cherenkov telescope array

# CTA Key Science Projects

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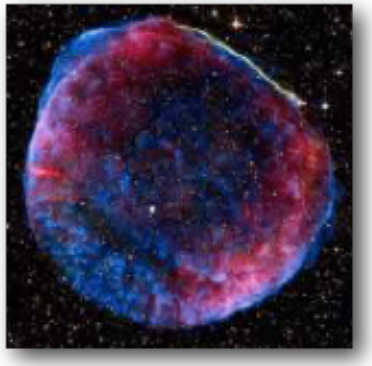
**for the CTA Consortium**

# CTA Main Scientific Themes

## 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 on Astroparticle Physics, Vol. 43, 1-356 (2013)

# CTA Key Science Projects

## The criteria used for selection of the baseline KSPs

1. Excellent scientific case and clear advance beyond the state of the art;

2. The production of legacy data-sets of high value to a wider community;

3. Clear added value of doing this as a KSP rather than as part of the Guest Observer Programme:
    1. the scale of the project in terms of observing hours - very large projects will be difficult to accommodate in the open time early in the lifetime of the observatory;
    2. the need of a coherent approach across multiple targets or pointings;
    3. the technical difficulty of performing the required analysis and hence reliance on consortium expertise.

# CTA Key Science Projects

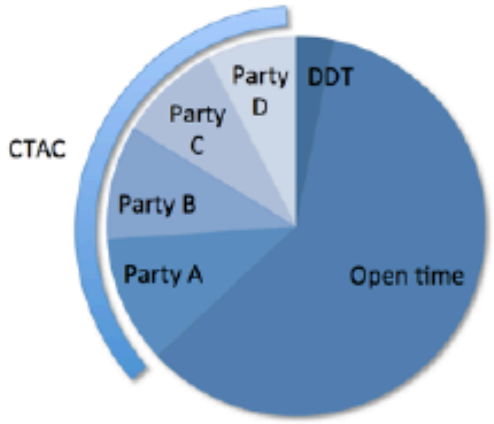
## Key Science Programs

| Theme | | Question | Dark Matter Programme | Galactic Centre Survey | Galactic Plane Survey | LMC Survey | Extra-galactic Survey | Transients | Cosmic Ray PeVatrons | Star-forming Systems | Active Galactic Nuclei | Galaxy Clusters |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Understanding the Origin and Role of Relativistic Cosmic Particles | 1.1 | What are the sites of high-energy particle acceleration in the universe? | | ✔ | ✔✔ | ✔✔ | ✔✔ | ✔✔ | ✔ | ✔ | ✔ | ✔✔ |
| | 1.2 | What are the mechanisms for cosmic particle acceleration? | | ✔ | ✔ | ✔ | | ✔✔ | ✔✔ | ✔ | ✔✔ | ✔ |
| | 1.3 | What role do accelerated particles play in feedback on star formation and galaxy evolution? | | ✔ | | ✔ | | | | ✔✔ | ✔ | ✔ |
| Probing Extreme Environments | 2.1 | What physical processes are at work close to neutron stars and black holes? | | ✔ | ✔ | ✔ | | | ✔✔ | | ✔✔ | |
| | 2.2 | What are the characteristics of relativistic jets, winds and explosions? | | ✔ | ✔ | ✔ | ✔ | ✔✔ | ✔✔ | | ✔✔ | |
| | 2.3 | How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time? | | | | | ✔ | ✔ | | | ✔✔ | |
| Exploring Frontiers in Physics | 3.1 | What is the nature of Dark Matter? How is it distributed? | ✔✔ | ✔✔ | | ✔ | | | | | | ✔ |
| | 3.2 | Are there quantum gravitational effects on photon propagation? | | | | | | ✔✔ | ✔ | | ✔✔ | |
| | 3.3 | Do Axion-like particles exist? | | | | | ✔ | ✔ | | | ✔✔ | |

## Surveys

## Targets

# CTA Science: KSPs and Guest Observers

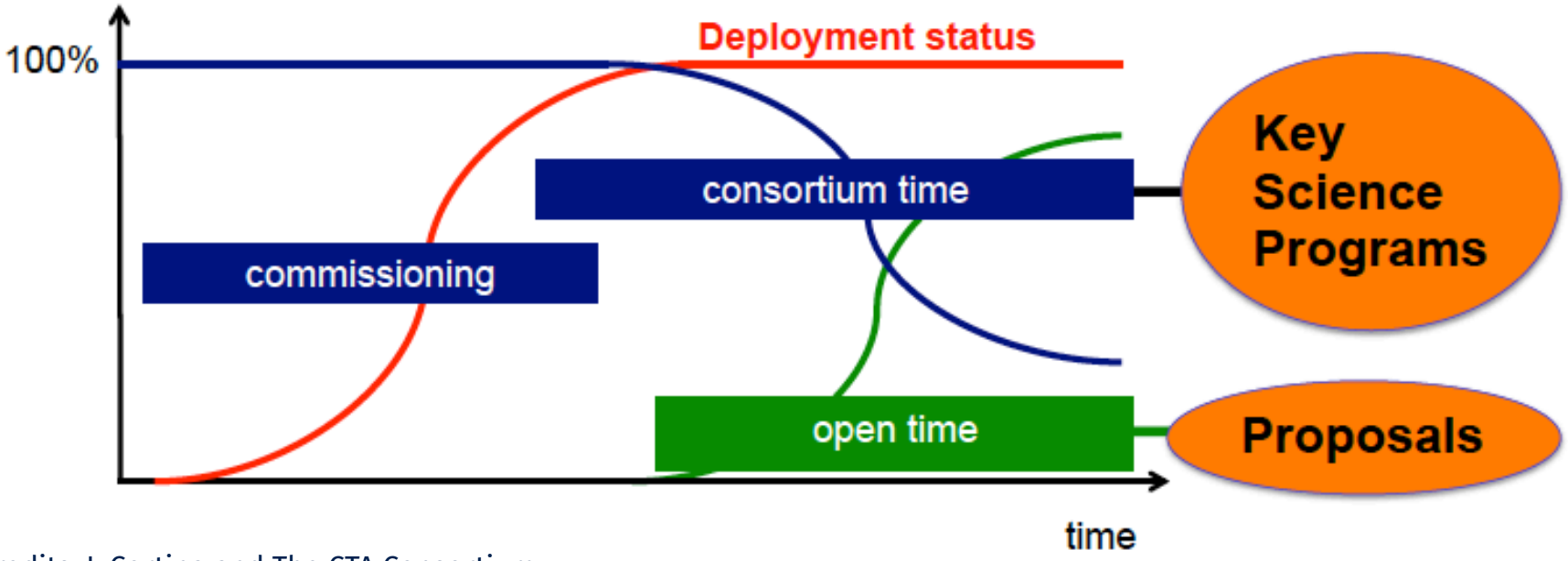



**Current assumptions**

CTA parties pool the observing time in:

- Open time (for scientists of party countries)
- Consortium time (Key Science Projects)

All data will become fully public after a proprietary period (typically one year)




Credits: J. Cortina and The CTA Consortium

# CTA Science: KSPs and Guest Observers

## Key Science Programmes

- Ensure that important science questions for CTA are addressed in a coherent fashion and with a well-defined strategy,
- Conceived to provide legacy data sets for the entire community

**Example: galactic and extragalactic surveys**

- Deep investigation of known sources
- Follow-up of KSP discovered sources
- Multiwavelength campaigns
- Follow-up of ToOs from other wavebands / messengers
- Search for new sources
- …

**Proposal-Driven User Programme**

Credits: W. Hofmann and The CTA Consortium

# CTA Key Science Projects

## Time for two topics

Extra-galactic Survey

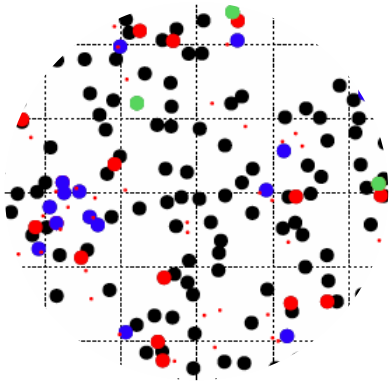
Galactic Plane Survey + Galactic Center Survey

## Caveat

a limited review, if interested please ask for more details

somewhat biased towards the SSTs contribution

# Extra-galactic Survey



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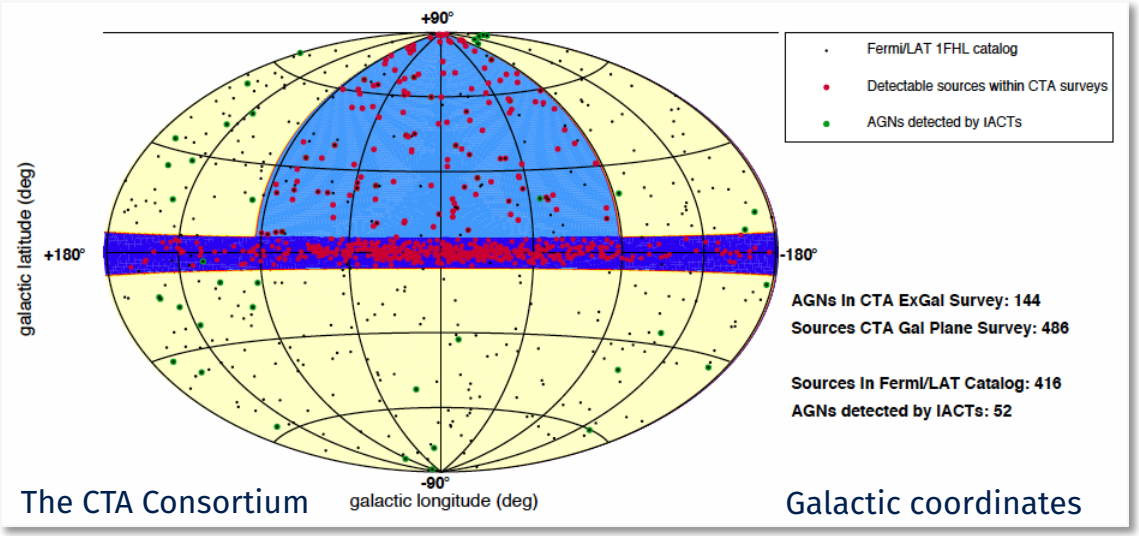
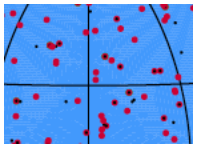
**The aim is to perform a blind survey of 25% of the sky**, and to construct an unbiased VHE extragalactic source catalogue with an integral sensitivity limit of ~5 mCrab.

**SSTs will have a relevant role thanks to their > 9º field of view**, in synergy with the deep MSTs sensitivity for E > 100 GeV.

We expect the **discovery of extreme BL Lac objects** peaking in the 0.1 – 1 TeV region, thanks to the good spectral coverage provided by MSTs and SSTs in the 0.1 – 10 TeV energy range.

# Extra-galactic Survey



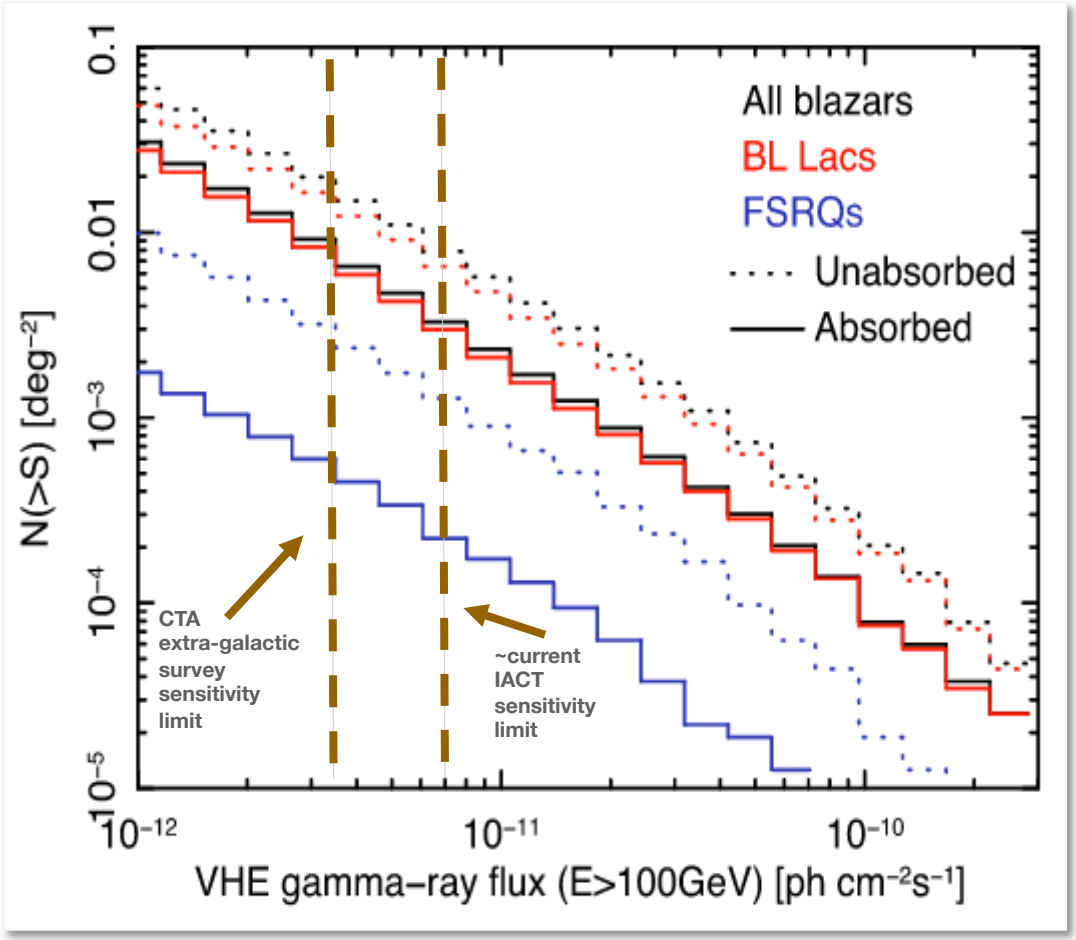
1/4 of the sky (~$10^4$ $deg^2$)
Limiting flux ~ 5 mCrab

The survey would connect with the Galactic Plane Survey ($|b| < 5^o$) over Galactic longitude $-90^o < l < 90^o$.

Several highly interesting regions such as the Virgo cluster, Coma cluster, and Fermi Bubbles (North) and Cen A (South) will be covered by the proposed survey.

Current simulations suggest that a wide-field, shallow survey should detect more sources than a narrow-field, deep survey (given an equal survey time).

# Extra-galactic Survey

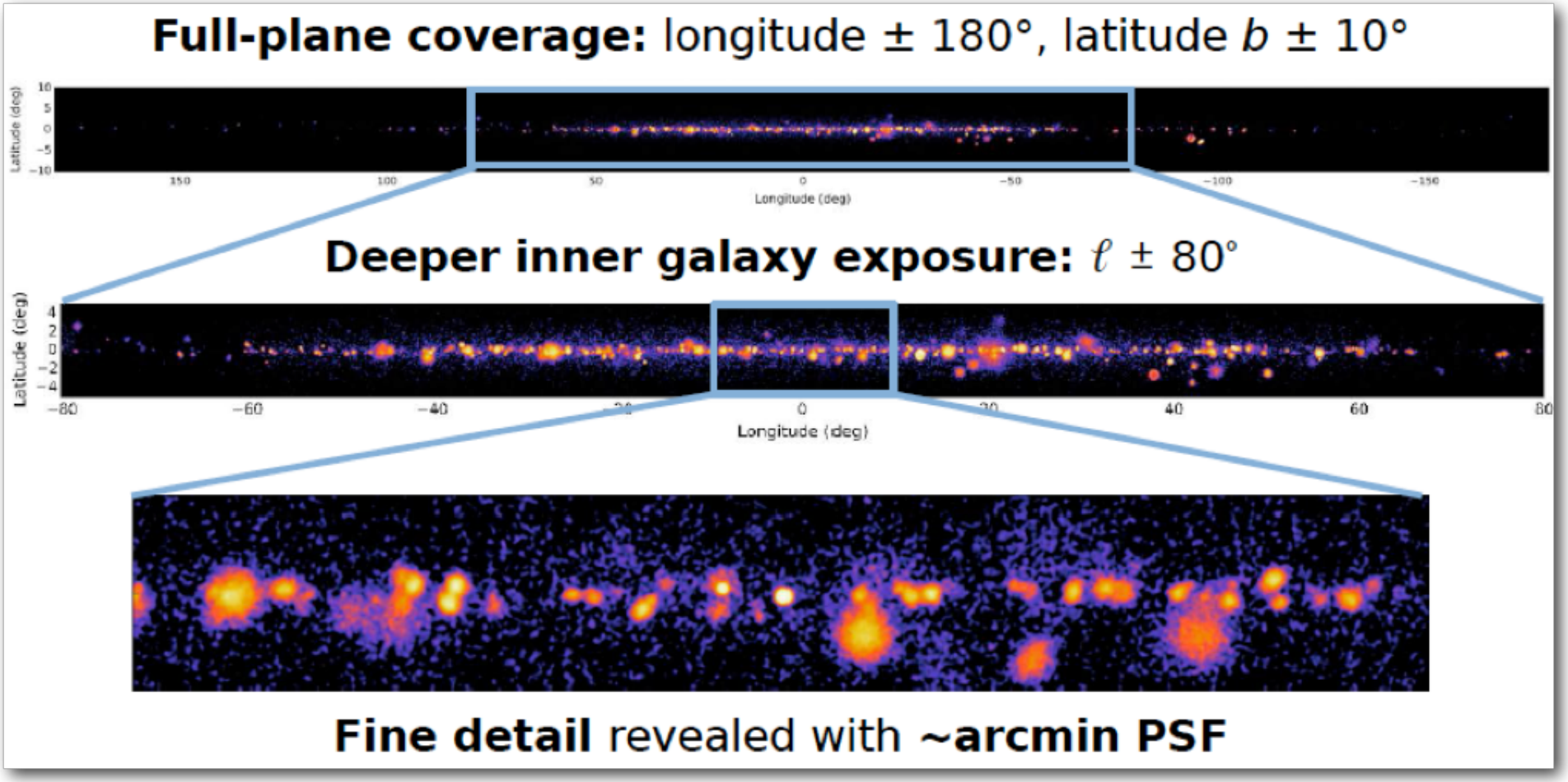



Padovani & Giommi (2015)

Padovani & Giommi (2015) derived the expected number of blazars on the sky in the GeV–TeV domain.

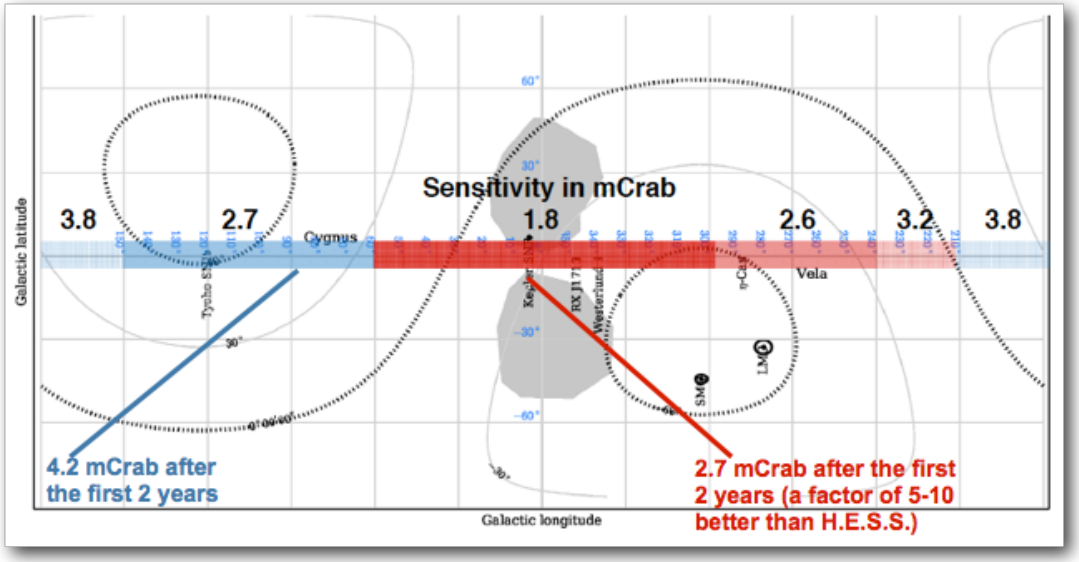
With the 5 mCrab sensitivity during the proposed survey**, CTA should detect around 100 sources in 10,000 deg$^2$.**

# Galactic Plane Survey




J. Knödlseder and CTA Consortium

# Galactic Plane Survey

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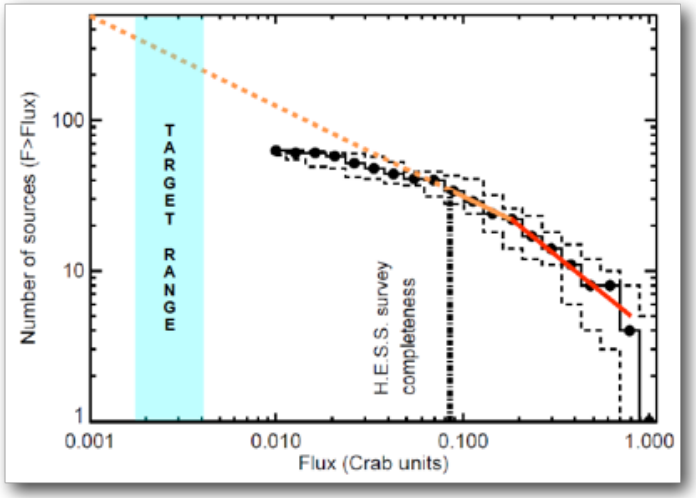
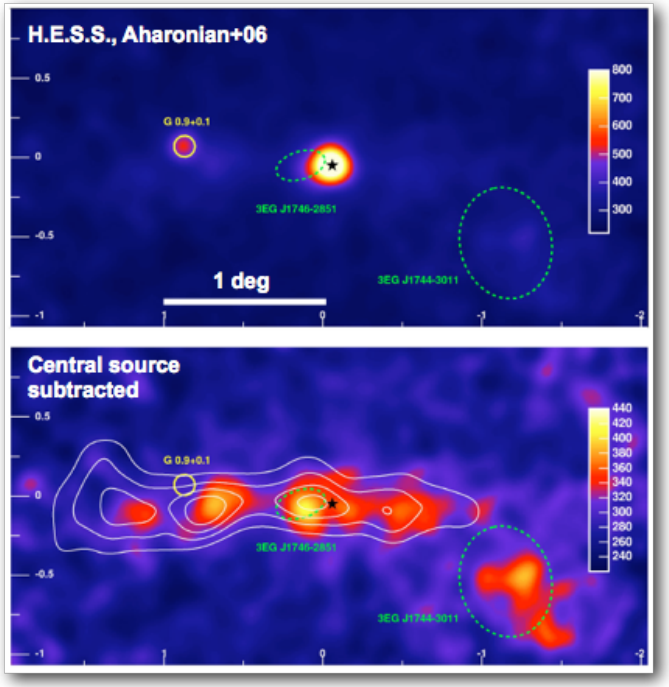
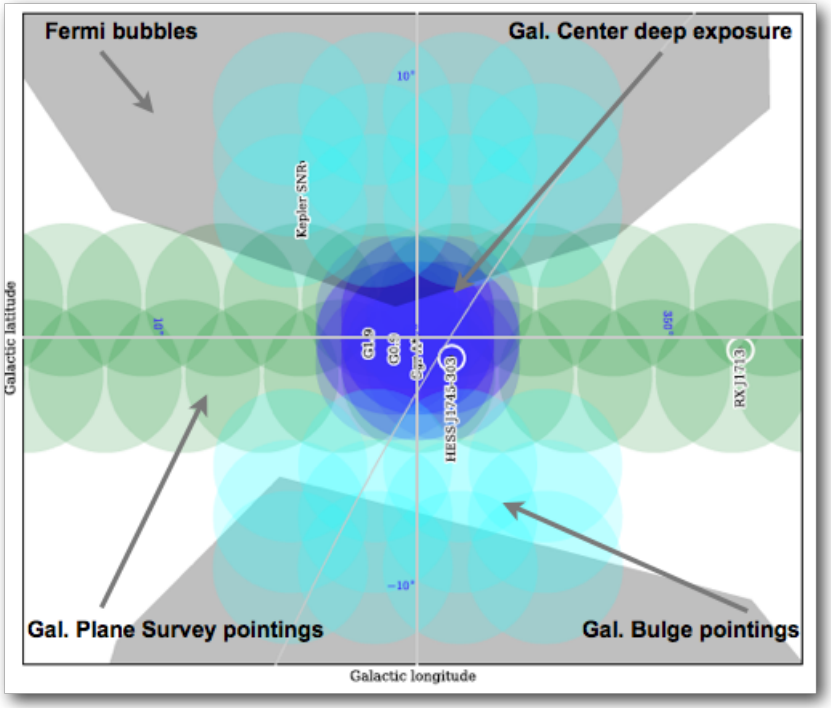



## Expected results

- 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

# Galactic Center Survey

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## 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

# CTA Science Working Groups

1. Galactic science:
   - SNRs
   - PWNs
   - Pulsars
   - Binaries
   - Other Galactic sources

2. Cosmic rays:
   - Molecular clouds
   - Diffuse emissions
   - Normal galaxies
   - Starburst galaxies
   - Galaxy clusters
   - Cosmic-ray nuclei
   - Cosmic-ray electrons

3. Extragalactic science:
   - Blazars
   - Non-blazar AGNs
   - Other extragalactic sources
   - Intergalactic magnetic fields
   - Extragalactic background light

4. Transients:
   - Galactic transients
   - Extragalactic transients
   - GRB
   - Multi-messenger studies

5. Dark Matter and exotic physics:
   - Dark Matter
   - Axions
   - Lorentz Invariance Violations

6. Intensity interferometry

# Conclusions

- CTA will be an observatory open to the scientific community.
- Science will focus on cosmic particle acceleration, extreme environment, and physics beyond the standard model.
- Proprietary time (significant fraction in the first years) will be articulated in Key Science Programmes.
- Science working groups are being renovated