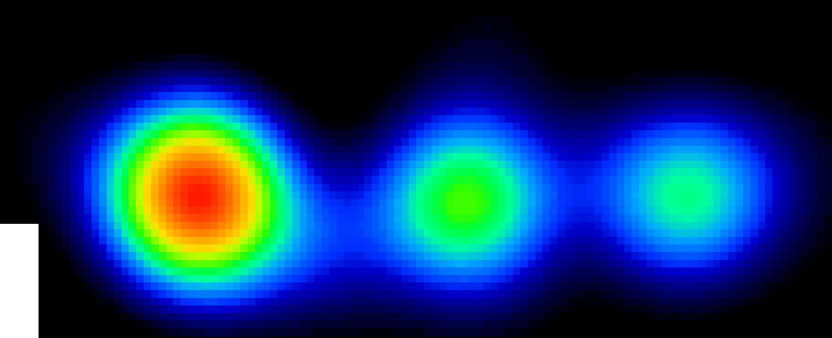
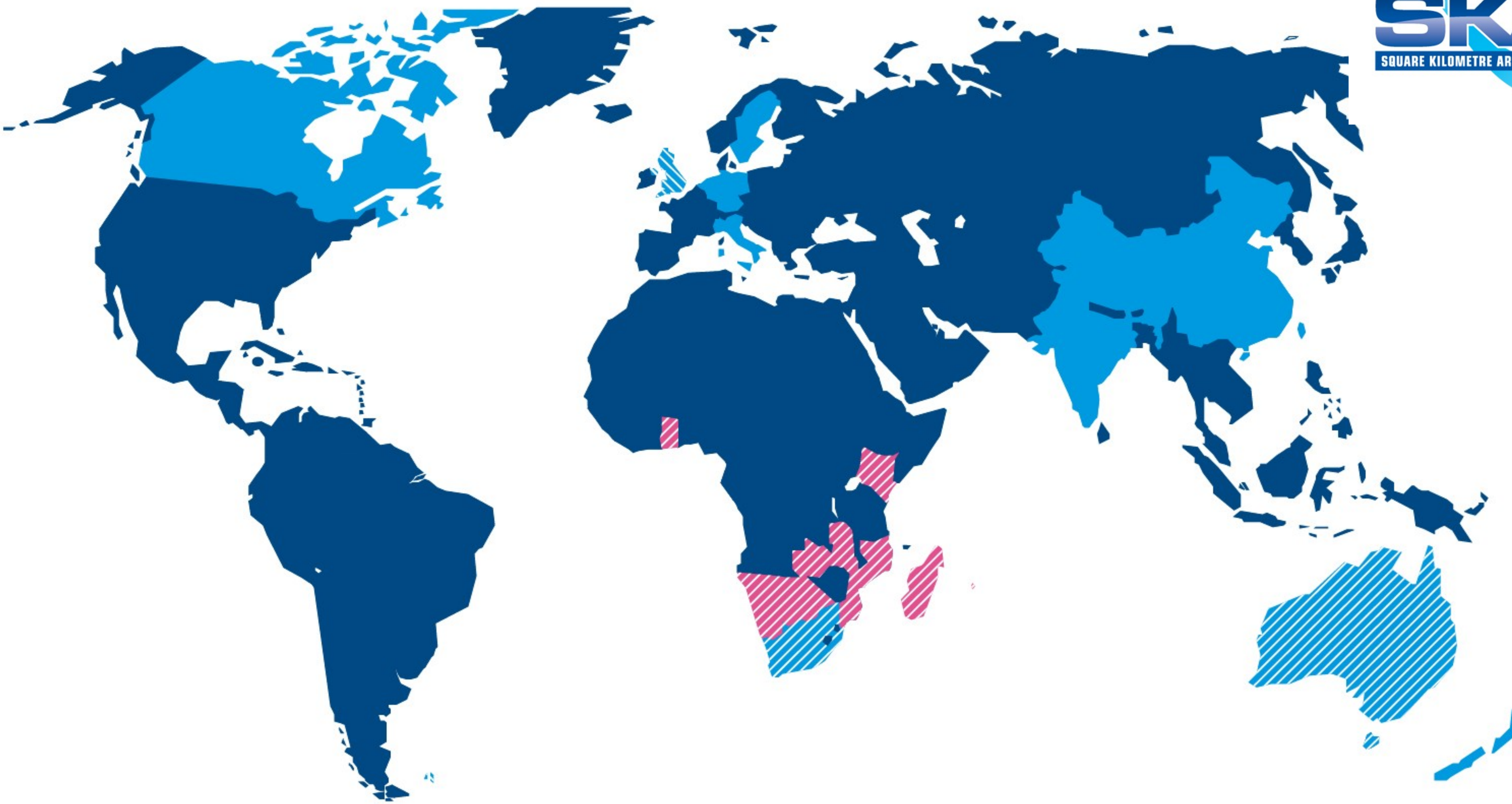
The Square Kilometre Array

Synergies between radio and X-ray surveys



Rob Fender (Oxford)



Full members

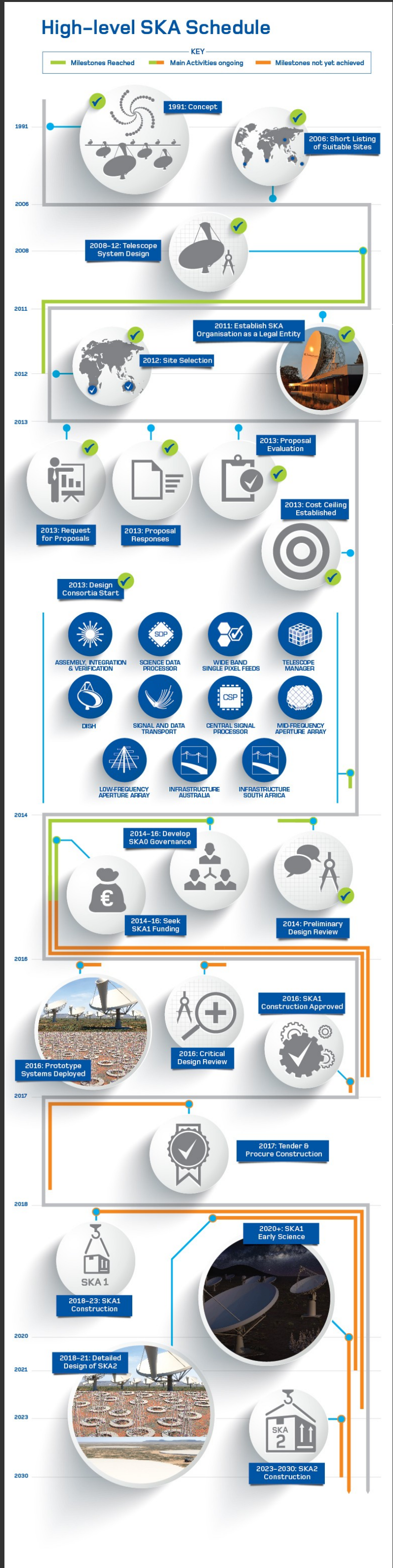
SKA Headquarters host country

SKA Phase 1 and Phase 2 host countries

African partner countries
(non-member SKA Phase 2 host countries)

This map is intended for reference only and is not meant to represent legal borders

The SKA timeline



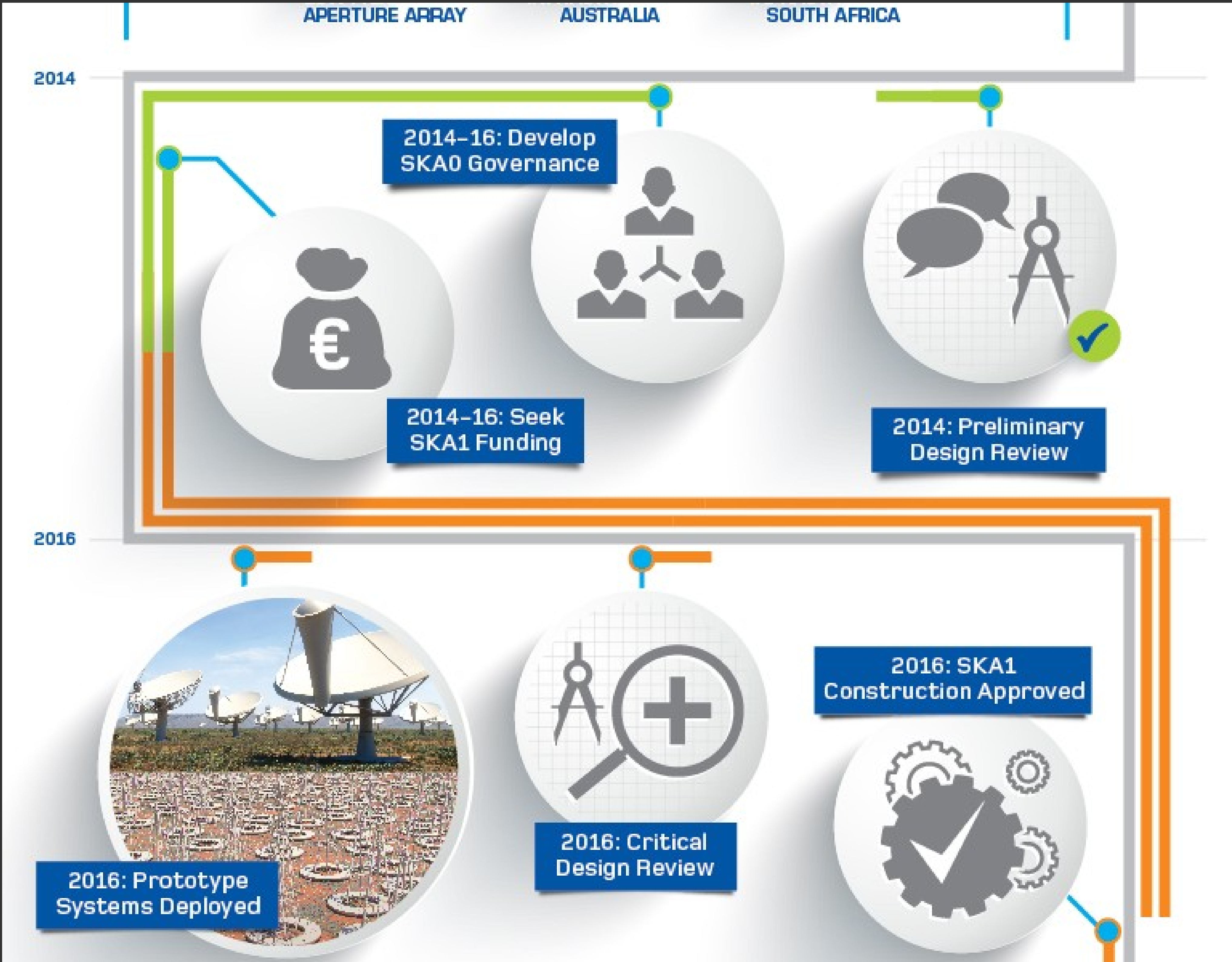
1990

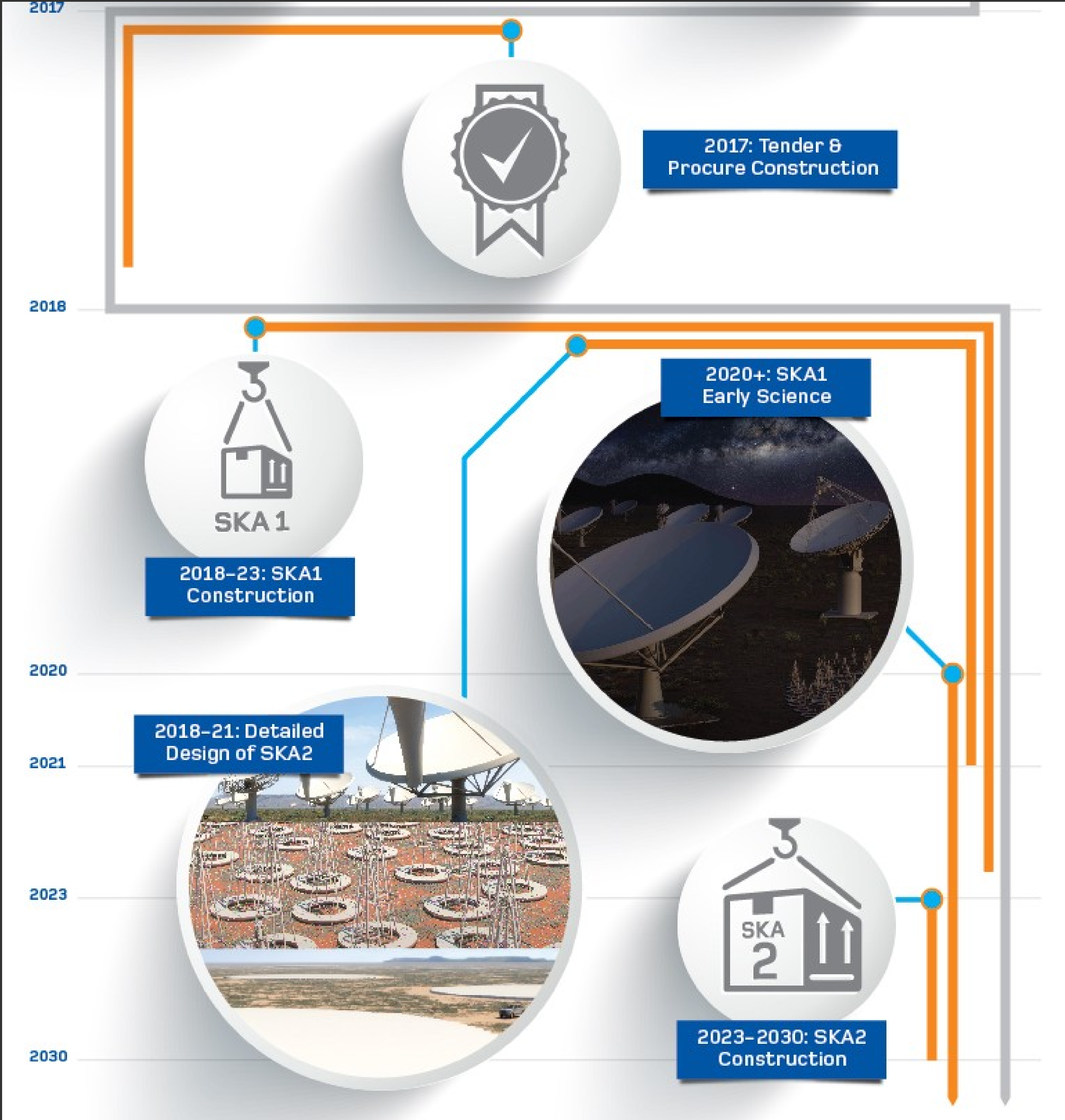
2010

NOW

(just post final site decision and “rescope” exercise)

2030


APERTURE ARRAY
AUSTRALIA
SOUTH AFRICA
2014
2014–16: Develop SKA0 Governance
2014–16: Seek SKA1 Funding
2014: Preliminary Design Review
2016
2016: Prototype Systems Deployed
2016: Critical Design Review
2016: SKA1 Construction Approved

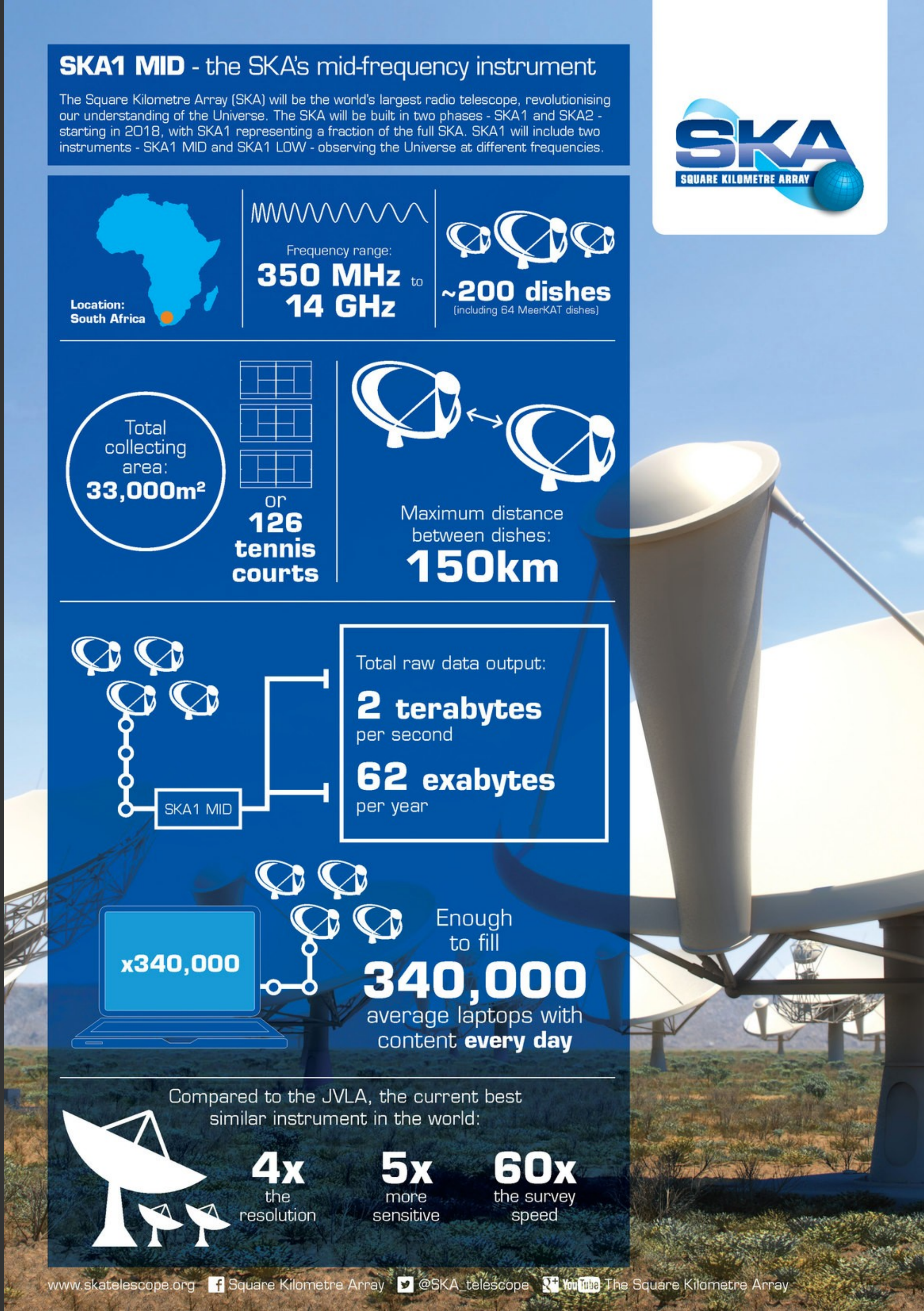


SKA SQUARE KILOMETRE ARRAY

In a nutshell:

2020s: SKA1

2030s: SKA2



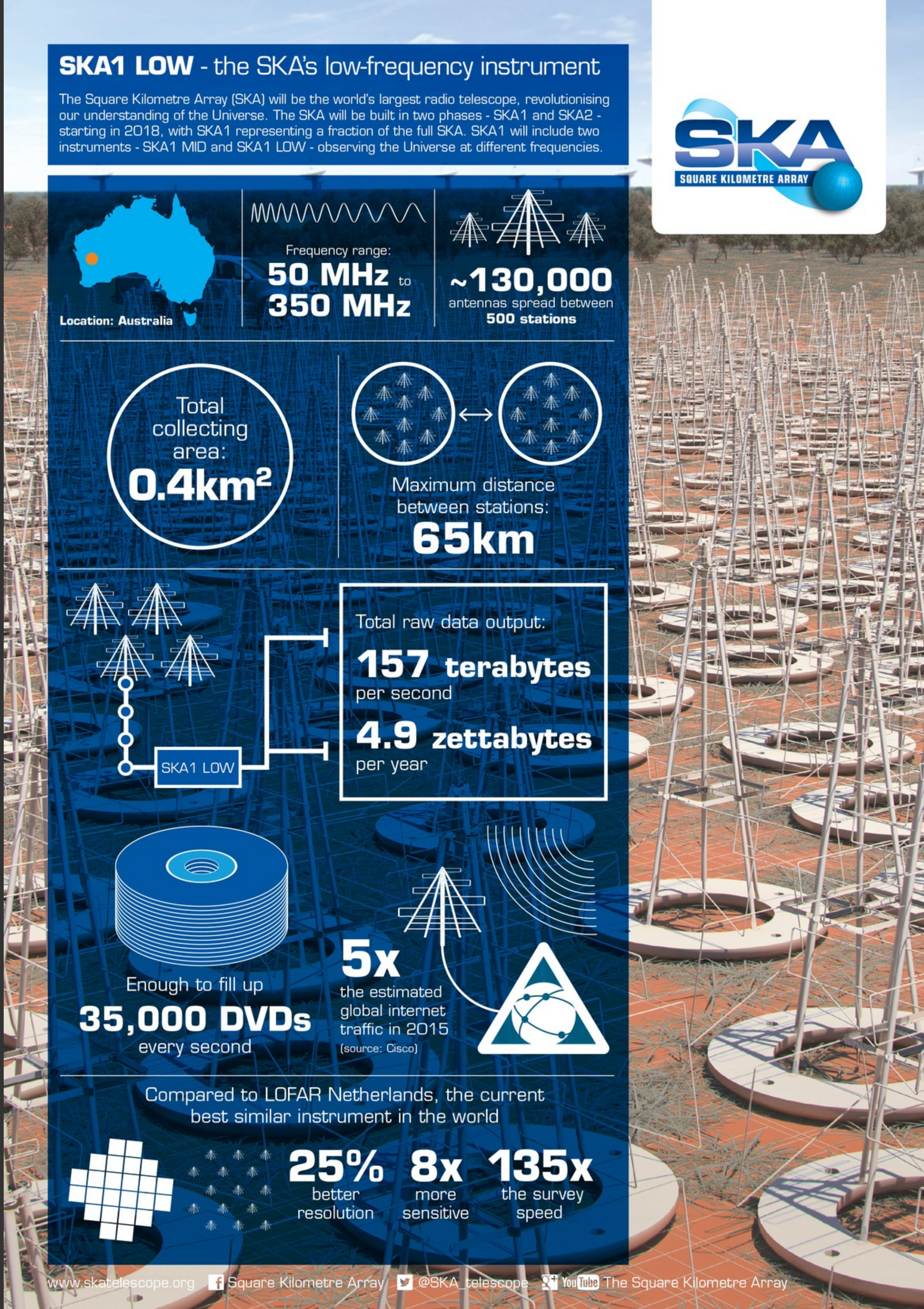
SKA1-MID: GHz frequencies (South Africa)

Large dish-based array with single-pixel feeds and wide (GHz) frequency coverage, built at MeerKAT site

Best for single point source / synchrotron flares

~1 μJy in 1 hr over 1 square degree


area:
33,000m²
or
SKA1-MID ~ Super-VLA
Compared to the JVLA, the current best similar instrument in the world:
4x the resolution
5x more sensitive
60x the survey speed
www.skatelescope.org Square Kilometre Array @SKA_telescope The Square Kilometre Array



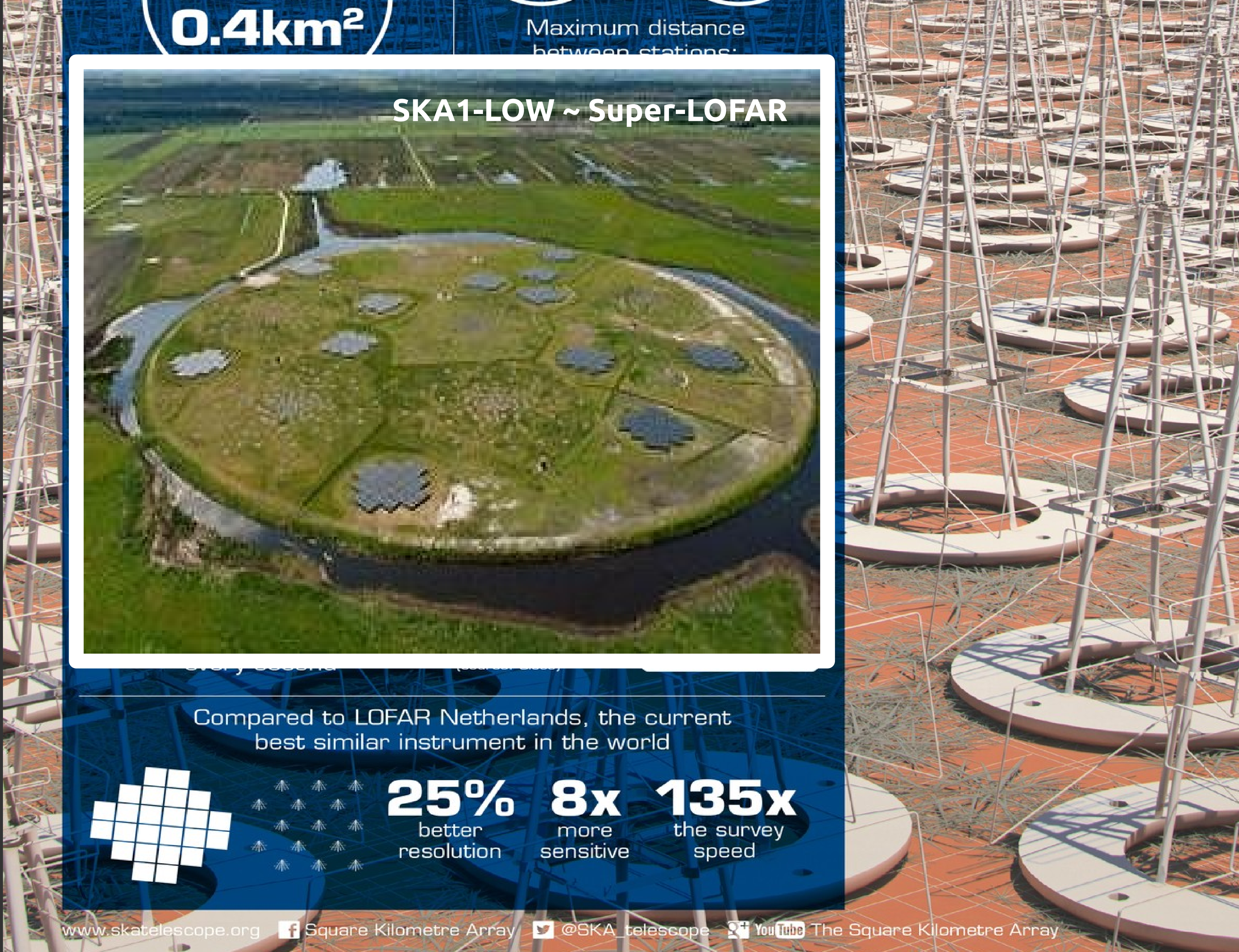
SKA1-LOW: MHz frequencies (Australia)

Dipole-based array (giant LOFAR) built at MWA site

Key science driver: EoR HI / pulsars

Excellent for surveys / coherent emission, less good for synchrotron flares

SKA1-LOW ~ Super-LOFAR



The full SKA (aka "phase II")

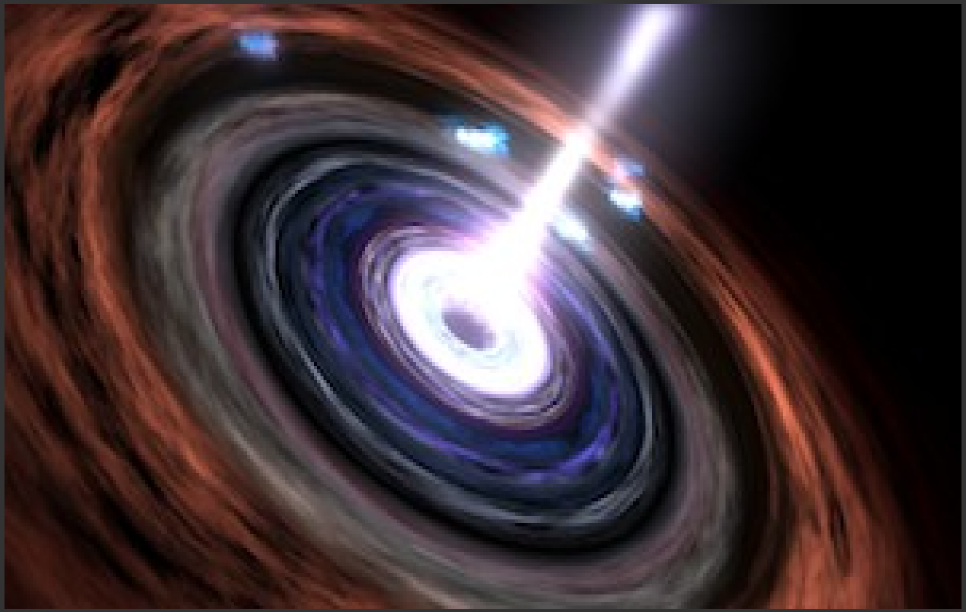
- Detailed design not yet undertaken (starting ~2018), but should be a further order of magnitude (or more) more sensitive than SKA1 and incorporate new wide-field technologies (aperture arrays up to 1 GHz, phased array feeds at higher frequencies)
- Will be built out of SKA1 in mid 2020s → same timescale as ATHENA and will regularly probe the nano-Jy universe
- Will require funding at the >1bEuro level

LOFAR/MWA/MeerKAT/ASKAP

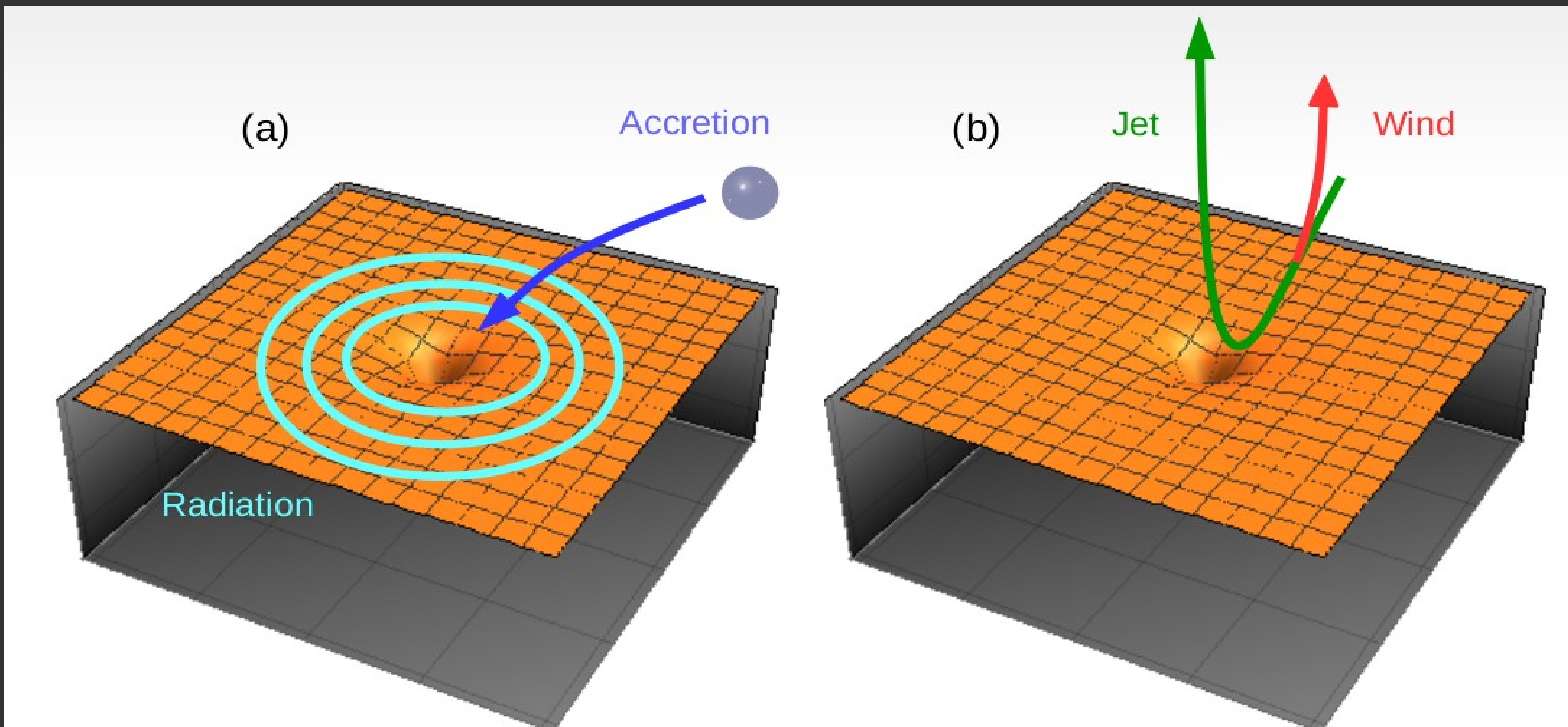
New radio telescopes operating while SKA is under construction

Radio:X-ray synergies

- Accretion processes, producing **X-ray emission** are nearly ubiquitously associated with **radio emission** originating in relativistic outflows
- The **X-rays** probe the rate and conditions in the accreting matter, the **radio** traces the kinetic feedback to the local environment (can be dominant sink of available accretion energy)



The balance of power

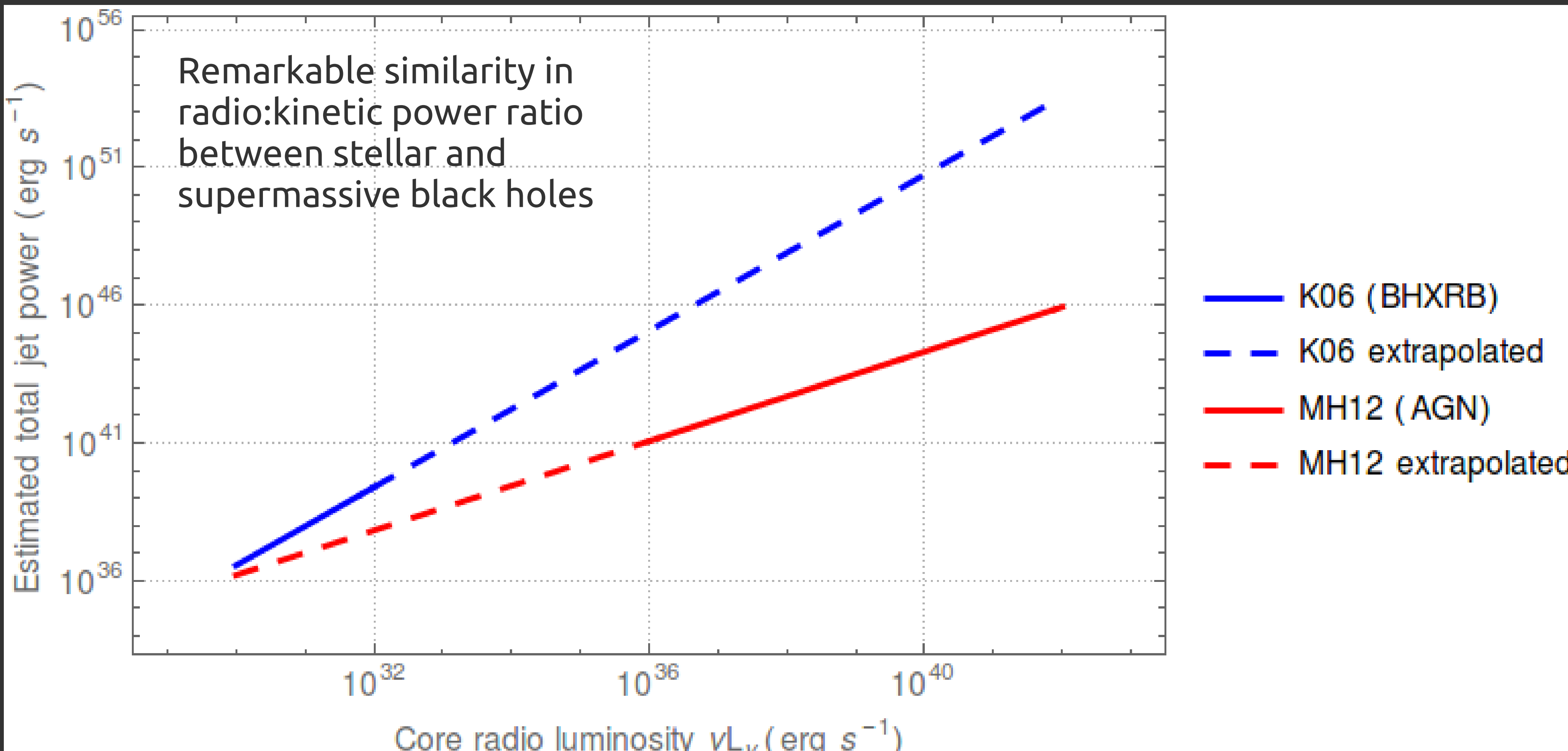


$$\eta \, \dot{m} \, c^2 +/- P_{spin} - P_{adv} = L_{radiation} + L_{wind} + L_{jet}$$

X-ray / optical

radio

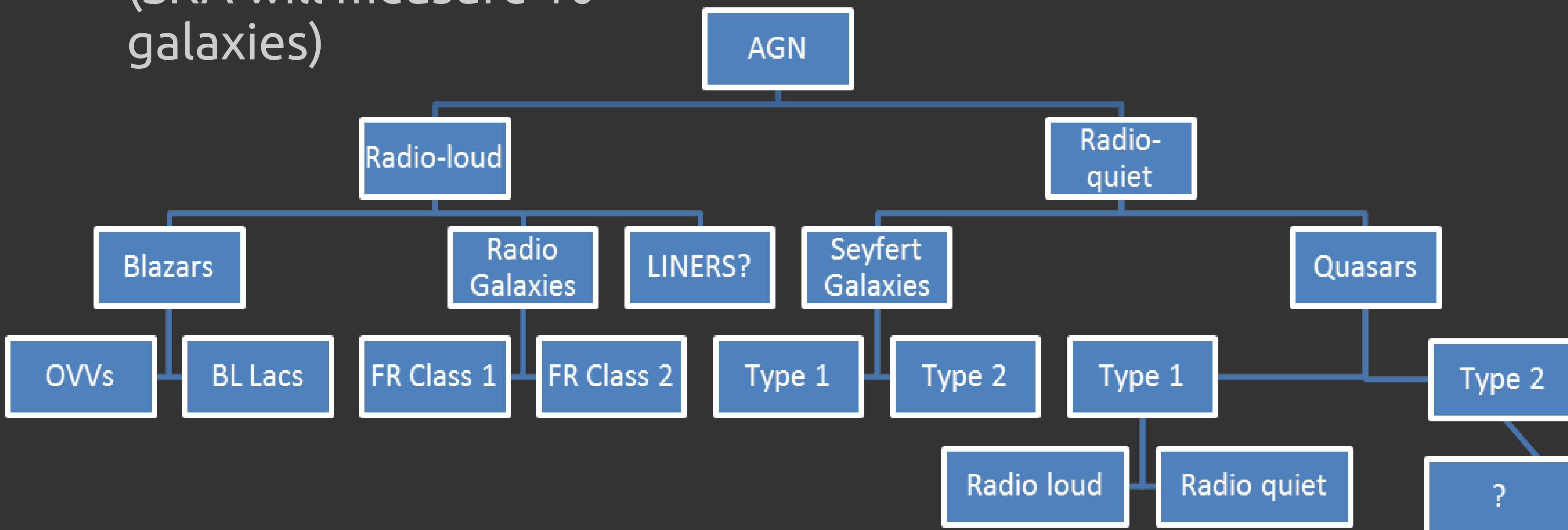
Radio emission as tracer of kinetic feedback



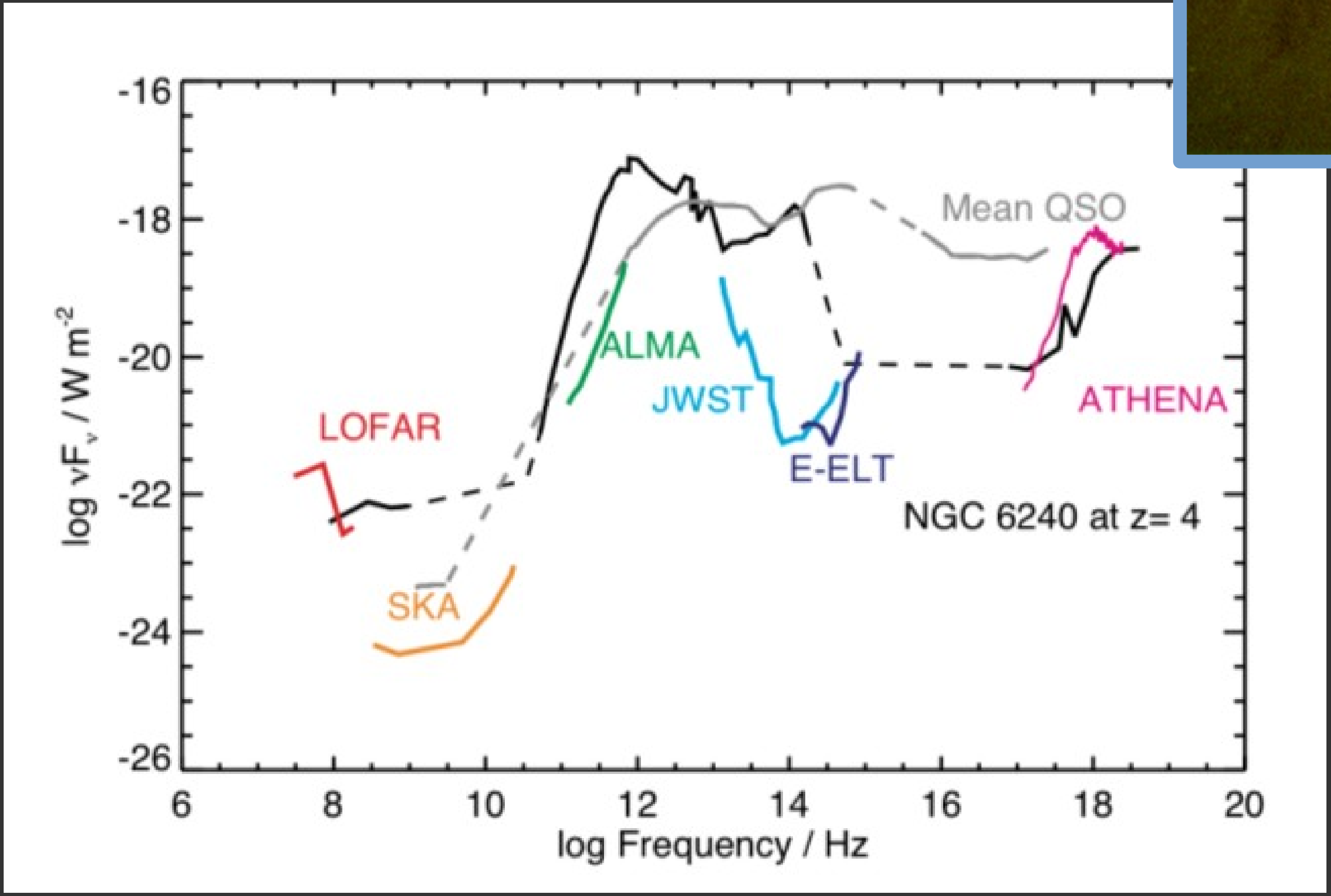
From Fender & Munoz-Darias (2015)
Extrapolating functions from Koerding et al. (2006) and Merloni & Heinz (2012)

SKA-ATHENA synergies: AGN populations

- ATHENA will measure the X-ray fluxes of **600,000** AGN
- At least 100,000 will also have radio measurements (SKA will measure 10^8 galaxies)
- Largest-ever census of accretion and feedback
- Understand better accretion:jet connection

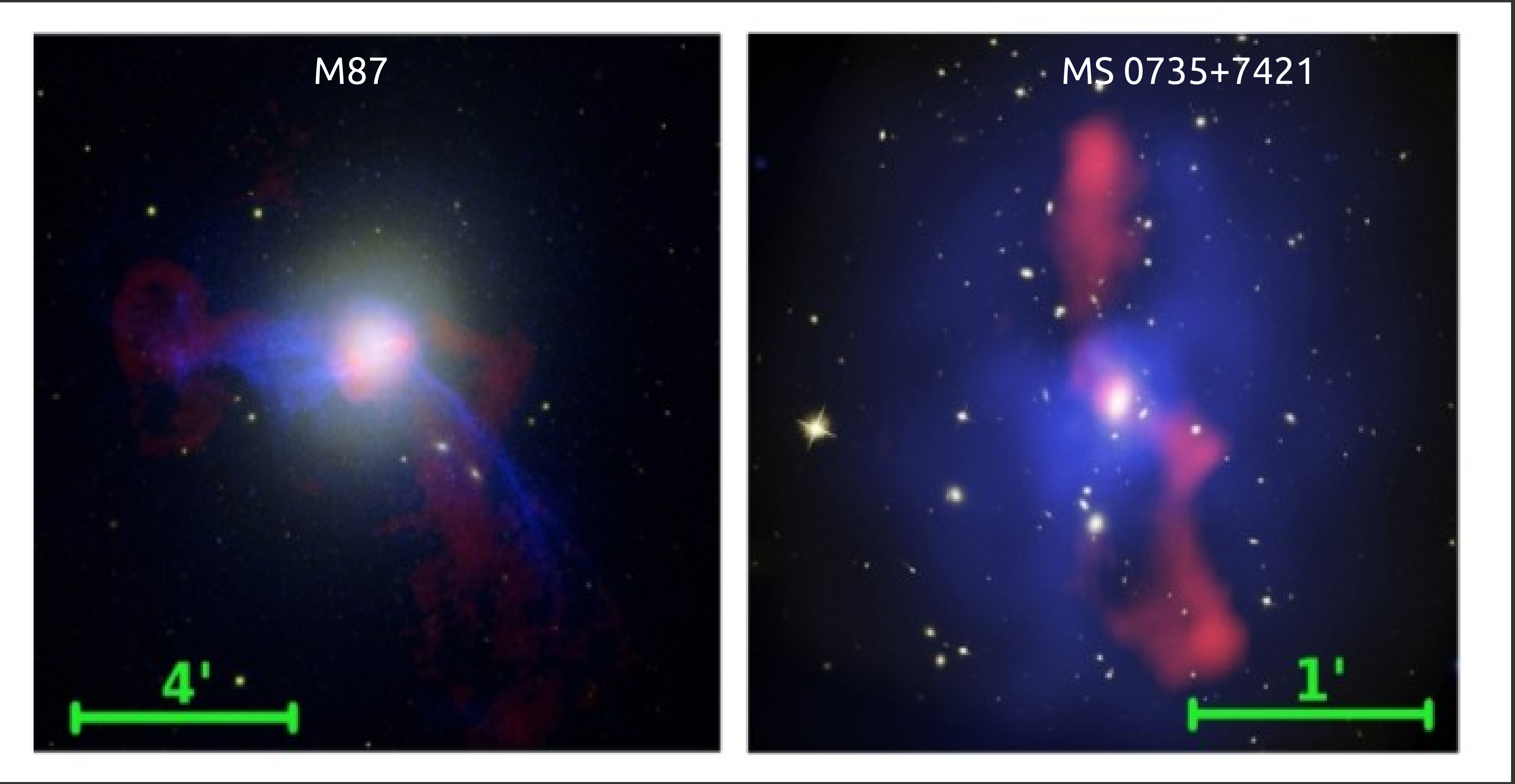


Multi-λ synergies



Merger-product dual-AGN galaxy NGC 6240 as seen at z=4

SKA-ATHENA+ synergies: imaging feedback

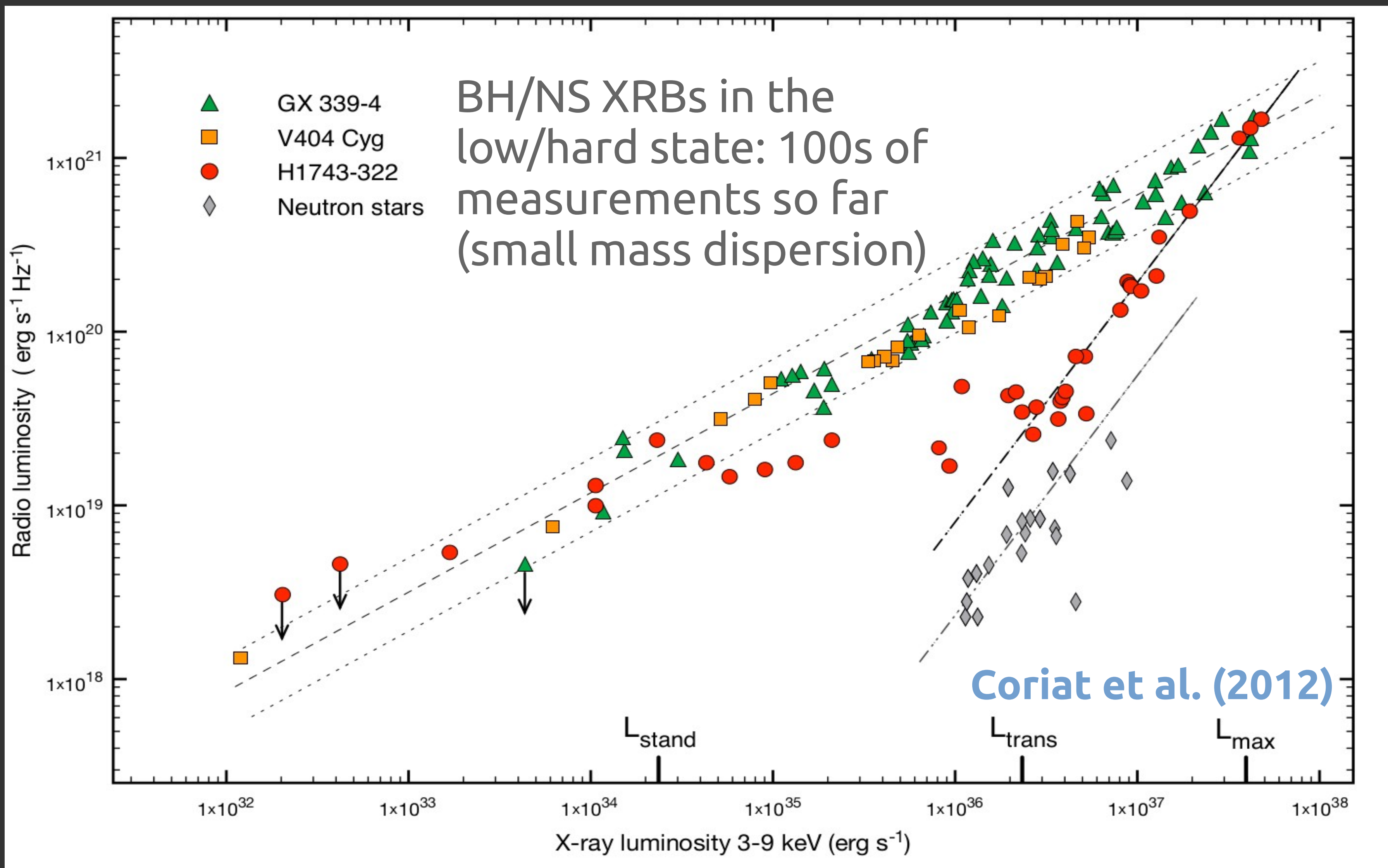


Re-map these clusters with SKA and ATHENA+ with over an order of magnitude better sensitivity

Galactic black hole binaries

MeerKAT → more than double this sample in 5yr
SKA1-MID → 1000s of measurements, revolutionise field
Full SKA → All galactic X-ray binaries, every day

radio luminosity



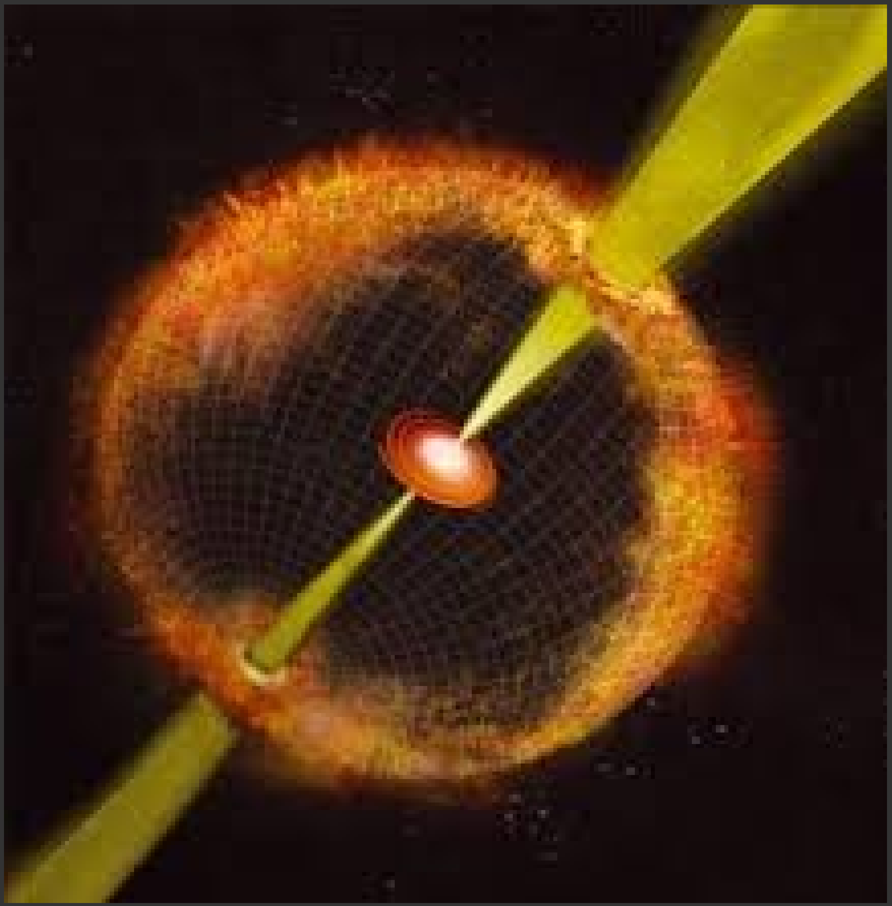
X-ray luminosity

SKA–ATHENA synergies: Extragalactic Transients

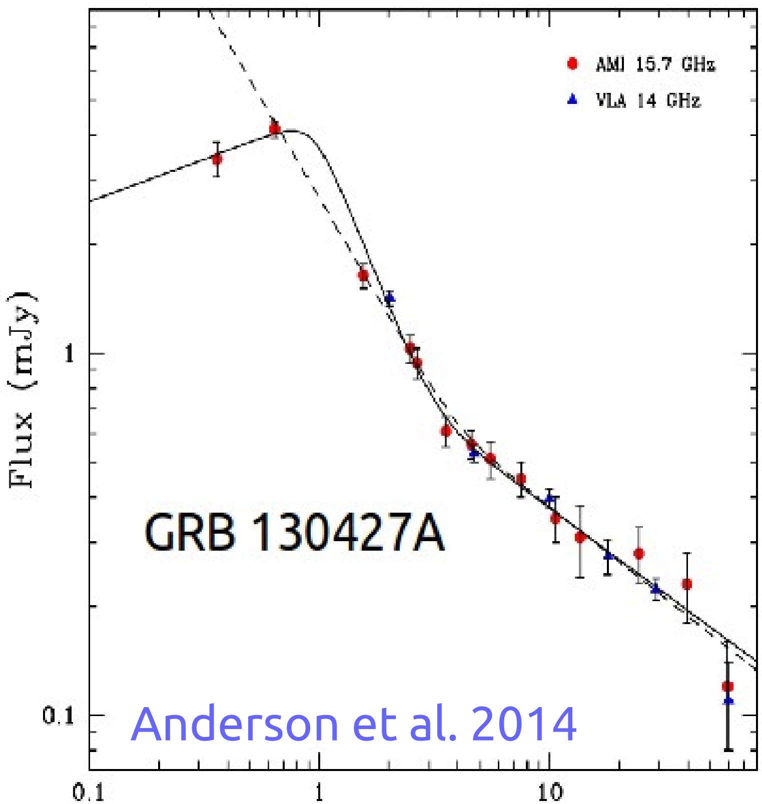
- Luminous Transients

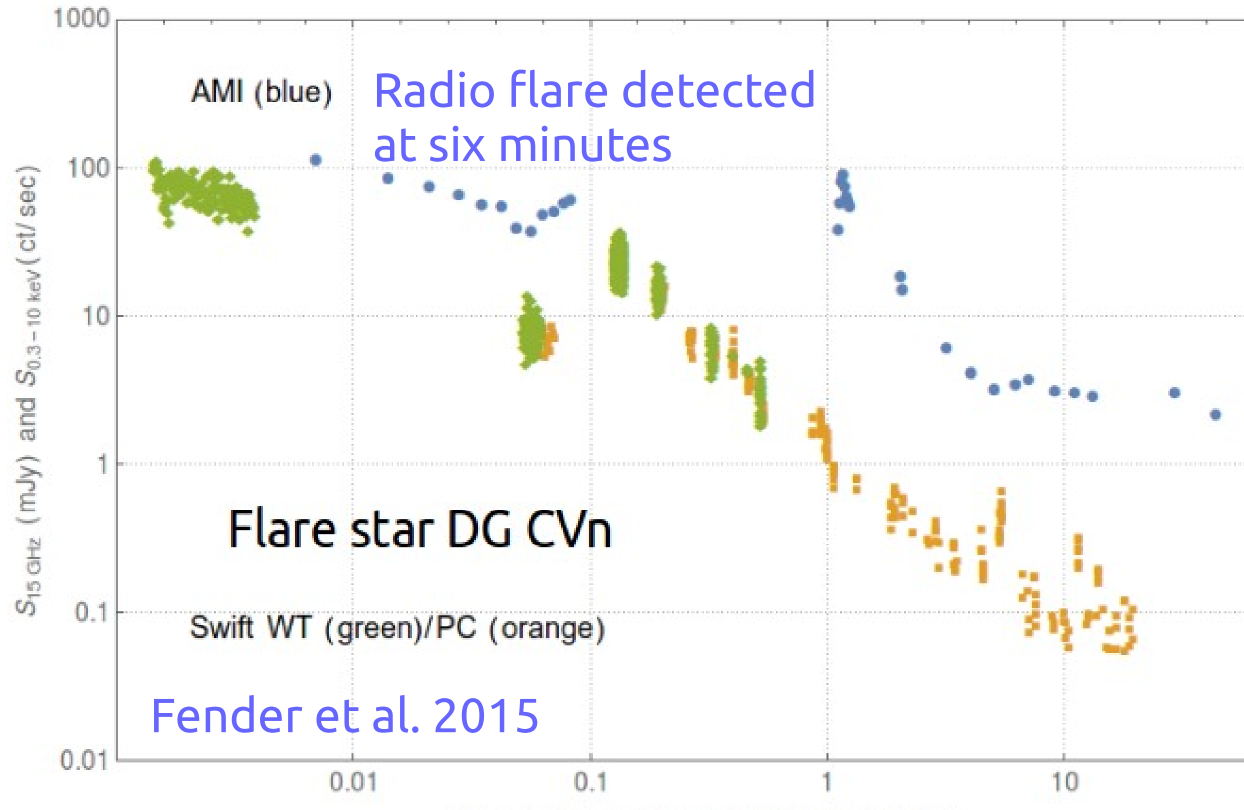
  ATHENA+ will respond to GRBs and other luminous extragalactic transients on 2—4hr timescale

- These events will have associated radio emission (both prompt and afterglow)
- SKA is designing real-time transient search and response system
- SKA predicted rate for jetted TDEs: 1—10 per week (Donnarumma et al. 2015)



The value of fast transient response → *Swift* + AMI/ALARRM





Early time detection (reverse shock) in GRB
Very fast radio transient from nearby flare star
Very early time radio detection of V404 Cyg 2015
Unbiased catalogue of GRB radio emission

World's only robotic
radio telescope array
4pisky.org

Summary

X-rays trace the accretion,
Radio emission traces the feedback
Combine these to understand what is happening and where all the energy goes

→ SKA + ATHENA will revolutionise our understanding of black hole feedback

ATHENA should also build-in flexibility to find, report and respond to transients **fast**