Astronomy, Astrophysics and Space Science PhD
Sapienza, Tor Vergata, INAF
Available theses for the XXXV cycle

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Contents

1 ABSTRACTS : Sapienza University of Rome

1.1 Development of advanced data analysis techniques for the search of periodic gravitational waves emitted by spinning neutron stars and their application to the data of Virgo and LIGO detectors

Supervisors: Pia Astone (INFN) and Piero Rapagnani (Physics Department, Sapienza University)
Contact: pia.astone@roma1.infn.it

Abstract: Spinning neutron stars, both isolated and in a binary system, are expected to emit periodic gravitational waves if asymmetric respect to the rotational axis. Such signals are very weak and their detection poses relevant challenges from the analysis and computational point of view. The Thesis work we propose is about the application of advanced data analysis techniques to develop a robust and computationally efficient pipeline for the search of periodic gravitational waves, and its application to the data produced by the LIGO and Virgo detectors. This work will be carried on within the Rome group of the Virgo Collaboration which is one of the world-wide leaders in this field. As part of the LIGO-Virgo collaboration we are guaranteed immediate access to the full data set. The detection of periodic signals, thanks to their long time duration and very specific features, will transform neutron stars in true laboratories for relativistic astrophysics and for nuclear physics, allowing unprecedented studies on high density matter and opening a new outstanding window on the study of neutron stars.

1.2 Extragalactic study of Anomalous Microwave Emission: observations and data analysis

Supervisor: Elia Battistelli (Physics Department, Sapienza University)
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Abstract: Anomalous Microwave Emission (AME) is an astrophysical emission that still lacks a full theoretical comprehension. The most updated models predict that the AME is dominated by electric dipole emission from rapidly rotating dust grains: the Spinning Dust, although the models are still far from being predictive. Of great interest is the possibility to detect AME from extragalactic sources as it represents a unique possibility to study astrophysical processes so far only studied in our Galaxy. During the PhD period, the student will perform observations and data analysis of microwave data taken form extragalactic sources like M31 galaxy taken from Radio telescopes like the Sardinia Radio Telescope (through an already approved Large Project) with the goal of increasing the comprehension of such Anomalous Emission.

1.3 Cosmic Microwave Background spectral distortion investigation: detectors development for the Antarctic COSMO experiment

Supervisor: Elia Battistelli (Physics Department, Sapienza University)
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Abstract: The CMB is characterized by an almost perfect black body spectrum. Deviations for such perfection are expected in the standard model due to energy injections in the primordial plasma, because of light elements recombination, because of CMB primary anisotropies dissipations at the last scattering surface and, at later times, because of the reionization. Several exotic scenarios also predict different kind of spectral distortions. Measuring the spectral distortion of the CMB has the potentiality to reveal the thermal history of the Universe allowing cosmologists to "look" at the Universe beyond the last scattering surface when it was opaque. During the PhD period, the student will work on forecast activity for the detectability of CMB spectral distortions and on the design, construction, test, calibration and data acquisition of the COSMO (COsmic Monopole Observer) experiment to be installed in the Italian/French Concordia Base in Antarctica. The work will be focused on Kinetic Inductance Detectors to be installed in the receiver.

1.4 Multimessenger search for High Energy Astrophysical Sources

Supervisor: Tonino Capone (Physics Department, Sapienza University)
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Abstract: Multimessenger observations may hold the key to learn about the most energetic sources in the universe. Measurements provided by present and new, large scale observatories (LIGO-VIRGO, IceCube, CTA, KM3NeT, ..) offer new possibilities in testing cosmic processes with alternative probes, such as high energy neutrinos and gravitational waves. The basic idea of multimessenger search is to combine information of electromagnetic signals (low and high energy photons as measured by Earth based telescopes) with neutrino observations to decipher a comprehensive picture of some of the most extreme cosmic processes. Transient sources will help in the identification of sources requiring the space and time coincidence of the observations. Particular attention will be devoted to the most promising photon emitter sources: transient Active Galactic Nuclei and sources of Gamma Ray Bursts. Electromagnetic information, including their spectral properties, will be acquired from public data-bases (like the ones provided by FERMI experiment), neutrino data will come from public IceCube data-base and by ANTARES data. The joint detection of electromagnetic signals and neutrinos from these sources will probe the physics of the sources and will be a smoking gun of the presence of hadrons in these objects which is still an open question. Conversely, the non-detection of neutrinos from these sources will be fundamental to constrain the hadronic content and gain information on the physics of these objects. This analysis method, based on the reduction of the background thanks to the space-time coincident observation of different messengers coming from the same source, is at present the most promising procedure to search for high energy astrophysical sources.

1.5 The super dense central environment of galaxies: dynamics, accretion and super massive objects

Supervisor: Roberto Capuzzo Dolcetta (Physics Department, Sapienza University) in collaboration with Univ. of Heidelberg and Univ. A. Bello, Chile.
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Abstract:
The central region of our Milky Way, as well as other galaxies, is characterized by the presence of a supermassive black hole, often embedded in a very dense stellar environment. This stellar environment constitutes a sort of Nuclear Star Clusters, with densities up to 10 million stars per cubic parsec. The formation of such extreme environment is still debated, as the local violent activity, like the, likely, frequent, merger events of stellar size or intermediate mass (>1000 solar masses) black holes with the central supermassive one. This PhD thesis will develop within the above frame with a theoretical approach complemented by numerical simulations.

1.6 Orbit Determination from Too Short Arc Optical Observations for the payload SPOT

Supervisor: Fabio Curti (School of Aerospace Engineering - Sapienza University of Rome)
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Abstract Over the last decades, the increasing number of space activities has led to the growth of the population of resident space objects, i.e. satellites and space debris. The availability of a complete catalogue of orbiting objects is therefore extremely useful for the reliability evaluation of present and future missions. The existing catalogs are essentially based on radars, or optical measurements obtained by on-ground instruments. The main limitation of this approach is related to the distance between the observer and the orbiting object. Such limitation can be solved by using space-based measurements. Within the framework of this application, the research proposes the use of star sensors as orbiting observers, profiting from their disseminated optical sensors. In fact, the star sensors are typically mounted on-board of satellites for the attitude determination. The proposed approach provides the opportunity of using them for objects' identification, thus minimizing the impact in terms of cost and system architecture with respect to dedicated space object observer missions. Optical observations constitute a source of angular measurements of an orbiting object. Commonly, these observations have very short durations with respect to the orbit period. As a consequence, the use of classical orbit determination algorithms, as Laplace, Gauss or Escobal methods, give very poor results. The present research aims at estimating the orbital parameters of an object using its optical streak acquired by the star sensor and developing orbit determination methods based on new techniques belonging to the fields of Artificial Intelligence, Swarm Intelligence, Meta-heuristics. This research is in the framework of the Italian Space Agency project SPOT (Star sensor image on-board processing for orbiting objects detection and identification) and the work includes additional activities for the In-Orbit Test and Validation.

1.7 Polarimetric measurements of the Cosmic Microwave Background: looking for signals from cosmic inflation

Supervisor: Paolo de Bernardis (Physics Department, Sapienza University)
Contact: paolo.debernardis@roma1.infn.it

Abstract: The measurement of Cosmic Microwave Background (CMB) polarization at large angular scales represents the best way to investigate the first split-second after the big-bang, and the cosmological inflation hypothesis. The Large-Scale Polarization Explorer (LSPE) is a mission to measure inflation-originated CMB polarization, significantly improving both the sensitivity and the control systematic effects with respect to current experiments. LSPE-SWIPE is a balloon-borne polarimeter for the Cosmic Microwave Background,

featuring a small aperture (50 cm diameter) cryogenic telescope feeding two large arrays of multi-mode TES bolometers. Polarization modulation is obtained using a rotating half-wave plate (HWP) as the first optical element of the instrument. The HWP is cooled cryogenically, levitated and rotated by means of a superconducting magnetic bearing. The PhD thesis will focus on the development and calibration of the polarimeter and of its cryogenic system, including the development of a custom calibration source. In addition, an in-flight calibration procedure will be devised and validated. The work will be completed with the participation in the flight campaign and the data analysis, with a key role in the in-flight calibration data reduction. The experience gained with the development of the LSPE polarimeter will be extremely useful for the development of the future LiteBIRD satellite, which uses the same polarimetry methods as LSPE. See also *http://lspe.roma1.infn.it* and *http://litebird.jp/eng/* .

1.8 The Large-Scale Polarization Explorer: attitude control system implementation, calibration, and flight-data analysis

Supervisor: Paolo de Bernardis (Physics Department, Sapienza University)
Contact: paolo.debernardis@roma1.infn.it

Abstract: The measurement of Cosmic Microwave Background (CMB) polarization at large angular scales represents the best way to investigate the first split-second after the big-bang and the cosmological inflation hypothesis. The Large-Scale Polarization Explorer (LSPE) is a balloon-borne polarimeter for the Cosmic Microwave Background, featuring a small aperture (50 cm diameter) cryogenic telescope feeding two large arrays of multi-mode TES bolometers. The polarimeter will fly on a stratospheric balloon during the polar night, and will spin in azimuth, at a limited set of fixed elevations, to cover a large fraction of the sky. The attitude control system (ACS) is composed of an azimuth pivot and a linear actuator for elevation chenges. Pointing reconstruction is based on GPS, fast star sensors, and laser gyroscopes. The thesis work will start from the setup of the star sensors, the development of their readout system, the interface towards the flight control computer. Will then plan and perform the ACS system calibration and validation during the launch campaign, and contribute to the data analysis, leading the pointing reconstruction effort, an extremely important step of the process. This will also involve the analysis of pointing-related systematic effects, propagating all the way to cosmological parameters estimates. See also *http://lspe.roma1.infn.it* .

1.9 Study of clusters of galaxies by hydrodynamic simulations and observations with cosmological implications

Supervisor: Marco De Petris (Physics Department, Sapienza University) in collaboration with Gustavo Yepes (Universida Autonoma de Madrid - Spain) and Frederic Meyet (LPSC, Université Grenoble Alpes - France)
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Abstract: Clusters of galaxies reveal useful astrophysical laboratories to study Universe composition and evolution. Among the several cluster characteristics, the project is focused on their total mass and IntraCluster Medium (ICM) spatial profiles. The mass of the clusters is an undirect estimate possibly affected by bias, mainly due to the not-always fulfilled applied approximations (see hydrostatic equilibrium, ideal gas, thermal pressure support of gas, etc.), resulting in some tension with Planck cosmological parameters. Among the several observational approaches, the Sunyaev-Zel'dovich (SZ) signal from a cluster is a powerful one to infer cluster total mass but the presence of ICM non-thermal pressure support, due to turbulent and/or bulk gas motions, among other possible effects, must be carefully considered. This Thesis project relies on available high spatial resolution SZ observations (data of tens of clusters already observed within the SZ Large Program with NIKA2, the kilo-pixels KIDs camera observing at 150 and 260 GHz at 30-m IRAM telescope) and synthetic clusters (extracted from N-body hydrodynamical simulations such as MUSIC, Marenostrum MUltidark SImulations of galaxy Clusters, and The Three Hundred project).

1.10 Characterization of an optical combiner for bolometric interferometry at millimetre wavelengths: models, tests and calibration

Supervisor: Marco De Petris (Physics Department, Sapienza University) in collaboration with C. O'Sullivan at National University of Ireland, Maynooth (Ireland)
Contact: marco.depetris@roma1.infn.it

Abstract: Bolometric interferometry at millimetre waves is an interesting technique to measure Cosmic Microwave Background radiation polarization with an excellent control of systematics combined with high sensitivity of cryogenic detectors. QUBIC (Q & U Bolometric Interferometry for Cosmology) is an instrument employing this optical solution, currently under integration and calibration phase in France and planned to be installed in Alto Chorrillos in Argentina. It is based on an aperture of 400 feedhorns array (in the final configuration) generating interferometric images on TES focal planes at 150 and 220 GHz by a cold optics operating as a combiner. The student will join the Optics Group of QUBIC working on several optical aspects of the instrument starting from the refining the optical models of the final synthesized beam pattern with widely recognised optics software, GRASP and Zemax. It is also expected to participate to the planned calibration campaigns in France to validate the models and to refine the knowledge of the beam pattern. Finally, the student will contribute to the scientific observations of QUBIC in Argentina.

1.11 Systematics in cosmic shear tomography for the Euclid survey

Supervisor: Roberto Maoli (Physics Department, Sapienza University) Roberto Scaramella (INAF-OAR)
Contact: roberto.maoli@roma1.infn.it

Abstract: Stage IV lensing surveys will make statistical errors orders of magnitude smaller than what is presently achieved in best experiments. Cosmic shear studies will therefore enter the realm of precision cosmology. However, in order this to be possible, one must take under control systematics errors which will be comparable (if not larger) than the statistical one. Although much has been done in recent years, there are still open questions to be addressed. Systematics can indeed come from the measurement process (e.g., PSF correction and shape measurement), instrumental setup (CTI and color gradient bias), and theoretical assumptions (power spectrum in the non linear regime, impact of baryons, high order effects). The present PhD project will aim at investigating these sources of systematics both proposing ways to characterize them for detection and devise methods to correct for them in the likelihood analysis. The student will have access to the activities of the Euclid Weak Lensing Science Working Group hence getting in contact with the frontier of lensing studies. He/she will gain experience in both observational and theoretical aspects thus increasing his/her cultural skills.

1.12 Spectral distortions of the Cosmic Microwave Background: development of the COsmic Monopole Observer

Supervisor: Silvia Masi (Physics Department, Sapienza University)
Contact: silvia.masi@roma1.infn.it

Abstract: The COsmic Monopole Observer (COSMO) is a staged effort to measure deviations of the Cosmic Microwave Background spectrum from a perfect Planckian. Deviations at low level (1 ppm) are expected due to physical processes happening before and after recombination. The COSMO instrument is a differential Fourier Transform Spectrometer comparing the brightness of the sky to that of an internal blackbody. In its first implementation, COSMO will be operated from the Concordia station in Dome-C (Antarctica), exploiting the fast response of Kinetic Inductance Detectors to perform fast sky-dips: this will allow the separation between atmospheric emission and sky monopole, strongly mitigating the effects of 1/f atmospheric noise. The target accuracy / sensitivity in the measurement of the spectral brightness is < 1 ppm, so that the instrument should be able to detect for the first time y-like spectral distortions due to ionized matter in the cosmic web and at reionization. A further implementation on a stratospheric balloon will allow a sensitivity improvement of a factor ~ 10. The thesis work will focus on instrument design optimization, development and calibration, with the opportunity to participate in the commissioning and first data taking and analysis.

1.13 Cosmic Microwave Background polarization with the QUBIC experiment

Supervisors: Silvia Masi (Physics Department, Sapienza University), Giancarlo De Gasperis (Physics Department, Tor Vergata University)
Contact: silvia.masi@roma1.infn.it

Abstract: The Q and U Bolometric Interferometer for Cosmology (QUBIC) is an innovative polarimeter for the Cosmic Microwave Background, combining the beam control of interferometers and the sensitivity of bolometers. QUBIC uses (Fizeau) interferometry to synthesize the beam of the instrument by means of a reconfigurable array of input apertures: this approach allows a number of very interesting features, link self calibration and correction of systematic effects. The QUBIC final instrument will be composed of three modules operating 97, 150 and 220 GHz from Alto Chorillo (Argentina) at an altitude of $\sim$ 4900 meters *asl* to beat atmospheric emission and its fluctuations. The operation of the first module of the instrument has been recently demonstrated, so the PhD thesis work will focus on detailed instrument calibration, commissioning, data taking and data analysis. For the calibration effort, a custom full-beam polarimetric calibrator will be developed and operated, both in Europe and, after installation, on the high altitude site. The PhD thesis will also focus on the development of custom analysis methods, needed to fully exploit the potential of the instrument. See also *http://qubic.in2p3.fr/wordpress/* .

1.14 Gravitational waves and cosmology

Supervisor: Alessandro Melchiorri (Physics Department, Sapienza University)
Contact: alessandro.melchiorri@roma1.infn.it

Abstract: The discovery of the GW170817 event opened the possibility of determining the Hubble constant and the acceleration of the Universe with gravitational waves. The research will focus on the cosmological impact of current and future standard sirens measurements considering also the possibility of modified gravity scenarios.

1.15 Tension Cosmology

Supervisor: Alessandro Melchiorri (Physics Department, Sapienza University)
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Abstract: Tensions at the level of three standard deviations and more are emerging between recent cosmological dataset (CMB, BAO, distance ladder, etc). The research will focus on identifying the statistical tools that could better quantify the level of discordance between the datasets and in searching for possible theoretical solutions that could present an indication for new physics.

1.16 Inspiral-merger-ringdown waveforms for boson-star coalescences

Supervisor: Paolo Pani (Physics Department, Sapienza University) and Carlos Palenzuela (University of Baleares Islands)
Contact: paolo.pani@uniroma1.it

Abstract: Boson stars are hypothetical self-gravitating objects that might form in a wide mass range if light bosonic fields (e.g. axions, dark photons, fuzzy dark matter) exist in the universe. Boson stars can be as massive and almost as compact as black holes, and provide an exotic alternative for the seed of supermassive objects. The coalescence of two boson stars carries some peculiar signature in the gravitational waveform relative to the standard case of two black holes. In order to search for these objects with current (LIGO/Virgo) and future (LISA/3G) detectors, it is mandatory to develop accurate inspiral-merger-ringdown waveform approximants. The scope of this thesis is to merge a variety of approaches (semi-analytical results in perturbation theory, post-Newtonian modelling, effective one-body framework, numerical-relativity simulations) to produce the first inspiral-merger-ringdown template for binary boson stars, using the same strategy adopted so far to model the gravitational-wave signal from binary neutron stars.

1.17 Characterisation of the atmospheres of extrasolar planets with ARIEL, the exoplanet spectroscopic space mission of the next decade

Supervisor: Enzo Pascale (Physics Department, Sapienza University)
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Abstract: Planets orbiting stars other than our Sun (exoplanets) are now detected in large numbers by dedicated surveys from the ground and from space. Despite this impressive achievement, our knowledge of these alien words remains limited to what can be learned from a measurement of the planet radius and mass, and from some sparse near-IR spectroscopy and broad band photometry from space. In the next decade, spectroscopic observations extending to the mid-IR with the ARIEL space mission (http://arielmission.space) will reveal us the chemical composition and thermodynamics of transiting planet atmospheres, unveiling their true nature, and allowing us to link planetary formation to evolution.

In this project you join the consortium that is designing ARIEL to perform a spectroscopic survey of about 1000 exoplanet atmospheres yielding the first statistically significant mapping of exo-atmospheres. You will assume a leading role in the ARIEL consortium on one or more of the following lines of investigation: optimisation of instrument design; estimates of science performance; development of data reduction and science analysis pipelines; characterisation of instrument and astrophysical systematics. Detailed project topic will depend from your personal interests and curiosity. Visit http://www.roma1.infn.it/∼pascalee for additional information and contacts.

1.18 LSPE-SWIPE instrumentation and data acquisition development

Supervisors: Francesco Piacentini (Physics Department, Sapienza University)
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Abstract: LSPE-SWIPE is a balloon-based telescope for the measurement of the CMB polarisation at large angular scales. Accurate measurement of CMB polarization allows to measure the presence of gravitational waves at the recombination epoch, thus measuring the inflation mechanism in the early Universe. Polarization measurements in the microwave band also allow to constrain the re-ionization history of the Universe, related to the formation of first stars; to measure the topology of the universe and possible anomalies; to characterize the matter distribution in the Milky way, and more. The participant will work within the LSPE collaboration, participating to the final development of the instrumentation, and in particular to the software of the data acquisition system. He will participate to the integration, calibration, and operation campaign. The activity will be completed by analysis of the retrieved data, consisting in producing maps of the CMB polarization and extracting the cosmological information encoded.

1.19 Data analysis for CMB polarization experiments: LSPE and Litebird

Supervisors: Francesco Piacentini (Physics Department, Sapienza University)
Contact: francesco.piacentini@roma1.infn.it

Abstract: Accurate measurements of CMB polarization allow to assess the presence of gravitational waves at the recombination epoch, thus testing the inflation mechanism in the early Universe. Polarization measurements in the microwave band also allow to constrain the re-ionization history of the Universe, linked to the formation of first stars; to measure the topology of the universe and possible anomalies; to characterise the matter distribution in the Milky way, and more. LSPE is composed by a ground-based instrument and a balloon-based instrument. It is an Italian program, with international collaborators, and will take data in the next years. LiteBIRD is a Japanese led space mission, with relevant contribution from US and EU countries. The applicant will contribute to data analysis of the two missions, development of next generation algorithms for instrument simulation, calibration, control of systematic effects, polarization extraction, component separation, measurement of the cosmological parameters, measurement of statistical anomalies, and much more.

1.20 Development of new technologies for mirror suspension and control for Third Generation Gravitational Wave Detectors

Supervisors: Piero Rapagnani (Physics Department, Sapienza University) and Paola Puppo (INFN)
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Abstract: After the first observation of gravitational waves in 2015, gravitational wave astronomy is now becoming more and more important. Currently, the three available detectors, (the 2 LIGO interferometers and Virgo), are at the beginning of a new observation run (O3), started on April 1st 2019. Just in one month, we have observed one signal from black coalescence every few days, and one signal coming from the coalescence of a binary neutron star. Of course this is only the beginning: we are preparing the construction of the new generation of instruments, with sensitivities improved by at least a factor ten with respect to the current ones. In Europe, we shall build the Einstein Telescope, a third generation gravitational wave interferometer that will use new technologies to reduce the intrinsic noises that limit the sensitivities of gravitational wave detectors. The Thesis we propose deals with the development of new methods to reduce the thermal noise of the test mass of the interferometer by means of cryogenics and the use of new low dissipation materials for the suspensions, to be applied to the mirrors of the Einstein Telescope.

1.21 Light and sound from the cosmic dawn: the origin and observational signatures of the first black holes

Supervisor: Raffaella Schneider (Physics Department, Sapienza University), in collaboration with Yuexing Cindy Li (Penn State University), Lucio Mayer (University of Zurich), Luca Graziani (Dipartimento di Fisica, Sapienza Università di Roma), Rosa Valiante (INAF/Osservatorio Astronomico di Roma).
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Abstract: The cosmic dawn is a crucial yet poorly understood epoch in the history of the Universe when the first generation of stars, galaxies and quasars lit up the dark ages. The discovery of a population of luminous quasars at high redshift $z \sim 6$ indicates the existence of billion-solar-mass black holes within the first billion years after the Big Bang. The origin and grow histories of these supermassive black holes, however, remain an unsolved puzzle. Recently, we have developed a suite of physical models and numerical tools to tackle the assembly of distant quasars and their multi-wavelength properties. In this project we propose to combine both numerical simulations and semi-analytical calculations to investigate the seeds and growth of the earliest supermassive black holes, and make predictions of observational properties of these objects in a full spectrum from electromagnetic radiation to gravitational waves for the next-generation telescopes and instruments such as the James Webb Space Telescope (JWST), the Athena X-ray observatory and the Laser Interferometer Space Antenna (LISA).

1.22 The assembly of the first galaxies in the era of ALMA and JWST

Supervisor: Raffaella Schneider (Physics Department, Sapienza University), in collaboration with Lucio Mayer (University of Zurich), Luca Graziani (Dipartimento di Fisica, Università di Roma) Roberto Maiolino (University of Cambridge), Michele Ginolfi (Geneva Observatory).
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Abstract: The advent of the Atacama Large Millimeter Array (ALMA) has opened a new window onto the high redshift Universe, shedding light on the cold interstellar medium (ISM) of normal star forming galaxies out to z > 6 -7. The information collected so far through observations that map the rest-frame emission (continuum and lines) in the infrared have mostly targeted UV bright galaxies, showing that their ISM is already remarkably enriched, with metals and dust masses that are comparable to those inferred for galaxies with similar UV luminosities and stellar masses at z < 4. In the near future, ALMA has the potential to increase the number of detected galaxies at z > 6 by a factor of 5 (25-30 galaxies, thank to more efficient detection techniques, such as scanning for ISM emission lines UV bright galaxies with good photometric redshift) probing dust growth over most of the reionization era. On the other hand, JWST will enormously increase the number of observed galaxies at z > 6 down to very faint UV luminosities, providing a completely new view of galaxy assembly at early cosmic epochs through their rest-frame UV properties. These two observatories will revolutionize our view of how galaxy form and grow in the first few hundreds of Myr of cosmic evolution. In this project, we propose to perform dedicated hydro-dynamical cosmological simulations to guide the interpretation of these complex data sets, allowing to extract at best their physical content. Close collaboration with observers involved in current and future high-z galaxy surveys with HST, ALMA and JWST is envisaged.

2 ABSTRACTS : Tor Vergata University of Rome

2.1 Models of galactic habitability

Supervisor: Amedeo Balbi (Physics Department, Tor Vergata University)
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Abstract: Exoplanetary observations performed over the past two decades provide strong evidence that our galaxy contains a vast number of rocky planets with astrophysical conditions potentially suitable for the presence of life. At the same time, however, there are strong reasons to believe that habitable environments may not be uniformly distributed in space and time, and that there may then exist a so-called 'galactic habitable zone' (GHZ), where life-bearing worlds could be preferentially found. In this thesis project, the candidate will produce theoretical models of the GHZ that revise and expand existing studies, by including the effect of all known astrophysical processes that may impact the habitability of planetary environments, with a particular emphasis on high-energy radiation sources that were previously not considered in detail, such as the emission of the super-massive black hole at the center of the Milky Way.

2.2 New signal analysis algorithms for identifying low SNR signals in astrophysics and space science

Supervisors: Francesco Berrilli (Physics Department, Tor Vergata University), Stuart Jefferies (Georgia State University, USA)
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Abstract: The analysis of extremely low signal-to-noise ratio data from space and ground-based multi-instrument experiments in astrophysics and space science requires even more sophisticated techniques for identifying and analyzing signals hidden in noise. This thesis project will make use of a mix of consolidated techniques and novel data analysis methods and modeling, introduced in the framework of non-linear physics, low SNR and non-stationary/quasi-oscillatory signal analysis, to extract information from the huge amount of data available from past and present experiments exploring the Sun, the Space Weather and the extrasolar planets.

2.3 Space Weather and Earth's climate: The Sun-Earth connection

Supervisors: Francesco Berrilli (Physics Department, Tor Vergata University)
Contact: francesco.berrilli@roma2.infn.it

Abstract: The active Sun is the driver of a wide number of physical processes that take place in the heliosphere and that affect the planetary bodies and their environments, Earth included. The study of such processes and how they interact with the planetary atmospheres has become one of the main scientific topics all over the world, which is generally addressed with the term "Space Weather and Space Climate". This thesis project aims to study the origin of solar activity and/or at monitoring, analyzing and modelling interactions of this activity with the near-planetary space. These analyses may also be employed to forecast and now-cast the possible impacts of Space Weather events on technological systems.

2.4 Dark matter content of nearby dwarf galaxies using both photometry and spectroscopy

Supervisor: Giuseppe Bono (Physics Department, Tor Vergata University)
Contact: bono@roma2.infn.it

Abstract: Nearby dwarf galaxies appear to be strongly dominated by dark matter, and indeed their Mass-to-Light ratios are of the order of several hundreds. Our group collected detailed and homegenous multiband photometric data with wide imagers available at the 4-8m class telescope to investigate their stellar populations and their variable star content. Moreover, we have also collected spectroscopic data using multi-object (slit, fiber) spectrographs to estimate the radial velocity and the metallicity distribution of both old and intermediate-age stellar populations. This empirical scenario will be used to estimate the ML ratios and their chemical enrichment history.

2.5 Cosmic distance scale: from primary to secondary distance indicators

Supervisor: Giuseppe Bono (Physics Department, Tor Vergata University)
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Abstract: We are facing a stark discrepancy between the estimate of the Hubble constant based on the CMB (Planck collaboration) and on primary (Classical Cepheids) plus secondary (SN Type Ia) distance indicators.

The current determinations indicate a difference at the 3 sigma level. The idea is to attack the problem fully exploiting novel distance determinations based either on Gaia or on theoretical Period-Luminosity relations. Moreover, it is also planned to follow a different path by using old distance indicators (RR Lyrae, Tip of the Red Giant Branch) to constrain possible systematics affecting the Cepheid distance scale.

2.6 Millimetre observations of galaxy clusters

Supervisor: Herve Bourdin and Pasquale Mazzotta (Physics Department, Tor Vergata University)
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Abstract: Being the largest and last matter inhomogeneities that collapsed across cosmic times, galaxy clusters occupy a unique place at the crossroads of astrophysics and cosmology. Complementary with X-ray observations, the thermal Sunyaev-Zel'dovich (tSZ) effect allows us to probe the hot gas content of galaxy clusters from their core to their peripheries. The tSZ signal being mixed up with CMB or (extra)-Galactic thermal dust anisotropies, we developed component separation algorithms using sparse representations (wavelet and curvelet transforms) to detect and map galaxy clusters from Planck data. Using these tools to analyse millimetre observations in combination with X-ray data (XMM-Newton, Chandra), the PhD student will perform research works such as:

1. measuring the Hubble constant from combined X-ray and SZ observations of clusters of the Planck catalogue;
2. extracting hot gas pressure profiles to investigate the physics of cluster atmospheres from nearby ($z<0.5$) to distant clusters ($z>0.5$) of the Planck catalogue;
3. developing new algorithms to combine Planck data with observations performed at higher angular resolutions (e.g. SPT) and detect more distant clusters ($z>1$).

2.7 The PILOT balloon borne experiment: Measurement of polarised emission of dust in the intergalactic medium at 1.2 THz.

Supervisor: Giancarlo De Gasperis (Physics Department, Tor Vergata University) in collaboration with J.P. Bernard (Institut de Recherche en Astrophysique et Planetologie IRAP, Toulouse), Paolo de Bernardis and Silvia Masi (Physics Department, Sapienza University)
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Abstract: PILOT (Polarized Instrument for the Long-wavelength Observations of the Tenuous ISM: see also http://pilot.irap.omp.eu) is a a balloon-borne astronomy experiment to study the polarization of dust emission in the diffuse Interstellar medium (ISM) in our Galaxy. it aims to:

- Reveal the structure of dust in the intergalactic medium and the magnetic field structure in our (and nearby) galaxy at a resolution of $\simeq 2'$;
- Characterise the geometric and magnetic properties of dust grains;
- Understand polarised foregrounds;
- Complement Planck observations at higher frequencies.

PILOT already observed the Galactic center and other nearby astrophysical sources for a total flight time of $\simeq 60\tilde{}$hours, preliminary results are being published (see https://arxiv.org/abs/1901.06196), and the full data analysis is still ongoing.

A third flight is scheduled for the end of 2019.

The thesis work aims at understanding and characterising the instrumental properties and the dataset of the first two flights of PILOT and preparing the calibration and data analysis step for the third flight, with a strong focus on instrument calibration, (real and simulated) data analysis, the science behind the ISM emission and finally to better understand the galactic dust foreground polarised emission, an essential step to CMB B-mode detection.

2.8 Planetary Space Weather

Supervisor: Dario Del Moro (Physics Department, Tor Vergata University)
Contact: dario.delmoro@roma2.infn.it

Abstract: Space Weather has become a major priority within the program of several national space agencies worldwide. Understanding the science behind Space Weather is a necessary requisite in the context of any effort related to Space Weather. The primary source of Space Weather is the Sun. Variations in the electromagnetic radiation and particle flux of solar origin often result in changes in the Earth's magnetosphere and upper atmosphere. In a similar way, interactions between the environment of a Solar System body other than the Earth and the impinging plasma/radiation affects that body in question. Moreover, the performance and reliability of space-borne and ground-based technological systems is influenced and, in some cases, human life or health can be endangered. The ambition of this project is to exploit the large amount of information acquired from solar and interplanetary space measurements to strengthen our forecasting capabilities about the solar wind conditions, solar flares, and CMEs, at different regions within the Heliosphere.

2.9 Adaptive optics for gravitational wave interferometers

Supervisor: Viviana Fafone (Physics Department, Tor Vergata University)
Contact: viviana.fafone@roma2.infn.it

Abstract: Precise interferometry plays a key role in the detection of gravitational waves. Thus any optical aberration will limit the detection capabilities of these instruments. The thesis project will focus on the development of adaptive optics correction systems for the upcoming next generation interferometers. The work will consist of two main phases: the development of numerical optical and thermo-mechanical simulations for the design of the prototype actuation system and its characterization and validation. The activity will be carried on in the Virgo laboratory at Tor Vergata University and at the European Gravitational Observatory where the PhD researcher will participate to the installation and commissioning of the system in view of future observing runs.

2.10 Optimization of squeezed states of light generation in next generation Gravitational Waves detectors

Supervisor: Viviana Fafone (Physics Department, Tor Vergata University)
Contact: viviana.fafone@roma2.infn.it

Abstract: Shot noise and radiation pressure noise, both arising from the Heisenberg uncertainty principle, will be the ultimate limiting factors in the sensitivity of ground based gravitational wave detectors. Techniques based on quantum optics (injection of squeezed states of vacuum) appear to be promising tools to overcome this fundamental limit. To take full advantage of these new technologies, a deep optimization process need to be performed for their implementation in large scale detectors. In particular, one of the main issues to be faced concerns the optical losses along the injection path of the squeezed light into the interferometer. The activity will focus on the reduction of that fraction of the losses arising from the presence of higher order laser beam modes both in the detector and in the squeezed beam itself. The project will include simulations and experimental activity to be carried out also in collaboration with the Advanced Virgo quantum optics working group.

2.11 Space Weather Machine Learning

Supervisor: Luca Giovannelli (Physics Department, Tor Vergata University)
Contact: luca.giovannelli@roma2.infn.it

Abstract: Solar and space physics has evolved from a exploratory and discovery-driven discipline to a mature, explanatory science. In the last years, the importance of predicting the changes induced by the Sun in the near-Earth environment, and the effects that those changes have on mankind's activities has become increasingly apparent. Forecasting Space Weather presents solar and space physicists with new challenges and opportunities in the areas of theory, computer modeling, and data exploration and mining. This project will explore the possibilities granted by applying state-of-the-art machine learning techniques to the extensive datasets available from satellite-borne and ground- based solar observatories, with the aim to define extreme events in Space Weather, evaluate their possible impact, and to what extent these events may be predictable.

2.12 A synergic strategy to identify habitable exoplanets

Supervisors: Luca Giovannelli (Physics Department, Tor Vergata University) , Maria Pia Di Mauro (INAF-IAPS)
Contact: luca.giovannelli@roma2.infn.it

Abstract: The goal of the present project is to characterize habitability of exoplanets by using the stellar properties deduced by Asteroseismology and exploring the possible factors influencing exoplanetary climate. The objective will be achieved by fulfilling the following tasks:

- Asteroseismology of solar-type stars by using Kepler or TESS data for determination of high-precision parameters of stars with detected rocky exoplanets

- Characterization of habitability by studying the planet-star interaction, modelling conditions of exoplanetary climate taking into account stellar activity and extreme space weather factors.

2.13 Physical Properties of Transiting Planetary Systems

Supervisor: Luigi Mancini (Physics Department, Tor Vergata University) in collaboration with Alessandro Sozzetti (Turin Astrophysical Observatory)
Contact: lmancini@roma2.infn.it

Abstract: The detection of extrasolar planets and their subsequent characterization are among the most exciting fields of modern astrophysics. Observations of the astonishing diversity of a) internal structures of both small and giant exoplanets, b) properties of their atmospheres, and c) global architectures of planetary systems continuously challenge our knowledge of planet formation, evolution, and interiors. By using instruments and telescopes like TESS, LBT, HARPS-N, ESPRESSO, GIARPS, this PhD project aims at furthering our understanding of key aspects of planet formation and evolution processes focusing on a two-fold, highly synergistic, multi-technique observational approach: I) the characterization of hot, warm, and temperate transiting small-size planets to determine their orbital (period, semi-major axis, eccentricity) and physical (radius, mass, density) parameters, and thus investigate their internal structure, formation, and evolution via a combination of high-sensitivity photometric and spectroscopic measurements; II) the study of the atmospheres of hot planets at high spectral resolution to determine their composition, investigate atmospheric dynamics, and possibly reconstruct their formation and migration history.

2.14 Witnessing the culmination of structure formation in the Universe from X-ray observations of clusters of galaxies

Supervisors: Pasquale Mazzotta and Herve Bourdin (Physics Department, Tor Vergata University)
Contacts: mazzotta@roma2.infnf.it , herve.bourdin@roma2.infn.it

Abstract: Clusters of galaxies provide valuable information on cosmology, from the physics driving galaxy and structure formation, to the nature of dark matter and dark energy. Their observable spatial distribution of mass components, that reflects the cosmic distribution of matter (85% dark matter, 12% X-ray emitting gas and 3% galaxies), their internal structure and their number density as a function of mass and redshift are powerful cosmological probes as their growth and evolution depends on the underlying cosmology (through initial conditions, cosmic expansion rate and dark matter properties). Clusters form at the nodes of the Cosmic Web, constantly growing through accretion of matter along filaments and via occasional mergers. Part of the gravitational energy dissipated during their grow is channeled, via shocks and turbulent motions, into the amplification of magnetic fields and acceleration of relativistic particles. These non-thermal components manifest themselves as diffuse cluster-scale radio emission. Clusters are thus excellent laboratories for probing the physics of the gravitational collapse of dark matter and baryons, as well as for studying the non-gravitational physics that affects their baryonic component. Using a large, unbiased, signal-to-noise limited Planck sample of clusters of galaxies observed in X-Ray with Chandra and XMM we will plan to:

1. obtain an accurate vision of the statistical properties of the local cluster population, and in the highest mass regime;
2. measure how their gas is shaped by the collapse into dark matter haloes and the mergers that built today's clusters;
3. uncover the provenance of non-gravitational heating;
4. resolve the major uncertainties in mass determinations that limit cosmological inferences.

2.15 Future CMB Polarization Space Missions: data analysis challenges

Supervisors: Marina Migliaccio, Nicola Vittorio (Physics Department, Tor Vergata University), Domenico Marinucci (Math. Dept. Univ. Tor Vergata), in collaboration with Paolo Natoli (University of Ferrara), Luca Pagano (University of Ferrara), Carlo Baccigalupi (SISSA), Anthony Challinor (University of Cambridge)
Contacts: marina.migliaccio@roma2.infn.it

Abstract: A large number of international observational campaigns are planned in the coming years which will be collecting cutting-edge measurements of the cosmic microwave background (CMB) polarization. The cosmology group at Tor Vergata is involved in the preparatory studies of several of those, and in particular of LiteBIRD, a space mission led by JAXA that will target primordial B-modes. Achieving such an ambitious goal will rely on the ability to separate the primordial signal from the astrophysical emissions (foregrounds) and the distortion induced by the large-scale structure in the Universe (lensing). Novel data analysis techniques are required to reach the needed accuracy in the statistical and geometrical characterization of the CMB polarization field. Examples include the development of efficient power spectrum estimators; the modelling of multi-component likelihood functions to constrain cosmological parameters; the study of methods for E- and B-modes separation which take advantage of the spin-wavelet decomposition. The new methods can also be used to produce improved analyses of polarization data already available, such as those recently delivered by Planck.

2.16 Fundamental Physics from the cross-correlation of cosmological probes

Supervisors: Marina Migliaccio (Physics Department, Tor Vergata University), Domenico Marinucci (Mat. Dept. Univ. Tor Vergata), in collaboration with Carlo Baccigalupi (SISSA), Nabila Aghanim (IAS Paris), Nicola Vittorio (Physics Department, Tor Vergata University), Massimiliano Lattanzi (INFN Ferrara)
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Abstract: Only recently cosmology has undergone a renaissance, transforming from a data-starved to a data-driven science. While observations supply strong evidence in favour of the standard model of cosmology (ΛCDM), some tensions have been found which could be hinting at systematic effects in the data or, more interestingly, at new physics beyond the standard model. With the advent of wide galaxy surveys, such as the ESA mission Euclid, and the recent high sensitivity full-sky maps of the microwave sky delivered by Planck, it is crucial and timely to investigate the interactions and complementarities of these diverse probes of the Universe. In particular, as different observations can be sensitive to the same physics, studying their cross-correlation appears as a unique tool to maximise the scientific outcome of each probe. Cross-correlating observables of the Cosmic Microwave Background, such as temperature and lensing data, with galaxy distribution and weak leasing data can allow to reconstruct the evolution of the large-scale structure across cosmic time and derive novel constraints on the nature of the dark side of the universe, i.e. the dark energy and dark matter.

2.17 Spectroscopic and variability study of highly-accreting supermassive black holes

Supervisors: Francesco Tombesi, Fausto Vagnetti (Physics Department, Tor Vergata University)
Contacts: francesco.tombesi@roma2.infn.it , fausto.vagnetti@roma2.infn.it

Abstract: Supermassive black holes (SMBH) are likely present at the center of every galaxy. During the peak of their growth, SMBHs may have had an impact on their host galaxies, leading to the observed SMBH-galaxy correlations. However, how such black holes grew their mass and how their feeding/feedback cycle is linked to galaxy evolution are still questions that need to be addressed. Accreting SMBHs are observed as active galactic nuclei (AGN) and they show complex accretion/ejection phenomenologies, possibly linked to their accretion rate. We propose to perform a systematic spectroscopic and variability study of a sample of highly-accreting SMBHs observed in the X-ray band. We will study their accretion disks through variability and spectral energy distributions, the power of outflows through detailed spectroscopy, and possibly the galaxy-scale environment through multi-wavelength observations. Finally, we will compare the overall parameters to other AGN samples in order to explore possible physical correlations with SMBH masses and accretion rates.

2.18 Investigating the multi-scale environment of active galactic nuclei in galaxy clusters

Supervisor: Francesco Tombesi (Physics Department, Tor Vergata University)
Contact: francesco.tombesi@roma2.infn.it

Abstract: Clusters of galaxies are the largest gravitationally bound structures in the Universe. Elements produced inside a galaxy cluster can rarely escape its deep gravitational potential well, therefore these constituents make clusters great probes for understanding the evolutionary history of their galaxies, the feedback from active galactic nuclei (AGN), chemical enrichment, and stellar evolution. In particular, very recent papers showed possible correlations between the mass of supermassive black holes (SMBHs) in the Brightest Cluster Galaxies (BCGs) and the thermodynamical properties of the cluster diffuse gas. In order to quantify the impact of accreting SMBHs to the largest cosmic scales we will select a complete archival sample of galaxy clusters observed in the X-rays and perform an extensive spectroscopic and imaging analysis to determine the multi-phase and multi-scale characteristics of the diffuse hot gas. This study will have important repercussions for future X-ray Integral Field Unit (X-IFU) instrument such as those onboard XRISM and Athena.

2.19 Future CMB Polarization Space Missions: theoretical challenges

Supervisors: Nicola Vittorio, Marina Migliaccio (Physics Department, Tor Vergata University), in collaboration with Erminia Calabrese (University of Cardiff), Sandeep Haridasu (University of Rome "Tor Vergata"),

Vladimir Lukovic (University of Rome “Tor Vergata”), Massimiliano Lattanzi (INFN Ferrara)
Contact: nicola.vittorio@uniroma2.it

Abstract: The cosmology group at Tor Vergata is actively involved in planning future observational campaigns targeting the cosmic microwave background polarization, and in particular LiteBIRD, a space mission led by JAXA, which will contribute to the quest for primordial B-modes. The accuracy of the forthcoming data will need to be matched by the development of accurate theoretical predictions, as the data will allow for unprecedented tests of cosmological models. High-sensitivity B-mode measurements represent a unique test-bed for cosmic inflation, requiring theoretical developments as well as accurate forecasts. Forthcoming polarization data at large angular scales will also provide an indirect channel to test the Universe reionization history against models of early galaxy evolution and star formation. Due to degeneracies between cosmological parameters, accurate CMB constraints on the reionization optical depth promise to constrain neutrino physics with an accuracy competitive to forthcoming neutrino dedicated experiments. In this way CMB polarization measurements will be at the crossroad between fundamental physics and astrophysics.

2.20 The 3D structure of the Galactic Bulge using primary distance indicators

Supervisor: Manuela Zoccali - Pontificia Universidad Catolica de Chile
Contact: mzoccali@astro.puc.cl

Abstract: This PhD project is focussed on the use of old, low-mass primary distance indicators (RR Lyrae, Type II Cepheids) to constrain the geometry of the Bulge together with its metallicity distribution and radial metallicity gradients. The project is based on optical (OGLE), near-infrared (VVV/VVVX, VISTA) and mid-infrared (SPITZER) images. The project might also include the analysis of both optical and NIR high-resolution spectra, already secured by our group.

2.21 A new approach to Stellar dating based on images collected with new Adaptive Optics systems

Supervisor: Manuela Zoccali - Pontificia Universidad Catolica de Chile
Contact: mzoccali@astro.puc.cl

Abstract: This project is focussed on accurate and deep near-infrared images collected with Adaptive Optics systems available at the 8-10m class telescopes of Galactic Globular clusters and the Galactic Bulge. Our group collected NIR images with both Sigle and Multi-Conjugated-Adaptive Optics available at VLT, LBT and GEMINI. The main goal of this project is to detect the main sequence knee in the lower main sequence and to use this evolutionary feature as distance and age indicator.

3 ABSTRACTS : INAF - IAPS (Institute for Space Astrophysics and Planetology)

3.1 Dynamical System and Information Theory Approaches to Space Plasma Dynamics

Supervisor: Giuseppe Consolini - INAF IAPS Roma,
Contact: giuseppe.consolini@inaf.it

Abstract*: In several astrophysical environments, space plasma show non-trivial complex and nonlinear dynamics, whose understanding requires the use of approaches borrowed from different research fields. In the recent past, chaos and turbulence has been found to play a relevant role in several dynamical phenomena dealing with plasma transport, energization and acceleration; phenomena which are still not completely understood and modeled. In this framework, the investigation of these phenomena using recent analysis methods developed in the field of dynamical system and/or based on information theory have been shown to be useful to unveil some aspects of the multiscale dynamics of space plasmas. The proposed work deals with the application of such novel techniques to characterize the dynamics of space plasma fluctuations form MHD scales down to kinetic ones in different heliospheric environments using in-situ satellite measurements.

3.2 Big Data and Machine Learning Approaches to Sun-Earth Relationship

Supervisor: Giuseppe Consolini - INAF IAPS Roma,
Contact: giuseppe.consolini@inaf.it

Abstract*: The study of Sun-Earth Relationship experienced a great benefit from the availability of a large amount of continuous measurements from both space and ground-based observations. In particular, the modeling of space weather events can be deeply investigated using this large amount of available datasets. In this framework, one of the most important aspect in relations with some manifestations of Space Weather effects on anthropic systems is the understanding of the relevant quantities, which can be used as basic variables/proxies for a possible forecasting of space weather effects and/or to construct some alert parameters. The aim of the proposed work is to disentangle the relevant cause-effect variables using novel methods based on Machine Learning approaches and information theory methods.

3.3 MAGNA: Multiple AGN Activity in galaxy mergers

Supervisor: Alessandra De Rosa - INAF IAPS Roma, in collaboration with Fausto Vagnetti, Phys. Dept. Tor Vergata University
Contact: alessandra.derosa@inaf.it

Abstract*: *Context:* There is growing evidence that galaxy mergers are the way through which Supermassive Black holes (SMBHs) grow and also form, especially at the highest luminosities. Numerical simulations have shown that strong inflows in a galaxy merger feed gas to the SMBH, thus powering accretion and triggering the AGN. Multiple supermassive Black Hole systems are of wide astrophysical relevance: (1) they could represent the main ingredients of triggering AGN and/or starburst activity in the host galaxy and within the BHs-galaxy co-evolution (the so-called feedback); (2) they play a role in the formation of radio jets in AGN; (3) coalescing binary SMBHs are strong emitters of gravitational waves detectable with LISA (ESA L3 Large Mission). The connection between AGN triggering and galaxy merger is not clear yet, despite several observational campaigns carried out in this field. Some studies in different wavebands show evidence of a higher fraction of dual AGN in galaxies with a close companion, suggesting that galaxy interaction plays a role in the AGN triggering process. However, there are other investigations revealing no increased AGN fraction in mergers compared to inactive galaxies. These apparently different results may be a consequence of different sample selection and observational biases. However, it is of undoubted evidence that the detection and characterisation of dual SMBHs at all scales is fundamental to understand the black hole accretion history in the Universe. The varied observational and numerical techniques adopted thus far are highly complementary, since different bands and/or numerical setups have inherently distinct limitations. *Aim:* The PhD work is dedicated to multi-messenger studies of multiple SMBHs, with emphasis on the best strategies for detections, applicable to the current and upcoming observatories, and the most updated and comprehensive numerical simulations and theories on the pairing and merging of SMBHs. Method Through the analysis of multi-wavelength data already available (proprietary and in the archive) in different bands (optical, radio, mm, IR, X-rays) the work aims at investigating the nuclear and environment properties of SMBH in merging galaxies such as: BH mass, AGN Luminosity, absorption gas column density, AGN accretion rate. These characteristics will be compared with those found in SMBH in isolated systems with the main goal of understanding the parameters that most drive the AGN triggering. Moreover the analysis will provide fundamental input for cosmological and idealized simulations of AGN formation. The work also envisages requests of new observational data in the wide waveband and feasibility study for future space and ground based missions. *Collaborators:* Italy: INAF-OAR; Uni RomaTre; Uni Bologna; Uni Milano Bicocca. Germany: MPIfR; Spain: CSIC, USA: Georgia Tech. ESA. The MAGNA team is composed by specialists in different fields: observations, theory and numerical simulations. The PhD could benefit of a close interaction with all team members. *References:* web: http://www.issibern.ch/teams/agnactivity/Home.html Koss et al, 2019, ASTRO2020 science white paper, https://arxiv.org/abs/1903.06720 De Rosa et al. 2018, 2018MNRAS.480.1639D De Rosa et al. 2015, 2015MNRAS.453..214D

3.4 Characterisation of analogue martian materials in the context of the ESA EXOMARS mission

Supervisor: Maria Cristina De Sanctis in collaboration with Giuseppe Piccioni - INAF IAPS Roma,
Contact: mariacristina.desanctis@inaf.it

Abstract*: The ExoMars 2020 mission will land on Mars in the Oxia Planum region. This site could have had environmental conditions in the past, suitable to habitability and could have preserved physical and chemical traces or biosignatures. The ExoMars mission is equipped with a rover carrying a number of scientific instruments among which a spectrometer, named Ma_MISS, operative in the VIS and NIR ranges (0.4-2.2 micron). Ma_MISS is hosted in the perforation system (a drill) carried by the Rover. In fact, part of the spectrometers is housed closed to the drill tip. Ma_MISS is capable of producing hyperspectral images of the interior of the boreholes drilled by the perforation system. This will allow the determination of the mineralogy and the stratigraphy of the subsurface layers down to a maximum depth of 2m. The spectrometer will operate periodically during the perforation activities The proposed thesis deals with the spectral characterization in laboratory of various materials (minerals, rocks and mixtures), which can be considered as analogues of those to be found in the rover's drilling region. The thesis work is split in several phases:

1. Study of the landing area (Oxia Planum) using data (spectral, imaging, composition, etc.) already acquired from remote sensing instruments onboard previous missions.
2. Selection of the best matching materials (minerals and rocks) with those present in Oxia Planum.
3. Sampling of naturally occurring minerals of rocks identified above. In case these are not available produce synthetic minerals.
4. Sample preparation for the laboratory analysis (grounding, sieving, production of mixtures, etc.)
5. Spectral analysis and characterization with available instrumentation. Among the various spectrometers available at IAPS also an Engineering Model of the Ma_MISS instrument shall be used.
6. Generation of a database of reference spectra for comparison with real data obtained by the Ma_MISS instrument on Mars.

The thesis work will be performed in an international context in collaboration with the other teams involved in the instrument and in the mission.

3.5 A synergic strategy to identify habitable exoplanets

Supervisor: Maria Pia Di Mauro - INAF IAPS Roma, in collaboration with Luca Giovannelli Phys. Dept. Tor Vergata
Contact: maria.dimauro@inaf.it

Abstract*: The goal of the present project is to characterize habitability of exoplanets by using the stellar properties deduced by Asteroseismology and exploring the possible factors influencing exoplanetary climate. The objective will be achieved by fulfilling the following tasks:

1. Asteroseismology of solar-type stars by using Kepler or TESS data for determination of high-precision parameters of stars with detected rocky exoplanets
2. Characterization of habitability by studying the planet-star interaction, modelling conditions of exoplanetary climate taking into account stellar activity and extreme space weather factors.

3.6 Development of the HERMES constellation of nanosatellites for GRB studies and Gravitational Wave counterparts

Supervisor: Yuri Evangelista - INAF IAPS Roma, in collaboration with Franco Meddi, Phys. Dept. Sapienza
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Abstract*: HERMES (High Energy Rapid Modular Ensemble of Satellites) is a space borne mission funded by ASI and by the Horizon 2020 EU program. The project is based on a constellation of nano-satellites in low Earth orbit, hosting new miniaturized detectors to probe the temporal emission of bright high-energy transients such as Gamma-Ray Bursts. Fast transient localization, in a Field of View of several steradians and with arcmin-level accuracy, is gained by comparing time delays among the same event detection epochs occurred on at least 3 nano-satellites. With a launch date in 2021, HERMES transients monitoring represents the keystone capability to support the 2020 new generation of interferometers, which will search for events in a sky volume 100 times larger than in the GW170817 case. INAF, in collaboration with INFN, Politecnico di Milano, University of Pavia, University of Udine and University of Cagliari, is developing the modular X-ray/gamma-ray monitor to be placed on-board 3U CubeSat buses. The successful candidate will join the HERMES team working on the instrument development, integration and test activities and will take part to the in-flight mission operation and data analysis.

3.7 Development of the Sino-European space mission eXTP (enhand X-ray Timing and Polarimetry mission) for X-ray Astronomy

Supervisor: Marco Feroci - INAF IAPS Roma, in collaboration with Leonardo Gualtieri, Physics Departmnet, Sapienza
Contact: marco.feroci@inaf.it

Abstract*: eXTP is a flagship mission led by the Chinese Academy of Sciences, developed in cooperation with a large European collaboration. The launch date is 2026 and the mission is currently entering its phase B. Two of the four instruments are developed and led by Europe. In particular, the Large Area Detector (LAD) is led by INAF/IAPS in Italy. The mission is aimed at studying matter under extreme conditions of gravity (tests of General Relativity in the strong-field regime), density (constraining the Equation of State of neutron stars) and magnetism (testing quantum electro-dynamics). The LAD is a collimated X-ray instrument operating in the 2-30 keV energy range. It will deploy the unprecedentedly large effective area of 3.4 m^2, measuring energy and time of arrival of each individual photon from the observed source. This instrument will enable for the first time high-throughput spectral-timing, with $<$250 eV spectral resolution and $<$10 μs time resolution, allowing a detailed characterization of the X-ray emission from the innermost regions around black hole and neutron star systems. The successful candidate will join the eXTP team working both on the instrument development at the PI institute (INAF/IAPS) and on the development of the science case on strong field gravity with the team at Sapienza University.

3.8 Consolidation of the Cryogenic AntiCoincidence detector baseline design for the Athena/X-IFU instrument

Supervisors : Claudio Macculi, Luigi Piro, in collaboration with Angela Bazzano - INAF IAPS Roma,
Contact: claudio.macculi@inaf.it

Abstract*: The PhD is in the context of Athena, the ESA 2nd Large class mission to be launched on 2031. One of the two on board instruments is X-IFU, a TES (Transition Edge Sensor) based kilo-pixels array able to perform simultaneous high grade energy spectroscopy (2.5eV@7keV) and imaging over 5' FoV. INAF/IAPS has the co-PI ship of X-IFU and it is also responsible to deliver the CryoAC (Cryogenic AntiCoincidence) detector required to reduce the particle background detected by the TES array: the lower the background, the higher the instrument sensitivity. The CryoAC is made of 4 Silicon suspended absorbers sensed by a network of Ir:Au TESes, and placed at a distance ¡ 1 mm below the TES-array. By 2021 (Athena mission adoption), ESA requires that critical subsystems must reach the Technology Readines Level 5. For the CyroAC, it translates in consolidating the baseline design by two main models:

1. pre-EM (Engineering Model) having the shape of the Flight one, but one only readout channel instrumented
2. a structural model required to test the pre-EM sample in relevant environment (vibrations test) The student will follow design, detector modelling, test activities in a multinational context.

3.9 Multiscale Galactic Star Formation: placing the Milky Way in the extragalactic context

Supervisor: Sergio Molinari in collaboration with Angela Bazzano - INAF IAPS Roma,
Contact: sergio.molinari@inaf.it

Abstract*: This study aims at relating the end-products of star formation measured by the Star Formation Rate (SFR) and Efficiency (SFE), to the physical mechanisms responsible for the onset of star formation. Doing this in very different places of the Galaxy and with significant statistics is the necessary step to put star formation in the global context and be a reference for extragalactic studies.

The measurement of the SFR-SFE requires that for all Galactic star and cluster-forming sites *i)* their basic physical parameters (mass, size, temperature) are measured, *ii)* their evolutionary stage is characterised and *iii)* their relationship to the progenitor dense filamentary structures is established.

We will rely on a set of available Galactic Plane surveys from the near-infrared to the radio that have generated samples of several tens-of-thousands dense clumps and filaments (e.g. Herschel/Hi-GAL), augmented with high-spatial resolution ALMA data to characterize the fragmentation of molecular clumps into individual star-forming cores. These datasets will be analysed in the framework of SF indicators generally used in extragalactic studies, to unveil the recipe ingredients at the foundation of star formation laws.

3.10 Broad-band electromagnetic observations of GW counterparts and the central remnant

Supervisor: Luigi Piro - INAF IAPS Roma,
Contact: luigi.piro@inaf.it

Abstract**: EM observations of GW counterparts, w.p.r.t. NS mergers, pin down the properties of the relativistic outflow produced after the collapse and carry fundamental information on the origin of the remnant. The group at IAPS leads a major campaign of follow-up observations from radio to hard X-rays on the GW sources detected in the O3 run of Virgo and Ligo, with approved time as PI and CoPI on ATCA, JVLA, Gemini, HST, XMM-Newton, Chandra and NUstar. The project aims at tackling fundamental questions such as the origin of the merger remnant, whether a BH or a massive NS. The candidate will work on data set of some of the key facilities from radio to gamma-rays gathered following the GW events, modelling the data with the most advanced models of relativistic outflow produced by the explosion. In addition a joint analysis of broad-band EM data and GW data will be implemented, further advancing the characterization of the remnant and its explosion, with particular regard to the geometry of the system. The candidate will also elaborate on the perspective results and advancement with future instrumentation in the field, including the next generation of GW antennas and high energy satellites, w.p.r.t the large X-ray observatory Athena.

3.11 Ground calibration and flight data analysis of X-ray photoelectric polarimeters

Supervisor: Paolo Soffitta - INAF IAPS Roma,
Contact: paolo.soffitta@iaps.inaf.it

Abstract**: IXPE (Imaging X-ray Polarimetry Explorer) is a mission of the Small Explorer class of NASA. Italian participation is important since we are responsible for the whole focal plane included the detector sensitive to polarization that will be calibrated at IAPS. The previews mission dates back in the '70 and measured a positive polarization from a single source. IXPE mission will be more sensitive by two order of magnitude at least and it promises to open a new window in High Energy Astrophysics. Ground and flight calibration are an essential part of this project. The instrument calibration will be held at IAPS, the main place for this doctoral thesis. The end-to-end calibration including the X-ray optics and the detectors will be held at NASA/MSFC. Both calibration will allow to study the performances of the experiment both with polarized and un-polarized radiation. This mission will fly in April 2021, therefore the candidate will be able to participate also to the analysis of the first data obtained during part of the first year of satellite operation also using the calibration data results he got during the first part of his doctorate period.

3.12 Spectroscopic analysis and modeling of the icy Galilean satellites in view of the JUICE mission and future observations

Supervisors: Federico Tosi, Francesca Altieri, in collaboration with Giuseppe Piccioni - INAF IAPS Roma
Contact: federico.tosi@inaf.it

Abstract*: The icy Galilean moons of Jupiter: Ganymede, Europa and Callisto, are often considered as three planetary bodies bound by a continuous transition both in terms of geologic activity and surface composition.

Because the interior of these moons is rich in liquid water, their surface represents the interface between their interior and the outer space, and as such it records both endogenous processes related to a more or less intense and frequent geologic activity, and exogenous processes induced by the surrounding space environment. These processes are responsible for the morphology and surface composition that is observed today. Studying this composition by means of spectroscopic techniques in principle can provide a deeper understanding of the connection existing between the geochemical state of their subsurface and the space environment surrounding them. One of the key objectives of the JUpiter ICy moons Explorer (JUICE) mission, due to be launched in 2022, is to perform an in-depth analysis of the surface composition and atmospheric composition and structure of the icy Galilean moons Ganymede, Europa and Callisto by means of several instruments, including a visible to near-infrared imaging spectrometer (MAJIS), where INAF-IAPS is deeply involved. With this PhD thesis we propose to undertake an extensive survey of the spectroscopic data of the icy Galilean moons, available both from previous space missions and from telecopic observations. As far as the surface of these moons is concerned, the goal is to test different spectral unmixing techniques, in order to better constrain the chemical composition. Furthermore, we plan to model the currently available data regarding the tenuous atmospheres of the Galilean icy satellites, incuding the plumes of Europa. This new analysis may refine and extend the results obtained previously on the available datasets, and provide a better assessment of the observables and performances needed to properly constrain the potential habitability of icy moons such as Europa and Ganymede. On the other hand, it would provide tools in view of the analysis of data acquired by future space missions such as JUICE and Europa Clipper, which will explore the Jupiter system in 2030-2033 and beyond. Our topic has a certain flexibility, to take into account the specific interests of the potentially interested student.

4 ABSTRACTS : INAF - OAAb (Astronomical Observatory of Abruzzo)

4.1 Unraveling the astrophysical properties of the gravitational wave sources: a key challenge in the newly born Multi-Messenger Era.

Supervisor: Enzo Brocato (INAF-OAAb)
Contact: enzo.brocato@inaf.it

Abstract*: The scientific aim of this thesis is to study and understand the nature and astrophysical properties of the sources of the gravitational waves measured by LIGO/Virgo interferometers.

The PhD student will have access to the whole sample of data obtained with several observational facilities made available for the observations of these counterparts by the GRAvitational Wave Inaf TeAm (GRAWITA, https://www.grawita.inaf.it). Data from these telescopes range from ultraviolet (Swift satellite) to optical and Near-infrared (LBT, VLT, VST, REM, NOT, TNG, Asiago and Campo Imperatore telescopes) up to the radio (SRT and SKA precursors). It is expected that she/he will acquire a relevant experience in observation techniques and data analysis as far as in the interpretation of the CCD images and spectral data. The PhD student will join GRAWITA and ENGRAVE collaborations (http://www.engrave-eso.org) and, typically, will spend a period abroad.

The observational results will be compared to the most recent models of Binary Neutron Star (BNS) and Black Hole – Neutron Stars (BHNS) coalescences taking advantage of the expertise of the GSSI and GRAWITA theoretical groups.

Note: this research line is part of a collaboration with researchers of La Sapienza and Tor Vergata, the co-supervisor will be identified later.

4.2 Formation of globular clusters as a tracer of galaxy formation: A synoptic study of extragalactic globular clusters and neutral hydrogen in the Fornax galaxy cluster

Supervisor: Michele Cantiello (INAF-OAAb)
Contact: michele.cantiello@inaf.it

Abstract*: Extra-galactic Globular Clusters (GC) are old, compact stellar systems, ubiquitously found in galaxies. As fossil tracers of their environment, GCs provide important and unique information constrain the history of formation and evolution of their host galaxy and its environments. A further tracer of the build up of galaxies, of their stellar mass, is the content of neutral hydrogen in and around galaxies.

The PhD candidate will analyze the optical properties of GCs in the second closest galaxy cluster, Fornax, observed for the VST Fornax Deep Survey (FDS, 30 square degrees, imaged in ugri bands). The optical properties of the sample will be correlated with the radio properties of the neutral hydrogen in the cluster, as observed with the SKA precursor MeerKAT for the MeerKAT Fornax Survey (12 square degrees), to constrain the structure formation and galaxy evolution picture in this cornerstone galaxy cluster.

Note: this research line is part of a collaboration with researchers of La Sapienza and Tor Vergata, the co-supervisor will be identified later.

4.3 Stellar and dynamical evolution of Globular Clusters

Supervisor: Oscar Straniero (INAF-OAAb) and Marco Merafina (Physics Department, Sapienza University)
Contact: oscar.straniero@inaf.it , marco.merafina@roma1.infn.it

Abstract:

Globular Clusters are building blocks of galactic halos. They are found in any galaxy type, spirals, ellipticals, dwarfs. Typically, they contain millions of stars linked by the reciprocal gravitational glue. Globular Clusters and their stars have been used to understand the early phases of the Milky Way history. Moreover, Globular Cluster stars provide a natural laboratory to investigate fundamental physics.

The proposed thesis concerns the development of theoretical tools to investigate the interplay of stellar evolution and stellar dynamics in Globular Clusters. The main goal is the search of hints of missing physical processes at different scales, from the long scale of the gravitational interactions among stars, to the nuclear and sub-nuclear scales of the weak and strong interactions that operate in hot and dense stellar cores. The student will be introduced to the most advanced applications of numerical simulations in astrophysics.

4.4 Nucleosynthesis in primordial stars, paving the route to SKA

Supervisor: Oscar Straniero (INAF-OAAb)
Contact: oscar.straniero@inaf.it

Abstract*: Among the last frontiers in cosmology and astrophysics there is the exploration of the era when the first stars and galaxies formed, causing the re-ionization of the Universe. The first stars were responsible of the first pollution of the interstellar gas after the epoch of the BBN nucleosynthesis. For the first time, elements from carbon to uranium, appeared in the naive Universe. SKA will be the most sensitive radio telescope able to reveals the breath of this primordial stellar population.

The program of the proposed thesis concerns the development of the theoretical tools needed to properly models the evolution and the nucleosynthesis of the first stars.

5 ABSTRACTS : INAF - OAR (Astronomical Observatory of Rome)

5.1 Higher order statistics in weak lensing from the Euclid survey

Supervisors: Vincenzo F. Cardone (INAF OAR Osservatorio Astronomico di Roma), Roberto Maoli (Physics Department, Sapienza University)
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Abstract*: The unprecedented quality and quantity of Euclid weak lensing data opens up the road to a characterization of the statistical properties of the shear and convergence fields which goes beyond what is the present day standard. Rather than relying on second order statistics, one can indeed extract information from the field non Gaussianity through higher order statistics. This includes both global estimators (e.g., higher order moments), topological indicators (such as Minkowski functionals, Betti numbers, and persistence diagrams), and local probes (as the 3pt − correlation function and the bispectrum). These probes can be used for both the shear and the convergence fields being affected by different kind of systematics. Part of the job will therefore be to understand which strategy is more promising in terms of both precision and bias. The project will address theoretical and observational aspects relying on both Euclid − like simulations and actual data from ongoing Stage III surveys. The work will be carried on within the activities of the High Order Statistics Work Package of the Euclid collaboration hence allowing the student to work in a highly formative environment.

5.2 The physical properties of high redshift VANDELS galaxies from spectro-photometric fitting

Supervisor: Adriano Fontana (INAF OAR)
Contact: adriano.fontana@inaf.it

Abstract: VANDELS is an ultradeep spectroscopic survey of high redshift galaxies and AGN. At the end of the survey we will obtain more than 2000 spectra of z 3-5 galaxies with unprecedented S/N such that it will be possible to derive physical parameters for the first time and study the physics of the objects. In this context the PhD student will be able to choose among various inter-related projects such as:

- Investigate the earliest stages of galaxy evolution through the analysis of emission line objects with particular focus on HeII emitters. From a combination of line ratios with photoionization models we will estimate ionization state and other properties which will be combined with other main properties (mass, sfr, ages, dust) from SED fitting, and sizes and morphologies from HST imaging.

- Use advanced spectro-photometric fitting codes to constrain the physical properties of high-redshift galaxies (stellar metallicity, age, star-formation history), to obtain more solid UV based extinction and SFR estimates and determine their effect in shaping the slope of the UV continuum.

- Perform a multi-variate analysis of the properties of Ly-alpha emitters and Lyman break galaxies across cosmic time, and up to the reionization epoch, providing solid statistical constraints on their distribution functions (UV luminosity, SFR, size, extinction).

5.3 Machine learning and computer vision for the next generation extragalactic surveys

Supervisor: Adriano Fontana (INAF OAR Roma)
Contact: adriano.fontana@inaf.it

Abstract: Astronomy is facing a change of paradigm, with the next years witnessing the first big-data driven revolution, as well as the advent of a number of new, revolutionary observational facilities and surveys. In parallel, the computational power for data analysis will keep increasing. Indeed, forthcoming cosmological surveys like Euclid and LSST will observe a large fraction of the sky yielding huge amount of imaging data on billions of galaxies. New methods and approaches are needed to thoroughly exploit such massive load of information. In this context the PhD student will be able to choose among various inter-related projects, including:

1. develop advanced machine learning methods to classify astronomical sources in existing extragalactic datasets (CANDELS, COSMOS, Frontier Fields) and in detailed simulations of the future Euclid catalog.

2. develop image analysis and computer vision tools to improve resolution and depth of survey images

3. use learning approaches to analyse, reconstruct and simulate complex galaxy morphologies in deep survey images

5.4 Indirect Dark Matter searches with current- and next-generation ground-based gamma-ray observatories

Supervisors: Saverio Lombardi (INAF OAR Osservatorio Astronomico di Roma), Roberto Capuzzo Dolcetta (Physics Department, Sapienza University)
Contact:

Abstract*: For the XXXV cycle, we propose a PhD fellowship research program on indirect searches for dark matter (DM) signatures at the TeV mass range with current- and next-generation Cherenkov telescopes. The PhD activities will be carried out in the very-high energy (VHE) group of the INAF Astronomical Observatory of Rome (INAF-OAR), in association with the Universities of Rome. The PhD candidate will exploit real data of highly DM-dominated astrophysical targets at VHE in order to pursue a remarkable DM scientific program. The data will be taken by the MAGIC Cherenkov telescopes (located in the Canary island of La Palma, Spain). Furthermore, detailed Monte Carlo (MC) simulation-based studies for indirect DM searches with the next-generation Cherenkov Telescope Array (CTA) will be performed for different optimal astrophysical targets in order to assess the CTA capabilities and optimize its multi-years program for indirect DM searches. The ASTRI mini-array, an array of telescopes proposed to be installed and operated during the pre-production phase of CTA in the southern hemisphere site (Paranal-Armazones, Chile), will also be considered for evaluating its scientific prospects for indirect DM searches. The scientific impact of the indirect DM search program discussed here would be the possibility either to detect hints of DM signatures from real data taken by the MAGIC telescopes, or (in case of no detection) to provide among the best and most reliable world-wide constraints for DM indirect searches at TeV mass scale, crucially contributing to the global ongoing multi-instruments efforts. In parallel, a valuable contribution to assess the actual capabilities of CTA (in its nominal final layout) and one of its foreseen precursor, the ASTRI mini-array, for indirect DM searches with different astrophysical targets is foreseen to be achieved by means of suitable MC simulations.

5.5 Hunting for the Missing Baryons at all possible Scales in the Universe

Supervisors: Fabrizio Nicastro and Enrico Piconcelli (INAF OAR Osservatorio Astronomico di Roma)
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Abstract*: The observed number of baryons in the local Universe falls about 40-50% short of the total number of baryons inferred by density fluctuations of the Cosmic Microwave Background. Theory provides a solution to this problem, by locating the missing baryons in hot and tenuous filamentary gas connecting galaxies (e.g. [1,2]). Our team has led the search for the missing baryons for over a decade now, providing the first validation of theory (e.g. [3-8]), but evidence is still sparse. Current observing facilities and data need to be thoroughly exploited to solidify current evidence and prepare the ground for future detailed studies with the selected ESA Large Observatory Athena. This PhD project is designed to tackle the problem from all possible sides and at all possible scales, by (a) selecting 'clean' samples of intervening HI Ly-alpha and OVI absorbers from archival Far-UV spectra of AGNs to be used as signposts for hot metal-enriched gas in the archival X-ray spectra of the same targets; (b) using hydro-dynamical simulations to constrain the physics of the detected hot absorbers; (c) constraining mass, physics and kinematics of the hot Circum-Galactic Medium of the Milky Way. See also the references: Cen & Ostriker, 2006, ApJ, 650, 560; Wijers et al., 2019, MNRAS, submitted; Nicastro et al., 2016, MNRAS, 457, 676; Nicastro et al., 2016, MNRAS, 458, L123; Nicastro et al., 2016, ApJ, 828, L12; Nicastro et al., 2003, Nature, 421, 719; Nicastro et al., 2005, Nature, 433, 495; Nicastro et al., 2018, Nature, 558. 406.

5.6 "Fast imaging" techniques with adaptive optics systems for next-generation solar and night-time telescopes

Supervisors: Fernando Pedichini (INAF OAR Osservatorio Astronomico di Roma) Dario Dal Moro (Physics Department, Tor Vergata University)
Contacts: fernando.pedichini@inaf.it, dario.delmoro@roma2.infn.it

Abstract*: The proposed thesis will be centred on the analysis and development of procedures aiming at the maximization of angular resolution and contrast in images acquired with telescopes equipped with state-of-the-art adaptive optics systems, for both night-time and solar astrophysical observations. More specifically, the activity research will focus on the techniques that exploit the additional feedback from the scientific images when these are acquired at high temporal cadence (up to 1kHz, the so-called fast imaging). The PhD student will carry out his work at the laboratories of the Tor Vergata University and of the INAF-Osservatorio Astronomico di Roma in Monte Porzio Catone, also in the framework of the activities of the ADONI national laboratory for adaptive optics.

5.7 Physics and co-evolution of the most luminous Quasars in the Universe

Supervisors: Enrico Piconcelli, Angela Bongiorno (INAF OAR)
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Abstract: This Ph.D. program focuses on investigating the most luminous quasars in the Universe. It is now widely accepted that the growth of SMBHs is linked to the process of galaxy formation. Specifically, quasar-driven outflows are believed to play a key role in SMBH-galaxy self-regulated growth, being able to deposit energy and momentum into the host galaxy gas reservoirs, i.e. the raw material for new stars, and effectively shut down the star formation. Understanding this "quasar feedback" mechanism is one of the major challenges in extra-galactic astrophysics. The power of feedback increases with AGN luminosity and hyper-luminous quasars hence provide a unique test-place for probing the feedback mechanism and the SMBH-galaxy co-evolution. The student will have the opportunity of analyzing proprietary/archival observations of luminous quasars collected at the largest astronomical facilities [i.e. VLT, LBT ALMA, Chandra] in collaboration with our internationally-recognized team. The data will be used to: (a) constrain the SMBH mass and accretion rate; (b) provide a multi-phase census of quasar-driven outflows and (c) reveal the properties of the host galaxy and its environment.

5.8 Cosmological parameters from the Euclid satellite

Supervisor: Roberto Scaramella (INAF OAR Osservatorio Astronomico di Roma)
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Abstract: The Euclid satellite is the next ESA mission dedicated to Cosmology and at present the largest ongoing astronomical project. Euclid will perform a spectroscopic and imaging survey over 15000 square degrees of the sky, providing both galaxy clustering and weak lensing data from billions of galaxies. As additional probes, Euclid will also detect the largest ever sample of galaxy clusters and, moreover, allow cross − correlation of the galaxy field with the CMB. In order to make the best use of the whole dataset, it is of paramount importance to investigate the cross − correlation among these different probes. This will not only increase the accuracy on the cosmological parameters but also to check for any systematics which can bias the results from a single probe. The proposed thesis will investigate a self − consistent approach to the Euclid data developing a likelihood analysis which correctly takes into account the covariance among each individual dataset and the effect of experimental biases. Validation of the proposed tools will be possible against Euclid − like ad hoc simulations done by the Consortium. A close interaction with the likelihood work packages present in the Euclid collaboration is foreseen placing the student in contact and collaboration with a large world community performing frontier research in cosmology. The student will become a member of the Euclid Collaboration and the thesis is timely tuned so that the results will be ready at the launch of the satellite.

5.9 Assess the nature and origin of multi-messenger transients with gamma-ray observations.

Supervisors: Antonio Stamerra, Marco Tavani (INAF OAR Osservatorio Astronomico di Roma)
Contacts:

Abstract*: The recent multi-messenger detections of a gravitational wave (GW) signal from a binary neutron star merger jointly with its electromagnetic kilonova and gamma-ray burst (GRB) counterparts, and of a neutrino in coincidence with a blazar flare at high and very-high gamma-ray energies (VHE, E>100 GeV), have opened a new window to the study of the Universe. The multi-messenger observations are providing new and powerful insights into the physical interpretation of transient phenomena. The proposed project aims at characterising the multi-frequency properties of the transient counterparts of GWs and high-energy neutrinos, that can be detected up to VHE gamma-ray band. This goal will be achieved by observations with the MAGIC Cherenkov telescopes, assembling multi-frequency data for VHE associations, and collecting and analysing X-ray and gamma-ray data during the follow-up campaigns. The work proposed will also investigate the prospects for the detection with the future observatories like the Cherenkov Telescope Array (CTA), and it will be instrumental to develop the science cases for CTA.

5.10 Diagnosing hot accretion flows and neutron star radii with partially-obscured relativistic Fe-line profiles

Supervisor: Luigi Stella (INAF OAR Osservatorio Astronomico di Roma),
Contact: luigi.stella@inaf.it

Abstract: The X-ray spectrum of disk accreting neutron stars and black holed comprises an extremely broad and redshifted Fe-K_α emission line around ~ 6.4 keV. Its profile is determined by relativistic beaming, red/blue-shifts and light bending of the X-rays emission by matter orbiting the inner disk regions with speed $> 0.1c$.

Obscuration of the Fe K_α photons generated in the innermost disk regions around collapsed object is expected to occur along the line of sight under a variety of circumstances. Examples are partial obscuration by neutron stars, inner Comptonising coronae and inhomogeneities orbiting the disk. We have undertaken a program to study the features generated by partial obscuration of relativistic Fe K_α profiles and single out the information they encode. Calculations will be carried out in full GR using the Kerr metric, except for those cases in which the precisionafforded by approximate formulae in the Schwarzschild metric suffices.

5.11 Binary pulsars as astrophysical laboratories

Supervisors: Luigi Stella & Alessandro Papitto (INAF OAR Osservatorio Astronomico di Roma)
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Abstract: Pulsars in binary systems provide us with a unique laboratory to study the interaction between matter inflowing towards the neutron star, the rotating magnetosphere and the outgoing radiation, particle wind and jets. A key diagnostic has proven to be the detection of coherent pulsations and aperiodic variability in different wavebands (radio, optical, X-ray, gamma-ray). This has recently led to the discovery of a class of transitional millisecond pulsars that undergo still enigmatic state changes over days/weeks. In 2017 thanks to a fast Silicon photo-multiplier developed at La Sapienza (SiFAP), we discovered optical millisecond pulsations, the first ever found at those wavelengths, from one of these systems. Timing analysis and interpretation of multi-waveband observations of both ultra-luminous and transitional millisecond pulsars in binary systems will be carried out by exploiting accepted programs with the world-class observing facilities. We plan also to use and possibly develop further the SiFAP detector.