TeV Gamma Rays

(Ground-based Very High Energy (VHE) Gamma-Ray Astronomy)

E. Lorenz, Max Planck Institute for Physics, Munich

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OVERVIEW

- INTRODUCTION, GENERAL COMMENTS
- SHORT OVERVIEW ON OBSERVATION TECHNIQUES
- THE MAIN PHYSICS GOALS AND OVERVIEW OF RESULTS
- A SHORT GLIMPSE TO THE FUTURE
- CONCLUSIONS

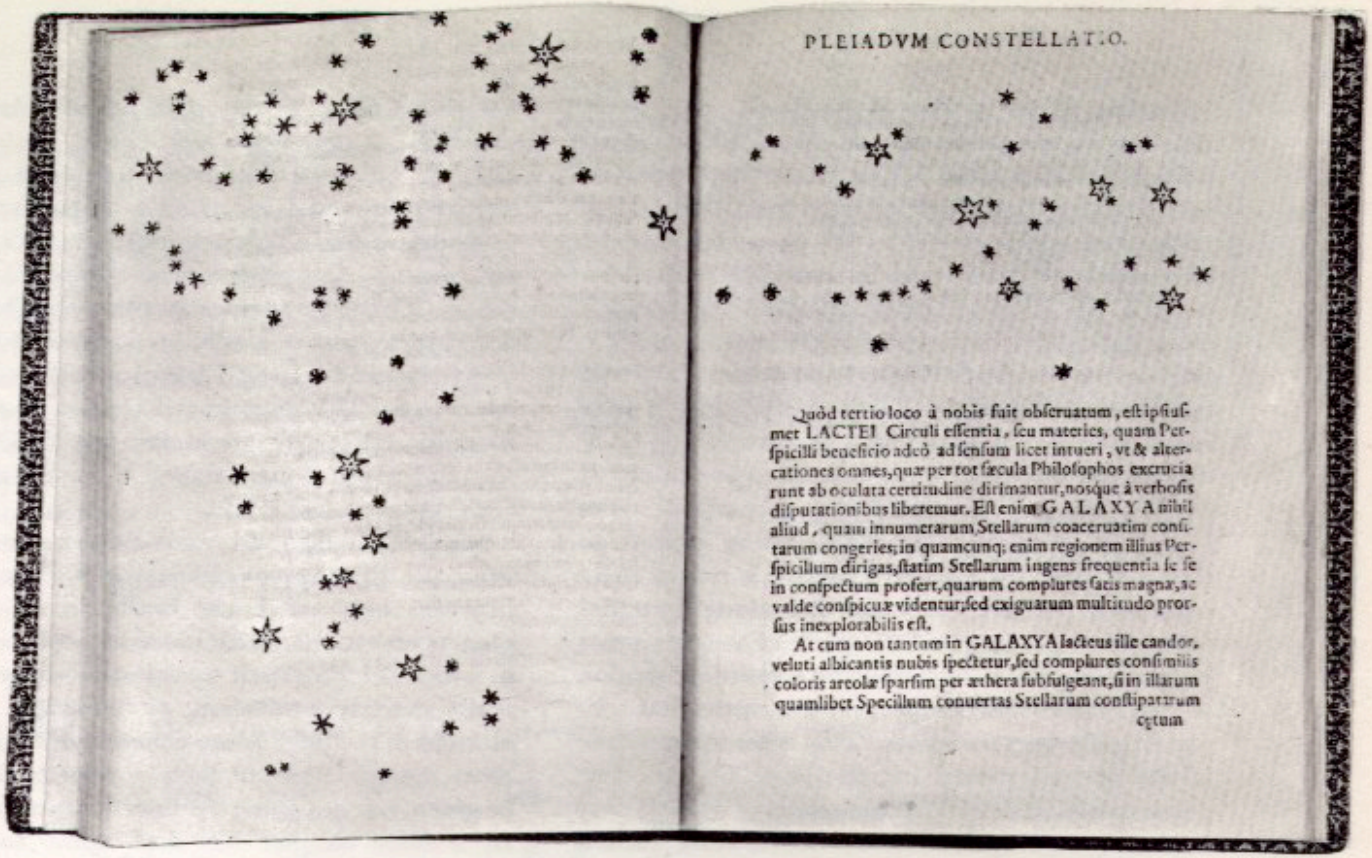
INTRODUCTION, GENERAL COMMENTS

WE HAD TWO YEARS AGO THE INTERNATIONAL YEAR OF ASTRONOMY,400y ASTRONOMY, 1609 FIRST ASTRONOMICAL OBSERVATIONS BY GALILEI WITH AN OPTICAL TELESCOPE, KEPLER PUBLISHED THE ASTRONOMIA NOVA (FUNDAMENTAL LAWS OF PLANET MOVEMENTS)

≈ 350 YEARS ONLY OPTICAL OBSERVATIONS OF THE SO-CALLED THERMAL UNIVERSE (HOT STARS)

1912 DISCOVERY OF HIGH ENERGY COSMIC RAYS (VICTOR HESS)
HIGH ENERGY PARTICLES COMING FROM OUTER SPACE (ORIGIN STILL PARTLY ENIGMATIC)

AFTER WWII RAPID OPENING OF OTHER ‚WINDOWS' OF THE EM SPECTRUM
-> RADIO ASTRONOMY, IR- ASTRONOMY, RÖNTGEN, X-RAY ASTRONOMY
GAMMA-RAY ASTRONOMY 10^{-6} TO 10^{14}, (10^{20}) eV
-> SIGNS FOR THE NON-THERMAL OR RELATIVISTIC UNIVERSE
-> HIGH ENERGY PARTICLE ASTRO PHYSICS (A NEW FUNDAMENTAL PHYSICS RESEARCH FIELD)
1989: OPENING OF THE WINDOW OF VERY HIGH ENERGY GAMMA-ASTRONOMY: THE DISCOVERY OF TeV GAMMA-RAYS FROM THE CRAB NEBULA BY THE WHIPPLE COLABORATION



PLEIADVM CONSTELLATIO.

Quòd tertio loco à nobis fuit obſeruatum, eſt ipſiuſmet LACTEI Circuli eſſentia, ſeu materies, quam Perſpicilli beneficio adeò ad ſenſum licet intueri, vt & altercationes omnes, quæ per tot ſæcula Philoſophos excrucia runt ab oculata certitudine dirimantur, nosque à verbosis diſputationibus liberemur. Eſt enim GALAXYA nihil aliud, quam innumerarum Stellarum coaceruatim conſitarum congeries; in quamcunq; enim regionem illius Perſpicillum dirigas, ſtatim Stellarum ingens frequentia ſe ſe in conſpectum profert, quarum complures ſatis magnæ, ac valde conſpicuæ videntur; ſed exiguarum multitudo prorſus inexplorabilis eſt.

At cum non tantum in GALAXYA lacteus ille candor, veluti albicantis nubis ſpectetur, ſed complures conſimilis coloris areolæ ſparſim per æthera ſubfulgeant, ſi in illarum quamlibet Specillum conuertas Stellarum conſtipatarum

ectum

These pages from Galileo's booklet show the many "new" stars which the early telescope revealed. Before 1610 the belt and sword of Orion (left) appeared as a group of only nine stars, the Pleiades (right) as a group of only seven stars. On the left is a replica of one of Galileo's telescopes.

WE WANT TO KNOW ALL ABOUT OUR UNIVERSE

BESIDES THE ‚THERMAL' UNIVERSE THERE EXIST A HIGH ENERGY WORLD

-> ASTROPARTICLE PHYSICS

WE CANNOT GO TO THE INTERESTING PLACES AND MEASURE THERE

WE NEED TO OBSERVE FROM DISTANCE (MOSTLY BY EM-WAVES/PARTICLES)

THE BEST ‚MESSENGERS' FROM RELATIVISTIC PROCESSES IN OUR UNIVERSE ARE:

GAMMA-RAYS ARE THE CURRENLY **BEST MESSENGERS** IN THE VERY HIGH ENERGY DOMAIN

BUT THEY AMBIGUOUS WRT THEIR PARENT PARTICLES (LEPTONIC OR HADRONIC ORIGIN)

VHE g ASTRONOMY

* ONLY NEUTRAL PARTICLES (g, n, n, (X??)) CAN BE EXTRAPOLATED BACK TO THEIR ORIGIN

- **CONNECTED TO MANY HIGH ENERGY PROCESSES**
- **point to the location of cosmic high energy processes (cosmic accelerators or tagets)**
- **carry time information (no mass)**
- **carry energy information ($E_g \leq E_{intrinsic}$)**
- **VHE gs must have VHE/UHE parent particles**
- **create electromagnetic showers in the atmosphere**

DIFFICULTIES

- **Universe not fully transparent for all energies (interaction with cosmic photon fields)**
- **The fluxes are very low**
- **One has to suppress the enormous hadronic cosmic ray background**
- **Best current detectors: Air Cherenkov telescopes that can record shower images**
- **can only run during night time. Background from night sky light >2* $10^{12}/m^2$ sec sterad (300-600 nm)**
- **light losses due to Rayleigh, Mie scattering**

=======

INITIAL PROGRESS IN VHE GAMMA-ASTRONOMY WAS SLOW

STARTED LATE 50th, OVER 20 YEARS SEARCH WITHOUT SUCCESS

1989 DISCOVERY OF THE FIRST TEV SOURCE: CRAB NEBULA

1992 DISCOVERY OF THE FIRST EXTRAGALACTIC TEV SOURCE: MKN 421

UNTIL 2001 ONLY 14 SOURCES FOUND
(DETECTORS WERE NOT GOOD ENOUGH- TOO HIGH THRESHOLD
TOO POOR SUPPRESSION OF THE HADRONIC BACKGROUND)

2002 START OF THE FIRST HIGH SENSITIVITY OBSERVATORY: HESS
FOLLOWED LATER BY CANGAROO III, MAGIC, VERITAS

VERY HIGH ENERGY GAMMA ASTRONOMY CAN ONLY BE DONE UP TO NOW
FROM GROUND. SATELLITES HAVE A TOO SMALL AREA BUT WITH FERMI
WE HAVE AN OVERLAP OF EXPLORED ENERGY

DEFINITION OF VERY HIGH ENERGY (VHE): 10^{11}-10^{14} eV, range running

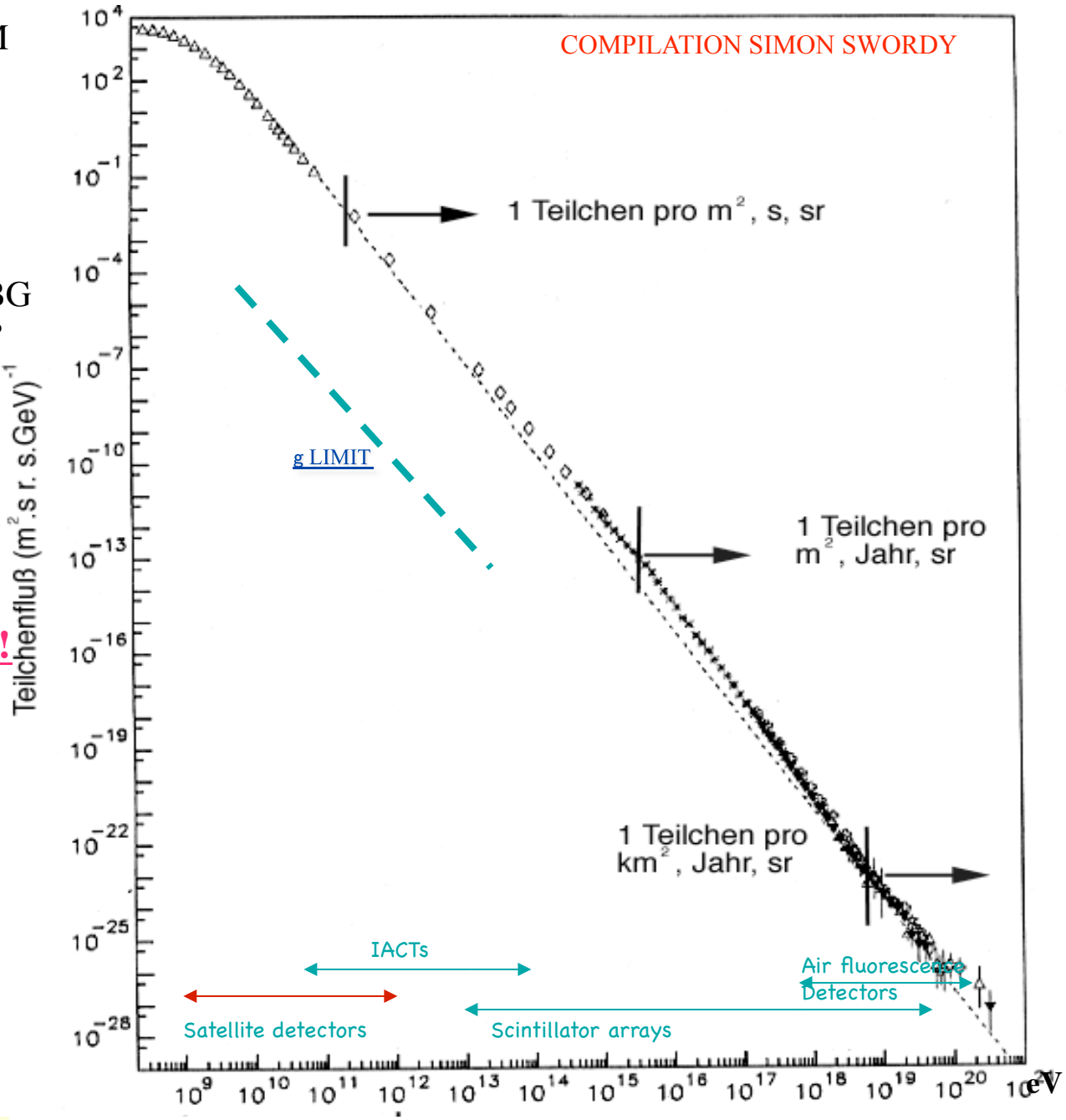
THE COSMIC RAY SPECTRUM

FRACTION OF γs UNKNOWN
$< 10^{-4}$ from Galactic Plane
$< 10^{-5}$ isotropic
Local g emission spots(stars) can reach g fluxes of a few % of CR BG
For typ. angular resolution of 0.1°

-> **g/hadron SEPARATION A BIG EXPERIMENTAL CHALLENGE**

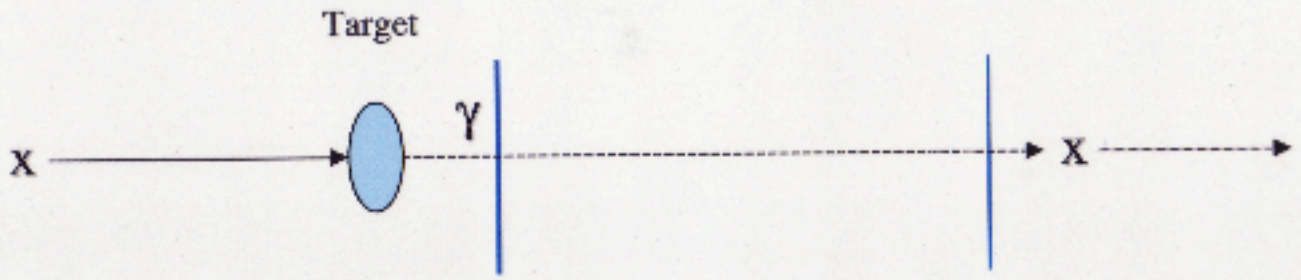
-> **Detectors are only useful for 2-3 decades in energy !!**

NOTE: NEARLY ALL SPECTRA FOLLOW IN FIRST ORDER A POWER LAW



THE 3(4) STEPS IN

γ - Astronomy



ACCELERATION
p,e ...

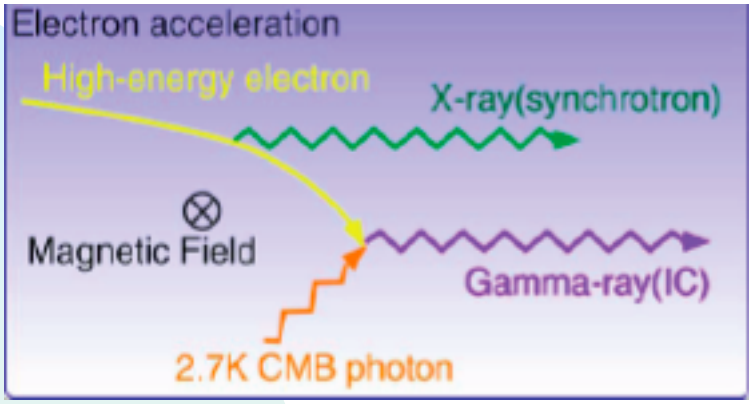
TRANSPORT
(how far can γ's go)

DETECTION
LOW FLUX,
LARGE HADRONIC
BACK GROUND

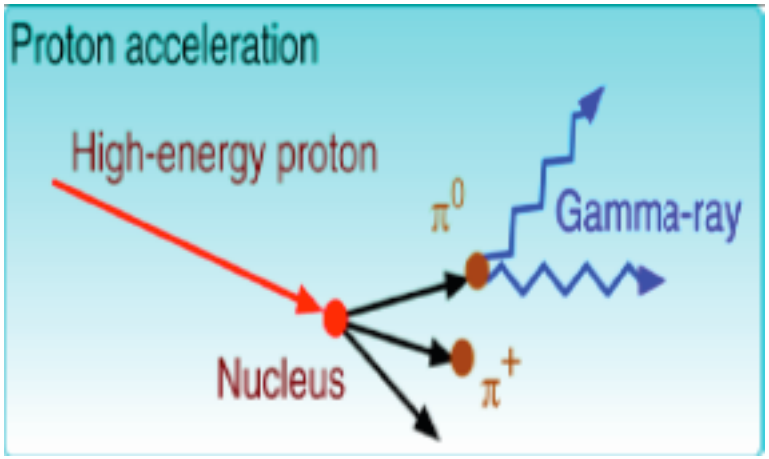
PHYSICS

GAMMA-RAY PRODUCTION

Leptonic production

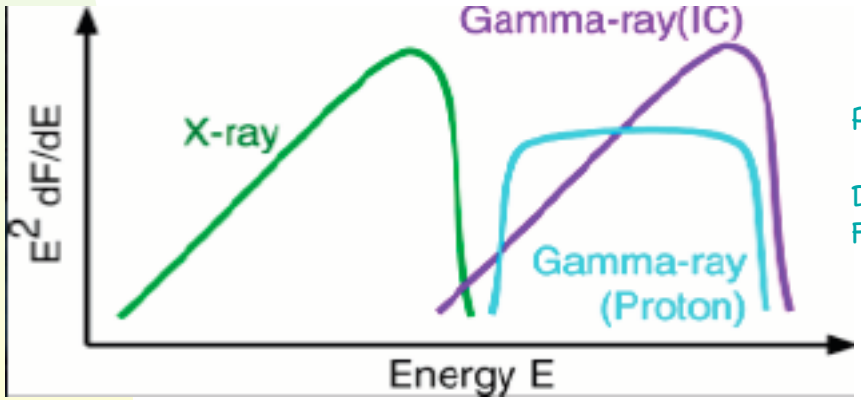


Hadronic production



NEARLY ALL OBSERVED GAMMA SPECTRA FOLLOW IN FIRST ORDER A POWER LAW WITH COEFFICIENTS: -2 TO -5

HOW TO DECIDE IF LEPTONIC OR HADRONIC ORIGIN?
STUDY SPECTRAL ENERGY DENSITY (SED): (DIFFERENTIAL FLUX)·E^2



PROBLEM: NO DETCTOR SPANS THE NECESSARY ENERGY RANGE
DIFFICULTIES TO JOIN DATA FROM QUITE DIFFERENT DETECTORS

The transport through the universe (from the production site to us)

THE UNIVERSE IS NOT TRANSPARENT FOR gs AT ALL ENERGIES

OUR UNIVERSE IS NOT TRANSPARENT TO PARTICLES OF THE HIGHEST ENERGIES DUE TO INTERACTION WITH VARIOUS (LOW ENERGY) PHOTON FIELDS :

COSMIC PHOTON FIELDS: EBL

RADIOWAVES, 2.7° MICROWAVE BACKGROUND, IR- BACKGROUND (UNKNOWN), STARLIGHT….

dominant process for the g absorption:

$g_{VHE} g_{EBL} \rightarrow e^+e^-$

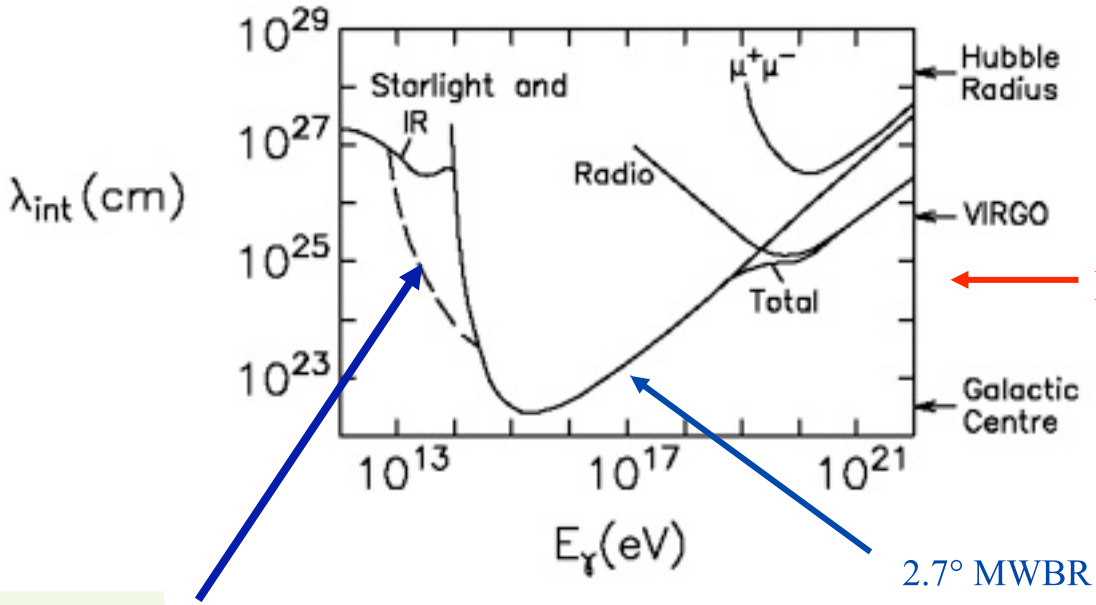
s(b) ~ $1.25 \cdot 10^{-25}(1-\beta^2) \cdot \left[2\beta(\beta^2-2) + (3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right] \mathrm{cm}^2$

Heitler 1960

maximal for: $\epsilon \simeq \frac{2m_e^2c^4}{E} \simeq \left(\frac{500\,\mathrm{GeV}}{E}\right)\mathrm{eV}$

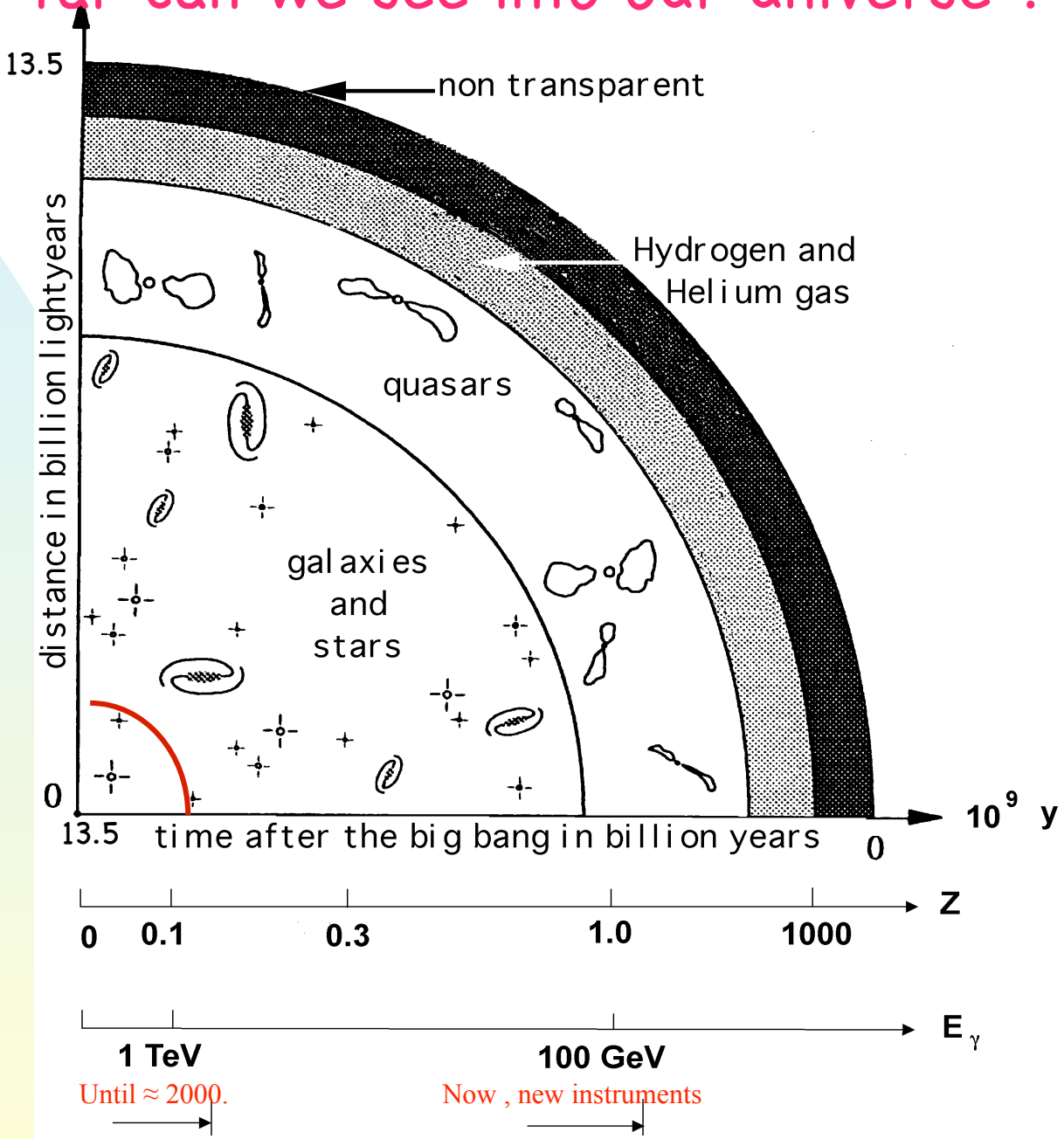
(2.7° K MWBG <--> 1015 eV gs : absorption length ≈ 10 kpc)**

ABSORPTION LENGTH l_{int}(cm) OF gs IN THE UNIVERSE AS FUNCTION OF ENERGY(Wdowczyk, Wolfendale, 1992)



Uncertainty due to unknown IR background -> EBL can distort the g spectra
But how to decide between source intrinsic processes and absorption processes
In the universe?
At around $10^{13.5\text{-}16}$ we can just see to the center of our Galaxy, we need for E> 10^{13} eV
Neutrinos as messengers for distant observations

How far can we see into our universe ?



HOW DO WE DETECT VERY HIGH ENERGY GAMMA RAYS ?

- THE EARTH ATMOSPHERE IS NOT TRANSPARENT FOR VERY HIGH ENERGY PARTICLES (gs)

- THE ESTIMATED FLUXES ARE ALL MUCH TOO LOW FOR SATELLITE BORNE DETECTORS

  all observed fluxes < few 10^{-10} gs/cm^2 sec at 100 GeV

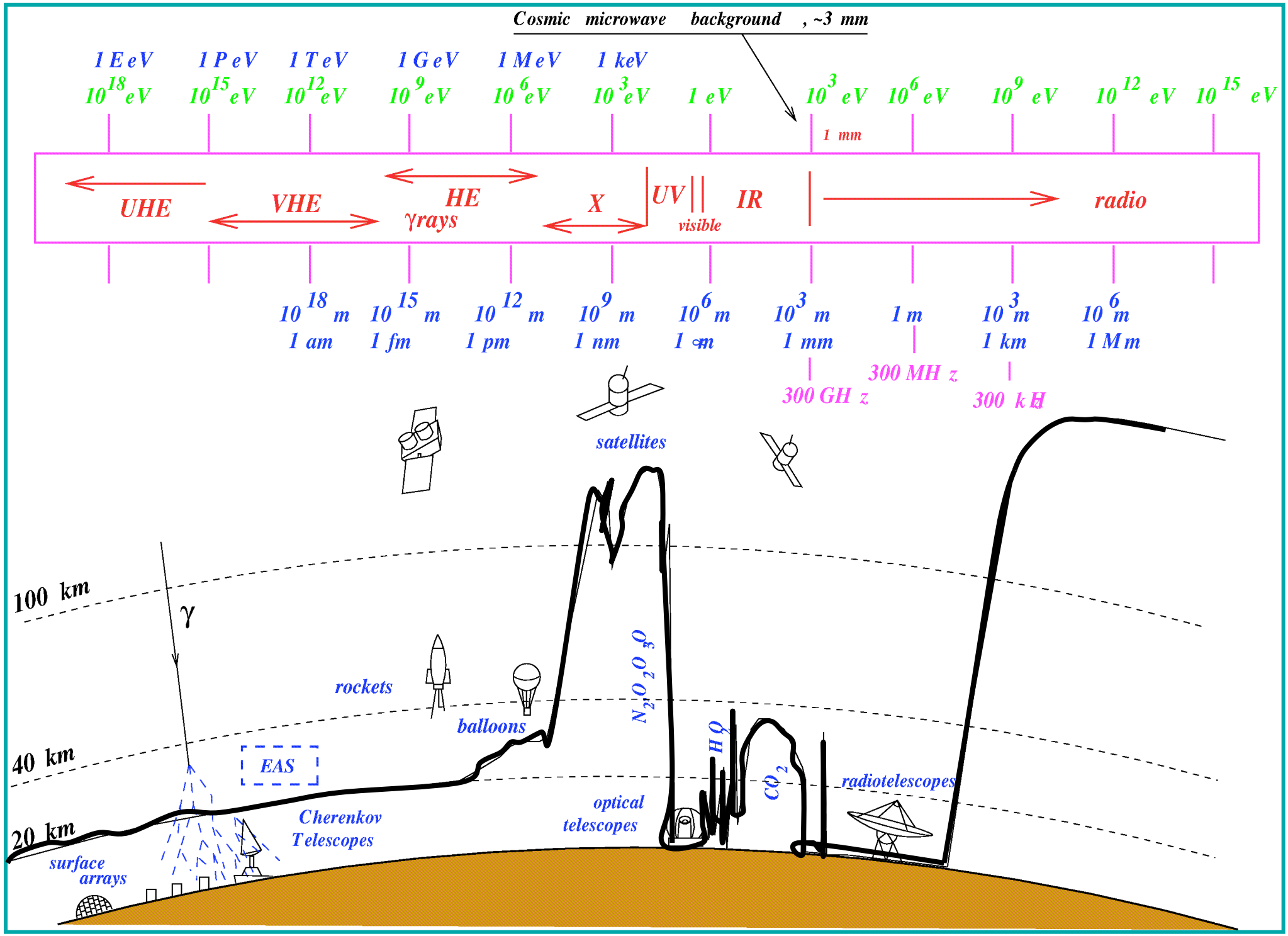
- GAMMAS (LIKE OTHER ENERGETIC COSMIC PARTICLES) IMPINGING ON THE EARTH ATMOSPHERE GENERATE EXTENDED AIR SHOWERS

- TRY TO DETECT THESE AIR SHOWERS AND ANYLSE THEM IN ORDER TO DETERMINE THE ENERGY AND DIRECTION OF THE INCIDENT PARTICLE AND THEN EXTRAPOLATE BACK TO THE SOURCE

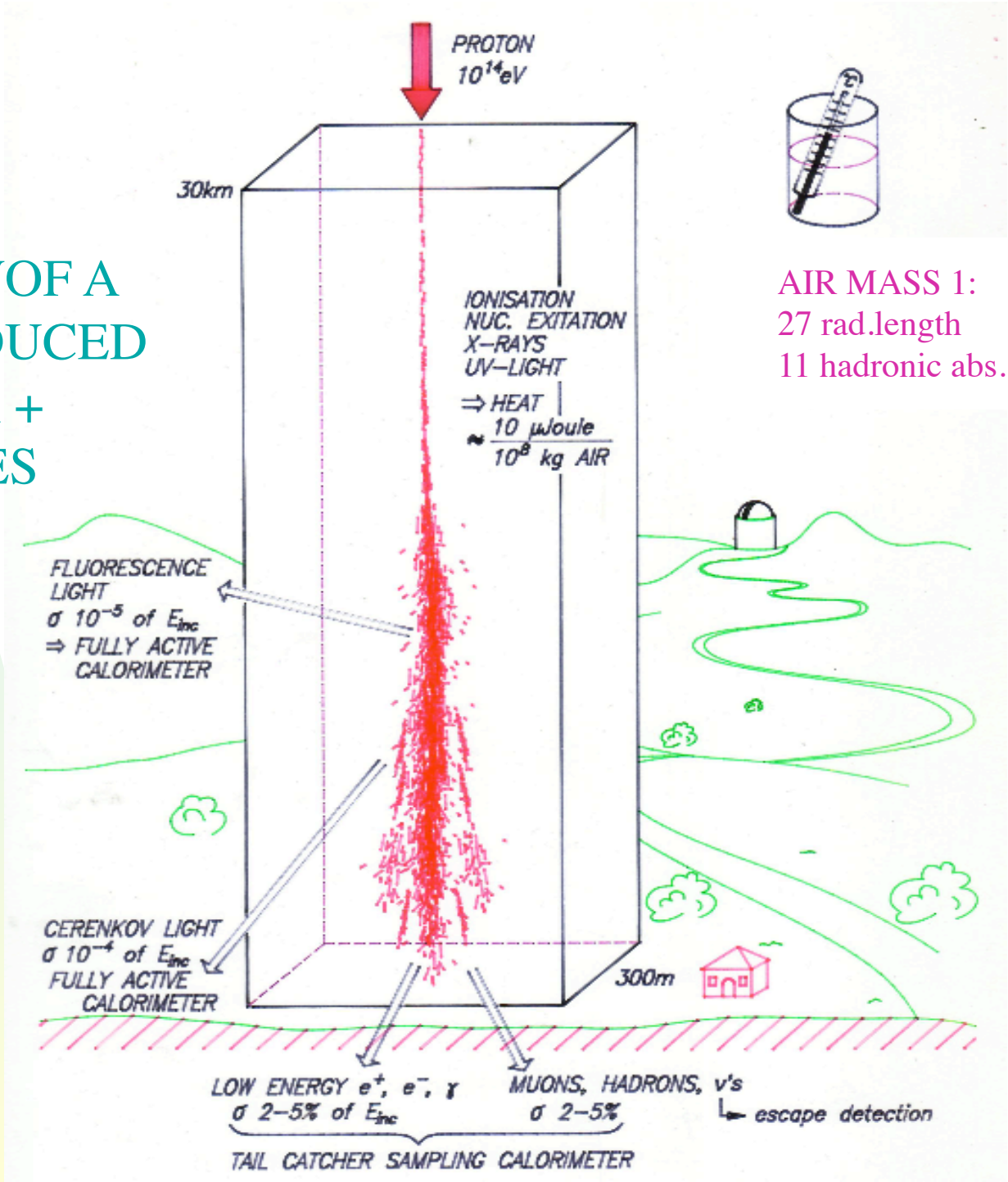
- FROM AN OBSERVATION OF MANY SHOWERS DETECT SOURCES, MEASURE LIGHTCURVE ENERGY SPECTRA AND DEDUCE PHYSICS

- OFTEN NECESSARY TO CORRELATE WITH OBSERVATIONS IN OTHER WAVELENGTH BANDS RADIO, OPTICAL, XRAYS

THE CURRENTLY BEST INSTRUMENT: LARGE TELESCOPES WITH A FINE PIXELIZED PMT CAMERA TO DETECT THE CHERENKOV LIGHT FOR AIR SHOWERS


Cosmic microwave background , ~3 mm
1 EeV
10^18 eV
1 PeV
10^15 eV
1 TeV
10^12 eV
1 GeV
10^9 eV
1 MeV
10^6 eV
1 keV
10^3 eV
1 eV
10^3 eV
10^6 eV
10^9 eV
10^12 eV
10^15 eV
1 mm
UHE
VHE
HE
γrays
X
UV
visible
IR
radio
10^18 m
1 am
10^15 m
1 fm
10^12 m
1 pm
10^9 m
1 nm
10^6 m
1 μm
10^3 m
1 mm
1 m
10^3 m
1 km
10^6 m
1 Mm
300 GHz
300 MHz
300 kHz
satellites
100 km
γ
rockets
balloons
40 km
EAS
20 km
Cherenkov
Telescopes
surface
arrays
optical
telescopes
N2 O2 O3
H2O
CO2
radiotelescopes

ARTIST VIEWOF A PROTON INDUCED AIR SHOWER + OBSERVABLES



AIR MASS 1:
27 rad.length
11 hadronic abs. length

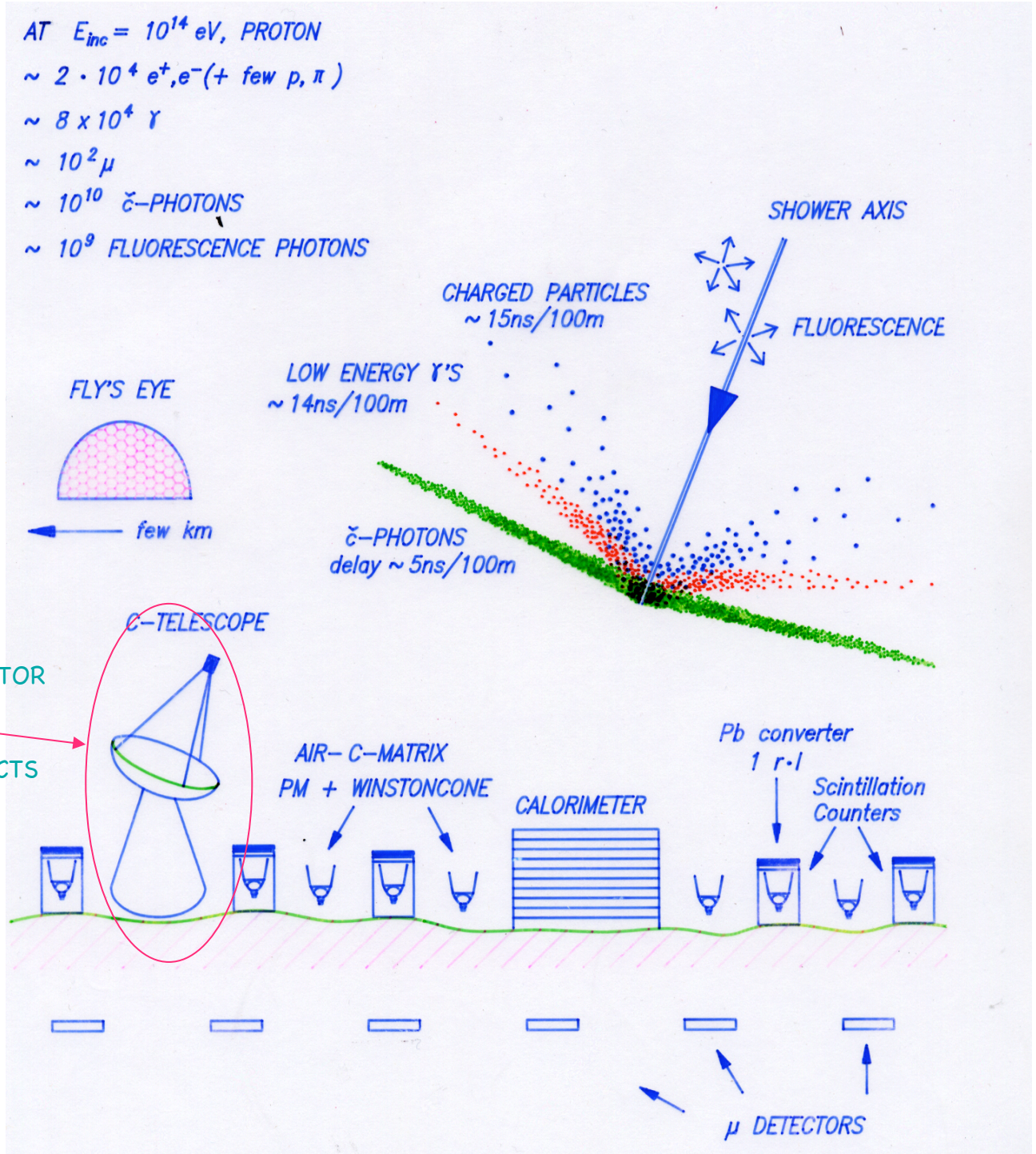
CARTOON

SHOWER FRONT (FLASH PHOTO BEFORE HITTING GROUND)

DETECTOR CONCEPTS

IMAGING CHERENKOV TELESCOPE
THE BY FAR MOST SUCCESSFUL DETECTOR

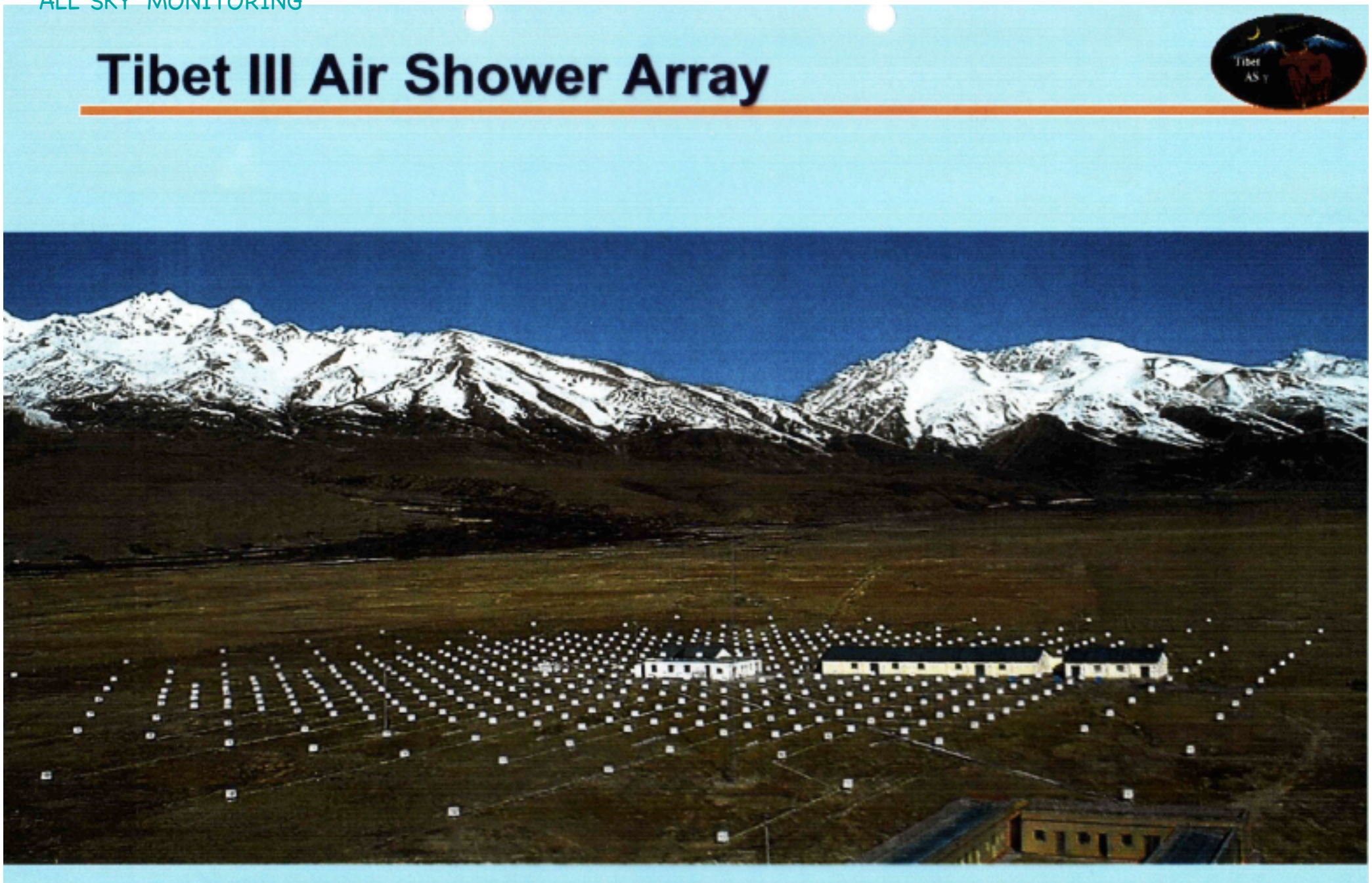
NEARLY ALL DETECTIONS MADE BY IACTS



Detection methods

- Below ≈10-100 GeV: Satellite borne detectors (Fermi)
  see talk from Steve Ritz
- Cherenkov telescopes
- Instruments that detect particles of the shower tail

A TYPICAL SHOWER TAIL CATCHER DETECTOR: LARGE ARRAY OF SCINTILLATING (OR TRACKING) DETECTORS, ACTIVE FRACTION NORMALY SMALL(0.5-2%), THRESHOLD ≈ $COS^{-5-7}Q, 24$ h UP-TIME, MODEST ENERGY RESOLUTION, MODEST ANGULAR RESOLUTION, MODEST g/hadron SEPARATION 'ALL SKY 'MONITORING



INCREASING ACTIVE AREA: USING LARGE WATER PONDS
WITH DOUBLE LAYER CHERENKOV LIGHT DETECTION FOR MUON DISCRIMINATION
MOST OTHER PARAMETERS SIMILAR TO SCINTILLATOR ARRAY DETECTORS

EXAMPLE : MILAGRO

The Milagrito Detector

Jemez Mountains, NM
February 1997 to May 1998

- ground-based air shower array for detecting gamma rays in the energy regime ~100 GeV – ~20 TeV
- used water Cherenkov technique to detect air shower particles
- located 2650 m above sea level

100 GeV - 100 TeV
Large Area
Good background rejection
Large Aperture & Duty Cycle

Partial sky survey & monitoring
Extended Sources
Transients (GRBs, AGN flares)
Highest Energies (>10 TeV)

THE CURRENTLY MOST SUCCESSFUL INSTRUMENT ABOVE 50 GeV:
THE CHERENKOV TELESCOPE TO DETECT AIR SHOWERS

THE BASIC DETECTOR PRINCIPLE IS USING THE ATMOSPHERE
AS AN ABSORBING CALORIMETER IN COMBINATION WITH
A CHERENKOV LIGHT DETECTOR

IT IS A FULLY ACTIVE CALORIMETER WITH IMAGING READOUT

THE ATMOSPHERE IS A VERY 'TRICKY' CALORIMETER

(NOT LIKE CALORIMETERS FOR HEP)

*LOW Z MATERIAL

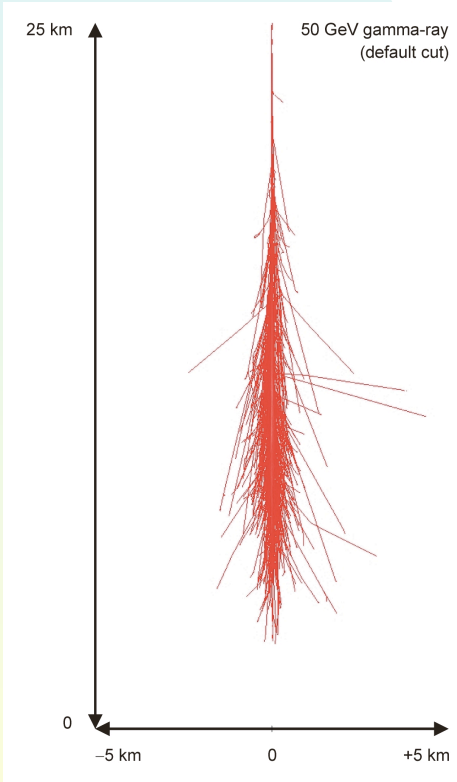
* EXPONENTIAL DENSITY DISTRIBUTION (x_{max} much more compressed)
* CHANGES PERMANENTY ITS MASS, DISTANCE TO THE OBSERVER (DUE TO EARTH ROTATION)
* HAS NO CONFINING WALLS -> BACKGROUND LIGHT
* CAN CHANGE ITS TRANSMISSION IN AN UNPREDICTABLE WAY ((CLOUDS..) -> NEEDS INSTRUMENTS TO CONTROL IT: LIDAR ….. -> YOU NEED GOOD INFO ABOUT METEOROLOGY
* CHERENKOV LIGHT NOT EXACTLY PROPORTIONAL TO ENERGY LOSS BY IONISATION
* A FULLY ACTIVE CALORIMETER BUT NOT COMPENSATING
* (AROUND 1 TEV:PROTON INDUCED AIR SHOWERS PRODUCE ABOUT HALF OF THE LIGHT COMPARED TO EM SHOWERS)

NO TEST BEAMS FOR CALIBRATION: RELY ON MC SIMULATIONS

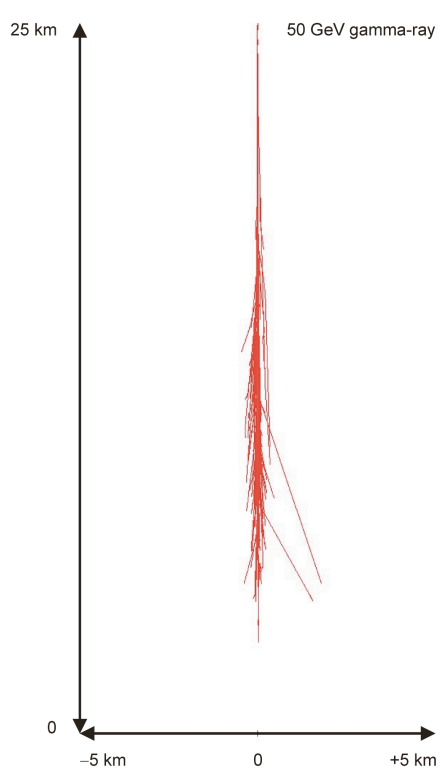
MONTE CARLO SIMULATIONS OF A GAMMA- AND A PROTON AIR SHOWER

50 GeV gamma:

all tracks

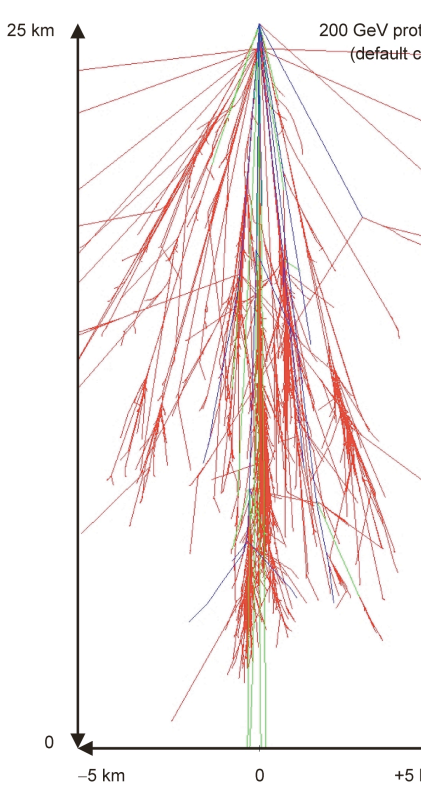


only tracks emitting C light



200 GeV proton

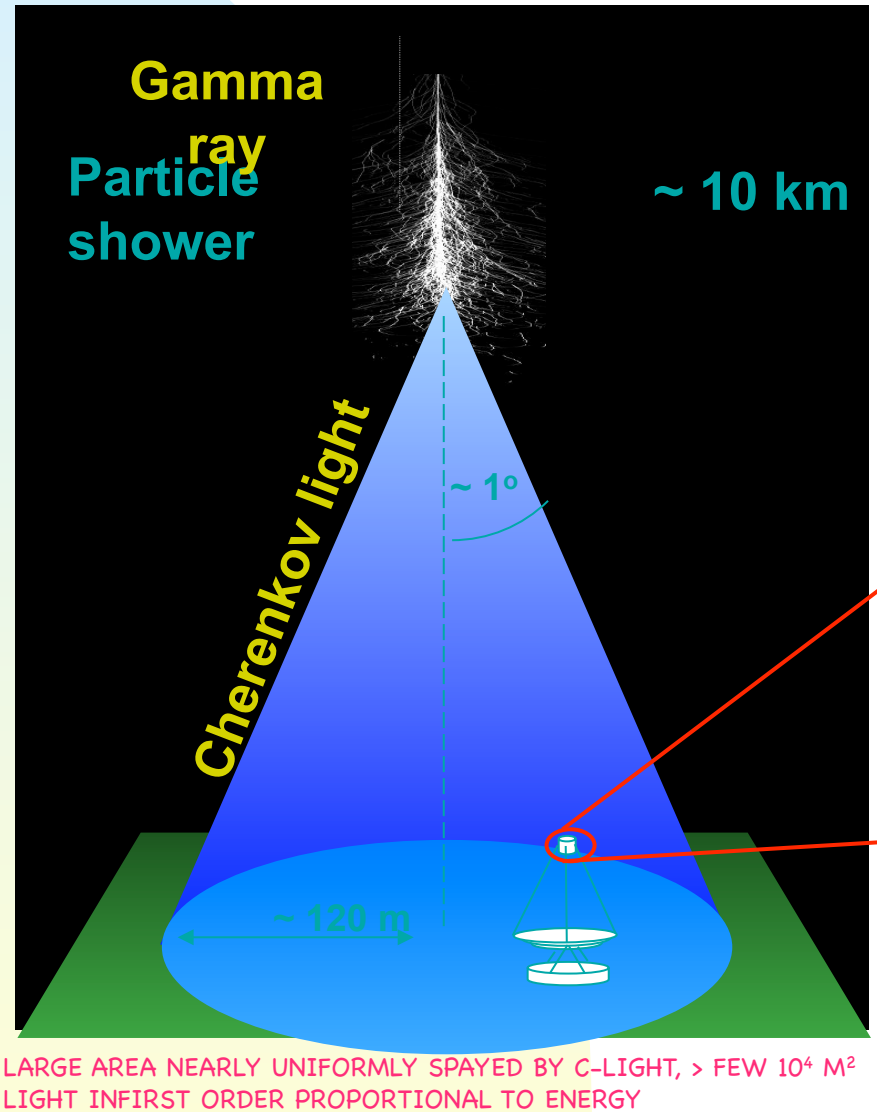
all tracks



only tracks emitting C light

Dario Hrupek

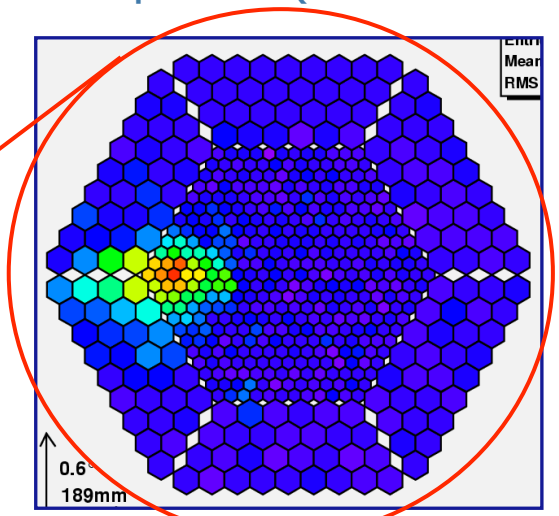
Imaging Air Cherenkov Technique



LARGE AREA NEARLY UNIFORMLY SPAYED BY C-LIGHT, > FEW 10^4 M^2
LIGHT INFIRST ORDER PROPORTIONAL TO ENERGY

Cherenkov light image of particle shower in telescope camera

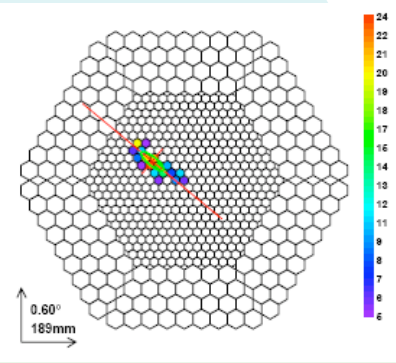
- fast light flash (nanoseconds)
- 100 photons per m^2 (1 TeV Gamma Ray)



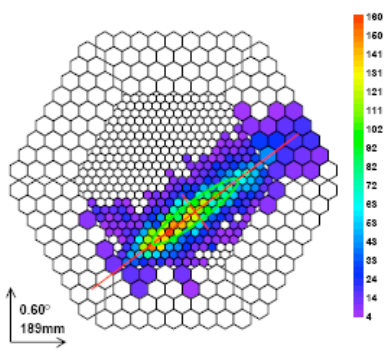
reconstruct:
arrival direction, energy
reject hadron background

Event Parameterization

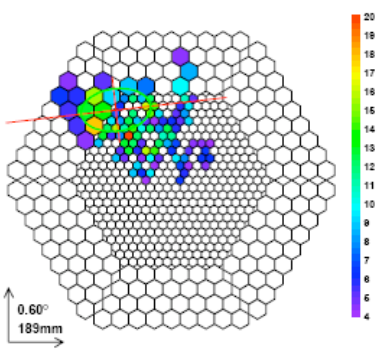
gamma candidate



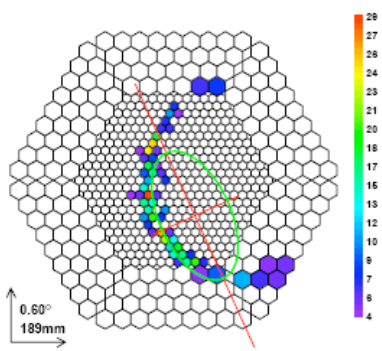
hadron



hadron



muon ring



event parameterization with principal component analysis

commonly known as Hillas parameters

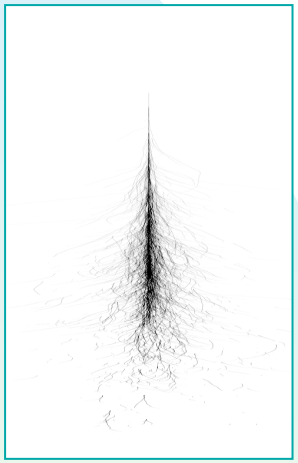
Note: > 99% of all recorded events are from hadronic background showers
Finding the gamma-rays is like searching for the needle in the haystack

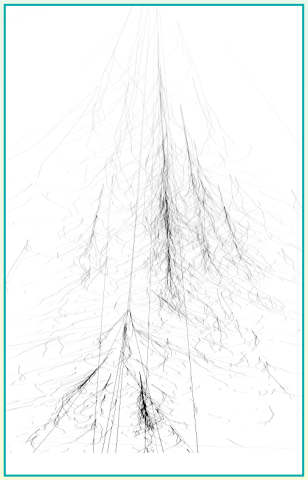
One has to observe during clear dark nights (MAGIC managed to observe also during weak moon shine)

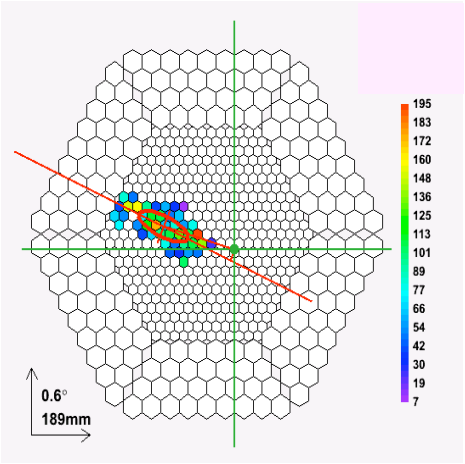
Even during dark nights aproblem by the night sky light background > 2.10^{12} photons/m^2 sec sterad
Observations only possible under such background because Cherenkov light flashes a few nsec duration

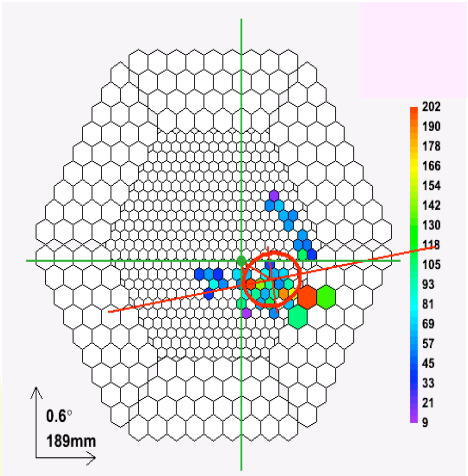
Background Rejection

gamma shower







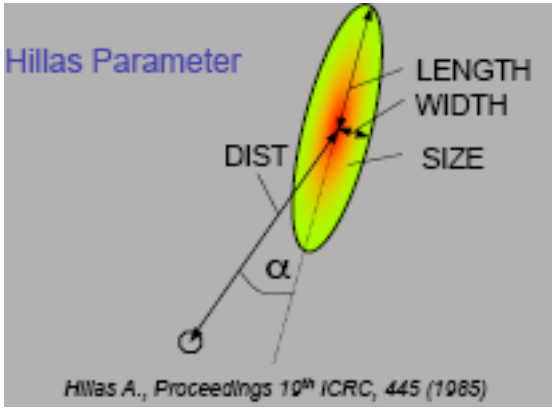


hadron shower (background)

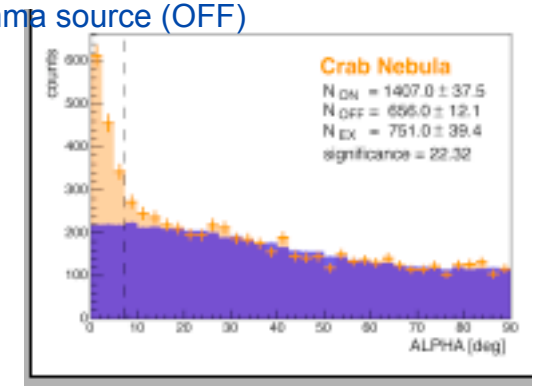
Example looks easy but quite some hadrons (p^0) look like gammas

Rejection based on shower shape
(hadron images are broader, longer fuzzier)

and on shower axis pointing to source location



and finally subtracting two data sets, one pointing towards source (ON) and one taken in an area without a gamma source (OFF)



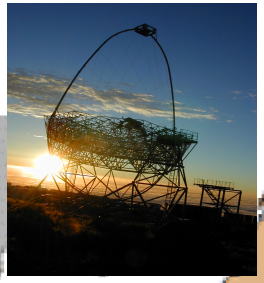
THE ‘STEREO CONCEPT

-> HIGHER PRECISION
more precise impact parameter
improved angular resolution
improved energy resolution
improved g/h separation

-> SENSITIVITY ≈ (1.2-1.4) x √ n

-> COSTS ≈ n

THE CURRENT GENERATION OF HIGH SENSITIVITY CHERENKOV TELESCOPES



MAGIC 1,2003
2 telescopes 17 meters Ø
MAGIC II, 2009

VERITAS

2007
4 telescopes
12 meters Ø

Whipple basecamp Arizona

Roque de los Muchachos, Canary Islands

CANGAROO III
Spring 2004
4 telescopes 10 meters Ø

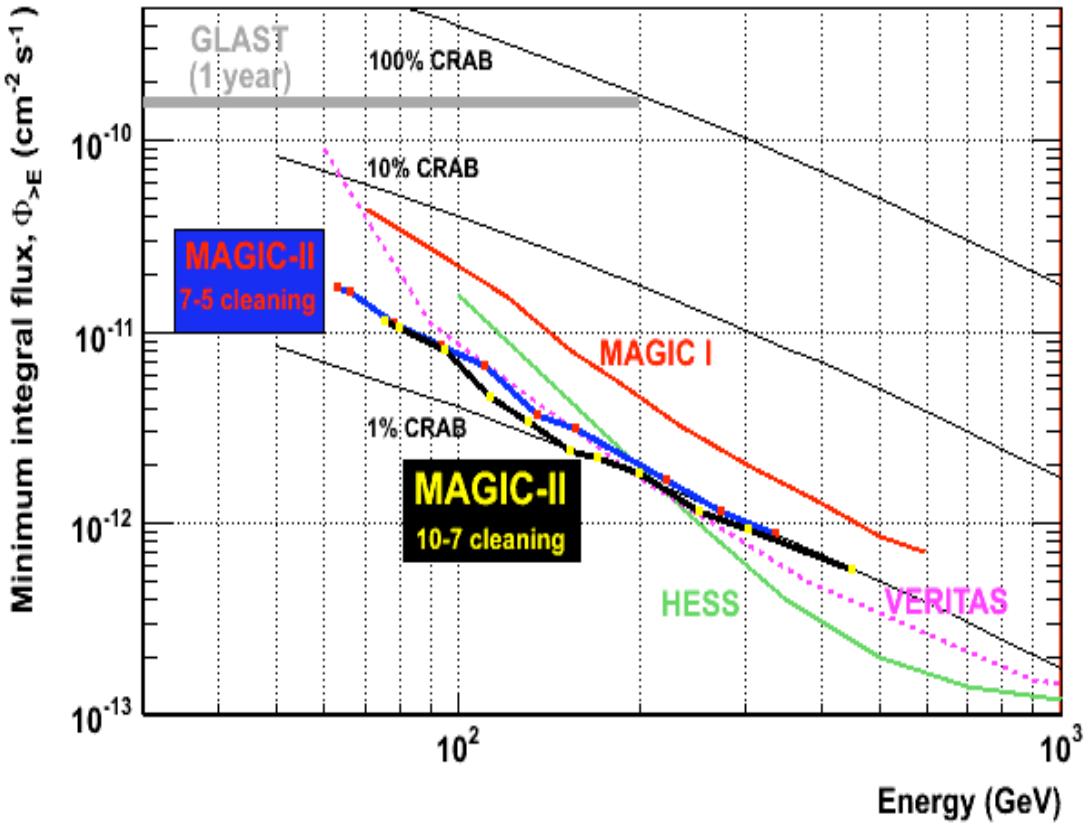
Windhoek, Namibia

HESS
Summer 2002
4 telescopes
12 meters Ø
HESS II, 2014
27 m Ø

Woomera, Australia

SOME MAGIC OBSERVATION PARAMETERS

FLUX SENSITIVITY FOR 50 H OBSERVATION TO SEE A 5 s EXCESS.



FLUX SENSITIVITY IS OFTEN QUOTED IN % OF CRAB FLUX

MAGIC I (2005) 3 % Crab flux
MAGIC I (2008) 1.6 % Crab flux

Energy resolution: ≈ 20-25 %, (150 GeV-few TeV), degrading below 150 GeV

Angular resolution: ≈ .1°/ sqrt(E) ; in TeV

Trigger rate: 400Hz - 1 KHz, ≈ 1 TBYTE/ NIGHT

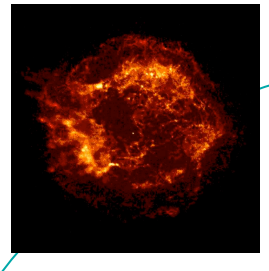
OVERVIEW RESULTS

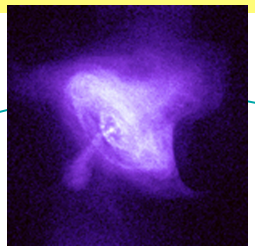
Galactic sources

Extragalactic sources

Fundamental Physics Studies

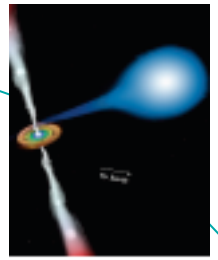
THE PHYSICS GOALS



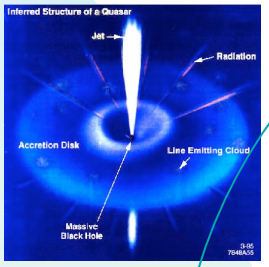


SNRs

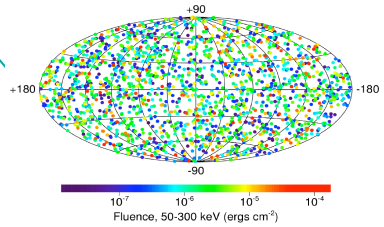
Pulsars



Binary Systems

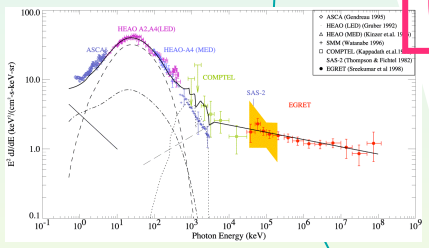


AGNs

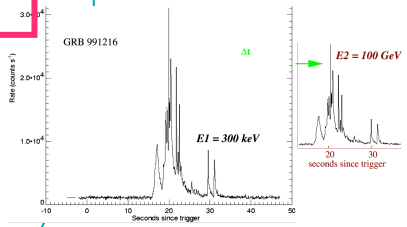


GRBs

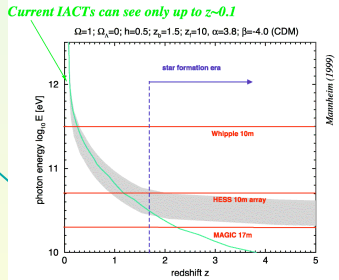
LOOKING TO THE ‚RELATIVITIC' UNIVERSE BETWEEN 10^{10} AND 10^{14} eV



Diffuse background



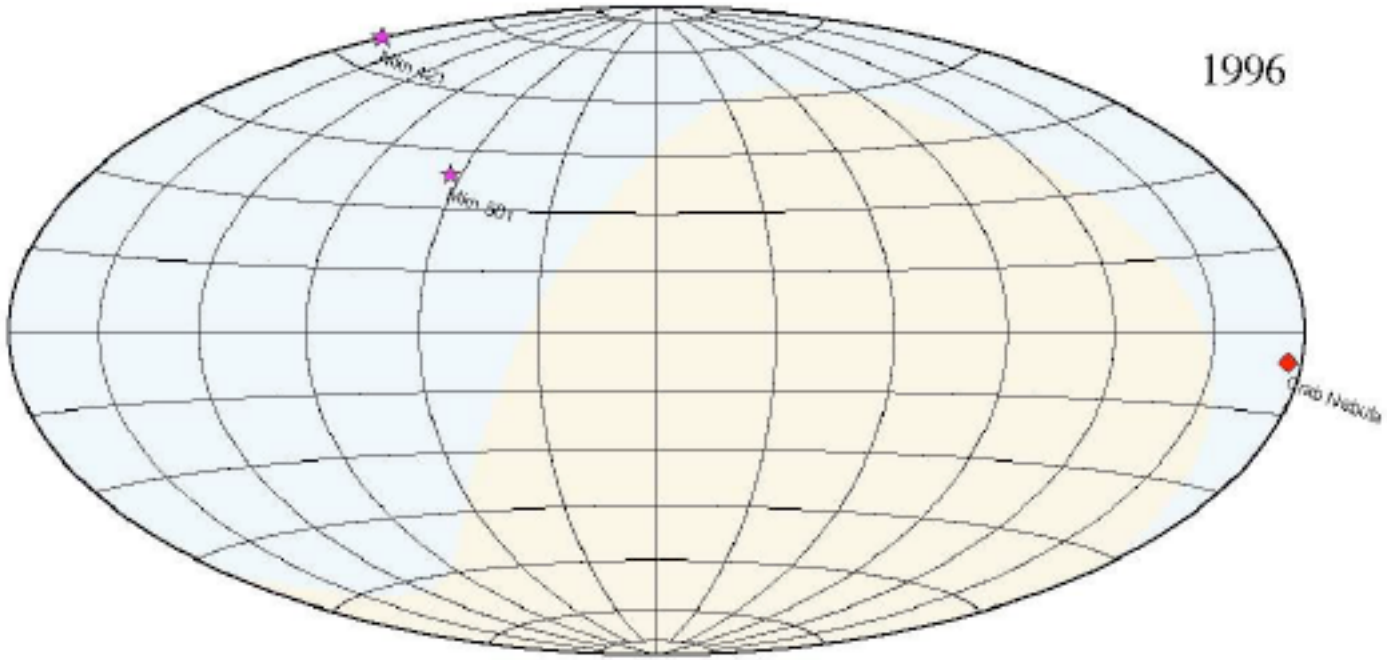
Quantum Gravity test



Cosmological horizon

Cold Dark matter

VHE SKYMAP1996

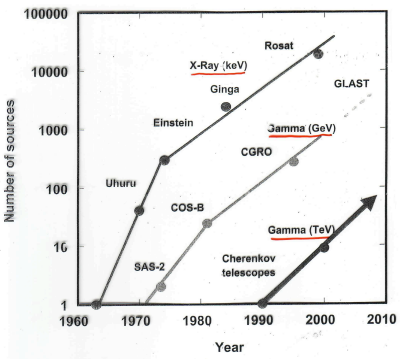


KIFUNE PLOT

VHE Gamma Sources (E > 100 GeV)

(Status August 2006)

44 SOURCES
(13 AGNs)



NOT ALL SOURCES IN INNER GALACTIC PLANE SHOWN

Galactic Coordinates

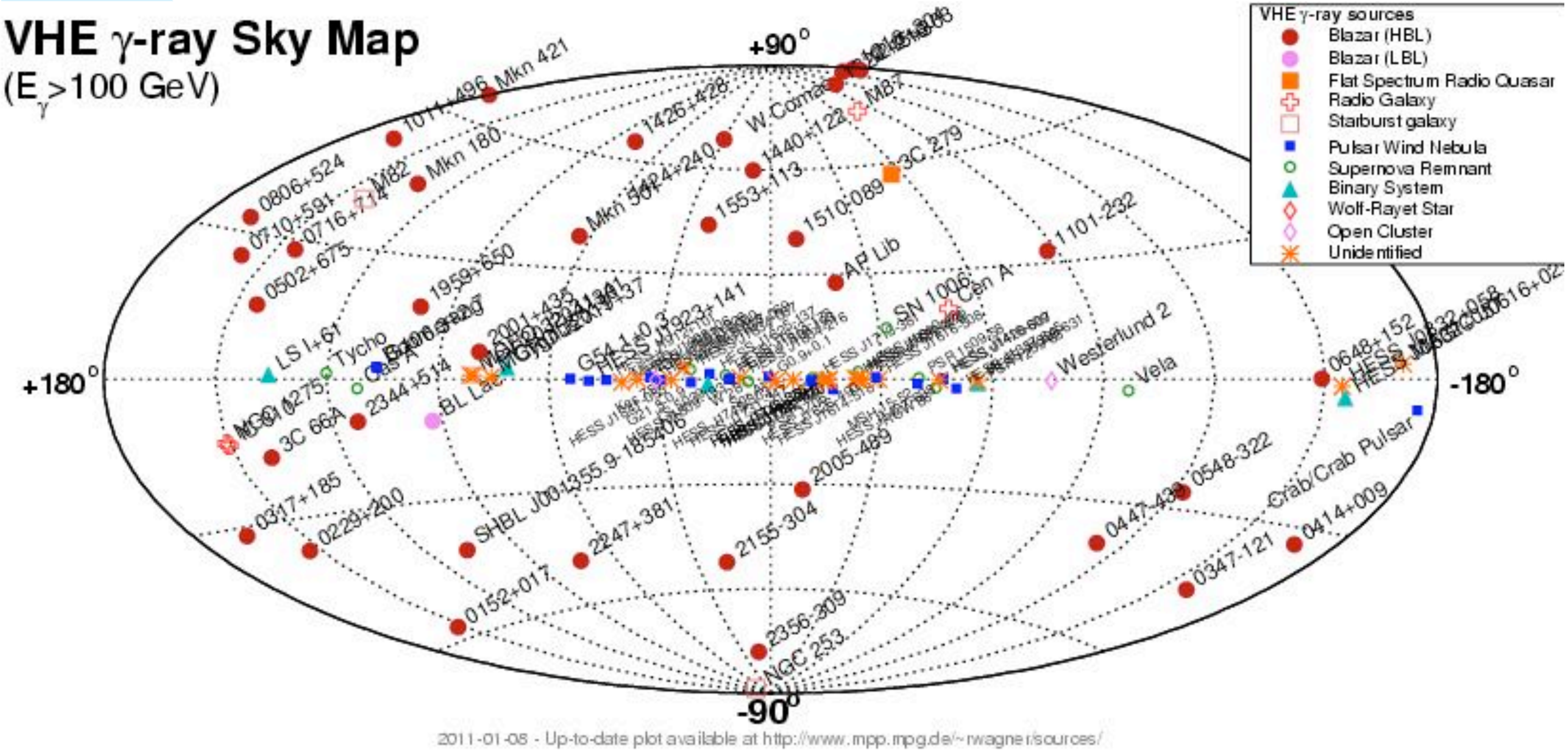
ALL SOURCES HAVE SPECTRA EXTENDING ABOVE 1 TEV, RARELY SPECTRA EXTEND ABOVE 10 TEV (CRAB->80 GEV)MANY AGNS HAVE A SOFT SPECTRUM

■ = Pulsar/Plerion □ = SNR ★ = Starburst galaxy ○ = OB association

◆ = AGN (BL Lac) ▲ = Radio galaxy ✖ = XRB ● = Undetermined

SKY MAP OF VHE g EMITTING SOURCES, JAN 2011

110 SOURCES



COURTECY ROBERT WAGNER

SOME SELECTED GALACTIC SOURCES RESULTS

The dominant part of the CRs up to 10^{15} eV is of galactical origin
What are the most likely sources: SuperNova Remnants (Shock wave accelerators)

Pulsar Wind Nebulae
SNR shells
Pulsars
Binaries
Exotics

Galactic plane mostly visible from southern sites (HESS, Cangaroo III)

THE CRAB REVISITED

THE CRAB NEBULA AND PULSAR EMITTING VHR GAMMA RAYS

- CRAB (in constellation Taurus): well documented Super Nova Explosion in 1054 (SNR was visible during daytime for a few weeks)

- CRAB nebula: First discovered VHE gamma-ray source (1989, Whipple, -> opened window of VHE gamma-astronomy)

- SNRs (PWN, Shell type) are the prime candidates for the sources of charged Cosmic Rays (AN OPEN QUESTION SINCE NEARLY 100 Y)

- CRAB Nebula is the strongest steady state VHE gamma source , it's used as calibrator for all instruments on the northern sky->Standard Candle

- Cherenkov telescopes: lack of fixed energy test beams to calibrate, up to last year no connection with direct gamma measurements possible

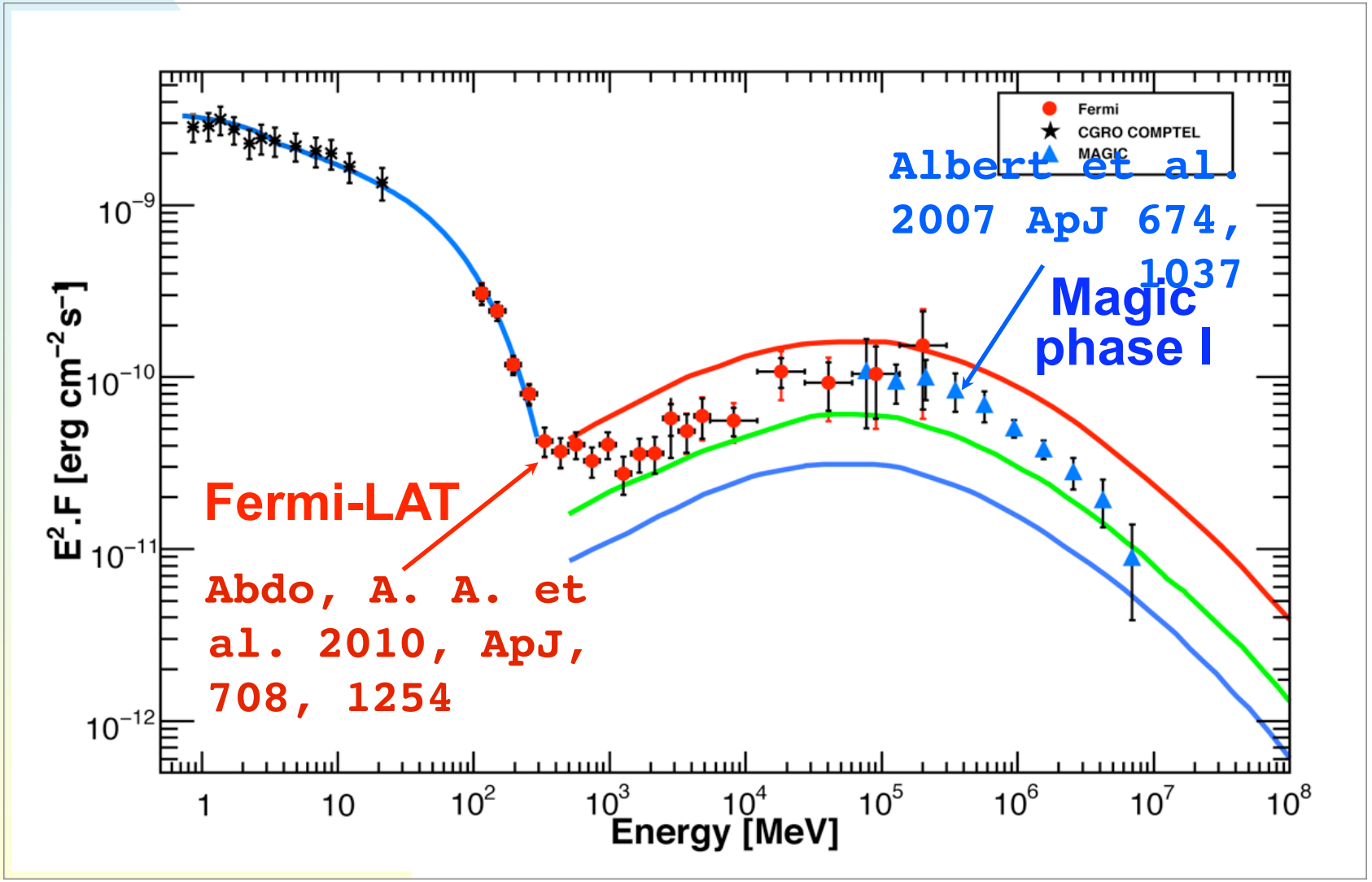
- The CRAB system is one of the best studied objects in astronomy From 10^{-6} eV up to 10^{14} eV

- 5 years ago a gap in observation: between ≈ 10 GeV (EGRET satellite) and 300 GeV (ground-based instruments)

IS THE CRAB FLUX REALLY STABLE?

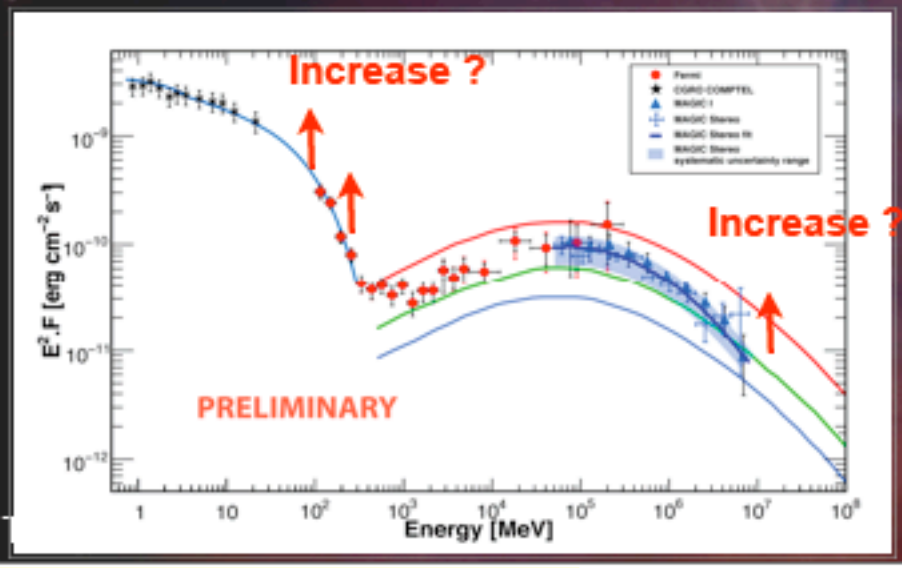
Crab Nebula spectrum

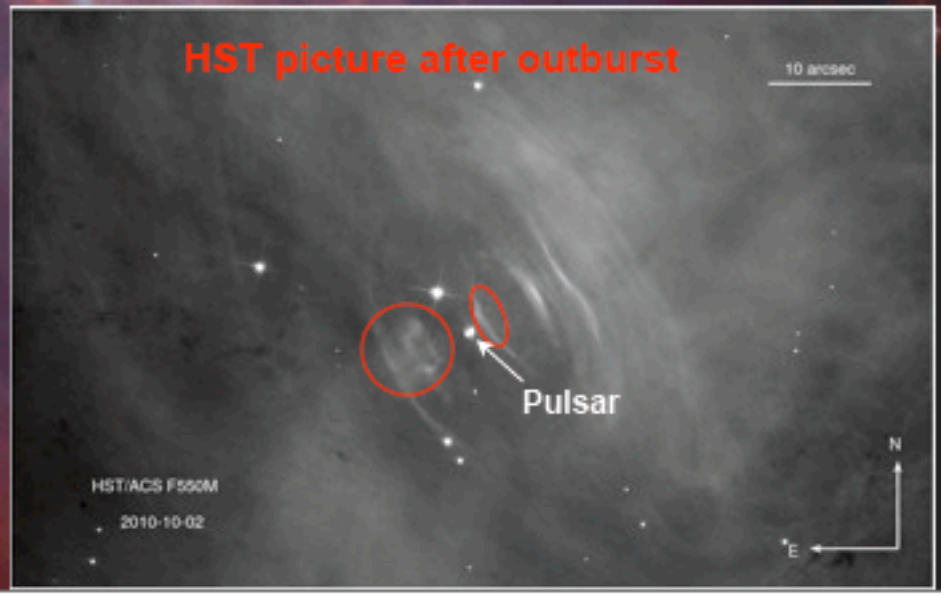
A longtime problem: a gap in the energy range of satellite observations and the energy range of IACTs- now first overlap



Short term variability in the nebula ?

- AGILE reported an enhanced gamma emission from the Crab nebula (4.4 sigma 19.September 2010), ATEL:2855
- Integral (20keV-400keV), BAT (15-150keV) and SWIFT/XRT (0.2-10 keV) see no FLUX increase --> no evidence for AGN
- FERMI sees more than double flux >100 MeV with 9 sigma from 18-22. of September
- Chandra sees that the previous bright knot at 6 arc seconds south-east extends to 3 arc-sec south-east, not clear if correlated with gamma event.
  structure south-east has changed significantly to one year ago.
- HST sees an increased emission 3 arcsec east of pulsar, wisps north-west appear bright
- ARGO: 3-4 time increased flux at TeV energies (Sept 17-22), 4 sigma
- MAGIC & VERITAS see no flux increase
- Radio timing: no significant variation of frequency (no glitch)





PULSARS AS POSSIBLE EMITTERS OF VHE GAMMA RAYS ? STILL ONE OF THE MOST INTERESTING COSMIC OBJECTS TO BE STUDIED

MANY PULSARS SEEN IN RADIO WAVES, OPTICAL, X-RAYS
FEW EXTEND TO MEV, VERY FEW TO GEV REGION

g–production: acceleration of electrons in pulsar environment
radiation emission by curvature rad.,syn. rad, Inverse Compton scatt
of x-rays from pulsar surface

g-rays interact with magnetic field -> magnetic pair production g + B -> e+e-
This process will result in a cut-off in the spectrum
-> measuring the cut-off allows to test in which area gs produced

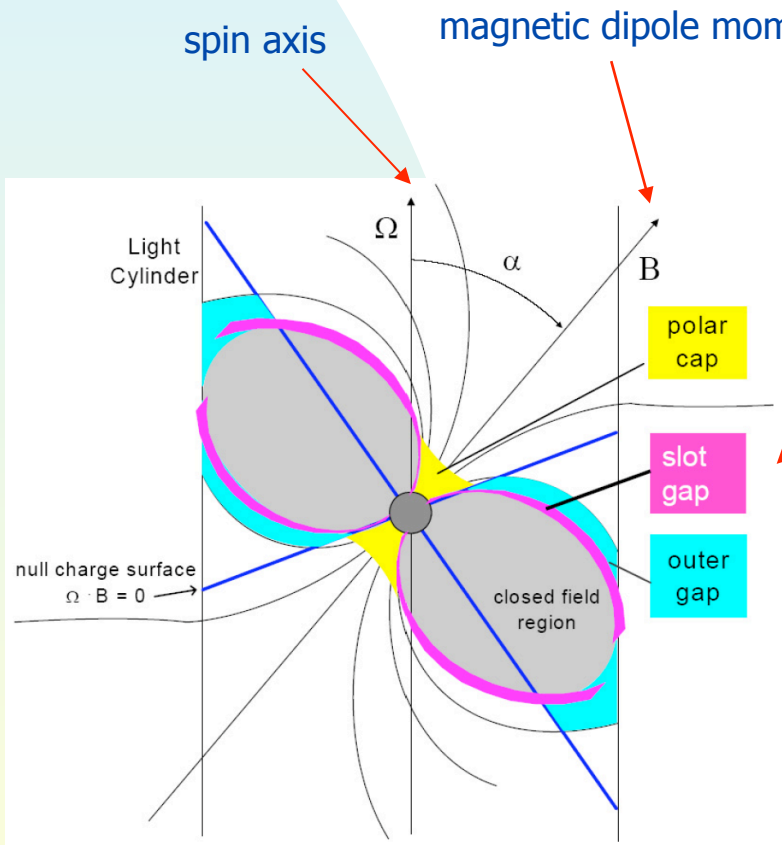
STUDY OF THE UPPER ENERGY CUTOFF AT VHE IMPORTANT TO DECIDE BETWEEN LEADING MODEL CLASSES:

POLAR CAP MODELS (Prediction sharp cut-off -> superexponential, lower E)
close to polar cap. g s interact with B field Magnetic pair production

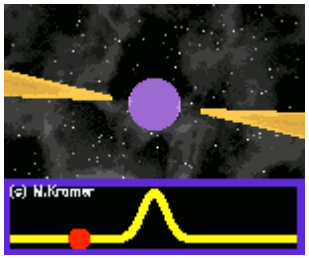
OUTER GAP MODELS (Prediction softer cutoff -> exponential, higher in E)
gammas produced near light cylinder, low B field-
spectrum expected to extend to higher E, softer cutoff

SLOT GAP MODELS (Prediction: a bit softer than polar cap spectrum)

Gamma-Ray Emission from Pulsars



- three sites favored for particle acceleration
- emission appears pulsed; lighthouse model

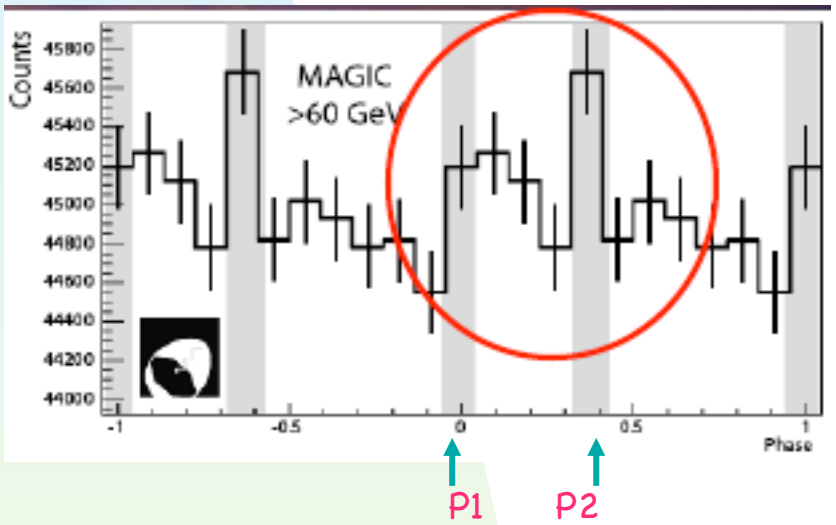


- complex electrodynamics; challenging for theory

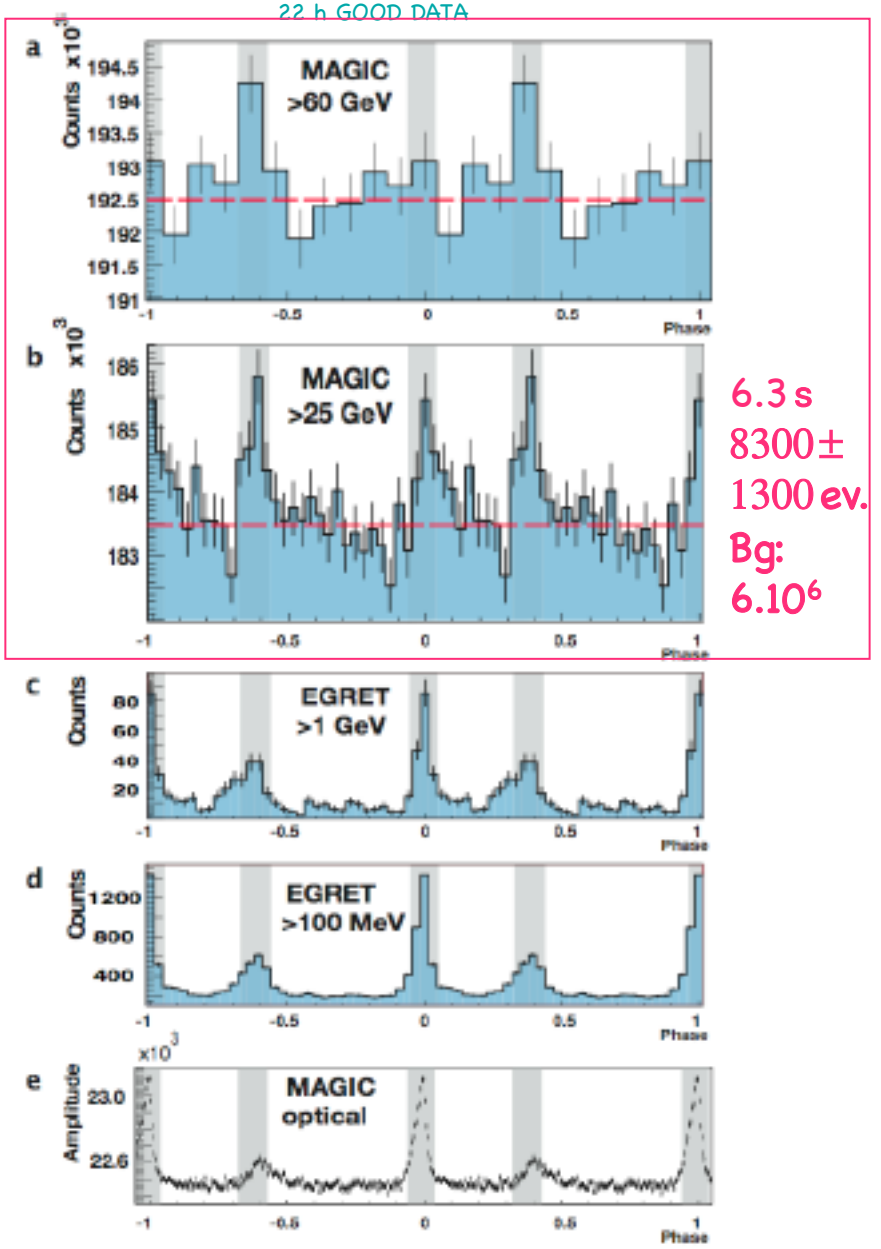
A. Harding

WE OBSERVED IN THE 2006 DATA A HINT OF A SIGNAL AT THE INTERPULSE P2 (3 SIGMA) BUT NO SIGNAL AT THE MAIN PULSE P1 –> TRIGGERED DEVELOPMENT OF NEW TRIGGER TO GO DOWN IN ENERGY: 26 GEV THRESHOLD

J. Albert et al., Astrophys. J. 674,1037 (2008)

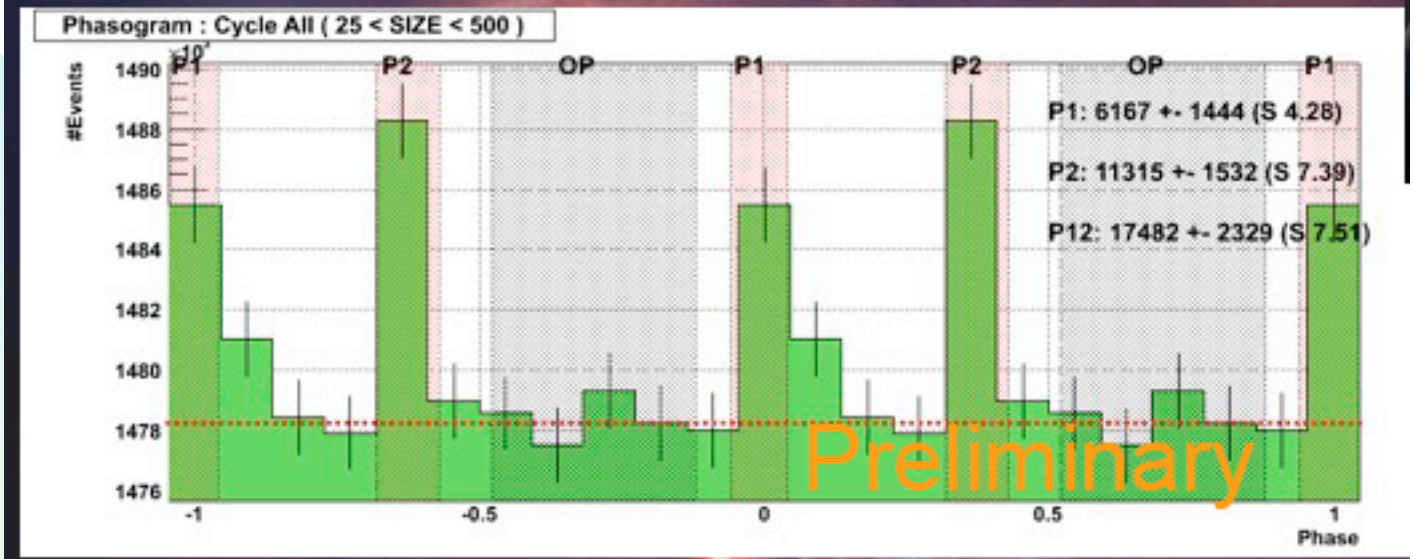


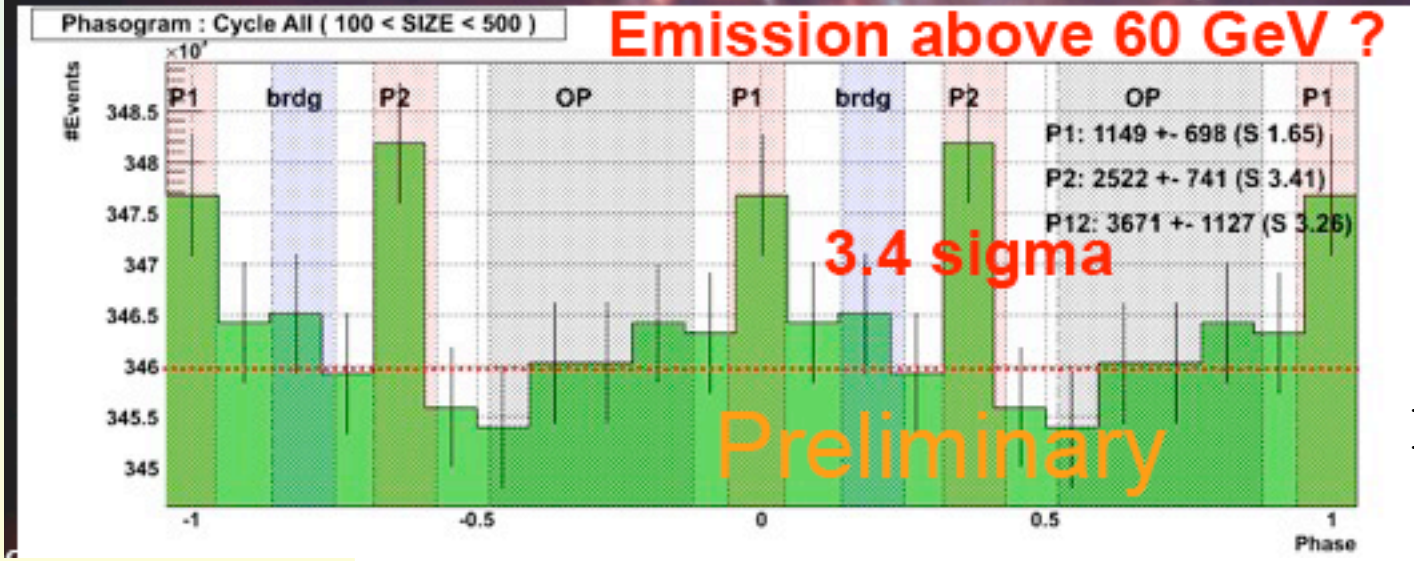
ANALYSIS OF NEW TRIGGER DATA
22 h GOOD DATA



6.3 s
8300 ± 1300 ev.
Bg: 6.10^6

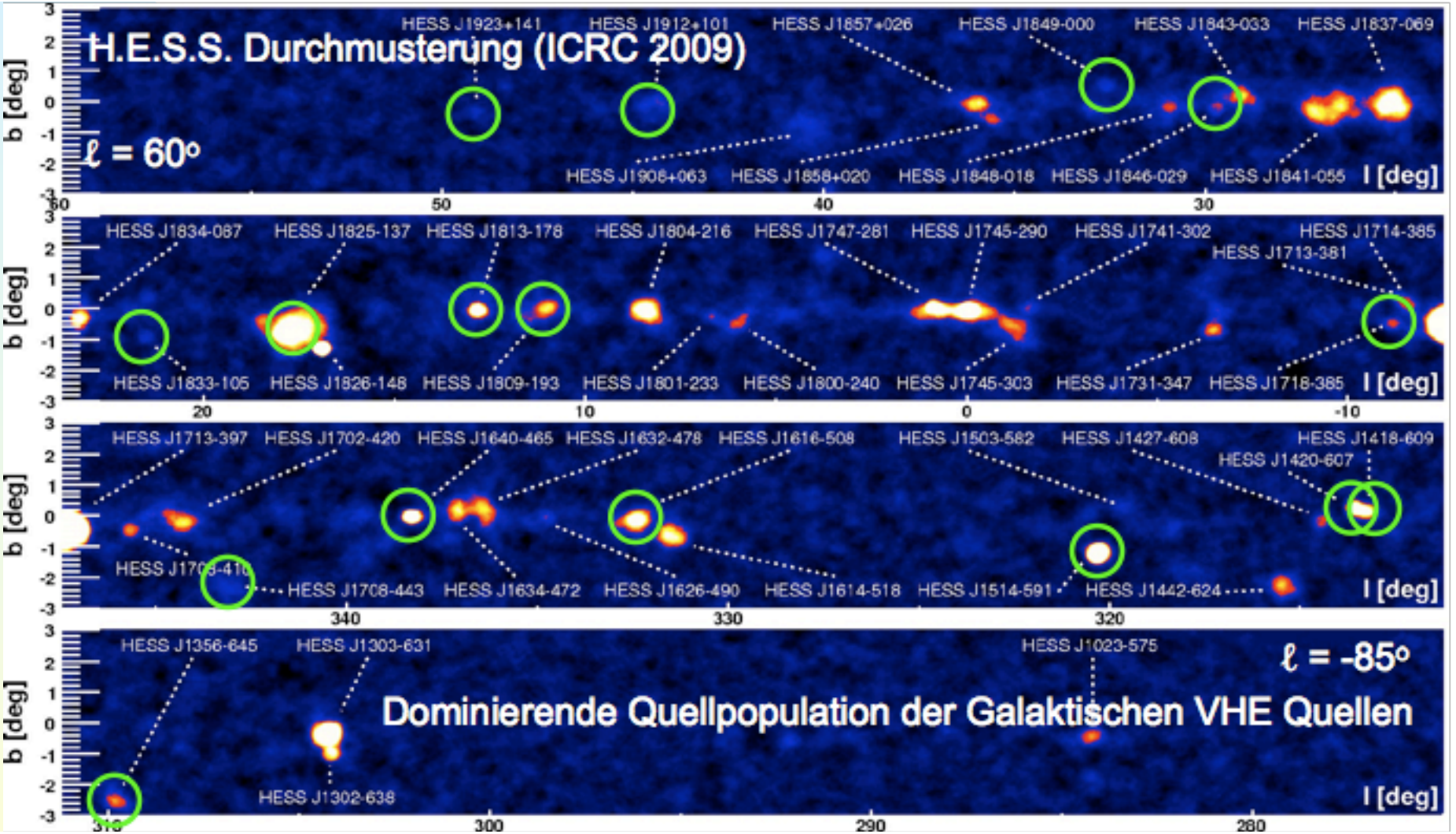
Follow-up observation 2007+2008: 7.5 Sigma above 25 GeV





T. SCHWEIZER
T.SAITO

SCAN OF THE GALACTIC PLANE AREA BY HESS,(NEEDS TO BE DONE FROM A SOUTHERN SITE) MANY PULSAR WIND NEBULAE-CANDIDATES FOR THE PRODUCTION OF COSMIC RAYS



BINARIES

FIRST DISCOVERY OF A TEV BINARY: LS 5039 BY HESS ON THE SOUTHERN SKY
(F. AHARONIAN et al., SCIENCE,309, 746(2005)

MAGIC SEARCHED FOR BINARIES ON THE NORTHERN SKY

LSI +61 303 (HIGH SIGNIFICANCE), CYGNUS X1 (4.1 s)

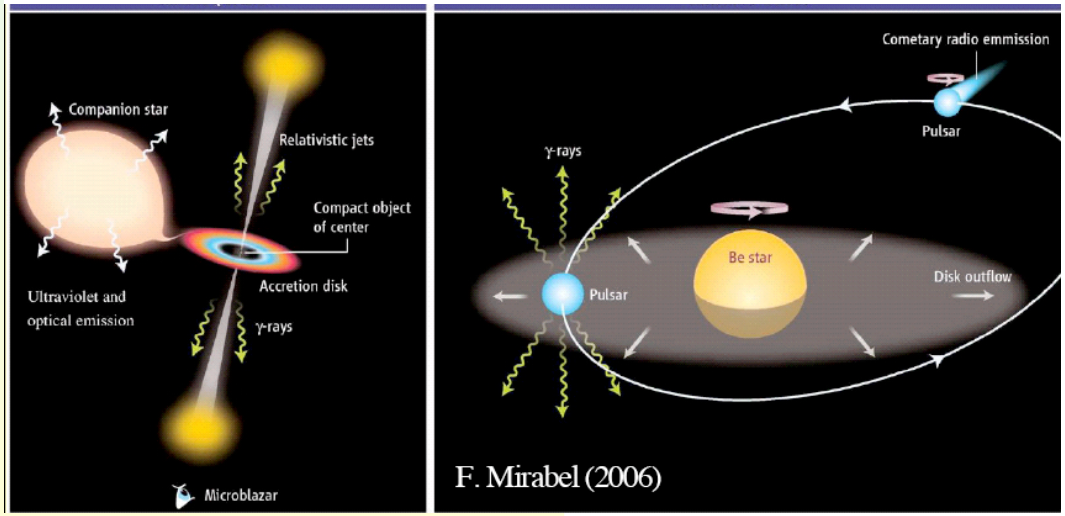
BINARIES MIGHT BE PROMIZING CANDIDATES FOR HADRONIC PRODUCTION NEUTRONO SOURCES ??

BINARY SYSTEMS AS SOURCE OF VHE GAMMAS

WAY BACK CONSIDERED AS THE SOURCES OF VHE GAMMAS

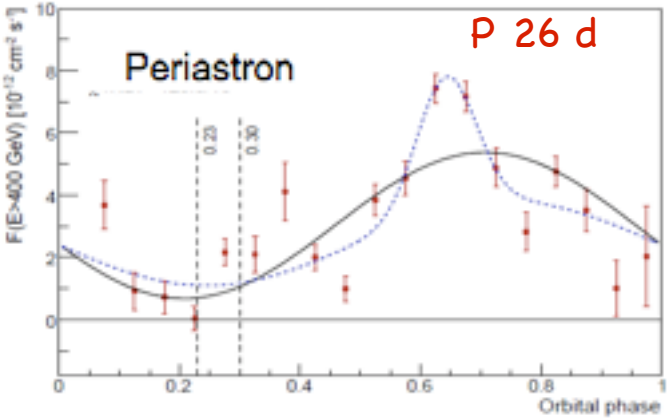
THE (FAKE) CYGNUS X-3 DISCOVERY IN 1984 STARTED MANY ACTIVITIES
(a 4.5 s enhacement from the direction of CYGNUS X3 seen by a group in Kiel
Seen by analysing muons from air showers)

BASIC MODELS
BO MAIN SEQUENCE STAR WITH CIRCULAR STELLAR DISK (Be STAR) CIRCULATED BY SMALL BL (PRODUCTION OF GAMMAS IN JETS) OR BY A PULSAR (INTERACTION OF RELATIVISTIC IONS,e WITH PULSAR WIND

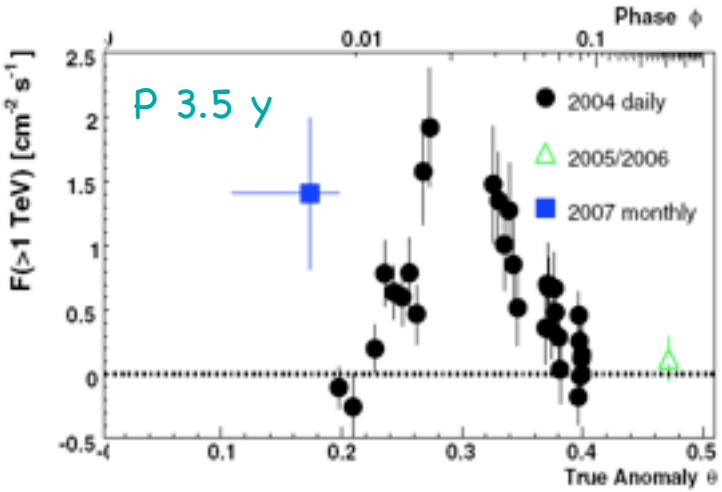


Binary systems

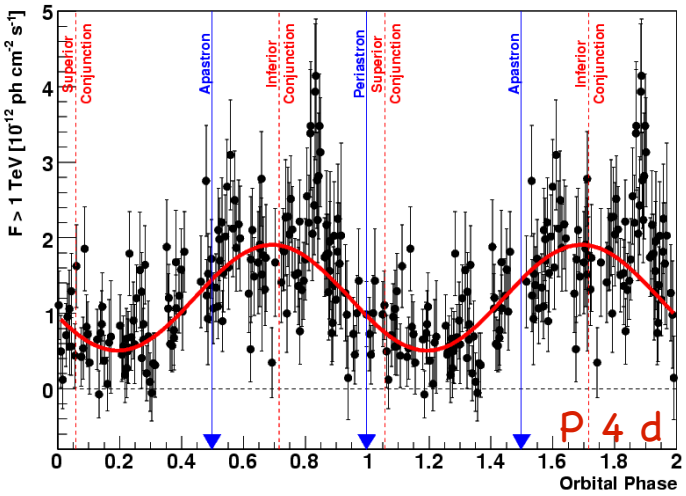
LSI +61 303, MAGIC



PSR B1259-63 HESS



LS 5039 HESS



EXTRAGALACTIC SOURCES

EXTRAGALACTIC SOURCES

INITIALLY NOT EXPECTED (SENSITIVITY MUCH TOO LOW TO SEE PULSARS PWN, SHELL SNRS... IN OTHER GALAXIES)

FIRST EXTRAGALACTIC SOURCE - MKN 421- DISCOVERED BY WHIPPLE IN 1993

NEARLY ALL DISCOVERED EXTRAGALACTIC SOURCES: BLAZARS, (FLARING)

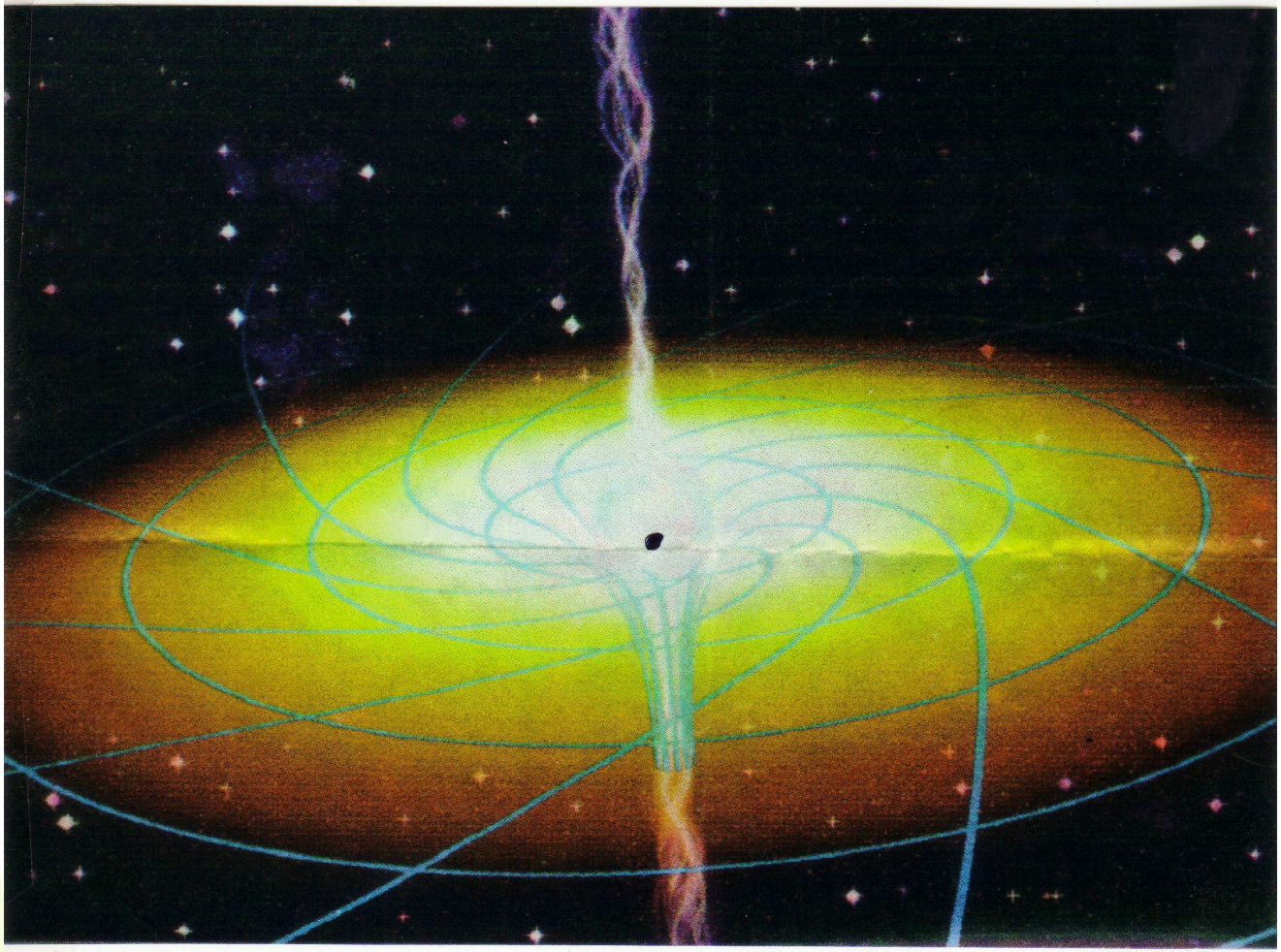
MANY BLAZARS ARE VERY POWERFUL VHE GAMMA RAY EMITTERS
POSSIBLY THE SOURCES OF EXTRAGALACTIC COSMIC RAYS SHOULD BE ALSO SOURCES OF NEUTRINOS

PHYSICS CLOSE TO BLACK HOLES; CAN OBSERVATIONS CONTRIBUTE TO UNDERSTAND WHAT IS GOING CLOSE TO BH?

MOST PROMIZING OTHER OBJECTS
GRBS (PROBLEM: HIGH REDSHIFTS -> NEEDS IACTS OF LOW THRESHOLD)

ARTIST VIEW OF
AN ACTIVE GALACTIC
NUCLEI (AGN)
MANY DIFFERENT
MODELS

relativistic jets, (bubbles)
superluminal when pointing towards earth



≈ 1.5 % of large extragalactic objects assumed to be AGNs
(AGNs active galactic nucleii, massive black hole in center)
show nonthermal emission (nearly no lines- > redshift ?)
Seyfert galaxies, Quasars, BL-Lac objects radio galaxies

NEARLY ALL OBSERVED AGNs SHOW RAPID FLARING

MOST VIOLENT COMPARED TO OTHER ENERGY RANGES

FLARING CAN BE VERY FAST: SHORTEST OBSERVED TIMES 2-5 MIN

FLARING OFTEN RELATED WITH RISE IN OPTICAL AND X-RAY ACT.
(-> GOOD FOR TRIGGERING OBSERVATIONS)

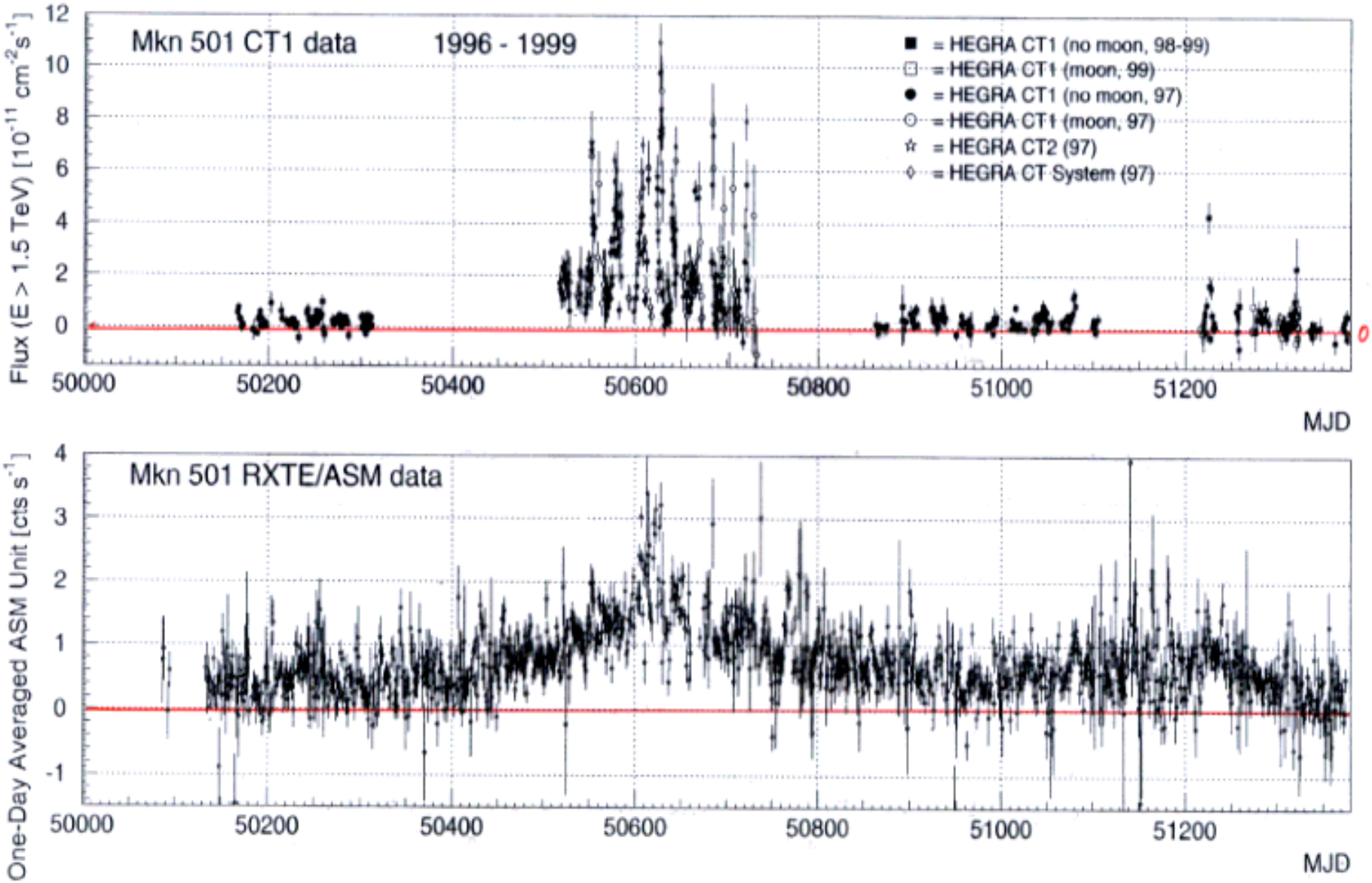
FLARING SETS LOWER LIMITS ON ACCELERATION VOLUMES
(GAMMA FACTOR CORRECTED)

MECHANISMS BEHIND FLARING STILL NOT UNDERSTOOD

TEST OF QUANTUM GRAVITY EFFECTS

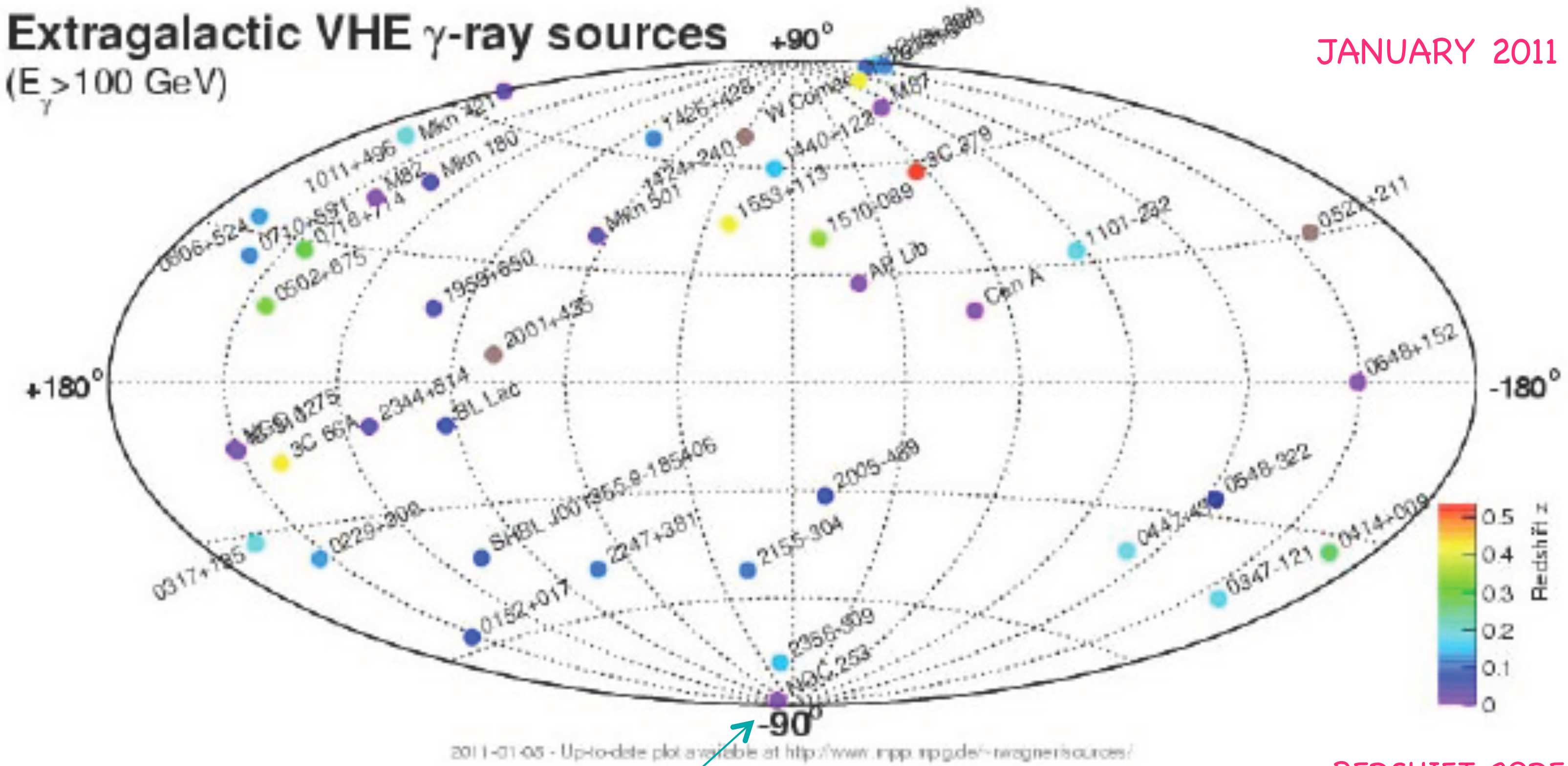
TO BETTER UNDERSTAND IT: NEED TO CORRELATE WITH OTHER
ENERGY BANDS

Example of pronounced flaring: mkn 501 1997



STRONGEST VARIATION IN THE VHE BAND, NO VARIATION SEEN IN THE VISIBLE, IR AND RADO SPECTRA !

ARTIST'S IMPRESSION OF A STAR (ORANGE CIRCLE) THAT IS STRECHED AND TORN APART BY THE ENOURMOUS GRAVITY OF A GIANT BLACK HOLE (NASA/CXC/M.WEISS)



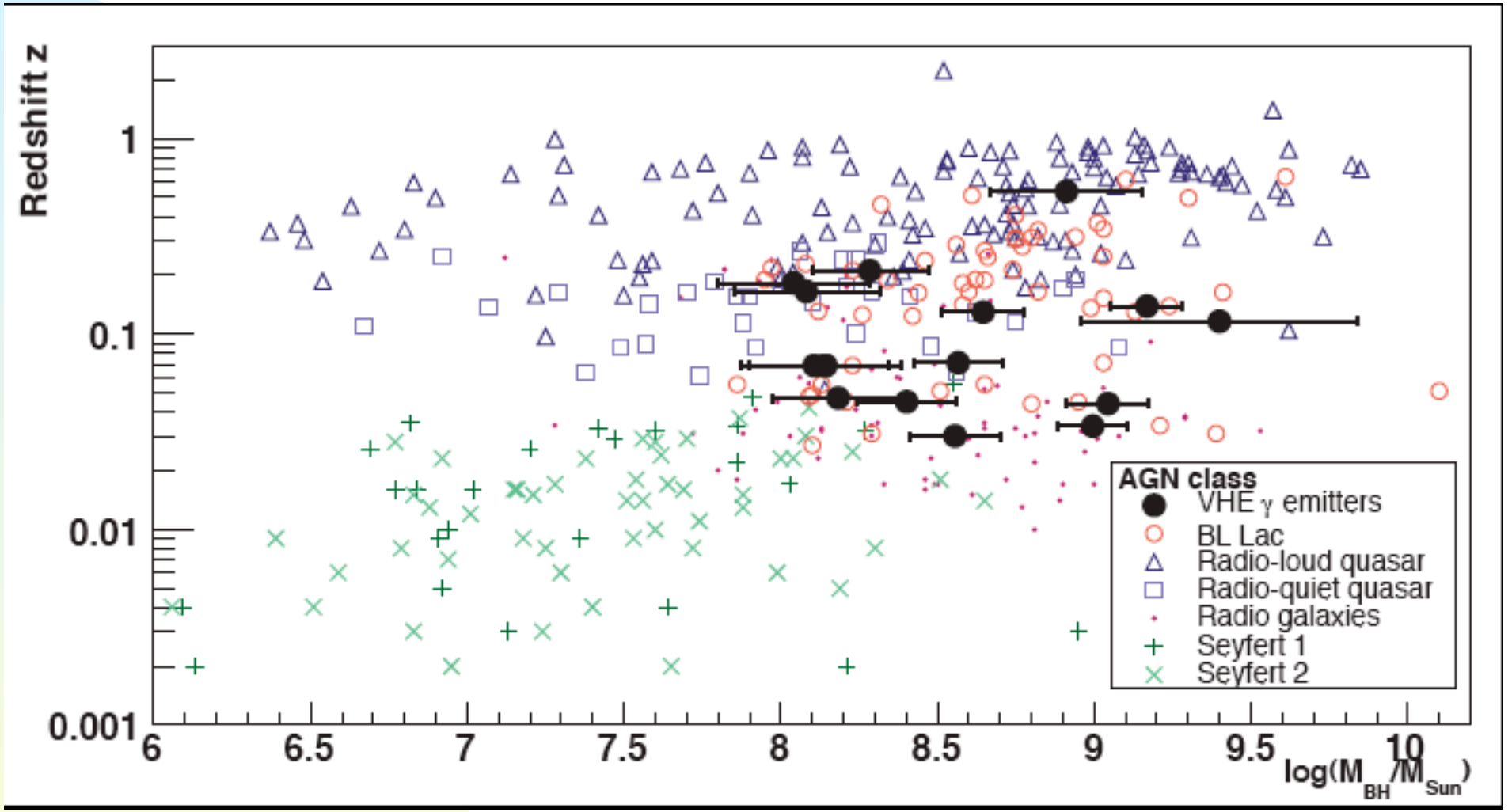
JANUARY 2011

REDSHIFT CODE

MOSTLY: <u>BLAZAR</u> TYPE ACTIVE GALACTIC NUCLEI (AGN)
(JET POINTS TOWARDS EARTH)
41 DETECTED
+ 1 ‚MISALIGNED BLAZAR (jet at 30°)‘: M87
STARBURST GALAXY NGC 253
RADIO GALAXIES IC 310, NGC 1275
FSRQ 3C297, PKS 1510-089, PKS 1222+216

MOSTLY LOW REDSHIFT
BECAUSE OF HIGH THRESHOLD
AND EBL ABSORPTION

CURRENTLY TWO MULTI-WL OBS
GUIDE SEARCHES:
FERMI OBSERVATIONS
CHANGE OF OPTICAL BRIGTHNESS


Redshift z
1
0.1
0.01
0.001
6
6.5
7
7.5
8
8.5
9
9.5
10
log(M_BH/M_Sun)
AGN class
VHE γ emitters
BL Lac
Radio-loud quasar
Radio-quiet quasar
Radio galaxies
Seyfert 1
Seyfert 2

LAT Bright AGN Sample (LBAS)

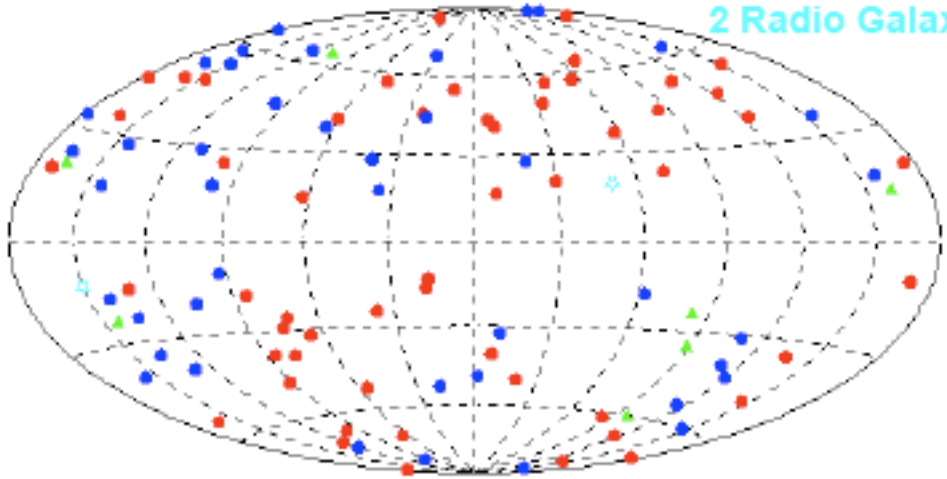
(Abdo et al. 2009, arXiv:0902.1559)

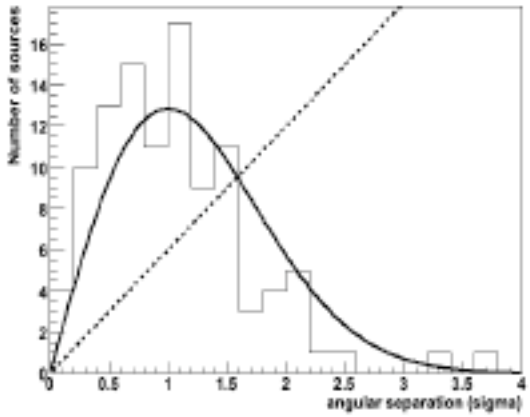
- 125 non-pulsar sources at |b|>10°
- 106 high-confidence (P>90%) associations with AGNs: (LBAS)
- 10 lower-confidence associations
- FSRQs: 57
- BLLacs: 42
- Uncertain class: 5
- Radiogalaxies: Cen A, NGC1275
- 40% BLLacs (23% for EGRET)
- 7 HBLs (3+1 for EGRET)
- 9 unidentified (3EG: 96/181 at |b|>10°)

(Contact authors: LAT AGN Science Group)

Preliminary

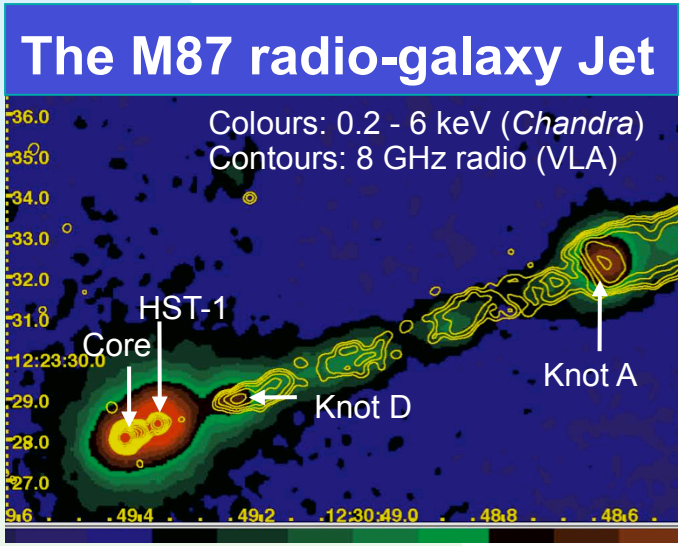
57 FSRQ
42 BLLac
5 of Uncertain class
2 Radio Galaxies

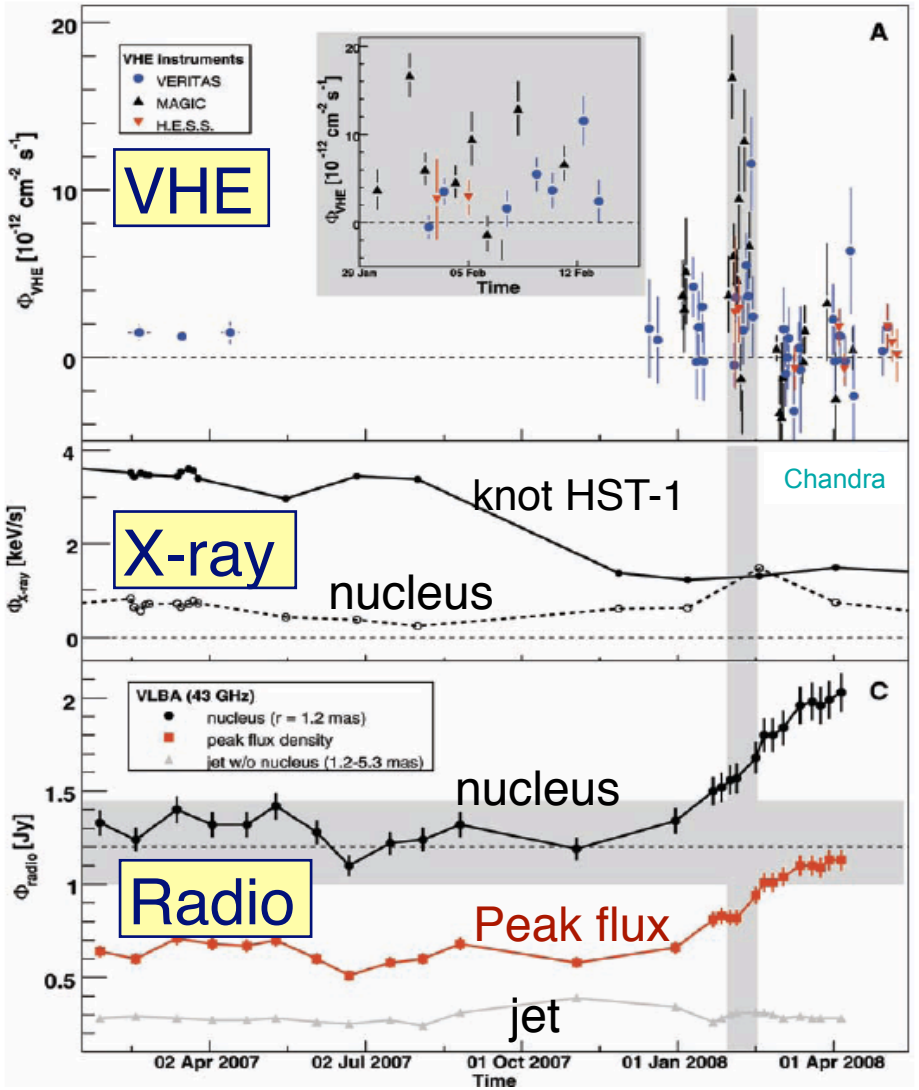




$\Theta_{95\%}$ ~0.14° (EGRET sample ~0.62°)

JOINT HESS, MAGIC, VERITAS OBSERVATION OF M87
M87 A MISALIGNED BLAZAR





- **Shared monitoring between** HESS, MAGIC VERITAS
- **Confirmation of day-scale variability at VHE.**
- **Evidence of correlation with the nucleus in X-ray & Radio.**
- **Evidence of central origin of the VHE emission (60Rs to the black hole)**

FUNDAMENTAL (AND SOME LESS FUNDAMENTAL) PHYSICS ISSUES

- DARK MATTER SEARCHES
- EBL DETERMINATION
- QUANTUM GRAVITY?
- SEARCH FOR GRBS ?
- EXOTICS: RELIC PARTICLES, TOPOLOGICAL DEFECTS, ISOTROPIC gS ???
- ORIGIN OF CRs
- VHE DIFFUSE ELECTRONS, POSITRONS
- VHE DIFFUSE gs FROM THE GALACTIC PLANE (ESTIMATE OF NEUTRINOS FROM GALACTIC PLANE ??

Dark Matter search

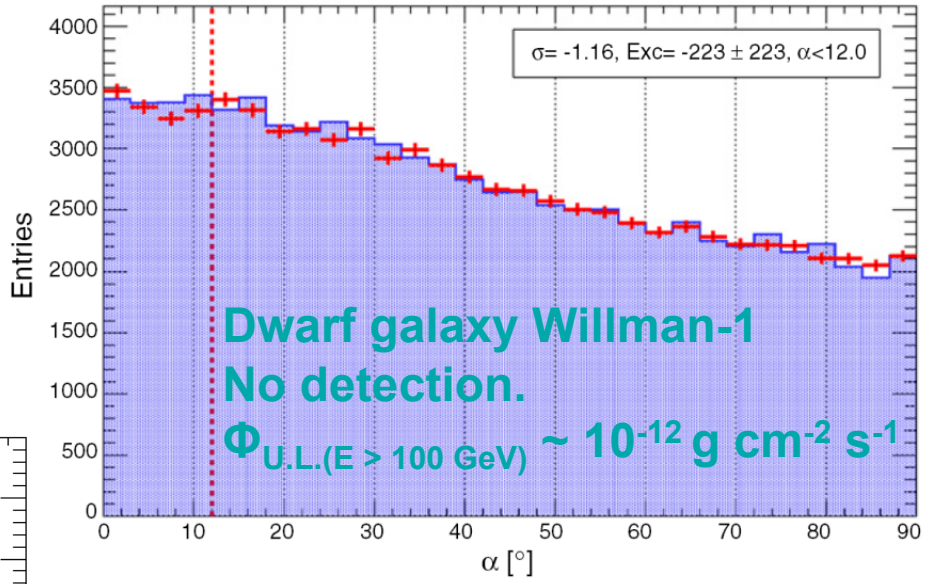
DM annihilation or decay can produce VHE gamma rays
Lines (highly suppressed), bulge on spectrum

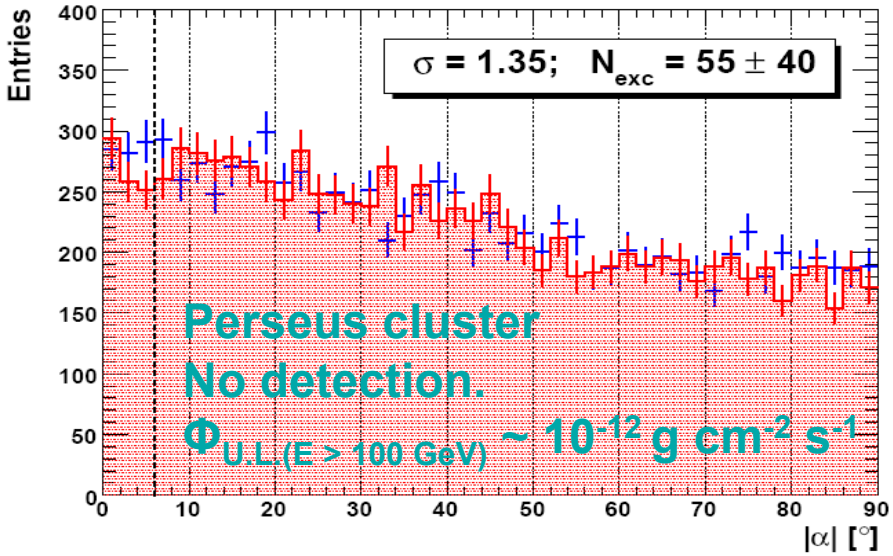
Targets:

- Galaxy center
- Nearby Dwarf galaxies
- Galaxy clusters
- Unidentified gamma sources
  (steady sources, hard spectra)

•High mass/luminosity ratio

•SEGUE 1, WILLMAN-1, Perseus C.





Only upper limits can be derived from current observations

Needs much higher sensitivity CTA?

QUANTUM GRAVITY ??
LORENTZ INVARIANCE VIOLATION

Test of invariance of speed of light

Lorenz Invariance Deformation

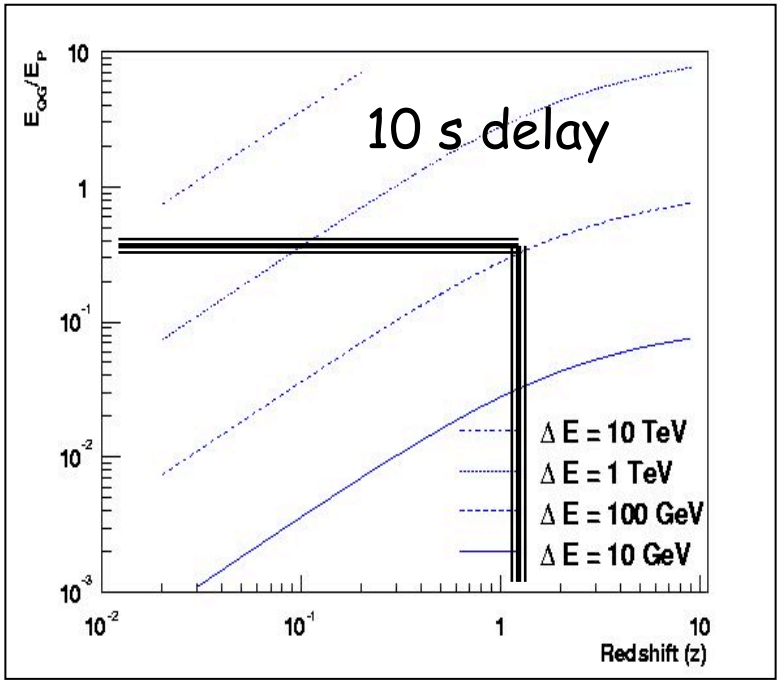
- Quantum Gravity models predict energy dispersion of **c.**
- Non trivial dispersion relation where EQG appears! (10^{16}-10^{19})
- Photon delay depending on energy over distance

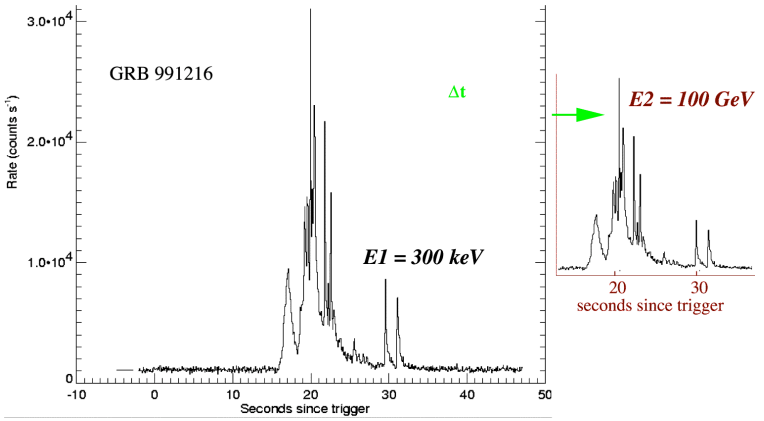
$$E^2 - c^2\vec{p}^2 \approx E^2\xi\left(\frac{E}{E_{QG}}\right)^{\alpha}$$

$$\Delta t \approx \xi \frac{\Delta E}{E_{QG}} \frac{L}{c}$$

$$4\cdot 10^{16}\,GeV \le E_{QG} \le 10^{19}\,GeV$$

Given the huge sensitivity, HESS, MAGIC VERITAS can observe fast transient phenomena like GRB and/or rapid flares of AGN (high z).





Fast Flares: a way to new physics?

ApJ 669 (2007) 892
Phys Lett B 668 (2008) 253

Energy-delayed flare of Mrk501:

Quantification of the delay:

(0.030±0.012) s/GeV

Probability of no delay: 2.6%

Possible explanations:

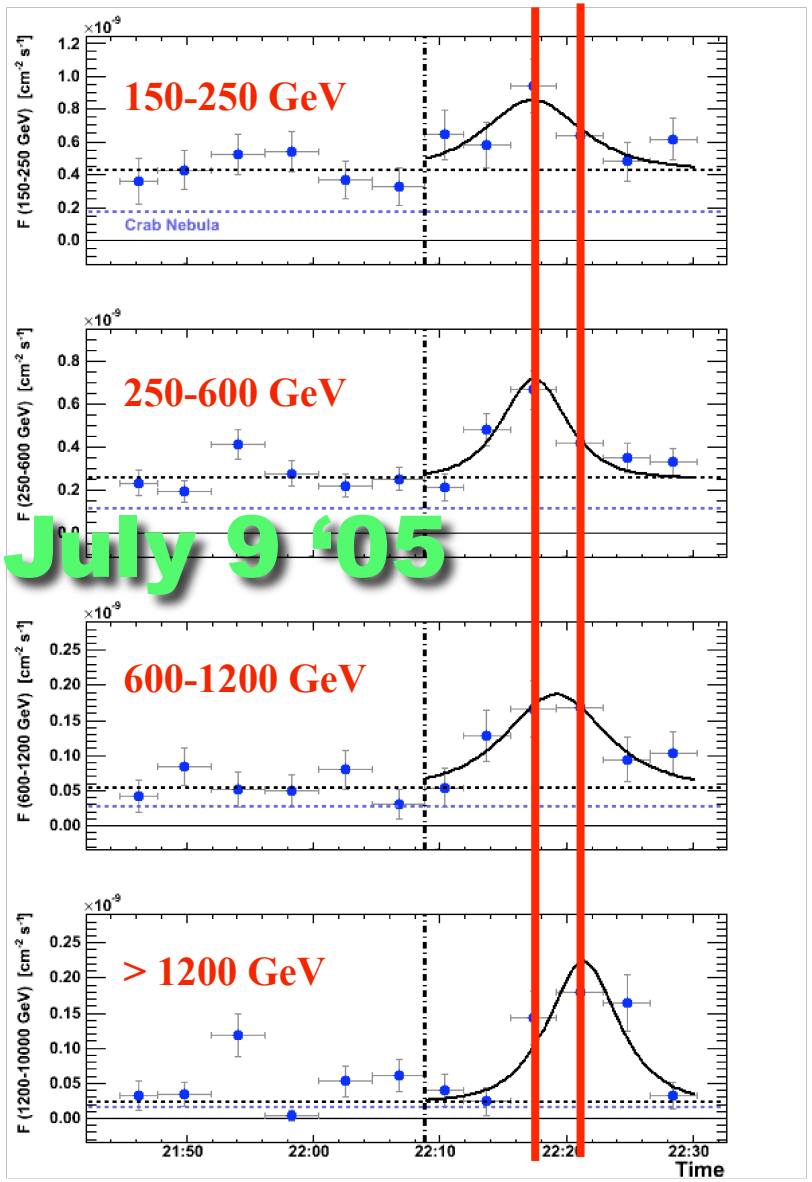
- Astrophysical: **intrinsic source** effects

IF

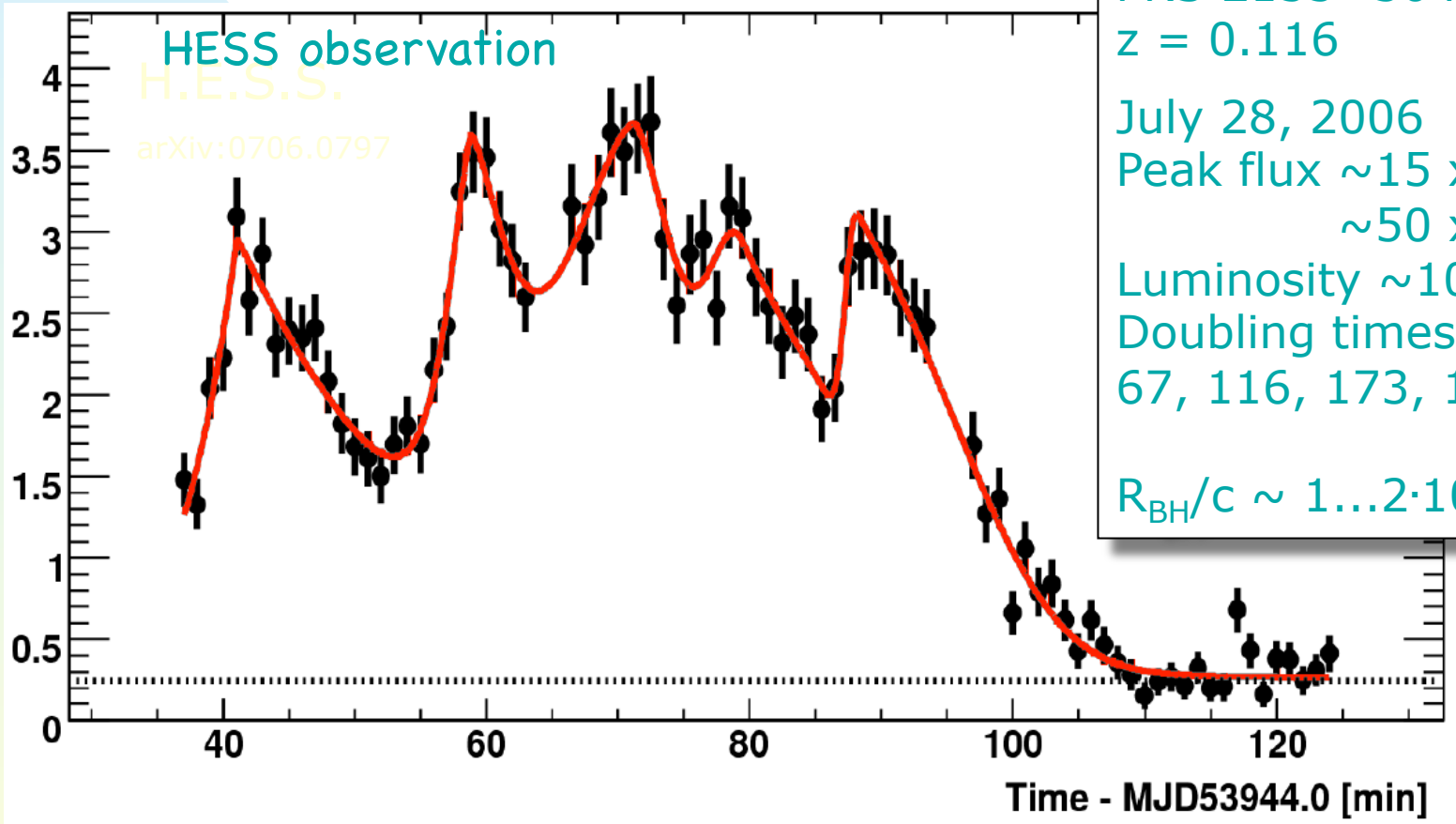
photons arrived with different energies were emitted simultaneously

- Propagation effect due to **Lorentz invariance violation**:

➔ Probing the Planck energy scale $\left[\frac{E}{E_s} \pm \xi \left(\frac{E}{E_s}\right)^2\right]$



PKS2155 Rapid variability



PKS 2155−304
z = 0.116

July 28, 2006
Peak flux ~15 x Crab
~50 x average
Luminosity ~10^{12} x Crab
Doubling times
67, 116, 173, 178 ±50 s

$R_{BH}/c \sim 1...2 \cdot 10^4$ s

HESS has seen no energy dependence of peak positions
We need more observations of fast flaring, high redshift Blazars

EBLissues

HOW FAR CAN WE SEE WITH VHE gs IN OUR UNIVERSE

THE EBL IS CORRELATED TO STAR FORMATION IN UNIVERSE

THE EBL IS BASICALLY A CALORIMETRIC MEASURE OF ALL STAR DEVELOPMENTS

MEASURING THE EBL SETS TIGHT LIMITS ON THE STAR FORMATION IN EARLY UNIVERSE

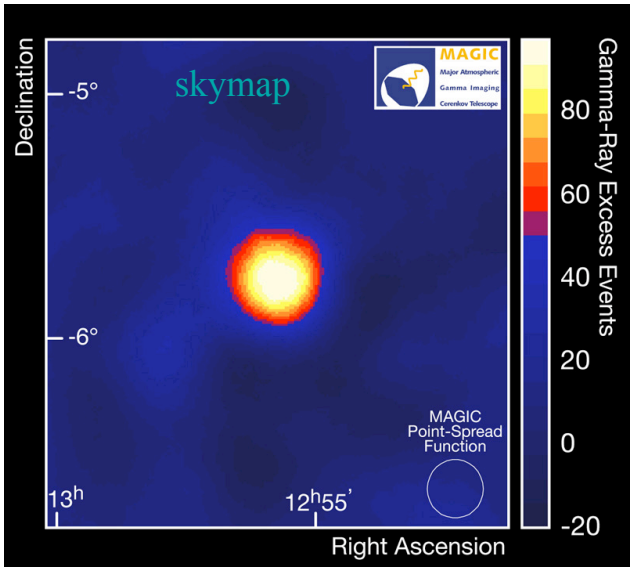
3C279 the most distant VHE AGN

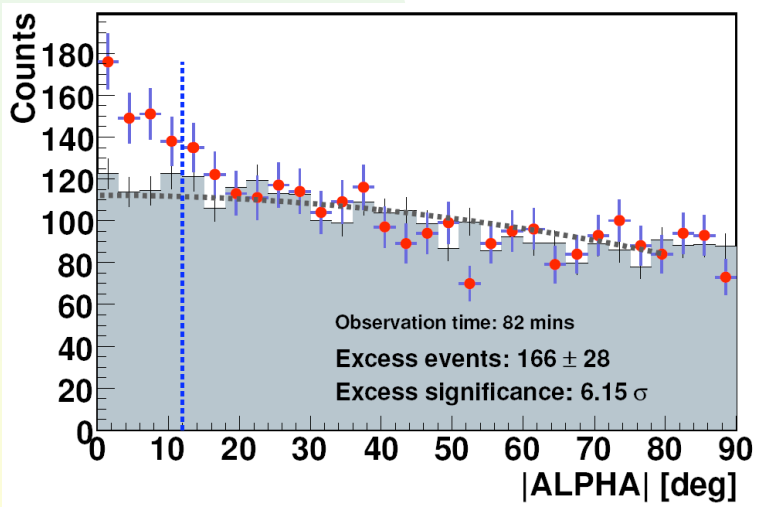
- flat-spectrum radio-quasar at **z=0.536**
- brightest EGRET source. Highly variable, fast variability (~6 hours)
- MAGIC observed it in 2006 during WEBT campaign for 9.7 hours in 10 nights
- Clear detection 23rd Feb 2006 (6.2s)

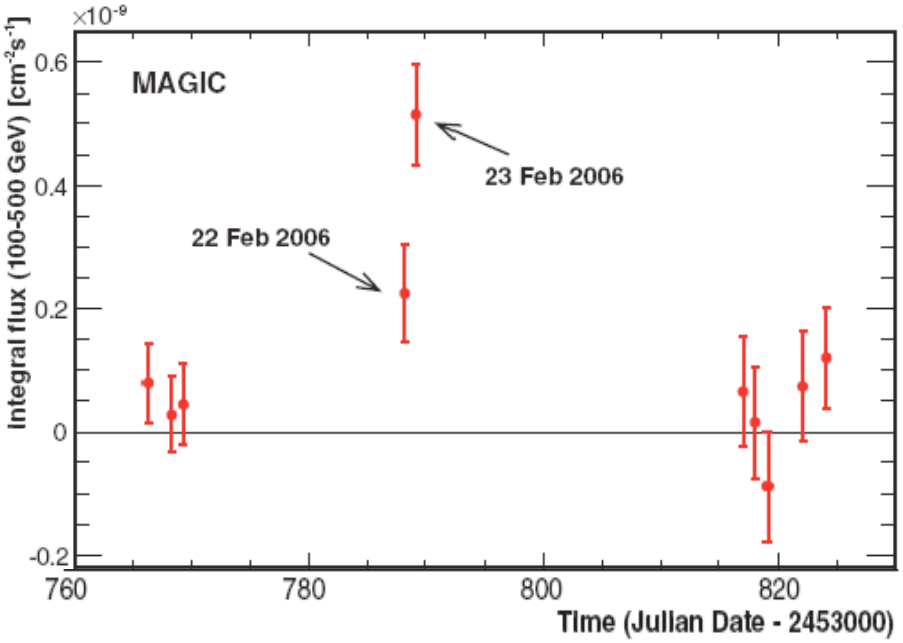
First FSRQ in TeV g-rays

Major jump in redshift

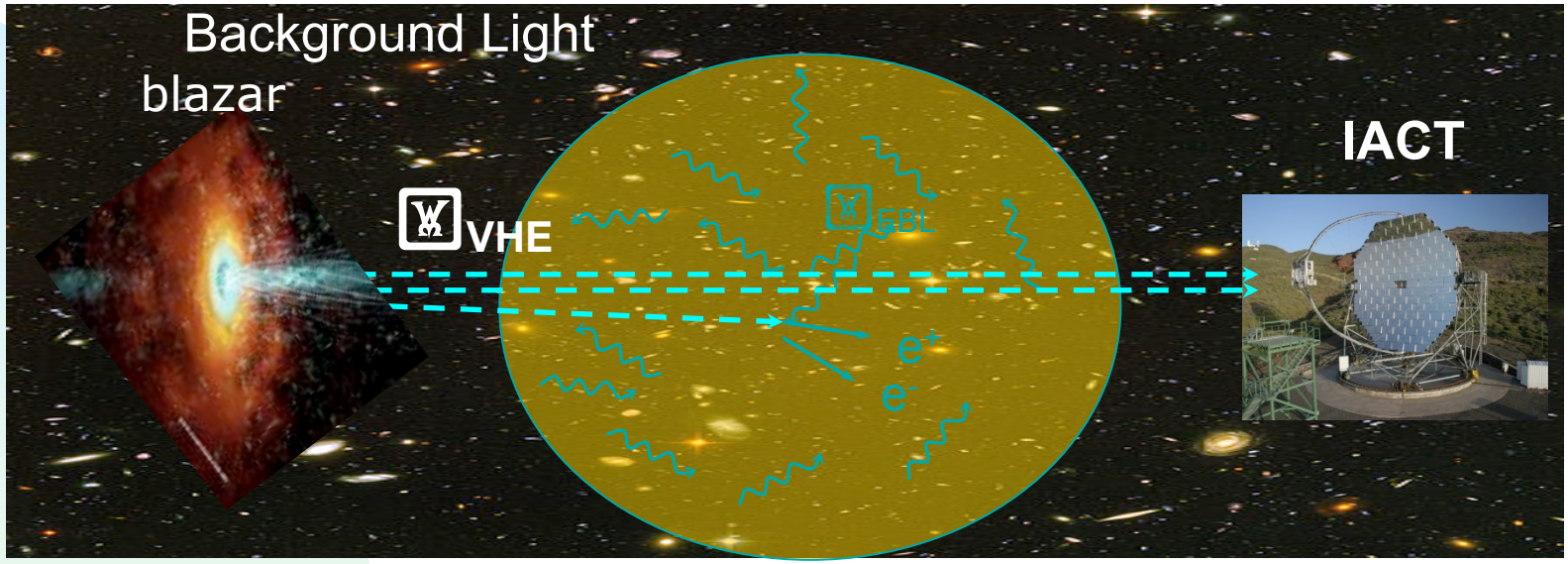
Science 320 (2008) 1752

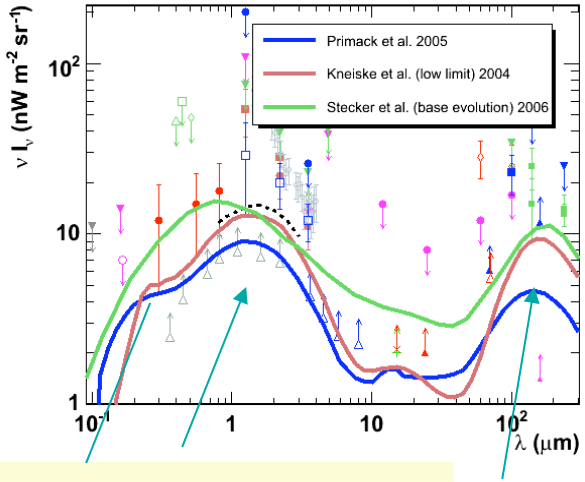




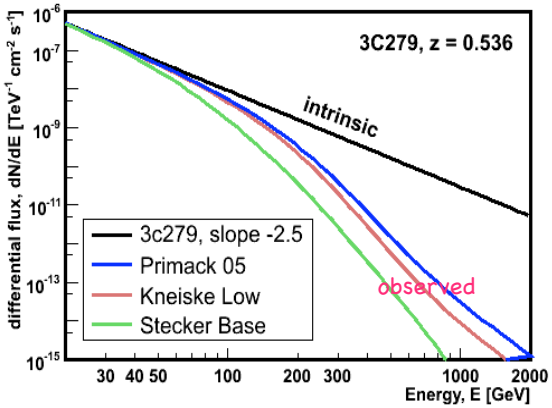


INTERACTION OF DISTANT VHE gs WITH LOW ENERGY COSMIC PHOTON BACKGROUND
-> LOSS OF EVENTS -> UNIVERSE IS NOT TRANSPARENT FOR ALL ENERGIES AND DISTANCES





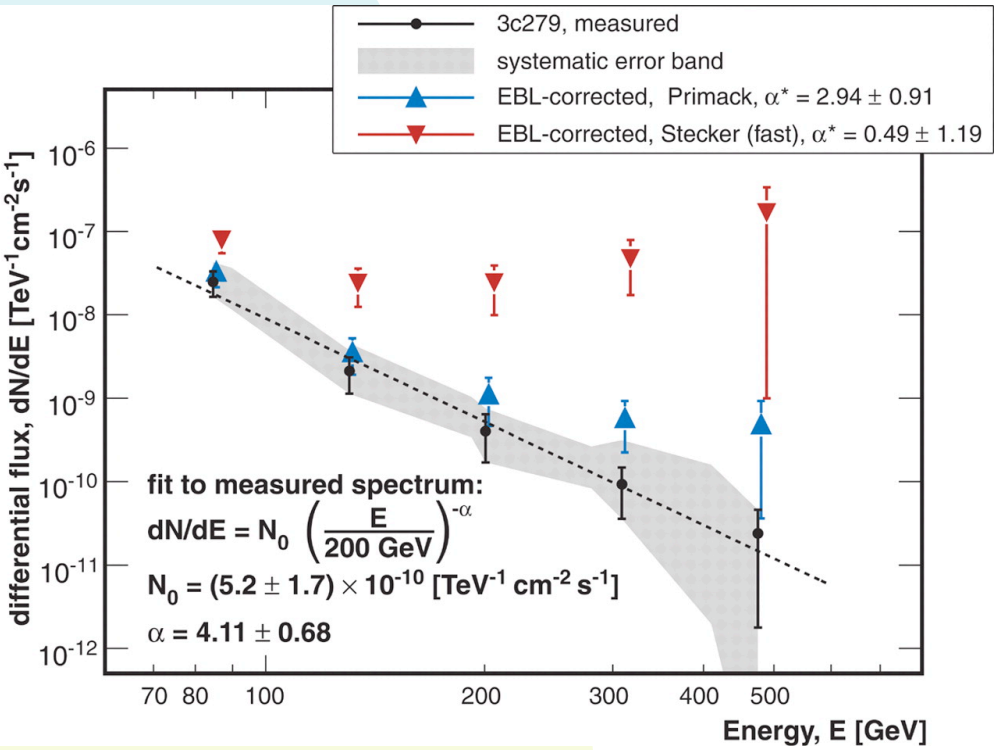
NOTE: EBL CORRELATED TO STAR FORMATION IN UNIVERSE
SETTING TIGHT LIMITS ON THE EBL CONSTRAINTS STAR FORMATION IN EARLY UNIVERSE

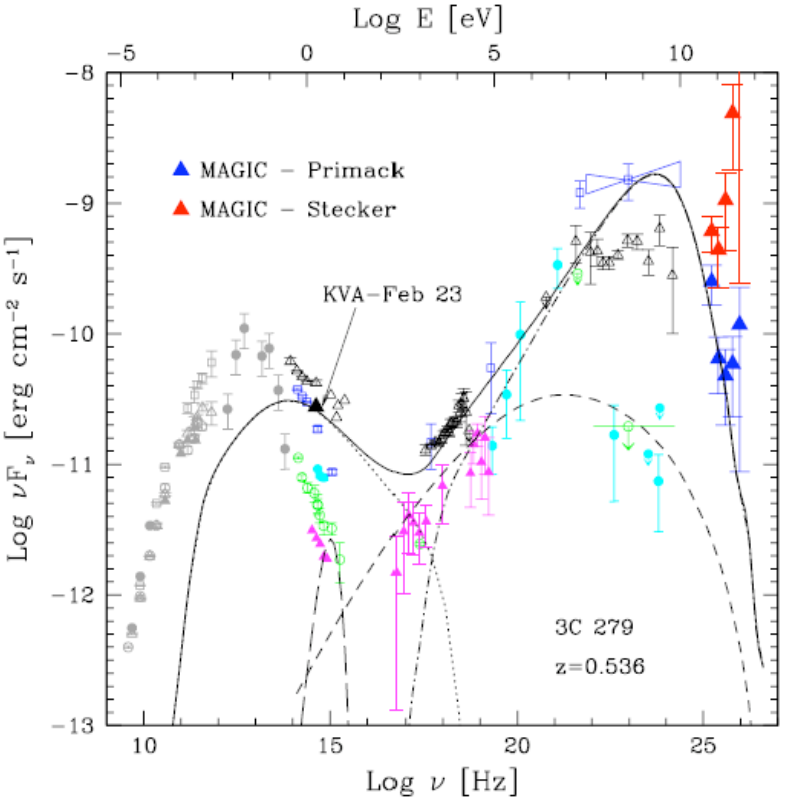


Measured data need to be corrected

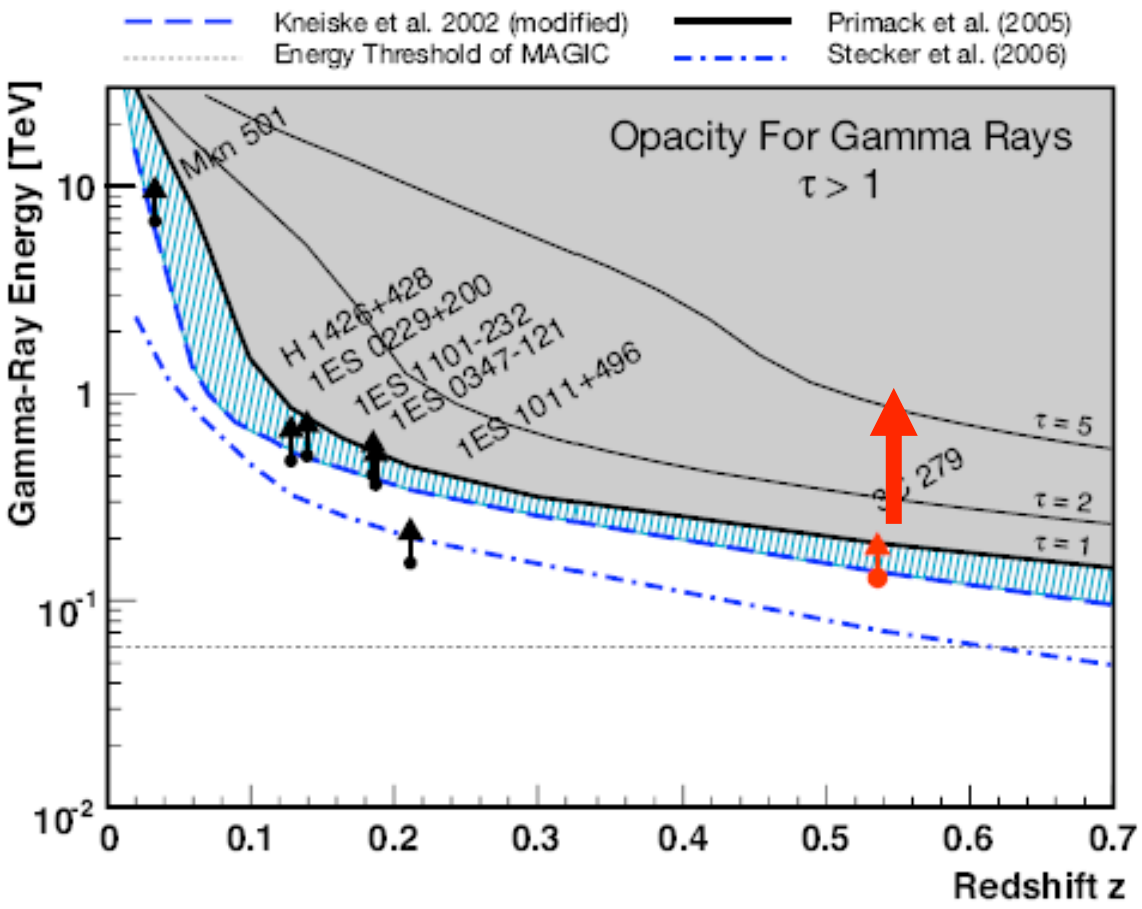
Energy spectrum of 3C279

Measured and EBL-corrected spectrum:



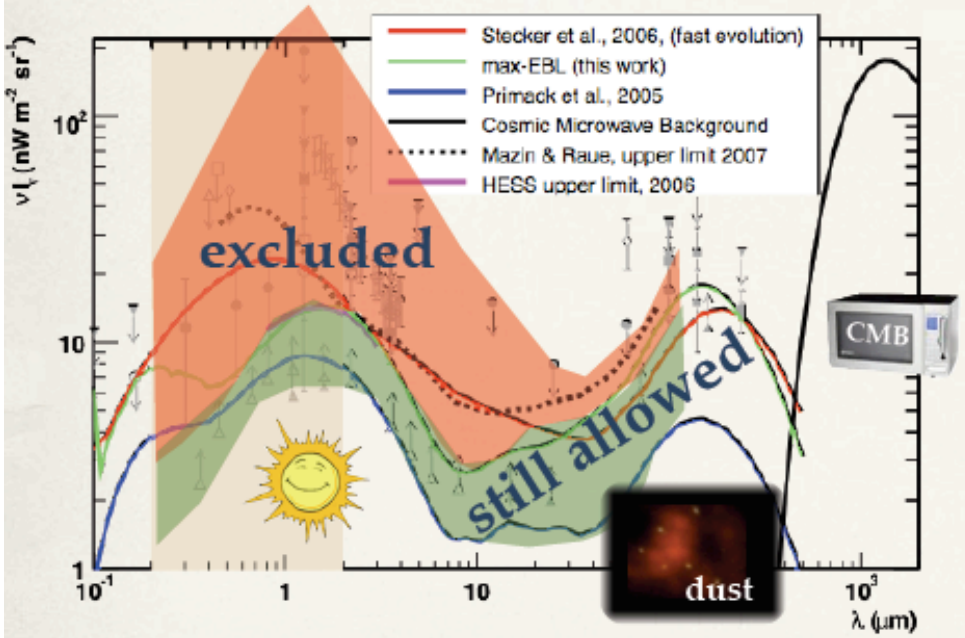


3C279 and the g-ray horizon



Test of the transparency of the universe extended to z = 0.536!

Low threshold = higher z



→ The universe is more transparent than we previously thought!

1ES 1011+496	**z = 0.21**	**FR-I**	**MAGIC**
1ES 0414+009	0.29	HBL	HESS
S5 0716+71	**0.31**	**HBL**	**MAGIC**
1ES 0502+675	0.34	HBL	VERITAS
PKS 1510-089	0.36	FSRQ	HESS
PKS 1222+21	**0.43**	**FSRQ**	**MAGIC**
3C 66A	0.44 ?	IBL	VERITAS
3C 279	**0.54**	**FSRQ**	**MAGIC**

WHAT COMES NEXT ?

HESS II

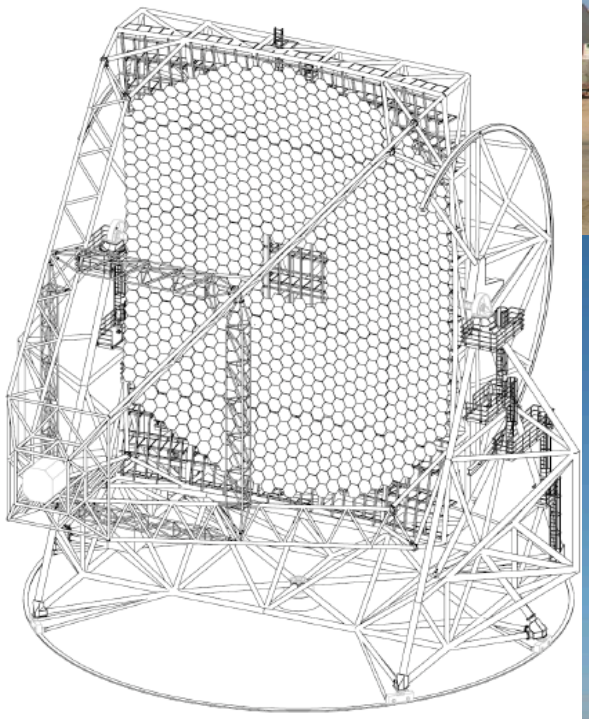
Under advanced construction

2013

HESS site, Namibia
27 mØ mirror
3.5° FOVcamera

Design:
MT Mechatronics
(former MT Aerospace,
MAN Technologie)

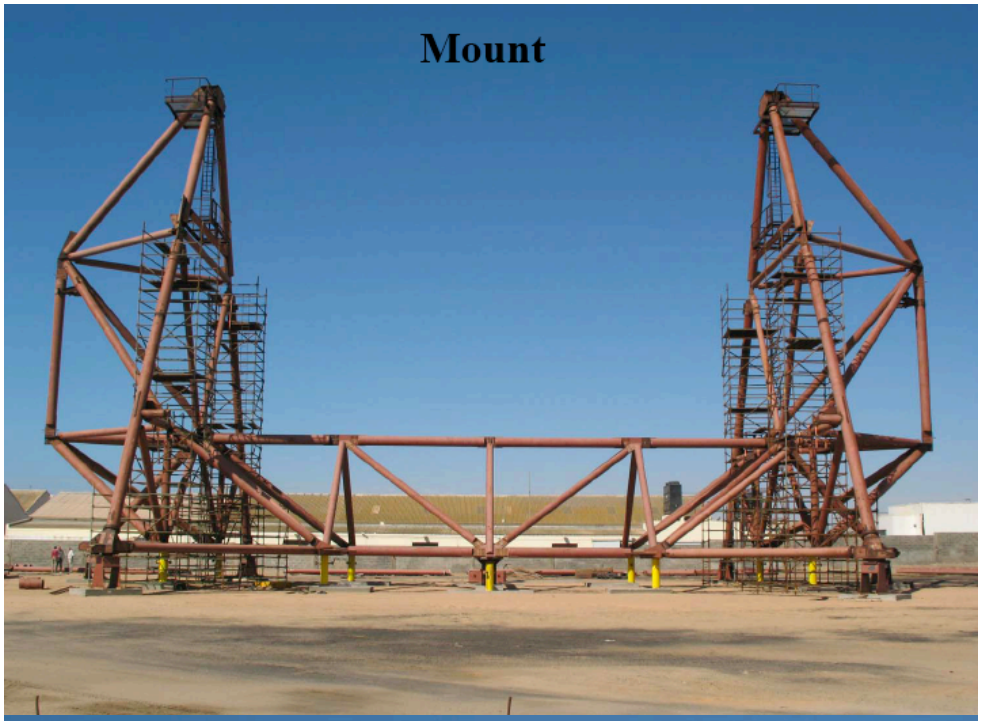
Production:
Kraatz Marine
Walvisbay, Namibia



Mirrors
about 850 hexagonal
90 cm glass facets

Camera
~2000 pixel (= PM)
~3tons

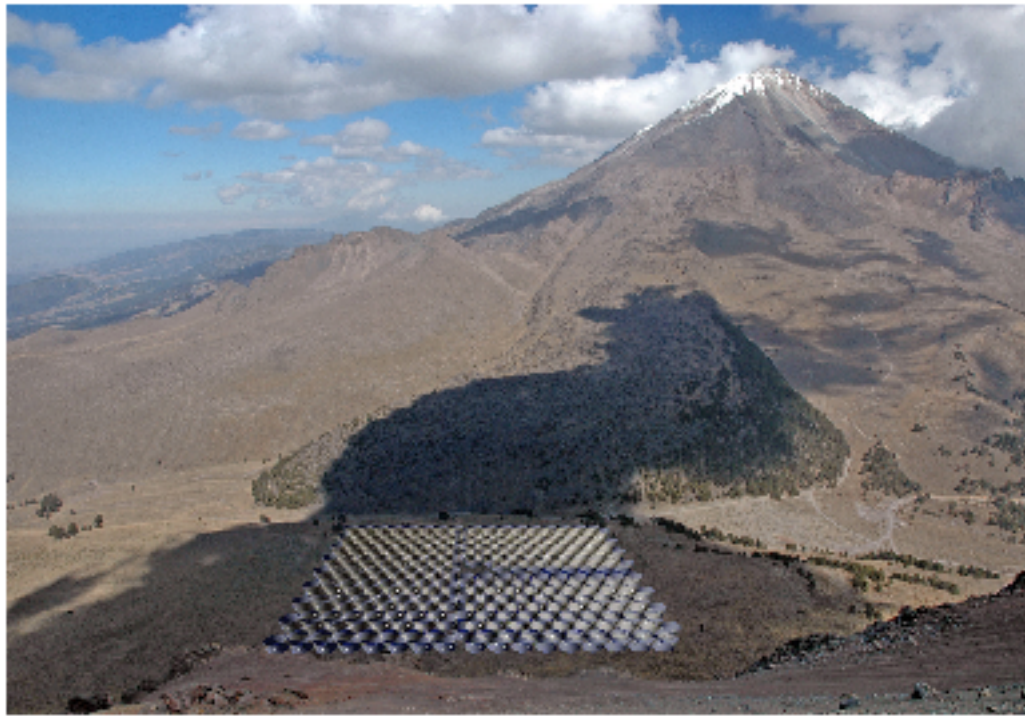
Total Weight 560 t



HIGH ALTITUDE WATER CHERENKOV EXPERIMENT HAWC

Inspired by the MILAGRO experiment

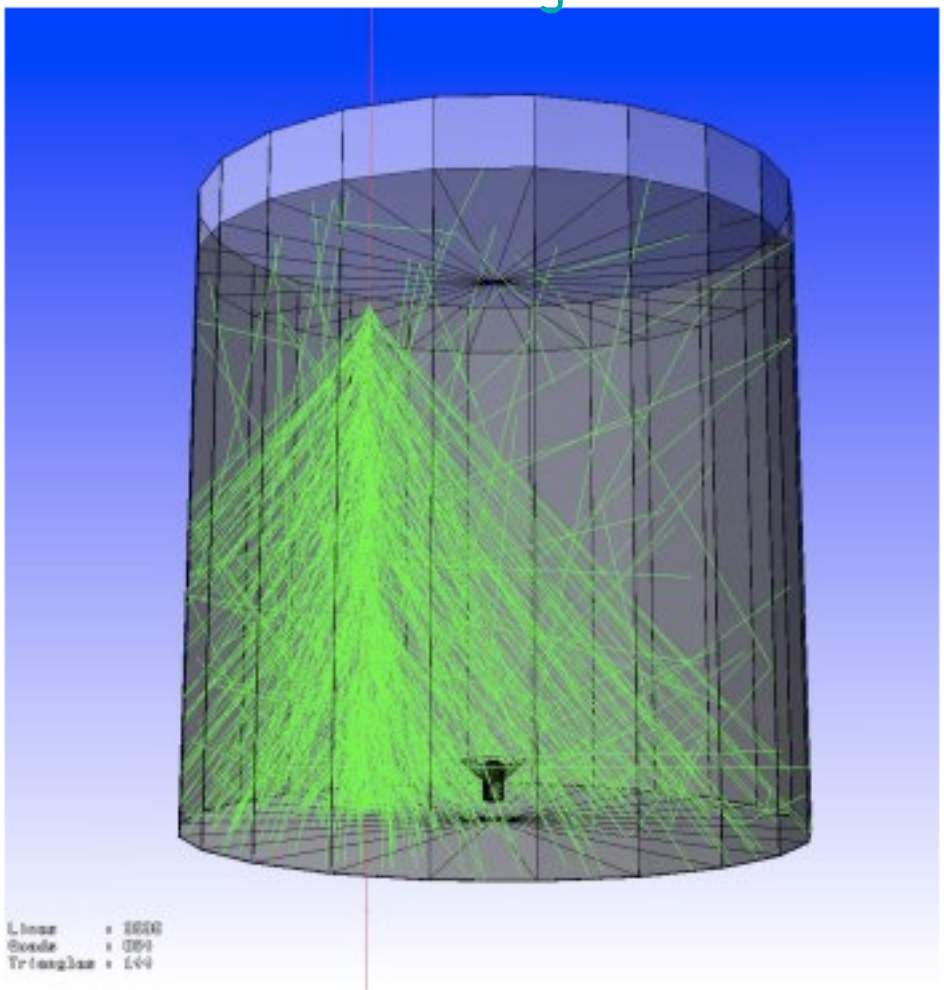
site



HAWC site at Sierra Negra with an artist's conception of the 300 HAWC tanks overlaid to show the location of HAWC. The volcano Pico de Orizaba is visible in the background.

Site in Mexico, 4100m asl., 18º59'N, 97º18'W
150x 115 m area, 300 large water tanks,
2 sterad acceptance, ≈ 100% up-time
100 GeV-100TeV, 0.1° angular resolution
≈ 10 times sensitivity of MILAGRO
Plan for completion 2014-15

A water tank design



A 5 meter diameter tank as simulated in Geant4 for a single vertical muon. The number of photons are reduced by a factor of 50 for vizualization.

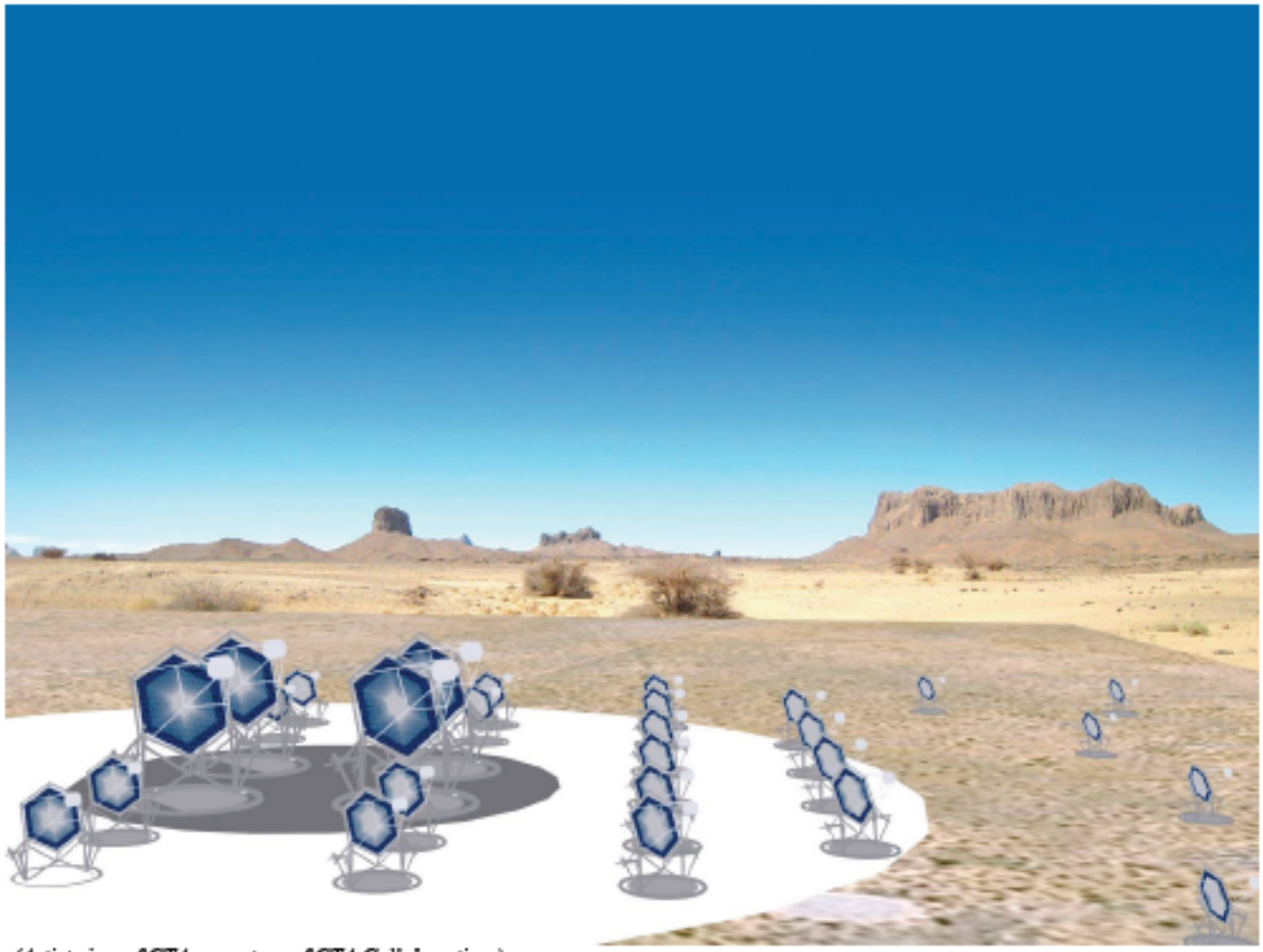
WHAT ARE THE PLANS FOR CHERENKOV TELESCOPES FOR THE FUTURE?

EXTRAPOLATING FROM RECENT RESULTS: AN INCREASE OF SENSITIVITY SHOULD RESULT IN THE DISCOVERY OF MORE THAN 1000 SOURCES -> REAL ASTRONOMY (NOTE: REALLY A BREATHTAKING SPEED IN DISCOVERIES BUT AFTER EVERY 4-6 YEARS DETECTORS ARE OBSOLETE AND NEED TO BE IMPROVED OR REPLACED BY MORE ADVANCED ONES)

CURRENTLY IN EUROPE: A PLAN TO BUILD A NEW DETECTOR WITH

- 10 TIMES BETTER SENSITIVITY COMPARE TO MAGIC AND HESS
- A THRESHOLD DOWN TO (10) 20 GEV WITH EXCELLENT OVERLAP WITH LATEST SATELLITES (FERMI)
- COVERING THE ENTIRE SKY: SOUTH (GALACTIC PLANE)+ NORTH
- OPERATE MORE LIKE AN OPTICAL OBSERVASTORY
- COST GOAL OF ≈ 150 M€ (Not enough to my estimates)
- ALREADY STRONG SUPPORT FROM FUNDING AGENCIES, EU (ONE OF THE 7 LARGE EUROPEAN RESEARCH PROJECTS IN ASTRO PARTICLE PHYSICS

CTA (CHERENKOV TELESCOPE ARRAY)



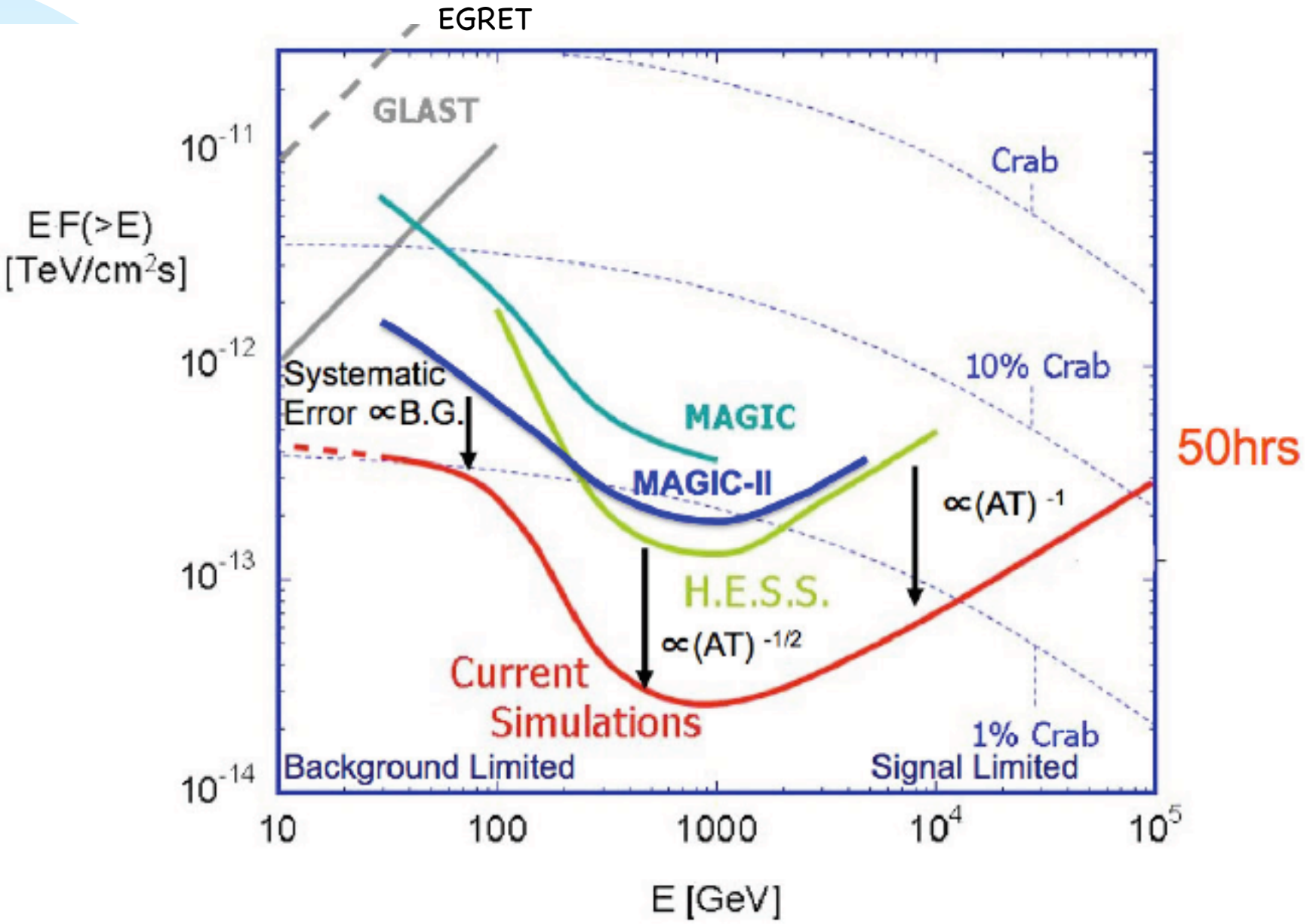
(Artist view of CTA - courtesy of CTA Collaboration.)

A TYPICAL ARRAY FOR THE SOUTHERN SITE: 4 large telescopes of 23mØ each, 35 telescopes Of 12 mØ, 60 telescopes of 6 mØ each, distributed over 1-2(5) km**2. Likely site: Namibia or Argentina or Chile

AT NORTHERN SITE: 4 large telescopes of 23 mØ, 10-20 telescopes of 12 m Ø. Likely site: Teneriffe(La Palma) or Baja, California

SENSITIVITY OF SOME PRESENT AND FUTURE HE GAMMA DETECTORS, MEASURED AS THE MINIMUM DESTECTABLE SIGNAL OF 5s.

THE SIGNAL FOR SATELLITE DETECTORS IS BASED ON 1 YEAR OBSERVATION AND THAT OF IACTS ON 50 h OBSERVATION TIME.



CONCLUSIONS

- VHE GAMMA-ASTRONOMY IS CURRENTLY IN A VERY PRODUCTIVE PHASE BUT MAINLY STILL IN THE INITIAL EXPLORING PHASE (LIKE CERN IN THE 50-70th)
  IT IS IN LINE WITH THE RAPIDLY EXPANDING FIELD OF HIGH ENERGY PARTICLE ASTROPHYSICS RESEARCH

- DOMINATING INSTRUMENTS: IMAGING AIR CHERENKOV TELESCOPES

- CURRENTLY MORE THAN 110 SOURCES FOUND, MOSTLY BY HESS, MAGIC AND VERITAS NEARLY ALLWAYS BE EXPLAINED BY LEPTONIC PRODUCRION

- SENSITIVITY OF A TYPICAL CAMPAIGN: 0.7-1 % OF CRAB FLUX WITHIN 50 h OBS. TIME

- MULTIWAVELENGTH OBSERVATIONS BECOME MORE IMPORTANT
  WAITING EAGERLY FOR FIRST RESULTS FROM MULTIMESSENGERS: NEUTRINO ASTRONOMY

- OVERLAP IN ENERGY WITH DATA FROM SATELLITES ACHIEVED

- STEADY IMPROVEMENTS IN THE TECHNOLOGY-> HIGHER SENSITIVITY

- CURRENTLY MORE PROGRESS IN ‚SOURCE FINDING' THEN IN SOLVING FUNDAMENTAL QUESTIONS

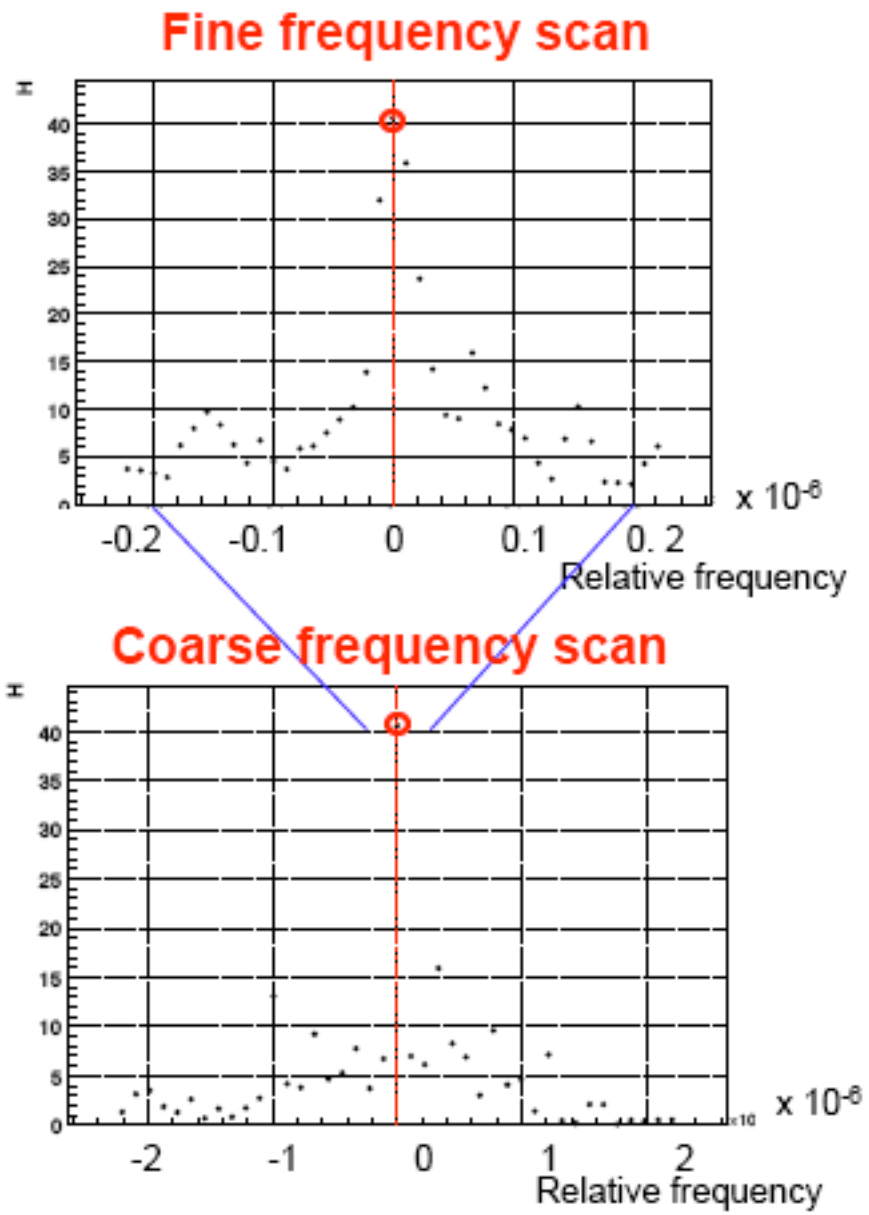
- NEXT GENERATION OF IMPROVED DETECTORS IN PREPARATION: CTA, AEGIS, LHAASO, HAWK, TUNKA..

- CTA IS VERY LIKELY THE ‚ULTIMATE' GAMMA-DETECTOR FOR THE NEXT 20 YEARS BUT STILL NEEDS QUITE SOME TIME TO BUILD

- CONGRATULATIONS TO THE COMPLETION OF ICECUBE AND THE BEST WISHES TO ‚BRING IN' SOON A SIMILAR RICH CROP OF RESULTS

BACKUPS

FOR THE PHASE ANALYSIS WE USED THE RADIO DATA, ALSO CROSS-CHECK OBSERVING OPTICAL PULSATION, ALSO FREQUENY SCAN CHISQR, H-TEST



The non baryonic Dark Matter

Stable weakly interacting massive particles (WIMPS) are attractive Cold Dark Matter candidates.

At one loop, neutralinos can annihilate to

$$\chi\chi \to W^+W^-, Z^0Z^0, \bar{q}q, e^+e^-, \ldots \to h's \qquad (30GeV \le m_\chi \le 1TeV)$$

In gamma astronomy there is a decay of high interest:

$$\chi\chi \to \gamma\gamma \Rightarrow E_\gamma = m_\chi$$

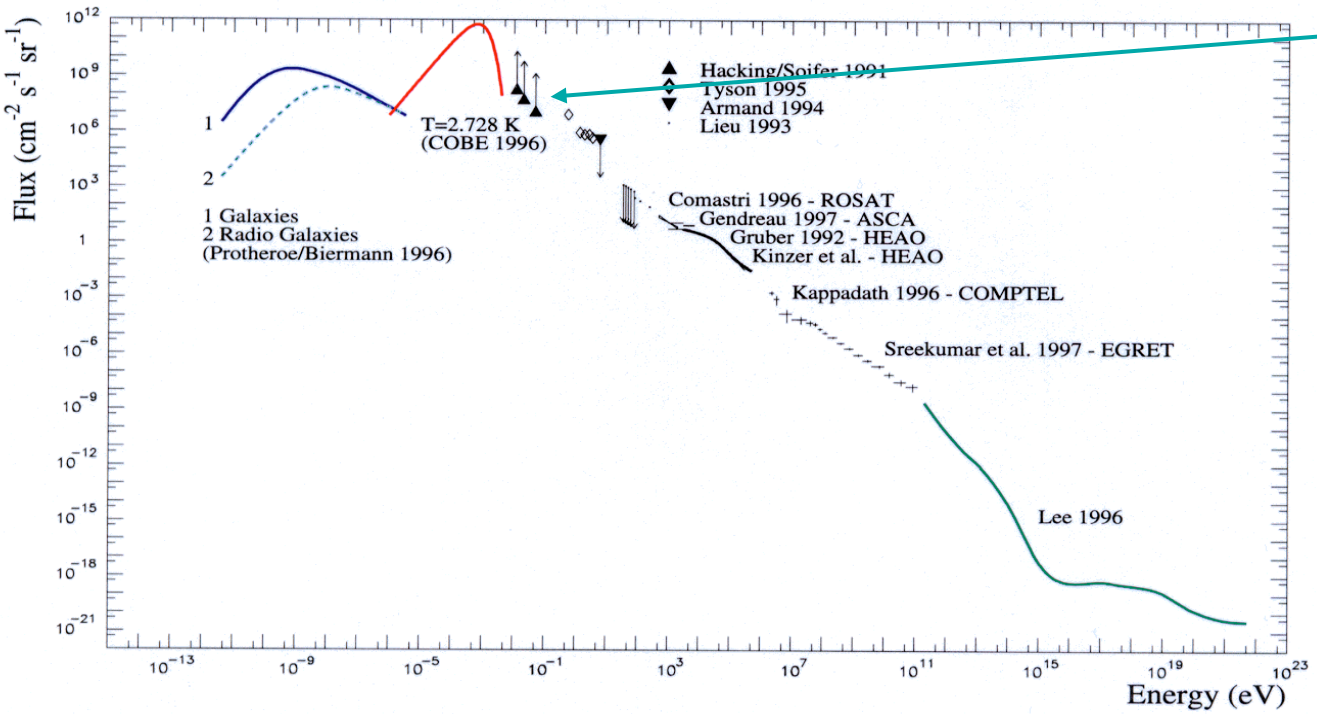
i.e. **monochromatic** gamma rays.

Feature of monochromatic gamma rays:

they keep their direction – no propagation uncertainties
the fluxes are generally low, but the signature should be very clear
the flux towards the galactic center depends strongly on the halo profile

Grand Unified Photon Spectrum

IR (UV) background poorly constrained by 'direct' measurements



lines (radio & HE gamma): model predictions

IR background
not well measured
difficult (DIRBE..)

linked to early star
Formation (Dark Matter)

limits VHE g horizon

g astronomy between
10-300 GeV can determine
IR photon density

- TeV γ-ray astronomy sensitive to infrared background due to

$$\gamma_{TeV} + \gamma_{IR} \rightarrow e^+ + e^-$$

with strongly peaked Thomson cross section and

$$E_{\rm th} = \frac{2(m_e c^2)^2}{\epsilon_{\rm IR}(1-\cos\Theta)(1+z_{jrc})^2} \rightarrow E_{\rm cutoff} \sim \frac{0.5{\rm eV}}{\epsilon_{\rm IR}}\,[{\rm TeV}]$$

HIGH ENERGY g PRODUCTION

(gs cannot be accelerated like charged particles, they need higher energy (or massive) parent particles)
Bottom-up and top-down processes

* **Hadronic production:** p (VHE,UHE) + h -> p' +….+ p± ….+ p°…..

nm → n-astronomy

gg → g-astronomy

* **Inverse Compton Scattering (IC)** e (VHE,UHE) + photon -> e (low) + g (VHE)

special case: electrons generate synchrotron photons and upscatter them to high energies (the SSC model A. Harding, O.C. DeJager)

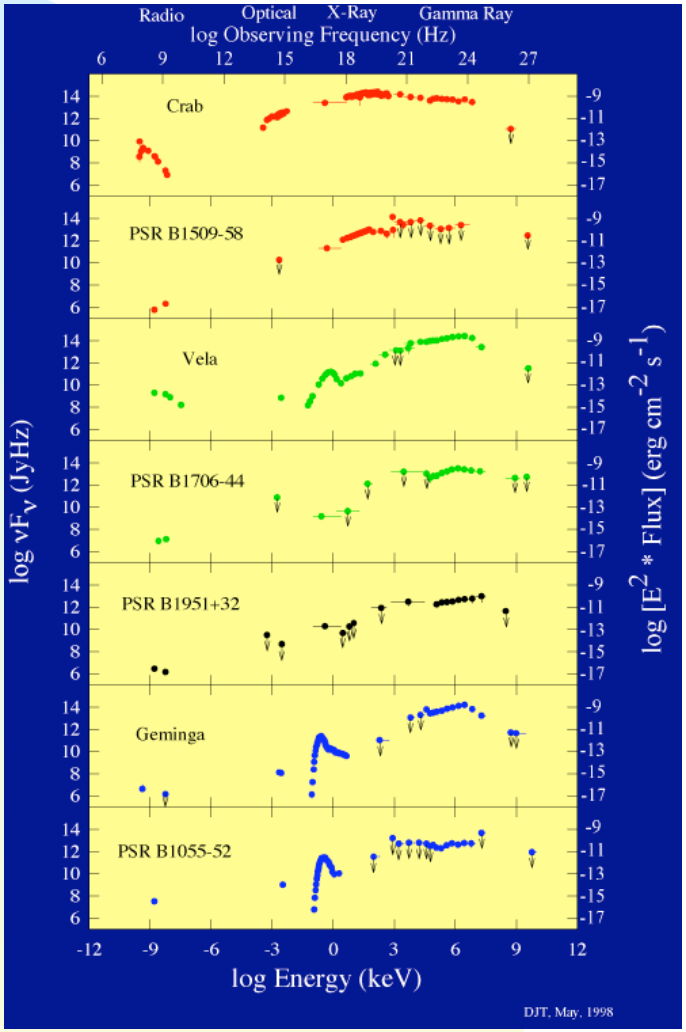
* **Unlikely, but not excluded: Decay of supermassive particles left over from the Early Universe Topological Defects, Relic Particles (Mass 10**16 GeV??), a top-down process.**

(*) VHE gs: boosted HE gs . Examples in Jets in AGNs (G≈ 10 in Mkn 501),-> blue shifted also in Gamma Ray Bursts (GRBs)

======

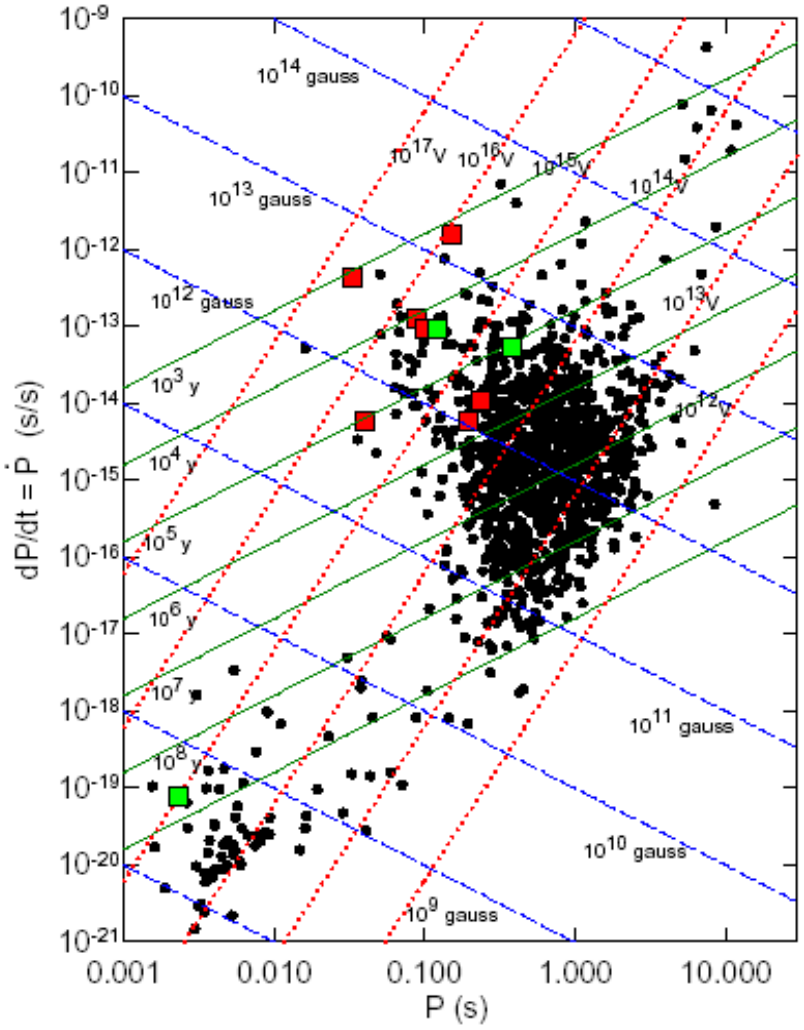
Acceleration of charged particles: in shocks (for example in Super Novae explosions, Fermi acceleration Type I, II (slow process)
Also electron acceleration by variable B fields near pulsars (betatron acc.)
Not likely, but possible: by large electrostatic fields 10**14 V ???

EGRET: NOT SENSITIVE ENOUGH ABOVE 1 GEV TO TEST CUT-OFF
-> NO TEST OF DIFFERENCES IN MODEL PREDICTION
FERMI WILL IMPROVE THE SITUATION BELOW 20-30 GEV
ABOVE: IACTS



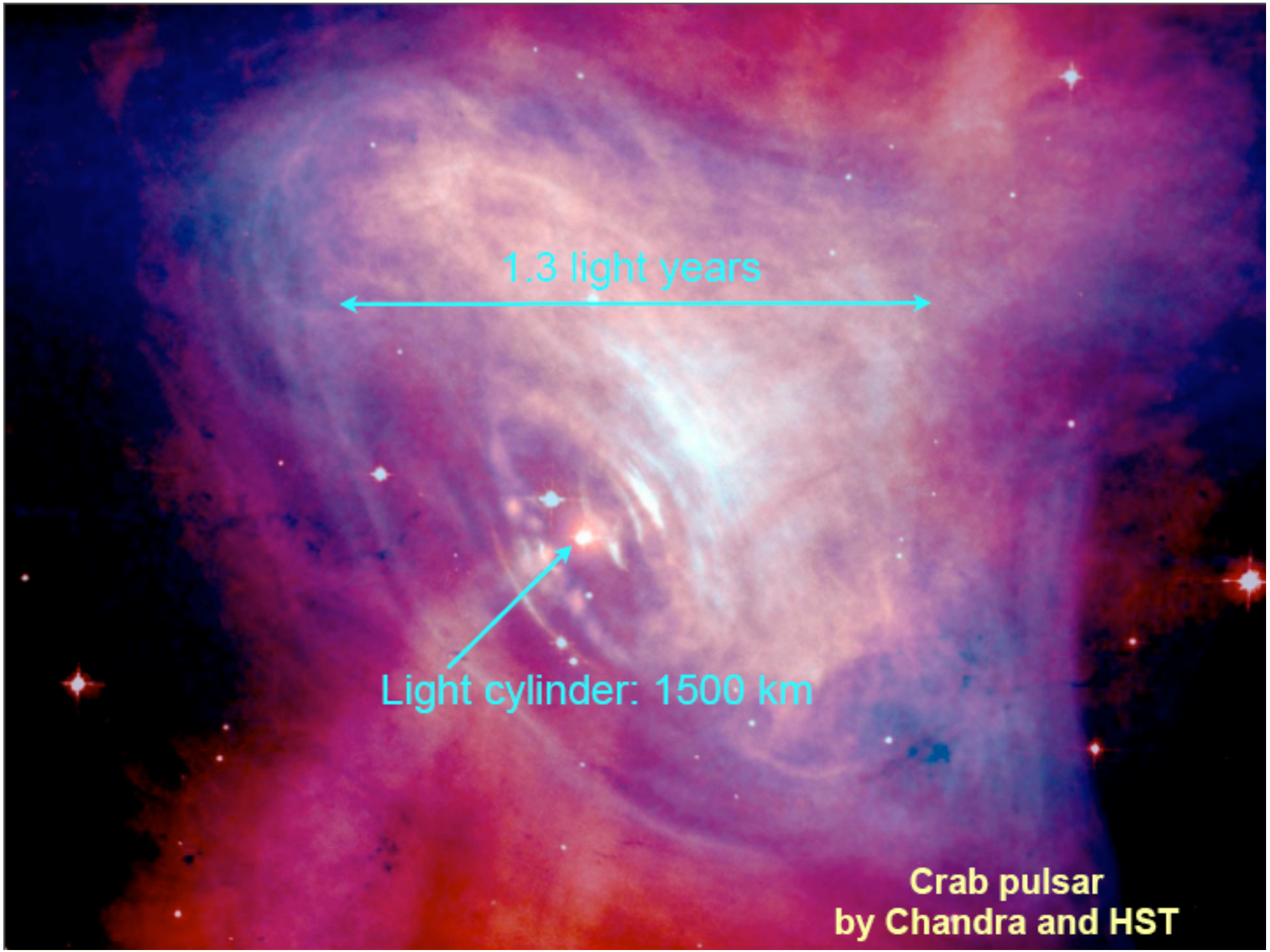
EGRET
(SITUATION WILL CHANGE WITH FERMI
MORE PULSARS, HIGHER ENERGY END, BUT
LIMIT AT 30-40 GEV)

PROMISING VHE PULSARS: HIGH SPINDOWN LOW PERIODS



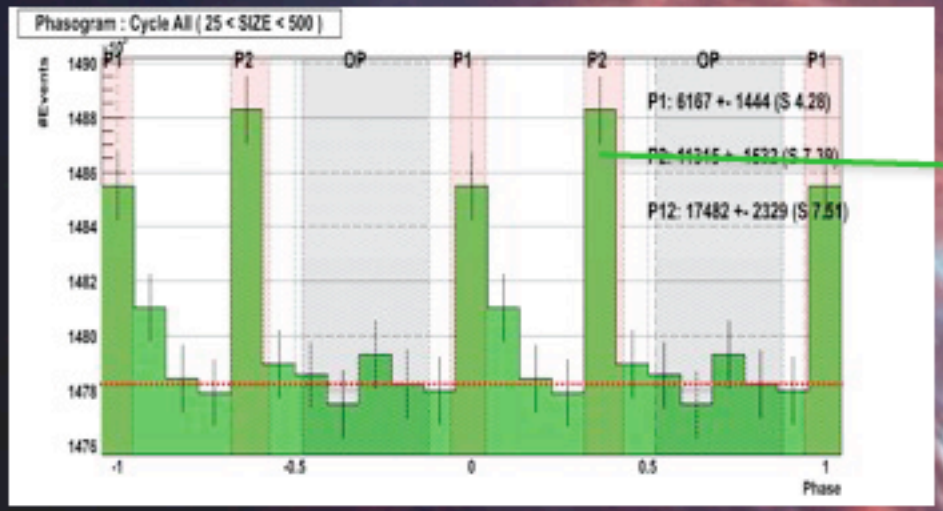
EGRET

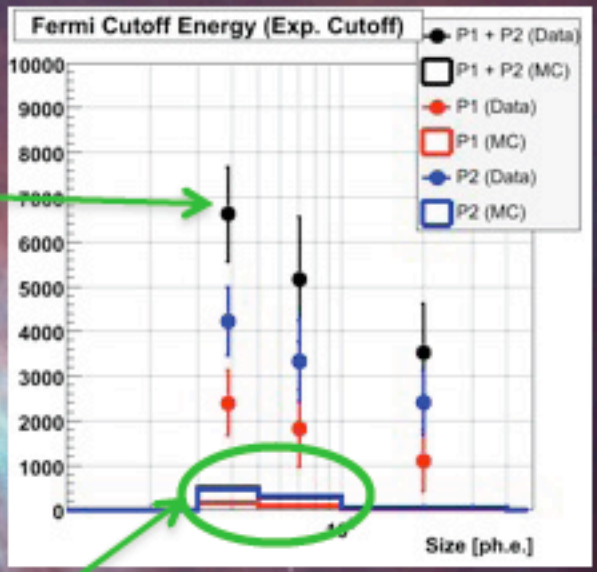
7 high confidence gamma-ray pulsars
Low confidence gamma-ray pulsars
(D. Thompson, 2003)

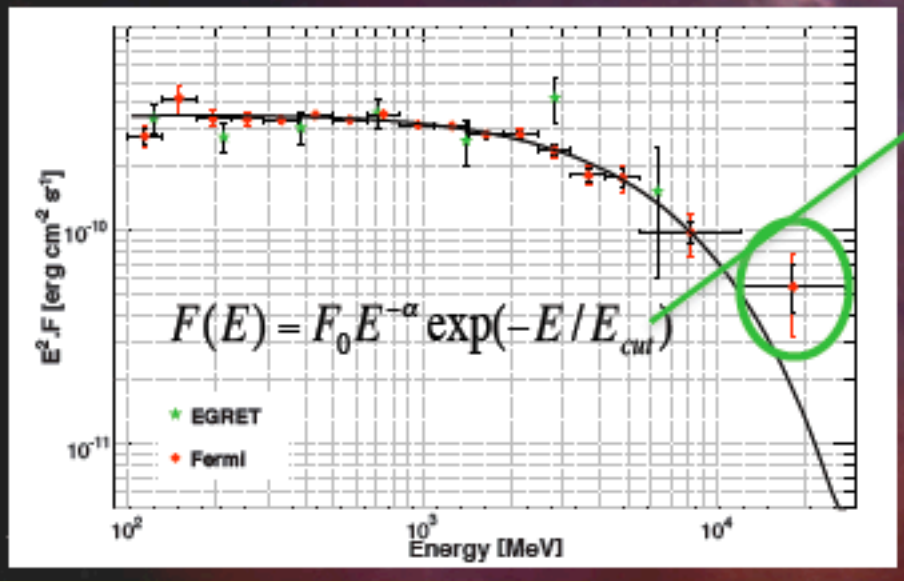

1.3 light years
Light cylinder: 1500 km
Crab pulsar
by Chandra and HST

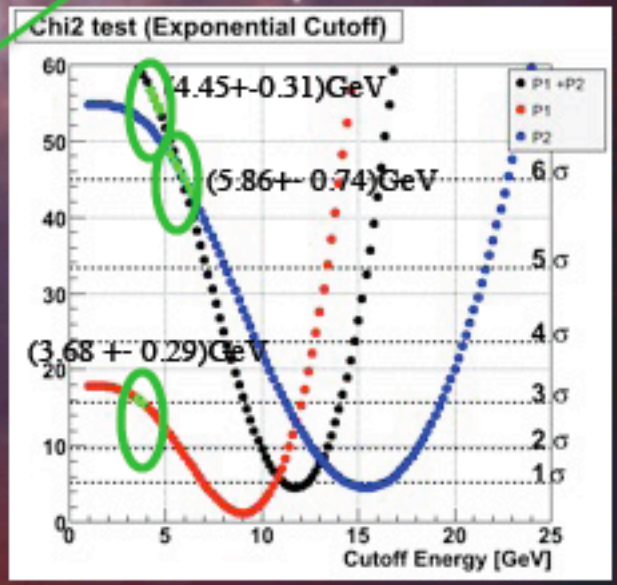
Test of compatibility of MAGIC observation with an exponential cutoff:

6.8+-0.2 Sigma inconsistency !!!









T. SCHWEIZER
T. SAITO

LSI +61 303

COMPOUND BINARY OF UNKNOWN NATURE (BE STAR CIRCULATED BY BL(mQSR) OR PULSAR
GAMMAS PRODUCED IN ACCRETION POWERED JETS OR BY ROTATIONAL POWERED RELATIVISTIC e FROM PULSAR.
DISTANCE 2kpc
HIGH EXCENTRIC ORBIT /e = 0.71±0.15 (Casares 2005) or 0.55±0.05 (Grundstrom 2007)
ORBITAL PERIOD IN RADIO 26,4960 d
PERIASTRON PASSAGE AT PHASE 0.23±0-02 (Casares 2005) or 0.301 ±0.011 (Grundstrom 2007)

PEAK RADIO OUTBURST NOT AT PERIASTRON BUT AT PHASE 0.7
DETECTED IN X-RAYS
SOURCE COINCIDES WITH EGRET SOURCE 3 EG J0291+6103
FIRST DETECTION IN VHE GAMMAS: MAGIV 2005-6
CONFIRMD BY WHIPPLE

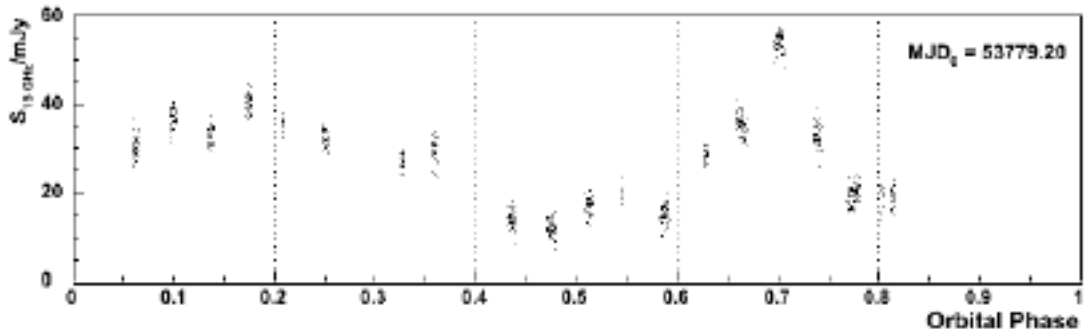
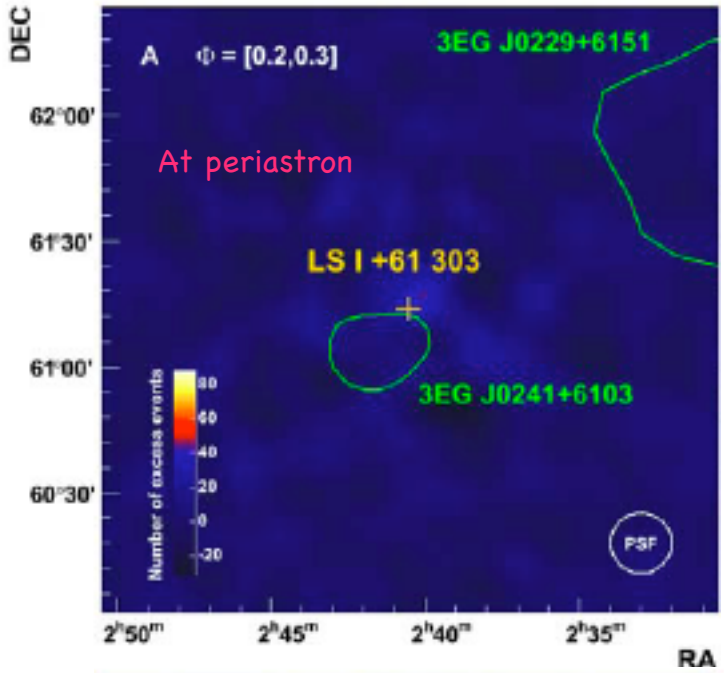
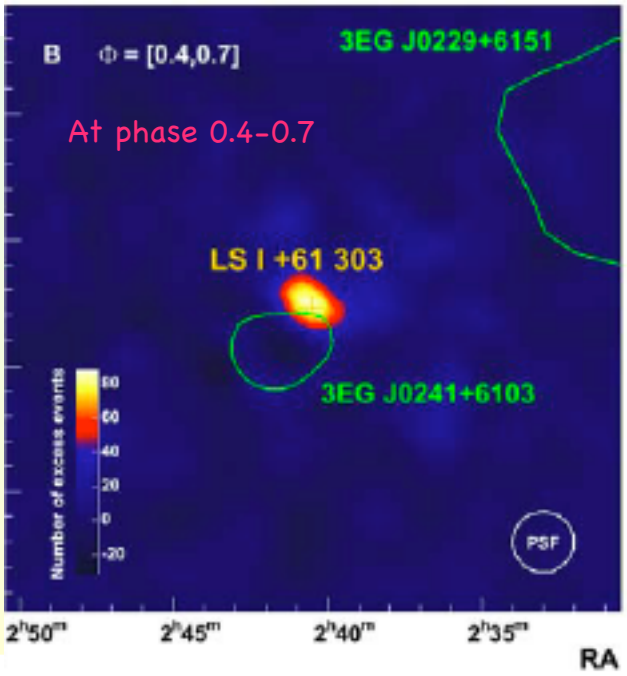
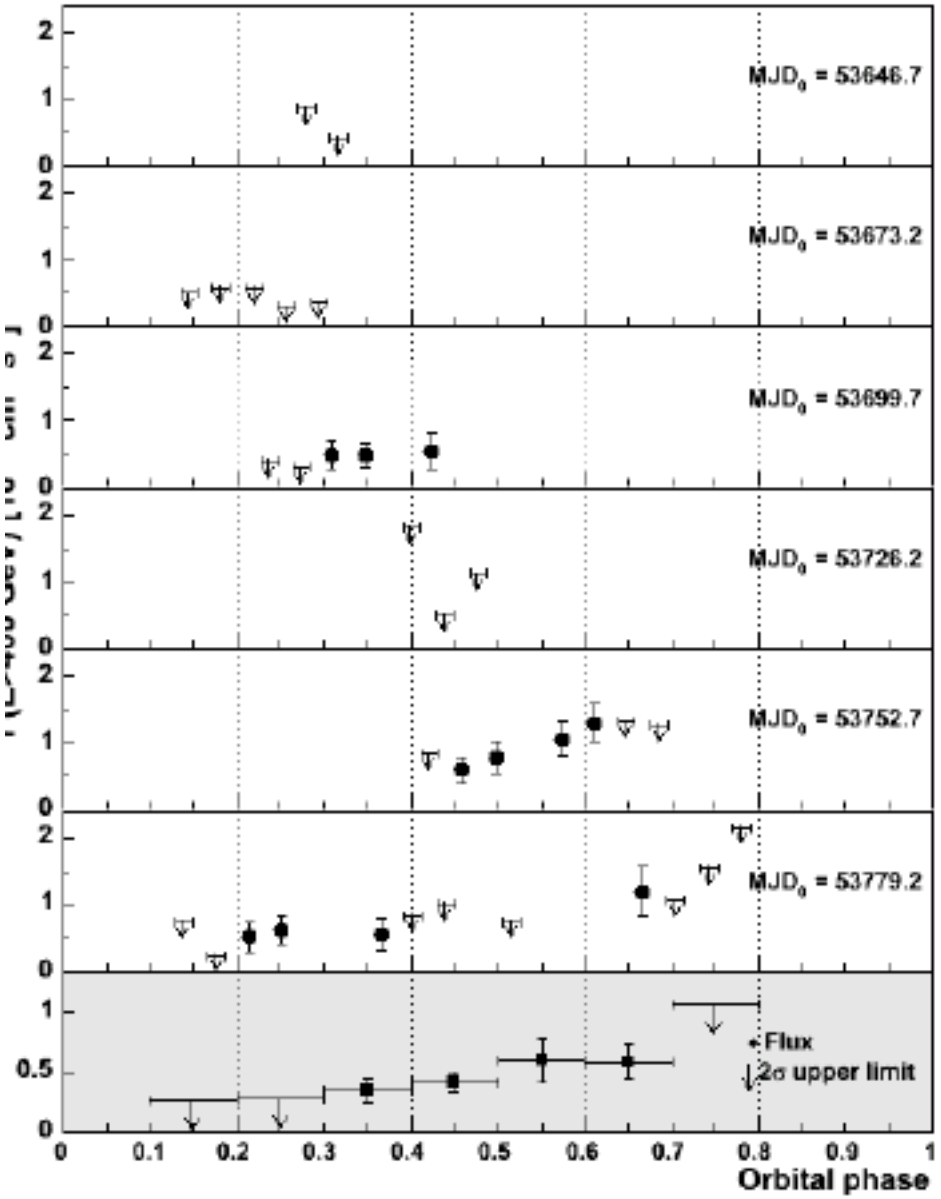


Fig. S1. LS I +61 303 radio flux density at 15 GHz measured with the Ryle Telescope for the last orbital cycle observed by MAGIC (from 14 February to 8 March 2006). The day corresponding to orbital phase 0 is indicated. The periodic radio outburst has its maximum at MJD 53798.8, corresponding to an orbital phase of 0.70.

RESULTS OBSERVATION IN 2005-2006







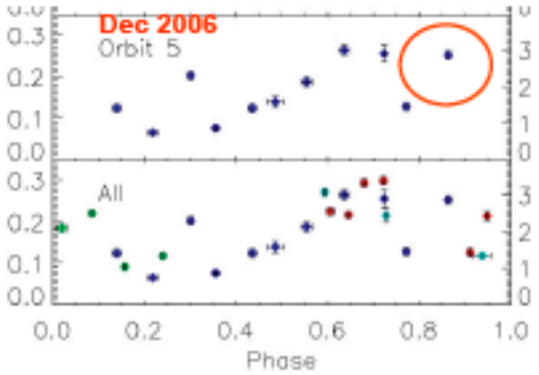
9 s signal

NEW STUDY IN FALL 2007,8 CONFIRM FIRST RESULTS

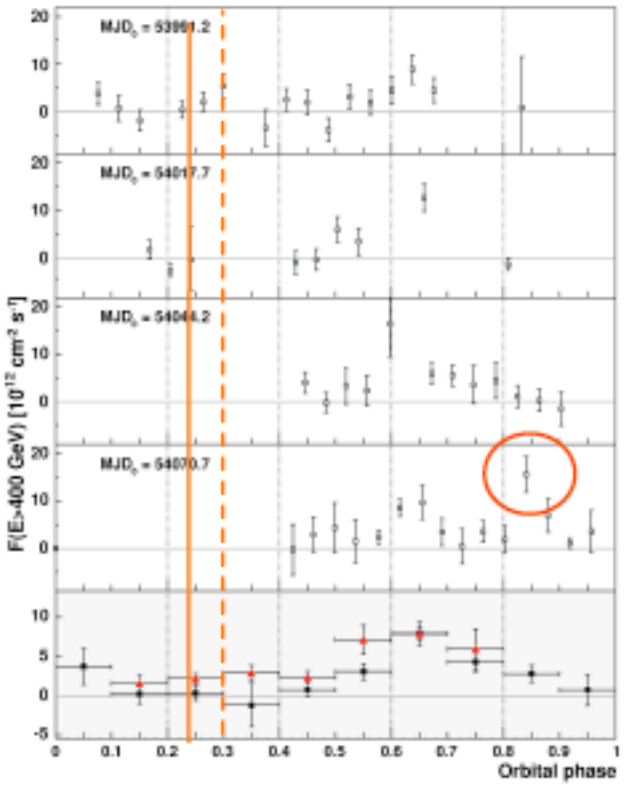
Light Curve of LS I +61 303

- Tobs= 112 h
- Highest emission phase 0.6-0.7, MJD 54035.11 shows the maximum flux @ 4.5 σ
- Highest emission phase 0.6-0.7
- Quiet at periastron
- Second peak in Dec 06 at 0.8-0.9

Swift, Esposito et al 2007



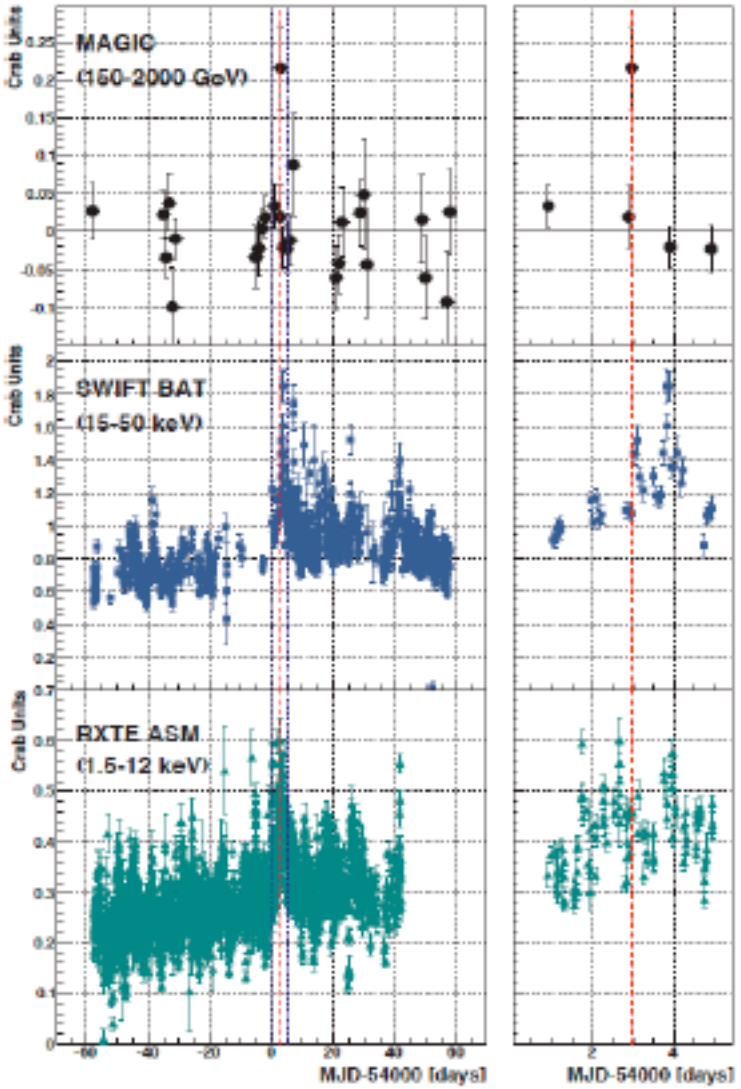
Periastron



Aonther binary object CYGNUS X1, only a 4.1 s dection, 1/2 h flare

- 24. September 2006
- VHE flare coincident with X-ray flares seen by Swift/BAT, RXTE/ASM and Integral
- TeV excess observed at rising edge of first hard X-ray peak
- No clear change in soft-rays
- Hard X-rays and VHE γ-rays could be produced at different regions of the collimated jet

➔shift between TeV- and X-ray peak



DATA FAVOR RELATIVELY HIGH CUTOFF ≈ 23 GeV WITH AN EXPONENTIAL CUT-OFF PARAMETER AND P2 EXTENDING > 60 GEV

DATA STRONGLY FAVOR OUTER GAP MODELS
POLAR CAP MODELS PREDICT SUPEREXP. CUT-OFF CLOSE ABOVE 1 GEV

DATA SHOW THAT ABOVE 40-50 GEV
THE INTERPULSE P2 DOMINATED OVER P1

MORE STUDIES ARE NEEDED FOR PRECISE ANALYSIS

SIMILAR DOMINANCE OF P2 > P1 SEEN NOW ALSO IN FERMI DATA FOR VELA (LOWER CUTOFF)

BUT FERMI SENSITIVITY INSUFFICIENT FOR STUDIES ABOVE 30-40 GEV
FERMI WELL SUITED FOR CUT-OFF STUDIES BELOW AN AROUND 1 GEV

THE MAGIC THRESHOLD OF 25 GEV (CLOSE TO ZENITH) IS BY FAR LOWEST OF ALL IACTs.

MAGIC for superexponential cutoff:

23.2 GeV+-2.9$_{stat}$ GeV+-6.6$_{syst}$ GeV

We can calculate the absorption of gamma photons in the magnetic field

$$\varepsilon_{\max} \approx 0.4\sqrt{P\frac{r}{R_0}}\max\left\{1,\frac{0.1B_{crit}}{B_0}\left(\frac{r}{R_0}\right)^3\right\}GeV$$

Baring et al., 2001

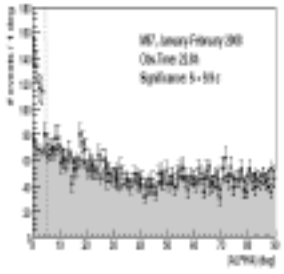
From which we can put a lower limit on the distance of the emitting region:

6.2 +- 0.2$_{stat}$ +- 0.4$_{syst}$ stellar radii

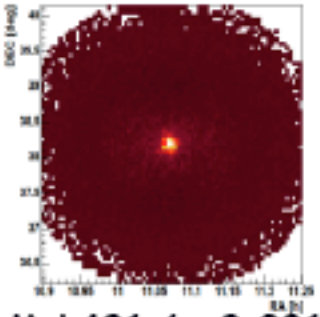
The high location of the emission region excludes the *classical* polar cap model (emission distance < 1 stellar radius) and challenges the slot gap model

New data with 4 time statistics taken past winter
Detailed analysis of P1 and P2 spectra ongoing

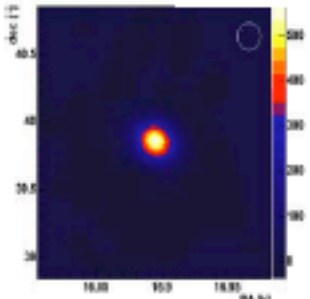
Highlights in MAGIC extragalactic observations



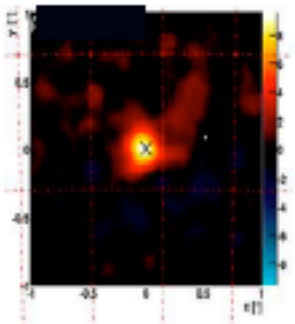
M87 (z=0.0043)



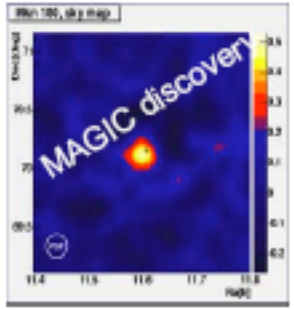
Mrk421 (z=0.031)



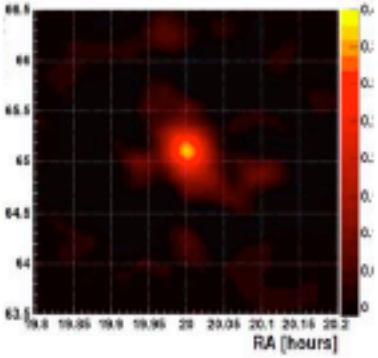
Mrk501 (z=0.034)



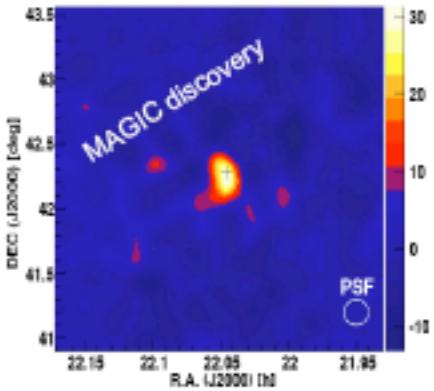
1ES2344 (z=0.044)



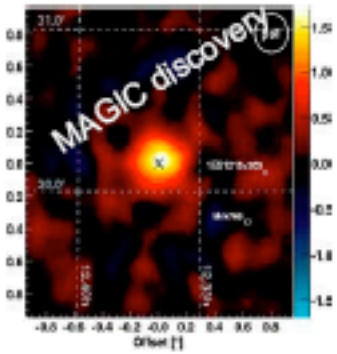
Mrk180 (z=0.045)



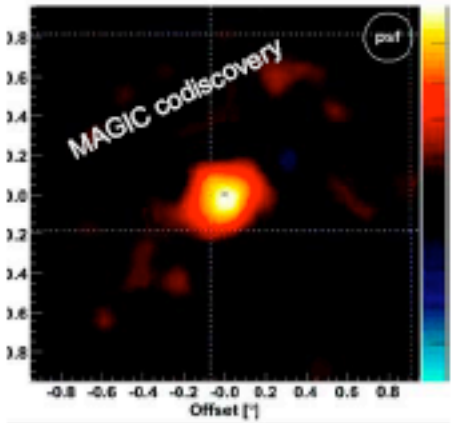
1ES1959 (z=0.047)



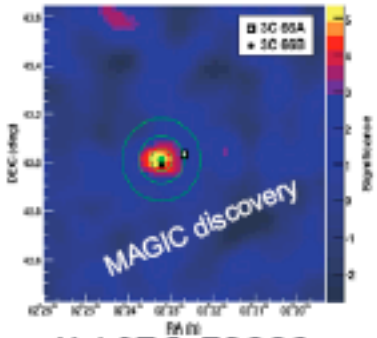
BL-Lacertae (z=0.069)



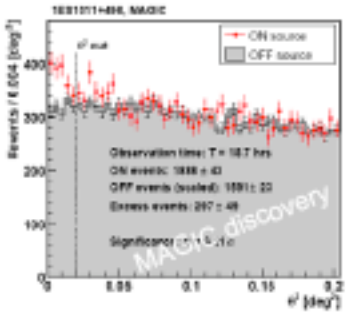
1ES1218 (z=0.18)



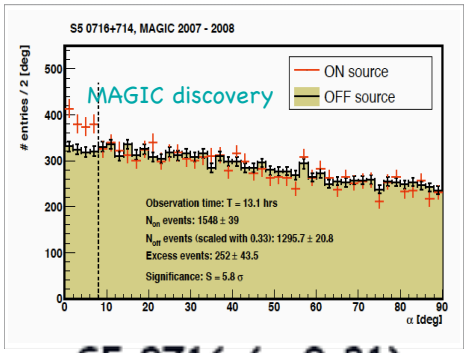
PG 1553 (z>0.09)



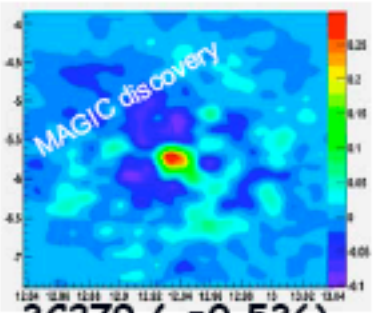
MAGIC J0223 (3C66B?)



1ES1011 (z=0.212)



S5 0716 (z=0.31)

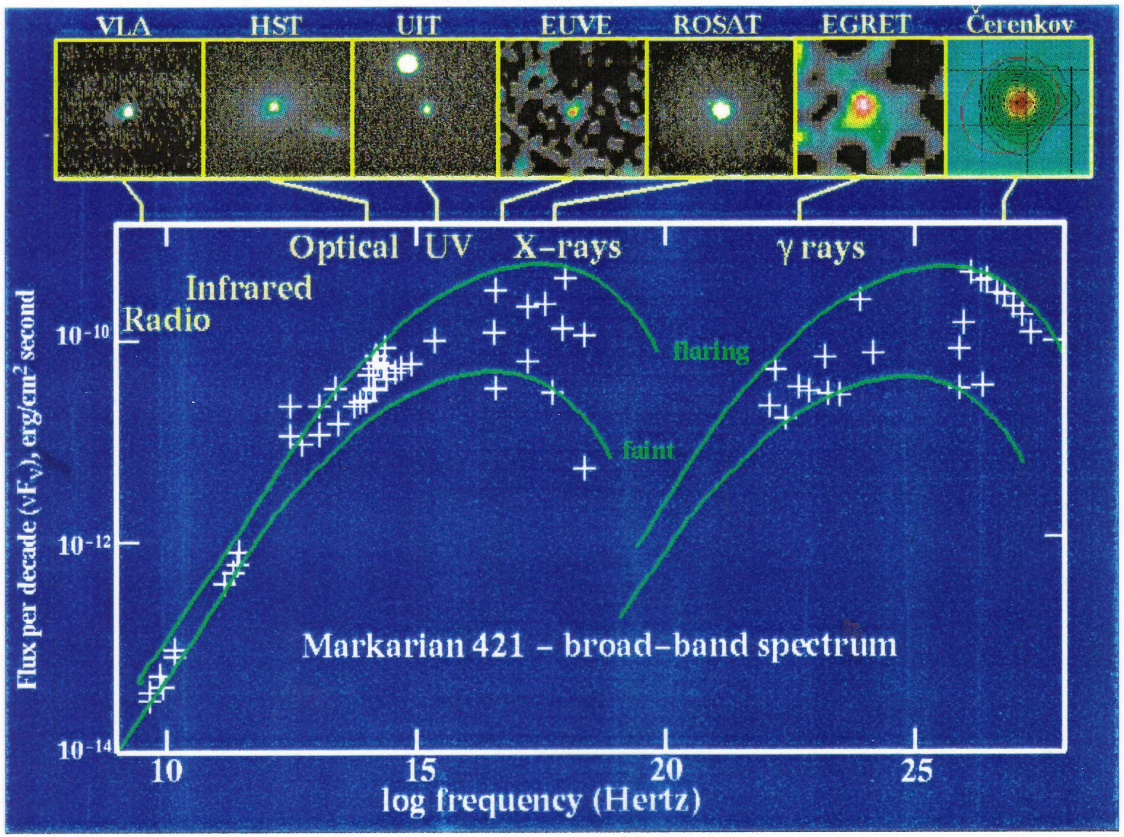


3C279 (z=0.536)

Energy flux for blazar type AGN

Example Mkn 421 (Fig. courtesy Bill Keel)

Typical example
Of SED
Two peak structure

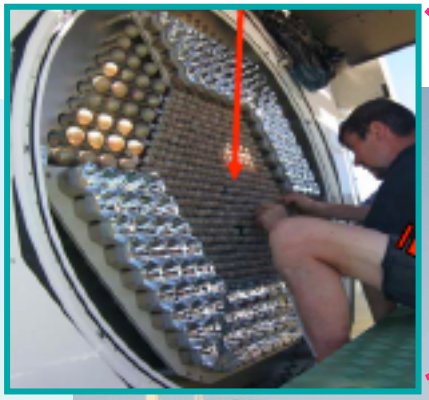


highest variability in X-ray and g-rays
highest energy probably emitted close to supermassive black hole
Source physics <------> black hole physics

THE 17 m Ø IMAGING AIR CHERENKOV TELESCOPE

MAGIC I LOCATION: LA PALMA, ISLAS CANARIAS

THE 577 PIXEL PMT CAMERA



BUILT AND OPERATED BY AN INTERNATIONAL COLLABORATION OF 150 PHYCISISTS FROM 26 INSTITUTIONS FROM 9 COUNTRIES, BUILT IN 2001-2003 with a large SPANISH CONTRIBUTION

SPECIAL FEATURES: FAST POSITIONING FOR GRB SEARCHES, OBSERVATION DURING MOON LIGHT