The Square Kilometre Array and the radio/gamma-ray connection toward the SKA era

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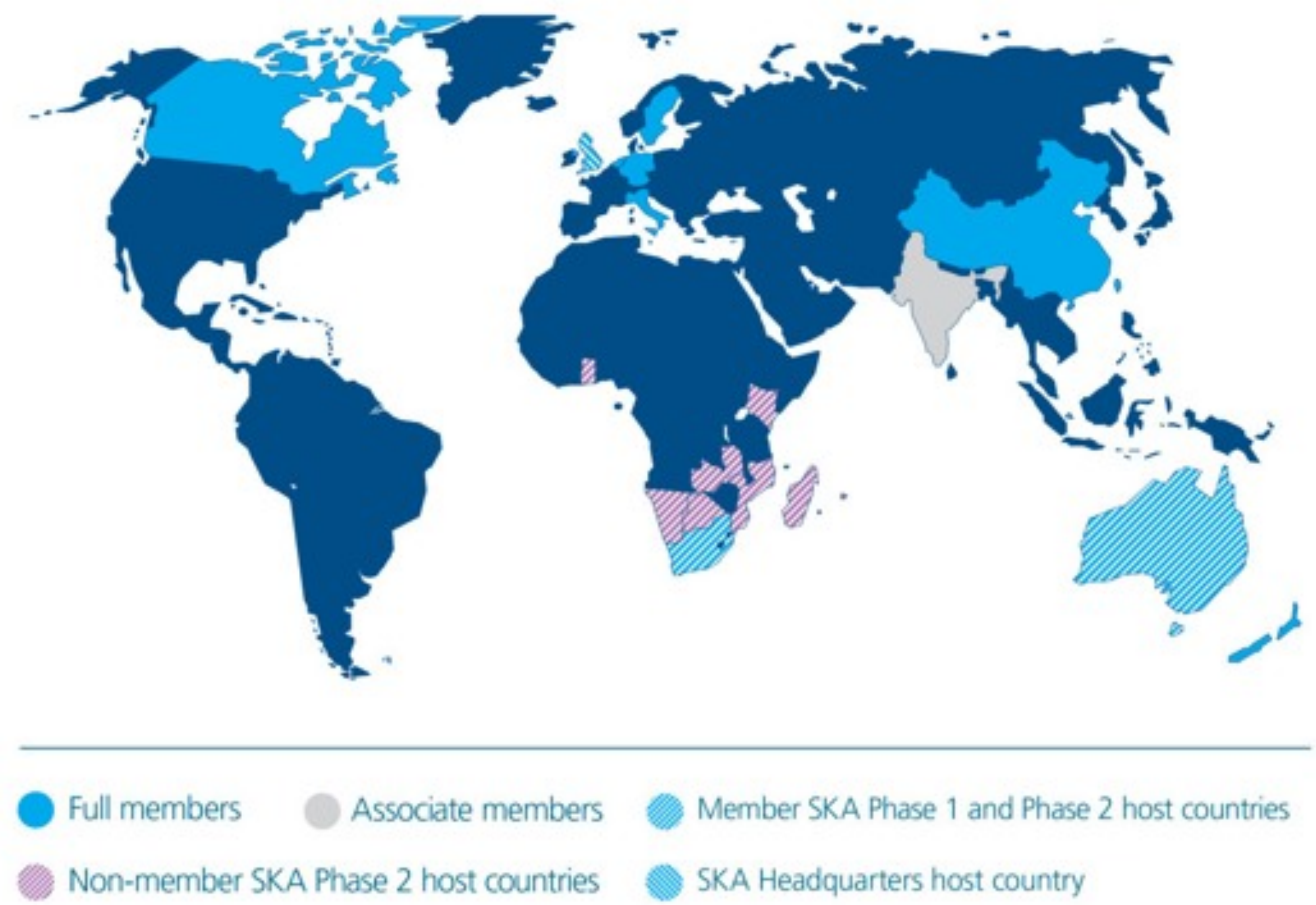
- What's in this talk:
  - SKA basics and quick history
  - Pathfinders and precursors: quick description and science overview
  - SKA details & synergy with high energy instruments
- What's not in this talk:
  - details on politics
  - details on technology

SKA: the Square Kilometer Array

- total collecting area of **1,000,000 m²**: the largest radio telescope array ever constructed
- conceived in the 1990's, will become operational in **2020+**
- members from 10+1 countries representing >40% of world population
- HQ in UK, instrument split between **South Africa** and **Australia**



- **Italy** is one of the **founding members** of the **SKA organization**

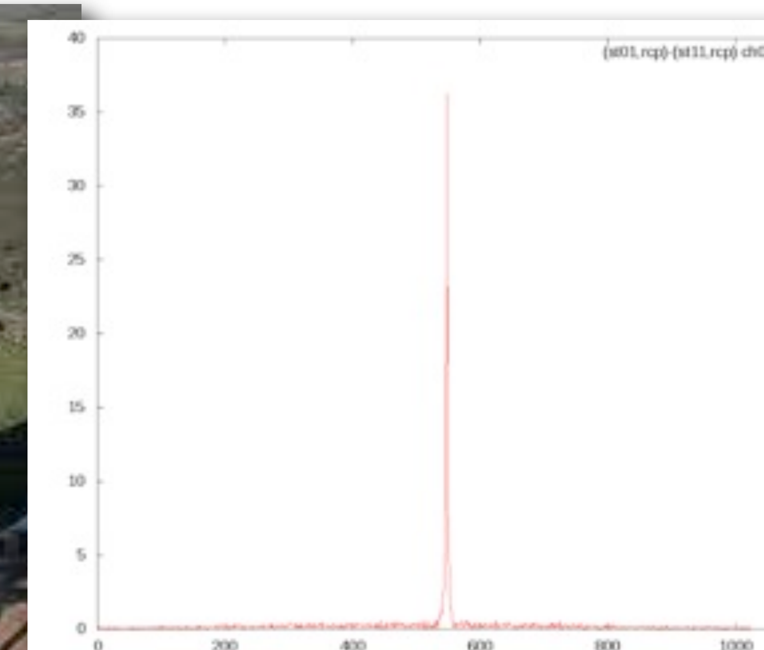
SKA challenges

- cost & organization
- computing: data transfer, correlation and storage
- technology: antenna design at low, mid, and high frequency
- pathfinders and precursors

- Pathfinders: e-VLA, e-MERLIN; e-EVN; LOFAR, LWA; and more...
- Precursors: MeerKAT; MWA; ASKAP
- Goals
  - real time large data transfer and management
  - wide field, aperture arrays, focal plane arrays
  - low frequency window

Pathfinders: the e-EVN

- a consortium of independently built and operated radio telescopes in Europe, extending to Asia, Africa, America
- Includes some of the largest apertures in the world (Arecibo, Effelsberg, WSRT, **SRT**); yet only ~0.03 km^{-2}
- Disks being abandoned and replaced by fast optical fibre links and real time correlation

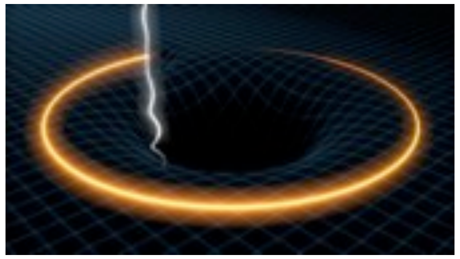


Precursors

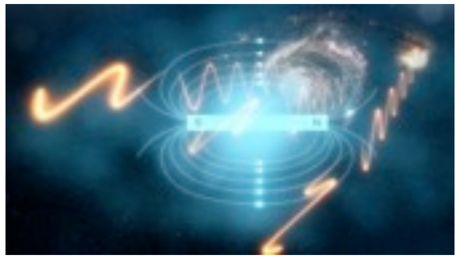
- MeerKAT (SA): 64x16m dishes, 1-1.75 GHz, 4km radius; pulsars, HI, and more
- ASKAP (Aus): 36x12m dishes with Phased Feed Array providing 30deg^2 field of view in 0.8-1.7 GHz
- MWA (Aus): fully operational, aperture array, 80-300 MHz

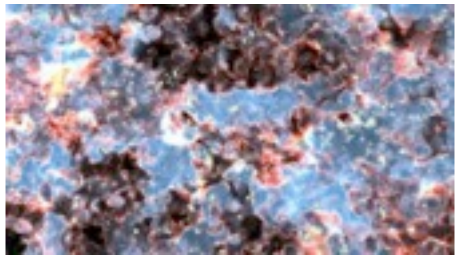
SKA Key Science Projects

- **Galaxy evolution, cosmology and dark energy**
  - How do galaxies evolve? What is dark energy?

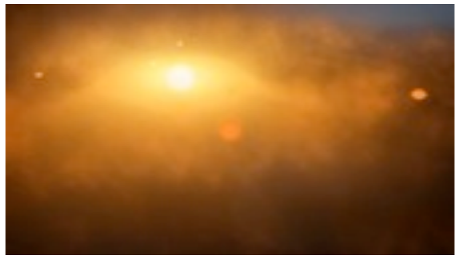


- **Strong-field tests of gravity using pulsars and black holes**
  - Was Einstein right about gravity?
- **The origin and evolution of cosmic magnetism**
  - What generates giant magnetic fields in space?





- **Probing the Cosmic Dawn**
  - How were the first black holes and stars formed?
- **The cradle of life**
  - Are we alone?



- **Flexible design to enable exploration of the unknown**

SKA design

- 2 phases
  - SKA1: construction 2018-203
  - SKA2: detailed design >2018
- SKA1: dual site, triple scope
  - **SKA1-low** (Aus)
  - **SKA1-mid** (SA)
  - **SKA1-survey** (Aus)

SKA1-low

- Australia
- Main driver: **highly redshifted 21 cm HI line** from the Epoch of Reionization and earlier
    - pulsars, magnetized plasma, extrasolar planets
- ~250000 antennas
- 50-350 MHz
- 1 km radius core
- 45 km maximum baseline
- 20 deg^2 field of view

SKA1-mid

- South Africa
- **pulsars**, nearby to mid-z **HI line**, high sensitivity **continuum** sources
- ~250 15m dishes (Meerkat +SKA1 dishes)
- 0.35-3 GHz; ready for additional receivers
- ~100 km maximum baseline

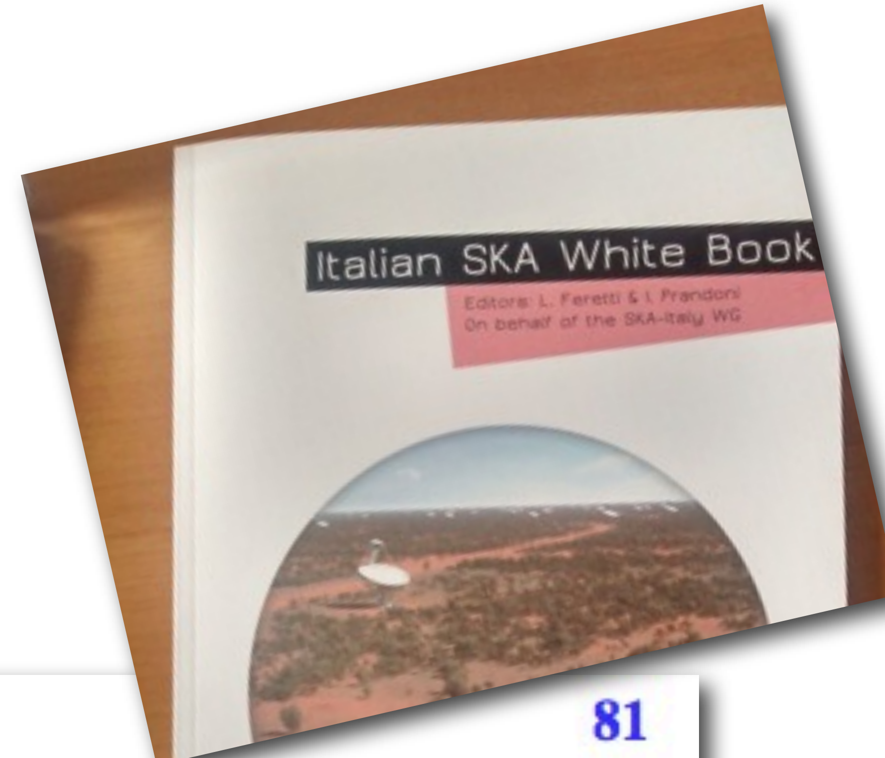
SKA1-survey

- Australia
- **survey** large areas of sky in line and continuum, **transients**
- ~100 15m dishes (ASKAP+SKA1 dishes)
- 0.6-1.7 GHz
- ~25 km maximum baseline
- **PAF (Phased Array Feed)**

SKA2 - early view

- Increase total collecting area
  - 1,000,000 m^2
- Improve angular resolution (longer baselines)
  - ~1 mas
- Extend frequency coverage (additional receivers)
  - 20 GHz

(a *biased* bit of) SKA science



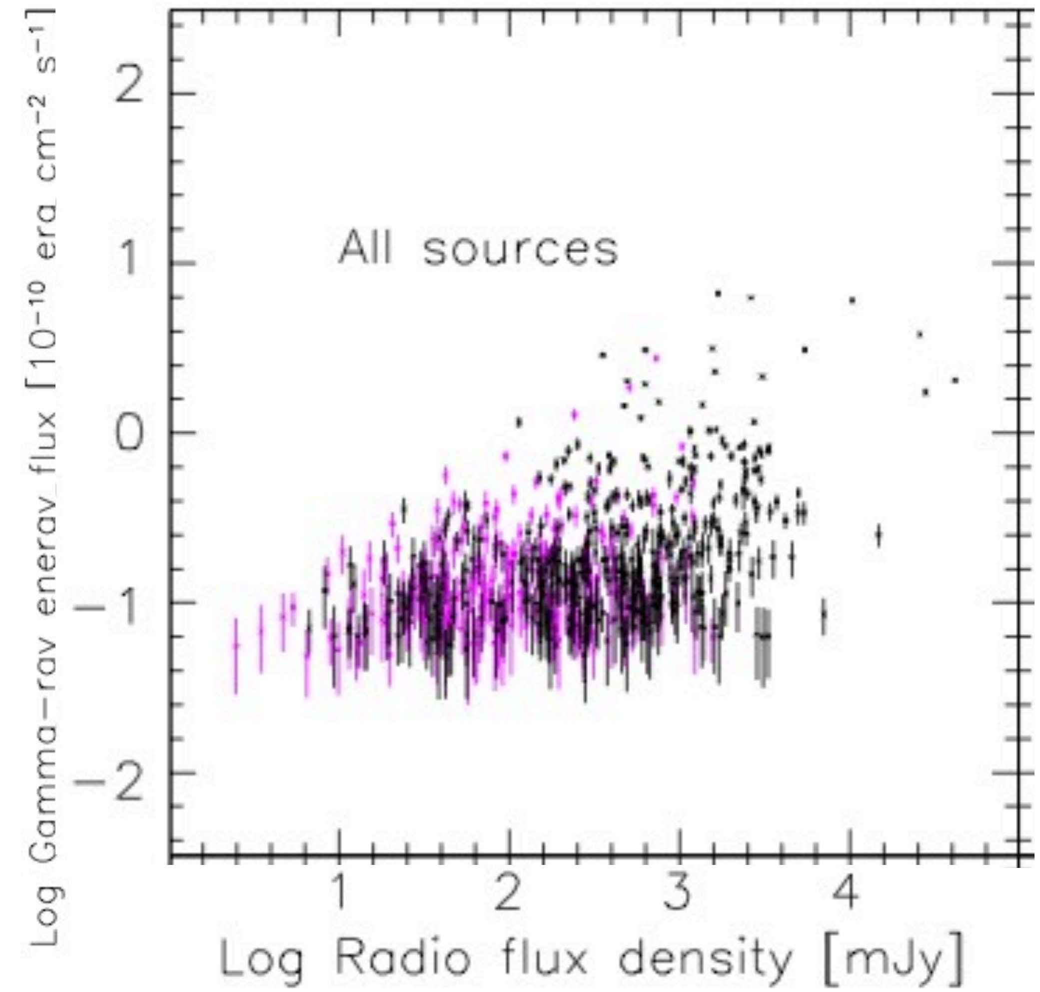
keywords: *sensitivity, polarization, variability*

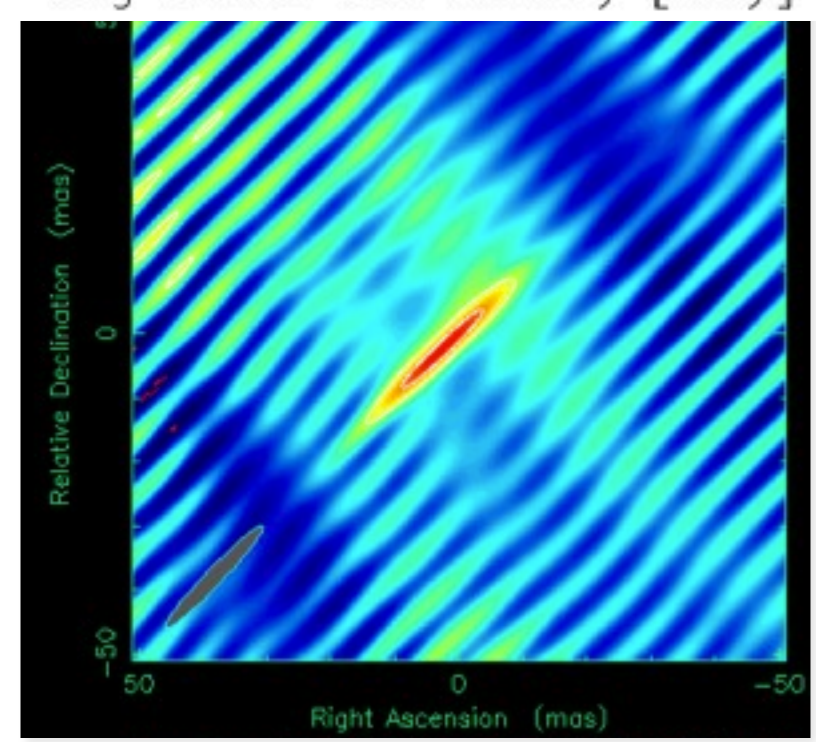
Possible strategies

- Deep observations can reveal weak nuclear emission in very weak or very distant nuclei, constraining physical properties through accurate spectral index, polarization, and variability measurments
- Space and time resolved polarization observations can reveal magnetic field structure in jets
- Great discovery space for fast transients

Towards SKA science: 1FHL EVN survey

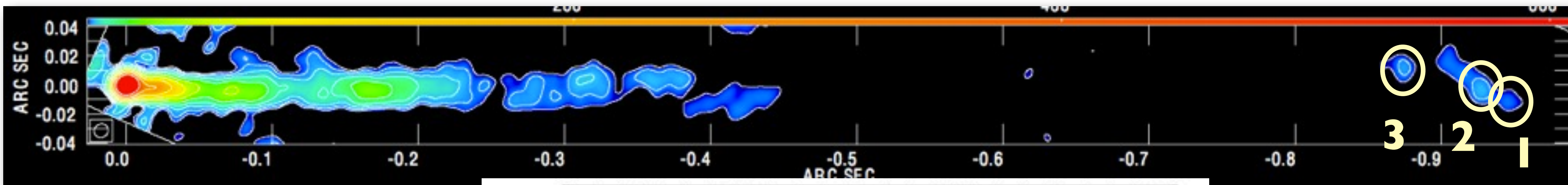
- Radio-MeV/GeV connection firmly established (Ackermann+11, Ghirlanda +10,11)
- Radio-VHE connection completely elusive
  - VHE sources **are** radio loud
  - brightest radio sources **are not** VHE detected
  - IACT observing mode is highly biased
- Let's start with **1FHL**: 514 sources detected above 10 GeV in uniform all-sky LAT survey
  - 100% detection rate for blazars,
  - **~70% detection rate for unassociated sources** (13% of 1FHL)



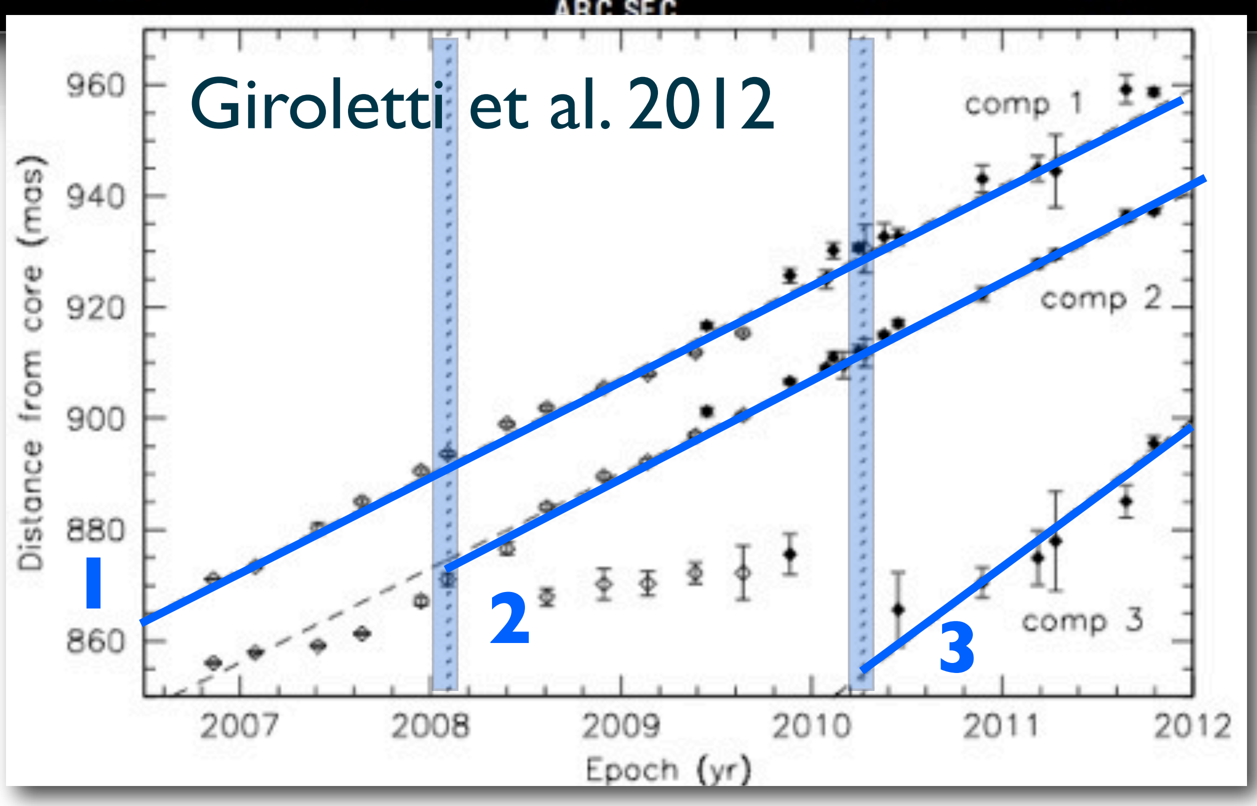


Towards SKA science: M87

Data from a long&dense monitoring with the eEVN reveal ejection of superluminal components within the jet knot HST-1 is temporally associated to 2008, 2011 VHE events.

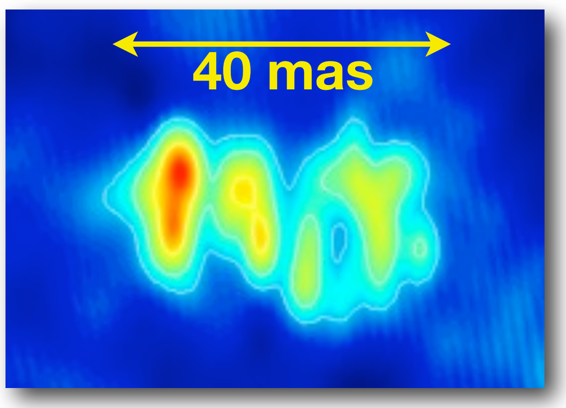


3C120, Agudo et al. 2012



v=(4.1+-0.1)c

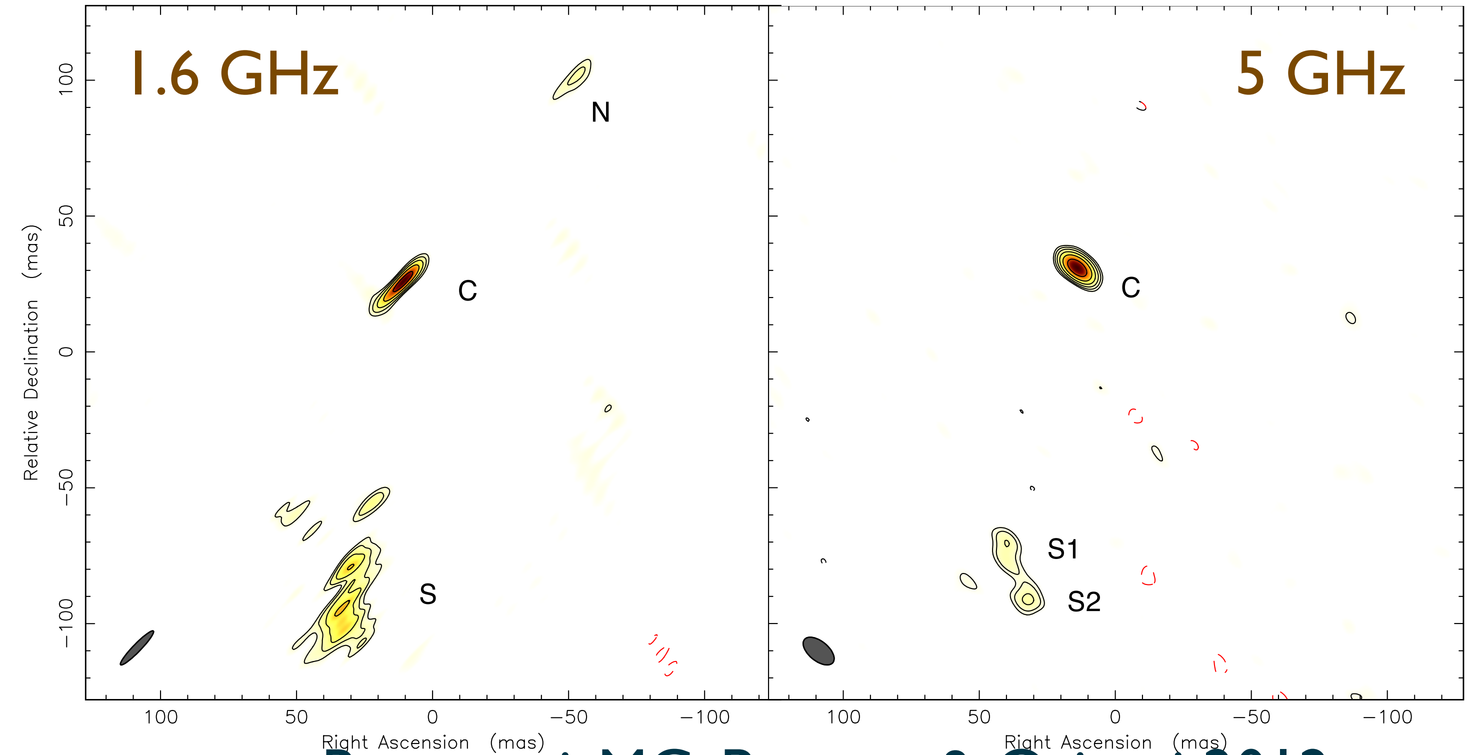
δ=1.5-4.0



Towards SKA science: LLAGN

- high sensitivity, dual frequency EVN observations reveal compact nuclear features in ~60% of local LLAGNs
- In cases like NGC3227, observations reveal a compact, flat spectrum component
- In other cases, the situation is much more complex (detection at just one frequency, or none, weak constraints on Tb etc.)
- Eventually, SKA could reveal radio emission from all black holes in the local universe

$\alpha \sim 0.5$
$T_b > 10^{7.5}$K
$L \sim 10^{19.5}$W Hz^{-1}
B~4.5 mG



Bontempi, MG, Panessa & Orienti 2012

Radio & gamma rays

- VLBI detection rate for unassociated sources with a candidate blazar counterpart based on IR colors or radio spectral index is 100% (yet: low statistics)
- physical information, even at low frequency, is of great help in picking right counterpart, particularly at low flux density
- other important parameters: polarization, variability

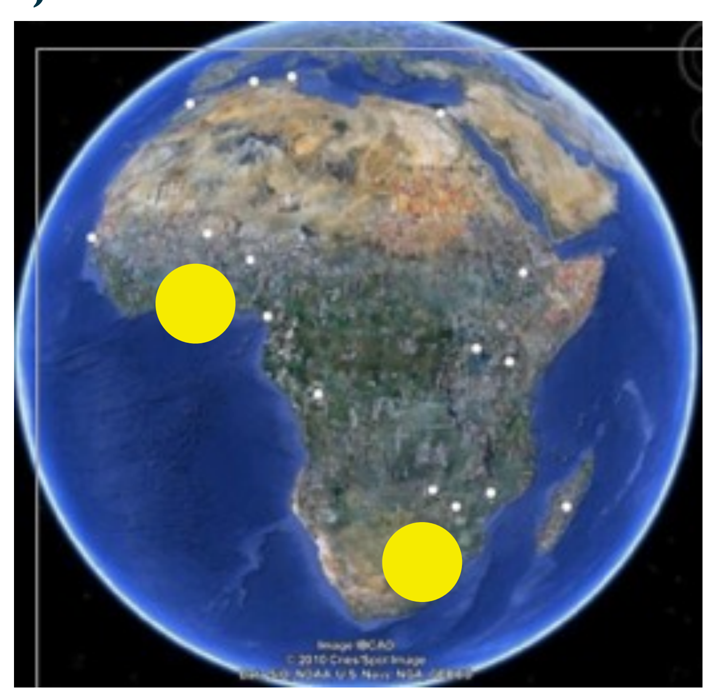
SKA & CTA

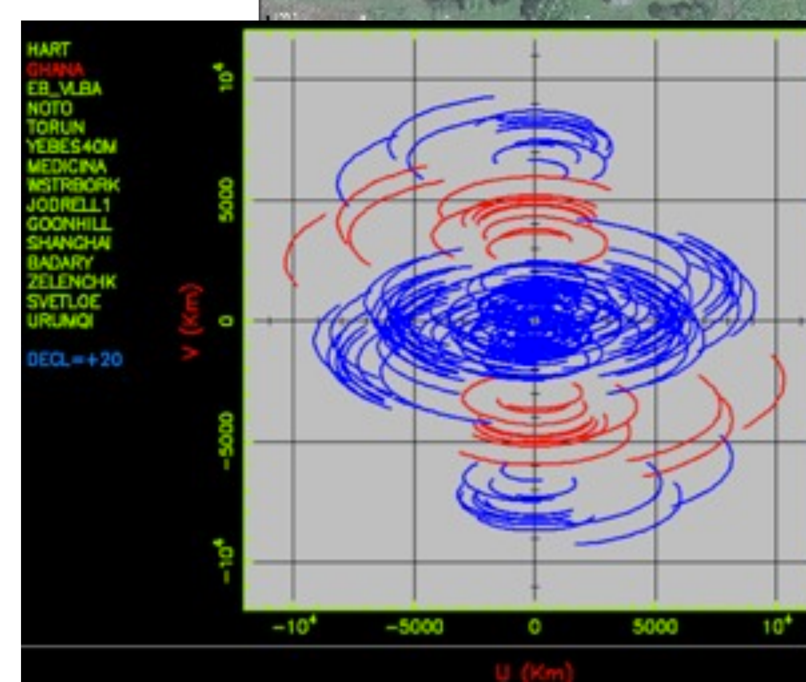
- >10x step over predecessors
- Large international collaborations
- Dual site
- Dual-multiple design & energy range
- Great computational challenge
- Non thermal universe

Potential for Africa VLBI Network

African Countries with Large Satellite Earth Station Antennas:

South Africa, Ghana, Kenya, Madagascar, Zambia (SKA partners) + Algeria, Benin, Cameroon, Congo Democratic Republic, Congo Democratic Republic, Congo People's Republic, Egypt, Ethiopia, Gabon, Malawi, Morocco, Niger, Nigeria, Senegal, Tunisia, Uganda, Zimbabwe





Summary

- Huge breakthrough for data, technology, and **science**
- For radio-gamma connection, main improvements through multi-λ polarization, variability
- and wait for SKA2!