VHE gamma-ray astrophysics from ground: MAGIC and CTA

Alessandro De Angelis
INFN-U.Udine/LIP-IST Lisboa

- VHE gamma rays
- The detection: Cherenkov Telescopes
- Some results
- What's next

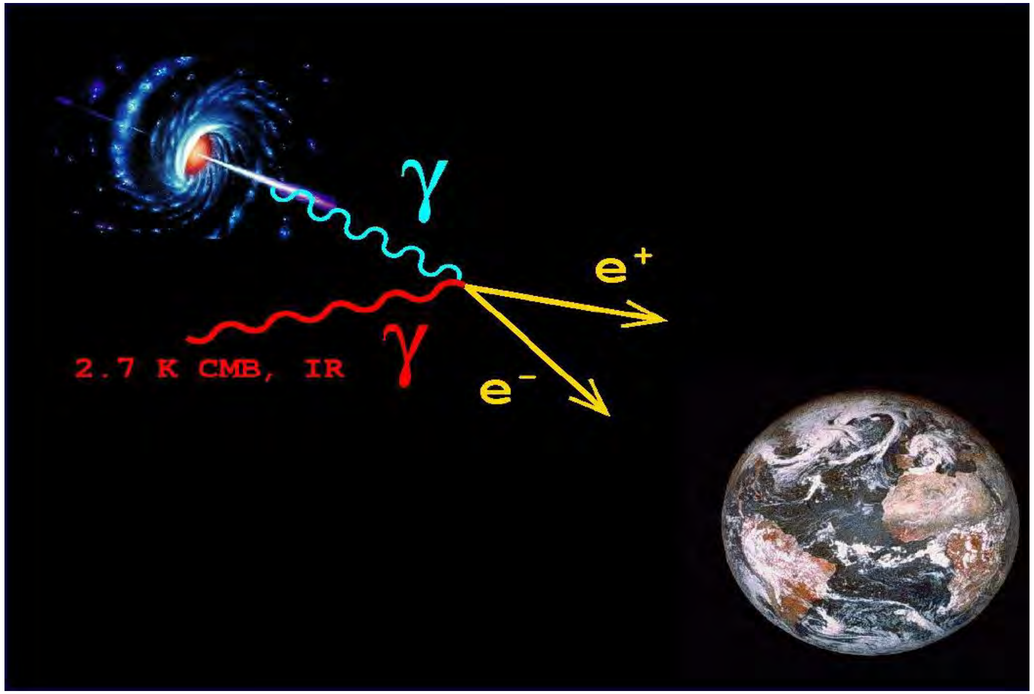
Gran Sasso, September 2013

How are VHE (above 30 GeV) gamma rays produced?

- Radiation from accelerated charged particles
  - Interaction with photon fields & clouds
  - Hadronic and leptonic mechanisms

- But also (unobserved up to now)
  - Top-down mechanisms
  - New particles? Dark matter?

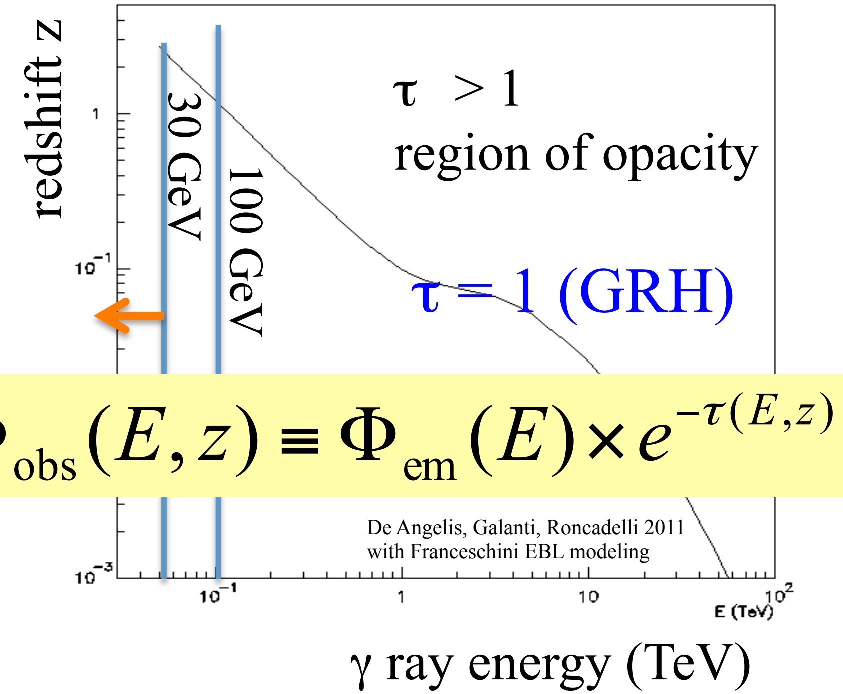
How do gamma rays reach us?



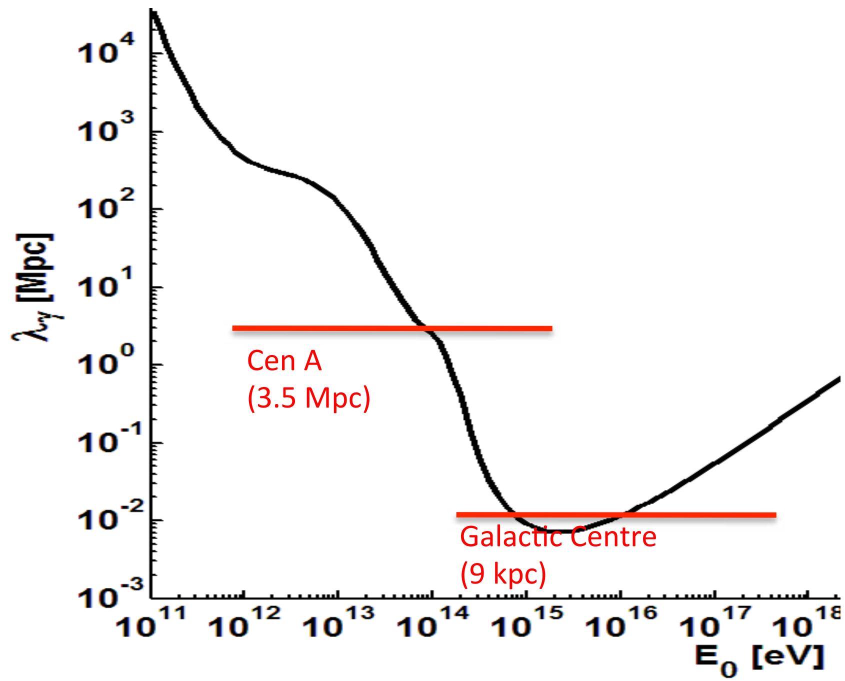
$$\gamma_{VHE}\gamma_{bck} \rightarrow e^+e^-$$

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

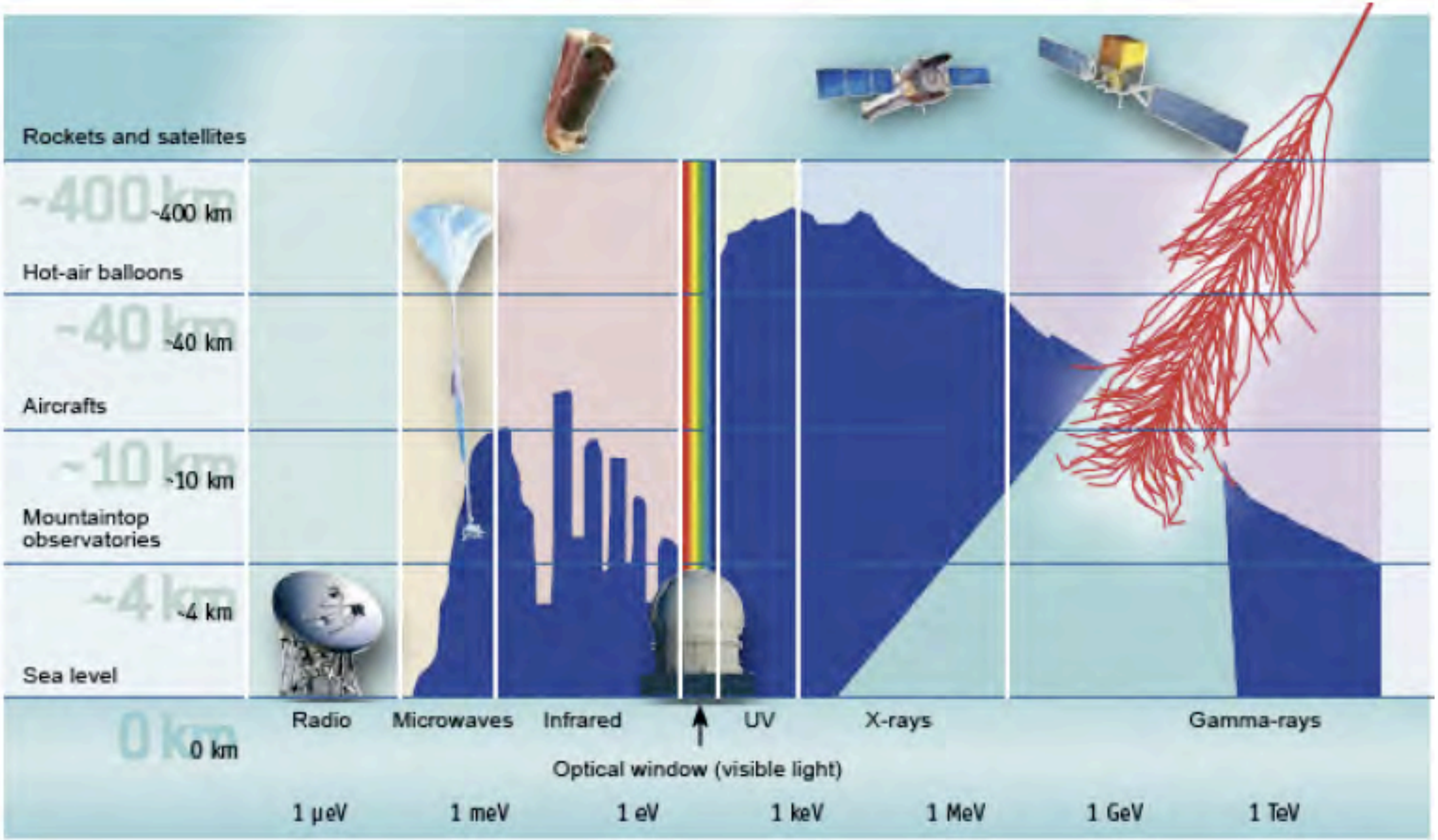
Max for: $\epsilon \simeq \frac{2m_e^2c^4}{E} \simeq \left(\frac{500\,\mathrm{GeV}}{E}\right)\mathrm{eV}$



$$\Phi_{obs}(E,z) \equiv \Phi_{em}(E) \times e^{-\tau(E,z)}$$



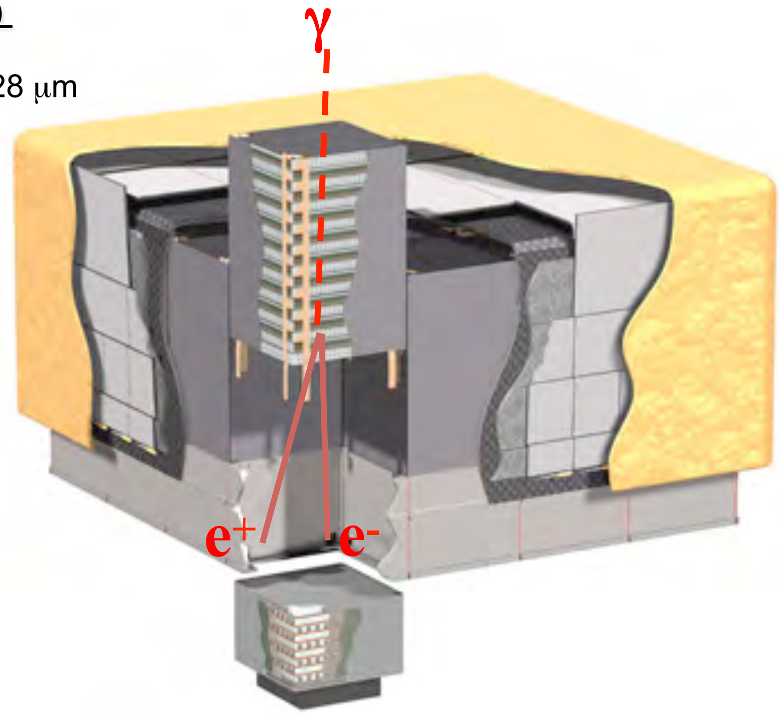
Gamma rays interact with the atmosphere



=> GeV (HE) detection requires satellites; TeV (VHE) can be done at ground

Detectors

Precision Si-strip Tracker (TKR)
18 XY tracking planes
Single-sided silicon strip detectors 228 μm pitch, $8.8\ 10^5$ channels
Measure the photon direction

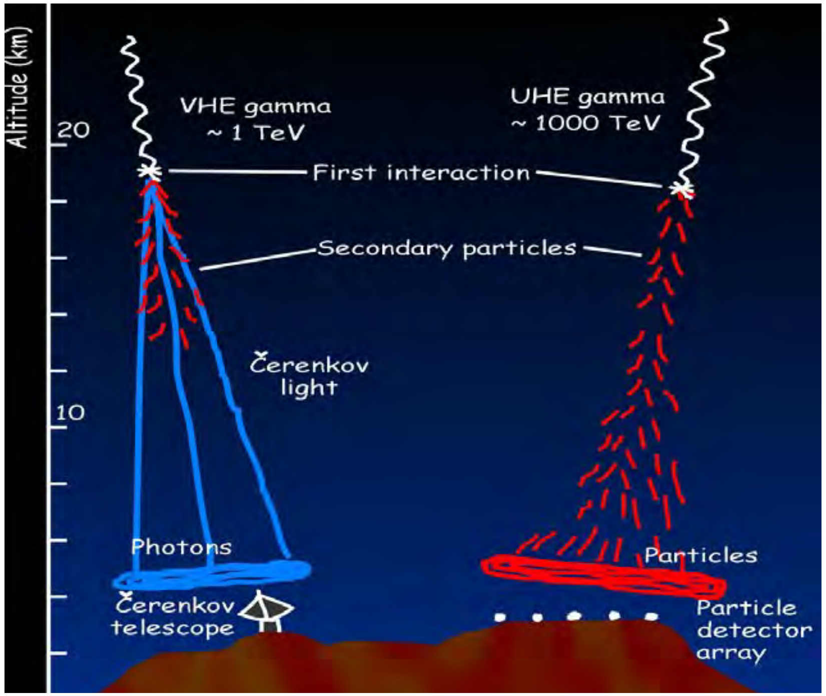


- Satellites (AGILE, Fermi)
  - Silicon tracker (+calorimeter)

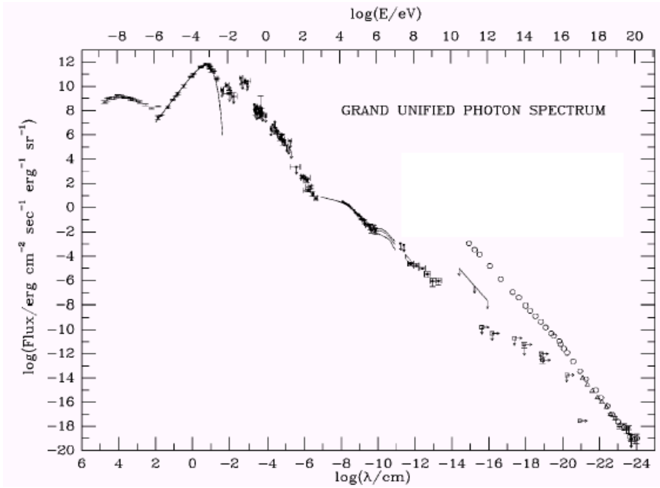
- Cherenkov telescopes (HESS, MAGIC, VERITAS)

- Extensive Air Shower det. (ARGO): RPC, scintillators

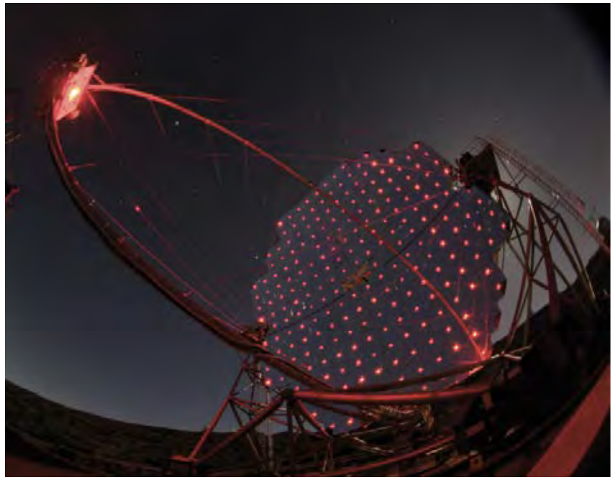
HEP detectors!



Why detection at ground?



- High energies
  - Only way to build sensitive >TeV instruments
  - Maximum flux < 1 photon/h/m^2 above 200 GeV
- High statistics /short timescales
  - Large collection areas O(km^2)
- Precision (IACTs)
  - Superior angular resolution
- Limitations?
  - IACTs
    - Smaller duty cycle
    - Smaller field of view
  - Ground particle detectors
    - Modest resolution and background rejection power
  - Complementary approaches



The Cherenkov technique

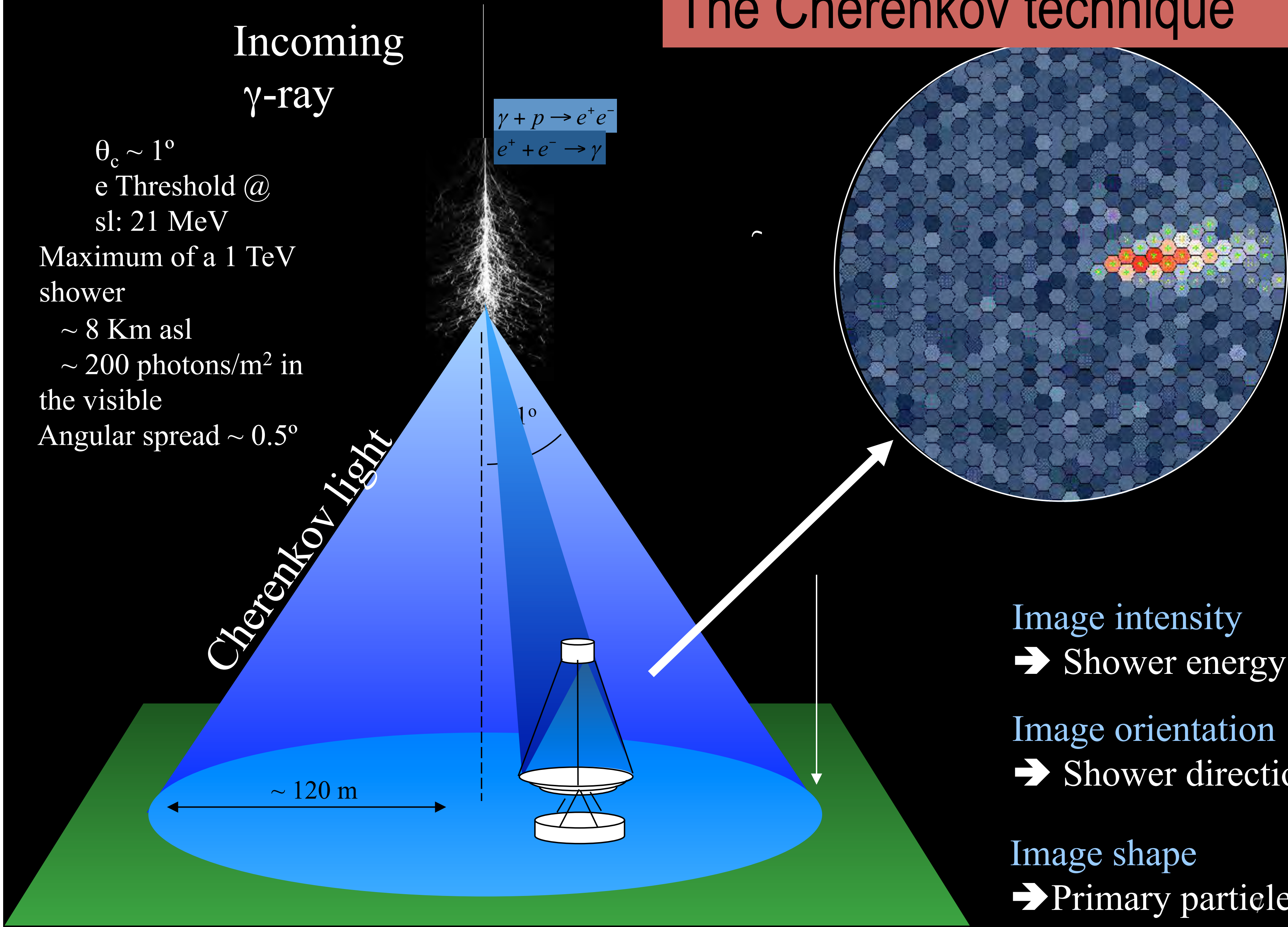
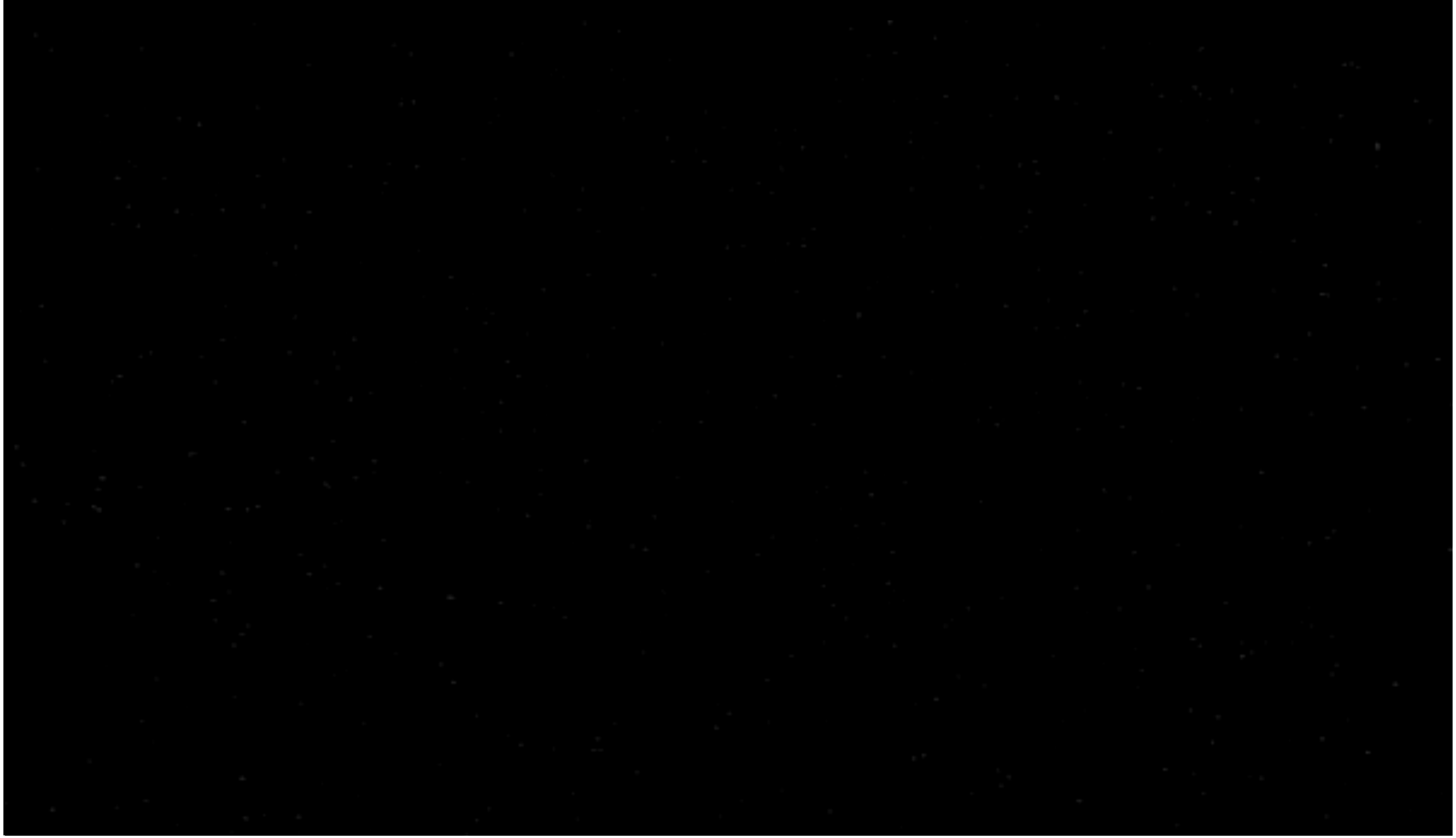


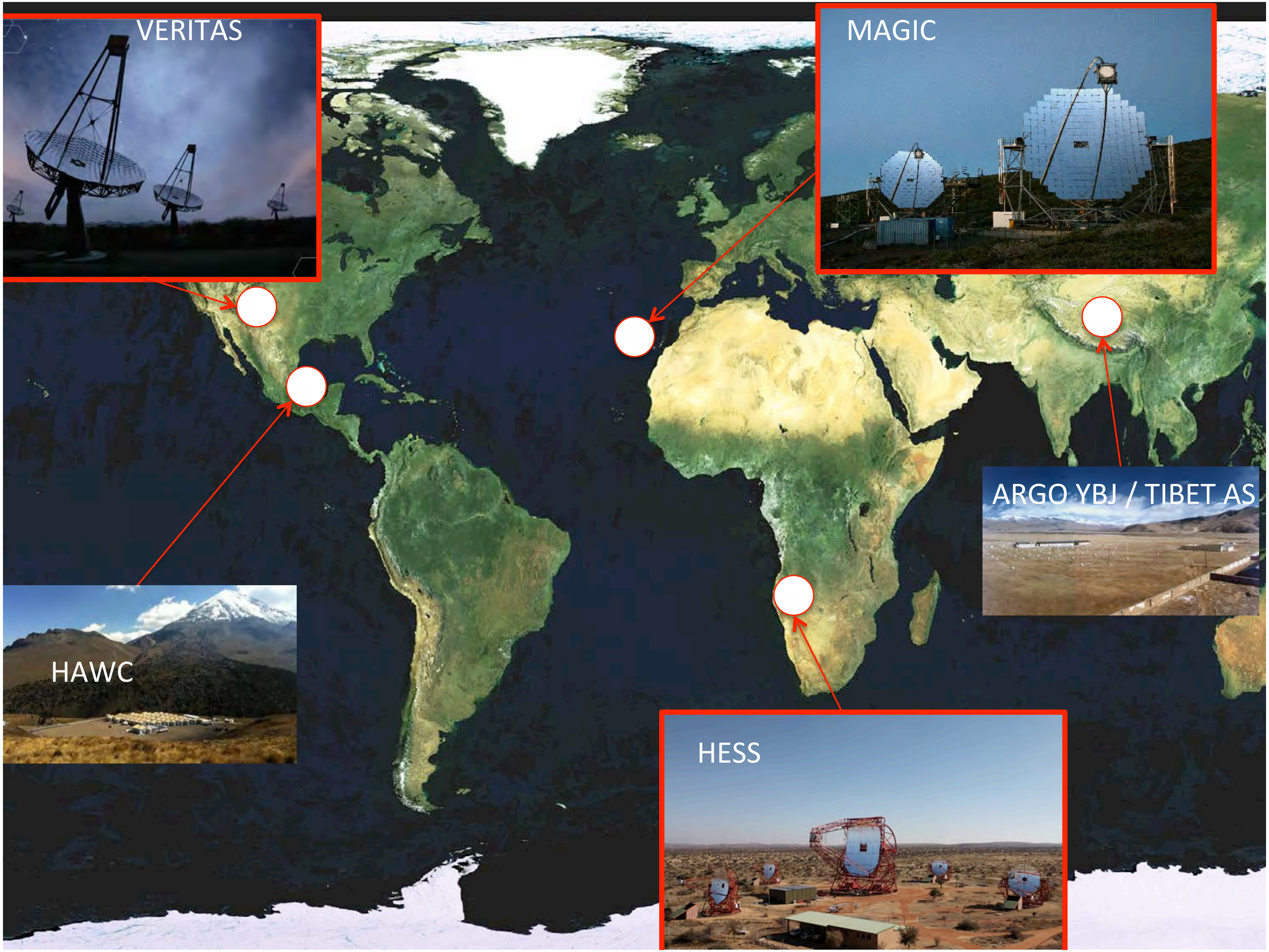
Image intensity
➔ Shower energy

Image orientation
➔ Shower direction

Image shape
➔ Primary particle

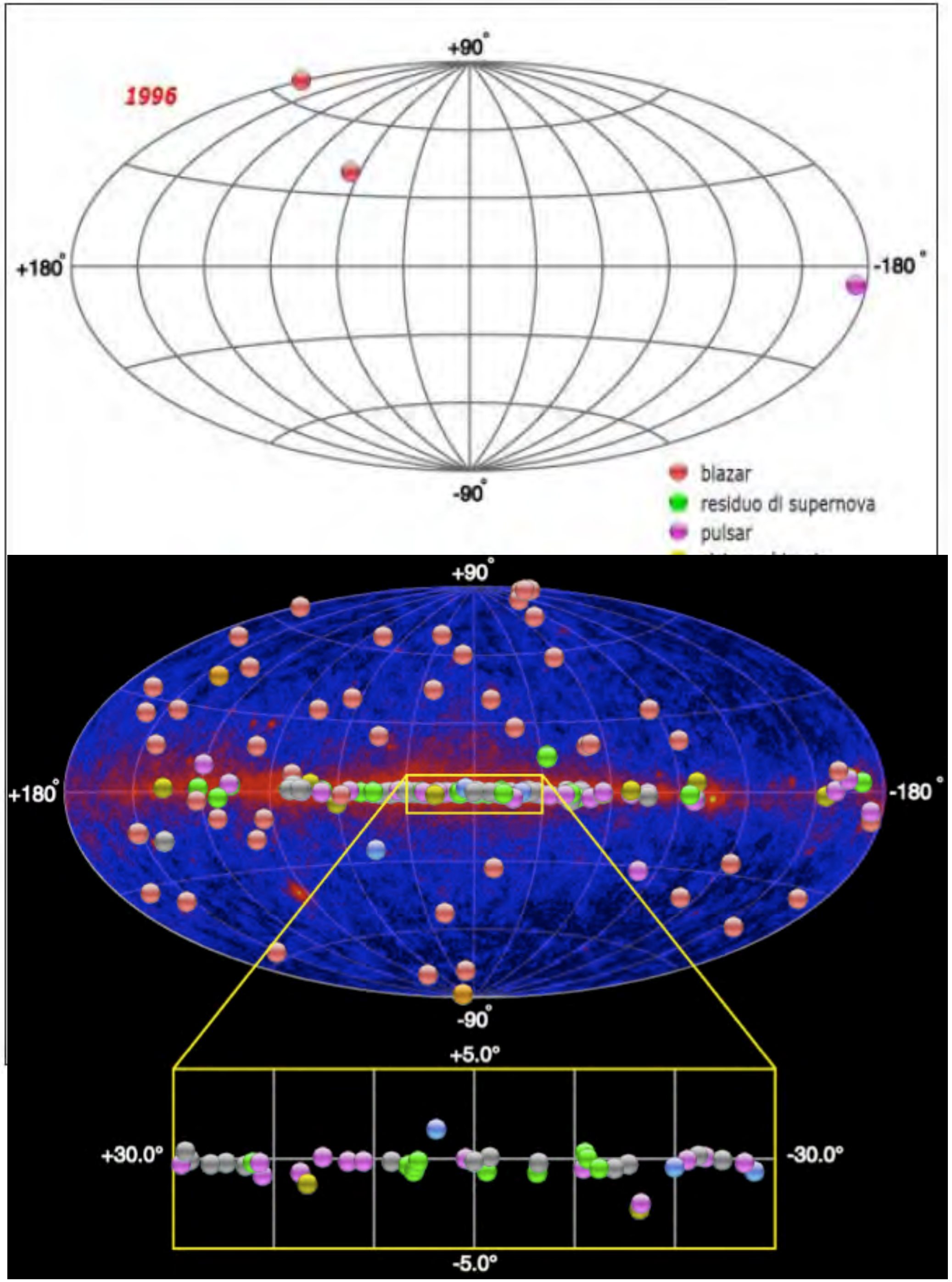
Signal duration: ~ 3ns




VERITAS
MAGIC
ARGO YBJ / TIBET AS
HAWC
HESS

Highlight in γ-ray astrophysics (MAGIC, HESS, VERITAS)

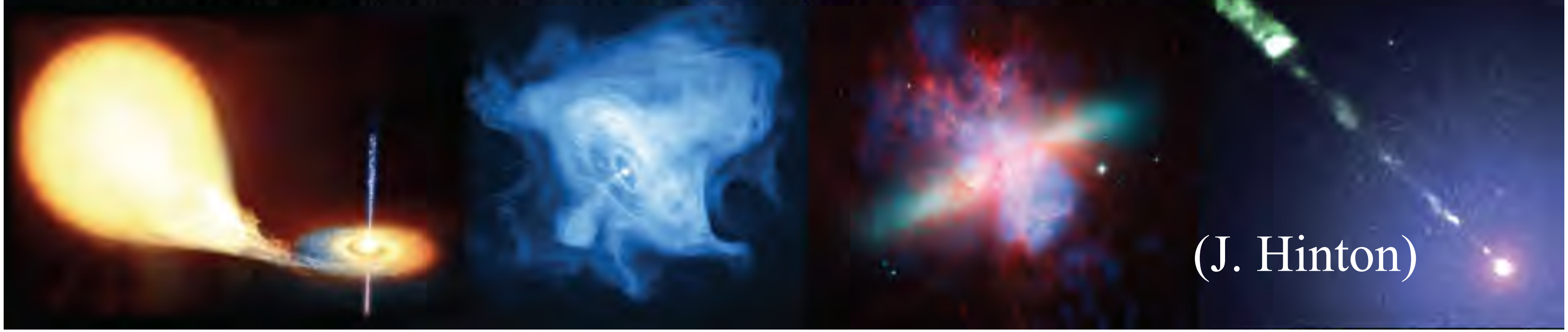
- Thanks mostly to Cherenkov telescopes, imaging of VHE (> 30 GeV) galactic sources and discovery of many new galactic and extragalactic sources: ~ 150 (and >200 papers) in the last 9 years
  - And also a better knowledge of the diffuse gammas and electrons
- A comparable success in HE (the Fermi realm); a 10x increase in the number of sources
- A new tool for cosmic-ray physics and fundamental physics



TeV Impact

Highlights from **HESS, MAGIC, VERITAS & MILAGRO**

- *Microquasars:* Science 309, 746 (2005), Science 312, 1771 (2006)
- *Pulsars:* Science 322, 1221 (2008), Science 334, 69 (2011)
- *Supernova Remnants:* Nature 432, 75 (2004)
- *The Galactic Centre:* Nature 439, 695 (2006)
- *Surveys:* Science 307, 1839 (2005), PRL 95, 251103 (2005)
- *Starbursts:* Nature 462, 770 (2009), Science 326,1080 (2009)
- *AGN:* Science 314,1424 (2006), Science 325, 444 (2009)
- *EBL:* Nature 440, 1018 (2006), Science 320, 752 (2008)
- *Dark Matter:* PRL 96, 221102 (2006), PRL 106, 161301 (2011)
- *Lorentz Invariance:* PRL 101, 170402 (2008)
- *Cosmic Ray Electrons:* PRL 101, 261104 (2009)



(J. Hinton)

Instr.	Tels. #	Tel. A (m^2)	FoV (°)	Tot A (m^2)	Thresh. (TeV)	PSF (°)	Sens. (%Crab)
H.E.S.S.	4	107	5	428	0.1	0.06	0.7
MAGIC	2	236	3.5	472	0.05(0.03)	0.06	0.8
VERITAS	4	106	4	424	0.1	0.07	0.7

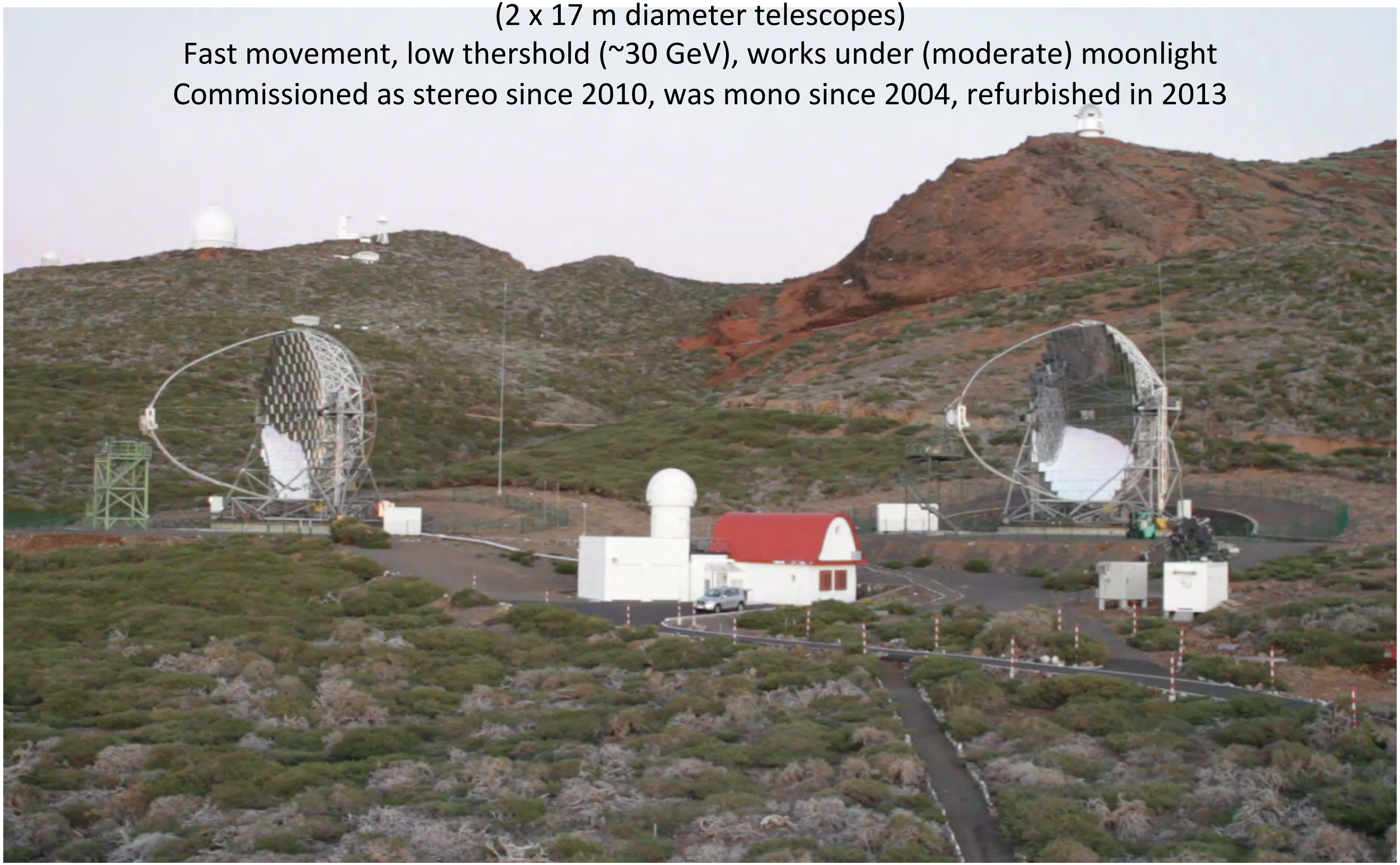

HESS
HESS-1: 4×12m tels
HESS-2: +28m tel.
Completed mid-2012

MAGIC at La Palma

(2 x 17 m diameter telescopes)

Fast movement, low thershold (~30 GeV), works under (moderate) moonlight

Commissioned as stereo since 2010, was mono since 2004, refurbished in 2013



The Main Telescopes of the *"Roque de los Muchachos"* European Northern Observatory



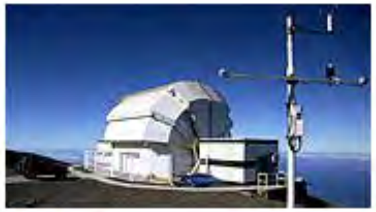


ORM is located on the Canary island of La Palma, at a height of 2200-2400 m a.s.l.










~170 Collaborating Astro-Physicists from 9 Countries

Bulgaria	Sofia
Croatia	Consortium (Zagreb, +...)
Finland	Consortium (Tuorla, +...)
Germany	DESY Zeuthen, U. Dortmund, MPI Munich, U. Würzburg
Japan	Consortium (Kyoto, +...)
Italy	INFN & U. Padova, INFN Pisa & U. Siena, INFN Como/Milano Bicocca, INFN Udine/Trieste & U. Udine, INAF (Consortium: Rome, +...)
Poland	Lodz
Spain	U. Barcelona, UAB Barcelona, IEEC-CSIC Barcelona, IFAE Barcelona, IAA Granada, IAC Tenerife, U. Complutense Madrid, CIEMAT Madrid
Switzerland	ETH Zurich

Main technological novelties of MAGIC

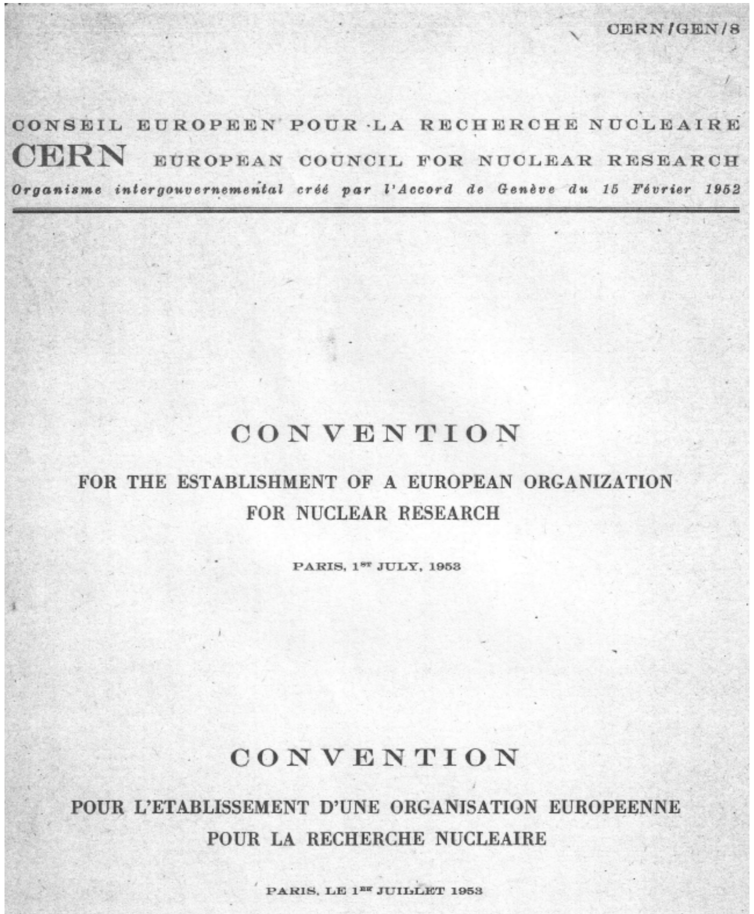
- Active mirror control
- Light weight (60 tons), fast repositioning to catch transients (GRBs etc.)
- PMTs with low gain, to enhance duty cycle
- 2 GB sampling
- Smart triggers for low energy
- Daily monitoring of mirror performance thanks to a CCD camera
- …

Main physics results and perspectives
(MAGIC: ~1 refereed paper/month)

- Cosmic Rays

- Photon propagation
  - Transparency of the Universe;
  - Energy of the vacuum;
  - Tests of Lorentz Invariance;
  - Cosmology

- Search for "WIMP" Dark Matter



CERN/GEN/8

CONSEIL EUROPEEN POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN COUNCIL FOR NUCLEAR RESEARCH
Organisme intergouvernemental créé par l'Accord de Genève du 15 Février 1952

CONVENTION

FOR THE ESTABLISHMENT OF A EUROPEAN ORGANIZATION
FOR NUCLEAR RESEARCH

PARIS, 1^{ST} JULY, 1953

CONVENTION

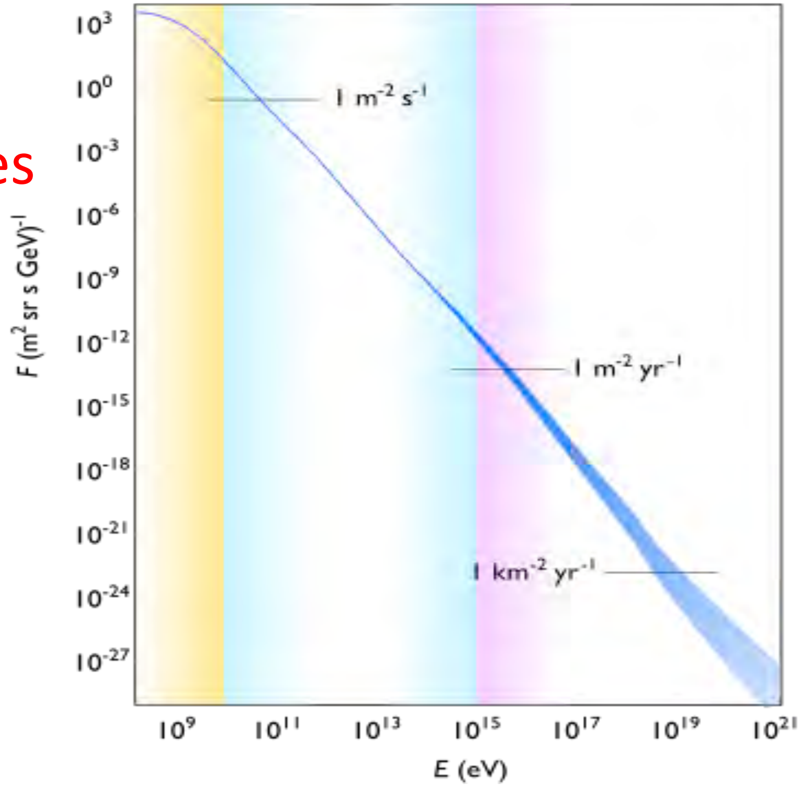
POUR L'ETABLISSEMENT D'UNE ORGANISATION EUROPEENNE
POUR LA RECHERCHE NUCLEAIRE

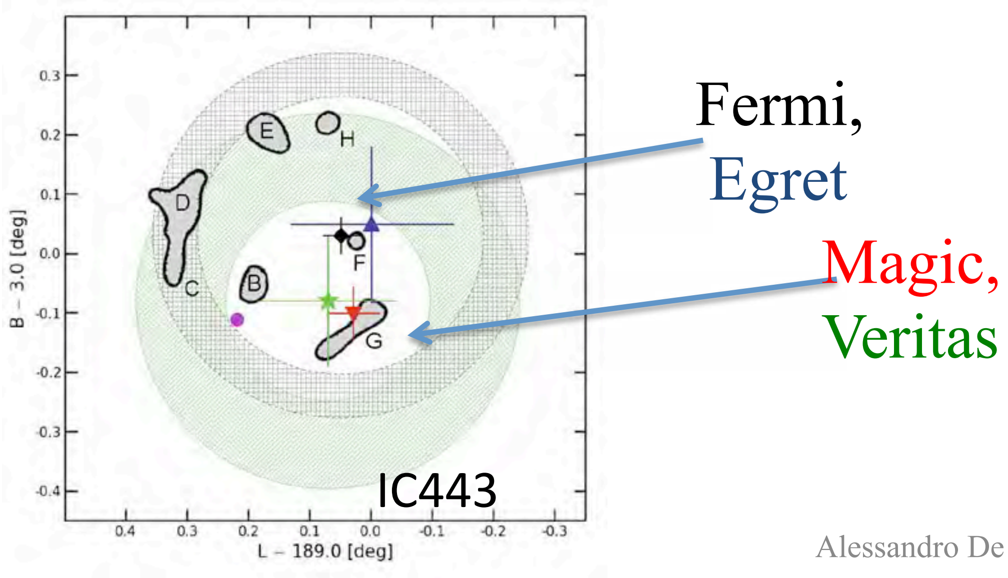
PARIS, LE 1^{ER} JUILLET 1953

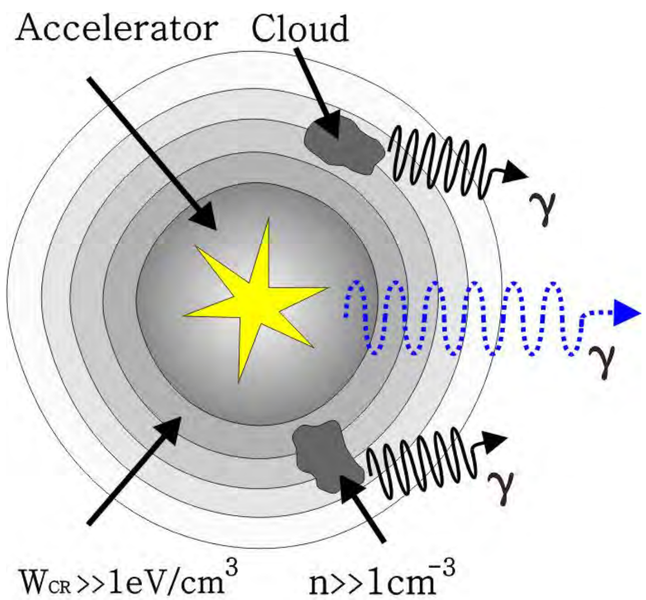
Sources of CR up to the knee

Cherenkov telescopes & gamma satellites

- Evidence that SNR are sources of CR up to ~1000 TeV (almost the knee) came from morphology studies of RX J1713-3946 (H.E.S.S. 2004)
- Striking evidence from the morphology of SNR IC443 (MAGIC + Fermi/Agile 2010)

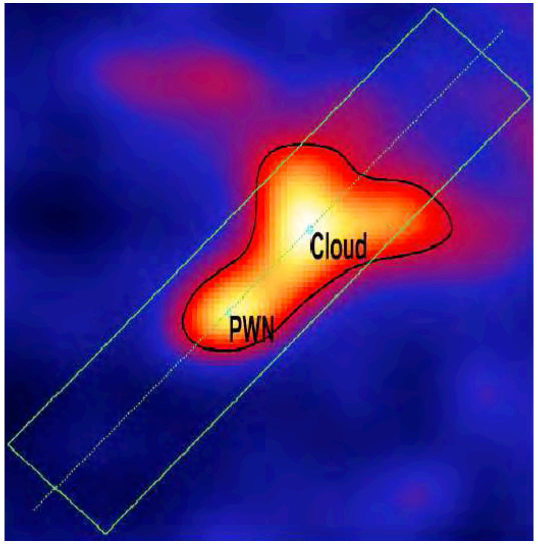


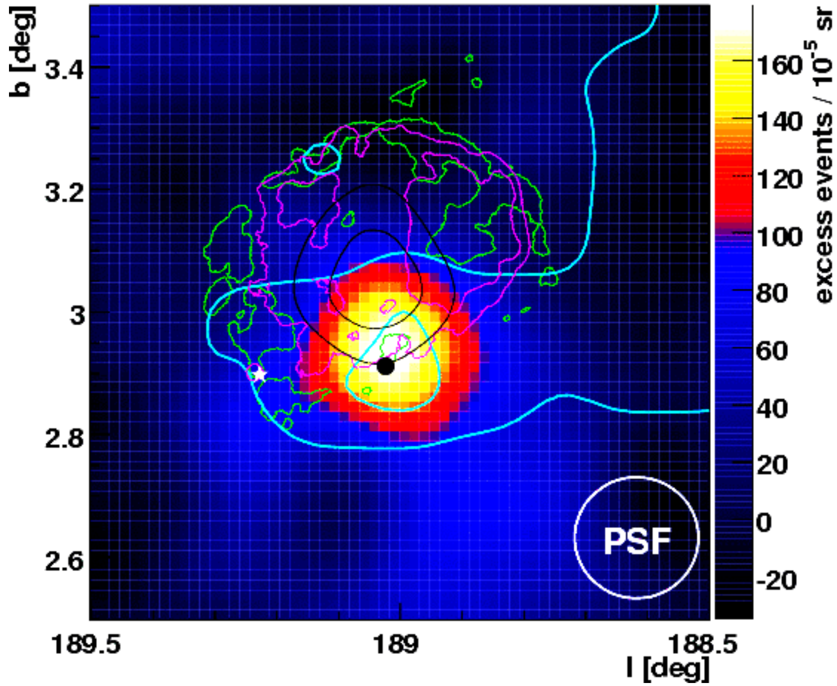


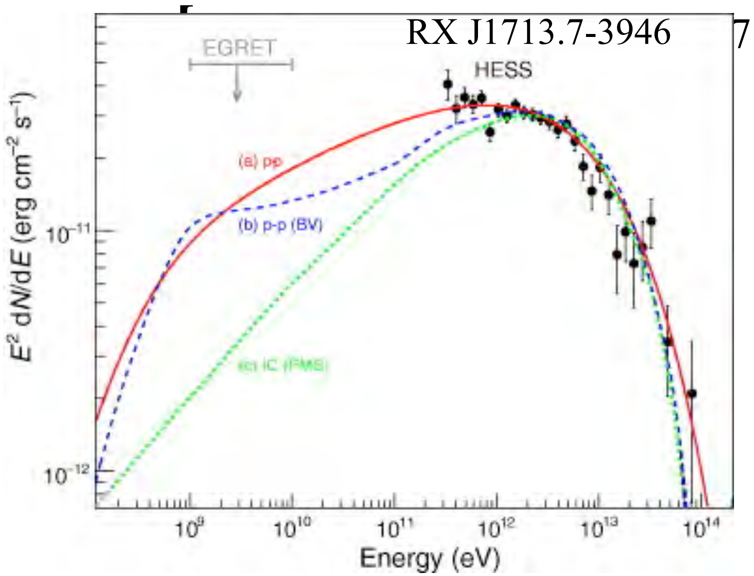


Molecular clouds close to IC 443, W51, RX J1713.7-3946

- VHE γ-ray excess compatible with cloud
- Differential energy spectrum prefers π^0 production





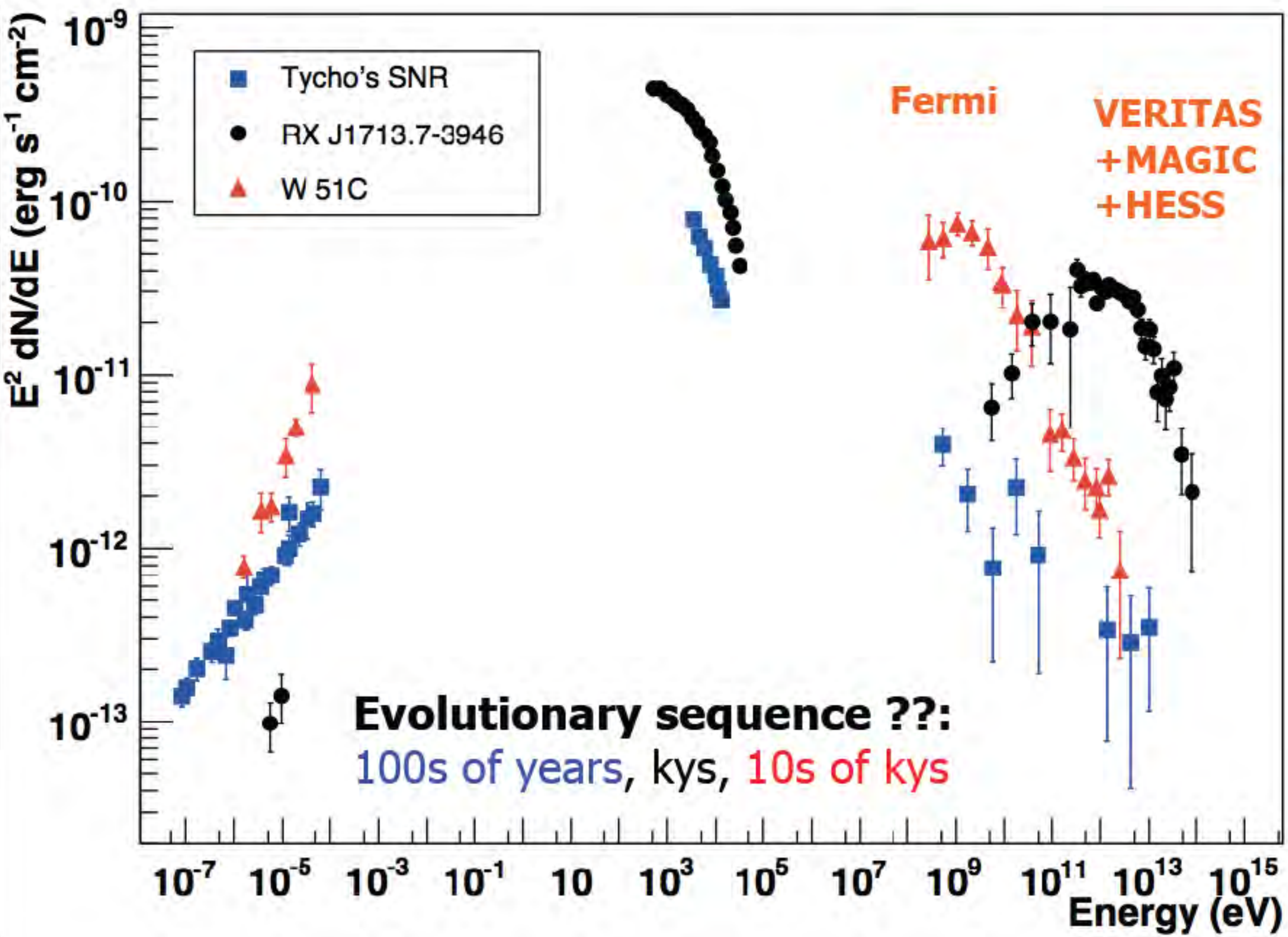


Supernova Remnants

- The Big News – Fermi/AGILE π^0 bump – but what about IACT results?
- Young SNRs:
  - Resolved shells in TeV
  - Acceleration to a few hundred TeV
    - But where are the Pevatrons? (see later)
- The middle aged SNRs
  - Interactions with nearby molecular clouds
    - As seen in GeV
  - In TeV: resolved emission +++
- In general
  - Impact of time-dependent acceleration, environment and particle escape, is being explored for the first time

(J. Hinton)

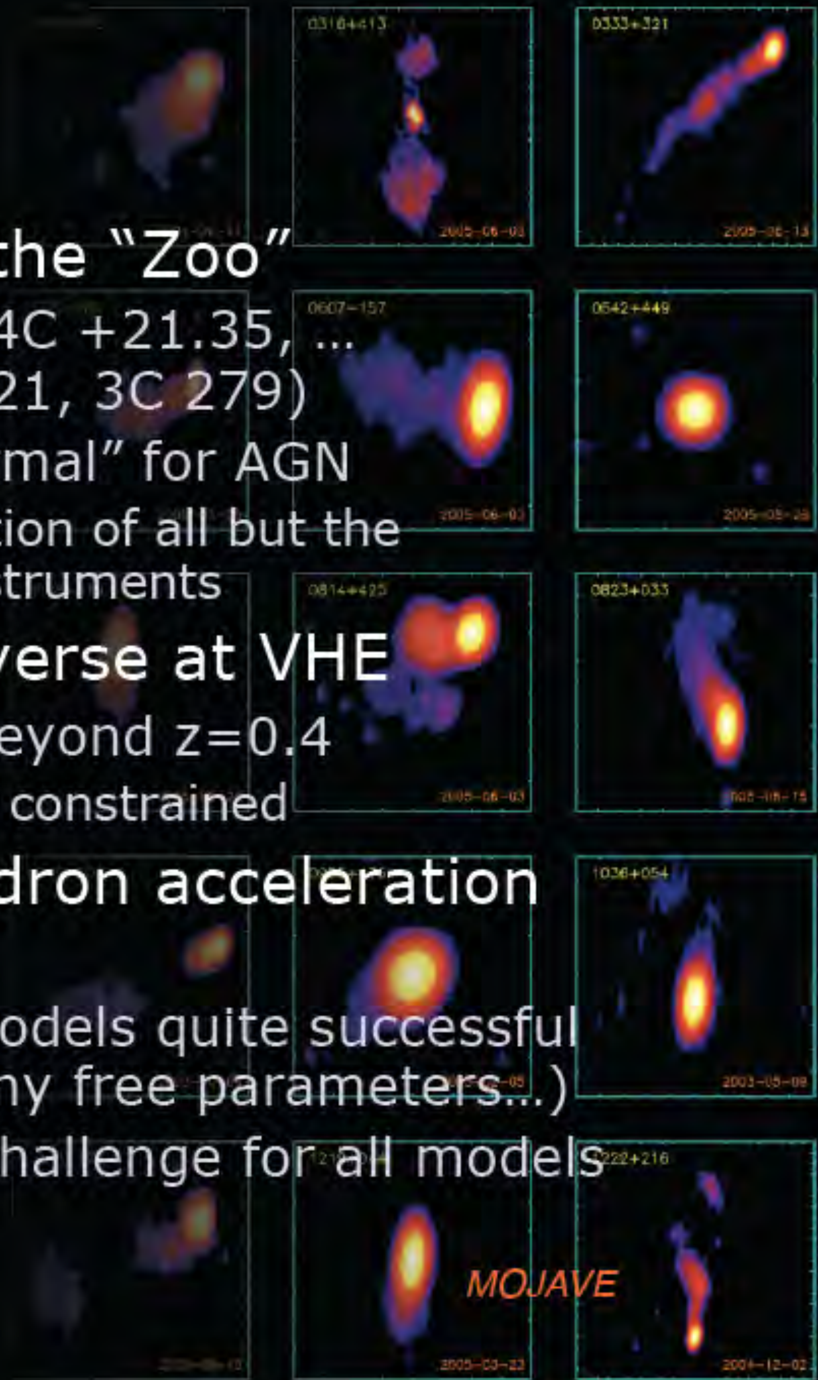
University of Leicester



E^2 dN/dE (erg s^{-1} cm^{-2})
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
Tycho's SNR
RX J1713.7-3946
W 51C
Fermi
VERITAS
+MAGIC
+HESS
Evolutionary sequence ??:
100s of years, kys, 10s of kys
10^{-7} 10^{-5} 10^{-3} 10^{-1} 10 10^{3} 10^{5} 10^{7} 10^{9} 10^{11} 10^{13} 10^{15}
Energy (eV)

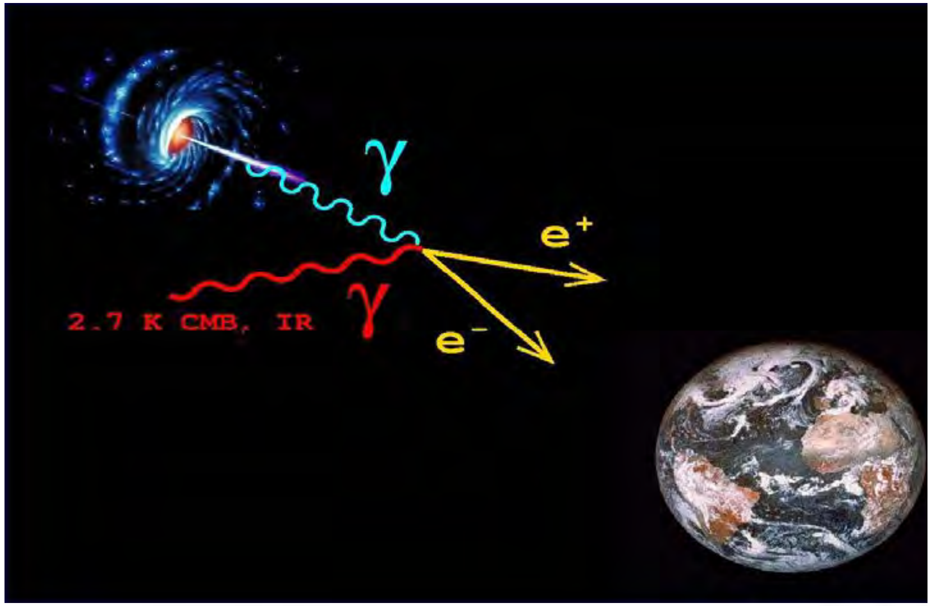
Active Galaxies

- Continued diversification of the "Zoo"
  - NGC 1275, IC 310, AP Librae, 4C +21.35, ...
    (cf Cen A, M 87, BL Lac, Mrk 421, 3C 279)
  - TeV emission seems to be "normal" for AGN
    - But beaming needed for detection of all but the closest objects with current instruments
- Expansion of the known universe at VHE
  - Now six VHE emitters known beyond z=0.4
    - and 12 with z>0.2, EBL tightly constrained
- Gamma-ray evidence for hadron acceleration in AGN jets still missing...
  - Multi-zone synchrotron + IC models quite successful (increasingly realistic - but many free parameters...)
  - Extremely fast variability is a challenge for all models



(J. Hinton)

How do gamma rays reach us?



$\gamma_{VHE}\gamma_{bck} \rightarrow e^{+}e^{-}$

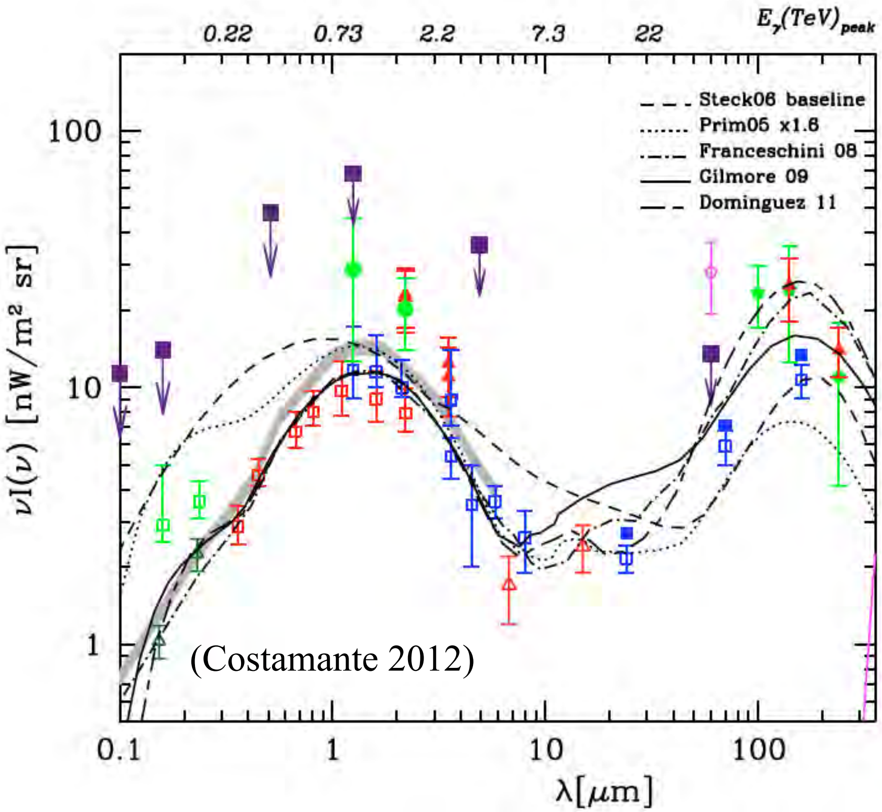
$$\epsilon > \epsilon_{\rm thr}(E,\varphi) \equiv \frac{2\,m_e^2\,c^4}{E\,(1-\cos\varphi)}$$

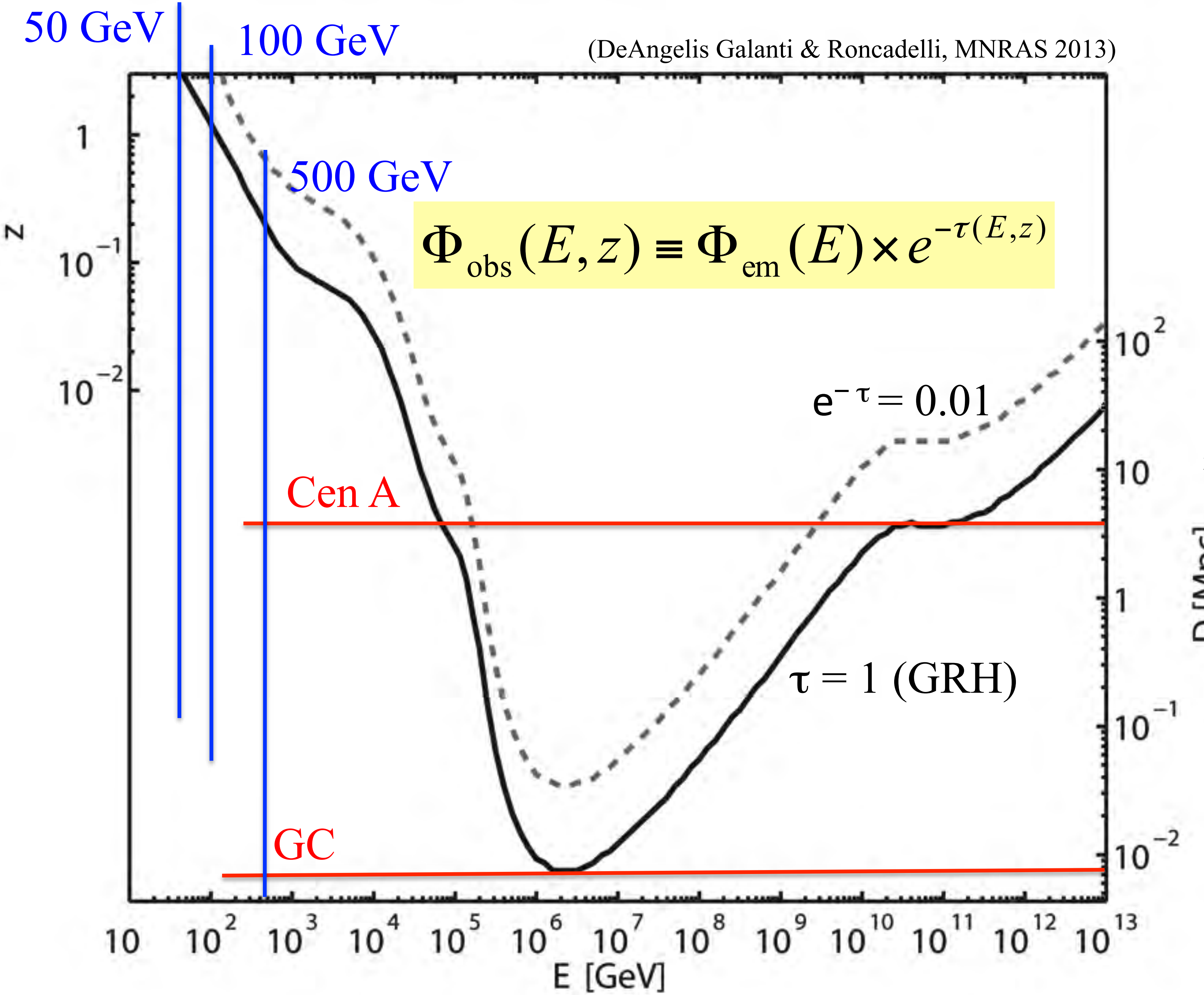
$$\sigma_{\gamma\gamma}(E,\epsilon,\varphi) = \frac{2\pi\alpha^2}{3m_e^2}W(\beta) \simeq 1.25\cdot 10^{-25}\,W(\beta)\,{\rm cm}^2\ ,$$

$$W(\beta) = \left(1-\beta^2\right)\left[2\beta\left(\beta^2-2\right)+\left(3-\beta^4\right)\,\ln\left(\frac{1+\beta}{1-\beta}\right)\right]$$

Maximum $\sigma_{\gamma\gamma}^{\rm max} \simeq 1.70\cdot 10^{-25}\,{\rm cm}^2$ for $\beta \simeq 0.70$.
For an isotropic background, it is maximized for

$$\epsilon(E) \simeq \left(\frac{900\,{\rm GeV}}{E}\right)\,{\rm eV}$$





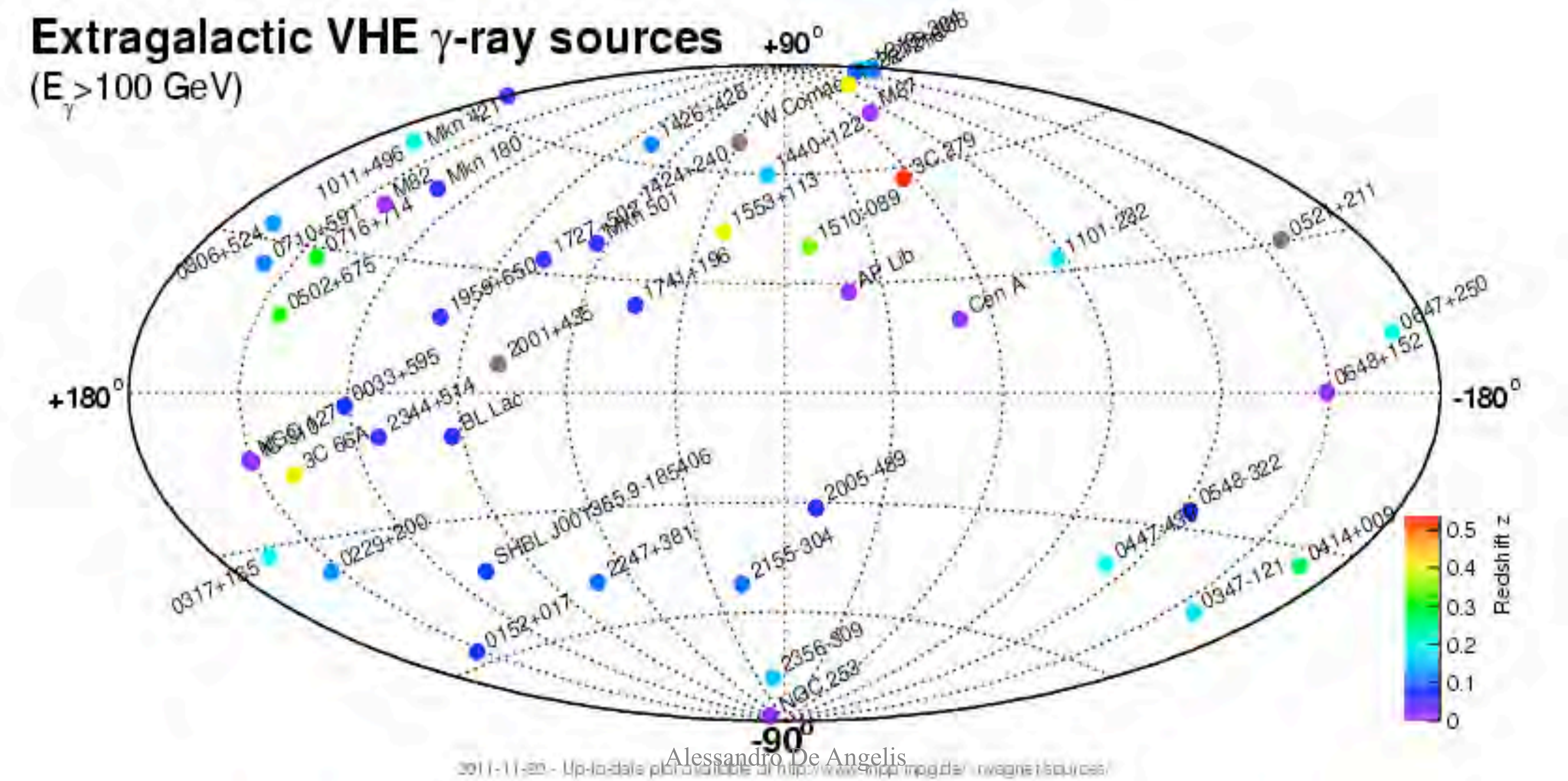
50 GeV
100 GeV
500 GeV
(DeAngelis Galanti & Roncadelli, MNRAS 2013)
$\Phi_{obs}(E,z) \equiv \Phi_{em}(E) \times e^{-\tau(E,z)}$
$e^{-\tau} = 0.01$
Cen A
$\tau = 1$ (GRH)
GC
z
1
10^{-1}
10^{-2}
D [Mpc]
10^{2}
10
1
10^{-1}
10^{-2}
10
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{8}
10^{9}
10^{10}
10^{11}
10^{12}
10^{13}
E [GeV]

Extragalactic Sources

~50 Sources

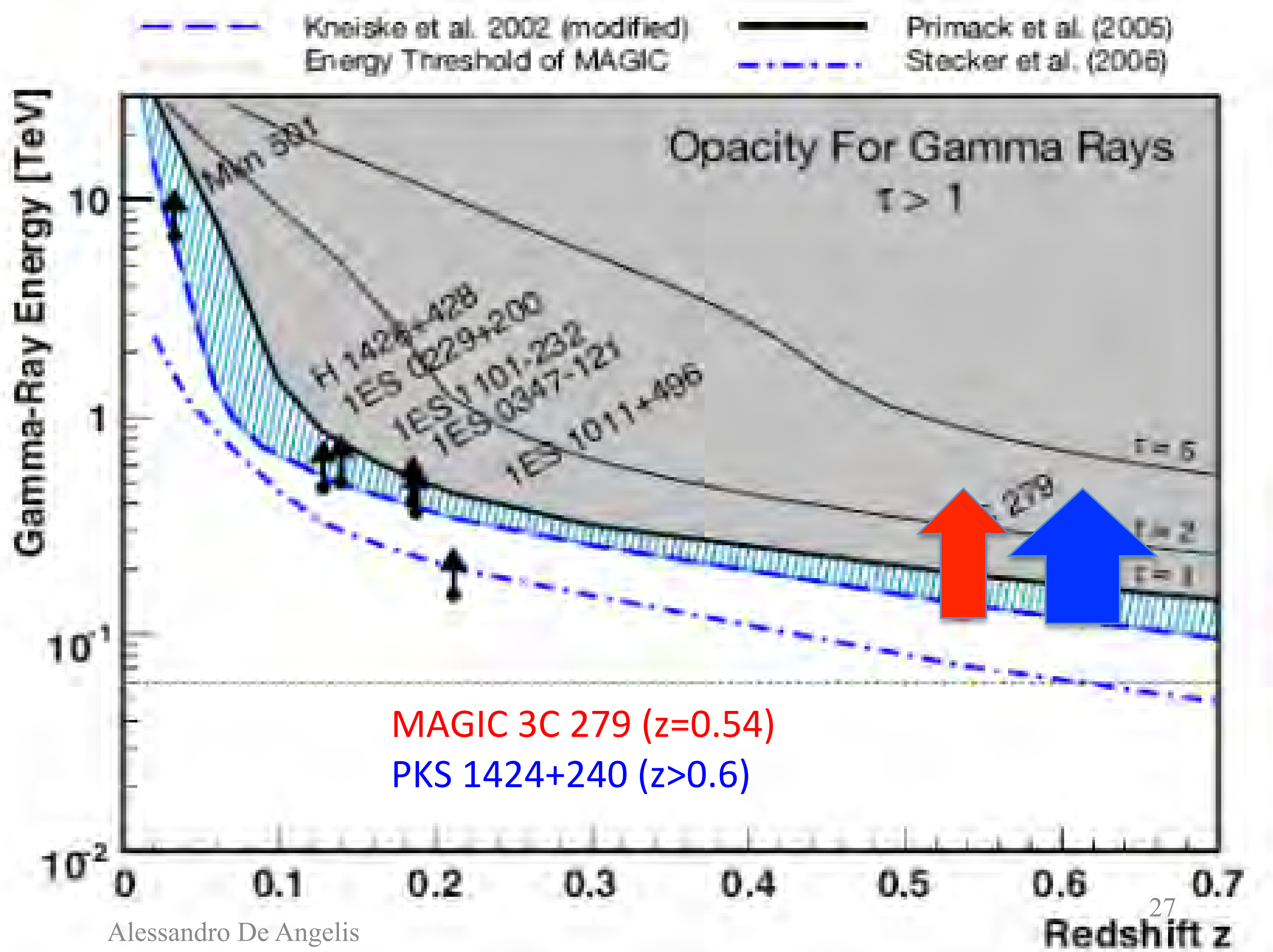
…

1ES 1011+496	**z=0.21**	**MAGIC 2007**
1ES 0414+009	z=0.29	HESS/Fermi 2009
S5 0716+71	**z=0.31±0.08**	**MAGIC 2009**
1ES 0502+675	z=0.34	VERITAS 2009
PKS 1510-089	z=0.36	HESS 2010
4C +21.43	**z=0.43**	**MAGIC 2010**
3C 66A	**z=0.44**	**VERITAS 2009**
3C 279	**z=0.54**	**MAGIC 2008**



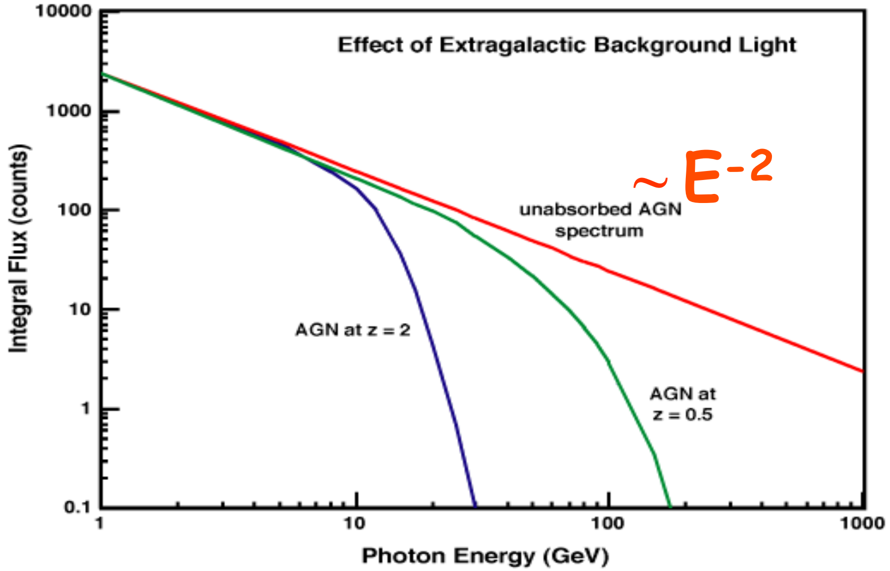
Alessandro De Angelis

Are our AGN observations consistent with theory (1) ?



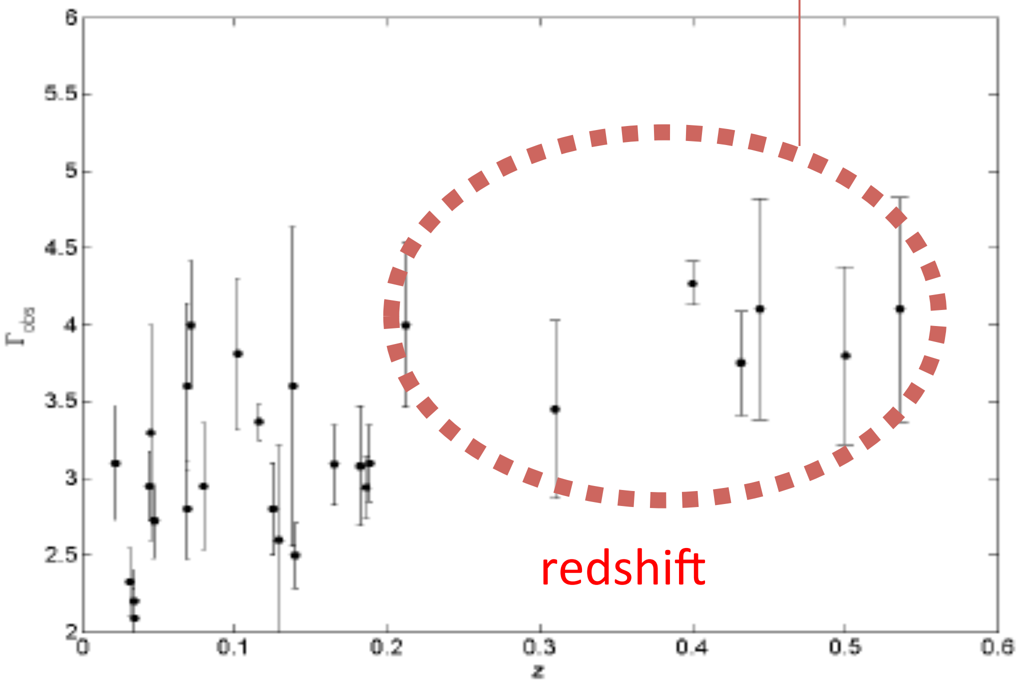
Are our AGN observations consistent with theory (2)?

Measured spectra affected by attenuation in the EBL:



Selection bias?
New physics ?

observed spectral index



redshift

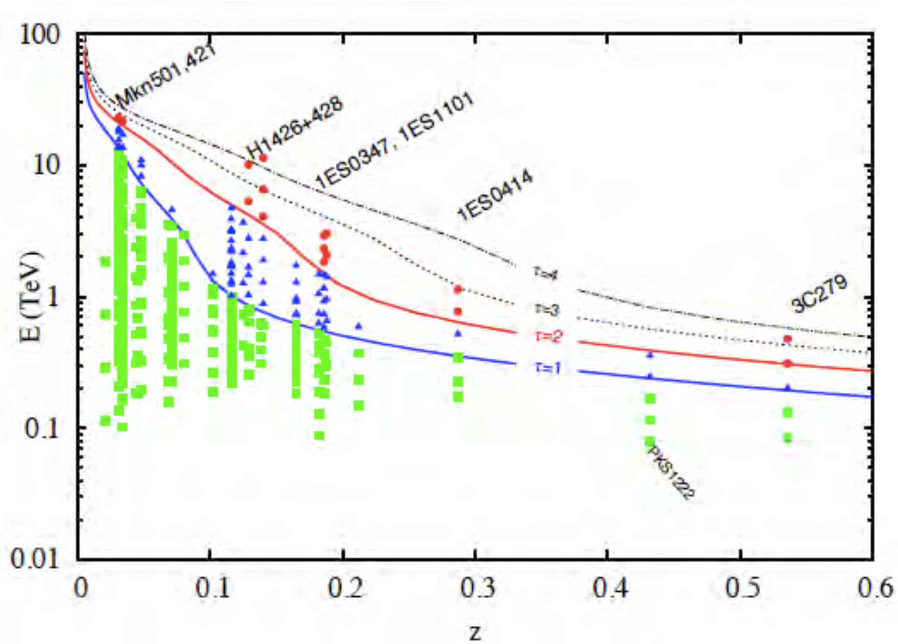
(DA, Galanti, Roncadelli; PRD 2011)

Attempts to quantify the problem overall

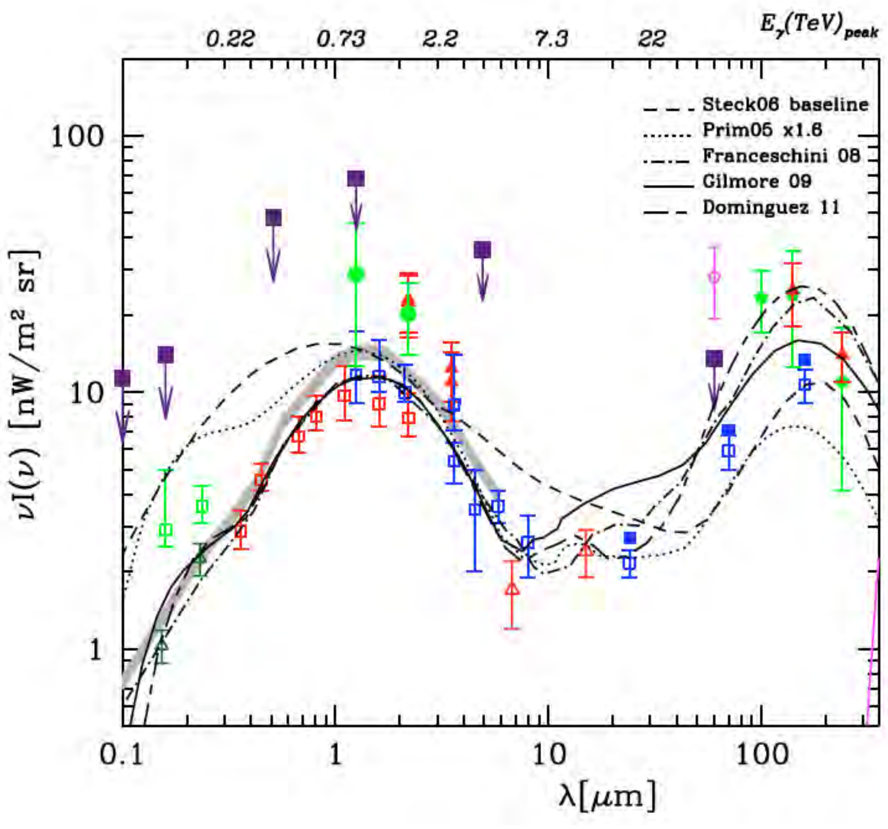
- Analysis of AGN
  - For each data point, a corresponding lower limit on the optical depth τ is calculated using a minimum EBL model
  - Nonparametric test of consistency
  - Disagreement with data: overall significance of 4.2 σ

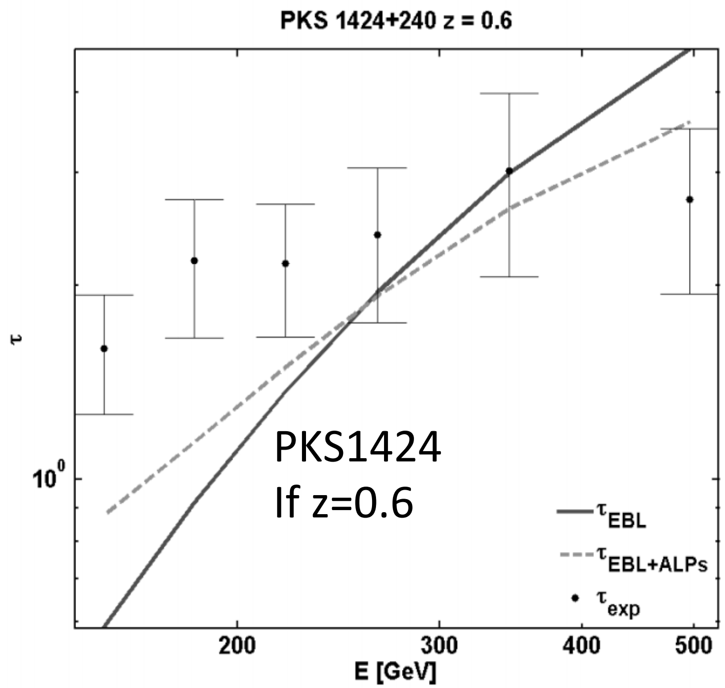
=> Understand experimentally the outliers

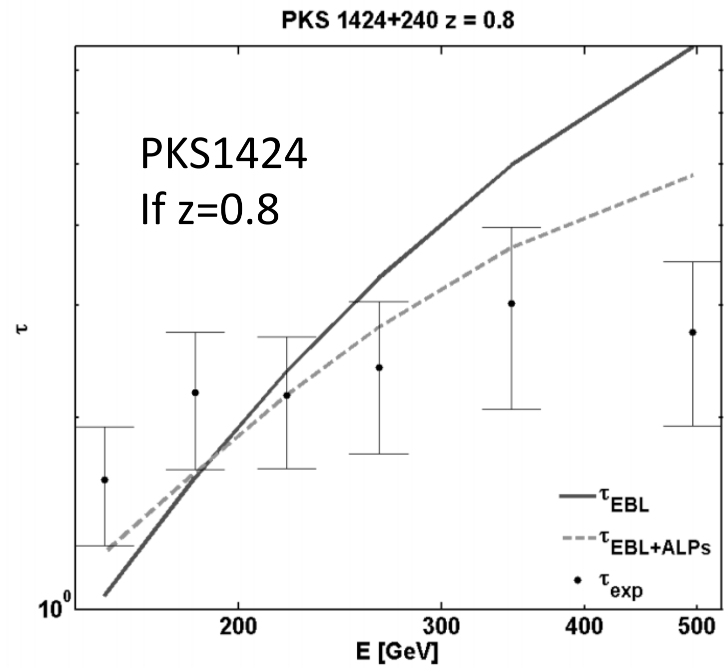
(Horns , Meyer 2011)



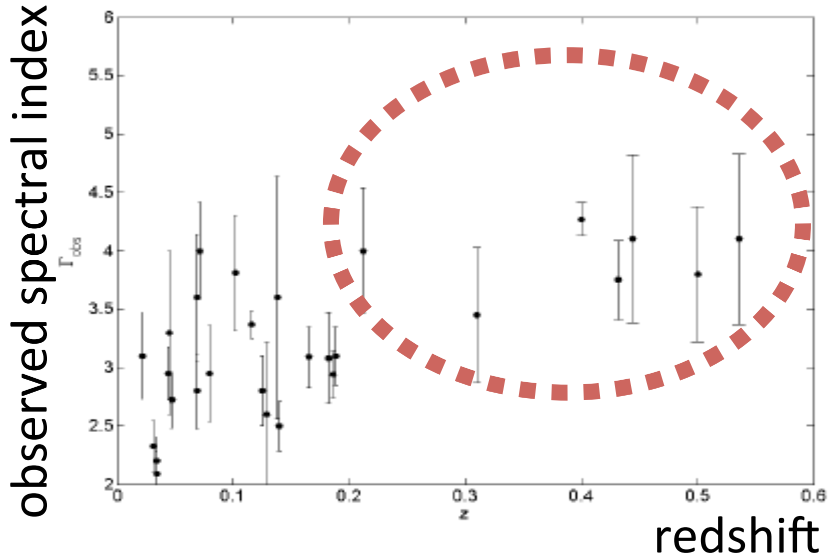
A reminder: EBL rather well constrained, and extrapolation from Fermi is possible

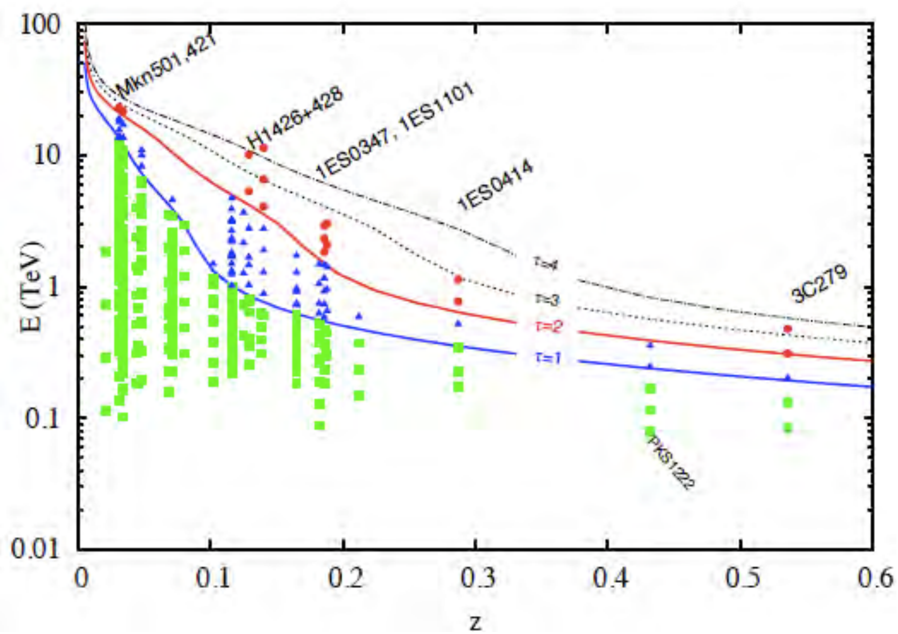






If there is a problem





Explanations from the standard ones

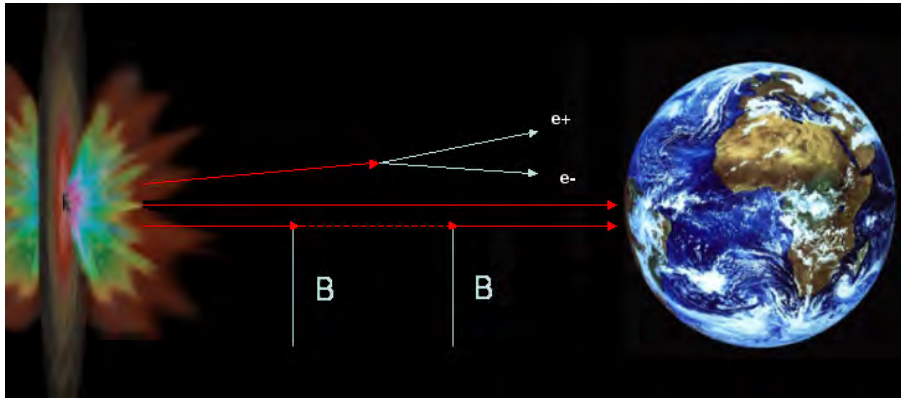
- very hard emission mechanisms with intrinsic slope < 1.5 (Stecker 2008)
- Very low EBL, plus observational bias, plus a couple of "wrong" outliers

to almost standard

- γ-ray fluxes enhanced by relatively nearby production by interactions of primary cosmic rays or ν from the same source

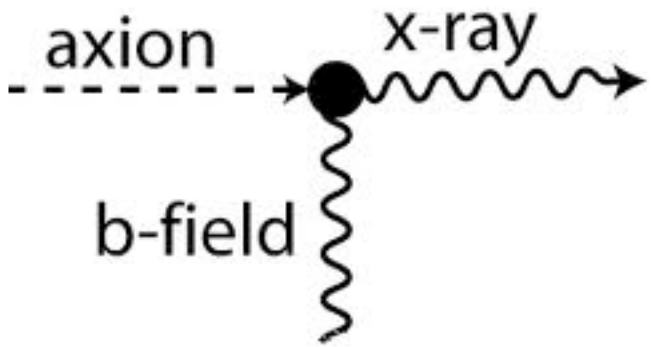
to possible evidence for new physics

- Oscillation to a light "axion"? (DA, Roncadelli & MAnsutti [DARMA], PRD2007, PLB2008)
- Axion emission (Simet+, PRD2008)
- A combination of the above (Sanchez Conde et al. PRD 2009)



Axions and ALPs

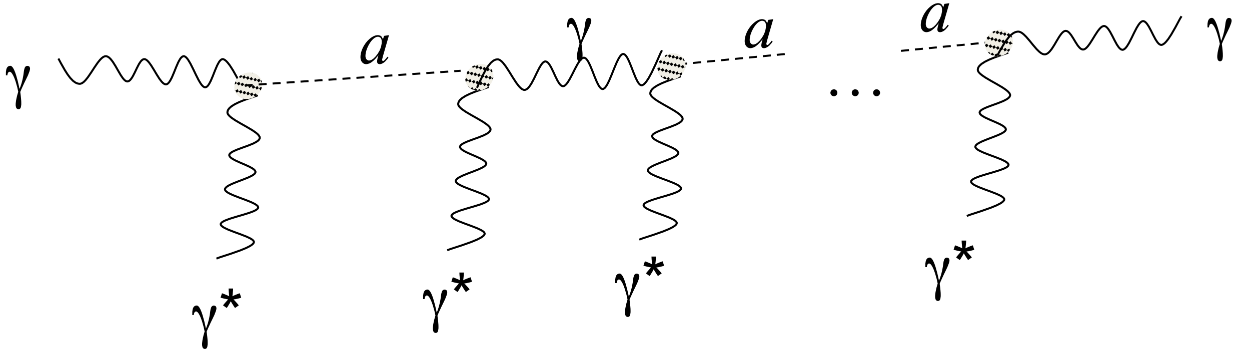
- The “strong CP problem”: CP violating terms exist in the QCD Lagrangian, but CP appears to be conserved in strong interactions
- Peccei and Quinn (1977) propose a solution: clean it up by an extra field in the Lagrangian
  - Called the “axion” from the name of a cleaning product
  - Pseudoscalar, neutral, stable on cosmological scales, feeble interaction, couples to the photon
    - Can make light shine through a wall
  - The minimal (standard) axion coupling g ∝ m; however, one can have an “ALP” in which g = 1/M is free from m



$$\frac{m}{1\,\mathrm{eV}} \simeq \frac{1}{M/6 \times 10^6\,\mathrm{GeV}}$$

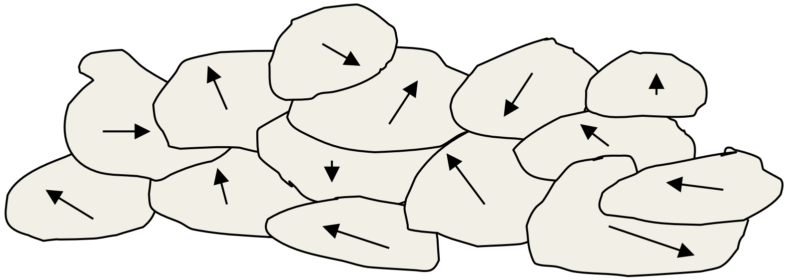
The photon-axion mixing mechanism

$$L_{a\gamma\gamma} = g_{a\gamma}\left(\vec{E}\cdot\vec{B}\right)a$$



Propagation: Raffelt-Stodolsky 1987; Csaki-Kaloper-Terning 2002; DA Roncadelli MAnsutti 2007; Simet Hooper Serpico 2008

- Magnetic field 1 nG < B < 1aG (AGN halos). Cells of ~ 1 Mpc

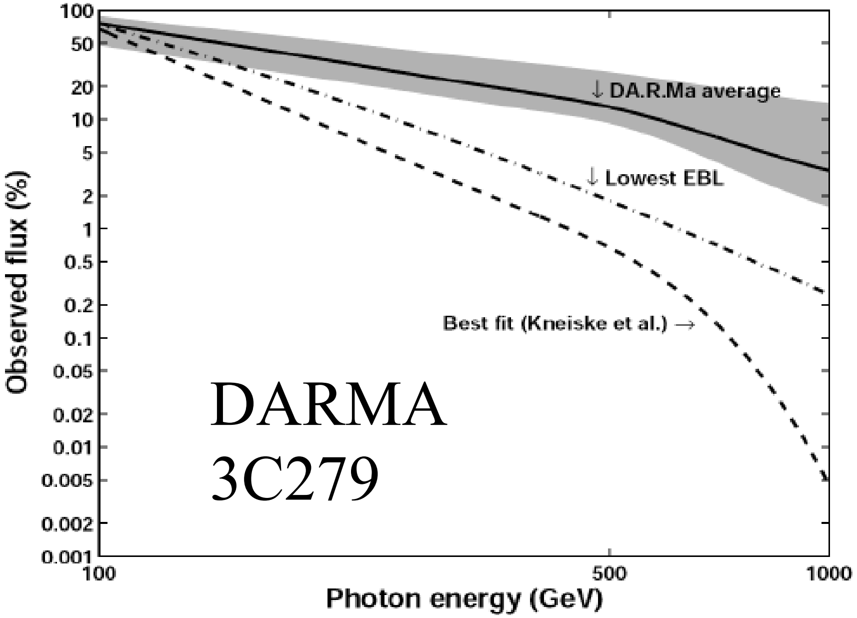


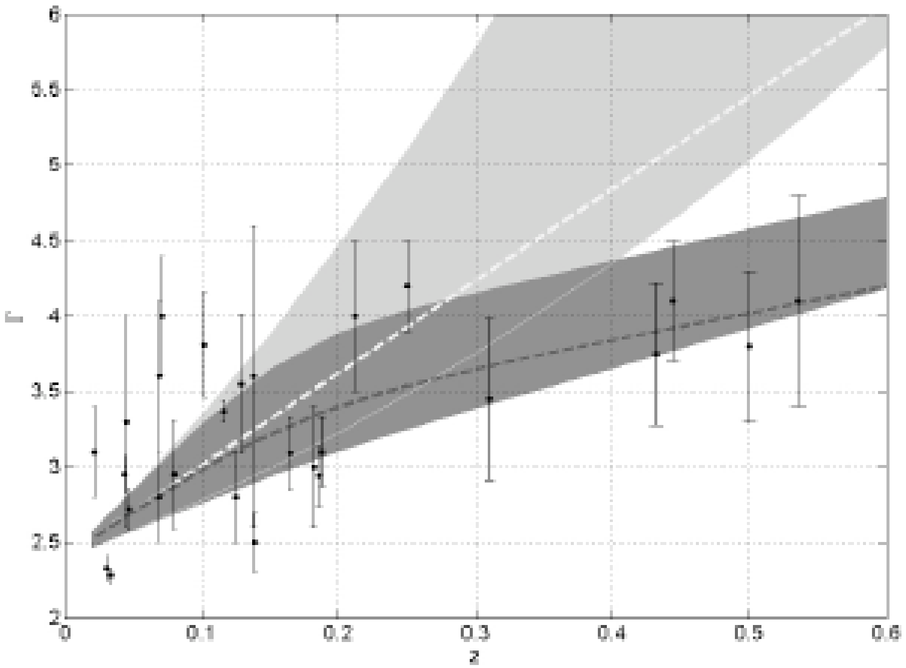
$$P_{\gamma\to a} \approx NP_1$$

$$P_1 \approx \frac{g_{a\gamma}^2 B_T^2 s^2}{4} \approx 2\times10^{-3}\left(\frac{B_T}{1\mathrm{nG}}\frac{s}{1\mathrm{Mpc}}\frac{g_{a\gamma}}{10^{-10}\,\mathrm{GeV}^{-1}}\right)^2$$

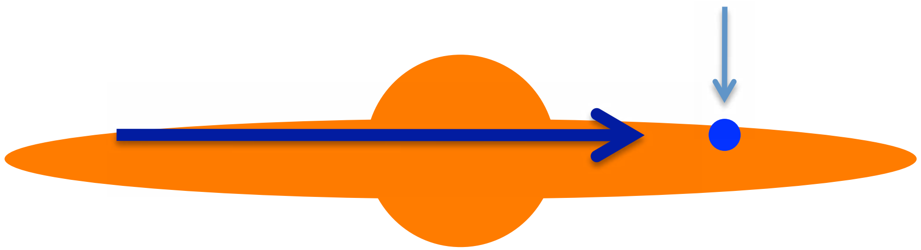
- m_a < 0.02 eV (direct searches)
- g < 10^{-10} GeV^{-1} from astrophysical bounds

If B ~ 0.1–1 nG, λ ~ 1-10 Mpc, observations can be explained





Note: if conversion "a la Simet-Hooper-Serpico",
=> the effect could be directional



- Could also be something else:

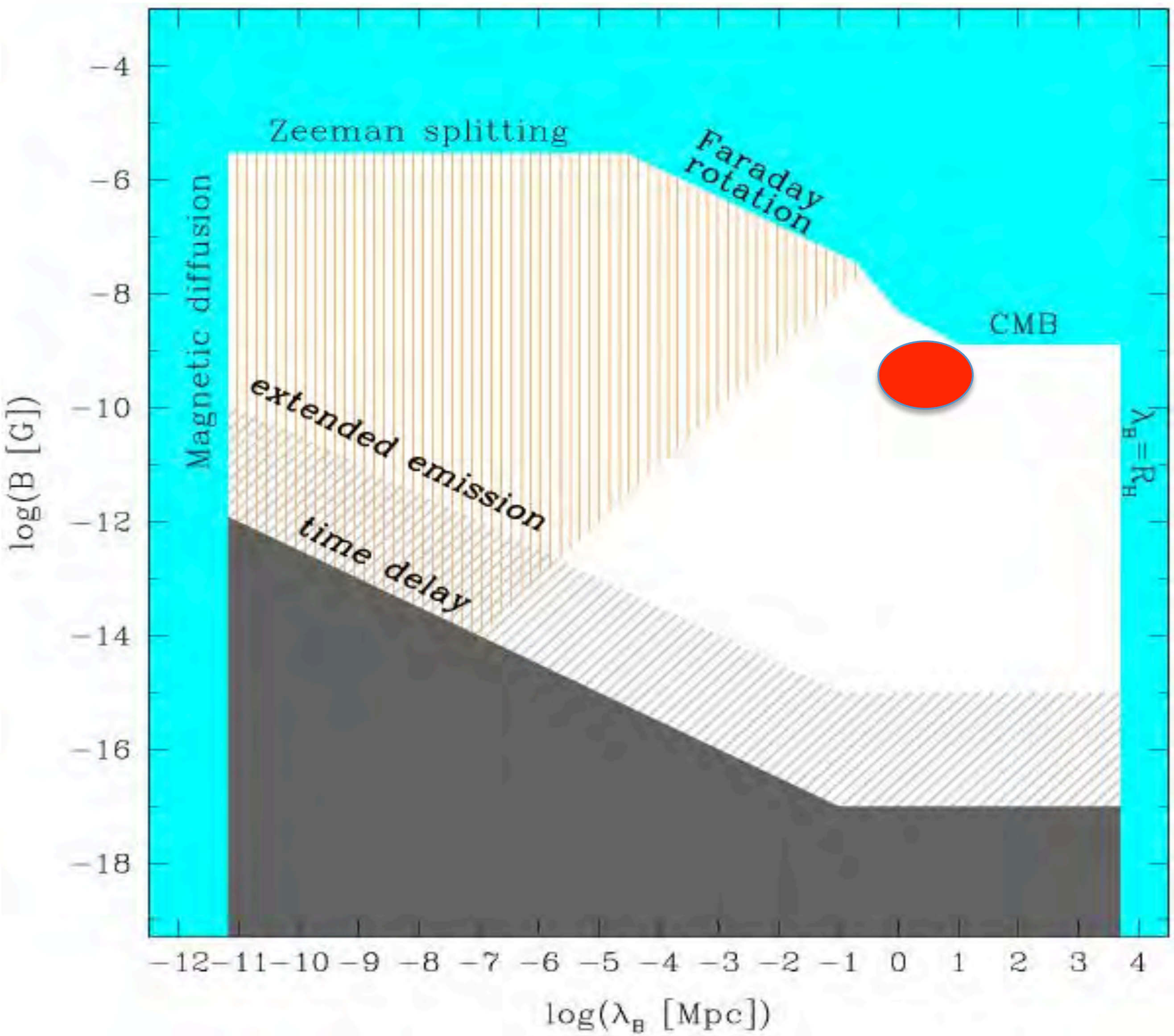
  Whatever (light and almost sterile) particle feebly coupling to the photon

  Exercise 2

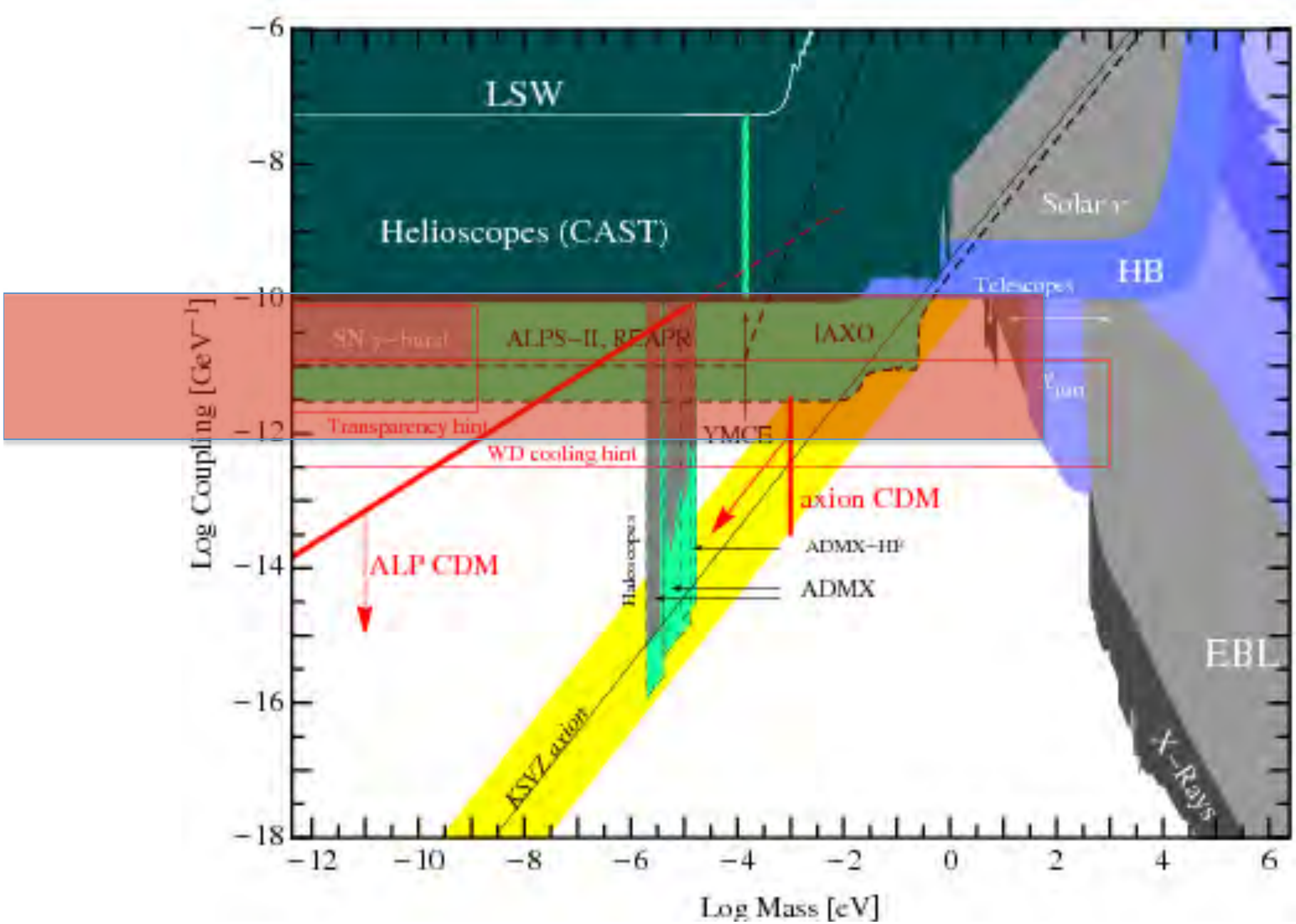
  – Paraphoton
    - Shadow photon

  – New millicharged particles

Intergalactic magnetic fields: indications from DARMA



Preferred values for m, g



Is Lorentz invariance exact?

- For longtime violating Lorentz invariance/Lorentz transformations/Einstein relativity was a heresy
  – Is there an aether? (Dirac 1951)
  – Many preprints, often unpublished (=refused) in the '90s

- Then the discussion was open
  – Trans-GZK events? (AGASA collaboration 1997-8)
  – LIV => high energy threshold phenomena: photon decay, vacuum Cherenkov, GZK cutoff (Coleman & Glashow 1997-8)
  – GRB and photon dispersion (Amelino-Camelia et al. 1997)
  – Framework for the violation (Colladay & Kostelecky 1998)
  – LIV and gamma-ray horizon (Kifune 1999)
  – …

LIV? New form of relativity?

- Von Ignatowsky 1911: {relativity, omogeneity/isotropy, linearity, reciprocity} => Lorentz transformations with "some" invariant c (Galilei relativity is the limit $c \rightarrow \infty$)
- CMB is the aether: give away isotropy?
- QG motivation: give away linearity? (A new relativity with 2 invariants: "c" and E_P)

- In any case, let's sketch an effective theory…
  - Let's take a purely phenomenological point of view and encode the general form of Lorentz invariance violation (LIV) as a perturbation of the Hamiltonian (Amelino-Camelia+)

A heuristic approach: modified dispersion relations (perturbation of the Hamiltonian)

- We expect the Planck mass to be the scale of the effect

$$E_P = \sqrt{hc/G} \cong 1.2 \times 10^{19}\,\text{GeV}$$

$$H^2 = m^2 + p^2 \rightarrow H^2 = m^2 + p^2\left(1 + \xi \frac{E}{E_P} + \ldots\right)$$

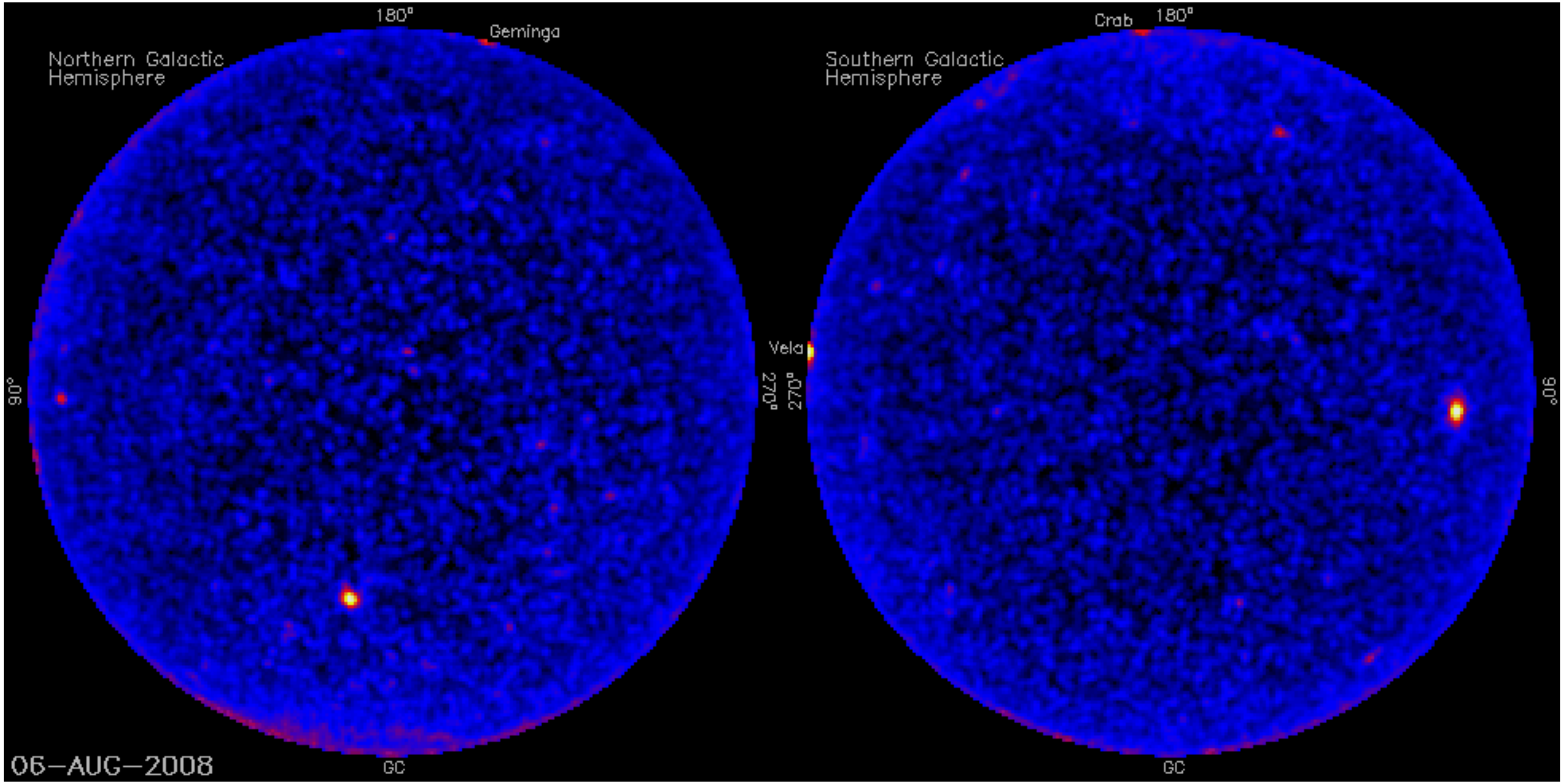
$$H \xrightarrow[p>>]{} p\left(1 + \frac{m^2}{2p^2} + \xi \frac{p}{2E_P} + \ldots\right)$$

$$v = \frac{\partial H}{\partial p} \cong 1 - \frac{m^2}{2p^2} + \xi \frac{p}{E_P} \Rightarrow \boxed{v_\gamma \cong 1 + \xi \frac{E}{E_P}}$$

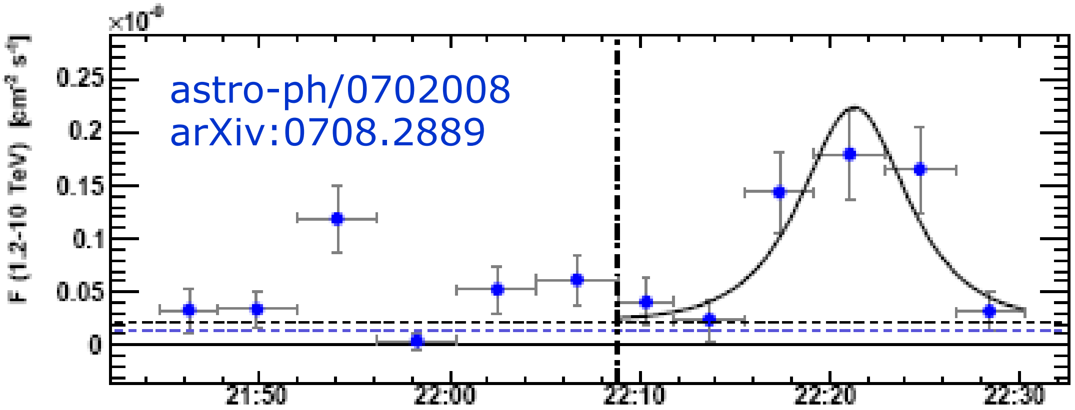
=> effect of dispersion relations at cosmological distances can be important at energies well below Planck scale:

$$\boxed{\Delta t_\gamma \cong T \Delta E \frac{\xi}{E_P}}$$

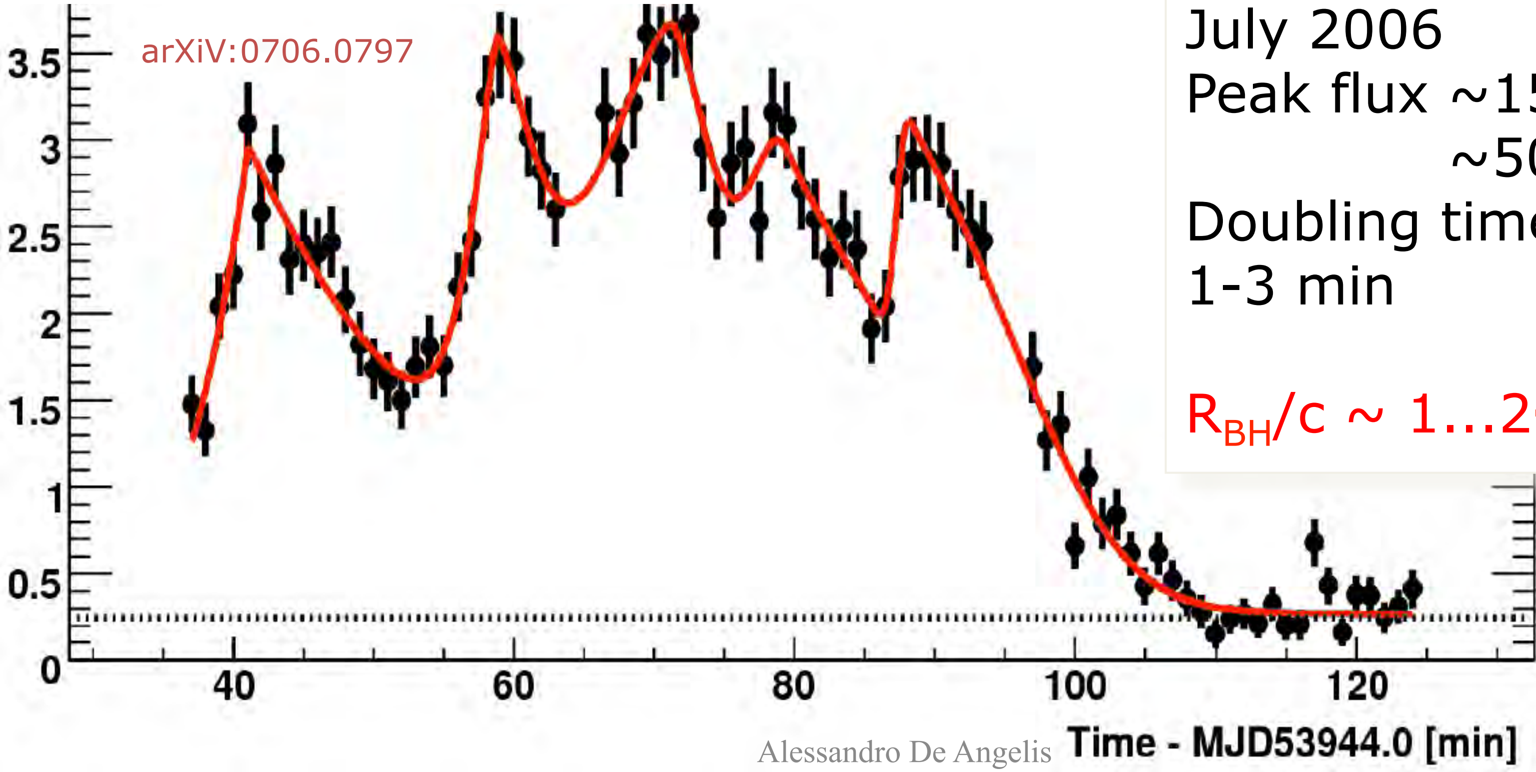
Variability



Rapid variability



MAGIC, Mkn 501
Doubling time ~ 2 min



HESS PKS 2155

z = 0.116

July 2006

Peak flux ~15 x Crab

~50 x average

Doubling times

1-3 min

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

2^{nd} order? Cherenkov rules!

$$(\Delta t)_{obs} \cong \frac{3}{2}\left(\frac{\Delta E}{E_{s2}}\right)^2 H_0^{-1}\int_0^z dz' \frac{(1+z')^2}{\sqrt{\Omega_M (1+z')^3 + \Omega_\Lambda}}$$

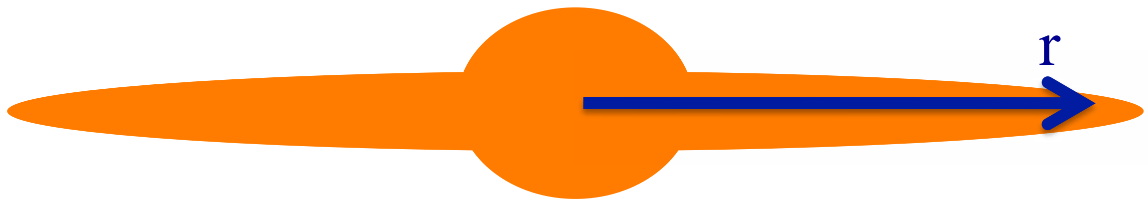
$E_{s2} > 6\ 10^{10}$ GeV ($\sim 10^{-9}$ M_P) (HESS, MAGIC)

A no-loss situation:

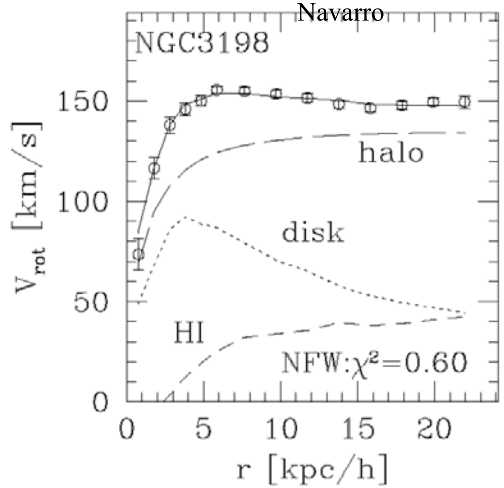
if propagation is standard, cosmology with AGN

The Dark Matter Problem

Measure rotation curves for galaxies:



Begelman/
Navarro

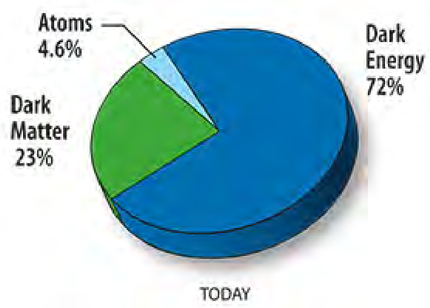


For large r, we expect:

$$G\frac{M}{r^2} = \frac{v^2(r)}{r} \quad \Rightarrow \quad v(r) \sim \frac{1}{\sqrt{r}}$$

we see: flat or rising rotation curves

Hypothesized solution: the visible galaxy is embedded in a much larger halo of Dark Matter (neutral; weakly interacting; mix of particles and antiparticles - in SUSY Majorana)



Famous Bullet Cluster

(B. Atwood)

Which signatures for gamma detectors?

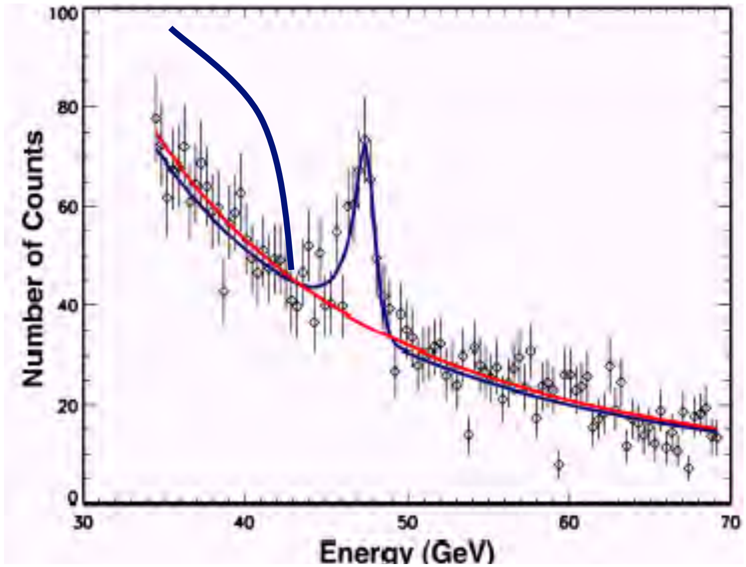
- Self-annihilating WIMPs, if Majorana (as the neutralino in SUSY), can produce:
  - Photon lines (γγ, γZ)
  - Photon excess at E < m from hadronization
- Excess of antimatter (annihilation/decay)
- Excess of electrons, if unstable

$$\Phi \propto \sigma \frac{\langle v \rangle}{m^2} \int_{los} \rho^2 \, dl$$

from particle physics

from astrophysics

Look to the closest point with M <<L

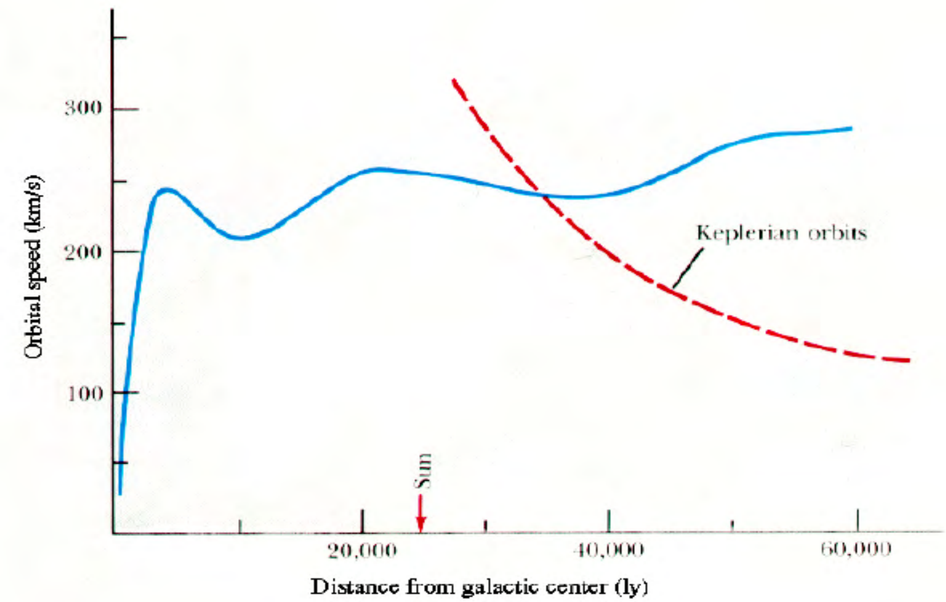


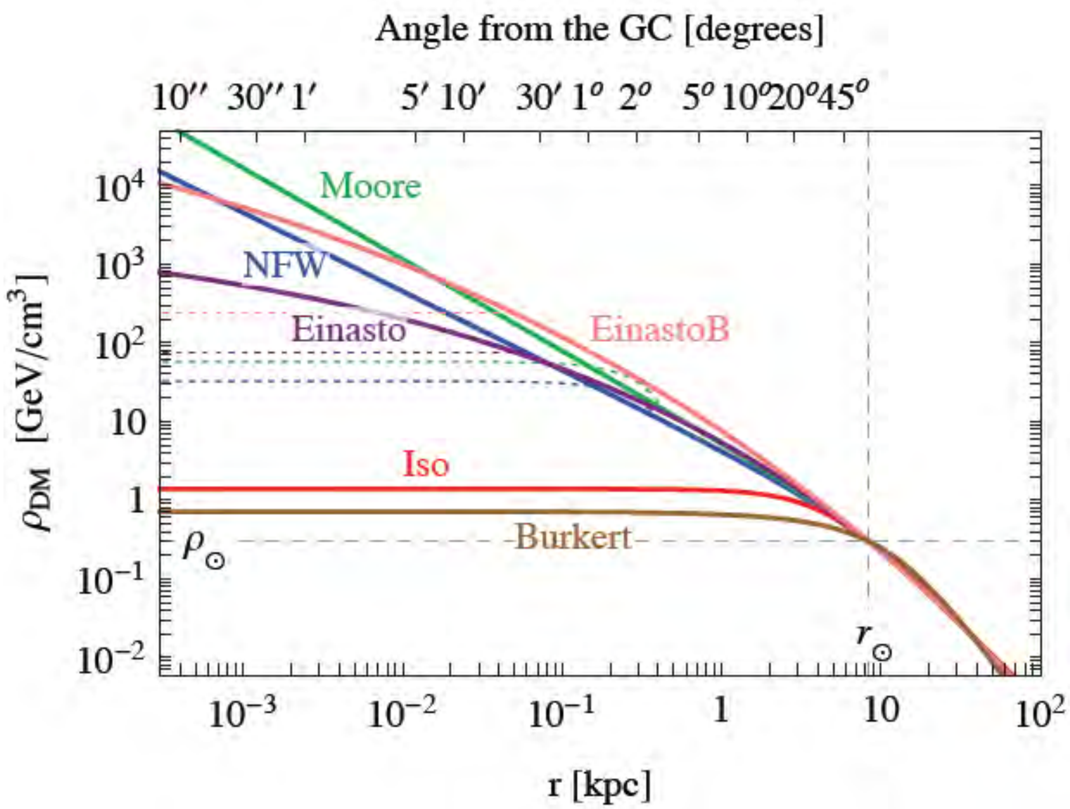
Uncertainties

- Largest uncertainty: density
- Density distribution is well known in the halo, where you do not expect most of the signal, while cusps are more uncertain

$$
\begin{aligned}
\text{NFW}: \quad \rho_{\rm NFW}(r) &= \rho_s \frac{r_s}{r}\left(1+\frac{r}{r_s}\right)^{-2} \\
\text{Einasto}: \quad \rho_{\rm Ein}(r) &= \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\} \\
\text{Moore}: \quad \rho_{\rm Moo}(r) &= \rho_s \left(\frac{r_s}{r}\right)^{1.16}\left(1+\frac{r}{r_s}\right)^{-1.84}
\end{aligned}
$$

=> Results are difficult to compare





Many Places to Seek DM!

Galactic Center

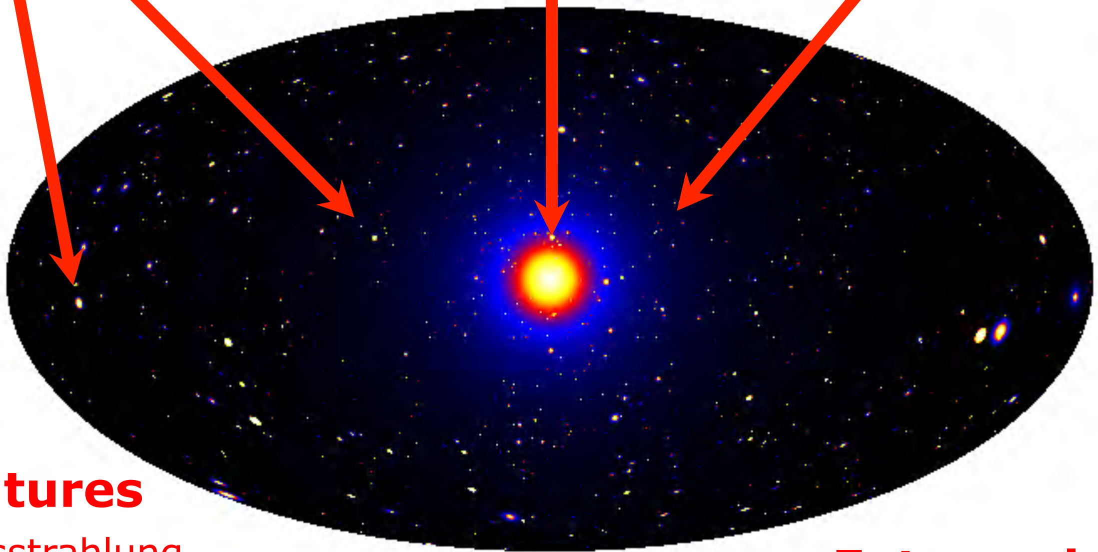
Good statistics but source confusion/diffuse background

Satellites

Low background and good source id, but low statistics, astrophysical background

Milky Way Halo

Large statistics but diffuse background



All-sky map of simulated gamma ray signal from DM annihilation (Pieri et al 2006)

Spectral Features

Lines, endpoint Bremsstrahlung,…

No astrophysical uncertainties, good source Id, but low sensitivity because of expected small BR

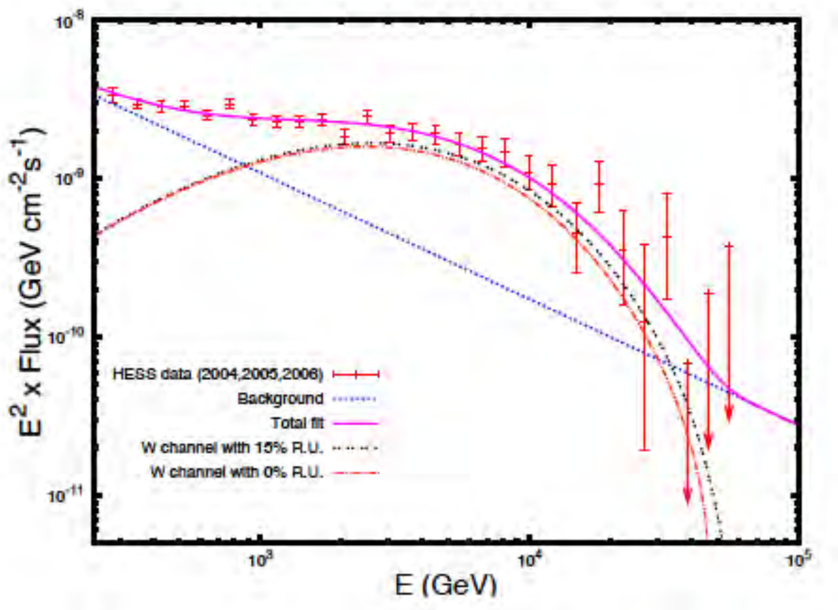
Extra-galactic

Large statistics, but astrophysics, galactic diffuse backgrounds

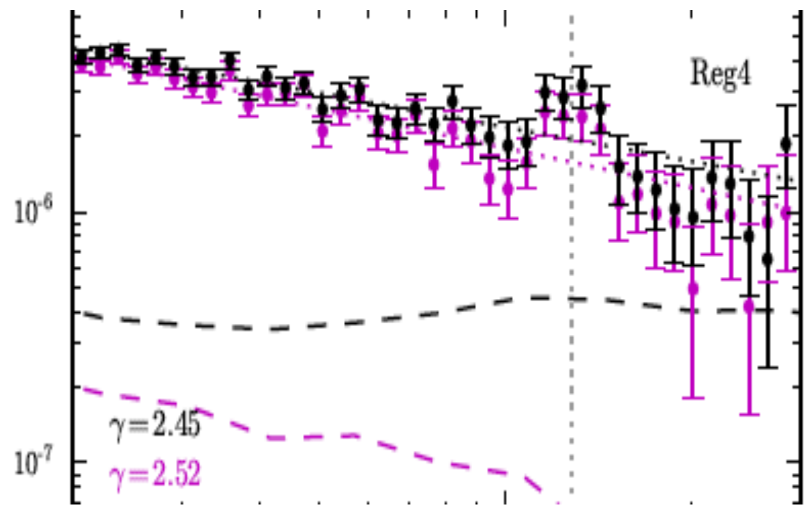
Plus data-driven searches

Results

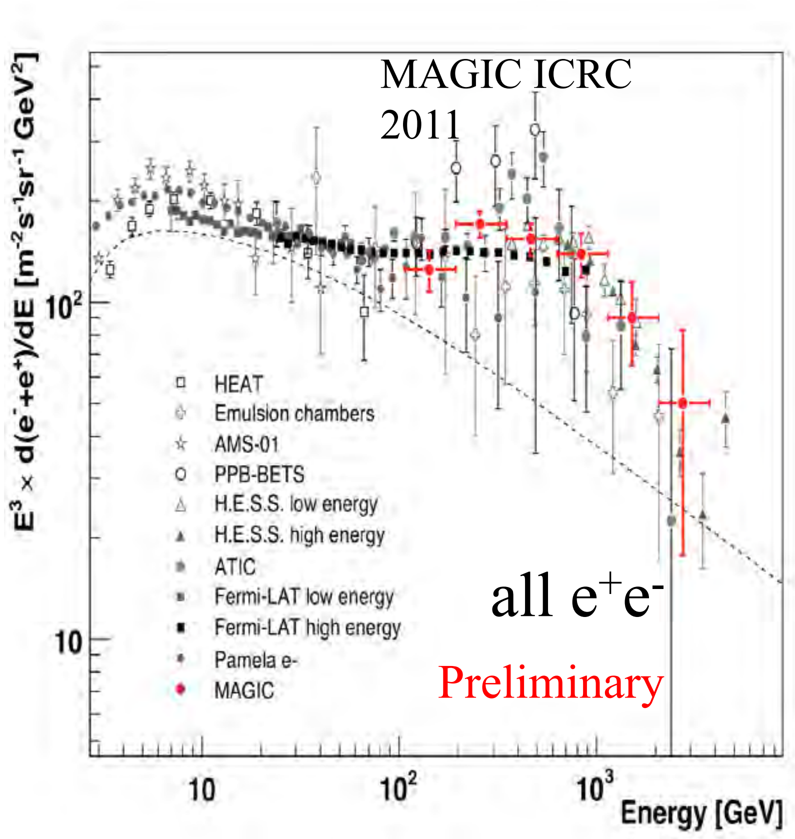
- No excess from GC
- No excess from DSph
- No sensitivity for halo

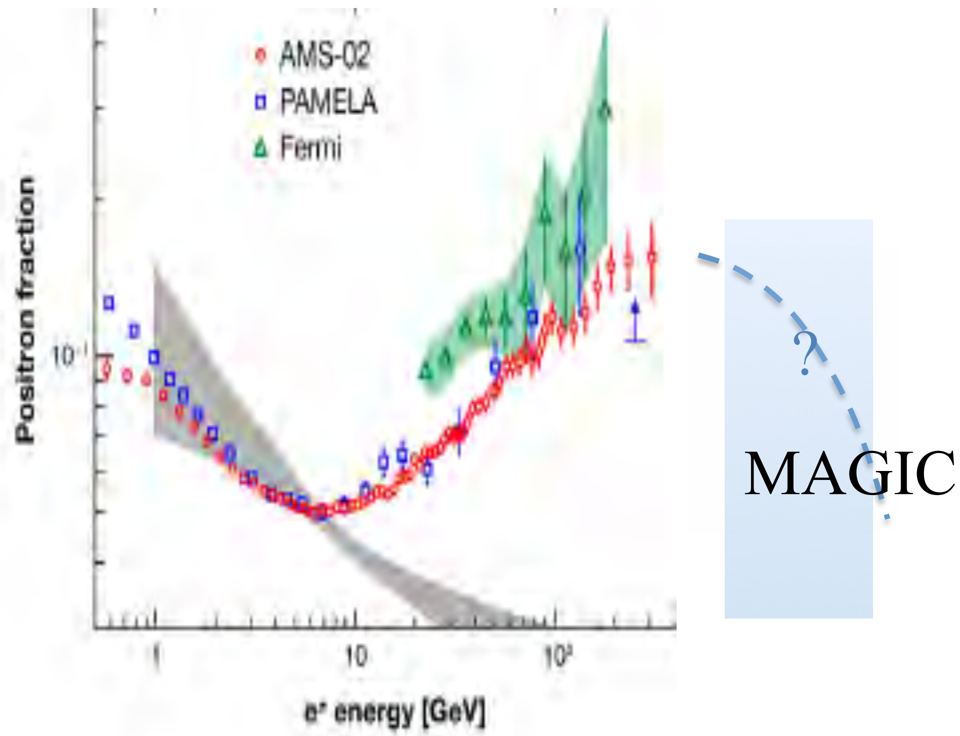


- Possible data-driven searches: no sensitivity to confirm nor disprove recent claims of an excess ~130 GeV



Cosmic e^+ and e^-: the ATIC & PAMELA anomalies





probe e+/e- ratio at 300-700 GeV

Flux of e+ plus e-: no peaks; a possible excess might have astrophysical explanations
Ratio e+/e-: needs more time, will be done

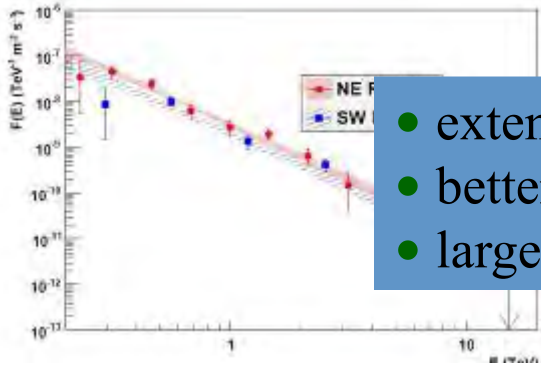
DM: interplay with accelerators

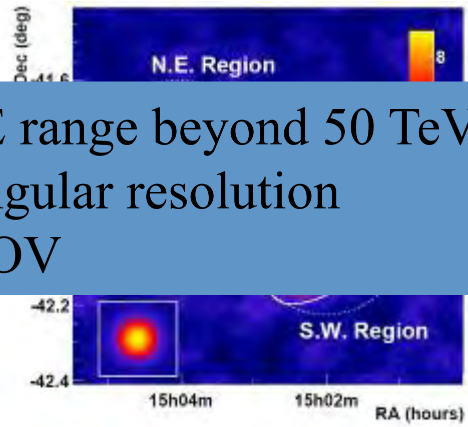
- LHC may find candidates but cannot prove that they are the observed Dark Matter, nor localize it
- *Direct searches (nuclear recoil) may recognize local halo WIMPs but cannot prove the nature and composition of Dark Matter in the sky*

- LHC reach limited to some 200-600 GeV; IACT sensitivity starts at some ~200 GeV (should improve)

A wish list for the future

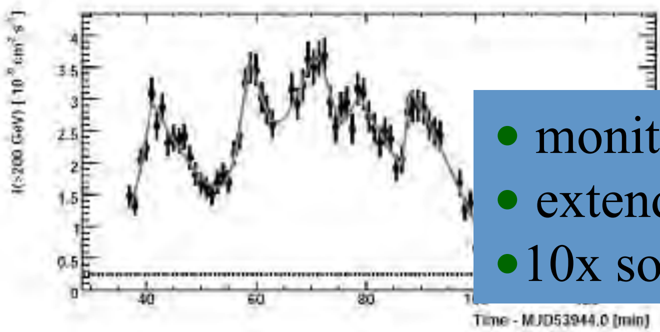
- Galactic sources & CR





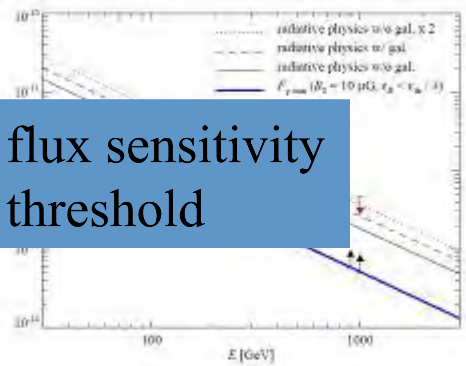
- extend E range beyond 50 TeV
- better angular resolution
- larger FOV

- AGN & gamma prop.



- monitor many objects simult.
- extend E range under 50 GeV
- 10x sources

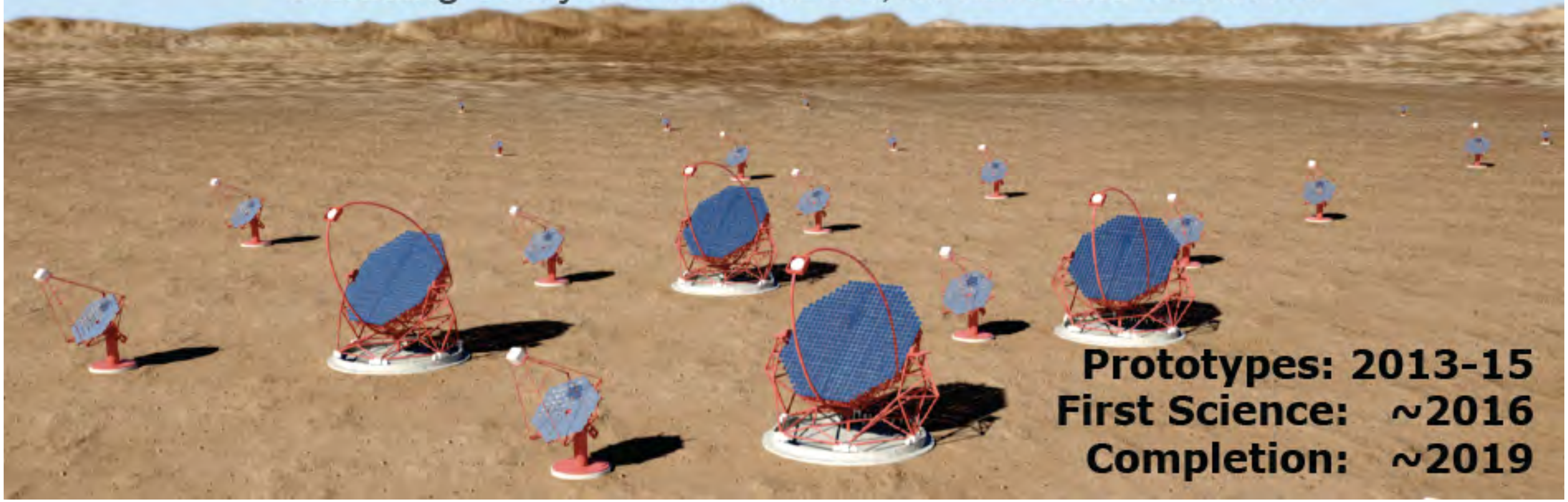
- New particles, new phenomena
  - dark matter and astroparticle physics



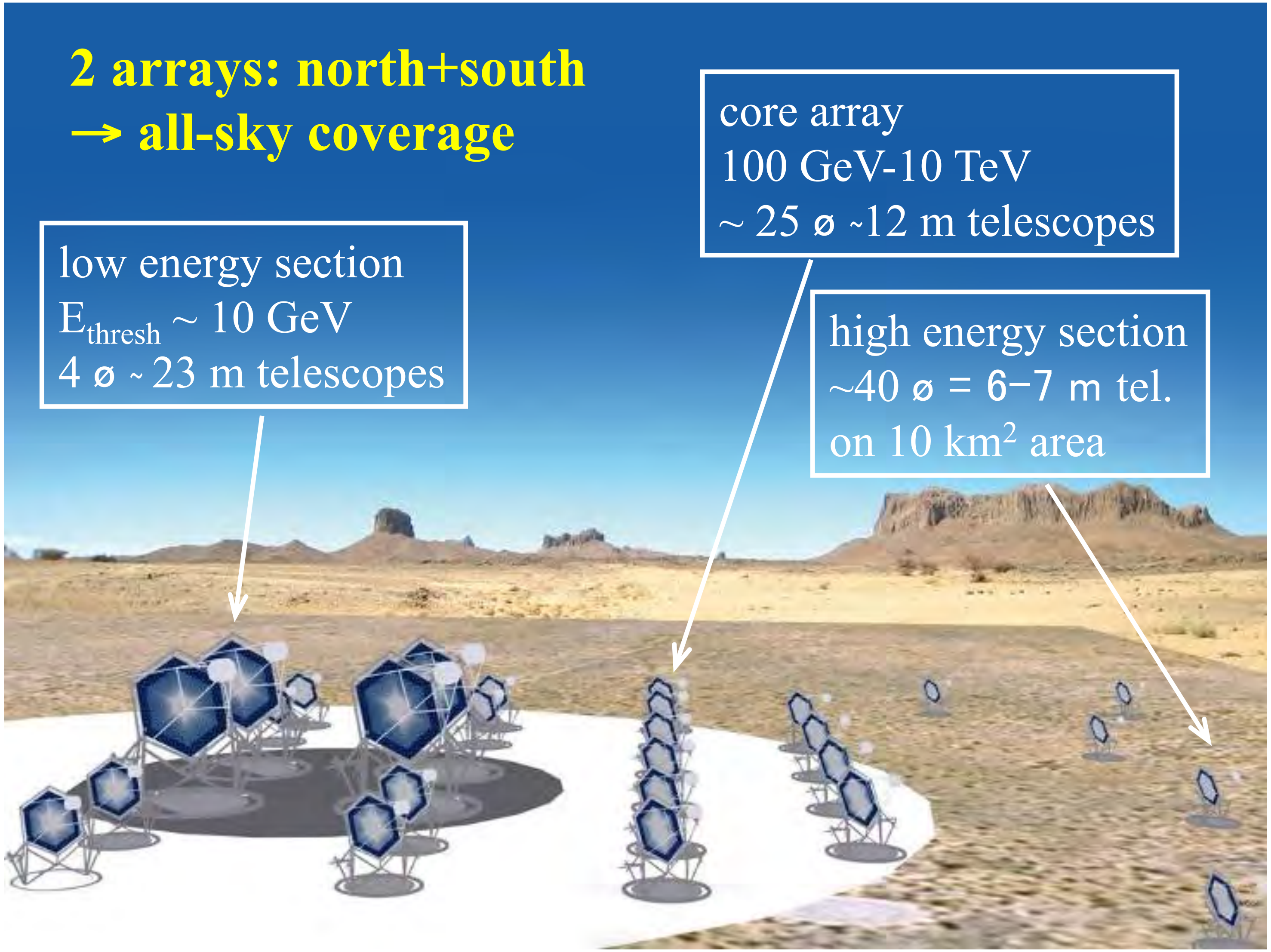
- better flux sensitivity
- lower threshold

The Cherenkov Telescope Array

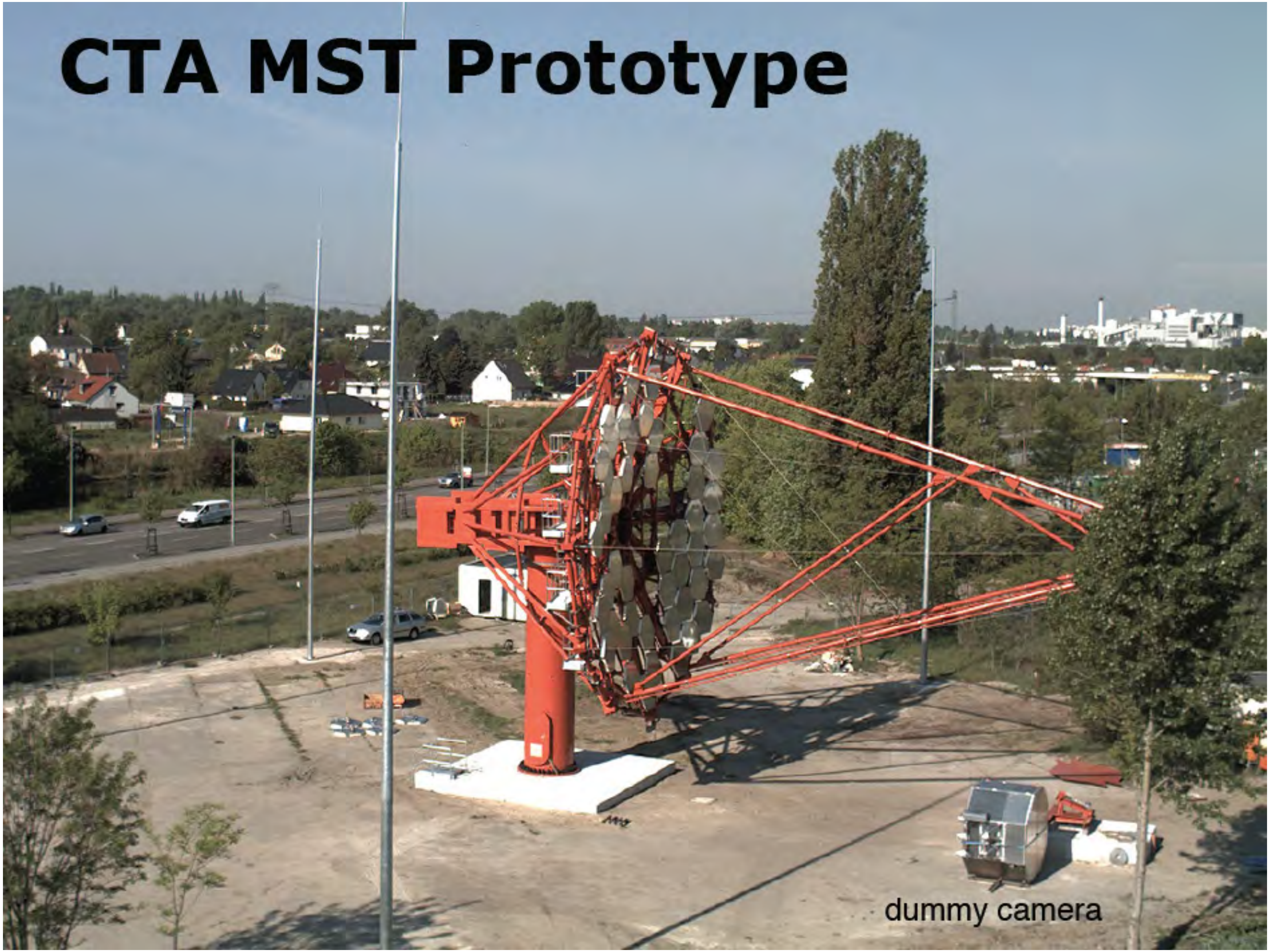
- A huge improvement in all aspects of performance
  - A factor ~10 in sensitivity, much wider energy coverage, much better resolution, field-of-view, full sky, …
- A user facility / proposal-driven observatory
  - With two sites with a total of >100 telescopes
- A 27 nation ~€200M project
  - Including everyone from HESS, MAGIC and VERITAS



The CTA concept (a possible design)



CTA MST Prototype



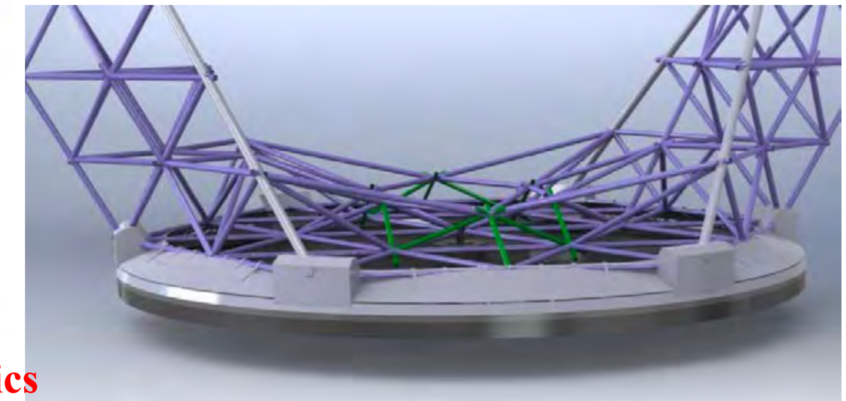
Design: 23 m Large Telescopes

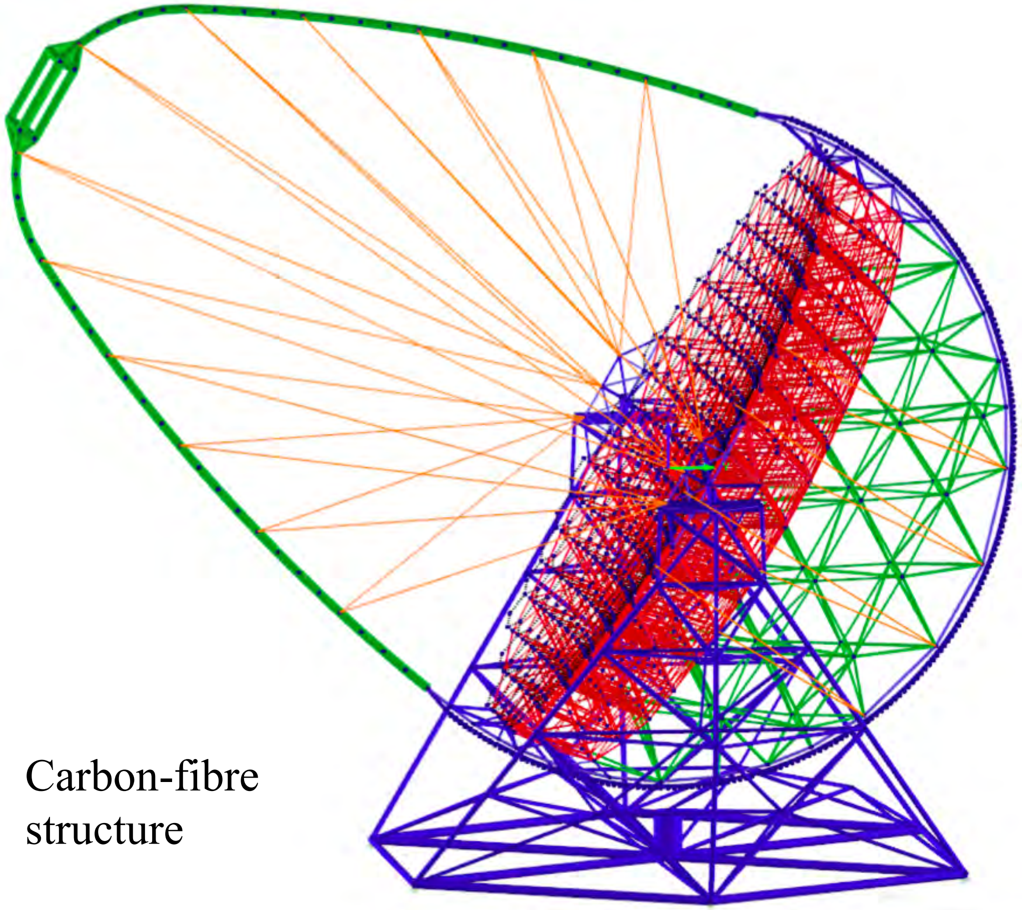
optimized for the range below 200 GeV

27.8 m focal length
4.5° field of view
0.1° pixels

400 m^2 dish area
1.5 m sandwich
mirror facets

On (GRB) target
in < 20 s





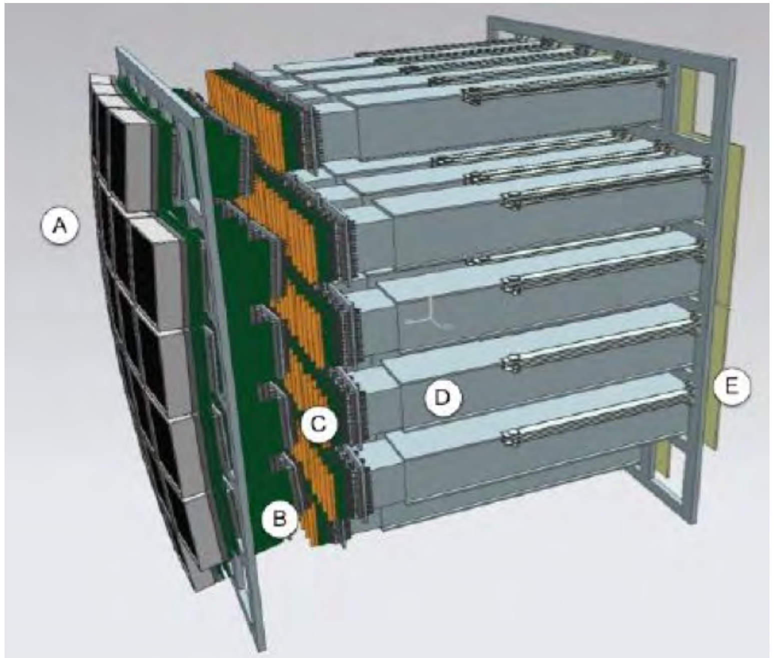
Carbon-fibre
structure

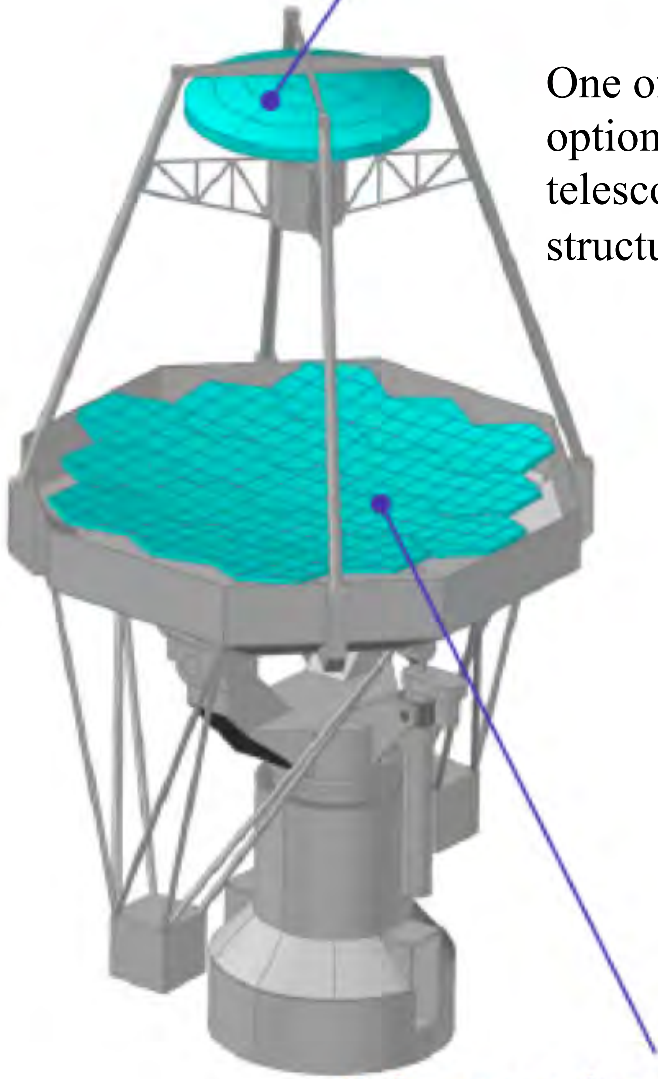
INFN working on cluster for a possible camera & electronics

Design: Small 4-6 m Telescopes

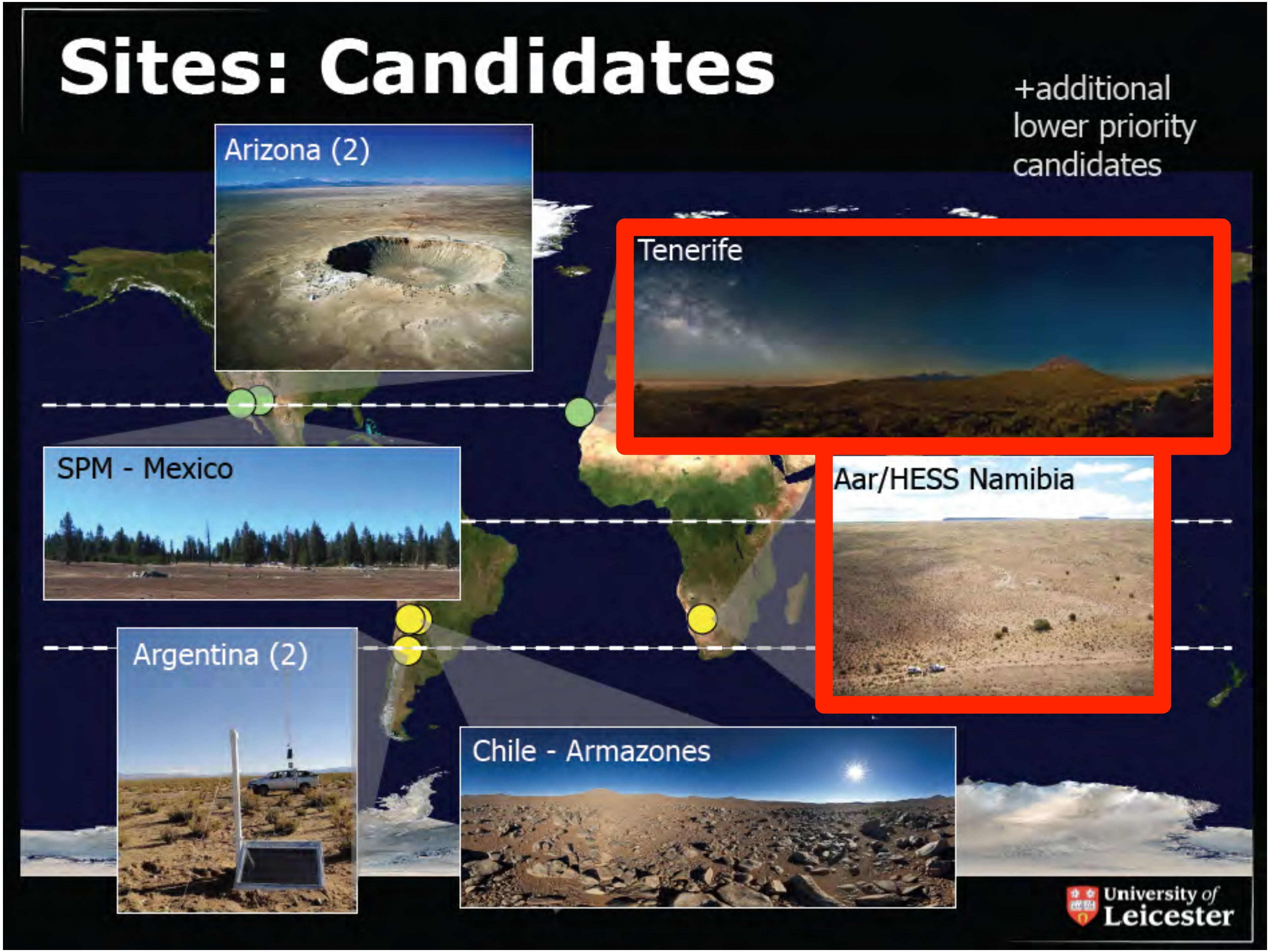
cover the range above few TeV across 10 km^2

PMT camera option

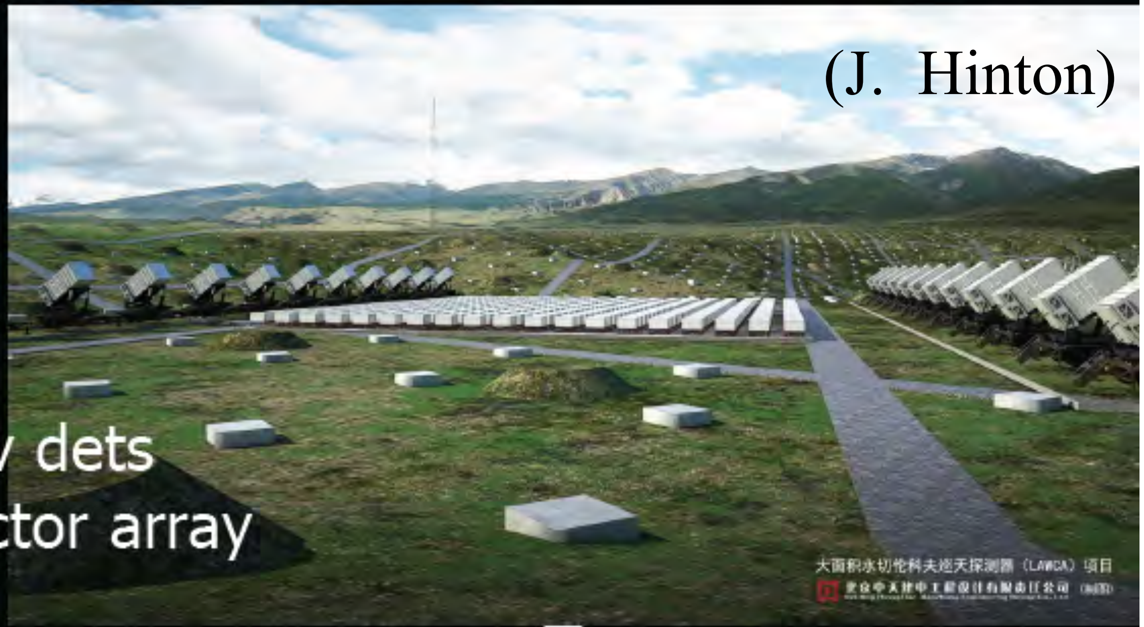




Under study:
dual-mirror optics with compact photo sensor arrays
single-mirror optics
PMT-based and silicon-based sensors
➜ Not yet conclusive which solution is most cost-effective
INAF prototype ready soon, INFN working on camera & electronics


Sites: Candidates
+additional lower priority candidates
Arizona (2)
Tenerife
SPM - Mexico
Aar/HESS Namibia
Argentina (2)
Chile - Armazones
University of Leicester

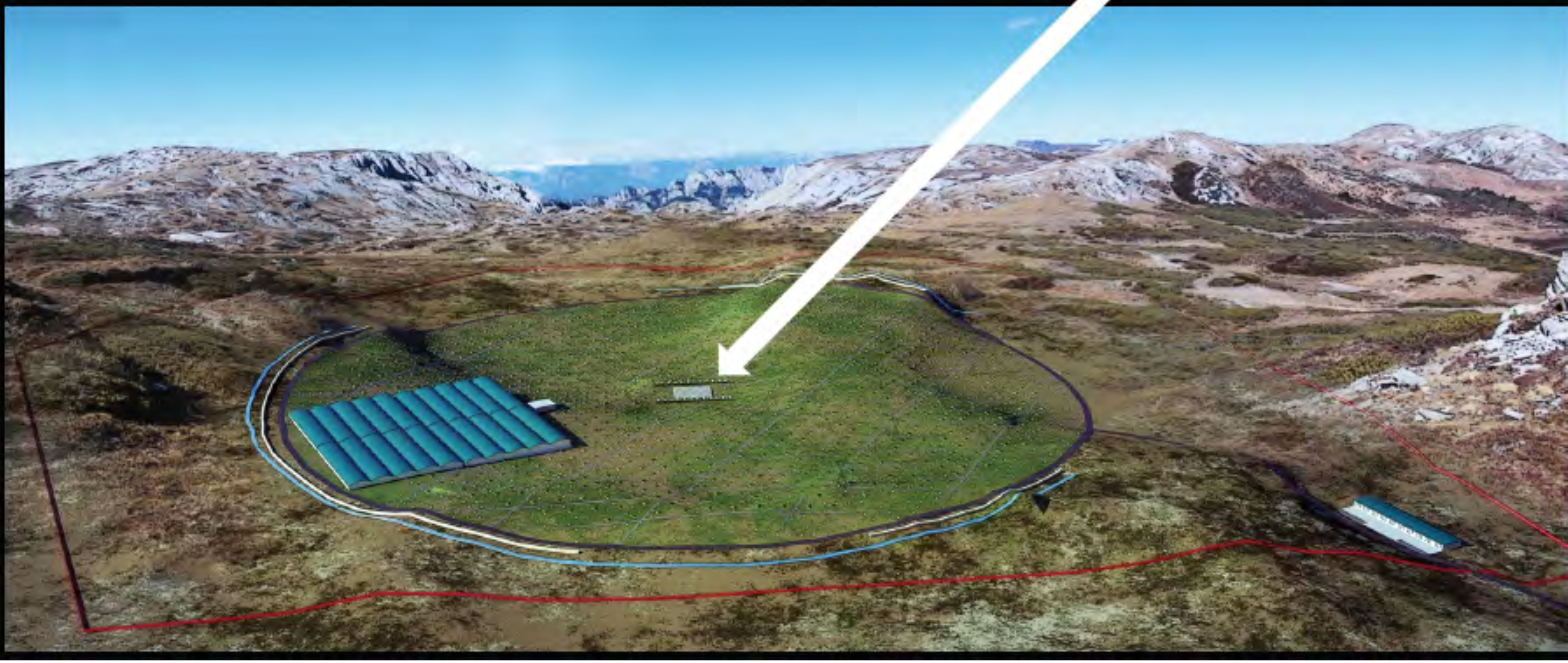
LHAASO



(J. Hinton)

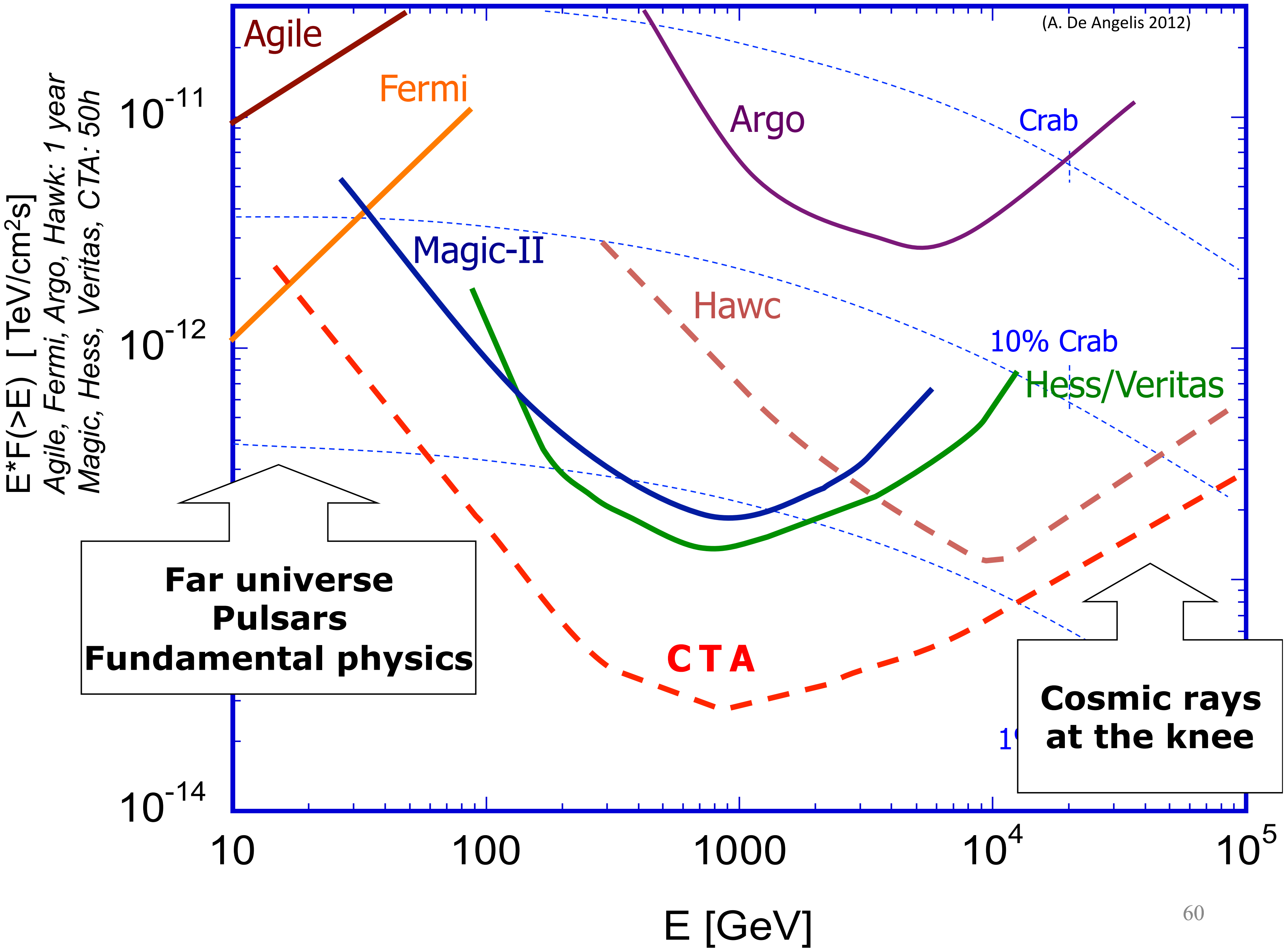
Gamma-ray surveys &
Cosmic ray studies

90k m^2 Water Cherenkov dets
1 km^2 Surface EAS detector array
++



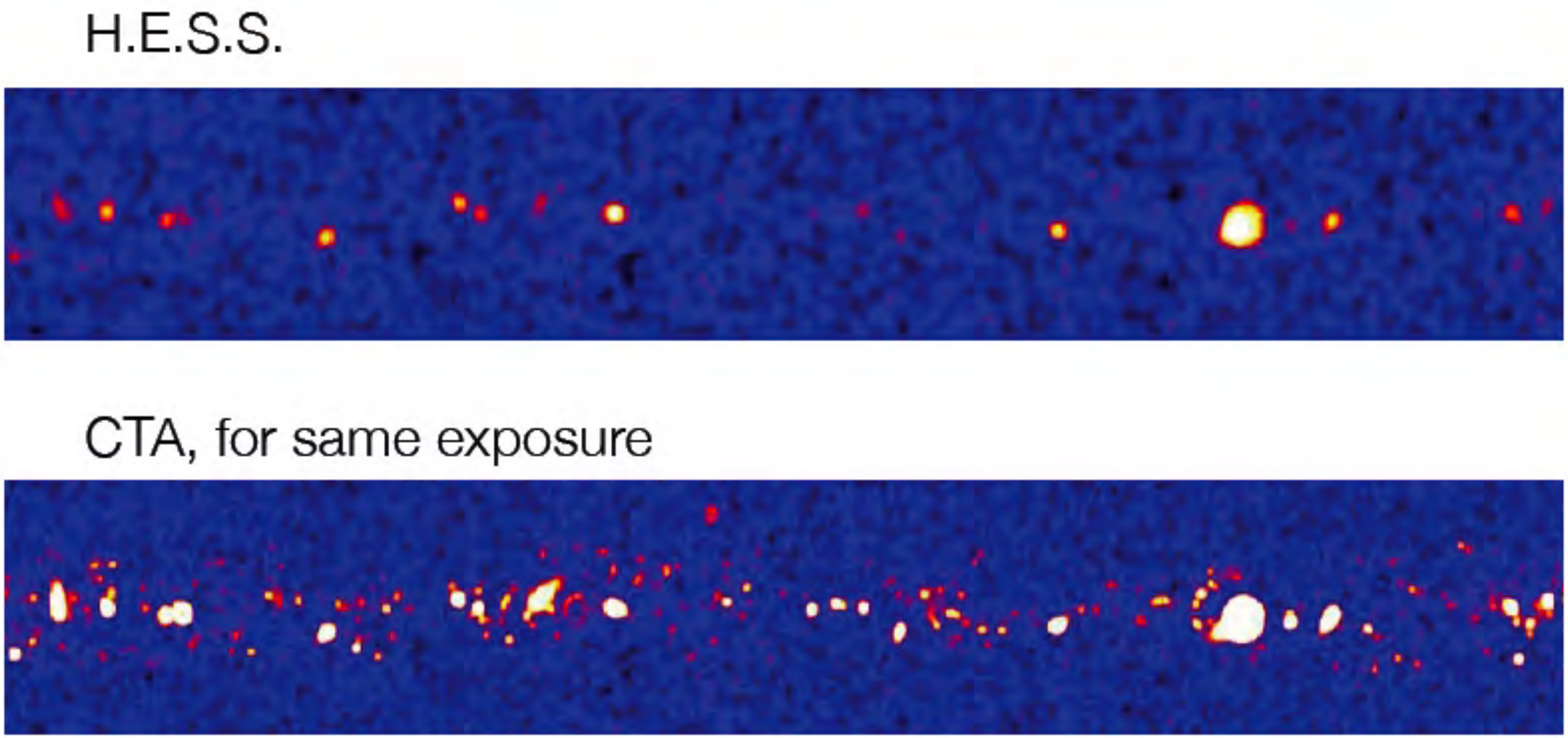
The INFN participation to CTA

- 3 INFN groups (Pd, Si, Ud) already in CTA since 2008, via national University funding
- ~40 INFN scientists working to INFN CTA-RD since September 2012
- January 2013: proposal of a “premiale” INAF + INFN; SiPM (industrial partnership with FBK) + electronics (CAEN, SITAEL); approved in September 2013
  - ~1.5 MEUR for INFN: 2/3 for SiPM, 1/3 electronics
  - Sensor ~ few mm for the SST camera (~1000 for a 60 cm detector), where granularity could be the issue
  - 1” for LST, where sensitivity might be the issue
  - Camera for SST; cluster of 7 counters for LST
- Prototypes for a new mirror technology
- Atmospheric monitoring
- Simulation & science; computing



(A. De Angelis 2012)
Agile
Fermi
Argo
Crab
Magic-II
Hawc
10% Crab
Hess/Veritas
CTA
Far universe
Pulsars
Fundamental physics
Cosmic rays
at the knee
E*F(>E) [TeV/cm²s]
Agile, Fermi, Argo, Hawk: 1 year
Magic, Hess, Veritas, CTA: 50h
10⁻¹¹
10⁻¹²
10⁻¹⁴
10
100
1000
10⁴
10⁵
E [GeV]

CTA: Expectations for Galactic plane survey



expect ~1000 detected sources

Summary

- Thanks mostly to Cherenkov telescopes (plus EAS VHE gamma instruments, and MWL observations with Fermi/Agile and low energy instruments), new insight on Cosmic Rays:
  - SNR as galactic sources established
    - Astronomy with charged CR is difficult
    - Astronomy with neutrinos will be difficult (see also the 2 PeV neutrinos from IceCube)
    - VHE photons can be the pathfinder
  - Mechanism of emission from AGN still to be understood
- Still no detection of DM
  - The information from no detection is not as good as for accelerators
- A few clouds might hide new physics
  - Photon propagation
- Rich fundamental science and astronomy/astrophysics
  - HEA is exploring regions beyond the reach of accelerators in the search for DM & new physics
  - "Simple" extensions of present detectors are in progress: CTA, …

4-6 June 2014 in Lisboa:
10 th SciNeGHE conference

(Science with the New Generation of High Energy Gamma-ray Experiments)