LOFAR: CHALLENGES AND SOLUTIONS TO OPERATE THE WORLD'S LARGEST RADIO TELESCOPE

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THE LOW FREQUENCY ARRAY – KEY FACTS



- Array of 52 dipole antenna stations distributed across EU (~2000 km baseline)
- Soon station also in Italy (2022)
- ▶ 10-250 MHz
- Low band antenna (LBA; 4800 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 96 MHz bandwidth (multi-beam option)
- \blacktriangleright 7 years of operations > 40000 hours of science delivered



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 next-gen facilities and data intensive astronomy

HARDWARE HEALTH

- Quality of the antennas severely reduced by mechanical and electronic problems -> hardware maintenance
- Station tests data spread across the system -> Maintenance Management Information System (MMIS)
- Station monitor: database with middleware to ingest and provide access to data through a REST API and a web user interface
- Challenge: present all data points from hundreds of station components in a comprehensive way
- Further evolution: <u>automatic</u> enabling/disabling of elements

See poster by M. Mancini (P8.5)



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SCHEDULING: RESOURCE ASSIGNER

- > Challenge: Keep steady data flow per Cycle: 7 PB products + ~50 PB raw data
- Scheduling on available resources
- > Pipeline queue handled <u>automatically</u>: SLURM
- > <u>Automatic</u> data cleanup after ingest
- > Manual ingest after data quality assessment

DATA QUALITY ASSESSMENT

- 6000+ validation plots automatically generated -> visual inspection prohibitive
- Next generation inspection plots based on AI are being tested
- > Dynamic spectrum plots presented to the user grouped per cluster
- On going research
- Goal: <u>automatic</u> observation reports

See poster by A.J. Boonstra (P3.5)

Collaboration with

Science center





DELIVERING SCIENCE-READY DATA

Challenge: deliver <u>automatically</u> high level data products ready for scientific exploitation -> make LOFAR accessible to an even wider community

> Method:

- Implement in production advanced reduction pipelines
- > Scientific exploitation of data *in loco*





See session 10 tomorrow: A. Mechev & A. Offringa

DELIVERING SCIENCE-READY DATA

- Concerted efforts of active project
 - SDF: contact: R. Pizzo
 - > EOSC: contact: H. Holties
 - > ESCAPE contact: Z. Meyer, Y. Grange
- Robust imaging on demand by Q1 2020
- 1. Select a pipeline workflow language
- Develop and maintain a pipeline management tool + web interface for execution (see talk by A. Mechev tomorrow)
- 3. Generate an advanced data product archive



Courtesy of H. Holties

CONCLUSIONS

LOFAR is a very complex system – important technological pathfinder for SKA

System complexity has important operational challenges attached

Hardware maintenance

Resource management

- Data quality inspection
- Delivering science-ready data

> We have challenges under control and we are rapidly advancing our procedures

> LOFAR is opening up a new window on the Universe