3rd ASTERICS-OBELICS Workshop
23-25 October 2018, Cambridge, UK

hipeCTA
a high performance library for the Cherenkov Telescope Array

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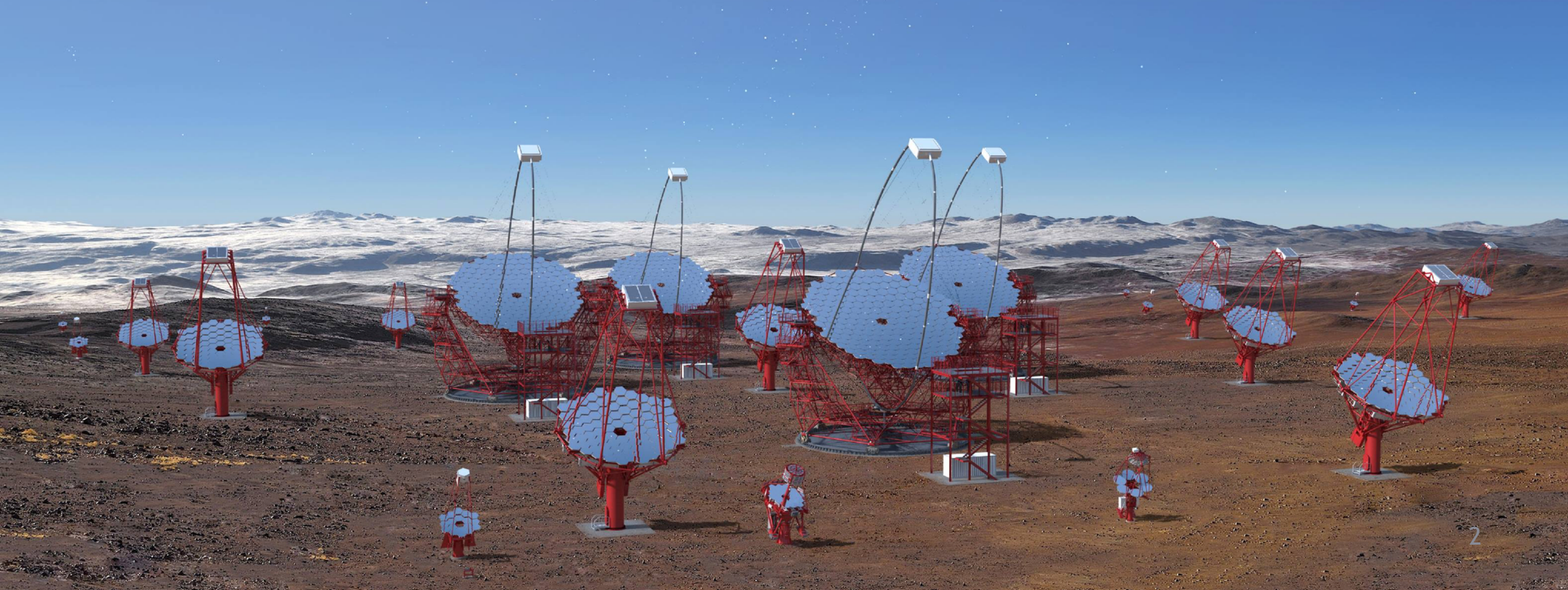
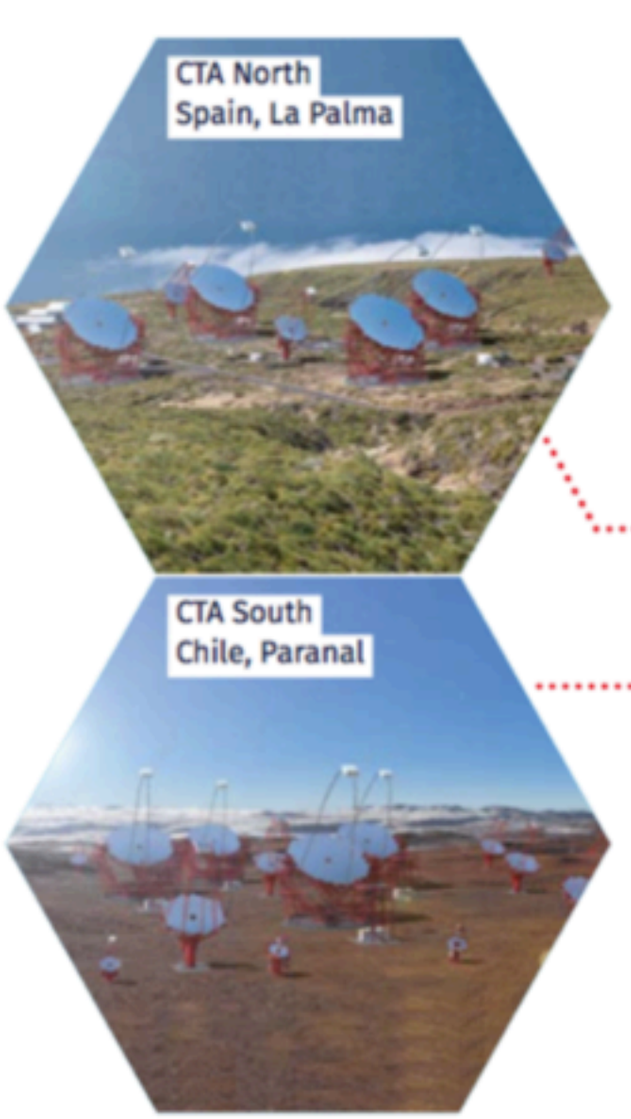
on behalf of P. Aubert, G. Maurin, J. Jacquemier,
T. Vuillaume and G. Lamanna

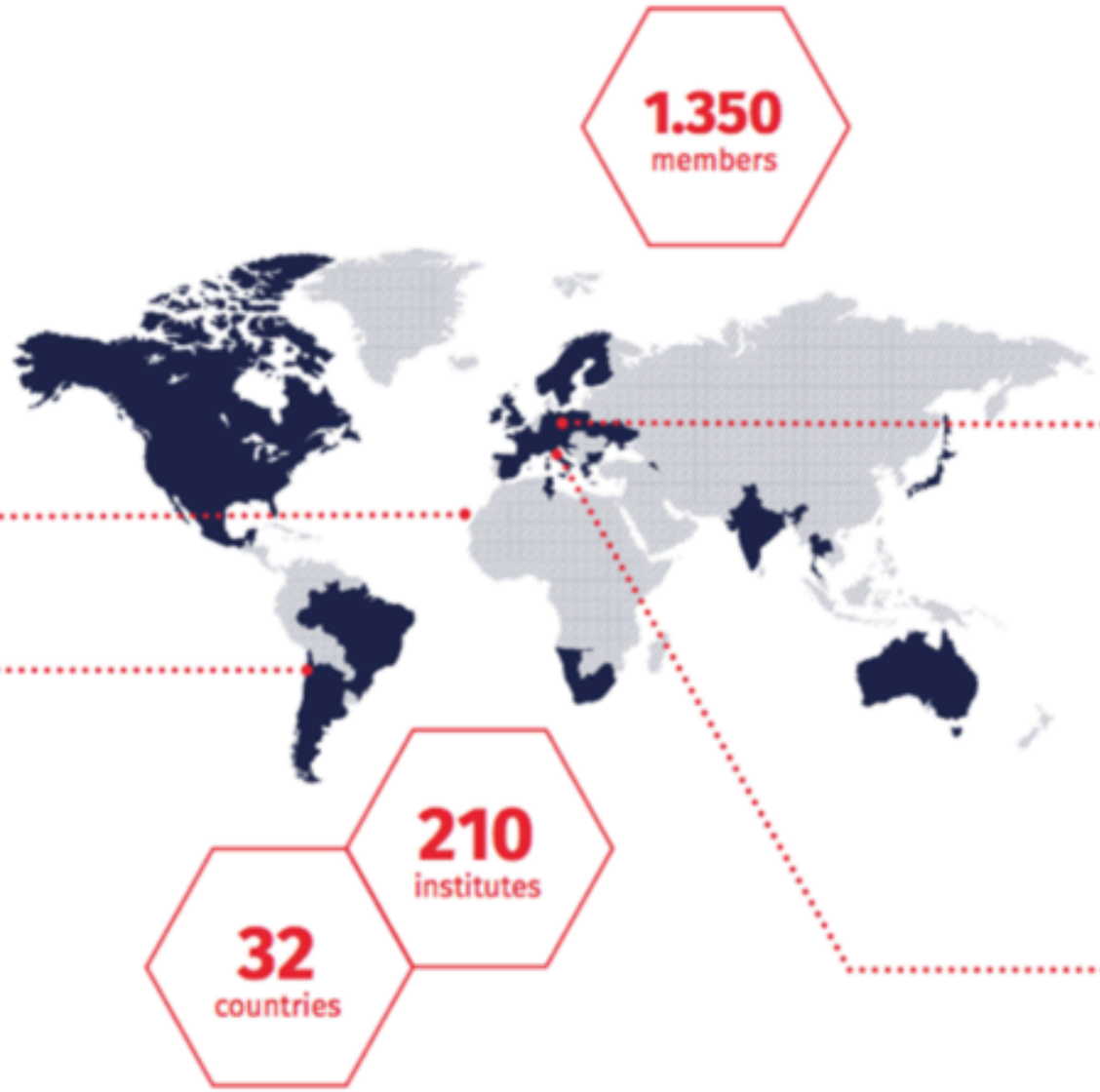
Cherenkov Telescope Array

- The future ground-based array of telescopes for gamma ray astronomy
- Composed of ~100 telescopes
- Using the imaging atmospheric Cherenkov technics



Cherenkov Telescope Array





Objectives

- **Observe cosmic phenomena at the highest part of the electromagnetic spectrum**

Study the VHE Universe

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Origin of UHE cosmic rays

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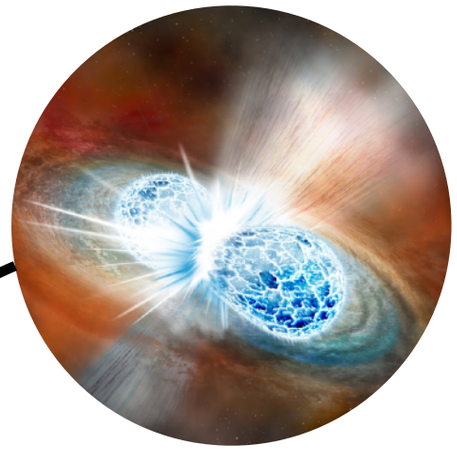
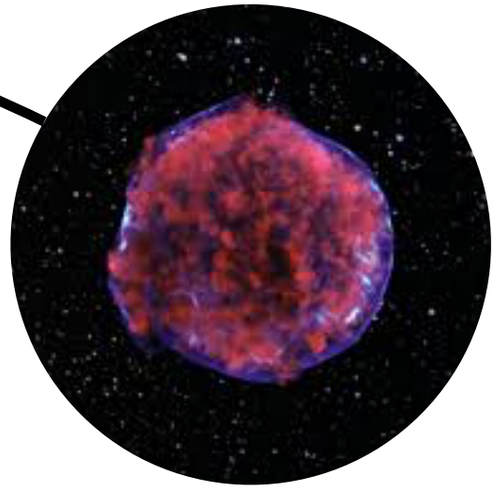


Astrophysical phenomena



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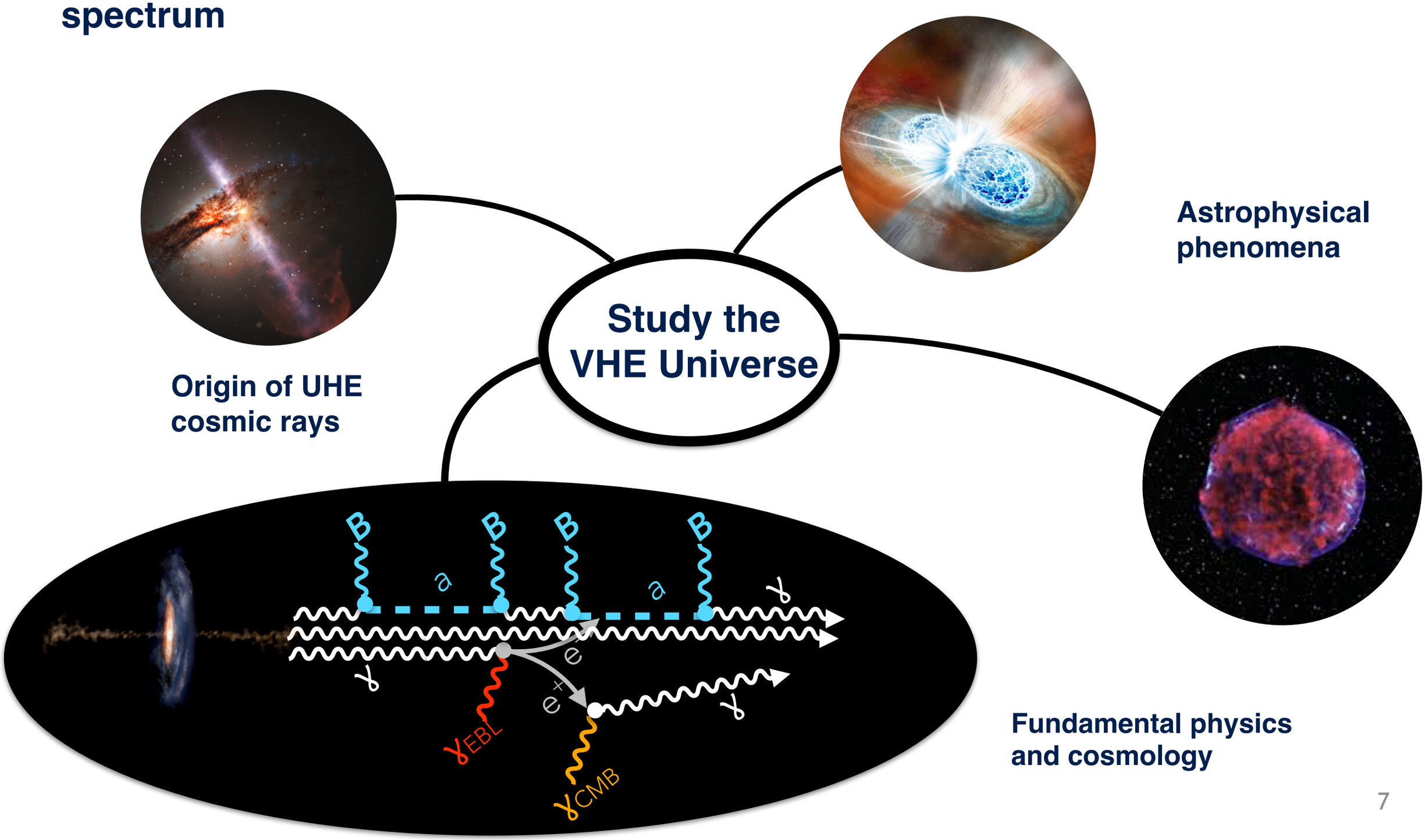
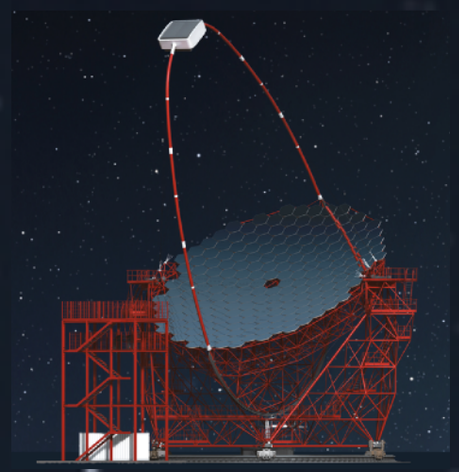


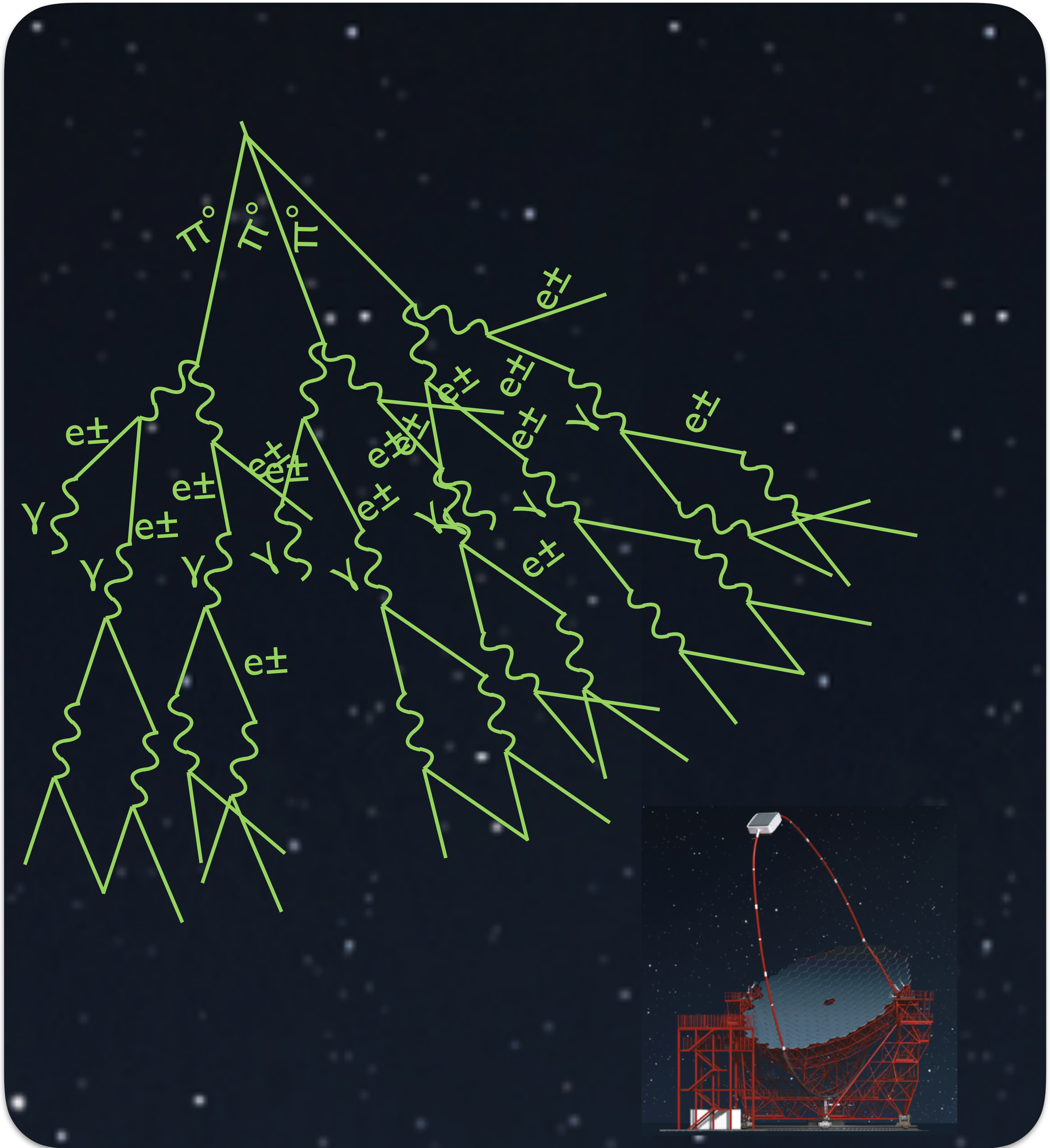
imaging atmospheric Cherenkov technics



imaging atmospheric Cherenkov technics

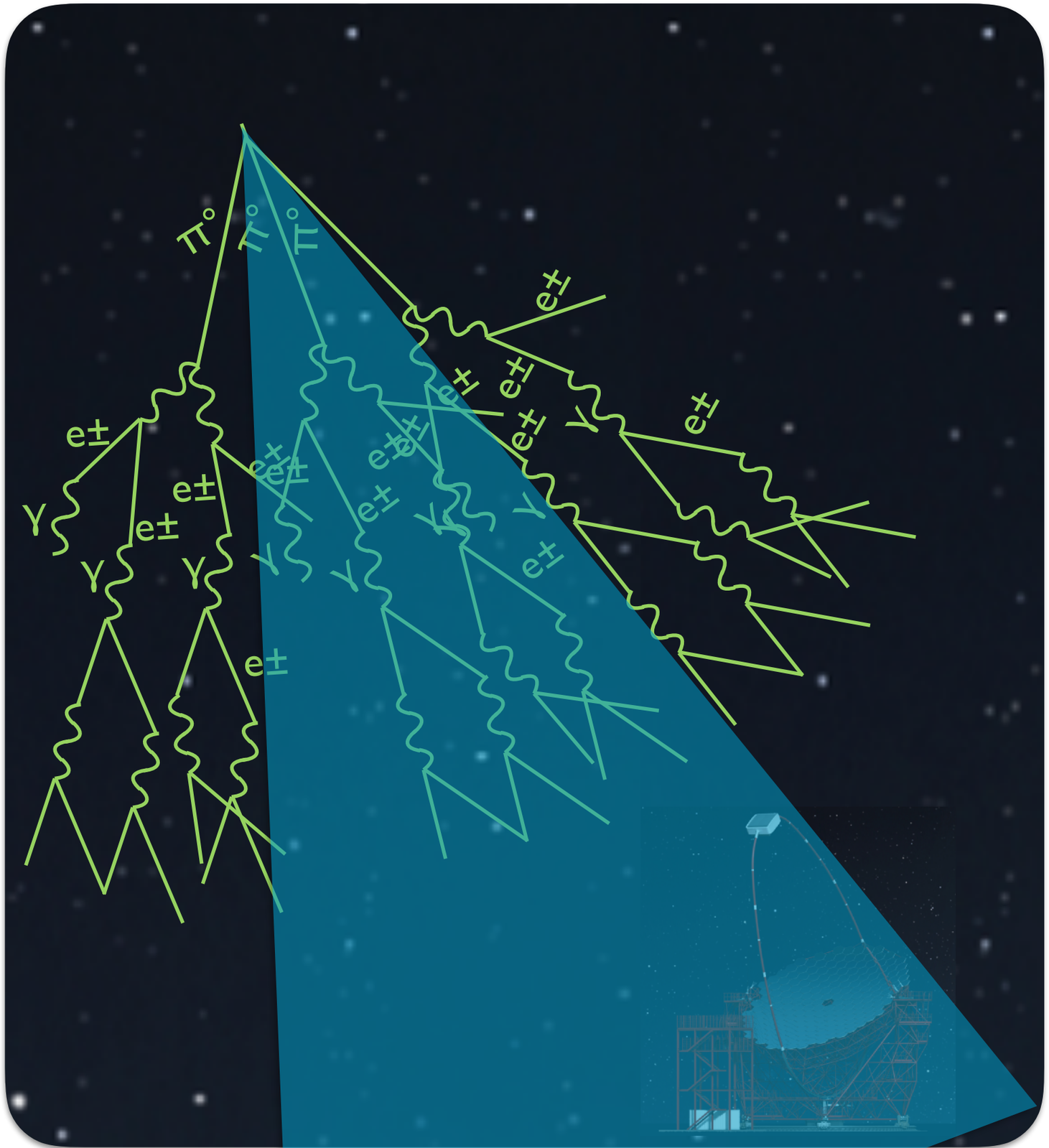
- **Gamma ray interaction in atmosphere**

imaging atmospheric Cherenkov technics



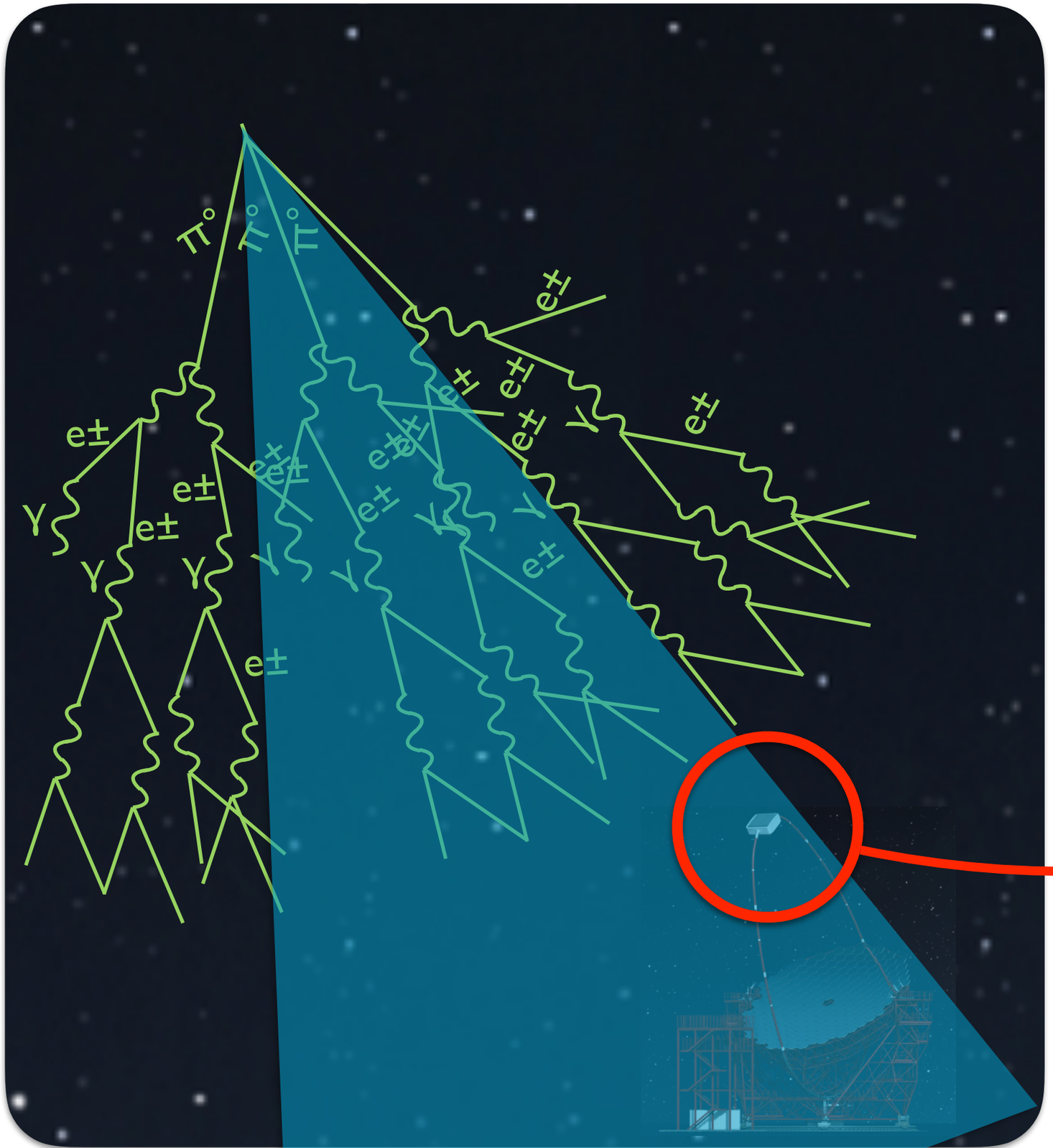
- **Gamma ray interaction in atmosphere**
- **EM cascade towards the ground at v>c/n**

imaging atmospheric Cherenkov technics



- Gamma ray interaction in atmosphere
- EM cascade towards the ground at v>c/n
- Cherenkov radiation covering several 100 meters around shower axis

imaging atmospheric Cherenkov technics



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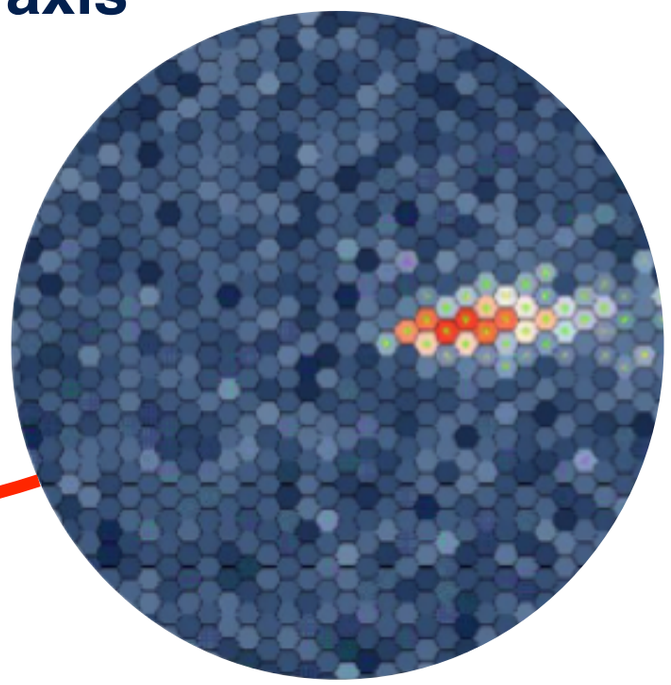

- Parameters of the shower, characteristics of the primary

Expected performances

- **3 telescope sizes to cover different energy bands**

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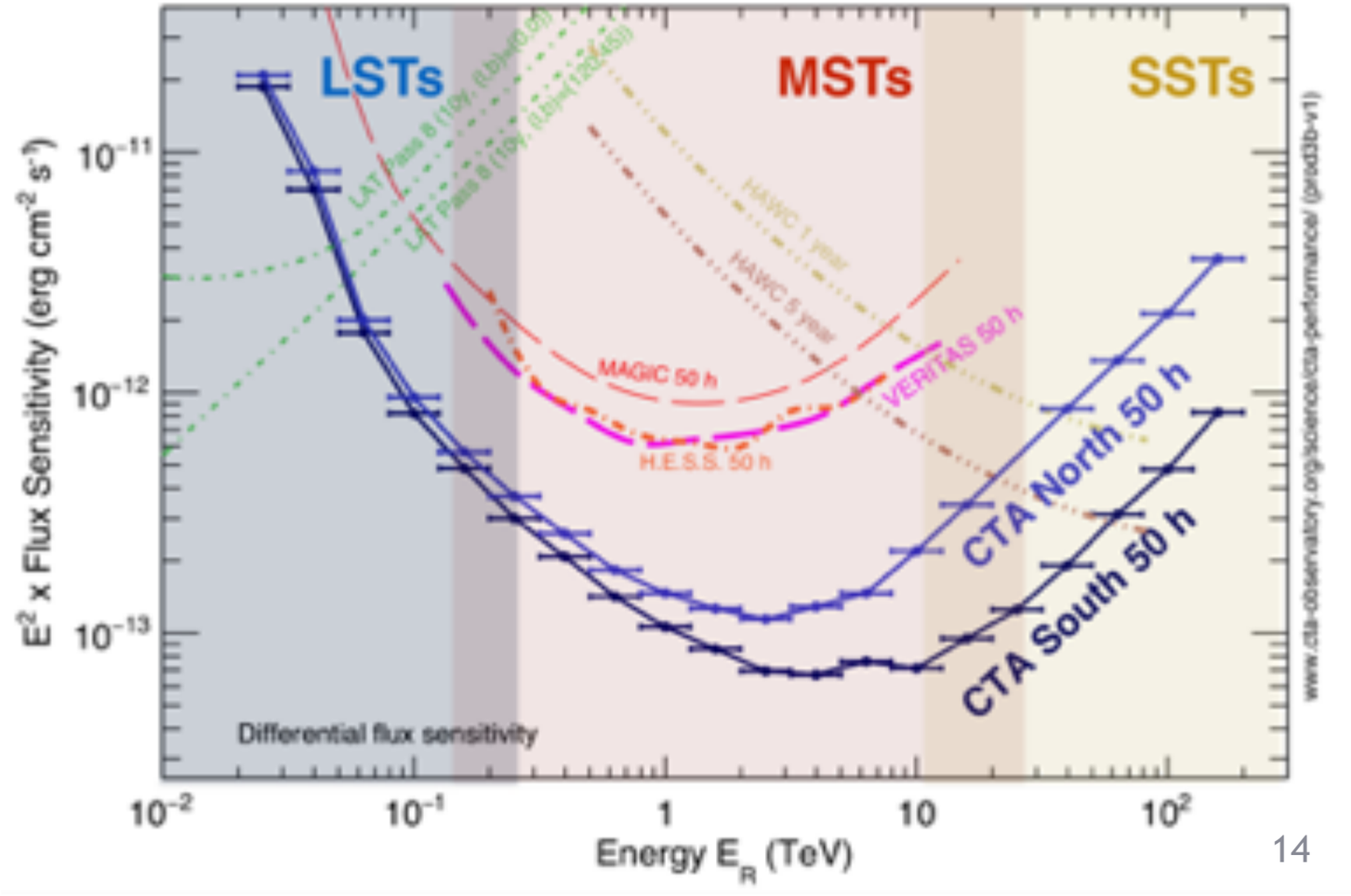
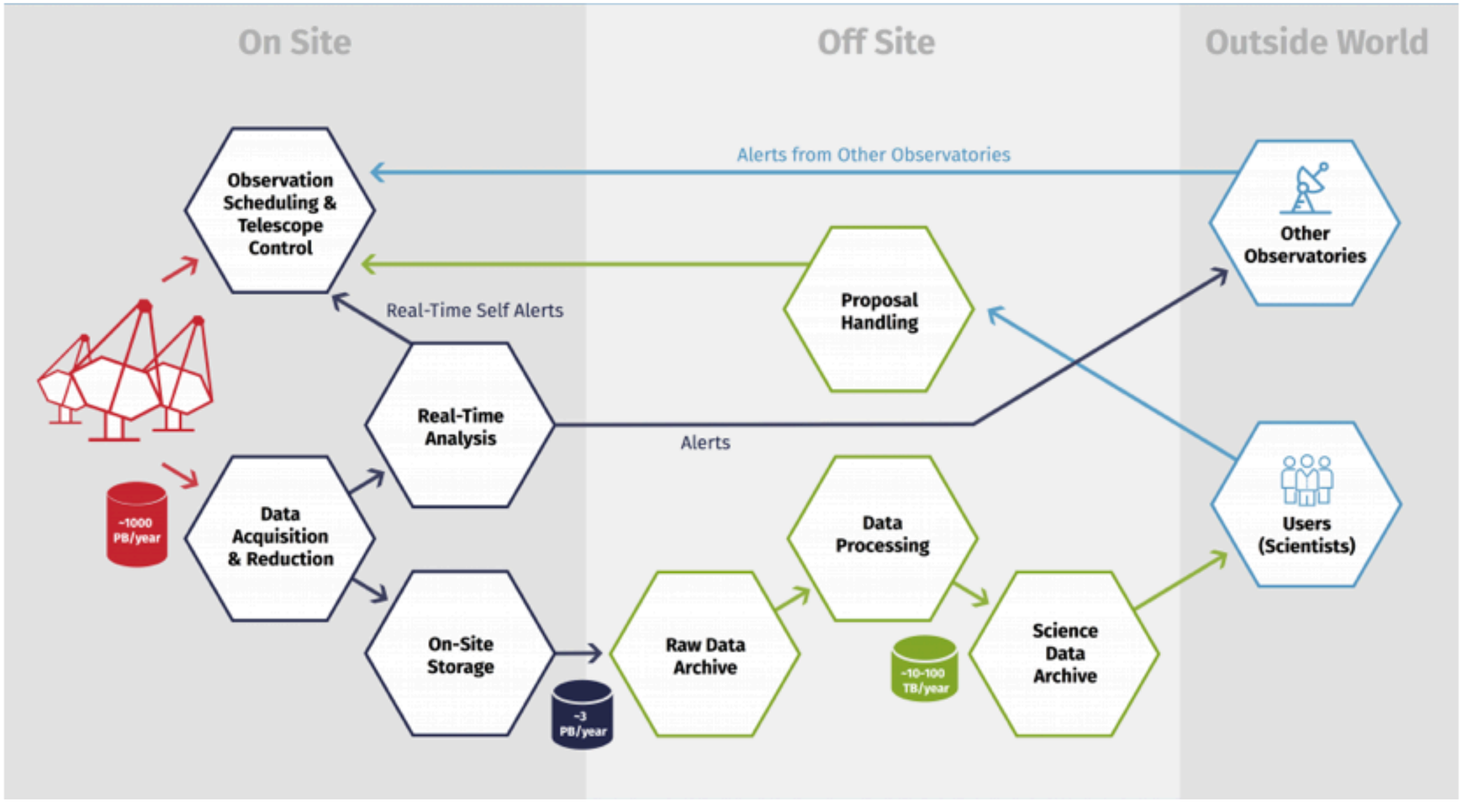
- **Sensitivity increased by a factors 5 to 10 compared to existing facilities**



Challenges

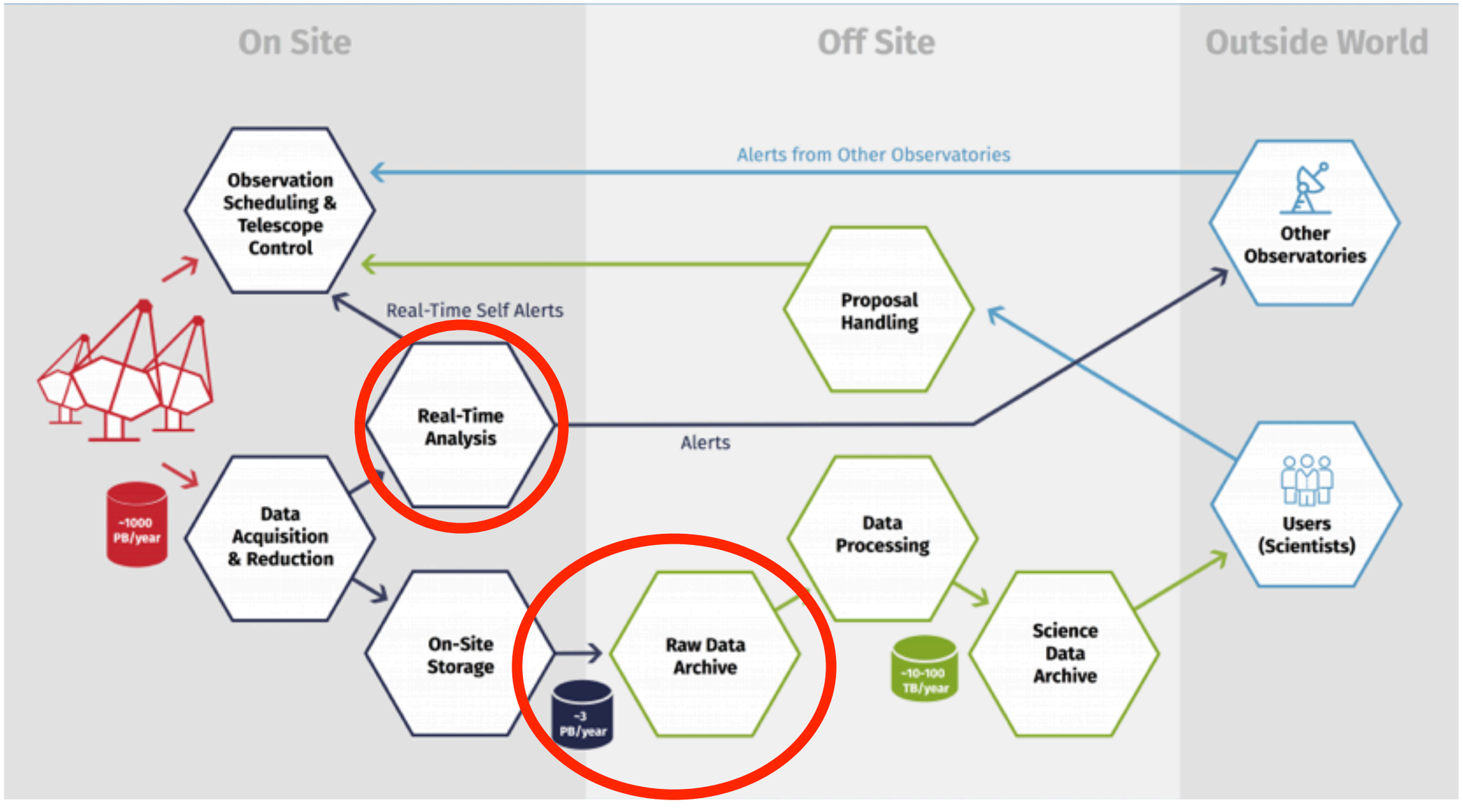
- **Very large amount of data produced every years**



Challenges

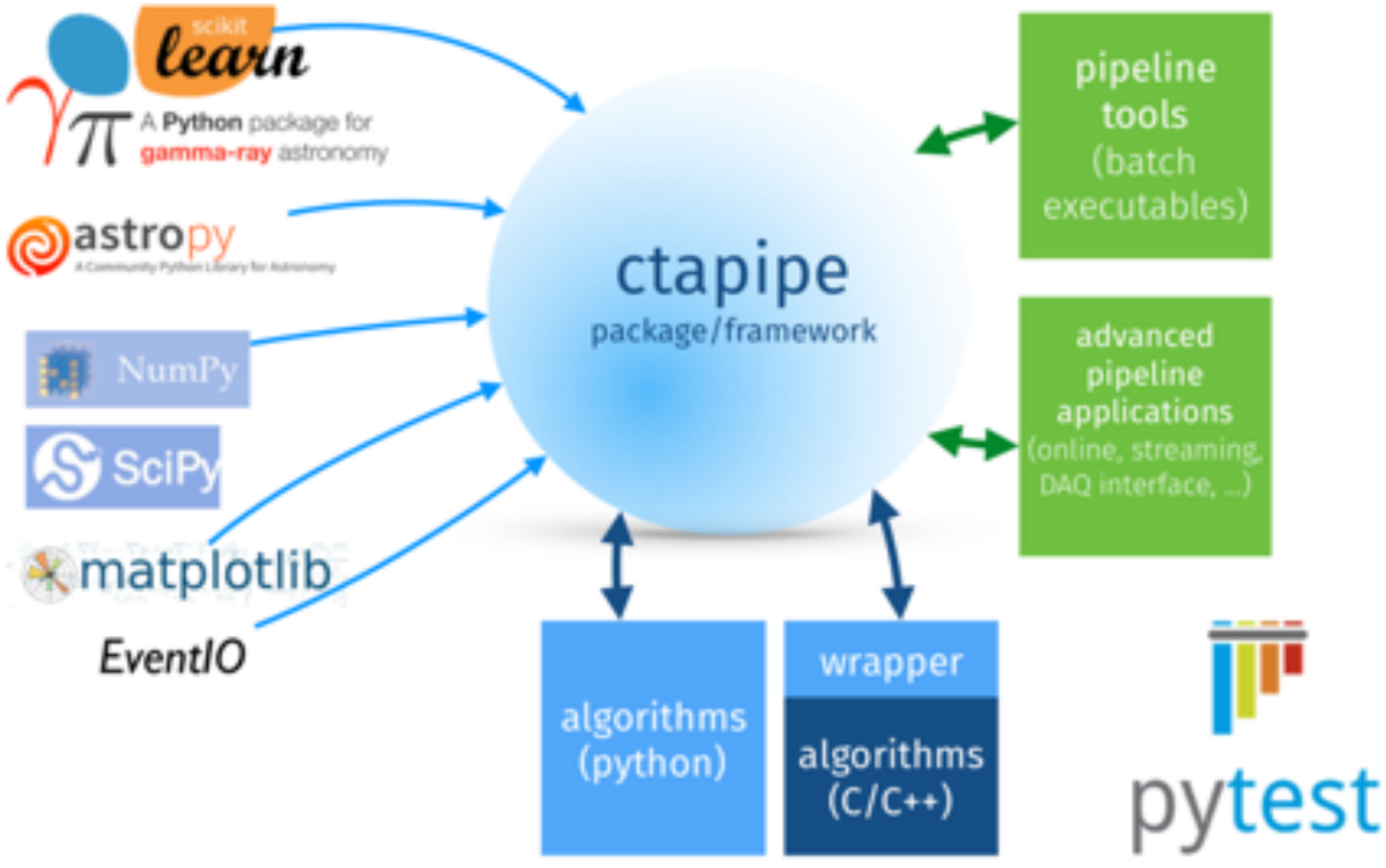
- **Very large amount of data produced every years**
  - **~3 PB/y of raw data**
  - **Real-time analysis**

Need efficient analysis



ctapipe: data reconstruction pipeline

- ctapipe: official reconstruction pipeline
- ctapipe will be glue between various components
- Provides common APIs and user interfaces packaging



Integration to ctapipe

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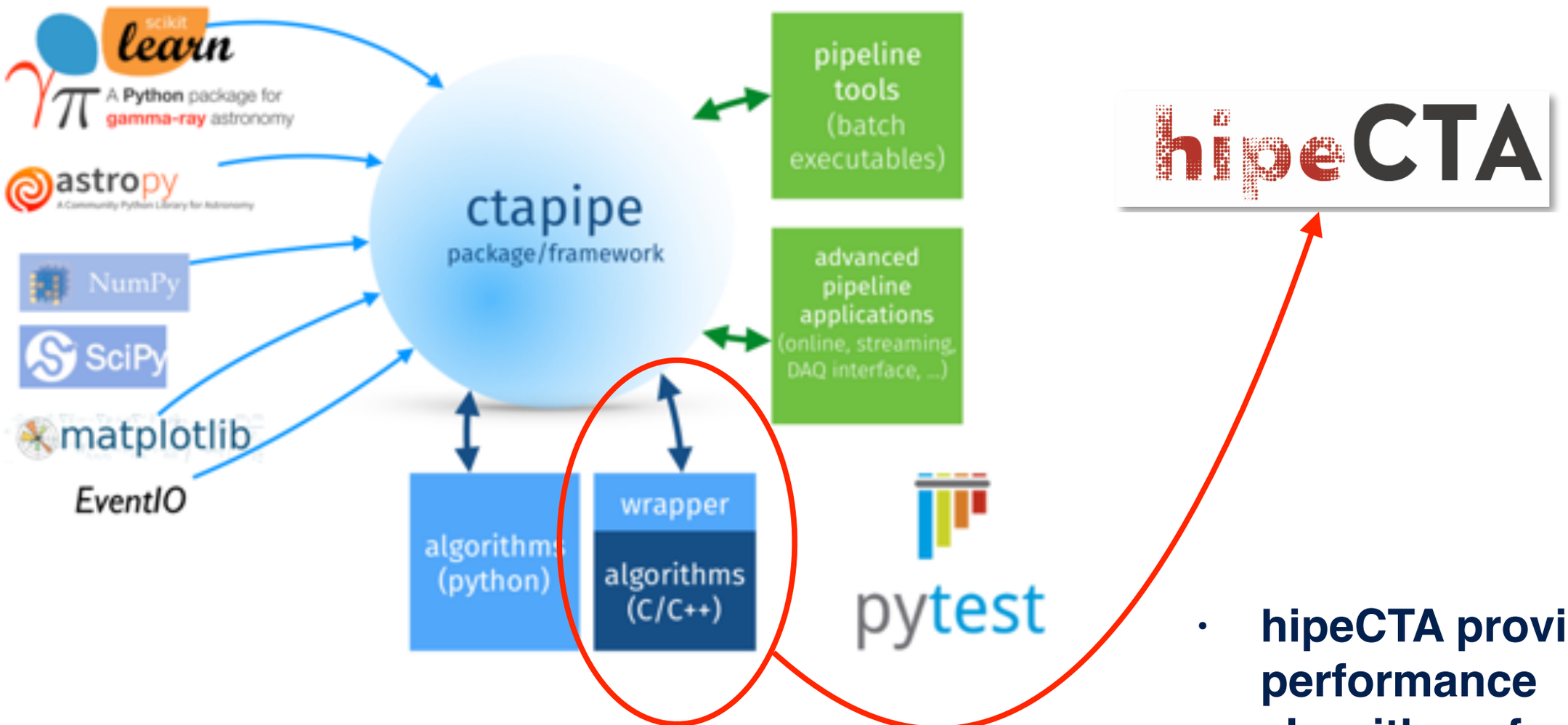
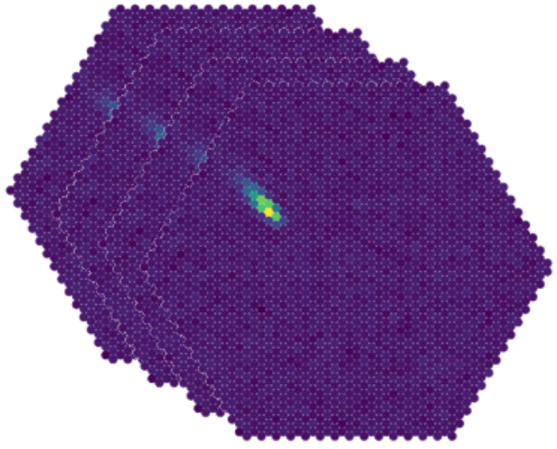
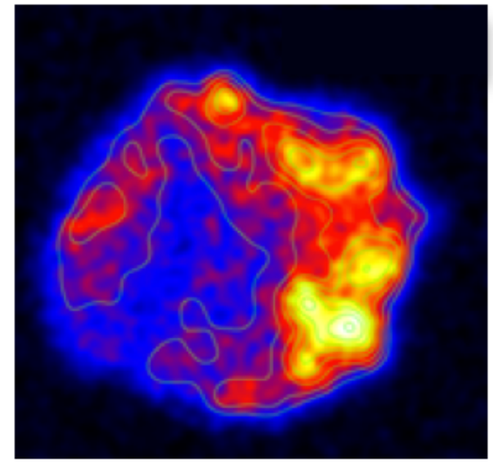


- hipeCTA provides high performance algorithms for CTA

Integration to CTA analysis chain

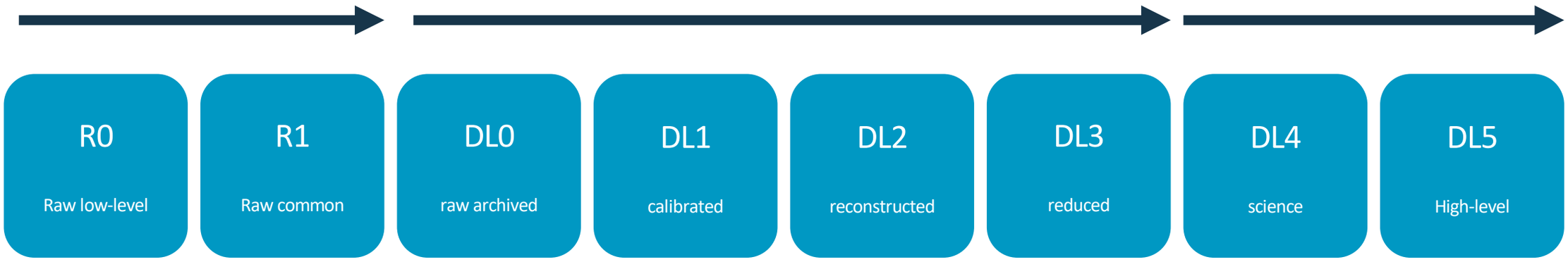




Camera softwares (internal)

Reconstruction pipeline (internal)

Science tools (external)



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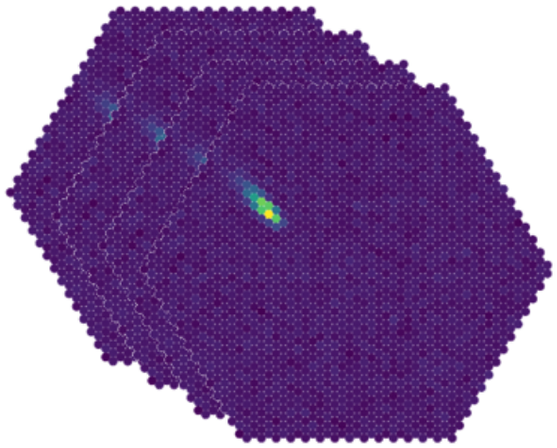
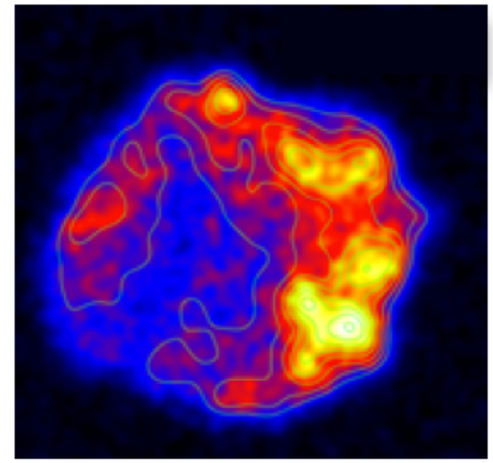


Event List



Camera softwares (internal)

Reconstruction pipeline (internal)

Science tools (external)

R0 — Raw low-level

R1 — Raw common

DL0 — raw archived

DL1 — calibrated

DL2 — reconstructed

DL3 — reduced

DL4 — science

DL5 — High-level

Philosophy & requirements

- Keep the python framework
  - Simplicity
  - Same framework for offline and online processing
- Introduce HPC where needed with wrapped C++
- Accessible as a Python library
  - Easy to use and install
- Intel CPU with vectorization enabled (SSE4, AVX)
  - Any recent CPU
- Aligned data
  - If not, can be aligned with hipeCTA
  - See T. Vuillaume's talk (data format generator)

technical details

- **Acceleration based on vectorization**
  - **Multiple operations per clock cycle**

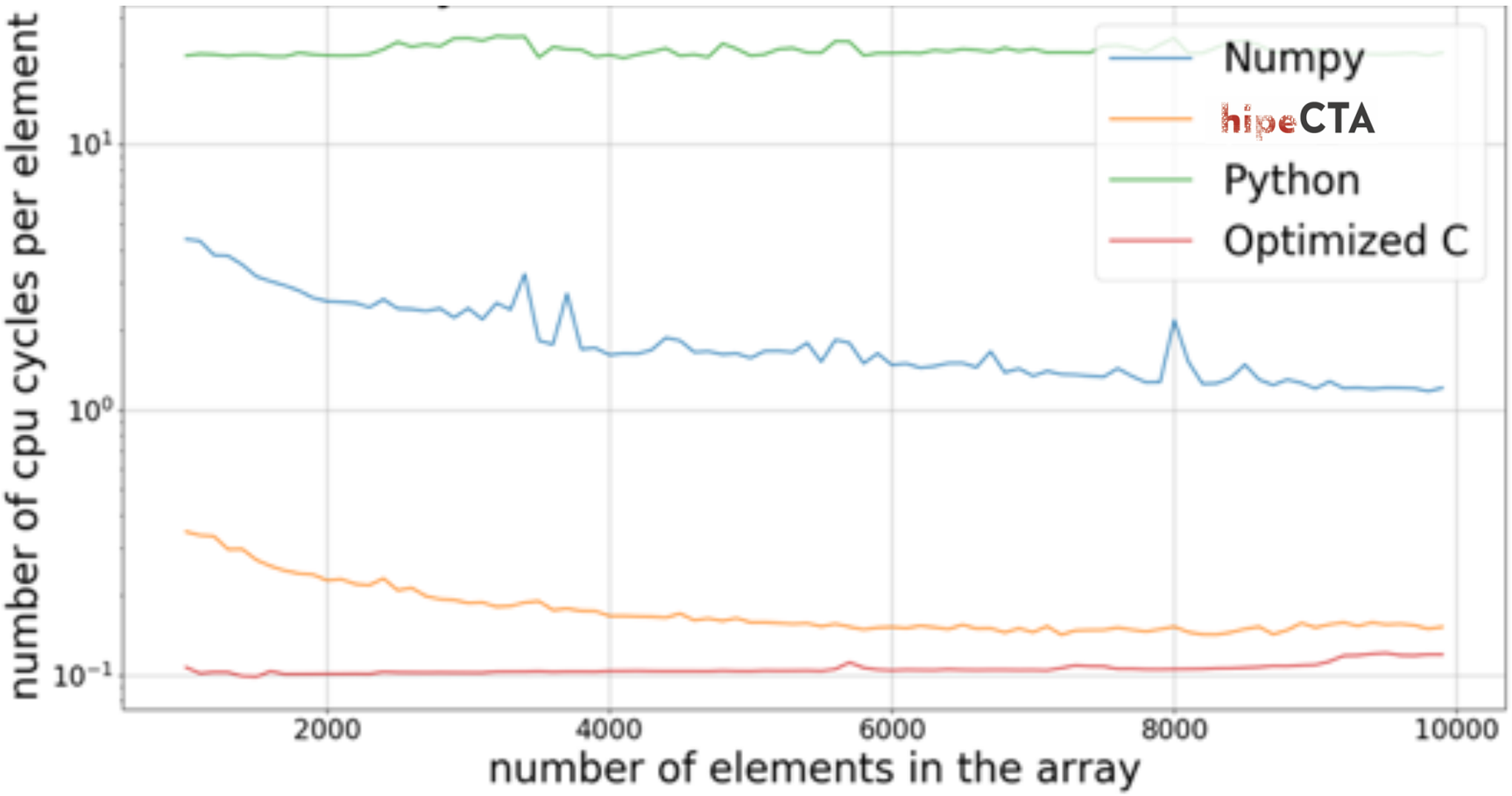
- **Works with gcc and clang compilers**
  - **Standard install via setup.py**

- **Wrapping = Python API**

- **Algorithms already available:**
  - **Numpy data alignement**
  - **Image calibration and samples integration**
  - **Image cleaning (standard tailcut and wavelet)**
  - **Hillas parameters calculation**
  - **Stereoscopic geometric reconstruction**
  - **More available in C++ waiting to be wrapped**

Performances examples

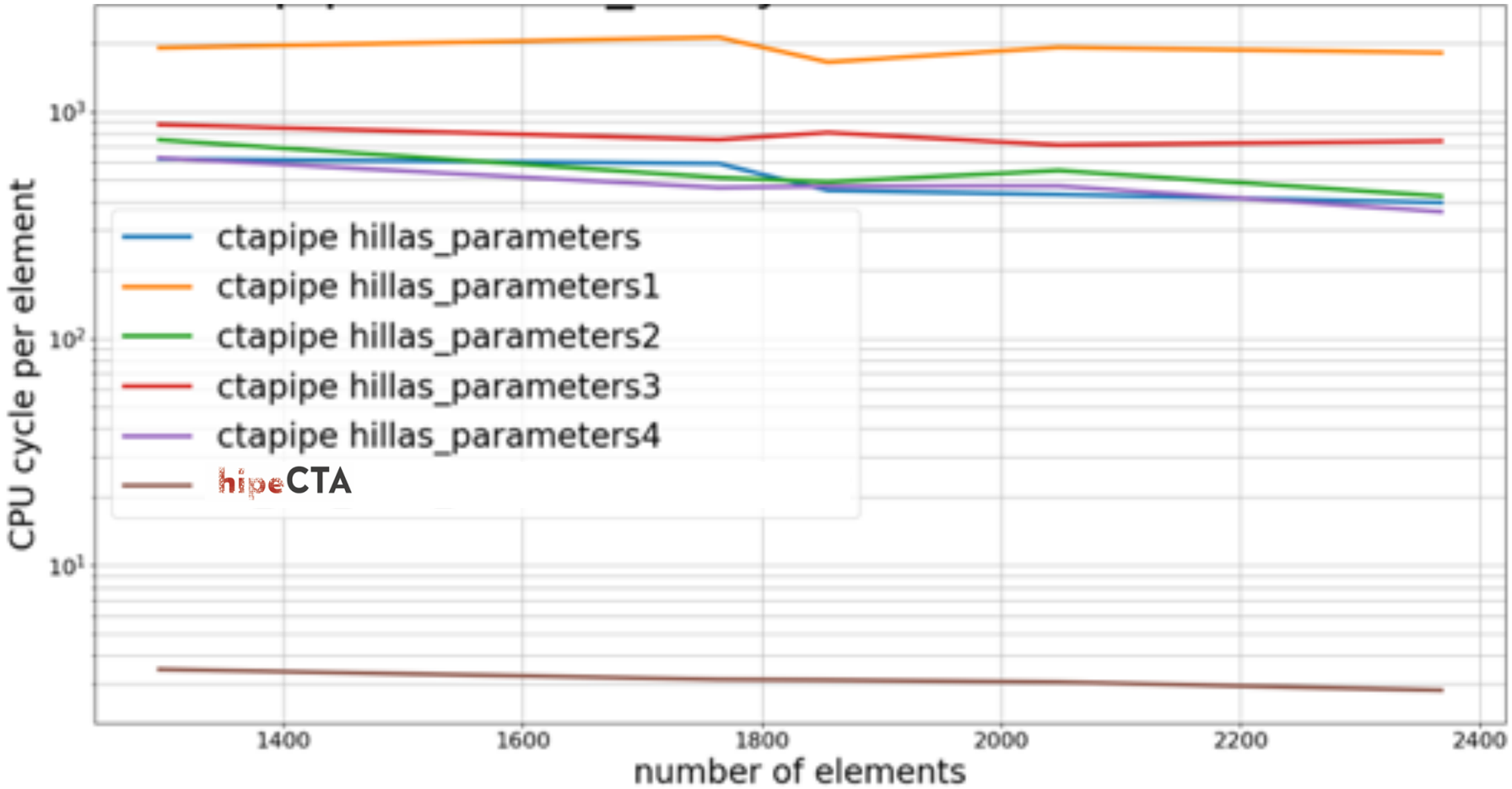
- **Array sum with Intel extension AVX2**



Only ~2 times slower than optimized C

Performances examples

- **Hillas parameters calculation ctapipe methods VS hipeCTA**



~150 times faster

Conclusion

- **hipeCTA is a Python library**
  - **Proposing high performance algorithms**
  - **Written in C++**
  - **Wrapped in Python**

- **Speeds-up processing by factors from few to hundreds depending on algorithms and hardware**

- **Open-source and available at https://gitlab.in2p3.fr/CTA-LAPP/HiPeCTA**

Take home message

- Developing HPC algorithms is costly in developments and maintenance

- But the potential gains make it worth the effort

- Available with any recent CPU

- Python wrapping has several advantages:
  - Easy to use and install
  - Keep the same framework for offline and online processing
  - Allows the use of HPC solutions

Acknowledgment

- **H2020-Astronomy ESFRI and Research Infrastructure Cluster (Grant Agreement number: 653477)**