

Indirect Dark Matter Search with MAGIC

Adrian Biland, ETHZ
MAGIC-Collaboration

DSU07, 06.06.07
Minneapolis



Major Atmospheric Gamma-ray Imaging Cherenkov Telescope

Roque de los Muchachos, Canary Islands, 2200m a.s.l.

~150 Physicists, 21 Institutes, 9 Countries

IFAE Barcelona, UAB Barcelona, U Barcelona,
Humboldt U Berlin, IAC Canarias, UC Davis,
U Dortmund, IAA Granada, INAF Italy,
U Lodz, UCM Madrid, MPI München,
U/INFN Padua, U Siena/INFN Pisa,
INR Sofia, Tuorla Observatory,
U Udine/INFN Trieste,
U Würzburg,
Yerevan Phys.Inst.,
DESY Zeuthen,
ETH Zurich

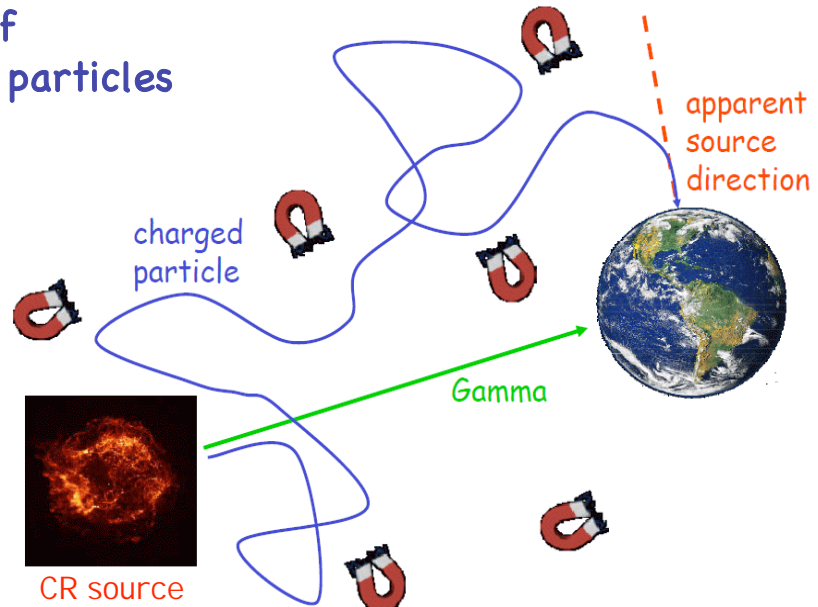
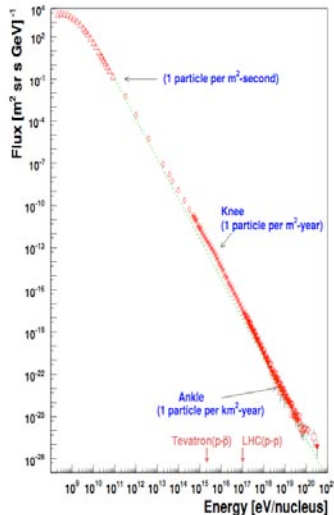
Start of construction: 2001
Inauguration: October 2003
Start regular data taking: Sept. 2004





Original Goal of VHE Astronomy

Identify source(s) of charged cosmic ray particles

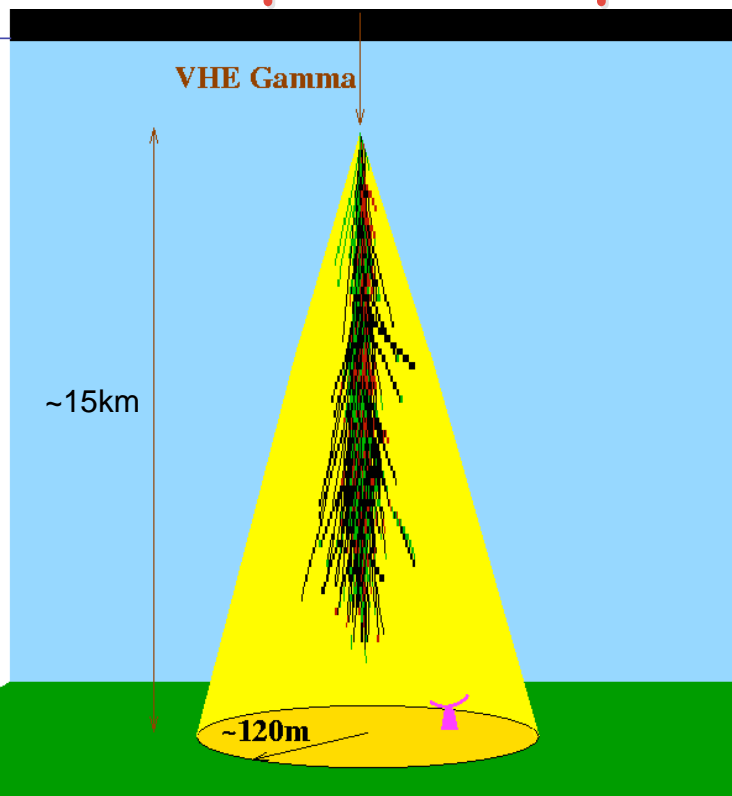


CR: existence known since 1912, but origin not (yet) understood..



Cherenkov Telescope Principle

- VHE γ hits the atmosphere
- produces extend. air-shower
- shower particles emit cherenkov light \Rightarrow light pool
- telescope catches cherenkov light (eff. area: $\approx 10^5 \text{ m}^2$ vs. 1 m^2 satellites)





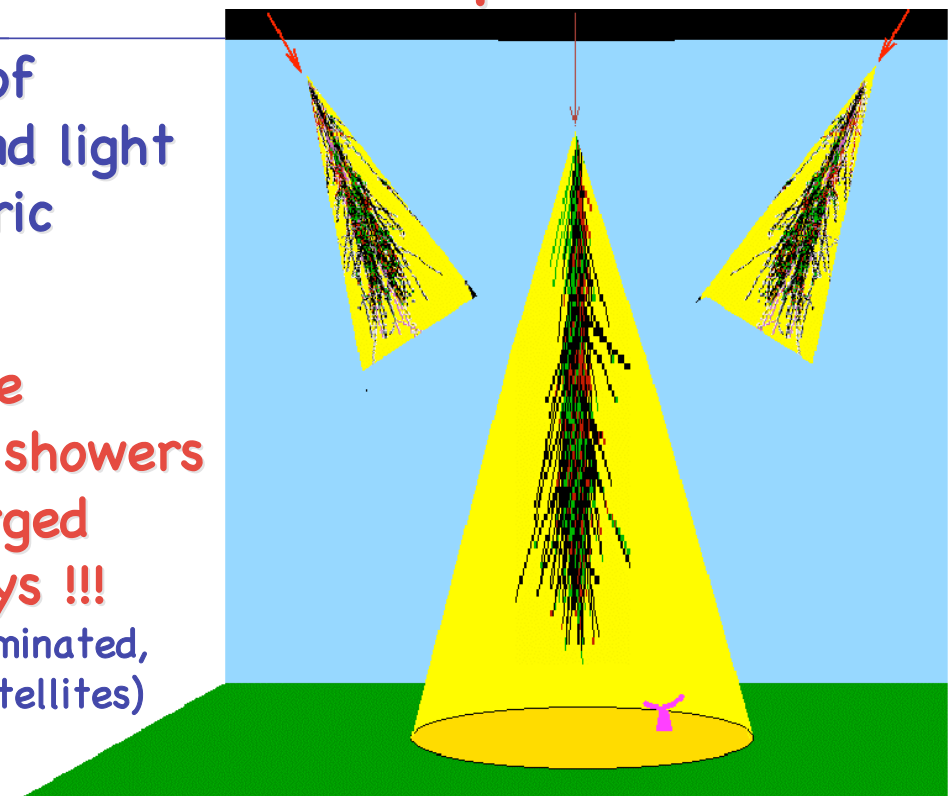
Cherenkov Telescope Problems

- all kinds of background light
- atmospheric conditions

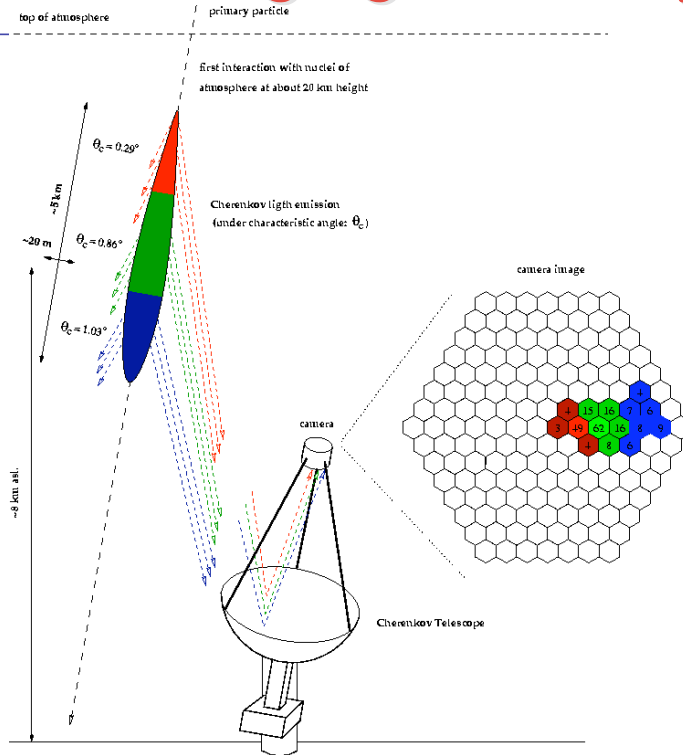


Cherenkov Telescope Problems

- all kinds of background light
 - atmospheric conditions
 - much more abundant showers from charged cosmic rays !!!
- (Background dominated, vs. BG-free satellites)



Imaging Technique



do not see lateral distribution on ground,
but see the projection of (part of) shower

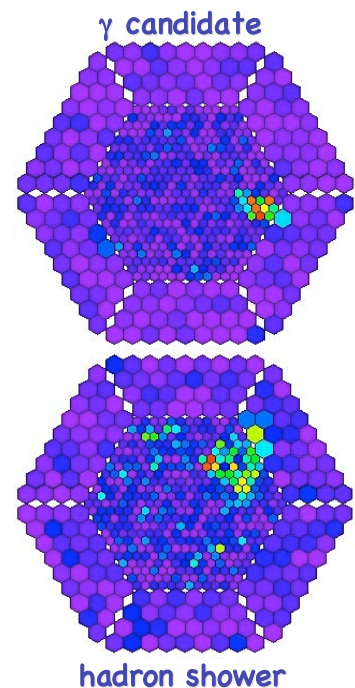
Imaging Technique

electromagnetic and hadronic showers have different shapes

====>

using a high resolution Camera allows to distinguish (statistically) between γ - and hadron-showers

Works excellent > 100 GeV
but very difficult < 100 GeV





MAGIC Telescope

Mirror:

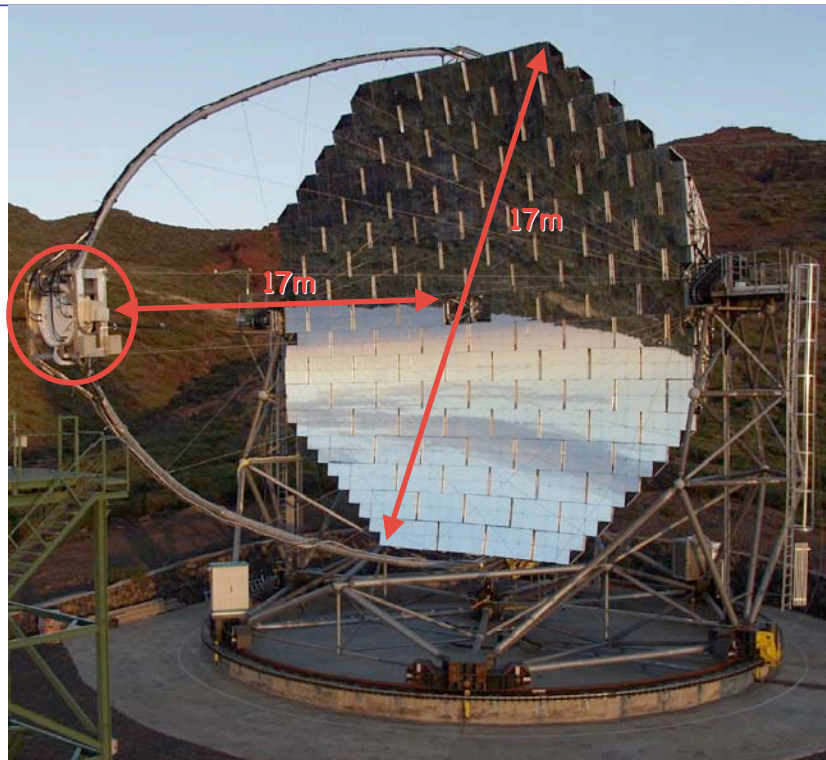
17m (234m²), f/d=1
parabolic shape
formed from 964 0.5x0.5m²
spherical Al-mirrors

Camera:

576 high QE PMTs,
FoV = 3.5°,
320GHz FADC
analog fibre readout ;

Obs. time:

~1000 h/yr dark
+ 500 h/yr 'moon'



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MAGIC Telescope

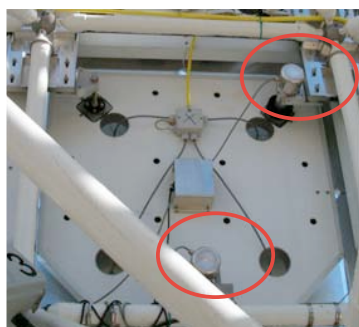
Fast Repositioning:

to keep total weight low,
use space frame made of
carbon fibre epoxy tubes
very strong,
but not very rigid

==>

Active Mirror Control:

494 stepping motors to
correct for gravitational
deformations ==>PSF 0.1°



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MAGIC Performance

Actual performance reached:

(for small zenith angles)

- energy threshold (trigger): ~ 50 GeV
- energy resolution: 30% (100GeV), 20% (1TeV)
- flux sensitivity (5σ): 2.5% of Crab flux in 50h
- angular resolution: $\sim 0.1^\circ$
- determination of source position (pointlike): $2'$
- repositioning: < 40 s (with reduced motor power)
(~ 20 s with full motor power possible)

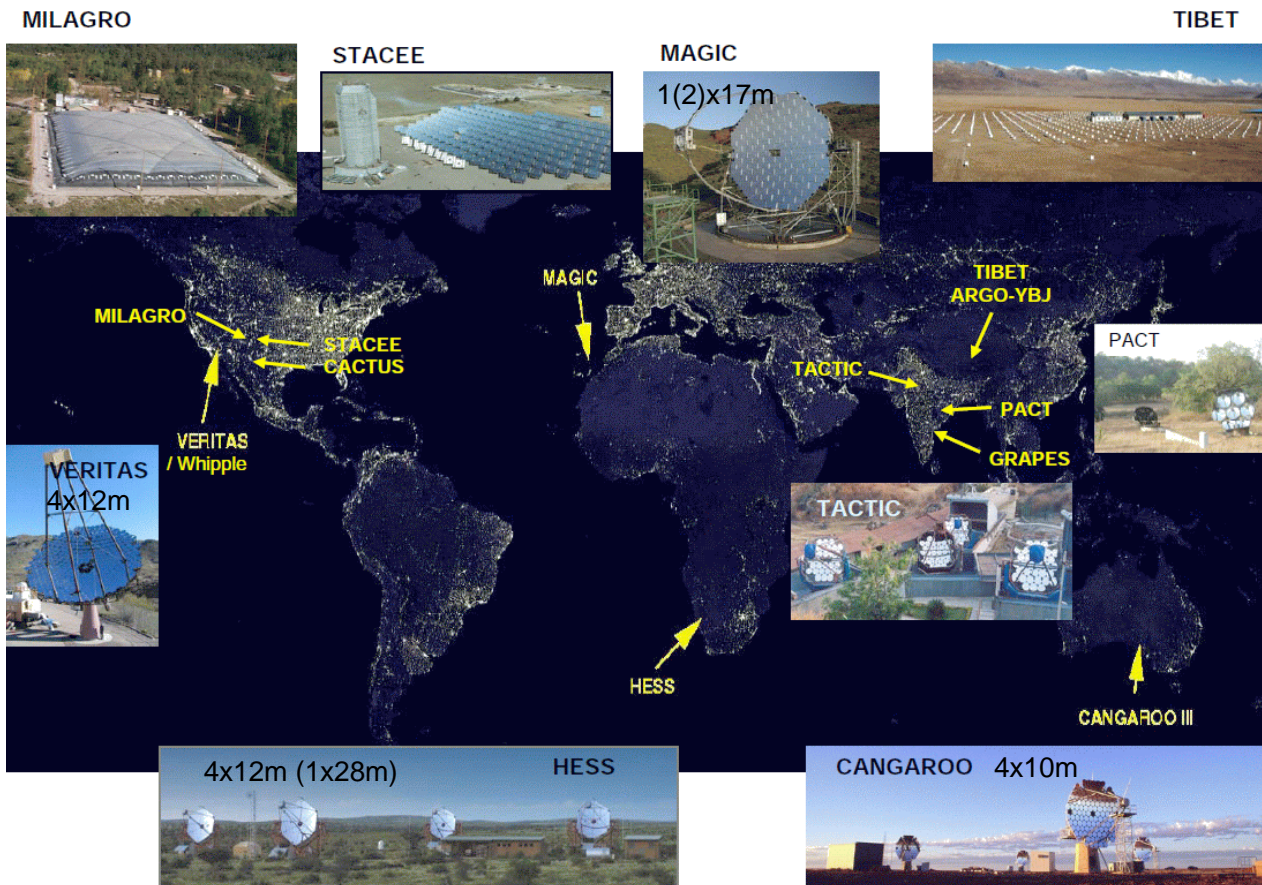


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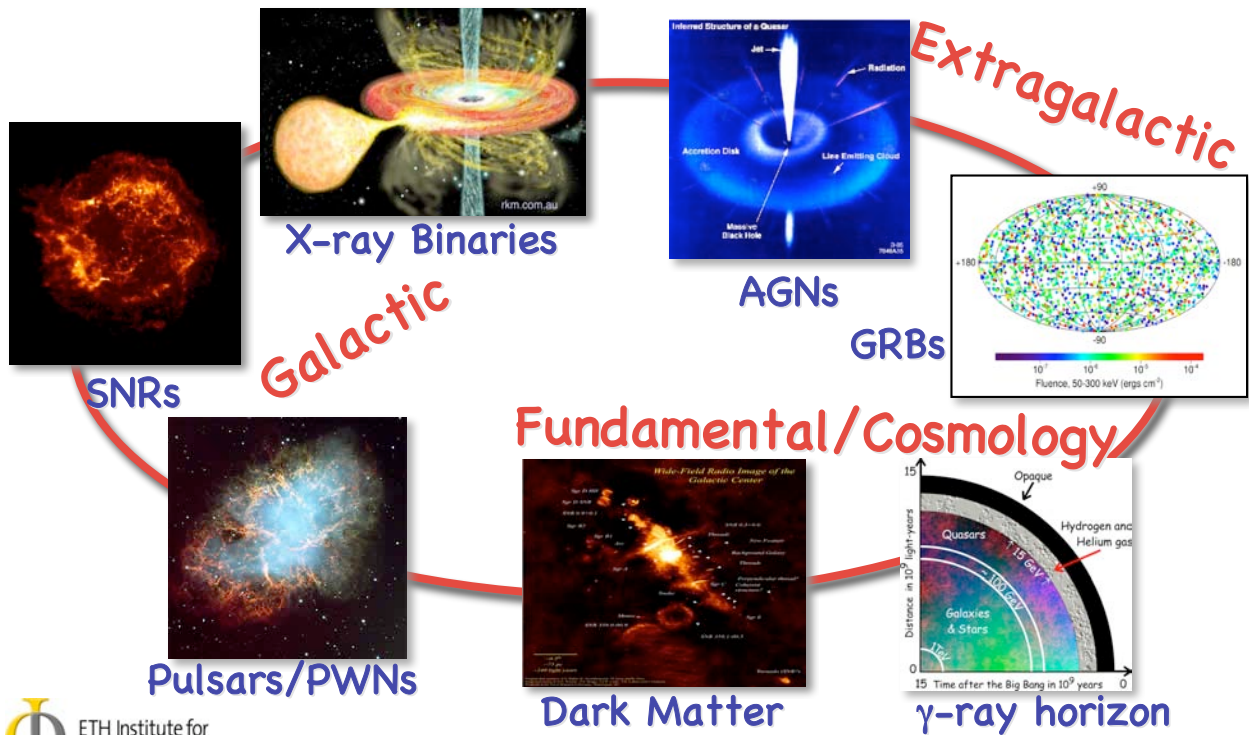
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Some Physics Objectives



Published Sources

MAGIC catalog was authorized by IAU: "MAGIC JHHMM+DDMM"

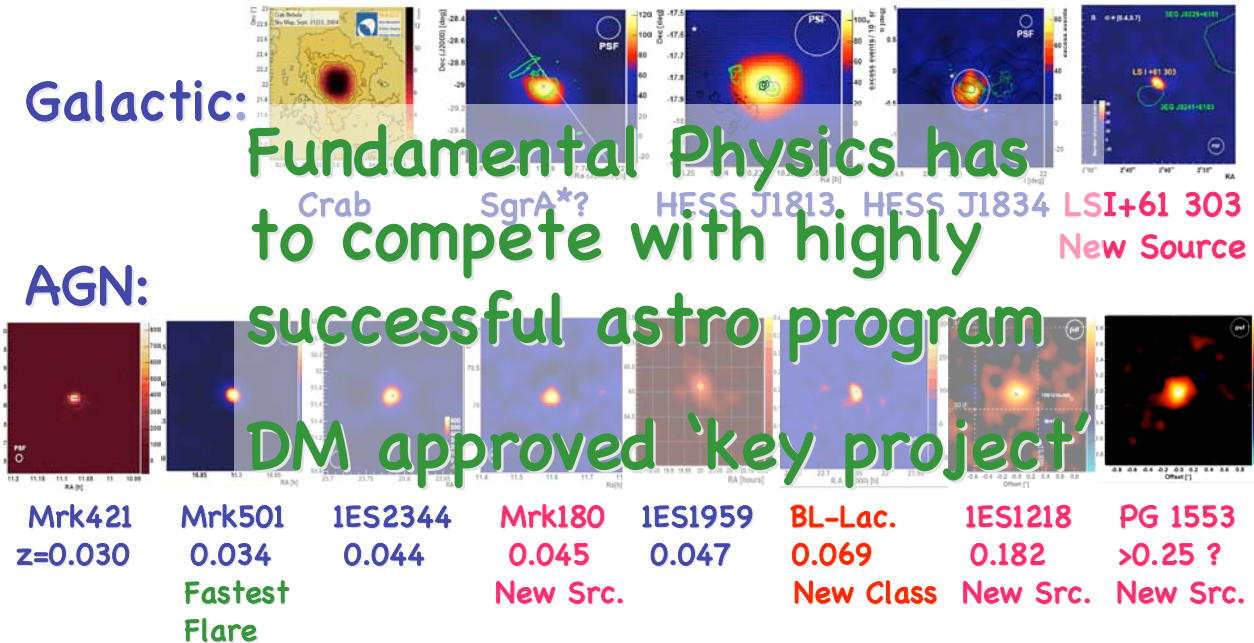
Galactic:

Fundamental Physics has

to compete with highly

successful astro program

DM approved 'key project'

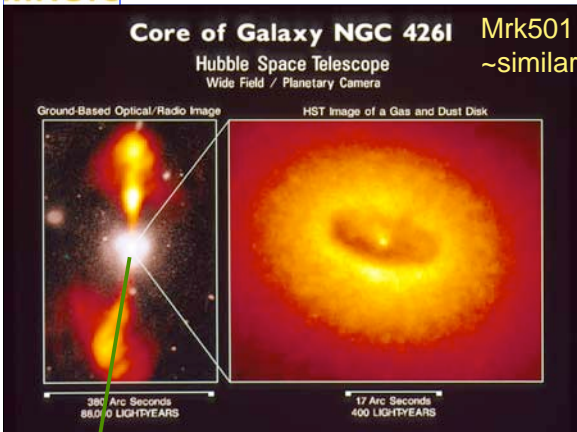


+ several upper limits + 3 new sources not yet published

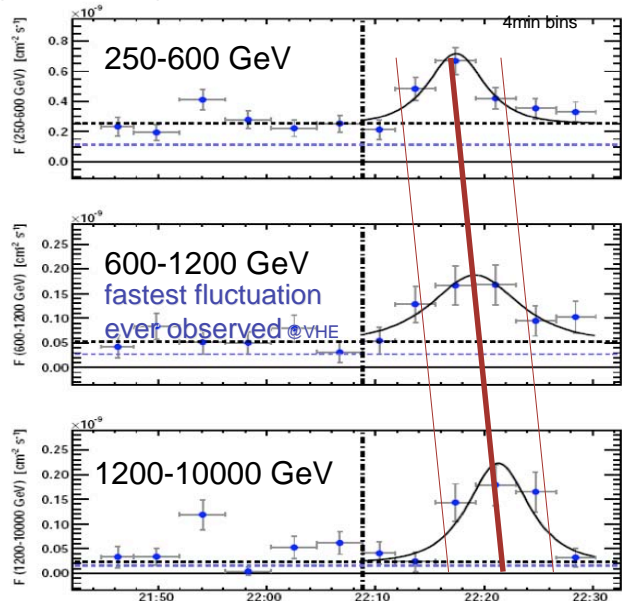


Extragalactic: Markarian 501 (AGN)

submitted to ApJ, astro-ph 0702008



AGN jets have sizes $>10^5$ Ly



But VHE flares on few minutes ==> small emission regions ?

Energy dep. arrival time !!? Intrinsic?? Quantum Gravity?? ...



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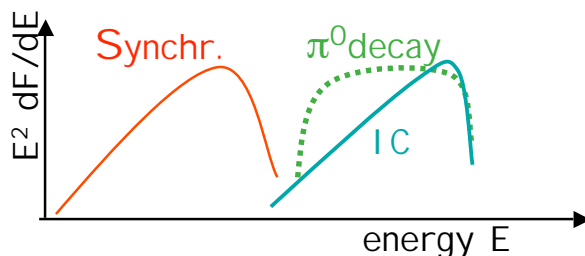
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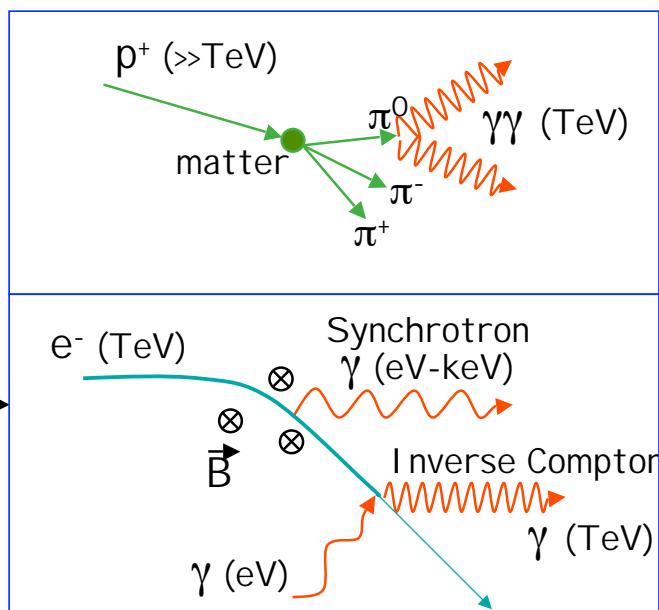
'Standard' Origins of VHE- γ

VHE photons do have non-thermic origin(s)

Do p or e^- act as seed particles?



distinguish hadronic vs. leptonic 'acceleration':
=> shape of spectrum;
Multi-wavelength



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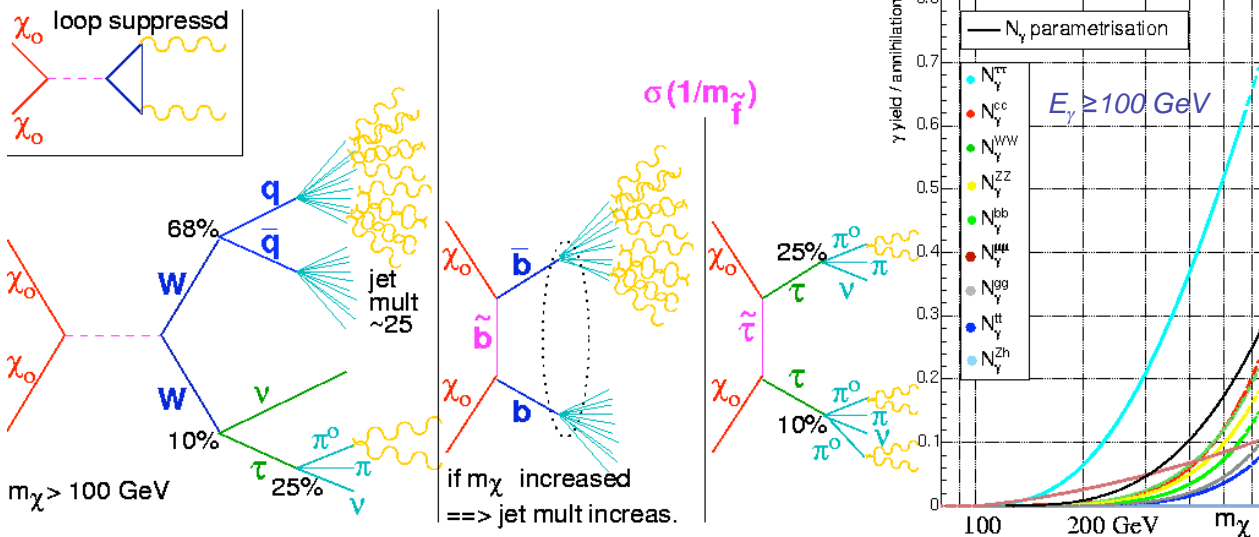
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VHE- γ from e.g. χ_0 -annihilation

χ_0 does not directly couple to γ (else not 'dark') ==>

Some important processes to produce VHE γ :



q-jets produce much more γ , but τ result in higher energy γ



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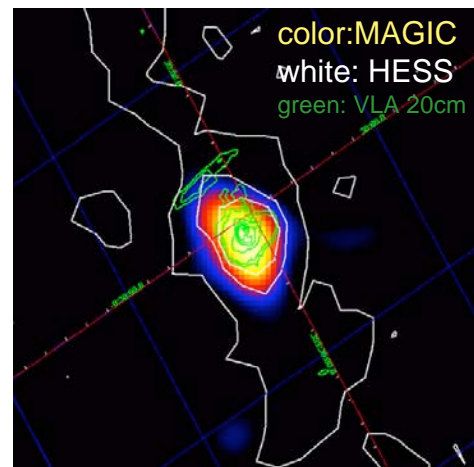
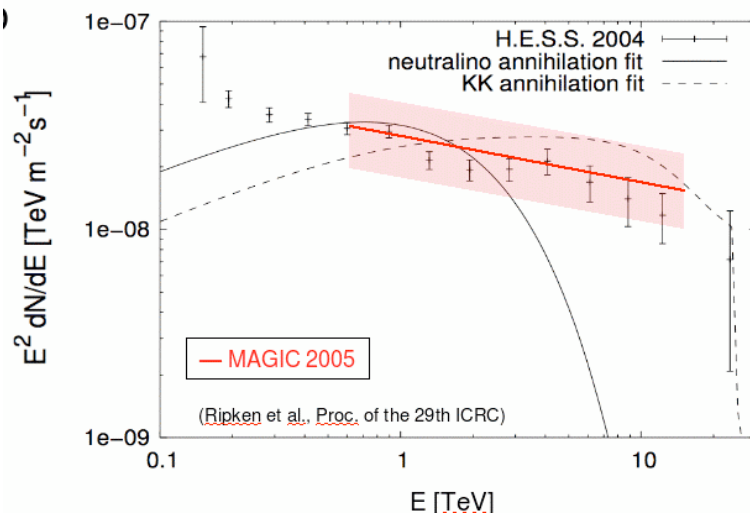
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Where to look for CDM ?

Galactic Center expected to be best candidate



Measurement from HESS, confirmed by MAGIC proof VHE dominated by unknown other source



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17.5' x 14.5'

Chandra X-rays

Object	Mass (M_{sun})	Distance	Ang. Size (vir rad/dist) (deg)	Optimum SNR (arb. units)	Optimum Aperture (deg)	Signal relative to GC (pt src)	Sensitivity requirement ($\text{erg cm}^{-2}\text{s}^{-1}$)
Minihalo	10^{-4}	0.5 pc	0.29	12	0.027	4×10^{-2}	2.3×10^{-13}
Dwarf Galaxy	10^8	75 kpc	0.15	5.8	0.020	1.1×10^{-2}	6.6×10^{-14}
GC	1.8×10^{11}	8.5 kpc	47	620	1.2	1.0	6.0×10^{-12}
Andromeda	1.8×10^{11}	730 kpc	0.48	5.6	0.034	2.7×10^{-2}	1.6×10^{-13}
Virgo Cluster	10^{14}	17 Mpc	0.39	1.5	0.034	0.6×10^{-2}	3.6×10^{-14}

J. Buckley, 2007

GC: bright; not accessible by MAGIC; strong foreground signal
 all other potential 'classical' sources: ~ 100 less DM signal

Andromeda/Virgo: prob. additional foreground signal (like GC)

Minihalos: no idea where to point at (need scanning)

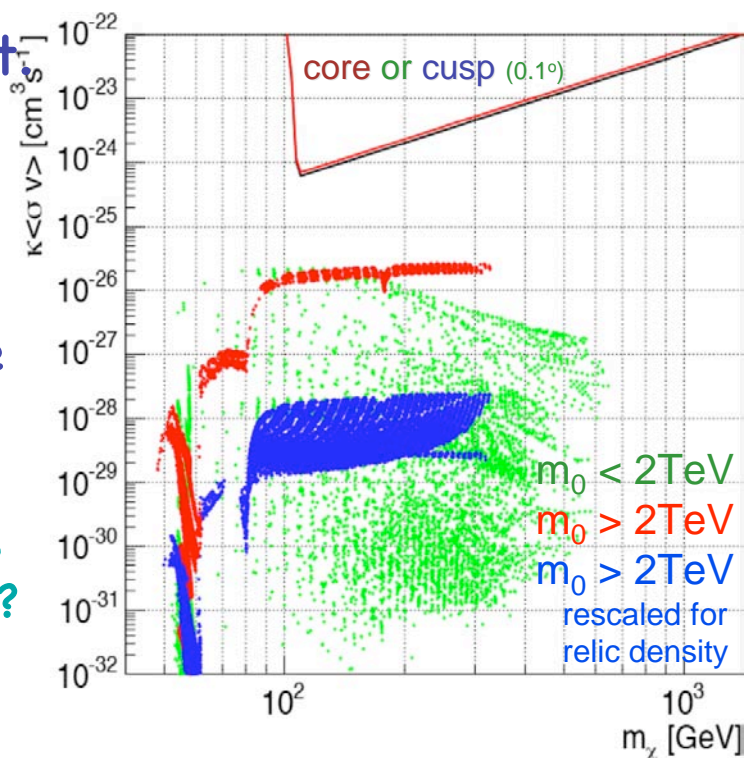


Dwarf Galaxies (DRACO)

predicted cross-section
 for possible SUSY
 parameters

line: 50h MAGIC
 \Rightarrow need looong time

boosting the flux by
 'clumpy' substructures
 by factor $< 10?$ $> 1000?$





Other Idea

Instead of observing known candidates, go for the dark...

CDM clumps could have high VHE flux, but very dim/invisible at long wavelengths (e.g. IMBH [Bertone et al. 2005])

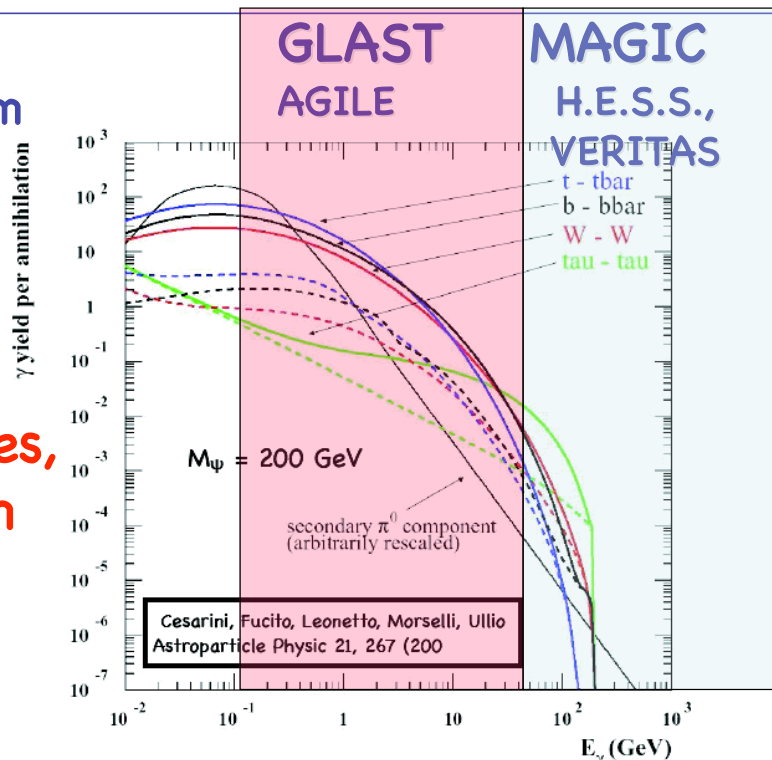
e.g. unidentified EGRET sources with hard spectrum could be good candidates... (and soon unidentified AGILE & GLAST sources)



Satellites measure position and spectrum in GeV range,

Telescopes search for cutoff energy

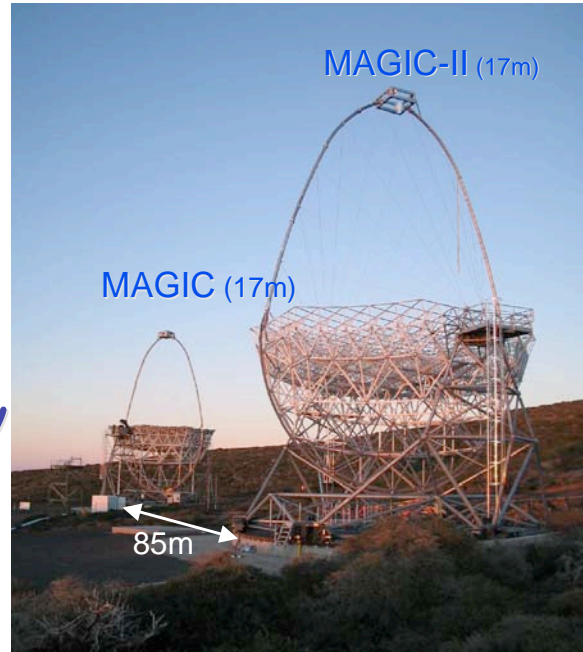
find several sources, universal spectrum = smoking gun !?!





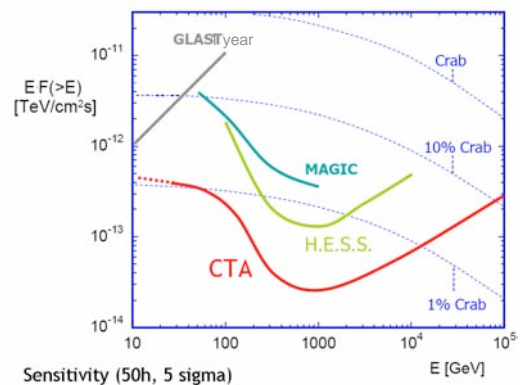
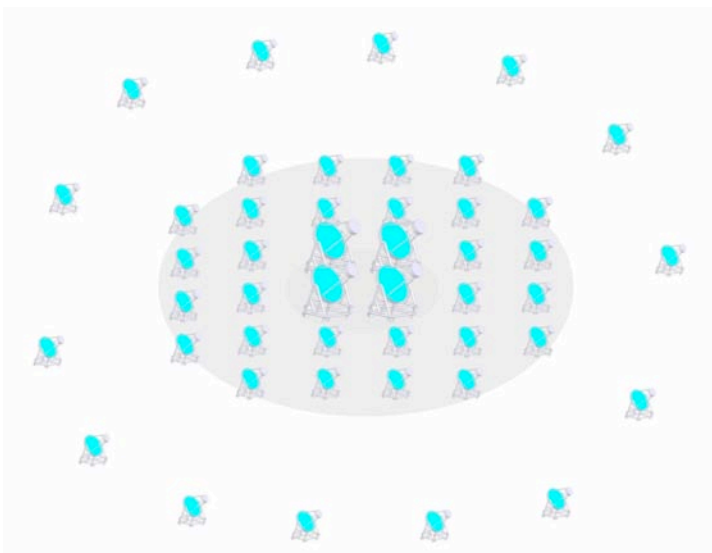
Outlook MAGIC

- MAGIC data-taking (and analysis) going on
- construction of 2nd telescope started (same size; some improvements) ==> stereo observations gain factor >2 sensitivity (goal: start operation mid 2008)
- also: HESS (HESS-II), VERITAS



and beyond MAGIC

- Goal: factor ~10 sensitivity extended Energy range ==> HESS/MAGIC combined working groups



100GeV--10TeV:
'just build more telescopes'
(must reduce price/telescope)

extended Energy:
need some R&D ...



CTA Physics

'Guaranteed' Physics in 100GeV-10TeV domain:

- ~1000 galactic sources (SNR, Plerions, Binaries, ...)
- many AGNs
- surprises

+ Cosmology and Fundamental Questions:

Pop-III stars, **Cold Dark Matter**, Quantum Gravity, ...

+ chemical composition of charged CR (up to knee ???)

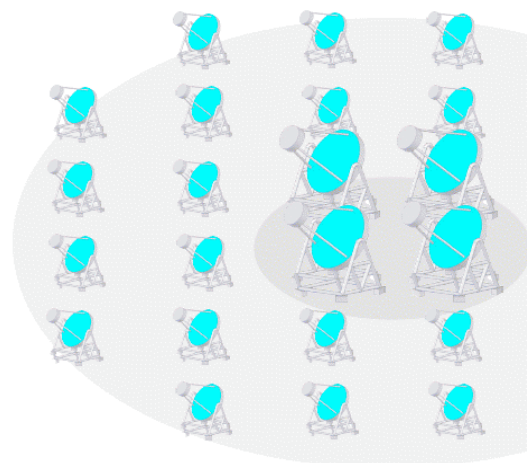
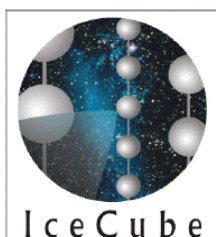
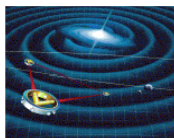
HESS/MAGIC/VERITAS: run as Experiment/Collaboration
private data, collab. publications

CTA: run as Observatory: guest observers (+core program)
data become public domain ???!!!!???



CTA fits into Future Multi-Wavelength and Multi-Messenger Environment

important
for CDM...





CTA Status

pan-european project ~150M€ ?!

APPEC: high priority project on 'preliminary road map'
ESFRI: promising 'emerging project' (not yet on roadmap)

FP7:

- LoI in preparation
- first **public** meeting 1.&2. March 2007 in Paris (several MAGIC/HESS meetings since Feb. 2006)
>300 physicists claimed interest to contribute
<http://www.mpi-hd.mpg.de/hfm/CTA>
- **request for FP7 design study submitted (May 2)**

comparable study/project exists also in the US: 'AGIS'



Conclusion

very interesting time for VHE-Astronomy
(and important for indirect CDM searches) ...

stay tuned !!!