

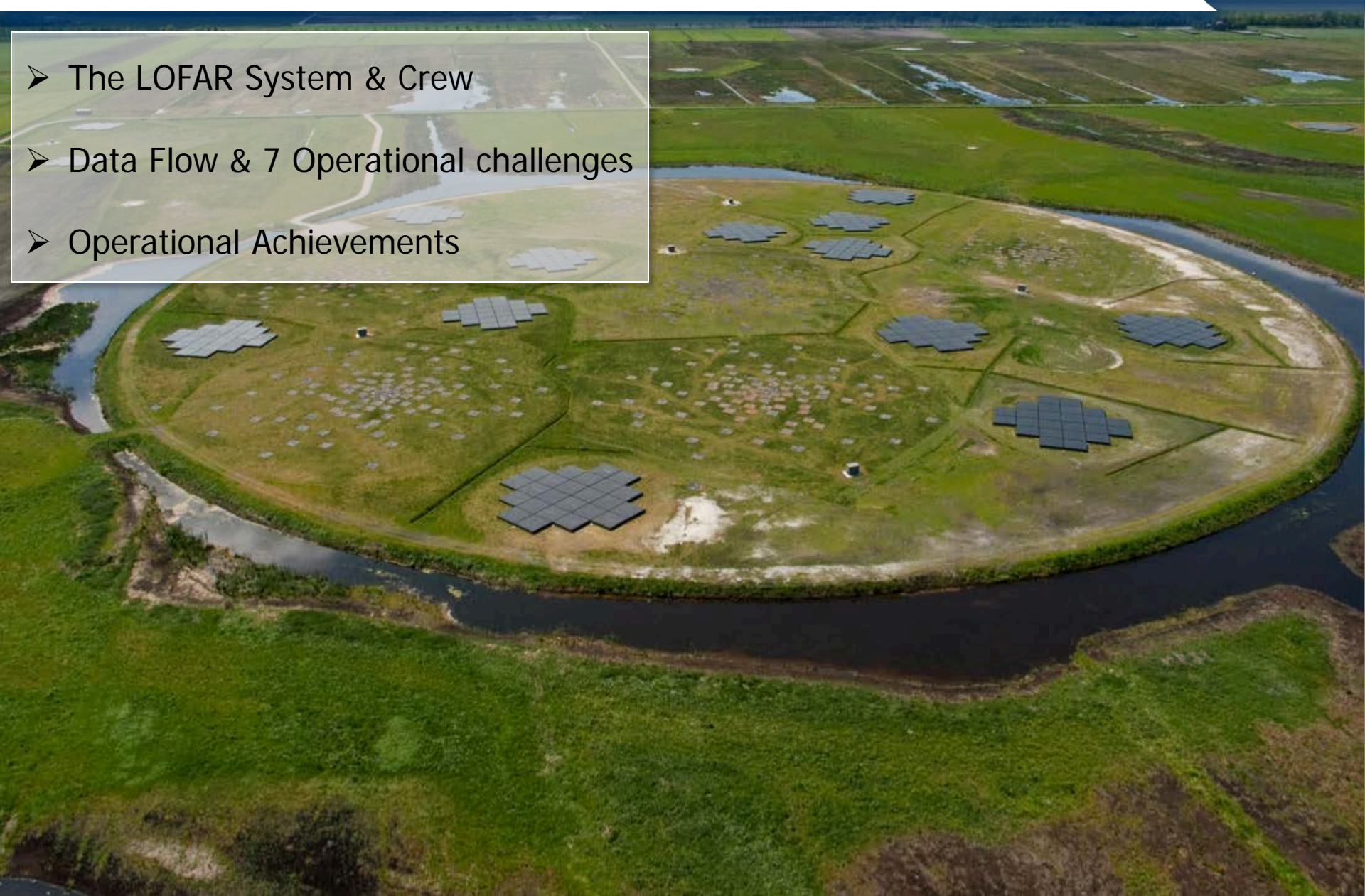
LOFAR OPERATIONAL CHALLENGES

R. F. Pizzo

Head Science Operations & Support –
LOFAR & WSRT/APERTIF



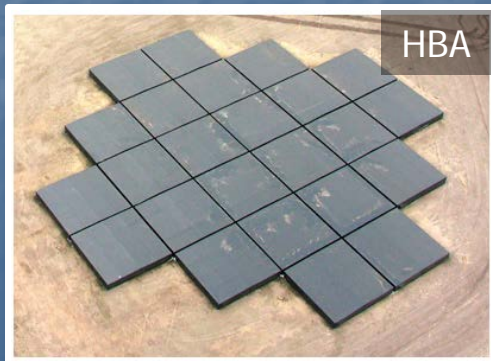
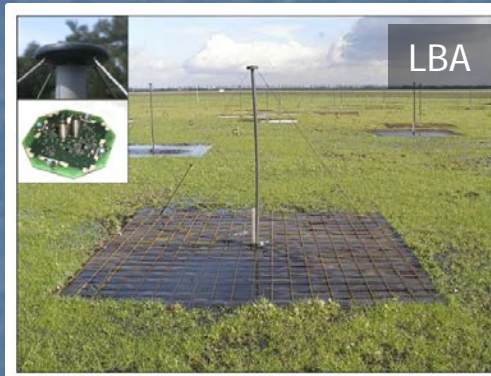
- The LOFAR System & Crew
- Data Flow & 7 Operational challenges
- Operational Achievements



THE LOW FREQUENCY ARRAY – KEY FACTS

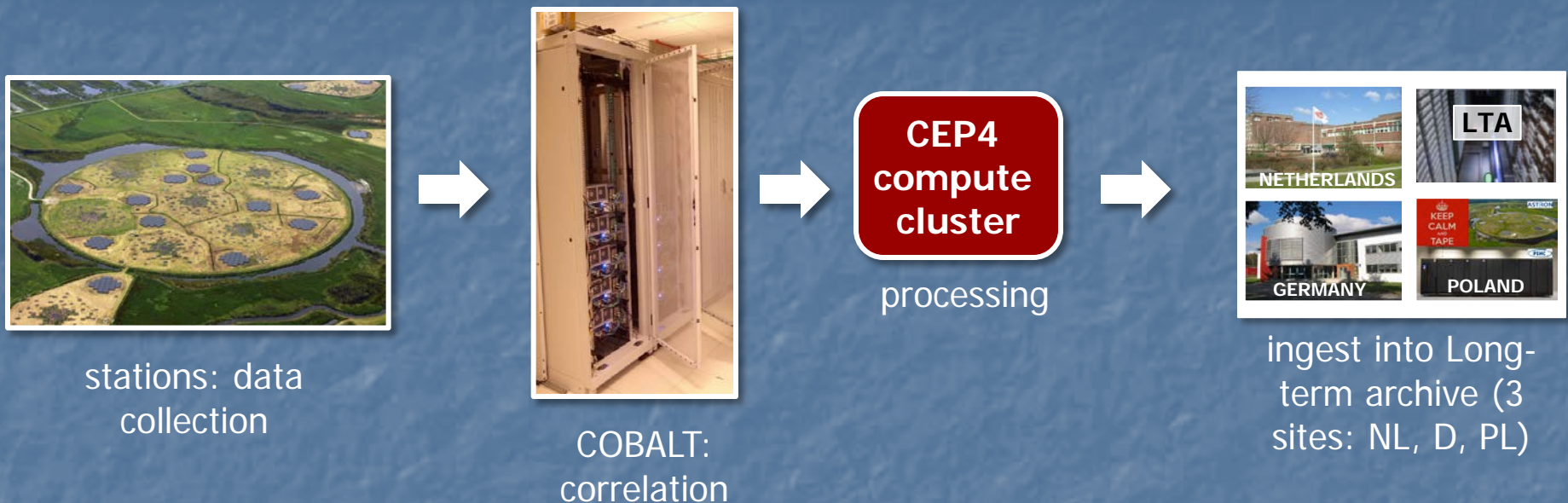


- Array of 50 dipole antenna stations **distributed across EU**
- **10-250 MHz**
- Low band antenna (LBA; 4896 dipole pairs, 96 LBA per station, Area ~ 75200 m²; 10-90 MHz)
- High Band Antenna (HBA; 47616 dipole pairs, 48/96 tiles per station in NL/EU, Area ~ 57000 m²; 110-250 MHz)
- **Several observing modes** (imaging, BF, BF+IM, TBB)
- **96 MHz bandwidth** (multi-beam option)





THE LOFAR SYSTEM: DATA FLOW



➤ **Transport, processing and storage** of large amounts of data :

- Data **flow** from all antennas combined: 1.7 Tbyte/s
- To COBALT from station after beamforming: 28 Gbyte/s
- Correlator output to disk: between 2-10 Gbyte/s
- Data **storage** challenges: ~ **80 TB/h**

➤ LOFAR: **important technological pathfinder for SKA**

THE LOFAR TASK FORCE & COORDINATION



O&M

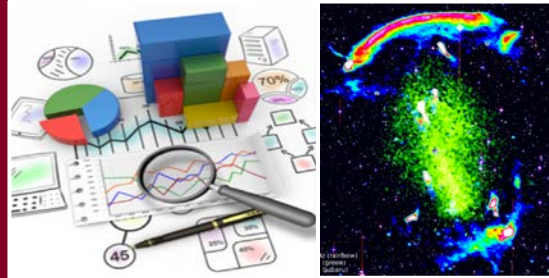
Operations & maintenance



- Hardware maintenance
- System monitoring

SOS

Science Operations & Support



- Link to community
- Data quality assurance
- Commissioning & research

SDOS

Software Development & Operational Support



- Software development
- Maintenance of software and compute clusters

Control Room



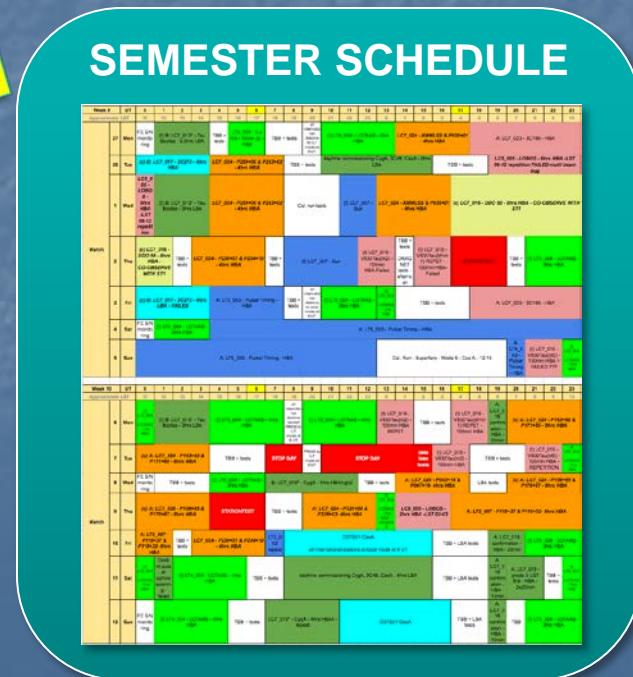
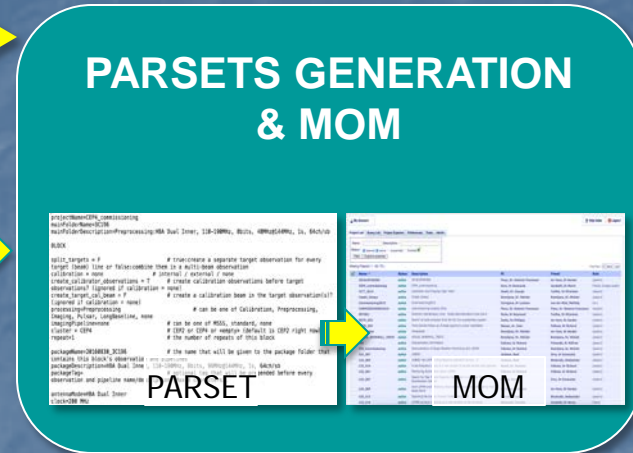
LOFAR Monitoring Systems





- Hardware maintenance
- Wet and corrosive environment
- Challenging to maintain a distributed system
- Monitoring software returns info on element status -> disabling -> maintenance -> re-enabling
- Design of a maintainable/accessible system is important
- Automation hardware status data management

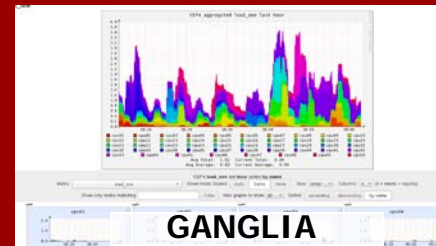
II: OBSERVING/PROCESSING SPECIFICATION



- Specification process reflects **instrument complexity**
- Roughly 1/3 time investment by SOS
- Essential to rely on **automatic** tools – new specification tool in progress
- **Next generation specification tools** under development (2018)

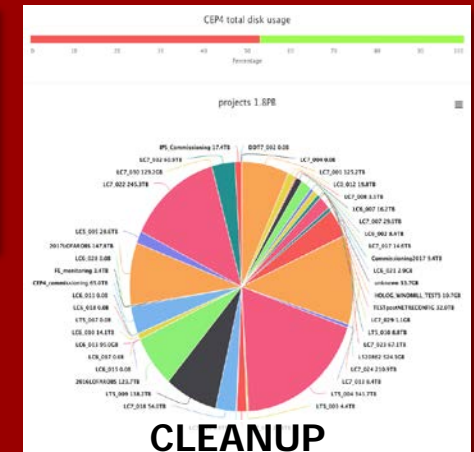


CEP4 - PROCESSING



GANGLIA

➤ CPU/network/memory/
SLURM/...



CLEANUP

**SCHEDULING:
RESOURCE ASSIGNER**

- Keeping steady data flow – per Cycle: 3.5 PB products + 20 PB raw data
- Scheduling on **available resources**
- Pipeline queue handled **automatically**: SLURM
- Data cleanup after ingest
- **Manual ingest** after data quality assessment



AMSTERDAM



LTA



JULICH



POZNAN

IV - DATA QUALITY ASSESSMENT

L560175

• Projects

[Cobalt ERROR log](#)

Max file sizes (MB):

Correlated data : 3451

Beamformed data : 0

All data sets are there

Input loss report

CS004HBA0: 0.0287%

CS004HBA1: 0.0027%

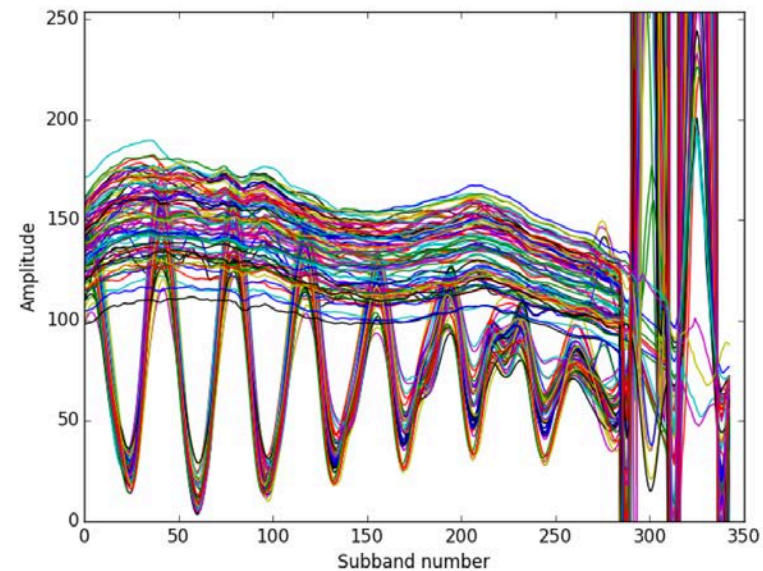
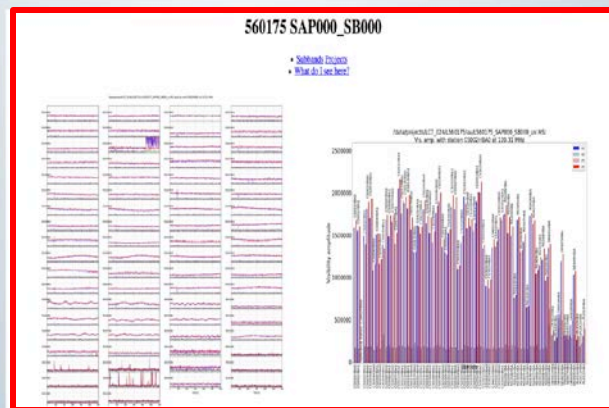
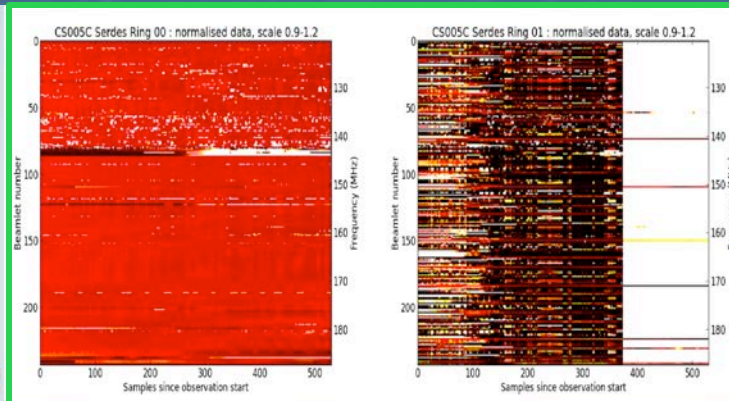
CS103HBA1: 0.0295%

RS508HBA: 0.8322%

DE603HBA: 6.0078%

[Station Dynamic Spectra](#)

Name	Subband	Freq.
(ID)	(MHz)	
SAP000_SB000	104	120.312
SAP000_SB001	105	120.508
SAP000_SB002	106	120.703
SAP000_SB003	107	120.898
SAP000_SB004	108	121.094
SAP000_SB005	109	121.289
SAP000_SB006	110	121.484
SAP000_SB007	111	121.680



SYSTEM NOTES

View Edit Revisions Translate

This web page lists the issues found in the system that might have affected the analysis of LOFAR data during the production Cycles. Each issue and its fix are discussed in the related subpage.

1. Wrong information in antenna tables of LOFAR Measurement Sets
2. Incorrect values in the WEIGHT SPECTRUM column of interferometric COBALT data
3. Incorrect information about broken cables and antenna elements in LOFAR Measurement Sets (March 2015)
4. Polarization leakage in beam formed data
5. Issue in Skymodels created with PyBDSM
6. Correction to the Station Address in the Long-Baseline pipeline
7. LOFAR Measurement Sets structure not conform with CASA standards
8. Wrong Imaging pipeline settings
9. Inaccurate flagging of LBA
10. Station sensitivity issue
11. Delay compensation issue
12. Faulty LBA calibration tables
13. COBALT geographical delays offset

- Inspection plots: > 6000 generated per observation
- Visual inspection - time intensive exercise
- Next generation inspection plots based on AI intelligence being worked on (2018)

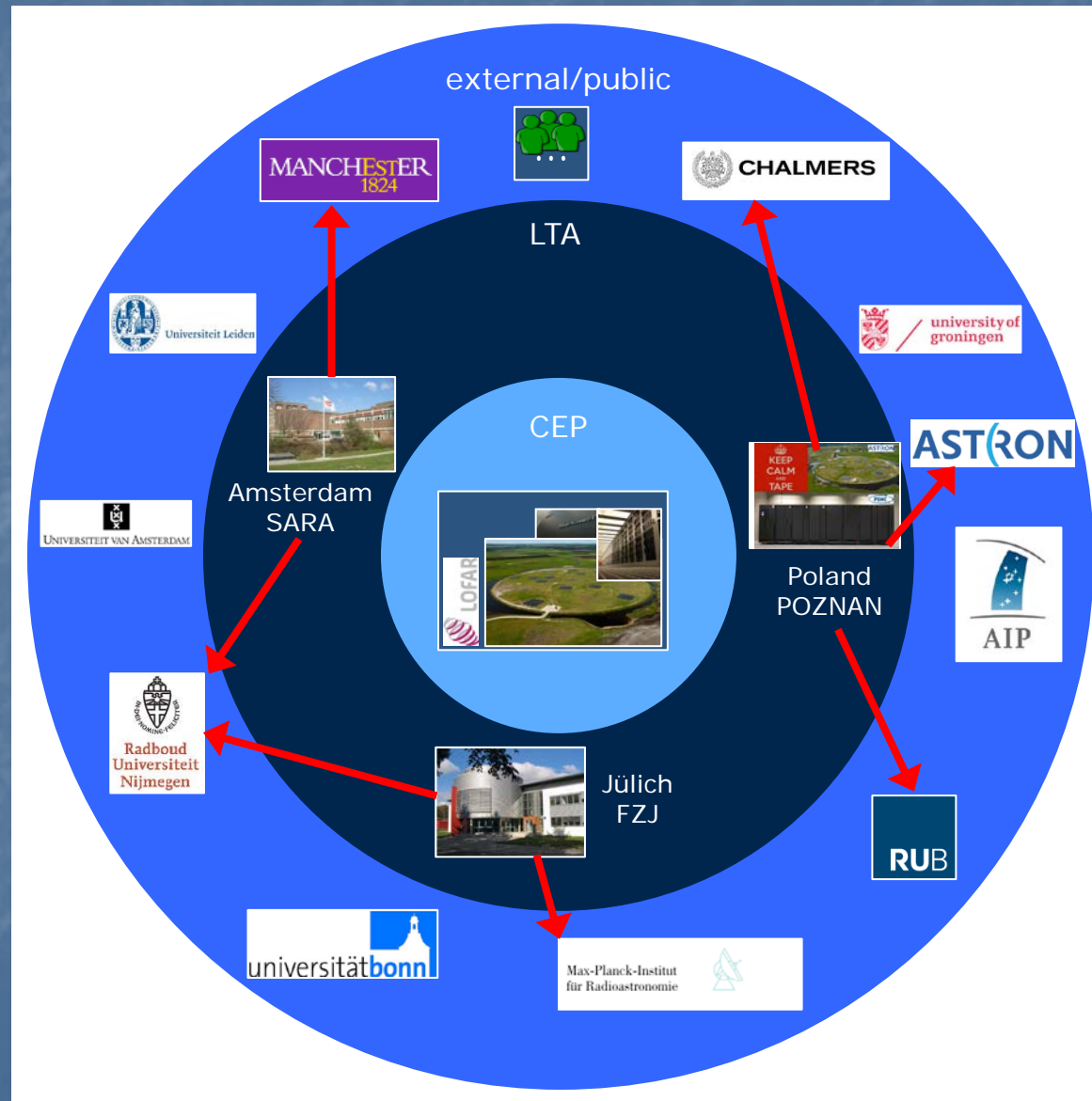


LOFAR

V - DATA SHARING

ASTRON

- **Scientific exploitation** -> data retrieval to external clusters
 - Download limited by **instability** and shared **resources**
 - **LOFAR software distribution** -> support needed
- **Moving large amount of data: impractical**
 - Exploiting processing resources at the LTA (2018)



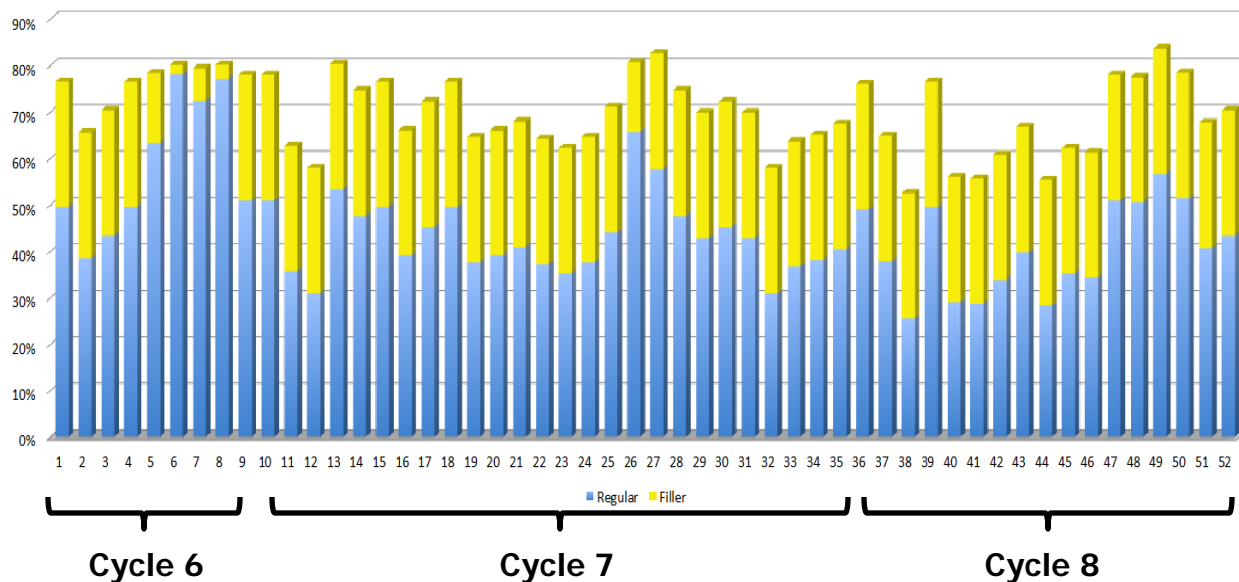


LOFAR

VI: OBSERVING EFFICIENCY

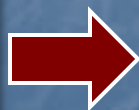
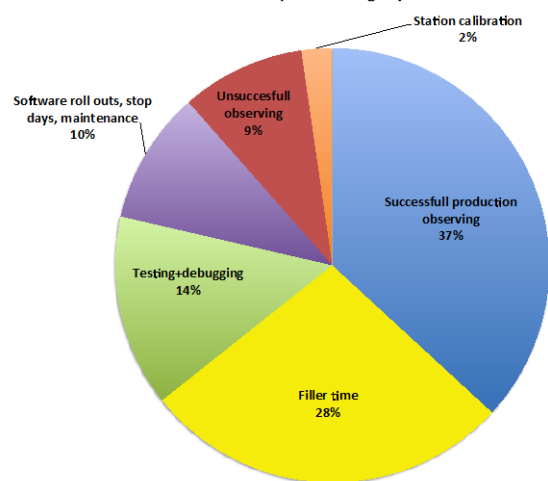
ASTRON

LOFAR Observing Efficiency Sep 2016 - Sep 2017

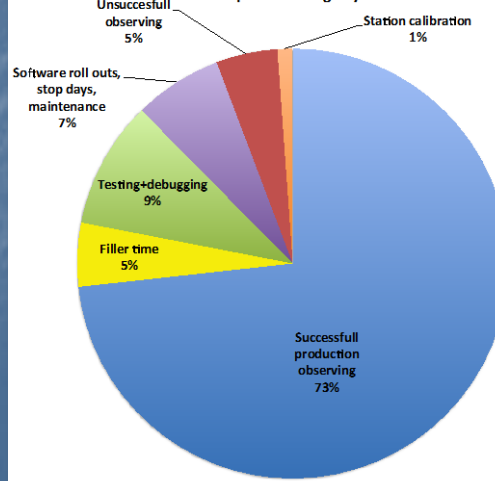


- LOFAR: **instrument on the move** – introducing new functionality -> **instability**
- Larger and more uniform efficiency requires **automation, robustness, and flexibility**
- Lesson learned: **good foundations are essential**
- **Efficiency project** is the answer (starts now)

Telescope Time Usage Cycle 5



Telescope Time Usage Cycle 13



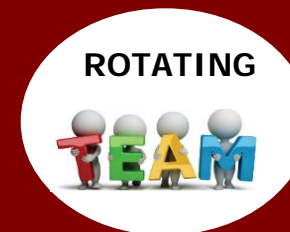
VII: CONTINUITY & CAREERS IN SOS



- Complex system demands **expertise & continuity**
- Expertise needs **career perspectives**



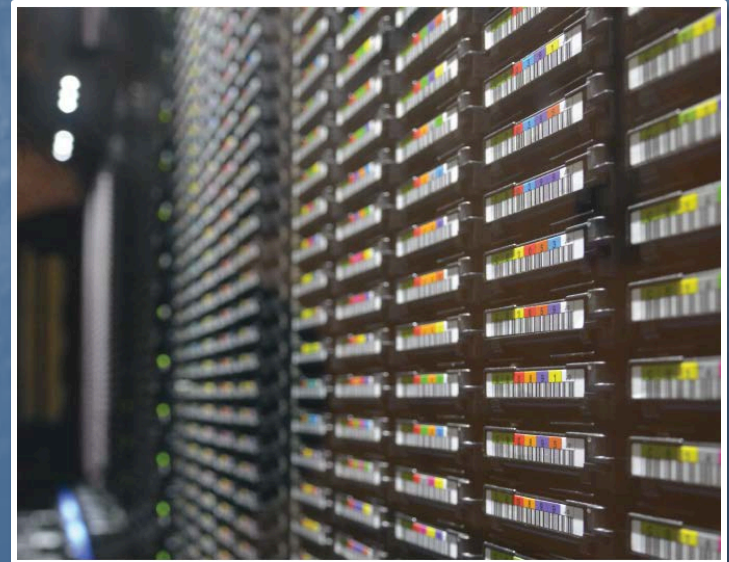
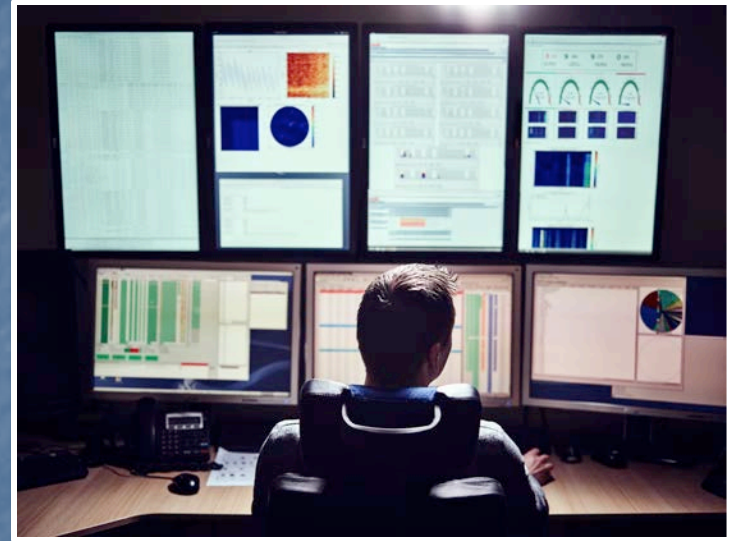
- '**Core team**' – permanent – balance: 2/3 support – 1/3 science research
- '**Rotating** component' – temporary – balance: 50%-50%
- **Trainees** (1-2 per year; share built up knowledge)



TRAINEESHIP IN SCIENCE OPERATIONS



- **Share knowledge & experience** in operating a massive aperture array
- 12 weeks
- Full immersion into the system
- **Direct involvement in operations**
- **Contact: pizzo@astron.nl**



OPERATIONAL ACHIEVEMENTS

- 8 operational Cycles completed:
15000+ hours observed
- LTA: **31 PB** - Largest astronomical data collection to date.
- Community growing in size: **550+ users**
 - LOFAR Schools (200+ participants)
 - 60 Busy Weeks

Current Radio Astronomy Archives

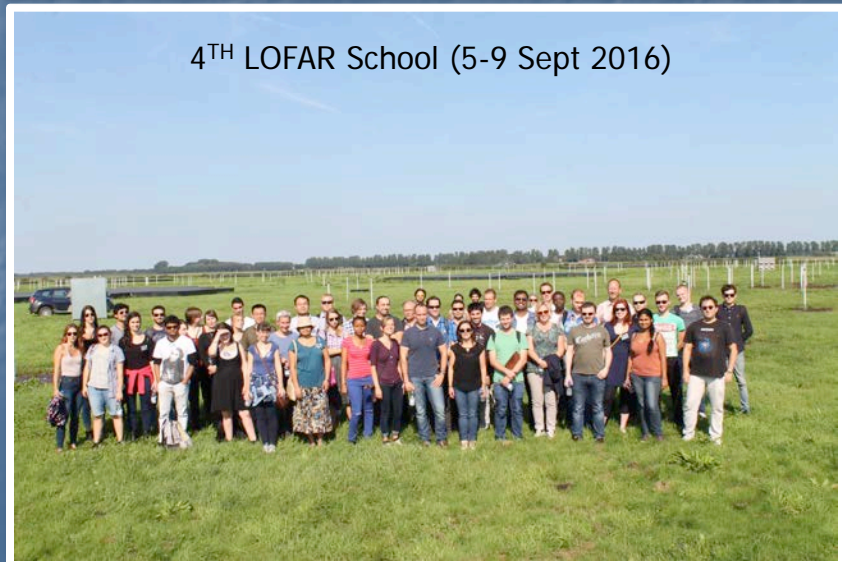
 **LOFAR**
Long Term Archive

31PB

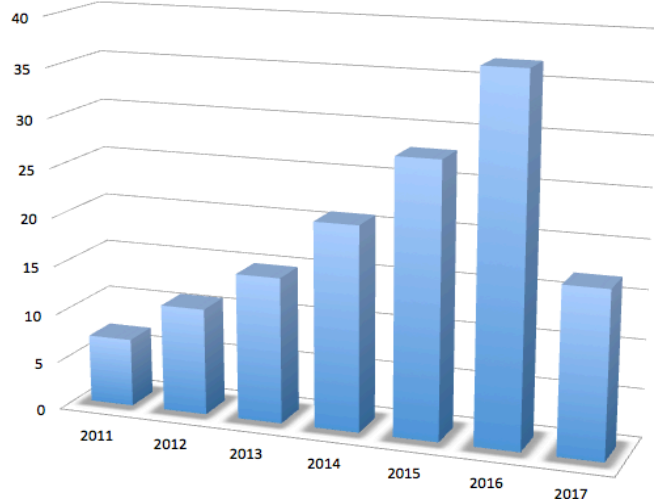


1 Petabyte (PB)

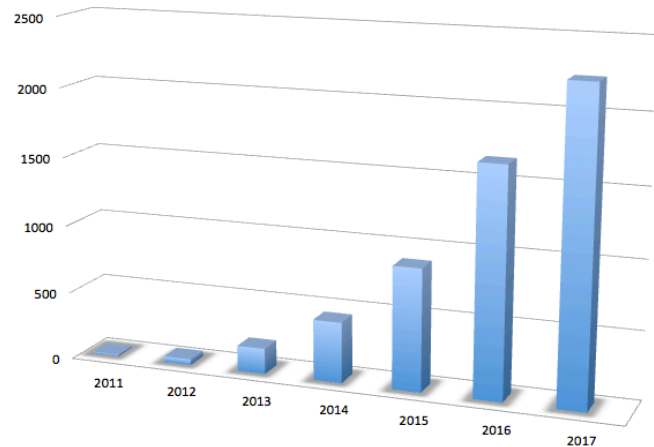
4TH LOFAR School (5-9 Sept 2016)



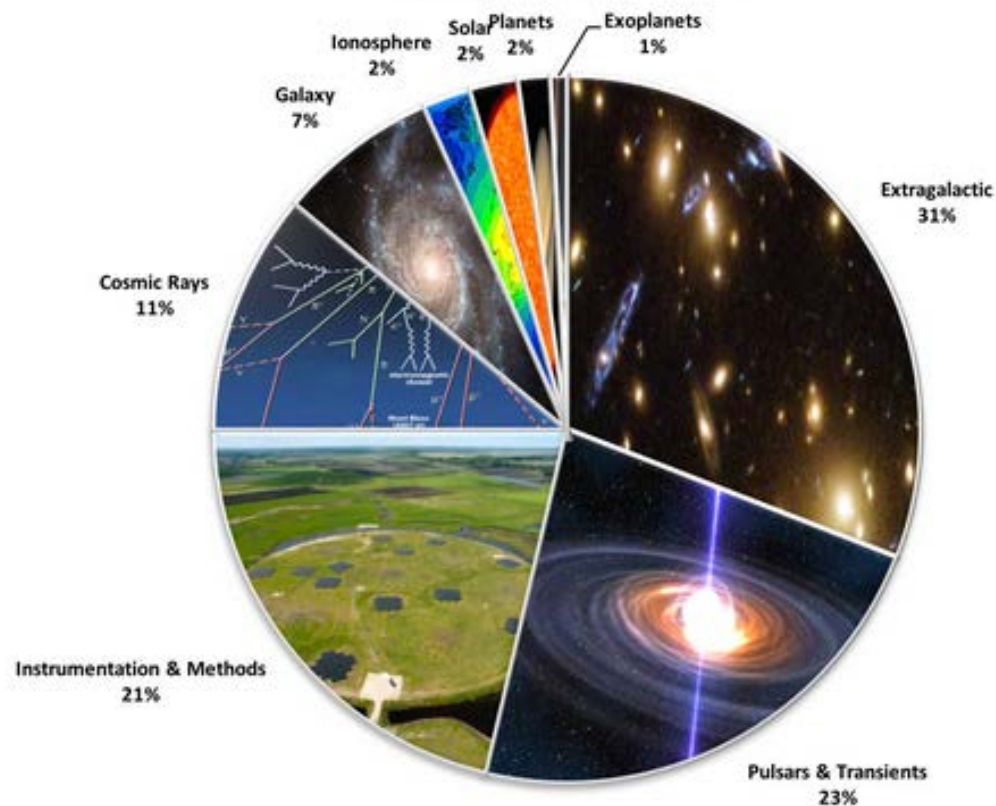
Number of refereed LOFAR papers per year until Oct 2017



Cumulative number of citations



Papers per Science Area



- 136 refereed papers
- 98 unique first authors
- 590 unique authors

CONCLUSIONS

- LOFAR is a very **complex system** – important **technological pathfinder** for SKA
- System complexity has important **operational challenges** attached
 - Hardware **maintenance**
 - Observing/pipeline **specification**
 - **Resource** management
 - **Data quality** inspection
 - **Data sharing**
 - **Efficiency**
 - **Continuity & careers**
- We have challenges in control and we are **rapidly advancing** our **procedures**
- LOFAR is opening up a new window on the Universe



