LOFAR and a Grid for European astronomy

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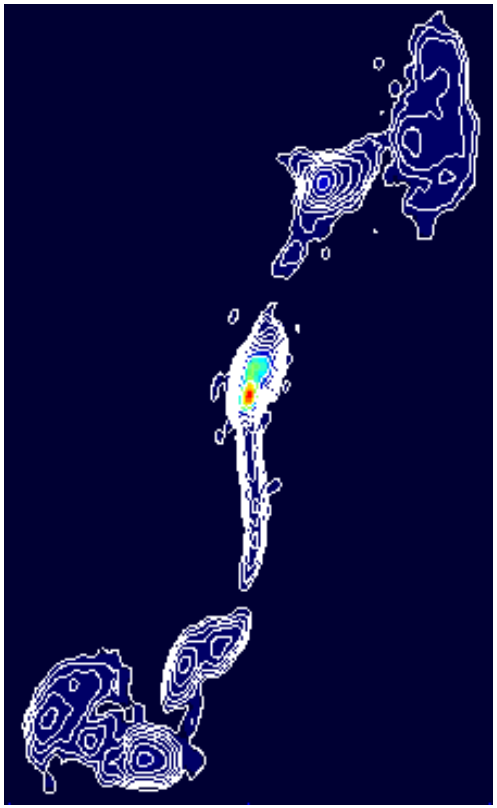
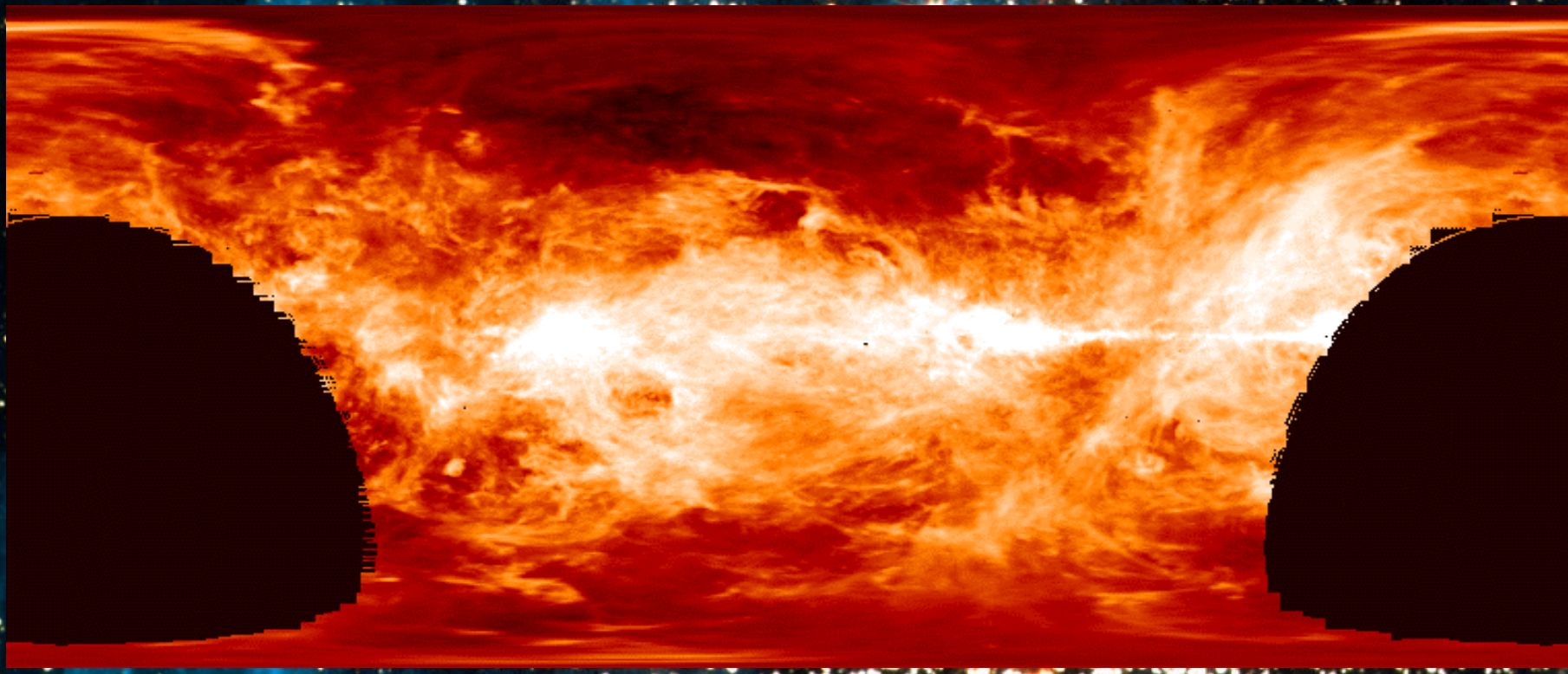
ASTRON

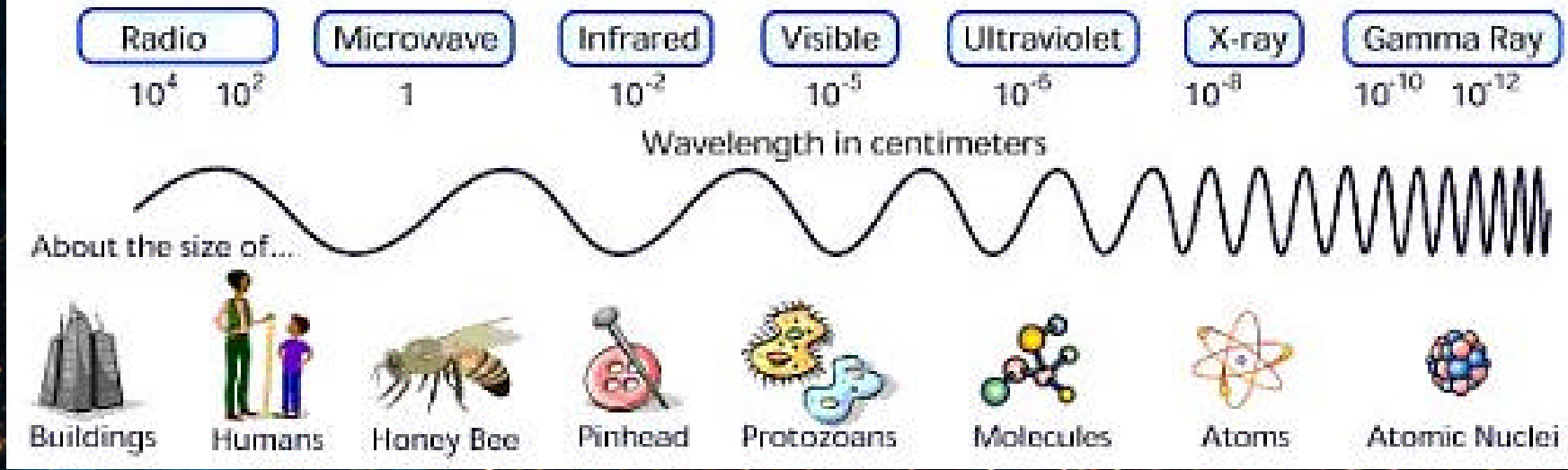
Knowledge institute for astronomical instrumentation

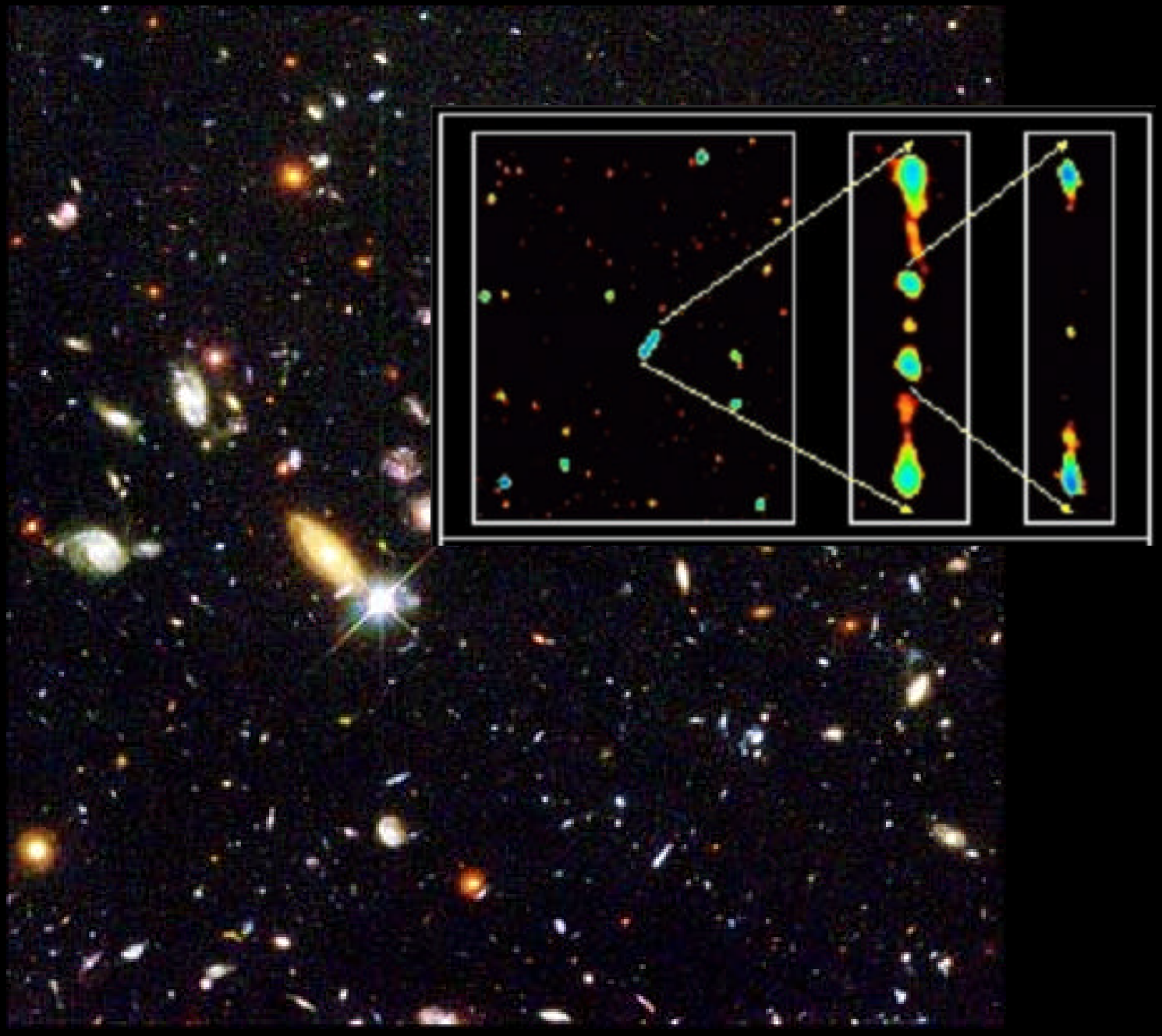
Our mission:

"Making astronomical discoveries happen through innovative observational facilities"

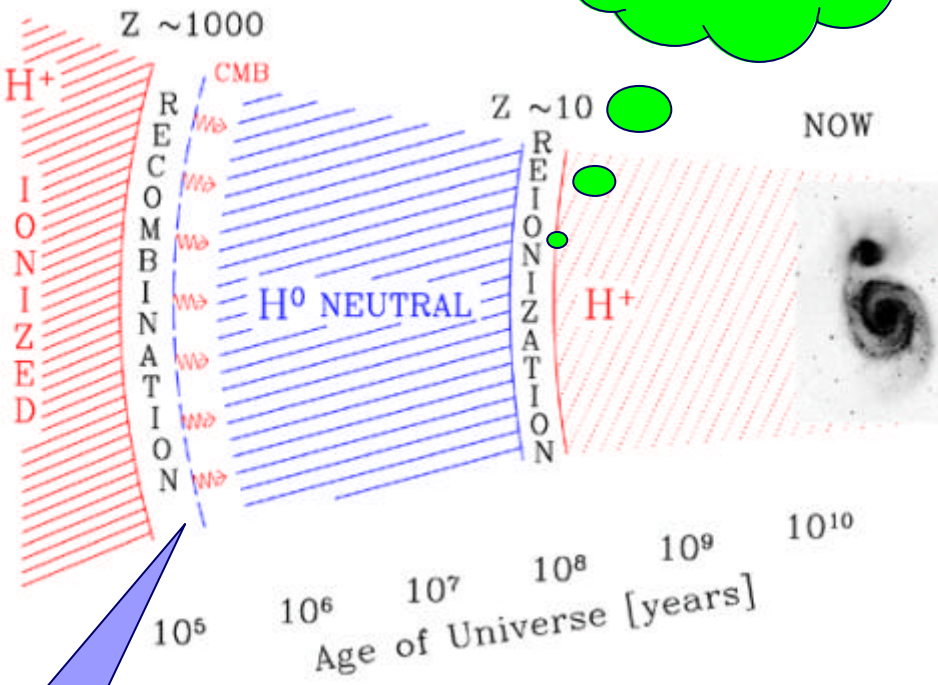





Radio
Microwave
Infrared
Visible
Ultraviolet
X-ray
Gamma Ray
10^{4} 10^{2}
1
10^{-2}
10^{-5}
10^{-8}
10^{-10} 10^{-12}
Wavelength in centimeters
About the size of....
Buildings
Humans
Honey Bee
Pinhead
Protozoans
Molecules
Atoms
Atomic Nuclei



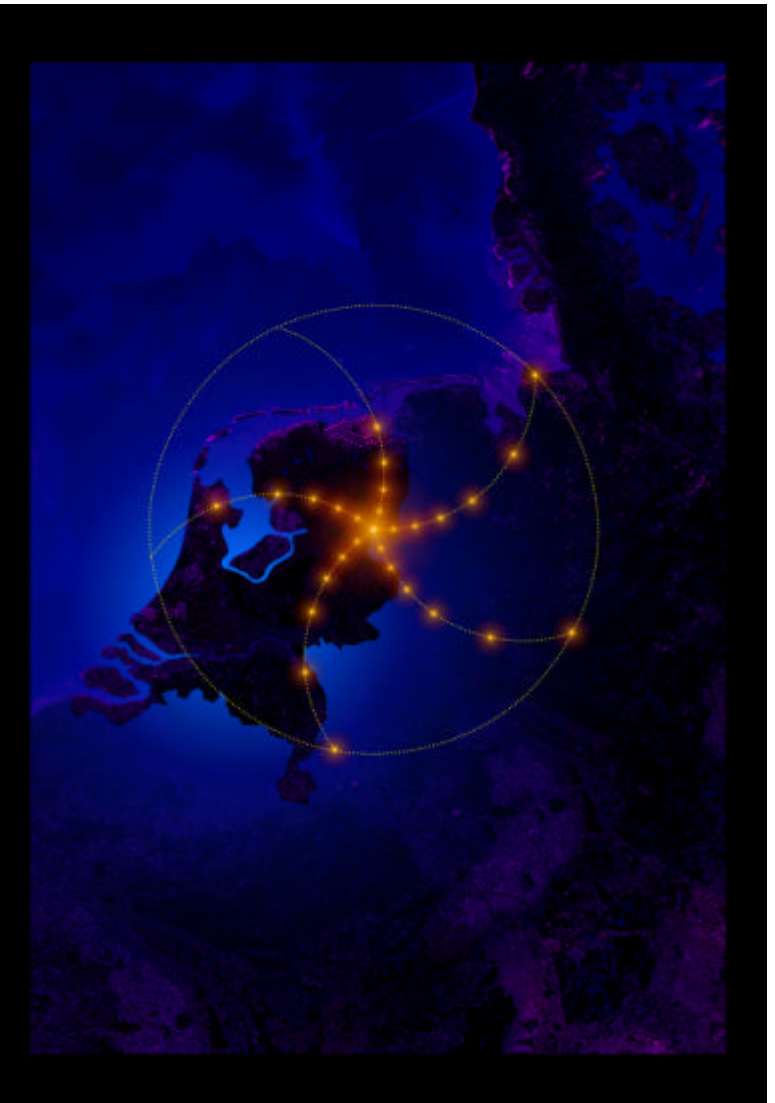
A brief history of the universe



Observable with LOFAR

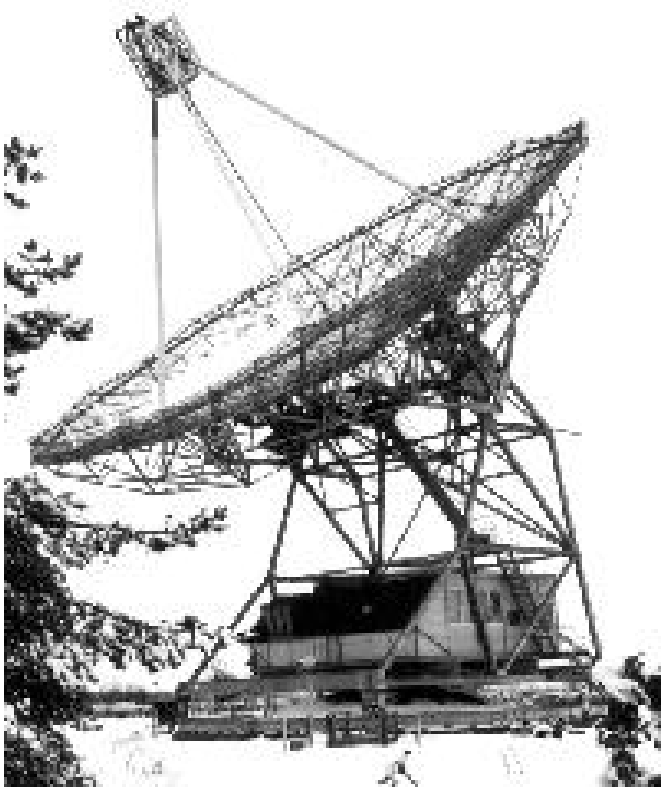
Observed with X-ray satellite

LOFAR as a Sensor Network

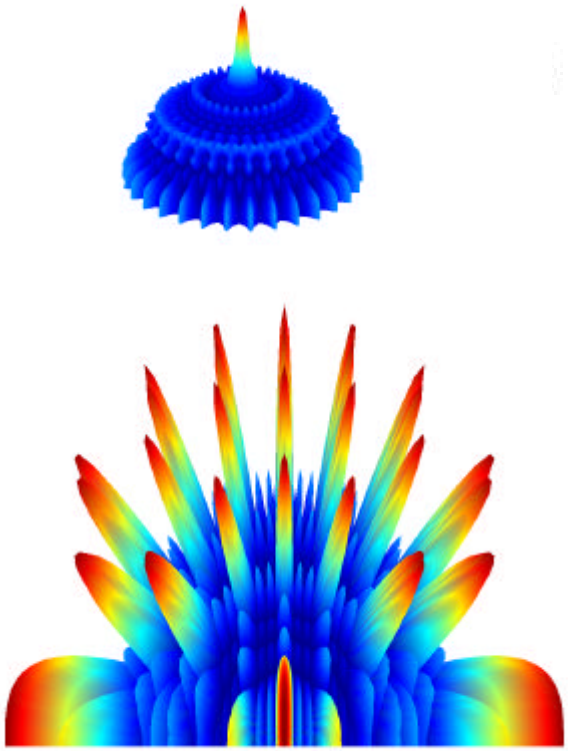


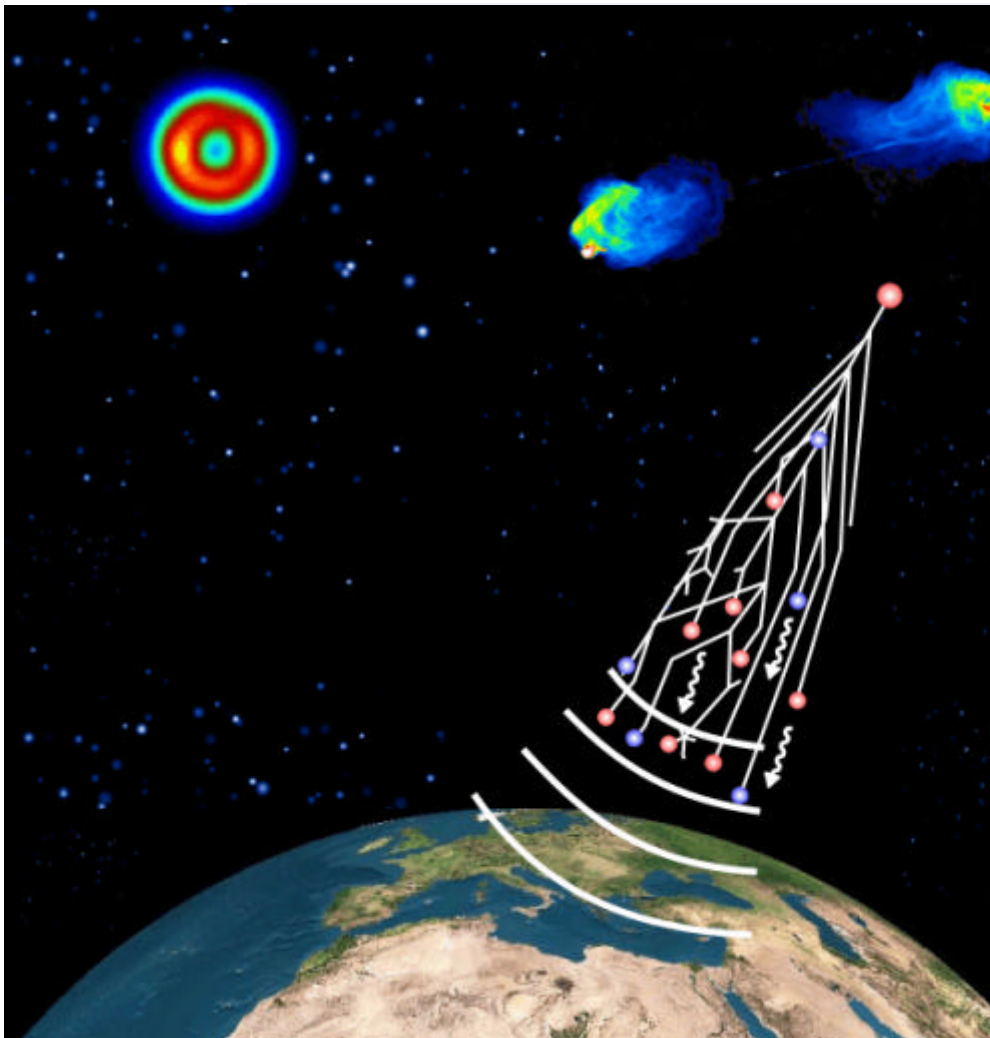
- LOFAR is a large distributed research infrastructure:
  - Astronomy:
    - >100 phased array stations
    - Combined in aperture synthesis array
    - 13,000 small “LF” antennas
    - 13,000 small “HF” tiles
  - Geophysics:
    - 18 vibration sensors per station
    - Infrasound detector per station
  - >20 Tbit/s generated digitally
  - >40 Tflop supercomputer
  - innovative software systems
    - new calibration approaches
    - full distributed control
    - VO and Grid integration
    - datamining and visualisation

From Steel to Software

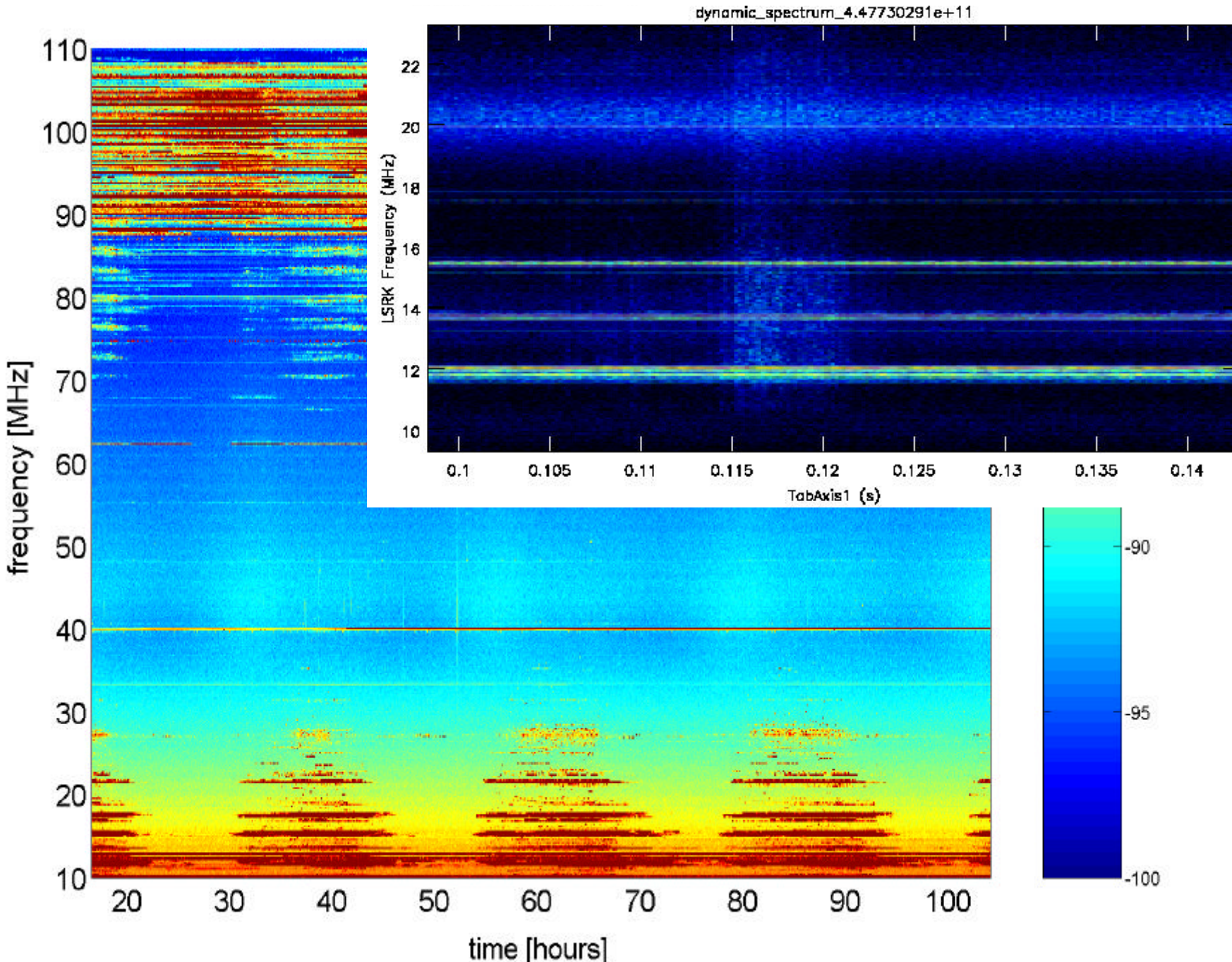


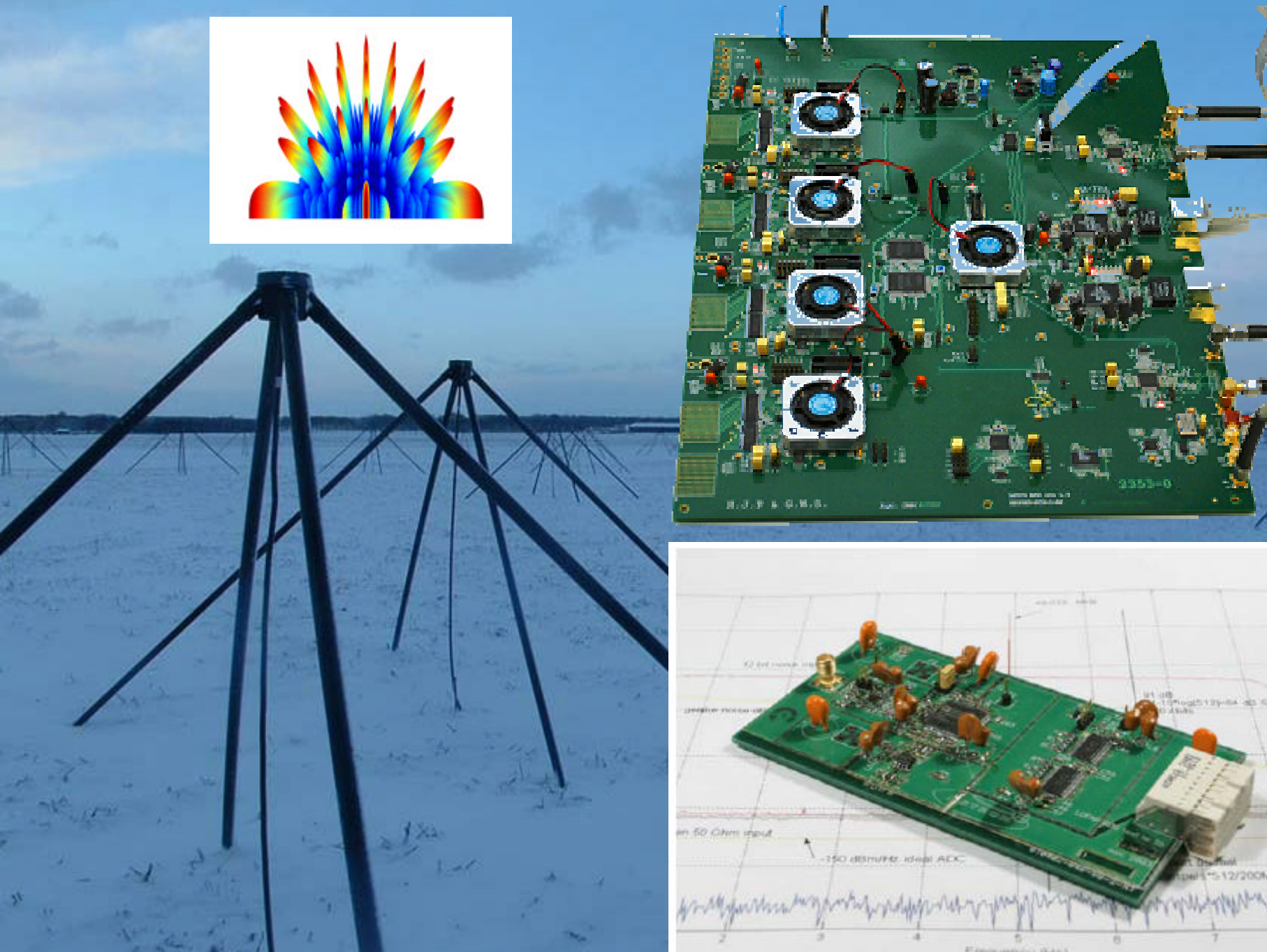
From Steel to Software



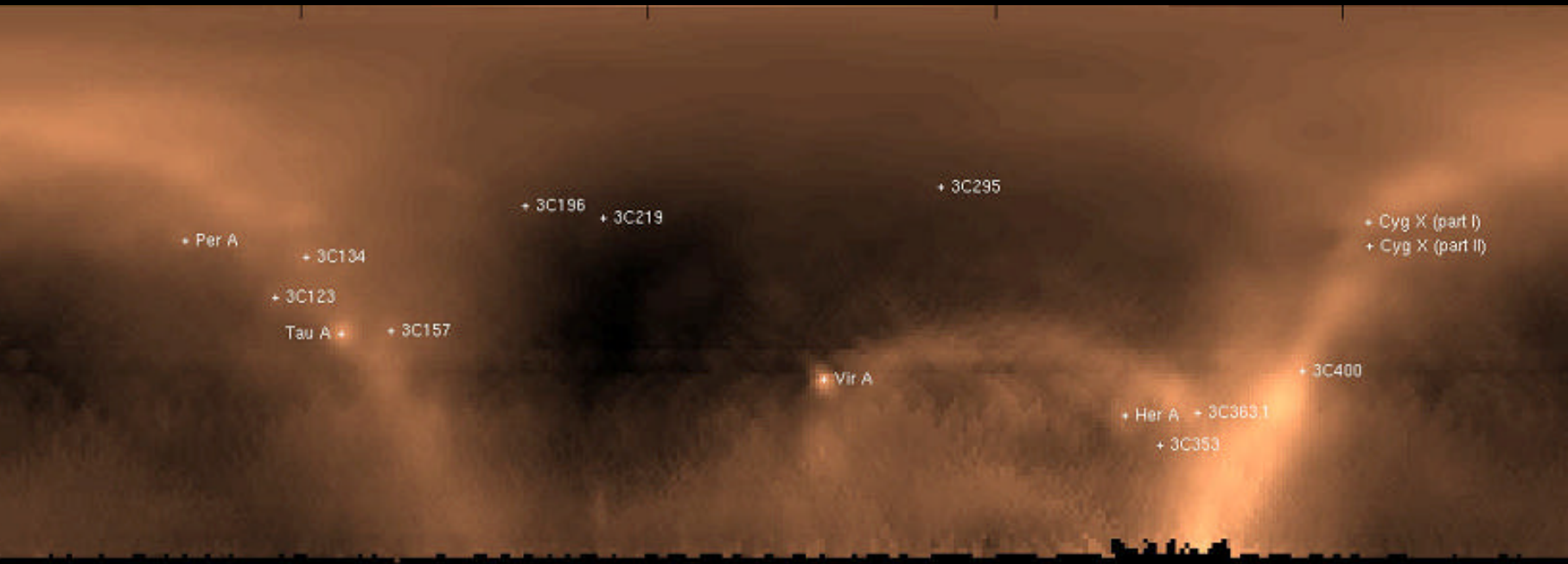



ASTRON


dynamic_spectrum_4.47730291e+11
LSRK Frequency (MHz)
TabAxis1 (s)
frequency [MHz]
time [hours]



Survey of the full sky made with a LOFAR Test Station

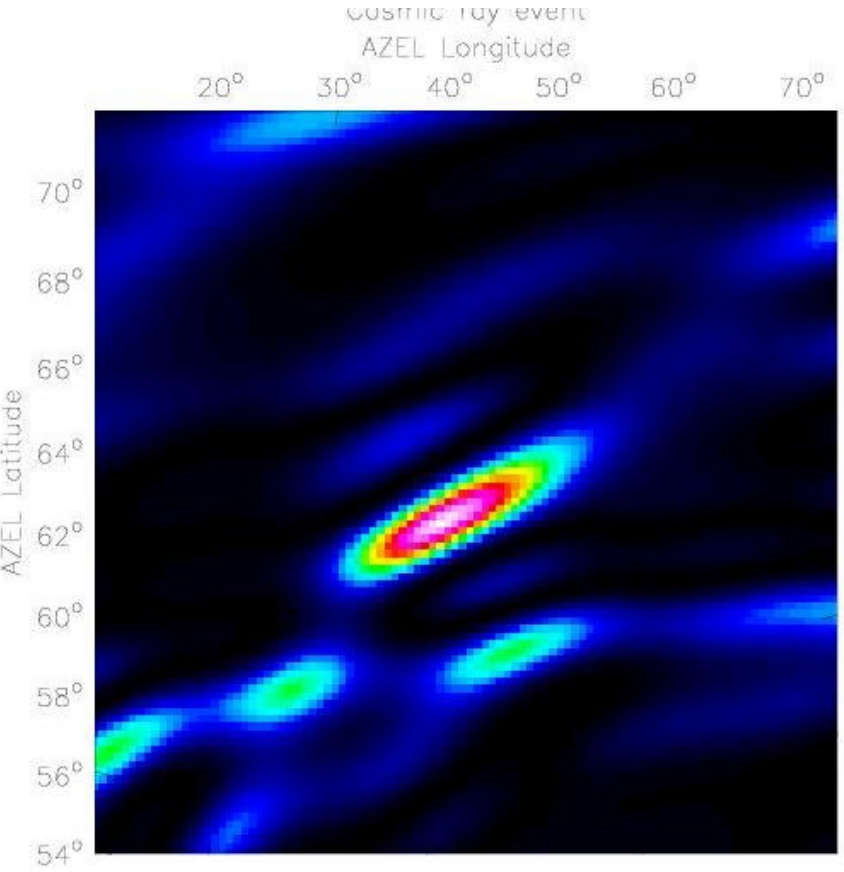


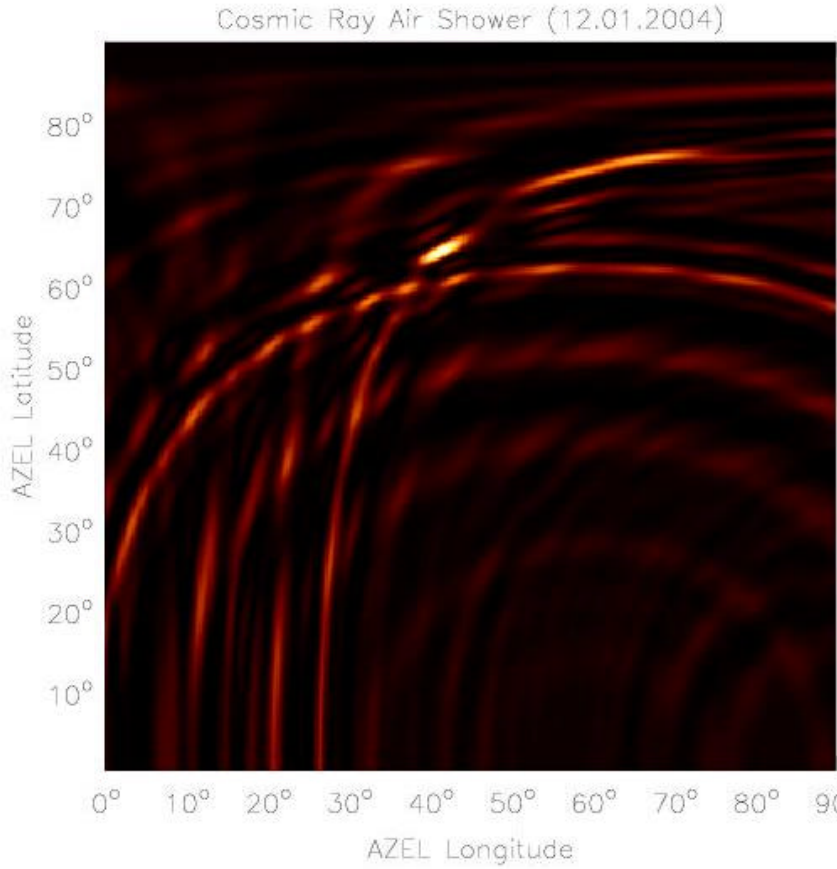
source	flux @178MHz (Jy)	source	flux @178MHz (Jy)
Perseus A	58	Hercules A	325
3C123	175	3C363.1	90
3C134	66	Cygnus X (part I)	230
Taurus A	1420	Cygnus X (part II)	410
3C157	210	3C353	203
3C196	59	3C295	73
3C219	44	3C400	400
Virgo A	970		

This map was produced using 86 snapshots with 6.7s of integration and 9.7kHz channels. First RFI free channels between 29.5 and 30.5 MHz were selected using a median filter. The selected channels were calibrated on the four strongest 3C sources (Cas A, Cyg A, Tau A, Vir A). After the calibration a first map was made by a flux conserving projection from the (l, m) grid of the individual snapshots to the (α, δ) grid of the all sky image. This map was dominated by the averaged out sidelobes of Cas A and Cyg A. Therefore these two sources were cleaned from the image resulting in this map.

www.lofar.org

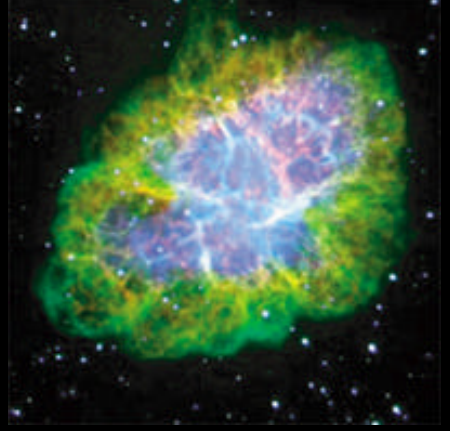
Cosmic ray detection with LOFAR antennas



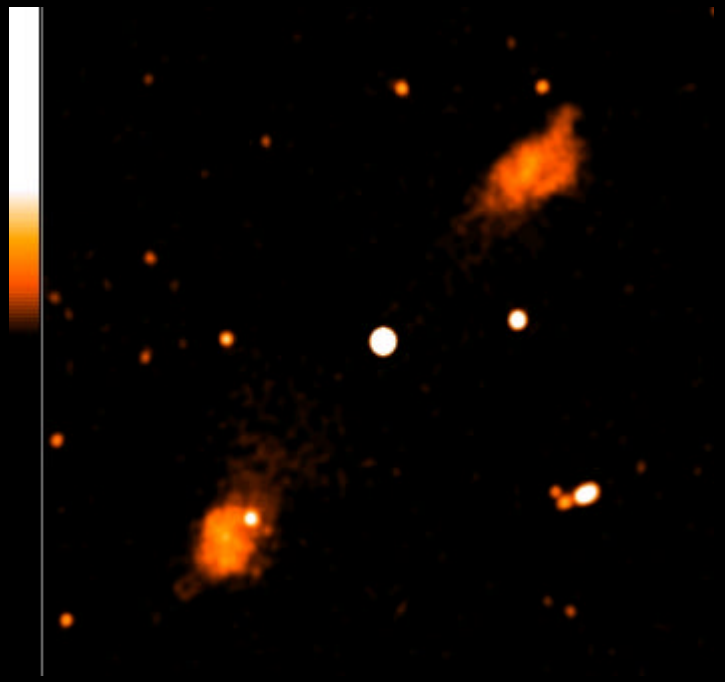


LOFAR

37 Tbps raw data (0.5 Tbps per station)



10 Gbps/station



10 Tbyte/day

250 Tbyte/day

Cluster of servers
4BG RAM/node
Infiniband interconnect

Cluster of servers
10 TB RAID per node
Infiniband interconnect

Cluster of servers
general purpose nodes
Infiniband interconnect

Cluster of servers
general purpose nodes
Infiniband interconnect

Arm6:

Central processor status:

DSP:
DISK:
CPU:

LOFAR

L	50	05/20/2003 01:28:36 F	RECEPTOR_S10_31.statı	Disconnecte	CAME	0	!!!		...
M	70	05/20/2003 01:29:32 F	RECEPTOR_S1_11.status	Disconnecte	CAME	0	!!!		...
H	10	05/20/2003 01:29:47 F	RECEPTOR_S1_21.status	Not available	CAME	2	!!!		...

4/4

root

02:11:42 PM 04/20/2003

RAM 56%
HDD 26%

UvA/Transients Science Center

RUL/Survey Science Center

NITG/Geo Science Center

RUG/EoR Science Center

KUN/UHECR Science Center

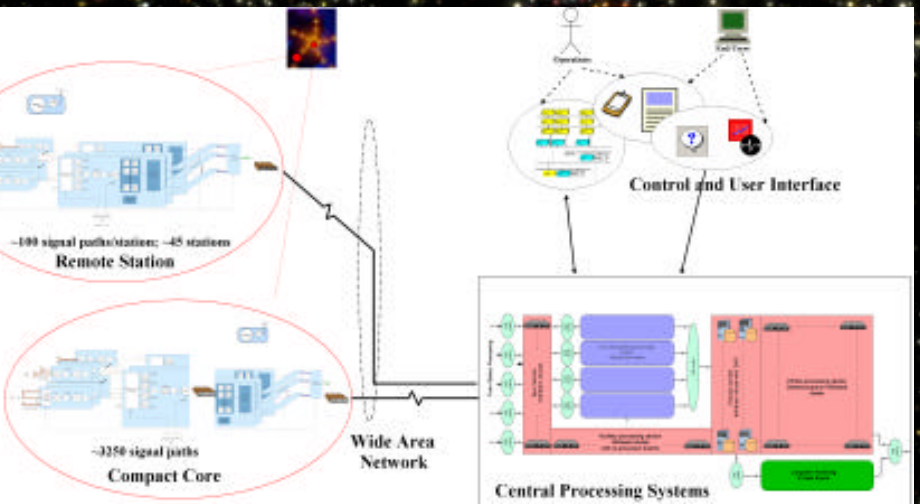
KNMI/Geo Science Center

Joint LOFAR Operations Center

SurfNet6

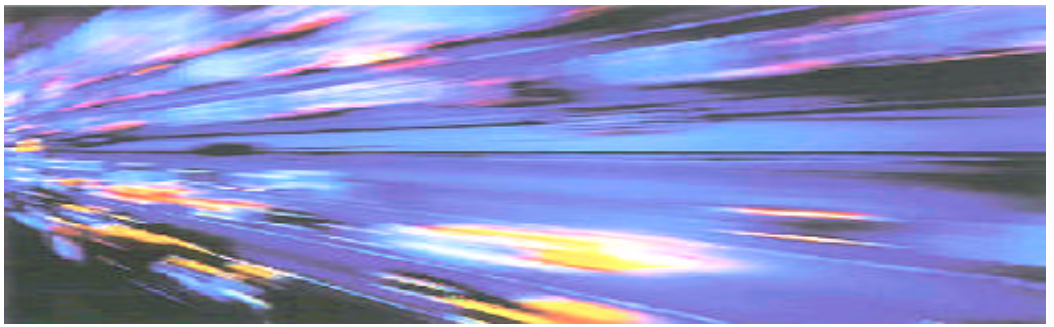
Geant

Bonn Science Cent

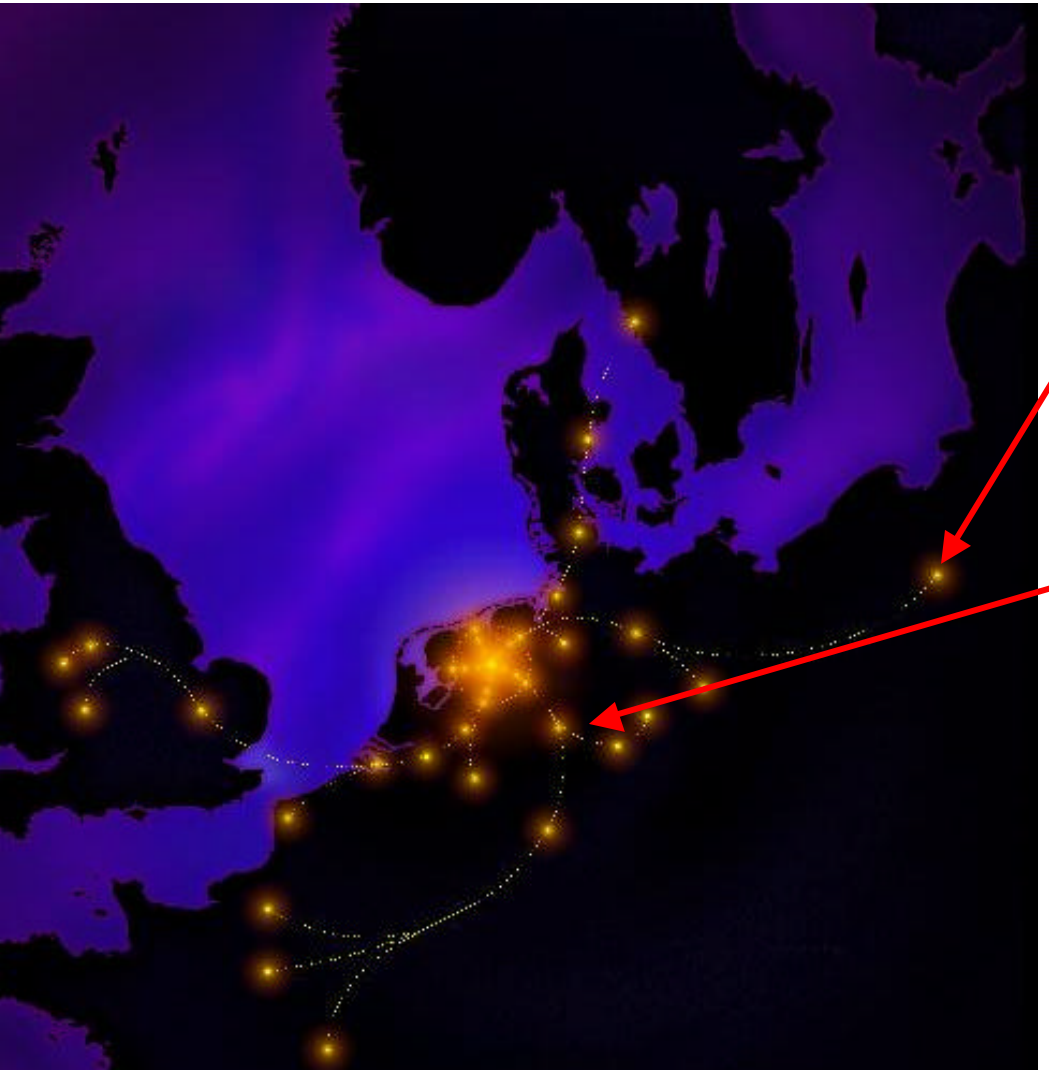


Mapping on GigaPortNG/Surfnet6

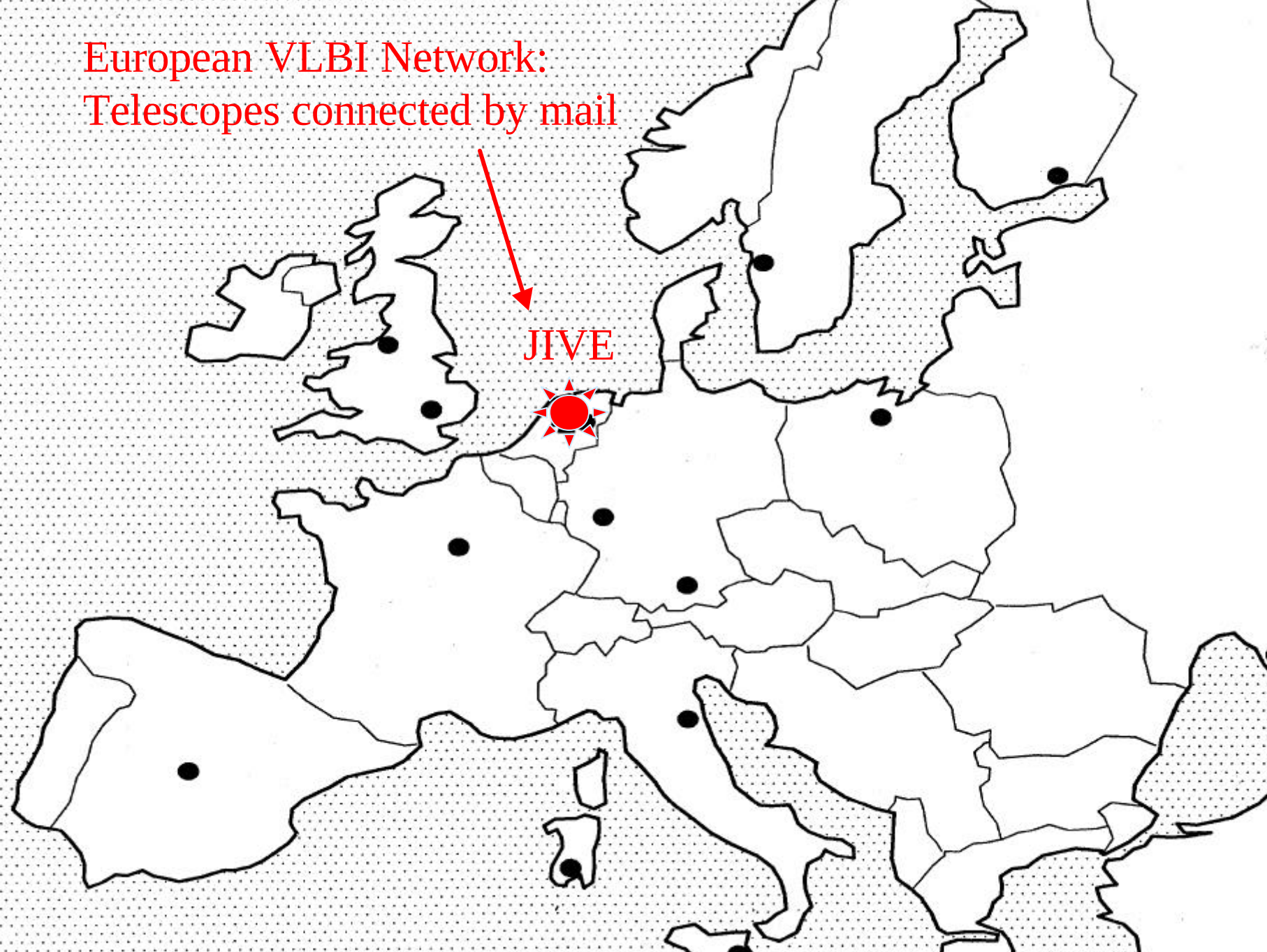
Location	Institute	Datarate	Role/Comments
Groningen	RUG/RC: CEP	40 Gbps	LOFAR Central processor ***total outgoing***
Dwingeloo	ASTRON	4...10 Gbps	LOFAR Operations Center
Groningen	RUG/Astronomy	n/a (local)	Epoch of Reionization; Science Support
Amsterdam	SARA	20 Gbps	Long term storage
Amsterdam	UvA/Astronomy	20 Gbps	Transients, pulsars (1 Gbps sustained)
Leiden	RUL/Astronomy	10 Gbps	Surveys
Nijmegen	KUN/Astronomy	20 Gbps	Cosmic rays (average 1 Gpbs sustained tbc)
Utrecht	TNO-NITG	10 Gbps	Geophysical data centre
Utrecht	KNMI	1 Gbps	Geophysical processing; weather data
Bonn	MPIfR	1 Gbps ?	German Science Centre (via Géant)

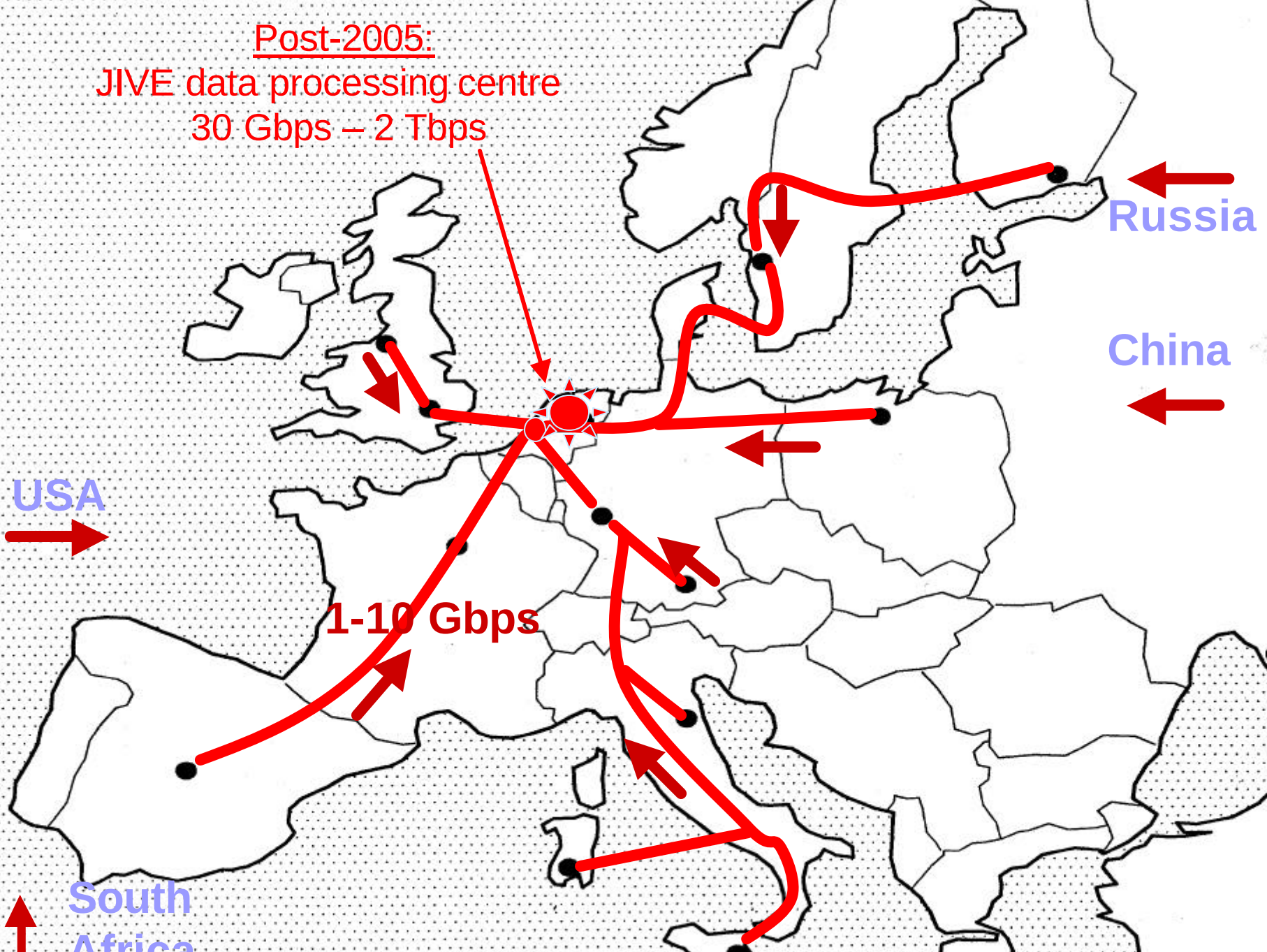


A European Grid for Astronomy

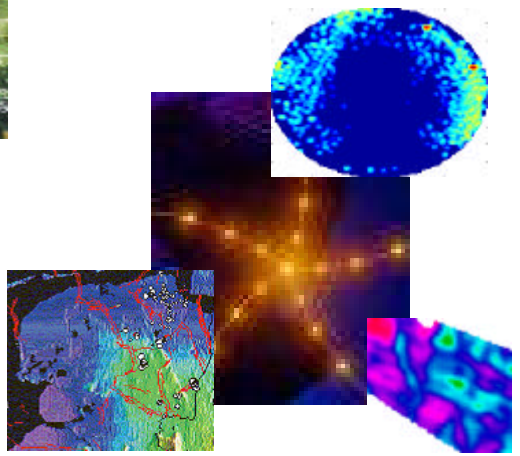


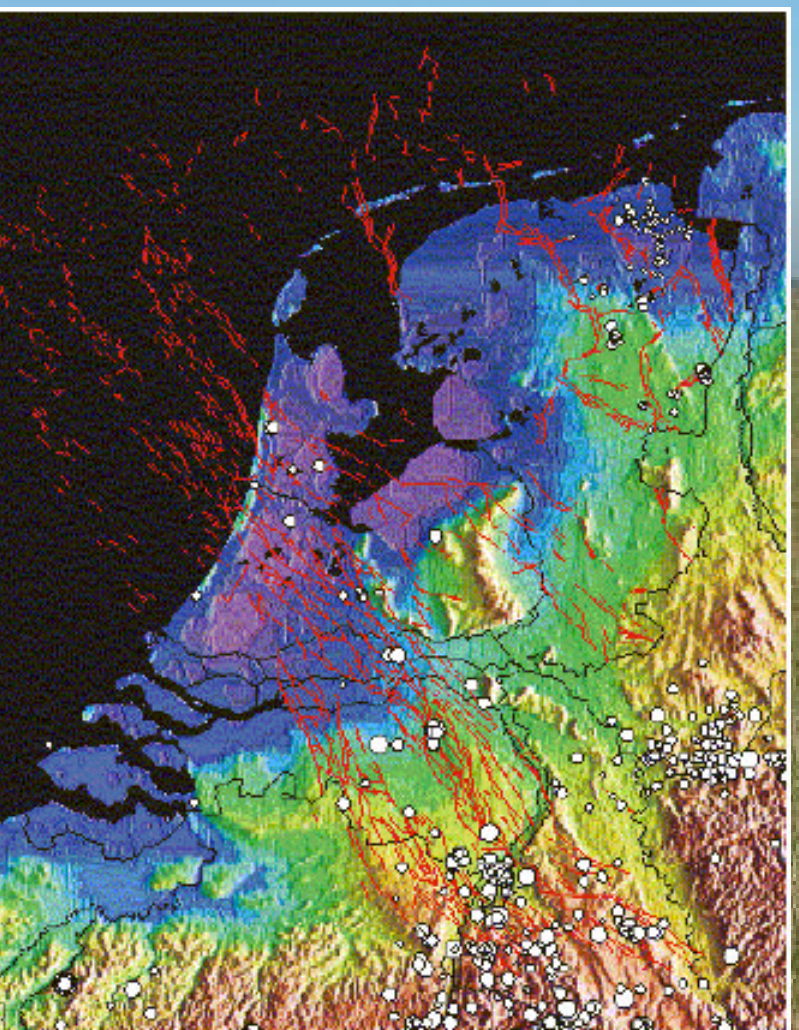
LOFAR Science Center


European VLBI Network:
Telescopes connected by mail
JIVE


Post-2005:
JIVE data processing centre
30 Gbps – 2 Tbps
Russia
China
USA
1-10 Gbps
South
Africa

From Antennas to Sensors



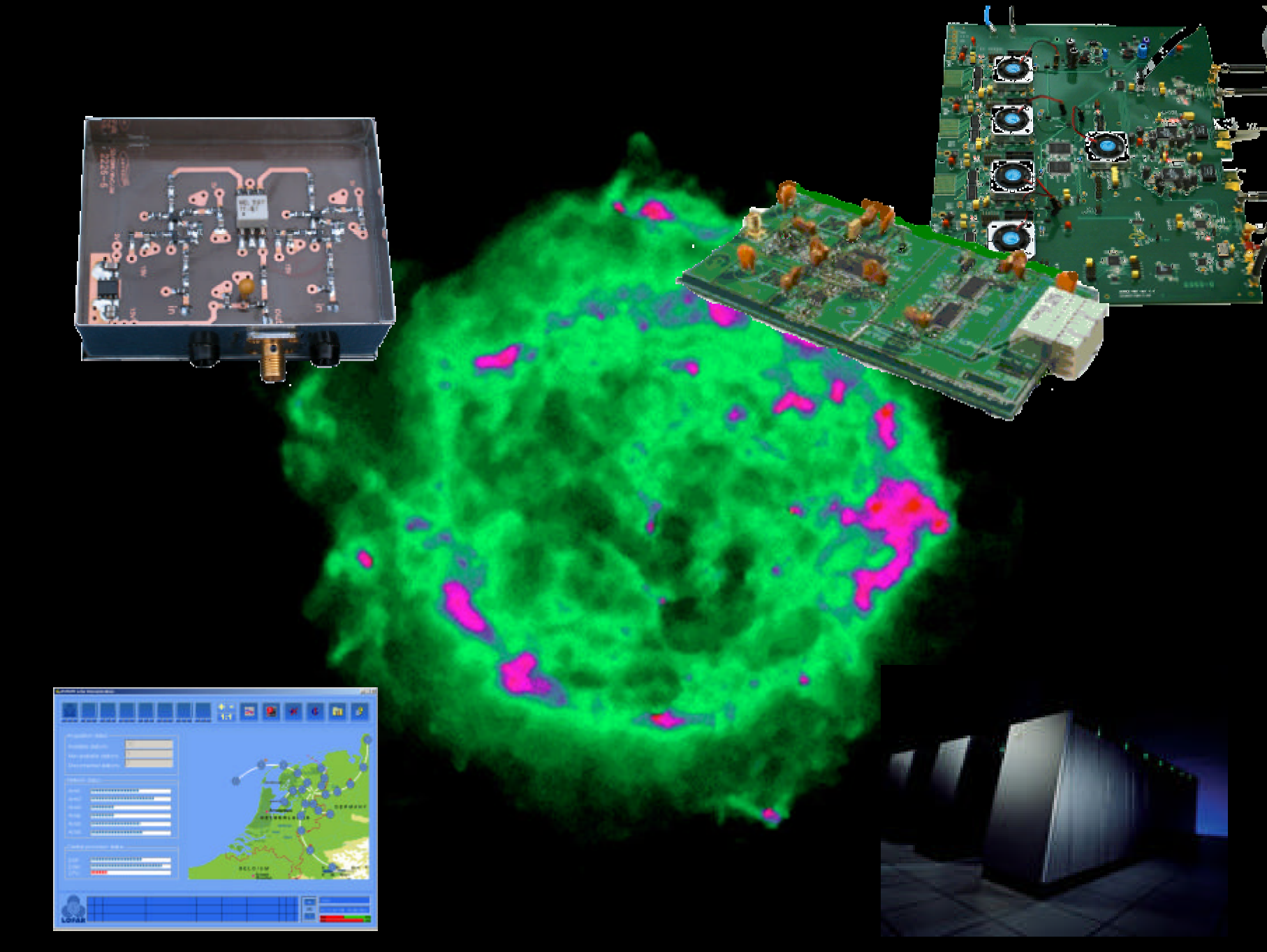


Towards a European Sensor Grid

LOFAR	For each Sensor Field	Phase 1 2008	European 2010
Sensor Fields (including Central Core)		77	93
Sensors			
Astronomical "LF" antennas	100	7700	9300
Astronomical "HF" antenna tiles	100	7700	9300
Geophysical vibration sensors (geophones)	18	1386	1674
Geophysical microbarometers (infrasound)	3	231	279
Agriculture sensors	80	6160	7440
Other sensors	8	616	t.b.d.!!!
Datarates			
Total digitized datarate from sensors	0.5 Tb/s	37 Tb/s	45 Tb/s
Datarate over LOFAR Backbone	10 Gb/s	0.8 Tb/s	1 Tb/s
Outgoing datarate over SURFnet6		40 Gb/s	60 Gb/s
European datarate over Géant		20 Gb/s	0.2 Tb/s
Installed Processing Power			
Total processing power		160 Tops/s	190 Tops/s
Distributed at Sensor Fields	1.5 Tops/s	116 Tops/s	150 Tops/s
Central Processor (including BlueGene)		43 Tflop/s	60 Tflop/s
BlueGene		33 Tflop/s	

Key features of Sensor Grids

- Different high level applications need different combinations of sensor-data and processing
  - Transparent access to distributed processing needed
  - Identity, access policies, … needed
- Extend the Grid-concept towards
  - Increasingly embedded processing
  - Streaming data-flows instead of static databases




European Sensor Networks
Bringing the
environment on-line