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First results of the glitching pulsars monitoring program at the Argentine Institute of Radioastronomy

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Although pulsars exhibit a particularly stable rotation, this stability can be affected by glitches. This phenomenon consists of a sudden increase in the rotation frequency of pulsars. Its cause is not well understood, but it is likely related to the behavior of matter inside neutron stars. Therefore, glitches can provide constraints on the equation of state of neutron stars. With the aim of thoroughly characterizing these glitches, since 2019 we have been conducting a high-cadence monitoring campaign of glitching pulsars from the Argentine Institute of Radio astronomy (IAR). Up to date, we have detected and characterized two giant glitches in the Vela pulsar, one in PSR J0742−2822, one in PSR J1740−3015, and two mini glitches in PSR J1048−5832. We fully describe them in this poster presentation.

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Stellar winds in the galactic centre: Variable accretion and formation of a disc

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Sgr A*, located only 8 kpc away, allows us to study in detail the accretion process on to a supermassive black hole. Only in our Galactic centre we can directly observe the source of the material feeding the accretion, which in this case corresponds to around 25 young, massive stars, with powerful stellar winds. We describe our hydrodynamical models of the gas surrounding Sgr A*, originating from the observed stars, with known orbits and stellar wind properties. Our simulations show that these winds and their collisions can naturally account for the properties of the hot plasma detected in X-ray observations. Moreover, the complex interaction of the winds with the medium produces cold clumps and streams, and perhaps even a disc around the black hole, as inferred from ALMA observations. Finally, the stellar orbits and the infall of streams make the accretion vary on time-scales of decades to millennia, potentially explaining the observed X-ray echoes related to past activity from Sgr A*.

For more details please see https://doi.org/10.3847/2041-8213/ab5e81.

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The length of the slow stable hybrid star branch and its linkage with neutron star observations

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The internal composition of neutron stars, one of the densest astronomical objects in the universe, is still unknown. Although in the last decade, with the onset of multi-messenger gravitational wave astronomy, several astrophysical observations placed strong constraints on these compact objects, there is still a lack of understanding of the dense matter equation of state. In this work, we model neutron stars as hybrid stars -composed of an inner core of quark matter and a mantle of hadronic matter-, considering an abrupt and slow first-order hadron-quark phase transition in their core. We model the hadronic phase with a piecewise polytropic fit, and the inner quark core through a Color Flavor Locked superconducting equation of state, with corrections due to the strong coupling constant, within the framework of the MIT Bag model. In the framework of this abrupt and slow scenario, it is possible to obtain an extended branch of stable stellar configurations. It has been shown that the appearance of such branches could resolve the existing tension between current astrophysical observations. We analyze the behavior of this extended stability branch by quantifying and systematically studying, for the first time, its length, relating this quantity to fundamental properties of the hybrid equation of state. This study allows not only a deeper understanding of the extended stability scenario with slow hadron-quark conversions but could help reveal the mystery of the composition of neutron stars and, consequently, clarify the uncertainty about the equation of state of dense matter.

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wI asteroseismology revisited: universal relationships that include slow stable hybrid stars

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We show that, within the slow hadron-quark conversion regime where extended branches of hybrid stars (SSHS) appear, all universal relationships for wI-modes available in the literature do not hold (for details, see Ranea-Sandoval et al. 2022). Then, we show newly discovered universal relationships that include SSHS, and present potential astronomical applications of such relationships, showing that, if the frequency and damping time of the fundamental mode are measured, its mass, radius, and dimensionless tidal deformability can be inferred (for details, see Ranea-Sandoval et al. 2023). The errors of such estimates are smaller than a few per cent for the mass and the radius. For the dimensionless tidal deformability, the errors for compact objects with masses above 1.4 solar masses are typically less than 100%.

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Impact of the matching formalism in neutron stars and their oscillation modes

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The interior of neutron stars (NS) contains matter with densities several times higher than nuclear atomic density. Obtaining an accurate equation of state (EoS) to describe NS is crucial for enhancing our understanding of matter in such extreme environments. To achieve this, we built ten EoS by considering three diferent crusts which are added to the core of these compact objects using a new thermodynamically consistent formalism. Essentially, for an isolated and cold NS, we assume a linear relationship for pressure and energy density in a small region between the core and the crust. This establishes an interpolation function in the pressure/baryonic-chemical-potential plane. We compared this new way of "gluing" EoS with the classical method that neglects causal and thermodynamic consistency. Then, we solved the TOV equations, which describe a non-rotating, spherically symetric and static object, to obtain the mass-radius relationship and compared it with the existing observational constraints of NS. In addition, we explored changes that the new matching formalism can cause in the oscillation modes. With alternative matching formalisms, even for two or three interpolations of the same crust, the p_1 mode exhibited differences in oscillation frequencies and damping times for low-mass NS. In contrast, no visible effects can be appreciated for the f mode, neither in the three models of the crust nor in the interpolations considered. We conclude that independently of the model used for the EoS, the method of construction will impact in NS observables such as the radius, frequencies and damping times of non-radial oscillations.

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A review of the current state of research on extragalactic sources that emit gamma rays in the TeV range, using the Cherenkov technique

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Gamma rays are a form of high-energy electromagnetic radiation that is unaffected by galactic magnetic fields. Although the study and detection of gamma-ray emissions, both from satellites and terrestrial sources, have experienced significant advances throughout history, starting with the installation of the MIT gamma-ray instrument in the 1960s, we will focus on the sensitivity of the Cherenkov atmospheric technique. Extensive air showers result from collisions between photons and protons. The total cross-section of these collisions has measured center-of-mass energies up to 200 GeV. The predominant interactions are electromagnetic, with cross-sections for the production of hadron and muon pairs much smaller than those for electron pairs. In this electromagnetic cascade, photons generate electron-positron pairs, and electrons and positrons generate photons through bremsstrahlung, exponentially increasing as it propagates through the atmosphere, dividing the primary energy among more and more particles. However, as the energy decreases, the ionization energy loss mechanism becomes more important than bremsstrahlung.

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Particle acceleration in the heliosphere and in supernova remnants

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Cosmic rays are charged particles that permeate astrophysical environments with energies much higher than the ambient thermal particles. The bulk of the galactic cosmic-ray protons and heavier nucleus, with energies up to PeV, are most probably energized in shocks resulting from supernova remnants (SNR) expansion in the interstellar medium, although the process is not yet fully understood. In the interplanetary medium, directly detected ions with energies in the tens of MeV range are correlated with shock fronts. This research aims to develop a one-dimensional model to study the confinement and injection of energized protons in the heliosphere, using magnetohydrodynamic (MHD) simulations, that can be compared with direct particle observations and also with previous models. Furthermore, this modified model, including a kinetic representation of the relativistic particles (Particle-In-Cell-MHD), was applied in SNR scenarios. Our models were able to reproduce the evolution of shock events observed in the heliosphere, in accordance with previous MHD models in the literature, with the advantage of providing the energy distribution of the energetic particles, which can be used to better constrain the acceleration and diffusion processes. In the SNR case, our simulations produced the instabilities believed to regulate the self-confinement of the particles which affect the acceleration efficiency. In the future, we intend to apply it to construct non-thermal emission models of SNR that can be compared to observations. This approach will contribute to the understanding of the cosmic ray acceleration process, as certain open questions, such as the development of instabilities near the shock, can be tested in the interplanetary medium, where direct observations are available.

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Breaking of quadrupolar f-modes universal relationships under the slow hadron-quark conversion regime

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In the past fifteen years, our understanding of compact stars has significantly advanced through key observations, such as the pulsars PSR J0348+0432 and PSR J0740+6620, whose radius has recently been estimated using NICER and XMM-Newton data, along with the analysis of gravitational waves (GW) events, as GW170817.

In this work, we consider polar perturbations, and we calculate the frequency and damping time of the quadrupolar fundamental f-mode of compact objects, constructed using a wide range of model independent hybrid equations of state that include quark matter. We give special attention to the impact of the hadron-quark conversion speed that, in the slow case, gives rise to a branch of slow stable hybrid stars. Moreover, we study the validity of universal relationships proposed in the literature and find out that none of them remains valid when slow stable hybrid stars are taken into account, as has also been shown for the wI-modes and f-modes in RaneaSandoval:2022bou, PhysRevD.107.123028 respectively. This fact could constrain the applicability of asteroseismology methods with fundamental modes designed to estimate the properties of pulsating compact objects. We hope that this result could be tested with the start up of the third generation gravitational wave observatories, which might shed some light on the f-mode emission from compact objects.

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The dark sector window with extreme laser pulses

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Parameter bounds for the dark matter candidates can be obtained not only from astrophysical sources or large particle colliders but also from laser experiments. One of these experiments consists of shining a wall with a laser and trying to convert the photon into a dark matter candidate particle through an external magnetic field coupling, named light shining through the wall (LSW). On the other side of the wall, another magnetic field region would reconvert the weak interacting particle into a photon before passing through a detector. We explore the possibility of implementing LSW to detect dark matter candidates, taking advantage of the power laser pulses achieved at the Extreme Light Infrastructure and the Shanghai Superintense Ultrafast Laser Facility shortly.

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A review on the post-merger gravitational waves emitted in binary neutron star mergers

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Gravitational waves detected from the inspiral stage of a binary neutron star merger give information about the nature of the initial components such as their masses, spins, radii and tidal deformabilities. Similarly, observations of the post-merger stage would give hints on the characteristics and the evolution of the remnant of these coalescences. Since post-merger observations by earth-based detectors are not available yet, only numerical simulations are used to study this stage. Therefore, we will review the main characteristics of this kind of mergers, as well as the results given by the numerical simulations in order to better understand the different outcomes that are produced in these systems and how the final fate is related to the initial components.

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