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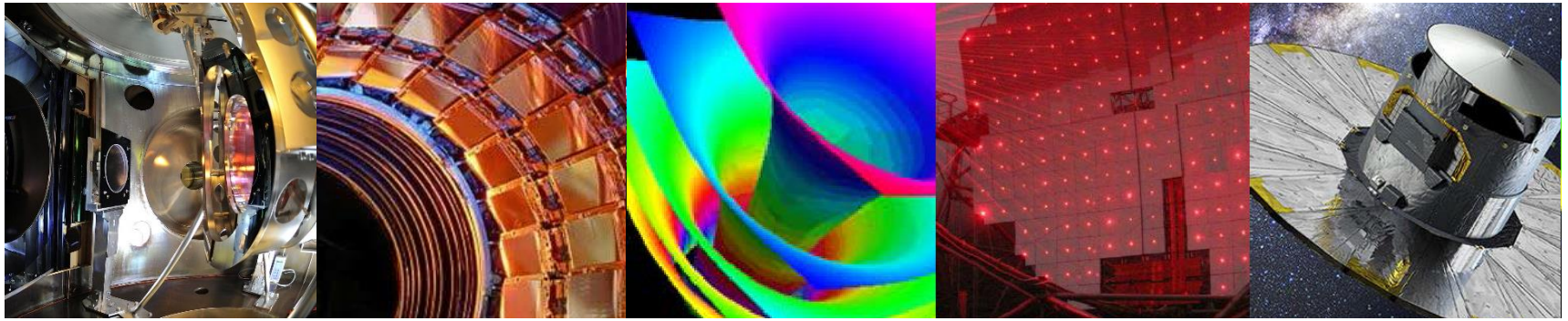
EXCELENCIA MARÍA DE MAEZTU 2020-2023



Current and future activities on **computing and software engineering** at the ICCUB Technological Unit

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Deputy technical director

Institute of Cosmos Sciences
Universitat de Barcelona

ICCUB Winter Meeting

Barcelona
8 February 2022

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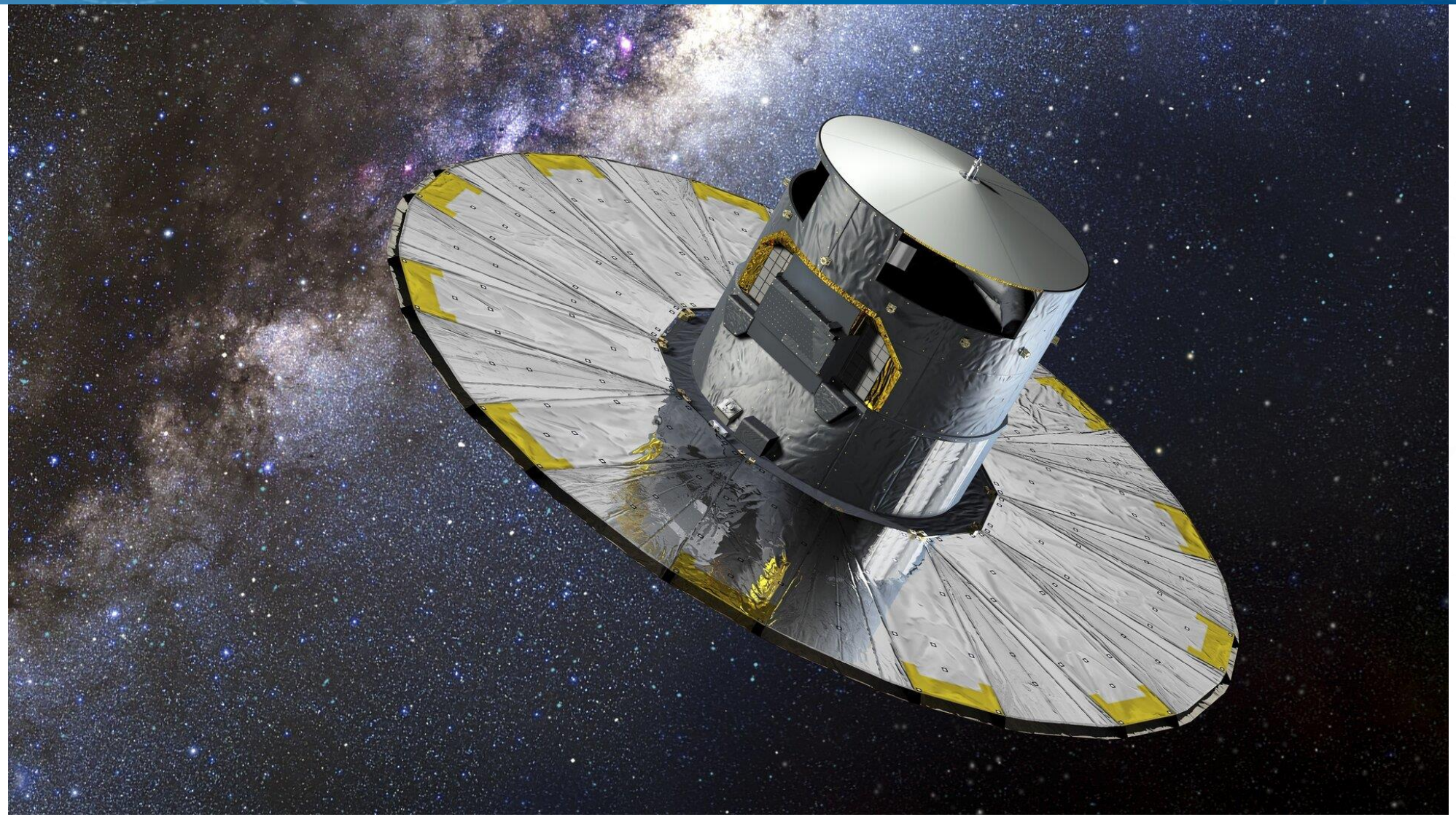
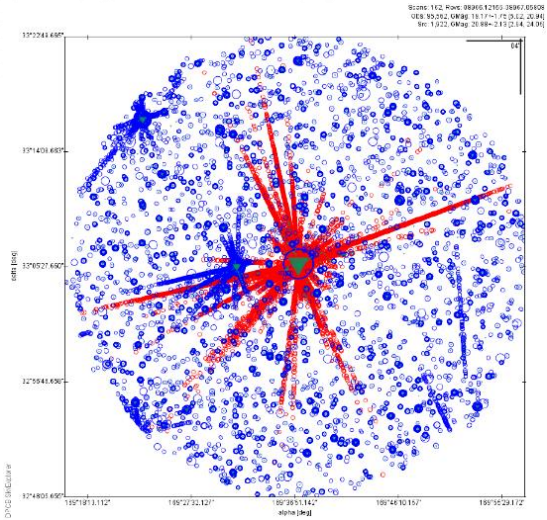
Gaia

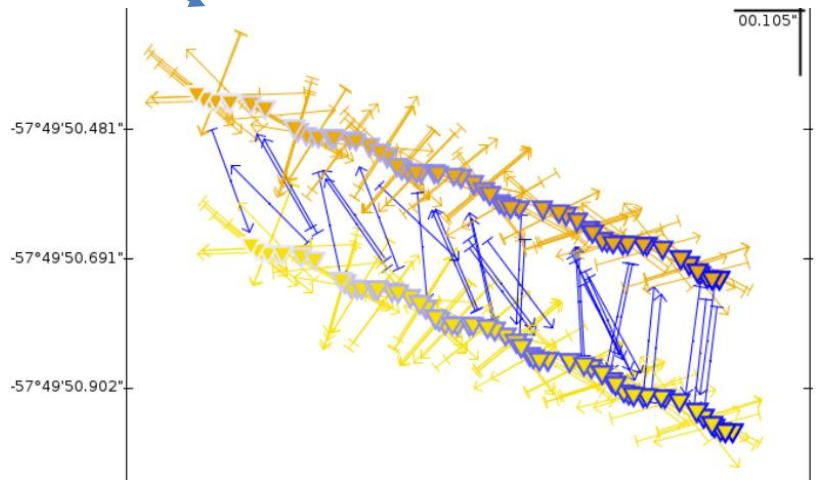


Gaia: Data processing, validation and visualization

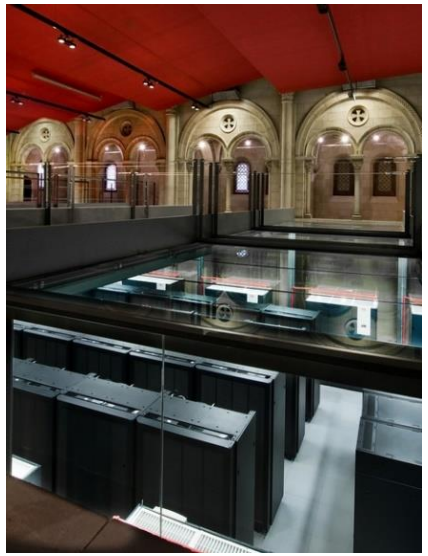
Most activities within the frame of the Gaia DPAC (Data Processing and Analysis Consortium):

- CU3 (Core Processing) unit, IDU (Intermediate Data Updating) system
  - Integration and test of algorithms: Instrumental calibrations, image parameters determination
  - **Development of new algorithms**: Attitude & Calibration bootstrap, spurious detections classification, cross-matching…
  - Recently: on-ground detection and resolution of **close star pairs**
    → improve catalogue resolution and completeness, specially in dense areas (e.g. clusters)





- DPCB (Data Processing Centre of Barcelona)
  - Operational runs at BSC (MareNostrum):
    5.5 years of mission, **65 TB** output, **5M CPU** hours, **142E9** observations processed…
  - Two runs like this (so far!) for this cycle (prep. DR4)
  - Official backup of the full MainDB and raw TM Archive
  - Data visualization tools



- CU3 / IDT (Initial Data Treatment)
  - Support to daily operations, monitoring and resolution of onboard/onground issues

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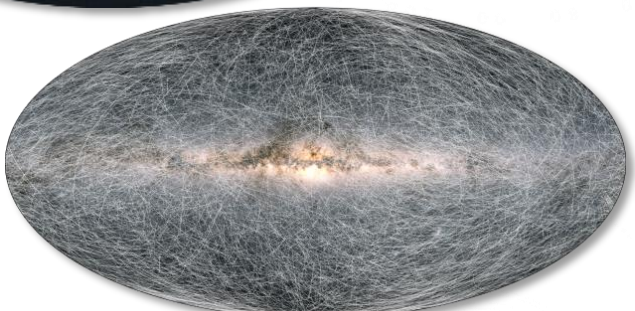
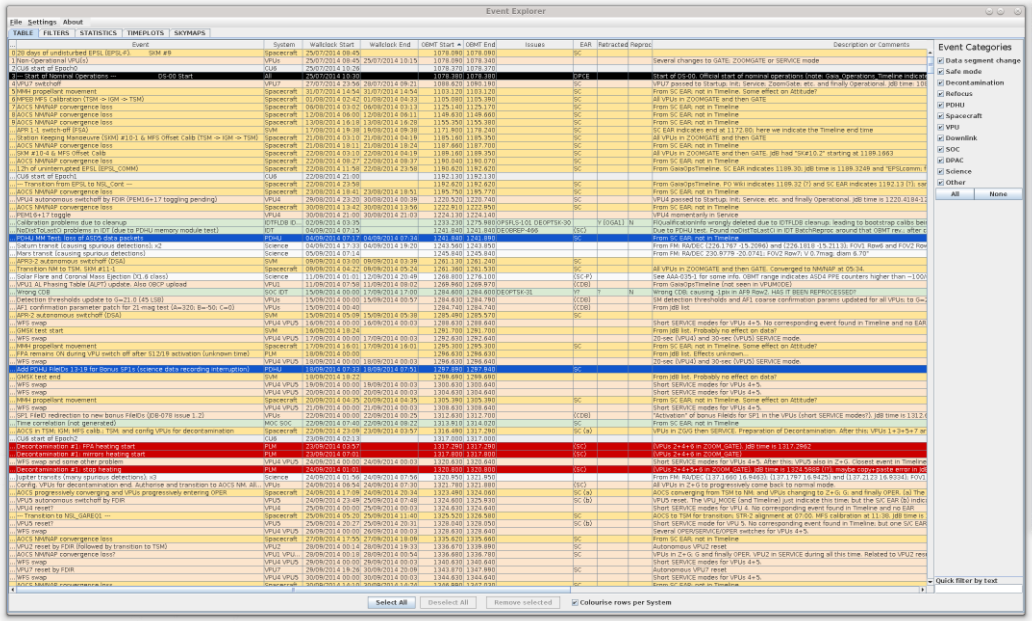
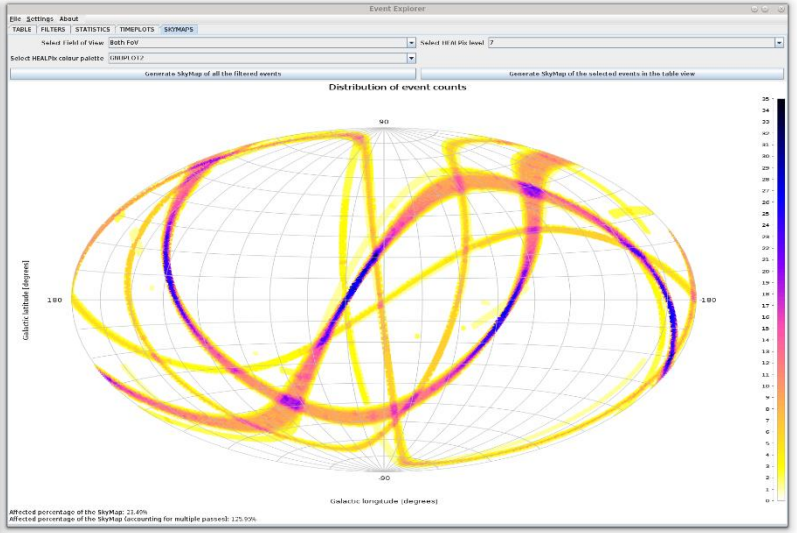
Gaia: Data processing, validation and visualization

Most activities within the frame of the Gaia DPAC (Data Processing and Analysis Consortium):

- CU9 (Catalogue Preparation)
  - Catalogue validation for EDR3 and **DR3**: many new data types, tables, parameters…
  - Development of software tools for statistics and validation
- Project Office
  - Technical interfaces between Units and Centres; technical support to other Units
  - Estimation of database and transfer sizes
  - Curation of Operational Event Logs, development of visualization tools
  - Support to additional (typ. cross-unit) investigations







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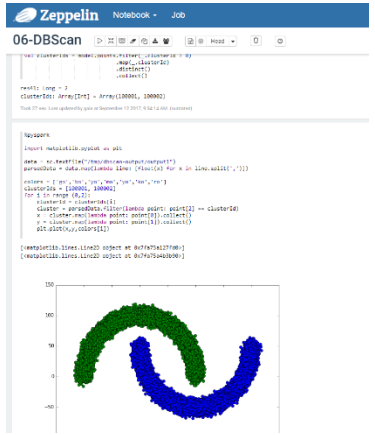
Gaia: Additional activities

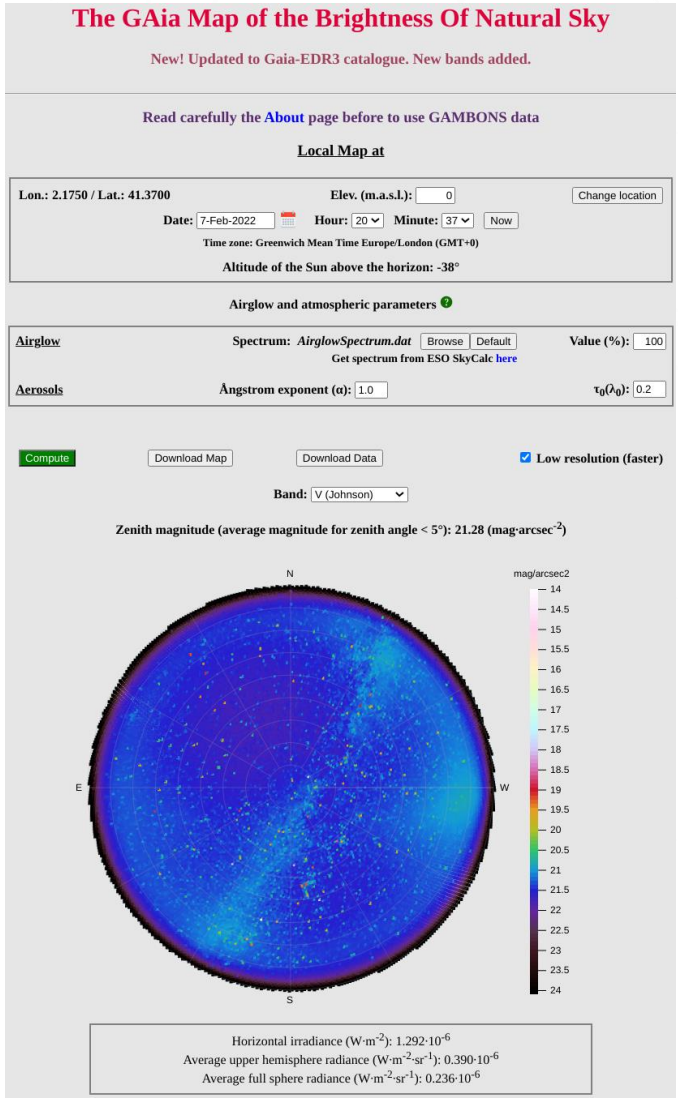
Beyond DPAC, some activities related to Gaia:

- OCRE / GalacticRainCloudS:
  - Galactic Research in Cloud Services
  - **Commercial Cloud Services** granted by OCRE (European Initiative) to do data mining and research on Gaia (E)DR3 data
  - Spark cluster + Data lake + Linux Virtual Machines + Machine Learning services + Notebooks
  - Run large simulations, get richer statistics, find correlations, improve current models

- GDAF:
  - Gaia Data Analysis Framework
  - Hadoop + Spark + Parquet + libraries + interfaces
  - Allow queries, plots and investigations on **Big Gaia Data**
  - Formerly deployed at CESCA/CSUC, now migrating to BSC



- Gaia4Sustainability (a.k.a. GAMBONS Plus):
  - Gaia map of the brightness of natural sky
  - Evaluate and identify sources of **light pollution**
  - Now improving it to offer a “proof-of-concept” service to users
  - Software development including modern web technologies and GPU programming



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Gaia: Recent achievements and outlook

- Early Data Release 3 (EDR3):
  - Released 3 December 2020
  - Mainly Astrometry+Photometry
  - Based on 34 months of data
- **Data Release 3 (DR3):**
  - **Scheduled 13 June 2022**
  - **Lots of new data products**

- Data Release 4 (DR4):
  - Full nominal mission (66 months)
  - Envisaged ~2025
  - **Epoch data** for all data products and sources (incl. astrometry, spectra, etc.)
- *Data Release 5 (DR5):*
  - *Extended mission, date TBD*
  - *Already working on it!*

	# sources in Gaia DR3	# sources in Gaia DR2	# sources in Gaia DR1
Total number of sources	**1,811,709,771**	**1,692,919,135**	**1,142,679,769**
	Gaia Early Data Release 3		
Number of sources with minimally 5 astrometric parameters	1,467,744,818	1,331,909,727	2,057,050
Number of 5-parameter sources	585,416,709		
Number of 6-parameter sources	882,328,109		
Number of 2-parameter sources	343,964,953	361,009,408	1,140,622,719
Gaia-CRF sources	1,614,173	556,869	2,191
Sources with mean G magnitude	1,806,254,432	1,692,919,135	1,142,679,769
Sources with mean G_{BP}-band photometry	1,542,033,472	1,381,964,755	-
Sources with mean G_{RP}-band photometry	1,554,997,939	1,383,551,713	-
	New data in Gaia Data Release 3 (pending validation)		
Sources with radial velocities	≈ 33,000,000	7,224,631	-
BP/RP spectra	> 100,000,000	-	-
RVS spectra	≈ 1,000,000	-	-
Variable source classifications	≈ 13,000,000	550,737	3,194
Object classifications	≈ 1,000,000,000	-	-
Sources with astrophysical parameters	≈ 500,000,000	161,497,595	-
Non-single stars	≈ a few 100,000	-	-
QSO host and galaxy morphological characterisation	≈ a few 1,000,000	-	-
Solar system objects	≈ 150,000	14,099	-
Reflectance spectra for solar system objects	≈ 50,000	-	-
Average BP/RP reflectance spectra of asteroids	≈ 10,000	-	-
Gaia Andromeda Photometric Survey (GAPS)	≈ 1,000,000	-	-

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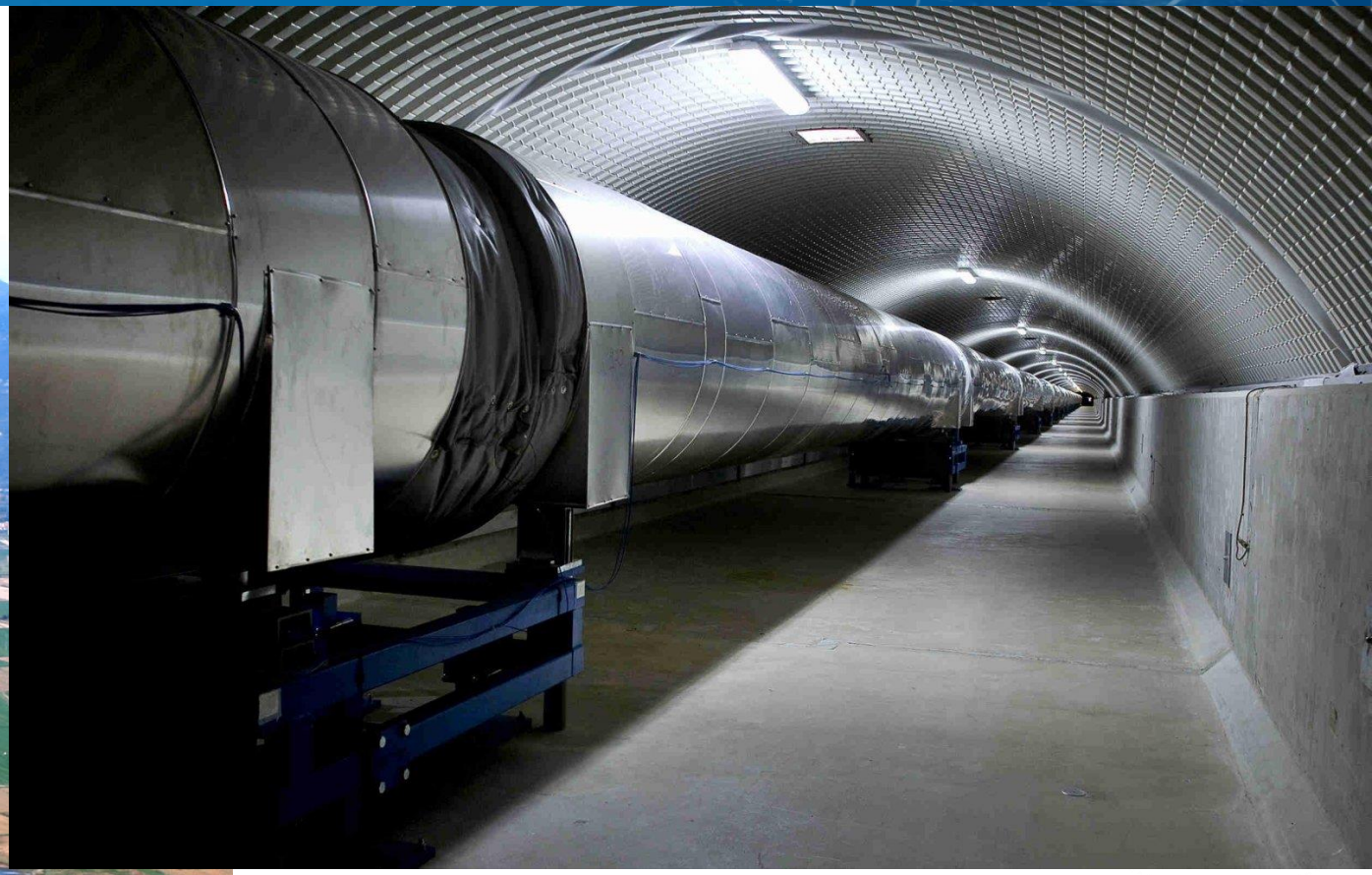
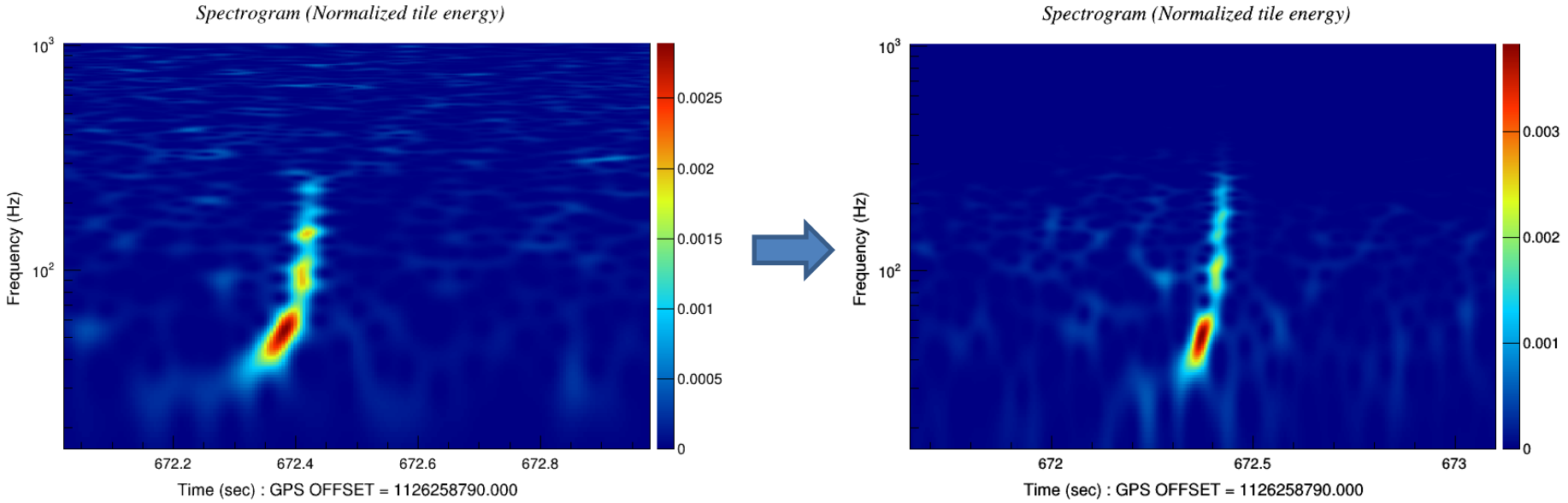
Virgo and GW



Virgo: Contributions to the Gravitational Waves Observatory

- ICCUB Virgo participation was triggered from the Technological Unit
  - Initially aiming at contributions on **Computing** and **Instrumentation**
  - Now also **outreach**, **data analysis** and **science modelling and exploitation** activities
  - Full member of the Virgo Collaboration since July 2019
  - ICCUB-Virgo group has grown a lot! Now 17 members and ~6 FTEs
  - Here we just focus on computing and data analysis
- Data analysis:
  - **Denoising** plugin (based on iterative rROF) for Bursts pipeline (unmodelled searches), up to ~2dB SNR improvement



VIRGO ICCUB

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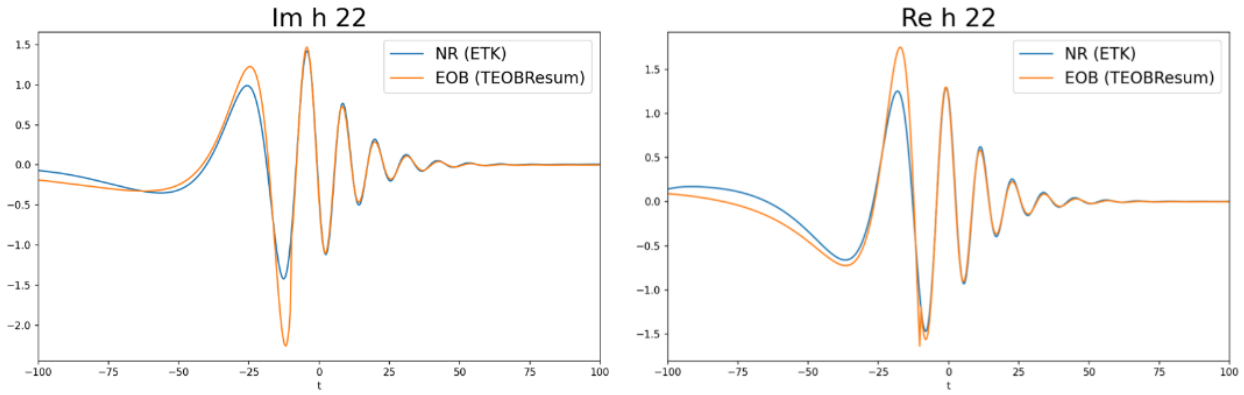
Virgo: Contributions to the Gravitational Waves Observatory

- Data analysis:
  - Working on new **GW templates** and models:
    High eccentricity, precession, gravitational lensing…
  - Also on new **pipelines** and improved template **interfaces**

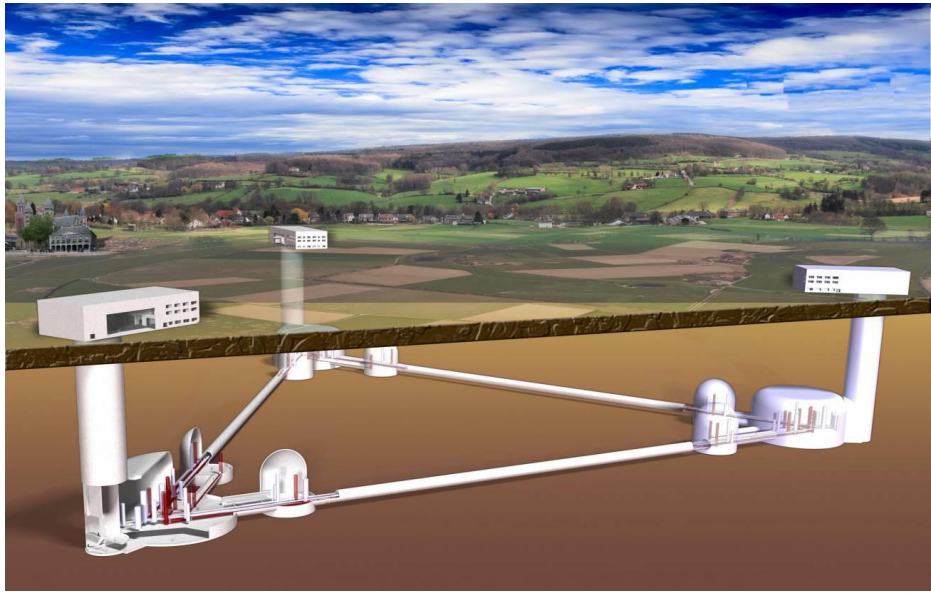


- Computing:
  - Now working on a federated **authentication service** for Virgo (in collab. with LIGO and KAGRA)
  - Soon:
    optimization of Continuous Wave pipeline
    support to scientists
    centralized monitoring of Rucio data handling and HTCondor jobs

Contributions to other **Gravitational Waves** projects

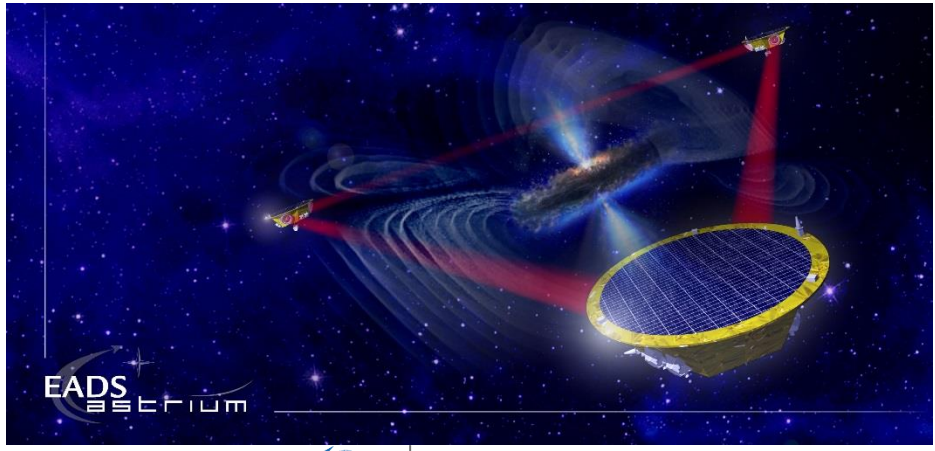
Einstein Telescope (ET):

- Third-generation GW observatory, expected ~2035
- 3 nested detectors, 10km arms, underground, cryogenic parts
- Now part of ESFRI roadmap
- Envisaged contributions from ICCUB:
  - Science case and data analysis
  - Outreach
  - **"E-Infrastructure" (Computing & Software)**:
    Contributions to the general computing model and architecture,
    efficient data handling, cloud and Big Data technologies, software engineering…
    Expected ~1 FTE Q2'2022



LISA:

- Space-based GW observatory, expected ~2037
- 3 detectors, 2.5 million km arms
- ICCUB contributions still being defined:
  probably data challenge / data analysis activities



Other projects

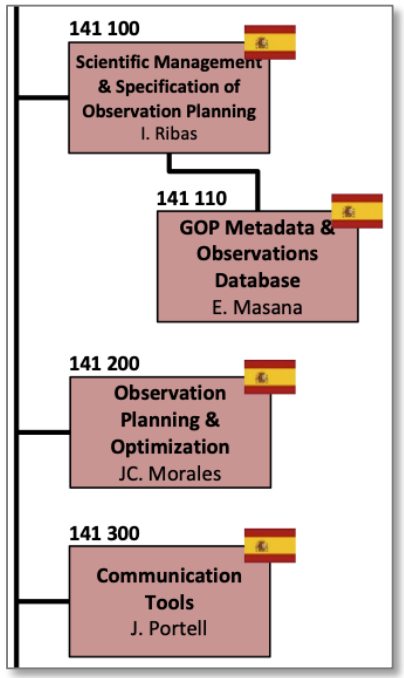
PLATO

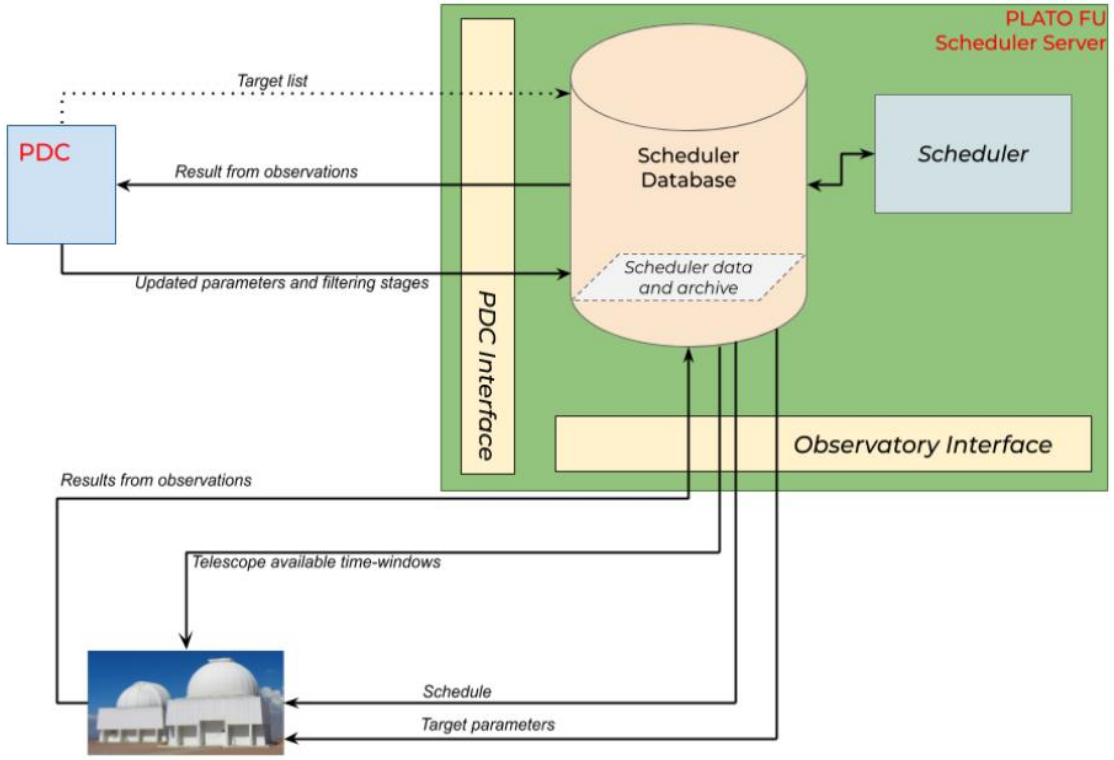
ESA mission, launch expected ~2026.

Ground-based follow-up of exoplanet candidates **(GOP, Ground-based Observation Programme)**:

- Definition of overall architecture and requirements
- Interfaces and protocols between PLATO Data Center and Observatories
- Database and metadata
- Observational constraints
- Software implementation

Now ramping up,
~1 FTE at ICCUB expected Q2'2022





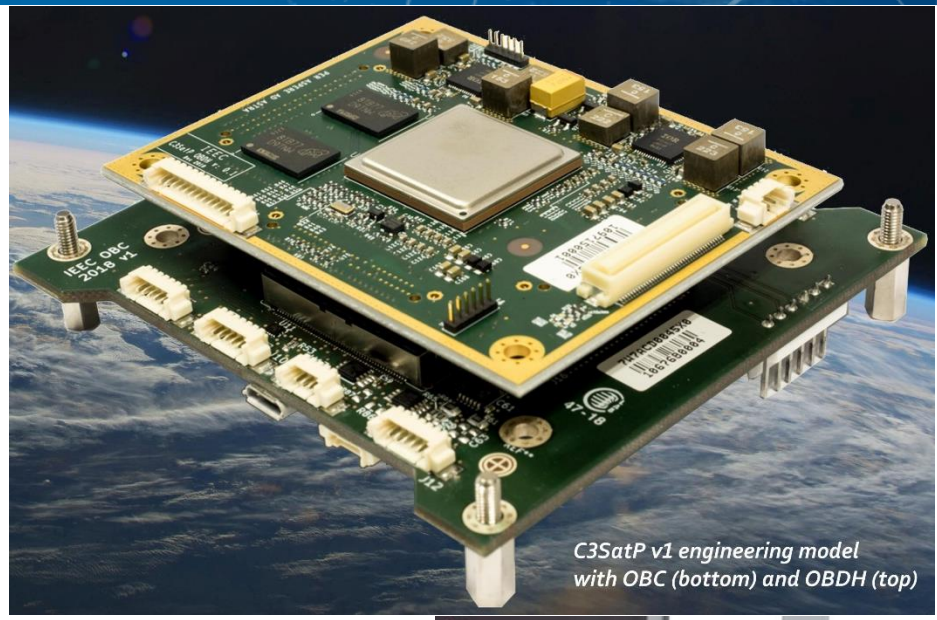
Nanosatellites

See talk by Chema Gómez!

Remarkably (on the software side):

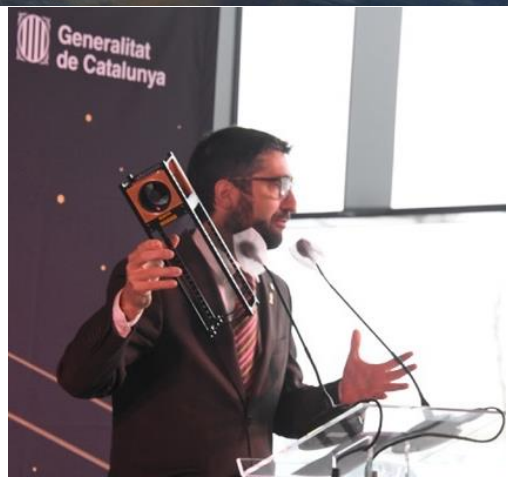
- IEEC's **C3SatP platform**:
  CCSDS packetisation stack,
  Reed-Solomon error detection and correction,
  efficient data compression (FAPEC)
  - Feasibility to compress payload data even on a low-end OnBoard Computer (OBC)
  - High-throughput software-based data compression
  - Collaboration with our spin-off (DAPCOM)

- IEEC's **PhotSat**:
  Support to mission definition and requirements



C3SatP v1 engineering model with OBC (bottom) and OBDH (top)

IEEC
Institut d'Estudis Espacials de Catalunya



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Other projects and activities

- **GaiaNIR**:
  - Support to initial definition
  - On-board data handling, on-ground raw data processing and initial data treatment, …

- **Euclid**:
  - Specific engineering tasks still being defined.

- **Jasmine**:
  - Also being defined: perhaps support to some PSF models, simulations, and eventually data processing/analysis

- Additional future activities to be funded by *Planes Complementarios*:
  - **Data fusion** of Gaia data with other catalogues: JPAS/JPLUS, WEAVE, Euclid, LSST...
  - Support to other projects: WEAVE, LSST, DESI, Lattice...

Summary

Main activities:

- Gaia
  - DPAC (data processing and validation), Cloud, Big Data, light pollution
- Virgo
  - Computing, pipelines, data analysis

Ramping up:

- PLATO
  - Ground-based followup
- Nanosatellites
  - Onboard software, data compression, mission design
- Other GW projects
  - ET (computing), LISA

Future projects:

- Euclid, Jasmine, GaiaNIR
- Growing soon! (Planes Complementarios)

Thank you

Jordi Portell (jportell@icc.ub.edu)

on behalf of the ICCUB-Tech Computing Division