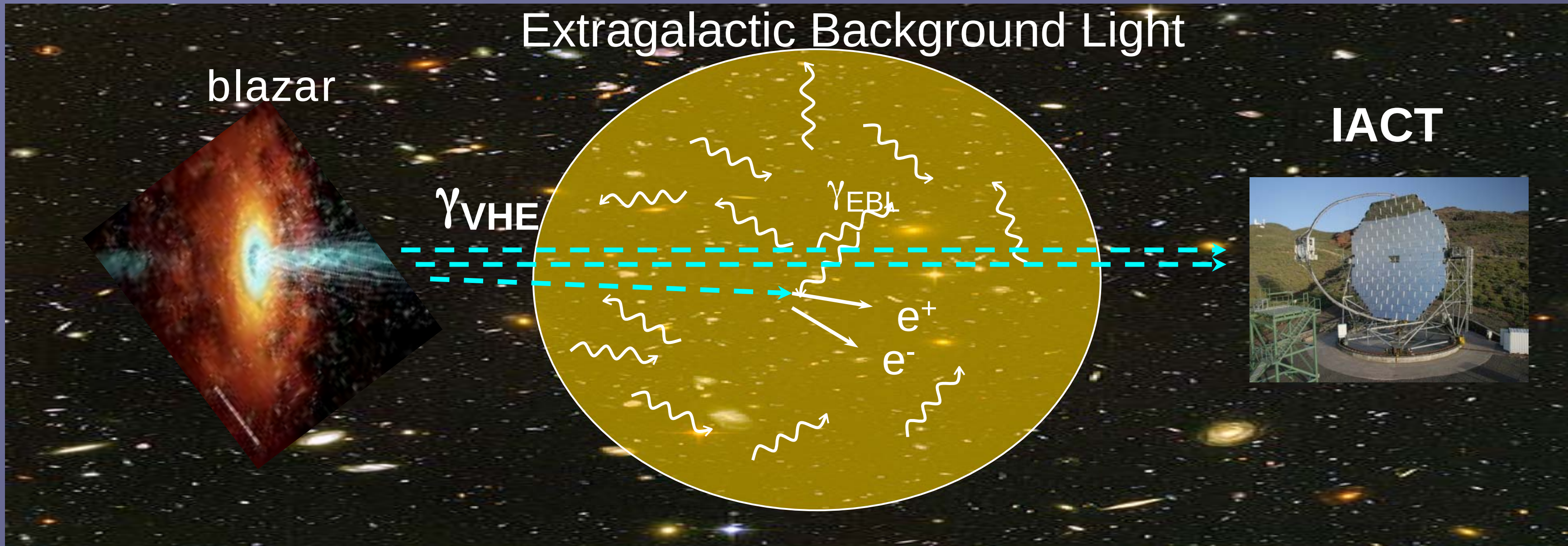
Good agreement between these 2 different instruments.

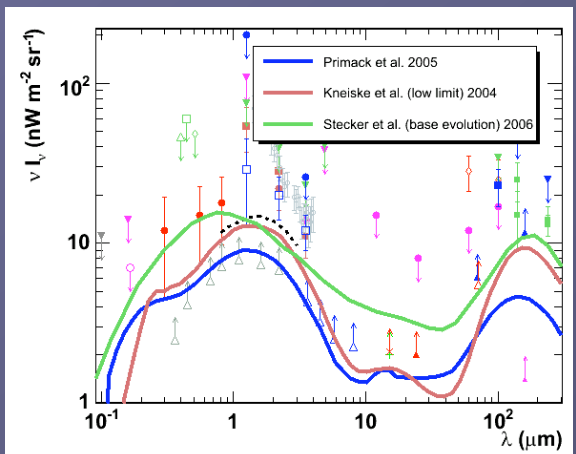
<u>Energy coverage of 5 orders of magnitude without GAPS.</u>

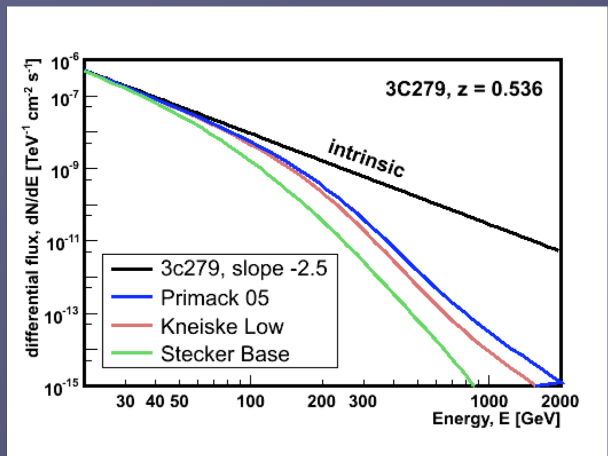
Important for modeling of the source

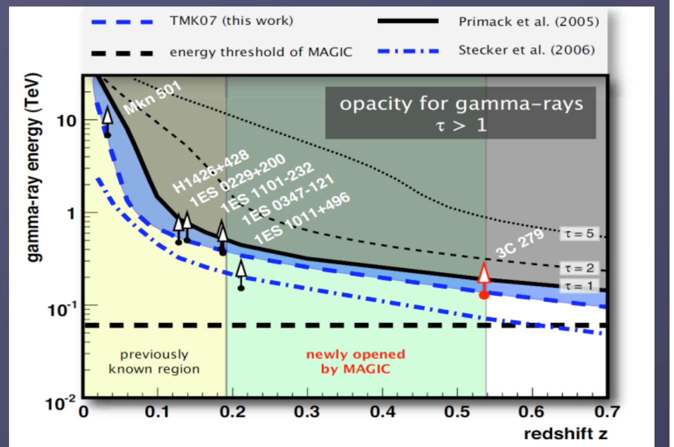


EBL（背景輻射）との衝突によるガンマ線吸収



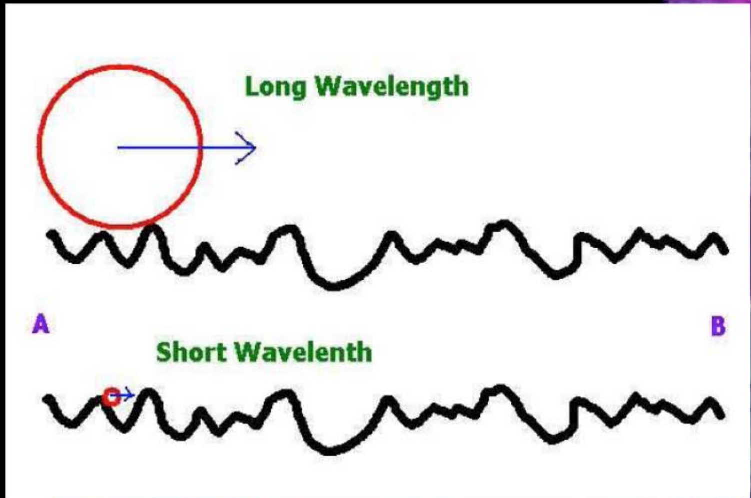






相対論・量子重力理論の検証

高エネルギー光子 x 長い伝搬距離



$$E_{Pl} = \sqrt{\frac{\hbar c^5}{G}} \approx 1.22 \times 10^{19}\, GeV$$

If Gravity is a Quantum theory,
at a very short distance it may show a very complex "foamy" structure due to quantum fluctuation.

Use gamma ray beam from AGNs/GRBs
to study the space-time structure

Energy 1000GeV ~ $10^{-16} E_{Pl}$
Distance 100~1000Mpc (10^{16-17}sec)

Visible time delay ~ 1 - 10 sec

Linear deviation:

$$\boxed{\xi_1 < 0; \quad v = c\left(1 - \frac{E}{M_{QG1}}\right); \quad n(E) = 1 + \frac{E}{M_{QG1}}}$$

Quadratic deviation:

$$\boxed{\xi_1 = 0; \quad \xi_2 < 0; \quad v = c\left(1 - \frac{E^2}{M_{QG2}^2}\right); \quad n(E) = 1 + \frac{E^2}{M_{QG2}^2}}$$

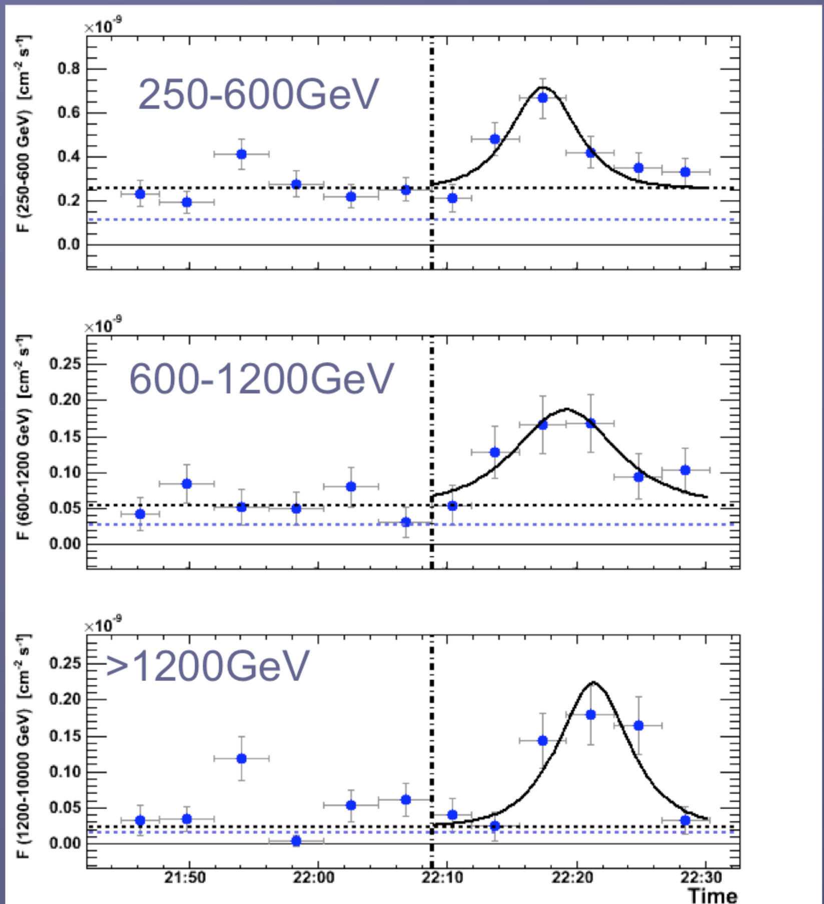
AGN からのガンマ線短時間変動
Mrk501 by MAGIC, PKS 2155 by HESS

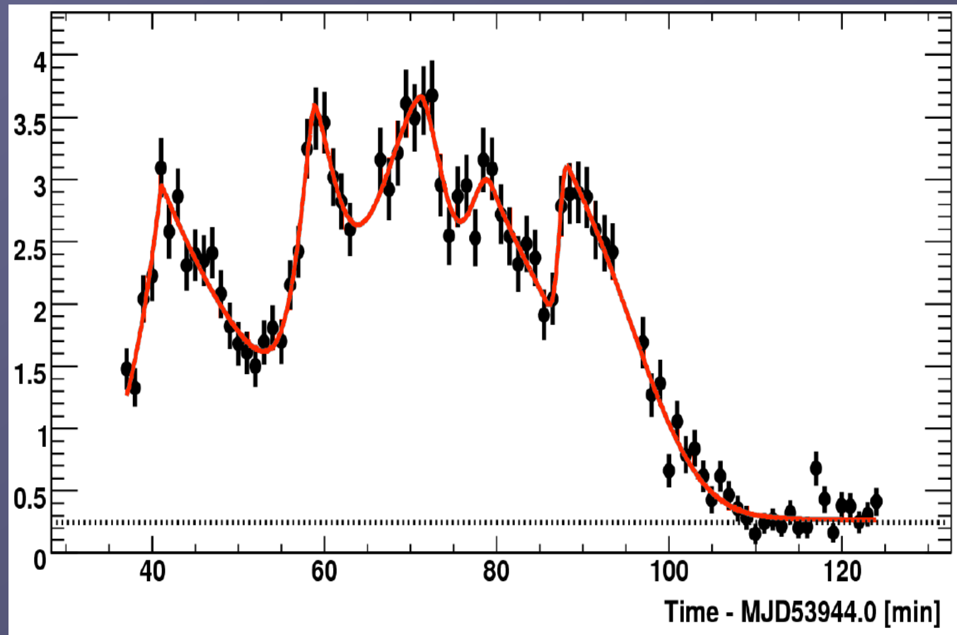
Mrk501(z=0.03) MAGIC observation

$M_{QG1} > 0.26 \times 10^{18}$GeV

PKS2155(z=0.116) HESS observation

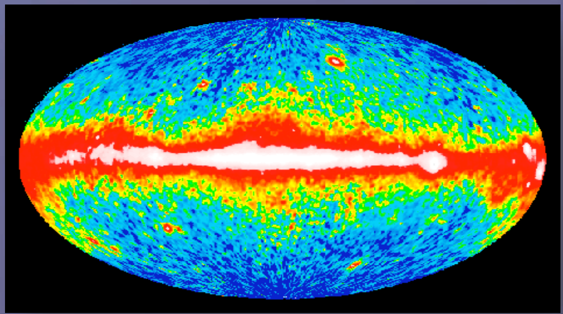
$M_{QG1} > 0.72 \times 10^{18}$GeV





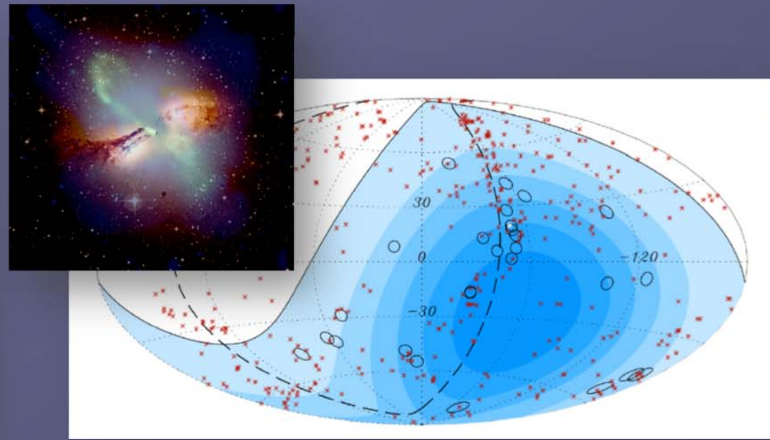
With CTA, we can have ~10sec time resolution for the fast variation

Possible New Classes of Sources



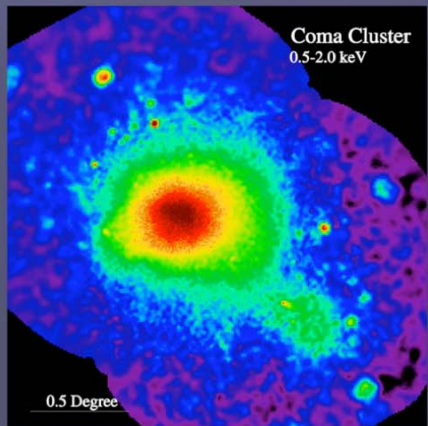
Galactic Diffuse

GRBs

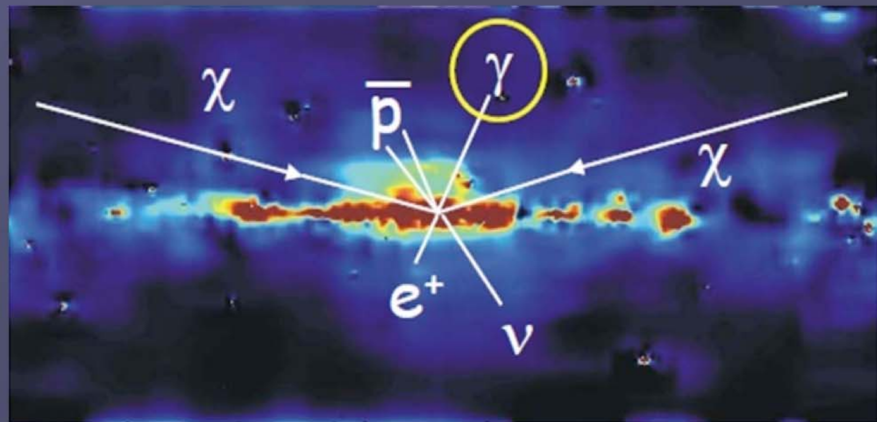


UHECR Sources

Starburst galaxies
Galaxy mergers



Clusters of galaxies



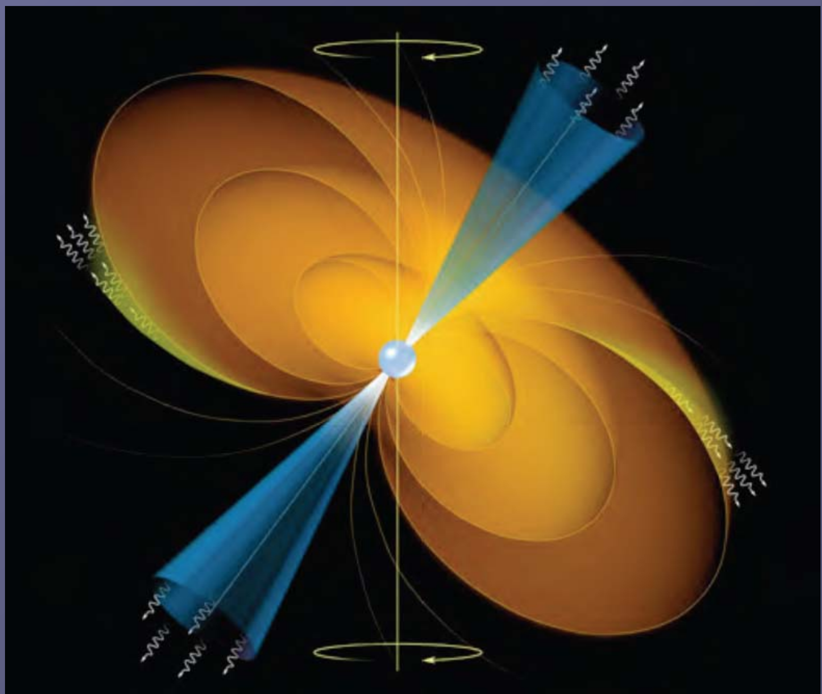
Dark Matter Annihilation

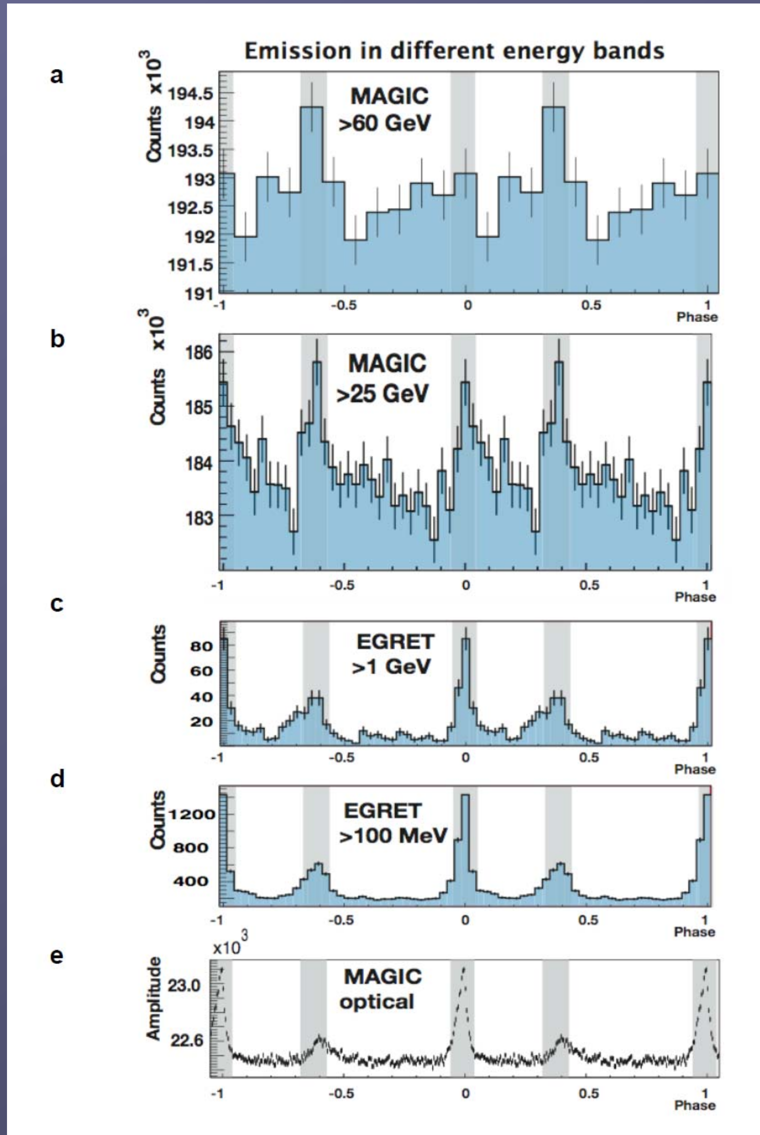
For pulsar studies the low threshold energy is essential

MAGIC result: Published in Science in 2008

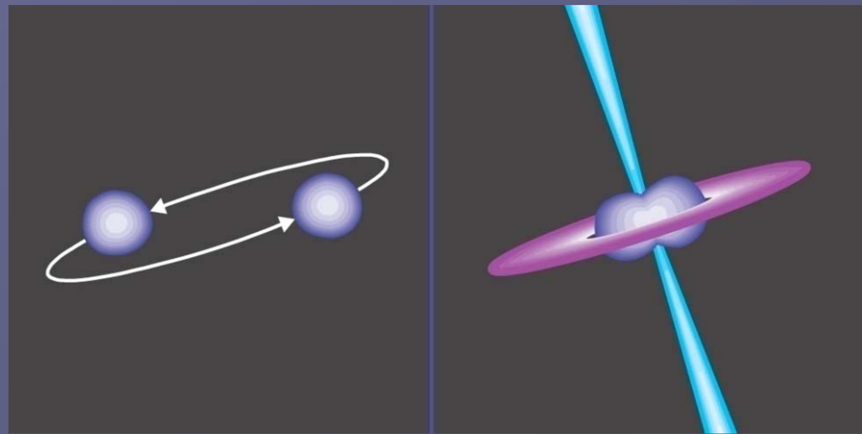
By measuring the spectrum around cutoff or at high energies is important to distinguish the emission model

Polar cap: double exponent
Outer gap: simple exponent

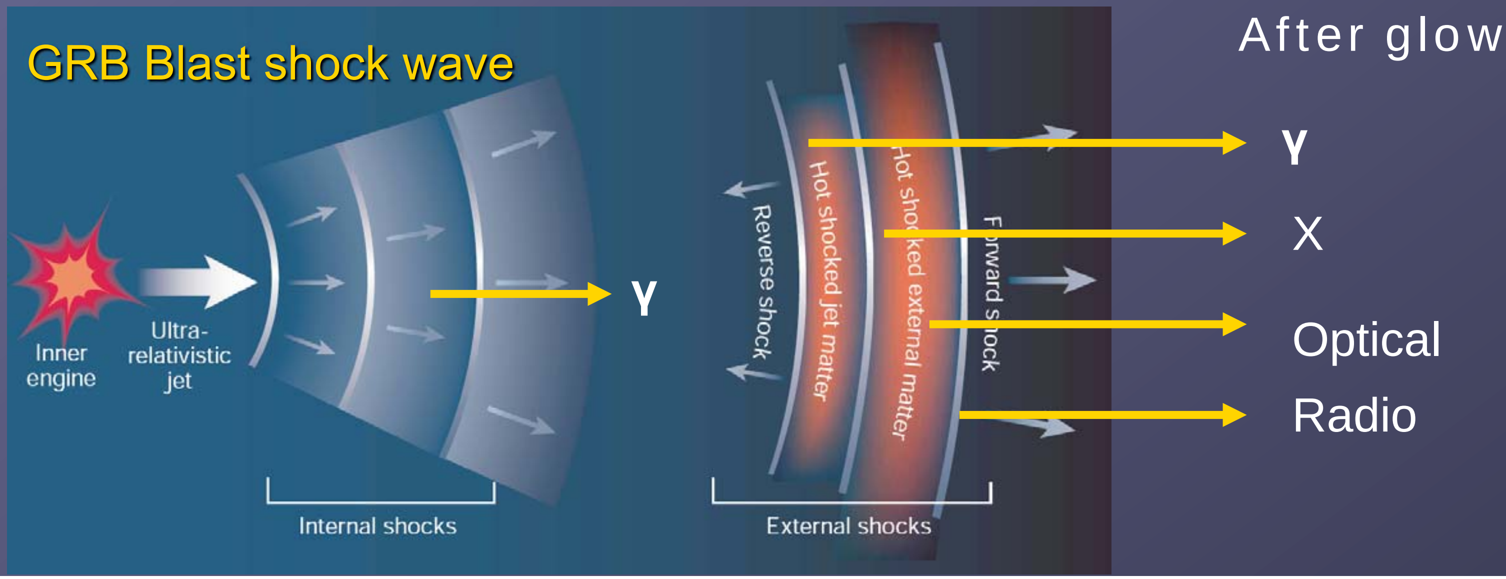




Gamma ray bursts

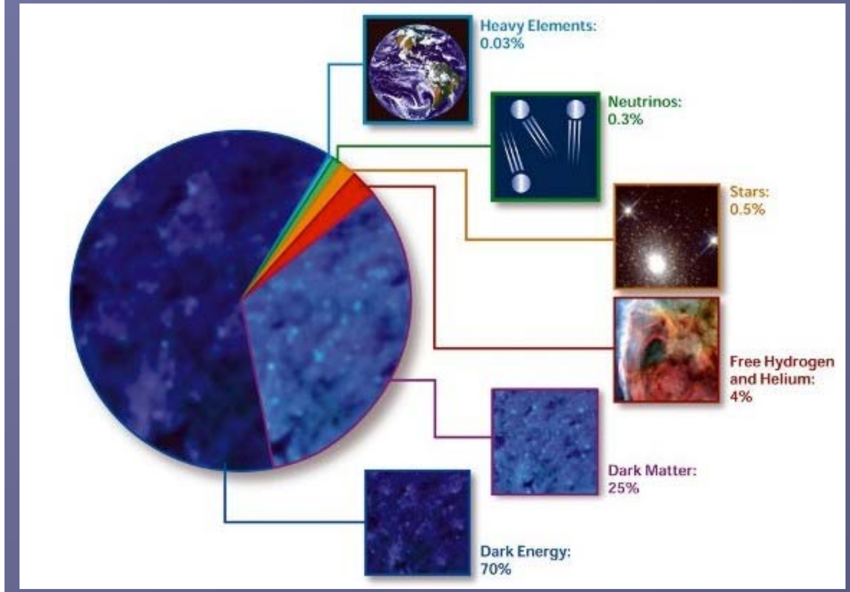


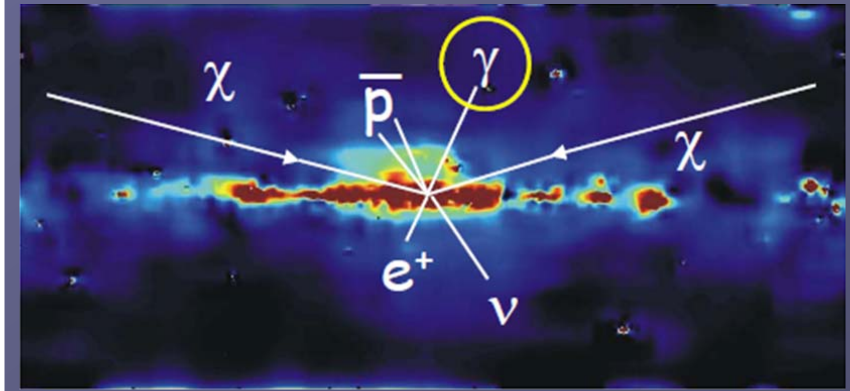
Binary neutron stars



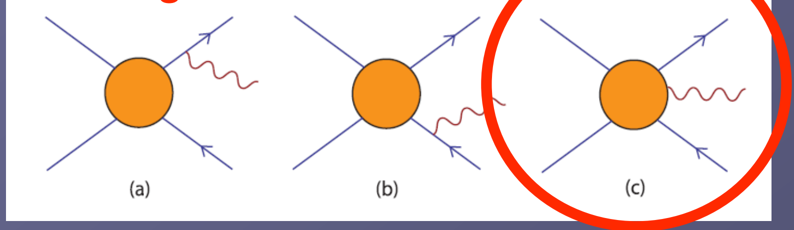
Gamma ray emission process from DM Annihilation

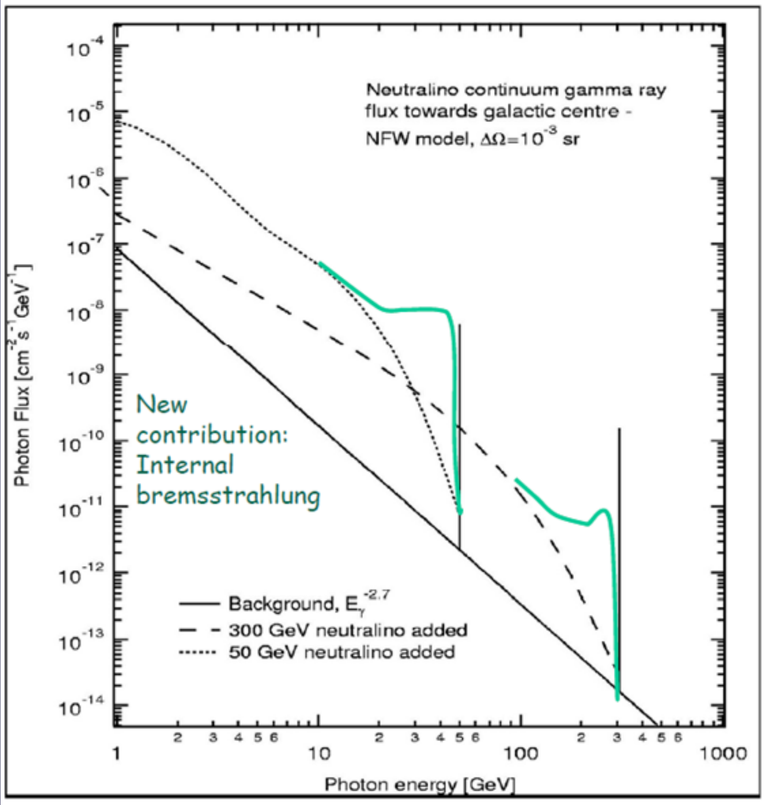
Dark Matter Annihilations





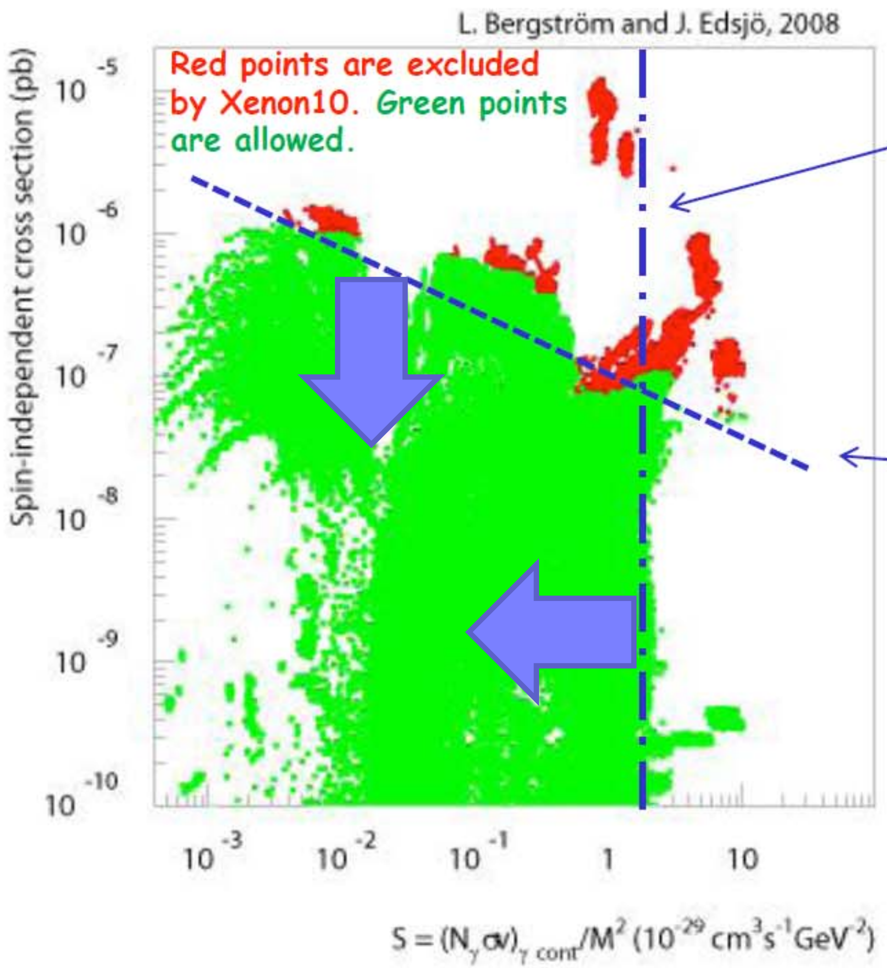
Bergstrom et al.





L.B., P.Ullio & J. Buckley 1998 T. Bringmann, L.B., J. Edsjö, 2007

Complimentarity with the direct search experiment



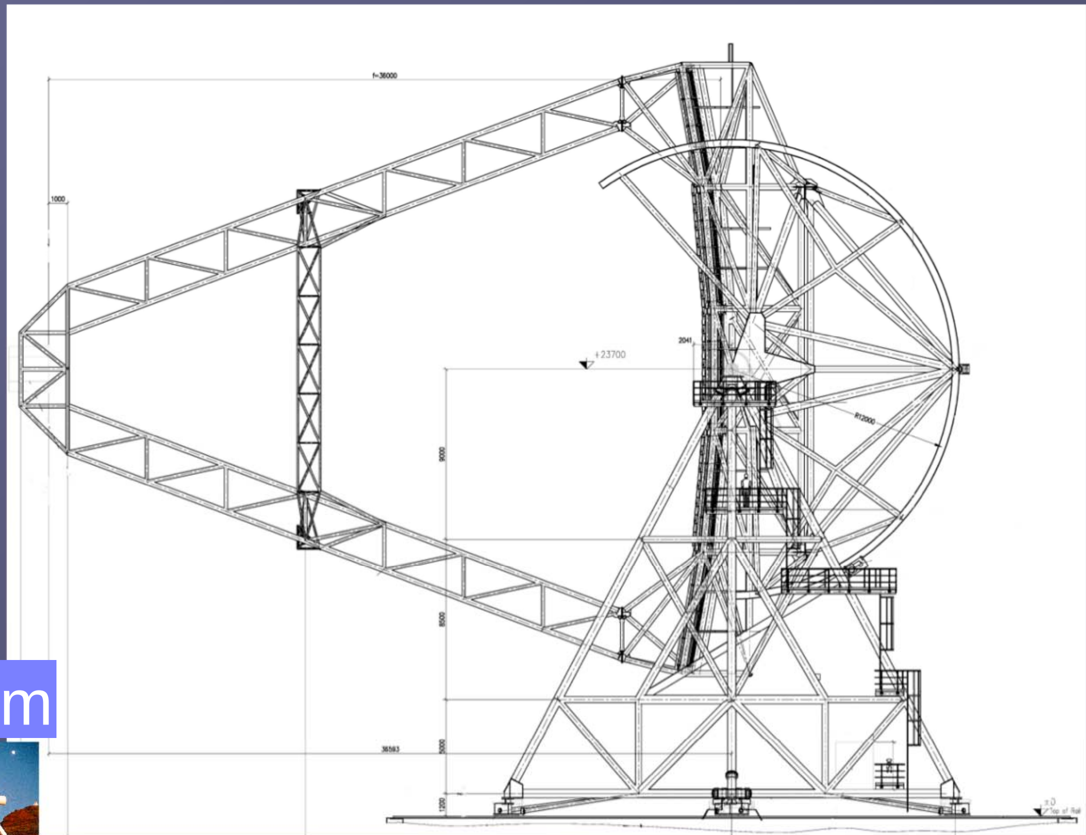
Expected sensitivity by Fermi

Present approximate limit from direct searches (Xenon10 experiment)

Telescope structures:
HESS / MAGIC / HEGRA as prototypes

MAGIC: 17m

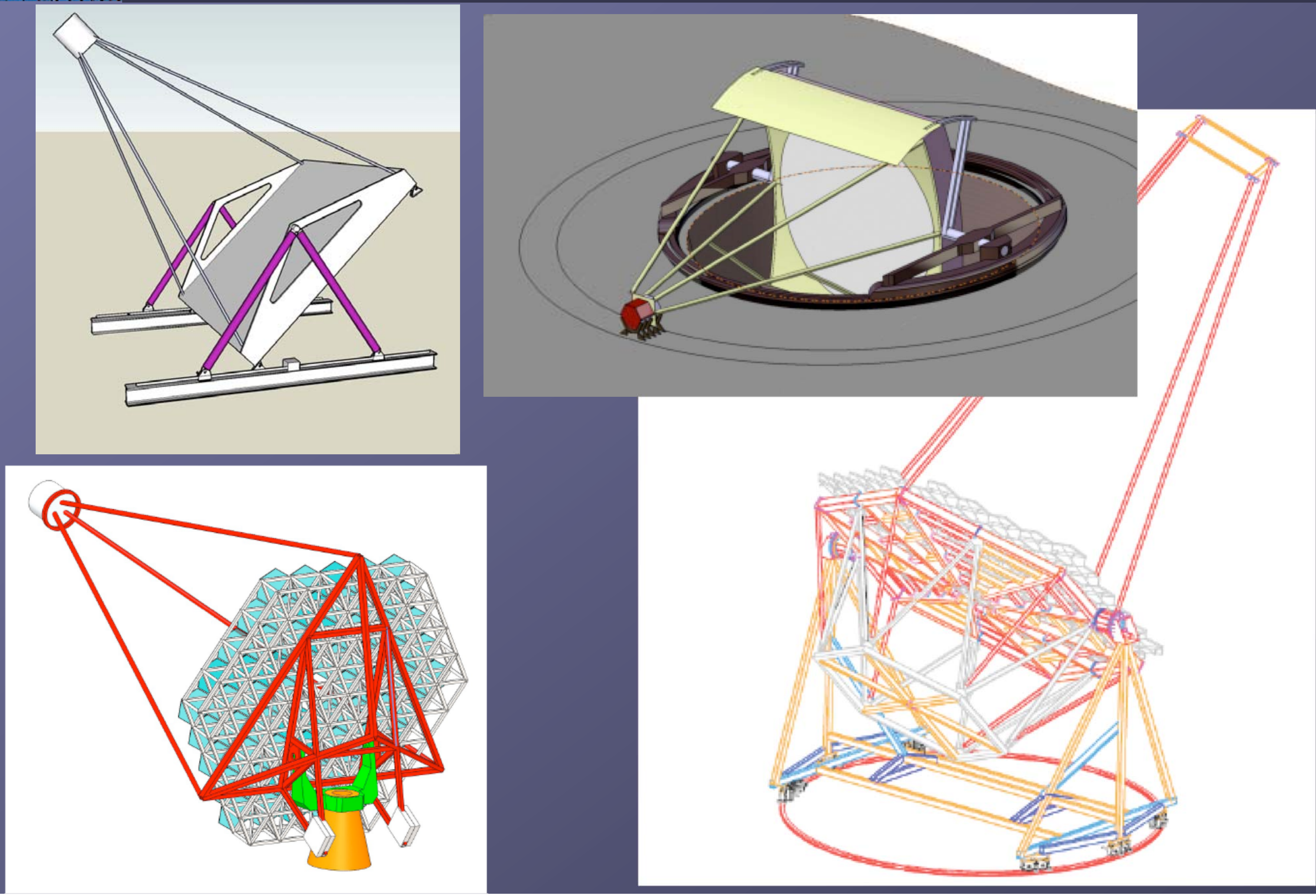
HESS II: 28m



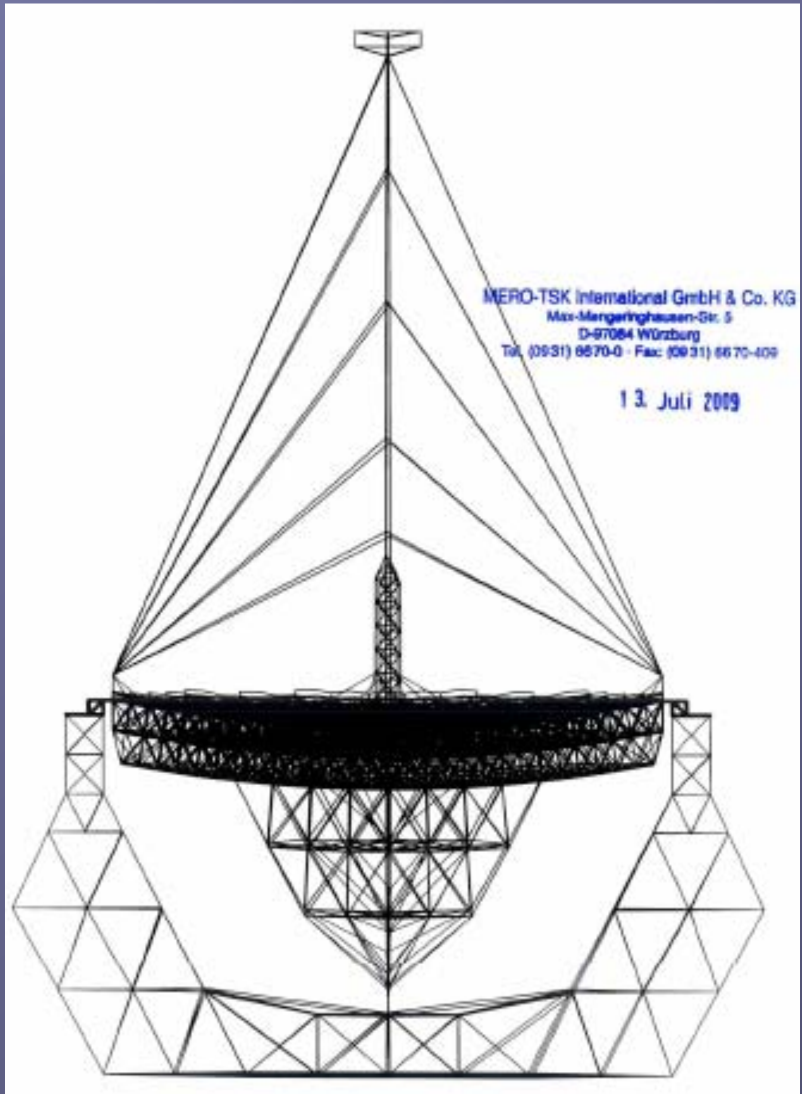
H.E.S.S. 12m

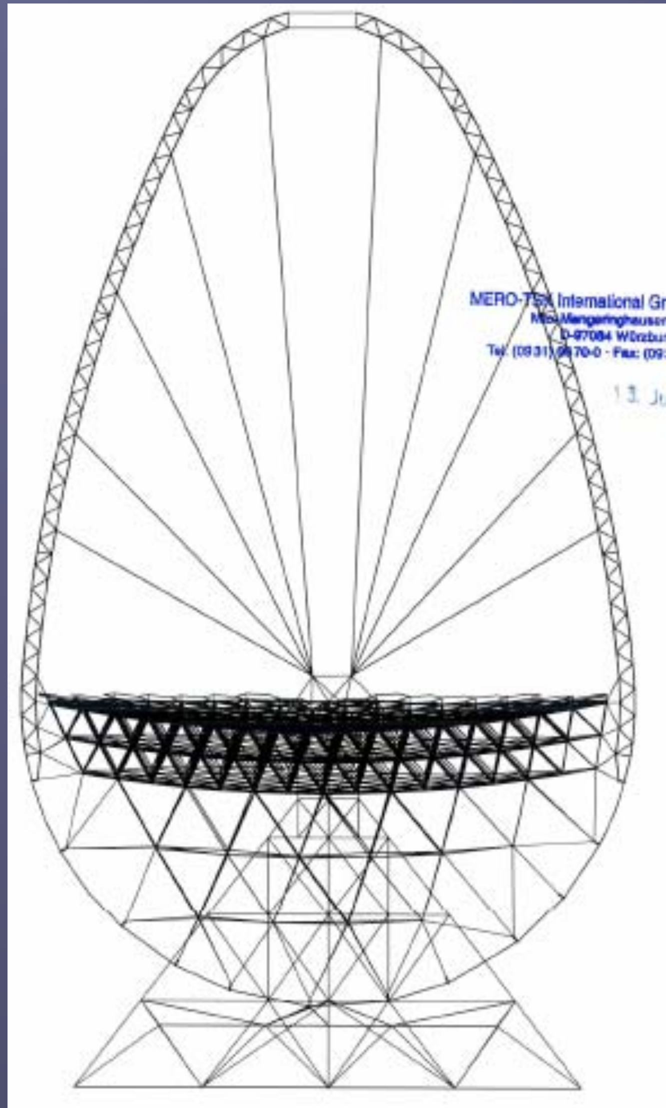
HEGRA: 4m

TEL/MIR: MST mouting scheme

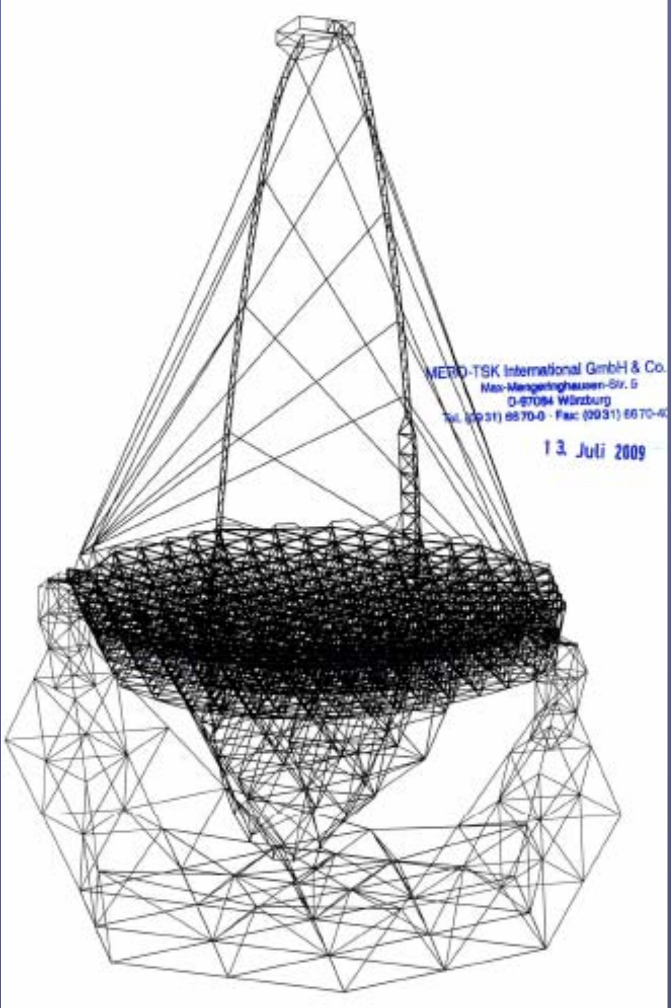


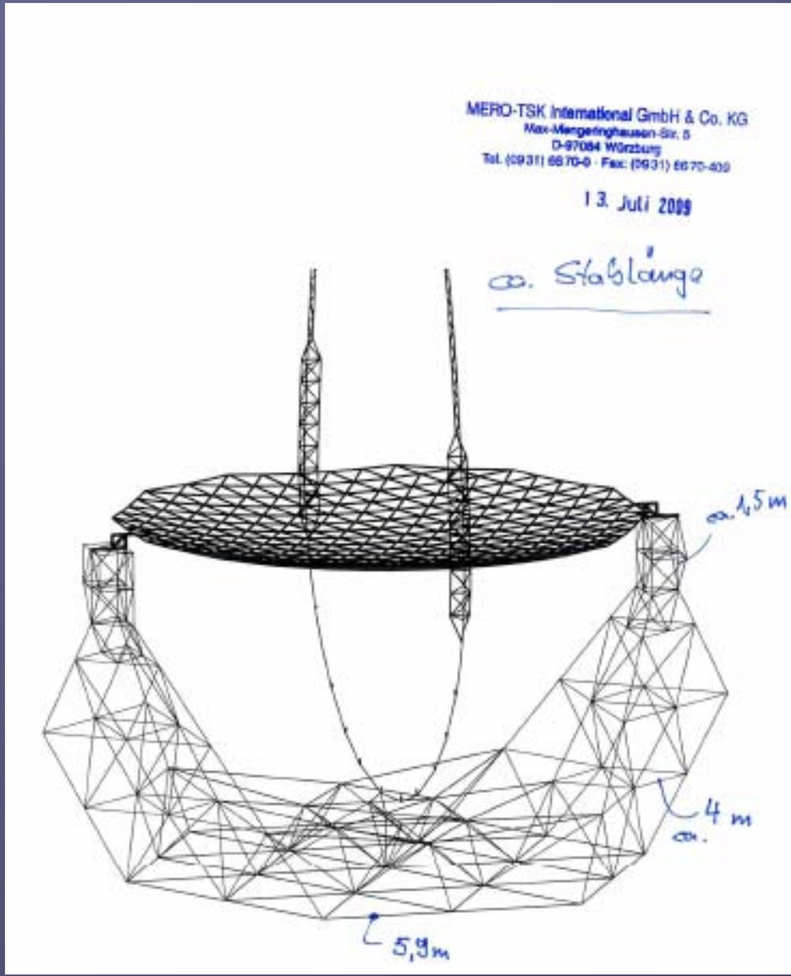
24m telescope design



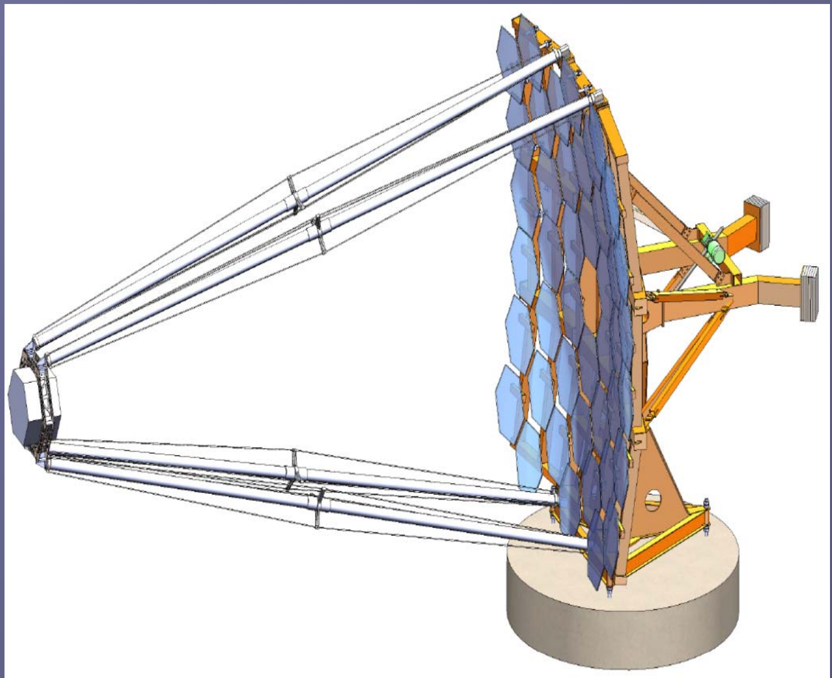


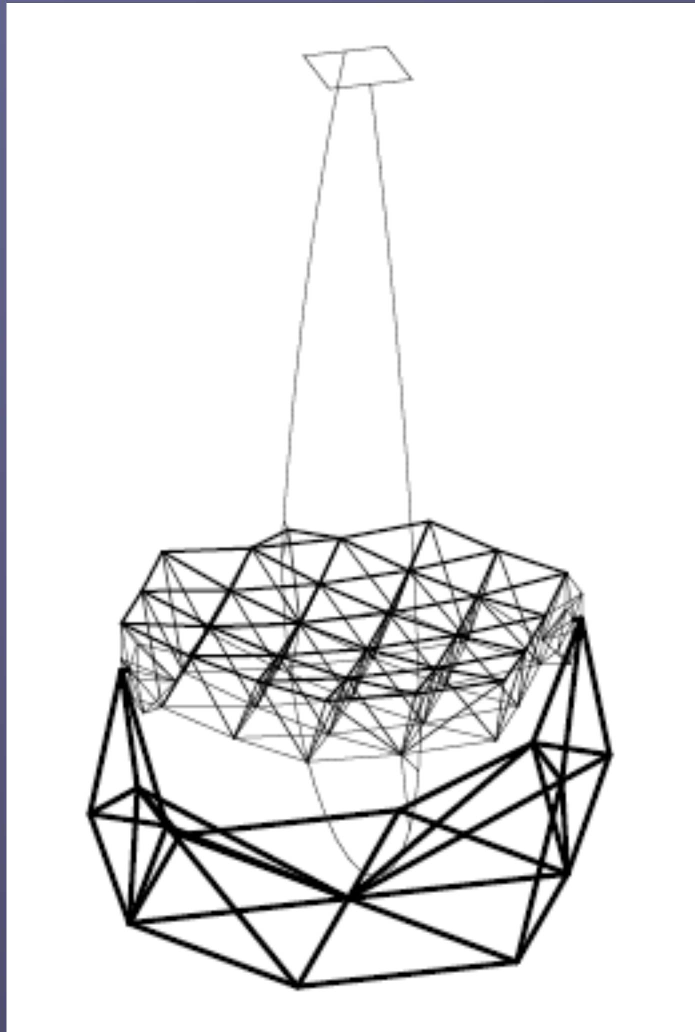
24m telescope design



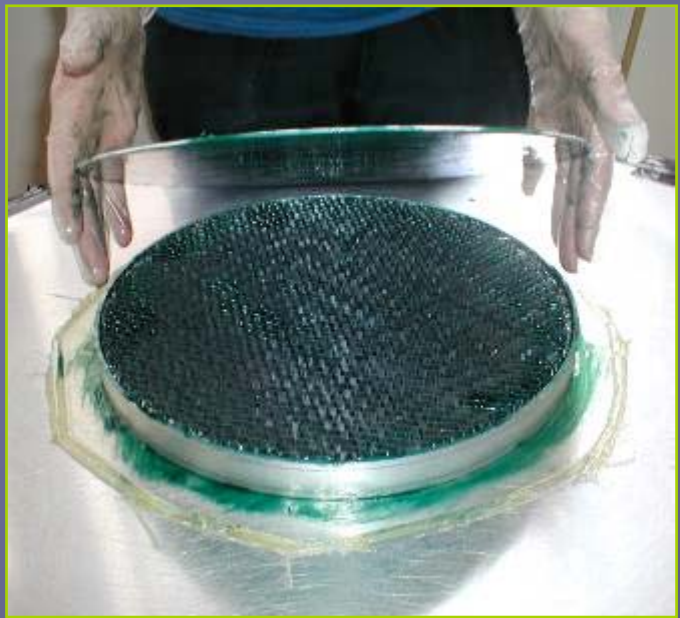


SST Options

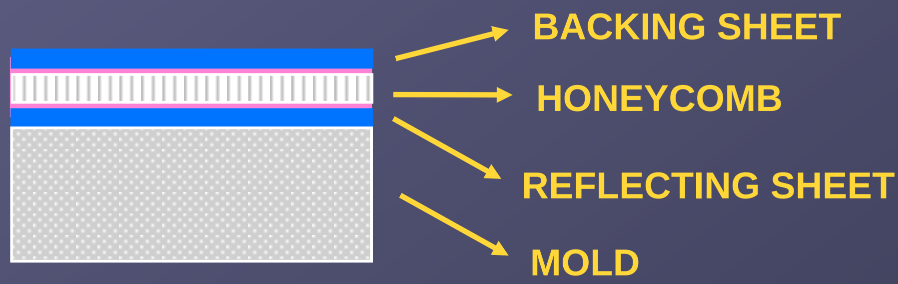




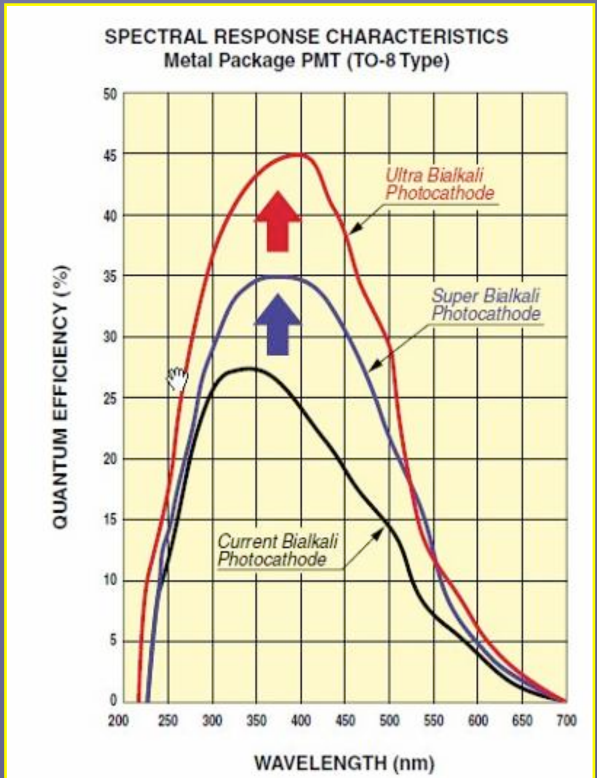
Mirrors must be cheap and good quality

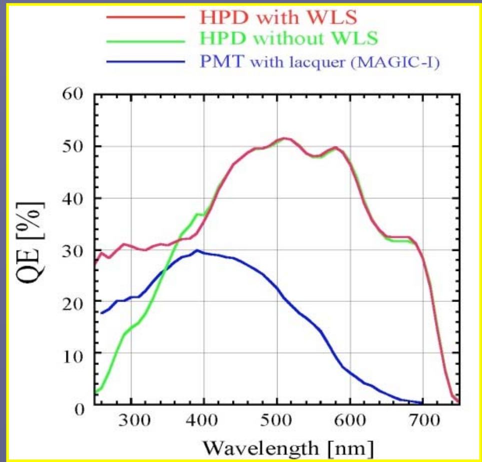


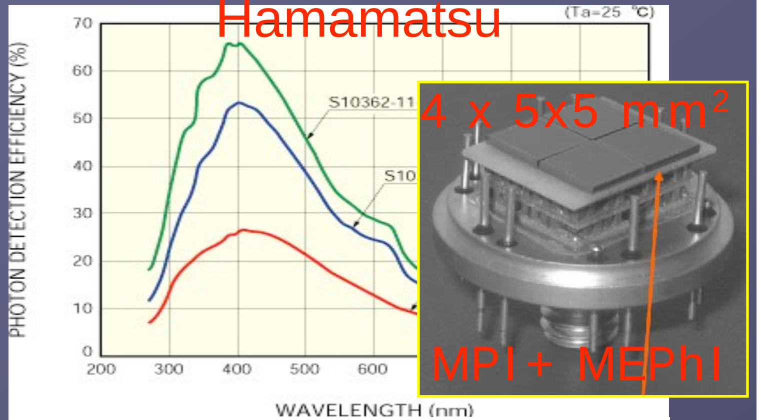
Replication techniques probably more promising for large-scale low-cost production, compared to grinding / milling of mirrors

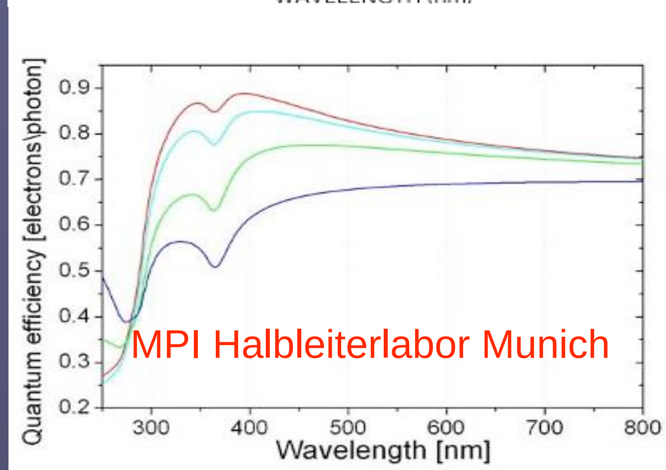


High QE photosensors









Hamamatsu & Photonis reach 45% QE
==> 40% PDE

GaAsP HPD:
50% PDE

SiPM
About 60% effective PDE will be realistic

Analogue Ring Samplers

economic high performance readout

DRS3 (--> DRS4)

12 x 1024 samples

up to 5 Gsamples/s

11.5 bit effective range

450 MHz bandwidth

25 mm^2

SAM

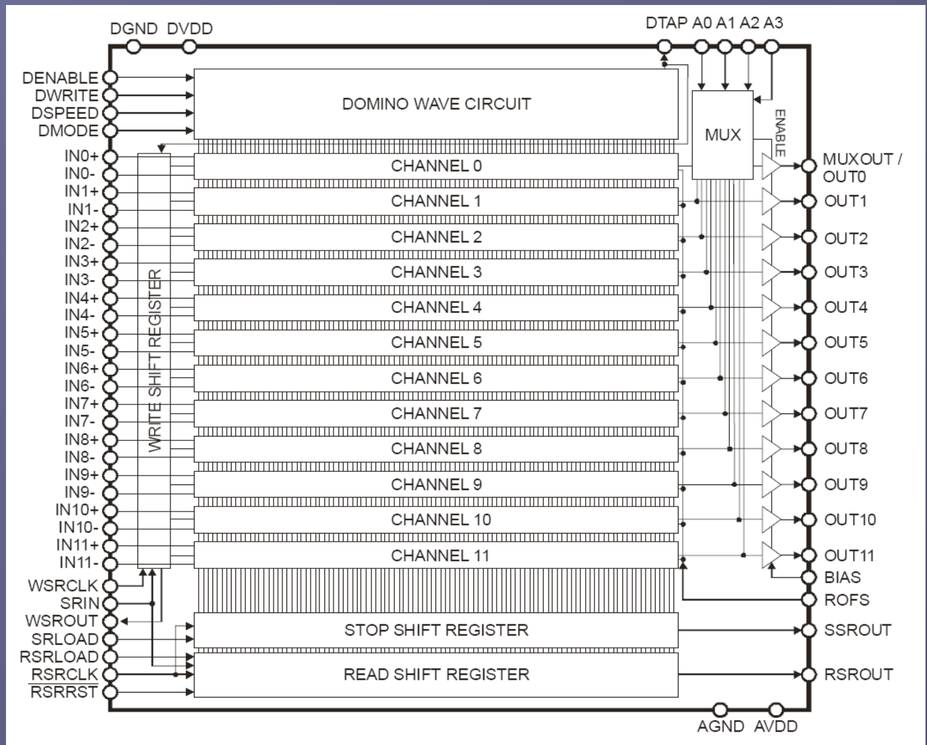
2 x 256 samples

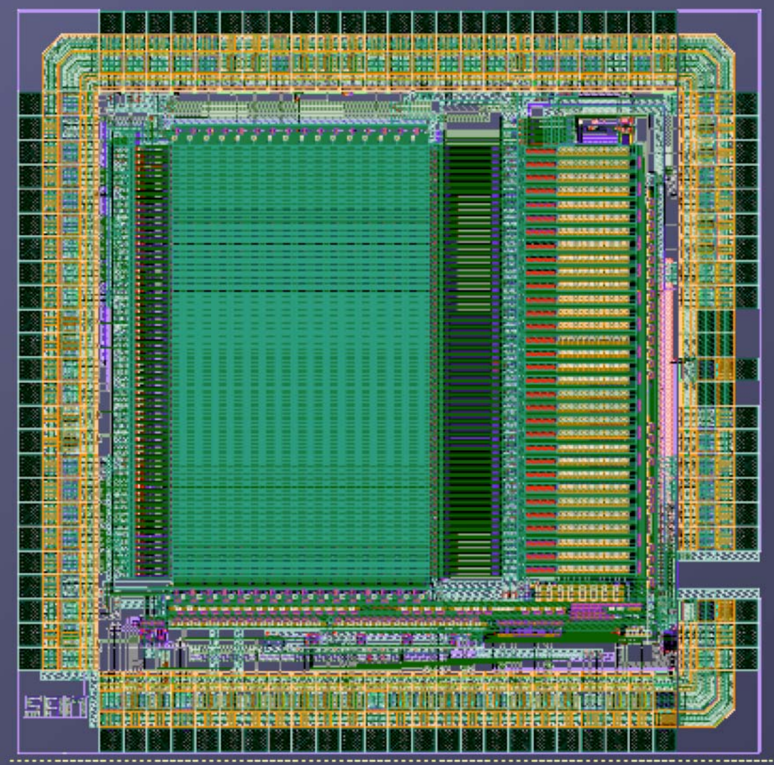
up to 2 Gsamples/s

12 bit effective range

350 MHz bandwidth

11 mm^2



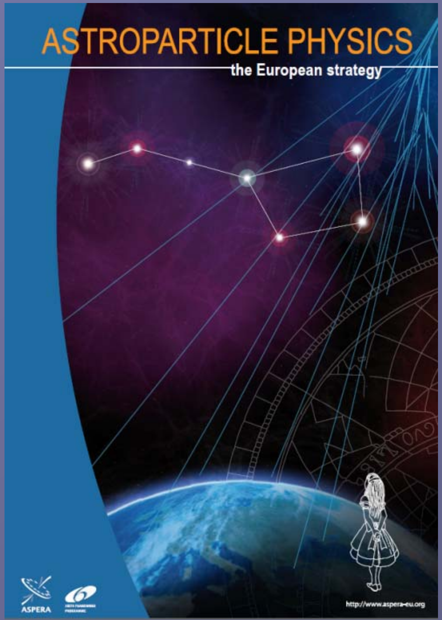


Data center and operation center for CTA


European space operations center

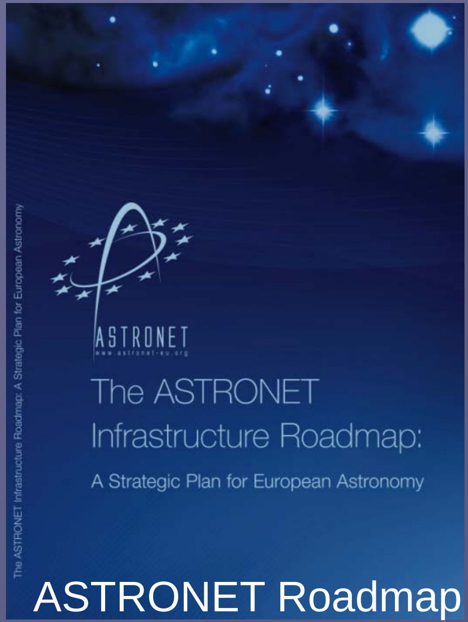
- Challenges
  - Huge data rates (~PBytes/yr)
  - Observatory
    Automatic calibration and analysis for users
- Organization structure
  - Array operation center
  - Data handling and analysis center
  - Science operation center
- Lots of man power (local technician, operation crew, professional data analyzers for the science operation)

Recommendations and supports



ASPERA Roadmap

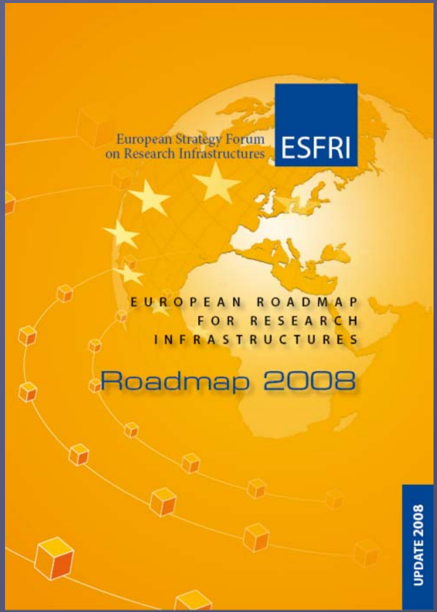
Magnificent Seven



ASTRONET Roadmap

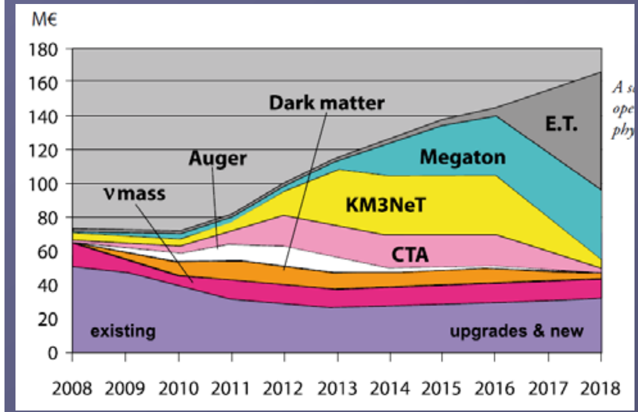
High Priority project

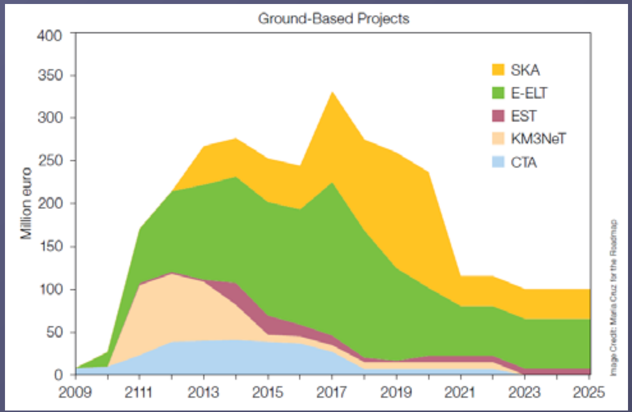
Ground based projects



CTA is newly added in 2008 update

8 Infrastructures from Physics and eng





Summary

- 高エネルギーガンマ線天文学のめざましい発展
- IACT 技術の熟成 ➔ CTA == 究極の IACT Array
  - 国際協力による次世代のインフラの構築
  - 目指す性能:
    - Broad band: 20-30GeV ~ 100TeV
    - 感度10倍: 10mCrab ➔ ~1mCrab
    - 角分解能3倍: 1~2 arcmin
- 高エネルギー天文学の今後
  - 未だ多くの謎、銀河系内外宇宙線起源、ジェットでの粒子加速 (例えば、短時間変動)
  - 高い時間分解能による フレアー時間変動
  - EBL の z 依存性
  - 新しいクラスの天体:パルサー、GRB、クラスター、未知天体、他
  - 基礎物理:相対論・量子重力効果、暗黒物質、宇宙論
- タイムスケジュール
  - 2009 末、Array Design を決定
  - 2010-2013 プロトタイプ
  - 2013- 2018 建設
  - AGIS 合流 in some day?
  - Community, Funding Agency, EU からの強い支援