# Cobrawap: from a specific use-case to a more general scientifically-technologically co-designed tool for neuroscience

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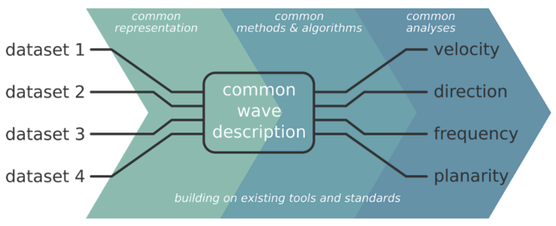
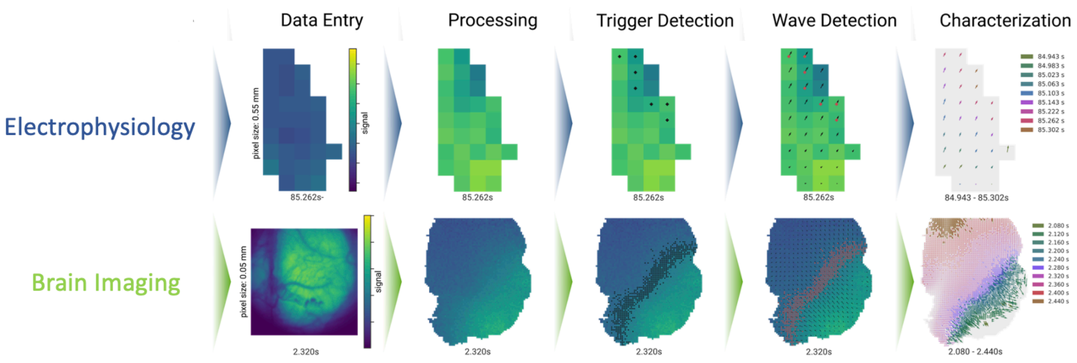
**Abstract** Cobrawap (Collaborative Brain Wave Analysis Pipeline) [1,2] is an open-source, modular and customizable data analysis tool designed and implemented by INFN (Italy) and Jülich Research Centre (Germany) in the context of the Human Brain Project, further enhanced within the EBRAINS and EBRAINS-Italy initiatives. Its foundational goal was to enable standardized quantitative descriptions of cortical wave dynamics observed in heterogeneous data sources, both experimental and simulated, also allowing for validation and calibration of brain simulation models. Current directions of development aim at enhancing generalizability beyond the set of originally considered use cases. Intercepting the increasing demand by the Neuroscience community for reusability and reproducibility, Cobrawap provides a framework suitable for collecting generalized implementations of established methods and algorithms. Inspired by FAIR principles and leveraging the latest solutions in software engineering, Cobrawap is structured as a collection of modular Python3 building blocks that can be flexibly arranged along sequential stages, implementing data processing steps and analysis methods, directed by workflow managers (Snakemake or CWL). The customization necessary to carry out the data analysis for specific datasets can be attained via human-readable configuration files. The collaborative approach behind the whole software allows users to seamlessly enrich its scope, by co-designing and implementing new processing or visualization blocks with the support of the Cobrawap "core team". In the same vision, also software deployment and execution on HPC premises have been engineered so to minimize the effort required on the user side, in the so-called "Cobrawap-as-a-Service" paradigm.

## The Cobrawap pipeline

Cobrawap is an open-source workflow designed for the analysis of brain wave activity [1,2].








### Main achievements of Cobrawap …

- Standardized data analysis (test-bench datasets [3])
  - understand mechanisms and features of the brain wave dynamics from experimental data;
  - identify multi-scale observables, develop and implement generalized methods, and design data-driven analysis tools;
  - compare and combine different datasets from different sources in a statistically significant manner.
- Model validation and calibration [4]
  - feed simulations and refine theoretical models with results from experimental recordings;
  - define methods and procedures for model validation and comparison (model vs model, or model vs data).

**… but an efficient and widespread exploitation requires larger computational resources and actions for reducing technical efforts demanded to the final users.**

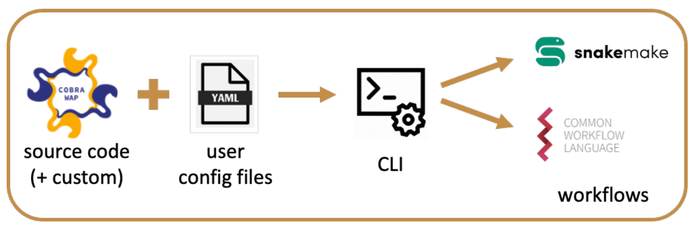
**Offer Cobrawap as an EBRAINS service!**

**Software delivery** — GitHub, docker, ESD

**Collab & KG interaction** — EBRAINS Collaboratory, jupyter, UNICORE

**Deploy & run on HPC** — FENIX RI: JSC, CSCS, CINECA

**Command-line interface handling workflows**

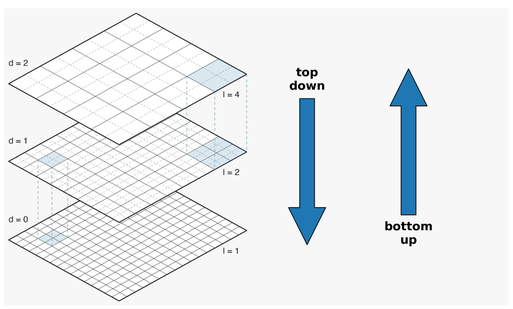


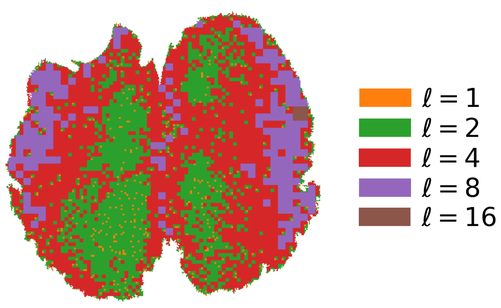

## Steps in the direction of user-friendliness

- Install and configure Cobrawap directly on HPC machines (ssh auth).
- Login on EBRAINS Collab, import Cobrawap from ESD (EBRAINS Software Distribution) and launch on HPC from Jupyter Notebook.
- Provide seamless interaction with workflow managers (Snakemake & CWL) via an intuitive CLI.
- Package the source code (PyPI, Docker, ESD) for easier installability.

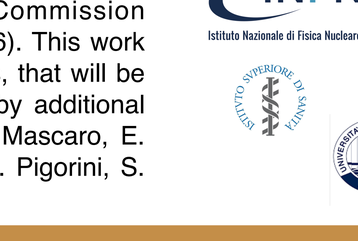
## Two recent applications: HOS & TVB

- HOS [5]
  - Designed as an algorithm for dynamically subsample high-res imaging datasets, through pixels of uneven size.
  - Enhances the signal-to-noise ratio, while reducing the global dataset size and keeping max resolution where needed.
  - Can be generalized to different scientific questions.




- TVB [6,7]
  - Powerful brain dynamics simulator, can be equipped with different neuron models and connectomes.
  - Its output can be processed by Cobrawap, for both calibration and validation purposes.
  - Is a reliable *in-silico* proxy for human brain dynamics, offering a perfect benchmark for Cobrawap extension toward human data.



## What's next

- Develop new blocks according to specific scientific questions and objectives (e.g. motifs in wakefulness);
- Generalize to further experimental recording techniques (e.g. EEG, intracranial electrode arrays, BOLD+fMRI, …) and simulations.
- Extend the analysis to other brain states and clinical conditions.
- Enable continuous development/integration/testing/deployment (CI/CD) of the software.
- Enhance data I/O via UNICORE or from the EBRAINS KG.
- Improve the usability of the workflow execution as a service, e.g. from the EBRAINS Dashboard.

## References

[1] github.com/NeuralEnsemble/cobrawap; cobrawap.readthedocs.io
[2] Gutzen, Lupo, Marmoreo, De Bonis (2025) Cobrawap v0.2.1, doi: 10.5281/zenodo.15005123
[3] Gutzen *et al* (2024), doi: 10.1016/j.crmeth.2023.100681
[4] Capone, De Luca *et al* (2023), doi: 10.1038/s42003-023-04580-0
[5] Lupo *et al* (2025), *in preparation*
[6] Sanz Leon *et al* (2013), doi: 10.3389/fninf.2013.00010
[7] Gaglioti *et al* (2024), doi: 10.3390/app14020890

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