The Big Bang of astronomical data. How to use Python to survive the data flood.

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The new astronomy

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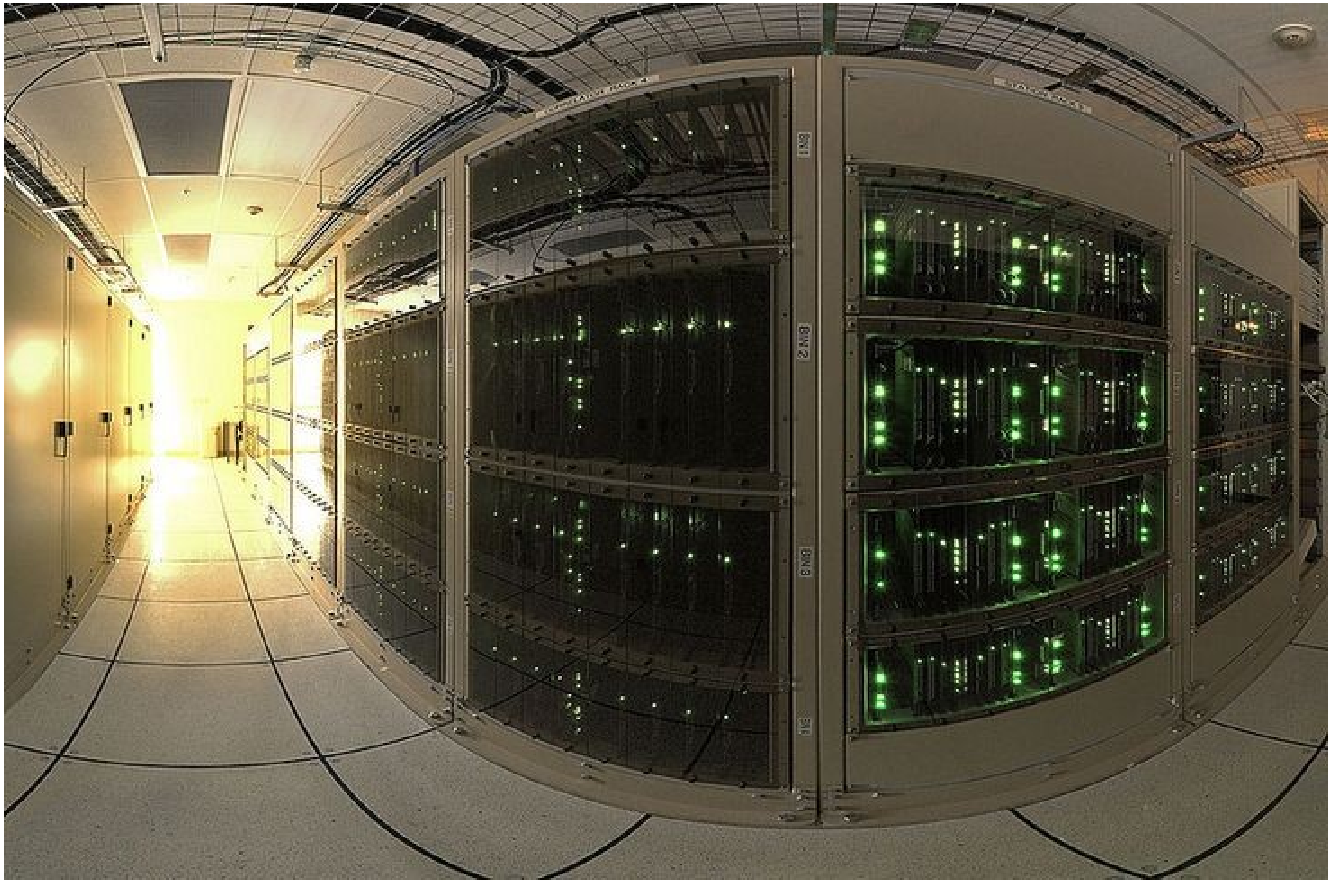


ALMA correlator

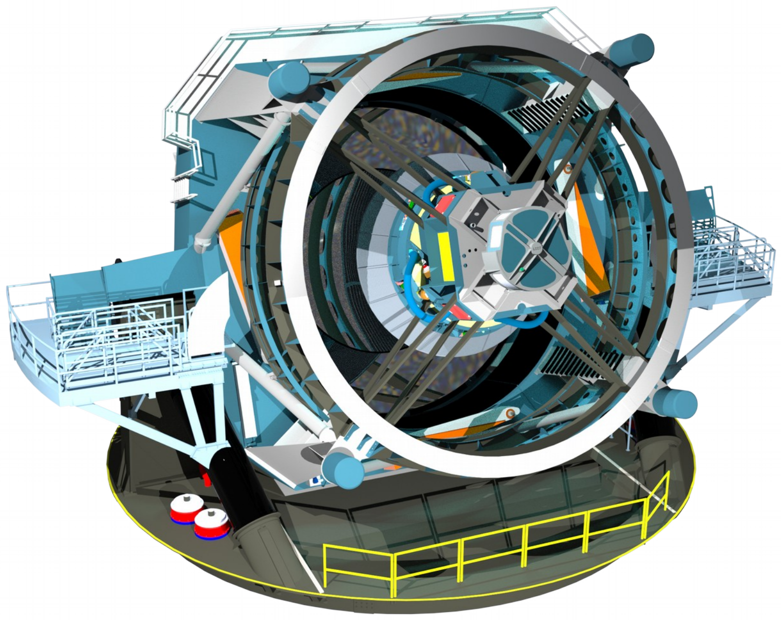
Astronomy and Python

- Python is currently the main language used for astronomy
- General Python computing libraries: numpy, scipy, matplotlib, pandas, emcee...
- Specific astronomical libraries (see http://www.astropython.org/packages/)
  - astroML: machine learning and data mining
  - astropy: main general library for astronomy
  - etc.

The future of astronomy

- New state of the art astronomical infrastructures that produce an overwhelming amount of data
- Examples:
  - ESA Gaia
  - Large Synoptic Survey Telescope
  - ESA Euclid
  - The Square Kilometre Array and its pathfinders (LOFAR, ASKAP, Meerkat...)
  - Etc.

Large Synoptic Survey Telescope

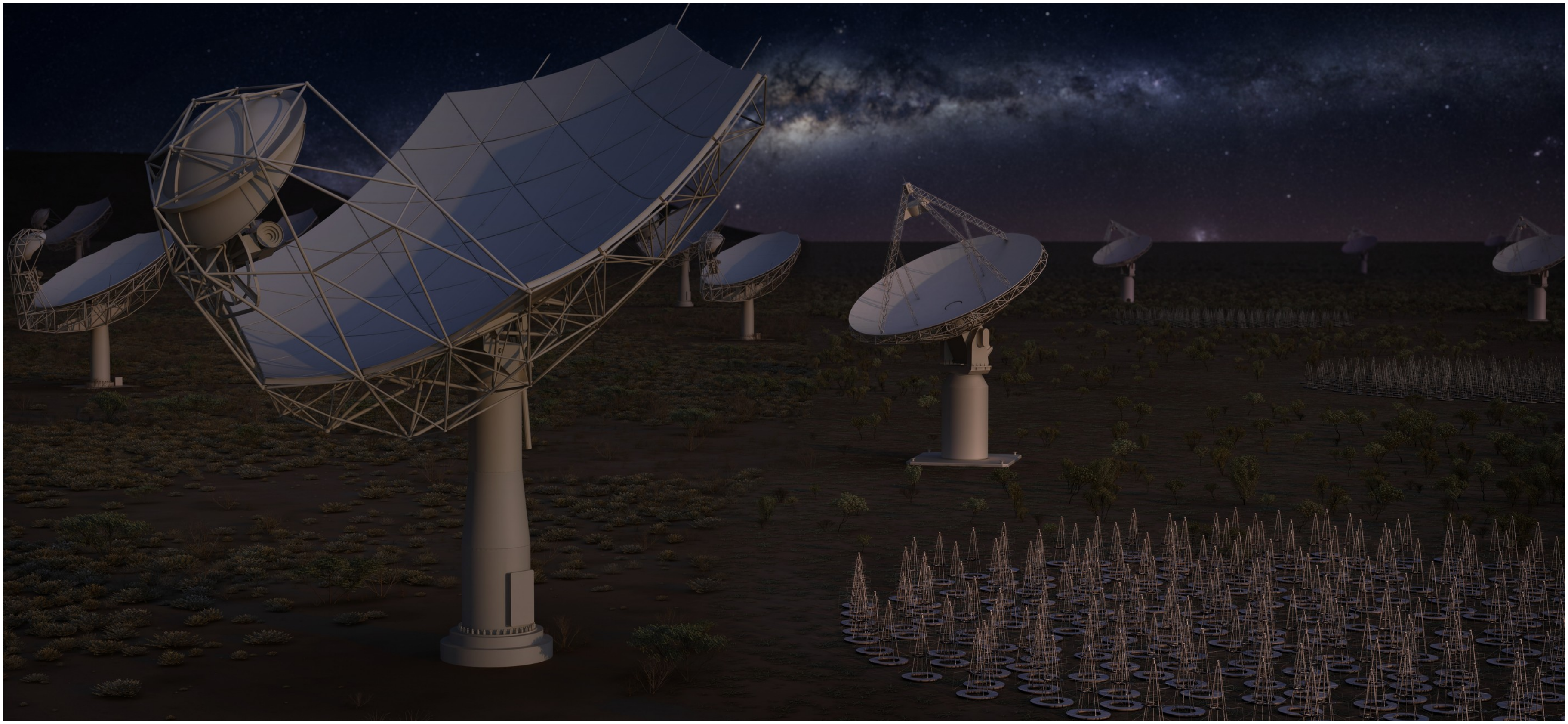


- 8.4 m mirror
- Covers the full visible sky every two nights
- Under construction - operational in 2022

Large Synoptic Survey Telescope

- Camera 189x16 Mpix
- Pipeline preprocessing: 3GB/s
- 30 TB per night during 10 years
- 2 M events triggered per night

Square Kilometre Array (SKA)

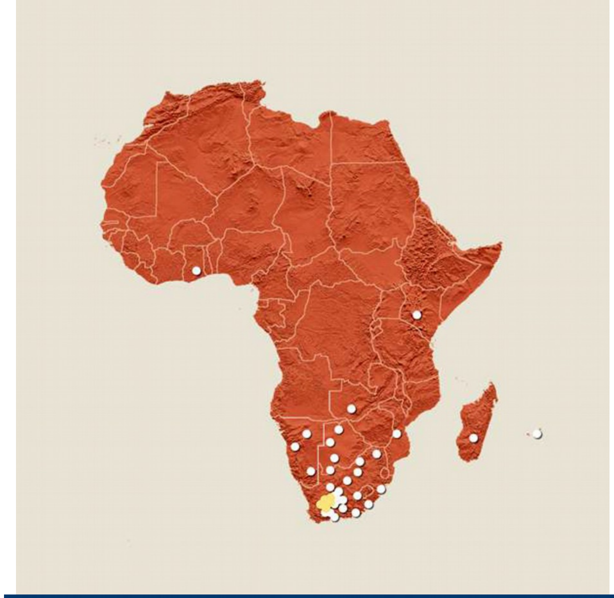


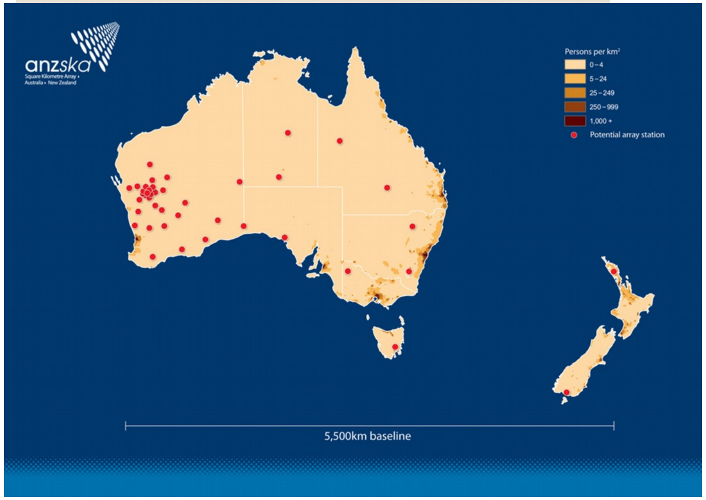
- Radio telescope with 1 km² of collecting area
- Phase 1 - 2020

SKA data

- Phase 1:
  - 10 TB/s from the antennas to the correlator
  - 40 GB/s of data → 70 PB per year
  - 1 MW infrastructure and 10 MW processing

SKA data



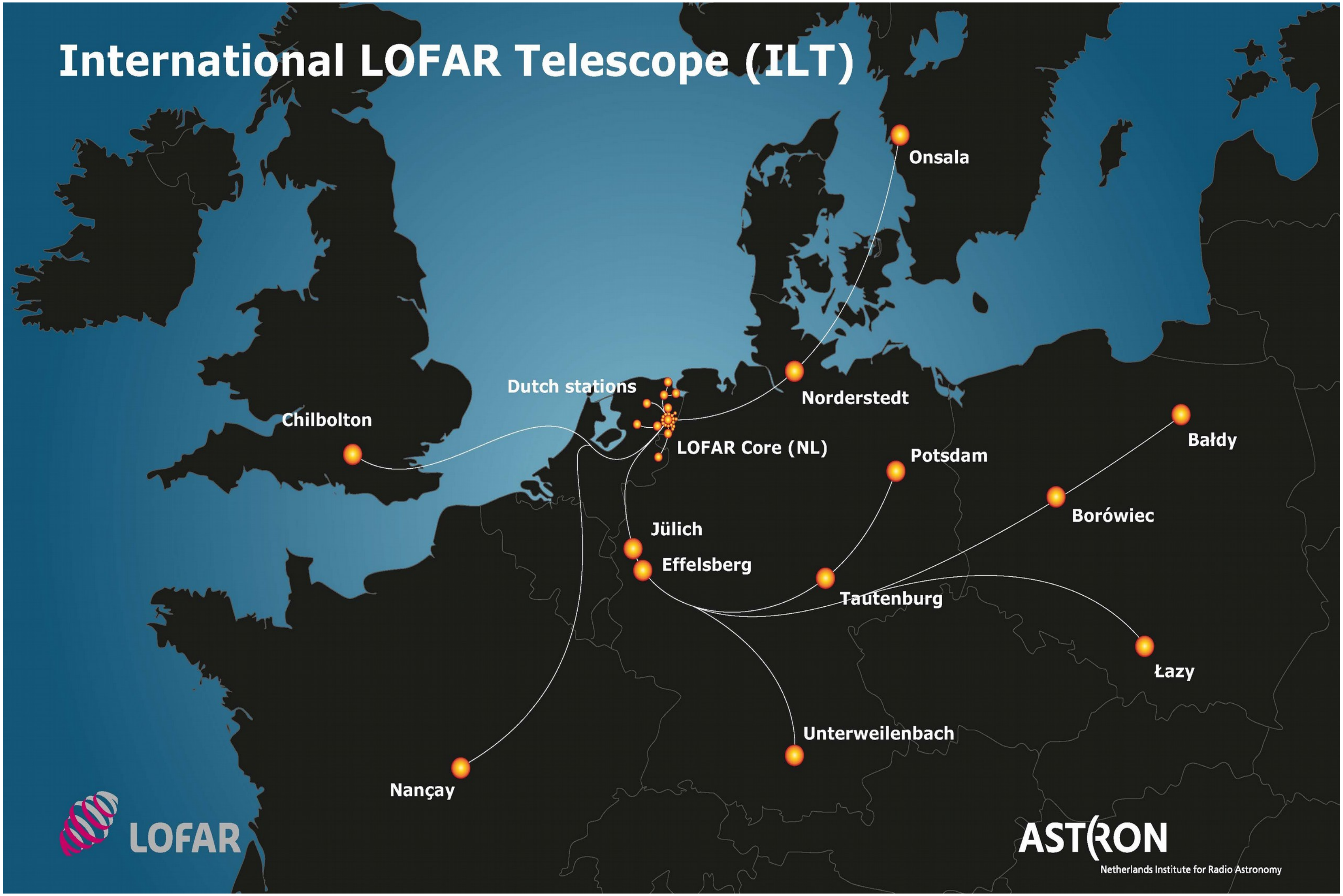


- Phase 2:
  - 160 TB/s from the antennas to the correlator
  - > 100 GB/s of data → 4.6 EB per year
  - 200 to 2000 dishes
  - 130K to 1M antennas

LOFAR

- Low Frequency Array
- Software defined radio-interferometer working at low frequencies (30 to 240 MHz)
- One of the Square Kilometre Array pathfinders

LOFAR Stations



LOFAR Stations

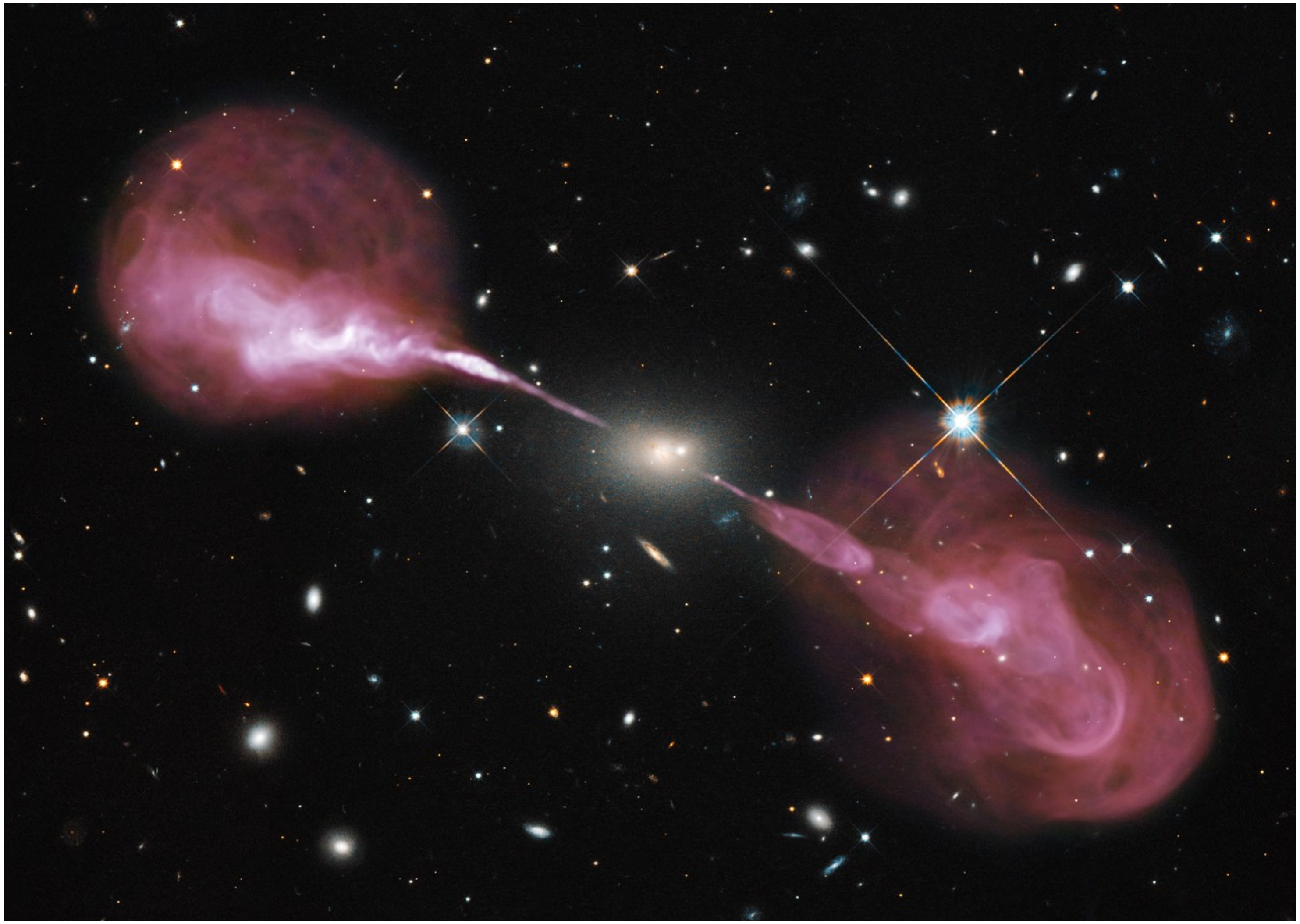
LOFAR frequencies

- LBA 30-80 MHz
- HBA 120-240 MHz

LOFAR science

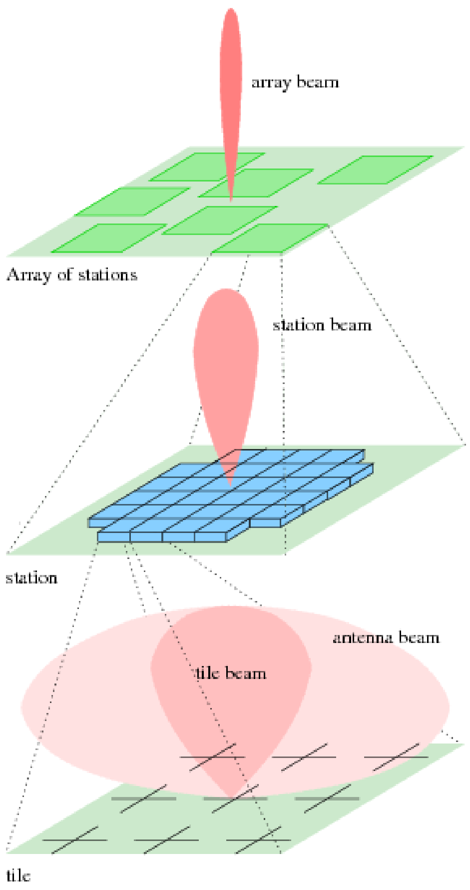
- Origin and evolution of galaxies and supermassive black holes
- Epoch of reionization
- Solar science and space weather
- Transients
- Map the galaxy using pulsars
- Exoplanets, SETI

Radio galaxies

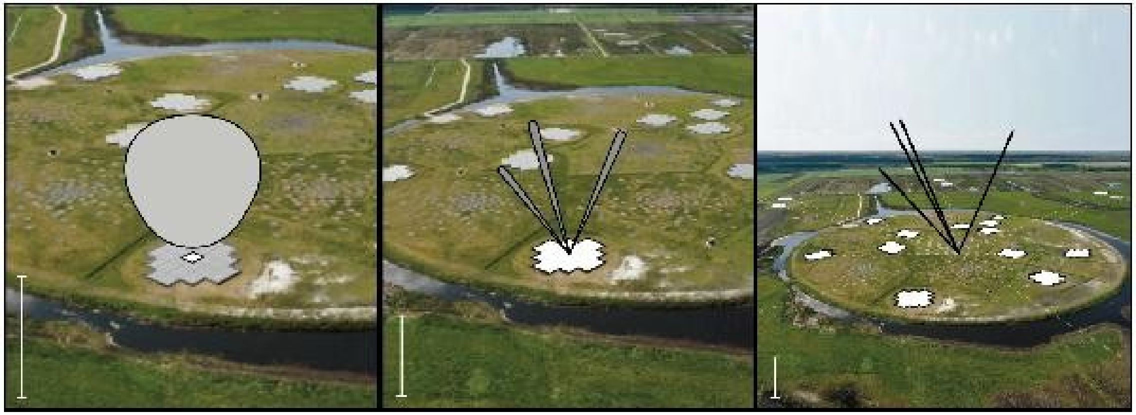


Hercules A. Credits: NASA and the NRAO

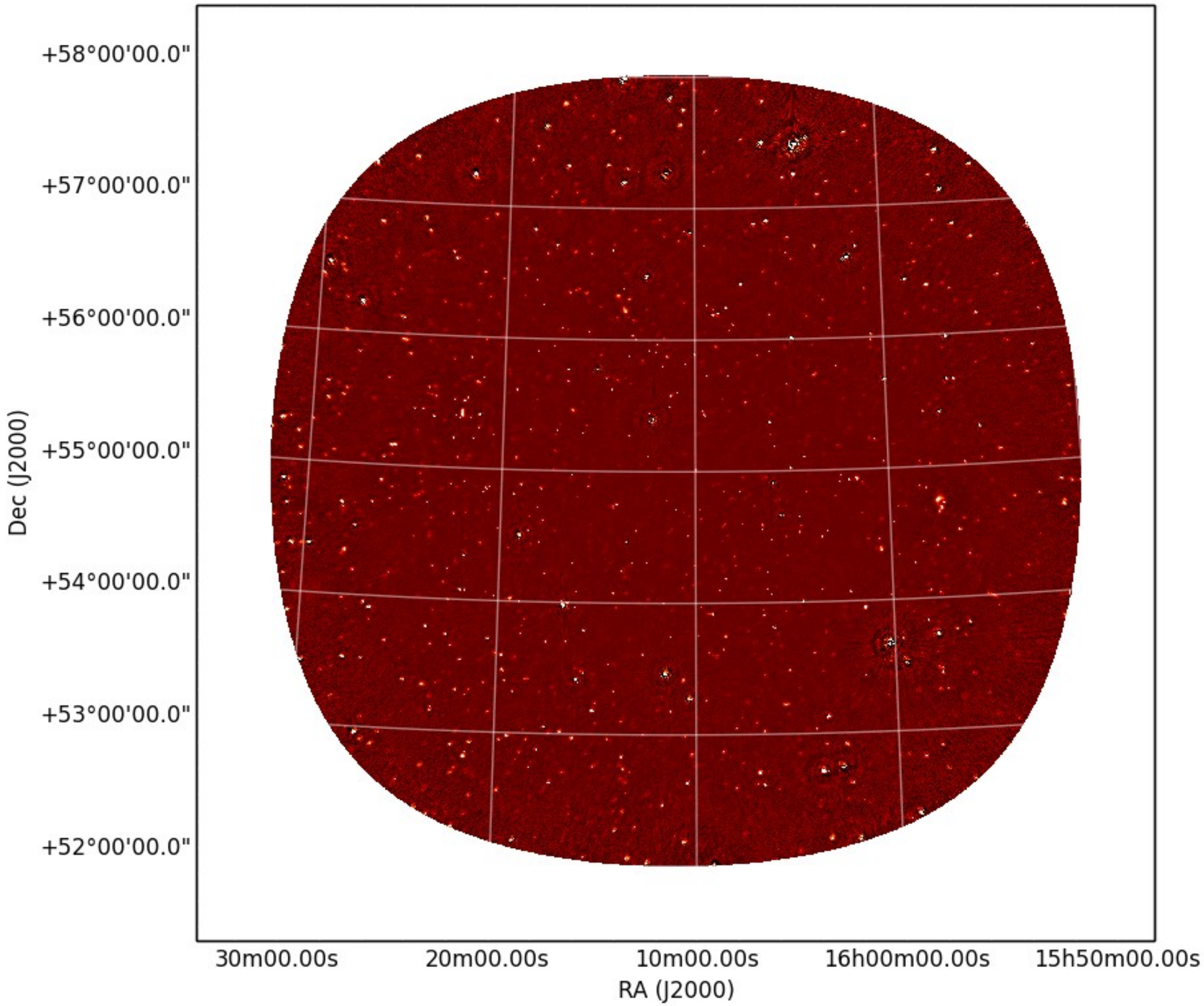
LOFAR aperture synthesis



- field of view diameter of ~5 deg at 150 MHz
- resolution < 5 arcsec (up to 0.1 arcsec)



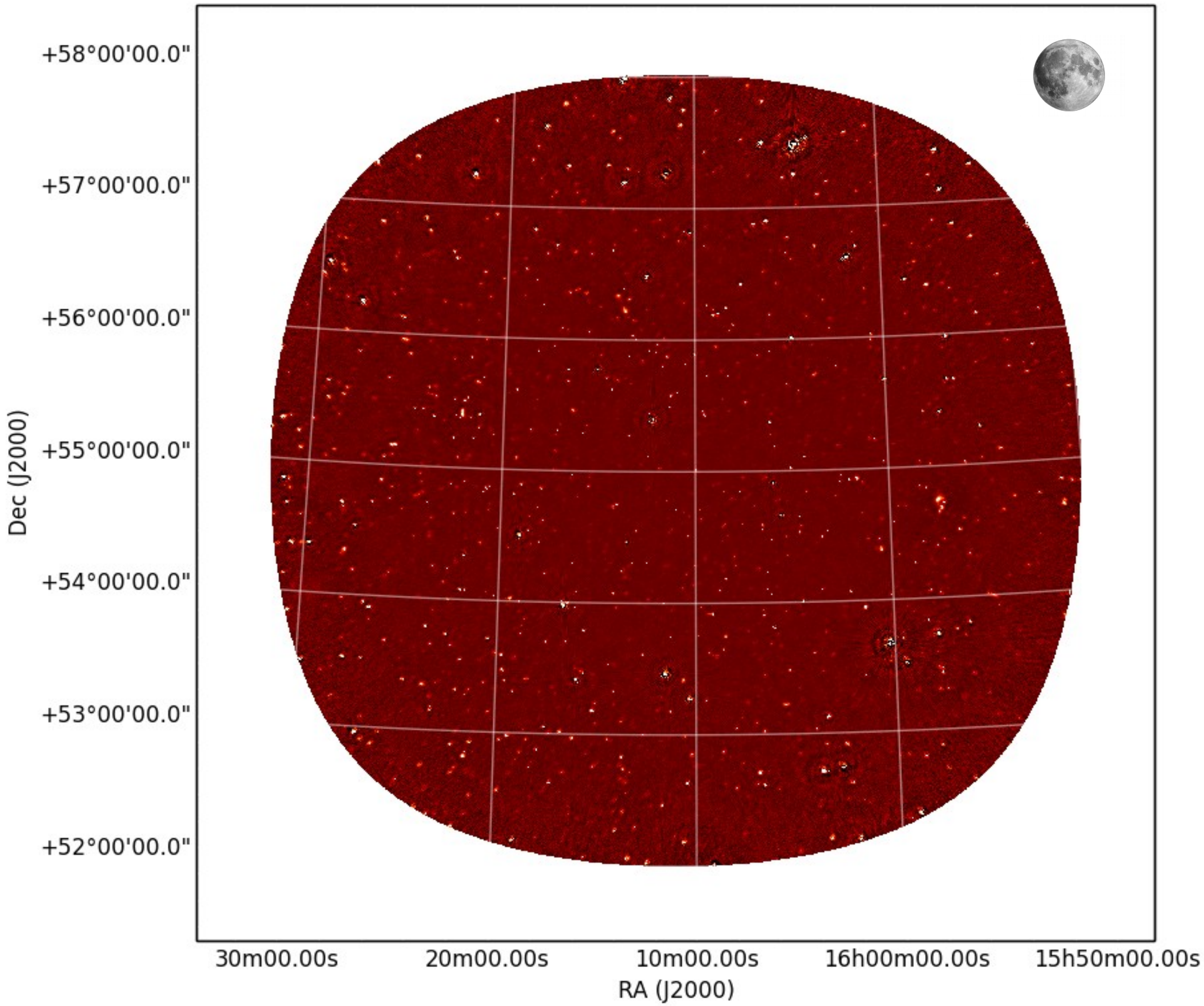
LOFAR imaging



In 8 hours
~40 sq. deg.
5000 sources

Calibration on
IAA (Granada) cluster

LOFAR imaging



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Calibration on
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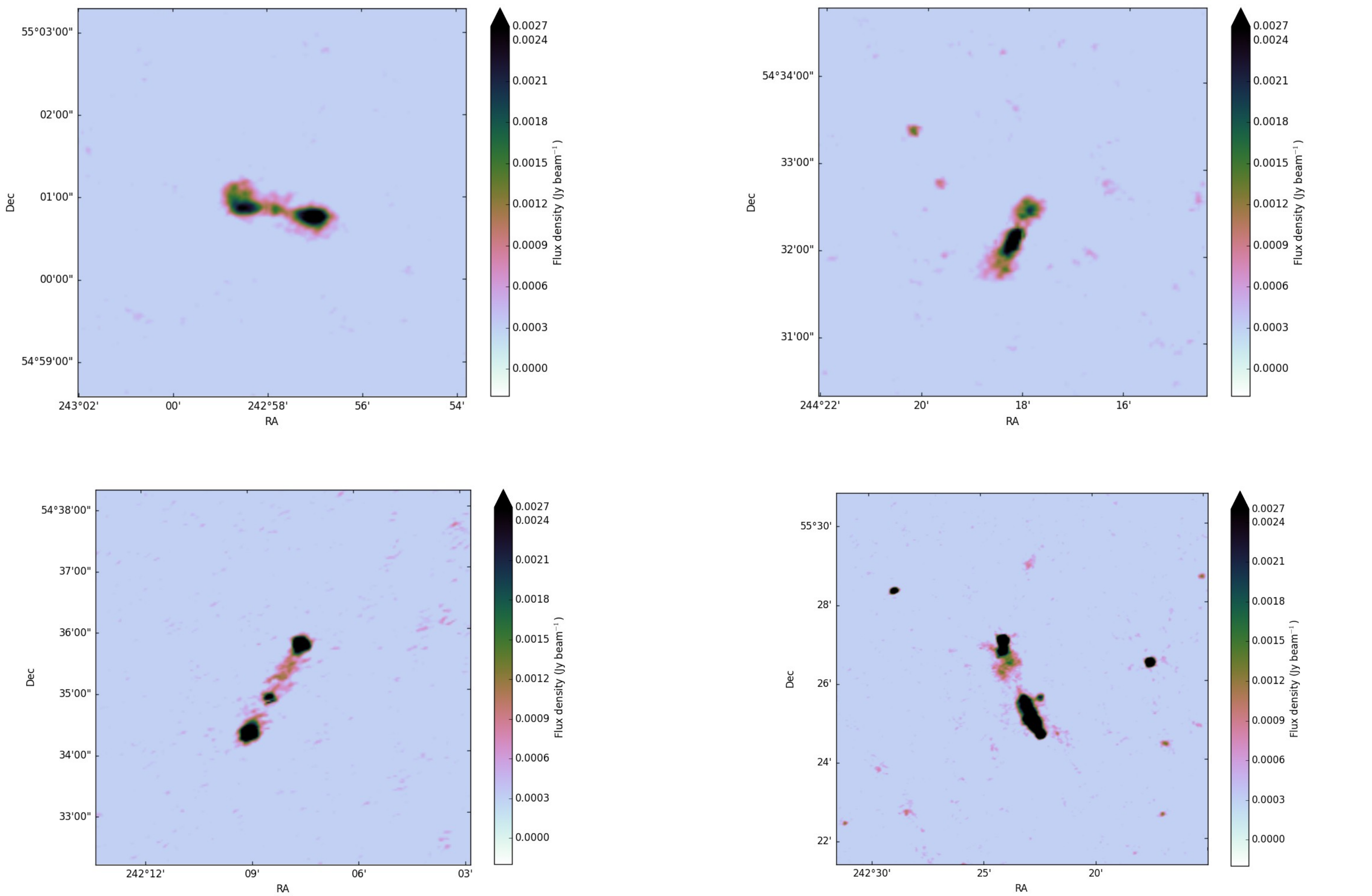
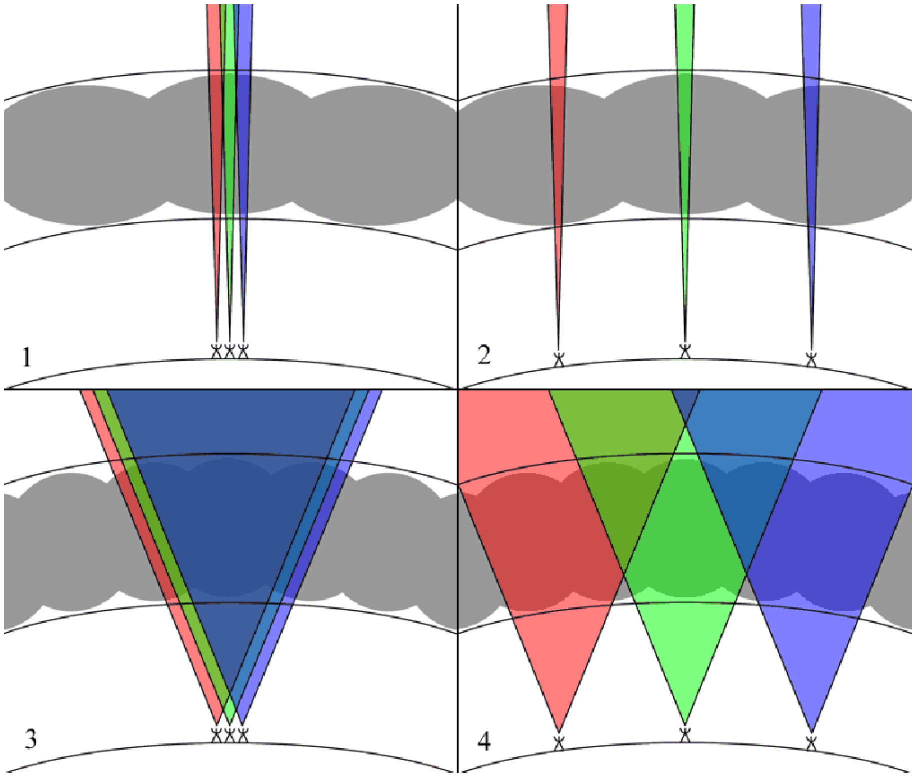
Extended sources



Ionosphere

- Effect depends on frequency, length of the baselines and f.o.v.
- LOFAR, worst case:
  - Wide field of view
  - Long distance baselines
  - Low frequency



H. Intema

Ionosphere

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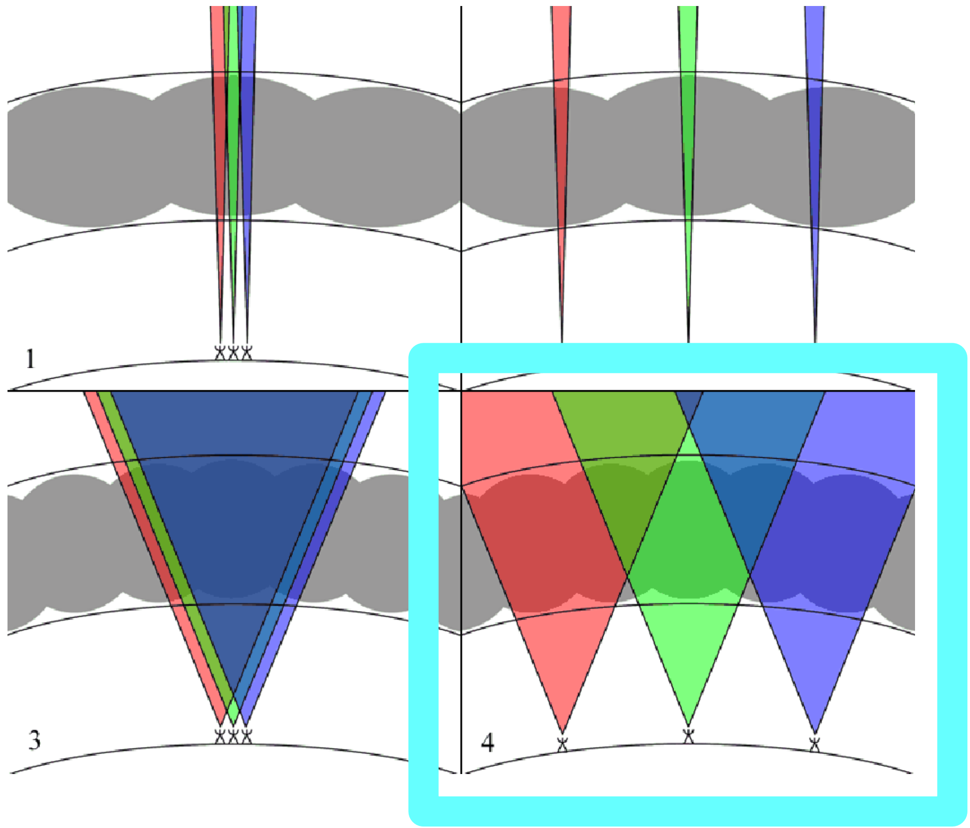

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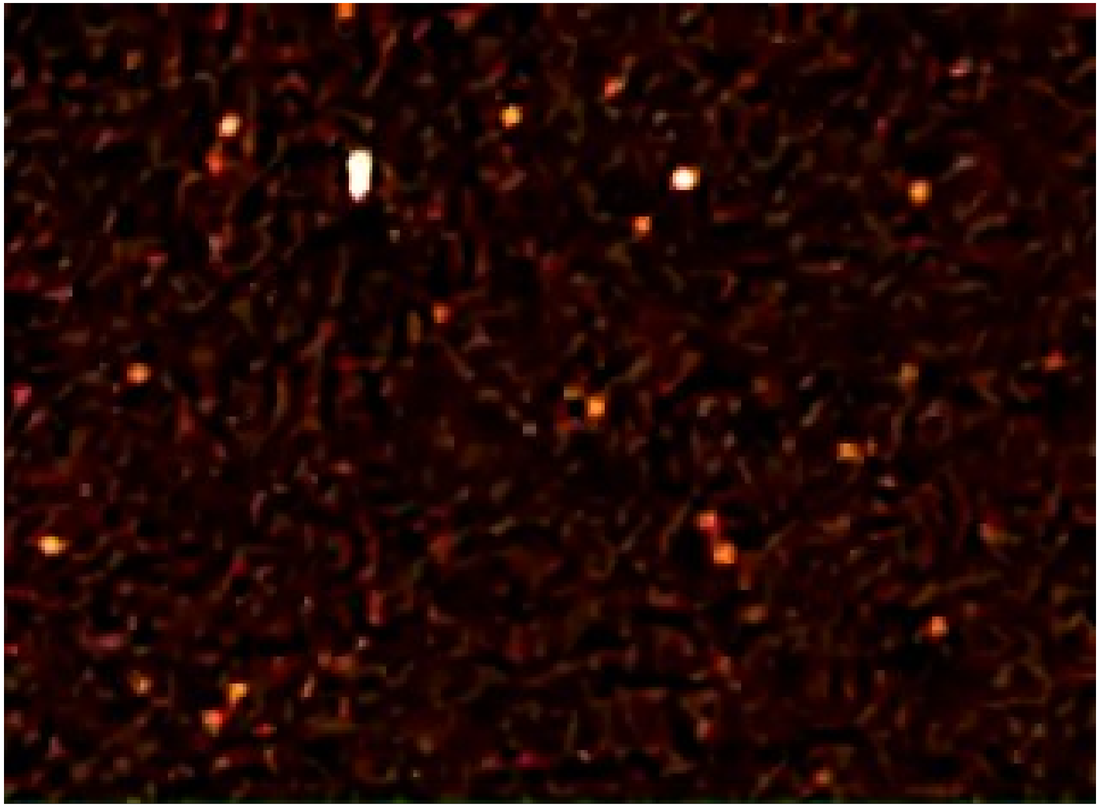


Challenges for the astronomer

- User data calibration (remove the effect of the ionosphere and the RFI)
  - 8 hours full resolution → ~20 TB
  - Minimum of 2 CPU years to run the calibration
  - Experimental pipeline
- LOFAR calibration software
  - Difficult to install
  - Continuous development

Computational solution needed

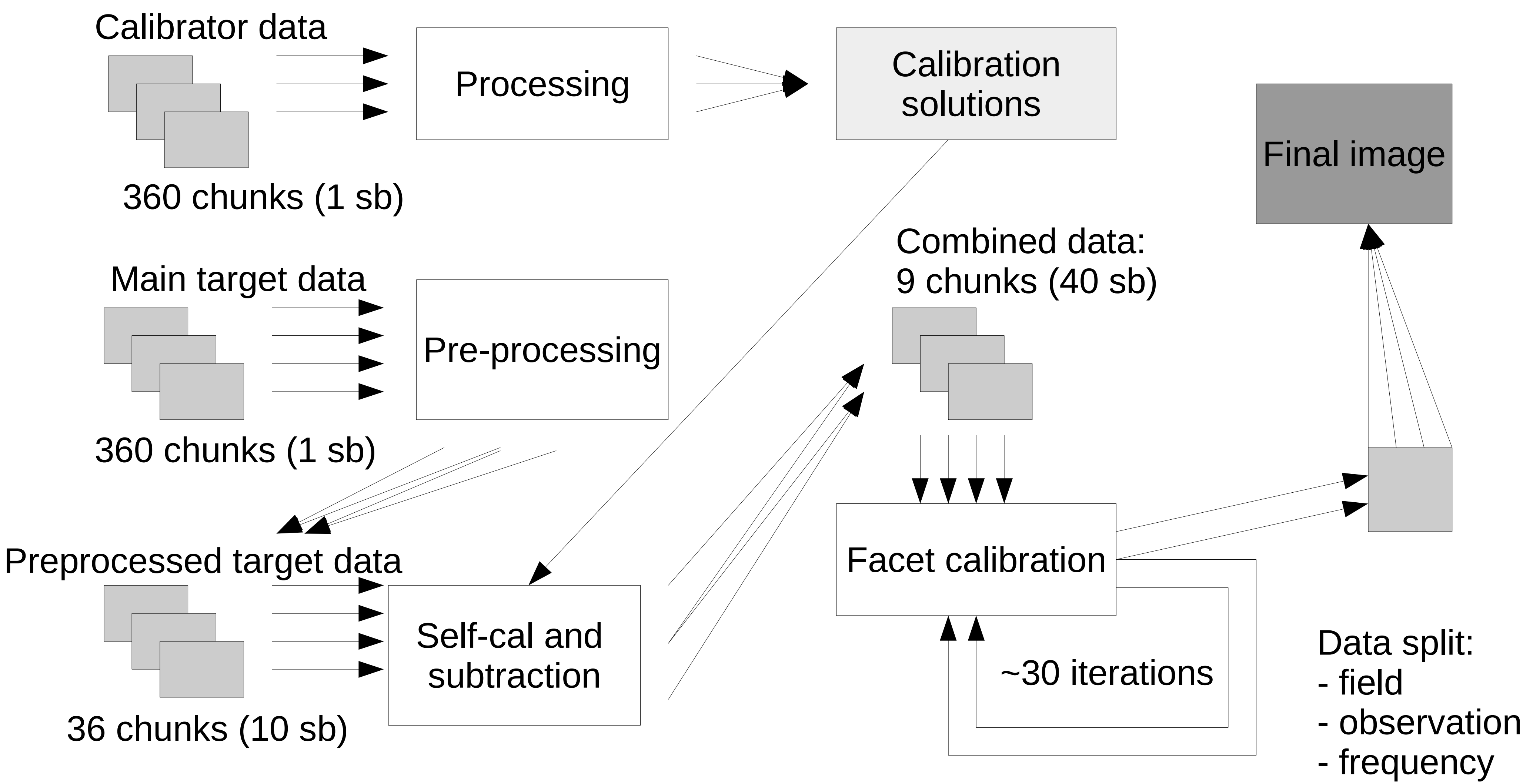
- Parallelizable:
  - Deal with a large amount of data in a reasonable time.
- Flexible:
  - Adapt the infrastructure (“hardware”) to different calibration strategies
  - Deal with quickly changing temperamental software
  - On-demand (optional but very useful)

HPC, HTC and cloud computing

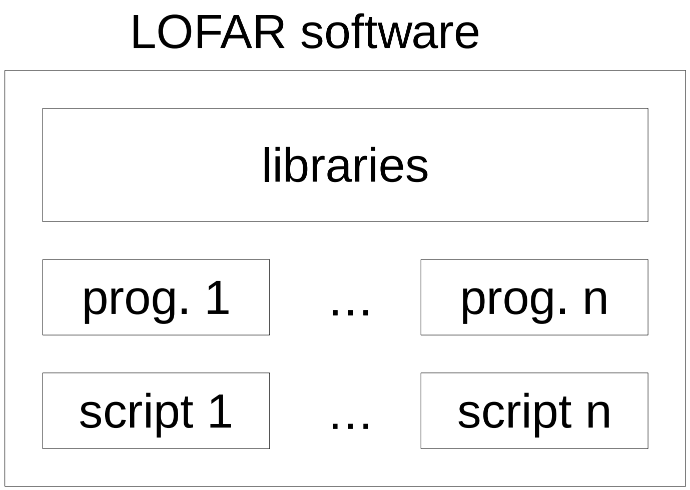
- Tests in different infrastructures: clusters, GRID, cloud, etcetera.
- SKA-AWS astrocompute proposal
  - Preparation of the base infrastructure (virtual machine images, check provisioning of spot instances, etc.)
  - Data transfer: 50 TB
  - Adapt calibration pipeline and run

http://www.lofarcloud.uk

Experimental calibration pipeline



The role of Python



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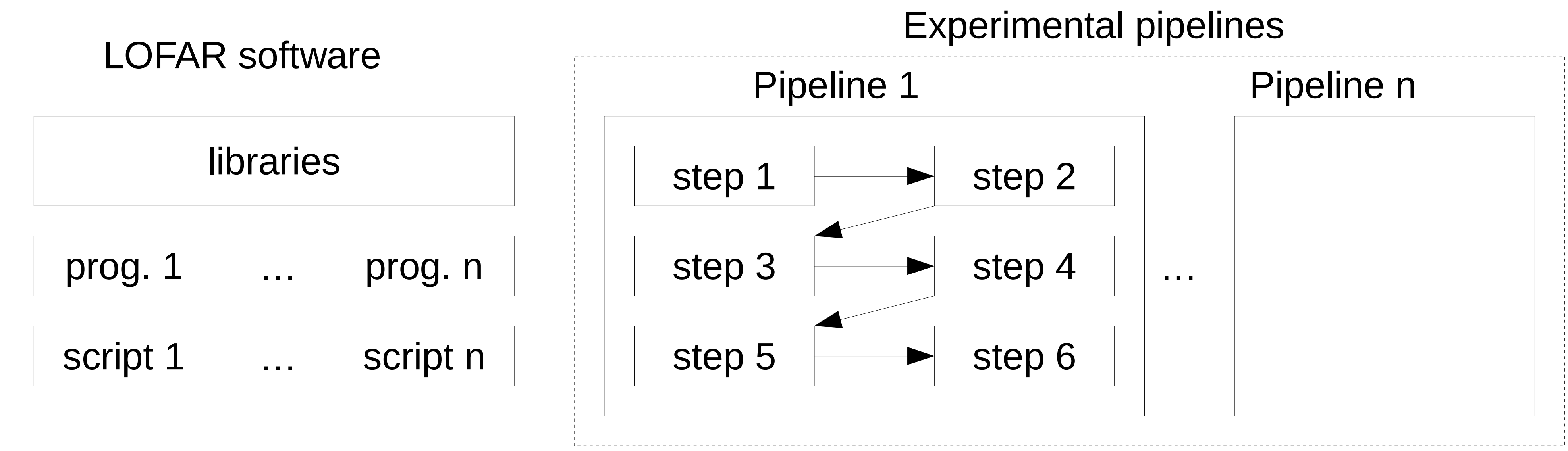

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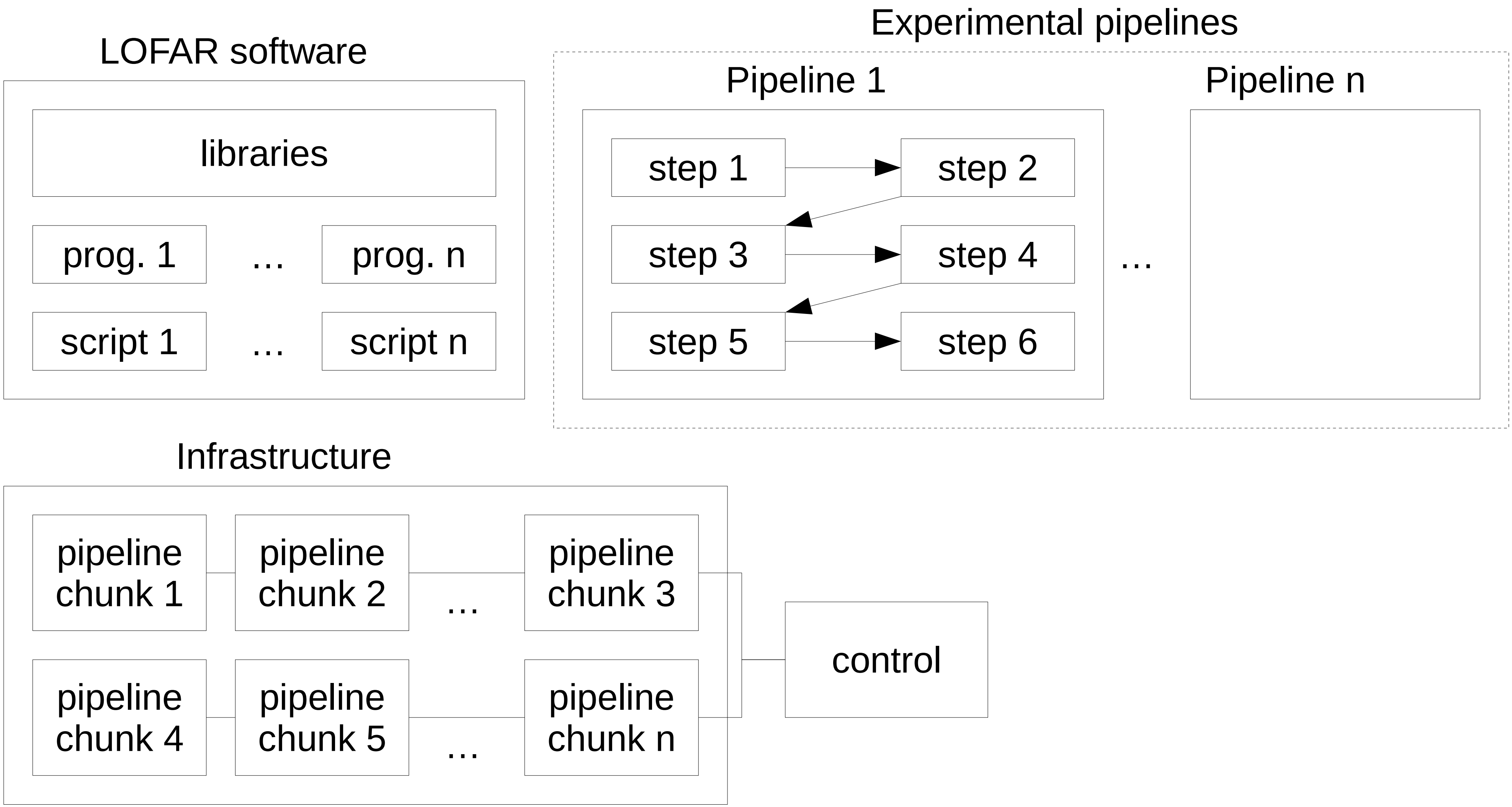

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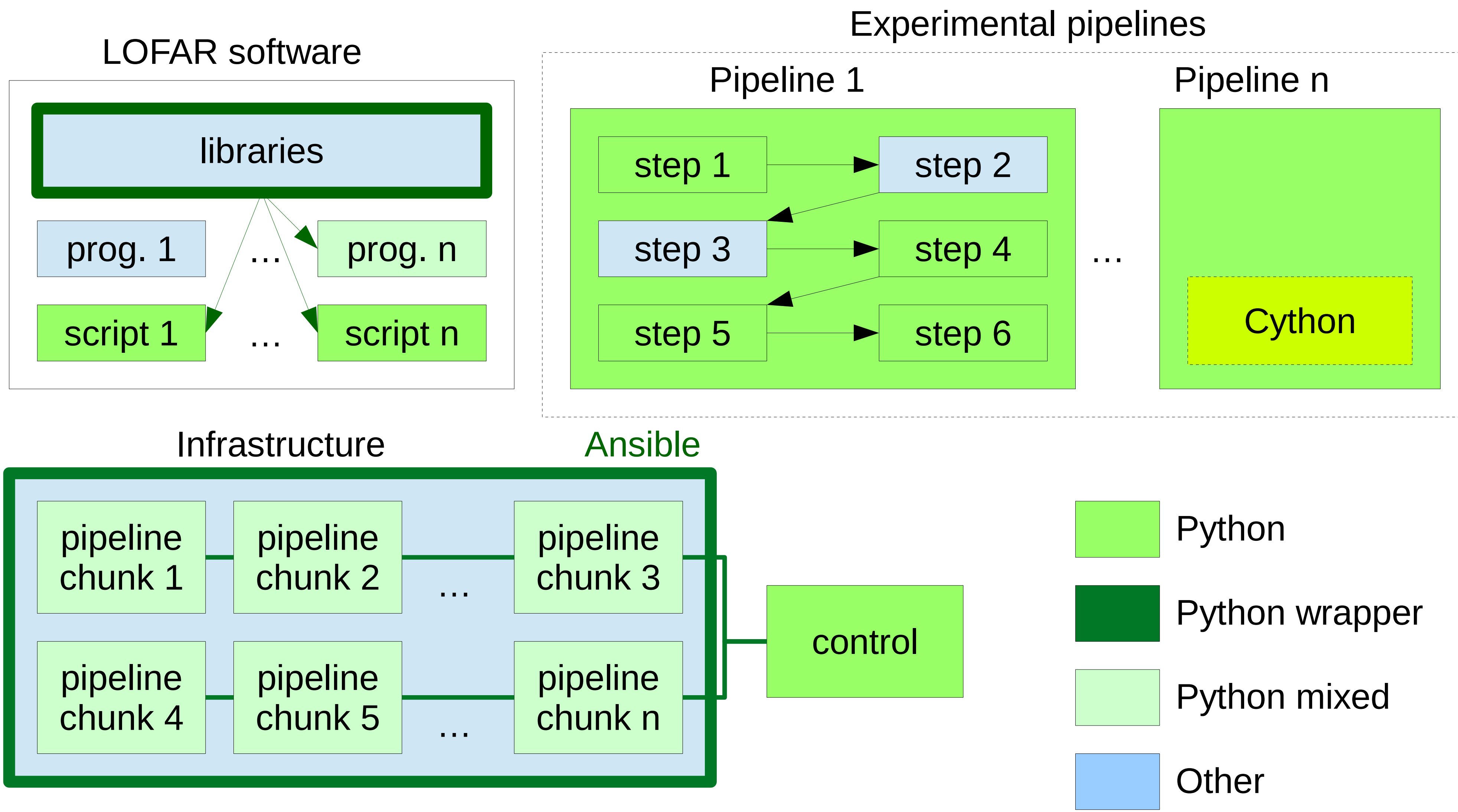

Summary

- Big software and data managing challenges associated to new astronomical infrastructures, even for final users.
- The role of Python:
  - Quick prototyping - fundamental for experimental pipelines and testing.
  - Multi-domain - Can be used for a wide range of problems.
  - Robust - Enough to write “real” efficient software.
  - Unifying tool - that holds all together.