Gravitational Geometry and Dynamics Group

gravitational physics in the context of astrophysics, cosmology and high energy physics

Coordinator: Alexandre Correia; **Members:** Alan Alves, Sónia Antón, Tjarda Boekholt, António Morais, Eugen Radu, Valério Ribeiro, João Rosa, Timothée Vaillant; **PhD Students:** Pedro Cunha, Jorge Delgado, João Oliveira, Alexandre Pombo, Rodrigo Vicente; **Collaborators:** Carlos Herdeiro, Helena Morais

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StronGrHEP: Strong Gravity and High Energy Physics **290 k€** by H2020 and MSCA (H2020-MSCA-RISE-2015-690904);
FunFiCO-ThAstroP: Fundamental Fields and Compact Objects **240 k€** by COMPETE 2020 and FCT (PTDC/FIS-OUT/28407/2017);
Higgs-PH: From Higgs Phenomenology to the Fundamental Interactions **240 k€** by COMPETE 2020 and FCT (PTDC/FIS-PAR/31000/2017);
Phobos: Origin, composition, evolution and exploration of Phobos **240 k€** by COMPETE 2020 and FCT (POCI-01-0145-FEDER-029932);
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Research Highlights:

LETTER

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A recurrent nova super-remnant in the Andromeda galaxy

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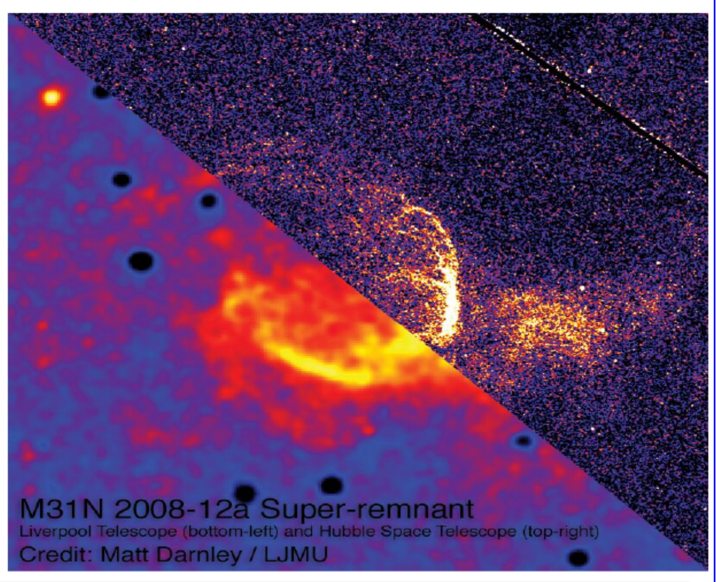
The accretion of hydrogen onto a white dwarf star ignites a classical nova eruption[1,2]—a thermonuclear runaway in the accumulated envelope of gas, leading to luminosities up to a million times that of the Sun and a high-velocity mass ejection that produces a remnant shell (mainly consisting of interstellar medium). Close to the upper mass limit of a white dwarf[3] (1.4 solar masses), rapid accretion of hydrogen (about 10^{-7} solar masses per year) from a stellar companion leads to frequent eruptions on timescales of years[4,5] to decades[6]. Such binary systems are known as recurrent novae. The ejecta of recurrent novae, initially moving at velocities of up to 10,000 kilometres per second[7], must 'sweep up' the surrounding interstellar medium, creating cavities in space around the nova binary. No remnant larger than one parsec across from any single classical or recurrent nova eruption is known[8–10], but thousands of successive recurrent nova eruptions should be capable of generating shells hundreds of parsecs across. Here we report that the most frequently recurring nova, M31N 2008-12a in the Andromeda galaxy (Messier 31 or NGC 224), which erupts annually[11], is indeed surrounded by such a super-remnant with a projected size of at least 134 by 90 parsecs. Larger than almost all known remnants of even supernova explosions[12], the existence of this shell demonstrates that the nova M31N 2008-12a has erupted with high frequency for millions of years.



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Editors' Suggestion

Stimulated Axion Decay in Superradiant Clouds around Primordial Black Holes

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The superradiant instability can lead to the generation of extremely dense axion clouds around rotating black holes. We show that, despite the long lifetime of the QCD axion with respect to spontaneous decay into photon pairs, stimulated decay becomes significant above a minimum axion density and leads to extremely bright lasers. The lasing threshold can be attained for axion masses $\mu \gtrsim 10^{-8}$ eV, which implies superradiant instabilities around spinning primordial black holes with mass $\lesssim 0.01\ M_{\odot}$. Although the latter are expected to be nonrotating at formation, a population of spinning black holes may result from subsequent mergers. We further show that lasing can be quenched by Schwinger pair production, which produces a critical electron-positron plasma within the axion cloud. Lasing can nevertheless restart once annihilation lowers the plasma density sufficiently, resulting in multiple laser bursts that repeat until the black hole spins down sufficiently to quench the superradiant instability. In particular, axions with a mass $\sim 10^{-5}$ eV and primordial black holes with mass $\sim 10^{24}$ kg, which may account for all the dark matter in the Universe, lead to millisecond bursts in the GHz radio-frequency range, with peak luminosities $\sim 10^{42}$ erg/s, suggesting a possible link to the observed fast radio bursts.

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Shadows of Kerr Black Holes with Scalar Hair

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Using backwards ray tracing, we study the shadows of Kerr black holes with scalar hair (KBHSH). KBHSH interpolate continuously between Kerr BHs and boson stars (BSs), so we start by investigating the lensing of light due to BSs. Moving from the weak to the strong gravity region, BSs—which by themselves have no shadows—are classified, according to the lensing produced, as (i) *noncompact*, which yield not multiple images, (ii) *compact*, which produce an increasing number of Einstein rings and multiple images of the whole celestial sphere, and (iii) *ultracompact*, which possess light rings, yielding an infinite number of images with (we conjecture) a self-similar structure. The shadows of KBHSH, for *Kerr-like horizons* and noncompact BS-like hair, are analogous to, but distinguishable from, those of comparable Kerr BHs. But for *non-Kerr-like horizons* and ultracompact BS-like hair, the shadows of KBHSH are drastically different: novel shapes arise, sizes are considerably smaller, and multiple shadows of a *single* BH become possible. Thus, KBHSH provide quantitatively and qualitatively new templates for ongoing (and future) very large baseline interferometry observations of BH shadows, such as those of the Event Horizon Telescope.

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Astronomy & Astrophysics

Letter to the Editor

Spin-orbit coupling and chaotic rotation for circumbinary bodies★

Application to the small satellites of the Pluto-Charon system

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ABSTRACT

We investigate the resonant rotation of circumbinary bodies in planar quasi-circular orbits. Denoting n_b and n the orbital mean motion of the inner binary and of the circumbinary body, respectively, we show that spin-orbit resonances exist at the frequencies $n \pm k\nu/2$, where $\nu = n_b - n$, and k is an integer. Moreover, when the libration at natural frequency has the same magnitude as ν, the resonances overlap and the rotation becomes chaotic. We apply these results to the small satellites in the Pluto-Charon system, and conclude that their rotations are likely chaotic. However, the rotation can also be stable and not synchronous for small axial asymmetries.

Key words. planetary systems – planets and satellites: dynamical evolution and stability – planets and satellites: individual: Pluto – planets and satellites: individual: Charon – celestial mechanics

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