U.S. Initiatives for Future VHE Telescopes

Simon Swordy (U. Chicago)
Jim Buckley (Washington U.)
CTA meet Paris, March 1 2007

Present Status

- MILAGRO Operational (see talk by Gus S.)
- Whipple 10m Operational (still! -> AGN monitoring)
- VERITAS Operational

VERITAS Cretum

T1 since 2005

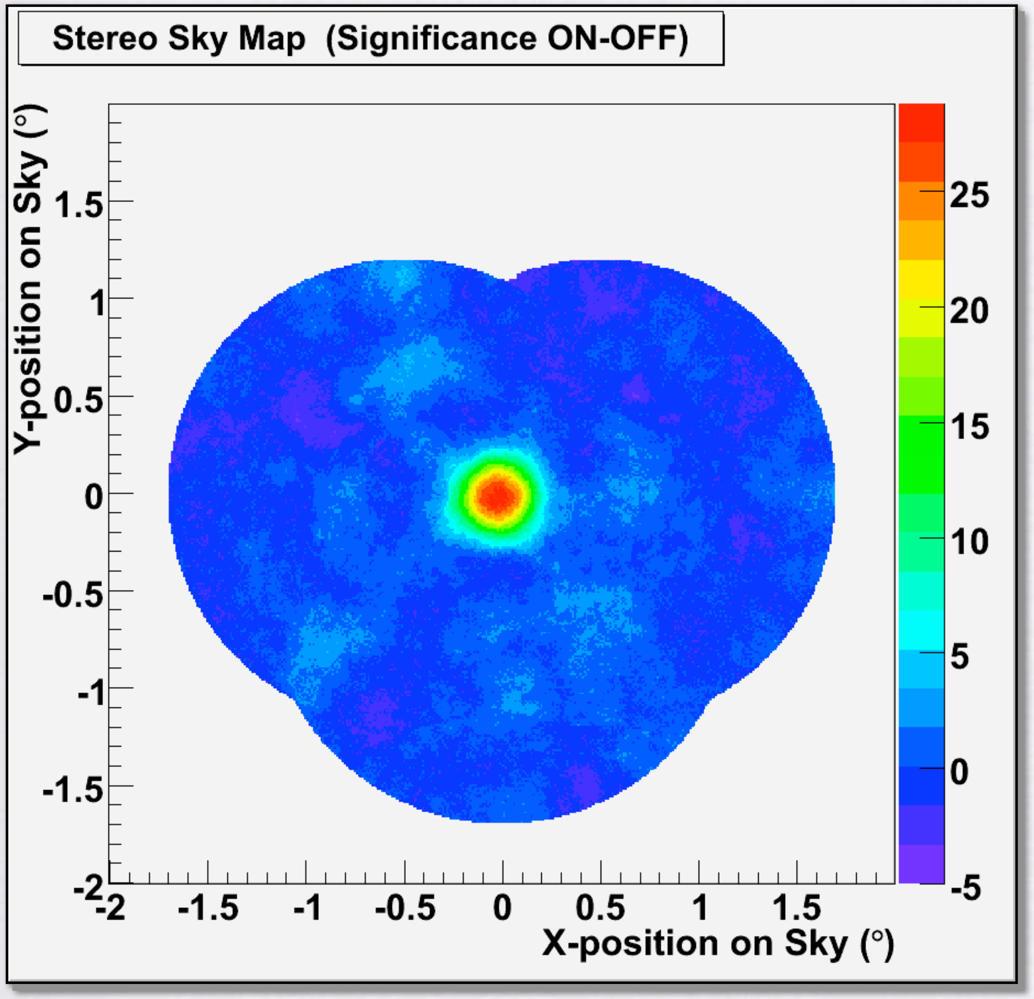
T4 March 2007

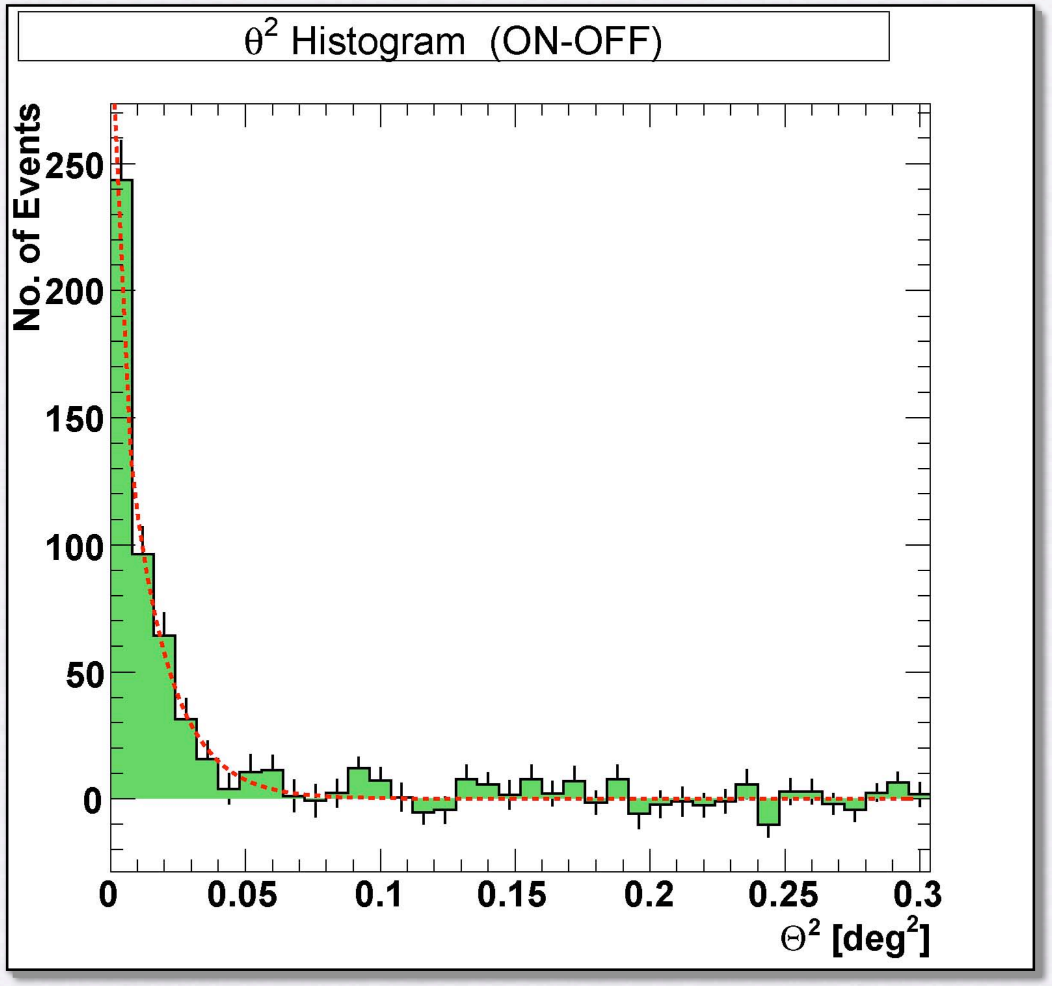
T3 since Nov 2006

T2 since 2006

3 Telescope Crab Data from January 2007

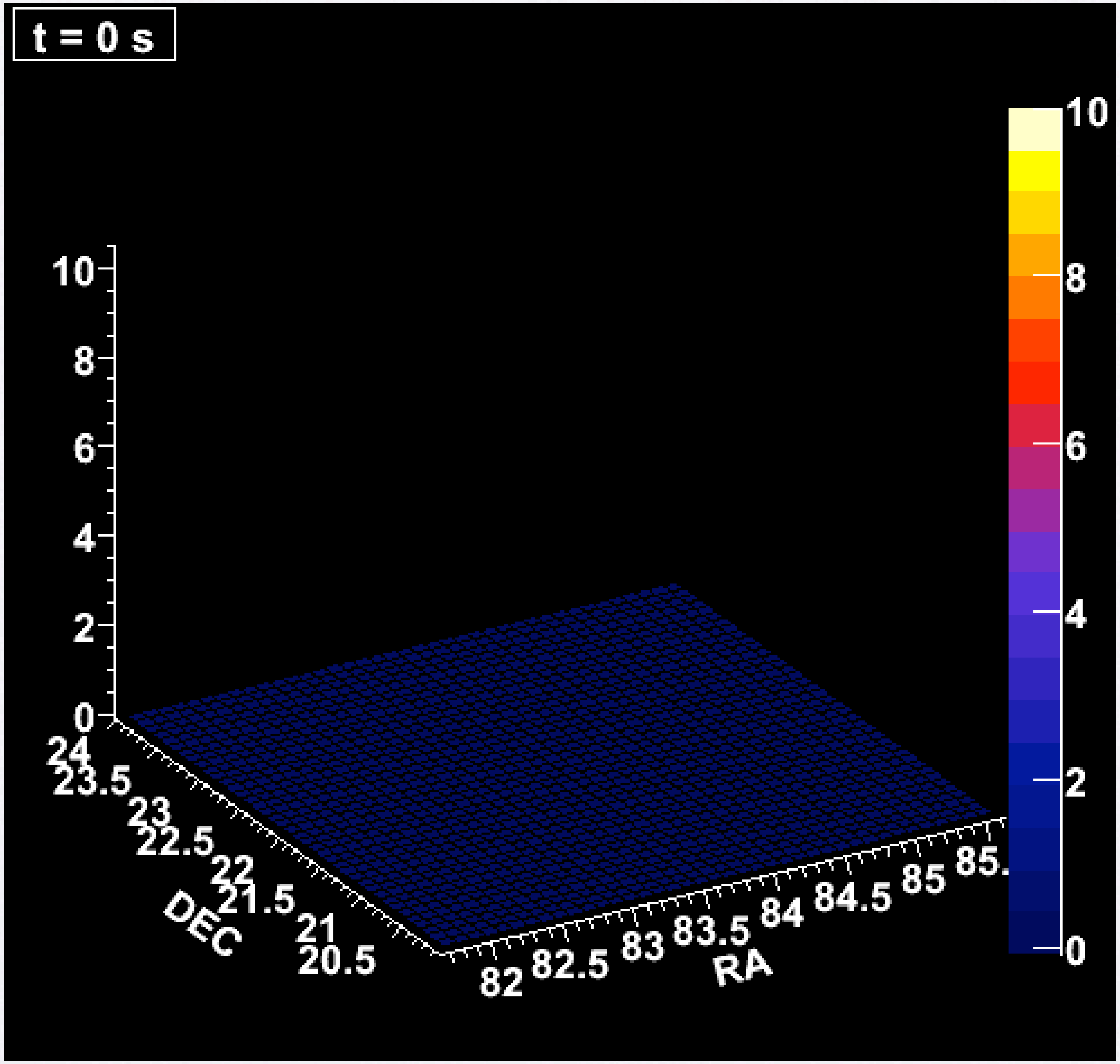
(from Dave Kieda GLAST symposium Feb)



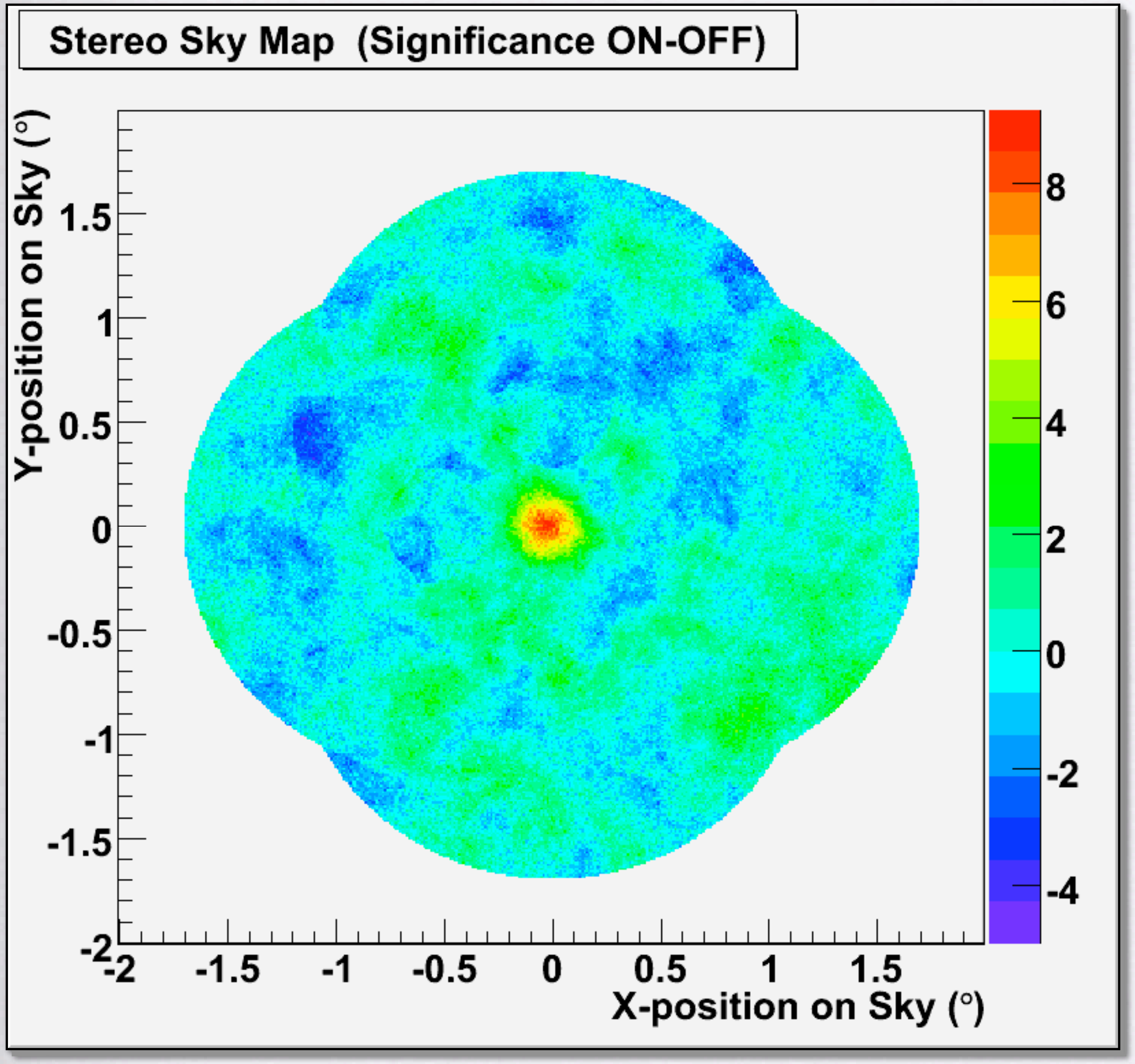


Crab appears at 5 sigma in
~5 minutes at VERITAS

Crab Signal (Scott Wakely Chicago)



Also......



1ES1218+30.4

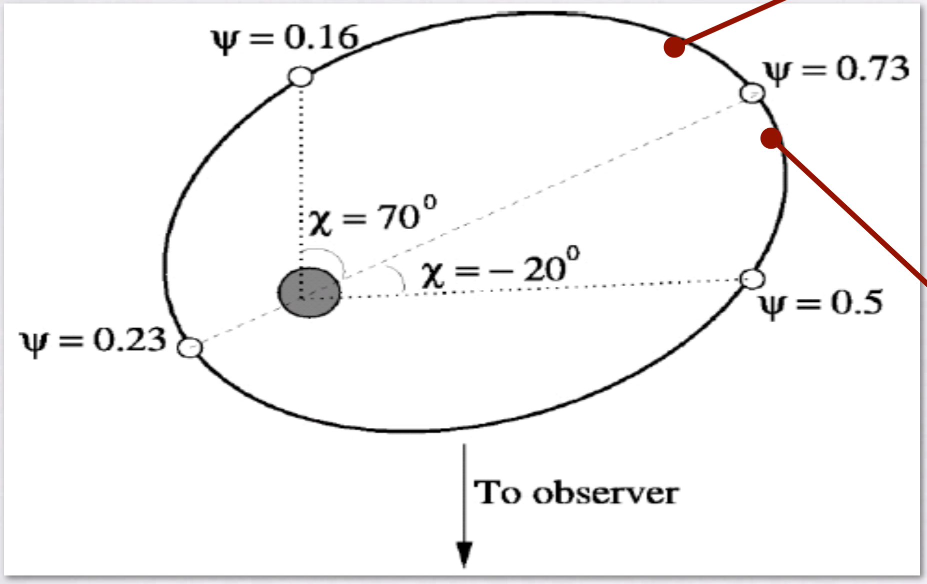
$z=0.182$

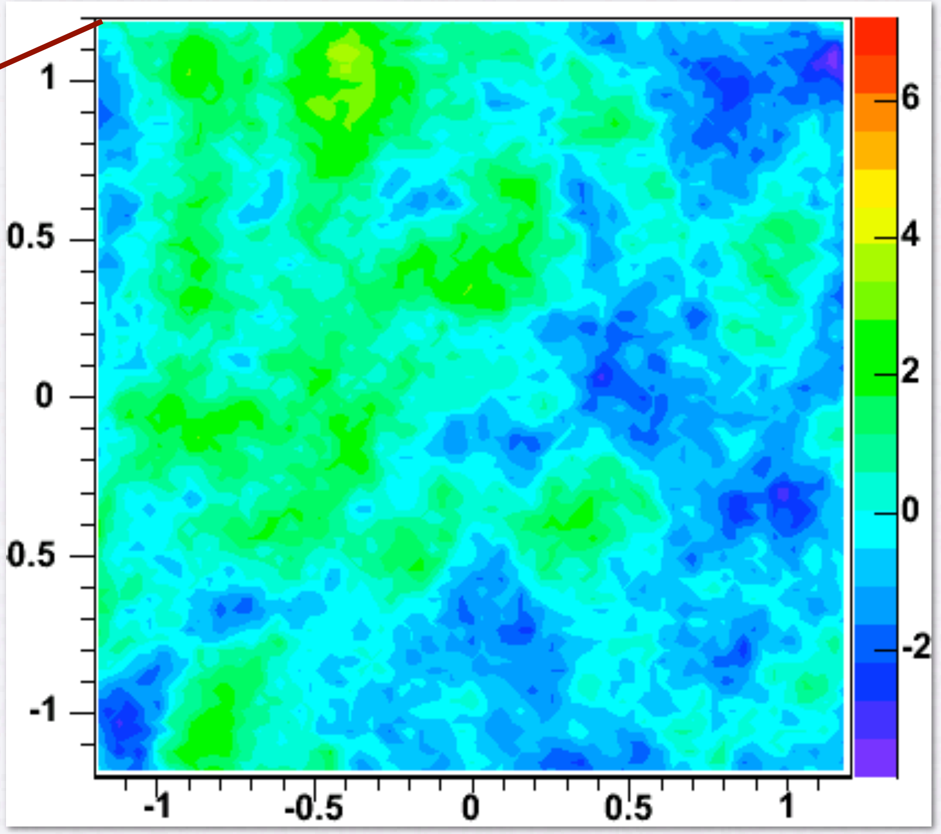
8.0 sigma with 20 hrs stereo

(discovered by MAGIC 6.4 sigma)

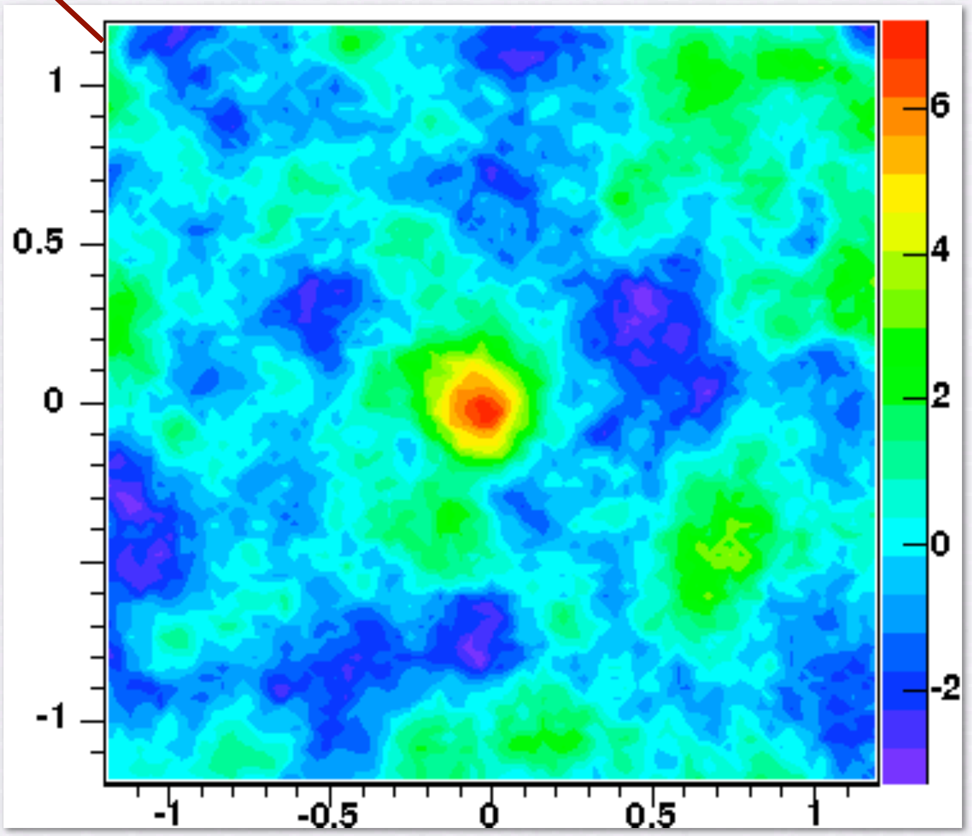
And..... LSI +61 303

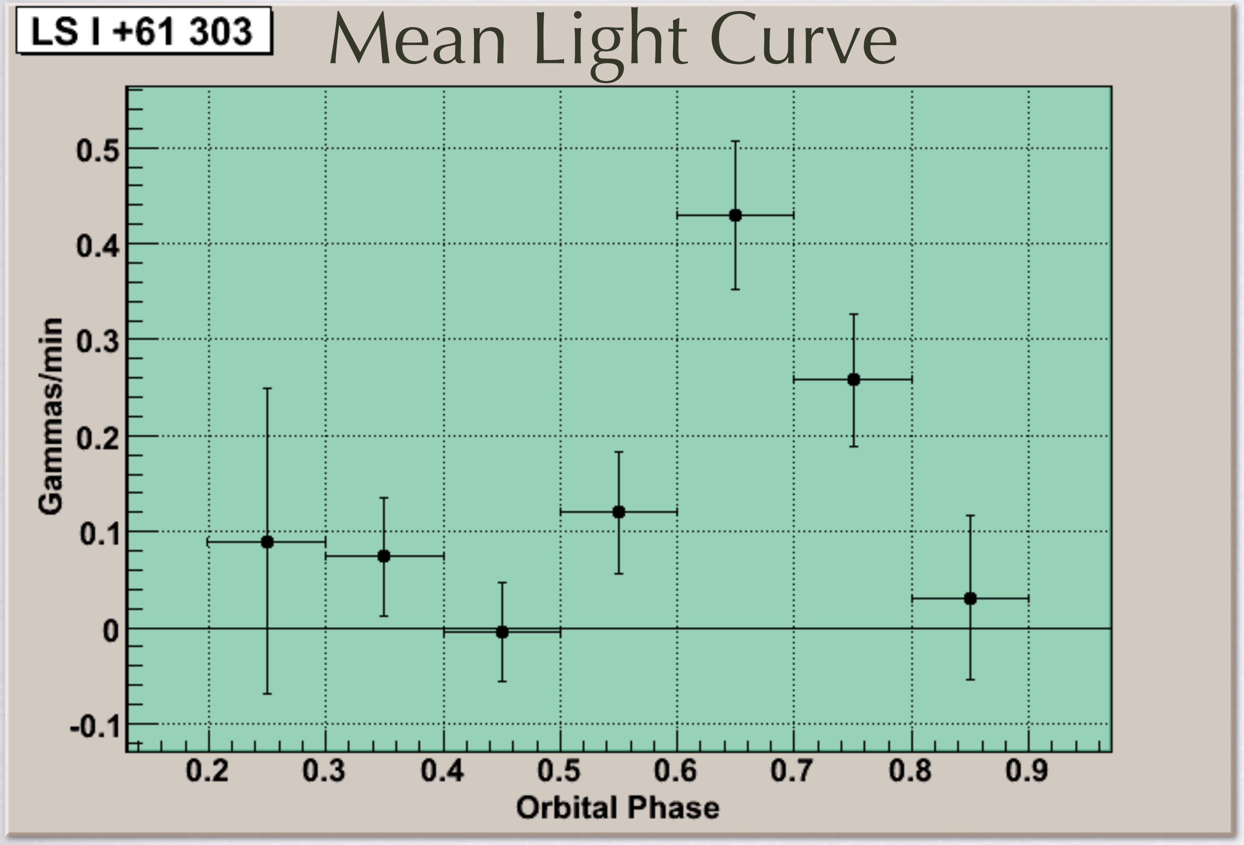
(MAGIC 2006)





7-8 hours each





- VERITAS has ~400 hours of observation through January
- 10 hours gets a sensitivity of a few percent of Crab
- VERITAS expects >800 hours of observation/year
- Sky survey of Cygnus region this spring/summer

VERITAS Phase I - at Kitt Peak Site in 2009

VERITAS Phase II - add 3 ~20m telescopes

- VERITAS Phase II
    - Add 3 ~20m telescopes at Kitt Peak
    - 1000-2000 channels, 4-8 deg FOV
    - At present a proposal in late 2007 is under discussion

Big Scale Astronomy Planning in the U.S.

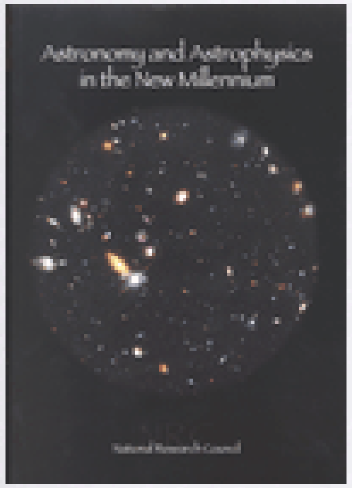
Support of VHE Astro. is no certainty
(because it has perceived low overlap with cosmology?!)

It is not on the high-level DOE roadmap, general interest among particle physics labs is low - but improving (e.g. ANL, SLAC). However, both DOE and NSF have been supportive for VERITAS.

Increasing interest among astronomers, but VHE is still tiny compared to other sub-fields, e.g. x-ray astronomy

GLAST will undoubtedly help us gain visibility -> very important

National Academy “Decadel Survey” used as an Astronomy Roadmap



“Astronomy and Astronomy in the New Millenium”

Last one in 2000 -> Next one ~2010

We need to be in the next one...........

Last time.....

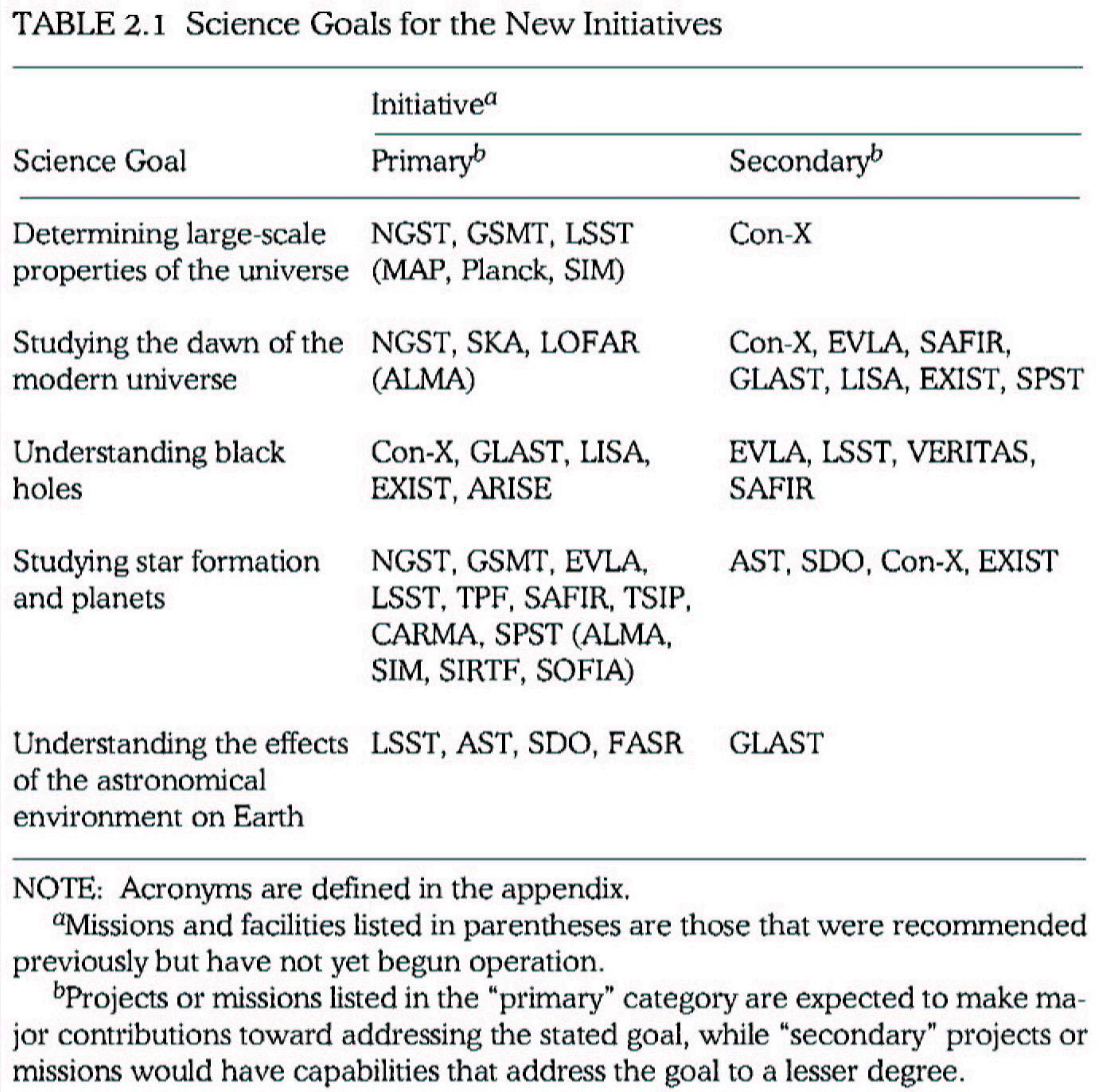


TABLE 2.1 Science Goals for the New Initiatives

	Initiative[a]	
Science Goal	Primary[b]	Secondary[b]
Determining large-scale properties of the universe	NGST, GSMT, LSST (MAP, Planck, SIM)	Con-X
Studying the dawn of the modern universe	NGST, SKA, LOFAR (ALMA)	Con-X, EVLA, SAFIR, GLAST, LISA, EXIST, SPST
Understanding black holes	Con-X, GLAST, LISA, EXIST, ARISE	EVLA, LSST, VERITAS, SAFIR
Studying star formation and planets	NGST, GSMT, EVLA, LSST, TPF, SAFIR, TSIP, CARMA, SPST (ALMA, SIM, SIRTF, SOFIA)	AST, SDO, Con-X, EXIST
Understanding the effects of the astronomical environment on Earth	LSST, AST, SDO, FASR	GLAST

NOTE: Acronyms are defined in the appendix.

[a] Missions and facilities listed in parentheses are those that were recommended previously but have not yet begun operation.

[b] Projects or missions listed in the "primary" category are expected to make major contributions toward addressing the stated goal, while "secondary" projects or missions would have capabilities that address the goal to a lesser degree.

Costs (Don't forget 2 dollars ~ 1 euro in funding world)

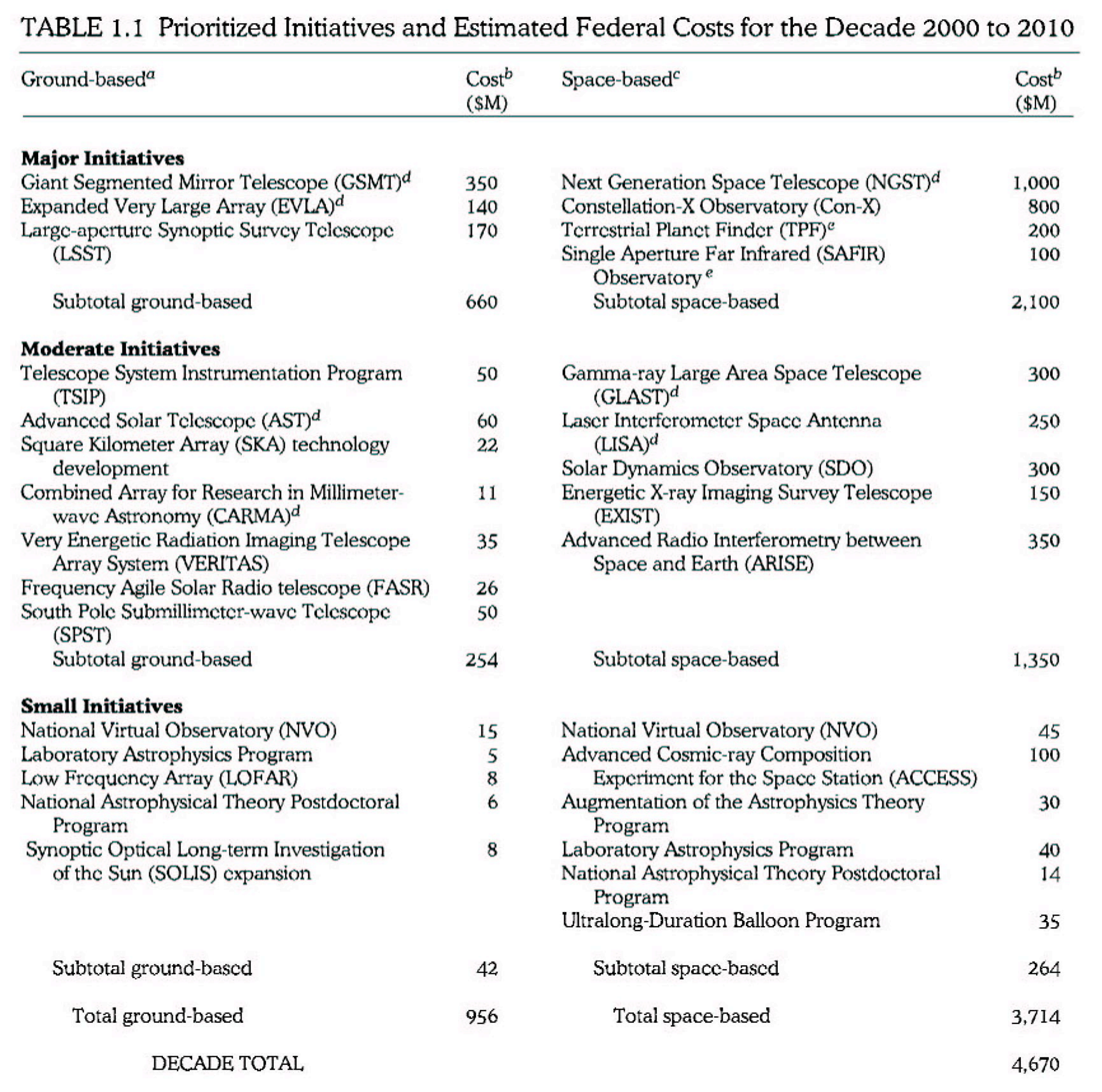


TABLE 1.1 Prioritized Initiatives and Estimated Federal Costs for the Decade 2000 to 2010

Ground-based[a]	Cost[b] ($M)	Space-based[c]	Cost[b] ($M)
Major Initiatives			
Giant Segmented Mirror Telescope (GSMT)[d]	350	Next Generation Space Telescope (NGST)[d]	1,000
Expanded Very Large Array (EVLA)[d]	140	Constellation-X Observatory (Con-X)	800
Large-aperture Synoptic Survey Telescope (LSST)	170	Terrestrial Planet Finder (TPF)[e]	200
		Single Aperture Far Infrared (SAFIR) Observatory[e]	100
Subtotal ground-based	660	Subtotal space-based	2,100
Moderate Initiatives			
Telescope System Instrumentation Program (TSIP)	50	Gamma-ray Large Area Space Telescope (GLAST)[d]	300
Advanced Solar Telescope (AST)[d]	60	Laser Interferometer Space Antenna (LISA)[d]	250
Square Kilometer Array (SKA) technology development	22	Solar Dynamics Observatory (SDO)	300
Combined Array for Research in Millimeter-wave Astronomy (CARMA)[d]	11	Energetic X-ray Imaging Survey Telescope (EXIST)	150
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	35	Advanced Radio Interferometry between Space and Earth (ARISE)	350
Frequency Agile Solar Radio telescope (FASR)	26		
South Pole Submillimeter-wave Telescope (SPST)	50		
Subtotal ground-based	254	Subtotal space-based	1,350
Small Initiatives			
National Virtual Observatory (NVO)	15	National Virtual Observatory (NVO)	45
Laboratory Astrophysics Program	5	Advanced Cosmic-ray Composition Experiment for the Space Station (ACCESS)	100
Low Frequency Array (LOFAR)	8		
National Astrophysical Theory Postdoctoral Program	6	Augmentation of the Astrophysics Theory Program	30
Synoptic Optical Long-term Investigation of the Sun (SOLIS) expansion	8	Laboratory Astrophysics Program	40
		National Astrophysical Theory Postdoctoral Program	14
		Ultralong-Duration Balloon Program	35
Subtotal ground-based	42	Subtotal space-based	264
Total ground-based	956	Total space-based	3,714
DECADE TOTAL			4,670

U.S. Initiatives for Future VHE Telescopes:
Part II - APS White Paper

Jim Buckley (Washington U.)
Simon Swordy (U. Chicago)
CTA meet Paris, March 1 2007

U.S. Gamma-Ray Community

- VERITAS group just begining operations (with similar sensitivity to HESS) but years late - need results before we can move forward
- Not just IACTs: MILAGRO group is moving forward with HAWC proposal
- GLAST will be launched around Jan 2008
- New groups, not traditionally part of the ACT community (e.g., Stanford) making major push

Overview

- Future Gamma-Ray Working Group: There is a loosely affiliated, primarily U.S.-funded group working to define the science drivers and technological approach for a large new experiment, in time for the next NRC decadal review (as Simon described).
- The activities of this group include a number of meetings, efforts to reach out to a broader community, and now a more focused effort on putting together a White Paper for an APS DAP study
- We (I) suspect that the answer will be that we need an order of magnitude improvement in sensitivity above 100 GeV, and a reduction in threshold to around 30-40 GeV.
- We have guessed that at least 100-200M$ will be required
  (note 100M$ total ≈ 50M$ equipment ≈ 35M€)

Meetings

“Towards the Future”

- "Ground-based Gamma-ray Astronomy: Towards the Future", October 20-21, 2005, UCLA, Mays' landing, Malibu, CA http://gamma3.astro.ucla.edu/future_cherenkov/

- "Ground Based Gamma Ray Astronomy: Towards the Future", May 11-12, 2006, LANL, SantaFe, NM, http://www.lanl.gov/orgs/p/g_a_d/p-23/gammaworkshop

APS Whitepaper

Following the Sante Fe meeting, we worked to initiate a study to determine the scientific case for a new ground-based gamma-ray instrument.

Working with James Ryan, chair of the APS DAP division, we prompted the APS to solicit a White Paper with the following official charge:

> "The Division of Astrophysics of the American Physical Society invites you to prepare a review or white paper on the status and future of ground based TeV gamma-ray astronomy. With the upcoming commissioning of VERITAS and the success of HESS and other is this emerging field, a review of the science accomplishments and potential would be welcome. Furthermore, given the long lead time for designing, developing and deploying new instruments, we need a clear path for proceeding beyond the near term."

WP Editorial Board

- Initial editorial board was formed Sept. 27, 2006 and expanded in Dec, 2006 to include external advisors
  - B. Dingus (MILAGRO)
  - H. Krawczynski (VERITAS, EXIST)
  - M. Pohl (Theory, GLAST)
  - V. Vassiliev (VERITAS)
  - W. Hofmann (HESS)
  - S. Ritz (GLAST)
  - F. Halzen (Ice Cube)
  - T. Weekes (VERITAS)

WP Working Groups

- Extragalactic Science - Henric Krawczynski (Washington U.)
- Dark Matter Science - Jim Buckley (WU)
- Gamma-ray Bursts - David Williams/Abe Falcone (Santa Cruz)
- Galactic Diffuse Emission, SNR and Origin of Cosmic Rays - Martin Pohl (Iowa State U.)
- Galactic Compact Objects - Phil Kaaret (U. Iowa)
- Technology - Karen Byrum (ANL)

APS White Paper

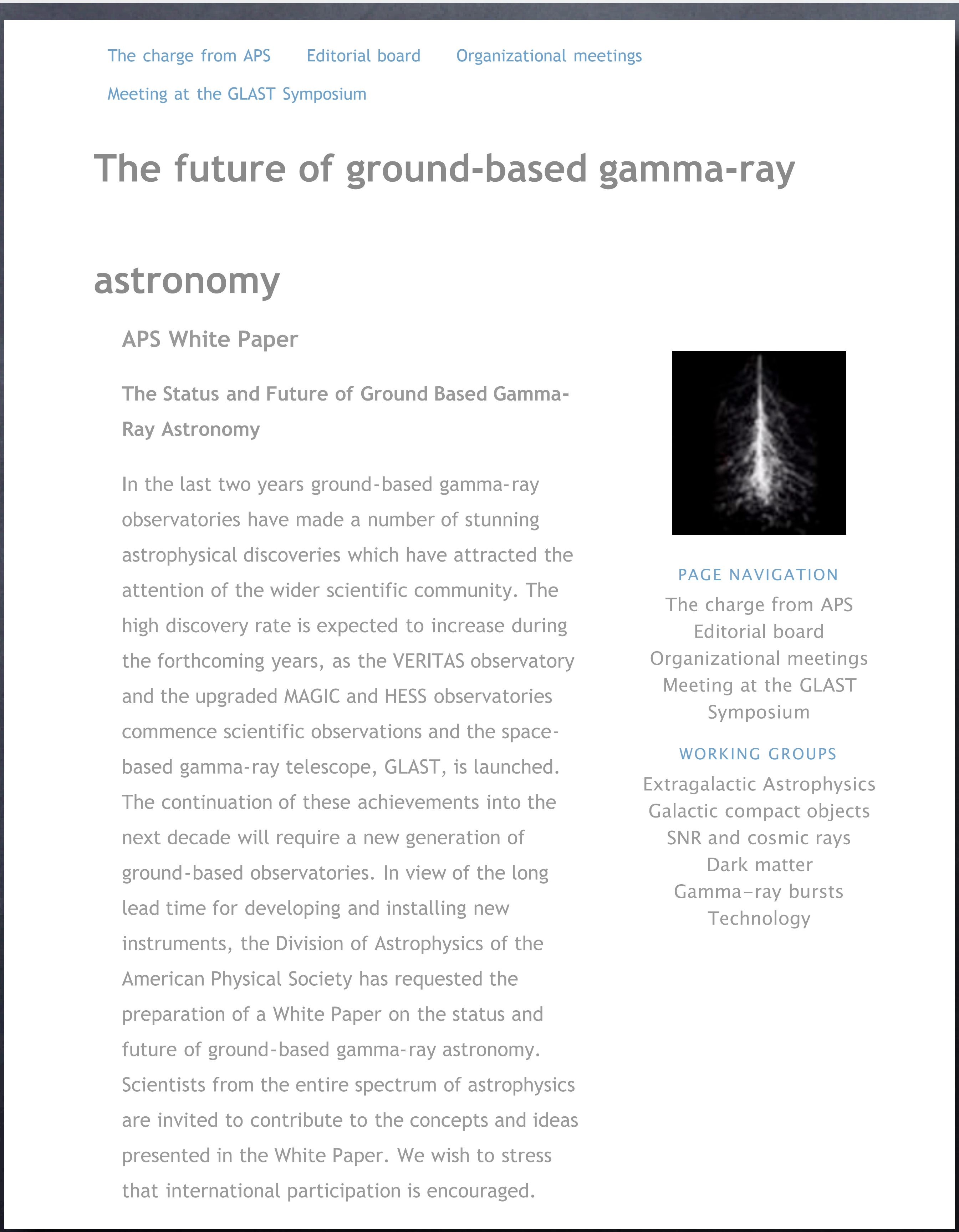
- Increase interest and involvement of broader scientific community.
- Define the science goals and instrument requirements for a future experiment. Build a strong science case to justify the project budget.
- Describe relevant performance specifications and identify areas of most important technology development.
- Estimate the timeframe and budget required to complete the project.

Example: DM Group

Ted Baltz (SLAC)	Savvas Koushiappas (LANL)
Jim Buckley (Wash U)	Henric Krawczynski (Wash U)
Karen Byrum (ANL)	Stephan LeBohec (U. Utah)
Brenda Dingus (LANL)	Martin Pohl (ISU)
Stephen Fegan (UCLA)	Stefano Profumo (Caltech)
Paolo Gondolo (U. Utah)	Joe Silk (Oxford)
Jeter Hall (U. Utah)	Vladimir Vassiliev (UCLA)
Dan Hooper (FNAL)	Scott Wakely (U. Chicago)
Deirdre Horan (ANL)	Matthew Wood (UCLA)

Theorist → Experimentalist/Theorist → Experimentalist

WP Web Site



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.

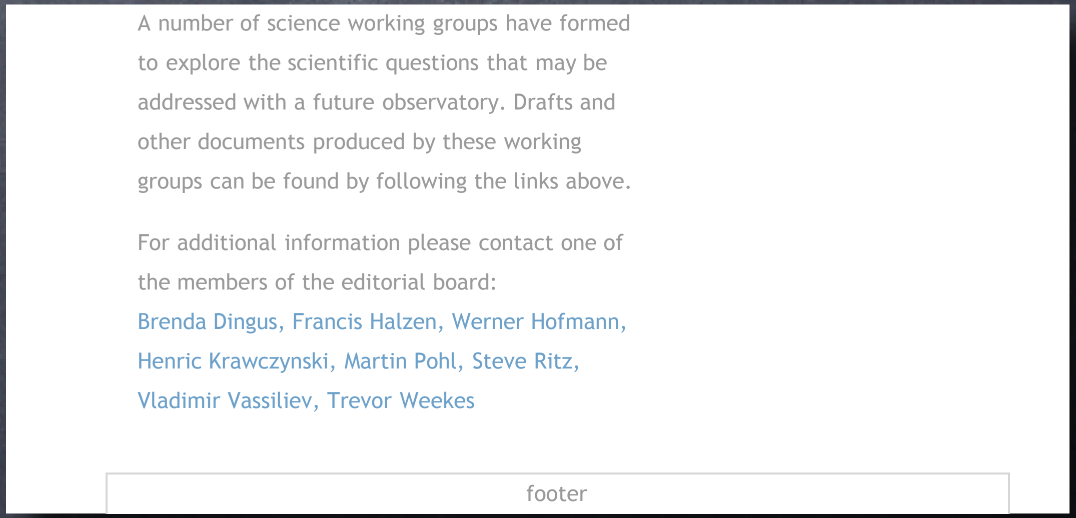
PAGE NAVIGATION

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

WORKING GROUPS

Extragalactic Astrophysics
Galactic compact objects
SNR and cosmic rays
Dark matter
Gamma–ray bursts
Technology

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



A number of science working groups have formed to explore the scientific questions that may be addressed with a future observatory. Drafts and other documents produced by these working groups can be found by following the links above.

For additional information please contact one of the members of the editorial board:
Brenda Dingus, Francis Halzen, Werner Hofmann, Henric Krawczynski, Martin Pohl, Steve Ritz, Vladimir Vassiliev, Trevor Weekes

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WP Document Status

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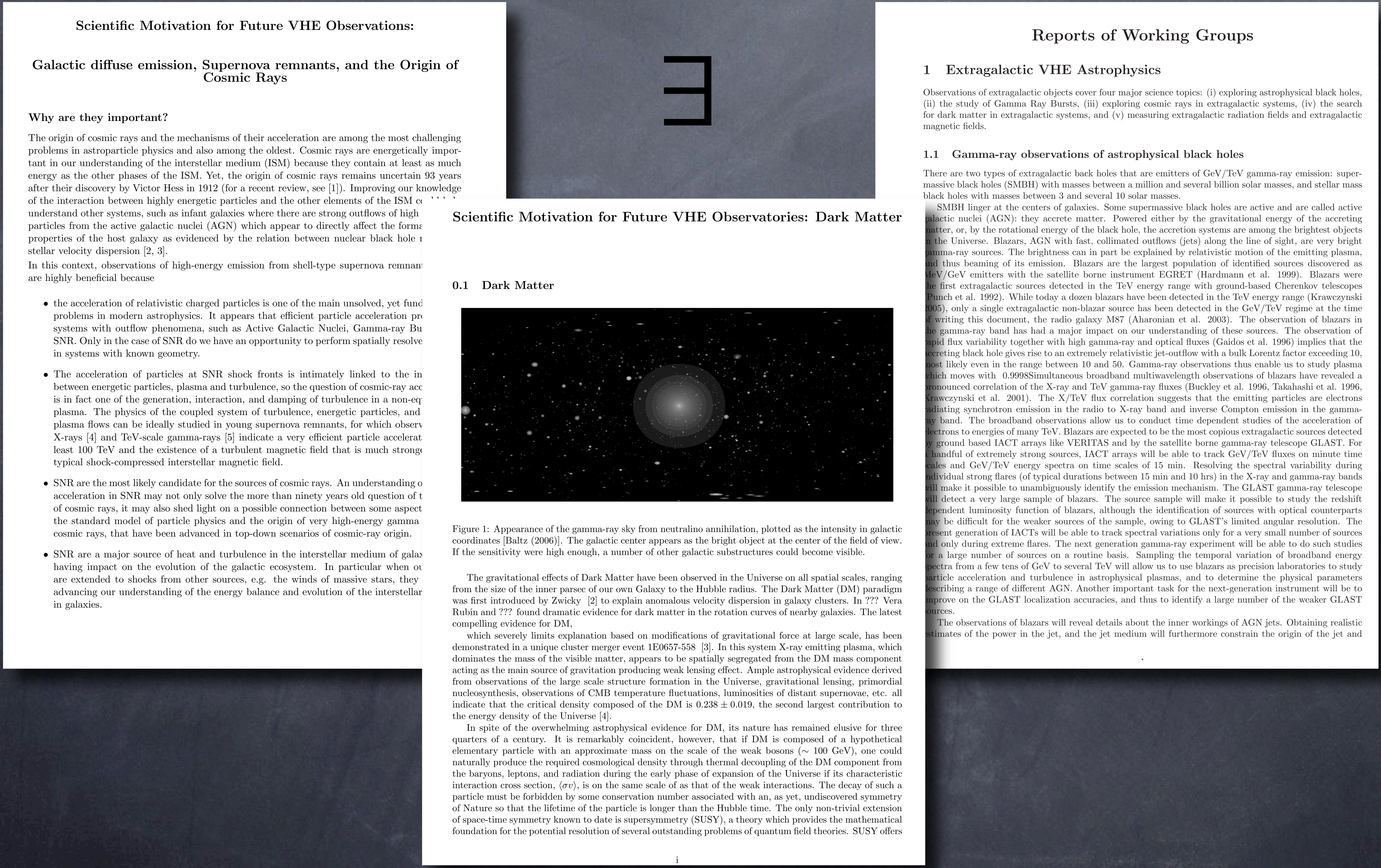

Scientific Motivation for Future VHE Observations:

Galactic diffuse emission, Supernova remnants, and the Origin of Cosmic Rays

Why are they important?

The origin of cosmic rays and the mechanisms of their acceleration are among the most challenging problems in astroparticle physics and also among the oldest. Cosmic rays are energetically important in our understanding of the interstellar medium (ISM) because they contain at least as much energy as the other phases of the ISM. Yet, the origin of cosmic rays remains uncertain 93 years after their discovery by Victor Hess in 1912 (for a recent review, see [1]). Improving our knowledge of the interaction between highly energetic particles and the other elements of the ISM c
understand other systems, such as infant galaxies where there are strong outflows of high
particles from the active galactic nuclei (AGN) which appear to directly affect the forma
properties of the host galaxy as evidenced by the relation between nuclear black hole
stellar velocity dispersion [2, 3].

In this context, observations of high-energy emission from shell-type supernova remnan
are highly beneficial because

- the acceleration of relativistic charged particles is one of the main unsolved, yet fund
problems in modern astrophysics. It appears that efficient particle acceleration pr
systems with outflow phenomena, such as Active Galactic Nuclei, Gamma-ray Bu
SNR. Only in the case of SNR do we have an opportunity to perform spatially resolve
in systems with known geometry.
- The acceleration of particles at SNR shock fronts is intimately linked to the in
between energetic particles, plasma and turbulence, so the question of cosmic-ray acc
is in fact one of the generation, interaction, and damping of turbulence in a non-eq
plasma. The physics of the coupled system of turbulence, energetic particles, and
plasma flows can be ideally studied in young supernova remnants, for which observ
X-rays [4] and TeV-scale gamma-rays [5] indicate a very efficient particle accelerat
least 100 TeV and the existence of a turbulent magnetic field that is much strong
typical shock-compressed interstellar magnetic field.
- SNR are the most likely candidate for the sources of cosmic rays. An understanding o
acceleration in SNR may not only solve the more than ninety years old question of t
of cosmic rays, it may also shed light on a possible connection between some aspect
the standard model of particle physics and the origin of very high-energy gamma
cosmic rays, that have been advanced in top-down scenarios of cosmic-ray origin.
- SNR are a major source of heat and turbulence in the interstellar medium of gala
having impact on the evolution of the galactic ecosystem. In particular when o
are extended to shocks from other sources, e.g. the winds of massive stars, they
advancing our understanding of the energy balance and evolution of the interstellar
in galaxies.

Scientific Motivation for Future VHE Observatories: Dark Matter

0.1 Dark Matter

Figure 1: Appearance of the gamma-ray sky from neutralino annihilation, plotted as the intensity in galactic coordinates [Baltz (2006)]. The galactic center appears as the bright object at the center of the field of view. If the sensitivity were high enough, a number of other galactic substructures could become visible.

The gravitational effects of Dark Matter have been observed in the Universe on all spatial scales, ranging from the size of the inner parsec of our own Galaxy to the Hubble radius. The Dark Matter (DM) paradigm was first introduced by Zwicky [2] to explain anomalous velocity dispersion in galaxy clusters. In ??? Vera Rubin and ??? found dramatic evidence for dark matter in the rotation curves of nearby galaxies. The latest compelling evidence for DM,

which severely limits explanation based on modifications of gravitational force at large scale, has been demonstrated in a unique cluster merger event 1E0657-558 [3]. In this system X-ray emitting plasma, which dominates the mass of the visible matter, appears to be spatially segregated from the DM mass component acting as the main source of gravitation producing weak lensing effect. Ample astrophysical evidence derived from observations of the large scale structure formation in the Universe, gravitational lensing, primordial nucleosynthesis, observations of CMB temperature fluctuations, luminosities of distant supernovae, etc. all indicate that the critical density composed of the DM is 0.238 ± 0.019, the second largest contribution to the energy density of the Universe [4].

In spite of the overwhelming astrophysical evidence for DM, its nature has remained elusive for three quarters of a century. It is remarkably coincident, however, that if DM is composed of a hypothetical elementary particle with an approximate mass on the scale of the weak bosons (∼ 100 GeV), one could naturally produce the required cosmological density through thermal decoupling of the DM component from the baryons, leptons, and radiation during the early phase of expansion of the Universe if its characteristic interaction cross section, $\langle \sigma v \rangle$, is on the same scale of as that of the weak interactions. The decay of such a particle must be forbidden by some conservation number associated with an, as yet, undiscovered symmetry of Nature so that the lifetime of the particle is longer than the Hubble time. The only non-trivial extension of space-time symmetry known to date is supersymmetry (SUSY), a theory which provides the mathematical foundation for the potential resolution of several outstanding problems of quantum field theories. SUSY offers

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Reports of Working Groups

1 Extragalactic VHE Astrophysics

Observations of extragalactic objects cover four major science topics: (i) exploring astrophysical black holes, (ii) the study of Gamma Ray Bursts, (iii) exploring cosmic rays in extragalactic systems, (iv) the search for dark matter in extragalactic systems, and (v) measuring extragalactic radiation fields and extragalactic magnetic fields.

1.1 Gamma-ray observations of astrophysical black holes

There are two types of extragalactic back holes that are emitters of GeV/TeV gamma-ray emission: supermassive black holes (SMBH) with masses between a million and several billion solar masses, and stellar mass black holes with masses between 3 and several 10 solar masses.

SMBH linger at the centers of galaxies. Some supermassive black holes are active and are called active
alactic nuclei (AGN): they accrete matter. Powered either by the gravitational energy of the accreting
atter, or, by the rotational energy of the black hole, the accretion systems are among the brightest objects
n the Universe. Blazars, AGN with fast, collimated outflows (jets) along the line of sight, are very bright
amma-ray sources. The brightness can in part be explained by relativistic motion of the emitting plasma,
nd thus beaming of its emission. Blazars are the largest population of identified sources discovered as
eV/GeV emitters with the satellite borne instrument EGRET (Hardmann et al. 1999). Blazars were
he first extragalactic sources detected in the TeV energy range with ground-based Cherenkov telescopes
Punch et al. 1992). While today a dozen blazars have been detected in the TeV energy range (Krawczynski
005), only a single extragalactic non-blazar source has been detected in the GeV/TeV regime at the time
f writing this document, the radio galaxy M87 (Aharonian et al. 2003). The observation of blazars in
he gamma-ray band has had a major impact on our understanding of these sources. The observation of
apid flux variability together with high gamma-ray and optical fluxes (Gaidos et al. 1996) implies that the
ccreting black hole gives rise to an extremely relativistic jet-outflow with a bulk Lorentz factor exceeding 10,
ost likely even in the range between 10 and 50. Gamma-ray observations thus enable us to study plasma
hich moves with 0.9998Simultaneous broadband multiwavelength observations of blazars have revealed a
ronounced correlation of the X-ray and TeV gamma-ray fluxes (Buckley et al. 1996, Takahashi et al. 1996,
rawczynski et al. 2001). The X/TeV flux correlation suggests that the emitting particles are electrons
adiating synchrotron emission in the radio to X-ray band and inverse Compton emission in the gamma-
ay band. The broadband observations allow us to conduct time dependent studies of the acceleration of
lectrons to energies of many TeV. Blazars are expected to be the most copious extragalactic sources detected
y ground based IACT arrays like VERITAS and by the satellite borne gamma-ray telescope GLAST. For
handful of extremely strong sources, IACT arrays will be able to track GeV/TeV fluxes on minute time
cales and GeV/TeV energy spectra on time scales of 15 min. Resolving the spectral variability during
ndividual strong flares (of typical durations between 15 min and 10 hrs) in the X-ray and gamma-ray bands
ill make it possible to unambiguously identify the emission mechanism. The GLAST gamma-ray telescope
ill detect a very large sample of blazars. The source sample will make it possible to study the redshift
ependent luminosity function of blazars, although the identification of sources with optical counterparts
ay be difficult for the weaker sources of the sample, owing to GLAST's limited angular resolution. The
resent generation of IACTs will be able to track spectral variations only for a very small number of sources
nd only during extreme flares. The next generation gamma-ray experiment will be able to do such studies
or a large number of sources on a routine basis. Sampling the temporal variation of broadband energy
pectra from a few tens of GeV to several TeV will allow us to use blazars as precision laboratories to study
article acceleration and turbulence in astrophysical plasmas, and to determine the physical parameters
escribing a range of different AGN. Another important task for the next-generation instrument will be to
mprove on the GLAST localization accuracies, and thus to identify a large number of the weaker GLAST
ources.

The observations of blazars will reveal details about the inner workings of AGN jets. Obtaining realistic
stimates of the power in the jet, and the jet medium will furthermore constrain the origin of the jet and

WP Meetings/Timetable

Future Gamma-Ray Observatories
APS White Paper Meeting
Thurs. 8 Feb 2007 in McGaw Hall 1:30-5:00

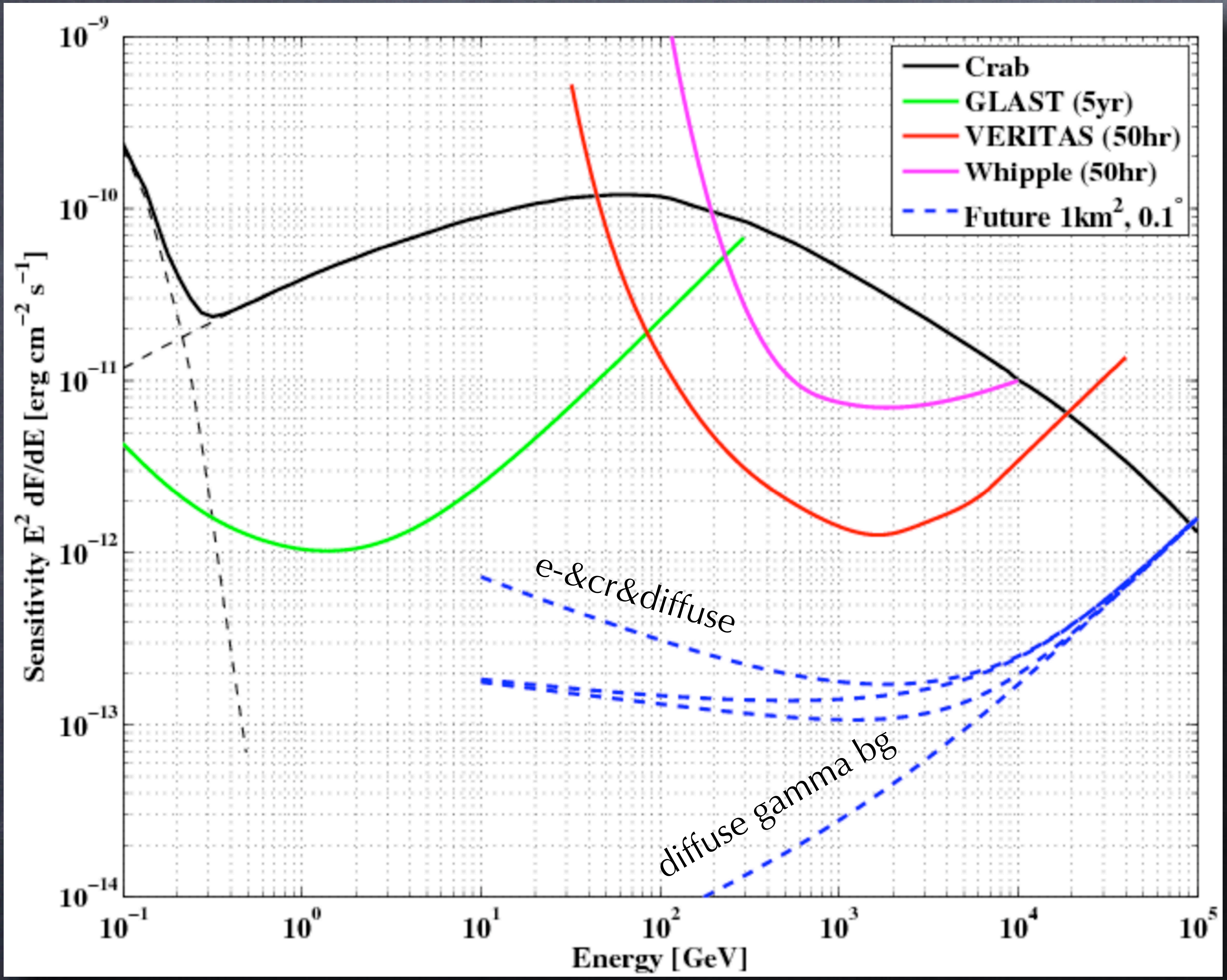
Bring a 1-viewgraph idea to share or just come and listen. Everyone is welcome and encouraged to participate now or in the future.

Organizing Committee:
Brenda Dingus, Henric Krawczynski, Martin Pohl, Vladimir Vassiliev
Additional Members of Editorial Board:
Francis Halzen, Werner Hofmann, Steve Ritz, Trevor Weekes

8 Feb 2007 AGENDA:
1:30-1:45 Motivation & Organization
1:45-2:10 Extragalactic Working Group
2:10-2:35 Gamma Ray Burst Working Group
2:35-3:00 Dark Matter Working Group
3:00-3:15 Break
3:15-3:40 Galactic Compact Sources Working Group
3:40-4:05 Galactic Diffuse Working Group
4:05-4:30 Technology Working Group
4:30-5:00 General Discussion

- Town-Hall style meeting, satellite meeting at end of GLAST Symposium (8 Feb 2007)
- APS special session with reports from each working group (14-17 April 2007)
- A third ``Towards the Future'' Workshop in Chicago (13-14 May 2007) contact Karen Byrum, see http://www.hep.anl.gov:80/byrum/next-iact/index.html
- Appendices should be close to final drafts (July 2007)
- Editorial committee will draw on appendices to produce the first complete draft of the WP, Oct. 2007

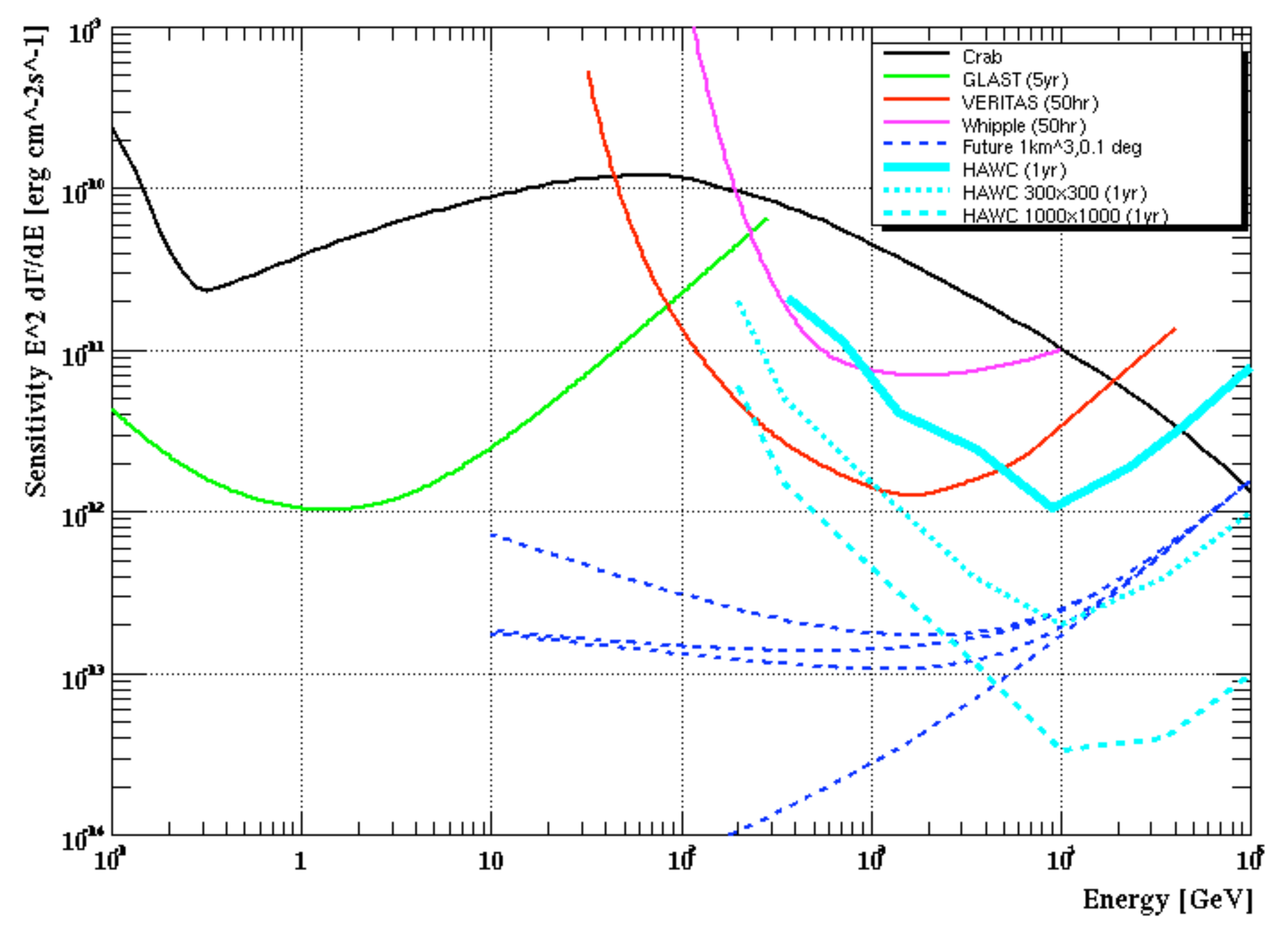
Best Performance Estimate



(Steven Fegan and Vladimir Vassiliev)

- In addition to determining required sensitivities from science drivers, we attempt to put a bound on the best possible performance
- Assume 1 km^2 (about 3 times a current instrument), no energy threshold, 0.1deg angular resolution, various irreducible backgrounds
- difficult to achieve better than 10^{-13} erg cm^{-1}sec^{-1}/√km^2

Water Cherenkov Perf.



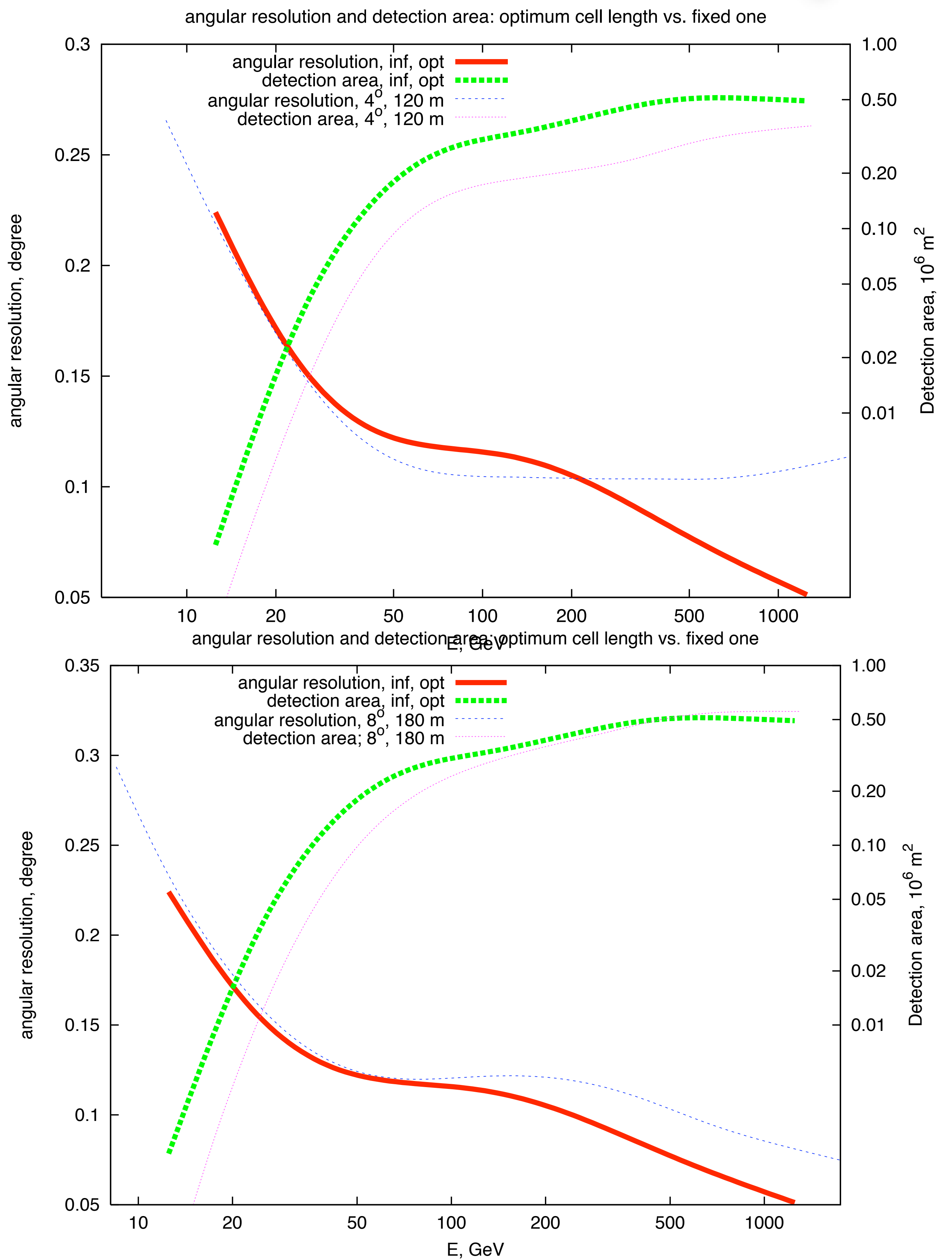
Differential sensitivity per quarter decade. The lines depict the 5 sigma detection flux level with at least 25 gamma rays. Data for GLAST, VERITAS, Whipple and the 1km^2 ACT courtesy of S. Fegan. For the 1km^2 ACT array, the 4 lines refer to 4 different background models.

(Andy Smith points from GLAST workshop added to Vassiliev and Fegan Figure)

Technological Approach

$$\nexists$$

Ideal Array Performance



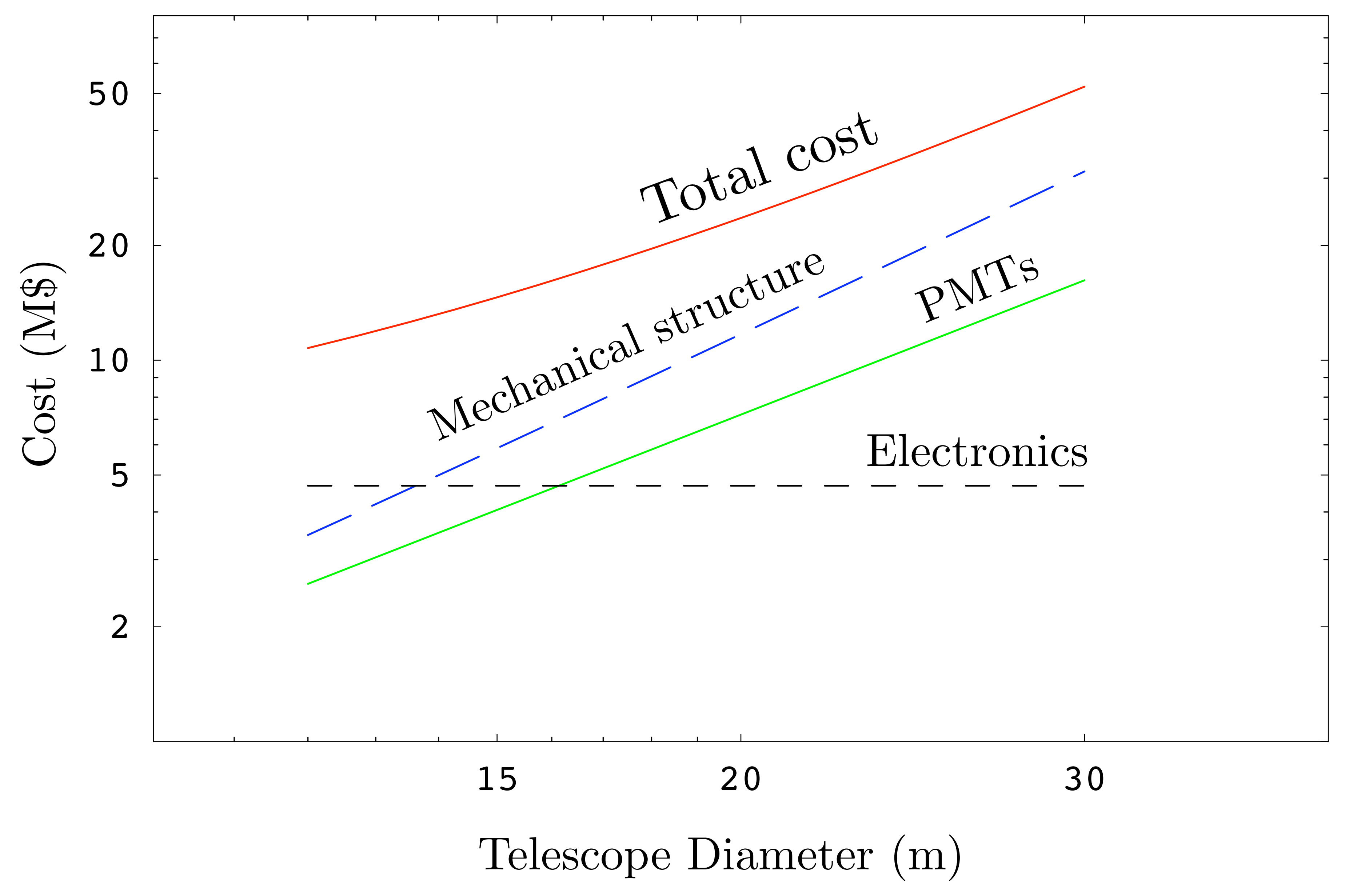
- Simulations of 3 20m telescopes, perfect optical system, no NSB - optimize quality factor based on Aeff and PSF
- Large FOV increases FOV, improves perf. at TeV energies
- 0.3 km^2 A$_{\text{eff}}$, 0.1deg resolution over 50 GeV-1TeV)

(Slava Bugaev, Wash. U.)

Rough Cost Estimate

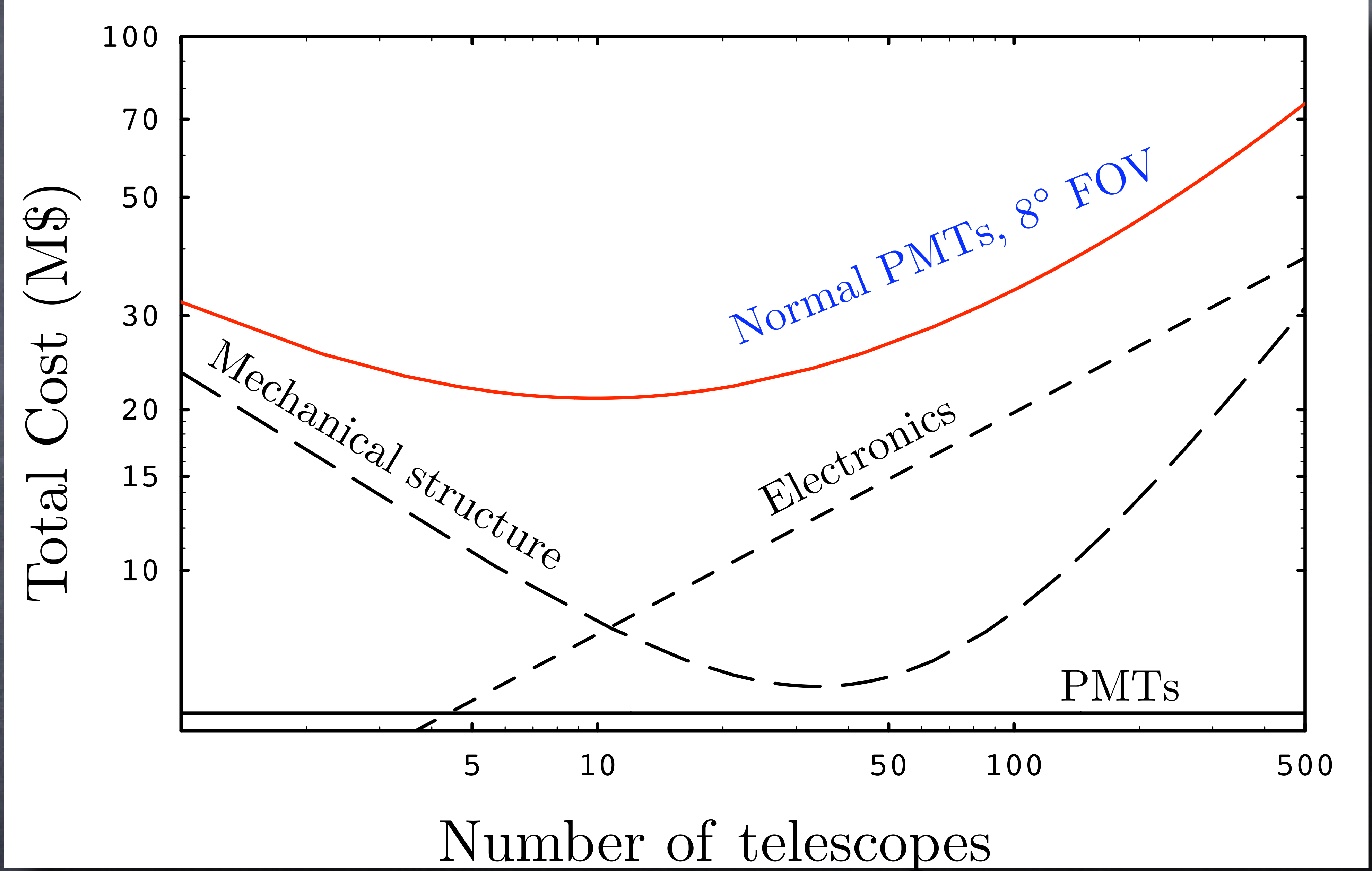
- VERITAS
  - camera cost: Current FADCs cost about $2M for 2300 channels, crates and chiller add about $300k, total cost of FADCs including engineering is about $1000/channel, equipment cost of boards was about $500/channel. Total camera cost is hard to estimate - perhaps $1.5k/channel (equip.)
  - telescope cost: was about $1M/telescope ($2M with personel support)
- HESS-I
  - camera cost: 670k€=$1.0k/channel
  - telescope cost: 770k€=$1.1M/telescope
- HESS-II
  - camera cost: $1.35k/channel
  - telescope cost: 7.25keur=$10.1M/telescope

Cost of 3 Telescope Array



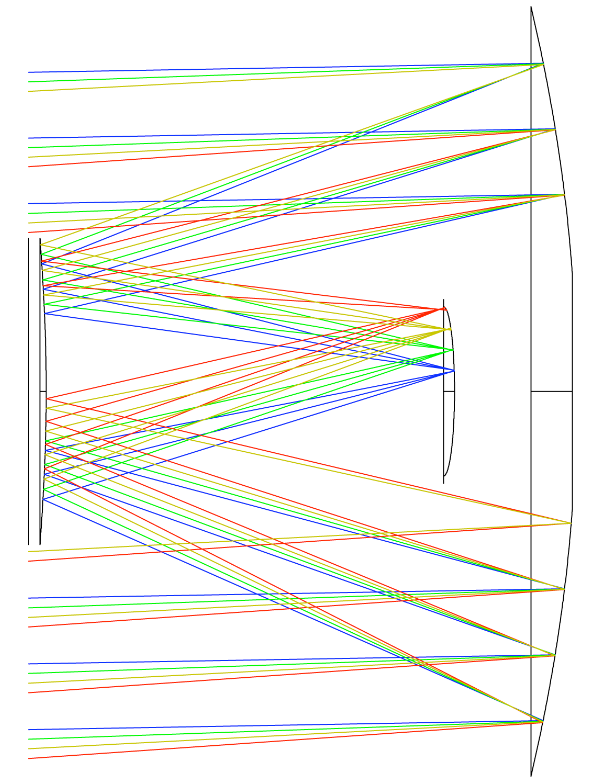
- Scale from VERITAS and HESS-I/II, assume 3 telescope with 8deg FOV, 4400 0.12 deg pixels, $500 electronic channels, $300 for 1″ PMTs
- Need >3 such arrays to reach 1 km^2

Many Small vs. one Large?

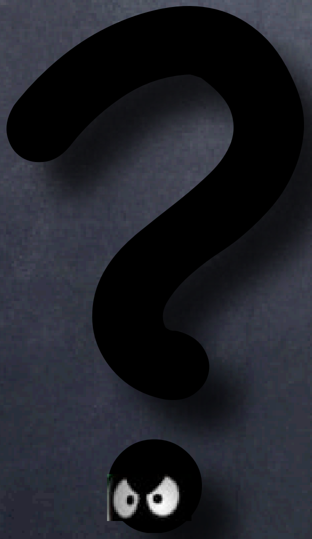


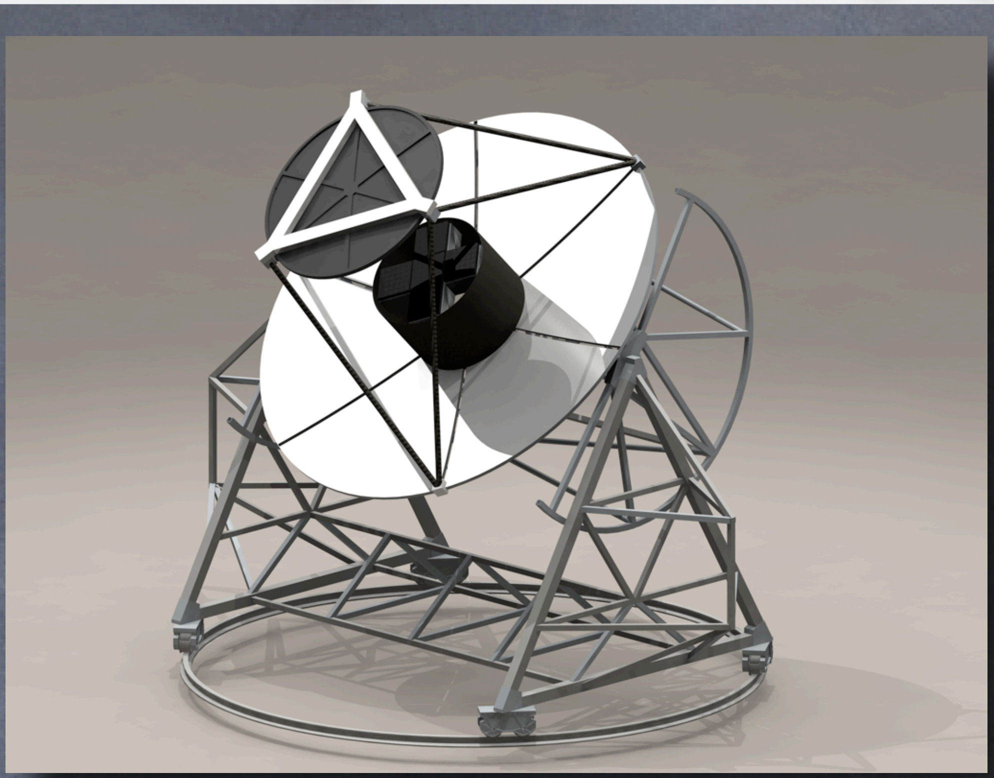
- Can make a 30m telescope with one large dish, or many small dishes - may be advantage for angular and energy resolution (Hofmann, Paris Cherenkov05)
- Optimum when camera cost ≈ telescope cost ⇒ 5-10 telescopes with diameter of 9-13m diameter

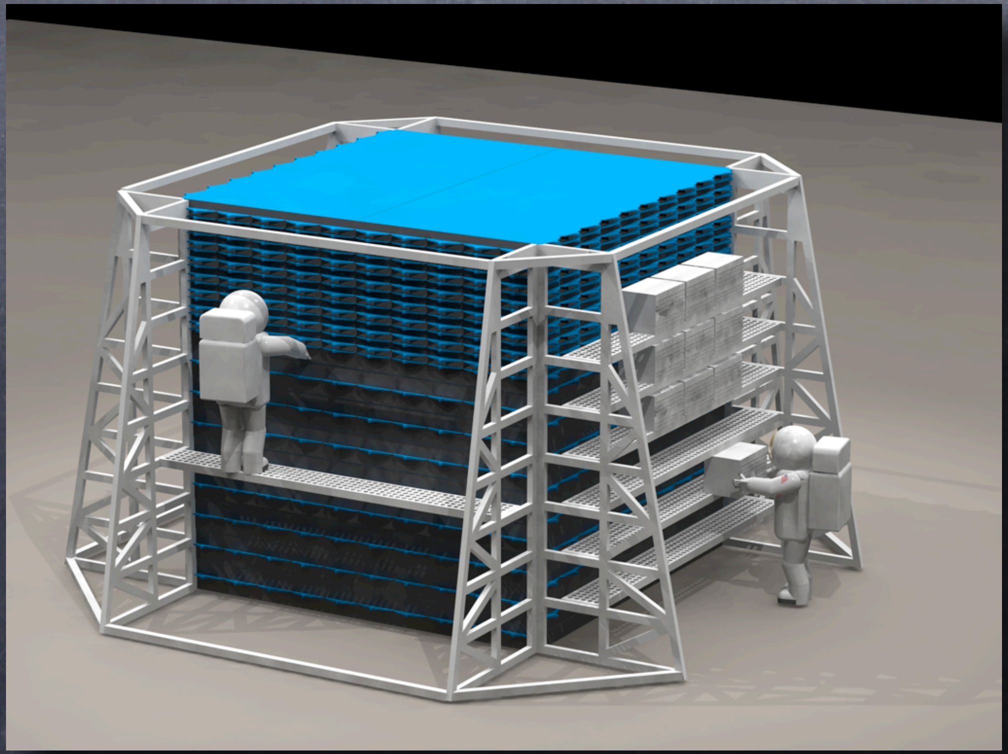
Technological Approach?



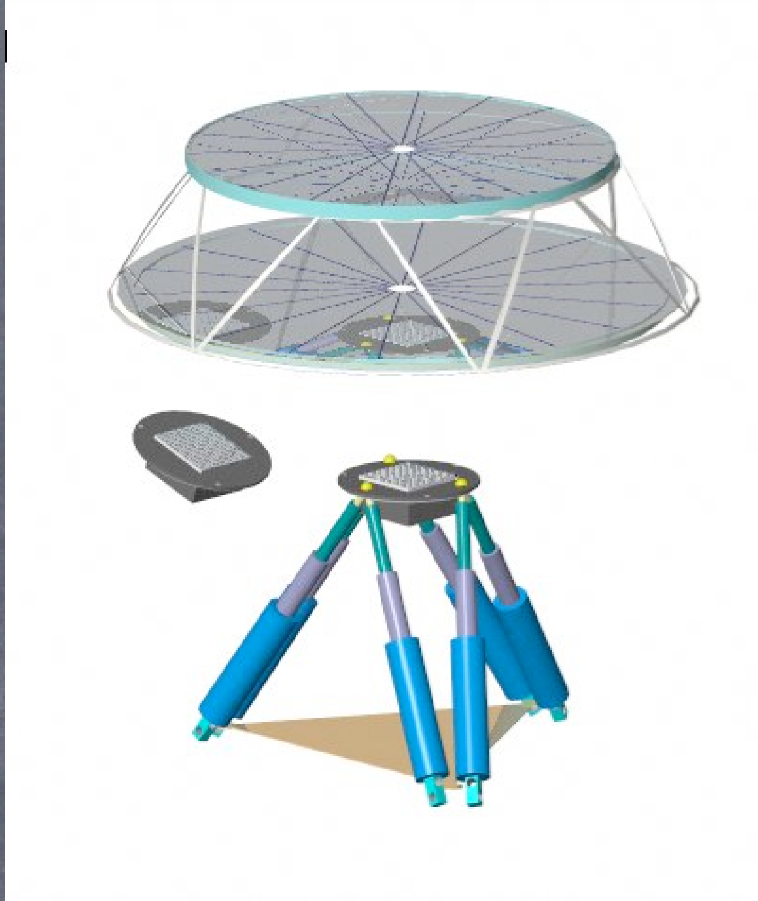
Ritchey-Chretien Optics?







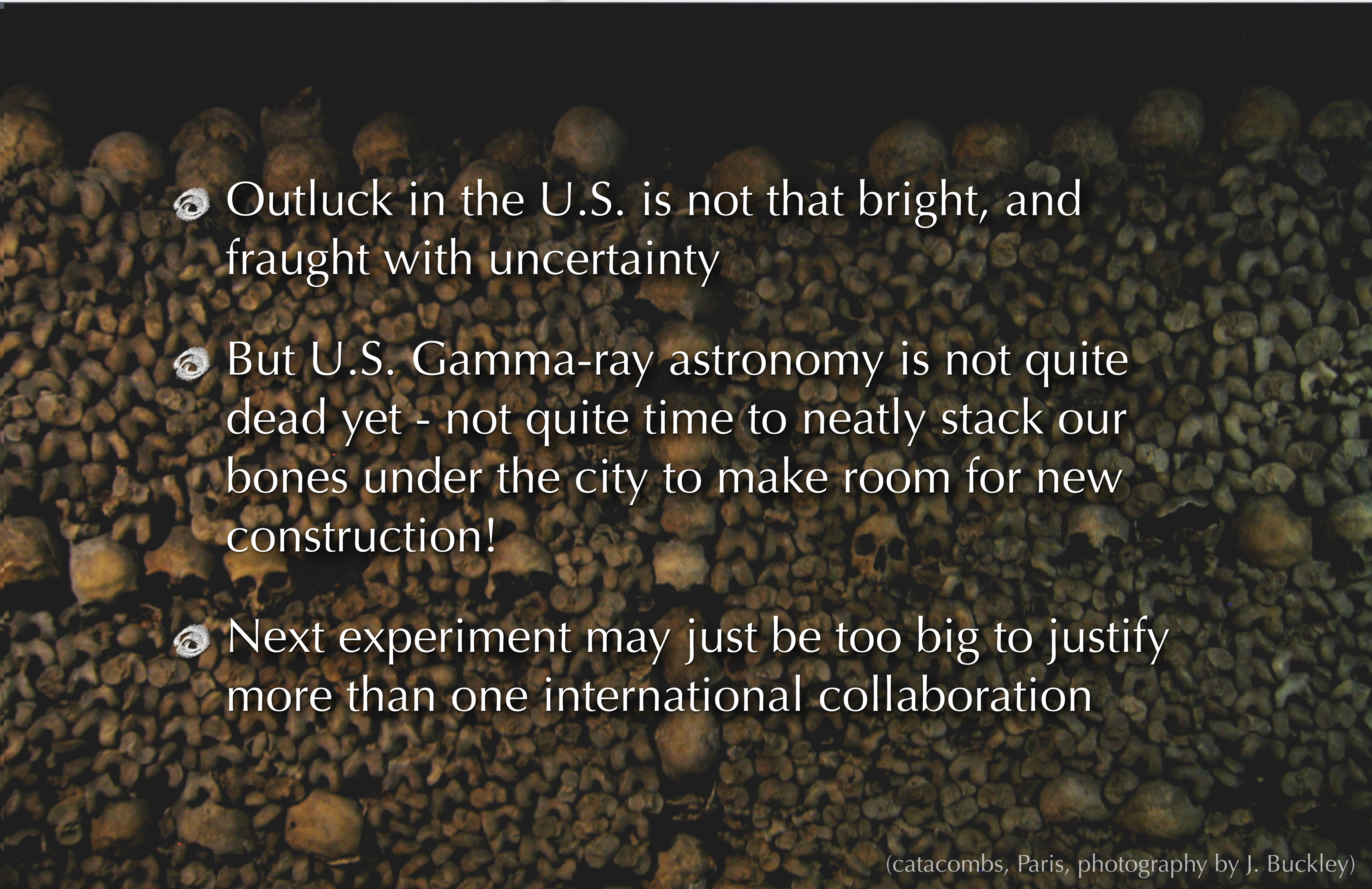
Lunar GLASTx30?



Refractive/Fresnel Optics?

Technological Approach?

Summary and Outlook



- Outluck in the U.S. is not that bright, and fraught with uncertainty
- But U.S. Gamma-ray astronomy is not quite dead yet - not quite time to neatly stack our bones under the city to make room for new construction!
- Next experiment may just be too big to justify more than one international collaboration

(catacombs, Paris, photography by J. Buckley)