Science with the Cherenkov Telescope Array

A multi-wavelength and multi-messenger perspective

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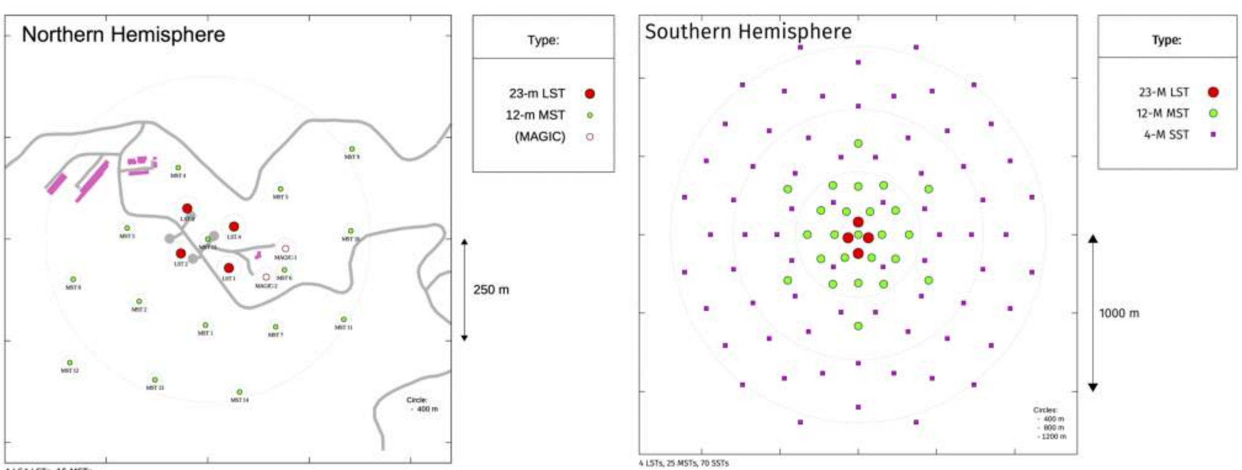
The Cherenkov Telescope Array

- CTA is the next generation ground-based gamma-ray astronomy observatory, operating in the range from **tens of GeV to 300 TeV.**
  - It will be the first facility in the field to function as an open observatory.
  - It will consist of two arrays of Imaging Atmospheric Cherenkov Telescopes (IACTs)
    - **Northern Array:** in La Palma, Canary Islands, Spain, concentrating in the lower energy range, with a focus on the study of extragalactic objects.
    - **Southern Array:** near Cerro Paranal, in Chile, with full energy coverage and a view to the Galactic Plane and the Galactic Center
  - Composed of three classes of telescopes
    - Large-, Medium-, and Small-Sized Telescopes (LST, MST, SST)

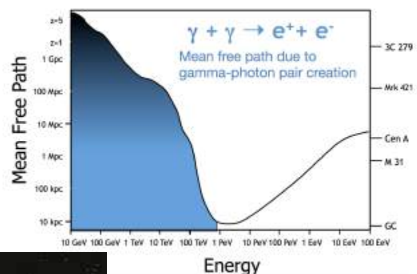


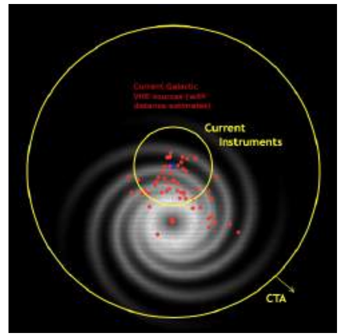
Schematic view of the planned northern (left) & southern (right) arrays

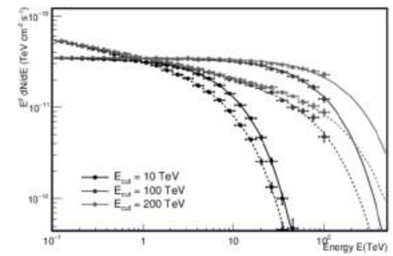
CTA Science & Capabilities

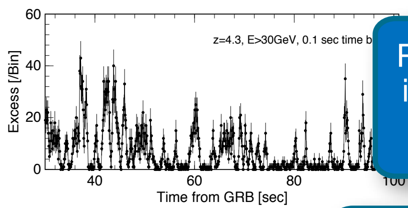
See “Science with the Cherenkov Telescope Array” book by World Scientific, also @ arXiv:1709.07997

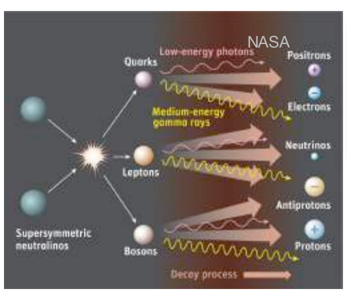
DESIGN DRIVERS

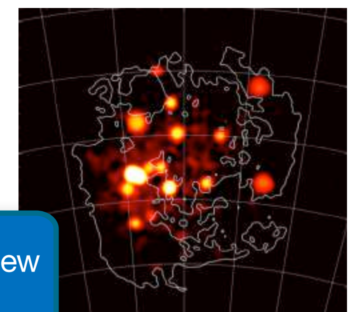


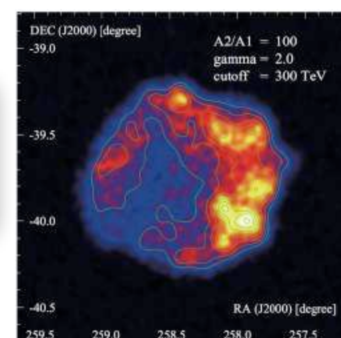








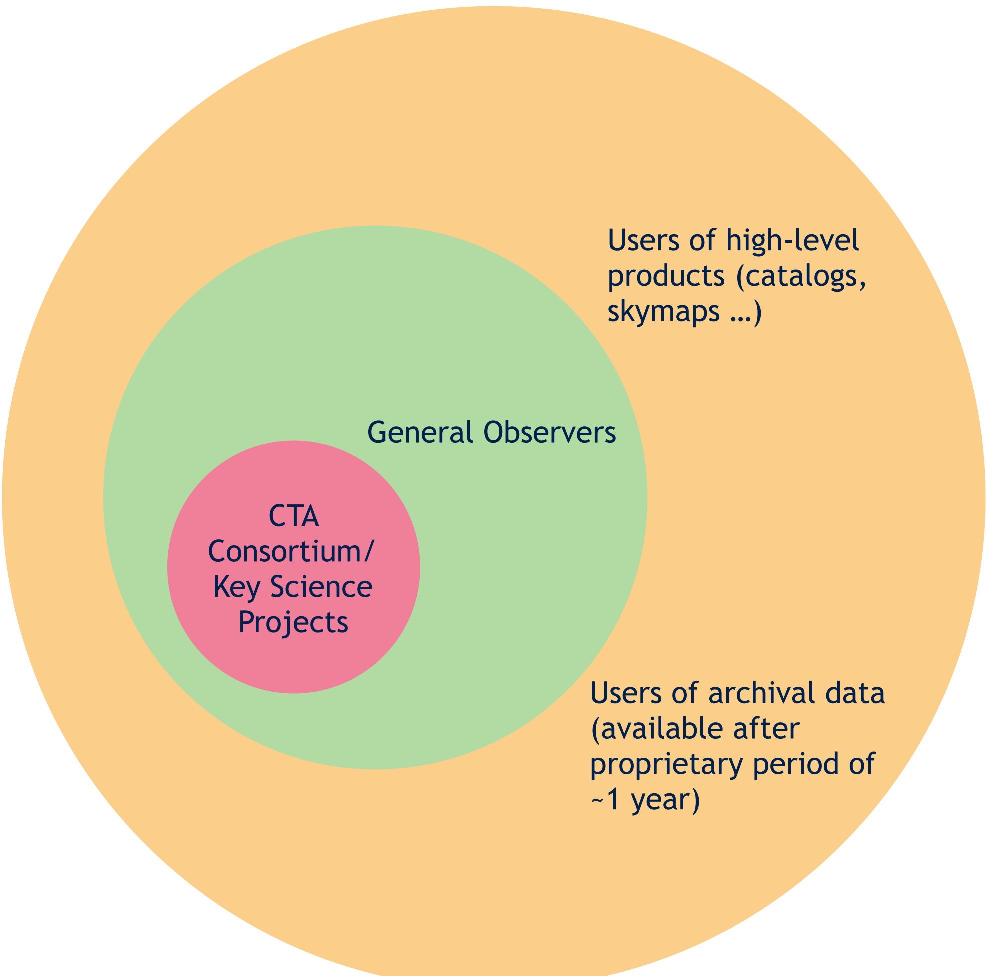




- 10 x Sensitivity, Large Collection Area → all topics
- Energies down to 20 GeV → Cosmology++
- Energies up to 300 TeV → Pevatrons
- Rapid Slewing in 20 seconds → transients
- 8° Field of View → surveys, extended objects
- 10% Energy Resolution → lines, features
- Few ‘ Angular Resolution → morphology

Open Observatory & Key Science Programme

CTA will function in two modes in the first decade



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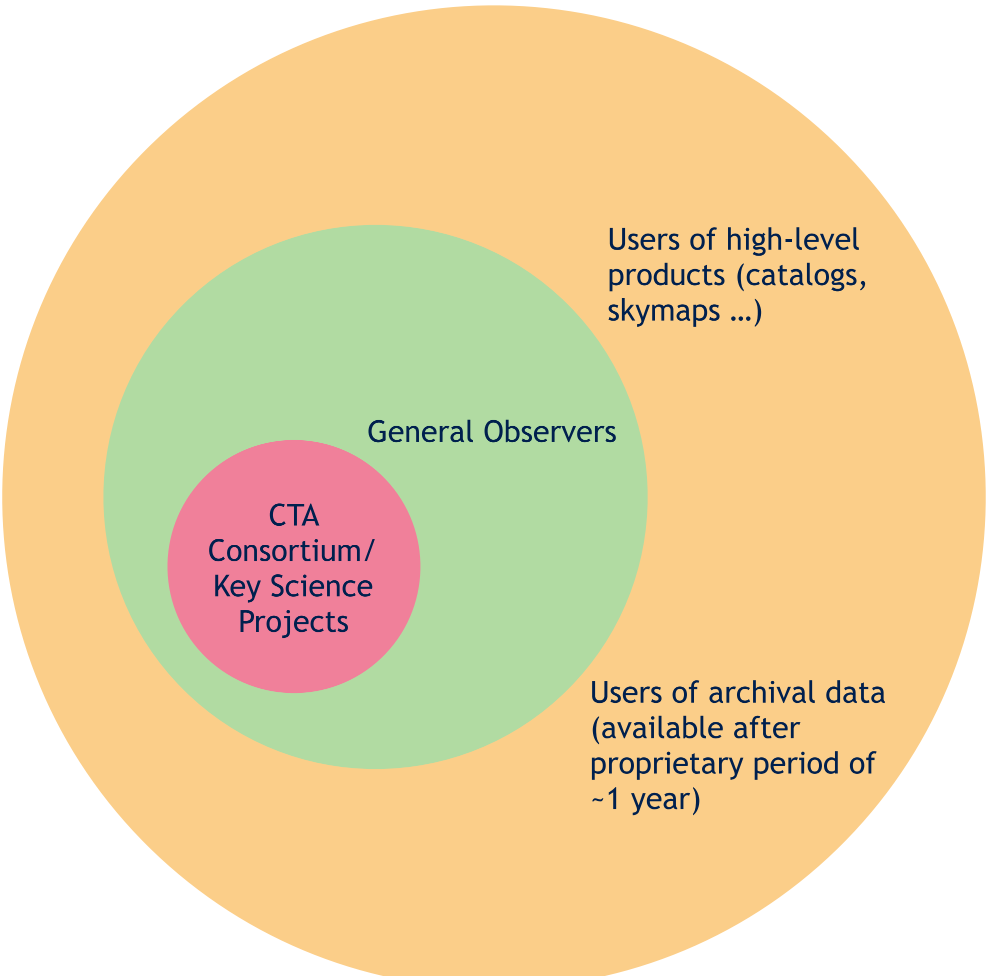
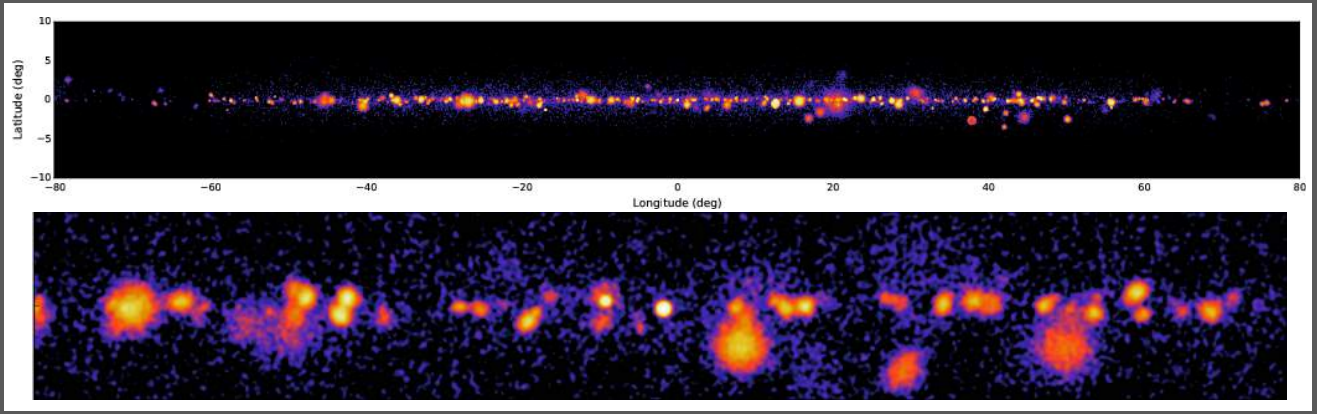


- Consortium Key Science Projects
  - 40% of the time for 10 years
  - legacy datasets for general observers
  - **all data** ultimately public
- Galactic KSPs
  - Galactic Plane Survey
    - Deep view of key topics: Galactic Center, PeVatrons, Star Forming Systems.
- Extragalactic KSPs
  - First Extragalactic Survey
- Dark Matter Programme

The Galactic Plane Survey

- Most primary goal of CTA Galactic Science: provide a census of Galactic VHE source populations
- To be performed down to ~ 2 mCrab in the inner Galaxy and Cygnus region, and ~ 4 mCrab elsewhere in the Galactic Plane.
- Detailed study of the diffuse emission
- Multi-purpose catalogue and legacy dataset



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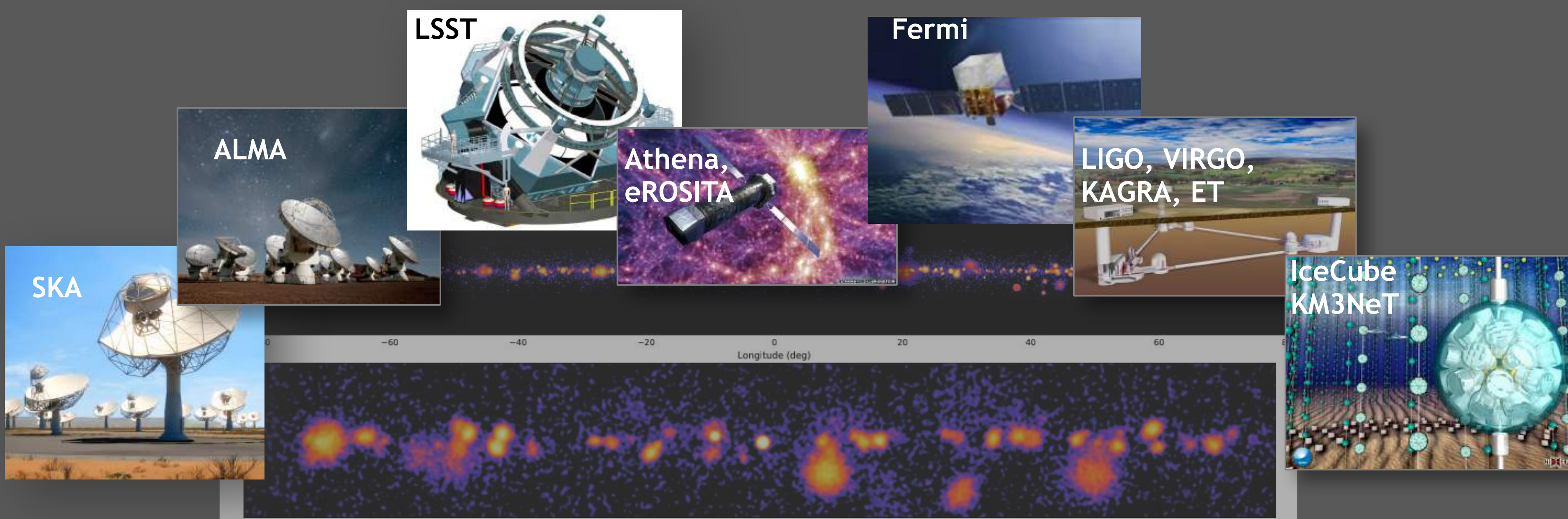


The Galactic Plane Survey

Catalogue cross-matching for source ID

21 cm atomic gas mapping

Recombination lines ionised gas census

Sub-mm imaging of molecular clouds

OH maps for Dark gas tracing

Optical catalogues of massive stars

Dust emission

Survey source counterpart ID

msec pulsars

Cross-matching of catalogues: source ID

PWN/SNR associations

Nebula properties

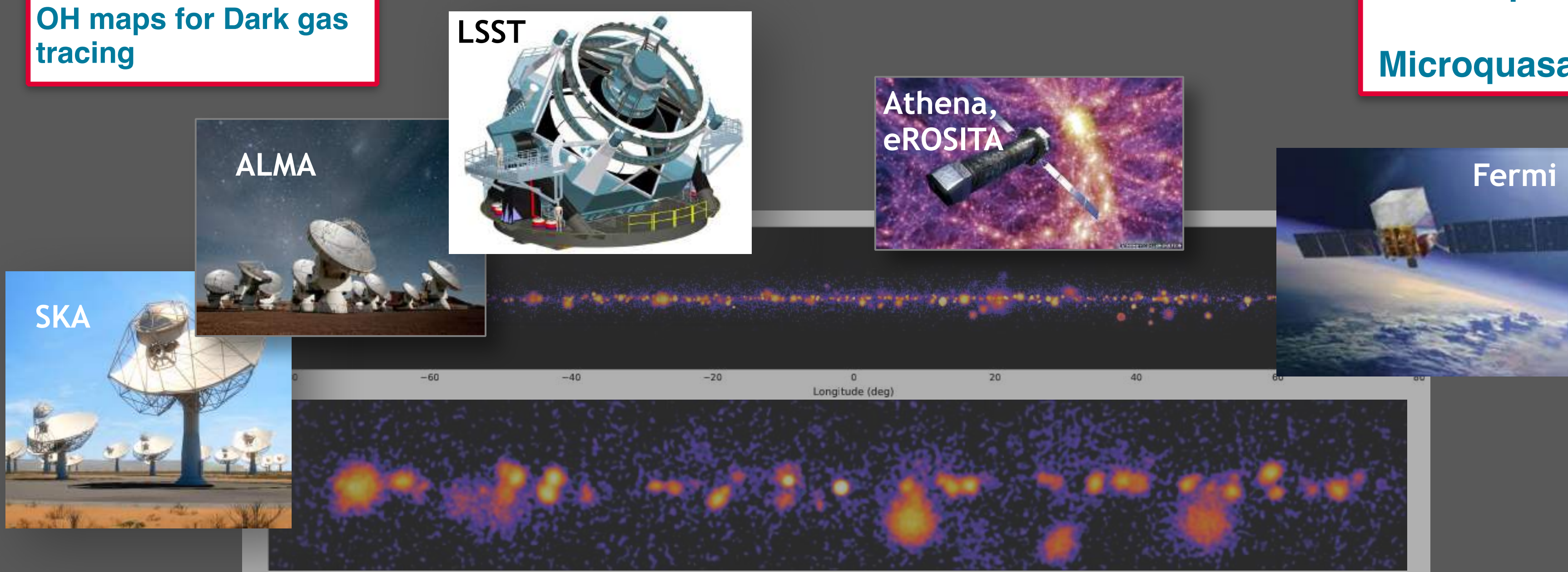
Microquasars

Spectral morphology studies

Source selection for further deep observations

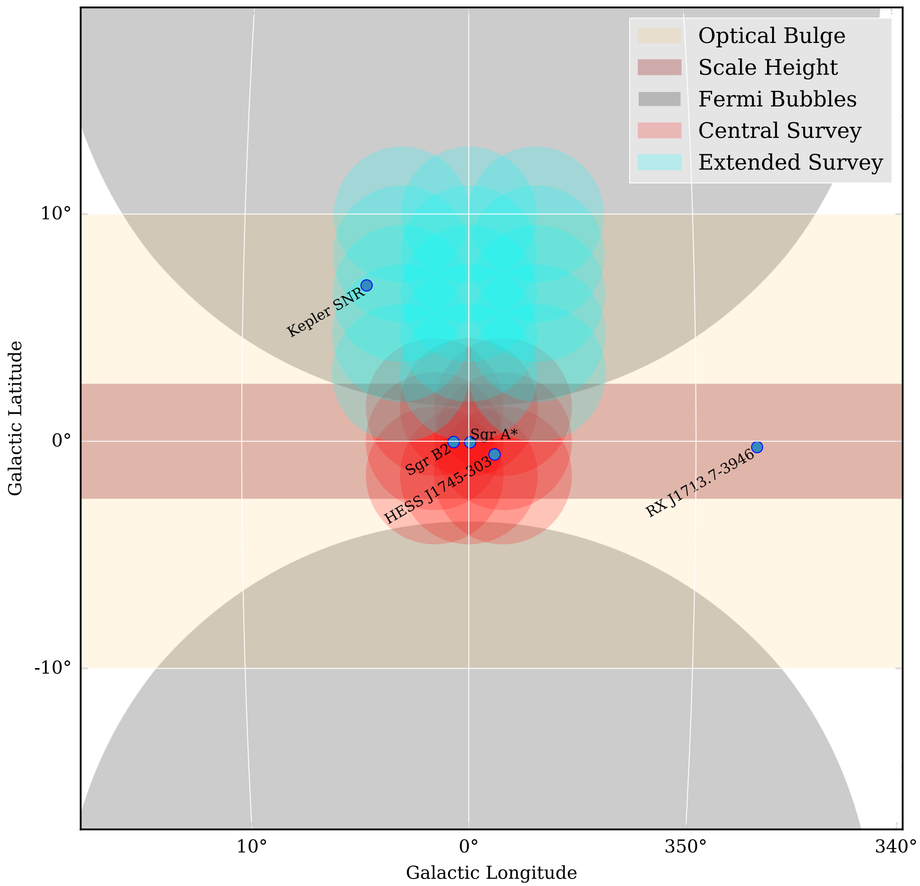
Survey source counterpart ID

Microquasars



The Galactic Center

The inner Galaxy will be focus of a deeper survey within the GPS



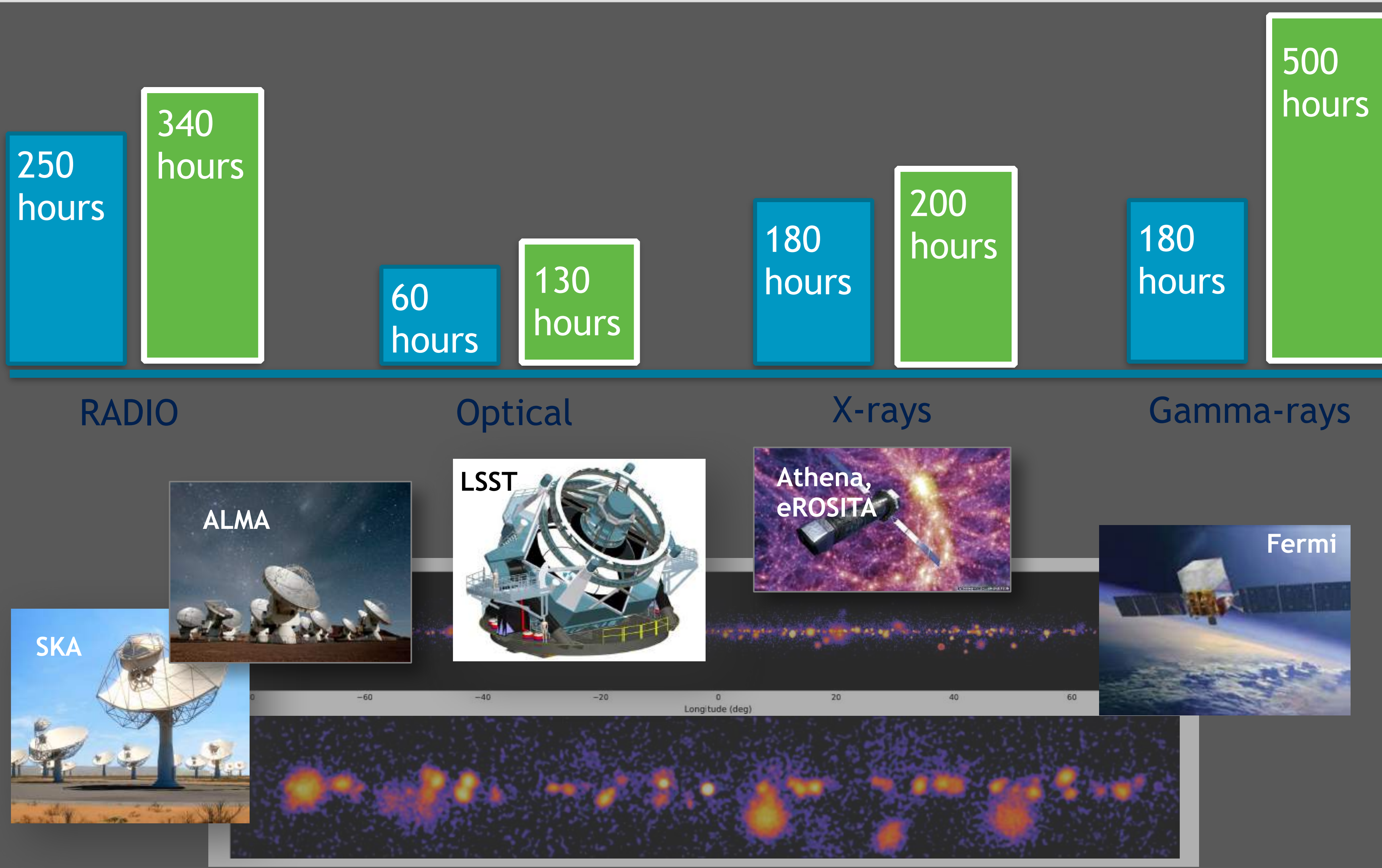
- Extended Survey will cover unexplored regions in the VHE at higher latitudes
  - edge of the bulge emission
  - base of the Fermi bubbles
  - other sources e.g. Kepler SNR

- Goals include
  - diffuse emission
  - dark matter signals
  - cosmic-ray acceleration
    - » PeVatrons

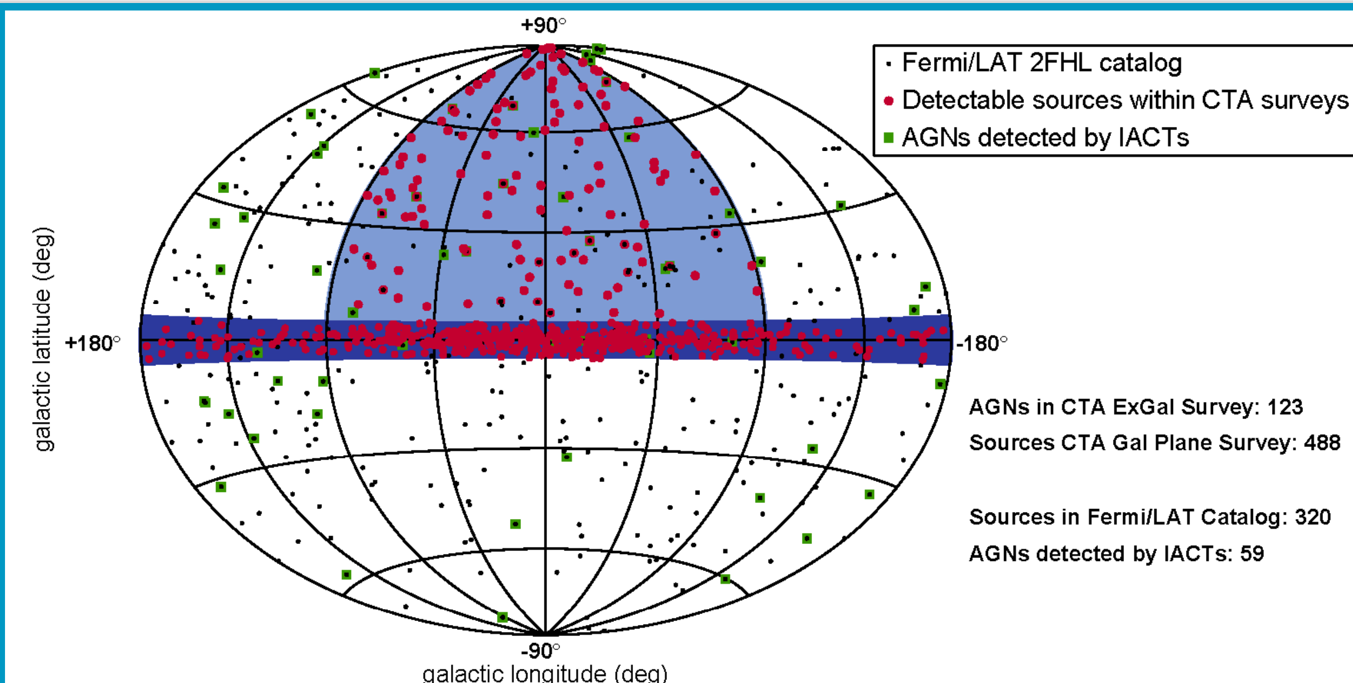
Galactic Transients

CTA counterpart time

External MWL time

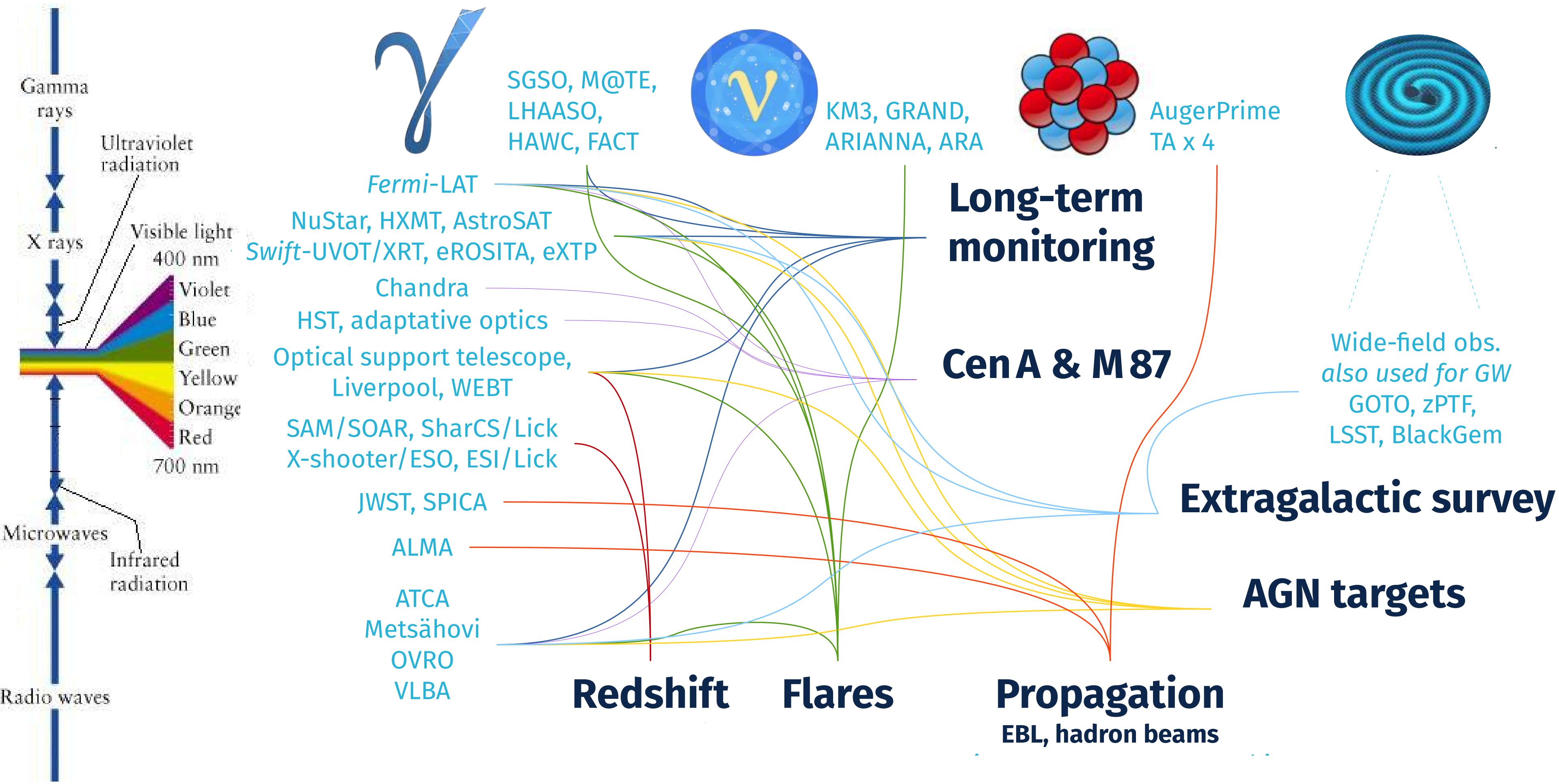


The Extragalactic Survey



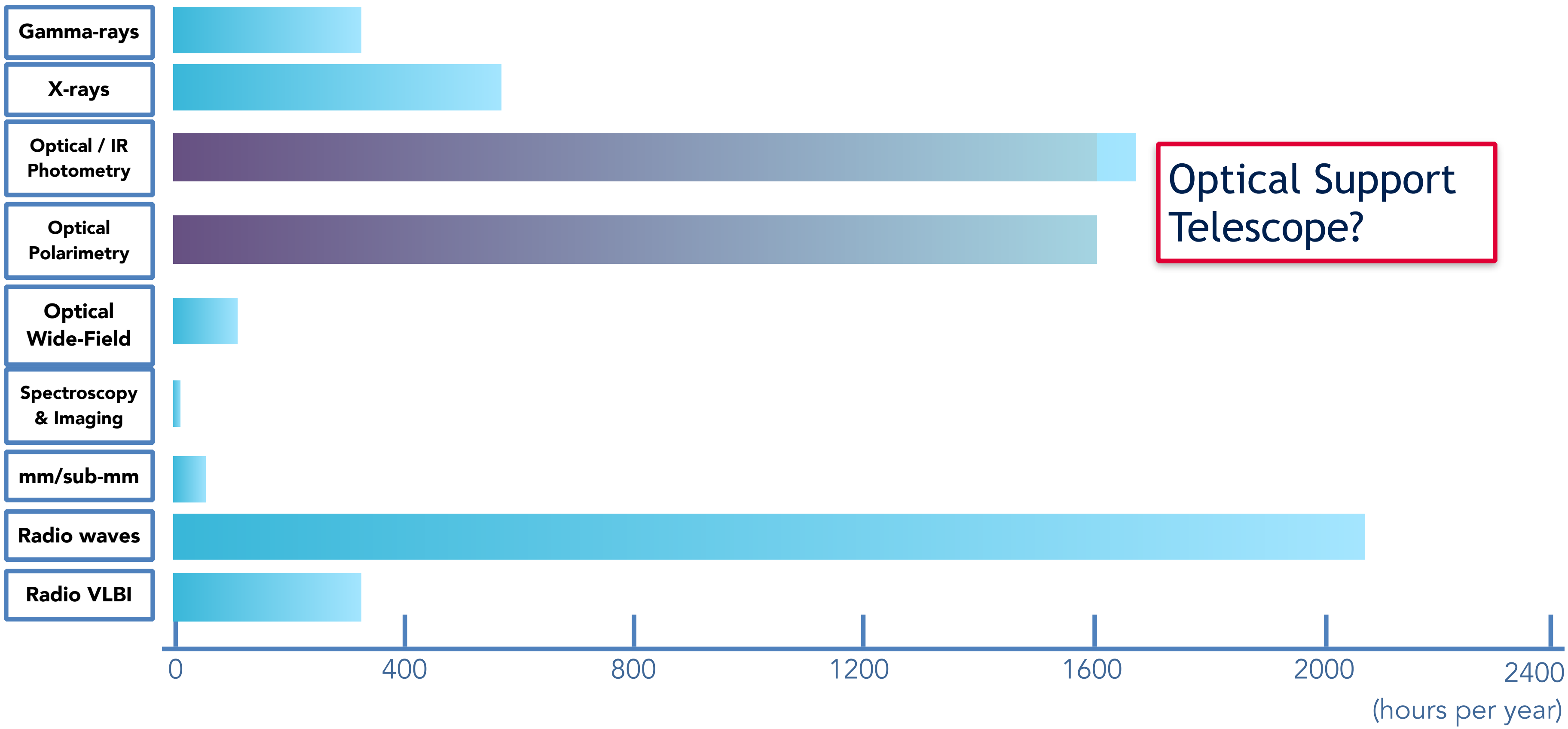
- Survey of 1/4 of the sky to limiting sensitivity of 5 mCrab.
- Unbiased determination of blazar luminosity function (LogN-LogS distribution)
- Probe of new source populations such as extreme blazars at the limit of current detectability
- Discovery potential – serendipity.

MWL & MM Links: Extragalactic



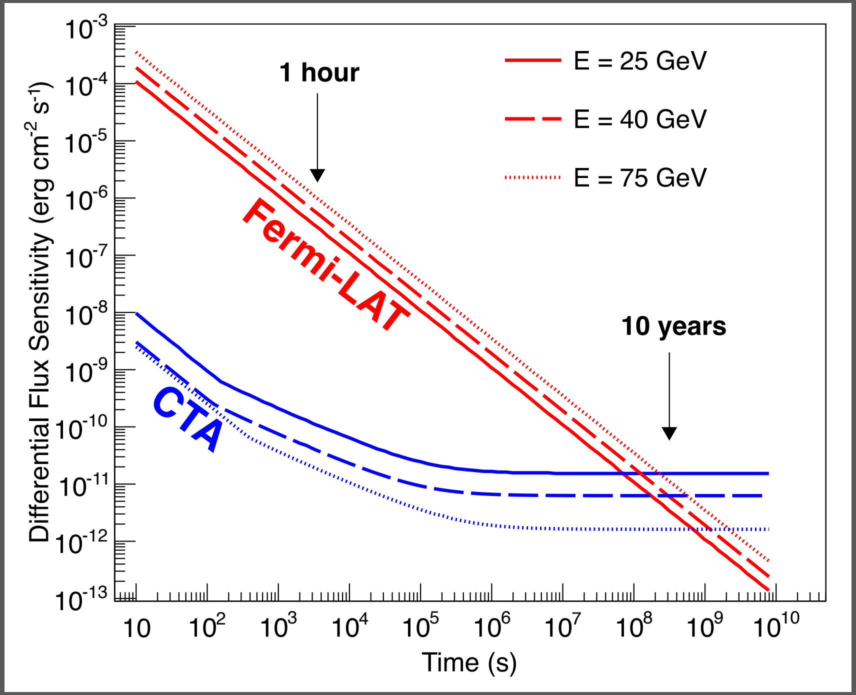
Adapted from slide by J. Biteau

MWL Synergies



- MWL synergies will demand significant (and challenging amount) of external time, especially for transients;
- Re-analysis of catalogued data or revisiting of survey fields is also envisaged.

See poster by F. Schüssler on Transients



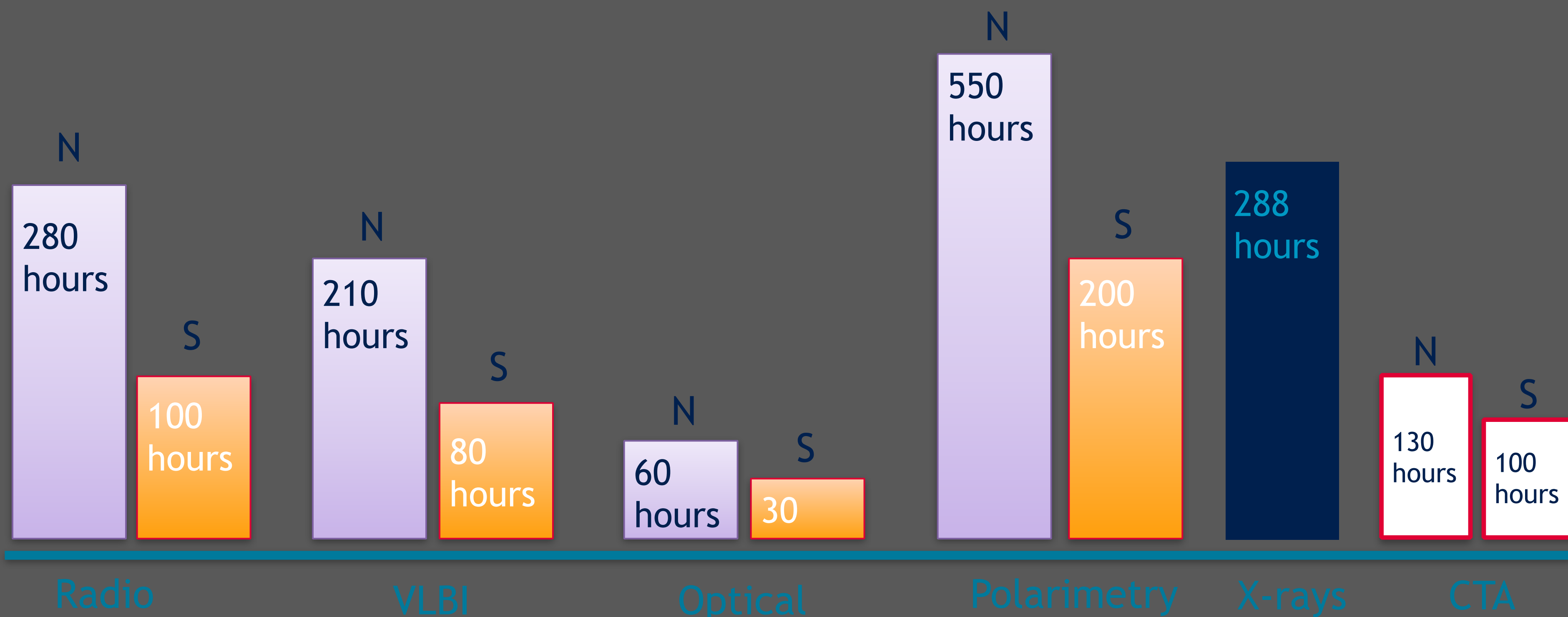
Transients with CTA

CTA's high sensitivity enables access to short timescales. Combined with a low energy threshold + rapid slewing capability & large field of view, this makes CTA an **ideal high-energy transient telescope.**

Transients with CTA

See poster by F. Schüssler on Transients

AGN Long-term Monitoring



Long-term monitoring of 11 Northern + 4 Southern objects for a detailed understanding of the variability and nature of jet emission in blazars.

Transients with CTA

See poster by F. Schüssler on Transients

	Triggers	Radio	Optical	X-rays	GeVs
AGN Flares	50-100	< 800 hours	< 300 hours	< 500 hours	–
GRBs	O(20), 4 det	50 h/trigger	50 h/trigger	30 h/trigger	30 h/trigger
Neutrinos	O(10), 2 det	?	?	?	?
Gravitational waves	O(10), 1 det	>50 h/trigger	50 h/trigger	25 h/trigger	20 h/trigger
FRBs	?	?	?	?	?

Extreme Transients with CTA

Follow-up of extreme extragalactic transient events, from external MWL / MM alerts, as well as CTA serendipitous discoveries (2-3 per year).

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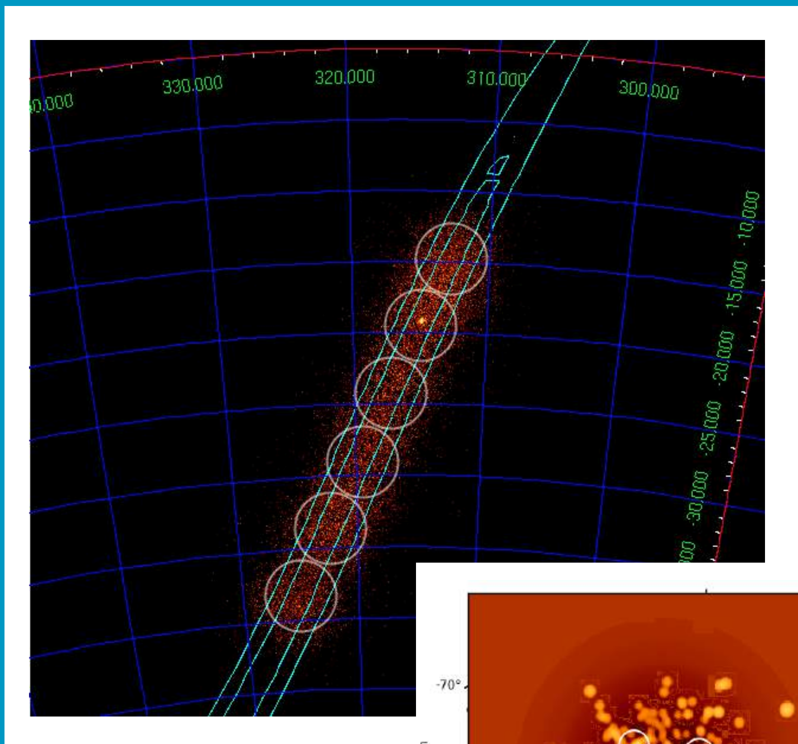
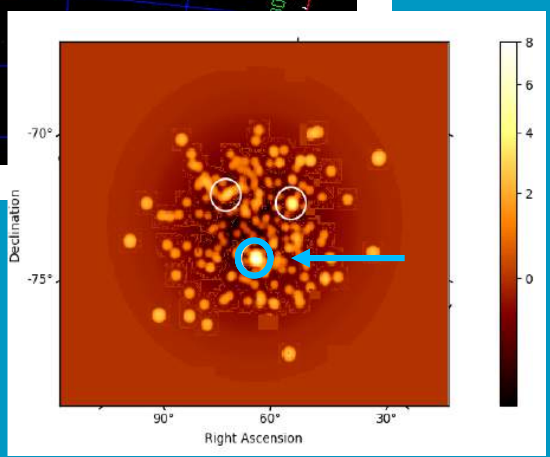
Multi-messenger science

Gravitational wave and neutrinos follow-up.

See poster by M. Seglar-Arroyo on GWs



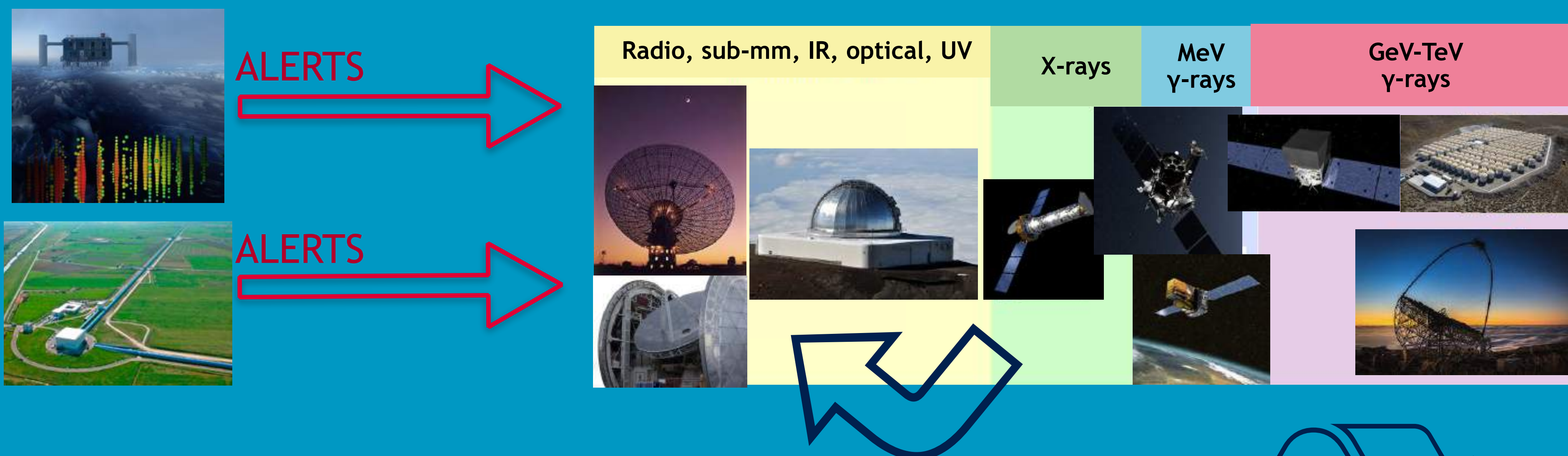


1. Fast scan of large GW signal region, est. time of 2 hours/trigger + follow-up
2. Real time analysis for statistical identification of potential EM counterpart for follow-up
3. MWL campaigns and cross-matching of multiple catalogues for source ID

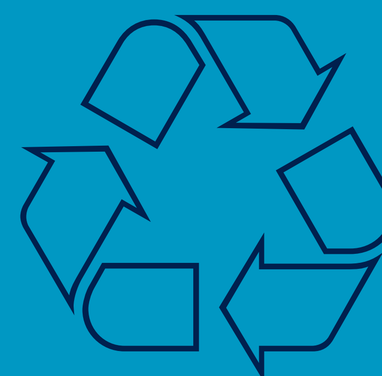
Multi-messenger science

Large MWL follow-up campaigns

Recent IceCube neutrino & GW events, and the sub-TeV GRB detection by MAGIC sparked large MWL / MM follow-up campaigns



low latency searches
for EM counterpart IDs



Follow-up campaigns of validated events

- Over 150 instruments participate in follow-up campaigns of such events and related MoUs; dozens of alerts in past years.
- Follow-up & RTA searches covering entire EM.

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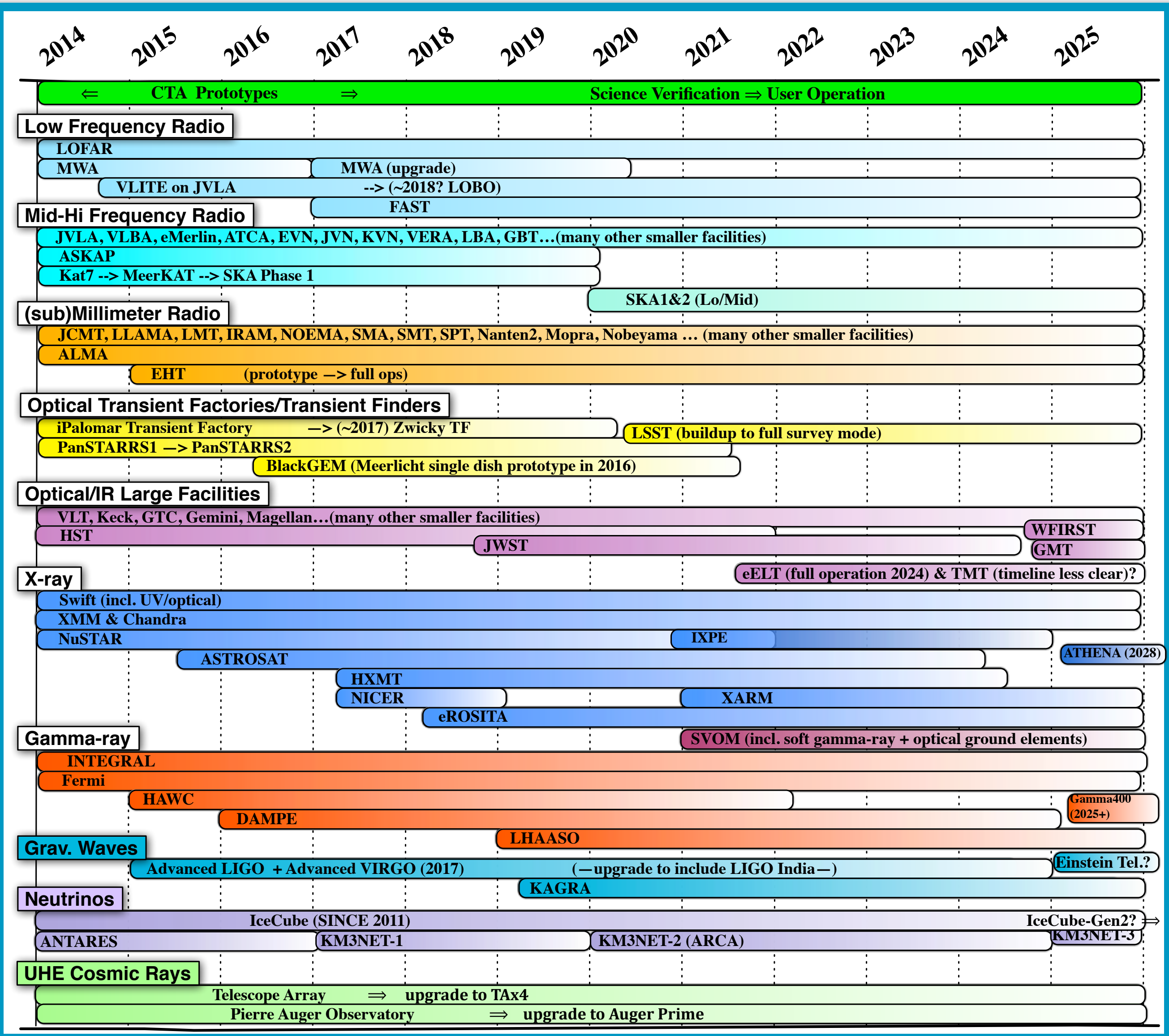
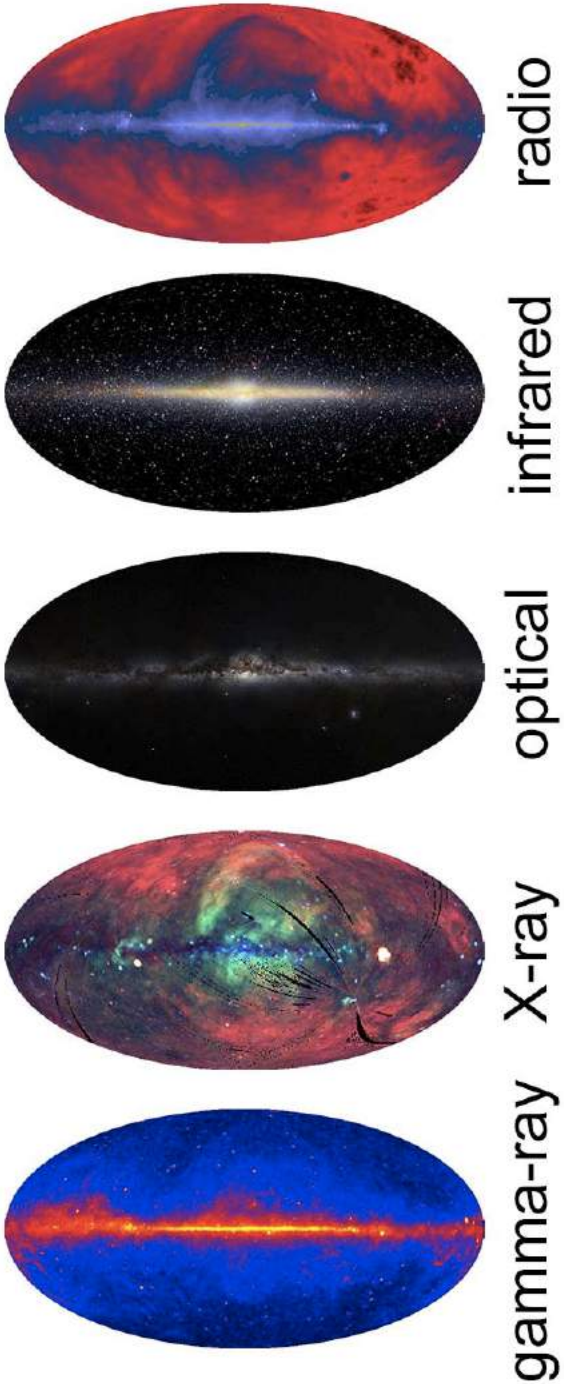
Multi-instrument coordination



Instrument coordination and data access via GOP, MoUs or open data policies.

Mapping of availability at each band (and time) is fundamental for success

Conclusions



MWL & Multi-messenger coordination within CTA:

1. CTA will demand significant amount of external data for achieving its KSP science goals

2. Transients science is specially demanding, requiring also close coordination of ToO observations

3. In optical support telescopes on site may be a solution for providing the dedicated coverage necessary.

BACK UP

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MWL Synergies

Mapping matrix: Science Cases <—> MWL / Multi-messenger

Band or Messenger	Astrophysical Probes	Galactic Plane Survey	LMC & SFRs	CRs & Diffuse Emission	Galactic Transients	Starburst & Galaxy Clusters	GRBs	AGNs	Radio Galaxies	Redshifts	GWs & Neutrinos
Radio	Particle and magnetic-field density probe. Transients. Pulsar timing.	✔	✔	✔	✔	✔	✔	✔	✔		✔
(Sub)Millimetre	Interstellar gas mapping. Matter ionisation levels. High-res interferometry.	✔	✔	✔		✔		✔	✔		
IR/Optical	Thermal emission. Variable non-thermal emission. Polarisation.	✔	✔	✔	✔	✔		✔	✔	✔	
Transient Factories	Wide-field monitoring & transients detection. Multi-messenger follow-ups.						✔	✔			✔
X-rays	Accretion and outflows. Particle acceleration. Plasma properties.	✔	✔	✔	✔	✔	✔	✔	✔		✔
MeV-GeV Gamma-rays	High-energy transients. Pion-decay signature. Inverse-Compton process	✔	✔	✔	✔	✔	✔	✔			✔
Other VHE	Particle detectors for 100% duty cycle monitoring of TeV sky.	✔	✔	✔		✔		✔			
Neutrinos	Probe of cosmic-ray acceleration sites. Probe of PeV energy processes.			✔			✔	✔			✔
Gravitational Waves	Mergers of compact objects (Neutron Stars). Gamma-ray Bursts.						✔				✔