Summary of Astroparticle Physics Working Group (experiments)

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University of Tokyo

21st International Workshop on
Weak Interactions and Neutrinos (WIN07), January 15-20, 2007,
Saha Institute for Nuclear Physics, Kolkata, India

Refer excellent review by Juan Jose Hernandes-Rey on the first day...

Astrophysical probes

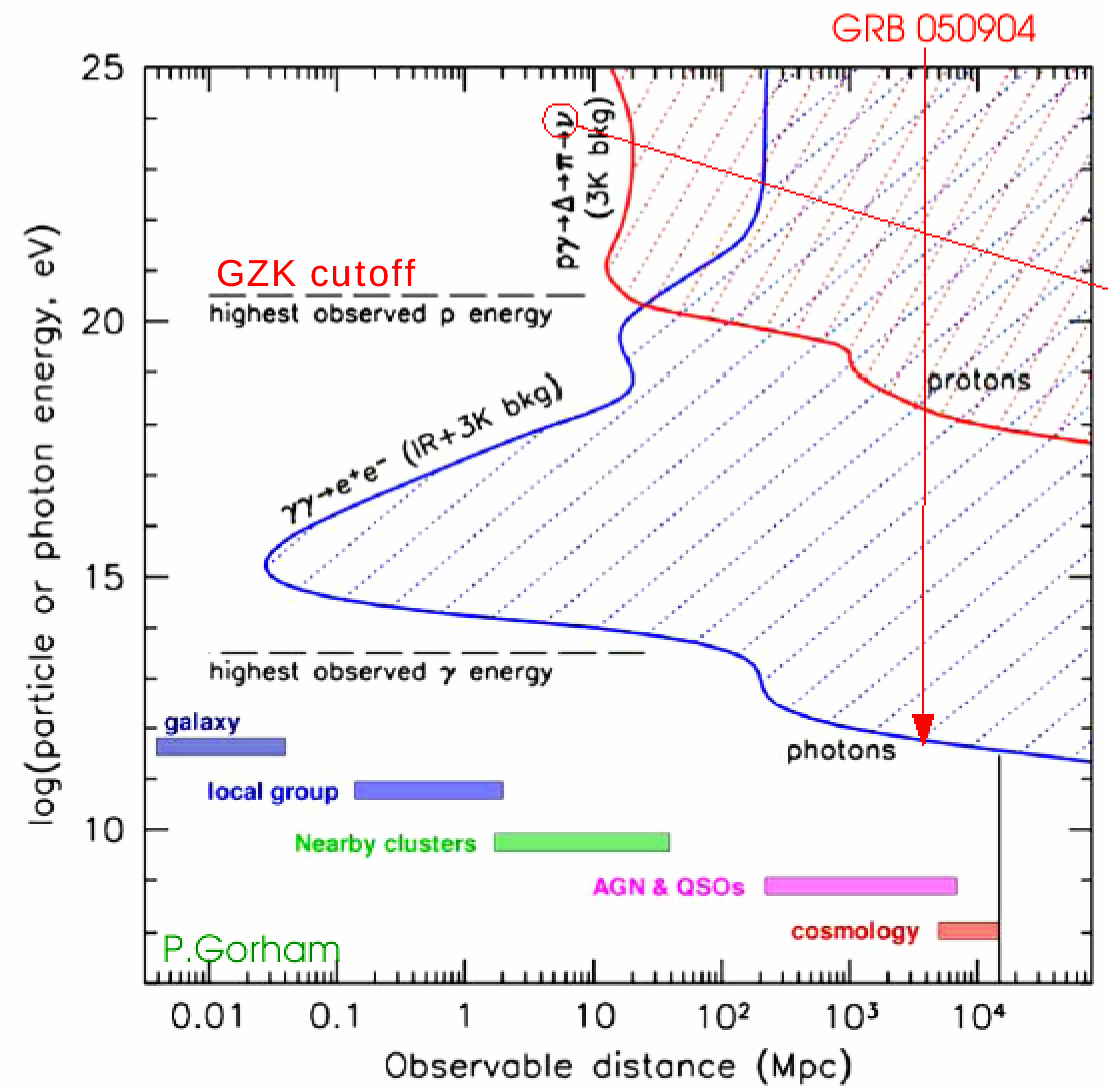
- Radio/IR/optical/X-ray photons probe (mainly) thermal Universe.
- Non-thermal, violent Universe needs to be explored by other probes.

- *General* cosmic-rays: lose directional information due to deflection by the Galactic magnetic field
- Probes which keeps directionality
  - Highest energy cosmic rays [1 talk]
  - Gamma-rays [5 talks]
  - Neutrinos [2 talks]
  - Dark matter [1 talk]
  - Gravitational waves [0 talk]

Utilization of directionality at present

Probe	Detector	$\Delta\theta$	Field of view
Highest CR	AS array	$\sim 1^\circ$	$\sim\pi$ sr
	Fluorescense	$\sim 1^\circ$	$\sim\pi$ sr
Gamma-rays	AS array	$\sim 1^\circ$	$\sim\pi$ sr
	Atmospheric Cherenkov	~1’	~0.01sr
Neutrinos	Water/ice Cherenkov	$\sim 1^\circ$	2π sr
Dark matter	Nuclear recoil	N/A	4π sr
Grav. wave	Interferometer	several deg	$\sim 2\pi$ sr

Probes have intrinsic length



Not applicable to neutrinos and gravitational waves!

(in other words: these are elusive!)

However, UHE neutrinos are absorbed by Earth!

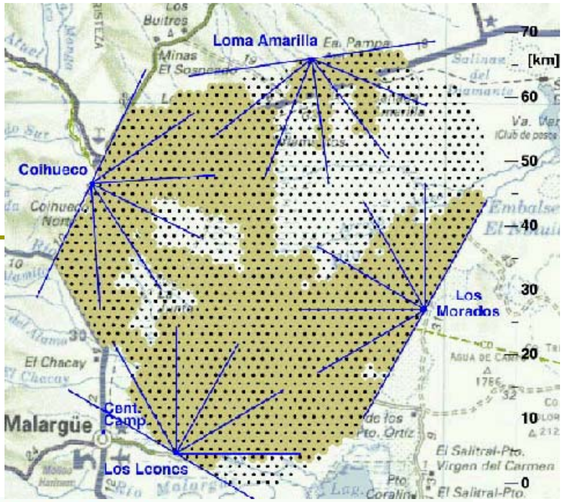
Presented by Markus Roth

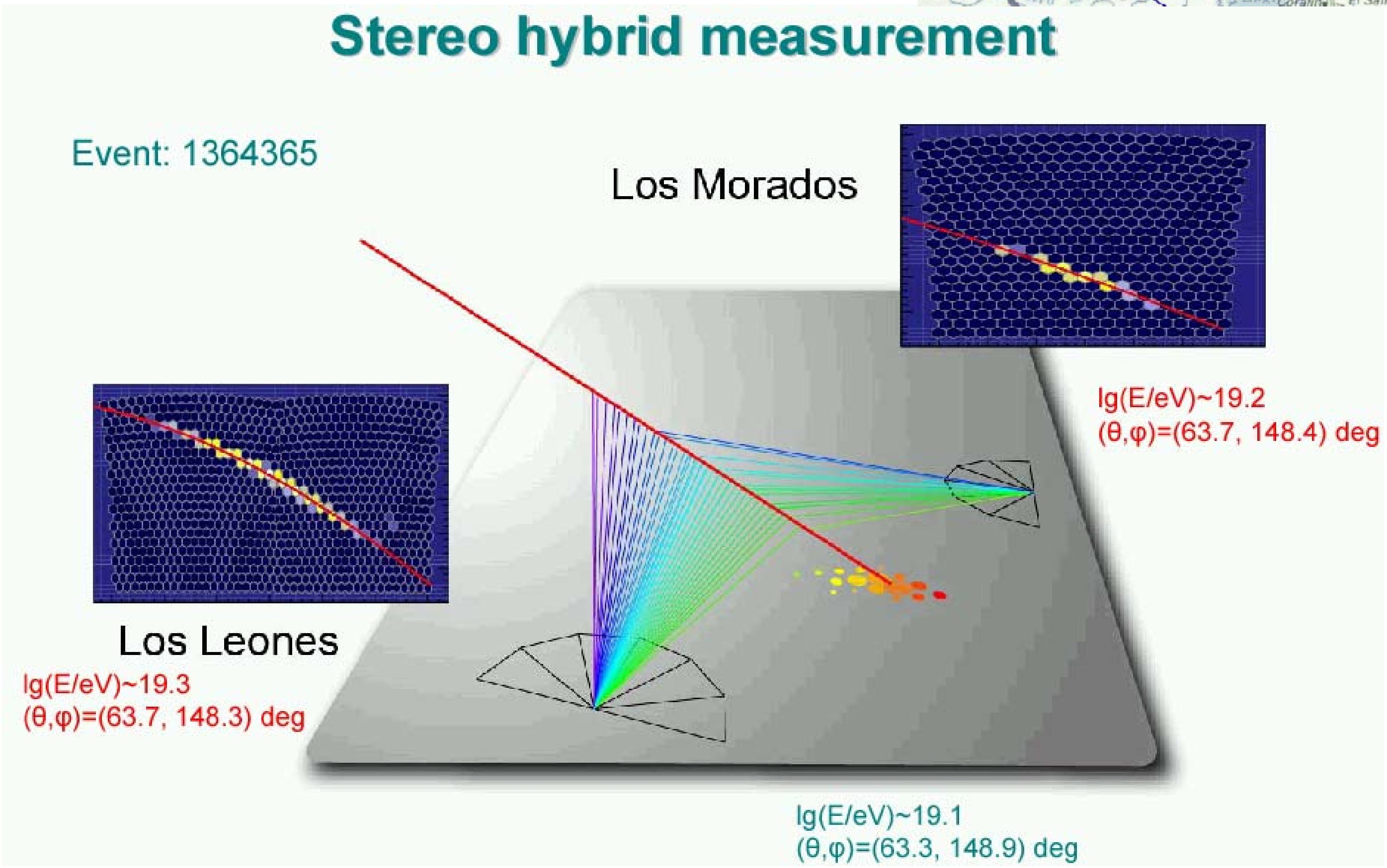
Highest energy cosmic rays: Pierre Auger project

Malargue, Argentina

1600 (1200) surface detectors

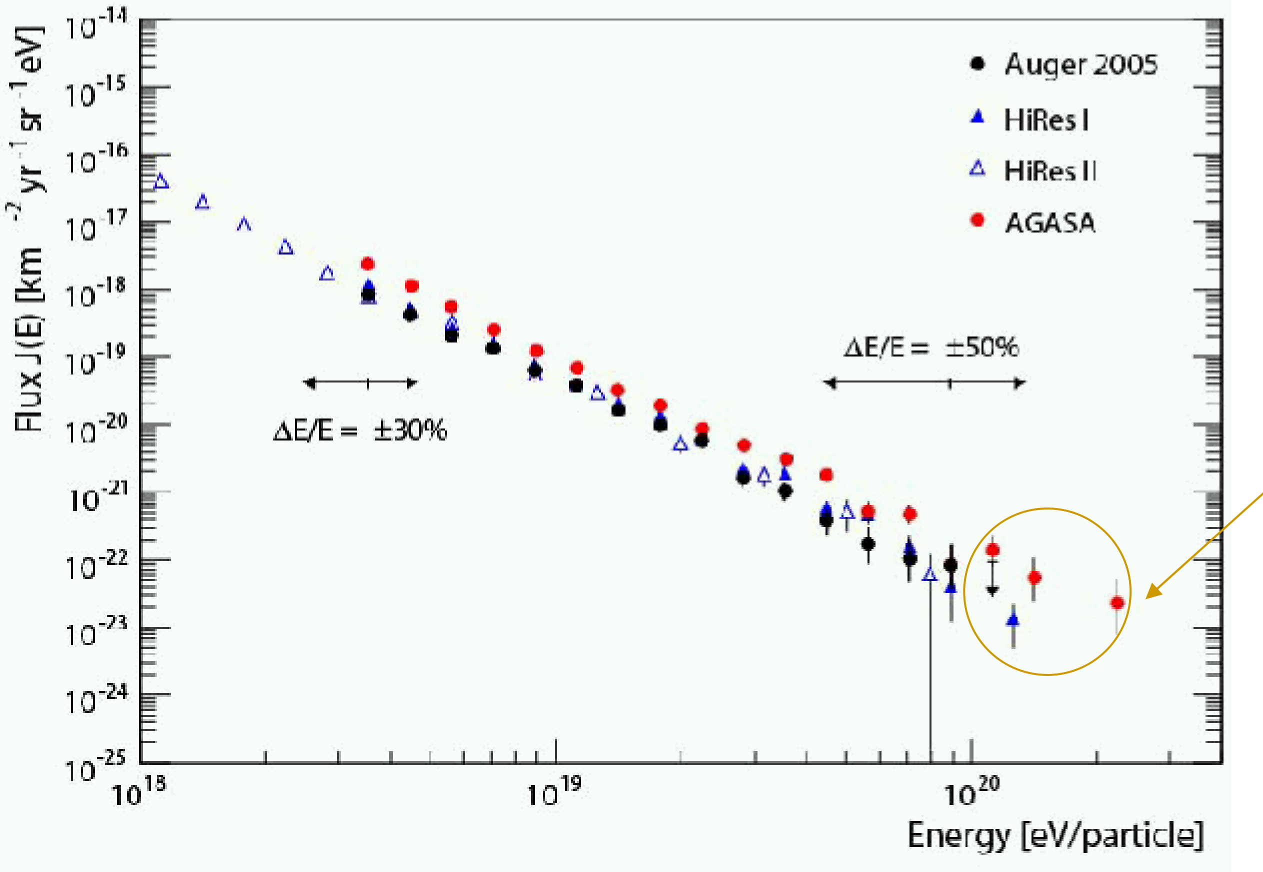
4 (3.9) fluorescence telescopes





Presented by Markus Roth

Highest energy cosmic rays: Pierre Auger project: energy spectrum



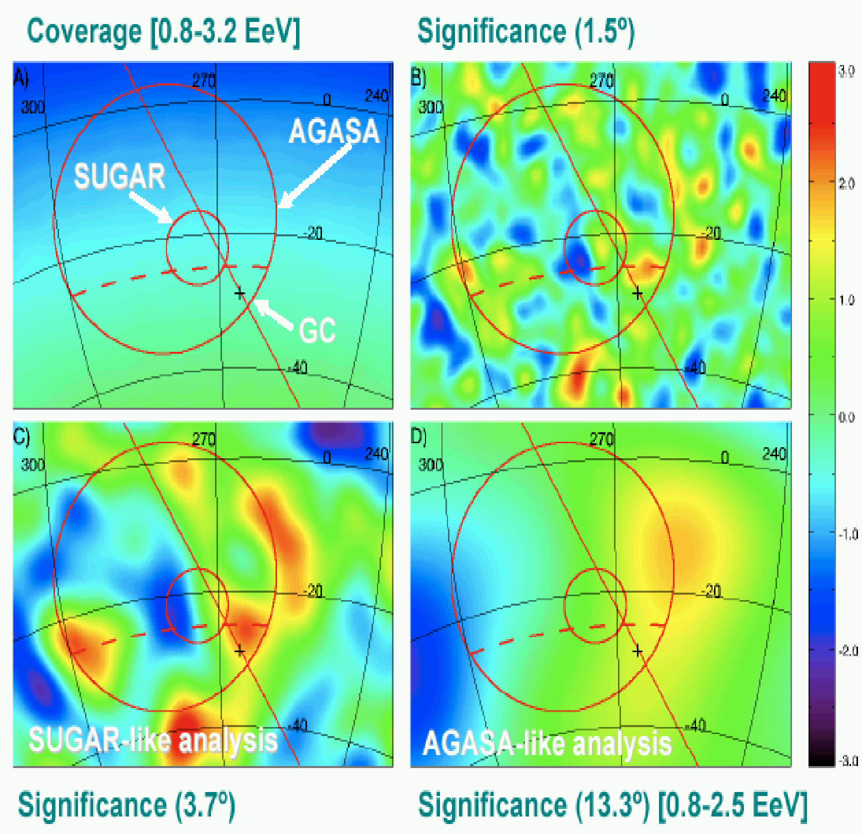
ΔE/E: *currently* dominated by fluorescence yield uncertainty (15%), fluorescence detector calibration (12%) and event statistics

4x statistics results to appear soon!

Presented by Markus Roth

Highest energy cosmic rays: Pierre Auger project: new results

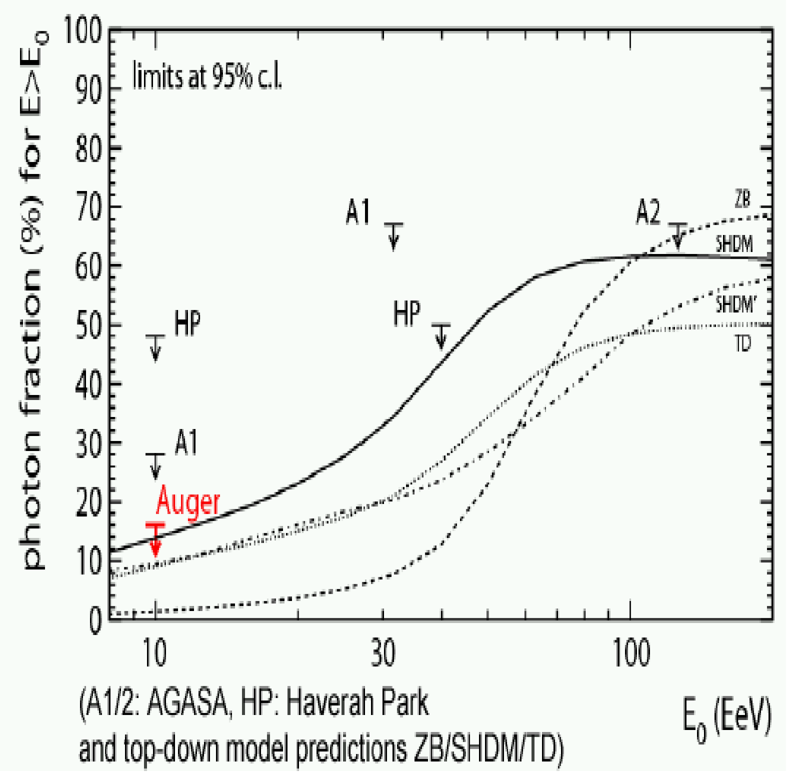
Galactic center region



$\Phi_S < 10.6\ 10^{-15}\ m^{-2}\ s^{-1}$

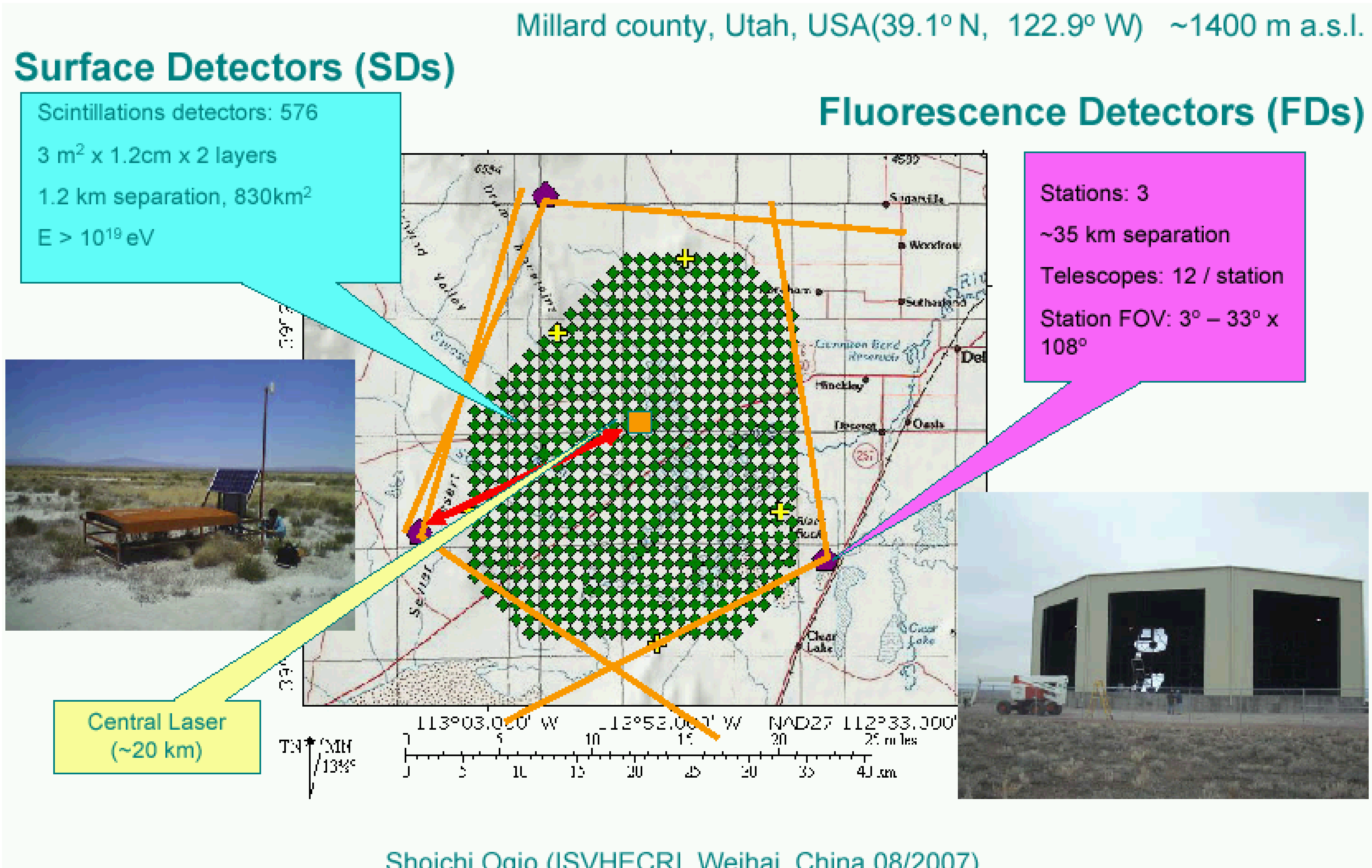
excludes neutron source at the GC

Photon flux limit above 10^{19}eV

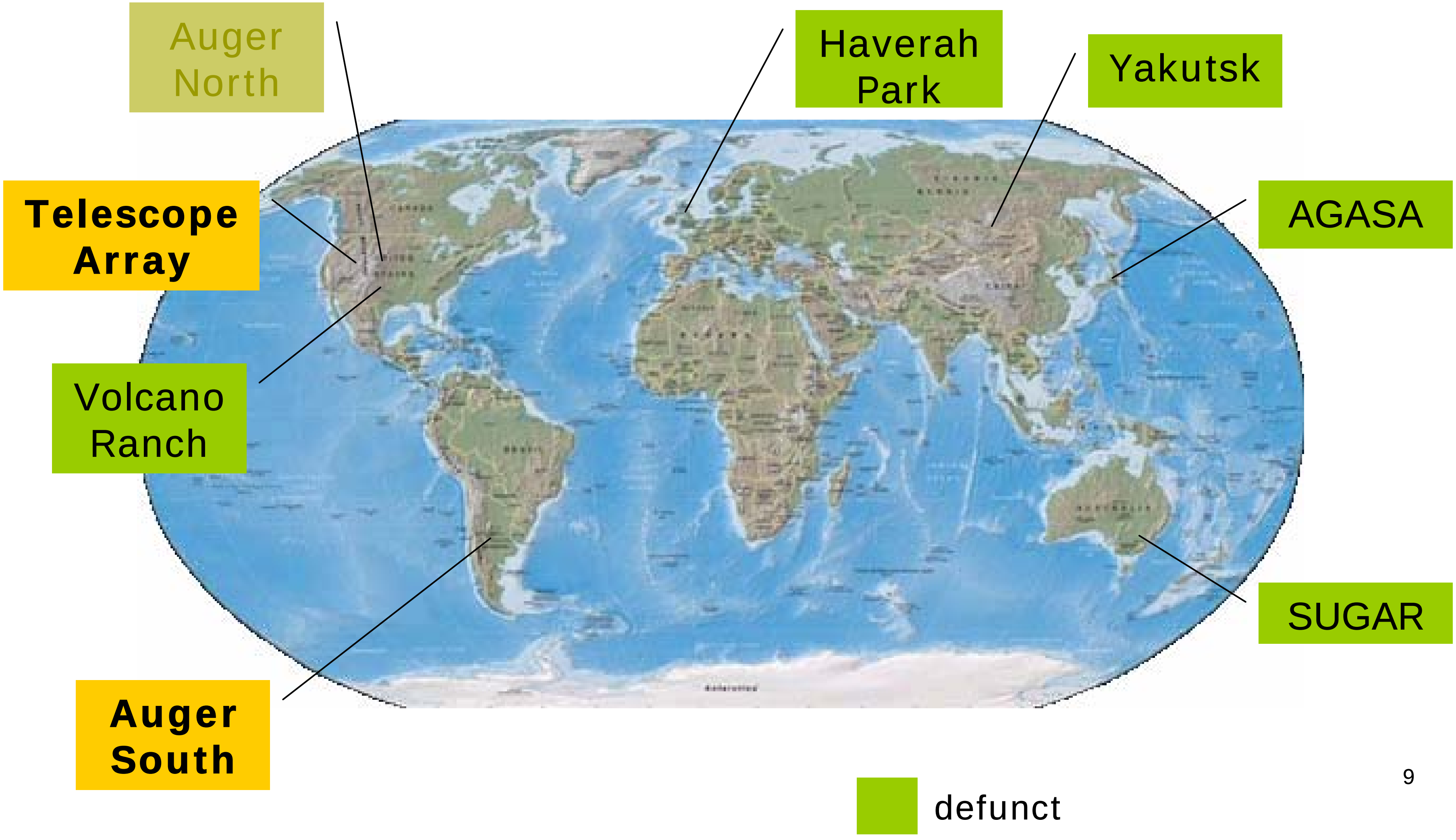


Highest energy cosmic rays: Telescope Array experiment

To be completed in March 2007

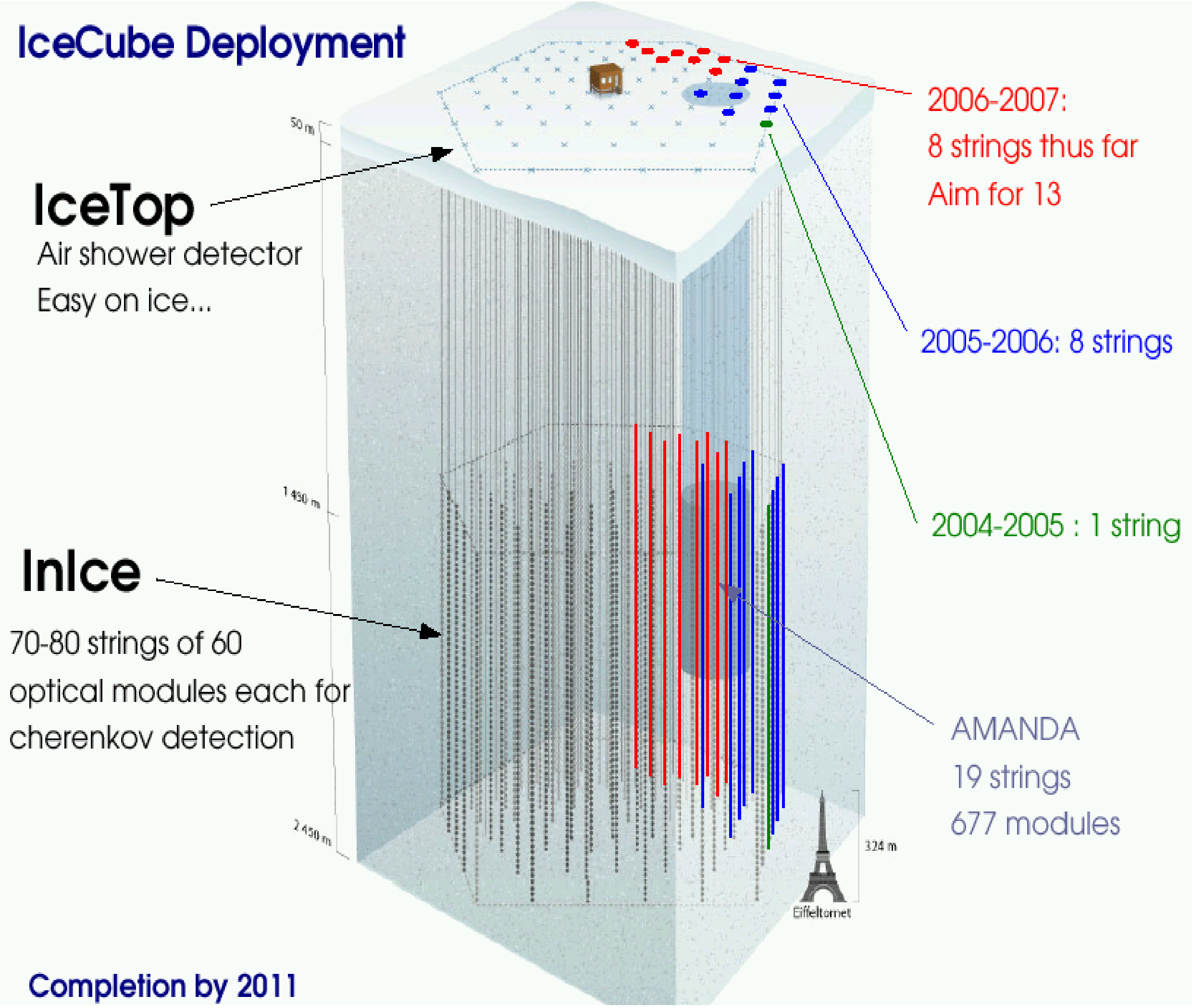


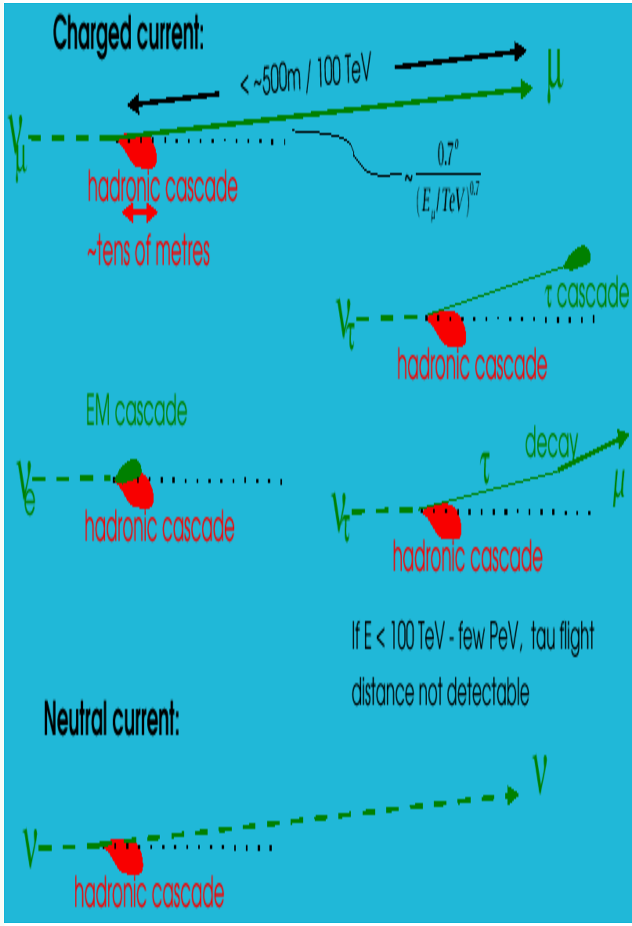
Highest energy cosmic ray detectors in the world



Presented by Klas Hultqvist

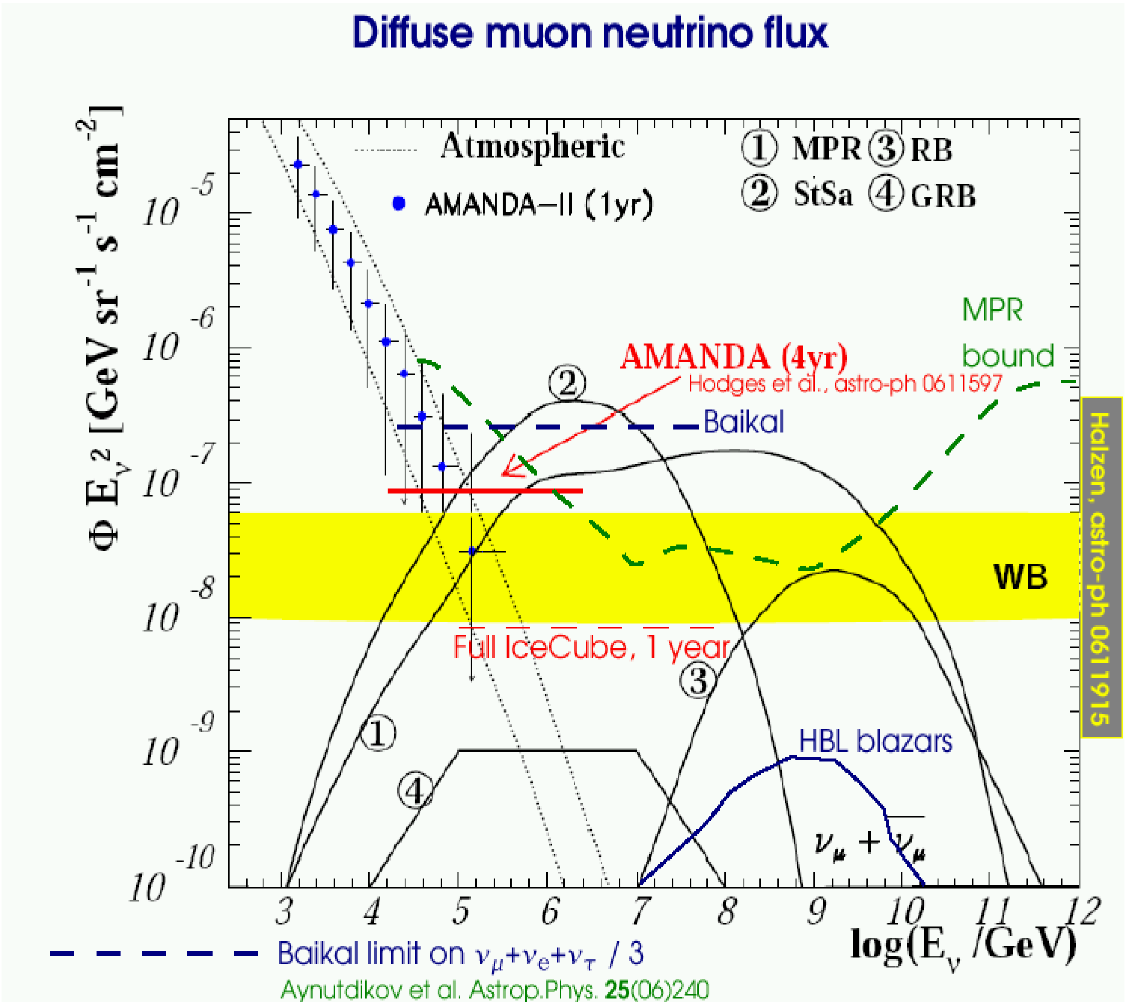
High energy neutrinos: IceCube at South Pole





Presented by Klas Hultqvist

High energy neutrinos: IceCube sensitivity

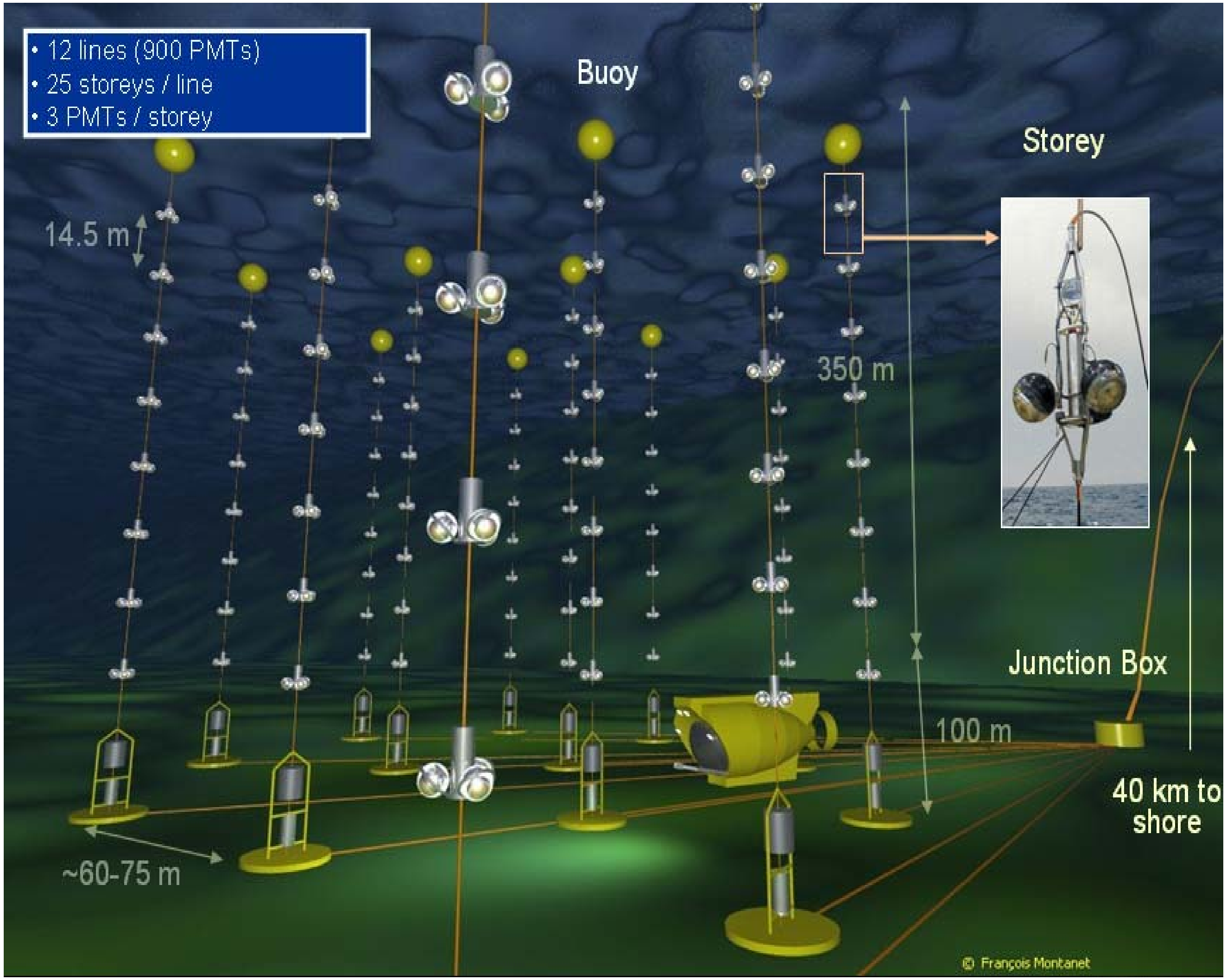


Other interests:

- TeV neutrino-gamma connection
- GRB coincidences
- WIMP search
- Supernova detection

Presented by Juan A. Aguilar Sanchez

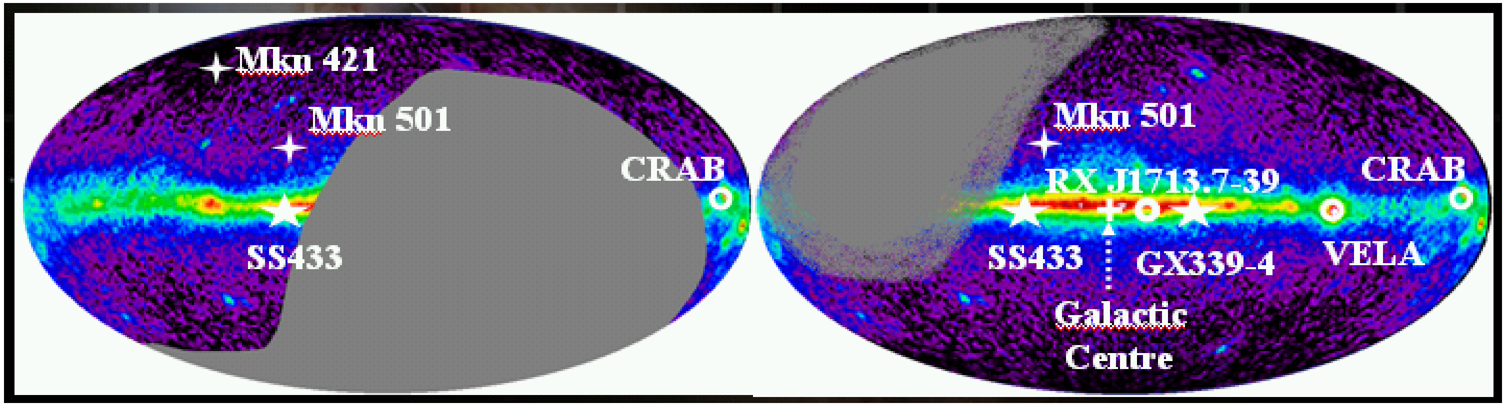
High energy neutrinos: ANTARES



- •Mediterranean Sea (42º50'N, 6º10'E) at 2500m depth, in the south coast of Toulon (France).
- • 4 lines already deployed.
- •To be completed in 2007.

Sky coverage by neutrino telescopes

AMANDA (South Pole) **ANTARES (43° North)**



NEMO (Capo Passero, Sicily) at a depth of 3500 m)

16 storey towers in 2007

NESTOR (Ionian Sea, Greece at a depth of 4000m)

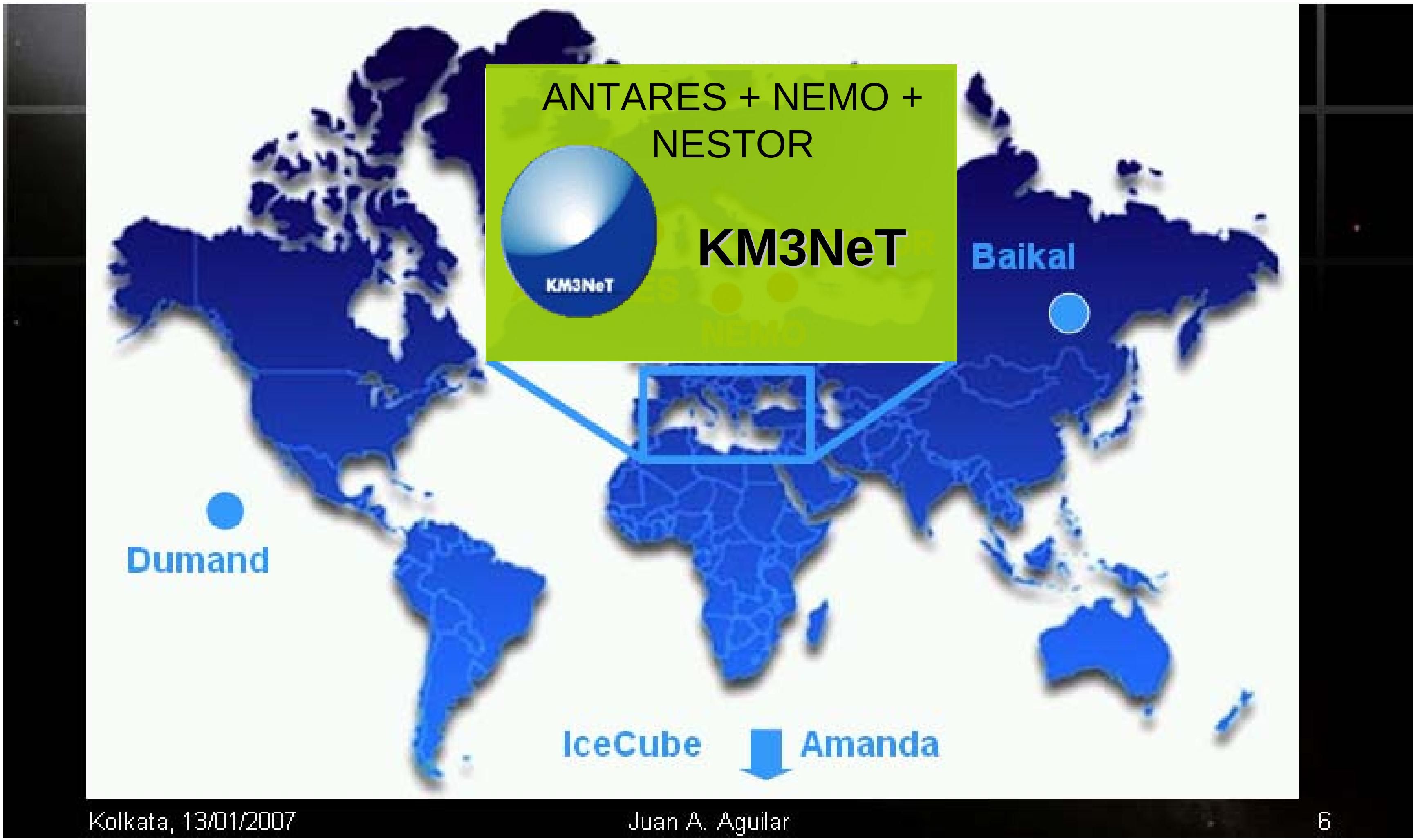
4 floors in 2007

KM3Net design study started in 2006

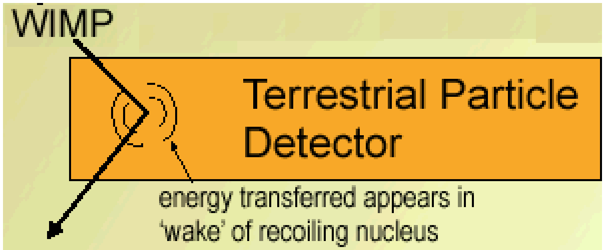
ANTARES + NEMO + NESTOR

KM3NeT

Neutrino telescopes in the world



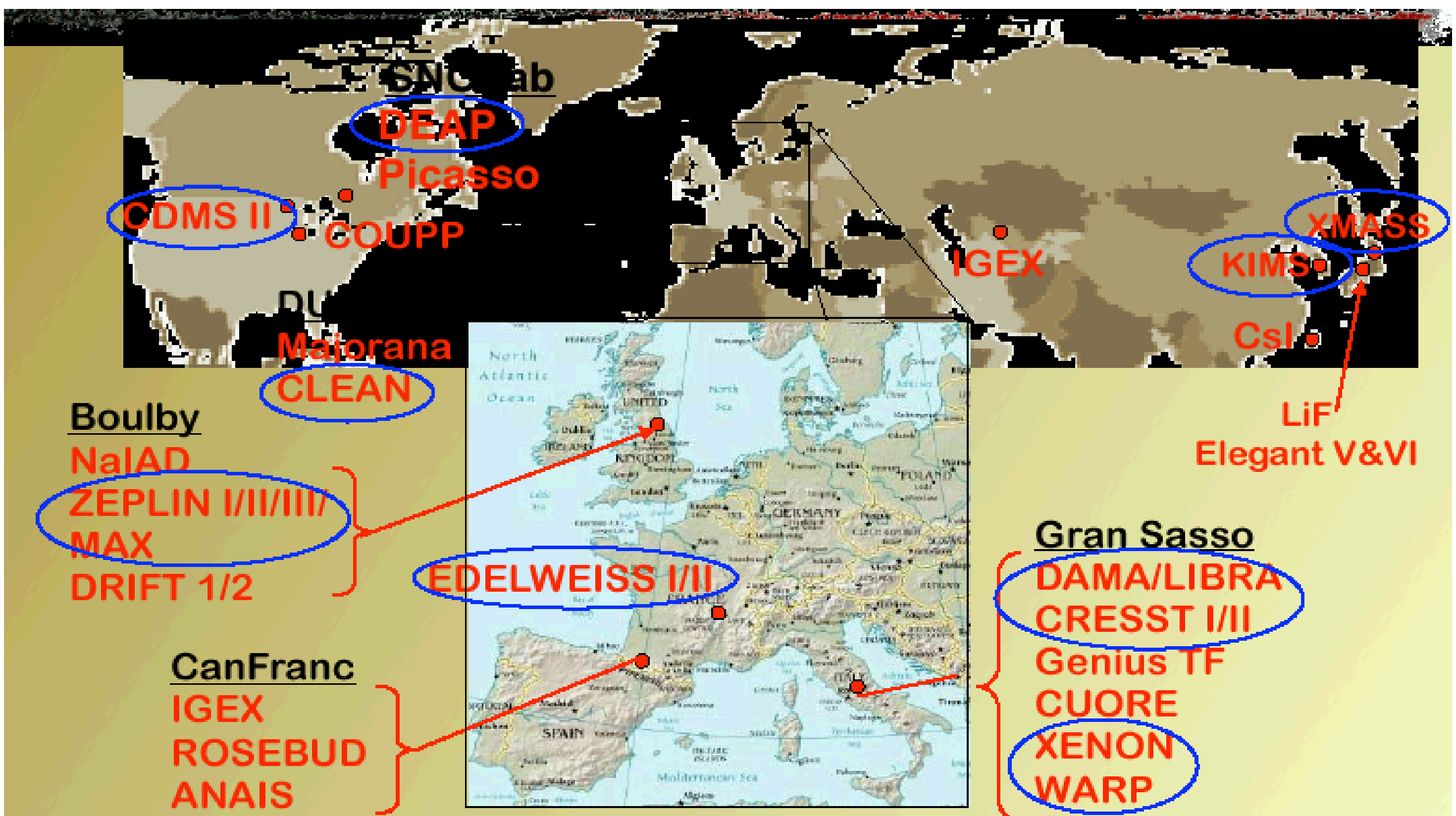
Direct search for dark matter



Neutralinos scatter elastically with nuclei:

$$Rate \sim N\, n_\chi \langle\sigma_\chi\rangle$$

N = number of targets in detector
n_χ = local neutralino density
$\langle\sigma_\chi\rangle$ = scattering cross section (mean over relative WIMP-detector velocity)

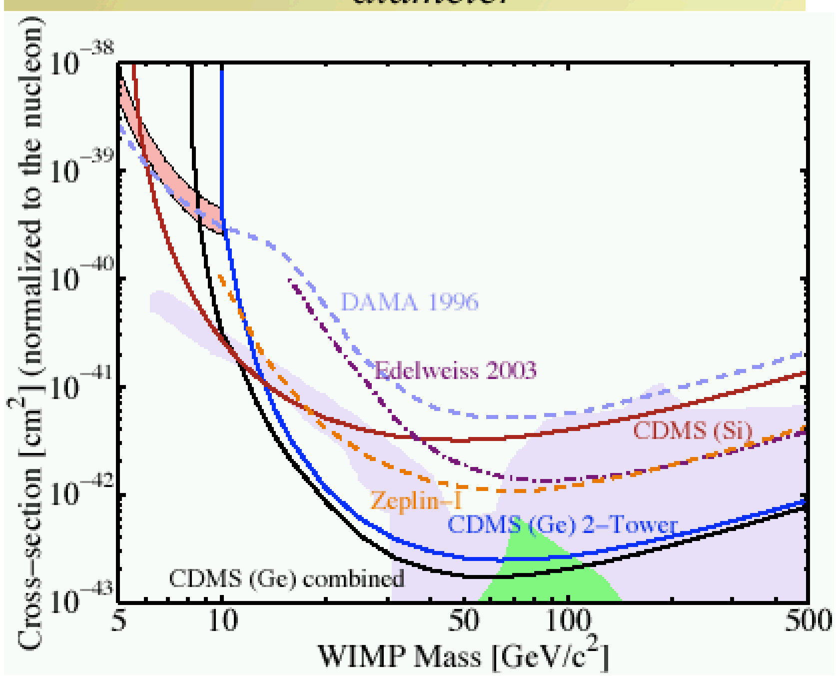


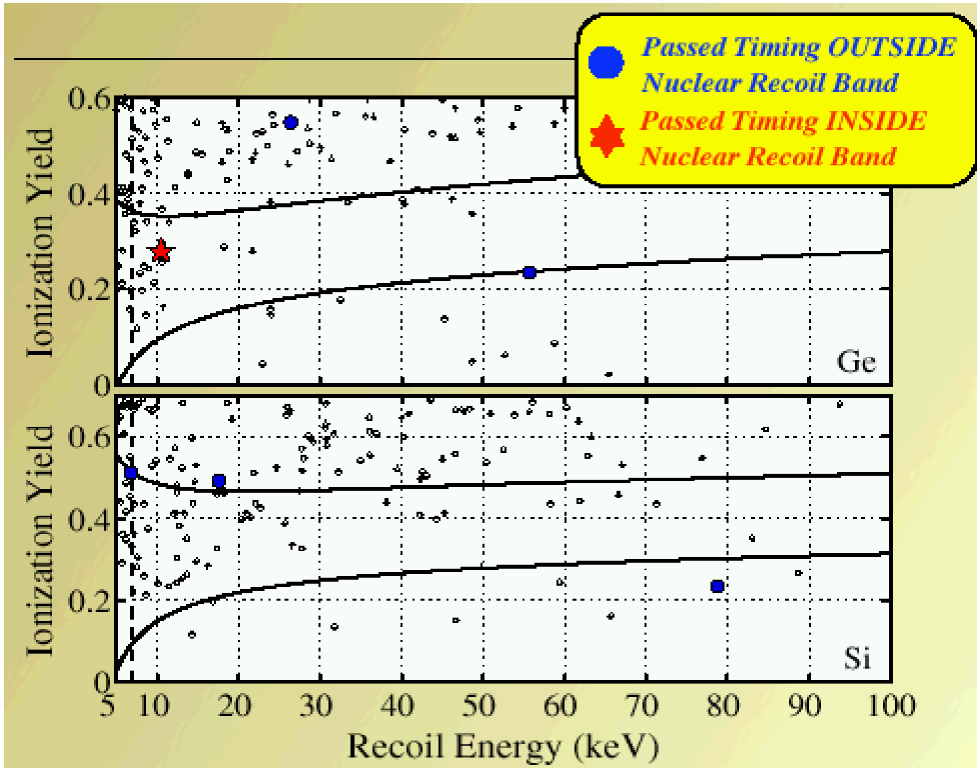
Direct search for dark matter: CDMS II

Experiment located in the Soudan Underground Mine, MN, USA (2070 mwe)

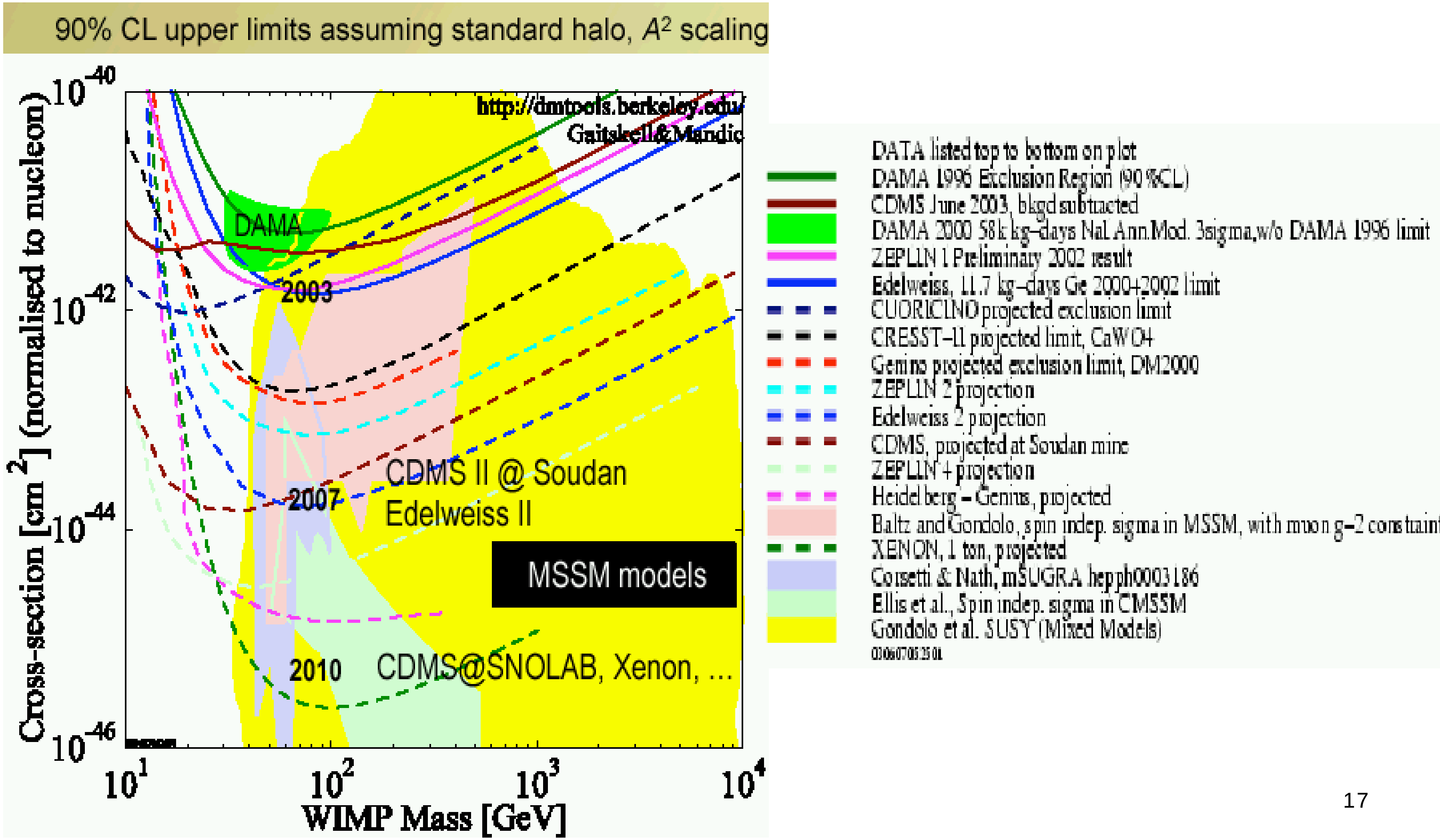
Most recent results based on 6 Ge (250 g) and 6 Si (100 g) crystals

Mass per crystal: 250 g Ge; 150 g Si
Dimensions: 1 cm thick x 7.5 cm diameter





Direct search for dark matter: near future



Comment: Dark matter anisotropy

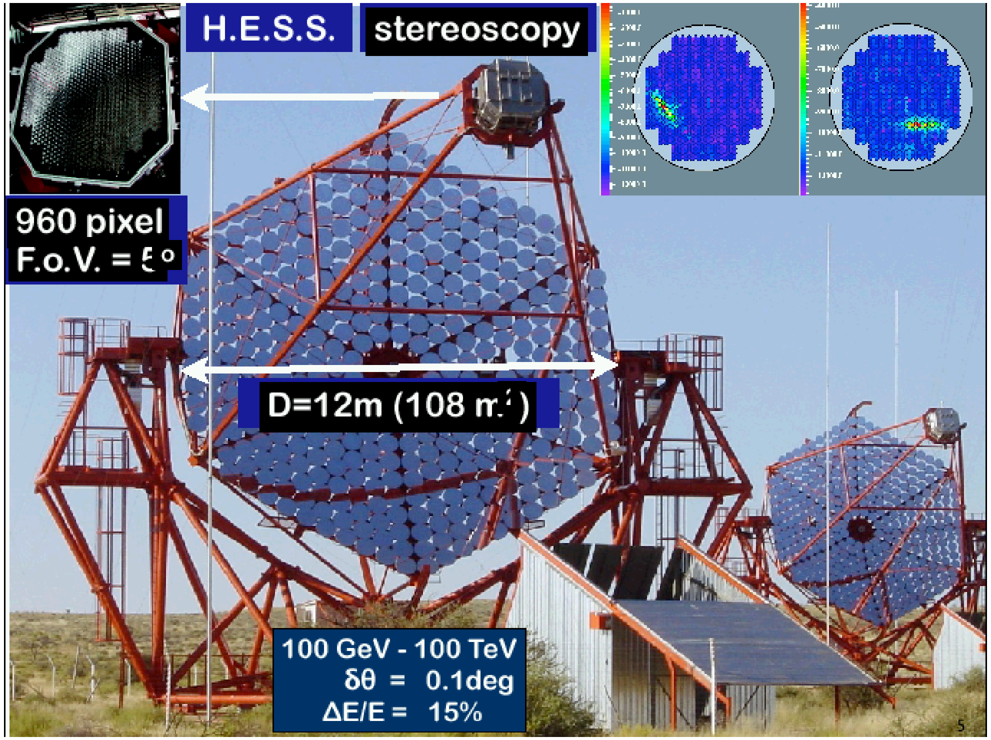
- Dark matter velocity hitting a detector fixed on the Earth surface

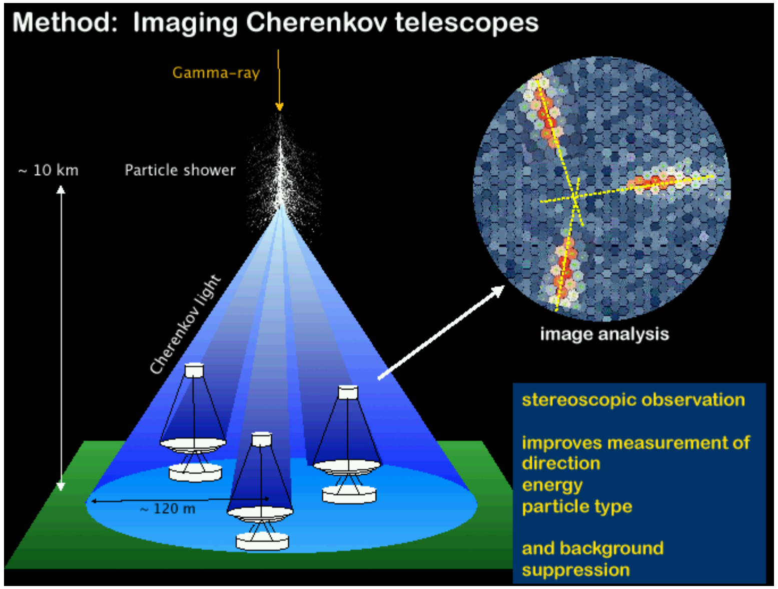
$$\vec{v} \approx \vec{v}_{\text{dispersion}} + \vec{v}_{\text{Galactic}} + \vec{v}_{\text{orbit}} + \vec{v}_{\text{rotation}}$$

  - $v_{\text{dispersion}} \sim 10^{-3}c$: random motion in halo
  - $v_{\text{Galactic}} \sim 7\times10^{-4}c$: Galactic rotation
  - $v_{\text{orbit}} \sim 1.0\times10^{-4}c$: Earth orbit
  - $v_{\text{rotation}} \sim 1.5\times10^{-6}c$: Earth rotation
- Directional dark matter can detect these motions except $v_{\text{dispersion}}$ via anisotropy
  - Ex. Track detectors, anisotropic crystal scintillators,…
  - Information on $v_{\text{dispersion}}$ if dark matter mass known

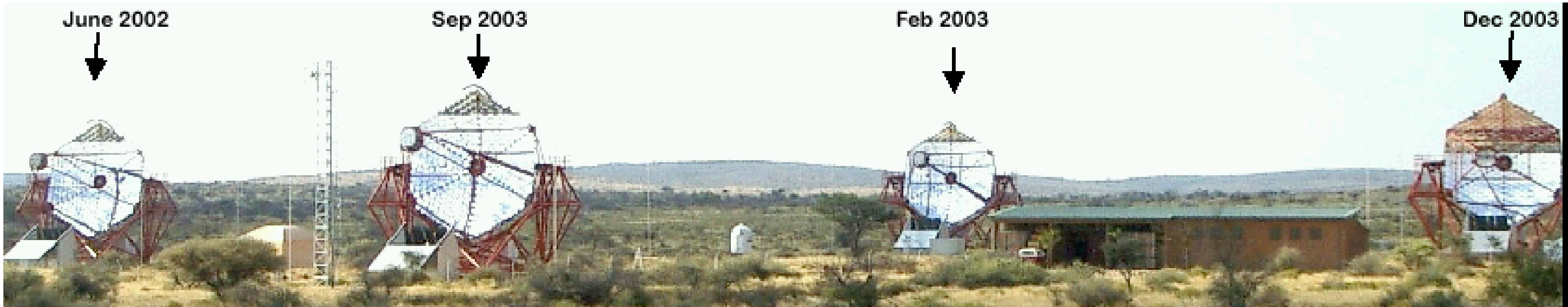
Presented by Goetz Heinzelmann

High energy gamma-rays: H.E.S.S.





Khomas Highland, Namibia, 1800m a.s.l.



Presented by Goetz Heinzelmann

High energy gamma-rays: H.E.S.S. – blazars

EBL: (Extragalactic Background Light)

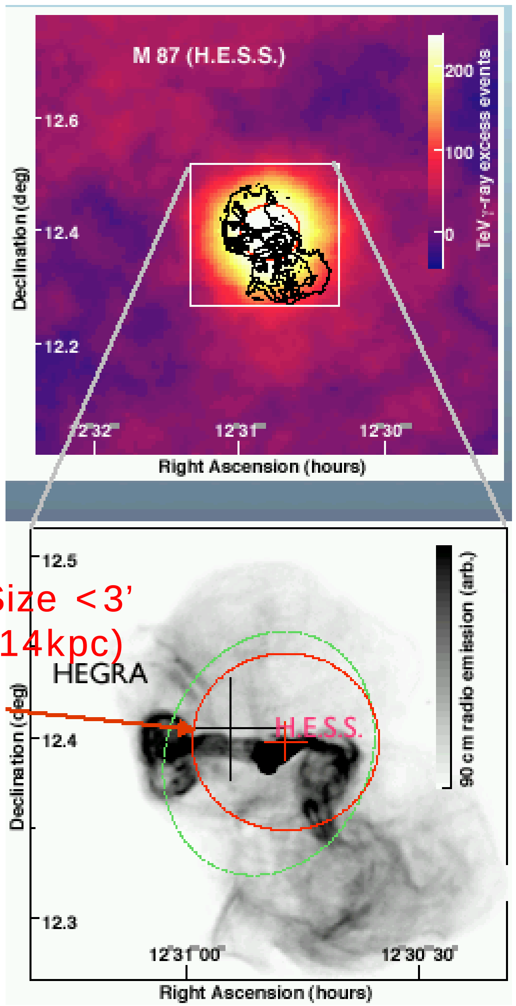
Blazars (BL Lac) discovered /observed by H.E.S.S.

	source name	redshift z	discovered	confirmed	flux [crab units]	
	Markarian 421	0.030	Whipple	many	up to 3	
	PKS 548-322	0.067	HESS prelim ~ 5σ		~ 0.01	
	PKS 2005-489	0.071	HESS		~ 0.03	
huge flare 2006	PKS 2155-304	0.116	Mark VI	HESS	up to 15	
	1ES 0229+299	0.139	HESS prelim > 6σ		~ 0.02	new
EBL density	H 2356-309	0.165	HESS		~ 0.02	confirm/ improve EBL limits
EBL density	1ES 1101-232	0.186	HESS		~ 0.02	confirm/ improve EBL limits
	1ES 0347-121	0.188	HESS prelim > 8σ		~ 0.03	confirm/ improve EBL limits
z ?	PG 1553+113	>0.25?	HESS / MAGIC		~ 0.02	

Presented by Goetz Heinzelmann

High energy gamma-rays: H.E.S.S. – other extragalactic objects

Radio galaxy M87

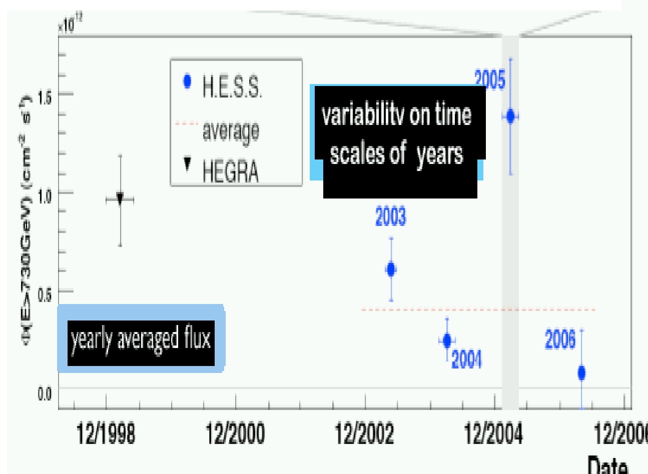


Size <3' (14kpc)

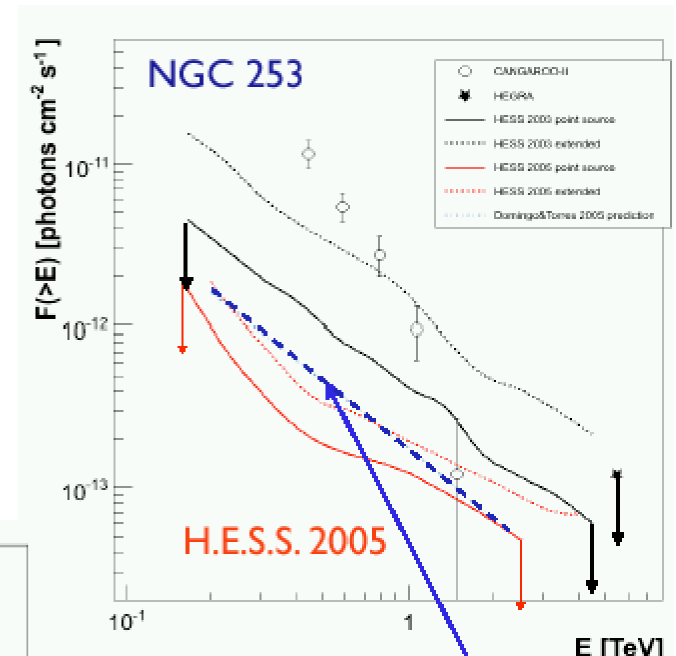
z=0.0044

Jet angle ~30deg (not a blazar)

Time variability suggests process near BH



Star burst galaxy NGC253



Model prediction:

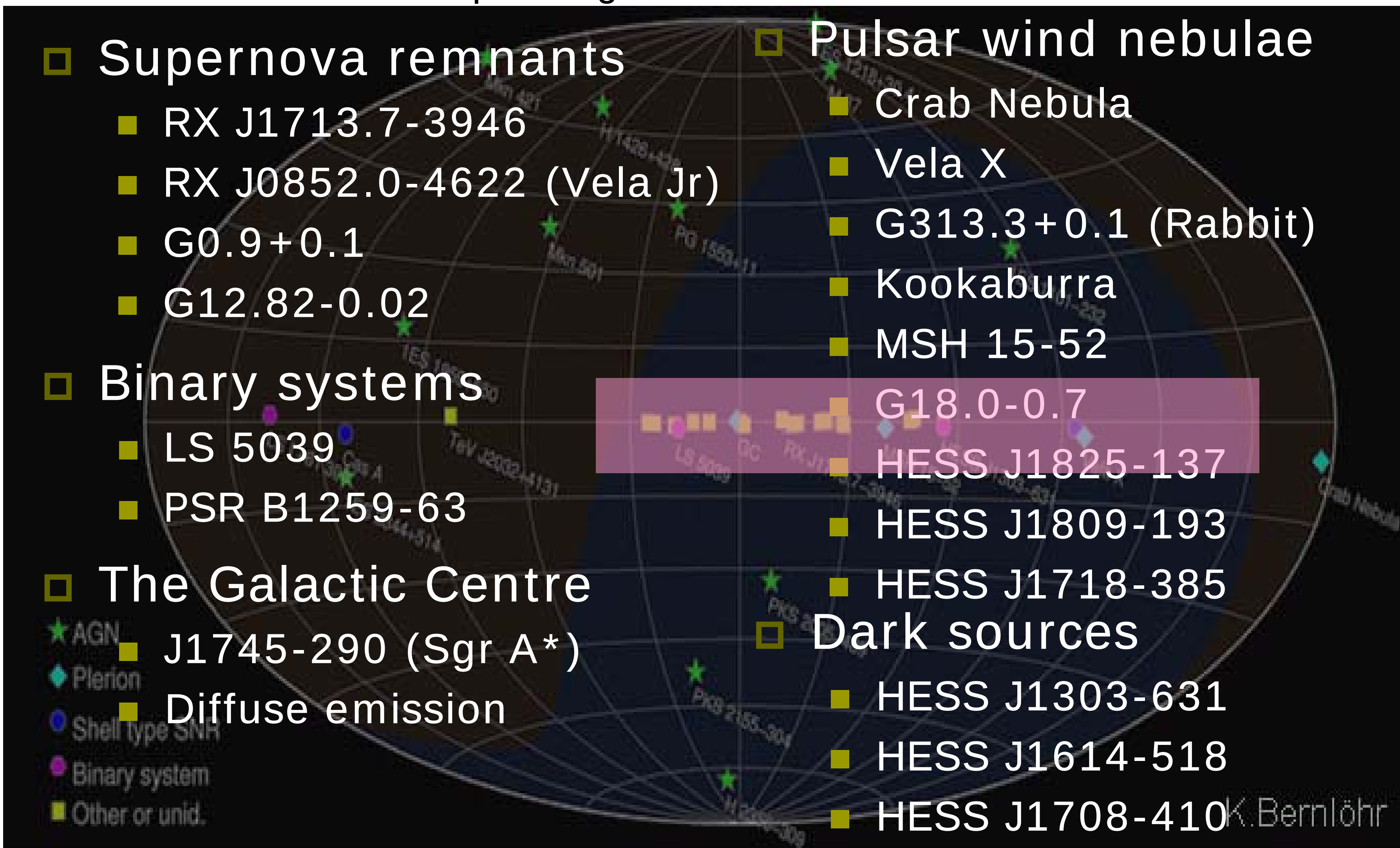
Domingo & Torres (2005)

Presented by Lowry McComb

High energy gamma-rays: H.E.S.S. – Galactic sources

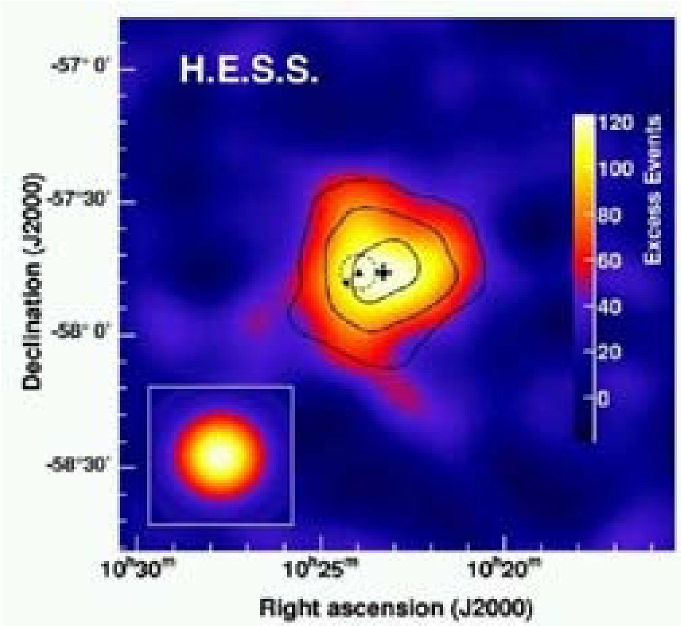
28 public galactic sources

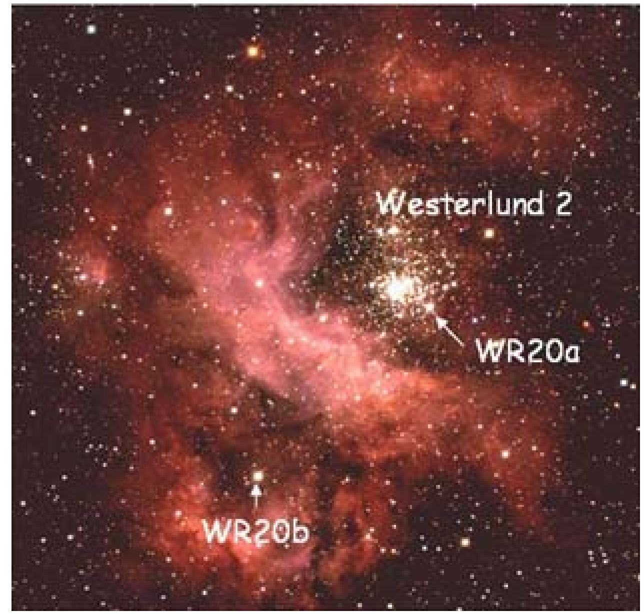
- Supernova remnants
  - RX J1713.7-3946
  - RX J0852.0-4622 (Vela Jr)
  - G0.9+0.1
  - G12.82-0.02
- Binary systems
  - LS 5039
  - PSR B1259-63
- The Galactic Centre
  - J1745-290 (Sgr A*)
  - Diffuse emission
- Pulsar wind nebulae
  - Crab Nebula
  - Vela X
  - G313.3+0.1 (Rabbit)
  - Kookaburra
  - MSH 15-52
  - G18.0-0.7
  - HESS J1825-137
  - HESS J1809-193
  - HESS J1718-385
- Dark sources
  - HESS J1303-631
  - HESS J1614-518
  - HESS J1708-410



Presented by Lowry McComb

High energy gamma-rays: H.E.S.S. – HESS J1023-575





Positionally coincident with Westerlund 2

Source significance 9σ

Extended source

Dotted circle = 1σ best fit

▲ = WR20a

▼= WR20b

CR accelerated in bubbles blown by massive stars in ISM?

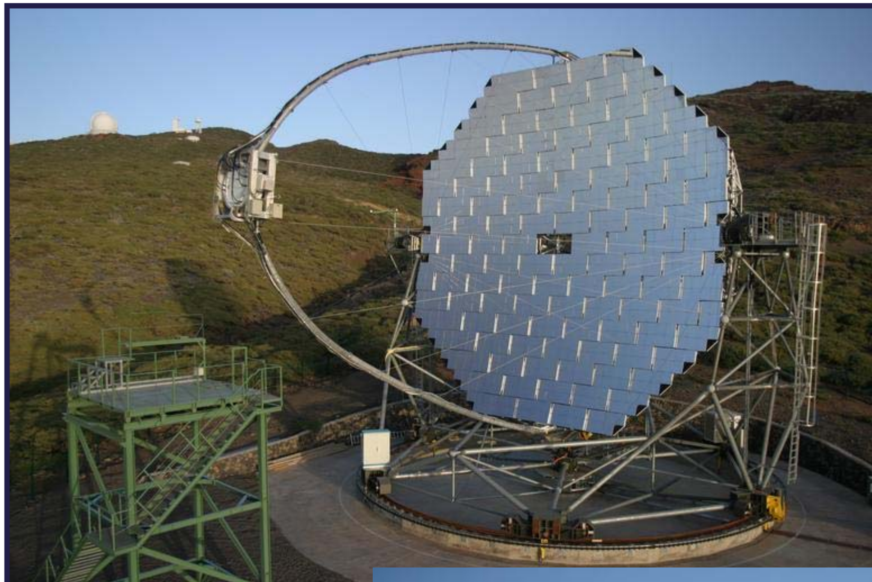
Westerlund 2

Young stellar cluster Westerlund 2 in HII region RCW 49.

Contains WR20a, a massive Wolf-Rayet binary (both ~70 M_{sun}) and WR20b, another WR.

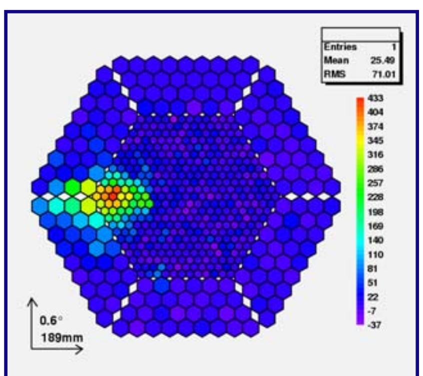
Presented by Masahiro Teshima

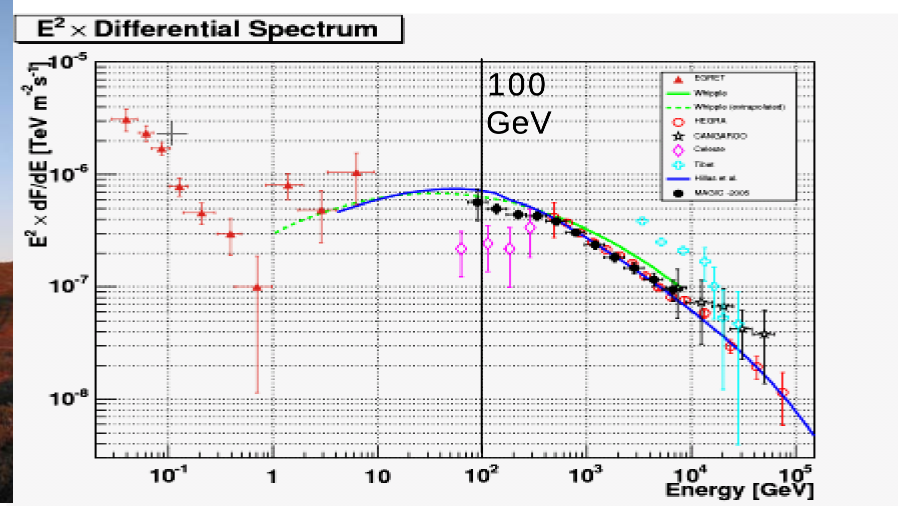
High energy gamma-rays: MAGIC



- La Palma, Canary Island
- 17m diameter world largest Cherenkov tel.
- High resolution camera
- Analogue signal fiber transmission
- Fast rotation for GRB < 40secs
- Trigger threshold 40-50GeV
- Sensitivity ~2.5% of Crab (50hrs)
- Angular resolution ~0.1 degrees
- Energy Resolution 20-30%

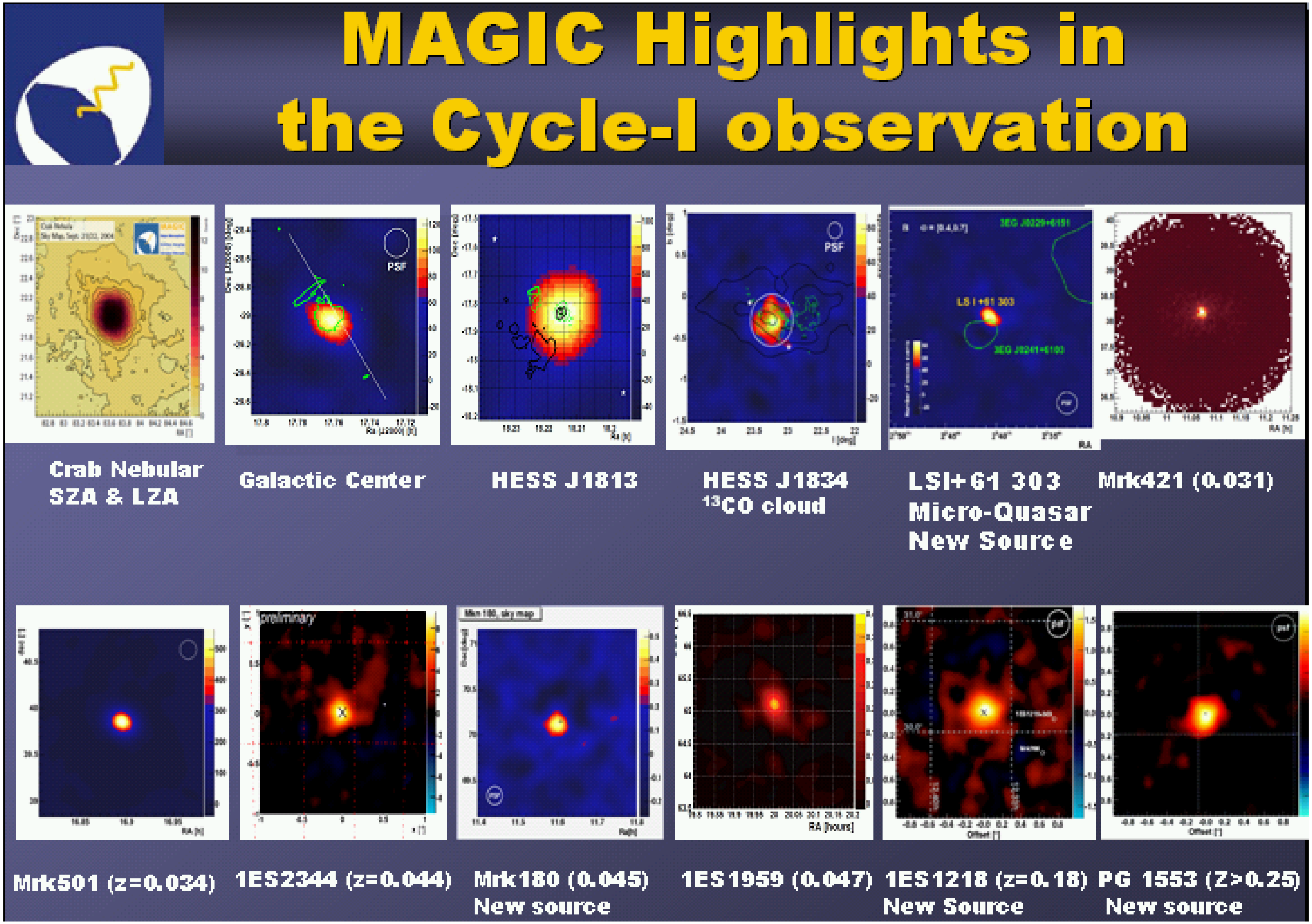
- MAGIC-II is under construction and will be completed in the fall of the next year to improve sensitivity by factor of two





Presented by Masahiro Teshima

High energy gamma-rays: MAGIC - results



High energy gamma-rays: CANGAROO-III / VERITAS

•Japan-Australia collaboration in Woomera, Australia

•Four 10m telescopes since 2004 March

Stereo observation results:

•Pulsar wind nebula Vela X

•SNR RX J0852.0-4622

•NGC 253 (U.L.)

•Blazar PKS 2155-304 flare

•Mainly US collaboration in Arizona, USA

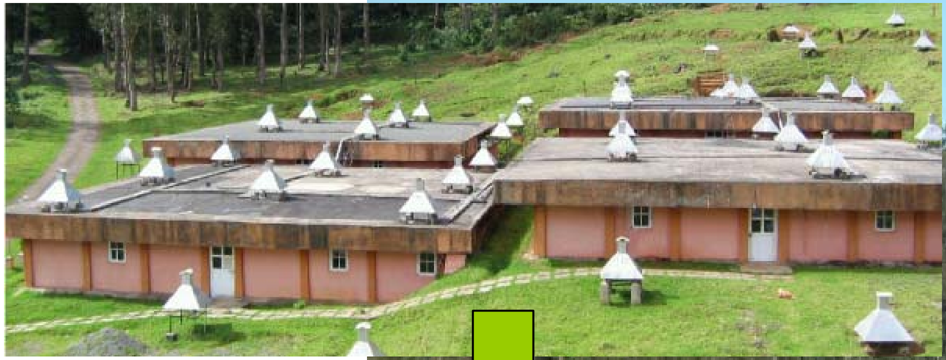
•Four 12m telescopes almost ready

1996 First Proposal to Smithsonian
2000 DOE funds VERITAS R&D
2003 March VERITAS funded for 4 telescopes in U.S. by DoE & NSF!
2004 Feb. Prototype Telescope at testsite operational
2004 July site at Kitt Peak approved!
2005 Feb. telescope 1 operational
2005 Tohono O'odham Nation files complaint --> site shutdown
2005 Fall Telescope 1 & 2 start operations @ FLWO basecamp
2006 Decision to built VERITAS-4 at basecamp + operate '07-(09
2006 Dec. Kitt Peak site issue still unresolved ...

Presented by Sunil K. Gupta

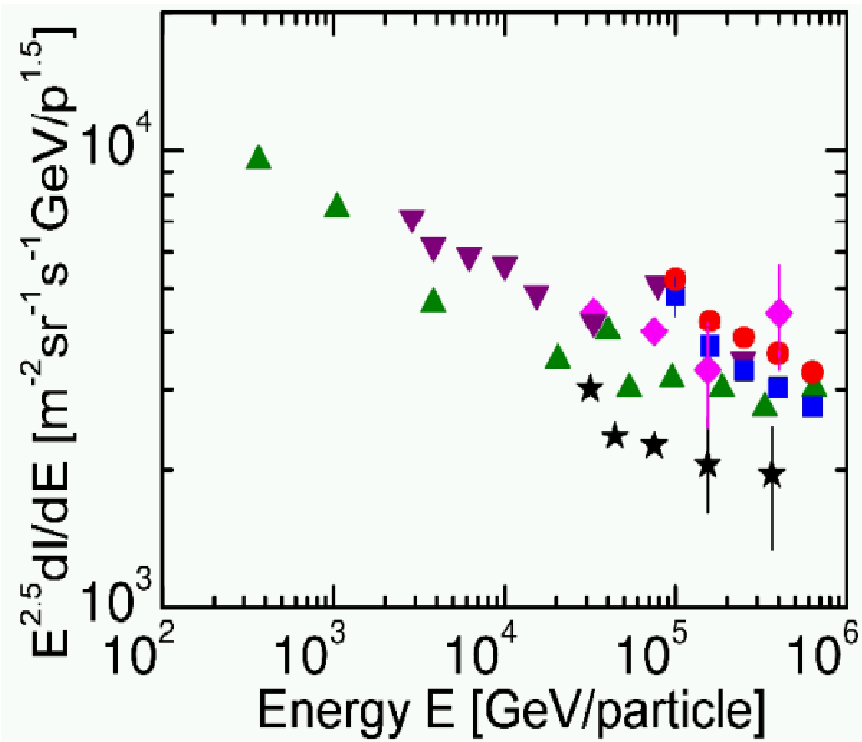
High energy gamma-rays and cosmic rays: GRAPES-3

- Air shower experiment by Japan-Indian collaboration since 1992 at Ooty, India
- 380 -Plastic Scintillator detectors (1 m^2 area)
- 3712 -Proportional Counters (6m x 0.1m x 0.1m) deployed in 4 crossed layer configuration as 1 GeV muon detector of area 560 m^2 .
- 15000 m^2 – Ooty Radio Telescope (326 MHz.)



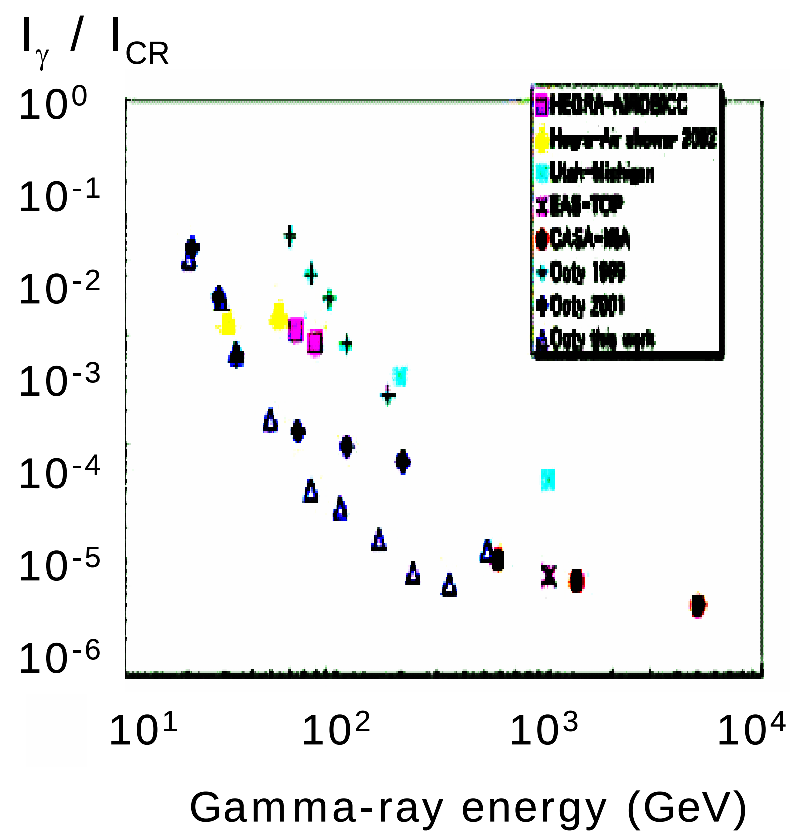
High energy gamma-rays and cosmic rays: GRAPES-3 – some results

Cosmic ray energy spectrum



- ● GRAPES-3 SIBYLL
- ■ GRAPES-3 QGSJET

Diffuse gamma-rays

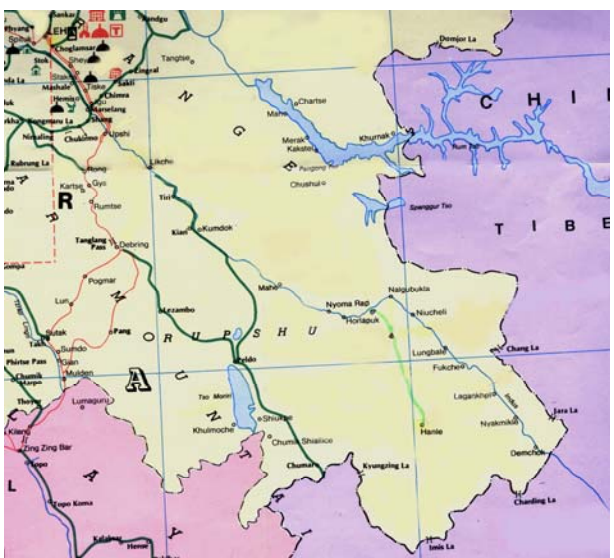


Good gamma/hadron separation by muon detectors

Presented by Ramesh Koul

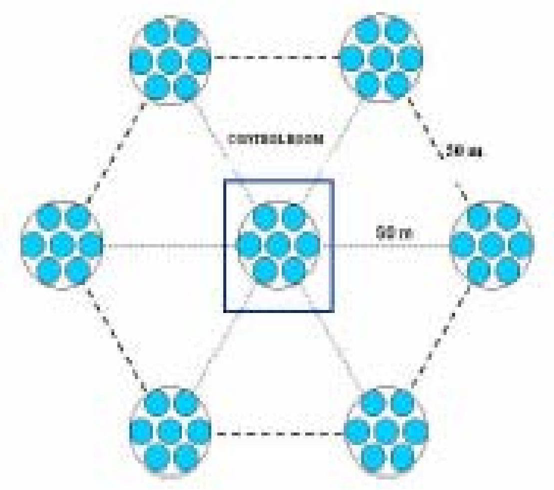
High energy gamma-rays: HiGRO (Himalayan γ-Ray Observatory)

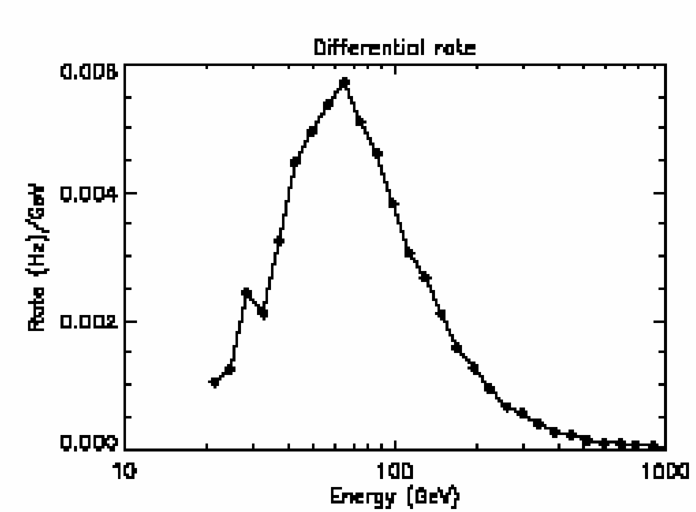
- 7 Element **HAGAR** (High Altitude GAmma Ray) experiment wavefront sampling telescope
- 21m dia. **MACE** (Major Atmospheric Cerenkov Experiment) Cerenkov imaging telescope
- Site: Hanle, Ladakh (32.7°N, 79°E, 4200m a.s.l.)
  - Limited time for out door work (May-Oct)
  - Road transportation of equipment (May-Oct)
  - 2m optical telescope functioning for 5 years



Presented by Ramesh Koul

High energy gamma-rays: HiGRO / HAGAR



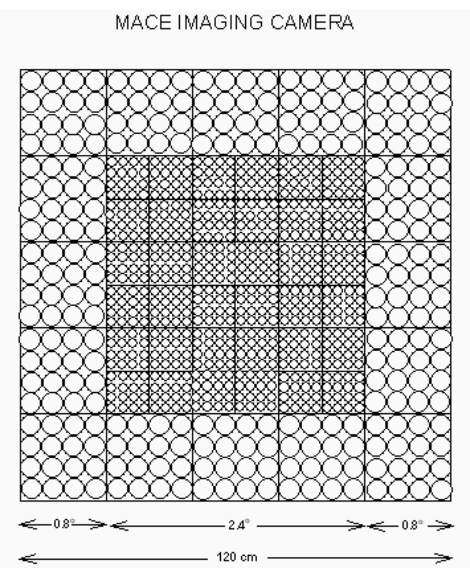


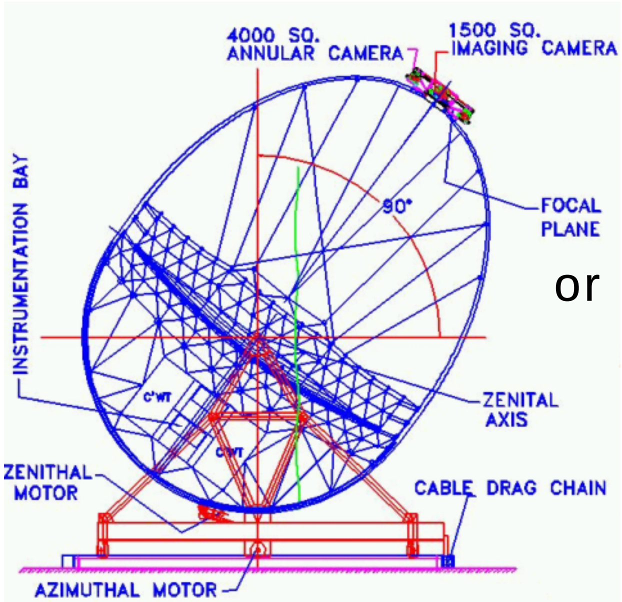
In commissioning phase now

Presented by Ramesh Koul

High energy gamma-rays: HiGRO / MACE

- 20GeV threshold, 337m^2 (=20mϕ), tessellated parabola
- Alt-azimuth mount, ~250t, 45m high
- 1000 pixels camera, GHz digitization electronics, 2m x 2m x 2m
- Linux based DAQ, capable of handling event rates up to a few kHz
- First light expected: June 2010





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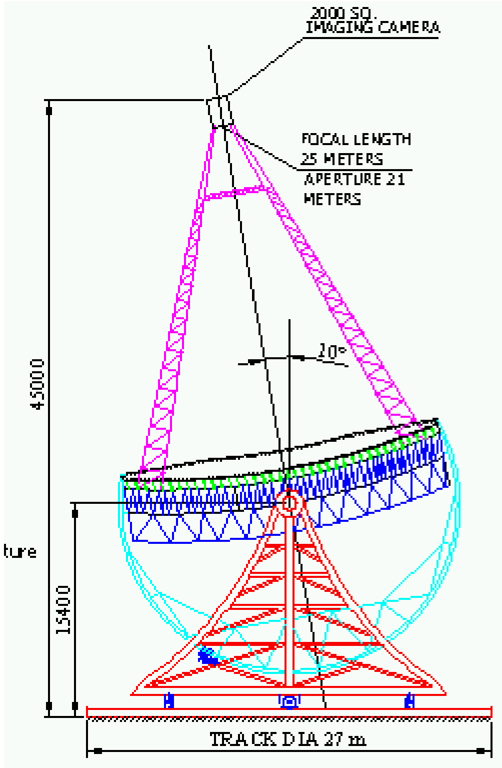
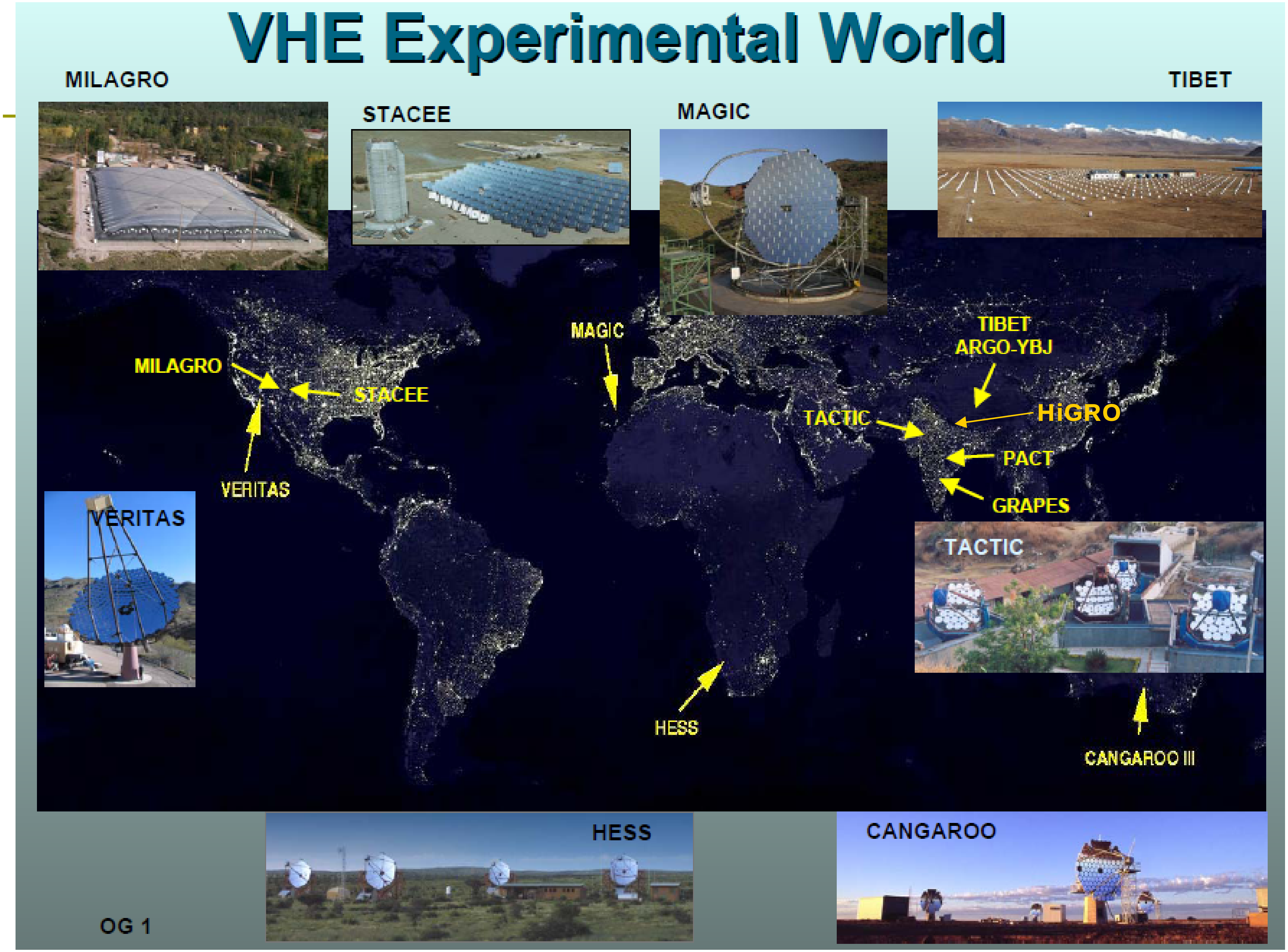
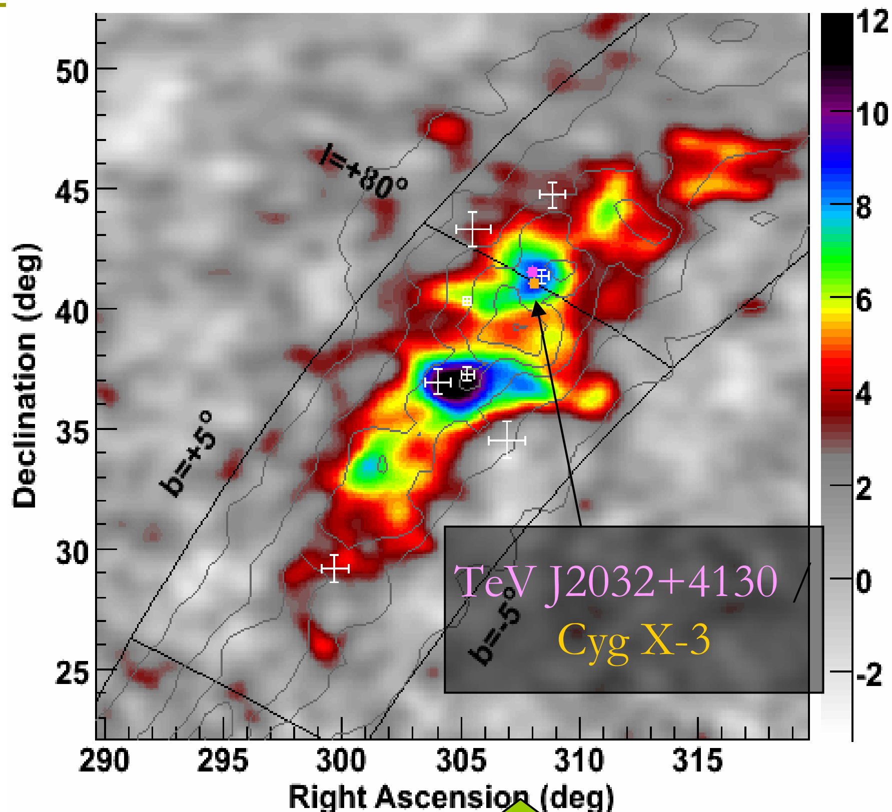


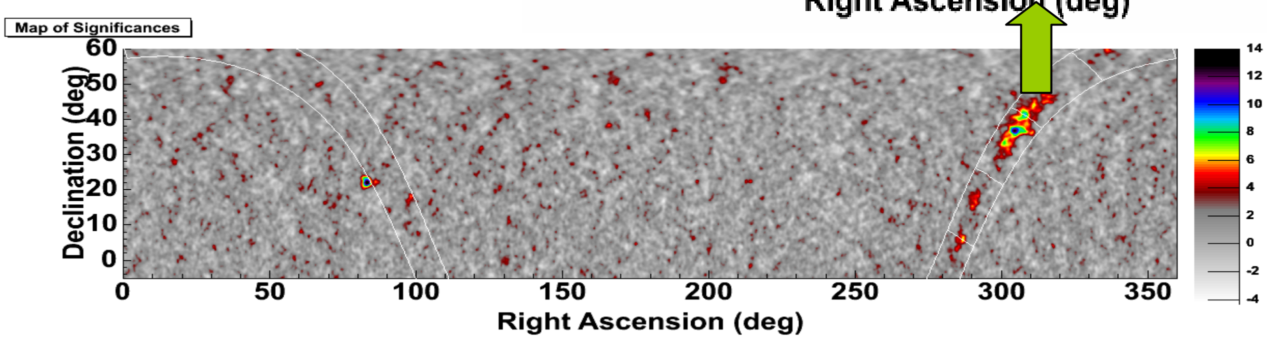
Rene Ong, ICRC2005 OG2 rapporteur talk



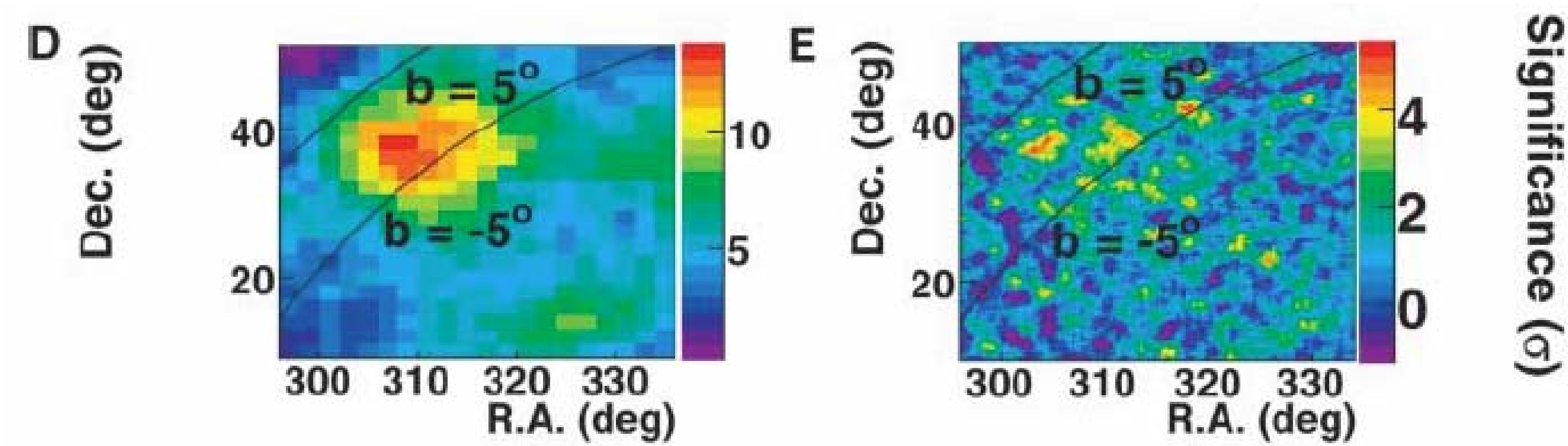
Diffuse source in Cygnus? (1)

- Crosses are EGRET sources
- Contours are EGRET diffuse model
- TeV/matter correlation good in Galactic latitude
- Brightest TeV Region
  - Coincident with 2 EGRET sources (unidentified) 3EG J2016+3657 3EG J2021+3716
- *Analysis in progress*



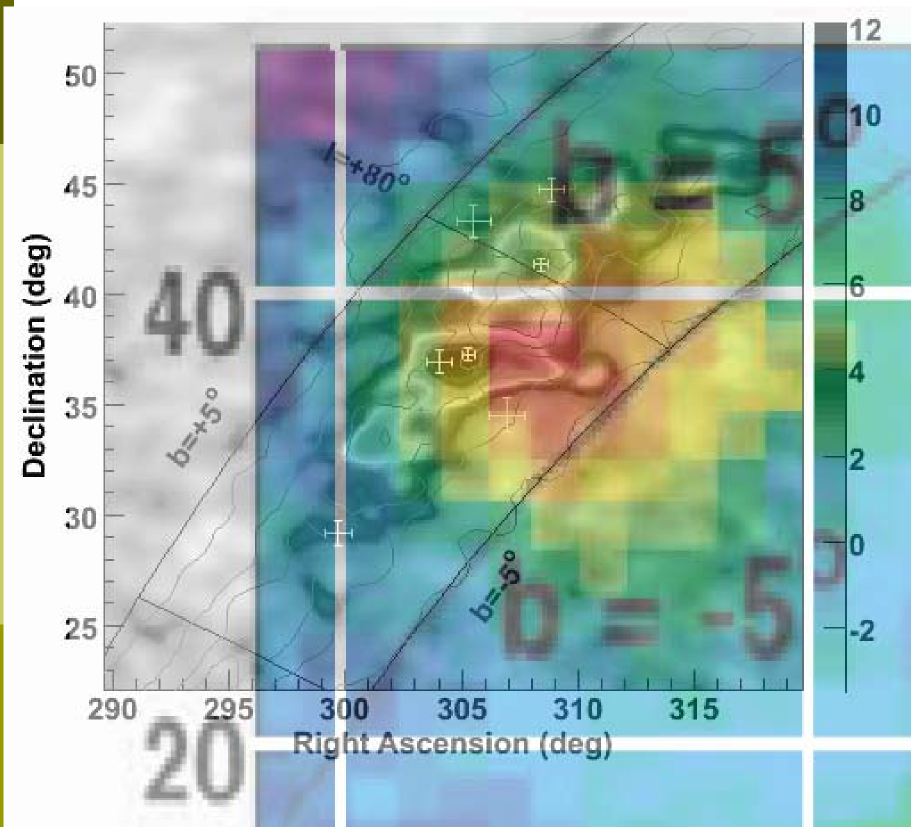


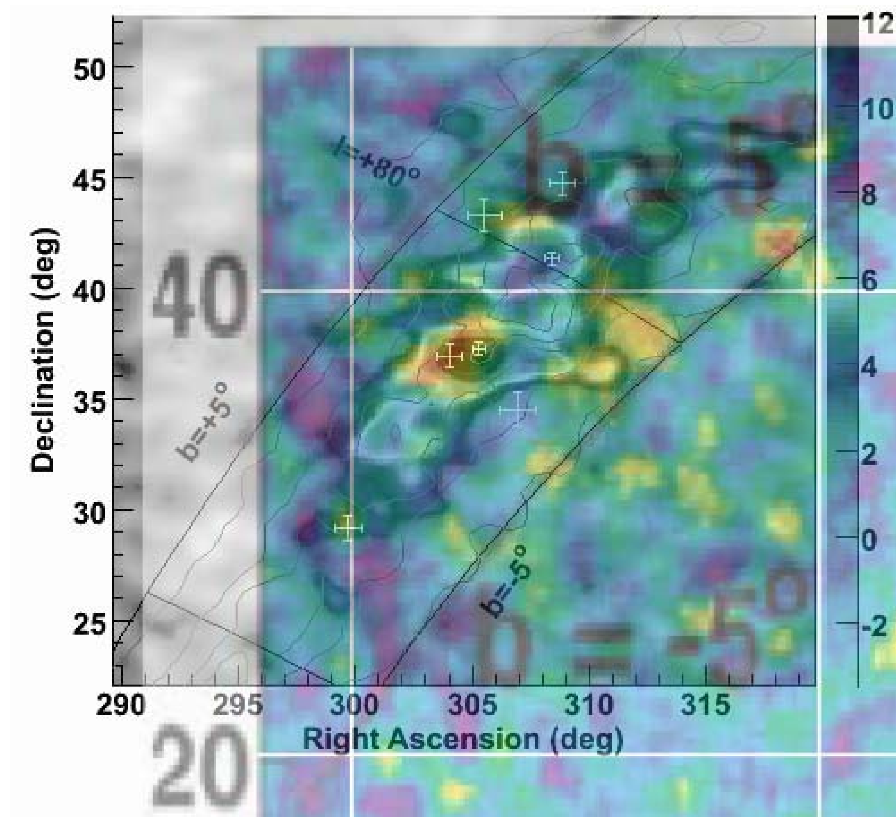
Diffuse source in Cygnus? (2)



(D) and (E) show significance maps of the Cygnus region [pixels in radius of 0.9° and sampled over a square grid of side width 0.25° for (E)] for data from 1997 to 2005. The vertical color bin widths are 0.69 SD and 0.42 SD for significance in (D) and (E), respectively. Two thin curves in (D) and (E) stand for the Galactic parallel b=±5°. Small-scale anisotropies (E) superposed onto the large-scale anisotropy hint at the extended gamma-ray emission.

Diffuse source in Cygnus? (3)





MILAGRO: A. Abdo, Santa Fe Workshop, May 2006
Tibet: Amenomori et al., Science 314, 439 (2006)

TeV gamma-ray source catalog

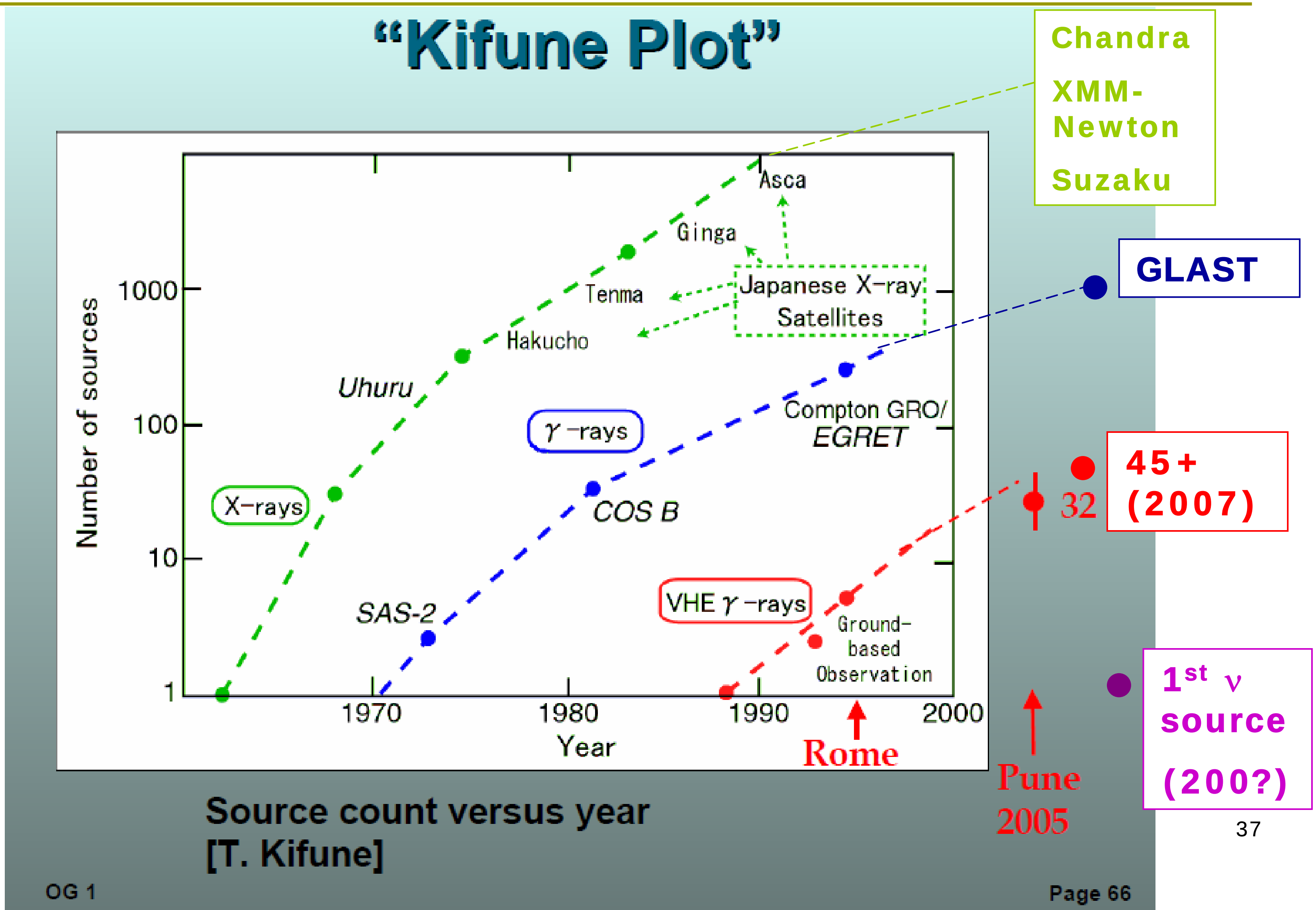
As of October 18, 2006, Compiled by M. Mori

http://www.icrr.u-tokyo.ac.jp/~morim/TeV-catalog.htm

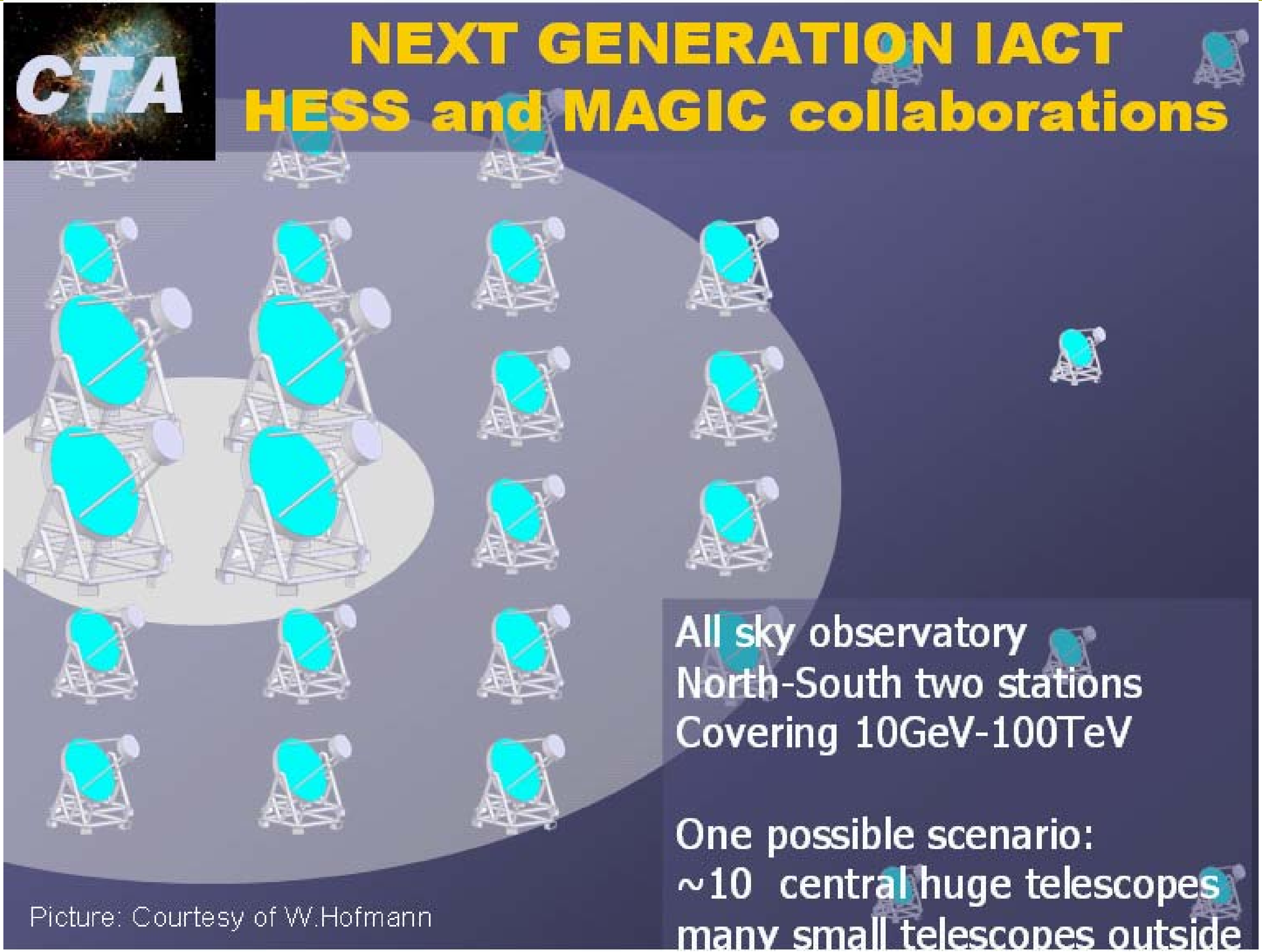
PG 1553+113	238.9294	11.1901	21.909	43.964	H, M	HBL, z>0.25?	17
HESS J1614-518	243.5679	−51.8442	331.497	−0.594	H		18
HESS J1616-508	244.1033	−50.8964	332.394	−0.140	H	PSR J1617-5055?	19
HESS J1632-478	248.04	−47.82	336.38	−47.82	H		20
HESS J1634-472	248.74	−47.27	337.11	−47.27	H		21
HESS J1640-465	250.1829	−46.5319	338.317	−0.021	H	G338.3−0.0?	22
Mkn 501	253.4672	39.76004	63.6	38.859	Many	XBL, z=0.034	23

Name	RA	Decl	GL	GB	Claim	Comment	No.
NGC 253	11.888	−25.2882	97.369	−87.964	C2, ~C3, ~H	Starburst Gal., z=0.00080	*
3C66A	35.66505	43.0355	140.143	−16.767	Cr,~HC,~W,~S	QSO, z=0.444	*
LSI +61 303	40.13194	61.2293	135.675	1.086	M	Microquasar, P_orb=26.5d. ~2kpc	1
PSR 0531+21	83.63288	22.01446	184.557	−5.785	Many	Crab pulsar/nebula	2
PSR 0833−45	128.8359	−45.1766	263.552	−2.787	C1, ~H	Vela pulsar	*
Vela X	128.3833	−45.7283	263.806	−3.371	H, C3	SNR, G263.9−3.3	3
RX J0852.0−4622	132.2458	−45.6333	265.385	−1.181	C2, C3, H	SNR, G266.6−1.2, Vela Jr.	4
1ES 1101−232	165.9065	−23.4917	273.189	33.079	H	HBL, z=0.186	5
Mkn 421	166.1138	38.20883	179.832	65.031	Many	XBL, z=0.031	6
Cen X−3	170.3132	−60.6233	292.09	0.336	D	X−ray binary	7
Mkn 180	174.1100	70.1576	131.910	45.641	M	HBL, z=0.045	8
1ES 1218+304	185.3414	30.1770	186.359	82.734	M	HBL, z=0.182	9
M87	187.7059	12.39112	283.778	74.491	H	Radio galaxy, z=0.00436	10
PSR 1259−63/SS2883	195.6987	−63.8357	304.184	−0.992	H	PSR/Be binary	11
HESS J1303−631	195.7642	−63.1986	304.241	−0.356	H	UnID, Cen OB1?	12
HESS J1418−609	214.5167	−60.9753	313.247	0.150	H	Kookabura NE wing? PSR J1420−6048?	13
HESS J1420−607	215.0375	−60.7600	313.558	0.268	H	Kookabura SW wing? Rabbit?	14
H1426+428	217.1354	42.67361	77.49	64.899	Many	XBL, z=0.129	15
SN1006	225.5919	−41.8962	327.514	14.642	C1, ~H	SNR, G327.6+14.6	*
MSH15−52	228.5292	−59.1575	320.330	−1.192	C1, H	SNR, G320.4−1.2, HESS J1514−591	16
PG 1553+113	238.9294	11.1901	21.909	43.964	H, M	HBL, z>0.25?	17
HESS J1614−518	243.5679	−51.8442	331.497	−0.594	H		18
HESS J1616−508	244.1033	−50.8964	332.394	−0.140	H	PSR J1617−5055?	19
HESS J1632−478	248.04	−47.82	336.38	−47.82	H		20
HESS J1634−472	248.74	−47.27	337.11	−47.27	H		21
HESS J1640−465	250.1829	−46.5319	338.317	−0.021	H	G338.3−0.0?	22
Mkn 501	253.4672	39.76004	63.6	38.859	Many	XBL, z=0.034	23
HESS J1702−420	255.69	−42.07	344.26	−0.22	H	G344.7−0.1?	24
HESS J1708−410	257.06	−41.08	345.67	−0.44	H		25
PSR 1706−44	257.426	−44.4825	343.1	−2.683	C1, D, ~H	3EGJ1710−4439	26
RX J1713.7−3946	258.425	−39.7667	347.346	−0.498	C1, C2, H	SNR, G347.3−0.5	27
HESS J1713−381	258.49	−38.20	348.65	0.38	H		28
HESS J1745−303	266.26	−30.37	358.71	−0.64	H		29
Sgr A*	266.4169	−29.0078	359.944	−0.046	C2, W, H, M	Gal.C.[Rogers et al.1994 ApJ434L59]	30
Galactic Center ridge	266.4169	−29.0078	359.944	−0.046	H	−0.8< l <0.8deg |b|<0.3deg	31
G0.9+0.1	266.8467	−28.1517	0.872	0.076	H	SNR	32
HESS J1804−216	271.1329	−21.6919	8.408	−0.027	H	G8.7−0.1 / W30?	33
HESS J1813−178	273.4079	−17.8428	12.813	−0.034	H, M	SNR AX J1813−178/G12.82−0.02	34
HESS J1825−137	276.5150	−13.7633	17.820	−0.743	H	G18.0−0.7 ?	35
LS 5039	276.5626	−14.8482	16.882	−1.289	H	XRB, HESS J1826−148	36
HESS J1834−087	278.7104	−8.7533	23.258	−0.329	H, M	G23.3−0.3 / W41 ?	37
HESS J1837−069	279.4279	−6.9275	25.206	−0.121	H	G25.5+0.0 ?	38
1ES 1959+650	299.9994	65.14852	98.003	17.67	U, W, HC, M	XBL, z=0.048	39
PKS 2005−489	302.3721	−48.8219	350.386	−32.611	H	XBL, z=0.071	40
TeV J2032+4130	308.0292	41.50833	80.254	1.074	HC	UnID: Cyg OB2?	41
PKS 2155−304	329.7169	−30.2256	17.73	−52.246	D, H	XBL, z=0.117	42
Cas A	350.8529	58.8154	111.736	−2.13	HC	SNR, G111.7−2.1	43
BL Lac	330.6807	42.27779	92.59	−10.441	~W, ~HC, Cr	z=0.0686	*
1ES 2344+514	356.7702	51.70497	112.891	−9.908	W	XBL, z=0.044	44
H 2356−309	359.7825	−30.6272	12.843	−78.035	H	HBL, z=0.165	45

"Evolution" in number of objects

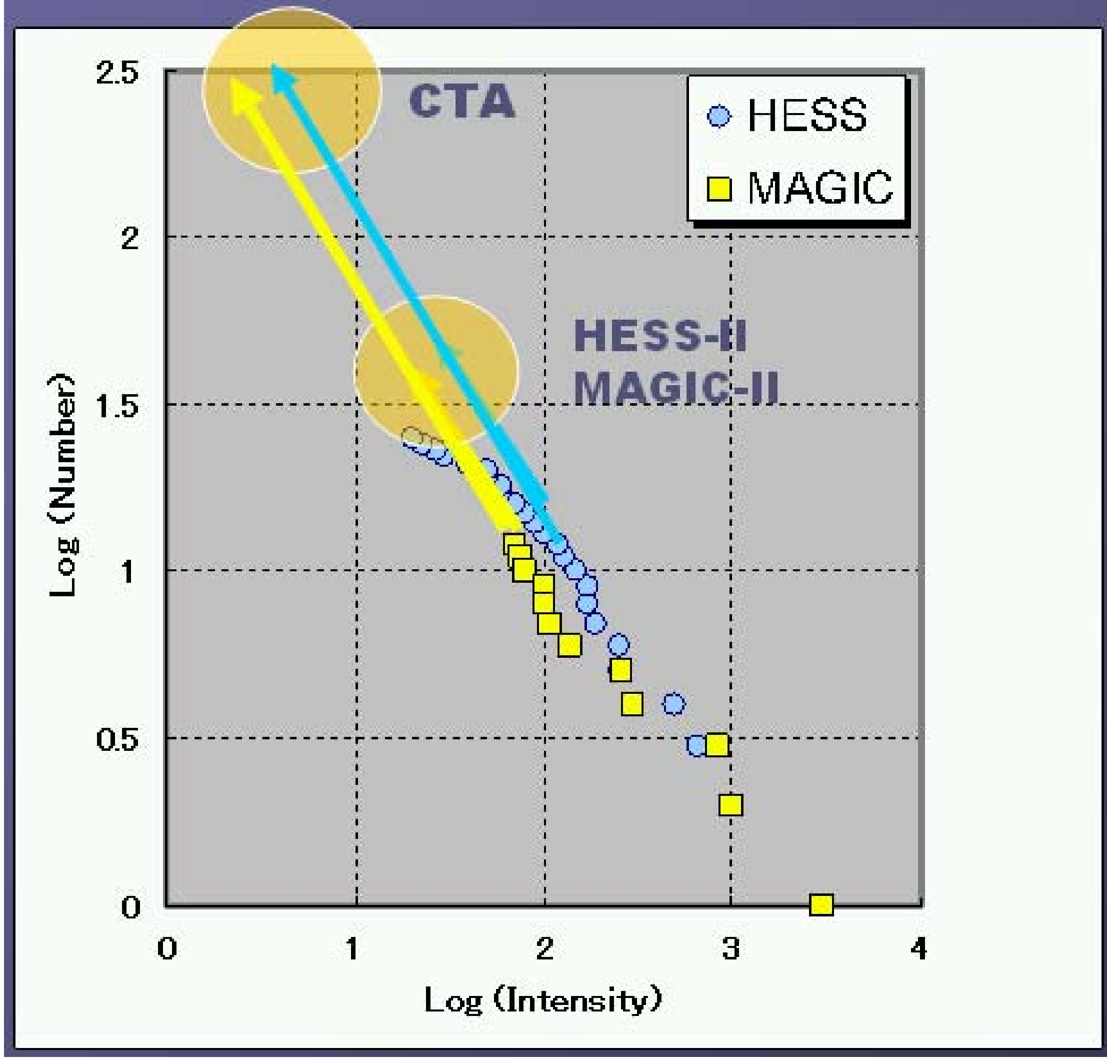


CTA (Cherenkov Telescope Array)



Presented by Masahiro Teshima

VHE Log(S) – Log(N) plot



HESS-I ~30 sources
MAGIC-I ~20 sources

Log(N) ~ -1.0 Log(S) ???

HESS-II ~60 sources
MAGIC-II ~40 sources

CTA 10x (MAGIC+HESS)
CTA South 300~600 srcs.
CTA North 200~400 srcs.

Final words

- Mysteries of highest energy cosmic-rays will be solved soon (I hope).
  - Hybrid detectors on both hemeisphere!
- High-energy neutrino sources should come up shortly.
  - They are guaranteed hadronic accelerators!
- Everyone hopes extensive search for Dark Matter will bear fruit in near future.
  - Now they are reaching sensitivities for discovery!
- High-energy gamma-rays are now established astrophysical probes, and efforts to extend frontiers are enthusiastic.
  - Hadronic vs electronic origin: still ambiguous...need more data!

- Evolution of astroparticle physics is fast!
  Stay tuned!

Thank you!