The MAGIC origin of galactic Cosmic Rays

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Outline

1. Myself
2. The big picture
   - Cosmic Rays
   - Supernova remnants
   - VHE-γ's
3. Very high energy γ-Astronomy
   - Imaging Air Cherenkov Technique
   - MAGIC

Julian Krause

Myself

- University study
  - Diploma in physiscs at the University of Bonn (Germany)
  - Topic of Diploma thesis: Galactic Cosmic Rays in spiral arms
- PhD 2009-2012(?!)
  - Max Planck Institut for physics in Munich (Germany)
  - Member of the MAGIC Collaboration

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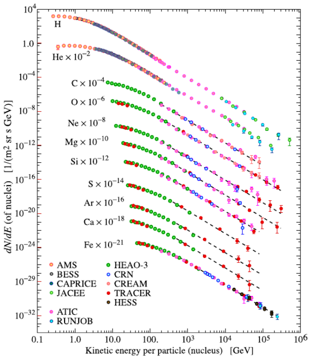
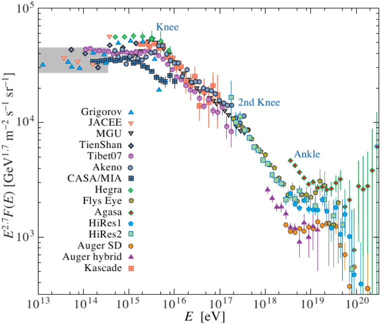
My PhD

- Galactic cosmic rays (GCR) and supernova remnants (SNR's)
  - Observations of VHE-γ emission from SNR's
  - Acceleration models of GCR in SNR's
  - combine theory and experiment

Cosmic Ray accelerators

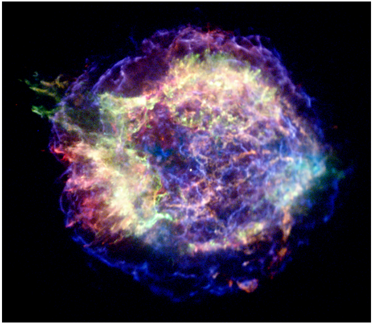


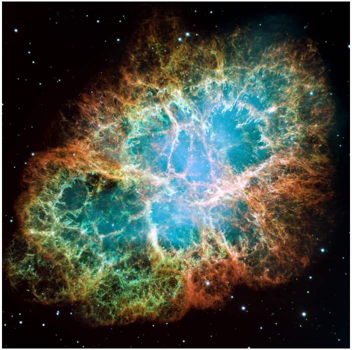


Requirements on galactic CR sources

- provide enough energy
- reproduce observed power-law spectrum
- accelerate CR up to the knee

Supernova remnants





Properties of SNR

- kinetic energy $\approx 10^{51}$ erg (5-20% needed for CR)
- diffusive shock acceleration $\rightarrow$ power-law spectrum
- self amplified magnetic fields $\rightarrow$ energies up to the knee

Current status of the origin of GCR

History

- Cosmic Rays detected: 1912 (Hess)
- Acceleration mechanism: 1946 (Fermi)
- SNR's claimed as sources of GCR: 1977-78 (Axford, Krymskii, Blandford & Ostriker, Bell)

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A lot of reasonable and clear hints from both theory and experiments

No proof!

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Tomorrow?!

A 100 years old question waits to be answered

I believe

From SNR's as CR sources to VHE-γ-rays

Search for CR sources

- Problem
  - CR's are charged
  - non homgeneous intestellar B-fields
  - isotropic distribution of CR's spectrum at Earth
- Solution
  - γ-rays
  - convert CR into γ's
  - γ's point back to interaction point

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Leptonic Channel

- Bremsstrahlung
  - matter
- Synchroton
  - magnetic fields
- Inverse Compton
  - photon fields

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Hadronic Channel

- π^0-decay
  - matter

Very high energy γ-Astronomy

- Young field of Astronomy
- Energy range GeV-TeV (wavlength $\leq 10^{-8} nm$)
- First source: Crab Nebula 1989 at the Whipple Observatory

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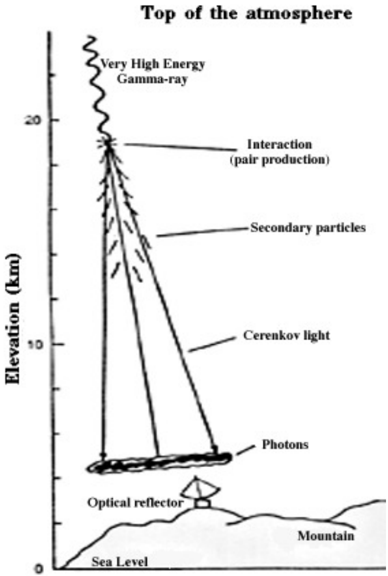
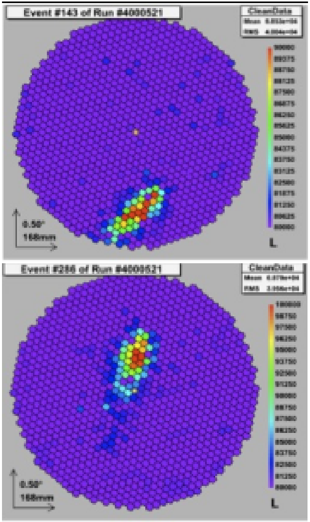
General comments

- No object in the universe is hot enough to radiate GeV photons
- Interaction of high energy particels needed
- Most *violent* objects are typical sources
  - Supernova remnants
  - Pulsars
  - Pulsar wind nebulae
  - Binaries with a compact object
  - Active galactic nuclei

Imaging Air Cherenkov Technique



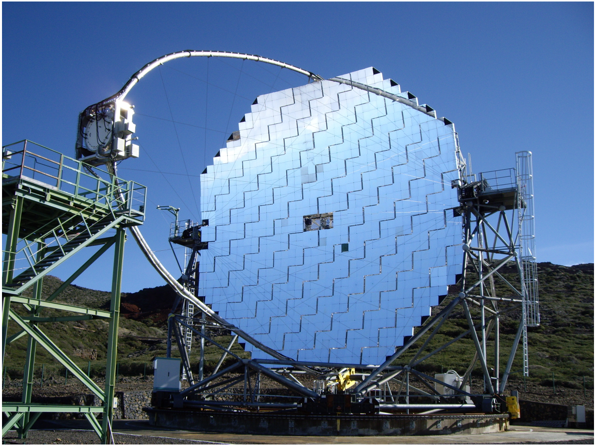


The MAGIC Telescopes

Major **A**tmospheric **G**amma **I**maging **C**herenkov Telescopes

- Location:
  Canary Island
  La Palma
  2200m altitude
- 17m diameter
- 60t weight
- Treshold:
  50 GeV

Mono Observations



PRO

- cheaper!
- symmetry in Azimuth

CONTRA

- difficult to reject background
- no precise 3d information

Stereo Observations

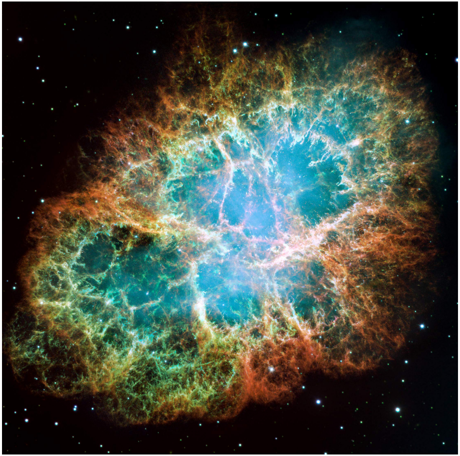
PRO

- Good 3d information
- better background rejection

CONTRA

- no symmetry in Azimuth
- more Systems

Classical astronomy vs. VHE-γ-astronomy



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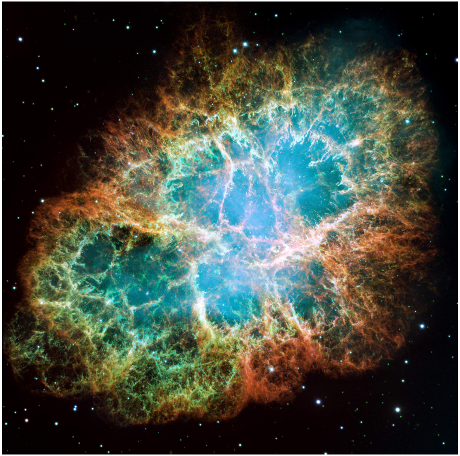

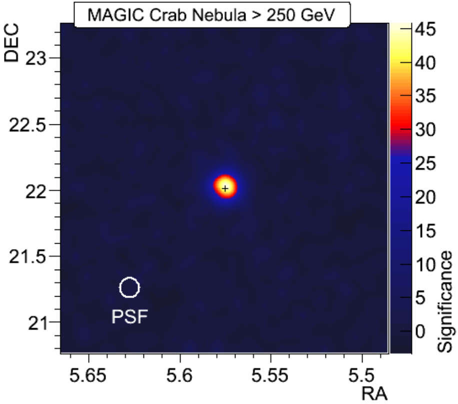

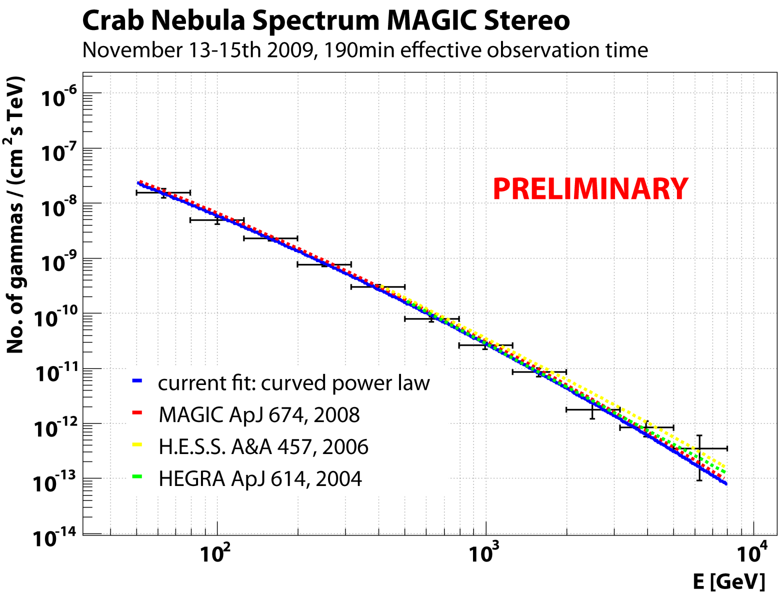
Crab Nebula Spectrum MAGIC Stereo
November 13-15th 2009, 190min effective observation time
No. of gammas / (cm^2 s TeV)
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
PRELIMINARY
current fit: curved power law
MAGIC ApJ 674, 2008
H.E.S.S. A&A 457, 2006
HEGRA ApJ 614, 2004
10^2
10^3
10^4
E [GeV]

The perfect source(s)

To detect the hadronic channel look for *purely* hadronic sources

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high magnetic fields

hadronic CR amplify B-fields
leptonic synchroton losses $\rightarrow$ high energy γ's hadronic

- SNR requierements
  - very young ($\approx$ 1kyr)
- disadvantages
  - very few objects ($\approx$15-50)
  - may lack target material

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dense targets

molecular clouds
leptons $\rightarrow$ Bremsstrahlung
hadrons π^0-decay

- SNR requierements
  - very close cloud $\approx$ pc
- disadvantages
  - few objects ($\approx$ 200)
  - leptonic γ's

Conclusion & Outlook

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- Origin of GCR still unresolved
- SNR's are still the best candidates
- Imaging Air Cherenkov Technique is working fine
- VHE-γ-astronomy is usefull tool to find CR sources
- Separating leptonic and hardronic channel is very challenging

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Outlook

- Select ideal source candidates
- Perform deep VHE-γ observations
- Use Multiwavelength data
- Test recent acceleration models
- Put more constraints on cosmic hadronic accelators