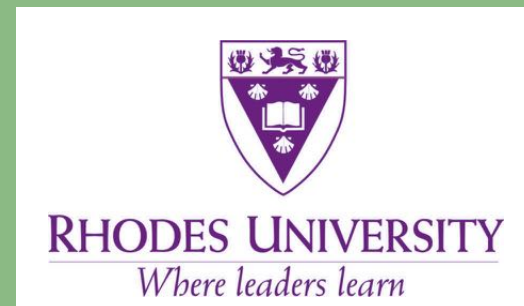


MeerKAT as an SKA Precursor



Justin Jonas

Chief Technologist: SKA South Africa
Professor & Director: Centre for Radio
Astronomy Techniques & Technologies,
Rhodes University



China/SA bilateral conference – Unhlanga Rocks – 21st November 2016

Rhodes University

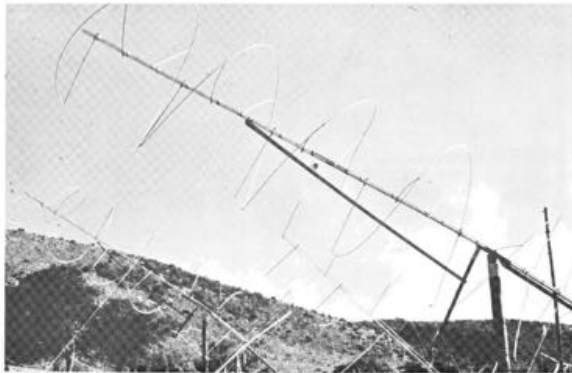


Fig. 7 Helical antenna of the Rhodes University swept-frequency polarimeter.

letters to nature

Nature 197, 474 - 475 (02 February 1963); doi:10.1038/197474b0

Radio Observations of Jupiter during 1962

J. A. GLEDHILL, G. M. GRUBER & M. C. BOSCH

Department of Physics, Rhodes University, Grahamstown, South Africa.
East London, South Africa.

It has been suggested by Barrow¹ that a rigorous comparison of solar, geomagnetic and Jupiter activity in radio emission cannot be made until continuous observation of Jupiter is possible throughout an apparition. The results summarized in this communication will, it is hoped, help to fill some gaps in the available figures for the 1962 apparition.

article

Nature 211, 808 - 810 (20 August 1966); doi:10.1038/211808a0

Millisecond Radio Pulses from Jupiter

E. E. BAART*, C. H. BARROW & R. T. LEE

Radio Observatory, Department of Physics, The Florida State University, Tallahassee, Florida

*On leave from the Department of Physics, Rhodes University, Grahamstown, South Africa.

Astrophysical Letters, 1971, Vol. 9, pp. 211-213

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The Highest Frequency of Jupiter's Decametric Radiation

E. E. BAART, J. G. GREENER, and A. WULFF *Rhodes University, Grahamstown, South Africa*

The position of the satellite Io relative to Jupiter is shown to be correlated with the highest frequency in Jupiter's decametric radiation which is received on earth. The variation in the highest frequency with sub-Io longitude provides a test for theories of the generation of the radiation.



Diaspora: Cambridge



article

Nature **236**, 440 - 443 (28 April 1972); doi:10.1038/236440a0

Galactic Structure and the Apparent Size of Radio Sources

A. C. S. READHEAD & A. HEWISH

Mullard Radio Astronomy Observatory, Cavendish Laboratory, Cambridge

Observations of radio sources at 81.5 MHz show that interstellar scattering is more important than some pulsar data suggest. Low frequency measurements also provide a new means for studying the distribution of ionized gas in the Galaxy.

Mon. Not. R. astr. Soc. (1974) **167**, *Short Communication*, 31P-35P.

Mon. Not. R. astr. Soc. (1974) **168**, *Short Communication*, 1P-6P.

THE MORPHOLOGY OF EXTRAGALACTIC RADIO SOURCES OF HIGH AND LOW LUMINOSITY

B. L. Fanaroff and J. M. Riley

(Received 1974 March 6)

SUMMARY

The relative positions of the high and low brightness regions in the extragalactic sources in the 3CR complete sample are found to be correlated with the luminosity of these sources.

RADIO AND OPTICAL STUDIES OF 4C 11.50

A. N. Argue, R. D. Ekers, B. L. Fanaroff, C. Hazard, M. Ryle, J. R. Shakeshaft, A. Stockton and A. S. Webster

(Received 1974 April 10)

SUMMARY

A 5 GHz map of 4C 11.50 with the 5-km telescope reveals a compact component coincident with the QSO 1548+115a, together with two extended components; their radio spectra are determined. A low upper limit is placed on radio emission from the nearby QSO 1548+115b and there is no evidence of any connection between the two QSOs. A photograph with the 224-cm telescope on Mauna Kea shows a small group of galaxies which may be members of a cluster at the same distance as the brighter QSO.

Diaspora: Jodrell Bank



AN EXPERIMENT TO MEASURE THE MAGNETIC FIELD OF THE GALAXY

I. TECHNIQUES OF MEASUREMENT

R. D. Davies, W. L. H. Shuter, C. H. Slater, G. L. Verschuur and P. A. T. Wild

(Received 1963 March 28)

Summary

The galactic magnetic field can be measured by investigating the Zeeman splitting of neutral hydrogen spectral features at 21 cm wavelength. Three versions of a basic measurement technique applied to the problem are described and their merits are discussed. Low noise receivers and switches at present available make it possible to extend the measurement of the Zeeman effect to weaker radio sources and to neutral hydrogen emission regions with narrow line widths.

article

Nature **222**, 933 - 937 (07 June 1969); doi:10.1038/222933a0

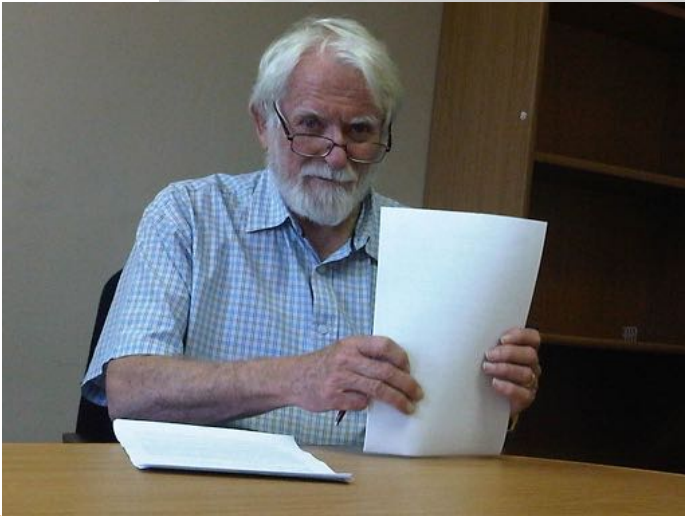
The Jodrell Bank Radio Frequency Digital Autocorrelation Spectrometer

R. D. DAVIES, J. E. B. PONSONBY, L. POINTON & G. DE JAGER

Nuffield Radio Astronomy Laboratories, Jodrell Bank, Macclesfield, Cheshire

A versatile digital autocorrelation spectrometer designed and built at Jodrell Bank is described, together with some examples of observations made with the new instrument.

NASA/DSN -> HartRAO - 1974



George Nicolson



THE ASTROPHYSICAL JOURNAL, 243:589-596, 1981 January 15
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VLBI OBSERVATIONS OF SS 433 AT 3.6 AND 13 CENTIMETERS

R. C. WALKER, A. C. S. READHEAD, AND G. A. SEIELSTAD
California Institute of Technology

R. A. PRESTON, A. E. NIELL, AND G. M. RESCH
Jet Propulsion Laboratory

P. C. CRANE AND D. B. SHAFFER
National Radio Astronomy Observatory, Green Bank

B. J. GELDZAHLER
Max-Planck-Institut für Radioastronomie

S. G. NEFF
National Radio Astronomy Observatory, Charlottesville

I. I. SHAPIRO
Massachusetts Institute of Technology Cambridge,

D. L. JAUNCEY
Division of Radiophysics, C.S.I.R.O., Sydney, Australia

AND

G. D. NICOLSON
CSIR, Johannesburg, South Africa

Received 1980 June 2; accepted 1980 August 6

A SURVEY OF SOUTHERN GALACTIC RADIATION AT 960 Mc/s

G. D. NICOLSON

National Institute for Telecommunications Research
C.S.I.R., Johannesburg, South Africa

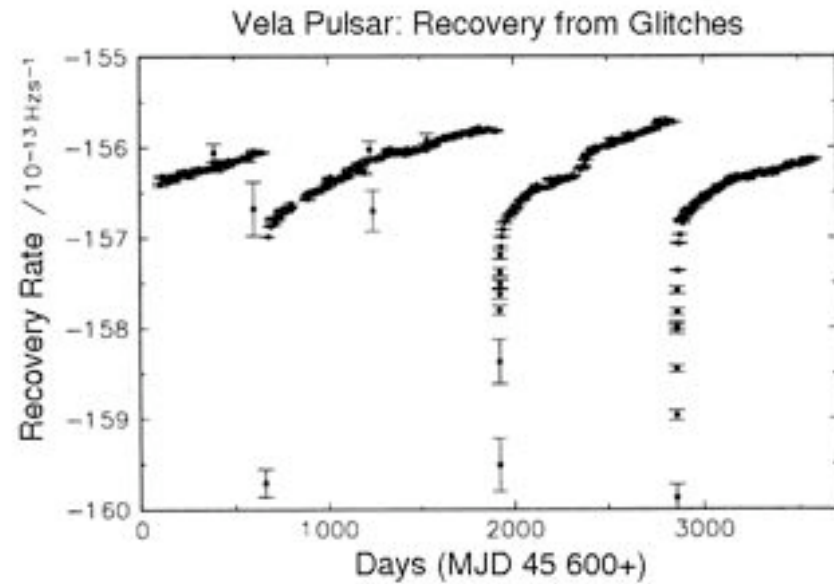
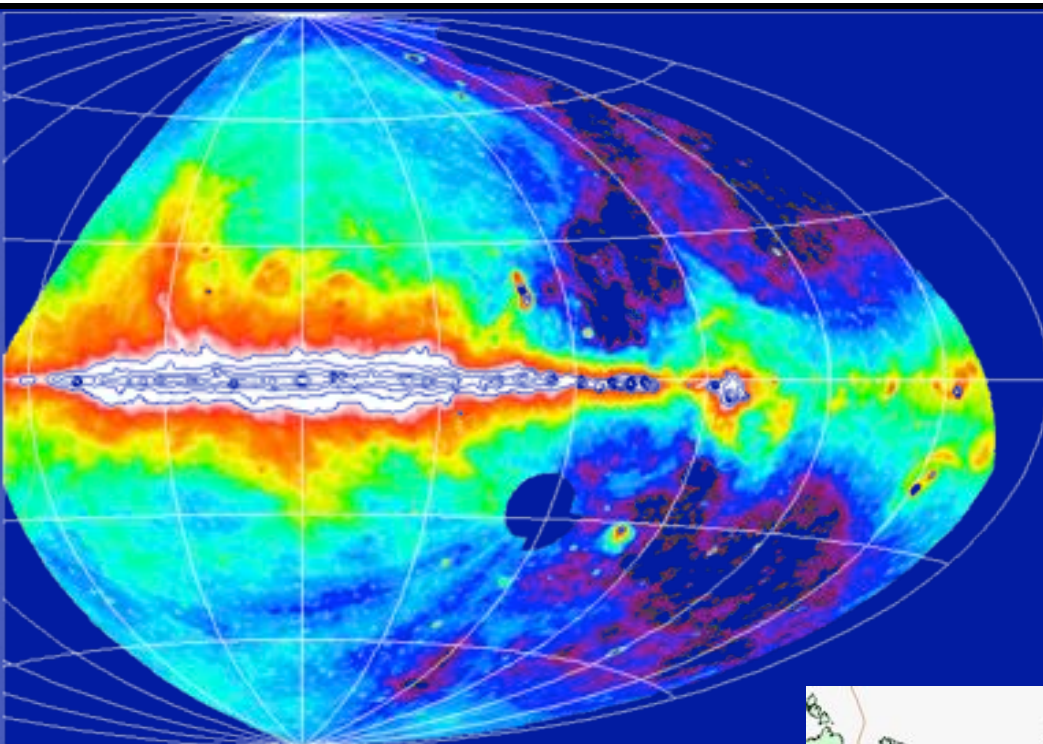
Received April 26, 1965

June 1974

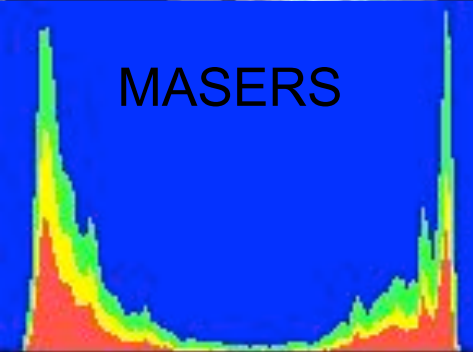
HartRAO Science



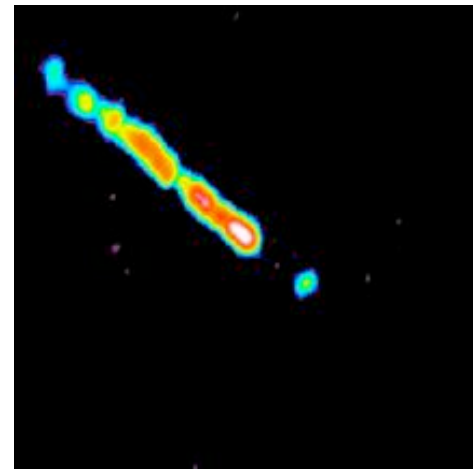
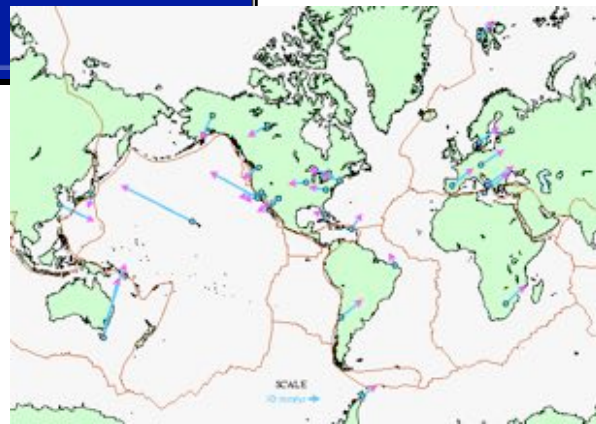
Rhodes/HartRAO 2326 MHz survey



VLBI



Space
Geodesy



The beginning of SKA in SA

January 2001

The Square Kilometre Array (SKA) in South Africa

Dear URSI Colleague

On Wednesday/Thursday this week (31/1/2001-1/2/2001) the NSF will be holding a foresight workshop to discuss the future of astronomy and space science in South Africa. This workshop will be attended by most professional astronomers in South Africa and representatives from the NSF and DACST (including Kheto Makhela and the DACST Director General, Rob Adam).

Following the successful launch of the Southern Africa Large Telescope (SALT) project, the SA government is canvassing for another large-scale international project to begin construction in ten year's time. A large fraction of the SA astronomy community (including the senior staff at SAAO and HartRAO) feel that a high-sensitivity, high-resolution radio telescope array such as the proposed Square Kilometre Array (SKA) would be the most viable and desirable candidate project.



...cont...



These challenges include:

- a) multiple beam-forming and beam-nulling with large antenna arrays
- b) RFI mitigation
- c) signal links between the array elements (1-3000 km)
- d) the design of Luneburg Lens elements
- e) the design of massive wide bandwidth signal correlators, spectrometers and other DSP hardware
- f) the supervisory electronics necessary to control this massive and extensive antenna array

I foresee three possible outcomes from the workshop:

- a) SA makes no attempt to join the SKA consortium
- b) SA joins the consortium with the aim of being involved in the technical development of the instrument and/or making observations with it.
- c) Same as (b), but SA makes a strong bid to host the array.

The purpose of this e-mail is to canvass sentiment and opinion from the SA Electronic Engineering community. Specifically I would like to report at the workshop the level of interest shown by local Engineering faculties in this project.

Overhead transparency



Recently canvassed opinion

Ron Ekers (Chair ISSC):

Great news to hear of your interest. We are developing the ideas for the SKA in an International context so I welcome news of your interest.

There have been a lot of developments since the establishment of the URSI large telescope working group. In particular there is now a formal International SKA Steering Committee (ISSC) and I have forwarded your request to the representatives on this group.

Peter Hall (SKA Program Leader, ATNF):

I'll also pass the text of your message around the Australian consortium and ask anyone who would like to contact you to do so directly. I imagine the issue may be discussed at our first formal national gathering (next week) and we might also forward you some commentary then.

Berkeley ISSC: July 2001



ISSC 11 – Cape Town 2004

Ron invited to SAIP (Sept 2002)



Khotso Mokhele



science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



Rob Adam



Adi Paterson



South African participation in the Square Kilometre Array (SKA)

Prof Justin Jonas

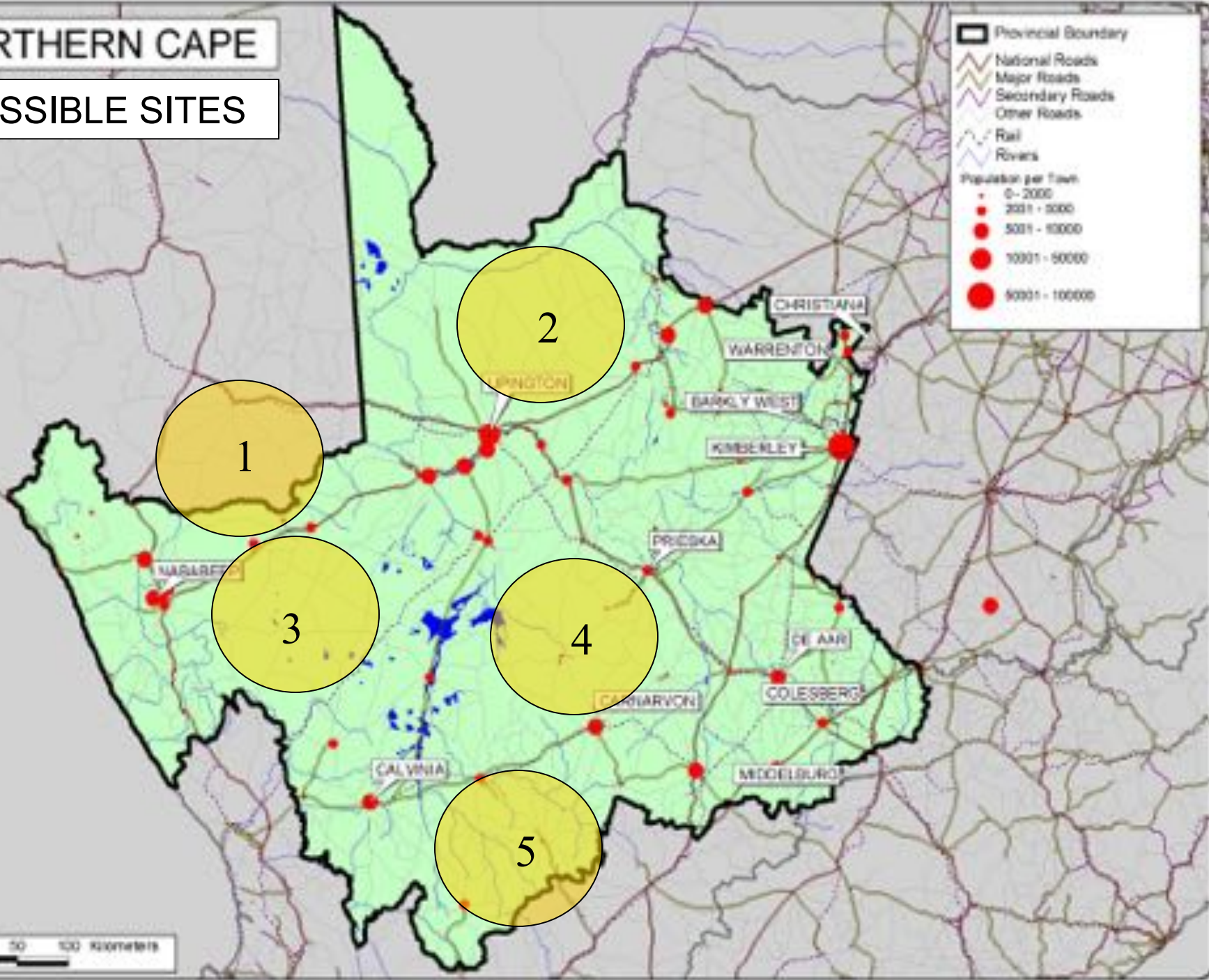
Department of Physics & Electronics



Tuynhuis, Cape Town
7 am Friday 14th February 2003

NORTHERN CAPE

POSSIBLE SITES



RFI Survey with ICASA



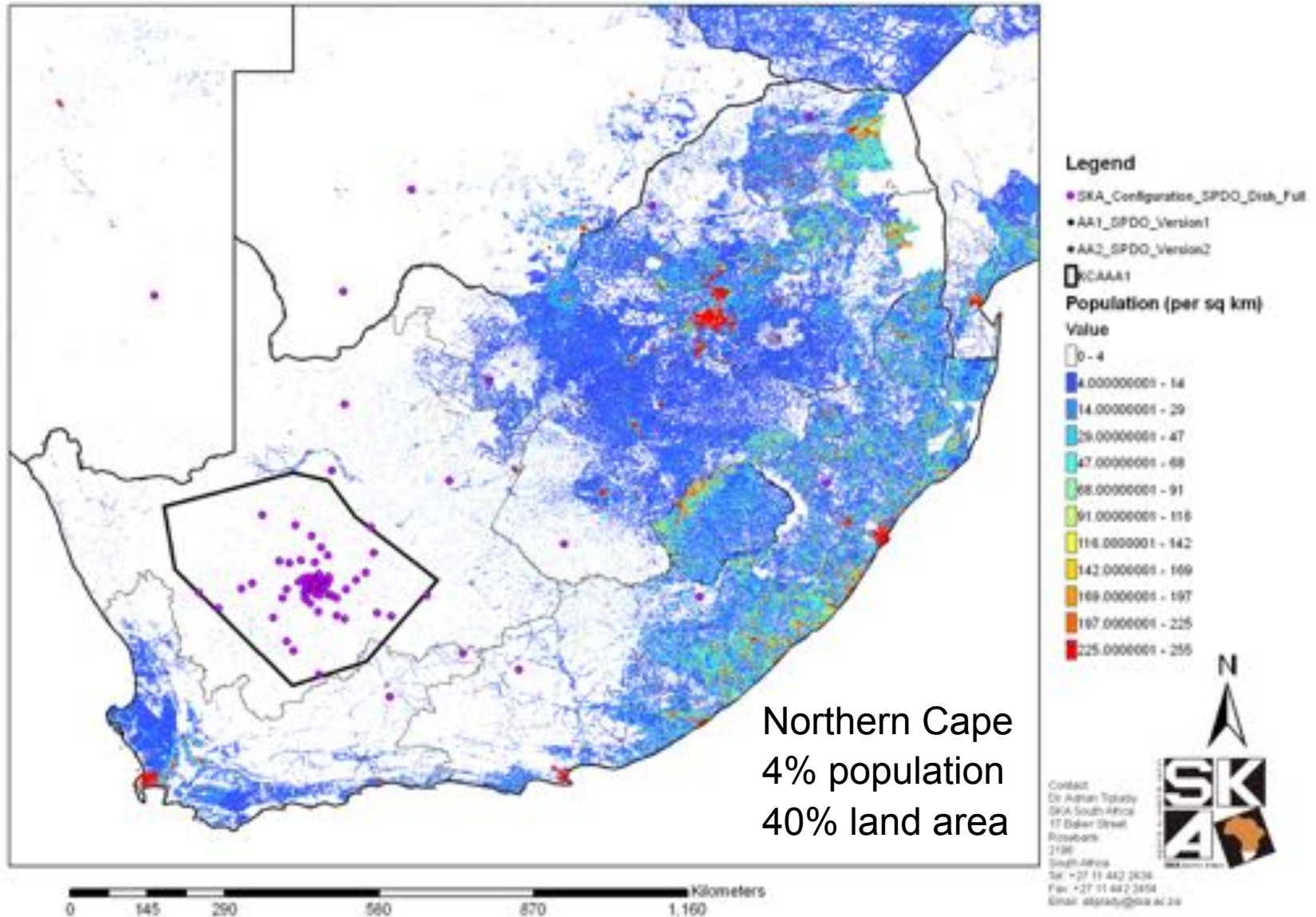
Let's put it here...



Over there Bernie ...



Population Density (and RFI)



Extracts from: *Specific Proposal for a South African Demonstrator* (16 June 2004)



- An array of **25 12-metre dish concentrators located at HartRAO** which provide an equivalent aperture to a single 60-m dish, i.e. about the same aperture as Parkes radio telescope which is the largest single dish in the southern hemisphere. This corresponds to an aggregate aperture of 2800 m².
- Operating in the L-band **frequency range of 700-1720 MHz** which complements the frequency coverage of the existing 26-metre dish at HartRAO which only operates above 1600 MHz. This frequency range includes both the HI and OH spectral line bands. The lower limit of 700 MHz might move up or down, depending on scientific and technology factors.

...cont...



- **The focal plane arrays** used with these dishes would be based on the technologies developed in SKADS DS4 and DS5. DS5 (i.e. EMBRACE) tiles would not be suitable because of their single polarization capability and 100 K noise temperature. DS4 outputs are expected to be suitable.
- An **8x8 element focal plane array might be adequate, but 12x12 is likely to be the maximum** required. This would be roughly 1-m² of SKADS patch. The use of a concentrator therefore gives a multiplier effect of about 100. Field of View (FoV) would probably be about 5-deg (1150 FoVs per hemisphere).
- A **maximum baseline of 1 km** to match science and physical layout of HartRAO valley, but it is likely that the array would be more compact than this (baselines of about 100 m).

SA SKA Pathfinder: Specifications

SKA Hybrid Design (nominal):

- Array of 20 x 15-m reflecting concentrators each fed with a focal-plane phased-array (10 x 10 element)
- Operating spectral range: 0.7 GHz – 1.75 GHz
- Dual polarization
- Instantaneous bandwidth: 500 MHz each polarization
- Antenna array baselines: 20 m – 1500 m
- Array resolution: 1' @ 1420 MHz
- 10 independent beams within 10-deg antenna FoV
- $T_{\text{sys}} < 50 \text{ K}$ ($< 0.5 \text{ dB}$ LNA noise figure)
- Fully digital with FPGA+HPC back-end
- Multiple Correlators (imaging)
- Located in the Northern Cape
- Four-year development and construction horizon
(very tight)

SA SKA Pathfinder: Science

- Source surveys & monitoring (continuum & spectral line)
 - Pulsar astrometry
 - Pulsar timing
 - Pulsar searches
 - Continuum variables
 - Galactic & Extragalactic OH masers
 - Galactic thermal line sources
- Intermediate redshift ($0 < Z < 0.4$) HI surveys
- Galactic continuum (polarisation, CMB, SNR)
- L/S-band VLBI (EVN, LBA, etc)
- Complement SALT/SAAO, H.E.S.S. & HartRAO

International Science Reference Panel

Individual Antenna

Cheap
Mass-produced
L/S-Band
Low-risk

Focal-plane
Phased-array
High-risk

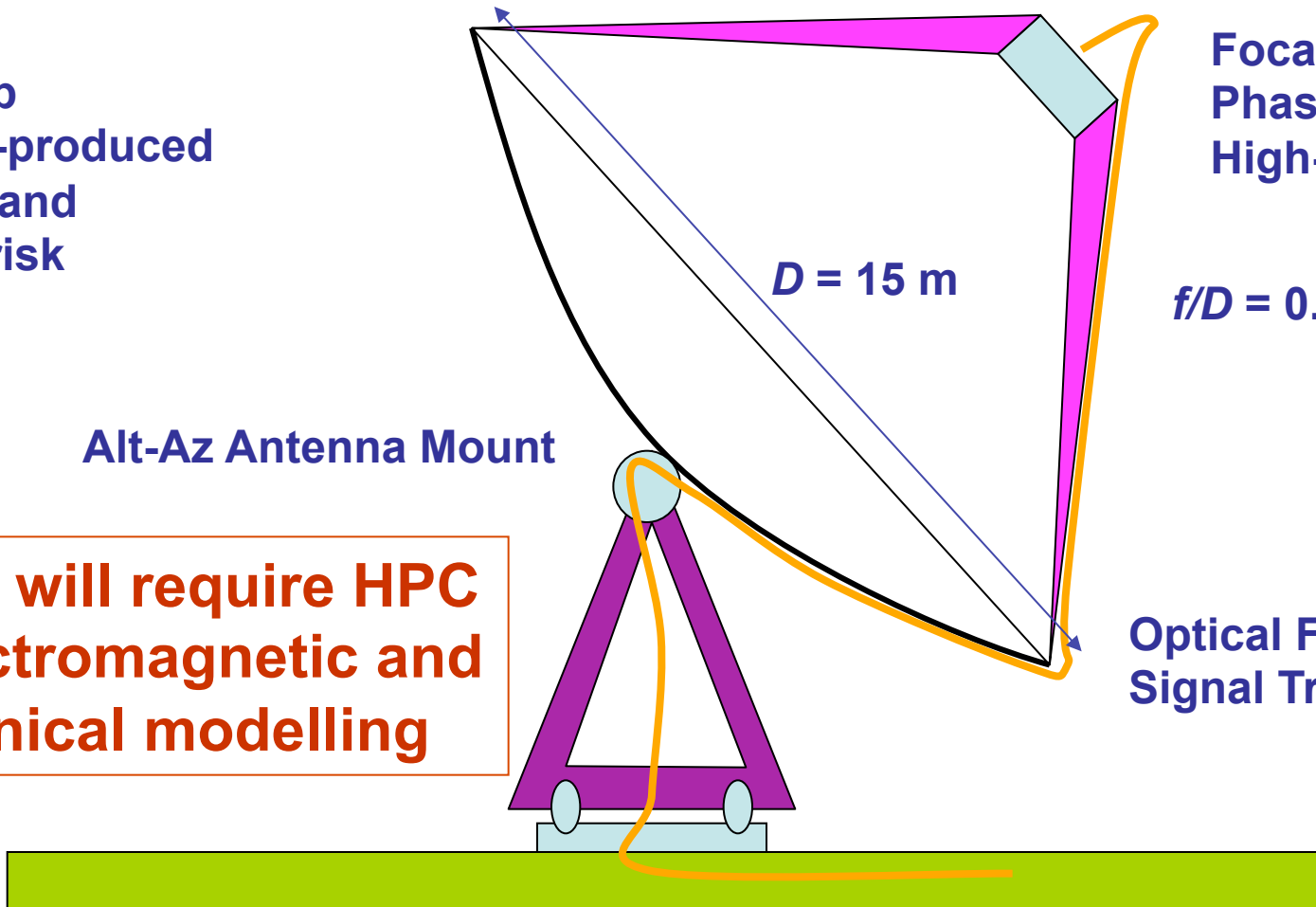
$D = 15 \text{ m}$

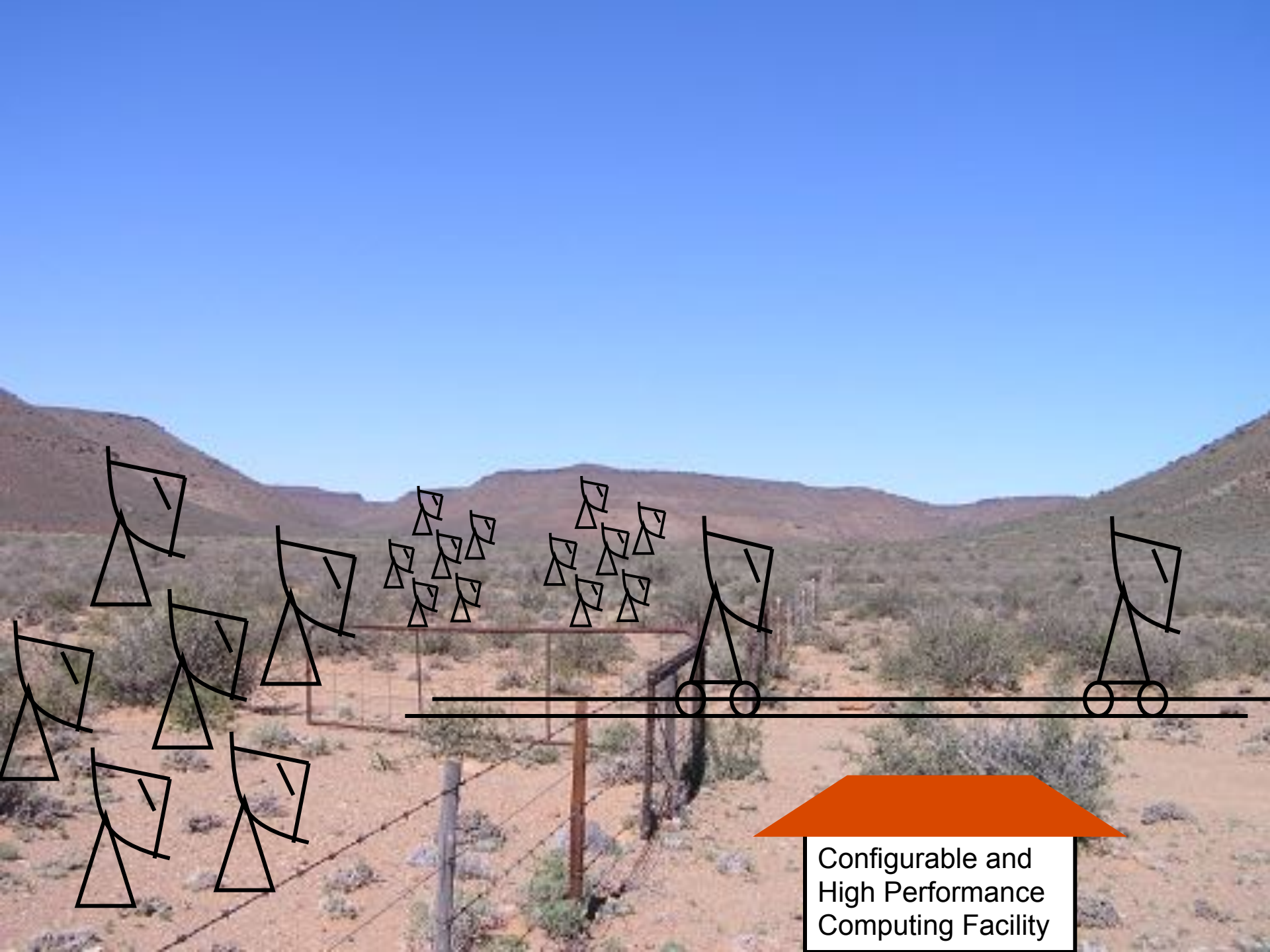
$f/D = 0.6$

Alt-Az Antenna Mount

Design will require HPC
for electromagnetic and
mechanical modelling

Optical Fibre
Signal Transport





Configurable and
High Performance
Computing Facility

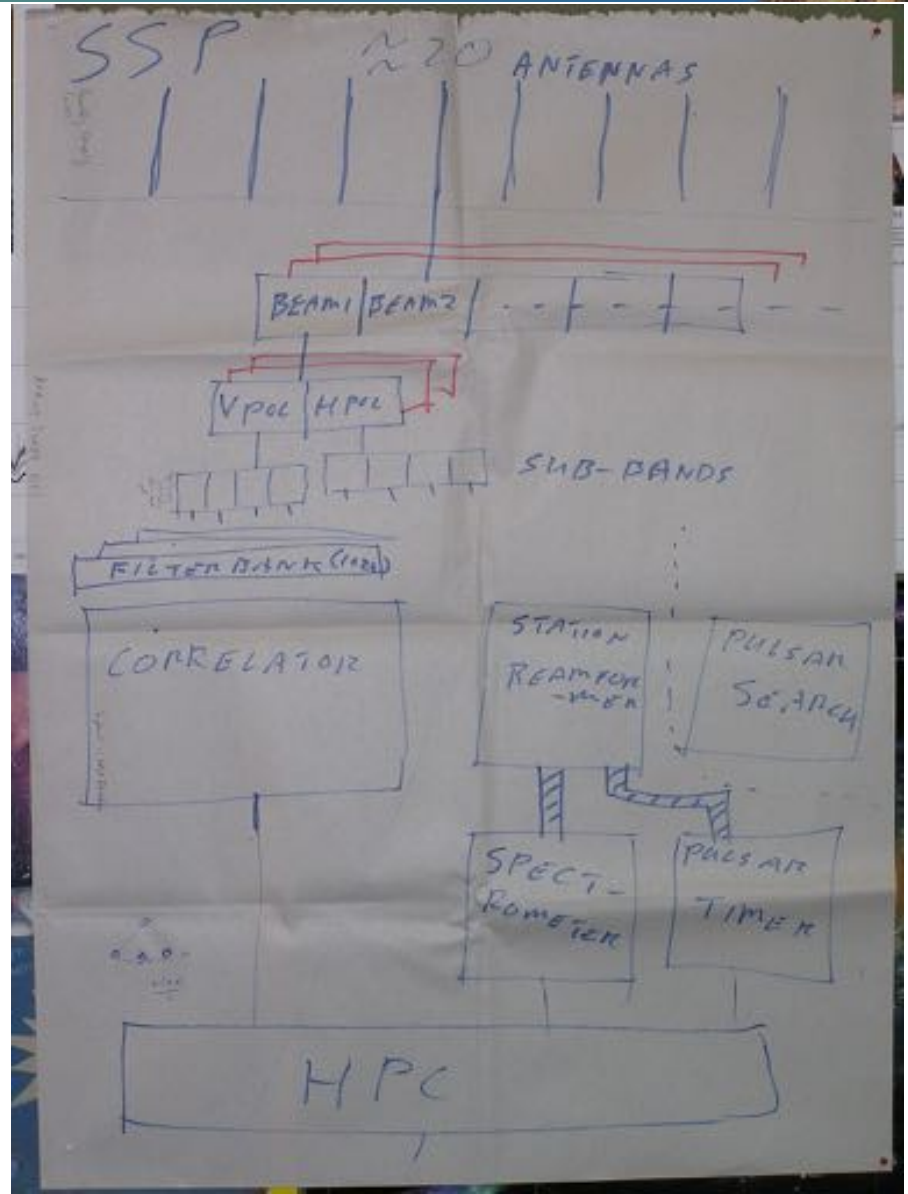
The Karoo Array Telescope (KAT)



First workshop with engineers

~ 2003

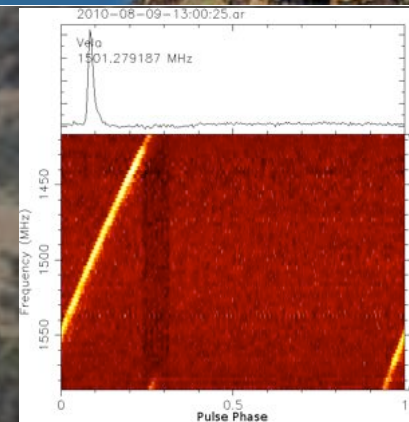
SKA technology
pathfinder with
high risk options



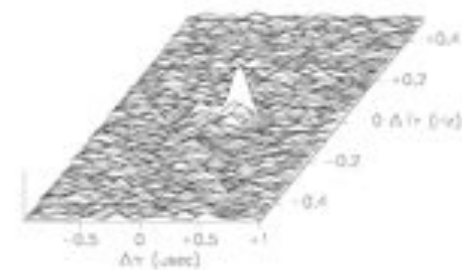
XDM 15-m composite & PAFs



XDM 15-m



Source: N140512, 1501.279187 MHz, 16MHz sampling
Date: 2010/08/09 08:18:38
Amp: 0.000935, SNR: 32.2 (no amp correction)
Delay Res (sec): 8.869e-08 Rate Res(x/s): 2.159e-12



KAT-7 Array



XDM Dish

Prime Focus

Symmetric

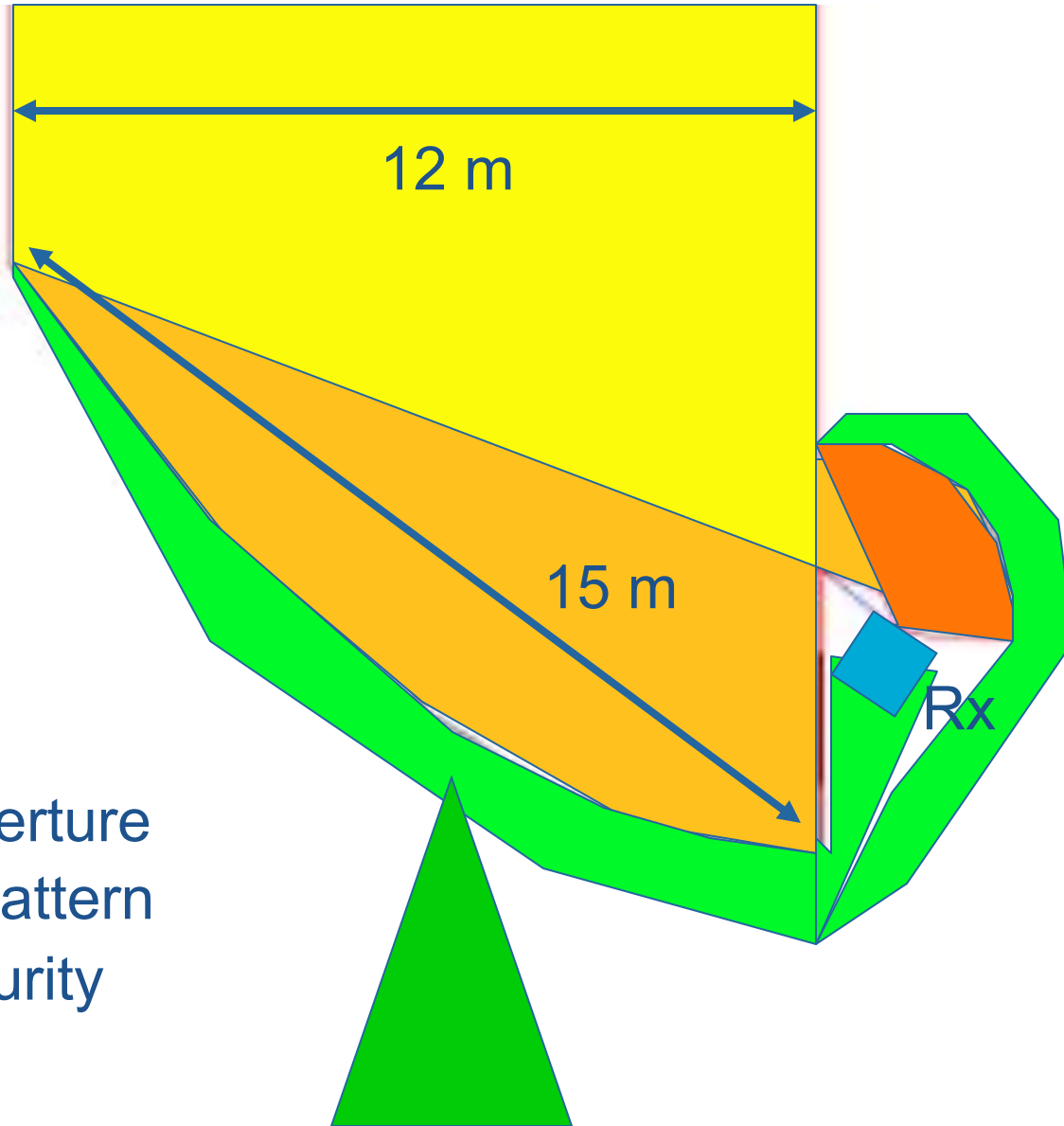
Complex aperture blockage

Complex sidelobe pattern
that rotates in the sky plane

S_{11} issues

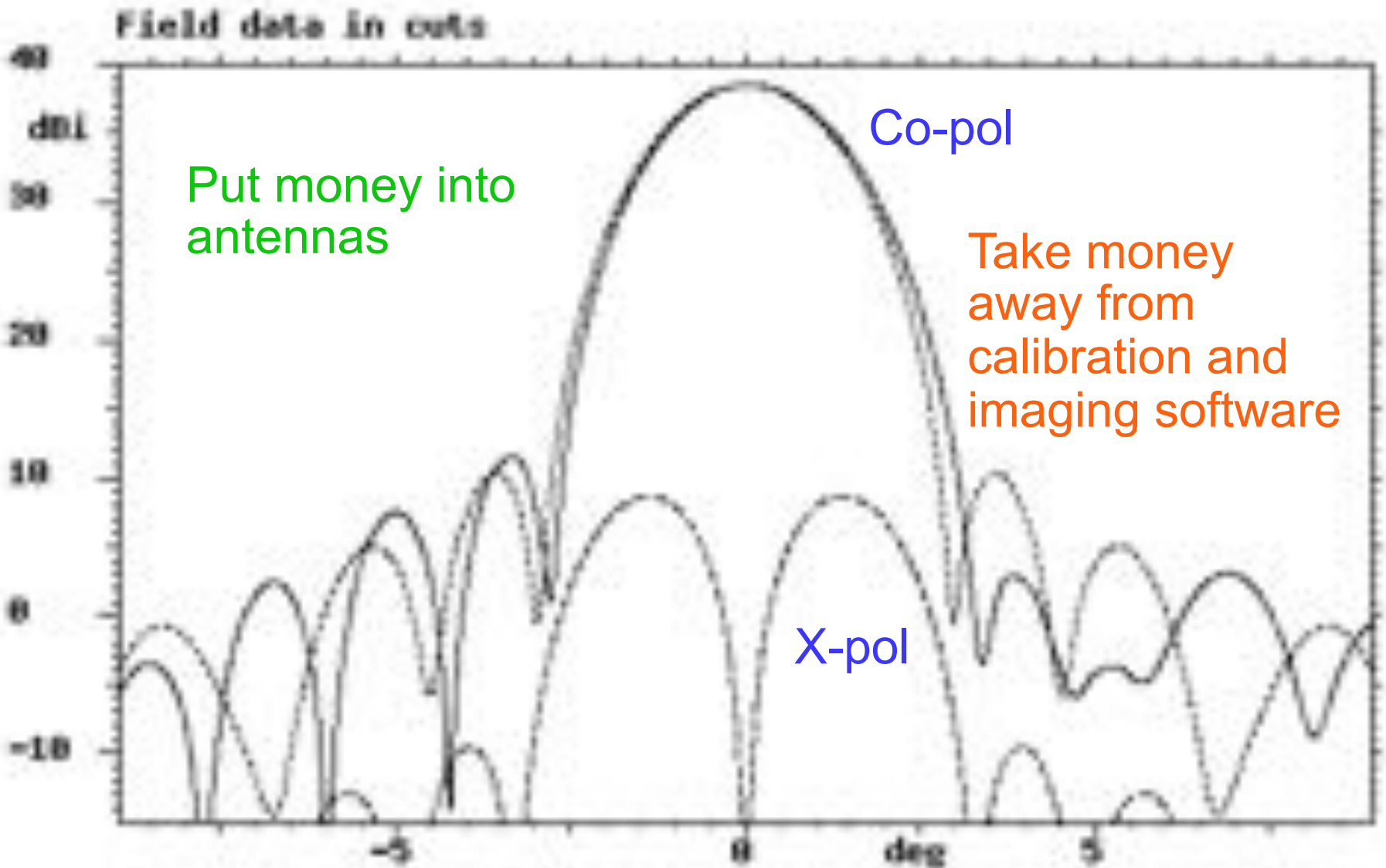


Offset Gregorian Optics



Unblocked aperture
Clean beam pattern
Polarization purity
S11 good

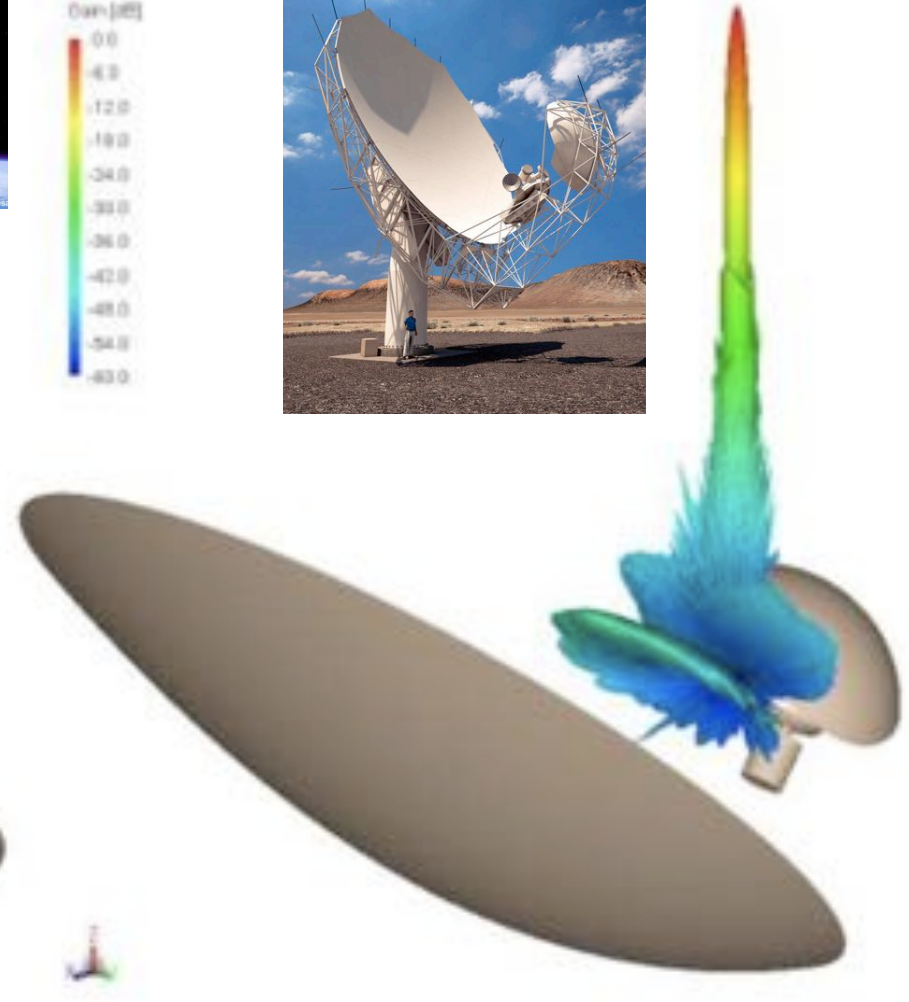
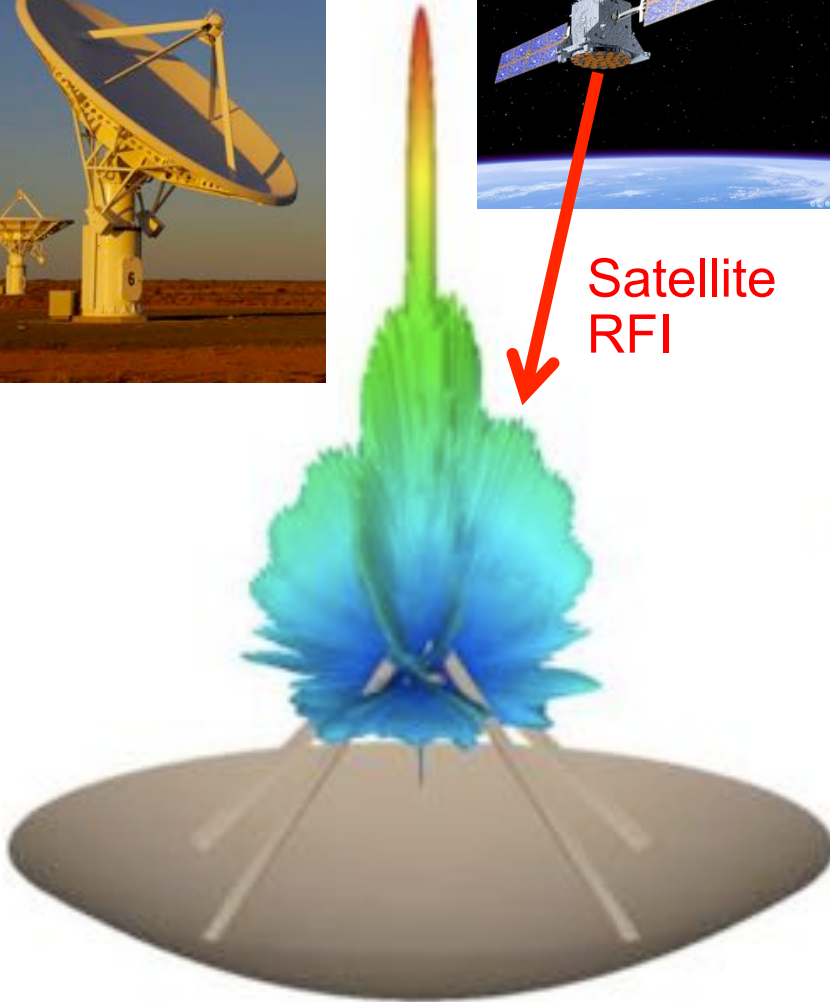
Low sidelobes - good polarization



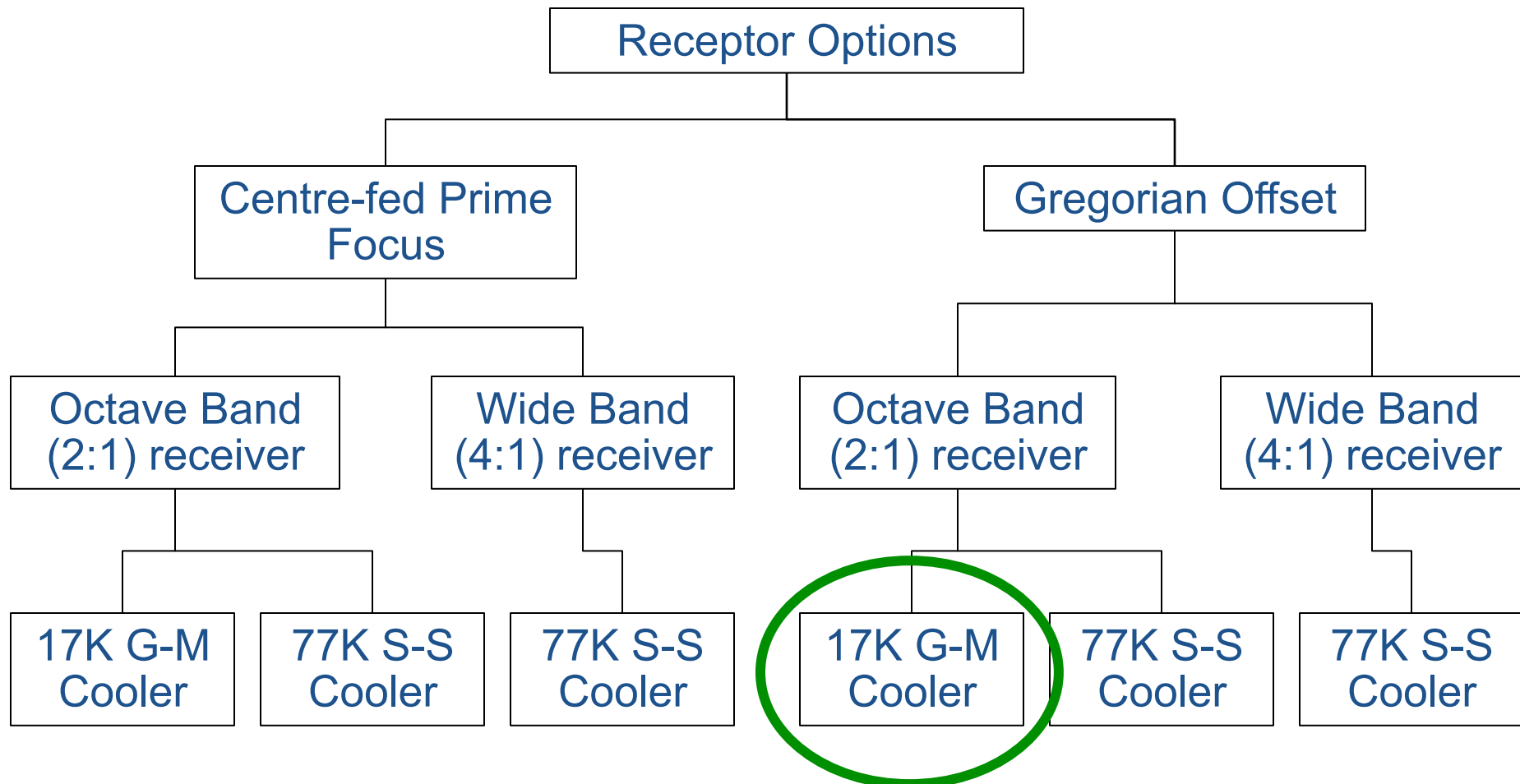
Electromagnetic Modeling



Satellite
RFI



CoDR: Concept Exploration & Trade-offs

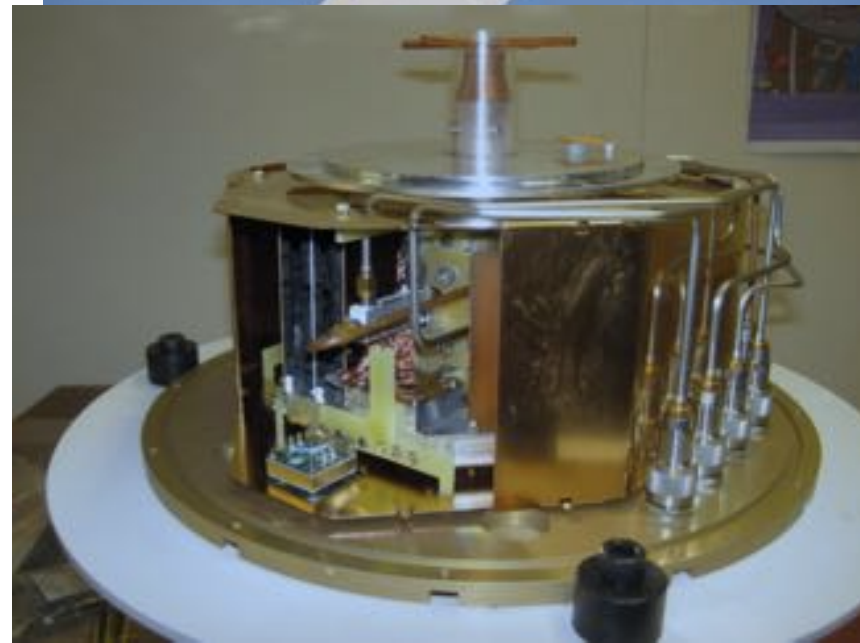


Cost functions traceably linked to Science & Operations Requirements
NOT post-facto justification for technology choice

KAT-7 — (*not* a MeerKAT prototype...)



- Symmetric centrefed dish
- Wide flare corrugated horn
- Compact OMT
- Stirling cycle cryogenics
- Water cooling
- Ion vacuum pump
- RF-over-fibre
- Heterodyne Rx
- Casper/Roach DSP



System Description

- Gregorian offset antennas (“feed low”)
 - Multiple receivers
 - RFI rejection
 - Spectral & imaging dynamic range
 - Low spillover, high efficiency
 - Sensitivity
- Cryo-cooled, octave band, single pixel receivers
 - Sensitivity
 - Stable and smooth/flat bandpass
- Compact array configuration
 - Imaging dynamic range and resolution
 - Sensitivity to extended low brightness structures
 - Transient detection
- Direct digitization at the receiver
 - No analog heterodyne stage
 - Spectral dynamic range
- FX correlator
 - Packet switched architecture
 - Heterogeneous processors
- 3G+ calibration
 - “exact” treatment of calibration solution

Innovation in every element



Pedestal fabrication & integration



Dish panel factory



Carbon-fibre Subreflector



Off and on-site production line

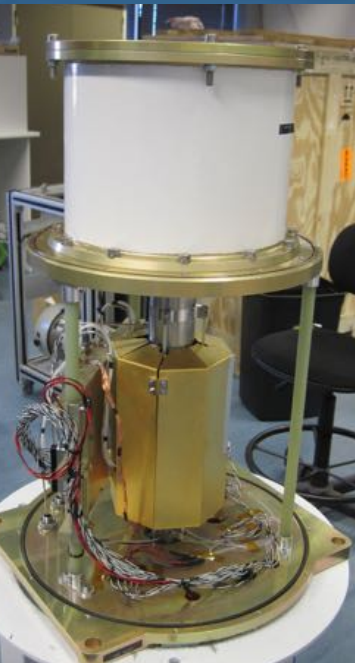
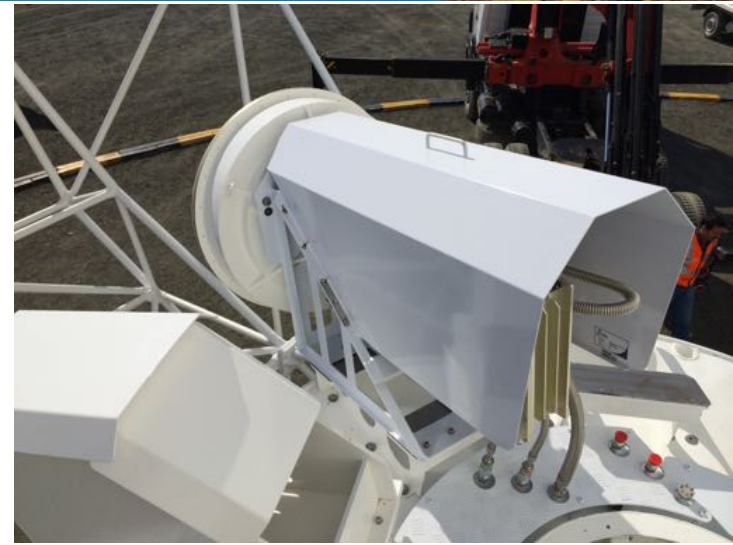


Completed main reflector





Cryogenic Receivers & Services



Big Data



Guest Instruments



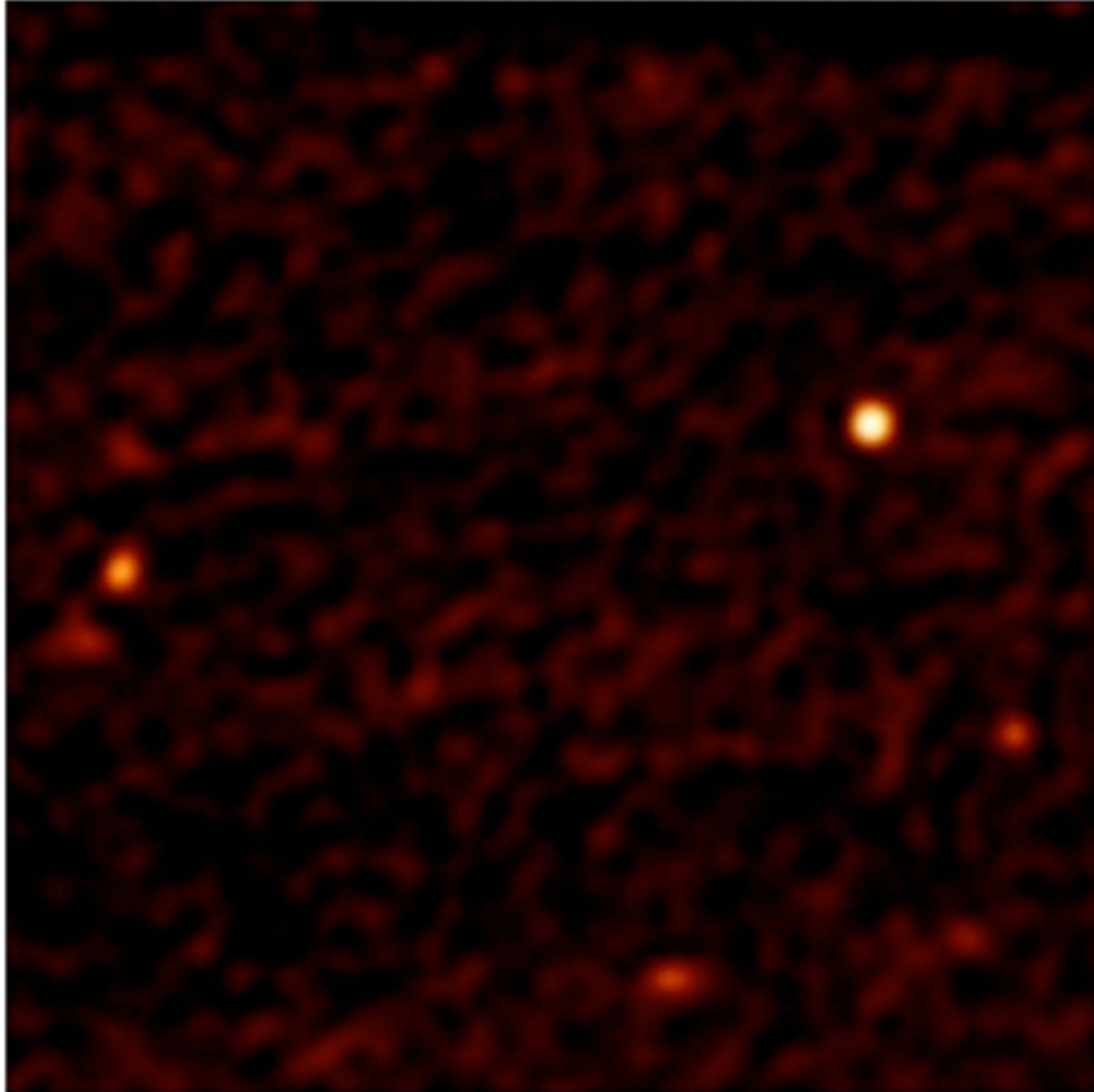
- Facility instruments
 - MPIfR S-band receivers 1.75-3.5 GHz (Kramer et al)
 - Swinburne pulsar timing machine (Bailes et al)
 - MPIfR back-end (Kramer et al)
 - MeerTRAP transient/pulsar machine (Stappers et al)
 - SETI??? (Breakthrough Listen)
- SKA prototypes
 - INFRA-SA prototype dish foundation
 - DVA-MP DISH prototype
 - ProtoNIP



SUMSS (courtesy of Tom Mauch)



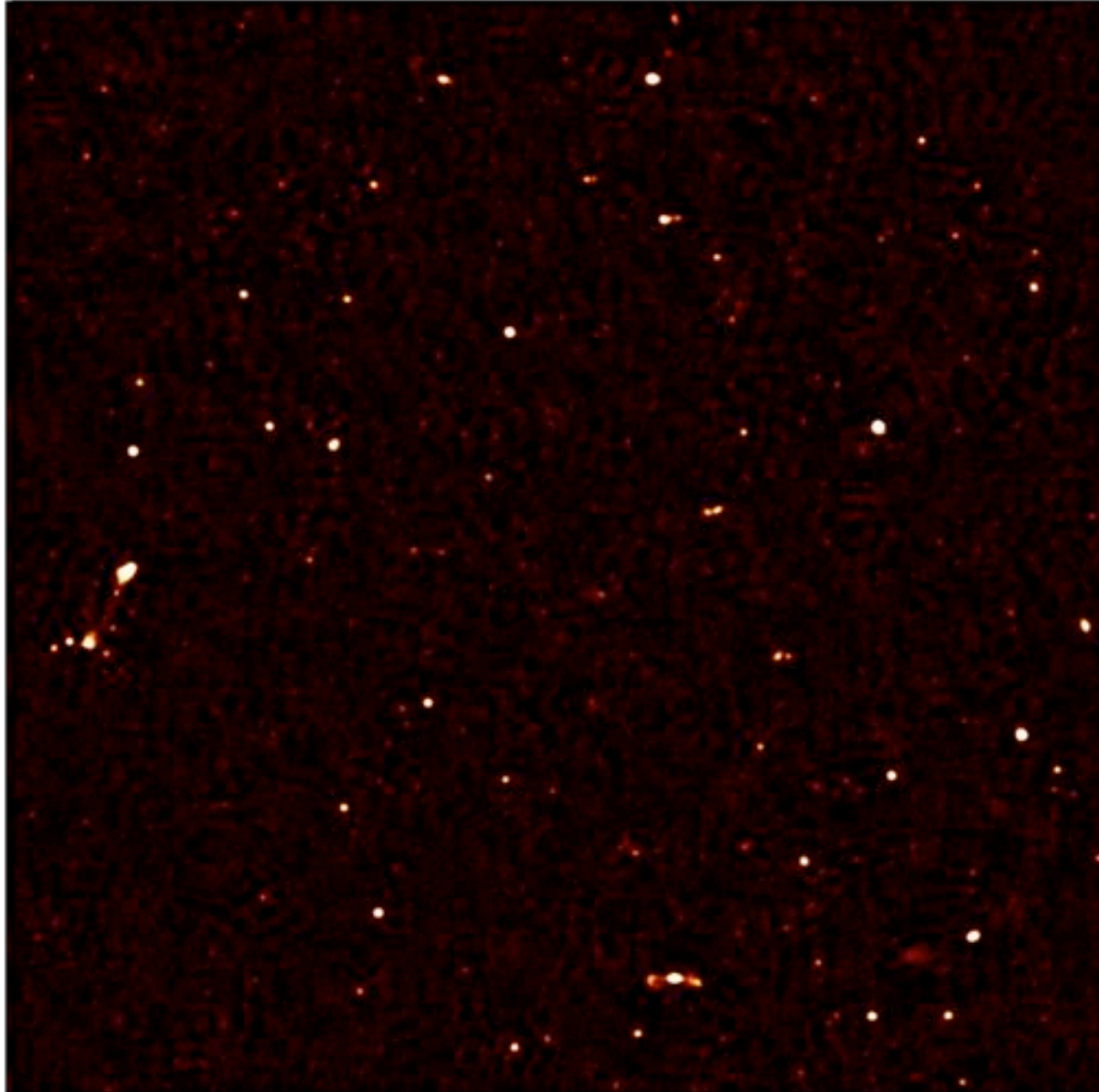
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Light image



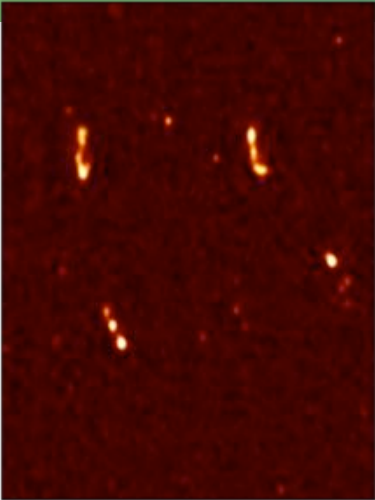
MeerKAT-16 (AR-1)



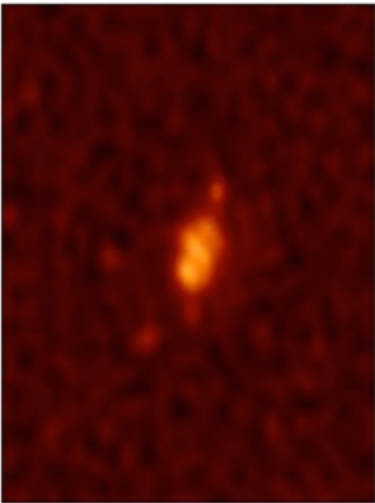
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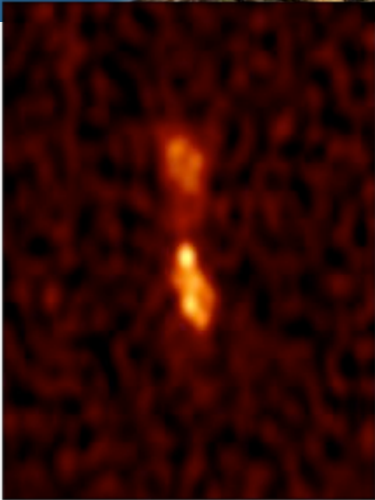
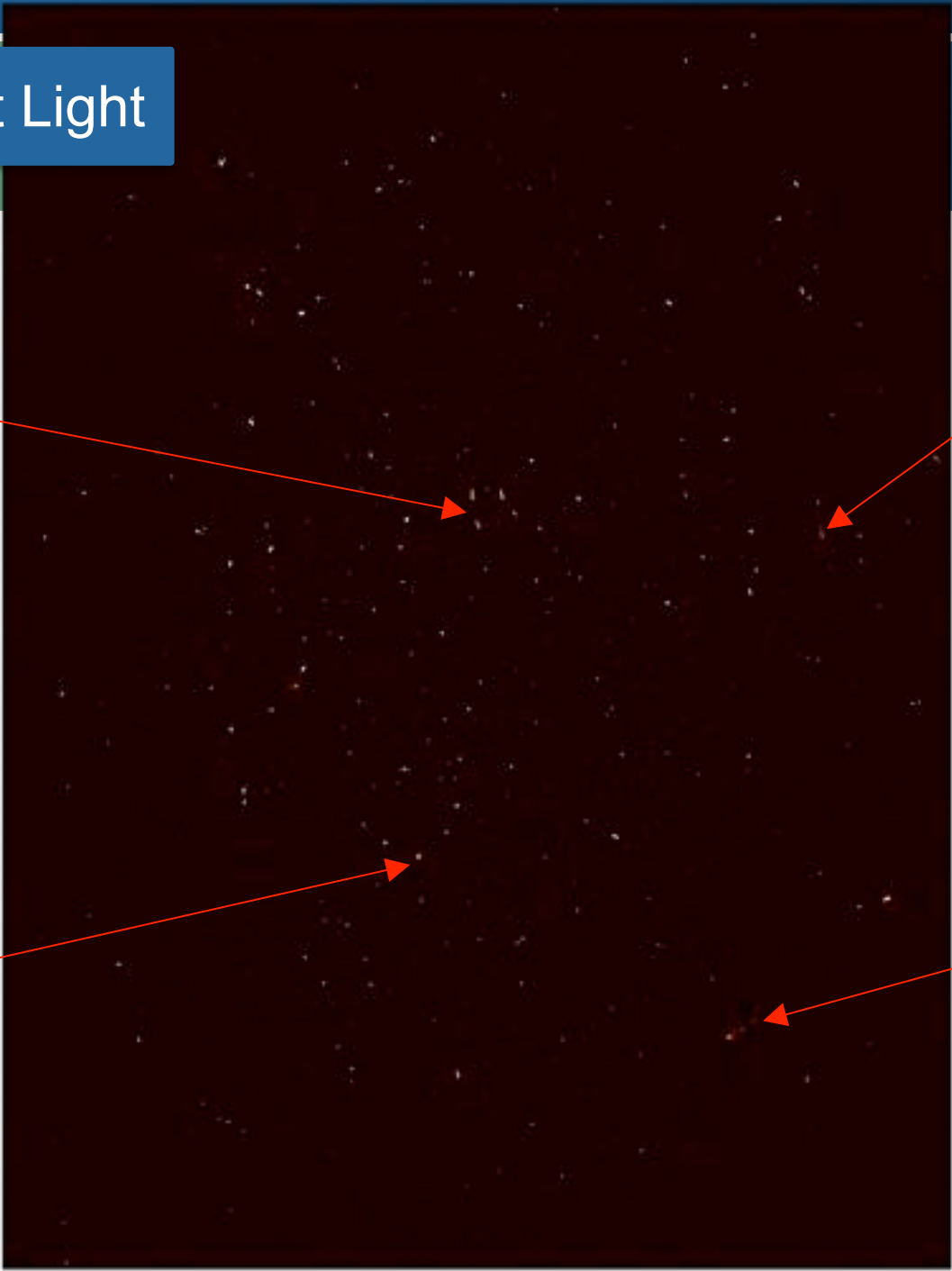
MeerKAT First Light



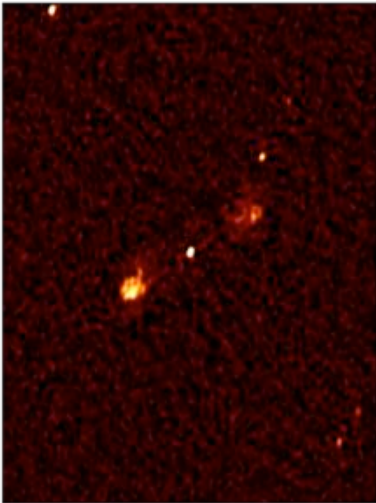
?



Star forming galaxy



FR1 radio galaxy



FR2 radio galaxy

