Future Plans

Vladimir Vassiliev
As we discuss below, not only has the number of detected objects increased (and with this the depth of the universe that is probed) but the number of kinds of extra-galactic sources has also increased; this is a prediction of good things to come as the sensitivity and range of the telescopes is improved.
Kifune’s Plot

- $\sim 10^0$ in 1990 by Whipple
- $\sim 10^1$ in 2000 by Whipple, HEGRA, CANGAROO
- $\sim 10^2$ in 2010 by HESS I&II, MAGIC I&II, VERITAS, CANGAROO III
- $\sim 10^3$ in 2020 by CTA?
Guaranteed Astrophysics

STATUS

- VHE (>100 GeV) γ-ray astronomy is firmly established as a division of astronomical sciences (50+sources)
- GLAST is expected to advance the field dramatically

FUTURE SCIENCE GOALS

- Cosmologically distant Universe (>10 GeV)
  - VHE transient Universe (>10 GeV)
- Full Sky Survey (>100 GeV) with 10x sensitivity of present day instrumentation
  - GLAST catalogue studies
Multi-wavelength and multi-messenger Astronomy

UHE Cosmic Rays
Auger Observatory, 2005-

X-ray and γ-ray satellites
GLAST, Launch late 2007

Neutrinos
IceCube, 2010

VHE γ-rays
VERITAS, April 2007
Globalization
Costs

Early British-Irish, and Russian Observatories, 1960-1970
Recycled military hardware
~50K$

Whipple 10m, HEGRA
1980-2000
~1-3M$

HESS, MAGIC, VERITAS
2000 --, ~30M$

CTA, AGIS
2010 --,
~150 -200 M$

(by J. Buckley, Wash.U.)
Emerging Proposal: CTA
The Cherenkov Telescope Array facility

ESFRI LoI defines CTA baseline
100M € (SS) + 50M € (NS) + 5M € (OC/y)

MAGIC I & HESS I

MAGIC II & HESS II

GLAST

(W. Hofmann Talk, Paris 2007)
The National Academy of Sciences - National Research Council (NRC) is the organization that convenes the Astronomy and Astrophysics Decadal Surveys (AADSs). The series of AADS reports has provided priorities for the federal investment ...

The AADS process is organized by the NRC's and with the active involvement of their joint subcommittee, Committee on Astronomy and Astrophysics. The CAA monitors the status of space- and ground-based astronomy and astrophysics, provides assessments to the NSF, the NASA, and other institutions, and assists the federal government in planning programs in astronomy and astrophysics.

NRC, 1991 (Bahcall report: DDA&A)  
NRC, 2001 (A&ANM)  
NRC, 2011 (?)

US Realities

- **AADS planning has just begun**, however, the Boards are considering adjustments in the decadal survey process (e.g. uncompleted recommendations, accuracy of cost estimates, scientific area vs. investigative technique, boundaries of astronomy and astrophysics, space vs. ground, major vs. moderate, international coordination, etc.) There is large uncertainty in the AADS prioritization approach and therefore in future support for VHE $\gamma$-ray astronomy.

- Although HESS and MAGIC discoveries has increased interest among astronomers, the “relatively young” VHE $\gamma$-ray community remains small comparing to well established ones, e.g. Radio, X-ray, etc. **GLAST is expected to make a major impact on the visibility of $\gamma$-ray studies** within the community of astronomers and physicists.

- Within the US there are at least three groups of scientists with an interest to pursue development of $\gamma$-ray instrumentation for future projects (VERITAS, some members of GLAST, MILAGRO) which are not yet unified adequately for a large project. Involvement of the particle physics labs (ANL, possibly SLAC) is just starting. However, both NSF and DOE have been supportive for all VHE $\gamma$-ray astronomy groups.
“Towards the Future...”

- "Ground-based Gamma-ray Astronomy: Towards the Future", October 20-21, 2005, UCLA, Mays' landing, Malibu, CA
  http://gamma1.astro.ucla.edu/future_cherenkov/

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

- "Ground Based Gamma Ray Astronomy: Towards the Future", May 13-14, 2007, ANL & UC, Chicago, IL,
Extensive discussions of the status of VHE $\gamma$-ray Astronomy with James Ryan, Chair of the APS DAP, took place during Santa Fe meeting. As a result the APS solicited 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."

B. Dingus (LANL / MILAGRO)
H. Krawczynski (WU / VERITAS, EXIST)
M. Pohl (ISU / Theory, GLAST)
V. Vassiliev (UCLA / VERITAS)

W. Hofmann (MPI / HESS)
S. Ritz (GSFC, NASA / GLAST)
F. Halzen (U. W-M / Ice Cube)
T. Weekes (CfA / VERITAS)

Formed in Sep – Nov, 2006
WP goals

- Define the science goals and instrument requirements for a future experiment (not VERITAS II). Build a strong science case to justify the project budget.
  - Describe relevant performance specifications and identify areas of the required technology development.
  - Estimate the timeframe and the budget required to complete the project.
- Increase interest and involvement of broader scientific community
  - Prepare for “decadal survey” (AADS)
WP Working Groups

- Galactic Compact Objects [22] – (Phil Kaaret, U. Iowa)
- Galactic Diffuse Emission, SNR and Cosmic Rays [19]– (Martin Pohl, ISU)
- Dark Matter [18]– (Jim Buckley, Wash. U.)
- Gamma-ray bursts [?] – (David Williams/Abe Falcone, UCSC)
- Technology [15]– – (Karen Byrum, ANL)

Participation of 60+ people, e.g.
Atoyan, Baltz, Blandford, Böttcher, Coppi, Dermer, Dwek, Georgonopulous, Jones, Koushiappas, Perlman, ...

The future of ground-based gamma-ray astronomy

WP Web Site: http://cherenkov.physics.iastate.edu/wp/
WS Meetings / Timetable

Satellite meeting associated with the First GLAST Symposium at Stanford University, California (Feb 8, 2007)

First version of “The Appendices“, SWG reports. (Mar, 2007)

Special WP session at the American Physical Society meeting, Jacksonville, Florida (April 15, 2007)
  - Next “Towards the Future” meeting, Chicago (May 13-14, 2007)
  - “The Appendices” close-to-final-drafts (June, 2007).
  - First draft of WP (late summer, 2007)
  - WP release (late fall, 2007)
Defining the Project (initial steps)

- A core group of interested people [30+] has been formed through the sequence of “Towards the Future ...” meetings.

- Working Groups on Science, Simulations, Technology (Optics, Camera, Trigger), Site, and Funding & Budget has been created.

- Significant preliminary work in all WGs has been accomplished, which lead to the definition of straw-man design of Advanced Gamma-ray Imaging System.
Differential sensitivity of ideal 1km² IACT array

Area: 1 km²
Angular resolution: 0.1°
\( \Delta E/E = 0.58 \) (4 bins per decade)

(S. Fegan & V. Vassiliev)
Important Milestones in VERITAS observatory history

- Weekes, T.C. First ideas, Proc. 12\textsuperscript{th} ESLAB Symp. (Frascati), 279, (1977)
- Endorsed as decadal survey initiative (NRC, 2001)
- VERITAS First Light Celebration (April, 2007)

From initial ideas to proposal ~ 20 years
From proposal to instrument ~ another 10 years
Funding of DS Initiatives

Astronomy and Astrophysics in the New Millennium (NRC, 2001)
...it is clear that for the foreseeable future, the defining questions for astronomy and astrophysics will be these:

- How did the universe begin, how did it evolve from the soup of elementary particles into the structures seen today, and what is its destiny?
  - How do galaxies form and evolve?
  - How do stars form and evolve?
    - How do planets form and evolve?
    - Is there life elsewhere in the universe?
Science goals

TABLE 2.1 Science Goals for the New Initiatives

<table>
<thead>
<tr>
<th>Science Goal</th>
<th>Initiativea</th>
<th>Secondaryb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determining large-scale properties of the universe</td>
<td>NGST, GSMT, LSST (MAP, Planck, SIM)</td>
<td>Con-X</td>
</tr>
<tr>
<td>Studying the dawn of the modern universe</td>
<td>NGST, SKA, LOFAR (ALMA)</td>
<td>Con-X, EVLA, SAFIR, GLAST, LISA, EXIST, SPST</td>
</tr>
<tr>
<td>Understanding black holes</td>
<td>Con-X, GLAST, LISA, EXIST, ARISE</td>
<td>EVLA, LSST, VERITAS, SAFIR</td>
</tr>
<tr>
<td>Studying star formation and planets</td>
<td>NGST, GSMT, EVLA, LSST, TPP, SAFIR, TSIP, CARMA, SPST (ALMA, SIM, SIRTF, SOFIA)</td>
<td>AST, SDO, Con-X, EXIST</td>
</tr>
<tr>
<td>Understanding the effects of the astronomical environment on Earth</td>
<td>LSST, AST, SDO, FASR</td>
<td>GLAST</td>
</tr>
</tbody>
</table>

NOTE: Acronyms are defined in the appendix.

*aMissions and facilities listed in parentheses are those that were recommended previously but have not yet begun operation.

*bProjects 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.

A&ANM / NRC, 2001
### TABLE 1.1 Prioritized Initiatives and Estimated Federal Costs for the Decade 2000 to 2010

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Ground-based</th>
<th>Space-based</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major Initiatives</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giant Segregated Mirror Telescope (GSMT)</td>
<td>350</td>
<td>1,000</td>
<td>1,350</td>
</tr>
<tr>
<td>Expanded Very Large Array (EVLAT)</td>
<td>140</td>
<td>900</td>
<td>1,040</td>
</tr>
<tr>
<td>Large-aperture Synoptic Survey Telescope (LST)</td>
<td>170</td>
<td>260</td>
<td>430</td>
</tr>
<tr>
<td>Subtotal ground-based</td>
<td>660</td>
<td></td>
<td>660</td>
</tr>
<tr>
<td><strong>Moderate Initiatives</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Telescope System Instrumentation Program (TSIP)</td>
<td>50</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>Advanced Solar Telescope (ASTS)</td>
<td>60</td>
<td>250</td>
<td>310</td>
</tr>
<tr>
<td>Square Kilometer Array (SKA) technology development</td>
<td>22</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>Combined Array for Research in Millimeter-wave Astronomy (CARMA)</td>
<td>11</td>
<td>150</td>
<td>161</td>
</tr>
<tr>
<td><strong>Very Energetic Radiation Imaging Telescope</strong></td>
<td></td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td><strong>Total Federal funding</strong></td>
<td>254</td>
<td>1,350</td>
<td>1,604</td>
</tr>
<tr>
<td><strong>Small Initiatives</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>National Virtual Observatory (NVO)</td>
<td>15</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Laboratory Astrophysics Program</td>
<td>5</td>
<td>100</td>
<td>105</td>
</tr>
<tr>
<td>Low Frequency Array (LOFAR)</td>
<td>8</td>
<td>100</td>
<td>108</td>
</tr>
<tr>
<td>National Astrophysical Theory Postdoctoral Program</td>
<td>6</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>Synoptic Optical Long-term Investigation of the Sun (SOLIS) expansion</td>
<td>8</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td><strong>Total ground-based</strong></td>
<td>42</td>
<td>264</td>
<td>266</td>
</tr>
<tr>
<td><strong>Total Federal funding</strong></td>
<td>966</td>
<td>3,714</td>
<td>4,680</td>
</tr>
</tbody>
</table>

A&ANM / NRC, 2001

**Science goal:** to be finalized by WP

**Budget:** Comply with the definition of “Moderate Initiative” in AADS (expected 100-130M$)
Science goal: to be finalized by WP
Budget: \(~130\text{M}\$\), “Moderate Initiative”
Observatory: \(~1\text{km}^2\) array of mid-size
telescopes to provide factor of 10
improvement in the sensitivity at \(E_\gamma \sim 1\text{ TeV}\).
This strategy guaranties scientific return
\((\log N \text{ vs } \log F)\) in the energy domain
proven to be most fruitful by HESS, MAGIC, and VERITAS.
**VERITAS**

Science goal: Understanding BHs  
Budget: 35M$, “Moderate Initiative”  
Observatory: small array of mid-IACTs  
IACTs: 7 identical telescopes

---

**AGIS**

Science goal: to be finalized by WP  
Budget: ~130M$, “Moderate Initiative”  
Observatory: ~1km² array of mid-IACTs  
IACTs: all telescopes are identical to minimize R&D, design, construction, and maintenance costs, and improve reliability of operation. Add-on specialized instruments are possible if provide unique scientific capabilities under assumption of fixed budget.

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A&ANM / NRC, 2001
CT Aperture

VERITAS

Science goal: Understanding BHs
Budget: 35M$, “Moderate Initiative”
Observatory: small array of mid-IACTs
IACTs: 7 identical telescopes
CT Aperture: 12 m

AGIS

Science goal: to be finalized by WP
Budget: ~130M$, “Moderate Initiative”
Observatory: ~1km² array of mid-IACTs
IACTs: 150-50 identical telescopes (+…)
CT Aperture: 5-12 m. Exact aperture TBD through simulations of fixed budget array configurations and science goals specifications

A&ANM / NRC, 2001
Technologies

VERITAS

Energetic X-ray Imaging Survey Telescope. EXIST will survey the entire sky every 90 minutes to search for weak and often time-variable astronomical sources of 5- to 600-keV x-ray photons. Such x rays emanate from many sources, including supermassive black holes in the centers of galaxies, stellar mass black holes, neutron stars, and embedded supernovae in our galaxy, and the mysterious distant sources of gamma-ray bursts of radiation. Attached to the International Space Station, EXIST will survey sources 1,000 times weaker than the sources in the previous hard x-ray survey by the High Energy Astronomical Observatory (HEAO-1). EXIST’s repeated surveys of the entire sky in the hard x-ray region will complement those by LSST at optical wavelengths.

Very Energetic Radiation Imaging Telescope Array System. VERITAS will perform the first sensitive sky survey for astronomical sources of extremely energetic photons—those with energies from 100 to 10,000 GeV. VERITAS will complement GLAST and EXIST in studying the cosmic sources of relativistic particles such as supermassive black holes, gamma-ray burst sources, pulsars, and supernova remnants. Making use of the established technology of the 10-m reflector at the Whipple Observatory, VERITAS consists of an array of seven 10-m diameter reflectors that will achieve more than an order of magnitude improvement in sensitivity and have a far greater ability than existing instruments to locate sources.

AGIS

Science goal: to be finalized by WP
Budget: ~130M$, “Moderate Initiative”
Observatory: ~1km² array of mid-IACs
IACs: 150-50 identical telescopes (+…)
CT Aperture: 5-15 m (#CTs & aperture TBD)
Technology: Builds on demonstrated AC technique, however, requires significant R&D to reduce costs and increase reliability

A&ANM / NRC, 2001
## Technology Development

### VERITAS

<table>
<thead>
<tr>
<th>Technology Initiative</th>
<th>Decade Cost ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground-based</strong></td>
<td></td>
</tr>
<tr>
<td>Megacorrelators</td>
<td>10</td>
</tr>
<tr>
<td>Infrared interferometry</td>
<td>40</td>
</tr>
<tr>
<td>Dark matter detectors</td>
<td>12</td>
</tr>
<tr>
<td><strong>Subtotal for ground-based technology</strong></td>
<td>62</td>
</tr>
<tr>
<td><strong>Space-based</strong></td>
<td></td>
</tr>
<tr>
<td>Spacecraft communication</td>
<td>70</td>
</tr>
<tr>
<td>X-ray interferometry</td>
<td>60</td>
</tr>
<tr>
<td><strong>Technology for next-generation observatories:</strong></td>
<td></td>
</tr>
<tr>
<td>Energy-resolving array detectors</td>
<td>40</td>
</tr>
<tr>
<td>Far-infrared array detectors</td>
<td>10</td>
</tr>
<tr>
<td>Refrigerators for space experiments</td>
<td>50</td>
</tr>
<tr>
<td>Large, lightweight optics</td>
<td>80</td>
</tr>
<tr>
<td>MeV detector technology</td>
<td>10</td>
</tr>
<tr>
<td><strong>Subtotal for space-based technology</strong></td>
<td>320</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>382</td>
</tr>
</tbody>
</table>

**Science goal:** to be finalized by WP
**Budget:** \(~130\text{M}$, “Moderate Initiative”
**Observatory:** \(~1\text{km}^2\) array of mid-IACs
**IACs:** 150-50 identical telescopes (+…)
**CT Aperture:** 5-15 m (#CTs & aperture TBD)
**Technology:** demonstrated AC technique

**R&D:** Innovative Camera, Optical, Trigger and DAQ systems to reduce costs and increase reliability

---

A&ANM / NRC, 2001
Technology Development

**VERITAS**

- **Science goal:** Understanding BHs
- **Budget:** 35M$, “Moderate Initiative”
- **Observatory:** small array of mid-IACTs
- **IACTs:** 7 identical telescopes
- **CT Aperture:** 12 m
- **Technology:** demonstrated AC technique
- **R&D:** none

**AGIS**

- **Science goal:** to be finalized by WP
- **Budget:** ~130M$, “Moderate Initiative”
- **Observatory:** ~1km² array of mid-IACTs
- **IACTs:** 150-50 identical telescopes (+…)
- **CT Aperture:** 5-15 m (#CTs & aperture TBD)
- **Technology:** demonstrated AC technique
- **R&D:** Novel OS, Camera, Trigger, DAQ

A&ANM / NRC, 2001
May be cost–effective

... incompatible with conventional prime focus telescope design

May be cost–effective

... incompatible with conventional operation at low energies

$\sim D^{2.6}$
Optical System
Wide field, small plate scale

Fp
concave

Fs
concave

S

F = Fp |Fs| / (|Fs| - s + Fp)

F/Dp > 1/2

\[ \frac{\pi}{4} \frac{\text{FoV}^2}{\pi} \frac{D^2}{4} \leq \text{FPS}^2 \times 90^2 \]

Aplanatic

Highly aspherical non-conic mirror surfaces

Astigmatism and high order Coma can be contained within specs for FoV ≈ 15 deg.

Focal Plane Size, FPS, cannot be made arbitrary small
2RMS < 3’ over full 15 deg FoV can be achieved

(V. Vassiliev, S. Fegan, astro-ph/0612718)
Performance: Plate Scale

Reduction of plate scale by a factor of 3-4 is possible

~1/10 Camera Cost

Camera Cost < 0.1M$ (potentially)
dramatic reliability increase
Segmented Optics

Required tolerance of optical system support and alignment is similar to radio telescopes in mm range, such as ALMA. Mirrors are not spherical and off-axis (costly?)

(V. Guarino, ANL)
Initial mechanical design study suggests that preliminary OSS deformation specifications (< 100 μm) can be met by employing Serrurier truss. A more detailed study of thermal, wind, and gravitational effects underway.
**Advanced Gamma-ray Imaging System**

*Science goal:* to be finalized by WP  
*Budget:* ~130M$, “Moderate Initiative”  
*Observatory:* ~1km² array of mid-I ACTs  
*I ACTs:* 150-50 identical telescopes (+...)  
*CT Aperture:* 5-15 m (#CTs & aperture TBD)  
*Technology:* demonstrated AC technique  
*R&D:* Novel Camera, OS, Trigger, DAQ  
*OS & Camera:*  
  a) Prime focus telescope + PMTs (baseline for cost estimates based on VERITAS scaling)  
  b) Aplanatic telescope + MAPMTs or II&CMOS  
  c) Catadioptric (?)  
*Field of View:* 5-12° (TBD through simulations, based on science goals, and cost study)
Baseline Layout

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

Telescope and Detector
1. ø10m equivalent
2. QE = 0.25 (Bialkali)
3. 15° field of view

Facts and Figures
1. Outer radius: 640m
2. Single cell area: 5543m²
3. Total area: 1.06km²

Different Operation Regime!
PE density after:
1. Atmosphere
2. Mirror reflection
3. Photocathode

Cell Geometry
Consider only the density within 80m of core

Midsized telescopes
φ10m, A=78m²
E=32 GeV, b=80m
→ n_{PE}=78
Array Collecting Area

Cell Operation Mode

QE+Elevation or Dish Size

Concept of “IACT-cell” Aharonian at el. Astroparticle Physics 6 (1997) 343-377
Small Telescope ARrays (STAR)

Small Telescope Arrays - Approach #1

- Save on mounts; cost $\sim d^{2.5}$
- Save on camera plate scale
- Digital electronics
- Fast slewing

Approach #1

- Trigger
- Many cameras
- Many positioners
- Maintenance

(H. Krawczynski & A. Falcone)
Small Telescope ARrays (STAR)

Monte Carlo Simulations

- Parabolic Mirror: Higher $A_{\text{eff}}$ in Sub-Threshold Region;
- Ang. Res.: Parabolic: 0.185°, Star: 0.20°

(H. Krawczynski & A. Falcone)
Largerly Unexplored "Corners"

Performance of large arrays of small telescopes at low energies (<100 GeV) might be further improved through a more “intelligent” trigger

Utilizing properties of distribution of photons in time domain

Utilizing properties of distribution of photons in angular domain

Non-conventional analysis may also have significant effect on array sensitivity below 100 GeV.
All Sky Coverage: “Fly’s Eye” Mode

Each telescope points in slightly different direction.

(S. Fegan)
Collecting Area vs. Field Of View

**Current IACTAs**
- Narrow field of view
  - <0.01 km² @ 40 GeV
  - 0.05-0.1 km² @ 100 GeV
  - 0.2-0.3 km² @ 10 TeV

**1 km² Array**
- Continuum of modes
- Trade area for solid angle

**Parallel mode**
- Narrow field of view
  - 1 km² @ 40 GeV
  - 2 km² @ 100 GeV
  - 4-5 km² @ 10 TeV

**“Fly’s Eye” mode**
- Wide field of view
  - 0.02-0.03 km² @ 40 GeV
  - 0.1-0.2 km² @ 100 GeV
  - 3-4 km² @ 10 TeV
All Sky Survey
One Year Sensitivity

(S. Fegan)
Large array of 7-10m aperture ACTs can operate efficiently at low energies

(S. Fegan)
**Advanced Gamma-ray Imaging System**

**Science goal:** to be finalized by WP
**Budget:** ~130M$, “Moderate Initiative”
**Observatory:** ~1km² array of mid-IACTs
**IACTs:** 150-50 identical telescopes (+... )
**CT Aperture:** 5-15 m (#CTs & aperture TBD)
**Technology:** demonstrated AC technique
**R&D:** Novel Camera, OS, Trigger, DAQ
**OS & Camera:**
  a) Prime focus telescope + PMTs (baseline)
  b) Aplanatic telescope + MAPMTs or II&CMOS
  c) Catadioptric (?)
**Field of View:** 5-12° (TBD)

**DAQ Elec.:** High degree of multiplexing
  a) Optical delays
  b) Fractional readout
  c) Integrated CMOS
  d) Switched capacitor pipelines
  e) Low cost QADC
**Telescope & Array Trigger:** (TBD)
**Site Elevation:** ~1500-4200

(artist view by J. Buckley, Wash.U.)
VERITAS II (HESS & MAGIC path)
Significant VERITAS upgrade: \(~30\text{M}$, e.g. \(+3\) \sim 20\text{m diameter telescopes}

**Advantage:** may provide best performance at low energies before CTA operation

**Disadvantage:** no significant participation in an international effort to construct global VHE γ-ray observatory during next decade.

AGIS (skip VERITAS II)

**Advantage:** may provide significant contribution toward global VHE γ-ray observatory and support European initiative (CTA)

**Disadvantage:** during R&D phase (\sim 4\text{ years}) significant scientific return is due to VERITAS I only.
AGIS: Possible roadmap

- Complete simulation studies
- Start R&D effort to construct single telescope (Aperture \(\sim7\text{-}10\text{m},\) FoV 8-10 deg) and estimate cost
- Build 3 telescopes and conduct sky survey at \(\sim500\) GeV (5\% Crab -1 year, 2\% Crab -5 years)
- If successful, define \(\sim1\text{km}^2\) project, budget, and propose to construct large array
Conclusion

- The global $\gamma$-ray observatory with estimated cost of 300+ M$ (South and North, CTA+) can only materialize through a significant international effort.
- It must involve international collaborating contributing parties, which maintain their strong identities, as $\gamma$-ray groups, to be supported by funding agencies at a significant level.
- It appears to be that all required initial conditions are in place to plan VHE $\gamma$-ray Astronomy future before our “wave function” spontaneously collapses into an undesirable state due to disagreements and inability to develop the project across the borders.
Scientific Potential

- Gamma-ray Astronomy above $10^4$ GeV: Natural extension of present day technology
  - Galactic sources & physics beyond standard model
- Gamma-Ray Astronomy from $10^2$ – $10^4$ GeV: Proven technology
  - Deep exploration of VHE sky
- “Gamma-Ray Astronomy from 10-100 GeV: a New Approach”
  - AGN, VHE transients, Cosmology

Weekes, T.C., Proc. 12th ESLAB Symp. (Frascati), 279, 1977