Selected Highlights from

TeV Particle Astrophysics II

28-31 August 2006, Madison, WI, USA

Jennifer Carson

GLAST lunch talk

September 7, 2006

Working groups & themes

- TeV Particle
- Gamma Astronomy – focus on
- UHECR – mention
- Neutrino Astronomy – mention
- Dark Matter
- Gravitational Waves – mention
- New Technologies

Morning plenary talks, afternoon “working groups”

Gamma astronomy

Gamma-ray astronomy wavebands

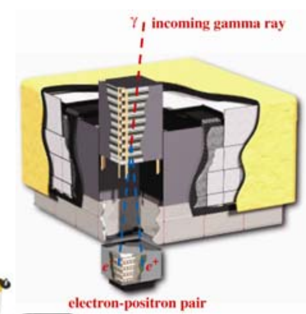
Ground-based air shower particle detectors

MILAGRO/HAWC: E >1-100 TeV

Ground-based atmospheric Cherenkov telescopes

MAGIC, HESS, VERITAS: 0.1-100 TeV

GLAST: 0.1-100 GeV

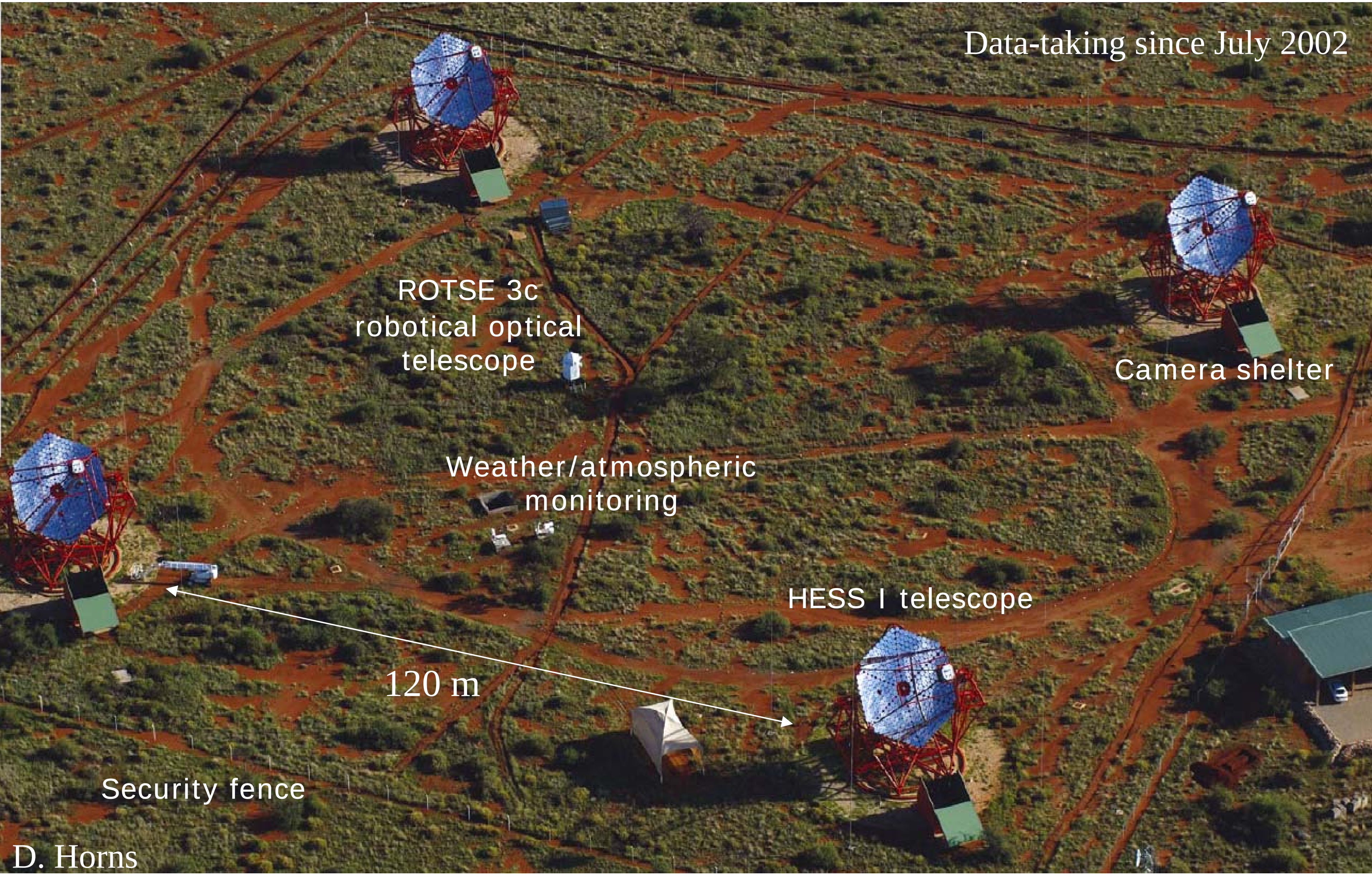


Space observatories

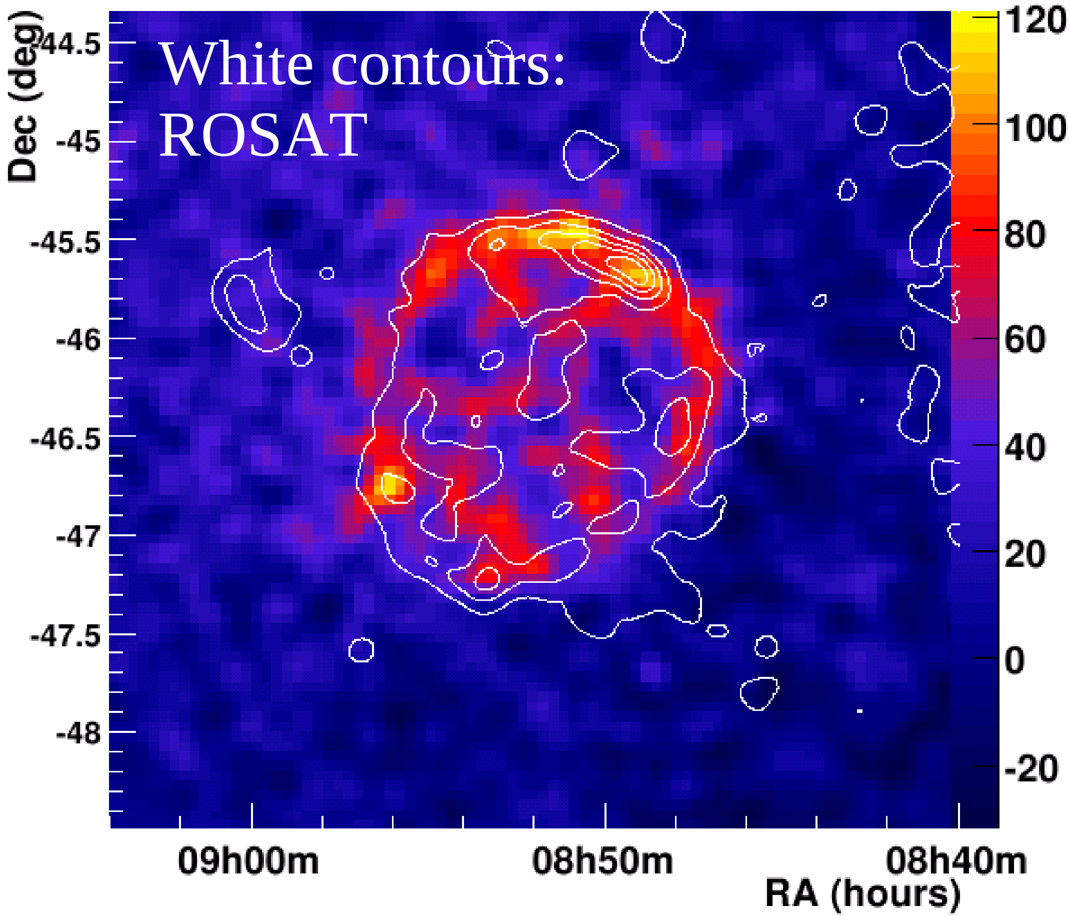
SWIFT: 15-350 keV

F. Krennrich

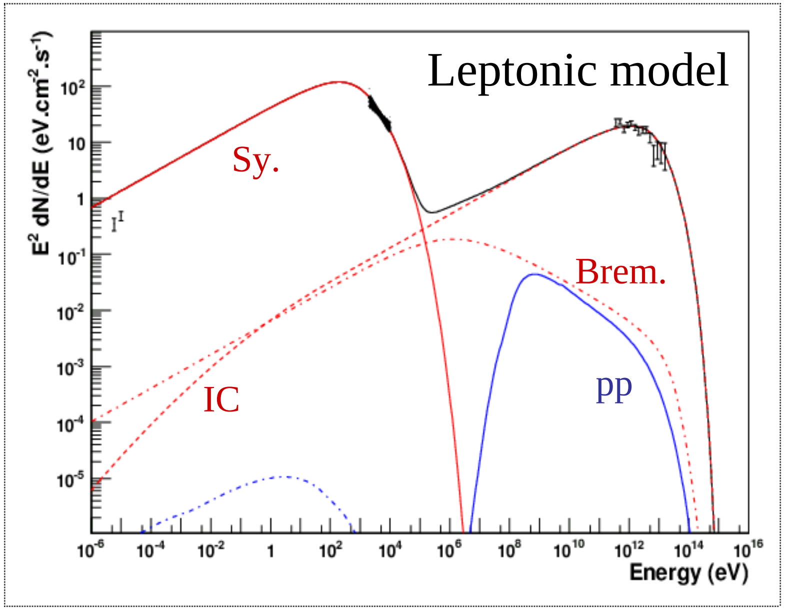
HESS


Data-taking since July 2002
ROTSE 3c
robotical optical
telescope
Camera shelter
Weather/atmospheric
monitoring
HESS I telescope
120 m
Security fence
D. Horns

HESS observations of SNR Vela jr.



- No correlation with gas density (CO observations):
  Hadronic model not likely!
- X-ray/TeV data can be fit by IC model
- Low B ~ 6 μG, low density 0.1 cm^{-3}
- Shell thickness - distance constraint

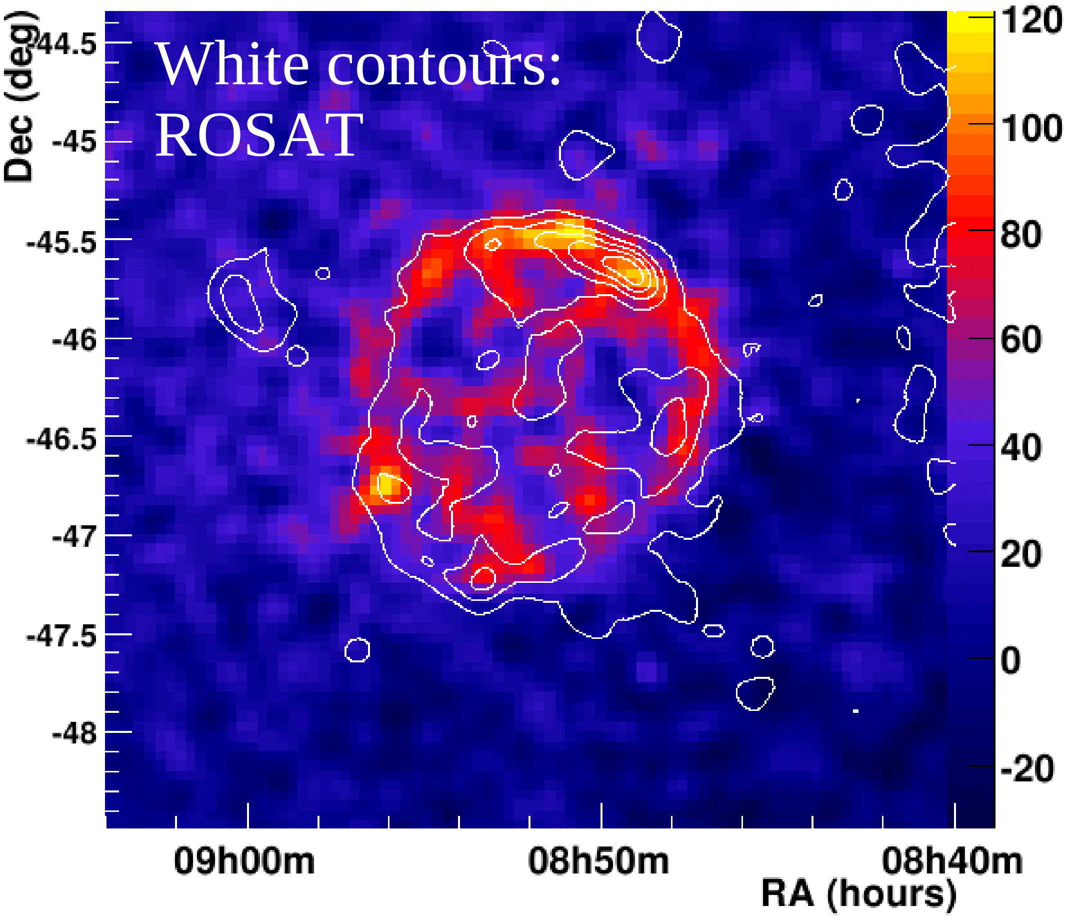


X-ray emission correlates with TeV emission at 70% level:

--> <u>could</u> be indication for leptonic origin

D. Horns

HESS observations of SNR Vela jr.



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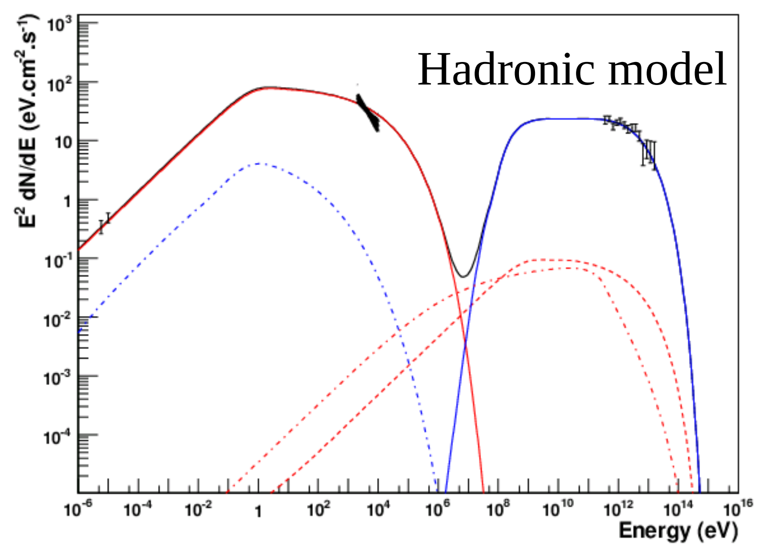


--> hadronic model does not fit SED

D. Horns

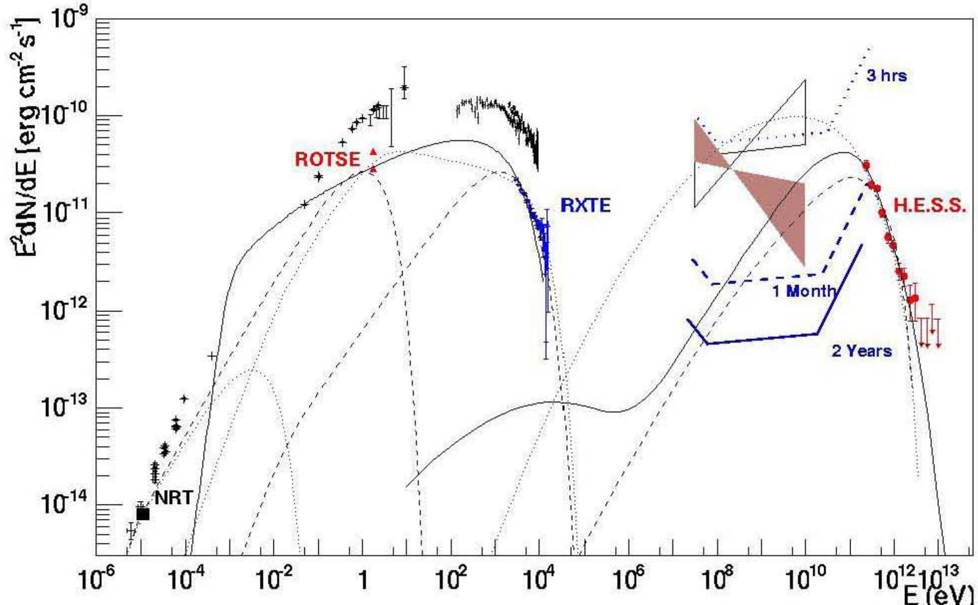
HESS extragalactic source: PKS 2155

- The brightest southern hemisphere extragalactic object

  Low var compared to Mkn's until Crab-level fluxes end July 2006 (ATel 867)

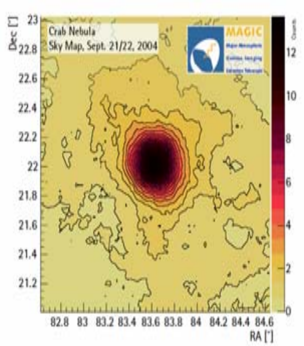
- VHE "quiescent" state *extremely* interesting for modelling - steady state emission is rarely mentioned

- Promising candidate for GLAST-HESS observations (steep spectrum)

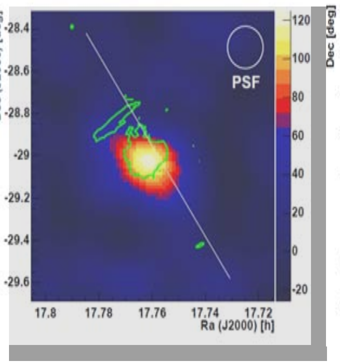


B. Giebels

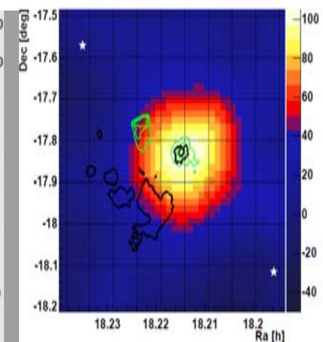
MAGIC highlights of the first year



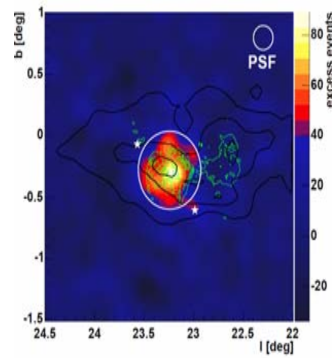
Crab Nebular
SZA & LZA



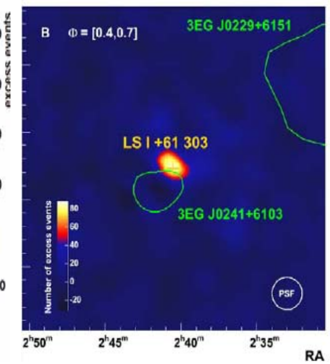
Galactic Center



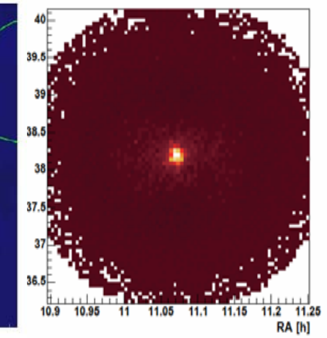
HESS J1813



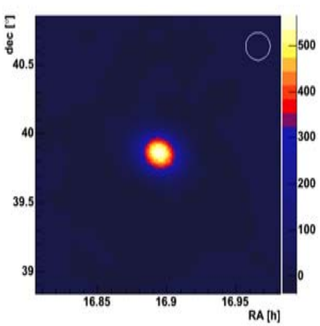
HESS J1834
^{13}CO cloud



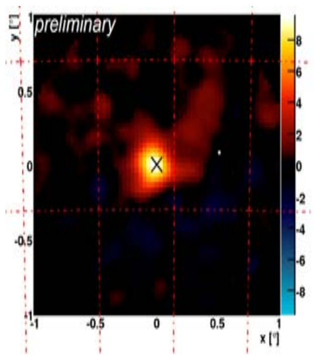
LSI+61 303
Micro-Quasar
New Source



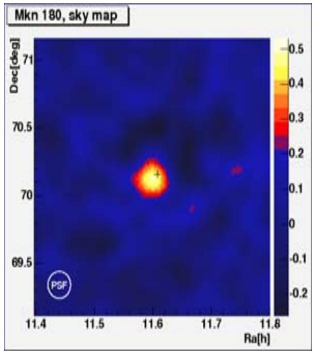
Mrk421 (0.031)



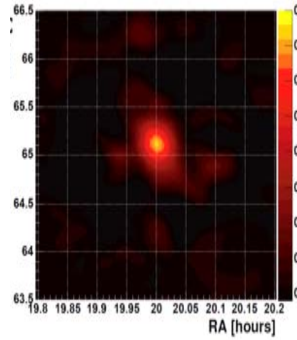
Mrk501 (z=0.034)



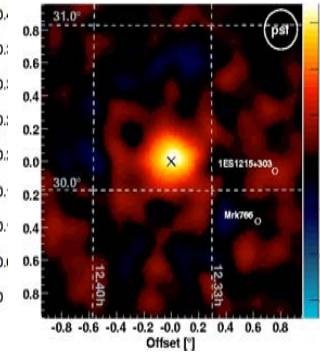
1ES2344 (z=0.044)



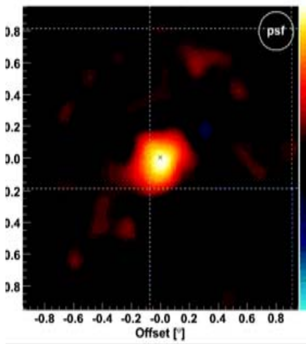
Mrk180 (0.045)
New source



1ES1959 (0.047)



1ES1218 (z=0.18)
New Source



PG 1553 (Z>0.25)
New source

M. Teshima

13 TeV AGN

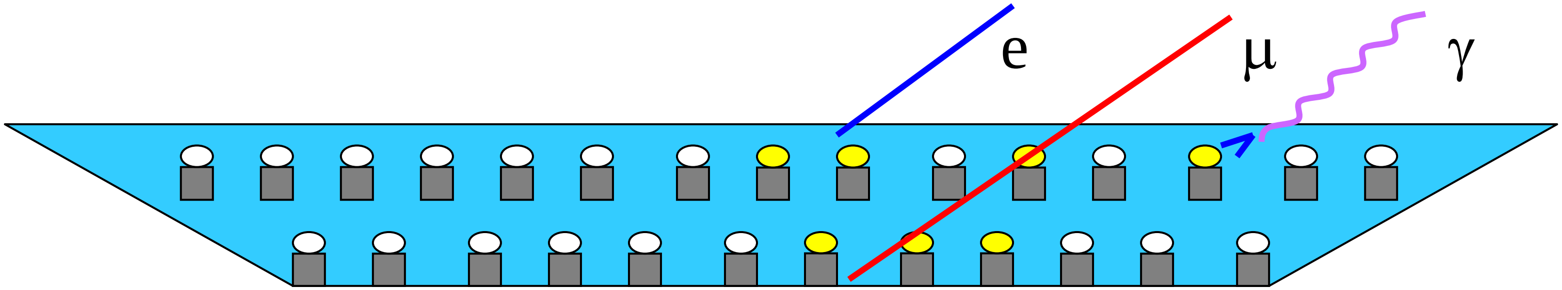
Radio galaxy: blazar viewed offaxis (~35 deg.)

Source	Redshift	Spectral Index	Type	First Detection
M87	0.004	2.9	FR I	HEGRA
Mkn 421	0.031	2.2	BL Lac	Whipple
Mkn 501	0.034	2.4	BL Lac	Whipple
1ES 2344+514	0.044	2.9	BL Lac	Whipple
Mkn 180	0.045	3.3	BL Lac	MAGIC
1ES 1959+650	0.047	2.4	BL Lac	Tel. Array
PKS 2005-489	0.071	4.0	BL Lac	HESS
PKS 2155-304	0.116	3.3	BL Lac	Mark VI
H1426+428	0.129	3.3	BL Lac	Whipple
H2356-309	0.165	3.1	BL Lac	HESS
1ES 1218+304	0.182	3.0	BL Lac	MAGIC
1ES 1101-232	0.186	2.9	BL Lac	HESS
PG 1553	>0.25	4.0	BL Lac	HESS/MAGIC

Extragalactic Background Light: EBL in near-IR

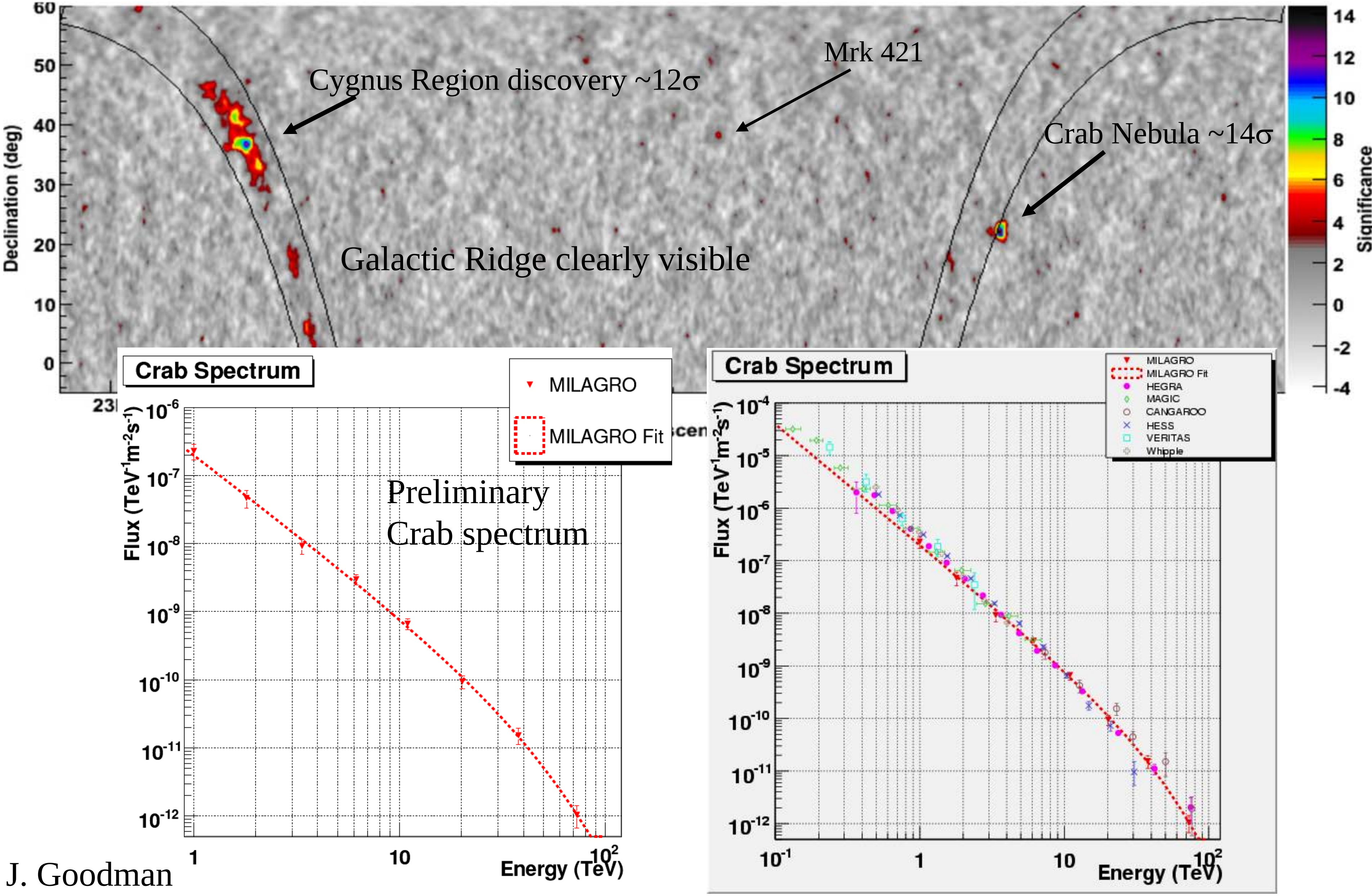
F. Krennrich

Milagro: ground-based particle detector



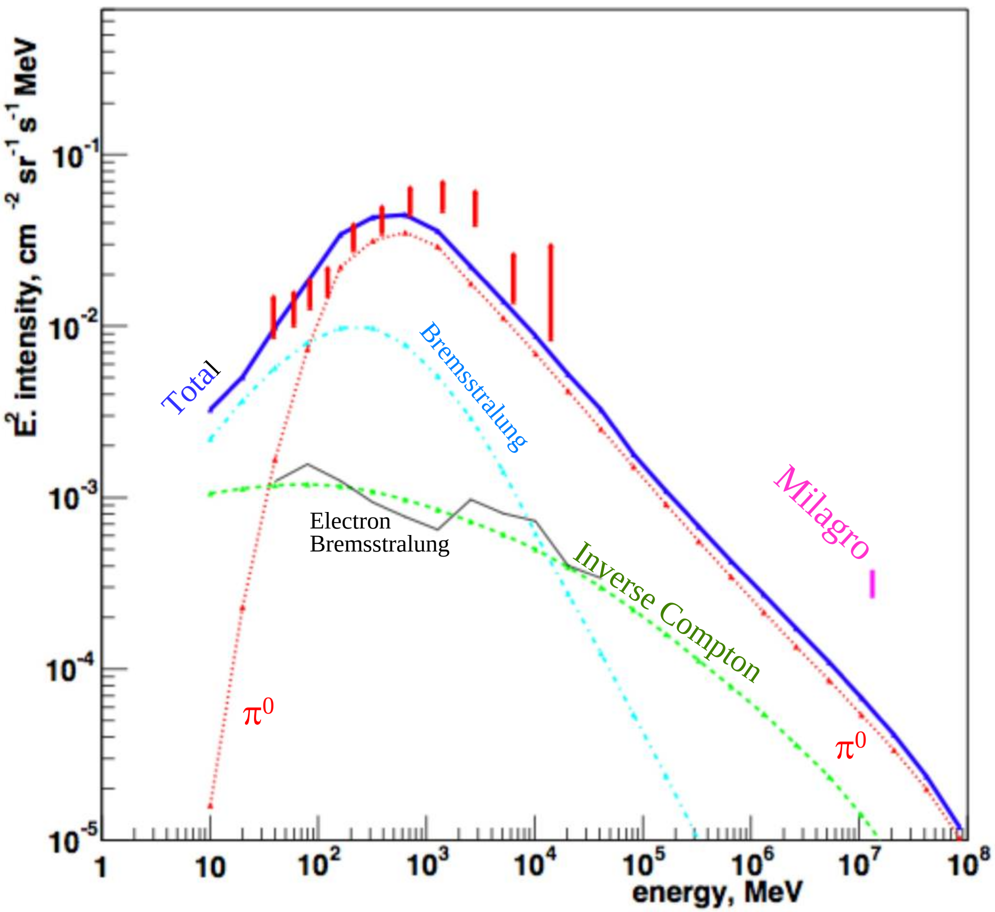
J. Goodman

Milagro sky survey



J. Goodman

Diffuse emission from Cygnus region



- Strong & Moskalenko standard model
  - Fit to EGRET < 1 GeV
  - Increase π^0 and IC component throughout Galaxy
  - Milagro ~5x above prediction
  - Unresolved sources?
  - Proton accelerators?

J. Goodman

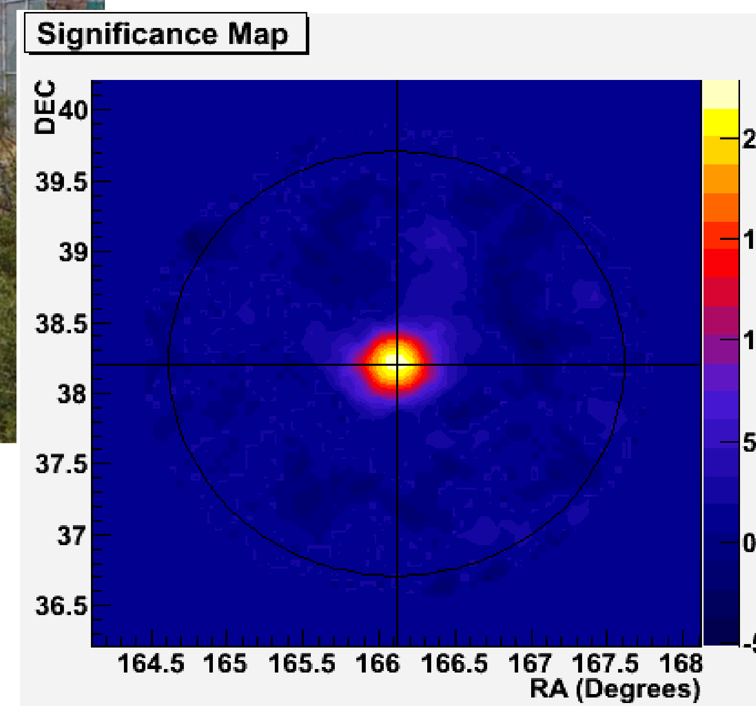
VHE source accounting

12 Blazars
1 Radio galaxy
2 Microquasars
2 Shell-type SNRs
10 PWNe
4 Composite PWNe/SNRs
1 Binary pulsar
15 UIDs (12+3)

47 sources + diffuse region!

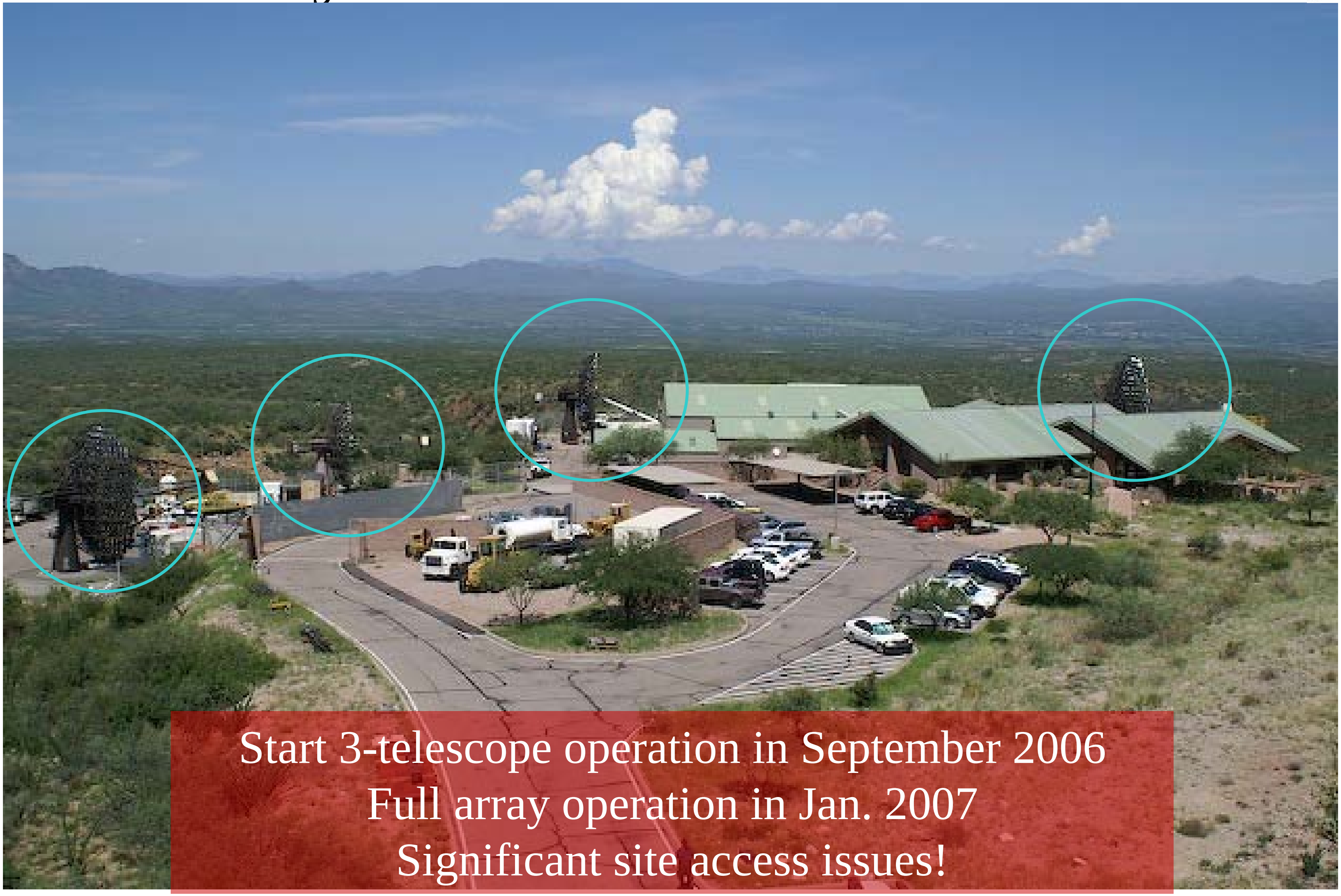
Very near future: VERITAS status

Mrk421 Stereo observation



F. Krennrich

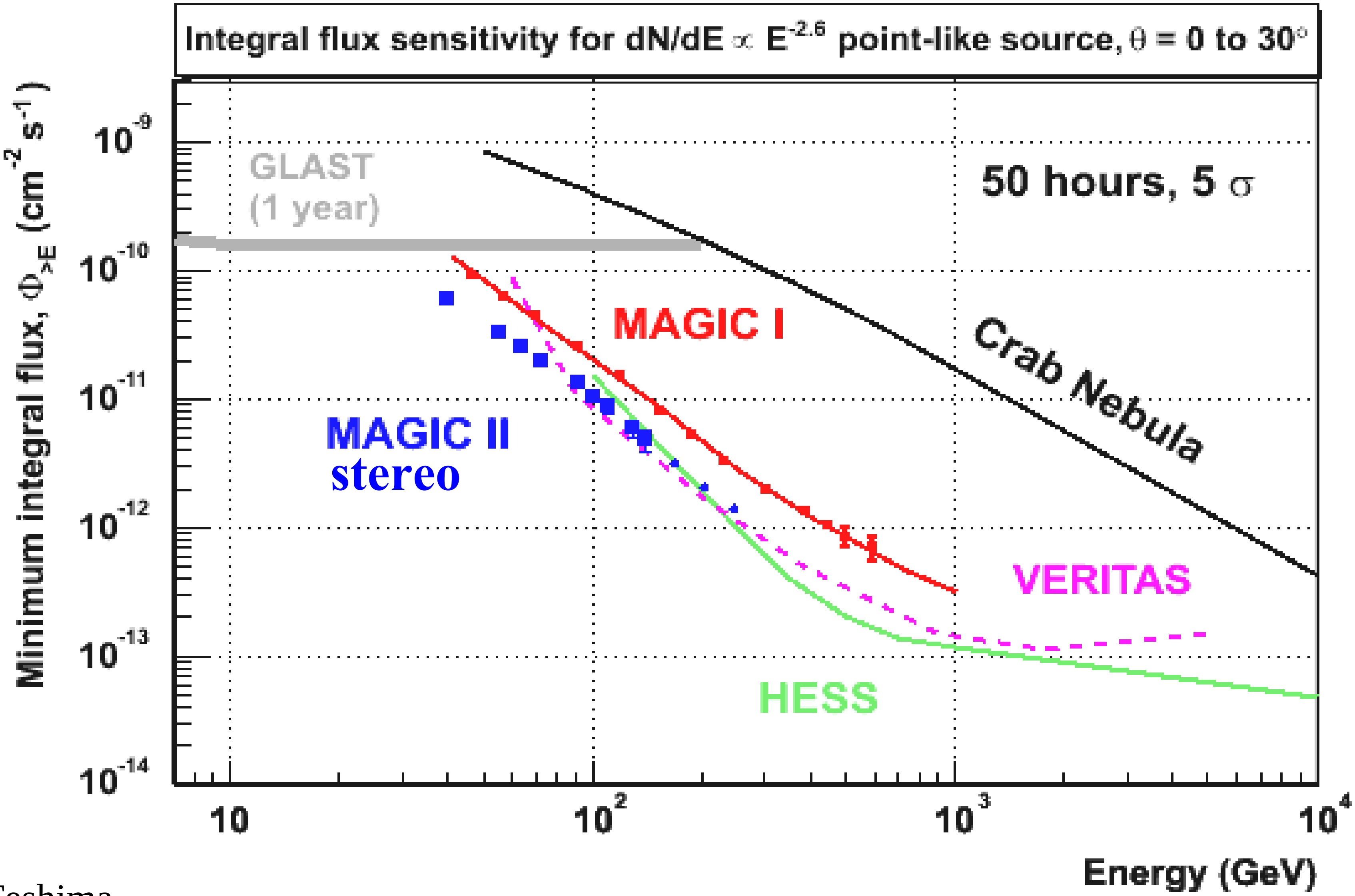
Very near future: VERITAS-4



Start 3-telescope operation in September 2006
Full array operation in Jan. 2007
Significant site access issues!

F. Krennrich

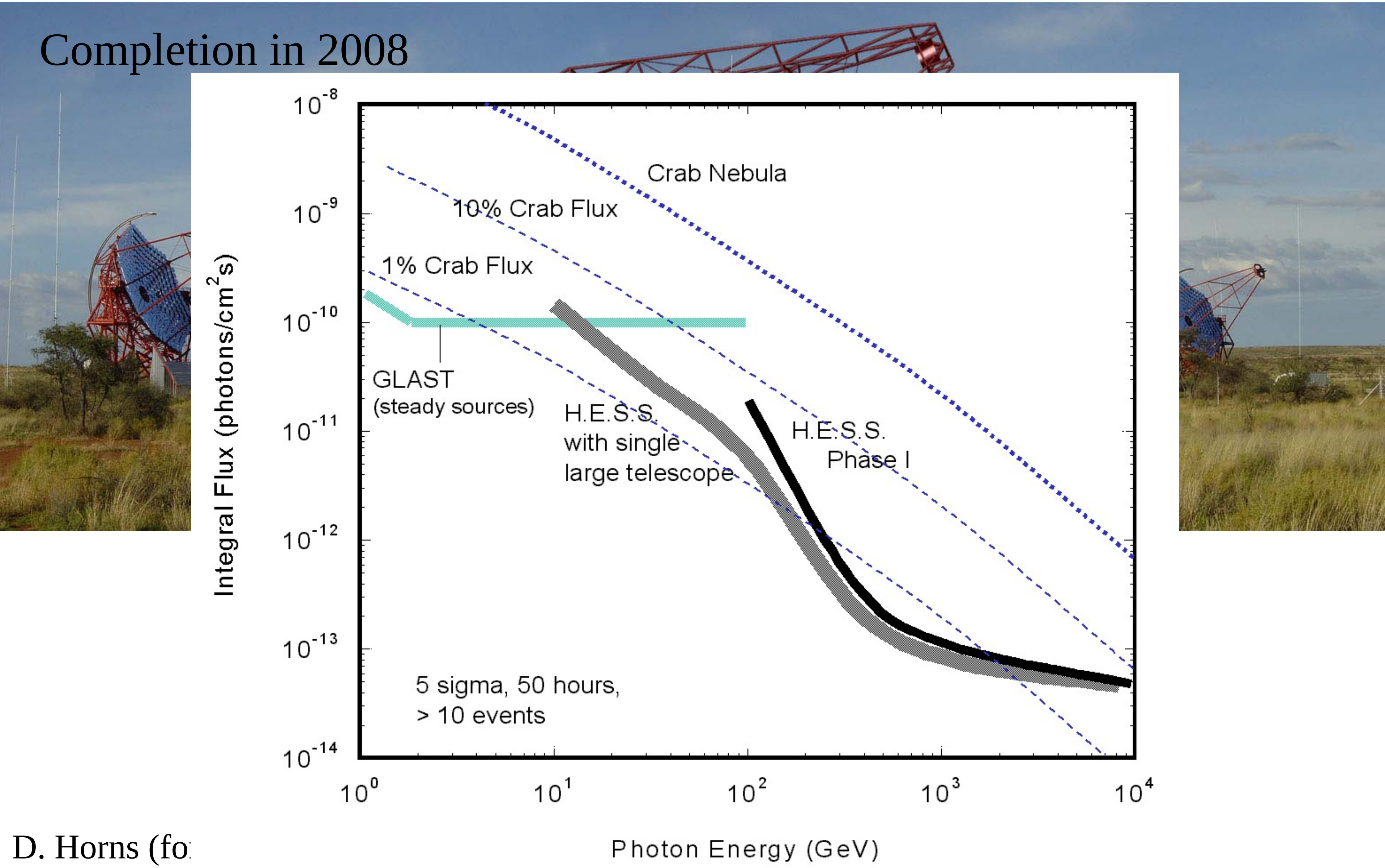
Near future: MAGIC-II



M. Teshima

Near future: HESS-II

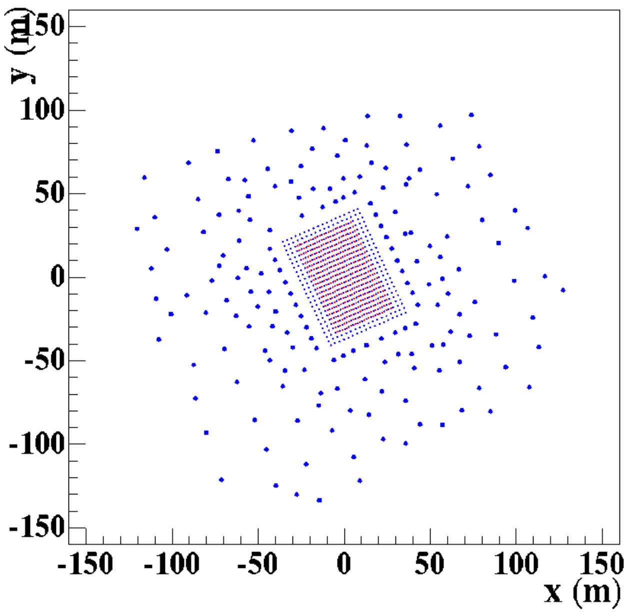
Completion in 2008



D. Horns (fo

Not-so-near future: **H**igh **A**ltitude **W**ater **C**herenkov Experiment

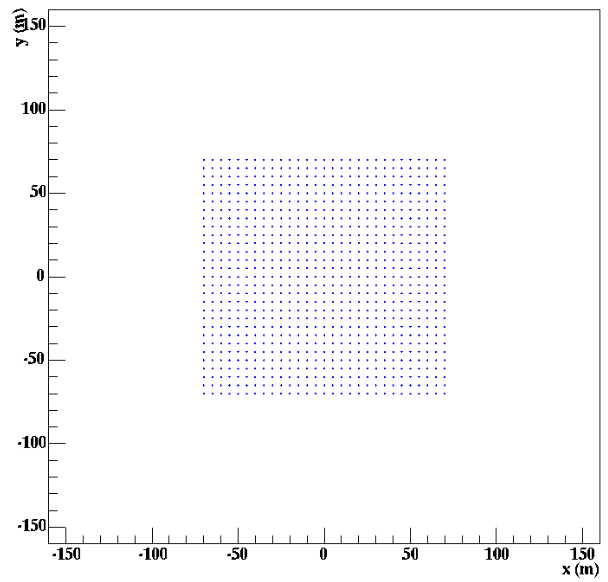
Milagro



450 PMT (25x18) shallow (1.4m) layer
273 PMT (19x13) deep (5.5m) layer
175 PMT outriggers

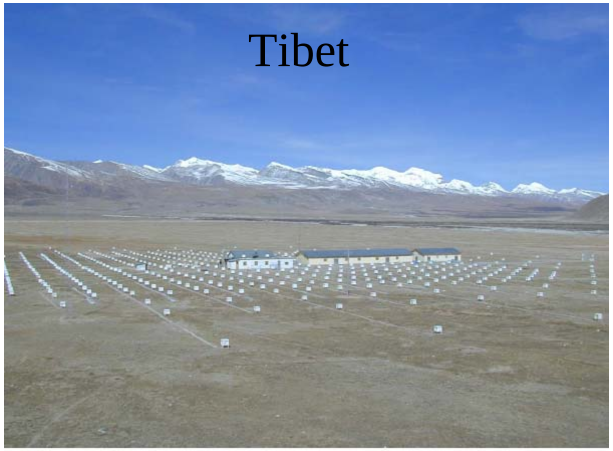
Instrumented Area:	~40,000m^2
PMT spacing:	2.8m
Shallow Area:	3500m^2
Deep Area:	2200m^2

HAWC



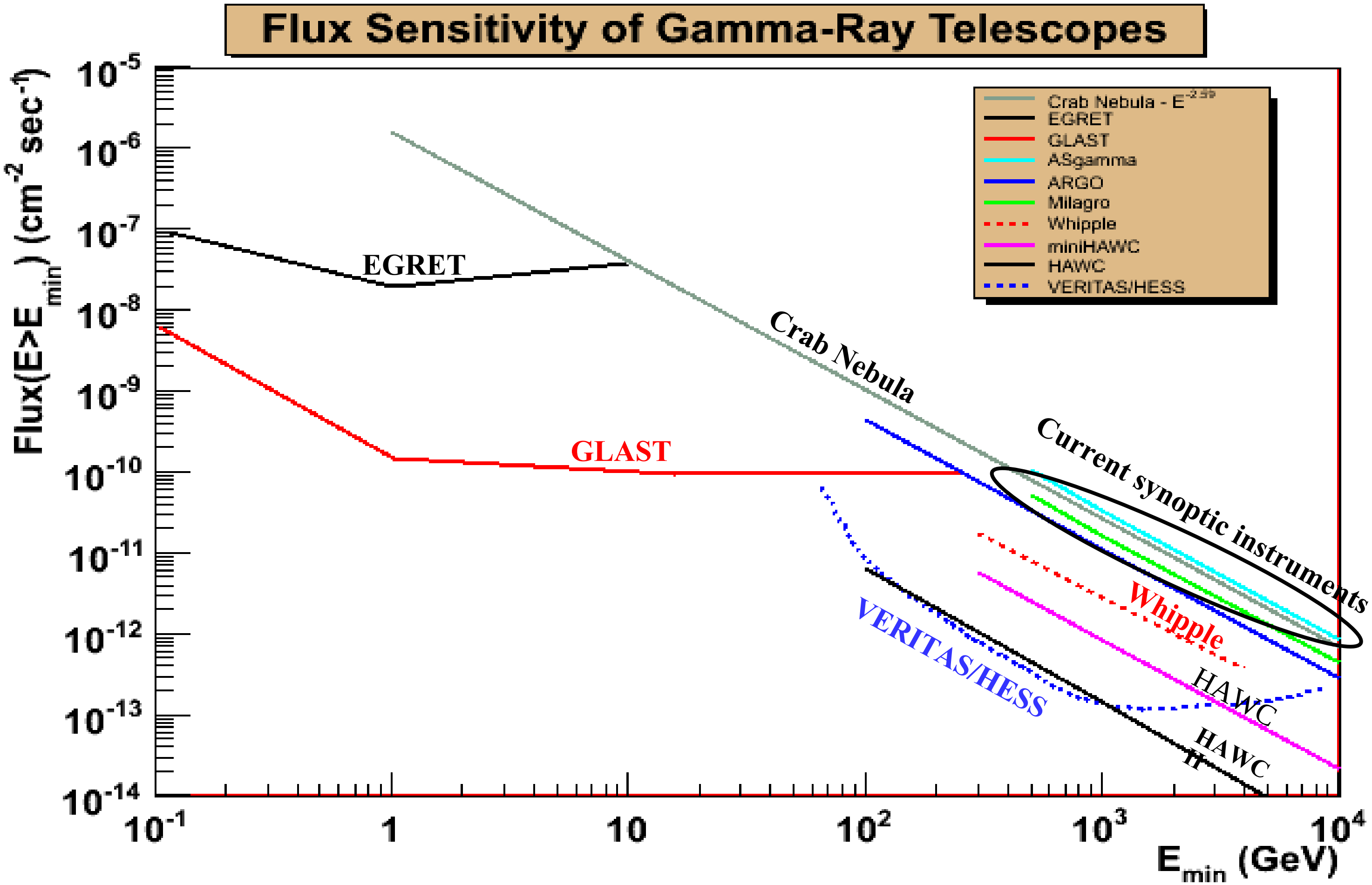
900 PMTs (30x30)
5.0m spacing
Single layer with 4m depth

Instrumented Area:	22,500m^2
PMT spacing:	5.0m
Shallow Area:	22,500m^2
Deep Area:	22,500m^2



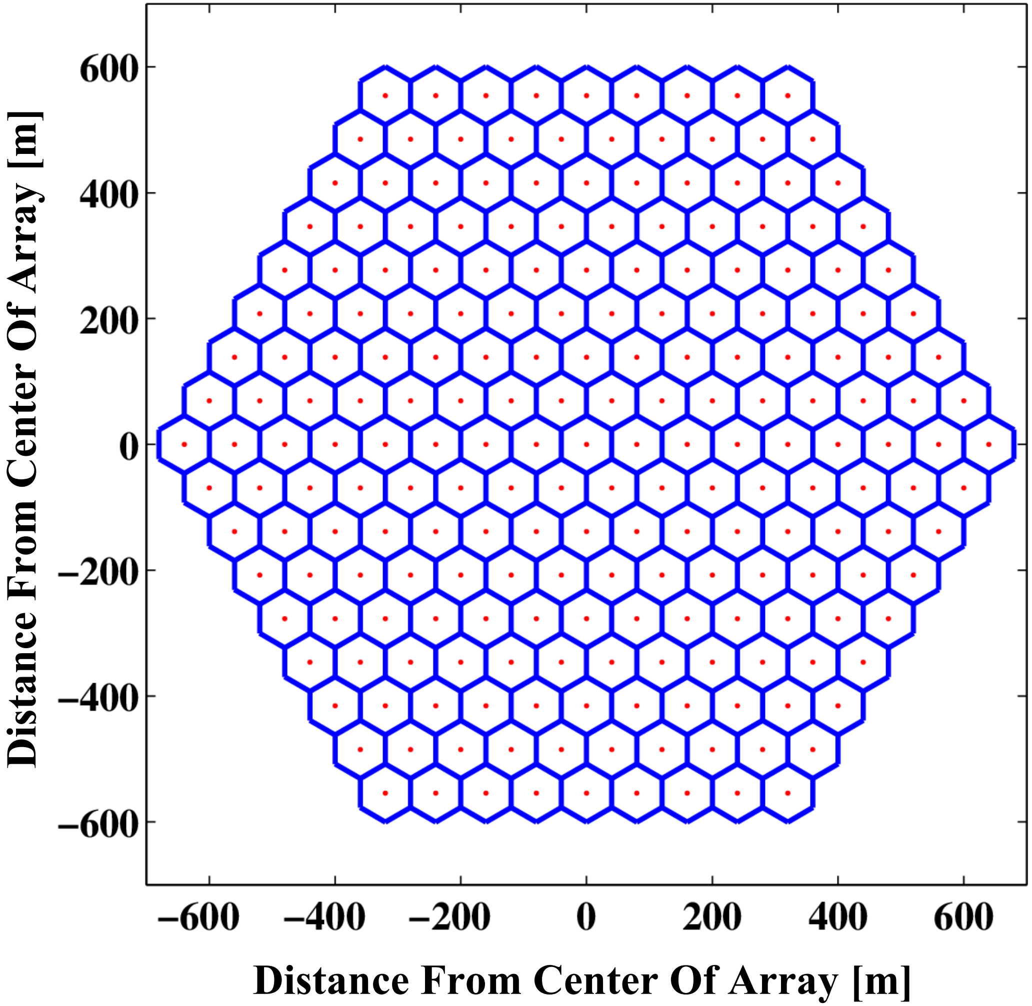
A. Smith

Not-so-near future: **H**igh **A**ltitude **W**ater **C**herenkov Experiment



A. Smith

Far future: **H**igh **E**nergy **A**ll **S**ky **T**ransient **R**adiation **O**bservatory



Array

1. **217 telescopes**
2. **8 hexagonal rings + 1**
3. **80m separation**

Telescope and Detector

1. **ø10m equivalent**
2. **QE = 0.25 (Bialkali)**
3. **15º field of view**

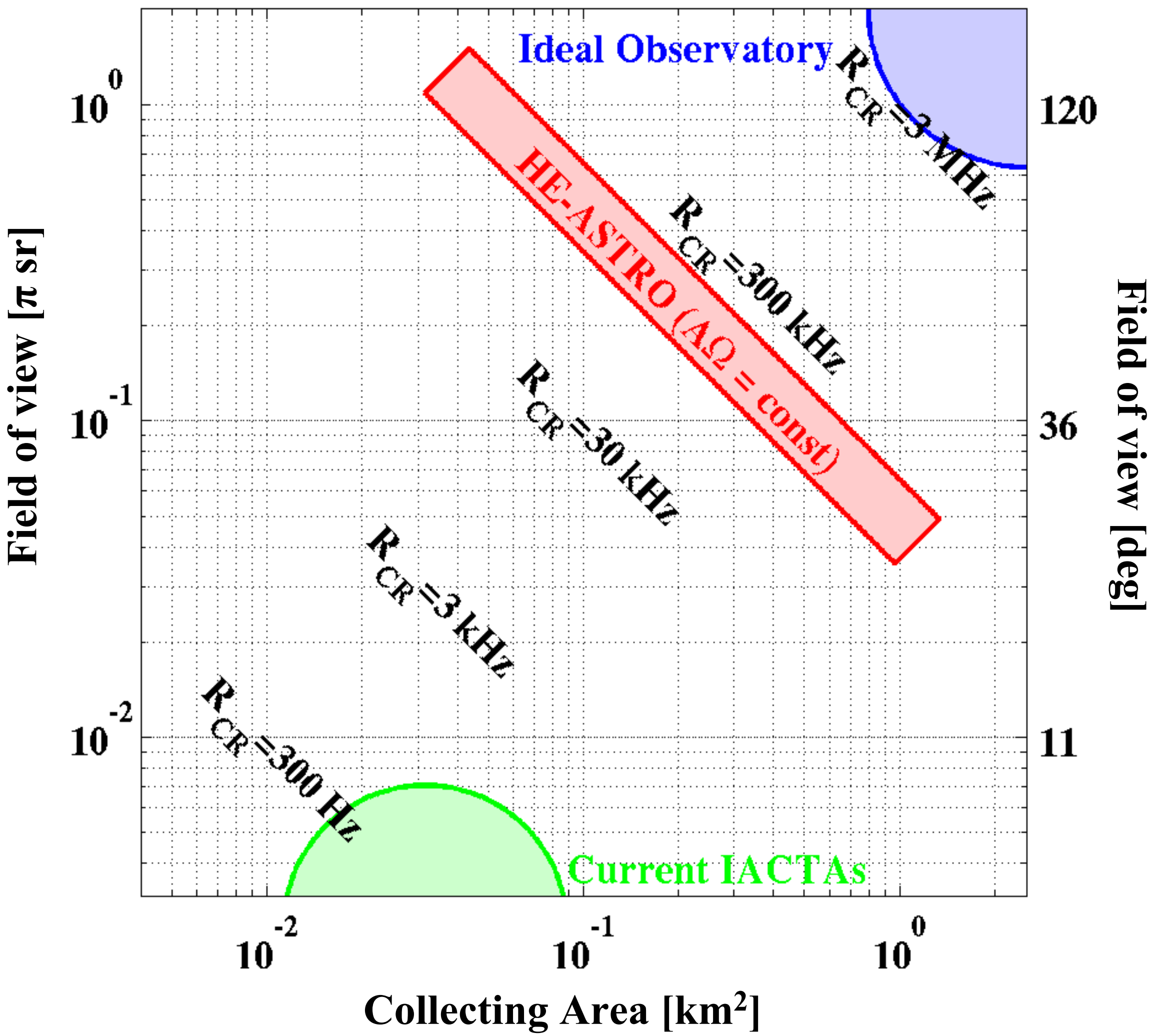
Facts and Figures

1. **Outer radius: 640m**
2. **Single cell area: 5543m^2**
3. **Total area: 1.06km^2**

S. Fegan, V. Vassiliev, UCLA, astro-ph/0511342

S. Swordy

Far future: **H**igh **E**nergy **A**ll **S**ky **T**ransient **R**adiation **O**bservatory



Current IACTAs
Narrow field of view
<0.01 km^2 @ 40 GeV
0.05-0.1 km^2 @ 100 GeV
0.2-0.3 km^2 @ 10 TeV

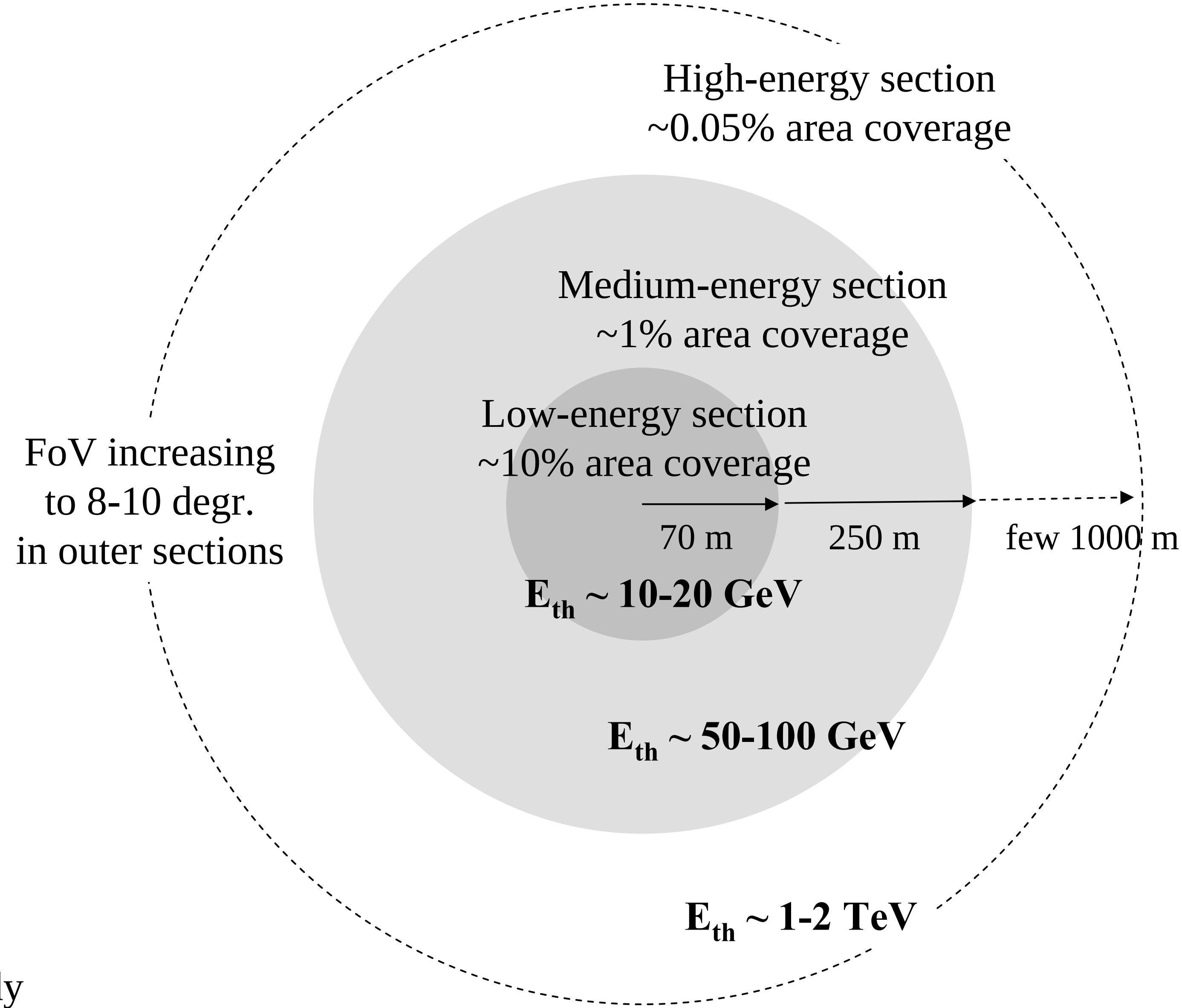
Square KM Array
Continuum of modes
Trade area for solid angle

Parallel mode
Narrow field of view
1 km^2 @ 40 GeV
2 km^2 @ 100 GeV
4-5 km^2 @ 10 TeV

"Fly's Eye" mode
Wide field of view
0.02-0.03 km^2 @ 40 GeV
0.1-0.2 km^2 @ 100 GeV
3-4 km^2 @ 10 TeV

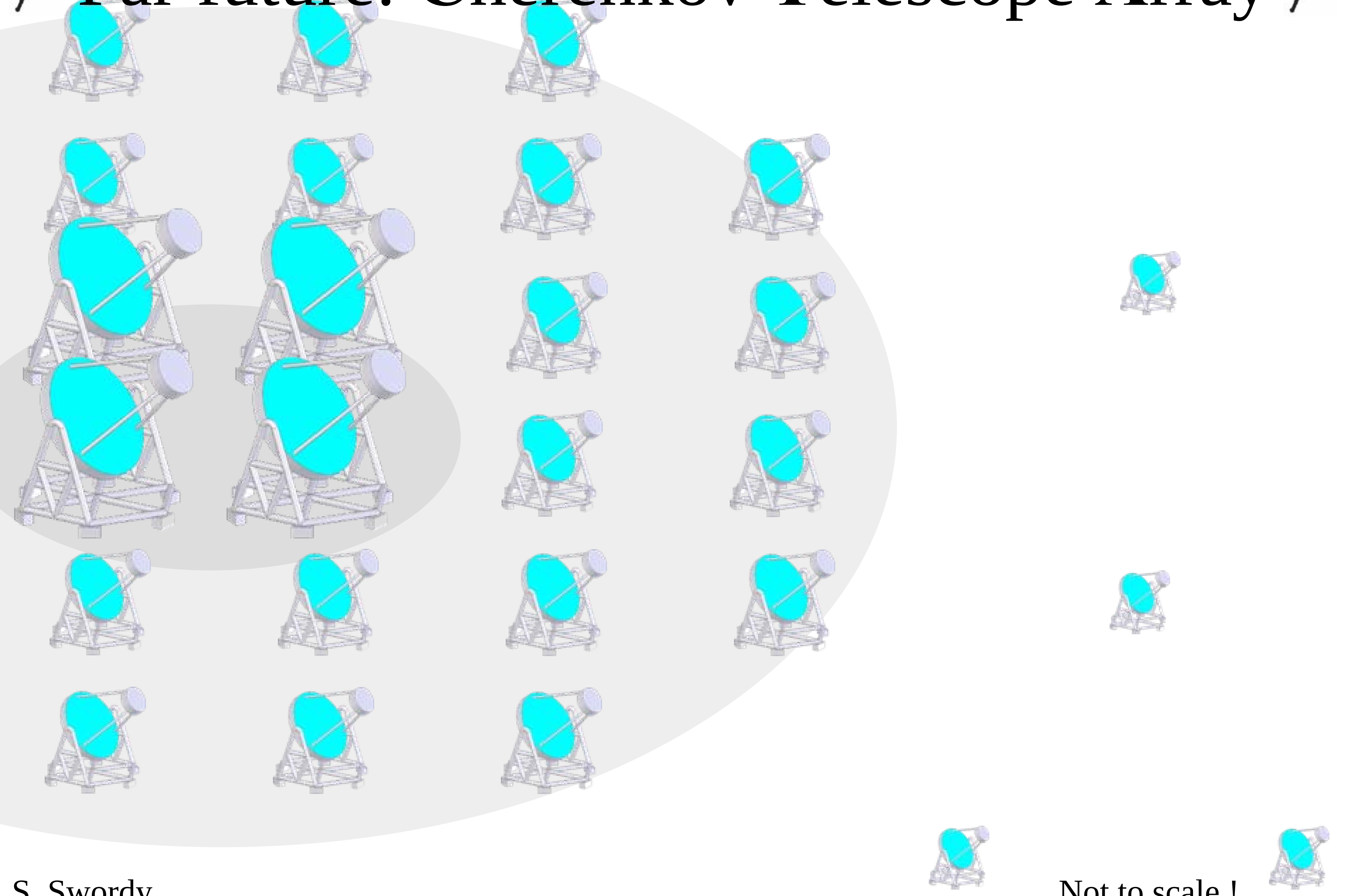
S. Swordy

Far future: **C**herenkov **T**elescope **A**rray



S. Swordy

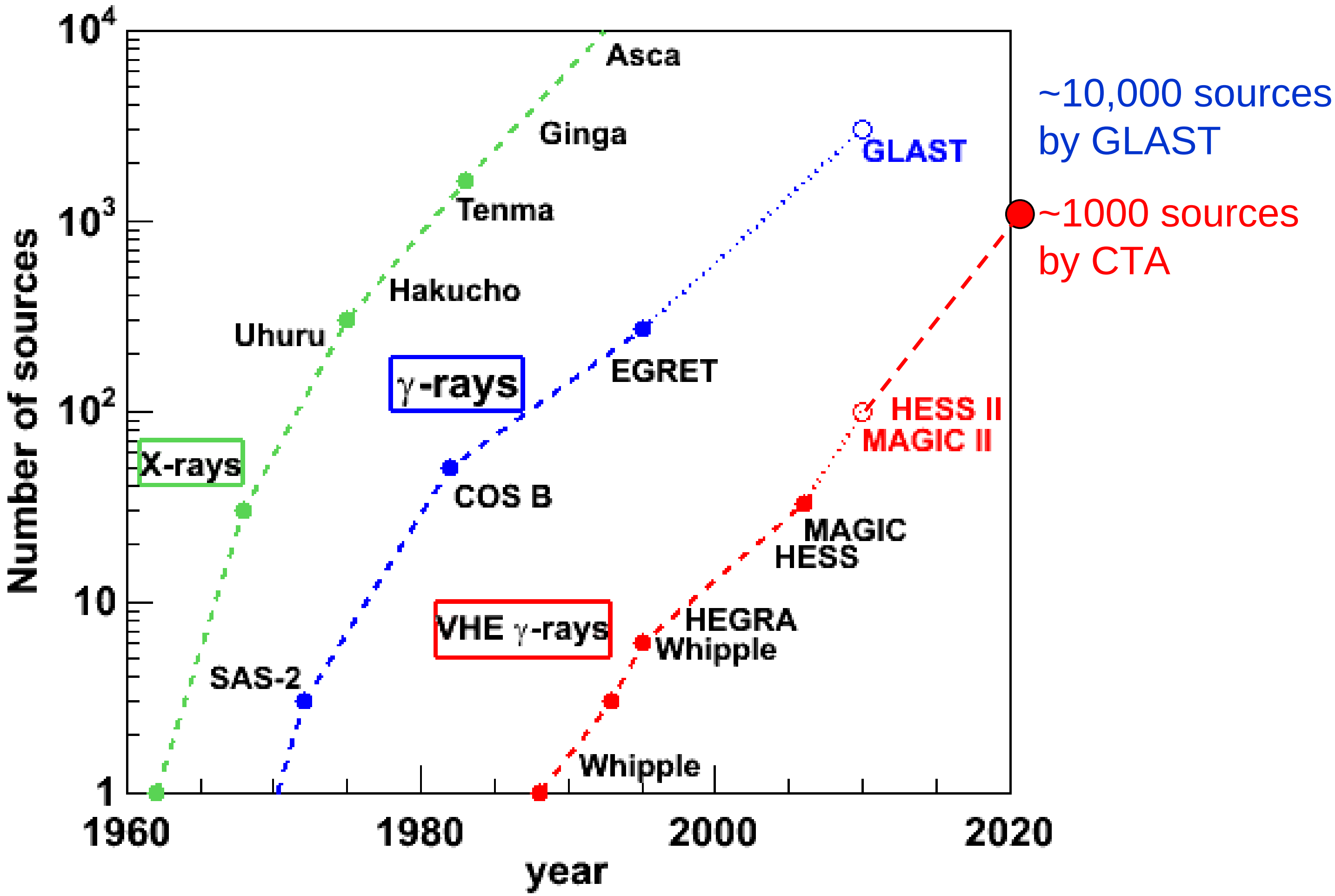
Far future: **C**herenkov **T**elescope **A**rray



S. Swordy

Not to scale !

“Kifune’s Plot”



M. Teshima

VHE science questions & answers

- Cosmic Rays: supernova remnant origin?

Not clear despite TeV detections: great techniques to probe hadrons!

- Relativistic jets: blazars, GRBs, microquasars, how do they work?

Testing emission models in jets! Probing closer to central objects!

- Galaxy in diffuse gamma rays: have we accounted for all contributors?

TeV detection, need more data with wide FOV and high ang. resolution!

- How transparent is the universe to gamma rays?

Probably more than previously thought, z ~ 1-1.5 at 100 GeV?

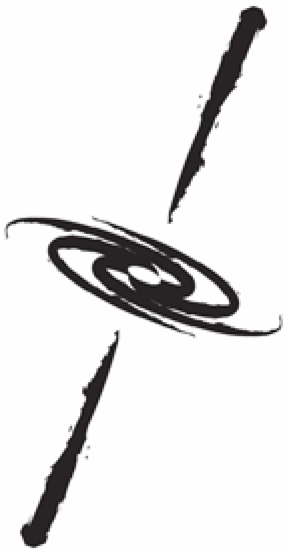
- GRBs: what are the prospects for very high energy emission?

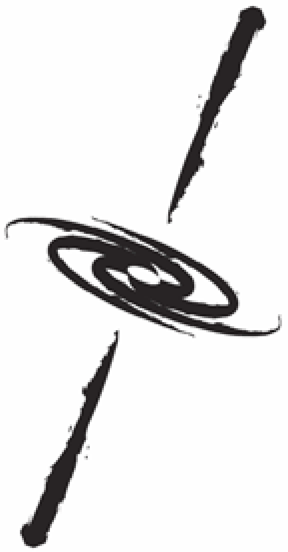
Early afterglow (X-ray flares) for IACTs at 100 GeV, low EBL!

- What is the future of this field?

Like X-ray astronomy but at a higher level! (TeV vs. keV)!

F. Krennrich





Cosmic rays

Cosmic ray spectrum

10^{20} eV proton

16 joules energy

Kinetic energy of Yanick Noah's second serve

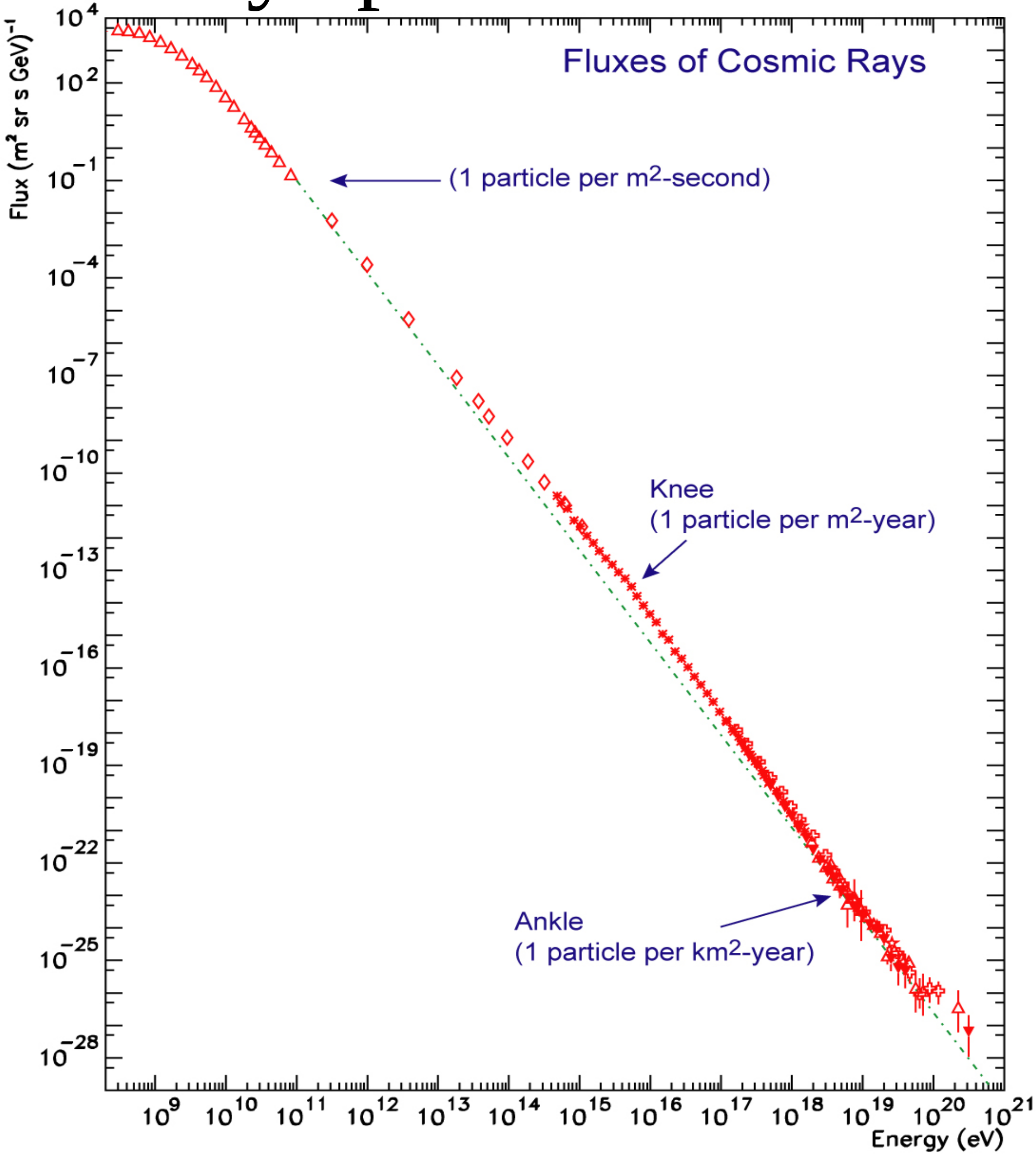
But momentum of a snail

Macroscopic energy in a microscopic particle

No known astrophysical sources "seem" able to produce such enormous energies

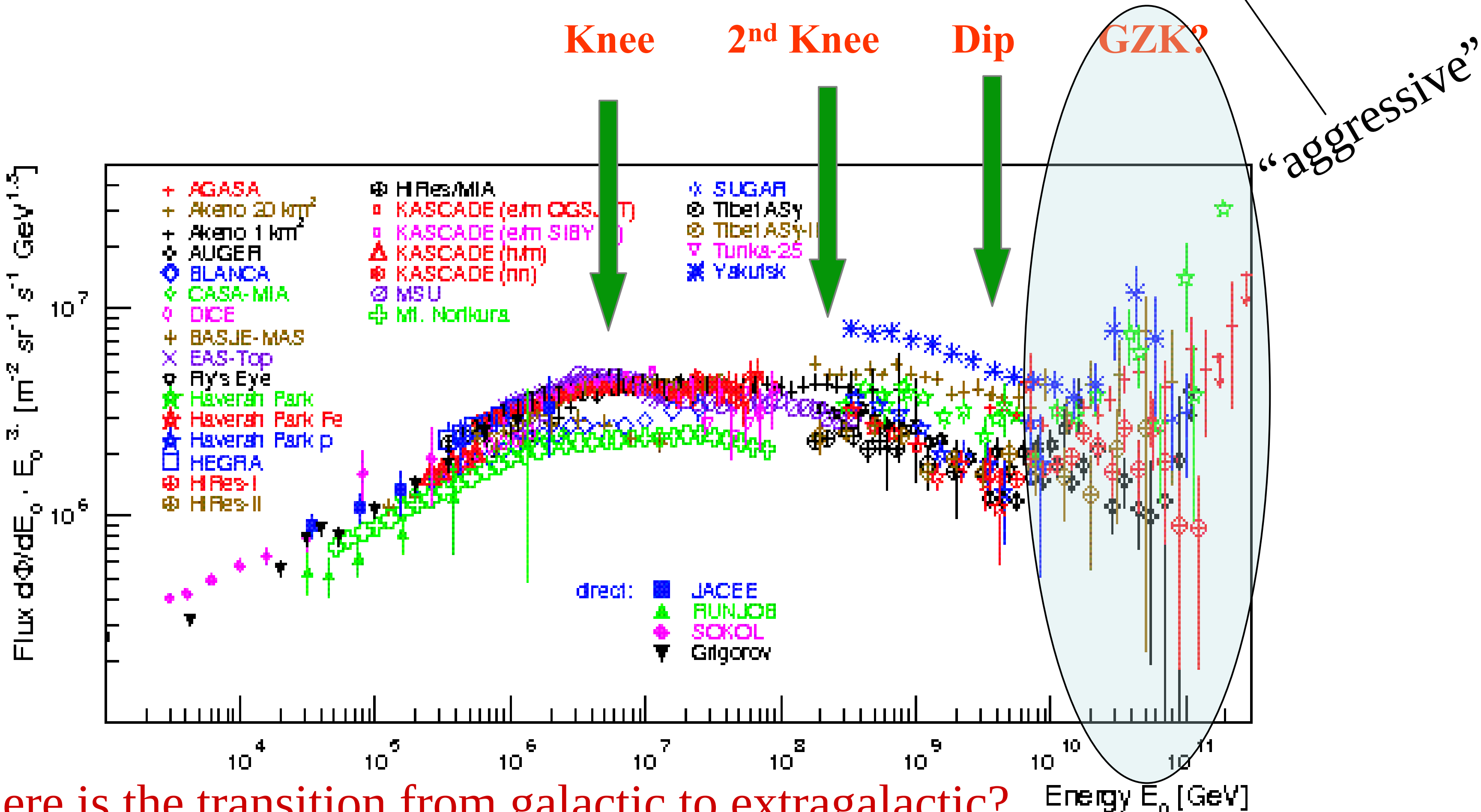
1/ km^2/ century

3000 km^2 -> 30 events / year



J. Cronin

High-energy CR spectrum (flux × E^3)



Where is the transition from galactic to extragalactic?

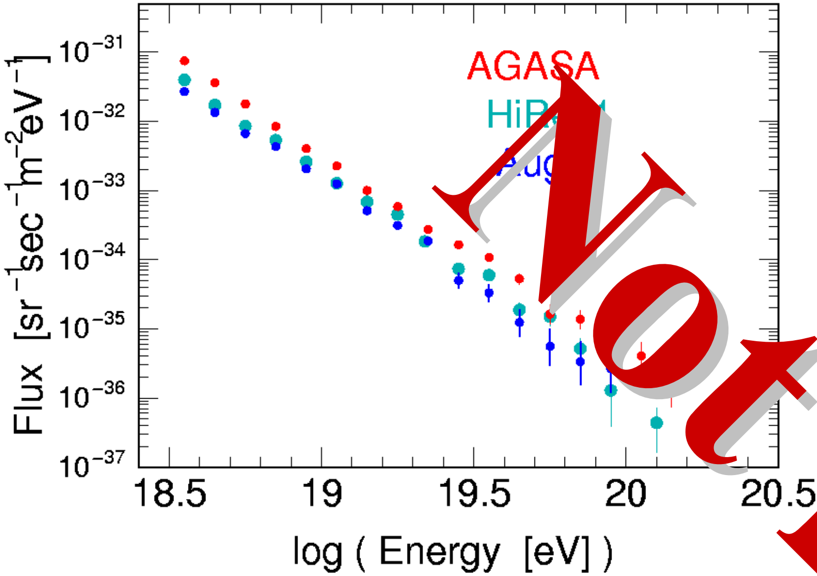
→ Second knee or ankle/dip

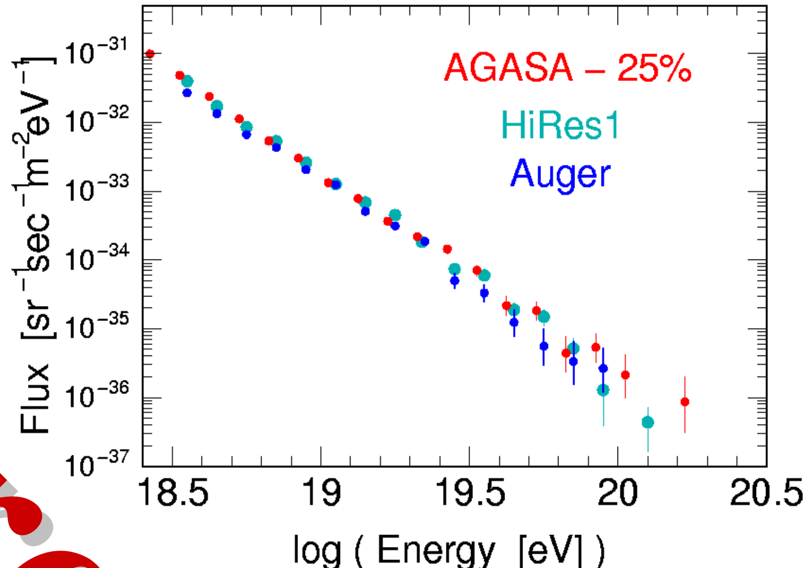
→ Very important for the origin of UHECRs

→ Composition is crucial to spectrum

P. Blasi

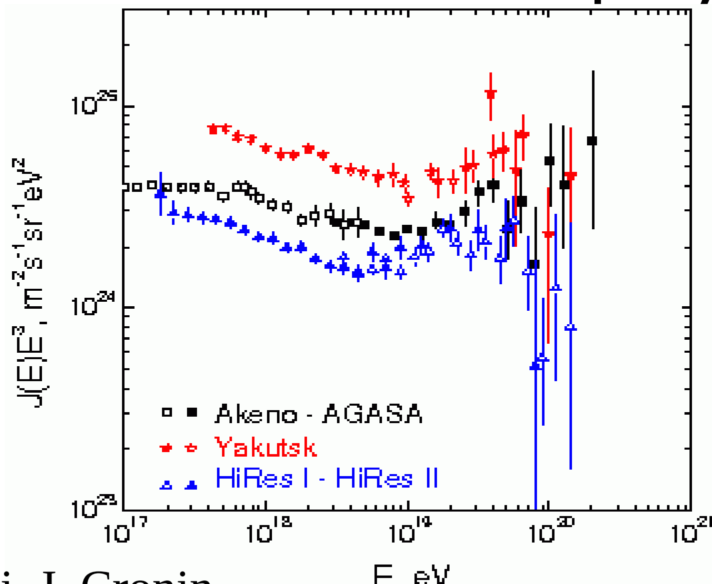
UHE discrepancy?

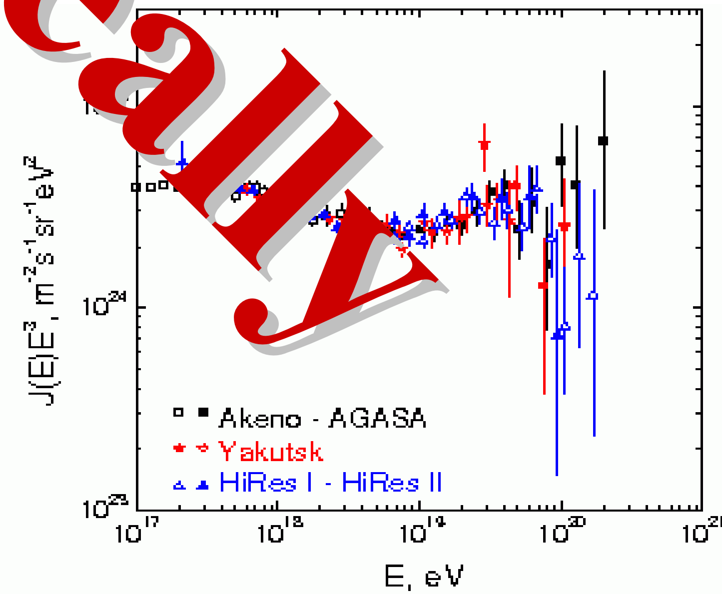




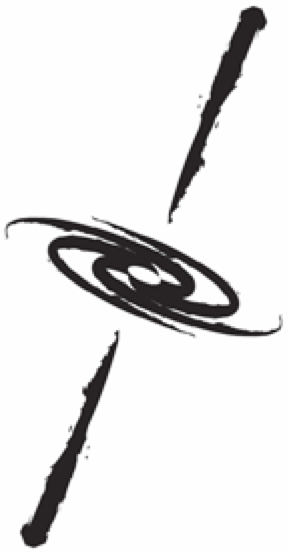
Not really

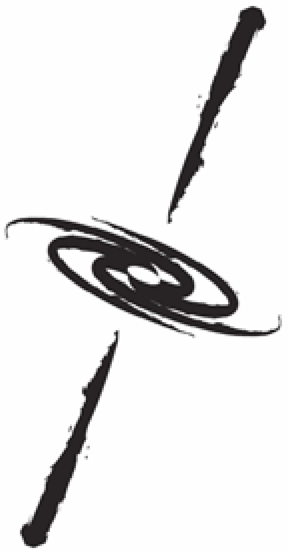
The actual discrepancy is 1-2 standard deviations





P. Blasi, J. Cronin





Neutrino astronomy

General Remarks on Neutrinos

Existence of Xgal neutrinos inferred from CR spectrum, up to 10^{20} eV,
and similarly, Galactic up to 10^{18} eV,

Need gigaton (km^3) mass (volume) for TeV to PeV detection [e.g. IceCube Xpt]
but a teraton of mass at 10^{19} eV
➔ SPACE-BASED [e.g. EUSO Xpt]

Neutrino eyes see farther (z>1),
and deeper (into compact objects) than gamma-photons,
and straighter than HECRs,
with no absorption at (almost) any energy

Tom Weiler,
Vanderbilt University

Neutrino-rays versus Cosmic-Rays and Photons

νs come from central engines

- near R_s of massive BHs
- even from dense "hidden" sources
  cf. νs vs. γs from the sun

νs not affected by cosmic radiation

(except for annihilation resonance)

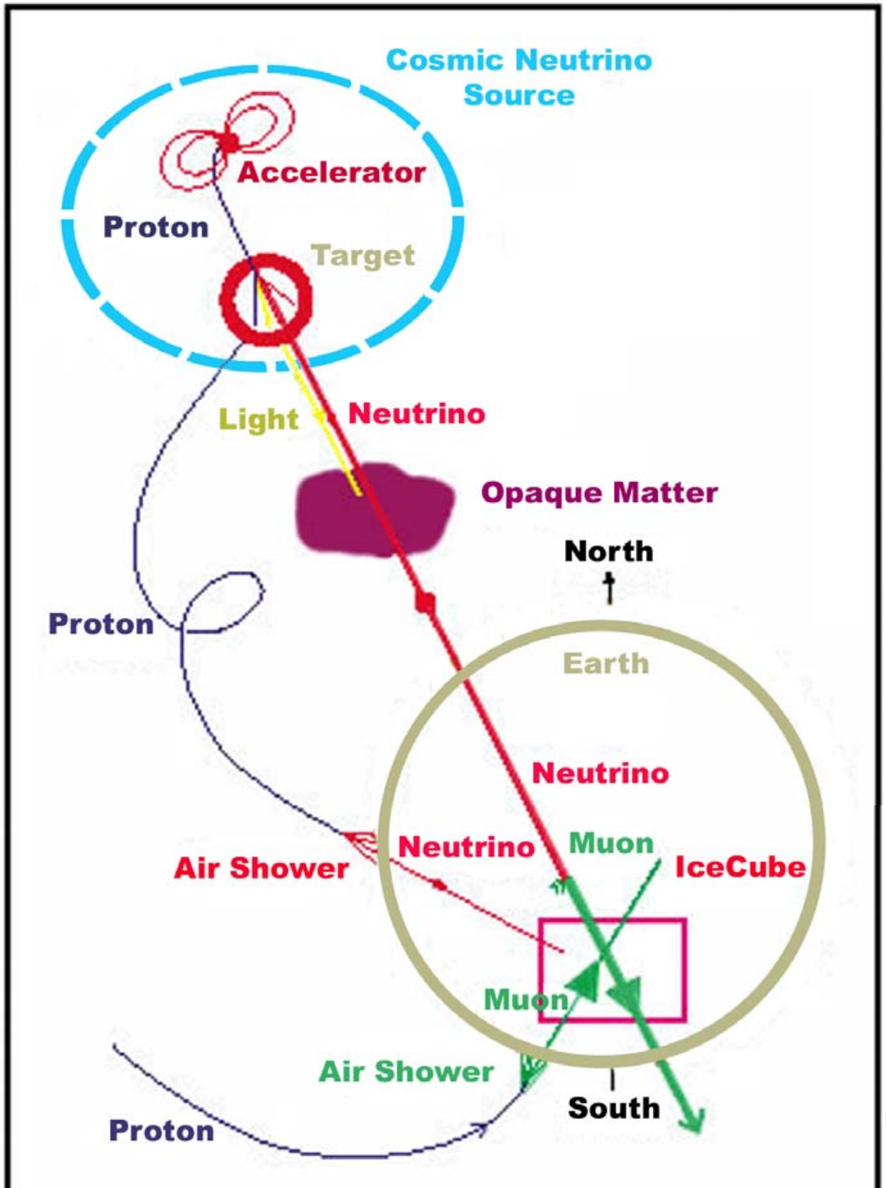
νs not bent by magnetic fields

- enables neutrino astronomy

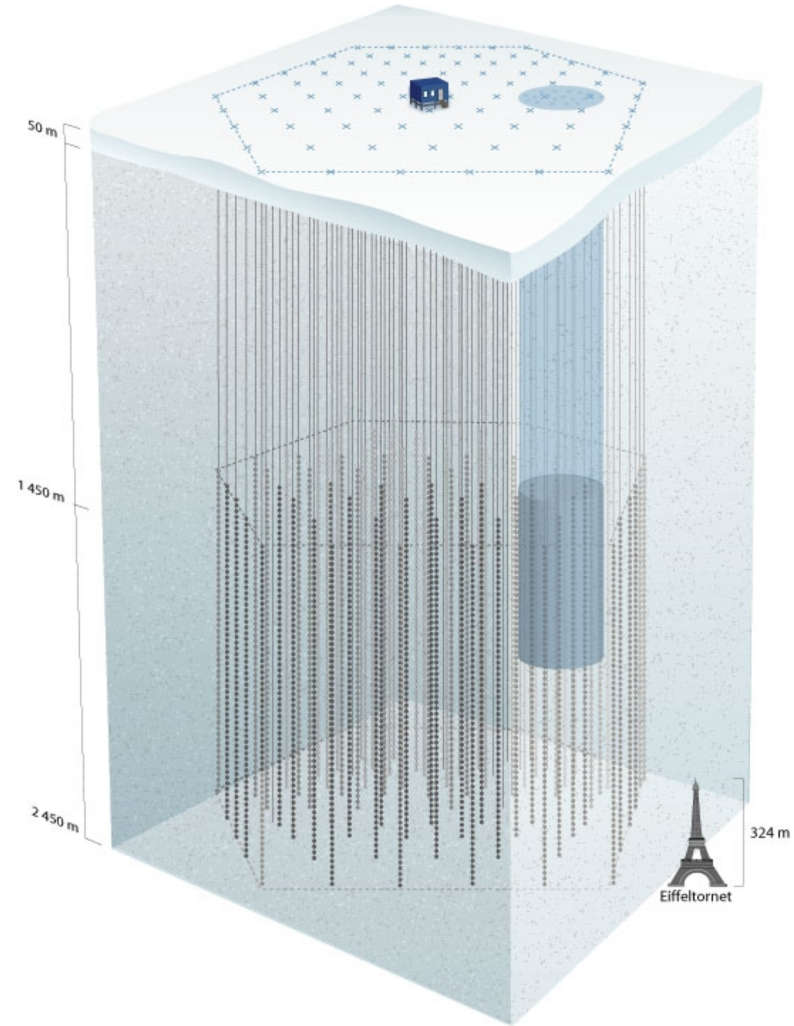
Also, besides Energy and Direction, ν's carry Flavor

Good news: nothing stops them
Bad news: nothing stops them

The optical Cherenkov technique

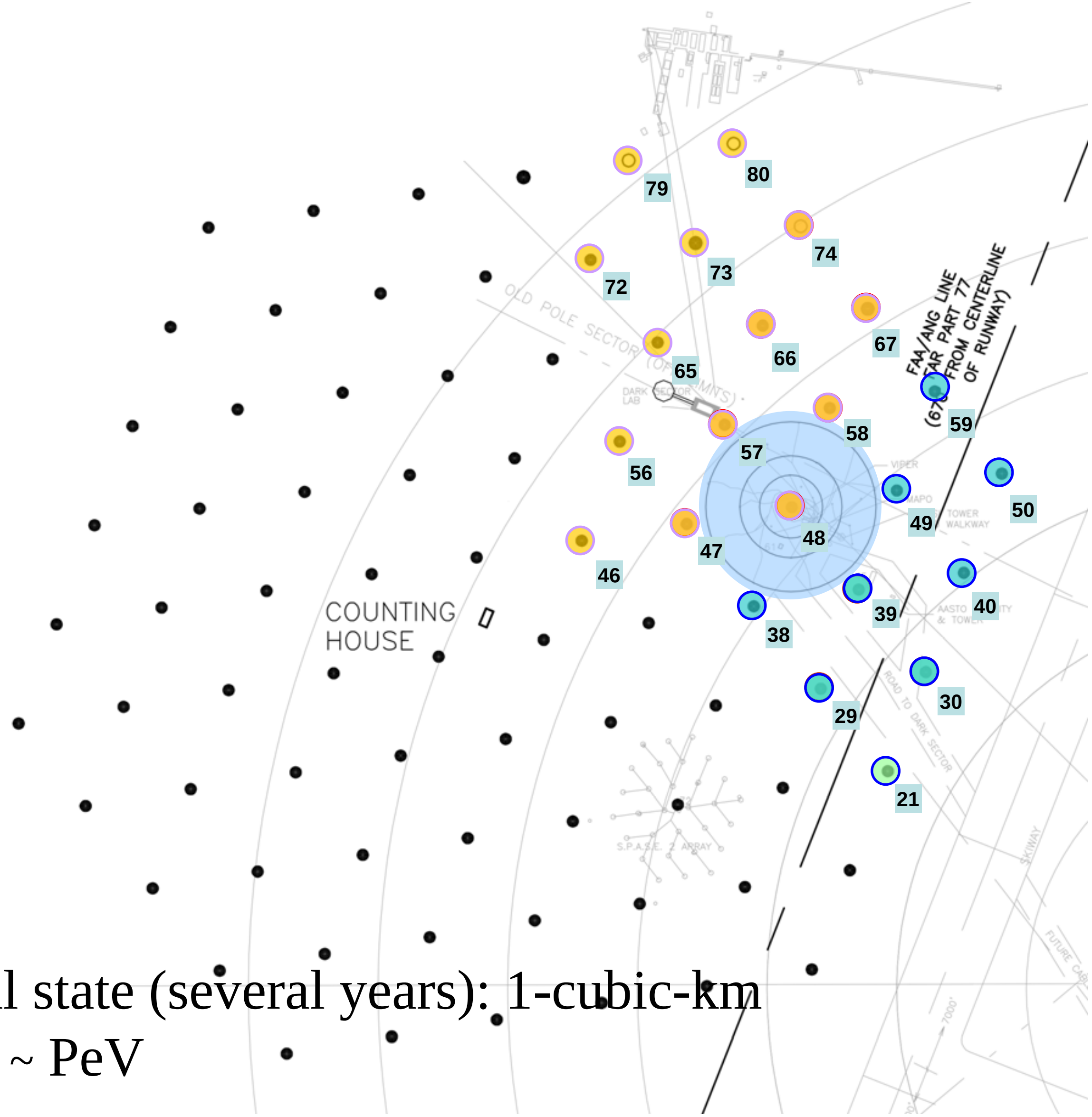


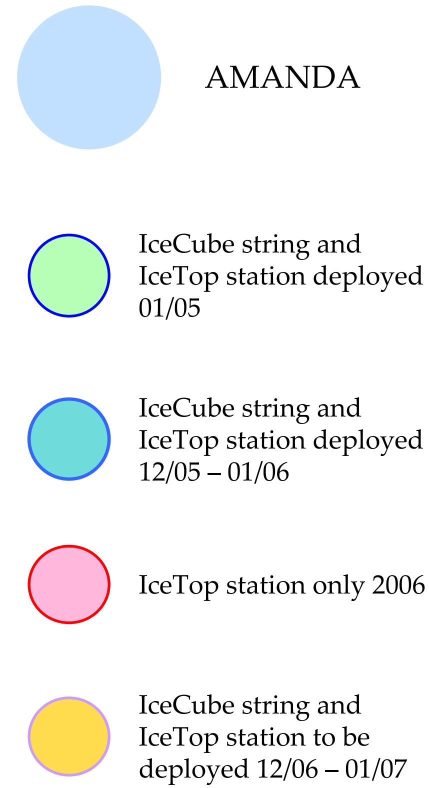
IceCube concept



K. Hanson

Status of IceCube





604 DOMs deployed to date

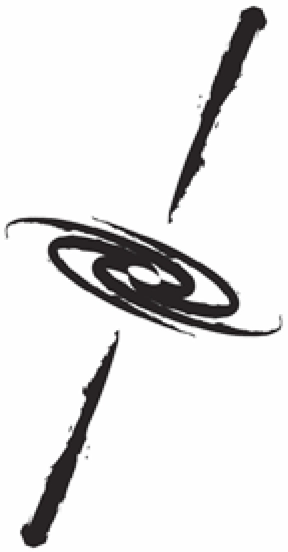
Next year looking for ≥ 12 strings. IceTop will be backed off to remain in line with hole deployment

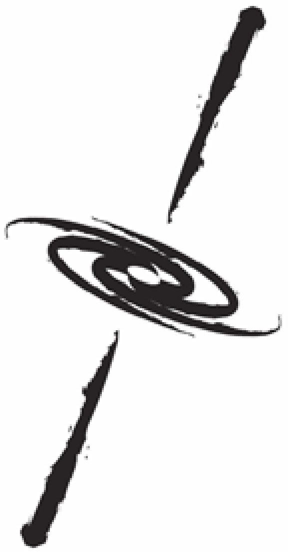
Want to achieve steady state of 14 strings / season.

Final state (several years): 1-cubic-km

E(υ) ~ PeV

K. Hanson





Gravitational waves

Recipe for Making Gravitational Waves

Ingredients: Large quantity of mass/energy
(any type will do)

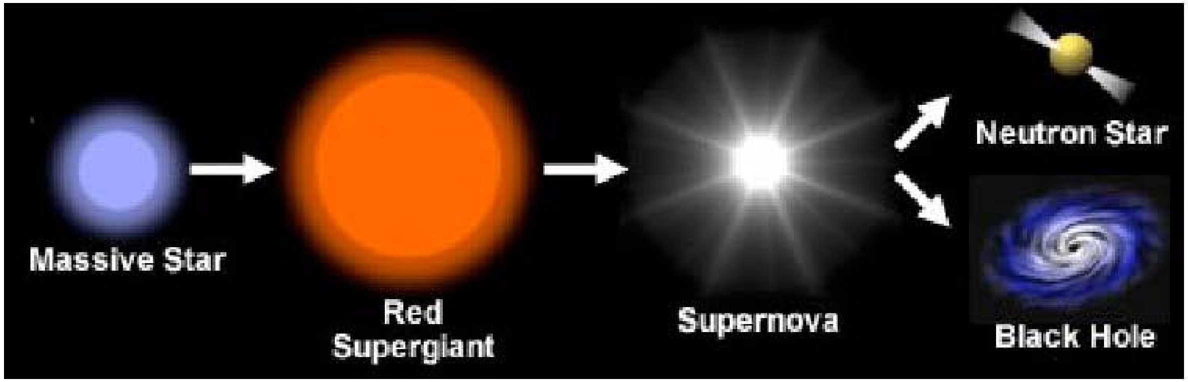
Directions:

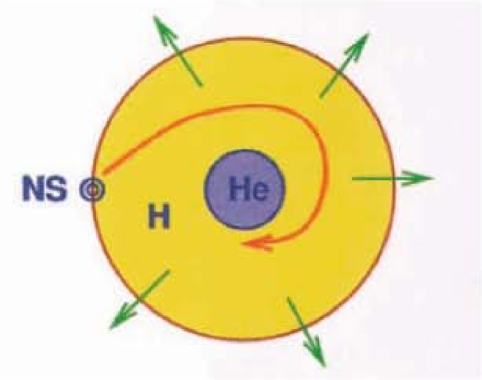
- Compress into a small, irregular lump
  (two lumps work better)

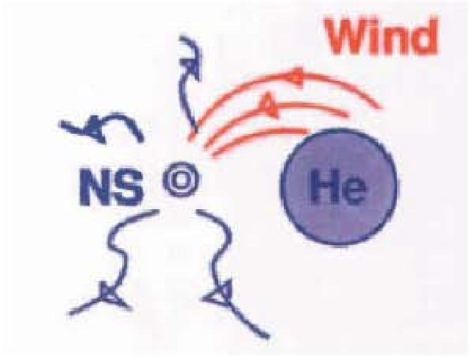
- Shake or stir vigorously

(Adapted from P. Brady)

Nature's Kitchen

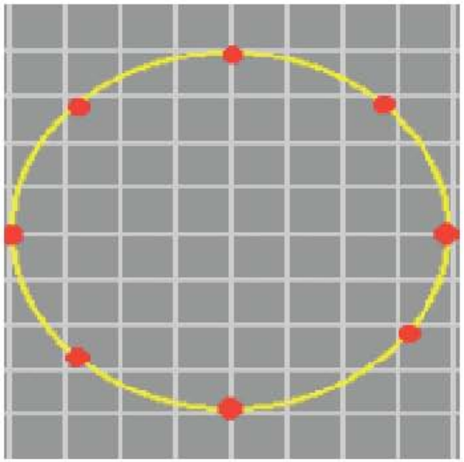




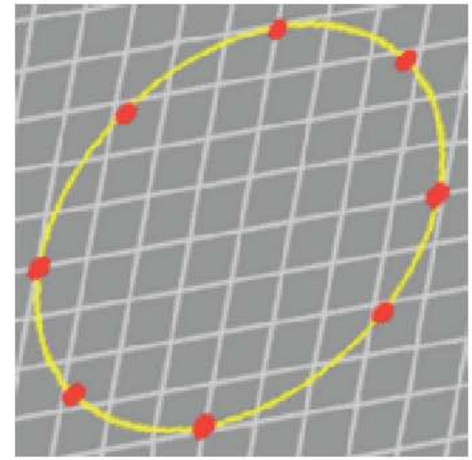


Gravitational Waves 101

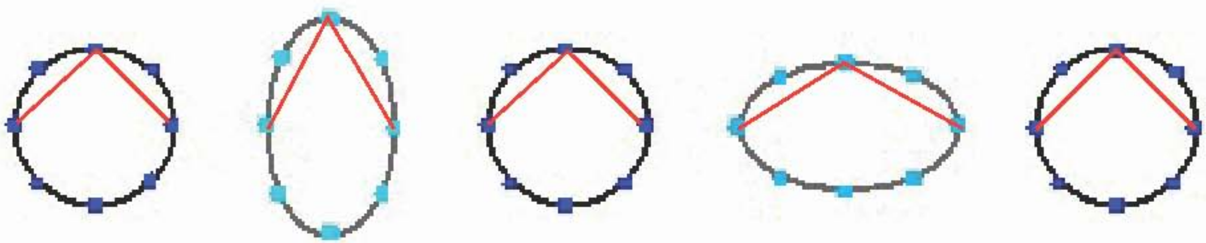
h_+



$h_\times$

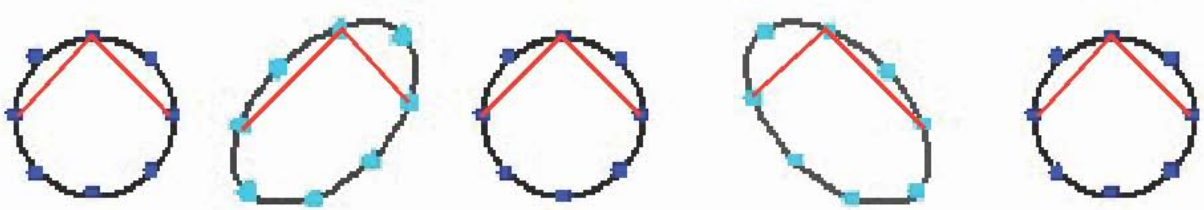


h_+



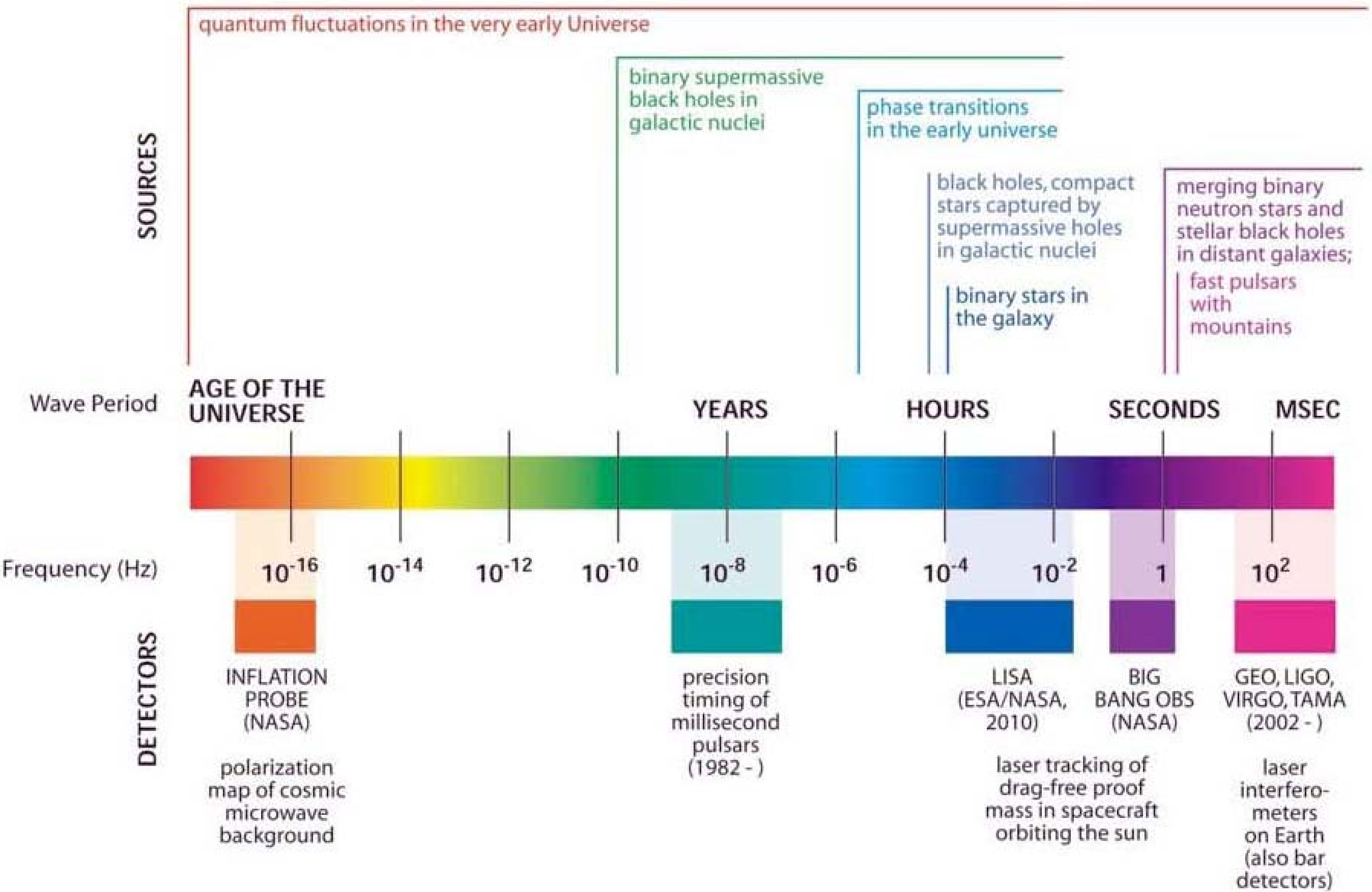
$$\Delta L(t) \sim h(t)\, L$$

$h_\times$



N.Cornish

THE GRAVITATIONAL WAVE SPECTRUM



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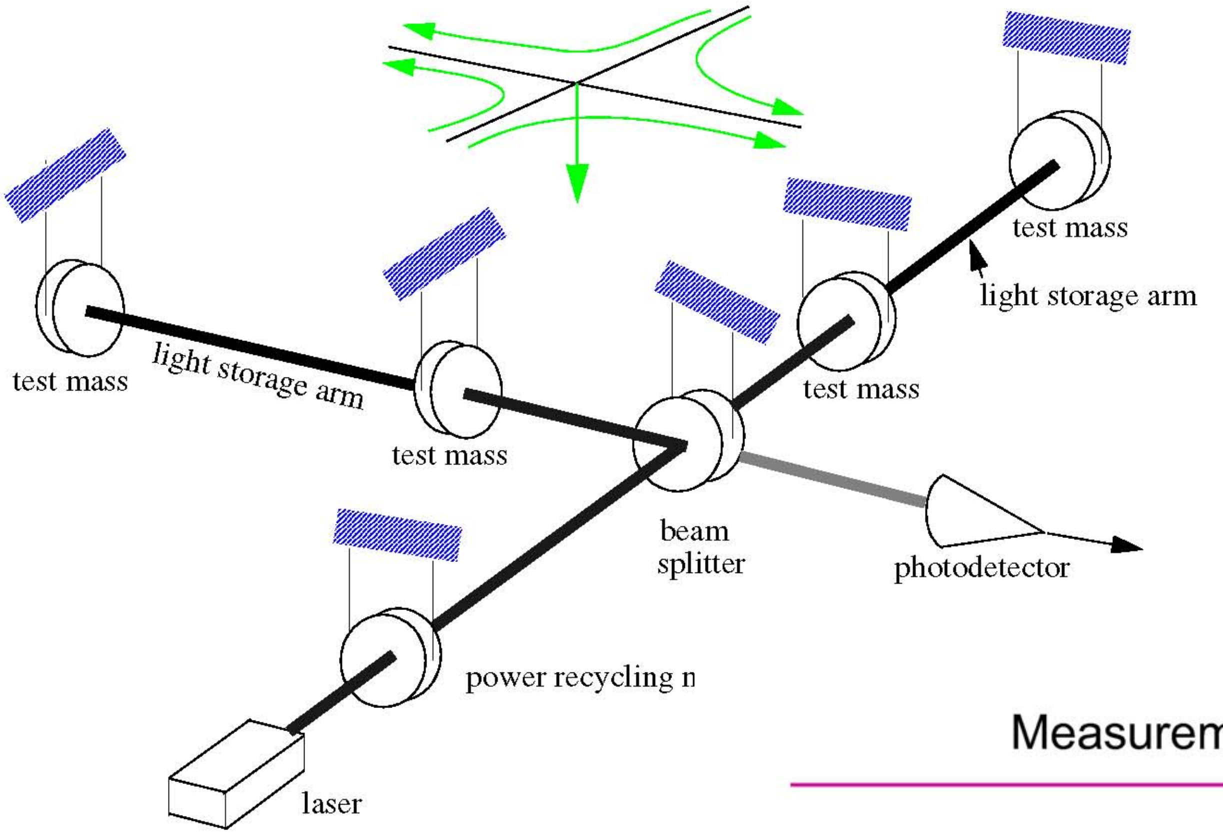
Gravitational wave detector concept



Measurement challenge

- Needed technology development to measure:

$$h = \Delta L/L < 10^{-21}$$

$$\Delta L < 4 \times 10^{-18} \text{ meters}$$

R. Weiss

The LIGO detectors

e.g. NS/NS Binary
inspiral in Virgo Cluster

$$h = \frac{\Delta L}{L} \sim 10^{-21}$$

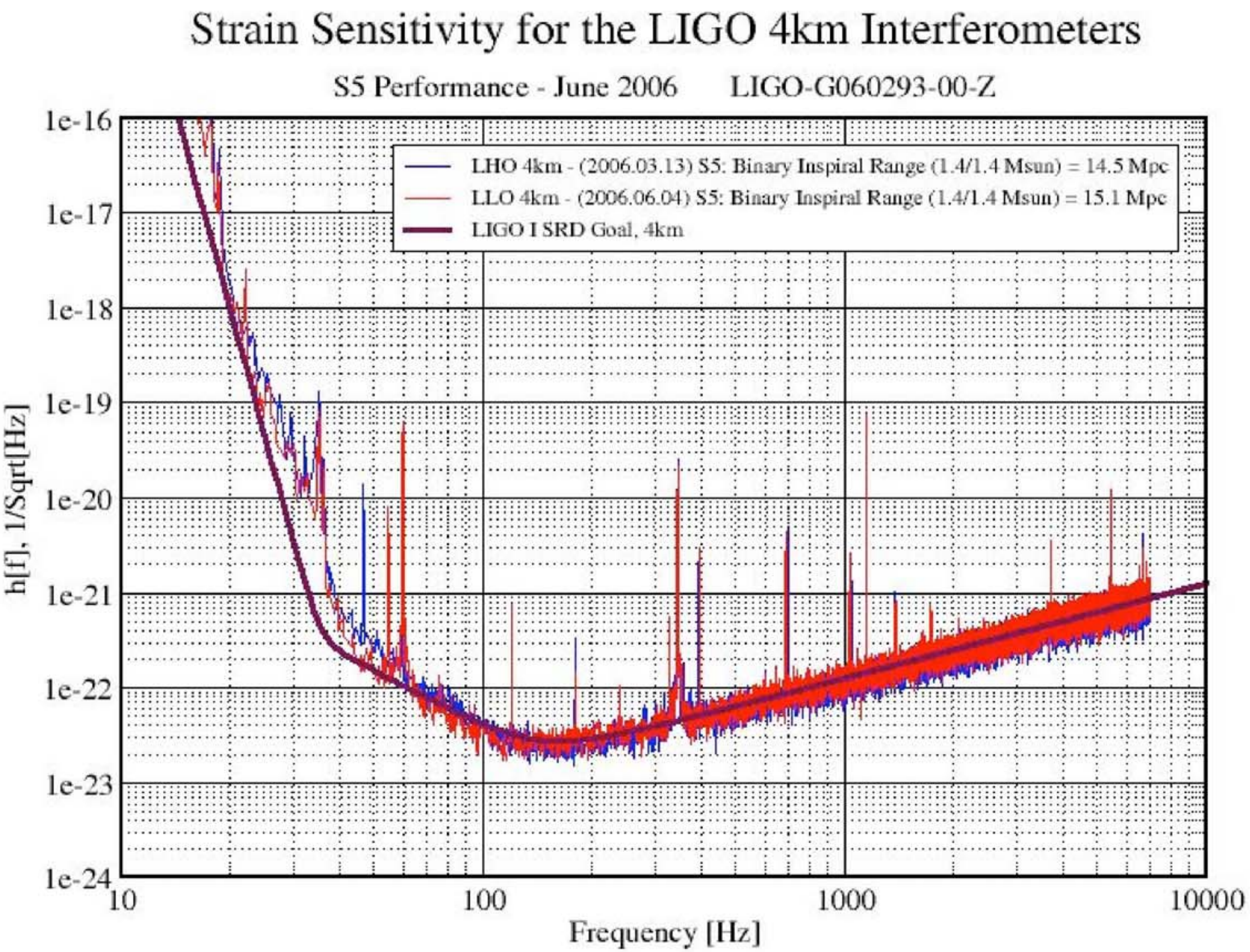
$$L \sim 4 \times 100\,\mathrm{km} \quad \Rightarrow \quad \Delta L \sim 0.1\,\mathrm{fm}$$

How do they do this?
Talk by R. Weiss

Latest News

- LIGO has reached design sensitivity, one year observation run in progress (S5)
- Major breakthroughs in numerical simulation of BH-BH merger
- LISA Pathfinder passed PDR, now in Phase B/C
- LIGO and VIRGO have joined forces
- Enhanced LIGO run (S6) now planned
- Advanced LIGO funding start in 2008
- LISA in Phase A, transition to Phase B in 2007 deferred

LIGO works!



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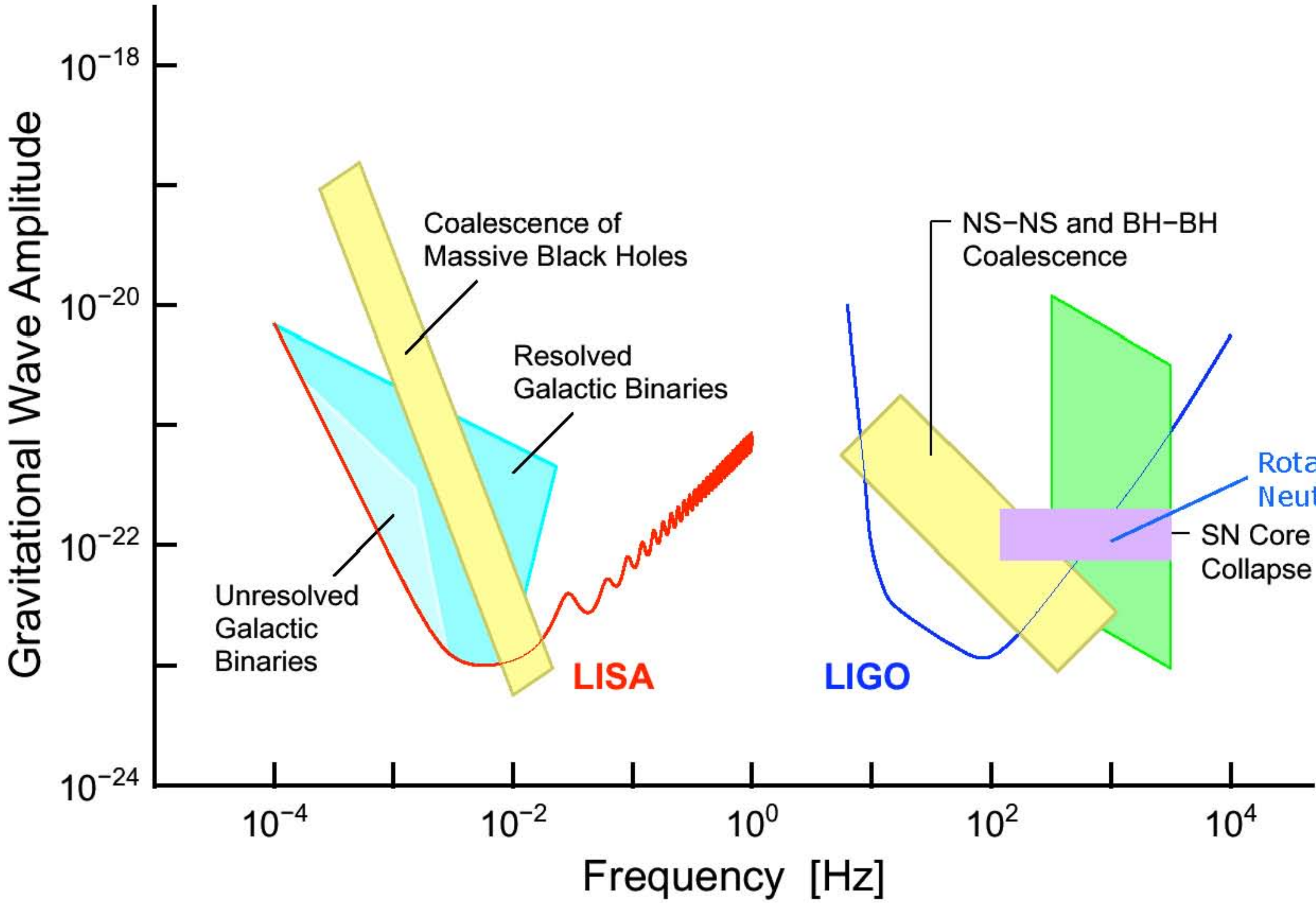
Toward Direct Detection



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LIGO Inspiral r year

First Detection by 2010

	From	Initial	Enhanced	Advanced
NS/NS	Observed binary pulsars + Pop. Synth. Kalogera et al.	0.007 - 0.04 - 0.13	0.06 - 0.3 - 1	20-1200-4000
NS/BH	Pop. Synth. Bethe/Brown/Lee	0.14 - 0.8 - 3	1 - 6 - 24	400-2400 -10000
NS/NS	Short gamma ray bursts Nakar et al	0.001 - 0.3	0.01 - 3	2-300
NS/BH	Short gamma ray bursts Nakar et al	0.01 - 3	0.1 - 30	20-1000
BH/BH	Population Synthesis	0.03 - 0.4	0.2 - 4	80-15000

(Table by Kip Thorne)

N.Cornish

And lots of other stuff…

Dark matter detections (direct & indirect),
WMAP update,
New detector technologies,
Neutrinos, neutrinos, neutrinos…

http://www.icecube.wisc.edu/tev/