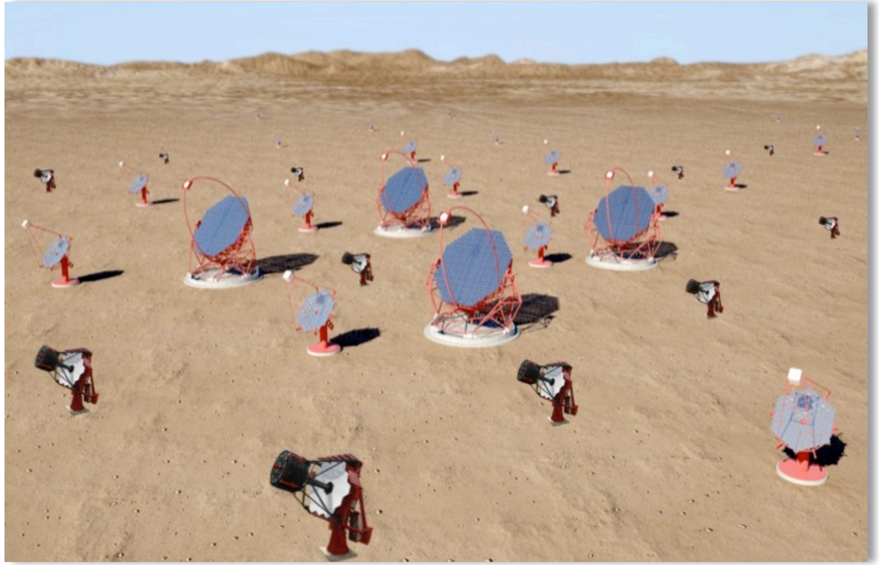
CTA@INAF
for
ASTERICS

L. A. Antonelli

INAF-OAR & ASDC

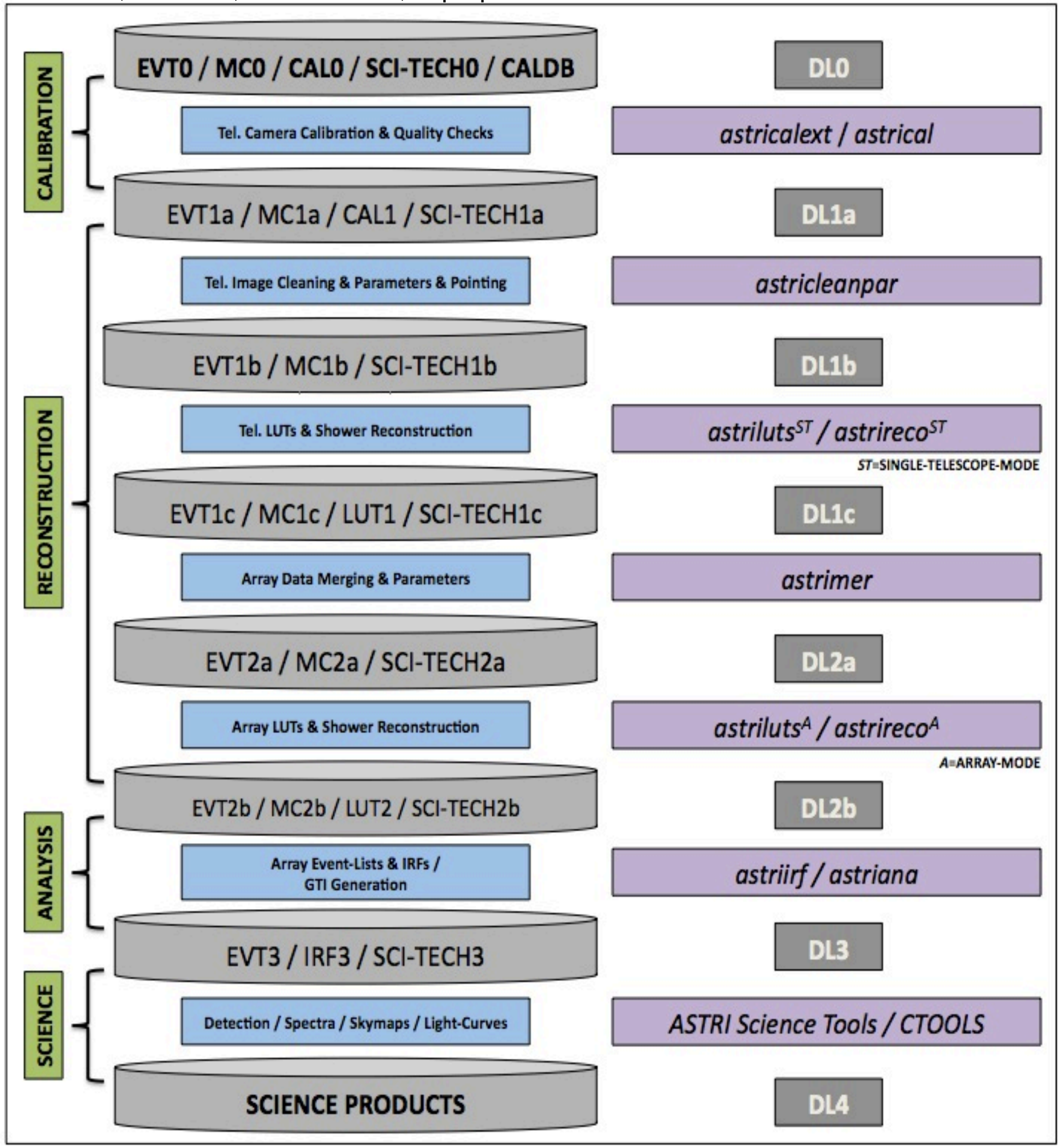
INAF, ASDC & UniPD: VHE Gateway



- MAGIC Experiment
- GAW and EASTOP
- AGILE, FERMI, INTEGRAL, XMM, SWIFT, SAX, …
- ASTRI CTA Small Telescope
- CTA

ASTRI-MA scientific data analysis

Lombardi, Antonelli, Bastieri et al., in prep.



Features:

✧ ASTRI-camera-like calibration

✧ Image-Momentum reconstruction

✧ RF for g/h separation, Energy reconstruction and Direction estimation

✧ Make use of CALDB

✧ DL1(c) ➔ DL2(b): data merging and stereo reconstruction under testing

✧ DL2(b)➔DL3 under testing

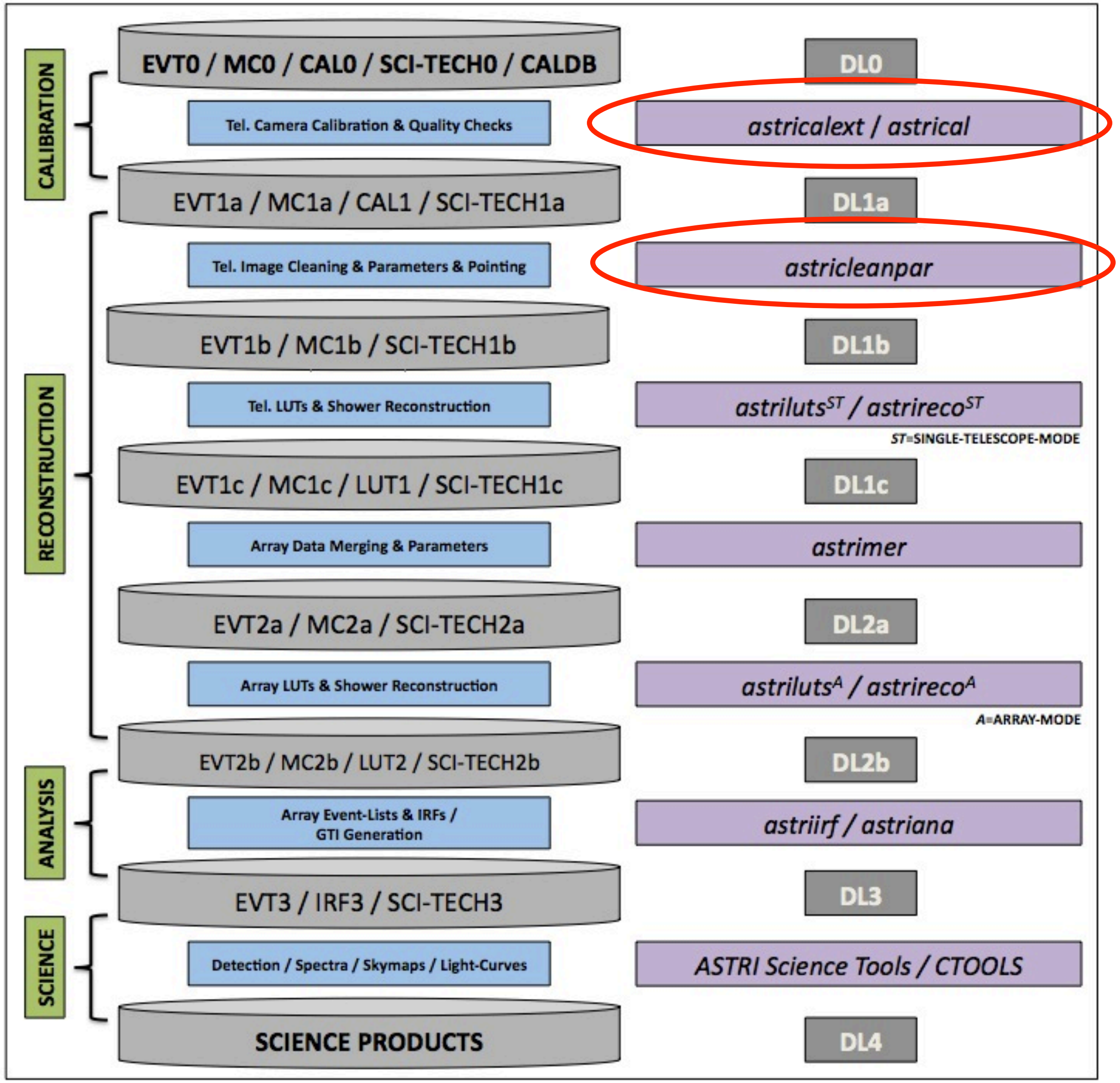
✧ DL3➔DL4 with *ctools* (under testing)

Status and Outlook:

✧ MC-Data PIPELINE almost ready for LUTs and IRF2/3 generation

✧ Implementation/integration of data handling for other telescopes (foreseen to be included in the CTA-S precursor) under evaluation

ASTRI Data Reduction Pipeline



Lombardi, Antonelli, Bastieri et al.

The SST-2M Prototype and Mini Array Data Pipeline

- Follows the general design and data model scheme defined in CTA Data Management
- Manages **FITS data** (from DL0 to DL3) adopting CFITSIO/CCFITS libraries;
- Is written in **C++** (Unix environment) / **CUDA7** (for GPU/ARM coding) / **Python**;

Algorithms parallelization

Pixel-level algorithms easily express parallelism

- **Calibration**

  Essentially an *embarrassingly parallel*,

  Fused Multiply-Add operation:

  PHE = ADC * coefficient + pedestal

  $0 = $0×$1+$2

- **Cleaning**

  Two pass cleaning (two threshold comparisons)

  Well suited to parallelism

CUDA Integration

Seamless and flexible integration of parallel code

- Build phase does not depend on CUDA toolkit (only CPU targets built)
- Software modules detect GPUs in the system and act accordingly (*thanks C++ polymorphism!*)
- CPU/GPU execution switchable on user request
- Results match within the limits of numerical precision

Embedded analysis

Low-level “Unified module”

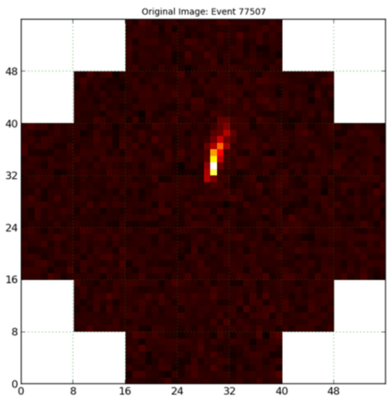
- Performs calibration + cleaning + parameters computation in a single, tightly integrated program

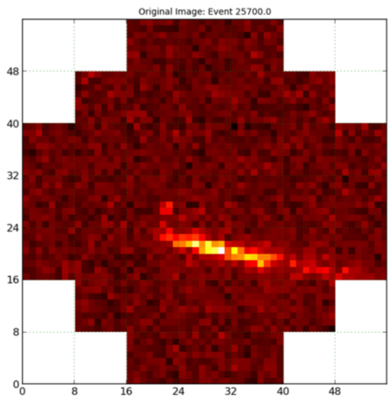
- Direct processing from DL0 to DL1b (fully-reduced data)

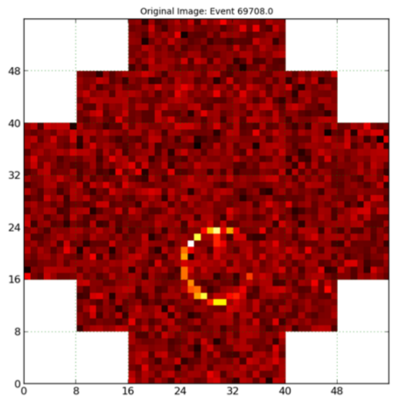
- 73x reduction in size (6.9MB output)

- Minimizes disk transfer time

Reference Test Case







- 500MB (= 55049 events) of simulated “real data”
- ≈ 110s of nominal acquisition rate (500Hz)
- ≈ 55s of projected peak rate (1000Hz)
- ≈ 80.5% of events survives pruning with default settings
- Compliant with format and size agreed with camera hardware team

Development system

Dual-processor Intel Sandy Bridge @ 2GHz with 16 physical cores and 128GB of RAM (8GB per core)

GPU gen3 READY and n.1 installed (up to 3 GPU drives)

8 disk slots of 4TB each (to export 2 different redundant drives of ~12TB each)

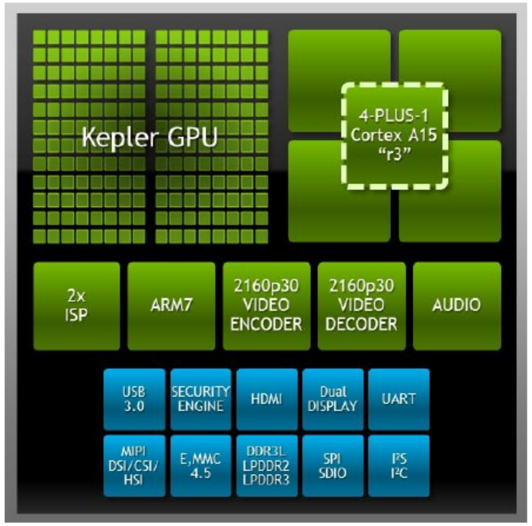
direct link and share with the storage system

- Installed @ OAR Monte Porzio Catone
- Accelerator: NVIDIA Tesla K20c (20-30% slower than K40)

On-line Analysis Jetson TK1

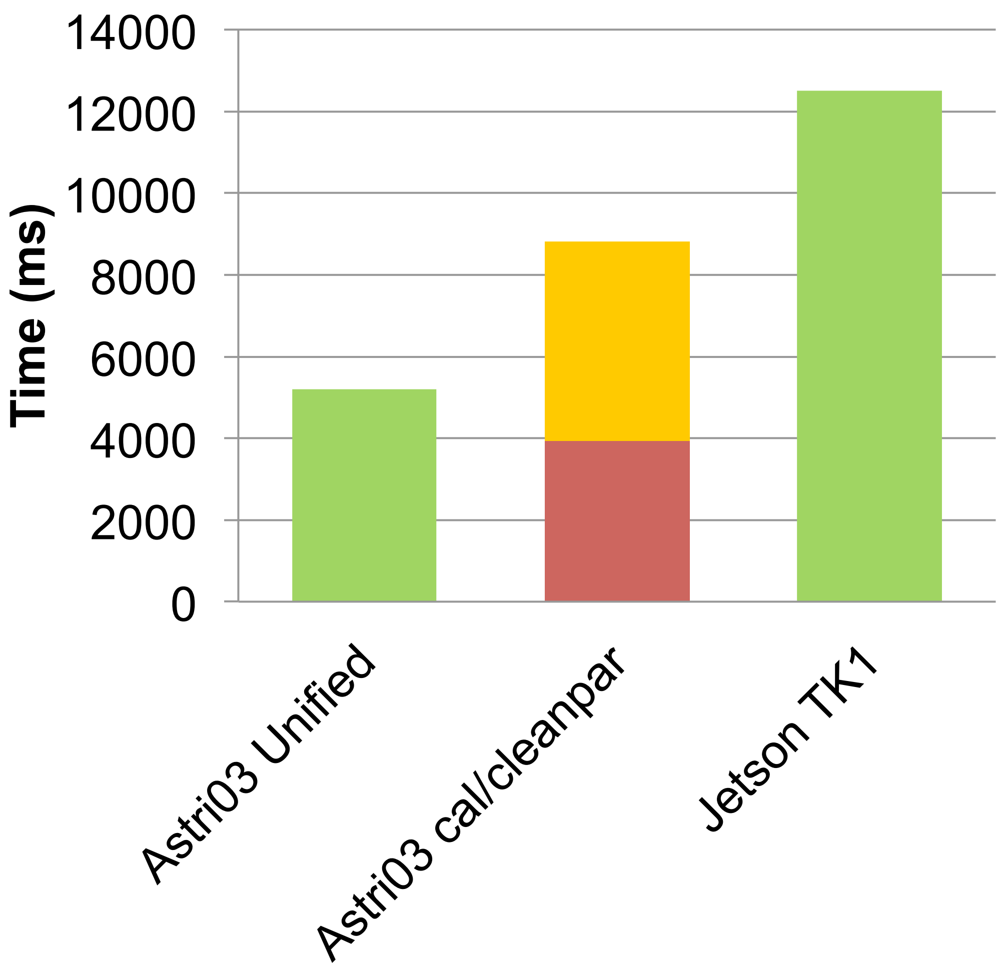
NVIDIA Jetson TK1

- Heterogeneous System-on-Chip
- CPU: Quad-core ARM A15
- GPU: Kepler architecture - 1 Multiprocessor
- RAM: 2GB (unified address memory)
- OS: Ubuntu 14.04 Linux for Tegra (L4T)
- CUDA 6.5
- I/O: SATA 3Gb/s HDD (no on-board eMMC)



Average power consumption: < 10 W

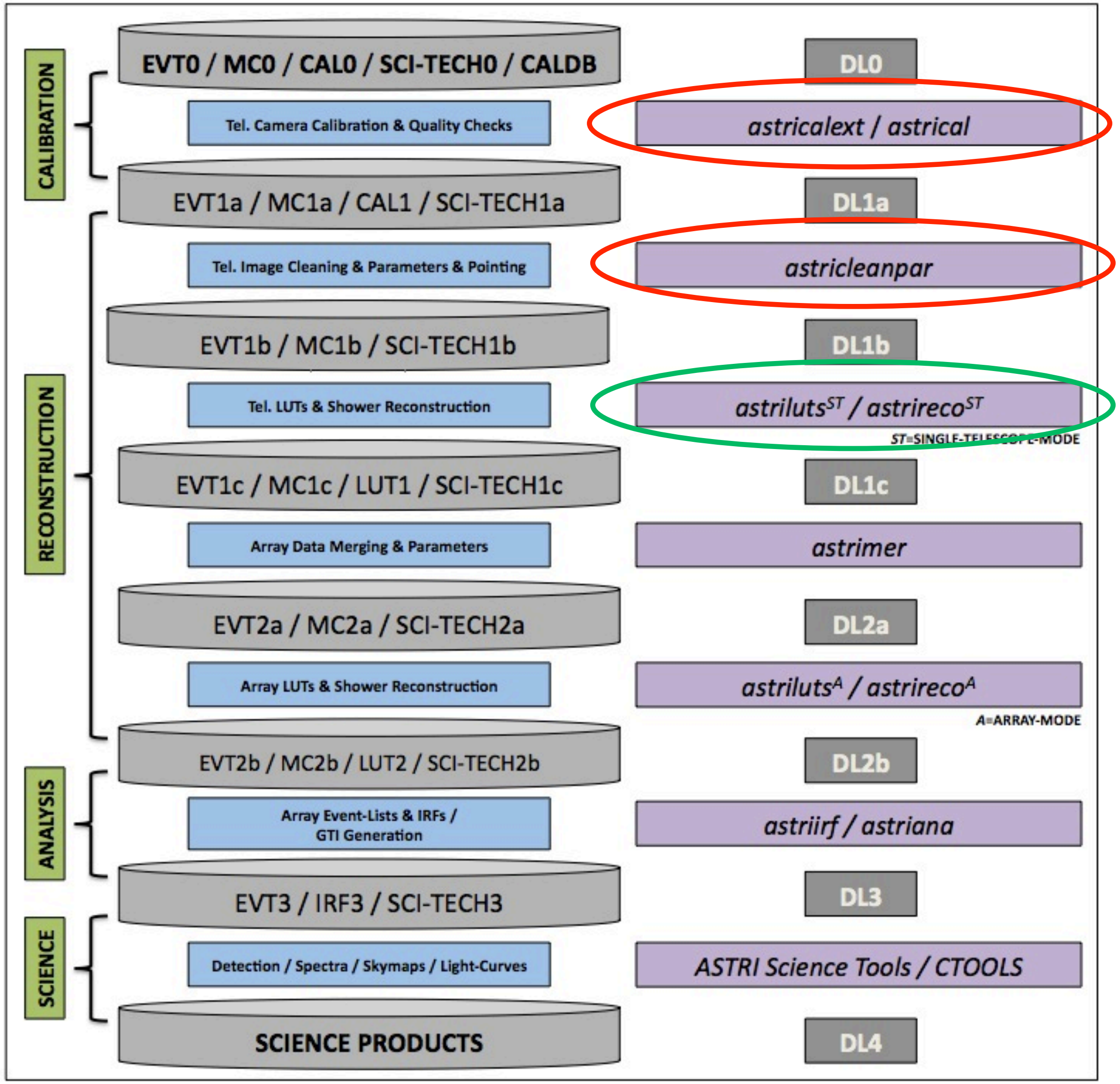
Low-power Unified module



Average of 5 runs

- Processing from DL0 to DL1b (fully-reduced data)
- All done in 12.5s:
  4400 evt/s
  > 4x peak acquisition rate
- 2.5x slower than server UM
  1.4x slower than separate modules
  30x less power
- Still plenty of time left for online analysis!

Not enough? New task for TK1!



Lombardi, Antonelli, Bastieri et al.

Feed Jetson with other tasks

astrireco

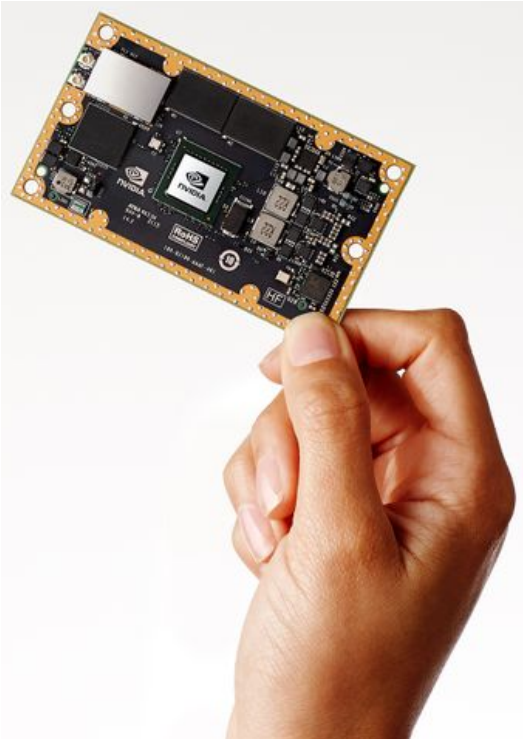
- Implements random forest application
- Loads pre-trained models (look up tables LUTs)
- Energy, direction and hadronness reconstruction

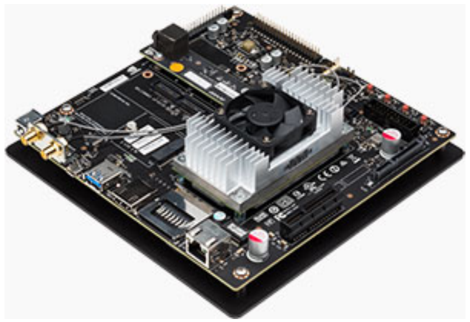
Execution time: 10s - 4 ARM core (using OpenMP)

Single telescope reconstruction pipeline

- Reduction + reconstruction = 22.5 s
- DL0 -> DL1c @ 2500 evt/s
- 2.5x of peak acquisition rate on embedded hardware

NVIDIA Jetson TX1





- Latest generation embedded module from NVIDIA (announced Nov. 11th 2015)
- Credit-card size, touted of same ≈10W consumption (max 15W)
- CPU: Quad-core ARM A57
- GPU: 256-core Maxwell arch (2 SMM multiprocessors)
- 4GB RAM, Gigabit Ethernet
- Devkit with carrier board: $600

Further development

- Portability of algorithms, libraries and software to other instruments.

  A natural application to:
  - MAGIC telescopes and cameras
  - LST prototype telescope and camera
  - MST prototypes and cameras
  - ….
  - other astronomical or astro-particle ground- and space- based observatories.

WP 3.2 GOALS

1. Surveying the real-time streaming data architectures applied and envisaged for the ESFRI and pathfinder facilities, to establish best practices and agree on common software frameworks or common software modules, extending e.g. LOFAR, ASKAP, HESS, MAGIC, ANTARES and ALMA frameworks.

2. Developing new and common data models and high performance formats for data streaming, compatible with interoperability standards beyond the existing FITS, ROOT and HDF5 leading to common standards.

3. Developing prototype libraries that allow robust and optimised handling of secondary data streams and meta-data (environmental and engineering data, temporary local archive, device control software and observation scheduling), ensuring long-term & shared maintenance of the proposed products.

4. Benchmarking low-power computer platforms (including Multicore, MIC, Microservers, GPU, FPGA, ARM) and software technologies/methods for data-driven scalable parallel programming. This subtask will also follow a three-step approach, and will last the full ASTERICS project duration, since it will evolve by monitoring the continuous evolution of the technologies and could be also inspired by progress made in other scientific domains. The expected measurable value is the up-take of these new computing and information technologies by the ESFRI facilities and there platforms.

Deliverables

Deliverables

Nr	Description	Task	Month
D3.1	Detailed WP3 Project plan	3.1	4
D3.2, 3.6, 3.10	Annual user engagement forum, workshops and training events	3.1	12, 24, 36
D3.3	Analysis Report on Standards and Libraries	3.2	12
D3.4, 3.17	Release of Software Libraries	3.4	12, 48
D3.5	Analysis Report on Resource Requirements	3.3	18
D3.7, 3.15	Processing Platform Technology Benchmark Report	3.2	24, 48
D3.8, 3.16	Database Technology Benchmark Report	3.3	24, 48
D3.9	Statistical Solvers Technology Benchmark Report	3.4	24
D3.11	Analysis Report on Frameworks and Architectures	3.2	36
D3.12	Repository of Services	3.3	36
D3.13	Repository of WMS Services	3.4	36
D3.14	Final Integral WP3 Report	3.1	48

Astérics

Astronomy ESFRI & Research Infrastructure Cluster

WP 3.2 D-GEX

L.A. Antonelli (INAF)

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WP 3.2 Organization

Partner	**INAF**	**UCM**	ASTRON	UCAM	CPPM	LAPP	IFAE	INFN
Effort (PM)	24	16	24	24	18	6	10	12

Project Redmine for document and sw repository

WiKi pages for discussion

CONTRIBUTIONS

Contact Points:

- Bojan Nikolic – UCAM - SKA
- Tammo Jan Dijkema – ASTRON - Lofar
- Pierre Aubert – LAPP – CTA
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