



cherenkov  
telescope  
array

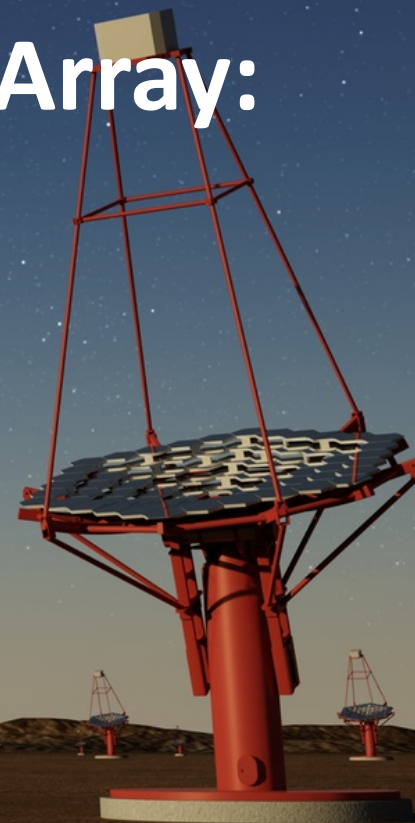
# The Cherenkov Telescope Array: a new eye on the VHE sky

R. Zanin

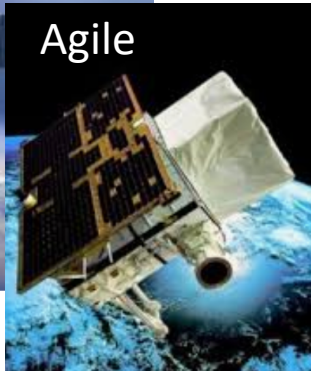
Project Scientist – CTA Observatory

[roberta.zanin@cta-observatory.org](mailto:roberta.zanin@cta-observatory.org)

& on behalf of the CTA Consortium



# Status of $\gamma$ -ray astronomy



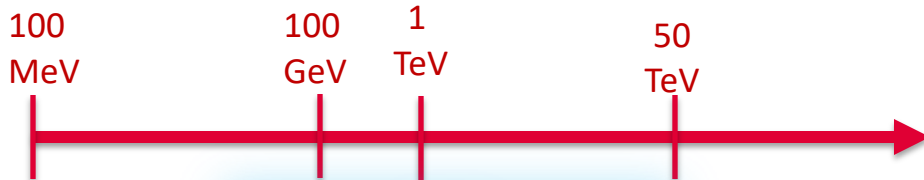


# Three different approaches

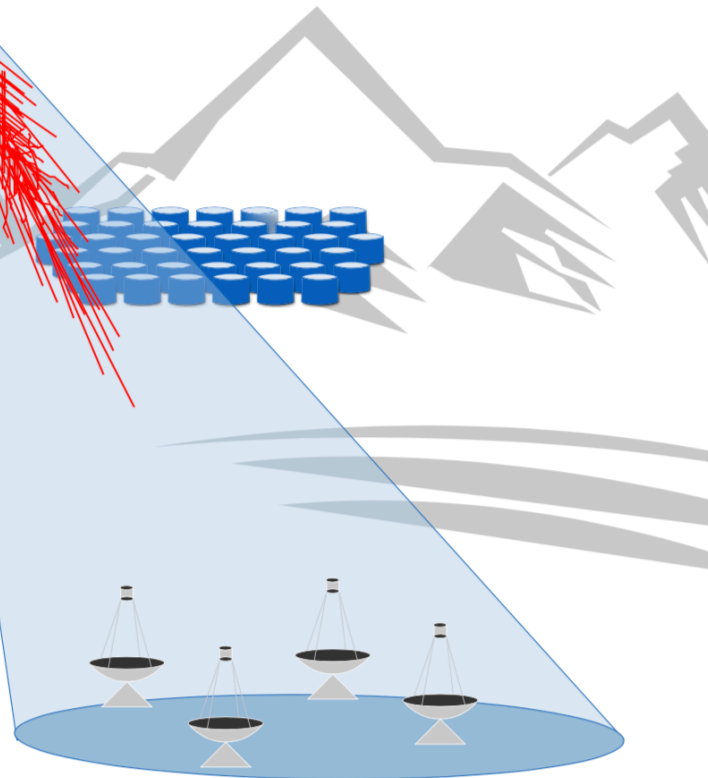
not to scale



Particle detector,  
4-5 km a.s.l.



IACTs, 1-2 km a.s.l.



# Three different approaches



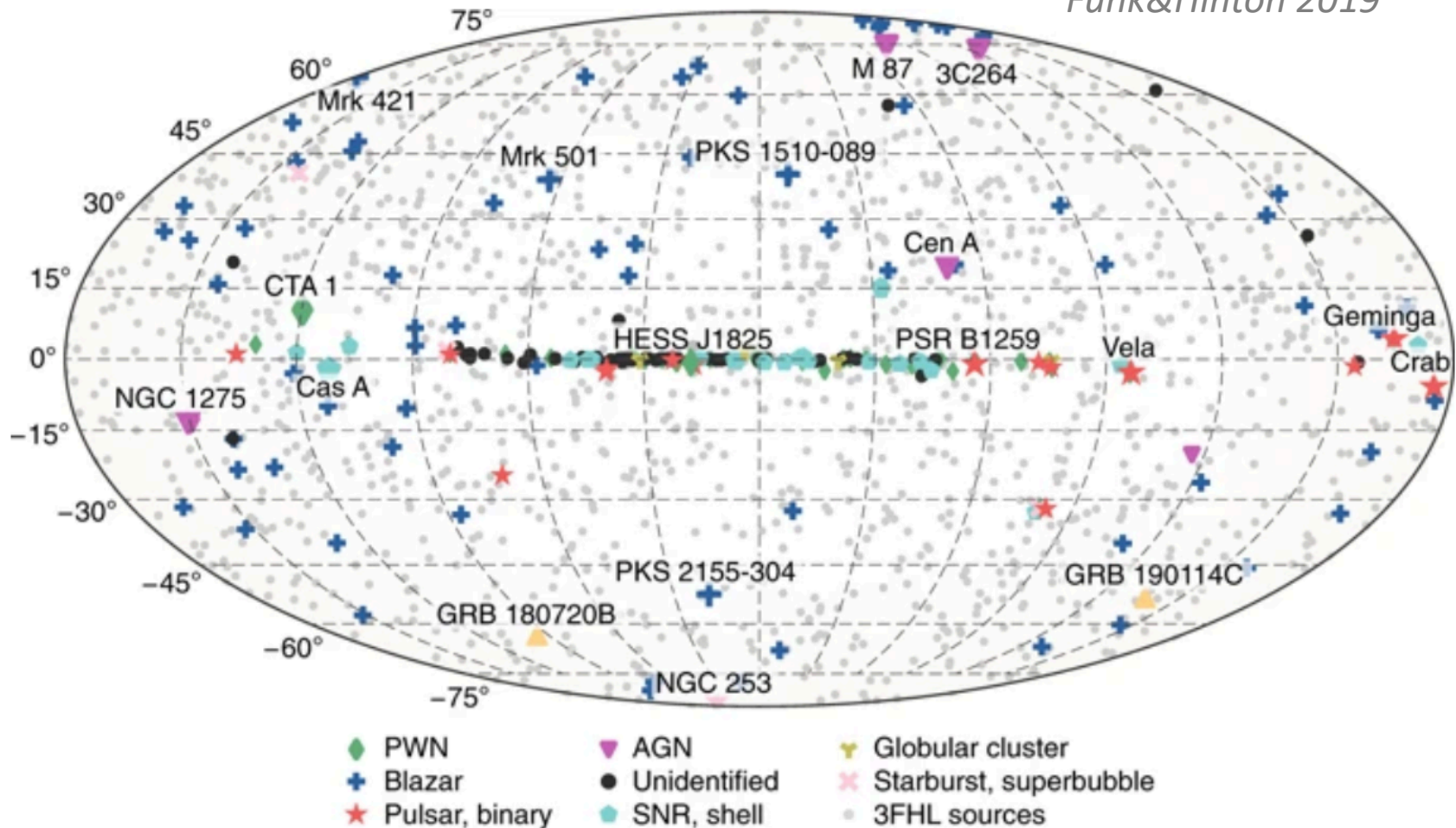
	Fermi LAT	IACTs	EAS arrays
Energy range	100 MeV – 1 TeV	50 GeV – 50 TeV	1 TeV – 200 TeV
FoV	20% of the sky	5 degree	15% of the sky
Effective area	1 m <sup>2</sup>	10 <sup>5</sup> m <sup>2</sup>	10 <sup>5</sup> m <sup>2</sup>
Duty cycle	Full year	1400 hr	Full year



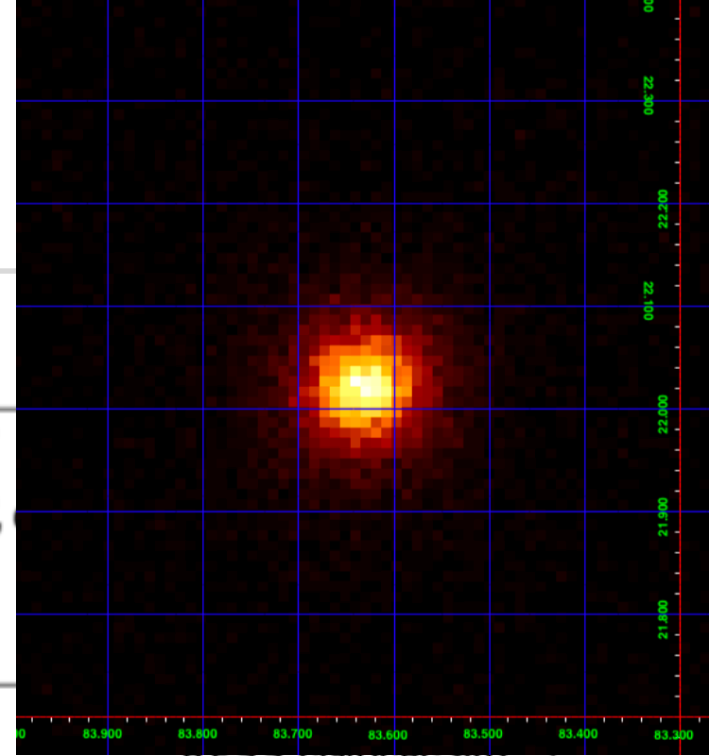
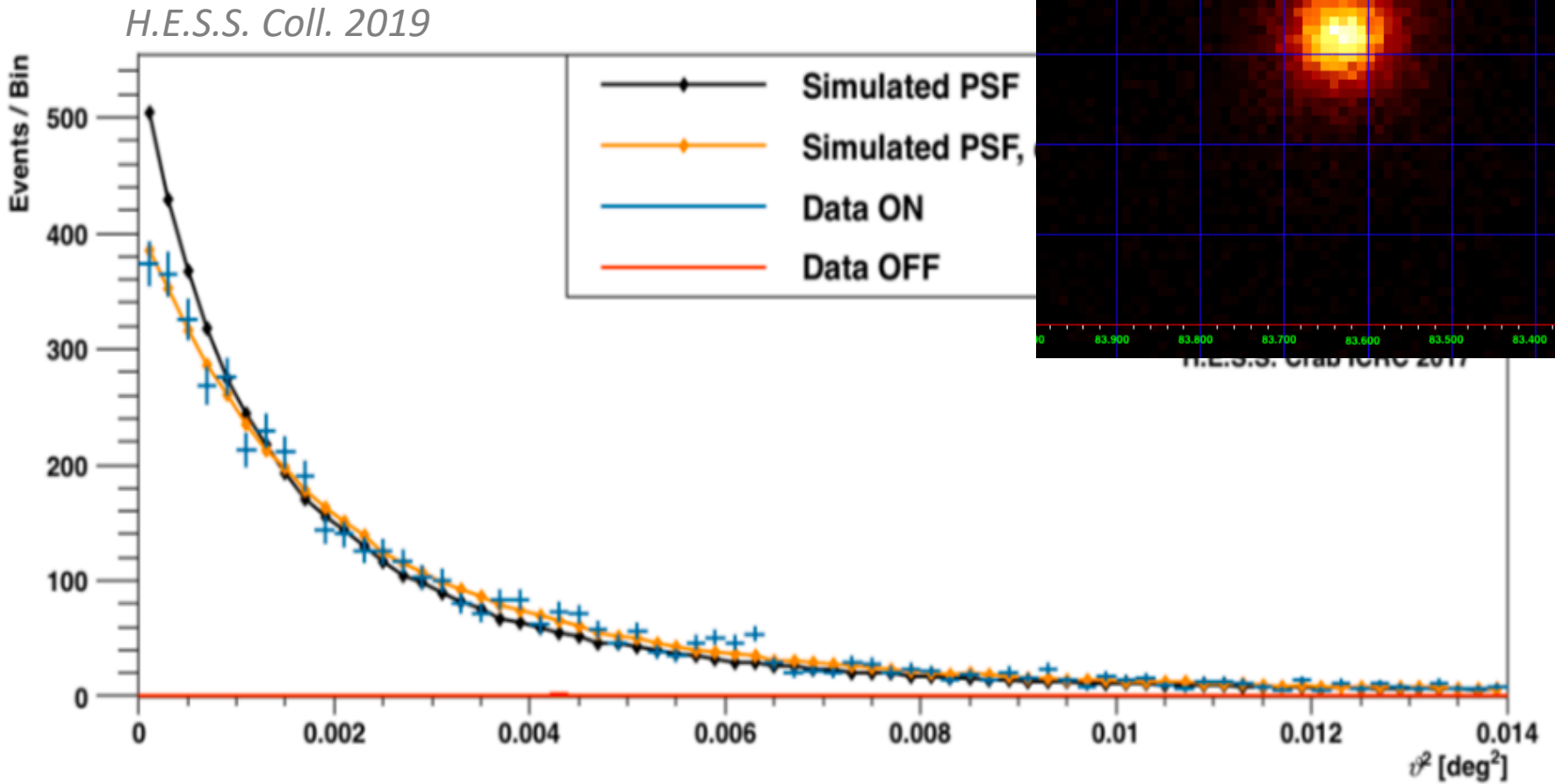
# The gamma-ray TeV catalogue



Funk&Hinton 2019



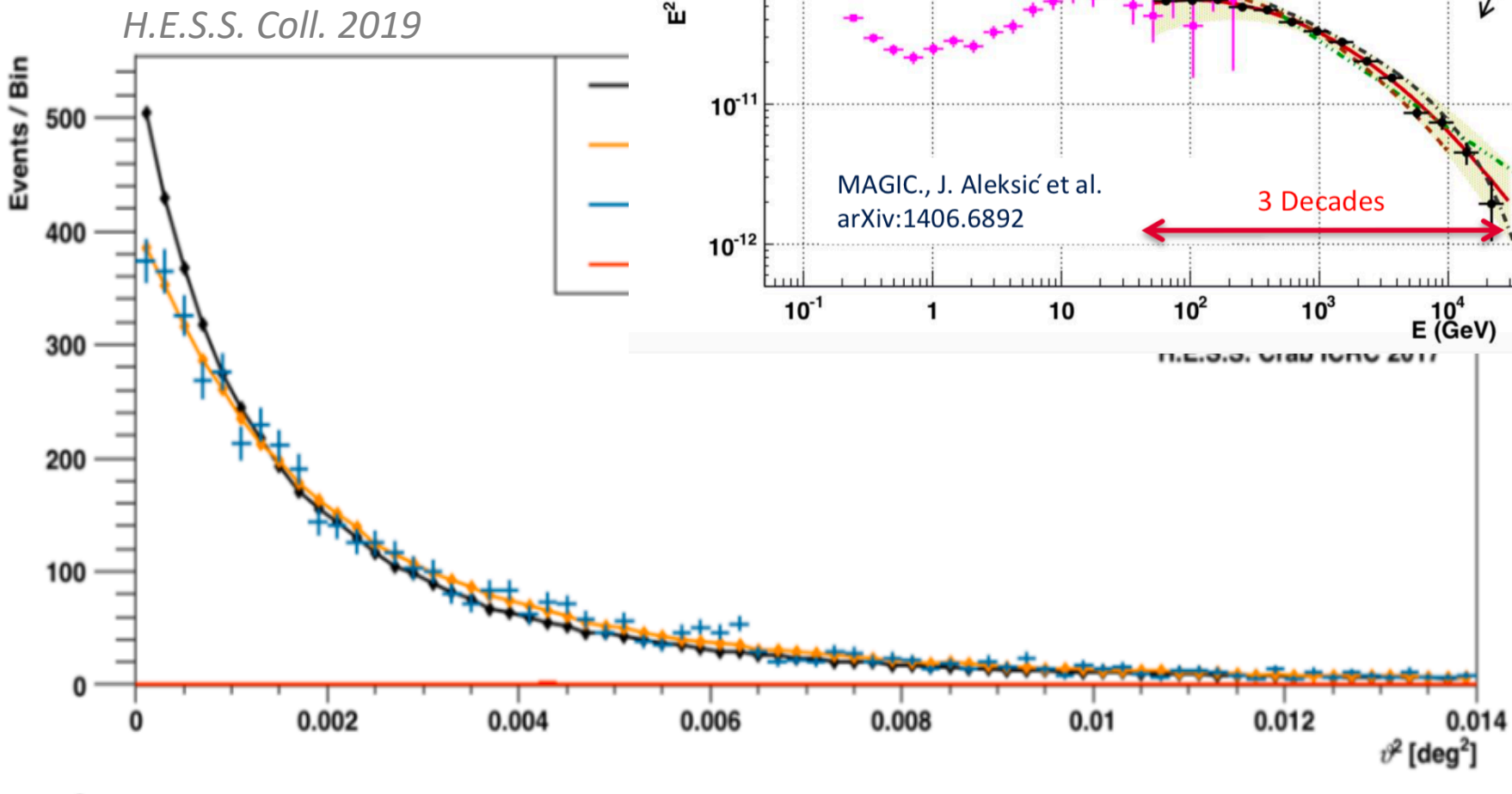
# Real astronomy



Size of Crab nebula: 52" +/- 3" +/- 8"

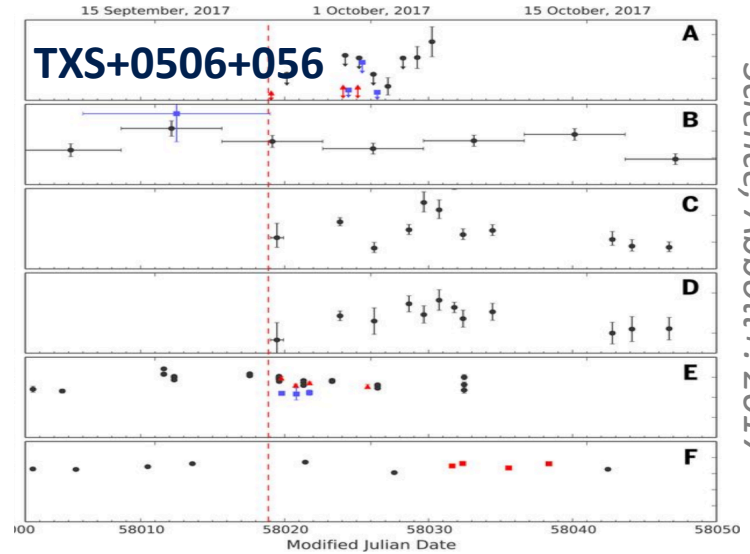
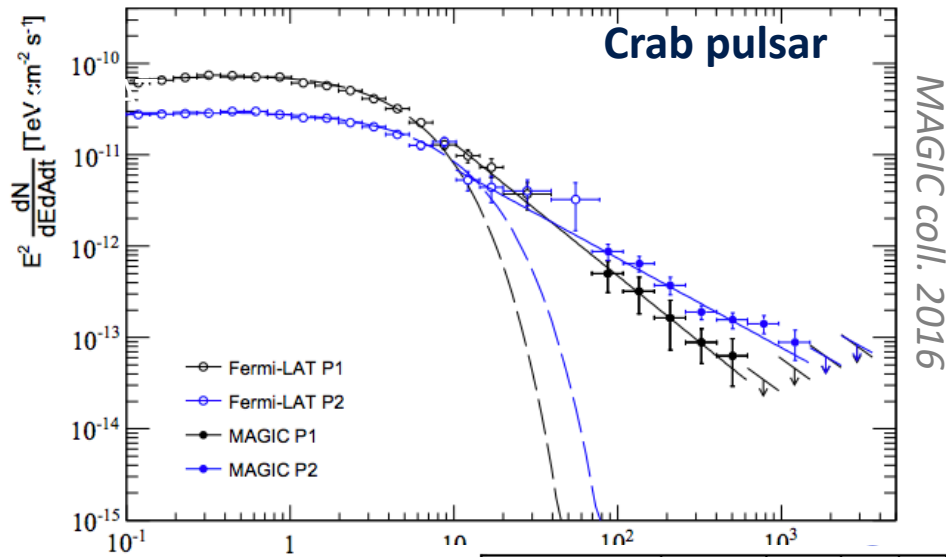


# Real astronomy

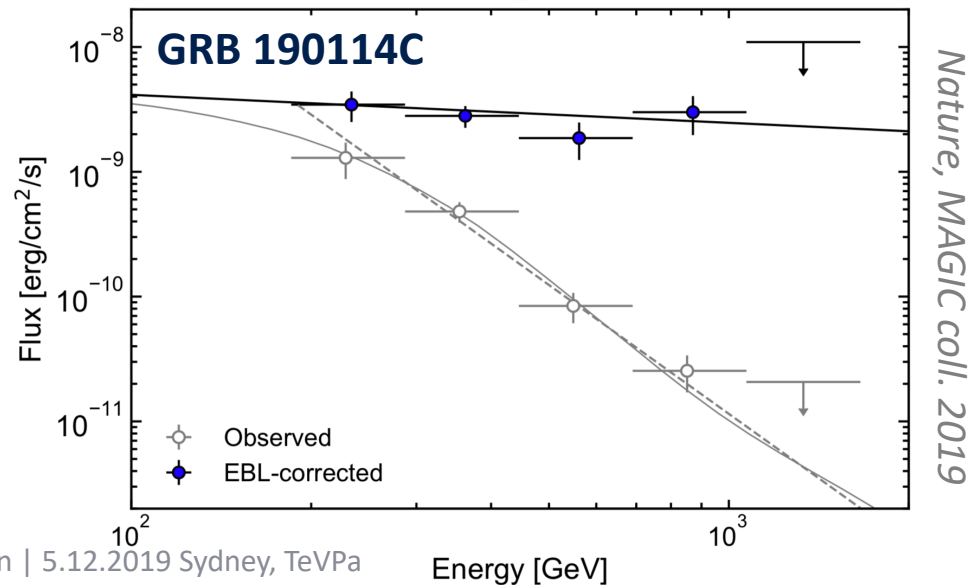


Size of Crab nebula: 52" +/- 3" +/- 8"

# Opening new windows



*Science, Abbott+. 2017*

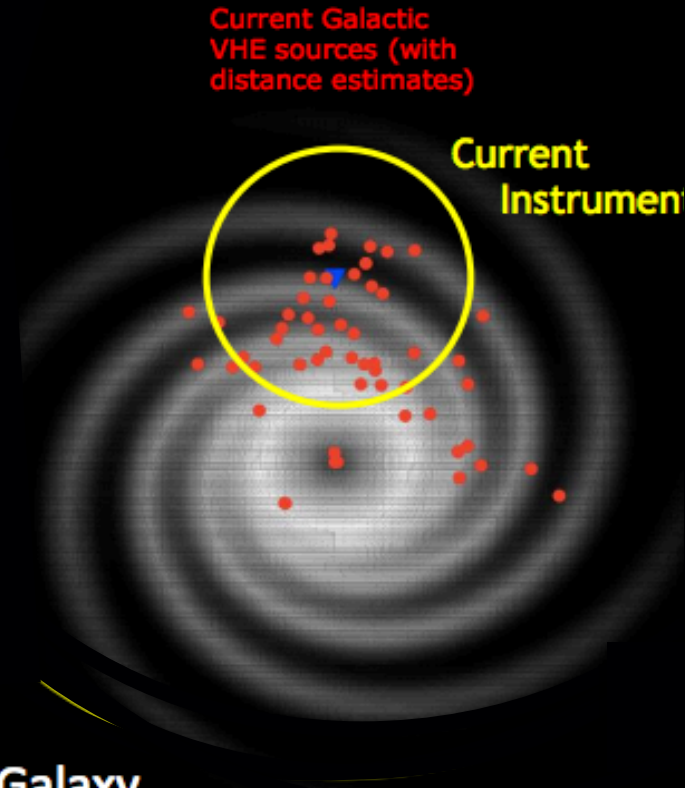




# A successful story, but ...



Current instruments  
provide exciting glimpses,  
but often fall short of  
providing the full answer

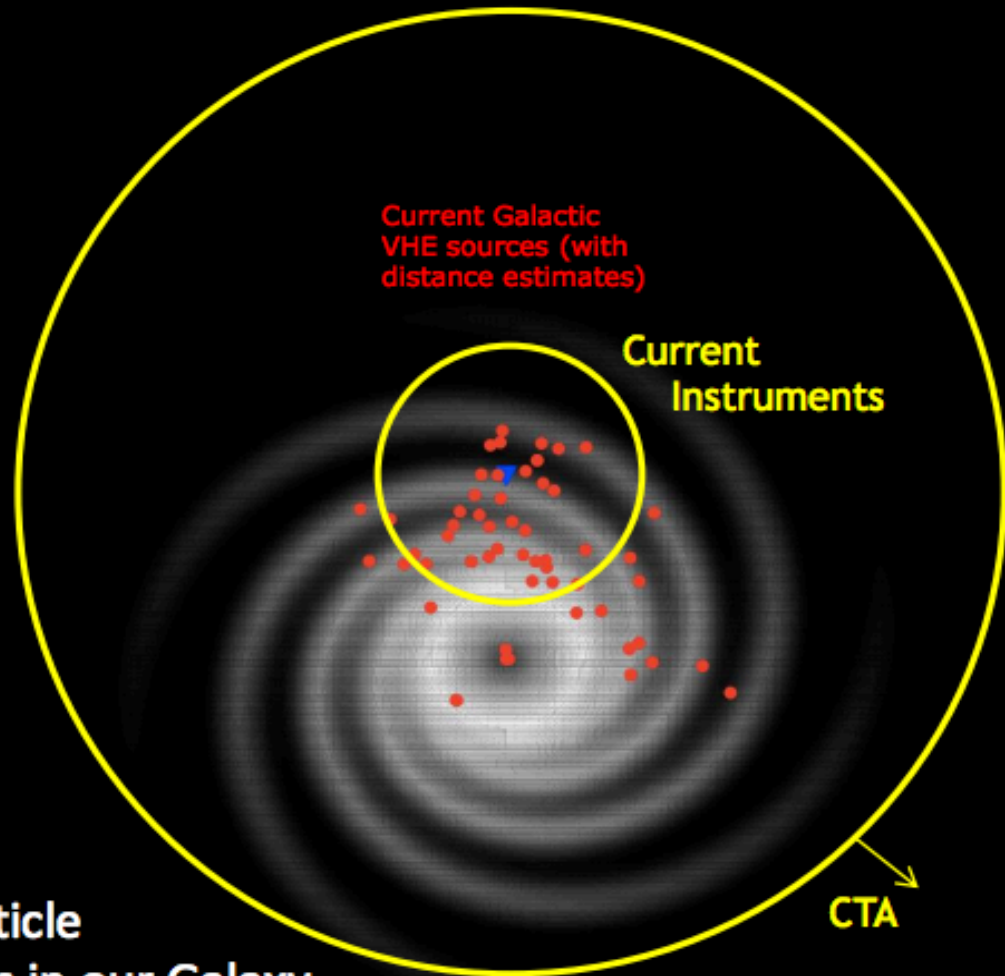


Cosmic particle  
accelerators in our Galaxy

# A successful story, but ...



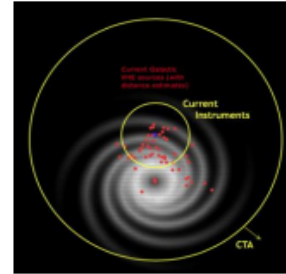
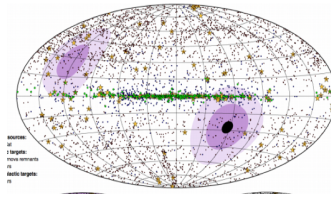
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Cosmic particle accelerators in our Galaxy

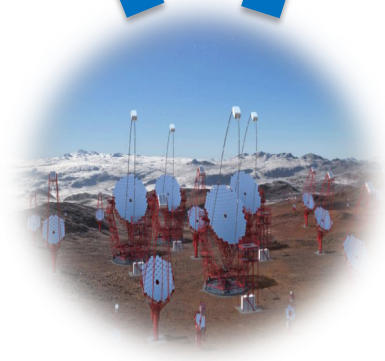


# Design drivers

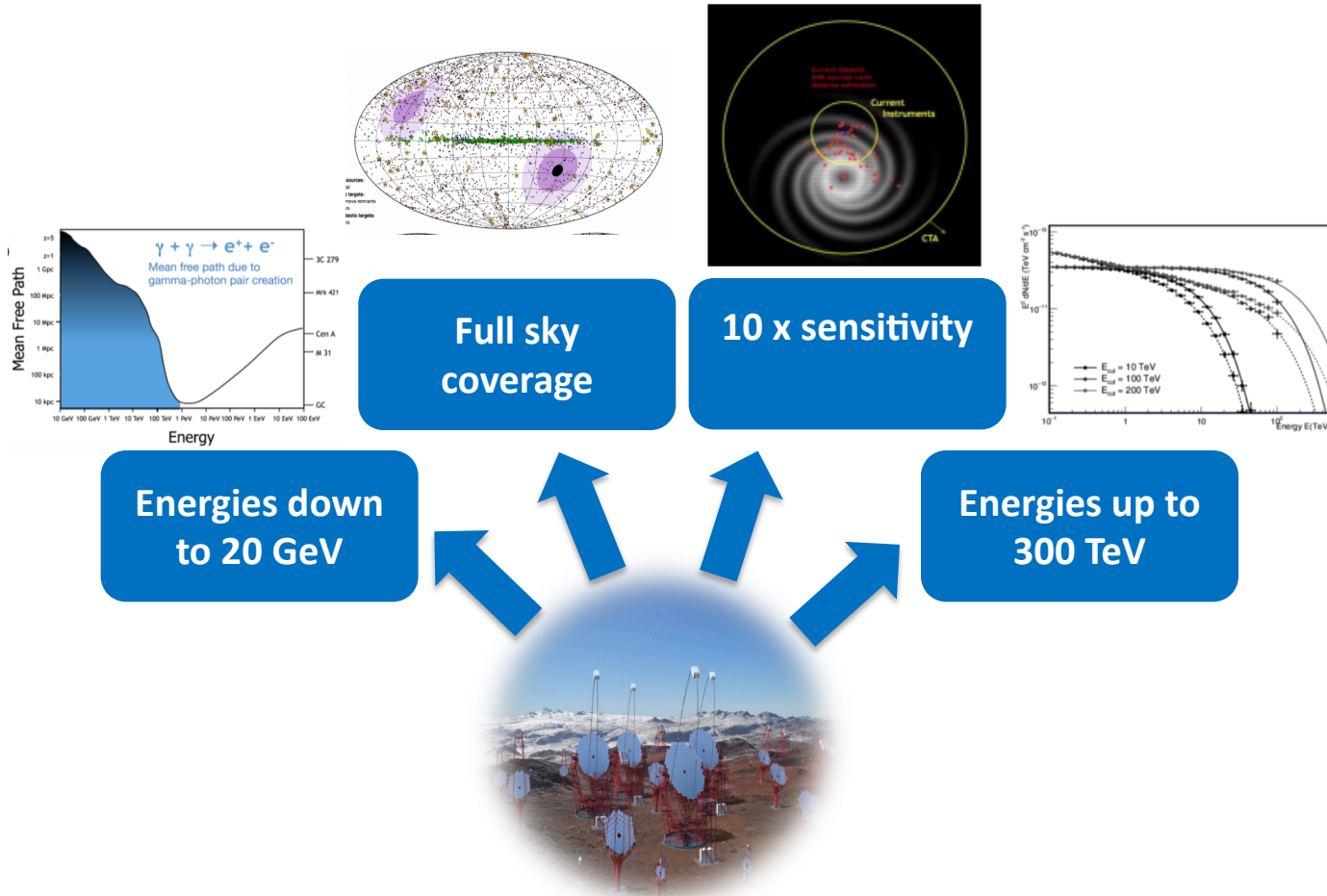


Full sky coverage

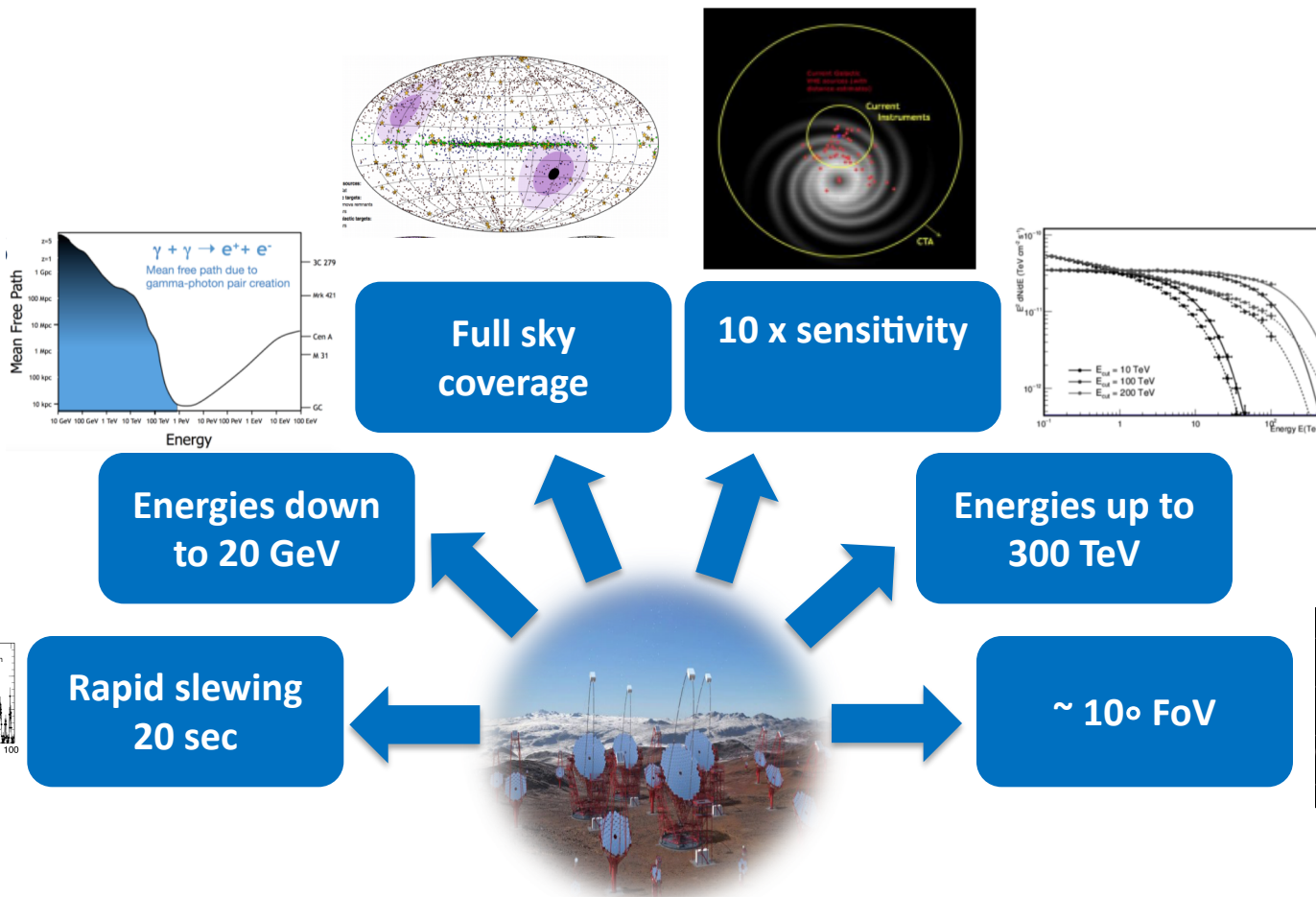
10 x sensitivity



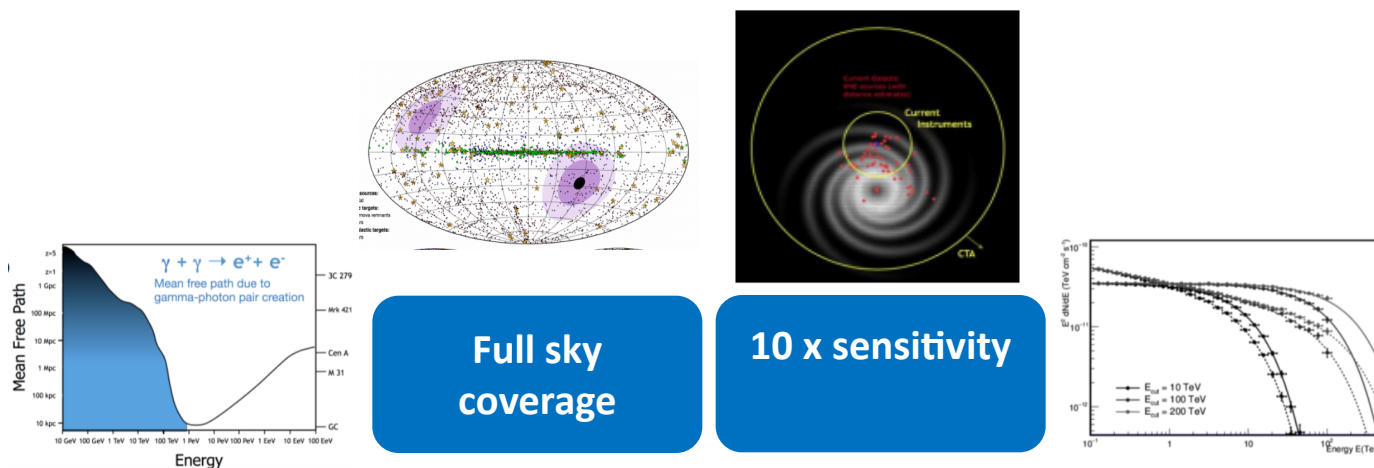
# Design drivers



# Design drivers



# Design drivers



**Full sky coverage**      **10 x sensitivity**

**Energies down to 20 GeV**

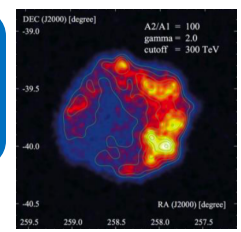
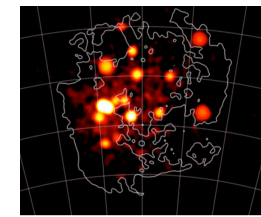
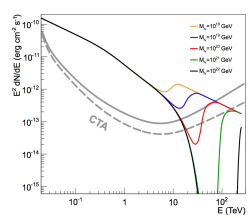
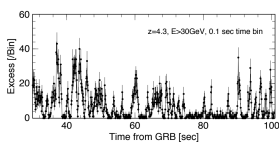
**Energies up to 300 TeV**

**Rapid slewing 20 sec**

**~ 10° FoV**

**10% energy resolution**

**arcmin angular resolution**





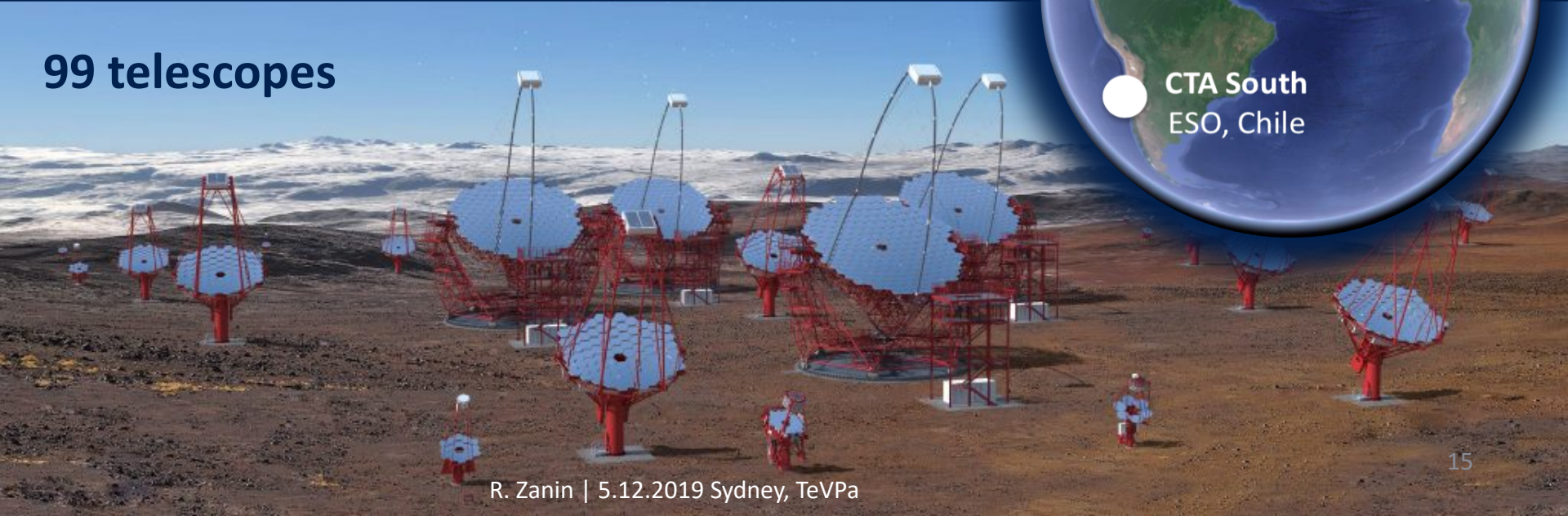
# Full-sky coverage – 2 sites



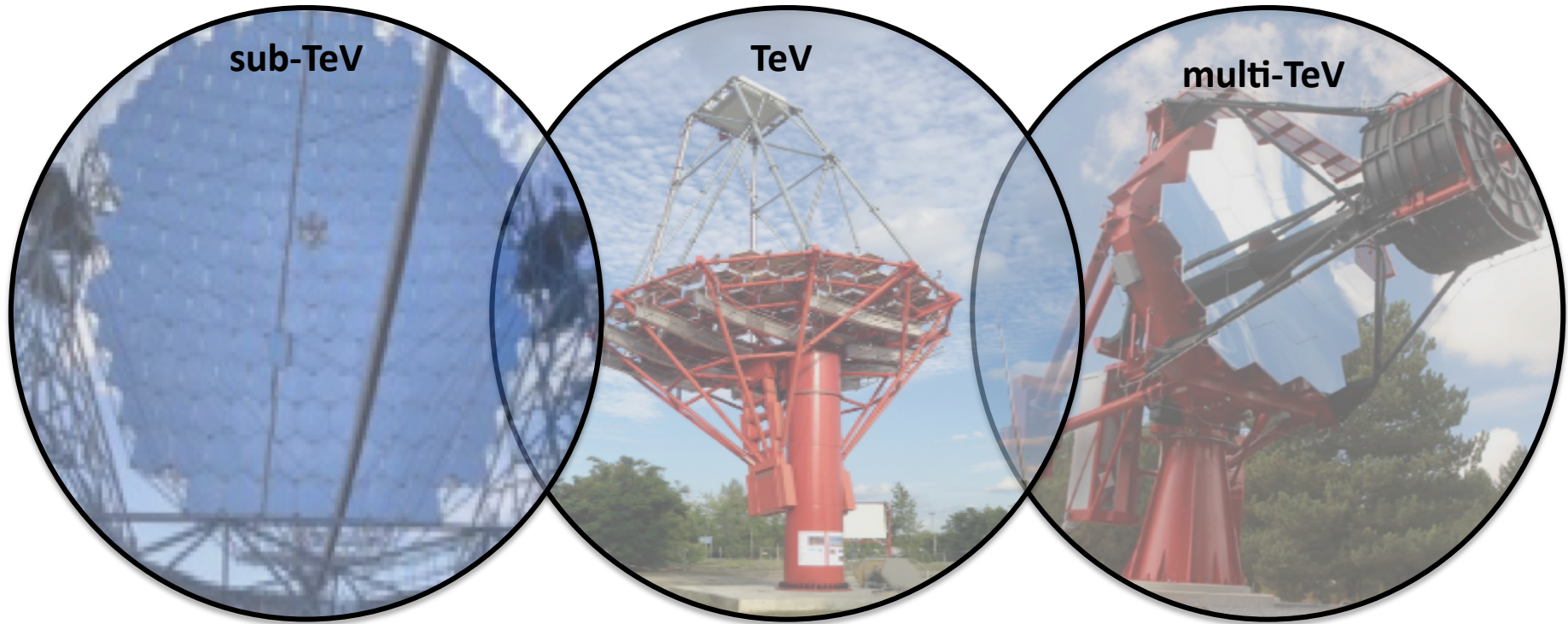
19 telescopes



99 telescopes



# Science cases and design



sub-TeV

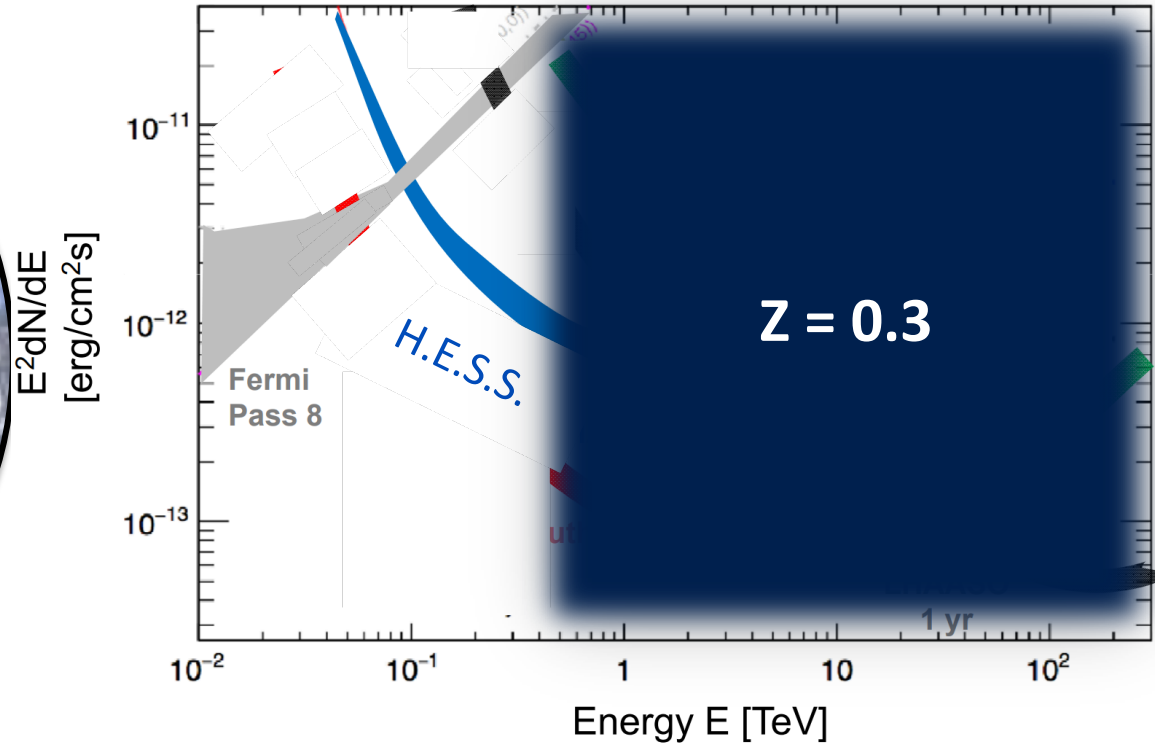
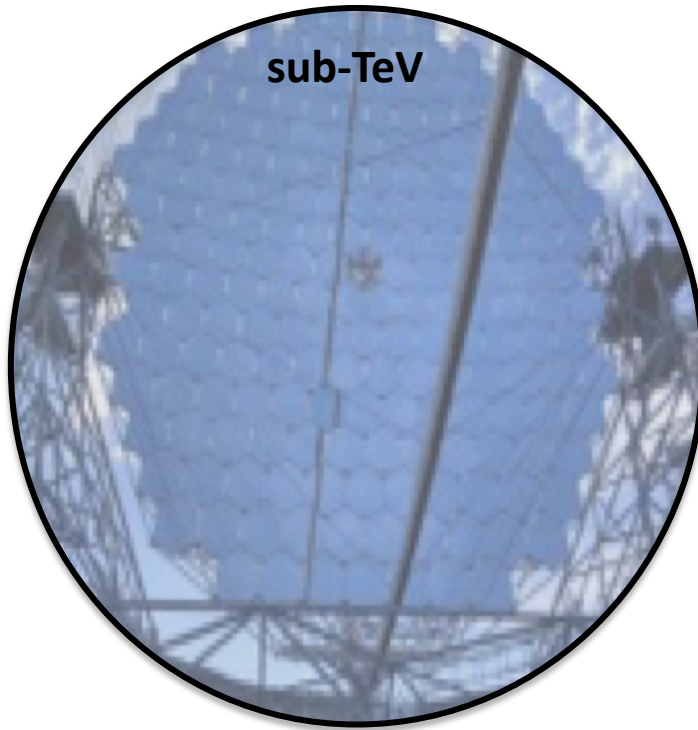
TeV

multi-TeV

- Parabolic optical design
- 23 m mirror diameter
- PMT camera
- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera
- Schwarzschild-Couder optical design
- 4 m dual mirror
- SiPM T camera

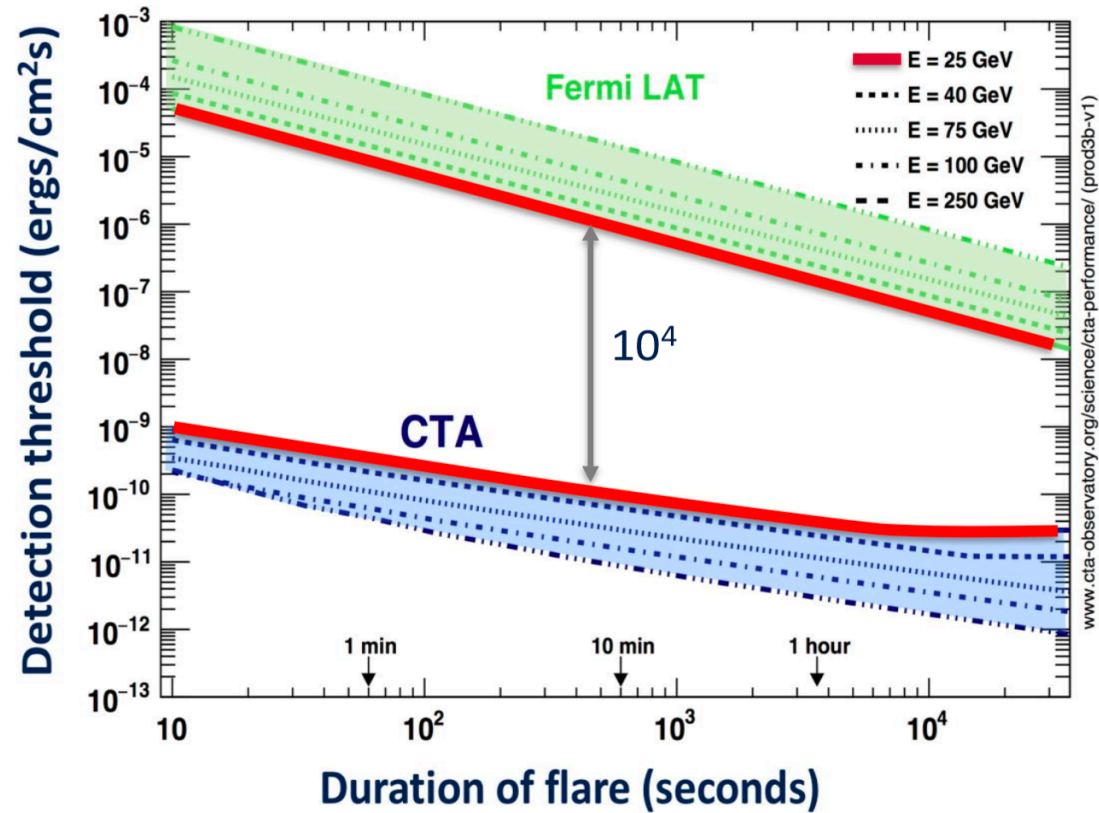
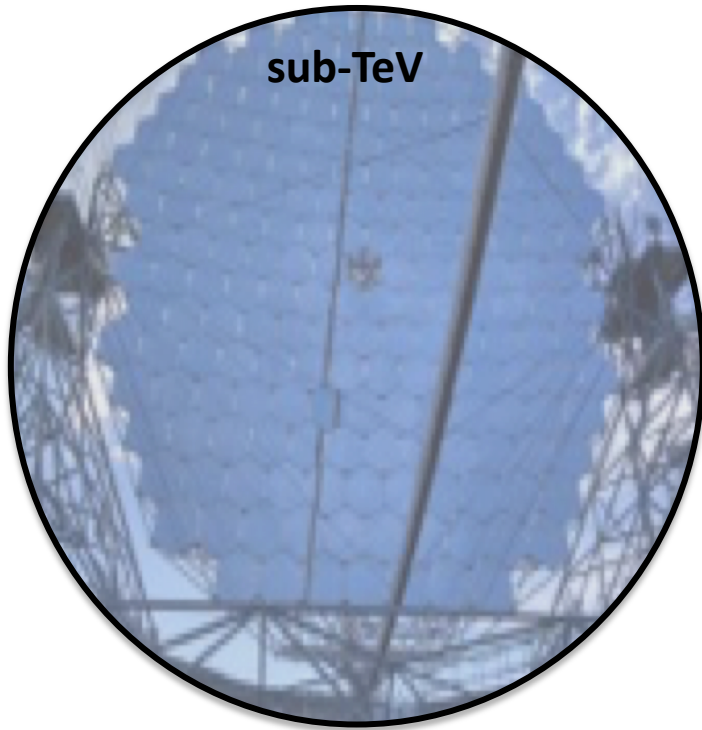


# sub-TeV energies



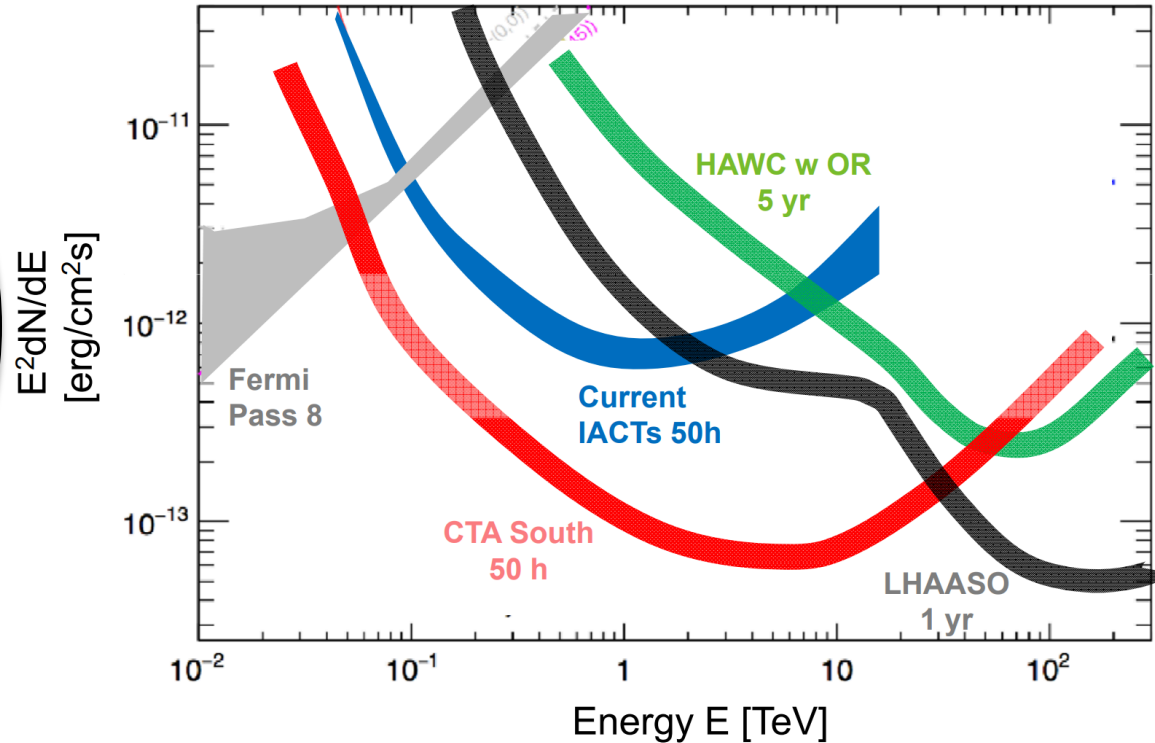
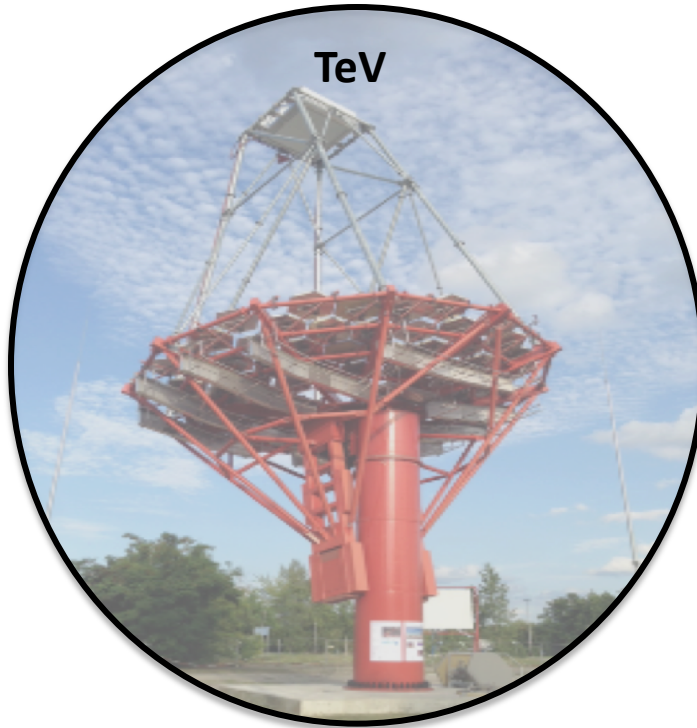
- Lowest energies (tens of GeV)  
→ **cosmological sources**
- Deepest sensitivity for short timescale phenomena  
→ **Time domain unexplored**

# sub-TeV energies - Transient sensitivity



- Lowest energies (tens of GeV)  
→ **cosmological sources**
- Deepest sensitivity for short timescale phenomena  
→ **Time domain unexplored**

# TeV energies - Sensitivity (steady sources)



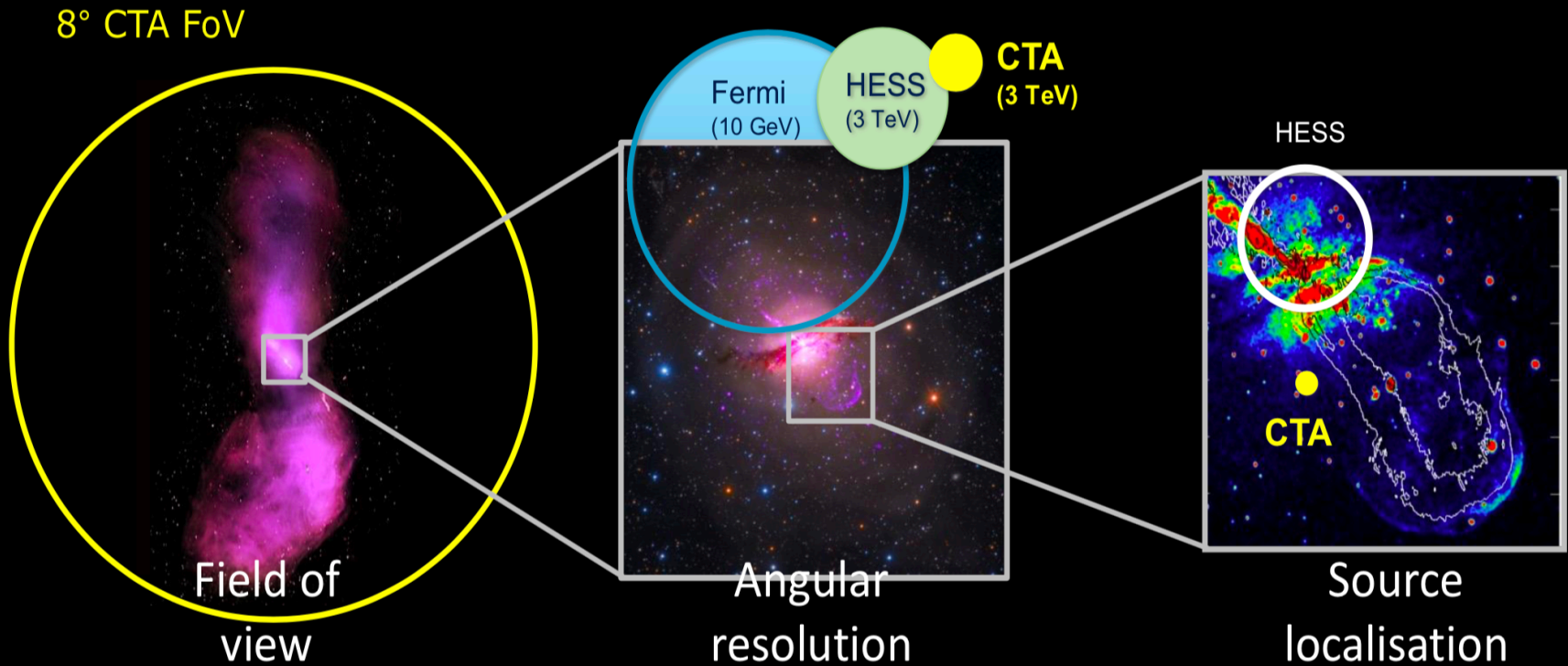
From  $10^{-12}$  to  $10^{-13}$  erg/cm<sup>2</sup>s

- deepest sensitivity ever
- arcmin angular resolution
- large FoV

- Surveys & precision studies

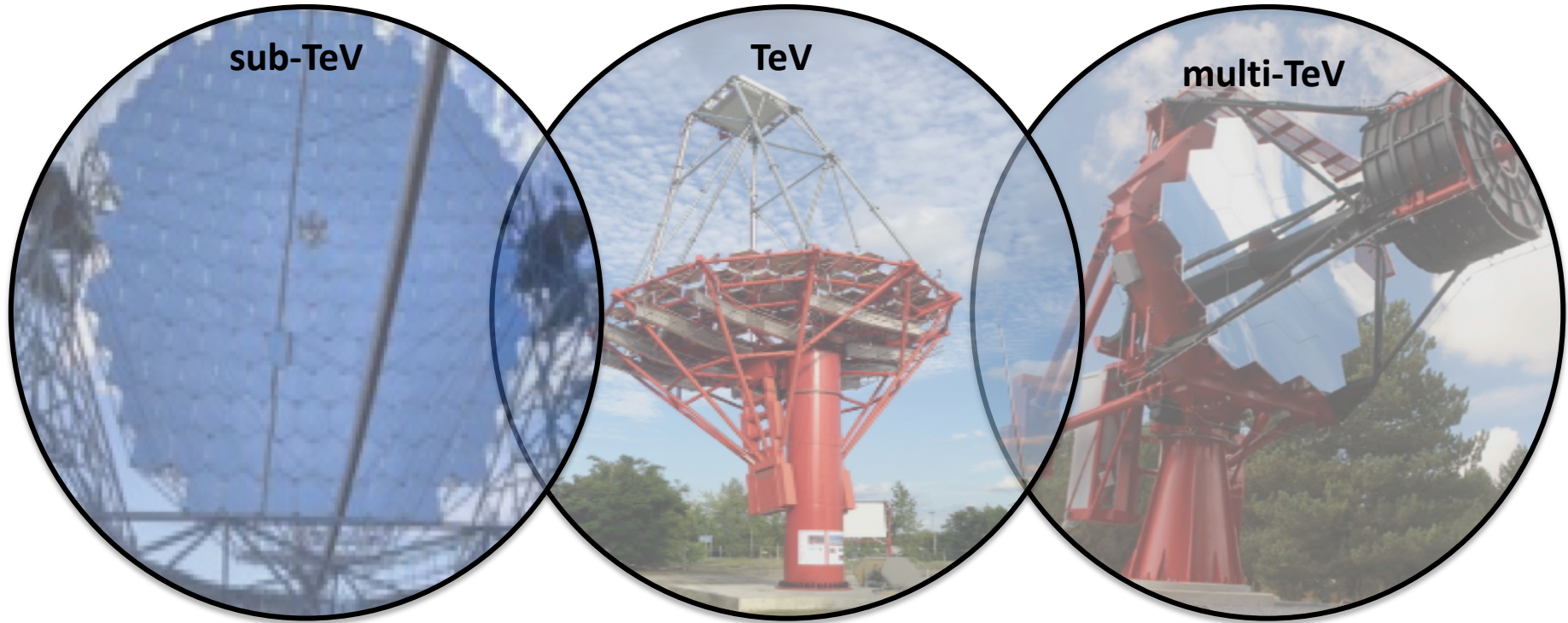


# TeV/multi-TeV energies - Resolving power



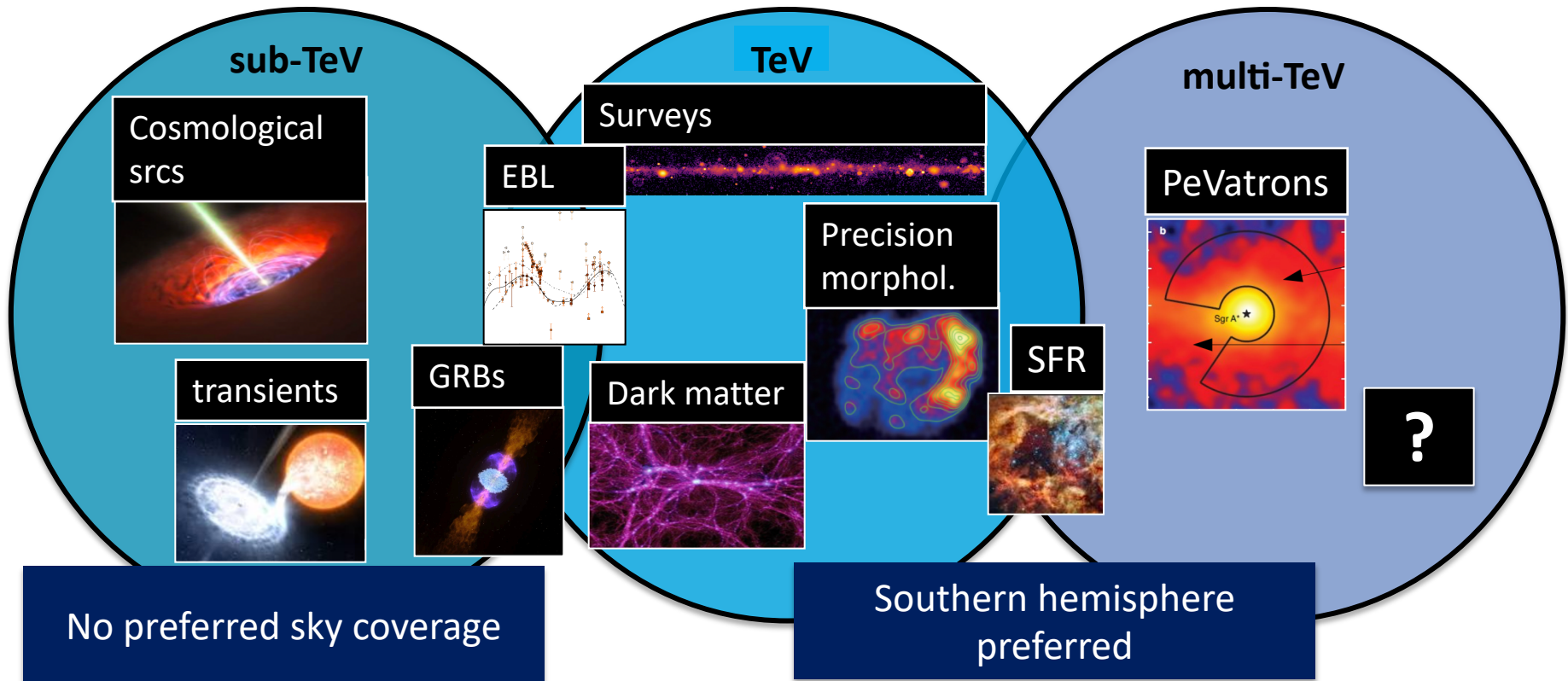
**Example:** nearby active galaxy Centaurus A

# Science cases and design



- Lowest energies (tens of GeV) → **cosmological sources**
- Deepest sensitivity for short timescale phenomena → **Time domain unexplored**
- **Surveys & precision studies**
- **100 TeV range unexplored**
- **precision studies**
- deepest sensitivity ever
- arcmin angular resolution
- large FoV
- Precision measurements in a still little explored energy range

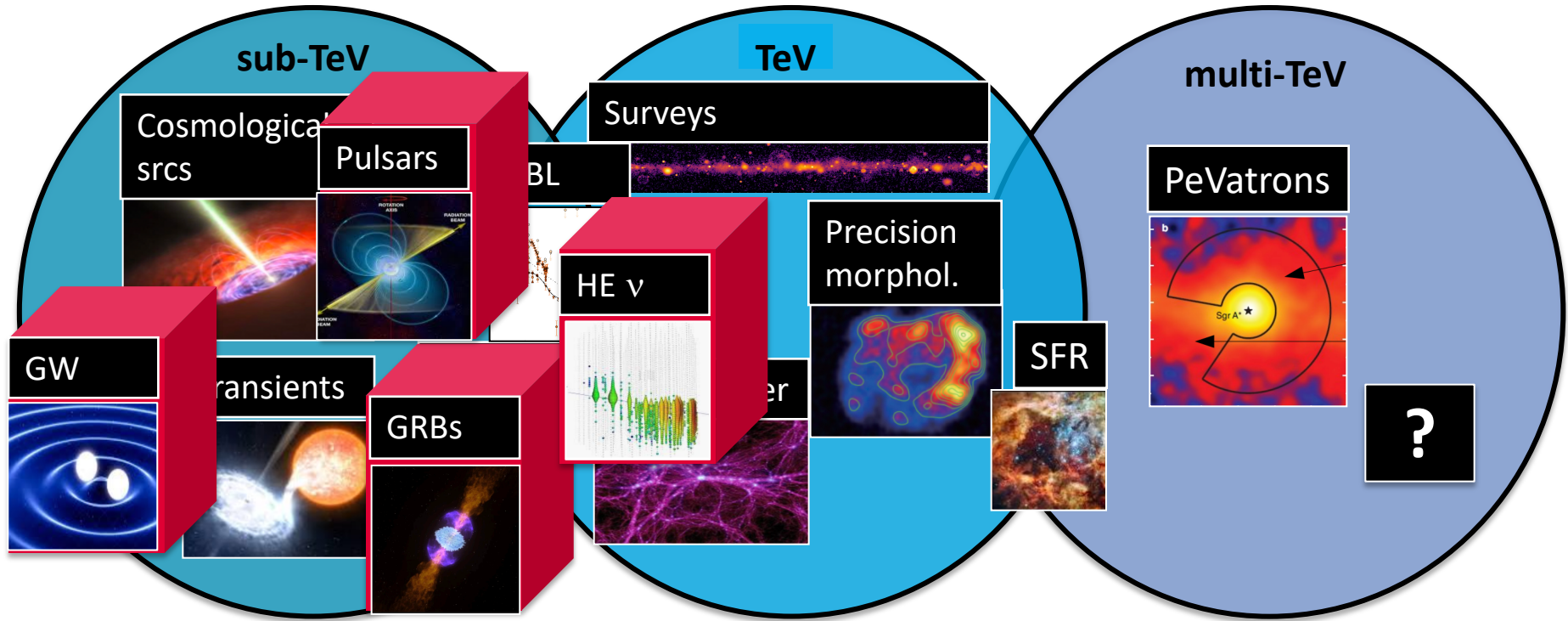
# Science cases



- **Mainly CTA consortium involved in the definition of the science cases**

(Science with CTA, CTA Consortium 2019 - <https://doi.org/10.1142/10986>)

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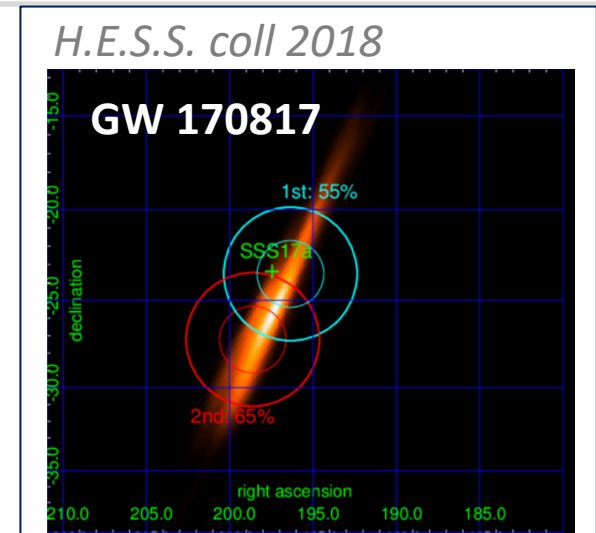


# Transients in the MM era

## Gravitational wave follow-up

*Schussler+2019,*

- **Violent events with electromagnetic counterpart established.**  
TeV emission? Shedding light on the physical parameters of the mergers



## High-energy $\nu$ follow-up

*Sataleka+2019*

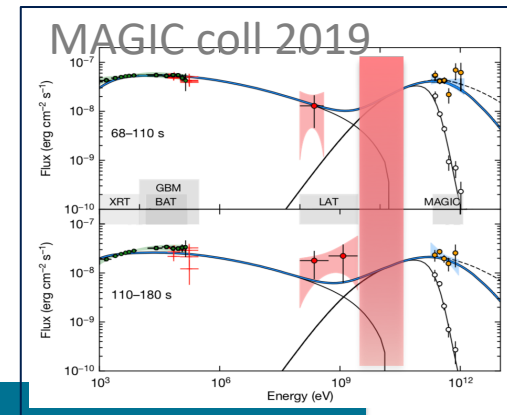
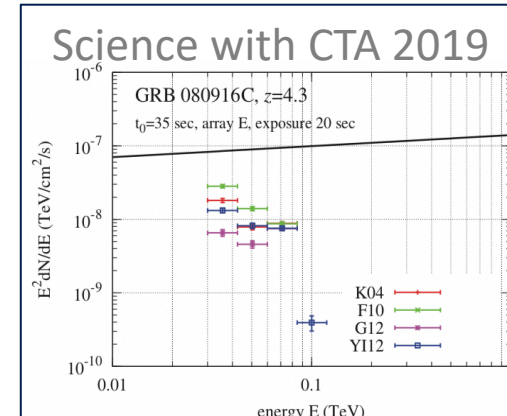
- **What's the origin of the TeV-PeV cosmic  $\nu$ ?**
  - **CTA can play a fundamental role in the event localization (arcmin)** given the coarse measurements from HE satellites/ $\nu$  detector
    - Real-time issuing alerts within 2 min



# Transients

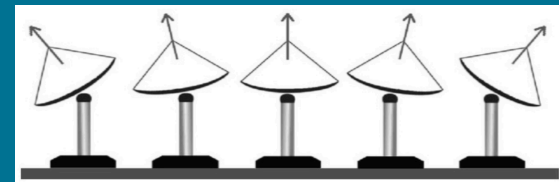
## GRBs *Di Girolamo+2017, Bernardini+2019*

- How does the prompt dynamic work?
- How does the afterglow dynamic work?
  - CTA has short-GRB at reach
  - CTA can detect GRB up to days after  $t_0$
  - CTA will probe the early universe
- What's the mechanism behind the VHE production?
  - Access to tens of GeV range is crucial



## Observational strategy

- Fast response to external alerts
- Joint MWL/MM campaigns to identify short bursts within FoV  
 → divergent pointing



# Transients

## Galactic transients:

- Novae, microquasars, tidal disruption events

## Serendipitous transients discovered by CTA *Schussler+2019*

- Extreme, high impact events
  - Real-time analysis issuing alerts (VO complaint) within 2'

## AGNs *Zech+2019, Martinez-Huerta+2019*

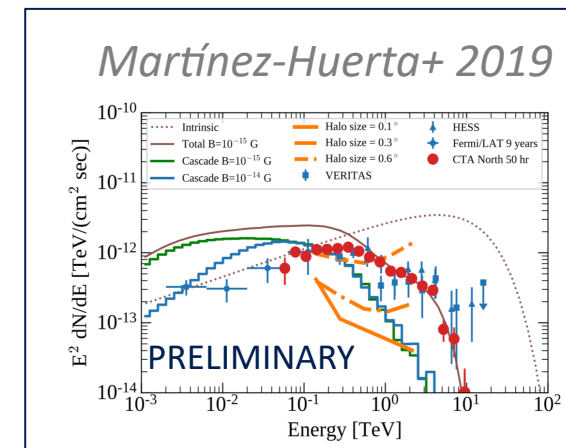
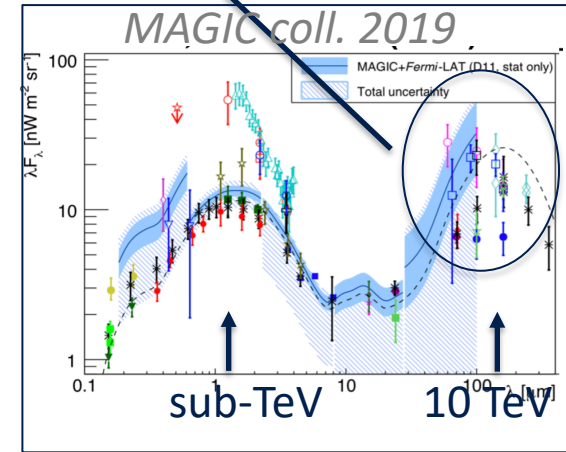
- Does the blazar sequence hold?
- Are there other classes of AGNs, other than blazars & radio galaxies ?
- Is there a strong population of extreme blazars?
  - monitoring program + deep observations of key sources + hunt for new sources

# $\gamma$ -ray cosmology



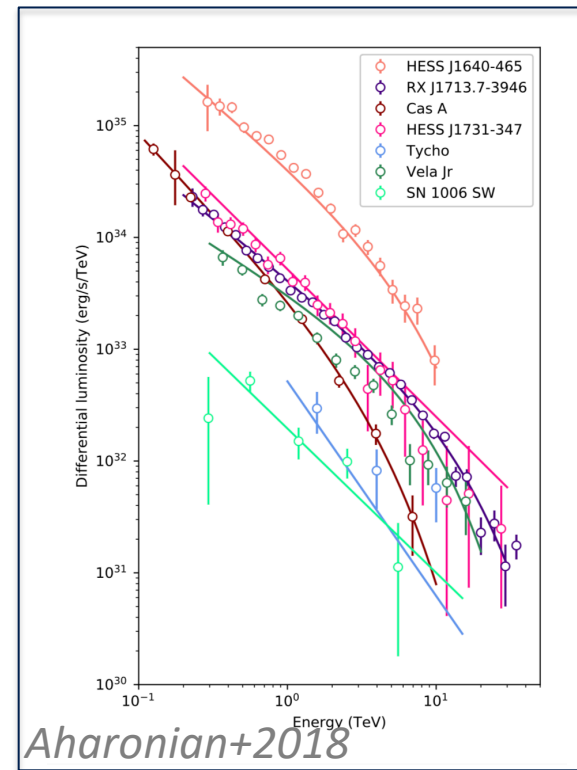
poorly constrained

- **What is the spectrum of the EBL at  $z=0$ ?**
  - CTA can improve precision & explore the IR range
    - CTA large energy coverage has the unique capability **to measure unabsorbed intrinsic (GeV) and attenuated (TeV) part of the spectra**
    - **Large sample of srcs at different  $z$** 
      - GRB are excellent candidates
- **How the EBL evolves with  $z$ ?**
- **What's the strenght of the IGMF?**



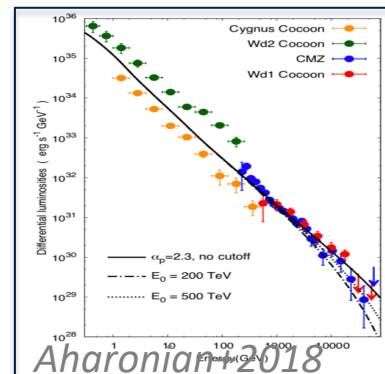
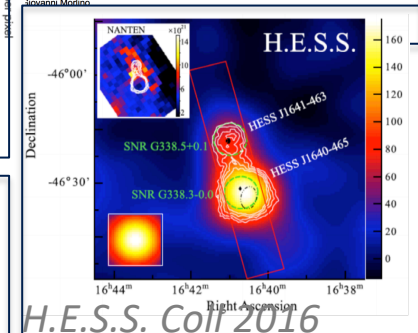
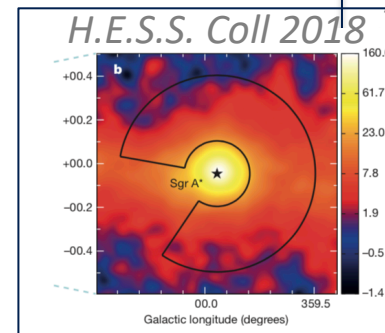
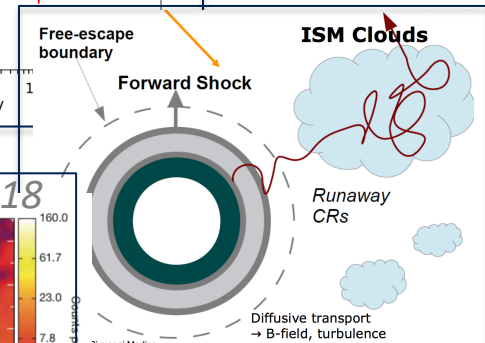
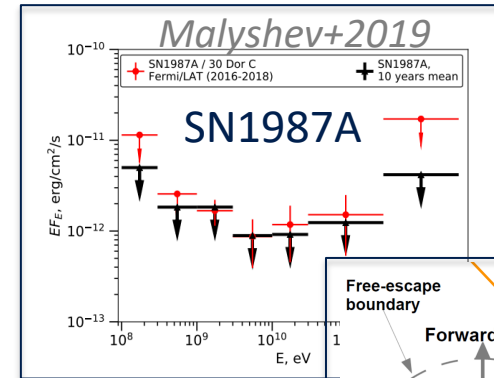
# Cosmic rays physics

- **Galactic CRs up to the knee**
  - Standard picture: **shock-accel. in SNRs**
    - satisfies energetics & spectrum
  - BUT: only a few SNRs provide evidence for hadronic accel & only up to 10-20 TeV



# Cosmic rays physics

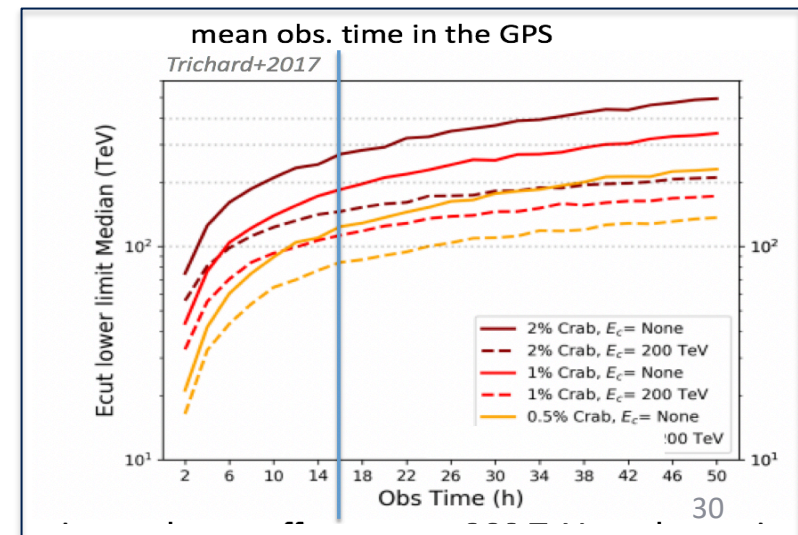
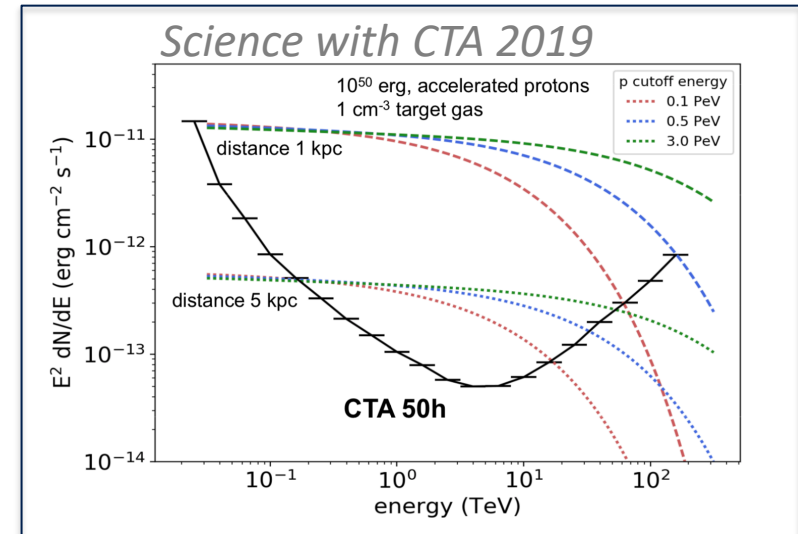
- **Who are the PeVatrons?**
  - SNR during a limited period (100 yr) in the earliest stages
    - SN1987A optimal test case
  - molecular clouds illuminated by escaping CRs  
(Aharonian1981, Casanova2010)
  - **Other sources?**
    - Galactic Center?  
(H.E.S.S. coll. 2018)
    - ??? → Unbiased scan  
(Anguner+2019)
    - Star forming regions?  
(Aharonian+2018)





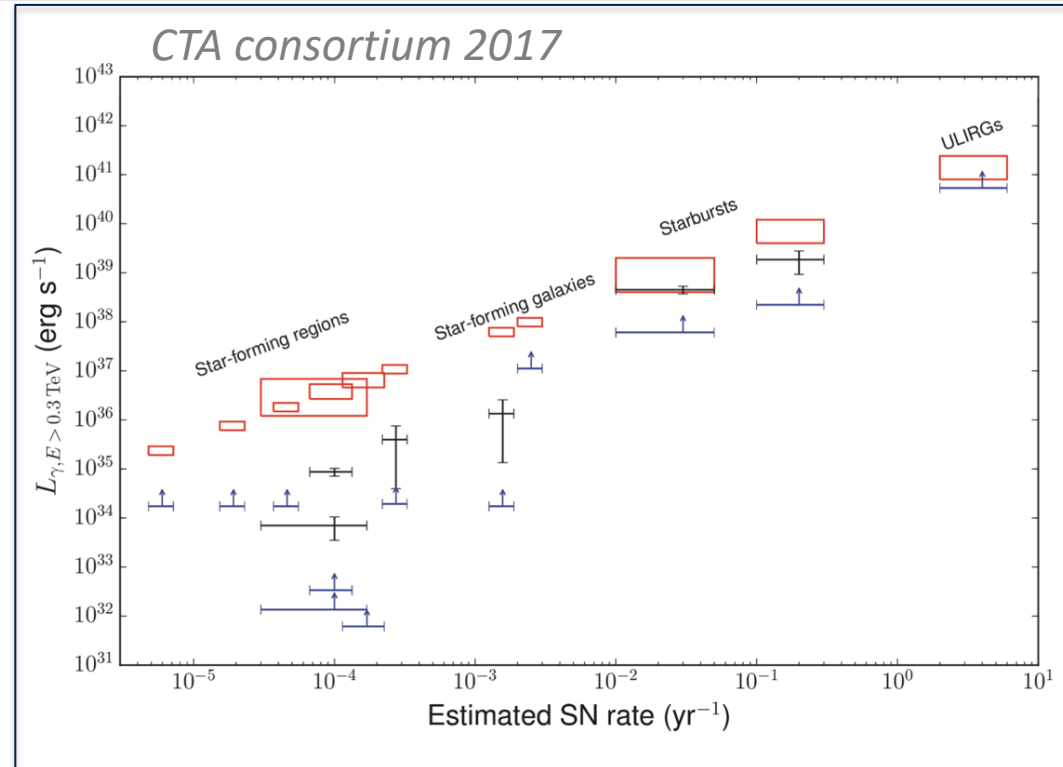
# Cosmic rays physics

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# Cosmic rays physics

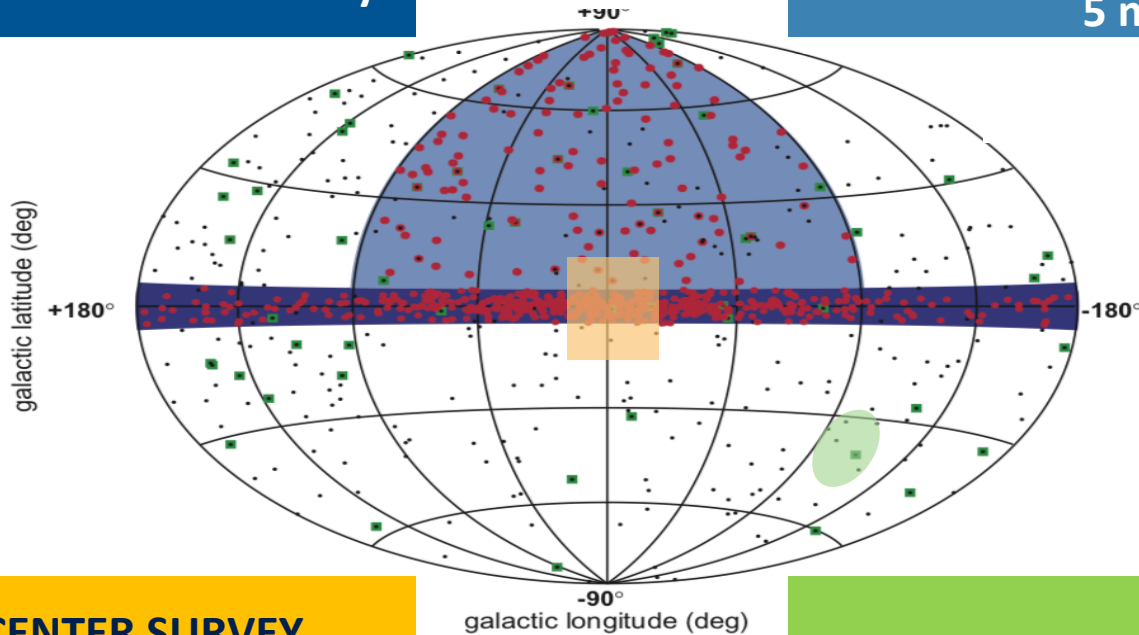
- **CR properties in SFRs?**
- What's the **relationship between star formation rate and CRs?**
  - Deep observations of a different set of sources: SFRs in our Galaxy, of star-forming Galaxies (LMC, Andromeda) and starburst Galaxies



# Surveys

**GALACTIC PLANE SURVEY**  
 not uniform sensitivity across the plane  
 2-4 mCrab  
 pilot survey: first results after 1-2 yr

**EXTRAGALACTIC SURVEY**  
 first unbiased survey of VHE sky →  
 huge discovery space  
 25% of the sky  
 5 mCrab



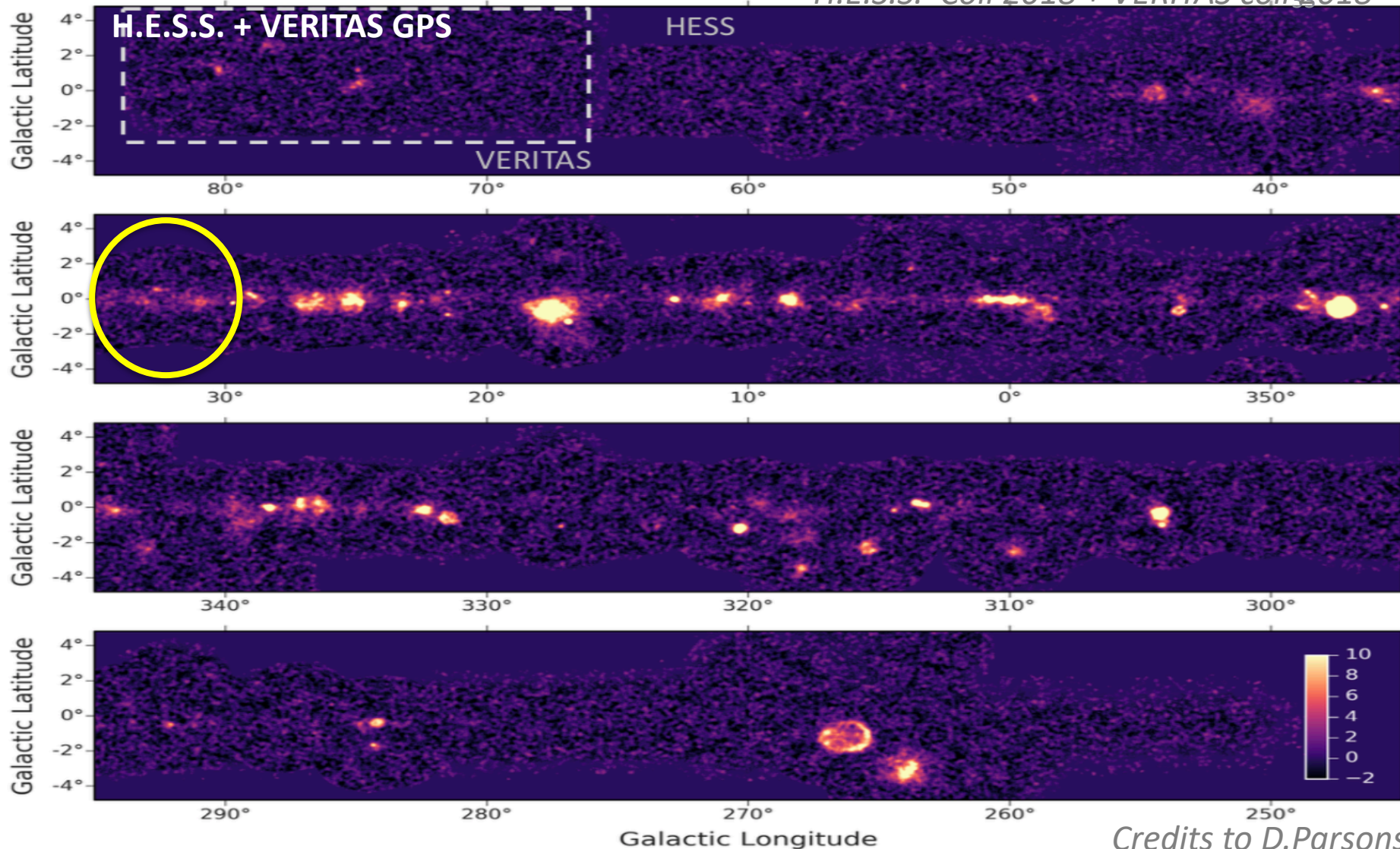
**GALACTIC CENTER SURVEY**  
 deeper obs around the GC,  
 10° x 10°  
 2 mCrab

**LARGE MAGELLANIC CLOUD SURVEY**  
 All region in 10 pointings

# Galactic plane survey



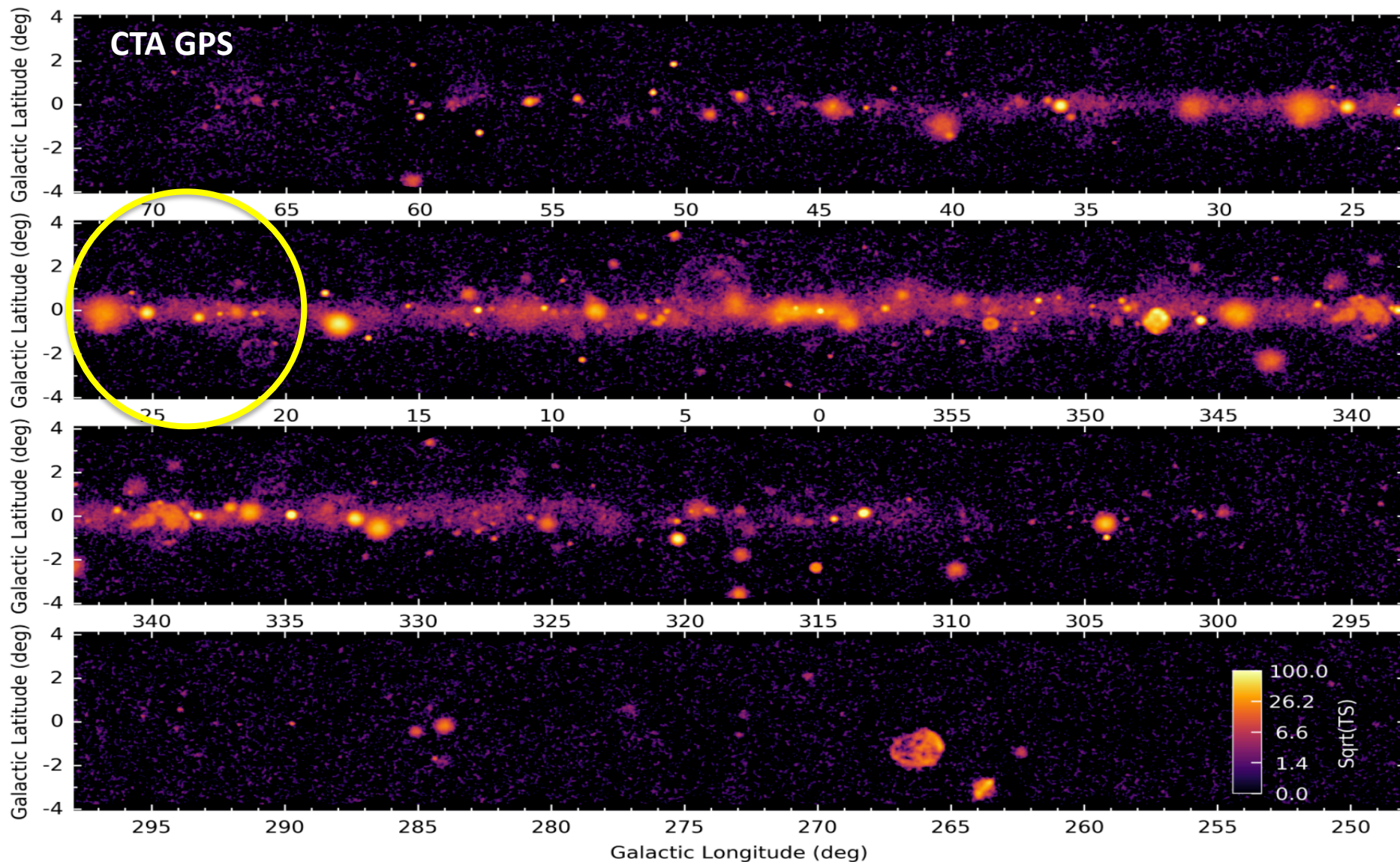
H.E.S.S. Coll 2018 + VERITAS coll 2018



Credits to D.Parsons



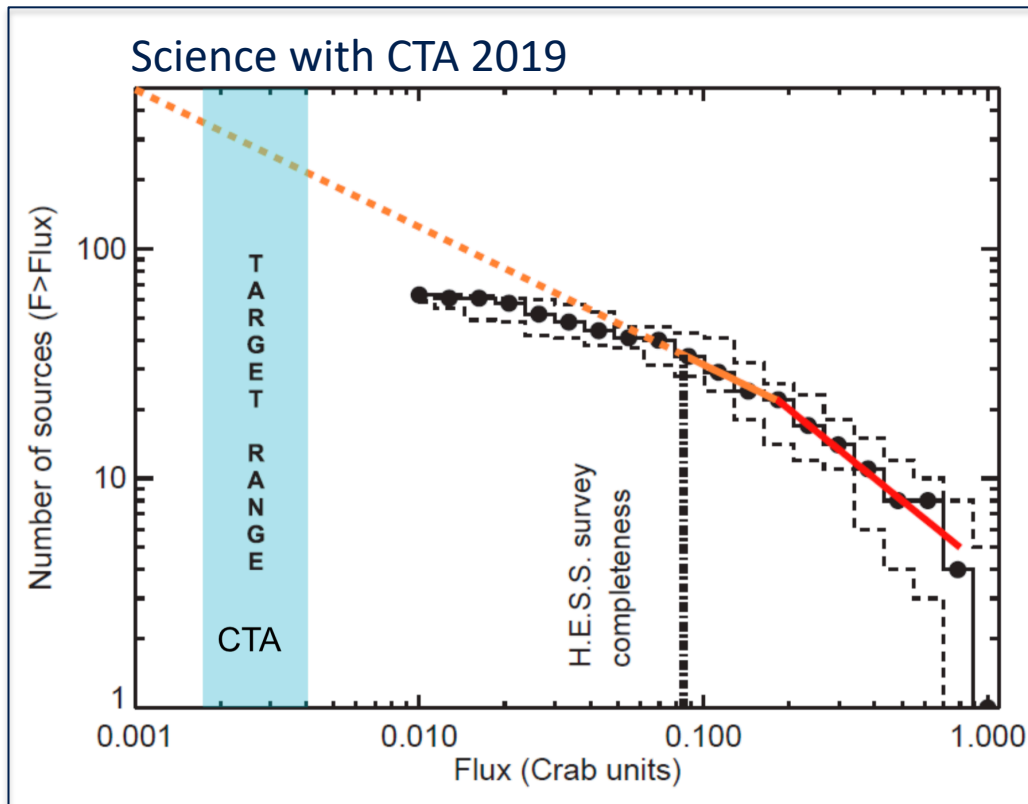
# Galactic plane survey





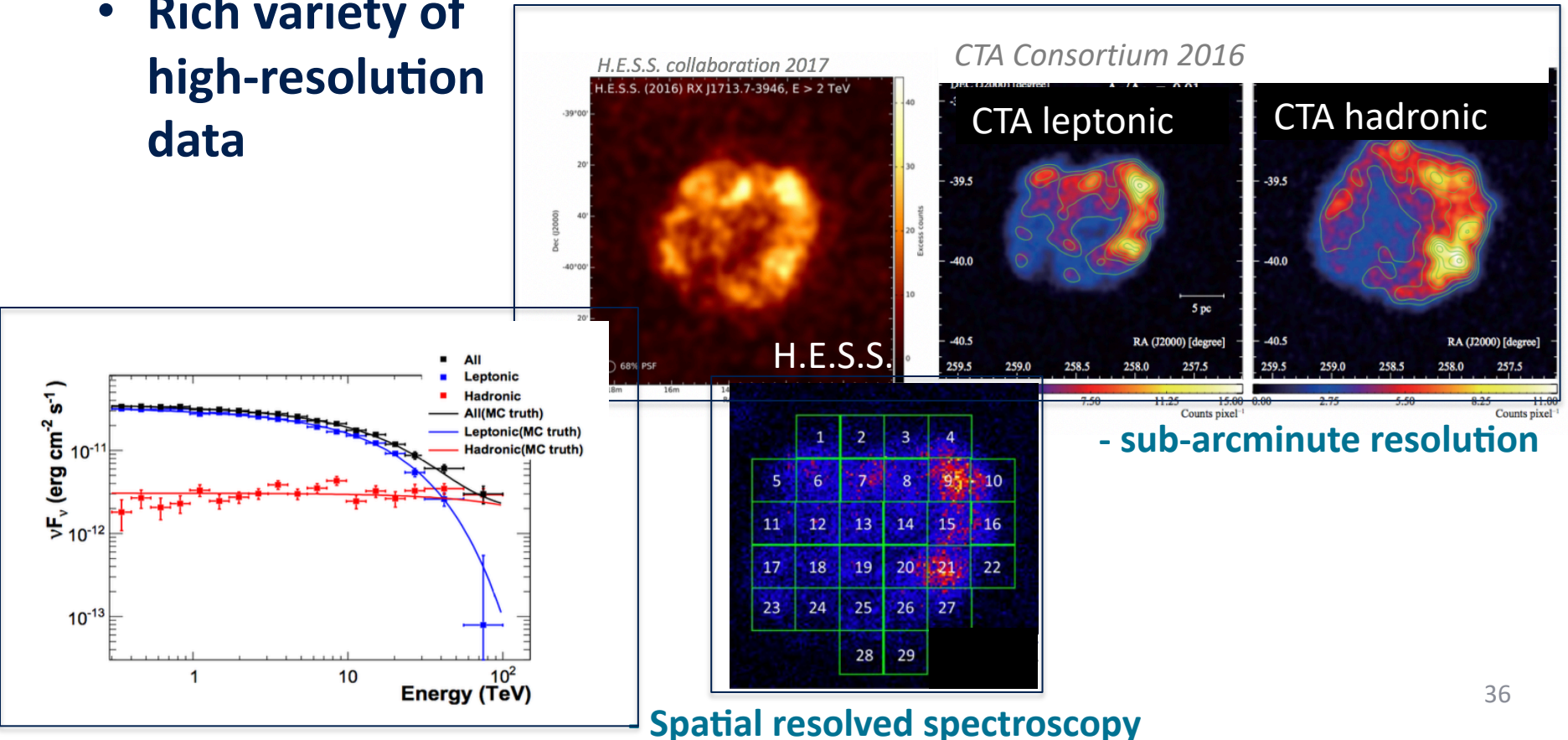
# Galactic plane survey

- The VHE census increased by a factor about 5

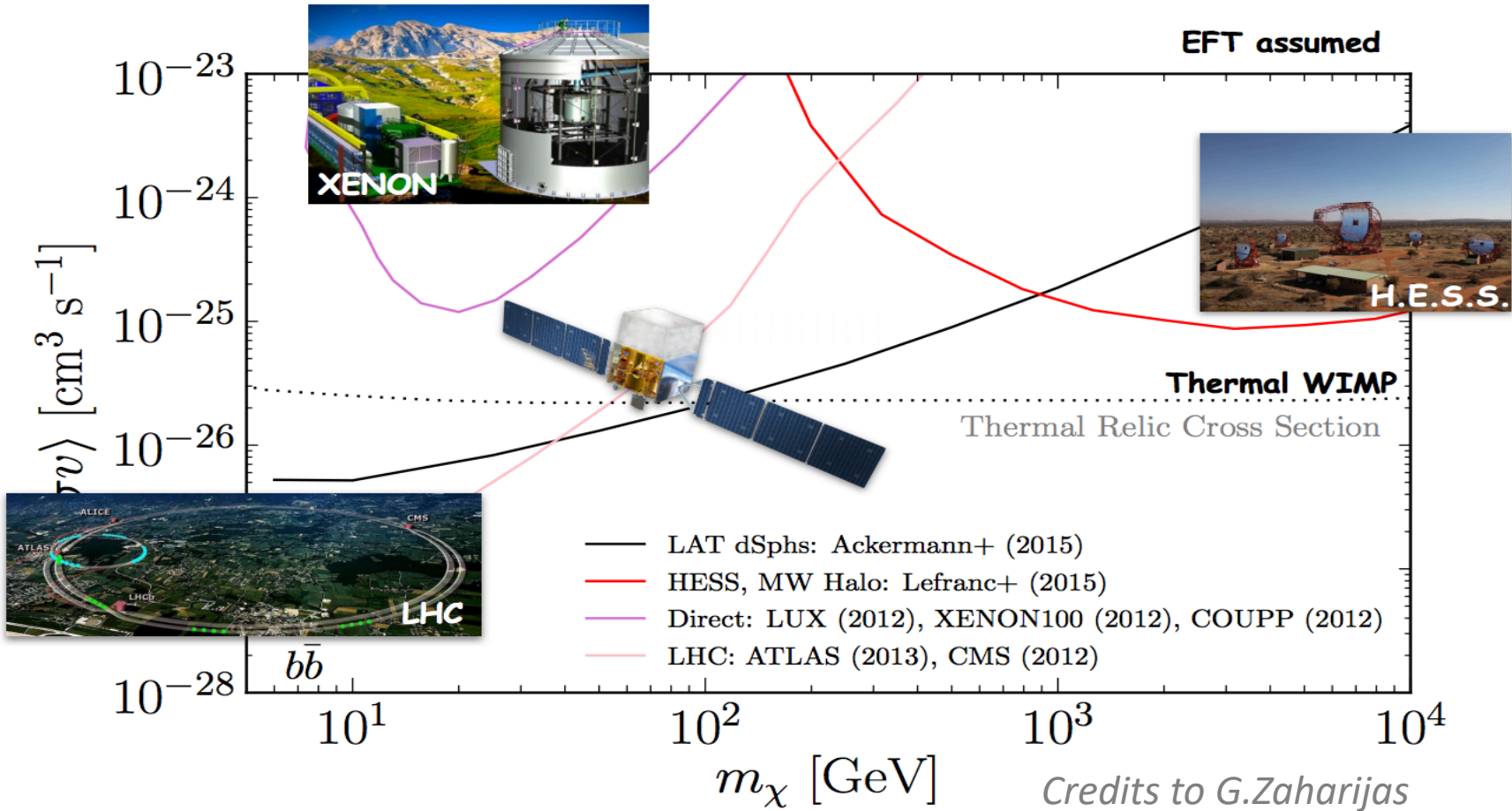


# Galactic plane survey

- The VHE census will increase by a factor about 5
- Study of the properties of the interstellar emission from large scale CR sea at TeV (*see Gavin Rowel's talk*)
- Rich variety of high-resolution data



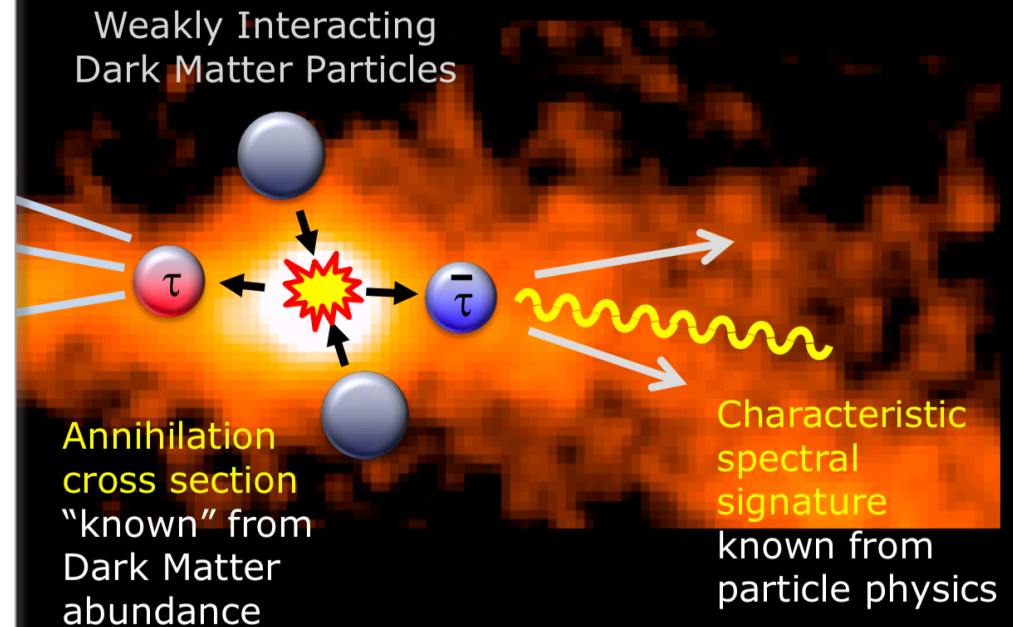
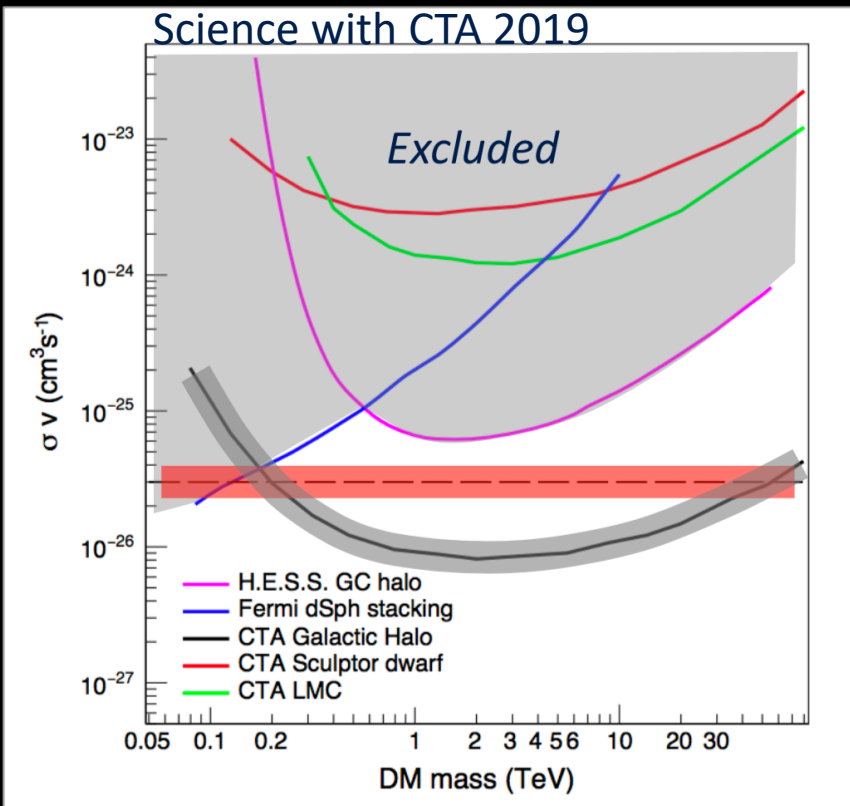
# Dark matter search



- WIMP is not ruled out (*Leane+ 2018*)
- The TeV mass domain is unexplored

# Dark matter search

- CTA will constrain the WIMP paradigm in case of non-detection



from: Science with CTA  
[www.worldscientific.com/worldscibooks/10.1142/10986](http://www.worldscientific.com/worldscibooks/10.1142/10986)

- **The first ground-based gamma-ray observatory**
  - serve large user community data & science tools in fair way
  - **Proposal driven observatory**
- **30 yr of lifetime**
  - Significant effort for maintenance and operations costs optimization
- **One legal entity: CTAO GmbH in the process to become an ERIC with HQ in Bologna (Italy)**
- **Two Telescope arrays, one Observatory**
  - Inter-site coordination
  - Uniform approach to scientific operations
- **The Science Data Mgmt Center in Zeuthen (Germany)**
  - CTA is a software instrument

# CTA Observatory





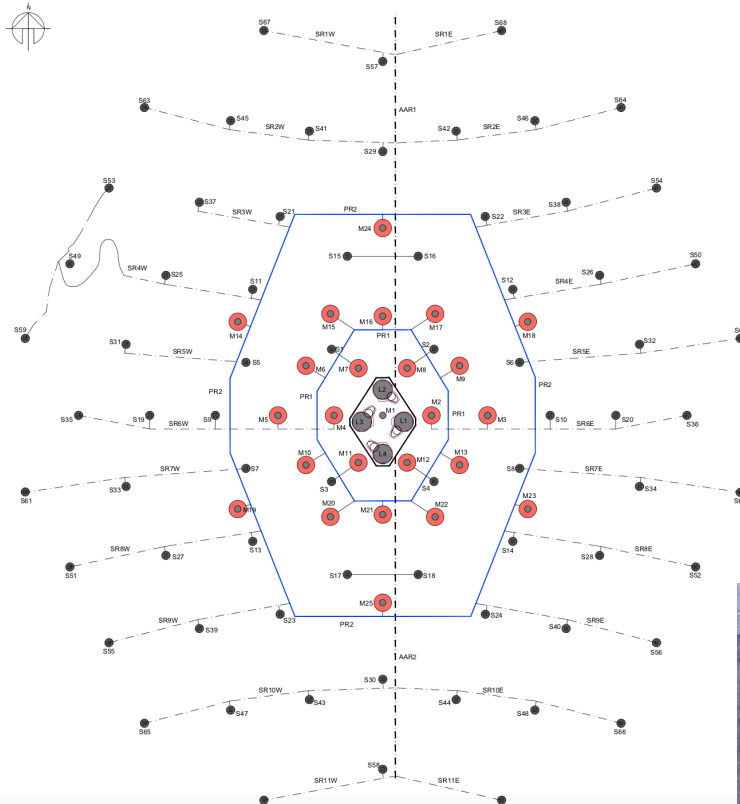


# CTA-North site





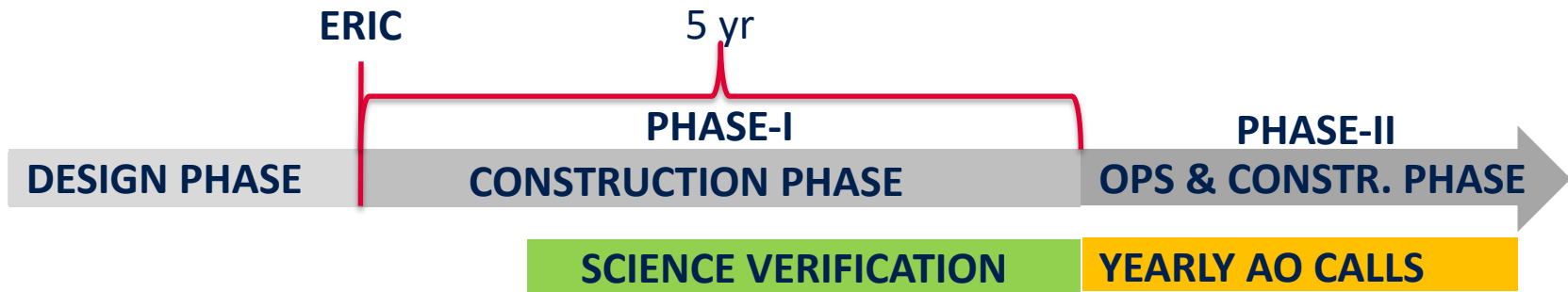
- 4 LSTs + 25 MSTs + 70 SSTs (baseline-configuration)



- Site agreement signed in Dec 2018
- Aim to start with site infrastructure construction soon



# Project Status



- **Phase-I: construction of a reduced-baseline configuration**
  - a significant performance improvement wrt the currently running facilities
    - guarantees high-impact science covering most of the science cases
    - guarantees a significant increase of the discovery space
- **Phase-II: operation of the phase-I configuration + construction towards the final baseline**

# Conclusions



- **CTA will usher in a new era in VHE Astrophysics**
  - Rich science program answering many open questions
  - Large new discovery space
- **The full exploitation of CTA science cases requires MWL/MM synergies**



- **CTA will be the first gamma-ray ground-based observatory, openly delivering data to the community**



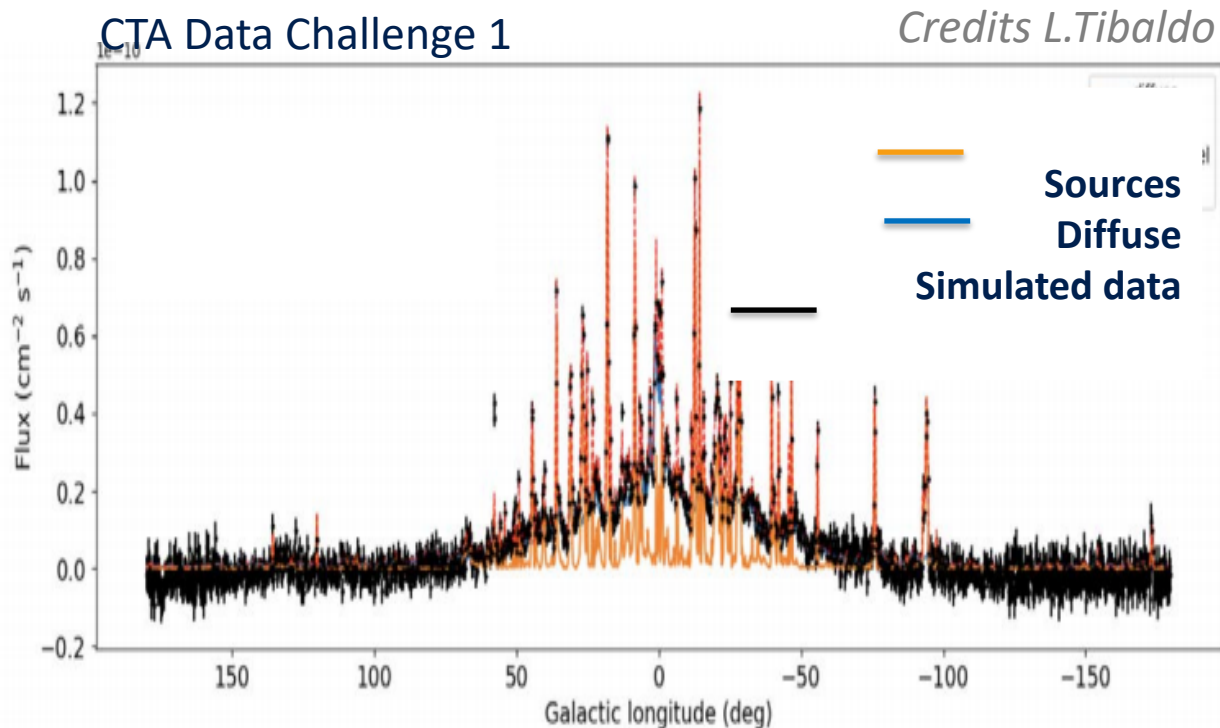
Thank you





# Diffuse emission

- CTA will provide the study of the diffusion emission across the Galactic plane
  - Interstellar fraction expected to be 70-90%



# Off-axis sensitivity

