

# Commissioning and Science Verification: MeerKAT

## *Complexity and Scale*

Simon Ratcliffe

# 64 Dishes Complete – Inaugurated 13 July 2018



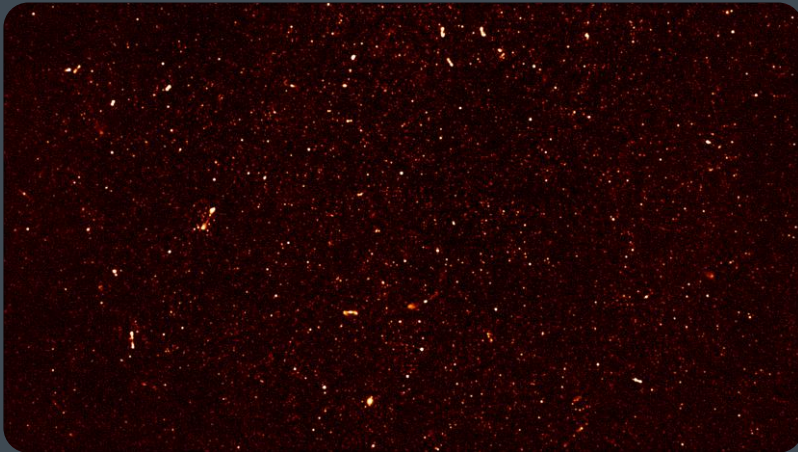
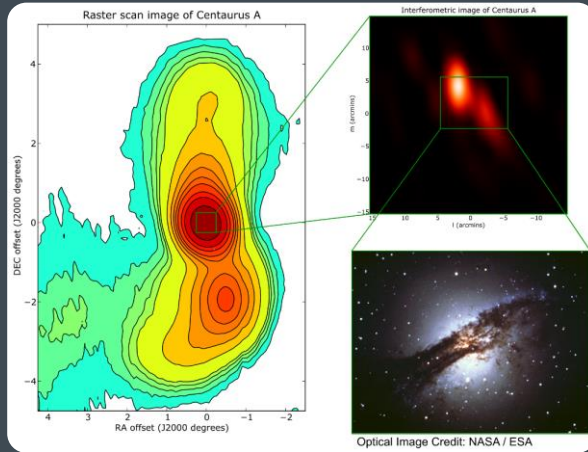
---

# *Continuous Commissioning*

---

## Two Dish Image

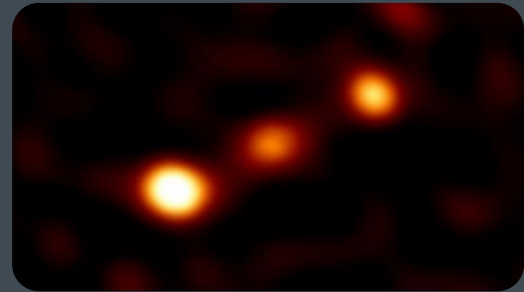
Single Dish Raster



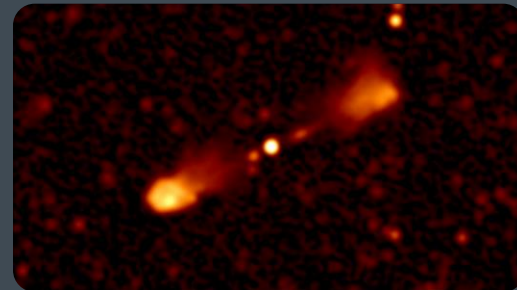
64 Dish MeerKAT



4 Dish MeerKAT

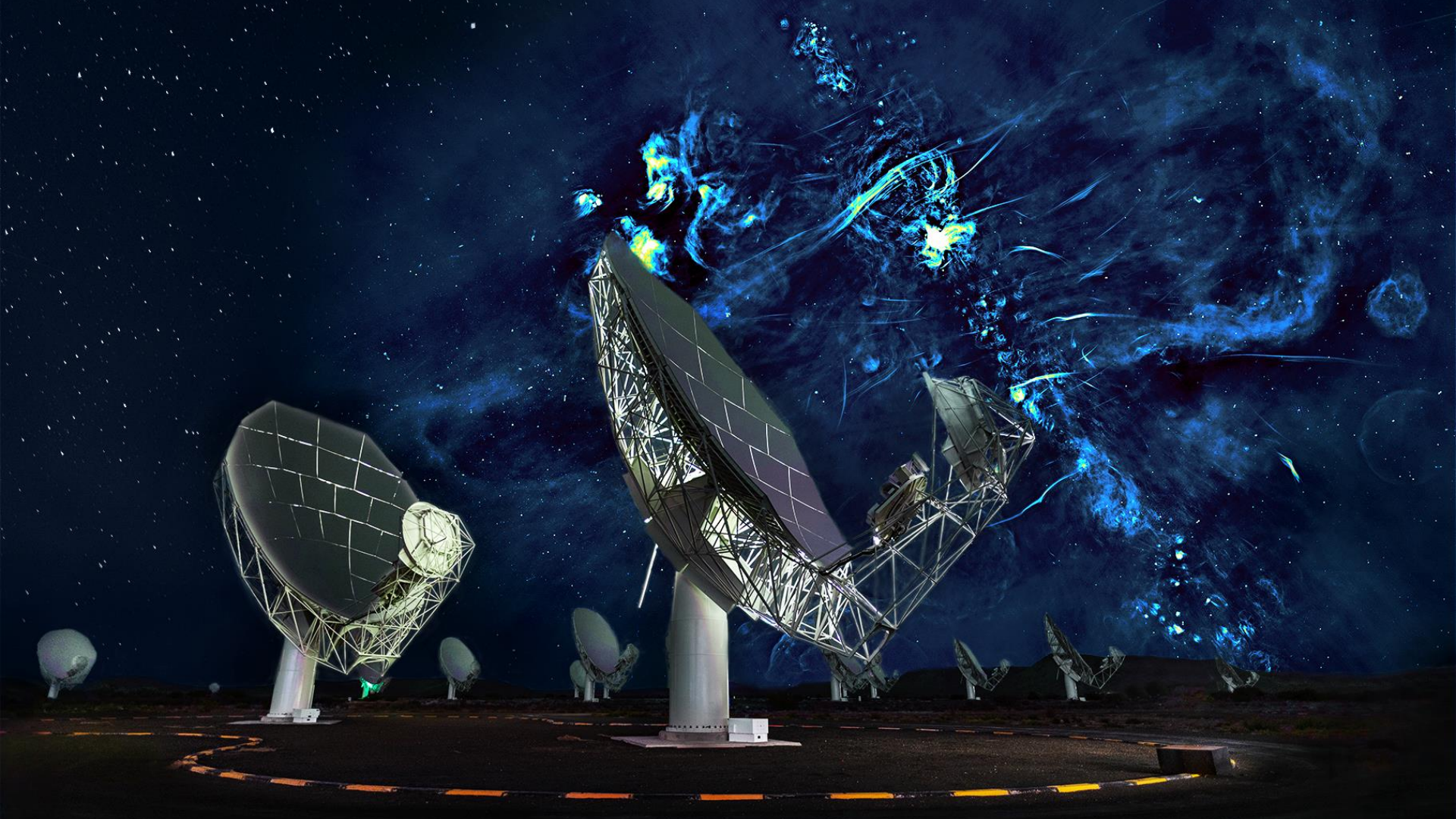


16 Dish MeerKAT

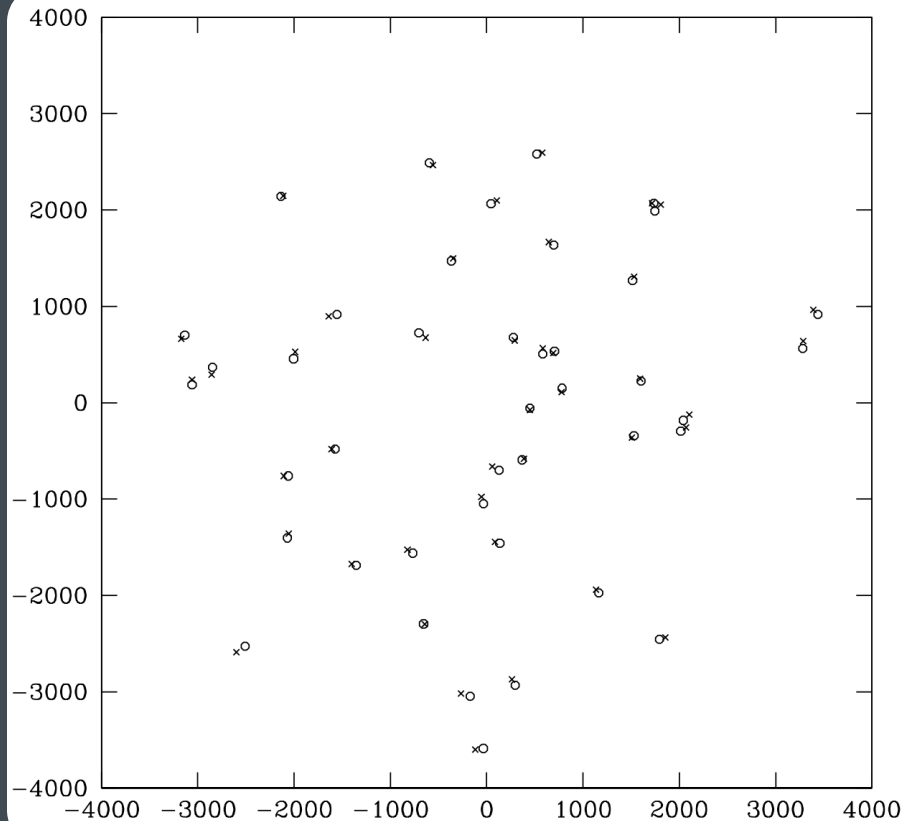


32 Dish MeerKAT





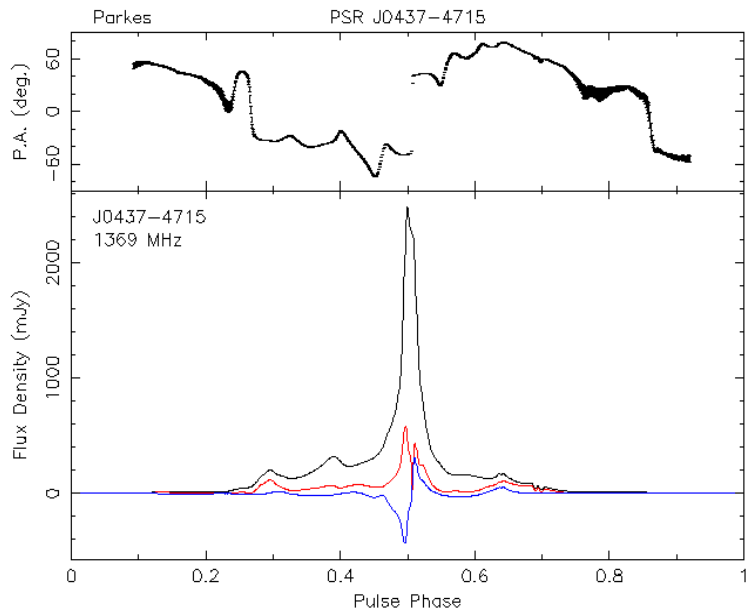
# Getting better all the time...



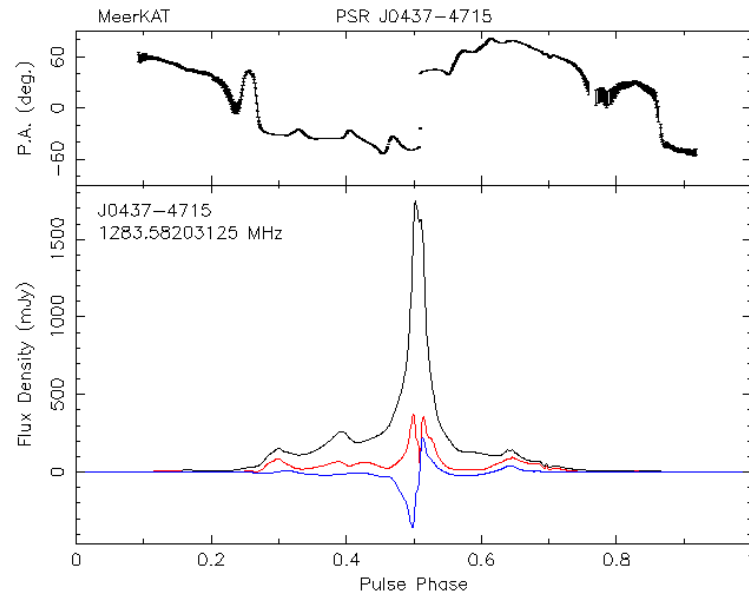
Mean offsets are  
**-0.08** arcsec in RA  
**+0.14** arcsec in DEC

J. Condon, B. Cotton, T. Mauch  
Axes are arcsec offset from phase center.  
Position differences x100 to show offsets.

# Partnerships with USE very beneficial



300 Hours



4 Hours - MeerKAT

# System Complexity is Starting to Hurt

Engineering agility, coupled with schedule pressure (WSJF) tends to favor producing **small features more often**.

For commissioning this introduces **more context switching** and pressure to understand the latest exciting feature before the old one is **fully verified**.

The system is getting **more complex** as it evolves - **mostly software** – which inevitably introduces **more bugs**

# That can't be right, we won't have bugs because...

We have code reviews

We have unit and smoke tests

We integrate early and often

We have simulators

We have continuous builds

We have signed ICDs

We have smart people

We test on the sky

We have a modular system

We can rollback changes quickly

We have a robust Engineering Change Process

We have a ticketing system

~~We have a silver bullet~~

# Complexity – An Aside

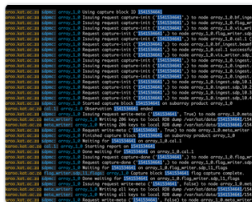
✓ SR-1458

ThunderKAT OBS files missing for P-ID:SCI-XXXXXX-AA-01



Document link for [Observation request UZ For](#)

## Attachments



## Linked issues



relates to

SR-1446 Observations not in archive - umbrella ticket



TO DO

## Activity

Comments ▾

# Complexity – An Aside

```
2019-03-05 16:24:22.230Z INFO Quorum = 90% -> 26 of 28 receptor(s), i.e. 2 straggler(s) tolerated
2019-03-05 16:24:22.237Z INFO Delay tracking = on
2019-03-05 16:24:22.237Z INFO Switching off all noise diodes
2019-03-05 16:24:22.354Z INFO Noise diode will not fire automatically while performing canned commands
2019-03-05 16:24:22.367Z INFO Stopping / readying antennas
2019-03-05 16:24:23.089Z INFO INIT
2019-03-05 16:24:23.089Z INFO Capture block ID = 1551803062
2019-03-05 16:24:23.304Z INFO -----
2019-03-05 16:24:23.308Z INFO New compound scan: 'interferometric_pointing'
2019-03-05 16:24:24.135Z INFO slewing to target
2019-03-05 16:24:56.211Z INFO Waiting for sensor 'lock' == True had 1 straggler(s): ['m044']
2019-03-05 16:24:56.212Z INFO target reached
2019-03-05 16:24:56.217Z INFO tracking target
2019-03-05 16:25:06.224Z INFO target tracked for 10.0 seconds
2019-03-05 16:25:06.226Z INFO Initiating 10-second track on target 'J0010-4153'
2019-03-05 16:25:06.226Z INFO Offset of (0.000000, -1.500000) degrees
2019-03-05 16:25:06.812Z INFO slewing to target
2019-03-05 16:25:13.941Z INFO target reached
2019-03-05 16:25:13.949Z INFO tracking target
2019-03-05 16:25:23.956Z INFO target tracked for 10.0 seconds
2019-03-05 16:25:23.957Z INFO Initiating 10-second track on target 'J0010-4153'
2019-03-05 16:25:23.958Z INFO Offset of (0.000000, -0.750000) degrees
```

# Complexity – An Aside

Filter Search

?

HELP

Newest First

Observer

Proposal ID

Target

Schedule Block

Frequency

Start Date

End Date

















Product Type

MeerKAT X KAT7 X

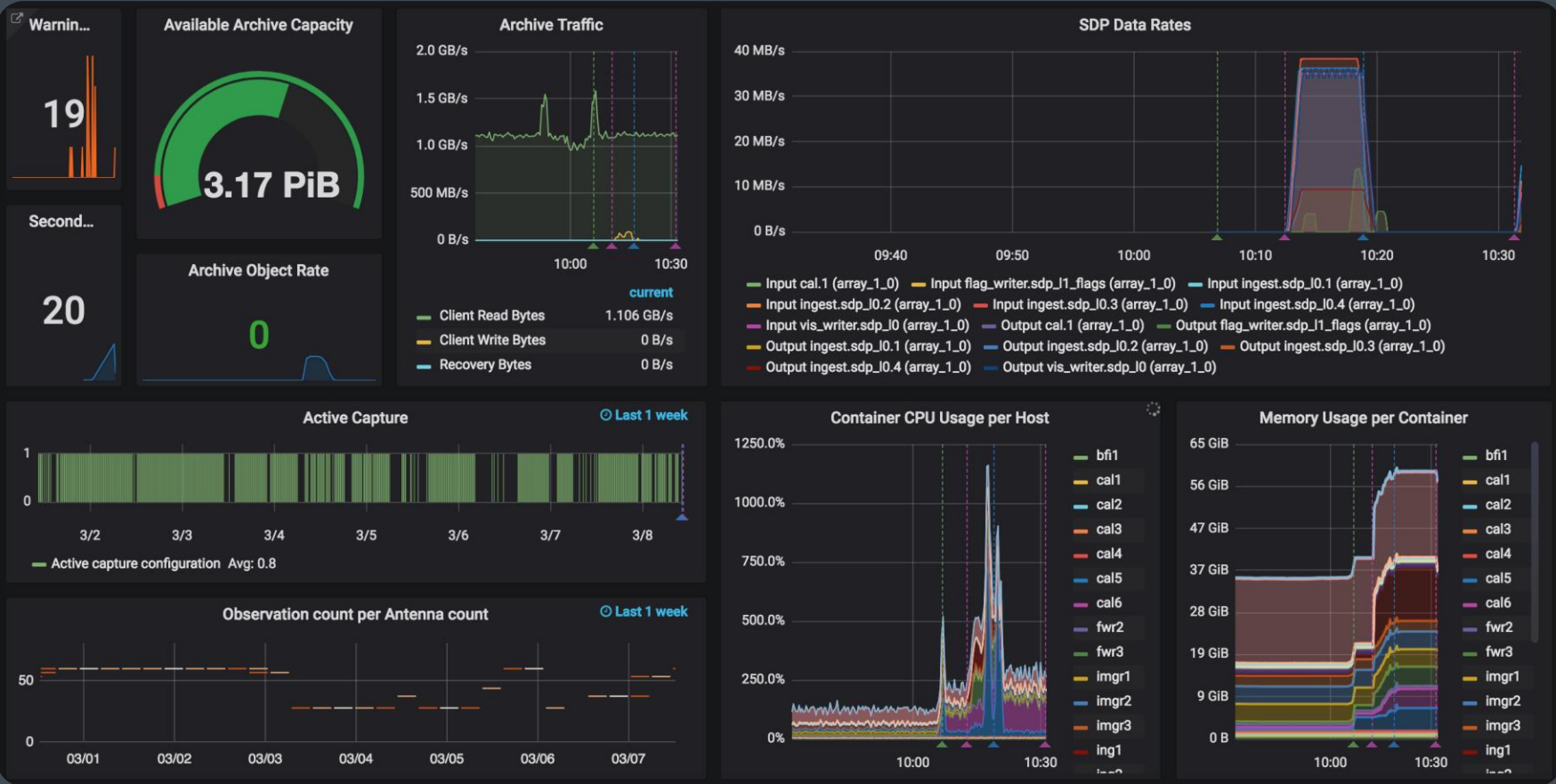
AR1 X Beamformer X

Location (RADEC)

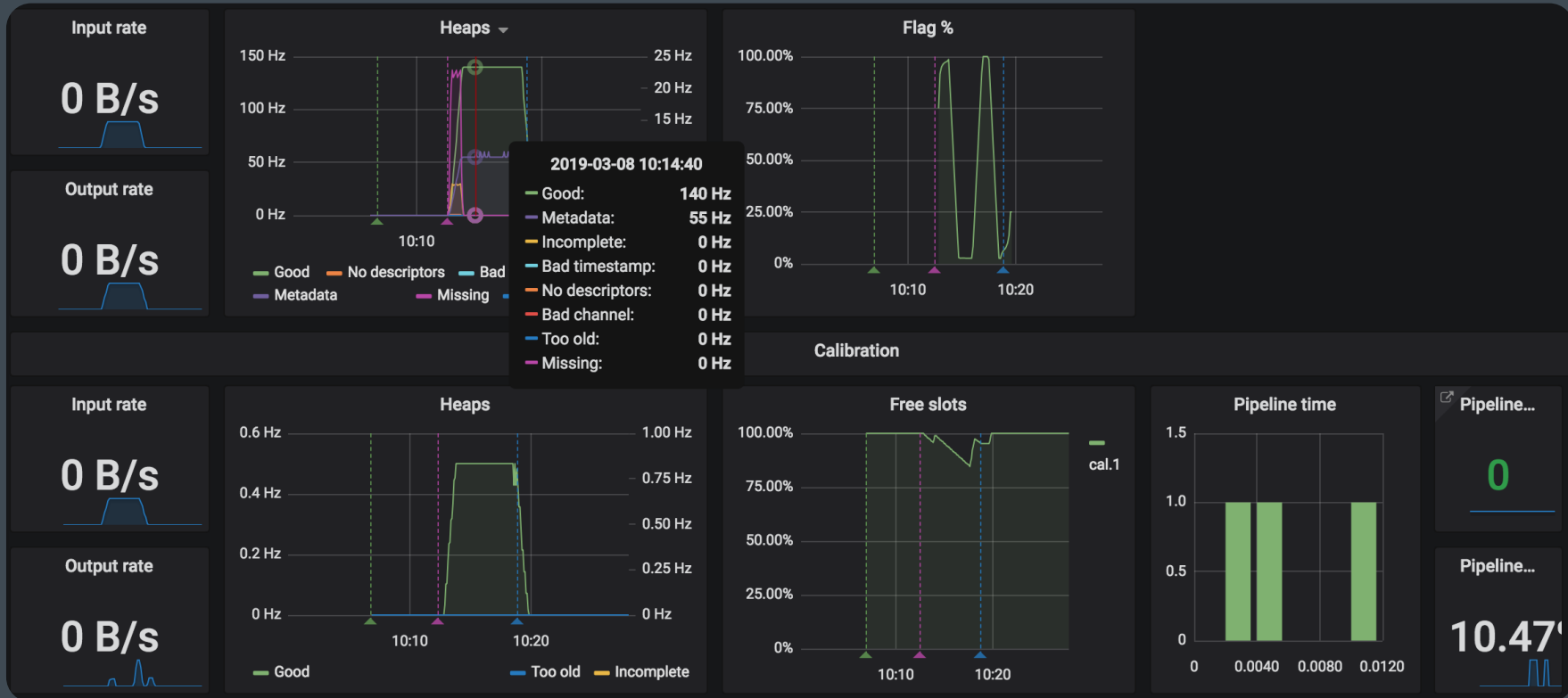
Location (AZEL)

Download	Proposal ID	Schedule Block StartTime	Target/s	Observer Description
<div><div></div></div>	20180306SB-02	20190308-0083 2019-03-08 10:12:26	PKS 1934-63	Sarah COMM-305 Generic skarab delaycal
<div><div></div></div>	SCI-20180516-MB-05	20190308-0082 2019-03-08 09:22:53	J2322-2650	sarah COMM 1K start-delay J2322-2650
<div><div></div></div>	SCI-20180516-MB-05	20190308-0081 2019-03-08 09:12:26	J1903-7051	sarah COMM 1K start-delay J1903-7051
<div><div></div></div>	SCI-20180516-MB-05	20190308-0080 2019-03-08 08:59:46	J0101-6422	sarah COMM 1K start-delay J0101-6422
<div><div></div></div>	SCI-20180516-MB-03	20190308-0079 2019-03-08 08:50:31	J2222-0137	sarah COMM 1K start-delay J2222-0137
<div><div></div></div>	SCI-20180516-MB-05	20190308-0078 2019-03-08 08:43:46	J2241-5236	sarah COMM 1K start-delay J2241-5236
<div><div></div></div>	COM-304	20190308-0077 2019-03-08 08:29:00	PKS1934-638	sarah COM-304 1K test flatten bandpass

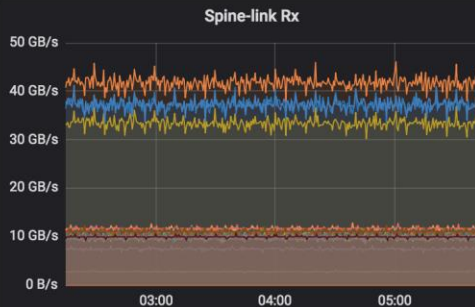
# Complexity – An Aside



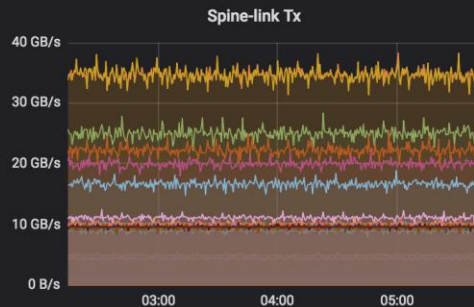
# Complexity – An Aside



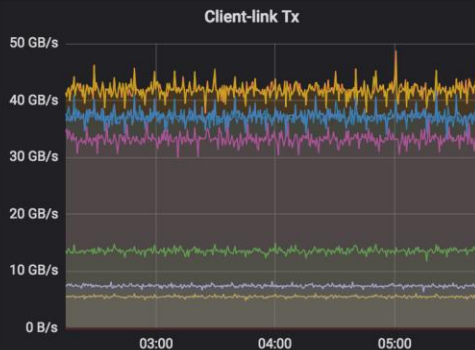
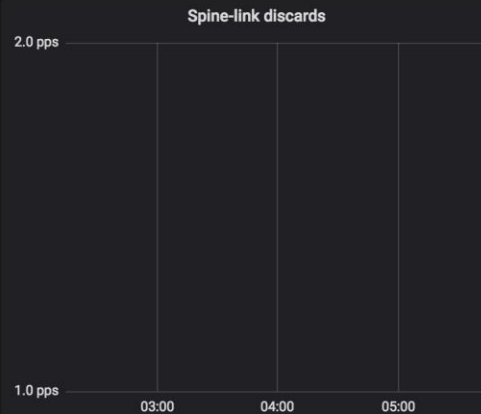
# Complexity – An Aside



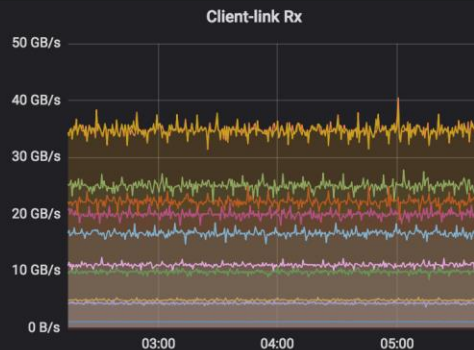
l1 l10 l11 l12 l13 l14 l15 l16 l17  
l18 l19 l2 l20 l21 l22 l23 l24 l25  
l26 l27 l28 l3 l4 l5 l6 l7 l8 l9  
s1 s11 s12 s13 s14 s15 s16 s17  
s18 s2 s3 s4 s5 s6 s7 s8 s9



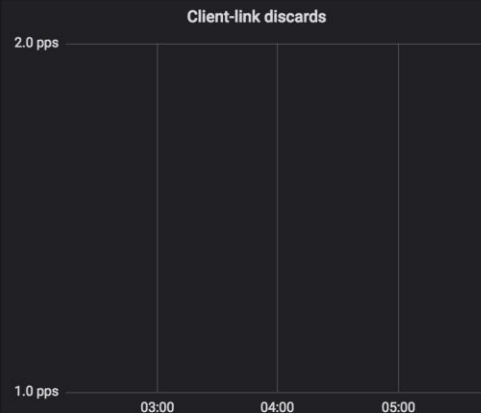
l1 l10 l11 l12 l13 l14 l15 l16 l17  
l18 l19 l2 l20 l21 l22 l23 l24 l25  
l26 l27 l28 l3 l4 l5 l6 l7 l8 l9  
s1 s11 s12 s13 s14 s15 s16 s17  
s18 s2 s3 s4 s5 s6 s7 s8 s9



l1 l10 l11 l12 l13 l14 l15 l16 l17  
l18 l19 l2 l20 l21 l22 l23 l24 l25  
l27 l28 l3 l4 l5 l6 l7 l8 l9



l1 l10 l11 l12 l13 l14 l15 l16 l17  
l18 l19 l2 l20 l21 l22 l23 l24 l25  
l27 l28 l3 l4 l5 l6 l7 l8 l9



# Complexity – An Aside



kibana



Discover



Visualize



Dashboard



Timelion



LogTrail



Dev Tools



Management

```
2019-03-08 10:08:47.265 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Subarray product array_1_0 successfully configured
2019-03-08 10:12:21.466 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Using capture block ID 1552039941
2019-03-08 10:12:21.470 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.flag_writer.sdp_l1
out 30s)
2019-03-08 10:12:21.471 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.vis_writer.sdp_l0
s)
2019-03-08 10:12:21.472 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.flag_writer.sdp_l1_flags s
2019-03-08 10:12:21.474 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.cal.1 (timeout 30s
2019-03-08 10:12:21.481 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.cal.1 successful
2019-03-08 10:12:21.778 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.vis_writer.sdp_l0 successf
2019-03-08 10:12:21.783 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.1 (t
2019-03-08 10:12:21.784 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.2 (t
2019-03-08 10:12:21.785 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.3 (t
2019-03-08 10:12:21.786 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.4 (t
2019-03-08 10:12:21.788 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.1 successful
2019-03-08 10:12:21.789 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.2 successful
2019-03-08 10:12:21.791 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.3 successful
2019-03-08 10:12:21.792 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-init ('1552039941',) to node array_1_0.ingest.sdp_l0.4 successful
2019-03-08 10:12:21.793 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Started capture block 1552039941 on subarray product array_1_0
2019-03-08 10:18:28.703 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.ingest.sdp_l0.1 (timeout 120s)
2019-03-08 10:18:28.705 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.ingest.sdp_l0.2 (timeout 120s)
2019-03-08 10:18:28.706 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.ingest.sdp_l0.3 (timeout 120s)
2019-03-08 10:18:28.707 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.ingest.sdp_l0.4 (timeout 120s)
2019-03-08 10:18:45.978 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.ingest.sdp_l0.1 successful
2019-03-08 10:18:46.035 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.ingest.sdp_l0.4 successful
2019-03-08 10:18:46.096 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.ingest.sdp_l0.2 successful
2019-03-08 10:18:46.179 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.ingest.sdp_l0.3 successful
2019-03-08 10:18:46.180 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.cal.1 (timeout 120s)
2019-03-08 10:18:46.181 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request capture-done () to node array_1_0.vis_writer.sdp_l0 (timeout 120s)
2019-03-08 10:18:46.398 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.vis_writer.sdp_l0 successful
2019-03-08 10:18:46.624 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request capture-done () to node array_1_0.cal.1 successful
2019-03-08 10:18:46.625 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Issuing request write-meta ('1552039941', True) to node array_1_0.meta_writer (ti
2019-03-08 10:18:46.707 mc1.sdp.mkat.karoo.kat.ac.za sdpmc: array_1_0 Request write-meta ('1552039941', True) to node array_1_0.meta_writer successful
```

# Complexity – An Aside

array\_1\_0

## CAPTURING

Tasks		Config		Capture blocks	
↕ Name	↕ State	↕ Mesos State	↕ Host		
telstate	READY	TASK_RUNNING	cal6.sdp.mkat.karoo.kat.ac.za		
cam2telstate	READY	TASK_RUNNING	cal6.sdp.mkat.karoo.kat.ac.za		
meta_writer	READY	TASK_RUNNING	fwr3.sdp.mkat.karoo.kat.ac.za		
ingest.sdp_10.1	READY	TASK_RUNNING	ing1.sdp.mkat.karoo.kat.ac.za		
ingest.sdp_10.2	READY	TASK_RUNNING	ing1.sdp.mkat.karoo.kat.ac.za		
ingest.sdp_10.3	READY	TASK_RUNNING	ing1.sdp.mkat.karoo.kat.ac.za		
ingest.sdp_10.4	READY	TASK_RUNNING	ing1.sdp.mkat.karoo.kat.ac.za		
cal.1	READY	TASK_RUNNING	cal5.sdp.mkat.karoo.kat.ac.za		
vis_writer.sdp_10	READY	TASK_RUNNING	fwr3.sdp.mkat.karoo.kat.ac.za		
flag_writer.sdp_11_flags	FINISHING	TASK_RUNNING	fwr3.sdp.mkat.karoo.kat.ac.za		
timeplot.sdp_10	READY	TASK_RUNNING	cal6.sdp.mkat.karoo.kat.ac.za		

```
kat@cms3:~/tbennett$ s3cmd -v --config s3cfg_kat_c1 ls s3://1551803062-sdp-l0/
DIR      s3://1551803062-sdp-l0/correlator_data/
DIR      s3://1551803062-sdp-l0/flags/
DIR      s3://1551803062-sdp-l0/weights/
DIR      s3://1551803062-sdp-l0/weights_channel/

kat@cms3:~/tbennett$
```



MESOS

Frameworks

Agents

Roles

Offers

Maintenance

mesos-ma

**Cluster:** mesos-master-karoo

**Leader:**

[mc1.sdp.mkat.karoo.kat.ac.za:5050](#)

**Version:** 1.5.0

**Built:** [a year ago by ubuntu](#)

**Started:** [a week ago](#)

## Active Tasks

Find...

Framework ID	Task ID	Task Name	Role	State	Health	Started ▼	Host
<a href="#">...8487d0863f89-0006</a>	<a href="#">array_1_0-00000239</a>	array_1_0.flag_writer.sdp_l1_flags	realtime	RUNNING	-	<a href="#">34 minutes ago</a>	fwr3.sdp.mkat.karoo.kat.ac.za

```
kat@fwr3:/$ telnet localhost 31173
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
Python 3.6.7 (default, Oct 22 2018, 11:32:17)
[GCC 8.2.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
---
This console is running in an asyncio event loop.
It allows you to wait for coroutines using the 'await' syntax.
Try: await asyncio.sleep(1, result=3)
---
>>> loop
<_UnixSelectorEventLoop running=True closed=False debug=False>
>>> await asyncio.sleep(1, True)
```

# Complexity – An Aside

```
Mar 3 00:57:01 fwr3 kernel: [2307278.036251] md: data-check of RAID array md0
Mar 3 01:03:48 fwr3 kernel: [2307685.087047] INFO: task xfsaild/md0:1881 blocked for more than 120 seconds.
Mar 3 01:03:48 fwr3 kernel: [2307685.087066] Tainted: G OE 4.13.0-41-generic #46~16.04.1-Ubuntu
Mar 3 01:03:48 fwr3 kernel: [2307685.087082] "echo 0 > /proc/sys/kernel/hung_task_timeout_secs" disables this message.
Mar 3 01:03:48 fwr3 kernel: [2307685.087098] xfsaild/md0 D 0 1881 2 0x80000000
Mar 3 01:03:48 fwr3 kernel: [2307685.087100] Call Trace:
Mar 3 01:03:48 fwr3 kernel: [2307685.087105] __schedule+0x3d6/0x8b0
Mar 3 01:03:48 fwr3 kernel: [2307685.087107] schedule+0x36/0x80
Mar 3 01:03:48 fwr3 kernel: [2307685.087110] wait_barrier+0x14e/0x1b0 [raid10]
Mar 3 01:03:48 fwr3 kernel: [2307685.087112] ? wait_woken+0x80/0x80
Mar 3 01:03:48 fwr3 kernel: [2307685.087114] raid10_write_request+0x3d/0x840 [raid10]
Mar 3 01:03:48 fwr3 kernel: [2307685.087115] ? r10bio_pool_alloc+0x24/0x30 [raid10]
Mar 3 01:03:48 fwr3 kernel: [2307685.087118] ? mempool_alloc+0x73/0x180
Mar 3 01:03:48 fwr3 kernel: [2307685.087120] ? md_write_start+0xc8/0x210
Mar 3 01:03:48 fwr3 kernel: [2307685.087122] ? find_busiest_group+0x47/0x4d0
Mar 3 01:03:48 fwr3 kernel: [2307685.087124] raid10_make_request+0xd0/0x130 [raid10]
Mar 3 01:03:48 fwr3 kernel: [2307685.087126] md_handle_request+0xb5/0x130
Mar 3 01:03:48 fwr3 kernel: [2307685.087128] md_make_request+0x6c/0x170
Mar 3 01:03:48 fwr3 kernel: [2307685.087130] generic_make_request+0x12a/0x300
Mar 3 01:03:48 fwr3 kernel: [2307685.087131] submit_bio+0x73/0x150
Mar 3 01:03:48 fwr3 kernel: [2307685.087132] ? submit_bio+0x73/0x150
Mar 3 01:03:48 fwr3 kernel: [2307685.087162] _xfs_buf_ioapply+0x2e7/0x4a0 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087177] ? xfs_buf_delwri_submit_buffers+0x14b/0x280 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087189] xfs_buf_submit+0x63/0x210 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087201] ? xfs_buf_submit+0x63/0x210 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087213] xfs_buf_delwri_submit_buffers+0x14b/0x280 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087225] ? xfs_buf_delwri_submit_nowait+0x10/0x20 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087237] xfs_buf_delwri_submit_nowait+0x10/0x20 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087248] ? xfs_buf_delwri_submit_nowait+0x10/0x20 [xfs]
Mar 3 01:03:48 fwr3 kernel: [2307685.087264] xfsaild+0x286/0x750 [xfs]
```

# Complexity – An Aside

SR-1445

 Give feedback

 3 

## Raid10 backed XFS partitions can lock on newer kernels



Digging further, any commands on the /data partition would hang. Syslog reported the following type of errors:

```
[1524442.735012] INFO: task xfsaild/md0:1877 blocked for more than 120 seconds.
```

```
[1524442.735032] Tainted: G OE 4.13.0-41-generic #46~16.04.1-Ubuntu
```

```
[1524442.735047] "echo 0 > /proc/sys/kernel/hung_task_timeout_secs" disables this message.
```

```
[1524442.735064] xfsaild/md0 D 0 1877 2 0x80000000
```

Looking further noticed the following before the errors started:

```
[1513652.617467] md: data-check of RAID array md0
```

Seems that there is a bug with XFS partitions on RAID10 devices with kernels newer than 4.10 (<https://bugs.launchpad.net/ubuntu/+bug/1767992>)

Only remedy here was to physically reboot the machine (which got stuck and needed hard power) and then prevent data checking with:

```
echo frozen > /sys/block/md0/md/sync_action
```

Since this stops telescope operations we need to find a remedy or workaround for this as soon as we can.

### STATUS

To Do 

### ASSIGNEE



Martin Slabber

### REPORTER



Simon Ratcliffe

### LABELS

None

### ESTIMATED FINISH DATE

None

### TIME TRACKING



No time logged

### PRIORITY



Urgent

---

*The solution*

---

?

## Aside from complexity, scale is next...

Increased reliability and new modes challenge commissioning due to ever increasing amounts of data

Since inauguration we have collected 1000's of hours of data. At least 50% of this has not been looked at in any significant detail.

It is only getting worse – commensal just started (narrow + wide) and 32k is once again imminent.

Increased system performance also starts to show the warts in our existing toolchain. Even with a responsive developer, getting changes in 3<sup>rd</sup> party packages takes time.

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# *The solution*

*(this time we do have something)*

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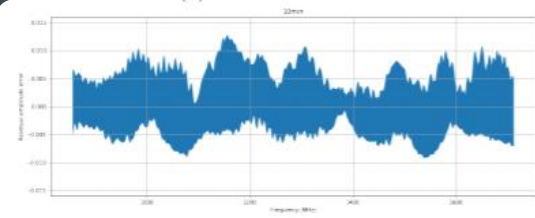
# Control your toolchain as far as practicable

Really helpful having science commissioning, science processing and RARG (Radio Astronomy Research Group) in **a single unit**.

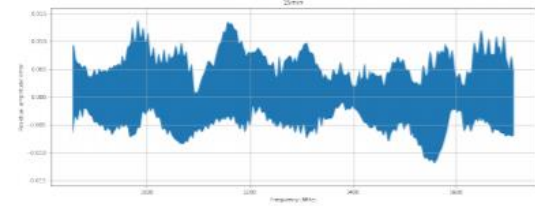
Allows us to push in **multiple directions simultaneously**, looking for both performant and high quality solutions.

Particularly for new algorithmic or quality issues this approach has shown real utility.

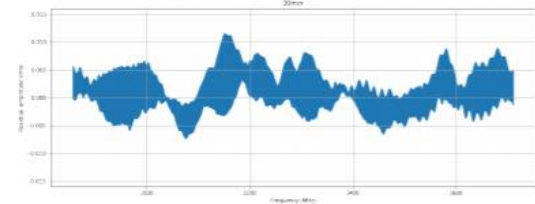
PKS 0407 Substructure  
Credit: B.Hugo et al



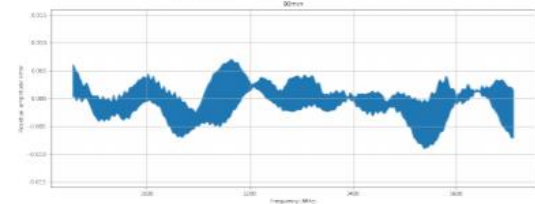
(c) 10 minute intervals



(d) 15 minute intervals



(e) 20 minute intervals



(f) 90 minute intervals

## MeerKAT Data Products (this month)

Continuum image pipeline: baseline subtraction, self-cal solutions, and **best effort images**.

Spectral line pipeline: image cubes (up to **100 hrs** joint)

Reduction for QA is done as standard for qualifying observations (currently 15mins on target for continuum / 3 hours for spectral)

Full res spectral cube is **24 TB**

Once stable for QA, effort switches to improving **science quality** under guidance from LSPs.

# Deployed Infrastructure

## Realtime Cluster

Ingest + Calibration

100 TFLOPs, 6TB RAM

## Batch Cluster

Spectral + Continuum Imaging

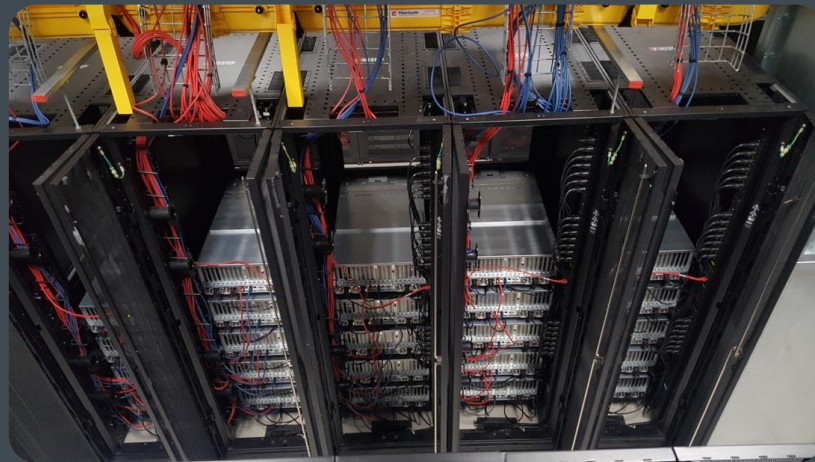
1.1 PFLOPs, 4TB RAM, 0.8 PiB buffer

## Storage

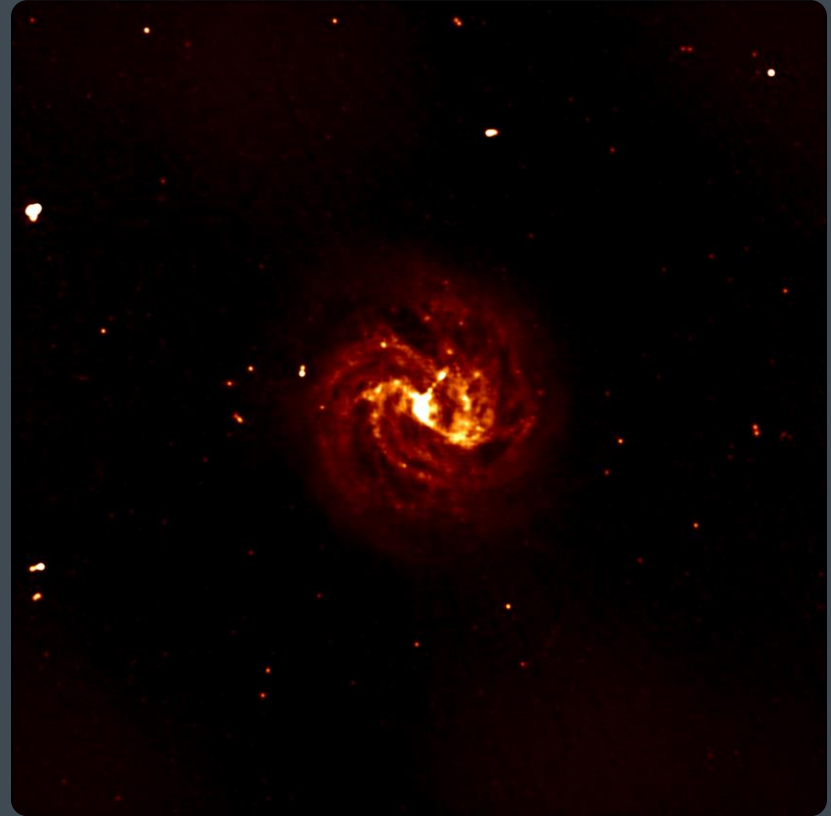
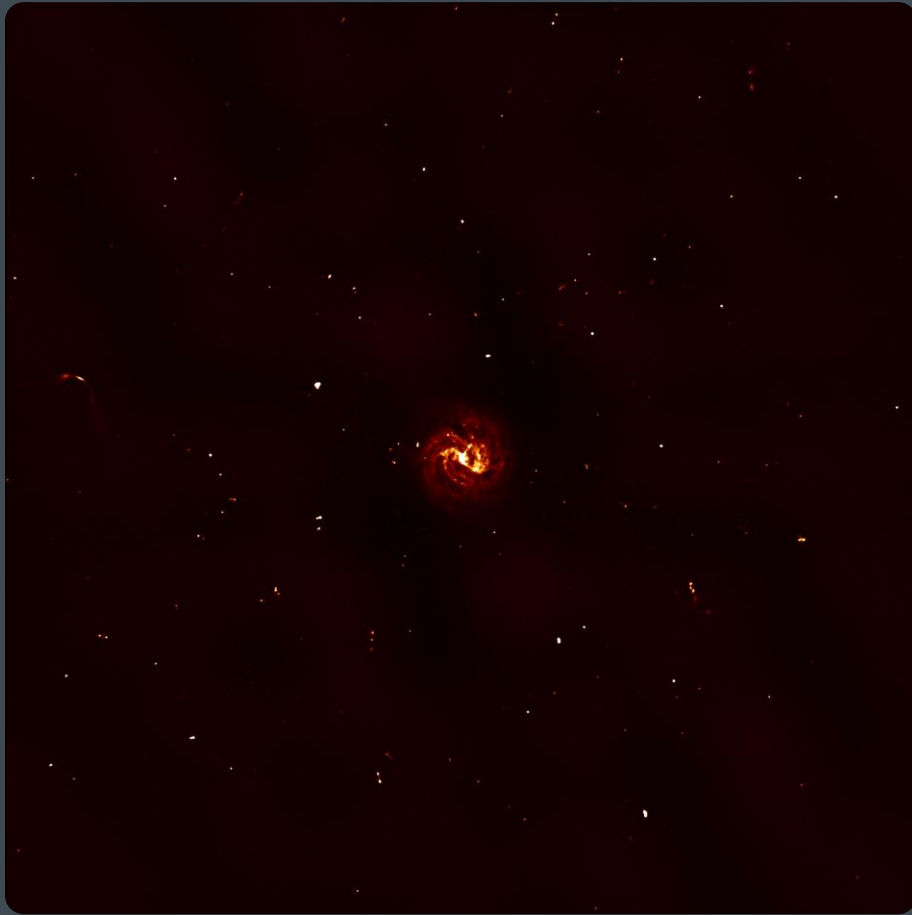
Vis Data + Science Products

object store: 20.5 PiB

tape: 19.2 PiB



## Our first hands-free image (M83)



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# *Relentless Imaging*

*(the first 7 days)*

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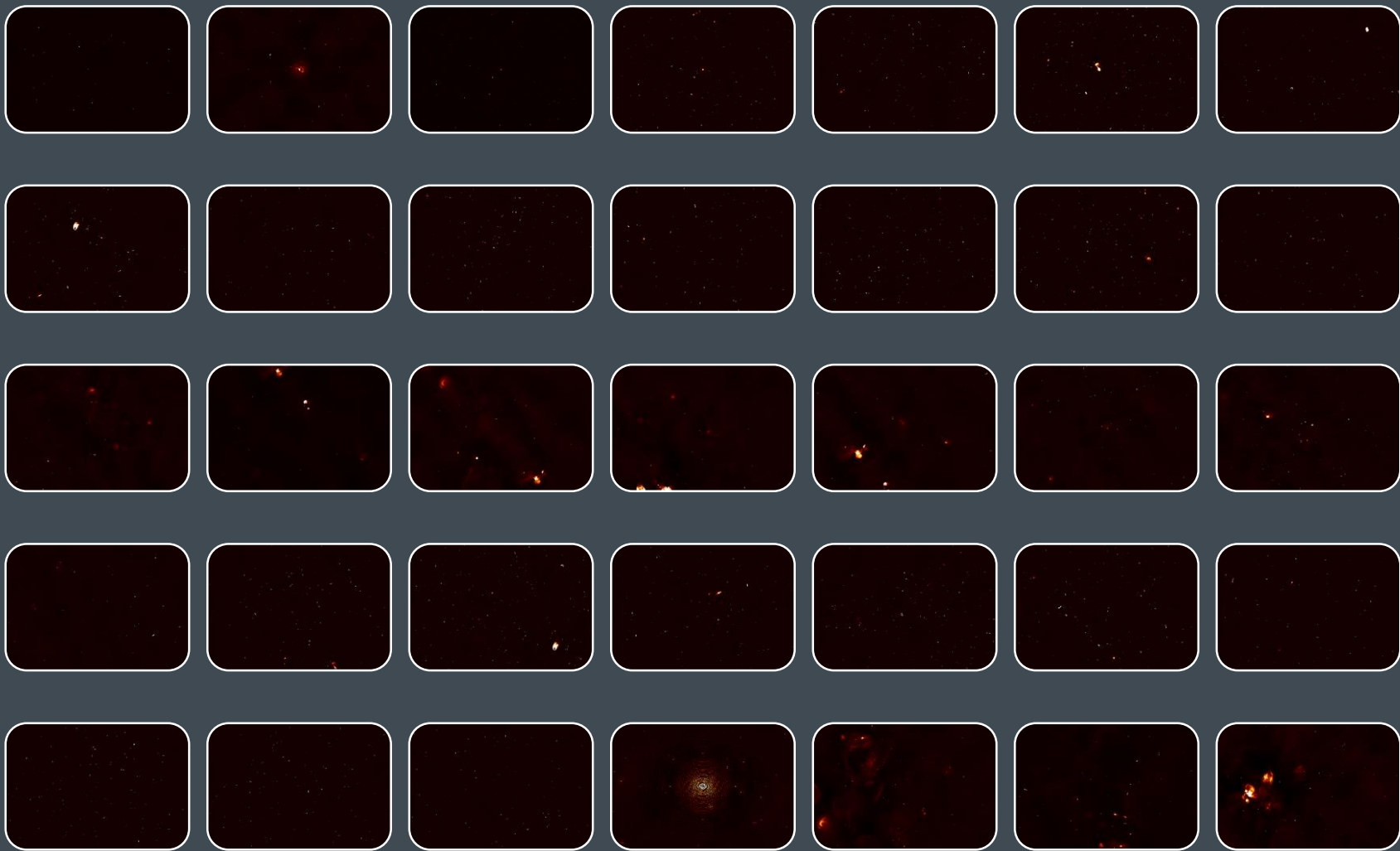
# Imaging Pipeline

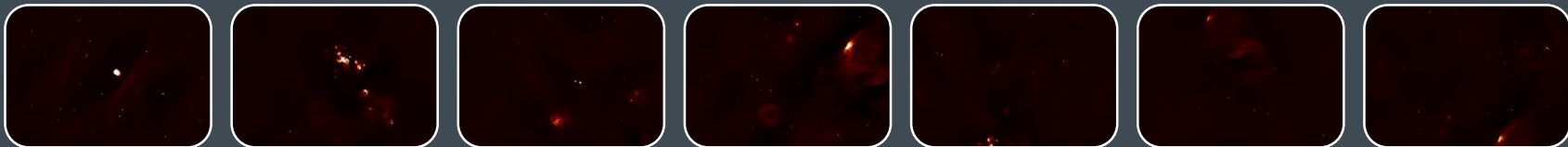
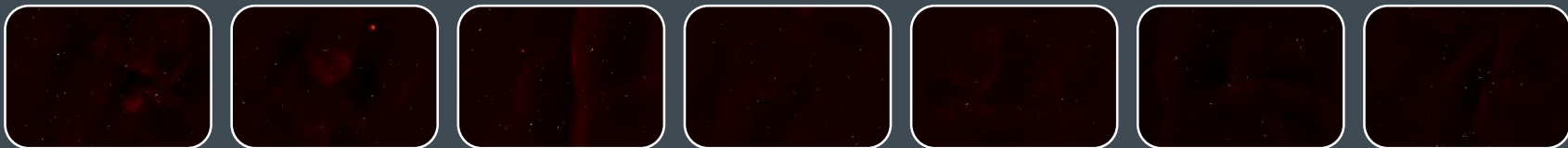
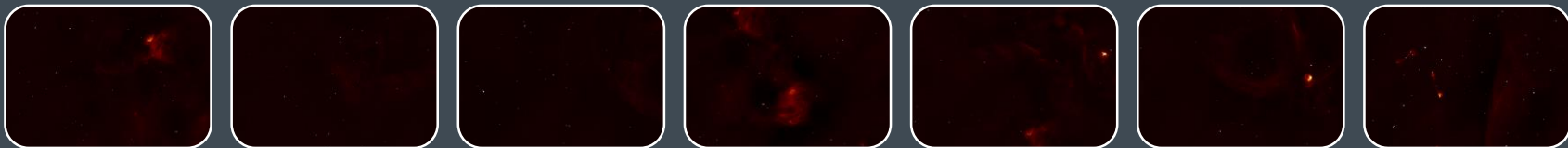
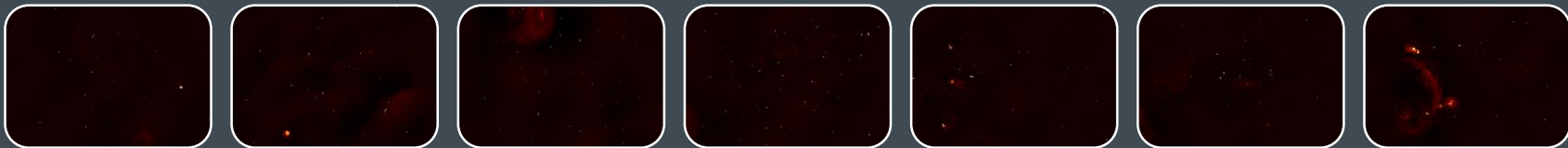
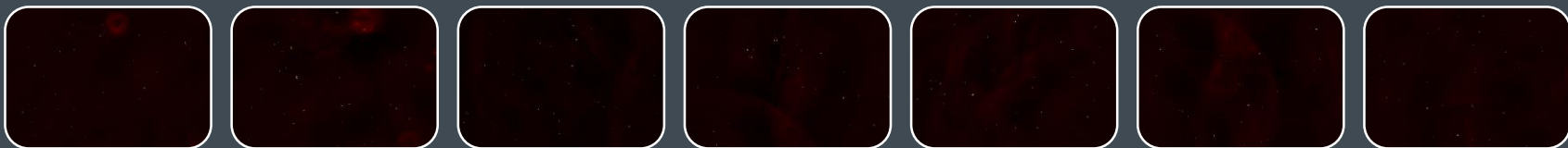
Deployed into production on 11 Nov. First week saw 76 fields imaged and in the archive.

Average time to image in archive: 1.4x target duration

No flux calibration (yet – check again next week)

Only a handful of spectral cubes so far – mostly limited by target time (< 3 hours)





## So what next...

Commissioning **starts at first light** and pretty much never ends.

Tight integration with engineering activities very helpful, but can be **frustrating** for commissioning group.

Don't underestimate the tooling needed, both from a **scale and performance** aspect.

**Backpressure** on feature development is important – the “greater good” needs a high level view.

