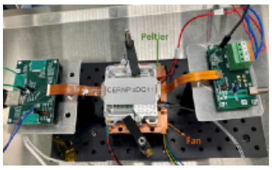
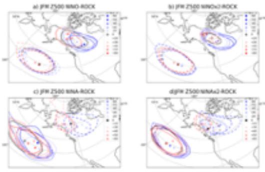
DEPARTMENT OF PHYSICS AND ASTRONOMY “AUGUSTO RIGHI”



ADVANCED SENSING LABORATORY



HIGH PERFORMANCE COMPUTING CLUSTER

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

OPH NEWSLETTER

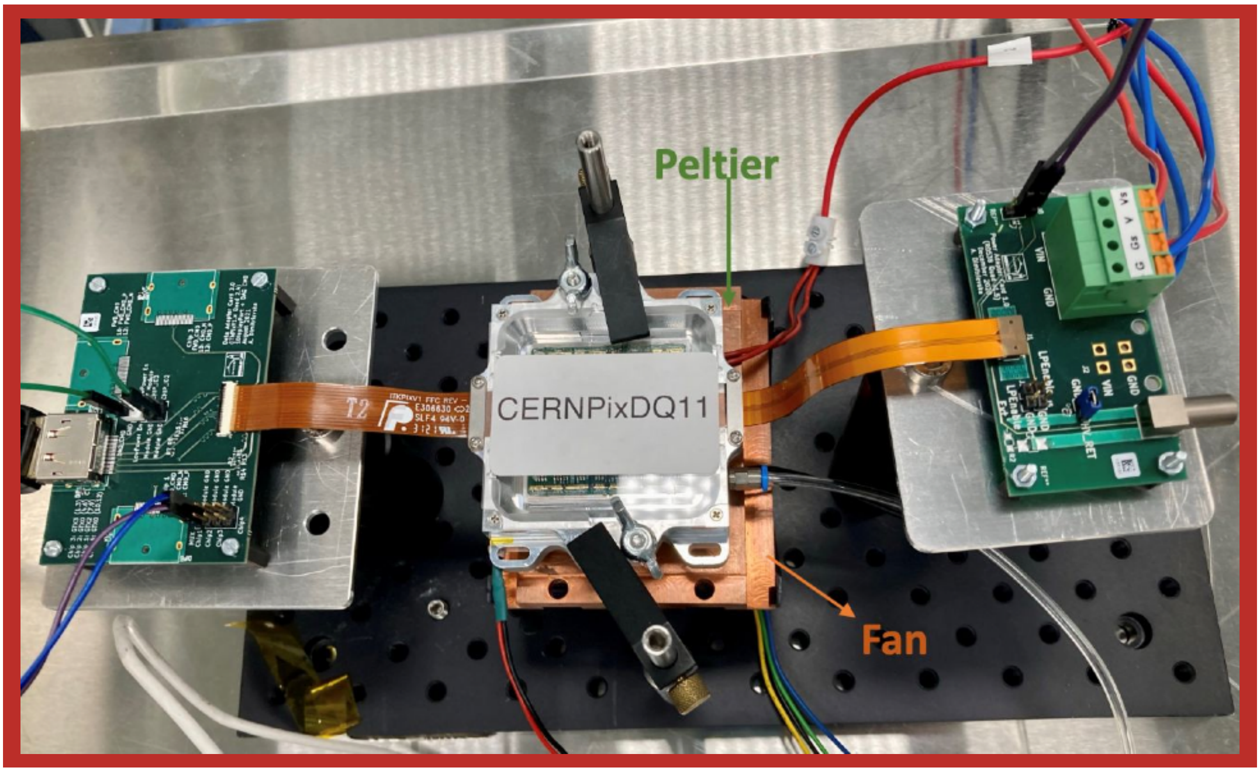
FOCUS: The OPH clean room and the construction of the ATLAS Inner Tracker for HL-LHC

Summary

The clean room co-financed by OPH and INFN is hosting a number of instruments and custom-developed software solutions that are enabling the local ATLAS team to qualify for participation in the construction of the future inner tracker of the ATLAS experiment at CERN, a task involving many Countries and Institutions spanning from Japan to the US. Building a silicon tracker with an instrumented surface in the order of 200 m² is not an everyday task; requirements on spatial resolution and radiation hardness pushed the involved technologies to their current limits. The (Bologna) clean room is now ready to start the process of Quality Control on the hybrid pixel modules that will be part of the ATLAS tracker. In ITk, pixel sensors of different flavours (both planar and 3D), thicknesses (down to 100 μm), area (2×2 and 4×4 cm²) and pixel sizes (either 50×50 μm² or 25×100 μm²) will have to withstand a

dose as high as 10^{16} n_{eq}/cm^2, while each readout chip (2×2 cm^2, and 152800 pixels) is designed to sustain a rate of 5 Gb/s. The quality of each module needs to be checked before deciding on its actual suitability: quality assessment is a fundamental step in the construction of any detector meant to work in harsh conditions for a defined period of time.

Joining the ITk project represents a great opportunity to develop further expertise and open new possibilities to young researchers eager to face technological challenges. A few students already spent their degree internship with the local team and helped develop the software infrastructure for continuous monitoring of the quality of the clean room environment in terms of temperature, humidity and air particulate - as requested by the tests to be performed there - as well as the control and monitoring of the operation of a climate chamber used to thermally cycle the modules between -55°C and +60°C. A cost effective implementation of instrument control, sensor reading, and data exchange can rely on modern IoT solutions: WiFi data exchange based on MQTT protocol, temporal series storage in InfluxDB, online visualisation via Grafana, and microcontrollers programmed via Arduino IDE are examples of arrangements found in our laboratory. The instrumentation includes an x-ray gun fit with a computer-controllable movement system, microscopes for visual inspections, a chiller and thermally isolated stations to run the modules at operating temperatures down to -25 °C, as well as computer-controlled power supplies and custom-developed hardware-interlock systems to guarantee the module safety in the event of unexpected conditions.
Although tests are performed locally, results are continuously shared among the different labs participating in the project, which represents a privileged road to experience international cooperation.



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Teaching and outreach

The 5th edition of the DIFA International Summer School on Physical Sensing and Processing

From 17 to 21 July 2023, the Aula Magna of the Department of Physics and Astronomy will host the **fifth edition of the Summer School on Physical Sensing and Processing**, this year focusing on Physics Measurements (link).

As in past editions, OPH significantly contributes in the financing and organisation of the event, which was programmed within the project financed by the University of Bologna with the call Alma Strutture promoting international activities at the department of Physics and Astronomy. For instance, this edition features special talks by recognised experts from the university of Notre Dame (USA) and Wollongong (Australia) – partners of this project. In addition, the program includes a public seminar by Peter Heering (Europa Universität Flensburg) presenting an overview on the role of experiments in the scientific progress.

The school is conceived for Master's and Ph.D students. The program is articulated in front lectures in the form of seminars and a series of special presentations aimed at providing the vision for the future developments of the experimental techniques discussed in the school. Six different project-oriented laboratory sessions (2 hour each) will take place in the afternoon. Students can actively reflect on the topics discussed during the lectures, transform them into skills to perform advanced experiments. Collaborative activities include data analysis and the preparation of a short presentation that will be hosted in the last day of the School.

In summary, the school is structured in lectures and hands-on sessions, designed to allow students to exercise with the topics introduced in the lectures. Given the vast variety of involved research fields, students will have a general overview of different kind of measurements in several disciplines. Consequently, the school can help in improving the multidisciplinary background of students: a basic pillar for advancement and innovation.

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High Performance computing cluster

The long and winding road...
(...that leads to a sustainable computing cluster)

The OPH computing cluster at DIFA is currently undergoing a major upgrade both in terms of its hardware equipment and software design. The rapid growth of the cluster size in terms of computational power, storage capacity, and number of users — as already outlined in the last OPH Newsletter — has led to the urgency of reshaping the facility infrastructure, redesigning its management, and ultimately imposing a radical change in the way users access the cluster resources.

Just to give an impression of the pace at which the cluster is growing, in the last Newsletter we were reporting the number of available cores having roughly doubled in the period 2018-2022, reaching 2184 cores at the end of last year. Only 6 months later, we are currently counting 3008 available cores with a planned further expansion that will lead to about 3500 cores by the end of 2024.

In the context of such a continuously expanding facility, the migration to the new setup of the cluster — still far from being completed — has progressively undisclosed multiple layers of inadequacy in the management, monitoring, and maintenance of the infrastructure, especially for what concerns the storage area that suddenly started suffering both hardware and software instabilities enforcing an extended period of offline maintenance. Also, the authentication procedures as well as the network bandwidth, that allowed for a relatively smooth interface with the cluster over the past years, started to appear inefficient with the continuous increase of the cluster usage and data traffic.

Although this may sound as the merciless report of a neverending frustration in the attempt to raise our original small machine to the rank of a medium-size computational infrastructure, it actually shows that the OPH computing cluster has fully accomplished its original missions: on the one side, it allowed a direct access to parallel computational resources and data storage for all DIFA researchers over the funding period of the OPH project, attracting significant external fundings and contributing to the scientific production of the Department, while on the other side it prompted and stimulated the development of in-site expertise and skills on designing, managing, and maintaining such a complex infrastructure.

This was actually the main reason why the OPH project preferred to invest part of its fundings on building a local computing facility rather than on buying computational resources from external providers: the added value in terms of expertise acquired while learning from our mistakes in the management of the cluster will remain as a strategic asset for the future developments of DIFA initiatives in computational physics.

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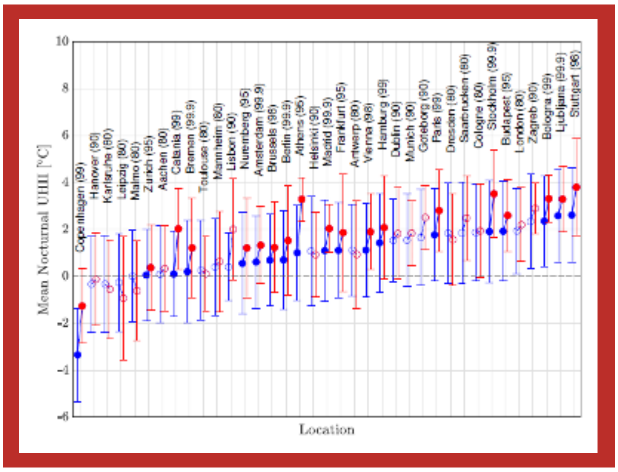
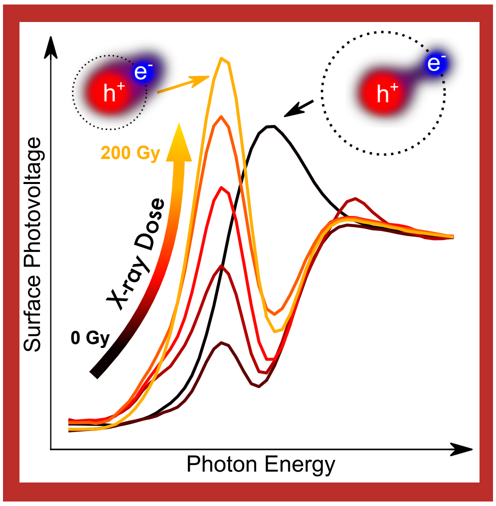
OPH Ph.D. students - 35th Cycle

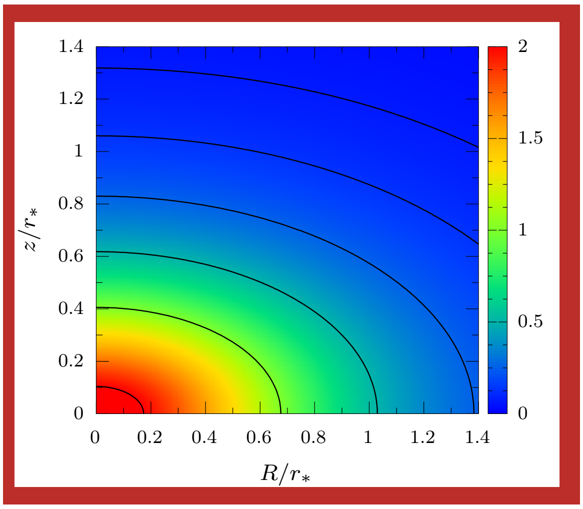
The Ph.D. students enrolled during the first year of OPH activity (A.Y. 2019/2020, 35th Cycle) are going to discuss their thesis. Hereafter their activity is described in short.



Marco Possega thesis, titled “*Analysis of heat-related phenomena and their interactions at different spatio-temporal scales*,” sheds light on how heat extremes propagate through different spatial and temporal scales and their impacts on various environments. The first part of his thesis examines the influence of large-scale heatwaves on the local-scale urban heat island effect, while the second part addresses different types of droughts and their temporal characteristics. In this respect, he adopted a climatological approach that involved mainly a statistical investigation of observational and reanalysis data, which was performed using the Data Analysis Cluster "BladeRunner" of OPH.

In his PhD research **Giovanni Armaroli** characterized the opto-electronic properties of metal halide perovskites (MHP), a promising class of novel semiconductors for solar, sensing, and lighting applications. In particular, he investigated the defects and issues that are currently hindering the commercialization of MHP devices. He studied the effect of ionizing radiation on the MHP opto-electronic properties, the consequence of mechanical stress on MHP-Silicon solar cells, ion migration phenomena, and degradation under exposure to environmental gases such as oxygen and water. For this research, he used the X-ray tube and the optical table setup of the OPH laboratory.





Antonio Mancino carries out his research in the fields of Stellar Dynamics and Fluid Dynamics. He works on the construction of new weakly flattened ellipsoidal galaxy models, combining an analytical treatment with a numerical exploration of their structural and dynamical properties. These models are useful in a number of astrophysical problems where it is important to test the effects on the internal dynamics of the shape of the stellar distribution. One of the immediate aims is the model implementation in hydrodynamical simulations of gas flows in galaxies, performed by using the OPH facilities.

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Publications related to OPH

The role of the atmospheric mean state for the ENSO teleconnection

Understanding to what extent the systematic error of global climate models affects the processes regulating the natural and forced variability of the general circulation is one of the grand challenges in climate science. One of the main drivers of tropical and extratropical variability is the El Niño-Southern Oscillation (ENSO). ENSO is a quasi-periodic, coupled ocean-atmosphere phenomenon able to impact both hemispheres through the propagation of Rossby waves. This joint study by DIFA and ISAC-CNR Bologna investigated how changes in the Pacific Jet mean state can modulate the ENSO-generated Rossby wave train propagating over the North American continent. The final aim of the study is to gather insight into the connection between the Pacific jet mean state and the ENSO teleconnection. Due to the need for large numbers of simulations spanning hundreds of years, an Earth system Model of Intermediate Complexity (EMIC) was used to perform original simulations where the orographic boundary condition of the Rocky Mountains is changed to induce a modification of the mean state of the Pacific Jet. The simulations show that different mountain heights are associated with different Pacific Jet intensities; as expected, the lower the Rocky Mountains, the stronger the wind. Then, four idealised ENSO sea surface temperature (SST) anomalies for each Rocky mountains (NINO/A-ROCK and NINO/Ax2-ROCK) configuration were run. Two of the four anomalies represent the standard intensity of an El Niño and La Niña event, and the other two are double-intensity anomalies. Results show rather clearly that the mean state of the Pacific jet modulates substantially the horizontal propagation of the ENSO-induced Rossby wave while leaving its amplitude unaffected (see Figure 1 and Di Carlo et al. 2022). The data analysis was performed using the OPH cluster and the work was supported by the HPC-Europa3 programme.

References

Di Carlo, E., Ruggieri, P., Davini, P. et al. ENSO teleconnections and atmospheric mean state in idealised simulations. Clim Dyn 59, 3287–3304 (2022). https://doi.org/10.1007/s00382-022-06261-w

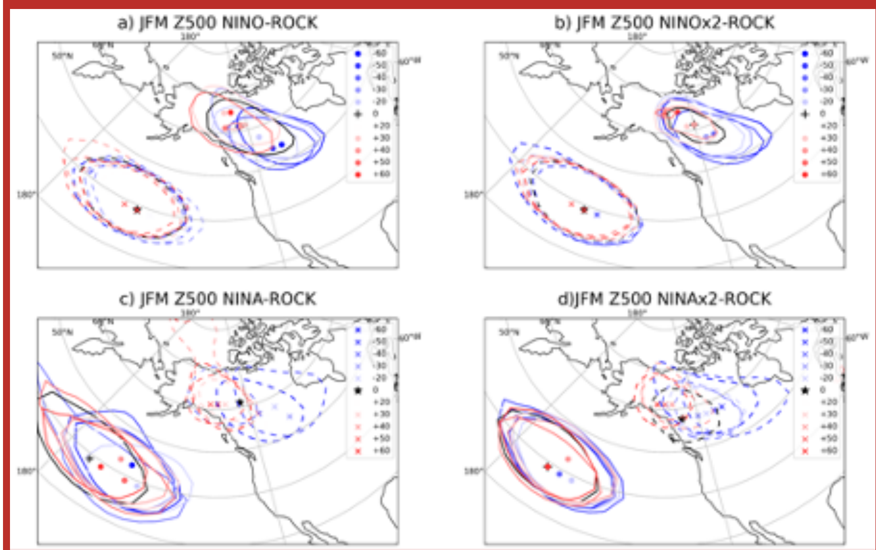

Figure 1: JFM dipole response to ENSO in the geopotential height at 500 hPa for (a) for NINO-ROCK experiments (b) for NINO-x2-ROCK experiments, (c) for NINA-ROCK experiments, and (d) for NINAx2-ROCK experiments. Only one contour for the North Pacific anomaly and only one for North America anomaly are drawn. Contours are chosen arbitrarily in order to highlight displacement of the anomaly. Dots show the positions of the maximum positive response and crosses the position of the minimum negative response. The value for the anomaly over the North American continent for the NINA experiments is about – 9 m, while the same for NINO reaches 15 m. Similarly, NINAx2 shows a maximum signal of about – 17 m, while NINOx2 gets up to 30 m

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Publications related to OPH

Unveiling the Peculiarities of DDO 68: Insights from Hydrodynamical N-body Simulations

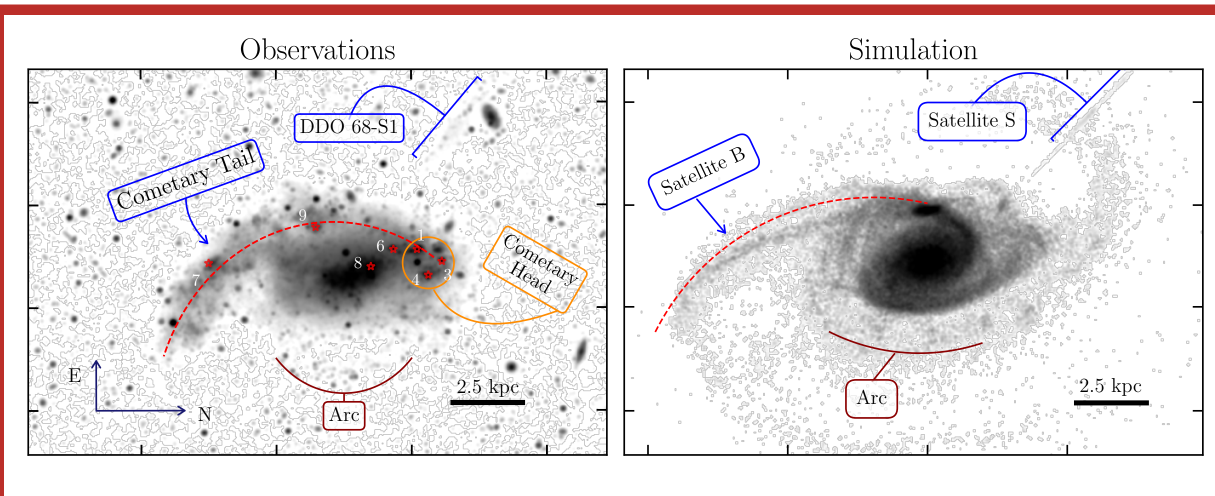
The study of dwarf galaxies challenges the widely accepted Λ cold dark matter paradigm (ΛCDM), which has successfully explained large-scale structures in the Universe. However, when it comes to comparing predictions with observations in the realm of dwarf galaxies, ΛCDM encounters certain discrepancies. These discrepancies can be partly addressed by incorporating baryonic physics, while alternative dark matter models also offer potential explanations. ΛCDM predicts that local dwarf galaxies are surrounded by satellites and stellar streams, exhibiting similarities to those found around massive spiral and elliptical galaxies.

Therefore, the investigation of satellites and stellar streams around dwarf systems provides a valuable and novel testing ground for cosmological models. An interesting case study is DDO 68, a local star-forming irregular galaxy that exhibits an extremely peculiar morphology (see left panel of Fig.1). It can be clearly appreciated by a simple eye inspection a bright and distorted stellar component to the south, known as the Cometary Tail. This feature extends approximately 10 kiloparsecs from the main body of the galaxy and encompasses approximately 10% of the total stellar mass in the system. Other unusual features include a roundish structure to the north of DDO 68, referred to as the Cometary Head, which hosts several HII regions where new stars form and serves as a hub for young stars. Additionally, a low-luminosity arc, known as the Arc, extends from the western edge of the galaxy, and a low surface brightness stellar stream, labeled DDO 68 S1, is located 5 kiloparsecs northeast of DDO 68.

Through the use of hydrodynamical N-body simulations conducted on the OPH computing cluster BladeRunner, we have successfully demonstrated that the peculiarities observed in DDO 68 can be comprehensively explained by interactions with two smaller satellite galaxies. The right panel of Fig.1 represents a mock observation generated from the simulation, where all the reproduced features are marked for comparison with the left panel. Furthermore, our findings are in well agreement with predictions from cosmology in terms of number and mass of satellites expected around galaxies with DDO 68's mass, and they indicate a remarkable likelihood of multiple accretion events currently occurring within this system.

References

Pascale R., et al., 2022, MNRAS, 509, 2940, 10.1093/mnras/stab3054



Left panel: Observation of DDO 68. The Cometary Tail, the Cometary Head,the stellar stream DDO 68-S1 and the Arc are marked by colored arrows andcircles. Right panel: mock observation of DDO 68 from the simulation of Section4. All the features reproduced by the simulation are marked as in the left panel. East is up, North is to the right.

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Useful links

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

OPH Newsletter: previous issues
#1 OPH_Newsletter_01_May 2020
#2 OPH_Newsletter_02_Februay 2021
#3 OPH_Newsletter_03_May 2021
#4 OPH_Newsletter_04_November 2021
#5 OPH_Newsletter_05_May 2022
#6 OPH_Newsletter_06_December 2022

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