Book of abstracts for the IPTA 2024 Meeting in Sexten

Section A: Updates from different PTAs/Outlook in the future

Talk 1

Title: **Overview of Indian PTA**

Author: **Keitaro Takahashi**

Affiliation: Kumamoto University

Abstract: The InPTA is an Indo-Japanese collaboration for pulsar timing array utilizing the Upgraded Giant Metrewave Radio Telescope, which enables us to perform low-frequency measurements and wide-band timing. Recent enhancements in strategy and processing pipelines have yielded promising results, with wide-band timing techniques applied to 300-500 MHz data, and have contributed to global PTA collaborations. We aim to quantify DM and scatter-broadening variations precisely alongside international counterparts, thereby enriching our understanding of low-frequency phenomena and reducing systematics in PTA analysis. In this talk, I will give an overview of the InPTA and show recent activities toward the second data release.

Talk 2

Title: **Progress of CPTA Timing**

Author: **Heng Xu**

Affiliation: National Astronomical Observatories, CAS

Abstract: I will present the progess of pulsar timing of Chinese Timing Array.

Talk 3

Title: **The Parkes Pulsar Timing Array: update and outlook**

Author: **Andrew Zic**

Affiliation: CSIRO

Abstract: The Parkes Pulsar Timing Array (PPTA) has now performed high-precision timing of millisecond pulsars for 20 years using Murriyang, the Parkes 64m Radio Telescope. The primary aim of this endeavour is to study nanohertz-frequency gravitational waves. In this talk, I will present an overview of the project, highlight recent results, and discuss opportunities presented by upcoming ATNF instrumentation for the PPTA. I will also summarise upcoming work, and discuss the ongoing role of the PPTA toward the era of the SKA.

Talk 4

Title: **EPTA updates: beyond EPTA DR2**

Author: **Golam Shaifullah**

Affiliation: University of Milano Bicocca

Abstract: I will give update on the progress of the EPTA Collaboration.

Talk 5

Title: **The first results of a search for gravitational waves with the MeerKAT Pulsar Timing Array**

Author: **Updates from NANOGrav Collaboration**

Affiliation: Vanderbilt University

Abstract: I will give updates on the progress of the NANOGrav Collaboration.

Talk 6

Title: **The first results of a search for gravitational waves with the MeerKAT Pulsar Timing Array**

Author: **Matthew Miles**

Affiliation: Swinburne University of Technology

Abstract: Through the use of pulsar timing arrays, a new window can be opened to study the gravitational-wave Universe. The gravitational-wave frequency band that pulsar timing arrays are sensitive to is expected to be dominated by a stochastic background produced by binary supermassive black holes. In order to detect the background, the presence of “Hellings-Downs” angular correlations between the pulsars in an array is required. Pulsar timing array experiments in Australia, North America, and Europe have recently observed evidence for these spatial correlations. However, in order to make a definitive detection, it is necessary to observe pulsars over a longer timing baseline, monitor a larger ensemble of pulsars, time pulsars to higher precision, or all. The MeerKAT Pulsar Timing Array monitors a large number of pulsars (83), to high precision, and at the highest cadence of any extant pulsar timing array.

Talk 7

Title: **MeerKAT 4.5 year dataset: Search for Anisotropies**

Author: **Kathrin Grunthal**

Affiliation: Max-Planck Institut für Radioastronomie

Abstract: In 2023, the EPTA, NANOGrav, PPTA, InPTA and CPTA presented compelling evidence for the presence of a Hellings-and-Downs-correlated common red noise signal in their data sets - the smoking gun of a nanohertz gravitational wave background. Undoubtedly, this shifts the driving science goal of PTA research from solely detecting such a background towards identifying the astrophysical origin of that signal. A gravitational wave background may emanate from merging supermassive black holes, phase transitions in the early Universe or other more exotic
scenarios.
Determining the gravitational wave power sky distribution is the cornerstone for understanding the origin of the common red noise signal. Skymaps created from PTA data sets help distinguish between individual gravitational wave hot spots (arising from supermassive black hole binaries)
and a broad, isotropic background (e.g. originating from phase transitions). Capitalising on the unique quality of the latest dataset of observations with the MeerKAT radio telescope, comprising of 83 pulsars and spanning 4.5 years, we present the most recent study of the gravitational wave power sky distribution.

Talk 8

Title: **New Results from the Gamma-ray PTA**

Author: **Matthew Kerr**

Affiliation: US Naval Research Laboratory

Abstract: I will present highlights from the second data release of the gamma-ray PTA, including improvements to the analysis techniques and results from searches for the stochastic GWB. If time allows, I will present results of a study of gamma-ray pulse profile stability and make comparisons to variations observed in some radio MSPs.

Talk 9

Title: **Adding a CHIME to the IPTA Orchestra**

Author: **Deborah Good**

Affiliation: University of Montana

Abstract: The Canadian Hydrogen Intensity Mapping Experiment pulsar system (CHIME/Pulsar) is an exciting and increasingly important part of the pulsar timing community. CHIME/Pulsar uses digital tracking beams to observe up to 10 pulsars simultaneously, allowing it to observe every northern hemisphere pulsar between 400-800 MHz at near daily cadence. These data are a treasure trove for a variety of science, including pulsar binary studies and interstellar medium studies. One of the most exciting applications of CHIME/Pulsar data is in PTA science. A small sub-set of CHIME/Pulsar observations are being included in IPTA DR3 and a much larger set of observations will be included in future NANOGrav data releases. In this talk, we'll discuss the benefits and challenges of pulsar timing observations with CHIME, provide an overview of previous CHIME/Pulsar results, and present recent data combination progress.

Talk 10

Title: **LOFAR2.0 -- a LOFAR reboot**

Author: **Caterina Tiburzi**

Affiliation: INAF-OAC

Abstract: LOFAR is undergoing a major hardware revision, that will bring to the synchronized inclusion of NenuFAR in the array, and to the possibility of simultaneously observing with the high-band antennae (100-240 MHz) and the low-band antennae (30-100 MHz) including NenuFAR. This prompted to a revision of the pulsar monitoring proposals as one of the few accepted Large Programs during the LOFAR2.0 era.

Talk 11

Title: **Pulsar and IPTA data analysis at the time of SKA: how to maximize the impact of the computational facilities**

Author: **Andrea Possenti**

Affiliation: INAF-Osservatorio Astronomico di Cagliari

Abstract: It is expected that the SKAO telescopes will generate of order 100 PBy of pulsar data during the first few years of activity. By that time, the largest computing facilities in the world will have reached exa-scale capabilities, and a network of so-called SKAO Regional Centers (SRCs) will be in place in order to perform the advanced analysis of the SKA data, as well as to cure and archive both the original data and the advanced data products. In this context, unprecedented opportunities might be opened for the full exploitation of pulsar and IPTA data, with the data from precursors and pathfinders of SKA possibly playing the role of testbeds.

Talk 12

Title: **An Evolutionary Picture of FRBs**

Author: **Di Li**

Affiliation: National Astronomical Observatories, Chinese Academy of Sciences

Abstract: The Five-hundred-meter Aperture Spherical radio Telescope (FAST), the largest single-dish telescope ever built , has been in operation for four years. Based on a novel high-cadence CAL injection technique, we have designed the Commensal Radio Astronomy FAST Survey (CRAFTS), which realizes, for the first time at any major facility, simultaneous data recording of pulsar search, HI imaging, HI galaxies, and transients (FRB and SETI). CRAFTS has discovered ~200 pulsars, ~10 FRBs including the only persistently active repeater FRB 20190520B, and ~5000 d^2 HI images with 1% calibration consistency, 5-10 times better than what is available from Arecibo. I will discuss FAST's science highlights regarding FRBs, particularly a new evolutionary picture. Critical pieces of evidence include a 10% drop of FRB 121102's DM on a decade time scale, the frequency evolution of active repeaters well

described by a single physical parameter sigma_RM, the B field reversal around 190520B, and the intriguing correlation of sigma_RM with PRS.

Talk 13

Title: **Enabling low-frequency MSP searches with the Murchison Widefield Array**

Author: **Christopher Lee**

Affiliation: International Centre for Radio Astronomy Research (ICRAR), Curtin University

Abstract: Millisecond pulsars (MSPs) are exquisite astrophysical tools which provide unique opportunities to advance fundamental physics. For this reason, MSPs are a key science case for the Square Kilometre Array (SKA) and many of its pathfinder/precursor facilities. The Murchison Widefield Array (MWA) is playing an important role in preparing for SKA science, having recently completed data collection for the Southern-sky MWA Rapid Two-metre (SMART) pulsar survey in the 140-170 MHz frequency band. With a dwell time of 4800 s and a high time resolution, SMART will be the most sensitive southern pulsar survey at low frequencies. Several pulsar discoveries have already been made, as well as the redetection of over 200 pulsars. To date, very few southern MSPs have been observed at such low frequencies. The SMART data provide a valuable resource for extending the frequency range of MSP detections in the southern sky, which can be used to study pulse profile evolution with frequency, improve DM and RM estimates, and constrain flux density spectra. Motivated by this, we are performing a census of known MSPs in the SMART survey, many of which have been detected at the lowest frequency to date. This census will inform pulsar population simulations aimed at assessing the detectable population of MSPs in the SKA-Low band, and will also feed into our plans for performing targeted, high-sensitivity searches for binary and millisecond pulsars towards unassociated Fermi gamma-ray sources covered by the SMART survey. I will present the progress to date from these efforts, including the updated MSP census and initial results from the ongoing searches.

Section B: Technical updates

Talk 14

Title: **NANOGrav's 15-year dataset: Customized chromatic noise models**

Author: **Jeremy Baier**

Affiliation: Oregon State University

Abstract: NANOGrav's GWB measurement reported in the 15-yr data set exhibits noise model dependence between the standard DMX and DMGP. This project revisits the NANOGrav results, creating customized chromatic noise models for all 67 pulsars in the data set. These new models utilize Gaussian Processes in both the time domain and Fourier basis to account for radio frequency-dependent time delays, including dispersion measure effects and scattering, while also including a global solar wind model. This study further investigates what affects these new noise models have on the GWB significance, parameter estimation, and spectral properties.

Talk 15

Title: **Single pulsar noise analysis with the CPTA DR1**

Author: **Siyuan Chen**

Affiliation: Shanghai Astronomical Observatory, CAS

Abstract: The Chinese Pulsar Timing Array (CPTA) PTAs has reported the finding of evidence for a gravitational wave (GW) signal in its first data release (DR1) in coordination with the European Pulsar Timing Array (EPTA) + Indian Pulsar Timing Array (InPTA), North American Nanohertz Observatory for Gravitational waves (NANOGrav) and Australian Parkes Pulsar Timing Array (PPTA), together as part of the International Pulsar Timing Array (IPTA) efforts towards detecting nanohertz gravitational waves. While the overview paper has been published, a series of papers analyzing the data set in greater details is planned. I will present the analysis of the single pulsar noise models, which are needed to search for GW signals. We compare a DMX style data set against the DM power law GP model. Following other PTAs, we employ Bayesian techniques to optimize the frequency bin choice for the power law model. In addition, we use four software packages to verify our results. Finally, comparison against other PTA results show very broad agreement, however given the different frequency range that is probed by the 3 years long CPTA DR1, the comparison should be viewed with caution.

Talk 16

Title: **The second data release of Indian Pulsar Timing Array experiment**

Author: **Prerna Rana**

Affiliation: Tata Institute of Fundamental Research, Mumbai, India

Abstract: The collaborative efforts of the International Pulsar Timing Array (IPTA) consortium are likely to further strengthen the first evidence for nano-Hertz gravitational waves (GW) announced by Pulsar Timing Arrays (PTAs) last year. Integral to this global initiative is the Indian PTA (InPTA: Indo-Japanese collaboration), an active participant in the IPTA consortium, which made its first official data release (DR1) featuring observations from 14 MSPs, concurrently monitored across the 300-500 MHz (Band 3) and 1260-1460 MHz (Band 5) frequency bands of the premier Indian radio astronomy facility, the upgraded Giant Metrewave Radio Telescope (uGMRT). The next pivotal milestone for the InPTA collaboration is its second data release (DR2) of a 7-year long uGMRT data set of 29 MSPs, which will also include data in the frequency range 550-750 MHz (Band 4). This presentation will include the intricacies of InPTA's second data release, focusing on the precise estimation of Dispersion Measures (DM) and pulsar Time of Arrival (ToA) and using the multi-band Narrowband and Wideband techniques. Additionally, I will also present the details of timing analysis and characteristics of our pulsar sample. Towards the end, a summary of the results along with the uniqueness of the InPTA experiment in context of IPTA efforts will be provided.

Talk 17

Title: **MeerKAT Pulsar Timing Array: understanding pulsar noise**

Author: **Ryan Shannon**

Affiliation: Swinburne University of Technology

Abstract: I strongly support Matt Miles giving the MeerTime result talk. I can follow up with more detail on the noise analysis.

Talk 18

Title: **Combining low-frequency observations with EPTA DR2new+ dataset**

Author: **Francesco Iraci**

Affiliation: University of Cagliari

Abstract: DM variations represent one of the main sources of noise in PTAs, and can be accurately determined using low-frequency data. The European interferometers LOFAR and NenuFAR, operating below ~240 and ~100 MHz respectively, have been collecting data at high observing cadences. In this work we are producing an extended version of the EPTA DR2new+ with the data coming from the pulsar observing campaigns conducted with LOFAR and NenuFAR since 2013 and 2019 respectively. These data will yield an improved precision on DM measurements and allow a more optimal disentanglement of the chromatic and achromatic red noise processes which might be present in the timing residuals.

Talk 19

Title: **Pulsar Timing Using the New Efflesberg Systems**

Author: **Jedrzej Jawor**

Affiliation: Max Planck Institute for Radioastronomy

Abstract: The Effelsberg 100 m telescope is one of the main telescopes contributing to the EPTA and thus features significantly in the recent EPTA data release. For over 20 years, the telescope has been used to observe millisecond pulsars. Naturally, the systems used for data collection have been upgraded over time, which has resulted in a gradual increase in timing precision. For some time now, a new backend software, the Effelsberg Direct Digitalization (EDD), has been used to record pulsar observations. In addition, the Ultra BroadBand receiver (UBB) has also recently been installed in the telescope and is currently being tested for use in pulsar timing. In this talk, the capabilities of EDD and UBB will be presented together with an improved data reduction pipeline. The comparison between the new systems and the old ones will be made, focusing on the improvements in: SNR, ToA, and timing precision.

Section C: GW detection techniques and statistical analysis

Talk 20

Title: **Impact of Single Pulsar Noise Modeling on GWB Recovery: The Case of SMBHBs**

Author: **Hippolyte Quelquejay**

Affiliation: APC

Abstract: The correlated signal found in the different PTA datasets last June suggests the potential detection of a Gravitational Wave Background (GWB) in the future. Analyzing the power distribution across frequencies allows us to interpret this signal by comparing it with various GWB models. However, inaccuracies in modeling single pulsar noises could bias the estimation of the GWB spectrum. We introduce a new approach to address these inaccuracies while preserving evidence of the GW signature. We then present the recovered GWB spectrum using this method and compare it with the expected signal from a population of Super Massive Black Hole Binaries, based on the Horizon-AGN cosmological simulation.

Talk 21

Title: **Systematic errors in searches for nanohertz gravitational waves**

Author: **Valentina Di Marco**

Affiliation: Monash University

Abstract: A number of pulsar timing arrays have recently reported preliminary evidence for the existence of a nanohertz gravitational-wave background. These analyses rely on detailed noise analyses, which are inherently complex due to the many astrophysical and instrumental factors that contribute to the noise budget. In this talk, I investigate whether realistic systematic error, stemming from misspecified noise models that fail to capture salient features of the pulsar timing noise, could lead to a false positive detection. I consider two plausible forms of misspecification: small unmodeled jumps and unmodeled chromatic noise. Using simulated data, I calculate the distribution of the commonly used optimal statistic with no signal present and using plausibly misspecified noise models. By comparing this distribution with the distribution created using ``quasi-resampling'' techniques (such as sky scrambles and phase shifts), we endeavor to determine the extent to which plausible misspecification might lead to a false positive. The results are reassuring: I find that quasi-resampling techniques tend to underestimate the significance of pure-noise datasets. I conclude that recently reported evidence for a nanohertz gravitational-wave background is likely robust to the most obvious sources of systematic errors; if anything, the significance of the signal is potentially underestimated. We also study the effect that these misspecifications have on the estimation of the spectral index of the common red noise induced by a gravitational wave background.

Talk 22

Title: **Moving towards a PTA likelihood without timing residuals**

Author: **Serena Valtolina**

Affiliation: Max Planck Institute for Gravitational Physics (AEI), Hannover

Abstract: The usual way a Pulsar Timing Array (PTA) likelihood is constructed, such as with Enterprise, is based on using timing residuals as the primary data. This means that all signal and noise processes that affect the timing residuals must be explicitly modeled. In this talk, I will show how to construct an alternative formulation of the PTA likelihood that is based entirely in Fourier space. The data is essentially a generalization of the Fourier transform, optionally enriched with extra data. The resulting PTA likelihood allows for the same modeling of the stochastic background of gravitational waves (GWB) and intrinsic red noise (IRN) processes as in the canonical analyses that we usually do with typical PTA analysis packages.

Talk 23

Title: **Removing pulsars one by one from the NANOGrav pulsar timing array**

Author: **Paul Brook**

Affiliation: University of Birmingham

Abstract: In order to explore the internal consistency of the NANOGrav 15-year result we investigate how the signal strength changes as we remove the pulsars one by one from the data set. We calculate the signal strength using the (noise-marginalized) optimal statistic, a frequentist metric designed to measure correlated excess power in the residuals of the arrival times of the radio pulses.

Talk 24

Title: **Principal component analysis as a method for pulsar timing in the presence of pulse shape changes**

Author: **Ross Jennings**

Affiliation: West Virginia University

Abstract: In pulsar timing, TOAs are typically generated from observed pulse profiles using a method that assumes the pulse shape is fixed. While this assumption is generally a good one, it does break down in certain cases. For example, when the observed profile is produced from a small number of pulses, short term stochastic variations in pulse shape become important. Additionally, events such as that recently seen in PSR J1713+0747 can produce pulse shape changes that vary systematically as a function of frequency and time. One possible way forward in such cases is to use principal component analysis of the profile residuals to inform TOA estimation. I will outline the benefits and limitations of this technique, with an eye toward using it to improve PTA sensitivity.

Talk 25

Title: **Detecting Anisotropies from SMBHBs**

Author: **Anna-Malin Lemke**

Affiliation: Hamburg University

Abstract: Anisotropies play a central role in distinguishing between cosmological and astrophysical sources of the GWB, as detectable anisotropies are expected for a GWB from a population of supermassive black hole binaries (SMBHBs) but not for cosmological sources. A search for anisotropies in the NANOGrav 15-year dataset resulted in a null detection. We show that this null detection is not yet in tension with an SMBHB-generated background by calculating the detection probabilities for anisotropies for present and future PTAs. We find that the NANOGrav 15-year dataset had only a ~6.5% probability for detecting anisotropies, whereas this probability might increase to ~16% for the IPTA DR3. We also identify SMBHB populations that are more likely to produce detectable levels of anisotropies. This information could be used together with the spectral properties of the GWB to characterize the SMBHB population.

Talk 26

Title: **All the Single Pulsars: Spectral Characterisation with Factorised Likelihoods in IPTA DR3**

Author: **William Lamb**

Affiliation: Vanderbilt University

Abstract: IPTA DR3 will be the largest pulsar timing array data set yet, featuring at least 18 years of data across 115 pulsars. Common uncorrelated red noise analyses scale with the number of pulsars in the data set, hence DR3 will slow down the already cumbersome enterprise-based spectral characterisation techniques. In this talk, I will present my work on factorised likelihoods and how they can speed up spectral characterisation from a few days or weeks on a high performance computer, to a few minutes on a laptop. These analyses are already revolutionising spectral characterisation with astrophysical and cosmological spectra. Using these methods, I will also show that only a subset of pulsars are important for spectral characterisation, paving the way for faster enterprise-based analyses too.

Talk 27

Title: **Franken-Stat: An Early Indicator IPTA Statistic**

Author: **Kalysta Wayt**

Affiliation: Oregon State

Abstract: Combining single pulsar timing array (PTA) datasets takes a significant amount of time and effort, therefore we have developed a version of the optimal statistic (Franken-Stat) which does not require direct combination of the datasets. Instead we combine the Bayesian posteriors from individual PTA analyses. This method will serve as an early indicator of what we will expect in future International PTA dataset. Here we demonstrate a version of our early indicator optimal statistical analysis on the EPTA, PPTA, and NANOGrav dataset, alongside simulation work that uses this method. We also present a theoretical calculation for the, Franken-Stat, SNR gain we would expect from the combined datasets.

Talk 28

Title: **PTA parameter estimation in real time with Discovery**

Author: **Michele Vallisneri**

Affiliation: Jet Propulsion Laboratory, California Institute of Technology

Abstract: The new PTA data analysis package Discovery, based on the numerical Python library JAX and on the conventions of Enterprise, enables extremely efficient parameter estimation on pulsar-timing-array datasets, using automated gradients and CPU/GPU parallelization for Hamiltonian Monte Carlo and normalizing flows. Inference for current PTA datasets can be completed in minutes. We present the package and some of its exciting applications.

Talk 29

Title: **An efficient pipeline for continuous gravitational wave detection using gradient-based sampling**

Author: **Gabriel Freedman**

Affiliation: University of Wisconsin-Milwaukee

Abstract: The pulsar timing array (PTA) community has found evidence for a correlated stochastic signal following the Hellings-Downs pattern indicative of an isotropic stochastic gravitational-wave background (GWB). The most likely source of such a background is a population of supermassive black hole binaries, and particularly loud individual sources could be detected in future datasets. Searching for these single continuous gravitational wave (CW) sources adds additional computational complexity to an already time-intensive analysis. This increases the already large number of parameters needed to be sampled concurrently and introduces strong covariance into the model, namely between binaries emitting at low frequencies and the GWB. We present a pipeline for efficiently performing joint Bayesian searches for both the GWB and CW sources. The pipeline utilizes particular Markov Chain Monte Carlo methods, namely the Hamiltonian Monte Carlo algorithm, which use sample proposals based in the gradient of the model likelihood to fully explore the high-dimensional covariant parameter space. We explore this method's capability at accurately recovering both the GWB and CW sources and present computational scaling arguments for this algorithm against the current prescriptions for PTA analyses.

Talk 30

Title: **Kalman tracking and parameter estimation of continuous gravitational waves with a pulsar timing array**

Author: **Tom Kimpson**

Affiliation: University of Melbourne

Abstract: Continuous nanohertz gravitational waves (GWs) from individual supermassive black hole binaries may be detectable with pulsar timing arrays. We present an alternative formulation of the data analysis procedure based on a state-space framework. We test the new method on synthetic data. We detect the GW signal and recover the the posterior distribution of the model parameters. The method complements existing approaches to PTA data analysis.

Talk 31

Title: **Project Delphi: Comparing Binary Search Approaches with IPTADR3-like Datasets**

Author: **Levi Schult**

Affiliation: Vanderbilt University

Abstract: The evidence for a stochastic gravitational wave (GW) background presented by IPTA constituents ignited the race to determine its source. Leading theories predict that an ensemble of super massive black hole binaries (SMBHBs) throughout cosmic history generated this background, as the emission of GWs shrinks their orbit to an eventual merger. One approach to confirm this theory is to find an individual SMBHB in PTA datasets. Existing methods to find such a source include template-based searches, where binary waveform parameters are searched over, and small-scale anisotropy searches, identifying regions of excess GW power on the sky. I will present results on a comparison between these techniques through a suite of simulations. These simulations were designed based on realistic predictions of IPTADR3 and encompass a variety of noise realizations and dataset timespans. The evolution of each search method's detection ability in subsequent datasets is examined, establishing guideposts for the future of binary searches. I will conclude with prospects for synergies between the various styles of individual binary searches.

Talk 32

Title: **Investigation of the interplay between stochastic and deterministic GW signals with EPTA-based simulations**

Author: **Irene Ferranti**

Affiliation: University of Milano Bicocca

Abstract: I will present the first results of realistic simulations of PTA data sets in the presence of a single resolvable source. All simulations are based on the second European PTA data release and the analyses focus on the accuracy and precision achieved in parameter estimation and on the subtleties of disentangling a single gravitational wave signal from the stochastic background. Searches are performed using the Enterprise pipeline for single resolvable searches, which is also used for IPTA data analysis.

Section D: Timing, Noise Modeling and IISM

Talk 33

Title: **Why PSR J0437-4715 is actually the best pulsar**

Author: **Daniel Reardon**

Affiliation: Swinburne University of Technology

Abstract: PSR J0437-4715 is well known as the nearest and brightest millisecond pulsar. It is valuable for pulsar timing arrays, is the primary target for the The Neutron Star Interior Composition Explorer (NICER) mission, and has revealed interesting and unexpectedly abundant plasma structures in the Local Bubble. In this talk I highlight recent timing and scintillation studies of this pulsar, resulting in the first measurements of the radial velocity, a tomographic view of the pulsars bow shock, and precise measurements of mass and distance. The latter are used as priors that are essential for the radius constraint obtained by the NICER mission to constrain the neutron star equation of state.

Talk 34

Title: **Shapiro Delay Measurements of the Bright Gamma-Ray MSP J1231-1411**

Author: **Thankful Cromartie**

Affiliation: U.S. Naval Research Laboratory

Abstract: PSR J1231-1411 is one of the brightest gamma-ray MSPs, but proves difficult to study at radio frequencies. We have combined high-cadence Nançay radio telescope data with superior conjunction-targeted Green Bank Telescope observations to create a comprehensive data set that constrains the mass and inclination angle of this MSP. Such a measurement serves as a prior on the mass-to-radius ratio obtainable with NICER X-ray observations, which in turn may help constrain the neutron star interior equation of state. We will describe the challenges involved in properly modeling white and red noise processes in these data and how these might affect our ability to constrain the pulsar's mass. We will also touch on recent advances from the Gamma-Ray Pulsar Timing Array, including discussing J1231-1411 as an example of what joint gamma-radio analyses will offer, as well as our plan to improve analysis tools and share data from our high-frequency PTA effort.

Talk 35

Title: **High Fluence Timing with Automatized Clustering**

Author: **Sophia Sosa Fiscella**

Affiliation: Rochester Institute of Technology / National Science Foundation

Abstract: Traditional pulsar timing techniques involve averaging large numbers of single pulses to obtain a high signal-to-noise (S/N) profile. This profile can then be matched to a template to measure the time-of-arrival (TOA). However, the morphology of individual single pulses can vary greatly due to pulse jitter, with only a few high-S/N pulses per observation contributing significantly to the pulse average. In this study, we propose a new method that accounts for these pulse variations by identifying a range of ``pulse states" and timing each state separately. To test this method, we selected a 1-hour observation of PSR J2145-0750 in two frequency bands at the Green Bank Telescope. We normalized the single pulse amplitudes to account for scintillation effects and probed different excision algorithms to account for radio-frequency interference. We then measured four pulse parameters (peak amplitude, position, width, and energy) to classify the single pulses using automated clustering algorithms. For each cluster, we calculated the average pulse profile and template and used both to obtain a TOA with its corresponding error. Finally, we performed a weighted average to obtain a global TOA error. In doing so, we obtained an improvement of the TOA error when clustering the single pulses.

Talk 36

Title: **Pulsar Timing with Single Pulses**

Author: **Natalia Lewandowska**

Affiliation: SUNY Oswego

Abstract: Pulsars are known for their extremely stable rotational behavior which is shown by averaging their emission over thousands of rotations. Timing pulsars has become a powerful technique for experiments that focus on tests of general relativity, probing the interior of pulsars and the detection of gravitational waves. With the availability of larger bandwidths and advances in digital signal processing pulsar timing studies have been extended towards single pulses. Resulting from individual rotations of a pulsar, single pulses have shorter pulse widths than average profiles and show pulse-to-pulse variability on various time scales. We developed alternative approaches for timing pulsars via their single pulses using templates to account for pulse shapes, fluxes and also polarimetric information and will present the first preliminary results of that study applied to a subset of pulsars.

Talk 37

Title: **Improving DM estimates using low-frequency scattering-broadening estimates**

Author: **Jaikhomba Singha**

Affiliation: University of Cape Town

Abstract: A pulsar's pulse profile gets broadened at low frequencies due to dispersion along the line of sight or due to multi-path propagation. The dynamic nature of the interstellar medium makes both these effects time-dependent and introduces slowly varying time delays in the measured times-of-arrival similar to those introduced by passing gravitational waves. In this talk, I will present a new method to correct for such delays by obtaining unbiased dispersion measure (DM) measurements using low-frequency estimates of the scattering parameters. This method has been evaluated by comparing the obtained DM estimates with those, where scatter-broadening is ignored using simulated data. A bias is seen in the estimated DMs for simulated data with pulse-broadening with a larger variability for a data set with a variable frequency scaling index, α, as compared to that assuming a Kolmogorov turbulence. Application of the proposed method removes this bias robustly for data with band averaged signal-to-noise ratio larger than 100. For the first time, the measurements of the scatter-broadening time and α from analysis of PSR J1643-1224, observed with upgraded Giant Metrewave Radio Telescope as part of the Indian Pulsar

Timing Array experiment, will be presented. These scattering parameters were found to vary with epoch and α was different from that expected for Kolmogorov turbulence. Finally, I will present the DM time-series after application of the new technique to PSR J1643-1224.

Talk 38

Title: **Cyclic Spectroscopy-Aided Studies of the ISM in PTA Observing Setups**

Author: **Jacob Turner**

Affiliation: Monash University

Abstract: We use cyclic spectroscopy to perform high frequency-resolution analyses of multi-hour baseband Arecibo observations of the millisecond pulsar PSR B1937+21. This technique allows for the examination of scintillation features in far greater detail than is otherwise possible under most pulsar timing array observing setups. We measure scintillation bandwidths and timescales in each of eight subbands across a 200 MHz observing band in each observation. Through these measurements we obtain robust, intra-epoch estimates of the frequency scalings for scintillation bandwidth and timescale. Thanks to our high frequency resolution and the narrow scintles of this pulsar, we resolve scintillation arcs in the secondary spectra due to the increased Nyquist limit, which would not have been resolved at the same observing frequency with a traditional filterbank spectrum using NANOGrav's current time and frequency resolutions, and the frequency-dependent evolution of scintillation arc features within individual observations. We observe the dimming of prominent arc features at higher frequencies, possibly due to a combination of decreasing flux density and undetermined effects due to the interstellar medium. We also find agreement with arc curvature frequency dependence predicted by Stinebring et al. (2001) in some epochs. Thanks to the frequency resolution improvement provided by cyclic spectroscopy, these results show strong promise for future such analyses with millisecond pulsars, particularly for pulsar timing arrays, where such techniques can allow for detailed studies of the interstellar medium in highly scattered pulsars without sacrificing the timing resolution that is crucial to their gravitational wave detection efforts.

Talk 39

Title: **Characterising the PSR J1713+0747 Profile Change Event using the Parkes Ultra-Wideband Receiver**

Author: **Rami Mandow**

Affiliation: Macquarie University / CSIRO

Abstract: The long-term stability of millisecond pulsar (MSP) pulse profiles enables high-precision timing experiments, including searching for low-frequency gravitational waves with pulsar timing arrays (PTAs). Whilst profile changes in MSPs are rare, a small number of these events has been reported. So far, the largest profile change event of any MSP has been the April 2021 profile change of PSR J1713+0747, one of the most frequently observed and precisely-timed MSPs. Given the critical role that MSP profile stability plays in PTA experiments, it is important to characterise any profile instability in these sources. This may also yield clues into dynamic physical processes in their magnetospheres. As part of the Parkes Pulsar Timing Array project, we investigate the April 2021 profile change event of PSR J1713+0747 observed with the ultra-wideband low-frequency receiver. In this talk, I will present a wide-bandwidth,

full-polarimetric analysis of the profile change event and highlight the recovery and potential reconfiguration of profile components over time.

Talk 40

Title: **Exploring Solar Wind using Gaussian Processes on LOFAR data**

Author: **Sai Chaitanya Susarla**

Affiliation: University of Galway

Abstract: Pulsars offer valuable insights into various phenomena, including interstellar weather like the Solar Wind (SW). The SW is a highly magnetized stream of plasma emanating from the Sun. Ecliptic pulsars, whose line-of-sight (LoS) comes close to the Sun, are particularly useful for tracking electron content variations in the SW, quantified by the Dispersion Measure (DM). DMs exhibit a strong, inverse dependency on observing frequency, making the LOFAR telescope ideal for studying SW effects as it covers frequencies below 240 MHz. We have collected data from 6 international LOFAR stations, as well as LOFAR core, over the past 10 years, observing at a weekly to monthly cadence.

Talk 41

Title: **Survey for Scintillation Arcs in NANOGrav Binary Pulsars**

Author: **Swarali Shivraj Patil**

Affiliation: West Virginia University, USA

Abstract: The scintillation of radio pulsars contains information on their local and intervening environments along an observer's line of sight. Scintillation arcs are observed as parabolic features in the two-dimensional Fourier Transform of the power spectrum of scintillating pulsar radiation across frequency and time. The curvature of scintillation arcs is related to the effective transverse velocity, distance to the pulsar, and distance to the scattering material. If the pulsar producing a scintillation arc resides in a binary system, then the arc-derived scintillation parameters can be interpreted to derive elusive orbital parameters, specifically the orbital inclination and longitude of the ascending node. Such independently determined orbital parameters are keys to intrinsic properties of the pulsar system. We present results of our survey for scintillation arcs for 12 NANOGrav binary pulsars using the Green Bank Telescope.

Talk 42

Title: **Epoch-dependent Interstellar Scintillations and Timing Variations for the Millisecond Pulsar B1937+21**

Author: **Timothy Dolch**

Affiliation: Hillsdale College / Eureka Scientific

Abstract: PSR B1937+21 is the brightest millisecond pulsar in the northern sky and serves as a laboratory for studying uncertainties and systematic changes in pulse times-of-arrival. Its high flux, its relatively high degree of scattering along the line-of-sight, and its giant pulses interact in a dynamic way to affect individual times-of-arrival on different timescales. Results are relevant to understanding the timing of other millisecond pulsars, and thus to the larger effort to detect gravitational waves with pulsar timing arrays. We present data from an Arecibo Observatory campaign on PSR B1937+21 with baseband data at 1.4 GHz (200 MHz bandwidth), where standard NANOGrav timing measurements are taken. By utilizing the rich dynamic spectrum data from these campaigns, we analyze the noise budget of this pulsar on very short and very long timescales due to the changing intervening interstellar medium. We quantify changes in the diffractive timescale of B1937+21 over months of observations, aided by high-resolution dynamic spectra and secondary spectra from cyclic spectroscopy.

Section E: IPTA session (closed)

Talk 43

Title: **The IPTA Data Release 3: where we are and what's next**

Author: **Kuo Liu**

Affiliation: SHAO

Abstract: The Data Release 3 (DR3) is a currently ongoing key project of the IPTA, receiving active contributions from many collaboration members. The project combines the most recent data from regional PTAs and the largest radio telescopes around the globe, anticipated to produce the most sensitive PTA dataset for gravitational wave searches to date. In this talk, I will present an update on the IPTA DR3 project. I will first give an overview of the DR3, including the early DR3 dataset, and describe the standardized procedures to combine the data from different regional PTAs and conduct noise analysis of the combined dataset. Then I will show the results from the data combination and single-pulsar noise analysis of the v0 EDR3 dataset. In addition, I will summarize lessons learnt from the EDR3 v0 data combination, and enlighten on the improvements that are being implemented in the current round of data combination and analysis. Finally, I will briefly discuss the plan and timeline of DR3 in the upcoming months.

Talk 44

Title: **DR3 update from the GWA**

Author: **Nihan Pol**

Affiliation: Oregon State University

Abstract: General overview of the DR3 projects in the GWA working group. Will co-ordinate with Aurelien and get a more detailed abstract ready soon.

Section F: Astrophysical interpretation/multimessenger astronomy

Talk 45

Title: **Optimizing Host Galaxy Identification of Individual Supermassive Black Hole Binaries**

Author: **Polina Petrov**

Affiliation: Vanderbilt University

Abstract: Supermassive black hole binaries present us with exciting opportunities for multi-messenger science. These binaries are thought to form as a natural consequence of galaxy mergers, with the potential to produce electromagnetic emission as well as individually resolvable continuous waves that can be detected with PTAs. We may find SMBHBs in a wide variety of systems, and each type of system may generate a distinct EM signature, or none at all. While the ambiguity in EM signatures makes direct multi-messenger searches challenging, a valuable approach is to identify the galaxy hosting the SMBHB. The primary challenge in this approach is the level of sky localization we can achieve, which is expected to be relatively poor for the first CW detections. In this talk, I will outline a host galaxy identification pipeline that begins with the injection of a putative binary into a potential host galaxy and simulates an IPTA-DR3-style dataset. The pipeline then searches for and recovers the CW signal, quantifies the localization region and number of galaxies contained therein, and introduces cuts on these galaxies using parameters such as the luminosity distance and total mass of the binary. I will discuss how the results of this pipeline vary for different parameters such as the sky location, GW frequency, inclination angle, and SNR of the injected signal.

Talk 46

Title: **Continuous Wave Predictions and Constraints**

Author: **Emiko Gardiner**

Affiliation: UC Berkeley

Abstract: Assuming that the gravitational wave background is produced by the stochastic overlap of many continuous waves from supermassive black hole (SMBH) binaries, the amplitude and shape of this gravitational wave background (GWB) weakly constrain models for galaxy mergers, SMBH--host galaxy relations, and SMBH binary evolution. We improve these constraints by incorporating the lack of a continuous wave (CW) detection in current pulsar timing array (PTA) observations. CW detectability of a given SMBHB model is assessed by injecting the simulated signal into pulsar times of arrival (toas) and running the simulated pulsar dataset through the full NANOGrav CW detection pipeline. We compare our simulated GWB SNRs to that of the current dataset and look at trends in single source detectability versus model parameters to identify scenarios that can be ruled out by the fact that we haven't confidently detected a CW. Finally, in anticipation of the upcoming International PTA dataset and future observations, we make predictions for the mass, distance, and frequency distribution of the single sources we are likely to detect, as well as estimates for the precision of these future binary properties measurements.

Talk 47

Title: **Constraining the origin of the nanohertz gravitational wave background using a simple, flexible model of black hole evolution**

Author: **Jean Somalwar**

Affiliation: Caltech

Abstract: The nano-Hertz gravitational wave background (GWB) is a key probe of supermassive black hole (SMBH) formation and evolution, if the background arises predominantly from binary SMBHs. The amplitude of the GWB encodes significant astrophysical information about the SMBH binary (SMBHB) population, including the mass and redshift distributions of SMBHBs. Recent results from a number of pulsar timing arrays have identified a common-spectrum noise process that is consistent with a loud GWB signal with amplitude ~1e-15, which is higher than typical predictions. These predictions usually assume theoretically-motivated but highly uncertain prescriptions for SMBH seeding and evolution. In this talk, I will discuss a simple, flexible model of SMBH evolution to explore the possible range of GWB amplitudes, given observational constraints. In particular, we focus on the possible contribution to the GWB from high redshift (z>~1) SMBHBs, for which few robust observational constraints exist. We find that the GWB amplitude may be higher than fiducial predictions by as much as ~0.5 dex if much of the SMBH mass density was established by z~1.

Talk 48

Title: **Electromagnetic signatures from accreting massive black hole binaries in time domain photometric surveys**

Author: **Fabiola Cocchiararo**

Affiliation: University of Milano Bicocca

Abstract: When two galaxies merge, the Massive Black Holes (MBHs) in their centres are expected to migrate toward the centre of the remnant and to form a binary. MBH binaries are expected to produce distinctive observational electromatic (EM) signatures, such as periodically modulated Light Curves, emitted by the accretion of gas around each Black Hole. I present the first computed Spectral Energy Distribution and Light Curves from 3D hyper-Lagrangian resolution hydrodynamic simulations of accreting massive black hole binaries at milli-pc separation. Exploring various parameters, including mass, eccentricities, and mass ratio, the computed flux reveals significant variability, particularly in high-energy regions. Optical flux modulations, crucial for observations by the Vera Rubin Observatory, display periodicities linked to the orbital and half-orbital periods, with additional longer timescales in equal mass binaries. My results suggest that unequal mass and/or eccentric binaries may be identified up to redshifts of 0.5 (for systems with bolometric luminosity of 10^42 erg/s) and 2 (for systems with bolometric luminosity of 10^44 erg/s), possibly pinpoint the origin of gravitational wave background signals observed by pulsar timing arrays experiments. Indeed, the identification of convincing EM counterparts will help pinning down the properties of the emitting systems, thus realising the promises of low frequency multi-messenger astronomy.

Talk 49

Title: **Dual AGN and their imprints on the gravitational wave background: predictions from the ASTRID cosmological simulation**

Author: **Nianyi Chen**

Affiliation: Carnegie Mellon University

Abstract: Active galactic nuclei (AGN) pairs are the precursors of massive black hole (MBH) mergers and the parent population of some of the heaviest MBHs in the high-redshift Universe. Recent observations have just begun to capture a sample of galactic-scale AGN pairs around the cosmic noon. In this talk, I will discuss from the theoretical perspective the electro-magnetic signatures of the high-redshift AGN pairs/multiplets and their subsequent gravitational wave(GW) signals, using the recent large-volume, high-resolution cosmological hydrodynamic simulation ASTRID. Notably, with the updated BH dynamics treatment and the >300Mpc^3 volume, ASTRID provides one of the largest statistical sample of the rare quasar pairs down to kpc scales. I will talk about the distinctive feature of AGN pairs compared to the underlying single AGN population, and the evolution of the pair systems during and after the galaxy merger. I will show that in the most massive halos, MBH pairs often exist in the offset AGN form, with the secondary deactivated by severe gas stripping and stall at ~5kpc for a few hundred Myrs. On the contrary, the pairing to GW emission timescales of dual AGN is typically less than 1Gyrs, and could as short as ~100Myrs for the brightest duals. Finally, I will show the SMBH binary and merger population from the dual AGN, and their imprint on the gravitational background detectable by the pulsar timing arrays.

Talk 50

Title: **Evolution of PTA Sources from Cosmological Initial Conditions**

Author: **Federica Fastidio**

Affiliation: University of Milano-Bicocca, University of Surrey

Abstract: Recent results from pulsar timing arrays (PTAs) have shown evidence for a gravitational wave background (GWB) consistent with a population of unresolved supermassive black hole binaries (BHBs). While the data are not yet constraining enough to draw definitive conclusions, studying the formation and evolution of a realistic population of BHBs can give us important insights into the observed signal. In this context, I will present results from state-of-the-art N-body simulations of galactic mergers with cosmological initial conditions. I have selected mergers of host galaxies to potential PTA sources from the cosmological simulation IllustrisTNG100-1. These tend to occur preferentially on highly eccentric orbits. I have then simulated the galactic merger, binary formation and hardening to separations of order a parsec, using the Fast Multipole Method (FMM) code Griffin. The final evolution to coalescence was then completed via a semi-analytical model. Given the crucial role of eccentric binaries in shaping the observable GWB, I have tracked the eccentricity evolution throughout the merger and assessed whether high eccentricity values are expected upon entry into the PTA band. I will also present accurate

evolutionary timescales for selected binaries and triples formed in consecutive mergers belonging to the same merger tree.

Talk 51

Title: **Efficient gravitational wave background evaluation through neural networks**

Author: **Matteo Bonetti**

Affiliation: University of Milano-Bicocca

Abstract: Supermassive black hole binaries (SMBHBs) are expected to form and evolve in the nuclei of galaxies. The extreme compact nature of such objects determines a loud and efficient emission of Gravitational Waves (GWs), which can be detected by the Pulsar Timing Array (PTA) experiment in the form of a GW Background (GWB), i.e. a superposition of GW signals coming from different sources across the Universe. Modeling the GWB traditionally involves assumptions on binary populations, and exploring the entire parameter space computationally is prohibitive. To address this, we train Neural Networks (NNs) on a semi-analytical model of the GWB generated by an eccentric population of SMBHBs interacting with the stellar environment. These NNs enable us to predict the GW signal characteristics in unexplored parameter regions quickly. Our framework provides insights into the amplitude, shape, and variance of GWB signals across different universe realizations.

Talk 52

Title: **Search for gravitational waves from individual supermassive black hole binaries in MeerTime data**

Author: **Beatrice Eleonora Moreschi**

Affiliation: 'G. Occhialini' Dipartimento di Fisica, Università degli Studi di Milano-Bicocca

Abstract: Although the recent evidence presented by PTAs is that for a stochastic gravitational wave background (GWB) which was most likely produced by the superimposition of a number of GW signals, simulations of the merger history of supermassive black hole binaries (SMBHBs) suggest a narrow possibility of the detection of some of the most massive or fortunately located individual continuous GW (CGW) sources in the highest precision PTA datasets that are currently being generated.

Section G: Unveiling New Physics with Pulsars

Title: **Gravitational waves from the early Universe at PTAs**

Author: **Fabrizio Rompineve**

Affiliation: Universitat Autònoma de Barcelona & IFAE

Abstract: TBD

Talk 53

Title: **Probing primordial black holes with PTAs**

Author: **Sonali Verma**

Affiliation: Universite Libre de Bruxelles (ULB), Brussels, Belgium

Abstract: In this talk, I will consider probing primordial black holes (PBHs) with a broad mass spectrum using the recent PTA signal. An enhanced stochastic gravitational wave (GW) background can result from late PBH binaries in clusters. Additionally, in the standard scenario for PBH production through the enhancement of power spectrum at small scales, second order gravitational waves are also expected. I will consider these various effects and discuss the parameter space of such models probed by the recent PTA signal.

Talk 54

Title: **Targeted searches for supermassive black hole binaries: preliminary results and future directions**

Author: **Chiara Mingarelli**

Affiliation: Yale

Abstract: Here we explore how strong gravitational lensing can act as a tool for increasing the detection prospects of supermassive black hole binaries (SMBHBs) by magnifying fainter sources and bringing them into view. We investigate gravitational wave (GW) signals from SMBHBs that might be detectable with current and future PTAs under the assumption that quasars serve as bright beacons that signal a recent merger. Using the black hole mass function derived from quasars and a physically motivated magnification distribution, we expect to detect a few strongly lensed binary systems out to z ~2. Additionally, for a range of fixed magnifications $2 \leq \mu \leq 100$, strong lensing adds up to ~30 more detectable binaries for PTAs.

Talk 55

Title: **Constraining ultralight dark matter with Pulsar Timing Array**

Author: **Ziqing Xia**

Affiliation: Purple Mountain Observatory, Chinese Academy of Sciences

Abstract: Ultralight dark matter (ULDM) is proposed as a theoretical candidate of dark matter particles with masses of approximately 10^−22 eV. The interactions between ULDM particles and standard model

particles would cause variations in pulse arrival times of millisecond pulsars, which makes the pulsar timing array (PTA) can be used to indirectly detect ULDM. In our first work, we utilize the PPTA to search for dark photon [1]. In the second work, we use the frist gamma-ray PTA (called the Fermi-LAT PTA) to test four ultralight dark matter effects, including gravitational effects for generalized ULDM with different Spin-0/1, the fifth-force coupling effect of dark photon, and the modified gravitational effect of the Spin-2 ULDM [2]. In both works, constraints on ULDM parameters are set with the 95\% confidence level, which provides a complementary check of the non-detection of ULDM for direct detection experiments.

Talk 56

Title: **Constraints on conformal ultralight dark matter couplings from the European Pulsar Timing Array**

Author: **Clemente Smarra**

Affiliation: SISSA

Abstract: Millisecond pulsars are extremely precise celestial clocks: as they rotate, the beamed radio waves emitted along the axis of their magnetic field can be detected with radio telescopes, which allows for tracking subtle changes in the pulsars' rotation periods. We consider a universal conformal coupling of an ultralight dark matter scalar field to gravity, which in turn mediates an effective coupling between pulsars and dark matter. If the dark matter scalar field is changing in time, as expected in the Milky Way, this effective coupling produces a periodic modulation of the pulsar rotational frequency. By studying the time series of observed radio pulses collected by the European Pulsar Timing Array experiment, we present constraints on the coupling of dark matter, improving on existing bounds.

Talk 57

Title: **Using pulsar polarization data to search for fuzzy dark matter signatures**

Author: **Nataliya Porayko**

Affiliation: University of Milano Bicocca

Abstract: Pulsars can be instrumental in solving the puzzle, which has perplexed the minds of the scientific community for almost a century – dark matter. The ultralight scalar field dark matter (also known as "fuzzy" dark matter), consisting of bosons with extremely low masses of m ~ 10^(−22) eV, is one of the compelling dark matter candidates, which solves some of the problems of the conventional cold dark matter hypothesis. As it was shown in Ivanov et al 2019, Castillo et al. 2022 the coupling of axion-like particles to photons alters the polarization properties of light, i.e. the plane of polarization of linearly polarized beam propagating through the axion field starts to oscillate with typical frequencies 10^(-8) – 10^(-5) Hz. High percentage of linear polarization of pulsars along with its negligible intrinsic Faraday rotation in the magnetosphere makes pulsars one of the best and most robust probes of ALP-photon coupling. I am using the full-Stokes archival pulsar data observed as a part of EPTA campaign with two radio telescopes, Effelsberg and Nançay, to search for the ALP dark matter signatures and put the stringent constraints on the coupling constant between photons and ALPs. We discuss the systematics

in pulsar polarization data that can mimic the signal from dark matter and possible methods to avoid the possible biases.

Section H: Non-PTA pulsar science (black widows, pulsar searches, scintillation)

Talk 58

Title: **Unveiling the Enigmatic Behavior of Spider Pulsars: Timing and Polarization Insights**

Author: **Ankita Ghosh**

Affiliation: National Centre For Radio Astrophysics

Abstract: I will present the timing solutions of two millisecond pulsars (MSPs) discovered through the GMRT High-Resolution Southern Sky (GHRSS) survey, PSRs J1242−4712, and J2101−4802. PSR J1242−4712, is a spider MSP, with a minimum companion mass of 0.08 $M_\odot$ and an orbital period of 7.7 hours, and observed eclipses below 360 MHz belongs to the spider pulsar (Ghosh et al. 2024). Observed eclipses and significant orbital period variability suggest that PSR J1242−4712 is possibly not a He−WD binary, but has a semi- or non degenerate companion, indicating a distinct category of spider MSPs, displaying characteristics that bridge the gap between known black widow and redback MSPs. Contrastingly, PSR J2101−4802, with a spin period of 9.48 ms, has a minimum companion mass of 0.12 $M_\odot$ and an orbital period of nearly 1 day which is quite large compared to the known redback population. In addition, I will present the orbital phase-dependent polarization properties of spider pulsars J1242−4712 and J1908+2105 using Parkes UWL observations. PSR J1908+2105, with an orbital period of 3.5 hours and a minimum companion mass of 0.055 solar masses (Deneva et al. 2021), closely resembles black widows but exhibits extensive eclipses covering nearly 40% of its orbit at frequency 400 MHz, akin to redback systems. For J1242−4712, we obtained an average RM of −3.92 ± 1.09 rad/m^2 at 815 MHz. Despite no eclipse detection at this frequency, evidence of eclipsing was observed through intensity and polarization fraction decreases near both superior and inferior conjunctions. At 2368 MHz, J1908+2105 displayed 32% linear polarization during non-eclipse phases, with a notable decrease in intensity and linear polarization fraction around superior conjunction. We found an average RM of 201.30 ± 1.09 rad/m^2, increasing to 230 ± 1.30 rad/m^2 near eclipse phases. We also observed intriguing behavior near eclipse boundaries for PSR J1908+2105, resembling lensing effects, with enhanced flux density and increased brightness in pulsed radiation at uGMRT band−3, which warrant further investigation. We found extensive eclipses (over 30% of its orbit) for this MSP even at frequencies above 3 GHz, suggesting an atypical companion size or dense plasma distribution around it. Such eclipses at high frequencies are exceedingly rare and can aid understanding of rather extreme conditions creating eclipses even above 3 GHz which was not reported for any MSP till now, to our knowledge.

Talk 59

Title: **Discovery of highly scattered pulsars associated with wind nebulae in ASKAP images**

Author: **Adeel Ahmad**

Affiliation: Western Sydney University

Abstract: Recent advancements in radio continuum surveys have facilitated the discovery of pulsars and pulsar wind nebulae (PWNe). Here, we report two of such discoveries. Firstly, PSR J1631–4721, a young pulsar associated with the Galactic SNR G336.7+0.5, detected using the Parkes/Murriyang telescope and potentially associated to a PWN revealed by the Rapid ASKAP Continuum Survey (RACS). With a rotation period of 118 ms, high dispersion measure (DM) of ~876 pc cm−3, spin-down luminosity of 1.3 × 10^36 erg s−1, and a characteristic age of 33 kyr, this pulsar joins the population of energetic Galactic pulsars. Secondly, the detection of a bow-shock PWN, named Potoroo, observed via radio continuum studies with ASKAP and MeerKAT, and its associated young pulsar J1638–4713 detected also with Murriyang telescope. PSR J1638–4713, have the second-highest DM among known pulsars (1553 pc cm−3), a spin period of 65.74 ms, and a spin-down luminosity of E-dot = 6.1 × 1036 erg s−1, the originating supernova remnant is not known so far. The PWN exhibits a cometary morphology and an unusually long projected length of over 21 pc. Due to such a high dispersion measure (DM), the pulse profile of both pulsars experience significant scattering at frequencies below 2 GHz, rendering it effectively undetectable in previous pulsar surveys, particularly at around 1.4 GHz.

Talk 60

Title: **Pulsar variability: a broad-band population perspective**

Author: **Lucy Oswald**

Affiliation: University of Oxford

Abstract:
A key limitation on pulsar timing accuracy is the intrinsic variability of pulsar radio emission. This variability is particularly pronounced for the slow pulsar population, making them the ideal testing ground for understanding its physical origins and so predicting its behaviour. To understand pulsar emission variability, we need to account for how pulse brightness, shape and polarization all evolve with emission frequency, with time, and across the pulsar population. On top of this, pulsar radio emission propagates through the interstellar medium, which delays, shifts and distorts the pulse profiles we observe - this too must be accounted for. In this talk I will give an overview of the challenges to be overcome when working with broad-band radio observations of the pulsar population, and the opportunities these data sets give us for advancing pulsar science.

Talk 61

Title: **Adding Spider Binaries to the Gamma-ray Pulsar Timing Array**

Author: **Colin Clark**

Affiliation: Max Planck Institute for Gravitational Physics (Albert Einstein Institute)

Abstract: Timing of Spider binaries - millisecond pulsars with low-mass non-degenerate stellar companions - can be significantly complicated by two factors: long and often unpredictable radio eclipses,

and significant variability in their orbital periods caused by quadrupole moment variations in the companion stars. However, Spiders host the fastest known pulsars, many of which are excellent timers, provided these issues are manageable. Fortunately, gamma-ray pulsations are unaffected by the diffuse intra-binary eclipsing material, and observations by the Fermi Large Area Telescope provide a long, continuous data set in which to track the complicated orbital variations. In this talk, I will present two new advances that enable us to make the most of this data. The first is a new timing model in which the orbital period variations are treated as a stochastic Gaussian process, whose parameters encode astrophysical information about the variable processes at work inside the companion star. The second is a new Gibbs sampling method, that makes the non-Gaussian gamma-ray timing likelihood analytically tractable, even with this high-dimensional timing model. Together these methods allows us to improve the sensitivity of the Gamma-ray Pulsar Timing Array through the inclusion of several bright Spider binaries.

Talk 62

Title: **Where do neutron stars get their mass from?**

Author: **Marisa Geyer**

Affiliation: University of Cape Town

Abstract: And how did the MeerKAT get its stripes? As in a children's book, observing intriguing phenomena, such as large ranges in neutron star (NS) masses, is just the first step, and in many cases the easier part, of a discovery. Understanding how such phenomena came to be, is far more ambiguous. The Relativistic Binary research programme as part of the Meertime LSP has been actively weighing neutron stars across many relativistic binary systems that contain a pulsating neutron star (or pulsar) and a white dwarf or main sequence companion. Optimal results from high precision pulsar timing analysis are achieved by conducting dedicated orbital campaigns during superior conjunction and often at both at UHF and L-band frequencies. In my talk I will highlight the results of studying a set of relativistic binaries and their implications for NS masses, including PSRs J1933-6211 and PSRs J1902-5105. PSR J1902-5105, analysed as part of a student project collaboration, is the most massive NS yet found in MeerKAT data, and at the edge of challenging NS formation theories. PSR J1933-6211 is a relatively rare system where the analysis of both its kinematic and relativistic orbital parameters, allowed us to fully map the binary's 3D orbital geometry and to obtain accurate mass estimates of both the pulsar and its companion (in spite of the orbital inclination being far from edge-on). These measurements solved the mystery of the nature of PSR J1933-6211's companion, and in analogy to the well-studied PSR J1644-2230 binary strengthens the case for neutron stars being massive not through accreting matter but because, just like how the MeerKAT got its stripes, they were born that way.

Talk 63

Title: **Search and Study of Pulsars in Globular Clusters with FAST and MeerKAT**

Author: **Lei Zhang**

Affiliation: National Astronomical Observatories, Chinese Academy of Sciences

Abstract: Pulsar search is an important foundation for studying compact star astrophysics, gravity test, and detecting nanoherz-frequency gravitational waves. Globular clusters, among the oldest celestial bodies in the universe, are dense stellar clusters and provide ideal environments for astronomers to explore compact

objects' evolution. Conducting high-sensitivity observations and efficient searches for pulsars in globular clusters is the optimal way to discover more high-value millisecond pulsars and exotic pulsar binary systems. In the last few years, the total known population of GC pulsars has increased dramatically, jumping from about 150 objects known in 2018, to more than 300 known today. Such a surge in new discoveries and the consequent "renaissance" of the field has been possible mainly thanks to two major radio facilities that have recently been built: the FAST radio telescope in the northern hemisphere and the MeerKAT radio telescope in the southern hemisphere. In the talk, I will present some major breakthroughs obtained in the science of pulsars in GCs, discuss the challenges that GC observations pose, and report on the main scientific results recently obtained in the field in the recent years.

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Invited speakers

Section A: Updates from different PTAs/Outlook in the future

Talk 64

Title: **SKA : Pulsar science and PTA experiments**

Author: **Bhal Chandra Joshi**

Affiliation: NCRA, Pune/IIT Roorkee India

Abstract: With the start of the construction of the Square Kilometer Array telescope (SKA) recently, a high sensitivity wide-band telescope with concurrent multiple beams in the sky is likely to become operational by the end of the decade. A key science driver for this large telescope is pulsar astrophysics. The main goal of the pulsar science with SKA is to address key fundamental physics questions about the constituents of matter at high density and gravitational astrophysics. Not only the large sensitivity of the telescope enhance the sample of currently known pulsars five folds, it is likely to yield interesting systems to provide a variety of tests of theories of gravity and constrain neutron star equation of state apart from providing a significant sample of accurate millisecond pulsar clocks for gravitational wave astronomy through pulsar timing array experiments. This talk will provide an overview of the SKA, its current state and future timeline. The potential science problems which can be addressed with the SKA will be presented. Towards the end of the presentation, possible configurations for a pulsar timing array experiment for addressing science questions posed by recent evidence of ultra-long wavelength gravitational waves will be discussed to motivate discussions on incorporating SKA data into IPTA data sets.

Talk 65

Title: **Pulsar timing array science with the DSA-2000**

Author: **Vikram Ravi**

Affiliation: Caltech

Abstract: The DSA-2000 is an upcoming radio survey instrument and multi-messenger discovery engine. The array will consist of 2000 5-m dishes operating between 0.7-2 GHz, delivering a sensitivity comparable to the SKA1-Mid but with a substantially greater survey speed. 25% of DSA-2000 observing time will be dedicated to pulsar timing. I will present the project design, status, and prospects for pulsar timing array science.

Section C: GW detection techniques and statistical analysis

Talk 66

Title: **Simple harmonic analysis for PTAs**

Author: **Bruce Allen**

Affiliation: Max Planck Institute for Gravitational Physics

Abstract: PTA harmonic analysis was pioneered in 2014 by Gair, Romano,Taylor, and Mingarelli. Their seminal paper is daunting, full of long equations involving "gradient" and "curl" tensor modes, Wigner matrices, and other esoterica. Here, I outline an easier approach (arXiv:2404.05677) which exploits a beautifully simple formula for the response of a pulsar to a GW. Using it, one can calculate everything of interest for PTA harmonic analysis in just a few lines.

Talk 67

Title: **Pulsar Timing Arrays require Hierarchical Models**

Author: **Rutger van Haasteren**

Affiliation: Albert Einstein Institute Hannover

Abstract: The PTA community has been more or less aware of biases in their analyses for quite some time. This has been addressed with simulations, model selection schemes, and modeling choices that seemingly work, but that are actually inappropriate for PTAs. It turns out, instead, that PTAs will actually need to move away from uninformative priors. I show how the use of Hierarchical Bayesian Models addresses these issues, and I will show how this changes the results of the datasets that were released in 2023.

Talk 68

Title: **Mapping the nanohertz gravitational-wave sky to reveal the origin of the stochastic background**

Author: **Eric Thrane**

Affiliation: Monash University

Abstract: A key question has emerged in the wake of recent observations in pulsar timing astronomy: what is the origin of the nanohertz gravitational-wave background? If the background can be firmly linked to the mergers of supermassive binary black holes, there will be important implications for cosmology: from the evolution of supermassive black holes over cosmic time to the formation of galaxies. On the other hand, if the binary black hole hypothesis can be falsified, this would likely imply new fundamental physics such as a phase transition in the early Universe. In this talk I argue that mapping the gravitational-wave sky is probably our most reliable method for testing the binary black hole hypothesis. I review methodology for "gravitational-wave cartography," and discuss some of the considerations as we seek to determine the origin of the nanohertz background.

Section D: Timing, Noise Modeling and IISM

Talk 69

Title: **Pulsar Scintillation in the Interstellar Zoo**

Author: **Stella Ocker**

Affiliation: Caltech & Carnegie Observatories

Abstract: Pulsars scintillate due to plasma density fluctuations in the interstellar medium (ISM). Scintillation manifests as frequency-dependent pulse intensity modulations, which induce timing errors. While scintillation is typically unresolved by pulsar timing experiments, dedicated high-resolution pulsar observations have revealed that scintillation is often dominated by one or two discrete scattering structures ('screens') traced by parabolic arcs in the secondary spectrum. I will discuss a pulsar scintillation observing campaign conducted at FAST, which has revealed many more scattering structures along pulsar lines-of-sight than seen by less sensitive telescopes. Comparing the distribution of these scattering screens to known ISM structures suggests that pulsar scintillation traces a zoo of ISM features, from stellar bow shocks and HII regions to the nascent turbulence of ionized gas. Characterizing this scattering distribution is especially important for pulsar timing arrays seeking to expand the pulsar sample.

Section F: Astrophysical interpretation/multimessenger astronomy

Talk 70

Title: **Electromagnetic and multi-messenger searches for supermassive black hole binaries**

Author: **Jessie Runnoe**

Affiliation: Vanderbilt University

Abstract: Supermassive black hole binaries are thought to be an inevitable product of the prevailing galaxy evolution scenarios where most massive galaxies host a central black hole and undergo mergers over cosmic time. The early stages of this process have been observed in the form of interacting galaxy pairs and widely separated dual quasars, but the close, gravitationally bound binaries that are expected to follow have proven elusive. The detection of this population is important because at the smallest separations they become bright sources of low-frequency gravitational waves and are prime targets for multi-messenger detections with pulsar timing arrays (PTAs) and the upcoming Laser Interferometer Space Antenna (LISA). In this talk, I will discuss observational signatures of binary supermassive black holes and prospects for multi-messenger detections with electromagnetic facilities and gravitational wave detectors.

Talk 71

Title: **Constraining merger timescales via observations of closely separated pairs of SMBHs**

Author: **Adi Foord**

Affiliation: University of Maryland Baltimore County

Abstract: Dual AGN – or pairs of AGN in merging galaxies at kpc-scale separations – are predicted to be a result of hierarchical galaxy formation and represent unique systems where the link between environment and merger evolution can be probed. The confirmation of many AGN pairs have been made via X-ray observations, but there are less than 50 directly detected pairs of AGN candidates to date, most with physical separations above 1 kpc. As a result, SMBH merger timescales, and the effect of various environmental parameters on these timescales, remain uncertain. I will present new results searching for the hidden population of closely separated dual AGN with Chandra, where using statistical tools on X-ray observations we are finding evidence for dual AGN with physical separations below 1 kpc. Lastly, I will highlight how future high-resolution X-ray observatories will revolutionize our understanding of SMBH mergers via the detection of hundreds of new dual AGN.

Section G: Unveiling New Physics with Pulsars

Talk 72

Title: **The induced gravitational wave interpretation of PTA data**

Author: **Guillem Domenech**

Affiliation: Leibniz University Hannover

Abstract: There are several gravitational wave (GW) signals associated with primordial black holes (PBHs). For instance, the GW background associated with the formation of planet mass PBHs, the so-called induced GWs, has a typical frequency of around nHz. What are the implications for PBHs and primordial fluctuations if we interpret the recent PTA with induced GWs? In this talk, I will explain how induced GWs are generated and their relation to PBHs. Then, I will provide a general overview of the induced GW interpretation of the PTA results. I will also discuss the implications for the PBH counterpart and the physics of the very early universe, considering CMB bounds on GWs and microlensing bounds on PBHs simultaneously.

Talk 73

Title: **Constraining modified gravity with PTA**

Author: **Zu-Cheng Chen**

Affiliation: Hunan Normal University

Abstract: TBD

Talk 74

Title: **Strong-field tests of gravity with radio pulsars/Testing Gravity with Pulsars around Sagittarius A***

Author: **Lijing Shao**

Affiliation: Peking University

Abstract: TBD

Talk 75

Title: **Dark Matter searches with PTAs**

Author: **Andrea Mitridate**

Affiliation: DESY

Abstract: The remarkable sensitivity of Pulsar Timing Arrays (PTAs) can be leveraged to search for spacetime fluctuations induced by sources other than Gravitational Waves. In this talk, I will discuss how we can use PTA data sets to search for the metric perturbations sourced by a variety of Dark Matter models, ranging from sub eV ultralight DM candidates to macroscopic DM halos.

Section I: Synergy between different instruments

Talk 76

Title: **Shedding new light on small-scale perturbation with CMB spectral distortions**

Author: **Jens Chluba**

Affiliation: JBCA

Abstract: CMB spectral distortions provide a powerful probe of early-universe and particle physics. Aside from several guaranteed distortions signals from the late Universe, one of the most important opportunities lies in probing the amplitude of small scale scalar perturbations with the mu distortion created by Silk damping. This opens new way to constrain inflation and also shed light on the primordial black hole formation process and scalar-induced GW signals. In my talk, I will give a brief overview of the broad science with CMB spectral distortions and then highlight some of the immense synergies that arise in combination with other probes.

Talk 77

Title: **A NICER View of Neutron Stars**

Author: **Devarshi Choudhury**

Affiliation: University of Amsterdam

Abstract: Neutron stars provide a unique laboratory for probing the nature of ultradense matter in the universe. NICER, the Neutron Star Interior Composition Explorer is a NASA X-ray telescope aboard the International Space Station designed for Pulse Profile Modeling (PPM) of rotation-powered Millisecond Pulsars (MSPs). PPM exploits relativistic effects on X-rays emitted from the hot magnetic polar caps on the surface of MSPs, allowing us to precisely measure the properties of these neutron stars, especially their masses and radii, providing new insights into dense matter Equations of State (EoS). This technique also lets us map the hot emitting regions, which form as magnetospheric particles slam onto the stellar surface. The science case is strongly enabled through information from PTAs. Precise ephemeris and prior constraints obtained by PTA make PPM an especially powerful technique.

Talk 78

Title: **Gravitational-wave detection with the Roman space telescope and other photometric surveys**

Author: **Kris Pardo**

Affiliation: University of Southern California

Abstract: Gravitational waves have offered us a whole new way of looking at our Universe. So far, we have seen them in the ~10-100 Hz range, and, most recently, in the nanohertz regime. However, there are parts of the frequency space that are currently not covered by any future or planned observations. I will explain how we can use upcoming photometric surveys, like the Roman Space Telescope's Galactic Bulge Time Domain Survey, to bridge the gaps in the spectrum through relative astrometric measurements. Similar to the pulsar timing array measurements, these astrometric measurements rely on the coherent spacetime distortions produced by gravitational waves at Earth. These induce coherent, apparent stellar position changes on the sky. Upcoming photometric surveys will have excellent relative astrometry and timing resolution, which will make them perfect for detecting gravitational waves in the microhertz regime. In this talk, I will discuss this measurement scheme, as well as our concrete steps to develop ideal estimators, and our work to mitigate systematics in real data.

Talk 79

Title: **Unveiling the Solution to the Final-parsec Problem by Combining LISA Observation and Active Galactic Nucleus Survey**

Author: **Xian Chen**

Affiliation: Peking University, P. R. China

Abstract: Massive black hole binaries (MBHBs) could be the loudest gravitational-wave (GW) sources in the millihertz (mHz) GW band, but their dynamical evolution may stall when the black holes reach the innermost parsec of a galaxy. Such a “final-parsec problem” could be solved if an MBHB forms in a gas-rich environment, such as an active galactic nucleus (AGN), but other solutions not involving AGNs also exist. Testing the correlation between these mHz GW sources and AGNs is difficult in real observation because AGNs are ubiquitous. To overcome this difficulty, we use a statistical method, first designed to constrain the host galaxies of stellar-mass binary black holes, to search for the MBHB–AGN correlation in different astrophysical scenarios. We find that by detecting only one MBHB at $z < 0.5$, a mHz GW detector, such as the Laser Interferometer Space Antenna, can already distinguish different merger scenarios thanks to the precise localization of the source. Future detector networks and deeper AGNs surveys can further testify to the MBHB–AGN correlation up to a redshift of about $z=2$ even if only a small fraction of MBHBs merge inside AGNs. These constraints will help settle the long-standing debate on the possible solutions to the final-parsec problem.