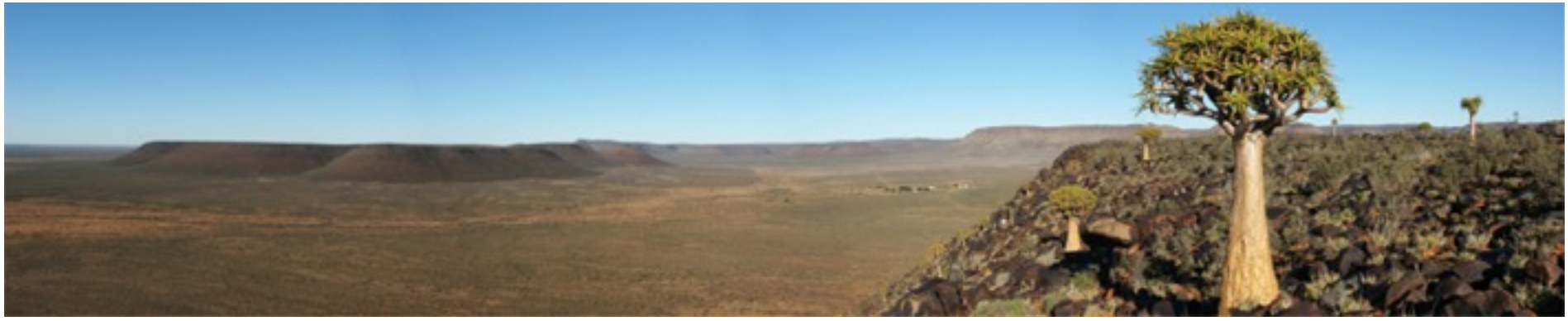
MeerKAT
Lessons Learnt?



Kurt van der Heyden

On behalf of SA SKA

& MIGHTEE

SKA SOUTH AFRICA
SQUARE KILOMETRE ARRAY

ACGC

The MeerKAT Programme

- Africa must have the legacy of a large radio telescope
  - Irrespective of the outcome of the SKA site competition
  - But not independent of the SKA
- MeerKAT is an SKA "precursor"
  - Engineering prototype
  - Early science (SKA "Phase 0")
  - Until the SKA is completed, MeerKAT should be one of the most sensitive radio interferometer in the L-band
  - Phased development: KAT-7, MeerKAT, SKA_1, SKA_2
  - MeerKAT will be the first 25% of SKA_1 (mid-frequency dish array)

SKA South Africa
Radio Astronomy Schedule

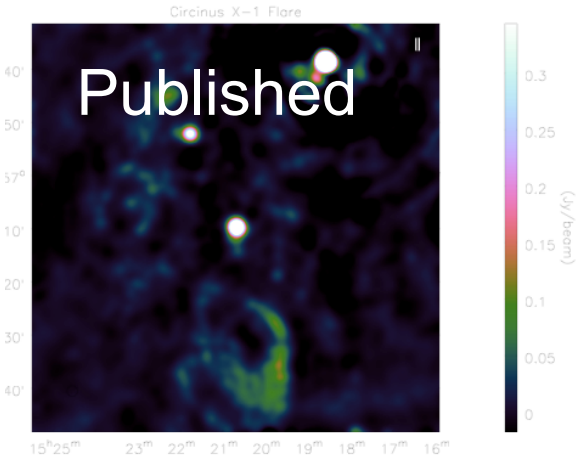
- **Phase 1**: construction of the pathfinder KAT-7 (7 antennae) completed in December **2010** & already in operation
- **Phase 2**: construction of the MeerKAT (64 antennae), fully funded (R3Bn ~EUR250M), should be completed by late **2016** & merged with SKA_1- mid ~2020?
- **Phase 3**: construction of the SKA-mid (phases 1&2) (~3000 antennae) should be completed ~**2025**

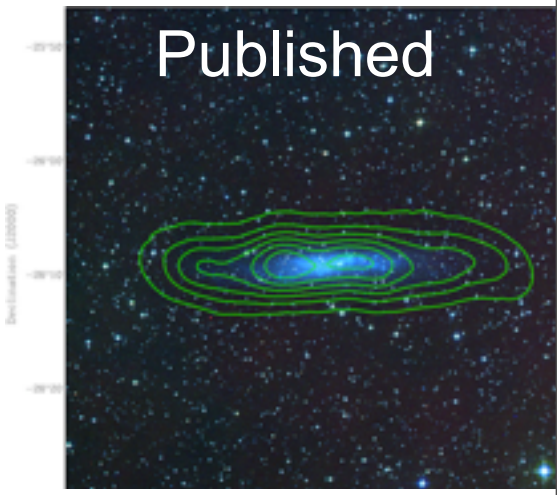
Prototype: KAT 7

- More on KAT-7 by Tony Foley at SPARCS meeting

First KAT-7 Science

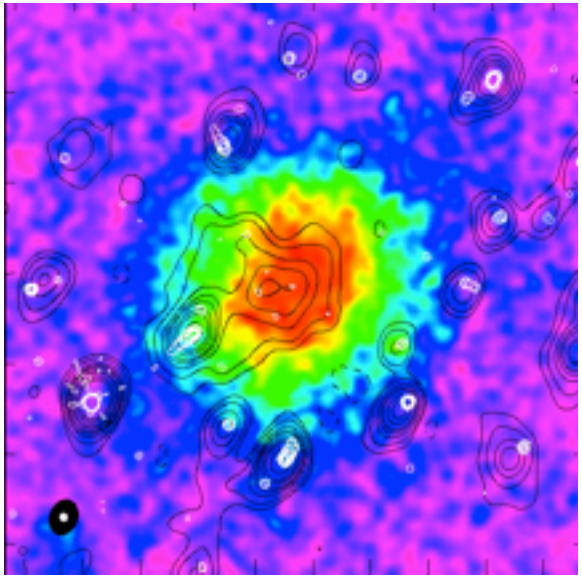
Circinus X-1
Monitoring
ThunderKAT team

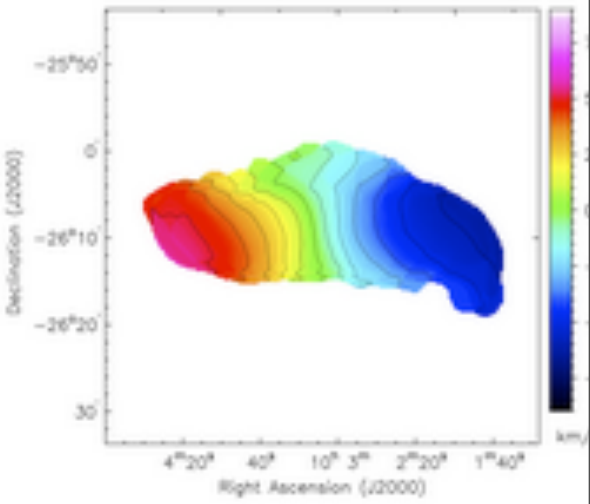




Tr-Aus
New Radio Halo

Nadeem Oozeer
& Anna Scaife
(MIGHTEE team
members)





NGC 3901 in HI
Brad Frank (Mhongoose team)

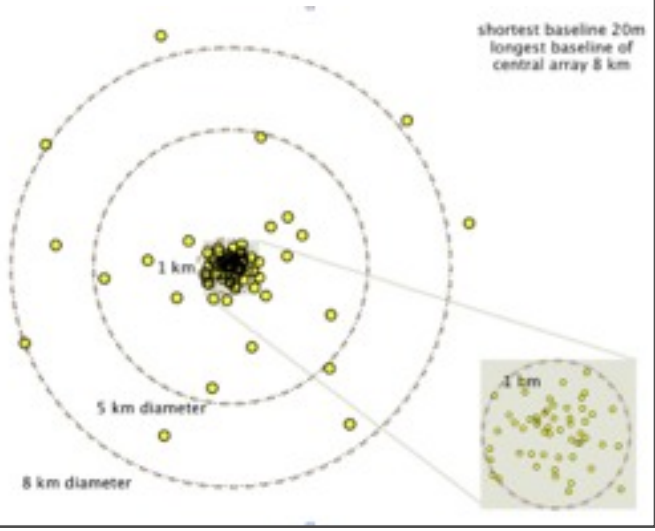
Lessons Learnt
Prototype

- KAT-7 was built purely as an engineering prototype.
  - ➡ been a huge learning experience and and opportunity to test out ideas and systems
- KAT-7 is starting to produce science results, and this has also assisted in the identifying issues and assisting with commissioning. Increasing student and PDF involvement.

- SKA does not really have a prototype (except for the pre-cursors?)
  - ➡ do science early and do it often (but engineering and commissioning takes priority)

Precursor array: MeerKat

- 64 antennae distributed in two components:
  - An inner dense core ~70% of the antennae (baselines: 29m to 1km), distributed in a 2D Gaussian uv distribution with a σ ~300 m
  - An outer component ~30% of the antennae (baselines: up to 8km), distributed in a 2D Gaussian uv-distribution with a σ ~2 500 m
  - Commissioning: 2014 - 2016
  - Science operations: 2017



Current MeerKAT Status

Plans on track to complete the 64-dish MeerKAT by the end of 2016. The projected milestones are:

- January 2014: First dish installed (following acceptance testing)
- April 2014: Two dishes installed / First receptor integrated / ready for testing
- November 2014: 6 dishes
- June 2015: 16 dishes
- November 2015: 32 working dishes
- September 2016: All 64 dishes completed & tested

Current MeerKAT Status

- Commissioning of MeerKAT will start in 2014 and ramp up with the increasing number of antennas
- It is anticipated that some early science may be possible/feasible once a significant fraction of the array is constructed (32 ~ Dec 2015) / but commissioning activities will take priority
- The full array will be available for commissioning in 2017, the plan is that most significant commissioning issues will have surfaced and be dealt with earlier so that there can be a rapid transition to MeerKAT science data collection by early 2018

Current MeerKAT Status

- The current planning is that 2018-2020 will be devoted to the MeerKAT large science (L-band) programs with some transition to SKA_1
- The current SKA_1 (190 dishes) construction is expected 2018-2021 (full array 190 + 64 dishes)
- The planning is that the sensitivity of SKA_1 dishes should equal that of MeerKAT around end 2020
- At that point, it may make scientific sense to integrate MeerKAT into SKA_1 (and use the SKA correlator, etc).
- *However, the actual SKA timelines are less certain than those for MeerKAT, at this stage.*

Current MeerKAT Status

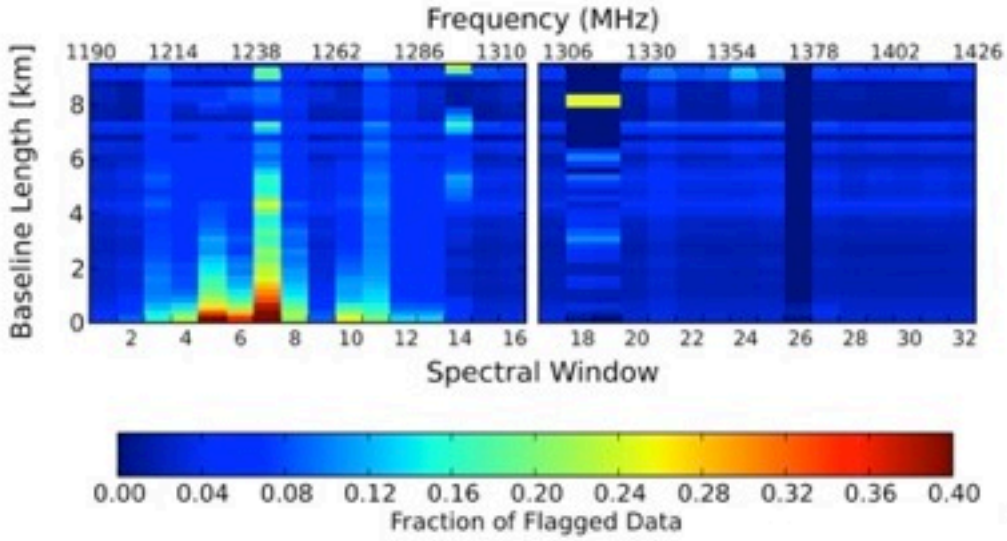
- Longest MeerKAT baselines are 8 km
  - planning is to work with the SKAO to ensure that the first few SKA_1 dishes are built at those kind of distances and used for this science in the 2019-2020 timeframe.
  - As the MeerKAT correlator would have 64 inputs, some of the MeerKAT core antennas would be disconnected to accommodate SKA_1 inputs for this science.

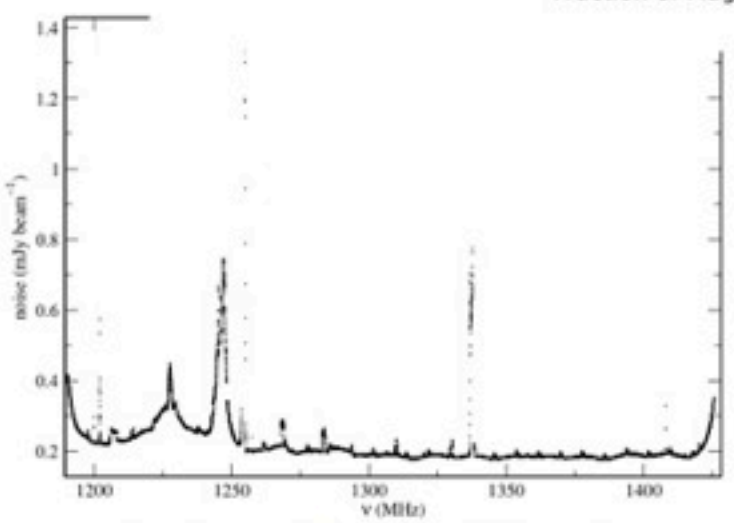
Lessons Learnt
communication?

- Have firm constraints on what can be done and be clear on what people can expect.
  - Don’t promise what you can’t afford
  - eg. The longer baselines or X-band receivers on MeerKAT
  - Somebody has to make the tough decisions. (eg. long baselines)

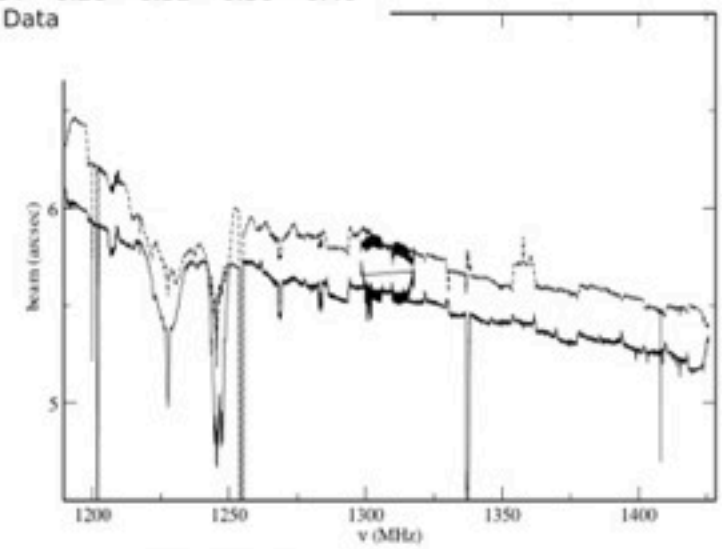
Chiles (JVLA) - RFI

Courtesy: J van Gorkem



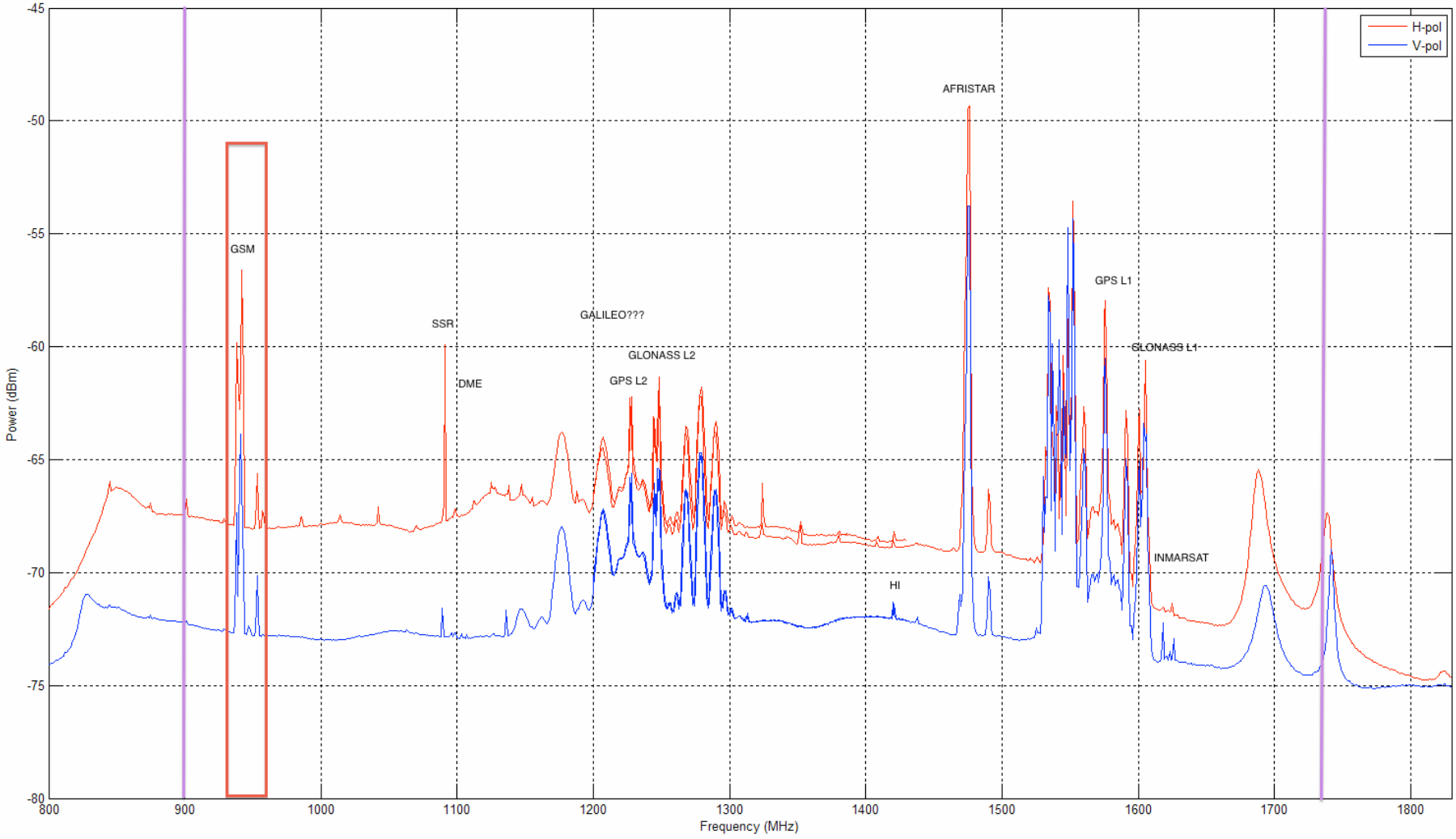


Rms noise as function of frequency



Synthesized beam

Karoo L-band RFI (Satellite)



Lessons Learnt

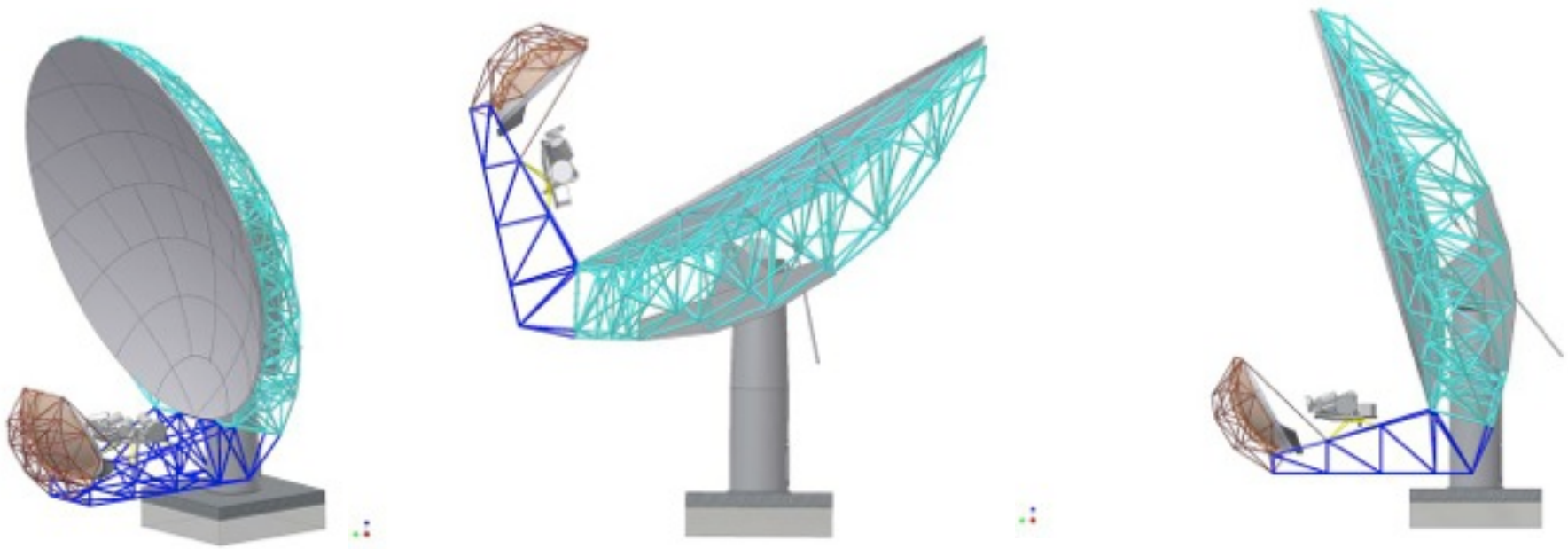
RFI

- RFI is a problem
- will need to flag lots of data
  - ➡ observing times/sensitivity adjustments
  - ➡ mostly short baselines will be affected (array layout?)

MeerKat's antennae

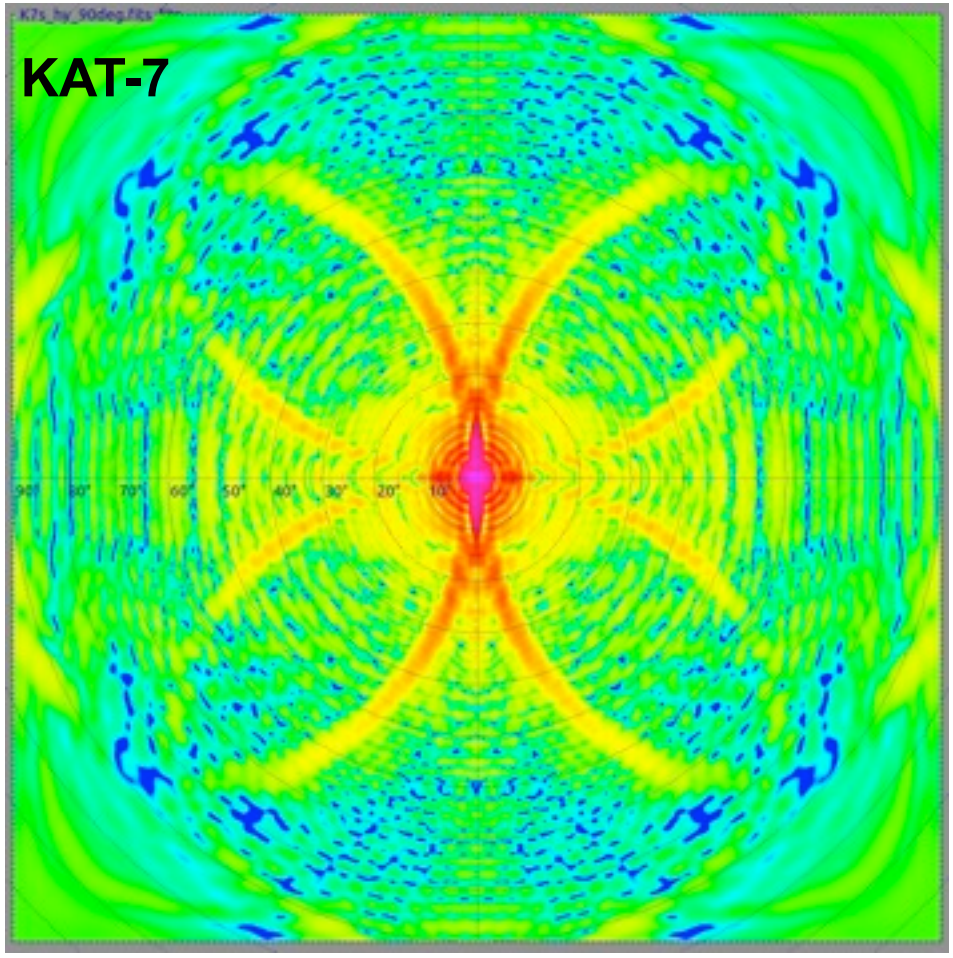
- Development of MeerKAT antennas on track by Stratosat Datacom / GDSatcom
- 1st antenna to be assembled on site and handed over to SKA SA for testing end of January 2014
- 2nd antenna to be handed over in April 2014
- Followed by extensive engineering testing by SKA SA for 6 months

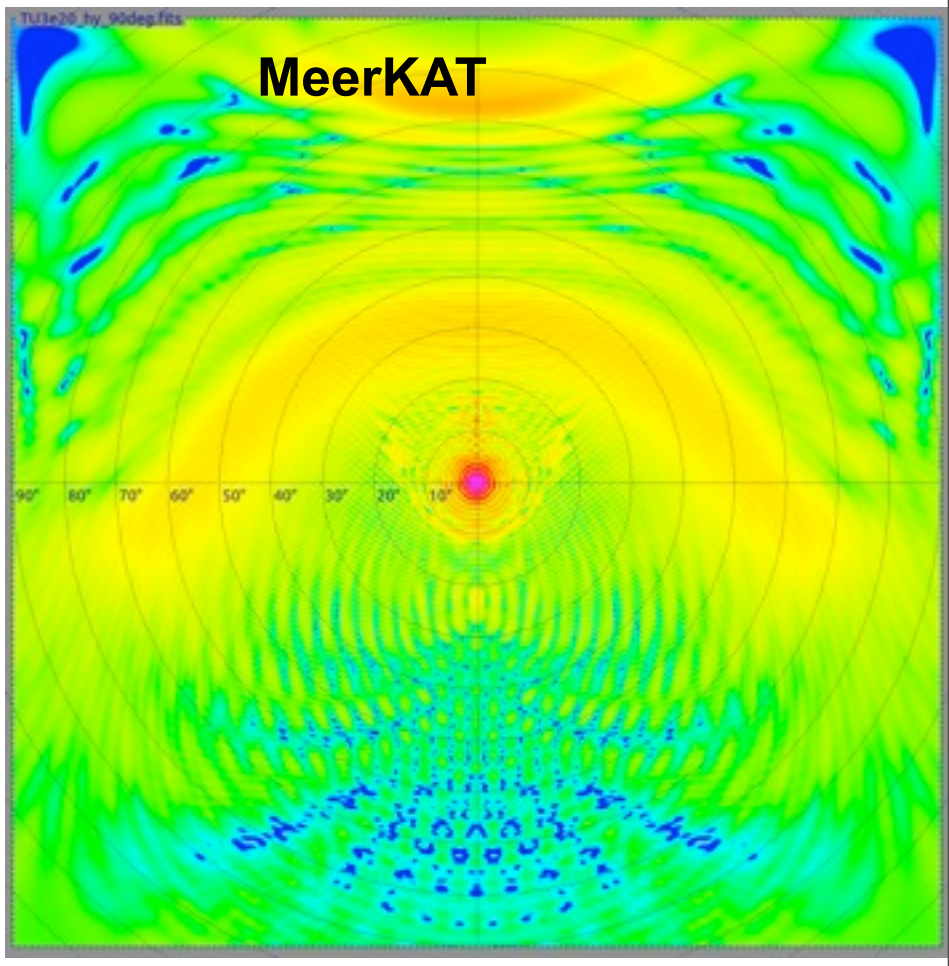
MeerKat antennae



- Offset Gregorian design: metal instead of composite dishes

Primary Beams

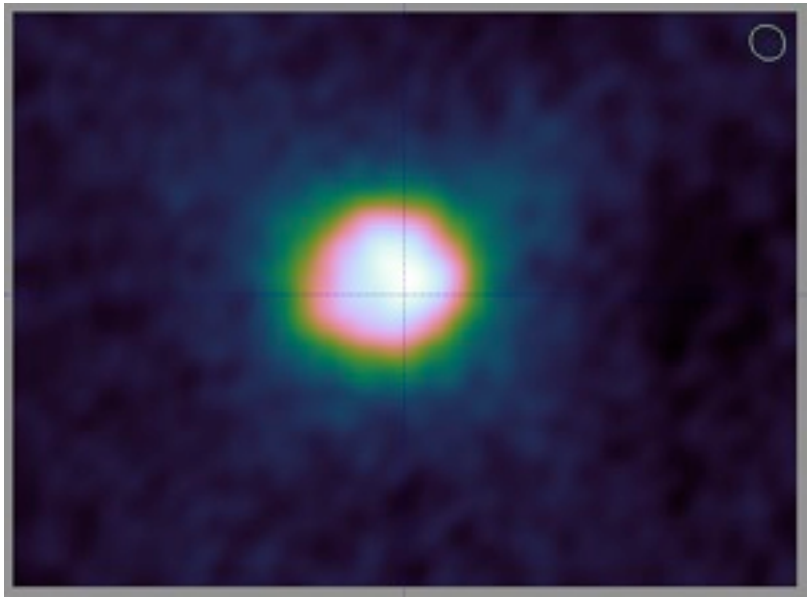


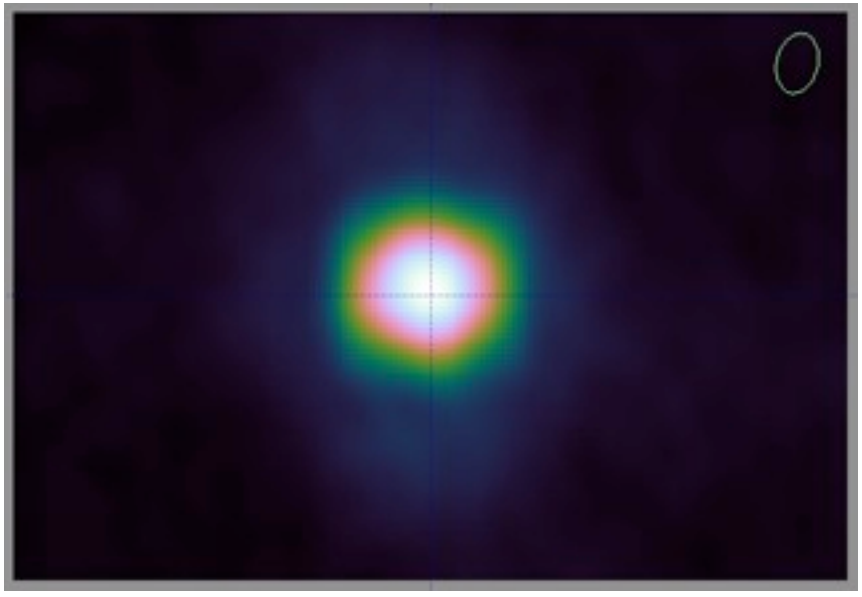


Doesn't completely restrict the FoV – only attenuates the rest of the sky, but the *PB sidelobes* are non-zero!

“Restricted” FoV?

- Sidelobes *attenuate* the rest of the sky, but don't completely eliminate it
- Example from a WSRT 300MHz observation: CasA and CygA (~60 and ~90 degrees away!):





MeerKat's Feeds & Receivers

- The L-band feeds and cryo receivers (0.9-1.67 GHz) development is on track (by EMSS)
- Functional prototypes with measured performance were demonstrated June 2013
- The first two production systems will be deployed on the first two MeerKAT antennas

MeerKat's Feeds & Receivers

- Based on the modeling and the actual performance tests to date, MeerKAT is expected to achieve a sensitivity in excess of 300 m^2/K rather than the originally specified 220 m^2/K at L-band
- The UHF cryo receiver (0.58-1.015 GHz) development has started. A decision on whether these will be included in $MeerKAT_1$ at the end of 2016 will be made in the near future
- The X-band receiver (8-14.5 GHz) remains in the plans, but is not currently funded

Lessons Learnt
systems engineering

- Receiver Choice - Single Pixel feeds
  - mature systems can still perform well & there is room for further development
- don’t consider a single subsystem in isolation, but consider the entire system.
  - eg. new technologies might be beneficial in one area, but might affect other subsystems (eg computing costs or energy consumption)

MeerKat's Infrastructure

MeerKAT related infrastructure on site to be completed end 2013. Currently under construction:

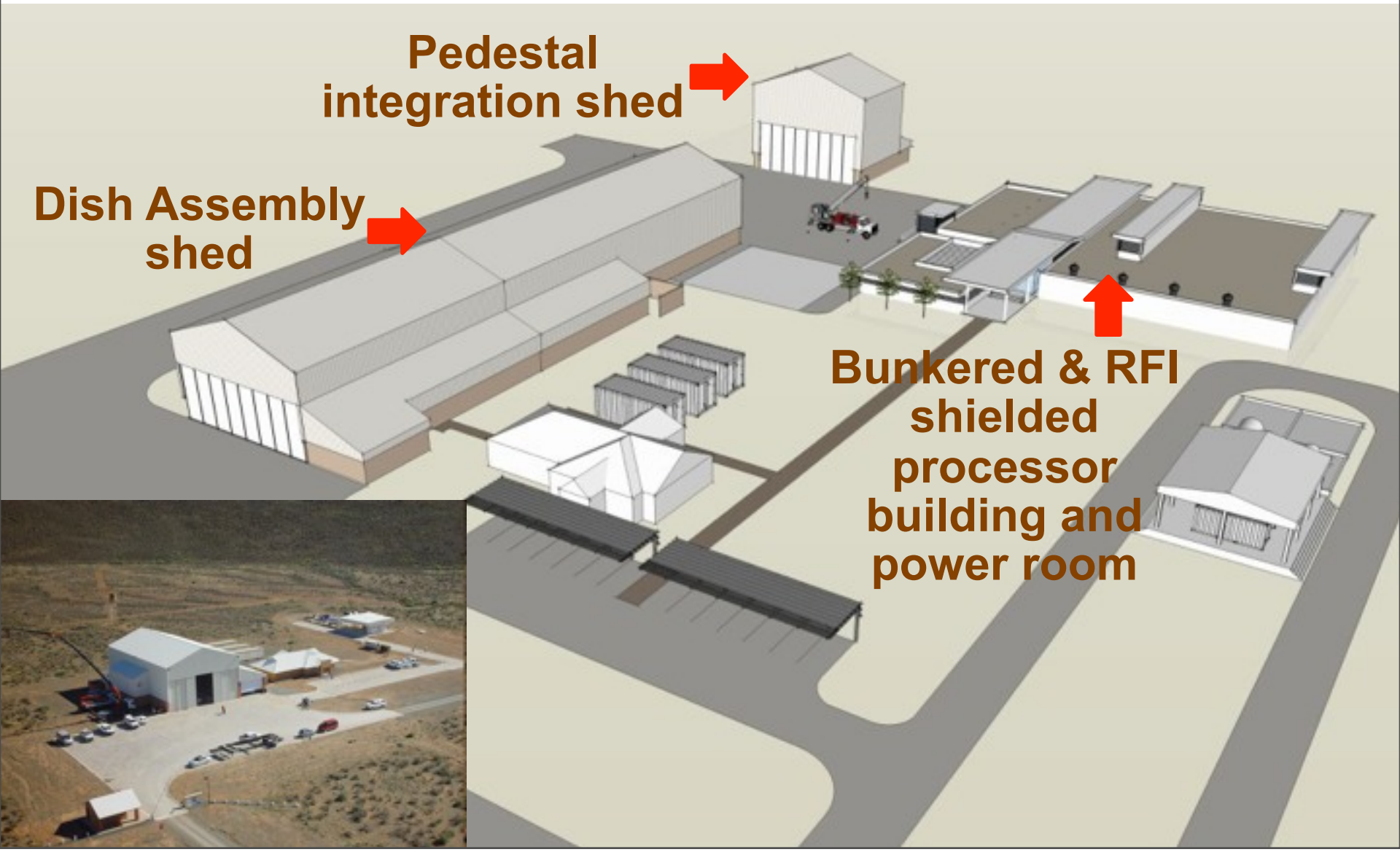
- Roads
- Reticulation (power & fiber)
- Foundations for MeerKAT antennas
- On-site tarred landing strip
- Extension of the site complex assembly building
- Karoo Array Processor Building (KAPB)
- Pedestal Assembly building

+ additional workshops at the Klerefontein support base

MeerKat: start of construction

July 25 2012

Site Complex extension for MeerKAT



Power and Infrastructure

Lessons Learnt
Communication again!

- The MeerKAT team are all in 1 location & there has been a strong systems engineering approach.
  - This helps to keep people on the same page, but even so communication is not always efficient.
- If people are spread over several institutes then it is important to have a strong central system
- Everyone has to be on the same critical path, and not only a best effort basis
- Keep communication channels open! (even with essentially one team, MeerKAT communication has not always been easy)

Synopsis

Important milestones for MeerKAT:

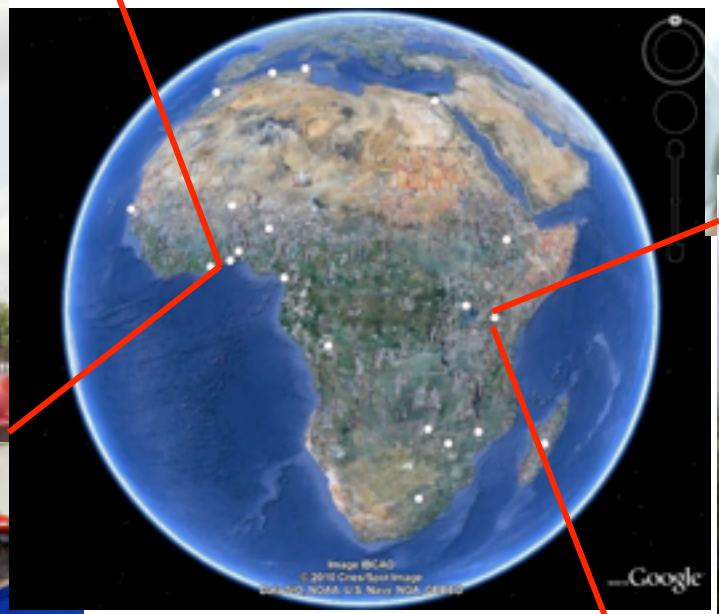
1. First antenna: January 2014
2. First receptor test system: April 2014
3. Antennas construction completed: June 2016
4. MeerKAT large science programmes (L-band + baselines up to 8 km): 2018 - 2019
5. MeerKAT large science programmes (continuum + baselines up to 20 km) 2019 - 2020

Synopsis: Lessons Learnt

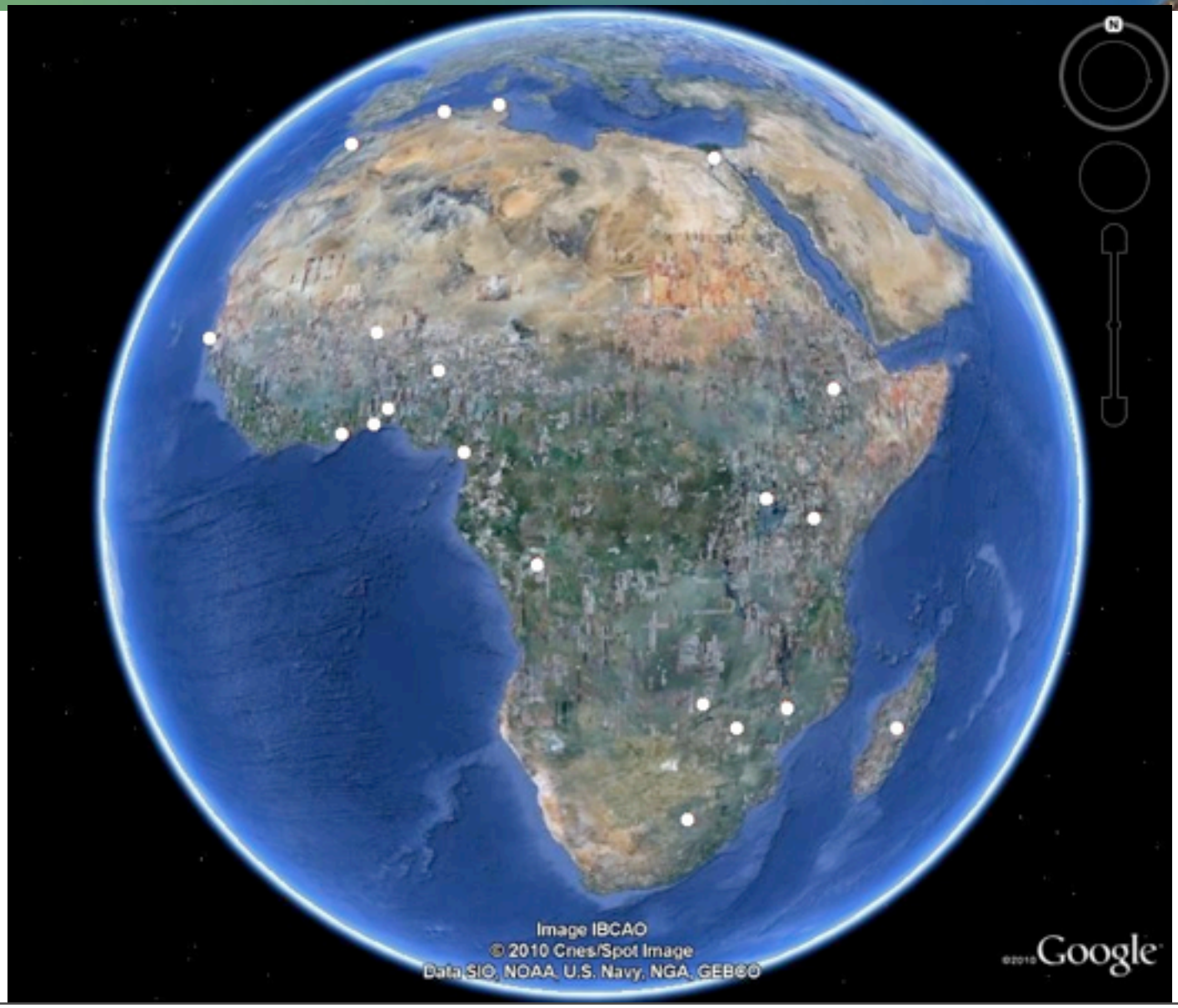
- Keep the communications channels open
- Do science early & do it often
- Somebody has to make the hard decisions (not all science can be done)
  - Also don’t promise what you cannot deliver
- systems wide evaluations - don’t evaluate subsystems in isolation

Thanks to
Justin Jonas & Jasper Horrell

African VLBI Network



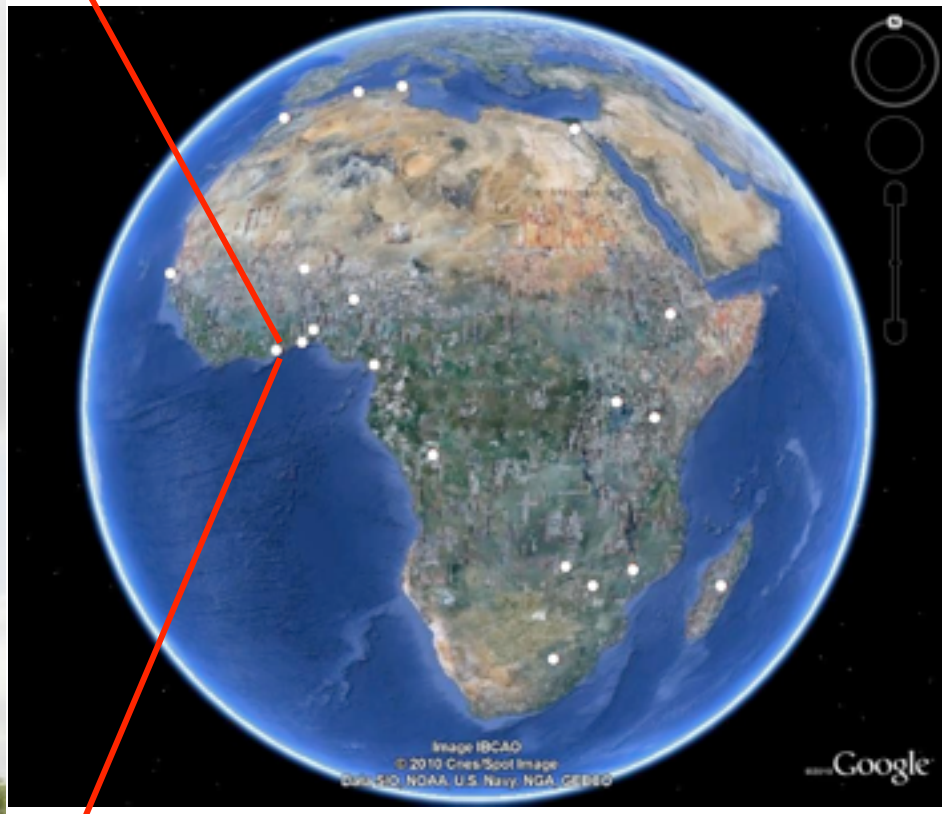
30-m class antennas in Africa



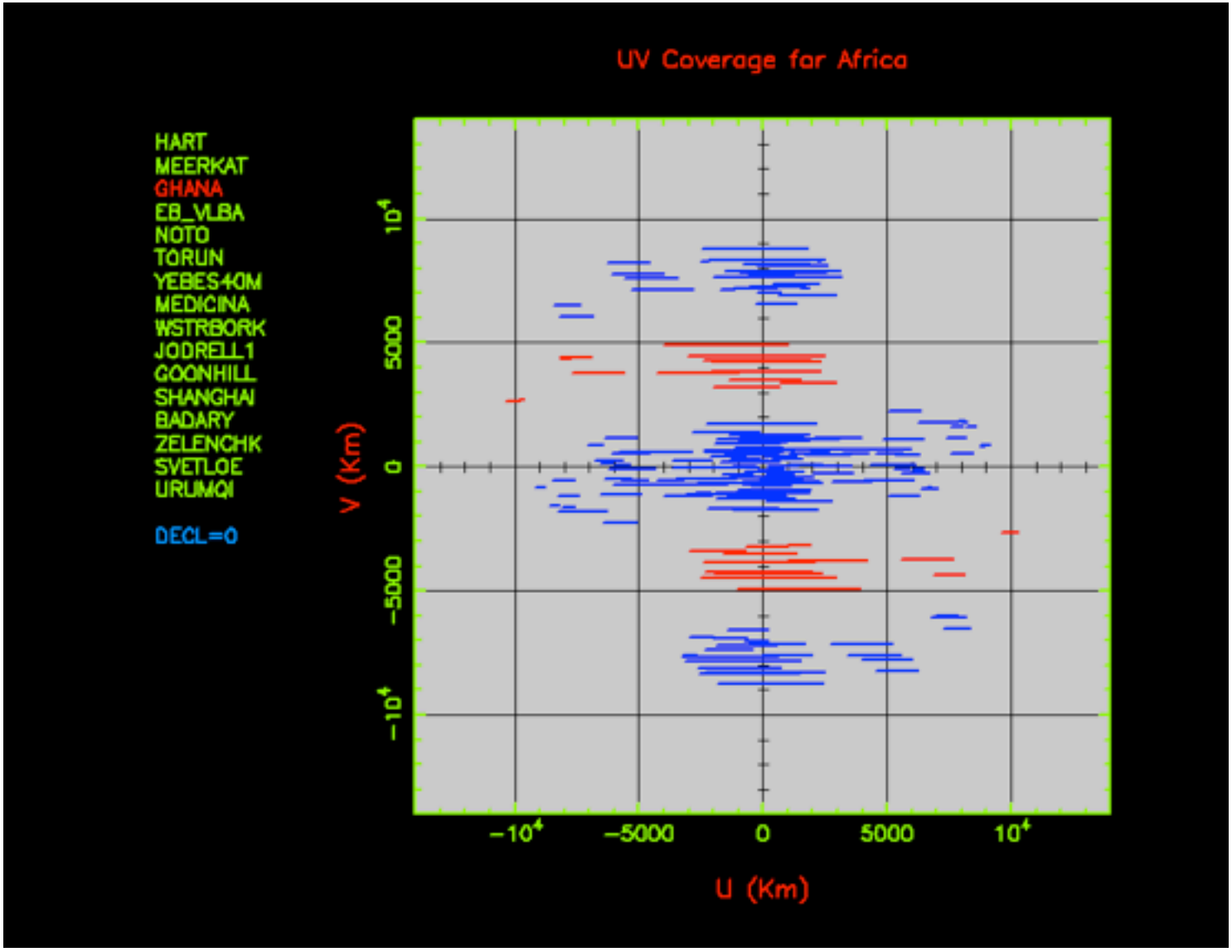
The African VLBI Network

- Convert existing communications antennas into radio astronomy facilities.
  - Maintain existing staff.
  - Install new receivers and instrumentation.
  - Create a VLBI array that will link with
    - MeerKAT
    - HartRAO
    - Europe, the USA and Australasia.

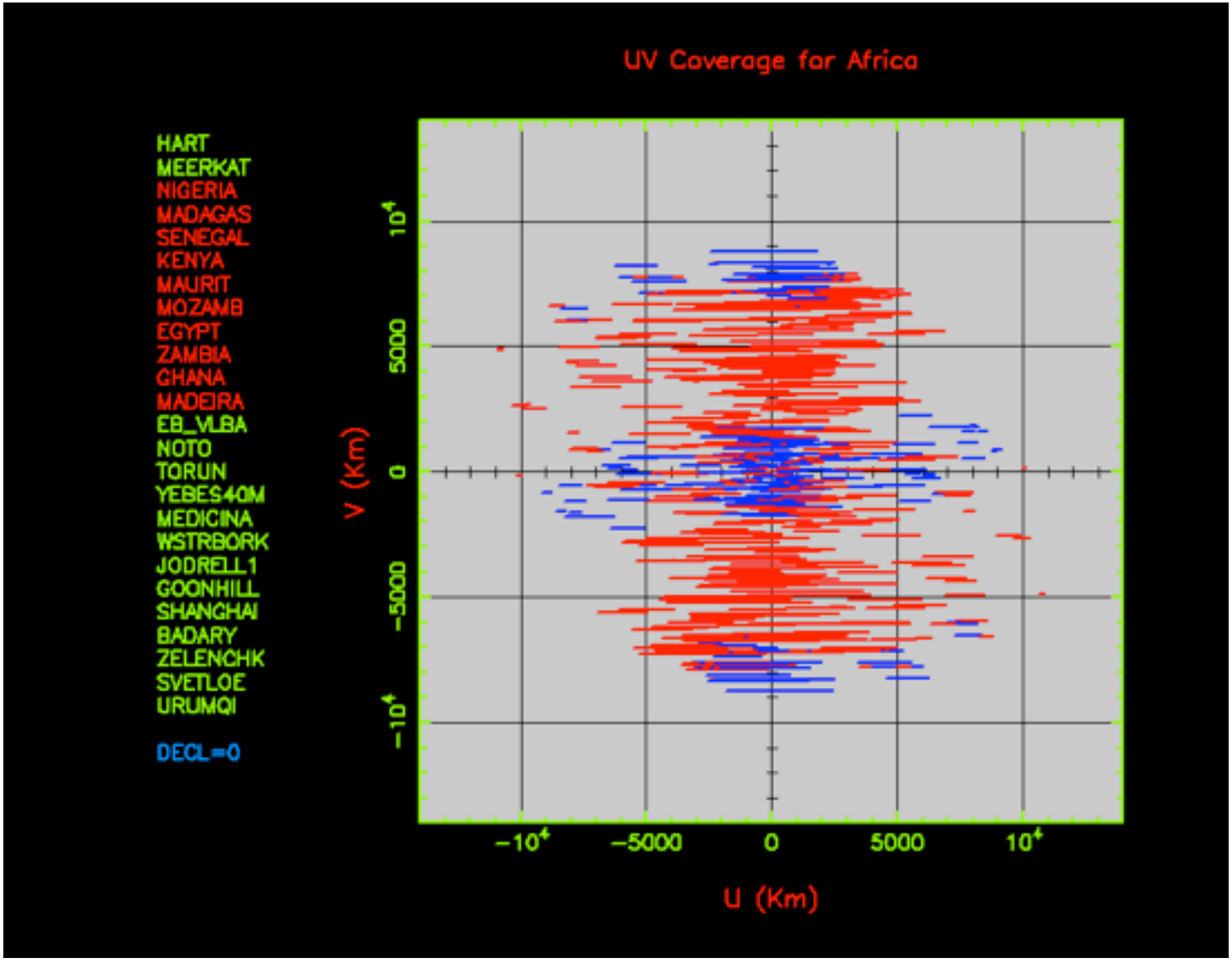
Nkutunse - Ghana



EVN + Ghana


UV Coverage for Africa
HART
MEERKAT
GHANA
EB_VLBA
NOTO
TORUN
YEBES40M
MEDICINA
WSTRBORK
JODRELL1
GOONHILL
SHANGHAI
BADARY
ZELENCHK
SVETLOE
URUMQI
DECL=0
V (Km)
U (Km)
10^4
5000
0
−5000
-10^4
-10^4
−5000
0
5000
10^4

EVN + AVN


UV Coverage for Africa
HART
MEERKAT
NIGERIA
MADAGAS
SENEGAL
KENYA
MAURIT
MOZAMB
EGYPT
ZAMBIA
GHANA
MADEIRA
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URUMQI
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