



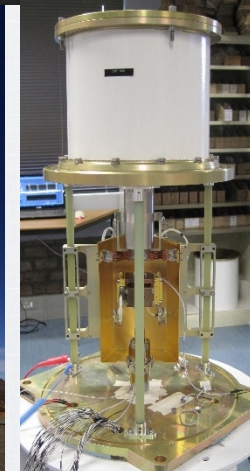
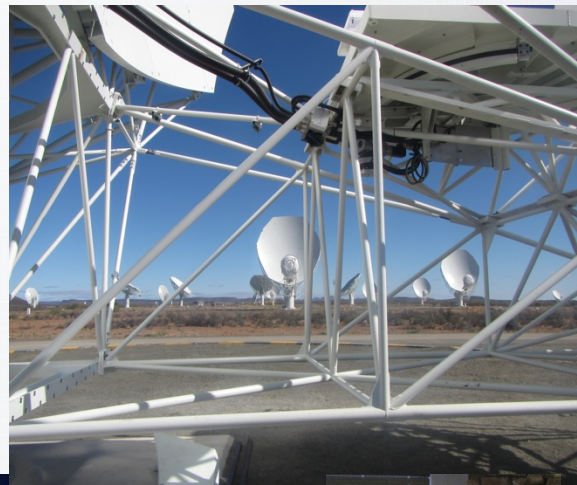
MEERKAT: PROGRESS AND PLANS

Fernando Camilo

SWISS SKA DAYS 2017 (MAY 22, LAUSANNE)

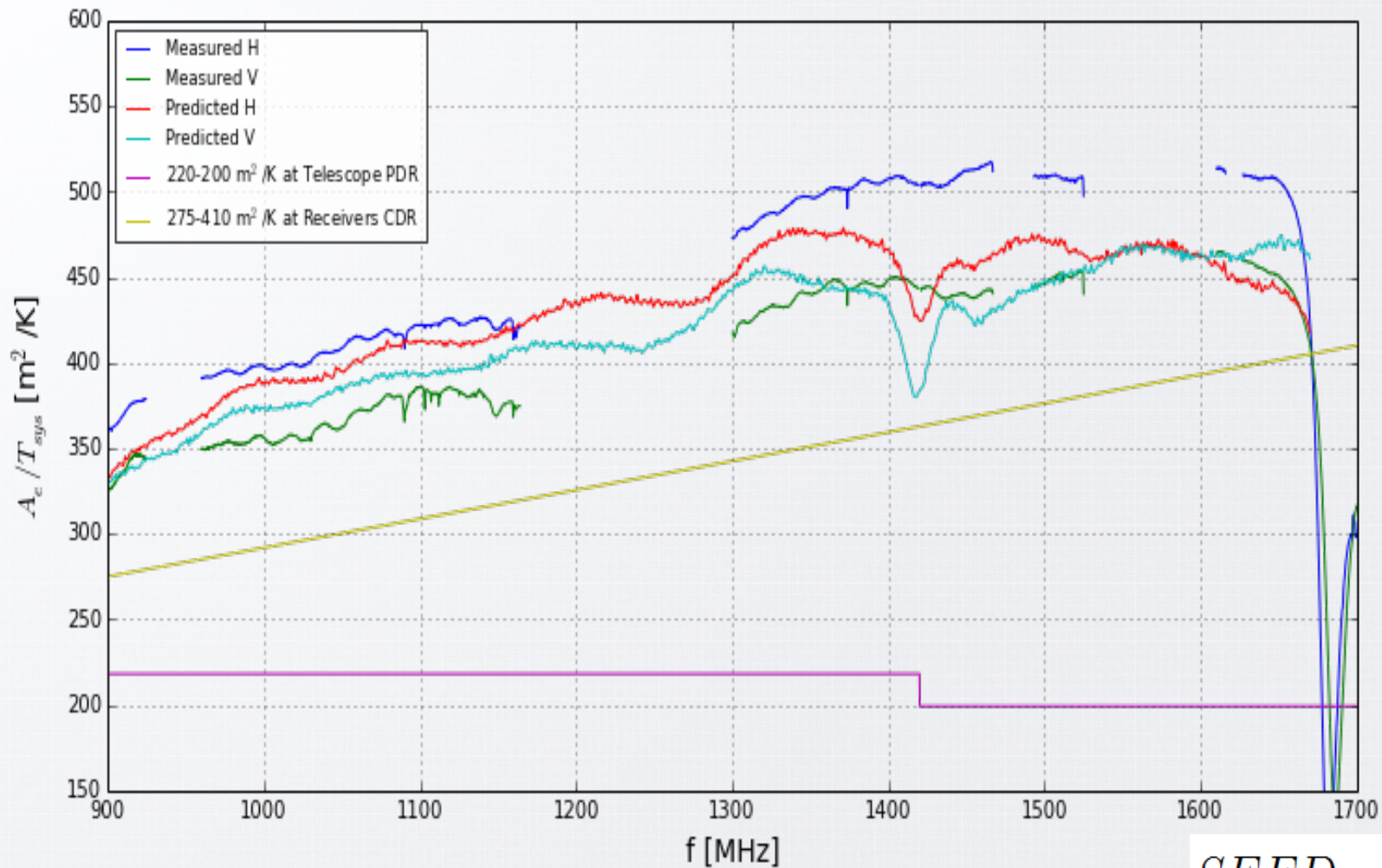


MeerKAT in the Karoo: SKA precursor under construction



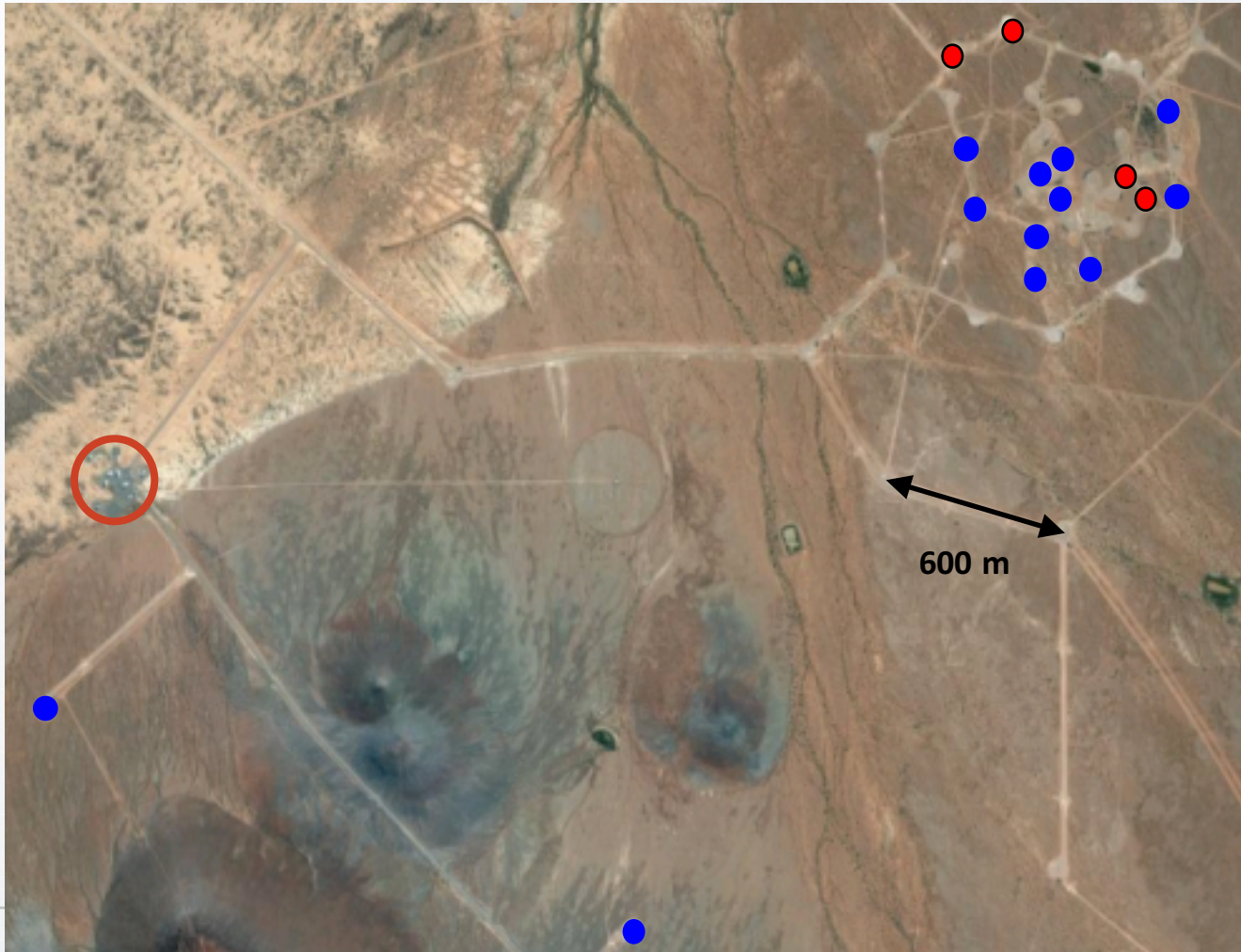
64 x 13.5-metre highly efficient offset Gregorian dishes spread over 8 km (~75% within ~1 km diameter); superb L-band receivers (0.9–1.67 GHz); also UHF (0.58–1.0 GHz) and S-band (1.75–3.5 GHz).

Extremely good L-band performance

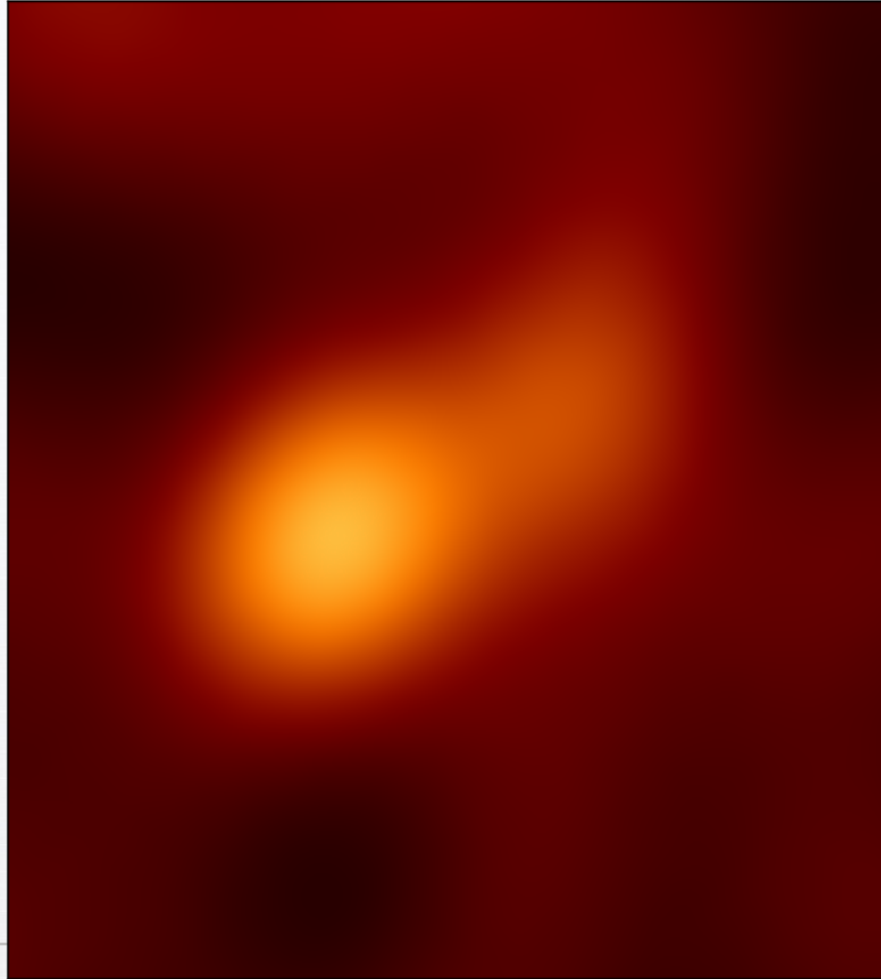


$$SEFD = \frac{2kT_{sys}}{\eta_a \frac{\pi}{4} D^2}$$

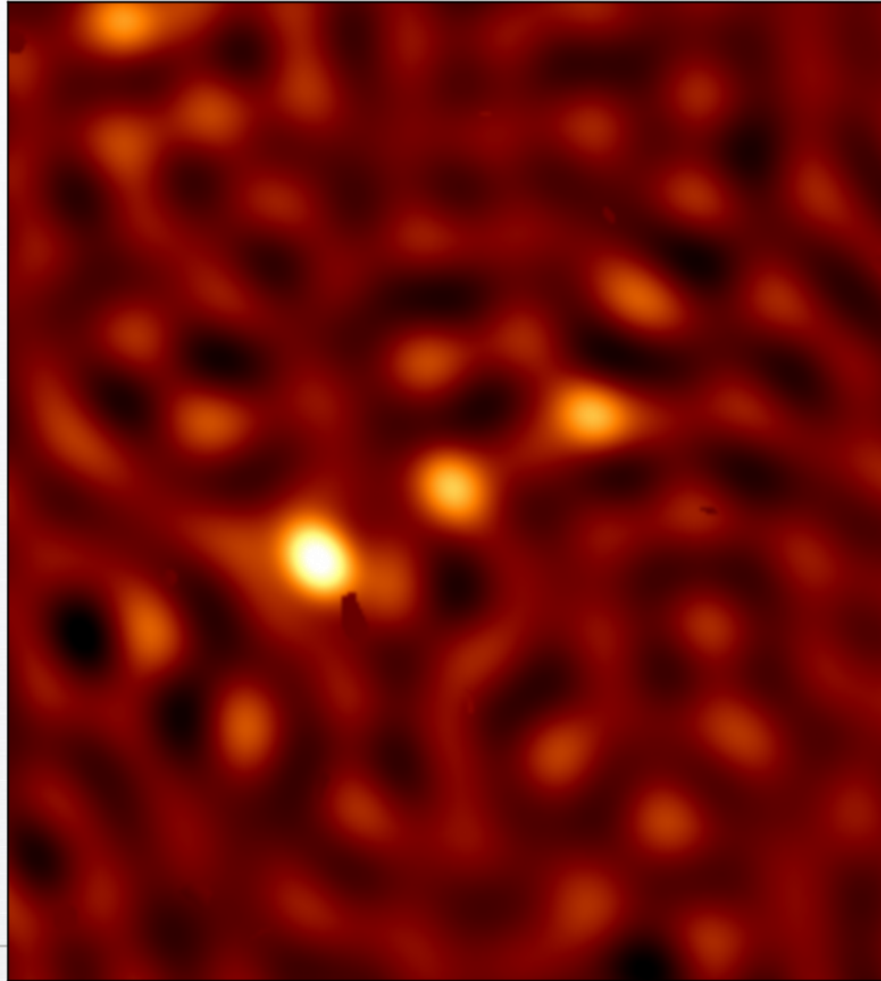
The SKA South Africa Karoo site: ever improving radio telescopes



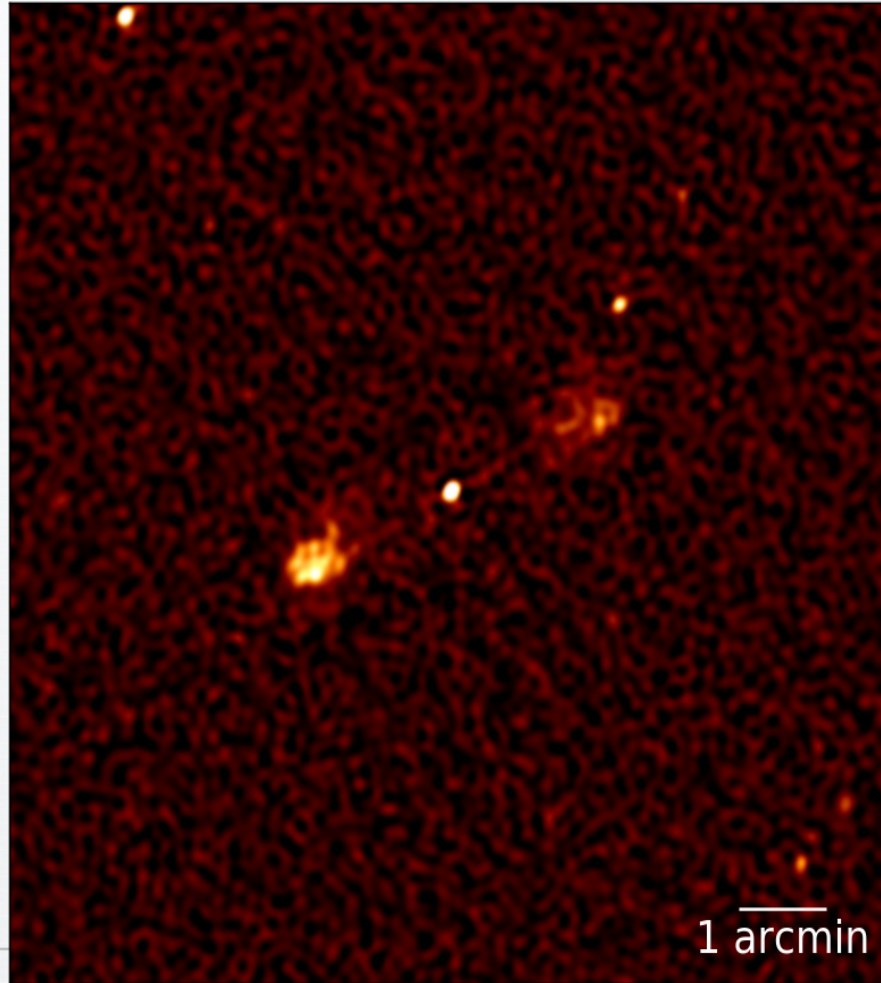
KAT-7 (engineering testbed) L-band image in 2012



4-dish MeerKAT in May 2016 (commissioning)



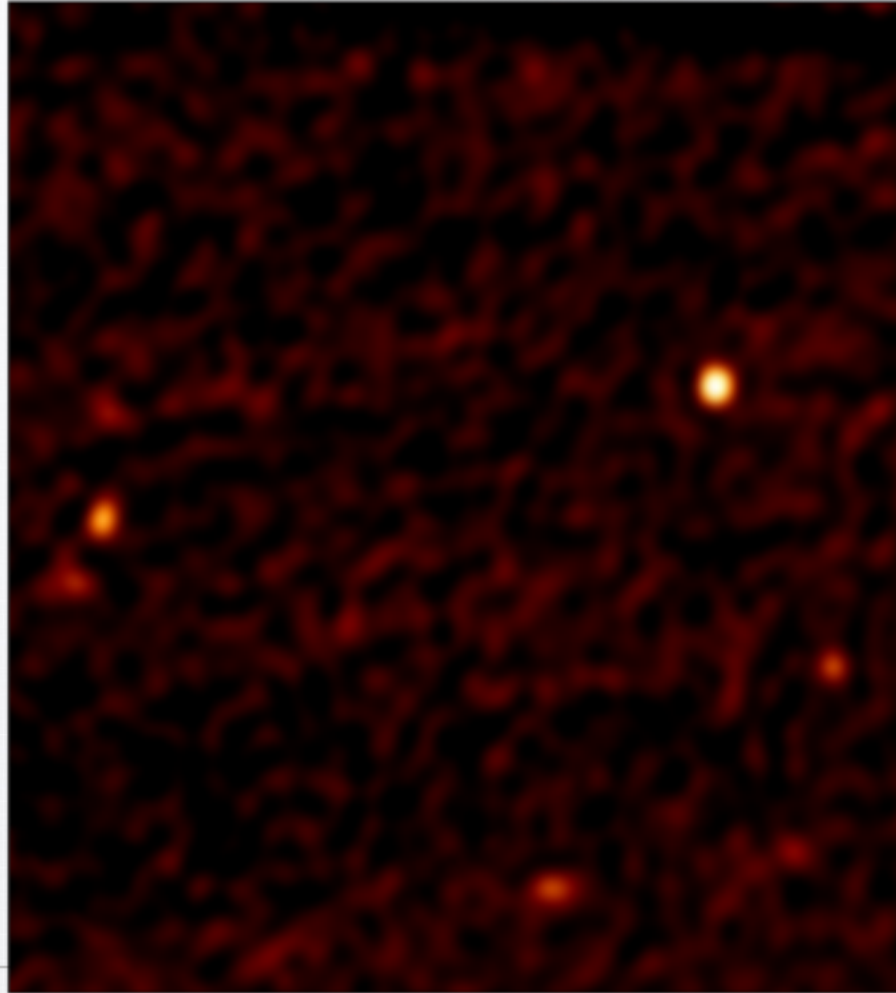
16-dish MeerKAT in June 2016 (Array Release 1)



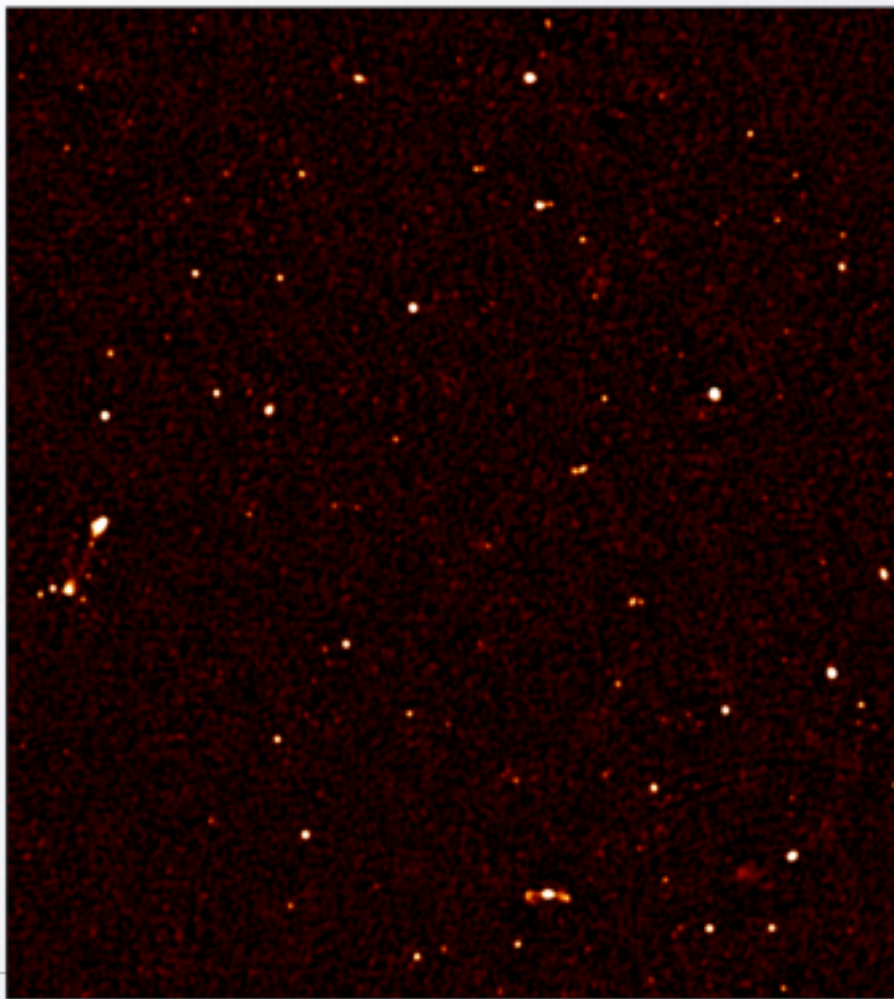
1% of First Light image

1 arcmin

Best image of this patch of sky before MeerKAT



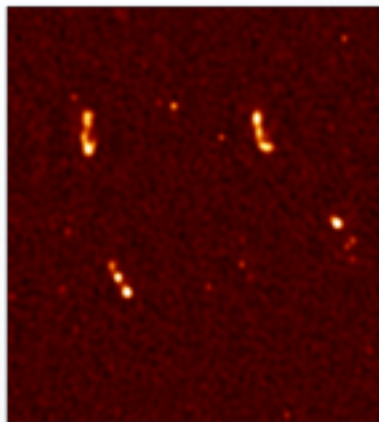
The MeerKAT sky



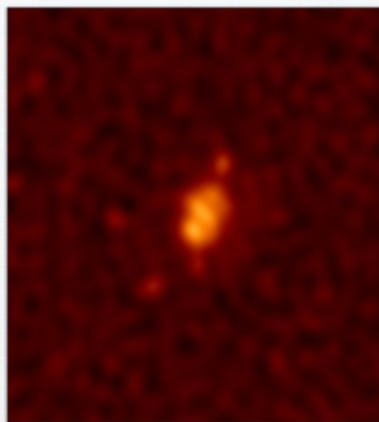
10% of First Light image

www.ska.ac.za

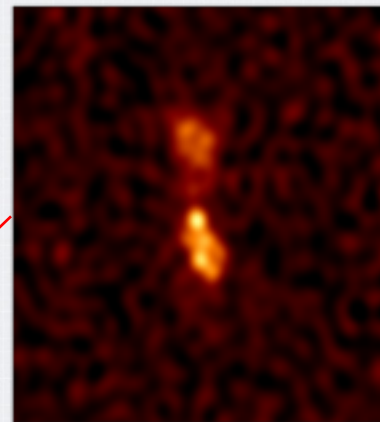
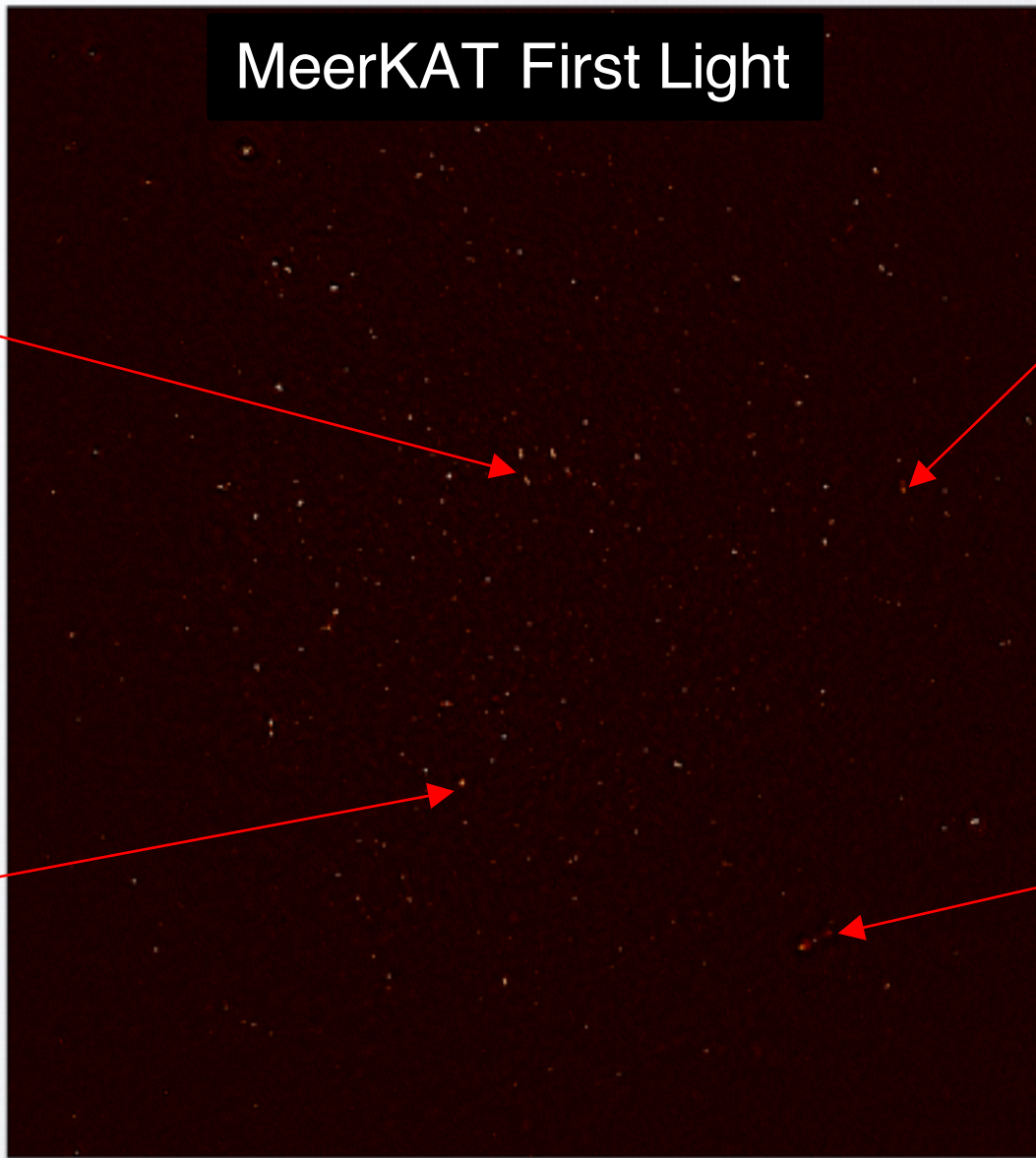
MeerKAT First Light



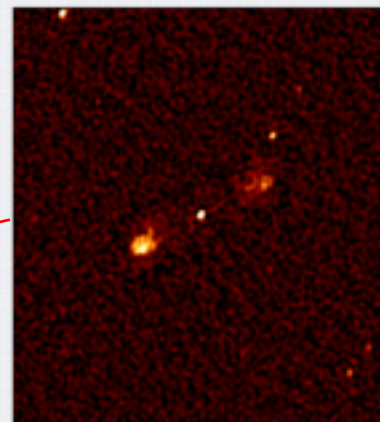
?



Star forming galaxy



FR1 radio galaxy



FR2 radio galaxy

MeerKAT science program

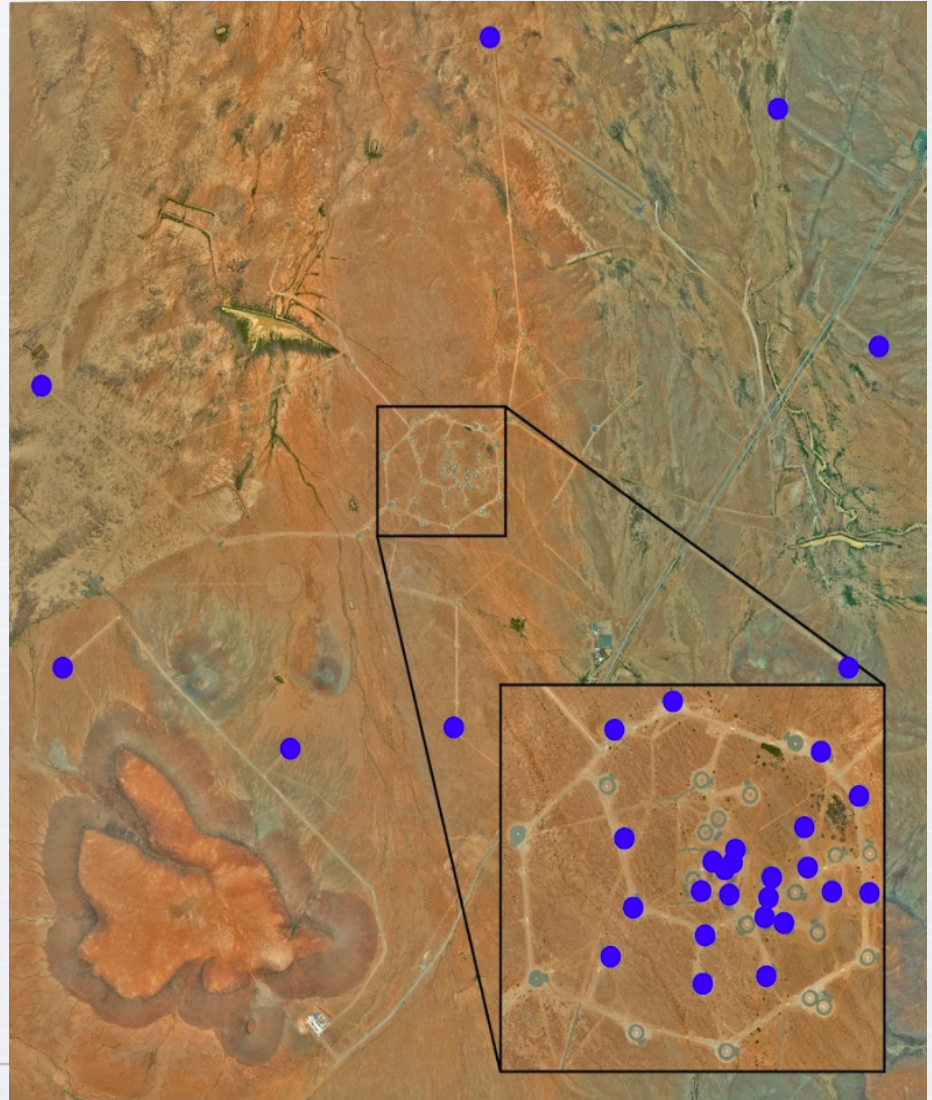
- **2010**: Open invitation by SKA SA to propose MeerKAT “Key Project Science” resulted in 10 approved “Large Survey Projects” (LSPs; each >1000 hours of telescope time over 5 years)
- **2016**: Scientific context has evolved; also, particularly at L-band, MeerKAT has improved sensitivity (but with shorter baselines, & lower frequencies)
- Therefore, in mid 2016 we requested revised LSP proposals (review underway)
- Plan to allocate ~70% of telescope time over 5 years to LSPs, ~30% to “Open Time” (to be allocated via periodic calls, open to researchers worldwide)
- Expect to have 64 antennas operational by April 2018 (+ continued development)
- Eventually MeerKAT will be integrated into the SKA Phase 1 MID-frequency array

MeerKAT science: LSPs approved in 2010

Radio Pulsar Timing	Bailes (AU)	7860 h
Testing Einstein's theory of gravity and gravitational radiation - Investigating the physics of enigmatic neutron stars through observations of pulsars		
LADUMA	Blyth, Holwerda, Baker (SA,NL,US)	5000 h
An ultra-deep survey of neutral hydrogen gas in the early universe		
MESMER	Heywood (UK)	6500 h
Searching for CO at high red-shift ($z > 7$) to investigate the role of molecular hydrogen in the early universe		
MeerKAT Absorption Line Survey	Gupta, Srianand (NL, IN)	4000 h
Survey for H and OH lines in absorption against distant continuum sources; OH line ratios may give clues about changes in the fundamental constants		
MHONGOOSE	de Blok (NL,SA)	6000 h
Investigations of different types of galaxies; dark matter and the cosmic web		
MeerKAT HI Survey of Fornax	Serra (NL)	2450 h
Galaxy formation and evolution in the cluster environment		
MeerGAL	Thompson, Goedhart (UK,SA)	3300 h
Galactic structure and dynamics, distribution of ionised gas, recombination lines, interstellar molecular gas and masers		
MIGHTEE	Jarvis, van der Heyden (UK,SA)	1950 h
Deep continuum observations of the earliest radio galaxies		
TRAPUM	Stappers, Kramer (UK, DE)	3080 h + commensal (timing)
Searching for, and investigating new and exotic pulsars		
ThunderKAT	Woudt, Fender (SA,UK)	3000 h + commensal (imaging)
Study of explosive radio transients with MeerKAT; accretion-induced outflow from compact stellar remnants, e.g. relativistic jets and (super)novae		

Array configuration

(April 2017, 32 antennas to choose from)



Commissioning in April 2017, up to 32 antennas

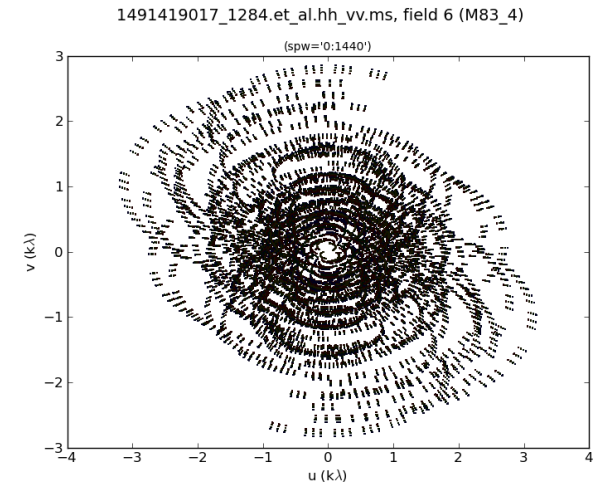
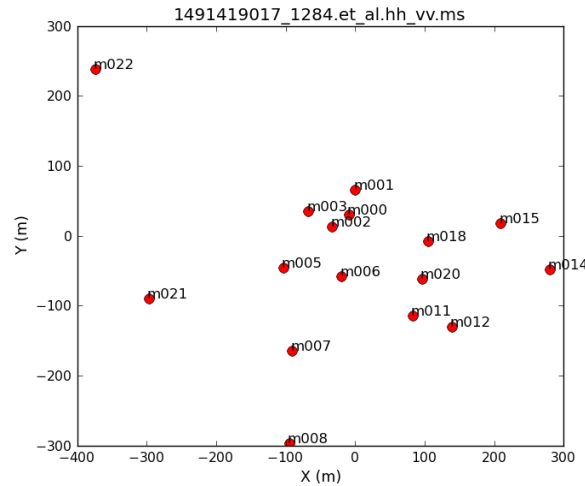
(but only 32 inputs into ROACH2 correlator)



HI emission in M83

(famous spiral galaxy discovered in Cape Town in 1752 by Nicolas Louis de La Caille)

- 9 hour track, 2017-04-05
- 32K (26 kHz) channels (140 imaged)
- 16 core antennas, dual polarisation
- Mosaic: 7 pointings
- ~50 minutes per pointing
- Min baseline (projected) 16 m
- Max baseline 711 m
- Beam 90x70 arcsec
- Measured rms 2.8 mJy (emission-free channel) vs 2.3 mJy theoretical



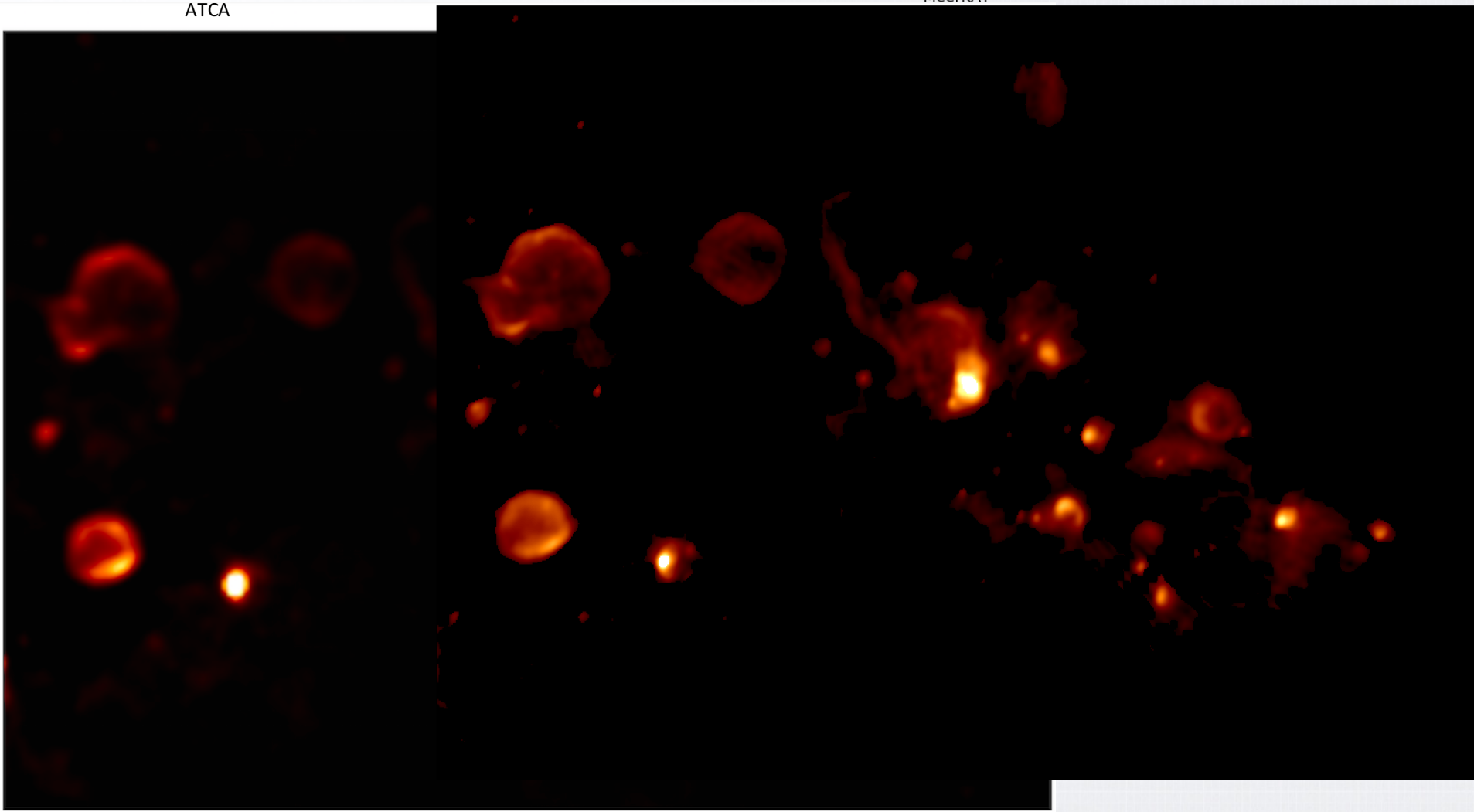
M83



G330.89-0.36 star forming region (continuum, 32k mode)

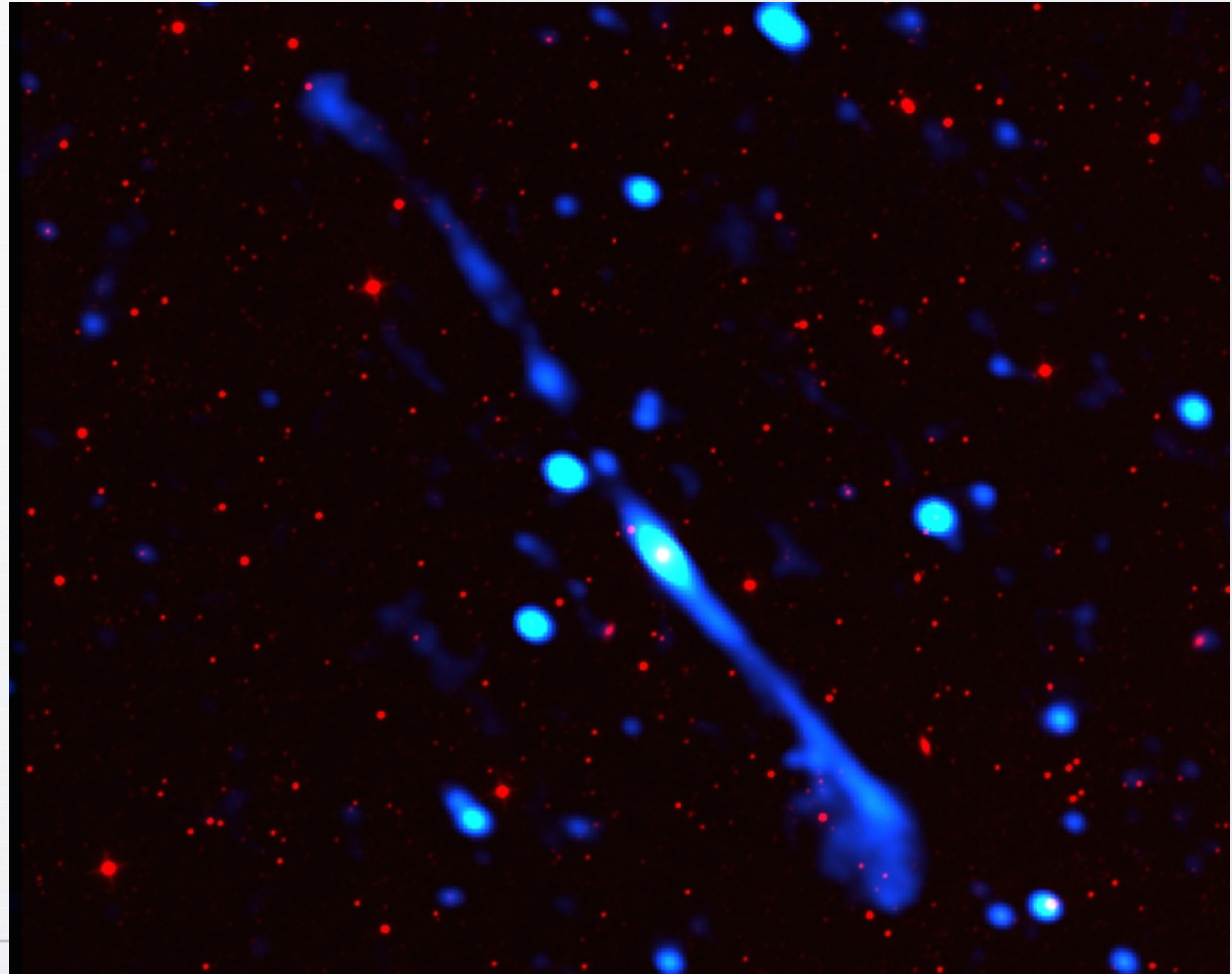
ATCA

MeerKAT

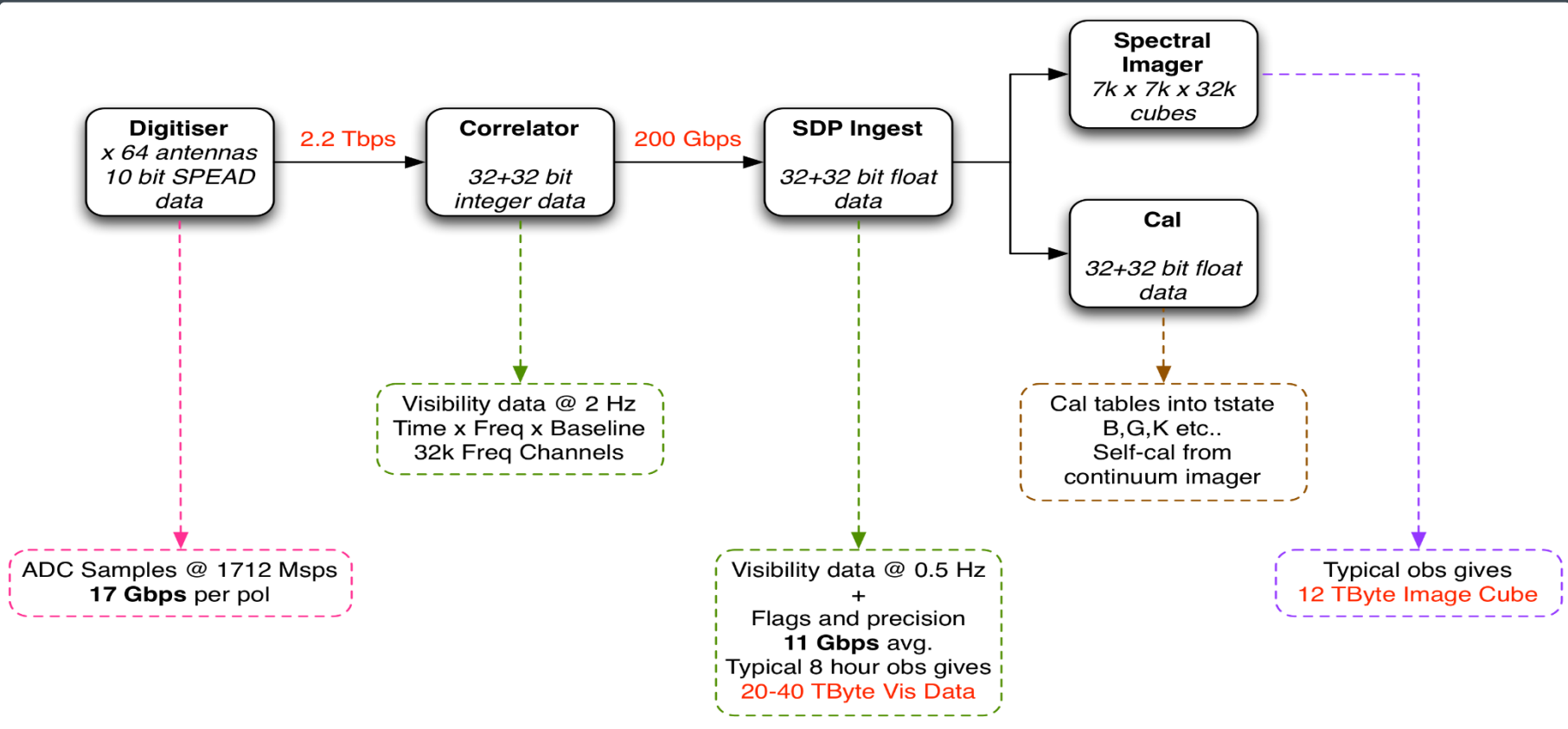


A newly identified Giant Radio Galaxy

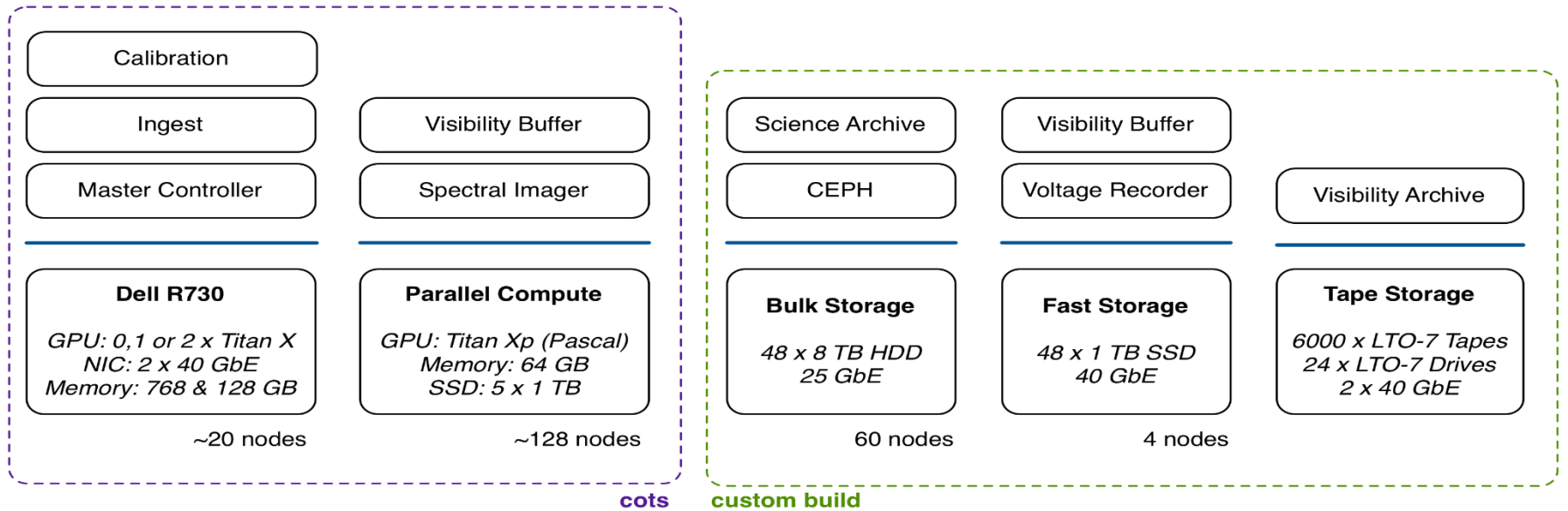
- Hint of extended source in SUMSS
- 7-point MeerKAT mosaic in 4K mode
- Radio source (blue) angular size = 0.8 deg; elliptical galaxy (red/IR) at $z = 0.02$; linear size = 1.2 Mpc: GRG



MeerKAT Data Rates



MeerKAT SDP Hardware Landscape



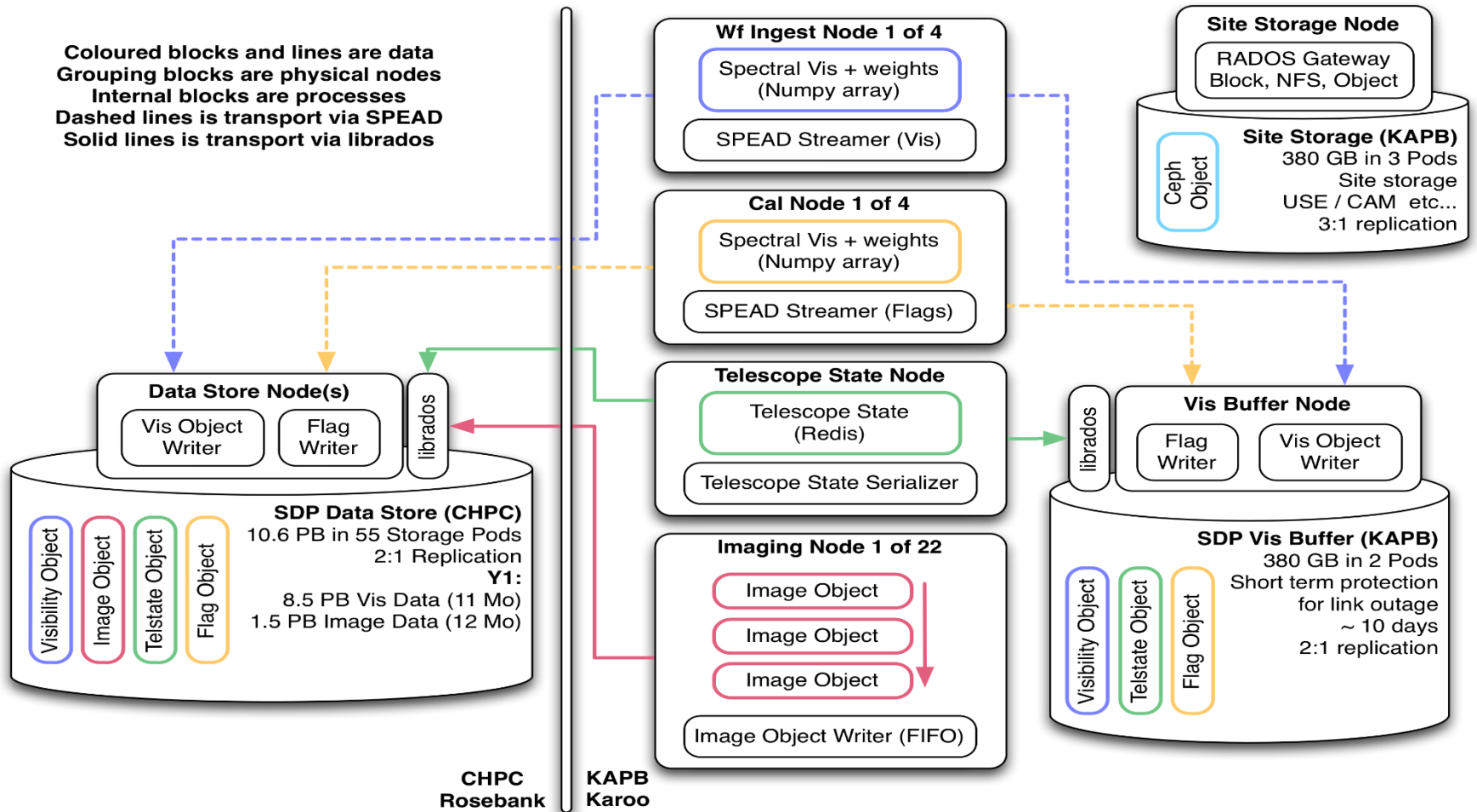
1.6 PFLOPs
(GPU)

23 PBytes
(Disk - CEPH)

40 PBytes
(Tape)

Data Flows and Hardware Location

Coloured blocks and lines are data
 Grouping blocks are physical nodes
 Internal blocks are processes
 Dashed lines is transport via SPEAD
 Solid lines is transport via librados



Dealing with the Data – Execution Framework

The screenshot displays the Mesos web interface. At the top, there are navigation tabs for 'Mesos', 'Frameworks', 'Agents', and 'Offers'. Below this, a 'Master' section shows the ID '023ca79e-2715-40b3-9352-a52e4d6b3e22'. On the left, a sidebar provides cluster details: 'Cluster: (Unnamed)', 'Server: 10.98.2.1:5050', 'Version: 1.1.0', 'Built: 4 months ago by ubuntu', 'Started: 2 weeks ago', and 'Elected: 2 weeks ago'. Below this is a 'LOG' section and an 'Agents' table with columns for 'Activated' (12) and 'Deactivated' (0). A 'Tasks' table shows counts for 'Staging' (0), 'Starting' (0), 'Running' (8), 'Killing' (0), 'Finished' (312), and 'Killed' (115). The main area is titled 'Active Tasks' and features a search bar with a dropdown arrow and the text 'Find...'. Below the search bar is a table with columns for 'ID', 'Name', 'State', 'Started', and 'Host'. The table lists several tasks in a 'RUNNING' state, each with a 'Sandbox' link. The tasks include 'array_1_bc856M4k-sdp.bf_ingest.1', 'array_1_bc856M4k-sdp.cam2telstate.1', 'array_1_bc856M4k-sdp.filewriter.1', 'array_1_bc856M4k-sdp.cal.1', 'array_1_bc856M4k-sdp.ingest.1', 'array_1_bc856M4k-sdp.timeplot.1', 'array_1_bc856M4k-sdp.telstate', and 'mesos-ui.3ef201b2-ff21-11e6-a43e-22495207da16'.

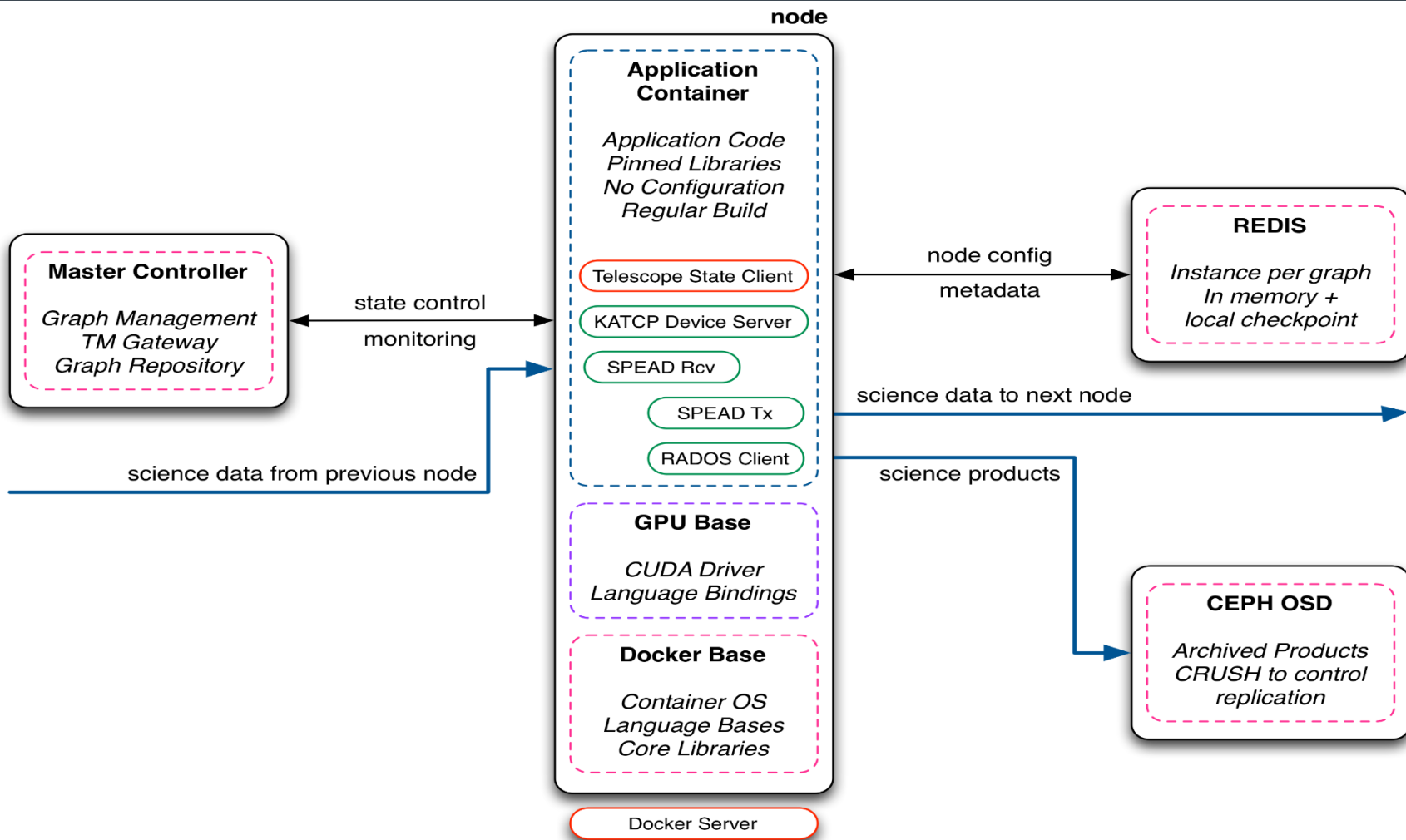
ID	Name	State	Started	Host	
array_1_bc856M4k-00000001	array_1_bc856M4k.sdp.bf_ingest.1	RUNNING	27 minutes ago	bf1.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000002	array_1_bc856M4k.sdp.cam2telstate.1	RUNNING	27 minutes ago	cal6.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000004	array_1_bc856M4k.sdp.filewriter.1	RUNNING	27 minutes ago	cal5.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000003	array_1_bc856M4k.sdp.cal.1	RUNNING	27 minutes ago	cal5.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000005	array_1_bc856M4k.sdp.ingest.1	RUNNING	27 minutes ago	ing1.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000006	array_1_bc856M4k.sdp.timeplot.1	RUNNING	27 minutes ago	ing1.sdp.mkat.karoo.kat.ac.za	Sandbox
array_1_bc856M4k-00000000	array_1_bc856M4k.sdp.telstate	RUNNING	27 minutes ago	cal6.sdp.mkat.karoo.kat.ac.za	Sandbox
mesos-ui.3ef201b2-ff21-11e6-a43e-22495207da16	mesos-ui	RUNNING	2 weeks ago	cal2.sdp.mkat.karoo.kat.ac.za	Sandbox

Pipelines expressed as graphs of **operations** (nodes) and **data transfer** (edges).

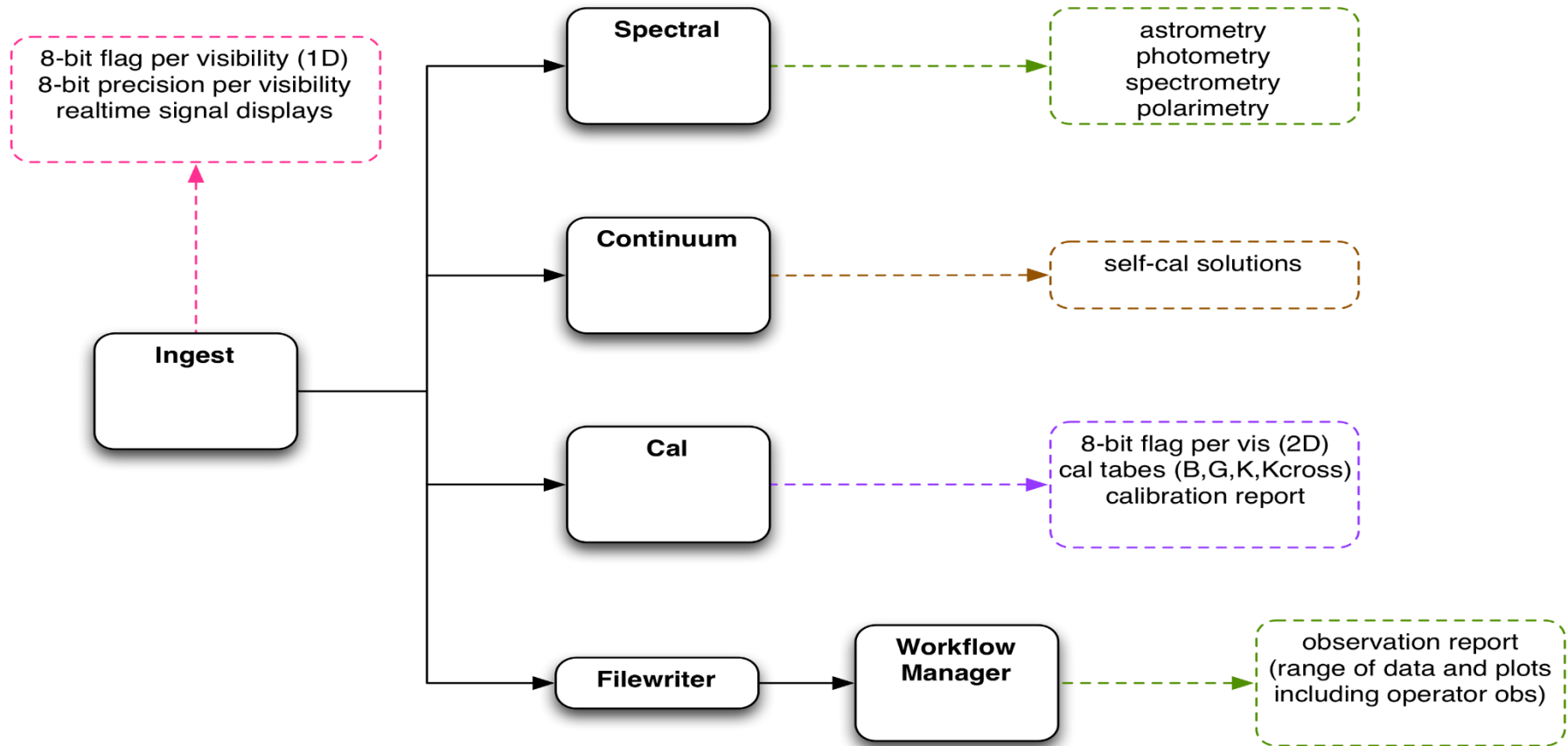
Execution Framework (based on Apache MESOS) deploys and **manages graph at scale**.

Container approach allows **easy deployment** of **new algorithmic ideas** within the pipeline infrastructure.

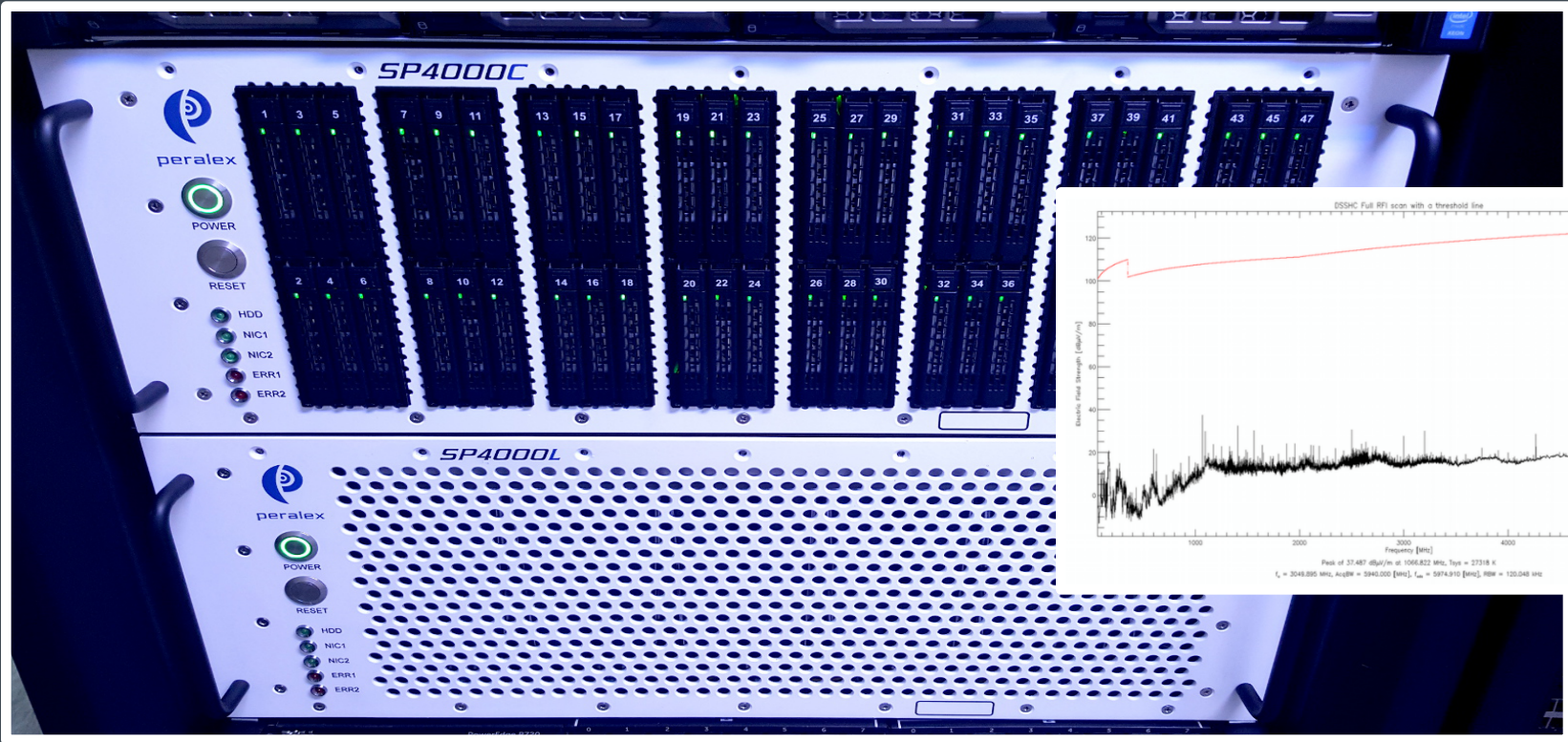
Dealing with the Data – Execution Environment



Dealing with the Data - Quality Metrics



CEPH Cluster – Custom Hardware

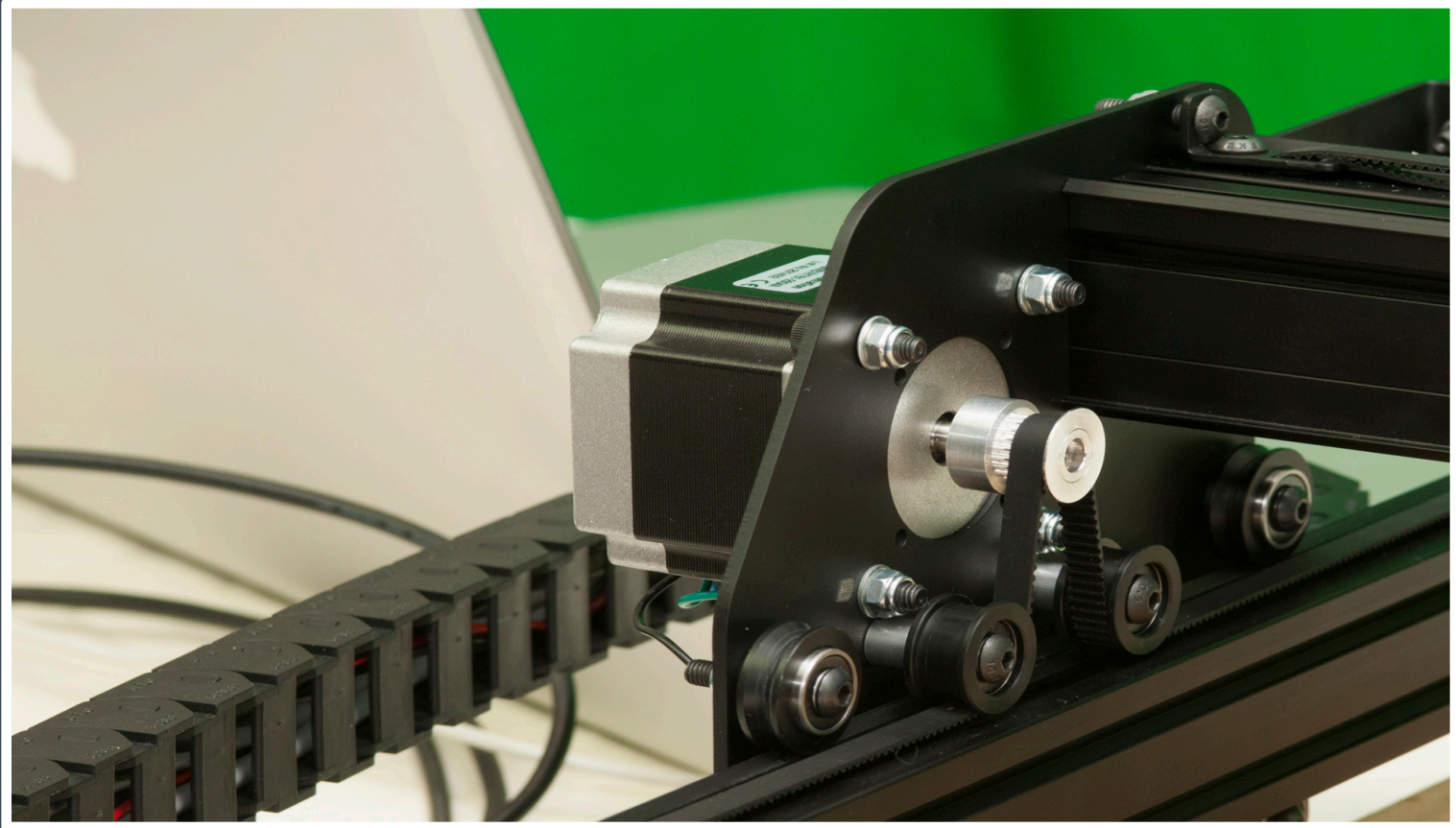


High Speed Pod: **40 Gbps** to disk / **40 TiB**

Bulk Pod: **25+Gbps** to disk / **360 TiB**

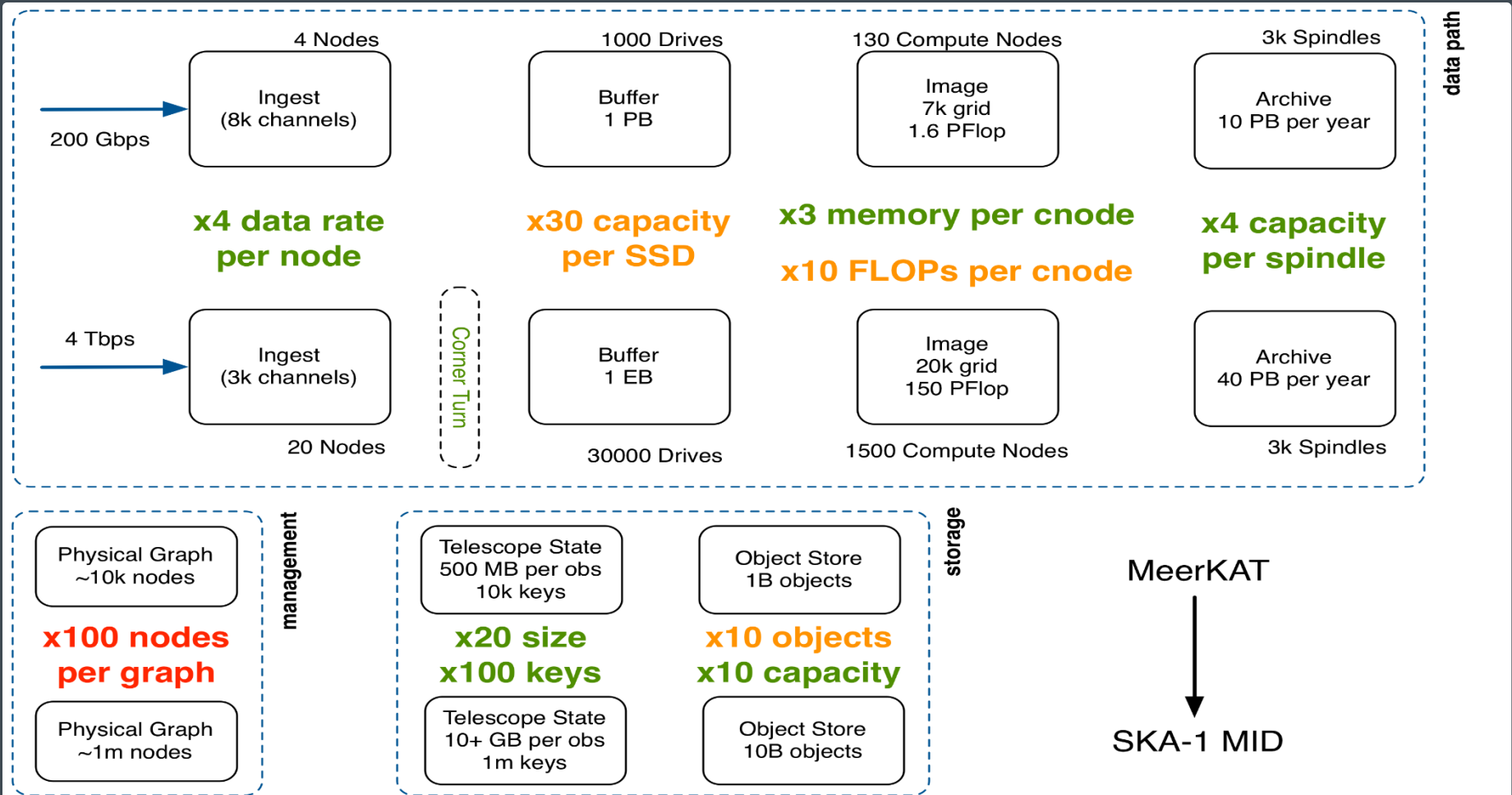
23 PB CEPH Cluster ~ **\$1.2 million** all in

Custom Tape Robotics



3k – 50k slot LTO tape library at **10x** cheaper

Scaling to SKA-1 MID





science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



NRF

National
Research
Foundation



SKA South Africa, a Business Unit of the National Research Foundation, is supervising South Africa's involvement in the SKA on behalf of the Department of Science & Technology.

Thank you