Survey of the Galactic Plane with the Cherenkov Telescope Array

Quentin Remy, Luigi Tibaldo, Fabio Acero,
for the CTA Galactic Science Working Group

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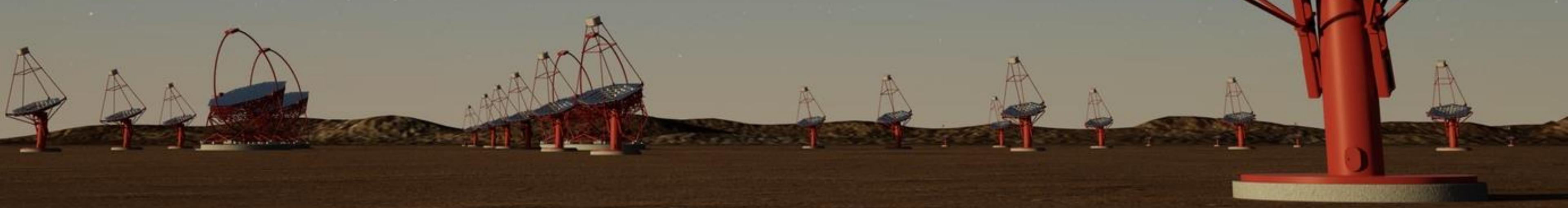
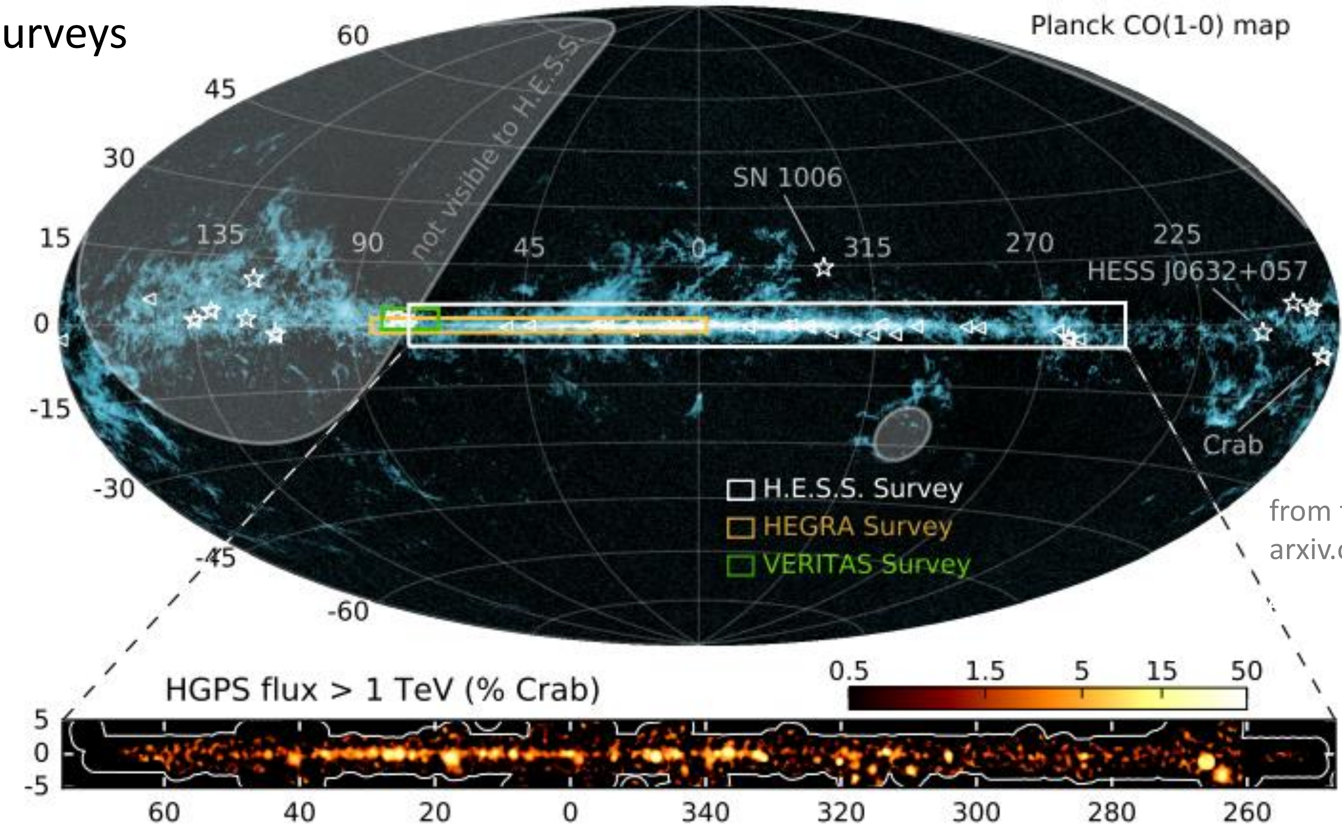


We gratefully acknowledge financial support from the agencies and organizations listed here:
http://www.cta-observatory.org/consortium_acknowledgments

Very-high-energy γ-ray surveys from IACTs

- Previous surveys



from the HESS-GPS (2018)
arxiv.org/abs/1804.02432

- Galactic plane Survey GPS proposed as Key Science Project for CTA
  5-20x more sensitive than previous surveys

Goals : - unprecedented census of VHE emitters in the entire Galactic plane
- studying diffuse gamma-ray emission
- searching for new and unexpected phenomena

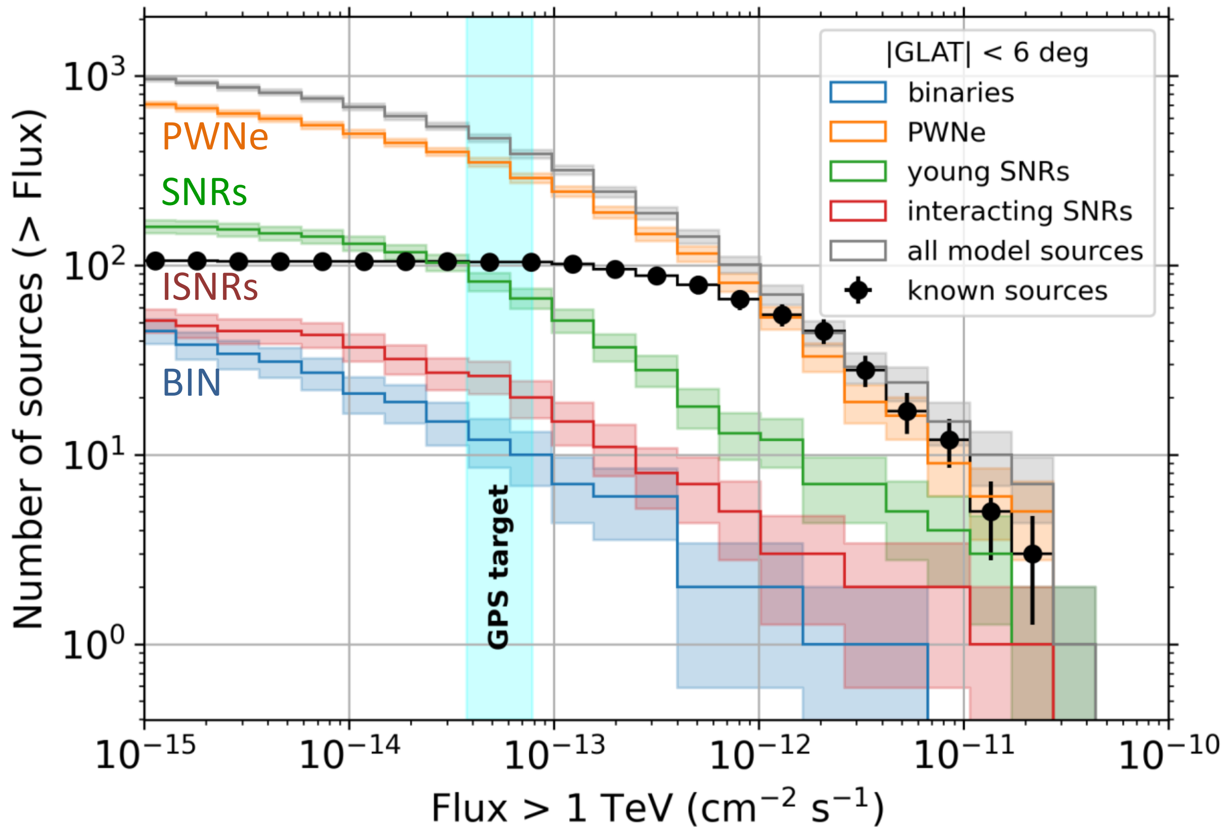
Sky model

❖ Known sources

- IACTS sources compilation (gamma-cat.readthedocs.io)
- Fermi-LAT 3FHL
- 2HAWC

❖ Source population synthesis based on physical modelling

- supernova remnants: young and interacting with interstellar medium (Cristofari et al. 2017, Rice et al. 2016)
- pulsar wind nebulae (Fiori et al. in preparation)
- binaries (Dubus et al. 2017)



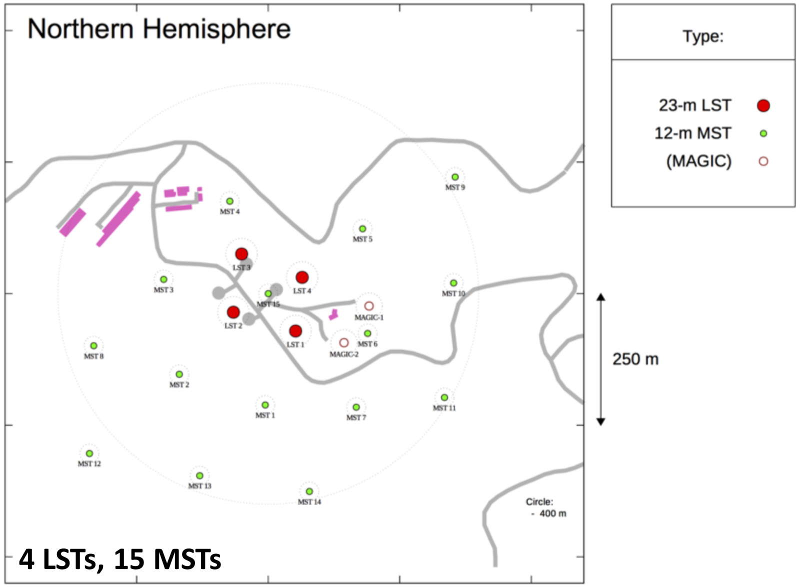
❖ Interstellar emission

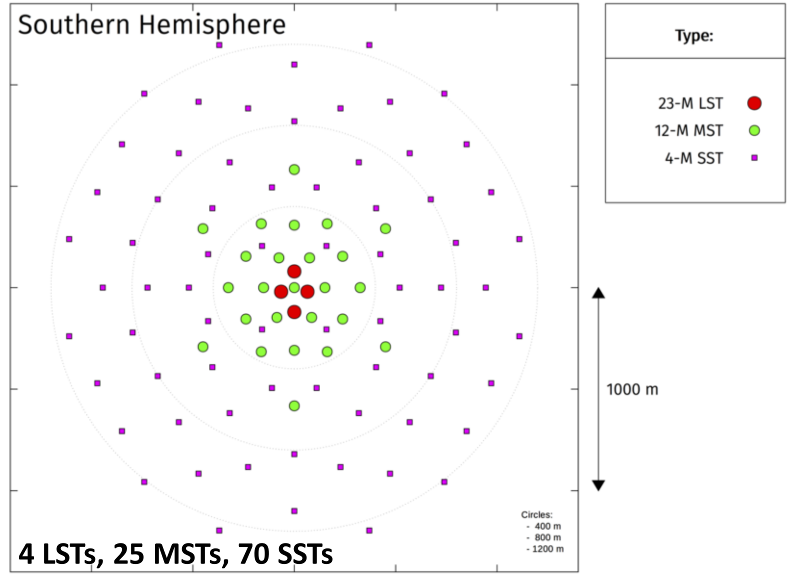
- Galactic Ridge
- Fermi-bubbles
- minimal model for gamma-ray emission from Galactic cosmic rays using DRAGON cosmic-ray propagation code

❖ available at github.com/cta-observatory/cta-gps-simulation-paper/tree/master/skymodel

Simulation setup

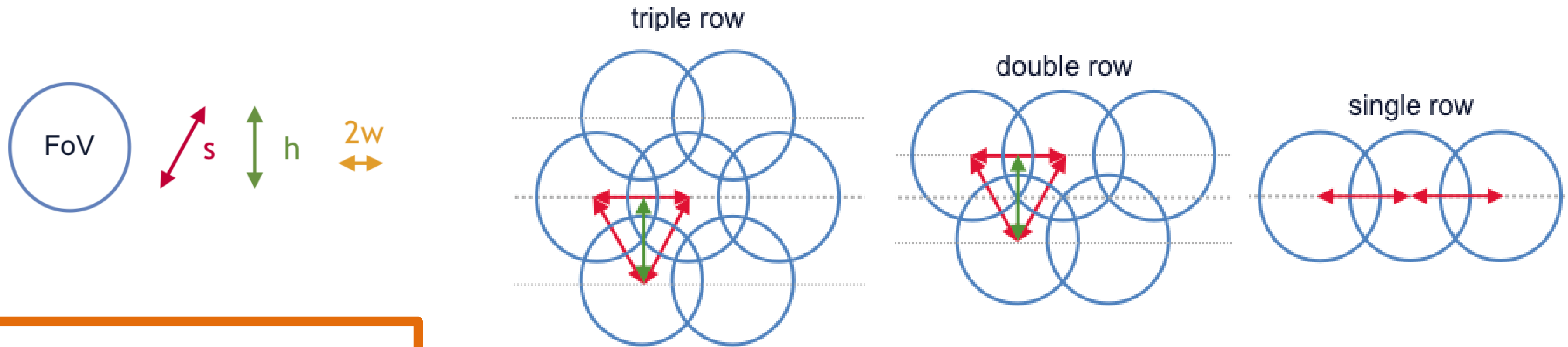
- Telescopes configuration : baseline (now called omega)

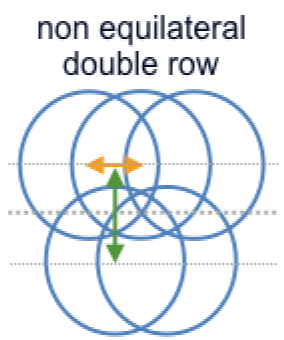




- Instrument responses functions: IRFs prod3b-v2 (cta-observatory.org/science/cta-performance/)
- Realistic scheduling strategy: 480h in 2 years + 1140h in 8 years
- Simulated with ctools package version 1.7.0
- 2 catalogues produced : (A) ctools, (B) gammapy
  different software with same features, but main differences from analysis strategies (candidates positions and parameters guess, order and types of model fitted…)

Pointing strategy optimization

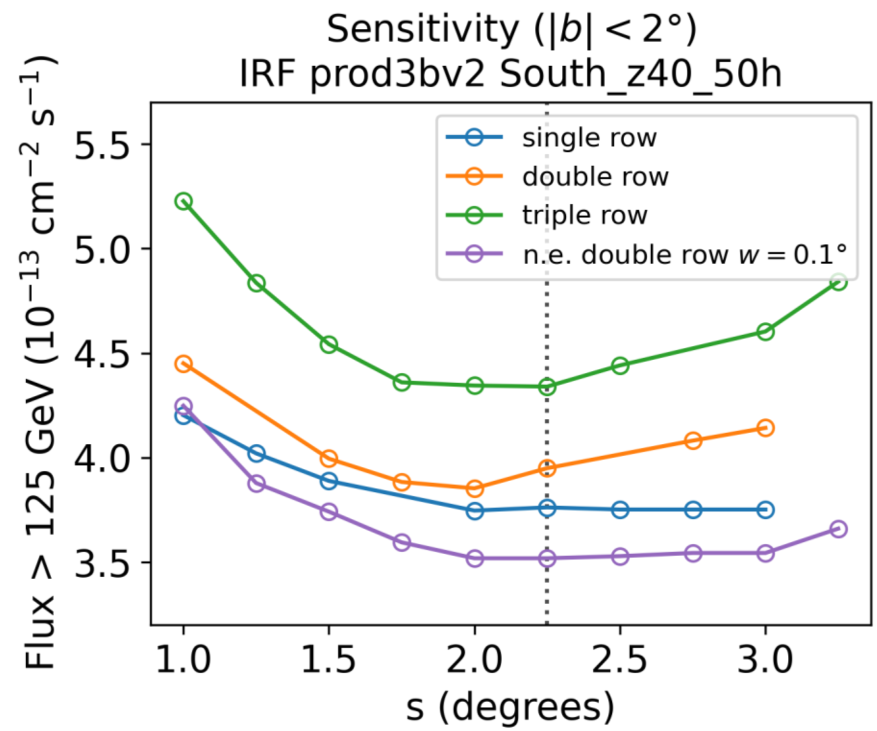




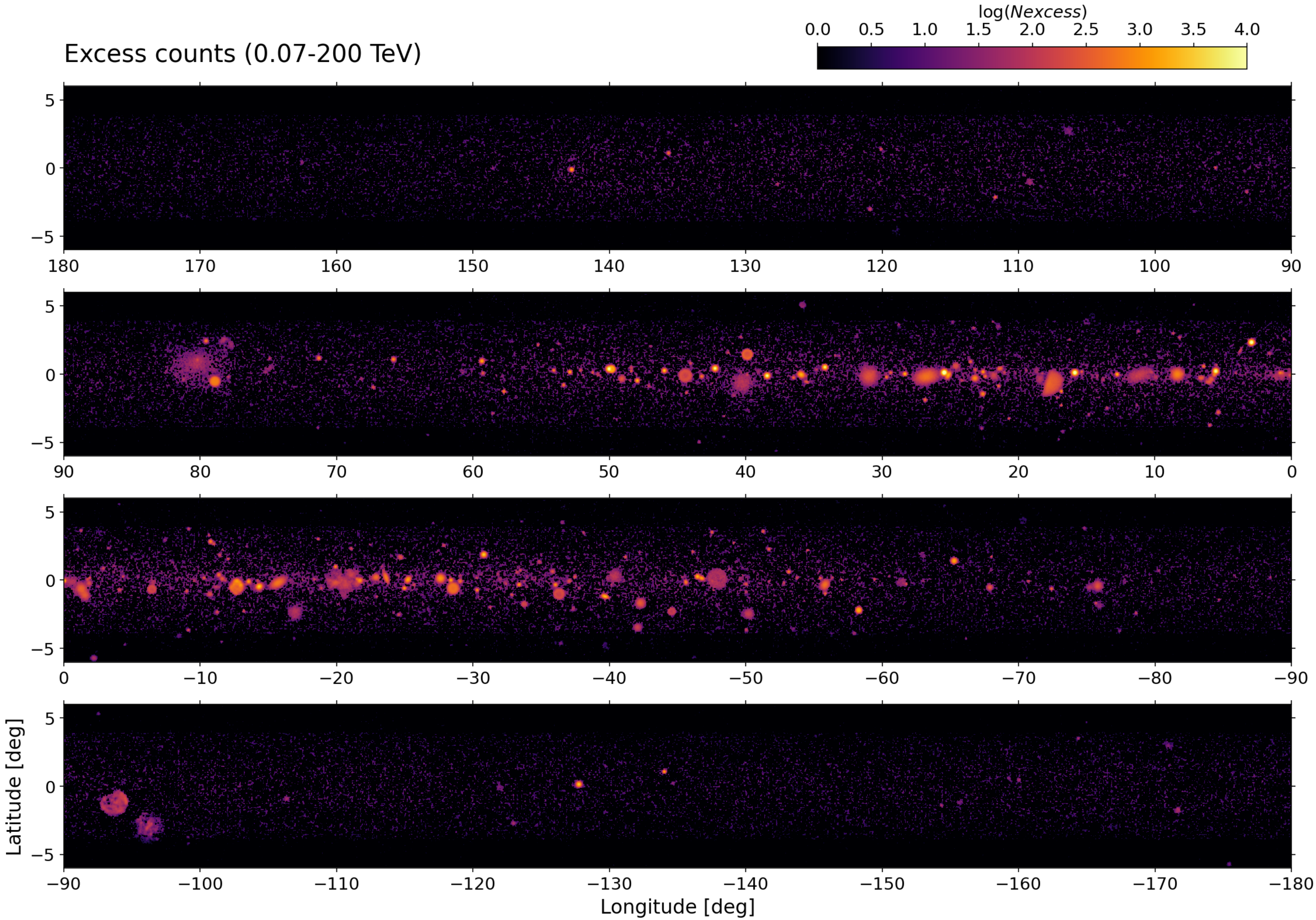
$$s=\sqrt{\frac{4}{3}}h$$

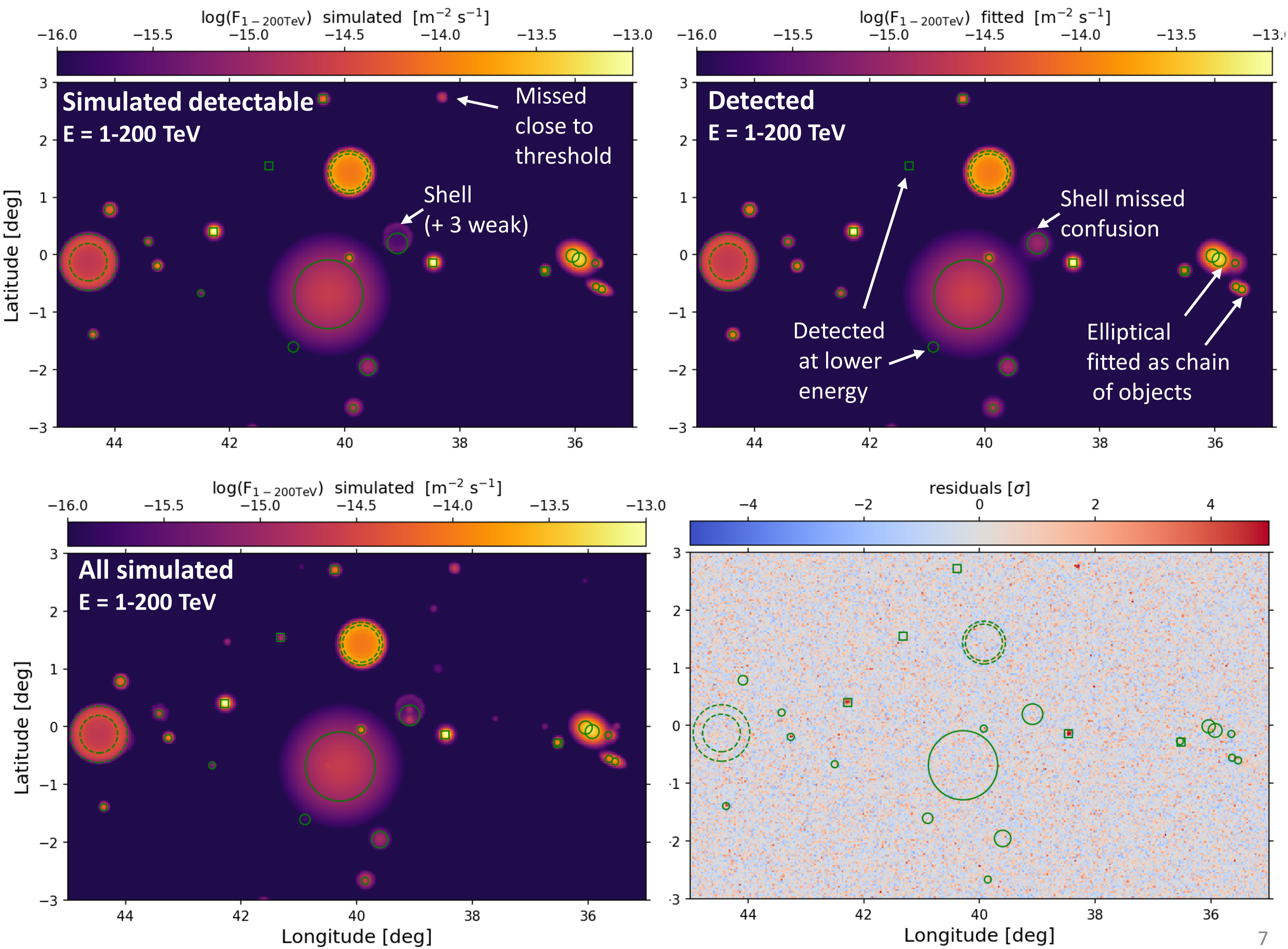
Selected : Non-equilateral double row
h=1.95°, s=2.25°

- best sensitivity in the Galactic plane
- as good as the triple-row pattern at higher latitudes

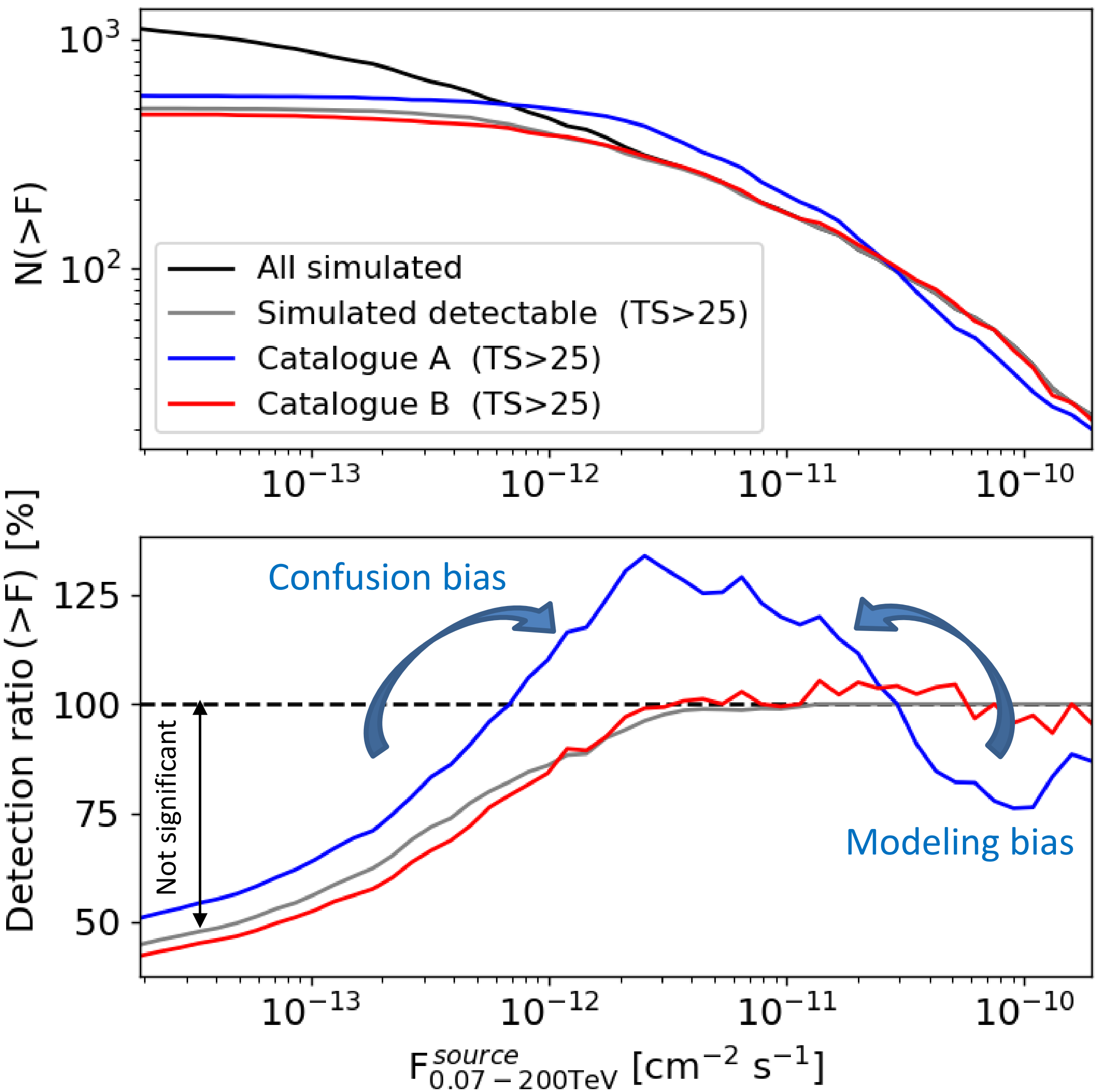


Excess counts (0.07-200 TeV)




log(F1−200TeV) simulated [m−2 s−1]
−16.0 −15.5 −15.0 −14.5 −14.0 −13.5 −13.0
Simulated detectable
E = 1-200 TeV
Missed close to threshold
Shell (+ 3 weak)
Latitude [deg]
log(F1−200TeV) fitted [m−2 s−1]
Detected
E = 1-200 TeV
Shell missed confusion
Detected at lower energy
Elliptical fitted as chain of objects
log(F1−200TeV) simulated [m−2 s−1]
All simulated
E = 1-200 TeV
Longitude [deg]
residuals [σ]
−4 −2 0 2 4
Longitude [deg]

Detection biases



- Most of weak sources not significant

- Detection ratio increases with flux

- Confusion bias: enhanced flux and TS of sources near threshold due to the sea of weaker sources (affects both catalogues)

- Modeling bias: complex sources fragmented in multiple detections of lower flux (mainly in Catalogue A)

- Catalogue B tests shells, ellipticals and merges templates sub-structures => better estimate of flux and number of objects

- Catalogue B tends to the expected detections limit

Simulated sources detectable and detected objects

Detectability criterion:

$$TS_{null} = 2\,\Delta\ln(L) > 25$$

with $\Delta\ln(L)$ the log-likelihood difference between the cases with and without the source

Object-Source matching criterion:

$$d_c < 0.1^{\circ} + 0.3 \times R_{object}$$

and best $SF_{overlap} = \frac{S_{object \cap source}}{S_{object \cup source}}$

(=> unique associations)

Matching fraction: $f_{match} = N_{match} / N_{detected}$

Detections with TS >25 for E = 0.07-200 TeV :

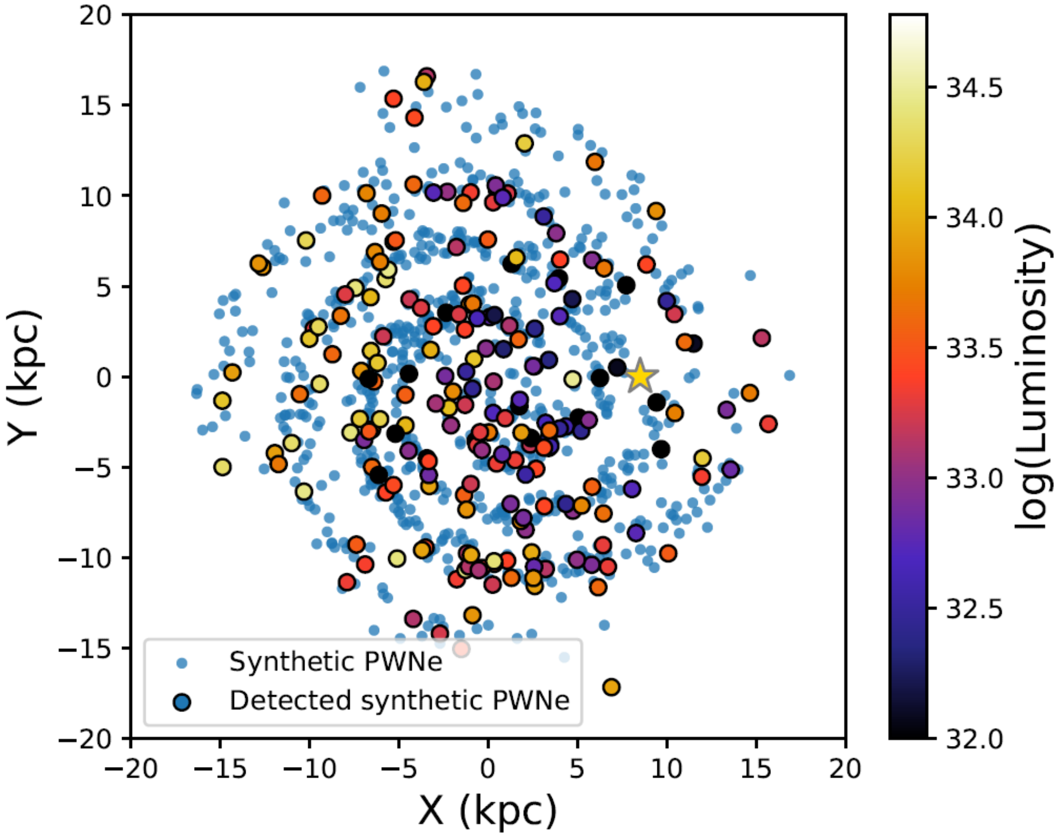
Name	PWN	SNR	ISNR	BIN	Known	No-match	Total	f_{match}
Simulated detectable	294	37	24	10	134	-	499	-
Catalogue A	241	16	20	10	111	169	567	0.70
Catalogue B	257	31	14	10	122	36	470	0.92

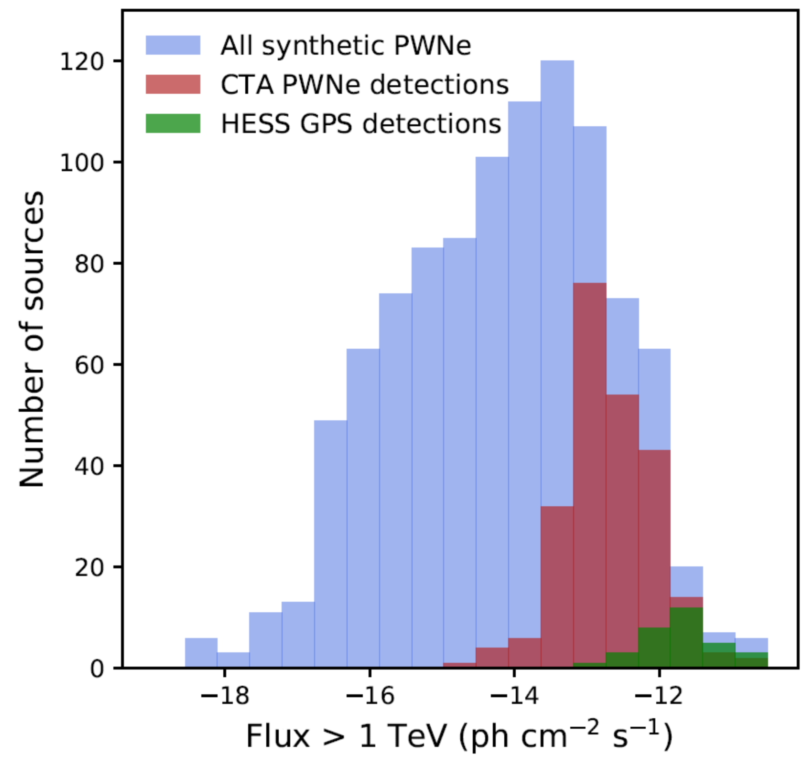
- Most of detectable sources are detected and only few spurious detections, differences mostly from source confusion effects rather than statistical effects
- about 6 times more sources detectable than in the HESS-GPS or HAWC catalogues

PWNe population

- Dominant population of the survey, about 250 new PWN detectable
  More than 7x current sample of PWNe, and 2.5x (PWNe + unidentified sources)

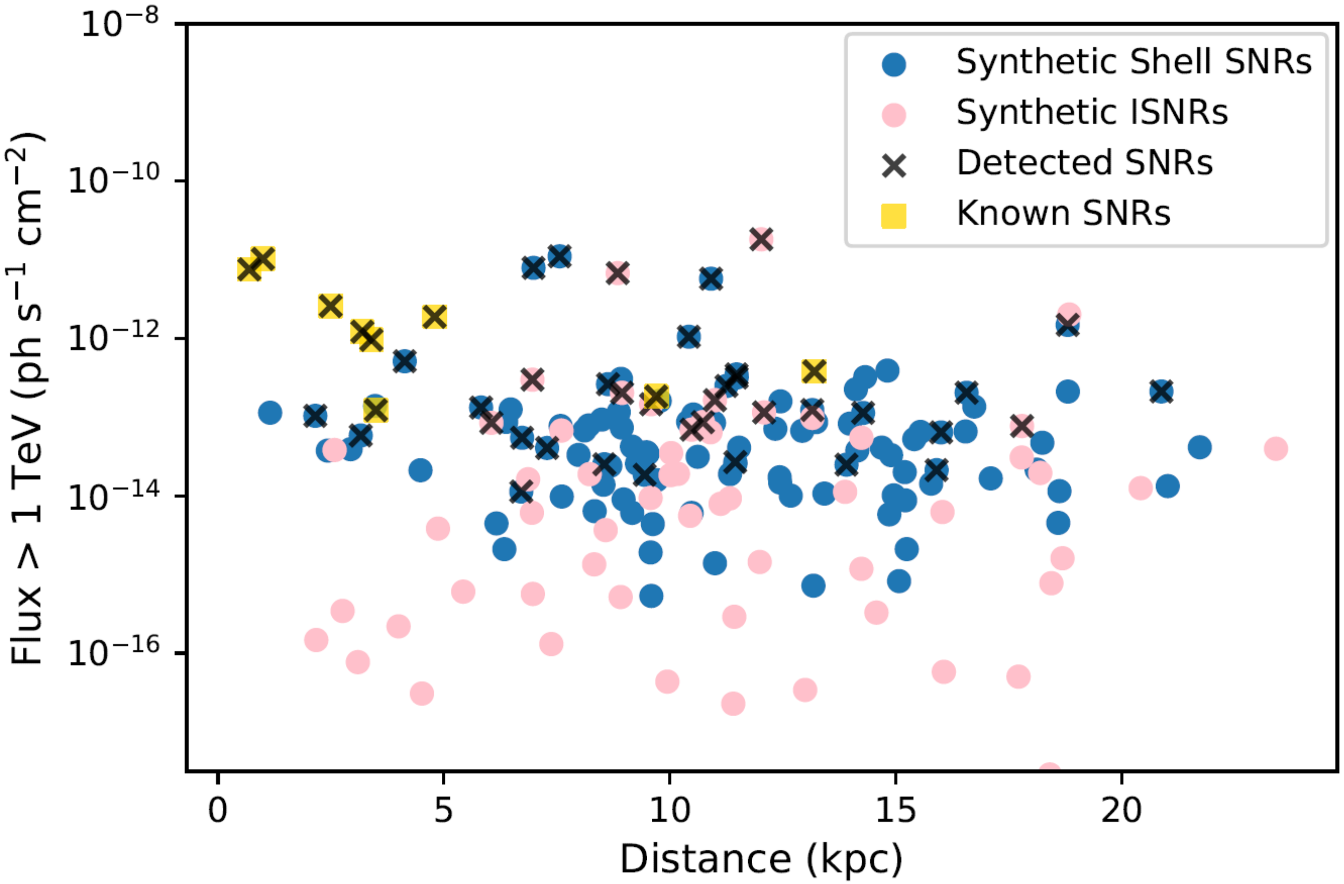
- Detection across the whole Galaxy and wider range in flux





SNRs population

- about 40 new SNRs detectable, half are significantly extended
- Detection of SNR up to 20 kpc, with ages up to 100 kyear
- 5-10 times better flux sensitivity than the current TeV SNR sample



Summary

- Galactic plane Survey GPS proposed as Key Science Project for CTA
  1620 hours of observations in 10 years
  5-20 more sensitive than previous surveys

- Simulated sources from Physical models of SNR, PWN and binaries populations and catalogues

- Simulations have been helping to optimize survey observation and analysis strategies

- up to 500 sources detectable with TS>25 in the 0.07-200 TeV energy range,
  about 6 times more sources detectable than in the HESS-GPS or HAWC catalogues

- Detection of PWNe and SNRs across the whole Galaxy,
  wider range in properties (age, luminosity…) scanned with CTA

- Much more not presented here, about pulsars, binaries, PeVatrons, diffuse emission…
  to be discussed in an upcoming paper