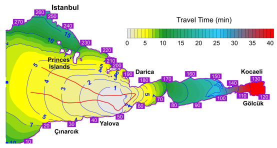
DEPARTMENT OF PHYSICS AND ASTRONOMY "AUGUSTO RIGHI"

Open Physics Hub

ADVANCED SENSING LABORATORY



HIGH PERFORMANCE COMPUTING CLUSTER

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

OPH NEWSLETTER

FOCUS: OPH equipment for biological systems investigations

The Physics Applied section of the OPH laboratories has to his credit a Biophysics computational and experimental vocation. The OPH Biophysics section supporting the experimental approach has been equipped with the aim to provide an advanced investigation of living biological samples in vitro. Around the Nikon Eclipse Ti epifluorescence microscope (Fig. 1A) have been implemented devices, such as the differential interference contrast (DIC) optical system and the z-axes scanning processed by the Nis Elements AR software deconvolution function, capable to provide in unstained and stained samples, pseudo tri-dimensional images (Fig. 1B). Long term time-lapse of high resolved large-scale images of both unstained and stained live cells is also

Summary

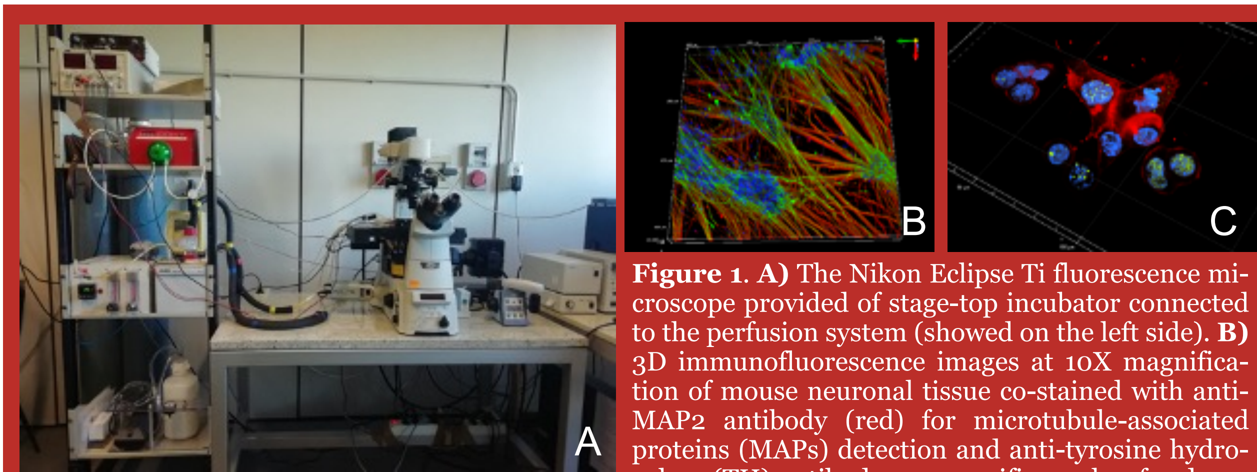


Figure 1. A) The Nikon Eclipse Ti fluorescence microscope provided of stage-top incubator connected to the perfusion system (showed on the left side). **B)** 3D immunofluorescence images at 10X magnification of mouse neuronal tissue co-stained with anti-MAP2 antibody (red) for microtubule-associated proteins (MAPs) detection and anti-tyrosine hydroxylase (TH) antibody as a specific marker for dopaminergic neurons (green). **C)** 3D fluorescence images at 100X of living cultures of LoVo cells line co-stained with the DNA double-stranded breaks (DBS) marker gamma-H2AX (green) and Phalloidina, an actin filaments marker (red). Nuclei are colored with DAPI (blue).

supported by a stage-top incubator that actively controls temperature, CO_2, O_2 and humidity.

The Biophysics Lab has a consolidated experience on the study of cellular bioelectrical properties in vitro. The recent acquisition of microelectrode arrays (MEA), connected home-made to the RHS stimulation/recording system (Intan Technologies) by the Physics of Condensed Matter, Atoms and Molecules group, will make it possibile to record, amplify, and analyze electrophysiological signals from single cells to networks. This MEA system has been designed to fit into the stage-top incubator described above and allocated under the microscope for long lasting bioelectrical activity acquisition in parallel with fluorescence/light contrast imaging (Fig. 2).

The system is also equipped with a perfusion system through which a pre-heated and controlled flow of culture medium can deliver interactive drugs to the cells (Fig. 1A). In this way, the time tracking of specific molecular target matched with the cellular behaviors can answer to specific questions on the functional activity of living cells in physiological or pharmacologically perturbed cultures. Therefore, the perfusion system improves the on-line observation of biological phenomena getting from a basic research level to a pharmacological one and leading to a translational meaning the experimental activity.

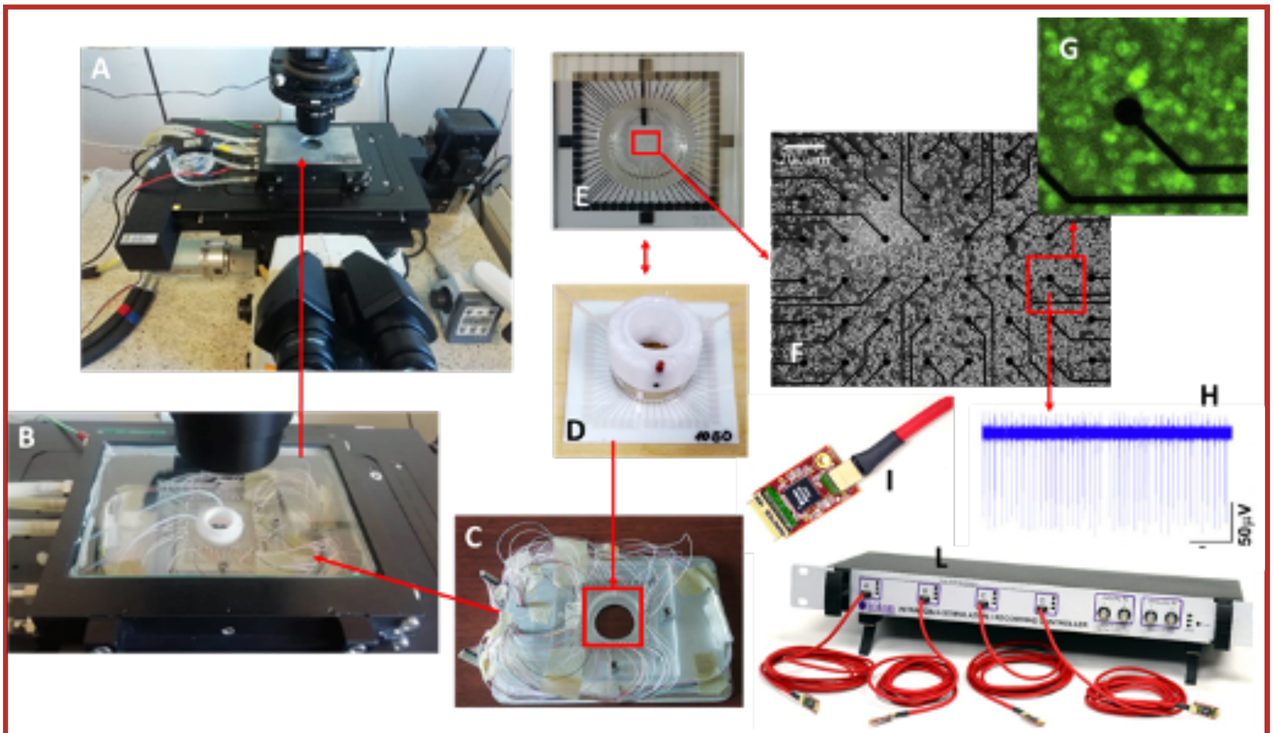


Figure 2. **A** and **B)** The stage-top incubator allocated on the Nikon Eclipse Ti microscope **C)** The home-made device connecting the Intan stimulation/recording system **(L)** through a RHS head-stage (**I**) to the microelectrode arrays **(D** and **E)**. **D)** MEA with a chamber cover of Teflon polymer permeable to gases but not to water and provided of two holes for the perfusion cannula insertion. Phase contrast **(F)** and fluorescence **(G)** micrographs from the central region of the MEA. Black dots are the Ø 30 mm planar electrodes as showed in the insert **G** connected by linear conductive pathways. **H)** MEA bioelectrical output from excitable cells.

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Teaching and outreach

The 4th edition of the DIFA International Summer School on Physical Sensing and Processing

From 14 to 20 July 2022, the Aula Magna of the Department of Physics and Astronomy hosted the fourth edition of the Summer School on Physical Sensing and Processing, which this year had the subtitle: "Quantum Sensing, Information Processing and Computing: shaping the future with the second quantum revolution" (link). As in past editions, OPH participated in the financing of the event, which was programmed within the project financed by the University of Bologna with the call for tender "International Cooperation Agreements with Higher Education Institutions" for the years 2023-24.

The course was attended by 55 Master's and Ph.D. students in person and more than 20 online auditors.

Four main cycles of lessons were held, one on each of the four "pillars" of the second quantum revolution - quantum sensing, information and communication, simulations, computation -, held by as many professors at the universities involved in the project: Prof. Gavin Brennen (MacQuire University-Australia), Prof. Giacomo De Palma (University of Bologna), Prof. Michael Kastner (Stellenbosch University, South Africa) and Prof. Vesna F. Mitrovic (Brown University, USA). Furthermore, ten seminars were added to these lectures, held by experts from academia and the private sector, which introduced many interdisciplinary connections.

Finally, the students in attendance participated in "Collaborative Work" activities, coordinated by a group of our doctoral students, during which they elaborated on the scientific innovations and the technological and social impact that characterize the second quantum revolution, and worked to devise a short informative text on these issues, addressed to school students and/or the public.

The days were very intense and full of discussions, which ended only on the last evening during a feast of pizza, at a large table under the arcades of Bologna.

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High Performance computing cluster

OPH cluster restructuring

The OPH parallel computing cluster was originally deployed with a total of 1160 cores for its two partitions named BladeRunner and Matrix, and 280 TB of disk storage space.

At the end of 2022 these numbers have almost doubled, with a current availability of 2184 cores and about half a Petabyte of disk storage, thanks to the constant attraction of new investments from project fundings of individual research groups at DIFA.

Correspondingly, the number of users has grown from the few tens of the early days to the more than 300 users we have today, including staff members, postdocs and students.

This rapid growth of both size and usage of the cluster came at the price of unveiling some limitations of our software, storage, and authentication infrastructures that were originally designed for a much smaller machine than the present one. Extremely long latencies in the browsing of the distributed storage filesystem and instability issues with the configuration of the MPI distribution started to appear in the past years and became progressively more severe.

To overcome these problems, the OPH Board decided to request an external counseling from a company specialized in the design of HPC systems for a complete re-engineering of the cluster software and authentication system, and for an upgrade of the cluster management infrastructure.

This major maintenance of the cluster started during the summer with a complete backup of the whole storage area that required an extended downtime of the machine for about 5 weeks, and continued in the following months with an analysis and profiling activity performed by the external company to define the optimal procedures to be adopted for the main upgrade intervention.

Such upgrade is planned for the last weeks of 2022, and a testing phase of the new infrastructure will be started in the second half of January 2023 to identify possible remaining issues. The opening of the new system to the users is currently expected for the second half of February 2023, with a progressive migration of the different research groups at DIFA from the old to the new machine.

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Publications related to OPH

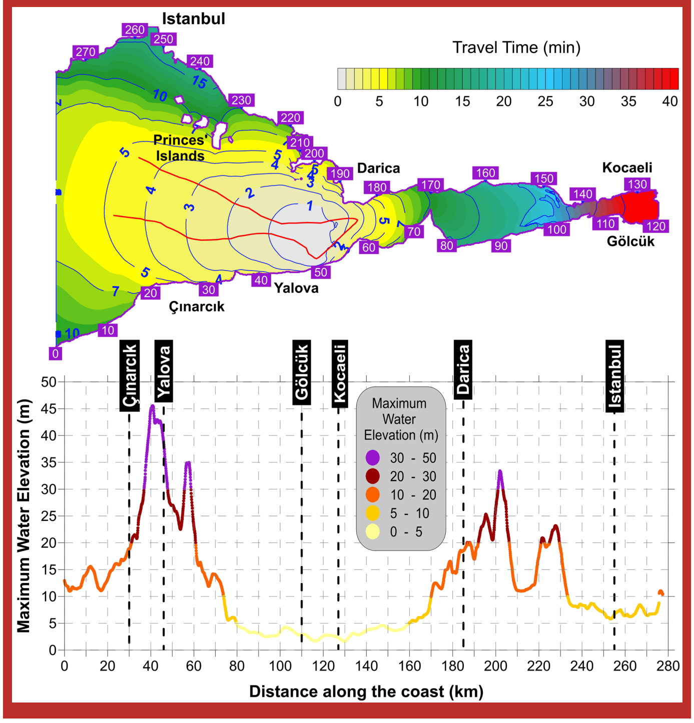
TSUNAMIGENIC POTENTIAL OF AN UNDERWATER LANDSLIDE IN THE EASTERN MARMARA SEA (TURKEY)

Numerical techniques can be of great help in the quantification of hazard related to natural events that can affect coastal communities. This is the case of tsunami-generated landslides, where many factors contribute to enhance the complexity of the phenomenon: the sliding motion along the slope, the mass-water interaction, the tsunami propagation, the coastal non-linear hydrodynamic effects. The DIFA Tsunami Research Team has developed and maintained in the years a set of numerical routines facing these different phases of the tsunami process, applying them to many cases of non-seismic tsunami sources, such as, for example, the Stromboli 2002 event [1] and the 1783 Scilla tsunami [2].

In this framework, a potential sliding mass of almost 4 km^3 has been identified and characterized through geophysical surveys in the Eastern Marmara Sea (Turkey) [3]. The shallow-water occurrence of the slide enhances considerably the hazard in the area, that is densely populated and industrialized along the coast. A set of numerical simulations making use of the serial codes UBO-BLOCK1 (slide motion), UBO-TSUFD (tsunami propagation) and ancillary programs were executed by means of the OPH cluster BladeRunner, performing a sensitivity analysis on the slide motion parameters, in order to assess their influence on the generated tsunami characteristics.

A summary of the output is reported in the figure on the right: the potential sliding motion (delimited by the red contour in the upper panel) entails maximum wave elevation exceeding 40 m close to the source, and reaches the area of Istanbul within 15 minutes (upper panel) with maximum waves of about 8 m (lower panel). This simulation represents a worst-case scenario, since the mass is considered to move in a single phase, and provides crucial indications for emergency planning. Further developments of this work can be the focus of the simulation of tsunami impact on selected areas, described with higher resolution and managed by means of the technique of nested grid: this operation increases considerably the computational power demand, and will require further uses of the OPH cluster, possibly implementing parallel coding.

TSUNAMI TRAVEL TIME AND MAXIMUM WAVE ELEVATION ON THE COAST



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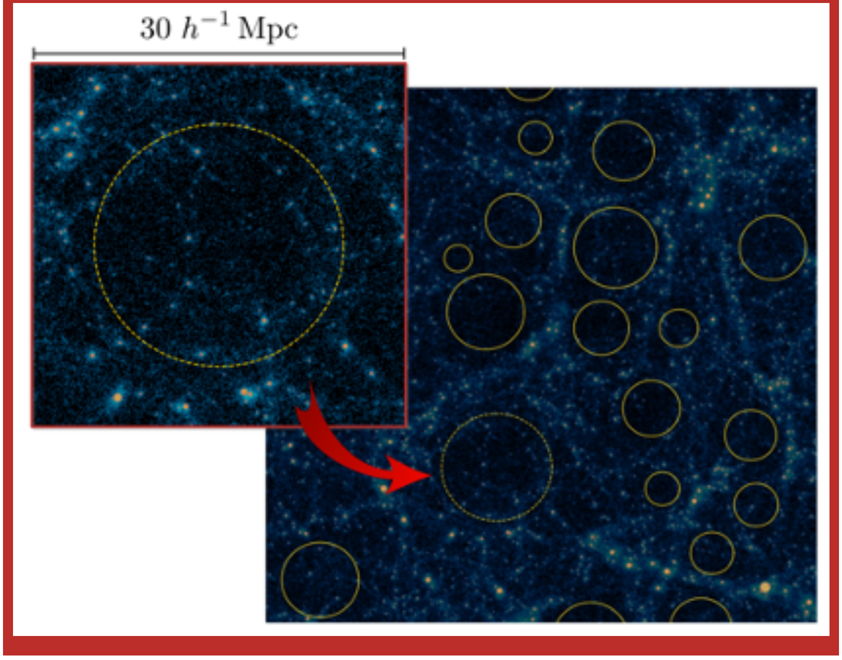
Publications related to OPH

THE ABUNDANCE OF COSMIC VOIDS

Distribution of cosmic voids



Cosmic voids are roundish underdense regions emerging between the filaments and the walls of the so-called cosmic web. With their impressive sizes, spanning from tens to hundreds of Megaparsecs, voids dominate the Universe in terms of volume. In recent years, the abundance of voids as a function of their size, i.e. the void size function, has demonstrated great potentiality in constraining the main parameters of the cosmological model [1]. However, for the cosmological exploitation of the void size function we need to deal with two main issues. First, being essentially devoid of luminous matter (e.g. galaxies and galaxy clusters) by definition, these underdense regions must be identified by means of void finding algorithms, which use the position of the mass tracers to infer the centre and the extension of each void. Second, large cosmological simulations or survey data catalogues are necessary to collect a statistically relevant sample of voids: both a high density of mass tracers and an extended volume are indeed required to identify small and large voids, respectively. Thanks to high-performance facilities of the OPH computing cluster Blade-Matrix, we overcame both these issues, producing large void catalogues to analyse with cosmological purposes. In particular, in [2] we made use of the DUSTGRAIN-pathfinder simulations to study the void size function in modified gravity scenarios characterised by the presence of massive neutrinos and in [3] we evaluated the constraining power expected from the void size function in the upcoming Euclid Mission. Both the works highlighted the impressive amount of cosmological information embedded in cosmic voids and the complementarity of the void size function constraints with those of standard probes such as weak lensing, galaxy clustering or, as recently demonstrated in [4], cluster counts.

References

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[2] Contarini S., Marulli F., Moscardini L., et al. (2021), MNRAS, 504, 5021
[3] Contarini S., Verza G., Pisani A., et al. (2022), arXiv:2205.11525, accepted by A&A
[4] Pelliciari D., Contarini S., Marulli F., et al. (2022), arXiv:2210.07248, submitted to MNRAS

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Useful links

OPH website
Department of Physics and Astronomy "A. Righi"
INFN
CNAF
OPH Computing Cluster user guide
International Summer School on Physical Sensing and Processing
Astronomy Public Conferences

OPH Newsletter: previous issues
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#2 OPH_Newsletter_02_Februay 2021
#3 OPH_Newsletter_03_May 2021
#4 OPH_Newsletter_04_November 2021
#5 OPH_Newsletter_05_May 2022

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