TeV Future: APS White Paper

APS commissioned a white paper on the "Status and Future of very high energy gamma ray astronomy. For preliminary information, see http://cherenkov.physics.iastate.edu/wp

Working Groups and leaders:

- Extragalactic - Henric Krawczynski
- Dark Matter - Jim Buckley (WU)
- Gamma-ray Bursts - Abe Falcone & David Williams
- Galactic Diffuse Emission, SNR, and Cosmic Rays - Martin Pohl
- Galactic Compact Objects - Phil Kaaret
- Technology - Karen Byrum

Editorial Board: B. Dingus, H. Krawczynski, M. Pohl, V. Vassiliev,
F. Halzen, W. Hofmann, S. Ritz, T. Weekes

TeV Future: APS White Paper

The charge from APS Editorial board Organizational meetings Meeting at the GLAST Symposium

The future of ground-based gamma-ray astronomy

APS White Paper

The Status and Future of Ground Based Gamma-Ray Astronomy

In the last two years ground-based gamma-ray observatories have made a number of stunning astrophysical discoveries which have attracted the attention of the wider scientific community. The high discovery rate is expected to increase during the forthcoming years, as the VERITAS observatory and the upgraded MAGIC and HESS observatories commence scientific observations and the space-based gamma-ray telescope, GLAST, is launched. The continuation of these achievements into the next decade will require a new generation of ground-based observatories. In view of the long lead time for developing and installing new instruments, the Division of Astrophysics of the American Physical Society has requested the preparation of a White Paper on the status and future of ground-based gamma-ray astronomy. Scientists from the entire spectrum of astrophysics are invited to contribute to the concepts and ideas presented in the White Paper. We wish to stress that international participation is encouraged.

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Galactic compact objects
SNR and cosmic rays
Dark matter
Gamma-ray bursts
Technology

http://cherenkov.physics.iastate.edu/wp/

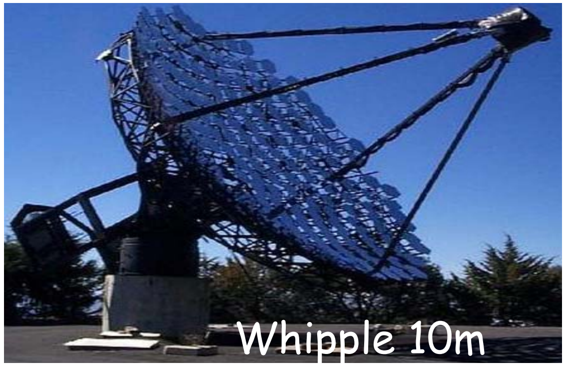
Science case being developed through working group interaction and through a series of open meetings

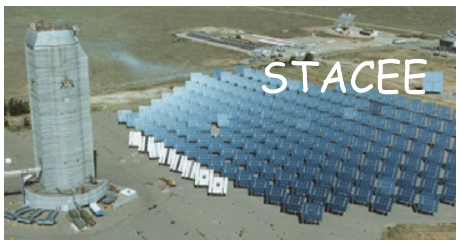
- “Ground-based Gamma-ray Astronomy: Towards the Future”, Oct. 20-21, 2005, Malibu (UCLA)
- “Ground-based Gamma-ray Astronomy: Towards the Future”, May 11-12, 2006, Santa Fe (LANL)
- Satellite meeting at GLAST Symposium, Feb 8, 2007, Palo Alto, CA
- “Future of Very High Energy Gamma-Ray Astronomy”, May 13-14, 2007, Chicago (U. Chicago)
- “Toward the Future of Very High Energy Gamma-Ray Astronomy”, November 8-9, 2007, SLAC

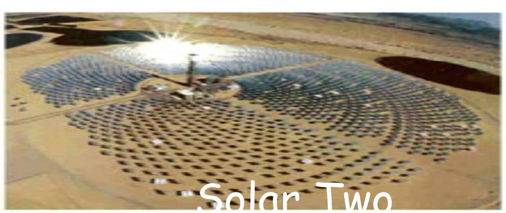
Findings

- ***F1*** - Field was invigorated by initial 1989 detection of Crab nebula, followed by steady progress through finding ~10 new sources throughout 15 years (primarily AGN). In the past ~3 years, the discovery potential has really been shown with ~75 news sources of varying classes, which probe new physics and astrophysics.

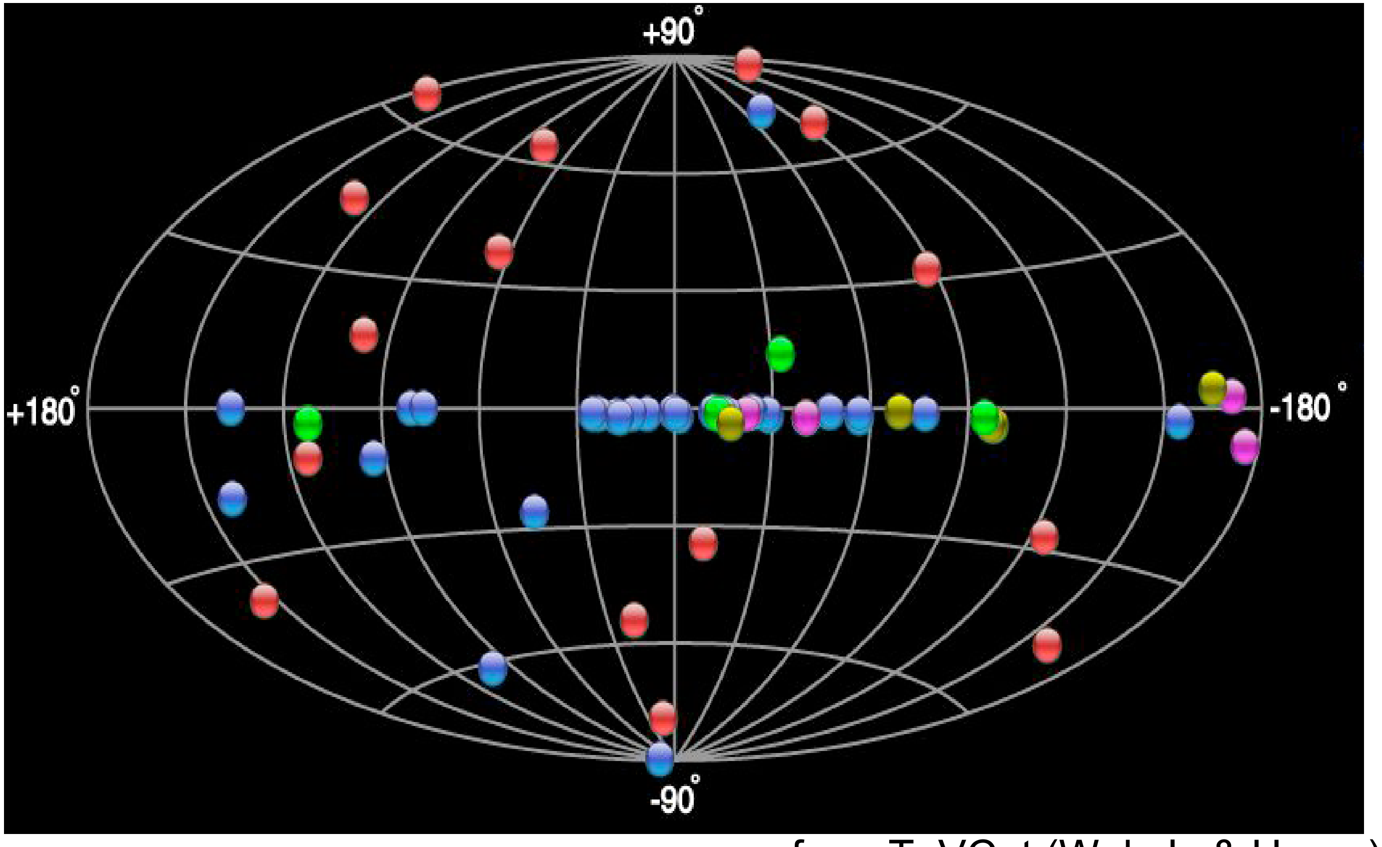
Past/Current Success







Motivation



from TeVCat (Wakely & Horan)

Source classes: Shell-type SNR, PWN, Binary Systems, Star Cluster, Diffuse Emission, Galactic Center, Blazars, Radio Galaxies, Unidentified Sources

Astrophysics topics: nonthermal particle populations, magnetic fields, neutron stars, black holes, jets, dark matter, astroparticle physics.

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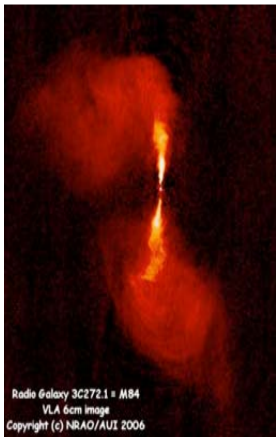
- ***F2*** - From the plethora of new sources, it is clear that sensitivity improvements could lead to fundamental contributions of TeV astronomy to i) studies of cosmic rays, both galactic and UHE, ii) darkmatter, iii) cosmic history of super-massive black holes and studies of jet formation, iv) stellar mass black holes and binary systems and therefore star formation history and GRBs

Motivation

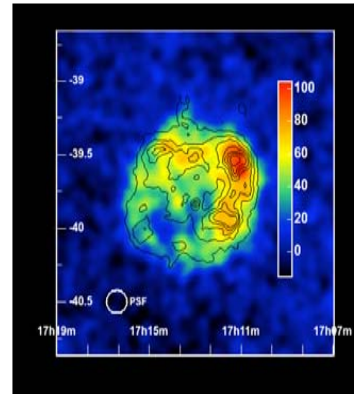
Extragalactic:

AGN Jets, EBL



Cosmic rays in other galaxies and galaxy clusters

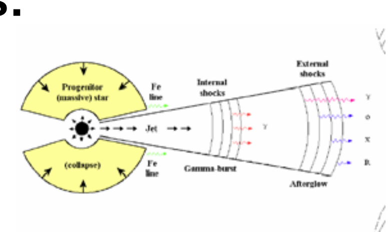
SNR & Cosmic Rays:



Are SNR the dominant source of Cosmic Rays up to 10^{15} eV?

GRBs:

Do GRBs accelerate UHECRs

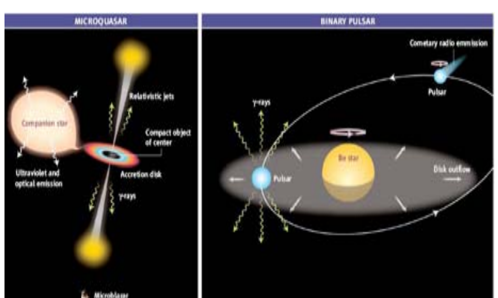


Probe Lorentz factor and optical thickness.

Galactic Compact Objects:

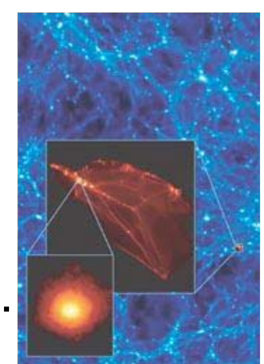
PWN

Accreting stellarmass black holes



Dark Matter:

Detect annihilation gamma-rays.



Findings

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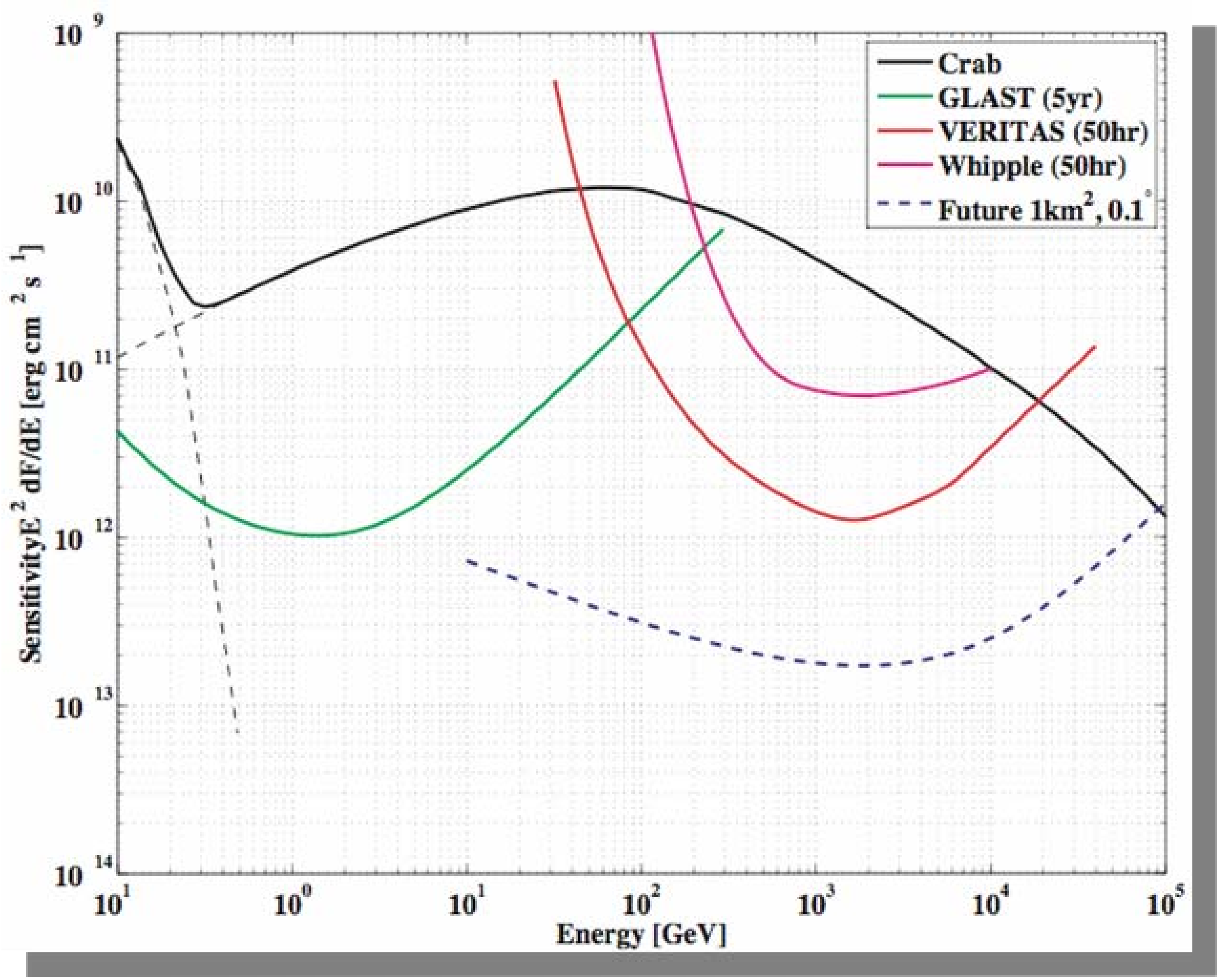
- ***F2*** - From the plethora of new sources, it is clear that sensitivity improvements could lead to fundamental contributions of TeV astronomy to i) studies of cosmic rays, both galactic and UHE, ii) dark matter, iii) cosmic history of super-massive black holes and studies of jet formation, iv) stellar mass black holes and binary systems and therefore star formation history and GRBs.
- ***F3*** - Large-scale gamma ray observatory would substantially increase science return from existing/planned observatories such as GLAST, LOFAR, LSST, IceCube, ANITA, LIGO, LISA, ...
- ***F4*** - TeV astronomy was pioneered in the US. For the US to remain in a leadership role, it is mandatory to start the next generation now.
- ***F5*** - A new observatory, sensitive from 30 GeV - 100 TeV, would be most cost effective and could achieve ~10x sensitivity increase soon.
- ***F6*** - Imaging Air Cherenkov Telescopes (IACTs) and Water Cherenkov (WCAs) complement one another. IACTs have excellent instantaneous sensitivity and angular resolution, while WCAs can study diffuse objects and bright transients.
- ***F7*** - If funded adequately, US groups could lead the field.

Recommendations

- ***R1*** - Based on extrapolations from current instruments, an investment of ~ $100M is required to achieve 10x sensitivity improvement that is required to guarantee a rich harvest of science from the existing discovery potential
- ***R2*** - Next generation observatory should consist of an imaging air Cherenkov array component with 1 km^2 area, complemented by water Cherenkov array
- ***R3*** - Timely construction of IACT array requires R&D now
- ***R4*** - A site, with expansion potential, should be chosen now. It should allow observations of the Galactic center and a significant fraction of the Northern Hemisphere
- ***R5*** - U.S. should intensify collaboration with European and Japanese colleagues, and should consider option of combining efforts
- ***R6*** - Broad impact strategies should be considered at all phases of development, and in particular, the U.S. groups should have data access policies that engage full community. They should also involve young scientists to train the future generation, and maintain active outreach efforts

AGIS Design Goal



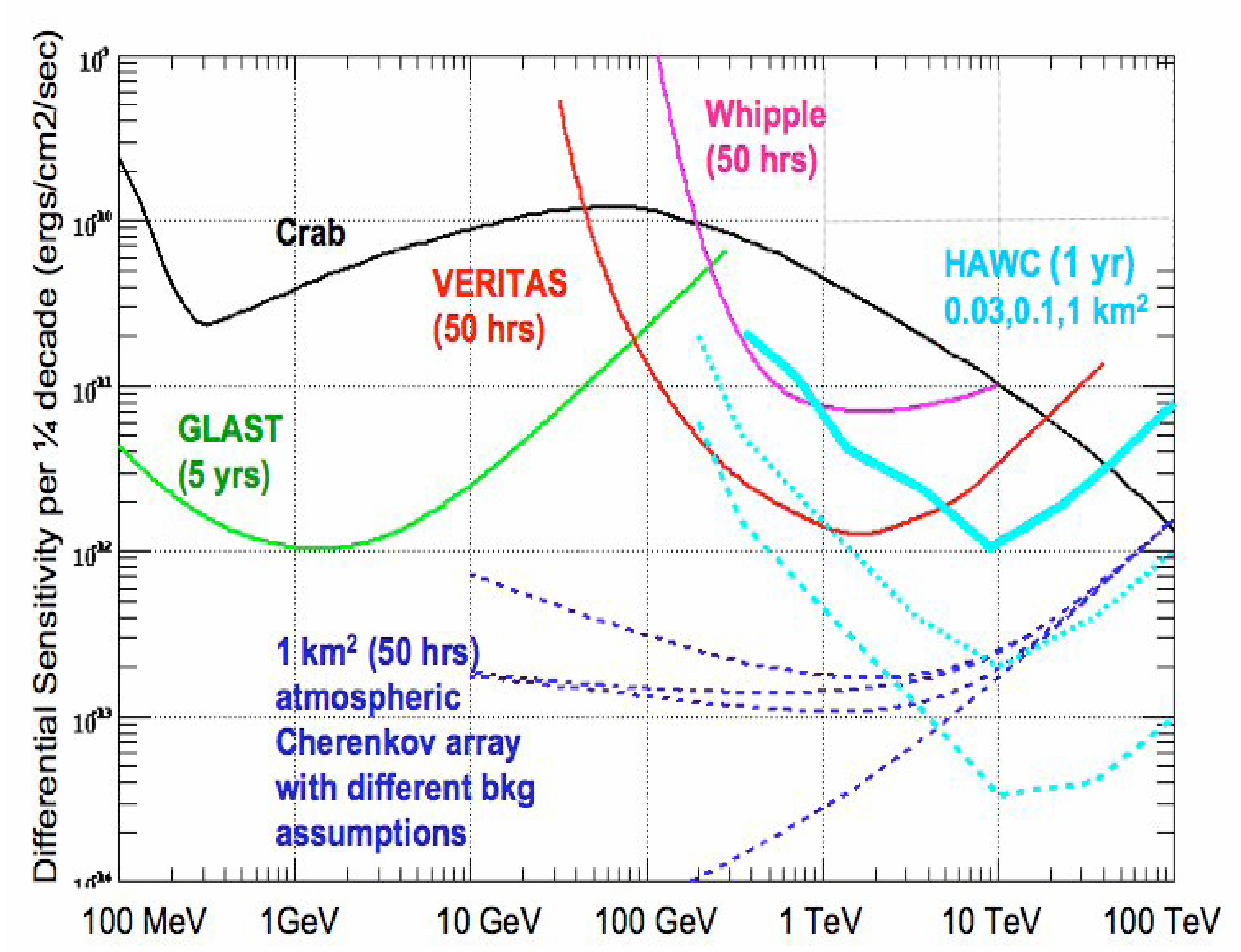
Differential flux sensitivity of an ideal km^2 telescope array sensitivity curve (courtesy S. Fegan)

Large IACT arrays

AGIS and CTA are being developed and proposed by US and European collaborations, respectively. Both of these concepts involve a large array of IACTs providing:

- km^2 effective area
- energy threshold down to ~40 GeV
- flux sensitivity down to $\sim 10^{-13}$ to 10^{-14} erg cm^{-2} s^{-1}(~10x better than VERITAS/HESS)
- 10% energy resolution
- angular resolution down to ~1-3 arcmin

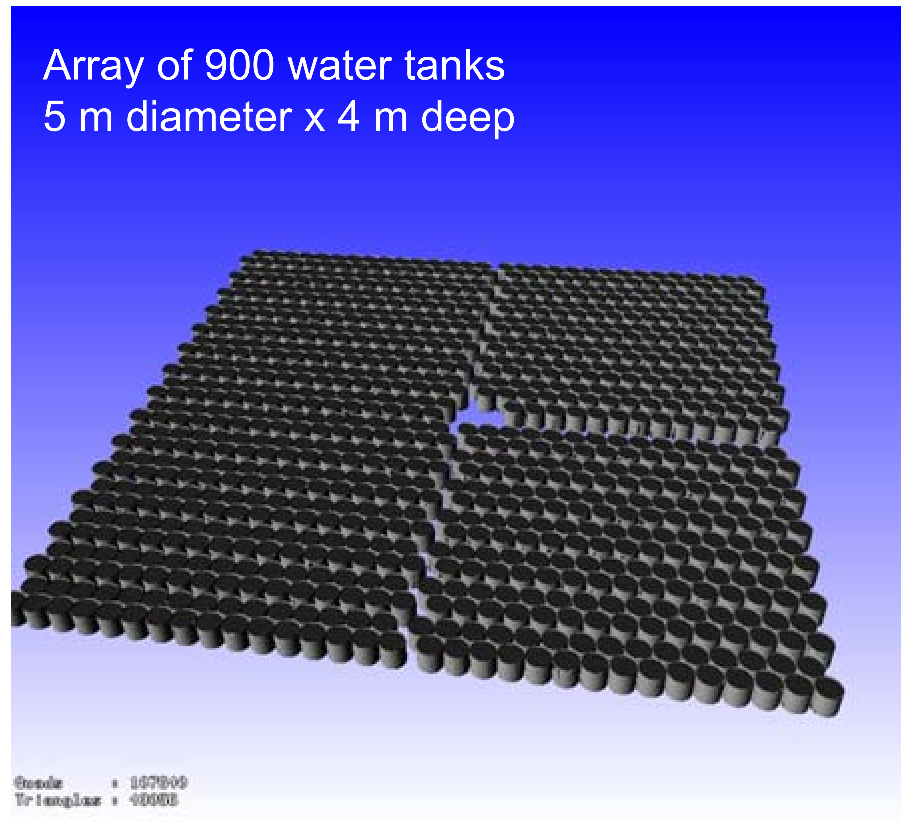
Differential Sensitivity of km² IACT



EAS Approach

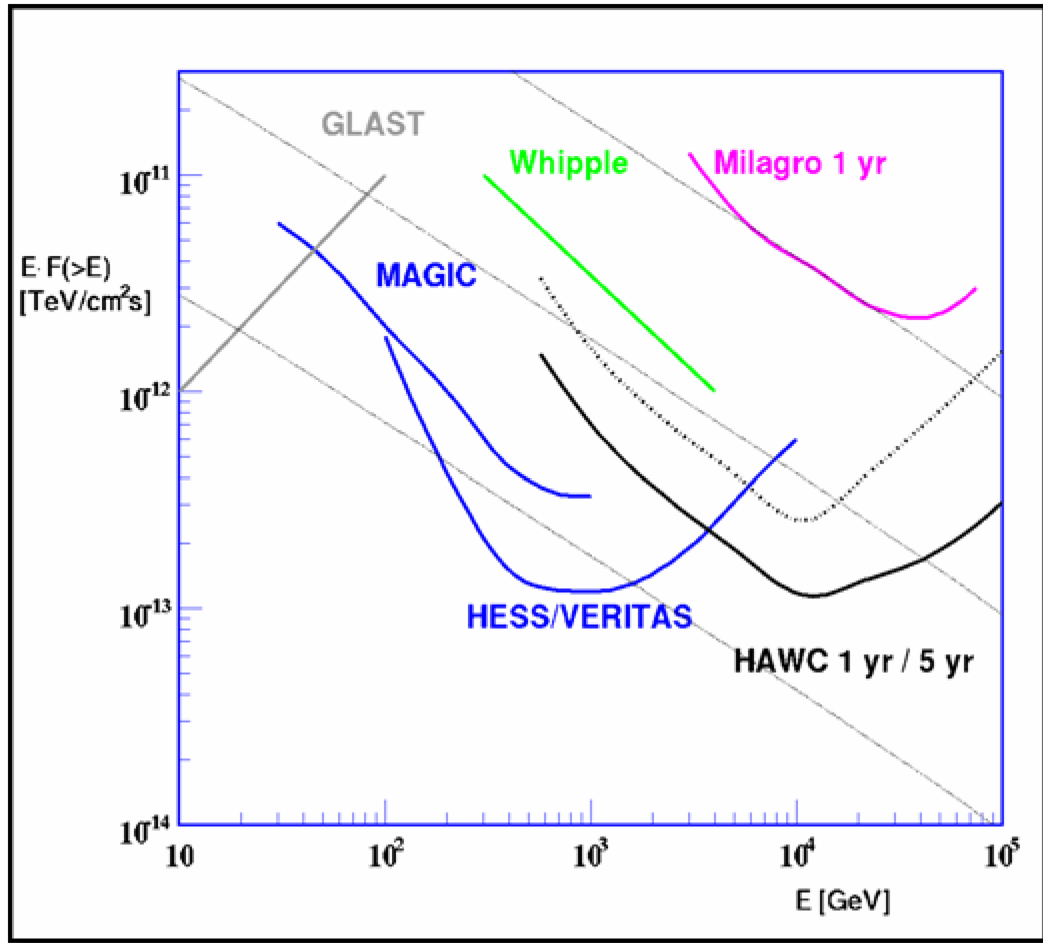
HAWC, a next generation version of Milagro, is also being proposed. This could provide:

- wide FOV -->
    - monitoring of bright sources
    - searches for bright transients
- Searches for diffuse emission
- High duty factor
- 10-15 times Milagro sensitivity



Integral Sensitivity of HAWC to Crab-like Point Sources

- Long integration times lead to excellent sensitivity at highest energies (> few TeV)
- 50 hr observation time assumed for IACTs, HAWC source transit 15º off zenith
- 5σ sensitivity to:
  10 Crab in 3 minutes
  1 Crab in 5 hours (1 transit)
  0.1 Crab in ⅓ year



Conclusions

- Since the TeV detection of the Crab in 1989, there has been steady progress in the field, but in the past 3 years a quantum leap in sensitivity has shown that there is a huge region of unexplored discovery space in the TeV gamma ray sky
- This could be exploited by building large IACT arrays to achieve point source sensitivity increases of ~10x (e.g. AGIS and CTA) with moderately increased FOV and lower energy threshold, while also building an all-sky monitor (e.g. HAWC) to explore the brighter transients and diffuse sources
- If adequately funded, these efforts could be completed in ~5 years, placing the US in a leading position in the field