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FRANCE 2030 PROGRAMME DE RECHERCHE NUMÉRIQUE POUR L'EXASCALE

SKA direction-dependent facet self-calibration use case

InPEx Workshop, Japan
April 15-17, 2025

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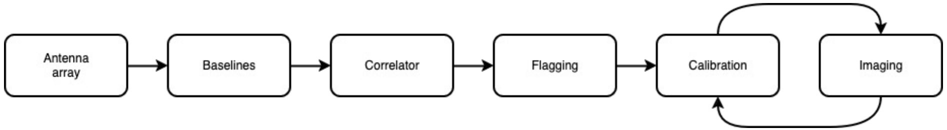
1. Context, the Square Kilometre Array (SKA)

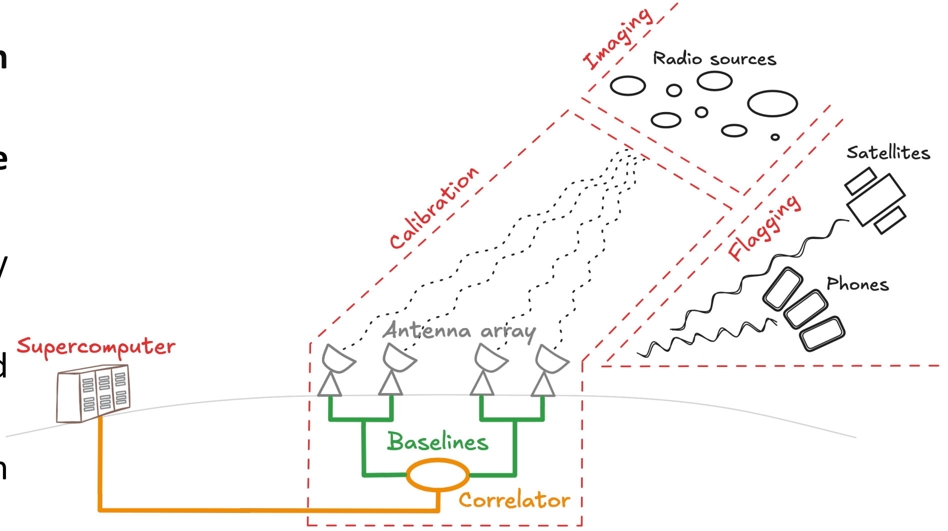
Overview of interferometers

The common data processing stages.



- **Antenna array** captures **radio signals** from **celestial sources**.
- **Baselines** measure the **distance** and **orientation** between pairs of antennas, defining **image resolution**.
- The **correlator combines signals** and **corrects time delays** to produce visibilities.
- **Flagging** identifies and **removes** radio frequency interference (**RFI**) and **corrupted data**.
- **Calibration corrects** for **instrumental** and **environmental effects**.
- **Imaging reconstructs images** of celestial sources from calibrated data.

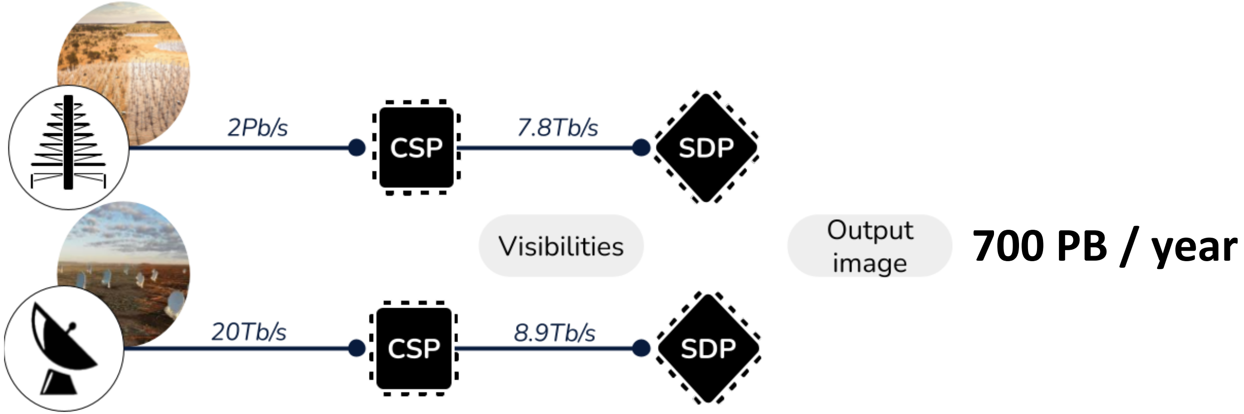
Interferometers data processing stages



Overview of the Square Kilometre Array (SKA)

Next generation radio telescopes

- The **SKA international radio telescope project**, consists of **antennas and dishes** located in **Australia** and **South Africa**. It **converts voltages into visibility** through the **CSP** pipeline processor and transforms these **visibilities into output images** using **SDP** processors, **generating 700 PB of data products per year.**

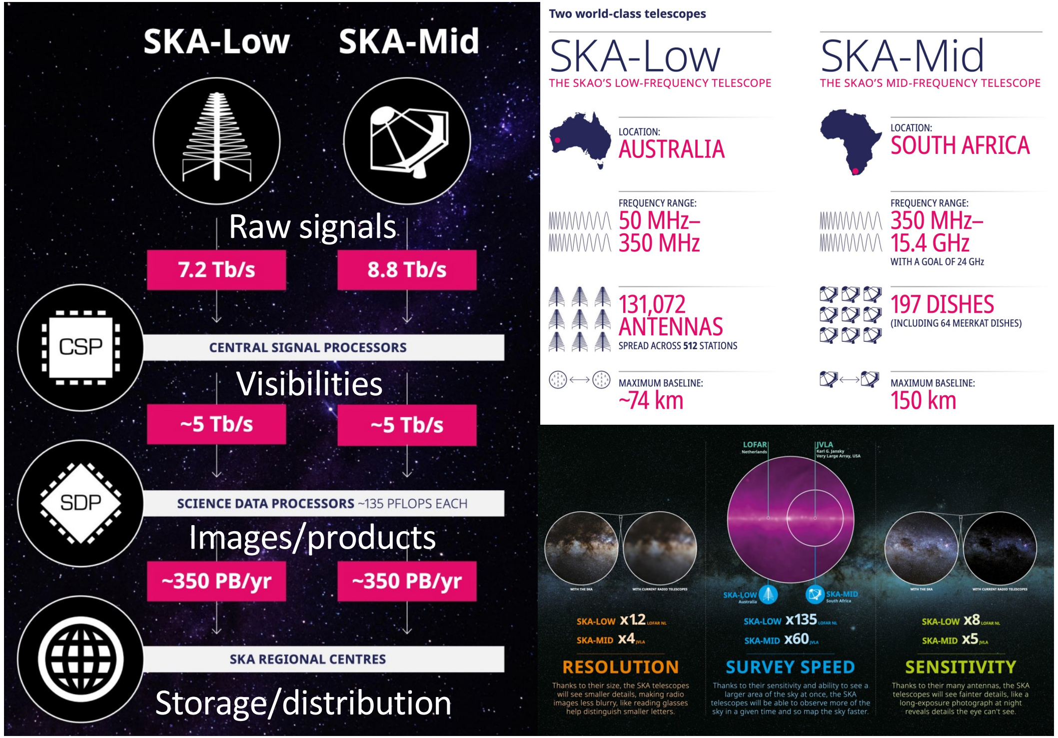


SKAO data processing stages

The SKA key challenges

Scaling up and resources allocation to handle several terabytes per second.

- **Scaling Up**: the SKA is expected to generate **700 PB of data per year**, posing significant challenges in **processing, storage and transport**.
- **Current state**: there is a **gap** between the **massive data volumes** being captured and the **resources and tools** available to process, store and transport this data effectively.
- **Future needs**: Meeting the challenge of **SKA's data scale** requires the creation of **advanced data processing tools** and a transition to **exascale computing**.



SKAO data processing stages

2. ECLAT, french virtual laboratory for astronomy

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ECLAT virtual laboratory

16 laboratories and teams to co-design future worfklows for astronomy.

- ECLAT (**E**xtreme **C**omputing **L**ab for **A**stronomical **T**elescopes) is a collaborative laboratory uniting **16 laboratories and research teams** to **co-design** and develop future **cyber-physical systems** for **astronomy.**
- Laboratory dedicated to **High-Performance Computing** (HPC) and **Artificial Intelligence** (AI) for **astronomical instrumentation.**
- **France contribution** to the **SKA** project by developing solutions for **supercomputer design**, **computational processes**, and **high-performance data transport**, **storage**, **compute** and **distribution.**
- **Directed by Damien Gratadour https://eclat-lab.fr/en/**

SEAMS
Project on new frugal technologies for intensive computing

STREAMS
Platform for the integration of new computational and AI technologies

Rising Stars
International Network on Cyber-Physics Systems under Real-Causes

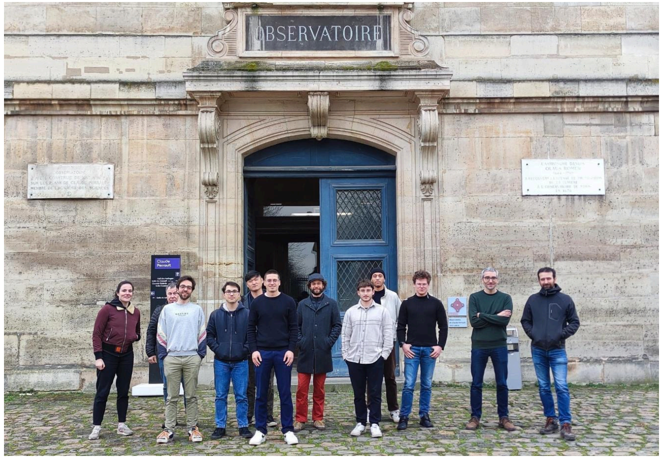
Numpex
NumPEx brings together 5 projects focusing on Exascale

ECLAT partners

ECLAT news

Hackathons, general assemblies, workshops, webinars each month…

- **First hackathon the 3-5th of February in Paris.**
  - **Code parallelization with MPI (both imaging and calibration software).**
  - **Jean Zay supercomputer deployment and testing.**
  - **Validation of new algorithmic approaches (deconvolution methods).**
- **Next hackathon the 2-6th of June in Brittany.**
  - **Study of software memory and I/O footprint.**
  - **Full code parallelization integrated in the ddf-pipeline.**
  - **Algorithmic approaches development, to reduce memory footprint.**



Participants in the first ECLAT hackathon at Paris Observatory

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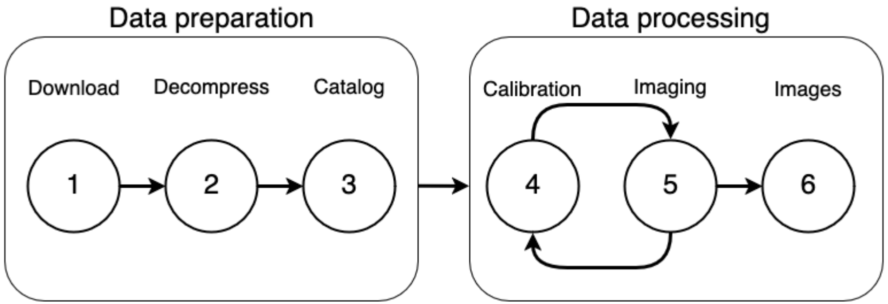
3. ddf-pipeline

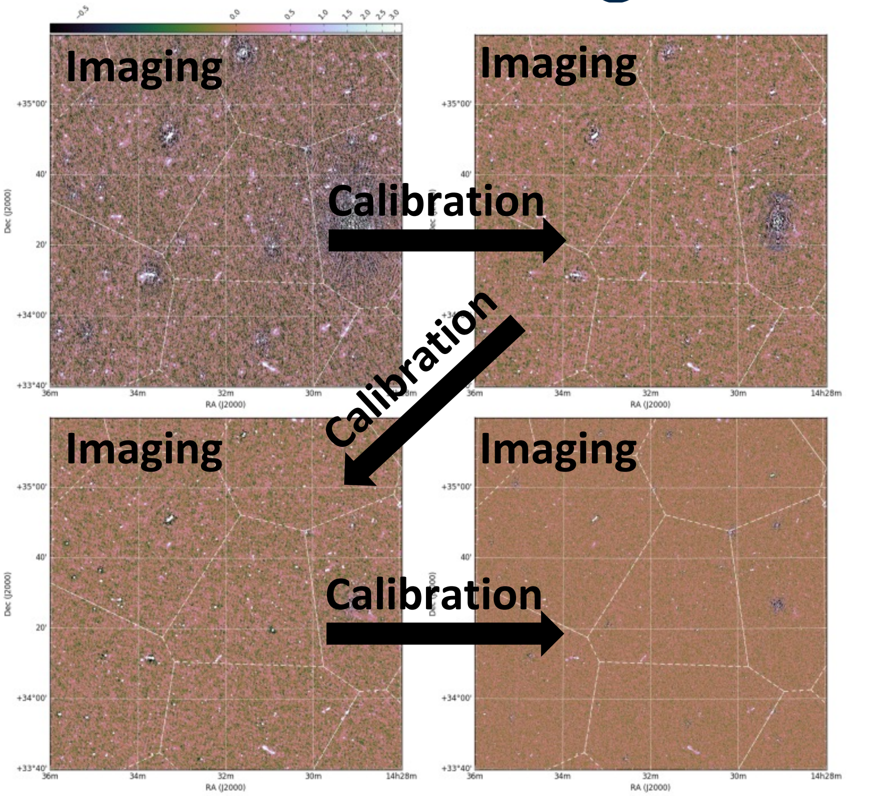
Overview of the ddf-pipeline

Radio astronomy data processing software.

- **Public software repositories.**
  - **ddf-pipeline**: https://github.com/mhardcastle/ddf-pipeline
  - Imaging, **DDFacet**: https://github.com/saopicc/DDFacet
  - Calibration, **killMS**: https://github.com/saopicc/killMS

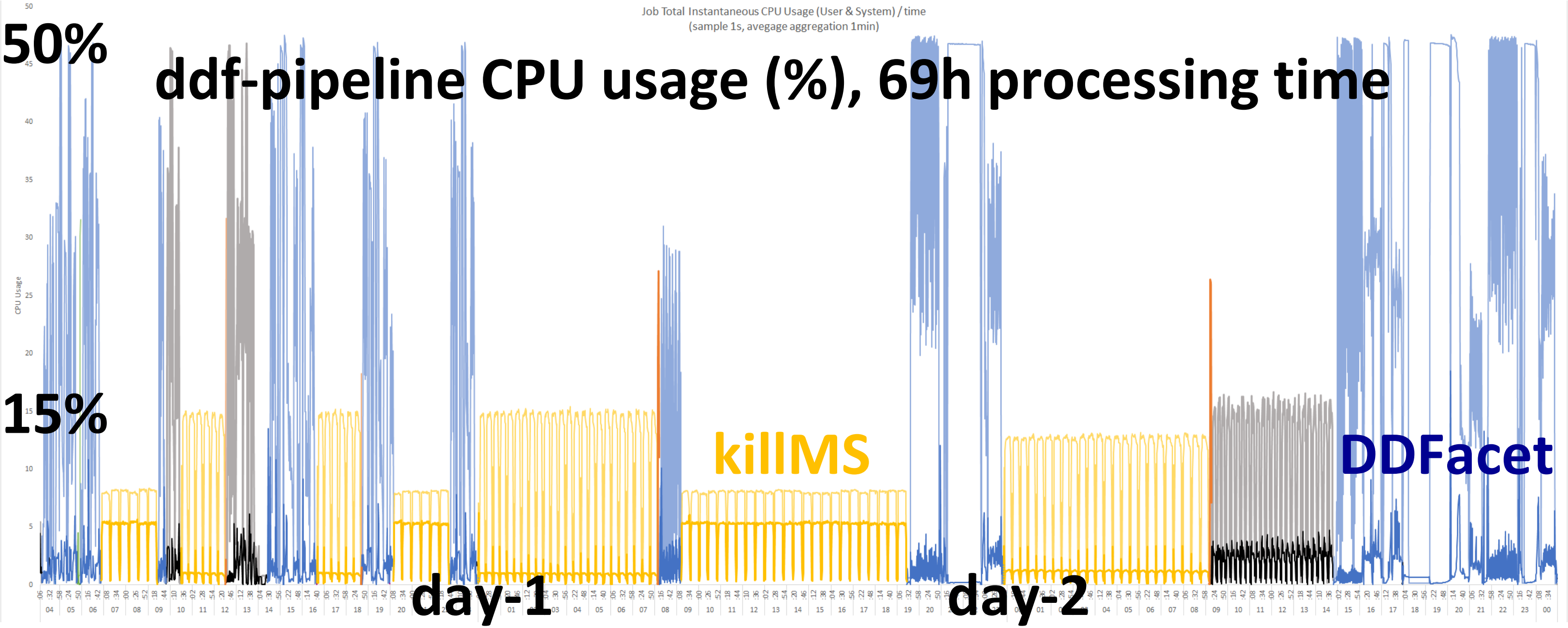


Main steps of the ddf-pipeline software



Tasse, Shimwell, Hardcastle et al. 2001

LogicA team, ddf-pipeline deployment in Eskemm Numérique



ddf-pipeline total execution CPU usage in %, dool monitoring tool

Eskemm single node, 128 CPU, 2 x AMD EPYC 7543 32-Core, 512 GB RAM

75h total execution, 69h for processing, 37h for calibration killMS, 23h for imaging DDFacet