The ASTRI/CTA mini-array

Fabrizio Tavecchio (INAF-OAB, Milan, Italy)

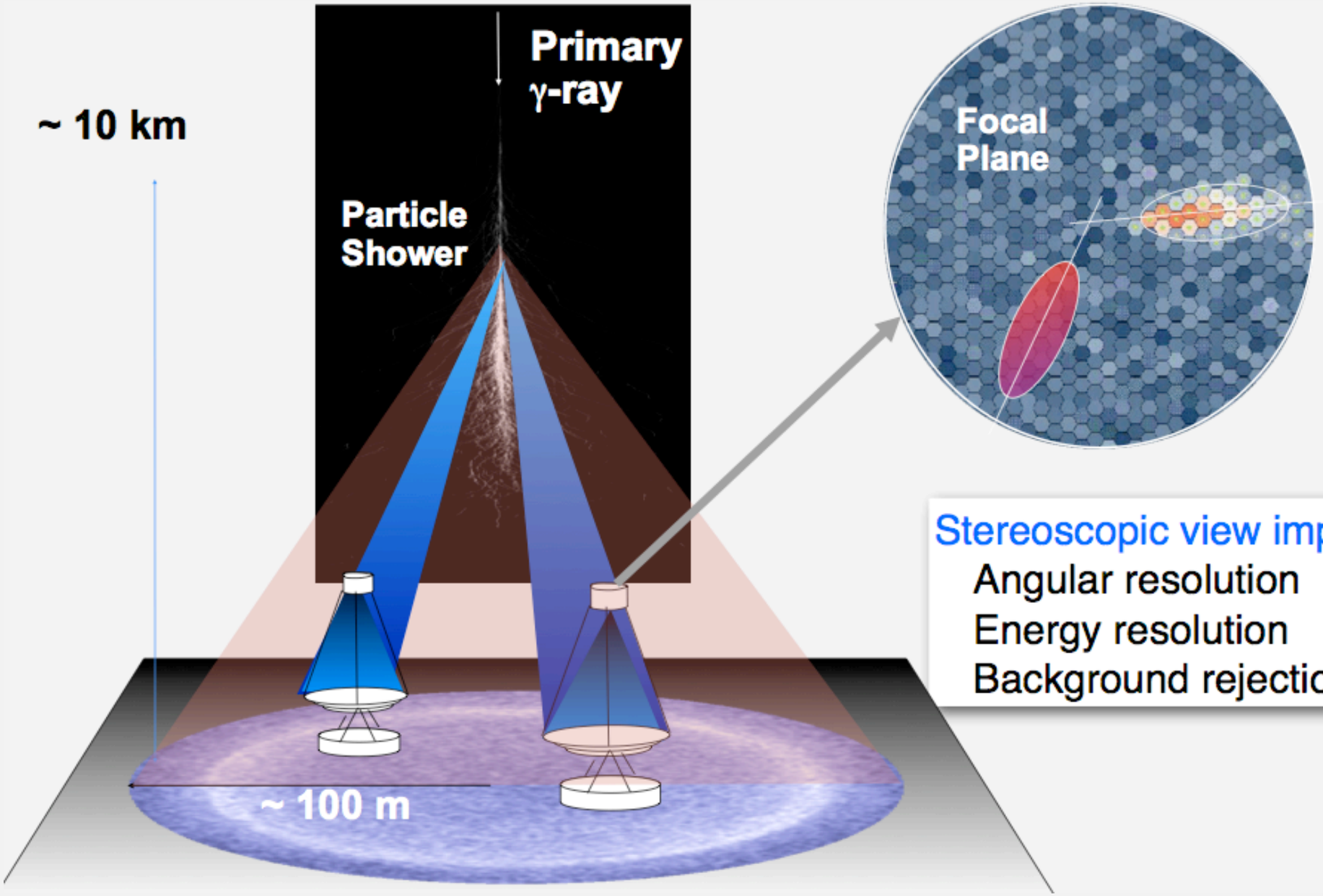
for the ASTRI Collaboration and the CTA Consortium

Fundamental contributions by
S. Vercellone & G. Bonnoli

Outline

- Introduction
- The ASTRI/CTA SST-2M mini-array
- Scientific cases: galactic and extragalactic

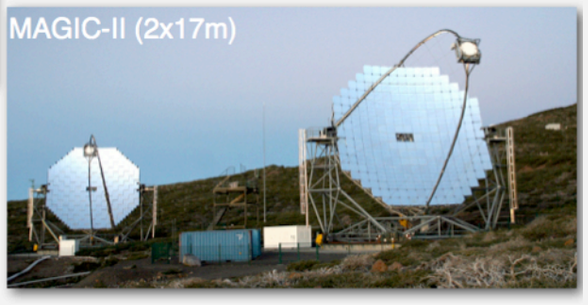
Cherenkov arrays



Stereoscopic view improves
- Angular resolution
- Energy resolution
- Background rejection

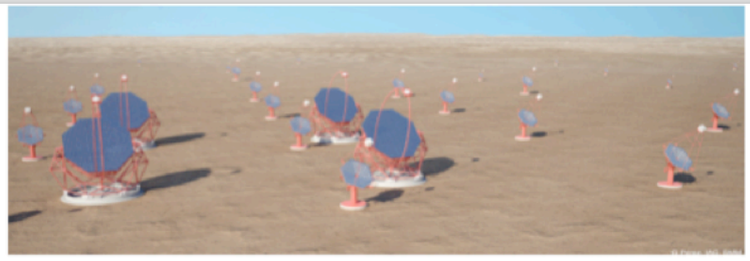
The ASTRI/CTA mini-array

Status



The present ...

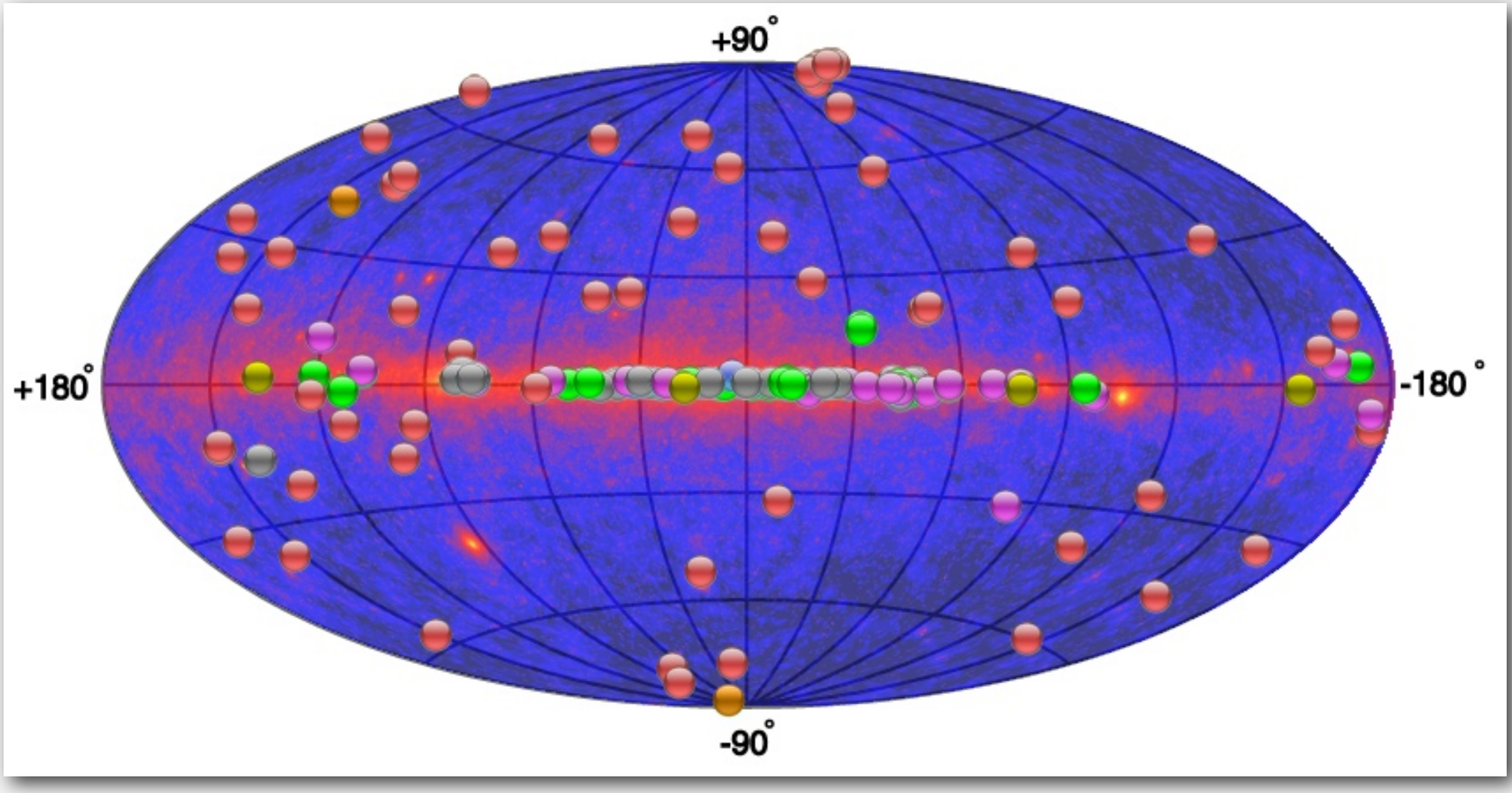
and the future ...



- **Two arrays**, one in the northern and one in the southern hemisphere
  - To provide all-sky coverage (construction starting from 2015).
- **4 Large size-telescopes** (LSTs, ⦸~23m) at the center of the array
  - To lower the energy threshold down to E~30 GeV
- **25 Medium size-telescopes** (MSTs, ⦸~12m) covering about 1km^2
  24 Schwarzschild-Couder dual-mirror telescopes (SCTs, M1 ⦸~9.5m) only in the southern site
  - To improve by a factor of ten the sensitivity in the energy range 0.1 – 10 TeV
- **50-70 Small size telescopes** (SSTs, M1 ⦸~4m, A_{eff}~5-10m^2) only in the southern site, covering about 10km^2
  - To extend the energy range beyond 100 TeV.

Status

The TeV sky



The ASTRI project

The INAF ASTRI Project

ASTRI is an Italian "Flagship Project" funded by the Ministry of Education, University and Research (MIUR) and led by the Italian National Institute for Astrophysics (INAF).

The main goals of the project are the design, development and deployment, within the CTA framework of:

- ✓ an **end-to-end prototype** of the CTA **small-size telescope in a dual-mirror configuration (ASTRI SST-2M)** to be tested under field conditions at the INAF Obs. on the Mt. Etna (Sicily) at the end of **2014**;
- ✓ a **SST-2M mini-array** to be placed at the chosen CTA Southern Site starting from **2016**

INAF is in charge of the design and production of the mirrors and the camera, the development of the end-to-end software, the Monte Carlo simulations and the calibration activities.

The ASTRI/CTA mini-array concept

Our goal is the deployment and the operation of a **mini-array composed of seven SST-2M telescopes** at the final CTA southern site.

ASTRI/CTA mini array

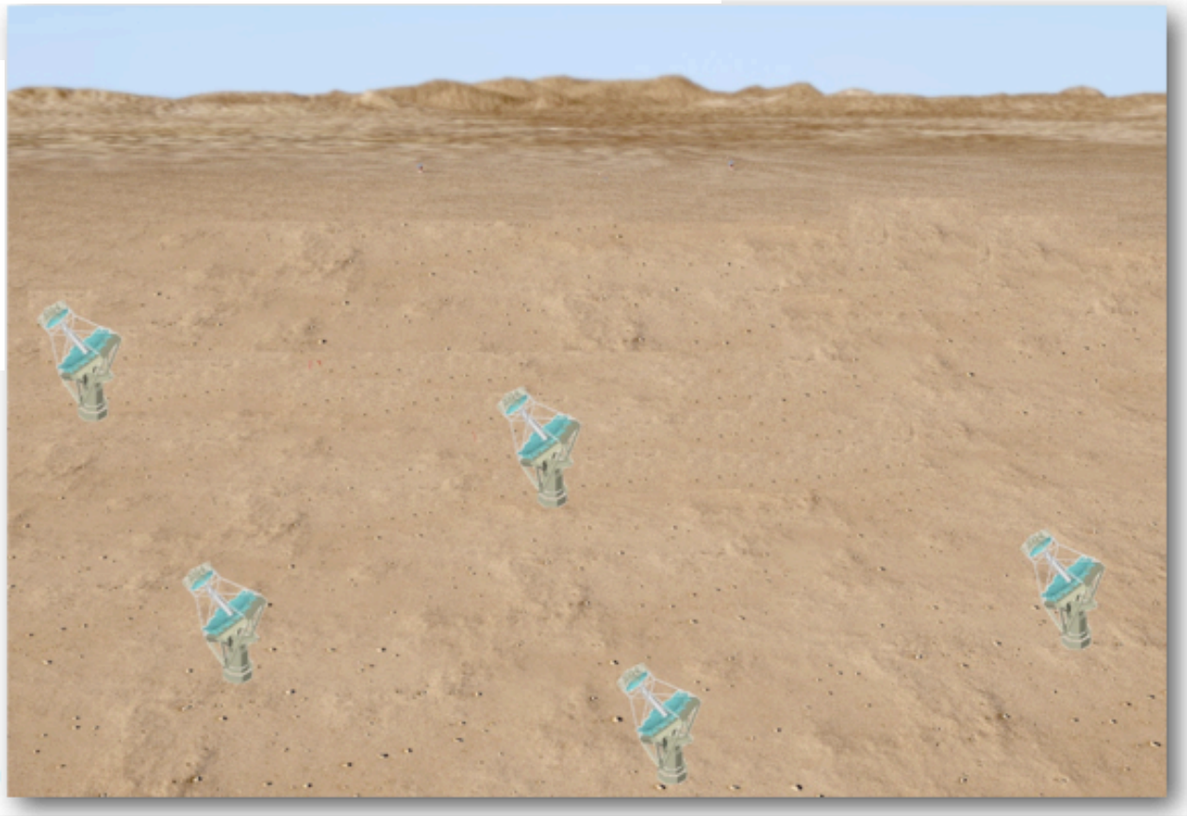
CTA Southern site should be decided at the end of 2014.

2014 - 2015 ➔ ASTRI/CTA mini-array re-assessment study phase

2016 ➔ ASTRI/CTA mini-array deployment phase

Currently:

- 3 units provided by ASTRI
- 1unit provided by a South African Consortium
- 3 units provided by a Brasilian Consortium (proposal almost accpt.)



The ASTRI/CTA mini-array performance

- ✓ **Limiting flux comparable or slightly better than H.E.S.S. above a few TeV for an array composed by 7 telescopes** (Di Pierro et al., 2013, 33rd ICRC).
- ✓ **Large field of view (for gamma-rays), not less than 2.5-3 degrees**
- ✓ **Should not expect better than a few arcmin angular resolution** (~0.08°)
- ✓ **Energy resolution of the order of 10-15 %**

PRELIMINARY

ASTRI/CTA Mini-array expectations

The ASTRI/CTA SST-2M mini-array can verify some array properties:

- ✓ **check of the trigger algorithms**
  - ➡ we expect a number O(5-7) of CTA-SSTs will trigger. The ASTRI/CTA mini-array could be the quanta of the whole SSTs sub-array
- ✓ **check of the wide field of view performance**
  - ➡ by detecting VHE showers with the core at a distance up to 500m
- ✓ **compare the mini-array performance with the Monte Carlo expectations**
  - ➡ by means of deep observations of a few selected targets
- ✓ **do the first CTA science**
  - ➡ by means of a few solid detections during the first year

Science with the mini-array

Strategy: well defined cases, few targets, long exposures

Science with the mini-array

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Galactic sources

Young SNR
Pevatrons
Interacting SNR
PWN
Gamma-ray binaries

Extragalactic sources

Extreme BL Lac objects
Radio-galaxies
EBL

Science with the mini-array

Strategy: well defined cases, few targets, long exposures

Galactic sources

Young SNR
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Gamma-ray binaries

Extragalactic sources

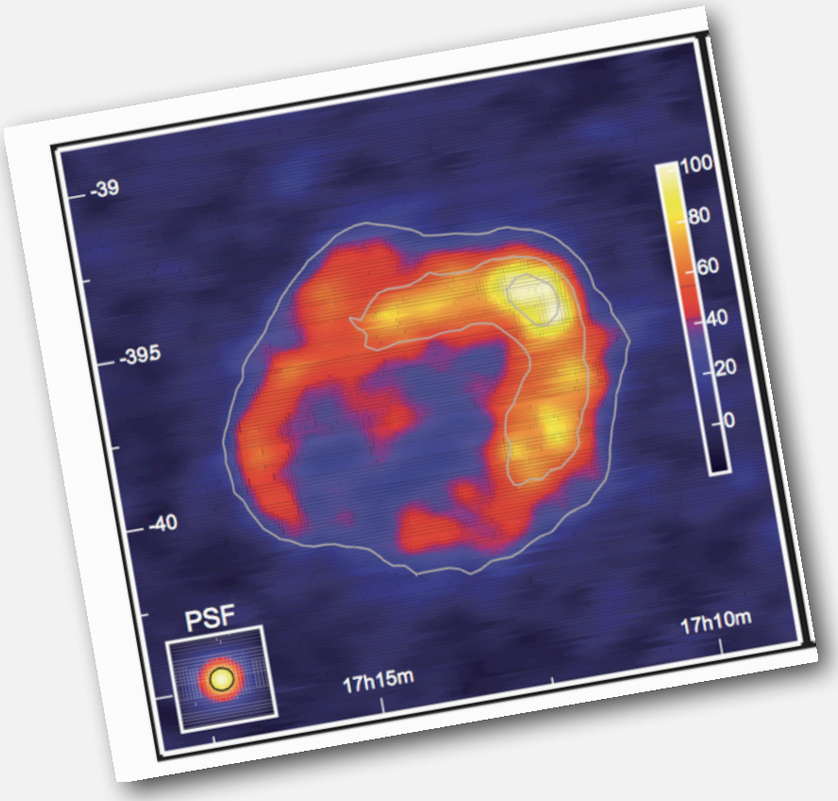
Extreme BL Lac objects
Radio-galaxies
EBL

Galactic sources: young SNR

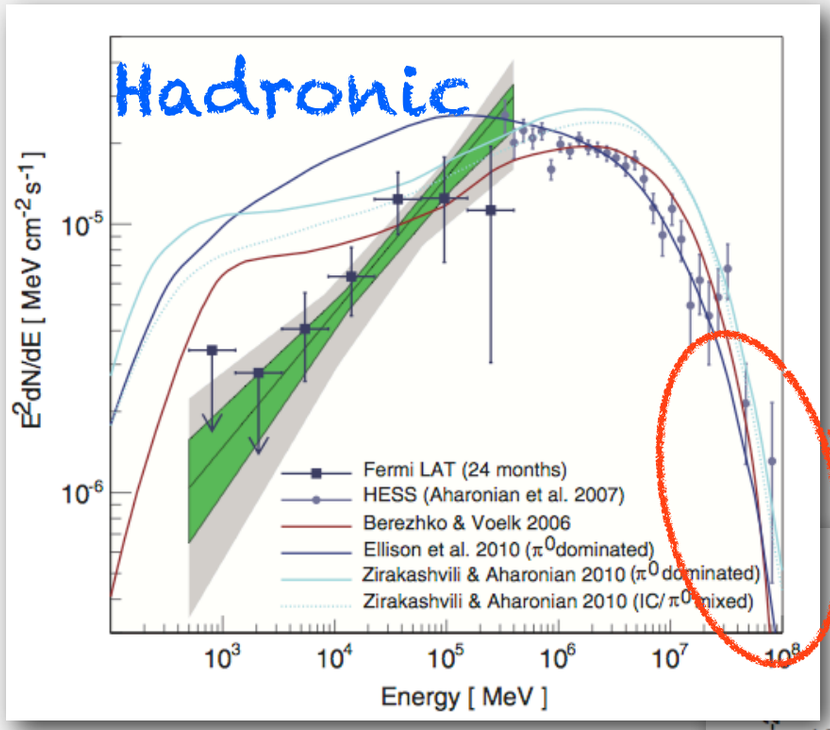
RX J 1713.7-3946

Young shell-like SNR
Fermi/LAT - 24 months
HESS - 63 hours
Significant emission E>30 TeV

Large extension

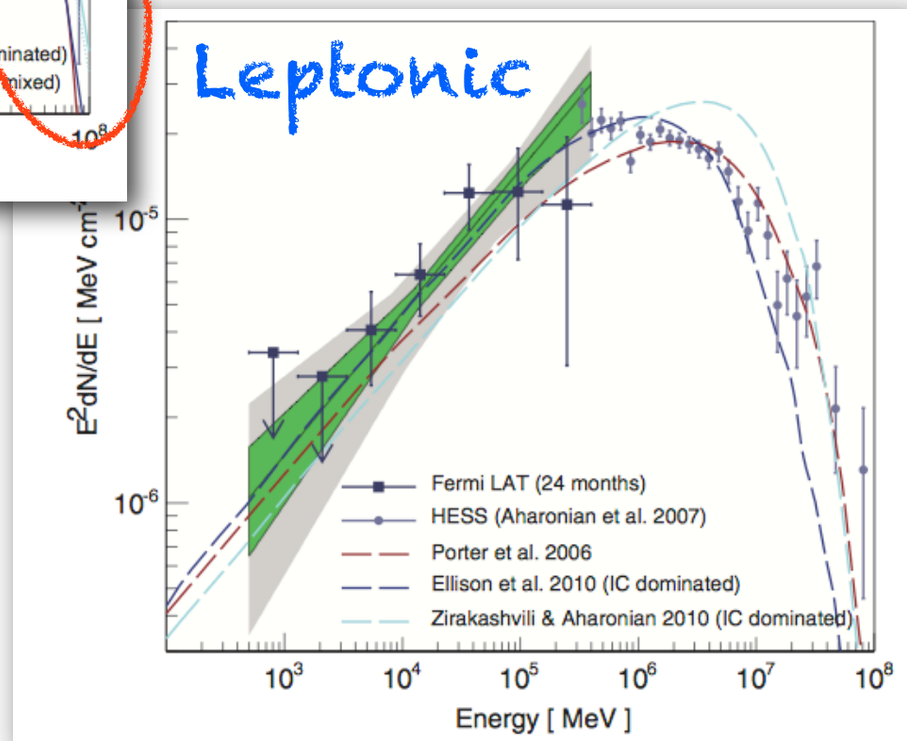


Acceptance-corrected
HESS image
Aharonian et al. 2007



Not compatible with hadronic emission?
(Abdo et al. 2011)

Emission up to several tens of TeV

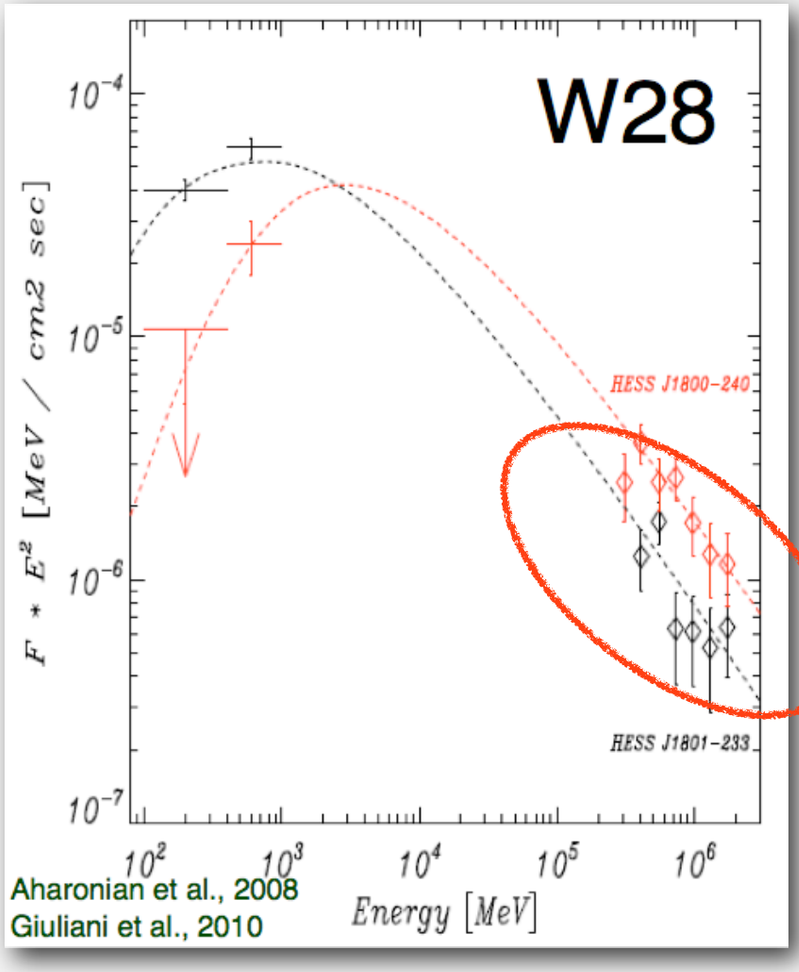


Galactic sources: interacting SNR

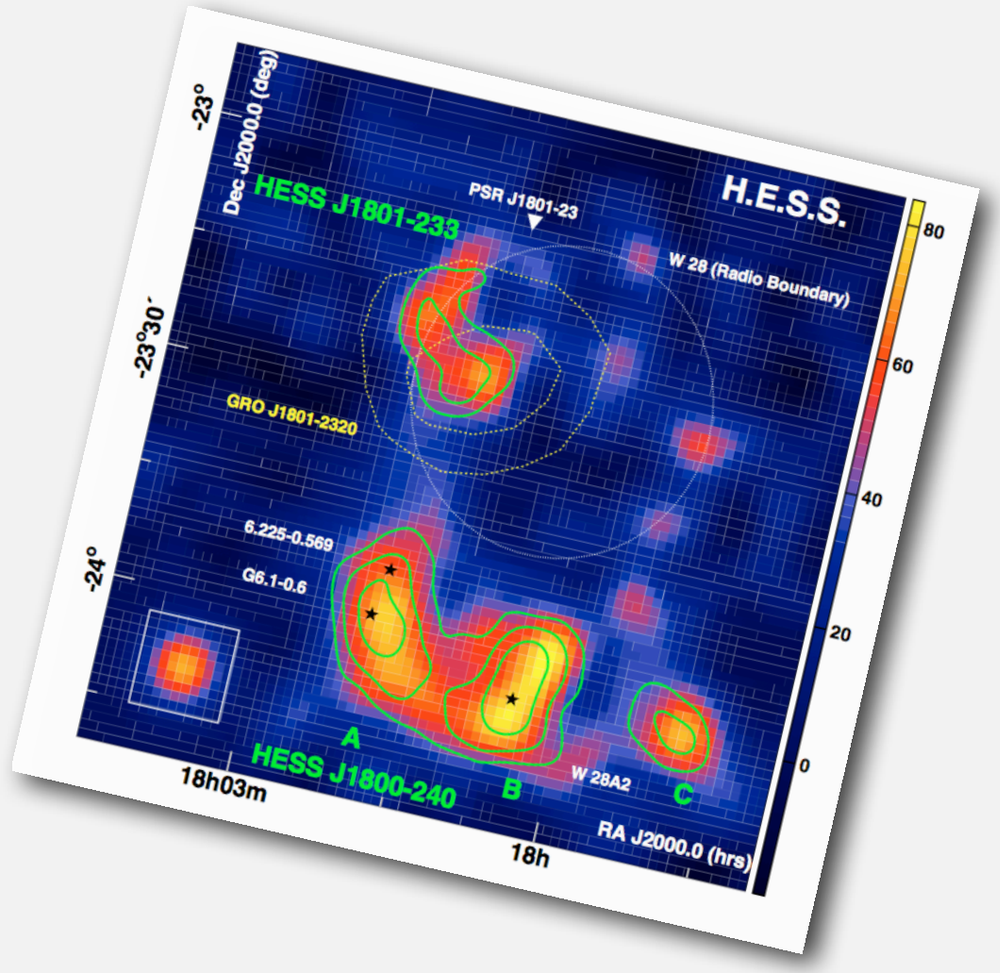
W28

Middle-age SNR interacting with Molecular Clouds

GeV bright source



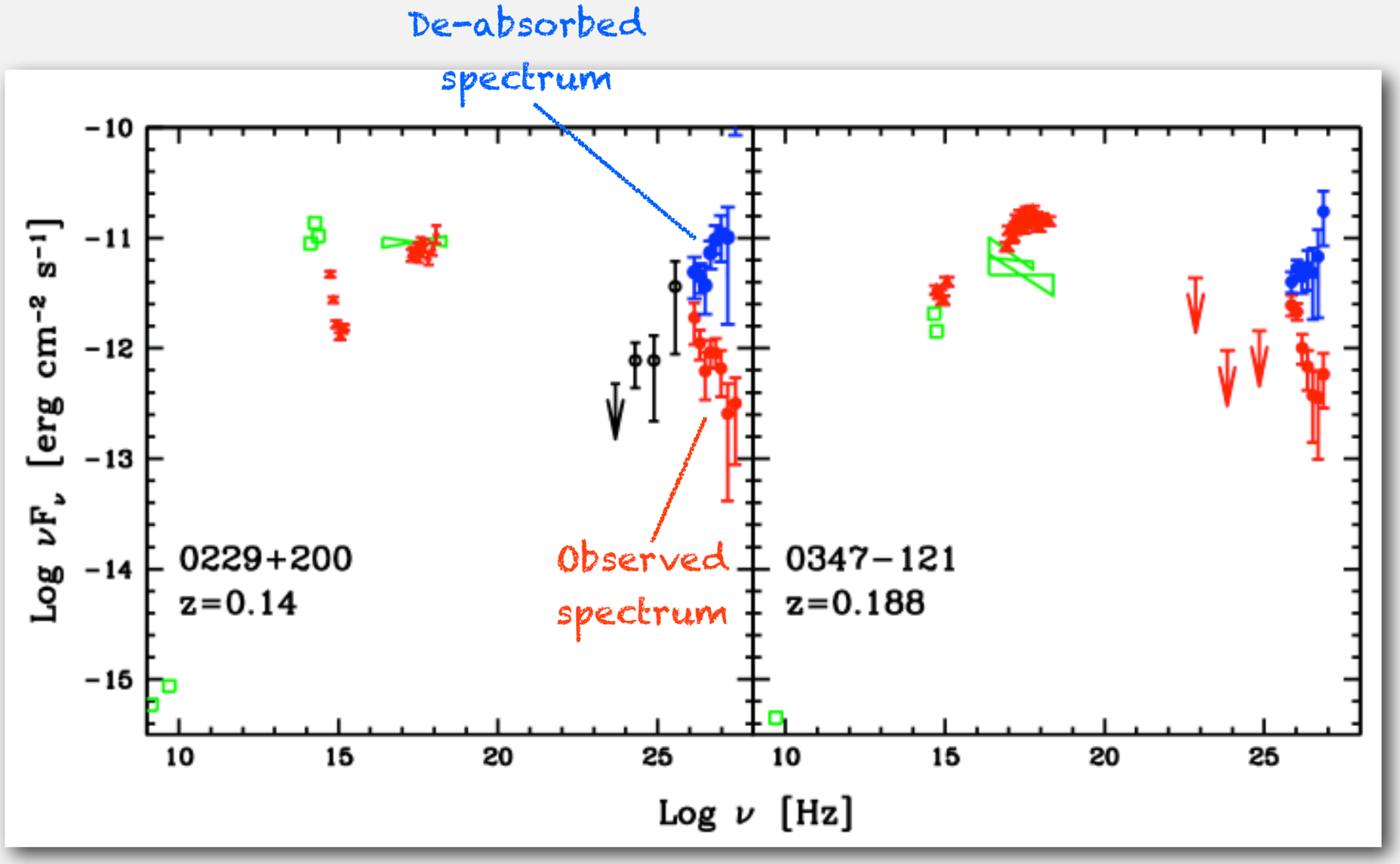
bright multi TeV emission



Ideal labs for to study particle escape from SNR and propagation

Mini-array can observe with better spatial and energy resolution

Extragalactic targets: EHBL



Extreme HBL (Costamante et al. 2011)

Very hard deabsorbed spectra

No (or weak) variability

Why are EHBLs so interesting?

- Jet mechanism (high minimum el. energy assuming SSC)

  Katarzynski+2006, Tavecchio+ 2009

- Hadron beams

  Essey & Kusenko 2010
  Dermer+ 2012
  Murase+ 2012

- ALPs

  Roncadelli+ 2007

- far-IR EBL-probes

  Franceschini+ 2008
  Dominguez+ 2011

- LIV and anomalies in EBL opacity

  Fairbairn+ 2014,
  http://arxiv.org/abs/1401.8178

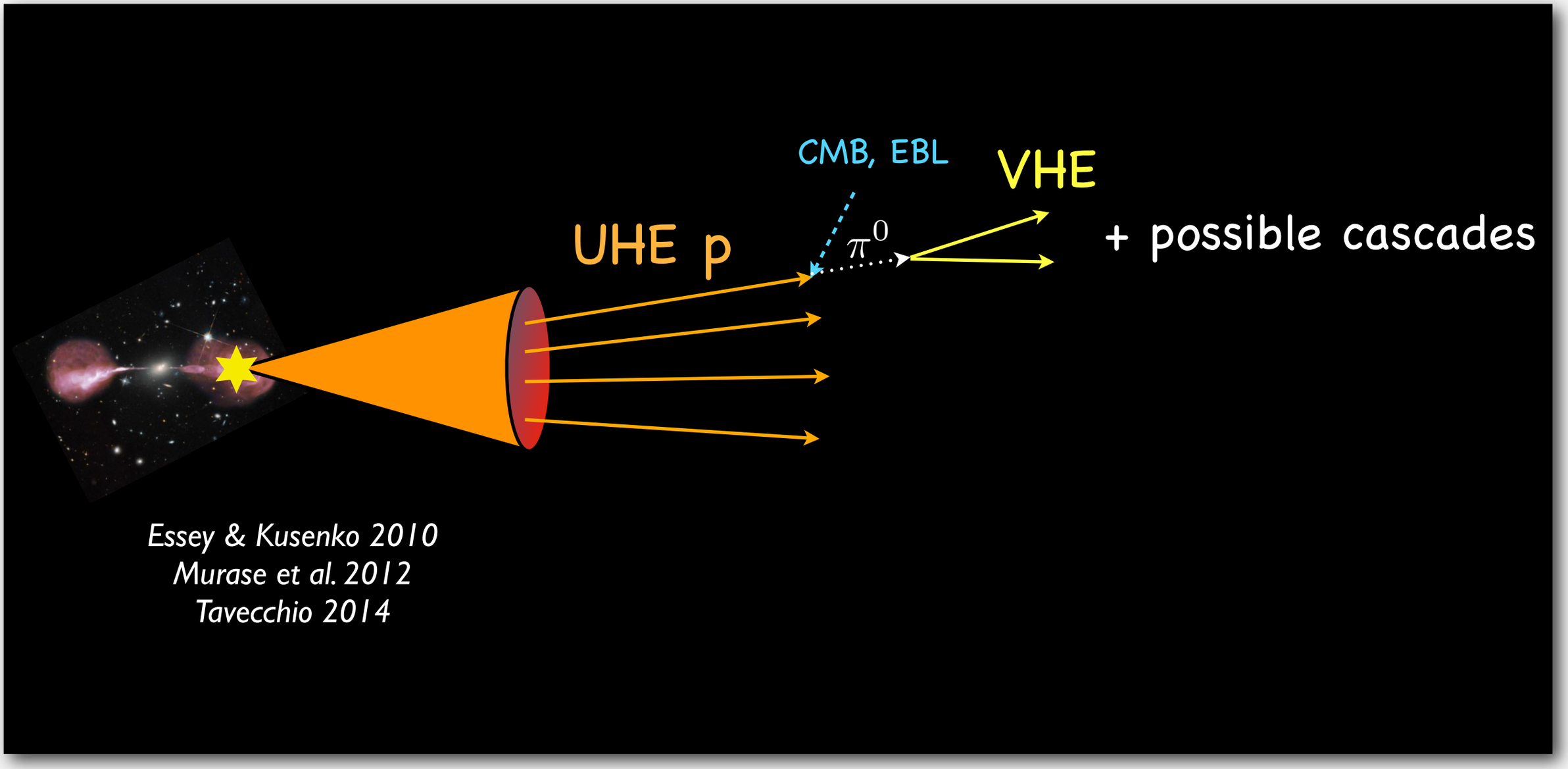
- HE gamma-ray background

  Inoue & Ioka 2012. Bonnoli+ in prep

- IGMF probes

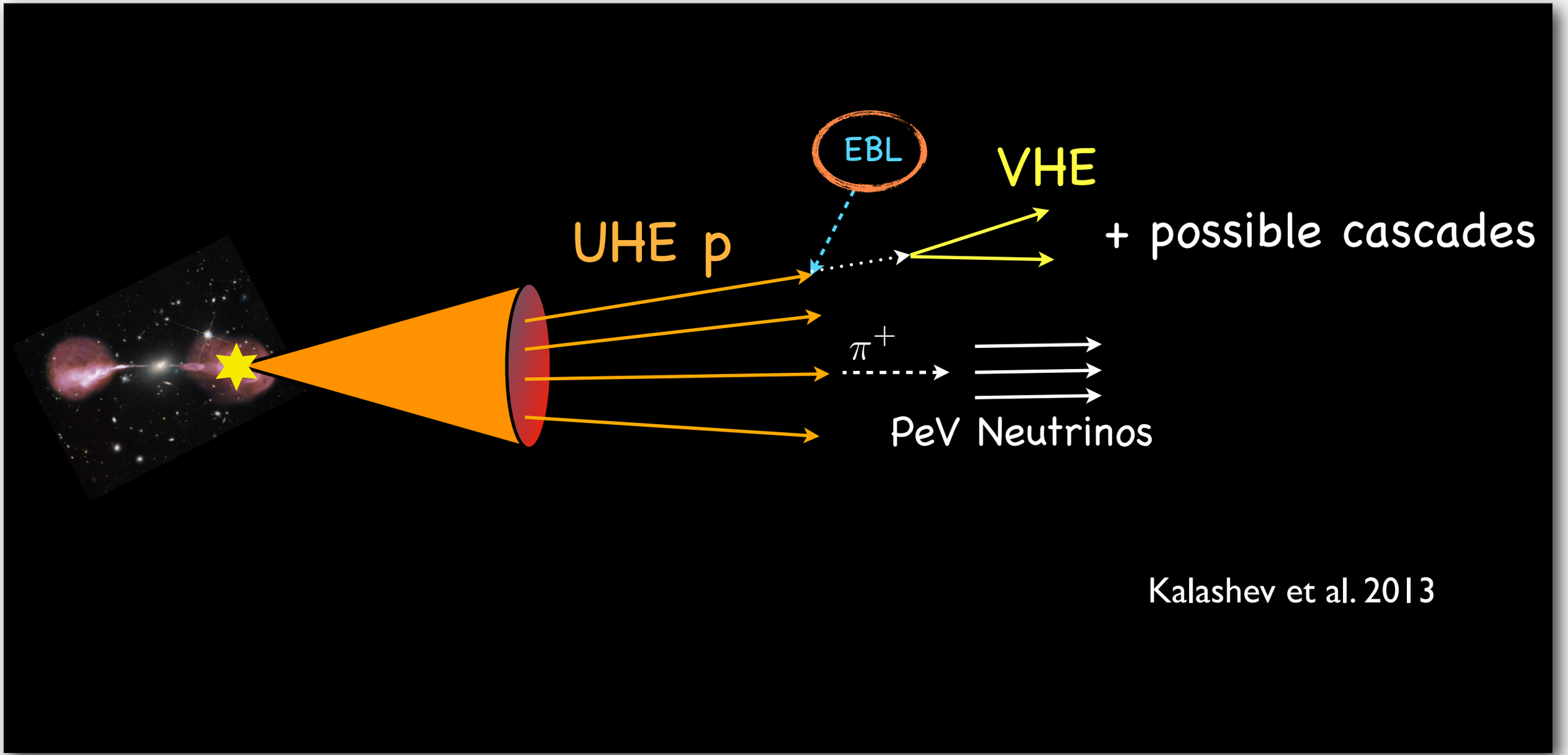
  Neronov 2010
  Tavecchio+ 2010

UHECR beams?



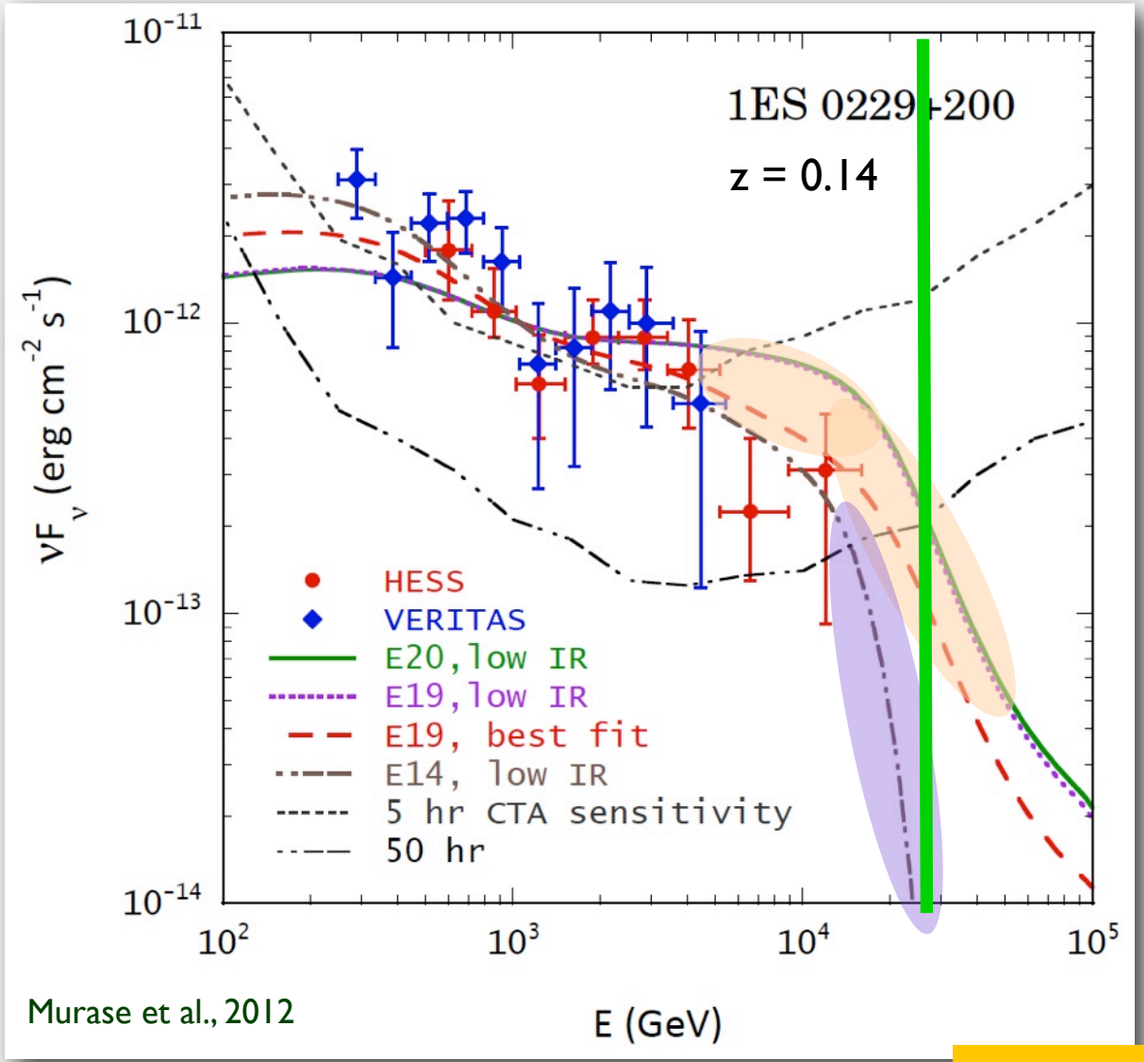
Essey & Kusenko 2010
Murase et al. 2012
Tavecchio 2014

UHECR beams?


EBL
VHE
+ possible cascades
UHE p
π^+
PeV Neutrinos
Kalashev et al. 2013

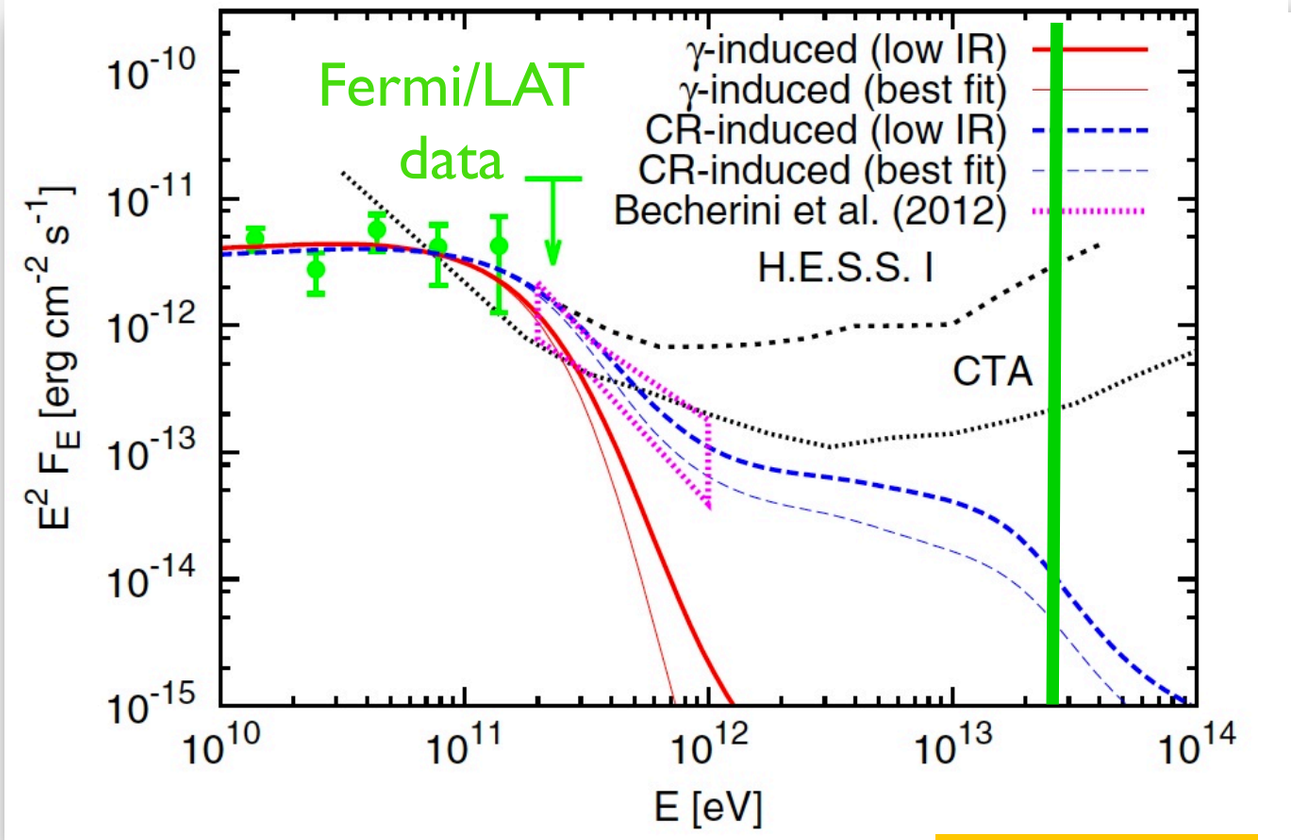
The ASTRI/CTA mini-array

UHECR beams?



Murase et al., 2012

Murase+ 2012



Takami+ 2013

- ✓ At higher energies, however, UHECR-induced cascade emission becomes harder than γ-ray-induced cascade emission.
- ✓ A detection of >25 TeV γ-rays from 1ES 0229+200 is only compatible if the γ-rays are hadronic in origin. Very deep ASTRI/CTA mini-array observation are required.

LIV and anomalies in EBL opacity

LIV induces an affective mass for the photon

$$\beta_\gamma = 1 - \left(\frac{E_\gamma}{M_{LVn}}\right)^n \quad ; \quad m_\gamma^2 = -\frac{E_\gamma^{2+n}}{M_{LVn}^n},$$

Modification of threshold for pair production at high E

LIV induces suppression of EBL-opacity

ASTRI/CTA Mini-Array

Fairbairn+ 2014

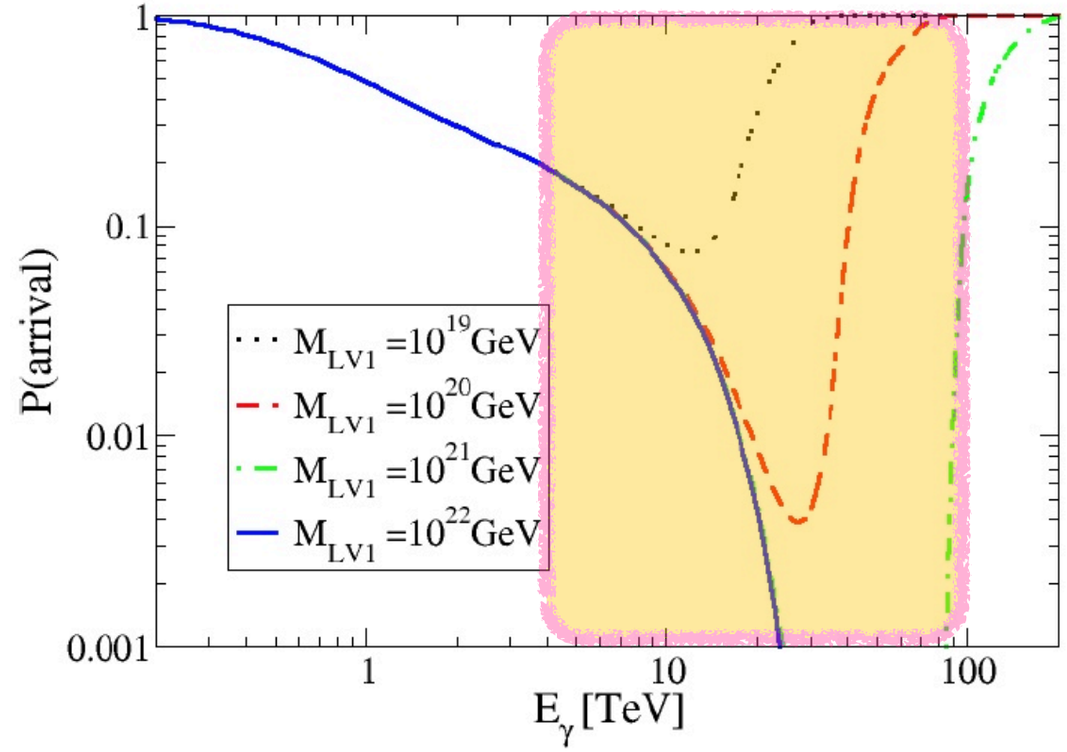
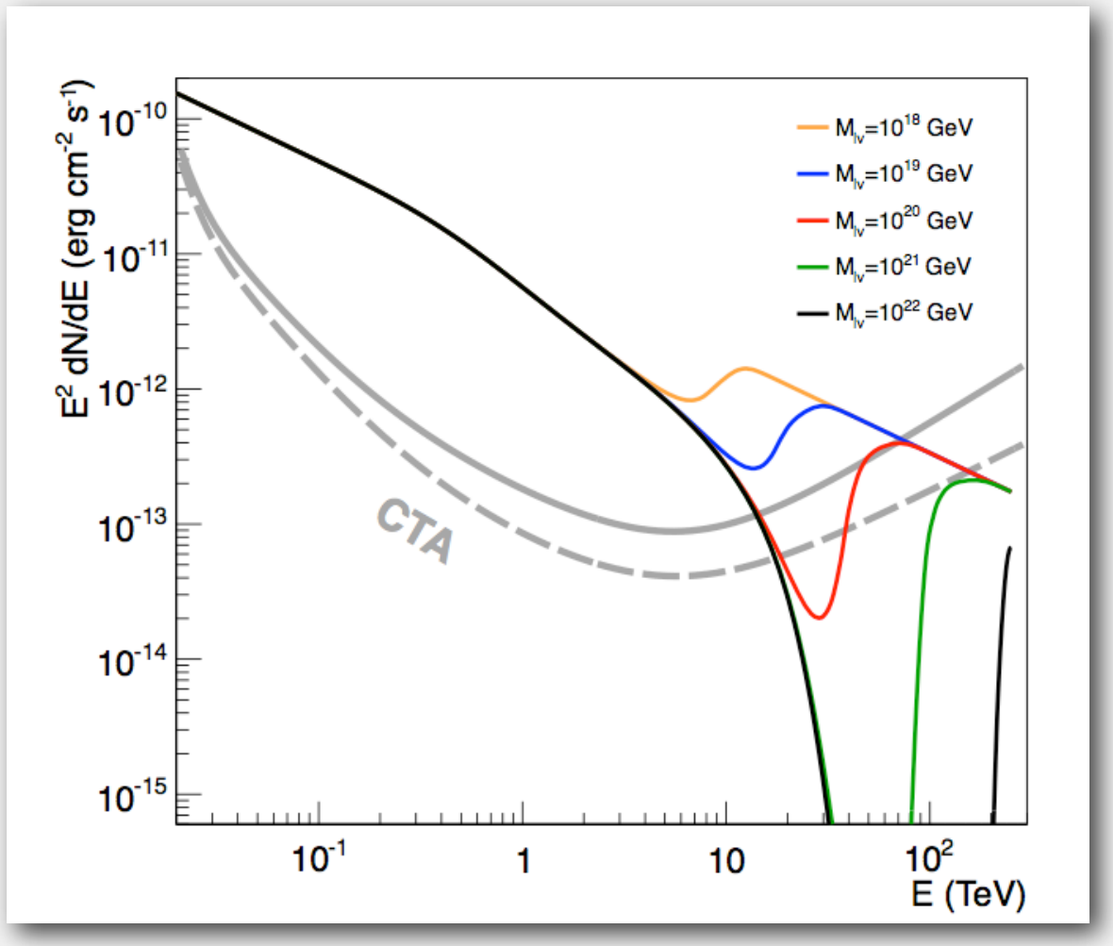
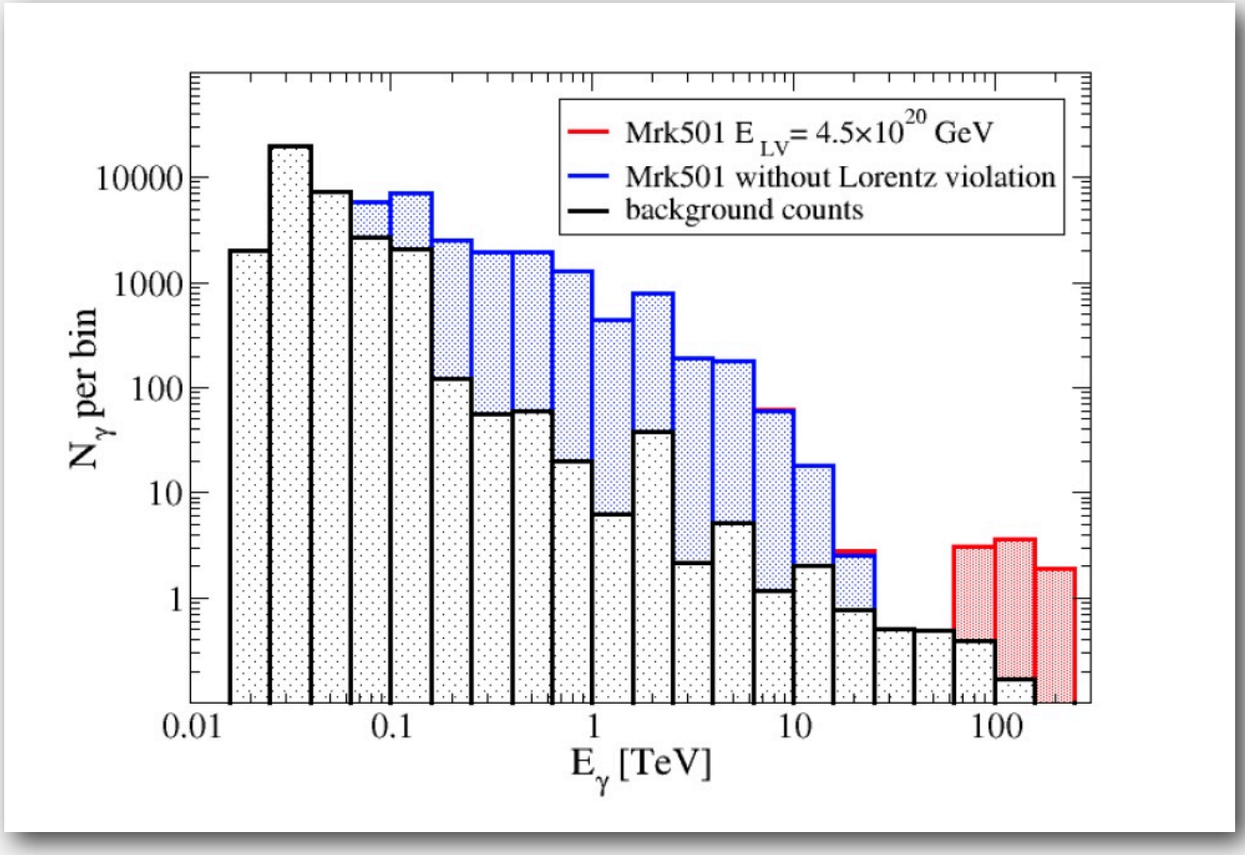


Figure 2. *The arrival probability of a photon emitted from a hypothetical source at redshift $z = 0.05$ as a function of energy. The different curves represent different values of the Lorentz-violating scale M_{LV1}. VHE photons with energies $\gtrsim 100$ TeV can travel through the CMB effectively unimpeded.*

LIV and anomalies in EBL opacity

Mrk 501

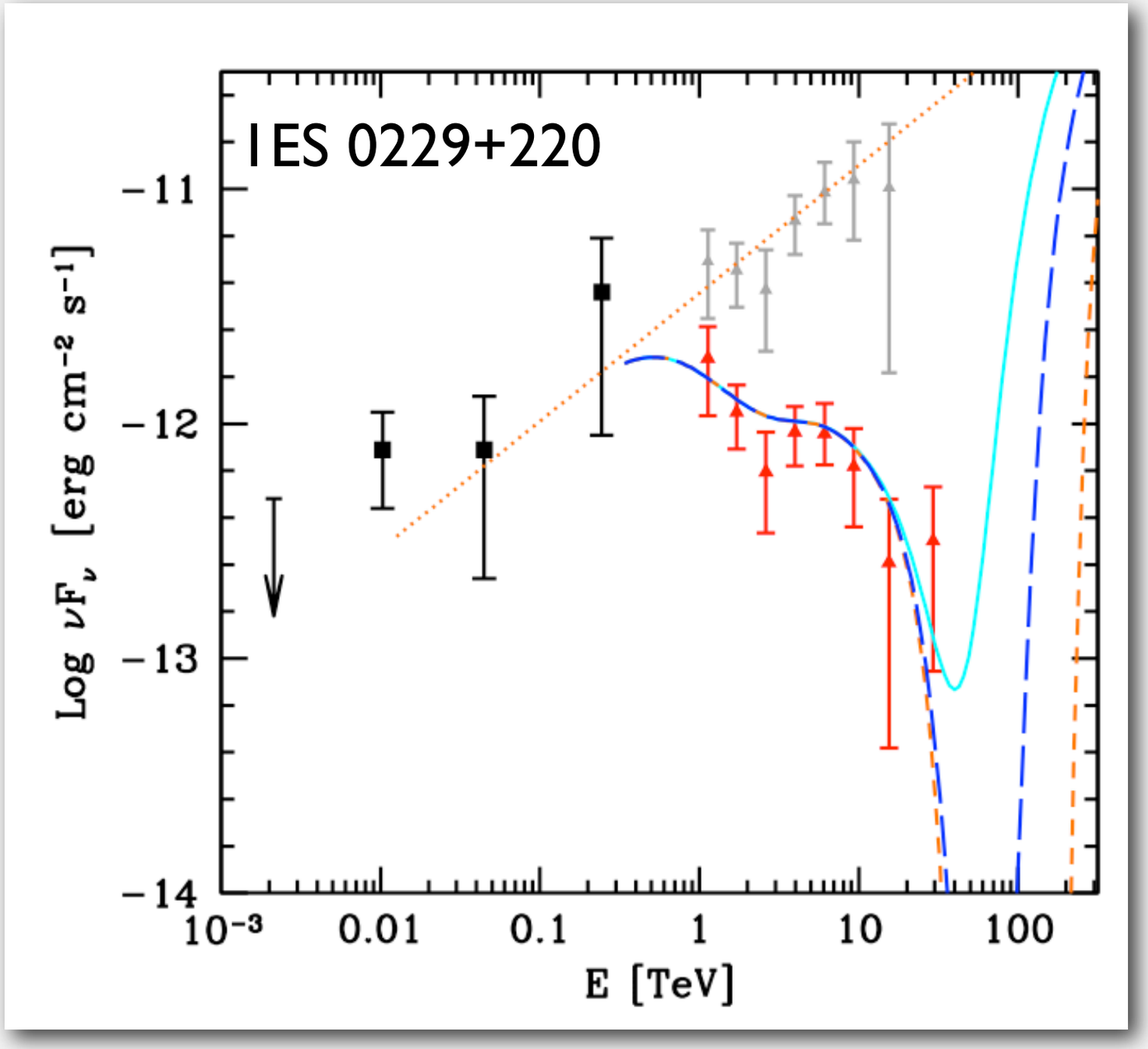




Fairbairn+ 2014

LIV and anomalies in EBL opacity

A better source...



Fermi/LAT
Vovk et al. 2012

HESS
Aharonian et al. 2007

HESS De-absorbed
with Dominguez+ 11

$M_{LVI} = 10^{19}\,\mathrm{GeV}$

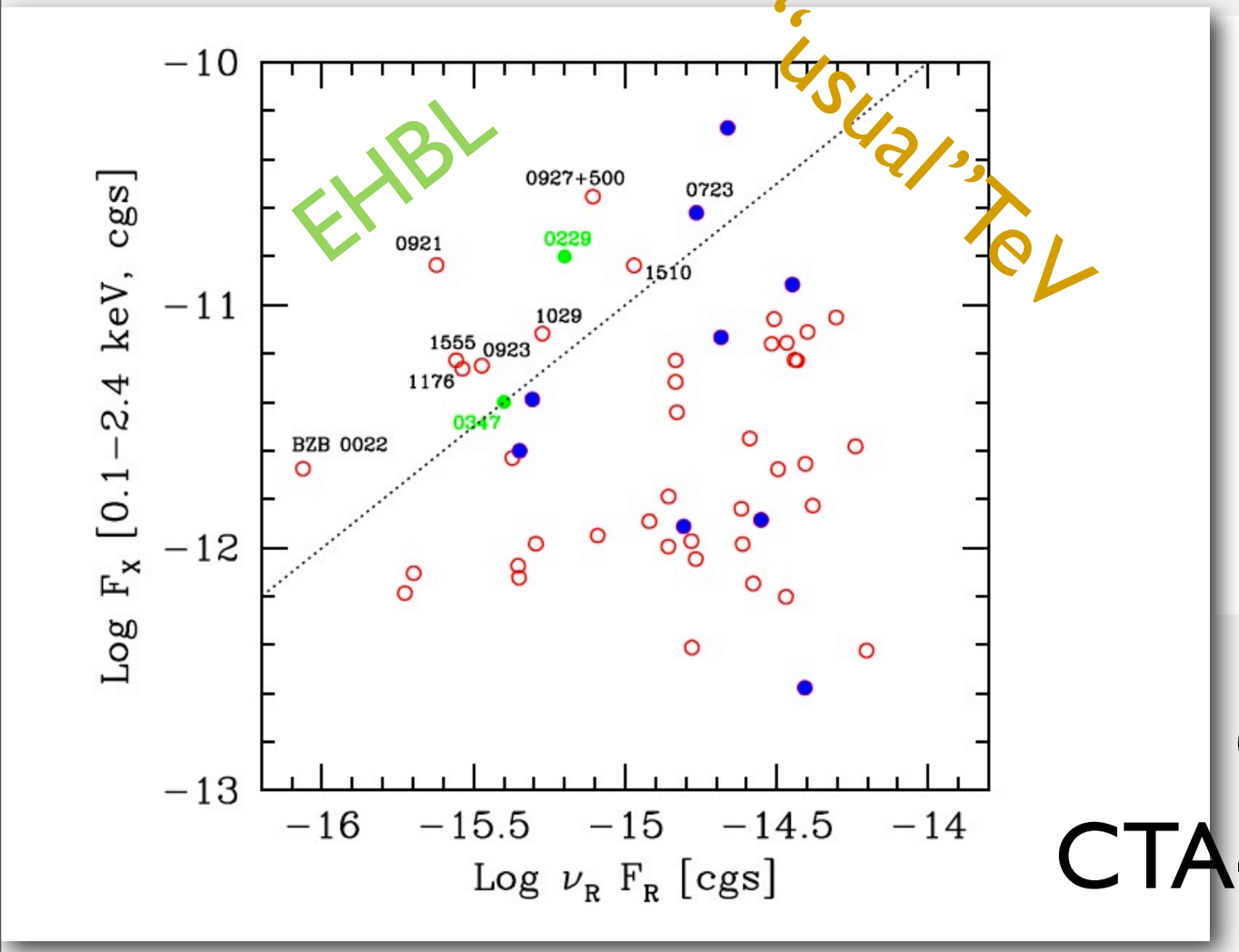
$M_{LVI} = 3 \cdot 10^{19}\,\mathrm{GeV}$

$M_{LVI} = 10^{20}\,\mathrm{GeV}$

Tavecchio et al. in prep

Selecting a sample of EHBL

Bonnoli+ in prep.



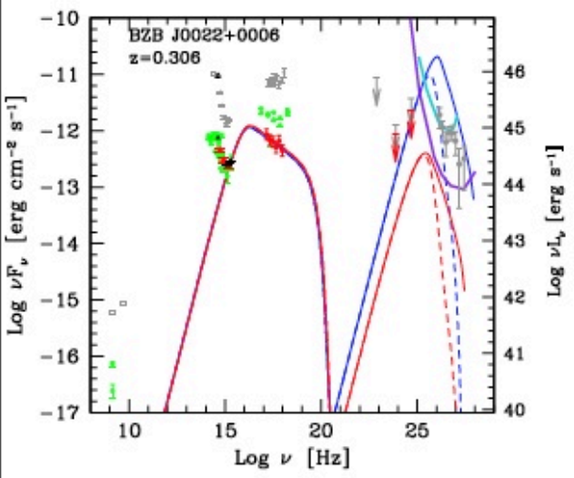
Source Name	RA(J2000)	DEC(J2000)	Redshift
BZB J0022+0006	5.503958	0.116083	0.306000
RBS 0723	131.803879	11.563958	0.198199
1ES 0927+500	142.6566271	49.8404308	0.186742
RBS 0921	164.027527	2.870417	0.236126
RBS 0923	164.346248	23.055220	0.378298
RBS 1029	176.396274	-3.667130	0.167907
RBS 1176	193.253983	38.440492	0.370856
RBS 1510	233.296880	18.908088	0.307079
RBS 1555	241.329345	54.350001	0.211773

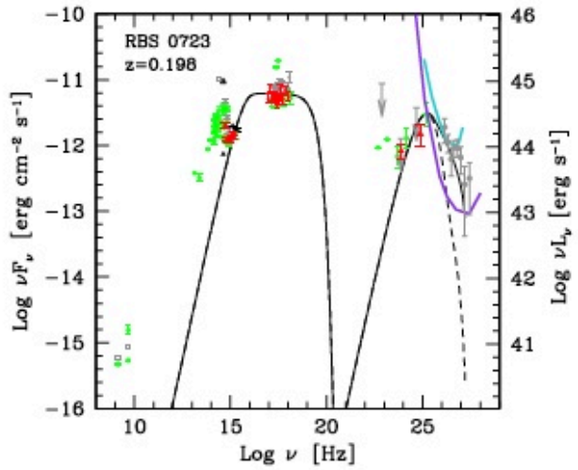
CTA-N: < 30-40° ZA

CTA-S: 3 out, 3 High-ZA, 3 OK

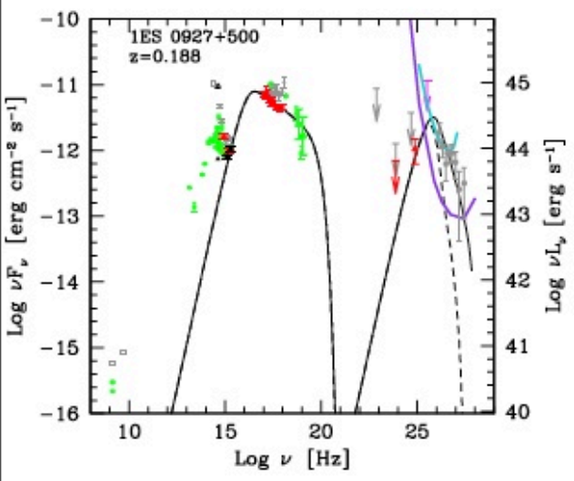
Criterion if confirmed could be applied on Southern Sky catalogues

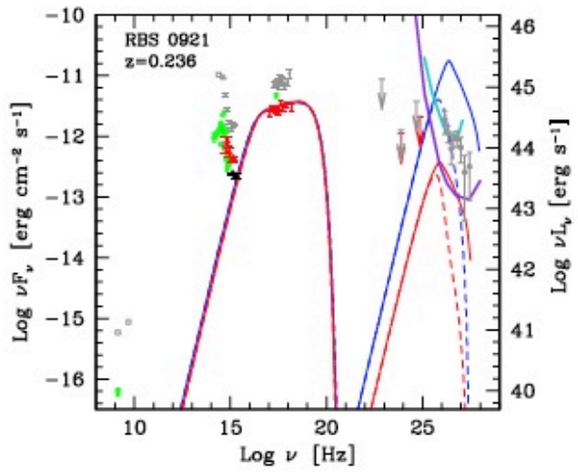
EHBL Spectral Energy Distributions

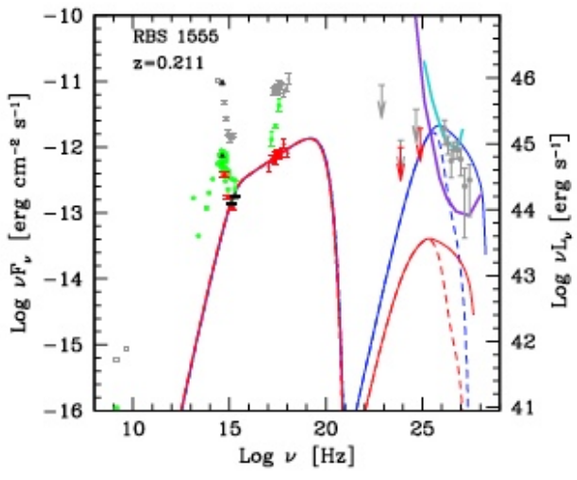


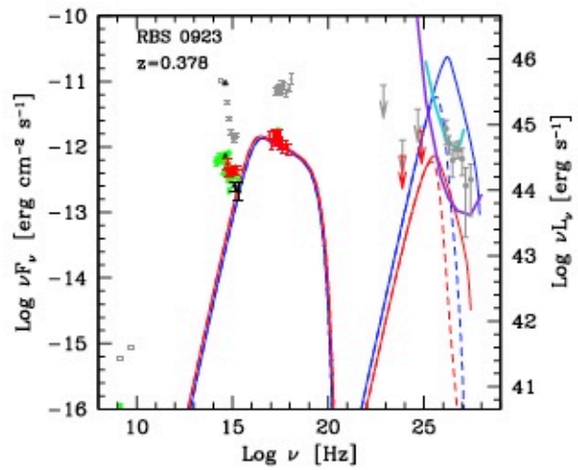


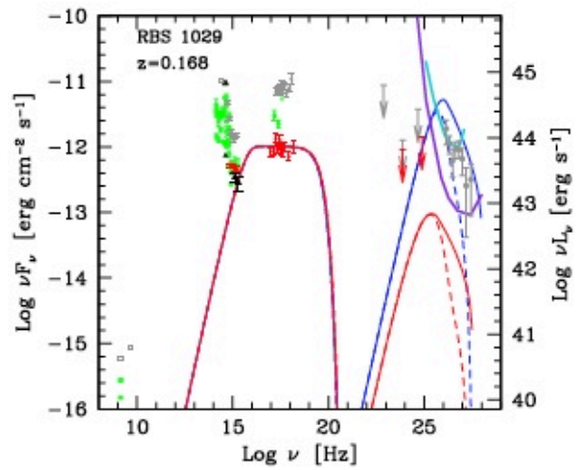
MAGIC-detected!!

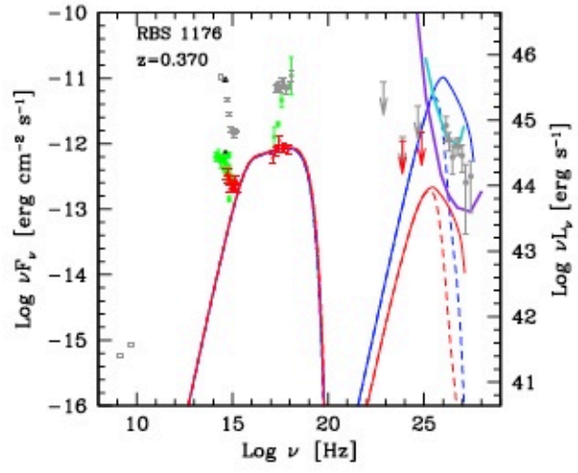


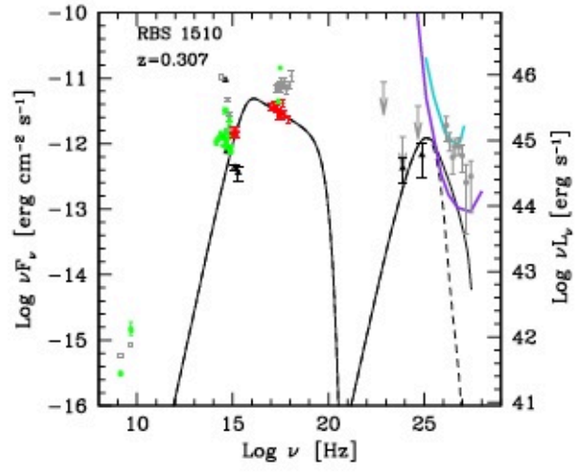












Bonnoli+ in prep.

Data from:

Swift

Fermi/LAT

WISE

Archive

Gray: SED of 1ES 0229+220 (for comparison)

Summary

- ✓ The **ASTRI SST-2M prototype**, operational starting at beginning of 2015 will perform the **first Crab observations with a Schwarzchild-Couder telescope equipped with SiPMs.**

- ✓ The **ASTRI/CTA mini-array** will constitute a ***seed* for the whole CTA array**, allowing us to probe technological solutions.

- ✓ **ASTRI/CTA mini-array deep observations of a few selected targets** will allow us to obtain a few solid detections during the first year, and to perform the **CTA early science**.

- ✓ The **ASTRI/CTA mini-array** will exploit excellent **synergies with *Swift* and *Fermi*** (in operation in 2016 and beyond).

Backup slides

The brand new TeV EHBL RBS 0723

DISCOVERY OF VERY HIGH ENERGY GAMMA-RAY EMISSION FROM RBS 0723 WITH THE MAGIC TELESCOPES

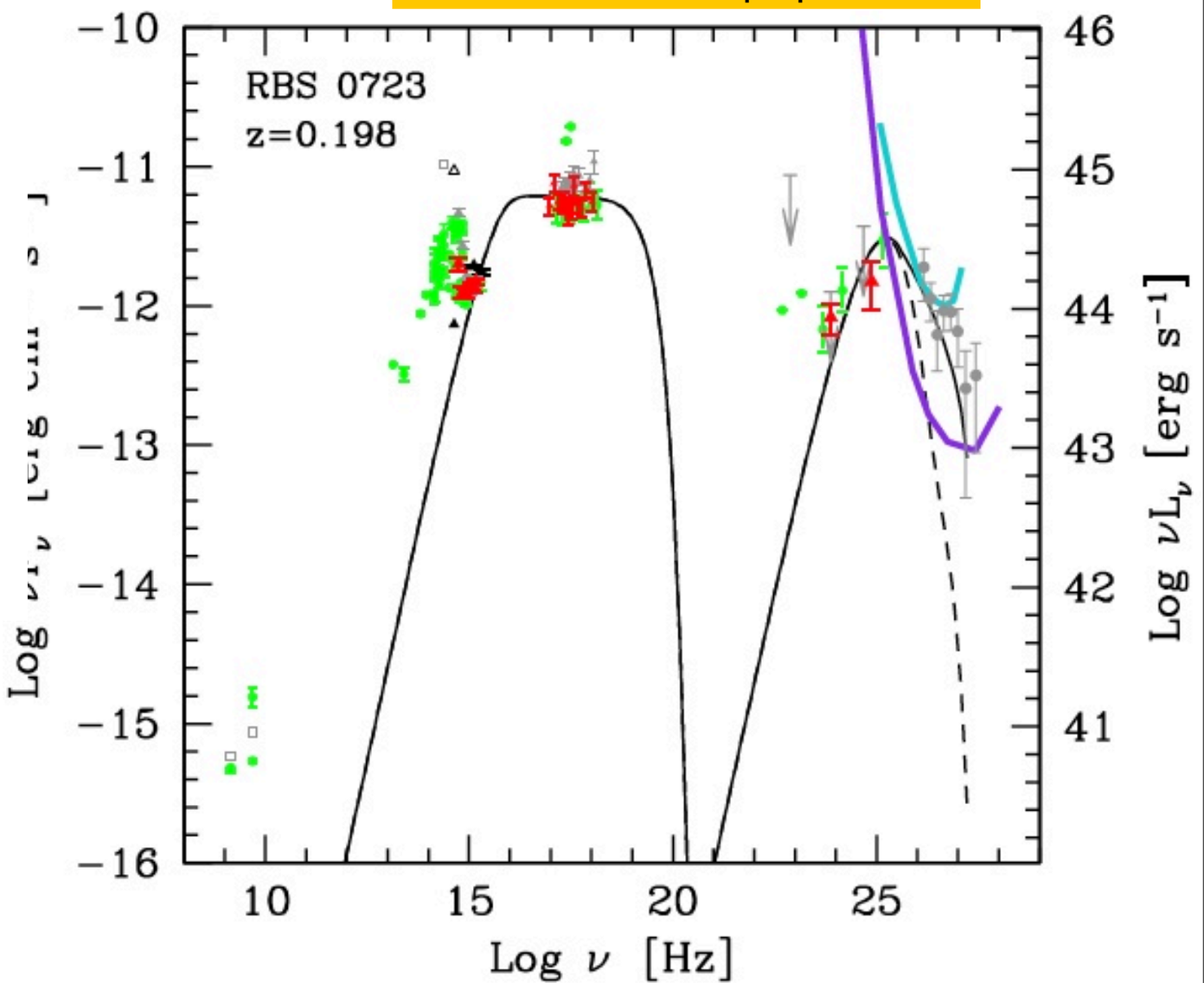
ATel #5768; *Razmik Mirzoyan (Max-Planck-Institute for Physics, Munich, Germany)*
on 15 Jan 2014; 17:53 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN

Tweet 10 Recommend 3

The MAGIC collaboration reports the discovery of very high energy (VHE; E>100 GeV) gamma-ray emission from RBS 0723 (RA: 08:47:12.9 DEC: +11:33:50, J2000.0) RBS 0723 is a BL Lac object at redshift z=0.198. The source has been detected by Fermi-LAT, in the Second Fermi-LAT source Catalogue (2FGL; Nolan et al. 2012) with F(>1 GeV) = (5.3+-1.2)e-10 cm^-2 s^-1 and with photon index 1.48+-0.16. It also belongs to the first Fermi-LAT catalog of >10 GeV sources (1FHL; Ackermann et al, 2013), showing a hard (photon index = 1.4 +- 0.4) and bright (photon flux = 9.6e-11 ph cm^-2 s^-1) emission above 10 GeV, and identified as a good candidate for VHE detection. The shape of the SED indicates it is one of the subclass of the extreme HBL characterized by extremely hard X-ray and VHE continua. RBS 0723 was observed starting on 2013 December 3. Data taken between 2014 Jan 1 and Jan 8 (about 10 hours) yields a source detection with a statistical significance of more than 5 standard deviations. The non-detection in the earlier

Bonnoli+ in prep.



- Detection by MAGIC of RBS 0723 suggests that these HBL are well within reach for full CTA
- ASTRI/CTA M-A has only a factor of few worse (<~10) area w.r.t. CTA
- Dedicated simulations ASAP for best observability

Even though variability may play a role, the model prediction looks conservative after MAGIC 10h detection