CTA

The next generation observatory for TeV Gamma Ray Astronomy

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Major IACTs in the world

HESS-II and MAGIC-II can be good R&Ds for CTA

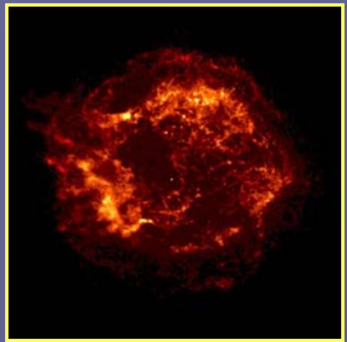
HESS-II
28m diameter telescope
Lower threshold energy
In 2008

MAGIC-II
2x17m, High Q.E. detectors
Lower threshold energy
High Precision
In 2007

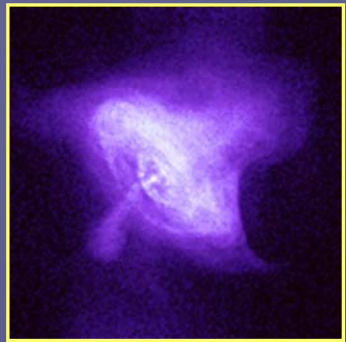
Inauguration on 21.Sep.2008

CTA

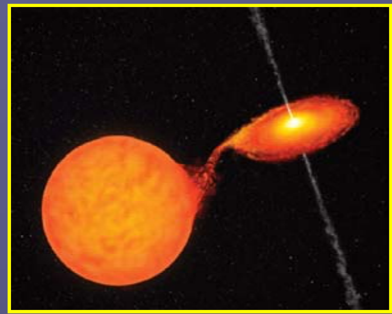
Scientific Objectives



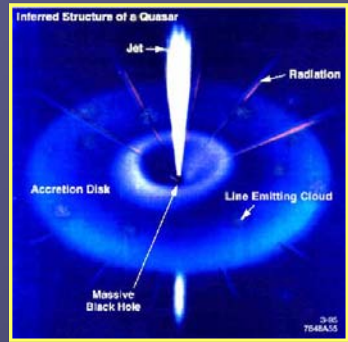
SNRs



Pulsars
and PWN



Micro quasars
X-ray binaries

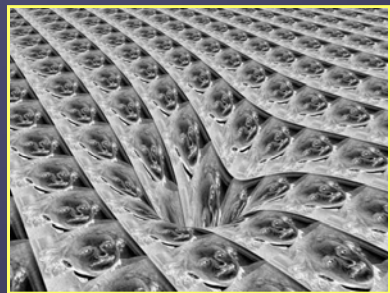


AGNs

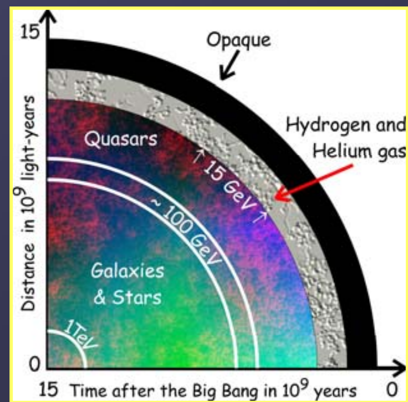
GRBs

Origin of
cosmic rays

Dark matter

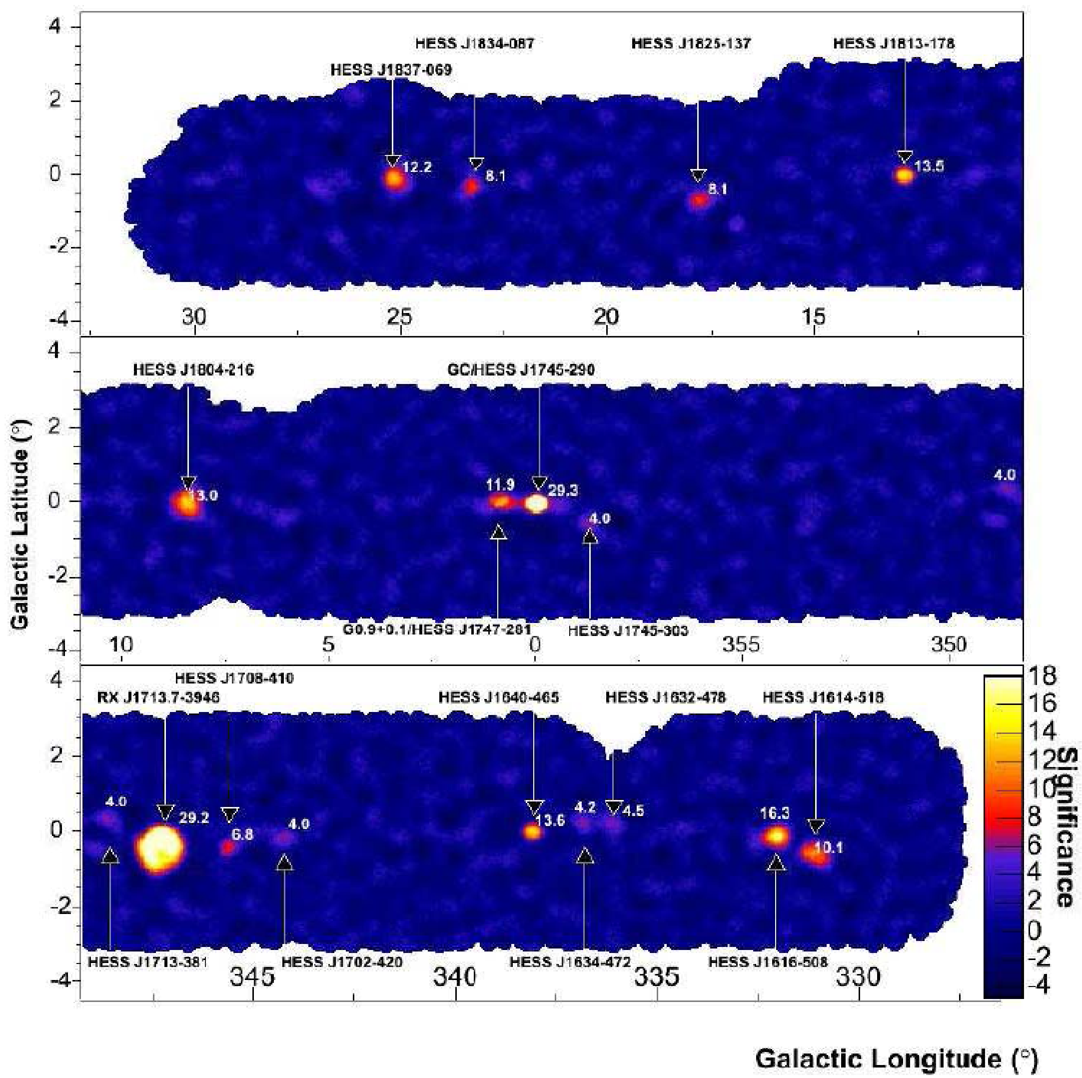


Space-time
& relativity



Cosmology

Great success of HESS Galactic plane survey



HESS Galactic plane Survey

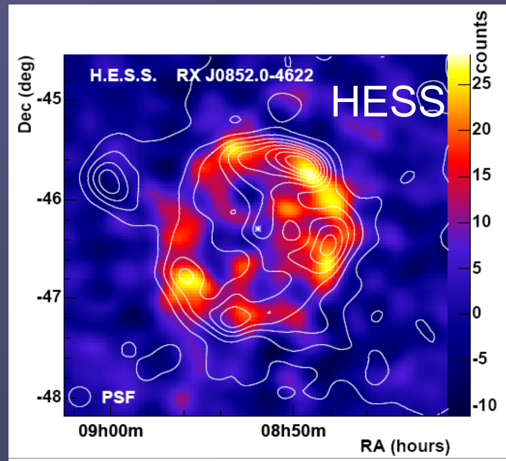
Survey in 2-3% Crab unit

Astro-ph/0510397
17 sources + Several

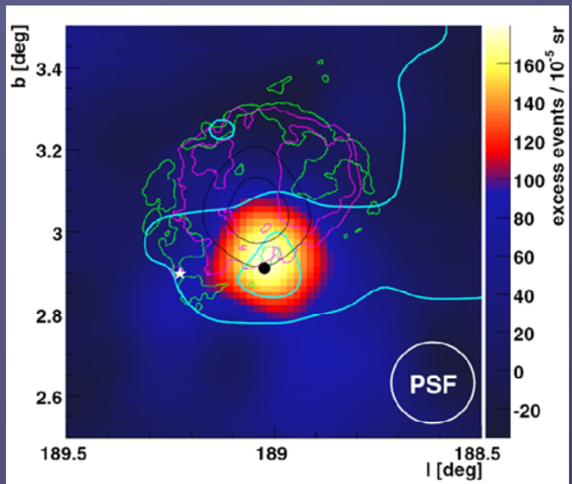
PWNs
Shell type SNRs
X-Ray Binary (Microquasars)
Un-ID sources

SNRs (10)

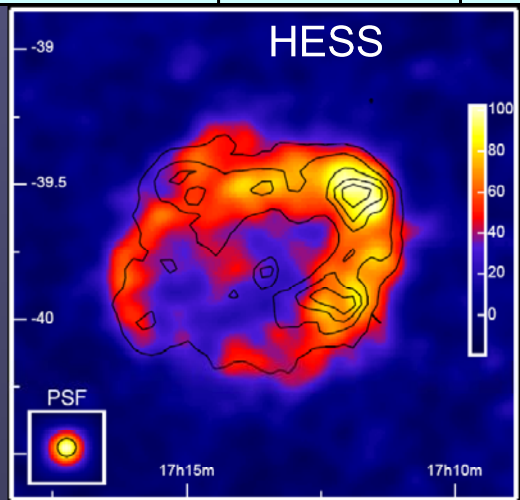
Category	Name	Discover	Obs.
SNR/Un-ID	MAGIC J0616+225 (IC443)	MAGIC	
SNR	Cas-A	HEGRA	
SNR	Vela Junior, RX J0852.0-4622	CANGAROO	HESS
SNR/Un-ID	HESS J1640-465 (G338.3-0.0; 3EG J1639-4702)	HESS	
SNR	G348.7+0.3 ?	HESS	
SNR	RX J1713.7-3946, G347.3-0.5	CANGAROO	HESS
SNR/PWN	HESS J1804-216 (G8.7-0.1 / W30; PSR J1803)	HESS	
SNR	HESS J1813-178 (G12.8-0.02; AX J1813-178)	HESS	MAGIC
SNR	HESS J1834-087 (G23.3-0.3 / W41)	HESS	MAGIC
SNR/Un-ID	HESS J1837-069 (G25.5+0.0; AX J1838.0-0655)	HESS	



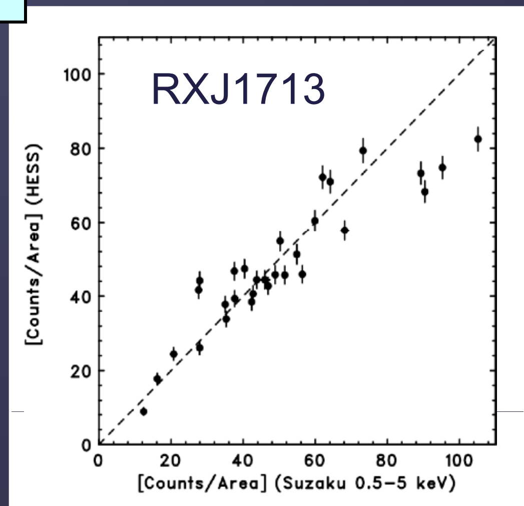
Vela Junior



MAGIC J0616+225 (IC443?)



RX J1713

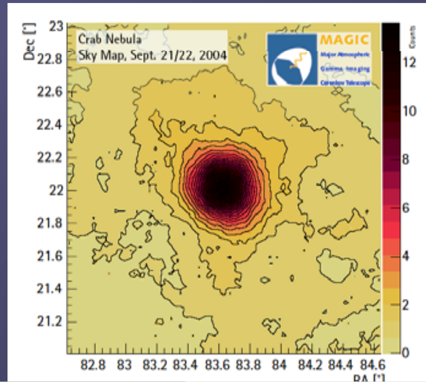


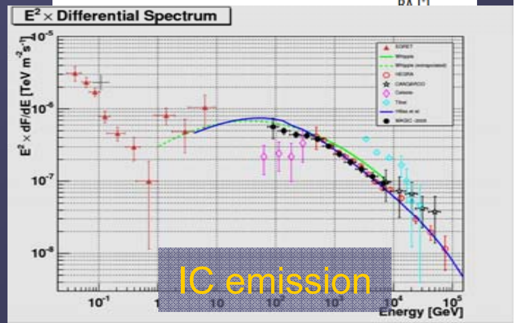
Y. Uchiyama, T. Takahashi
Texas Symp. 2006

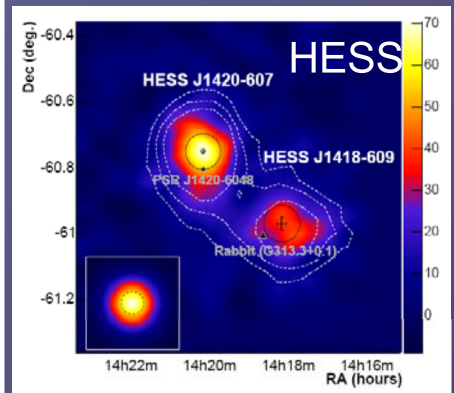
PWN (9)

Category	Source	Discovery	Obs.
PWN	Crab Nebula	Whipple	many
PWN	Vela X	CANGAROO	HESS
PWN	HESS J1418-609 (G313.3+0.1, Rabbit)	HESS	
PWN	HESS J1420-607 (PSR J1420-6048, Kookaburra)	HESS	
PWN	MSH 15-52, PSRB1509-58	CANGAROO	HESS
PWN	HESS J1616-508 (PSR J1617-5055)	HESS	
PWN	HESS J1718-385	HESS	
PWN	HESS J1747-281 (G0.9+0.1)	HESS	
PWN	HESS J1825-137 (PSR J1826-1334)	HESS	

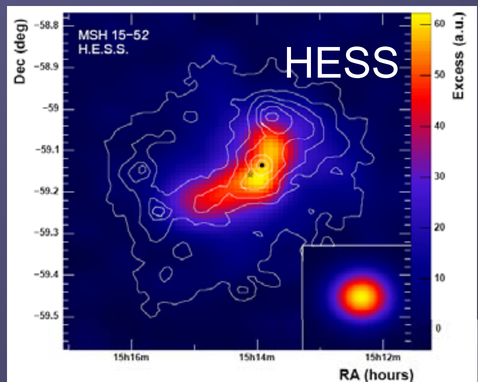
MAGIC Crab Nebula



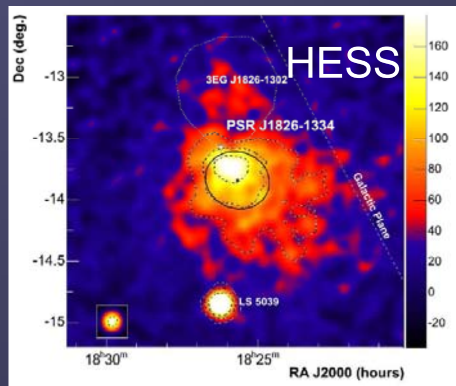




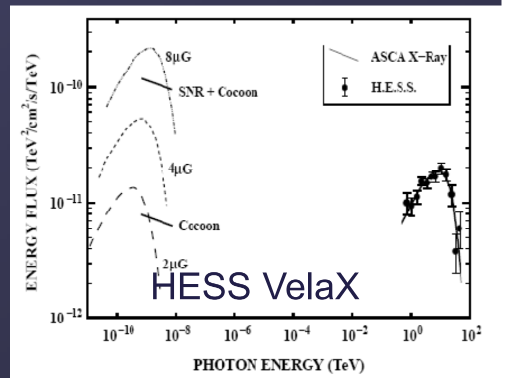
Kookaburra



MSH 15-52



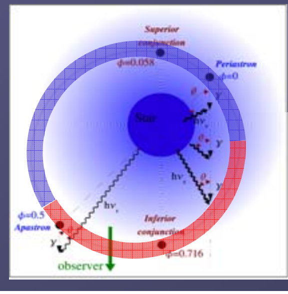
HESS J1825

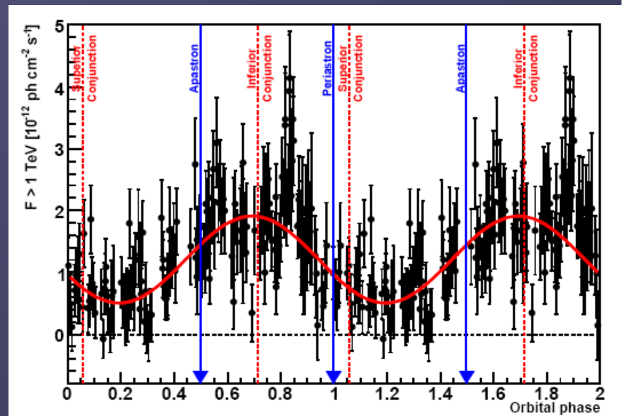


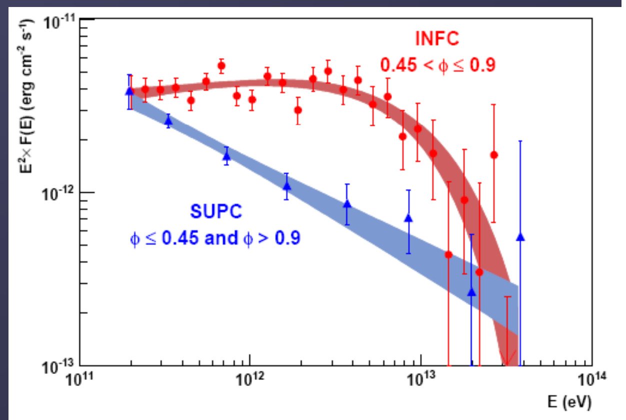
Binary System (6)

Category	Source	Discovery	Obs.
Binary	PSR B1259-63 / SS 2883	HESS	
XRB	IGR J16320-4751	HESS J1632-478	
XRB/SNR	IGR J16358-4726 ?; G337.2+0.1 ?	HESS J1634-472	
XRB	LS 5039	HESS	
XRB	LSI+61303	MAGIC	VERITAS
XRB	Cyg X-1	MAGIC	

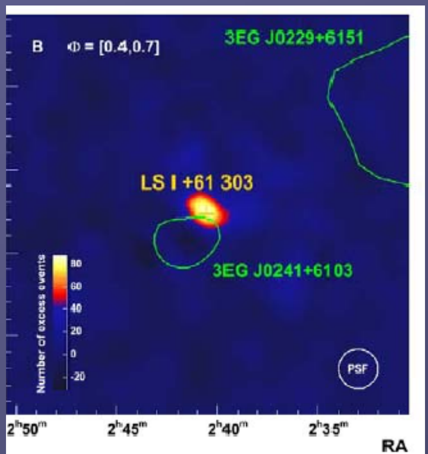
LS 5039
HESS



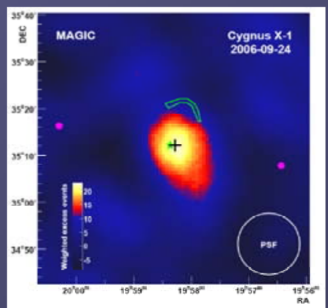


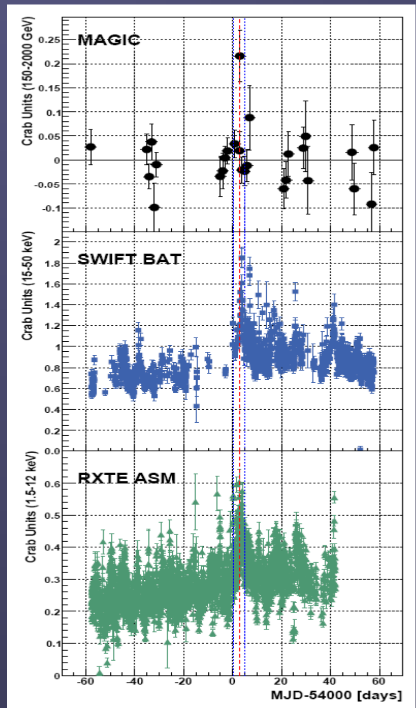


MAGIC LSI +61 303



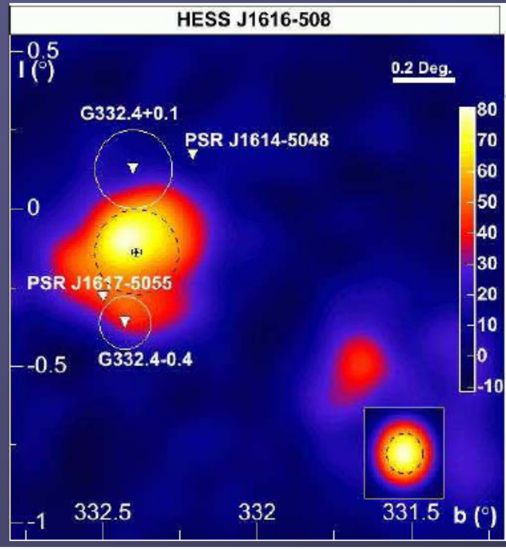
MAGIC Cyg X-1



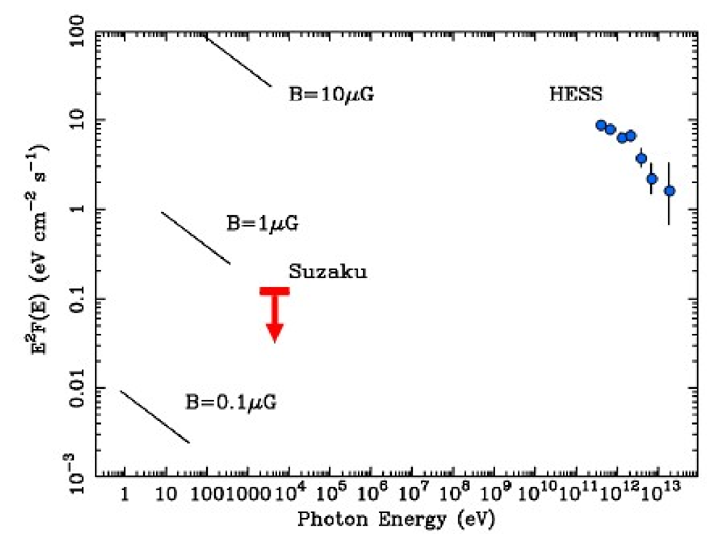


Un-IDs (Dark Source)

Category	Source	Discovery	Observation
Un-ID	TeV J2032+4130	HEGRA	
Un-ID	HESS J1303-631	HESS	
Un-ID	HESS J1614-518	HESS	
Un-ID	HESS J1702-420	HESS	
Un-ID	HESS J1708-410	HESS	
Un-ID	3EG J1744-3011 ?	HESS J1745-303	



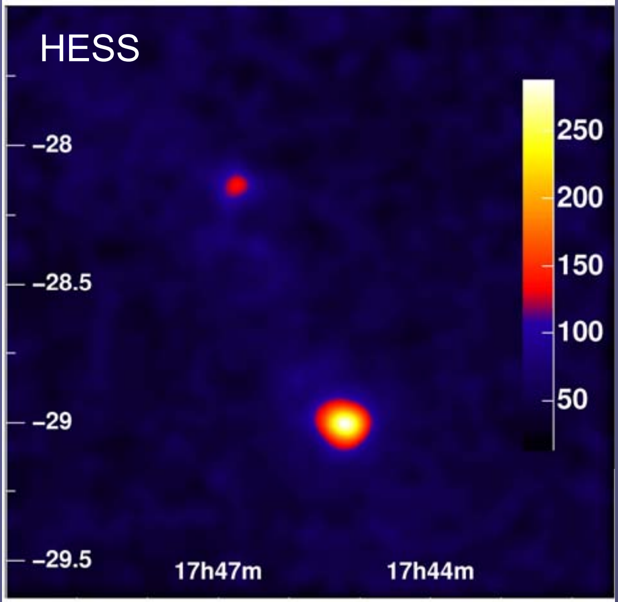
Name	Possible counterpart	Type[a]	$\Gamma^b_{\rm TeV}$	$f^c_{\rm TeV}$	$N^d_{\rm H}$	$\Gamma^e_{\rm X}$	$f^f_{\rm X}$	$f_{\rm TeV}/f_{\rm X}$	Reference[g]
HESS J0852−463	RX J0852−4622	SNR	2.1	6.9	4	2.6	∼10	∼ 0.7	1, 2, 3
HESS J1303−631	—	?	2.4	1.0	20	2.0	<0.64	>1.6	4, 5
HESS J1514−591	PSR B1509−58	PWN	2.3	1.6	8.6	2.0	3.2	0.5	6, 7
HESS J1632−478	AX J1631.9−4752	HMXB?	2.1	1.7	210	1.6	1.7	1.0	8, 9
HESS J1640−465	G338.3−0.0	SNR	2.4	0.71	96	3.0	0.30	2.4	8, 10
HESS J1713−397	RX J1713.7−3946	SNR	2.2	3.5	8	2.4	54	0.065	11, 12
HESS J1804−216	Suzaku J1804-2142	?	2.7	0.48	2	-0.3	0.025	19	8, 13
HESS J1804−216	Suzaku J1804-2140	?	2.7	0.48	110	1.7	0.043	11	8, 13
HESS J1813−178	AX J1813−178	?	2.1	0.89	110	1.8	0.70	1.3	8, 14
HESS J1837−069	AX J1838.0−0655	?	2.3	1.4	40	0.8	1.3	1.1	8, 15
TeV J2032+4130	—	?	1.9	0.20	?	?	<0.20	>1.0	16
HESS J1616−508	—	?	2.4	1.7	4.1	2.0	<0.031	>55	This work

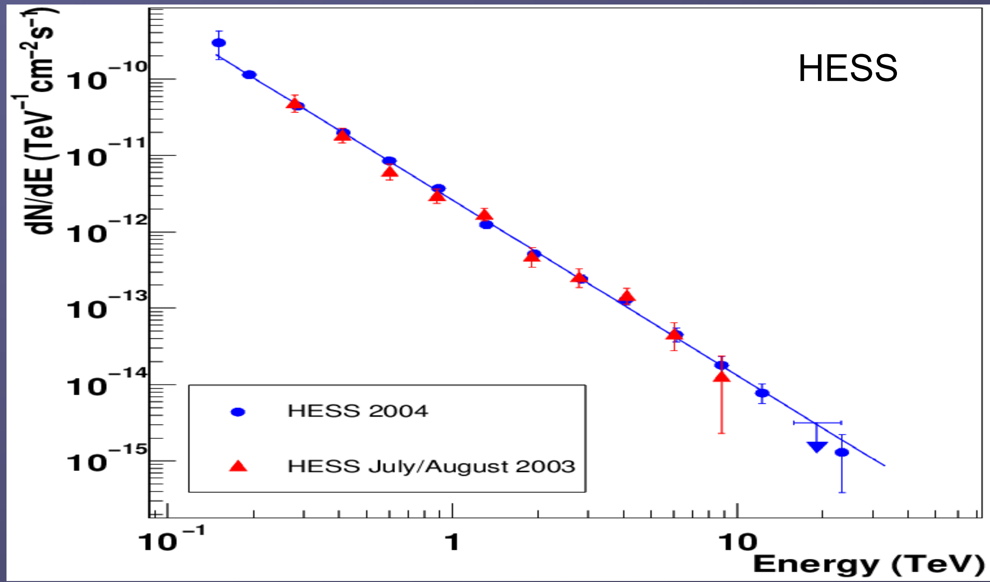


Suzaku (Matsumoto et al. 1996)

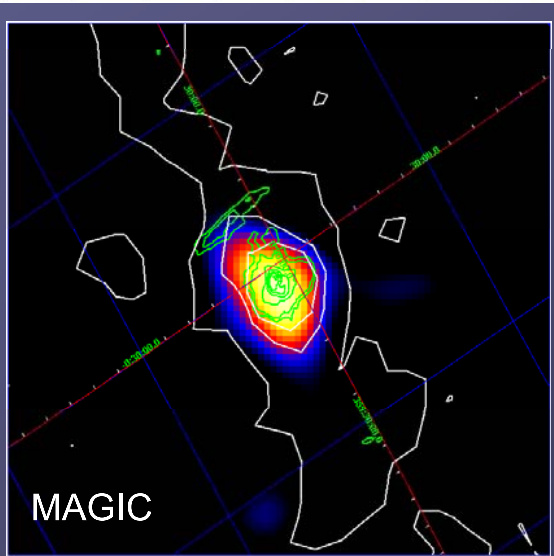
Galactic Center(1) B.H., SNR, DM?

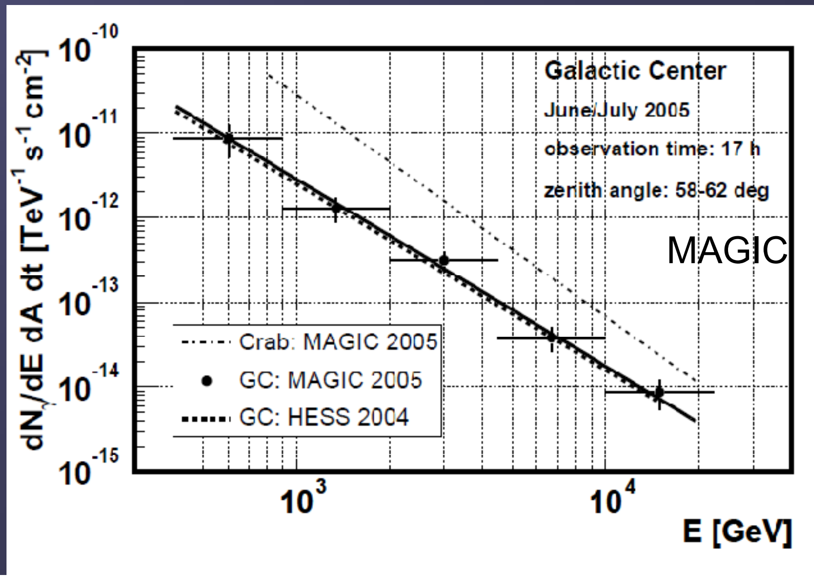
HESS Observation



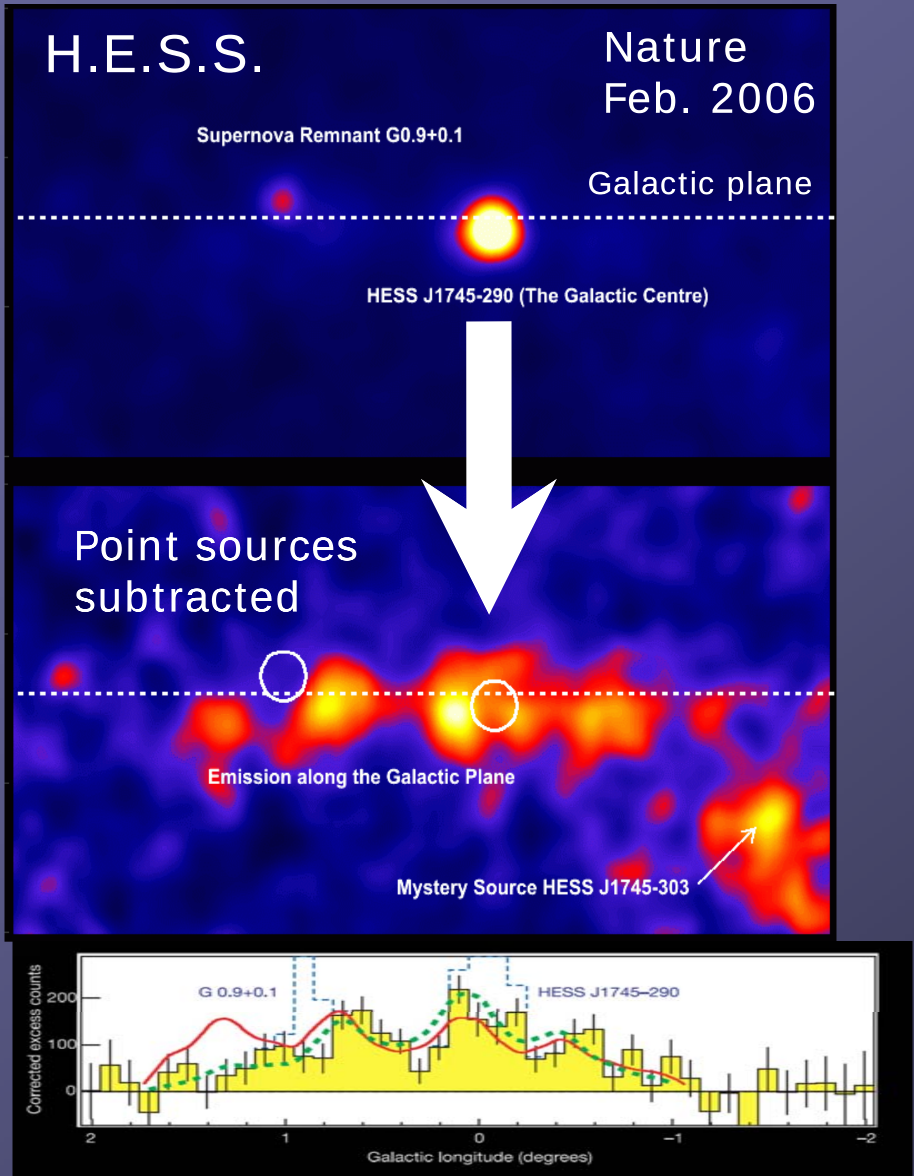


MAGIC Observation



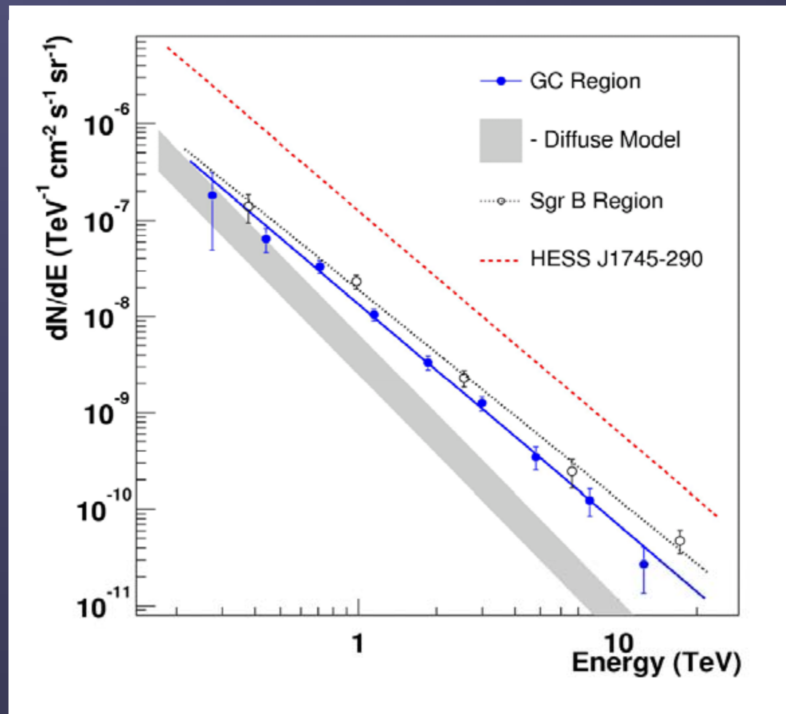


Probing Cosmic rays in the Galaxy



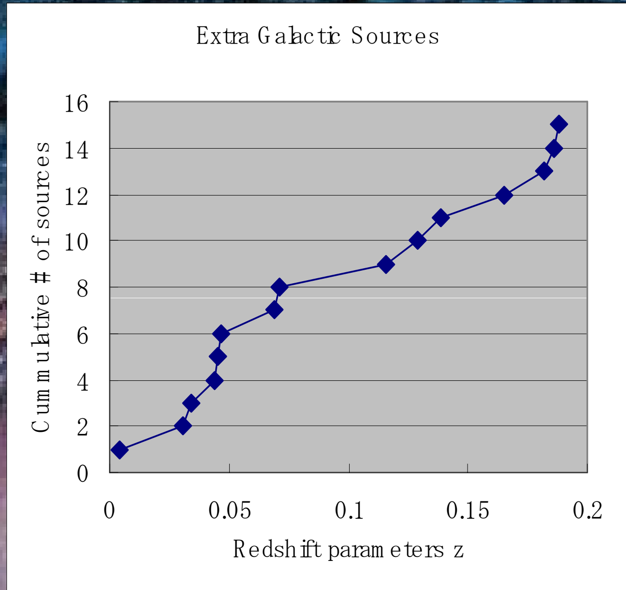
Spectral index
2.29 ± 0.07 ± 0.20

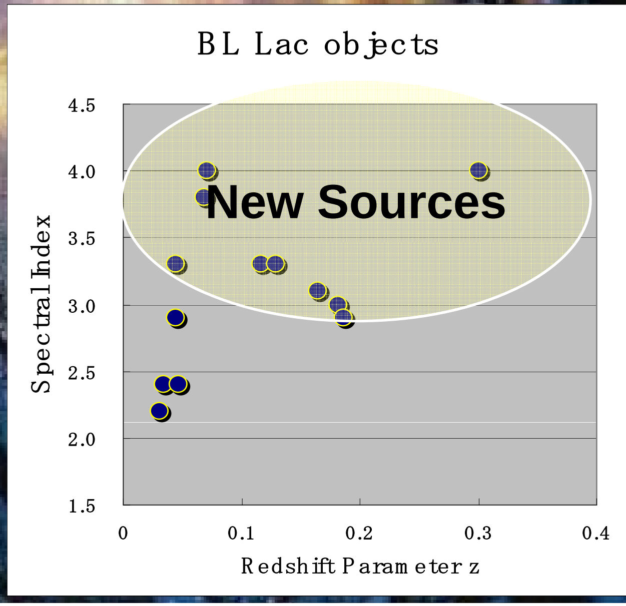
Implies harder
CR spectrum than in
our solar system



Extragalactic sources(16)

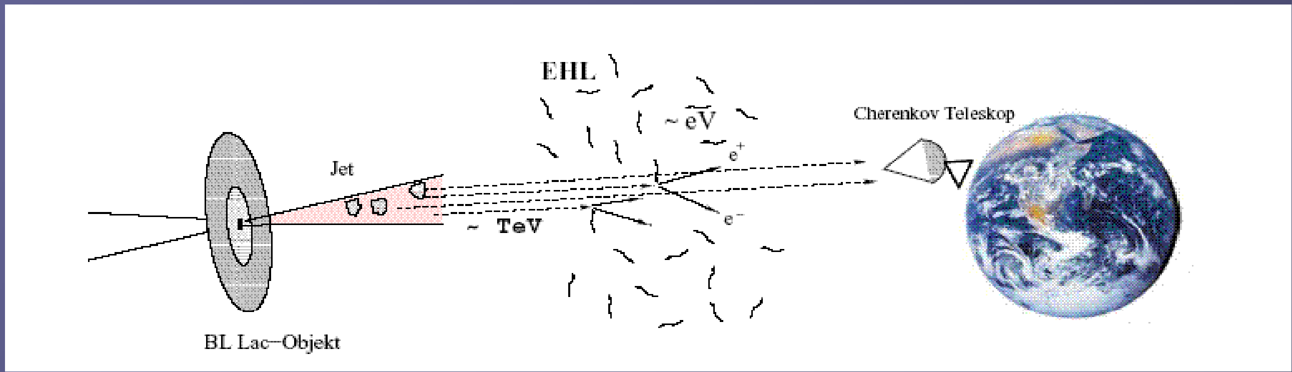
Source	Redshift	Sp. Index	Types	Discovery	Observation
M 87	0.004	2.9	FR-I	HEGRA	HESS
Mkn 421	0.031	2.2	HBL	Whipple	many
Mkn 501	0.034	2.4	HBL	Whipple	many
1ES 2344+514	0.044	2.9	HBL	Whipple	MAGIC
Mkn 180	0.045	3.3	HBL	MAGIC	
1ES 1959+650	0.047	2.4	HBL	7TA	many
PKS 0548-322	0.069		HBL	HESS	
BL Lac	0.069	3.6	LBL	MAGIC	
PKS 2005-489	0.071	4.0	HBL	HESS	
PKS 2155-304	0.116	3.3	HBL	Durham	HESS
1ES 1426+428	0.129	3.3	HBL	Whipple	HEGRA
1ES 0229+200	0.139		HBL	HESS	
H 2356-309	0.165	3.1	HBL	HESS	
1ES 1218+304	0.182	3.0	HBL	MAGIC	VERITAS
1ES 1101-232	0.186	2.9	HBL	HESS	
1ES 0347-121	0.188		HBL	HESS	
PG 1553	0.3	4.0	HBL	HESS/MAGIC	

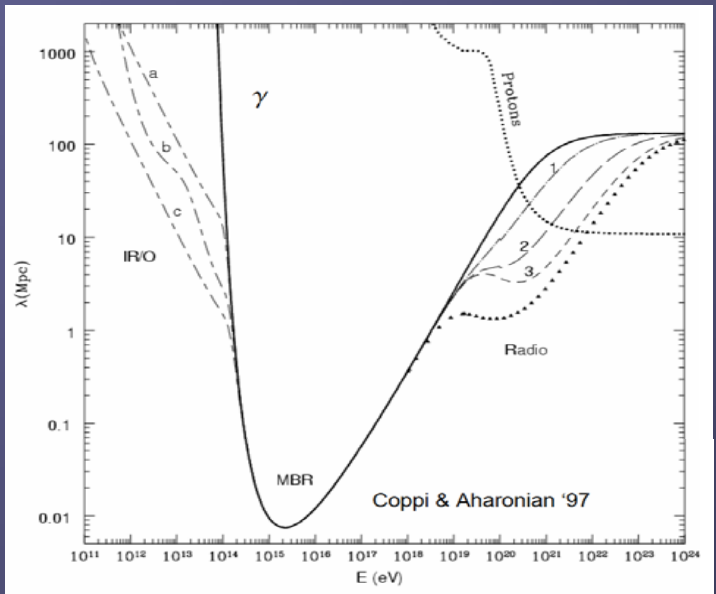


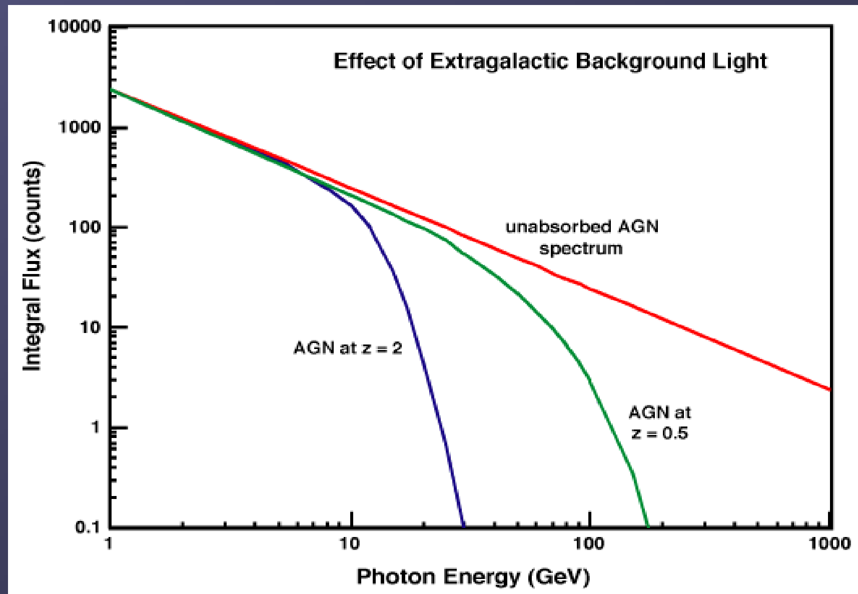


Absorption of gamma rays in the universe

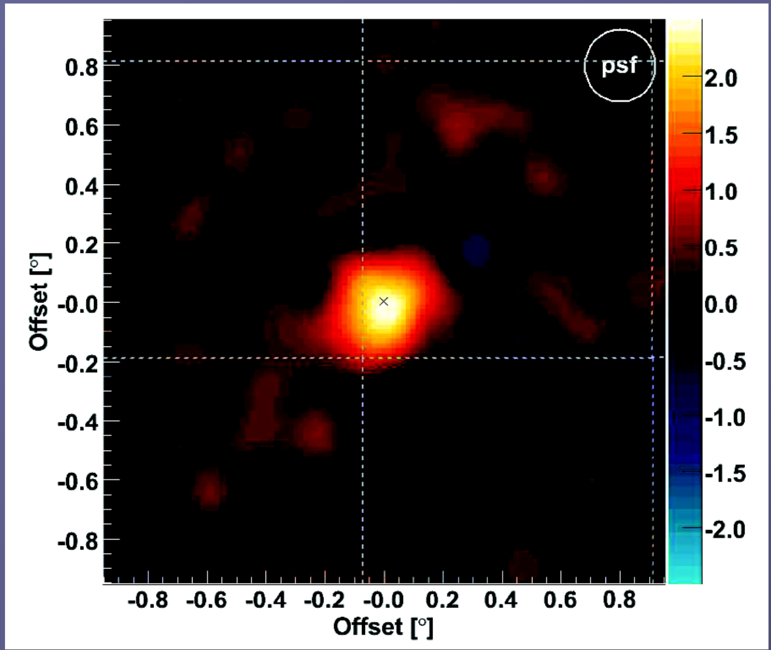
Pair Creation; $\gamma + \gamma \rightarrow e^+ + e^-$

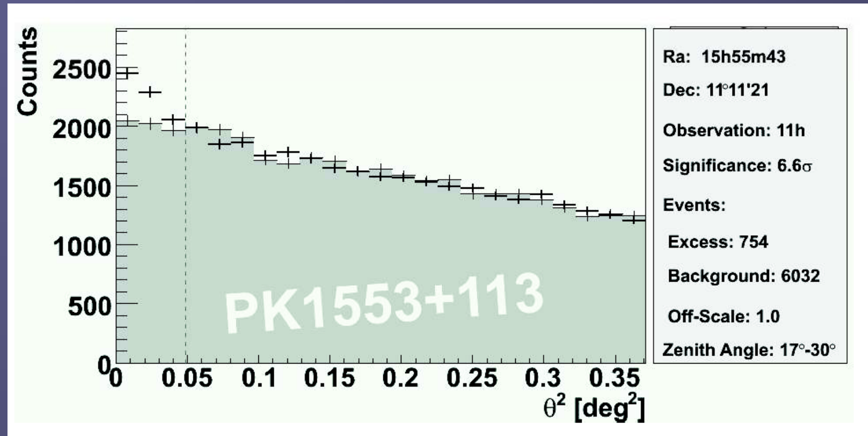


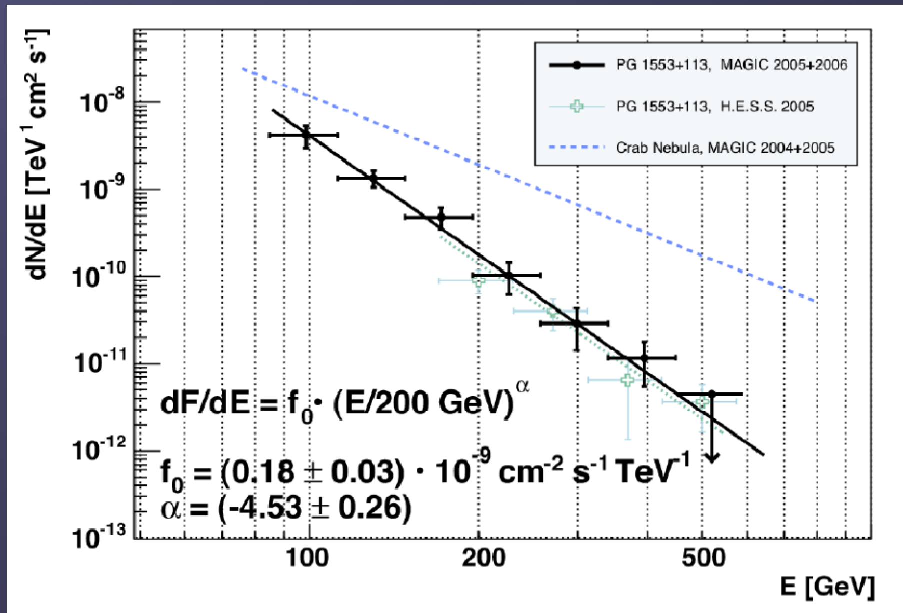




PG 1553 (z>0.25 unknown)





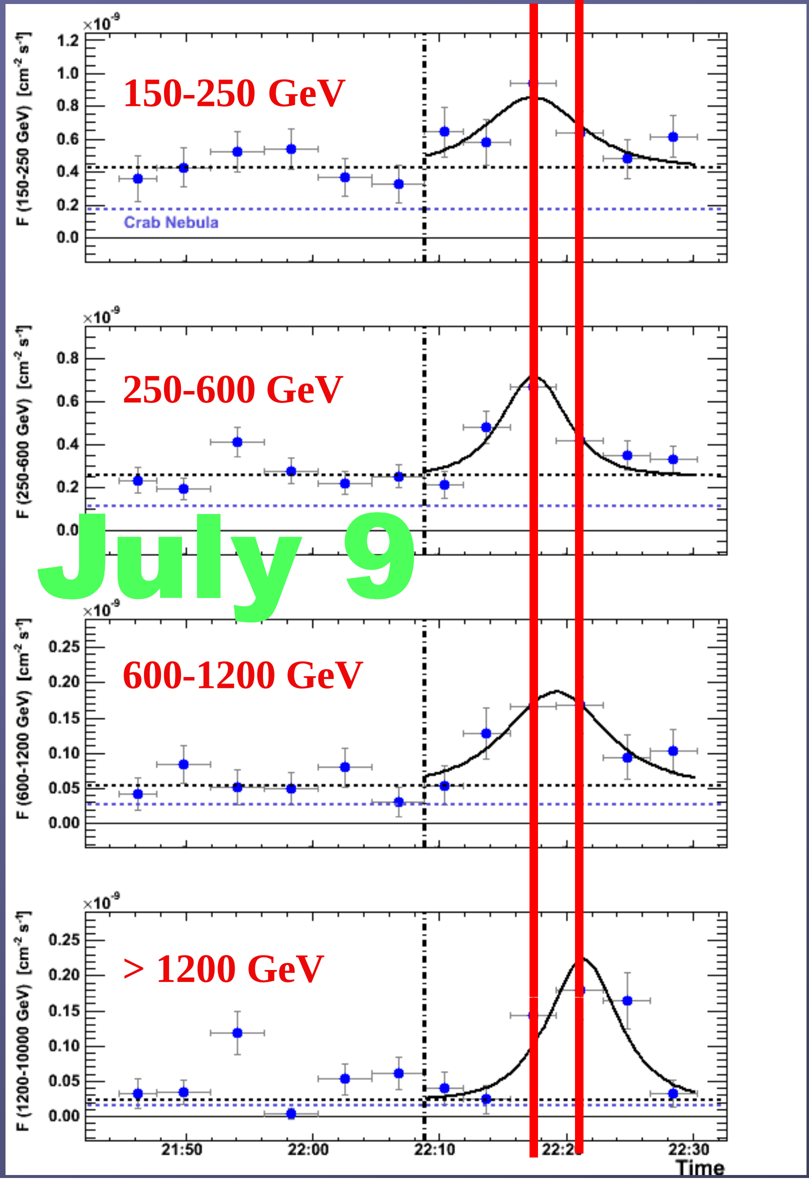


Very Soft energy spectrum

the attenuation by pair creation
or nature of SSC mechanism

MAGIC+HESS ➔ Z < 0.42
D.Mazin and F.Goebel

Mrk501 MAGIC observation
Time lag for higher energies?



4min
bin

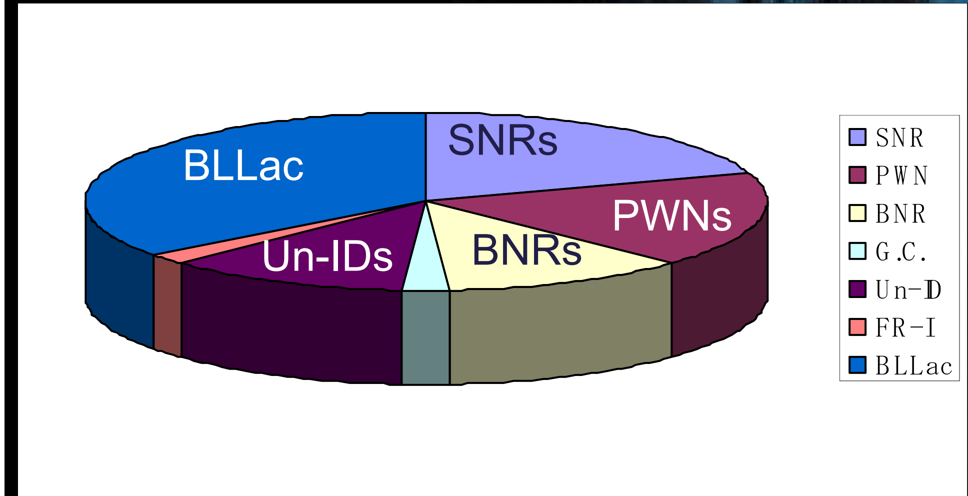
IF

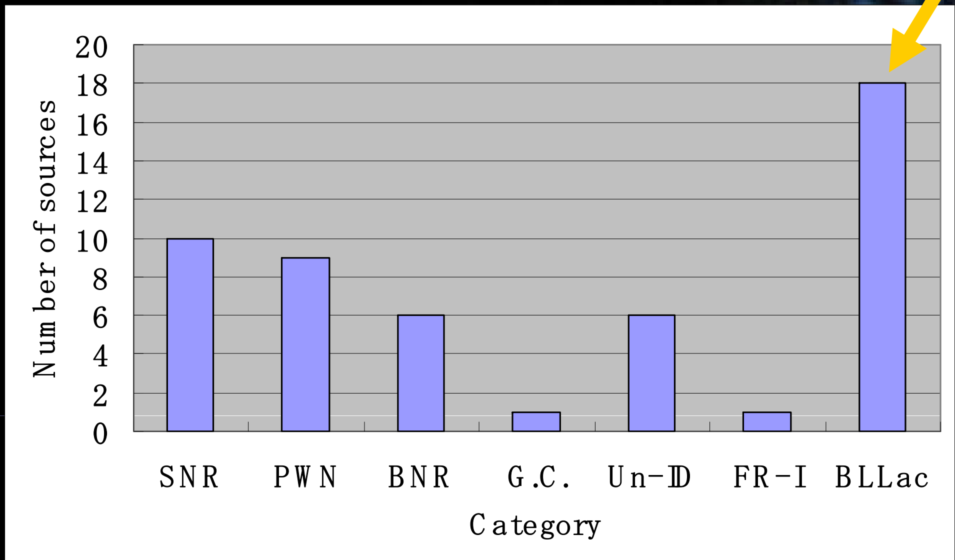
Photons at different energies were emitted simultaneously

$$\Delta T = 4 \pm 1\ min;\ \Delta E \sim 1\ TeV$$

$$E_{QG} = \frac{L}{c} \cdot \frac{\Delta E}{\Delta t} = (0.6 \pm 0.2) \cdot 10^{17}\ GeV$$

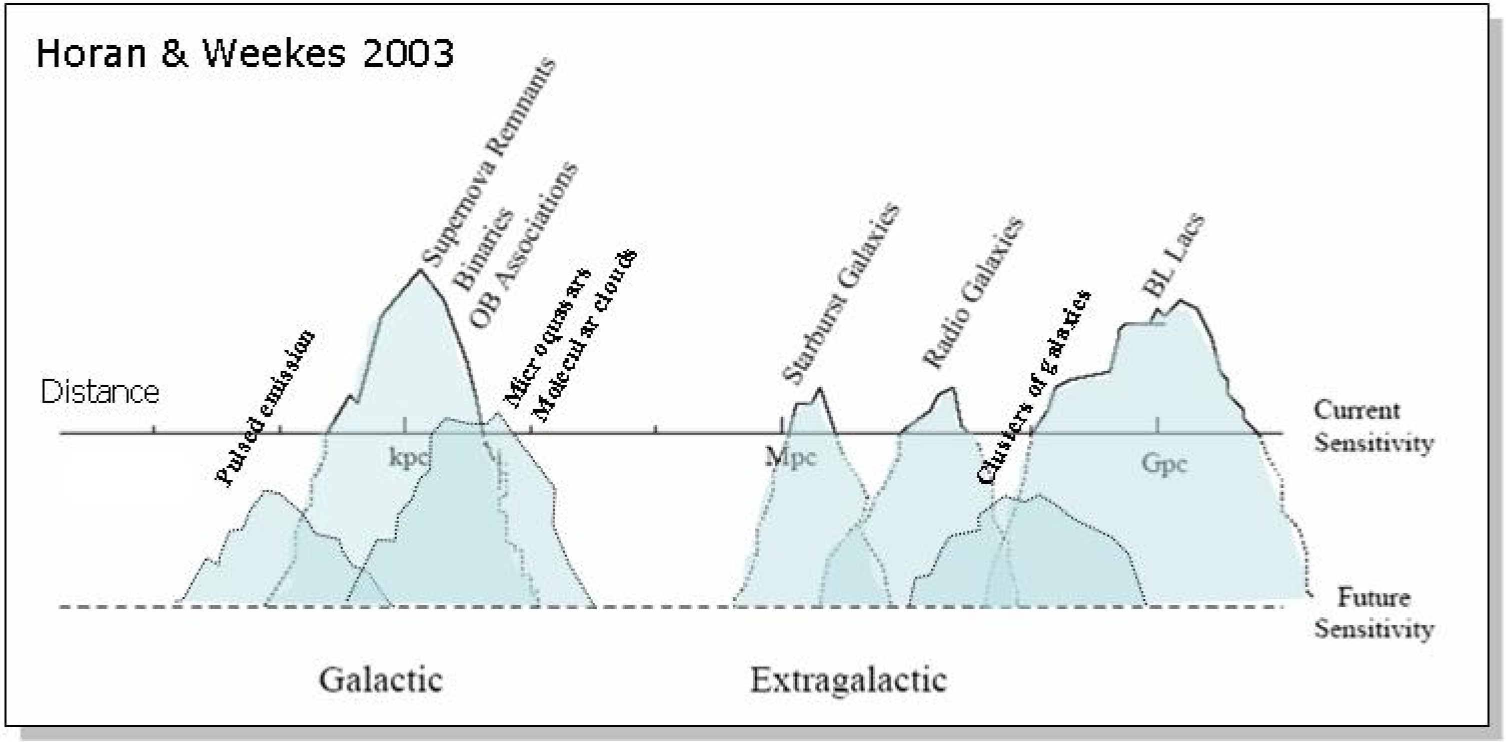
Number of sources (51+α)





BL-Lac is the champion in the number!!

Science potential



- 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

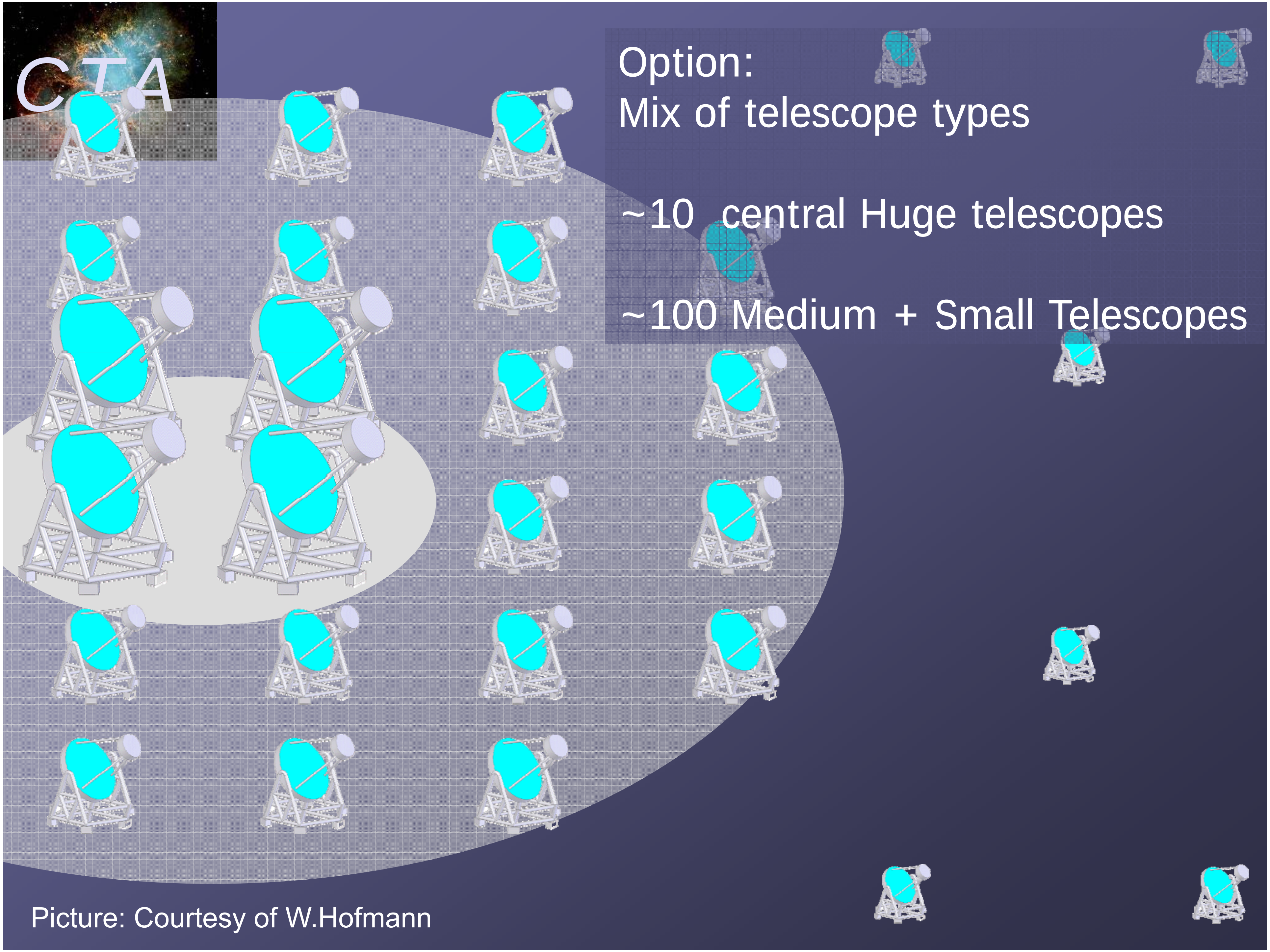
Idea of CTA

- The next generation detector (Observatory) for gamma ray astronomy after CANGAROO, HESS, MAGIC, and VERITAS

- Energy range a few 10s of GeV-100TeV
  - A few 10s of GeV to see sources in the cosmological distance
  - 100TeV to understand the origin of galactic cosmic rays
- ~10 times better sensitivity than HESS, MAGIC
  - Increase number of sources a factor of ~30
- All sky observatory
  - North a few 10s of GeV – 1TeV
    - ~10 huge telescopes
  - South a few 10s of GeV – 100TeV
    - ~10 huge telescopes + ~100 small telescopes

- Overlap with GLAST mission
  - GLAST Mission 2007-2012+

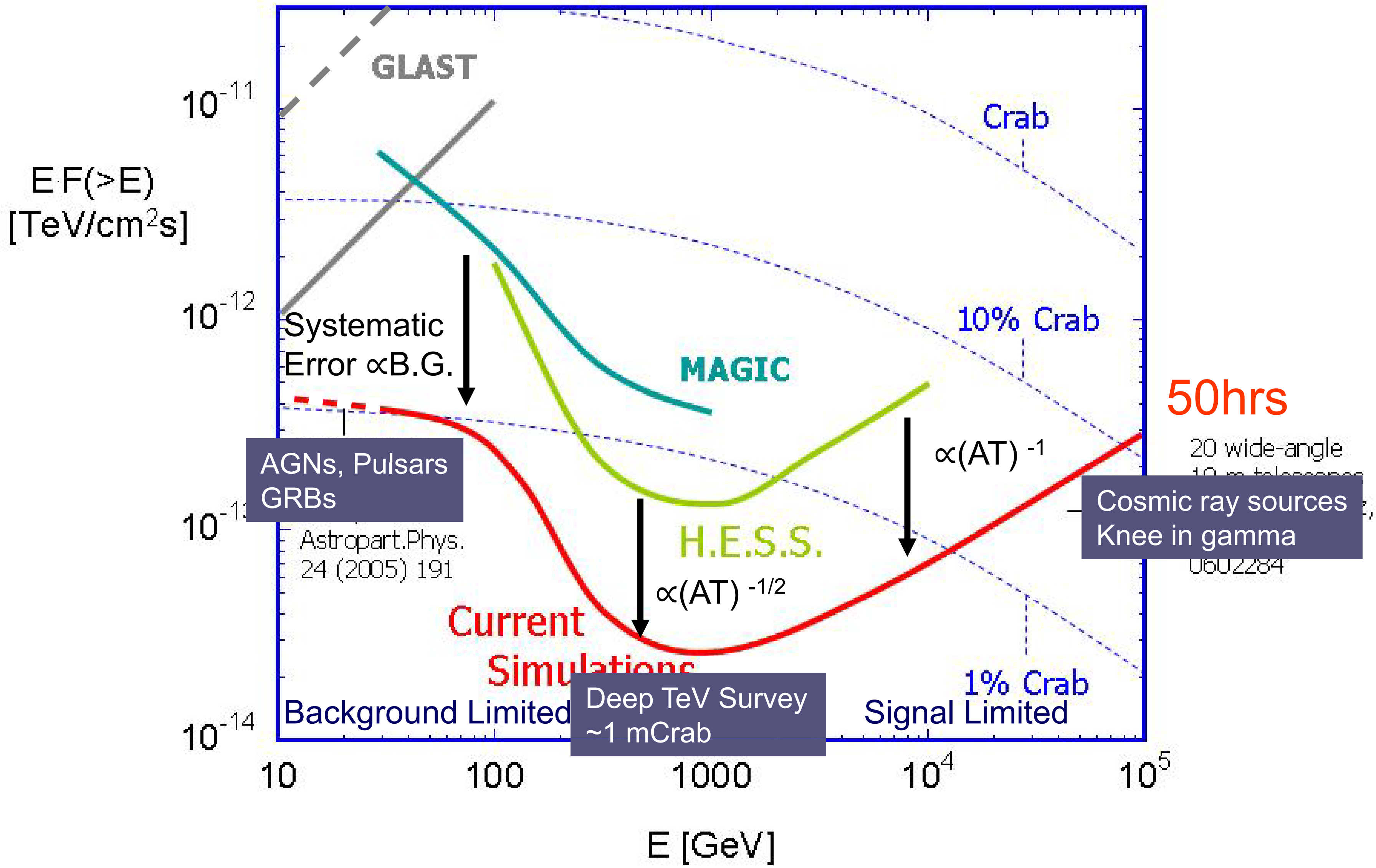
- Budget size ~150MEuro
  - EU will support <20% of total budget, other >80% must be supported by agencies in each country


CTA
Option:
Mix of telescope types
~10 central Huge telescopes
~100 Medium + Small Telescopes
Picture: Courtesy of W.Hofmann

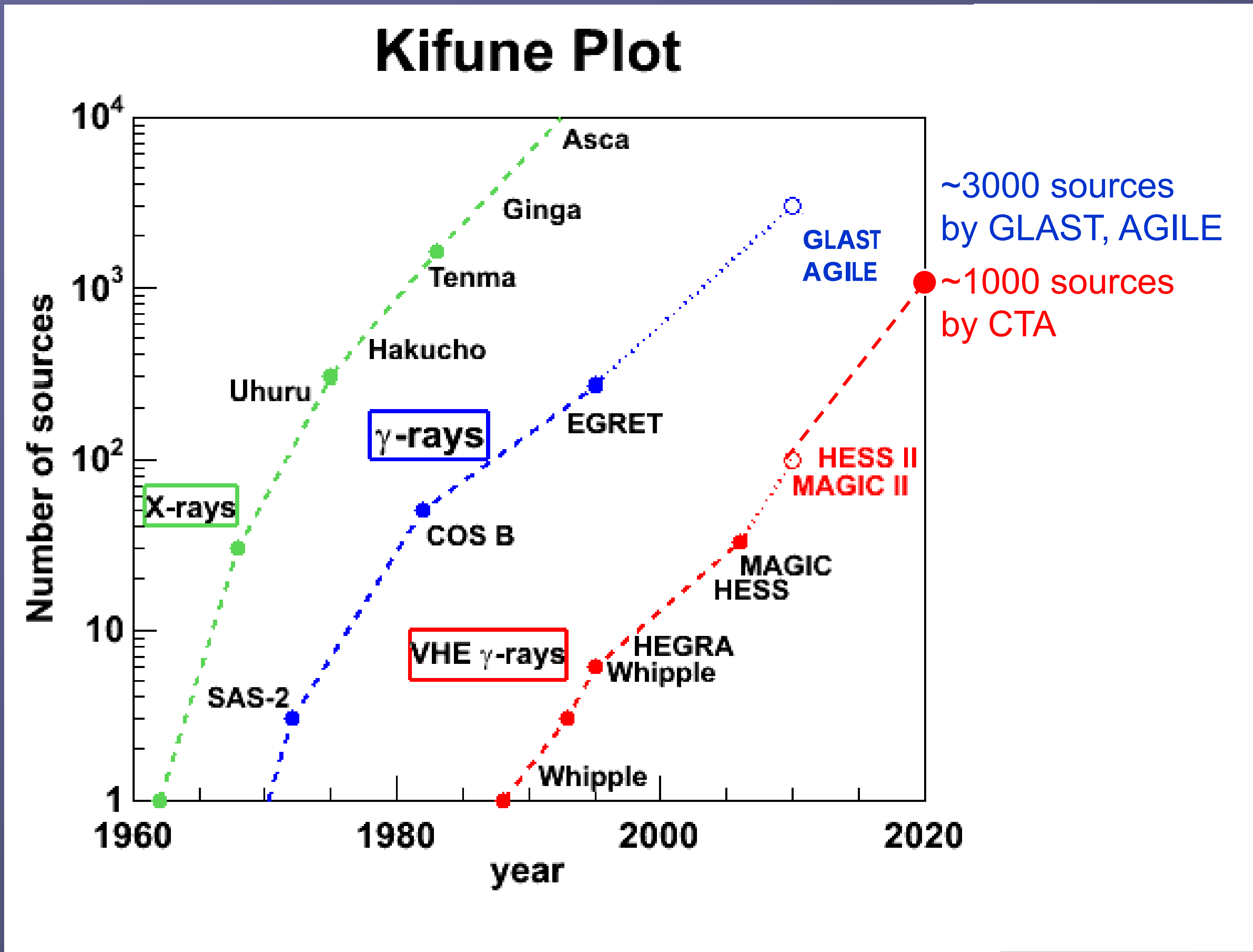
Sensitivity

By W.Hofmann

An advanced facility for ground-based high-energy gamma ray astronomy

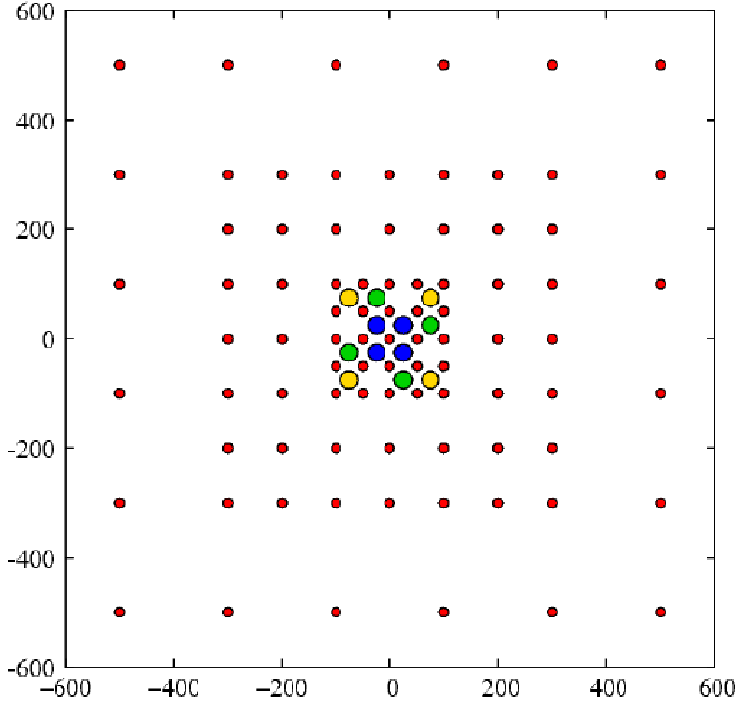


Kifune’s Plot (my optimistic expectation)



CTA Sensitivity M.C. Study

Configurations: 97 tel. hybrid system

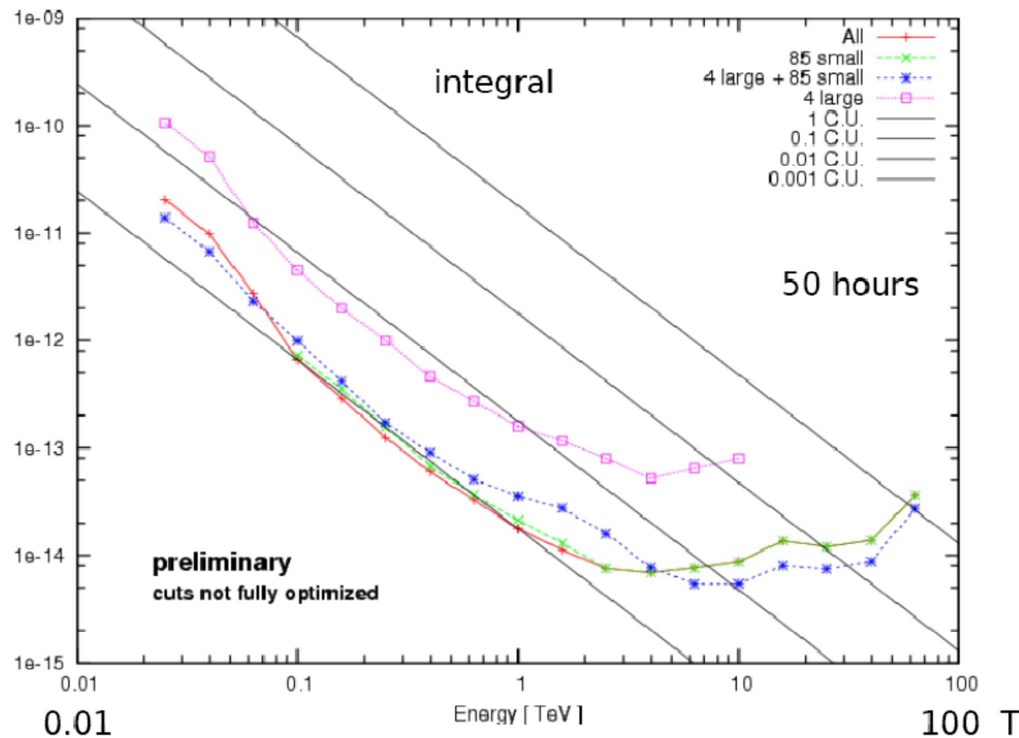


Hybrid system of
- 12 600 m² class tel.
- 85 100 m² class tel.

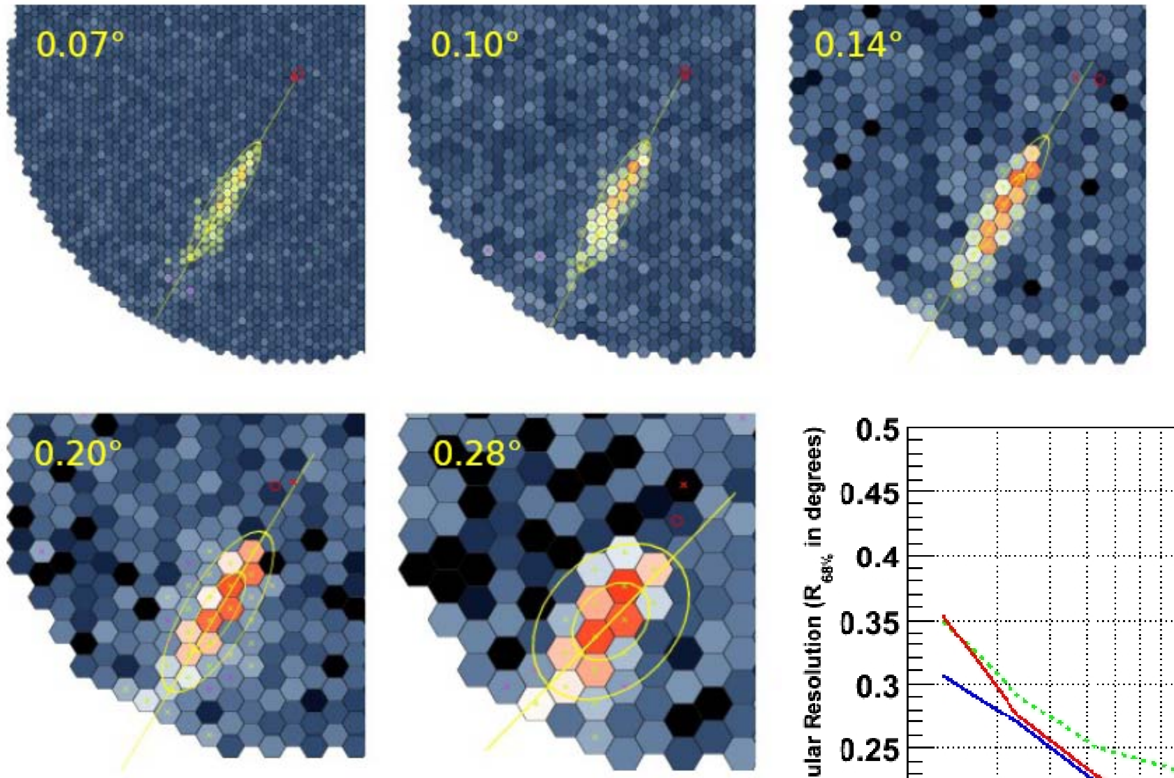
with 1.4* larger f.o.v.

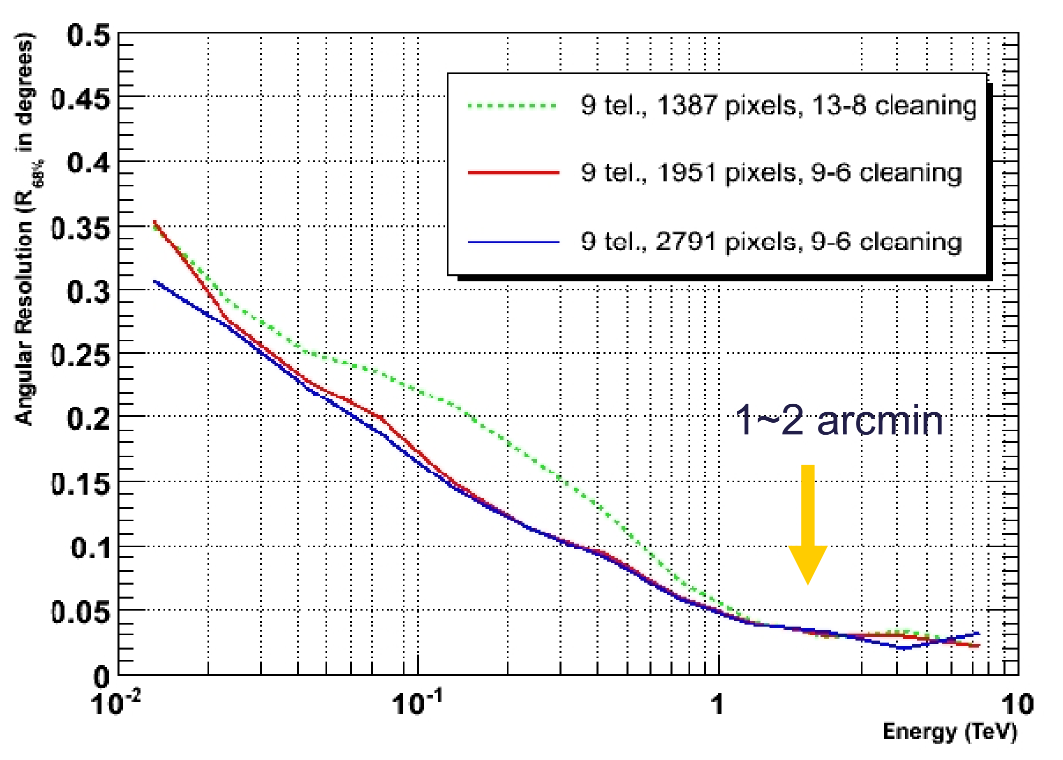
a

c



CTA Angular resolution M.C. Study



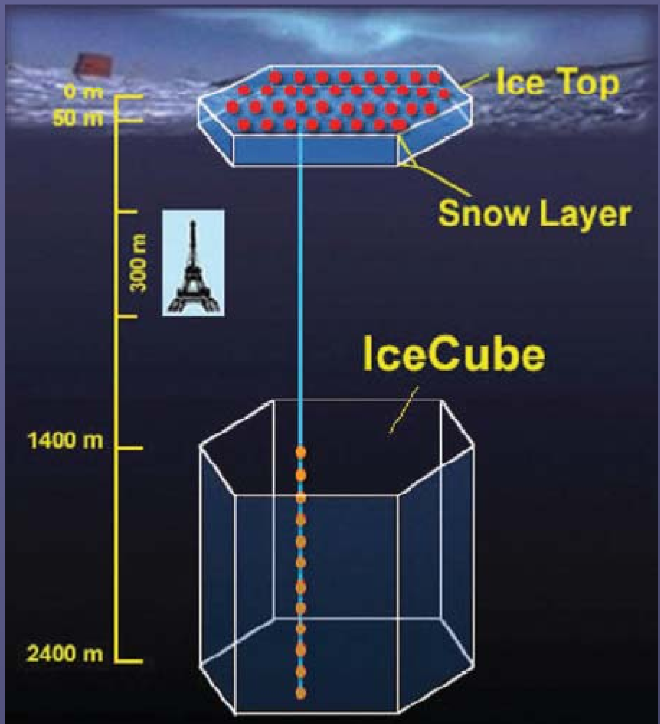


Multi-wave/-messenger observation
All sky observatory (N,S stations)

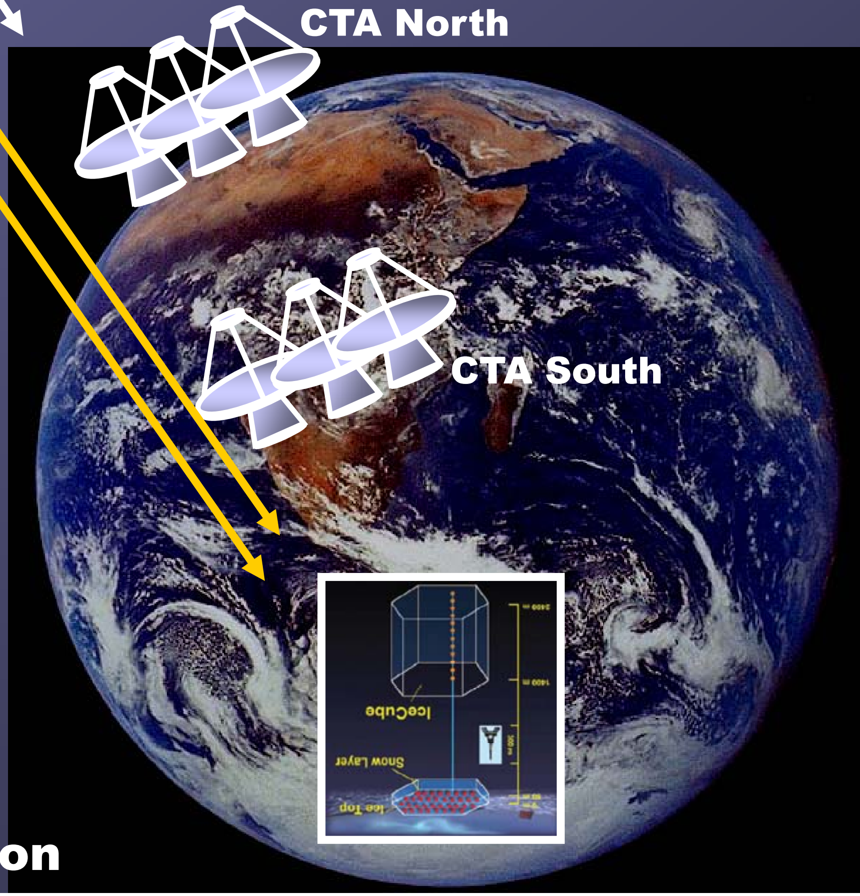
Gamma Rays

Gamma Ray & X-Ray Satellites

Neutrinos



CTA North



IceCube:
2010 Completion of the construction

European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP FOR RESEARCH INFRASTRUCTURES

Report 2006

CTA

Baseline in ESFRI LOI

6. Maturity of proposal (including possible timetable)
The performance and scientific potential of arrays of Cherenkov telescopes has been studied in significant detail; what remains to be decided is the exact layout of the telescope array. Ample experience exists in constructing and operating telescopes of the 10-12 m class (H.E.S.S., VERITAS). Telescopes of the 17 m class and 28 m class are operating (MAGIC) or under construction (H.E.S.S. II) and will serve as prototypes. Photon detectors with improved quantum efficiency are under advanced development and testing and will be available when the array is constructed. After a phase of detailed design (2006-2008), implementation could start in 2009/10, with full operation in 2012, allowing significant overlap with the GLAST satellite instrument to be launched in 2007, which covers the energy range below some 10 GeV and which serves as an all-sky monitor, triggering pointed observations at higher energies.
7. Budgetary information (preparation, construction and operation costs)
Depending on the exact number and size of the telescopes to be deployed, about 100 M€ are required for a southern site which will cover a wide energy range from some 10 GeV to 100 TeV for observations of our Galaxy at high resolution. A complementary site in the northern hemisphere would focus on extragalactic and cosmological objects, with instrumentation optimized for low energies (10 GeV-1 TeV), at a cost of about 50 M€. The stations would be constructed and operated by a single consortium. Total operating and maintenance costs are currently estimated to 3 to 5 M€ per year, including local staff. Up to 10 M€ are needed for site exploration, detailed design and industrial prototypes.

>Emerging proposals

During the preparation of the roadmap the experts have also received and identified emerging proposals that may constitute a base for future upgrades of the roadmap itself.

They are listed here below divided by the name of the corresponding ESFRI Roadmap Working Group. At this stage ESFRI does not offer any opinion on whether they will subsequently enter the full roadmap in the future. It is fully expected that future editions will substantially add to this list of emerging proposals.

Biological and Medical Sciences

European Infrastructure for Chemical Biology

Chemical compounds are the traditional products for medical therapies and agricultural/ecological management. Chemical biology is opening new doors for research in the genome era and for direct translation into benefits for basic science and for the health of the public. This infrastructure will incorporate a European Molecular Library Resource Centre (EMLRC) and a European Resource for

European Infrastructure for Synthetic Biology

Synthetic biology is concerned with applying the engineering paradigm of systems design to biological systems in order to produce predictable and robust systems with novel functionalities that do not exist in nature. In essence, synthetic biology will enable the design of "biological systems" in a rational and systematic way. The objective of this infrastructure would be to provide key service functions to the synthetic biology community, to enable standardisation of biological parts on which synthetic biologists can draw, including the provision of reference methods and materials, as well as associated research and top level training.

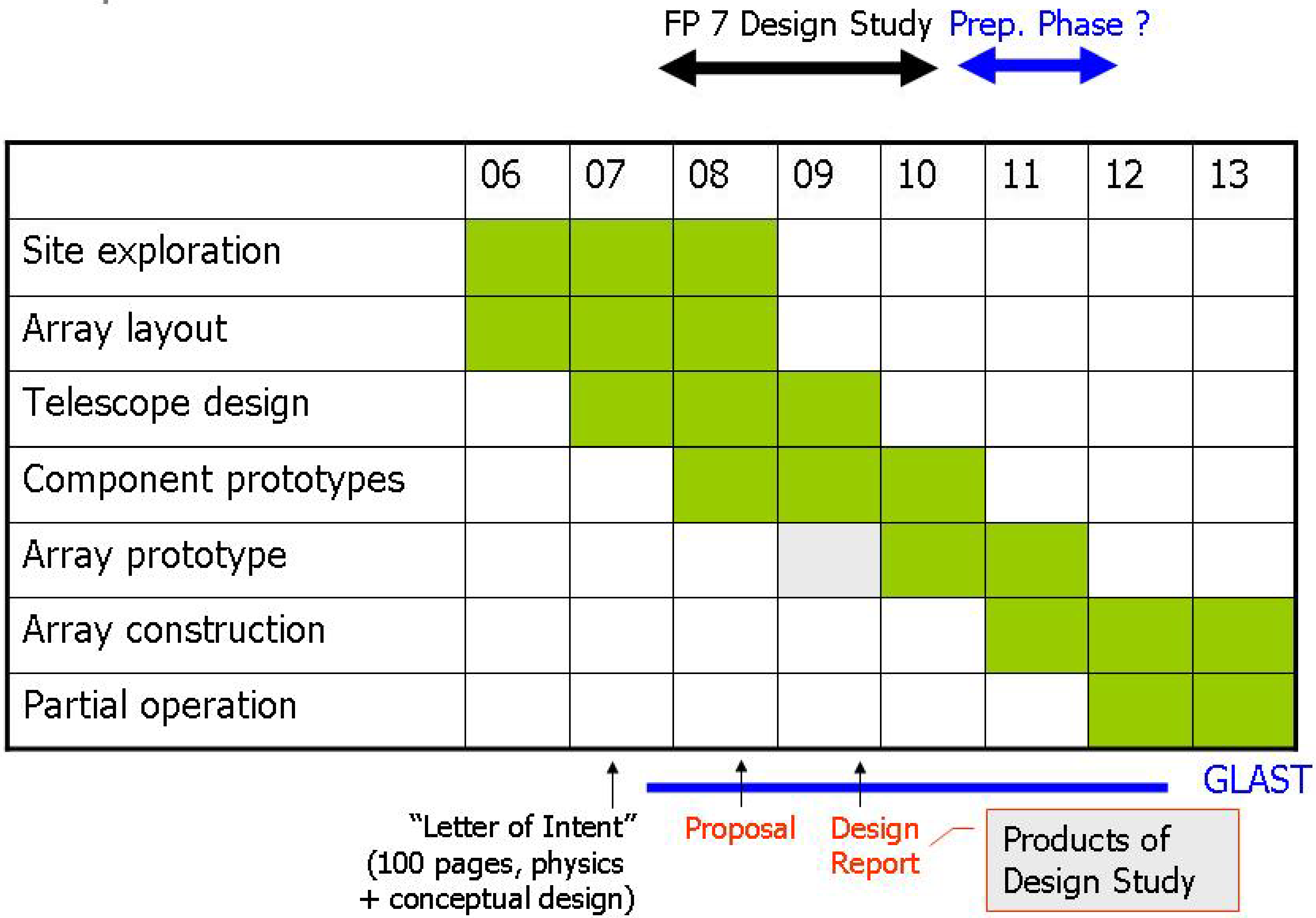
European Infrastructure for Research in Biomedical Imaging (EIRBI)

A number of *in vitro* techniques are now available to biologists for assessing, at the molecular level, the occurrence of abnormal gene expression that accompanies the development of a pathological state. The field of biomedical imaging is challenged to translate these tremendous achievements into early diagnosis and efficient follow-up of therapeutic treatments as well as developing novel, imaging-guided, drug-delivery and minimally invasive treatments. The establishment of EIRBI is essential to this challenge, and will further maintain the competitiveness of European industries and academic institutions in the field of imaging.

High security laboratories for emerging and zoonotic diseases and

Possible Schedule

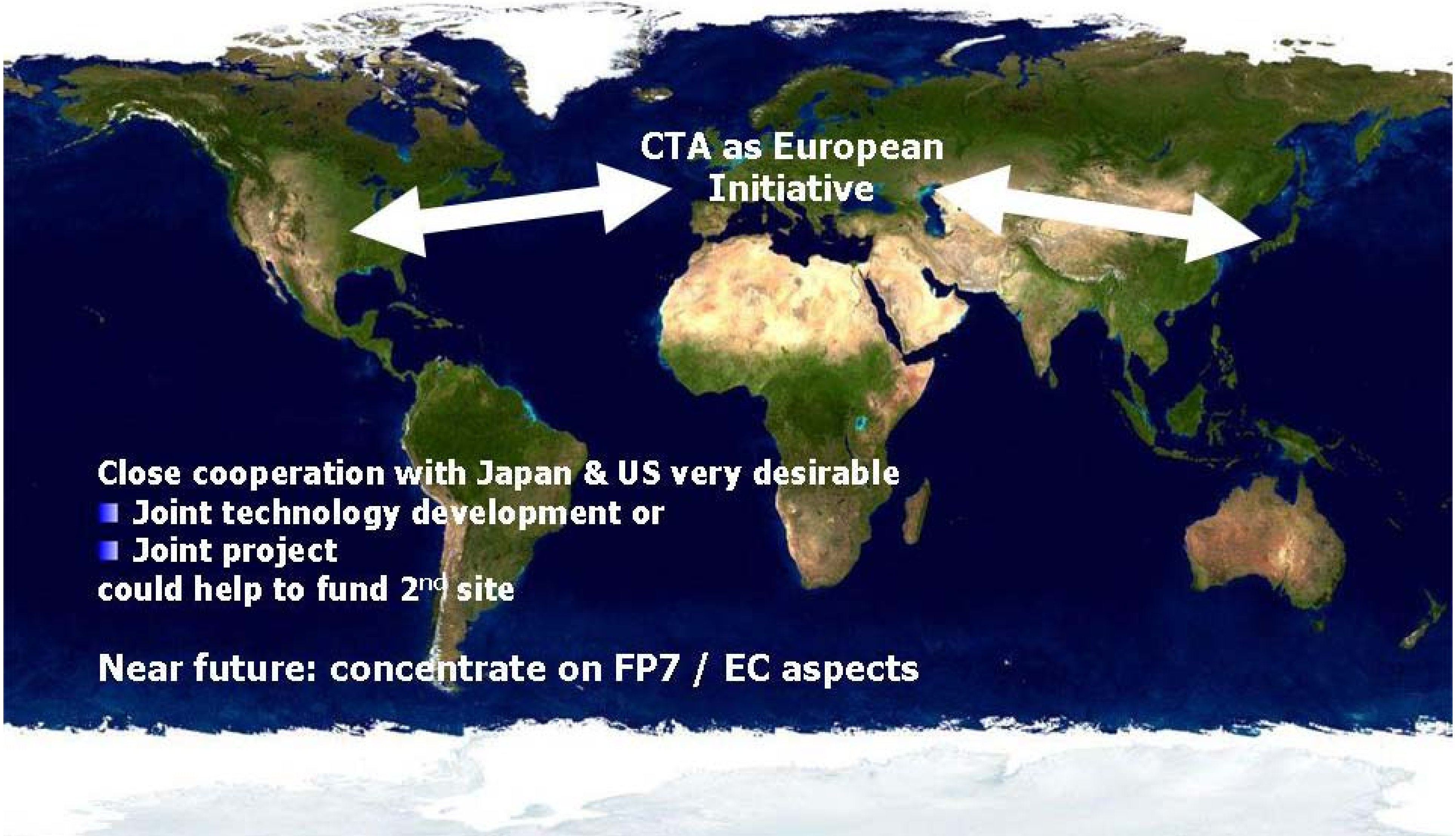
An advanced facility for ground-based high-energy gamma ray astronomy



CTA

World wide context

An advanced facility for ground-based high-energy gamma ray astronomy



Close cooperation with Japan & US very desirable

- Joint technology development or
- Joint project

could help to fund 2nd site

Near future: concentrate on FP7 / EC aspects

Summary (Physics and Motivation)

- Now we know about 50 sources in TeV energy region. The number of sources is exploding!!
- The physics in TeV gamma ray astronomy is very rich and still there are many open questions.
- We definitely need CTA for the development of TeV gamma ray astronomy after HESS, MAGIC, VERITAS and CANGAROO.
- ~1000 sources will be observed in 10-20 years by CTA.
- All sky observatory is ideal (north & south stations)
  - Maybe two steps construction
- Now ~400 scientists show the interest to join CAT
  - MAGIC(150), HESS(100), Radio and X-Ray astronomers (100), and theoreticians (50)
- Multi-wavelength and multi-messenger observation are very important to understand the nature of high energy sources
  - GLAST, IceCube, KM3, Auger, etc..

Thanks

Distance of PG1553

Test with combined spectrum (Z<0.42)