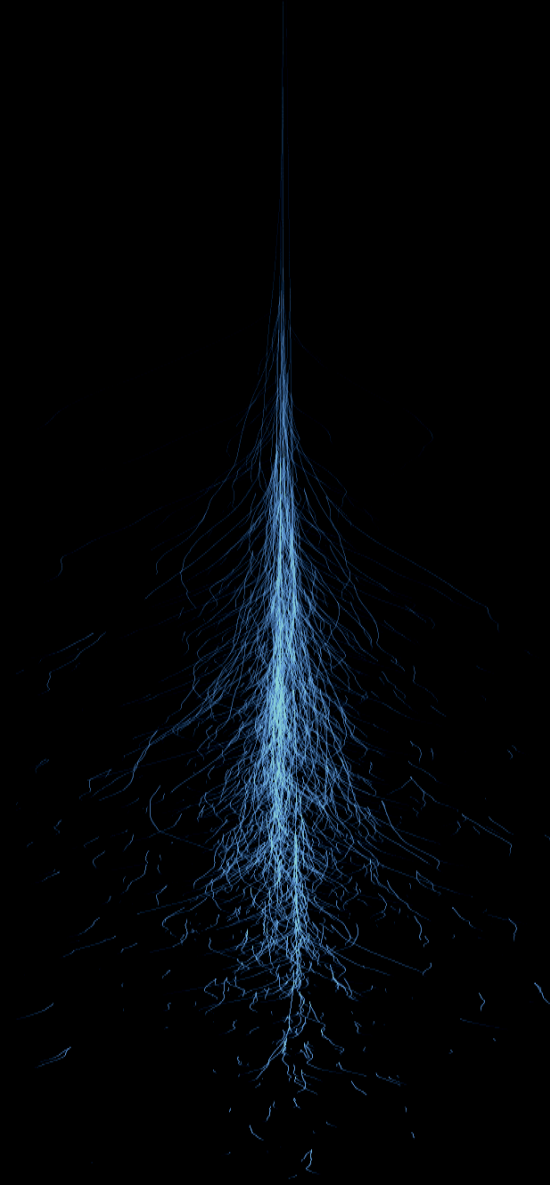
MAGIC Telescopes
- Status and Results

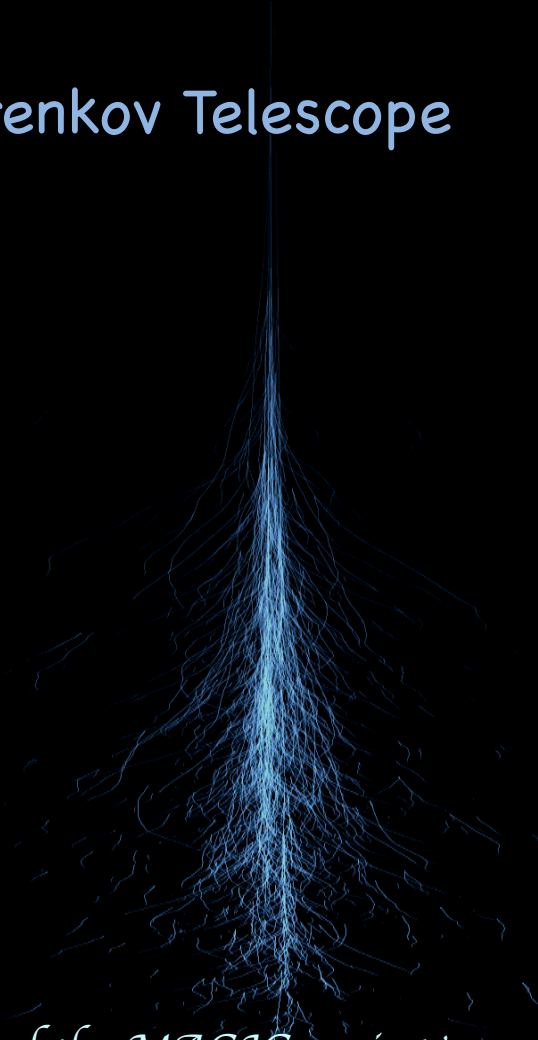
Isabel Braun
Institute for Particle Physics, ETH Zürich
for the MAGIC Collaboration



ETH Institute for Particle Physics

CHIPP Plenary Meeting 2009, Appenberg

Major Atmospheric Gamma-Ray Imaging Cherenkov Telescope



„The story of the MAGIC project is a textbook example of the merging of particle physics and astronomy into the modern field of astroparticle physics."

Major Atmospheric Gamma-ray Imaging Cherenkov Telescopes

Mirrors:

- 2 x 17m (234m^2), f/d=1
- parabolic shape
- formed from 964 / 247 spherical mirrors

total weight: ~65 t each
fast repositioning

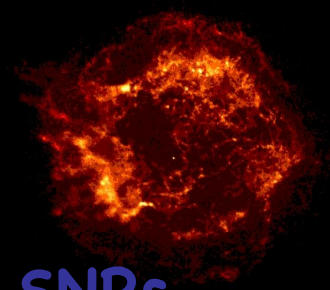
Cameras:

- 576 / 1039 PMTs,
- FoV = 3.5° ,
- observation possible with moon above horizon ==> gain ~50% observation time

angular resolution O(0.1°)
lowest Trigger Threshold:
50 GeV (M1)

Scientific Pillars

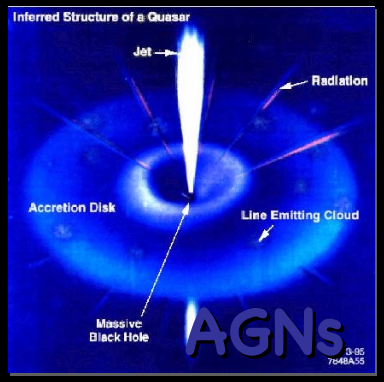
Galactic



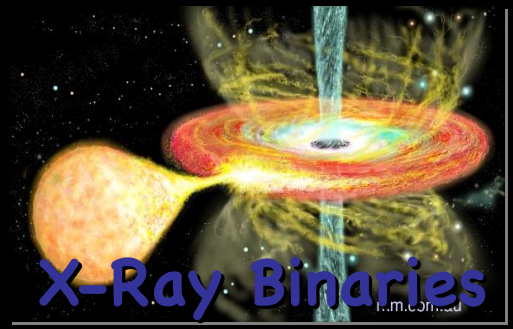
SNRs

Pulsars/PWNs

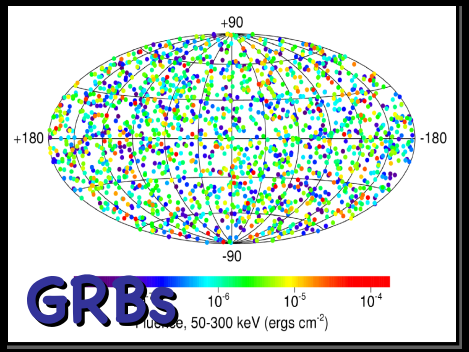
Extragalactic



AGNs



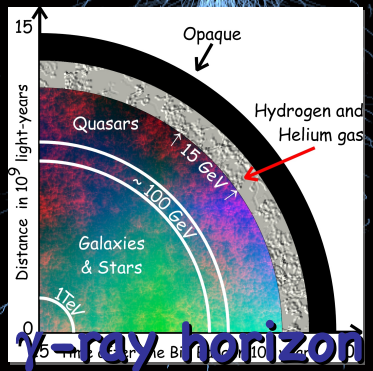
X-Ray Binaries



GRBs

Fundamental/ Cosmology

Dark Matter



γ-ray horizon

+ Quantum gravity, Cosmic Rays...

MAGIC science paper presented @ last year's meeting:

Very high energy gamma rays from a distant Quasar: How transparent is the Universe?
MAGIC Collaboration, Science 320 (2008) 1752

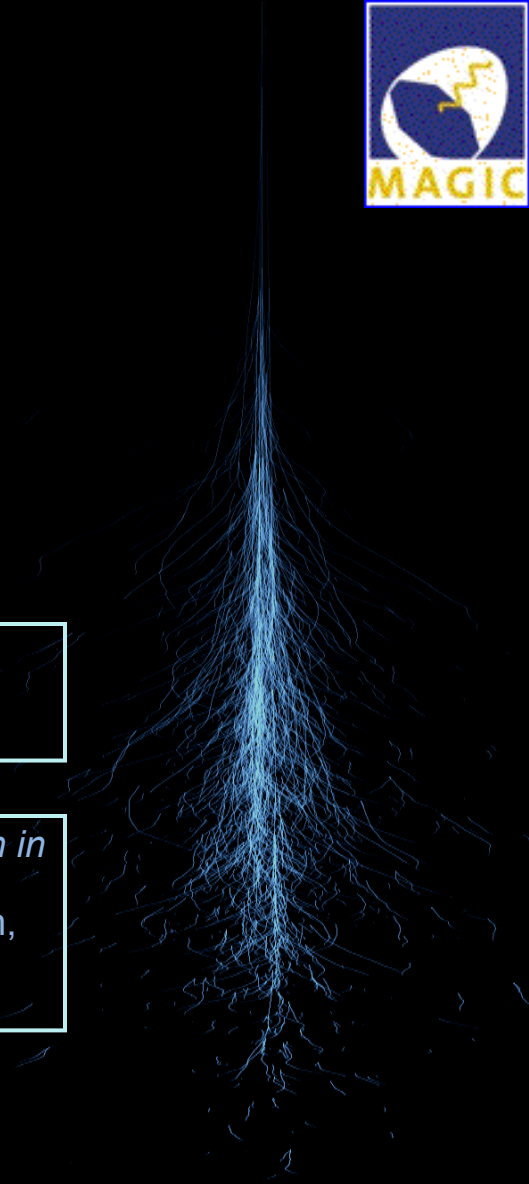
MAGIC since the last CHIPP meeting:

17 MAGIC publications in Refereed Journals
+ 1 accepted, 1 submitted, more in preparation..

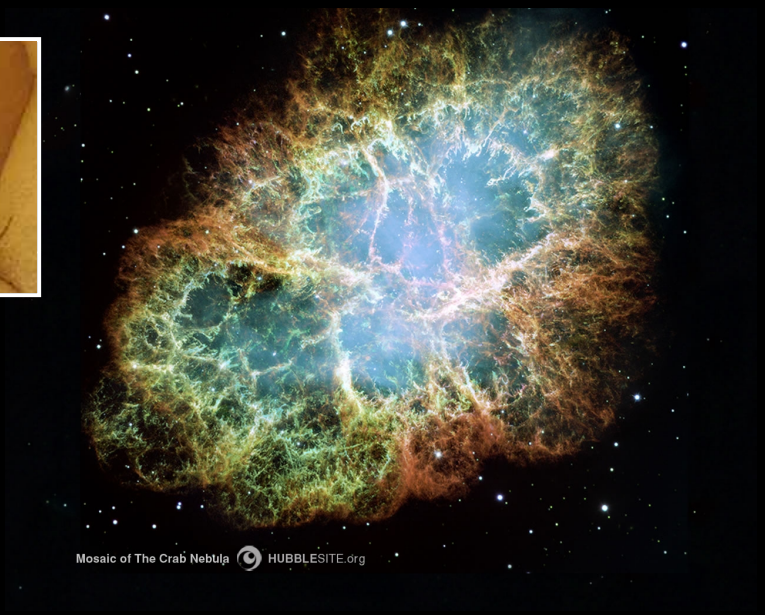
including 2 more in the "Science" Magazine:

- *Observation of Pulsed gamma-Rays Above 25 GeV From the Crab Pulsar with MAGIC*
  MAGIC Collaboration, Science 322 (2008) 1221

- *Radio Imaging of the Very-High-Energy gamma-Ray Emission Region in the Central Engine of a Radio Galaxy*
  The VERITAS Collaboration, the VLBA 43 GHz M 87 Monitoring Team, The H.E.S.S. Collaboration, The MAGIC Collaboration
  Science 325 (2009) 444-448



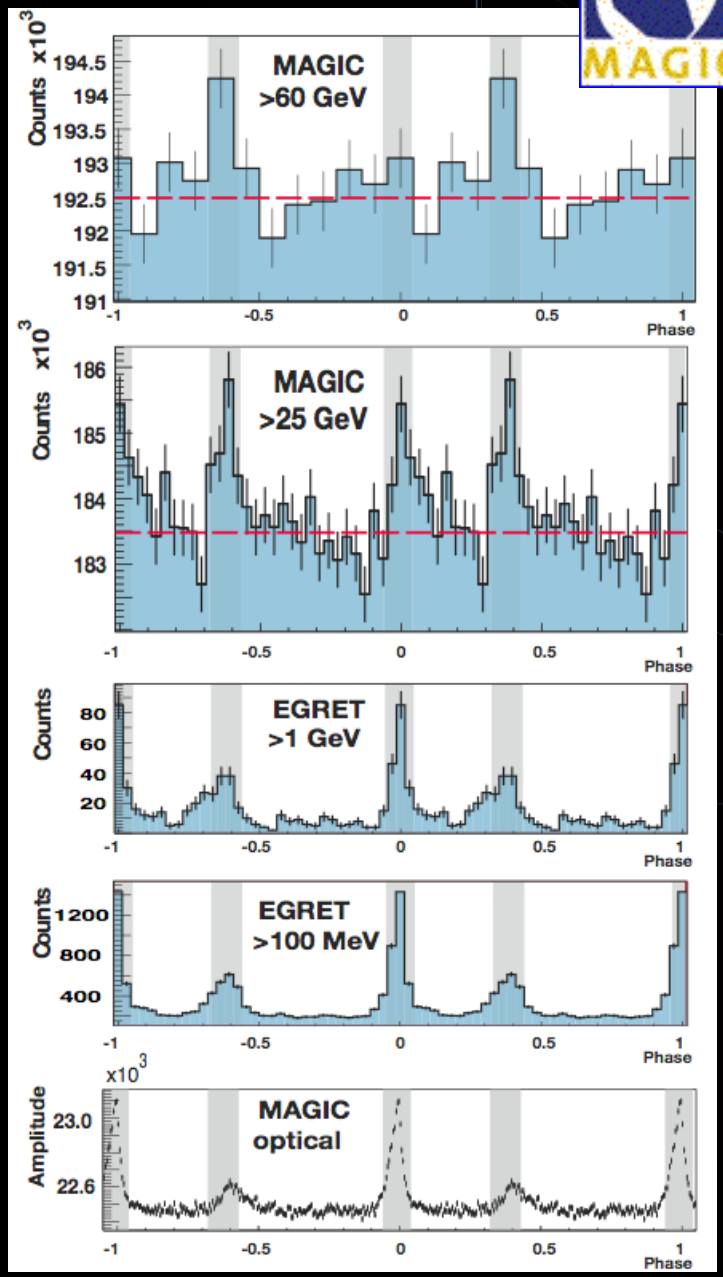
Galactic Highlight: The Crab Pulsar



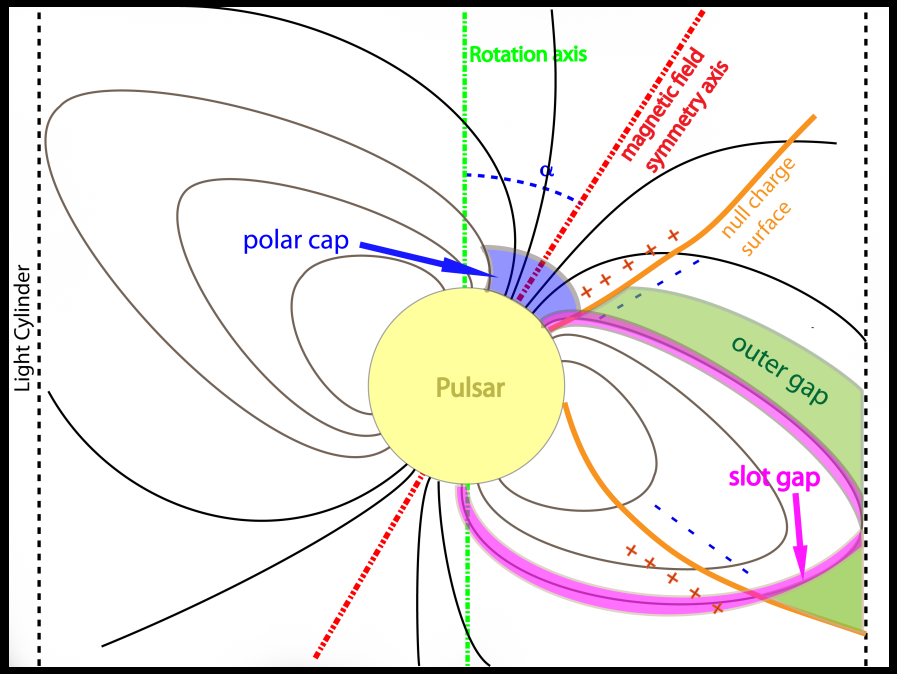
Whipple 1989:
First VHE source detected, continuous - Crab nebula

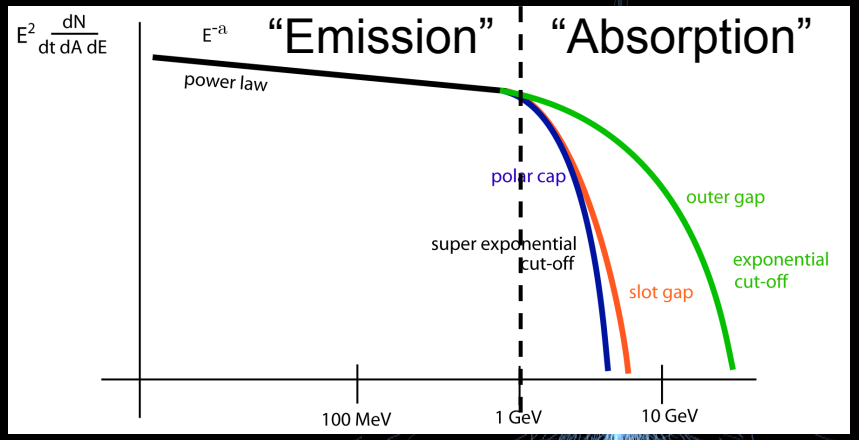
MAGIC 2008:
First detection of pulsed γ Rays > 25 GeV

cut-off offers possibility for cross-calibration with Fermi



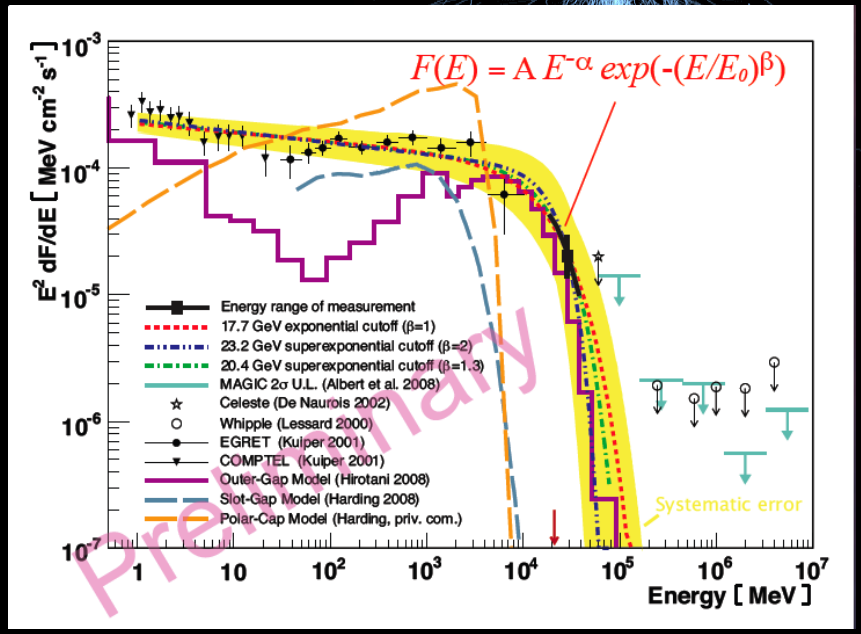
The Crab Pulsar - Implications





25 GeV threshold for pulsed emission (new trigger + phase information)

cutoff -> lower limit of 6 stellar radii
-> polar cap excluded,
slot gap challenged



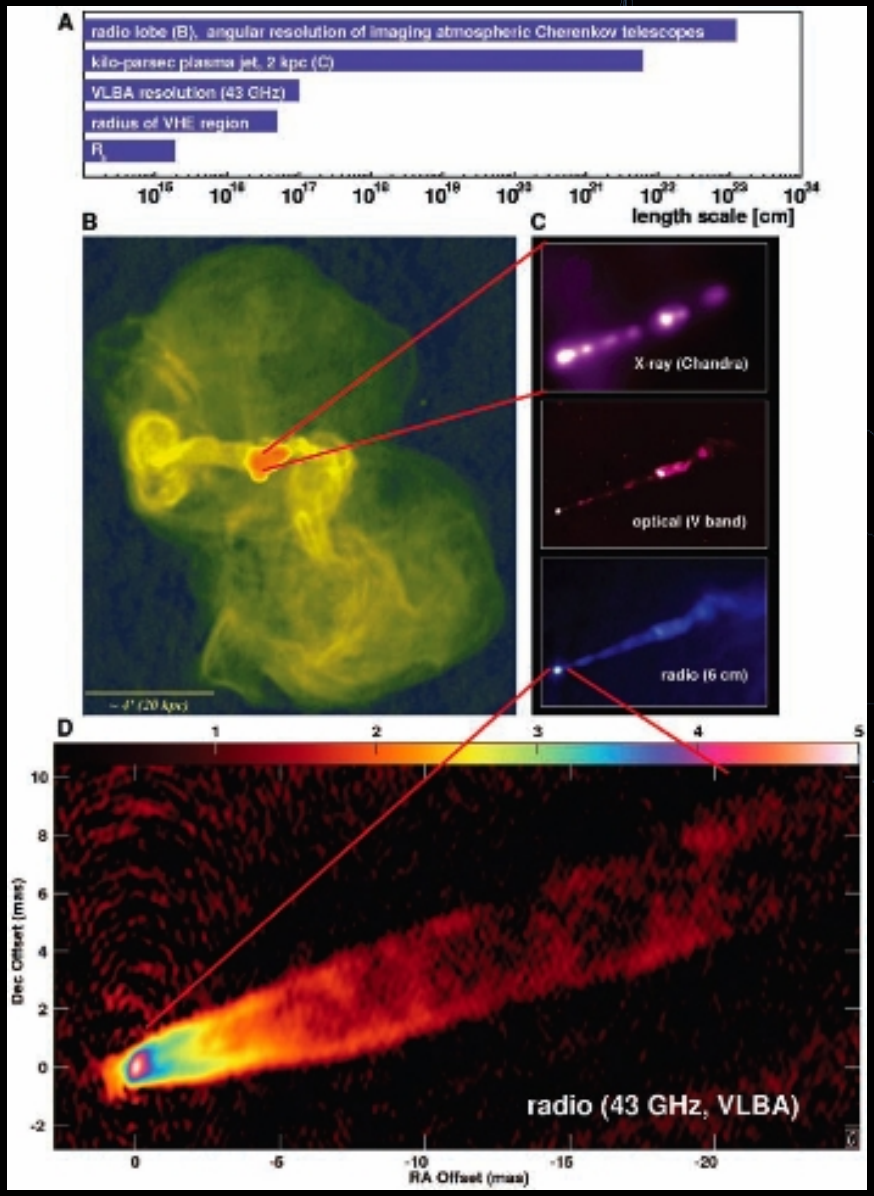
Extragalactic Highlight: M87

Giant Radio Galaxy (FR-1)
Virgo Cluster
very close: 16.7 Mpc away
SMBH: ~6 · 10^9 solar masses
angle jet - line of sight: 15 - 25 deg

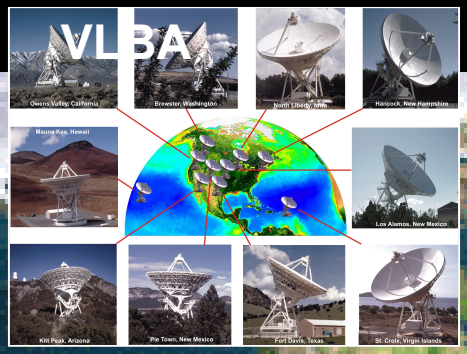
HEGRA 1999:
first indication for VHE emission
for a long time the only RG in VHE

interpreted as ‘misaligned blazar’

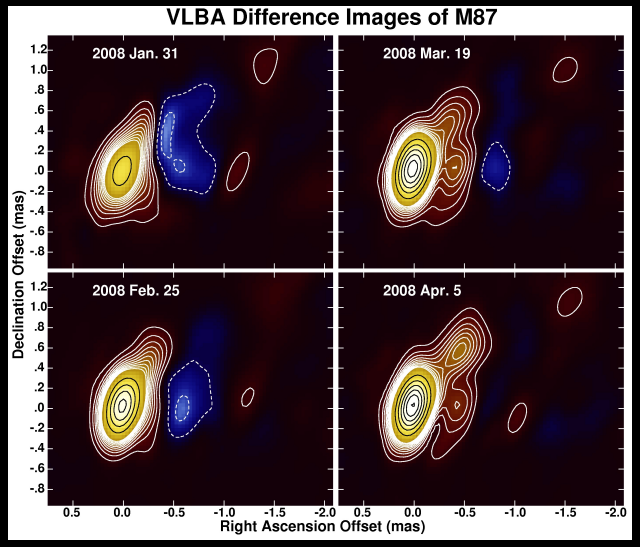
H.E.S.S. 2006:
variability years - 2 days
constrains emission region

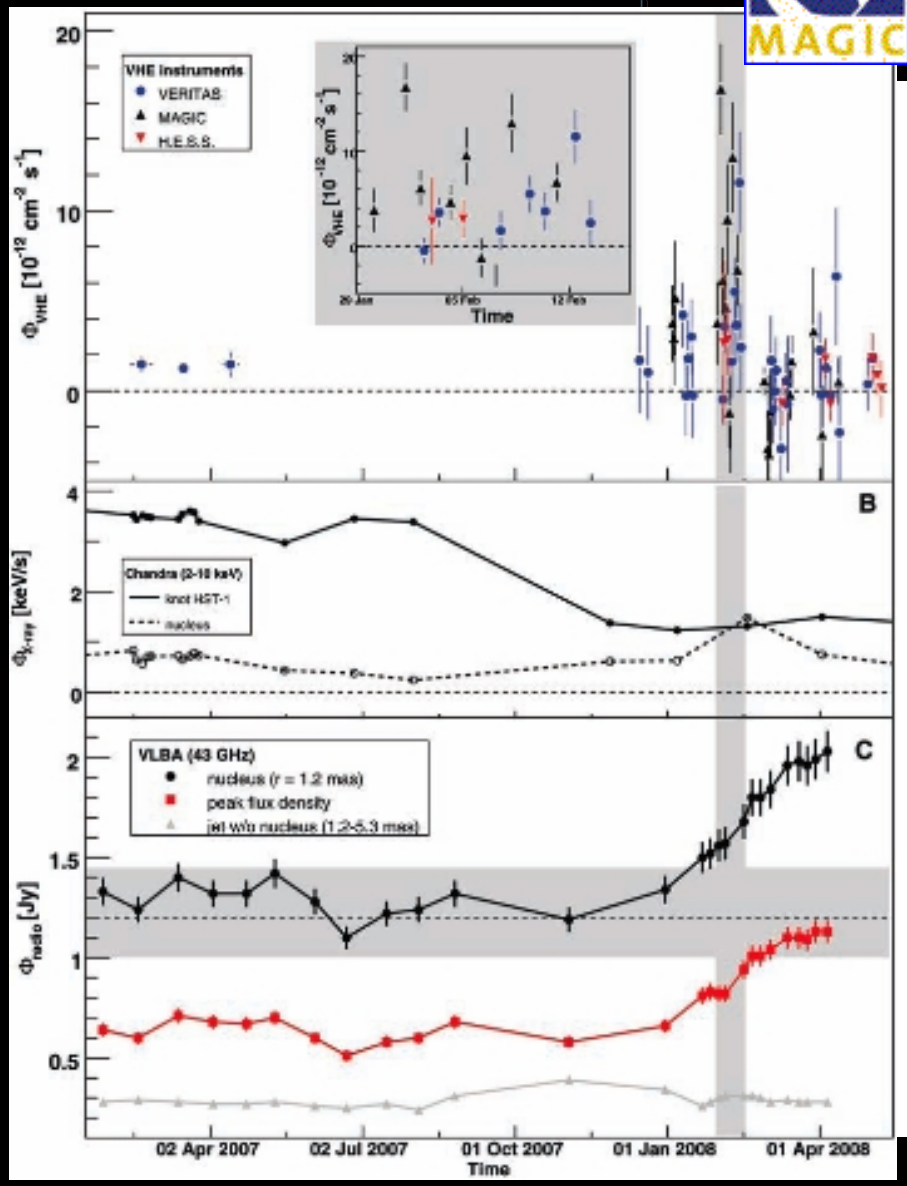


„M87 Collaborators"



Extragalactic Highlight: M87





Huge flare in 2008
-> MAGIC triggered follow up observations

<1d variability timescales above 350 GeV

VLBA sees high state of core,
Chandra sees low state of HST 1

->indicates TeV emmission from central region of M87!

MAGIC Instrumentation 2009:

- Drive upgrade

- 2nd MAGIC telescope inaugurated April 25th 2009!!
  (ETH contribution: Active mirror control)

- MAGIC -II DAQ based on DOMINO chip from PSI

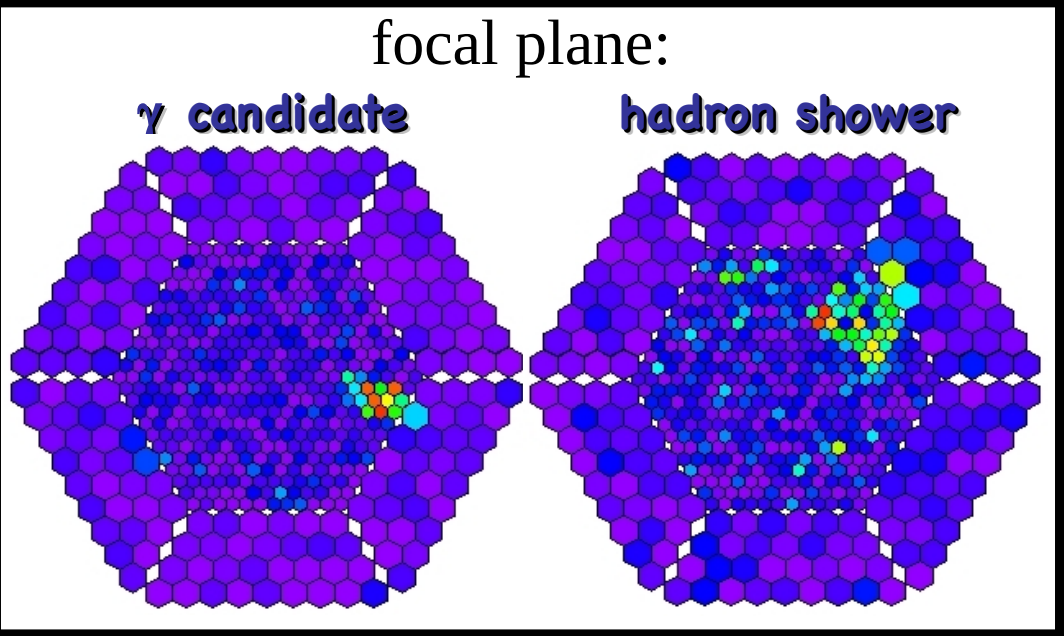
gain more than just duplication...

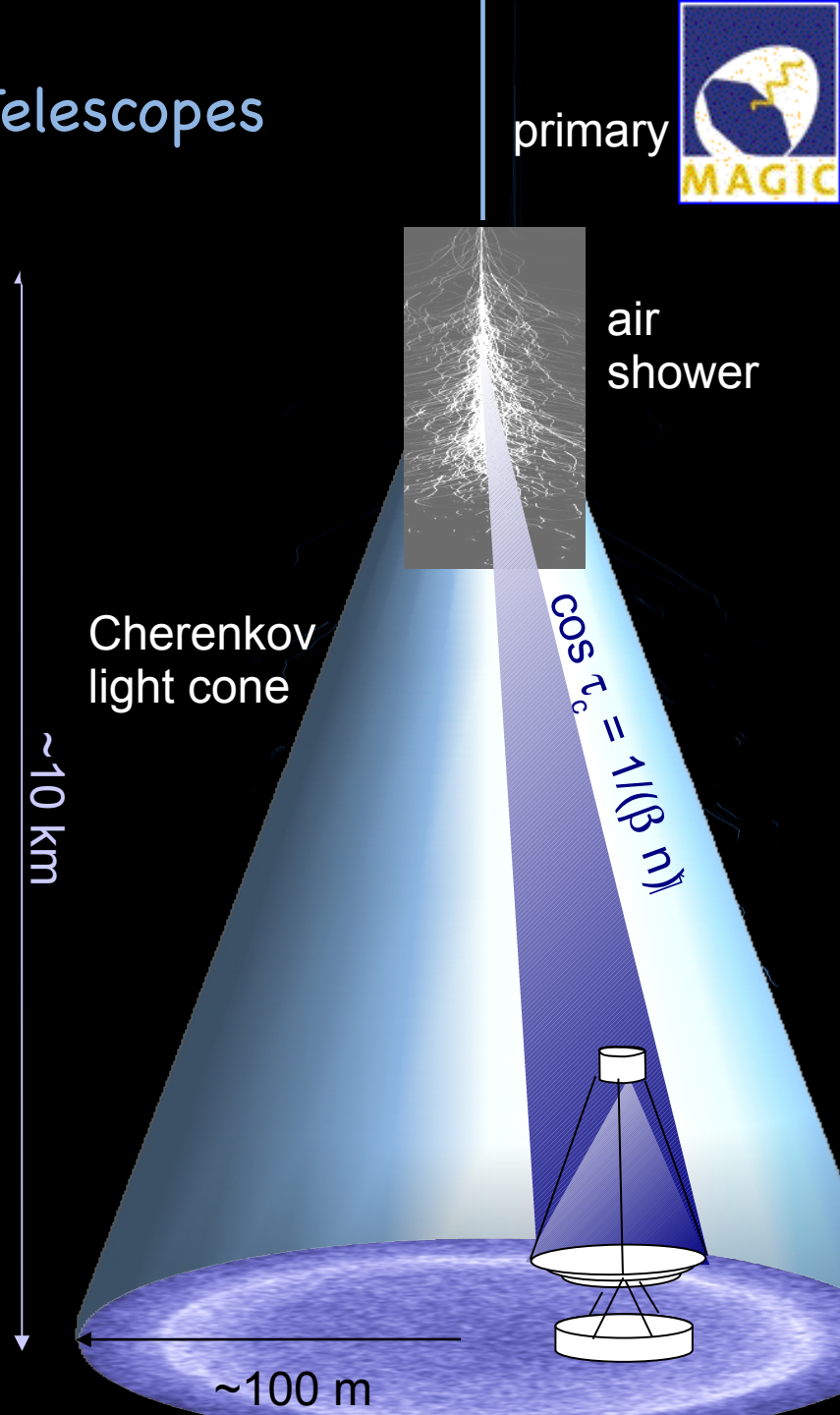
Imaging Atmospheric Cherenkov Telescopes

huge detection area (~ 10^5 m^2)
compared to satellites (~1 m^2)

but: faint (~100 γ_c / m^2) and fast (few ns)

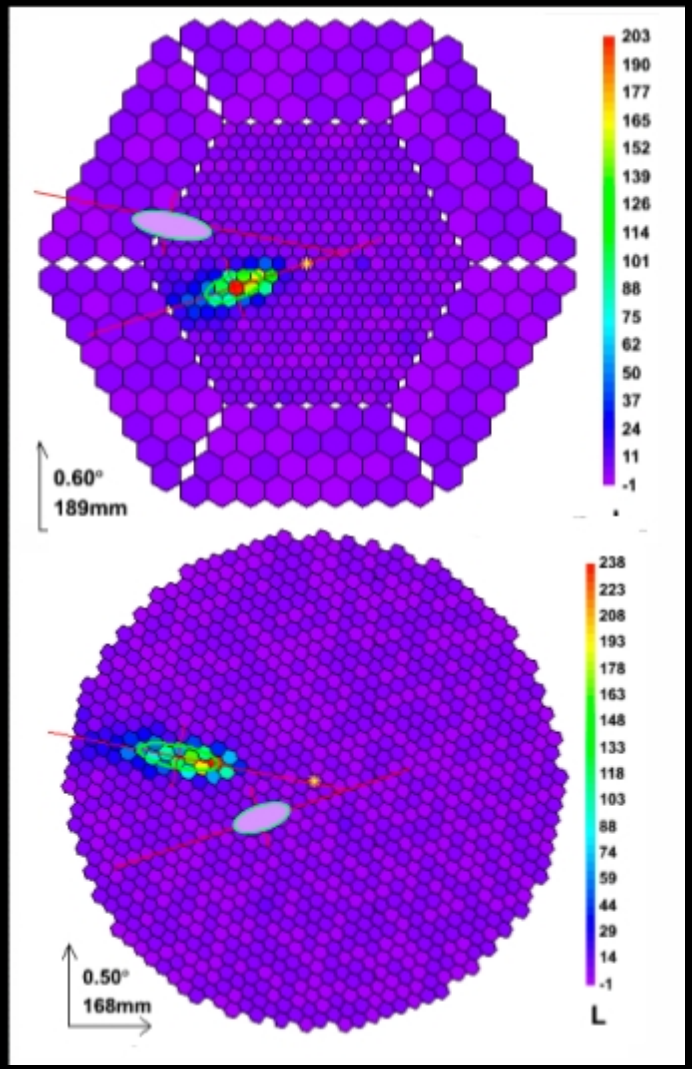
background: isotropic Cosmic Rays (x 10^4 !)
*-> **imaging** telescopes*

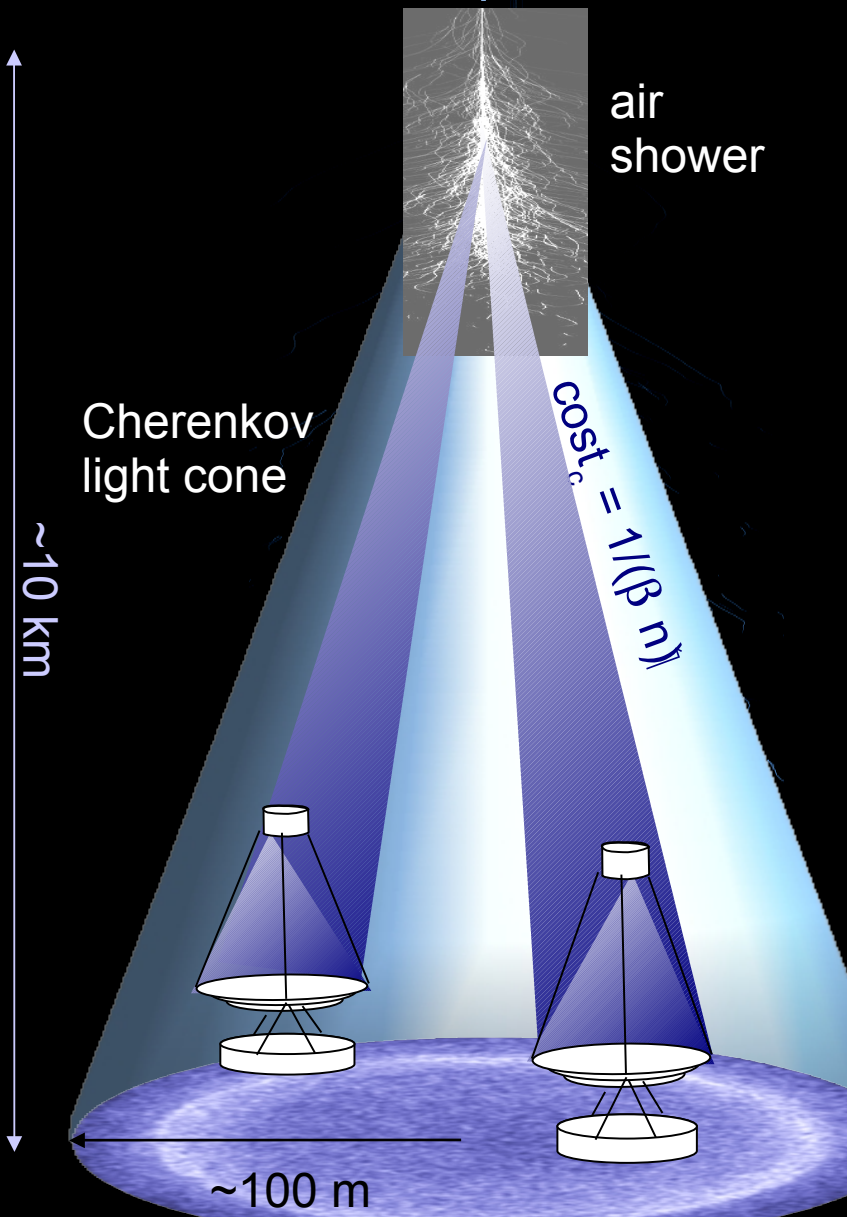




Imaging Atmospheric Cherenkov Telescopes

primary



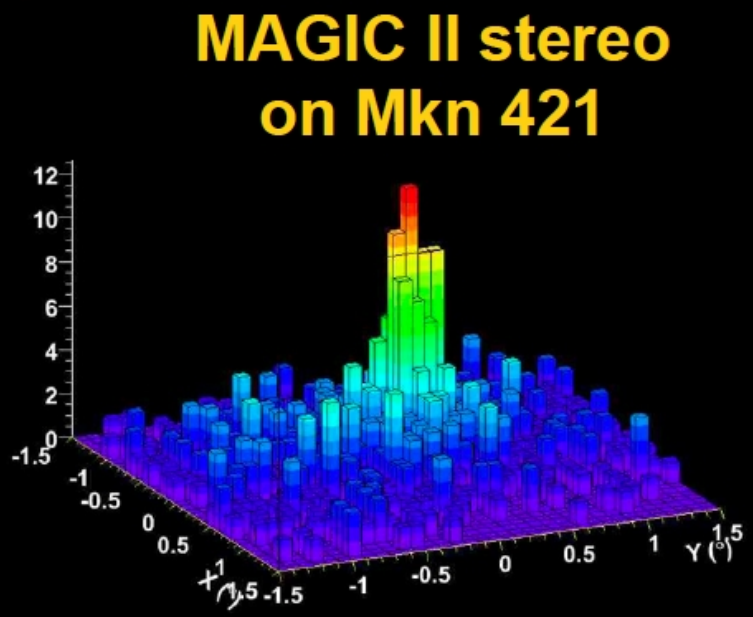


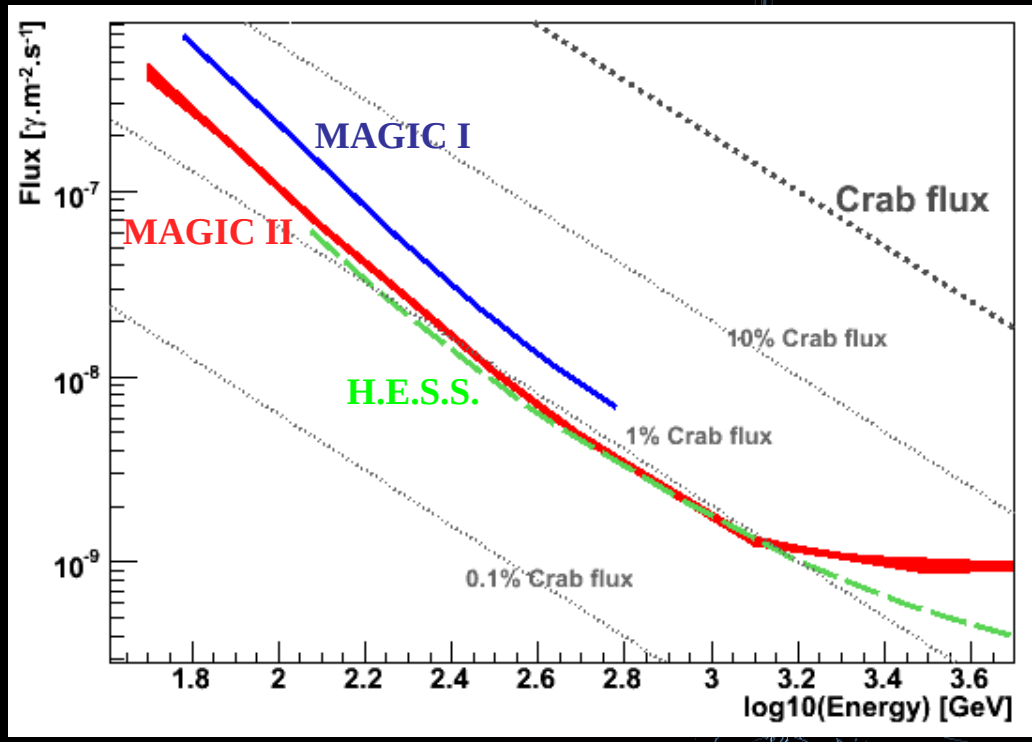
Stereo Summary

improved angular resolution (~30% better)

improved energy resolution (25% -> 15%)

improved sensitivity (by factor of 2-3)





regular stereo observations starting October 2009

Summary

Science Highlights last year:

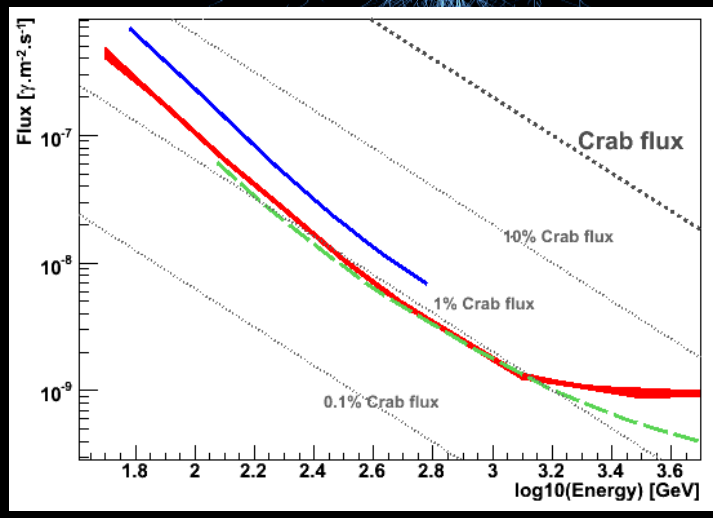
- Pulsars Physics: pulsation to > 25 GeV => indicates emission further away from central object

- Extragalactic Physics: M87 => indicates emission from close to the central BH

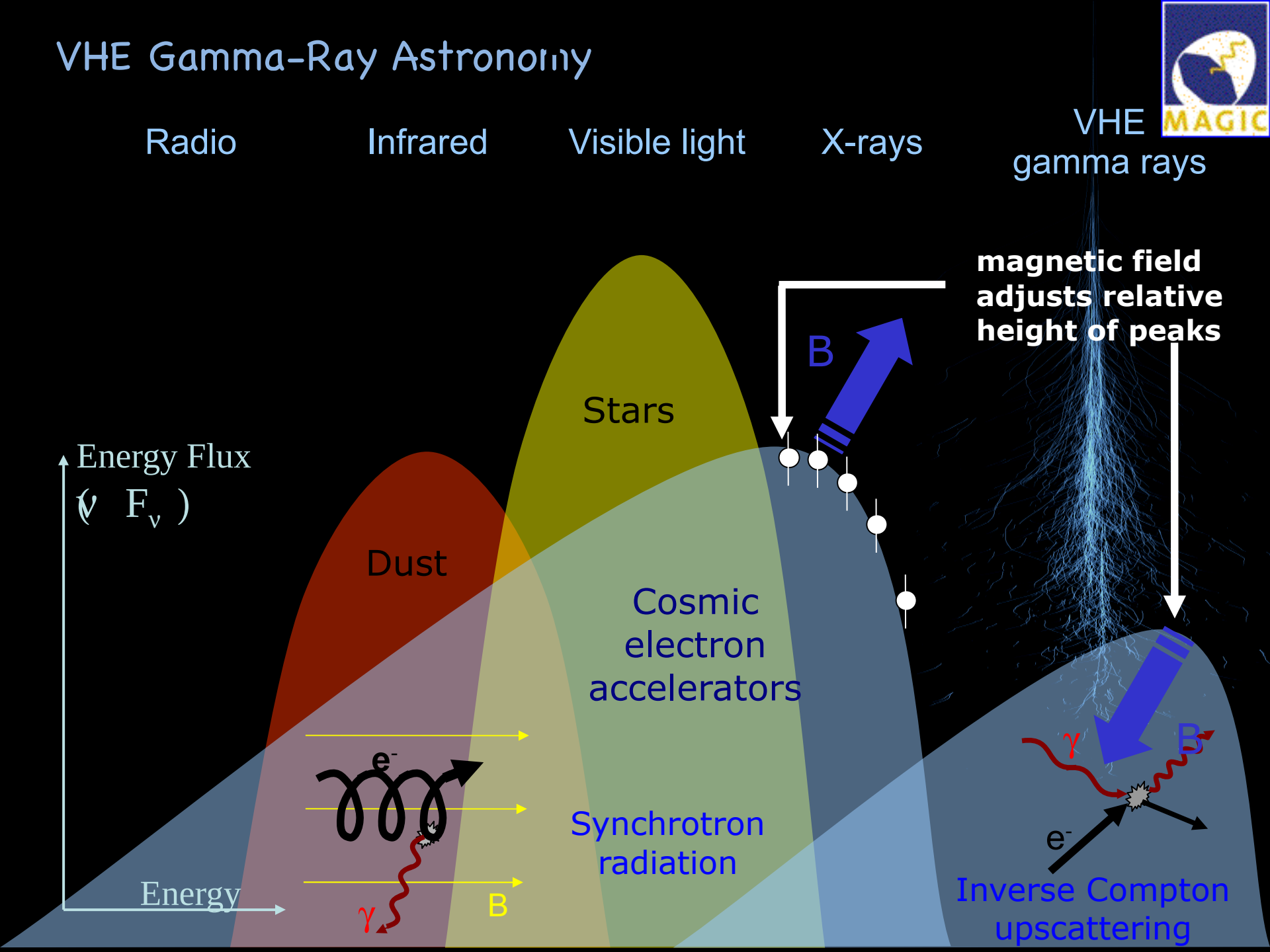
MAGIC II:

all hardware installed,
end of commissioning phase,
first signal detected,
unrivalled sensitivity below 200 GeV

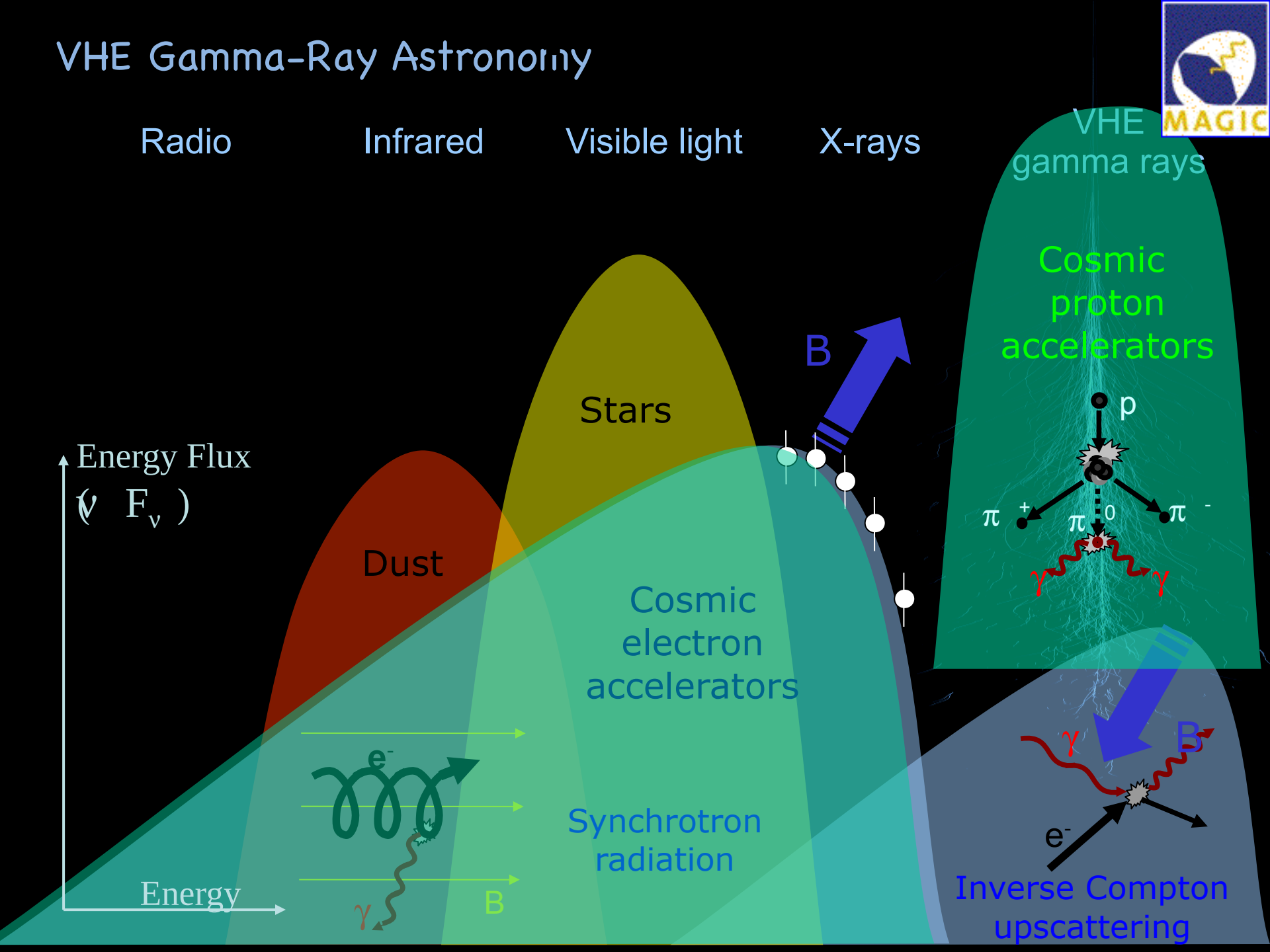
Interesting times ahead!



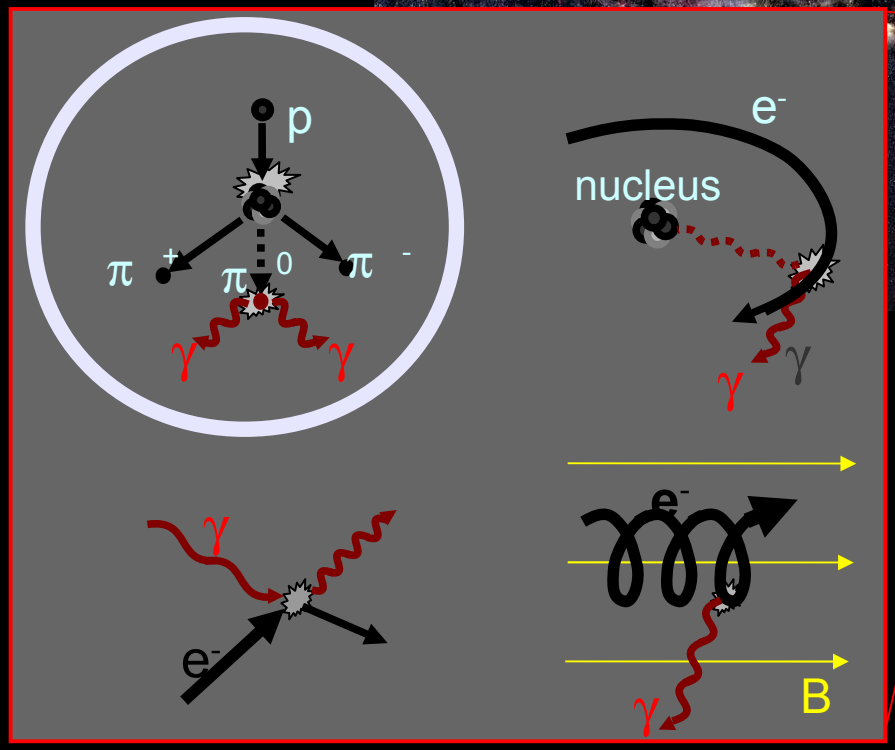
VHE Gamma-Ray Astronomy

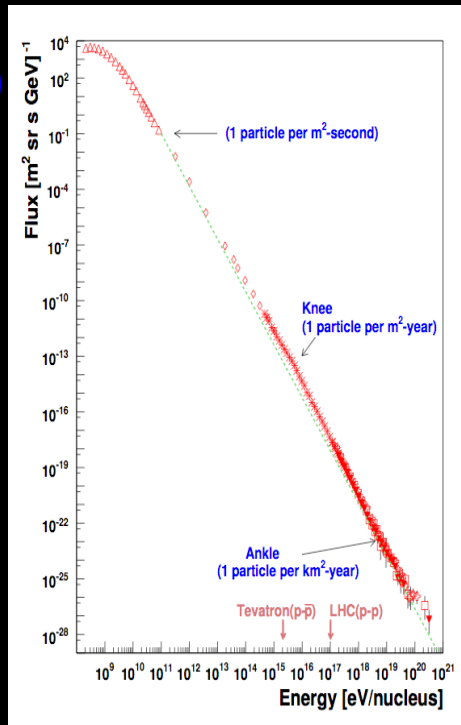


VHE Gamma-Ray Astronomy



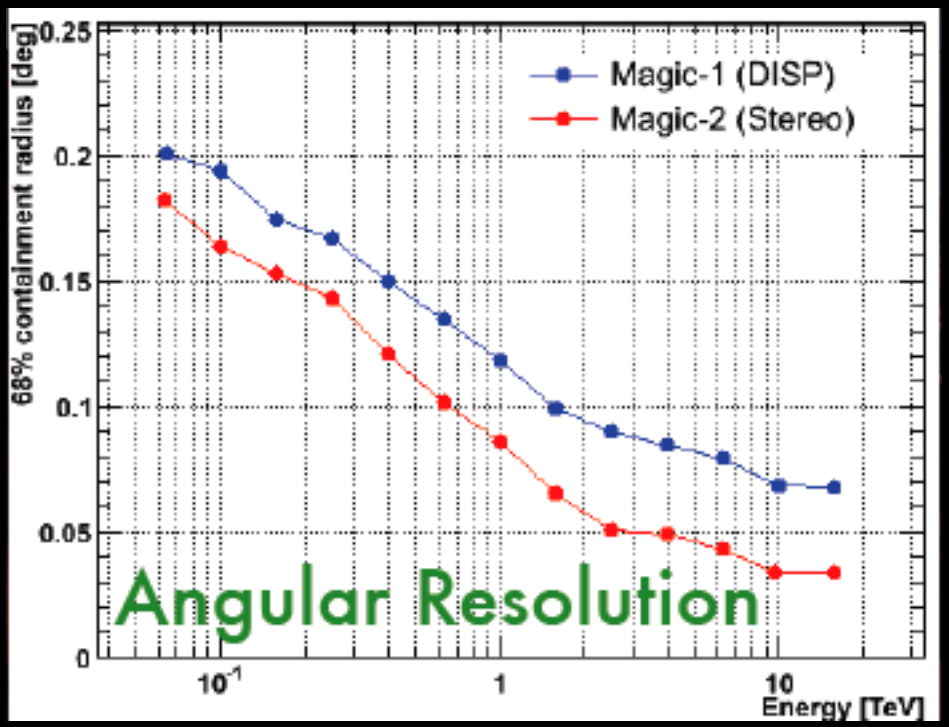
Original Question: Origin of Cosmic Rays

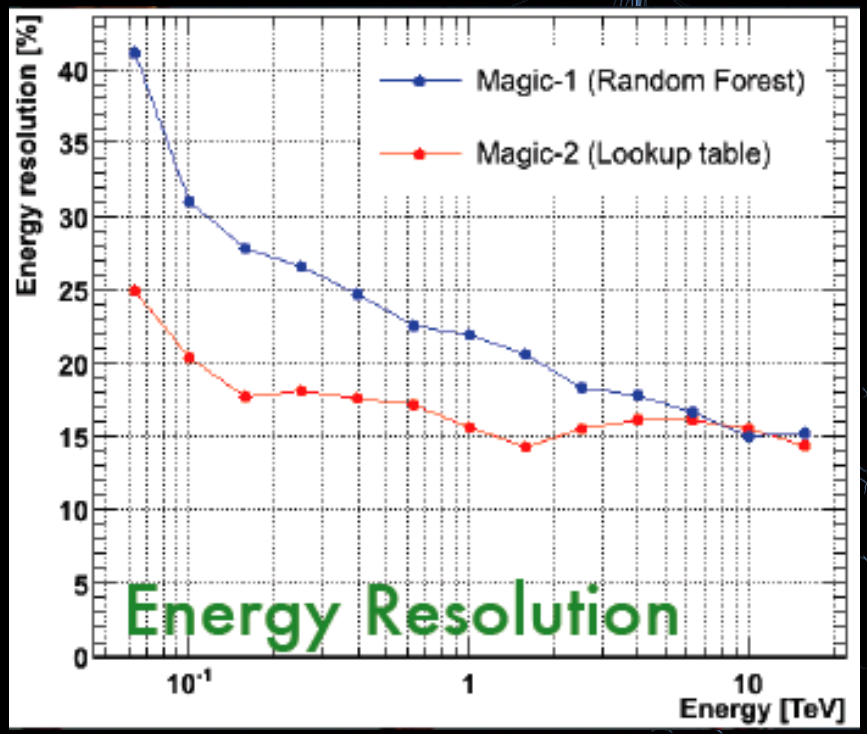




energetic particles +
"something" (matter/photons/fields) -> γ-rays

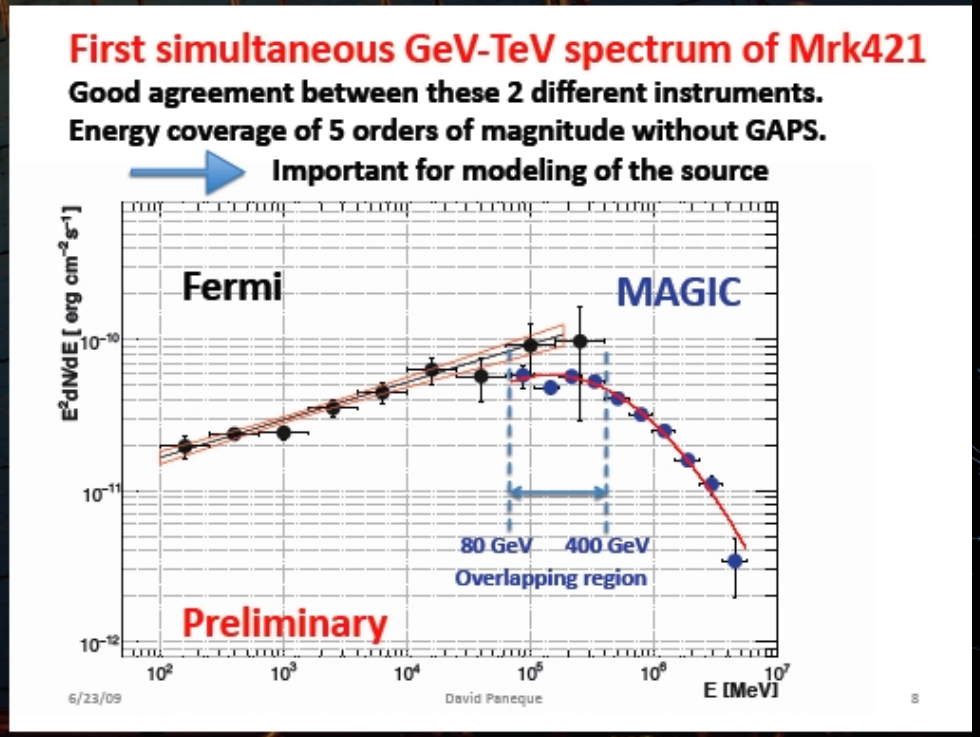
Stereo Simulations





Mkn 421: First combined spectrum: Fermi and MAGIC

- 10 day multiwavelength campain Jan 20 - May 31, 2009
- Radio:OVRO, Effelsberg, Noto…
  Infrared: WIRO,
  Optical: GASP, GRT, MITSuMe…
  X-ray: Swift, RXTE
  Gamma-ray: Fermi
  VHE: MAGIC, VERITAS
- Spectra fit within a factor two !
  (Bins are not exactly time-coincident because Fermi observes 24h)



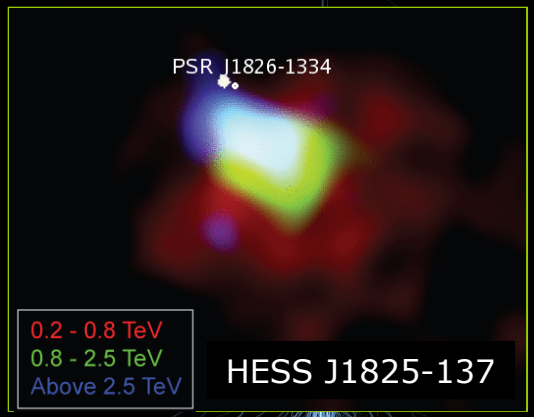
Just Scratching More Galactic Science...

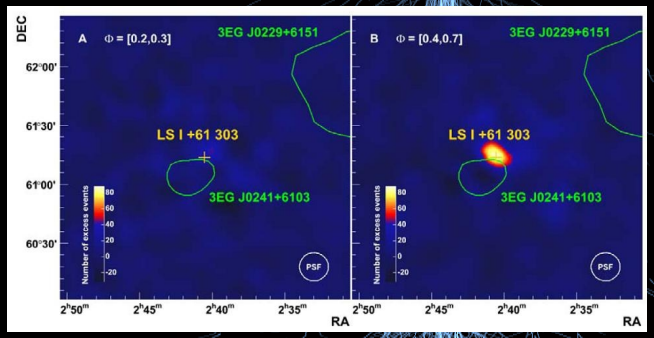
-Majority of sources: Pulsar wind nebulae
-> population studies, energy dependent morphology..

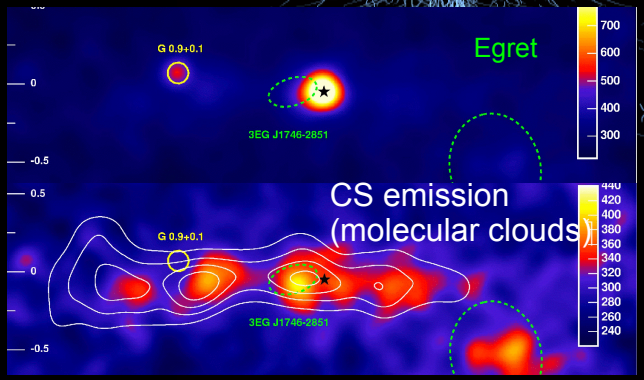
-X-Ray binaries:
-> emission modulated with orbital periodicity,
phase dependent spectra..

-Molecular Cloud near the Galactic Centre:

-"Dark" sources...

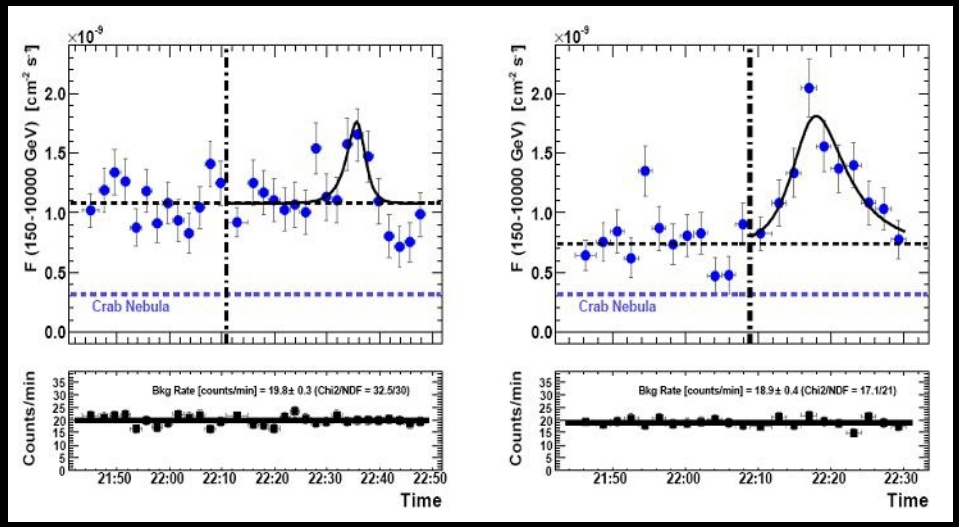




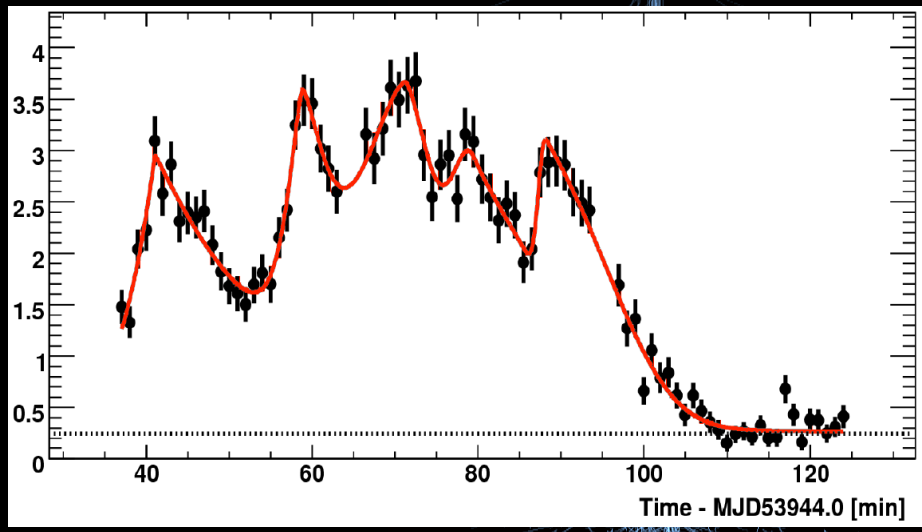


Rapid Variability

MAGIC on Mrk501



HESS on PKS 2155-304

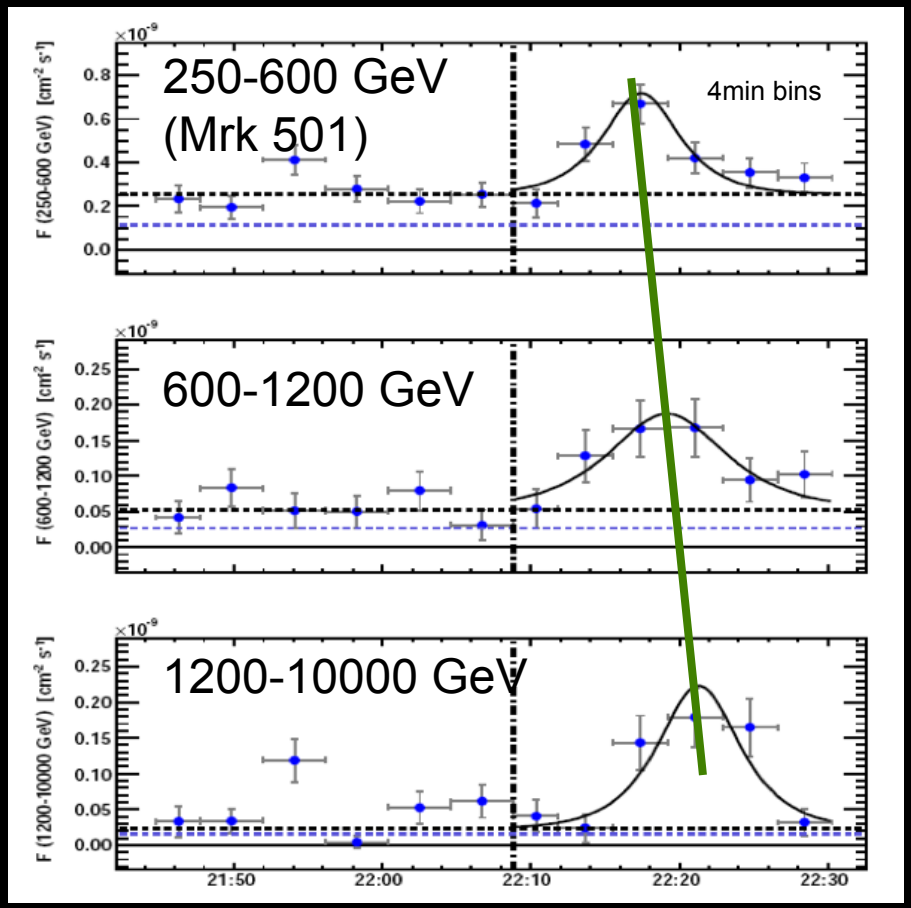


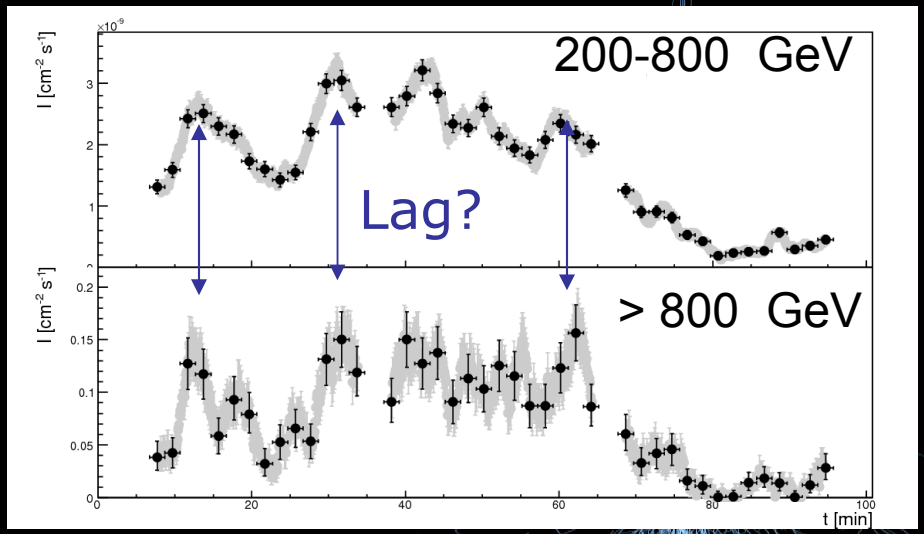
VHE flares on min timescales

-> small emission region

AGN jet sizes >10^5 Ly

Flaring Active Galactic Nuclei





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

[astro-ph/0702008]

[astro-ph/0810.3475]

Probe for Quantum Gravity

Some quantum gravity models predict effective energy dependence of c

$\Delta c/c = -E/M_{QG1}$ or $\Delta c/c = -(E/M_{QG2})^2$

-> need large distances & energy differences, but also timestamp

Assuming energy-independent emission time, dispersion caused by Quantum-Gravity effects:

- *Whipple for Mrk 421 (z=0.031):* $M_{QG1} > 4\ 10^{16}$ GeV

- *Magic for Mrk 501 (z=0.034):* $M_{QG1} \sim 0.4\ 10^{18}$ GeV *or 95% lower limits:* $M_{QG1} > 0.26\ 10^{18}$ GeV

- *H.E.S.S. in PKS 2155 (z=0.116):* $M_{QG1} > 0.72\ 10^{18}$ GeV

- *Fermi from GRB 080916C (z=4.35):* $M_{QG1} > 1.3\ 10^{18}$ GeV!!

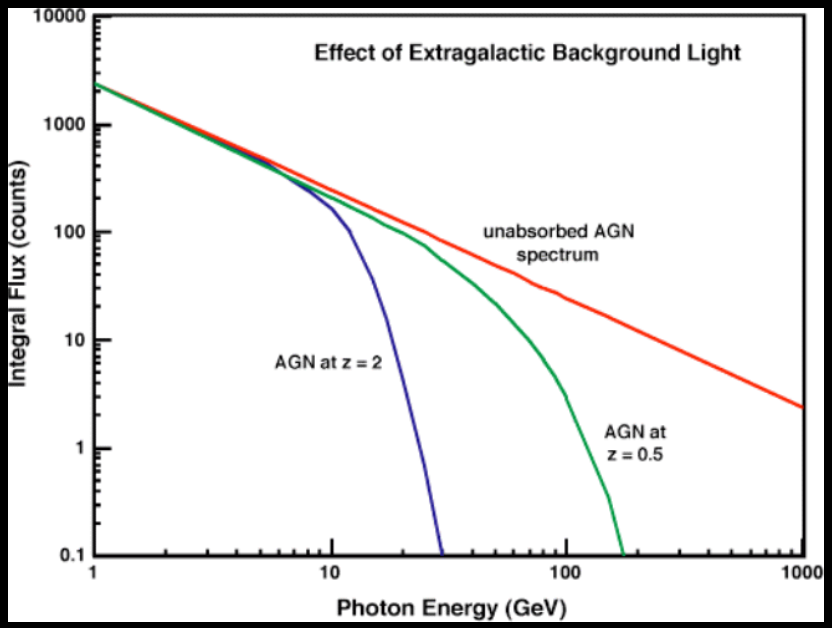
Source-intrinisc time shift -> lower limits would get higher!

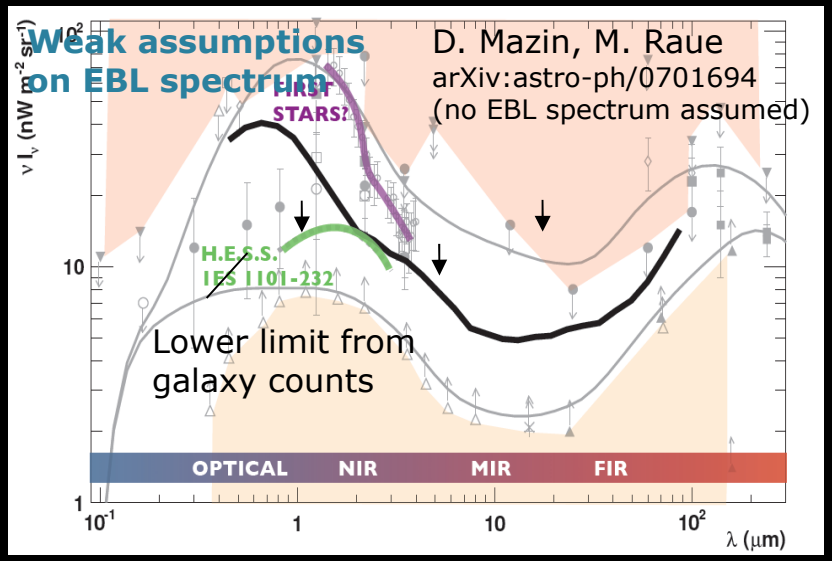
More sensitive instruments -> greater redshift -> smaller dt, larger dE -> improve limits

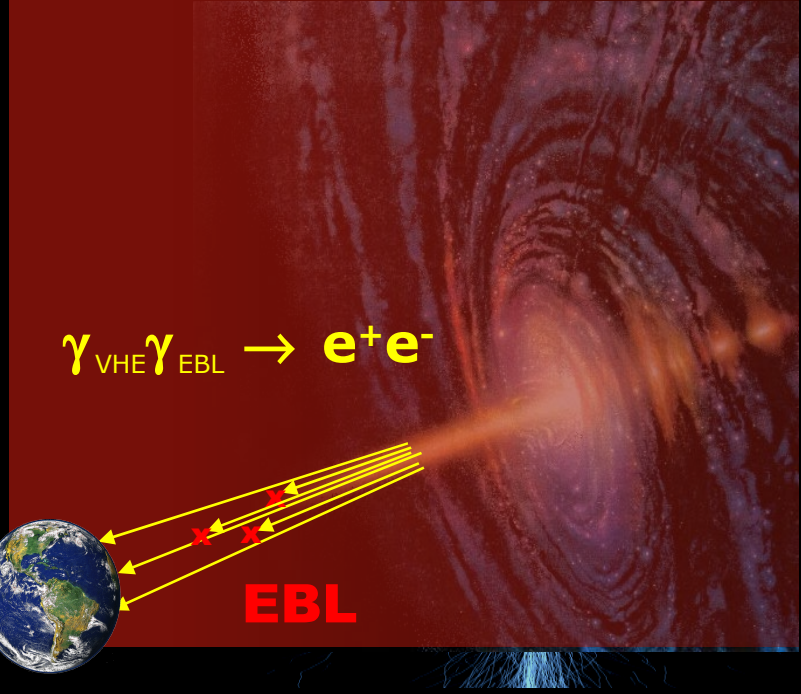
Collect more statistics - of one source for consistency of results

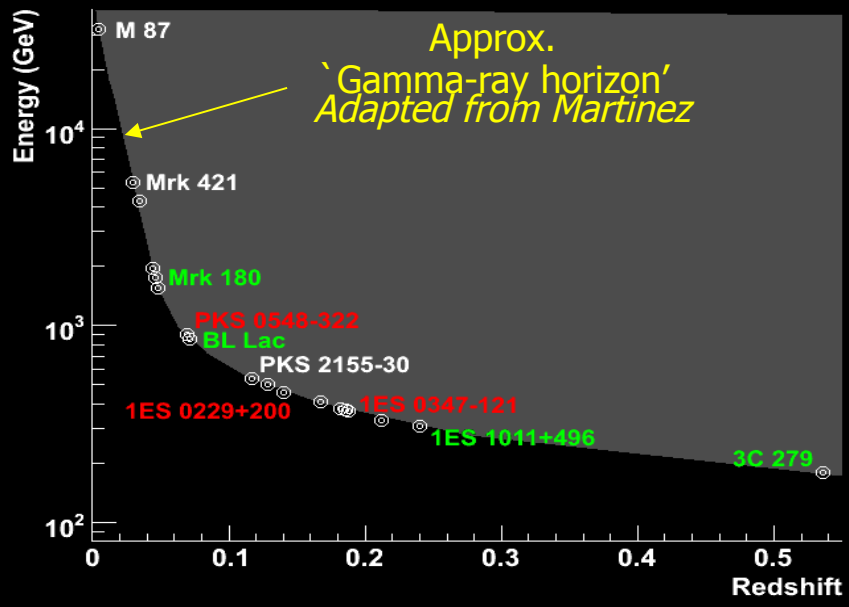
- of sources at different z to disentangle from astrophysical effects

EBL: AGN at large redshift









- Universe more transparent for gamma rays!

Indirect Dark Matter Search

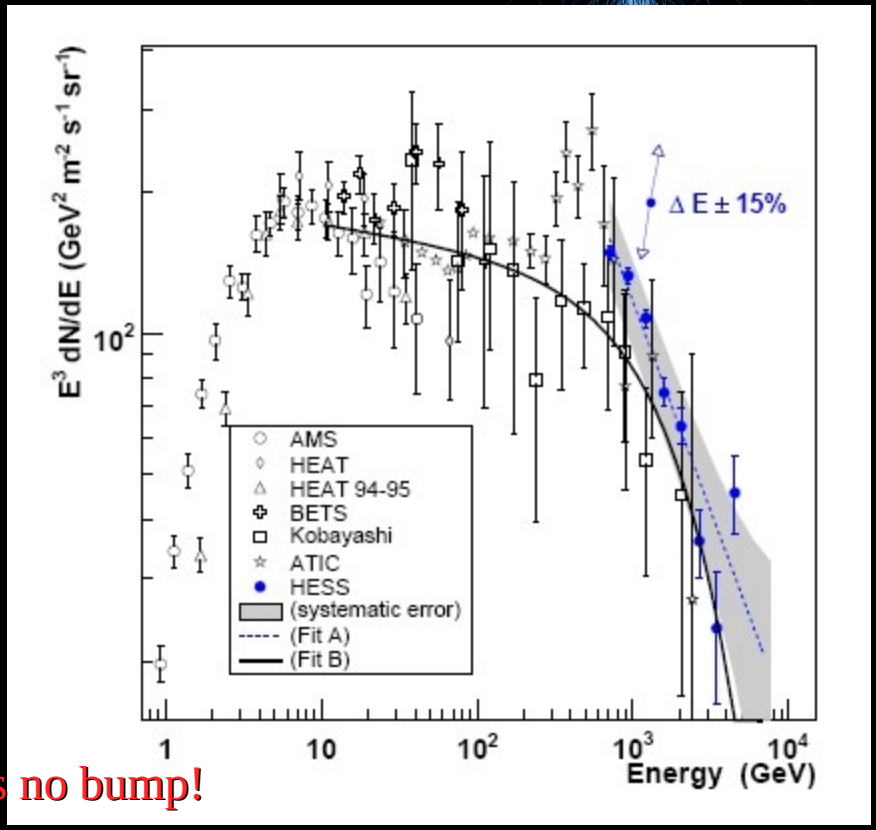
Overwhelming evidence from rotational curves, galaxy collisions, WMAP, SN cosmology...: cold non-barionic dark matter needed (CDM)

Natural candidates: WIMPs (e.g. SUSY neutralino, lightest stable Higgs particle, Kaluza-Klein DM...)

recent results from PAMELA and ATIC (if DM) point to rel. heavy particles (~1 TeV), ideal for Cherenkov Telescopes

Possible signatures
-Lepton - Excess with spectral break (propagation)

-Annihilation "line" + cutoff



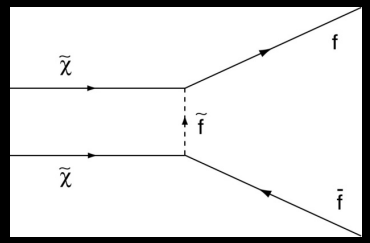
BUT: astroph/0905.0105: LE analysis shows no bump!

New Gamma-Ray Contributions from Dark Matter

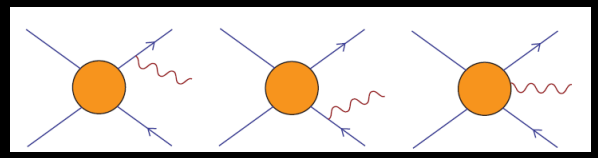
New Gamma-Ray Contributions to Supersymmetric Dark Matter Annihilation

Torsten Bringmann*
SISSA/ISAS and INFN, via Beirut 2 - 4, I - 34013 Trieste, Italy

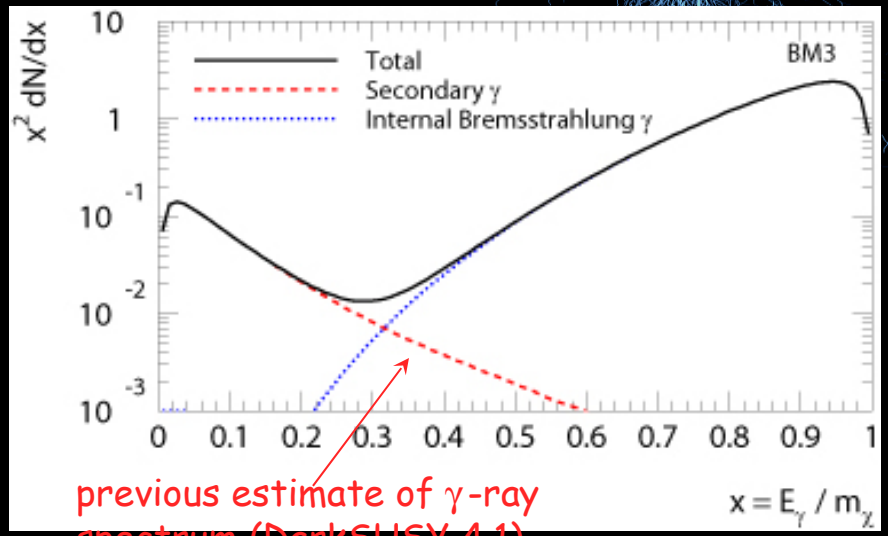
Lars Bergström† and Joakim Edsjö‡
Department of Physics, Stockholm University, AlbaNova University Center, SE - 106 91 Stockholm, Sweden
(Dated: October 16, 2007)



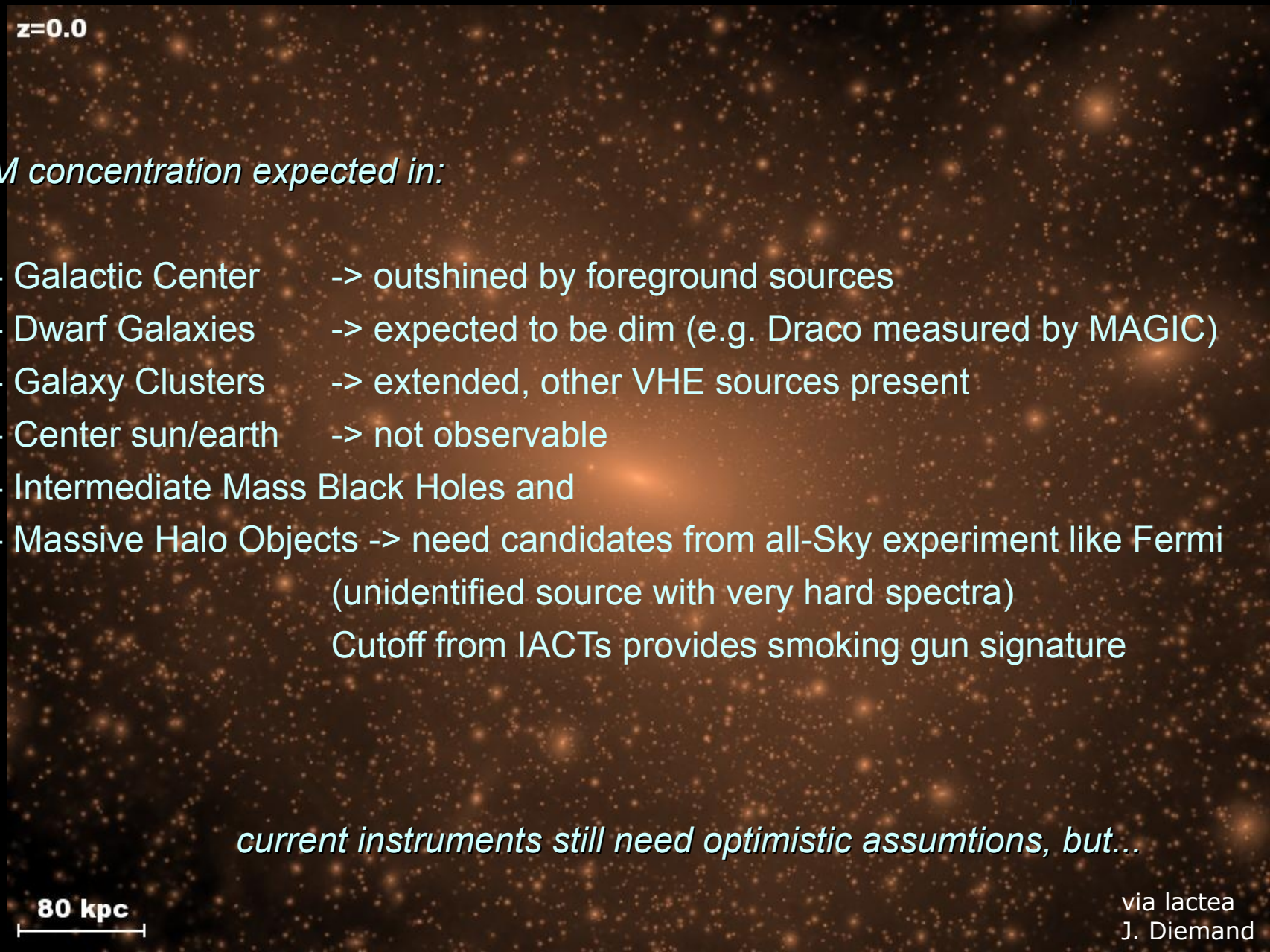
Intermediate bremsstrahlung not helicity suppressed
-> Enhanced flux and clear observational signature from Majorana particle annihilation



Example: benchmark point BM3,
mass = 233 GeV,
fulfils all accelerator constraints,
has WMAP-compatible relic density



But where to look?



High DM concentration expected in:

- Galactic Center -> outshined by foreground sources
- Dwarf Galaxies -> expected to be dim (e.g. Draco measured by MAGIC)
- Galaxy Clusters -> extended, other VHE sources present
- Center sun/earth -> not observable
- Intermediate Mass Black Holes and
- Massive Halo Objects -> need candidates from all-Sky experiment like Fermi
  (unidentified source with very hard spectra)
  Cutoff from IACTs provides smoking gun signature

current instruments still need optimistic assumtions, but...

via lactea
J. Diemand