CTA Key Science Projects

Stefano Vercellone (INAF/IASFPA) 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

<table>
<thead>
<tr>
<th>Theme</th>
<th>Question</th>
<th>Dark Matter Programme</th>
<th>Galactic Centre Survey</th>
<th>Galactic Plane Survey</th>
<th>LMC Survey</th>
<th>Extragalactic Survey</th>
<th>Transients</th>
<th>Cosmic Ray PeVatrons</th>
<th>Star-forming Systems</th>
<th>Active Galactic Nuclei</th>
<th>Galaxy Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding the Origin and Role of Relativistic Cosmic Particles</td>
<td>1.1 What are the sites of high-energy particle acceleration in the universe?</td>
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<td>1.2 What are the mechanisms for cosmic particle acceleration?</td>
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<td>1.3 What role do accelerated particles play in feedback on star formation and galaxy evolution?</td>
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<td>2.1 What physical processes are at work close to neutron stars and black holes?</td>
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<td>2.2 What are the characteristics of relativistic jets, winds and explosions?</td>
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<td>2.3 How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?</td>
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<td>Exploring Frontiers in Physics</td>
<td>3.1 What is the nature of Dark Matter? How is it distributed?</td>
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<td>3.2 Are there quantum gravitational effects on photon propagation?</td>
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<td>3.3 Do Axion-like particles exist?</td>
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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
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 > 9° 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.
The survey would connect with the Galactic Plane Survey ($|b| < 5^\circ$) over Galactic longitude $-90^\circ < l < 90^\circ$.

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).

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

Full-plane coverage: longitude $\pm 180^\circ$, latitude $b \pm 10^\circ$

Deeper inner galaxy exposure: $\ell \pm 80^\circ$

Fine detail revealed with $\sim\text{arcmin PSF}$

J. Knödlseder and 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
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