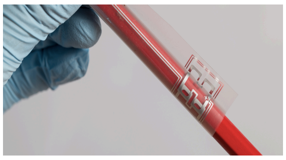
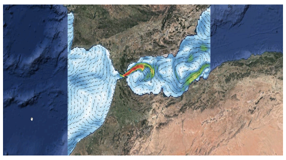
DEPARTMENT OF PHYSICS AND ASTRONOMY "AUGUSTO RIGHI"



ADVANCED SENSING LABORATORY



HIGH PERFORMANCE COMPUTING CLUSTER

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# OPH NEWSLETTER

## FOCUS: the FLIR thermal camera

The OPH FLIR T1020 infrared (IR) camera is a high-definition portable instrument able to capture and record high-quality images. T1020 has an uncooled infrared sensor with a Full HD resolution of 1024 x 768 pixels, increasing up to 3.1 MP with the Ultra-Max super-resolution mode. The IR camera uses FLIR OSXTM HDIR precision optics, the auto/manual focus lens has a 1–8x continuous digital zoom and provides a lens-dependent field of view.

### Summary



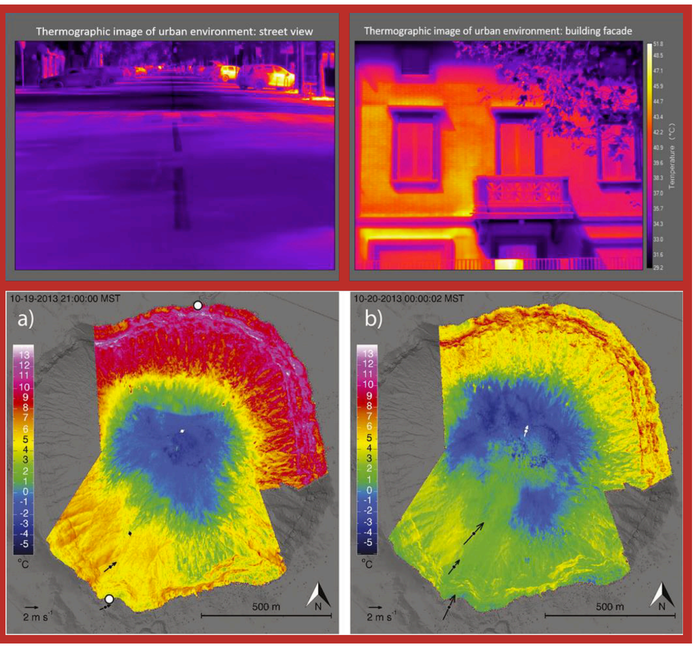
Image of the FLIR T1020 thermal camera (left) along with 28° and 12° lenses (right). The table below provides the technical details of the thermal camera.

| | |
|---|---|
| IR resolution | 1024 × 768 (786,432 pixels) |
| UltraMax® | 3.14 Mpixels |
| Field of view (FOV) | 28° × 21° (36 mm lens) and 12° × 9° (83 mm lens) |
| Spectral range | 7.5 – 14.0 µm |
| Object temperature range | -40° C to +2000°C |
| Thermal sensitivity | < 20 mK at 30°C |
| Operating temperature range | -15°C to 50°C |
| Accuracy | ±1°C or ±1% at 25°C for T from 5°C to 150°C |
| Image frequency | 30 Hz |
| Video streaming frequency (via Wi-Fi or USB) | up to 240Hz through the high-speed interface |

## EXAMPLE OF APPLICATIONS

Thermal imaging, i.e., the process of converting infrared radiation into visible images, can be used to map the surface temperature of any object with high thermal, temporal and spatial resolution. Compared to thermometers or thermocouples, the advantage of using the infrared cameras relies in their capability to deliver truly bidimensional measurements allowing for a reconstruction of accurate surface temperature maps even in the presence of large temperature gradients [**1,2**]. As a remote sensing device, the camera conducts the measure without perturbing the phenomena under investigation. Finally, thermal imagery presents high sensitivity and low response time, ensuring the possibility to measure convective heat fluxes over a body surface with both steady and transient techniques.

High-resolution thermal imaging can be used to detail surface thermal characteristics, flows and turbulence, in a variety of meteorological applications. The detailed reconstruction of the temperature distribution at street level has allowed to evaluate the temperature gradients present in the urban environment, and their impacts on ventilation and pollutant removal [**3**]. Similarly, IR thermography is also used in mountain meteorology to evaluate the surface thermal characteristics, enabling a more exhaustive characterization of key processes such as the formation and destruction of a surface cold pool or the onset and evolution of slope winds [**4**]. Finally, thermal imagery provides a quantitative measure of the thermal forcing to evaluate more realistic boundary conditions within local-scale fluid dynamics and dispersion models. These innovative applications open up new paths for the inclusion of the OPH thermal camera in a wide range of national and international research proposals, as for example recently done in two research proposals presented in the PRIN2020 call for applications.




(Top panels) Example of IR camera applications in urban environments (Laura Bassi Street in Bologna): street view on the left, and image of a building façade on the right. Both images were taken during the summer intensive thermographic campaign carried out during the iSCAPE H2020 experimental field campaign (August-September 2017). (Bottom panels) Georeferenced brightness temperature overlay on the Meteor Crater topography (Source: Whiteman et al., 2018).

**References**

[1] Astarita T., Carlomagno G.M. (2013). Springer, Berlin/Heidelberg, Germany.

[2] Carlomagno G.M., Cardone G. (2010). Experiments in Fluids, 49, 1187-1218.

[3] Di Sabatino S., Barbano F., Brattich E., Pulvirenti B. (2020). Atmosphere, 11(11), 1186.

[4] Whiteman C. D., Lehner M., Hoch S. W. et al. (2018). J Appl Meteorol Climatol, 57(4), 969-989.

Back to Summary

# OPH: second year activity report

After 2 years since the project kick off, all OPH components are now operational. In fact, both the Advanced Sensing Laboratory and the High-Performance Computing (HPC) cluster are being continuously used for excellent, innovative and interdisciplinary research by researchers of and linked to DIFA. Therefore, OPH seems to meet our unique research needs. For instance, since last February, 5 different research projects related to OPH have been approved and granted by Large Scale Facility (European Synchrotron Radiation Facility and ELETTRA Synchrotron), University of Bologna and Regione Emilia Romagna, respectively. Moreover, in the same period, 12 Research Projects of Relevant National Interest (PRIN) and 2 Horizon 2020 projects linked to OPH have been submitted. In 7 of these projects the principal investigator is from DIFA. Thanks to the instrumentation made available by OPH, 15 articles were published in the most important peer reviewed international journals in 2020. For more details, highlights of these publications spanning over exceptionally different research fields - from astrophysics to material science, and from nuclear physics to air quality modelling - are reported at pag. 6 and 7 of this newsletter. Moreover, OPH infrastructures help young researchers and PhD students to make their challenging research projects possible, as reported in the next page.

In addition to boosting research activities of the department and related research institutes, OPH has been improving the quality of teaching. As an example, in 2020 11 master's and bachelor's students have prepared their thesis taking advantage of the equipments of the Advanced Sensing Lab as well as the HPC cluster. Furthermore, the "International Summer School on Physical Sensing and Processing" was organised in collaboration with Cornell University, Caltech University, NVIDIA, IBM, CERN, CNR and INFN. More than 140 students from Europe and outside Europe attended the online classes.

OPH objectives

- Promotion of research initiatives on Advanced Sensing Technologies for scientific, societal, and industrial applications and on High-Performance Scientific Computing and Big Data Analytics.
- Participation to national and international projects and competitive calls.
- Promotion and implementation of innovative teaching initiatives.
- Stimulating Outreach campaigns.
- Supporting research initiatives that envisage a direct or indirect industrial or societal application.
- DIFA Internationalisation.

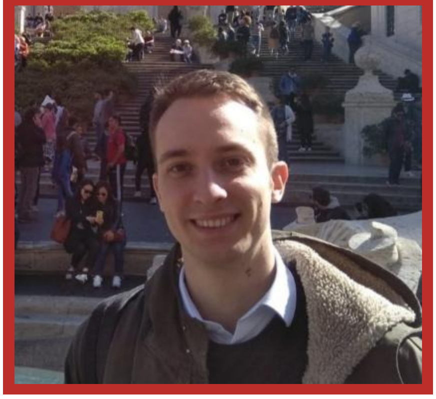
In summary, these examples represent the enormous potential of OPH. We expect the best has till to come in the next years, when OPH will be operating at full capacity.

Back to Summary

# OPH PhD students

OPH offers **three Ph.D. fellowships** every year, one for each of the Ph.D. programs hosted by DIFA. In the following, the three students attending the XXXV cycle (second year of activity) are accounted.

MARCO POSSEGA



**Marco Possega** is enrolled in the "Future Earth, climate change and societal challenges" PhD program. His research activity focuses on the study of dynamical interactions between extreme heat events acting at different scales (urban heat islands, heatwaves and droughts), with particular interest for phenomena acting on regions characterized by coastal topography. For this purpose, the two approaches he is adopting consist of statistical analysis of observational data and numerical simulations through mesoscale models performed using the Data Analysis Cluster "Blade-Runner" of OPH.

ANTONIO MANCINO

**Antonio Mancino** carries out his research in the field of Stellar Dynamics. He is currently working on the construction of new ellipsoidal galaxy models, and combines an analytical treatment with a numerical exploration of their dynamical properties. These models are useful in many astrophysical problems where it is important to test the effects of varying the galaxy structure. Immediate aims are the model implementation in hydrodynamical simulations of gas flows in galaxies to be carried out on the OPH facilities, and the porting of a parallel version of our Jeans code JASMINE2.

GIOVANNI ARMAROLI

In his research, **Giovanni Armaroli** studies radiation-induced defects in hybrid halide perovskite single crystals for applications in ionizing radiation detection. For this purpose, he is currently using the microfocus X-ray tube and the UV laser diode in the in the OPH laboratory. In his experiments, he first irradiates the samples with a fixed dose of X-ray photons from the microfocus source. Then, he uses the UV laser diode to photoexcite it and collect the photoluminescence spectrum before and after irradiation.

Back to Summary

# Teaching and outreach

## THE 3RD EDITION OF THE DIFA INTERNATIONAL SUMMER SCHOOL ON PHYSICAL SENSING AND PROCESSING

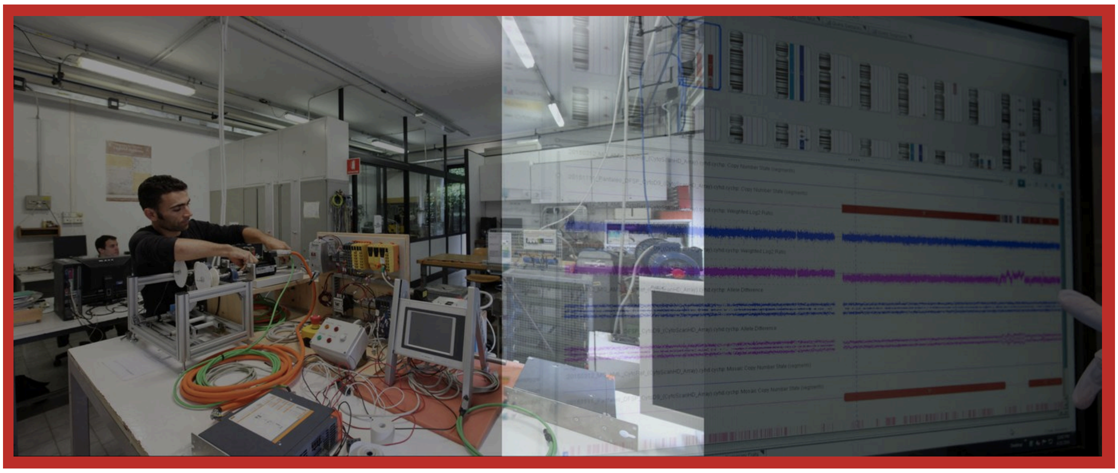
The OPH summer school "Physical Sensing and Processing", reaching this year its third edition, will offer a teaching program focused on **four main research topics**:

- the problem of Dark Matter in the Universe;
- the identification and evolution of an epidemic breakout;
- the modeling and predictability of Earth's climate;
- and X-ray tomography for the reconstruction of anatomic structures.

For each of these topics, three different lecturers from national and international universities will provide specific insights on the related **experimental and computational challenges**, following the main pillars of the OPH activities, i.e. advanced sensing and computing.

The topical lectures will be complemented by a series of additional presentations aiming to **provide the vision for possible future developments** of the main experimental and computational techniques that are transversally employed in all the four main topics of the school. For these special talks, the school will host the presentations of three experts in the fields of High-Performance Computing, Machine Learning, and high-energy X-ray physics.

The school will take place from **5 through 9 July 2021** and will be held (hopefully for the last time) fully remotely, with no registration fee and with a dedicated web conference interface. The **preliminary program** of the school is now available here.



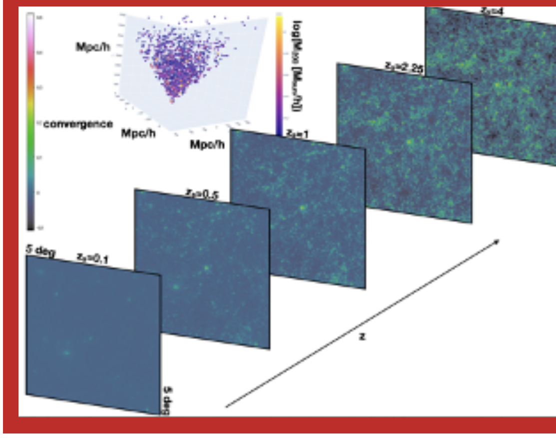
Back to Summary

# Publications related to OPH

## SPEEDING UP WEAK LENSING SIMULATIONS

Weak gravitational lensing represents one of the primary cosmological probes of different future wide field surveys, like the [**Euclid-ESA** mission] [**1**]. This effect manifests itself in a slight modification of the intrinsic shape of distant background galaxies, due to the light bent by the intervening matter density distribution along the line-of-sight. Because the effect is very small, ray-tracing simulations are needed to calibrate all the possible systematics that may have a cosmological and astrophysical dependence. In this work we have developed a fast and accurate method to create highly detailed light-cone simulations starting from cosmological runs [**2**]. We have tested the reliability of the method using only the halo population and then by *"panting"* an analytical model on it, finding a very good agreement with the full runs [**3**]. The computational resources of **the OPH computing cluster BladeRunner** have allowed us to produce a large number of light-cone realizations for a variety of cosmological models. In addition we have interfaced the weak lensing pipeline with approximate N-body methods, like PINOCCHIO, being able for the first time to construct self-consistent weak lensing covariance matrices [**4**], which are required for a full derivation of the cosmological parameters using bayesian methods.

Projected Density Field



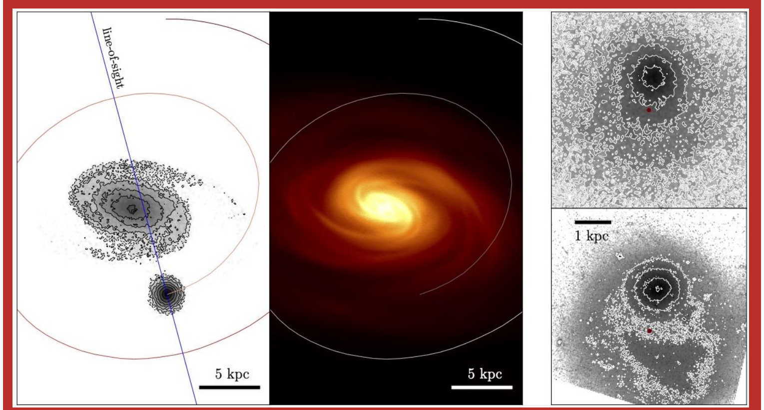

**References**

[1] Laureijs et al. (2011), arXiv e-prints, arXiv:1110.3193.
[2] Giocoli C., Monaco P, Moscardini L. et al. (2020), MNRAS, 496, 1307
[3] Giocoli C., Baldi M., Moscardini L. (2018), MNRAS, 481, 2813
[4] Giocoli C., Di Meo S., Meneghetti M. (2017), MNRAS, 470, 3574

## HYDRODYNAMICAL *N*-BODY SIMULATIONS OF DWARF GALAXIES

Irregular galaxies with peculiar structure and kinematics are ubiquitous in the Universe. However, the galaxy NGC 5474 – a local star-forming galaxy, satellite of the Pinwheel Galaxy and member of the M 101 Group – is one of a kind. Indeed, this galaxy features an unusually large offset between its putative bulge and its kinematic center whose origin is difficult to explain (see the bottom right panel of the Figure). Thanks to high-resolution hydrodynamical N-body simulations, performed on the **OPH computing cluster BladeRunner** with moving-mesh hydrodynamic code *AREPO***,** we have shown that the round off-set stellar component of NGC 5474 is not the bulge of the galaxy [**1**]. Exploiting the structural similarity between a dwarf Elliptical galaxy and the "bulge" of NGC 5474, we have demonstrated that the offset can be reproduced by projection effects, if the "bulge" is a satellite galaxy of NGC 5474. Finally, the gravitational interaction between the two systems can also explain the formation of NGC 5474 loose spiral pattern and partially account for the formation of its warped HI disc. The Figure shows a view of the stellar (left panel) and gas (right panel) distribution of the NGC 5474 + satellite system from the simulations. For selected lines-of-sight (left-panel, blue curve) the simulations reproduce the observations (right panels).

Stellar and gas distribution




**References**

[1] Pascale R., Bellazzini M., Tosi M. et al. (2021), MNRAS, 501, 2091.

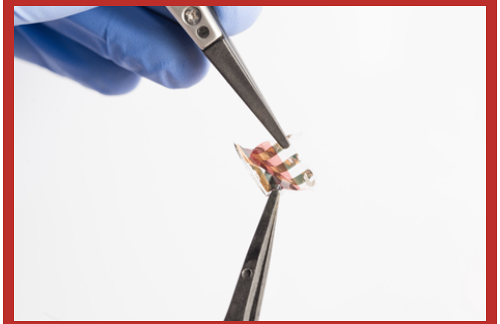
Back to Summary

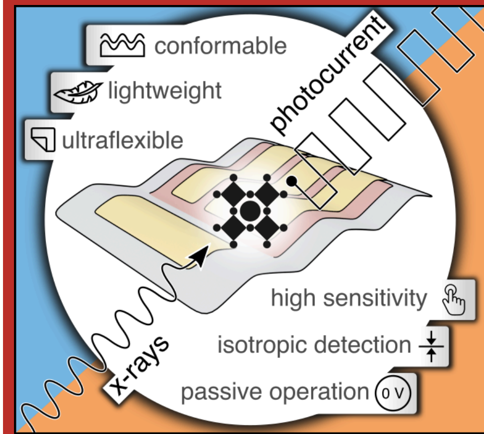
# Publications related to OPH

## FLEXIBLE AND LARGE AREA X-RAY PHOTOCONVERSION

The interest on organic/hybrid semiconductors as active material for novel highly sensitive ionizing radiation detection systems originates from the exceptional properties of these materials, above all the possibility to deposit them from solution onto non-conventional flexible substrates and over large areas by means of easy low-cost processing techniques. Recently, researchers at DIFA, led by Prof. B. Fraboni, and their collaborators, investigate the physical processes behind X-ray photoconversion employing organic thin-films [**1**] and exploiting their medical applications as tissue-equivalent dosimeters [**2**, **3**]. Besides organics, hybrid lead halide perovskites are rapidly advancing as novel high performing materials in the field of semiconductor devices. In this framework, ultraflexible, lightweight, and highly conformable passively operated thin film perovskite direct X-ray detector have been realized, assessing their outstanding real-time detection performances [**4**, **5**]. The projects have been carried on thanks to the irradiation facilities (X-rays and UV laser diode) available in the OPH Advanced Sensing Lab.

**FLEXIBLE X-RAY DETECTOR**






**References**

[1] Temiño I., Basiricò L., Fratelli I. Et al. (2020), Nat Commun, 11, 2136.

[2] Basiricò L., Ciavatti A., Fratelli I. et al. (2020), Front. Phys. 8:13.

[3] Posar J., Davis J., Large M. et al. (2020), Med. Phys. 47,8..

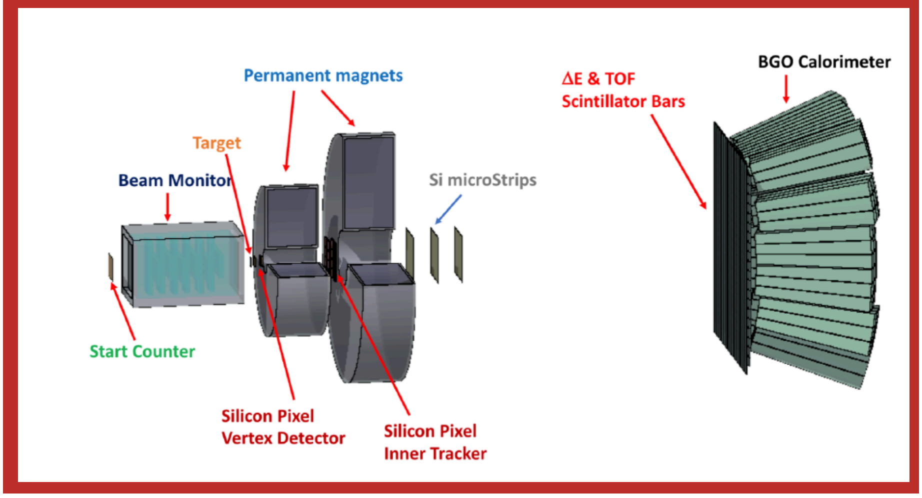
[4] Ciavatti A., Sorrentino R., Basiricò L. et al. (2021), Adv. Funct. Mater., 31, 2009072.

[5] Demchyshyn S., Verdi M., Basiricò L. et al. (2020), Adv. Sci., 7, 2002586.

## THE FOOT EXPERIMENT

The FragmentatiOn Of Target (FOOT) experiment aims to provide precise nuclear cross-section measurements for two different fields: hadrontherapy and radio-protection in space. The main reason is the important role the nuclear fragmentation process plays in both fields, where the health risks caused by radiation are very similar and mainly attributable to the fragmentation process. The paper [**1**] describes in detail structure and design of Data Acquisition System, developed at the Bologna University taking advantage of the electronic modules made available by OPH.

**THE FOOT EXPERIMENT**




**References**

[1] Biondi et al (submitted), arXiv:2010.16251v1

Back to Summary

# Contacts

**OPH Spokesperson**: Andrea Cimatti
**OPH Coordinator**: Mauro Villa
**OPH Contact Point**: Eleonora Ciccone
**OPH Computing Facilities**: Marco Baldi
**OPH Advanced Sensing Lab**: Cristian Massimi

# Useful links

**OPH website**
https://site.unibo.it/openphysicshub/en/

**Department of Physics and Astronomy**
https://fisica-astronomia.unibo.it/it

**INFN**
http://www.bo.infn.it/

**CNAF**
https://www.cnaf.infn.it/en/

**OPH Computing Cluster user guide**
https://site.unibo.it/openphysicshub/en/internal

**International Summer School on Physical Sensing and Processing**
https://site.unibo.it/school-physical-sensing-and-processing/en

**Astronomy Public Conferences**
https://www.oas.inaf.it/it/conferenze-specola/

**OPH Newsletter: previous numbers**
**#1**_ OPH_Newsletter_01_May2020.pdf
#2_ OPH_Newsletter_02_Feb2021.pdf

**Edited by**
Filippo Zaniboni, Cristian Massimi

**Contributions**
Giovanni Armaroli, Marco Baldi, Francesco Barbano, Silvia Biondi, Erika Brattich, Andrea Ciavatti, Francesca Di Nicola, Silvana Di Sabatino, Carlo Giocoli, Antonio Mancino, Federico Marinacci, Lauro Moscardini, Carlo Nipoti, Raffaele Pascale, Marco Possega, Paolo Ruggieri

Back to Summary