Gamma-Ray Astronomy from the Ground

Dieter Horns
University of Hamburg

Introduction - summary

Many new Results from ICRC 2015

- No – we haven't discovered dark matter, yet
- Yes – we have discovered sources of cosmic rays
- Yes – we have detected the optical extra-galactic background light
- Yes – we are sensitive to new physics (LIV/ALPs)
- Yes – there are at least 160 Gamma-ray sources detected from ground
- Yes – upgrades and new experiments are coming

Gamma-ray astronomy with Air showers: Curse and Blessing

- Blessing: Large collection area
- Curse: Huge background
- Two strategies (complementary → hybrid):
  - Air Cherenkov imaging technique
  - Non imaging technique (particle/light sampling)

Dieter.Horns@physik.uni-hamburg.de

Status of instruments: HAWC

Mon Parallel Session, Miguel Mostafa

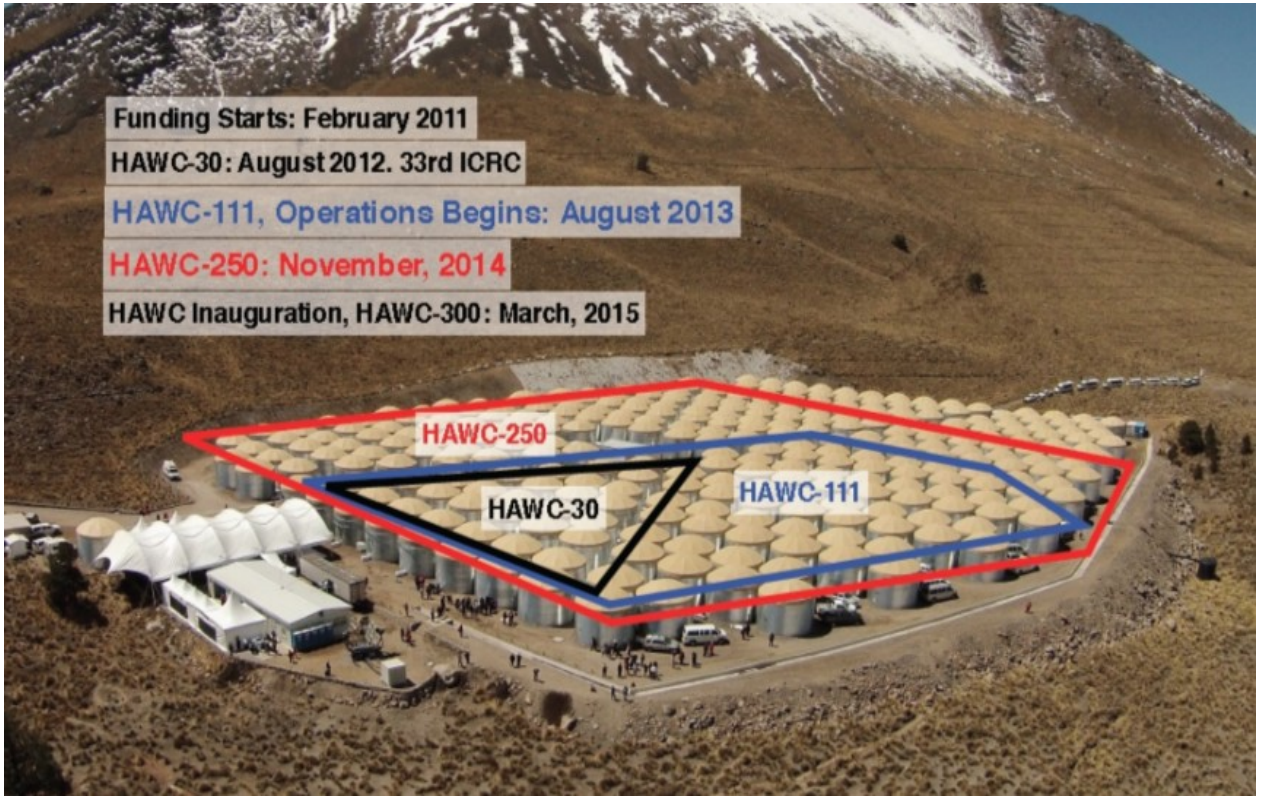
300 Water Cherenkov detectors on a 22 000 m^2 surface at high altitude (4100 m a.s.l.)

100% duty cycle, 1 srad

Fully operational since 3/2015

Data will be public >2017

Sparse outrigger extension for improved >10 TeV sensitivity



Dieter.Horns@physik.uni-hamburg.de

H.E.S.S.-Phase II

Thursday
Carlo Romoli

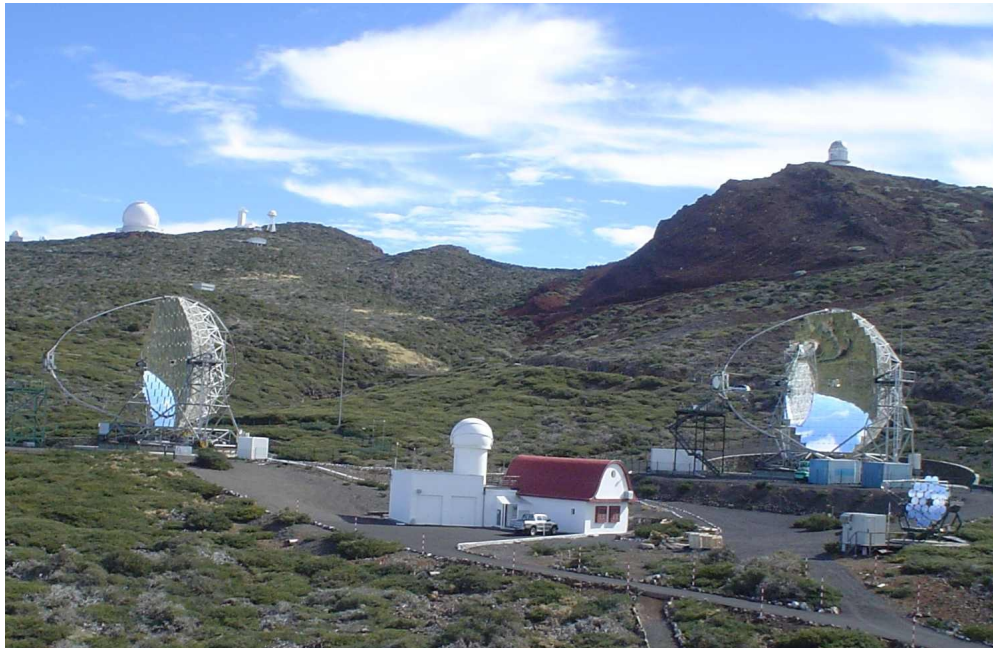
- Since 7/2012: 4x12m telescopes + 28 m telescope (“CT5”)
- Energy range 30 GeV – 100 TeV
- Major upgrade of CT1-CT4 cameras ongoing

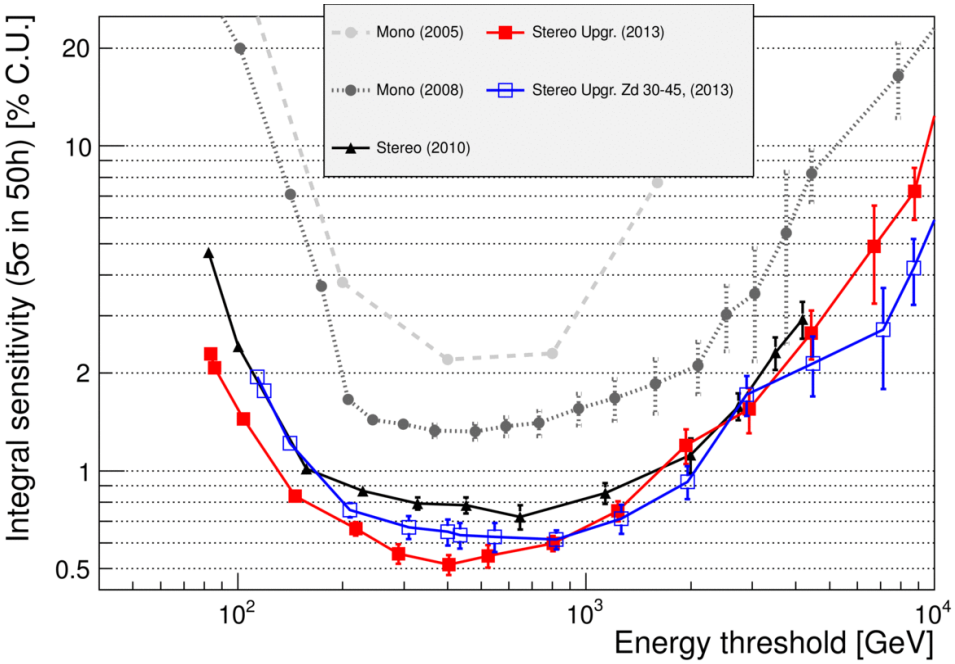
Dieter.Horns@physik.uni-hamburg.de

MAGIC^2: 2 x 17 m IACTs

Mon Parallel Session, David Paneque

- Improved triggering scheme → reduced threshold of ~35 GeV
- 4fold improvement of Sensitivity
- Correction of data for changes of the atmosphere with LIDAR



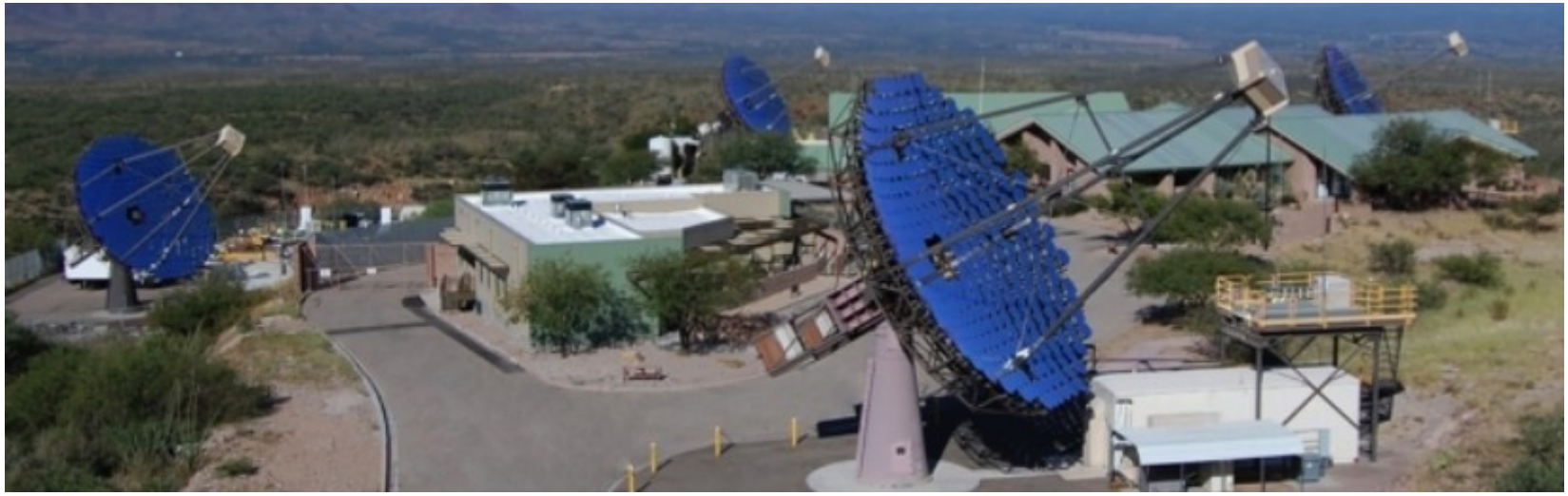


Dieter.Horns@physik.uni-hamburg.de

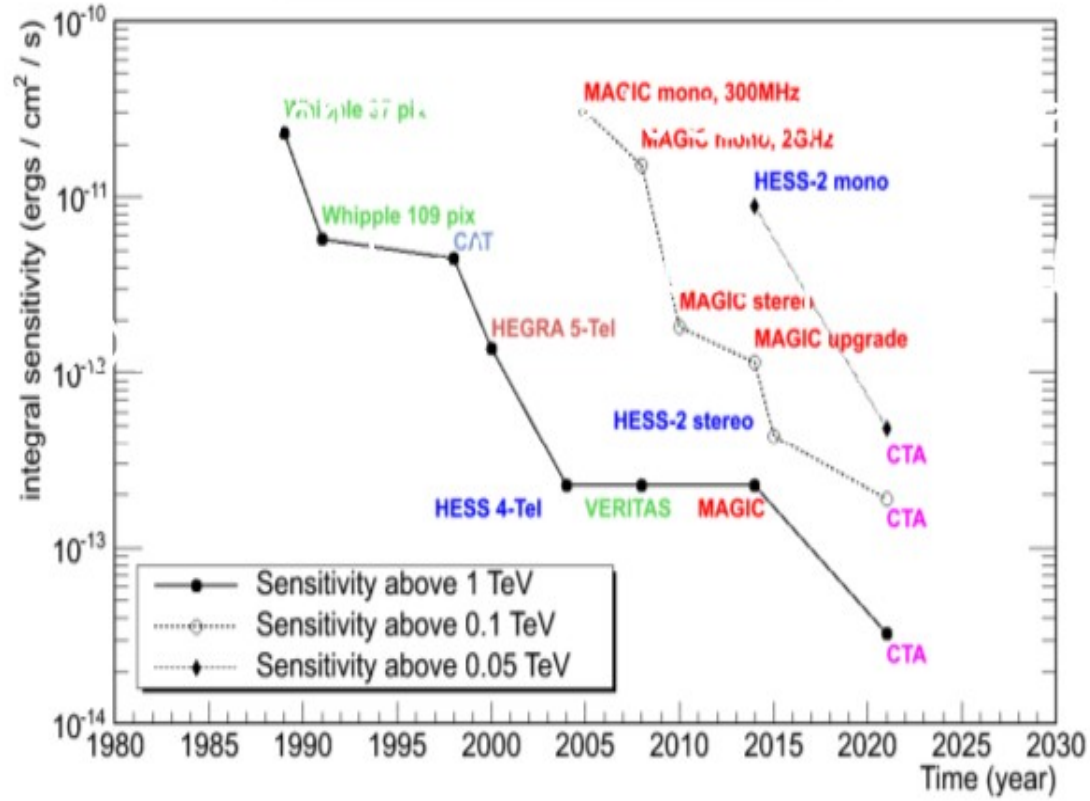
VERITAS: 4 x 12 m IACTs

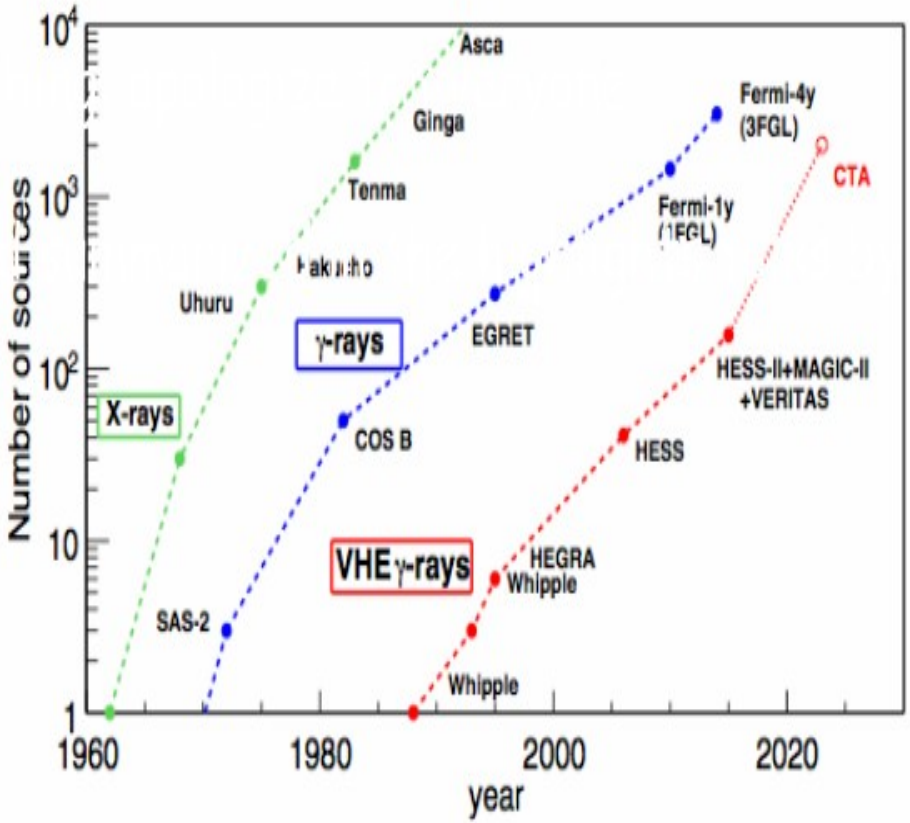
Mon Parallel Session, Lucy Fortson

- Upgrades of PMTs in 2012
- Observations with moon light



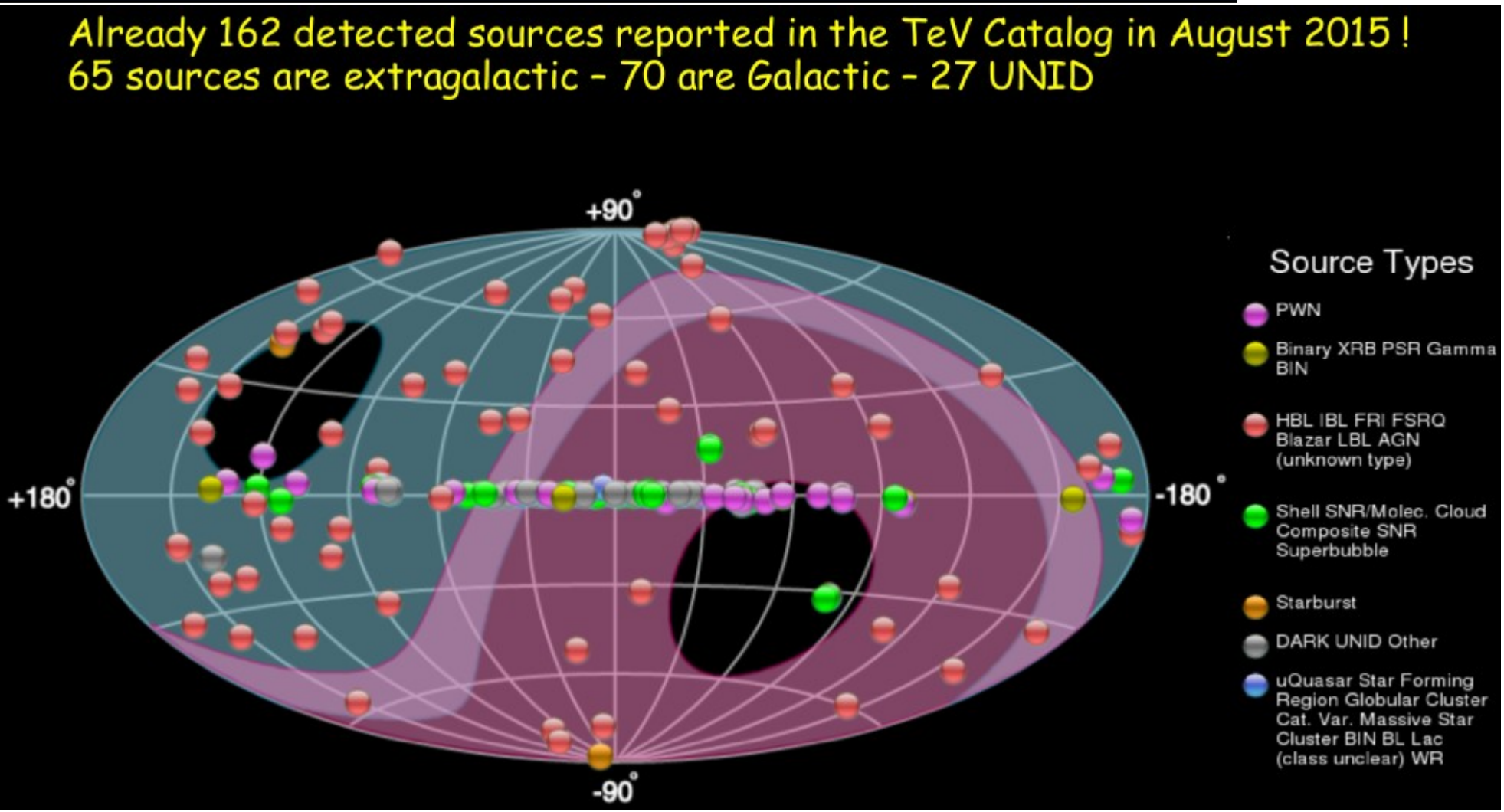
Improvements/Sensitivity





Dieter.Horns@physik.uni-hamburg.de

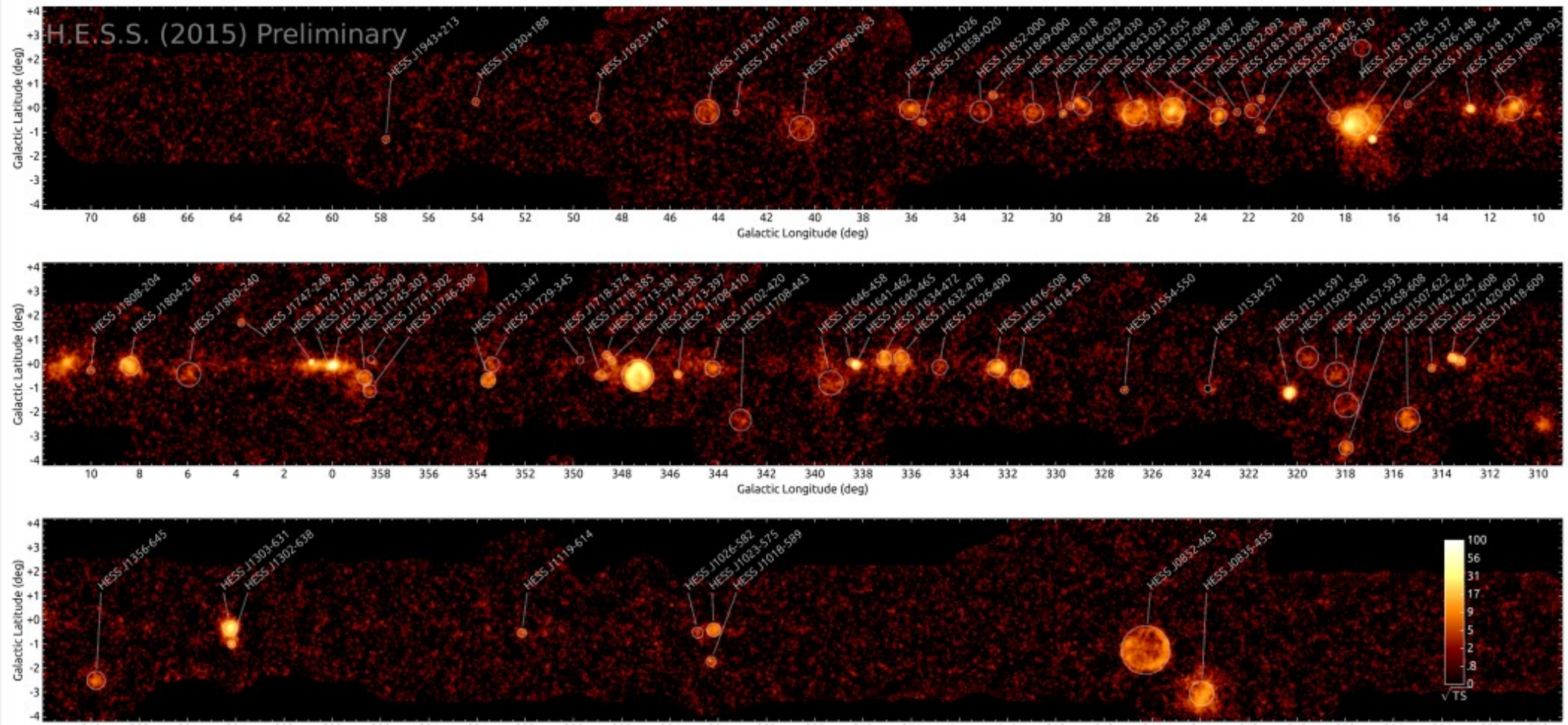
TeV Sky as of now



Dieter.Horns@physik.uni-hamburg.de

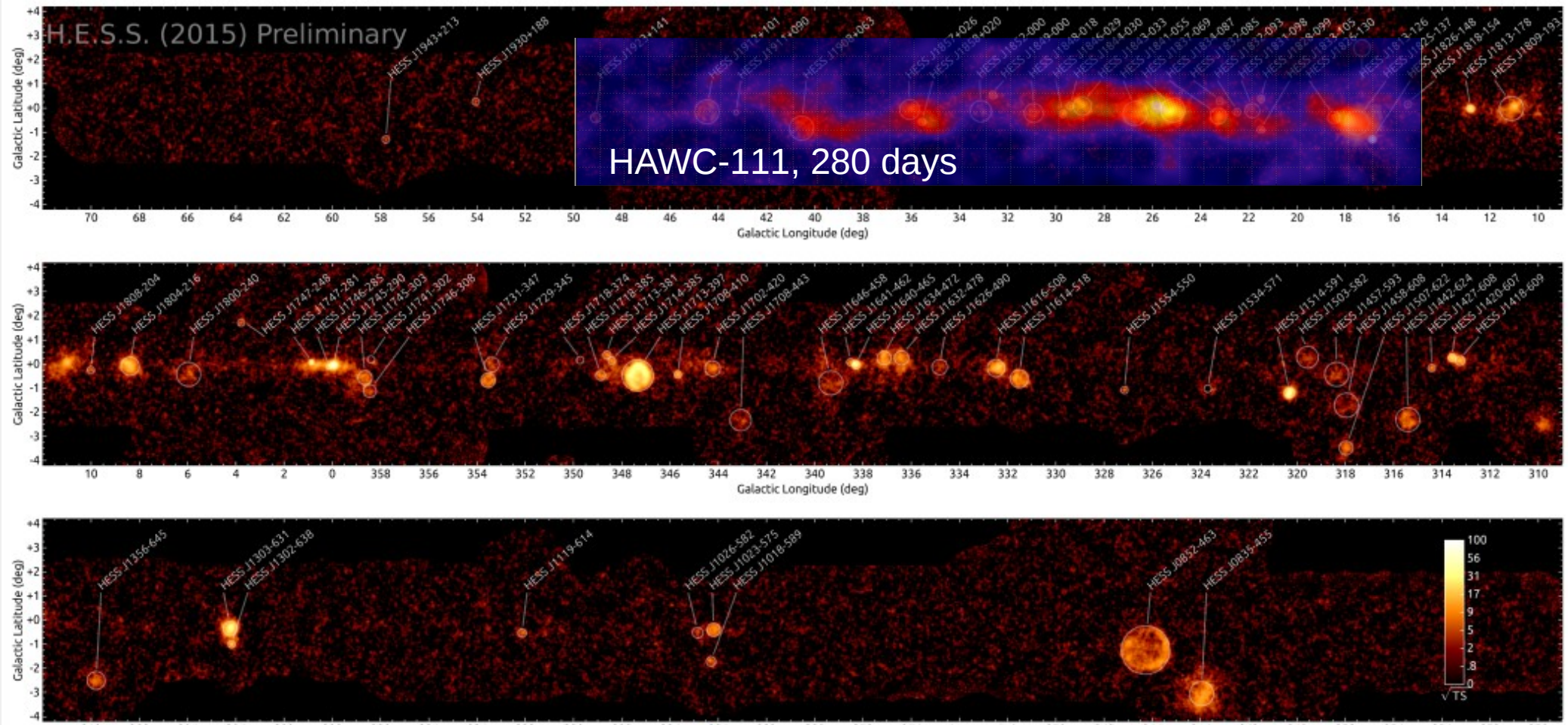
Highlights: Galactic plane

- Gamma-rays from the survey – comparison HESS and HAWC, 3000 hrs of HESS, 64 sources + 13 complex source regions



Highlights: Galactic plane

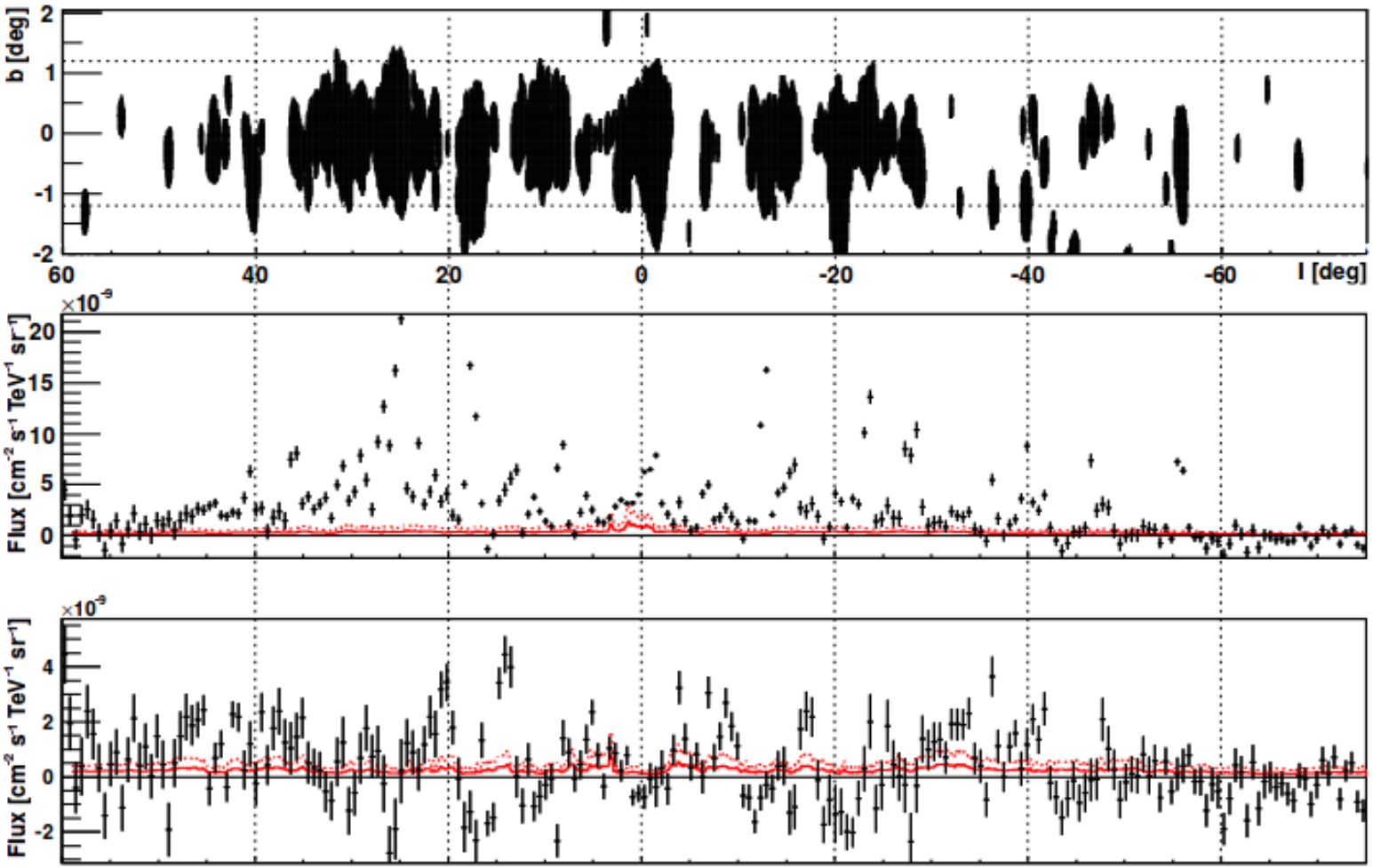
- Gamma-rays from the survey – comparison HESS and HAWC, 3000 hrs of HESS, 64 sources + 13 complex source regions



Diffuse emission from the inner Galaxy

[1411.7568]

H.E.S.S. Coll.



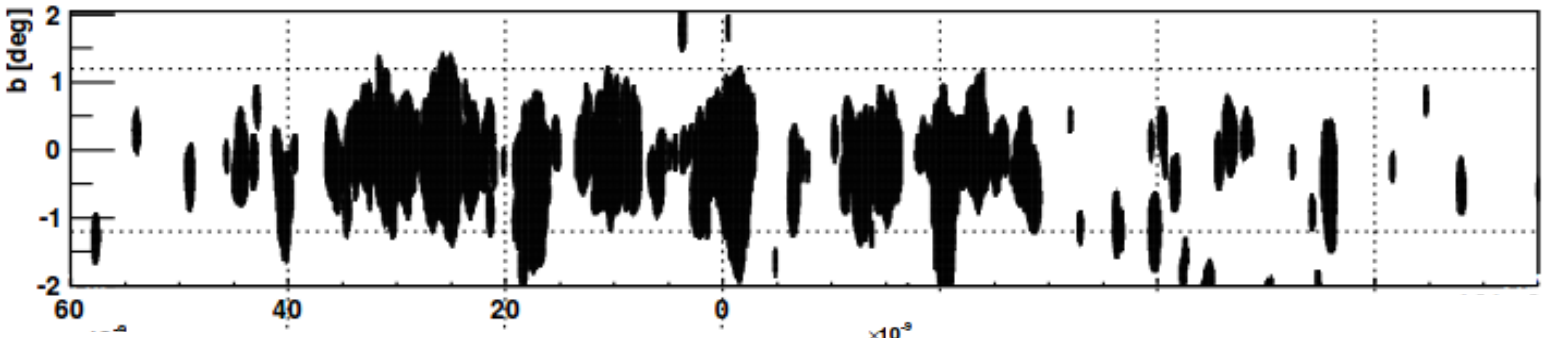
Masking sources

Inclusive flux (|b|<2°)

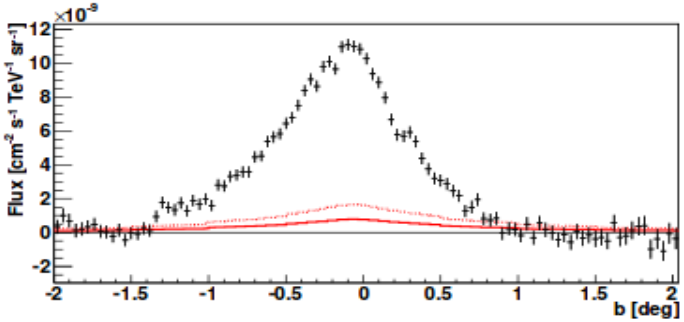
Diffuse flux (|b|<2°)

Diffuse emission from the inner Galaxy (HESS)

[1411.7568]

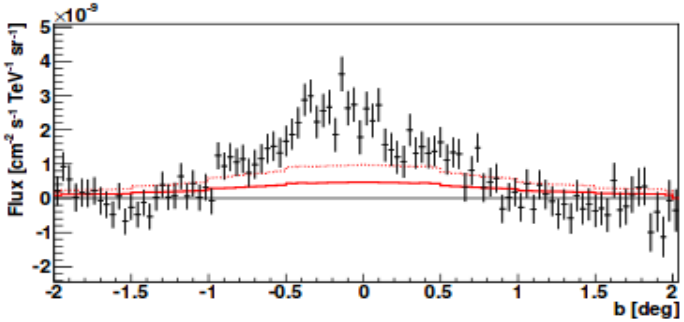


Masking sources



Inclusive flux (|l|<70°)

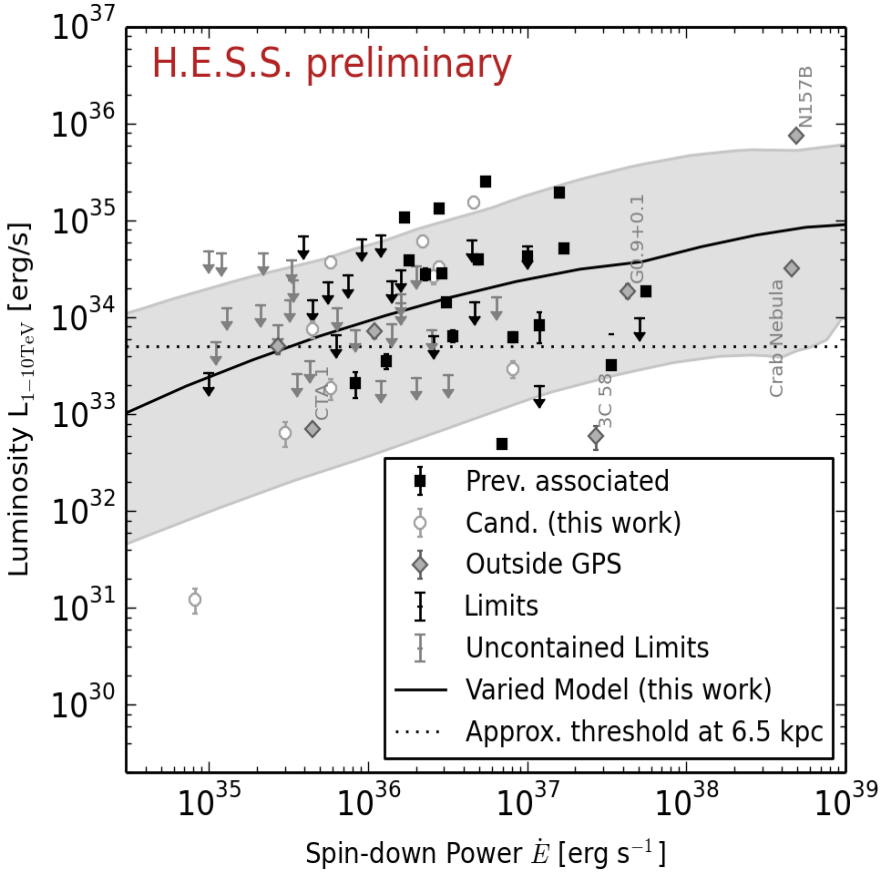
Comparison (red lines) Emission from CR-Gas interaction



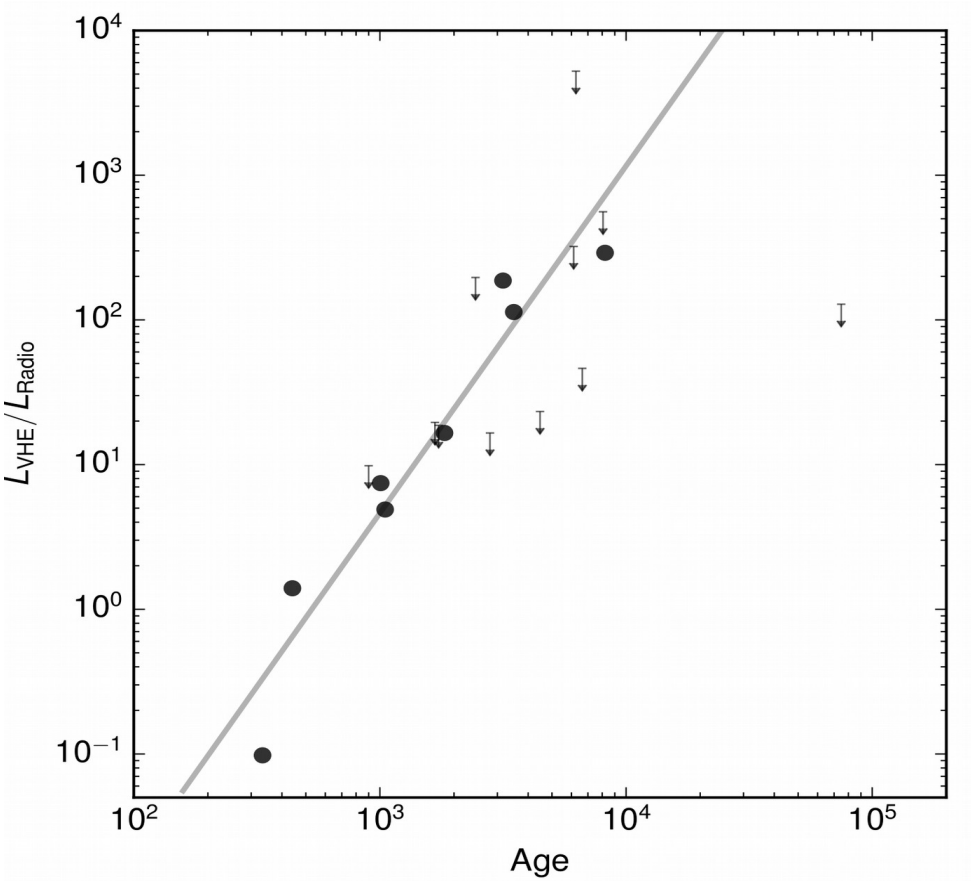
Diffuse flux (|l|<70°)

Population studies…

Pulsar wind nebulae
[Klepser et al. 2015]



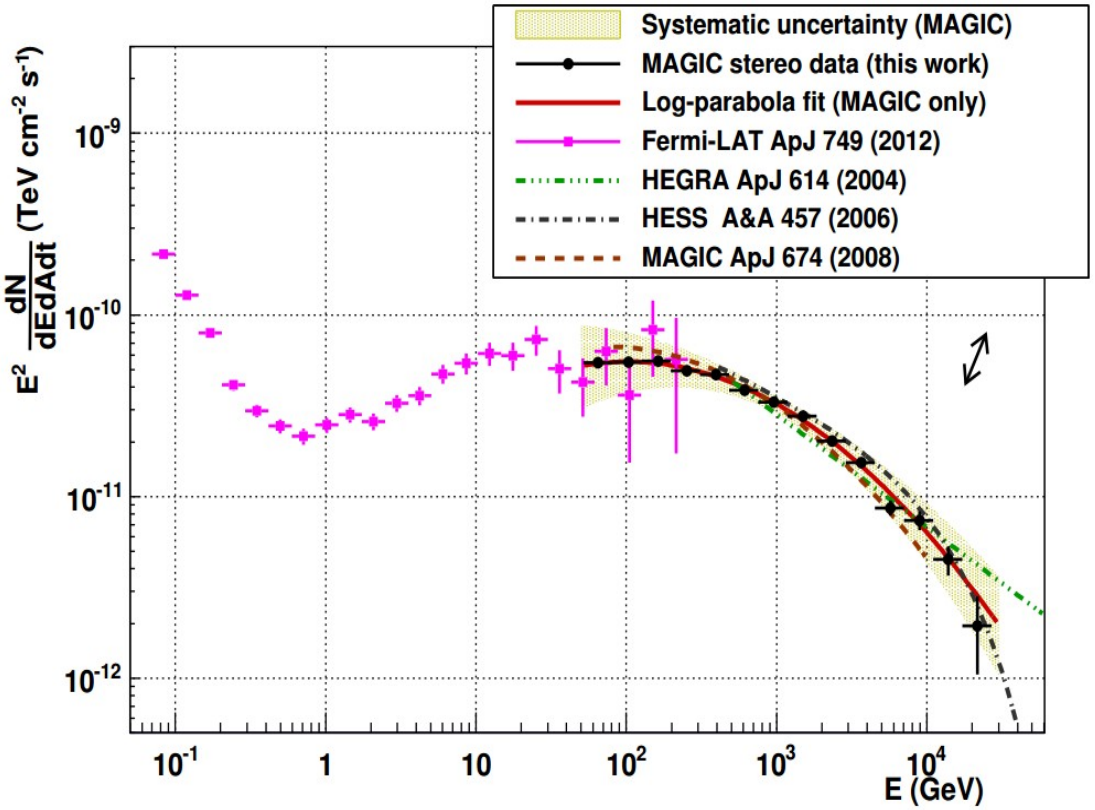
Shell-type Supernova remnants
[Hahn et al. 2015]



Dieter.Horns@physik.uni-hamburg.de

Crab nebula

- New measurements from the ground → very good overlap / consistency with Fermi-LAT
- Difficult time for models (none fit..)

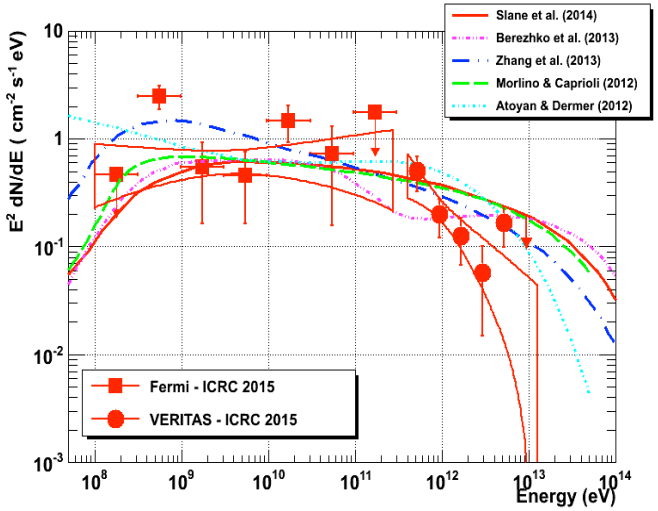


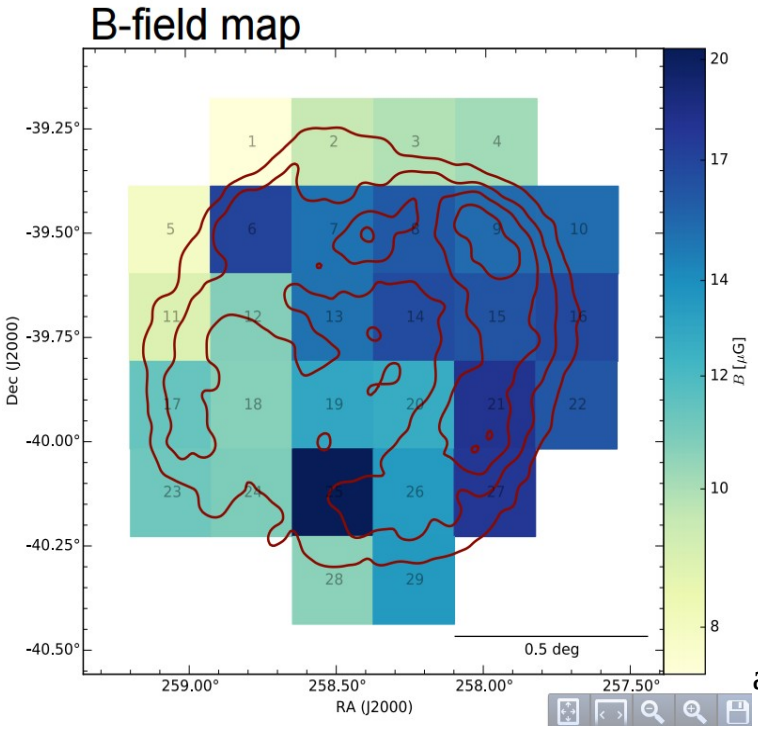
R. Zanin et al. 2015

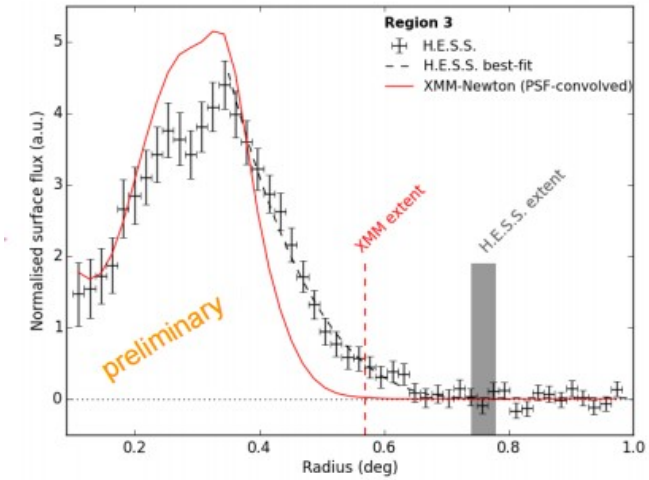
Shell-type supernova remnants

Tycho SNR

- Spectra not consistent with the hadronic scenario
- Interesting new developments in spatially resolved spectra





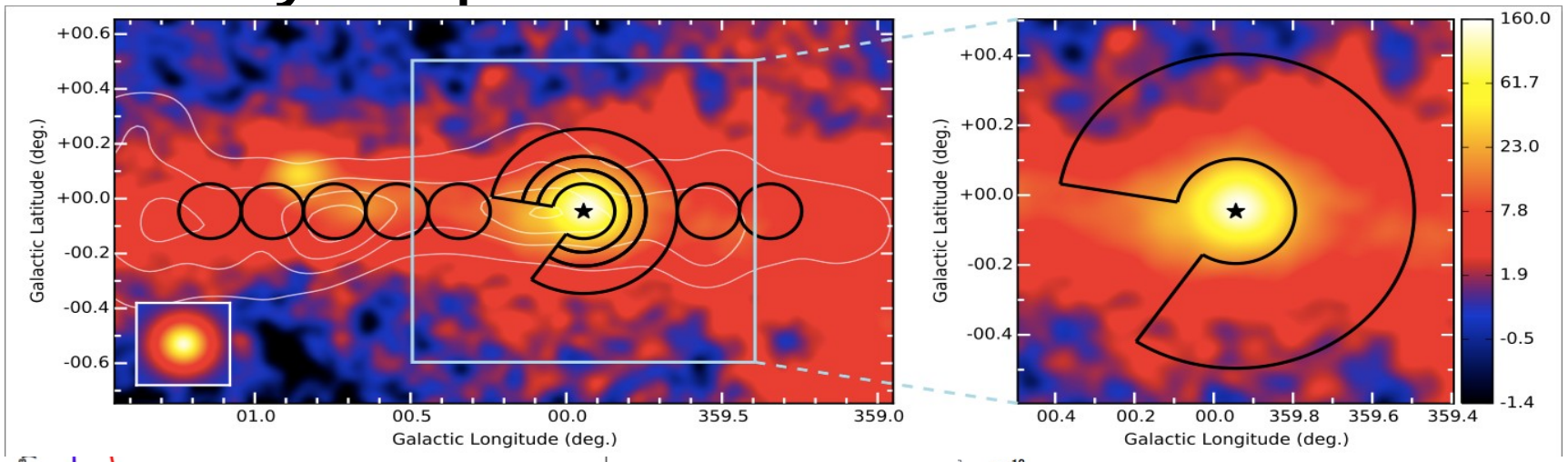


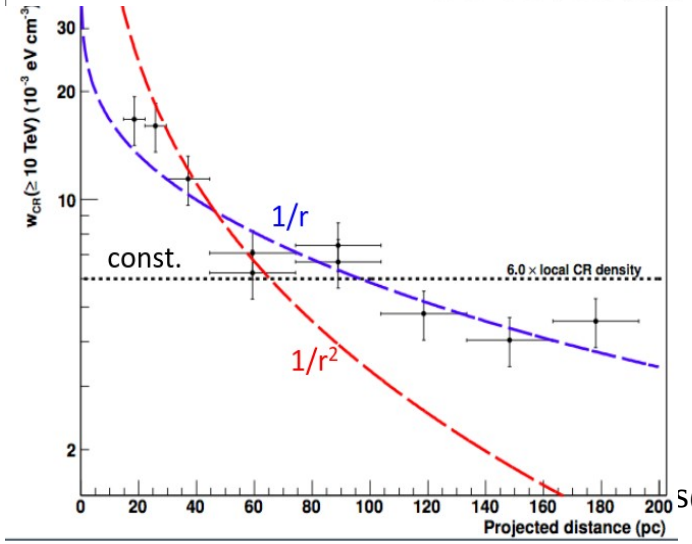
amburg.de

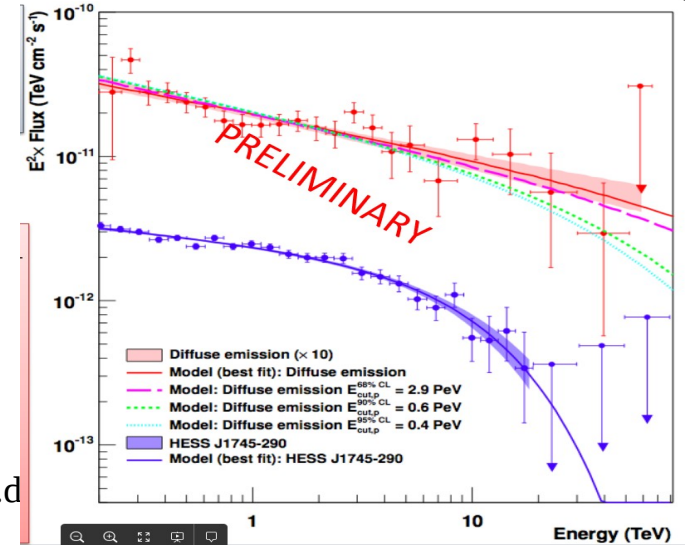
Galactic center: Pevatron

Viana et al.
ICRC 2015

- CR density + spectrum

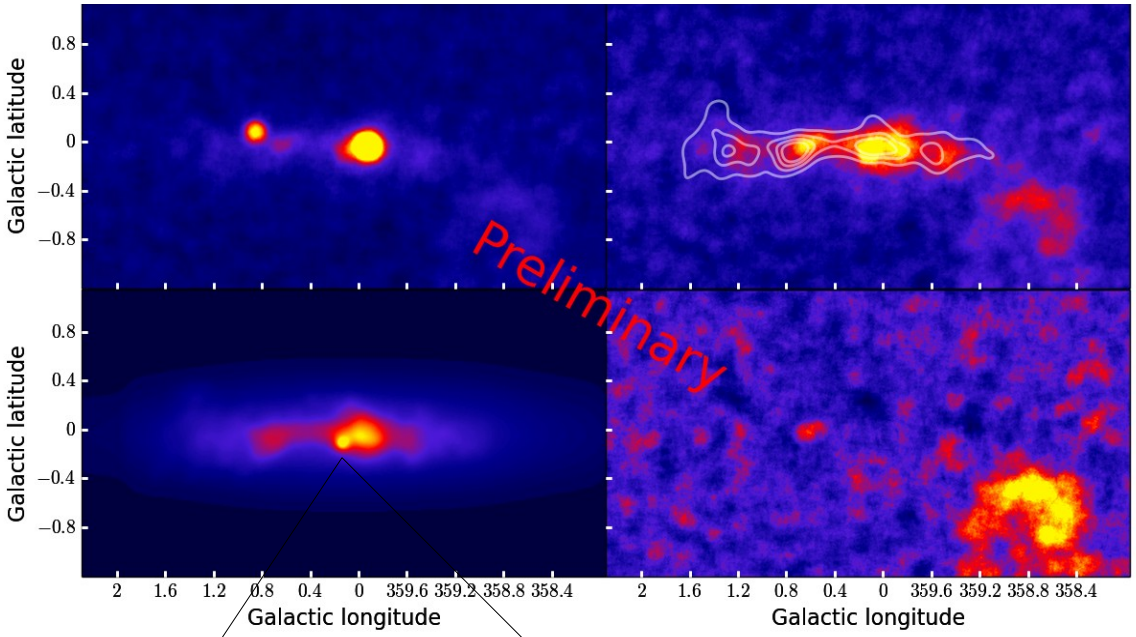


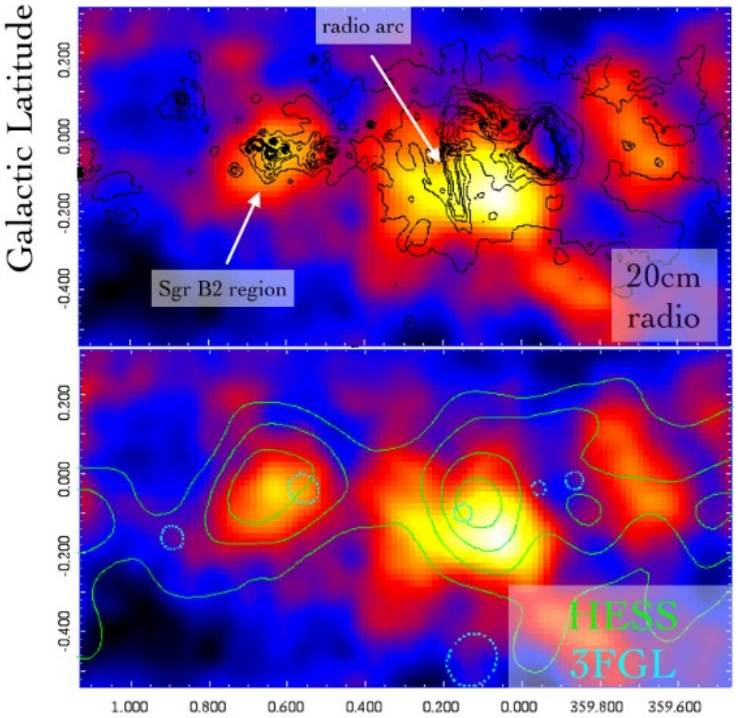




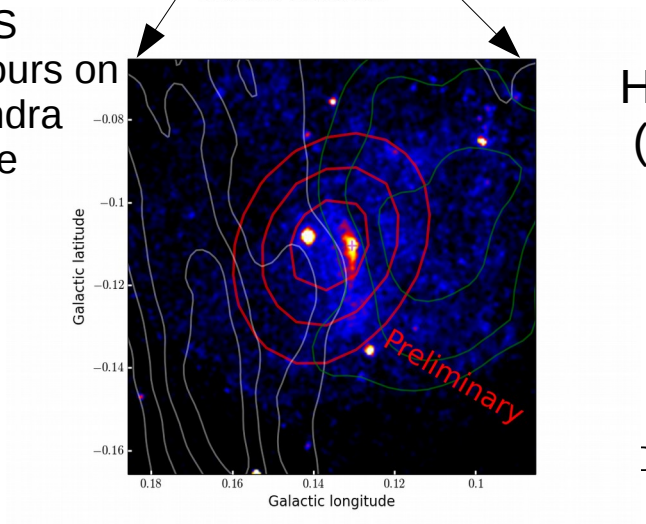
s@physik.uni-hamburg.d

Galactic center: arch!





HESS contours on Chandra image



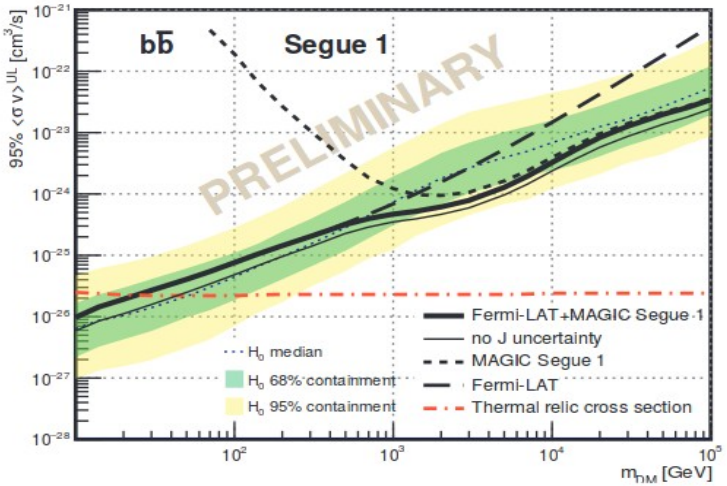
H.E.S.S.
(Lemière et al. 2015)

VERITAS, E>2 TeV
(Smith et al. 2015)

Dieter.Horns@physik.uni-hamburg.de

Dark matter searches

- No detection – but limits are improving
- New combinations: Fermi-LAT combined with MAGIC



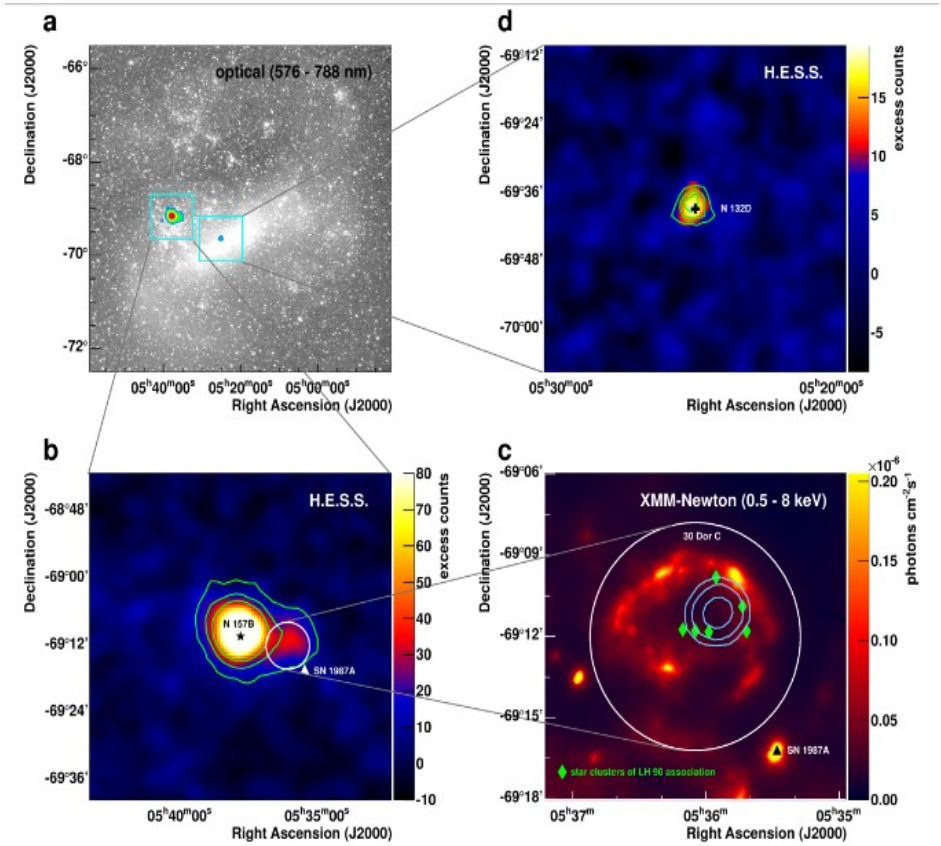
Rico et al. 2015

- Main targets:
  - Inner Galaxy (halo)
  - Dwarf galaxies (including newly identified obj.)
  - Dark halo objects (unid. Fermi-LAT sources)

Large Magellanic cloud

HESS coll.
Science 2015

- PWN N157B
  Crab-like (lower B-field)
- 30 Dor C
  Superbubble
- N 132 D
  SNR
- But:
  no detection from SN1987A

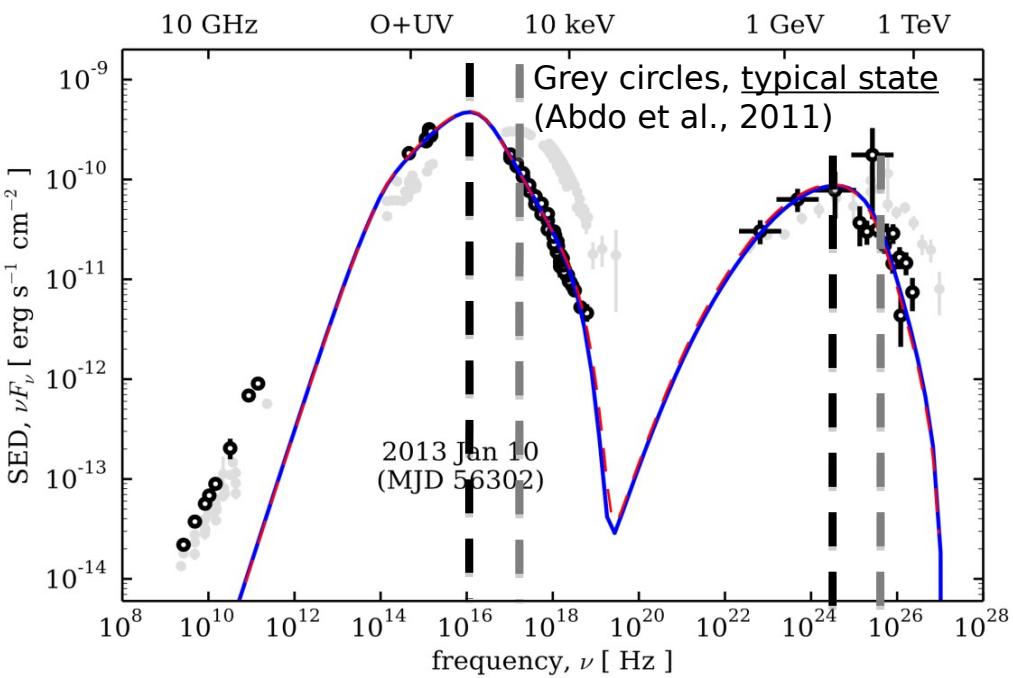


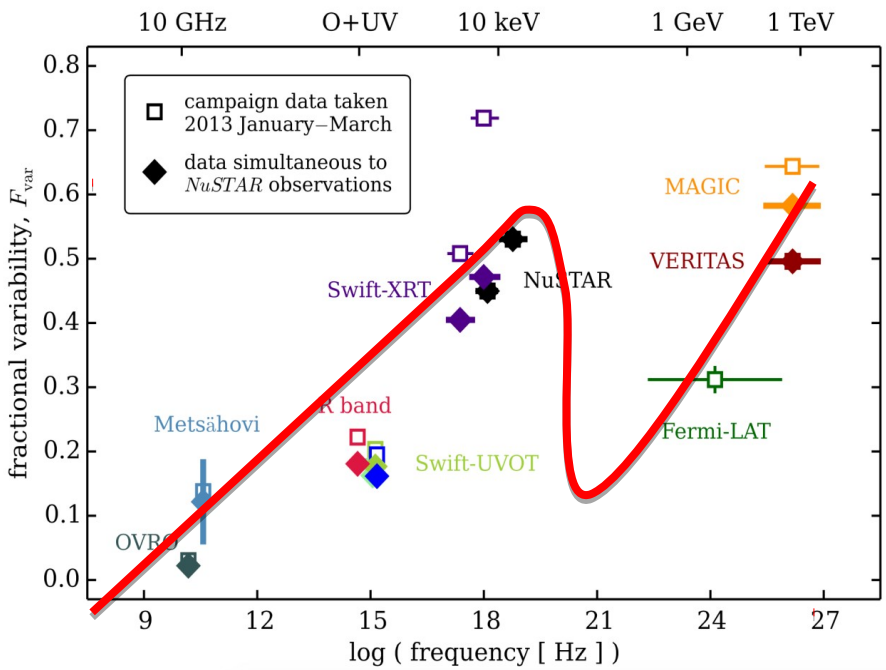
Dieter.Horns@physik.uni-hamburg.de

Other Galaxies: AGN

- Common understanding (Synchrotron/IC):

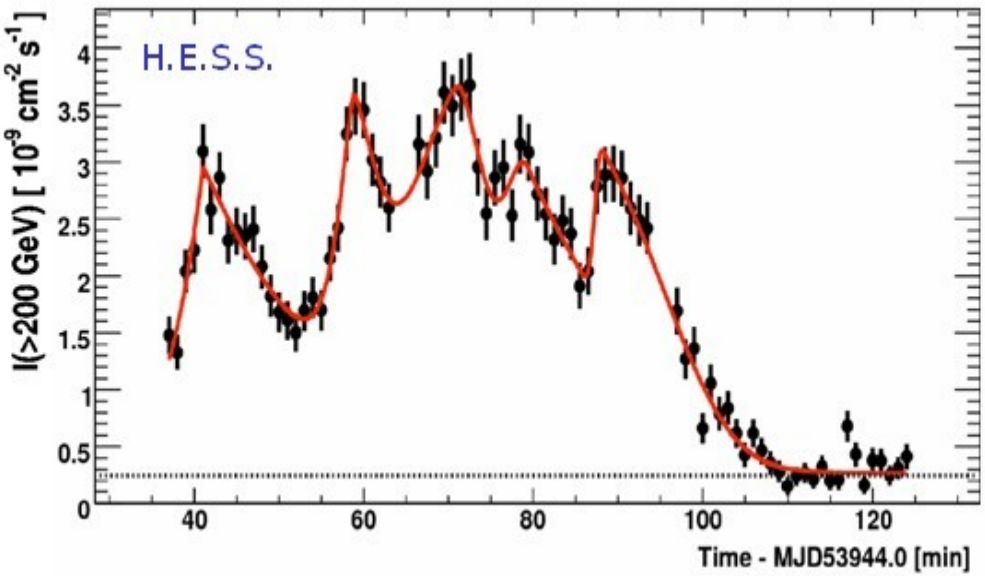
  Gamma-rays from accelerated electrons in relativistic outflows

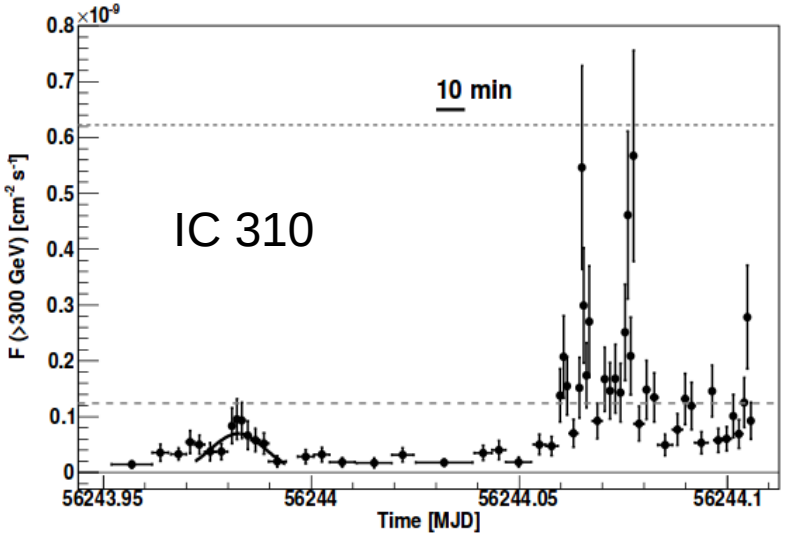




(at least) two surprises

- Variability time scale too short ($t_{var} < r_s/c$) for supermassive black holes
- PKS 2155-304 ($M \sim 10^9\ M_{sun}$ but t_{var}=2') (HESS coll. 2009)
- IC 310 (MAGIC coll. 2014), no beaming, but t_{var}<4'



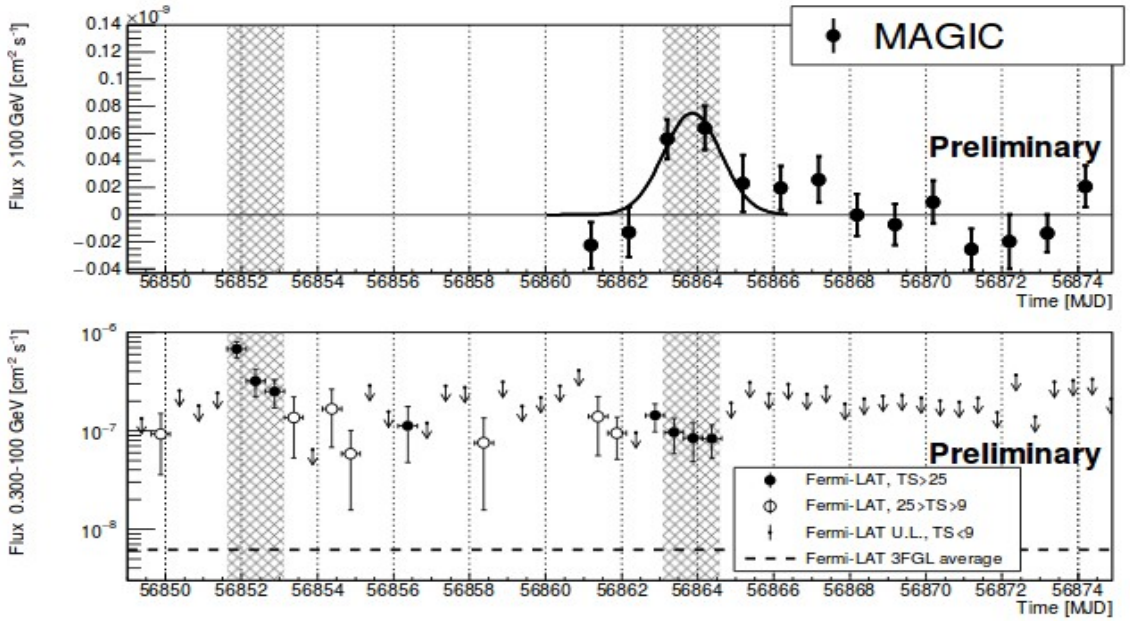


Closer look with Grav. lenses

Vovk&Neronov 2015

- Discovery of gamma-ray emission from B0218+357 with MAGIC (Sitarek et al. 2015)
- Delayed signal from grav. Lensing. Variable ratios?
- Observation of micro-lensing would constrain the size of the emission region to be ~10^{15} cm and its velocity to be sub-luminal..

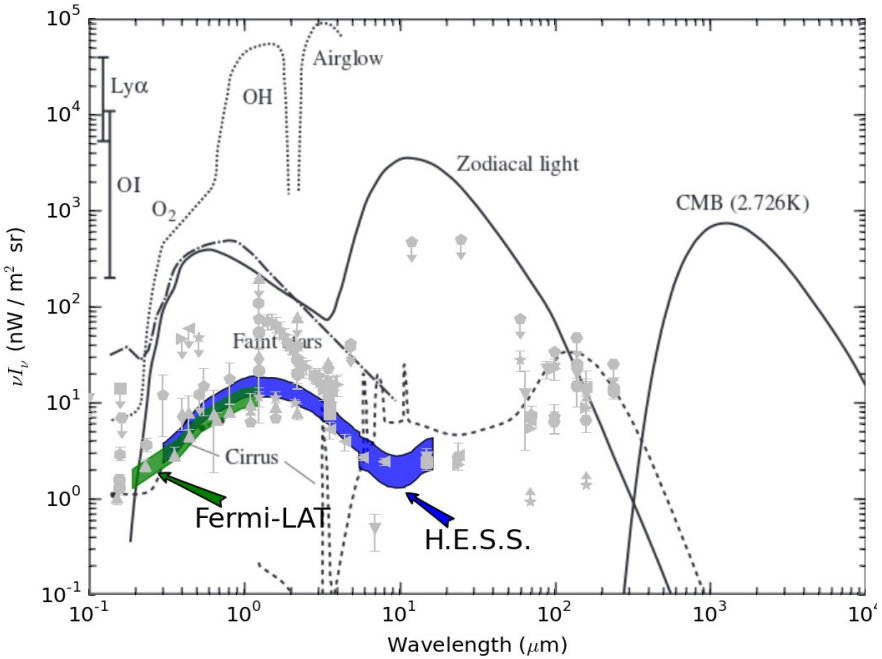
B0218+357
Z=0.944
Lens at z=0.684
Delay of 11d



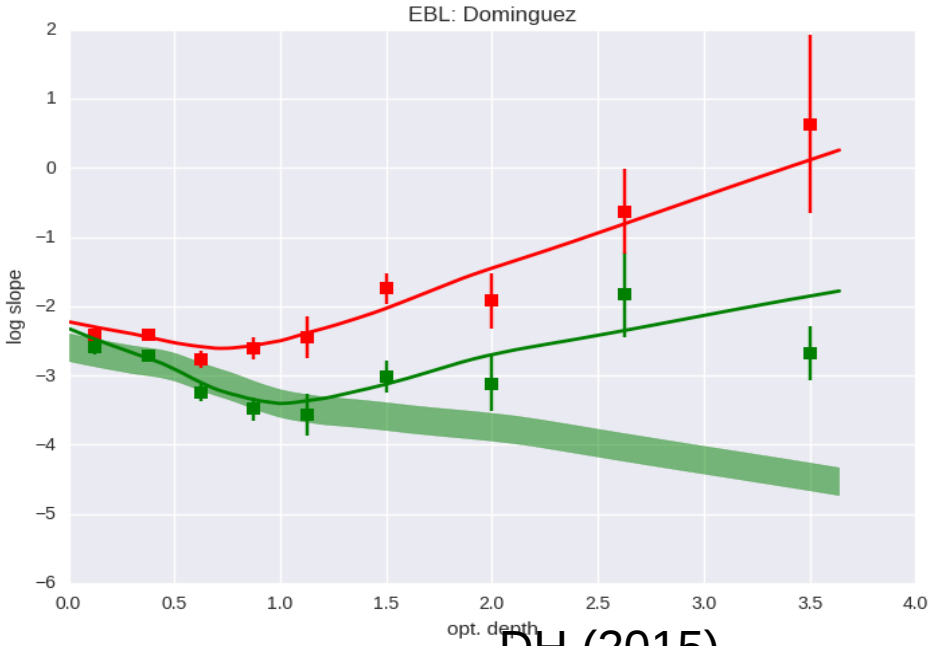
Diet

More surprises?

- Absorption of gamma-rays due to pair-production on the extra-galactic background light (EBL) – however spectra are hardening?



DH&Jacholkowska (2015)

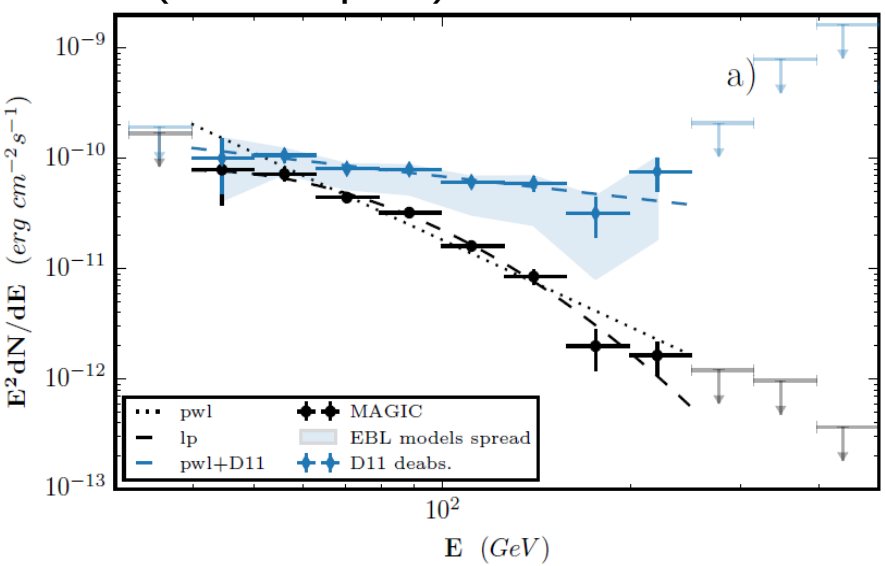


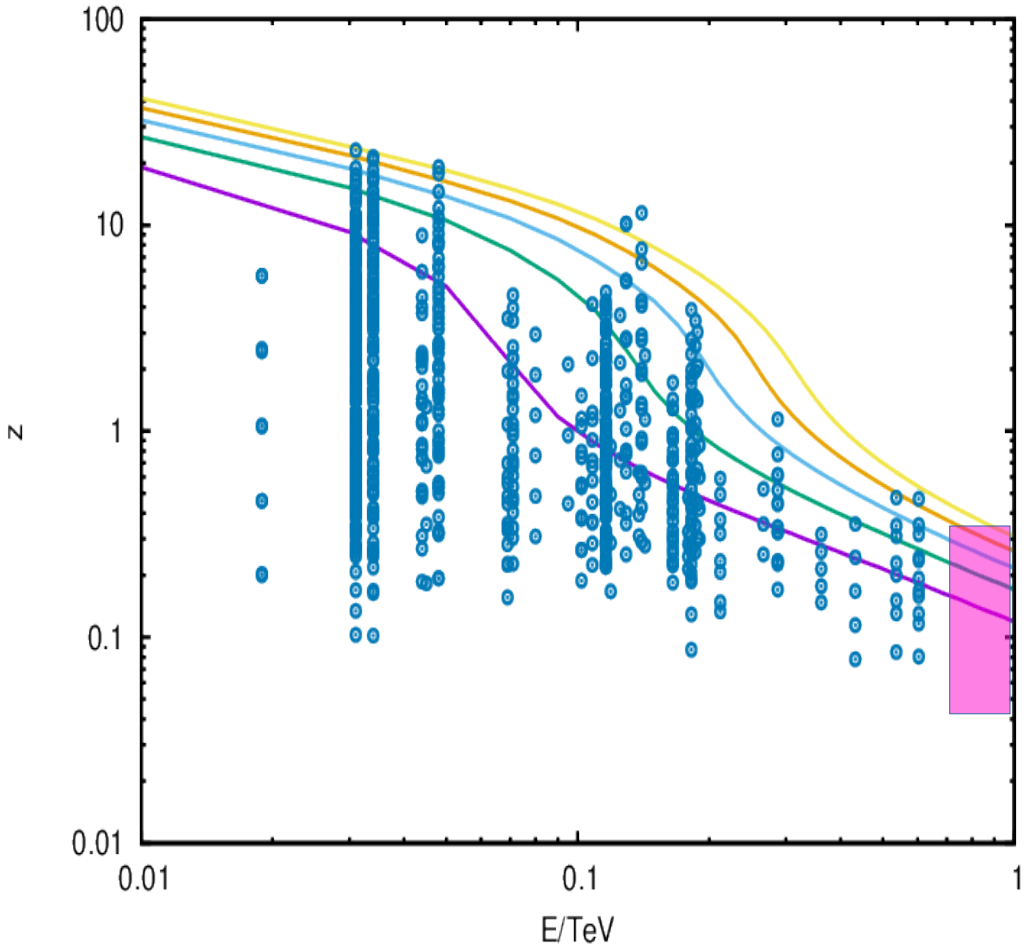
DH (2015)

Pushing the red-shift barrier…

New sources discovered:
PKS 1441+25 (z=0.939)
(MAGIC and VERITAS)
B0218+357 (z=0.944)
(MAGIC 2015)

PKS 1441+25 (z=0.939)
(MAGIC prel.)





s@physik.uni-hamburg.de

Searching for Lorentz-invariance breaking

- Dispersion relation of Photons modified:

$$E^2 \simeq p^2 c^2 \times \left[1 - \sum s_{\pm} \left(\frac{E}{E_{\mathrm{QG}}}\right)^n\right]$$

- Energy/distance dependent delay + modified absorption (shift of threshold)

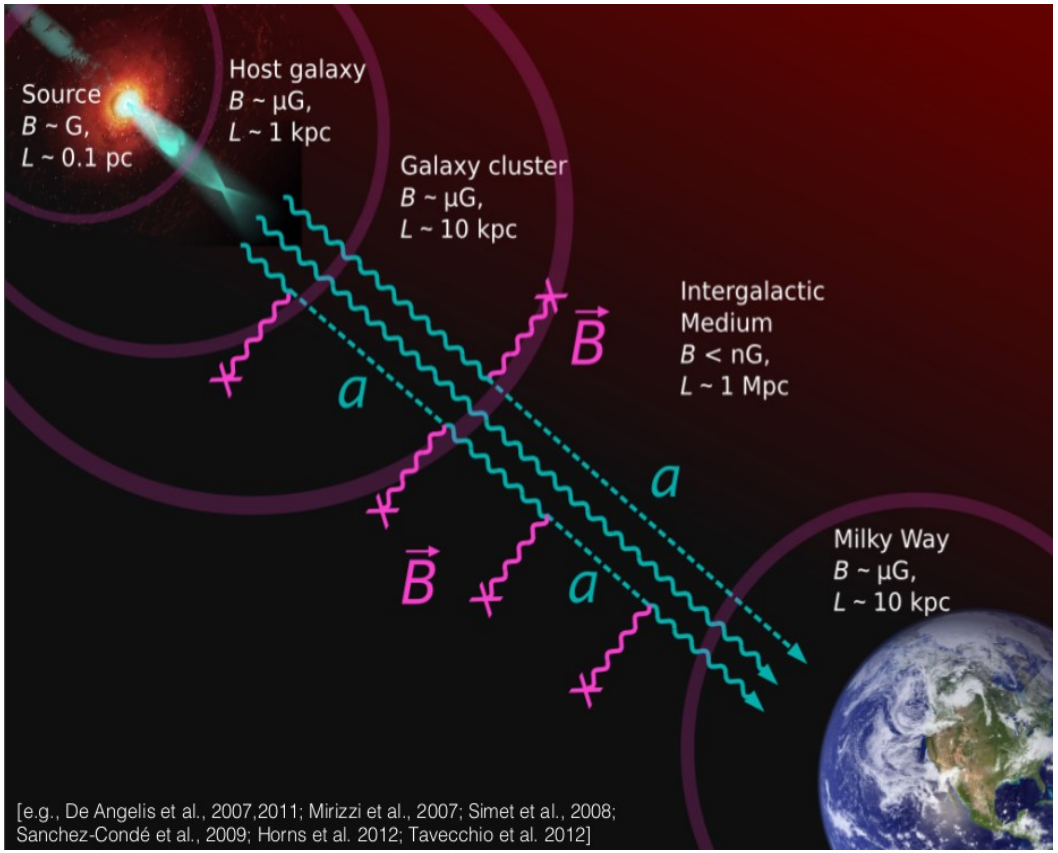
Property	GRBs	AGNs	Pulsars
Redshift	< 8.2	< 0.8	0
Energy range	< 100 GeV	< 10 TeV	< 300 GeV
Relevant time scales	10-100 msec	1-10 min	10 msec
Intrinsic effects	known	moderate	under control
Best results	GRB 090510 (Fermi)	PKS 2155-304 (H.E.S.S.)	CRAB (VERITAS)

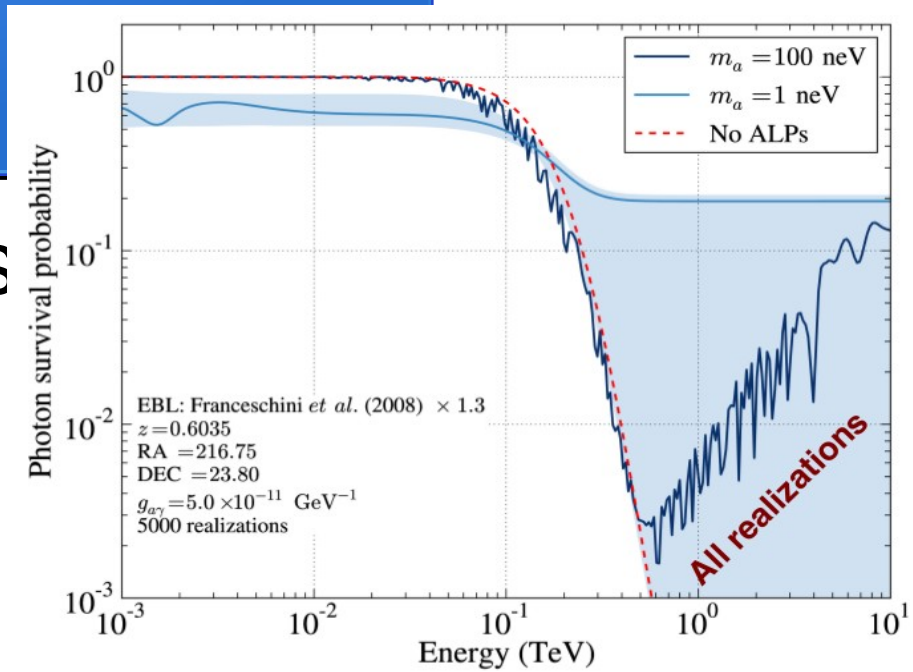
DH&Jacholkowska (2015)

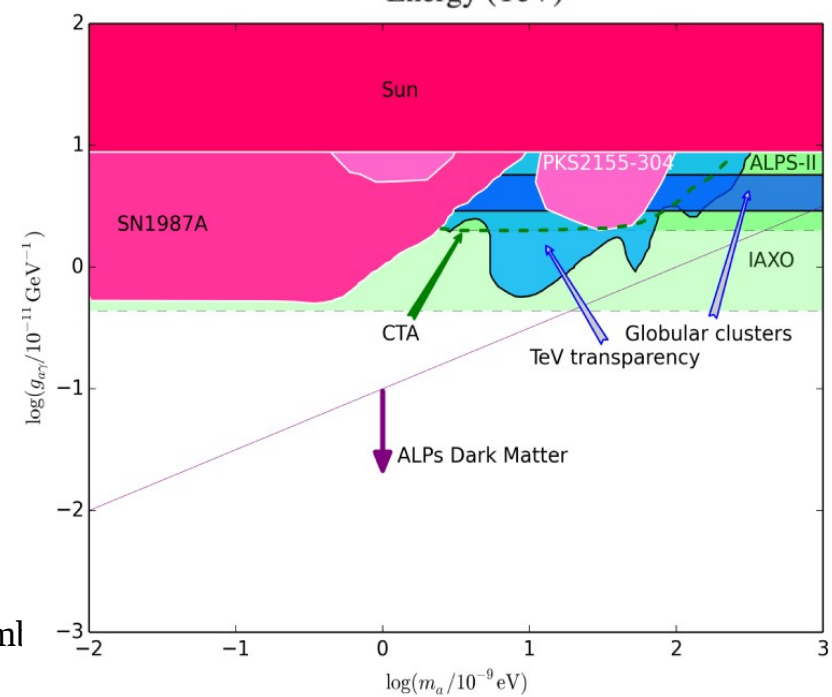
Searching for light pseudoscalars (Axion-like particles)

Montanino
Tue PS

- Spectroscopic signatures



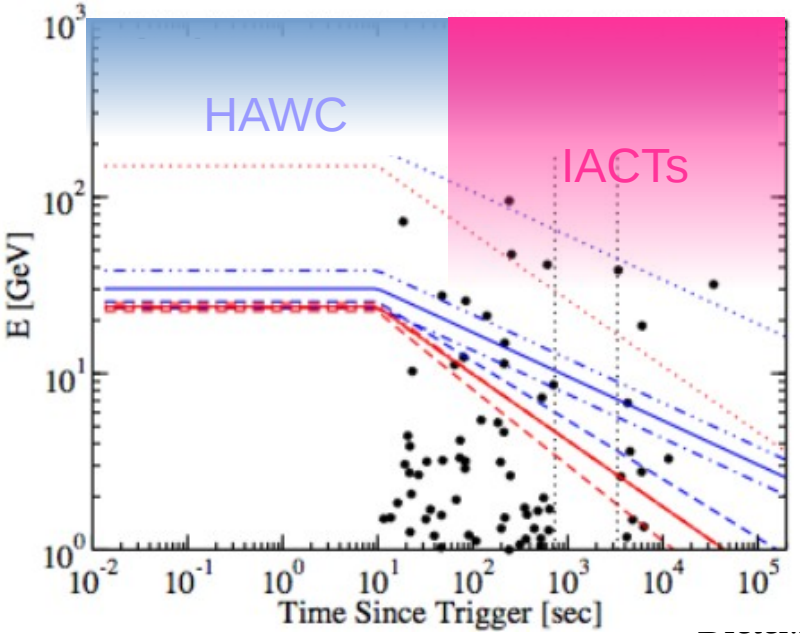


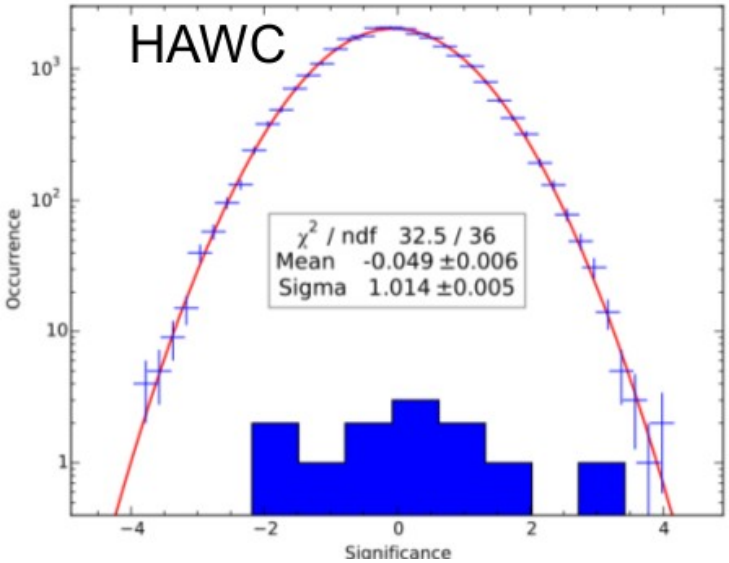


Dieter.Horns@physik.uni-haml

Gamma-ray bursts

- Not detected, yet
- Just wait a little bit, either HAWC or fast response IACTs (MAGIC, HESS II) will detect them





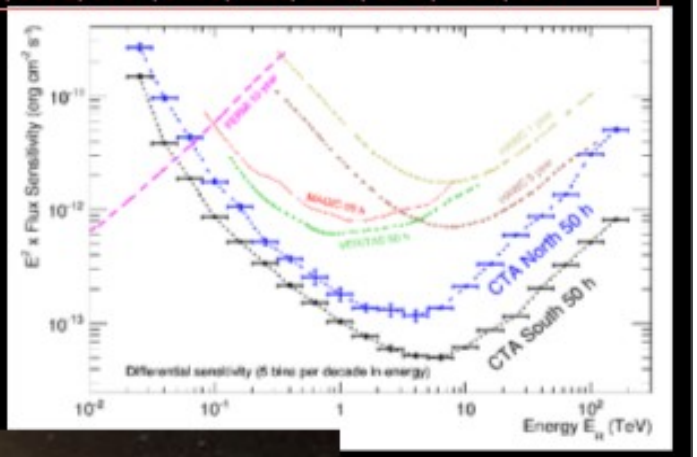
New instruments: CTA

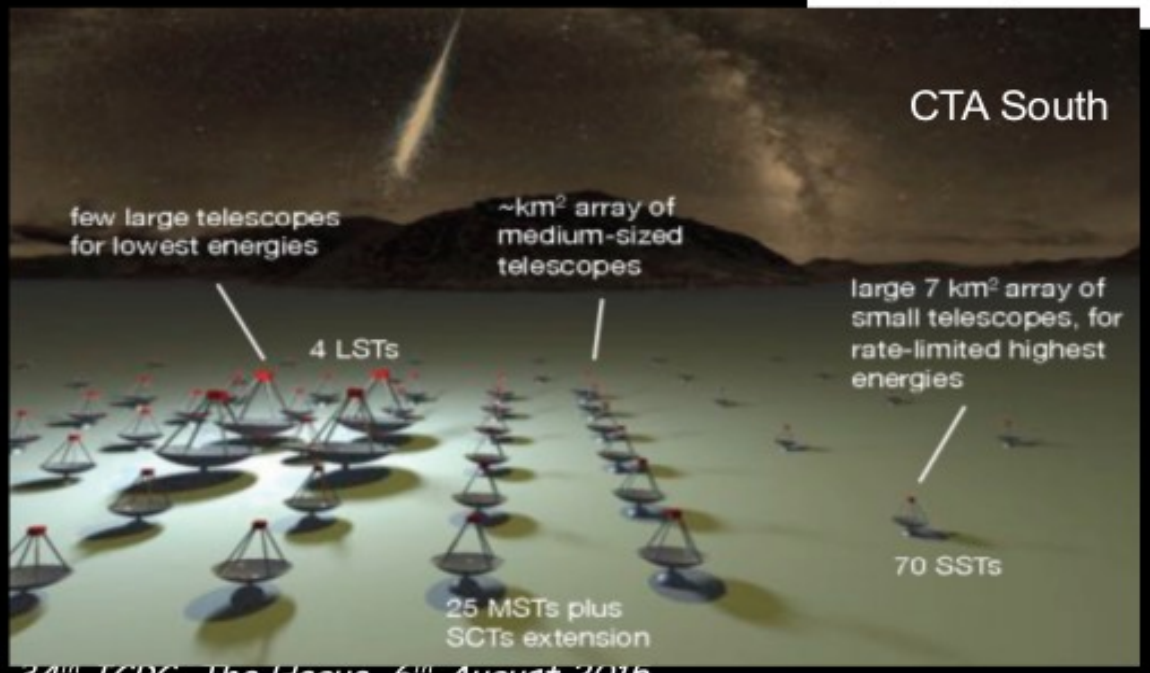
Lindfors
Thursday
Bonnoli, Pareschi
(ASTRI)
Thursday

The Cherenkov Telescope Array (CTA)

46, 47, 58, 61, 62, 63, 65, 78, 83, 202, 204, 209, 210, 236, 249, 252, 264, 265, 274, 276, 294, 305, 318, 329, 370, 372, 395, 424, 465, 469, 506, 556, 603, 605, 610, 629, 665, 673, 674, 684, 699, 723, 736, 773, 824, 862, 882, 900, 954, 965, 1052, 1057, 1058, 1101, 1179, 1319, 1324, 1397

- > 1200 members
  - 194 Institutes from 31 countries
- 2 sites selected:
  - North (La Palma, Spain)
  - South (Paranal, Chile)
- Initial construction could start in 2016
- Early science: towards the end of the decade

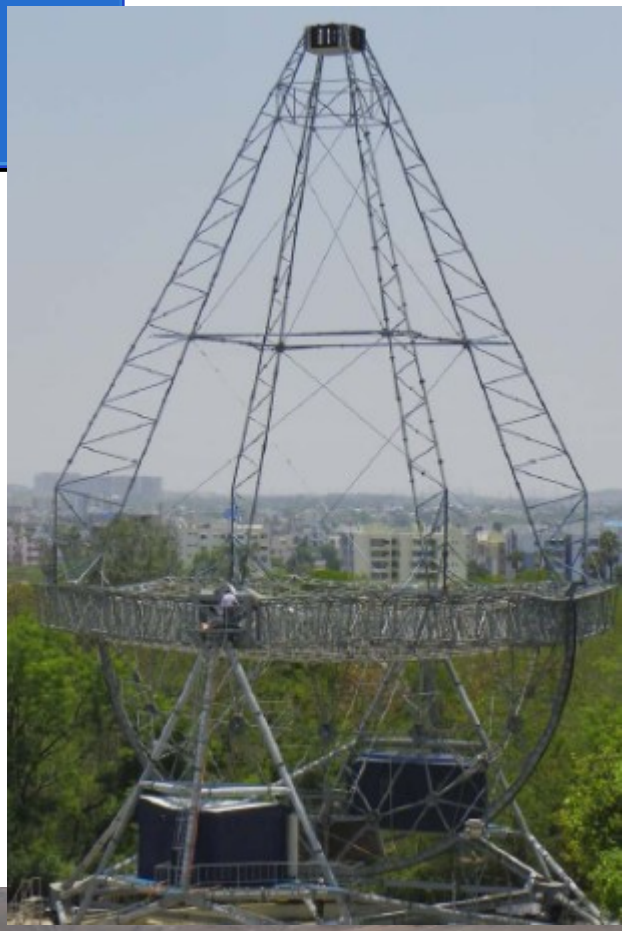




M. Lemoine-Goumard, 34th ICRC, The Hague, 6th August 2015

Towards lower energies MACE

Thursday
Achaya

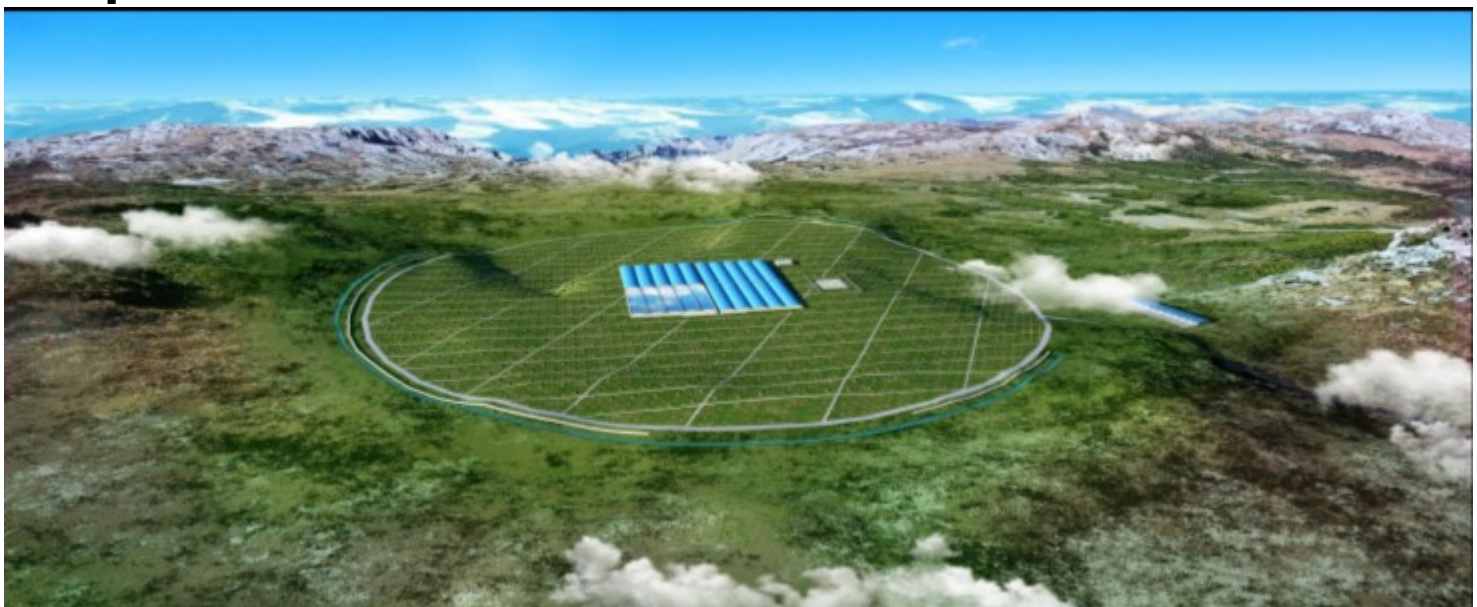


- High altitude air Cherenkov detection (Hanle site)
- Non-imaging (HAGAR)
- Imaging (MACE)

Towards higher energies: LHAASO

Silvia Vernetto
Monday
Parallel session

- Air shower array 1 km^2
- 75 000 m^2 of Water Cherenkov Detector array
- 12 Wide field imaging air Cherenkov telescopes

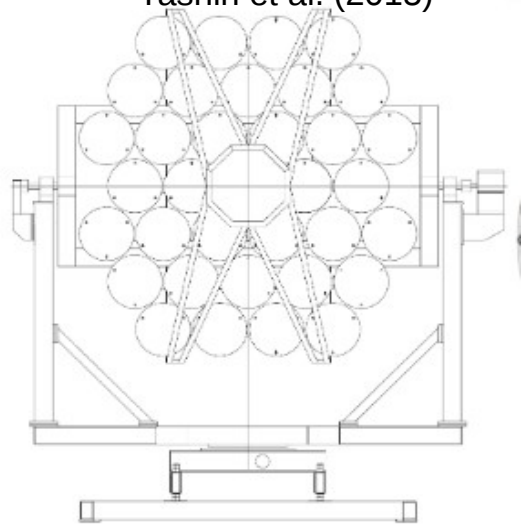


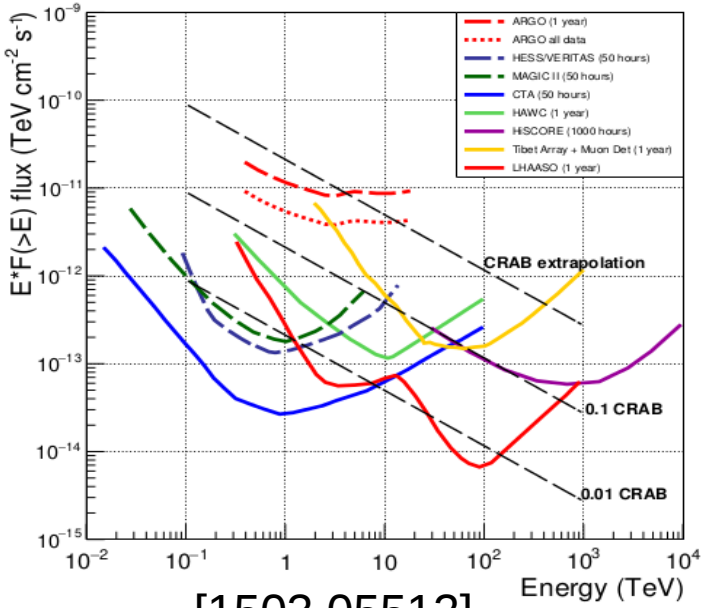
Towards Higher energies: TAIGA

Parallel
Session Thursday
Budnev

- Non-imaging air Cherenkov detector field (currently ~0.5 km^2), upgradable to ~5 km^2
- Planned upgrade: imaging air Cherenkov telescopes with 8° f.o.v.

Yashin et al. (2015)





[1503.05512]

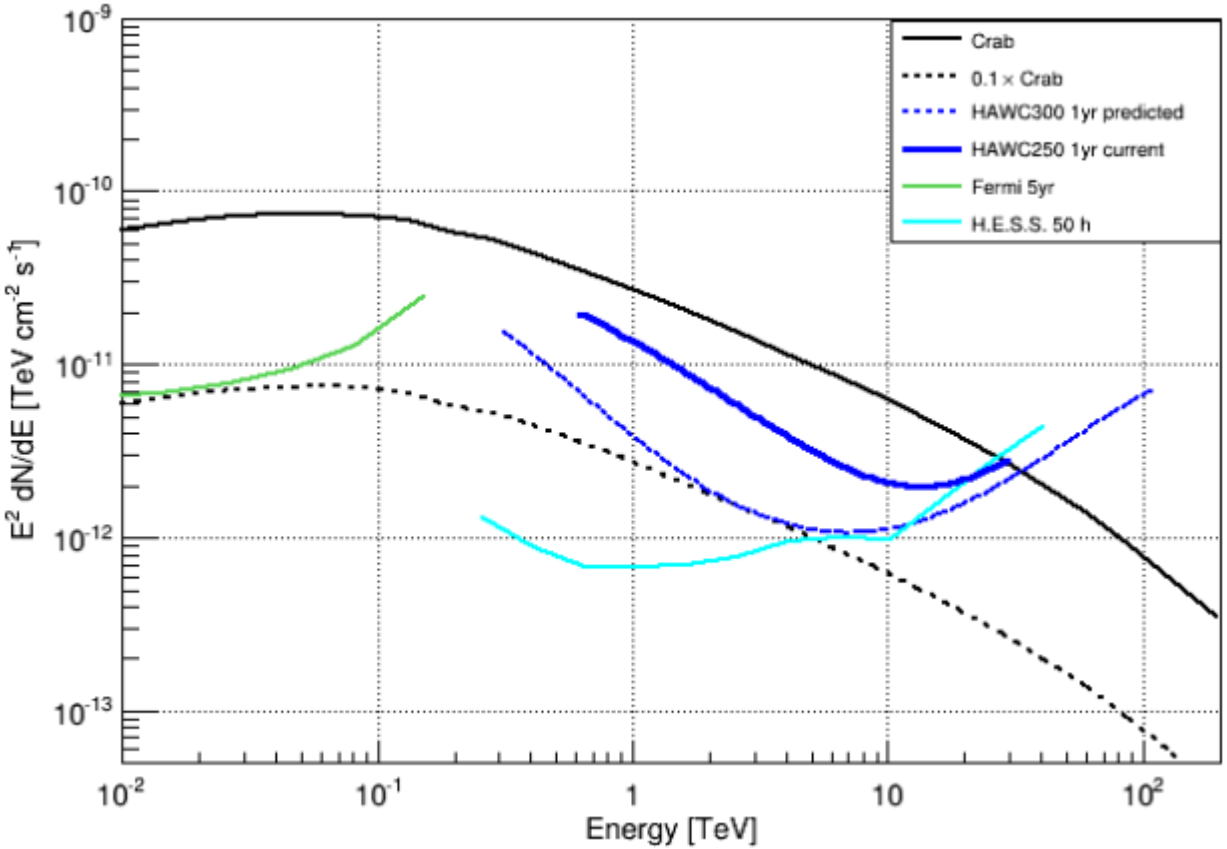
Dieter.Horns@physik.uni-hamburg.de

Perspectives

- Gamma-ray astronomy – rich phenomenology of cosmic-ray accelerators
- Fundamental sciences – unique sensitivity to propagation effects and massive self-annihilating dark matter
- Impact on low-energy astrophysics: constraining star formation
- Extreme acceleration in relativistic environment

End of presentation

Dieter.Horns@physik.uni-hamburg.de



Dieter.Horns@physik.uni-hamburg.de