LOFAR – A NEW MAP OF THE SKY

JSC'S END-OF-YEAR COLLOQUIUM 2023 | CRISTINA MANZANO AND DR. ARPAD MISKOLCZI

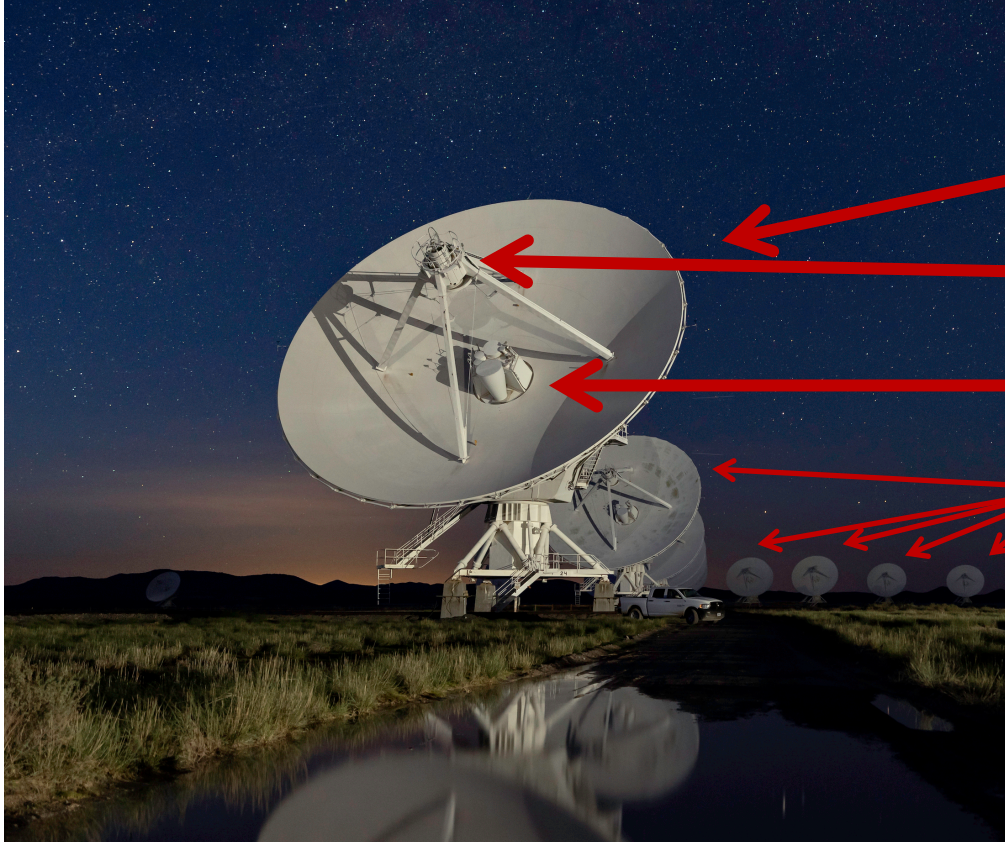# CONTENTS

~~All~~ Some things LOFAR

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THE ~~LOFAR~~ TELESCOPE

Regular radio telescope

- Large dish

- Secondary reflector

- Receiver

- Multiple antennas in an array

Karl G. Jansky Very Large Array
Credit: Jeff Hellerman, NRAO/AUI/NSF

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THE LOFAR TELESCOPE

Huh?

- No dish

- No moving parts

- Flat squares

- Small antennas

Single antennas. M. Jahn, RUB

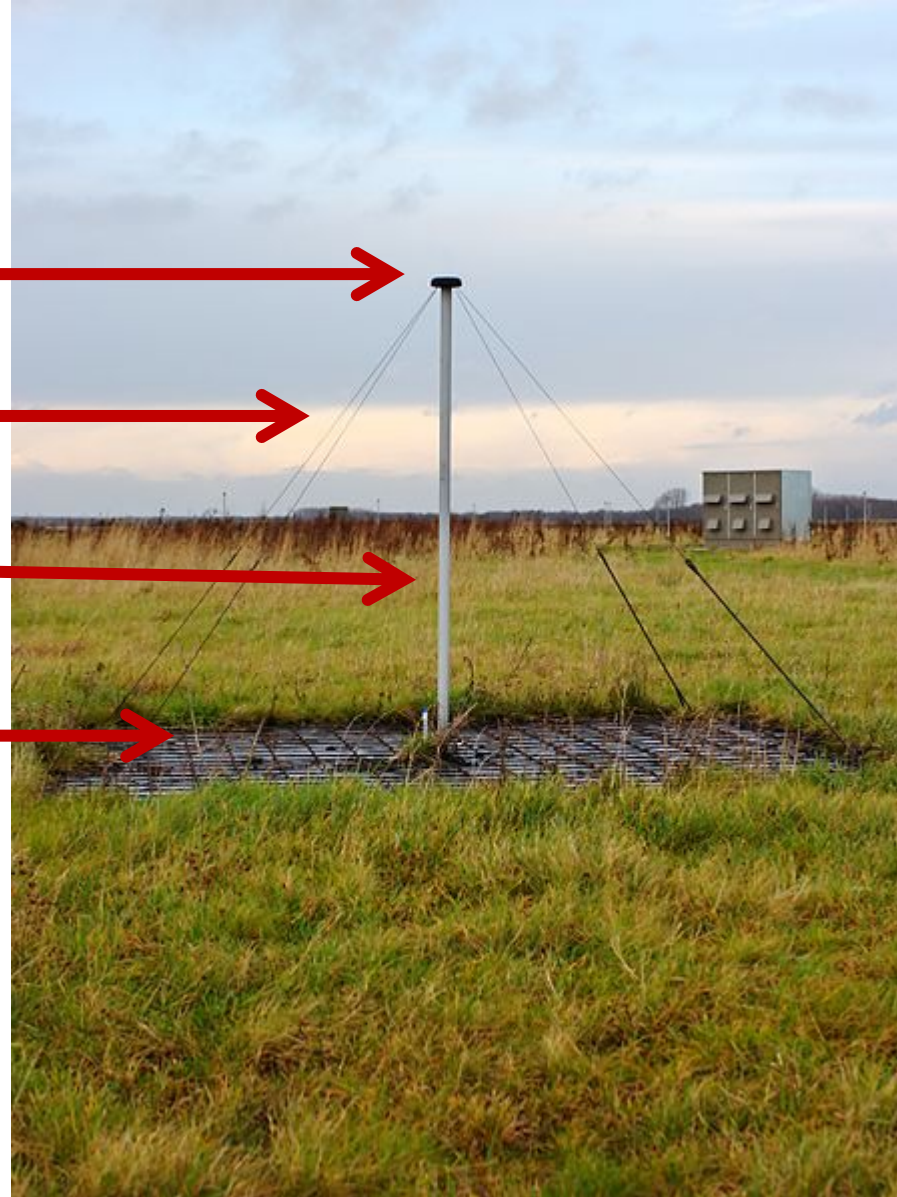High Bandwidth Antenna (HBA)
110 - 240 MHz

Low Bandwidth Antenna (LBA)
10 - 80 MHz

LOFAR station at FZJ

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THE LOFAR TELESCOPE

Poles

- Receiver
- Wires
- Pole
- Reflector

Single antenna. A. R. Offringa

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THE LOFAR TELESCOPE

HBA and LBA each have 96 single antennas

384 cables converge in a container where the signals is processed

➡ HBA / LBA each work as one single antenna

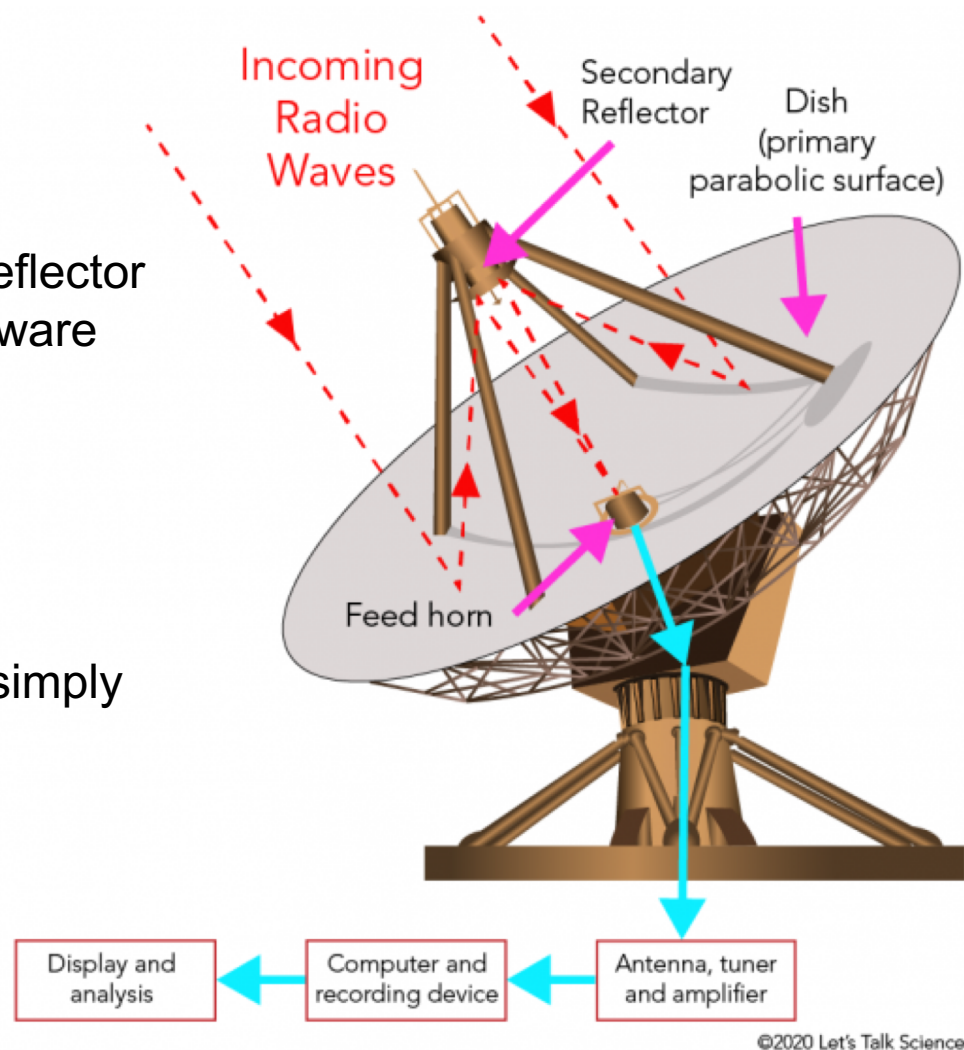Container in which all cables converge. ©Daniel Fischer

THE LOFAR TELESCOPE

But... How?

Regular radio telescope
- Focuses radio waves onto secondary reflector
- Signal is reflected to the receiving hardware

To observe another target, the dish is simply turned into the desired direction

THE LOFAR TELESCOPE
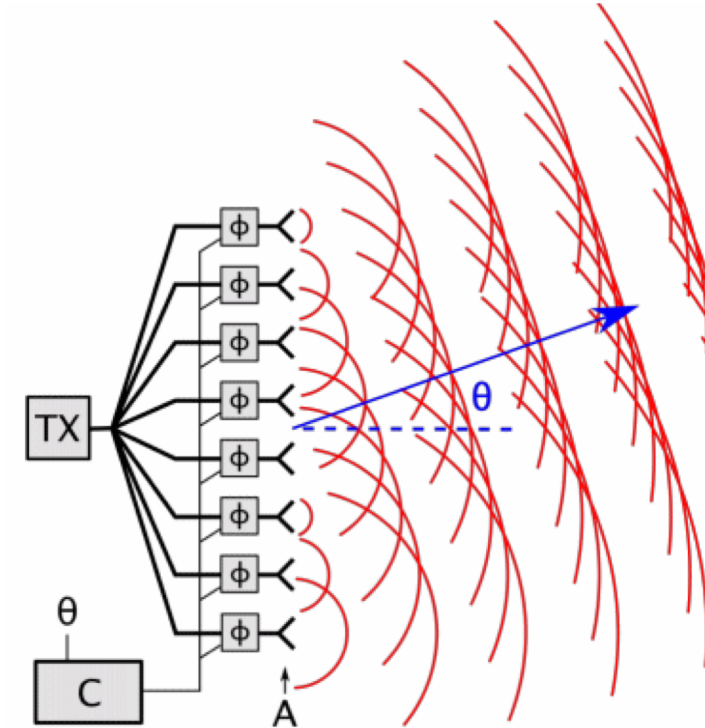
But... How?   - Like the radar in modern jets!

CAPTOR-E active phased-array radar in the nose of a Eurofighter Typhoon

Phased Array Telescope
- Time delay while receiving
- Sensitivity to only particular direction
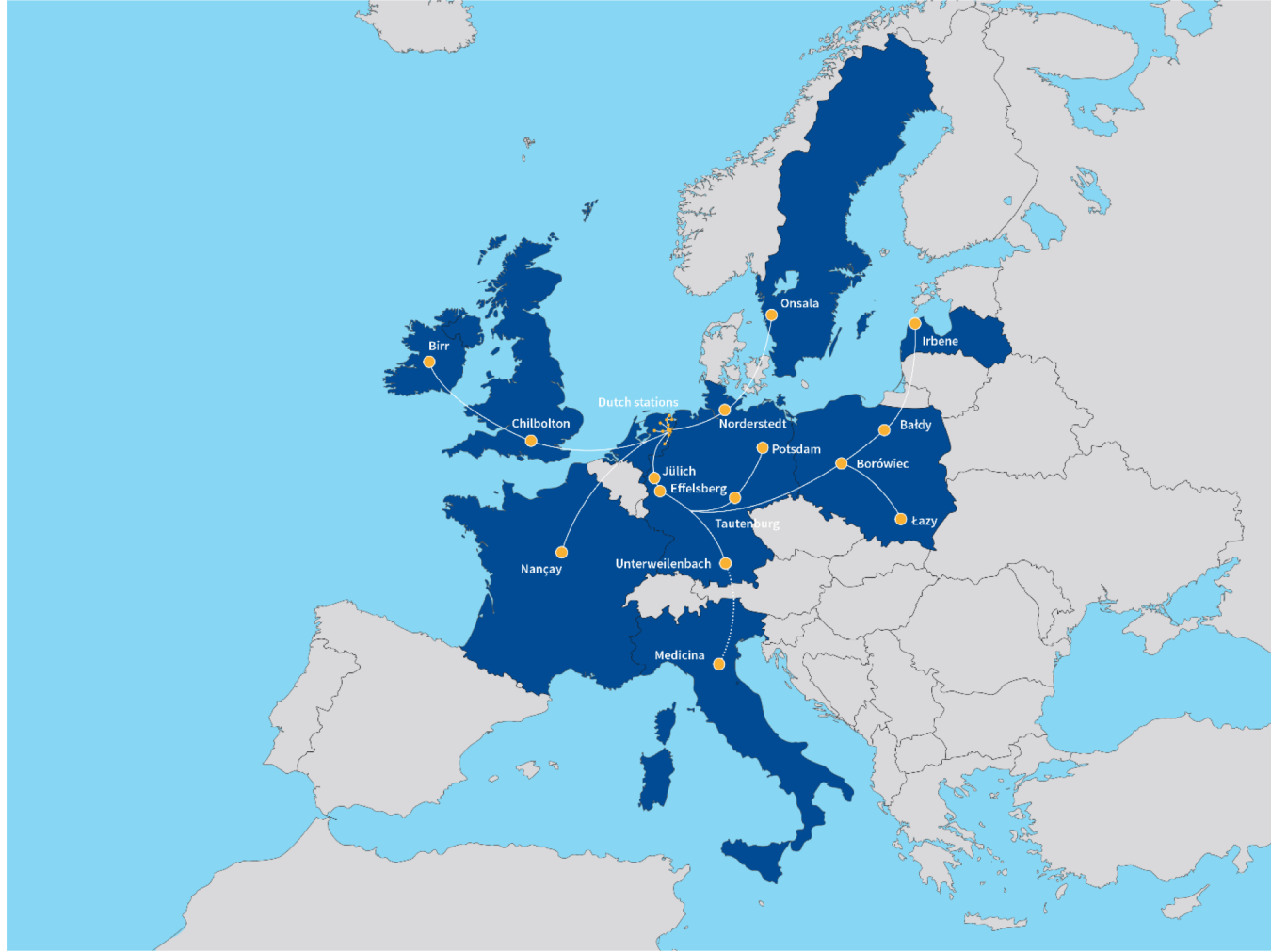- Multiple targets at the same time with fast hardware

Phased Array emitter

Phased array diagram, Wikipedia

- Small time delay leads to superposition of waves
- Superposition defines emitting direction

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LOFAR STATIONS IN EUROPE

Effelsberg © Foto: Peter Sondermann, VisKom/City-Luftbilder

Superterp | Source: https://www.astron.nl/telescopes/lofar/

Tautenburg © Foto: M. Hoeft

Source: https://www.astron.nl/telescopes/lofar/

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LOFAR NETWORK – JÜLICH PERSPECTIVE

GPU-Cluster

LTA

Dwingeloo/Groningen

Surfnet/Netherlight DWDM-connection

2 x 10GE provided by Surfnet

FZJ-JSC - Surfnet Peering at Aachen

~45 Km Fibre DWDM-connection, 2 x 10GE, owned and run by FZJ-JSC

FZJ-JSC

Juwels

JuNet

Jureca-DC

Tape-Storage

100GE

10 LTA-Server
7 x 100GE
3 x 10GE

GLOW-/Meerkat-Cluster

Juelich Antenna Field

X-Win / Internet

LTA Access via Public Internet and D-Cache authentication/ protocols

Antenna Fields (observations (international- and GLOW-mode) and inband access to Juelich LTA)

DFN

Hamburg/Norderstedt
Bonn/Effelsberg
Garching/Unterweilenbach
Tautenburg
Potsdam

LOFAR/GLOW-network designed, operated and monitored by JSC (Olaf Mextorf)
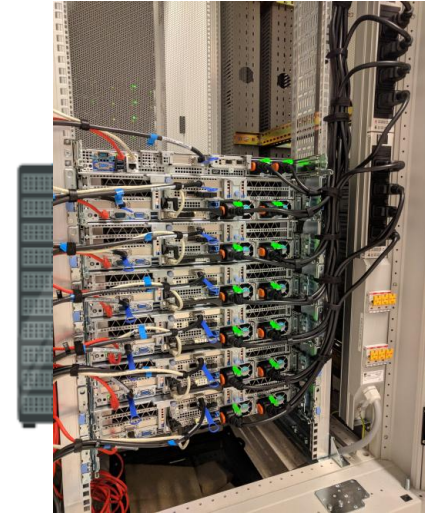
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LOFAR SIGNAL PATH

LOFAR Station
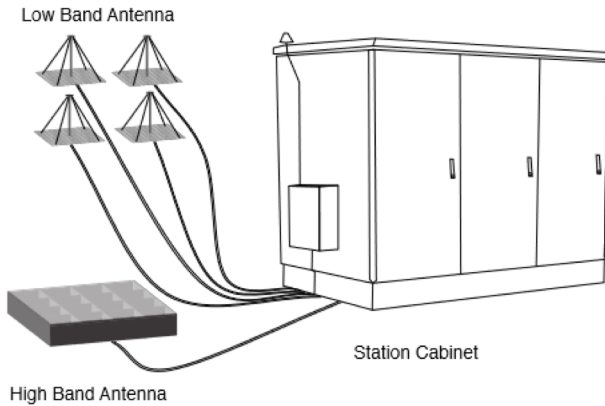
- Analog filters

- Sampling 160/200 MHz -> Digital signal

- Splitting signal into subbands

- Beam forming

Central Processing @ Groningen

- Delay compensation, fringe tracking

- Separation subband into channels

- Beam forming

- Post processing

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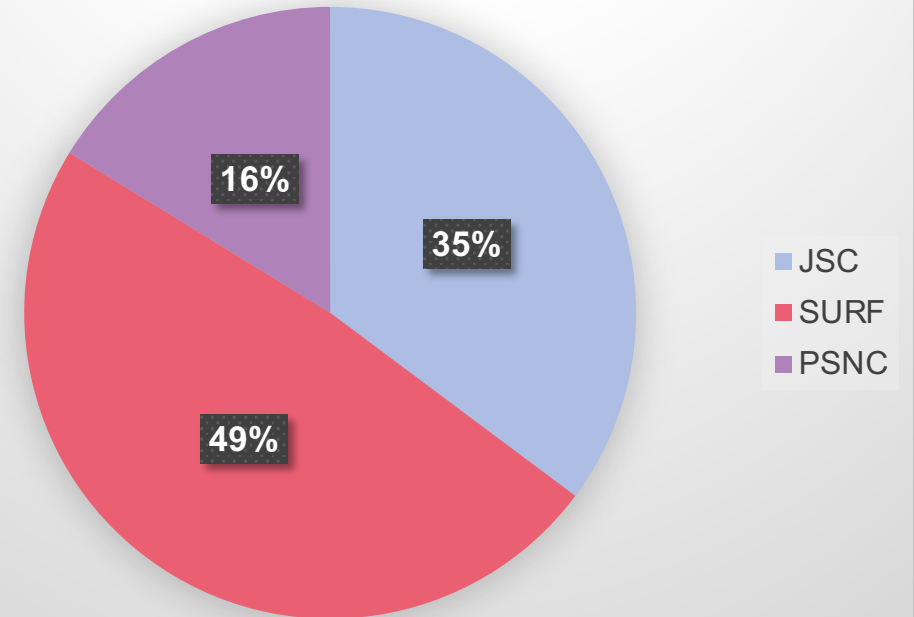
LOFAR LONG TERM ARCHIVE (LTA)

Central Processing @ Groningen

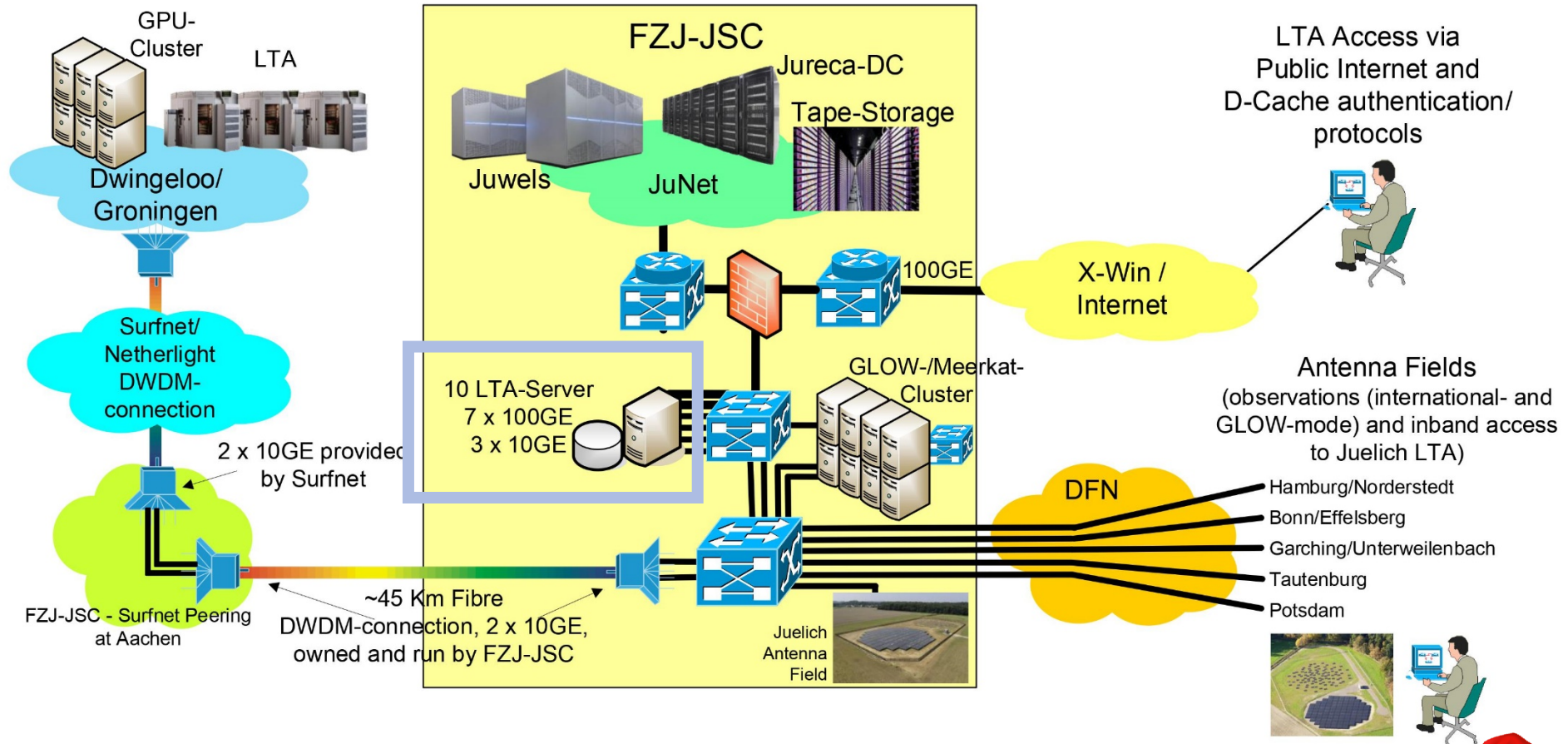**Data-providing node:** read data from disk, package, checksum -> send data stream to data-transfer node

Data-transfer node: checksum, piped to GridFTP client -> Storing into LTA
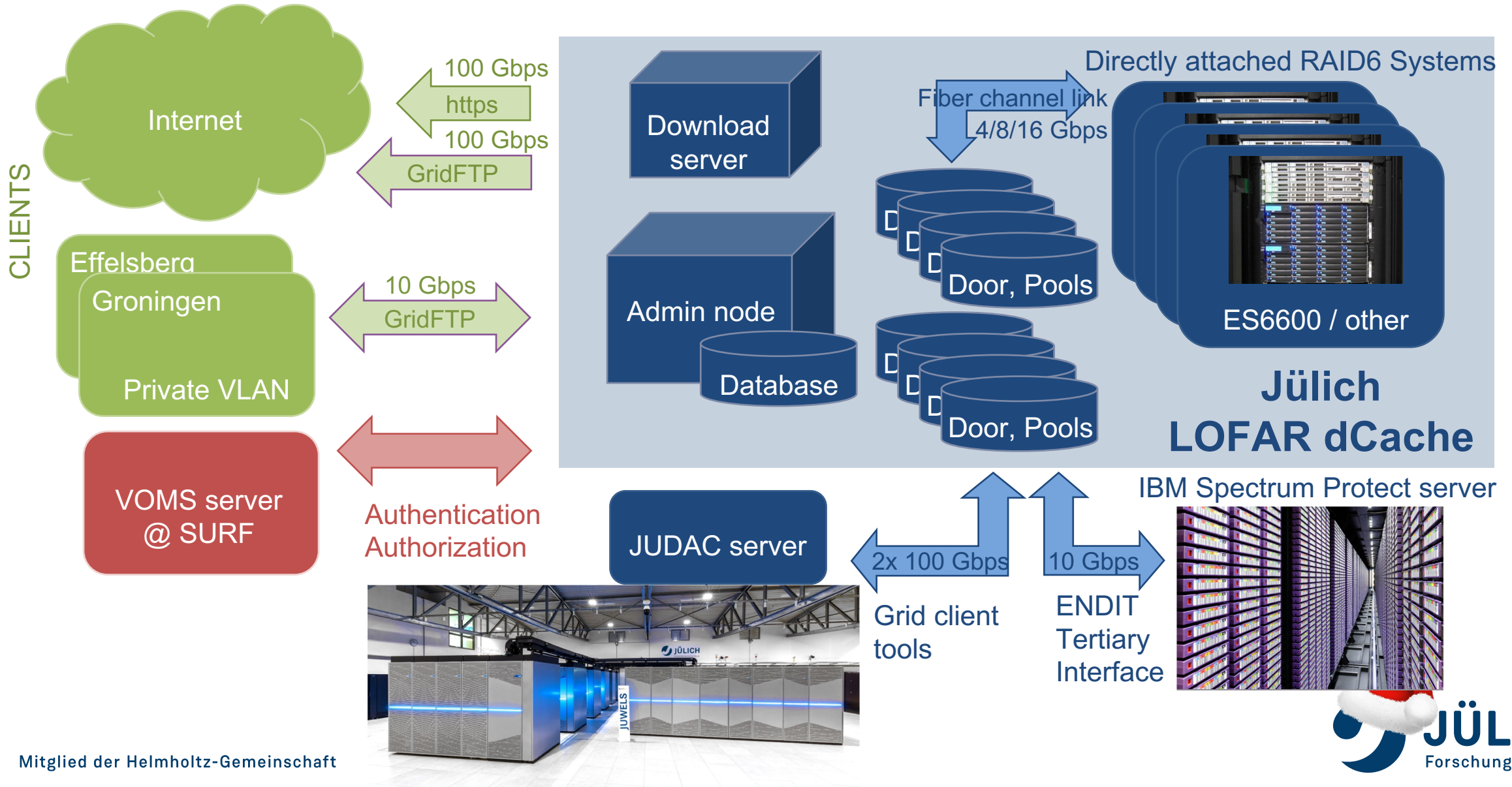
Total LOFAR LTA Data (62.2 PB)

- JSC 35%
- SURF 49%
- PSNC 16%

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LOFAR NETWORK – JÜLICH PERSPECTIVE

LOFAR/GLOW-network designed, operated and monitored by JSC (Olaf Mextorf)

LOFAR LTA @ JÜLICH

CLIENTS

Internet

100 Gbps — https
100 Gbps — GridFTP

Effelsberg
Groningen
Private VLAN

10 Gbps — GridFTP

VOMS server @ SURF

Authentication Authorization

Download server

Admin node
Database

Door, Pools

Door, Pools

Directly attached RAID6 Systems

Fiber channel link
4/8/16 Gbps

ES6600 / other

Jülich LOFAR dCache

JUDAC server

2x 100 Gbps — Grid client tools

10 Gbps — ENDIT Tertiary Interface

IBM Spectrum Protect server

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Mitglied der Helmholtz-Gemeinschaft

LOFAR – A MAP OF THE SKY

The new sky map includes 4.4 million galaxies, 1 million of these were previously completely unknown.
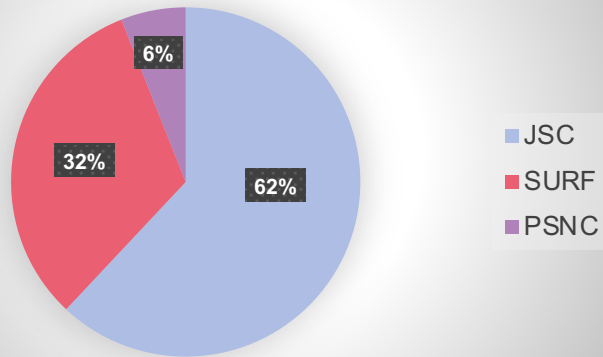
LOFAR Two-metre Sky Survey (LoTSS)
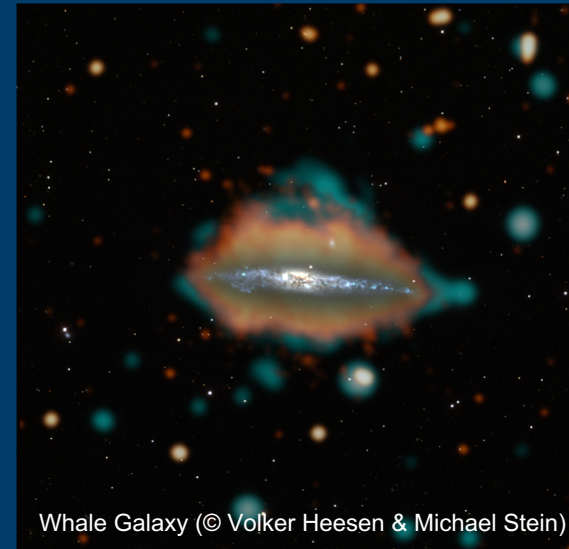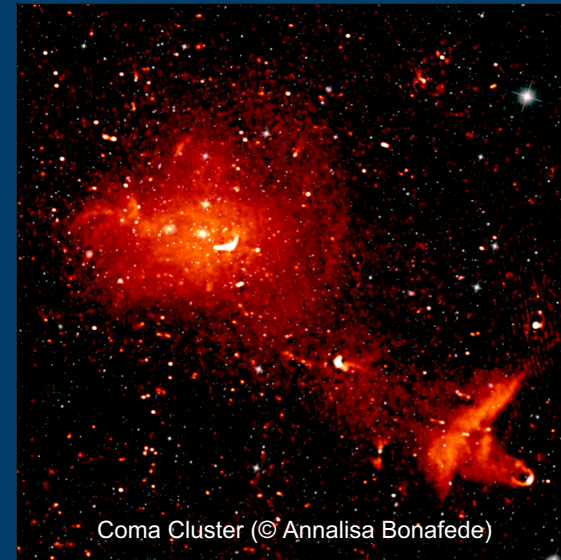 27% northern sky
  3451 hours observation time HBA
  Released datasets images:
  - 120-168 MHz
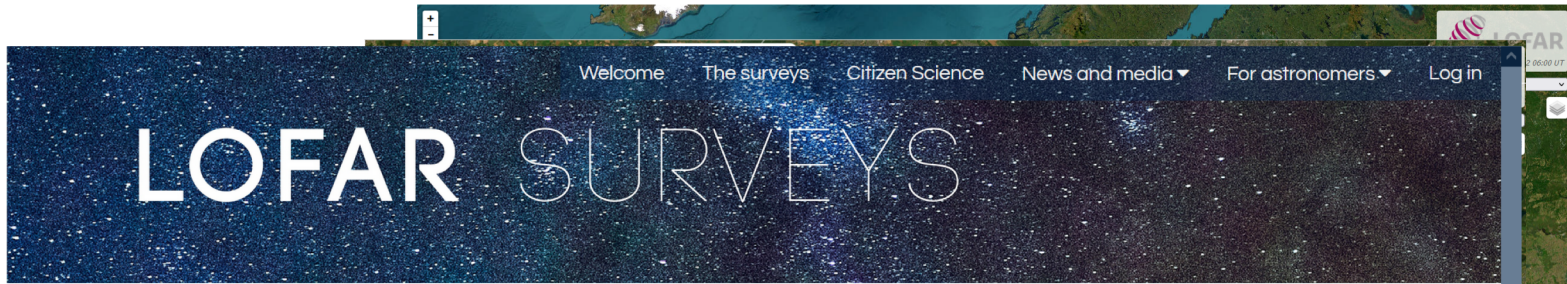 - 8.8 TB each

LoTSS processed data (7.6 PB)

6%

32%

62%

JSC
SURF
PSNC

Coma Cluster (© Annalisa Bonafede)

Supernova Cygnus Loop (© Jennifer West)

Whale Galaxy (© Volker Heesen & Michael Stein)

Jellyfish Galaxy (© Ian Roberts)

LINKS, INFOS

- https://www.astron.nl/telescopes
- https://science.astron.nl/telescop
- https://www.astron.nl/lofartools/lo
- https://lofar-surveys.org/
- https://www.fz-juelich.de/en/ias/j
  communities/special-community-
- https://www.fz-juelich.de/en/ias/j
  systems/dcache