cherenkov telescope array

# Opportunities in CTA

Thesis Day, Bologna December 10st

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# Outline

- Introduction to CTA
  - » Why CTA?
  - » What is CTA?
  - » How does CTA work?

- Thesis Proposals
  - Real-time Analysis
    - » **Thesis 1:** “Identification of gamma-ray transients”
    - » **Thesis 2:** ”Electromagnetic counterparts of gravitational wave events”
    - » **Thesis 3:** “Machine Learning algorithms”
  - Thesis 4: AGN radio-loud

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# INTRODUCTION TO CTA

Courtesy of F. Dazzi

# Why CTA?

- Some Fundamental Questions:
  - » Cosmic Particle Acceleration
    - How and where are particles accelerated?
    - How do they propagate?
    - What is their impact on the environment?
  - » Probing Extreme Environments
    - Which/how are processes close to neutron stars and black holes?
    - What physical processes are at work close to neutron stars and black holes?
    - What happens in the relativistic jets, winds and explosions?
  - » Physics Frontiers
    - What is the nature of dark matter?
    - How dark matter is it distributed?
  - » … and many others…

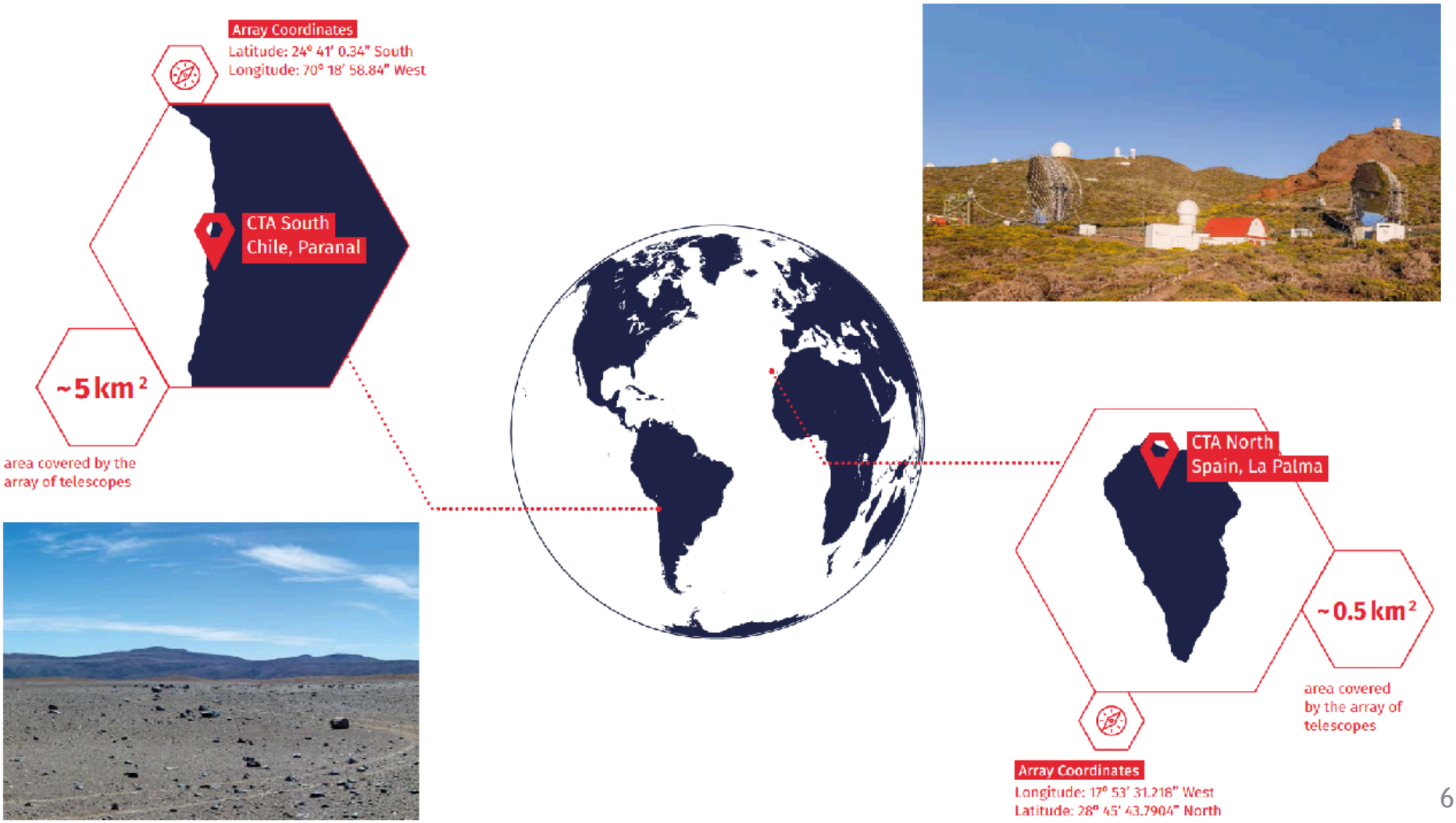
Ref.: Science with the Cherenkov Telescope Array - https://arxiv.org/abs/1709.07997

# Why CTA?

- The key targets in the Universe are:

# What is CTA?

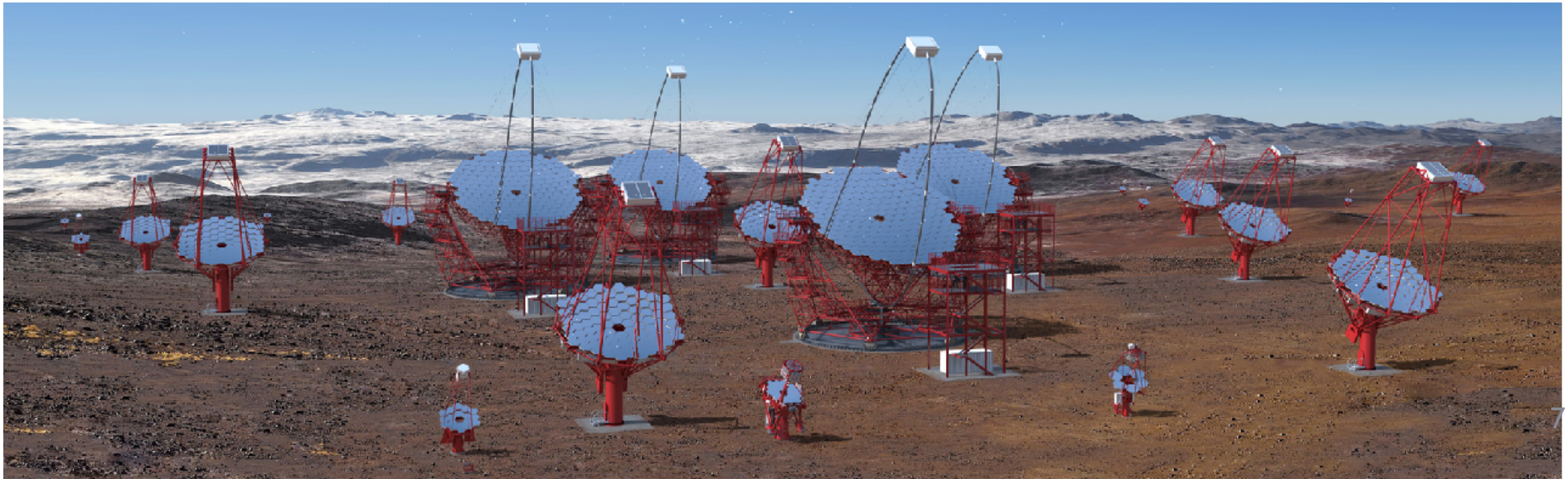
- Two “eyes” (arrays of Cherenkov Telescopes) on the sky



# What is CTA?

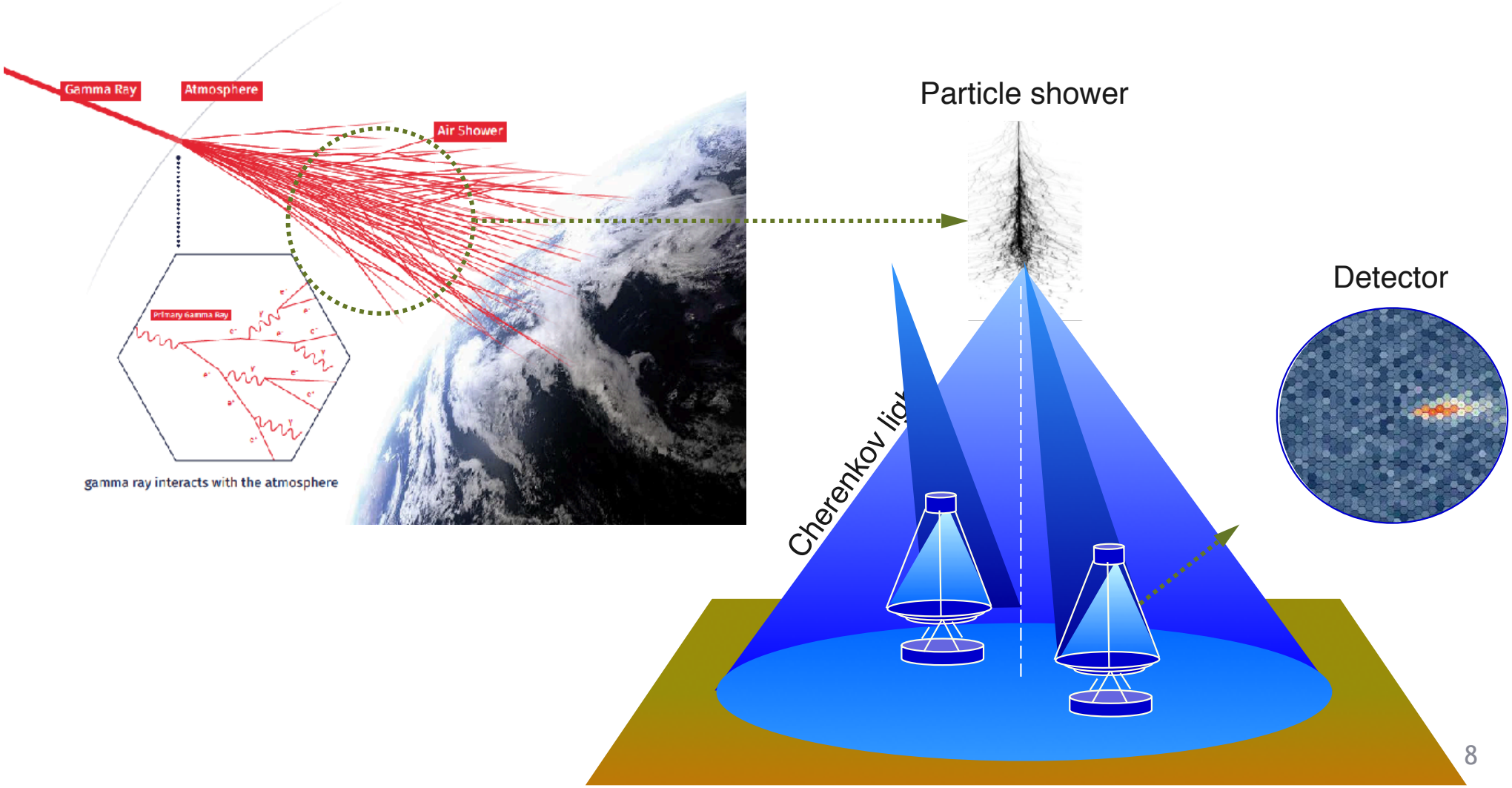
- North: 19 telescopes spread out over ~0.4km$^2$ (4 LSTs, 15 MSTs)

- South: 99 telescopes spread out over ~5km$^2$ (4 LSTs, 25 MSTs, 70 SSTs)



# How does CTA work?

- Capture the Cherenkov light produced during the interaction between a gamma particle and the Earth atmosphere.



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# THESIS PROPOSALS

# Reference people @ INAF/OAS Bologna

- Advisor: Prof. Cristian Vignali (Università di Bologna)
- Contact point: Andrea Bulgarelli (INAF) (andrea.bulgarelli@inaf.it)
- INAF people involved in these proposals for the CTA Consortium: Massimo Cappi, Vito Conforti, Filippo D'Ammando, Mauro Dadina, Giovanni De Cesare, Adriano De Rosa, Valentina Fioretti, Fulvio Gianotti, Paola Grandi, Luciano Nicastro, Eliana Palazzi, Nicolò Parmiggiani, Eleonora Torresi, Massimo Trifoglio, Vito Sguera, Giulia Stratta

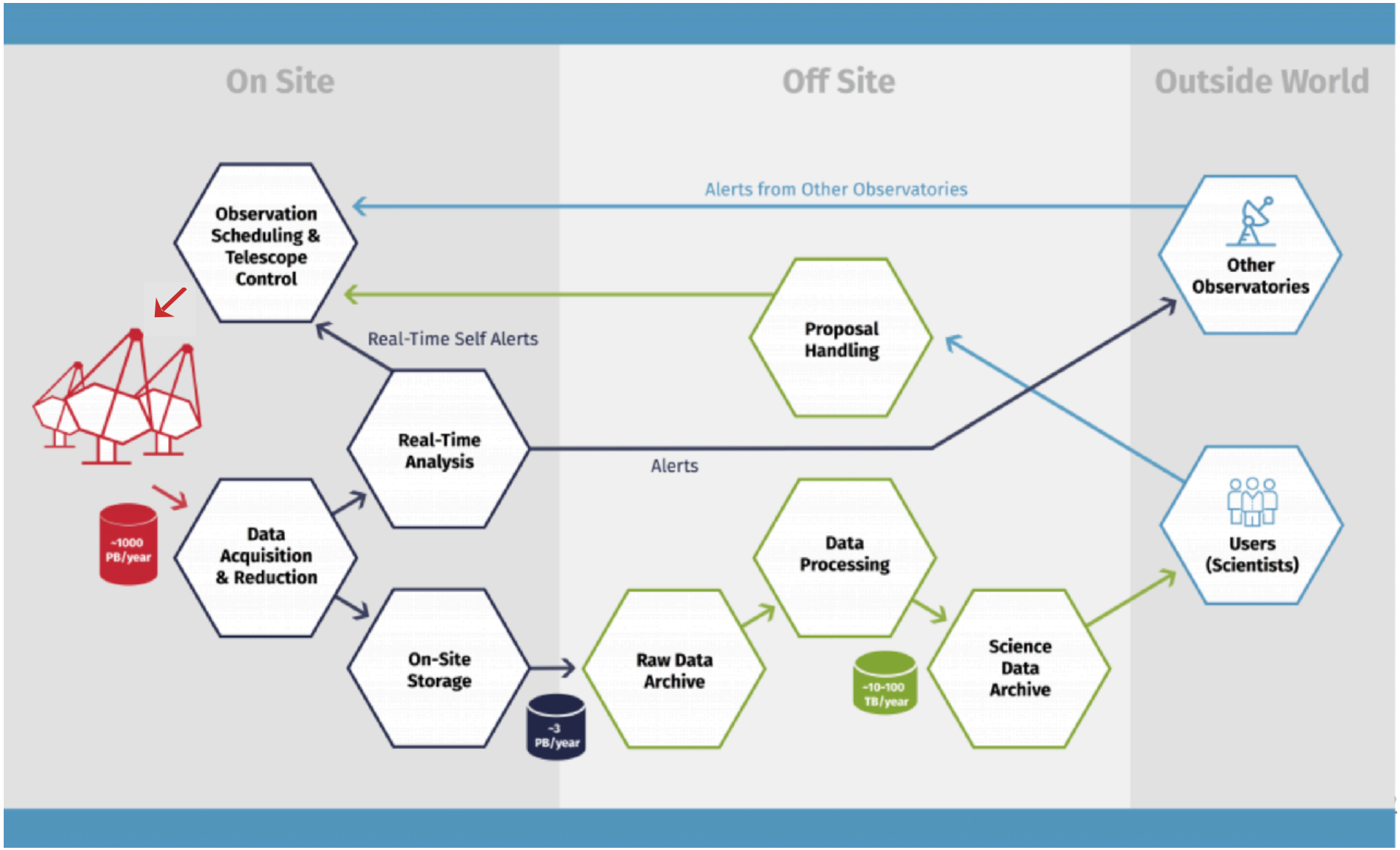
# Thesis 1

- **Topic:** "***Optimization strategies for identification of gamma-ray transients for the CTA Real-Time Analysis***"

- **Objectives:** the candidate will deal with several aspects of CTA's transient sky, in particular:
  - » triggered by external instruments
  - » transient identification with the real-time analysis for serendipitous discoveries, e.g., blind search strategies
  - » Identification of criteria to promote a transient detection of a CTA science alert to external astrophysical community and external instruments
  - » observational strategy of transients for CTA, based on association with known counterparts
- Possible Scientific topics:
  - » AGNs
  - » Gamma-ray binaries
  - » Neutrino events
  - » GRBs
  - » GWs

# Thesis 1

- The Context:



# Thesis 1

- **Duration:** 6-12 months
- Not mandatory **prerequisites**: Python and interest on gamma-ray sky and on time domain astronomy
- **Tasks:** the tasks will also depend on the interest of the candidate. A single science topic will be selected. An example, based on AGN flare topic:
  - » Identification of specific AGN that CTA could observe
  - » Simulation of these AGNs (light curves, sky maps) using CTA Science Tools
  - » Analysis of simulated light curves using different time-scales and with different Science Tools: identification of best strategies for the detection of flaring events
  - » Identification of criteria for the generation of a science alerts from AGNs flares
  - » Identification of possible follow-up strategies (by CTA, with the full-array/ sub-arrays, coordination between North and South sites, and with external instruments)

# Thesis 2

- **Topic: “Study and optimization of observational strategies for electromagnetic counterparts of gravitational wave transient events with CTA”**

- **Objectives:**
  - » identification of "observational strategies", i.e., analysis with real-time analysis, pointing, binning, trigger to and from CTA, coordination between the two sites North and South.

# Thesis 2

- **Duration:** 6-12 months

- Not mandatory **prerequisites**: Python and interest on gamma-ray, multi messenger and time domain astronomy. Interest of source of Gravitational Waves.

- **Tasks:** the tasks are focused on LIGO/VIRGO-EM connections:
  - » Study and selection of electromagnetic emission models of binary mergers (also based on the recent breakthrough result of the LIGO/VIRGO-EM community)
  - » Best strategies for the identification of sky regions within the LIGO/VIRGO error region taking into account CTA capabilities for the real-time follow-up
  - » Simulation of the physical models with CTA Science Tools
  - » Analysis of simulated models using different time-scales with the CTA real-time analysis: identification of best strategies for the detection of electromagnetic counterparts

# Thesis 3

- **Topic: "*Machine Learning algorithms for identification of gamma-ray transients for CTA and AGILE*"**
  - » Within the machine learning field, the Deep Neural Networks are a set of algorithms, modelled loosely after the human brain, that are designed to recognize patterns.
  - » They could be used for:
    - ❖ Classification: assign a pattern to a known phenomena/object of the real world
    - ❖ Clustering is the detection of similarities without knowing in advance the "features" of the phenomena
    - ❖ Predictive analysis: to establish correlations between present events and future events
  - » The application of Deep Neural Network techniques on Astrophysics is in the early phase.

- **Objectives:**
  - » understanding of Deep Learning technologies;
  - » understand the effectiveness of these technologies in the field of the real-time astronomy.

# Thesis 3

- **Duration:** 6-12 months
- Not mandatory **prerequisites**: Python, interest on time domain astronomy and on enabling information technologies
- **Tasks:**
  - Study of Deep Learning algorithms and techniques
  - Identification of a science use case (see Thesis 1 or 2): selection of one or more emission models
  - Development of a neural network for the identification of transient emission of the selected science use case. We have different scenarios
    - extract gamma-ray excesses from a counts map (work on the space/energy domain)
    - detect gamma-ray flares from a light curve (work on time/energy domain)
      - field of exploration: predictive analysis of a gamma-ray flare?
  - Performance measurement to understand the applicability of this technology to the CTA real-time analysis
- Potential future **opportunities**:
  - In addition, find work on private companies (already happened this year)