Preparing for the next generation of (radio) observatory operations

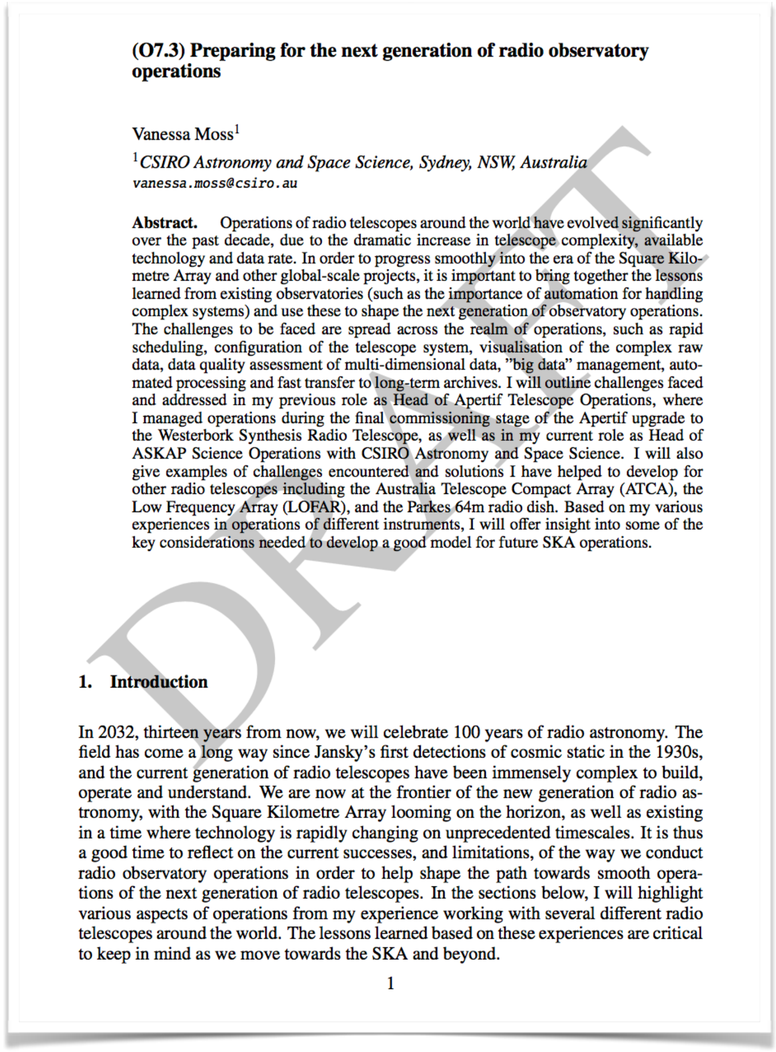
Vanessa Moss

CSIRO Astronomy and Space Science

IMAGE CREDIT: A. CHERNEY

Key takeaway points

- **1. People:** *Role of the technical astronomer*
- **2. Automation:** *Automate all the things*
- **3. Communication:** *Communication is the source of all the world's problems*
- **4. Overview:** *The big picture is just as important as the details*
- **5. Testing:** *There is no test like an observational test*
- **6. The shadowy place**



(O7.3) Preparing for the next generation of radio observatory operations

Vanessa Moss[1]

[1]*CSIRO Astronomy and Space Science, Sydney, NSW, Australia*
vanessa.moss@csiro.au

Abstract. Operations of radio telescopes around the world have evolved significantly over the past decade, due to the dramatic increase in telescope complexity, available technology and data rate. In order to progress smoothly into the era of the Square Kilometre Array and other global-scale projects, it is important to bring together the lessons learned from existing observatories (such as the importance of automation for handling complex systems) and use these to shape the next generation of observatory operations. The challenges to be faced are spread across the realm of operations, such as rapid scheduling, configuration of the telescope system, visualisation of the complex raw data, data quality assessment of multi-dimensional data, "big data" management, automated processing and fast transfer to long-term archives. I will outline challenges faced and addressed in my previous role as Head of Apertif Telescope Operations, where I managed operations during the final commissioning stage of the Apertif upgrade to the Westerbork Synthesis Radio Telescope, as well as in my current role as Head of ASKAP Science Operations with CSIRO Astronomy and Space Science. I will also give examples of challenges encountered and solutions I have helped to develop for other radio telescopes including the Australia Telescope Compact Array (ATCA), the Low Frequency Array (LOFAR), and the Parkes 64m radio dish. Based on my various experiences in operations of different instruments, I will offer insight into some of the key considerations needed to develop a good model for future SKA operations.

1. Introduction

In 2032, thirteen years from now, we will celebrate 100 years of radio astronomy. The field has come a long way since Jansky's first detections of cosmic static in the 1930s, and the current generation of radio telescopes have been immensely complex to build, operate and understand. We are now at the frontier of the new generation of radio astronomy, with the Square Kilometre Array looming on the horizon, as well as existing in a time where technology is rapidly changing on unprecedented timescales. It is thus a good time to reflect on the current successes, and limitations, of the way we conduct radio observatory operations in order to help shape the path towards smooth operations of the next generation of radio telescopes. In the sections below, I will highlight various aspects of operations from my experience working with several different radio telescopes around the world. The lessons learned based on these experiences are critical to keep in mind as we move towards the SKA and beyond.

1

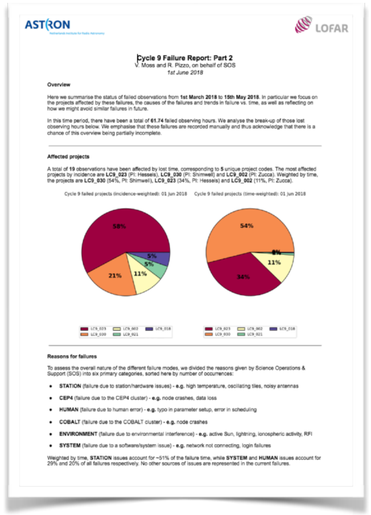
1. People

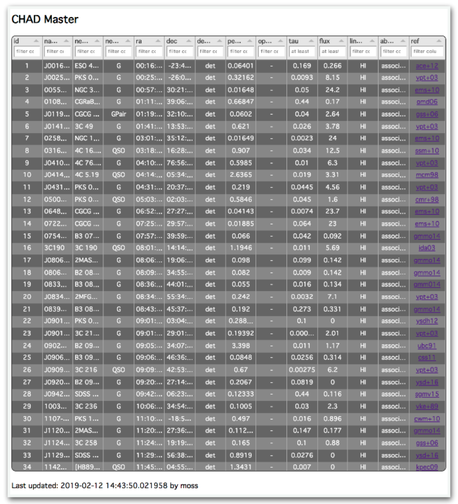
Role of the technical astronomer

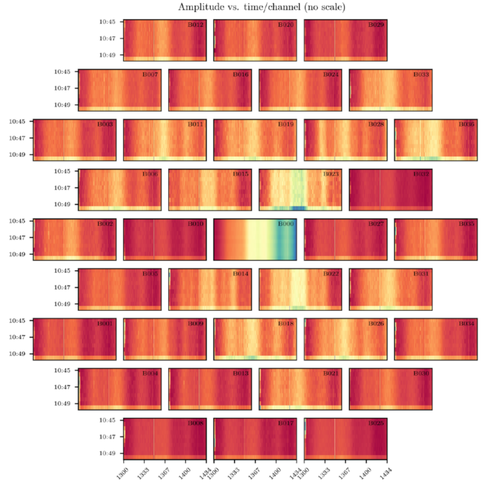
Role of the technical astronomer

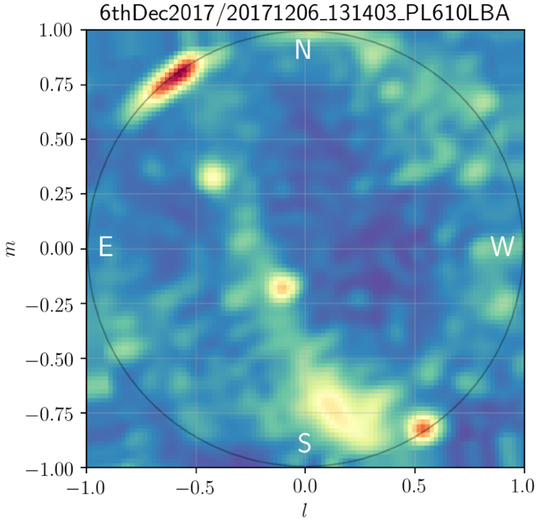
- **Observational radio astronomy** has become more specialised and contained in the recent past, compared with the broader experience of past astronomers
- Now, radio astronomers tend to be more focused on specific parts of the overall process, particularly if they are **technically inclined**
- It is particularly important that we **recognise** and **encourage** contributions of technical astronomers in the middle 3 boxes here:

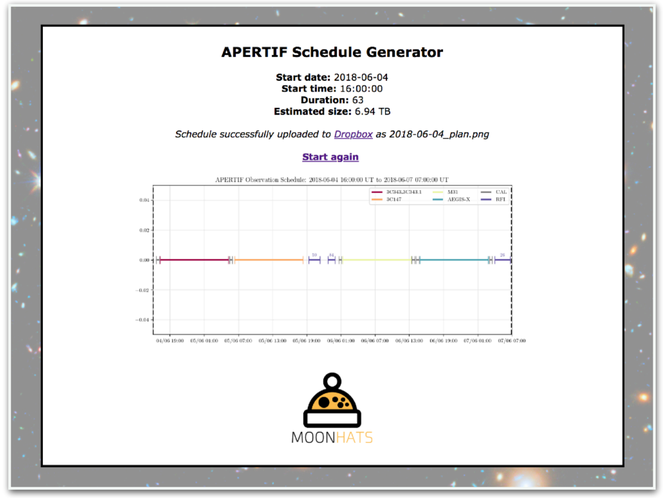
Types of technical contributions

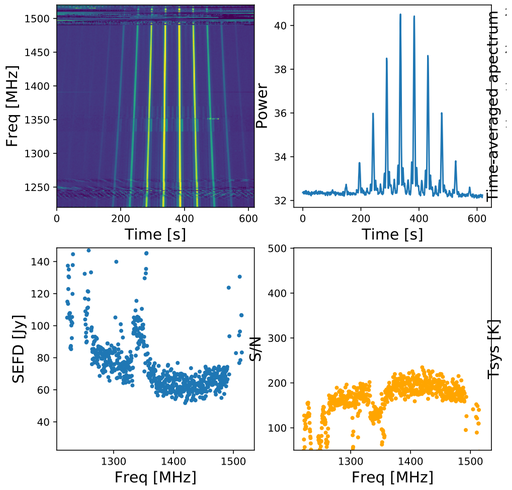


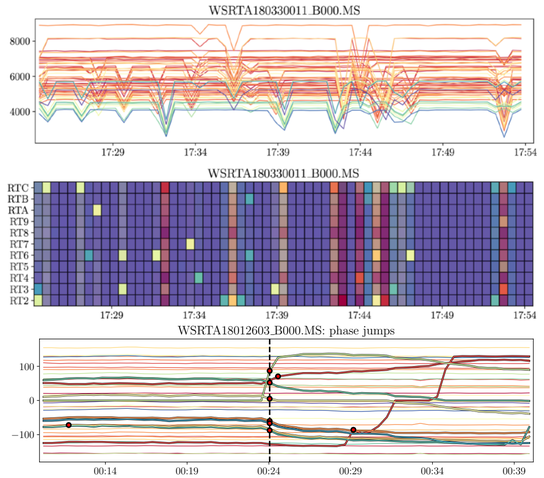


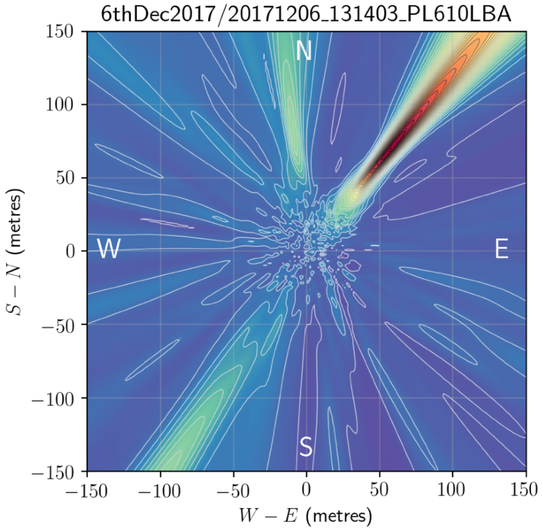












Represents work by: V. Moss, L. Connor, L. Oostrum, M. Brentjens, M. Norden

The future of operational roles

- There are many examples of roles at current radio institutes which demonstrate the **growing need** for technical astronomers

- **Science operations:** NRAO support scientists, LOFAR SOS, JIVE telescope scientists

- **Observatory experience:** co-supervision programs, LOFAR traineeships, radio schools

- As a field, we must recognise the need for this role and provide **viable career options** for technical astronomers going forward

Images: LOFAR SOS, CASS-ATNF

2. Automation

Automate all the things

Apercal Triggers APP 18:15

AutoCalBot

AutoCal Status Report: happili-01

Apercal pipeline triggered for 1904280

2019-05-01 16:15:56.830060 UTC

OSA: N/A

FYI: @moss @betsey

```
Calibrator #1: 3C147 (190428024-190
Calibrator #2: 3C286 (190429001-190
Beams: 0,1,2,3,4,5,6,7,8,9
```

Show less

AutoCalBot

AutoCal Status Report: happili-04

Apercal pipeline triggered for 1904280

2019-05-01 16:15:57.344727 UTC

OSA: N/A

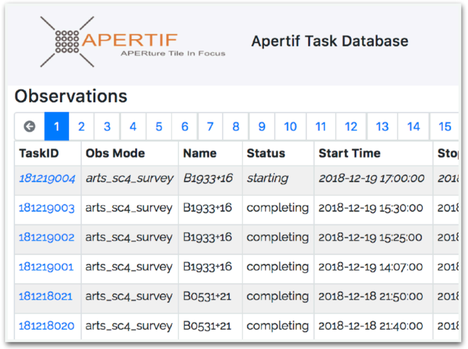
FYI: @moss @betsey

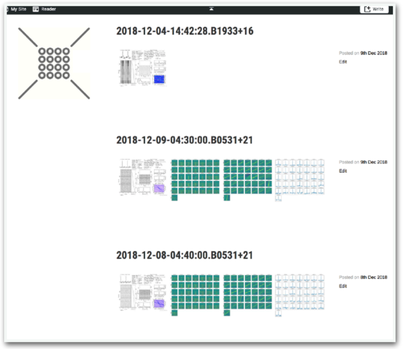
```
Calibrator #1: 3C147 (190428054-190
Calibrator #2: 3C286 (190429031-190
Beams: 30,31,32,33,34,35,36,37,38,3
```

Show less

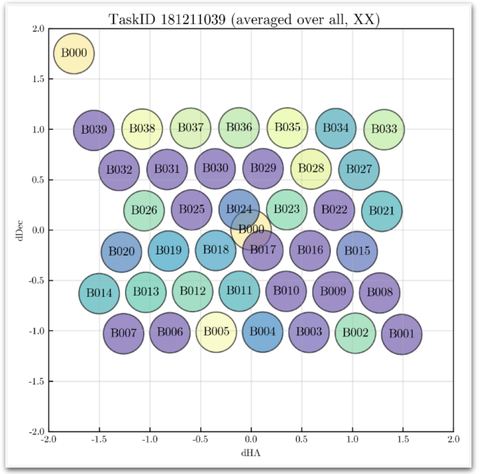
Automating Apertif

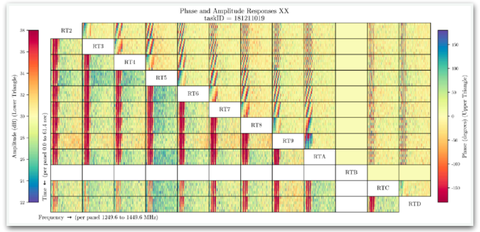
- **ATDB:** The Apertif Task DataBase coordinates specification, observations, ingest (ALTA, **P5.1**) and deletion with minimal human effort (**P9.9**)
- **ATDBspec:** Python lib to convert astronomy specification to system specification (+ARTS)
- **Apercal:** a scripted pipeline to process/assess imaging data using preset parameters (**P10.47**), producing science-quality data (**P5.7**)
- **AutoApercal:** auto-detection of new targets
- **ARTS:** real time transient pipeline (**P10.52**)

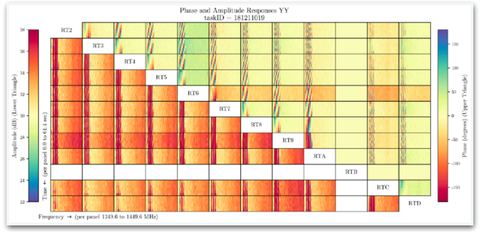




	1	2	3	4
start_pipelin	0:00	0:00	0:00	0:00
prepare	0:26	0:30	0:30	0:26
preflag	7:13	7:16	7:16	10:30
ccal	5:13	5:23	5:10	5:16
QA	0:33	0:16	0:16	0:16
convert	4:30	4:26	4:16	4:30
scal	9:00	6:16	7:43	8:03
continuum	0:00	2:26	1:40	2:43
	26:56	26:36	26:53	31:46







Images: N. Vermaas, T. Dijkema, V. Moss

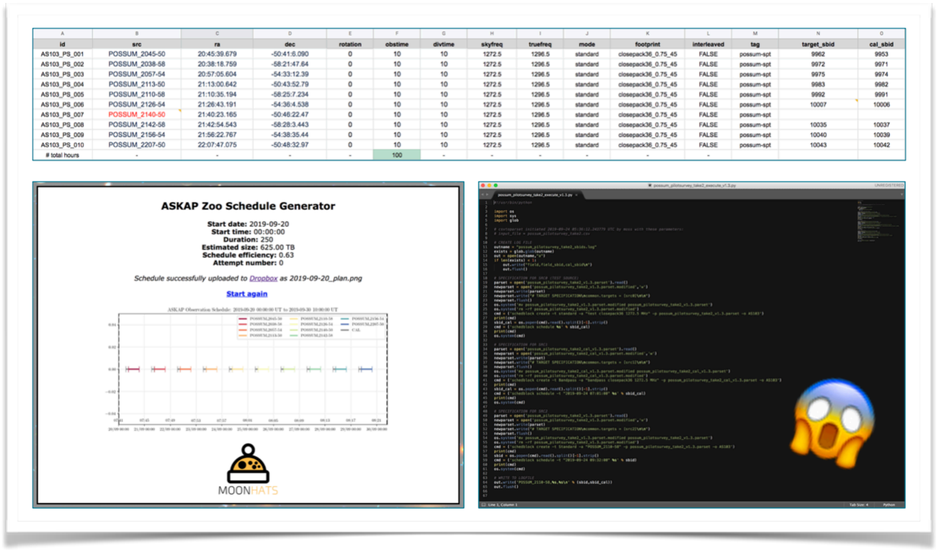
Automating ASKAP

- A lot of work has been done in automating various aspects of ASKAP **prior** to my role (thanks ASKAP team!)

- We make use of an online web tool - **ASKAP OMP** - to provide an **overview** of the system and interact with the **observation database**

- The **ASKAP-X** project has just begun, which is a SAFe Agile software development project to improve **operational stability** and **automation**

- As a scheduler/operator, I can also interact with the system via "**hacky**" Python scripts

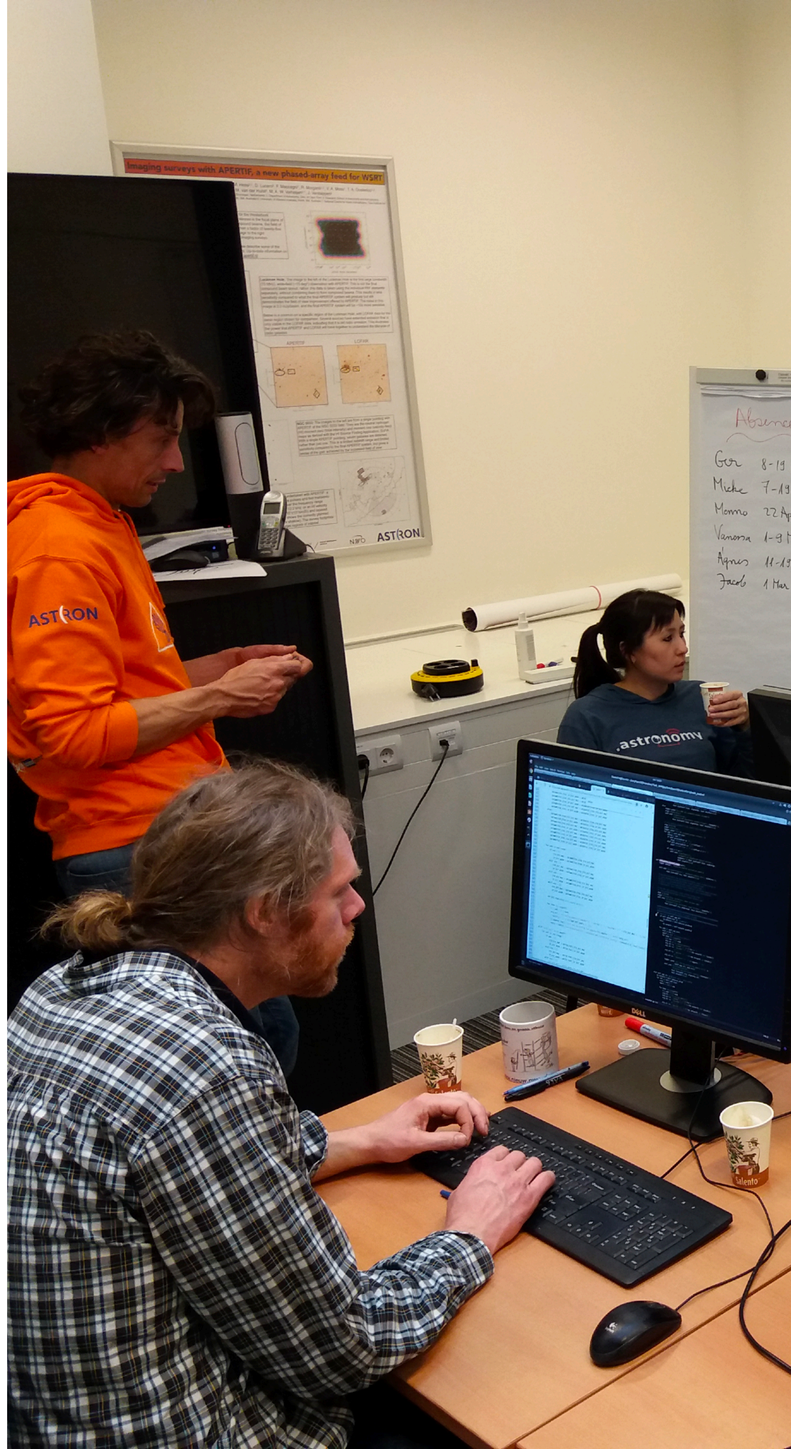


ADASS 2019 (V. Moss, @cosmicpudding)

Represents work by: X. Yu, S. Mader, V. Moss

3. Communication

Communication is the source of all the world's problems



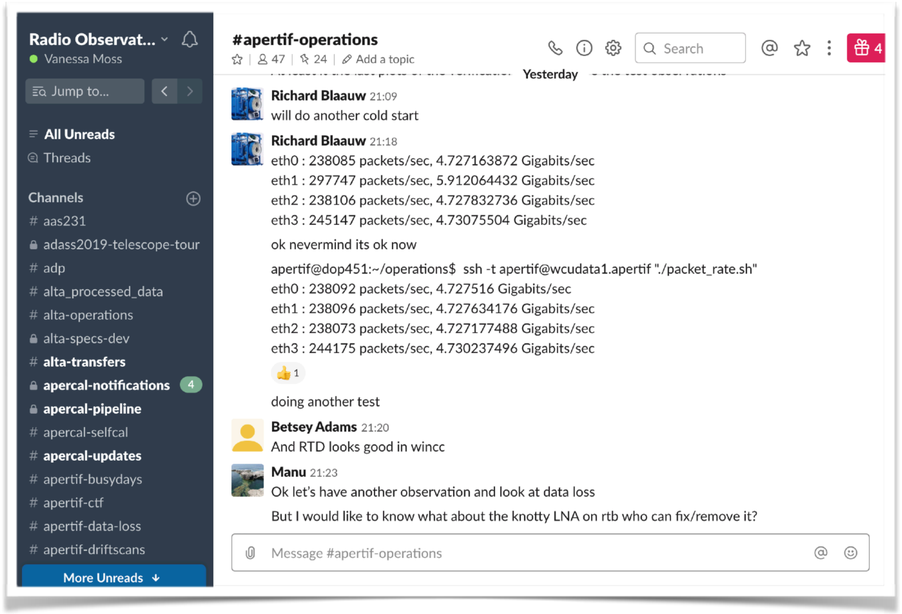
The right tool for the right job

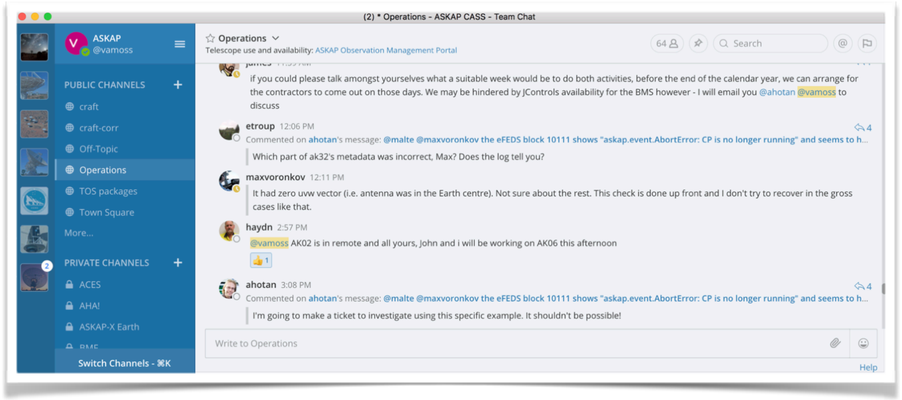
- There are **endless ways** to communicate: email, meeting, telecon, phone, **ADASS**, Slack, wikis, reports, WhatsApp, hallway chats, **BoFs!**
  note: "dear diary" meetings are rarely useful

- **Daily communication:** Slack or Mattermost are excellent tools to keep the conversation going, especially in **open channels**

- **Weekly communication:** a contained (to the point) meeting, or an online written briefing

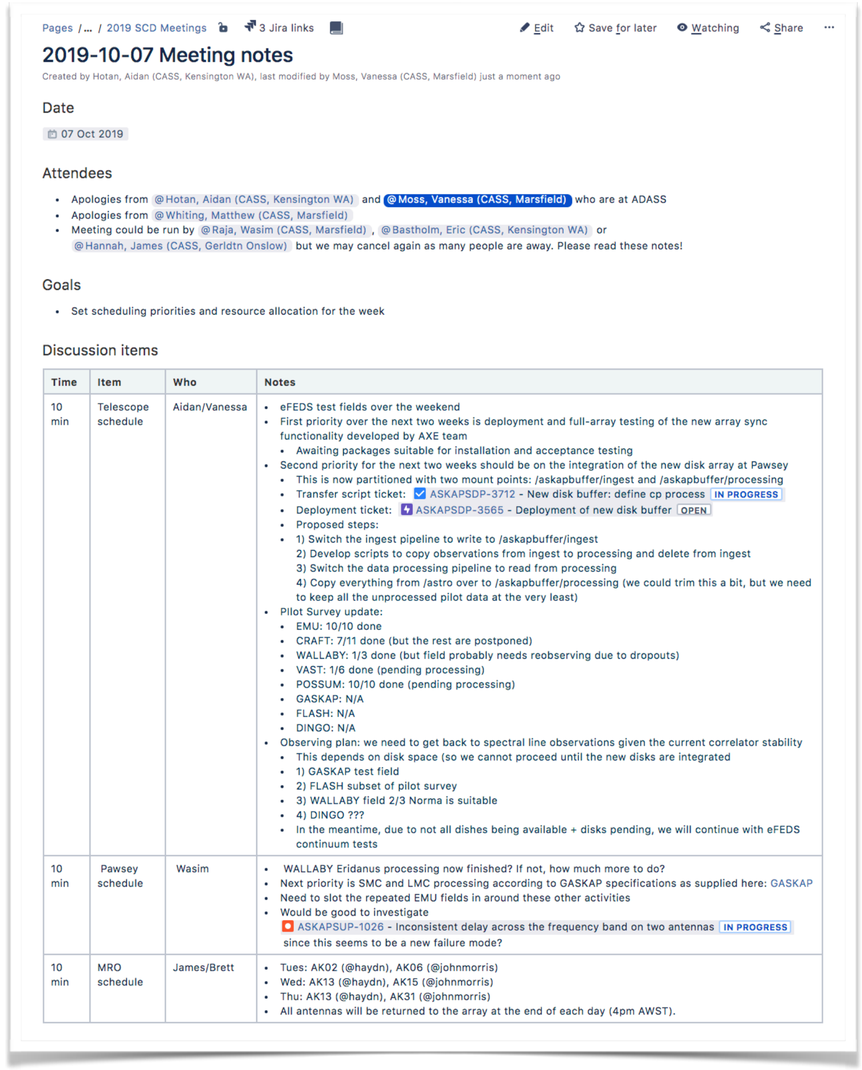
- **Long-term communication:** reports or documents, large-scale meetings, telecon





Scheduling meetings

- Meetings can be **powerful**, when used wisely
- **Every Monday 15:30 AEST:** ASKAP scheduling meeting, focused on operations, processing and on-site maintenance (30 MINUTES ONLY!)
- This meeting brings together a very effective group of people to **make a plan** for the week ahead and get everyone on the **same page**
- It is also a very **small tax** on people's time, and we do our best to keep within the time limit
- We notice the **absence** of this meeting!



Pages / ... / 2019 SCD Meetings 3 Jira links Edit Save for later Watching Share

2019-10-07 Meeting notes

Created by Hotan, Aidan (CASS, Kensington WA), last modified by Moss, Vanessa (CASS, Marsfield) just a moment ago

Date

07 Oct 2019

Attendees

- Apologies from @Hotan, Aidan (CASS, Kensington WA) and @Moss, Vanessa (CASS, Marsfield) who are at ADASS
- Apologies from @Whiting, Matthew (CASS, Marsfield)
- Meeting could be run by @Raja, Wasim (CASS, Marsfield) , @Bastholm, Eric (CASS, Kensington WA) or @Hannah, James (CASS, Gerldtn Onslow) but we may cancel again as many people are away. Please read these notes!

Goals

- Set scheduling priorities and resource allocation for the week

Discussion items

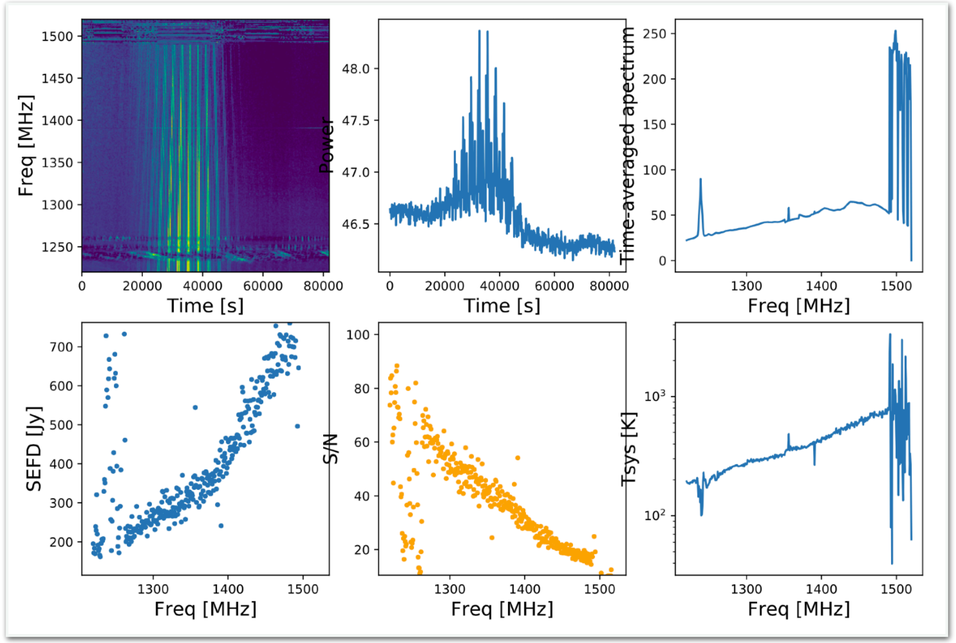
Time	Item	Who	Notes

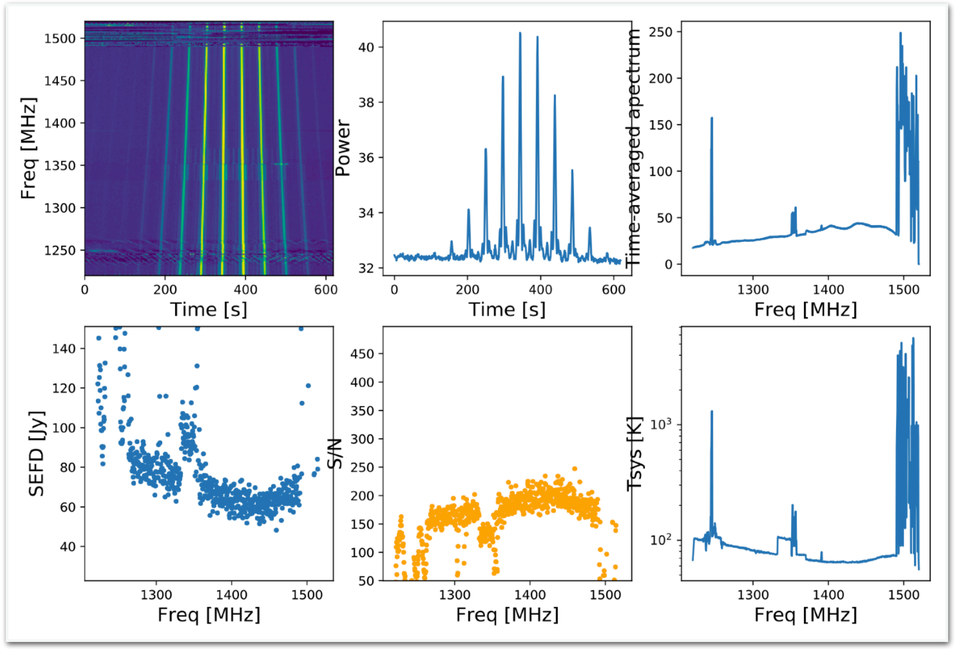
10 min	Telescope schedule	Aidan/Vanessa	• eFEDS test fields over the weekend
			• First priority over the next two weeks is deployment and full-array testing of the new array sync functionality developed by AXE team
			  • Awaiting packages suitable for installation and acceptance testing
			• Second priority for the next two weeks should be on the integration of the new disk array at Pawsey
			  • This is now partitioned with two mount points: /askapbuffer/ingest and /askapbuffer/processing
			  • Transfer script ticket: ASKAPSDP-3712 - New disk buffer: define cp process IN PROGRESS
			  • Deployment ticket: ASKAPSDP-3565 - Deployment of new disk buffer OPEN
			  • Proposed steps:
			  • 1) Switch the ingest pipeline to write to /askapbuffer/ingest
			  2) Develop scripts to copy observations from ingest to processing and delete from ingest
			  3) Switch the data processing pipeline to read from processing
			  4) Copy everything from /astro over to /askapbuffer/processing (we could trim this a bit, but we need to keep all the unprocessed pilot data at the very least)
			• Pilot Survey update:
			  • EMU: 10/10 done
			  • CRAFT: 7/11 done (but the rest are postponed)
			  • WALLABY: 1/3 done (but field probably needs reobserving due to dropouts)
			  • VAST: 1/6 done (pending processing)
			  • POSSUM: 10/10 done (pending processing)
			  • GASKAP: N/A
			  • FLASH: N/A
			  • DINGO: N/A
			• Observing plan: we need to get back to spectral line observations given the current correlator stability
			  • This depends on disk space (so we cannot proceed until the new disks are integrated
			  • 1) GASKAP test field
			  • 2) FLASH subset of pilot survey
			  • 3) WALLABY field 2/3 Norma is suitable
			  • 4) DINGO ???
			  • In the meantime, due to not all dishes being available + disks pending, we will continue with eFEDS continuum tests

10 min	Pawsey schedule	Wasim	• WALLABY Eridanus processing now finished? If not, how much more to do? • Next priority is SMC and LMC processing according to GASKAP specifications as supplied here: GASKAP • Need to slot the repeated EMU fields in around these other activities • Would be good to investigate ASKAPSUP-1026 - Inconsistent delay across the frequency band on two antennas IN PROGRESS since this seems to be a new failure mode?
10 min	MRO schedule	James/Brett	• Tues: AK02 (@haydn), AK06 (@johnmorris) • Wed: AK13 (@haydn), AK15 (@johnmorris) • Thu: AK13 (@haydn), AK31 (@johnmorris) • All antennas will be returned to the array at the end of each day (4pm AWST).

Results from ACTF

- **ACTF:** Apertif Calibration Task Force, initiated by A. Schoenmakers, led by V. Moss/B. Adams
- Consisted of members from across the ASTRON departments to **consult** on calibration issues, including A. Hotan from CSIRO/ASKAP
- 4+ meetings (**27/3, 18/4, 21/5, 18/6**) to address current issues and suggest paths to solutions
- **Outcomes**: warm start + beam weights successfully improved sensitivity, progress in debugging cause of off-beam phase slopes





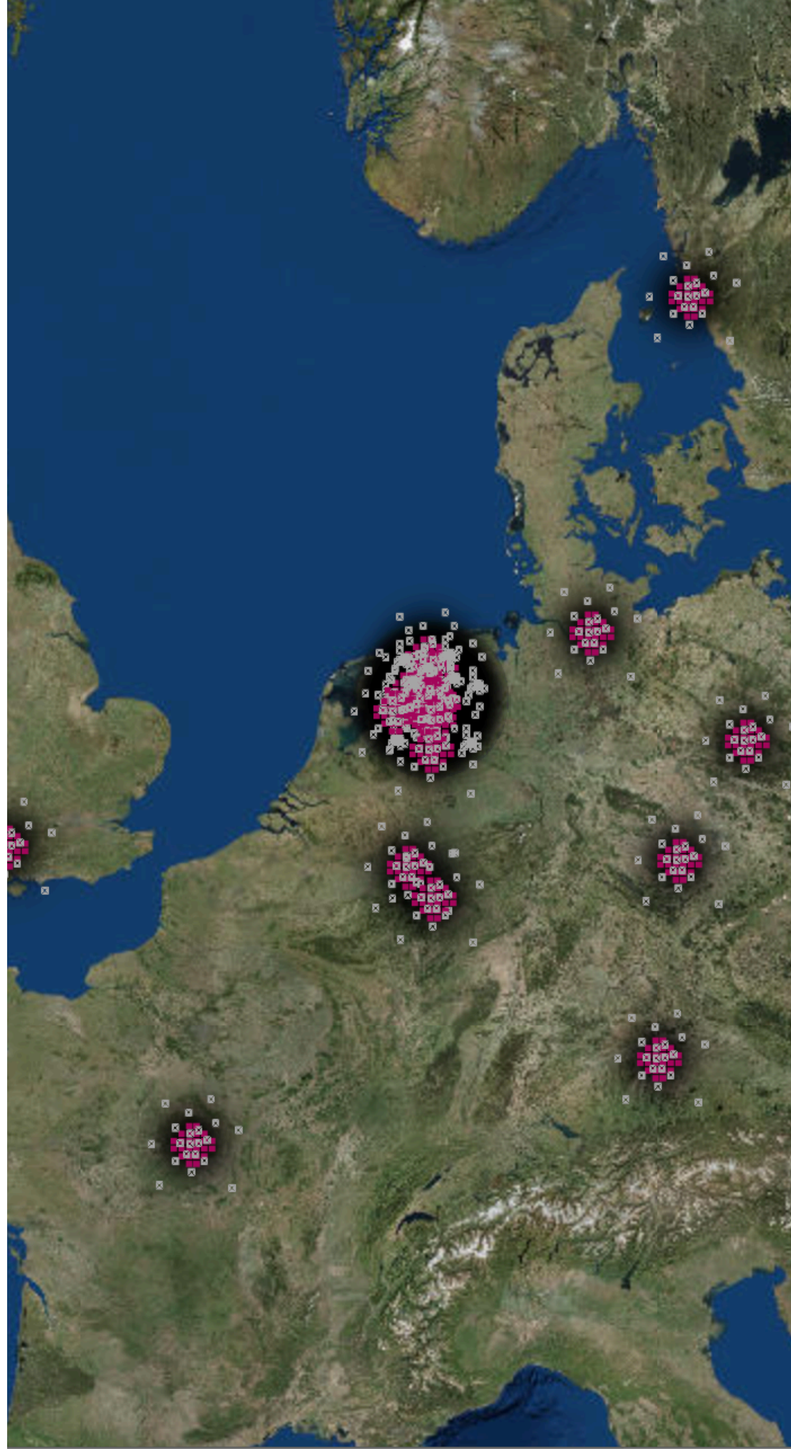
Images: L. Connor, L.Oostrum, J. van Leeuwen

ADASS BoF #4

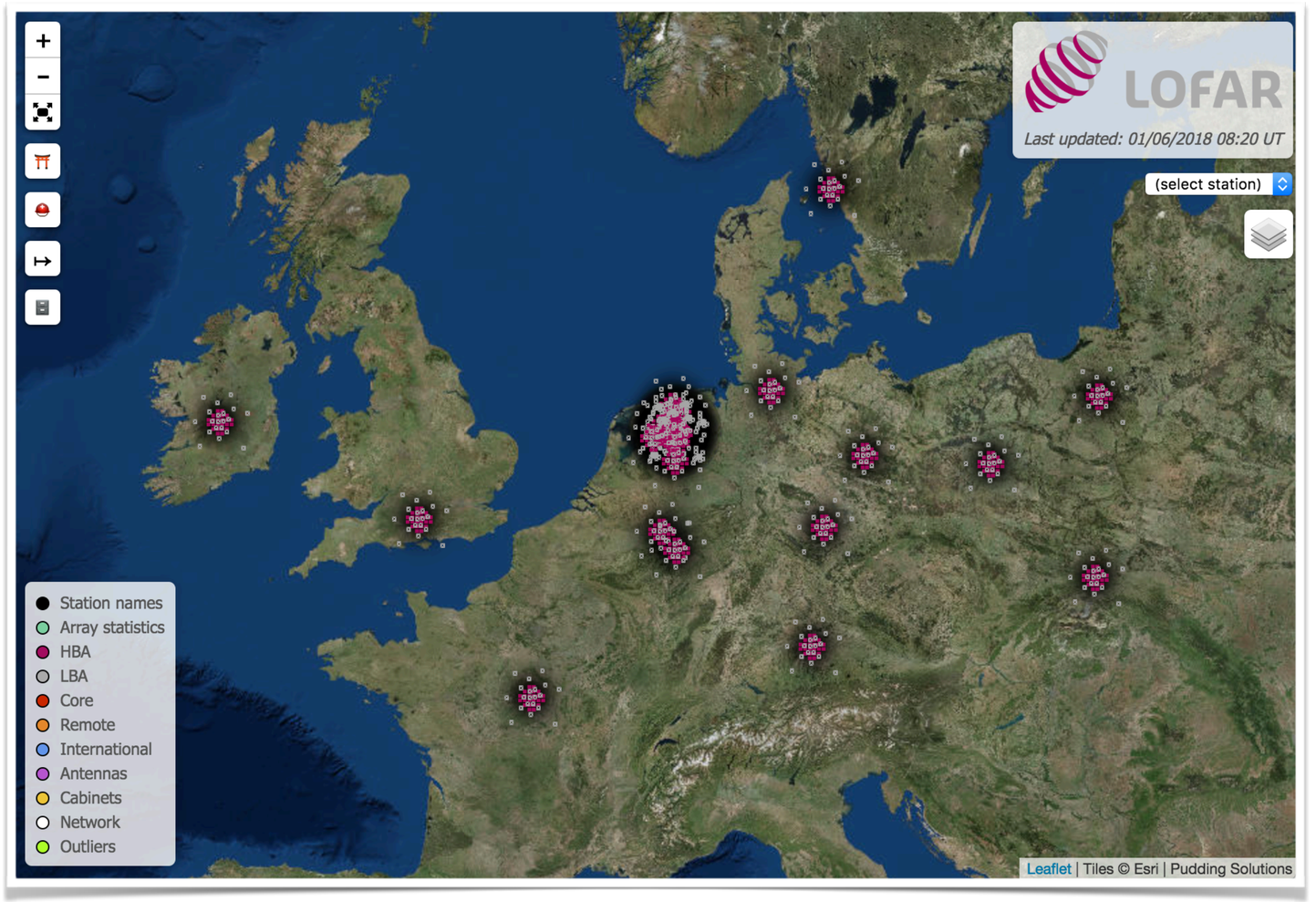
Thanks to everyone who came to the BoF!

4. Overview

The big picture is just as important as the details



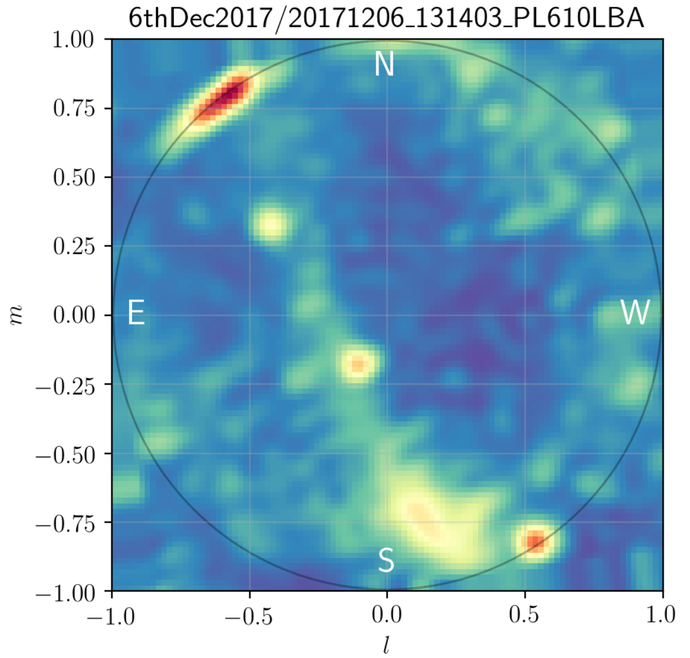
Interactive LOFAR map

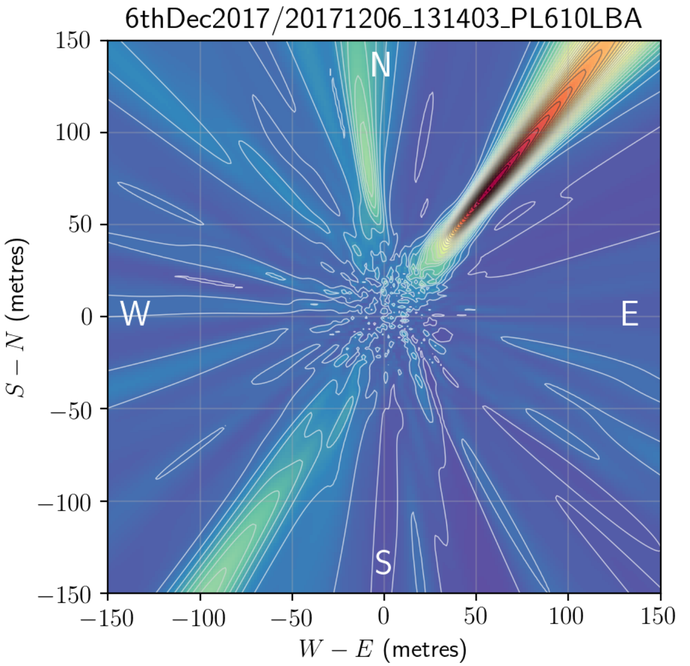


http://astron.nl/lofartools/lofarmap.html

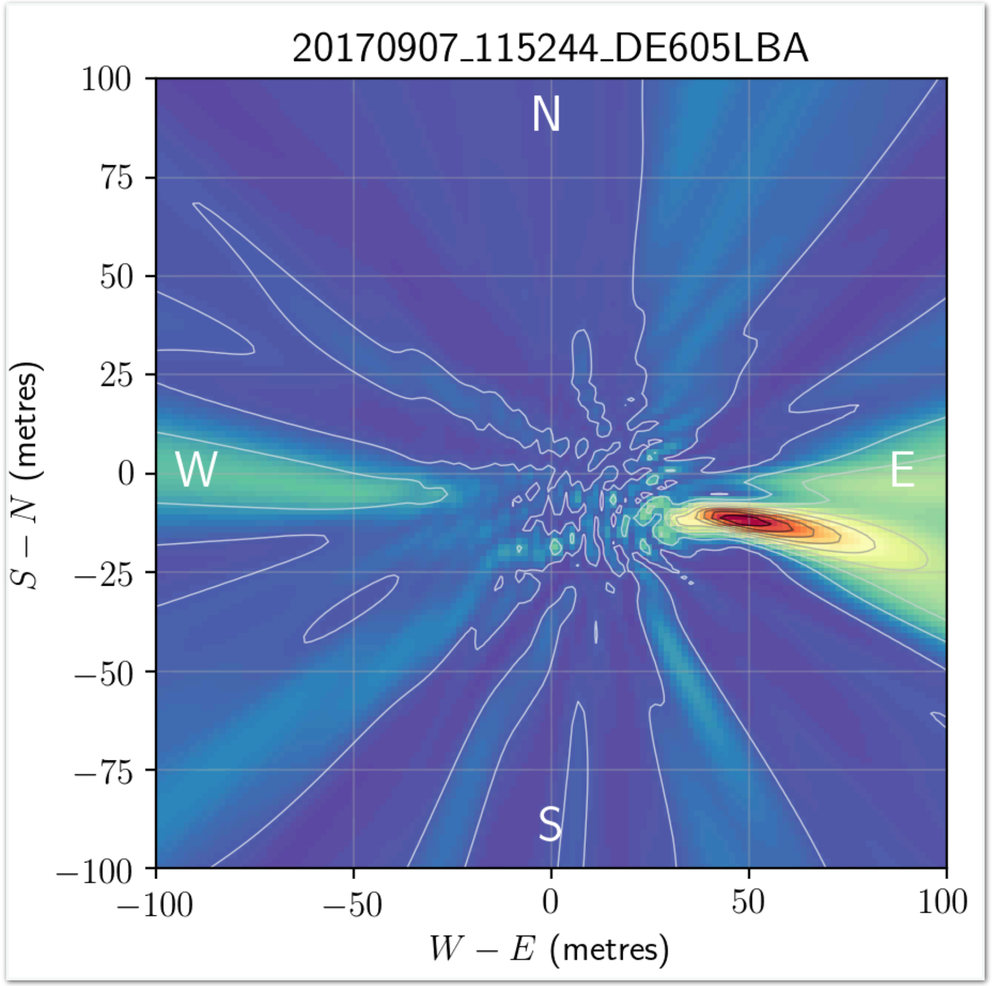
RFI near-field imaging

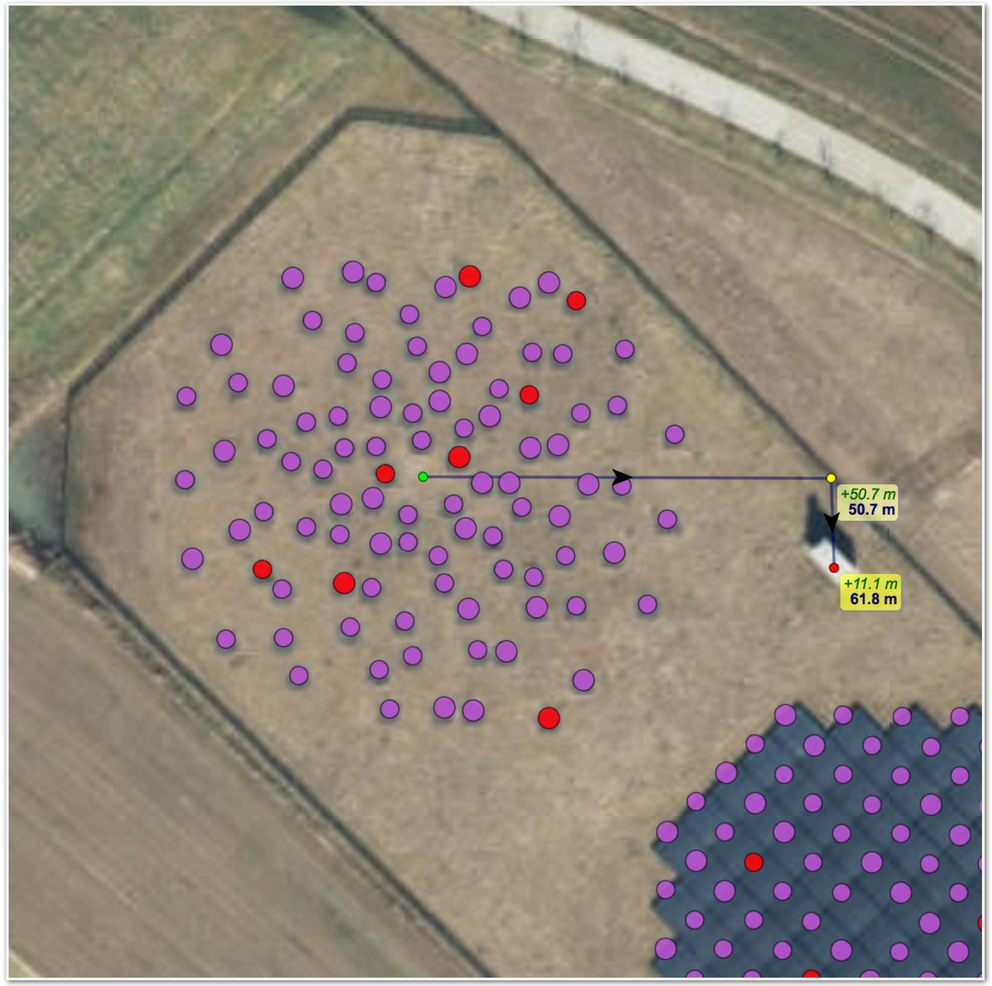
- Began as a tutorial on **quick imaging** of LOFAR data from M. Brentjens
- We record data from an individual station, in the form of the **cross-correlation matrix** and then image this using Python
- From this, it is possible to image **both the sky and the ground plane** - if there is RFI, we can hunt for its location
- Alongside detections of RFI, this method gives us insight into the **environmental overview**



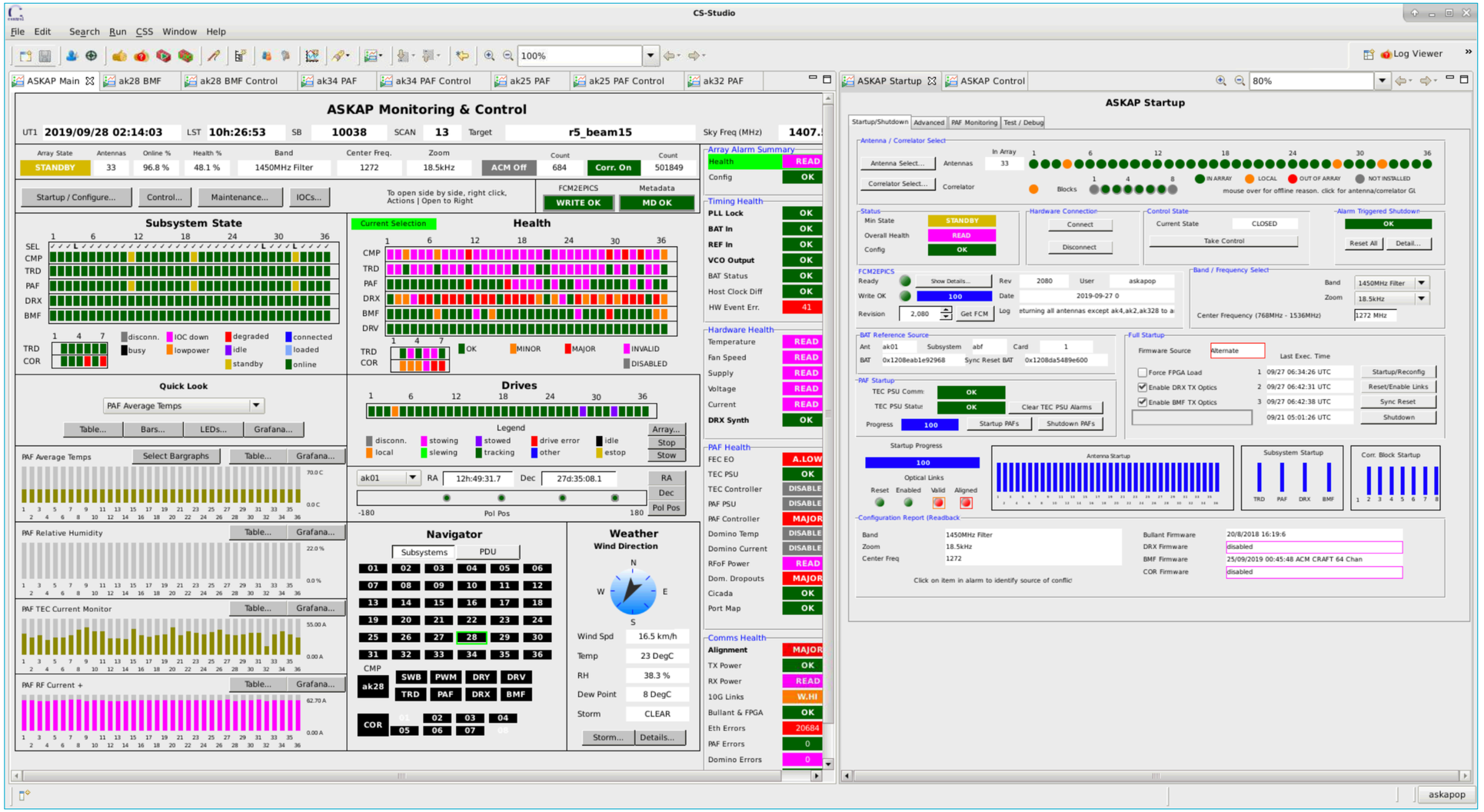


RFI near-field imaging



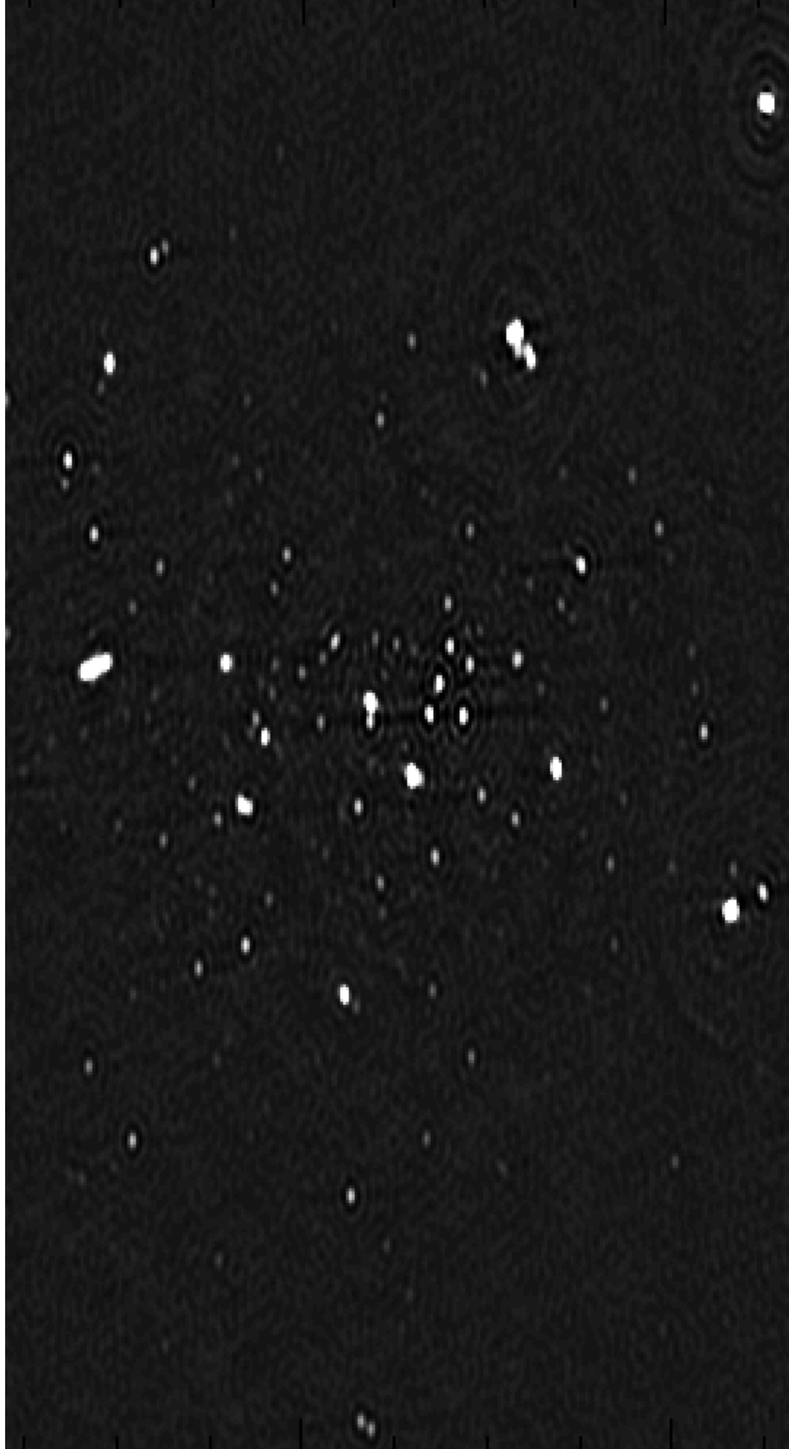


ASKAP CSS


CS-Studio
File Edit Search Run CSS Window Help
ASKAP Main
ak28 BMF
ak28 BMF Control
ak34 PAF
ak34 PAF Control
ak25 PAF
ak25 PAF Control
ak32 PAF
ASKAP Monitoring & Control
UT1 2019/09/28 02:14:03
LST 10h:26:53
SB 10038
SCAN 13
Target r5_beam15
Sky Freq (MHz) 1407.
Array State STANDBY
Antennas 33
Online % 96.8 %
Health % 48.1 %
Band 1450MHz Filter
Center Freq. 1272
Zoom 18.5kHz
ACM Off
Count 684
Corr. On
Count 501849
Startup / Configure...
Control...
Maintenance...
IOCs...
To open side by side, right click, Actions | Open to Right
FCM2EPICS WRITE OK
Metadata MD OK
Subsystem State
SEL
CMP
TRD
PAF
DRX
BMF
TRD
COR
disconn.
busy
IOC down
lowpower
degraded
idle
standby
connected
loaded
online
Current Selection
Health
OK
MINOR
MAJOR
INVALID
DISABLED
Quick Look
PAF Average Temps
Table...
Bars...
LEDs...
Grafana...
Drives
Legend
disconn.
local
stowing
slewing
stowed
tracking
drive error
other
idle
estop
Array...
Stop
Stow
PAF Average Temps
Select Bargraphs
PAF Relative Humidity
PAF TEC Current Monitor
PAF RF Current +
ak01
RA 12h:49:31.7
Dec 27d:35:08.1
RA
Dec
Pol Pos
-180
180
Navigator
Subsystems
PDU
CMP
ak28
SWB
PWM
DRY
DRV
TRD
PAF
DRX
BMF
COR
Weather
Wind Direction
N
W
E
S
Wind Spd 16.5 km/h
Temp 23 DegC
RH 38.3 %
Dew Point 8 DegC
Storm CLEAR
Storm...
Details...
Array Alarm Summary
Health READ
Config OK
Timing Health
PLL Lock OK
BAT In OK
REF In OK
VCO Output OK
BAT Status OK
Host Clock Diff OK
HW Event Err. 41
Hardware Health
Temperature READ
Fan Speed READ
Supply READ
Voltage READ
Current READ
DRX Synth OK
PAF Health
FEC EO A.LOW
TEC PSU OK
TEC Controller DISABLE
PAF PSU DISABLE
PAF Controller MAJOR
Domino Temp DISABLE
Domino Current DISABLE
RFoF Power READ
Dom. Dropouts MAJOR
Cicada OK
Port Map OK
Comms Health
Alignment MAJOR
TX Power OK
RX Power READ
10G Links W.HI
Bullant & FPGA OK
Eth Errors 20684
PAF Errors 0
Domino Errors 0
Log Viewer
ASKAP Startup
ASKAP Control
ASKAP Startup
Startup/Shutdown
Advanced
PAF Monitoring
Test / Debug
Antenna / Correlator Select
Antenna Select...
Correlator Select...
Antennas
Correlator
In Array
Blocks
IN ARRAY
LOCAL
OUT OF ARRAY
NOT INSTALLED
mouse over for offline reason. click for antenna/correlator GI
Status
Min State STANDBY
Overall Health READ
Config OK
Hardware Connection
Connect
Disconnect
Control State
Current State CLOSED
Take Control
Alarm Triggered Shutdown
OK
Reset All
Detail...
FCM2EPICS
Ready
Show Details...
Rev 2080
User askapop
Write OK
100
Date 2019-09-27 0
Revision 2.080
Get FCM
Log
eturning all antennas except ak4,ak2,ak328 to a
Band / Frequency Select
Band 1450MHz Filter
Zoom 18.5kHz
Center Frequency (768MHz - 1536MHz)
1272 MHz
BAT Reference Source
Ant ak01
Subsystem abf
Card 1
BAT 0x1208eab1e92968
Sync Reset BAT 0x1208da5489e600
Full Startup
Firmware Source Alternate
Last Exec. Time
Force FPGA Load 1 09/27 06:34:26 UTC
Enable DRX TX Optics 2 09/27 06:42:31 UTC
Enable BMF TX Optics 3 09/27 06:42:38 UTC
09/21 05:01:26 UTC
Startup/Reconfig
Reset/Enable Links
Sync Reset
Shutdown
PAF Startup
TEC PSU Comm OK
TEC PSU Statu OK
Clear TEC PSU Alarms
Progress 100
Startup PAFs
Shutdown PAFs
Startup Progress
100
Optical Links
Reset
Enabled
Valid
Aligned
Antenna Startup
Subsystem Startup
TRD
PAF
DRX
BMF
Corr. Block Startup
Configuration Report (Readback
Band 1450MHz Filter
Zoom 18.5kHz
Center Freq 1272
Click on item in alarm to identify source of conflic
Bullant Firmware 20/8/2018 16:19:6
DRX Firmware disabled
BMF Firmware 25/09/2019 00:45:48 ACM CRAFT 64 Chan
COR Firmware disabled
askapop

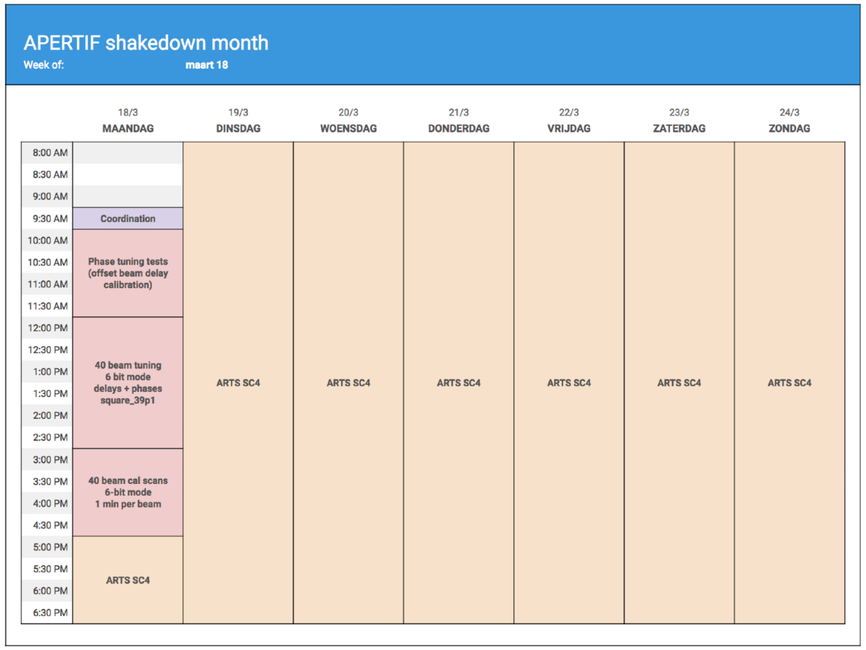
5. Testing

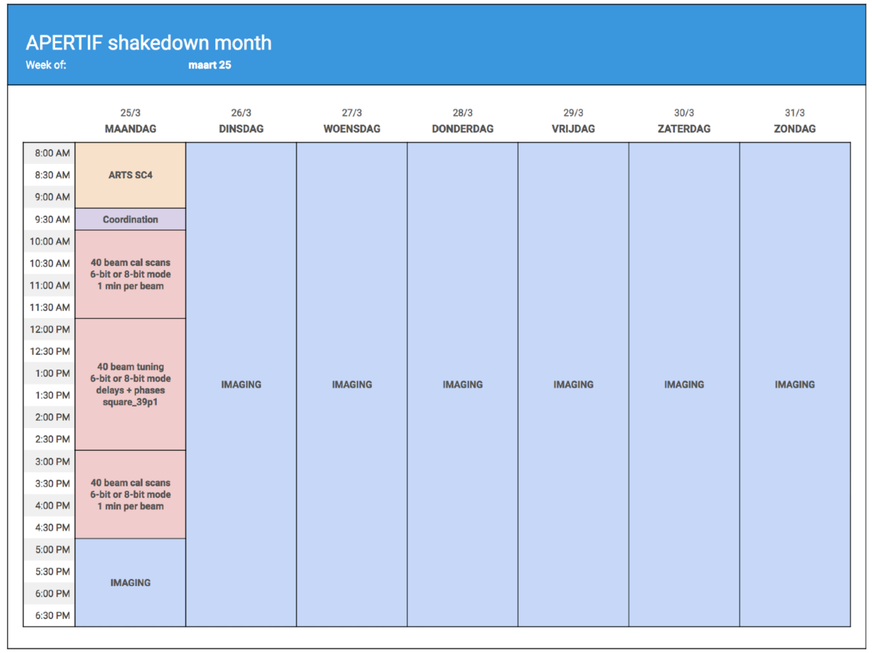
There is no test like an observational test



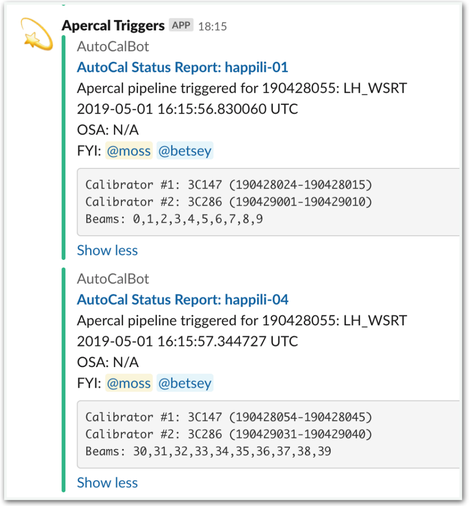
The SVC

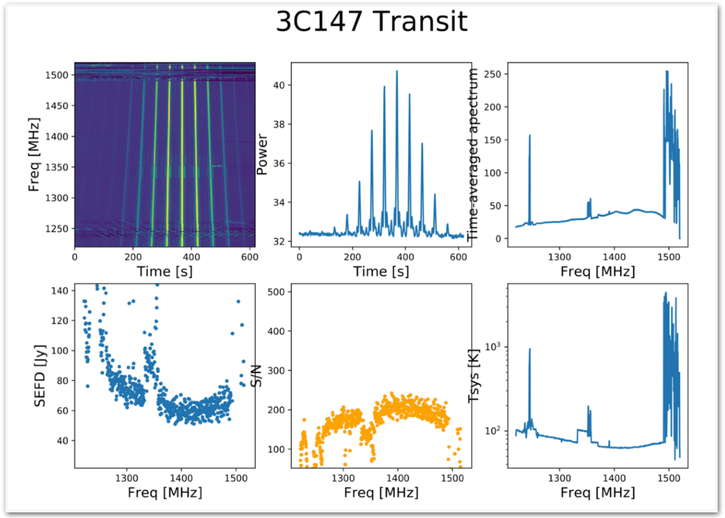
- **SVC:** Science Verification Campaign
- A month-long campaign instigated by the MT to focus specifically on the **data quality** for the imaging and time-domain Apertif surveys
- **All development halted**: observations and calibration only to take place on system
- Imaging and ARTS team then conducted observations in as close to **survey mode** as possible, with data quality to be quantified
- Precursored by 2 operational "**shakedowns**"

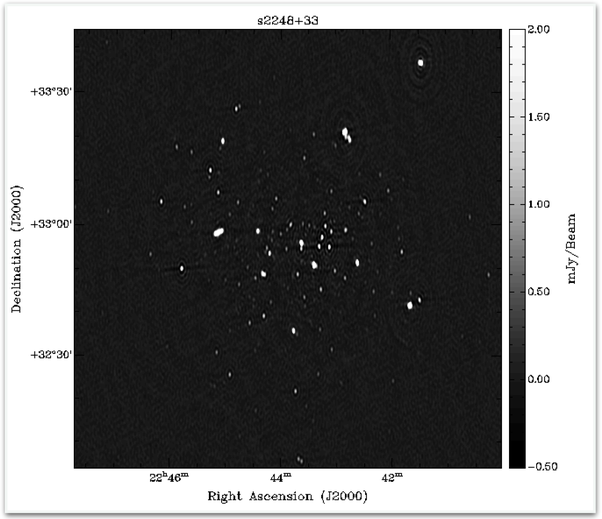


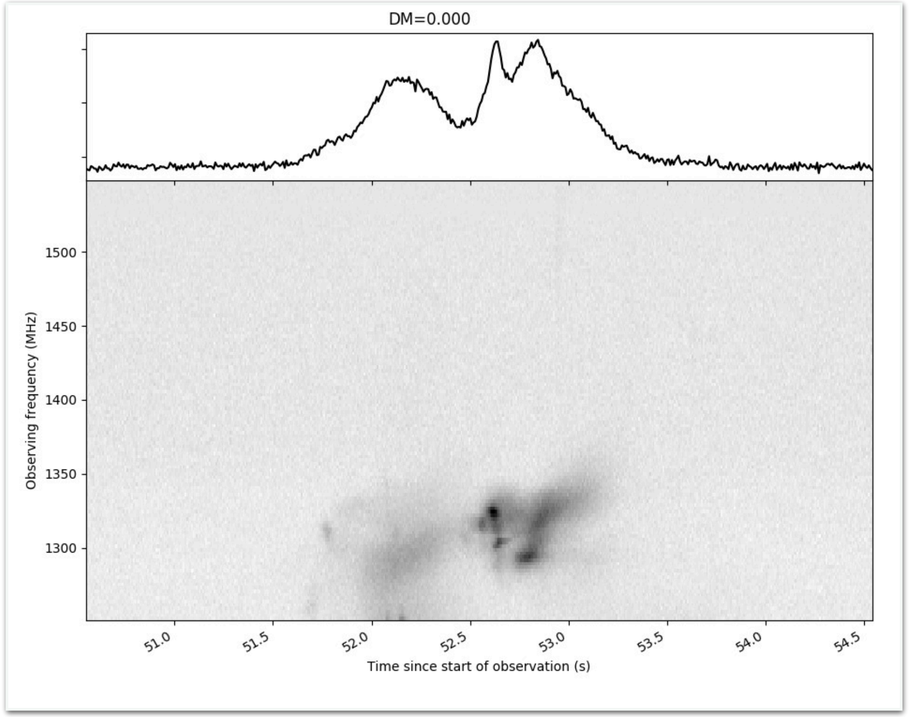


SVC highlights









Images: L. Connor, L.Oostrum, J. van Leeuwen, A. Mika, E. Petroff, V. Moss

ASKAP Pilot Surveys

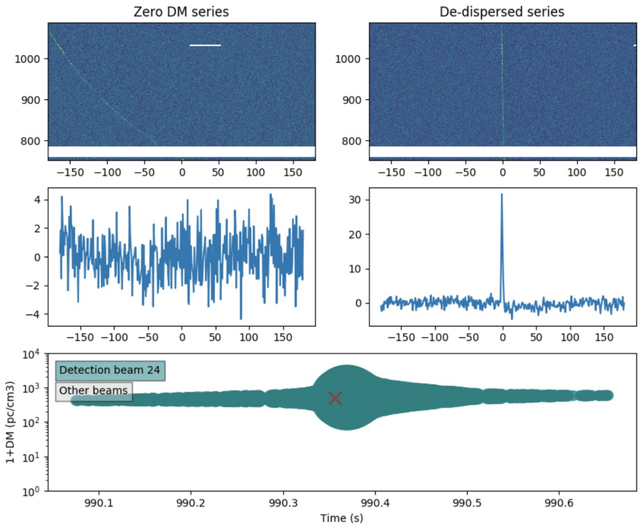
- Pilot Surveys are **100 hr** blocks of time allocated to existing ASKAP SSTs

- The Pilot Surveys have a **number of goals:**
  - Give each SST a **representative** set of data to work with
  - Test full survey strategy on a **subset** of sky
  - Push system to **operational limits** to find pressure points
  - Use Pilot Survey period to inform operations of **full surveys**
  - Assess ASKAP pipeline **processing readiness (P10.22)**

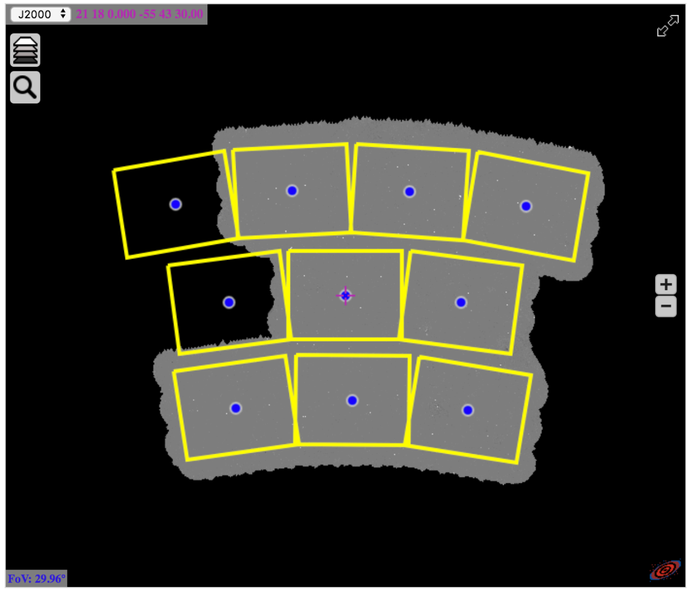
- We started the Pilot Surveys on **15th July 2019**

- EMU, WALLABY (1/3), VAST (1/6), CRAFT (7/10), POSSUM now "**complete**"! More to come…

The Great Radio School
FRB of 2019



EMU 940 MHz Pilot Survey

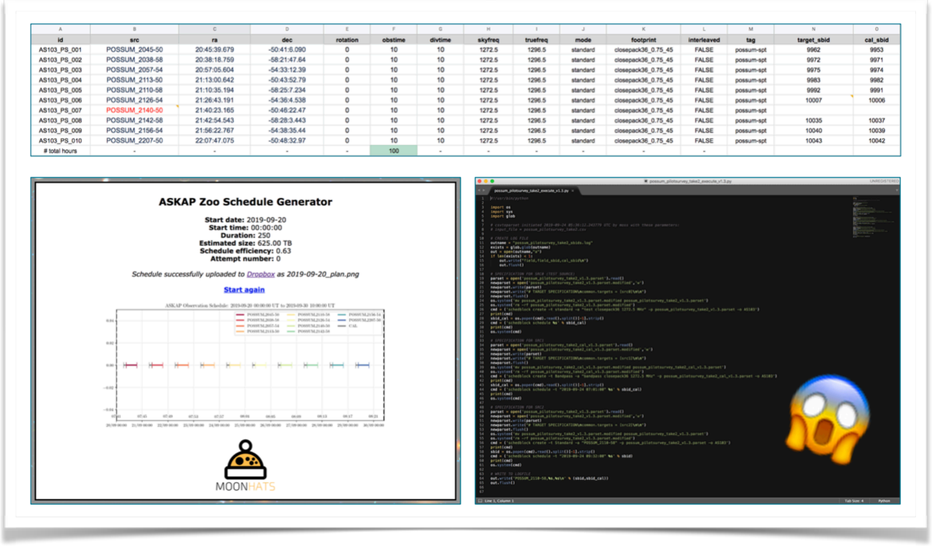


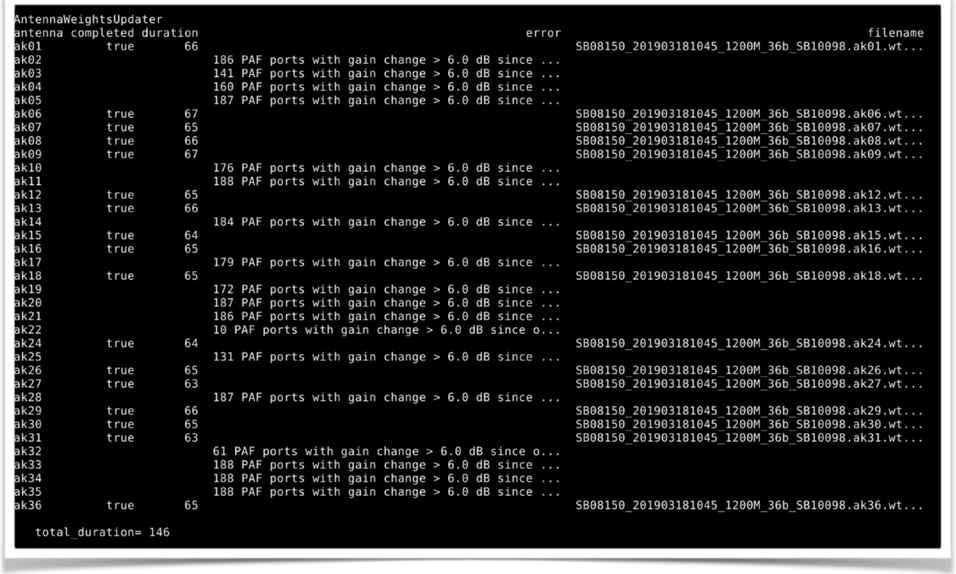
6. The shadowy place

The challenges we continue to face in operations

The shadowy place

- I've focused here on **key themes** that are important for operations, alongside **successes** - but there are significant **challenges** too!
- **Automation** in the scope of a complex system: "hacky" code vs. the "proper solution"
- Distribution of **specialised expert knowledge** to non-experts for operations/diagnostics
- Keeping **communication channels** open
- **Fractional** commitment and its role in the curse of the **95% finished** product or feature





Conclusions

- Astronomy has entered a new era driven by **technology** and larges amounts of **data**
- Radio observatory operations are in the **process** of adapting, but there is more to do!
- **Key:** people, automation, communication, overview, testing and the shadowy place
- We can **learn lots** from other observatories, other science fields and also industry
- Pathfinder telescope experience is **directly relevant** for next-generation facilities e.g. SKA