

The High Energy Stereoscopic System Highlights

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Rencontres de Blois
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H.E.S.S. : High Energy Stereoscopic System

An array of telescopes for very-high energy gamma ray astronomy



The H.E.S.S.
Collaboration

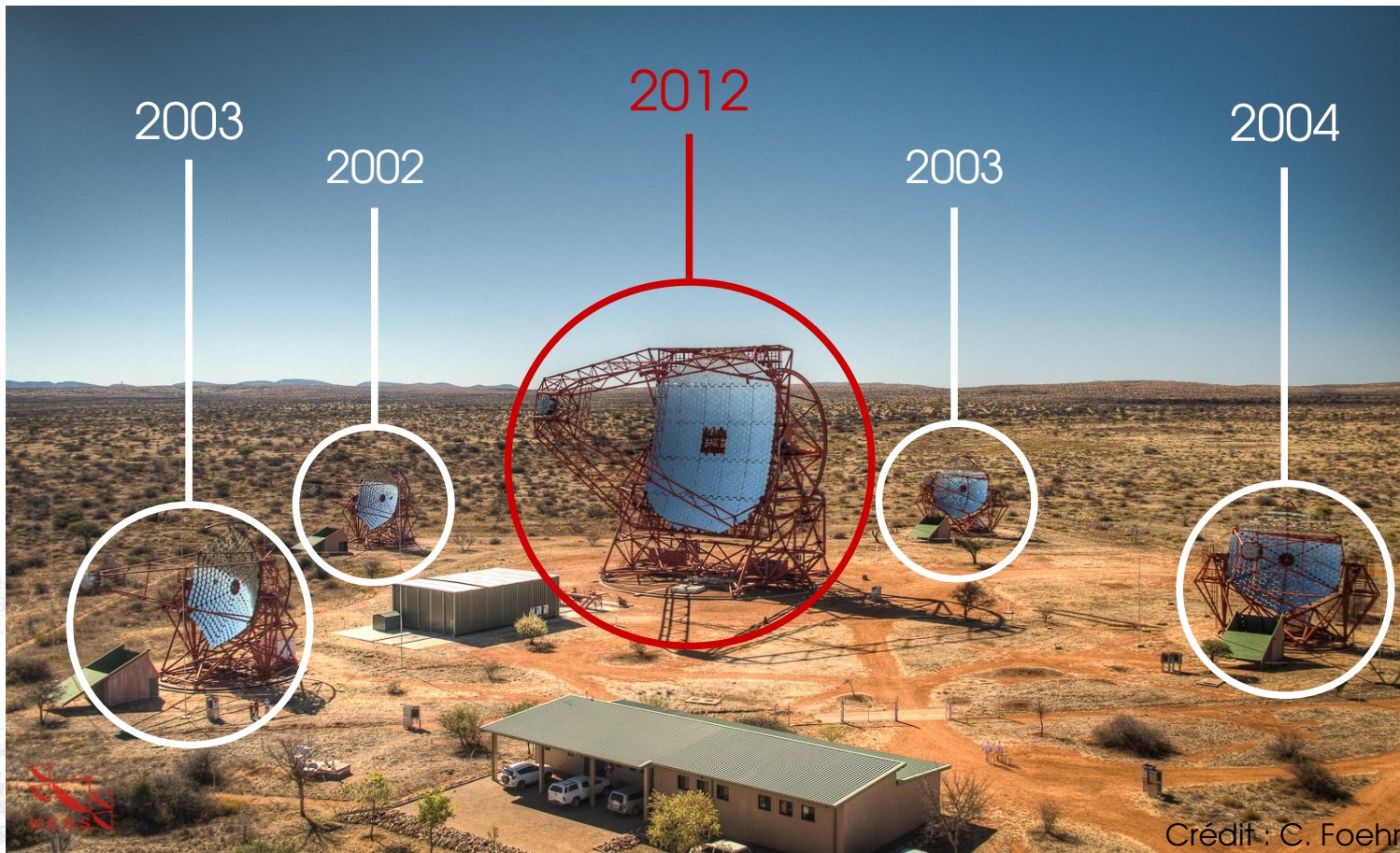
38 institutes
from 13
countries

~ 230 members

- Mont Khomas, Namibia

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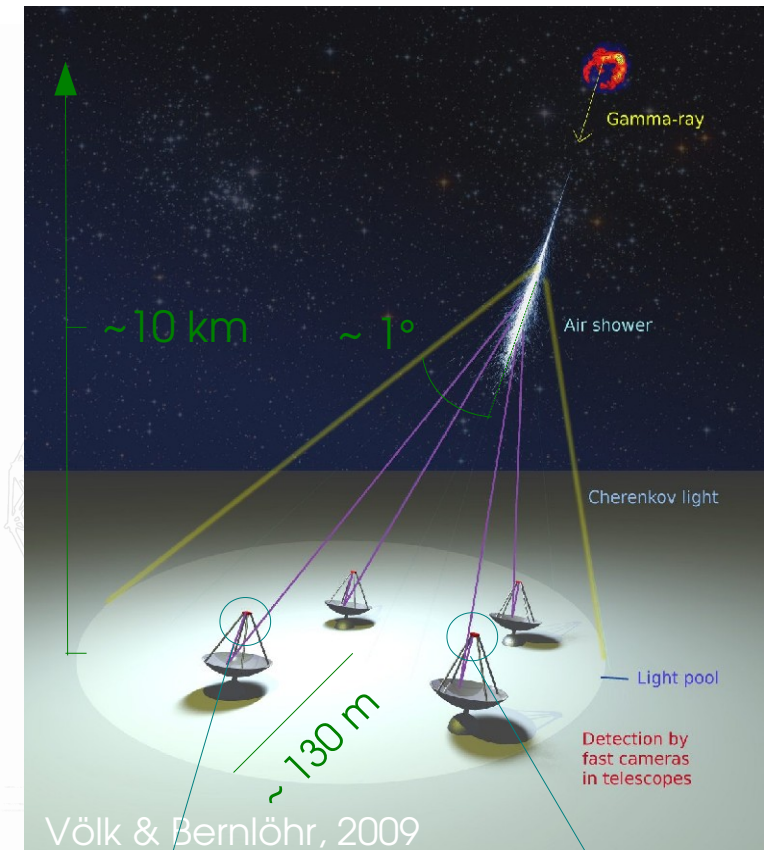
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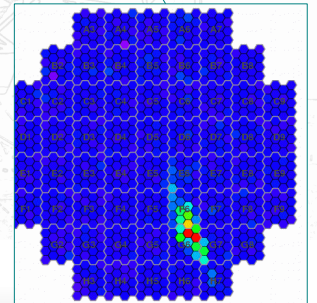
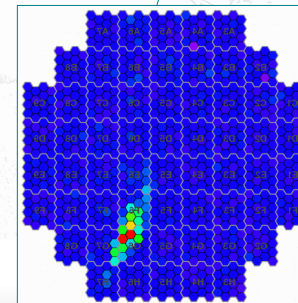
- Mont Khomas, Namibia
- H.E.S.S. I : 4 telescopes – 2004
- H.E.S.S. II : 5 telescopes - 2012

The imaging atmospheric Cherenkov technique

- γ interacts in the atmosphere
- Development of a particle shower
- Emission of a brief (\sim few ns) and weak flash of Cherenkov light
- Image of the shower with cameras at the focal plane of telescopes

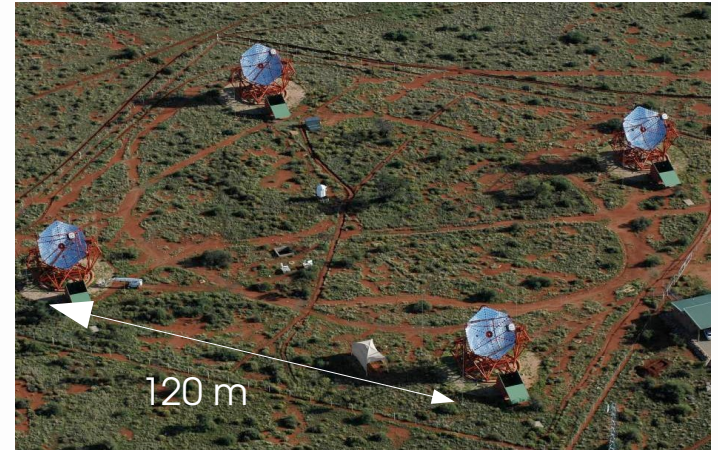


Orientation \rightarrow Direction
Intensity \rightarrow Energy
Shape \rightarrow Discrimination



The H.E.S.S. array

- High Energy Stereoscopic System
 - 4 telescopes of 107 m²
 - Cameras with 960 PMTs
 - Field of view : 5°
 - 100 GeV – 50 TeV (resolution ~ 10%)
 - Angular resolution < 0.1°



« Real » astronomy at TeV energies

- A sensitive instrument (1 % « Crab ») ...
... on more than 2 orders of magnitude in energy
- Morphology studies
- Survey capabilities
- Detailed light-curves

Instruments currently in operation

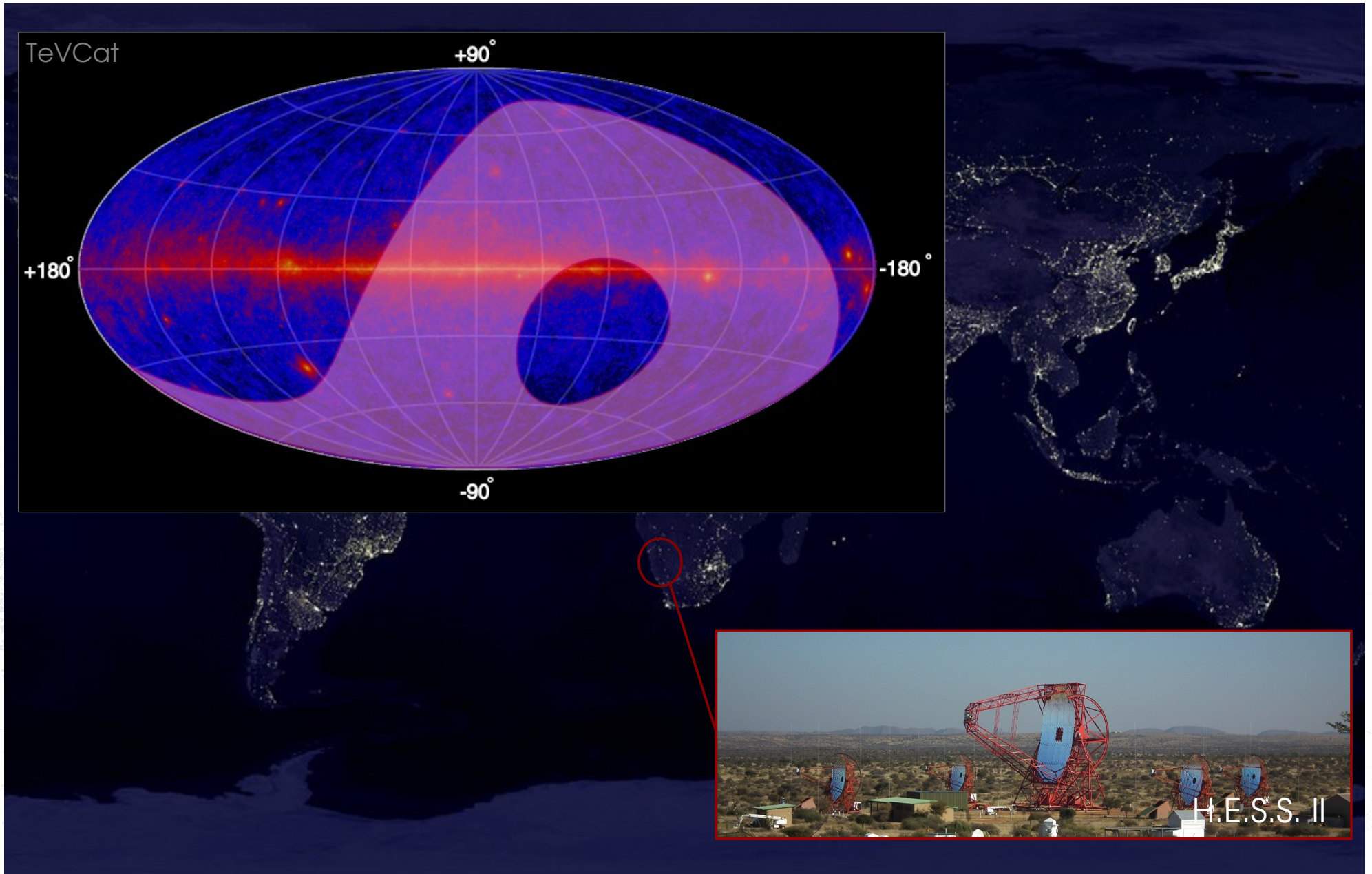


VERITAS

MAGIC

H.E.S.S. II

A southern hemisphere observatory



H.E.S.S. I : 10+ years of operation

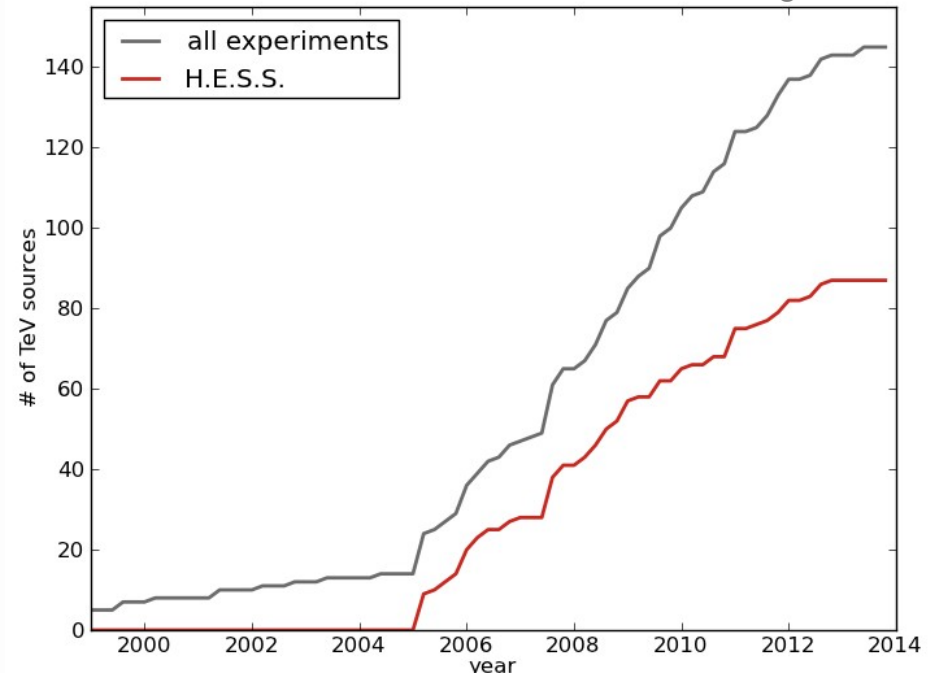
~ 10 000 hours of observations

- ~50% Galactic / 50% extragalactic
- $> 6 \times 10^9$ events

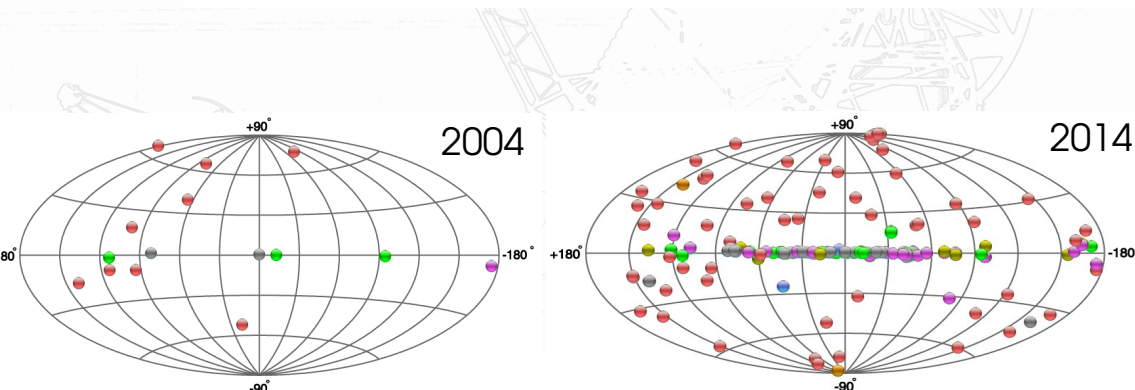
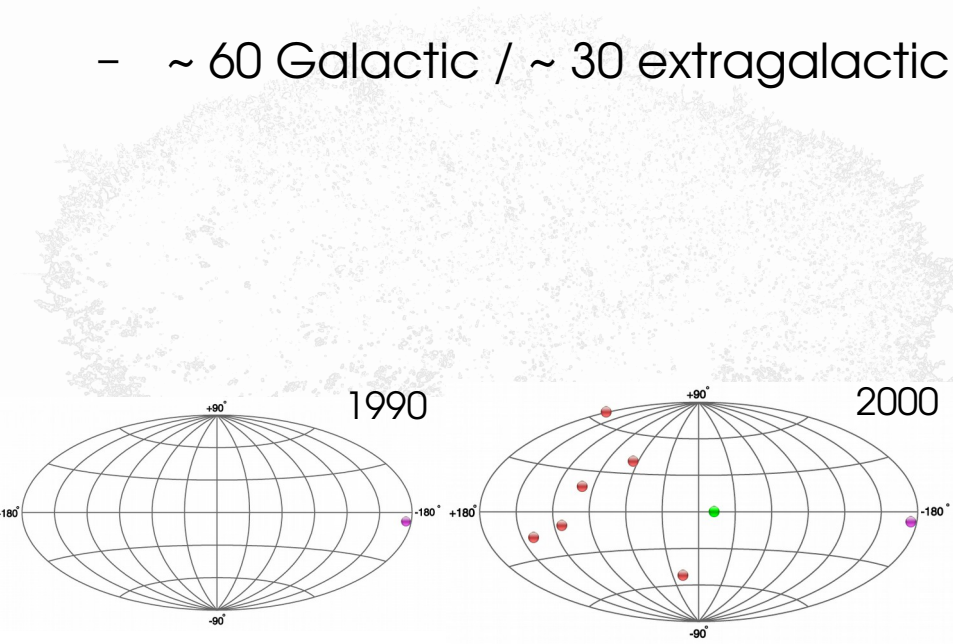
~ 90 new sources

- ~ 60 Galactic / ~ 30 extragalactic

tevcat.uchicago.edu

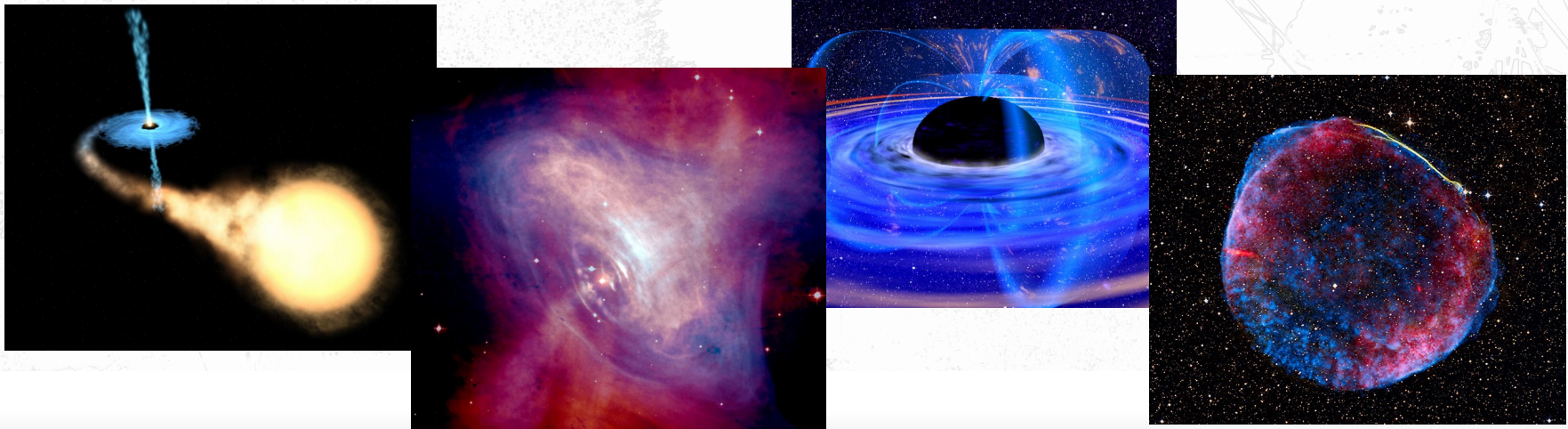


All: Whipple, Crimea, Telescope Array, Durham, MAGIC, VERITAS, H.E.S.S.



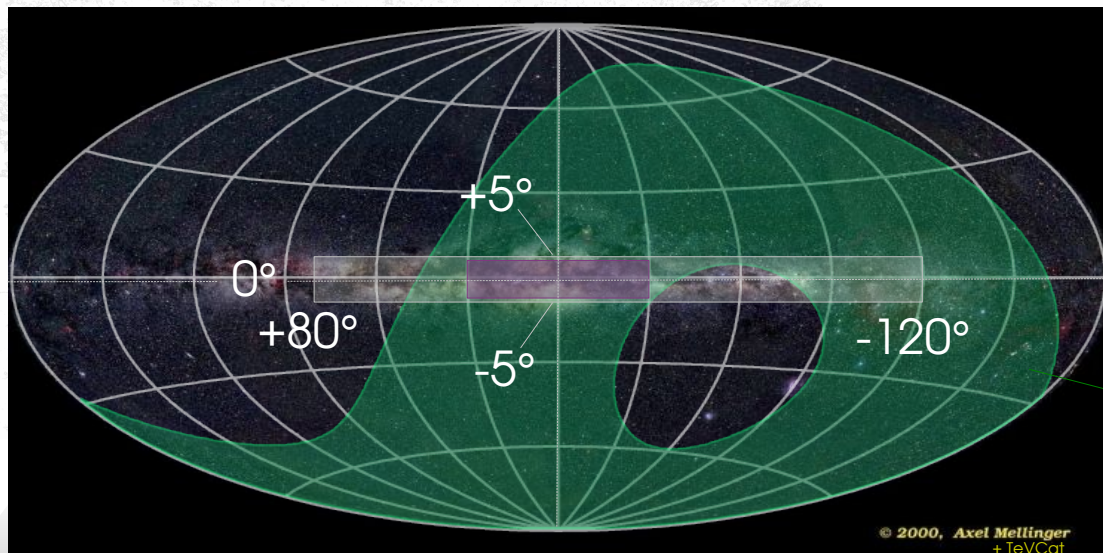
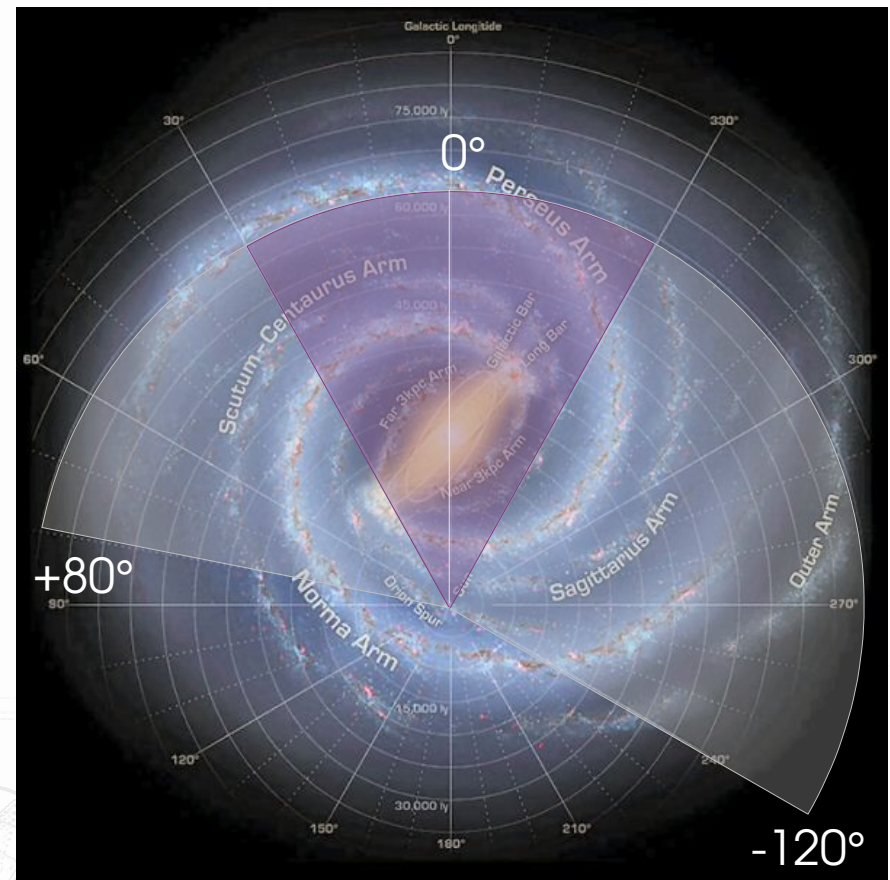
The HESS Galactic Plane Survey

- **Goal** : Map the inner regions of the Galaxy to discover new TeV sources
 - Search for the sources of Galactic Cosmic Rays
 - Study of charged particles acceleration in astrophysical sources
 - Study high-energy particles propagation in the Galaxy
 - Connection to fundamental physics (Lorentz Invariance, Dark Matter, Axions,...)
- **Each new source of VHE gamma rays is a new laboratory !**



The HESS Galactic Plane Survey

- **Goal** : Map the inner regions of the Galaxy to discover new TeV sources
- **First Survey (2004)** :
 - 230 h. of observation
- **Since 2004** :
 - x10 in observation time
 - -120° to $+80^\circ$ in longitude
 - -5° to $+5^\circ$ in latitude

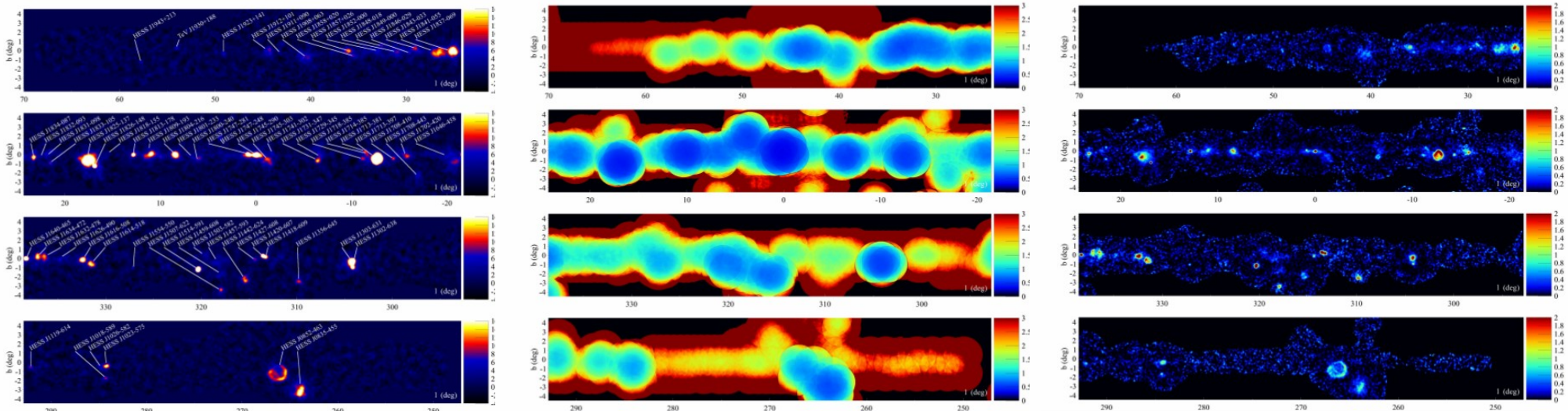


Optimal H.E.S.S. visibility

The HGPS : Latest version

- « Final » HESS catalog of survey sources
 - Data collected 2004 – 2013
 - 2673 h after quality selection
- Available soon :
 - Maps : Significance, sensitivity, flux (+errors) and upper limits maps

COMING SOON!



The HGPS : Latest version

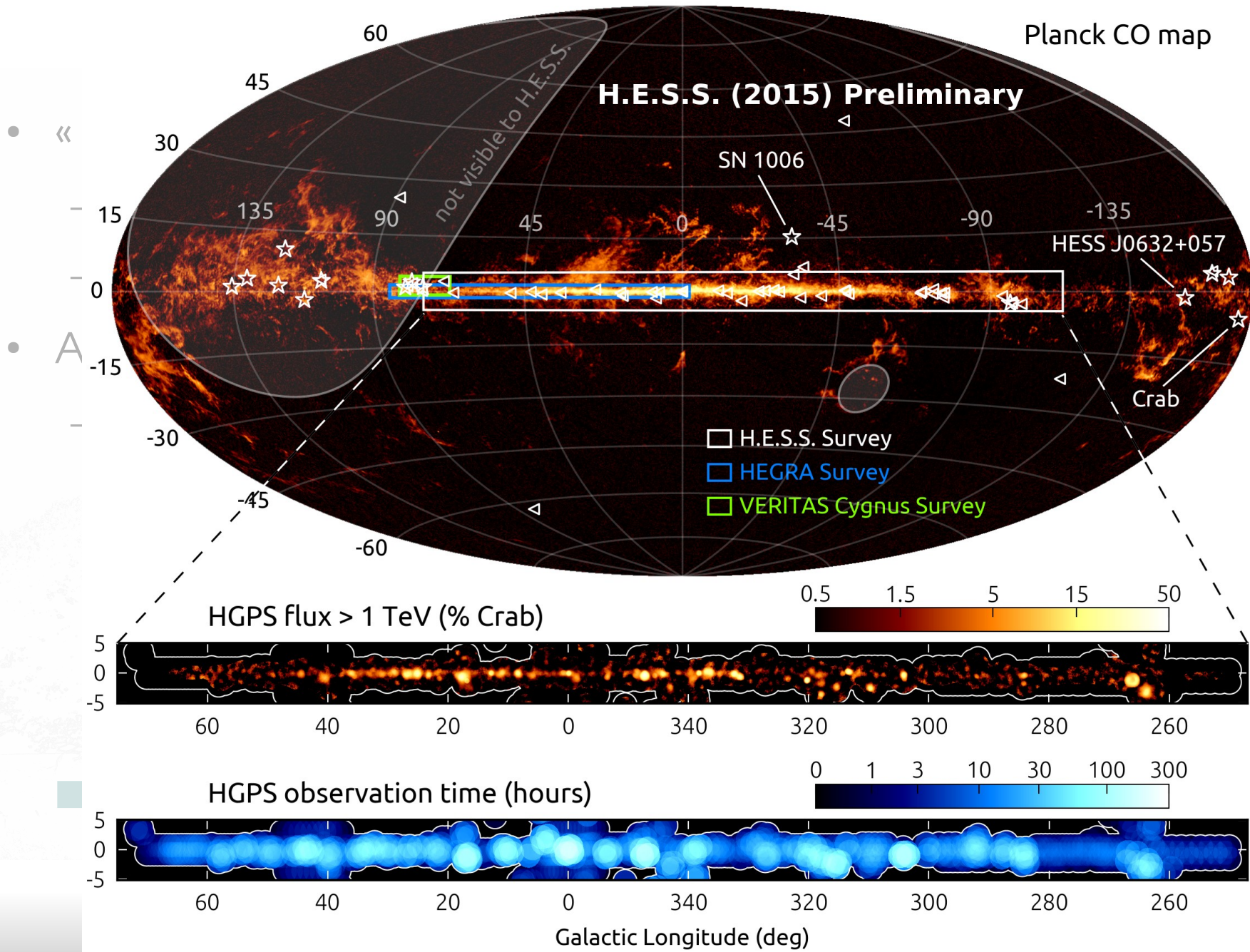
- « Final » HESS catalog of survey sources
 - Data collected 2004 – 2013
 - 2673 h after quality selection
- Available soon :
 - Catalog : Automatic pipeline for source extraction
 - Survey region split into overlapping Regions of Interest
 - Likelihood fit of emission by multiple Gaussian components + diffuse background
 - Overlapping emission components combined

COMING
SOON!

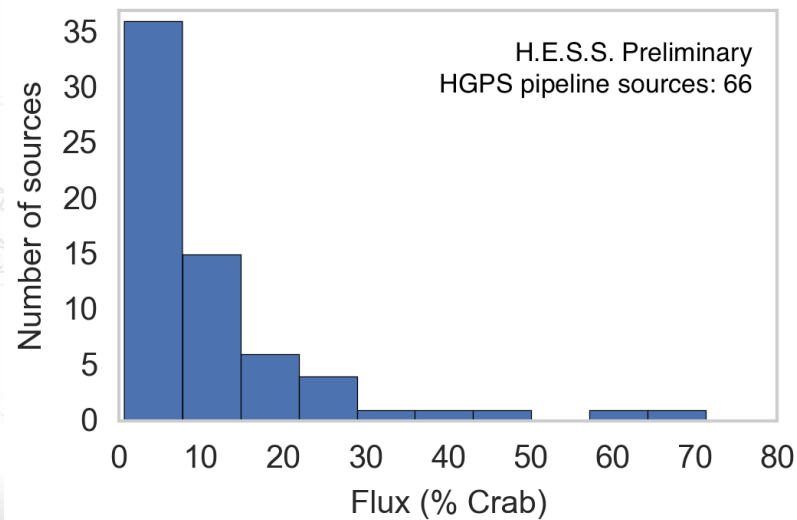
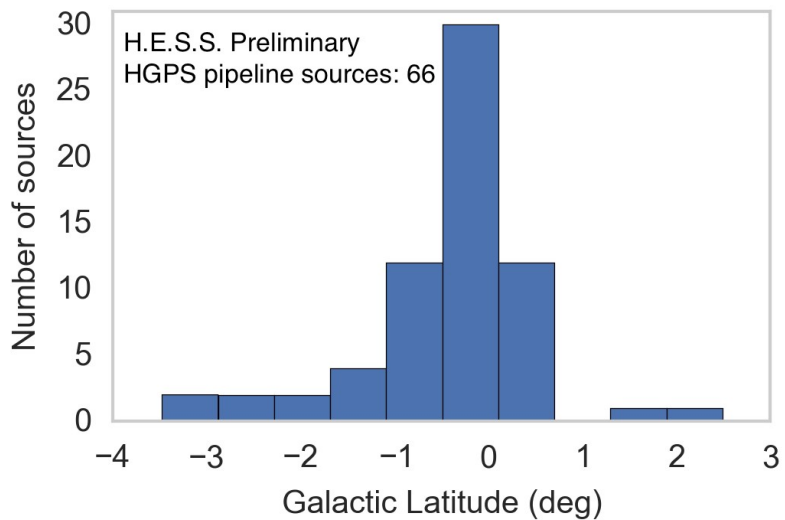
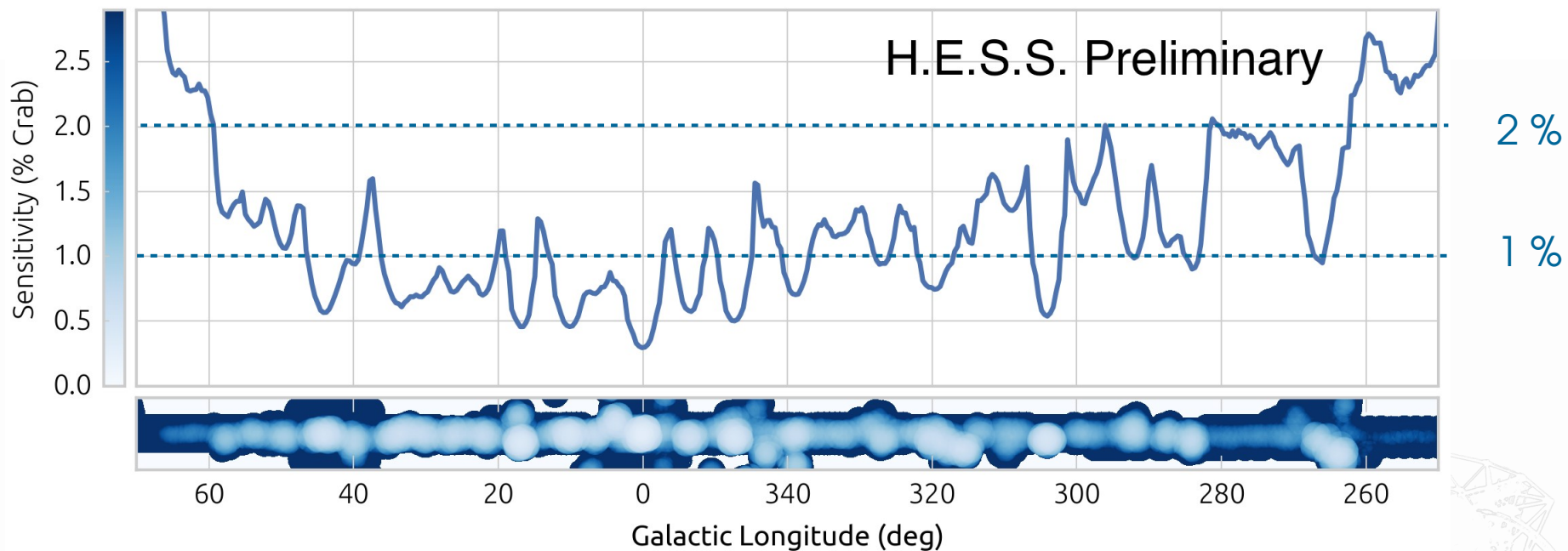


66 VHE sources + 11 complex sources (e.g. shell SNR)
excluded from pipeline

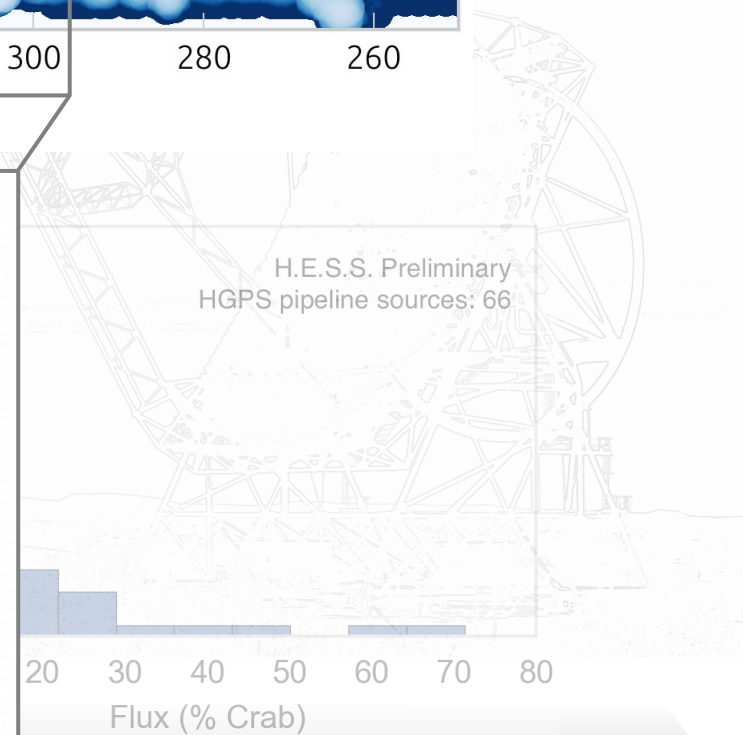
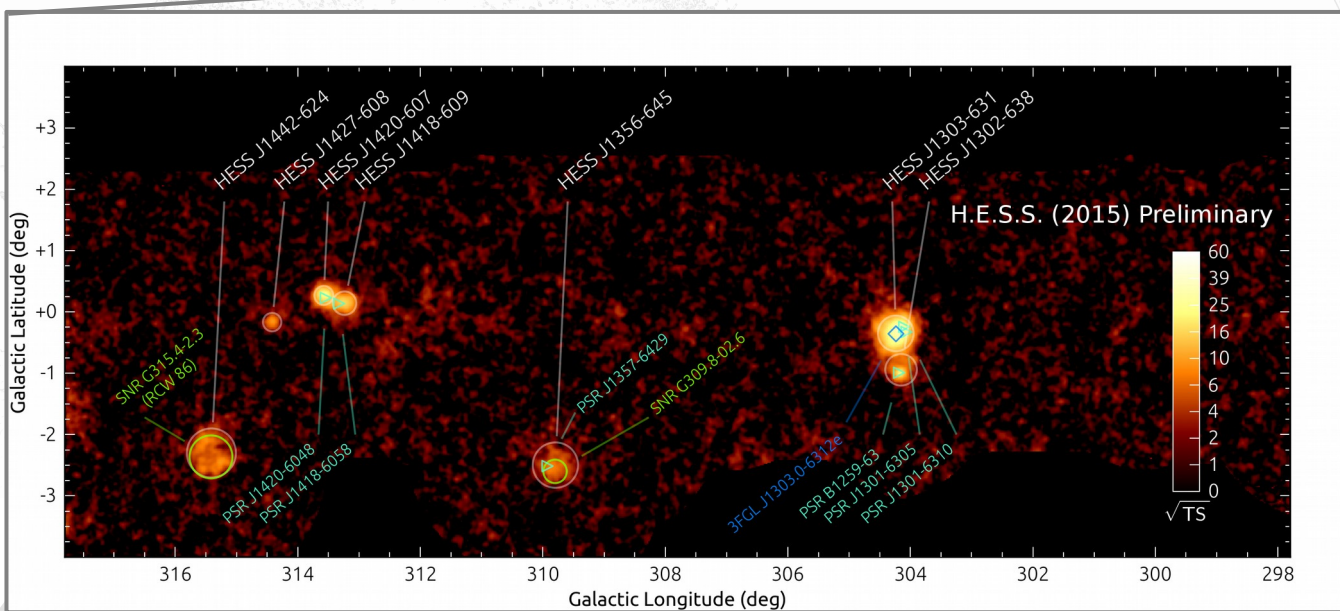
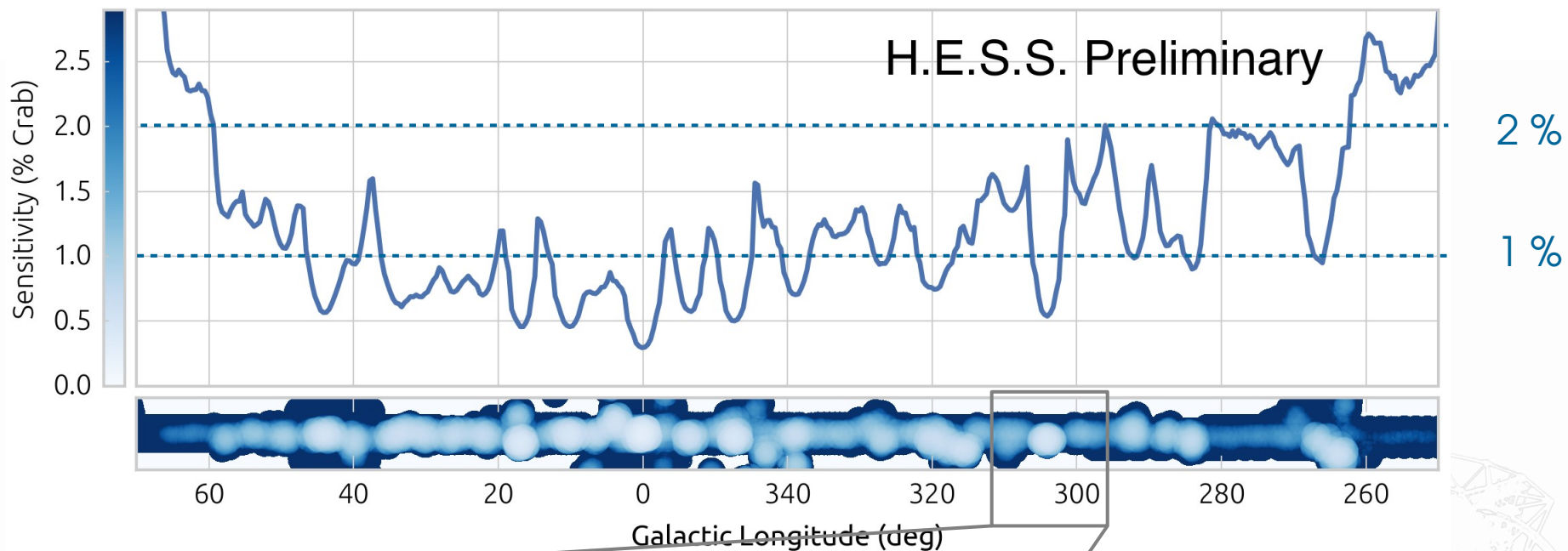
The HGPS : Latest version



The HGPS : Sensitivity and Sources distributions

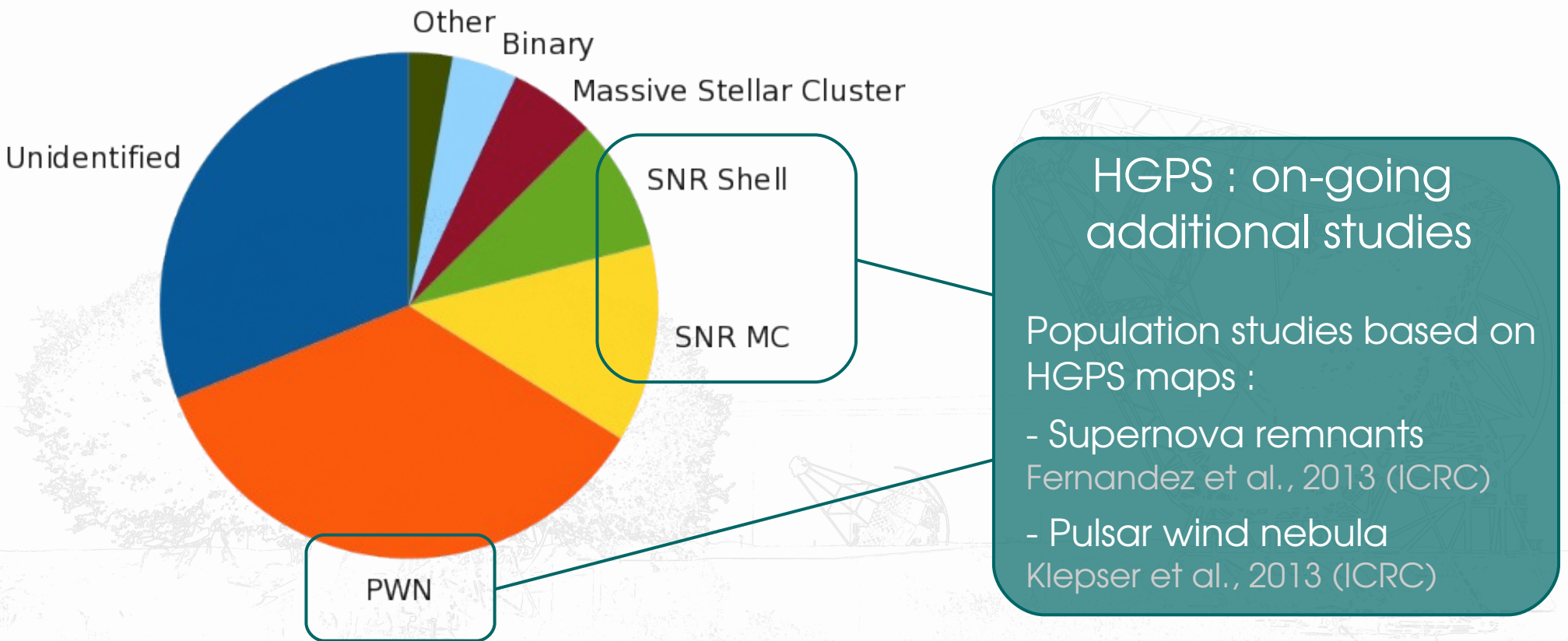


The HGPS : Sensitivity and Sources distributions



The HGPS : sources types

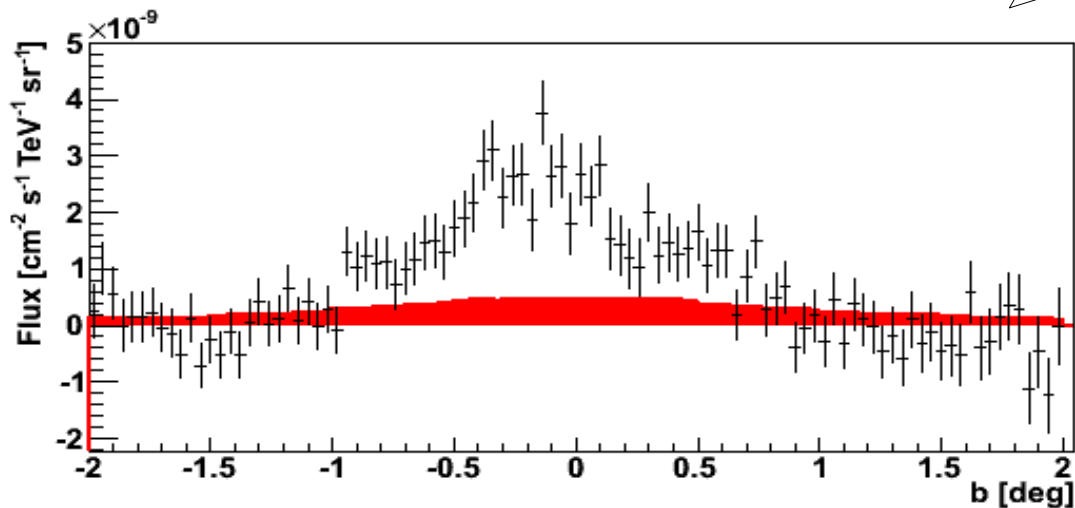
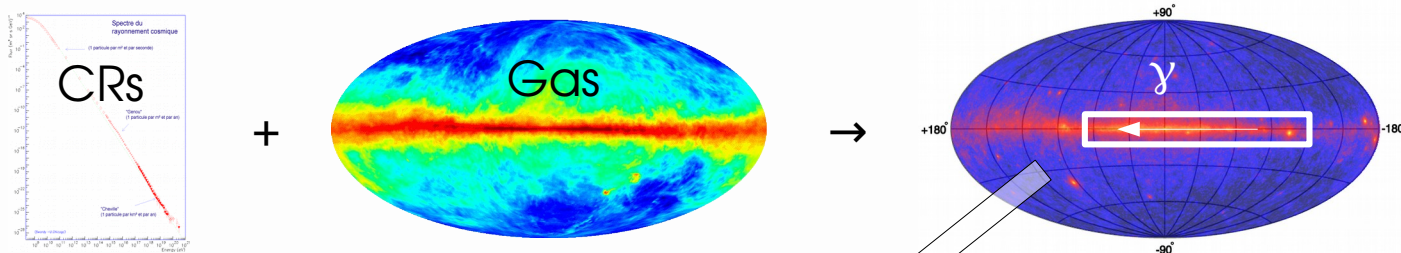
- More than **60 new sources detected** at very high energies with H.E.S.S.
 - Large variety of source types : supernova remnants, pulsar wind nebulae, binaries...



...to be revised with follow-up H.E.S.S.-II and MWL observations

The HGPS : additional studies

- Study of **diffuse emission** in the Galactic plane



Total flux outside sources regions versus Galactic latitude :

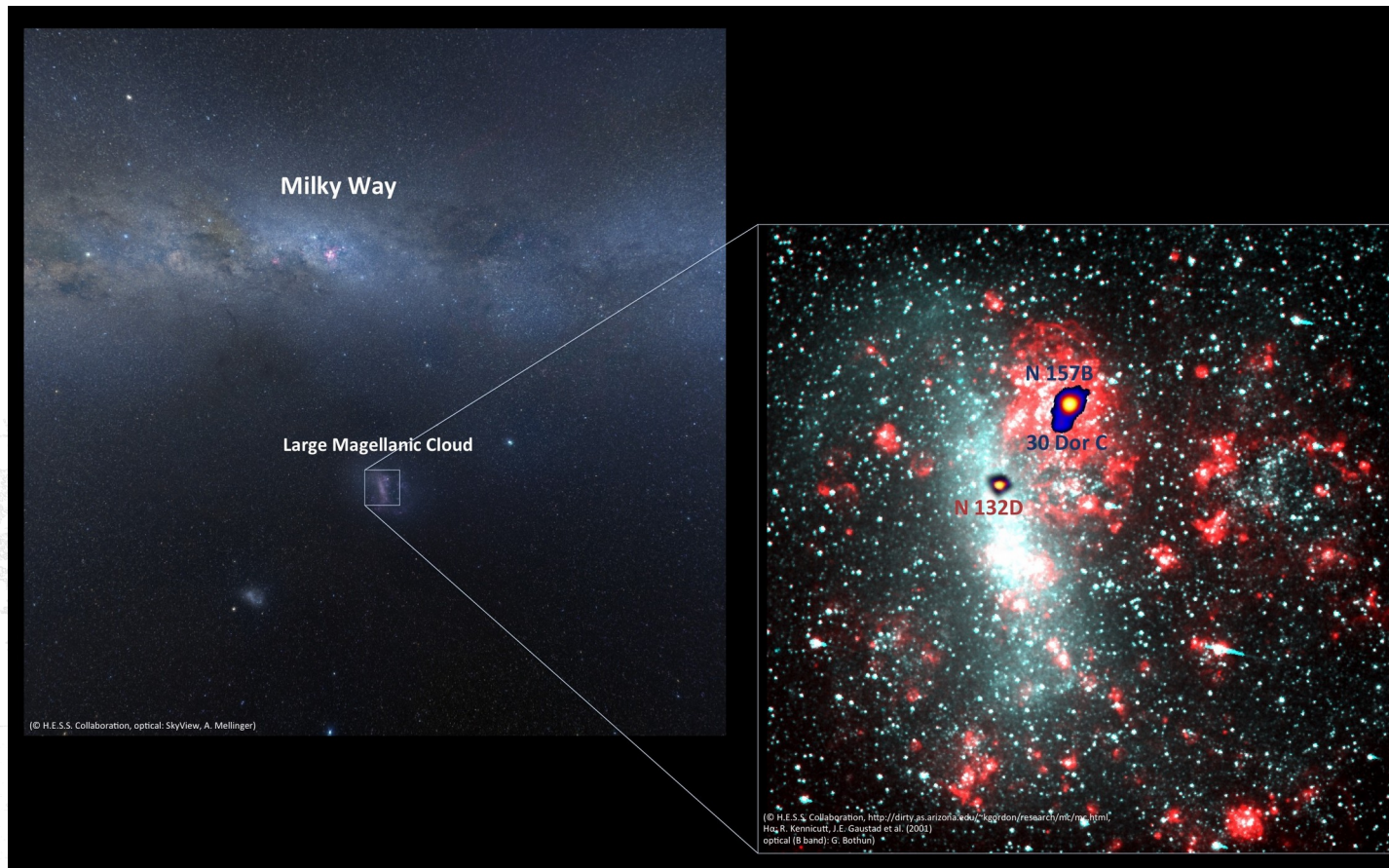
~ 25% = Galactic cosmic rays

~ 75% = Unresolved sources

HESS Collaboration, PRD 2014

Stellar VHE sources beyond the Milky way

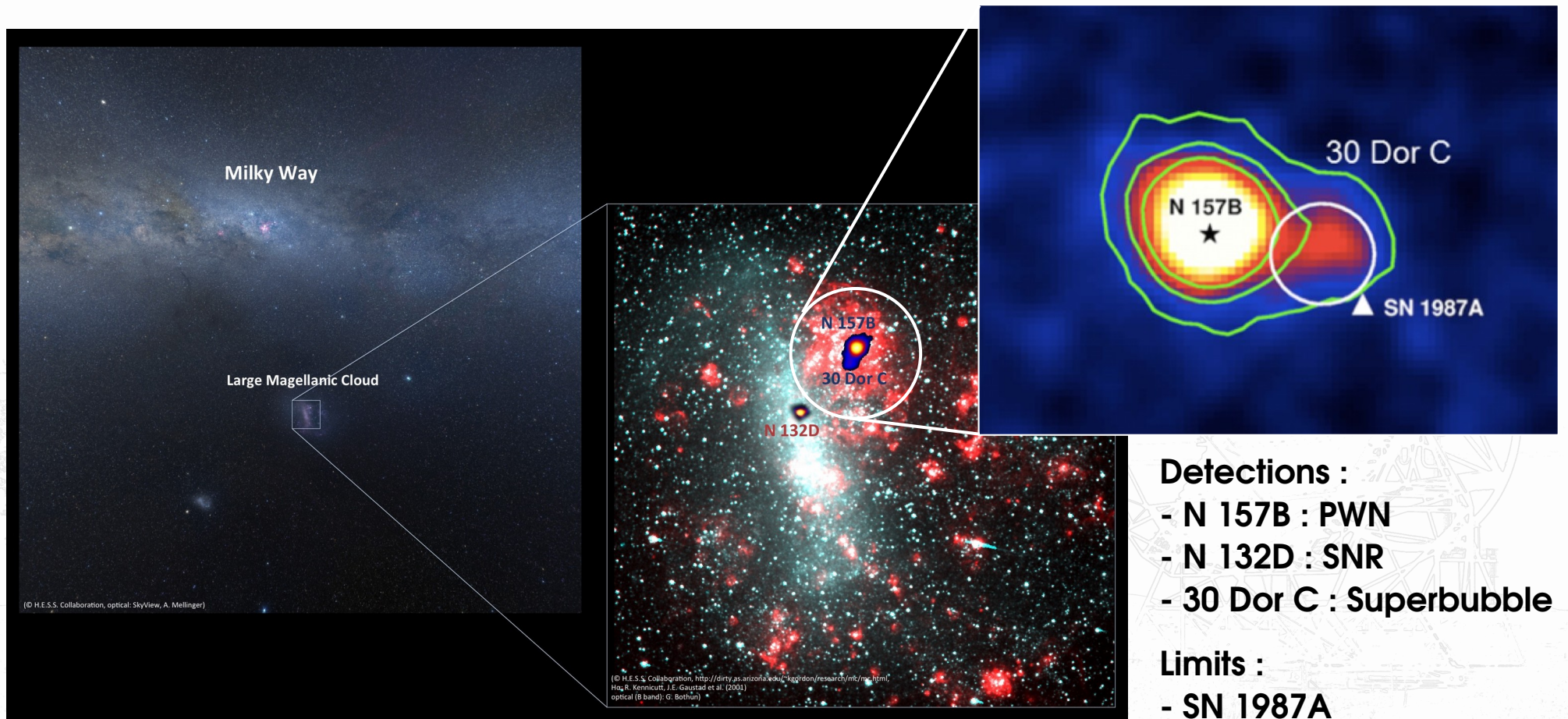
- Cosmic accelerators in the Large Magellanic Cloud
 - Galaxie of the local group (d = 50 kpc)



HESS Collaboration, Science 347 (2015) 406

Stellar VHE sources beyond the Milky way

- Cosmic accelerators in the Large Magellanic Cloud
 - Galaxie of the local group (d = 50 kpc)

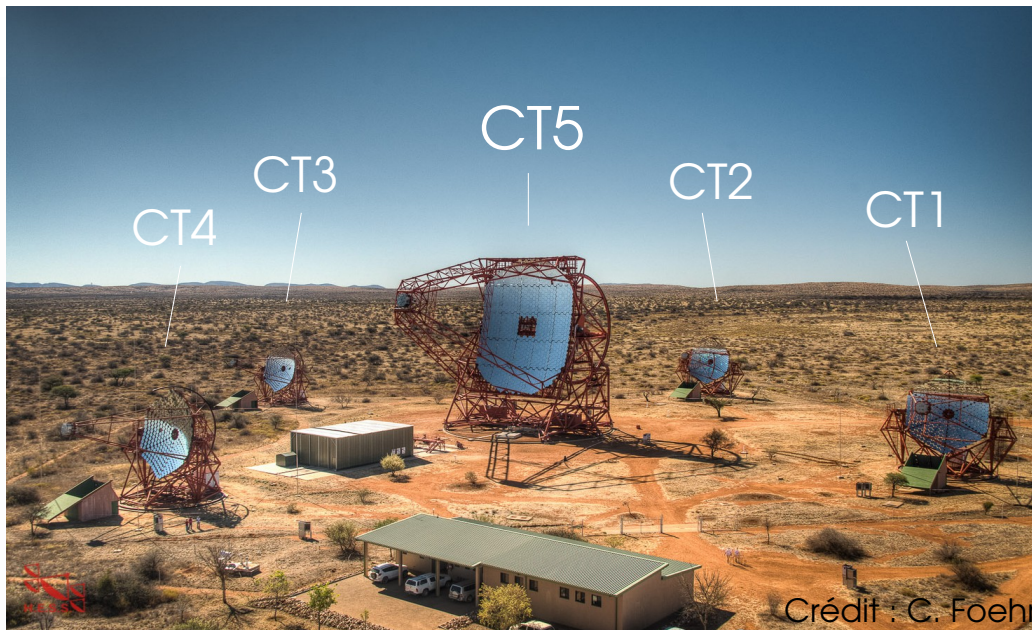


HESS Collaboration, Science 347 (2015) 406

H.E.S.S. II



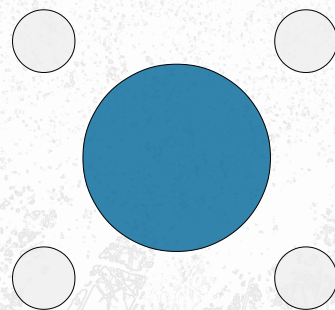
The H.E.S.S. array – Phase 2



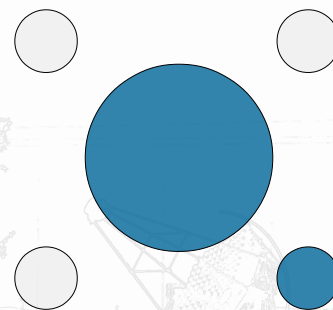
H.E.S.S. II : additional 5th telescope at the center

- 28 m in diameter, 600 m², 36 m focal length
- Energy threshold lowered to ~ 30 GeV
- Improved sensitivity and angular resolution

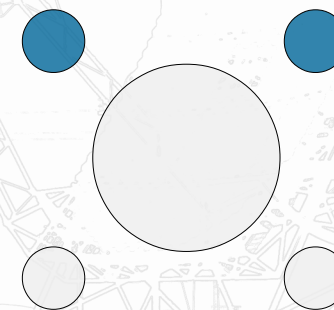
Array Trigger modes :



CT5 "mono":
lowest threshold
no stereo views
~65% of events



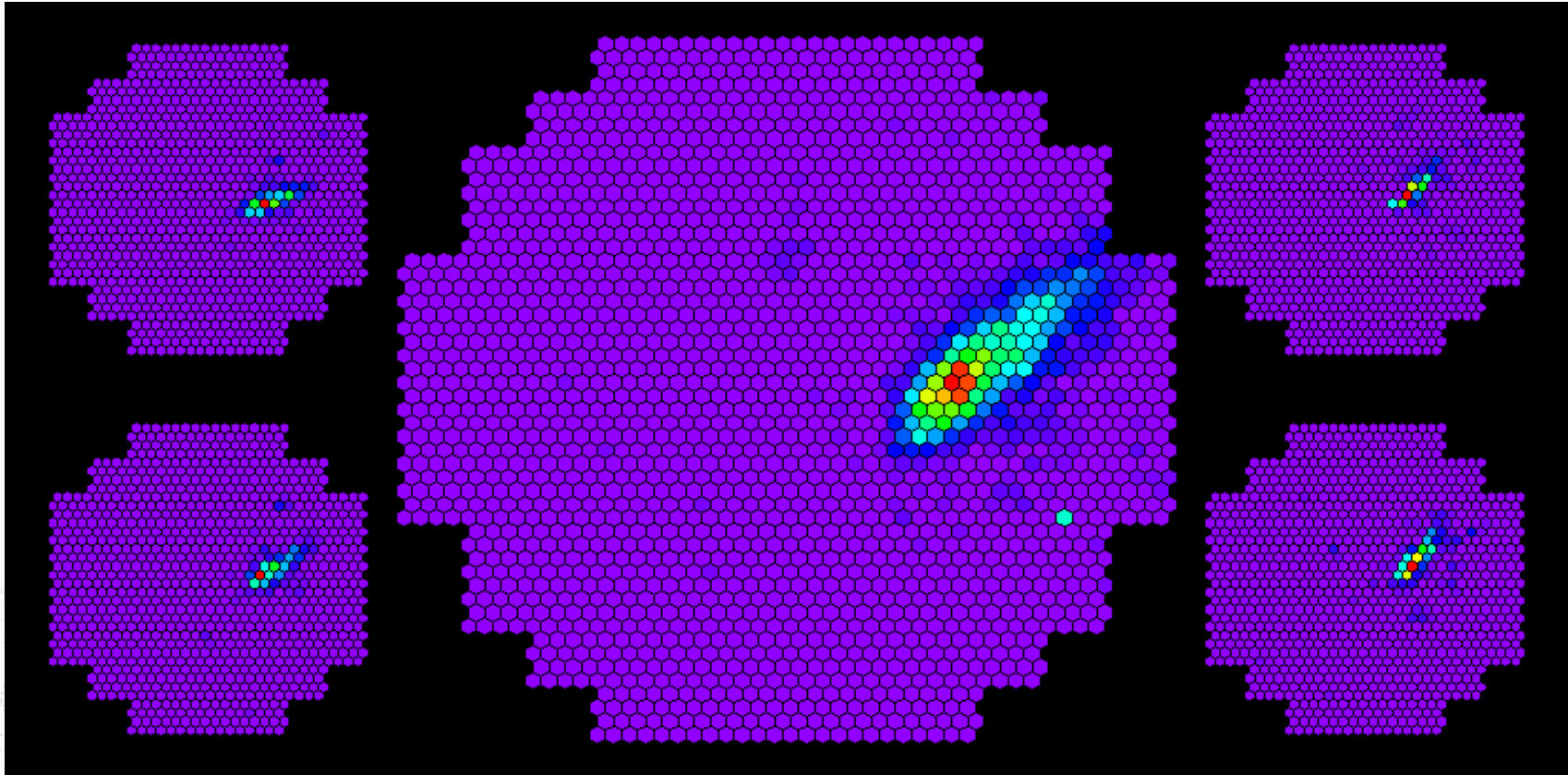
CT5 + ≥ 1 of CT1-4
"hybrid"
~30% of events



≥ 2 of CT1-4
~5% of events

H.E.S.S. II : Analysis

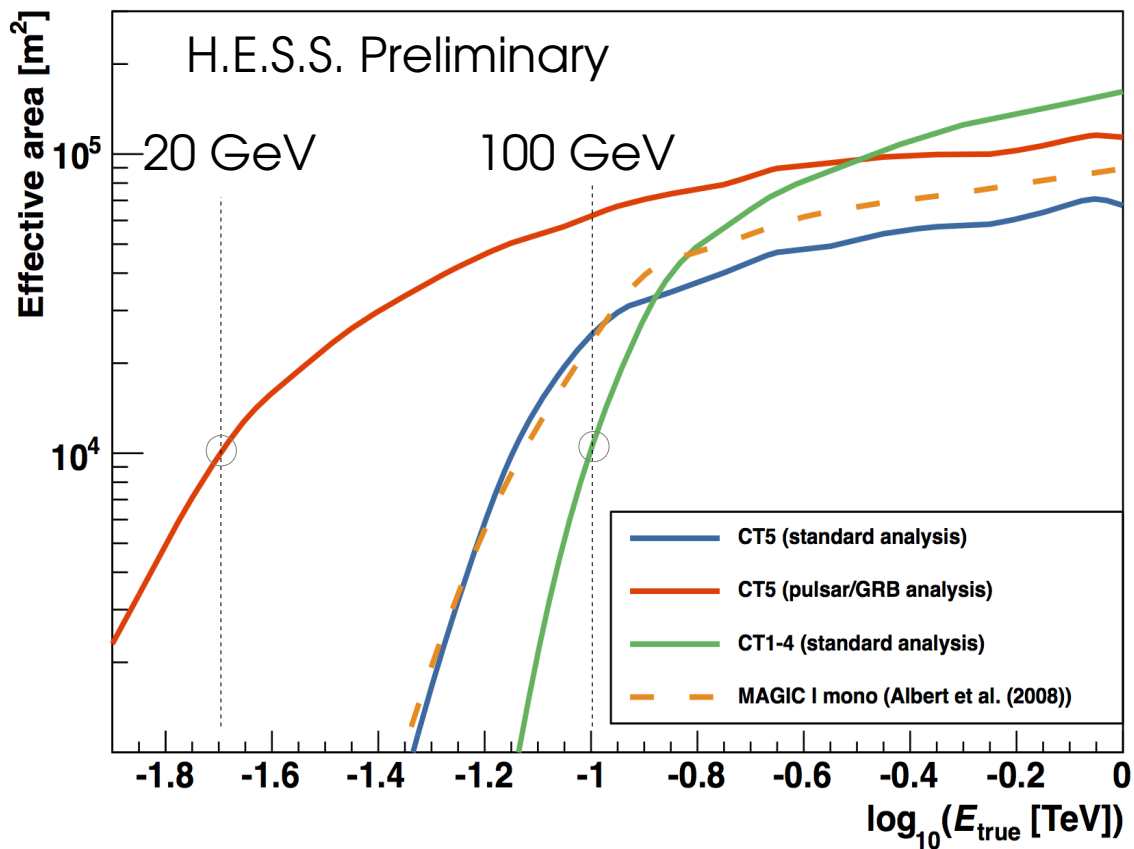
Event seen by the 5 telescopes in coincidence



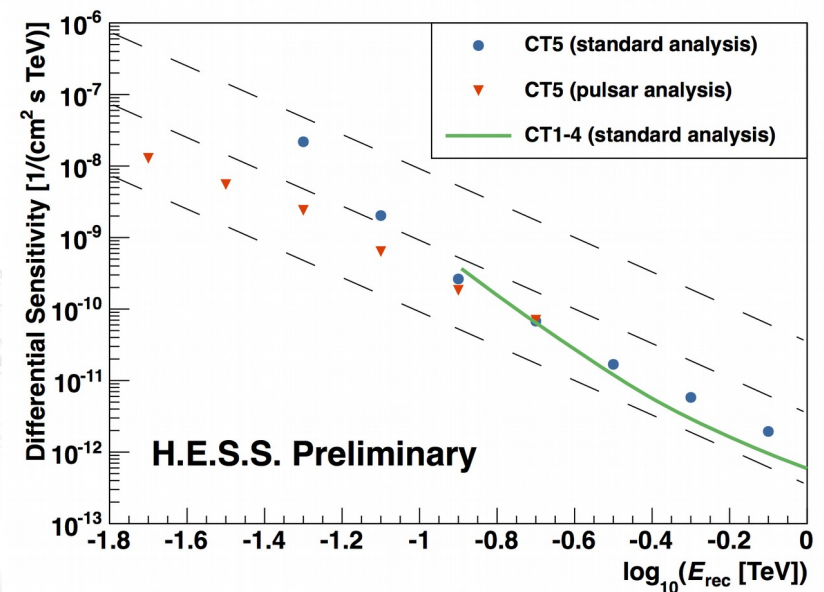
First « hybrid » array of Cherenkov telescopes !

Upgrade of the H.E.S.S. I cameras planned in 2015/2016

H.E.S.S. II : Performances (mono analysis)



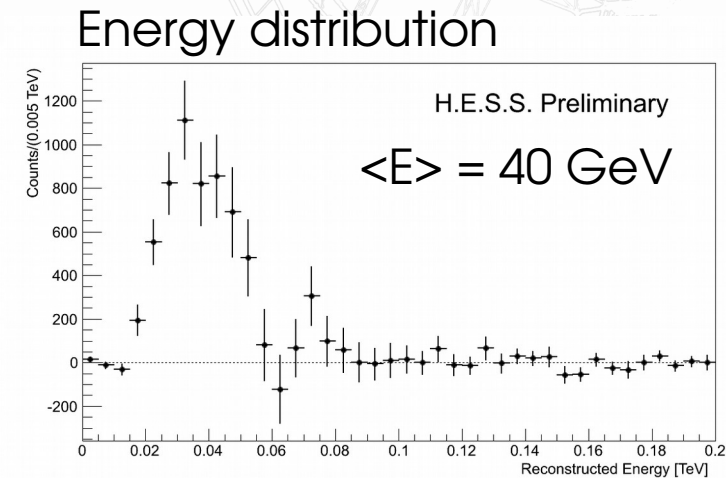
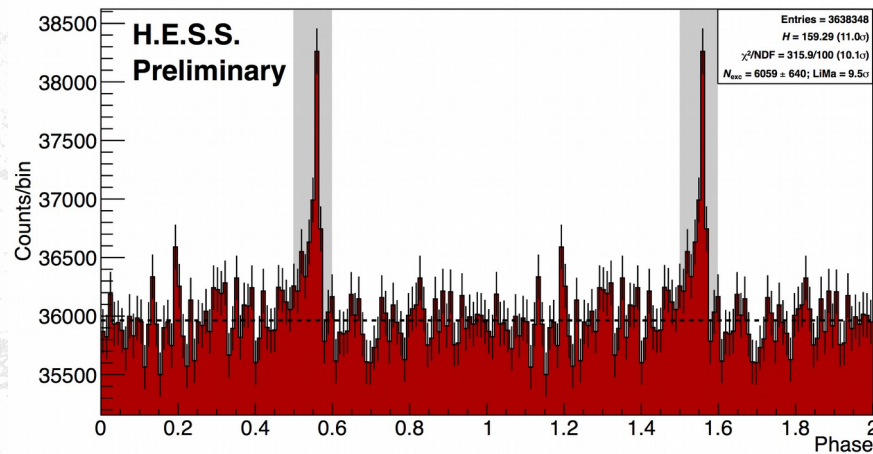
- Template (model/MC) based photon reconstruction techniques (de Naurois et al. 2009, Parsons et al. 2013)
- *Standard analysis* (optimised for steady sources) + *PSR/GRB analysis* (for low E detections)



In preparation : Combined analysis
 - Mono analysis for CT5 only events
 - Stereo analysis for Hybrid or « HESS 1 » events

Science with H.E.S.S. II

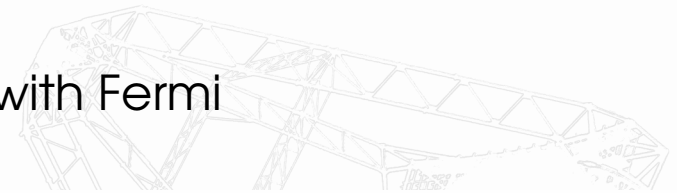
- Lower energy threshold :
 - Pulsars
 - MAGIC & VERITAS detection of the pulsed emission of the Crab
 - H.E.S.S. II detection of pulsed emission from Vela PSR :



First H.E.S.S. II (mono) results (Conferences, summer 2014)

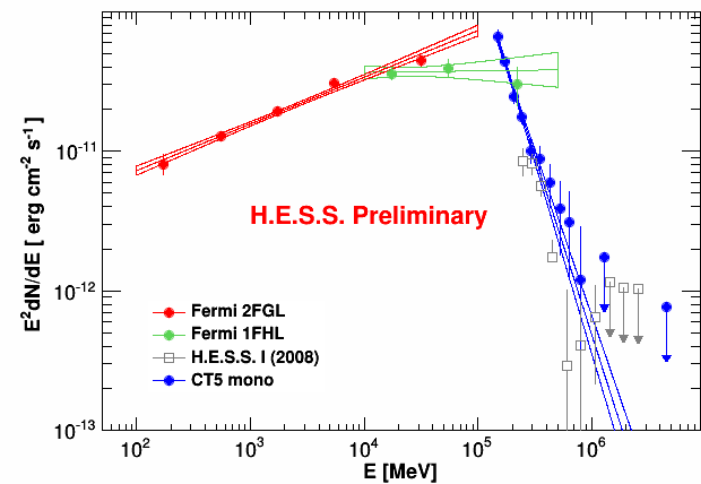
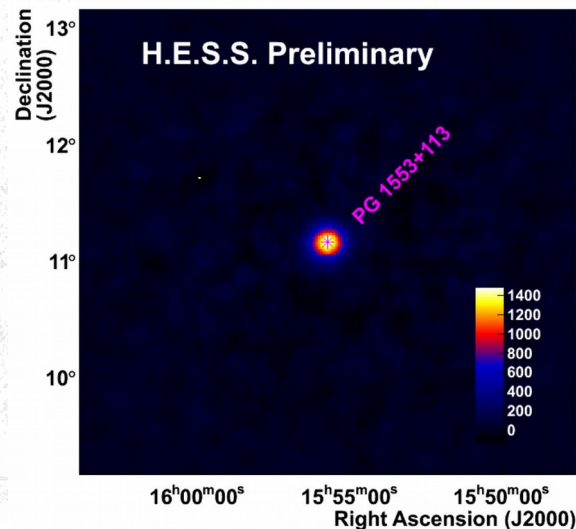
Science with H.E.S.S. II

- Lower energy threshold :
 - Pulsars
 - AGN less absorbed by EBL
 - More objects !
 - Part of the energy range common with Fermi



PG 1553+113

Live time : 15,1 h
Excess : 2508 γ
Significance : 26,6 σ
Zenith angle : $\sim 35^\circ$
Rate : $2,77 \pm 0,11 \gamma/\text{min}$



First H.E.S.S. II (mono) results (Conferences, summer 2014)

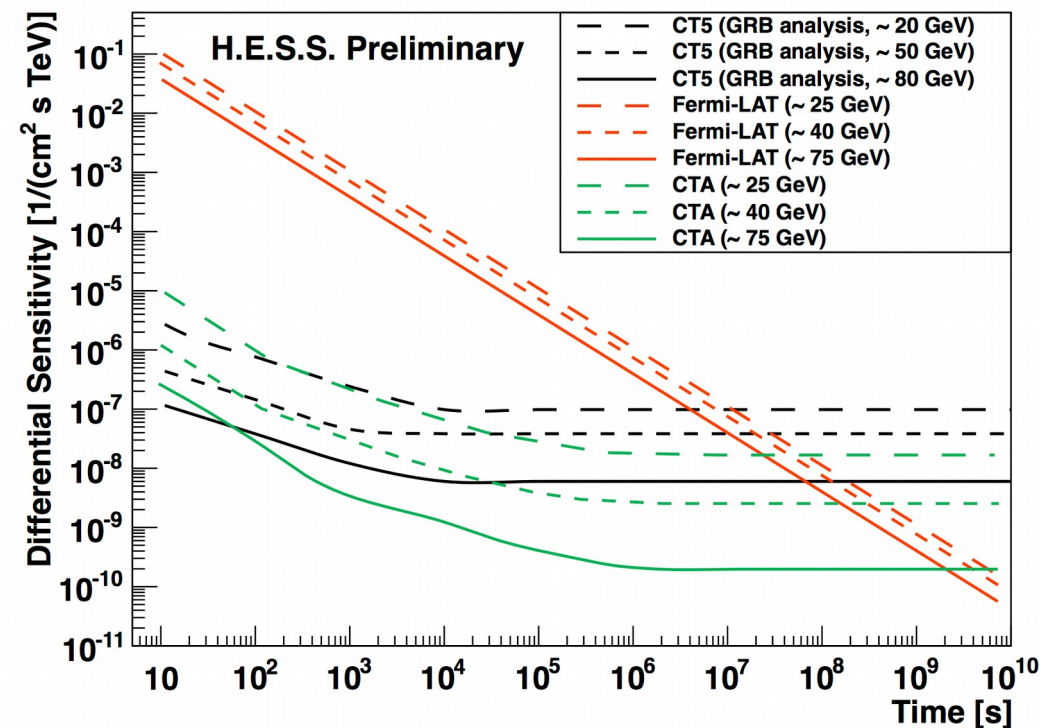
Science with H.E.S.S. II

- Lower energy threshold :
 - Pulsars
 - AGN less absorbed by EBL
 - More objects !
 - Part of the energy range common with Fermi
 - Dark matter constraints (see K. Mora's talk in DM session)
- Increased sensitivity to variable/transient sources
 - GRB detection ?

H.E.S.S. Array : ToOs

CT5 : Faster structure \rightarrow re-pointing < 2 minutes

- Fully automatic Target of Opportunity alert system
- Response time to a ToO greatly improved in the last years (change of the software design)
- Further speed up due to telescope reverse pointing imminent
- Hopefully first detection of a GRB in VHE gamma-rays soon :-)



Adapted from Funk & Hinton (2013)

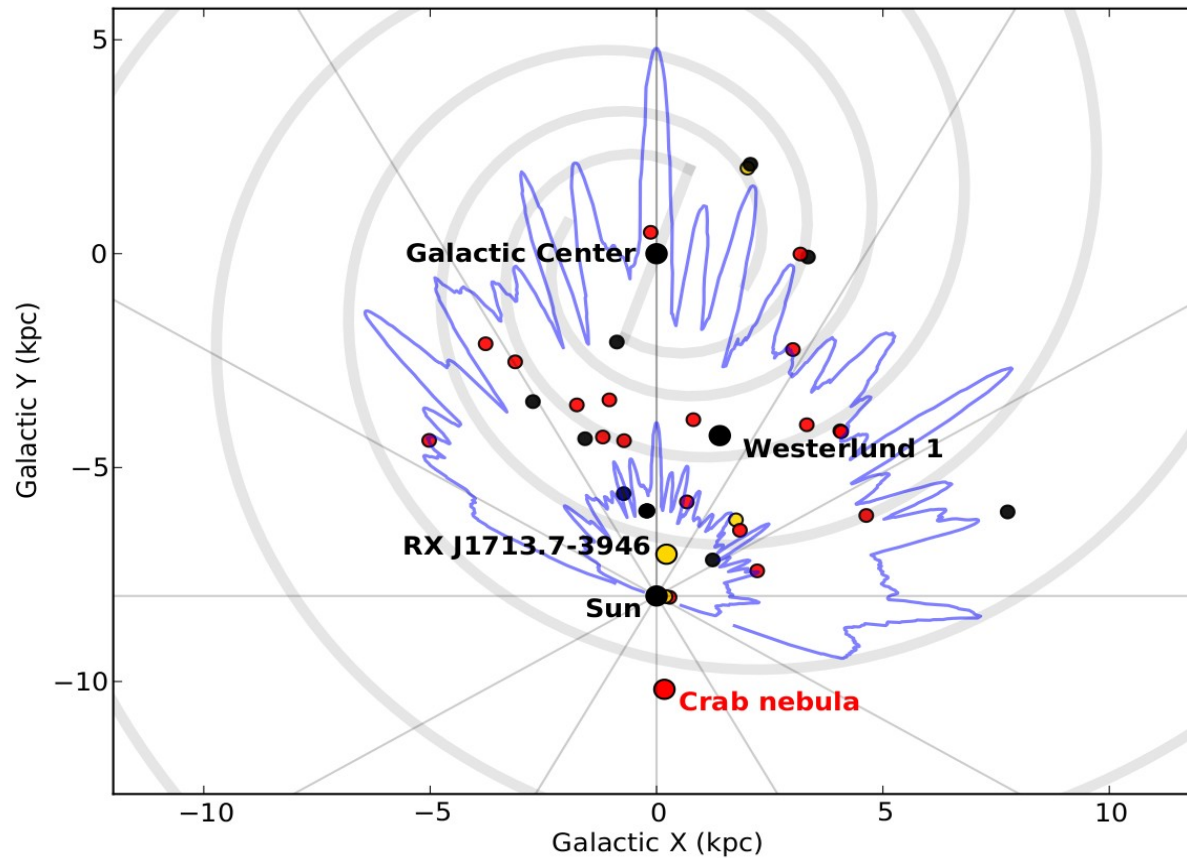
- H.E.S.S. I legacy survey of the inner Galaxy available soon
- First H.E.S.S. II results already available (Vela PSR, Crab, AGNs)
- Many more H.E.S.S. results to come soon (ICRC 2015)
 - HESS I & II
- Exciting times ahead !



**Stay tuned &
Thanks for your attention !**

The HESS Galactic Plane Survey

Horizons for 10% and 1% of the Crab luminosity



S. Carrigan et al., 2013 (ICRC)

The HESS Galactic Plane Survey

