The Transient Universe 2023

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IESC Cargèse

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Open and FAIR science

As a researcher, you are not only producing scientific articles. Most likely, you are creating valuable data sets, that could be re-used and used in a different context if available and in the right format. You might produce software that might benefit other researchers.
Open and FAIR Science is the concept of sharing research results and ensuring that data are indeed FAIR, i.e. findable, accessible, interoperable, and reusable.
In this lecture we explore the path to Open and FAIR Science. What does it require, what are the benefits and risks? Where can one find help and what is done at national and international level to make Open Science possible?

Student talks / **42**

RAINBOW Light curve fitter

Feature extraction is one of the crucial stages in trying to apply machine learning to tasks on real astronomical data. In particular, when dealing with transients where light-curves are sparsely sampled, with varying numbers of points and in the presence of uncertainties. One of the standard methods to extract features from a light curve is to find the best fit parameter values to a particular parametric equation and use them as features. Typically the telescope's measurements are taken with different filters and therefore the previous operation is repeated for each of them. The collection of all minimized parameters over all filters constitutes a complete feature set describing the object. This approach has the advantage of completely describing the phenomena in a computational quick manner, but it has several drawbacks. First the number of features scales directly with the number of filters. Then, each filter must contain enough data points for the fit to be mathematically constrained. If even one filter is lacking measurements, the feature extraction won't be computable. Finally, an independent fit of each filter results in very correlated features, and completely ignores constraints from one filter to another. In order to solve all these problems, we propose the RAINBOW framework. It is a feature extraction method that uses a single three dimensional parametric equation instead of a collection of two dimensional parametric equations. By adding wavelength as an input,we ensure that the whole object is fitted at once, independently of the number of filters. The function itself is based on the blackbody equation, includes a phenomenologically motivated combination of exponentials to represent the bolometric flux and a sigmoid-like temperature evolution hypothesis. We demonstrate the efficiency of RAINBOW on SN-like objects from the PLASTiCC Kaggle challenge. Based on a complete benchmark including goodness of fit estimation, maximum peak time prediction and classification exercises, we show that the method is consistently better than the traditional approach, while offering a denser and more physically meaningful feature extraction. This represents a significant improvement in our ability to extract meaningful information from partial data from astronomical transients.

Student talks / **55**

The powering mechanism of broad-emission-line dominated hydrogen-rich luminous supernovae

Superluminous supernovae II (SLSNe II) are a sub-class of Type II SNe defined by light-curve peaks brighter than ~ -20 mag in optical bands. This definition is somewhat arbitrary. The scarcity of these events complicate the study of their origins. Systematic studies of large sample of SNe II usually do not include events with light-curve peaks brighter than ~ -18.5 mag in the V band, indicating these events are scarce too. We refer to them as luminous SNe II (LSNe II). Thanks to modern surveys, the detected number of LSNe II is growing. If persistent narrow lines are seen in the SNe spectra they are classified as SNe IIn and the extra luminosity is attributed to interaction of the ejecta with dense circumstellar material (CSM). A continuum of observational properties has been detected between SNe IIn and SLSNe IIn hinting towards a common origin. However, the powering mechanism is not clear when narrow lines are absent. Understanding the powering mechanism of LSNe II without persistent narrow lines would allow us to evaluate whether a continuum exists bridging the gap between less luminous SNe II and SLSNe II. In this talk I will present an analysis of a sample of six LSNe II followed up by the ePESSTO collaboration. We propose an interaction scenario with CSM that is not dense enough to be optically thick to electron scattering on large scales - thus, no narrow emission lines are observed. This conclusion is based on the observed light curves and spectral features. The shared characteristics of the sample support a similar powering scenario for all of them.

Student talks / **58**

Revealing Clumps in the Changing Structure of Type-Ib SN 2012au

SN 2012au is a key intermediate object between Type Ib supernovae (SNe), superluminous SNe and the highly-energetic, hypernovae. This unusual SN had a higher mass loss rate than other hypernovae but likely arose from a progenitor star of about 80 solar masses. These two findings contradict previous theories that more massive stars could not produce such an explosion, suggesting that a jet-powered mechanism caused SN 2012au. I present 6 epochs of spectropolarimetric data for SN 2012au observed by the Supernova Spectropolarimetry Project between 0 and 295 days post-maximum brightness. The unique combination of polarization information with multi-observation spectra gives us a detailed picture of the distribution of elements in the explosion and how these structures change over time. Spectropolarimetry is a powerful piece of the multi-messenger toolkit that enables us to identify individual components in the SN's geometry, such as clumps and jets that otherwise cannot be resolved. Our spectropolarimetric data show that SN 2012au exhibited a dominant axis in early epochs, which is associated with a jet-like feature. We also see signatures in the helium line polarization that suggests this material is distributed in clumps with a different symmetry axis than the jets. By comparing our observations with radiative transfer models, we offer a picture of the structure of SN 2012au and discuss the implications our findings have for this unique breed of supernova.

Student talks / 38

Observing Transients In Their Infancy

Observations of supernovae (SNe) within a couple of days post explosion have the potential to probe the physics of their early evolution. This could provide insight into physics of several phenomenon including shock breakout, interactions with circumstellar material, and companion interactions. Unfortunately these early time observations are rare. I will present my work on automating the follow up of transients discovered in data from the the Gravitational wave Optical Transient Observatory (GOTO) in order to obtain this observations within the first few days post explosion. To this end I am looking into ways to use the pt5m telescope to provide an initial vetting of discovered transients. This involves simulating pt5m observations using archival and model data, and making use of machine learning to attempt to find criteria by which transients of interest can be identified. Following on from this work the goal will be to have the Liverpool Telescope (LT) take spectroscopic observations of these identified transients, with the ultimate goal of having all the observations taken autonomously within the same night.

Student talks / 47

Invisible jets: a new mystery in active galactic nuclei

A few decades have passed since the identification of narrow-line Seyfert 1 (NLS1) galaxies as a subclass of active galactic nuclei (AGN). NLS1s show a Seyfert 1-like spectrum, but with emission line widths similar to those of Seyfert 2 spectra. Such features are often believed to be produced by a high accretion rate, close to the Eddington limit, coupled with a low-mass black hole (< 108M⊠). Although few compared to the non-jetted sources, also jetted NLS1s have been discovered. By means of targeted observations of radio-quiet and -silent jetted NLS1s, seven sources with an inverted radio spectrum and extreme radio variability were identified. They show rapid high-frequency (37 GHz) flares that increase their flux density up to 9000-fold (Jy level). On the other hand, at low frequency (<9 GHz) and in the low state, they only reach flux densities up to mJy levels. Such behaviour may be produced by absorption of the jet emission, via synchrotron self-absorption or free-free absorption. These objects are known as absorbed jets (AJs). Until now, the only common feature that characterises all AJs is their radio spectra. I will present the results of a multi-epoch analysis, devoted to searching optical variability in AJs, using data retrieved from public surveys. For this purpose I performed light curve fitting following different approaches, such as Fourier and Wavelet analysis, and chi-square minimisation techniques, to find any similarity between the AJs. Moreover, a long-term comparison between radio and optical light curves has been carried out, investigating if the optical emitting regions are connected with those generating radio variability. Such strong radio variability had never been observed before in any AGN, making this work an important key to understanding the AJ phenomenon. Furthermore, understanding the physics behind this peculiar phenomenon may ultimately help us reveal a new and unexplored population of jetted AGN.

Student talks / 61

The beaming effect for Fermi FR-I radio galaxies

Our knowledge of Giga-electron volt (GeV) Active galactic nuclei (AGNs) has been revolutionized by the Fermi-LAT Telescope. Fermi-LAT-detected blazars show stronger beaming effects than non-Fermi-LAT-detected blazars (Pushkarev et al. 2009; Linford et al. 2011 ;Wu et al. 2014). Based on the unifi-cation of blazars and radio galaxies (Urry & Padovani 1995), it is reasonable to consider that Fermi-LAT-detected radio galaxies may be the transition sources that exhibit intermediate Doppler beaming effects or special properties, due to these objects residing on the boundary between blazars and radio galax-ies. In this work, we collected 30 Fermi-detected Fanaroff–Riley Type I radio galaxies (FR-Is) with available γ-ray emission and redshift. From the unification of FR-Is and BL Lacertae objects (BL Lacs), we propose a formula to estimate the Doppler factors and discuss the beaming effect for Fermi LAT-detected FR-Is. Our main conclusions are as follows: (1) The estimated Doppler factors for 30 Fermi-LAT-detected FR-Is are in a range of δI=0.88−7.49. The average Doppler factor (⟨δI⟩=2.56±0.30) of the 30 FR-Is is smaller than that (⟨δBL⟩=10.28±2.03) of the 126 Fermi-LAT-detected BL Lacs, supporting the unification model that FR-Is are regarded as the misaligned BL Lacs with smaller Doppler factors; (2) We propose that the different regions of FR-Is in the plot of theγ-ray luminosity against the photon spectral index (logLγ–aph) may indicate the different beaming effects; (3) The average Doppler factor of the 6 Tera-electron volt (TeV) FR-Is is similar to that of the 24 non-TeV FR-Is, which implies that the difference between the TeV and GeV emissions is not driven by the beaming effect in the Fermi-LAT-detected FR-I samples.

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Welcome cocktail

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Active galactic nuclei 2/2

Please find my slides on the first time slot for this lecture (Wednesday, 31st May).

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Radiative processes 2/2

Student talks / 73

Nebular spectra models for type Ibc supernovae

Supernovae (SNe) play an essential role in accounting for the origin of the elements observed in our universe. To translate the information on the ejected elements contained in observed SN-spectra, careful modelling of the SNe is required. In this talk, I will discuss the nebular phase spectra resulting from modelling a set of He-star explosions (progenitors of type Ibc SNe). The set spans a large range of progenitor masses and modelling epochs, allowing us to discern trends and differences in the final spectra. The main focus in this talk will be on the relation between the SN-progenitor mass and the fractional luminosity of the recently discovered [NII] λλ6548, 6583 emission feature. This relation can be used as a diagnostic to better constrain progenitor masses of observed SNe. Some time will also be devoted to how well the model spectra compare to observations.

Student talks / 71

Search for gamma-ray emission from a sample of tidal disruption events

Tidal disruption events (TDEs) are transient events that occur when a star approaches the vicinity of a supermassive black hole (SMBH) and the tidal forces of the latter rip the star apart. About half of the star's material is swallowed, while the other half is accreted around the black hole, generating a luminous outburst ranging from radio to X-ray wavelengths. In addition, three candidate TDEs have been associated with high-energy neutrino events observed by the IceCube Observatory. However, no gamma-ray emission originating from a TDE has been reported so far. Several models suggest gammaray emission from TDEs through magnetic dissipation in the vicinity of the hot corona (core model), in magnetized non-relativistic winds (wind model) or through interactions between the wind and the debris of the tidally disrupted star. The jetted models predict not only gamma-ray emission but are also favored as models potentially explaining the observed neutrinos. Furthermore, even years delayed gamma-ray emission is predicted through interactions between the wind and the interstellar medium or between the wind and the torus (in the latter scenario, the host galaxy is an active galactic nucleus, AGN). Understanding the lack of gamma-rays is essential to improving our TDE models and explaining the proposed neutrino production. In this framework, we search for gamma-ray emission from a sample of spectroscopically confirmed TDEs using Fermi data. I use Fermipy to create test statistic (TS) maps in order to look for gamma-ray excess at the optical position of each TDE. Thanks to the extended time windows used during the data analysis, even years delayed gamma-ray flares can be caught. In the case of a non-detection, an upper limit on the energy flux is calculated. When a gamma-ray excess is found near a TDE, the localization method of Fermipy is used to reveal the origin of the excess. In my talk, I plan to explain the results and how upper limits can constrain the TDE models and possibly reveal the absorption of gamma rays.

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Neutrions and Cosmic-Rays

Student talks / 43

The IceCube Realtime Program

In 2013, the IceCube collaboration announced the detection of diffuse high-energy astrophysical neutrino flux. The origin of these particles is still unknown as there is still no identification of a source at the 5-sigma level. To answer this question, IceCube releases realtime alerts triggering follow-up observations in multiple wavelengths looking for electromagnetic counterparts to individual neutrinos. One of these alerts permitted in 2017 the evidence of the association between the neutrino event IC160427A with the flaring blazar TXS 0506+056 at a 3-sigma level. This work presents an overview of the IceCube Realtime Program with a brief exposition of possible future improvements to overcome issues with systematic errors, such as incomplete knowledge of the Antarctic ice.

Student talks / 69

Multiwavelength Follow-up Observations Of Astrophysica lNeutrino Events

On September 22, 2017, the IceCube Neutrino Observatory detected a high-energy neutrino of potential astrophysical origin which was found by follow-up electromagnetic observations to spatially and temporally coincide with the flaring state of a known blazar, TXS 0506+056. Since then, several additional neutrino events have been found in spatial correlation with known highenergy sources. Multiwavelength follow-up observations of astrophysical neutrino events such as these, and the continued monitoring of previously-identified sources such as TXS 0506+056 are imperative in finding sources of the diffuse neutrino flux detected by IceCube as well as the mechanisms that produce high-energy cosmic rays. In this talk, I will present results from multiwavelength follow-up observations of astrophysical neutrino candidate events with potential gamma-ray counterparts, including observations at X-ray and gamma-ray energies performed by the Neil Gehrels Swift Observatory, NuSTAR, and the Fermi Gamma-ray Space Telescope.

Student talks / 49

Particle content of inclined cosmic ray air showers for radio signal modeling

The origin of ultra-high-energy cosmic rays (UHECRs) is still unknown. They are likely produced in powerful cosmic accelerators but, because of their low flux and their deflections when they propagate across the magnetized Universe, it is difficult to collect them with large statistics and to infer their sources. When reaching the Earth, UHECRs penetrate the atmosphere and induce air-showers, which are cascades of secondary particles that emit a radio signal. The reconstruction of very inclined air-showers is a new challenge for next-generation radio experiments such as GRAND, which focus on the detection of UHE particles. To tackle it, we study the electromagnetic particle content of very inclined air showers, which has scarcely been studied so far. The features of the radio signals emitted by very inclined air-showers are significantly different from those of vertical ones; in particular, they present a drastic drop of the geomagnetic emission amplitude. Using the simulation tools CORSIKA and CoREAS, and analytical modeling from physical principles, we explore the energy range of the particles that contribute the most to the radio emission, quantify their lateral extent, and estimate the atmospheric depth at which the radio emission is strongest. We find that the distribution of the electromagnetic component in very inclined air-showers has characteristic features that could impact the reconstruction strategies of next-generation radio-detection experiments.

Student talks / 45

Searching for Tidal Disruption Events with VAST

A Tidal Disruption Event (TDE) occurs when a star gets close enough to a supermassive black hole, such that the tidal forces are able to rip the star apart, causing a multiwavelength transient flare. These events illuminate the complex environments of galactic centers in what may otherwise be quiescent galaxies. TDEs are typically discovered at shorter wavelengths (optical, Xray) but with new systemic surveys using radio telescopes, we now have an unprecedented opportunity to discover TDEs in the radio regime. A population of radio-discovered TDEs provides distinct insights including an independent TDE rate estimate, and new perspectives on their host galaxies. In this talk, I will present our search for TDE-like transients identified with the the recently completed Variables and Slow Transients (VAST) Pilot Survey, a time domain radio survey from the Australian Square

Kilometre Array Pathfinder.

Student talks / 50

Black Holes in L-Galaxies (L-Galaxies-BH): application to tidal disruption events

There have been many studies to explain the observed Tidal Disruption Events (TDE) rates, although we started identifying such events only in the last decade. Some predict that the rates are unexpectedly high and others conclude the observed TDE rates are what we would expect when combining the BH mass function and our understanding of the mechanism triggering a TDE. Our study offers as the first comprehensive view of tidal disruption events with semi-analytic models of galaxy evolution, allowing for further understanding of the TDE host galaxies properties, examination of the cosmological evolution of the rates and contribution to mass-growth of black holes at early times, as well as their co-evolution with either bulges or nuclear star clusters. In this first-of-its-kind approach, by solving for a broad range of the parameter space the 1D Fokker-Planck equation for a population of stars in a spherical potential, we produce time-dependent realistic rates, that are then assigned to a semi-analytic model specialised to model black holes (L-Galaxies-BH) which populate the volume of 100 cubic Mpc of the Millennium II Cosmological simulation. We investigate dichromatic stellar mass functions, with main-sequence stars (0.38 solar mass) and a population of stellar BH. These rates offer as a viable additional growth channel of the seed black holes, beyond traditional gas accretion, both at steep bulge profiles and at Nuclear Star Clusters. With the calculated instant TDE rate for every black hole (unique mass and spin), we have to make some reasonable assumptions to translate to detectable rates in optical and X-rays, based on recent developments of the physics underlying the TDE phenomenon (spin-dependent horizon suppression, physics of circularization, radiative efficiencies and bolometric corrections depending on type of TDE, stream precession, relativistic jets). The transformation it's a challenging computation itself, and I am going to focus a great part of my talk to this topic.

Student talks / 56

Transient science with the Transiting Exoplanet Survey Satellite

The Transiting Exoplanet Survey Satellite (TESS) has been conducting a wide-field, space-based survey of the entire night sky to identify transiting exoplanets. Additionally, its large field of view (2304 sq. deg) and continuous, high-cadence, monthlong observations of a given region of the sky lend it well to the discovery and characterization of transients. TESS can work in conjunction with other observatories, both throughout the electromagnetic spectrum and in gravitational waves (GWs), enabling its use as a tool to advance multi-messenger astronomy. In this talk, I will discuss some of the population-level studies that TESS has enabled for transients such as Type Ia supernovae. I will also discuss our progress on building a transient identification pipeline to extract transient candidates from TESS full-frame images for follow-up study. Finally, I will touch on our recent results showing that TESS may be well-positioned to observe a kilonova counterpart to a compact object merger as part of the LIGO-Virgo-KAGRA GW network's next observing run, slated to start in May 2023.

Acceleration processes 1/2

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Gravitation theory 1/2

Student talks / 46

Stochastic GW background from compact binary mergers

Stochastic gravitational-wave backgrounds (SGWB) derive from the superposition of numerous individually unresolved gravitational-wave (GW) signals. In this talk, I will present a detailed modelization of the SGWB from compact binary mergers. I will discuss the use of population synthesis models to estimate the expected rate and properties of binary mergers for different types of compact objects such as neutron stars and black holes. I will also show how these predictions are used to calculate the resulting SGWB amplitude and spectral shape, taking into account the redshift evolution of the binary merger rate and the gravitational-wave strain from individual mergers. Finally I will discuss the prospects for detecting the SGWB with current and future gravitational-wave detectors.

Student talks / 76

Monitoring the neutrino sky for the next galactic supernova

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Acceleration processes 2/2

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Software and development methods

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Gravitation theory 2/2

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Gravitational waves

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Breakfast at the institute

Also on Sunday there is breakfast offered at the institute. But no lunch!

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Gamma Ray-Bursts 1/2

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Radio Transients

Student talks / 75

Discovering radio transients using the power of humans and machines

The study of radio transients probes an immense range of astrophysical regimes - from flare stars to FRBs - and with the advent of current interferometers we can sample wide swathes of the radio sky with unprecedented sensitivity and cadence. Firstly, I will discuss recent, serendipitous discoveries being made with the MeerKAT radio telescope and how we can make the best of new facilities coming online. This includes how citizen scientists have scoured our data and uncovered 100s of new variable sources - this is the first ever crowd sourcing project dedicated to radio transients in this manner. Secondly, I will discuss novel machine learning techniques being developed to speed up the search for interesting and anomalous sources, methods that will prove invaluable as we look towards observatories such as the SKA.

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Gamma Ray-Bursts 2/2

Student talks / 41

Investigating the FRB-magnetar connection in nearby galaxies with the Northern Cross Radio Telescope

Fast radio bursts (FRBs) are intense, millisecond-long radio signals of unknown extragalactic origin. The detection of the very first galactic FRB-like signal from the magnetar SGR J1935+2154 has strengthened the connection between FRBs and magnetars. Using the Northern Cross radio telescope, we conducted a targeted search for FRBs in a sample of seven nearby galaxies, with a total observation time of ~ 700 hours. Our observational campaign yielded one FRB detection in the direction of the galaxy M101, observed with a DM = 302.9 pc cm−3, which supports the idea that it originated from a much distant source. From our nondetections on the galaxies we observed we can place an upper limit of 0.4 yr−1 on the rate of FRBs from magnetars like SGR J1935+2154, which disfavors them as the sole progenitors of cosmological FRBs, supporting the evidence for at least another, more exotic population of magnetars, not born via core-collapsed supernovae.

Student talks / **52**

Internal shock model for Prompt GRBs

Internal shocks are one of the prominent dissipation mechanisms for the prompt gamma-ray emission. In internal shocks, each collision between two shells forms a pair of forward and reverse shocks, which dissipate part of their kinetic energy. This dissipation is governed by the hydrodynamics. However, most studies in the literature treat this as a plastic collision of two infinitely thin shells without any reference to hydrodynamics. In our study we start with basic properties of the central engine and derive the physical properties of the shells before and after their collision. Consequently, we estimate the internal energy dissipation rates at both shock fronts. We find that under generic physical conditions, the shock strengths and the dissipation rates associated with both shock fronts are typically significantly different. In particular, the reverse shock tends to be stronger than the forward shock. This can have interesting observable consequences such as different luminosities, peak times and peak photon energies from these two shocked regions.

Student talks / **60**

Resolving the Geometry of Off-Axis Gamma-Ray Burst Jets

Merging neutron stars (and most likely also black hole-neutron star mergers) emit gravitational waves (GW) and electromagnetic radiation. These mergers are followed by the launching of ultra-relativistic jets that presumably produce a short gamma-ray burst GRB that we detect across the entire EM spectrum. The geometry of these jets is of special interest. Their observing angle can significantly improve the accuracy of the measurement of H0 using GW, while the jet core angle is related to its total energy, propagation, and the launching mechanism. A unique property of mergers detected by their GW signal (unlike those detected by their GRB emission) is that they are nearby, and the jets are seen off-axis (i.e., pointing away from us). This combination opens a special opportunity to measure the system geometry. High-resolution radio observations that can resolve the motion of the GRB afterglow image play a key role in decoding the jet geometry. In my talk, I will present a model for the afterglow image, and a study of the accuracy at which the viewing angle and the jet core angle can be measured from afterglow observations. I will also discuss the potential for resolving the Hubble tension using a small number of optimally observed merger afterglows.

Student talks / **37**

The bright dust scattering X-ray rings of GRB 221009A

X-ray rings produced by scattering on interstellar dust grains can be observed around transient bright sources in the direction of the Galactic Plane. The study of the rings emission, allows us to derive with extraordinary precision the details of the X-ray burst producing them (fluence and the spectral shape) and - at the same time - to characterize the dust properties along the line of sight. The intensity of the scattered radiation depends - indeed - not only on the flux of the source but also on the dust distribution along the line of sight and the proprieties of the grains. On 2022 October 9 an extraordinarily bright gamma-ray burst (GRB221009A) was observed behind the Galactic Plane. The first imaging X-ray instrument to react to the explosion was onboard the Swift satellite which discovered 9 bright expanding rings about one day after the GRB. Soon after that, the rings were observed by the ESA satellite XMM-Newton. Thanks to the XMM large effective area and the long exposure time, we obtained the spectrum of the rings with unprecedented statistics. This allows us to discriminate between dust models (e.g. different grain compositions and size distributions) and constrain the Soft X-Ray emission, not directly observed by any instruments.

Student talks / 54

Gamma Ray Burst polarimetry with a CubeSat mission

Despite their discovery 50 years ago, emission mecanisms and models of gamma ray bursts (GRBs) are not well constrained by spectrometry alone. Precise polarimetric measurement could bring new insights on the way these transient events are produced. COMCUBE is a project of CubeSat constellation using Compton telescopes to detect polarity of GRB prompt emission from about 100keV up to 1MeV. I work on the estimation of the performance of the detector to determine how many instruments will be needed, what should be the constellation configuration to achieve certain detection performance and what constraints it could bring on GRB prompt emission models.

Student talks / 67

A blind search for millimeter transients in ACT data

Until now, the millimeter transient sky has been largely unobserved. CMB surveys now have sufficient resolution, sensitivity, and sky coverage to study these events. Synchrotron radiation associated with strong magnetic fields is the likely source of many millimeter flares. Studying these flares can provide insight into the mechanisms behind this radiation as well as constraints on statistical properties of the transients. In this talk, I will present the current state of millimeter transient astronomy and its possible applications to studying gamma ray bursts, fast radio bursts, flaring stars, and other synchrotron transient events. In particular, I will focus on my work completing a blind search of millimeter transients in data from the recently decommissioned Atacama Cosmology Telescope (ACT). I will also demonstrate the importance of building a millimeter transient alert system for all-sky CMB surveys, highlighting how ACT data will help prepare us to do millimeter transient science with upcoming CMB surveys such as Simons Observatory, CCAT-Prime, and CMB-S4.

Student talks / 72

GeV excess detected in a merger-driven GRB

The origin of gamma-ray bursts (GRBs) is still mysterious. We believe that binary neutron star (BNS) mergers produce short GRBs, while long GRBs are associated to the collapse of massive stars. This GRB dichotomy, based on the duration of the prompt pulse, was recently challenged by the detection of the bright and relatively close (z = 0.076) GRB 211211A. Despite its long duration (~ 30 s), the discovery of an optical-infrared kilonova (KN) points to a compact object binary merger origin. We have analysed the radio-to-GeV afterglow emission of this source. In particular, the analysis of the high energy (HE, 0.1 – 10GeV) data, provided by Fermi/LAT, revealed a significant emission (> 5σ) detected in two epochs at late times (~ 103 and ~ 104 s after the burst) with approximately constant flux (~ 5 ·1010erg/cm2/s). The multi-wavelength afterglow emission is well modelled by synchrotron emission from electrons accelerated in the forward shock (FS). The model includes also the optical/NIR KN emission, which accounts for the excess in the r-band, and synchrotron-self-Compton, which is not dominant at these energies (< 10 GeV). Nonetheless, the LAT emission in the second epoch (~ 104 s) is in substantial excess with respect to the FS+KN best-fit model. This intrinsically faint excess (Liso ⊠ 1046erg/s) was never observed before in neither short nor long GRB populations. We interpret this new spectral component as external Inverse Compton (EIC) emission from KN optical photons and electrons accelerated in the low-power jet.

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Svom: mission and onboard prompt GRB detection

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Svom: ground-based GRB follow-up observation

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Svom: onboard GRB follow-up observation

Student talks / 63

Investigating the nature of cosmic gamma-ray bursts with MXT aboard SVOM

Gamma-Ray Bursts (GRB) are short (up to few tens of seconds) and intense flashes of gamma-rays, appearing from random directions over the entire sky. These flashes are either created by the collapse of very massive stars (more than 50 times the mass of the Sun), or the merging of two compact objects (e.g. two neutron stars). The event of the 17th August 2017, as the first joint observation of a gamma-ray burst electromagnetic signal along with its gravitational wave counterpart, opened the way to multi-messenger astrophysics, and offered astrophysicists solid evidences to hone models involving the merging of two neutron stars. However, some aspects of those models remain open questions. In particular, the nature of the object arising from such a merger is still widely discussed. SVOM (Space based Variable astronomical Object Monitor) is a Sino-French mission, dedicated to the study of these cosmic explosions. It is planned for launch late 2023 for a nominal mission lifetime of three years. It will carry on-board four instruments, among which the Micro-channel X-ray Telescope (MXT), a focusing X-ray telescope with a field of view of about 1°x1°, sensitive in the 0.2-10 keV energy range. In this talk, we will present the SVOM mission in the context of the multi-messenger era, review MXT performances, and discuss how this mission, and in particular MXT, will enable us to better understand GRBs progenitors.

Student talks / 66

ECLAIRs on-board trigger performance impacted by efficiency inhomogeneity and heat-pipes noise in 4-8 keV

The Space-based multi-band astronomical Variable Objects Monitor (SVOM) is a Chinese-French mission dedicated to the study of the transient sky, scheduled for launch in 2024. Its core program focuses on the gamma-ray bursts (GRB) detection thanks to the ECLAIRs telescope and its onboard trigger system. This instrument under French responsibility is a large field of-view coded mask telescope. ECLAIRs is designed to record photons from 4 keV up to 150keV. It is the first time the detection energy band is extended down to 4 keV for a code mask telescope on a space mission. In 2021 the ECLAIRs telescope underwent various calibration campaigns in vacuum chambers to evaluate the performance of its camera. At low energies, the response of the detection plane appears to be non-uniform, and shows the heat-pipes noise in two side of the detector. In order to optimize the detection of soft X-ray rich sources, this non-uniformity and heat-pipes noise must be corrected prior to sky image reconstruction. We focus on the analysis of the data collected between 4 and 8 keV and identify distinct families of pixels that compose the detection plane. We study different strategies in order to correct the non-uniformity and the heat-pipe noise at low energies in terms of the quality of the produced sky images and the detection sensitivity. We highlight the corresponding operations performed by the onboard trigger software and discuss the impact on the detection of soft X-ray rich sources.

Student talks / 64

Study of accretion and ejection processes in variable back hole systems with SVOM

Student talks / 53

GRB 201015A & the soft GRB population

My PhD research has been on GRB 201015A, a GRB with lower energetics and a softer spectrum than the majority of the population. I extensively studied the afterglow observations of GRB 201015A. Evidence of energy injection has been found from a surprising shallowing in the x-ray light curve. I studied a small sample of GRBs with similar properties, and I expect the launch of SVOM will add further soft GRBs to the sample. My future work involves simulating the spectra of such events detected by the MXT and ECLAIRs instruments.

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GRB 080928 afterglow polarization analysis and GRBs spectropolarimetry

In the context of modern astrophysics, transient phenomena are among the most fascinating and challenging to observe and analyse, usually arising from physically extreme conditions. Gamma-ray bursts (GRBs), the most energetic phenomena in the whole Universe, fall into this category, being produced after the collapse of a massive star or a compact binary merger. Their main emission, lasting from a fraction to hundreds of seconds, peaks in the gamma-rays and it is followed by an afterglow, covering the whole electromagnetic spectrum at different timescales. Despite several years of observations and the large number of GRBs analysed to date, a unique, general picture describing GRBs physics is still missing: further observations and additional, independent techniques are needed to reconcile observations with theoretical models and predictions. Polarimetry constitutes a really powerful tool since it allows us to investigate some features of the source that are difficult to determine with different techniques, such as the geometry of the emitting region and the local magnetic field configuration. Time-resolved polarimetric analysis of GRB afterglows would allow us to compare observed light curves and polarisation curves with theoretical expectations, possibly inferring some features of the burst emitting region and of the physics behind the event. A not so diffused - yet extremely efficient - technique is spectro-polarimetry, which can allow us to investigate the spectral dependence of the polarised radiation and to identify possible contributions given to the total polarisation by different sources. Indeed, the total detected polarisation could be the combination of intrinsically polarised radiation emitted from the burst and interstellar polarisation induced by the dust aligned along the line of sight, both in the host galaxy and in the Milky Way. Spectro-polarimetric analysis can tell us if the observed polarisation is due to a standard afterglow (i.e. constant behaviour with lambda) or if it comes from a dominant dust-induced contribution, which is wavelength dependent. However, despite its importance in this context, only a handful of bursts detected by space telescopes were accompanied by ground-based spectro-polarimetric follow-up to date. In the talk I will present (spectro-)polarimetric analysis of GRB 080928, an event not yet properly analysed, for which multi-epoch polarimetric observations were obtained, both in the imaging polarimetry and spectro-polarimetry modes. The analysis revealed the detection of a polarisation degree P~ 4% after 1.70 days from the trigger at 4σ confidence level, and the comparison with theoretical models suggested the presence of a homogenous jet observed inside the cone. More in general, I will discuss the role of spectro-polarimetry in GRBs afterglow analysis, also showing how it was applied to the other very few bursts analysed with this technique, i.e. GRB 020813, GRB 021004, GRB 030329, GRB 191221B.

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The VHE emission of structured GRB jets: the case of GW170817 and prospects for future detections

The binary neutron star merger gravitational-wave event GW 170817 and the multi-wavelength observations of its off-axis afterglow have allowed to probe the lateral structure of its associated relativistic jet. In addition, several gamma-ray bursts such as GRB 190114C or GRB 221009A (the brightest GRB ever observed) have recently been detected at Very High Energy (VHE, > 1 TeV) and are challenging the radiative models explaining the afterglow emission by synchrotron radiation only. In this talk, I will present our model of GRB afterglows, including both the lateral structure of the jet, and a detailed treatment of the synchrotron emission and synchrotron self-Compton (SSC) scatterings in the Thomson and Klein-Nishina regimes. This model is computationally-efficient, allowing for multi-wavelength data fitting, up to the energy range of instruments such as H.E.S.S., MAGIC and the CTA. In the case of GW 170817, the SSC flux is much dimmer than the upper limit from H.E.S.S. observations. However, we show that either a smaller viewing angle or a larger external density would make similar events detectable at VHE. In particular, large external densities at the location of BNS mergers may be frequent if a channel of fast-merging binaries exists, in which case VHE detections would help probing efficiently such a sub-population.

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General public conference in French : Quand deux étoiles à neutrons se rejoignent, ondes gravitationnelles et lumière

General public conference (in French)

La fusion de deux étoiles à neutrons est un phénomène rare mais particulièrement extrême, qui s' accompagne d'une intense émission d'ondes gravitationnelles (que l'on sait détecter depuis 2015) et de nombreux signaux lumineux, des ondes radio aux domaines infrarouge et visible et aux rayons X et gamma. Croiser ces différents signaux qui apportent des informations très complémentaires constitue une nouvelle approche très prometteuse en astrophysique. Cet exposé décrira l'émergence de cette nouvelle astrophysique multi-messagers, en particulier à travers l'exemple d'un événement exceptionnel observé en 2017.

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Accretion

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Neutron Stars

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X-ray Binaries 1/2

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Kilonova In Short Gamma Ray Bursts

Student talks / **65**

High-energy emission of Microquasars with INTEGRAL and SVOM

Microquasars are Black Hole X-ray binaries that show bright emission at energies above 1 keV along with radio jets. These are transient objects that are typically only visible for a few months during their so-called "eruption", and go back into quiescence for years or decades. During these eruptions, the Black Hole accretes matter from its stellar companion and the resulting accretion disk is visible in X-ray around 1 keV. Some of those photons are reprocessed by inverse Compton scattering on a hot corona around the BH which is detectable in gamma-ray between 10 and 150 keV. A new high-energy component above 150 keV has been seen in some sources and its precise origin is still unknown: it could come either from Compton scattering on relativistic nonthermalized electrons of the corona, or from the base of the jet. The cumulated data of the INTEGRAL satellite over its 20+ years of observations will help us understand this "hard gamma-tail". The SVOM mission will also be a precious ally for combined observation of the most prominent microquasars (Cyg X-1, GRS1915, etc⋯).

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The first outburst of the young magnetar Swift J1818.0-1607

Swift J1818.0-1607 is a rapidly rotating magnetar (P ~ 1.36 s) that was discovered in March 2020 during an outburst. Follow-up radio observations confirmed its nature and identified it as the sixth radio-loud magnetar known to date. Swift J1818.0-1607 is also one of the most rapidly spinning magnetars and one of the youngest neutron stars in the galaxy. In this talk, I will present the results of X-ray observations of Swift J1818.0-1607 using the XMM-Newton, NuSTAR, and Swift telescopes. These observations allowed us to study its spectral and temporal properties in great detail during the first 7 months of its outburst. Additionally, we conducted a long-term study of the flux and the spectral evolution over the first 19 months of the outburst. This study revealed a decrease in luminosity by a factor of about 90 over 1.5 years since the outburst onset. We also observed Swift J1818.0-1607 with the VLA, which allowed us to detect the radio counterpart of the magnetar and a half-ringlike structure of bright diffuse radio emission. We suggest that this radio structure may be associated with a supernova remnant.

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Evolution of pulsar wind nebula - supernova remnant systems

Neutron stars are typically born in core-collapse supernova explosions, and are often rapidly spinning with a large initial rotational energy E0 that can approach or even exceed the SN explosion' s kinetic energy, ESN. Their considerable surface dipole magnetic field causes them to spin down, channeling their rotational energy into an extremely relativistic MHD wind. This inflates a pulsar wind nebula (PWN) that is confined within and drives a shock into the part of the stellar envelope that was ejected in the SN explosion, known, at later times, as a SN remnant (SNR). Such wind nebulae emit synchrotron radiation from radio to X-ray and are observed around many young Galactic pulsars, as well as around one magnetar. Here we study the long term dynamics of a PWN-SNR system, including the many different dynamical phases of the interactions between the wind and SNR as well as the SNR and the surrounding circum-stellar medium, which forms shocks on both sides of the SNR. For example, when the reverse shock created at the interaction with the circumstellar medium reaches the outer edge of the PWN, it compresses it and the system enters the "reverberation"phase, which is hard to study analytically. In particular, we focus on the differences between fast (E0 > ESN) and slow (E0 < ESN) initial rotation, and the inner structure of the flow within the wind nebula. Following several 3D MHD simulations studies that found a low magnetization within the PWN in agreement with PWN observations, we use relativistic hydrodynamic simulations and neglect the effect of magnetic fields on the PWN's dynamics. We exploit self-similar properties of the shock structures to initialize our simulations as close to the reverberation phase as we need it to be, bypassing the free-expansion phase to save on computation time and thus allowing the study of a greater range of timescales.

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Simulation-based inference for pulsar-population synthesis

Although about a billion neutron stars are expected to exist in the Milky Way, observational constraints limit us to only observing a few thousand. Pulsar population synthesis bridges this gap by simulating the entire population and comparing it to the observed sample to constrain neutronstar physics. In this talk, we explore the possibility of using simulation-based inference based on neural networks to estimate the parameters governing the magnetic and rotational properties of isolated

Galactic radio pulsars. For this purpose, we implement a population-synthesis framework able to simulate the stars' dynamical and magneto-rotational evolution as well as their radio emission and incorporate selection biases of typical radio surveys. We then generate a dataset of mock pulsar populations to train and validate a mixture-density neural network. In particular, we demonstrate how the combined information from P-Pdot diagrams from different radio surveys can help us to recover the posterior distribution of the model parameters governing the properties of neutron stars at birth.

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The accreting millisecond pulsar SAX J1808.4 3658 during its 2022 outburst

Accreting millisecond pulsars (AMSPs) are rapidly rotating neutron stars hosted in a tight binary system with a low-mass companion. Their millisecond periods result from a Gyr-long phase in which old radio pulsars are spun up by accreting matter from a donor via a Roche lobe overflow. SAX J1808.4-3658 was the first AMSP discovered in 1998. Since then, the source has undergone ten ~ 1-month-long outbursts with ~ 2-3 years recurrence, making it the most thoroughly investigated of its type. When the onset of a new outburst was detected in August 2022, we performed a multiwavelength campaign with three X-ray telescopes - XMM-Newton, NuSTAR, and NICER -, the fast optical photometer TNG/SiFAP2, and the HST. I will present a coherent timing analysis of X-ray pulsations during this latest outburst, confirming the long-term spin-down rate compatible with the expected energy losses from a rotating magnetic dipole of 108 G. This may indicate that a radio pulsar is active in the system during quiescence. For the first time in the last twenty years, we found hints of an orbital decay. I will discuss this evolution in terms of a gravitational coupling between the orbit and variations in the mass quadrupole of the companion star.

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Probing the wind and funnel formed in super-Eddington accretion using X-ray reverberation

X-ray reverberation is a powerful technique used to measure the black hole in the thin disk system. Recent observation of tidal disruption events shows that X-ray reverberation arising from characteristic Fe Kα photons can also happen in the super-Eddington system. State-of-the-art simulations show that optical and geometrical thick wind can be launched in the super-Eddington accretion. The new geometry and wind kinematics should shape the Fe Kα line together with the strong gravitation field. We run a series of simulations to understand the spectral dependence on these factors. The result shows a double-peak feature similar to the spectra from a thin disk system but with a completely different physical origin.

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High-energy neutrinos from Interacting Supernovae

X-ray high resolution spectroscopy

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X-ray Binaries 2/2

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Optical transients with LSST and Fink

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Optical spectroscopic analysis of the Black Hole MAXI J1305-704

We report on the results obtained by an optical spectroscopy study performed on the black hole transient MAXI J1305−704 during its 2012 outburst. We analysed two observations taken by the Magellan Clay Telescope during two consecutive nights, when the source was in a soft X-ray spectral state. Then, we extracted 12 phase-resolved spectra and performed a spectral fitting of the dominant H-alpha feature. The line profile is characterised by an asymmetric emission and an absorption feature which vary during the orbital phase. Although the interpretation of our results is not straightforward, we attempt to provide a self-consistent explanation for this phenomenology.

Student talks / **36**

Optical and NIR Spectroscopy of the Black Hole Transient GX 339-4

Low Mass X Ray Binaries (LMXBs) are transient systems whose outbursts are characterised by a variety of accretion and ejection phenomena, such as jets, winds of ionized material and intense X-ray emission. These objects have been extensively studied in the X-ray band, in which they are usually discovered, but during the past few decades the focus has shifted towards their optical and infrared properties leading, among others, to a better characterisation of the accretion disc and to the discovery of cold winds. In this presentation I will focus on GX 339-4, a LMXB known to show periodic outbursts. I will briefly present the optical and near-infrared spectroscopic analysis of this object, performed considering four epochs of spectroscopy corresponding to different outbursts and accretion states, paying special attention to he evolution of the main emission lines and potential outflows signatures.

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Astrophysical X-Ray Polarimetry with the IXPE Mission

My PhD project deals with astrophysical X-ray polarimetry. The state-of-art is the Imaging X-ray Polarimetry Explorer (IXPE), launched on 9 December 2021 (collaboration NASA and ASI) to measure the linear polarization of different astrophysical sources over the photon energy range 2-8 keV. One of the goals of my project is the analysis of IXPE data provided by current observations. In particular, I am focusing on Blazars, as, for example, Markarian 421. In such sources, called high-synchrotron-peaked BL Lacertae objects (HSP), the synchrotron luminosity peaks at X-ray energies. The polarization provides a way to study the order and geometry of their magnetic field and to better understand which acceleration process dominates in their relativistic jet. I am performing both time integrated and time-binned analysis in order to investigate about the time variability of the polarization vector, that could provide a way to study the shock mechanisms (e.g. magnetosonic shocks, magnetic reconnection, …). These data are the results of the IXPE good imaging capabilities and unprecedented polarization sensitivity achieved thanks to the Gas Pixel Detectors (GPDs). The second goal of my PhD is a laboratory activity aimed to the characterization of GPD, studying also possible improvements in view of future missions (e.g. eXTP). I perform this work using the X-ray Calibration Facility (XCF), available at the Physics Department at the University of Turin, that employs an X-ray tube as source, with the possibility of varying the anode, to select the desired energy, and generating two identical beams. One of them is polarized via Bragg diffraction on a polarizing crystal. Thanks to a handling system, the GPD can measure both the unpolarized and polarized beams: a comparison between these two signals will provide a way to characterize the GPD itself.

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Identification of Orphan Gamma-Ray Burst Afterglowe in Rubin-LSST Data with the Alert Broker FINK

Gamma-Ray Bursts (GRBs) are among the most energetic phenomena in the Universe. The interaction of their blast wave with the Interstellar Medium produces an afterglow that can be observed from a larger angle, in a wide range of the electromagnetic spectrum and during more time than the prompt emission. Viewed off-axis, this emission has a negligible gamma-ray flux and is hence called ”GRB orphan afterglow”. Their properties make them good candidates to learn more about the GRB physics and progenitors or for the development of multi-messenger analysis, like in the case of GW170817A. According to most theoretical models, orphan afterglows should be found as slow and faint transients. This is why the Rubin Observatory shall significantly improve their detection : thanks to its limiting nightly magnitude of 24.5 and its large field of view, it should be able to detect up to 50 orphans per year. To identify orphan afterglows in Rubin LSST data, we plan to use the characteristic features of their light curves which depends on several parameters defined by the chosen model, here the forward shock model associated with the electron synchrotron model. In this work, we generated a population of short GRBs and simulated their afterglow light curves with the afterglowpy package using a statistical distribution for each of the studied parameters. We then used the rubin sim package to simulate pseudo-observations of these orphan afterglows with Rubin LSST and we found that about 4% of the afterglows will be observable orphan afterglows. These results are used to study the correlations between the parameters of the GRBs afterglow model and the features of the pseudo-observed orphan afterglow light curves, and will ultimately allow us to implement a filter in the alert broker FINK.

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Supernova Wind Breakout

One aspect of Supernova (SN) explosions that has received attention is the shock breakout, which occurs when the radiation from the shock caused by the explosion starts to escape. This can happen at the surface of the star, generating a rapid flash, or at much larger radii, if the star has a dense circum-stellar material (CSM) surrounding it, potentially extending the breakout timescale to days or longer. Extended CSM breakouts have been suggested as the source of various powerful transients, including IIn, “double peak”and super-luminous SNe, as well as X-ray flashes, and low-luminosity gamma-ray bursts. However, previous approaches to calculating CSM breakouts have faced challenges due to the formation of a collisionless shock at breakout, the non-steady shock structure and including Inelastic Compton scatterings. As we show, these have a crucial role shaping the light curve and spectrum producing X-ray radiation. Understanding the impact of these physical processes, we plan to derive a self-consistent quantitative description of the optical- X-ray spectra and high energy photon and neutrino emission of CSM shock breakouts in diverse environments. This will enable us to provide useful predictions for the emitted signal, testing the explanations of the related transients, and use observation in order to derive constraints on the progenitors. In this work, we solved numerically the spectral radiation-hydro equations, modeling the SN ejecta as a constant-velocity spherical piston in a ⊠!” “Wind”-type Hydrogen CSM. We show that a collisionless shock must develop at breakout, generating a non-thermal and hot radiation spectrum at typical X-ray (10keV) energies. We provide an analytic estimation of the hard component of this spectrum, and detail our future work intentions.

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Nuclear transients and tidal disruption events uncovered by eROSITA

The SRG/eROSITA all-sky survey offers a unique insight into the transient X-ray sky. Using data obtained during the first two all-sky surveys, we have compiled the largest systematically-selected sample of X-ray transients associated with the nuclei of galaxies without prior signs of AGN activity to date. Benefiting from the unprecedented sensitivity of eROSITA, we have characterised the diversity of the population of nuclear transients. In this talk, I will present the selection of this sample, review its key properties (e.g., X-ray luminosity function, light curve properties, spectra and spectral evolution, optical properties, rates), and discuss how stellar Tidal Disruption Event (TDEs) candidates are identified against a background of non-TDE induced transients. This subsample of eROSITA-selected TDE candidates provides insights into otherwise quiescent massive black holes, letting us explore the formation of accretion disks, and probe different regimes of accretion, as well as the production of outflows.

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Barbecue

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Svom: Demonstration of Burst-Advocates’ tools

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Kilonovae and Charged Particle Thermalization

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LHAASO and the observation of the brightest GRB 20221009A

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Concluding remarks