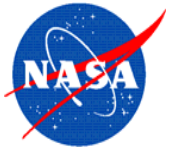


SpacePart 2006
19 - 21 April, 2006
Beihang University of Beijing

Particle Astrophysics in Space in the U.S.

The Astrophysics Division Program
National Aeronautics and Space Administration
and
The High Energy Physics Program
Department of Energy (DOE)

Presented by

W. Vernon Jones
Science Mission Directorate
NASA Headquarters
Washington, DC 20544

U.S. Department of Energy
Office of Science
Office High Energy Physics (HEP)

Goal: Explore the Fundamental Interactions of Energy, Matter, Time, & Space

- Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe

→We coordinate our program with the National Science Foundation (NSF), NASA and International Efforts

Components of the Program:

Accelerator-based physics is our primary tool →

Top quarks, Higgs search, extra dimensions, supersymmetry; neutrino studies, b-quarks, CP violation

Non-accelerator physics – a growing and important sector →

Atmospheric, solar and reactor Neutrinos, dark matter, dark energy, high energy cosmic & gamma rays

Theory – elementary particles and fields

Technology R&D - for accelerator and detector technologies

The 2006 NASA Strategic Plan

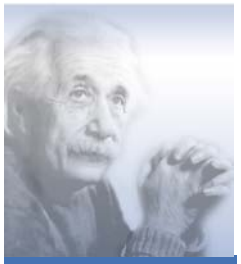
- Strategic Goal 1: Fly the Shuttle as safely as possible until its retirement, not later than 2010.
- Strategic Goal 2: Complete the International space Station in a manner consistent with NASA's International Partner commitments and the needs of human exploration.
- **Strategic Goal 3: Develop a balanced overall program of science, exploration, and aeronautics consistent with the redirection of the human spaceflight program to focus on exploration.**
- Strategic Goal 4: Bring a new Crew Exploration Vehicle into services as soon as possible after Shuttle retirement.
- Strategic Goal 5: Encourage the pursuit of appropriate partnerships with the emerging commercial space sector.
- Strategic Goal 6: Establish a lunar return program having the maximum possible utility for later missions to Mars and other destinations.

NASA Strategic Goal 3

- Sub-goal 3A: Study Earth from space to advance scientific understanding and meet societal needs.
- Sub-goal 3B: Understand the Sun and its effects on earth and the solar system.
- Sub-goal 3C: Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.
- **Sub-goal 3D: Discover the origin, structure, evolution, and destiny of the universe, and search for Earth-like planets.**
- Sub-goal 3E: Advance knowledge in the fundamental disciplines of aeronautics, and develop technologies for safer aircraft and higher capacity airspace systems.

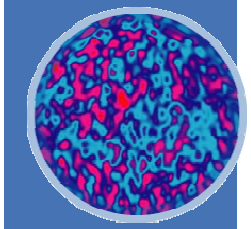
Scientific Exploration

- To understand physical contents of the universe and the processes that govern their behavior, and answer fundamental questions:
  - How did Big Bang unfold?
  - What happens at the edge of a black hole?
  - What is causing the expansion and acceleration of the universe?
  - How were stars and galaxies created?
  - Are there other Earth-like planets?
  - Does life exist elsewhere in the cosmos?
- Some missions in the NASA program to address these questions:
  - HST to continue its outstanding observations and discoveries and to have its life extended with another servicing mission, SM-4
  - Chandra to continue its high spatial resolution X-ray imaging and spectroscopy over the 0.1 to 10 keV range
  - Spitzer Space telescope to continue studying formation and evolution of planetary systems
  - Herschel & Planck to explore origin and destiny of the universe (> 2007)
  - JWST to discover how first stars and galaxies formed and changed over time to become the recognizable objects in present universe (> 2013)
  - Beyond Einstein program to understand the expansion and acceleration of the universe and to study its space-time structure (> TBD)



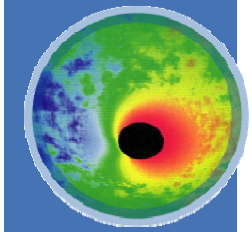
Completing Einstein's Legacy

Einstein's legacy is incomplete, his theory fails to explain the underlying physics of the very phenomena his work predicted



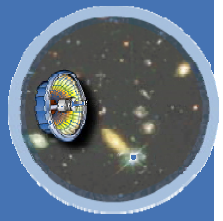
BIG BANG

What powered the Big Bang?



BLACK HOLES

What happens at the edge of a Black Hole?



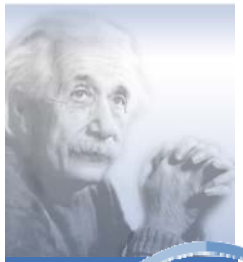
DARK ENERGY

What is the mysterious Dark Energy pulling the Universe apart?

Beyond Einstein will employ a series of missions linked by powerful new technologies and common science goals to answer these questions …

… and launch the revolution of the 21st century!

Beyond Einstein Program



Science and Technology Precursors

WMAP

LIGO

Hubble

Chandra

GLAST

microwave background detection

gravitational wave detectors

optical imaging

x-ray imaging

mega-channel electronics

INFLATION PROBE

LISA

DARK ENERGY PROBE

CONSTELLATION-X

BLACK HOLE FINDER PROBE

big bang physics

space interferometry, gravitational wave detection

space interferometry

dark energy physics

dark matter physics

black hole physics

black hole census

BIG BANG OBSERVER

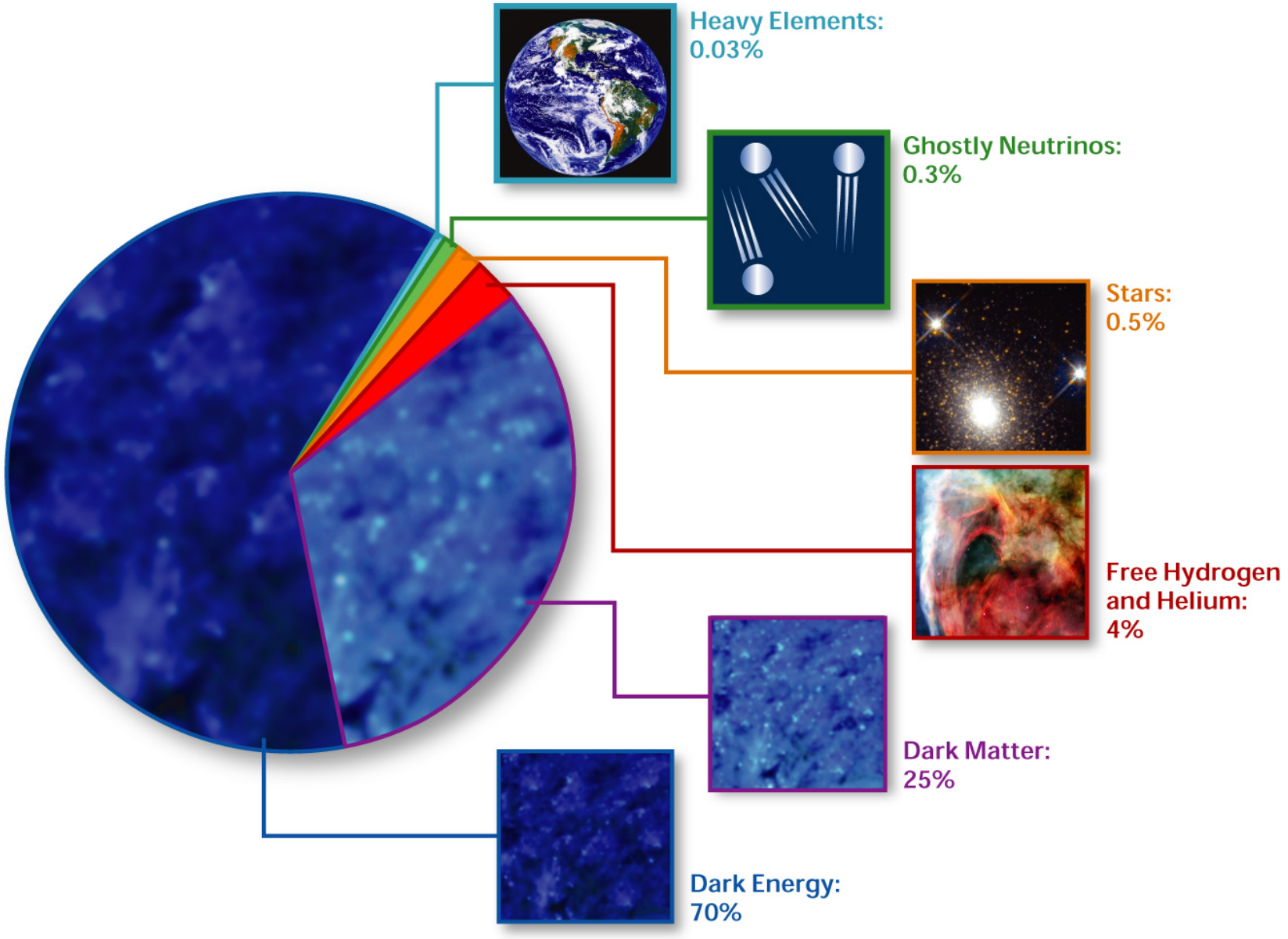
BLACK HOLE IMAGER

GREAT OBSERVATORIES

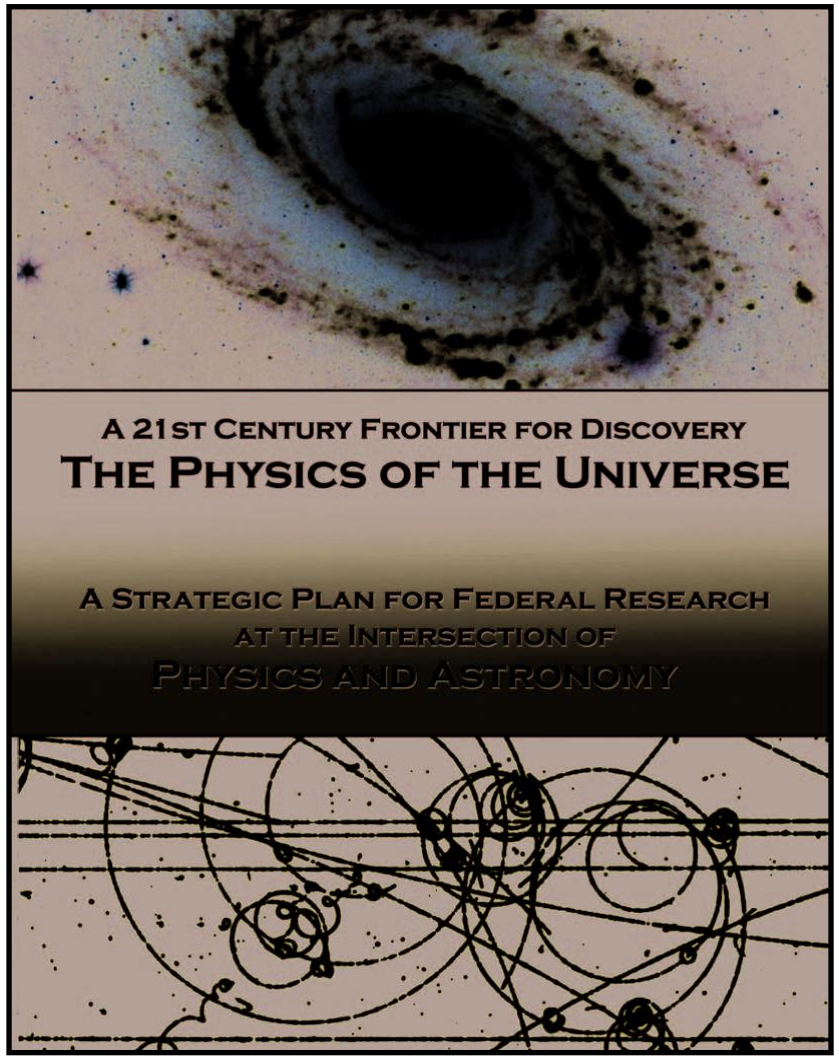
PROBES

VISIONS

We Do Not Know What 95% of the Universe is made of !



The Physics of the Universe Report (2004)



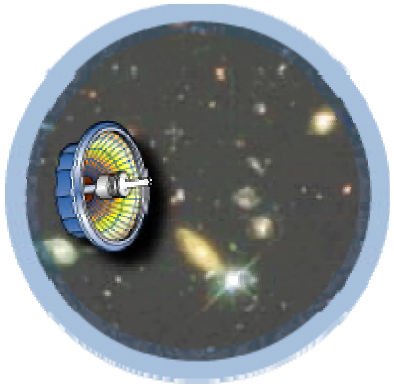
Strategic Plan for Federal Research at Intersection of Physics and Astronomy

Interagency Working Group on the Physics of the Universe
Committee on Science
National Science and Technology Council
Office of Science and Technology Policy
Executive Office of the President

Recommendation on Dark Energy

- NASA and DOE will develop a Joint Dark Energy Mission (JDEM). This mission would best serve the scientific community if launched by the middle of the next decade. Studies of approaches to the JDEM mission undertaken now will identify the best methodology.

JDEM Program Status

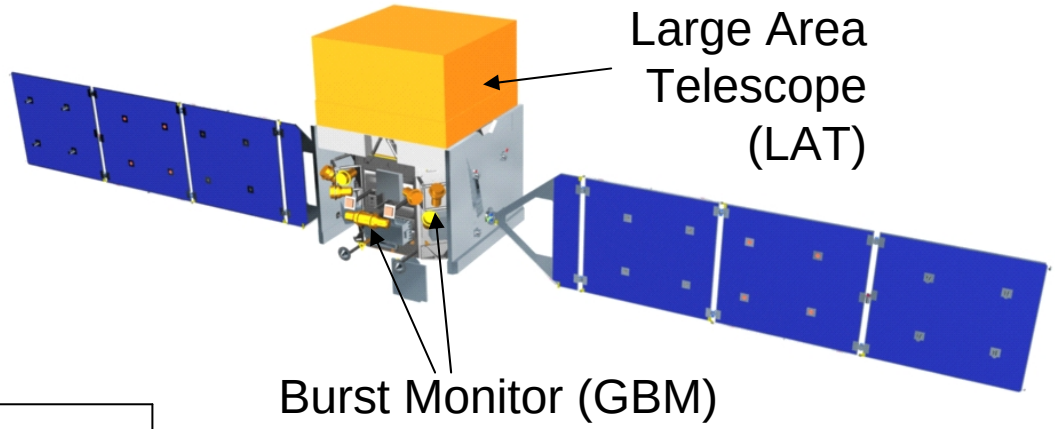


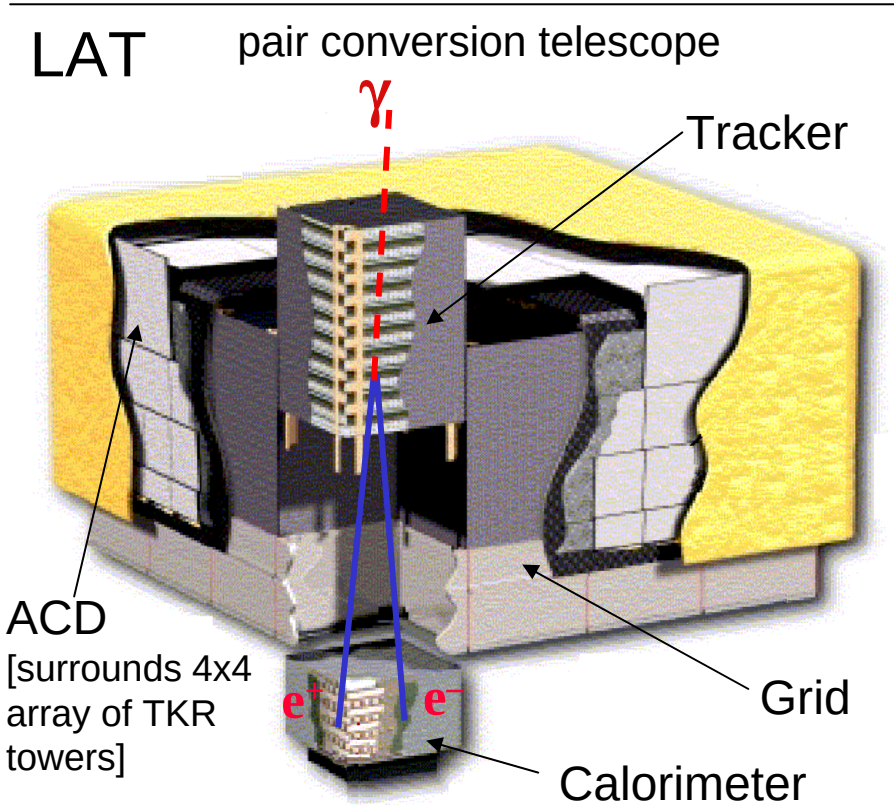
- NASA and DOE have agreed to implement a Joint Dark Energy Mission (JDEM) as follows:
  - The Dark Energy science investigation will be PI-led
  - Competitive selection will be used
  - NASA is responsible for the overall success of the mission
- A number of mission concepts being studied
  - Concepts: SNAP (Perlmutter), DESTINY (Morse), JEDI (Wang)
  - Additional “collaborative” or “technology” studies
- NASA and DOE Have Appointed a JDEM Science Definition Team with Goal to:
  - Determine the case for a space mission
  - Write science requirements document for JDEM AO,
  - Provide feedback for JDEM pre-project office, when it exists

Gamma-Ray Large Area Space Telescope

Successful DOE/NASA Partnership

- **GLAST will provide a direct view into the Universe's largest accelerators, probing cosmological distances.**
- **Larger field of view (FOV), higher sensitivity, and broader energy detection range than any previously flown gamma-ray mission.**





Two GLAST instruments:
LAT: 20 MeV – >300 GeV
GBM: 10 keV – 25 MeV

- **Collaboration of particle physics and high energy astrophysics communities**
- LAT built by collaboration with France, Italy, Japan, Sweden – managed at SLAC
- **Launch Readiness Date: Sept 7, 2007**
- Mission Duration: 5 yrs (10 yr goal)

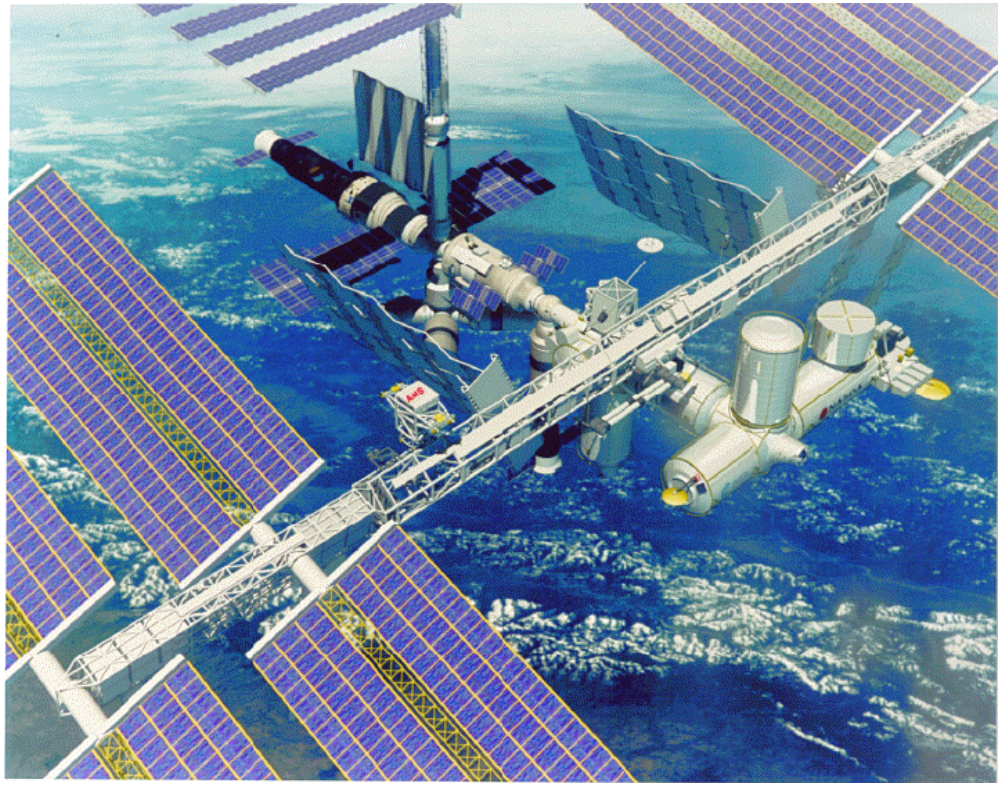
Office of High Energy Physics Program

Very Energetic Radiation Imaging Telescope Array System (VERITAS)

- Scientific Purpose: Study of celestial sources of very high energy gamma-ray sources in the energy range of 50 GeV-50 TeV & search for dark matter candidates
  - Uses atmospheric Cherenkov 4-telescope array
- Funding: NSF, DOE plus Smithsonian and foreign institutions
- Status: Installation at Kitt Peak in Arizona is on hold while the environmental study is redone. Planning to fabricate and commission the telescopes (starting 2007) at another site while waiting for Kitt Peak access

Alpha Magnetic Spectrometer (AMS)
on the International Space Station (ISS)

- Major 16 nation science mission sponsored by DOE for flight on the external truss of the ISS
- Search for cosmological dark matter, anti-matter (anti-helium or heavier), and strange matter.



- The precursor AMS (AMS-01) mission was successfully flown on Space Shuttle flight STS-91 in 1998.
- The upgraded AMS (AMS-02) instrument is approaching final assembly prior to installation on the (ISS).
- The Earliest launch readiness date is late 2008 or early 2009.
- The AMS launch vehicle is currently under NASA review.

Pierre Auger (w/NSF & foreign partners)

Water Cherenkov surface detectors

Search for very high energy cosmic rays.

Detector array covers a 3000 km^2 site in Argentina

As of Fall 2003, it became the largest air-shower detector in the world

Fluorescence telescopes

Partial operations have started – construction expected to be completed by early 2007.

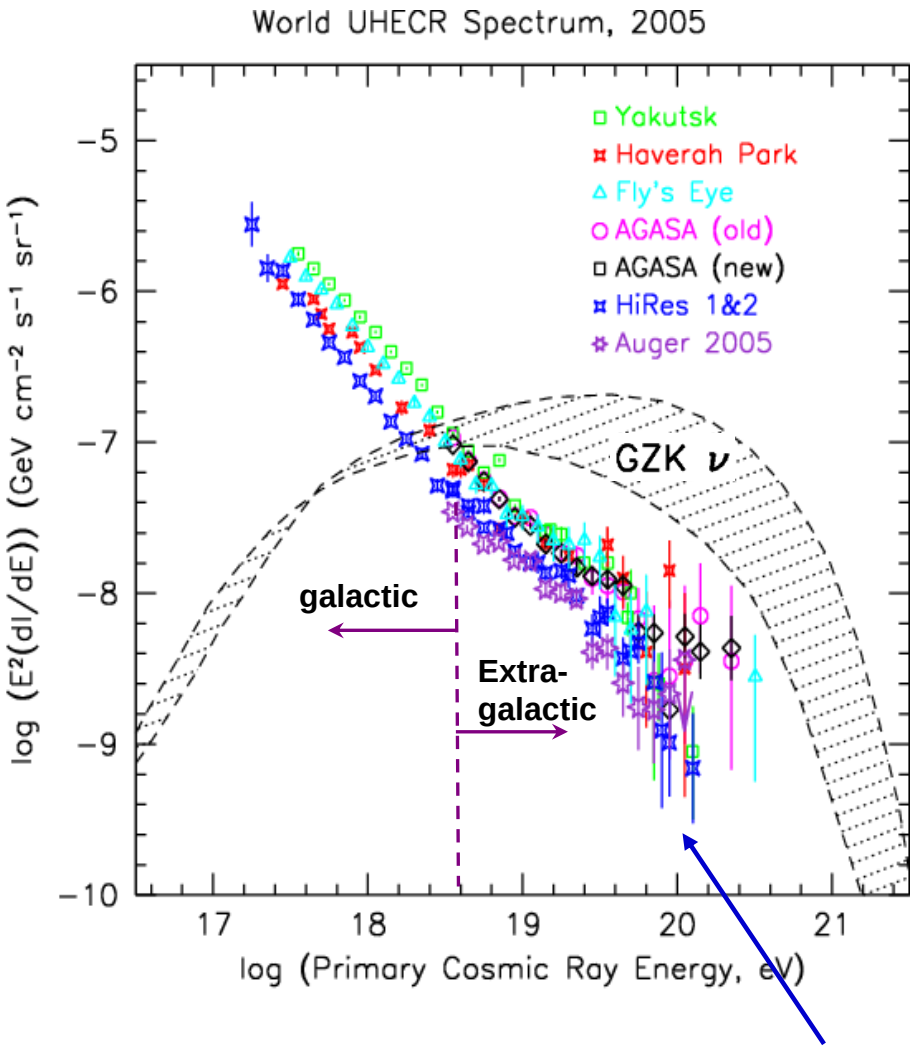
Current status (January 2006)

- Fluorescence telescopes: 18 (out of 24) operating
- Surface Cherenkov detectors: 1069 (out of 1600) deployed, 910 operating

The Mystery of Ultra-High Energy Cosmic Rays and Neutrinos

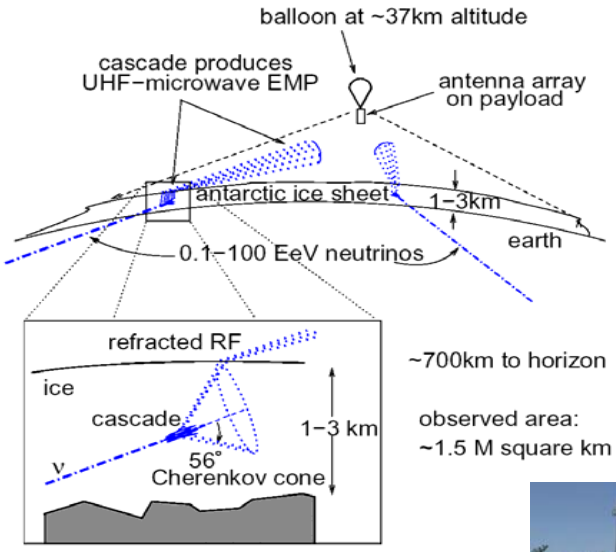
- Neither the origin nor acceleration mechanism of cosmic rays above 10^{19} eV is known, after 40 years!
- A paradox:
  - No **nearby** sources of UHECRs observed
  - distant sources **excluded** due to GZK process: collisions with 2.7 K CMBR, <100 Mpc maximum
- Neutrinos at $10^{17\text{-}19}$ eV **guaranteed** by standard-model physics through the GZK process

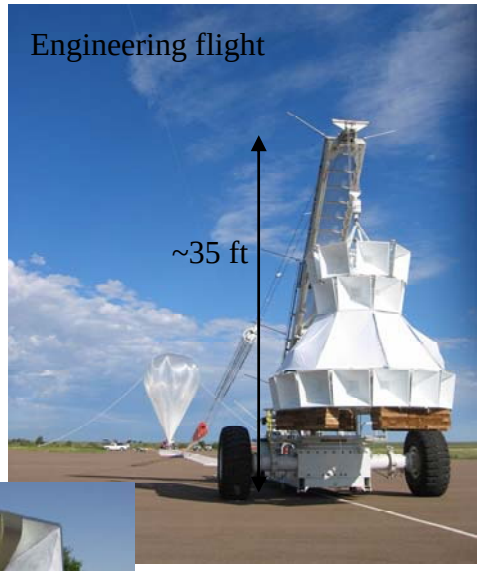
  - Observing them is crucial to resolving the GZK paradox
- Neutrino Astronomy?
  - Neutrinos are unattenuated from BH event horizons, GRB fireballs …
  - Neutrinos are the only unattenuated messengers possible above ~ 100 TeV

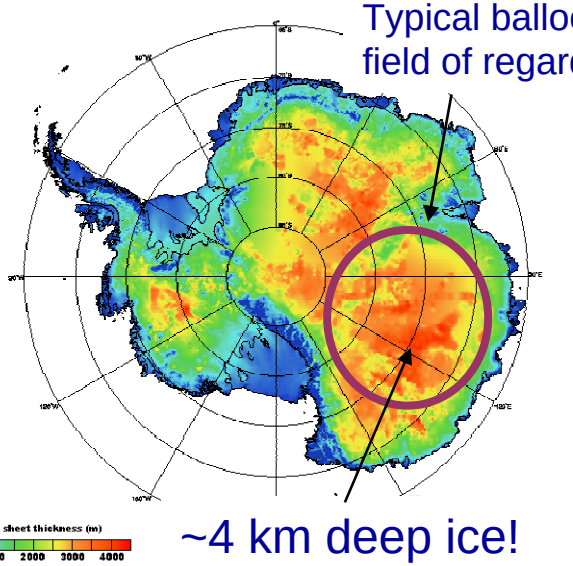


10^8 times Tevatron

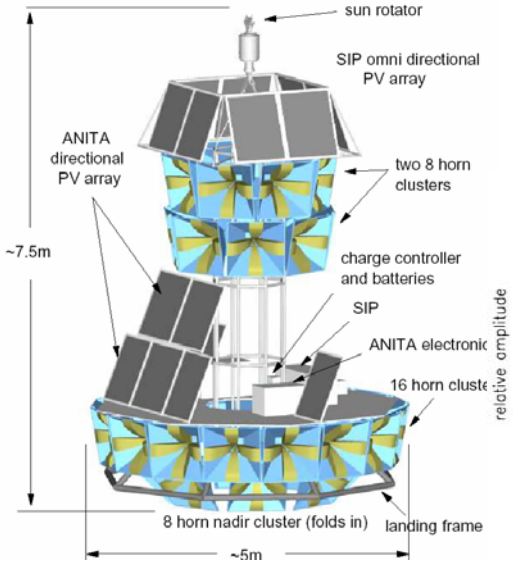
Antarctic Impulsive Transient Antenna (ANITA)

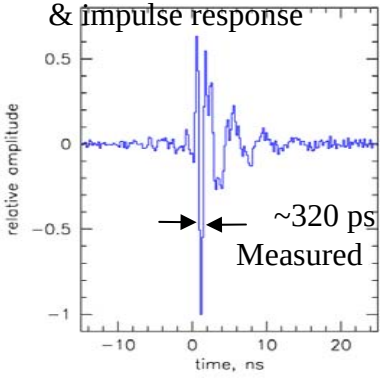






Quad-ridge horn Antenna & impulse response





- NASA SR&T start in 2003
- 18-day Prototype flight (ANITA-lite 2004) verified ultra-low Antarctic EMI levels
  - Physical Review Letters, in review, astro-ph/0512265
- Full-scale engineering flight (ConUS) in Aug. 2005, flight system proven
- 2006-2007 Antarctic flight will give 2 - 3 orders of magnitude improvement in sensitivity!

Concluding Remarks

- A Dark Energy Task Force panel is laying out a scientific roadmap for DOE, NASA and NSF
  - Report to be released in May
- The implementation of NASA's Vision for Space Exploration has resulted in a significant slow down in the Beyond Einstein Program
  - Nothing has been cancelled !
  - Investments that enable Beyond Einstein missions are being made
  - Expect 2009 decision on the queue for JDEM, LISA, and Con-X
- JDEM is high priority in the DOE Strategic Plan
  - A joint DOE/NASA Science Definition Team for JDEM is ongoing
- DOE is providing R&D support for future space and/or ground telescopes in cooperation with NSF and foreign partners, as well as NASA
  - SuperNova/Acceleration Probe (SNAP)
  - Ground-based Dark Energy Survey (DES) and Large Synoptic Survey Telescope (LSST)

ACRONYMS

ACE - Advanced Composition Explorer
ADMX – Axion Dark Matter eXperiment
AMS – Alpha Magnetic Spectrometer
ANITA - Antarctic Impulsive Transient Antenna
ATIC - Advanced Thin Ionization Calorimeter
BES – Beijing Spectrometer experiment at China's IHEP
BESS - Balloon Borne Experiment with Superconducting Spectrometer
CDF – Collider Detector Facility experiment at the Fermilab Tevatron
CDM - Command Data Module
CDMS – Cryogenic Dark Matter Search
CERN – Center for European Nuclear Research in Geneva, Switzerland
CMB - Cosmic Microwave Background
CMS – Compact Muon Solenoid experiment under construction for CERN's Large Hadron Collider
CP – charge-parity symmetry
CREAM - Cosmic Ray Energetics And Mass
DES – proposed Dark Energy Survey experiment
EXO – proposed Enriched Xenon Observatory dark matter experiment
GLAST – NASA's Gamma-ray Large Area Space Telescope
HEP – Office of High Energy Physics at the U.S. DOE
ISS – International Space Station
JDEM – NASA and DOE Joint Dark Energy Mission
KamLAND - Kamioka Liquid Scintillator Anti-Neutrino Detector in Japan
LAT – Large Area Telescope, the primary instrument on GLAST
LDB - Long Duration Balloon
LHC – Large Hadron Collider at CERN
LSST – proposed Large Synoptic Survey Telescope
NSF – U.S. National Science Foundation
R&D – Research and Development
SDSS – Sloan Digital Sky Survey experiment
SLAC – Stanford Linear Accelerator Center
SNAP – SuperNova/Acceleration Probe – a proposed concept for JDEM
Super-K – Super Kamiokande experiment in Japan
SUSY – SUper-SYmmetry
TRACER - Transition Radiation Array for Cosmic Energetic Radiation
ULDB - Ultra-Long Duration Balloon
WIMP- Weakly Interacting Massive Particle – possible form of dark matter
WMAP - Wilkinson Microwave Anisotropy Probe