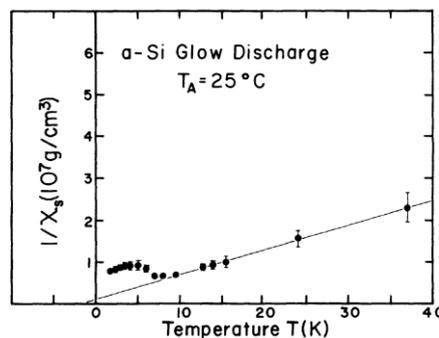
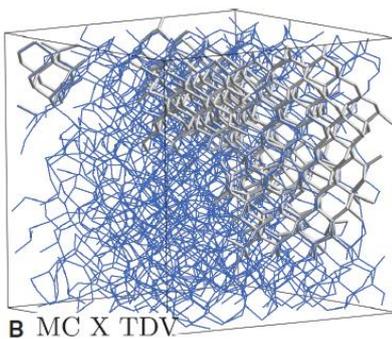


Amorphous Solid-State Physics

Almost all research in the field of solid-state physics is still dealing with the physics of crystals. However most solids in Nature and more and more in technological applications are amorphous, or topologically disordered. Let us just think of glasses and all their ubiquitous uses. Yet these materials (and related organic solids) still represent a formidable challenge for studying their properties at the microscopic level, progress being slow but steady thanks to simplifications occurring at low temperatures. Degrees of freedom called Tunneling Systems exist at low- T and can be used as probes for investigating the real structure of these materials at the intermediate-range atomic level. The great surprise from this research (theoretical, but matched by the available experimental data) is that the amorphous solid appears to be a new type of solid, namely heterogeneously disordered and cell-like organized, different from the crystal (even when defect ridden) and that ought to be no longer thought of as a dynamically arrested liquid as is commonly believed. The images below refer to the case of a-Si structure and mysterious data (mag. suscept. χ).



A paracrystal in the atomic structure of a-Si (left), and the puzzling magnetic response of non-magnetic a-Si.

Are they related?

Much has been done in the past 15 years to understand the silicate glasses at low- T , with a model that is now being tested for the understanding of amorphous Si and Ge (films). Especially a-Si is a material of great technological significance, but as mysterious as ordinary SiO₂-based glasses. Yet the experimental data – still unexplained – available at low- T show the very same phenomenology as discovered for the silicate glasses in the presence and absence of a magnetic field. Work is being done to adapt the model to these systems and to then infer on the real atomic structure and its relevance for useful research projects like the improvement of efficiency of a-Si based solar cells.

Research on a more fundamental level is also being carried out in order to elucidate the main assumptions (and consequences) of the phenomenological tunneling model. For example lightly Li-doped KCl single crystals are considered as model systems that can be treated – to an extent – in a truly microscopic way and that show at low- T similar phenomenology as the cold glasses. The challenge is to see if the model for a-SiO₂, a-Si etc. can also be employed, and better understood, for KCl:Li. In parallel, the

consequences of said model for a new description of the glass transition are being investigated., always comparing theory to available experiments.

Reference Person: Giancarlo Jug (Giancarlo.jug@uninsubria.it)

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Dynamical systems

The research activity is focused on statistical properties of dynamical systems, in a wide perspective, encompassing both deterministic and stochastic evolutions.

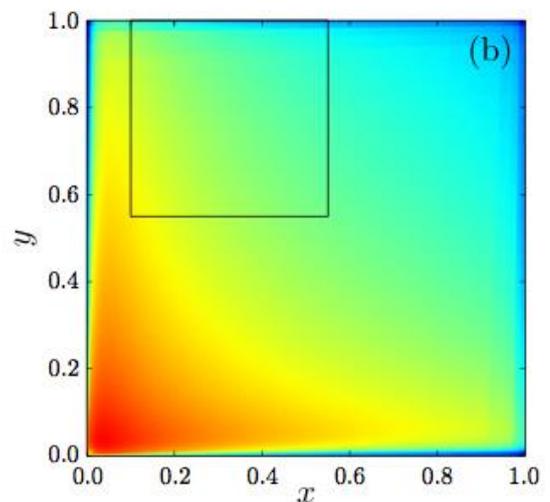
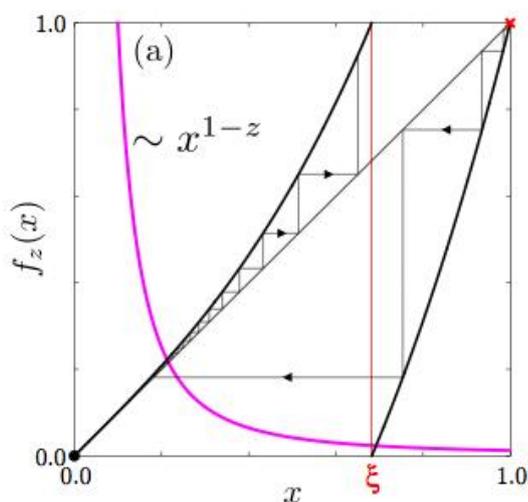
While we have reached quite a profound understanding of important cases (regular *integrable* systems, or fully chaotic *unstable* models) the behaviour in between is still rich of open problems, of physical significance, since this *middle land* is thought to be generic. The same situation appears in the stochastic setting, when we modify the picture of simple random walks, for instance. A typical signature of this intermediate situation is the occurrence of *anomalies*, like long time tails, ergodicity breaking, anomalous transport and so on. A more detailed understanding of these features would not only enrich our mathematical understanding of dynamics: as a matter of fact anomalous behaviour has been observed in a huge variety of contexts, from animal foraging to migration of cell constituents, from epidemic spreading to fluctuations in stock markets.

Detailed research proposals may be found at the link

http://www.dfm.uninsubria.it/artuso/Roberto_web_page/theses.html

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http://www.dfm.uninsubria.it/artuso/Roberto_web_page/home.html

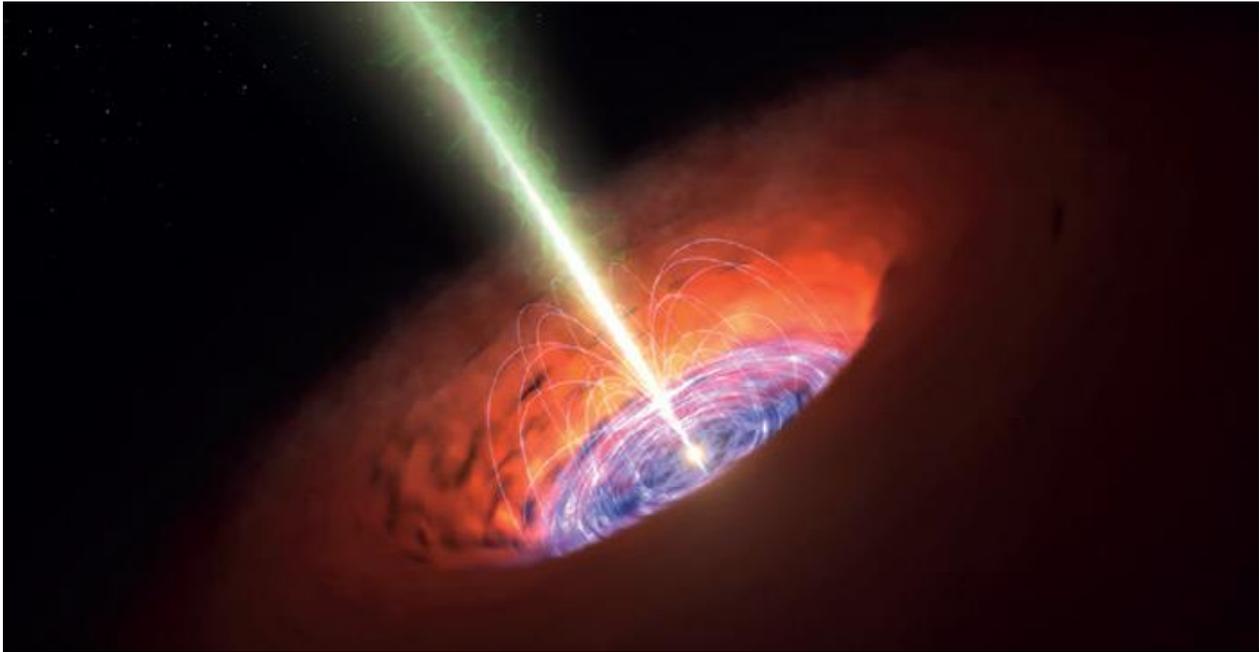
A weakly chaotic map

Coupled intermittent map: phase space

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Blazars

About 10% of Active Galactic nuclei, beside accreting matter, have two anti-parallel jets in which the matter flows relativistically, reaching bulk Lorentz factors $\Gamma \sim 10-15$. When the jet points in our direction the source is called *blazar*.

The fast motion makes the emission beamed, in such a way that the flux we receive from blazars is strongly enhanced, and for this reason well visible at high redshifts: blazars are therefore excellent probes of the far Universe. One example: we estimate that the black hole mass of some of them exceed one billion of solar masses even at redshifts 4-5, when the Universe was ~ 1 billion years old. And for each blazar with such a heavy black hole, there must exist hundreds of other sources, pointing elsewhere, with the same mass.

The emission produced by blazars ranges from the radio to the high-energy γ -rays, reaching the TeV band. Due to this extreme energy emission, we wonder if blazars can be the sources of high energy neutrinos recently detected, and even of the highest energy cosmic rays (*Gabriele Ghisellini, Fabrizio Tavecchio*).

The power of relativistic jets is larger than the luminosity of their accretion disks Ghisellini G., Tavecchio F., Maraschi L., Celotti A., Sbarrato T., 2014, Nature 515, 376

High energy cosmic neutrinos from spine-sheath BL Lac jets
Tavecchio F., Ghisellini G., 2015, MNRAS, 451, 6020

Gamma-Ray Bursts

The heaviest stars, at the end of their life, are able to produce colossal amount of energy in two ways: a supernova and a gamma ray burst (GRB). While the supernova

involves the motion of a few solar masses at speeds of 5,000-10,000 km/s, in GRBs we have a tiny fraction ($1e-4$ - $1e-5$ solar masses) of mass going at $G \sim 100-1000$ along two well collimated jets (as in blazars). Even if the GRB research was frantic in the last 20 years, there still are controversial issues that deserve to be studied. The most serious one concerns the origin of the radiation we see during the 10-50 seconds of the so-called “prompt” emission, usually in the hard X-rays and very variable. Is it synchrotron? Inverse Compton? Multi temperature thermal emission? We do not know yet. This ignorance severely limits our ability to infer the physics from what we observe. At the same time, this implies a very active research about this issue (Giancarlo Ghirlanda, Gabriele Ghisellini).

Short GRBs at the dawn of the gravitational wave era

Ghirlanda G., Salafia O.S., Pescalli A., et al., 2016, A&A 594, A84

The faster the narrower: characteristic bulk velocities and jet opening angles of Gamma Ray Bursts Ghirlanda G., Ghisellini G., Salvaterra R., et al., 2013, MNRAS, 428, 1410

Fast Radio Bursts

They have been discovered very recently and serendipitously, through radio observations able to catch bursts of flux lasting about a millisecond. From the dispersion of the arrival time as a function of frequency, we can infer the amount of material through which the emission passed, that implies that the sources are extragalactic, at a redshift around unity.

Recently, one of these events was seen to repeat, enabling the search of a counterpart, and confirming the extragalactic nature. This implies a huge power emitted in the radio band. Fast follow-ups in other bands have been made, with null results. The nature of these objects is still a complete mystery. And their emission process is a mystery as well: what we know is that only a coherent process can account for the huge brightness temperatures we observe, that are comparable to the ones of the radio pulses of pulsars, whose origin is still debated (Gabriele Ghisellini).

Synchrotron masers and fast radio bursts

Ghisellini G., 2017, MNRAS, 465, L30

Reference person: Gabriele Ghisellini (gabriele.ghisellini@brera.inaf.it)

Hadron Spin Physics

The main theme of the group's activity is "Hadronic Spin Physics", with particular emphasis on transverse-spin effects. Philip G. Ratcliffe is author of a seminal paper [1], co-author of a well-known review article [2] and a book [3] on the subject and is also member of the International Advisory Committee of a series of International Workshops on "Transverse Polarisation Phenomena in Hard Processes", having organised the first edition in 2005, hosted at Villa Olmo in Como.

There is an on-going and active collaboration with Oleg Teryaev (Dubna), on the construction of a unified theoretical picture for the description of single transverse-spin asymmetries in hard hadronic collisions. Collaborations such as COMPASS at CERN, HERMES at DESY, STAR and PHENIX at Brookhaven, and PAX at GSI (Philip Ratcliffe is a member of the PAX collaboration) are now producing (or will produce) large amounts of data from many different experiments performed with transversely polarised beams and targets.

Attention has been directed towards single transverse-spin effects in Drell-Yan processes, a topic on which there has been much discussion in the literature: not only is there disagreement on the overall normalisation by as much as a factor $2^{\pm 1}$, but also on the possible presence of special derivative terms. Our work confirms the results of Teryaev and co-workers; a clarifying paper has been published [4].

The Como group participates in the I3HP Projects "HadronPhysics2" and "HadronPhysics3" of the VII European Framework Program; the group also participates in the Italian PRIN2008 research program entitled "Parton distributions and their dependence on intrinsic motion: theory, phenomenology and experimental techniques" and as part of the Pavia node of the continuation proposal for a PRIN2011.

Reference person: Philip Ratcliffe (philip.ratcliffe@uninsubria.it)

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[4] G. Re Calegari and P.G. Ratcliffe

“Single Transverse-Spin Asymmetries in Drell–Yan Processes”

Eur. Phys. J. C74 (2014) 2769; arXiv:1307.5178.

[5] P.G. Ratcliffe

“SU(3) Breaking in Hyperon Beta Decays: A Prediction for $\Xi^0 \rightarrow \Sigma^+ e \nu$ ”

Phys. Rev. D59 (1999) 014038; hep-ph/9806381.

INSULAB

The INSULAB group led by Michela Prest is involved in detector development in particle physics, space physics, medical physics. The group consists of senior physicists, post-doc, PhD and first and second level degree students with different skills in software and hardware items, collaborating with scientific national and international institutes: the National Institute for Nuclear Physics (INFN, Sections of Trieste, Milano Bicocca, Padova, Pavia, Ferrara, Roma1), CERN, S. Anna Hospital in Como, PSI.

The group is expert in the the development of detectors systems based on scintillators, scintillating fibers, silicon detectors and their related frontend and readout electronics to be used for tracking, calorimetry, imaging. It is involved in several collaborations/projects:

- **ENUBET (Enhanced NeUtrino BEams from kaon Tagging - project ID 681647, ERC-CoG-2015):** to measure quantities such as the CP violating phase, next generation neutrino experiments will need very precise measurements of oscillation probabilities and will be limited by systematics uncertainties, in particular due to cross sections. A precise determination of the absolute neutrino cross sections, especially for ν_e , is thus considered mandatory. The uncertainty derives from the lack of knowledge on the initial neutrino flux that cannot be measured directly. This limit can be overcome measuring directly the ν_e interaction rate at the detector while monitoring the positrons produced in the decay tunnel and originating from the $K^+ \rightarrow e^+ \pi^0 \nu_e$ (K_{e3}) decay. If the decay tunnel is short ($\sim 50\text{m}$ for 8GeV secondaries) K_{e3} represents the only source of ν_e : the corresponding ν_e flux can thus be inferred from the positron rate in the decay tunnel with a precision of 1%. The goal of the project is the development of a cost-effective technology based on fast shashlik calorimeters with longitudinal sampling readout by Silicon PhotoMultipliers and able to measure the rate of positrons identifying them against the background of charged pions and converted photons.

Website: <http://enubet.pd.infn.it/>

- **AXIAL (INFN CSNV project):** the project belongs to the field of crystal physics in which the INSULAB group has been involved since 2008. This last development concerns the study of axial and quasi-axial phenomena in crystals for beam steering and electromagnetic radiation generation. The INSULAB group is responsible of the tracking and calorimetric systems, of the data taking and online analysis on the CERN extracted beamlines. The project foresees also the test of a crystal based steering of the 70-250 MeV protons used by the proton therapy facility in Trento.

For crystal physics and tests, see dedicated thesis at:

http://insulab.dfm.uninsubria.it/index.php?option=com_content&task=section&id

=13&Itemid=60

- **PHYSICS EDUCATION:** since 2010, the INSULAB group is developing innovative approaches in teaching science for schools of all grades, working directly in the schools with teachers and students. For a description of part of our activities

see:

http://insulab.dfm.uninsubria.it/images/download_files/rabaioli_thesis_master.pdf

http://insulab.dfm.uninsubria.it/images/download_files/thesis_armandaferrarini_phd.pdf

Reference person: Michela Prest (michela.prest@uninsubria.it)

For the complete list of publications: <https://irinsubria.uninsubria.it/simple-search?query=prest#.V-kEoNERjyw>

Neutron Stars

The scientific career of Patrizia A. Caraveo (pat@iasf-milano.inaf.it, PAC hereafter) now spans more than 30 years. It can be characterized by a first 10 y period dedicated mostly to data analysis and interpretation of gamma-ray astronomy (ESA's COS-B) and X-ray astronomy (NASA's Einstein, ESA's Exosat) data.

In the second decade, the field of interest widens to include the full range of observational multiwavelength astronomy, with significant emphasis on optical observations and to include also interpretative work.

In the last decade, PAC has further broadened her interests, to include work on instrument design and mission planning, as well as managerial tasks at national and international level.

The constant scientific theme of PAC's contribution to science is the phenomenology of galactic compact objects. Special attention is given to isolated neutron stars, their velocity distribution, their distances and their relations to supernova remnants. **PAC is a recognized leader in the study of neutron stars behavior at different wavelengths**

In parallel, PAC took active part in the development of several high-energy missions, such as the Spectrometer Instrument of the Integral mission (in close collaboration with the French Space agency CNES), the Italian mission AGILE, and the NASA missions SWIFT and GLAST, now known as Fermi.

PAC is now the leader of the Italian participation to the Cherenkov Telescope Array (CTA), a project devoted to very high-energy astronomy from the ground, where Italy is one of the major partners.

Within the National Institute of Astrophysics (INAF), PAC is responsible for the exploitation of the Fermi data which are changing our view of the gamma-ray sky. Fermi has shown that a sizable fraction of previously unidentified galactic gamma-ray sources are indeed radio-quiet gamma-ray pulsars, similar to Geminga.

In recognition of her leading role in the study of the high-energy emission of isolated neutron stars, PAC was invited to write a review paper for Annual Review of Astronomy and Astrophysics. The paper, entitled **"Gamma-Ray Pulsar Revolution"**, appeared in September 2014.

Currently, PAC is Director of the Istituto di Astrofisica Spaziale e Fisica Cosmica in Milano, Professor of "Introduction to Astronomy" at the University of Pavia and Associate Editor of the *Journal of High Energy Astrophysics*.

PAC won the prize **Premio Nazionale Presidente della Repubblica** in 2009 and shared with her Swift, Fermi and Agile colleagues the **Bruno Rossi prize of the American Astronomical Society in 2007, 2011 and 2012**.

In 2014 she received the **Outstanding Achievement Award** from the Women in Aerospace European Society.

Her list of publication can be seen at <http://www.iasf-milano.inaf.it/~pat/WEBpage/pat-pub.pdf>. It features: 404 papers published on international referee journals, 147 conference papers (several invited papers), hundreds of papers for the general public.

Her impact factor is very high. ADS, the system widely used by the astronomical community, quotes an h index >90, with more than 33.000 citations.

Indeed, in 2014 PAC has been included by Thomson Reuters in the list of **Highly Cited Researchers** for Space Science.

More info at <http://www.iasf-milano.inaf.it/~pat/personal.html>

References:

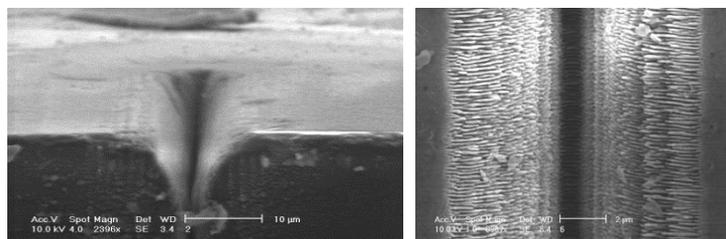
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Parallax Observations with the Hubble Space Telescope Yield the Distance to Geminga
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Science, 331, 736
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Gamma-Ray pulsar revolution
Ann. Rev Astron Astrophys. 52, 211
<http://www.annualreviews.org/doi/full/10.1146/annurev-astro-081913-035948>

ULTRAFAST NON-LINEAR OPTICS

Starting from Nonlinear Optics, we contributed in merging expertise from the ultrafast, spatial soliton-and-pattern and linear optics communities, which boosted the growth of the "space-time" light localization investigation. The research currently outlines nonlinear conical waves as the best candidate for a comprehensive understanding of ultra-short and intense pulse propagation inside transparent dielectrics, and for a number of relevant applications including parametric generation, creation of long and stable plasma channels, laser micro-fabrication.

1) Laser beam shaping and application to laser microfabrication

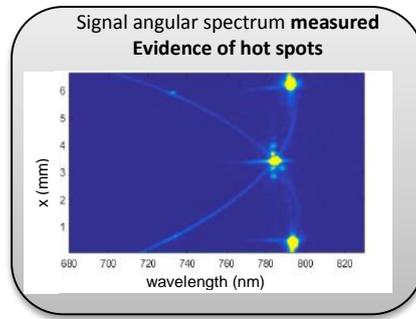
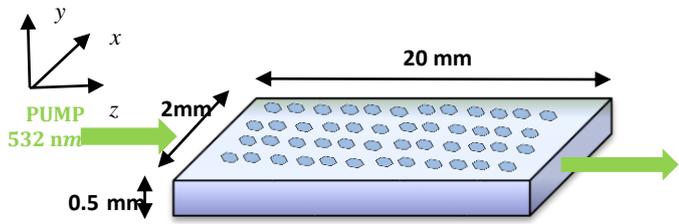
- Laser micromachining of transparent materials by means of Bessel beams: waveguides and high aspect-ratio channel generations in different materials; laser machining for surface functionalization
- Laser surface micromachining of diamond for microfluidics and biosensing applications
- Cutting and drilling of glass for technological applications
- Study of the dynamics of the fabrication process- collaboration with group of Dr. Couairon (Ecole Polytechnique of Paris)



2) Engineering of quantum states of light in parametric processes

- Parametric down conversion and generation of entangled states of light in the mesoscopic regime (high intensity) in periodically poled crystals
- Pump beam shaping and application to nonlinear parametric processes
- Characterization of the spatio-temporal coherence and correlation properties of the superfluorescent radiation

Collaboration with the Quantum Optics group of Dr. Alessandra Gatti (Insubria university); group of Prof. Katia Gallo (KTH, Stockholm).



Reference Person: Ottavia Jedrkiewicz (ottavia.jedrkiewicz@uninsubria.it)

Photo Controlled Deformable Mirrors: from material design to sky demonstrator

Deformable mirrors are active optical devices that have been founding an increasing interest in many technological field from astronomy to microscopy and high power lasers. The capability of such devices to change their optical surface makes possible to correct aberrated wavefronts (by the atmosphere or the inhomogeneous medium) and reaching a better resolution of the optical system and, in some cases, the diffraction limit performances.

This approach, known as adaptive optics, is crucial in modern ground-based astronomical instrumentation, where the potential resolution of large mirror telescope can be exploited only if the atmosphere distortion is compensated and the disk seeing is squeezed toward the Airy disk shape.

Different approaches have been developed to make a deformable mirror. The most common are: piezoelectric actuators (stack or bimorph), voice coils, MEMS (both electrostatic and electromagnetic). In spite of the fact that the actual technologies match most of the requirements of the astronomical field, we have to pay a big complexity of the device with risks in terms of reliability and duration.

The possibility to avoid the presence of real, physical actuators is attractive and this possible thanks to the Photo Controlled Deformable Mirrors (PCDMs), where a light pattern is sent on the back of a photoconductor slab. The light pattern defines the size, shape and density of actuators that can be optimized according to the wavefront to correct. In the illuminated areas of the photoconductor, a change in the electrostatic pressure is produced that locally modify the deformation of a reflective membrane which is electrically coupled with the photoconductor.

The performances of the device depend on many parameters and a suitable model for the device is desirable in order to find strategies and guidelines to improve it. The model has to cover the electrical, optical and mechanical parts of the device and has to describe both the behavior in the transient and in the regime condition.

Both organic and inorganic photoconductors are considered with different final applications. Indeed, inorganic photoconductor will be used to build fast deformable mirrors, whereas organic materials will be chosen for memory effect mirrors, where a certain shape is induced and kept for a certain time.

Starting from the output of the model, the photoconductor materials will be selected and/or synthesized and characterized. Based on them, the deformable mirror will be built and tested at the laboratory level and the results compared with those predicted by the model. A suitable projection system will be developed to produce the virtual actuators

pattern. At the same time, scientific astronomical cases that could benefit from this technologies will be studied.

The candidate will perform research activities focusing on different aspect of the presented technology. In particular, there will be the development of an opto-electric-mechanical model of the PCDM in the different working regimes; moreover, the candidate will be involved in the design and realization of mirror prototypes. Finally, a key step in the research program will involve the simulation of expected performances of an adaptive optical system in the field of astrophysics.

This research project is part of the EU Horizon2020 OPTICON project (Optical Infrared Coordination Network for Astronomy).

Reference Person: Andrea Bianco (andrea.bianco@brera.inaf.it), Marco Landoni (marco.landoni@brera.inaf.it)

Quantum Optics

The InsLight group is an experimental group led by Dr. Maria Bondani, Researcher of the Institute of Photonics and Nanotechnologies of CNR, operating at the University of Insubria.

The group is involved in two main research activities, as testified by the presence of two Laboratories, namely the Quantum Optics Lab and the Photophysics and Biomolecules Lab.

At present, other two people belong to the group, Dr. Alessia Allevi, tenure-track Researcher at the University of Insubria, and Giovanni Chesi, PhD student at the University of Insubria as well.

The group has a stable cooperation with two external collaborators, Dr. Luca Nardo (University of Milano Bicocca) and Marco Lamperti (Polytechnic of Milan), which are still involved in the research activities performed in the Photophysics and Biomolecules Lab.

The group has several national and international collaborators, among which the group of Prof. Matteo Paris at the University of Milan, the group of Prof. Jan Perina and Prof. Ondrej Haderka at the Joint Laboratory of Optics of the Palacky University in Olomouc (Czech Republic) and the group of Gruppo Prof. Hanne Tønnesen at the University of Oslo.

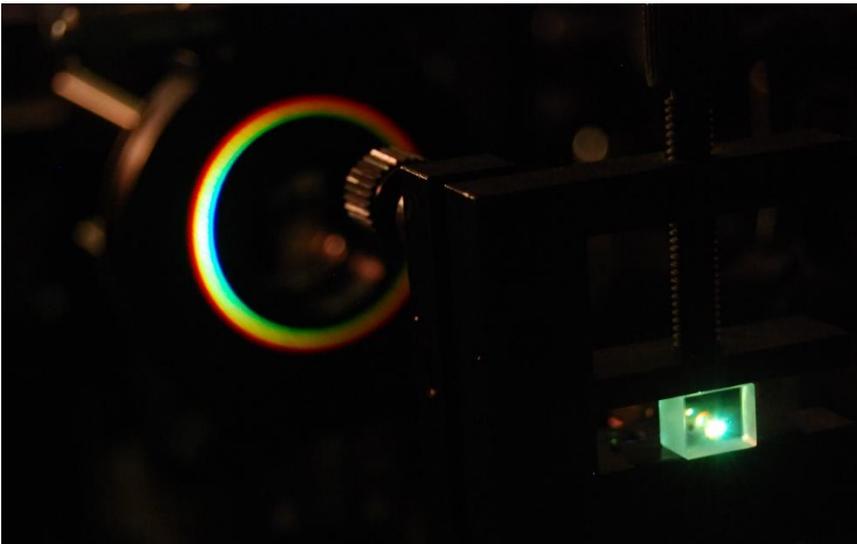
The research activity in the Quantum Optics laboratory includes some relevant topics in light-matter interaction, such as nonlinear optics, quantum optics, quantum information and characterization of different classes of photodetectors. Thanks to the availability of different kinds of laser systems and detection chains, the experimental investigations are performed in different intensity regimes, ranging from the single-photon level up to the macroscopic domain, passing through the so-called mesoscopic photon-number domain, in which pulsed optical states with sizeable numbers of photons per pulse are produced and photon-number resolving detectors are employed.

The research activity addresses the generation and characterization of both classical and nonclassical states useful for applications in the field of Quantum Information and Quantum Communication. At the same time, new detection schemes aimed at investigating both the particle-like and wave-like properties of light are being developed.

The research activity in the Photophysics and Biomolecules Lab is aimed at characterizing and exploiting biological compounds for technological applications. The experimental investigations are based on different techniques, such as time-correlated single-photon counting (TCSPC), fluorescence fluctuation spectroscopy (fluorescence correlation spectroscopy (FCS) and photon-counting histogram (PCH)). In particular, TCSPC is used to characterize new drug substances and nano-scaled drug delivery systems, as well as new polymeric organic and metallorganic compounds for selective adsorption, catalysis and fuels storage. Moreover, this technique is exploited to perform high resolution assessments on biomolecular conformations (recently particularly focused on DNA G-quadruplexes)

through time resolved fluorescence energy transfer measurements. Combined FCS and PCH measurements are being used to study the aggregation of the amyloid beta protein, which is involved in the Alzheimer onset. Moreover, the same techniques are useful to investigate the statistics of light emitted by single-molecules.

In addition to research, the group is strongly involved in Physics Outreach and Education. The research activities aim at finding new educational strategies and, in particular, at encouraging and supporting the experimental activity in high schools. By exploiting the expertise of the members of the group, many activities involve Optics experiments. Among the other initiatives, we mention the project “LuNa – La natura della Luce nella luce della Natura”, the annual “Joint International Physics Summer School – Optics”, organized in Como and in Olomouc (Czech Republic), the Workshop “Officina di didattica e divulgazione della Fisica” on different aspects of Physics and devoted to high-school students and teachers, the organization of PLS (Progetto Lauree Scientifiche) laboratories.



Reference person: Maria Bondani (maria.bondani@uninsubria.it)

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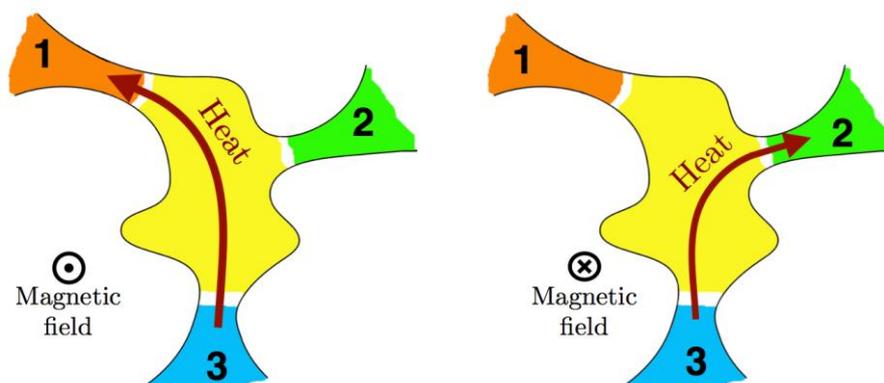
Quantum Transport and Thermodynamics

Since the industrial revolution, the transformation of heat into work has been at the centre of technology. The earliest examples were steam engines, and current examples range from solar cells to nuclear power stations. The quest to understand the physics of this transformation led to the theory of thermodynamics.

In recent years we have become increasingly interested in machines that convert heat into electrical power at a microscopic level. The perfect example of this are thermoelectric and photovoltaic devices. Nanotechnology has significantly advanced efforts in this direction, giving us unprecedented control of individual quantum particles. The questions of how this control can be used for new forms of heat to work conversion has started to be addressed in recent years.

This scientific activity has been boosted by the increasing importance placed on sustainable energy for the world's population. On the one hand, heat management at the nanoscale could dramatically reduce the energy cost of operating electronic devices and nanoscale scalable thermal engines could efficiently convert part of the waste heat into electricity. On the other hand, efficient thermoelectric Peltier cooling would underpin a wide range of quiet, long-lived refrigeration devices, with low environmental impact.

Our main objective is to better understand the laws of nature. More particularly, we aim to better understand what heat and entropy mean for quantum objects, and to better understand how such objects thermalize. We also aim to understand what quantum machines can be capable of, and what the laws of physics do not allow. At the same time, more practical goals include using ideas from quantum transport and quantum thermodynamics to devise more efficient thermal rectifiers, thermoelectrics and photovoltaics.



A model of a magnetic thermal switch for nanoscale heat management [for details see Phys. Rev. B 91, 205420 (2015)]

Reference person: Giuliano Benenti (giuliano.benenti@uninsubria.it)

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Lecture Notes in Physics vol. 921 *Thermal transport in low dimensions: from statistical physics to nanoscale heat transfer*, edited by S. Lepri (2016).

- [2] G. Benenti, G. Casati, K. Saito and R. S. Whitney, *Fundamental aspects of steady state conversion of heat to work at the nanoscale*, preprint arXiv:1608.05595 [cond-mat.mes-hall], submitted to Physics Reports.

Silicon PhotoMultipliers, introducing the Digital Age in Low Light Detection

The Department of Science and High Technology at Università dell'Insubria in Como hosts the activities of the team lead by Massimo Caccia, professor. The team develops instruments and methods based on the use of Silicon detectors of ionizing particles and light.

Since a decade, the core activities have been based on the use of Silicon Photomultipliers (SiPM), single photon sensitive devices with single photon sensitivity, photon number resolving capability, low bias supply, robustness, low cost, magnetic field immunity, extreme time resolution and, last but not least, design flexibility.

The team is collaborating with the major sensor producers and it has been involved in a number of projects, in collaboration with research teams and industry. Among them, it is worth mentioning:

- RAPSODI, a project supported by the European Commission within the VI Framework program. RAPSODI addressed the use of SiPM in homeland security, medical dosimetry and radon detection.
- MODES-SNM, a project supported by the European Commission within the VII Framework program. MODES targeted the development of a detector suite for homeland security, based on scintillation light by high pressure noble gases
- The collaborative projects with AWE (the Atomic Weapons Establishment) and KROMEK, a British public company) on the characterization of novel scintillators for neutron detection and neutron/gamma discrimination
- A series of developments with British and German companies in the medical domain.
- A joint development Laboratory established with CAEN s.p.a., a leading Italian company in the nuclear electronics market
- The design and construction of Dual Readout Calorimeter module, supported by Texas Tech, Iowa State University and INFN.

Recently, the team addressed as well the use of Silicon Photomultipliers for the analysis of biological samples. Last but not least, it is collaborating with a team from University of Aveiro (Portugal) and CAEN s.p.a. on the development of a table top, low cost Positron Emission tomography scanner.

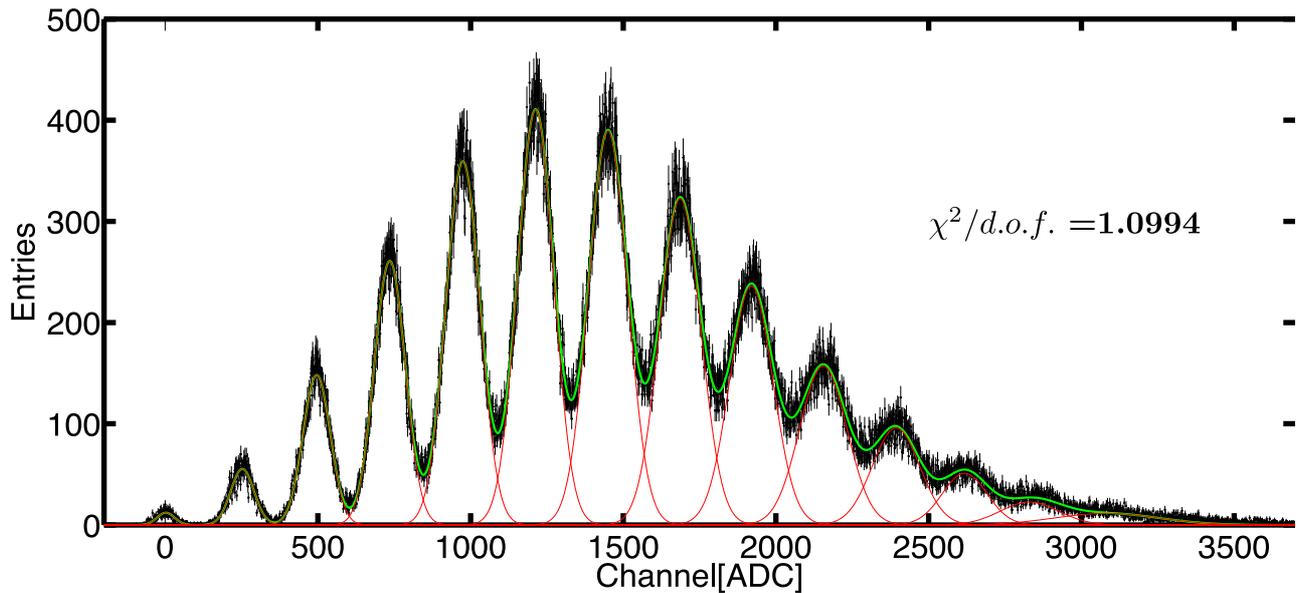


Figure 1. The picture is showing the response of a SiPM sensor to a high statistics of nanosecond long light bullets, illuminating the sensor at kHz rate. The peaks correspond to the number of illuminated pixels, proportional to the number of incoming photons. The different areas of the peaks are due to the statistical properties of the light source, notably following the Poisson distribution..

Reference persons: Massimo Caccia (Massimo.Caccia@uninsubria.it), Romualdo Santoro (Romualdo.santoro@uninsubria.it)

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- V. Arosio et al., A robust and semi-automatic procedure for Silicon Photomultipliers characterisation, 2017 *JINST* 12 C03030
- M. Ramilli et al., Photon Number Statistics with Silicon Photomultipliers, *J. Am. Opt. Soc. B*, 27 (2010), 852-862

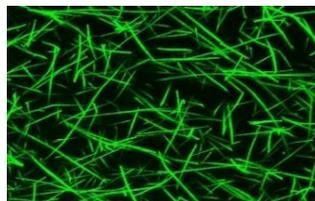
Light Scattering & To.Sca.Lab

The Light Scattering group, led by Prof. Fabio Ferri, works in the field of nano-particle and complex fluid characterization, with particular emphasis on the development of new optical methods for static and dynamic light scattering, turbidimetry, novel imaging techniques, speckle metrology, velocimetry and particle sizing.

The experimental activities are being carried out at two optics laboratories located at the Department of Science and High Technology in Como:

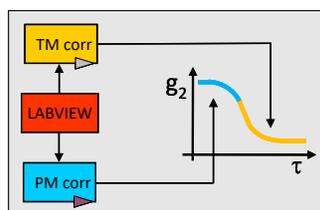
Light Scattering Lab (<http://www.dfm.uninsubria.it/laboferri/>) is an optic laboratory whose main activities regard:

- study of the growth kinetics and structure characterization of fibrin gels by using Light Scattering, turbidimetry, and Small Angle X-ray Scattering techniques.



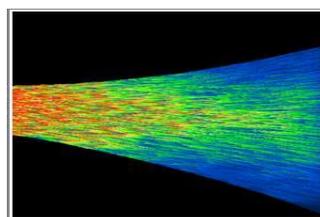
confocal image of a fibrin gel

- development of new data analysis algorithms and software correlators for Dynamic Light Scattering and Fluorescence Correlation Spectroscopy.



Our software 10 ns correlator

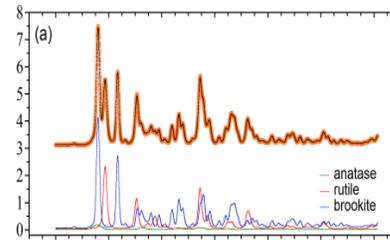
- development of speckle imaging velocimetry techniques based on the statistical analysis of the speckle produced by a moving fluid seeded with scattering nanoparticles.



Speckle imaging velocimetry

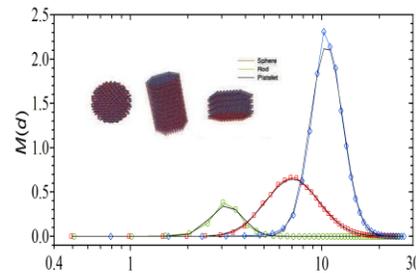
To.Sca.Lab (<http://toscalab.uninsubria.it/>) is an experimental and computational Laboratory that merges theoretical and experimental expertise in Chemistry, Crystallography and Physics within a unifying project based on Scattering Techniques (from X-rays to Visible Light), aiming at reconstructing structural, microstructural and dynamic behavior of nano-crystalline, partially ordered and disordered materials at different length scales (ranging from atomic resolution up to the mm size), and to correlate it with the material functional properties. The main activities regard:

- Debye Function Analysis (DFA) of Wide Angle X-ray Total Scattering (WAXTS) data for recovering structural, morphological and sizing information on crystalline nanoparticles.



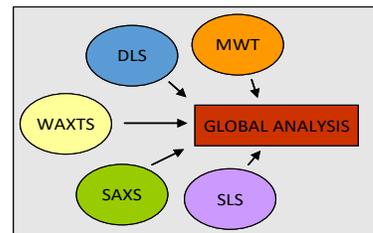
WAXTS data of TiO₂ nanocrystals

- development of inversion algorithms alternative to the WAXTS-DFA analysis, for the recovering of multi-variate nanoparticle sizing distributions.



Multi-phase inversion of WAXTS data

- development of a global data fitting and data inversion procedures in which the data coming from different techniques are *globally* processed for the nano-sample characterization.



Multi-techniques global analysis

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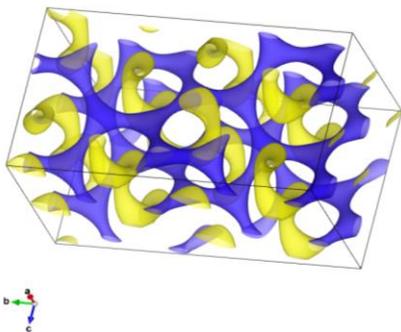
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- F. Ferri, G. Re Calegari, M. Molteni, et.al., Macromolecules, **48**, (2015) 5423
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Soft matter physics

Complex fluids belong to the broad class of systems, known collectively as soft matter. They are solutions, typically water-based, of macromolecular entities (often called colloidal particles) with typical sizes ranging from 1 to 1000 nm: much larger than the atomic size but still small on a macroscopic scale. This class of systems permeates diverse fields of science, including physics, chemistry and biology, also playing a major role in the paint, food, cosmetic and pharmaceutical industry.

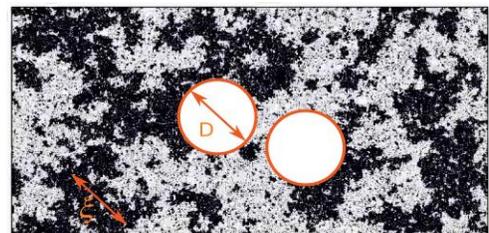
In physics, complex fluids are exploited both as magnified models of traditional atomic and molecular systems and as building blocks for genuinely novel materials. Nano-particle dispersions typically contain, in addition to the solvent, smaller components such as salt ions or free polymer chains and, possibly, other macromolecules. Due to the presence of these additional components (a phenomenon known as "macromolecular crowding") the colloidal particles often display physical properties quite different from those expected on the basis of their intrinsic structure: The external environment affects the behavior of the guest particles due to strong correlation effects. A physical understanding of the role of correlations in nano-particle suspensions is instrumental for a forthcoming exploitation of their peculiar properties. Our group, in collaboration with the experimental Soft Matter Laboratory of Polytechnic University of Milan, develops statistical models to describe the collective behaviour of these systems both at and out of equilibrium. Few illustrative examples, often leading to a surprising behavior are:

Pattern formation at the mesoscopic scale



D.Pini, A.Parola:
*Pattern formation and self-assembly driven
by competing interactions*
Soft Matt. **13**, 9259 (2017)

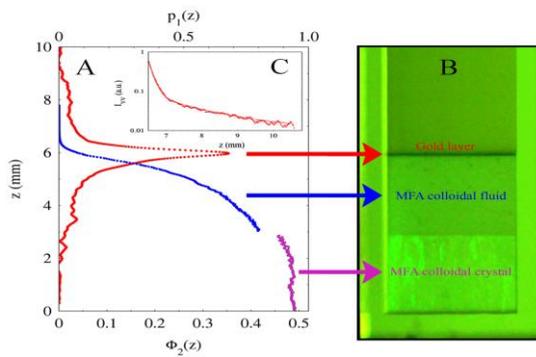
Fluctuation induced aggregation



S.Buzzaccaro, J.Colombo, A.Parola, R.Piazza
Critical depletion

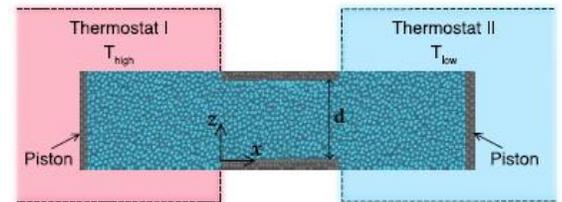
Phys. Rev. Lett. **105**, 198301 (2010)

Anomalous buoyancy



R.Piazza, S.Buzzaccaro, E.Secchi, A.Parola
What buoyancy really is.
A generalized Archimedes' principle for sedimentation and ultracentrifugation
Soft Matt. **8**, 7112 (2012)

Thermal Forces



R.Piazza, A.Parola
Thermophoresis in colloidal suspensions

J.Phys. Cond. Matt. **20**, 153102 (2008)

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Building the Son of X-Shooter infrastructure: a web interface for scientists

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1. Introduction

The Son Of X-Shooter (SOXS) is a new spectrograph for the European Southern Observatory (ESO) 3.6m New Technology Telescope (NTT). SOXS is an international project, led by INAF, with participation of Weizmann Institute (Israel), Turku University (Finland), Millenium Institute of Astrophysics (Chile), Queen's Belfast University (QUB, UK), Tel Aviv University (Israel), and Niels Bohr Institute (Denmark).

The instrument is expected to start operations in early 2021 and the consortium will be awarded with 180 observing nights per year for five years.

2. Scientific rationale and state of the art

SOXS comes from the idea that the number of transient and variable sources discovered every day is growing hugely thanks, mainly, to optical wide-field surveys. These new transient sources remain however unexplored, lacking a spectroscopic follow-up. The situation will worsen in the future with the start of very large projects like ZTF (now), LSST (2021), as well as new high-energy missions (Swift, SVOM), radio (SKA and its precursors), very high-energy (CTA), and gravitational wave experiments (Ligo & Virgo) and neutrino experiments.

All these experiments call for a spectroscopic follow-up, to secure a distance (redshift), and to exploit their science content.

In this context, a unique database able to collect data from any survey with the possibility to store the photometric history of any transient,

queryable and easy to use (especially fast) is a key step for a worldwide successful instrumentation (like SOXS).

3. The proposed project

The SOXS consortium will manage the NTT observing schedule for the 5 years. The idea is to have a dynamical schedule that have to be updated day by day by SOXS scientists to include the most urgent transients to be observed. The schedule can also be changed on the fly if, e.g., a GW event takes place and should also be able to manage, at the same time, SOXS targets and ESO community targets (for the other half of the observing time), keeping a record of all the observations performed.

Nowadays there is an ESO public survey, called ePESSTO, with similar aims as SOXS, but *with a limited number of nights and scientific aims* (it is focussed on supernovae). ePESSTO has a software system to manage the observations, called Marshall base at QUB and it should provides the start for the SOXS infrastructure. Our infrastructure will also have to interface with ESO archive and overall database system.

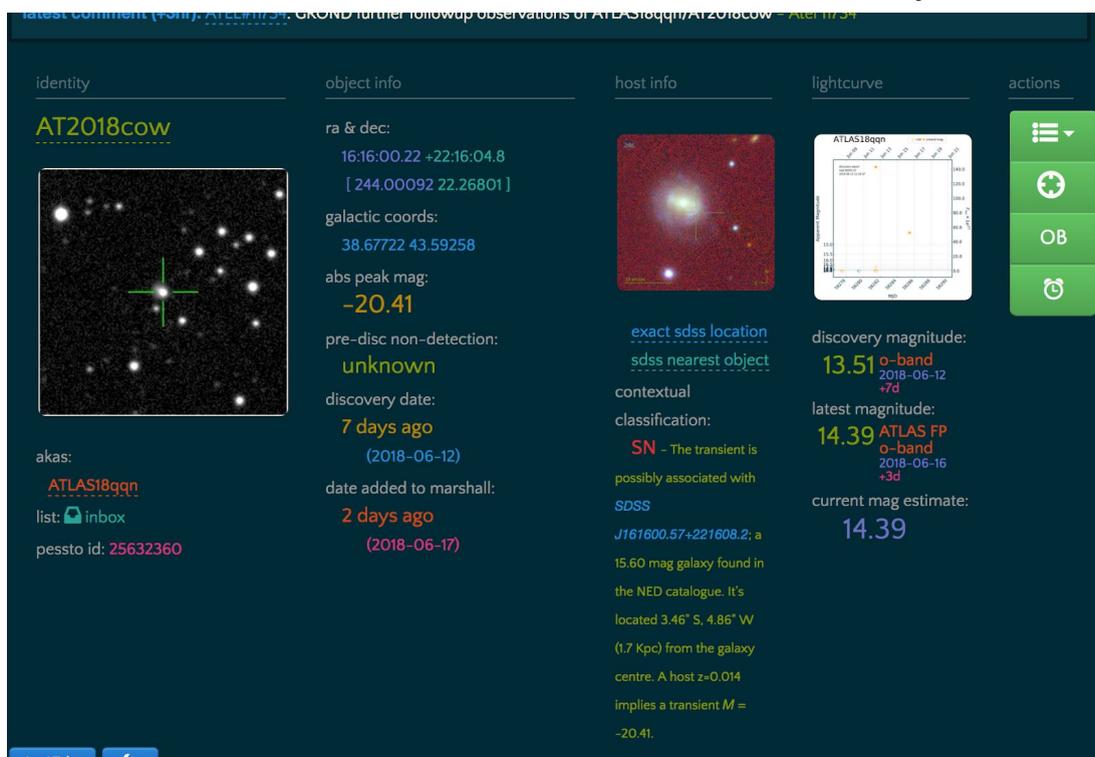


Fig. 1 Example of Marshall information for one source.

The PhD project is then targeted on the development of a web interface to include directly sources from different ongoing (mainly optical) surveys, characterise them in terms of database searches with other catalogs, provide finding charts from existing surveys, generating Observing Blocks (i.e. the instructions from a suited software to perform the observation) and, a posteriori, to keep the raw SOXS spectra, apply the analysis pipeline, and work out the final 1D spectrum.

4. Technology behind

The design, implementation and fruitful dissemination of the proposed project, which involves both killing science and technological challenges, require to investigate proper IT platform in terms of computational environment (such as main Cloud Platforms) and state-of-the-art scripting and application language (like *Node JS*, *Python*).

In particular, we propose to implement a full, **scalable** and **reliable** Web interface able to cope with the main features available in ePESSTO with the great advantage to include sources from different ongoing (mainly optical) surveys. This will require to investigate proper databases systems and big data technology (noSQL, SQL, ...) to cope with the huge amount of gathered data.

Finally, the student will be able to deploy the full infrastructure to the SOXS community using current cloud platform services (e.g. *Google Cloud Platform*, already used for scientific purposes on our Institute) to drop the cost of ownership while maintaining the necessary infrastructure to run a scalable application.

5. Lesson learned and outlooks

The student involved in this project will gather the main skills required in the field of big data and technology applied to astrophysics with a great

outlook on important IT and data analysis standards exploitable both in research and industrial R&D.

He/She will also work in an international environment with close interaction, at least, with QUB and ESO, possibly with short periods (~month) spent outside to learn first and set up a proper interface later.

The student will be inserted in a large international collaboration. The PhD thesis work will not only be limited to software development. In order to properly assess the needs of a scientist the student will get acquainted with all the classes of transient sources and pursue her/his research line in the field.

THERMODYNAMICAL PROPERTIES OF WEAK-LENSING SELECTED CLUSTERS

Stefano Andreon, Ginevra Trinchieri, Alberto Moretti (OA Brera, stefano.andreon@brera.inaf.it)

Galaxy clusters are fundamental for both astrophysics and cosmology. The various components present in a cluster, dark matter, intracluster medium, and galaxies, are deeply interconnected: galaxy formation and evolution depend on the large scale environment in which they live, and on the physical and chemical properties of the intergalactic gas from which they form; this gas in turn is affected by galaxy feedback.

The baryons in the intracluster medium offer us the unique opportunity of determining the dynamical status of clusters, their formation and evolution, through thermodynamic radial profiles (electron density, temperature, pressure, and entropy). However, our current knowledge of them comes primarily from detailed studies of systems selected by their minority component (hot baryons and stars), used to identify them (through X-ray, SZ, or optical/IR surveys). It is now generally recognized that X-ray selection yields a biased view of the cluster population (Pacaud et al. 2007; Stanek et al. 2006; Pratt et al. 2006; Andreon, Trinchieri & Pizzolato 2011; Andreon & Moretti 2012; Eckert et al. 2011; *Planck* Collaboration 2011, 2012; Maughan et al. 2012; Andreon et al. 2015) because at a given mass, brighter-than-average clusters are easier to select and be included in a sample. Considerable efforts have been made to correct for this effect, but the results are not definitive because the correction depends heavily on assumptions about the unseen population (Vikhlinin et al. 2009; Andreon et al. 2011, 2016, 2017). SZ-selection offers a less biased view and indeed samples a broader population (e.g., in gas content) than X-ray selection (e.g., *Planck* Collaboration 2011, 2012). However, an X-ray unbiased sample unveils the existence of an even larger variety of clusters at a given mass (Andreon et al. 2016, 2017).

Ideally, selection by total mass (i.e. weak-lensing) should provide a bias-free sample, and is preferable to a selection that relies on indirect signals triggered by baryons in hot gas and stars, linked to total mass through models. The release of the first catalog (Miyazaki et al 2018) of high signal-to-noise shear detections in the Hyper Suprime-Cam Subaru Survey (Aihara et al. 2018) allows us to select clusters independently of their baryon content and to investigate, for the first time, the bias of the baryon selection. The thesis uses X-ray and SZ data acquired by our group to measure thermodynamic profiles of these weak-lensing selected clusters and, from them, the whole spread of the population properties and the bias present in samples studied so far.

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True colour ($z'JK$) image of the cluster at the highest redshift known, JKCS 041 (Andreon et al. 2009, 2014). The smooth, blue emission is the X-ray emission detected by Chandra. North is up and East is to the left, the field of view is 5×5 arcmin.