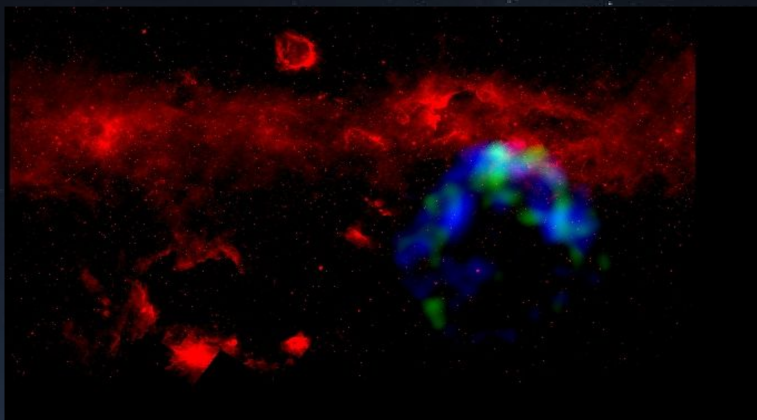
The Cherenkov Telescope Array : Status & its Linkages

Gavin Rowell Uni. Adelaide (for CTA)



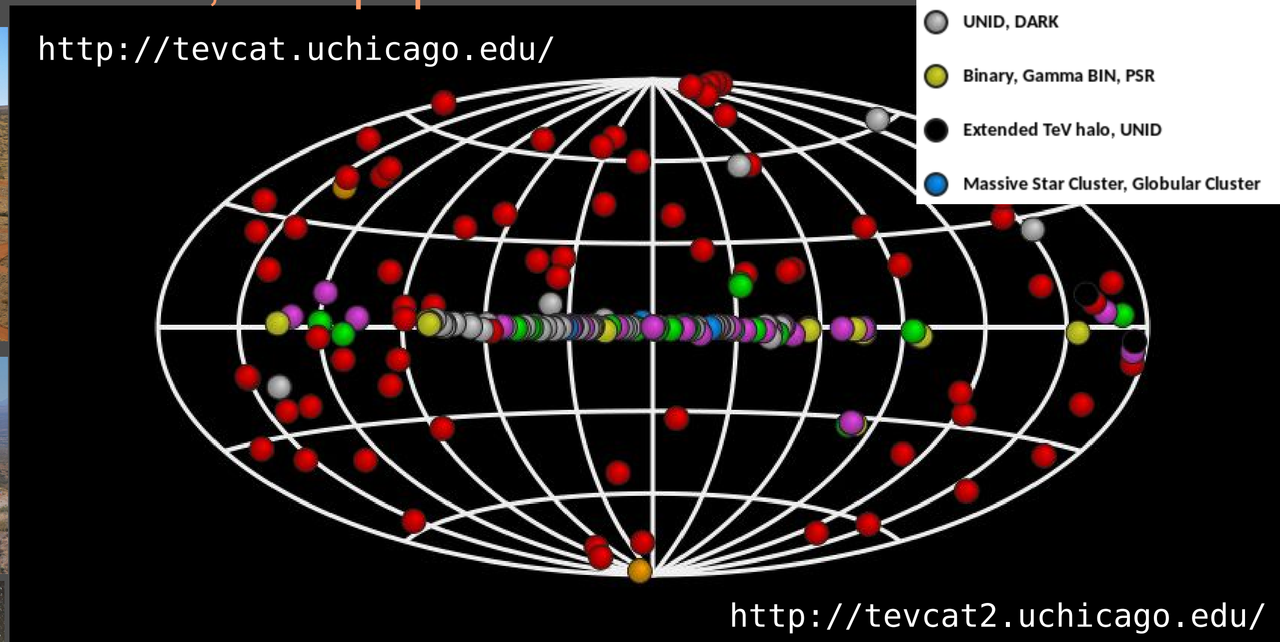
cta
cherenkov telescope array

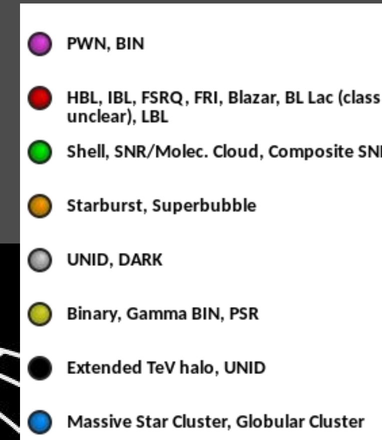
CTA-Oz Workshop #6 (Monash Uni.) Apr. 2018

Gamma-rays (~30 GeV to ~500TeV)

Ground-based detection of Cherenkov emission

High impact > 20 Nature, Science, PRL papers since 2004



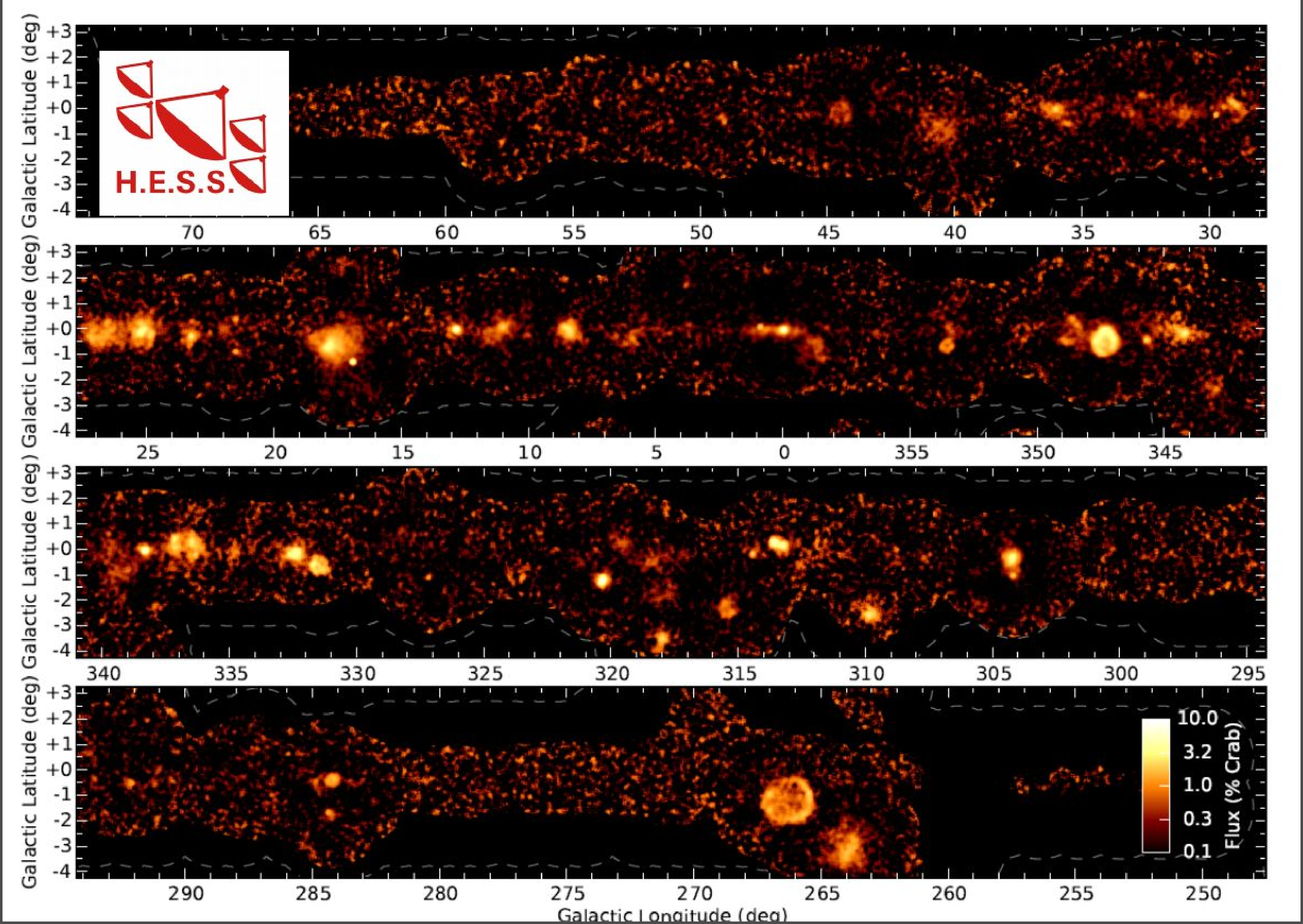


Great success with HESS, VERITAS, MAGIC, HAWC, building on the pioneering efforts of Whipple, HEGRA, CAT, MILAGRO....

HESS Galactic Plane Survey (HGPS)

→ 78 sources (13 new sources)

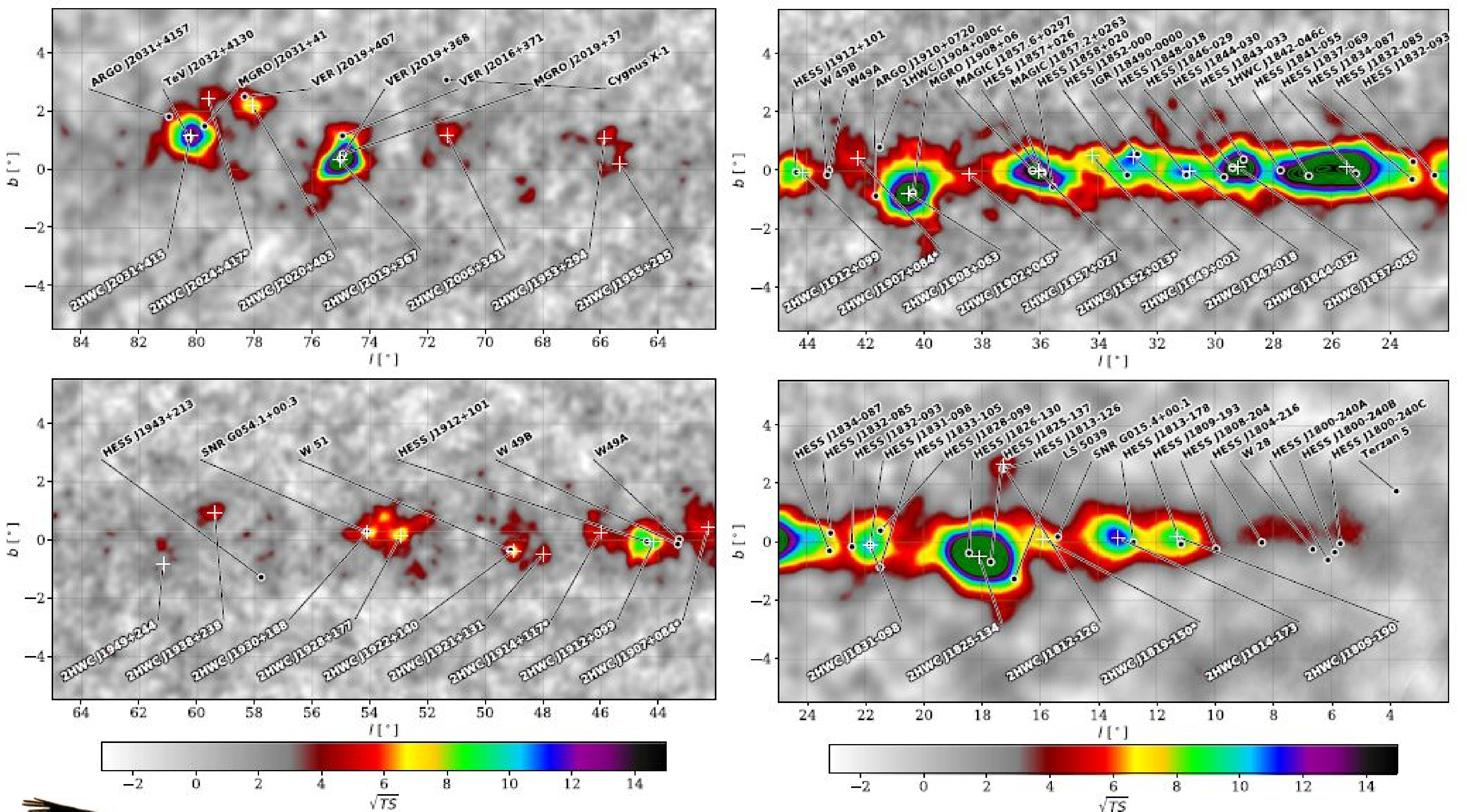
Deil et al 2015, HESS 2017



HAWC Galactic Plane Survey (2HWC)

→ 39 sources (17 new sources)

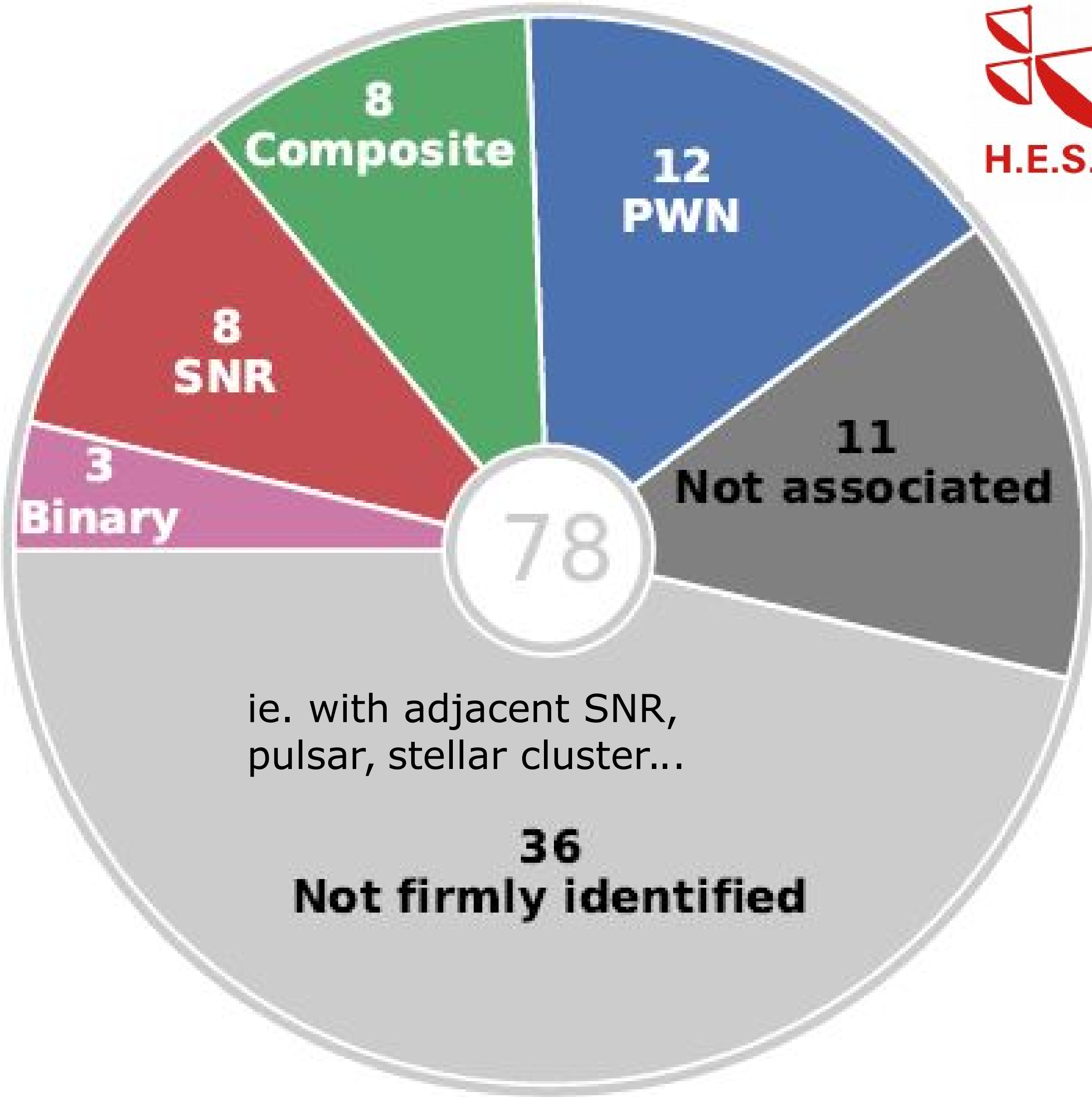
Abeysekara etal (HAWC) 2017



Some new sources with no <10 TeV counterparts

→ Very hard spectra?

→ PeVatrons?


8
Composite
12
PWN
8
SNR
3
Binary
11
Not associated
78
ie. with adjacent SNR,
pulsar, stellar cluster...
36
Not firmly identified

TeVCat v2 Extragalactic Sources

http://tevcat2.uchicago.edu/

RegExp Search

× XGal

Filter by Observer

AND

AND

Sync To Map | Filter Selected

Reset | Table Columns

Name	RA	Dec	Type Tags	Distance	Catalog	Seen By?
S3 0218+35	02 21 05.5	+35 56 14	XGal,AGN,Blzr,F...	z=0.954	Default Catalog	MAGIC
3C 279	12 56 11.1	-05 47 22	XGal,AGN,Blzr,F...	z=0.5362	Default Catalog	MAGIC
PG 1553+113	15 55 44.7	+11 11 41	XGal,AGN,Blzr,B...	z=0.5	Default Catalog	VERITAS,MAGIC,...
1ES 0033+595	00 35 16.8	+59 47 24.0	XGal,AGN,Blzr,B...	z=0.467	Default Catalog	MAGIC
1ES 0647+250	06 50 46.5	+25 03 00	XGal,AGN,Blzr,B...	z=0.45	Newly Announced	VERITAS,MAGIC
4C +21.35	12 24 54.4	+21 22 46	XGal,AGN,Blzr,F...	z=0.432	Default Catalog	VERITAS,MAGIC
PKS 1510-089	15 12 52.2	-09 06 21.6	XGal,AGN,Blzr,F...	z=0.361	Default Catalog	MAGIC,H.E.S.S.
PKS 0447-439	04 49 28.2	-43 50 12	XGal,AGN,Blzr,B...	z=0.343	Default Catalog	H.E.S.S.
3C 66A	02 22 41.6	+43 02 35.5	XGal,AGN,Blzr,B...	z=0.34	Default Catalog	Crimea,VERITAS
1ES 0502+675	05 07 56.2	+67 37 24	XGal,AGN,Blzr,B...	z=0.340	Newly Announced	VERITAS
OT 081	17 51 32.82	+09 39 00.73	XGal,Blzr,BLLac,...	z=0.322	Newly Announced	MAGIC
S5 0716+714	07 21 53.4	+71 20 36	XGal,AGN,Blzr,B...	z=0.31	Default Catalog	MAGIC
1ES 0414+009	04 16 52.96	+01 05 20.4	XGal,AGN,Blzr,B...	z=0.287	Default Catalog	VERITAS,H.E.S.S.
PKS 0301-243	03 03 23.49	-24 07 35.86	XGal,AGN,Blzr,B...	z=0.2657	Default Catalog	H.E.S.S.
S2 0109+22	01 12 05.8	+22 44 39	XGal,AGN,Blzr,IBL	z=0.265	Newly Announced	MAGIC
1RXS J023832.6-311658	02 38 32.5	-31 16 58	XGal,Blzr,BLLac,...	z=0.232	Newly Announced	H.E.S.S.
MS 1221.8+2452	12 24 24.2	+24 36 24	XGal,AGN,Blzr,B...	z=0.218	Newly Announced	MAGIC
1ES 1011+496	10 15 04.1	+49 26 01	XGal,AGN,Blzr,B...	z=0.212	Default Catalog	VERITAS,MAGIC
RBS 0723	08 47 12.9	+11 33 50	XGal,AGN,Blzr,B...	z=0.198	Newly Announced	MAGIC
RBS 0413	03 19 47	+18 45 42	XGal,AGN,Blzr,B...	z=0.19	Default Catalog	VERITAS
PKS 0736+017	07 39 18.0	+01 37 05	XGal,Blzr,FSRQ	z=0.18941	Newly Announced	H.E.S.S.
1ES 0347-121	03 49 23.0	-11 58 38	XGal,AGN,Blzr,B...	z=0.188	Default Catalog	H.E.S.S.
1ES 1101-232	11 03 36.5	-23 29 45	XGal,AGN,Blzr,B...	z=0.186	Default Catalog	H.E.S.S.

Sources Listed: 74

Gamma-rays (GeV to TeV Energies)

- **Gamma rays: Highly effective tracer of particle acceleration**
- **Many TeV gamma-ray source types + astro/particle physics impact**

  - ***Supernova remnants***
  - ***Pulsars & pulsar-wind nebulae***
  - ***Compact binaries, stellar black holes, transients***
  - ***Galactic centre region***
  - ***Massive stellar clusters and star formation regions***
  - ***PeVatrons → our galaxy's extreme accelerators***
  - ***Relativistic outflows; stellar winds; wind interactions***
  - ***Formation of molecular gas; ISM; magnetic fields***
  - ***Unidentified & Dark TeV sources***
  - ***Active Galaxy Cores – super-massive black holes***
  - ***Star-burst galaxies***
  - ***Globular clusters***
  - ***Constraints on extragal. IR background → cosmology***
  - ***Indirect search for dark matter, quantum gravity (Lorentz invariance), axions***
  - ***Cosmic ray electrons***

The Cherenkov Telescope Array

- Next generation gamma-ray observatory
- Huge improvement in all aspects of performance
  - x10 better sensitivity, better FoV + angular resolution, wider energy coverage, collection area >few km^2, wider survey capabilities
- User facility / proposal-driven observatory
  - CTA Consortium time (Key Science Projects) to lead off
- An international project ~ €300M capital cost
  - Involves >90% of current TeV gamma-ray scientists + many others
- EU ESFRI ranked project
- EU ASTERICS (CTA, SKA, E-ELT, KM3Net)

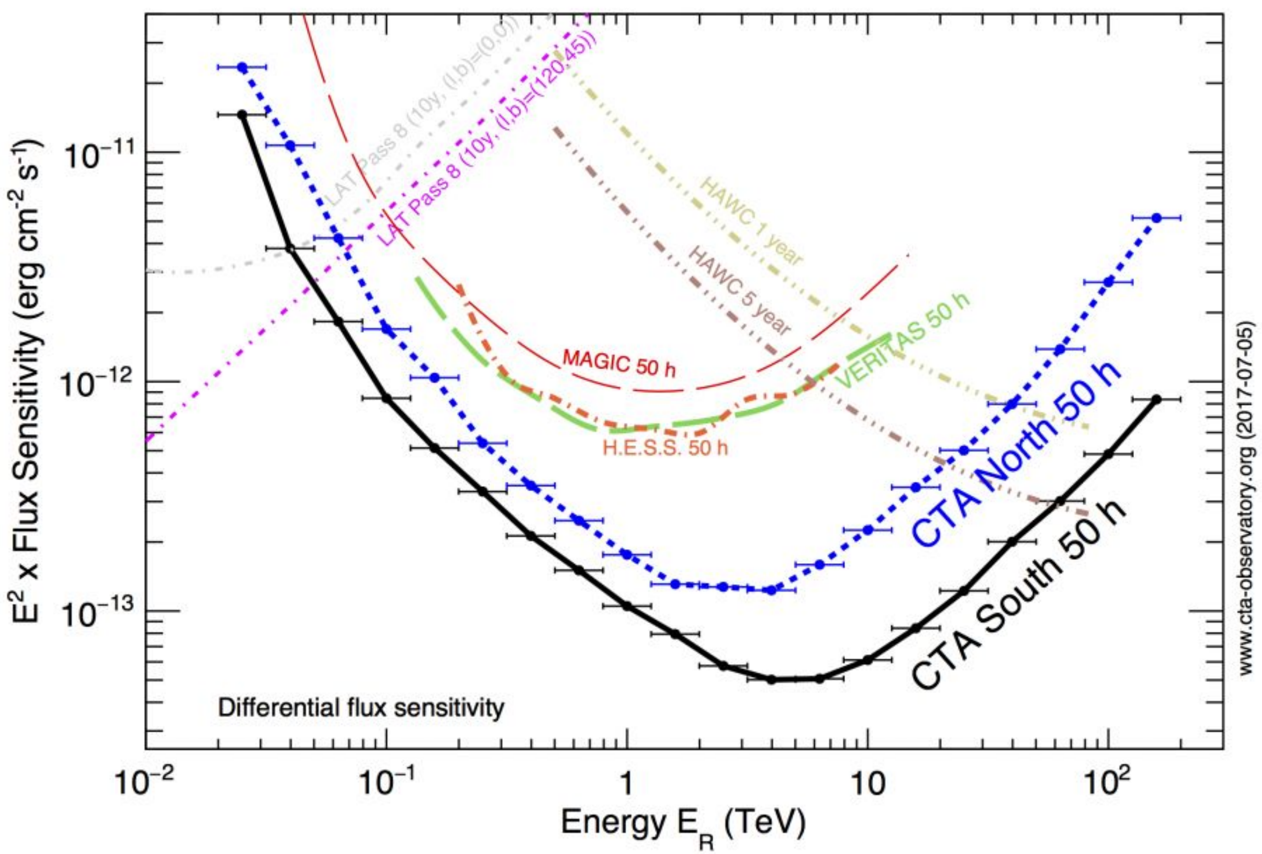
© G. Pérez, IAC (SMM)

https://www.cta-observatory.org

CTA Performance

Energy coverage ~20 GeV to >200 TeV

Differential Sensitivity



A factor of 5-10 improvement in sensitivity in the domain of about 100 GeV to some 10 TeV.

Extension of the accessible energy range from well below 100 GeV to above 100 TeV.

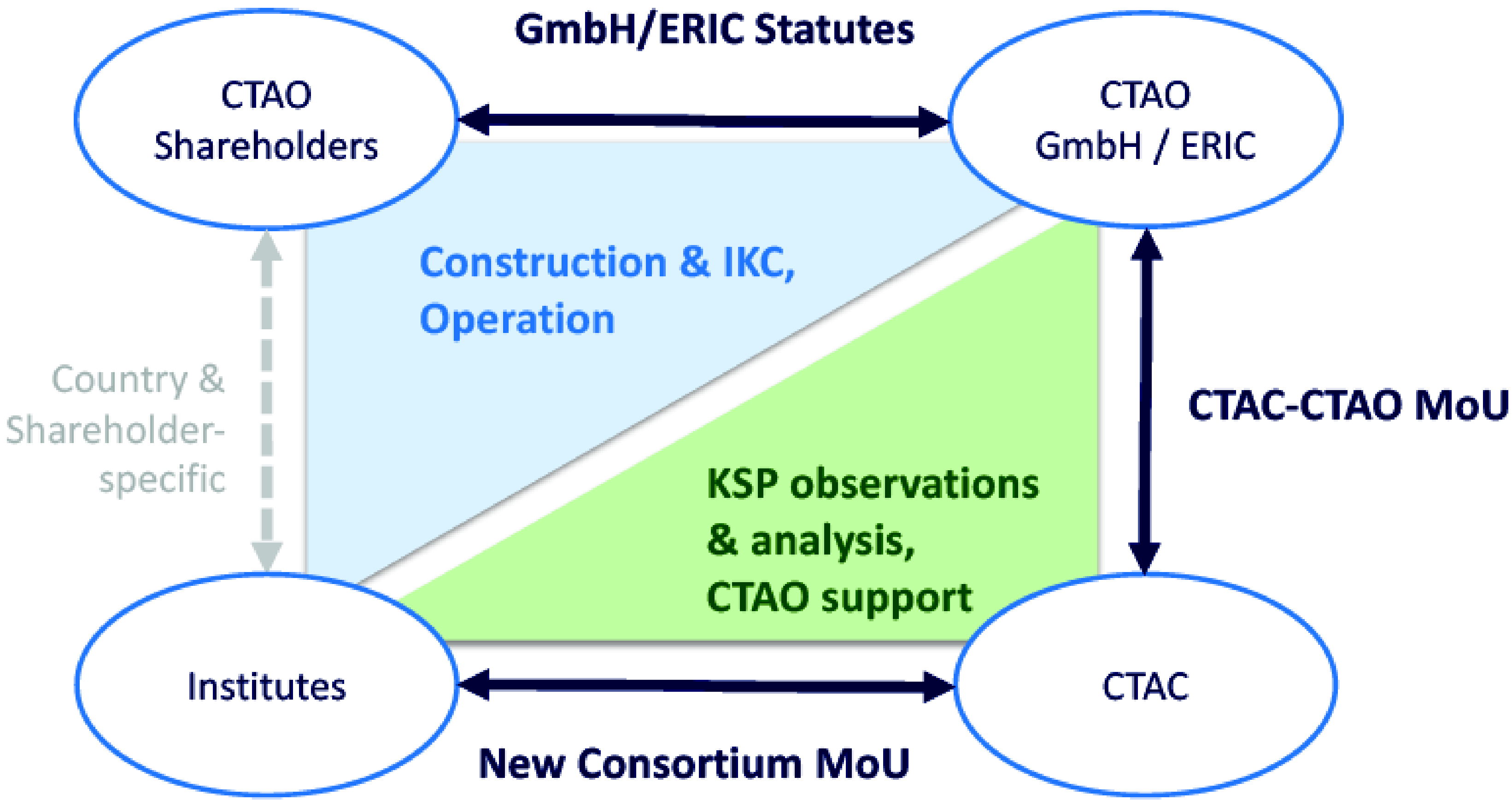
Credits: The CTA Consortium

CTA Consortium (CTAC)

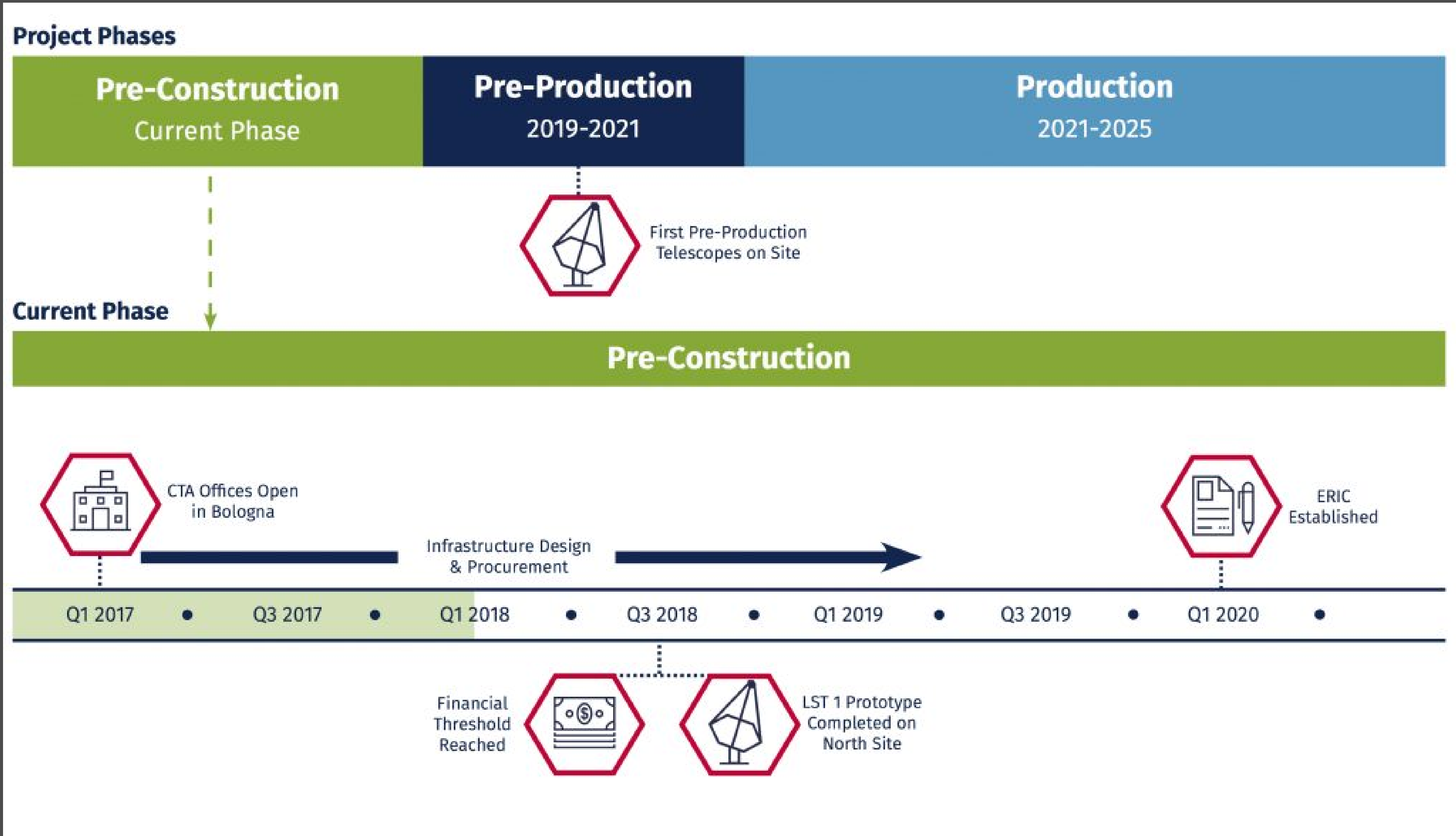
Apr. 2018

32 countries
94 parties
210 institutes
1420 members (484 FTE)

Consortium Organisation: CTA Consortium MoU

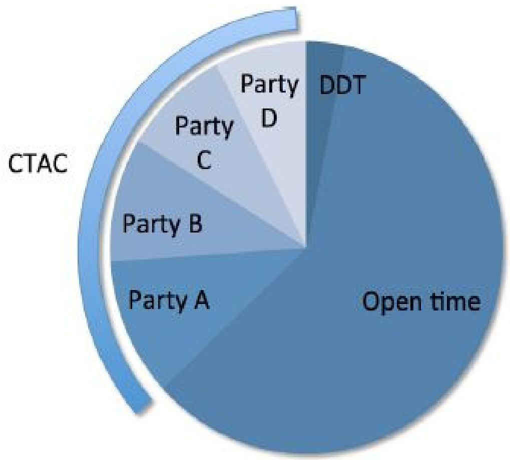


CTA Timeline (early 2018 status)



Science operations from ~2021/22 (90% of all telescopes)

CTA observing time



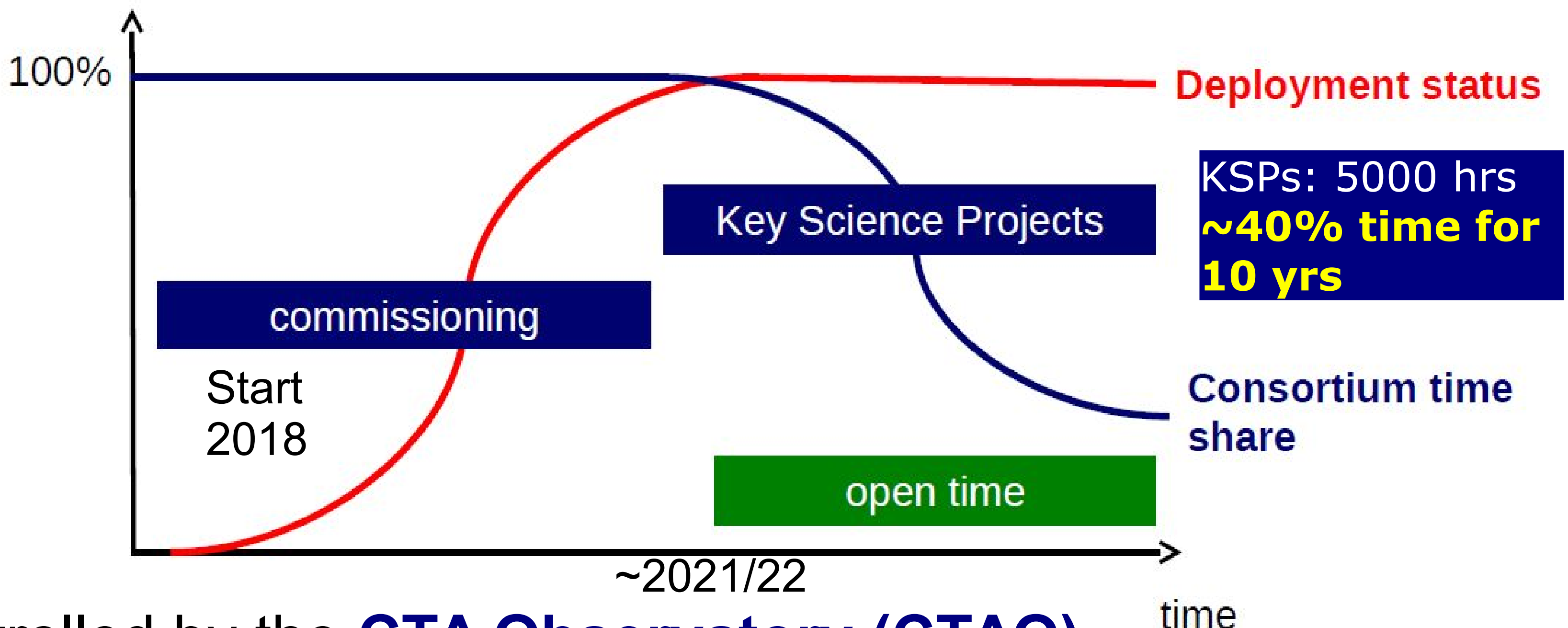
Current model

Contributing parties pool their time:

- Open time (accessible to scientists in contributing countries)
- CTA Consortium time (legacy Key Science Projects)
- Director's Discretionary Time

All data will become public to worldwide community after some proprietary period

(cf. C. Boisson)



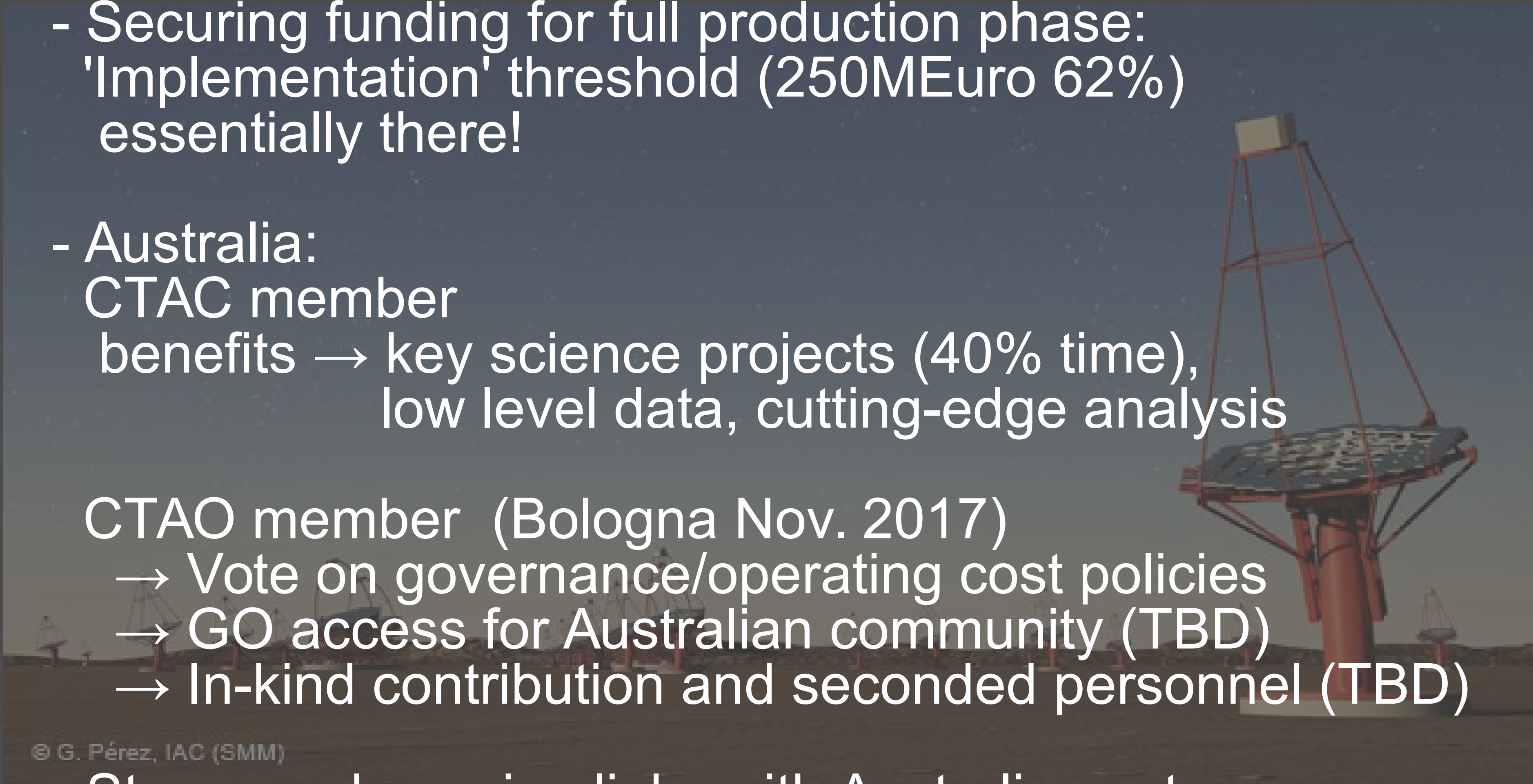
Controlled by the **CTA Observatory (CTAO)**

CTA Sites


Zeuthen
DESY
CTA Science Data
Management Centre
Spain
La Palma
CTA-North
Bologna
INAF
CTA HQ
northern hemisphere
southern hemisphere
Chile
Paranal
CTA-South
La Palma Map: ©2015 Google, Inst. Geogr. Nacional
Paranal Map: ©2015 Google
Array Sites
Headquarters
Science Data Management Centre

Status (Apr. 2018)

- Most prototypes running (in part):



- Securing funding for full production phase:
  'Implementation' threshold (250MEuro 62%)
  essentially there!

- Australia:
  CTAC member
  benefits → key science projects (40% time),
  low level data, cutting-edge analysis

  CTAO member (Bologna Nov. 2017)
  → Vote on governance/operating cost policies
  → GO access for Australian community (TBD)
  → In-kind contribution and seconded personnel (TBD)

- Strong and growing links with Australian astronomy
  → multi-messenger astronomy

CTA – Australia

U. Adelaide
G. Rowell, B. Dawson, R. Clay, S. Einecke, P. Veitch, D. Ottaway, M. White, F. Voisin, V. Stamatescu, L. Bowman, N. Wild, P. McGee

UNSW
M. Ashley, C. Braiding, N. Maxted, G. Wong

WSU
M. Filipovic, N. Tothill

ANU
G. Bicknell, R. Crocker, I. Seitenzahl

Monash
C. Balazs, D. Galloway

U. Syd
A. Green, S. Breen

Funding
ARC LIEF 2015 + 2017-21 (hardware/commissioning/software/labour)

NCRIS/AAL (travel, meetings, CTAO membership)

Australia's Roles in CTA (actual + potential)

CTA Hardware & Array Design

- Telescope hardware & commissioning (ARC LIEF funding)
- Atmospheric studies (LIDAR, cloud monitoring)
- Analysis techniques & effect of clouds on CTA performance

Multi-wavelength/messenger strengths

- ISM surveys/studies (Mopra, ATCA, ASKAP, SKA)

  (sub)arcmin surveys vital for CTA's Galactic science
- Radio continuum: transients/steady (ATCA, MWA, UTMOST, ASKAP, SKA)
- X-ray astronomy (e-ROSITA, XMM-Newton, Chandra)

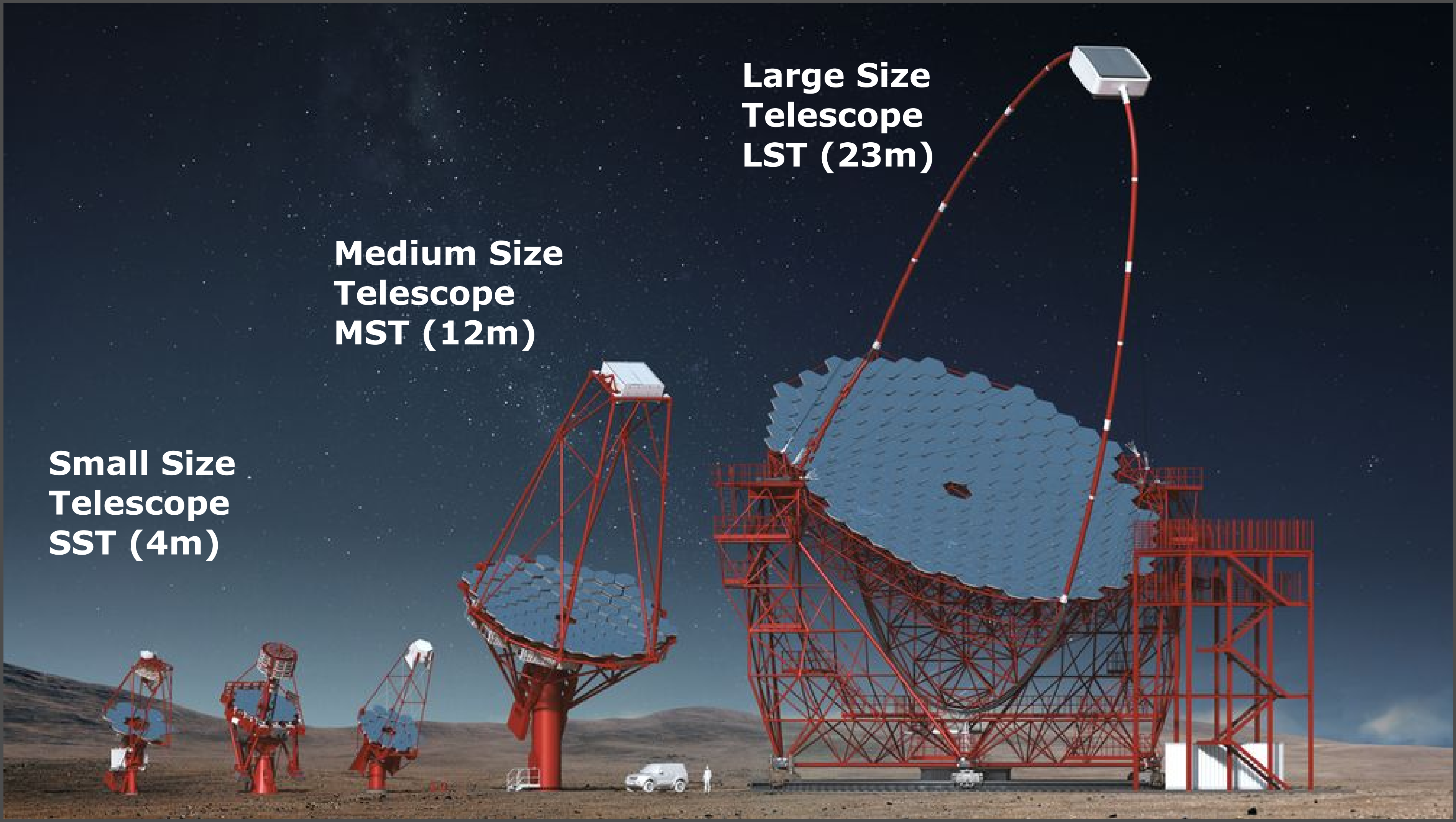
Theory Strengths

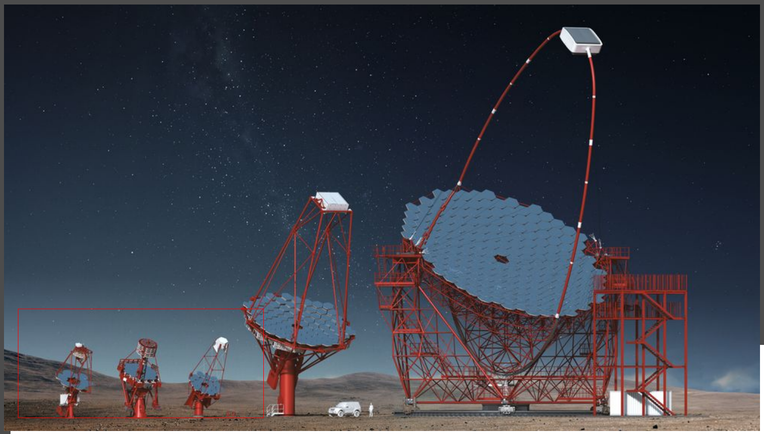
- Theoretical high energy astrophysics (e.g. Galactic Centre, jets/outflows)
- Astro-particle physics – Dark matter properties

Great potential to link with....

- Radio (ASKAP-EMU, -POSSUM, -VAST/CRAFT, -GASKAP, MWA, UTMOST)
- Optical (e.g. GALAH, Skymapper), interferometry, transients
- Cosmic-rays (Pierre Auger Obs.)
- Grav. Waves (A/LIGO)
- Neutrinos (IceCube)
- HP Computing (ASVO node....) transients, machine learning, local data

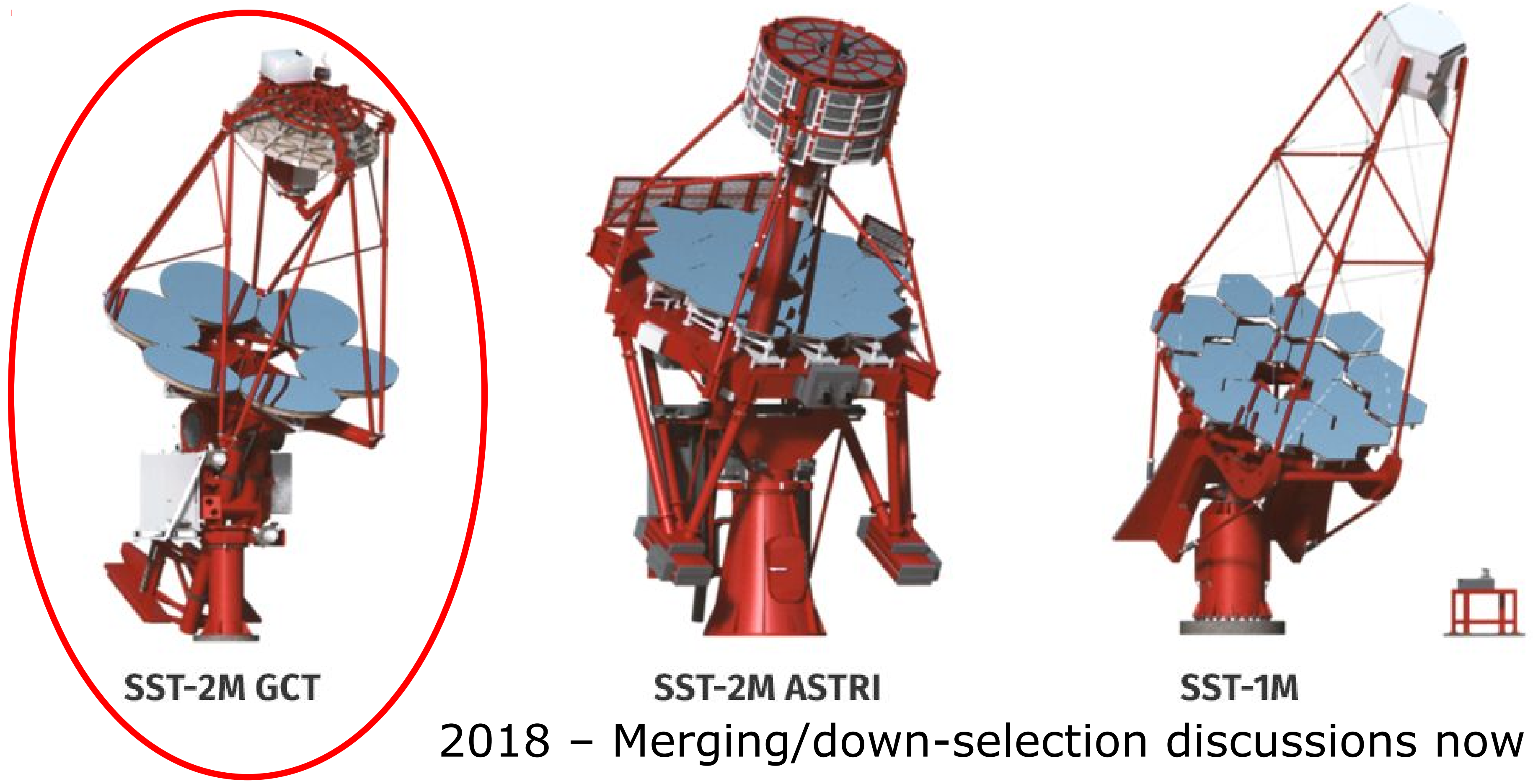
CTA's Telescopes....





Australia contributes ARC-LIEF funding to the “GCT” SST via

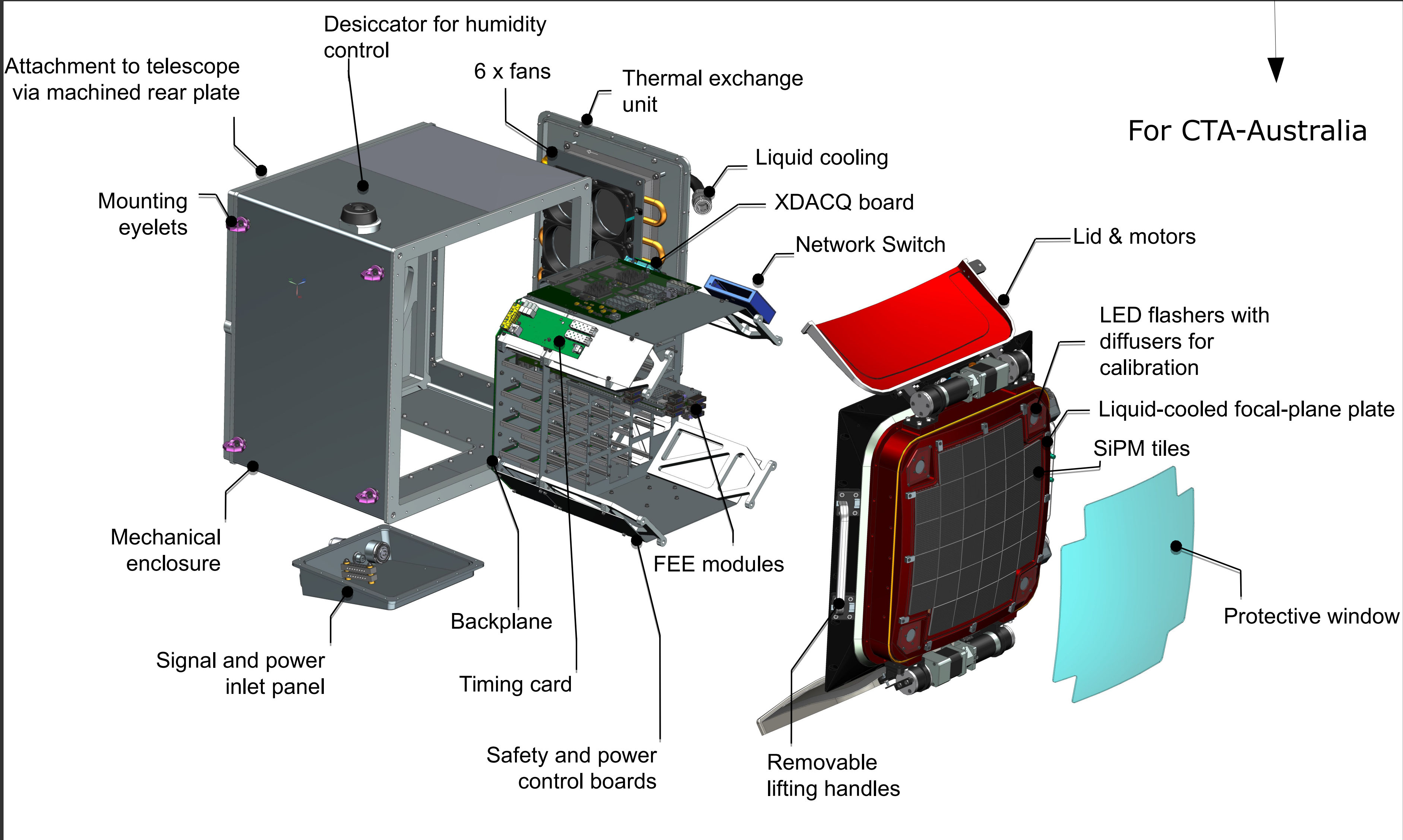
- “CHEC” camera



2018 – Merging/down-selection discussions now

CHEC-S (Compact High Energy Camera) – For the SST-2M (GCT & ASTRI)

- 2048 Si-PM light sensors
- 9 degrees Field of View



Telescope prototypes....

SS-2M GCT (Paris)

SST-2M ASTRI (Sicily)

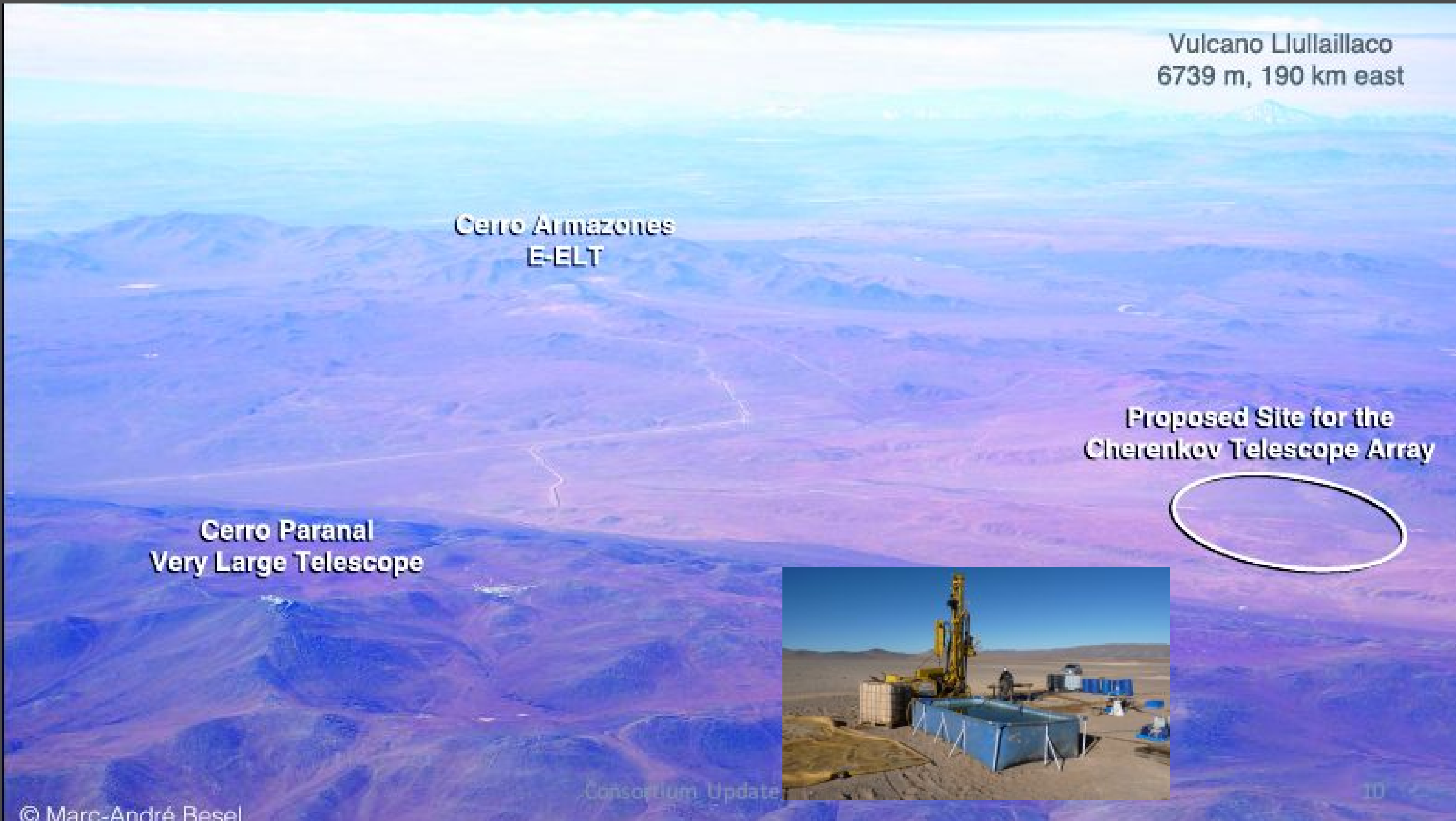
SST-1M (Cracow)

MST (Berlin)

SCT-MST (Arizona)

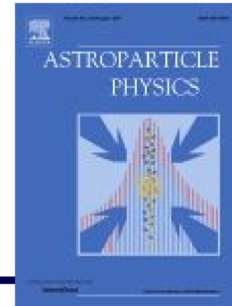
First LST at CTA-North – Main dish installed (Tues 3 Apr 2018)

CTA South : Paranal, Chile



Negotiations with ESO/Chile nearing completion

KEY SCIENCE PROJECTS



Special Issue Vol 43, Pg 1-356 (Mar 2013)

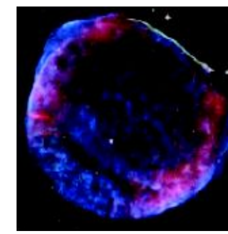
cta
cherenkov telescope array

– Galactic Plane Survey
– Galactic Centre Survey
– Large Magellanic Cloud Survey
– Extragalactic Survey
– Transients
– Cosmic-Ray PeVatrons
– Star-Forming Systems
– Active Galactic Nuclei
– Clusters of Galaxies
– Dark Matter
– Non-Gamma-Ray Science

intensity interferometry
fast optical transients – milli-magnitude occultations (Kuiper belt population..)

Three Themes

1. Cosmic Particle Acceleration



2. Probing Extreme Environments

3. Physics Frontiers: Beyond Standard Model

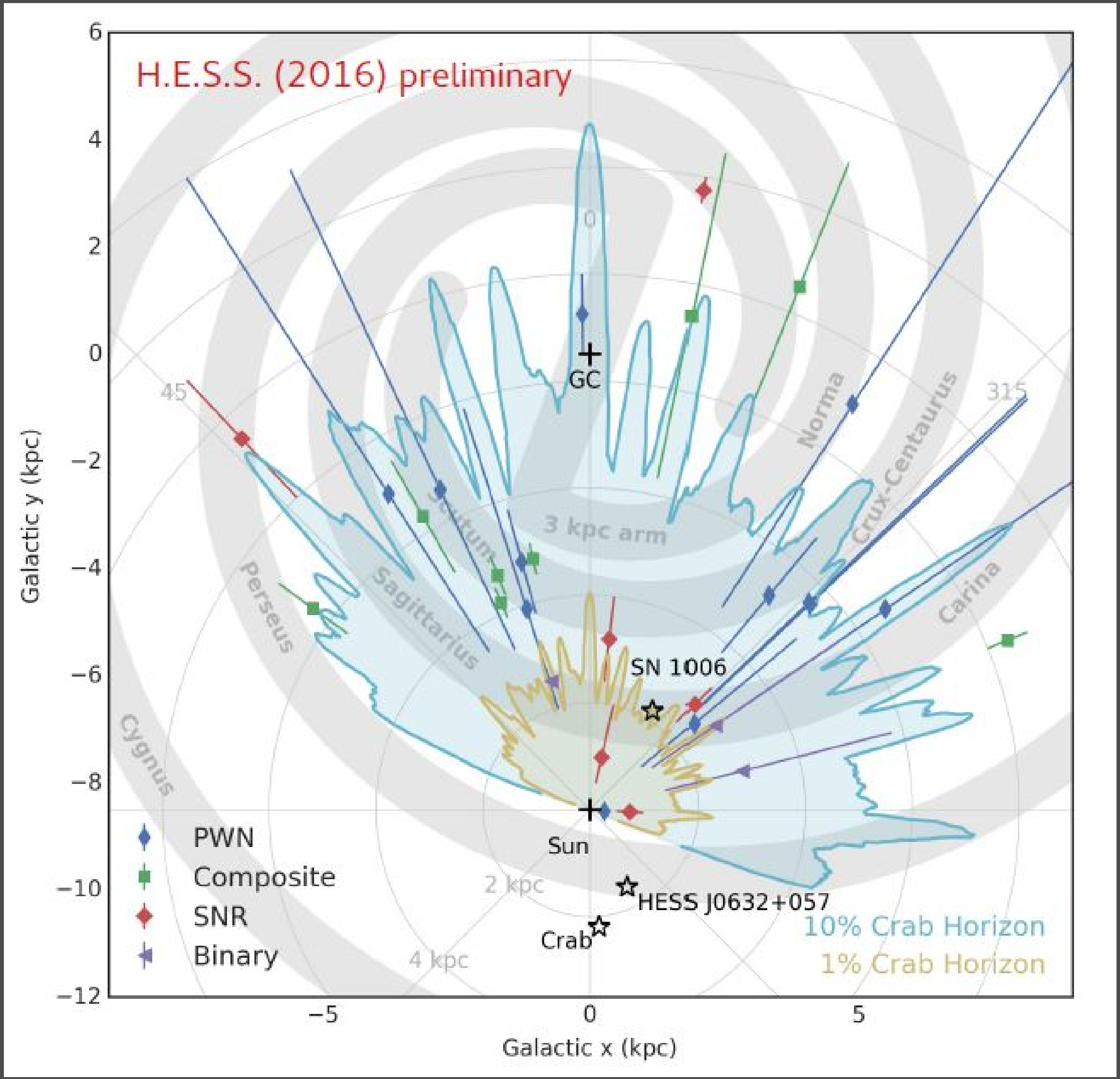
CTA: Science Case

Contents

Chapters and corresponding authors:

ArXiv:1709.07997

Published by World Scientific (Apr. 2018)

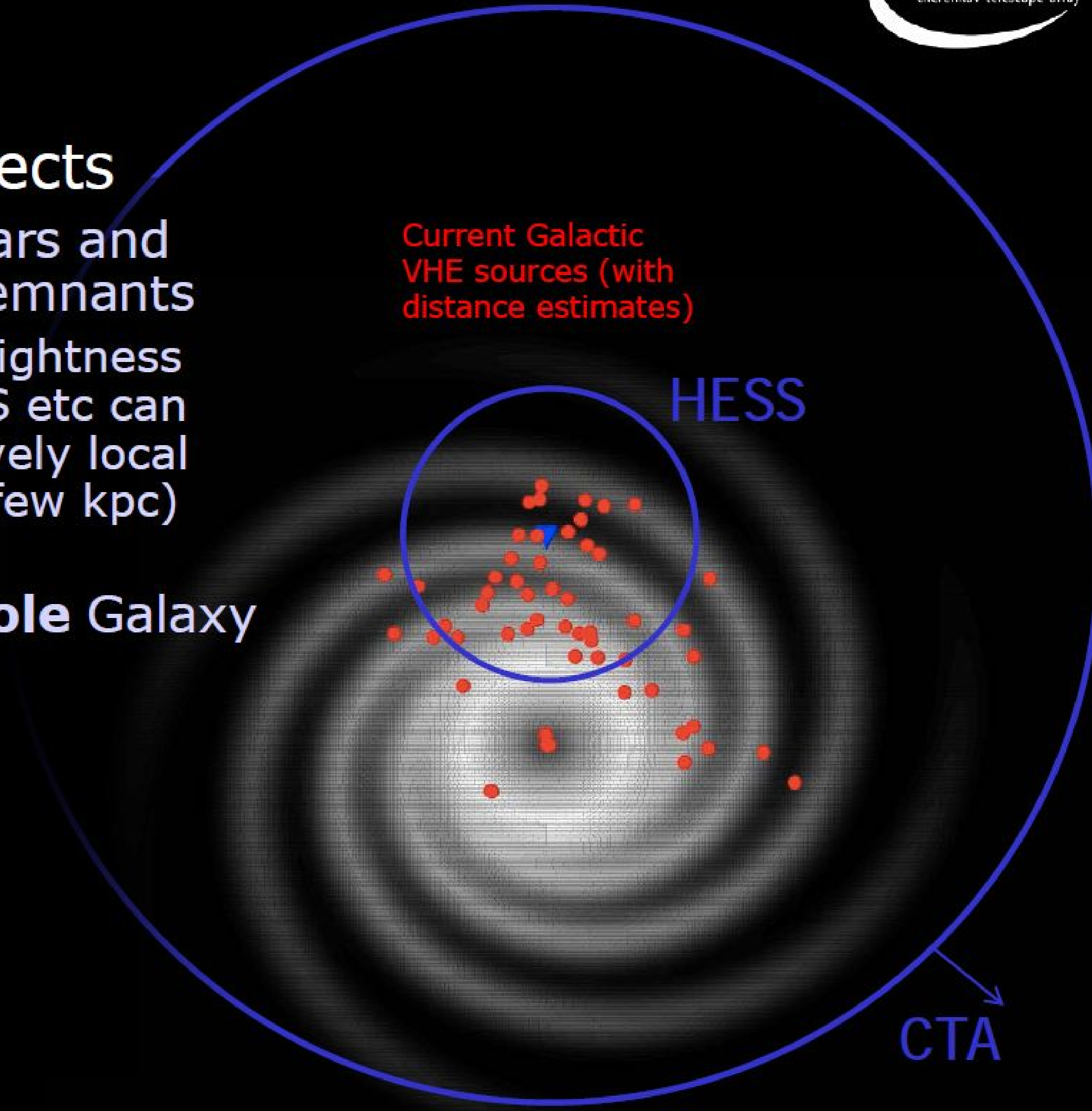


H.E.S.S. (2016) preliminary
Galactic y (kpc)
Galactic x (kpc)
6
4
2
0
−2
−4
−6
−8
−10
−12
−5
0
5
0
45
315
GC
Norma
Crux-Centaurus
Carina
Scutum
3 kpc arm
Sagittarius
Perseus
Cygnus
SN 1006
Sun
HESS J0632+057
Crab
2 kpc
4 kpc
PWN
Composite
SNR
Binary
10% Crab Horizon
1% Crab Horizon

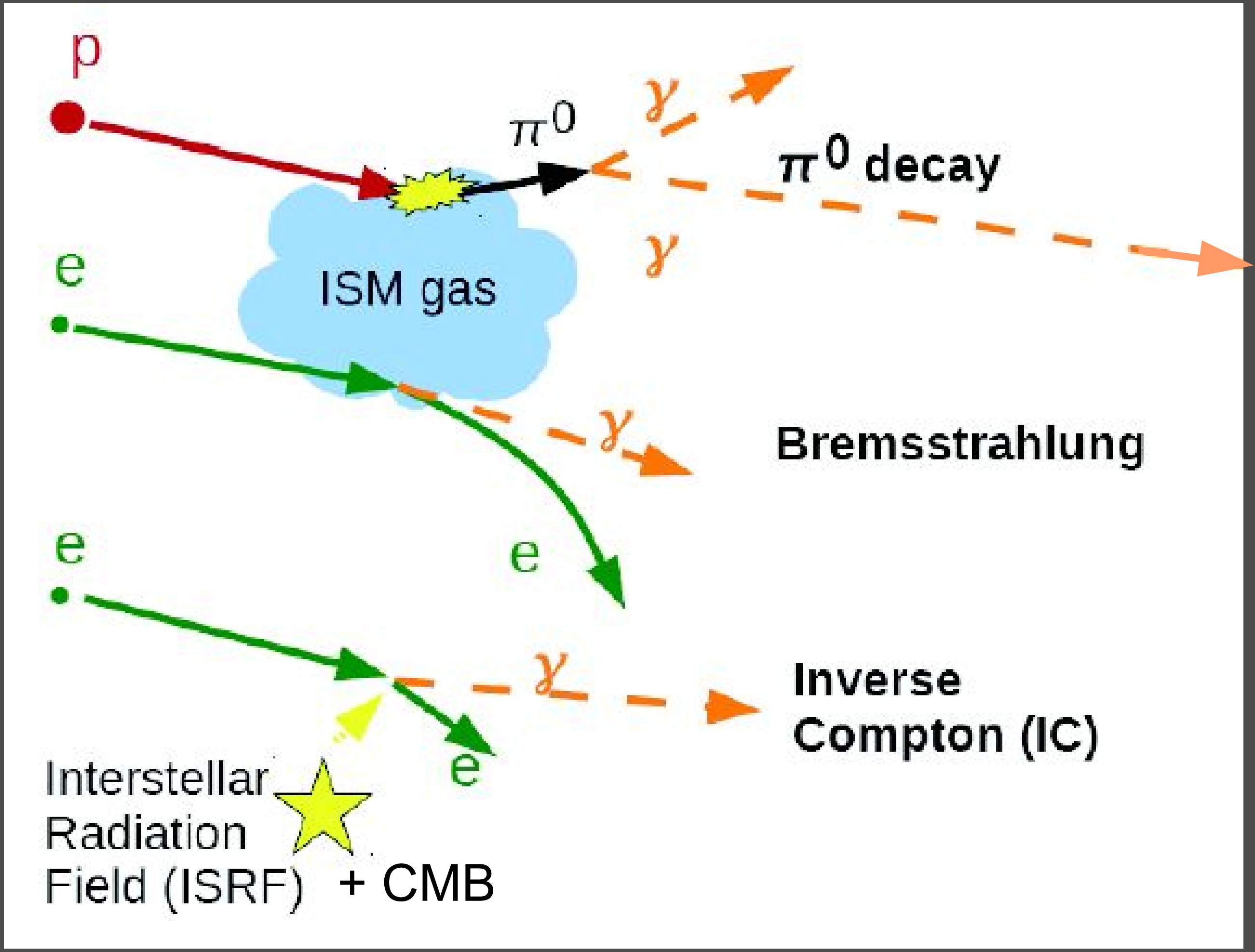
CTA Galactic Science

- e.g. Galactic objects
  - Newly born pulsars and the supernova remnants
    - have typical brightness such that HESS etc can see only relatively local (typically at a few kpc) objects
  - CTA will see **whole** Galaxy

- Survey speed ~300×HESS



Gamma Rays from multi-TeV particles



Protons: Gamma-rays and gas targets are generally spatially correlated
(need to map atomic and molecular ISM → mm radio astronomy)

Electrons: Gamma-ray (IC) + non-thermal X-ray, radio emission (synchrotron) highly coupled

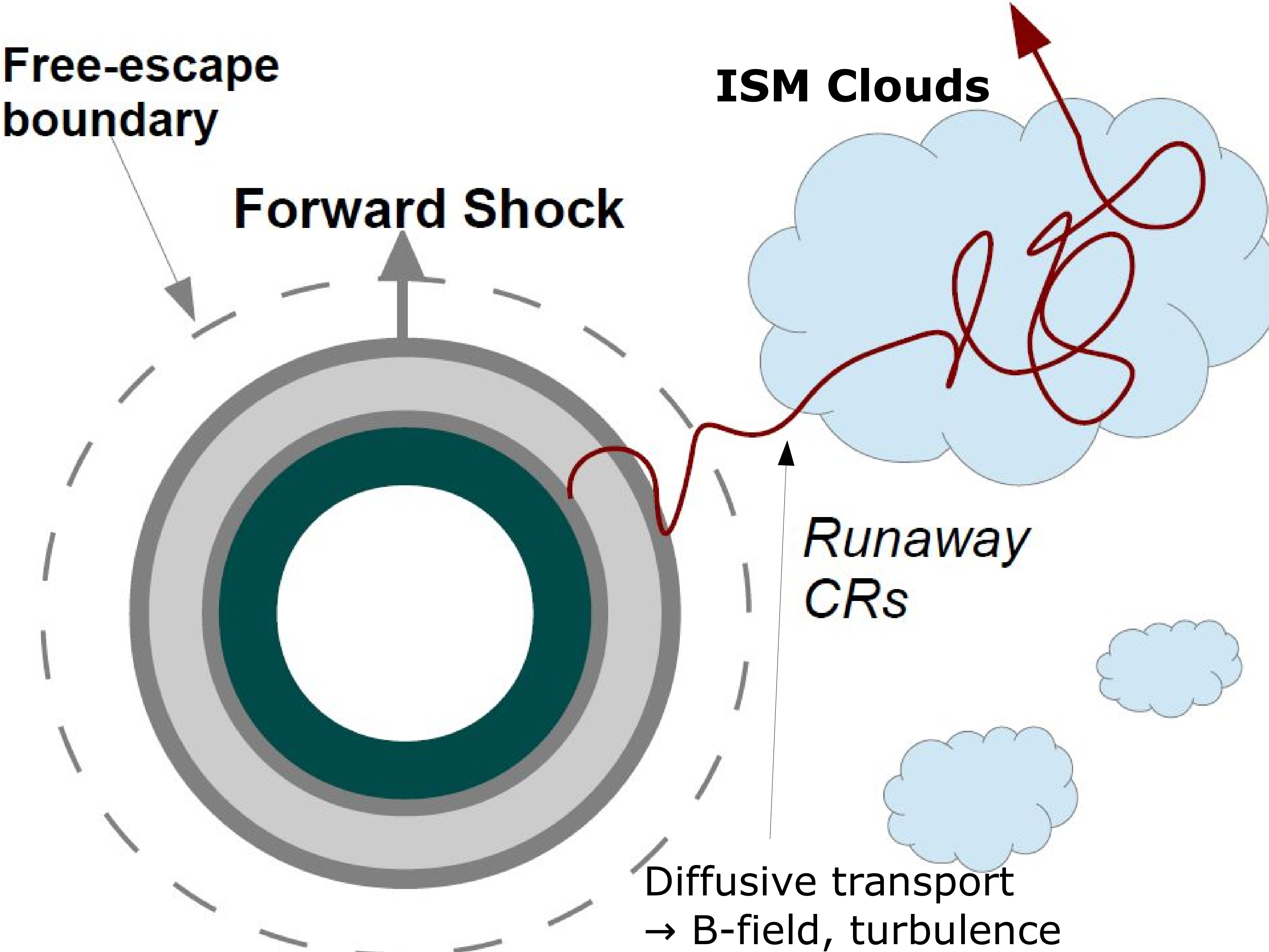
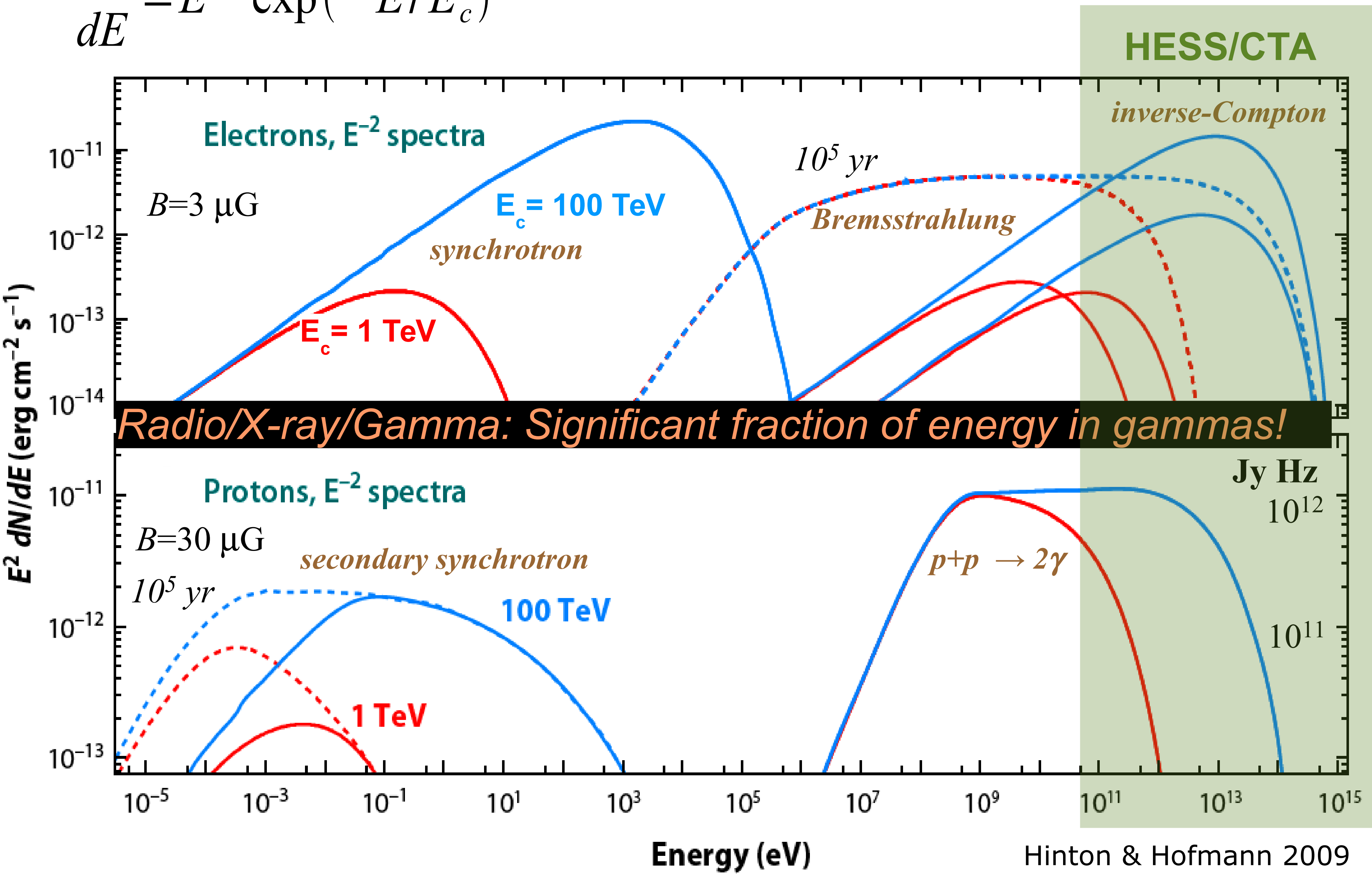


Image from Giovanni Morlino

Non-Thermal Energy-fluxes (From a hypothetical particle accelerator)

$$\frac{dN}{dE} = E^{-2}\exp(-E/E_c)$$

$W_p = W_e = 10^{48}$ erg; d = 1 kpc; Age = 10^4 yr,
CMB+FIR+Opt; n=100 cm^{-3}



Radio/X-ray/Gamma: Significant fraction of energy in gammas!

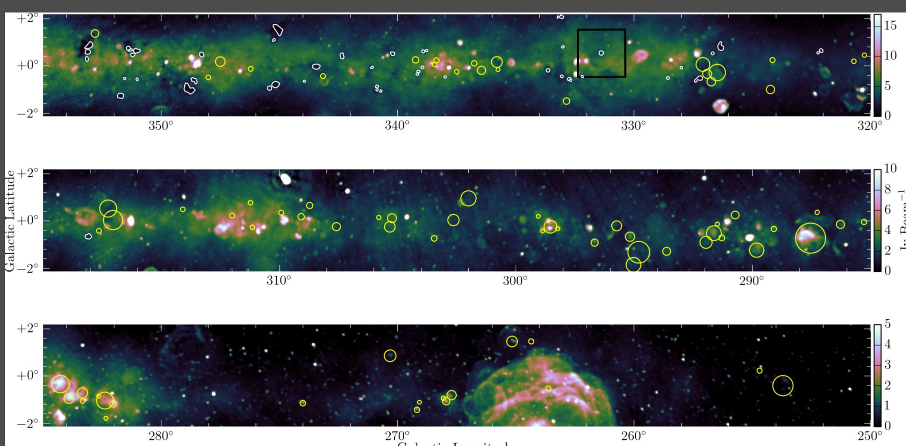
Hinton & Hofmann 2009

Synergies with Radio Continuum Surveys

- Radio synchrotron & TeV gamma-ray (esp. hadronic) are often 'relics' of earlier particle acceleration.

- Dark TeV Sources:
  → Old/evolved SNRs & PWNe?
  → Missing Supernova remnants?

ASKAP – EMU, POSSUM
MWA - GLEAM



MWA GLEAM 88 MHz (MWA Prelim 2016)

TeV gamma-rays & non-thermal radio to X-ray

1. Cooling Time $t = E / (dE/Dt)$

Pi-zero decay: $t_{pp} = (n\sigma_{pp} f c)^{-1} \approx 5.3 \times 10^7 (n/\mathrm{cm}^3)^{-1}$ yr

IC scattering: $t_{IC} \approx 3 \times 10^8 (U_{rad}/\mathrm{eV}/\mathrm{cm}^3)^{-1} (E_e/\mathrm{GeV})^{-1})$ yr

Bremsstrahlung: $t_{br} \approx 4 \times 10^7 (n/\mathrm{cm}^3)^{-1}$ yr

Synchrotron: $t_{sync} \approx 12 \times 10^6 (B/\mu\mathrm{G})^{-2} (E_e/\mathrm{TeV})^{-1}$ yr

→ Radiative propagation limits for particles (e.g. source size)

→ Source age $>10^4$ yr

common for TeV gamma + Radio synch. ($B<10\mu G$)

2. Diffusive Transport: distance ~ $[6\ D(E,B)\ t]^{0.5}$

(for turbulent B-field)

diffusion coefficient D(E,B)

ISM density n; B-Field B(n)

→ ISM has critical influence on gamma-ray source size and spectra.

→ Radio to X-ray non-thermal emission tied to electron properties

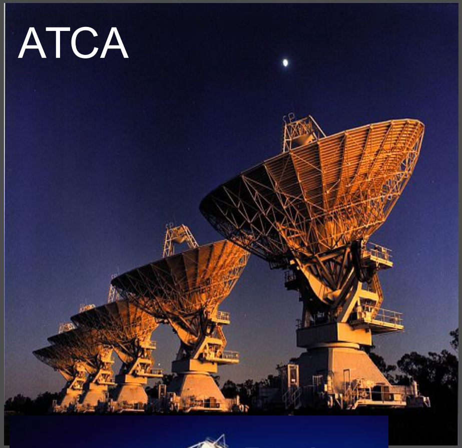
Surveys of the interstellar gas: tracers & telescopes..

www.atnf.csiro.au/research/HI/sgps

HI (atomic H), OH, CS — CO — CO, NH_3, CS, SiO...

Gas density

$\sim 10^{1\ \mathrm{to}\ 4}\ \mathrm{cm}^{-3}$ — $\sim 10^{3}\ \mathrm{cm}^{-3}$ — $>10^{3\ \mathrm{to}\ 4}\ \mathrm{cm}^{-3}$

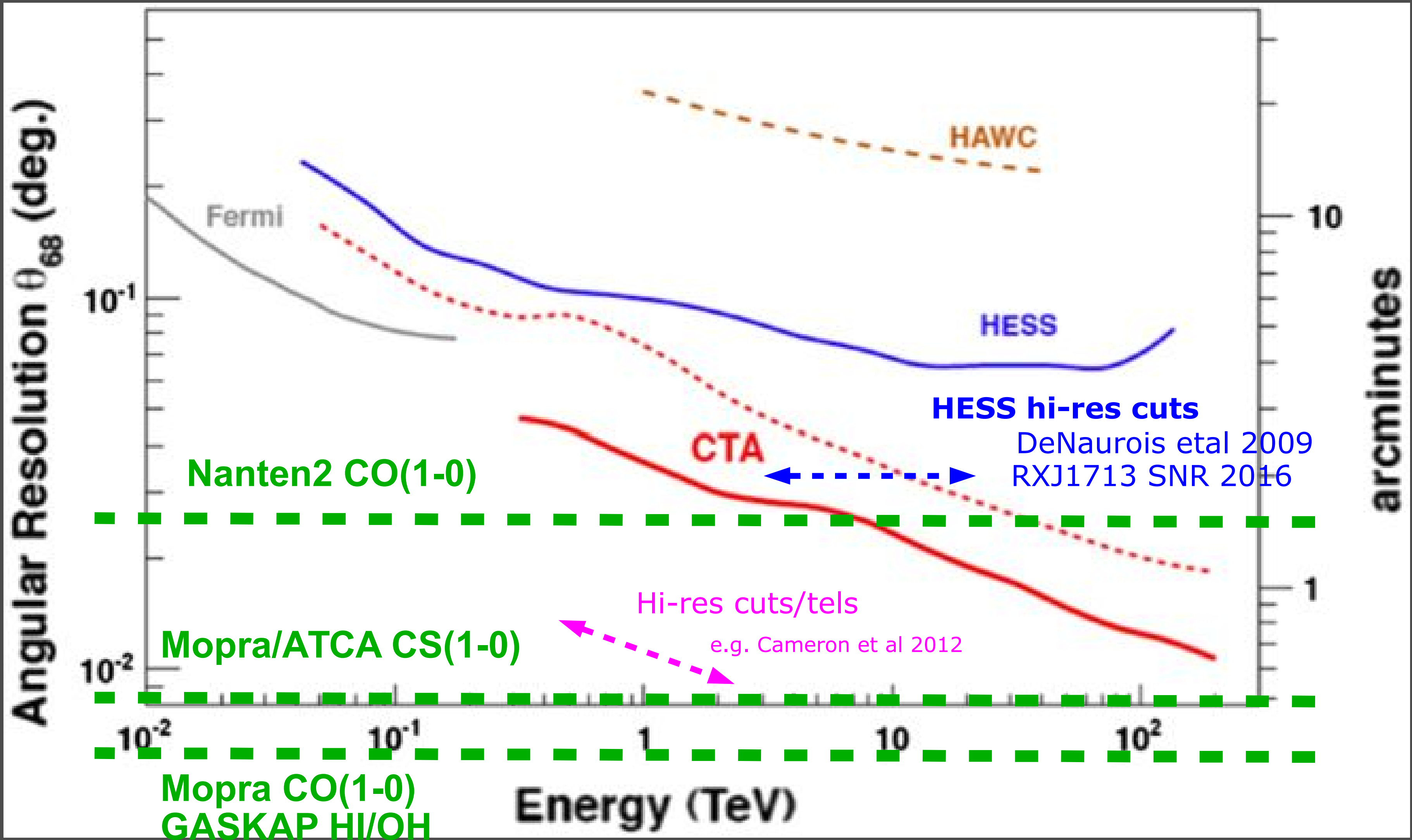


THz (Antarctica & High-alt)
[CI] + [CII]

Mopra Telescope

Angular Resolution 68% PSF (HESS, CTA..)

Acharyara etal 2013

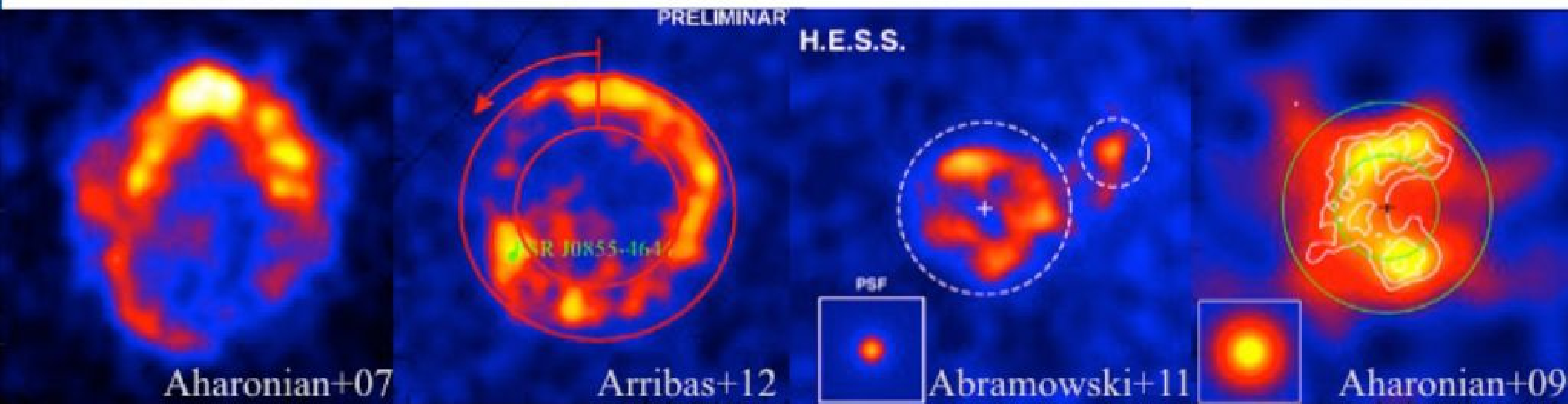


Beam Sizes 68% containment radius

Young TeV Shell-Type SNRs

- 4 TeV gamma-ray SNRs age ~2000 yrs
- They are interacting with ISM.

RX J1713.7–3946	RX J0852.0–4622	HESS J1731–347	RCW 86

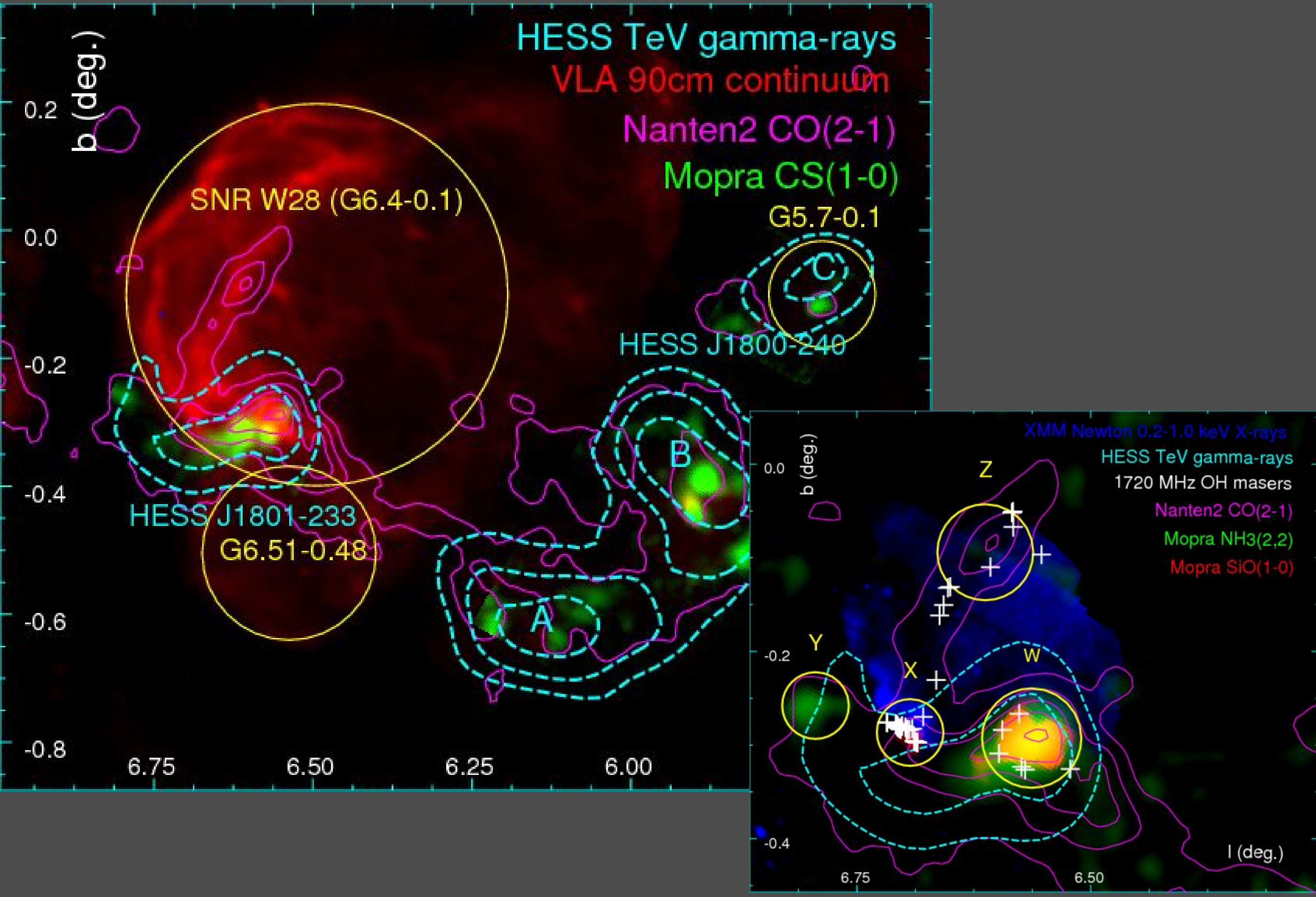


	RX J1713.7–3946	RX J0852.0–4622	HESS J1731–347	RCW 86
diameter:	~1 deg.	~2 deg.	~0.5 deg.	~0.5 deg.
age:	~1600 yr	~1700–4300 yr	~3600–7200 yr	~1800 yr
ISM:	rich CO + cold HI	rich HI + little CO	rich CO + HI cavity	rich HI + little CO
X-rays:	pure synchrotron	pure synchrotron	pure synchrotron	thermal + non-thermal

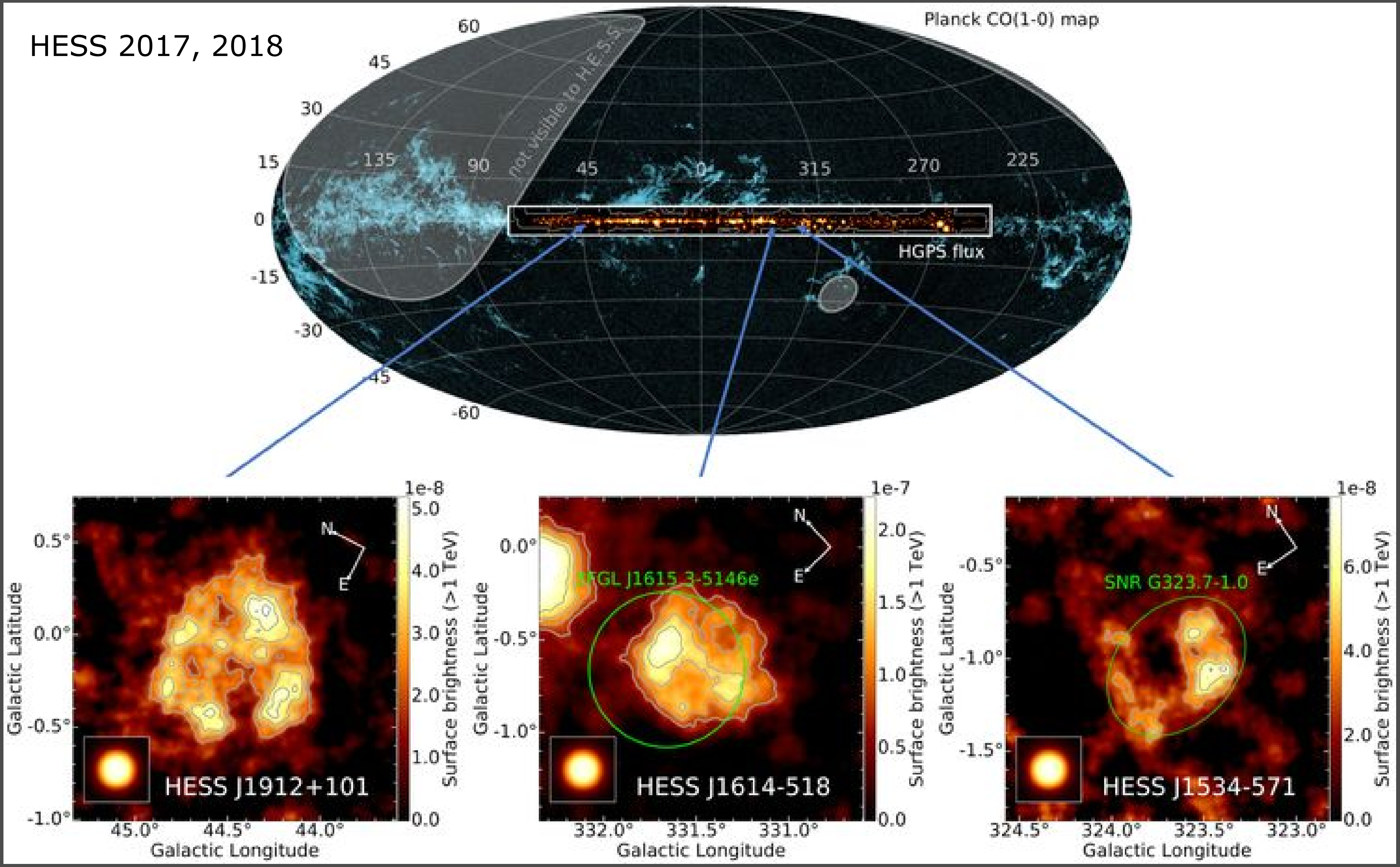
Slide from H. Sano (2017)

Mature SNR W28 – Radio to TeV

HESS 2008, Niicholas etal 2011, 2012, Maxted etal 2017

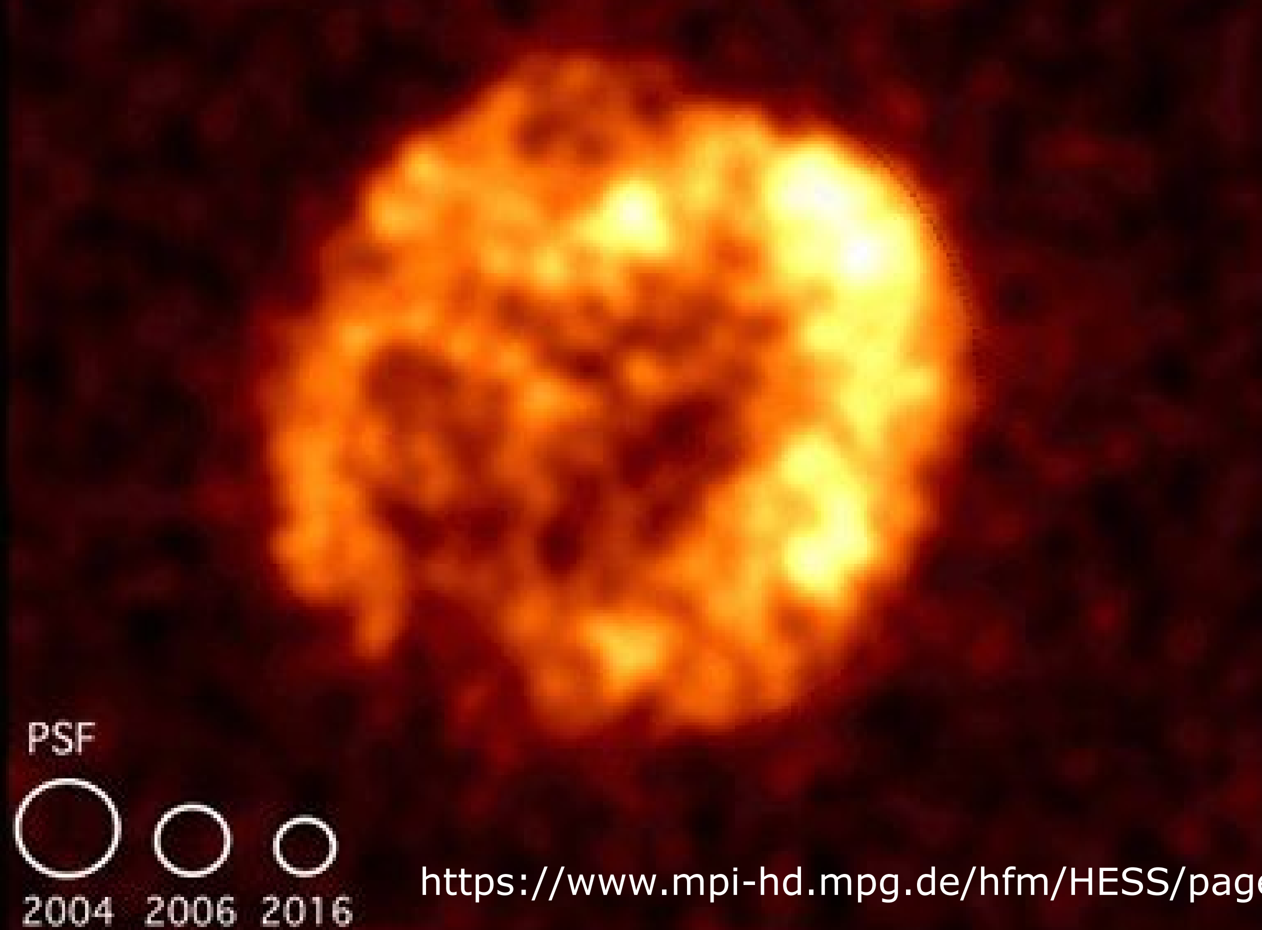


New TeV "Shells" → New supernova remnants?



H.E.S.S. RX J1713.7-3946

The sharpest gamma-ray image so far!
PSF (68%) ~ 2 - 3 arcmin (FWHM ~ 5 arcmin)
HESS Collab. arXiv:1609.08671



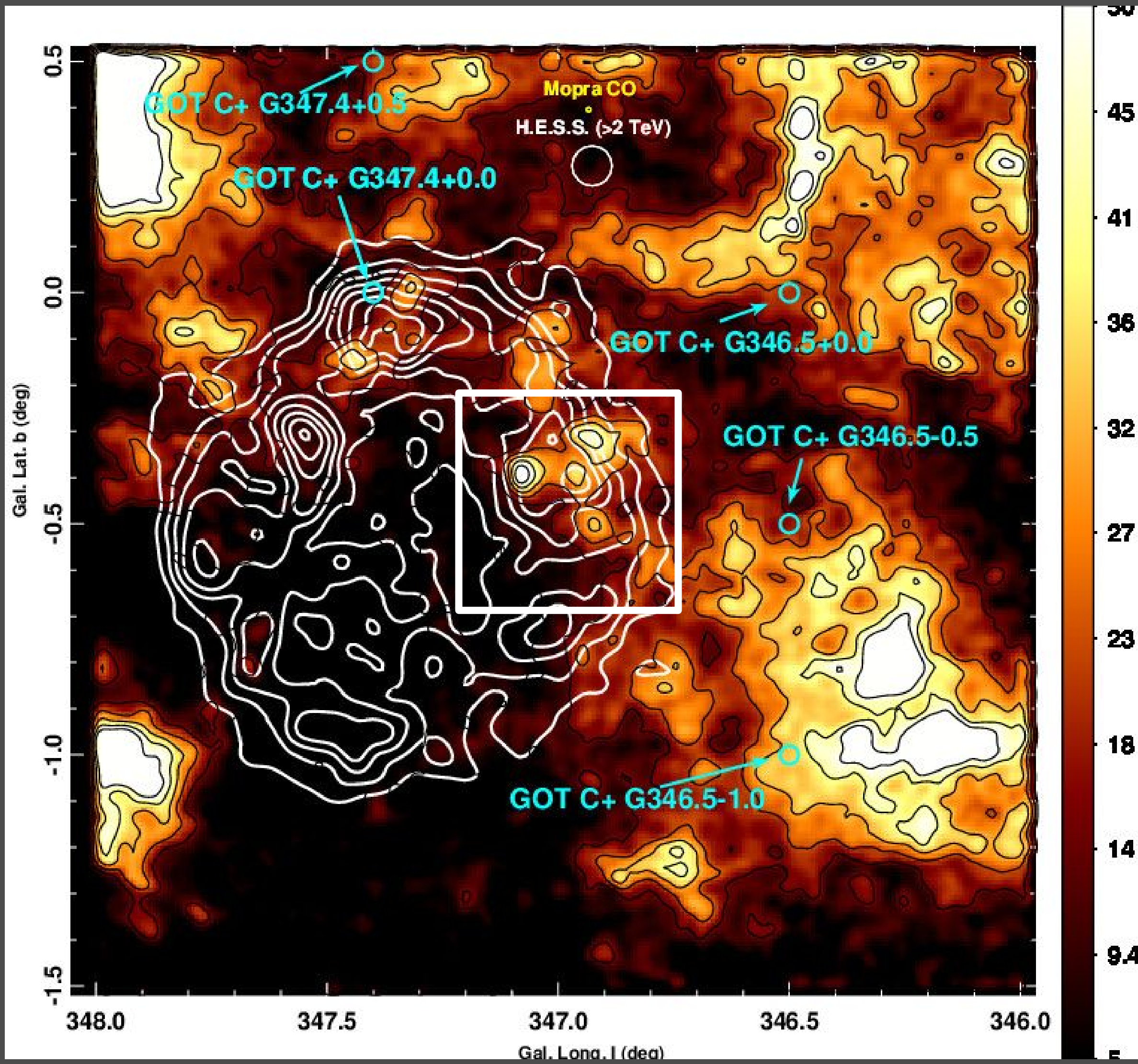
Year	2016
Live-time	164h
Energy	> 0.25 TeV
PSF (R_{68})	2.9 arcmin
γ's	31,000

CTA
~1 arcmin

https://www.mpi-hd.mpg.de/hfm/HESS/pages/home/som/2016/09/

RXJ1713 TeV and ISM Comparison on Parsec Scales!

Mopra CO(1-0) Image + HESS > 2 TeV contours



→ Probe diffusion properties of CR/e.

– (HESS 2016) TeV SNR radius > X-ray radius. CR escape and/or IC/synch cooling?

Active Galactic Nuclei

Credits: ESA/NASA

Also TeV-Detected

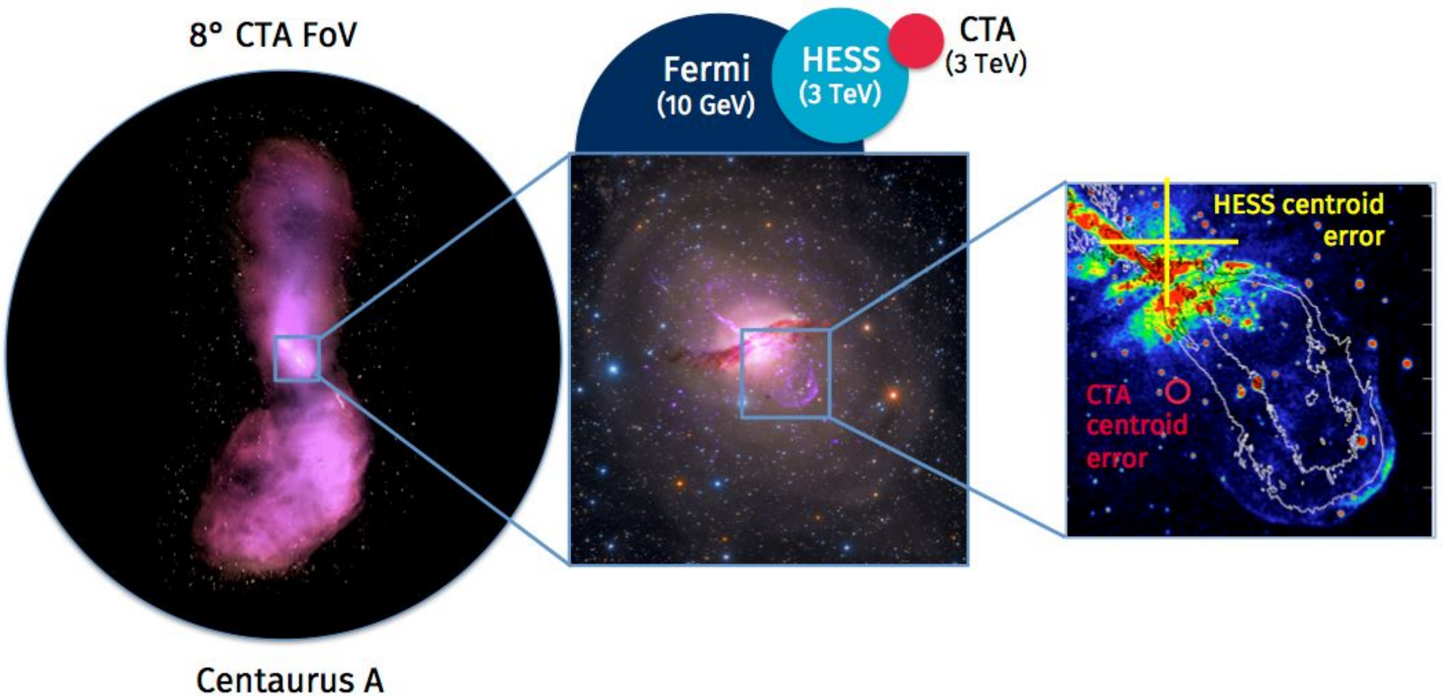
- **Radio galaxies**
- **Starburst gal.**
- **Grav. lensed flare**

AGNs are known to emit **variable radiation** across the entire electromagnetic spectrum up to multi-TeV energies, with fluctuations **on time-scales** from **several years** down to **a few minutes.**

VHE observations of active galaxies harbouring super-massive black holes and ejecting relativistic outflows represent a unique tool to probe the **physics of extreme environments**, to obtain precise measurement of the **extragalactic background light** (EBL) and to constrain the strength of the **intergalactic magnetic field** (IGMF).

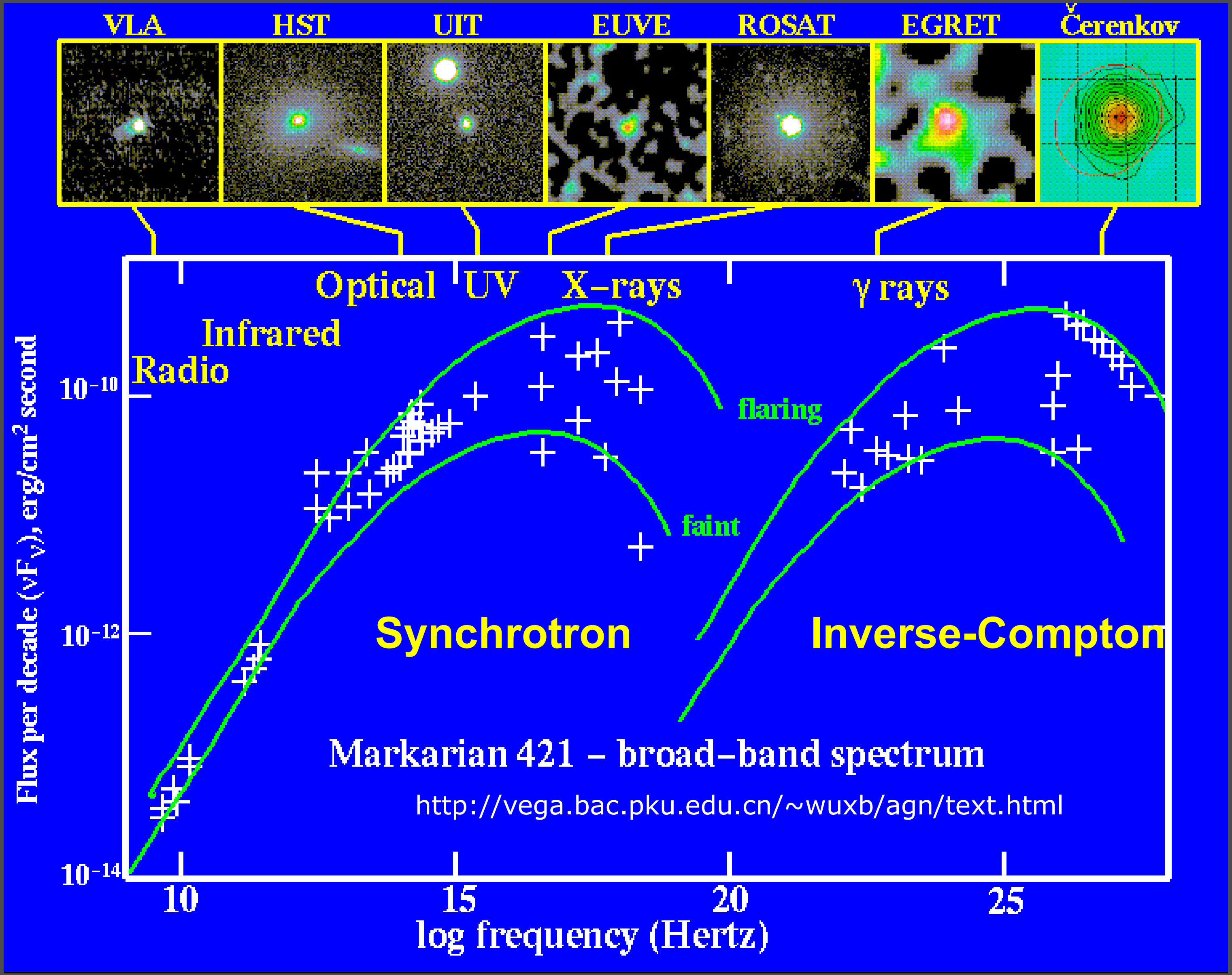
AGNs will be useful to investigate fundamental physics phenomena such as the **Lorentz invariance violation** and signatures of the existence of **axion-like particles**.

Cen-A – What and where are the particles accelerated?



With an 8 degree field of view (FoV), CTA will be able to cover the giant lobes of the nearby active galaxy Centaurus A in one exposure, despite an apparent size 20 times the diameter of the full moon (and a true size of around 2 million light years). Furthermore, CTA has the resolving power to see sub-structures in the inner regions of the active galaxy, something which is impossible with current gamma-ray telescopes.

Radio to TeV SED: AGN Blazars

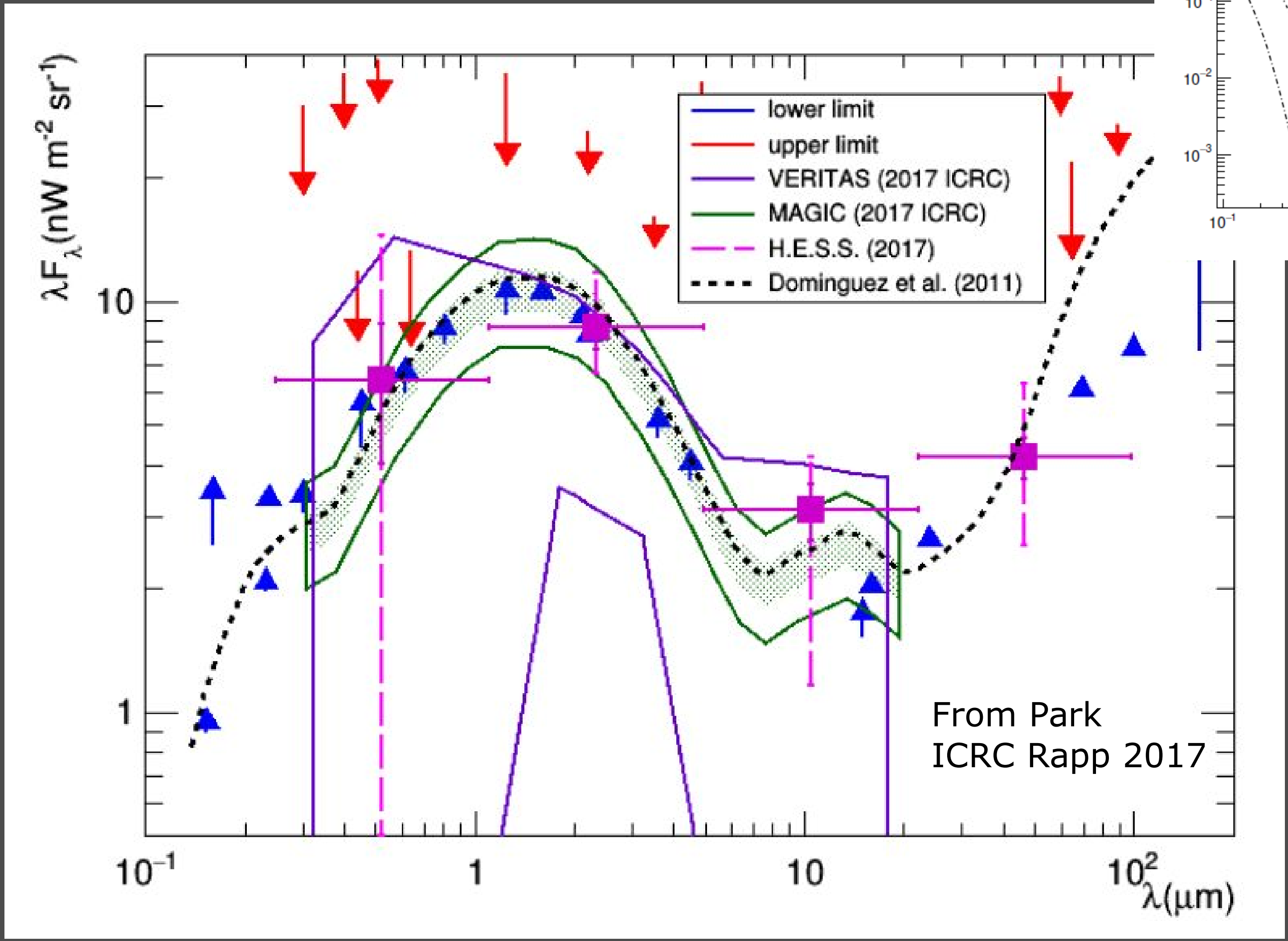


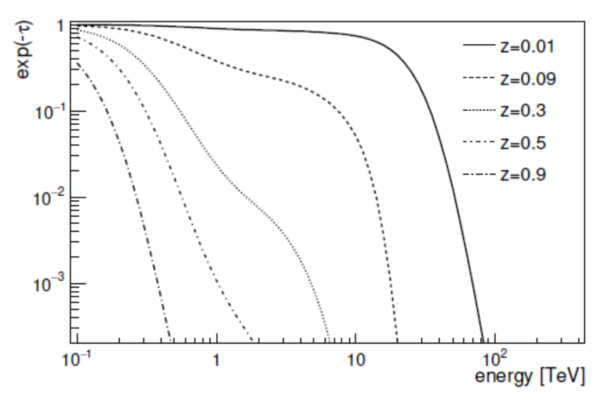
ATCA (+ MWA recently) used in blazar/AGN studies

– e.g. TeV/GeV flare follow-ups

Constraints on the Extragalactic Background Light

Flux = $Flux_{souce}\ e^{-\tau}$

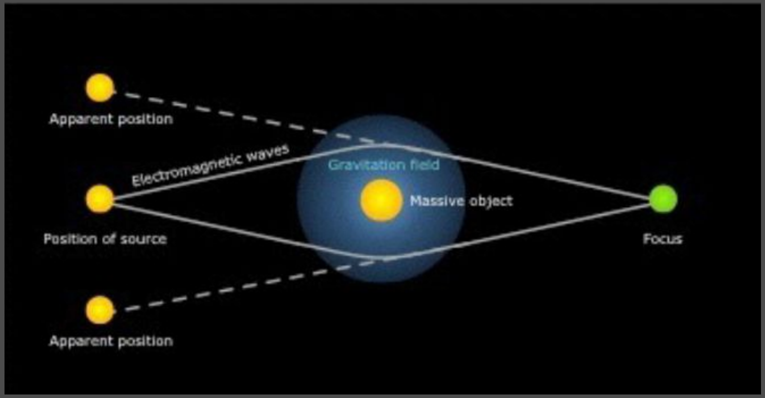




See talks by S. Wagner, F. Rieger, E. Prandini + Posters #356, #353

S3 0218+35 Most distant TeV source (z=0.954)

MAGIC 2014, 2016



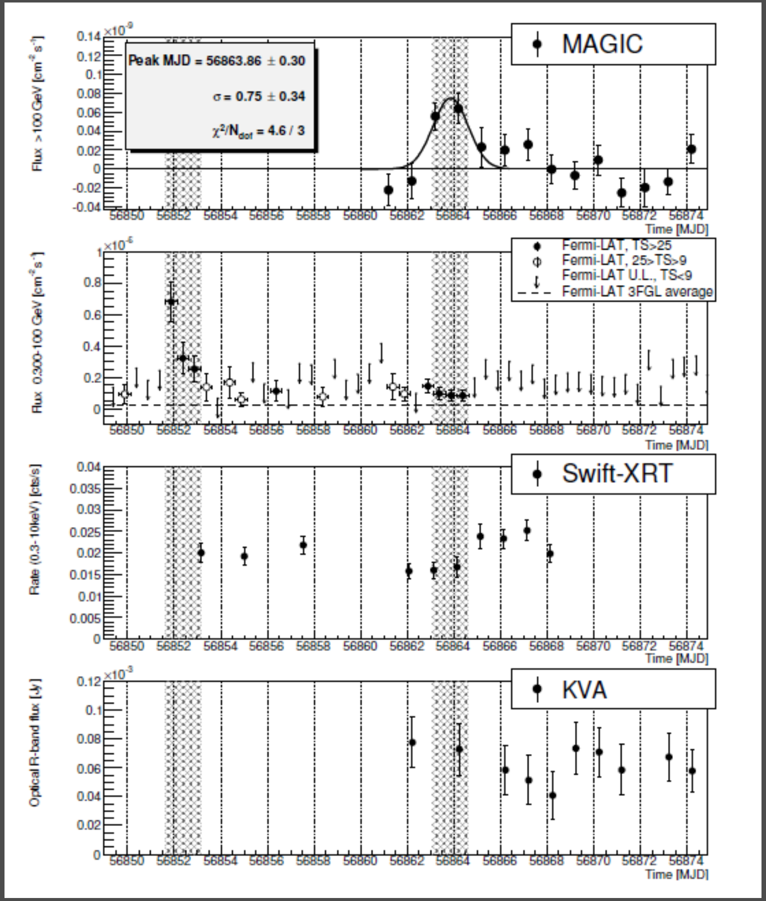
Detection by the MAGIC telescopes of the farthest very high energy gamma-ray source, S3 0218+35, thanks to its delayed gravitationally lensed emission

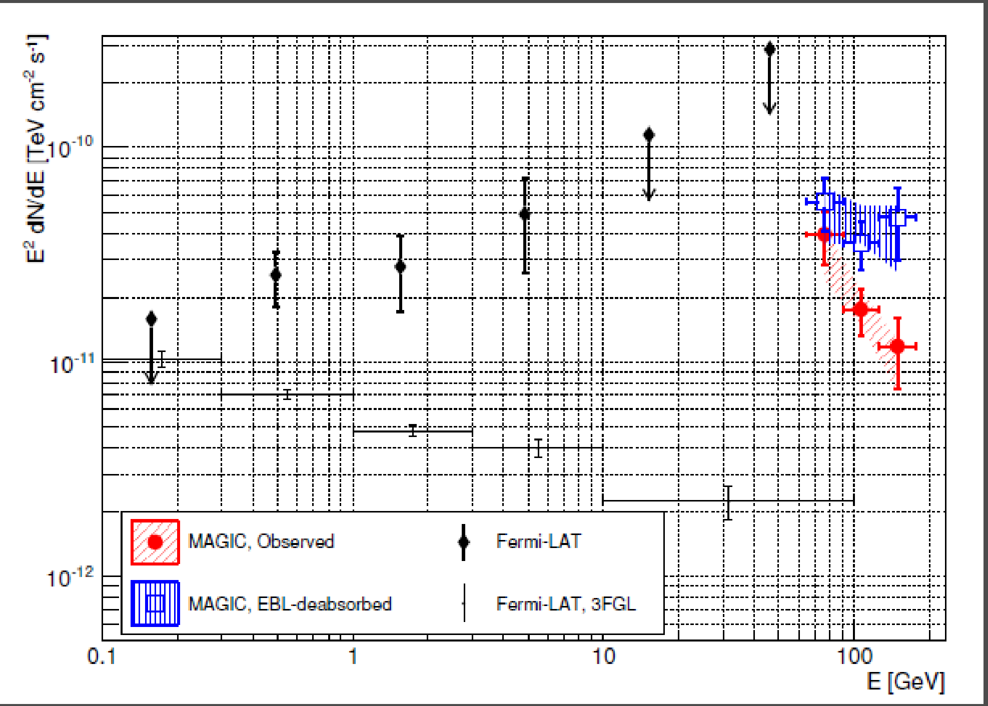
MAGIC

Daniel Mazin (ICRR, Tokyo and MPI for Physics, Munich)

5th Fermi Symposium 2014

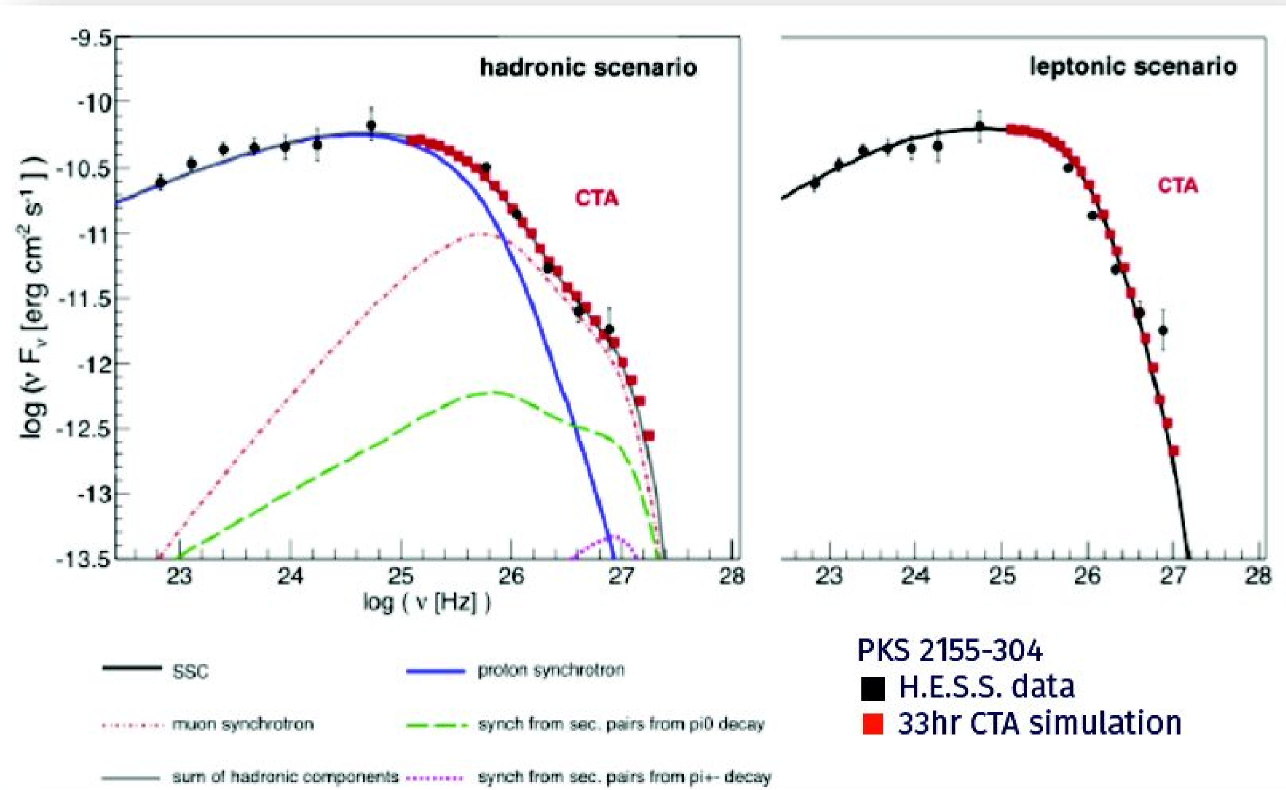
J. Sitarek, J. Becerra, S. Buson, D. Dominis, E. Lindfors, M. Manganaro, M. Nievas, A. Stamerra, Ie. Vovk for the MAGIC collaboration*





Active Galactic Nuclei

Testing emission scenarios

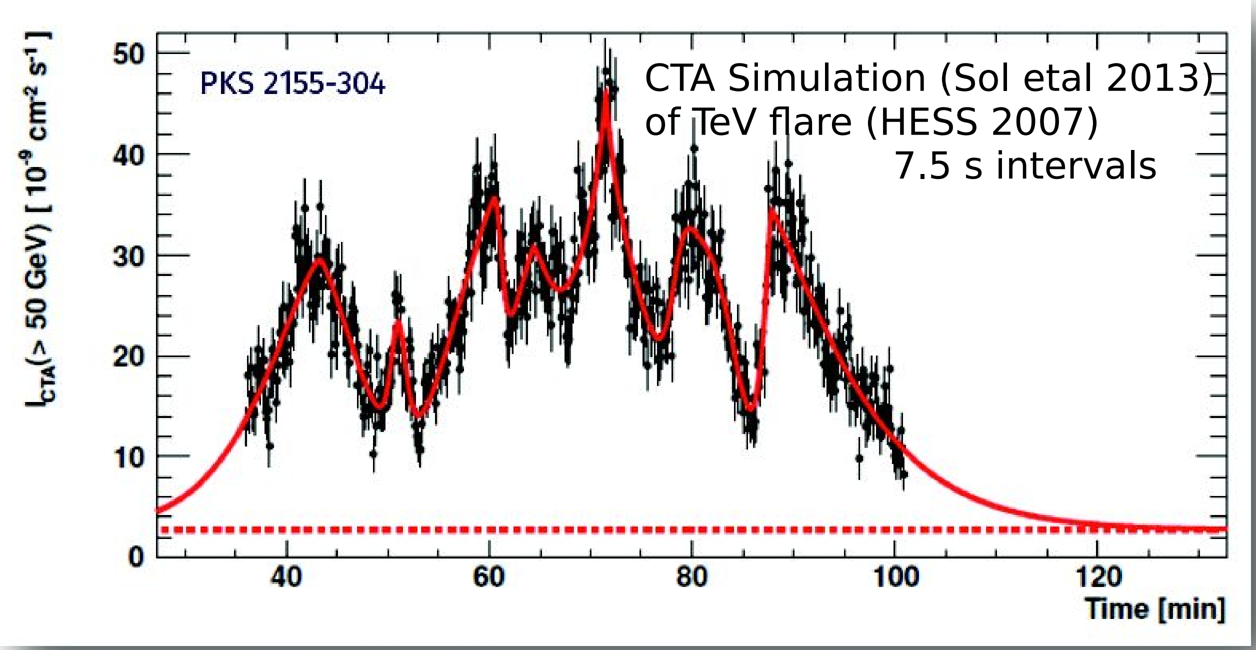


A set of high-quality spectra from different blazar types and different redshifts is needed to unambiguously distinguish intrinsic spectral features, such as shown here, from external absorption.

Zech etal 2013, Cerutti etal 2015, CTA Science Case

Active Galactic Nuclei

Testing variability in AGNs



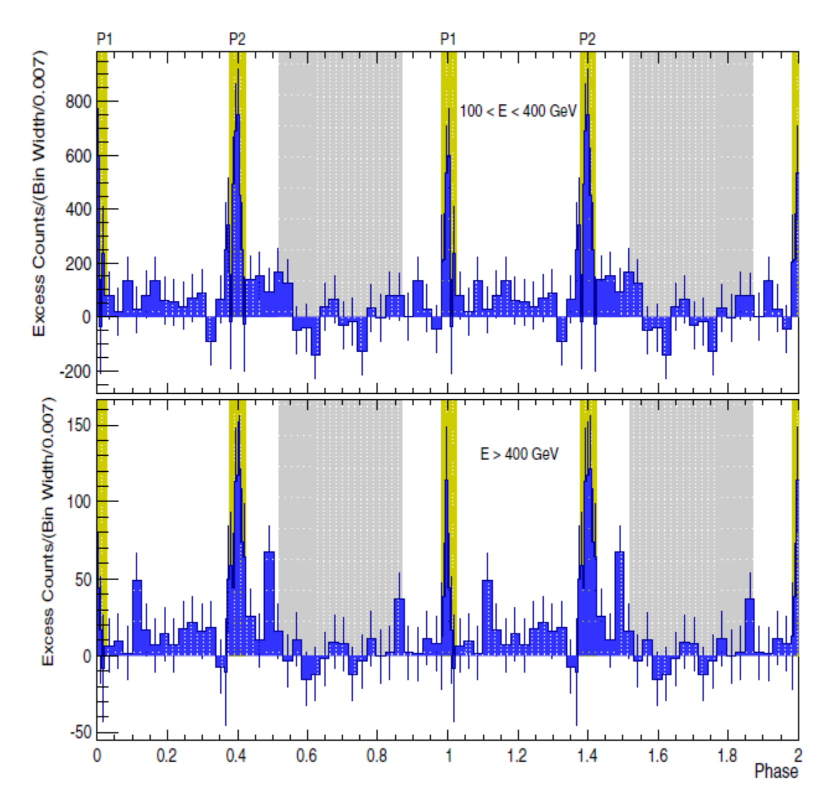
Sampling blazar fluxes below the light-crossing time scale of the SMBH, $T_G \sim 3hr \times (M/10^9 M_\odot)$, is a key strategy to understand the flickering behaviour of blazars on short time scales.

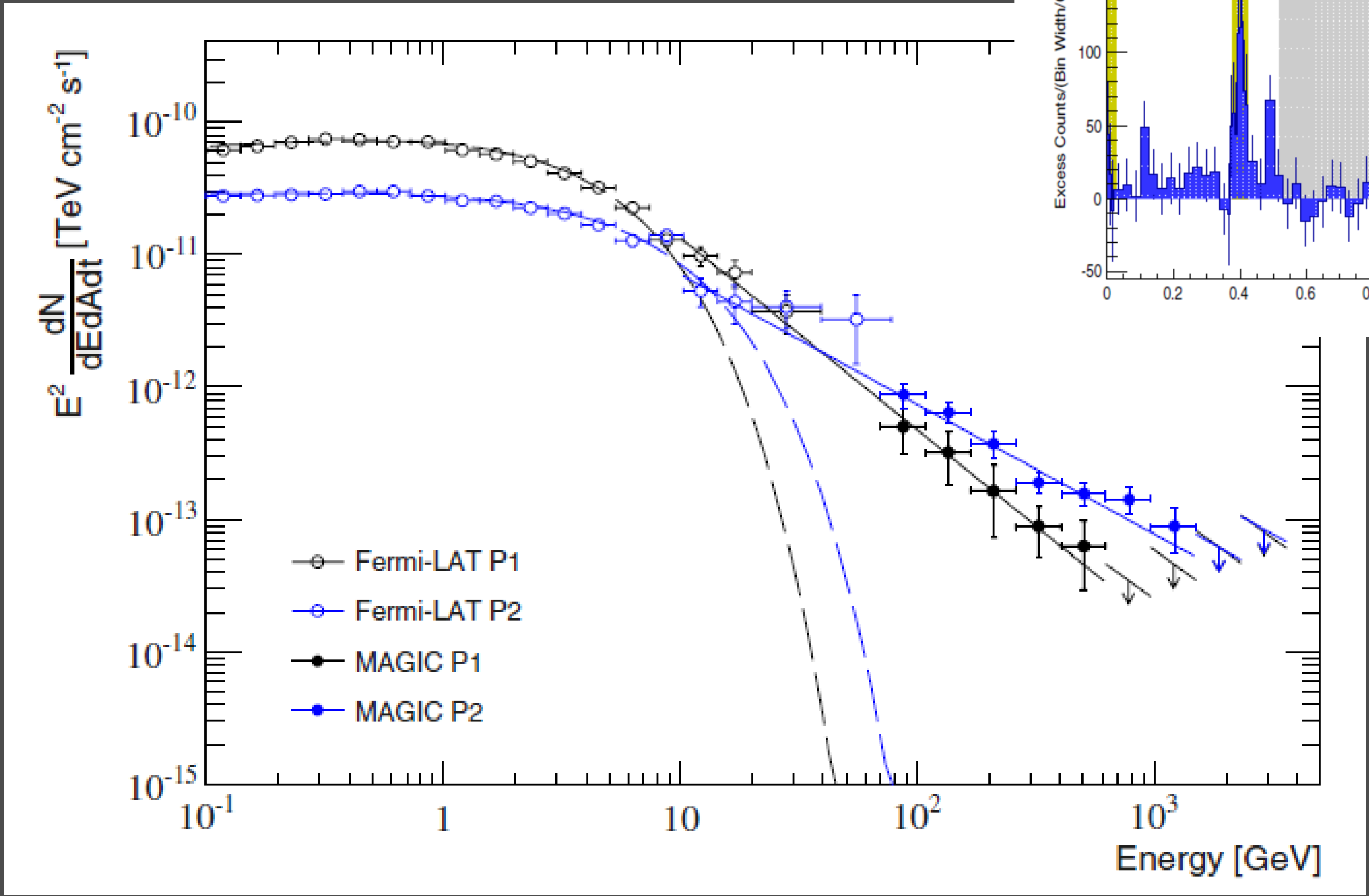
Such measurements put strong constraints on the bulk Doppler factor, as well as on particle acceleration and cooling processes.

Crab Pulsed Emission
(MAGIC + VERITAS)

- Up to ~ 1 TeV !   MAGIC 2016

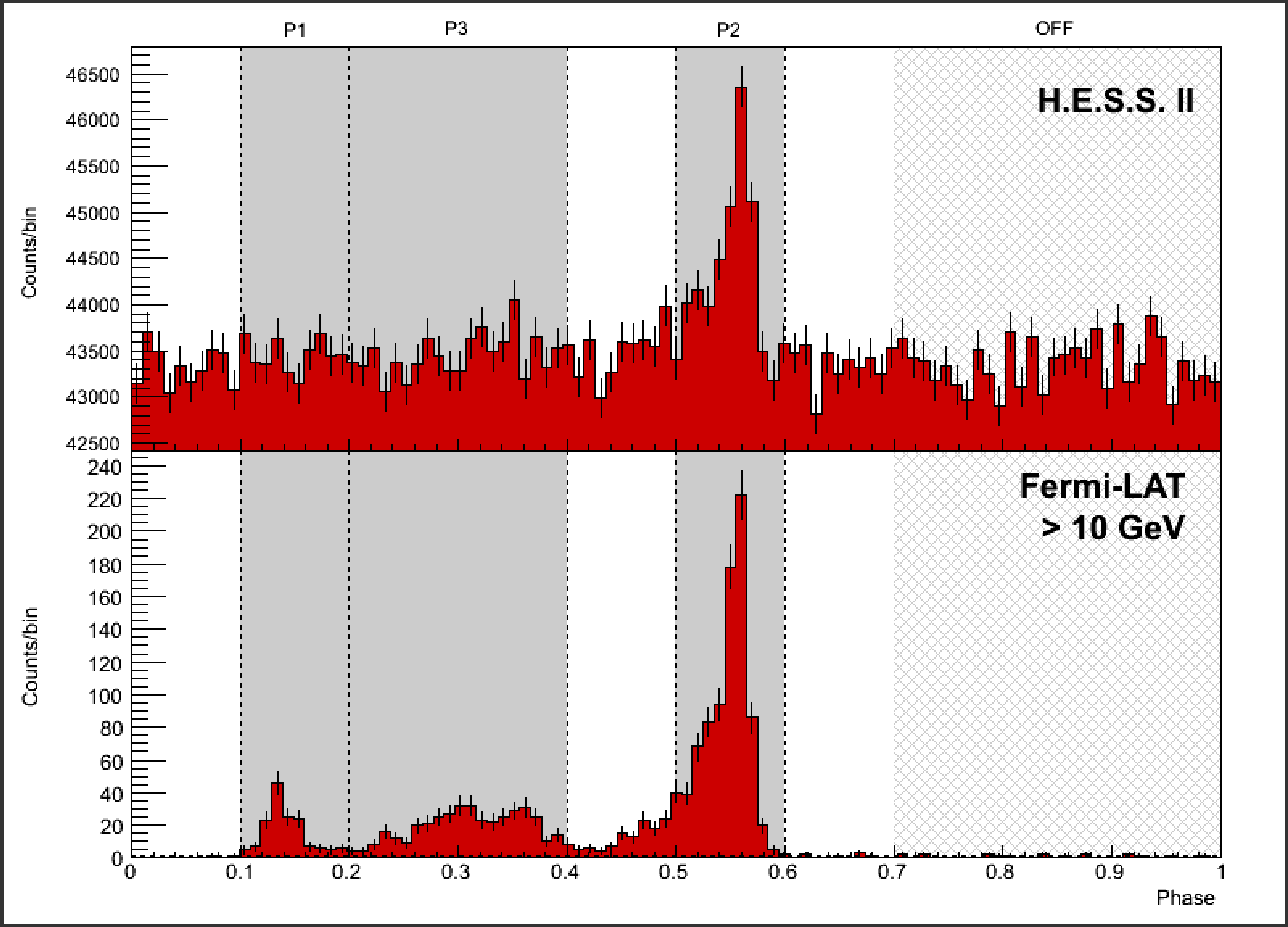
→ >TeV population of pulsed electrons





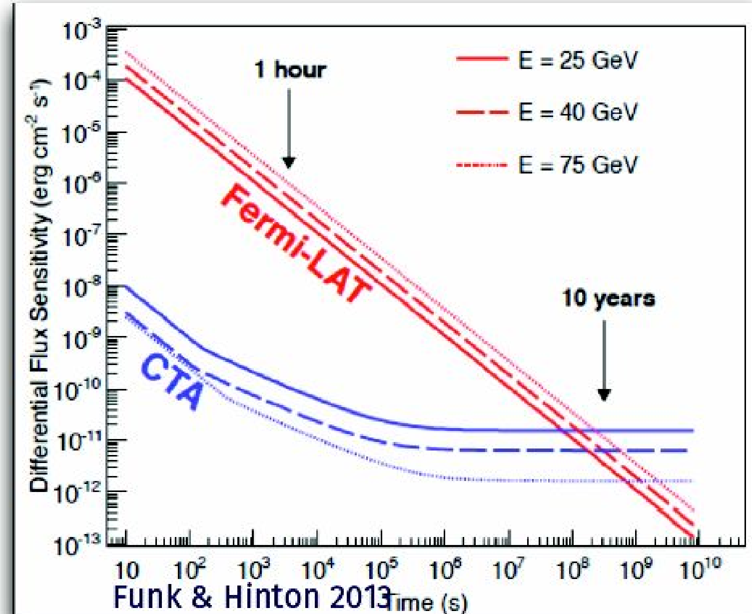
Vela Pulsar?

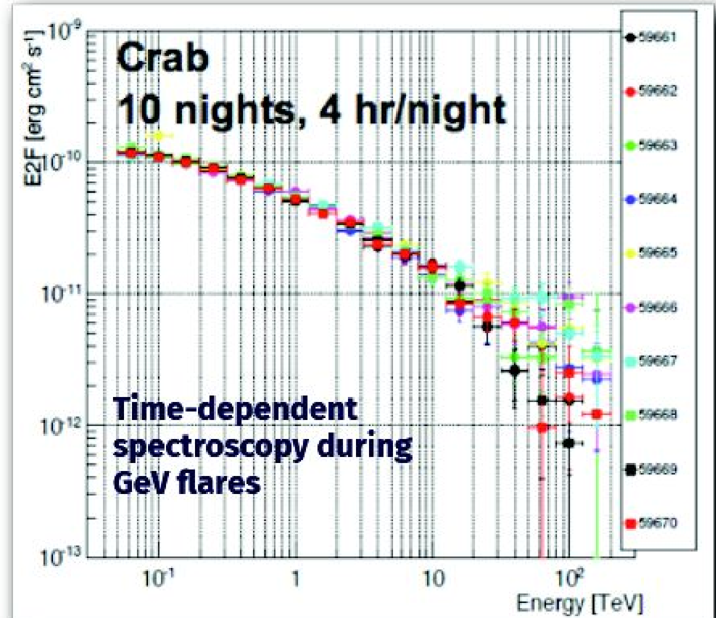
HESS-II Pulsed >20 GeV Emission from Vela Pulsar

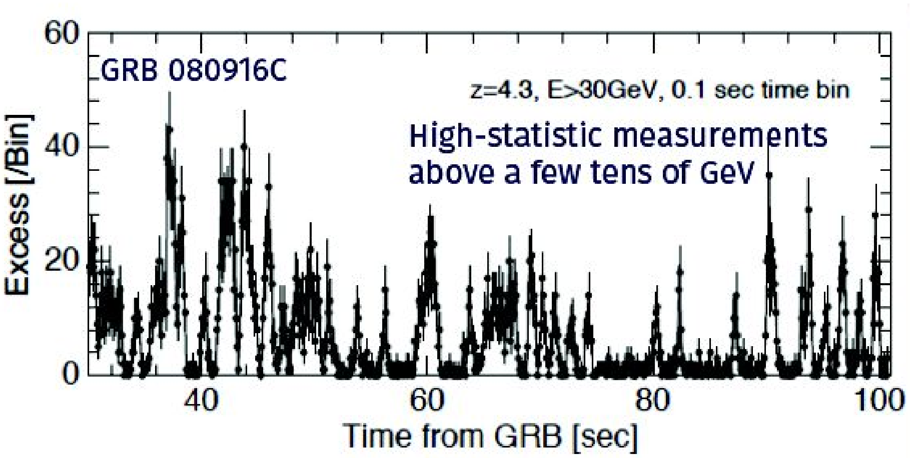


HESS 2017, 2018

Transients





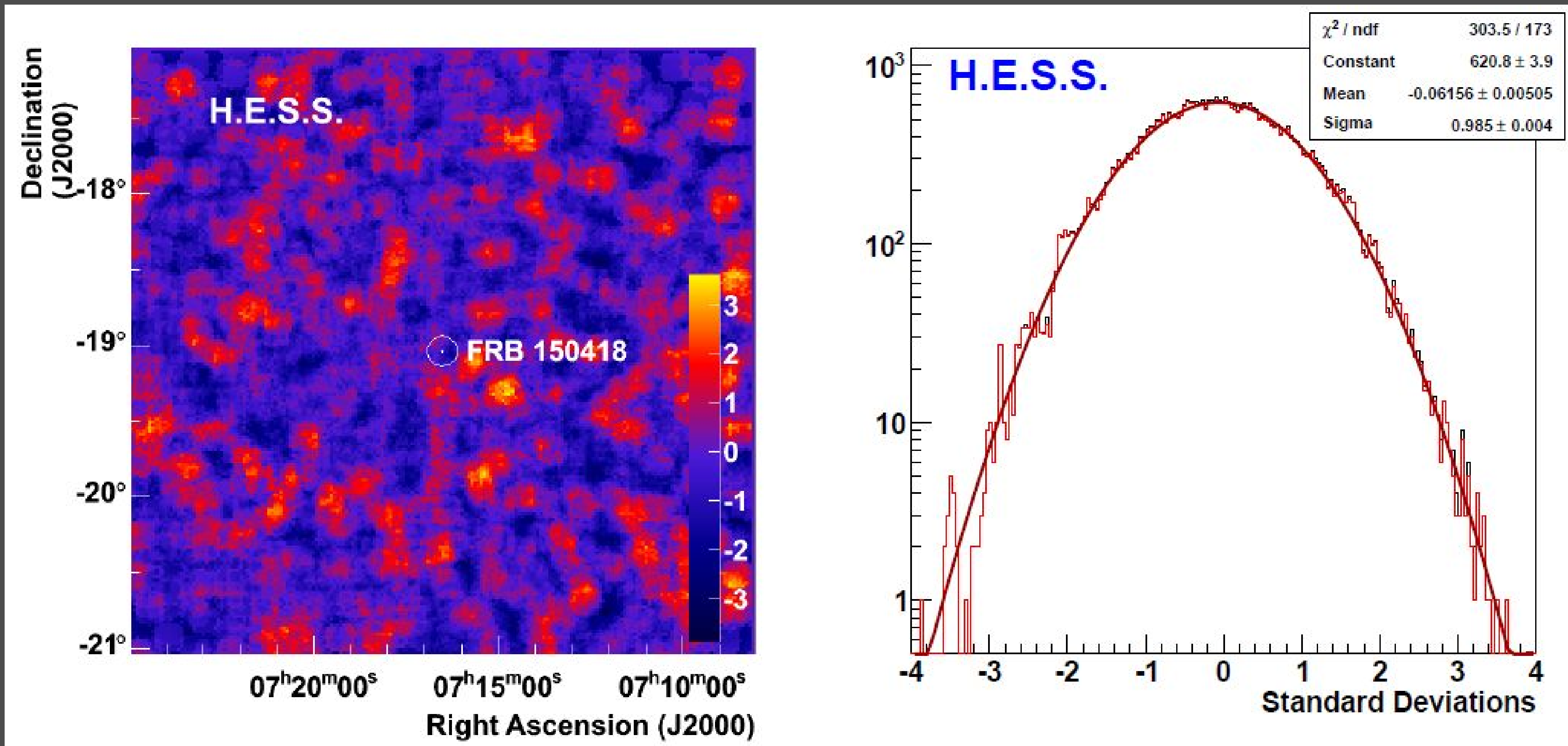


Inverse-Compton component of the 2011 April Crab flare assuming Γ=50. The variable tail from 10 to 100 TeV is clearly detectable.

The assumed GRB template is the measured Fermi-LAT light curve above 0.1 GeV, extrapolating the intrinsic spectra to VHE with power-law indices as determined by Fermi-LAT. We expect to detect ~1 GRB yr^{-1} site^{-1}.

HESS Follow-up of FRB 150418 (T+14.5hr)

- Triggered via email from the Parkes SUPERB team



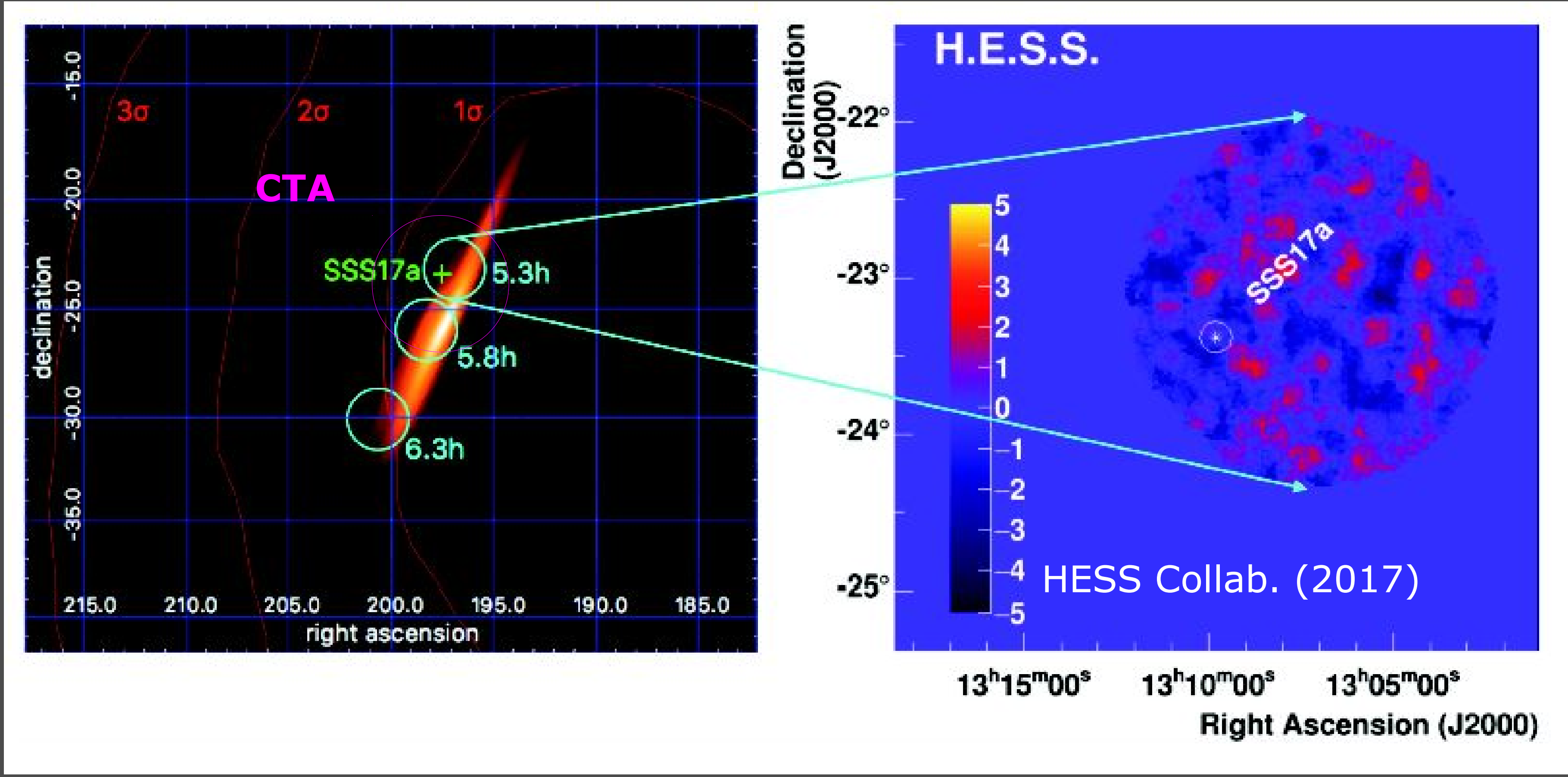
- TeV upper limit only (HESS+SUPERB A&A 2016)

→ Faster response needed: auto alerts & auto slewing ala GRBs

- Now receiving alerts from ASKAP-CRAFT (email)

GW170817 – HESS Follow-up

- 5.3h after GW event (first pointed telescope on target!)

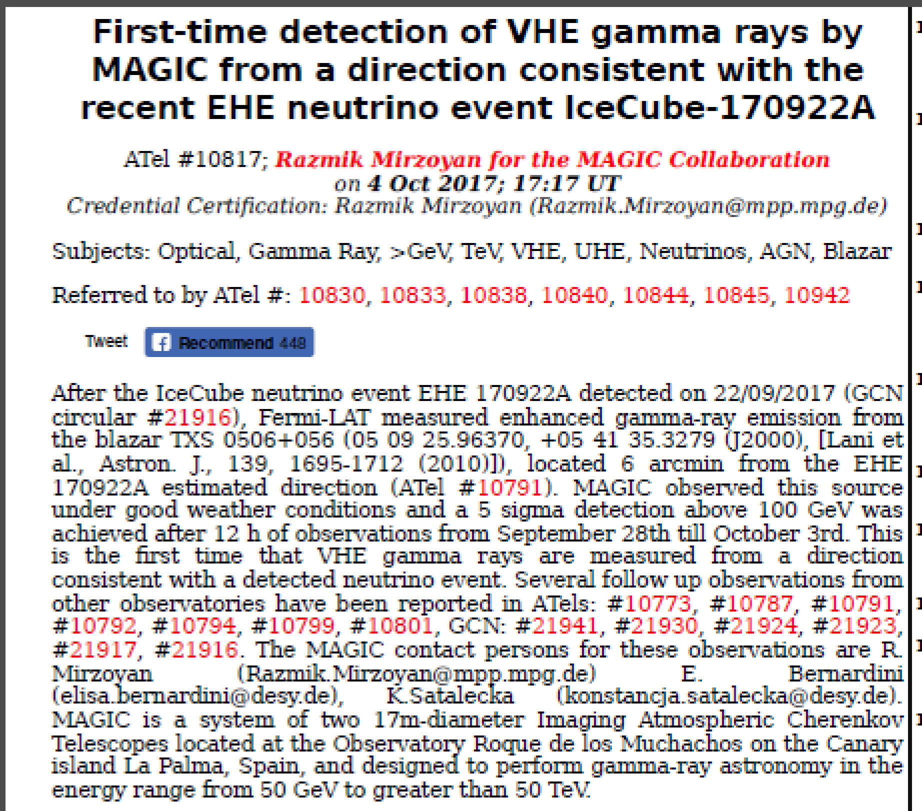


FoV FWHM: HESS ~3.0 deg
CTA >5.0 deg

- TeV upper limit only.
- EM counterparts in radio, optical, X-ray

Neutrino Event (IceCube EHE 170922A)

- TeV flare (5σ) from MAGIC
ATel #10817



First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

ATel #10817; ***Razmik Mirzoyan for the MAGIC Collaboration***
*on **4 Oct 2017; 17:17 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

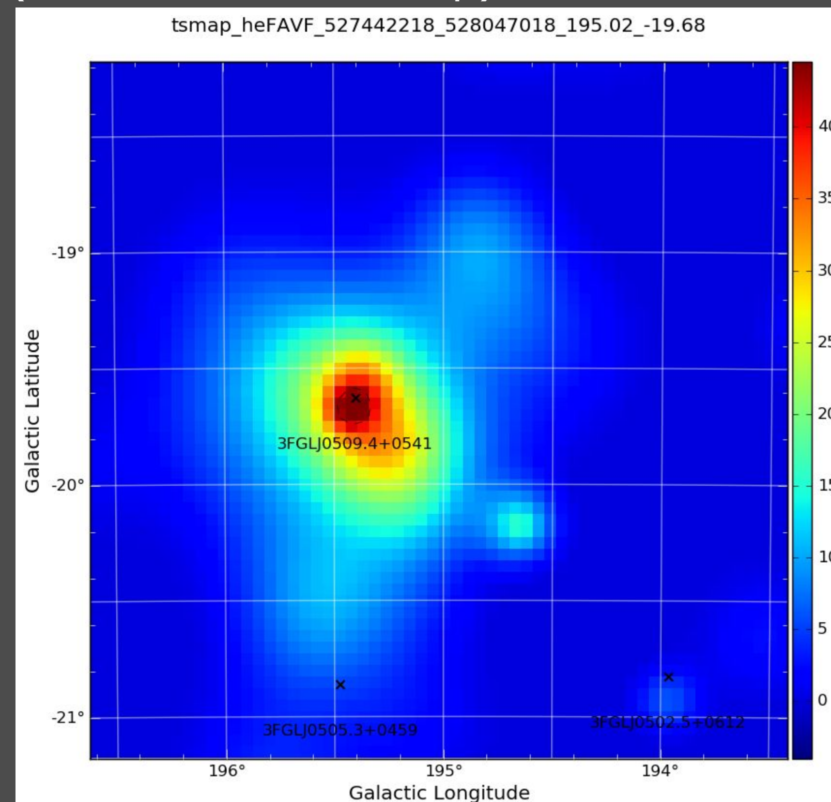
Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

Tweet Recommend 448

After the IceCube neutrino event EHE 170922A detected on 22/09/2017 (GCN circular #21916), Fermi-LAT measured enhanced gamma-ray emission from the blazar TXS 0506+056 (05 09 25.96370, +05 41 35.3279 (J2000), [Lani et al., Astron. J., 139, 1695-1712 (2010)]), located 6 arcmin from the EHE 170922A estimated direction (ATel #10791). MAGIC observed this source under good weather conditions and a 5 sigma detection above 100 GeV was achieved after 12 h of observations from September 28th till October 3rd. This is the first time that VHE gamma rays are measured from a direction consistent with a detected neutrino event. Several follow up observations from other observatories have been reported in ATels: #10773, #10787, #10791, #10792, #10794, #10799, #10801, GCN: #21941, #21930, #21924, #21923, #21917, #21916. The MAGIC contact persons for these observations are R. Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de) E. Bernardini (elisa.bernardini@desy.de), K.Satalecka (konstancja.satalecka@desy.de). MAGIC is a system of two 17m-diameter Imaging Atmospheric Cherenkov Telescopes located at the Observatory Roque de los Muchachos on the Canary island La Palma, Spain, and designed to perform gamma-ray astronomy in the energy range from 50 GeV to greater than 50 TeV.

- GeV flare from Fermi-LAT
ATel #10791
(0.8-300 GeV TS map)

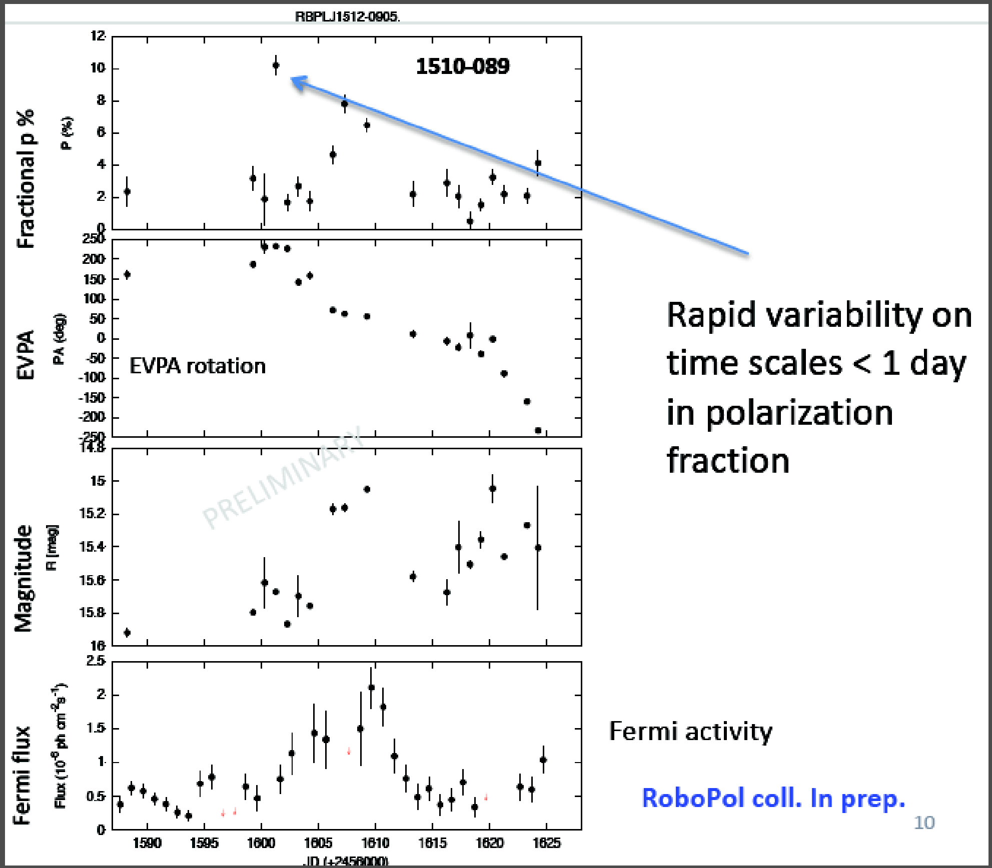


→ Linked to AGN TXS 0506+056
→ More multi-messenger astronomy!!

CTA: Optical Telescope Support

On-site telescope:
Meet ~30% of CTA's optical
 Needs (AGN, transients..)

- Photometry magnitude ~20
- Polarimetry magnitude ~17
- Polarimetric accuracy 0.5-1%
- 5'x5' FoV
- Intranight cadence
- Fast (<2') repointing

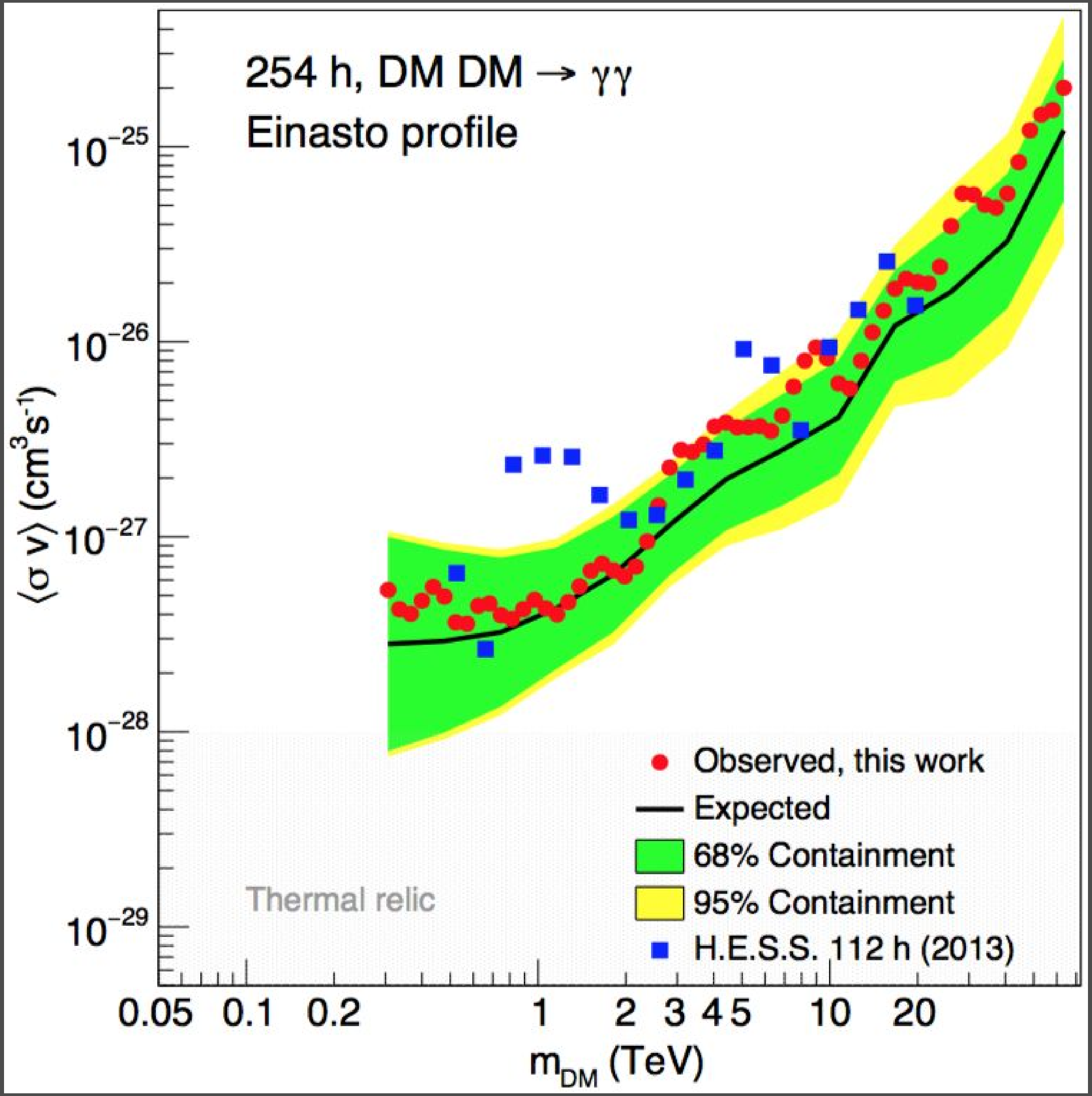


Optical Support Committee Conclusions

On-site 1m telescope + access to >2m telescopes via MoUs time purchase etc. will fulcil science needs.

Australian optical tels.
Not contemporaneous but essential for 24hr monitoring coverage
→ MoUs etc.??

Dark Matter Line at the Galactic Centre?



CTA will certainly lower this limit >1 TeV

HESS Phys Rev. Lett 2018

Items for Discussion...

1. Domestic/International Meetings (2018/19)
   1st CTA Symposium - Bologna (Nov/Dec "fall" 2018)

2. Linkages with Australian Surveys (Radio, Optical)
   - CTA/ASKAP Survey shadowing (few hrs common time in S)
   - CTA optical requirements
   - CTA data in Australia → ASVO node?
   - MoUs/agreements? Start thinking now.

3. Getting involved in CTA's Work Packages (WPs)
   - CTA analysis algorithms
   - Data Challenge (DC)
   - Optimise science cases for WPs

4. Next CTA-Australia Meeting (April 2018)

5. CTA-Australia Website
http://www.physics.adelaide.edu.au/astrophysics/CTA_Australia/index.html

Upcoming Meetings 2018+

- WP-PHYS Face to face Barcelona 14-18 Apr
  Einecke

- General Meeting Paris 14-18 May
  Rowell, Einecke, ….

- ASA/ASM Swinburne 25-29 June
  Rowell (CTA status poster, +HESS HGPS?).
  Snoswell, Voisin, Blackwell, Curzons (HESS/ISM/modeling posters)

- TeVPA Berlin 27-31 Aug

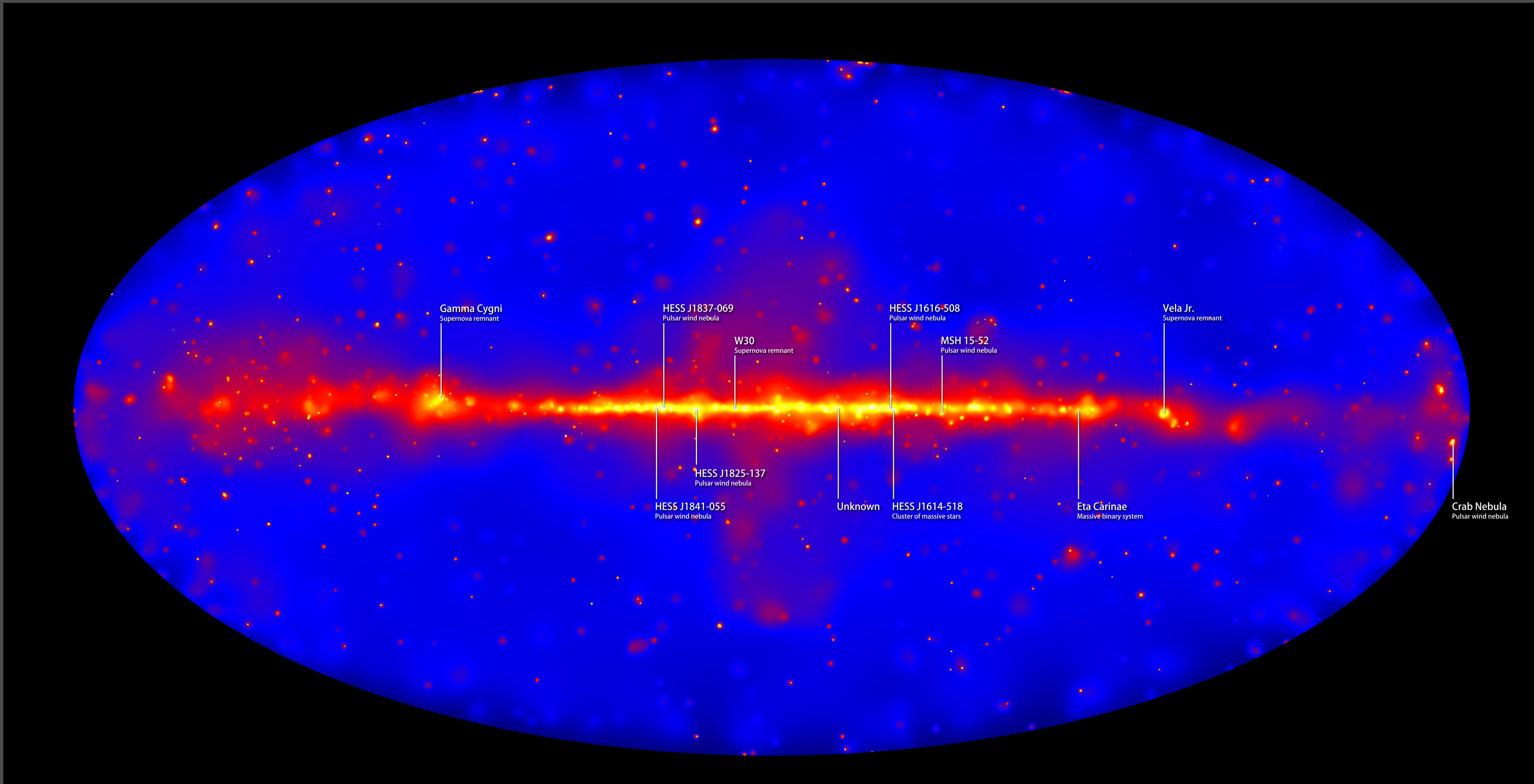
- General Meeting DESY-Berlin 24-28 Sept

- 1st CTA Symposium Bologna (Nov/Dec "fall" 2018)
  → strengthen MWL/MM links

- CTA-Australia Meeting #7 Late 2018   Adelaide?

Thank you....

Fermi-LAT 2FHL >50 GeV



https://www.nasa.gov/sites/default/files/thumbnails/image/2fhl_all-sky_labels_0.jpg

→ Probably a good precursor to CTA's survey potential.

Science Working Group:
1st CTA Data Challenge

Aims:

Simulate realistic version of future CTA data as delivered to users

Involved larger number of CTAC members in looking at "data"

Test and develop analysis tools

Simulated data set:

3 years of CTA KSP data, for both sites

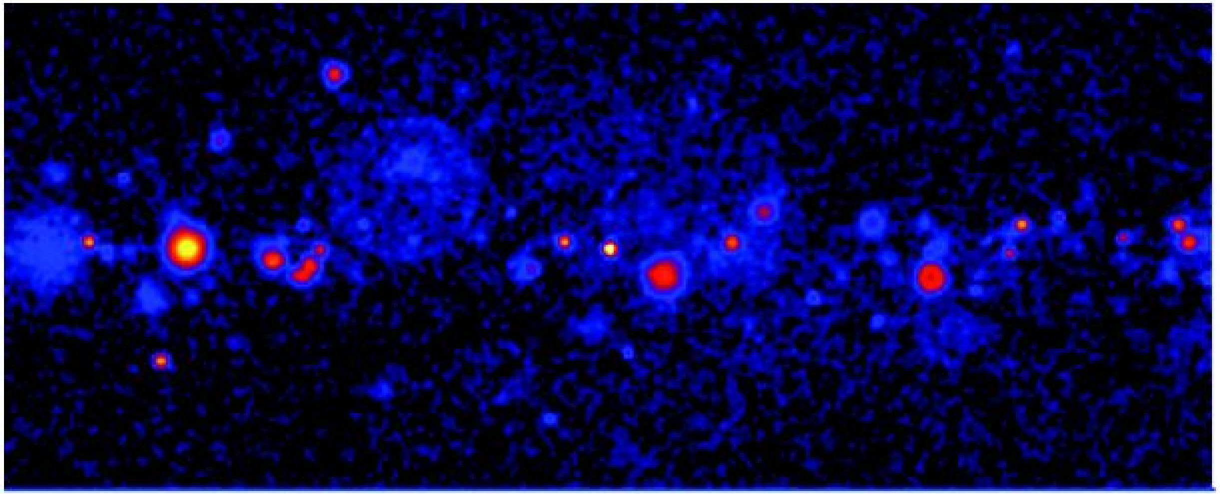
Galactic Plane Survey (1620 h), Galactic Centre Survey (825 h), Extragal. Survey (500 h), AGN monitoring (960 h)

Data released late August 2017

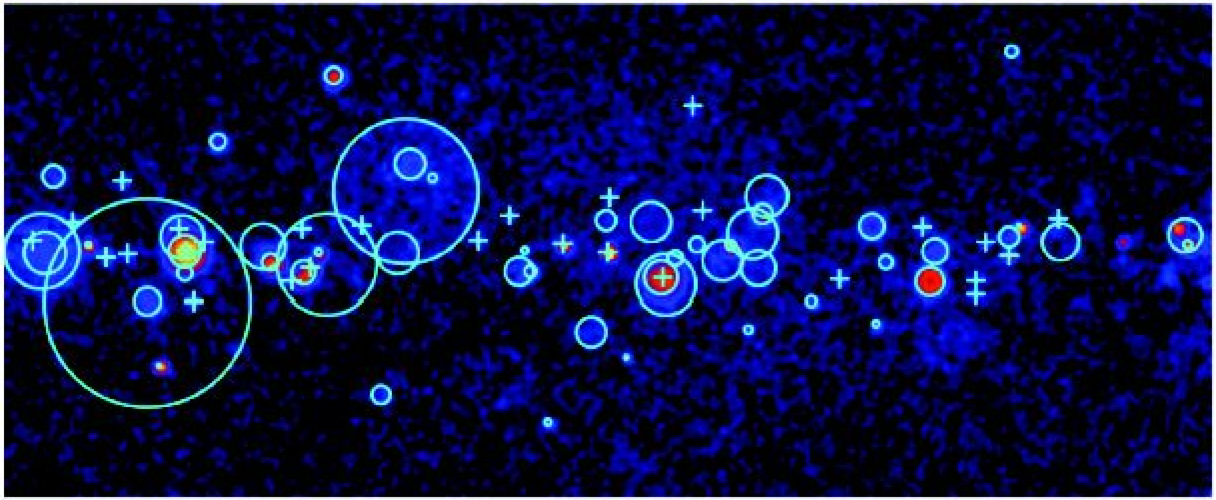
- Analysis software based on common tools & data structures used widely in astronomy (FITS, ftools, python..)

ctools - http://cta.irap.omp.eu/ctools/

Science Working Group: 1st CTA Data Challenge



Section of simulated Galactic Plane Survey



Sources detected by early version of an analysis pipeline

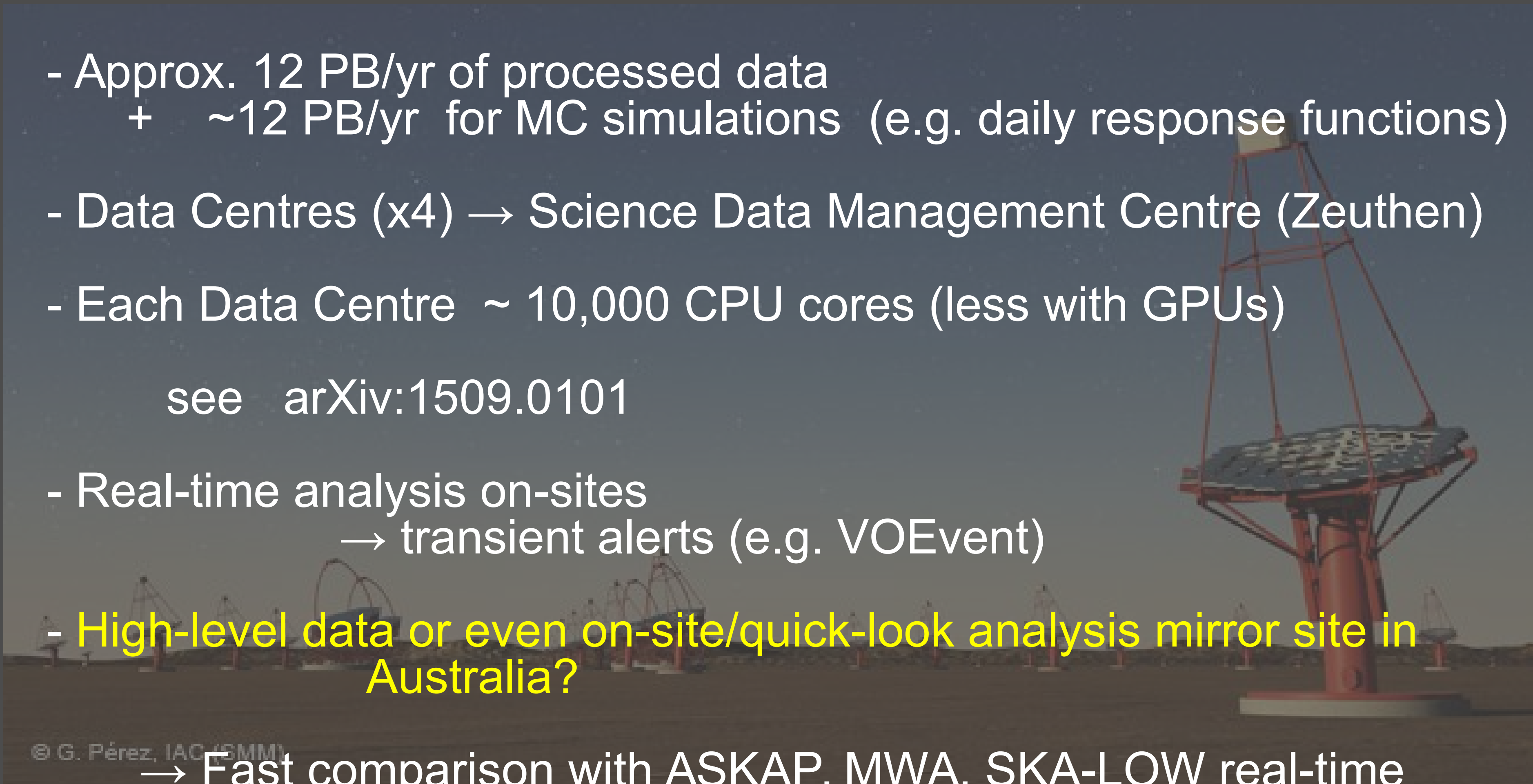
Computing Model summary

Experiment	Long term storage	Archive type	Computing Model
ALMA Observatory	0.400 PB/year (2017)	ALMA Front End Archive and ALMA Science Archive (50/50)	Central Archive in Santiago then copy to ALMA Regional Center Europe, North America and East India. Distributed User Support
LSST	55PB/year (2023) plus 15PB Science Archive (2033)	Long term Archive and Science Archive	Three datacenters with full copy of raw and processed data in each. Distributed Data Access Service.
LHC	73PB/year (2016)	Raw data and Science Archive	Distributed (Tier-0, 13 Tier-1, 130 Tier-2) Grid, Cloud, opportunistic resources.
SKA Observatory	300PB/year (2024)	Phase 1 - Science Archive	Two Science Data Processing Center in host countries, n Regional Data Centers – Distributed user support

cta: 12PB (including 0.6PB for Science Archive)

Slide from N. Neyroud

CTA: Data



- Approx. 12 PB/yr of processed data
  + ~12 PB/yr for MC simulations (e.g. daily response functions)

- Data Centres (x4) → Science Data Management Centre (Zeuthen)

- Each Data Centre ~ 10,000 CPU cores (less with GPUs)

  see arXiv:1509.0101

- Real-time analysis on-sites
  → transient alerts (e.g. VOEvent)

- High-level data or even on-site/quick-look analysis mirror site in Australia?

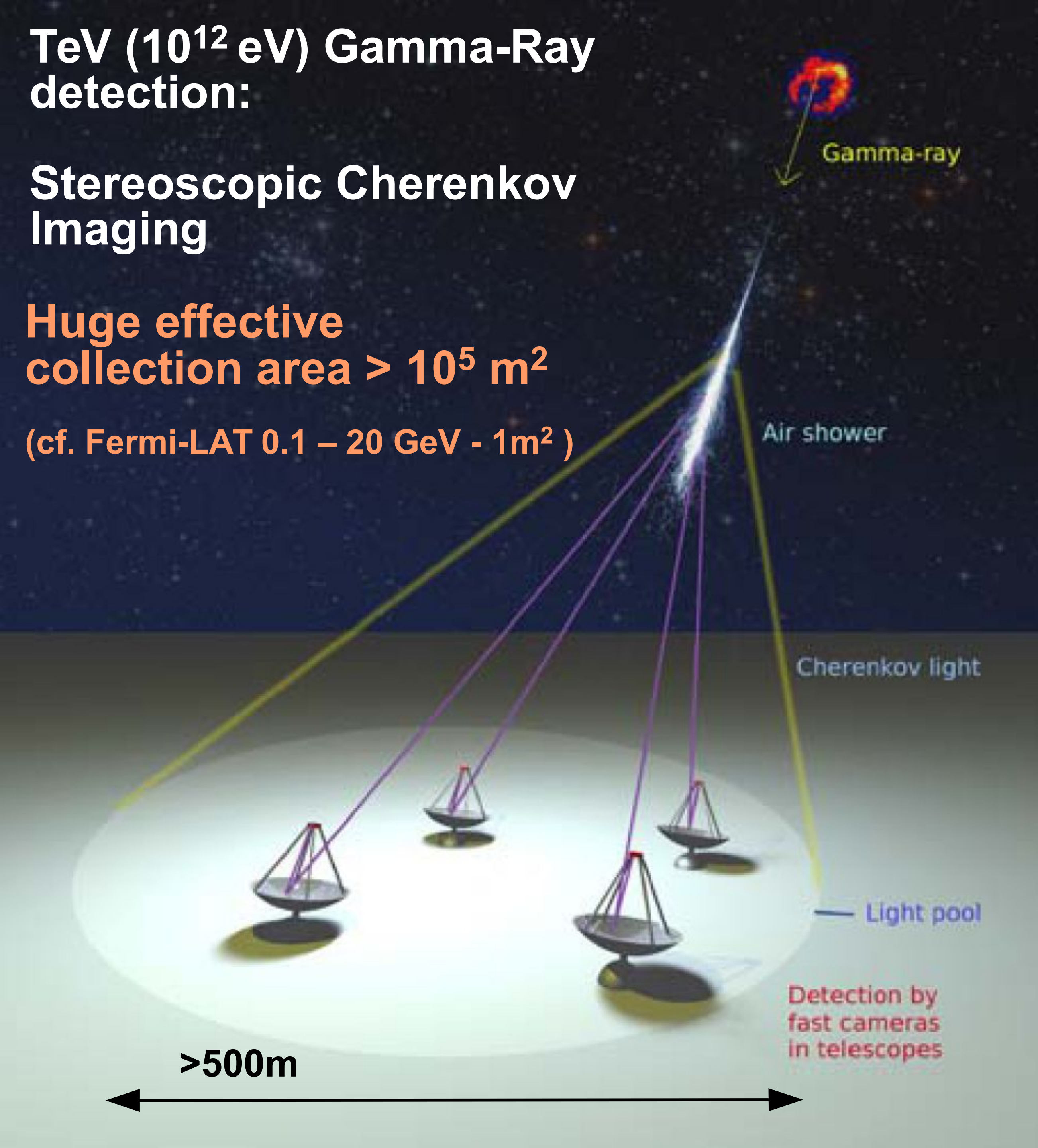
  → Fast comparison with ASKAP, MWA, SKA-LOW real-time analyses of transients....

TeV (10^{12} eV) Gamma-Ray detection:

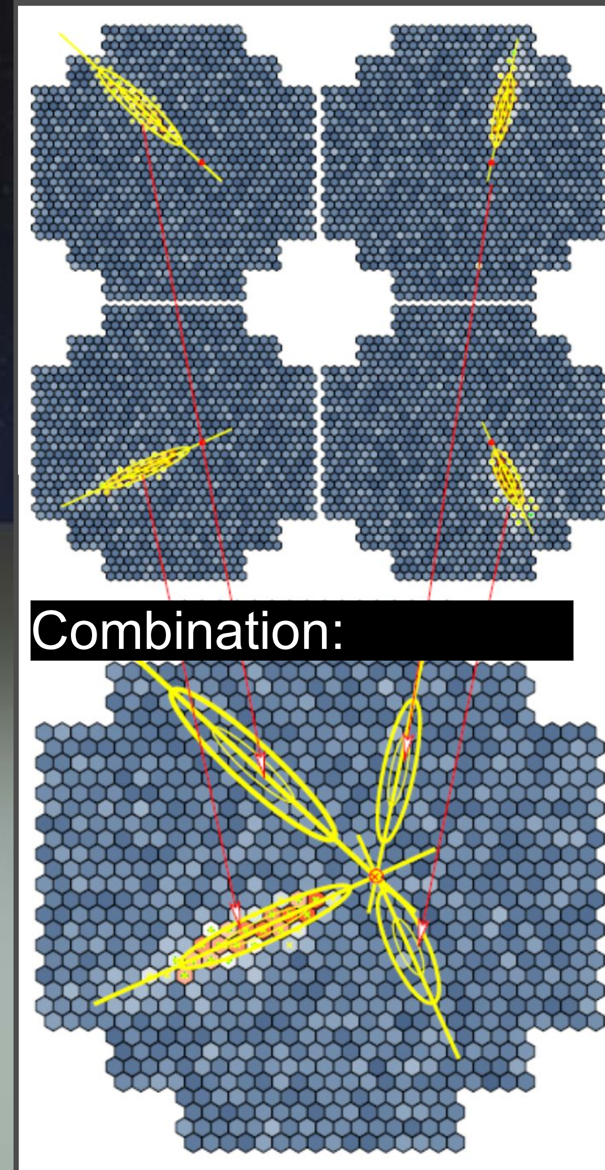
Stereoscopic Cherenkov Imaging

Huge effective collection area > 10^5 m^2

(cf. Fermi-LAT 0.1 – 20 GeV - 1m^2)



Cherenkov 'image' as viewed by each telescope



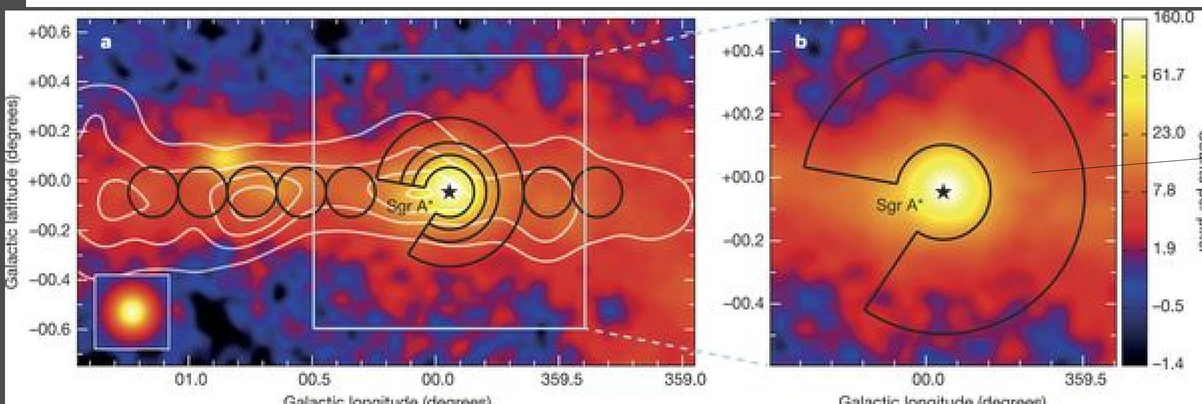
LETTER

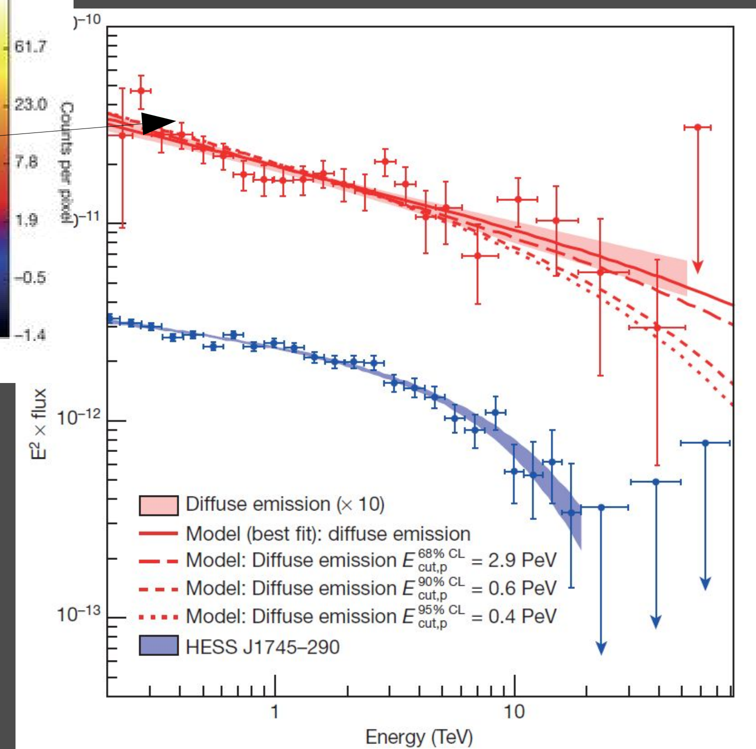
doi:10.1038/nature17147

Acceleration of petaelectronvolt protons in the Galactic Centre

H.E.S.S.

HESS Collaboration*





- Hard spectrum from diffuse region 70pc
- Cutoff ~ PeV energies
- Continous CR injector over ~few1000yr

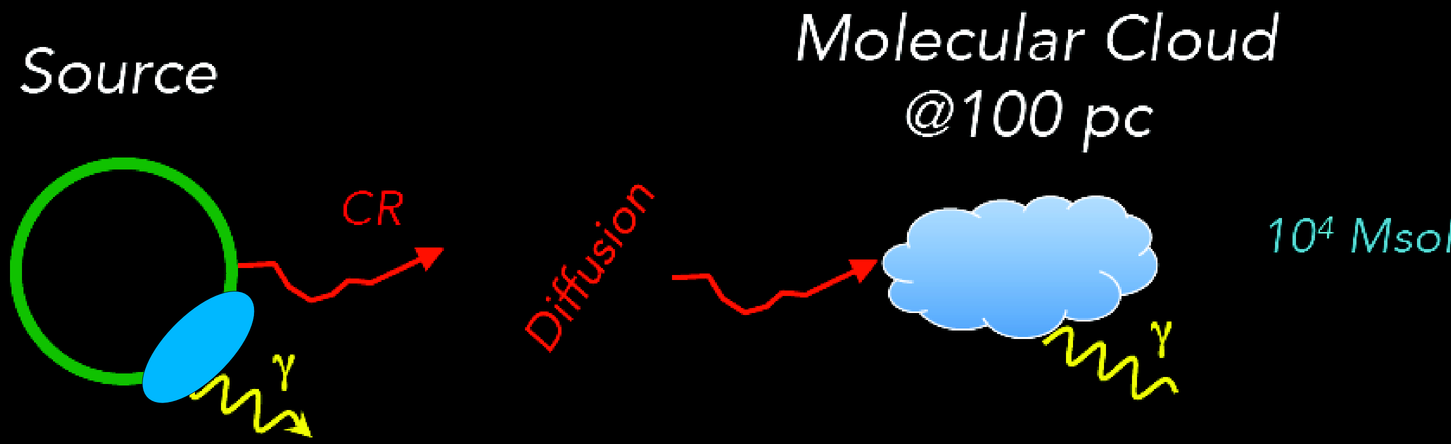
→ Central BH most likely accelerator

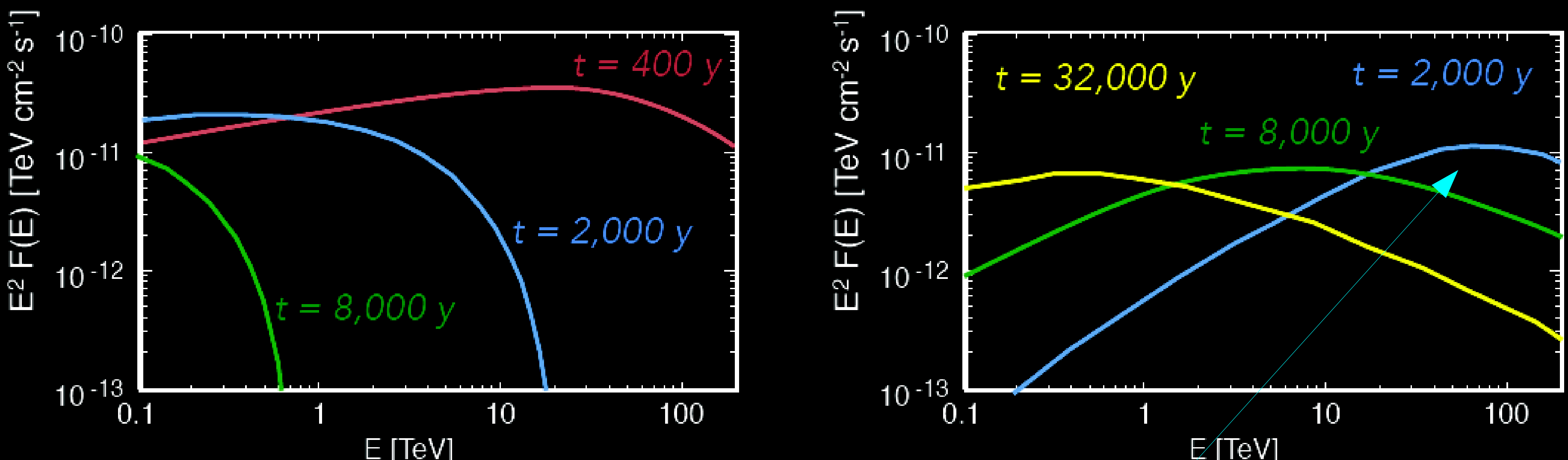
→ Could explain galactic CRs >0.1 PeV if BH more active in past.

(SNRs may still contribute some PeV CRs)

Gamma-ray spectra from local and escaped CRs

e.g. Aharonian & Atoyan 1996





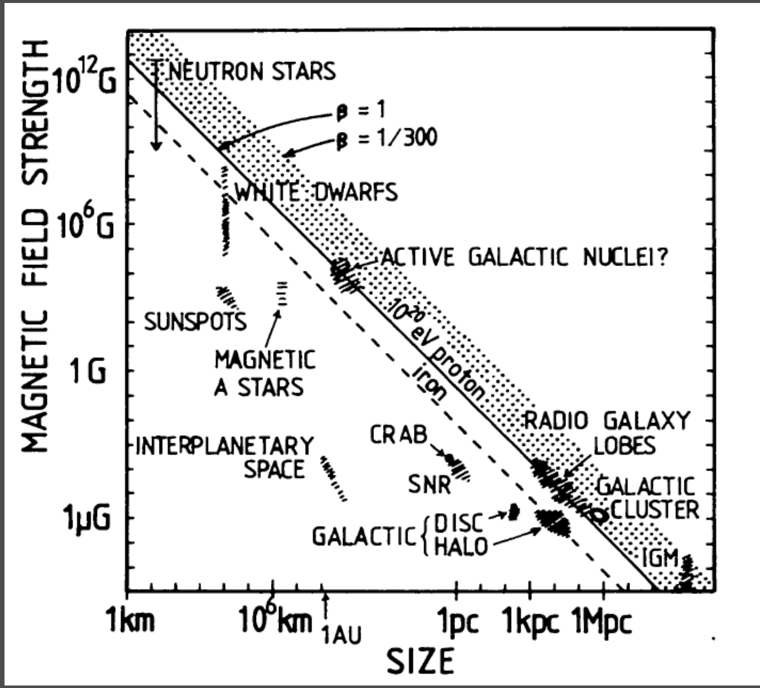
From Gabici & Aharonian (2007)

Slide from Richard White

→ Ideal way to search for PeVatrons! (E_γ > 100 TeV)

Galactic **TeVatrons** and **PeVatrons**

What are the particle accelerators to E ~ 10^{15} eV (1 PeV)?



- Shell Type Supernova Remnants?
W_{CR} ~ 10^{50} erg per SNR

$$E \approx 1(B/\mathrm{mG})(\Delta T/100\ \mathrm{years})\ \mathrm{PeV}$$

- Pulsar Wind Nebulae?
Pulsar *spin-down* power

$$\dot{E} = I\omega\dot{\omega} \sim 10^{32} \text{ to} \sim 10^{39} \text{ erg s}^{-1}$$

- Pulsars? Rotating dipole B

$$E_{max} \approx 8 \times 10^{20} Z (B/10^{13}\mathrm{G})(\omega/3000\mathrm{Hz})^2 \text{ eV}$$

- WR, O & B stars, Massive Stellar Clusters,
Stellar wind KE
B-star L_w~$10^{34\text{-}35}$ erg/s   ***WR star L_w*** **~ $10^{38\text{-}39}$ erg/s**

$$L_w = \frac{1}{2}\dot{M}v_\infty^2$$

→ Superbubbles (kpc-scale shocks)?   **→ Hillas plot**

- X-Ray Binaries, Microquasars, Active galaxies (AGN)
Accretion power
Galactic $L_{acc} \sim 10^{40} \text{ erg s}^{-1}$ **AGN** $L_{acc} \sim 10^{46} \text{ erg s}^{-1}$