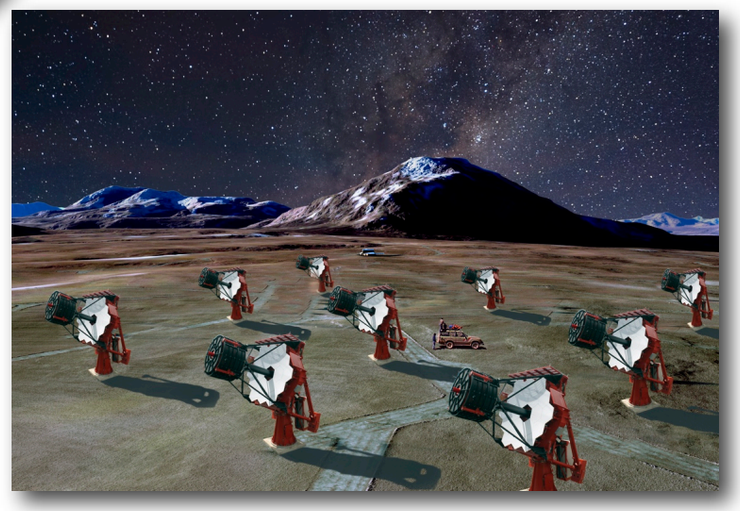


Astrofisica con Specchi a Tecnologia Replicante Italiana

cherenkov telescope array

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

Universidade de São Paulo
Instituto de Astronomia, Geofísica e Ciências Atmosféricas

MIUR

NORTH-WEST UNIVERSITY
YUNIBESITI YA BOKONE-BOPHIRIMA
NOORDWES-UNIVERSITEIT

Il Cherenkov Telescope Array e scienza con ASTRI

Stefano Vercellone (INAF/IASF Palermo)
for the ASTRI Collaboration & the CTA Consortium

Outline

The Cherenkov Telescope Array (CTA)

Galactic Key Science Projects

The ASTRI mini-array

Galactic science goals

Credits: E. Giro

The Cherenkov Telescope Array (CTA)

Galactic Key Science Projects

Most of the CTA material is still under embargo. If you need more information, please, contact me:

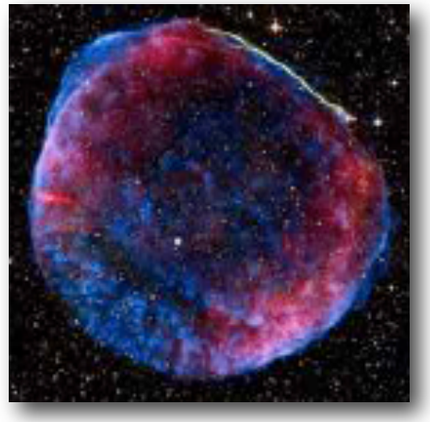
stefano@ifc.inaf.it

Credits: E. Giro

The CTA Project - What?

Cosmic Particle Acceleration

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



Probing Extreme Environments

- Processes close to neutron stars and black holes
- Processes in relativistic jets, winds and explosions
- Exploring cosmic voids

Physics frontiers – beyond the Standard Model

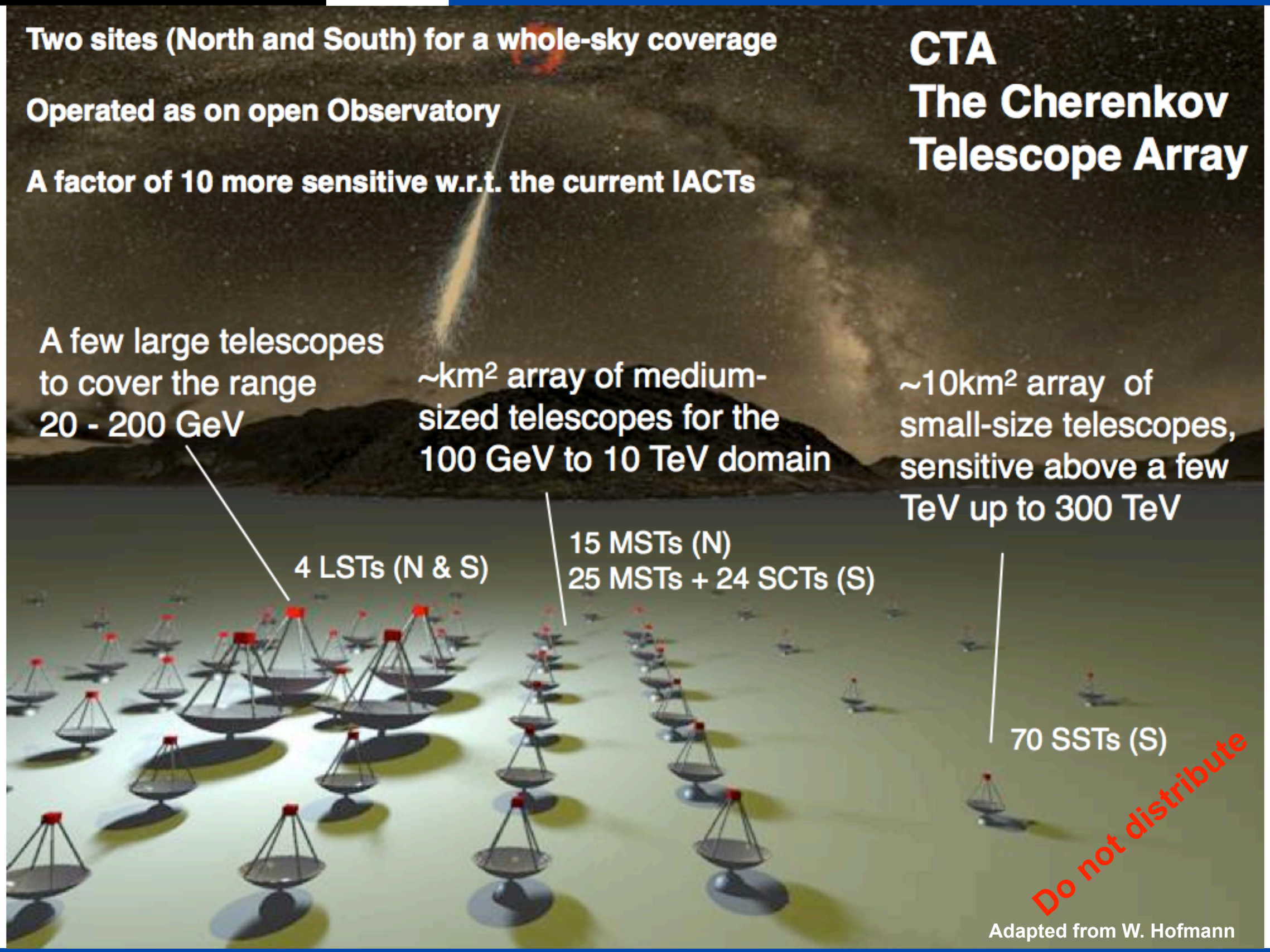
- What is the nature of Dark Matter? How is it distributed?
- Is the speed of light a constant for high-energy photons?
- Do axion-like particles exist?

Adapted from J. Knödlseder

More information:

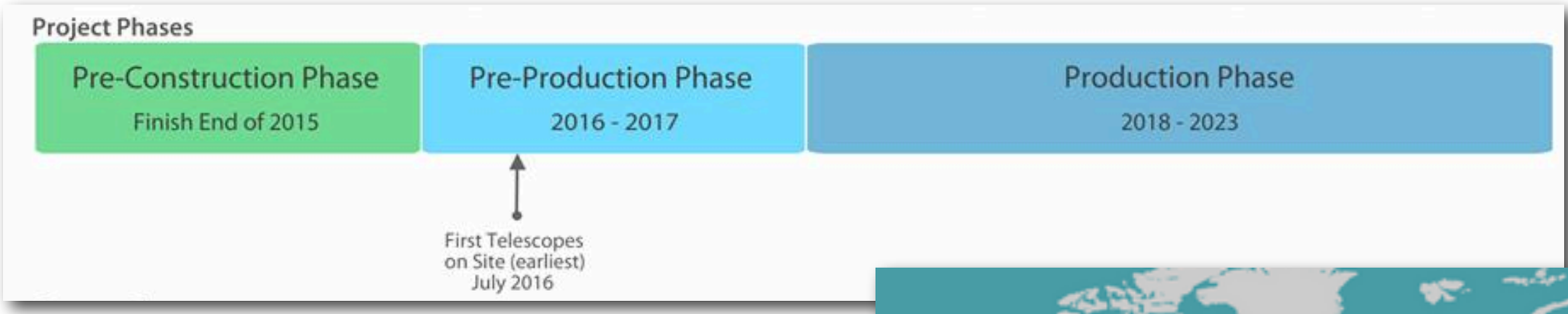
Astroparticle Physics, Vol. 43, 1-356 (2013) & 2015 ICRC Conference Proceedings, arXiv:1508.05894

The CTA Project - How?



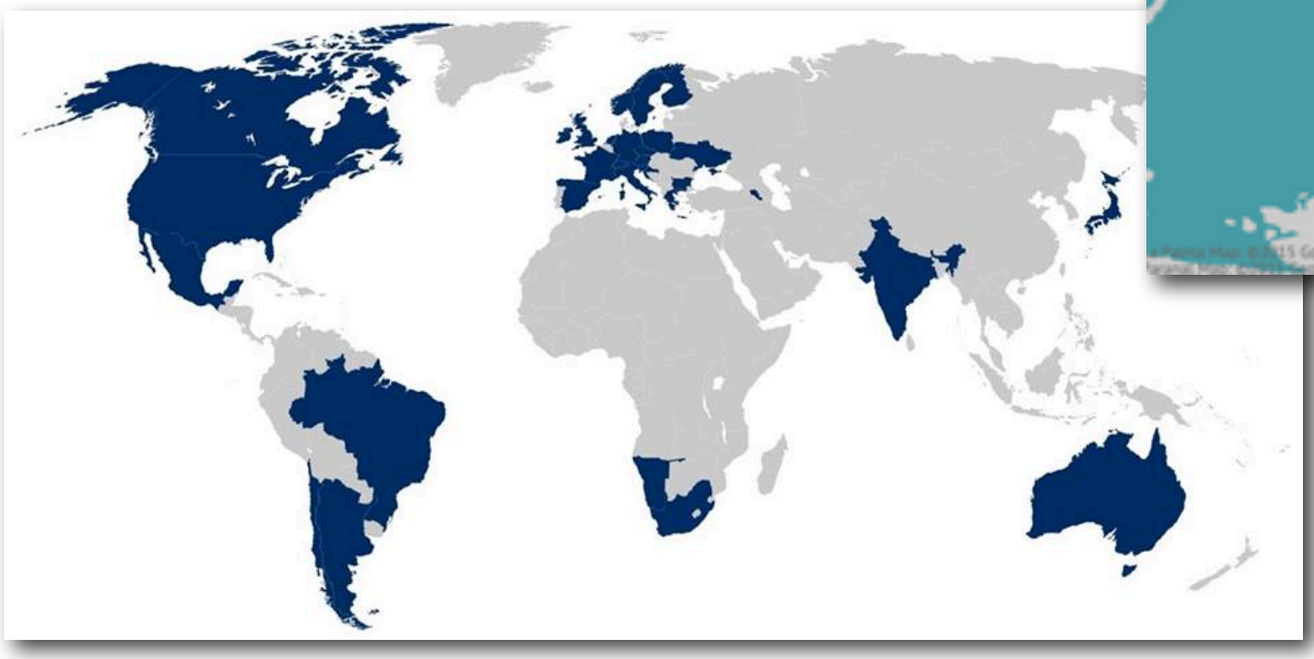
Adapted from W. Hofmann

The CTA Project - Who, Where & When?



CTA Consortium

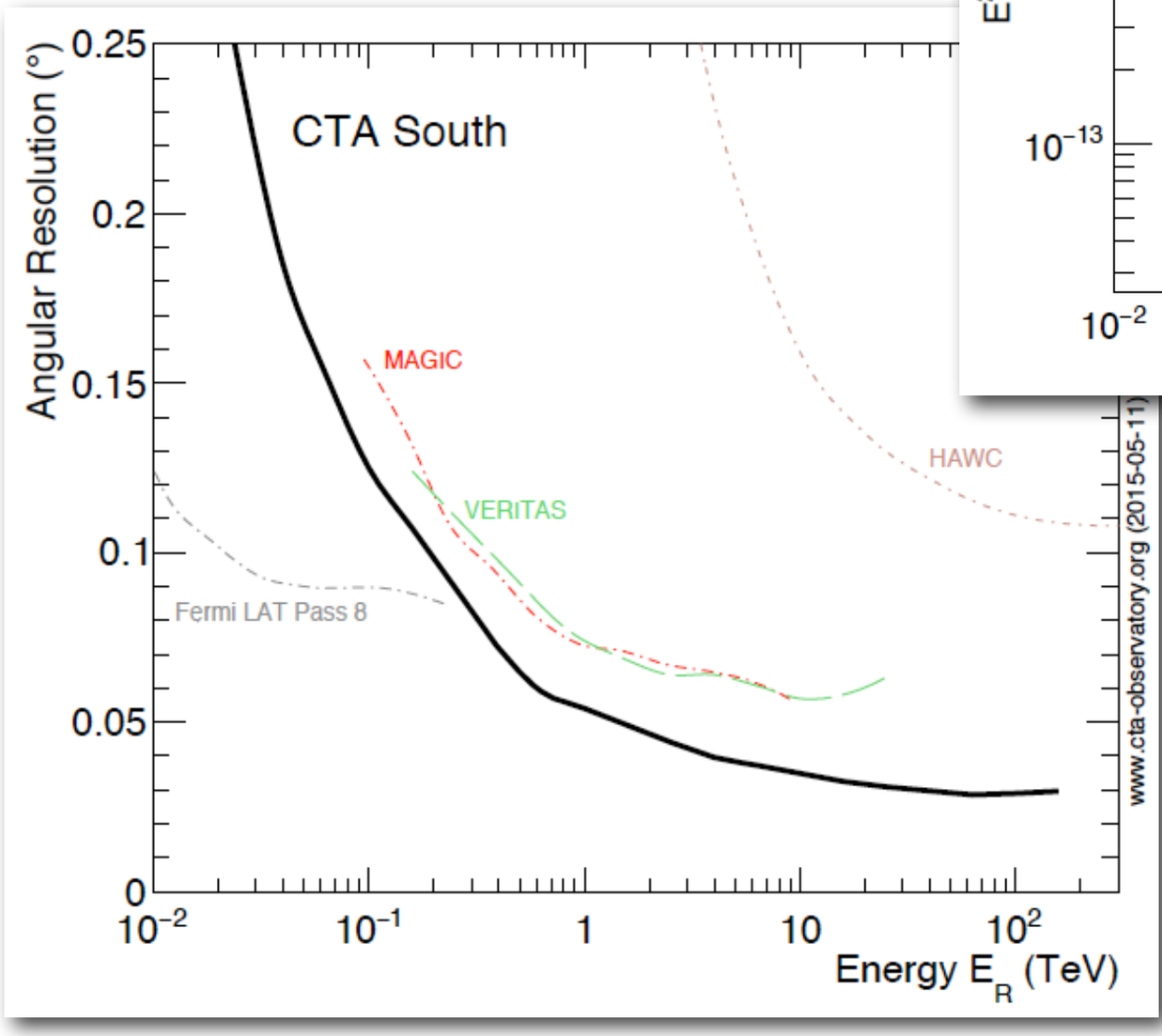
5 Continents
31 Countries
194 Institutes
1281 Members

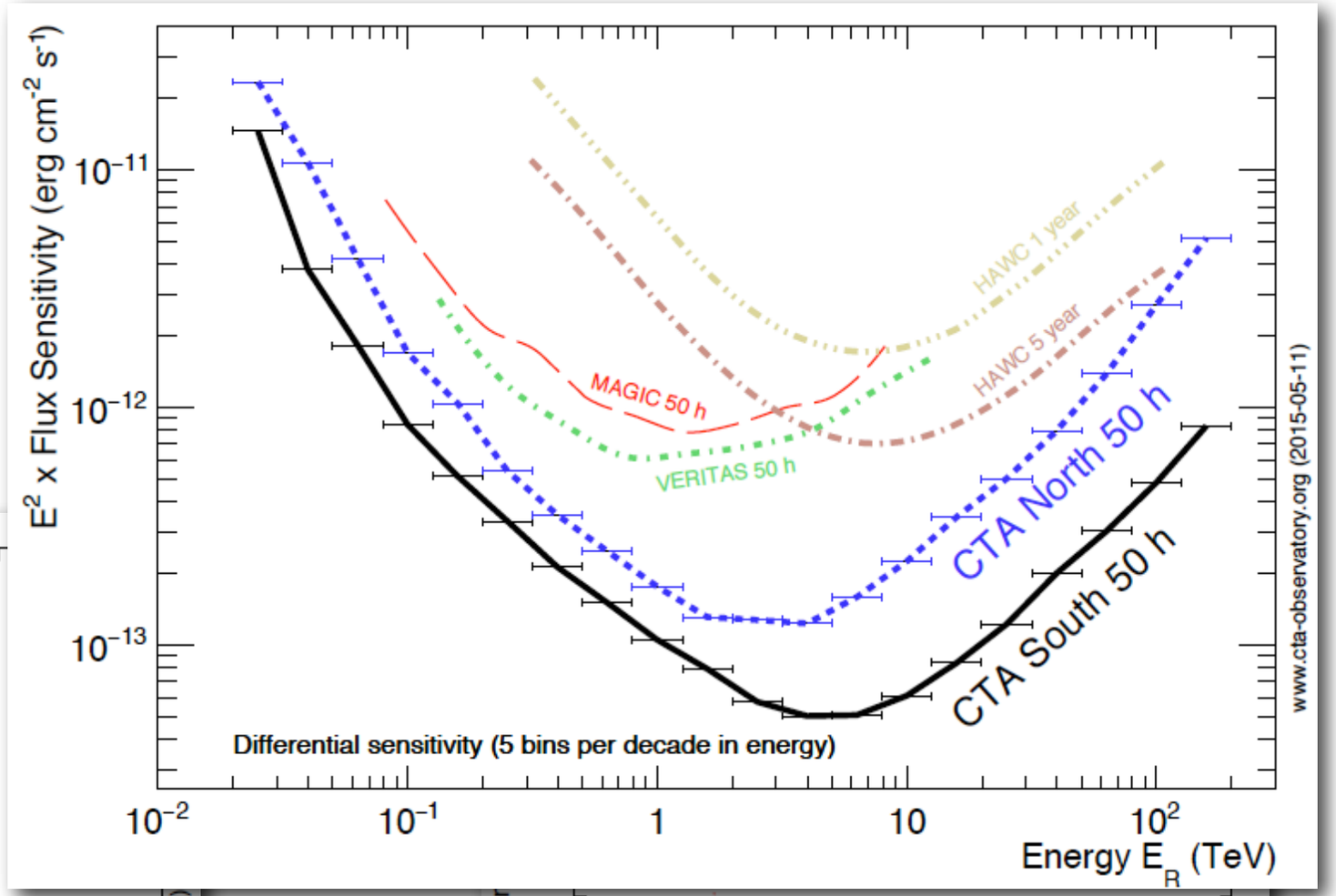


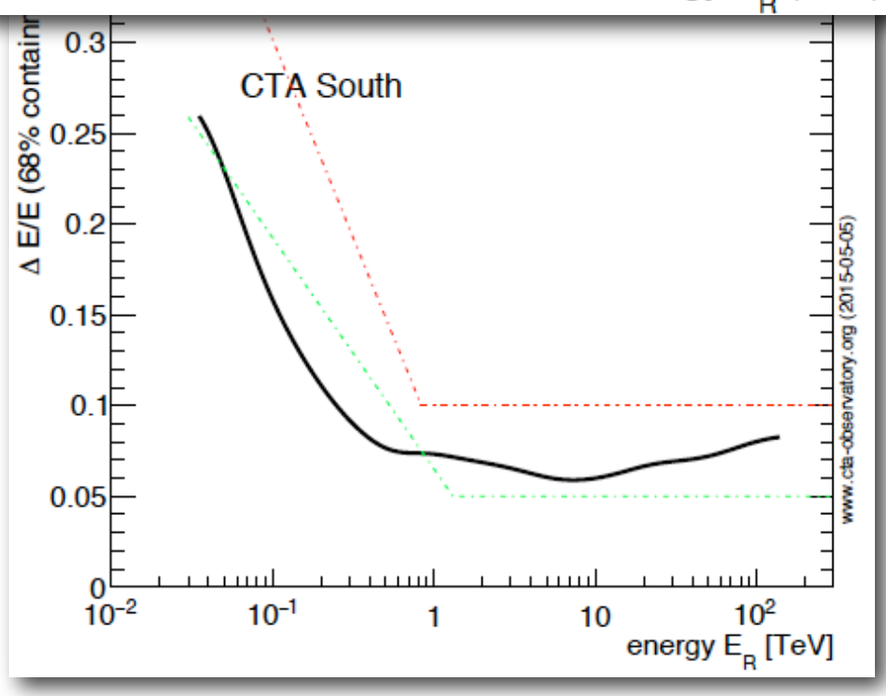
Courtesy of The CTA Consortium

CTA main performance

Courtesy of The CTA Consortium

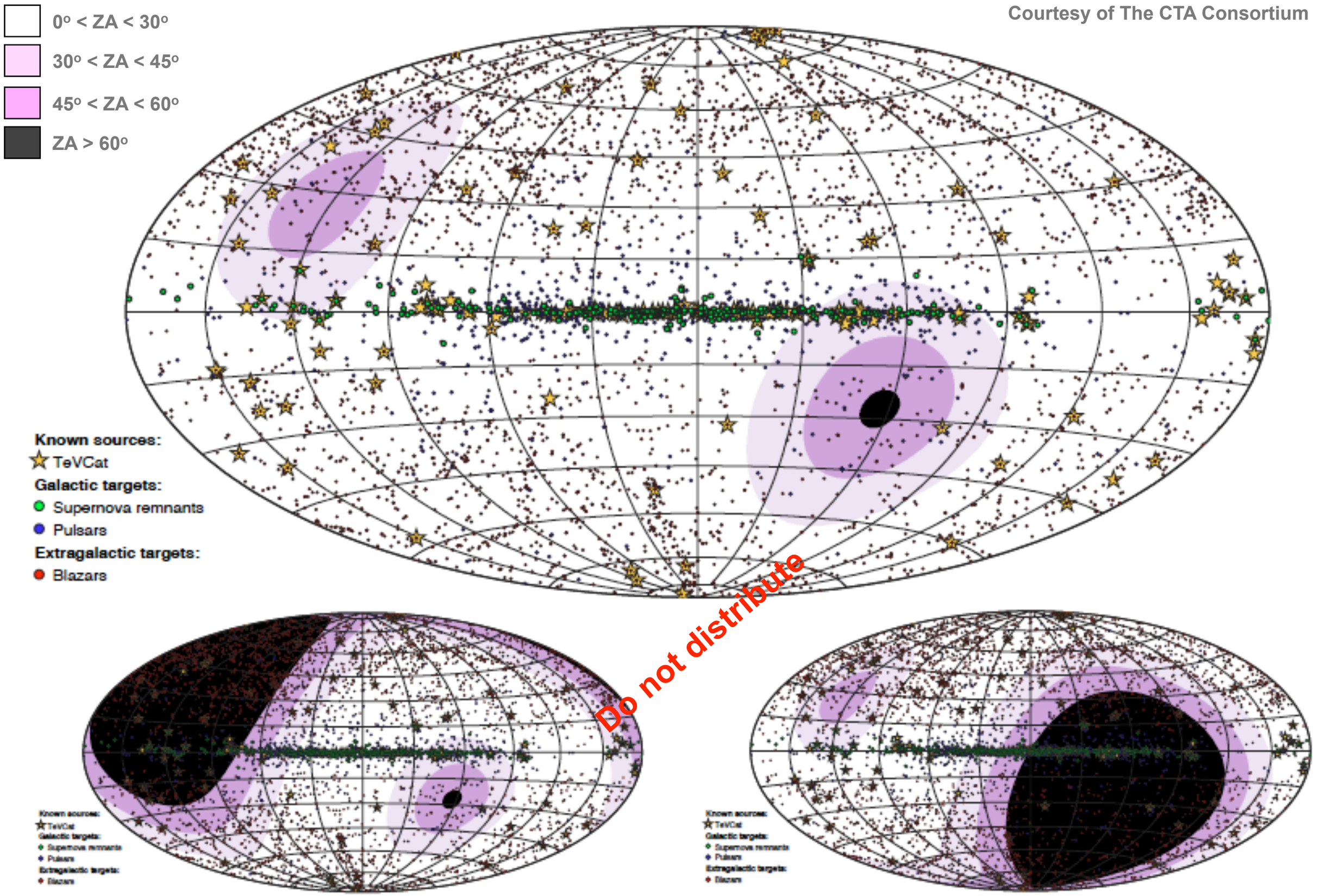






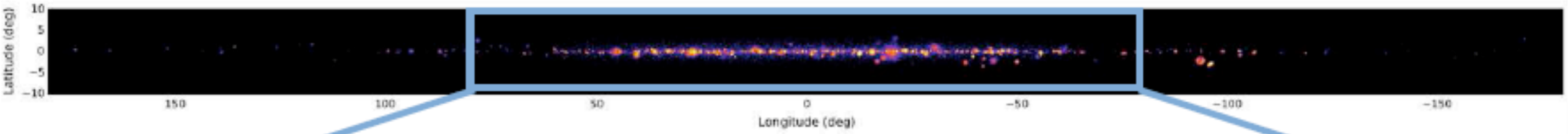
CTA as a whole-sky Observatory

Courtesy of The CTA Consortium

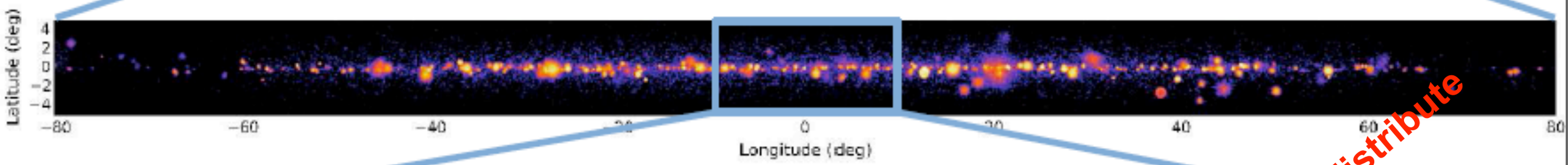


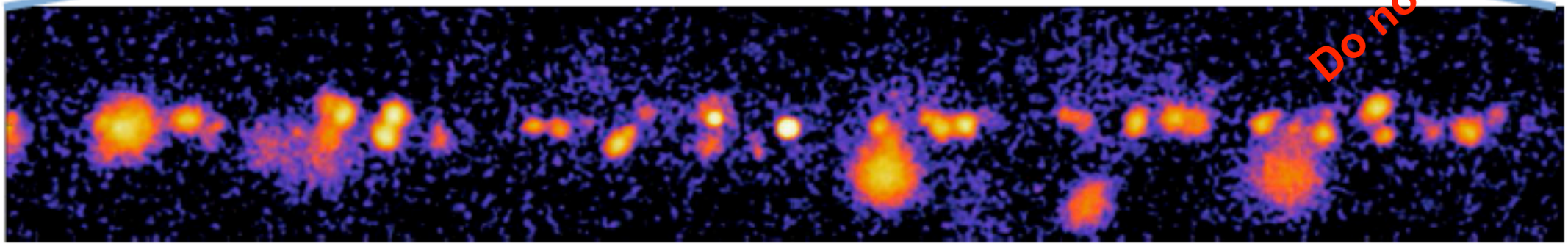
CTA as a survey facility

Full-plane coverage: longitude ± 180°, latitude b ± 10°



Deeper inner galaxy exposure: ℓ ± 80°



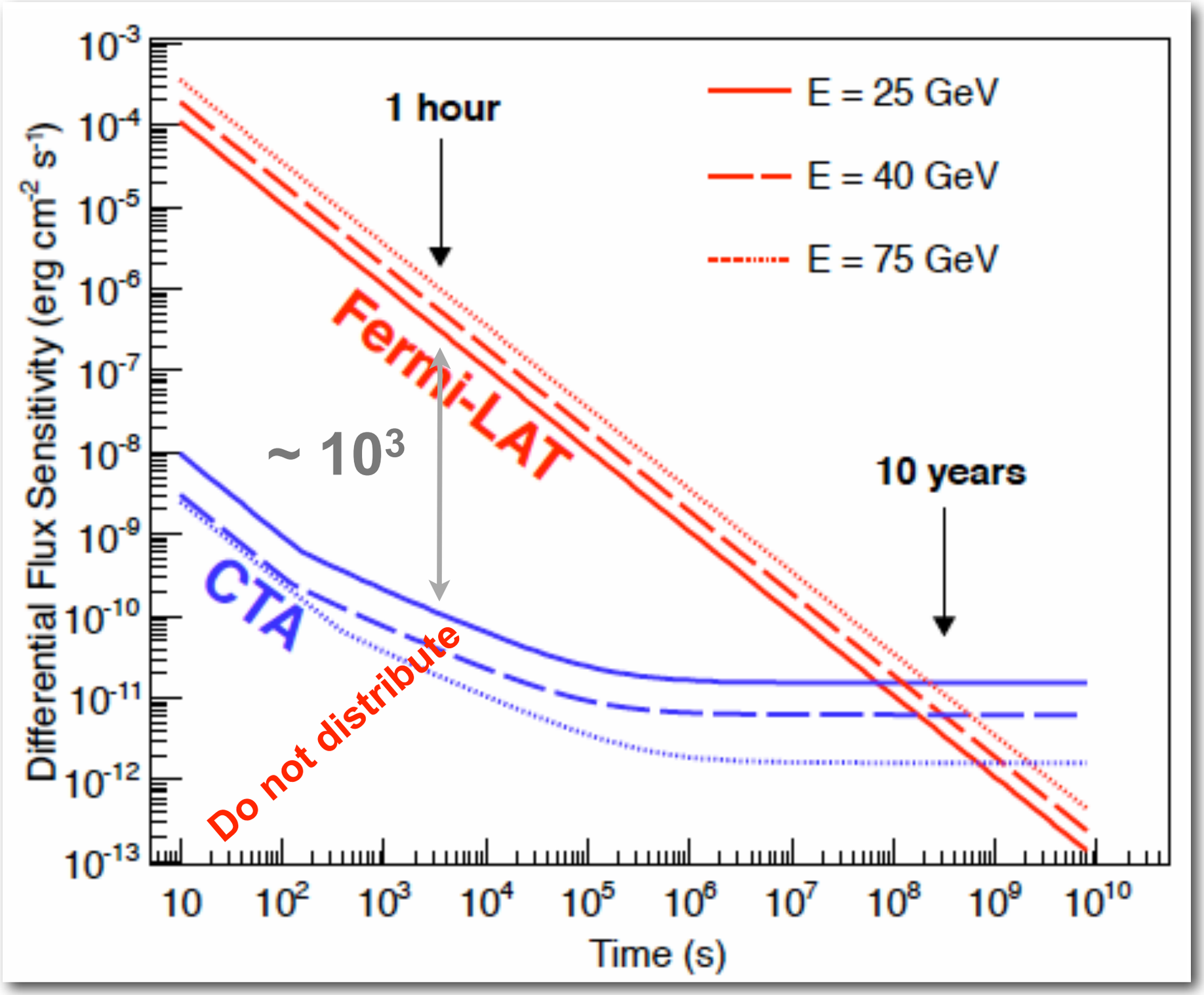


Fine detail revealed with **~arcmin PSF**

J. Knödlseder and CTA Consortium

CTA as a transient factory

Adapted from Funk & Hinton, 2013

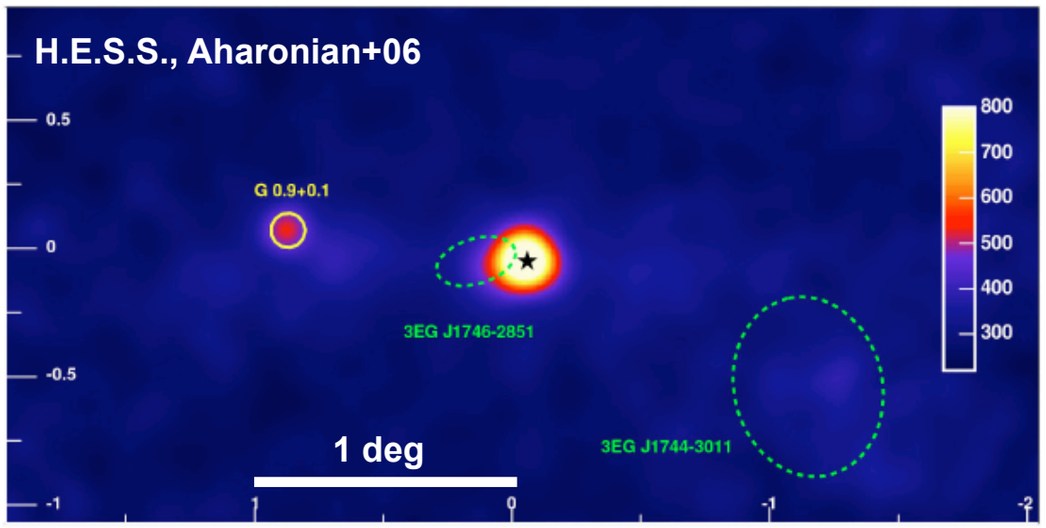


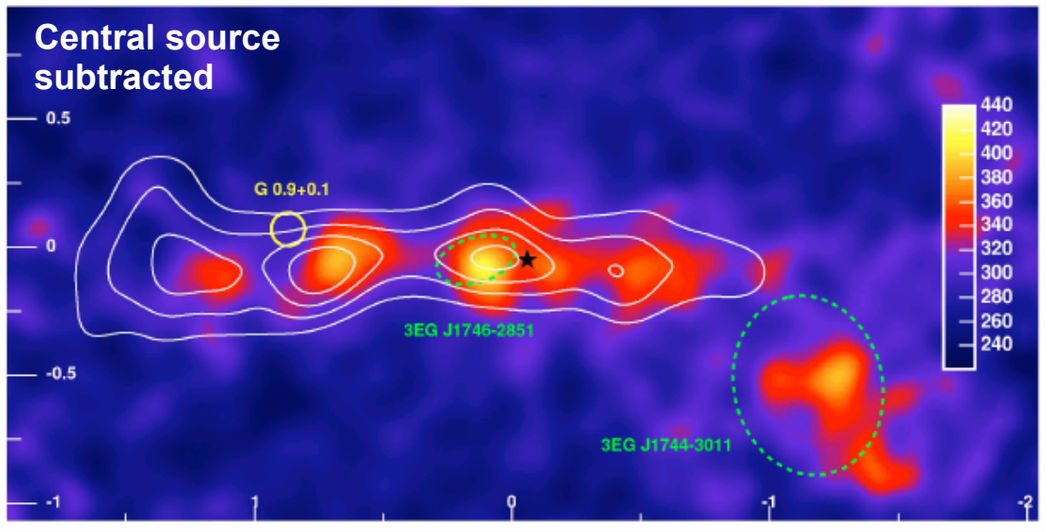
Surveys

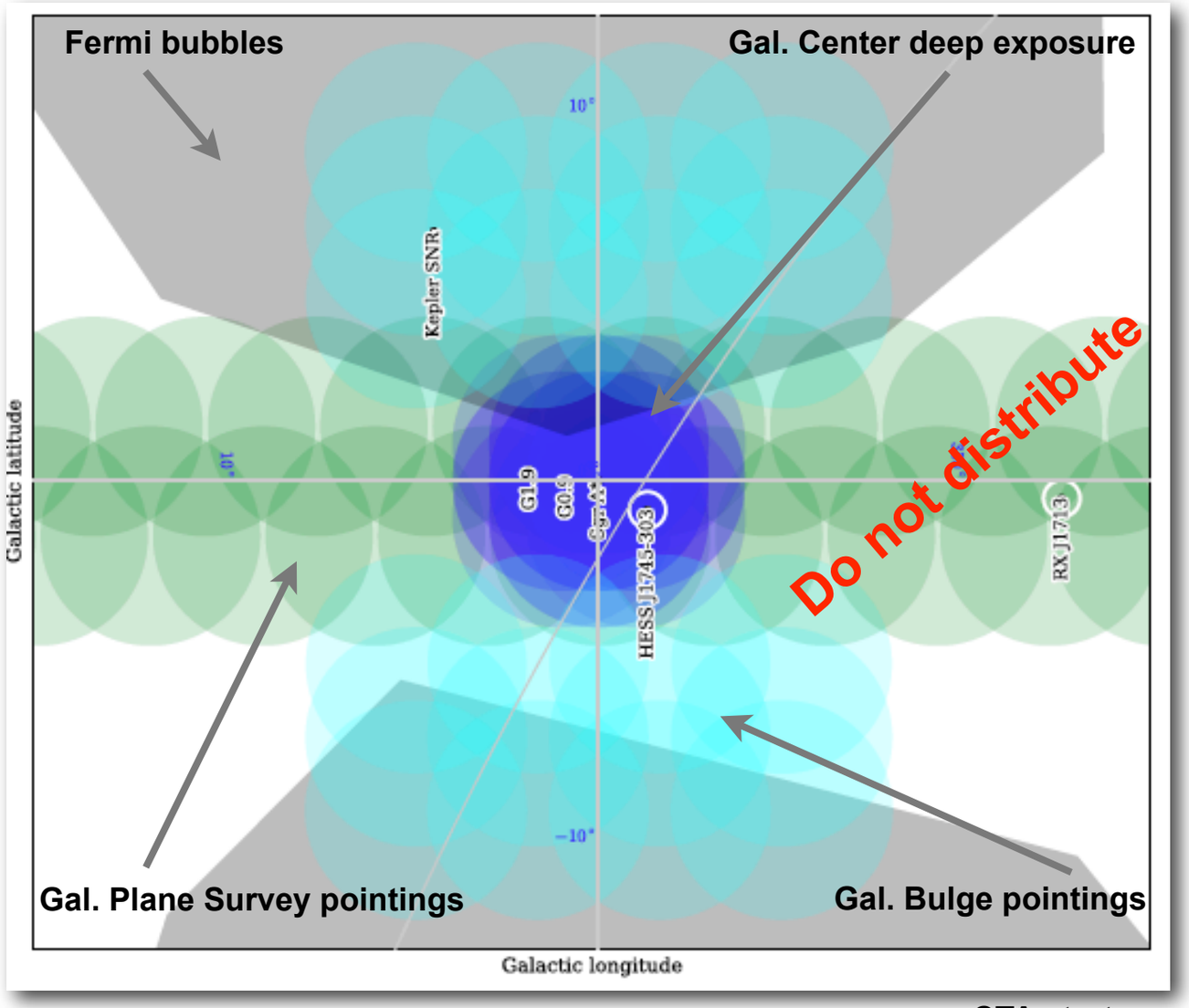
- Dark matter
- **Galactic Center**
- **Galactic Plane**
- LMC
- Extragalactic
- **Transients**
- **CR PeVatrons**
- SF Systems
- AGNs
- Gal. Clusters

KSP/Programme		Required Dark Time (hours) South	Required Dark Time (hours) North	Main data products
Dark Matter Programme*			**300**	
	Dwarf Galaxy Satellites		300	Data cubes and DM parameter space interpretation
Galactic Centre Survey		**825**		
	Sgr A	525		Data cubes, maps, light curve
	Extended halo	300		Data cubes, maps
Galactic Plane Survey		**1020**	**600**	
	300 < l < 60	780		Catalogue, Diffuse emission model, PeVatron candidate list, variability detections
	240 < l < 300	180		
	210 < l < 240	60		
	60 < l < 150		450	
	150 < l < 210		150	
LMC Survey		**490**		
	LMC	340		Catalogue, Diffuse emission model
	SN 1987A	150		Light curve and spectrum
Extragalactic Survey		**200**	**300**	
	-90 < l < 90, b > 5	200	300	Catalogue
Transients		**1010**	**1010**	
	GRBs	500	500	Lightcurves and spectra
	Galactic transients	60	60	
	High-energy neutrino tansients	50	50	
	GW transients	50	50	
	Optical and radio transients	100	100	
	Serendipitous VHE transients	250	250	
Cosmic Ray PeVatrons		**300**		
	5 candidates from GPS	250		Data cubes and maps, spectra for sources
	RX J1713.7-3946	50		
Star Forming Systems		**290**	**430**	
	Cygnus		130	Data cubes and maps, spectra for sources
	Carina	100		
	Westerlund 1	40		
	M 31		150	
	NGC 253	100		
	M 82		100	
	Arp 220	50	50	
Active Galactic Nuclei		**985**	**1890**	
	AGN: pointed blazars	105	150	Catalogue
	AGN: radio galaxies	150	110	Catalogue
	AGN: monitoring	195	555	Long-term light curves, spectra
	AGN: flare follow-up	310	475	Flare light curves, spectra
	AGN: snapshots & verification	225	600	Flare alerts
Galaxy Clusters			**300**	
	Perseus		300	Data cubes, light curves and spectra for sources
Total		**5120**	**4830**	

The Galactic Center







Courtesy of The CTA Consortium

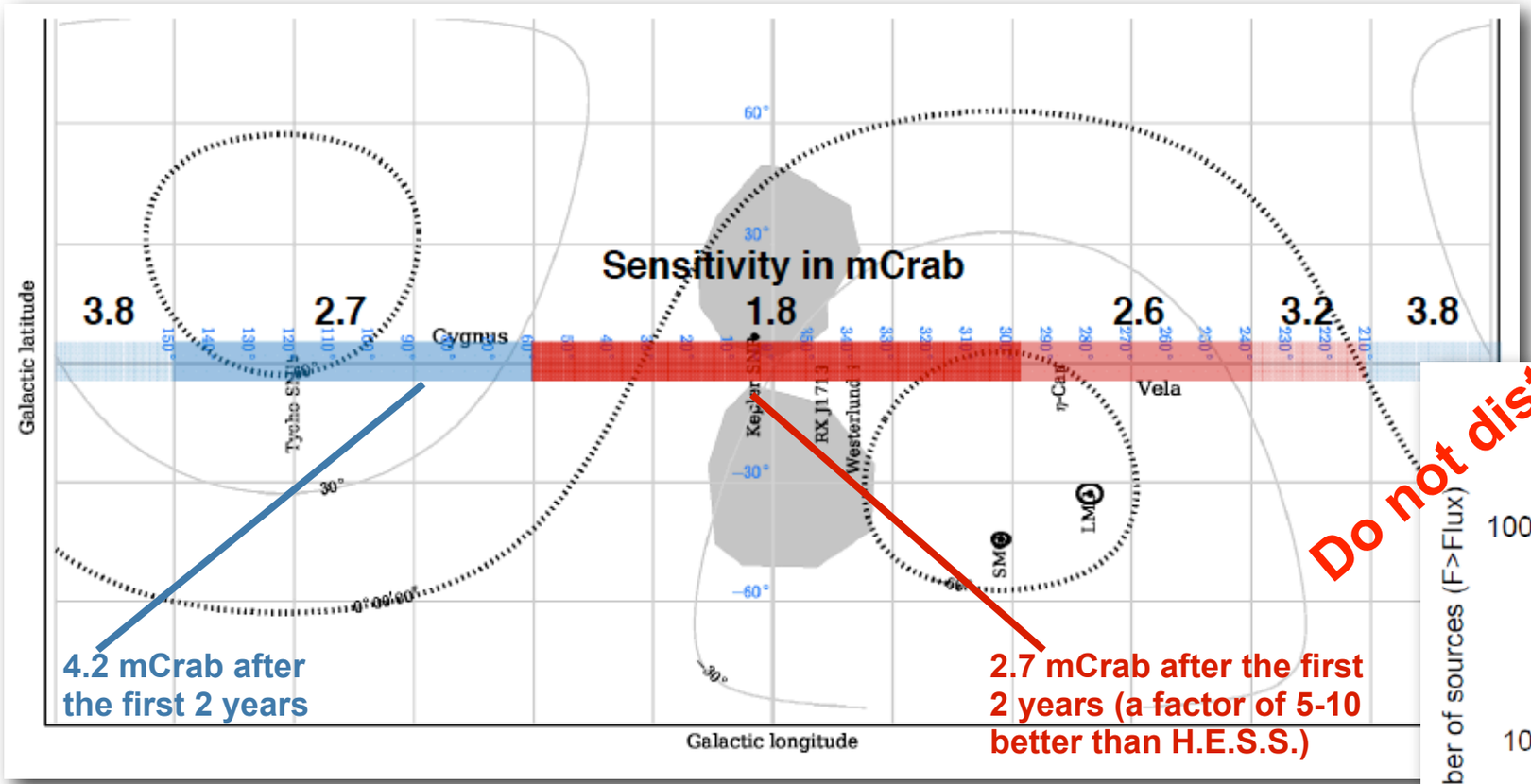
CTA strategy

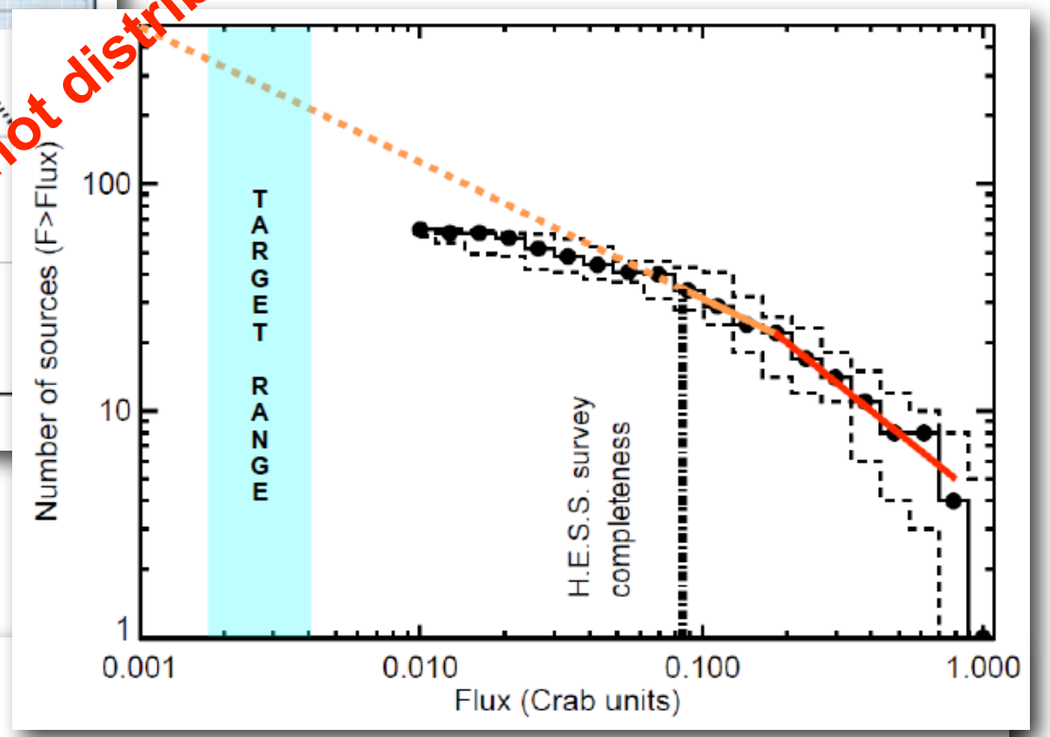
Expected results

- **Determination of the nature of the central source**
- A detailed view of the VHE diffuse emission
- Resolving new, previously undetectable sources
- Search for variability in the VHE source near Sgr A*
- Studying the interaction of the central source with neighbouring clouds

The Galactic plane

Courtesy of The CTA Consortium



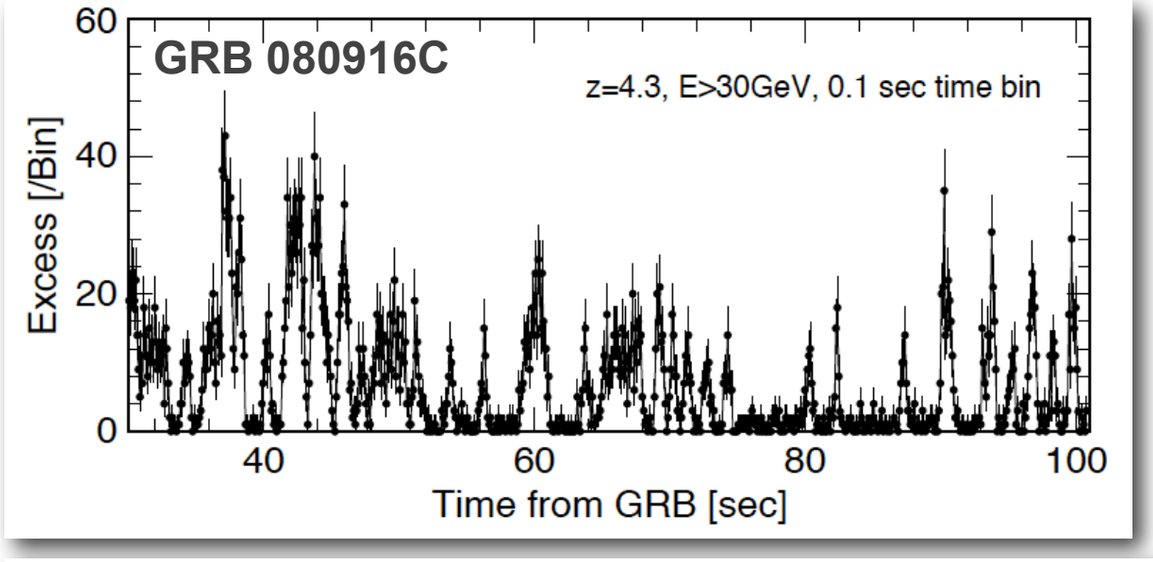


Expected results

- Discovery of new and unexpected phenomena in the Galaxy
- **Discovery of PeVatron candidates ➡ origin of cosmic rays**
- **Detection of many new VHE sources O(300 – 500), particularly PWNe and SNRs**
- Measurement of the large-scale diffuse VHE gamma-ray emission
- **Discovery of new VHE gamma-ray binaries**
- **Production of a multi-purpose legacy data set**
- The GPS will produce and periodically release sky maps and catalogues

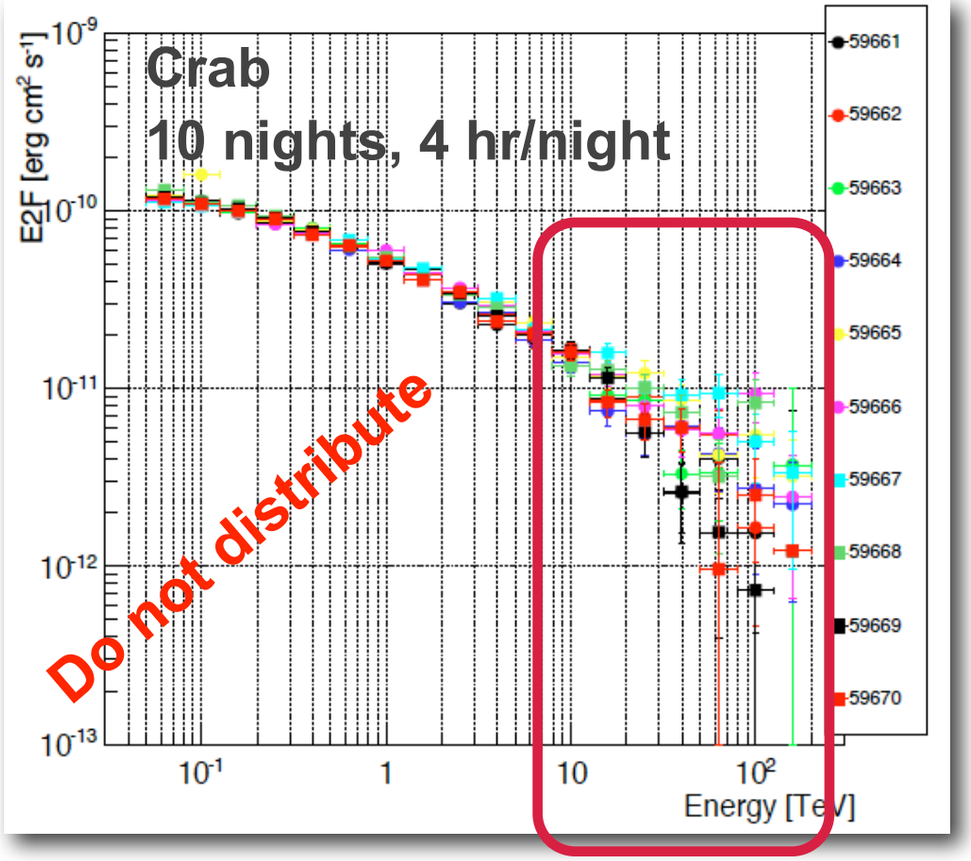
Transients

Rank	Source or type	Known @ VHE	Physics goal	Trigger	Rate (yr^{-1})	Urgency	Activity	Strategy	Time (h)	Site
1	Magnetar giant flares	No	Highest E	GRB-like	0.1	1 min	1–2 d	Max. h/night	10	A/B
2	Crab nebula flares	Not the flares	Test IC comp.	HE	1	1 d	5–20 d (HE)	4 h/night	50	S&N
3	Cygnus X-3	No, but HE	Highest E	HE/X-ray	0.5	1 d	50–70 d (HE)	Max. h/night	50	N
4	Cygnus X-1	Maybe HE/VHE	Highest E	HE/X-ray	0.2	1 d	1–10 d ?	Max. h/night	30	N
5	HE transients	Probably not	Detection/nature	HE	1	1 d	?	2 h/night	20	A/B
6	SXTs (LMXBs)	No	Highest E	X-ray/radio	1	1 d	Weeks	2 h/night	20	A/B
7	Novae	No, but HE	Hadronic nature	HE/opt.	2	1 d	Weeks	2 h/night	20	A/B
8	Transitional pulsars	No, but HE(?)	HE cut-off	Radio/opt.	0.5	1 d	Weeks	2 h/night	20	A/B
9	HXTs (HMXBs)	No	Highest E	X-ray	1	1 d	Weeks	2 h/night	20	A/B



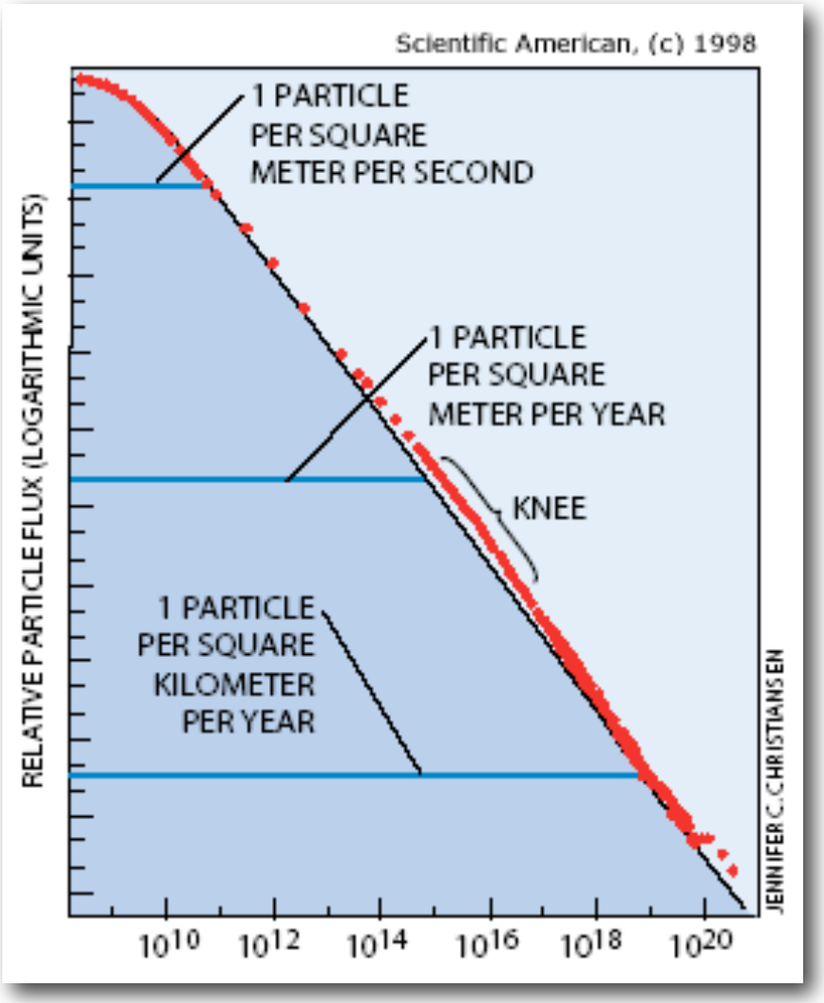
GRB: 1-10 yr^{-1} $site^{-1}$, depending on fast response

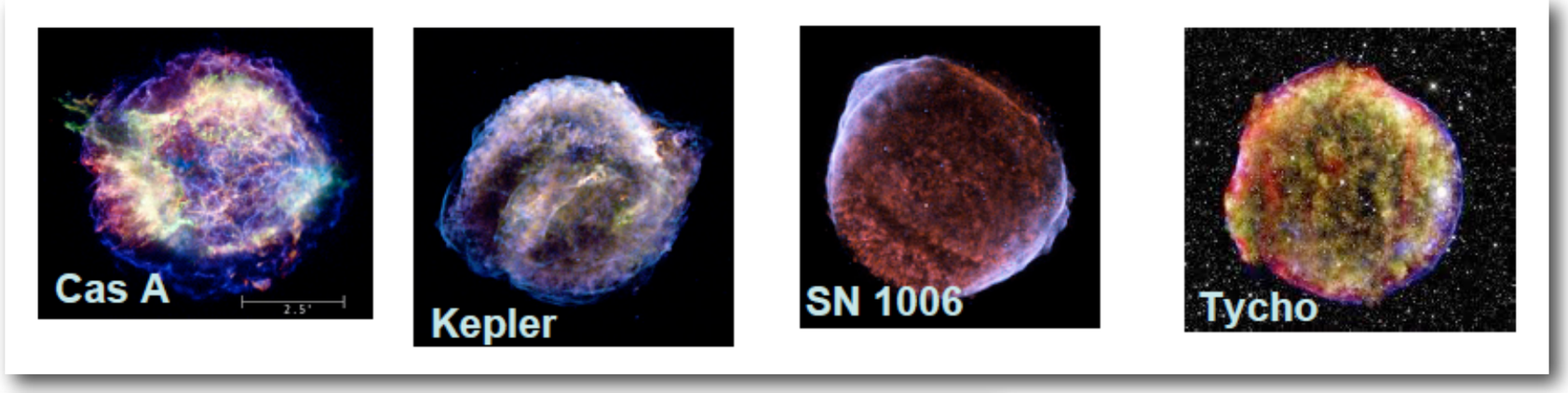
Crab: constraints on the Γ of the putative moving plasma blobs with **time-dependent spectroscopy**

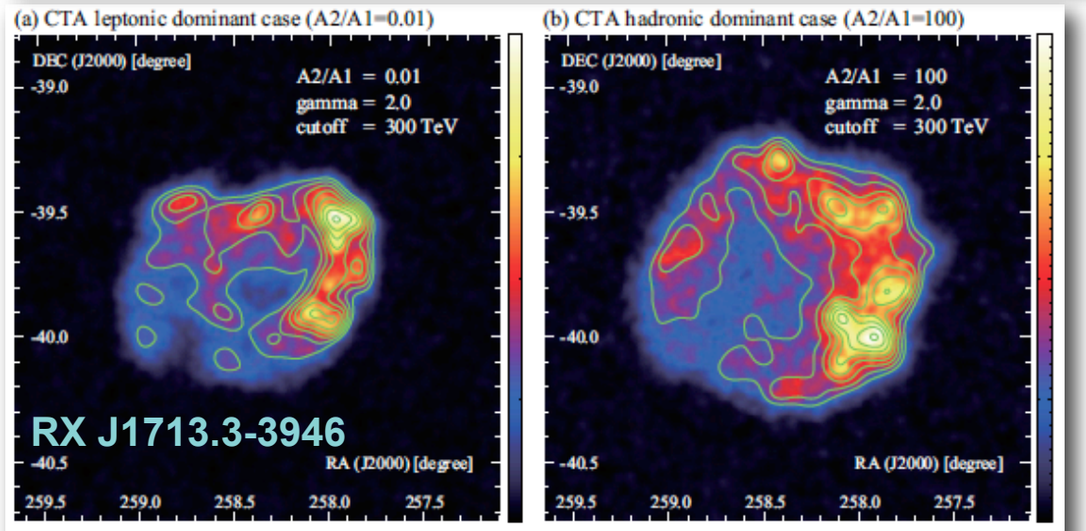


Courtesy of The CTA Consortium

PeVatrons







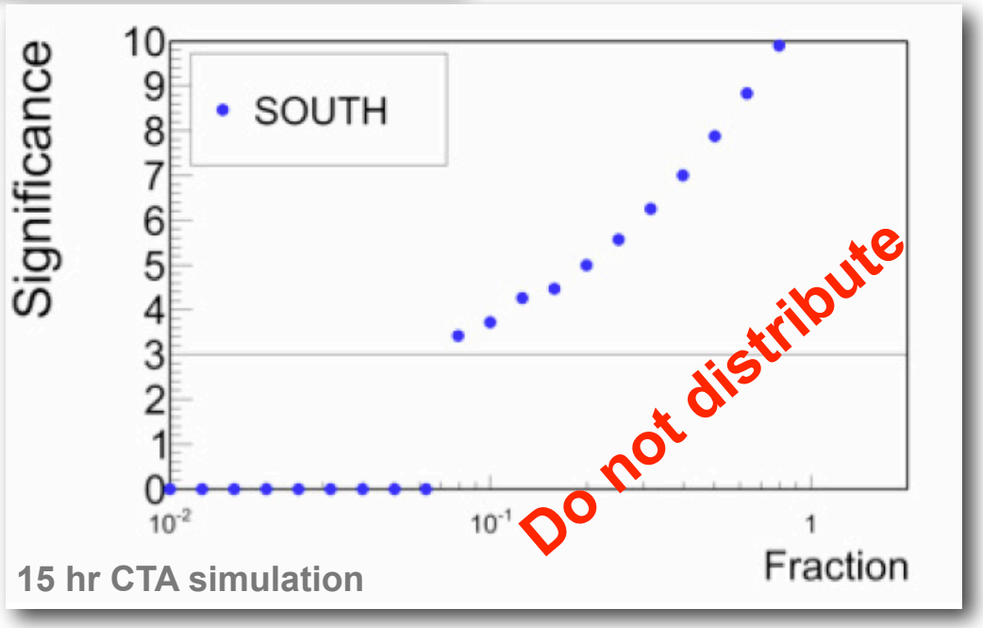
50 hr CTA simulation
Nakamori+15

$F = F_0(E/E_{TeV})^{-\Gamma}$
$F_0 = 2.1 \times 10^{-11}$ cm^{-2} s^{-1} TeV^{-1}
$\Gamma \sim 2$

The detection up to E ~100 TeV implies:

the emission is hadronic, because the leptonic emission is strongly suppressed at such high energies due to Compton losses in the Klein-Nishina regime;

the SNR is a PeVatron, because ~100 TeV photons are produced by ~PeV protons.



The Cherenkov Telescope Array (CTA)

Galactic Key Science Projects

The ASTRI mini-array

Galactic science goals

Credits: E. Giro

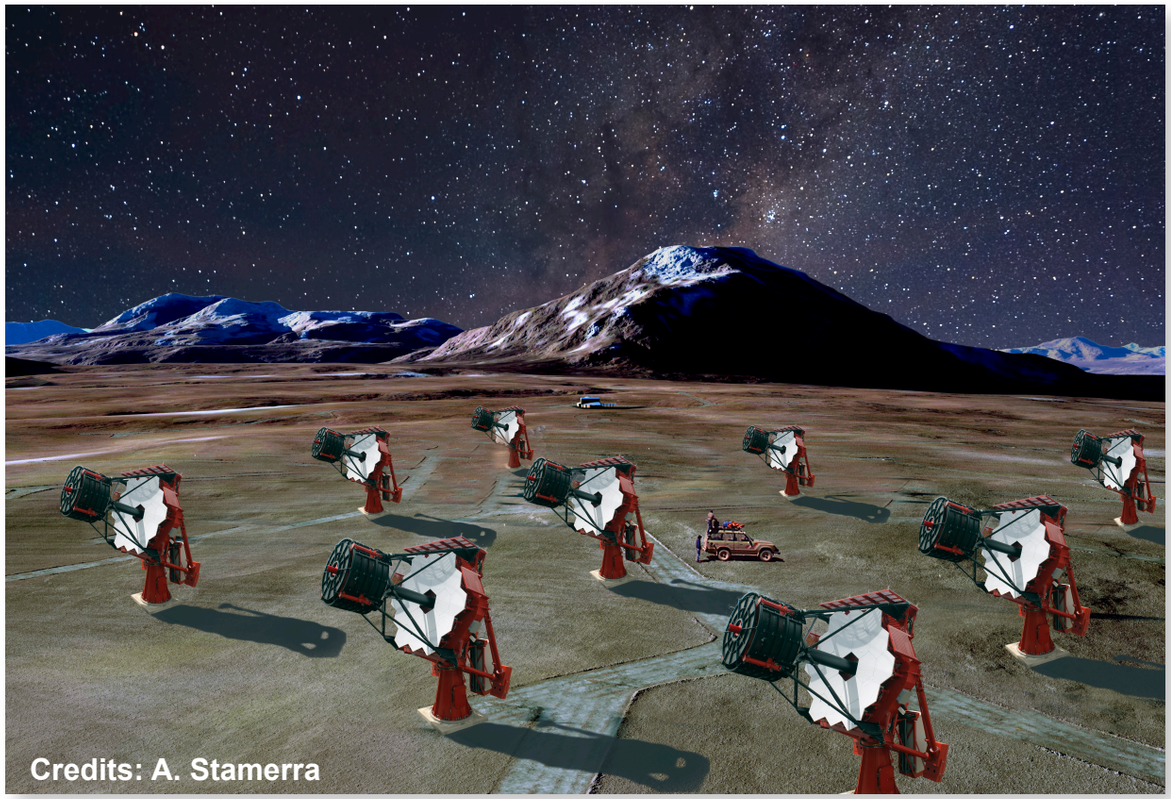
The ASTRI Project

The INAF-led **ASTRI Project** has two main goals:

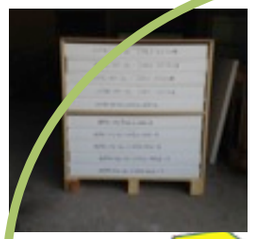
- an **end-to-end prototype** of the **CTA small-size telescope** in a dual-mirror, Schwarzschild-Couder configuration (ASTRI SST-2M), inaugurated on 2014 Sept. 24th and currently under test at the INAF observing station on Mt. Etna (Sicily);

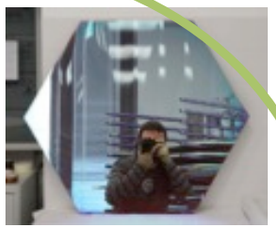
- an **ASTRI mini-array** of precursors composed of **nine telescopes** proposed to be installed at the chosen CTA Southern site in 2016.

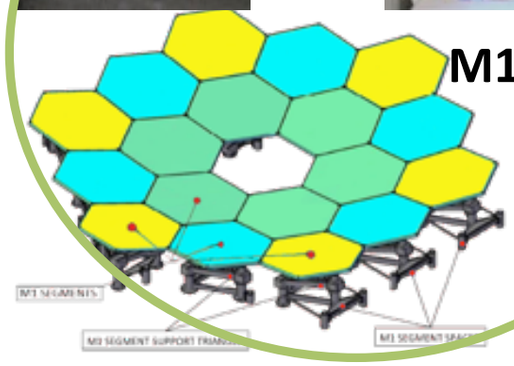

Credits: T. Abegg


Credits: A. Stamerra

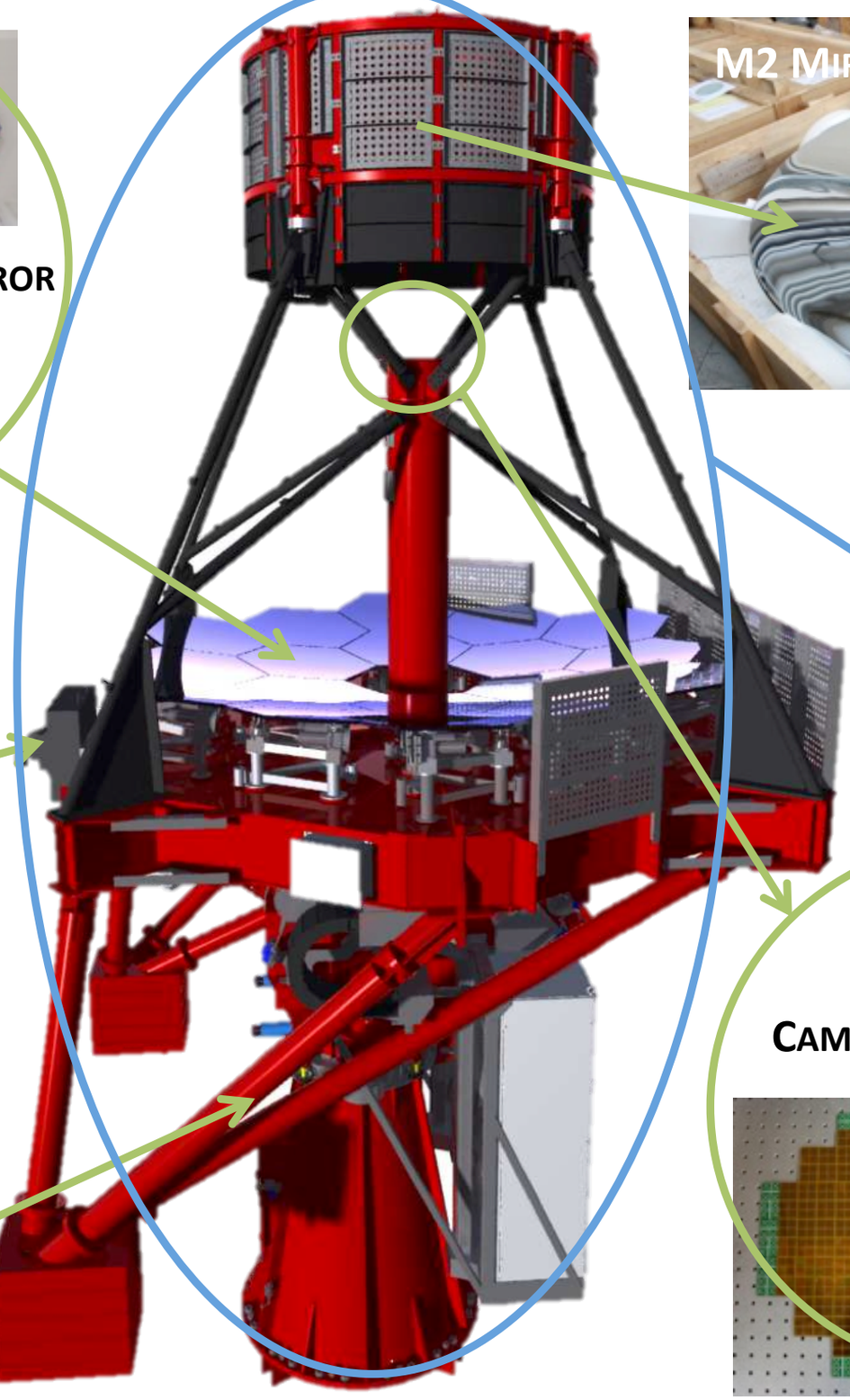
ASTRI SST-2M end-to-end approach







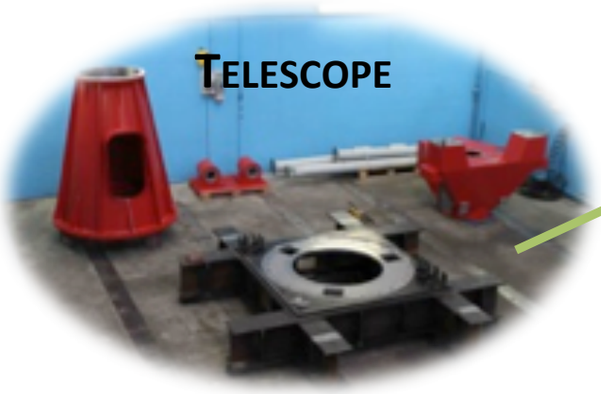
M1 MIRROR



M2 MIRROR

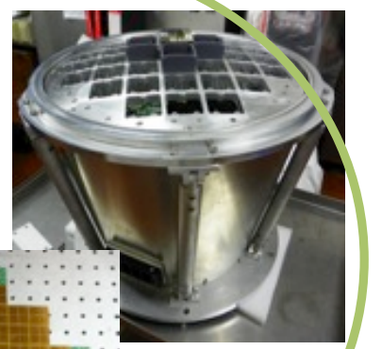
Software

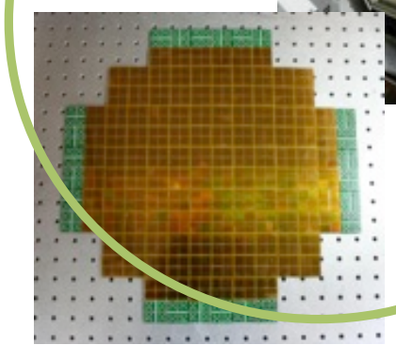
AUX



TELESCOPE

CAMERA





★ Science !

For E > 1 TeV we should be able to detect **1 Crab at 5σ in about a few hours**

More information:
Vercellone et al., 2015, arXiv:1508.00799 (and references therein)

ASTRI SST-2M **innovative solutions**:

Dual-mirror optical layout
- first time for VHE IACTs
- reduces the plate-scale
- ★ optimal PSF across the entire FoV

SiPMs photo-detectors
- ★ small pixel-size
  can work during moonlight
  fast front-end and control electronics

Wide field-of view (9.6º)
- excellent for:
  - ★ extended sources
  - surveys

The ASTRI mini-array

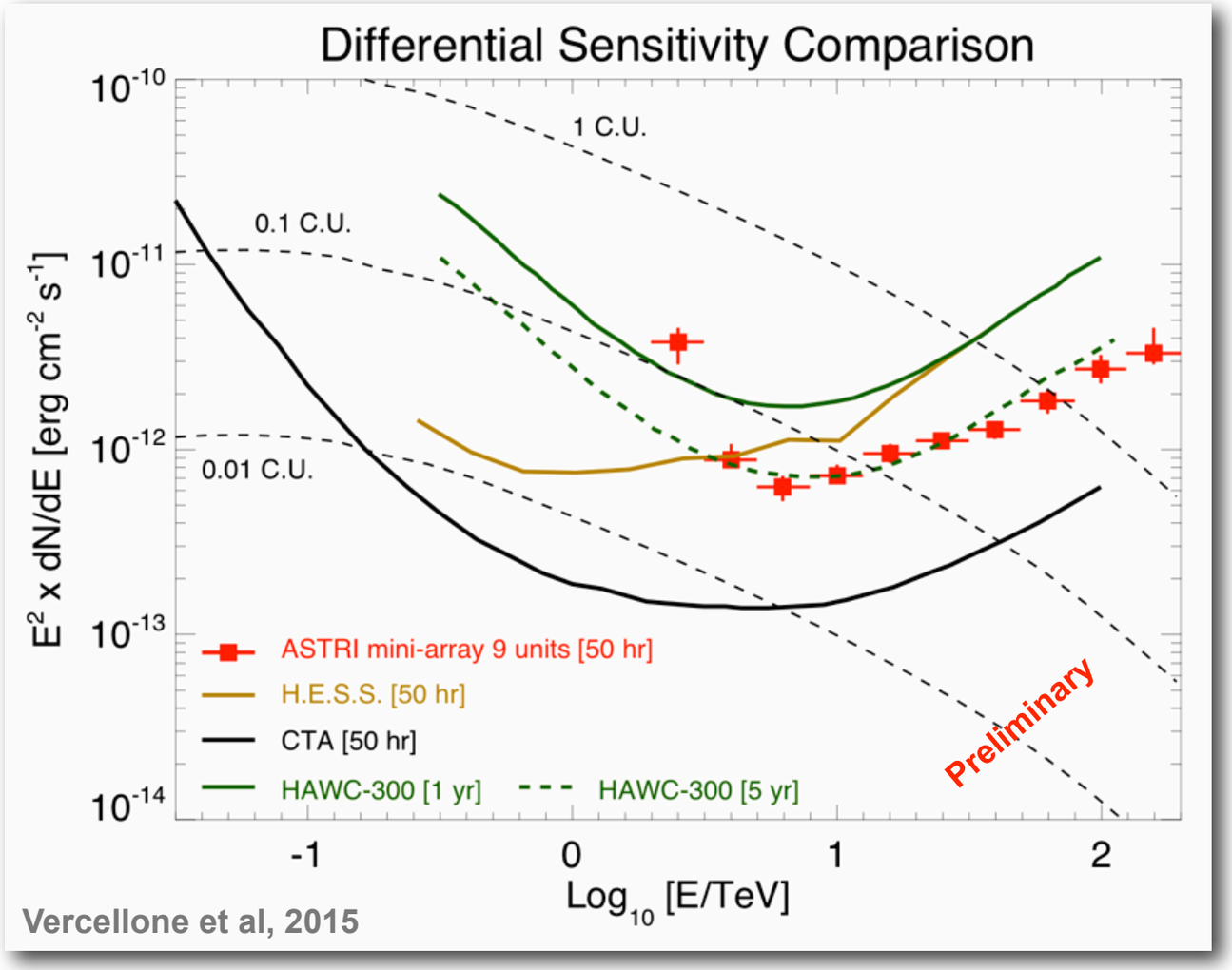
Led by the Italian National Institute for Astrophysics in collaboration with:

Universidade de São Paulo & FAPESP, Brazil

North-West University, South Africa

Credits: A. Stamerra

Sensitivity comparison



Limiting flux

slightly better than the H.E.S.S. one above a few TeV for an array composed of 9 telescopes

Angular resolution

a few (4-5) arcmin

Energy resolution

of the order of 10-15 %

We will have **a better sensitivity at E>10 TeV for extended sources**

The ASTRI mini-array can:

reach the HAWC 1-yr sensitivity in about a few weeks of pointings

study, by means of deep observations, sky “hot-spots” detected by HAWC

ASTRI mini-array scientific rationale

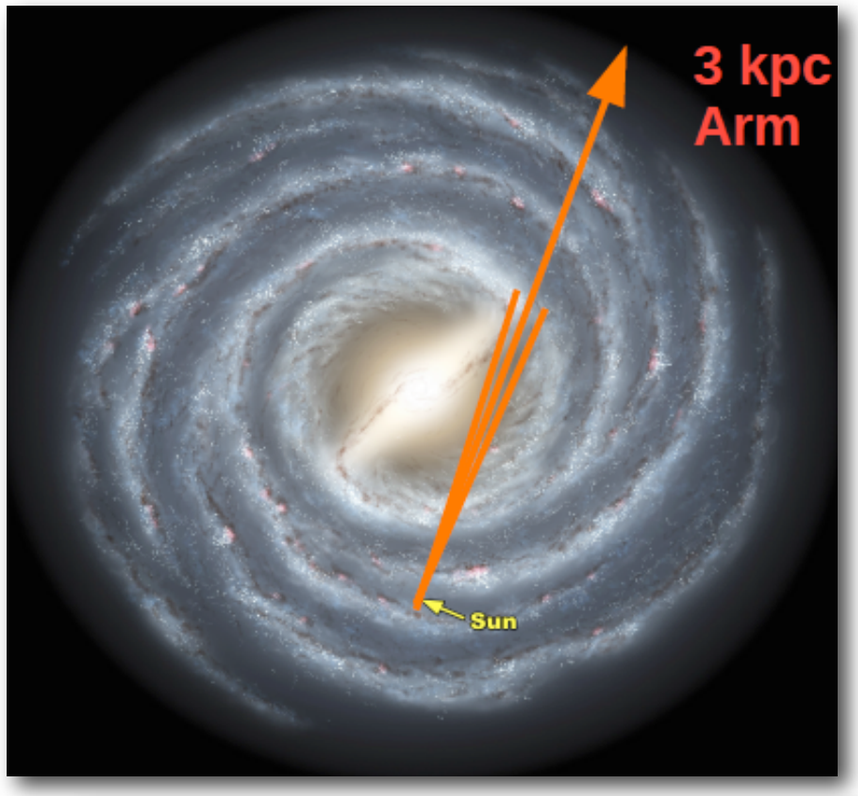
- The aim is to **test both the SST-2M technological and scientific performance** at energies above a few TeV by means of **prolonged pointings**.★

- **Galactic science** → choose sky regions containing multiple targets. ★

- **Extra-galactic science** → select a few promising targets.

- **Synergies with MSTs and LSTs** precursors are of paramount importance.

The wide field of view and our Galaxy



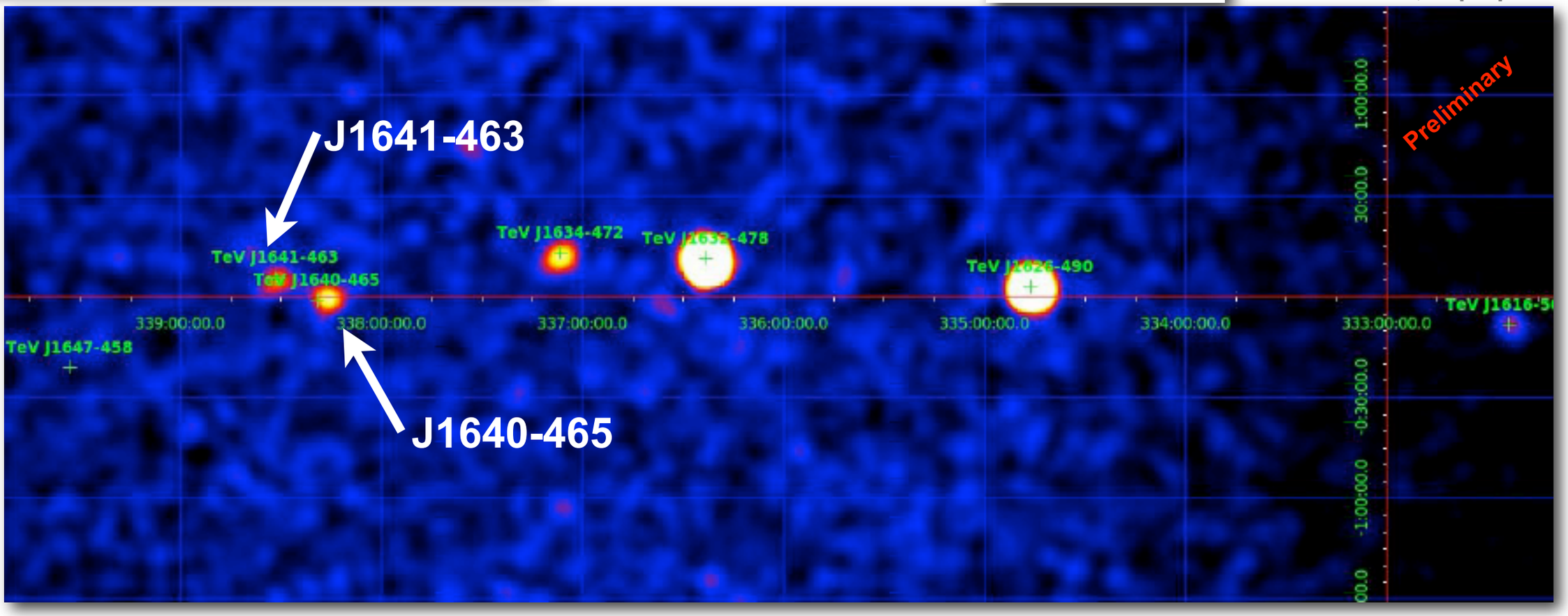
ASTRI mini-array 200 hrs simulation for E > 10 TeV

- This region can be monitored in the period [Feb. - Sept., ZA < 35deg] for more than 400 hrs
- Several sources can be investigated during a single pointing

200 hr

3 kpc Arm

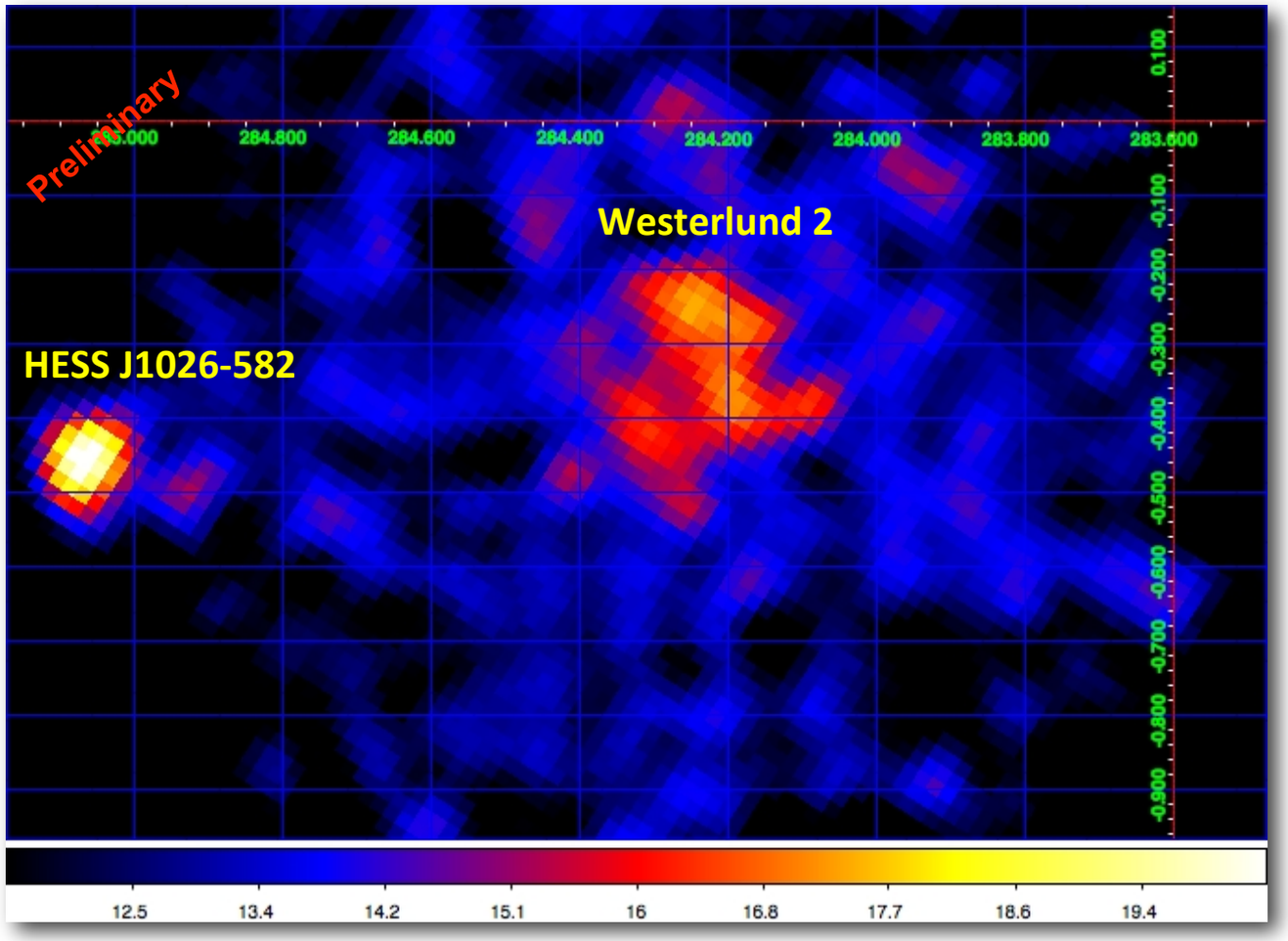
Giuliani et al., in prep.



The wide field of view and our Galaxy

eta-Car region

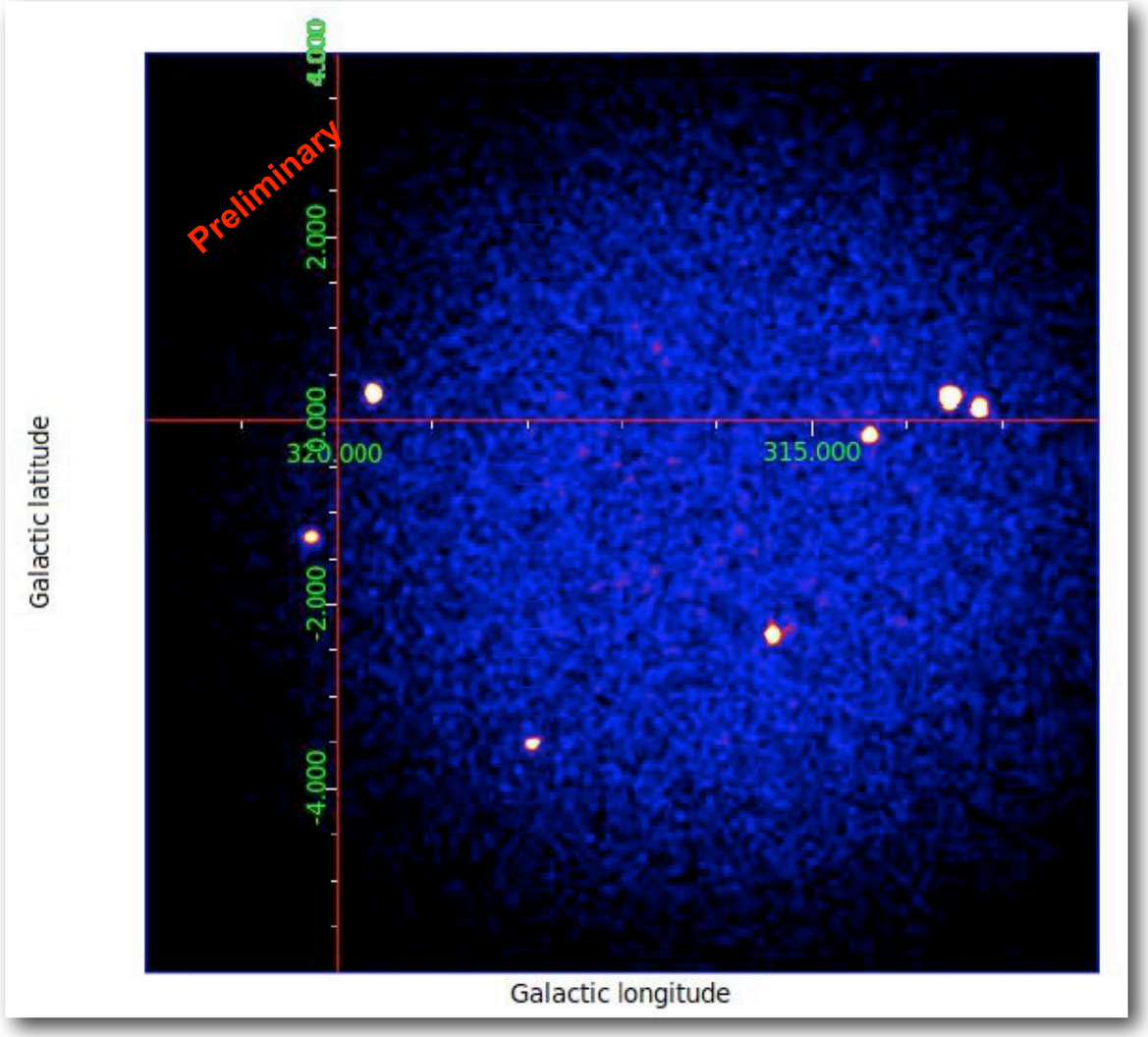
270 hr



Sabatini, Donnarumma et al., in prep.

Crux Arm

200 hr



Giuliani et al., in prep.

SNRs, PWN

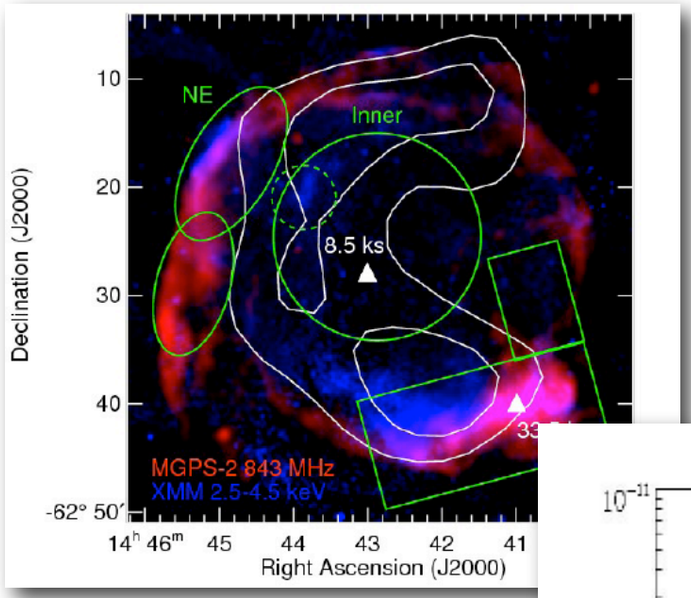
SNR RCW 86

Fairly young SNR (2000 yrs)

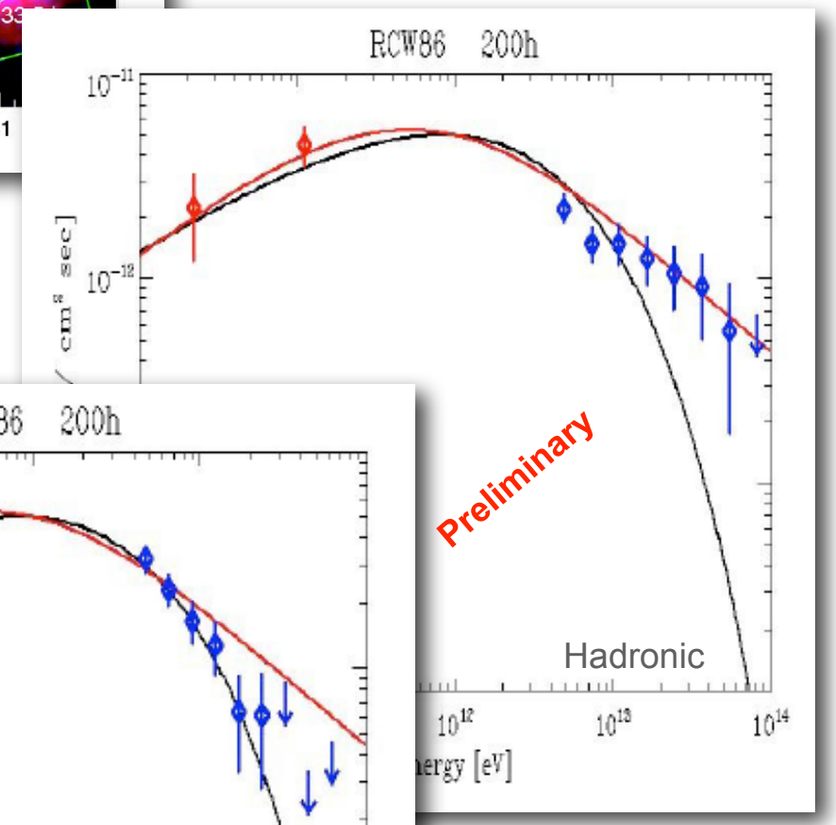
Seen in Radio, X, GeV (*Fermi*), TeV (H.E.S.S.)

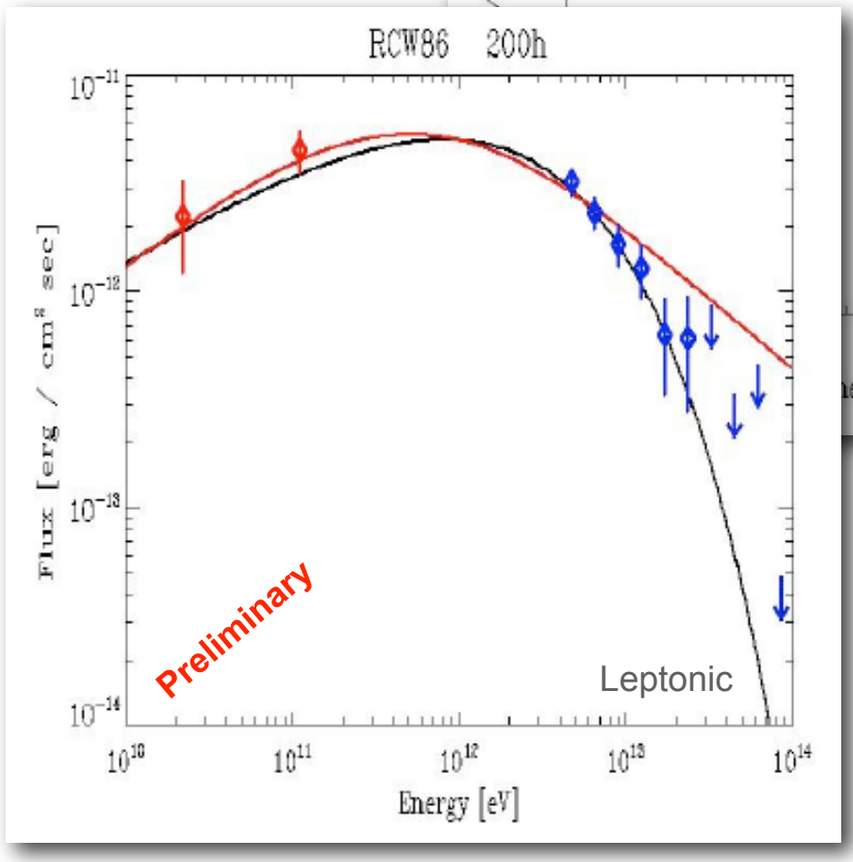
Debated origin:
- interacting source with molecular clouds or RX J1713-like source ?

ASTRI mini-array (blue points, simulated data) can discriminate between hadronic and leptonic scenario and (if hadronic) look for VHE(~5x10^{14} eV) CRs



Giuliani et al, in prep.





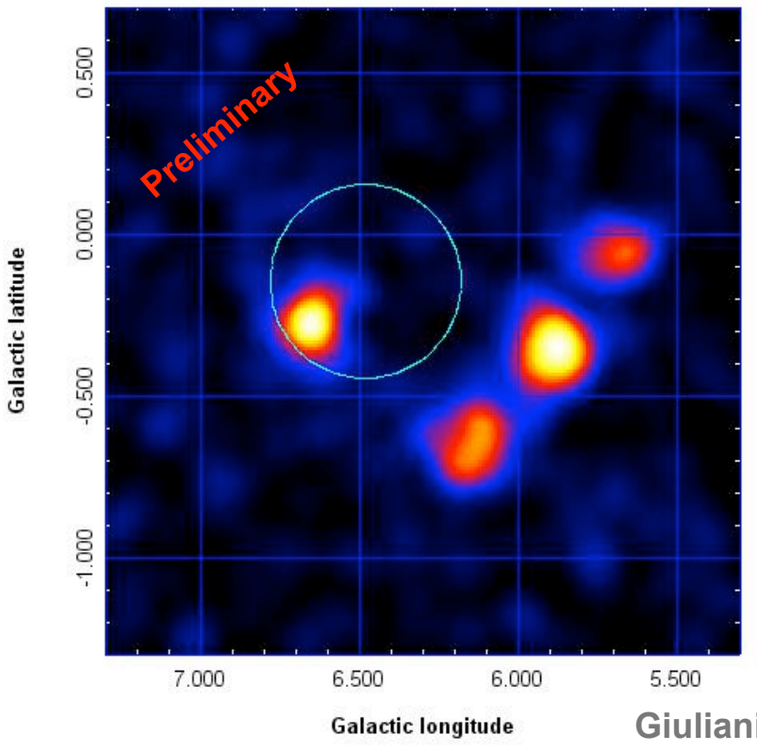
SNR W 28

Evolved SNR interacting with a giant MC, very bright @ TeV

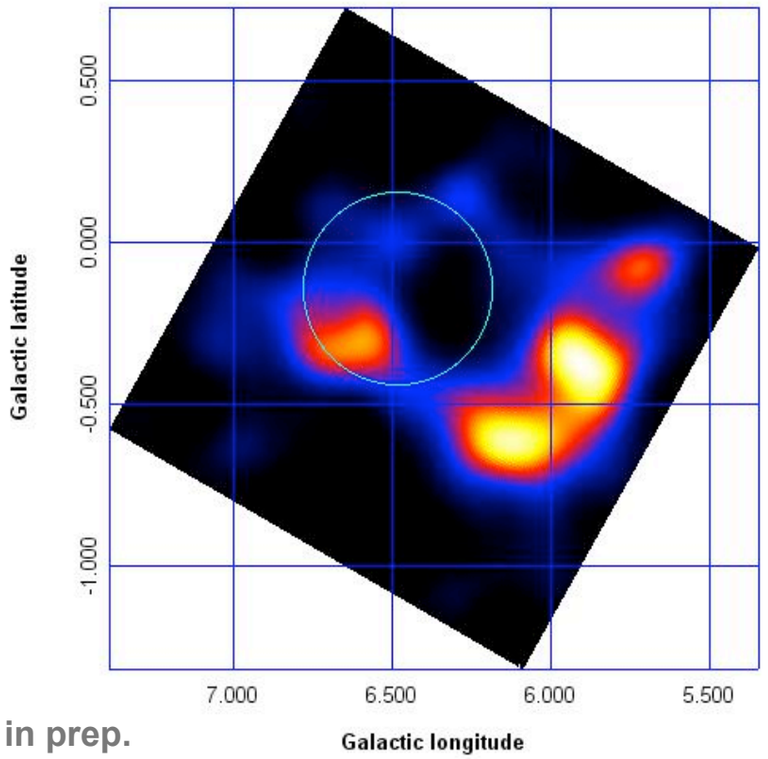
H.E.S.S. resolved this source in almost 4 point-like sources near the MC

ASTRI mini-array can better resolve the source and study the diffusion of CR far from the SNR shell (blue circle)

ASTRI mini-array simulation

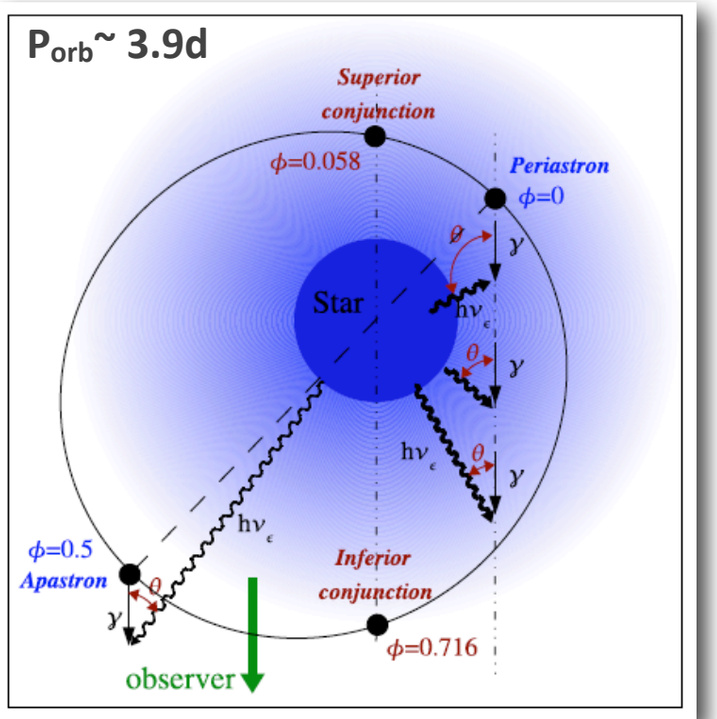


H.E.S.S. data

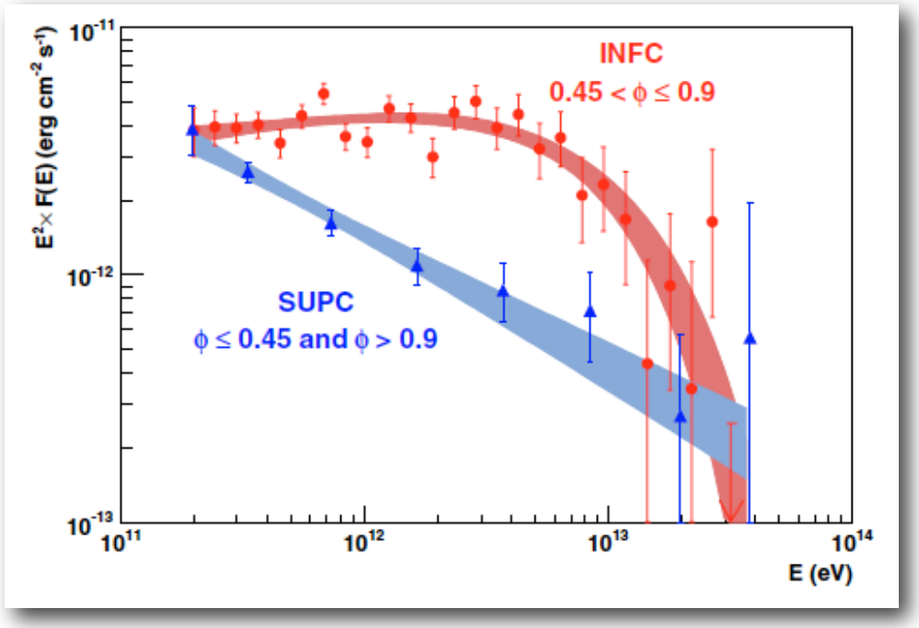


Giuliani et al., in prep.

μ-QSO: LS 5039



Aharonian+ 06

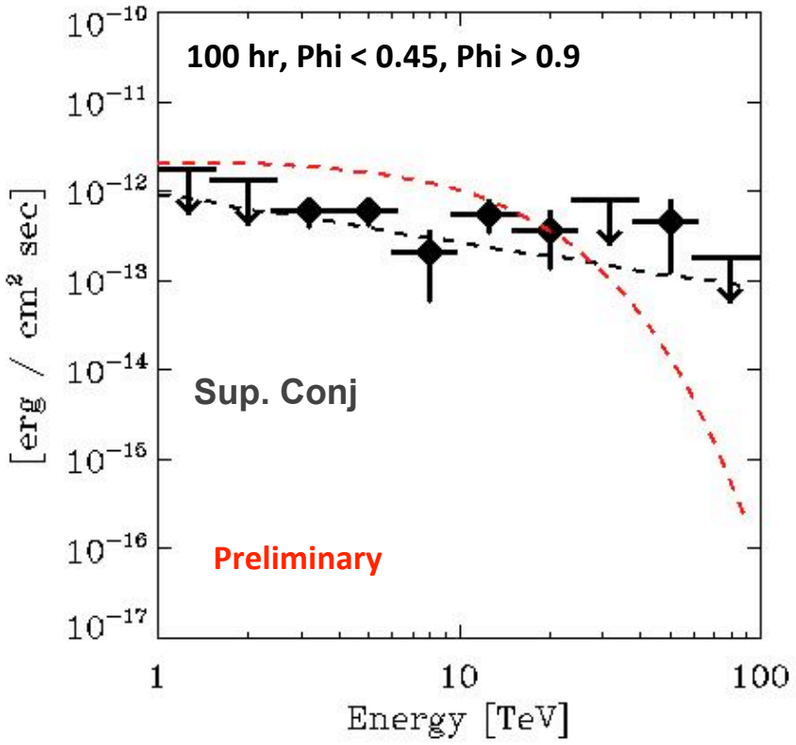


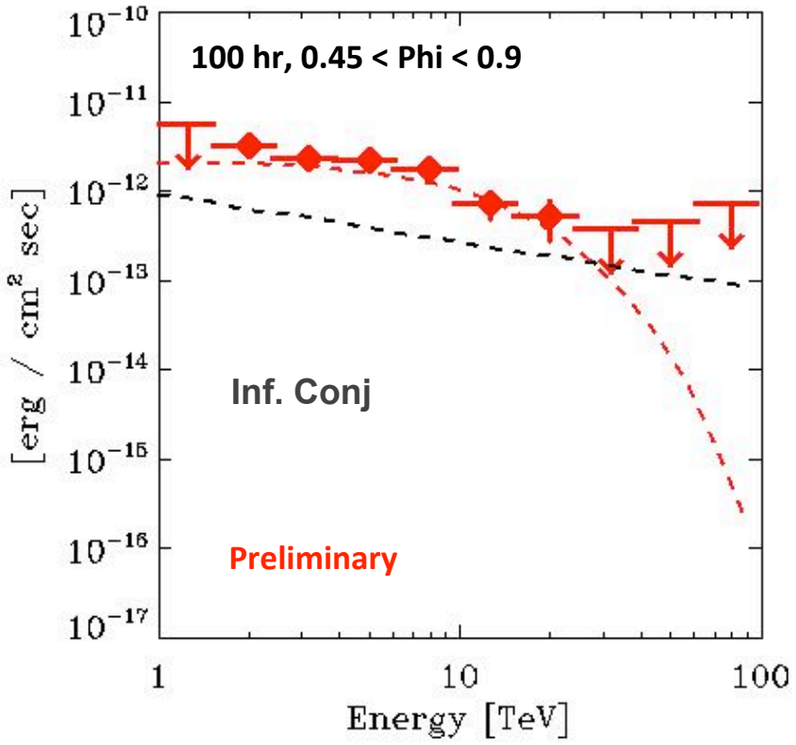
Data are not well constrained above 10 TeV

We can investigate:

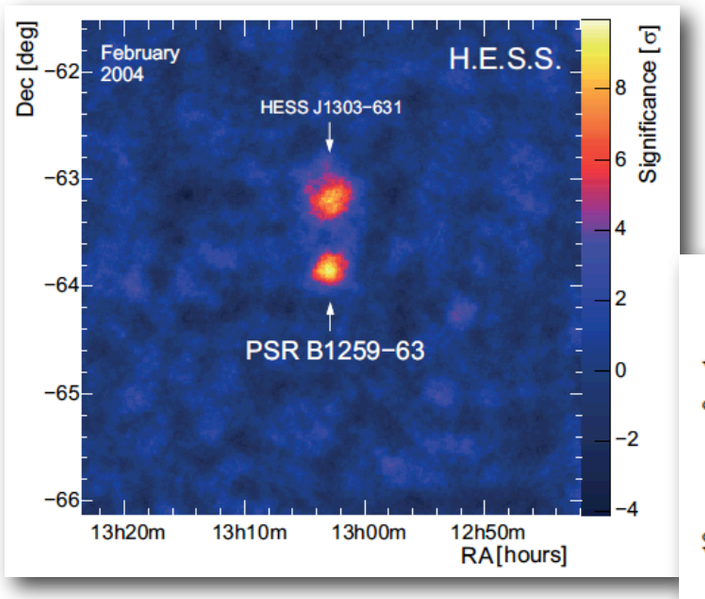
- phase-dependent gamma-ray absorption/ emission;
- phase-dependent spectral modulation.

Romano, Vercellone, Giuliani et al., in prep.

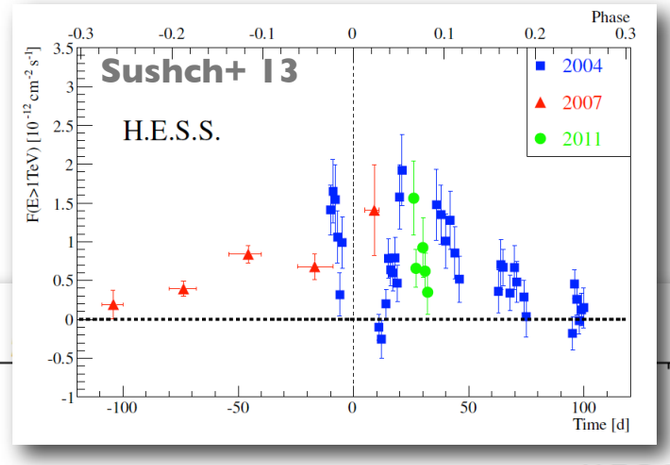


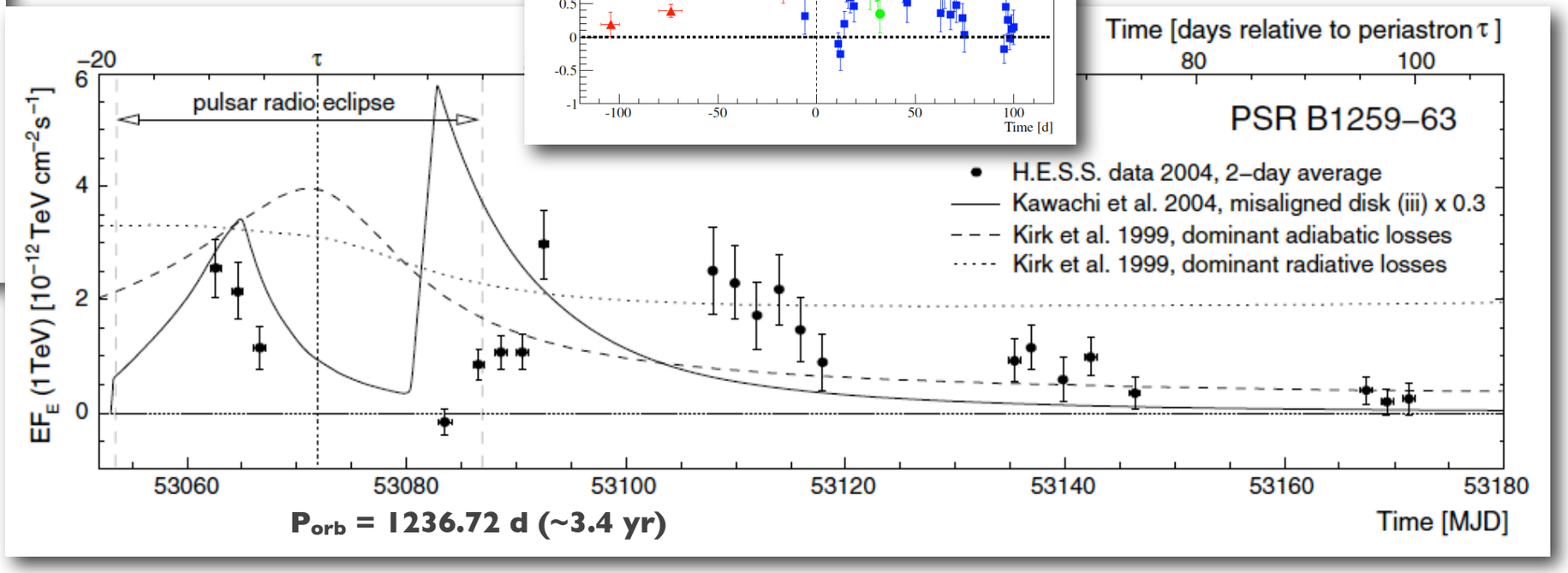


ms-PSR + Be: PSR B1259-63



Aharonian+ 05



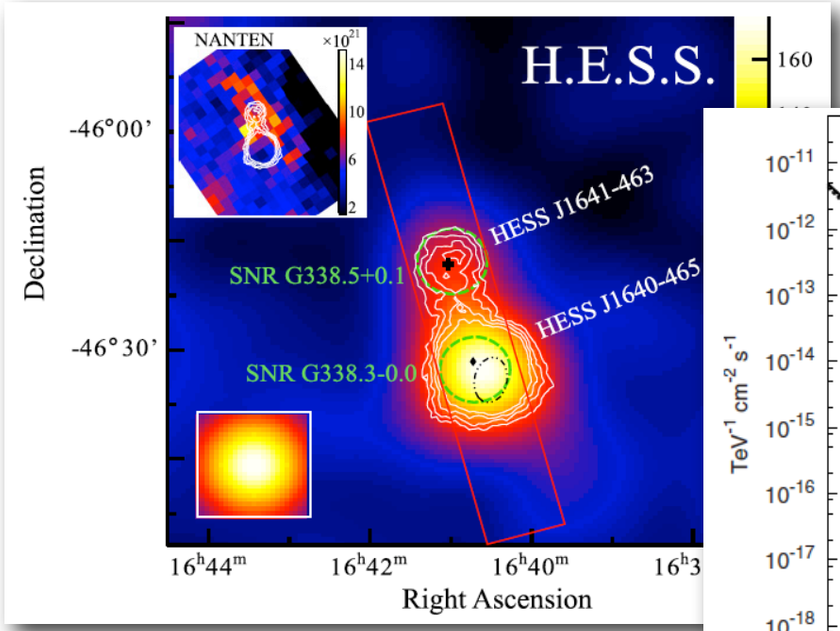


H.E.S.S. spectrum accumulated in 50 hr
Detected above a few TeV

Romano, Vercellone, Giuliani et al., in prep.

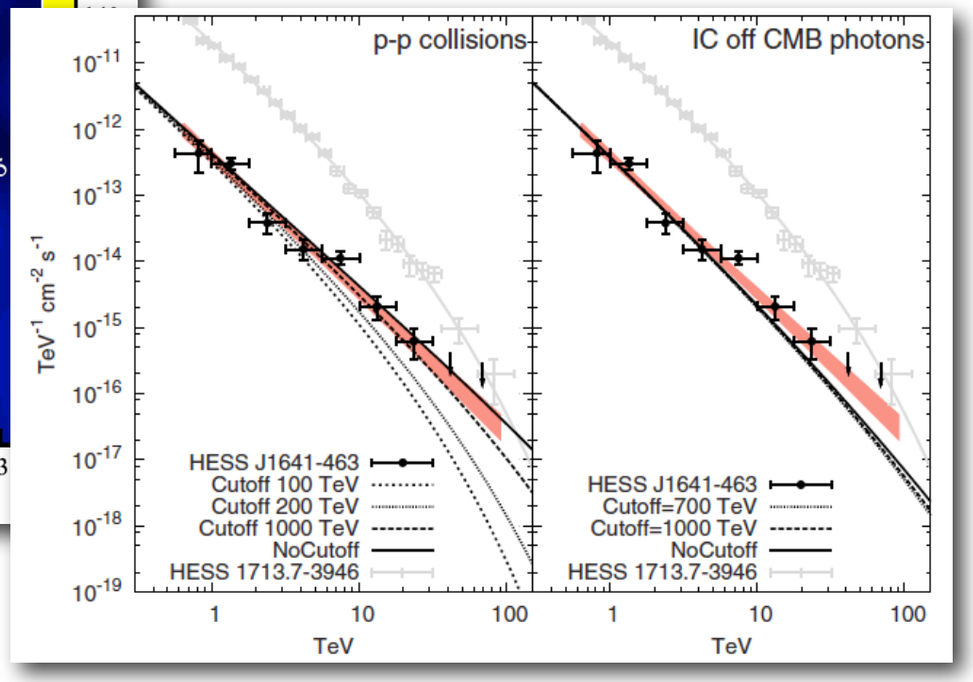
It can be monitored [Jan. - Jun, ZA<35º] for more than **150 hr**
In the same FoV: **PWN HESS J1303-631**
We can investigate [next periastron passage: **~ 2017.09.21**]:
phase-dependent gamma-ray flux, probing different theoretical emission model (peak and dim around periastron, is it periodic?)

γ-ray UNID: HESS J1641-463

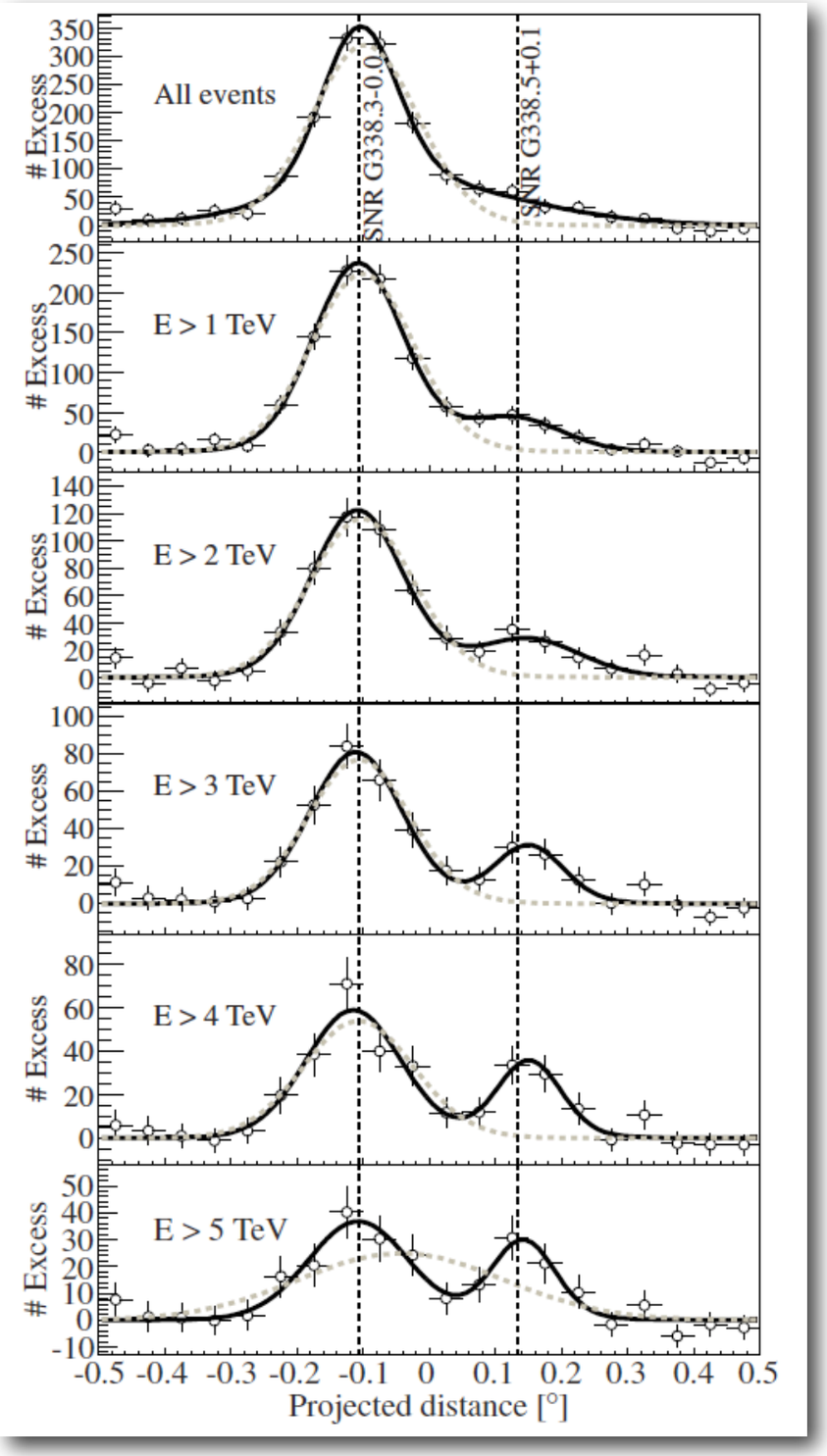


Abramowski +14

Abramowski+ 14



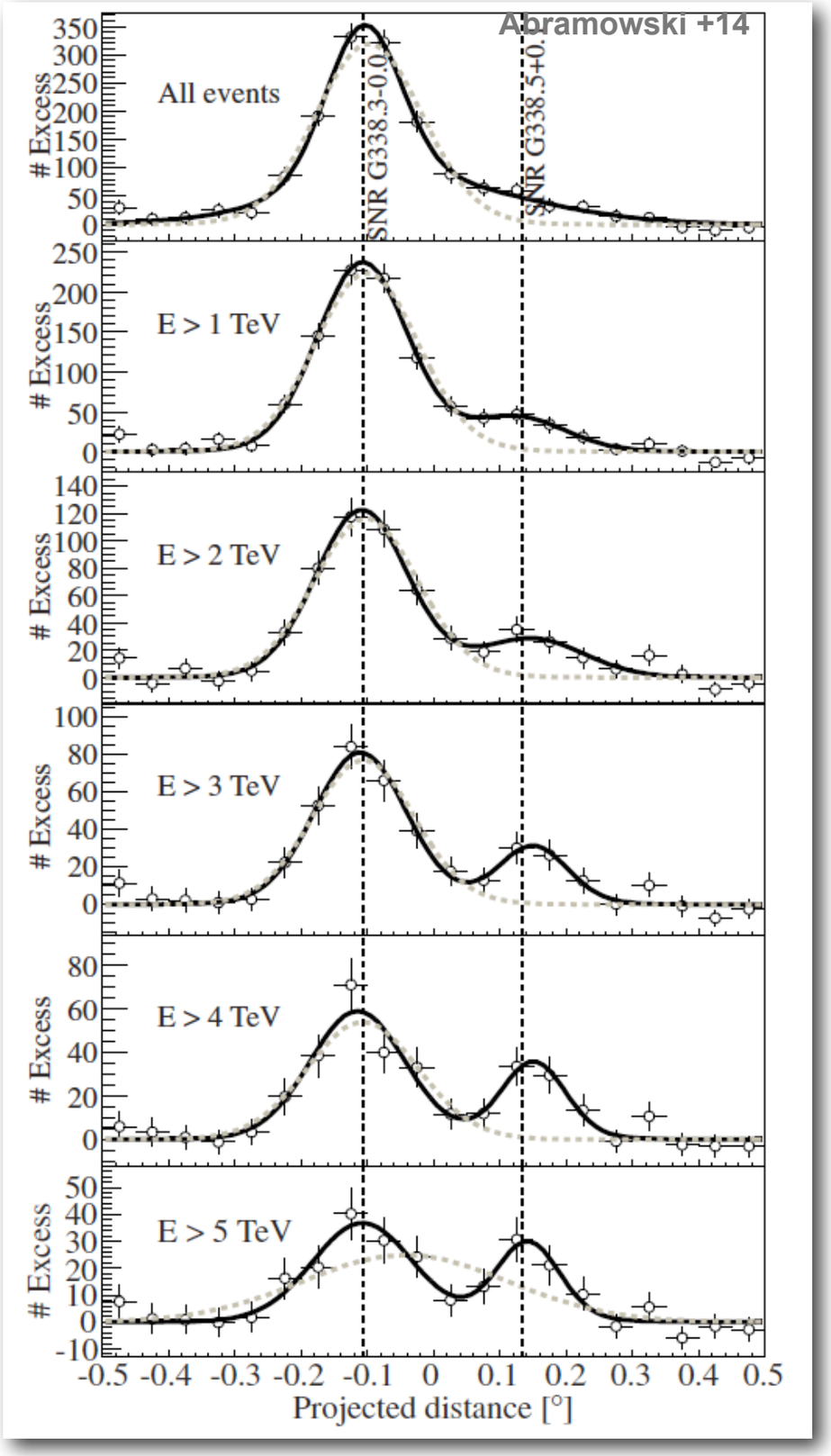
Abramowski +14

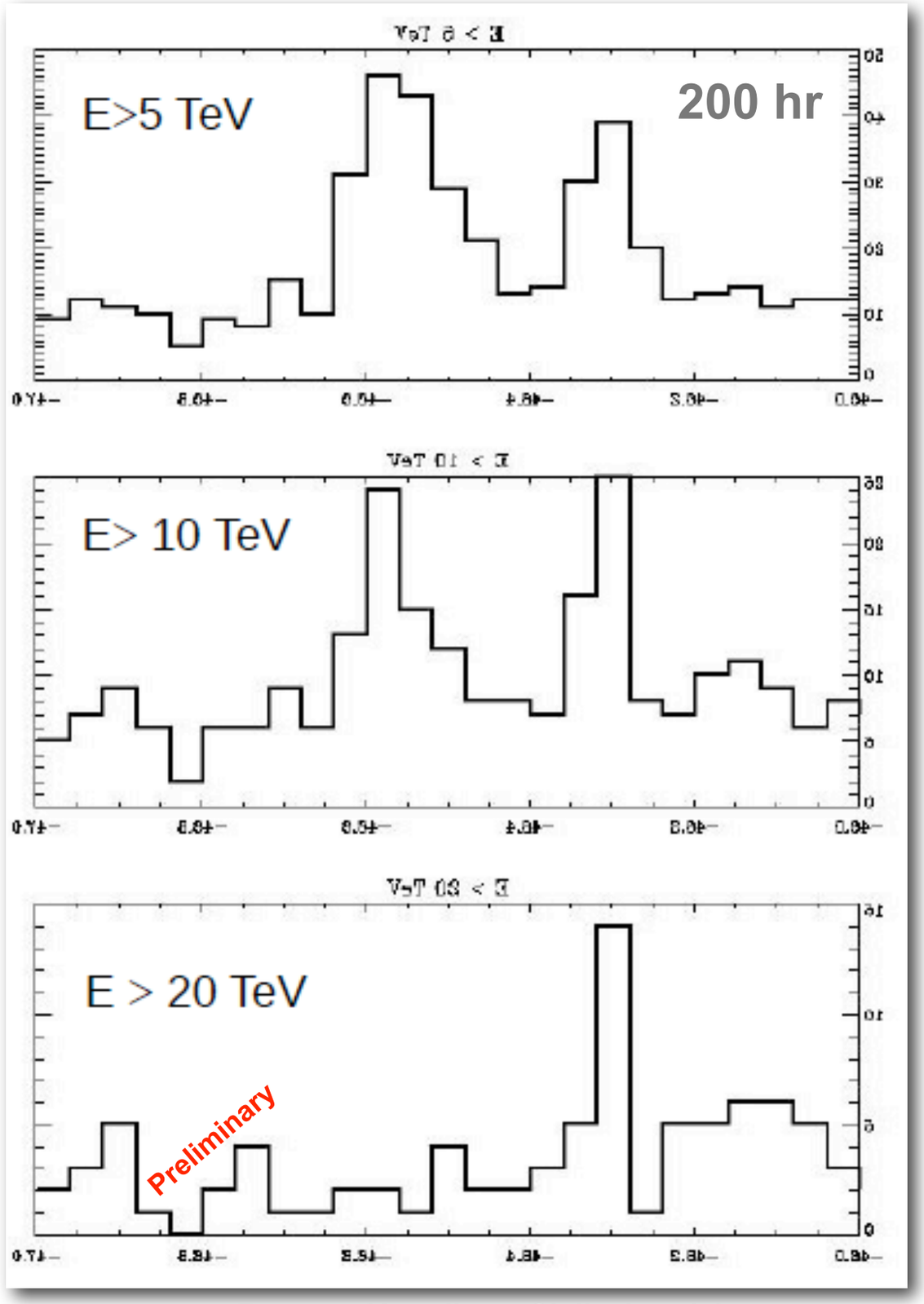


H.E.S.S. spectrum accumulated in 72 hr
Very hard source Γ ~ 2.1

It can be monitored [Feb. - Sept., ZA<35º] for **492 hr**
In the same FoV: **HESS J1640-465**
We can investigate:
- performance of the mini-array (SVP);
- is there a spectral cut-off? at which energy?
- nature of this source - SNR? PWN? Binary?

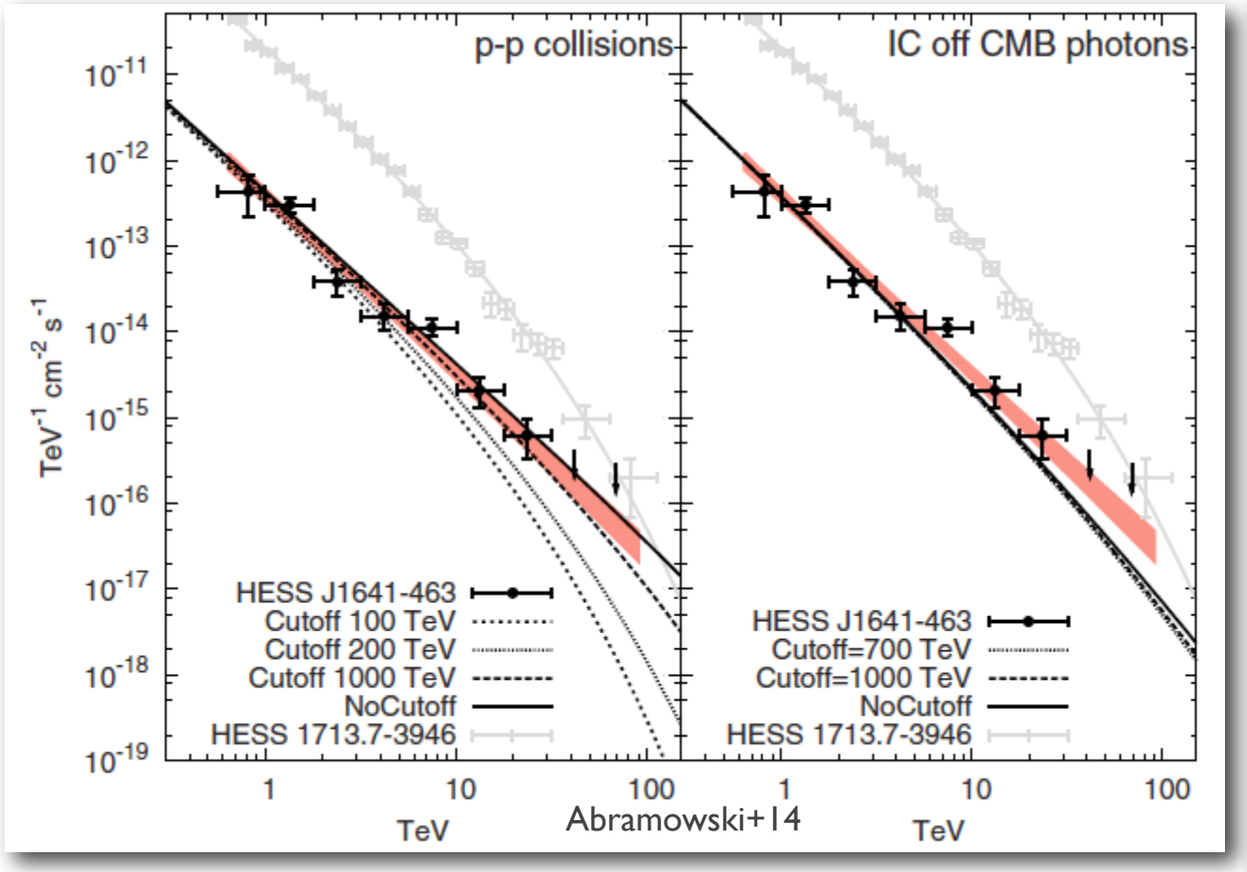
γ-ray UNID: HESS J1641-463





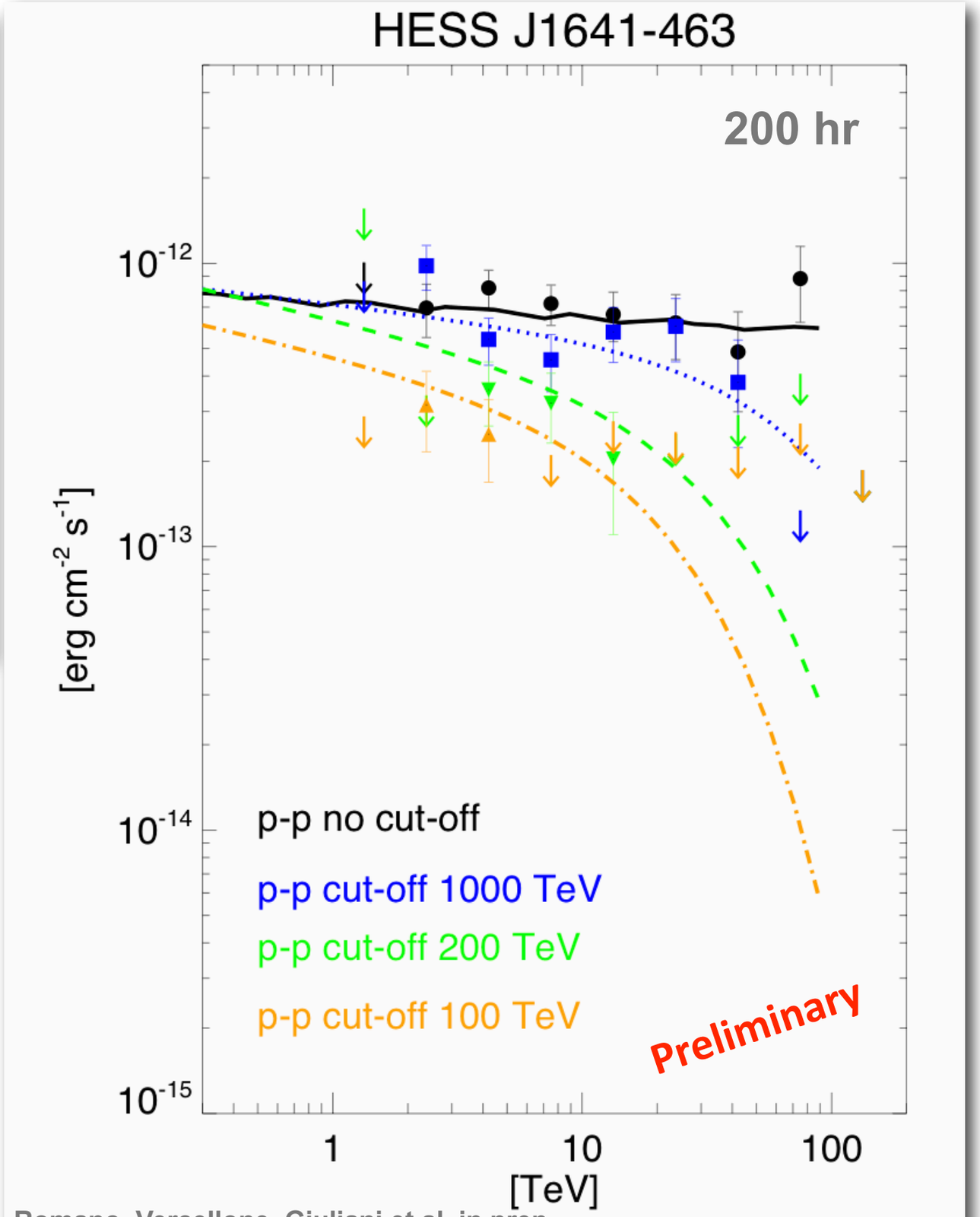
Romano, Vercellone, Giuliani et al. in prep.

γ-ray UNID: HESS J1641-463



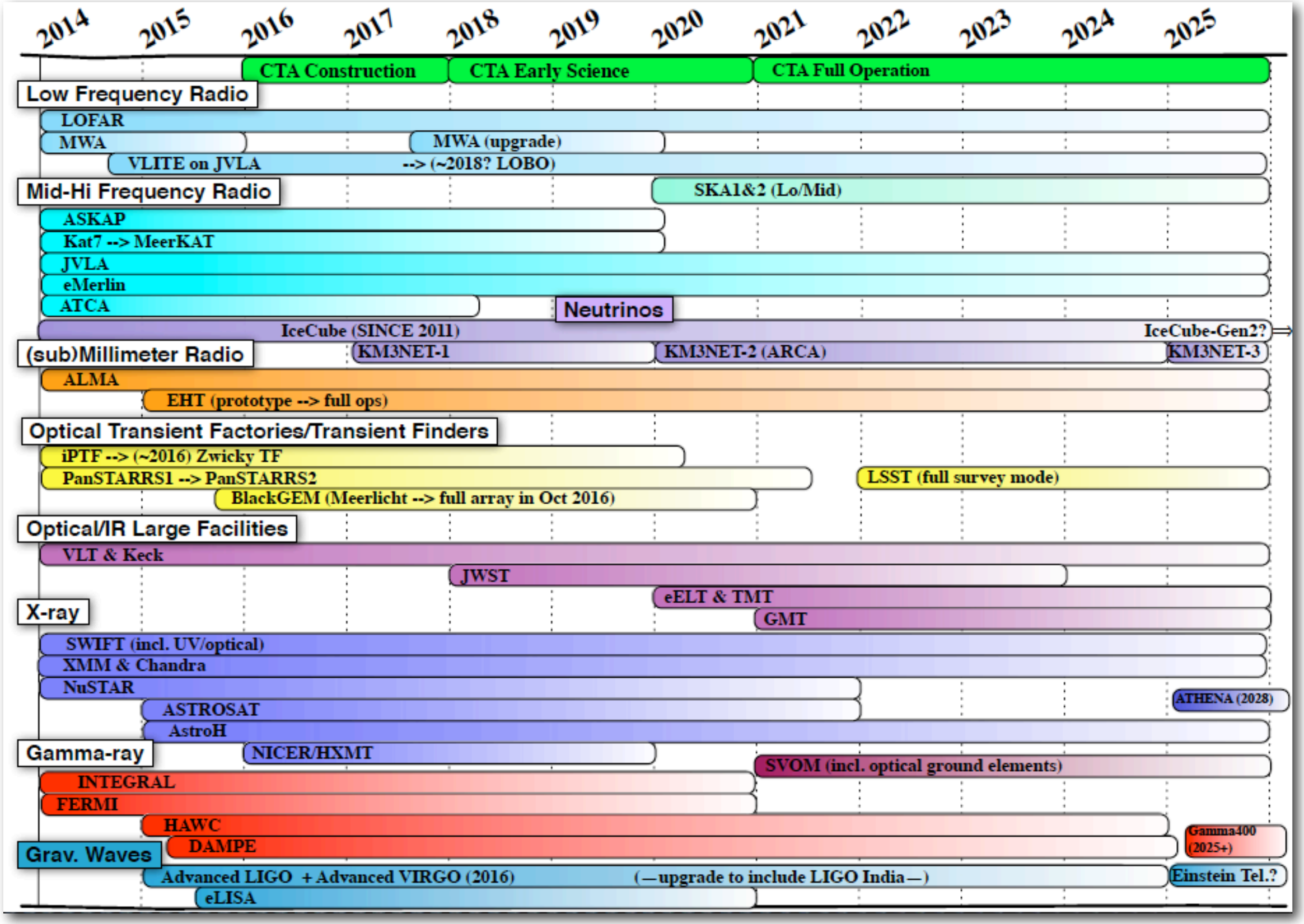
We can investigate:

- **presence of a spectral cut-off (and its energy)**
- **nature of this source**



Romano, Vercellone, Giuliani et al. in prep.

MWL & MM facilities



S. Markoff 2015, ASTRI science meeting

Summary

- **CTA will be the major Observatory for very high-energy astrophysics** in the next decades, and it will investigate currently open issues on several astrophysical topics.

- **The ASTRI SST-2M prototype**, inaugurated on September 24th 2014, will perform the first observations with a Schwarzschild-Couder telescope equipped with SiPMs at the end of 2015.

- **The ASTRI mini-array** will constitute a *precursor* for the whole CTA array, allowing us to investigate innovative technological solutions.

- **CTA precursor early science** performed by means of ASTRI mini-array observations of a few selected targets will allow us to obtain several solid detections during the first year.

- **Excellent synergies** with other CTA precursors (MSTs, LSTs) and with several observing MWL & MM facilities from 2017 and beyond.

http://www.brera.inaf.it/astri/

Credit: R. Canestrari