Computation in space missions: the Euclid case

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The Euclid mission

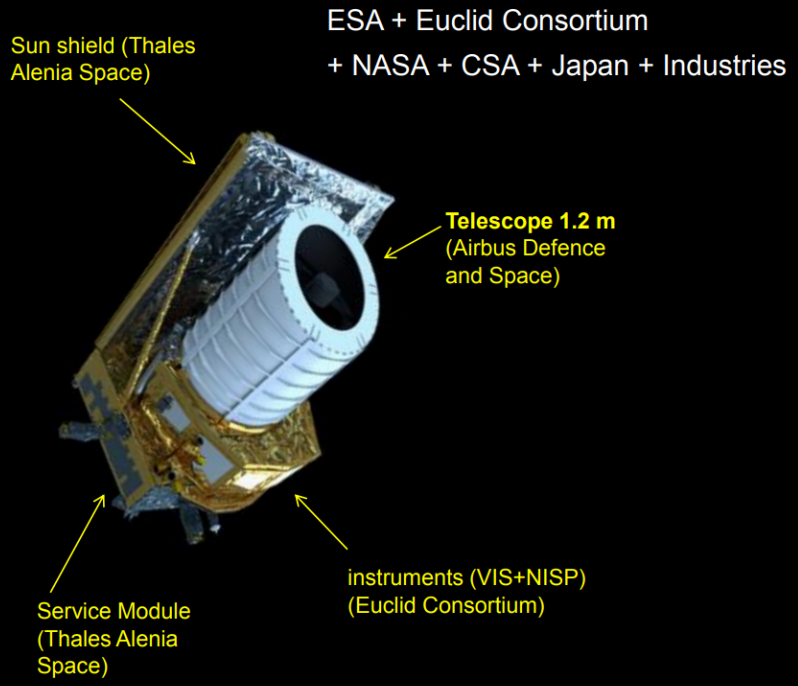
M2 mission in the framework of the **ESA Cosmic Vision Programme**

Euclid mission objective is to map the geometry and understand the nature of the dark Universe **(dark energy and dark matter)**

Actors in the mission: **ESA** and the **Euclid Consortium** (institutes from 14 European countries, USA, Canada, Japan, funded by their own national Space Agencies)

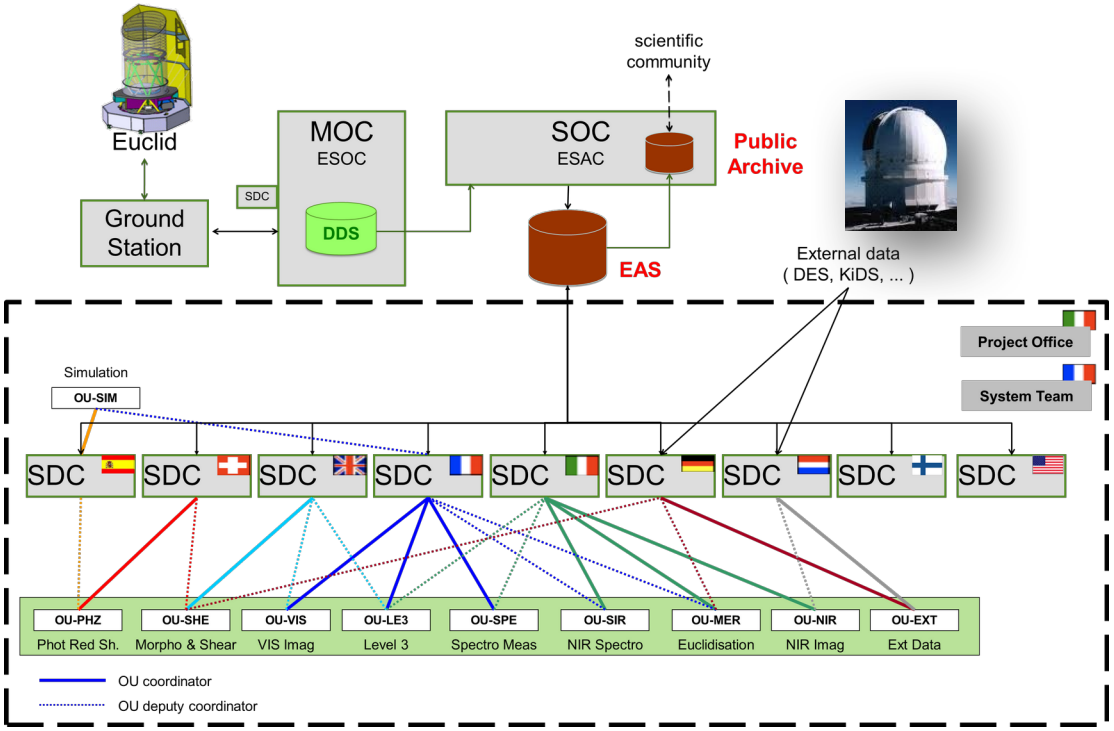
Euclid Consortium:
17 countries
200+ institutions
2700 members

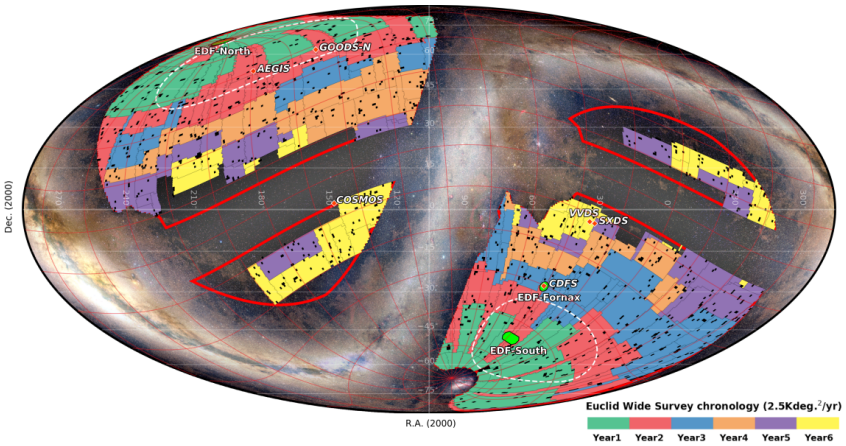
- ➢ 2008 – 2009: Assessment Phase
- ➢ 2010 – 2011: Definition Phase
- ➢ 2012: Adoption by ESA
- ➢ 2015: PDR → construction
- ➢ 2018: CDR passed
- ➢ 2023: launch in July (Space-X Falcon 9)

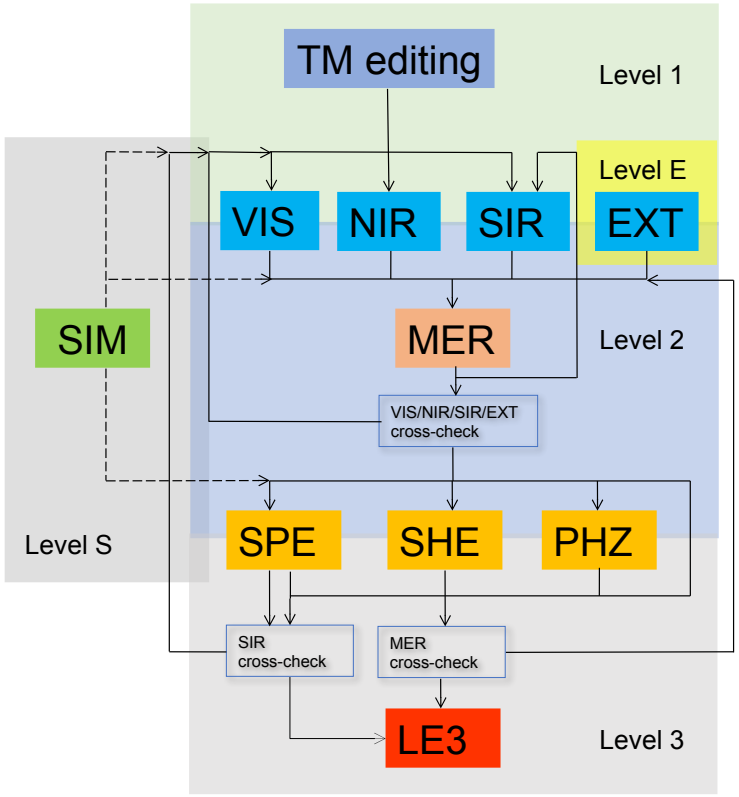


For more information see :
https://www.esa.int/Science_Exploration/Space_Science/Euclid
http://www.euclid-ec.org

Euclid Ground Segment

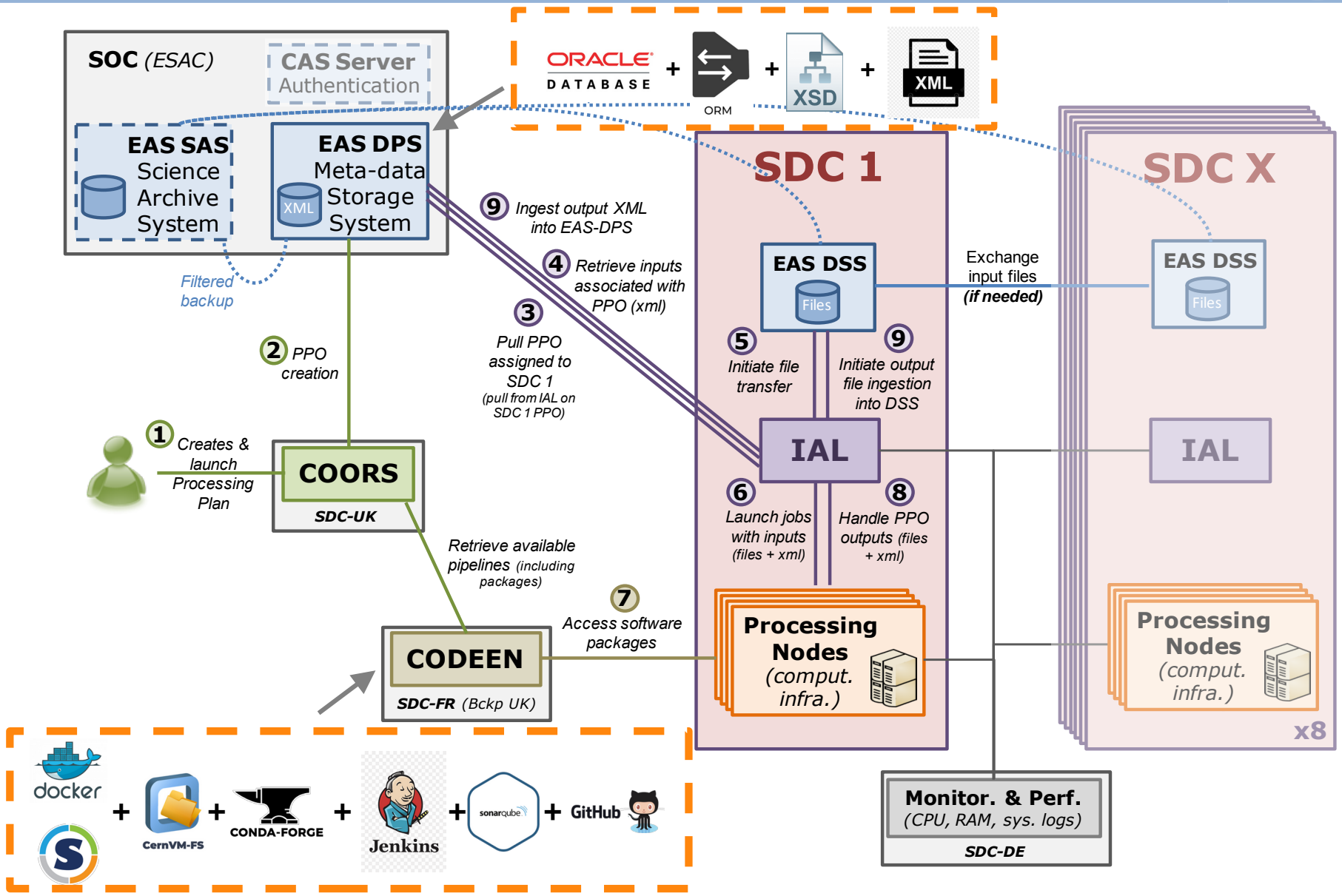






20-30 PB
(EXT data included)

The SGS software infrastructure



Data model, Metadata archive, Object Storage

- **Euclid common data model**
  - Formalized with the XSD language (with guidelines)
  - Description of metadata (and data)
  - Corresponding API with bindings in python and C++
- **Euclid Archive System (EAS)**
  - central metadata archive based on Oracle
  - Object-to-relational mapping
  - Custom query language (data product oriented) with REST API
  - Results as XML files

Some issues met:

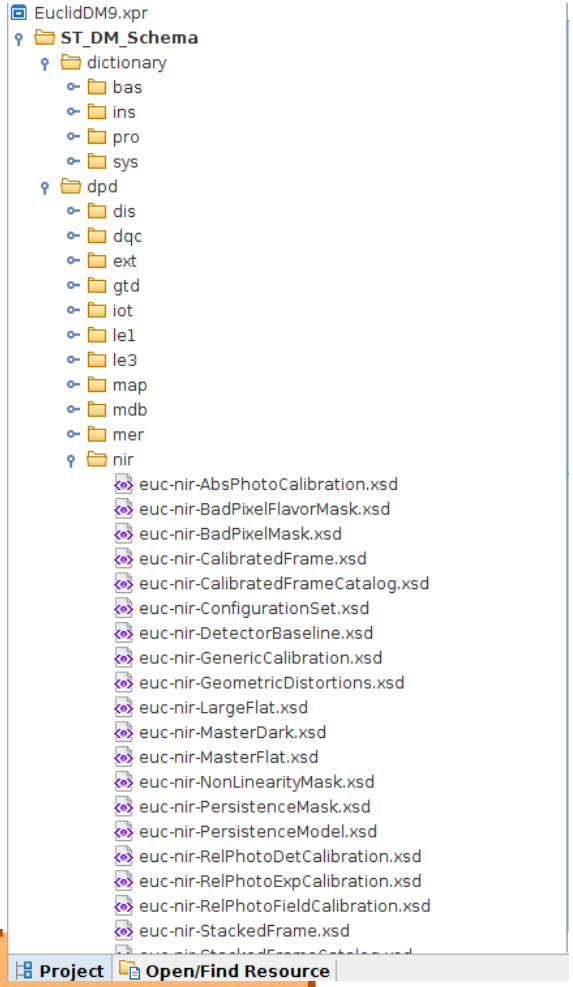
Metadata updates to be agreed periodically (through CCB)

Too much nesting in the metadata descriptions

- **Distributed Storage System (DSS)**
  - implementation of a distributed Object Storage (one instance per SDC)
  - transparent location of the file from any instance and http transfers

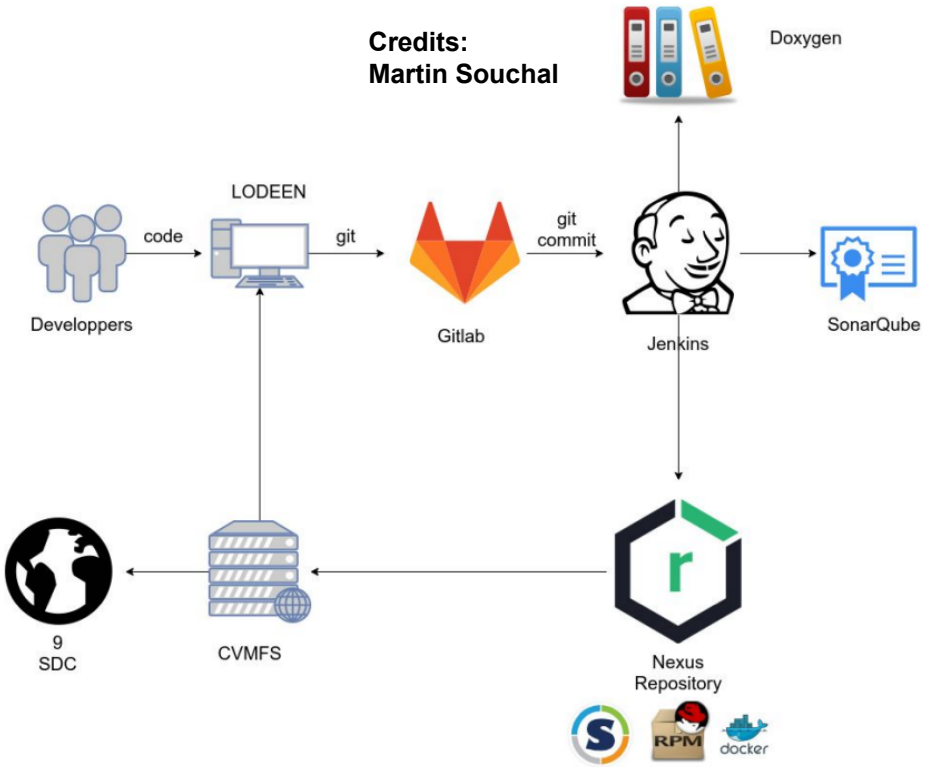
Some issues met:

HTTP not suitable for a band saturating transfer (mitigated with multiple files batch transfers)



Software workflow in the Euclid SGS

- Processing pipelines organized in several software projects
  - Possible dependencies between them
  - Branches: develop, release-x.x
- In SDC-IT, custom gitlab runner for commits and merge req.:
  - Building and unit test issues
  - Badges creation (redmine links, license, etc.)
  - Deployment in custom node (with GPU)

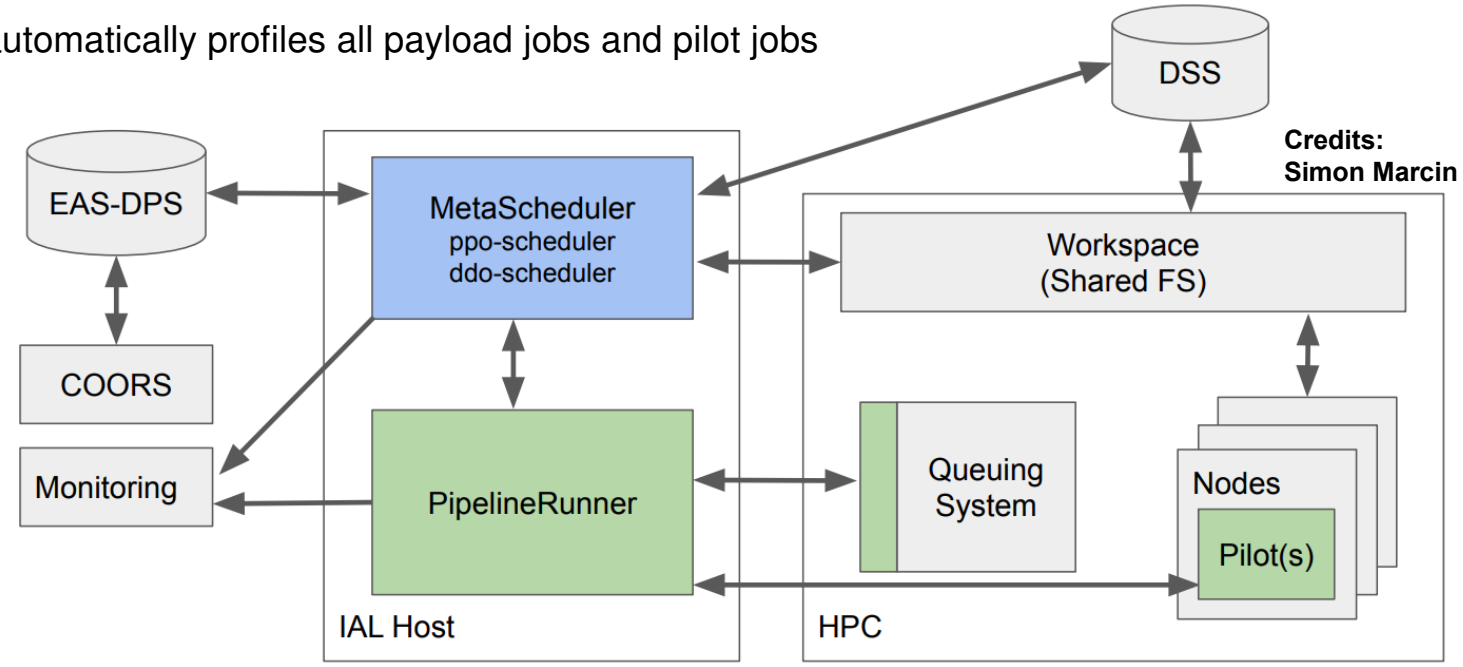


Jenkins stages per project

	check	build	doc	test	quality	package	deploy	test-release-deps	Declarative: Post Actions
Average stage times: (Average full run time: ~7min 57s)	24s	25s	55s	10s	1min 51s	1min 18s	2min 22s	19s	2s
#5 Sep 02 17:21 No Changes	24s	25s	55s	10s	1min 51s	1min 18s	2min 22s	19s	2s

Infrastructure Abstraction Layer

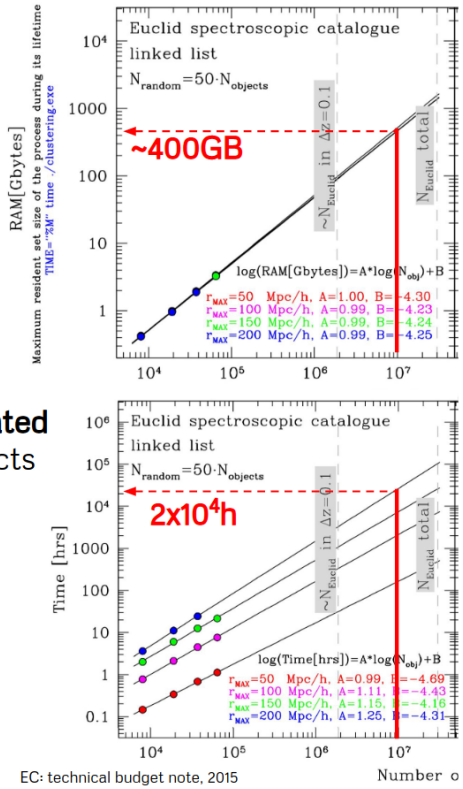
- Both a meta-scheduler and a workflow manager
  - IAL DRM: abstraction over several queuing systems
- Python language to define the workflow (with custom interpreter)
- For each task we define
  - resources: n. cores, peak RAM, max walltime
  - File input and output ports
- From one job per task to the so called pilot jobs
- It automatically profiles all payload jobs and pilot jobs



Code optimization – SDC-IT team

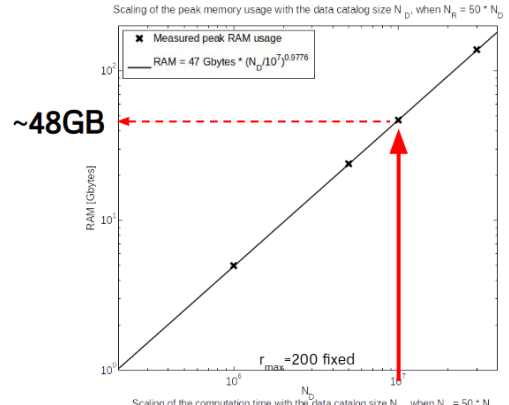
- Example: LE3 Galaxy Clustering 2-point correlation function software

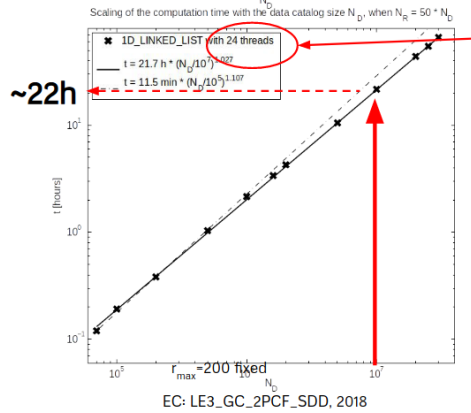
Before…
on Euclid **estimated** size of ~10^7 objects



EC: technical budget note, 2015

…after **measured** on simulated catalogs (ML2A)



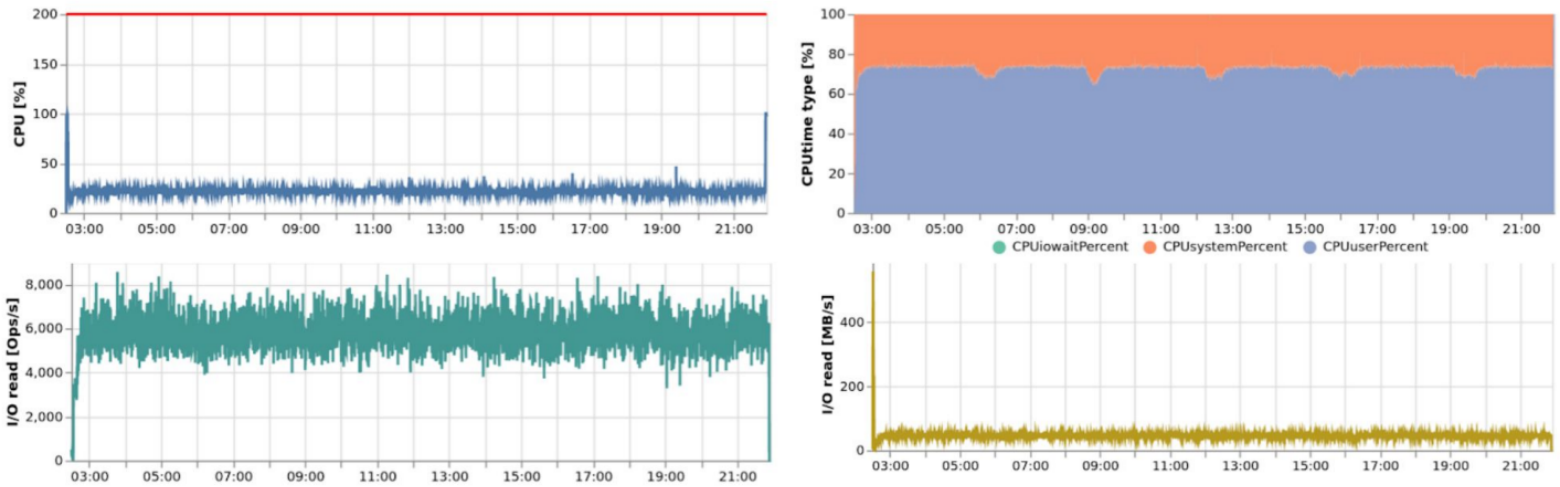


24 threads

EC: LE3_GC_2PCF_SDD, 2018

I/O intensive tasks and issues

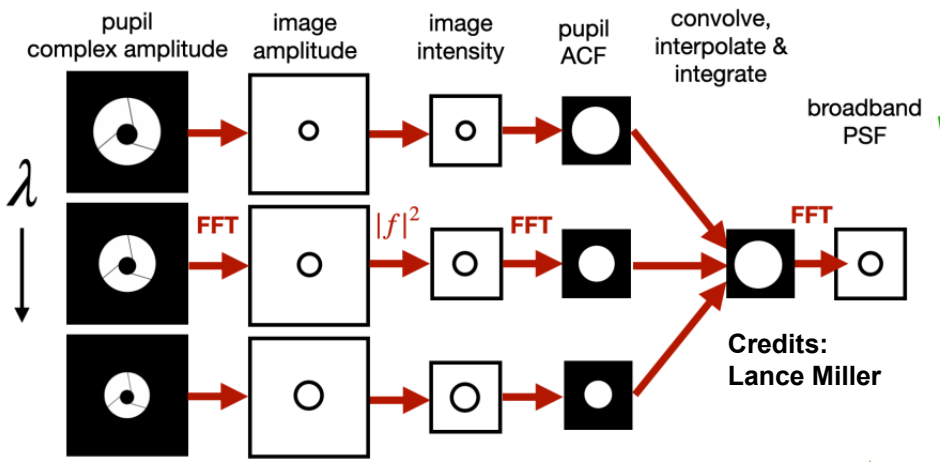
- Few tasks within the SGS pipelines have very high I/O rates, causing issues when using a network file system
  - Low CPU usage, 10 times higher walltime, slow down of the network file system (crash in some cases)



- Most of the time, solved by re-engineering the I/O part of the software
- However, local /tmp storage (~1 TB) requested for each node of the SDCs, to workaround I/O intensive tasks that cannot be modified

GPU computing

- GPU usage has been limited for production software in Euclid
- Knowledge of the VIS PSF is fundamental to the weak lensing shear measurement
  - must meet extremely challenging requirements
  - both accurate and fast
- Initial model calibration requires a relatively small dataset
  - 120 VIS exposure x 12 pointings
  - Just one pointing results in performing some 5.4M PSF Generations (500 stars x 120 exposures x 9 parameters x 10 iterations)
- 264 CPU/GPU-hours vs 27,000 core CPU hours per pointing
- Mission and time critical (1-2 days max processing):
  - PV and pre-survey phases
  - Monthly PSF calibration
  - Post-thermal-decontamination



Legacy software re-engineering

- Several Euclid pipelines depend on the AstrOmatic software
  - SExtractor (source detection, background estimation)
  - SWarp (image coadding, mosaic creation)
  - SCAMP (astrometric solution)
  - PSFEx (Point Spread Function estimation)
- Some workaround were necessary to build them in recent distributions
- Necessity to add new methods to the existing software
- Guarantee maintenance for the mission lifecycle
- Re-engineering effort, in C++, performed by several groups within Euclid, involving
  - SExtractor++ (SDC-CH and SDC-DE)
  - SWarp++ (M. Kuemmel, SDC-DE)
  - SCAMP++ and PSFex++ (ALTEC, with the support of OU-NIR and SDC-IT)
  - Significant FTEs involved. As an example, SCAMP+PSFex overall have required a total of ~1.3FTE for (in ~2 years) and work is still on-going
  - Maintenance must be planned

Computing infra procurement planning

- Resources estimation
  - periodic end-to-end tests with simulations and prototype analysis software (Scientific Challenges)
  - Incrementing simulations complexity, sky area covered, number of processing levels included
- Different approaches among the SDCs:
  - Dedicated resources (e.g. SDC-IT/ASI/ALTEC)
  - Resources shared with other projects (e.g. SDC-FR/CC-IN2P3)
- SDC-IT case:
  - Development phase: resources procured by INAF (with some ASI funding)
  - Operation phase: procurement assigned to industry (ALTEC) and coordinated by ASI and INAF-OATs

The team: summary of space projects

- Planck/LFI (1999 – 2021)
  - LFI DPC
  - LFI IOT Coordination
  - Beyond Planck
- Euclid (2008 - ongoing)
  - SGS Management
  - SDC-IT
  - VIS+NISP IOT Coordination
- LiteBIRD (Spring 2020 - ongoing)
  - WP 4-6X11 “Science Ground Segment”