Synergies between CTA, SKA, and Athena

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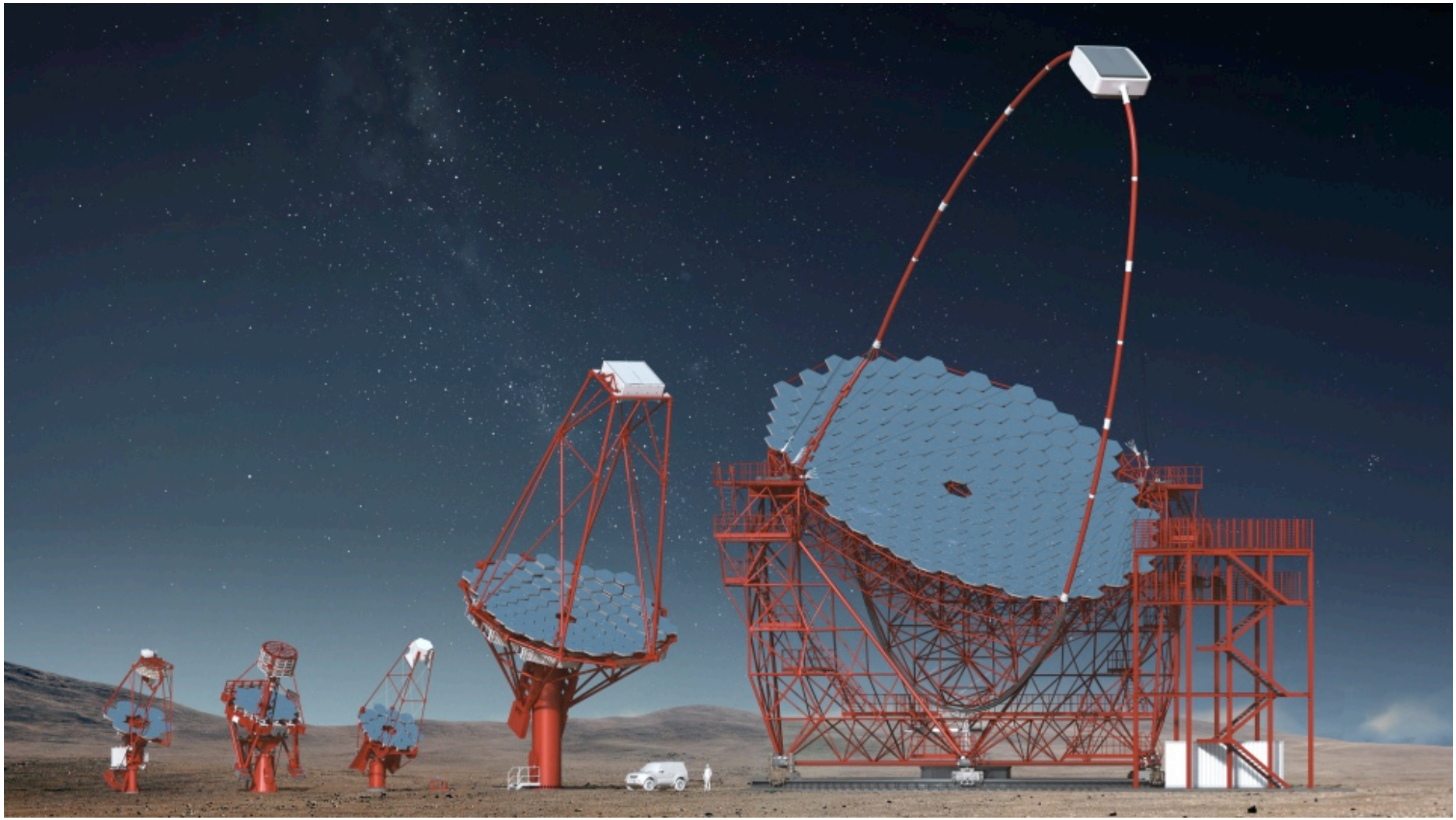
Outline of the talk:

- CTA overview
- SKA overview
- Athena overview

- Astrophysical synergies between CTA, SKA, and Athena
- Operational synergies
- Data managent and analysis synergies

- Summary

cherenkov telescope array



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

CTA: One observatory, two sites, and two office locations

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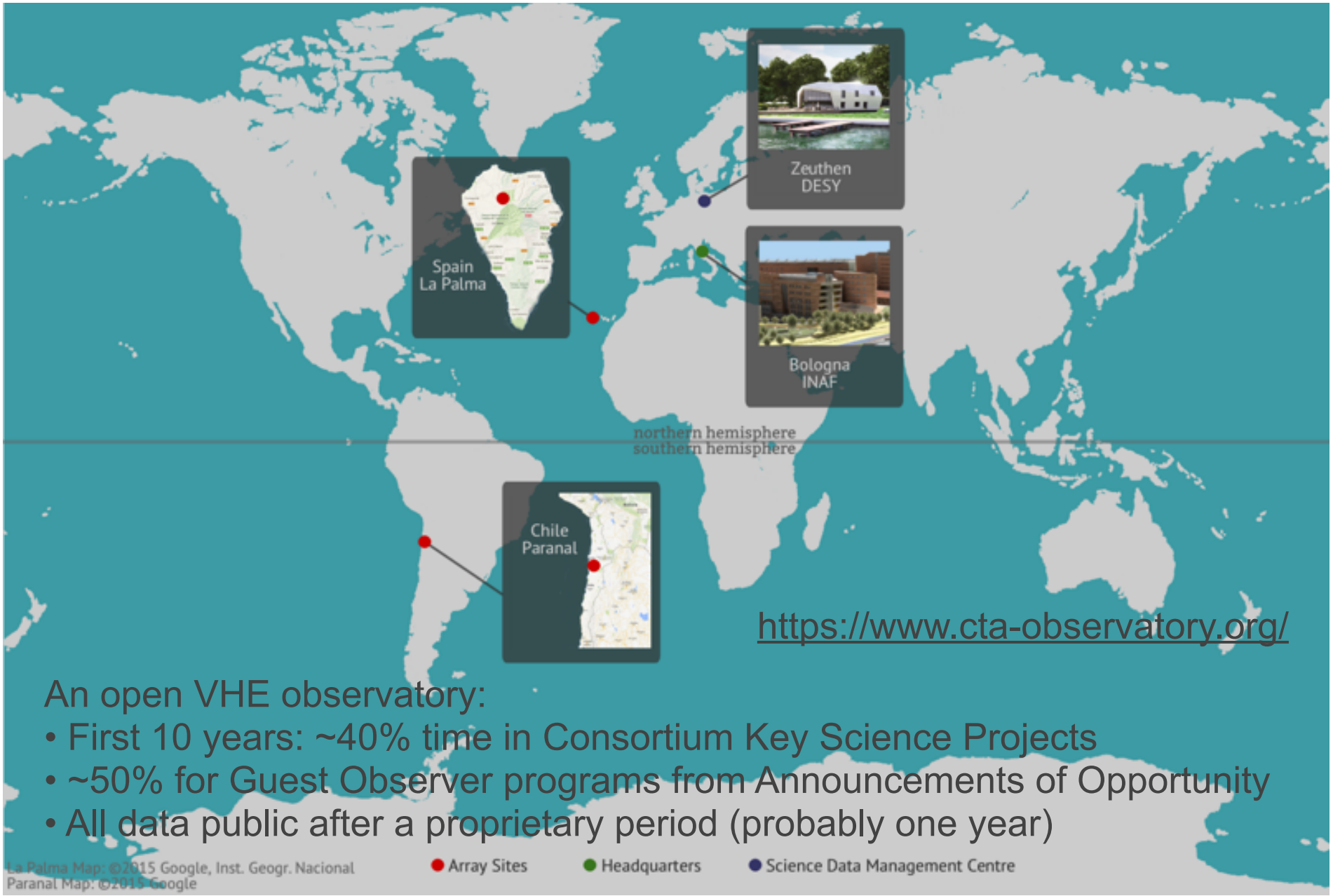
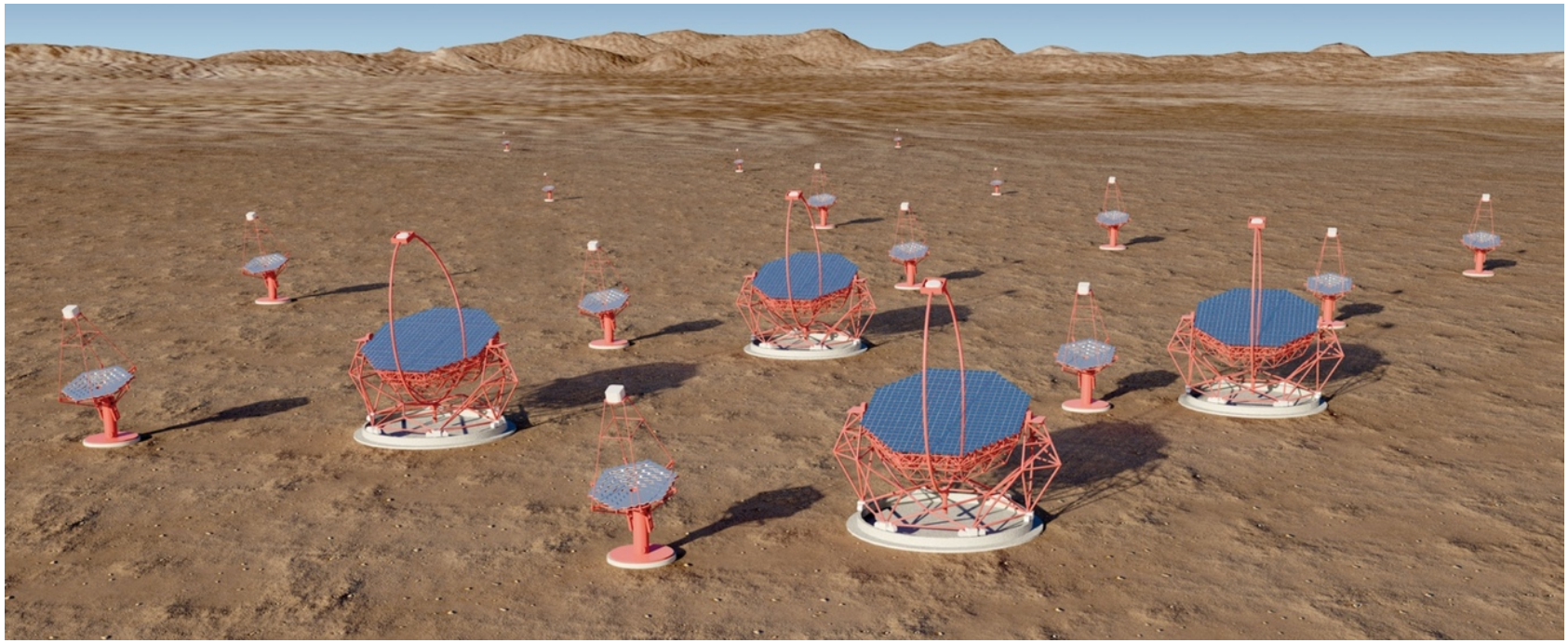
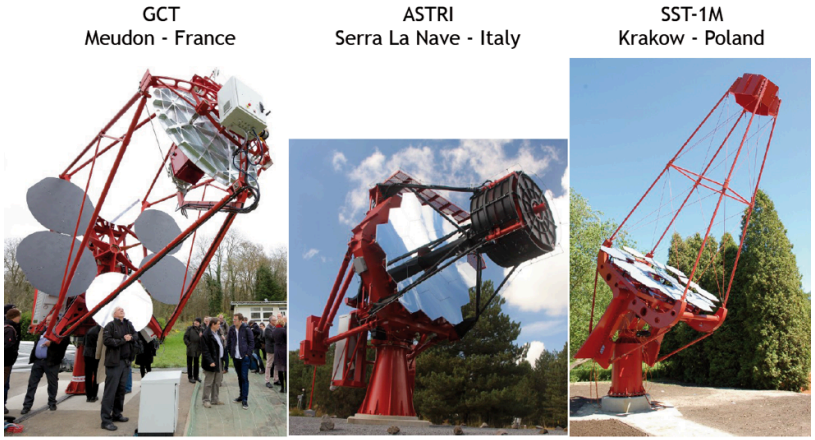


CTA: North and South

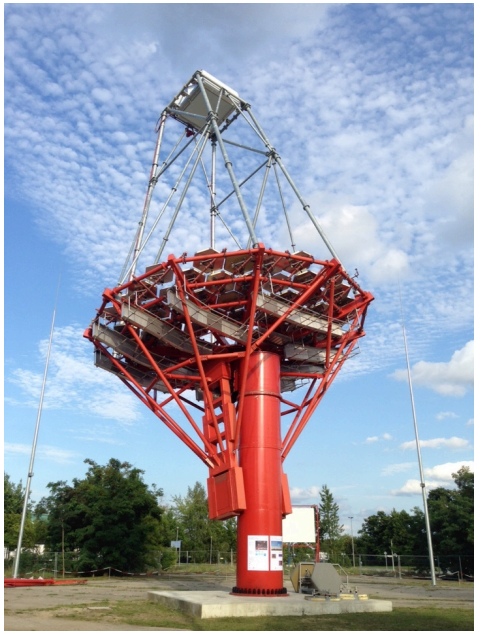
Baseline: 99 telescopes in the South, 19 telescopes in the North



CTA: Prototypes



4m-SSTs



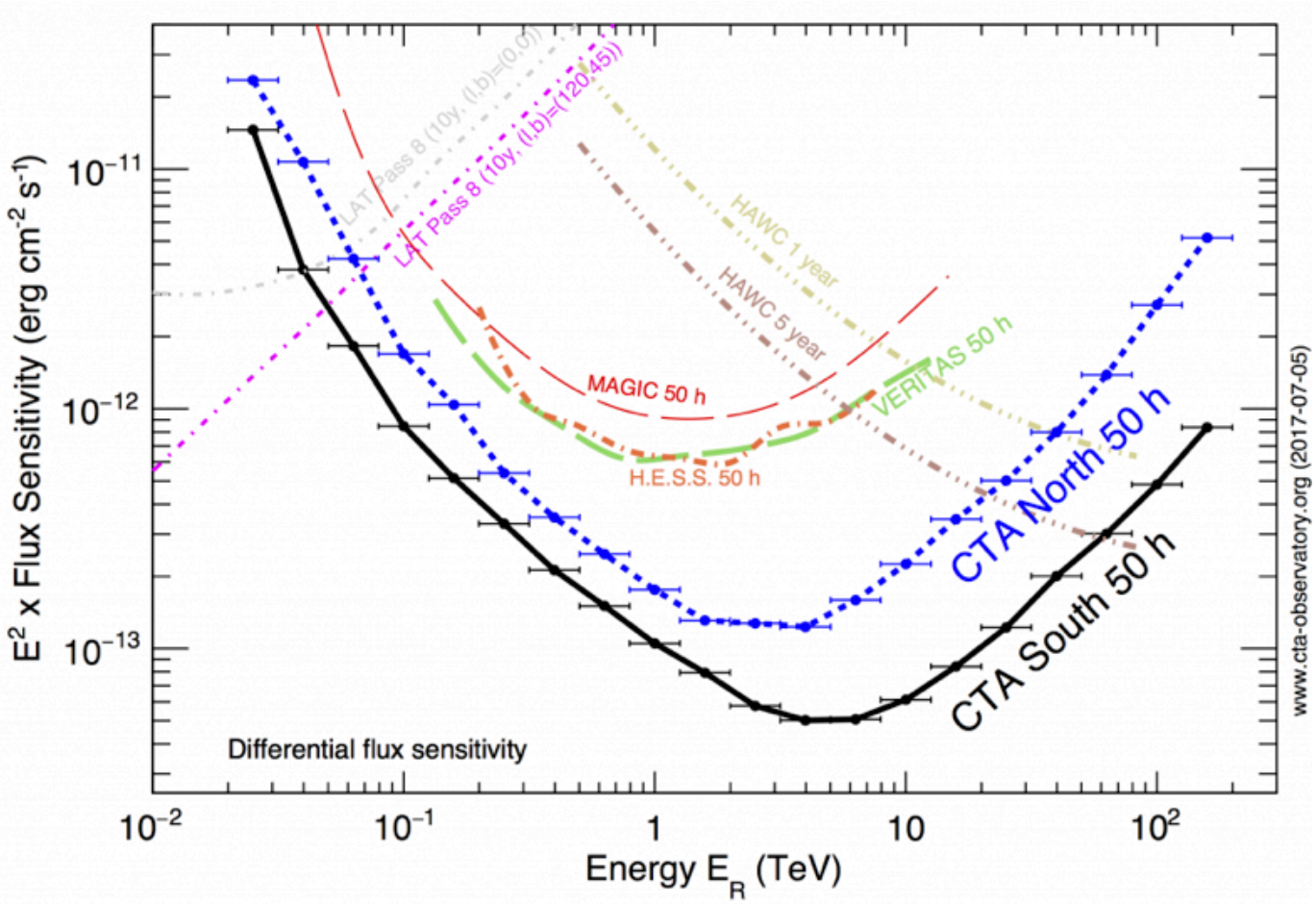
12m-MST, Zeuten, Germany

Construction of the 23m-LST1 already started in La Palma!
https://www.cta-observatory.org/about/array-locations/la-palma/

10m-SCT, FLWO, USA

CTA: Profile

- Energy range ~20 GeV to >300 TeV (10x better E coverage than before)
- An order of magnitude better sensitivity at TeV energies
- Larger field of view so far (4.5 to 9 deg., depending on energy)
- Improved angular resolution (~arcminute scale at >0.1TeV)
- Full sky coverage (combining North+South sites)



CTA: Science

Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles

- What are the sites of high-energy particle acceleration in the universe?
- What are the mechanisms for cosmic particle acceleration?
- What role do accelerated particles play in feedback on star formation and galaxy evolution?

http://arxiv.org/abs/1709.07997

CTA: Science

Theme 2: Probing Extreme Environments

- What physical processes are at work close to neutron stars and black holes?

- What are the characteristics of relativistic jets, winds and explosions?

- How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?

http://arxiv.org/abs/1709.07997

CTA: Science

Theme 3: Exploring Frontiers in Physics

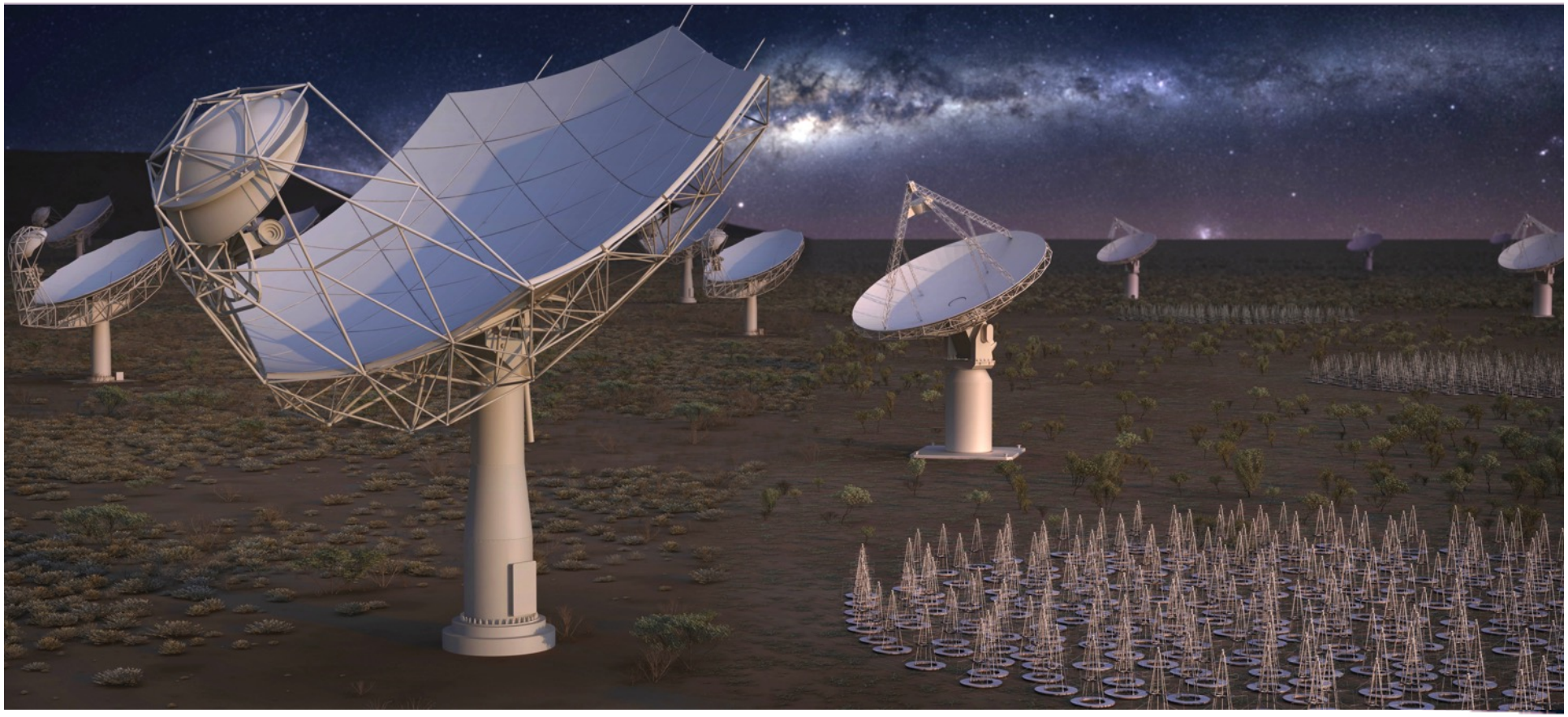
- What is the nature of dark matter? How is it distributed?

- Are there quantum gravitational effects on photon propagation?

- Do axion-like particles exist?

All this science will be developed by a number of CTA Key Science Projects

http://arxiv.org/abs/1709.07997

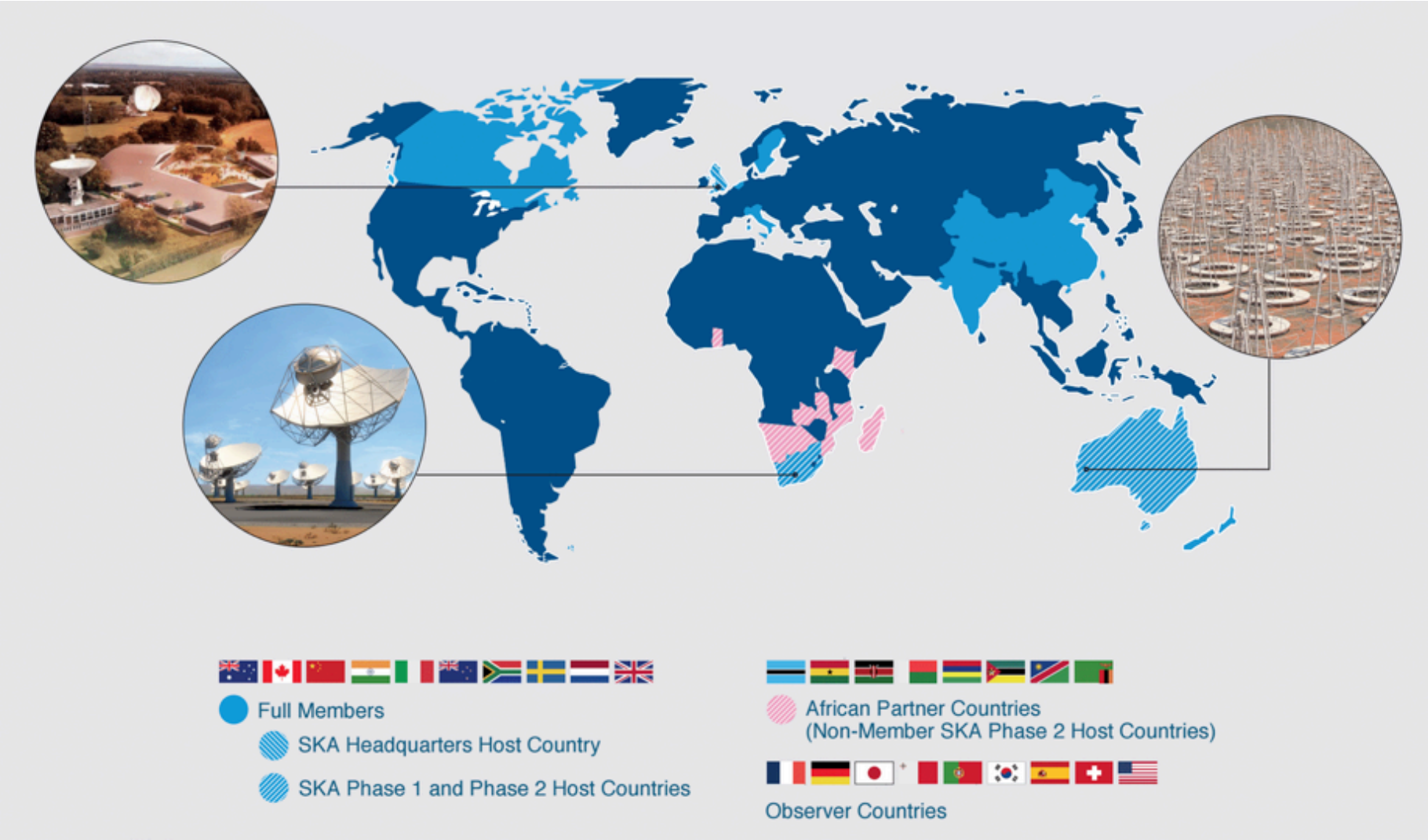


SQUARE KILOMETRE ARRAY

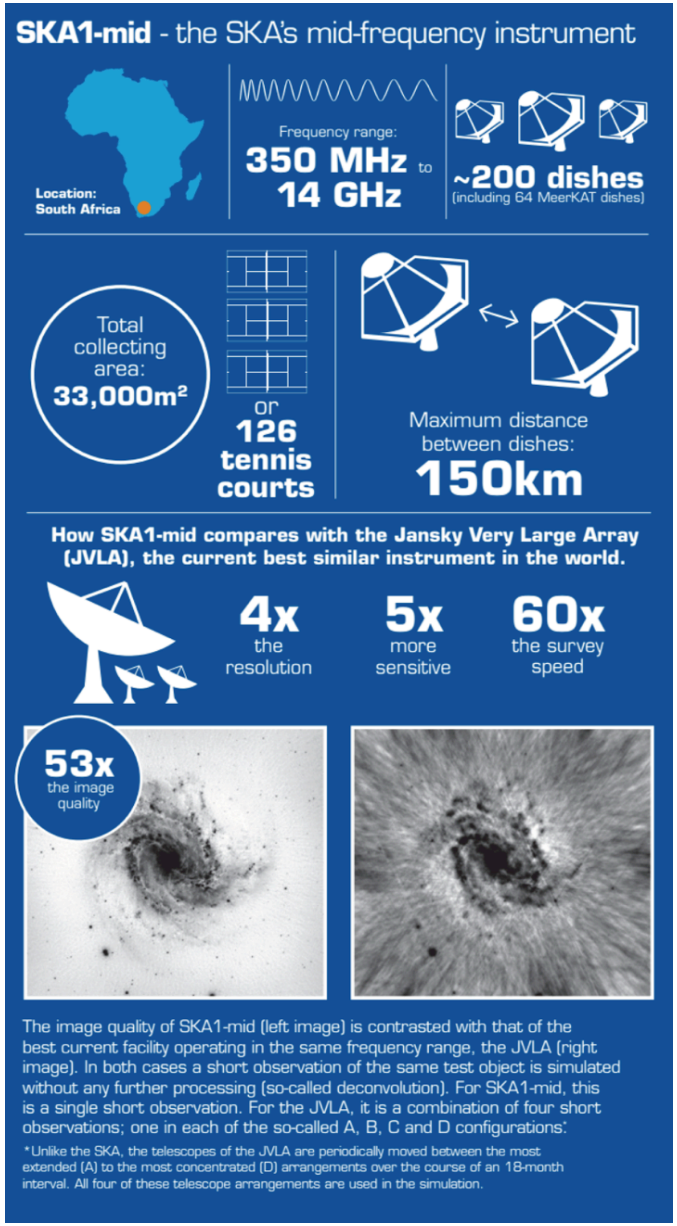
Exploring the Universe with the world's largest radio telescope

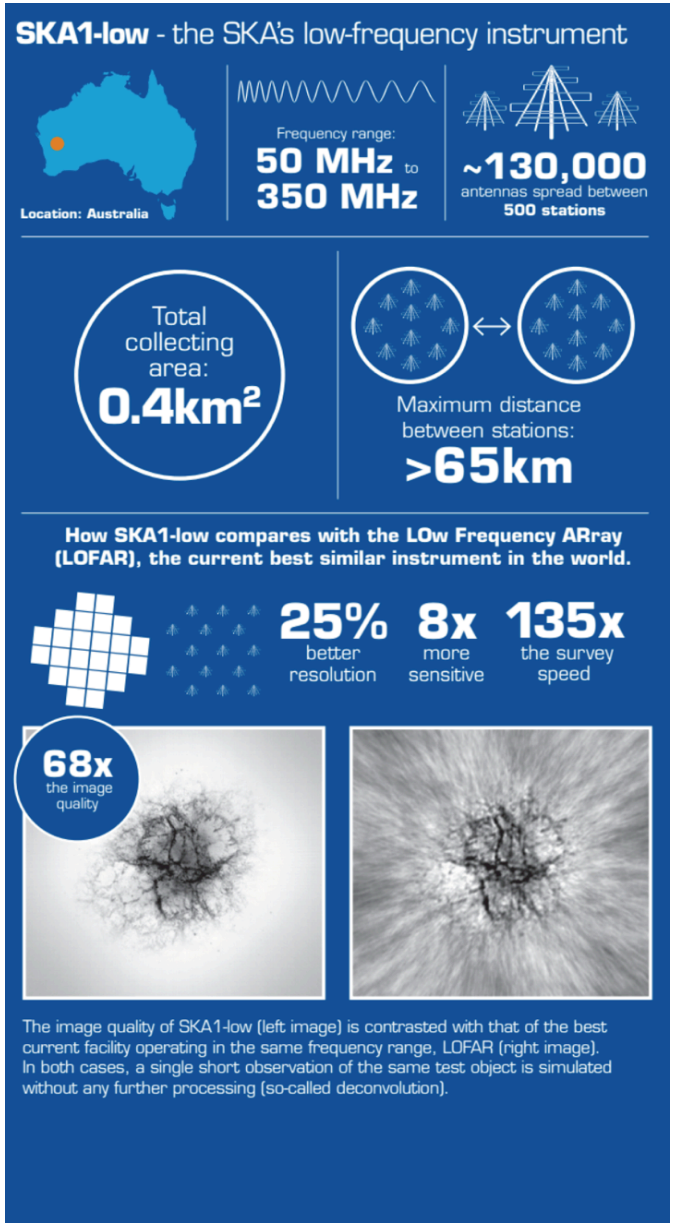
http://skatelescope.org/

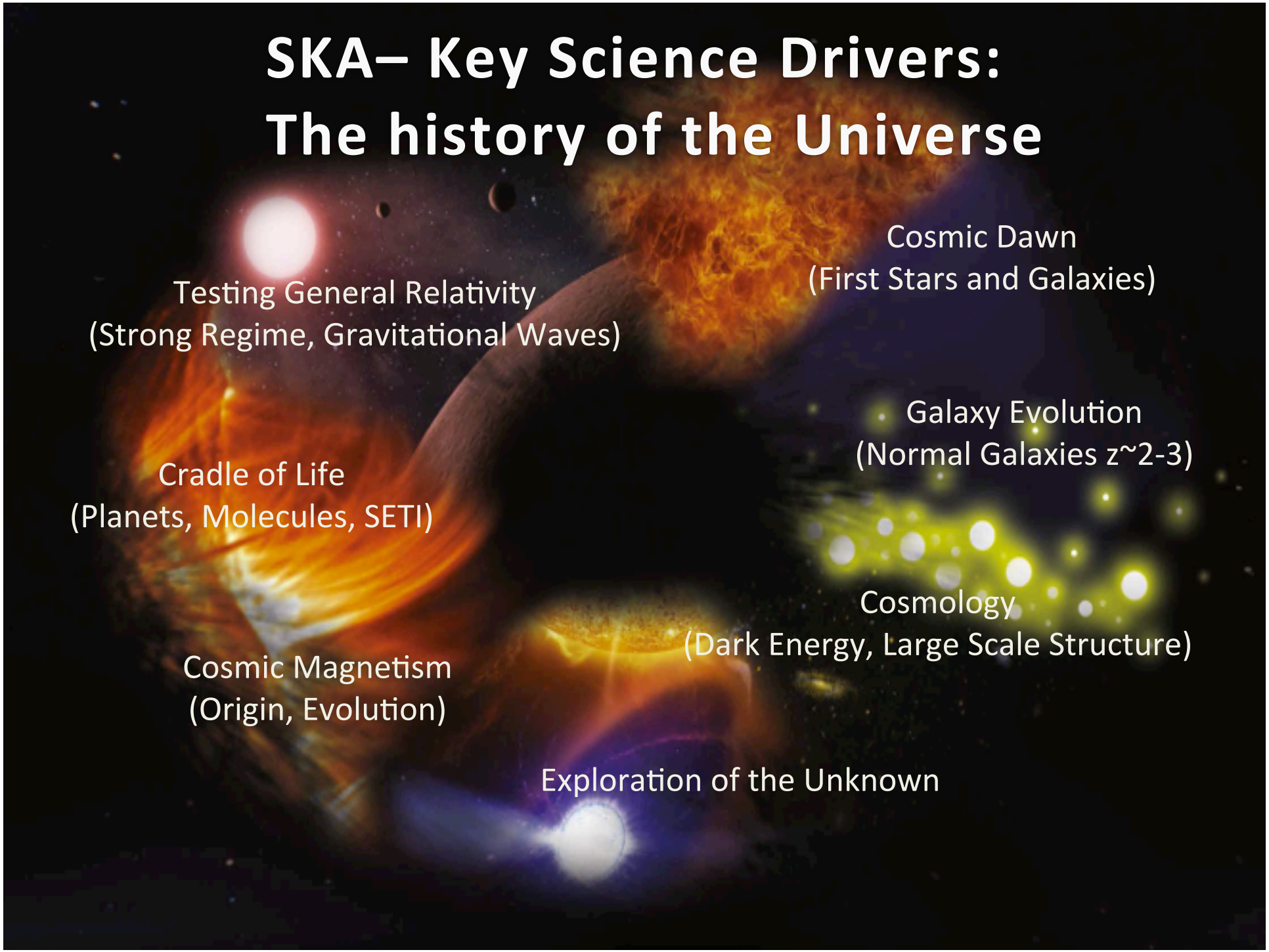
SKA: One observatory, three sites



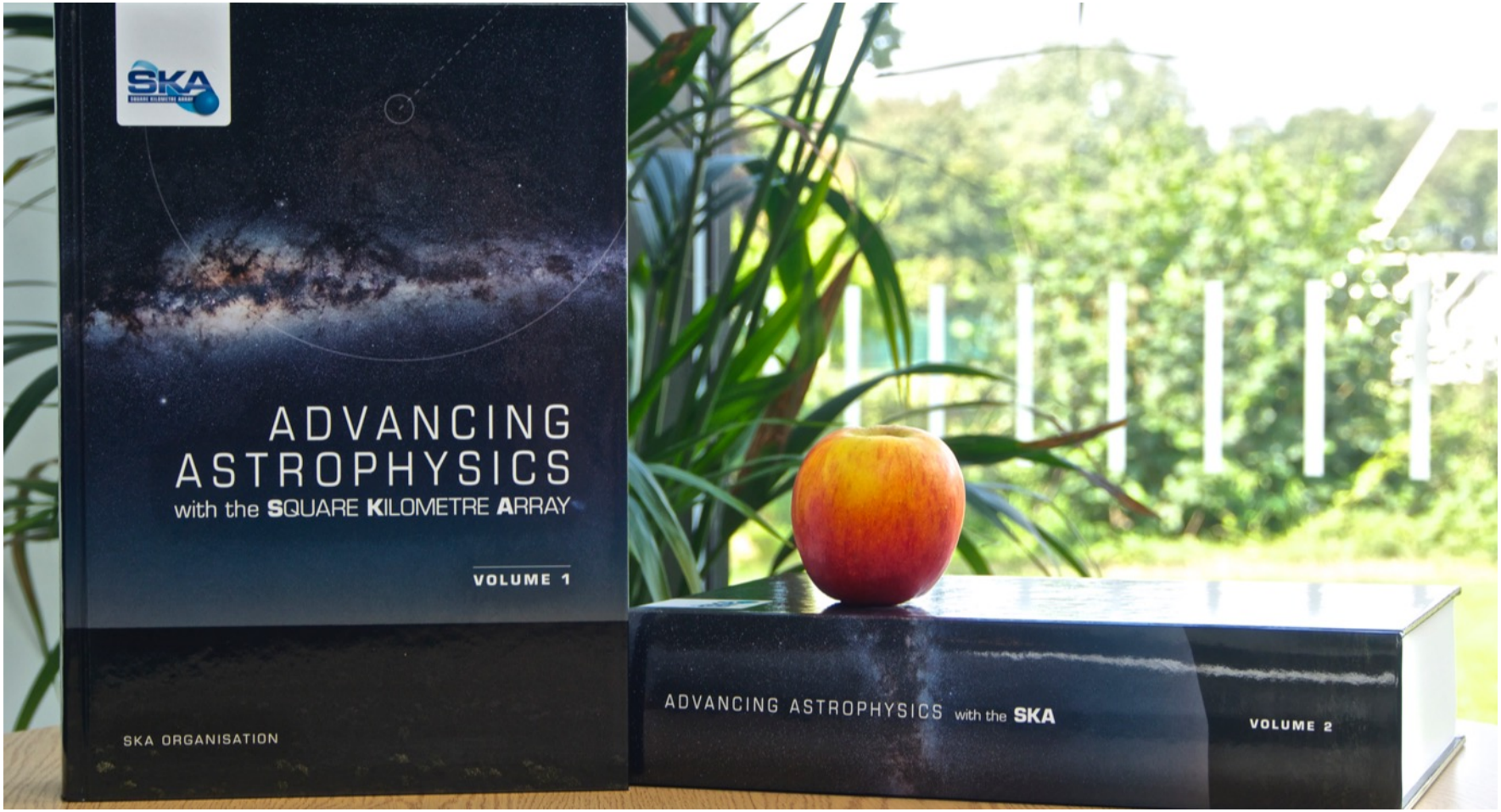
SKA: Profile


SKA1-mid - the SKA's mid-frequency instrument
Location: South Africa
Frequency range:
350 MHz to 14 GHz
~200 dishes
(including 64 MeerKAT dishes)
Total collecting area:
33,000m²
or
126 tennis courts
Maximum distance between dishes:
150km
How SKA1-mid compares with the Jansky Very Large Array (JVLA), the current best similar instrument in the world.
4x the resolution
5x more sensitive
60x the survey speed
53x the image quality
The image quality of SKA1-mid (left image) is contrasted with that of the best current facility operating in the same frequency range, the JVLA (right image). In both cases a short observation of the same test object is simulated without any further processing (so-called deconvolution). For SKA1-mid, this is a single short observation. For the JVLA, it is a combination of four short observations; one in each of the so-called A, B, C and D configurations*.
*Unlike the SKA, the telescopes of the JVLA are periodically moved between the most extended (A) to the most concentrated (D) arrangements over the course of an 18-month interval. All four of these telescope arrangements are used in the simulation.


SKA1-low - the SKA's low-frequency instrument
Location: Australia
Frequency range:
50 MHz to 350 MHz
~130,000
antennas spread between
500 stations
Total collecting area:
0.4km²
Maximum distance between stations:
>65km
How SKA1-low compares with the LOw Frequency ARray (LOFAR), the current best similar instrument in the world.
25% better resolution
8x more sensitive
135x the survey speed
68x the image quality
The image quality of SKA1-low (left image) is contrasted with that of the best current facility operating in the same frequency range, LOFAR (right image). In both cases, a single short observation of the same test object is simulated without any further processing (so-called deconvolution).


SKA– Key Science Drivers:
The history of the Universe
Cosmic Dawn
(First Stars and Galaxies)
Testing General Relativity
(Strong Regime, Gravitational Waves)
Galaxy Evolution
(Normal Galaxies z~2-3)
Cradle of Life
(Planets, Molecules, SETI)
Cosmology
(Dark Energy, Large Scale Structure)
Cosmic Magnetism
(Origin, Evolution)
Exploration of the Unknown

SKA: Science Book

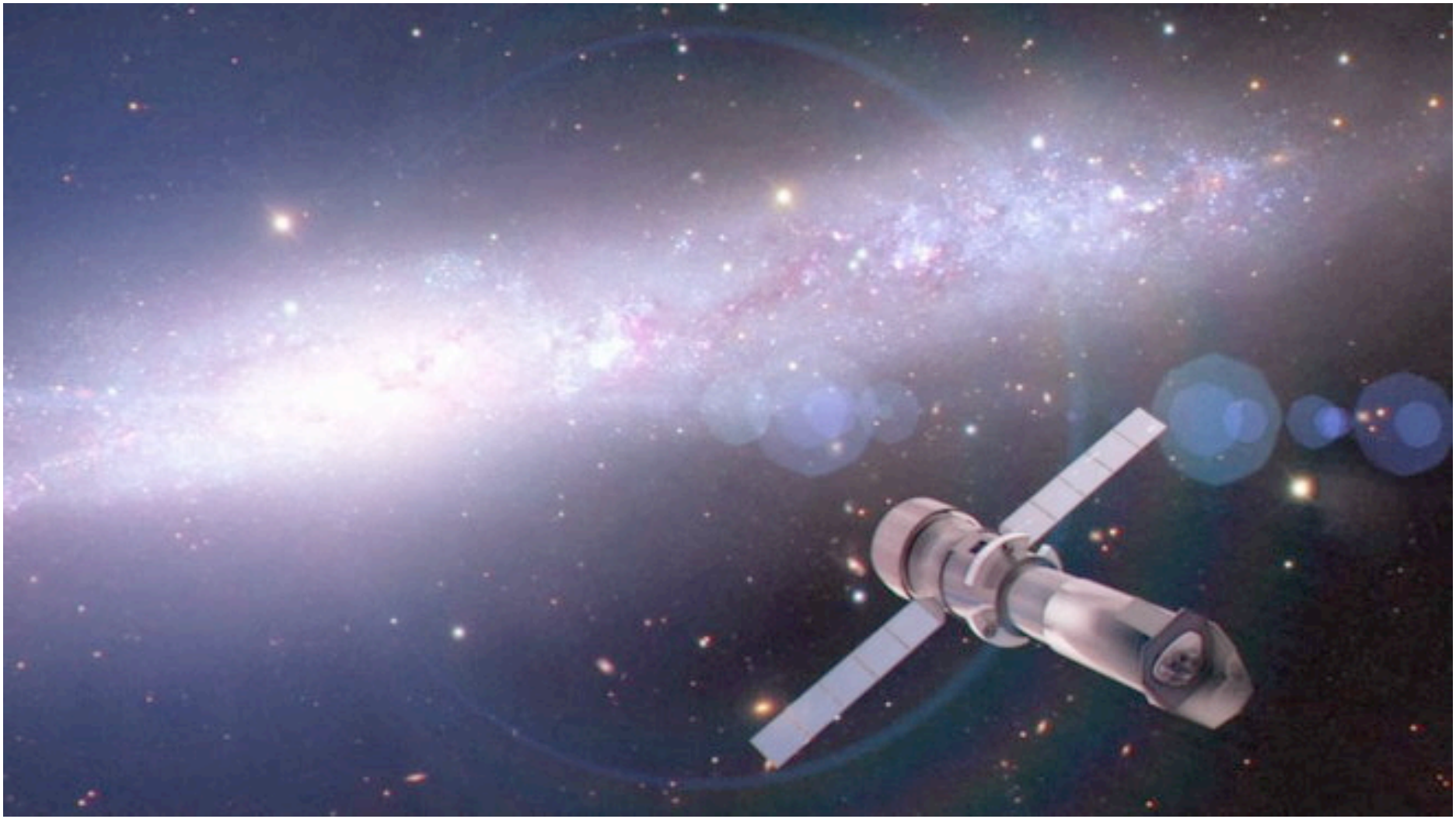


135 Chapters, 2000 pages, 8.8 kg

Plus new science directions that continue to emerge!

https://skatelescope.org/news/ska-science-book/

ATHENA

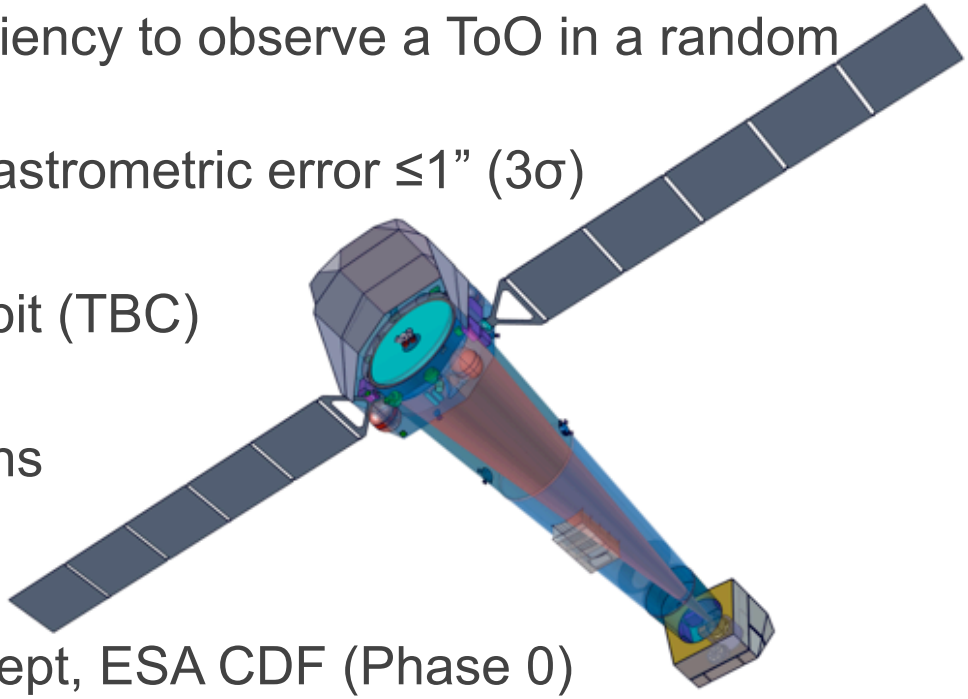


L2 mission of ESA 2015-2035 http://www.the-athena-x-ray-observatory.eu

The Athena X-Ray Observatory: Mission Concept

- Single telescope, Silicon Pore Optics (SPO) technology, 12 m focal length, 1.4-2 m2 area@1 keV, 0.25 m2 @6 keV
    - WFI (Active Pixel Sensor Si detector): wide-field (40'x40') spectral-imaging, CCD-like energy resolution (120-150 eV@6 keV)
    - X-IFU (cryogenic imaging spectrometer): 2.5 eV energyresolution, 5'x5' field-of-view, ~5" pixel size

- Defocusing capability increases count rate dynamical range
- ≥4 hours response with a ≤50% efficiency to observe a ToO in a random position in the sky
- Metrology system to achieve a final astrometric error ≤1" (3σ)
- Launch 2028, Ariane 6.4, L2 halo orbit (TBC)
- Nominal life-time 4 years + extensions



Athena concept, ESA CDF (Phase 0)

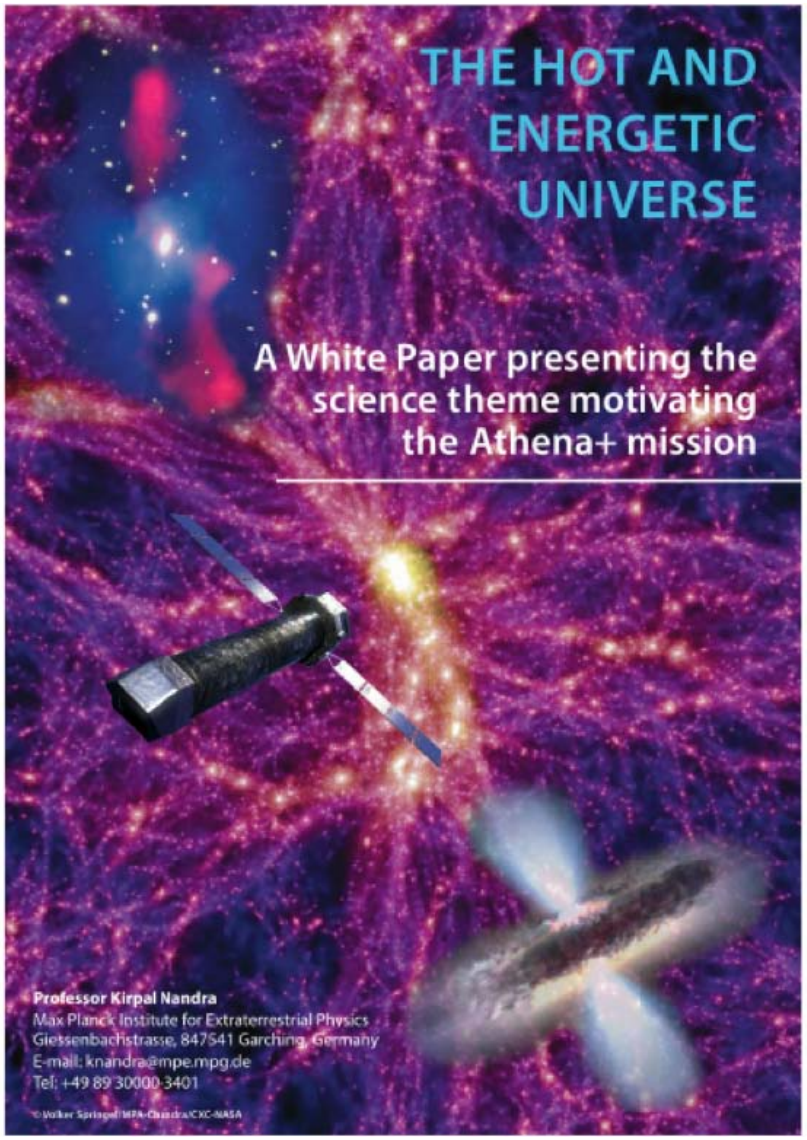
The Athena X-Ray Observatory: Science

- The Hot Universe: How does the ordinary matter assemble into the large-scale structures that we see today?
  - >50% of the baryons today are in a hot (>10^6 K) phase
  - there are as many hot (> 10^7 K) baryons in clusters as in stars over the entire Universe

- The Energetic Universe: How do black holes grow and influence the Universe?
  - Building a SMBH releases ~30x the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays

- Also, observatory science across all corners of Astrophysics

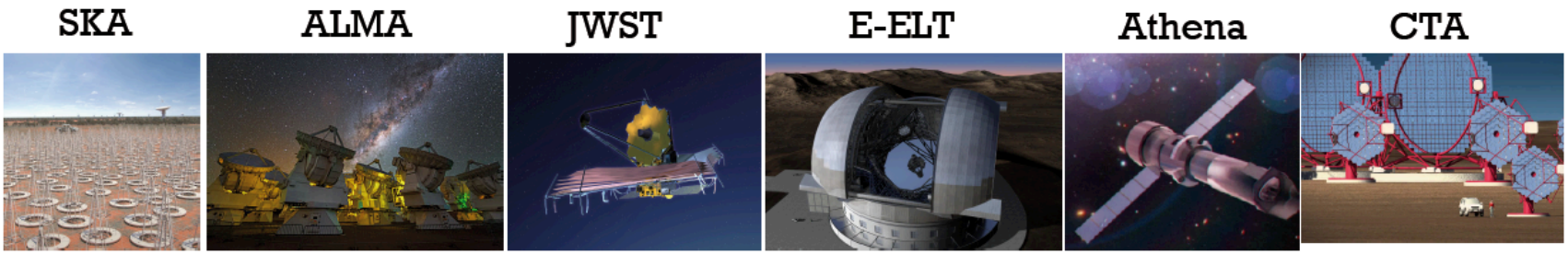
(fast reaction ToO capability to study transient sources)

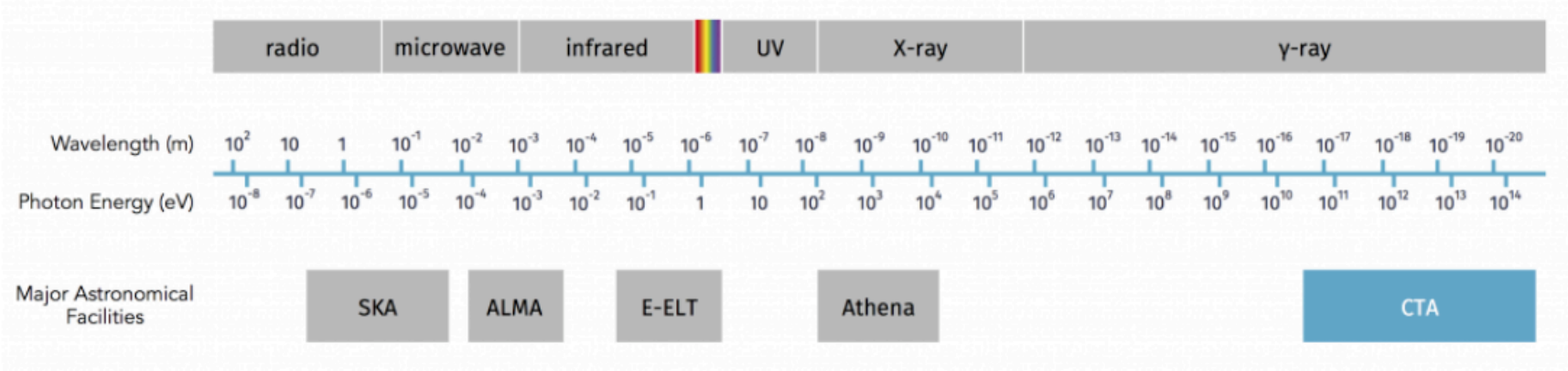


Nandra, Barret, Barcons et al. arXiv:1306.2307

Synergies between CTA, SKA, and Athena

Exploring Synergies between CTA, SKA and Athena





- Since the observatories are spread over the entire electromagnetic spectrum

- Synergies between them lie mainly (but not only) on study of non-thermal astrophysical processes along the entire electromagnetic spectrum

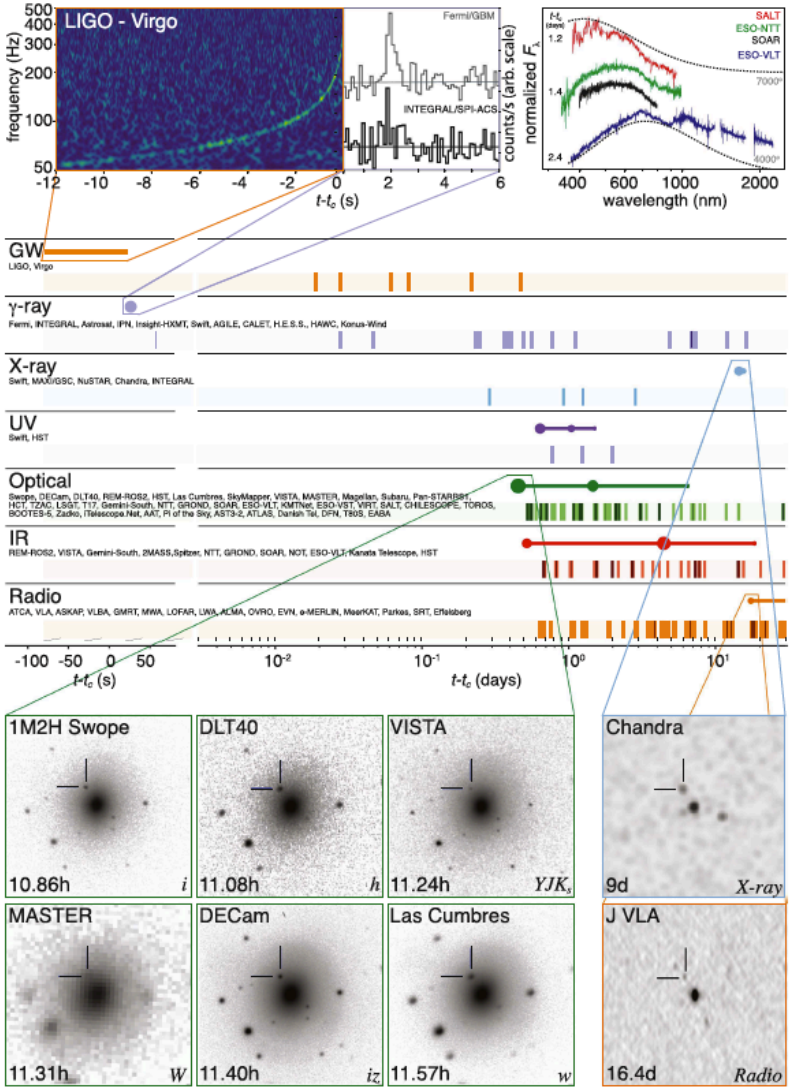
Exploring Synergies between CTA, SKA and Athena

List of potential scientific synergies on the study of:

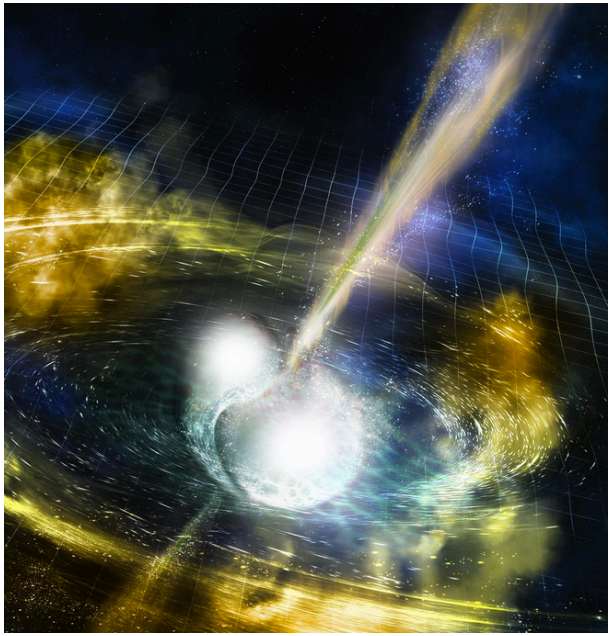
- Gravitational wave - electromagnetic event studies
- Other transient and/or explosive phenomena (e.g. neutrino sources, TDEs, FRBs, GRBs)
- Sgr A* and the Galactic Plane
- AGN jet studies, also cosmology of radio loud AGN
- Galaxy clusters

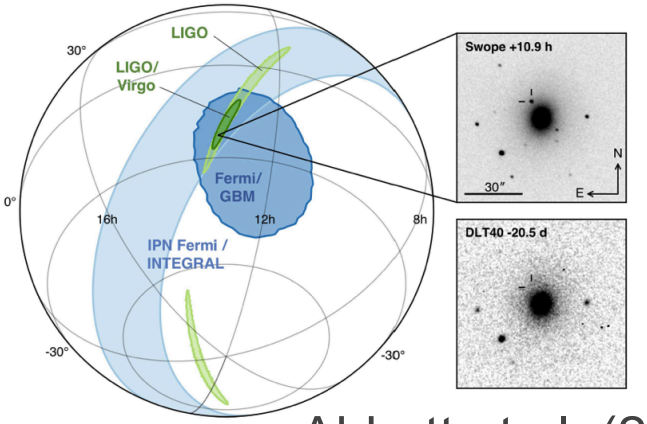
Exploring Synergies between CTA, SKA and Athena

Gravitational wave-electromagnetic event studies: GW170817



Abbott et al. (2017)



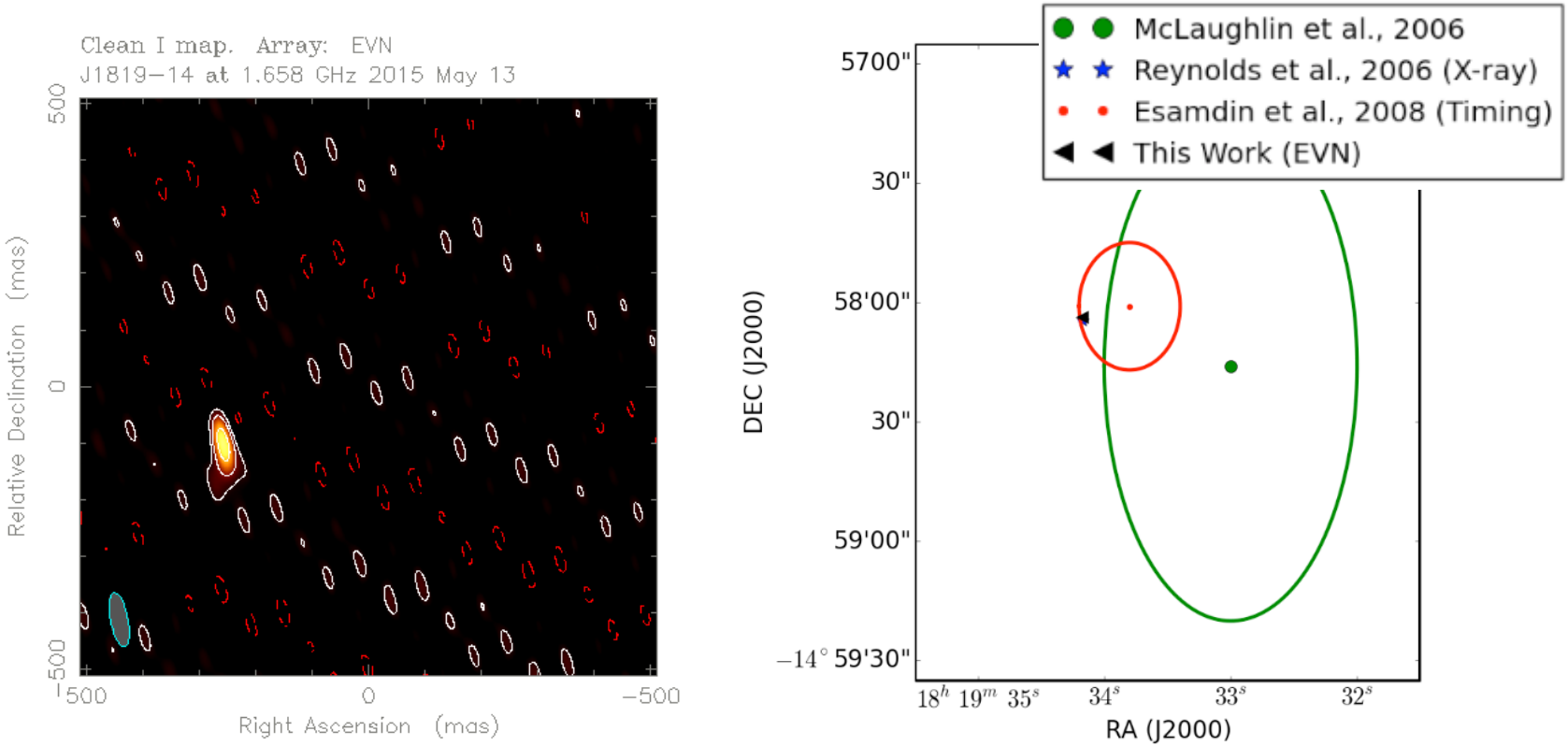


Abbott et al. (2017)

Exploring Synergies between CTA, SKA and Athena

SKA, and SKA-VLBI localization of transients in support of CTA+Athena

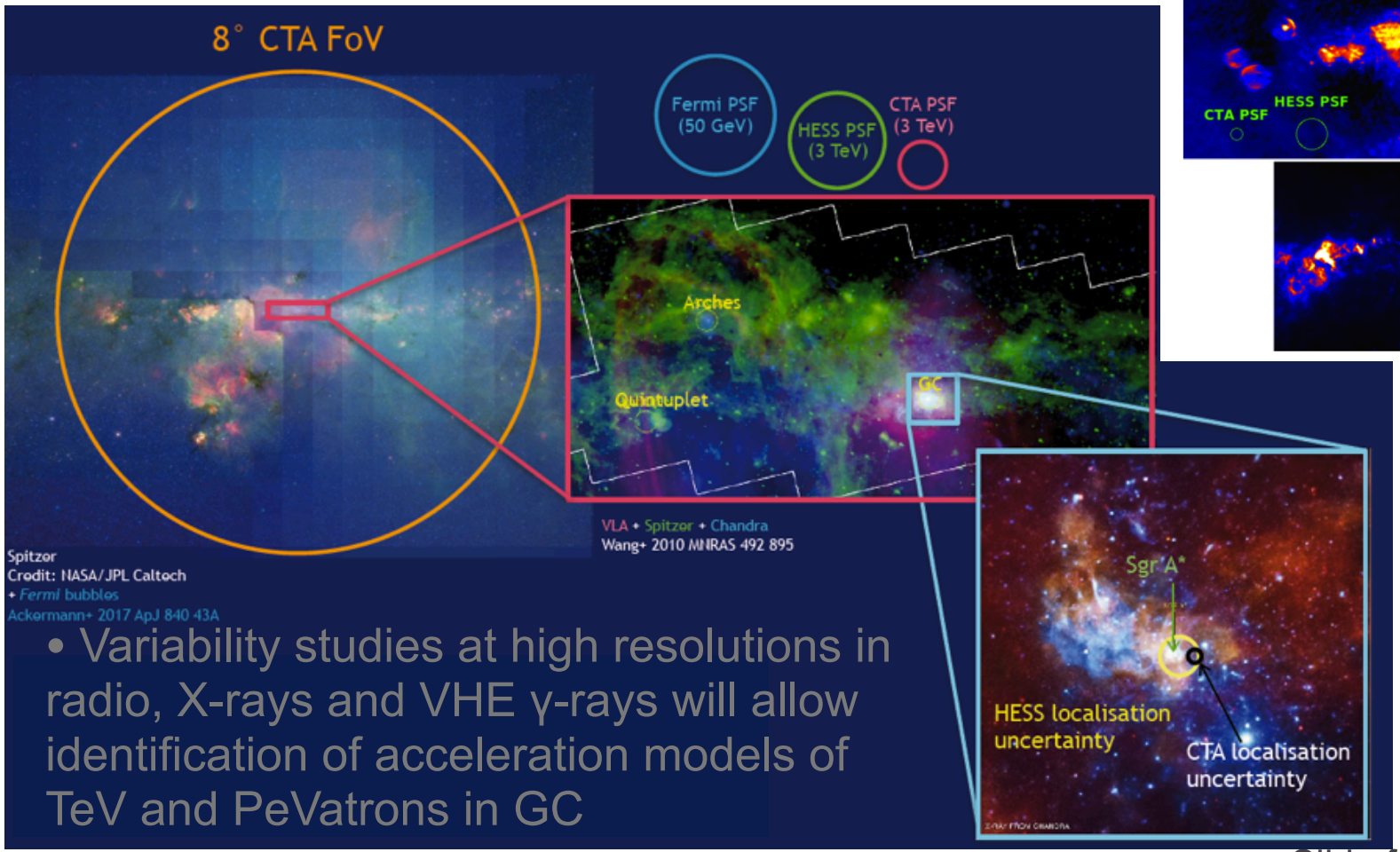
Precise (arcsecond and/or milliarcsecond) localization of transients and proper motion characterization (e.g. TDEs, FRBs, GRBs, v's, etc)

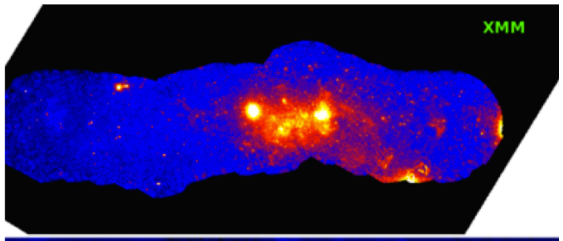


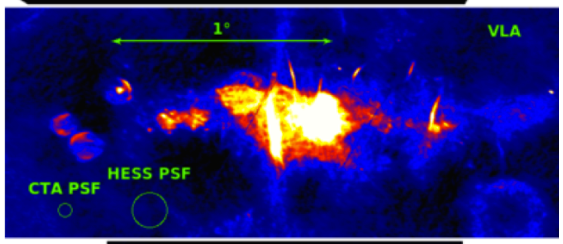
Paragi, Wen, Keimpema, Siemion et al. (preliminary)

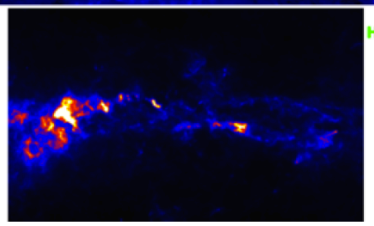
Exploring Synergies between CTA, SKA and Athena

Sgr A* and the Galactic Plane:









- Variability studies at high resolutions in radio, X-rays and VHE γ-rays will allow identification of acceleration models of TeV and PeVatrons in GC

Slide from L. Tibaldo

Exploring Synergies between CTA, SKA and Athena

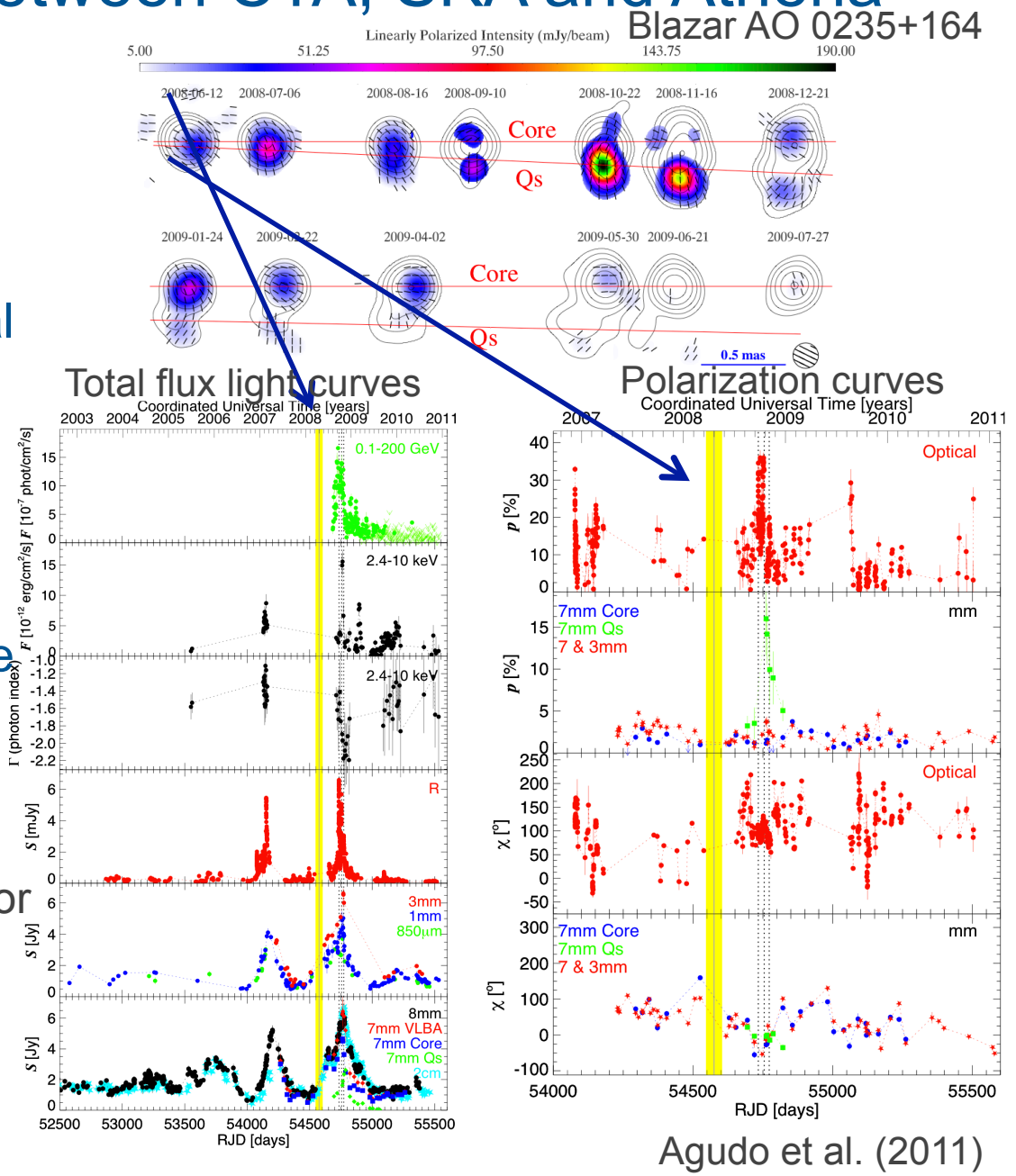
The blazar enigma:

Total flux, and polarization evolution curves has demonstrated to be instrumental

Emission processes at high energies and particle acceleration mechanisms

VLBI crucial to have an absolute localization of the relevant emission regions

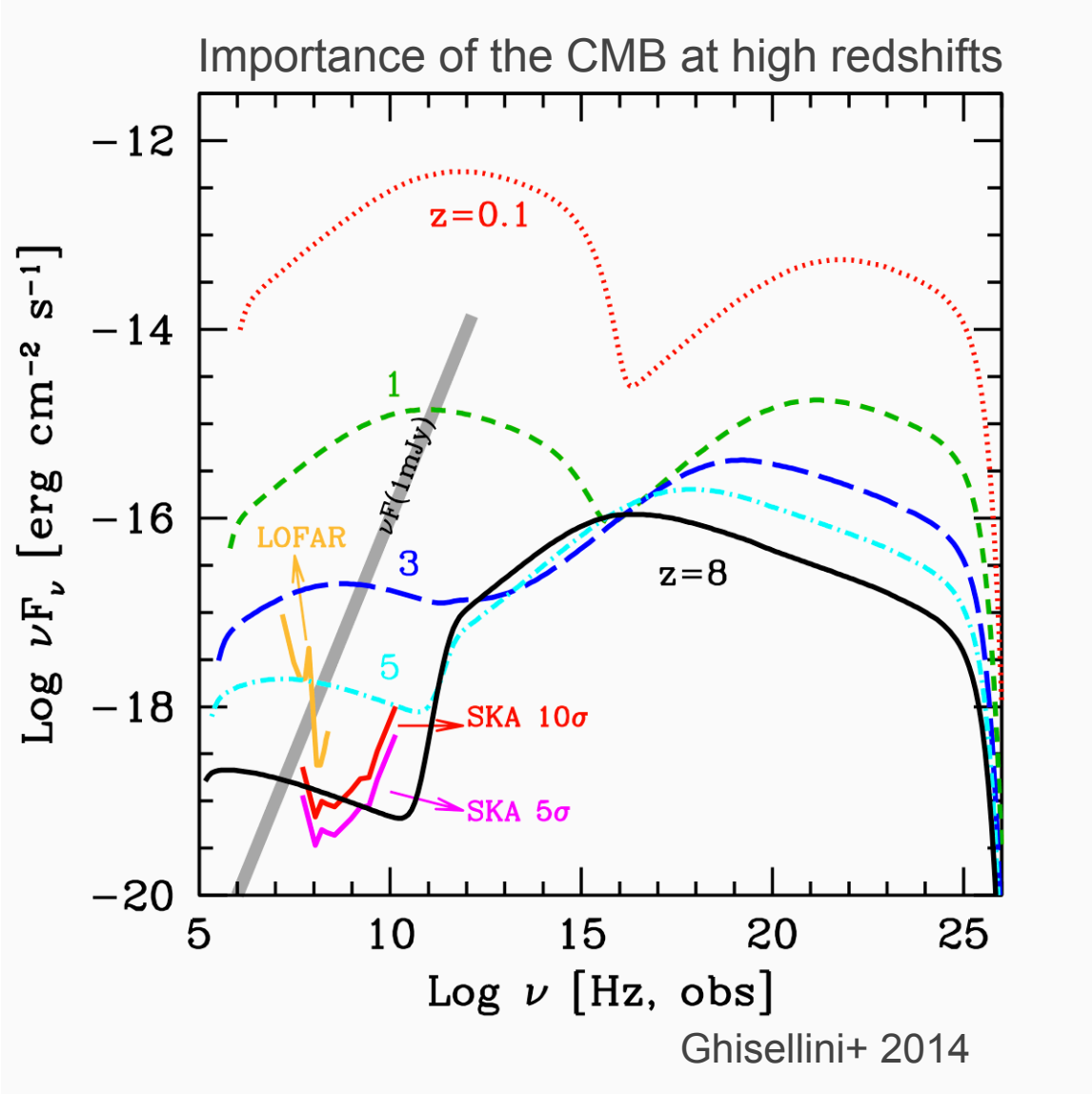
- However, this is done so far only for a handful of sources only and the actual emision and acceleration mechanisms are still not well constrained.



Agudo et al. (2011)

Exploring Synergies between CTA, SKA and Athena

Powerful AGN jets along cosmic time:



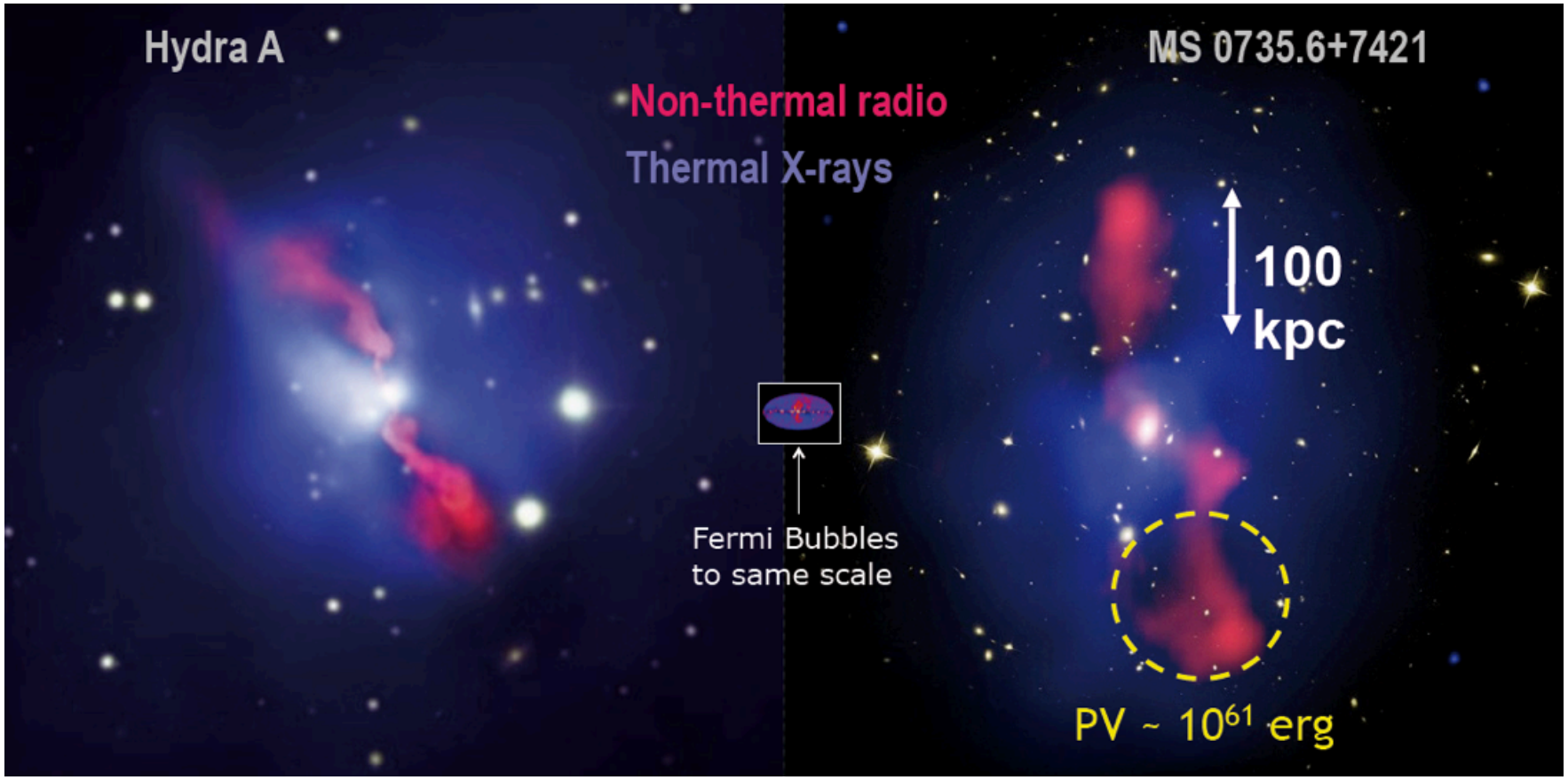
Relevant problem: Detection of radio loud AGN at high z (≳8)

Has recently been demonstrated to be feasible for SKA, and also for Athena and CTA up to z~8

Discovery space for MWL observations, to study not only the jet phenomenon at high redshifts, but also the intergalactic environment at very high z

Exploring Synergies between CTA, SKA and Athena

Clusters of galaxies:



(slide from S. Markoff)

CTA hopes to detect VHE γ-ray emisson associated to the non-thermal component of emission in clusters, which will add extra information to the comprehensive data sets provided by Athena and SKA in this field for better understanding of energetics and AGN feedback

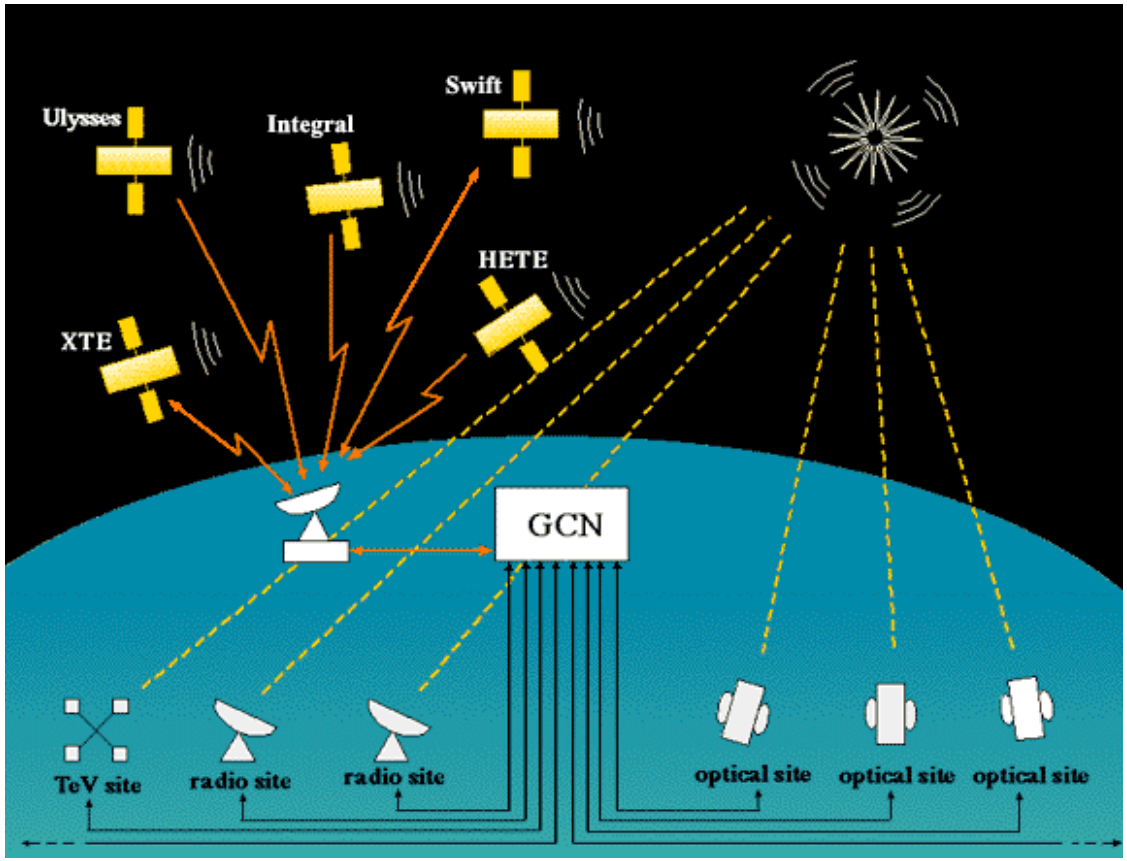
Exploring Synergies between CTA, SKA and Athena

Operational synergies:

- Development of coordinated observing programs to maximize science output

- Specially critical for transient science cases (e.g. GCN: Gamma-ray Coordination Network)

- Agreements and MoUs should be signed by facilities to share private information

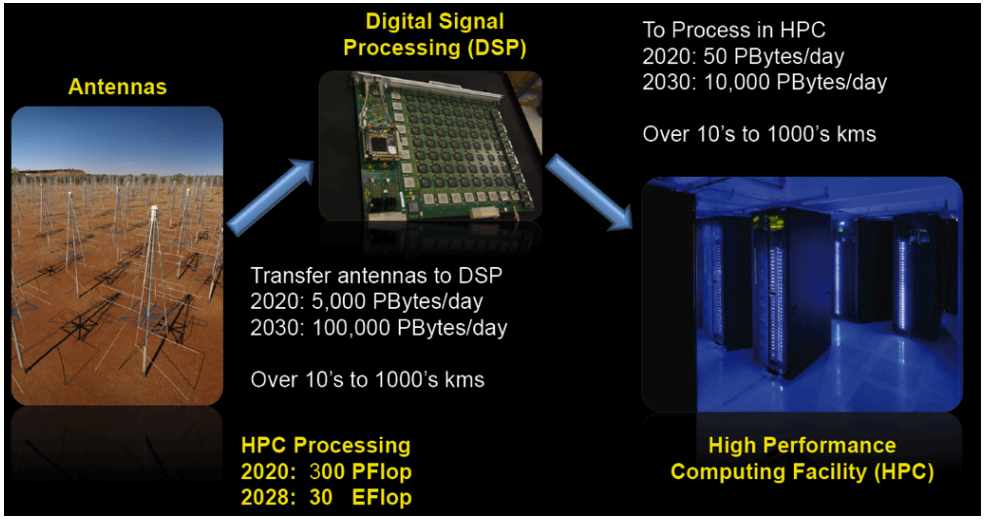


Exploring Synergies between CTA, SKA and Athena

Synergies on data management and analysis: A really serious data challenge!

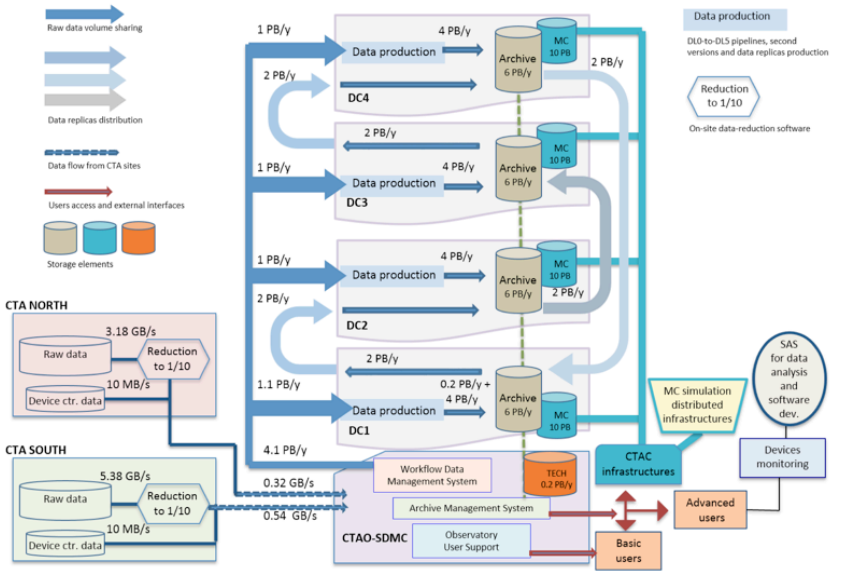
- Sharing networks on petabyte-scale data management & transfer
- Sharing experience on user access to data and analysis tools
- Sharing modern methods for reproducible astronomy and astrophysics

SKA



(slide from P. Alexander)

CTA



(credit: CTAO)

Summary:

- CTA, SKA and Athena will come online together by the end of next decade
- Unprecedented sensitivity and FoV along the electromagnetic spectrum.
- Variety of exciting science to be done together with CTA, SKA and Athena
  - Gravitational wave - electromagnetic event studies
  - Other transient and/or explosive phenomena (e.g. neutrino sources, TDEs, FRBs, GRBs)
  - Sgr A* and the Galactic Plane
  - AGN jet studies, also cosmology of radio loud AGN
  - Galaxy clusters
- Relevant synergies regarding operations, data management, user access and reliability of science outcome should also be explored

Thanks a lot for your attention!