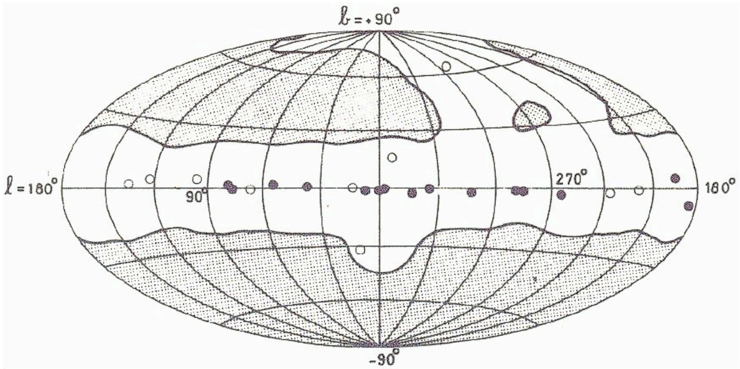
Opportunities in ground based gamma-ray astronomy

Perspectives for the UK

Joachim Rose
University of Leeds

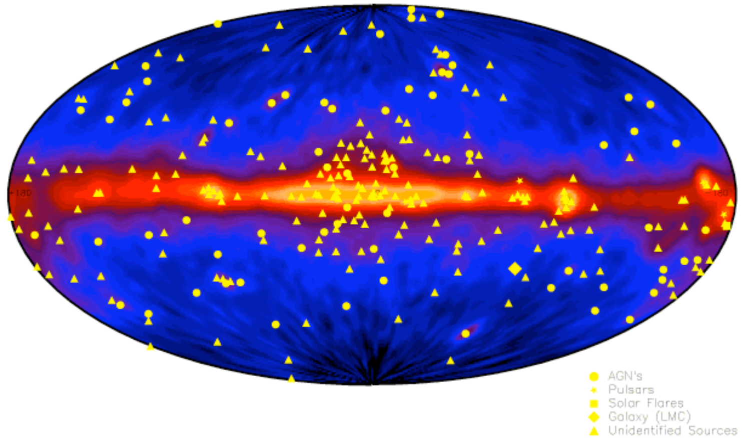
High-energy gamma-ray sky time evolution

COS-B 1975 - 1982



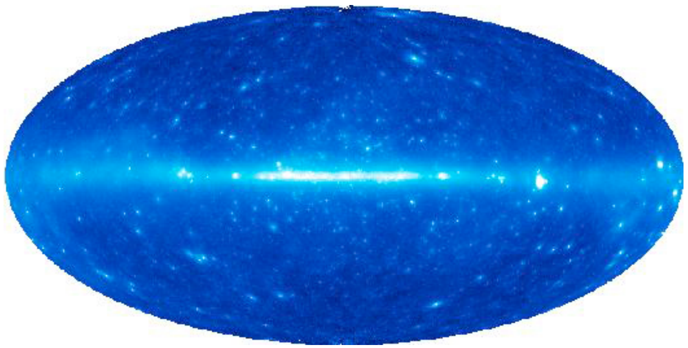
First TeV source 1989

EGRET 1991 - 2000



TeV southern plane survey 2005

GLAST 2007 - ?



TeV sky in 14 years?

High energy gamma-ray astronomy

Rapidly increasing source count

New classes of objects

Astrophysics

Fundamental physics

Technology development

Overview

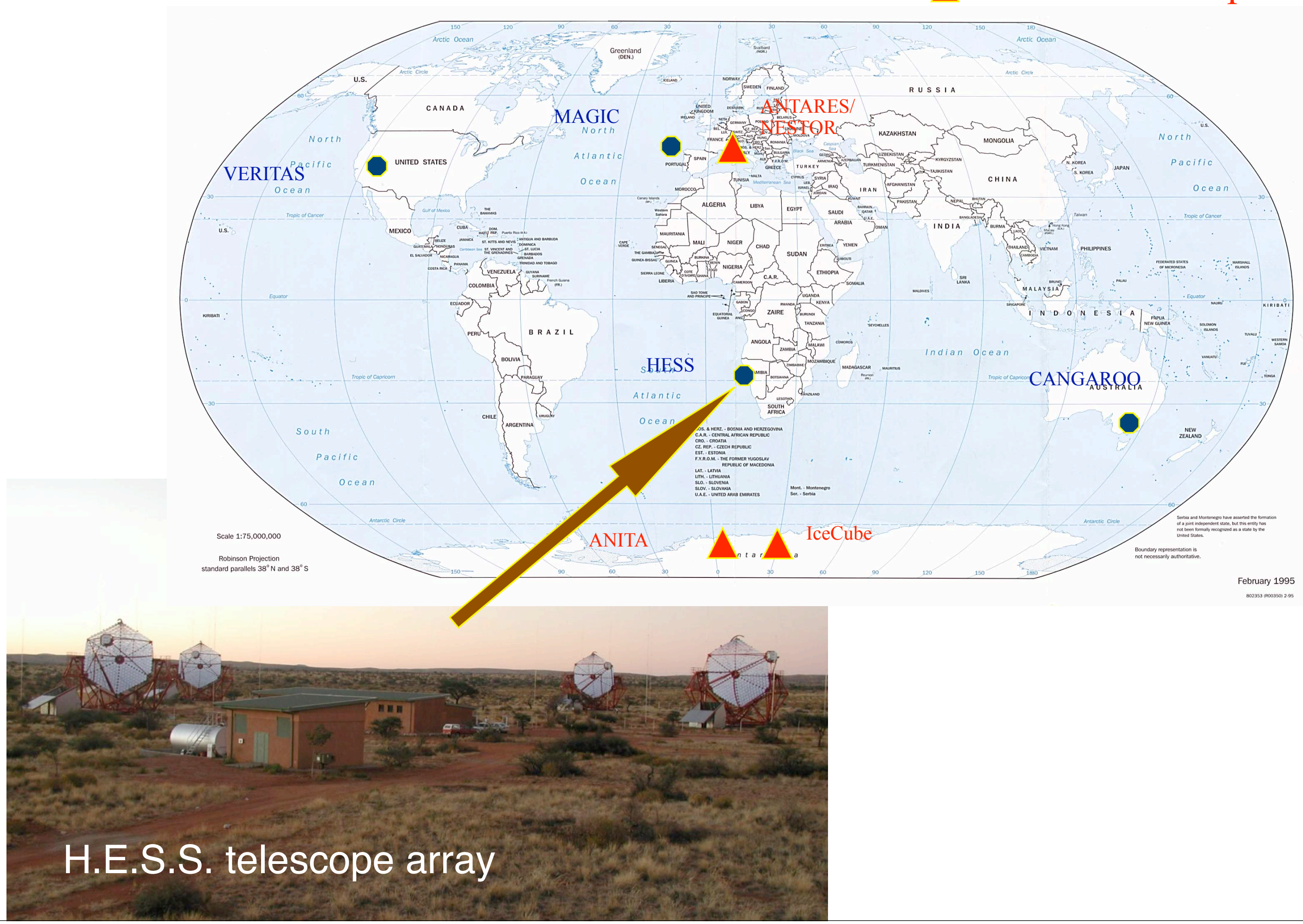
- Introduction: current observatories
- Science case
- Existing opportunities
- Medium term prospects
- Technology programme

Current and future HE telescopes

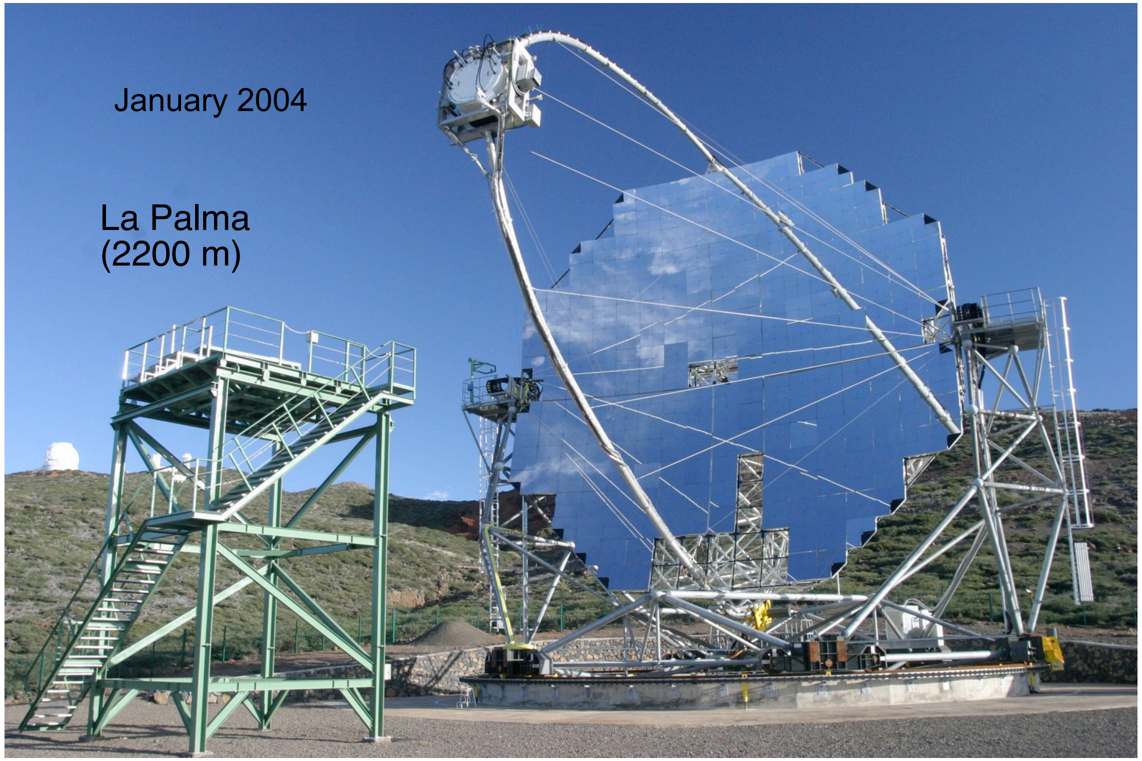
In space GLAST, SWIFT

γ-ray telescopes

Neutrino telescopes



MAGIC



Single large 17 m reflector.
High-tech components.
Sensitivity at low energies (40 GeV)

Observing programme has started

Second 17 m telescope (c.2006)

Future third telescope?

Seven hours time difference with VERITAS.

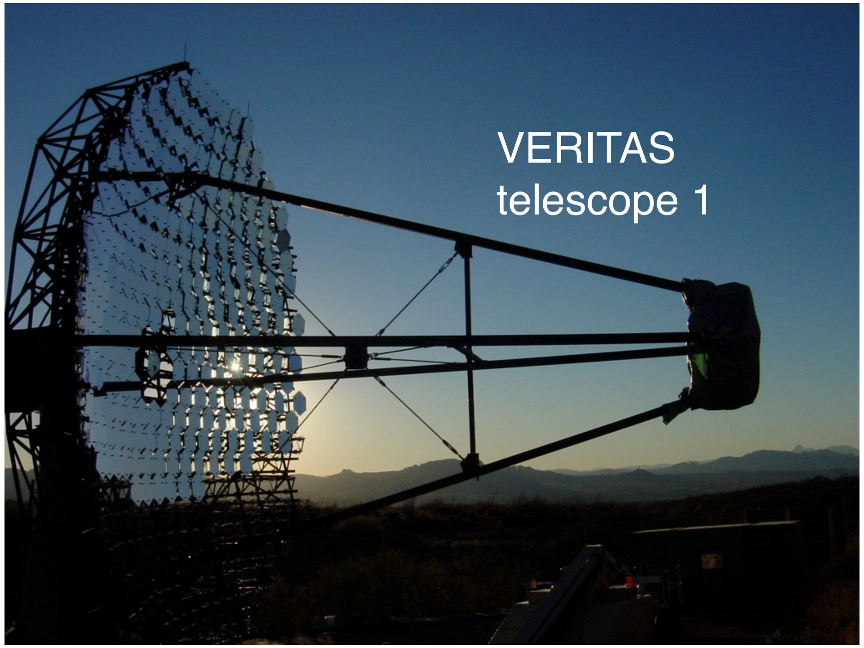
Opportunity for

---> AGN long exposure monitoring (~10h)

---> joint multi-wavelength campaigns

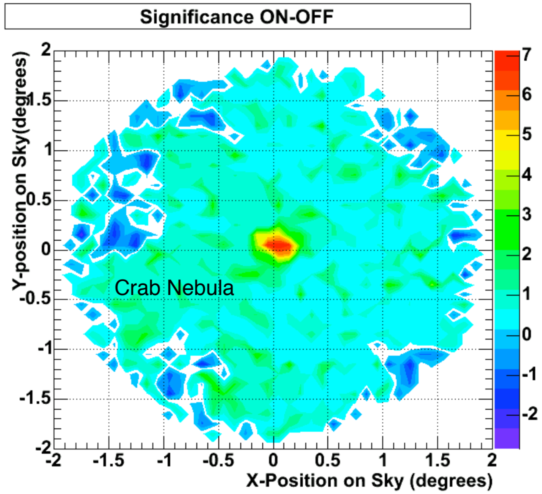
---> alerts, confirmation of results, cross calibration

VERITAS

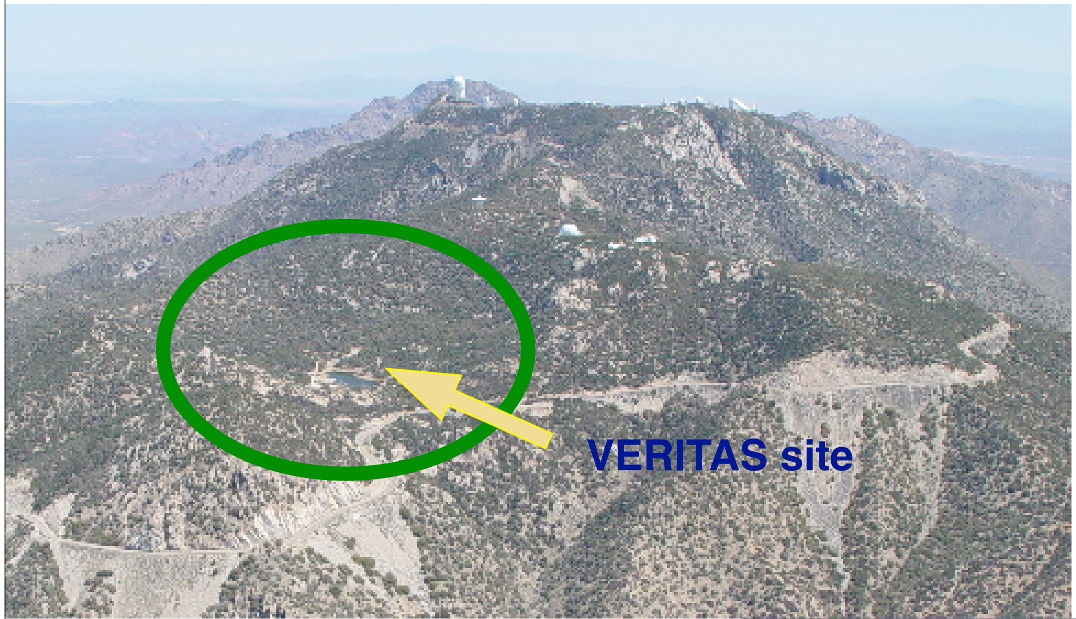


Whipple 10 meter observing programme continues.

First VERITAS 12 meter telescope completed.



VERITAS construction

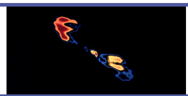
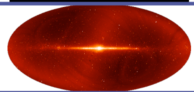
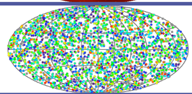
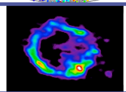
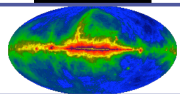
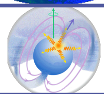
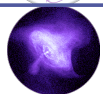
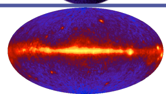
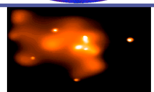
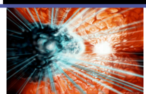


Site at Kitt Peak National Observatory, South West of Tucson, Arizona

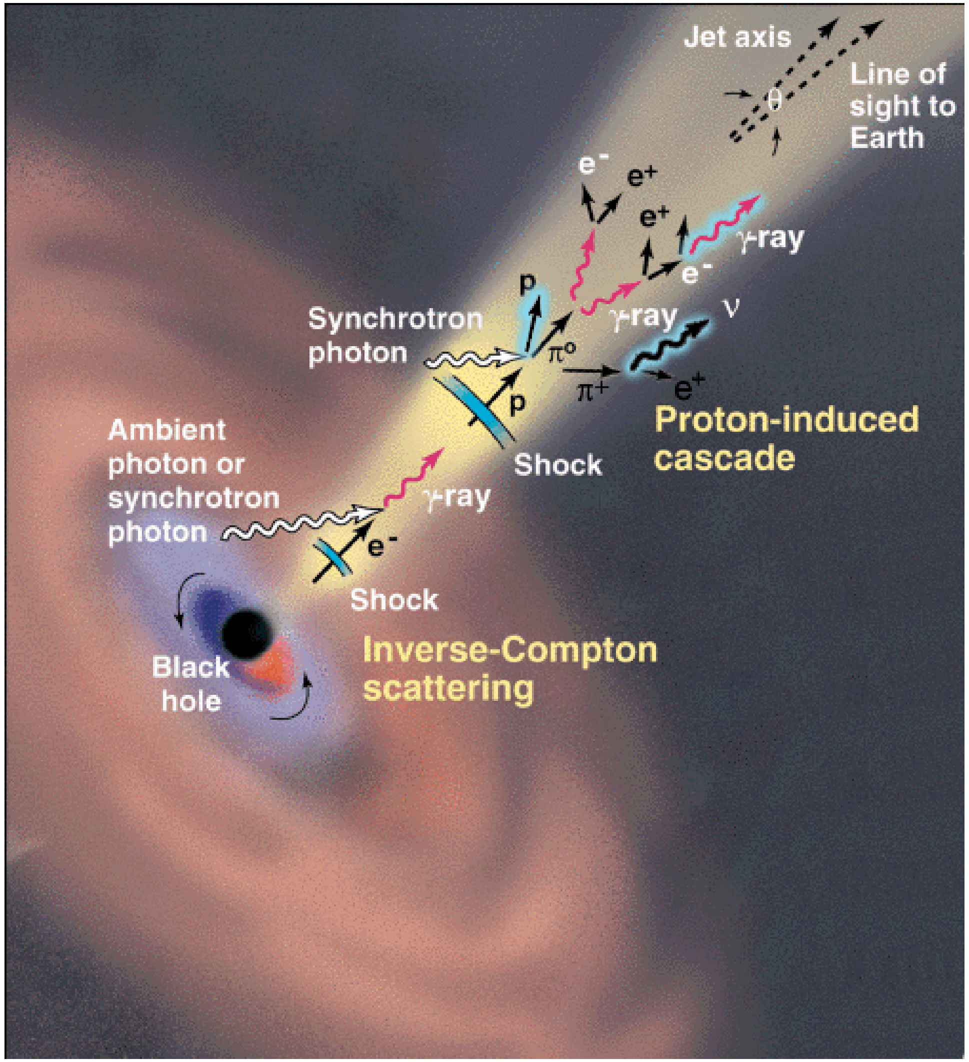
VERITAS telescope assembly at Kitt Peak in parallel during 2005.

Start of astrophysics observations in 2006.

Ground based gamma-ray science

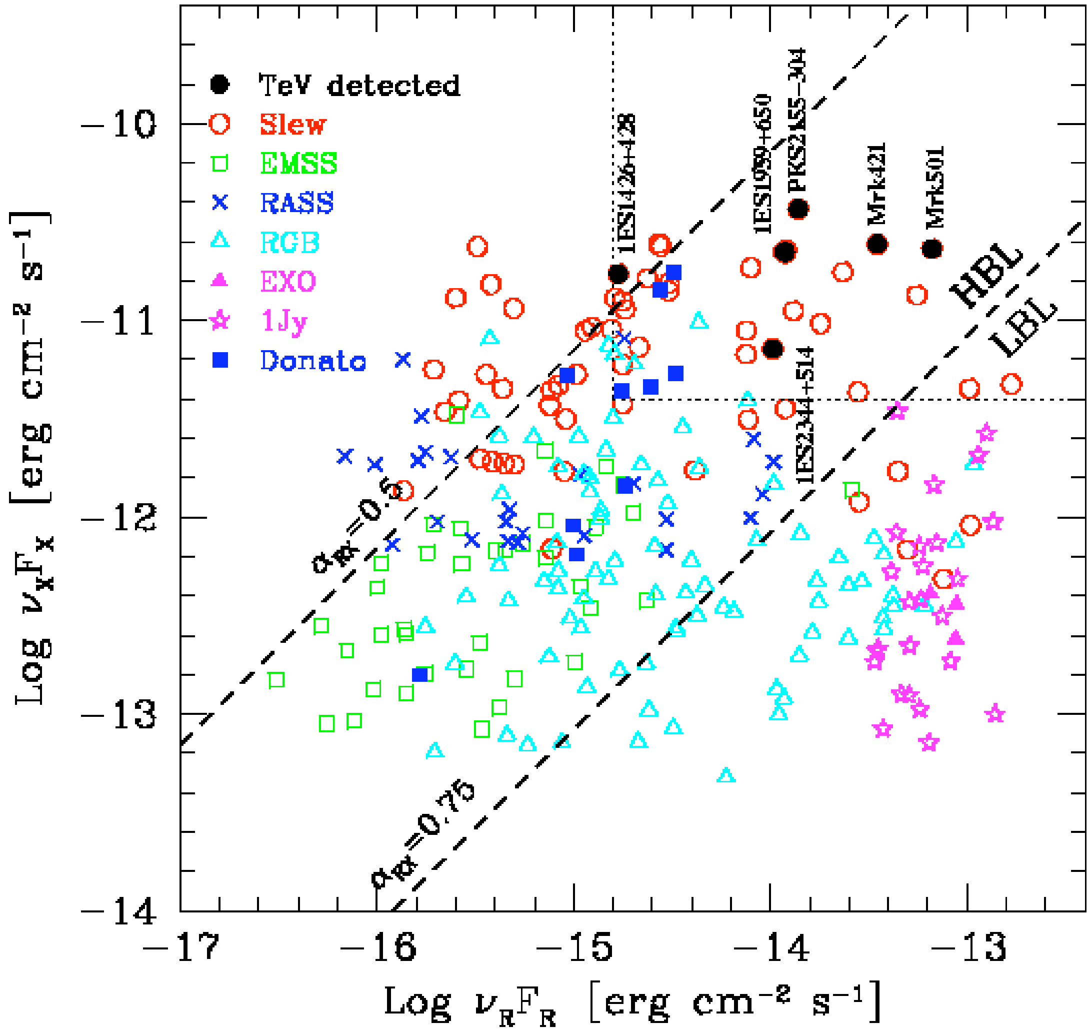
	Active Galactic Nuclei *
	Extra-galactic Background Light
	Gamma Ray Bursts ✓
	Shell-type Supernova Remnants ✓
	Galactic Diffuse Emission
	Gamma-ray Pulsars
	Plerions and Pulsar Binaries ✓
	Unidentified Galactic EGRET Sources
	Galactic Centre, Dark Matter, Neutralinos ✓
	Cosmic Ray Origin ✓
	Lorentz Symmetry Violation

TeV photons from jets in AGN



- Current paradigm:
  - **Synchrotron Self Compton**
  - External Compton
  - Proton Induced Cascades
  - Proton Synchrotron
- Energetics, mechanism for jet formation and collimation, nature of the plasma, and particle acceleration mechanisms are still poorly understood.
-
- **Expect to find more than 30 new VERITAS sources.**
-
- Limited observing time and number of telescopes will be a problem!

Search for radio and X-ray selected AGN



All five confirmed TeV AGN:
- high radio flux (at 5 GHz)
- **high X-ray flux** (at 1 keV)

Latest new detection 1ES1959:
J Holder et al. (VERITAS)
Astrophys.J.583:L9-L12,2003

Search strategy and upper limits in
I de la Calle Perez et al. (VERITAS),
Astrophys.J.599:909-917,2003

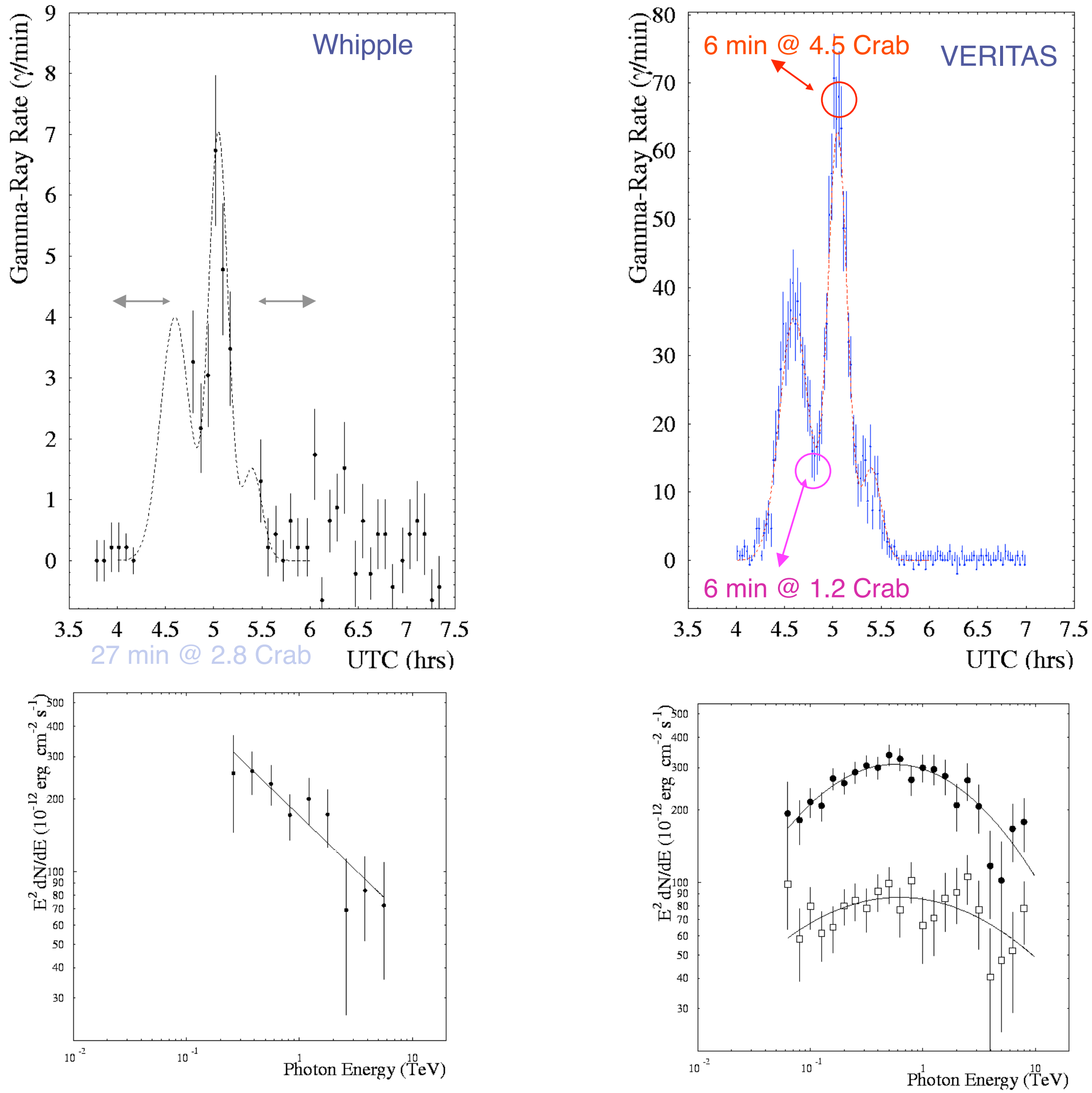
TeV and X-ray fluxes are time variable!

Demand for X-ray monitor with
- wide-field of view
- 1 - 10 keV energy range
- fast alerts (minutes)

At present RXTE, XMM, INTEGRAL.

In future: AGILE? **SWIFT?**

Variability: time resolved energy spectra

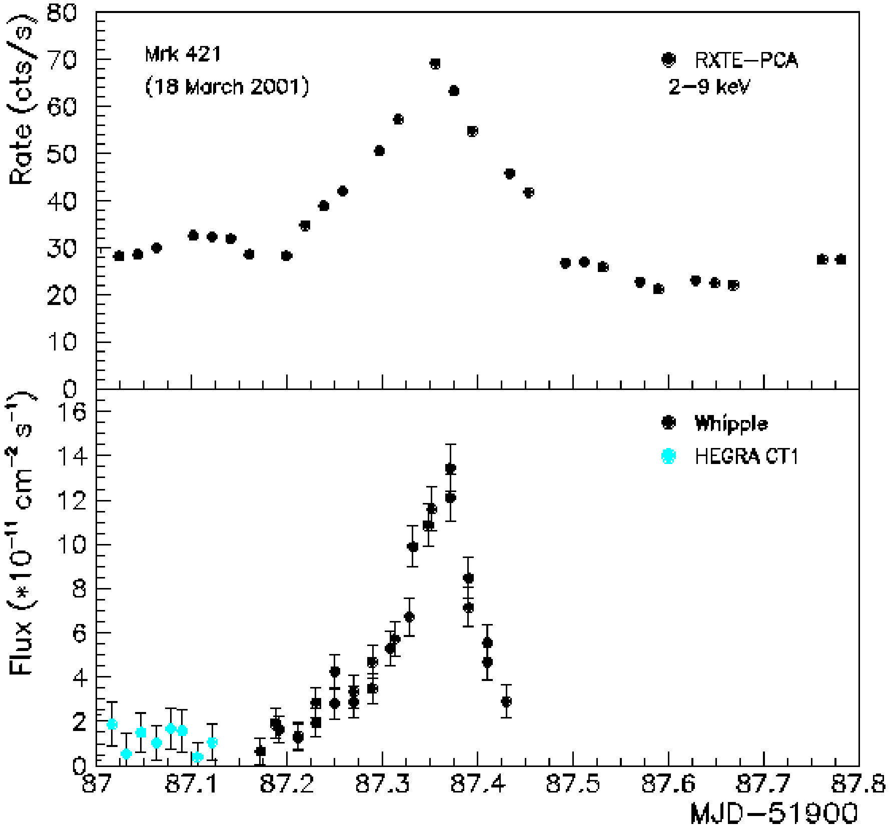


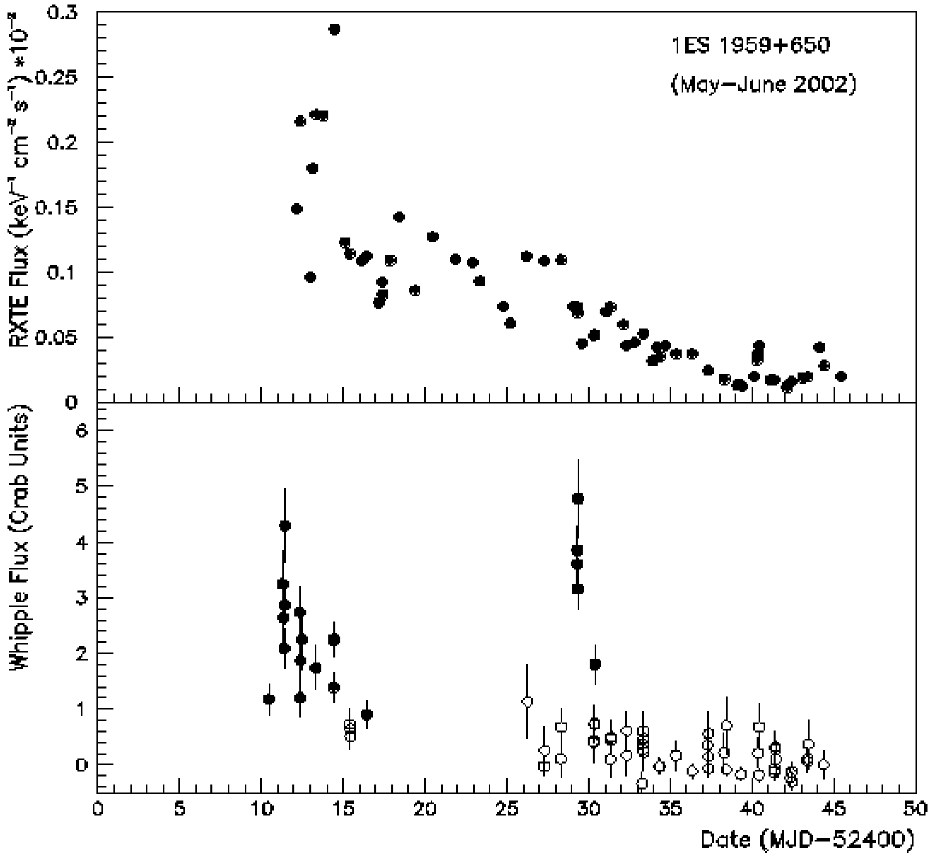
(Krennrich, 2002)

- Probe intrinsic variability timescales; **test model predictions**, for example SSC vs EC.
- VERITAS will make **time resolved spectral measurements** not possible with any other technique above a few keV.
- Discriminate between a **time constant external IR EBL absorption feature** and time variable intrinsic curvature.

Study of flares in X-ray and high energy gamma rays

VERITAS (Whipple 10 m) and RXTE X-ray data

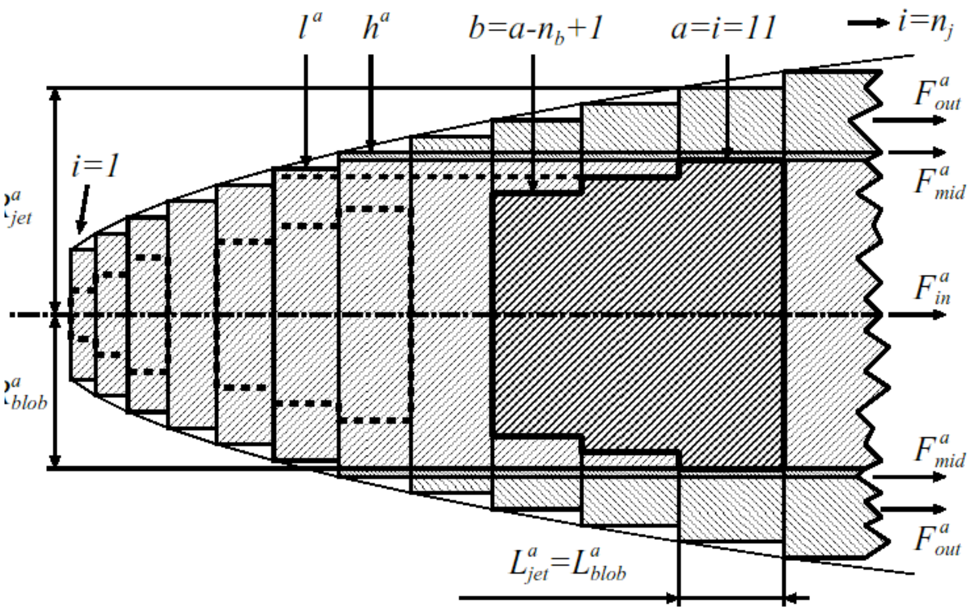




Work in progress:

Evaluate full data sets --> time structure function	Use spectral information --> X-ray **and** TeV spectra
Monitor complete SED --> multi-wavelength campaigns	Make model comparisons --> SSC and EC models

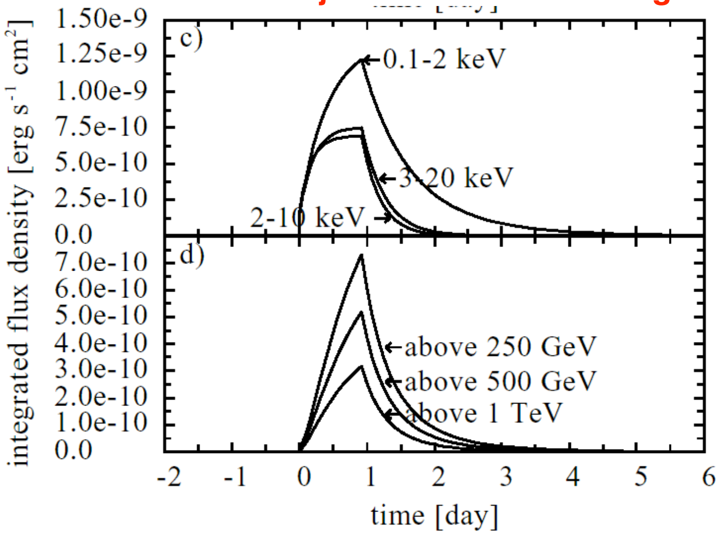
Example model predictions



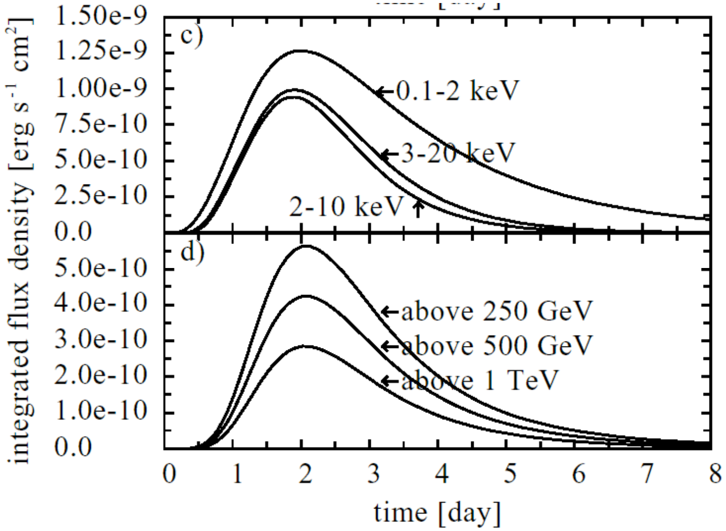
Plots shown from
The multifrequency variability of Mrk 421,
K. Katarzynski; H. Sol and A. Kus, A&A 410, 101–115 (2003)

In preparation:
External Compton model(s);
fit to time resolved spectra

scenario I: electron injected from central engine



scenario II: in situ electron acceleration



Existing opportunities

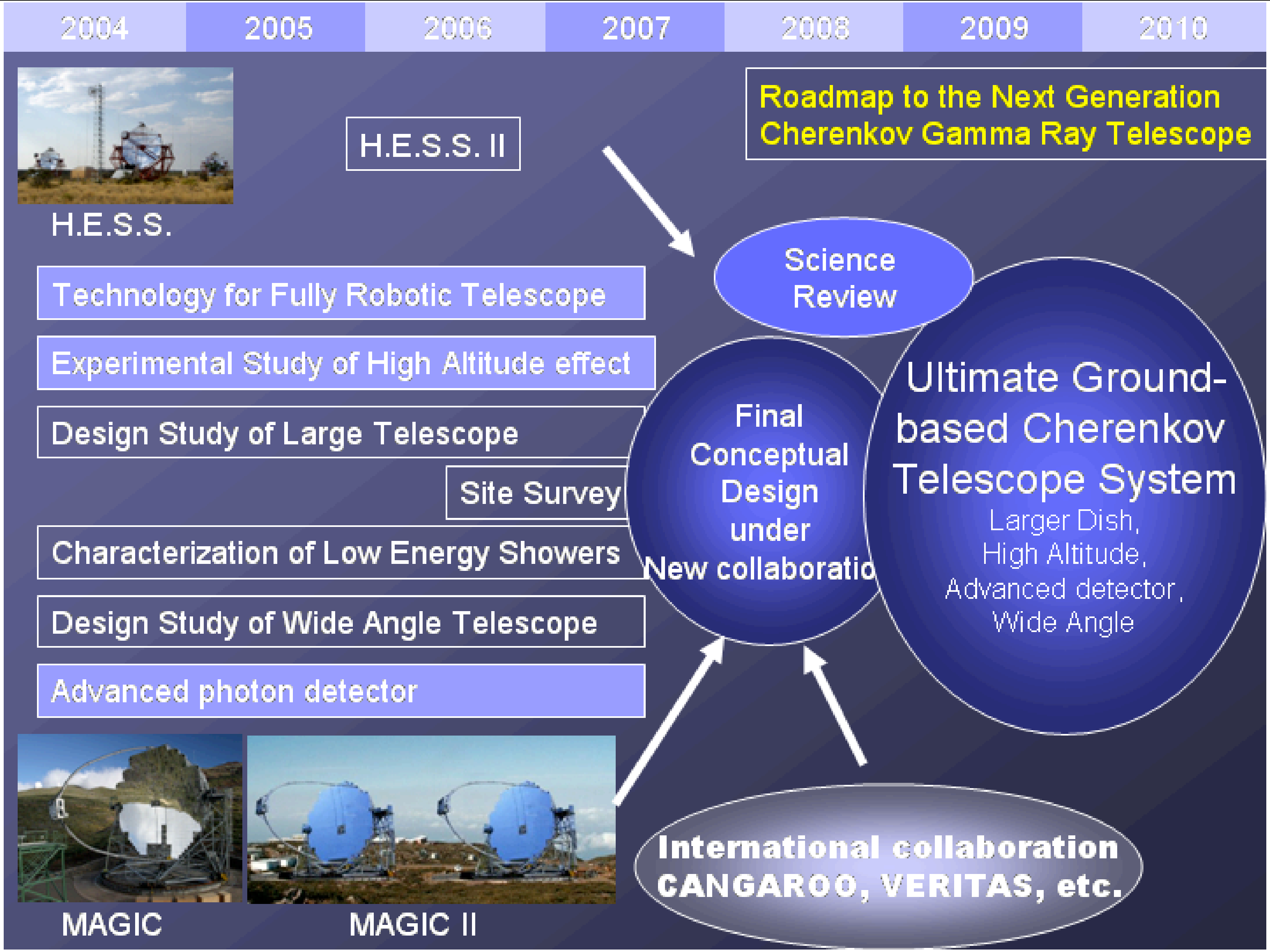
- Multi-wavelength observations
- Guest observer
- Associate programme
- Collaboration membership

Medium term prospects

Towards a Network of Atmospheric Cherenkov Detectors, April 27-29, Paris

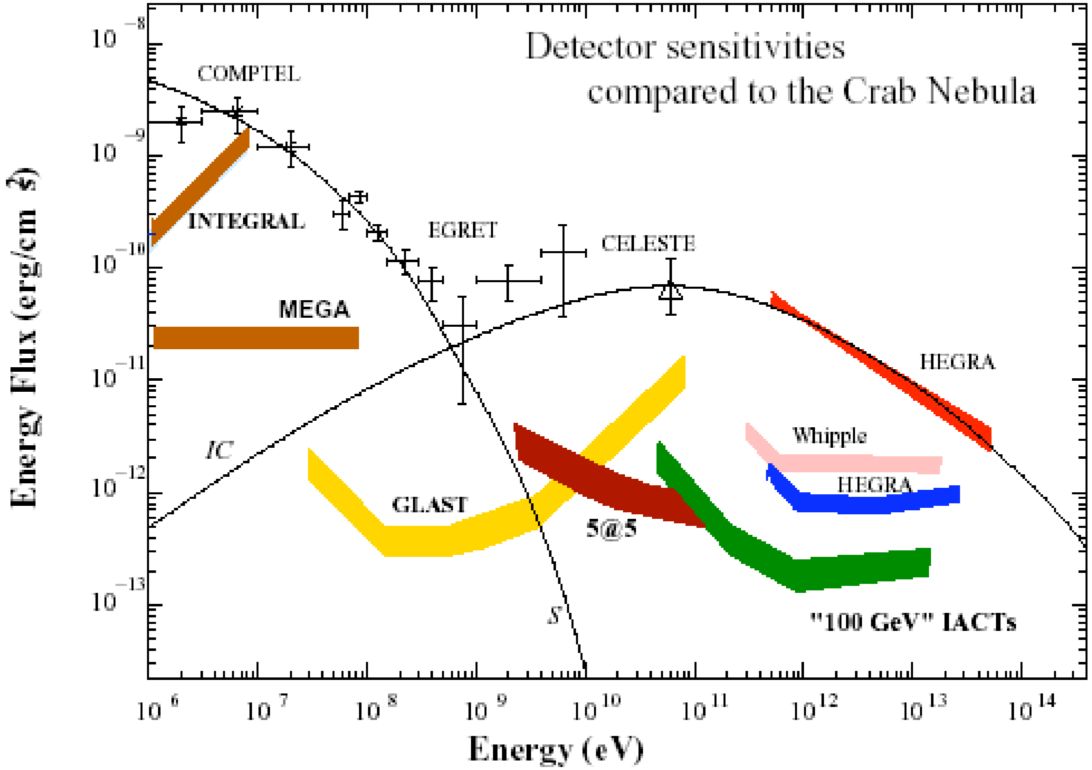
Aim: Understand and co-ordinate
- scientific exploitation
- multi-wavelength observations
- future developments

European roadmap



M Teshima,, MPI für Physik, Munich

5@5



A telescope array providing an energy threshold of 5 GeV at an altitude of 5 km.

Aharonian et al, Astroparticle Physics, 2003

VLACT concept

VERITAS
Large Air
Cherenkov
Telescopes

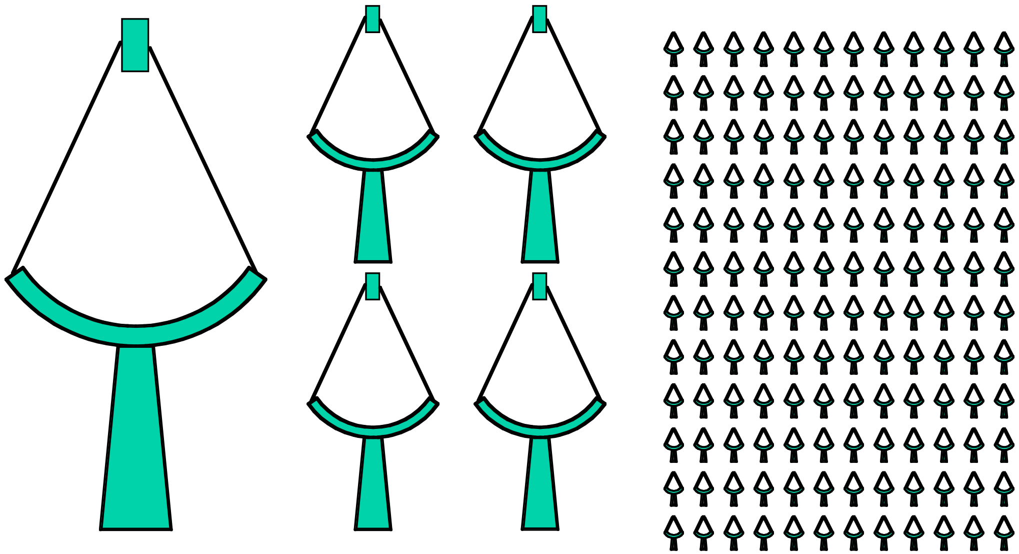
J Buckley et al.

VERITAS site
Array of three 20-25m telescopes costing $42M
Secondary optics
8° FOV with 4000 pixels per camera
In addition to rapid slewing VERITAS-4
Pipelined image processing for prompt ToOs

STAR

STAR concept

A Falcone,
H Krawczynski
et al.



Mirror: 30 m
Camera: 1.8 m
$6 Million

Mirror: 15 m
Camera: 0.9 m

Mirror: 2.5 m
Camera: 15 cm
$1.7 Million

Assuming Price of Mount $\propto d^{2.5}$

Make equivalent of one large aperture (30-50 m) telescope from many small telescopes (>144 telescopes with ~2.5 m diameter)

ACME

Atmospheric Cherenkov Modular Experiment

Collection area of several km^2

Spread out imaging telescopes over a large area.

cost: $200k per telescope

J Holder, I de la Calle, et al

Allen Telescope Array:
350 6m diameter radio telescopes for SETI

Next generation ideas and proposals ....

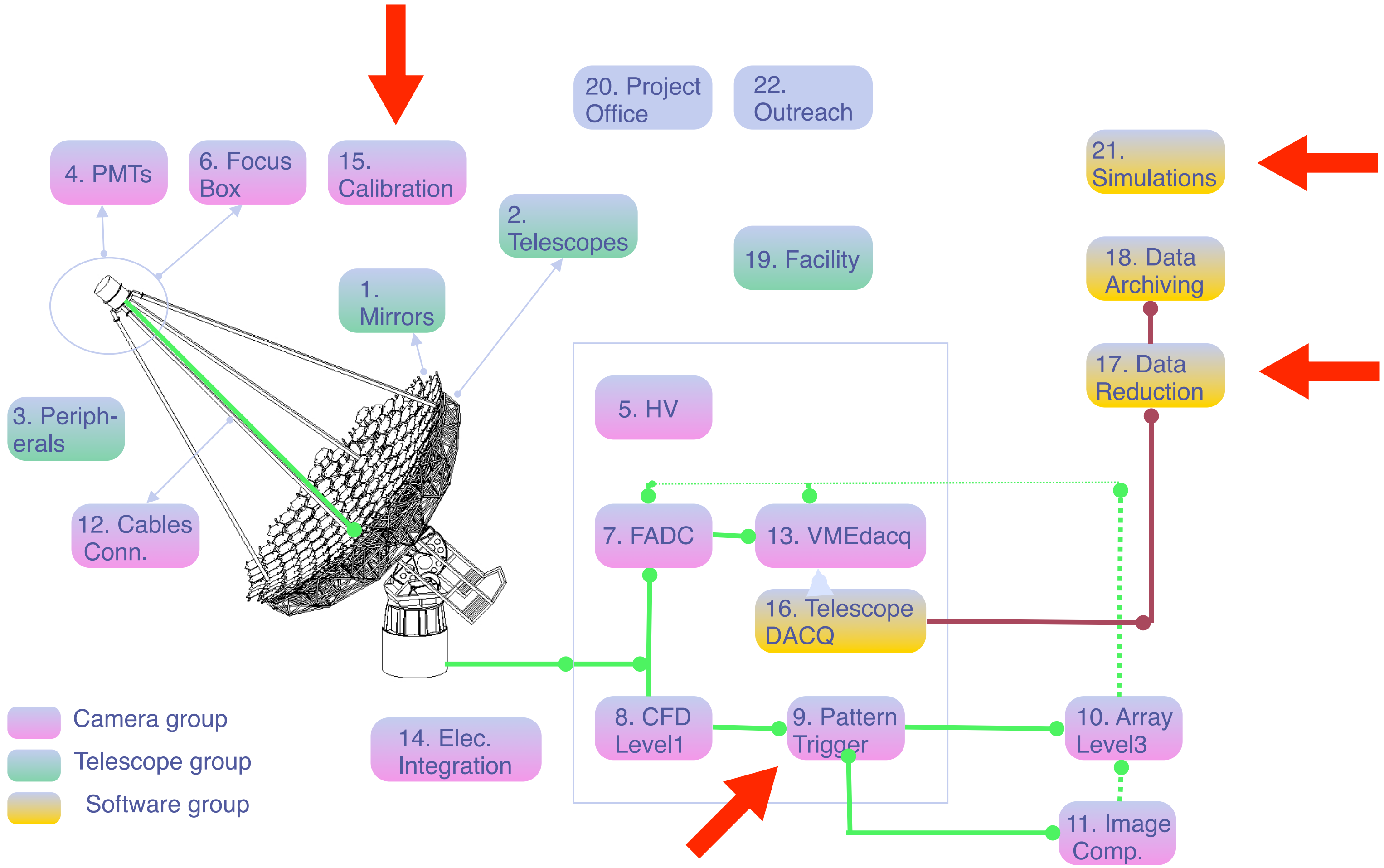
project	site	characteristic(s)	science driver(s)
5@5	ALMA	lowest threshold	dark matter search, high-redshift
ECO	La Palma	Cherenkov observatory, lowest threshold, all sky monitor	high-redshift, transient sources
STAR	VERITAS	alternative to large mirror area design	high-redshift, transient sources
ACME	many candidates	large effective area, source monitor	Sensitivity at highest energies
VLACT	VERITAS	fast slew, wide field, low threshold	GRB, high-redshift, IR background

Different telescope types, aimed at different science.

UK Technology Programme

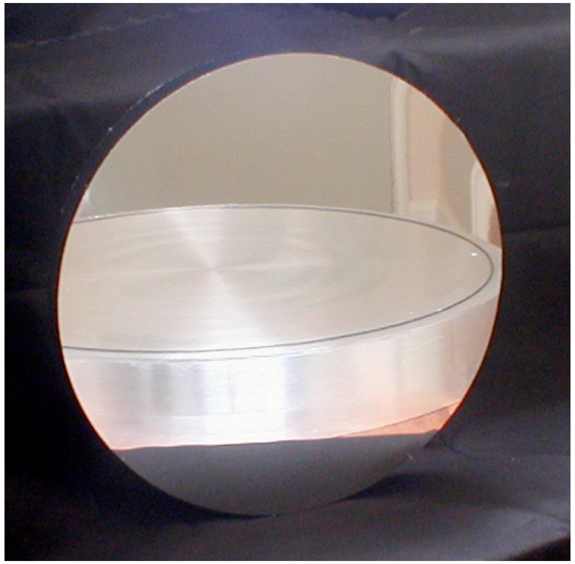
- Existing efforts at Durham and Leeds
- Cherenkov telescopes are RICH detectors
- Existing HEP expertise and facilities in the UK
- Low cost of entry

Tasks in building a new instrument

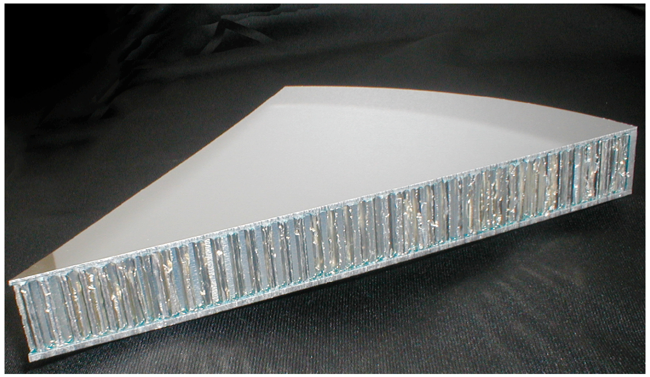


current UK involvement

Vacuum Formed Mirrors

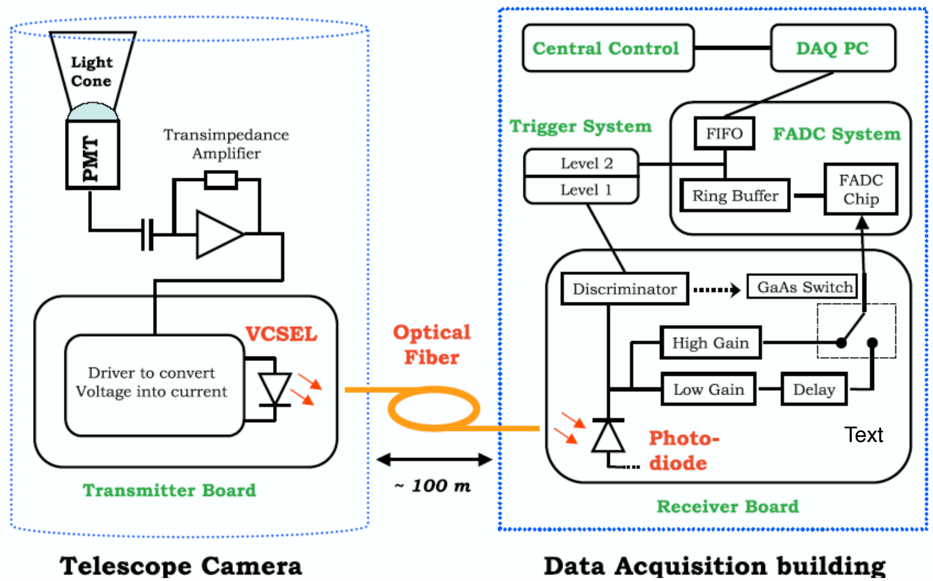


MirraTech

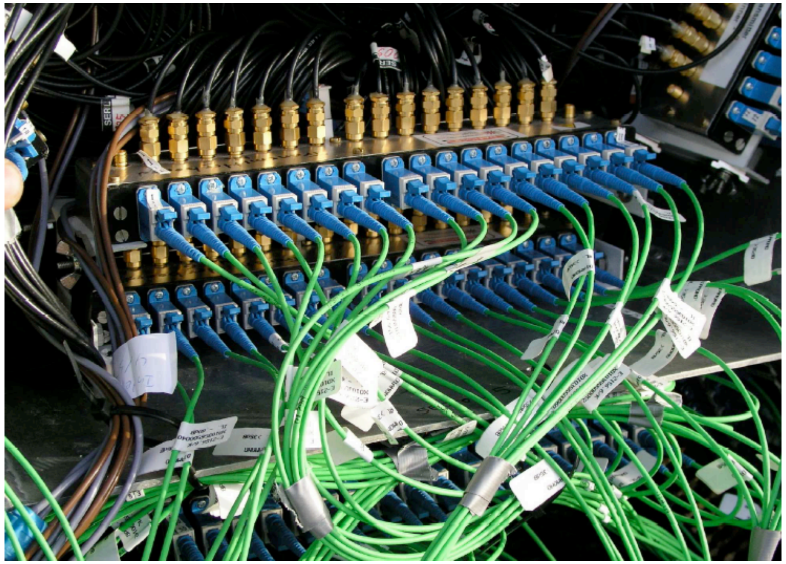


Durham
University

Signal transmission over fibre



First generation systems successfully deployed in Whipple (120 ch) and in MAGIC telescope (500 ch).



D Paneque, PhD thesis 2004, MAGIC collaboration

S/N ~ SQRT(telescope mirror area)
S/N ~ SQRT(charge integration time)

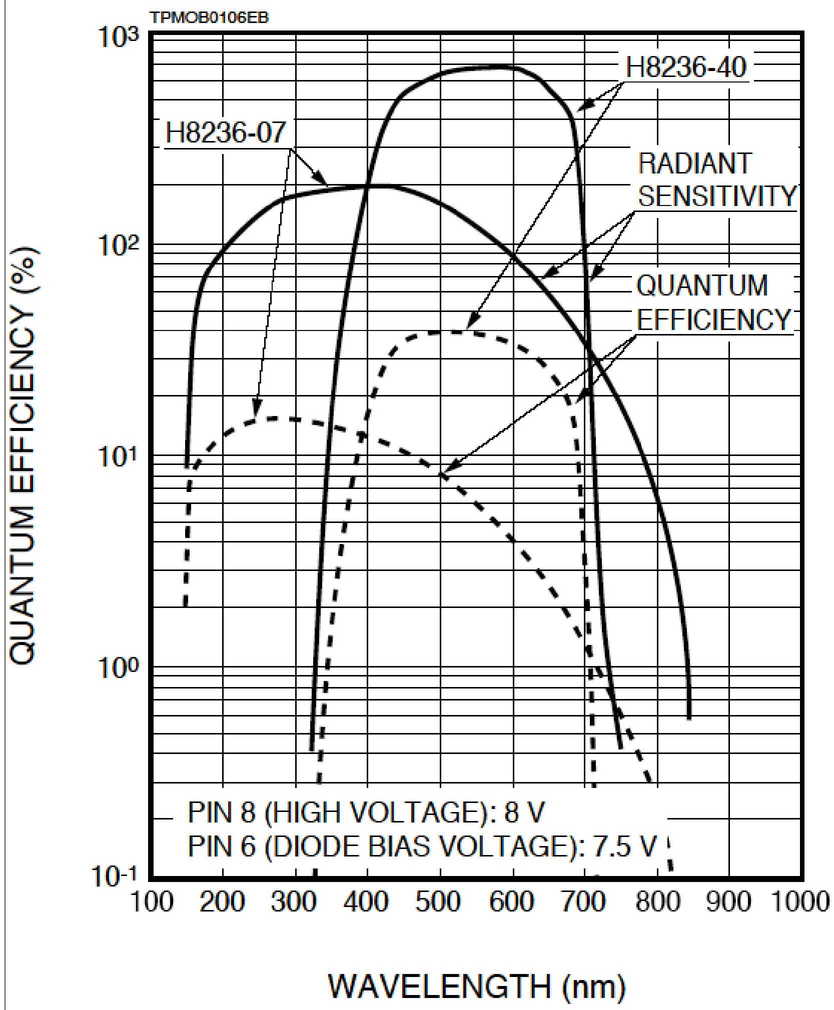
Present charge integration time: 10 - 20 ns.
No reason not to aim for 5 ns or lower.

Twice the effective mirror area!

Hybrid photomultipliers

HAMAMATSU
PRELIMINARY DATA
APR. 2000

HPD (HYBRID PHOTO-DETECTOR) MODULES
H8236-07, -40



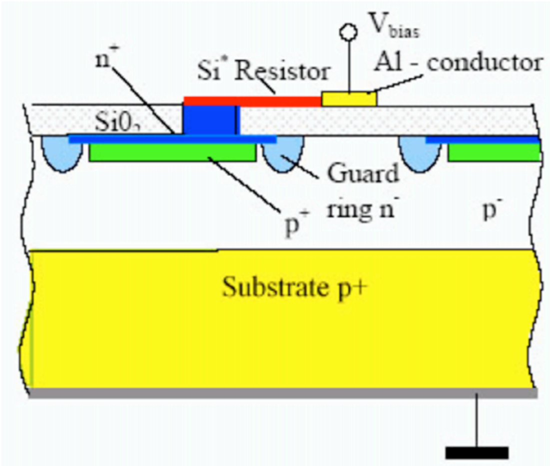
Hybrid photomultiplier (HPD):
- GaAsP(Cs) photocathode
- simple electric field geometry
- gain from APD electron detector

Next MAGIC telescope camera will use high quantum efficiency HPD.

Detected photon number doubles.

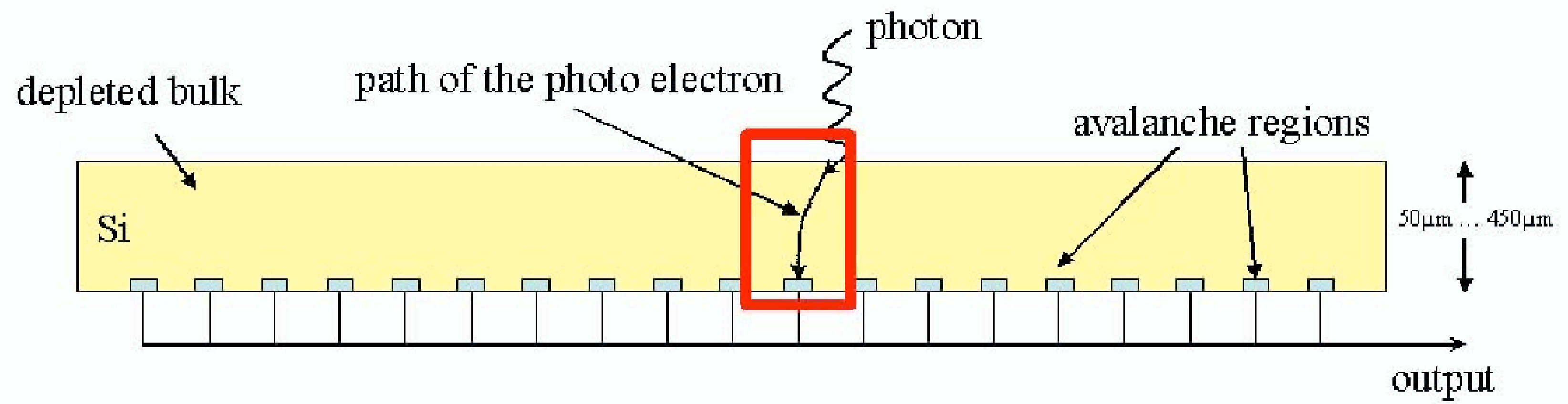
Twice the effective mirror area!

SiPM: Geiger mode APD array



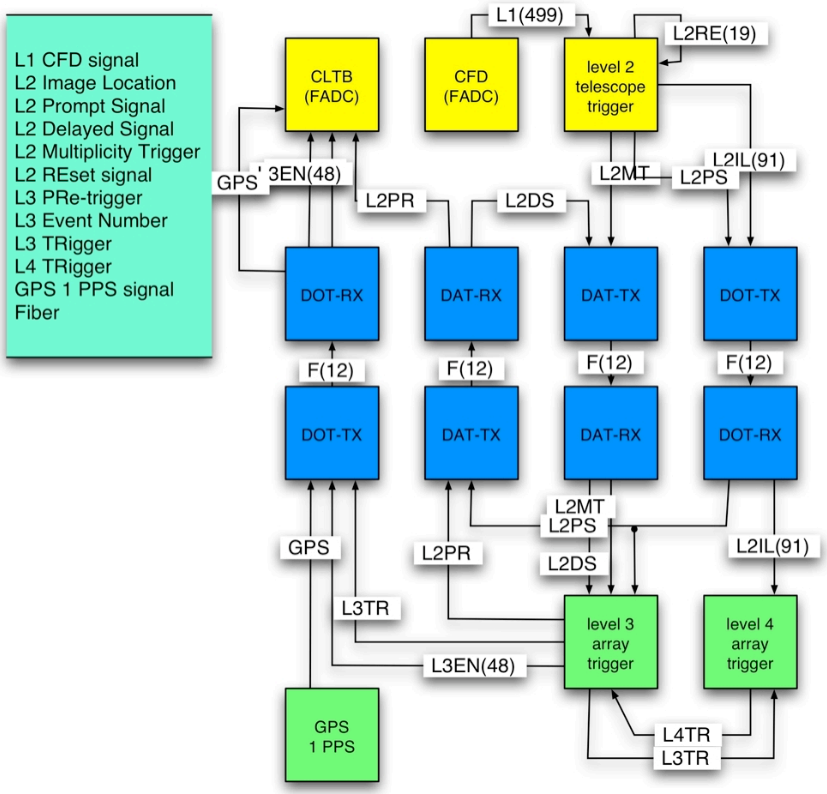
- standardized pulses for single photoelectrons
- large intrinsic gain 10**5 – 10**6
- no need for sophisticated preamplifiers
- fast pulses (1 ns)
- low operating voltages 20–100 V
- low time jitter for single photoelectrons (100 - ps)
- no sensitivity to magnetic fields, no pickup
- low power consumption (10 μW/mm**2)
- low costs because of production process

SiPM developments are expected to succeed in enhancing the PDE **beyond 50%** in the blue wavelength region.



A. N. Otte, to appear in IEEE proceedings, 2005

Future trigger systems



Simplified **VERITAS trigger system** diagram
yellow - telescope system
blue - parallel optical links
green - central trigger system

Next generation

Fully digital front end
Distributed, asynchronous
Adjustable, usec deep delays
Dead time free (pipeline)
~10**4 channels
~10**8 Hz single channel rate
~10$ cost per channel

Avoiding multiple time coincidences
Image comparison, pixel-pixel level

Technology
High density FPGA, sub-nanosecond jitter
Parallel optical links at >20 Gbps

UK camera technology project

Earlier initiatives:
- EU FP6 PHOTODAC
- Reincarnated within EU FP6 HEAPNET
- JREI and SRIF funded infrastructure
- small scale PPARC support

Would require **critical mass** in the UK:
  - light collection
  - **photodetectors**
  - low weight camera mechanics
  - **fast signal transmission**
  - Gsample digitisation
  - **advanced low cost trigger**
  - **calibration** and monitoring
  - peripherals and control systems
  - **data analysis**
  - systems integration, project management

Existing models:
  - Astronomy: provide focal point instrumentation
  - HEP: contribute RICH detectors