Gamma-ray Astronomy

PAAP Town Meeting, January 2021

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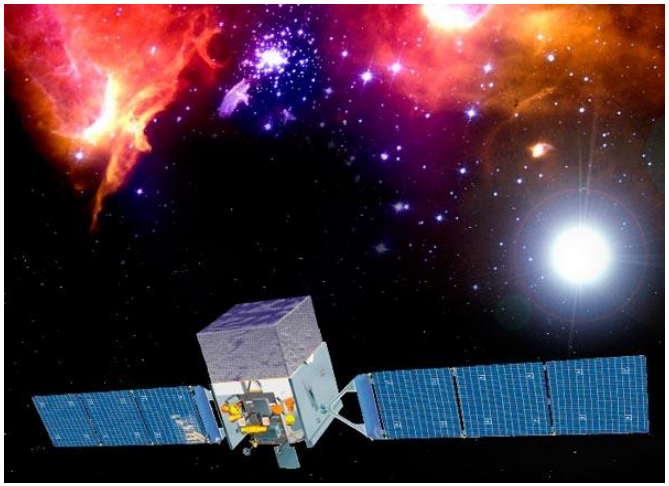
Contents

- A (very) brief introduction to gamma-ray astronomy
- An update on the Cherenkov Telescope Array (CTA)
  - Including the science…
- A brief word about the Southern Wide-angle Gamma Ray Observatory (SWGO)
- Introducing the PPTAP
  - Importance for Particle Astrophysics

Space vs. Ground in Gamma Rays



Space

Few MeV to ~100 GeV (Fermi: ~100 MeV to ~100 GeV)

Collection area ~ m^2 -> low instantaneous sensitivity, drop off at high energies

Poor angular resolution ~ 1 deg.

BUT large field-of-view, all-sky capability

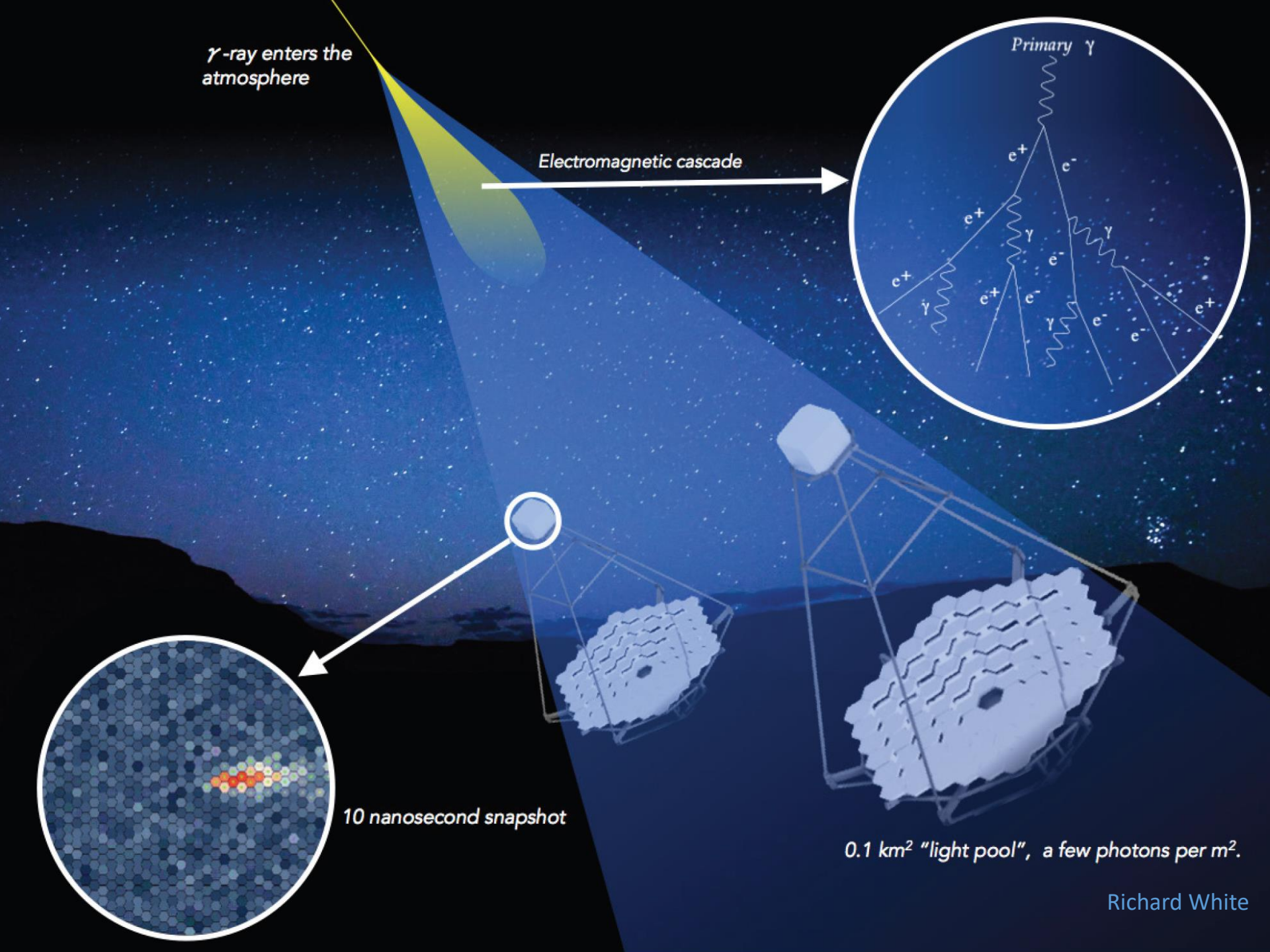
Ground

Few 10s of GeV to few 100 TeV

Collection area ~ 10^4 m^2 -> excellent instantaneous sensitivity

Better angular resolution ~0.1 deg.

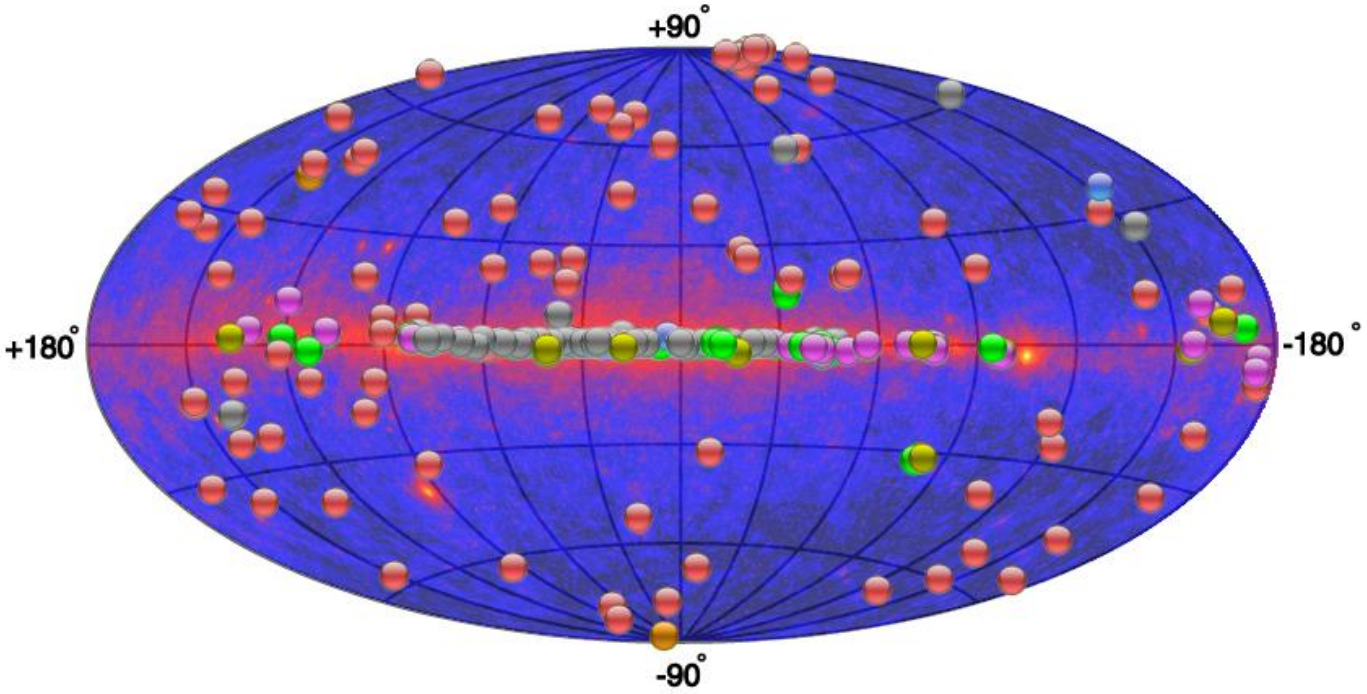
BUT small field-of-view, low duty cycle


γ-ray enters the atmosphere
Electromagnetic cascade
Primary γ
10 nanosecond snapshot
0.1 km² "light pool", a few photons per m².
Richard White

Present Imaging Atmospheric Cherenkov Telescopes

The use of multi-pixel cameras allows for very effective background suppression.

The Gamma-ray Sky



Source Types

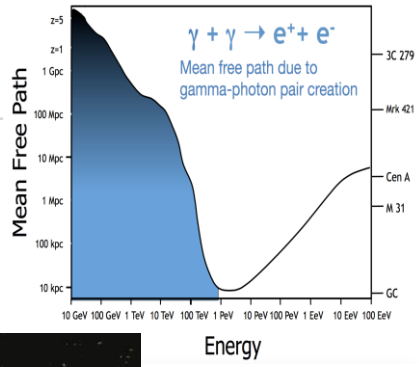
- TeV Halo PWN/TeV Halo PWN
- Binary XRB PSR Gamma BIN
- HBL IBL GRB FRI FSRQ Blazar LBL AGN (unknown type)
- Shell SNR/Molec. Cloud Composite SNR Superbubble
- Starburst
- DARK UNID Other
- uQuasar Star Forming Region Globular Cluster Cat. Var. Massive Star Cluster BIN BL Lac (class unclear) WR

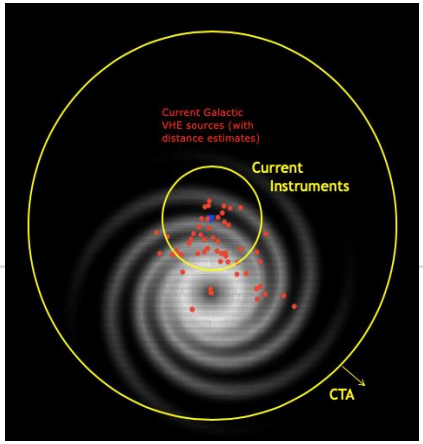
228 objects detected with ground-based instruments as of 04/11/20 – a rich panorama of many different types, suggesting there is much more to be seen. Time to build some new telescopes…

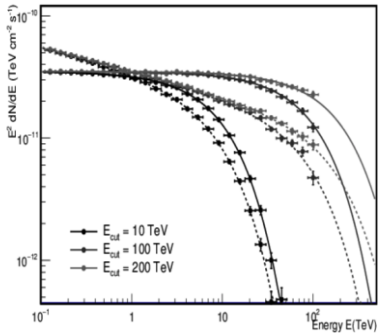
Cherenkov Telescope Array Consortium

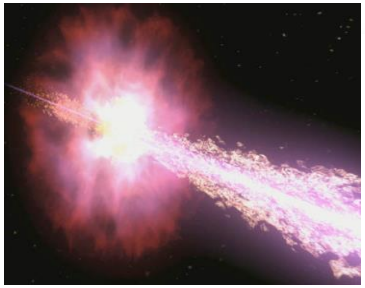
32 Countries
200+ institutes
1500+ members
One aim!

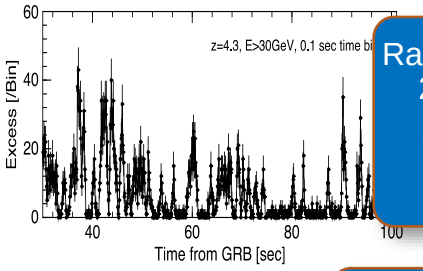
CTA Locations











10 x Sensitivity, Large Collection Area
→ all topics

Energies down to 20 GeV
→ Cosmology++

Energies up to 300 TeV
→ Pevatrons

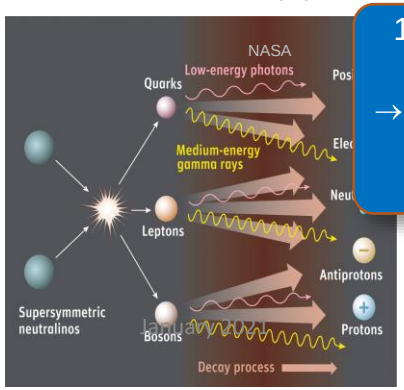
Rapid Slewing in 20 seconds
→ transients

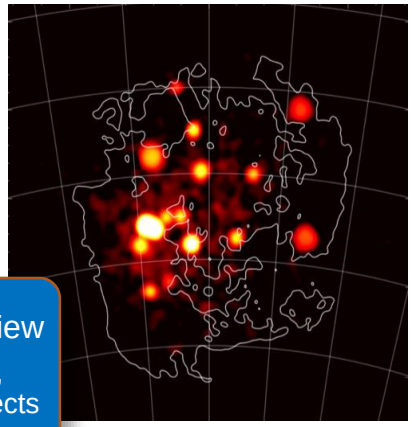
8º Field of View
→ surveys, extended objects

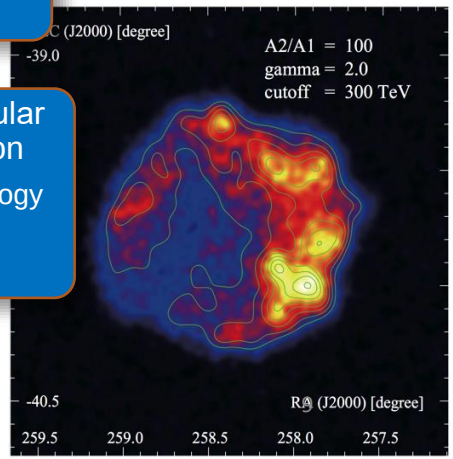
10% Energy Resolution
→ lines, features

Few ' Angular Resolution
→ morphology

cta

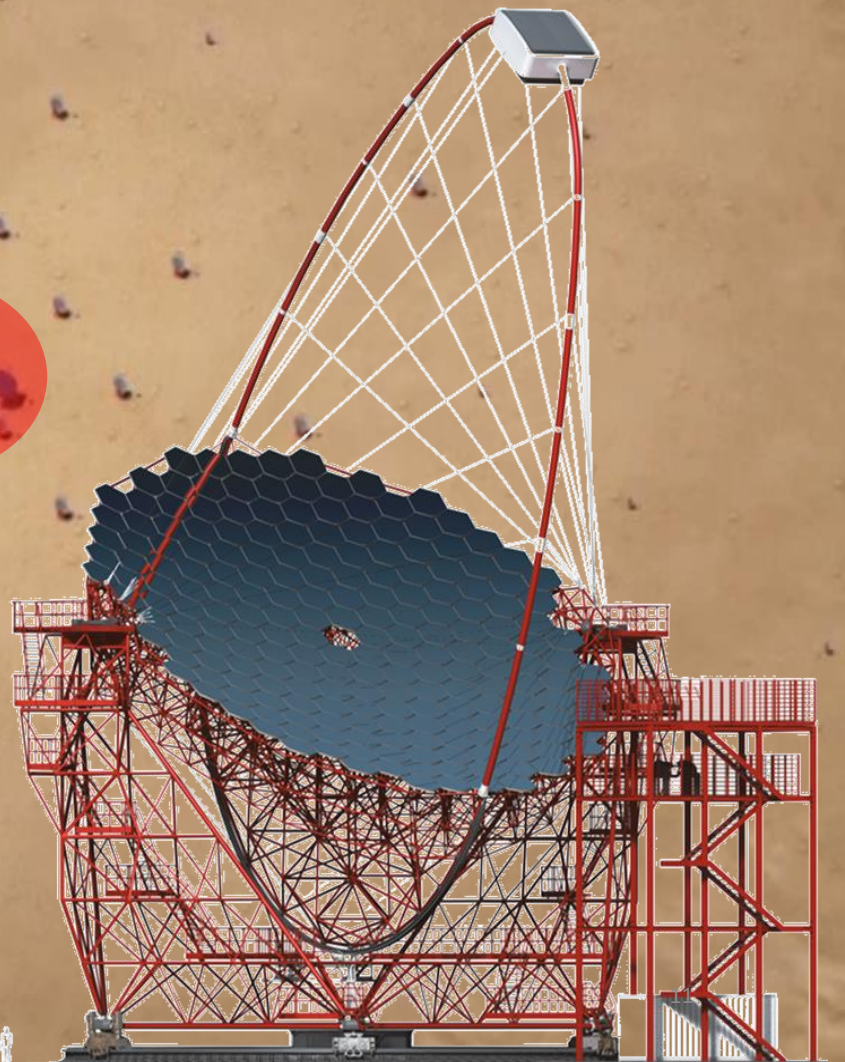




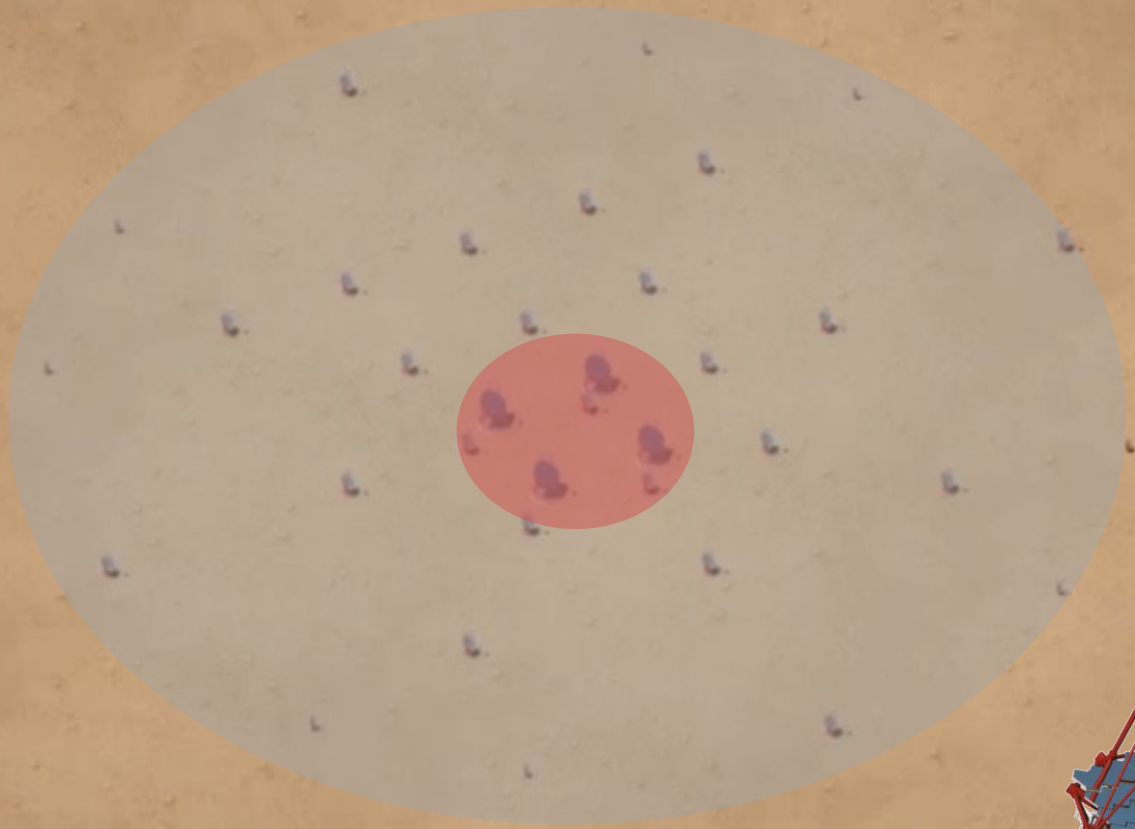


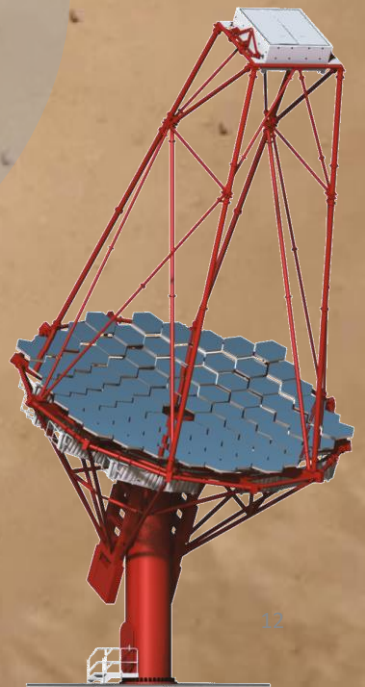

10 GeV
100 GeV
1 TeV
10 TeV
100 TeV
1000 γ / h km²
10 γ / h km²
0.1 γ / h km²
Southern array
of Cherenkov telescopes
- about 3 km across
Also stolen from Werner Hofmann!

4 x 23 m ø Large Size Telescopes (LST)



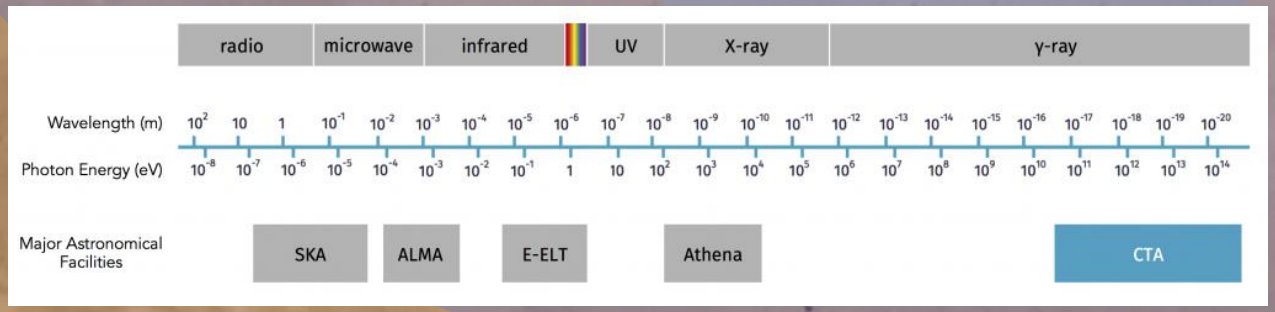
25 x 12 m ø Medium Size Telescopes (MST) (North: 15)

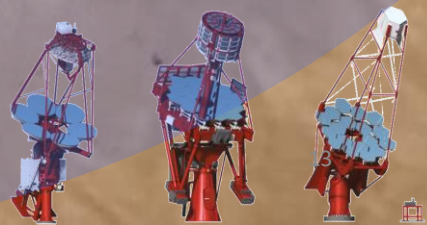




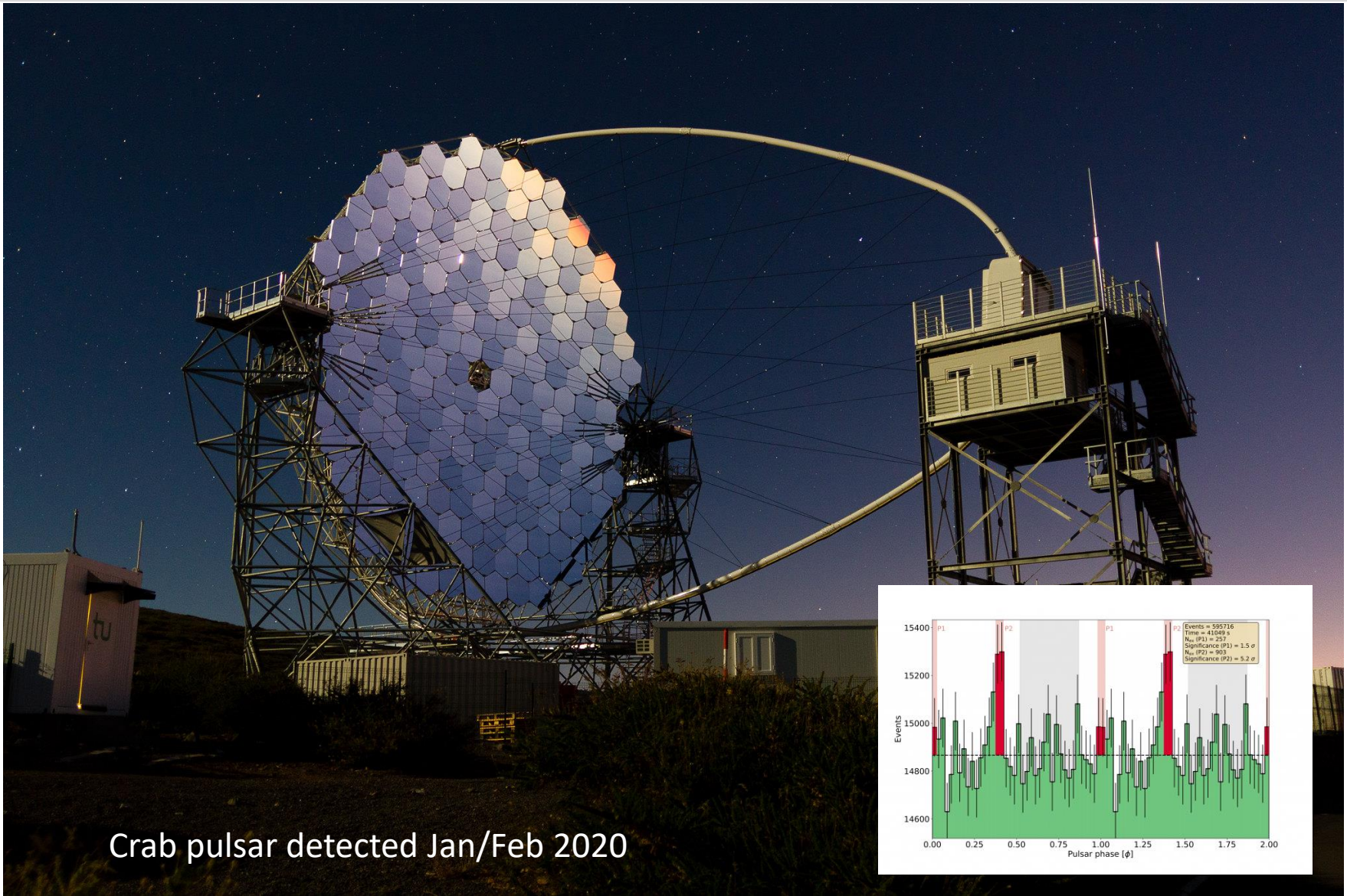
10 GeV | 100 GeV | 1 TeV | 10 TeV | 100 TeV

70 x 4 m ø Small Size Telescopes (SST) (South)

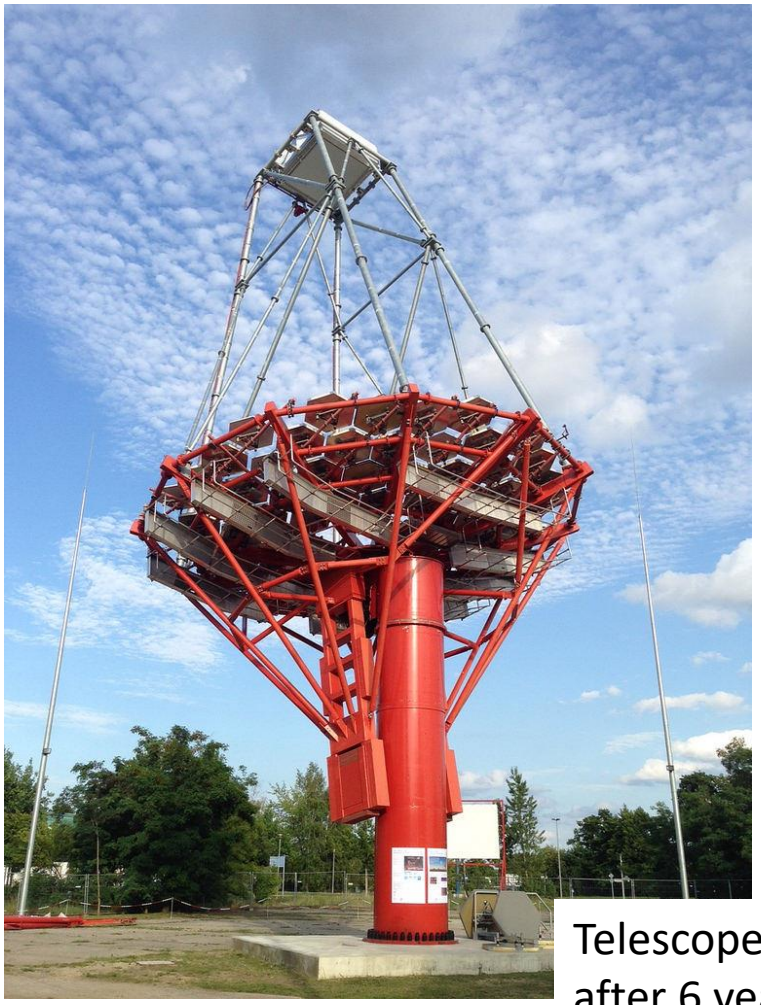




(Prototype) Large Sized Telescope



Prototype Medium Sized Telescope

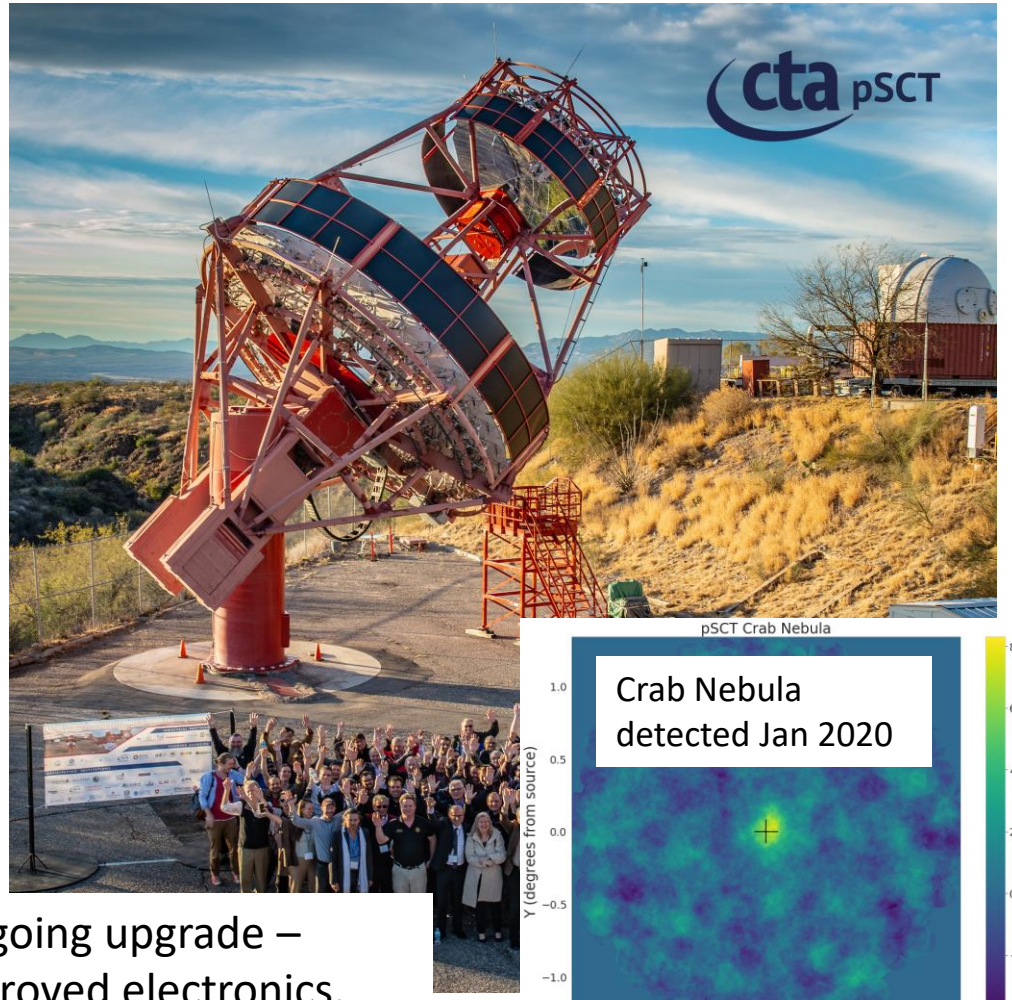


FlashCAM

NectarCAM

Telescope dismantled in Feb 2020 after 6 years of successful tests.

Prototype S-C Telescope

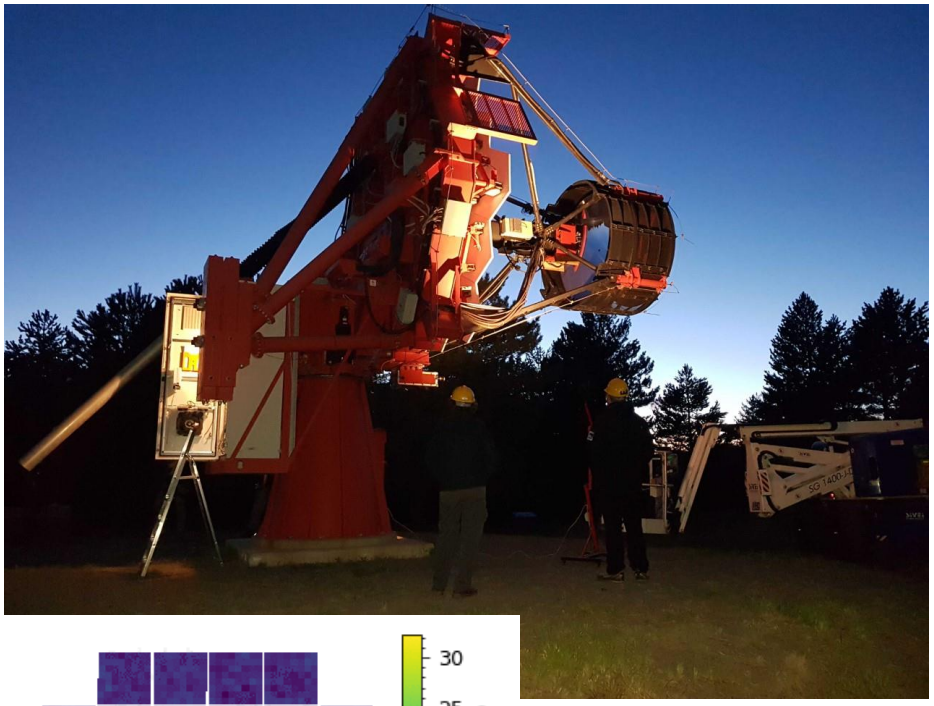


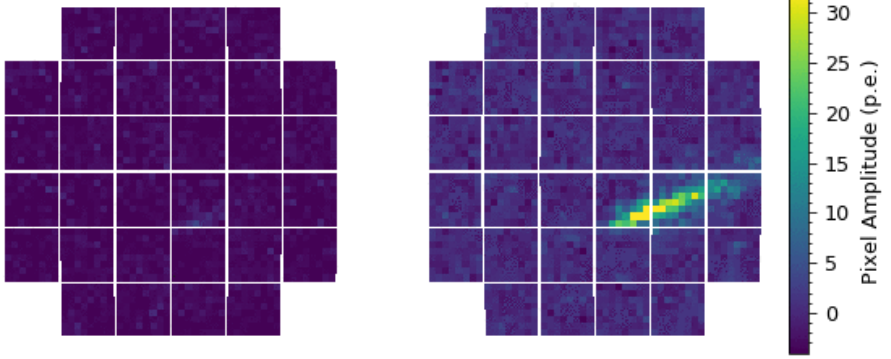
Camera now undergoing upgrade – more channels, improved electronics.

Prototype Small Sized Telescopes

Now harmonized to a single design – includes the camera to which the UK is contributing

The SST Camera – SiPM-based





Collaboration: Australia, Germany, Japan, Netherlands & UK

Now finalising camera (and telescope) for production

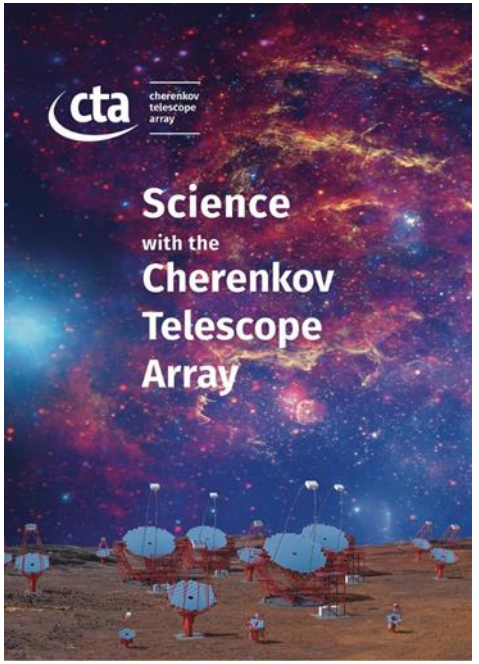
UK experimental groups: Armagh, Durham, Leicester, Liverpool, Oxford

Milestones

- Early science
  - CTA-N end 2022
  - CTA-S mid/end 2023
- Phase 1 completion, start of Phase 2
  - CTA-N & S 2025
- Full array completion not too long thereafter
- Dependent on the rate (and amount!) of arrival of funds from the many consortium countries
- And of course a certain virus…

What about the science?

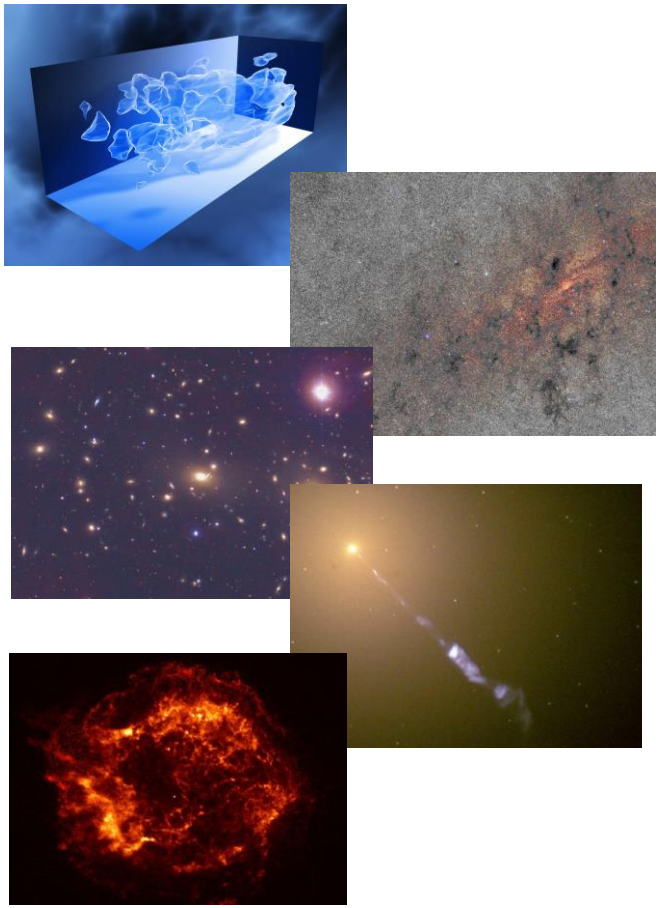
- Theme 1: Cosmic Particle Acceleration
  - How and where are particles accelerated?
  - How do they propagate?
  - What is their impact on the environment?
- Theme 2: Probing Extreme Environments
  - Processes close to neutron stars and black holes?
  - Processes in relativistic jets, winds and explosions?
  - Exploring cosmic voids
- Theme 3: Physics Frontiers – beyond the SM
  - What is the nature of dark matter? How is it distributed?
  - Is the speed of light constant for high energy photons?
  - Do axion-like particles exist?



ArXiv: 1709.07997

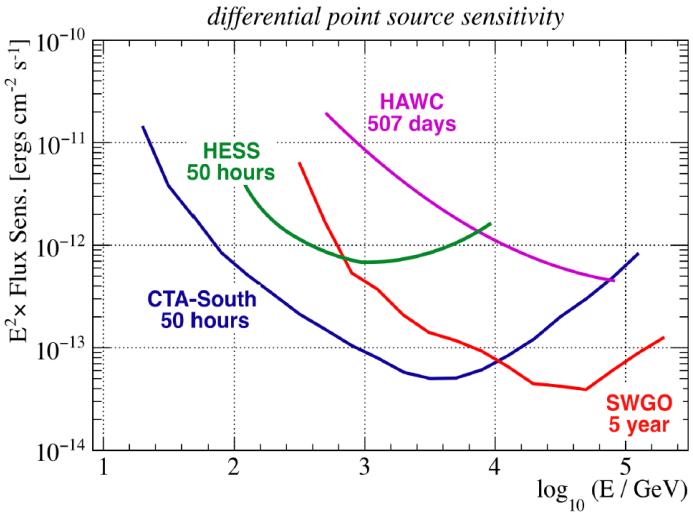
Key Science Projects (KSPs)

1. **Dark Matter Programme**
2. Galactic Centre
3. **Galactic Plane Survey**
4. Large Magellanic Cloud Survey
5. **Extragalactic Survey**
6. **Transients**
7. Cosmic-ray PeVatrons
8. **Star-forming Systems**
9. **Active Galactic Nuclei**
10. **Cluster of Galaxies**
11. **Beyond Gamma Rays**

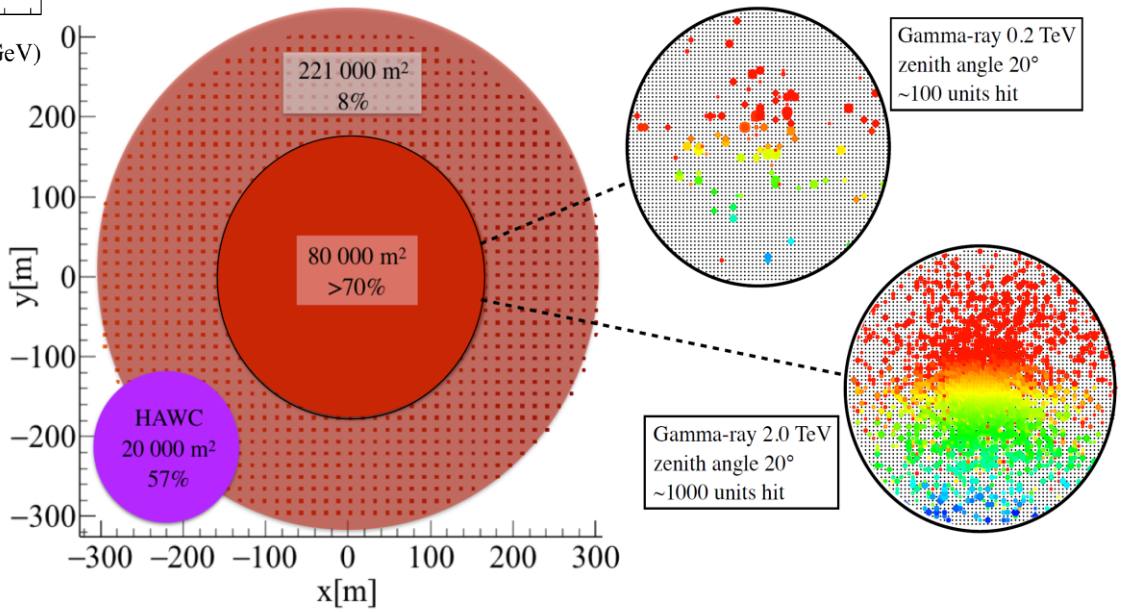


Stay tuned: https://www.cta-observatory.org/

Particle Detectors – complementary to CTA



Southern Wide-field Gamma-ray Observatory



Introducing PPTAP – Particle Physics Technology Advisory Panel

- A link between Executive Board, Council, the Technology and Accelerator Advisory Board (TAAB) and the community to produce a coherent UK position on the development of the R&D Roadmaps related to the European Strategy for Particle Physics Update
  - **This includes Particle Astrophysics!**
- Develop a coherent, strategic and holistic approach to planning of particle physics and the associated accelerator R&D activities within the European context
  - **We will be asking you for input…**
- Work to establish the need for UK particle physics and associated accelerator R&D activities, in the context of the overall PP projects roadmap, as well as the current level of expertise and relevant activity within the UK
- The panel will produce a final report given an overview of the R&D needs of the STFC particle physics roadmap and existing areas of related expertise.