# A Comparative Study of Two Bidirectional Reflectance Models for Asteroid Surfaces

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This study uses laboratory reflectance data to compare the Lumme-Bowell and Hapke models (bidirectional reflectance models) to assess how well they describe light scattering from asteroid surfaces. A mixture of olivine and basalt, brown corundum, silicon carbide, and boron carbide were among the examined laboratory samples from Kar et al. (2021) (our laboratory data), which have been used in this study. We expect these samples closely resemble natural asteroid regolith regarding particle sizes (13μm to 88μm) and porosity values (0.40 to 0.72). The chi-square error minimization method evaluated how well both models fit the experimental data. Compared to the Lumme-Bowell model, the results show that the Hapke model offers a significantly better fit to the experimental data, at least for the above materials with the given particle size and porosity ranges. These discoveries help us understand how light interacts with asteroid surfaces and enable more precise studies.

# Enhancing Photometric Redshift Estimation with Morphology-Based Feature Selection via Copula Entropy

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Precision photometric redshift (photo-z) estimation is critical for cosmological probes such as weak gravitational lensing and galaxy evolution. While broadband photometry forms the backbone of most machine learning‑based photo-z methods, galaxy morphology, like shape, size, and brightness, encodes complementary redshift information quantitatively. However, indiscriminate use of morphological parameters can increase bias and outliers, undermining photo-z accuracy. We introduce a copula entropy‑based framework to pinpoint morphological features with the strongest statistical dependence on spectroscopic redshift, enabling targeted and performance-driven inclusion into a desired set of band photometry, depending on the scientific goal. Based on galaxies from SDSS DR19, which ranges from $0 < z < 1$, we identify the i-band DeVaucouleur fit magnitude (DeVMag_i), i-band Exponential fit magnitude (expMag_i), and i-band Composite fit magnitude (cModelMag_i) as the most informative set with the copula entropy of -1.5886. The Random Forest Regressor model is trained on two samples: (a) all galaxies and (b) the faint galaxy subset (petroMag_i > 20), with both five-band (U, G, R, I, Z) and three-band (G, R, I) photometry. Even though the gains are small, they are consistent and substantial: The Root-Mean-Square-Error (RMSE) improves by ~0.3% for five-band photometry and ~2% for three-band photometry for the full sample and by ~3% and ~6% for the faint sample. However, in the faint galaxy sample, three-band photometry case, outlier fractions drop by ~16% due to the selected set of morphological parameters. Moreover, the predictive contribution of those parameters rises significantly from ~1% for the full sample, five-band photometry, to ~29% for the faint galaxy sample, three-band photometry. Morphology delivers the greatest benefits under suboptimal conditions, where photometry is sparse or galaxies are faint and non-representative, when the correct set of combinations is chosen right. Future work will explore the influence of these optimal features on the photo-z probability distribution function, p(z), and redshift distribution, N(z), both essential for weak lensing analyses. This statistically rigorous approach offers a scalable, survey-ready pathway to sharper photo-z estimates in next-generation cosmology.

# Electron Bunching and Coherent Curvature Radiation Driven by Inertial Alfvén Dynamics in Pulsar Magnetospheres

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The inner magnetosphere of pulsars, characterized by a low plasma beta ($\beta \ll m_e/mi$) due to intense magnetic fields [1], provides an ideal environment for inertial Alfvén waves. This region hosts a complex electron-positron-ion (e-p-i) plasma, comprising relativistic electron-positron pairs generated through pair cascades and a minor component of heavy ions, such as $Fe^{26+}$, extracted from the neutron star's surface due to extreme electric fields (~$10^{12}$ V/m) [2]. The plasma density is governed by the Goldreich-Julian [3] density, $n_{GJ} = \Omega B/(2\pi ec)$, where $\Omega$ is the pulsar's angular frequency, B is the magnetic field, e is the electron charge, and c is the speed of light, with pair cascades enhancing electron-positron densities by factors of $10^2$ -$10^6$ [4]. The low β, driven by dominant magnetic pressure over thermal pressure, results in dispersion dominated by the inertial properties of the pair plasma rather than thermal effects. Using the Sagdeev pseudo-potential method, we investigate the nonlinear dynamics of inertial Alfvén waves, deriving soliton solutions under specific existence conditions. Both sub- and super-Alfvénic solitons are identified, with their profiles showing significant electron density enhancements along magnetic field lines, forming dense electron bunches along curved field lines that facilitate coherent curvature radiation (CCR), a primary mechanism for pulsar radio emissions. This study uniquely connects inertial Alfvén wave properties to observable pulsar characteristics, including spin period (P), period derivative ($\dot{P}$), plasma composition, and relativistic temperatures. By incorporating magnetic field models, dipolar within the light cylinder and transitioning to toroidal beyond it, and density models tied to $n_{GJ}$, we quantify how pulsar parameters influence wave dispersion and soliton characteristics. For instance, shorter periods (P) yield smaller light-cylinder radii ($R_{LC}$), stronger magnetic fields, and higher plasma densities, affecting soliton amplitude and width. The period derivative ($\dot{P}$) affects surface magnetic field strength, modulating inertial effects. Plasma composition, including the ion fraction and pair multiplicity, and relativistic temperatures further shape wave dynamics. These dependencies reveal how pulsar properties govern inertial Alfvén wave behavior, which in turn drives electron bunching and enhances CCR power. We calculate the radiation power from these electron bunches, providing novel insights into the mechanisms underlying CCR across diverse pulsar classes, from millisecond to canonical pulsars, thus advancing our understanding of energy transport and particle acceleration in pulsar magnetospheres.

References

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# Master functions of Reissner-Nordström black hole perturbations and their Darboux transformation

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Lenzi and Sopuerta developed a new method to construct master functions for the perturbation of vacuum black holes. We extend this method to black holes coupled with electromagnetic field and cosmological constant by allowing the master functions to be linear combinations of the metric and electromagnetic-potential perturbations, as well as their first-order derivatives. Requiring these master functions satisfy wave equations with yet-to-be-determined effective potentials, we reduce the linearized Einstein-Maxwell system to a set of algebraic-differential constraints. Solving these constraints reveals four master function branches in each parity sector: two standard branches, which coincide with the Zerilli-Moncrief formalism, and two Darboux branches, characterized by their effective potentials. Within each parity sector, a Darboux transformation exists which connects the standard and Darboux branches, preserving the quasinormal mode spectrum and confirming their physical equivalence.

# Autocorrelation signatures in time-resolved black hole flare images: secondary peaks and convergence structure

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The strong gravitational field of a black hole bends light, forming multi-level images, yet extracting precise spacetime information from them remains challenging. In this study, we investigate how gravitational lensing leaves unique and detectable signatures in black hole movies using autocorrelation analysis. By examining the two-dimensional autocorrelation of a movie depicting a hotspot orbiting a Kerr black hole, as viewed by a near-axis observer, we identify a persistent secondary peak structure induced by gravitational lensing. Notably, these secondary peaks converge toward an approximately fixed point in the time-angle lag domain, largely independent of the orbital radius of the hotspot. This key property suggests that combining future flare observations with precise autocorrelation analysis could effectively disentangle lensing effects from orbital dynamics, enabling direct measurement of black hole parameters.

# BCDDM:Branch Correction Denoising Diffusion Model for Black Hole Image Generation

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The properties of black holes and accretion flows can be inferred by fitting Event Horizon Telescope data to simulated images generated through general relativistic ray tracing (GRRT). However, due to the computationally intensive nature of GRRT, the efficiency of generating specific radiation flux images needs to be improved. This paper introduces the Branch Correction Denoising Diffusion Model (BCDDM), a deep learning framework that synthesizes black hole images directly from physical parameters. The model incorporates a branch correction mechanism and a weighted mixed-loss function to enhance accuracy and stability. We have constructed a data set of 2157 GRRT-simulated images for training the BCDDM, which spans seven key physical parameters of the radiatively inefficient accretion flow model. Our experiments show a strong correlation between the generated images and their physical parameters. By enhancing the GRRT data set with BCDDM-generated images and using ResNet50 for parameter regression, we achieve significant improvements in parameter prediction performance. BCDDM offers a novel approach to reducing the computational costs of black hole image generation, providing a faster and more efficient pathway for data set augmentation, parameter estimation, and model fitting.

# Quasinormal Modes of Schwarzschild Black Holes in the Dehnen-(1, 4, 5/2) Type Dark Matter Halos

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The Dehnen - type dark matter density distribution model is mainly used for dwarf galaxies. In recent years, researchers have speculated that black holes may exist in this dark matter model and have given the black hole metric solutions. On this basis, this paper conducts a systematic study on the quasinormal modes of a Schwarzschild black hole in a Dehnen - (1,4, 5/2) dark matter halo, revealing the influences of dark matter distribution and perturbation field types on the black hole's quasinormal modes.The research uses the shadow radius data of the M87* black hole. Through the geodesic equation, two sets of dark matter halo parameter values of $\rho_s$ and $r_s$ are determined, and the specific numerical values of the black hole's event horizon radius, photon sphere radius, and shadow radius under the corresponding conditions are obtained. The wave equations and effective potentials of the black hole under the perturbations of the scalar field, electromagnetic field, and axial gravitational were analyzed. It was found that the larger the values of $\rho_s$ or $r_s$, the smaller the peak value of the effective potential, and the wave function oscillation slows down with a lower frequency. The black hole remains stable under perturbations. These studies provide relevant data for the quasinormal modes of the Schwarzschild black hole in the Dehnen- (1,4, 5/2) type dark matter halo. They also offer crucial evidence for understanding the interaction mechanism between the black hole and the dark matter halo.

# Thin accretion disk around Schwarzschild-like black hole in bumblebee gravity

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The physical properties and optical appearance of a thin accretion disk surrounding a Schwarzschild-like black hole (BH) are investigated within the framework of bumblebee gravity. To understand how the Lorentz symmetry breaking (LSB) parameter l affects the disk’s behavior, we analyze main characteristics such as energy flux, temperature distribution, and emission spectrum. In addition, direct and secondary images of the accretion disk are generated and examined to explore how both the observational inclination angle and the LSB parameter l shape the visual profile. Furthermore, we compute the redshift and observed flux distributions of the disk from the perspective of distant observers at various inclination angles. Our results indicate that the redshift factor grows as l decreases. Notably, the BH appears least luminous for positive values of l, while it becomes increasingly luminous when l takes on negative values. These findings highlight the crucial influence of the LSB parameter l on the observable features of BHs.