cta cherenkov telescope array

Observations of the Perseus Cluster and its AGNs with Cherenkov Telescope Array

Elina Lindfors on behalf of the CTA Consortium

With special credits to Fabio Zandanel and Manuel Meyer

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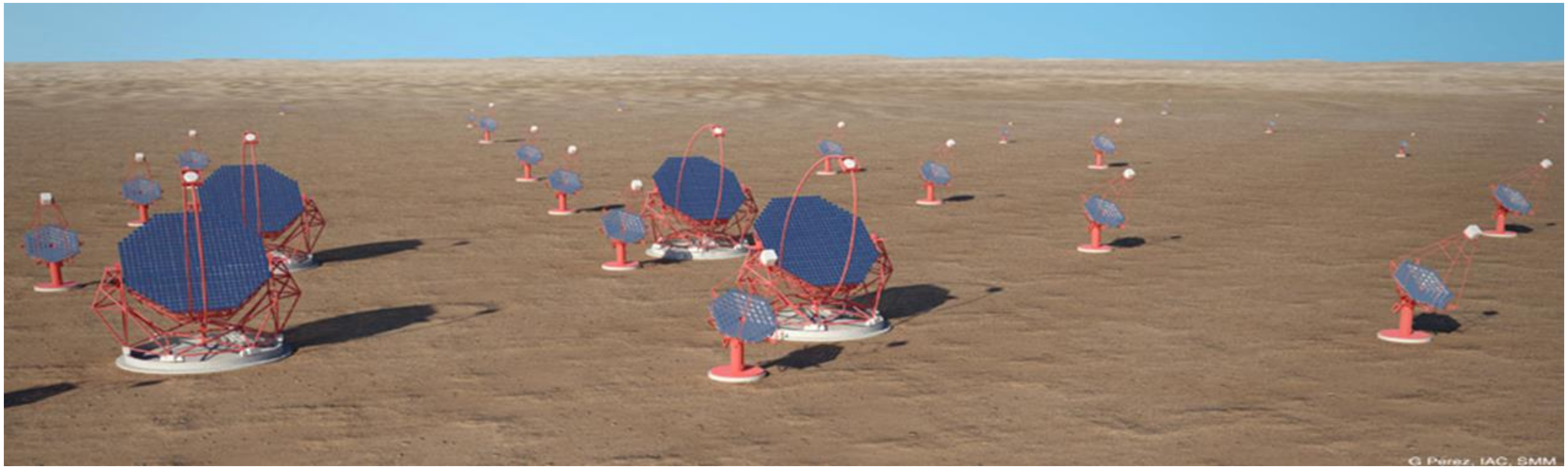
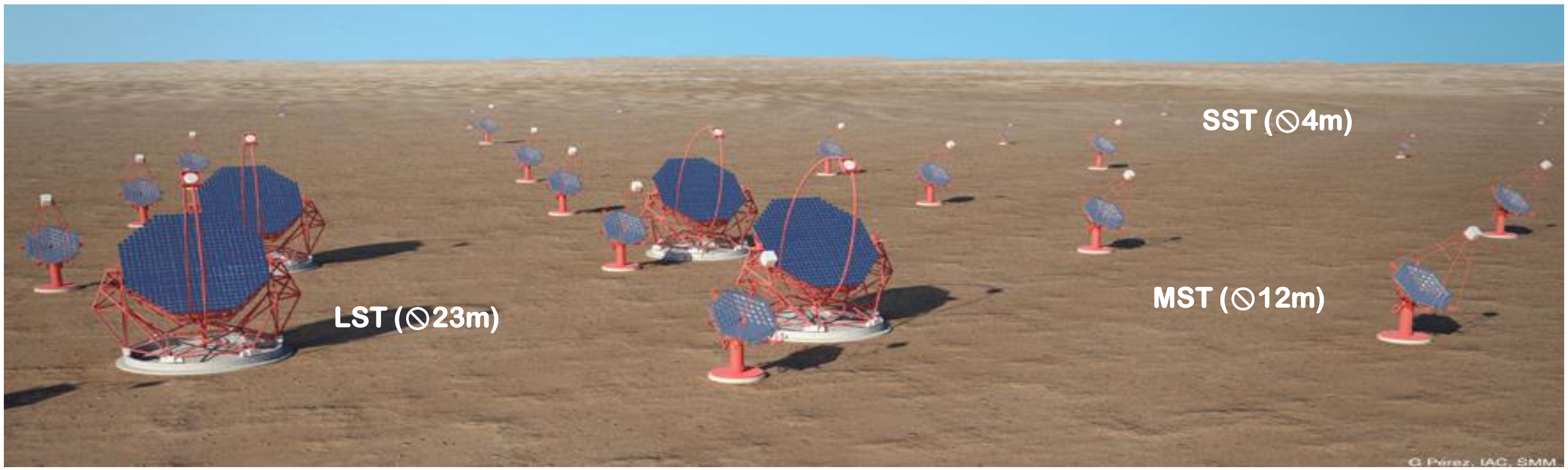
CTA in nutshell

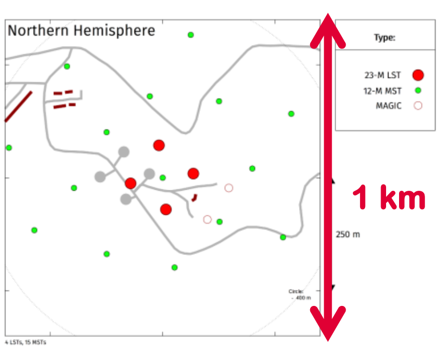
- First Open Observatory for VHE (>100 GeV) gamma-ray astronomy
- Motivated by the success of current Imaging Air Cherenkov Telescope experiments MAGIC, HESS, VERITAS
- Operations to begin in 2022 and array construction to be completed in 2025.



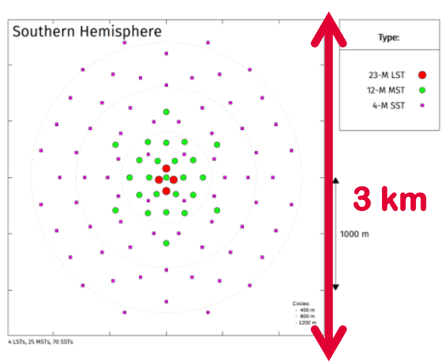
The CTA Observatory



North



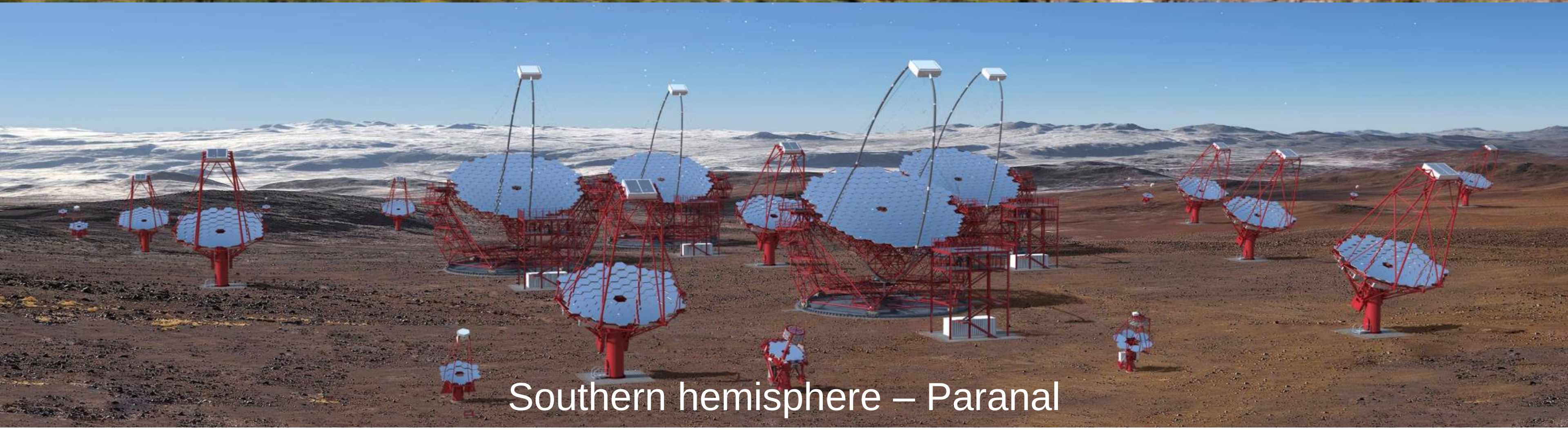
South



Characteristics
2 sites (north & south)
3 telescope size classes
118 telescopes in total

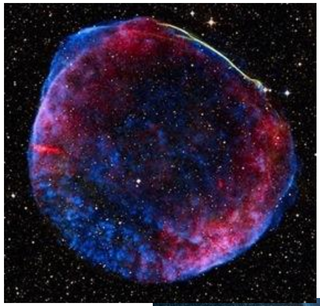
SITES


Northern hemisphere – La Palma


Southern hemisphere – Paranal

LST-1 Construction Started !

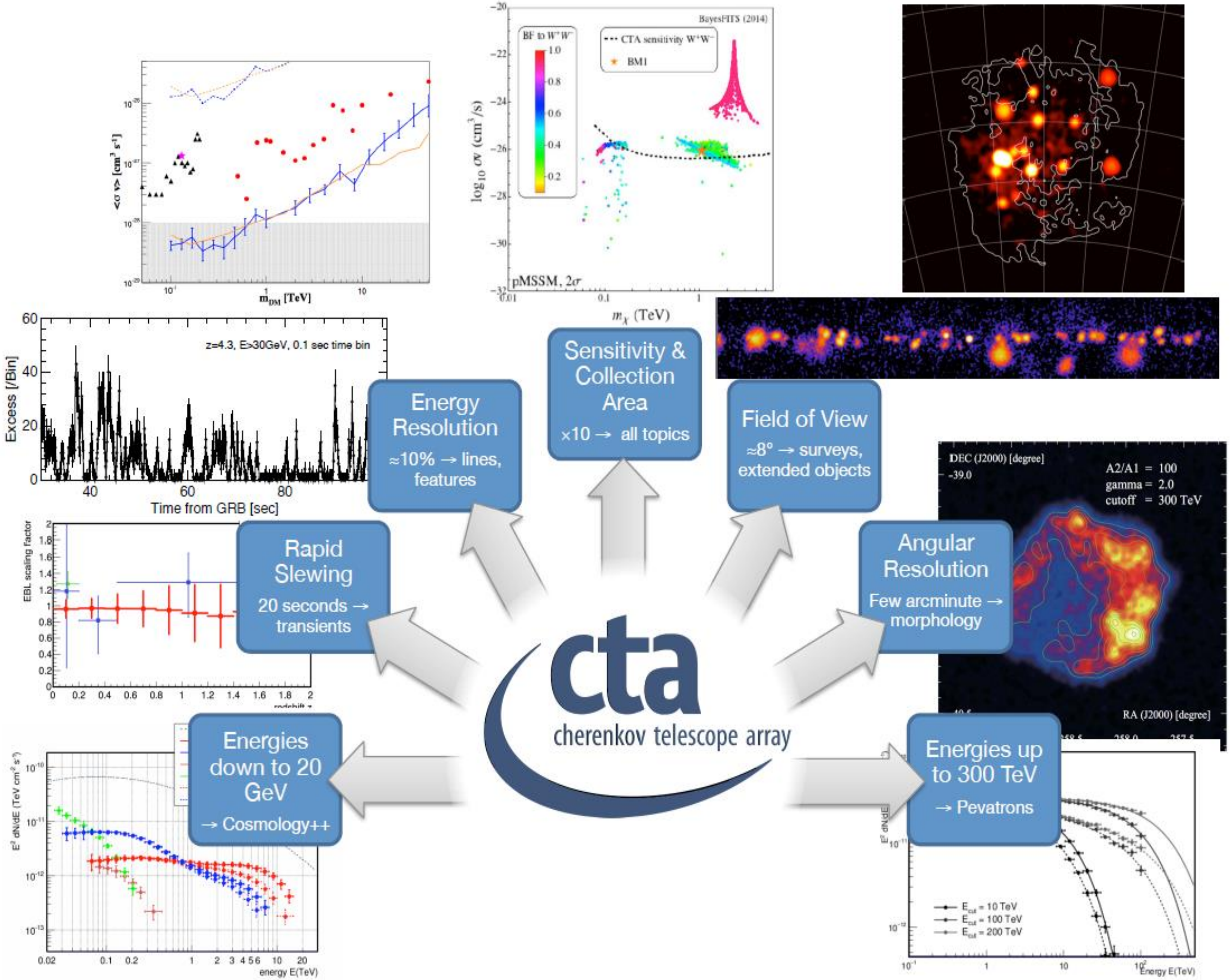
CTA Key Science



Cosmic Particle Acceleration
How and where are particles accelerated?
How do they propagate?
What is their impact on the environment?

Probing Extreme Environments
Processes close to neutron stars and black holes?
Processes in relativistic jets, winds and explosions?
Exploring cosmic voids

Physics frontiers – beyond the Standard Model
What is the nature of Dark Matter? How is it distributed?
Is the speed of light a constant for high-energy photons?
Do axion-like particles exist?



Energy Resolution
≈10% → lines, features
Sensitivity & Collection Area
×10 → all topics
Field of View
≈8° → surveys, extended objects
Rapid Slewing
20 seconds → transients
Angular Resolution
Few arcminute → morphology
Energies down to 20 GeV
→ Cosmology++
Energies up to 300 TeV
→ Pevatrons
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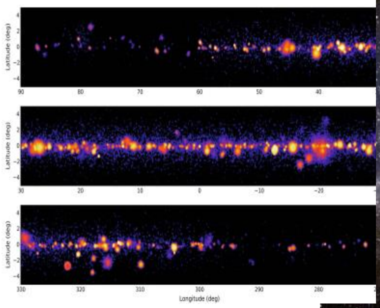
BayesFITS (2014)
CTA sensitivity W+W−
BM1
BF to W+W−
pMSSM, 2σ
log10 σv (cm3/s)
mχ (TeV)
<σ v> [cm3 s-1]
mDM [TeV]
z=4.3, E>30GeV, 0.1 sec time bin
Excess [/Bin]
Time from GRB [sec]
EBL scaling factor
DEC (J2000) [degree]
A2/A1 = 100
gamma = 2.0
cutoff = 300 TeV
RA (J2000) [degree]
energy E(TeV)
Energy E(TeV)
Ecut = 10 TeV
Ecut = 100 TeV
Ecut = 200 TeV

CTA Science Projects



Key Science Projects (executed by consortium)

Ensure that important science questions for CTA are addressed in a coherent fashion and with a well-defined strategy

Conceived to provide legacy data sets for the entire community

Surveys: galactic center, galactic plane, extragalactic and LMC

Transients

Cosmic Ray PeVatrons

Starforming systems

Active Galactic Nuclei

Galaxy Clusters

Proposal-driven User Programme

Deep investigation of known sources

Follow-up of KSP discovered sources

Multi-wavelength campaigns

Follow-up of ToOs from other wavebands

messengers

Search for new sources

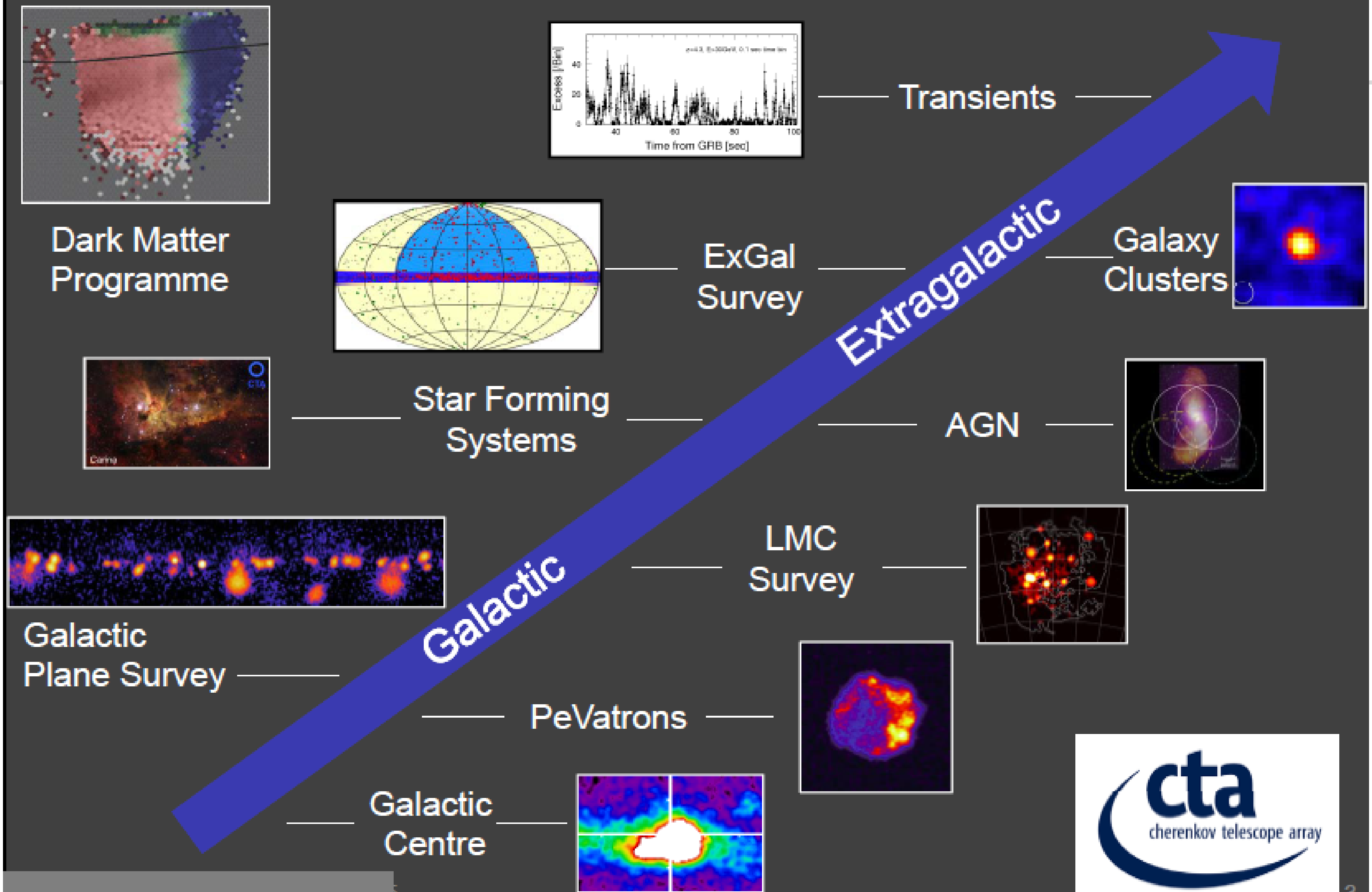
…

Updated Science Case released in September 2017

https://www.cta-observatory.org/cta-releases-updated-science-case/

https://arxiv.org/abs/1709.07997

CTA KEY SCIENCE



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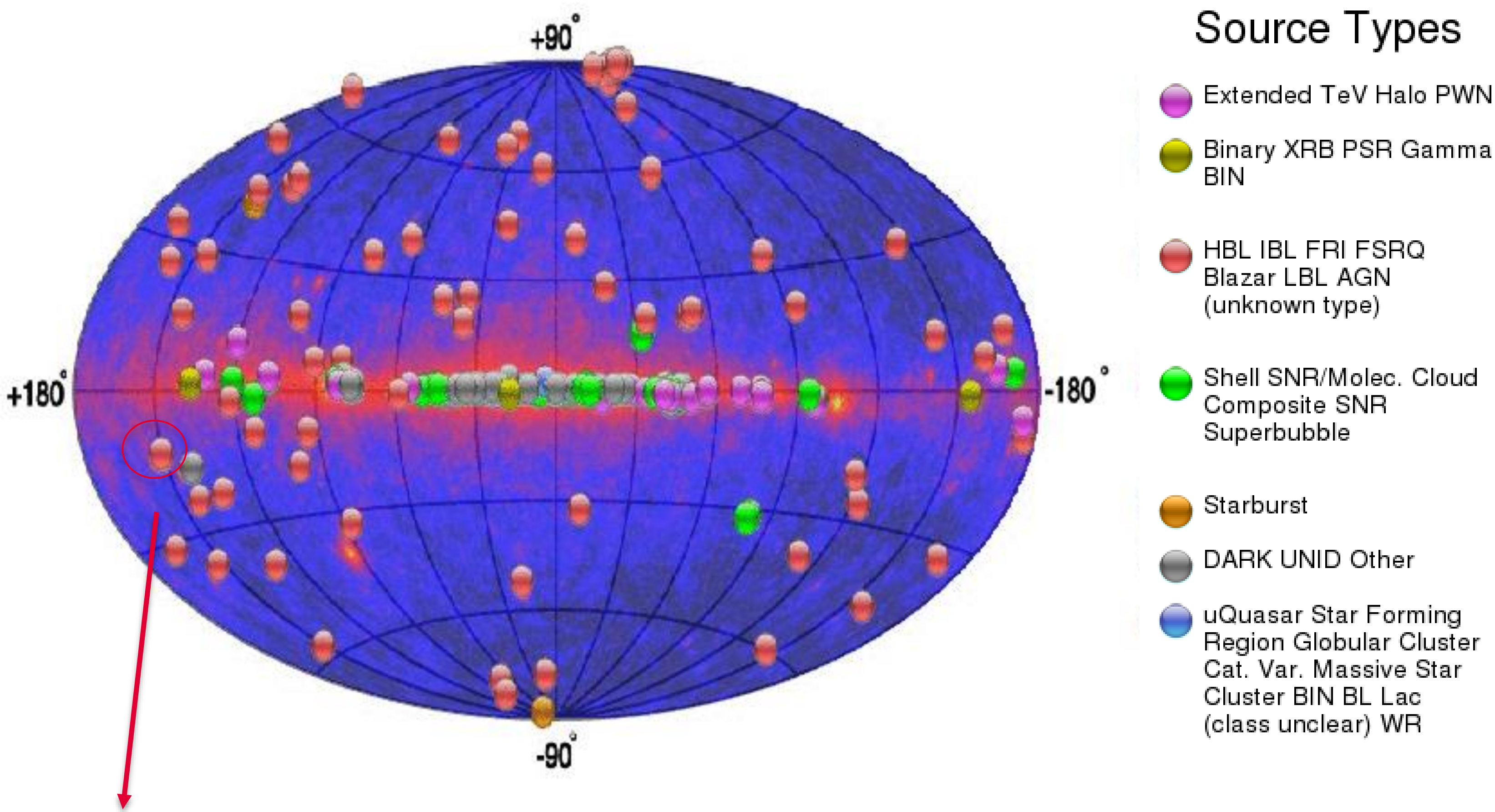
Very High Energy Gamma-Ray Sky



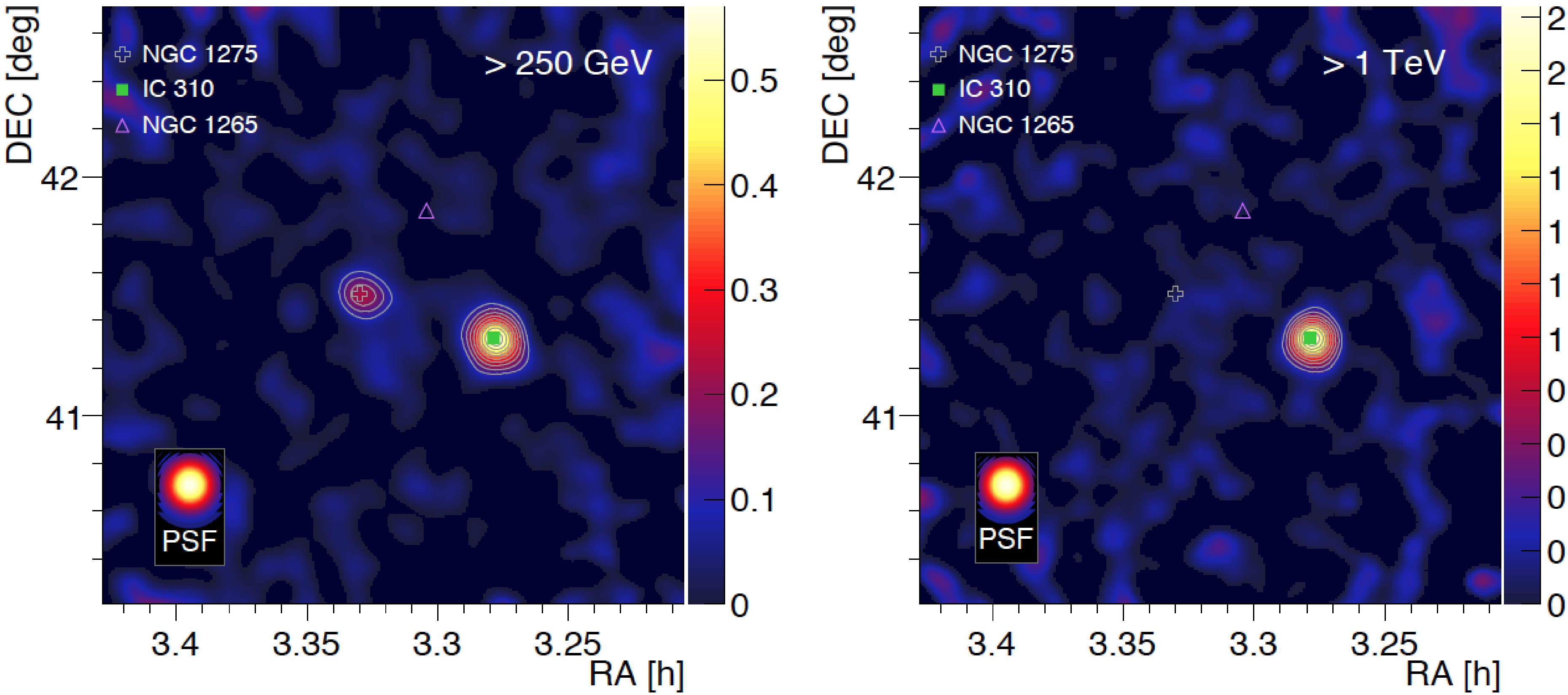
Perseus Cluster AGNs
NGC1275 and IC310

~200 sources

MAGIC Observations of Perseus

250 hours observations 2009-2014

(MAGIC Coll. 2010a-b, 2012a-b, 2014a-b; in collaboration with Pinzke & Pfrommer)



MAGIC Coll. (2016) – P. Colin and FZ as Corr. Authors

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Active Galactic Nuclei

Key Science Project will address:

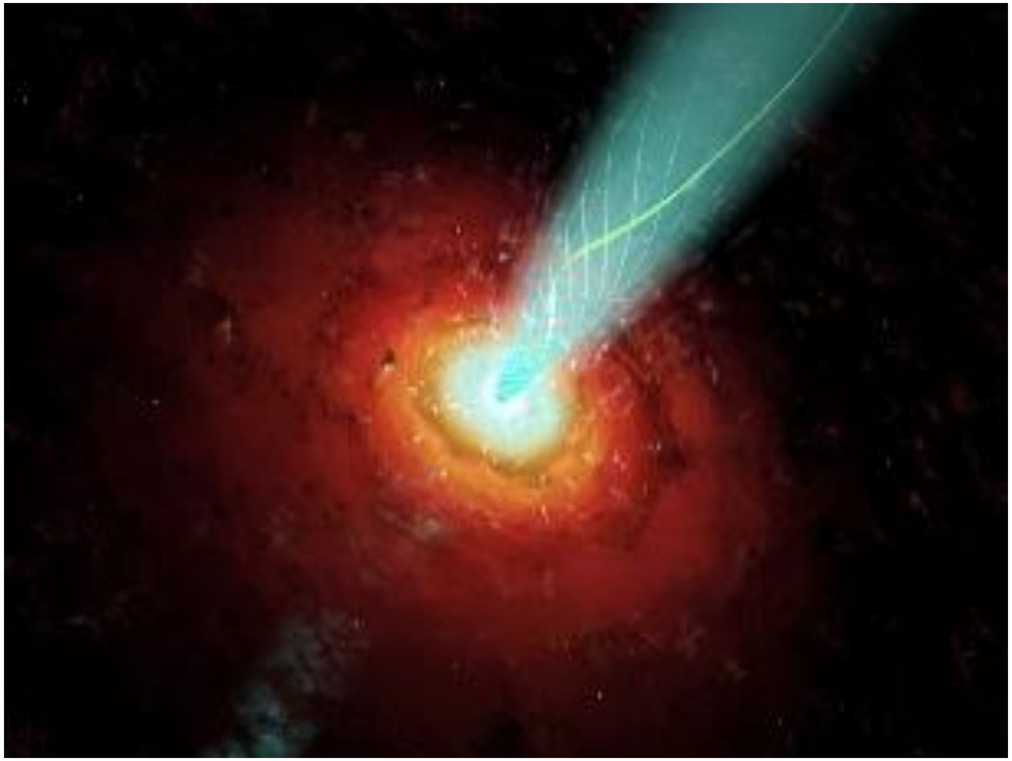
-AGN physics at Very High Energies

-gamma-ray cosmology

-ultra high energy cosmic rays and fundamental physics

Observational strategies:

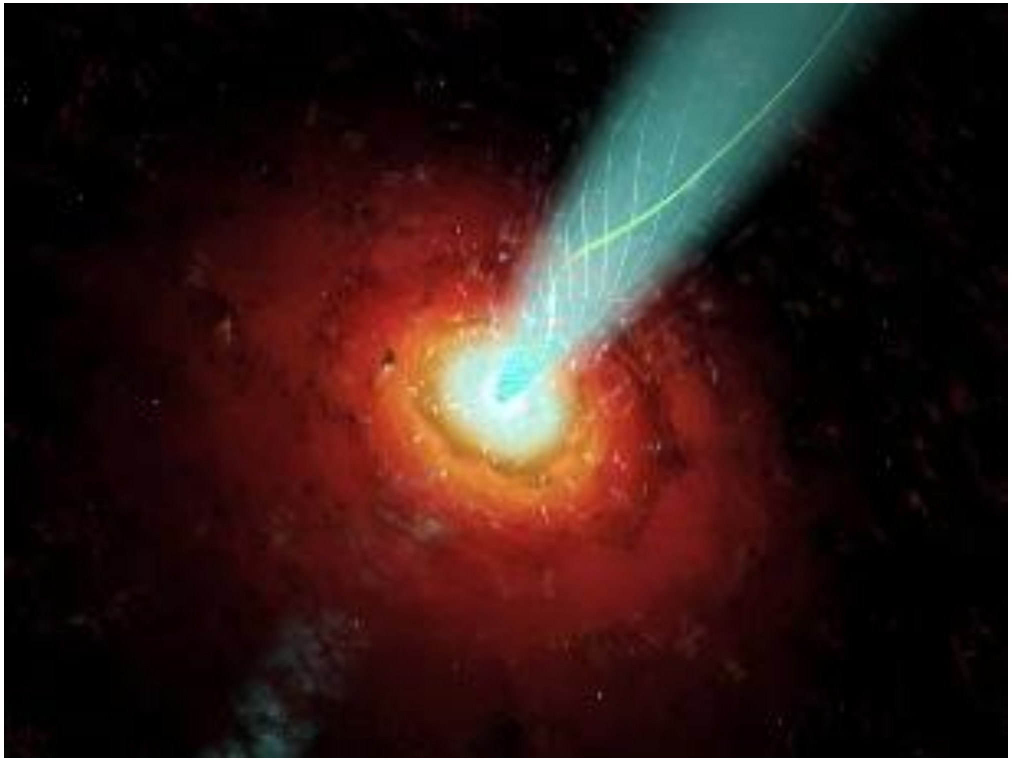
1. Long-term monitoring
2. High-quality spectra
3. AGN flare program



Active Galactic Nuclei

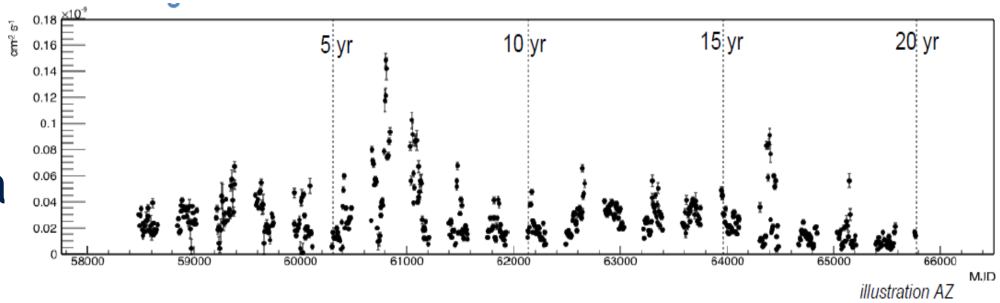
Observational strategies:

1. Long-term monitoring: 15 AGNs from all subclasses, including NGC1275.
2. High-quality spectra: 40 AGNs covering different redshift bins, including IC310
3. AGN flare program: observations of any flaring AGN, including NGC1275 and IC310.

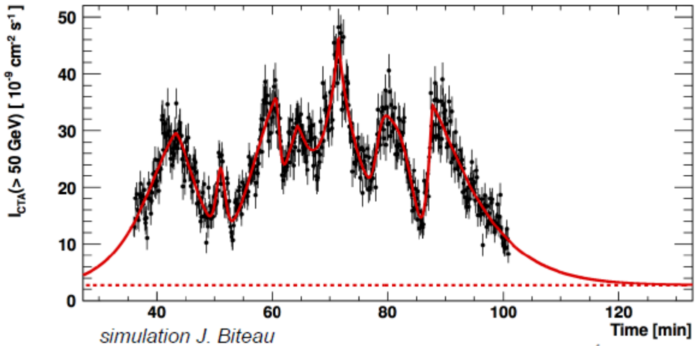


Active Galactic Nuclei

- **Variability from longest timescales:**
  - -Duty Cycle
  - -(quasi) periodicities
  - -breaks in the power spectra



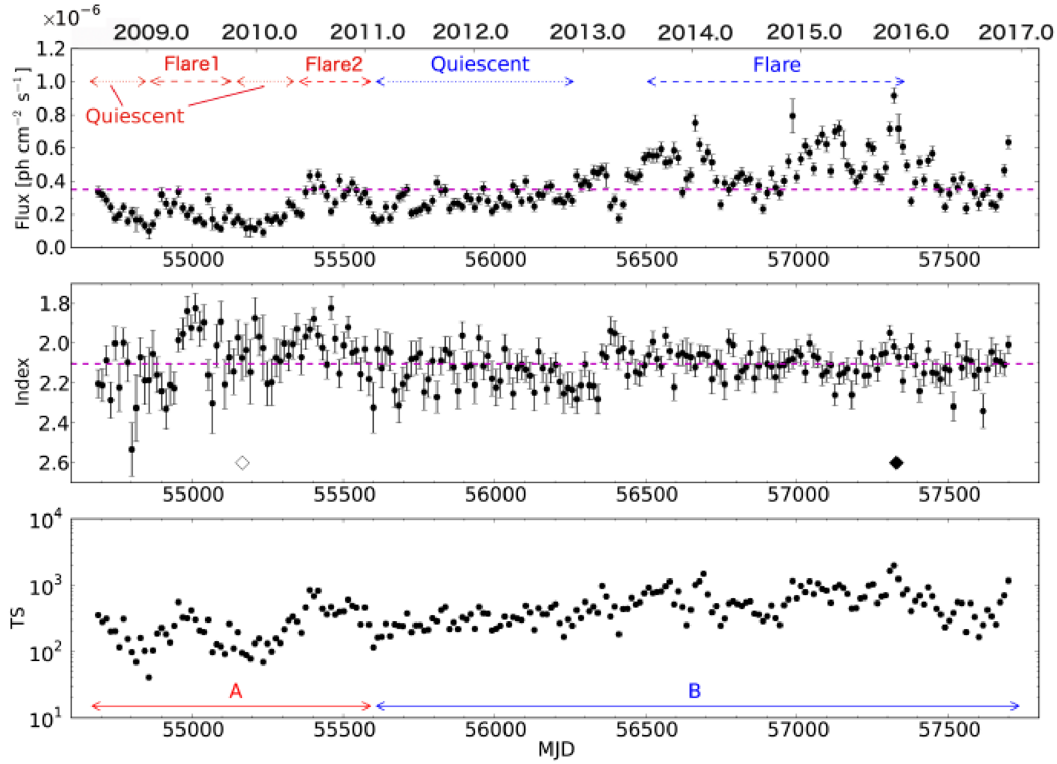
- **to shortest:**
  - -size (location, nature) of the emission region
  - -acceleration and cooling mechanisms



simulation J. Biteau
(H. Sol, AZ, C. Boisson et al. 2013)

Active Galactic Nuclei : Monitoring

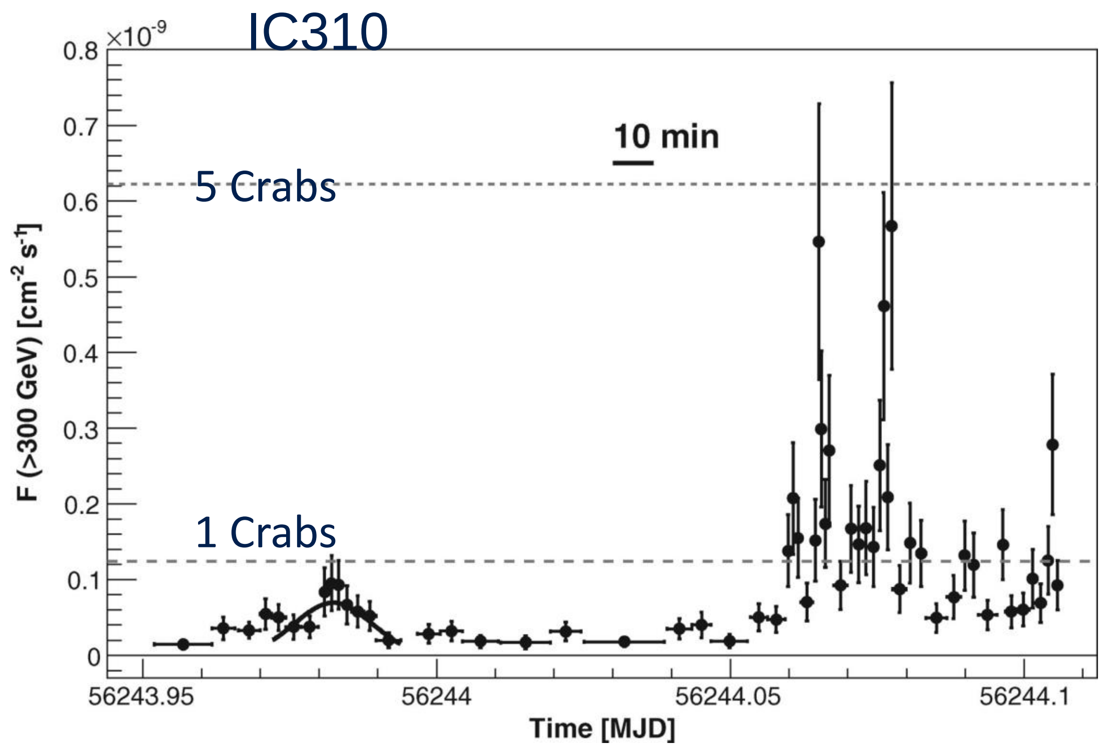
- Long term behaviour of NGC1275 from Fermi-LAT: ”The gamma-ray flux from NGC 1275 is highly variable on short (~ days to weeks) timescales, and has steadily increased over the 8-year timespan”
- Long term flux increase in radio and optical
- Long term behavior in VHE?
- NGC1275 is detectable in 30 minutes by CTA even in low state: true weekly monitoring possible!



Tanada et al. 2018, ApJ, in press

Active Galactic Nuclei: Flares

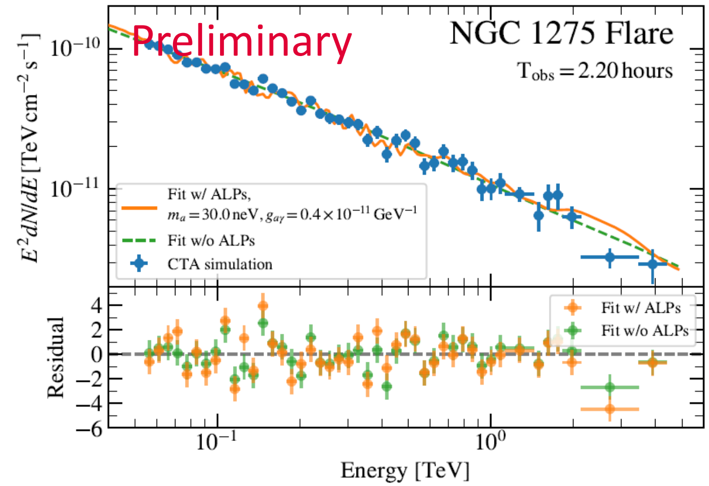
- Extreme flaring event of IC310 in November 2012
- Extreme flaring detected also from NGC1275 in January 2017 (ATel #9929, MAGIC Collaboration)
- CTA sensitivity will allow us to scope the shortest timescales and spectral variability during the flares with superior accuracy

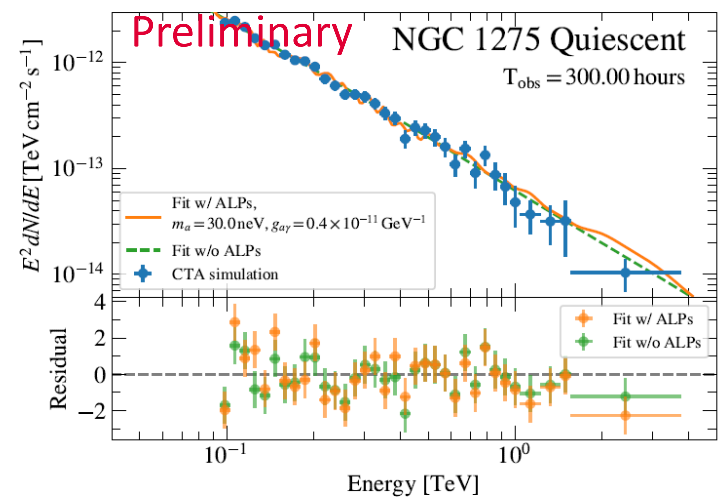


MAGIC Collaboration 2014, Science

Active Galactic Nuclei: Flares

- Simulated spectra of a flare. Observation 2.2 hours @0.6Crab as seen by VERITAS in January 2017
- Simulated quiescent (300 hours) state as seen by MAGIC (MAGIC Collaboration, 2016)
- Extension to several TeV's or cut-off
- In addition to AGN physics, NGC1275 spectra during flares can also be used to probe Axion Like Particle Dark Matter





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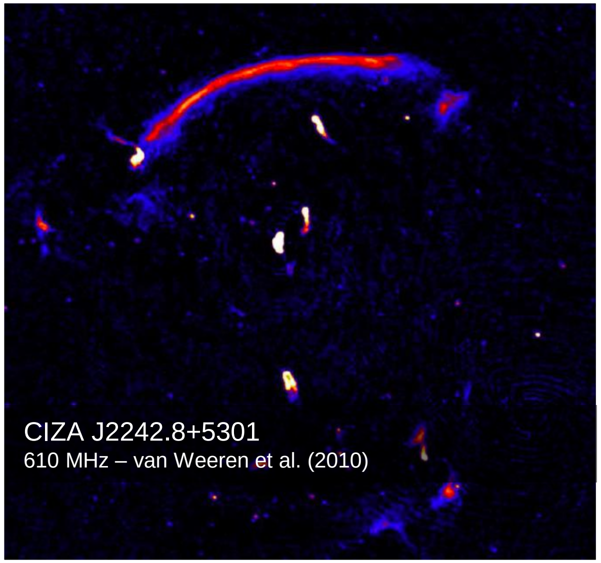
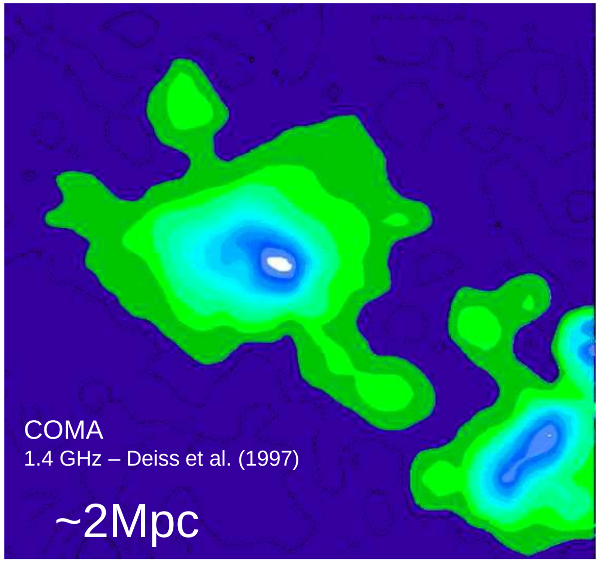
Simulations by M.Meyer

Clusters of Galaxies

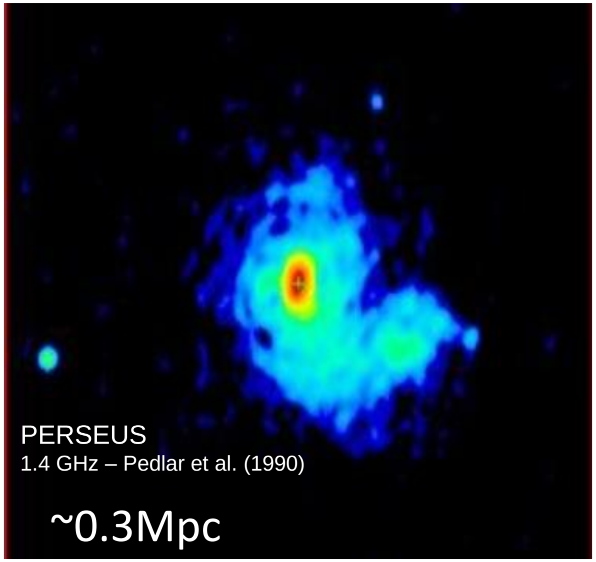
RELICS



GIANT HALOS



MINI HALOS

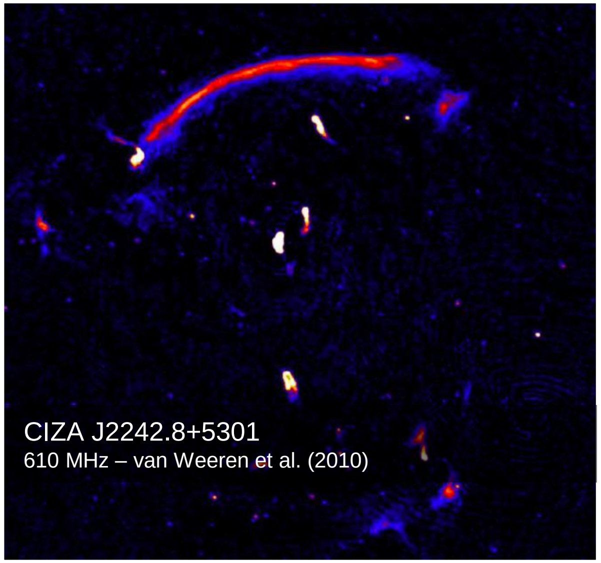


Synchrotron Radio Emission:

- Origin of radio-emitting electrons and magnetic fields?
- Contribution of cosmic-ray protons?
- Impact on cluster environment (P_{cr}/P_{th})?

Clusters of Galaxies

RELICS



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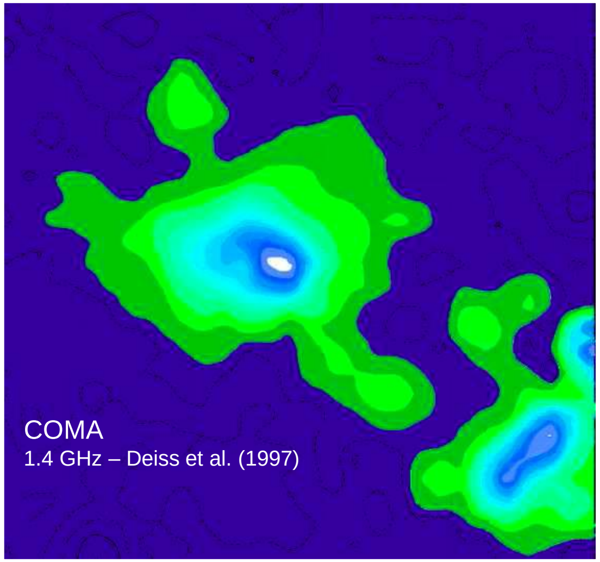

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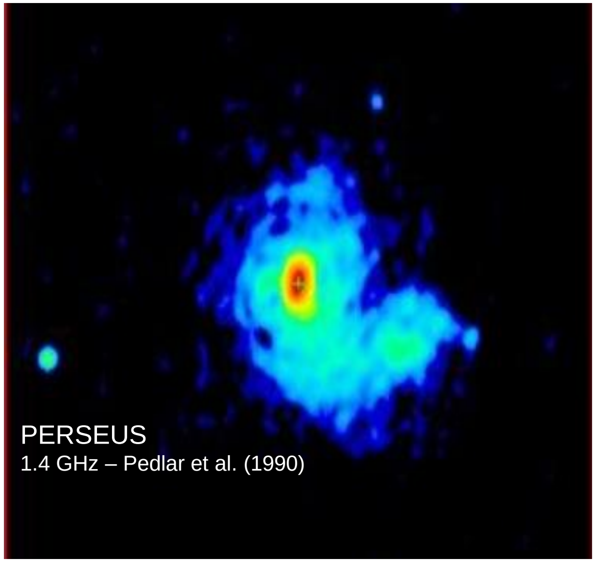


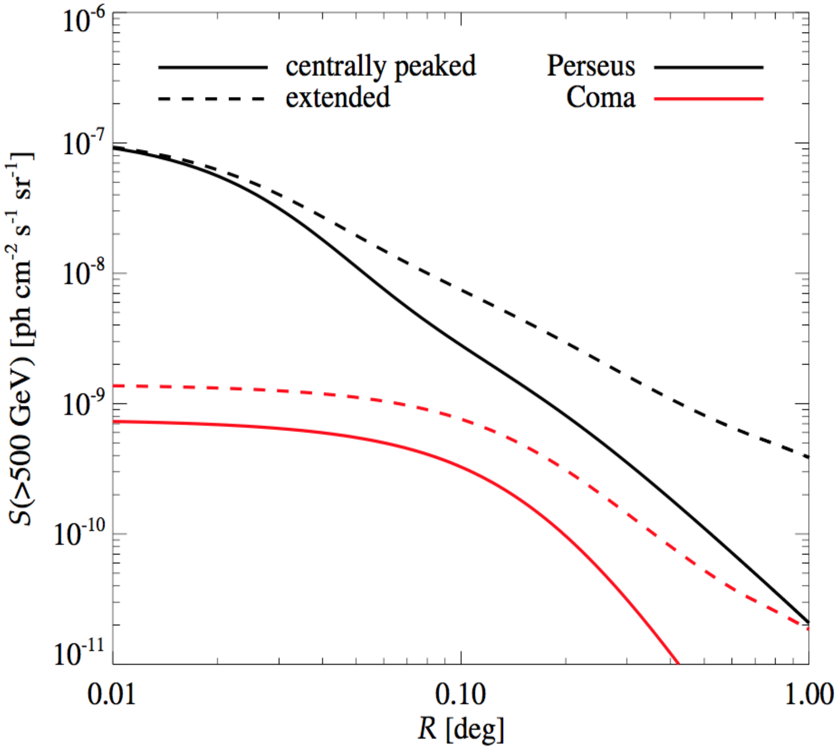
Assuming radio is <u>mainly</u> of "<u>hadronic" origin</u> <u>(including re-accelerated secondaries)</u>:

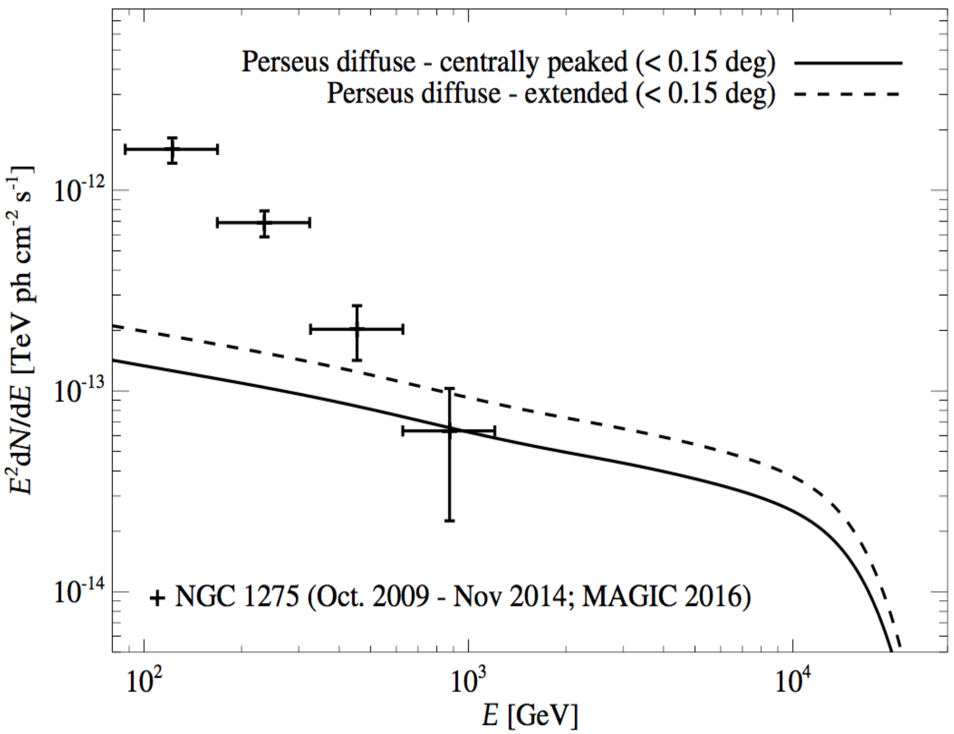
RADIO → SYNCHROTRON → SECONDARY ELECTRONS
MAGNETIC FIELD

GAMMA RAYS & NEUTRINOS → PION DECAYS → PROTONS

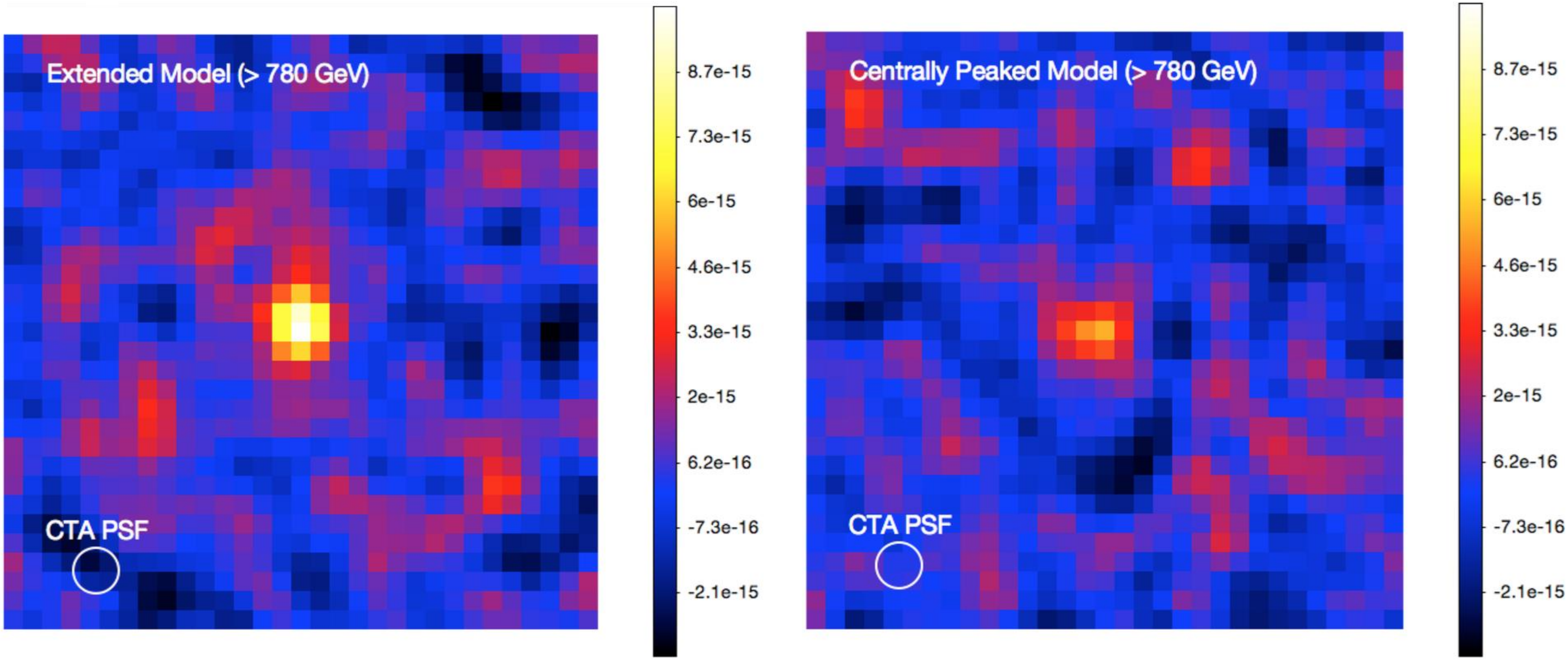
Clusters of Galaxies

Perseus is the most promising target for CTA



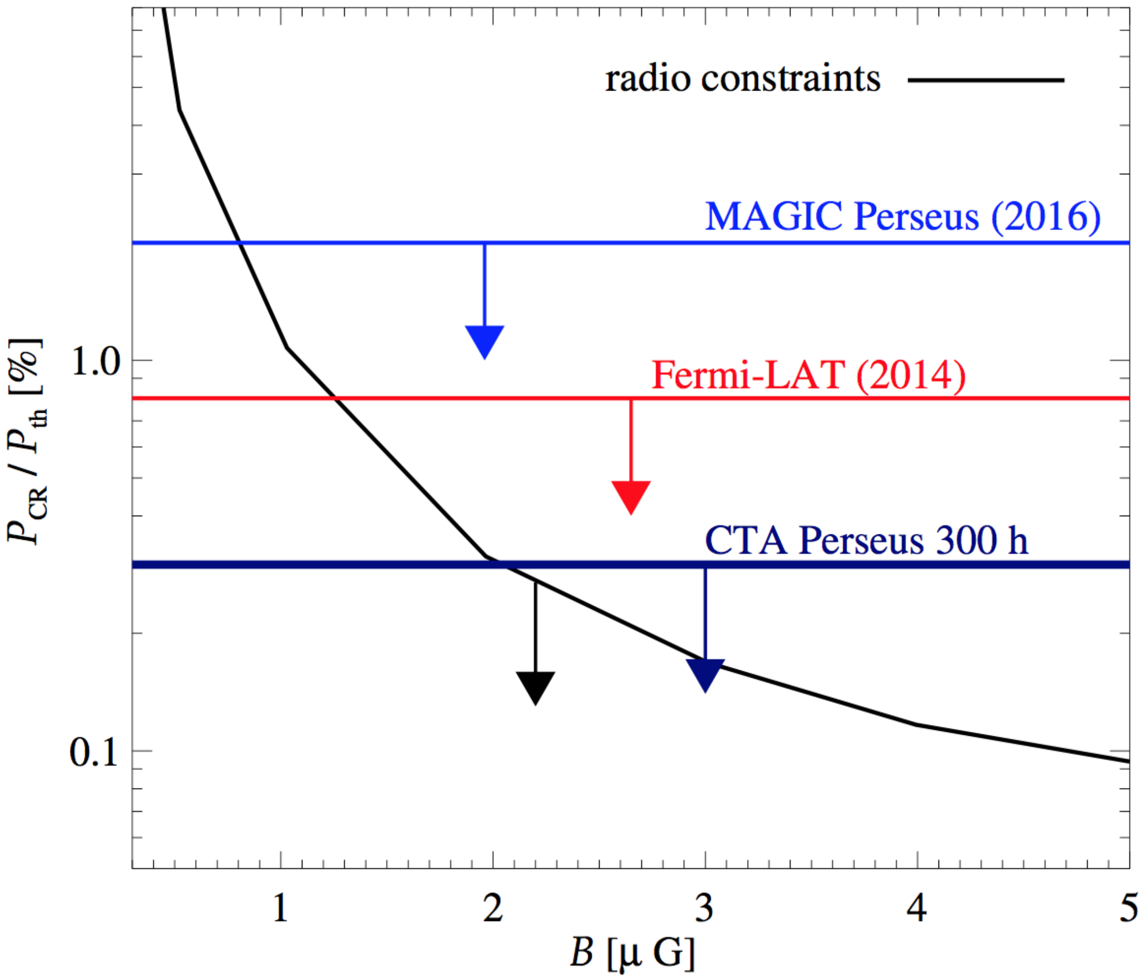


Clusters of Galaxies



Simulated gamma-ray flux for 100 hr of observation of the Perseus cluster assuming models with B_0 = 10 μG

Clusters of Galaxies



A factor of 6 improvement on current MAGIC constraints on Perseus

Summary

- CTA Key science programs combine guaranteed scientific return with large discovery potential; Key Science Programs include *deep observations of Perseus* **and** *monitoring and ToO observations of its AGNs*

- CTA AGN Key Science Program will probe the long term behaviour of NGC1275 and IC310 for the first time and give unprecedented time resolution on flaring behaviour of the two sources.

- CTA can detect / improve significantly on Perseus:
  test hadronic origin for $\alpha_p \leq 2.3$ + $B_0 \geq 20$ μG + $P_{cr}/P_{th} < 0.1 – 2.5$ % (peaked CRs) to < 5% (flat CRs)

- Updated Science Case released in September 2017 https://www.cta-observatory.org/cta-releases-updated-science-case/
  https://arxiv.org/abs/1709.07997

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