Technical Review on BCG Signal Processing

Introduction

Ballistocardiography (BCG) signal processing is a vital area of research with applications in non-invasive cardiac monitoring. This document provides a technical review of recent publications on this topic from arXiv.

Publications

1. Block CG algorithms revisited

- **Authors:** Petr Tichý, Gérard Meurant, Dorota Šimonová
- **Published:** 2025-02-24
- **arXiv ID:** 2502.16998v1
- **URL:** http://arxiv.org/pdf/2502.16998v1
- **Categories:** math.NA, cs.NA, 65F10
- **Summary:** Our goal in this paper is to clarify the relationship between the block Lanczos and the block conjugate gradient (BCG) algorithms. Under the full rank assumption for the block vectors, we show the one-to-one correspondence between the algorithms. This allows, for example, the computation of the block Lanczos coefficients in BCG. The availability of block Jacobi matrices in BCG opens the door for further development, e.g., for error estimation in BCG based on (modified) block Gauss quadrature rules. Driven by the need to get a practical variant of the BCG algorithm well suited for computations in finite precision arithmetic, we also discuss some important variants of BCG due to Dubrulle. These variants avoid the troubles with a possible rank deficiency within the block vectors. We show how to incorporate preconditioning and computation of Lanczos coefficients into these variants. We hope to help clarify which variant of the block conjugate gradient algorithm should be used for computations in finite precision arithmetic. Numerical results illustrate the performance of different variants of BCG on some examples.

2. Error norm estimates for the block conjugate gradient algorithm

- **Authors:** Gérard Meurant, Petr Tichý
- **Published:** 2025-02-20
- **arXiv ID:** 2502.14979v1
- **URL:** http://arxiv.org/pdf/2502.14979v1
- **Categories:** math.NA, cs.NA, 65F10
- **Summary:** In the book [Meurant and Tichy, SIAM, 2024] we discussed the estimation of error norms in the conjugate gradient (CG) algorithm for solving linear systems $Ax=b$ with a symmetric positive definite matrix A, where b and x are vectors. In this paper, we generalize the most important formulas for estimating the A-norm of the error to the block case. First, we discuss in detail the derivation of various variants of the block CG (BCG) algorithm from the block Lanczos algorithm. We then consider BCG and derive the related block Gauss and block Gauss-Radau quadrature rules. We show how to obtain lower and upper bounds on the A-norm of the error of each system, both in terms of the quantities computed in BCG and in terms of the underlying block Lanczos algorithm. Numerical experiments demonstrate the behavior of the bounds in practical computations.

3. The stellar mass composition of galaxy clusters and dependencies on dark matter halo properties

- **Authors:** Daniel Montenegro-Taborda, Vladimir Avila-Reese, Vicente Rodriguez-Gomez, Aditya Manuwal, Bernardo Cervantes-Sodi
- **Published:** 2025-02-11
- **arXiv ID:** 2502.07927v1
- **URL:** http://arxiv.org/pdf/2502.07927v1
- **Categories:** astro-ph.GA, astro-ph.CO
- **Summary:** We analyze 700 clusters from the TNG300 hydrodynamical simulation ($M*{200}\geq5\times10^{13}* \,M{\odot}$ at (z=0)) to examine the radial stellar mass distribution of their central objects, consisting of the brightest cluster galaxy (BCG) and the intracluster light (ICL). The BCG+ICL mass fraction weakly anticorrelates with $M*{200}$, but strongly correlates with the concentration, $c*{200}$, the assembly redshift, $z*{50}$, and the mass gap between the most massive and the fourth more massive member, $\Delta M*{\rm \ast, 4th}$. We explore different aperture radii to nominally separate the ICL from the BCG and calculate ICL fractions. For $r*{\rm{ap}}=2r*{\rm half}$, where $r*{\rm half}$ is the radius containing half the BCG+ICL mass, the ICL fraction is nearly independent of $M*{200}$, $c*{200}$, and $z*{50}$ with values $M*{\ast,\rm ICL}/(M*{\ast,\rm ICL}+M*{\ast,\rm BCG})= 0.33\pm0.03$. Including the stellar mass of the satellites, the fraction $M*{\ast,\rm ICL}/(M*{\ast,\rm ICL}+M*{\ast,\rm BCG}+M*{\rm \ast,sat})$ weakly anticorrelates with $M*{200}$ and strongly correlates with $c*{200}$, $z*{50}$, and $\Delta M*{\rm \ast, 4th}$, suggesting that in more concentrated/earlier assembled/more relaxed clusters more stellar mass is lost from the satellites (by tidal stripping, and mergers) in favour of the ICL and BCG. Indeed, we find that ex-situ stars dominate both in the BCG and ICL masses, with mergers contributing more to the BCG, while tidal stripping contributes more to the ICL. We find that the difference between the projected and 3D ICL fractions are only a few per cent and suggest using $2r*{\rm half}$ to separate the ICL from the BCG in observed clusters.

4. Using Neural Networks to Automate the Identification of Brightest Cluster Galaxies in Large Surveys

- **Authors:** Patrick Janulewicz, Tracy M. A. Webb, Laurence Perreault-Levasseur
- **Published:** 2025-01-31
- **arXiv ID:** 2502.00104v1
- **URL:** http://arxiv.org/pdf/2502.00104v1
- **Categories:** astro-ph.GA, astro-ph.CO
- **Summary:** Brightest cluster galaxies (BCGs) lie deep within the largest gravitationally bound structures in existence. Though some cluster finding techniques identify the position of the BCG and use it as the cluster center, other techniques may not automatically include these coordinates. This can make studying BCGs in such surveys difficult, forcing researchers to either adopt oversimplified algorithms or perform cumbersome visual identification. For large surveys, there is a need for a fast and reliable way of obtaining BCG coordinates. We propose machine learning to accomplish this task and train a neural network to identify positions of candidate BCGs given no more information than multiband photometric images. We use both mock observations from The Three Hundred project and real ones from the Sloan Digital Sky Survey (SDSS), and we quantify the performance. Training on simulations yields a squared correlation coefficient, R^2, between predictions and ground truth of $R^2 \approx 0.94$ when testing on simulations, which decreases to $R^2 \approx 0.60$ when testing on real data due to discrepancies between datasets. Limiting the application of this method to real clusters more representative of the training data, such those with a BCG r-band magnitude $r_{\text{BCG}} \leq 16.5$, yields $R^2 \approx 0.99$. The method performs well up to a redshift of at least $z\approx 0.6$.

We find this technique to be a promising method to automate and accelerate the identification of BCGs in large datasets.

5. Cold Gas and Star Formation in the Phoenix Cluster with JWST

- **Authors:** Michael Reefe, Michael McDonald, Marios Chatzikos, Jerome Seebeck, Richard Mushotzky, Sylvain Veilleux, Steven Allen, Matthew Bayliss, Michael Calzadilla, Rebecca Canning, Megan Donahue, Benjamin Floyd, Massimo Gaspari, Julie Hlavacek-Larrondo, Brian McNamara, Helen Russell, Arnab Sarkar, Keren Sharon, Taweewat Somboonpanyakul
- **Published:** 2025-01-15
- **arXiv ID:** 2501.08527v1
- **URL:** http://arxiv.org/pdf/2501.08527v1
- **Categories:** astro-ph.GA
- **Summary:** We present integral field unit observations of the Phoenix Cluster with the JWST Mid-infrared Instrument's Medium Resolution Spectrometer (MIRI/MRS). We focus this study on the molecular gas, dust, and star formation in the brightest cluster galaxy (BCG). We use precise spectral modeling to produce maps of the silicate dust, molecular gas, and polycyclic aromatic hydrocarbons (PAHs) in the inner $\sim$50 kpc of the cluster. We have developed a novel method for measuring the optical depth from silicates by comparing the observed H$*2$ line ratios to those predicted by excitation models. We provide updated measurements of the total molecular gas mass of $2.2^{+0.4}*{-0.1} \times 10^{10}$ ${\rm M}\odot$, which agrees with CO-based estimates, providing an estimate of the CO-to-H$*2$ conversion factor of $\alpha*{\rm CO} = 0.9 \pm 0.2\,{\rm M}*{\odot}\,{\rm pc}^{-2}\,({\rm K}\,{\rm km}\,{\rm s}^{-1})^{-1}$; an updated stellar mass of $M* = 2.6 \pm 0.5 \times 10^{10}$ ${\rm M}*\odot$; and star formation rates averaged over 10 and 100 Myr of $\langle{\rm SFR}\rangle*{\rm 10} = 1340 \pm 100$ ${\rm M}*\odot\,{\rm yr}^{-1}$ and $\langle{\rm SFR}\rangle*{\rm 100} = 740 \pm 80$ ${\rm M}*\odot\,{\rm yr}^{-1}$, respectively. The H$_2$ emission seems to be powered predominantly by star formation within the central ~ 20 kpc, with no need for an extra particle heating component as is seen in other BCGs. Additionally, we find nearly an order of magnitude drop in the star formation rates estimated by PAH fluxes in cool core BCGs compared to field galaxies, suggesting that hot particles from the intracluster medium are destroying PAH grains even in the centralmost 10s of kpc.

6. Enabling Cardiac Monitoring using In-ear Ballistocardiogram on COTS Wireless Earbuds

- **Authors:** Yongjian Fu, Ke Sun, Ruyao Wang, Xinyi Li, Ju Ren, Yaoxue Zhang, Xinyu Zhang
- **Published:** 2025-01-12
- **arXiv ID:** 2501.06744v1
- **URL:** http://arxiv.org/pdf/2501.06744v1
- **Categories:** cs.HC, eess.SP
- **Summary:** The human ear offers a unique opportunity for cardiac monitoring due to its physiological and practical advantages. However, existing earable solutions require additional hardware and complex processing, posing challenges for commercial True Wireless Stereo (TWS) earbuds which are limited by their form factor and resources. In this paper, we propose TWSCardio, a novel system that repurposes the IMU sensors in TWS earbuds for cardiac monitoring. Our key finding is that these sensors can capture in-ear ballistocardiogram (BCG) signals. TWSCardio reuses the unstable Bluetooth channel to stream the IMU data to a smartphone for BCG processing. It incorporates a signal enhancement framework to address issues related to missing data and low sampling rate, while mitigating motion artifacts by fusing multi-axis information. Furthermore, it employs

a region-focused signal reconstruction method to translate the multi-axis in-ear BCG signals into fine-grained seismocardiogram (SCG) signals. We have implemented TWSCardio as an efficient real-time app. Our experiments on 100 subjects verify that TWSCardio can accurately reconstruct cardiac signals while showing resilience to motion artifacts, missing data, and low sampling rates. Our case studies further demonstrate that TWSCardio can support diverse cardiac monitoring applications.

7. HST Observations within the Sphere of Influence of the Powerful Supermassive Black Hole in PKS0745-191

- **Authors:** Julie Hlavacek-Larrondo, Hyunseop Choi, Minghao Guo, Annabelle Richard-Laferrière, Carter Rhea, Marine Prunier, Helen Russell, Andy Fabian, Jonelle L. Walsh, Marie-Joëlle Gingras, Brian McNamara, Steve Allen, André-Nicolas Chené, Alastair Edge, Marie-Lou Gendron-Marsolais, Michael McDonald, Priyamvada Natarajan, Jeremy Sanders, James F. Steiner, Benjamin Vigneron, Anja von der Linden
- **Published:** 2025-01-06
- **arXiv ID:** 2501.03339v1
- **URL:** http://arxiv.org/pdf/2501.03339v1
- **Categories:** astro-ph.GA, astro-ph.HE
- **Summary:** We present Space Telescope Imaging Spectrograph observations from the Hubble Space Telescope of the supermassive black hole (SMBH) at the center of PKS0745-191, a brightest cluster galaxy (BCG) undergoing powerful radio-mode AGN feedback ($P*{\rm cav}\sim5\times10^{45}$ erg s^{-1}). *These high-resolution data offer the first spatially resolved map of gas dynamics within a SMBHs sphere of influence under such powerful feedback. Our results reveal the presence of highly chaotic, non-rotational ionized gas flows on sub-kpc scales, in contrast to the more coherent flows observed on larger scales. While radio-mode feedback effectively thermalizes hot gas in galaxy clusters on kiloparsec scales, within the core, the hot gas flow may decouple, leading to a reduction in angular momentum and supplying ionized gas through cooling, which could enhance accretion onto the SMBH. This process could, in turn, lead to a self-regulating feedback loop. Compared to other BCGs with weaker radio-mode feedback, where rotation is more stable, intense feedback may lead to more chaotic flows, indicating a stronger coupling between jet activity and gas dynamics. Additionally, we observe a sharp increase in velocity dispersion near the nucleus, consistent with a very massive $M*{\rm BH} \sim1.5\times10^{10} M_\odot$ SMBH. The density profile of the ionized gas is also notably flat, paralleling the profiles observed in X-ray gas around galaxies where the Bondi radius is resolved. These results provide valuable insights into the complex mechanisms driving galaxy evolution, highlighting the intricate relationship between SMBH fueling and AGN feedback within the host galaxy.

8. Heartbeat Detection from Ballistocardiogram using Transformer Network

- **Authors:** Ruhan Yi, Mihail Popescu, James M. Keller, Grant Scott, Laurel Despins, David Heise, Marjorie Skubic
- **Published:** 2024-12-18
- **arXiv ID:** 2412.14376v1
- **URL:** http://arxiv.org/pdf/2412.14376v1
- **Categories:** eess.SP
- **Summary:** Longitudinal monitoring of heart rate (HR) and heart rate variability (HRV) can aid in tracking cardiovascular diseases (CVDs), sleep quality, sleep disorders, and reflect autonomic nervous system activity, stress levels, and overall well-being. These metrics are valuable in both clinical and everyday settings. In this paper, we present a transformer network aimed primarily at detecting the precise timing of heart beats from predicted electrocardiogram (ECG), derived from input Ballistocardiogram (BCG). We compared the

performance of segment and subject models across three datasets: a lab dataset with 46 young subjects, an elder dataset with 28 elderly adults, and a combined dataset. The segment model demonstrated superior performance, with correlation coefficients of 0.97 for HR and mean heart beat interval (MHBI) when compared to ground truth. This non-invasive method offers significant potential for long-term, in-home HR and HRV monitoring, aiding in the early indication and prevention of cardiovascular issues.

9. Evidence that pre-processing in filaments drives the anisotropic quenching of satellite galaxies in massive clusters

- **Authors:** Harry Stephenson, John Stott, Joseph Butler, Molly Webster, Jonathan Head
- **Published:** 2024-12-10
- **arXiv ID:** 2412.07834v2
- **URL:** http://arxiv.org/pdf/2412.07834v2
- **Categories:** astro-ph.GA
- **Summary:** We use a sample of 11 $z\approx0.2-0.5$ ($z*{\text{med.}} = 0.36$) galaxy clusters from the Cluster Lensing And Supernovae survey with Hubble (CLASH) to analyse the angular dependence of satellite galaxy colour $(B-R)$ and passive galaxy fraction ($f*{\text{pass.}}$) with respect to the major axis of the brightest cluster galaxy (BCG). This phenomenon has been dubbed as \say{anisotropic quenching}, \say{angular conformity} or \say{angular segregation}, and it describes how satellite galaxies along the major axis of the BCG are more likely to be quenched than those along the minor axis. A highly significant anisotropic quenching signal is found for satellites, with a peak in $(B-R)$ and $f*{\text{pass.}}$ along the major axis. We are the first to measure anisotropic quenching out to cluster-centric radii of $3R*{200}$ ($R*{200\text{, med.}} \approx 933$ \si{\kilo\parsec}). We find that the signal is significant out to at least $2.5R*{200}$, and the amplitude of the signal peaks at $\approx1.25R*{200}$. This is the first time a radial peak of the anisotropic quenching signal has been measured directly. We suggest that this peak could be caused by a build-up of backsplash galaxies at this radius. Finally, we find that $f*{\text{pass.}}$ is significantly higher along the major axis for fixed values of local surface density. The density drops less rapidly along the major axis and so satellites spend more time being pre-processed here compared to the minor axis. We therefore conclude that pre-processing in large-scale structure, and not active galactic nuclei outflows (AGN), is the cause of the anisotropic quenching signal in massive galaxy clusters, however this may not be the cause in lower mass halos.

10. Miscentering of Optical Galaxy Clusters Based on Sunyaev-Zeldovich Counterparts

- **Authors:** Jupiter Ding, Roohi Dalal, Tomomi Sunayama, Michael A. Strauss, Masamune Oguri, Nobuhiro Okabe, Matt Hilton, Rogério Monteiro-Oliveira, Cristóbal Sifón, Suzanne T. Staggs
- **Published:** 2024-11-18
- **arXiv ID:** 2411.12120v1
- **URL:** http://arxiv.org/pdf/2411.12120v1
- **Categories:** astro-ph.CO
- **Summary:** The "miscentering effect," i.e., the offset between a galaxy cluster's optically-defined center and the center of its gravitational potential, is a significant systematic effect on brightest cluster galaxy (BCG) studies and cluster lensing analyses. We perform a cross-match between the optical cluster catalog from the Hyper Suprime-Cam (HSC) Survey S19A Data Release and the Sunyaev-Zeldovich cluster catalog from Data Release 5 of the Atacama Cosmology Telescope (ACT). We obtain a sample of 186 clusters in common in the redshift range $0.1 \leq z \leq 1.4$ over an area of 469 deg^2. By modeling the

distribution of centering offsets in this fiducial sample, we find a miscentered fraction (corresponding to clusters offset by more than 330 kpc) of ~25%, a value consistent with previous miscentering studies. We examine the image of each miscentered cluster in our sample and identify one of several reasons to explain the miscentering. Some clusters show significant miscentering for astrophysical reasons, i.e., ongoing cluster mergers. Others are miscentered due to non-astrophysical, systematic effects in the HSC data or the cluster-finding algorithm. After removing all clusters with clear, non-astrophysical causes of miscentering from the sample, we find a considerably smaller miscentered fraction, ~10%. We show that the gravitational lensing signal within 1 Mpc of miscentered clusters is considerably smaller than that of well-centered clusters, and we suggest that the ACT SZ centers are a better estimate of the true cluster potential centroid.

11. A stable one-synchronization variant of reorthogonalized block classical Gram--Schmidt

- **Authors:** Erin Carson, Yuxin Ma
- **Published:** 2024-11-11
- **arXiv ID:** 2411.07077v1
- **URL:** http://arxiv.org/pdf/2411.07077v1
- **Categories:** math.NA, cs.NA, 65F10, 65F25, 65G50, 65Y20
- **Summary:** The block classical Gram--Schmidt (BCGS) algorithm and its reorthogonalized variant are widely-used methods for computing the economic QR factorization of block columns X due to their lower communication cost compared to other approaches such as modified Gram--Schmidt and Householder QR. To further reduce communication, i.e., synchronization, there has been a long ongoing search for a variant of reorthogonalized BCGS variant that achieves $O(u)$ loss of orthogonality while requiring only \emph{one} synchronization point per block column, where u represents the unit roundoff. Utilizing Pythagorean inner products and delayed normalization techniques, we propose the first provably stable one-synchronization reorthogonalized BCGS variant, demonstrating that it has $O(u)$ loss of orthogonality under the condition $O(u) \kappa^2(X) \leq 1/2$, where $ \kappa(\cdot)$ represents the condition number. By incorporating one additional synchronization point, we develop a two-synchronization reorthogonalized BCGS variant which maintains $O(u)$ loss of orthogonality under the improved condition $O(u) \kappa(X) \leq 1/2$. An adaptive strategy is then proposed to combine these two variants, ensuring $O(u)$ loss of orthogonality while using as few synchronization points as possible under the less restrictive condition $O(u) \kappa(X) \leq 1/2$. As an example of where this adaptive approach is beneficial, we show that using the adaptive orthogonalization variant, s-step GMRES achieves a backward error comparable to s-step GMRES with BCGSI+, also known as BCGS2, both theoretically and numerically, but requires fewer synchronization points.

12. A spatially-resolved spectral analysis of giant radio galaxies with MeerKAT

- **Authors:** K. K. L. Charlton, J. Delhaize, K. Thorat, I. Heywood, M. J. Jarvis, M. J. Hardcastle, Fangxia An, I. Delvecchio, C. L. Hale, I. H. Whittam, M. Brüggen, L. Marchetti, L. Morabito, Z. Randriamanakoto, S. V. White, A. R. Taylor
- **Published:** 2024-11-11
- **arXiv ID:** 2411.06813v1
- **URL:** http://arxiv.org/pdf/2411.06813v1
- **Categories:** astro-ph.GA
- **Summary:** In this study we report spatially resolved, wideband spectral properties of three giant radio galaxies (GRGs) in the COSMOS field: MGTC J095959.63+024608.6 , MGTC

J100016.84+015133.0 and MGTC J100022.85+031520.4. One such galaxy MGTC J100022.85+031520.4 is reported here for the first time with a projected linear size of 1.29 Mpc at a redshift of 0.1034. Unlike the other two, it is associated with a brightest cluster galaxy (BCG), making it one of the few GRGs known to inhabit cluster environments. We examine the spectral age distributions of the three GRGs using new MeerKAT UHF-band (544-1088 MHz) observations, and L-band (900-1670 MHz) data from the MeerKAT International GHz Tiered Extragalactic Exploration (MIGHTEE) survey. We test two different models of spectral ageing, the Jaffe-Perola and Tribble models, using the Broadband Radio Astronomy Tools (\textsc{brats}) software which we find agree well with each other. We estimate the Tribble spectral age for MGTC J095959.63+024608.6 as 68 Myr, MGTC J100016.84+015133.0 as 47 Myr and MGTC J100022.85+031520.4 as 67 Myr. We find significant disagreements between these spectral age estimates and the estimates of the dynamical ages of these GRGs, modelled in cluster and group environments. Our results highlight the need for additional processes which are not accounted for in either the dynamic age or spectral age estimations.

13. Volume entropy and rigidity for RCD-spaces

- **Authors:** Chris Connell, Xianzhe Dai, Jesús Núñez-Zimbrón, Raquel Perales, Pablo Suárez-Serrato, Guofang Wei
- **Published:** 2024-11-07
- **arXiv ID:** 2411.04327v1
- **URL:** http://arxiv.org/pdf/2411.04327v1
- **Categories:** math.DG, math.GT, math.MG, 53C23, 46E36
- **Summary:** We develop the barycenter technique of Besson--Courtois--Gallot so that it can be applied on RCD metric measure spaces. Given a continuous map f from a non-collapsed RCD$(-(N-1),N)$ space X without boundary to a locally symmetric N-manifold we show a version of BCG's entropy-volume inequality. The lower bound involves homological and homotopical indices which we introduce. We prove that when equality holds and these indices coincide X is a locally symmetric manifold, and f is homotopic to a Riemannian covering whose degree equals the indices. Moreover, we show a measured Gromov--Hausdorff stability of X and Y involving the homotopical invariant. As a byproduct, we extend a Lipschitz volume rigidity result of Li--Wang to RCD(K,N) spaces without boundary. Finally, we include an application of these methods to the study of Einstein metrics on 4-orbifolds.

14. The shape of the Chameleon fifth-force on the mass components of galaxy clusters

- **Authors:** Lorenzo Pizzuti, Valentina Amatori, Alexandre M. Pombo, Sandeep Haridasu
- **Published:** 2024-11-01
- **arXiv ID:** 2411.00538v1
- **URL:** http://arxiv.org/pdf/2411.00538v1
- **Categories:** astro-ph.CO, gr-qc
- **Summary:** In the context of Chameleon gravity, we present a semi-analytical solution of the chameleon field profile in accurately modelled galaxy cluster's mass components, namely: the stellar mass of the Brightest Cluster Galaxy (BCG), the baryonic mass in galaxies (other than the BCG), the mass of the Intra-Cluster Medium (ICM) and the diffuse cold dark matter (CDM). The obtained semi-analytic profile is validated against the numerical solution of the chameleon field equation and implemented in the \textsc{MG-MAMPOSSt} code for kinematic analyses of galaxy clusters in modified gravity scenarios. By means of mock halos, simulated both in GR and in modified gravity, we show that the combination of velocities and positions of cluster member galaxies, along with data of the stellar velocity dispersion profile of the BCG, can impose constraints on the parameter

space of the Chameleon model; for a cluster generated in GR, these constraints are at the same level as a joint lensing+kinematics analysis of a cluster modelled with a single mass profile, without the BCG data.

15. SleepNetZero: Zero-Burden Zero-Shot Reliable Sleep Staging With Neural Networks Based on Ballistocardiograms

- **Authors:** Shuzhen Li, Yuxin Chen, Xuesong Chen, Ruiyang Gao, Yupeng Zhang, Chao Yu, Yunfei Li, Ziyi Ye, Weijun Huang, Hongliang Yi, Yue Leng, Yi Wu
- **Published:** 2024-10-30
- **arXiv ID:** 2410.22646v1
- **URL:** http://arxiv.org/pdf/2410.22646v1
- **Categories:** eess.SP, cs.LG
- **Summary:** Sleep monitoring plays a crucial role in maintaining good health, with sleep staging serving as an essential metric in the monitoring process. Traditional methods, utilizing medical sensors like EEG and ECG, can be effective but often present challenges such as unnatural user experience, complex deployment, and high costs. Ballistocardiography~(BCG), a type of piezoelectric sensor signal, offers a non-invasive, user-friendly, and easily deployable alternative for long-term home monitoring. However, reliable BCG-based sleep staging is challenging due to the limited sleep monitoring data available for BCG. A restricted training dataset prevents the model from generalization across populations. Additionally, transferring to BCG faces difficulty ensuring model robustness when migrating from other data sources. To address these issues, we introduce SleepNetZero, a zero-shot learning based approach for sleep staging. To tackle the generalization challenge, we propose a series of BCG feature extraction methods that align BCG components with corresponding respiratory, cardiac, and movement channels in PSG. This allows models to be trained on large-scale PSG datasets that are diverse in population. For the migration challenge, we employ data augmentation techniques, significantly enhancing generalizability. We conducted extensive training and testing on large datasets~(12393 records from 9637 different subjects), achieving an accuracy of 0.803 and a Cohen's Kappa of 0.718. ZeroSleepNet was also deployed in real prototype~(monitoring pads) and tested in actual hospital settings~(265 users), demonstrating an accuracy of 0.697 and a Cohen's Kappa of 0.589. To the best of our knowledge, this work represents the first known reliable BCG-based sleep staging effort and marks a significant step towards in-home health monitoring.

16. Testing Refracted Gravity with kinematics of galaxy clusters

- **Authors:** Lorenzo Pizzuti, Federico Fantoccoli, Valeria Broccolato, Andrea Biviano, Antonaldo Diaferio
- **Published:** 2024-10-25
- **arXiv ID:** 2410.19698v1
- **URL:** http://arxiv.org/pdf/2410.19698v1
- **Categories:** astro-ph.CO, gr-qc
- **Summary:** Refracted Gravity (RG) is a a classical theory of gravity where a gravitational permittivity $ a monotonically-increasing function of the local density rho , is introduced in the Poisson equation to mimic the effect of dark matter at astrophysical scales. We use high precision spectroscopic data of two massive galaxy clusters, MACS J1206.2-0847 at redshift z=0.44, and Abell S1063 (RXC J2248.7-4431) at z=0.35, to determine the total gravitational potential in the context of RG and to constrain the three, supposedly universal, free parameters of this model. Using an upgraded version of the MG-MAMPOSSt algorithm, we perform a kinematic analysis which combines the velocity distribution of the cluster galaxies and the velocity dispersion profile of the stars within the Brightest Cluster Galaxy (BCG). The unprecedented dataset used has been obtained by an

extensive spectroscopic campaign carried out with the VIMOS and MUSE spectrographs at the ESO VLT. We found that RG describes the kinematics of these two clusters as well as Newtonian gravity, although the latter is slightly preferred. However, (i) each cluster requires a different set of the three free RG parameters, and (ii) the two sets are inconsistent with other results in the literature at different scales. We discuss the limitation of the method used to constrain the RG parameters as well as possible systematic effects which can give rise to the observed tension, notably deviations from the spherical symmetry and from the dynamical equilibrium of the clusters.

17. Microfinance in Thailand: Navigating Challenges and Unlocking Opportunities

- **Authors:** Worrawoot Jumlongnark
- **Published:** 2024-09-05
- **arXiv ID:** 2409.03157v2
- **URL:** http://arxiv.org/pdf/2409.03157v2
- **Categories:** econ.GN, q-fin.EC
- **Summary:** This review article explores the challenges and opportunities faced by the Bank for Agriculture and Agricultural Cooperatives (BAAC) in Thailand from a microfinance perspective. It examines the role of BAAC as a specialized financial institution in assisting underprivileged households and small businesses in accessing financial services. The study emphasizes the challenges and opportunities faced by BAAC in promoting sustainable development. It also explores BAAC's role in advancing the BCG Model policy, which fosters sustainability in the agricultural sector through Bio Economy Credit, Circular Economy Credit, and Green Credit. These initiatives support investments in biotechnology, waste reduction (Zero Waste), organic farming, and safe food production, all aimed at enhancing farmers' quality of life, stimulating growth in agriculture, and preserving the environment. Moreover, BAAC remains committed to upholding transparency, fairness, and operational standards.

18. The Hierarchical Growth of Bright Central Galaxies and Intracluster Light as Traced by the Magnitude Gap

- **Authors:** Jesse B. Golden-Marx, Y. Zhang, R. L. C. Ogando, B. Yanny, M. E. S. Pereira, M. Hilton, M. Aguena, S. Allam, F. Andrade-Oliveira, D. Bacon, D. Brooks, A. Carnero Rosell, J. Carretero, T. -Y. Cheng, L. N. da Costa, J. De Vicente, S. Desai, P. Doel, S. Everett, I. Ferrero, J. Frieman, J. García-Bellido, M. Gatti, G. Giannini, D. Gruen, R. A. Gruendl, G. Gutierrez, S. R. Hinton, D. L. Hollowood, K. Honscheid, D. J. James, K. Kuehn, S. Lee, J. Mena-Fernández, F. Menanteau, R. Miquel, A. Palmese, A. Pieres, A. A. Plazas Malagón, S. Samuroff, E. Sanchez, M. Schubnell, I. Sevilla-Noarbe, M. Smith, E. Suchyta, G. Tarle, V. Vikram, A. R. Walker, N. Weaverdyck, P. Wiseman
- **Published:** 2024-09-03
- **arXiv ID:** 2409.02184v1
- **URL:** http://arxiv.org/pdf/2409.02184v1
- **Categories:** astro-ph.GA
- **Summary:** Using a sample of 2800 galaxy clusters identified in the Dark Energy Survey across the redshift range $0.20 < z < 0.60$, we characterize the hierarchical assembly of Bright Central Galaxies (BCGs) and the surrounding intracluster light (ICL). To quantify hierarchical formation we use the stellar mass - halo mass (SMHM) relation for the BCG+ICL system and incorporate the magnitude gap (M14), the difference in brightness between the BCG (measured within 30kpc) and 4th brightest cluster member galaxy within 0.5 $R_{200,c}$. The inclusion of M14, which traces BCG hierarchical growth, increases the slope and decreases the intrinsic scatter in the SMHM relation, highlighting that it is a

latent variable within the BCG+ICL SMHM relation. Moreover, the correlation with M14 decreases at large radii from the BCG's centre. However, the stellar light within the BCG+ICL transition region (30kpc - 80kpc) most strongly correlates with the dark matter halo mass and has a statistically significant correlation with M14. As the light in the transition region and M14 are independent measurements, the transition region may grow as a result of the BCG's hierarchical two-phase formation. Additionally, as M14 and ICL result from hierarchical growth, we use a stacked sample and find that clusters with large M14 values are characterized by larger ICL and BCG+ICL fractions, which illustrates that the merger processes that build the BCG stellar mass also grow the ICL. Furthermore, this may suggest that M14 combined with the ICL fraction can be used as a method to identify dynamically relaxed clusters.

19. Cosmic dance in the Shapley Concentration Core II. The uGMRT-MeerKAT view of filaments in the brightest cluster galaxies and tailed radio galaxies in the A3528 cluster complex

- **Authors:** G. Di Gennaro, T. Venturi, S. Giacintucci, M. Brüggen, E. Bulbul, J. Sanders, A. Liu, X. Zhang, K. Trehaeven, D. Dallacasa, P. Merluzzi, T. Pasini, S. Bardelli, G. Bernardi, O. Smirnov
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- **Categories:** astro-ph.CO, astro-ph.GA
- **Summary:** Superclusters are the largest-scale environments where a number of galaxy clusters interact with each other through minor/major mergers and grow via accretion along cosmic filaments. We focus on the A3528 complex in the core of the Shapley Supercluster. This system includes three clusters, A3528 (composed itself by two sub-clusters, namely A3528N and A3528S), A3532 and A3530, and presents a mildly active dynamical state. We study how minor mergers affect the evolution of radio galaxies and whether they are able to re-accelerate relativistic electrons in the ICM. We used observations from the uGMRT (Band 3, 4 and 5) and MeerKAT (L-band) telescopes to obtain images and spectral index maps over a wide frequency band and spatial resolutions. We compare these data with those from the SRG/eROSITA X-ray telescope. We detect faint diffuse radio emission associated with the radio galaxies. The BCGs in A3528S and A3532 show filaments of diffuse radio emission which extend for $\sim200-400$ kpc out of the radio galaxy. The spectral index of these filaments is extremely steep and almost constant ($\alpha\sim -2, -2.5$). Contrary to the radio tails in A3528N, the spectral properties of these radio filaments are not consistent with standard models of plasma ageing. We also detect roundish diffuse radio emission around the BCG in A3528S which could be classified as a radio mini-halo. The radio tail in this cluster appears longer that in earlier detections, being ~300 kpc long at all frequencies. We linked the presence of extended radio emission in the form of filaments and threads in the A3528 complex with the effect of minor mergers. This is reinforced by the increasing X-ray fluctuations in correspondence with the radio extended emission in A3528S. Despite the less energy involved, our findings support the hypothesis that these events can re-energise plasma originating from radio galaxies.

20. Core formation by binary scouring and gravitational wave recoil in massive elliptical galaxies

- **Authors:** Nader Khonji, Alessia Gualandris, Justin I. Read, Walter Dehnen
- **Published:** 2024-08-22
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- **URL:** http://arxiv.org/pdf/2408.12537v1

- **Categories:** astro-ph.GA
- **Summary:** Scouring by supermassive black hole (SMBH) binaries is the most accepted mechanism for the formation of the cores seen in giant elliptical galaxies. However, an additional mechanism is required to explain the largest observed cores. Gravitational wave (GW) recoil is expected to trigger further growth of the core, as subsequent heating from dynamical friction of the merged SMBH removes stars from the central regions. We model core formation in massive elliptical galaxies from both binary scouring and heating by GW recoil and examine their unique signatures. We aim to determine if the nature of cores in 3D space density can be attributed uniquely to either process and if the magnitude of the kick can be inferred. We perform N-body simulations of galactic mergers of multicomponent galaxies, based on the observed parameters of four massive elliptical galaxies with cores > 0.5 kpc. After binary scouring and hardening, the merged SMBH remnant is given a range of GW recoil kicks with 0.5-0.9 of the escape speed of the galaxy. We find that binary scouring alone can form the cores of NGC 1600 and A2147-BCG, which are < 1.3 kpc in size. However, the > 2 kpc cores in NGC 6166 and A2261-BCG require heating from GW recoil kicks of < 0.5 of the galaxy escape speed. A unique feature of GW recoil heating is flatter cores in surface brightness, corresponding to truly flat cores in 3D space density. It also preferentially removes stars on low angular momentum orbits from the galactic nucleus.

Summary of Publications

Recent research in BCG signal processing has explored various aspects of cardiac monitoring. Block CG algorithms revisited [1] investigated Our goal in this paper is to clarify the relations...Error norm estimates for the block conjugate gradient algorithm [2] investigated In the book [Meurant and Tichy, SIAM, 2024] we dis...The stellar mass composition of galaxy clusters and dependencies on dark matter halo properties [3] investigated We analyze 700 clusters from the TNG300 hydrodynam...Using Neural Networks to Automate the Identification of Brightest Cluster Galaxies in Large Surveys [4] inv...