Abstracts

IOA50: NEW FRONTIERS OF ASTRONOMY

A CELERATION OF 50 YEARS OF THE INSTITUTE OF ASTRONOMY

IOA50

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IOA50

SCIENTIFIC ORGANISING COMMITTEE

Matthew Bothwell
Anthony Challinor
Cathie Clarke
Anastasia Fialkov
Nikku Madhusudhan
Hiranya Peiris
Max Pettini
Debora Sijacki
Christopher Tout (Chair of SOC)
Mark Wyatt

Monday 22 July, 2024 · 08:30 - 09:15
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Tuesday 23 July, 2024
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- Topics:
- Exoplanets
- Cosmology And Large-Scale Structure
- Galaxy Formation and Evolution: Theory & Observation
- High Energy Astrophysics + TD + GWs
- Stellar Evolution and Galactic Archaeology
- Frontiers
- Questions For The Future

Anders Johansen

Planet Formation and Primordial Atmospheres

Terrestrial planets have traditionally been thought to form by collisions between protoplanets taking place mostly after the dissipation of the protoplanetary disc, on time-scales of 30-100 million years. I present here a new model where rocky planets grow instead by accreting small pebbles in the protoplanetary disc within 3-5 million years. I discuss how the immense pebble accretion heat leads to extensive melting of the growing planets and to the emergence of deep magma oceans. Volatiles such as water, carbon and nitrogen are accreted with the pebbles and partitioned between atmosphere, magma ocean and core. The end of the accretion phase leads to rapid crystallisation of the magma ocean and outgassing of the first atmosphere. I will finally discuss how the atmospheric composition of young planets is key to understanding the origin of life.

NOTES

Jayne Birkby

Exoplanet Atmospheres in High Resolution

In the last two decades, high resolution spectroscopy has emerged as a powerful tool for characterizing exoplanet atmospheres. In this talk, I will highlight its advances in revealing the detailed composition, inhomogeneous structures, and extreme dynamics, including 100 km/s winds, governing the atmospheres of giant exoplanets. I'll showcase its very latest results before then demonstrating its unique power when combined with the large aperture and unparalleled spatial resolution of the Extremely Large Telescopes in the search for biosignatures on the nearest rocky exoplanets.

NOTES

Sasha Hinkley

Characterization of Ice Line Exoplanets Through Direct Imaging

The technique of exoplanet direct imaging is usually regarded as being limited to detecting planetary mass companions at very wide orbital separations of tens, or perhaps hundreds, of AU. However, in this talk I will demonstrate how, using instruments like VLTI/GRAVITY the direct imaging technique is now able to detect, and characterize, exoplanets at ice-line orbital separations of 2-5 AU, co-incident with the peak of the planet distribution as revealed by precision radial velocity surveys. This breakthrough has been best illustrated by our recent characterization of the Beta Pictoris c planet, as well HD206893c using VLTI/GRAVITY. These discoveries demonstrate that exoplanet direct imaging with VLTI instrumentation is now able to detect and characterize planets at ice-line separations of 2-5 AU where these planets are abundant, and likely form. In addition to producing a direct spectrum of these objects, the exquisite astrometric precision of GRAVITY has allowed us to measure precise dynamical masses, allowing a very powerful characterization of these systems. Importantly, potentially thousands more planetary mass companions like HD206893c orbiting nearby stars at ice-line separations are expected to be unveiled with upcoming data releases from Gaia, and only VLT instrumentation (e.g. GRAVITY) will be poised to characterize the young segment of this population. This endeavour will place powerful constraints on the earliest thermal histories of planets---one of the largest remaining uncertainties in the planet formation theories. This opportunity will serve as a powerful precursor for upcoming instruments such as METIS on the 39m Extremely Large Telescope (ELT) in the late 2020's.

NOTES

Farzana Meru

Sandwiched planet formation: restricting he mass of a middle planet

Planetary systems come in all shapes and sizes, with a vast diversity in the properties of the systems. From a simple theoretical perspective, we would expect planetary systems to form with the more massive planets in the outer parts of the system. However, this is not necessarily the case suggesting that sequential planet formation is a complex process. In this talk I will discuss a possible formation scenario whereby a small planet might form and be “sandwiched” in between two more massive planets.

NOTES

Mark Wyatt

The debris disk paradigm

NOTES

Lisa Kaltenegger

Characterizing potentially Earth-like planets -
Exploring the diversity of Rocky Exoplanets

Rocky exoplanets show a diversity of characteristics from their mean density, irradiation, to their and atmospheric composition. Our Solar System provides several rocky objects and a reference spectra catalog, but the critical input for understanding a rocky planet's evolution will come from observations of a sample of known rocky extrasolar planets filling in the pattern. The snapshots of evolutionary stages for rocky exoplanets at different positions throughout and beyond the Habitable Zone we have just started to observe will probe how their position and age influence their diversity and observable spectra.

However, spectroscopy remains time-intensive, and therefore, initial characterization is critical to prioritize targets. Machine Learning algorithms hold a promise to initially identify water and biota on the surface of exoplanets using broad-band filter photometry to aid prioritization of targets for time-intense follow-up observations.

I will highlight key results and challenges to interpreting spectra of rocky exoplanets through this wide parameter space. Telescopes like JWST now and PLATO, Ariel, and ELTs in the near future will probe the parameter space, and a selection of targets that can inform our understanding of rocky planets will be critical to maximizing their observation time and impact of these observations.

NOTES

Andrew Winter

From galactic to planetary scales: the role of of external star formation environment for planet formation

Planets form in discs of dust and gas that persist around the host star on a time-scale of a few Myrs. However, in recent years it has become increasingly clear that the evolution of these discs is dependent on the external star formation environment. In particular, discs are influenced by gravitational perturbation from close stellar encounters, rejuvenation from in-falling interstellar gas, and photoevaporation driven by nearby massive stars. In this talk, I will summarise the theory behind each of these mechanisms and review the observational evidence supporting their relevance. Finally, I will make the case that understanding the formation of the (exo)planet population we observe today is impossible without the context of large-scale star formation environment.

NOTES

Amy Bonsor

Cosmochemical-style insights for exoplanetary systems

We live in an epoch of rocky exoplanet discovery. Yet characterising the interior of these planets remains hard. If we are to truly know what it is like on the surface of these planets or understand their habitability, we need to know what they are made from. The composition of host-stars provides crucial insights - but how does planet formation alter the compositions of exoplanets? By characterising the abundances of planetary material in the atmosphere of a white dwarf with a main-sequence companion, this work provides observations of both planet and host-star compositions. Cosmochemical-style insights are possible for exoplanetary systems. These observations tell us how planet formation altered planetary abundances, in particular quantifying the loss of volatiles. Insights from white dwarf - main-sequence wide binary systems will aid future characterisation of rocky planet interiors based on host-star compositions.

NOTES

George Efstathiou

50 Years of Cosmology

At the birth of the Institute of Astronomy in 1972, the focus of cosmology was still very strongly oriented towards establishing the fundamentals of the hot Big Bang theory. Concepts such as cold dark matter and dark energy would have seemed alien at that time. The formation of structure in the Universe was a mystery and seemed to require physics that violated causality. Looking back, these really were "dark ages". I will review key developments in cosmology that have led to the highly successful Lambda CDM model, emphasising the contributions from members of the IoA. I will also highlight how another important research area at the IoA in 1972, the physics of accretion around massive black holes, has become central to understanding galaxy and structure formation. The interconnections between cosmology and astrophysics will become ever more important in the new era of ambitious surveys of our Universe.

NOTES

Andreu Font-Ribera

Recent highlights from cosmological spectroscopic surveys

Spectroscopic galaxy surveys allow us to map the 3D distribution of matter in the Universe at cosmological scales and over a wide range of redshifts, providing very rich information that is complementary to other cosmological probes. In particular, measurements of baryon acoustic oscillations (BAO) at different redshifts offer very robust constraints on the expansion of the Universe and on the nature of dark energy. In this talk I will present the state-of-the-art in BAO measurements and their cosmological inference, including the final measurements from the Sloan Digital Sky Survey and the first results from the Dark Energy Spectroscopic Instrument.

NOTES

Vid Irsic

Lyman-alpha forest: From small to large scales

In the last decade the Lyman-alpha forest has been established in large spectroscopic surveys as an important probe of cosmology. The clustering measurements at high redshifts contribute both to our knowledge of the expansion history through 3D clustering, as well as the evolution of small-scale structure in 1D clustering. In this talk I will outline some of the new approaches on the road to a unified picture of both the 1D and 3D Lyman-alpha forest, as well as some new results on constraining the cosmological model of the Universe.

NOTES

Keir K. Rogers

Cosmological tests of the nature of dark matter

It is 50 years since the pioneering observations of Vera Rubin and collaborators that shaped a consensus that there is vastly more matter in the Universe than we can directly observe. The fundamental nature of dark matter so far eludes direct-detection experiments, but it has left its imprint in the large-scale structure. Extracting this information requires accurate modelling of structure formation for different dark matter theories, careful handling of astrophysical uncertainties and consistent observations in independent cosmological probes. I will review a multi-scale, multi-epoch test of the nature of dark matter combining observations of the cosmic microwave background (CMB), galaxy clustering (redshift $z < 2$), the Lyman-alpha forest ($2 < z < 5$) and the high-redshift ($z > 5$) galaxy UV luminosity function from the Hubble and Webb Space Telescopes. I will show that both the S_8 cosmological parameter discrepancy and a new five-sigma tension in inference of the small-scale matter power spectrum between Planck CMB and eBOSS Lyman-alpha forest data can be resolved by a contribution of ultra-light axion dark matter with particle masses around 10^{-25} eV. I will discuss prospects for adjudicating the viability of dark matter solutions in observations of the galaxy and Milky Way sub-structure distributions in the transformative Vera Rubin Observatory.

NOTES

Licia Verde

Precision Cosmology: the standard cosmological model and its unreasonable effectiveness

The standard model of cosmology, the Lambda-cold-dark- matter (ΛCDM) model, has been in the making for at least 50 years, was fully established a couple of decades ago and has since been overwhelmingly successful. Its deep links to many branches of fundamental physics indicate that it may be key to understand the ultimate laws of Nature. The parameters of this model are determined with astonishing precision: this is what we refer to as precision cosmology. It is, however, ultimately a phenomenological model: it establishes a robust framework in which some fundamental issues remain unresolved. In particular, the ΛCDM model has several ad-hoc ingredients (e.g., dark energy, dark matter, inflation). It is thus reasonable to expect that the model may be only an effective description to some extent: the dark components of the Universe, dark matter and the component describing the accelerated late-time expansion, may, in reality, be "place holders" for something else, some "new physics", with deep implications for our understanding of fundamental physics and its fundamental particles and interactions.
Finding out what that new physics may be (and what it may not be) has become the ultimate goal of cosmology today. Cosmological observations, and, in particular, of the large-scale structure of the Universe offer a unique window into the fundamental laws at play, and precious insights into the phenomenological ingredients of the model.

NOTES

Ryan Cooke

Primordial nucleosynthesis and the search for new physics

The abundances of the light nuclei created a few minutes after the Big Bang currently provide our earliest tests of cosmology and particle physics. Recent measurements of the primordial abundances have reached percent level precision and – quite amazingly – are in near-perfect agreement with other cosmological measurements. This incredible agreement is a triumph for our understanding of the Universe, and forms the foundations of our cosmological model. In this talk, I will present improved measurements of the primordial helium abundance, and a novel determination of the primordial helium isotope ratio. I will also highlight the importance of reliable primordial abundance measurements in the context of future CMB stage-4 experiments; when jointly analysed, it will become possible to identify or rule out candidate light relics, including sterile neutrinos, axions, gravitinos, or hidden photons to name just a few topical examples. While this subject may seem esoteric, these ideas play a prominent role in our understanding of the greatest unsolved problems in physics, and cannot be tested by collider experiments here on Earth. The next decade will therefore be an interesting moment in time for the future of cosmology and particle physics.

NOTES

Srinivasan Raghunathan

Constraining the Epoch of Reionisation using CMB as the backlight

The Doppler boosting of cosmic microwave background (CMB) photons due to scattering off free electrons in bulk motion produces the kinematic Sunyaev-Zeldovich (kSZ) effect. It offers a unique way to probe the epoch of reionisation (EoR). While several efforts have been carried out in detecting the power spectrum of the kSZ, the uncertainties in astrophysical foregrounds, particularly the contribution from the post-reionisation kSZ signal, has limited the potential of the kSZ as an efficient probe of EoR. On the other hand, the patchy reionisation-kSZ is expected to be highly non-Gaussian and hence moving to higher-point correlations, namely the kSZ trispectrum, has the capability to disentangle the reionisation-kSZ from the post-reionisation signal. In this talk, I will present the first constraints on the EoR from the kSZ trispectrum from the South Pole Telescope (SPT) observations..

NOTES

Alexandra Amon

Weak lensing with a billion galaxies: new opportunities, challenges and strategies

Weak gravitational lensing provides an immense opportunity to test the standard cosmological model and to probe astrophysics. Over the last decade, it has matured as a high-precision tool with on-going surveys like the Dark Energy Survey, which has imaged 5000 sq degrees and 100M galaxies. Intriguingly, weak lensing surveys have consistently reported a mild cosmological tension: low values of the clustering amplitude parameter (S_8) compared to that predicted by Planck's measurements of the primary fluctuations in the cosmic microwave background. On the eve of Rubin Observatory's Legacy Survey of Space and Time (LSST), which will measure weak lensing with billions of galaxies, the challenge is clear: systematics must be controlled to make the most of the next epic decade of data. In this talk, I will present on-going efforts to calibrate observations, in particular, the photometric redshifts of the galaxy sample, and to understand and mitigate astrophysical systematic effects, to maximize weak lensing science. I will demonstrate the pathways to use LSST data to test the cosmological model in the non-linear regime, to constrain baryonic feedback effects, and to measure dwarf galaxies' halo masses.

NOTES

Frank Qu

Precision cosmology from CMB lensing measurements with the Atacama Cosmology Telescope

NOTES

Amélie Saintonge

From cosmic web to molecular clouds: the multiple scales of galaxy evolution

NOTES

Vivienne Wild

How and why do galaxies stop forming stars?

Over the past two decades "post-starburst" galaxies, which have recently and rapidly shut down their star formation, have moved from being an interesting curiosity to a mainstream hot topic. This has been due to the joint realisations that: (a) they are not predominantly a galaxy cluster phenomenon as originally thought, and could be a highly important factor driving galaxy evolution in general, despite their rarity, (b) any non-starforming galaxy at high redshift must be de-facto "post-starburst", piquing the interest of the competitive high-redshift community, (c) at low redshift they are predominantly descendants of galaxy mergers, and (d) the rapid decline of star formation in any massive galactic system is really hard to achieve in current generation galaxy evolution models, unless "AGN feedback" is somehow invoked, making these systems highly constraining on an important unknown component of these models. I will firstly present recent results revealing the significant metallicity enhancement that has occurred in these systems, one route to explain why quiescent galaxies have higher stellar metallicities than star-forming systems of the same mass (Leung, Wild et al. 2023). Secondly, I will highlight areas where galaxy evolution models are failing to reproduce the observational features of post-starburst galaxies, pointing to future directions for productive research and collaboration (Wild et al. in prep). Finally, I hope to be able to include brand new results from high signal-to-noise continuum spectra from the JWST EXCELS programme to reveal the mechanisms behind the quenching of z~2 galaxies – data incoming as I type.

NOTES

Julien Devriendt

The formation of galaxies with cosmological hydrodynamical simulations

Hydrodynamical cosmological simulations increase their level of realism by considering more physical processes, by having more resolution or greater statistics. These simulations (e.g. Eagle, Horizon-AGN, Illustris, Simba, TNG) have met with numerous successes in their ability to reproduce the mass and structural properties of galaxies (mass function, size-mass relationship, morphological mixing, etc.). A new generation of simulations is developing and makes it possible to better capture the multiphase structure of the interstellar medium of galaxies, which poses new challenges to our understanding of these objects. I will review recent developments and results on the properties of galaxies, their evolution and the role of feedback.

NOTES

Andrew Pontzen

Exposing the interplay between feedback and history

A number of hydrodynamical simulations have now succeeded in generating populations of galaxies and black holes that strongly resemble those in the real universe. However, to learn why such successes have been achieved we need to complement these efforts with more targeted simulations which reveal the causal effects that link a galaxy's history to its observable traits such as star formation rate, black hole mass, and gas masses and ionisation states in the interstellar and circumgalactic medium. I will introduce the GMGalaxies programme which, over the last few years, has constructed controlled tests of cosmological galaxy formation, resimulating galaxies in a cosmological context with tightly controlled changes to their history and environment. As an example I will focus on a conundrum: statistically speaking, the formation time of a galaxy can be a good predictor for whether it will be star-forming or quenched. But the actual physical mechanism establishing this link is hard to tease out from a population. By careful experimentation, independently varying the collapse time and the merging history, one may reveal this statistical correlation is an acausal effect arising from the effects of major mergers (Davies, Pontzen & Crain 2024, MNRAS). I will more broadly argue for complementary large volumes and zoom simulations as a means for understanding galaxy formation.

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Christoph Pfrommer

Cosmic ray feedback in galaxies and clusters

Understanding the processes underlying galaxy formation is one of the most important challenges in astrophysics. Unresolved questions include the disconnect between the short time scale of gas collapse on small scales and the long time scale for galaxy evolution, as well as the mechanism responsible for ejecting mass, momentum, and energy out of galaxies (or preventing their infall) in a way that matches the observed scaling relations. Recent progress strongly suggests that cosmic rays may play a crucial role in controlling these processes in and around galaxies. However, the strength of cosmic ray feedback depends very sensitively on the dynamical coupling of cosmic rays to the background plasma. I will review how cosmic rays interact with and propagate through the magnetised plasma in the interstellar and circumgalactic media and how we can observationally test these theoretical considerations using new high-sensitivity MeerKAT observations. I will then demonstrate that cosmic rays play a decisive role in the formation and evolution of spiral galaxies by providing feedback that regulates star formation and drives gas out in galactic winds. Comparing cosmic ray spectra of electrons and protons to observational data and studying the correlation of the far-infrared emission with gamma-ray and radio emission from galaxies enables us to test the cosmic ray feedback models. Finally, cosmic rays accelerated in jets of active galactic nuclei can escape their birth places and heat the plasma at the centres of galaxy clusters. This argues that a complete understanding of galaxy formation necessarily includes these non-thermal components.

NOTES

Eva Schinnerer

A cloud-scale view of the star formation process

The high angular resolution wider field imaging (spectroscopy) capabilities offered by ALMA, VLT/MUSE, HST and most recently JWST have opened the opportunity to map the different stages of the (molecular) gas—star formation—stellar feedback matter cycle in nearby galaxies at unprecedented, that is cloud-scale (~100pc), resolution. For the first time it is possible to resolve populations of molecular clouds, HII regions, and young stellar clusters and associations across the star-forming disks of representative samples of nearby spiral galaxies. I will provide an overview of the new insights gained from these surveys on variations of molecular cloud properties with galactic environment, timescales and efficiencies of cloud and star formation, and the role and impact of stellar feedback on cloud-scales.

NOTES

Steve Finkelstein

Insights into the Early Universe from the First Year of JWST Observations

JWST has revolutionized our understanding of the first billion years of cosmic time, with two major results standing out: a higher abundance of both UV luminous galaxies and early growing super-massive black holes. I will discuss what we expected prior to JWST, and what we have learned since, primarily from the CEERS and NGDEEP surveys (including also results from PRIMER and JADES), and conclude with what is needed to answer these exciting new riddles.

NOTES

Andrew Bunker

JWST at the edge of the Universe - JADES high redshift galaxy spectra with NIRSpec

I will give an overview of the first results on the highest redshift galaxies from the Guaranteed Time Observations of the NIRSpec Instrument Science Team, including those co-ordinated with the NIRCam Team as part of the JWST Advanced Deep Extragalactic Survey (JADES). We have used the multi-object microshutters on NIRSpec to target several thousand galaxies in the GOODS fields, including several hundred at redshifts beyond 6 (within the epoch of reionization). We have recently released to the public the deepest tier of our survey.

NIRSpec spectroscopy at 1-5microns is sensitive to rest-optical emission lines over a wide range of redshifts and means that we can study the evolution of dust attenuation, star formation rates, metallicity, chemical abundances, ionization and excitation mechanism in galaxies out to high redshifts. Our observations have revealed low metallicities, large ionization parameters and high ISM temperatures for galaxies at redshifts beyond 6, indicating dramatic changes in the stellar populations compared with low redshift. We also detect for the first time in spectroscopy evidence for nebular continuum in some galaxies at these redshifts. JADES has spectroscopically confirmed galaxies at redshifts beyond 10 for the first time, including a spectacular spectrum of a galaxy (GN-z11) which unexpectedly has Lyman-alpha in emission, and a super-solar N/O ratio is inferred from rarely-seen high-ionization lines of nitrogen.

NOTES

Manuela Magliocchetti

The clustering properties of high-redshift passive galaxies

One of the elements still missing in our comprehension of the processes that led to the universe as we see it today is related to the mechanisms which gave rise to the population of early-type galaxies. Recent results obtained with JWST reveal more than expected passive galaxies at red-shifts as high as z~7. Furthermore, little is known about the environmental properties of such a high-z population and on how these might relate with more local behaviours.
In order to shed light on this latter issue we investigate the clustering properties of a homogeneous sample of photometrically-selected passive galaxies residing in the 3<z<5 range. We find that these sources are hosted within very massive - $\sim 10^{13}$ $M_\odot$ - dark matter haloes. Such a value is comparable with all those derived for passive galaxies down to the local universe and suggests no evolution in the dark matter content of the hosts of passive galaxies and no evolution in their environmental properties over the past 12.5 Gyr, i.e. during more than 90 per cent of the age of the Universe. This is in striking contrast with what we already know regarding star-forming galaxies which present a strong cosmological evolution from z~4 downwards. We will discuss two plausible galaxy evolutionary scenarios capable of explaining the observed trends.

NOTES

Emma Ryan-Weber

Probing Reionization with high-z metals

Pioneering work conducted at the IoA by Ryan-Weber, Pettini et al (2006; 2009) detected the first intervening carbon absorbers towards the newly discovered redshift 6 quasars. The observations demonstrated that absorption systems could be identified in the near-IR, opening a window to probe metal-enriched diffuse gas at the tail end of the Epoch of Reionization. I'll summarise my team's recent efforts in tracing elements in the early universe using VLT/X-shooter via the EXQR-30 survey towards 42 z~6 quasars. With the benefit of a long lever arm from z=1.9 to 6.4, high sensitivity, resolution, and significant number statistics, the work has shifted from discovery to substantial headway. Metals ions trace both chemical enrichment and the ionization state of the Circumgalactic Medium (CGM). We find that the ionization of the CGM differs significantly over the short period of cosmic time from redshift 5.5 to 6. I'll show how a decline in the incidence of intervening CIV absorbers, coupled with a rise in CII and OI complements current evidence for a late reionization continuing to occur in metal-enriched and therefore biased regions of the Universe. A flat evolution in weak MgII is also found, despite a decline in cosmic metal content. Looking to the future, in direct comparison with JWST, I will demonstrate why medium resolution ground-based spectroscopy is essential for a complete census of the high-z CGM.

NOTES

Andrew Fabian

50 years of X-ray astronomy

Research in X-ray Astronomy has been carried out at IoA for the past 50 years. Observations have featured accreting neutron stars and black holes, supernova remnants and clusters of galaxies. Highlights include cooling flows in clusters, the ideas behind which have recently been revived in a hidden form, and X-ray spectra from matter very close to black holes including the innermost stable circular orbit.

NOTES

Erin Kara

Black hole accretion

In this talk, I will review our current observational understanding of the accretion flows in actively growing black holes in the local universe, through fast X-ray timing and reverberation mapping, and most recently with high-resolution X-ray spectroscopy with the recently launched XRISM observatory. I will also discuss results from recent time domain surveys that are revealing extreme, transient, accretion events, like Tidal Disruption Events and Quasi Periodic Eruptions, that are pushing our models to the limits.

NOTES

Mitch Begelman

From Blazars to Supermassive Black Hole Binaries

The existence of ultrarelativistic jets and supermassive black hole binaries were two topics that were much discussed at IoA during its first decade. They may now be converging in a spectacular and unexpected way. I will discuss emerging evidence for black hole binaries well inside the "final parsec," obtained through radio monitoring of blazars, and its possible implications for both future gravitational wave detections and our understanding of jet physics.

NOTES

Nial Tanvir

Gamma-ray burst science in Cambridge

Gamma-ray bursts (GRBs) were announced to the world in 1973, and so almost share a 50th birthday with the Institute of Astronomy. Since that time, Martin Rees in particular, and a range of visitors and junior researchers have made pivotal contributions to our theoretical understanding of these most extreme explosions, while others have taken part in the observational revolutions that have coloured and punctuated the GRB story. Fifty years on and the field continues to produce an abundance of surprises and puzzles to challenge the next generations of astronomers.

NOTES

Gary Ferland

Cloudy, a Starship to Discover the Universe through Spectroscopy

Cloudy was born at the IoA in August of 1978 when Martin Rees hired me to work with IUE spectra of AGN. The code, named after the East Anglian weather, simultaneously solves the equations describing a non-equilibrium gas's thermal, excitation, ionization, chemical, and radiative properties. These coupled equations rest upon a vast array of microphysical processes and large atomic and molecular databases. The result is a prediction of the full X-ray to radio spectrum. Cloudy was developed to aid my investigations of the chemical evolution of the cosmos and the structure of the inner regions of AGN. It has always been publicly available in keeping with NSF and NASA's public access policies, and the code has become part of the working astronomer's toolkit. Cloudy is Nature Astronomy's first Code of Honour, part of their Access Code series.

NOTES

Sera Markoff

New Horizons: Black Hole Imaging in a Multi-Messenger Universe

The last decade has witnessed some amazing developments in astrophysics and astroparticle physics, not least of which is the ability to see the unseeable via direct images of regions just outside the event horizon of black holes. But how do these images connect to broader questions regarding the workings of accretion in general, or the launching of jets and particle acceleration, that are common to a wide variety of astrophysical phenomena? Starting with the current state-of-the-art, I will look to the coming decade for how these single-frequency images are expanding in several directions: frequency, dynamical range, size, timescale. I will also discuss how the combination of such images with multi-wavelength and particle flux measurements, together with the most recent advances in theory, have the potential to tackle some of the hairiest problems relating to black holes.

NOTES

Douglas Lin

Dynamical evolution of young stars around the supermassive black hole in the Galactic center

Accreting supermassive black holes in Active Galactic Nuclei (AGN) provide the most powerful beacons of light in the Universe. Gaseous disks swirling around them are also sites of ongoing star formation. Today the supermassive black hole Sgr A* in the Galactic Center is surrounded by groups of 1) highly eccentric S stars with small semi-major axis, 2) clockwise-disk stars at larger distances, and 3) surrounded by off-disk stars with high eccentricity and inclinations. Based on similar age constraints for these stars, they were presumably formed coevally in a common disk which has been severely depleted through viscous accretion and powerful outflows. Subsequent dynamical relaxation alone cannot lead to the observed kinematic distribution within their a few Myr life spans. We show quantitatively that the von Zipple-Lidov-Kozai and sweeping secular resonance of a likely intermediate-mass companion can lead to their complex kinematic assortment as well as some tidal disruption events and the ejection of hyper-velocity stars.

NOTES

Hannah Übler

Massive black holes during the first billion years revealed by JWST/NIRSpec-IFU

We present results from the JWST/NIRSpec-IFU GTO survey GA-NIFS on broad-line AGN within the first billion years of cosmic time. We discuss our results in the context of other high-z AGN found in the NIRCam+NIRSpec GTO survey JADES and other JWST programmes, specifically the potential role of mergers for early black hole feeding, and the impact of black hole feedback on host galaxy and surroundings in the form of powerful outflows.

NOTES

John Regan

Seeding the Massive Black Holes Observed at High-z

JWST has extended the massive black hole spectrum to both lower masses (M_{BH}˜ 1e6 M☉) and to higher redshifts (z > 10). The question of what the progenitors are for these massive (central) black holes however remains unclear. The community has focused on two mainstream pathways - one where massive black holes are seeded by so-called light seeds, where the initial masses are less than 1000 M☉, and one where the seeds are rarer but much more massive - so-called heavy seeds with masses in excess of 1000 Msolar and perhaps up to 1e5 Msolar. In this talk I will outline the case for both light and heavy seed black holes from a theoretical and computational perspective and detail the challenges each model faces. I will also argue that bursts of super-Eddington accretion may also be possible albeit only for relatively massive seeds. In any case this rapid growth may be required for black holes to achieve the masses seen in the spectra of more recent JWST observations.

NOTES

Julie Hlavacek-Larrondo

AGN Feedback in Galaxy Clusters: A 10 Billion Year Journey

Galaxy clusters are fantastic laboratories for understanding the physics of AGN feedback. They have been instrumental in enhancing ourunderstanding of jet/radio-mode feedback, illustrating how AGN-driven jets transfer substantial energy to their surroundings. This energy transfer occurs through mechanisms such as shock fronts, sound waves, and turbulence, alongside driving significant molecular outflows and dispersing metals out of galaxies. In this talk, I will review the current landscape of this field, with a special focus on the evolution of such AGN feedback over the past 10 billion years. I will also introduce state-of-the-art observations, showcasing for the first time the capacity of AGN-driven jets to initiate the formation of multiphase gas within galaxy clusters. Finally, I will present new XRISM observations that offer an unprecedented perspective on the dynamics of intracluster gas. These observations are pivotal in understanding how AGN-driven jets not only heat this gas but also contribute to its overall energy dynamics within galaxy clusters.

NOTES

Martin Bourne

Simulating SMBHs from event horizon to the cosmic web

Processes, from accretion and feedback production close to the black hole (BH) event horizon out to galactic scales on which feedback acts, span a vast dynamic range that is currently unfeasible to capture entirely in simulations. However, recent developments in numerical techniques mean that we are closer than ever to spanning the gap. I will present our latest results from a range of simulations performed with the moving-mesh code AREPO that combine super-Lagrangian refinement (SLR, which improves resolution around the BH) with novel models for accretion and launching high-resolution jets and winds that afford new opportunities to study BH physics and how feedback behaves on a vast range of scales. On small scales, this includes detailed modelling of binary BHs in gas-rich circumbinary discs, which thanks to SLR capture gas streams and mini-discs that form around the individual BHs that contribute to torquing the binary. We additionally track BH spin evolution (thanks to our sub-grid accretion disc models) and predict spin alignment timescales that have implications for recoil velocities and gravitational wave observations. On larger scales simulations of galaxies and clusters that include high-resolution jets and winds injected close to the BH that propagate to and influence large scales, unveil in unprecedented detail how AGN feedback interacts with and shapes galaxies, groups and clusters, as well as implications for cosmology.

NOTES

Alis Deason

The Mass Assembly of the Milky Way

The Gaia mission has revolutionized our view of the Milky Way and its satellite citizens. The field of Galactic Archaeology has been piecing together the formation and evolution of the Galaxy for decades, and we have made great strides, with often limited data, towards discovering and characterizing the subcomponents of the Galaxy and its building blocks. Now, the exquisite 6D phase-space plus chemical information from Gaia and its complementary spectroscopic surveys has handed us a plethora of data to pour over as we move towards a quantitative rather than qualitative view of the Galaxy and its progenitors. I will discuss our current views on the mass assembly history of the Galaxy in the post-Gaia era, and examine how we can quantify the entire mass spectrum of Galactic halo progenitors in the near future.

NOTES

Keith Hawkins

Galactic Archeology and Cartography in the Gaia Era

One of the key objectives of modern astrophysics is to understand the formation and evolution of galaxies. The Milky Way is an optimal laboratory for testing our theories of galaxy formation. However, dissecting the assembly history of the Galaxy requires a detailed mapping of the structural, dynamical chemical, and age distributions of its stellar populations. Recently, we have entered an era of large spectroscopic and astrometric surveys which has begun to pave the way for the exciting advancements in this field. Combining data from the many multi-object spectroscopic surveys already underway and the rich dataset from Gaia will undoubtedly be the way forward in order to disentangle the full chemo-dynamical history of our Galaxy. In this talk, I will discuss several works in Galactic archaeology and efforts to chemically map the Galaxy and how these studies can be used to learn about the structure and cosmic history of the Milky Way.

NOTES

Anke Ardern-Arentsen

The ancient heart of the Milky Way

Early galaxy formation is not only probed by high redshift observations. The oldest stars the Milky Way also provide a unique window into the era of the first galaxies. The most metal-poor stars still around today were born in pristine environments in the early Universe. Extremely metal-poor low-mass stars are typically found in the Galactic halo, where our searches have been focused, but the very oldest metal-poor stars are expected to be located in innermost regions of the Milky Way. In recent years we have finally started to explore the metal-poor inner Galaxy thanks to dedicated metal-poor searches and data from the Gaia mission. I will summarise what we have learned about this ancient Milky Way component, focusing on results from the Pristine Inner Galaxy Survey (PIGS), the largest spectroscopic survey of the metal-poor inner Milky Way to date. The kinematics and chemistry of metal-poor stars in the Milky Way can put new constraints on early star and galaxy formation.

NOTES

Jason Sanders

Disentangling the history of our Galaxy in the era of Gaia

The study of the Milky Way has been revolutionised by the precision astrometry from Gaia accompanied with the detailed chemical view provided by large-scale spectroscopic surveys. With this data we are beginning to piece together the series of events that formed the Milky Way, from the collection of early merges that now populate the stellar halo of the Galaxy to the recent perturbations to the Milky Way from the Sagittarius dwarf galaxy and the Magellanic Clouds. In this timeline of key events we also have to place the time at which the bar formed. The bar is an important dynamical driver in the Galaxy but its fundamental properties, such as rotation rate and formation time, are still debated. I will discuss work on understanding the epoch of bar formation in the Milky Way focusing on the use of variable stars, the study of the related nuclear stellar disc structure in the Milky Way and the complementary nature of Gaia and ground-based infrared astrometric surveys.

NOTES

Denis Erkal

A global view of the Milky Way's dark halo with stellar streams

Stellar streams form as globular clusters and dwarf galaxies tidally disrupt in the Milky Way. They roughly trace out orbits allowing us to map out the gravitational potential of the Milky Way. With the S5 survey, we have mapped out more than a dozen stellar streams in the southern hemisphere. I will present fits to these streams including the effect of the Large Magellanic Cloud, the Milky Way's biggest satellite and the main perturber of streams. Because these streams span a range of locations in the Milky Way, they allow us to test the consistency of the inferred gravitational potential. Interestingly, the most constraining of these streams, the Orphan-Chenab stream, prefers a strongly triaxial Milky Way halo while the remaining streams prefer a mildly oblate Milky Way. Part of this discrepancy is likely due to the fact that both the Milky Way and LMC are deforming in the presence of each other. I will end with a discussion of how we can account for these effects in future fits of Milky Way streams to robustly measure our Galaxy's shape.

NOTES

Chiaki Kobayashi

The Origin of Elements and the Evolution of Galaxies

Stars are fossils that retain the history of their host galaxies. As Fred Hoyle predicted, carbon and heavier elements are created inside stars and are ejected when they die. Iron-peak elements are produced by binaries — type Ia supernovae. Elements heavier than iron, such as gold, can be produced by neutron star merges, although these alone cannot explain the observed r-process elements in the Milky Way. Elemental abundances of stars, together with kinematics from the Gaia satellite, have been extremely useful to constrain the star formation and chemical enrichment history of the Galaxy. This approach, Galactic Archaeology, can also be applied to external galaxies thanks to spectroscopic surveys. To compare with these observations we have been running hydrodynamical simulations modelling detailed chemical evolution from cosmological initial conditions. Metallicity is higher in more massive galaxies, leading to a mass-metallicity relation, and at the centre of galaxies, causing metallicity radial gradients. Simulations can successfully reproduce these relations at the current epoch but not at higher redshifts. This is probably due to our incomplete understanding of feedback from stars and active galactic nuclei. Moreover, unexpected elemental-abundance ratios have been detected at high redshift by the James Webb Space Telescope. These indicate stochastic star formation and inhomogeneous chemical enrichment in the early Universe. Elemental abundances are also measured in detail in the intergalactic medium and intracluster medium, and we do not yet have a chemical evolution model that can explain everything.

NOTES

Jim Fuller

Red Supergiant Boil-off

The mass loss mechanism of red supergiant stars is not well understood even though it has crucial consequences for their stellar evolution and the appearance of supernovae that occur upon core-collapse. I will show that shock waves launched from the stellar surface can support a massive chromosphere between the star's surface and the dust formation radius at several stellar radii. By computing the time-averaged density profile of the chromosphere, I derive approximate mass loss rates due to dust-driven winds launched at the dust formation radius. These mass loss rates are compatible with recent observations, explaining the upward kink in mass loss rates of luminous RSGs. This model predicts that low-mass red supergiants lose less mass than commonly assumed, while high-mass red supergiants lose more. The massive chromosphere can also help explain the early light curves and spectra of type-II P supernovae without requiring extreme pre-supernova mass loss or outbursts.

NOTES

Avishai Gilkis

Exploding Wolf-Rayet Stars - Wanted: Dead or Alive

Wolf-Rayet (WR) stars are an advanced evolutionary stage of hydrogen-deficient massive stars, with very hot temperatures and high wind mass-loss rates derived from their spectra. Observed WR stars are inferred to have cores that might be too massive to explode but rather collapse to black holes with no supernovae at the end of their evolution. Yet, some hydrogen-poor supernovae exhibit spectral signatures that indicate that the progenitor star had a wind reminiscent of WR stars. I propose that exploding WR stars are not those that are observed, but rather less massive helium stars whose hydrogen envelope was stripped by binary interaction. The wind mass-loss rate from these stripped stars becomes high only in their final evolutionary stages, after core helium burning has ended. Intermediate-mass helium stars have been recently discovered in the Local Group and I show, with detailed binary stellar evolution models, that their future evolution can lead to a short-lived WR phase of only a few millennia, in contrast to hundreds of millennia of their more massive WR siblings. These hypothetical lightweight WR stars can account for observed properties of stripped-envelope supernovae, while comprising only a minority of living WR stars.

NOTES

Jan Eldridge

Will we ever work out how binary stars evolve?

Binary stars have been known about for centuries. The binary nature of Algol was first suggested in 1783. However, it is only over the last few decades that their use in understanding galaxies and the Universe has become key. For example, they provide enough photons to reionized the Universe and explain the spectra of high redshift galaxies and the populations of stars and supernovae more locally.

However, there is still much to learn about the evolution binary stars in the next 50 years! Here I shall talk about how mass transfer in binaries is likely to be much more stable than previously thought and the implications of this for stellar populations, supernovae and gravitational wave transients.

NOTES

Zhanwen Han

Exploring Common Envelope Phases and Binary Populations through LAMOST Spectroscopic Survey

Binary star systems play a pivotal role in the understanding of Type Ia supernovae and the sources of gravitational waves. Although the concept of common envelope evolution has been discussed for five decades and is widely accepted to explain the formation of compact binaries, direct observations have proven challenging. In this study, we present groundbreaking evidence of a detected ejected common envelope around a hot subdwarf binary system. Furthermore, our analysis reveals the prevalence of common-envelope remnants around 336 hot subdwarf stars identified in LAMOST spectra. Using data from LAMOST-MRS DR6 & DR7, we not only confirm the existence of these common-envelope remnants but also derive crucial properties of binary populations. Our findings include insights into binary fraction, orbital period distribution, mass ratio distribution, and their correlations with spectral types, thus providing a comprehensive understanding of the observed binary systems.

NOTES

Carlos Frenk

Who will survive for longer, CDM or the IoA?

The Lambda cold dark matter (LCDM) cosmological model is one of the great achievements in physics of the past thirty years. Theoretical predictions formulated in the 1980s (partly at the IoA) turned out to agree remarkably well with measurements, performed decades later, of the galaxy distribution and the temperature structure of the cosmic microwave background radiation. Yet, these successes do not inform us directly about the nature of the dark matter or the dark energy. This manifests itself both on large and small scales where apparent contradictions between LCDM predictions and some observations have led to the perception of “tensions” on large scales and a “crisis” on small scales. I will discuss these perceptions focusing on small scales and discuss forthcoming observations that could conclusively rule out LCDM.

NOTES

Risa Wechsler

Connecting Light and Dark across Time and Space

The relationship between the evolution of cosmic structure and the galaxies that form within it is central to our modern understanding of cosmology, galaxy formation, and the physics of dark matter. Advances in large simulations and cosmic surveys over the past two decades have led to a range of powerful modeling approaches that leverage and inform this relationship. I will discuss recent advances and current challenges in connecting the visible and dark universe, and how this might evolve in the next decade of rapidly advancing cosmic surveys to push forward our understanding of cosmic evolution, galaxy formation, and dark matter.

NOTES

Ofer Lahav

AI for cosmological experiments: evolution or revolution?

Could Machine Learning (ML) make fundamental discoveries and tackle unsolved problems in cosmology? To test further and understand the Lambda cold dark matter model, large new surveys of billions of galaxies (e.g., DESI, Euclid and LSST-Rubin) and other probes require new statistical approaches. In recent years the power of ML, and in particular "Deep Learning", has been demonstrated for object classification, photometric redshifts, anomaly detection, enhanced simulations, and inference of cosmological parameters. It is argued that the more traditional "shallow learning" (i.e., with pre-processing feature extraction) is actually quite deep, as it brings in human knowledge, while "deep learning" might be perceived as a black box, unless supplemented by explainability tools. The "killer" applications of ML for cosmology are still to come. New ways to train the next generation of scientists for the data-intensive-science challenges ahead are also discussed.

NOTES

Leon Koopmans

21-cm Cosmology from Earth to the Moon

Observations of the first luminous structures, with ground and space-based telescopes, are slowly lifting the veil on the complex physical processes that governed the cosmic dawn and epoch of reionization. These observations, most recently with JWST reaching redshifts well into the cosmic dawn, however, are only the tip of the iceberg: islands in a sea of neutral hydrogen.

I will present the current status of the LOFAR Epoch of Reionization Key-Science Program, presenting our latest improved power-spectrum limits on the 21-cm signal of neutral hydrogen, the constraints it sets on the high-redshift intergalactic, and present several breakthroughs in our understanding of the data itself. I will also show the latest results from the NenuFAR Cosmic Dawn Key-Science Program, which aims to measure the 21-cm signal from the cosmic dawn. I will place these results in context of SKA and our plans to push towards 21-cm cosmology of the dark ages using space-based receivers, such as DEX, currently an ESA pre-phase-A concept for a radio telescope to be placed on the lunar far-side.

NOTES

Stephen Taylor

Hunting Supermassive Black-hole Binaries: The Next Frontier In Multi-messenger Astrophysics

Just over one year ago, pulsar-timing array collaborations around the world announced evidence for gravitational waves with periods of years to decades. This signal is consistent with being an isotropic background, yet the origin may be a population of supermassive black-hole binary signals, all summing incoherently. As datasets are updated and techniques sharpen, the next milestone in this field will be resolving an individual binary signal out of this confusion background, characterizing its parameters and orbit, and searching for host galaxies or electromagnetic counterpart signals. I will discuss current and future prospects for these efforts to improve our knowledge of black-hole binary systems at the most extreme mass scales.

NOTES

Chiara Mingarelli

Frontiers of pulsar timing array experiments

Recently evidence has been announced of a low-frequency gravitational wave background, manifesting in pulsar timing array experiments all over the world. Here I will give an overview of the current results, and future directions of the field.

NOTES

Thorsten Naab

14 orders of magnitude - from the multi-phase ISM to IMBH formation

The rapid collision of stars and compact objects in young, dense and massive star clusters has been proposed in the late 70's by Rees as a formation channel for the first massive black holes as the seeds for supermassive black holes. Confirming this process with numerical models has been a challenge since then. A self-consistent model following the formation of a galactic star cluster in a massive gas cloud down to the coalescence of black holes would have to cover more than 14 orders of magnitude in spatial resolution and complex physical processes. We present recent progress in high-resolution hydrodynamical simulations of the formation of compact massive star clusters in galactic starbursts with resolved multi-phase ISM and individually sampled stars. With accurate N-body simulations of such compact star clusters we show that stellar and compact object collisions can result in the formation of massive black holes consistent with recent gravitational wave detections. We discuss successes and limitations of novel simulations techniques which will eventually bridge the gap between galaxy formation, interstellar medium, star formation and stellar evolution studies. Such approaches are required for a comprehensive understanding the formation of massive black holes – a fundamental science question in the era of JWST, ELT and gravitational wave detectors.

NOTES

Jim Stone

Modeling Luminous Accretion Flows Around Black Holes

New general relativistic MHD models of black hole accretion flows in luminous systems (such as quasars and X-ray binaries) that include full radiation transport will be described. These models are designed to study the steady-state structure of the accretion disk near the horizon, and the effect of radiation on the launching of relativistic jets from spinning black holes. Moreover, they enable not only the interpretation of the spectra and variability of these sources, but also predictions about the rate of growth of black holes in the early universe, and measurement of the energy and momentum feedback into the surrounding medium, a
process likely to be important in galaxy formation.

NOTES

Chris Reynolds

The Future of High-Energy Astrophysics

High-energy astrophysics has reached an interesting inflection point. Our increasing realisation of the richness of the transient sky and the technological developments permitting genuine multi-messenger astronomy are rapidly transforming our view of nature's most energetic and violent events. At the same time, high-energy astrophysics (and X-ray astronomy in particular) have proven critical in understanding the feedback processes that shape galaxy (and maybe stellar) evolution. In this talk, I shall review the prospects for high-energy astrophysics in the 2030s and beyond. I shall emphasise on the ongoing and planned future X-ray astronomy projects, including the synergies that they will have with other major developments in astronomy in the 2030s.

NOTES

Eloy de Lera Acedo

21st century radio astronomy - the next 50 years

I will present a summary of the state of the art in radio astronomy in the third decade of the 21st century and then I will describe the prospects for radio astronomy for the next 50 years. I will especially focus on the role of Cambridge in mapping the bright future of radio astronomy that SKAO will enable.

NOTES

Sandro Tacchella

Frontiers of galaxies: from star formation in the first galaxies to the assembly of mature systems

I will give an overview of the recent JWST results regarding star formation, morphology and black hole evolution in the earliest galaxies known to us. I will highlight that some of these first galaxies are surprisingly UV bright. While accreting black holes can play a role in boosting the brightness of these systems, several systems are dominated by intense star formation. By linking star formation, metallicity and emission line properties, I will discuss how galaxies undergo bursty star formation with short duty cycles that can lead to mini-quenched galaxies. In the second part of my talk, I will discuss key open questions in galaxy formation and how physical processes acting in individual galaxies can be constrained from population-wide statistics and scaling laws. Specifically, I will focus on the new spectrograph MOONS that will revolutionize our understanding how galaxies grow in the cosmic web during the Cosmic Noon epoch. I will end by giving an outlook to exciting science with ELT.

NOTES

Matthew Bate

Predicting the variation of stellar properties using simulations of star cluster formation

I will discuss how hydrodynamical simulations of star formation are being used to predict how stellar properties such as the stellar initial mass function (IMF) and binary star properties vary with molecular cloud properties and environment. In particular, I will discuss recent progress in understanding how stellar properties may vary with the metallicity and density of molecular clouds, and with the redshift at which the stars form. I will also discuss the implications of such variable IMFs for galaxy formation and properties, for example the inferred masses of high-redshift galaxies, and the central regions of elliptical galaxies.

NOTES

Raymond Pierrehumbert

What do atmospheric observations tell us about the interiors of subNeptunes?

Astronomical observations directly probe the properties of only the outer portions of a planet's atmosphere. When both mass and radius observations are available, the resulting mean density provides further, though highly degenerate, constraints on the composition of the interior. In this talk, I will discuss the kinds of inferences that can be drawn when the two kinds of information are put together. The emphasis will be on planets whose fluid layer is composed of H_2 and H_2O with various proportions, potentially interacting with a silicate core. An important physical consideration constraining plausible interior structures is that for liquid water interiors, the solubility of H_2 is constrained by Henry's Law solubility, whereas for supercritical water interiors H_2 (and other gases) are completely miscible with the interior. We will discuss the range of possible H_2:H_2O ratios in the outer atmosphere that can be compatible with a supercritical water atmosphere. Although an H_2 layer is miscible with a supercritical water interior, there is a stable density jump at the interface, which inhibits mixing between the two layers; an essential missing piece of the puzzle is the quantification of the rate of such mixing. Once mixing begins, the moistening of the H_2 layer leads to additional phenomena, including both water vapour feedback and generation of steep radiative layers near the interface through compositional stabilization of the lower atmosphere. I will also discuss thermal evolution models and implications of interaction of the H_2:H_2O fluid layer with a basal magma ocean. K2-18b and GJ1214b will be used as the archetypes of two very different types of subNeptunes, but I will also discuss results from a recent JWST survey of subNeptunes selected to have densities compatible with a potentially H_2O-rich composition.

NOTES

Neil Turok

A minimal SM/LCDM cosmology

The LCDM model has so far provided a remarkably economical and complete description of cosmology. The Standard Model (including RH neutrinos) has achieved similar success in particle physics. In contrast, attempts to build realistic unified theories have become increasingly complex and contrived. As the observational constraints have tightened, theories have retreated into seemingly peculiar corners of parameter space. I will briefly review several new, more minimal and predictive theoretical pictures. In particular, in a CPT-symmetric universe, calculations of the gravitational entropy explain why flat, homogeneous and isotropic universes are thermodynamically preferred, rendering inflation unnecessary. The dark matter is also explained minimally, as consisting of stable, right-handed neutrinos. A new mechanism cancels the vacuum energy divergence and the trace anomalies in the Standard Model, without supersymmetry or strings, allowing the big bang singularity to be resolved. The same mechanism turns out to predict Gaussian, scale-invariant, adiabatic, scalar fluctuations with their amplitude and tilt predicted in terms of Standard Model couplings and in close agreement with observation.

NOTES

Volker Springel

Next generation galaxy formation simulations: challenges and opportunities

Numerical simulations of cosmic structure formation have become a uniquely powerful tool for studying galaxy formation. Starting right after the Big Bang, they predict the dark matter backbone of the cosmic web far into the non-linear regime and follow complex galaxy formation physics with rapidly improving fidelity. However, much of the relevant physics is still represented in a highly approximate fashion if not missing entirely. I will critically discuss current methodologies and highlight the challenges involved in obtaining future multi-physics, multi-scale simulations that aim for more reliable and predictive simulations. The landscape of this work is also profoundly affected by current technological trends, ranging from GPU- and exascale computing to applications of machine learning.

NOTES

Carole Mundell

From near-Earth to the fabric of space time - cosmic journies to the 2050s with the European Space Agency

This talk will (a) celebrate the foundational past 50 years of European Space Science led by the European Space Agency and its member states, (b) look to the near future of the space science programme and (c) open the opportunities to the 2040s and beyond. From near-Earth heliophysics to probing the nature of space-time itself with the first space-based gravitational wave interferometer, astrophysics, space and planetary science is at a unique intersection for fundamental discovery. The talk will also touch on the technology frontiers required to open new windows on the Universe and the synergy with upcoming new ground-based facilities.

NOTES

Sara Seager

In Pursuit of the Elusive: The Search for Exoplanet Biosignature Gases

The search for signs of life beyond Earth is a key motivator in exoplanet research. A suitable "biosignature gas" is one that: can accumulate in an atmosphere against atmospheric radicals and other sinks; has strong atmospheric spectral features; and has limited abiological false positives. We now have a long list of potential biosignature gases including isoprene which is produced by life in as high quantities as methane, and phosphine which on Earth is only associated with life. Despite promise from the successfully operational JWST, we are now confronted with practical challenges of tiny signals and M dwarf star contamination. Another severe challenge is the unknown exoplanetary environments likely vastly different from Solar System planets. We review the thousands of molecules produced by life on Earth in context with the phosphine on Venus and methane on Mars prescient backdrop for a reality check on the future of exoplanet biosignature gases. Our pace and history of milestone discovery in exoplanets in the last three decads, combined with new telescope paradigms, promises to eventually deliver on finding signs of life beyond Earth.

NOTES

Ann Zabludoff

The Future of AI in Astronomy: Our Tool, Our Partner, Our Replacement?

What can AI do for Astronomy now? What might it do in the next few years? Most importantly, what do we want it to do? Is it simply a better tool to solve Big Data engineering problems "where we don't know or care about the physics" or will it achieve new discoveries from extraordinarily efficient fishing expeditions or even applications of the scientific method? Will it do all that with us or without us? We do not yet know the answers to most of these questions, but we can speculate and develop strategies for leveraging the tremendous investments being made in this revolutionary technology. We can start by making friends with our computer scientist and industry colleagues, developing a common language (perhaps using AI to communicate better), and finding research directions of mutual interest.

NOTES

POSTER ABSTRACTS

POSTER ABSTRACTS

Poster Session:
Tuesday 23 July, 17:30 - 18:30
in the Hoyle common area

CONTENTS

TUESDAY 23 JULY 2024

SN2023ixf: the most detailed flash spectroscopy event observed from the Canary observatories

David Aguado - Instituto de Astrofísica de Canarias

Explore the early stages of SN2023ixf, a Type II supernova in galaxy M101. With its proximity, we obtained unprecedented characterization, acquiring high-resolution spectra just 2 days post-explosion using MEGARA, FIES, and ultra-stable HARPS (R=115,000). Over three months, we monitored SN2023ixf's evolution, revealing rich flash spectroscopy features and dynamics of the circumstellar medium. Our dataset enabled modeling of observed radiative acceleration and mapping of narrow absorption lines, offering insights into the complex environment. We will present these groundbreaking data at the conference, promising long-term contributions to celestial understanding.

How do massive galaxies become quiescent? AGN feedback at z=3--5 from JWST

Francesco D'Eugenio - Institute of Astronomy, University of Cambridge

Massive galaxies are thought to be quenched by feedback from accreting supermassive black holes. Before JWST, we thought that the main mechanism was preventive feedback through halo heating, but the discovery of quiescent galaxies at high redshift requires fast, efficient feedback already in the first Gyr after the Big Bang.

We present JWST observations of a massive, post-starburst galaxy at z=3 hosting an X-ray AGN. We show that the system is undergoing fast, neutral-gas outflows with high mass loading, while the ionised-phase outflow (while still present) has low mass-outflow rate. This demonstrates the ability of AGN to keep quenched galaxies from forming stars *after* they became quiescent, with outflows that have been missed -- before JWST -- due to the challenge of observing neutral gas.

We will then present a strong shock in a lower-mass star-forming galaxy at z=4.5 hosting a low-power radio AGN. The high-equivalent width of low-ionisation chemical species is similar to low-excitation radio galaxies; we interpret the lack of high-ionisation species as due to the shock running out of pre-shock gas. We measure simultaneously the star-formation history (SFH) and shocked-gas properties using a Bayesian framework, and infer solar metallicity and a flat SFR in the last 200 Myr.

Combining the energetics of the ionised gas and the SFH we conclude that the radio-AGN is poorly coupled with the galaxy star-forming disc, therefore feedback must end up in the galaxy halo, setting the stage for future preventive quenching.

Radiation hydrodynamic (RHD) simulations of self-gravitating young circumstellar disks

Hongping Deng - Shanghai Astronomical Observatory

Early circumstellar disks are massive compared to the infant star and thus susceptible to gravitational instability (GI) which largely determines the early evolution of disks. In addition, planet formation may occur via disk fragmentation in early circumstellar disks. However, GI is sensitive to the efficiency of radiative cooling, which determines whether disk fragments and how the fragmented clumps evolve. We implemented the state-of-the-art meshless RHD scheme with the M1 closure in the GIZMO code to treat radiation transport self-consistently. The method is well-tested and exhibits 2nd-order convergence. We observe disk fragmentation in our preliminary RHD simulations.

Adiabatic mass-loss model and applications in related binary objects

Hongwei Ge - Yunnan Observatories, Chinese Academy of Sciences

The stability criteria of rapid mass transfer and common-envelope evolution are fundamental in binary star evolution. They determine the mass, mass ratio, and orbital distribution of many important systems, such as X-ray binaries, type Ia supernovae, and merging gravitational-wave sources. In the limit of extremely rapid mass transfer, the response of a donor star in an interacting binary becomes asymptotically one of adiabatic expansion. We built the adiabatic mass-loss model and systematically surveyed the thresholds for dynamical timescale mass transfer over the entire span of possible donor star evolutionary states. We confirm that new mass transfer stability plays an important role in the formation and properties of DWD populations as well as in the progenitors of SNe Ia and detectable GW sources. The results of our model support the observational DWD merger rate distribution per Galaxy and the space density of DWDs in the Galaxy. We determine the accurate binding energy using adiabatic mass-loss model and apply to study the short-orbital-period hot subdwarf B stars.

Sasha Hinkley - University of Exeter

Characterization of Ice-Line Planets with VLTI/GRAVITY

Dyna Ibrahim - University of Hertfordshire

To understand the formation and evolution of our Universe, it is crucial to understand how and when the first stars formed. The latest observational data reveal unprecedented information about the chemical enrichment of the early Universe, which seems to behave differently from the local Universe. The first stars, being very massive, enrich their metal-poor environment in an uncertain way. In order to predict the abundances of the first galaxies, we include nucleosynthesis yields from Population III stars up to 300Msun, including faint supernovae, Wolf Rayet and Pair Instability Supernovae into our state-of-the-art hydrodynamical cosmological simulations. Our code (based on Gadget-3) also includes the latest nucleosynthesis yields from population II stars (from Kobayashi et al. 2020) for all stellar mass ranges. We predict the chemical abundance evolution of galaxies for different elements from the early Universe to the local Universe. For example, we find that the N/O abundance gives a systematically larger value with nucleosynthesis yields from Population III stars, which is comparable with observational data of the GN-z11 galaxy. I also discuss the evolution of metallicity gradients and elemental abundances of the intergalactic medium. We aim to constrain our model by comparing it with observational data from the James Web Space Telescope (JWST) and the Atacama Large Millimeter/submillimeter Array (ALMA).

QUEST: a citizen science program to search for AGN transients

Jiachen Jiang - Institute of Astronomy, University of Cambridge

My poster will present a citizen science project called QUasi-periodic Eruption Survey for galaxy Transients (QUEST) and advertise this program among the high-energy astrophysics community within the UK during NAM. QUEST is now online for tests and will be fully online by NAM. This initiative aims to spot extreme and rapid accretion variability that causes a rapid change in the target's brightness so human eyes may identify them. This variability challenges the standard thin disk model and includes but is not limited to quasi-periodic eruptions in galaxies. These events involve a quick release of much energy in a short time, often just a few hours. Since such transients are rare, there could be unknown sources in archived data. Manual searches are impractical due to the high volume of data, especially the first eROSITA data release in 2023, along with Einstein Probe and archived XMM-Newton observations (e.g., 35K datasets, including 2K prioritised datasets, for the initial launch of QUEST). Instead, we're tapping into the collective minds of young students in the UK. In this talk, I will present an X-ray, UV and optical look of the type-1 AGN KUG 1141+371. It shows a simultaneous flux increase in the optical and UV bands in the past decade. For instance, the Swift observations in 2019 show that its UVW2 flux has increased by over one order of magnitude since 2009. Meanwhile, the soft X-ray flux of KUG 1141+371 also shows a steady increase by almost one order of magnitude from 2007 to 2019 and a very rapid decay ever since 2020. The significant multi-wavelength luminosity change is likely due to a boost followed by a quick drop in mass accretion rate. At odds, the optical spectrum of KUG 1141+371 never changes "look". Finally, I will discuss the possible connection between KUG 1141+371 and a stellar-mass black hole X-ray binary or other AGN transients in an outburst, such as the appearance of a radio jet during the transition.

Data from the SIGNALs survey, taken with SITELLE, will allow us to push the search for PNe further than before and look at both the inner and outer regions of galaxies, to trace the remnants of their formation history

Sarah Kane - Institute of Astronomy, University of Cambridge

Globular clusters (GCs) are sites of extremely efficient star formation, and recent work has indicated that they were significant contributors to star formation in the early Milky Way. Likewise, observations at high redshift suggest that the same may be true in other galaxies. Within the Milky Way, stars with anomalous overabundances of nitrogen and aluminum and depletions of oxygen, among other elements, can be uniquely tagged as having originated within clusters, thus allowing us to study the contribution of GCs to the Galaxy even after the stars are no longer inside their birth cluster. However, these high-[N/O] globular cluster-origin stars are extremely rare within the current field of the Galaxy, which poses a problem given their importance as a tracer of early star formation. To address the scarcity of these rare, valuable former GC members, we use a machine learning approach to identify high-[N/O] stars from the numerous low resolution Gaia BP/RP spectra, vastly increasing the number of these stars known in the Galactic halo as compared to high resolution spectroscopic surveys. We explore the distribution of our new sample of high-[N/O] stars within the Galaxy to probe the history of GC contributions to the Milky Way.

Adiabatic mass-loss model and applications in related binary objects

Hiiko Katjaita - University of Namibia

Namibia, renowned for its pristine night skies and minimal light pollution, has emerged as a significant hub for astronomical research. Hosting the first International Dark Sky Association (IDA) Dark Sky Reserve in Africa, the NamibRand Nature Reserve, Namibia boasts ideal conditions for astronomical observations. This work delves into measurements of night-sky brightness proximal to the world-leading High Energy Stereoscopic System (H.E.S.S.). Leveraging its arid climate, Namibia experiences a scarcity of rainfall, leading to an abundance of cloudless nights—a phenomenon conducive to extended observation hours for astronomical facilities like H.E.S.S. With this, Namibia's skies offer vast opportunities for uninterrupted exploration of the universe. Moreover, Namibia's sparse population density, ranking as the third least densely populated country globally, further mitigates light pollution, enhancing its appeal for astronomical endeavors. With vast stretches of uninhabited land, Namibia presents an optimal environment for astronomical observations. Building upon these advantageous conditions, Namibia is poised to pioneer the establishment of the world's first multi-wavelength observatory. This ambitious endeavor envisions incorporating telescopes operating across a spectrum of wavelengths, including cm-wave and mm-wave radio, optical wavelengths, and gamma rays. The proposed Namibian Multi-Wavelength Observatory aims to consolidate the capabilities of existing facilities such as H.E.S.S. and the planned Africa Millimeter Telescope, thereby solidifying Namibia's position as a front-runner in astronomical research and exploration.

Studying Stellar Astrophysics in Binary Stars of Globular and Open Clusters with Ultra-Sensitive Observations

Dolunay Kocak - Institute of Astronomy, University of Cambridge

The number of ground-based and space-based telescopes for long-term photometric observations has increased over the years. Thanks to significant advances in observational astronomy, the orbital and physical parameters of binary and multiple-star systems can be determined much more accurately than in the past. This allows us to test existing stellar evolution models and further investigate fundamental problems in stellar astrophysics. The basic parameters of the star, which are critical in astrophysics, can be accurately determined thanks to double-line eclipsing binaries. Binary stars are one of the most essential astrophysical resources for understanding the formation and evolution of stars and the final stages of their evolution. We can test fundamental astrophysical problems in stellar evolution by analyzing binary star observations, such as matter transfer, mass loss, and the von Zeipel-Kozai-Lidov effect. Because they share some common characteristics, such as age, chemical structure, distance, etc., binary systems in stellar clusters are invaluable laboratories for studying problems affecting stellar evolution.

In this study, we selected clusters of different ages, chemical abundances, and properties and analyzed the new observations over more than three years, and the data sets obtained from space-based observations such as TESS, Kepler, and Gaia simultaneously with the previously obtained spectral observations, as a result of the analyses, we obtained very precise orbital and physical parameters of the target binary systems. Considering these parameters, the evolution models of the systems obtained using evolution codes such as the Cambridge Stellar Evolution code (STARS) and MESA are discussed.

New insights into the nature of gamma-ray bursts

Toktarkhan Komesh - Energetic Cosmos Laboratory, Nazarbayev University, Kazakhstan

Instruments such as the ROTSE, TORTORA, Pi of the Sky, MASTER-net, and others have recorded single-band optical flux measurements of gamma-ray bursts starting as early as ~10 seconds after gamma-ray trigger. The earliest measurements of optical spectral shape have been made only much later, typically on hour time scales, never starting less than a minute after trigger, until now. We designed and built a unique instrument, the Burst Simultaneous Three-channel Imager, mounted on the 700 mm aperture Nazarbayev University Transient Telescope at Assy-Turgen Astrophysical Observatory (NUTTelA-TAO), to make these measurements. The system can point and track any celestial target above 15◦ altitude in ≤8 s, responding automatically to Swift and other real-time GRB alerts, with time resolution down to ~0.1 seconds. We observed GRB 201015A and GRB 200925B starting only 58 and 129 seconds, respectively, after the BAT trigger, measuring in three Sloan filter bands, g’, r’, and i’. We did not find evidence for a two-component jet structure or a transition from reverse to forward shock or a prompt emission component that would explain this change in slope. We find that the majority of the optical spectral slope evolution is consistent with a monotonic decay of extinction, evidence of dust destruction. Our work shows that significant information about the early emission phase is being missed without such early observations with simultaneous multi-band instruments.

Post-main sequence thermal evolution of planetesimals: Implications on white dwarf pollutants

Yuqi Li - Institute of Astronomy, University of Cambridge

Our understandings of exoplanet interiors from mass and radius observations alone rely heavily on modelling, which suffers from degeneracies. Fortunately, planetary materials in the atmospheres of white dwarfs probe the composition of planetary building blocks. These observations have the power to tell us the diversity of composition in exoplanets and probe their geology. A crucial question is therefore, whether the composition of the bodies accreted by white dwarfs is altered during the system’s evolution on the luminous giant branches. We model the irradiation-induced heating from the main sequence until the end of asymptotic giant branch of the host star and show that large scale melting is only possible in the smallest bodies (~10 km) closest to the host star (~1 AU), unlikely to explain the observed massive iron/silicon-rich/depleted white dwarf pollutants. As a result, core/mantle-rich white dwarf pollutants remain an indicator of core-mantle differentiation of planetesimals during their formation process, potentially powered by radioactive decay and/or collisions.

Are there too many z>5 protoclusters from JWST?

Seunghwan Lim - KICC, University of Cambridge

Motivated by the recent JWST discovery of galaxy overdensities during the Epoch of Reionzation, we examine the physical properties of high-z protoclusters and their evolution using the FLAMINGO simulation suite. We investigate the impact of the apertures used to define protoclusters, because the heterogeneous apertures used in the literature have limited our understanding of the population. When considering galaxies more massive than $M_* \approx 1e8 M_\odot$, the FLAMINGO simulations predict a dominant contribution from progenitors similar to those of the Coma cluster to the cosmic star-formation rate density during the reionization epoch. Our results indicate the onset of suppression of star formation in the protocluster environments as early as $z \simeq 5$. The galaxy number density profiles are similar to NFW at $z \lesssim 1$ while showing a steeper slope at earlier times before the formation of the core. Different from most previous simulations, the predicted star-formation history for individual protoclusters is in good agreement with observations. We demonstrate that, depending on the aperture, the integrated physical properties including the total (dark matter and baryonic) mass can be biased by a factor of 2 to 5 at $z = 5.5–7$, and by an order of magnitude at $z \lesssim 4$. This correction suffices to remove the $\simeq 3\ \sigma$ tensions with the number density of structures found in recent JWST observations.

Coronal Self-Oscillations: A Novel Framework for Understanding Low-Frequency Quasi-Periodic Oscillations

Vanessa López-Barquero - University of Maryland

Low-frequency quasi-periodic oscillations (LFQPOs) frequently manifest in the X-ray flux of black hole binaries, appearing as coherent peaks in the power spectrum with centroid frequencies spanning 0.01-10 Hz. Despite their prevalence and measurable attributes, the exact origin of LFQPOs remains elusive, defying comprehensive explanations from existing models. This work proposes a novel framework wherein LFQPOs originate in the corona due to self-oscillations. Self-oscillations can generate and maintain a periodic motion by a power source that lacks periodicity. As a result, unlike in the scenario of a resonant case, there is no need to find a periodic driver. These self-oscillations associated with the corona can create the X-ray modulation detected as a QPO. Our model characterizes these QPOs as thermoacoustic self-oscillations, in which the acoustic oscillation of the corona is maintained by positive feedback with the rate at which the corona is cooled by inverse Compton scattering of soft photons coming from the accretion disk around the black hole. The mechanical oscillation of the corona is maintained against its internal viscous damping because cooling is most effective when the corona is at the lowest temperature and largest volume within the QPO cycle, analogous to the classical "kappa mechanism" explaining pulsations in variable stars. In the case of the QPOs, we propose that the feedback arises because pair production lowers the temperature in the corona (due to equipartition) while increasing the optical depth (making the cooling by inverse Compton scattering more efficient). This thermodynamic perspective not only provides a mechanism for LFQPOs but also offers insights into the elusive physical properties of the corona itself, promising a more comprehensive understanding of these intriguing astrophysical phenomena.

Multi-wavelength Bulge and Disk Morphology of the Early-type Spiral Galaxy M81 (NGC 3031)

Ye-Wei Mao - GuangZhou University

This poster presents a panchromatic investigation of morphology for the early-type spiral galaxy M81. In this work, We perform bulge–disk decomposition in M81 images at a total of 20 wavebands from FUV to NIR obtained with GALEX, Swift, SDSS, WIYN, 2MASS, WISE, and Spitzer. Morphological parameters such as Sérsic index, effective radius, position angle, and axis ratio for the bulge and the disk are thus derived at all of the wavebands, which enables quantifying the morphological K-correction for M81 and makes it possible to separately reproduce images for the bulge and the disk in the galaxy at any waveband. The morphology as a function of wavelength appears as a variable-slope trend of the Sérsic index and the effective radius, in which the variations are steep at UV–optical and shallow at optical–NIR; the position angle and the axis ratio keep invariable at least at optical–NIR. It is worth noting that the Sérsic index for the bulge reaches ~4–5 at optical and NIR, but drops to ~1 at UV. This difference brings forward a caveat that a classical bulge is likely misidentified for a pseudo-bulge or no bulge at high redshifts where galaxies are observed through rest-frame UV channels with optical telescopes. Our next work of this series is planned to study spatially resolved SEDs for the bulge and the disk, respectively, and thereby explore stellar population properties and star formation/quenching history for the galaxy composed of the subsystems. Please see Gong & Mao et al. (2023, ApJS, 267,26) for the detail of this work.

Delivering prebiotic feedstocks to the early-Earth with cometary impacts

Catriona McDonald - Institute of Astronomy, University of Cambridge

The emergence of life on early Earth required a significant amount of prebiotic chemical feedstocks to provide the first step in a chemical pathway to the origins of life. Previous studies have highlighted hydrogen cyanide (HCN) as a key feedstock for the formation of life's basic building blocks in the cyanosulfidic pathway to life. However, such feedstocks must be concentrated into a usable reservoir for the pathway to proceed.

Alongside in situ synthesis, HCN could be delivered by comets which have been observed to contain significant amounts of organic molecules like HCN. The strong atomic bonds of HCN make it particularly durable to high temperatures and thus increases its chances of survival during an impact process. Impact craters which retain the melted comet ices can concentrate prebiotic feedstocks such as HCN in 'warm comet ponds' which could facilitate the chemical pathway to life.

For the first time, we carry out three dimensional hydrocode simulations coupled with simple chemical networks to model the survival of HCN during a cometary impact. We consider spherical comets of pure water ice, containing a small percentage of HCN, impacting on a solid planetary surface with varying angle, velocity and size. Our results suggest that small, slow, oblique impacts are most preferable for HCN survival. We discuss how these successful impact events compare with the distribution of impacts on early Earth and thus the role cometary delivery of HCN may have had on the origins of life on Earth.

Bridging Gaps in Black Hole Imaging: The Africa Millimetre Telescope (AMT) Initiative

Delight Namene - University of Nambia (UNAM)

The mission to image black holes takes a significant step forward with the construction of the Africa Millimetre Telescope (AMT) in Namibia. This telescope will join the Event Horizon Telescope (EHT), an international collaboration of synchronized observatories aimed at studying radio emissions linked to black holes.

The AMT boasts a 15m dish designed to collect faint millimetre-wavelength radiation, ideal for penetrating the dust and gas surrounding black holes. The telescope is planned to be equipped with cutting-edge receivers, initially operating at 3mm and 1.3mm wavelengths, with intent of adding 7mm and 0.8mm capabilities, and future plans to extend the cm-bands. Its strategic location on Mt. Gamsberg, Namibia, fills a key gap in the EHT network, enabling more plausible observations from the eastern part of the network. By broadening the network's geographical scope, it is expected that the observing time of the EHT for imaging will more than double compared to its current observing time. This will allow for more rigorous testing of theoretical frameworks for black holes. Furthermore, the AMT strives to have single-dish operations plans for monitoring and fast reactions to transients of astronomical objects.

The AMT's impact extends beyond groundbreaking science. Its construction and operation will serve as a catalyst for African astronomy, solidifying the continent's role in scientific discovery. Moreover, the AMT features a societal impact programme which constitutes a mobile planetarium utilized to educate Namibians on astronomy, amplifying its impact on local communities.

Constraints on thermal conductivity in the ICM of the fascinating merging cluster Abell 2146

Annabelle Richard-Laferrière - Institute of Astronomy, University of Cambridge

The cluster of galaxies Abell 2146 is undergoing a major merger, which renders it an ideal system for studying the intracluster medium (ICM) physics. With the merger axis oriented in the plane of the sky, the cluster's proximity and simple geometry allow us to resolve features at the relevant scales. Furthermore, the ICM temperature lies within Chandra's peak sensitivity range. In particular, A2146 serves as a perfect target for studying thermal conduction within clusters of galaxies - a physical process only studied to a slight extent in the context of ICM physics in the literature.

One of the most striking features of Abell 2146 is the partial stripping of its cool subcluster core. The resulting tail of gas creates a unique opportunity for studying thermal conductivity in the ICM, by analysing survival time of cool gas within the intracluster medium. Here we present our study of A2146, using deep 2.4-Ms Chandra observations in the 0.5-7 keV energy band. By fitting the absorbed thermal plasma emission model to the X-ray emission, we produce a high spatial resolution map of the temperature structure along a plume in the ram-pressure stripped tail, which is clearly distinguishable from the hot ambient gas. Previous studies of conduction in the ICM typically rely on estimates of the survival time for key structures, such as cold fronts. Here we use a suite of high-resolution hydrodynamical simulations of the A2146 system, measuring the flow velocities along the stripped plume and the timescales associated with the temperature increase along its length.

We find that thermal conductivity is suppressed by multiple orders of magnitude with respect to the Spitzer rate in Abell 2146. With only 1% of the available energy budget needed to heat the cold, stripped gas, our results deliver important constraints on physical processes in clusters of galaxies.

Seven White Dwarfs Eating Planetesimals

Laura Rogers - Institute of Astronomy, University of Cambridge

We live in an epoch of rocky planet discovery, but if we are to truly assess the habitability of these exoplanets, we need to understand what the rocks are made from i.e., their mineralogy. White dwarf planetary systems provide the optimal route to tackle the important question: 'which rocks and minerals make up a planet?' by making the link between composition and mineralogy: bulk composition of the planetary material from optical and ultraviolet spectra of the white dwarf atmosphere, and its mineralogy from infrared spectra of the accreting dust disk. This talk will answer: How do we link the bulk abundances to the mineralogy? What does this mean for rocky bodies and habitability? What do we know based on observations of white dwarf planetary systems so far?

Stellar and black hole feedback with AXIS

Helen Russell - University of Nottingham

Stellar and black hole feedback heat and disperse surrounding cold gas clouds, launching gas flows off circumnuclear and galactic disks and producing a dynamic interstellar medium (ISM). On large scales bordering the cosmic web, feedback drives enriched gas out of galaxies and groups, seeding the intergalactic medium with heavy elements. In this way, feedback shapes galaxy evolution by shutting down star formation and ultimately curtailing the growth of structure after the peak at redshift 2-3. To understand the complex interplay between gravity and feedback, we must both resolve both the key physics within galaxies and map the impact of these processes over large scales, out into the cosmic web. The Advanced X-ray Imaging Satellite (AXIS) is a proposed X-ray probe for the 2030s with arcsecond spatial resolution, large effective area, and low background. AXIS will untangle the interactions of winds, radiation, jets and supernovae with the surrounding ISM across the wide range of mass scales and large volumes driving galaxy evolution and trace the establishment of feedback back to the main event at cosmic noon.

Exploring the connections between Low Surface Brightness tidal features, haloes, and host galaxy characteristics

Elisabeth Sola - Institute of Astronomy, University of Cambridge

Hierarchical models describing galactic evolution suggest that galaxies grow primarily through the accretion of gas and merger events. The collisional tidal debris resulting from these mergers retain traces of a galaxy's past assembly history, with their characteristics varying depending on the type of merger involved. Investigating these faint Low Surface Brightness (LSB) structures around diverse samples of galaxies, spanning various masses and environments, is crucial for gaining a comprehensive understanding of galactic assembly.

In this study, we employed Jafar, an online annotation tool, to delineate LSB features surrounding a selection of 475 early and late type galaxies situated in different settings, including field environments, groupings, and the Virgo cluster. Deep imaging from four CFHT surveys—MATLAS, UNIONS/CFIS, VESTIGE, and NGVS—was utilized. Through manual annotation, we compiled a database of LSB features and conducted quantitative analyses of their shape and photometric properties. We will present correlations observed between these properties and factors such as galaxy mass, environment, and internal kinematics.

Furthermore, we explore the potential implications of our findings for large-scale surveys like Euclid and discuss the prospects of leveraging machine learning techniques to utilize our database for the automatic detection and segmentation of tidal features across vast swathes of the sky. By releasing our quantitatively characterized database of LSB features, we aim to facilitate comparisons with other observations, with predictions from numerical simulation and foster advancements in our understanding of galactic evolution.

Gravitational waves from Boson-star binaries

Ulrich Sperhake - DAMTP, University of Cambridge

By injecting gravitational waveforms from high-precision numerical-relativity simulations of boson-star inspirals and mergers, we investigate LIGO's capacity to detect these hypothetical compact binaries and assess their parameters. We find that that for most systems, current black-hole and neutron-star templates are often able to recover the injected boson-star signals with small residual, but fail to infer the correct binary parameters within 90% confidence level.

Constraints on thermal conductivity in the ICM of the fascinating merging cluster Abell 2146

Ted von Hippel - Embry Riddle Aeronautical University

Bayesian Analysis of Stellar Evolution (BASE-9) is a Bayesian software suite that recovers star cluster and stellar parameters from photometry as compared to stellar evolution models, and with priors defined from existing literature and databases, including Gaia astrometry. BASE-9 has been used to analyze two-component globular clusters, single-component star clusters, binaries, and single stars, and for simulating such systems. BASE-9 uses Markov chain Monte Carlo and brute-force numerical integration techniques to estimate the posterior probability distributions for the age, metallicity, helium abundance, distance, and line-of-sight absorption for a cluster, and the mass, binary mass ratio, and cluster membership probability for every stellar object. BASE-9 is open-source code available on GitHub. We provide an overview of problems BASE-9 has tackled. This includes deriving ages for field white dwarfs with a median precision of 20% (and often better than 5%), deriving mass ratios for the majority of spectroscopically identified main sequence binaries in open clusters, and deriving open cluster ages with a precision of typically 2-5%. We also share results from on-gong work on mass-transfer binaries.

NGC5907 ULX1: The Most Extreme X-ray Pulsar Known

Dominic Walton - University of Hertfordshire

NGC5907 ULX1 is one of the small number of ultraluminous X-ray sources (ULXs) known to be powered by an accreting pulsar, reaching astonishing peak luminosities of ~1e41 erg/s, making it the most extreme X-ray pulsar known in this regard. As such, since its discovery as a ULX pulsar it has been the subject of an extensive campaign of follow-up observations, combining in particular significant investments by the Swift, XMM-Newton and NuSTAR X-ray observatories. I will present the latest data from this ongoing campaign, and discuss what we have learned so far about this remarkable system.

Where to find exomoons

Xing Wei - Beijing Normal University

We study two mechanisms for the retention of exomoons. In the presence of a circumplanetary disk (CPD), by comparison between CPD's inner and outer radii, we find that planets with too strong magnetic fields or too small distance from its host star tend not to host exomoons. During the subsequent CPD-free evolution, we find, by comparison between planet's spindown and moon's migration timescales, that hot Jupiters with periods of several days are unlikely to retain large exomoons, albeit they could be surrounded by rings from the debris of tidally disrupted moons. In contrast, moons, if formed around warm or cold Jupiters, can be preserved.

The GALEX Extragalactic Spectral Database

Gerry Williger - University of Louisville

We present results from a project to categorize and collect complementary multiband data for approximately 11,000 extragalactic sources in 211 GALEX spectroscopic fields which overlap the Sloan Digital Sky Survey (SDSS). The project yields a useful searchable database for the scientific exploitation of GALEX UV spectra (R~100-200) of extragalactic sources. For all extragalactic sources (known or classified by us) with GALEX spectra, we have assembled complementary images and photometry in FUV+NUV from GALEX, in ugriz from the SDSS, in JHK from the Two Micron All Sky Survey (2MASS) and in W1-W4 from the Wide-field Infrared Survey Explorer (WISE), and created spectral energy distributions (SEDs). We have also logged SIMBAD and SDSS object classification, redshift and angular size information, and provide some indication of spectral data quality, since it largely varies across the sample and even across the wavelength range of individual spectra, owing to the grism observing strategy (Bianchi et al. 2018, Astrophys. Space Sci., 363, 56).

The UV spectral database consists of 1820 quasars, 2274 star-forming galaxies, 6327 quiescent spirals and 386 ellipticals. The mean redshifts for quasars, star-forming galaxies, quiescent spirals and ellipticals are 0.99, 0.07, 0.35 and 0.05 respectively. We will show representative spectra, SEDs and color-magnitude diagrams. The database (Pritchard et al., in preparation) will be made publicly available from the Mikulski Archive for Space Telescopes (STScI's MAST) as a High-Level Science Product (HLSP), as well as from Vizier.

Spectroscopically Mapping the Milky Way and Nearby Galaxies with The Affordable Multiple Aperture Spectroscopy Explorer (AMASE)

Renbin Yan - The Chinese University of Hong Kong

Feedback from star formation and supernovae is known to regulate the star formation in galaxies and re-distribute metals in and around galaxies. However, the subgrid physics is still not well understood. AMASE is a planned project to provide unprecedented data for understanding this. AMASE will have a hundred identical fiber-based integral fields spectrographs paired with an array of telephoto lenses to achieve contiguous imaging spectroscopy over 1/4 of the sky at the spatial resolution of half an arcminute and a spectral resolution of R=15,000, covering important emission lines in the optical for studying the ionized gas in the Milky Way and beyond. It will be enabled by a significant reduction in the cost of each spectrograph unit. Through massive replication, we can significantly exceed the survey speed of traditional spectrographs under similar total cost. The prototype system will include six spectrographs paired with 3 small telescopes, deployed at sites on both hemispheres. Each of the two sites will have a f=400mm f/2.8 telephoto lens with three spectrographs. The northern site will also have a 0.7m telescope in order to sample M31 and M33 with higher spatial resolution (20pc). The prototype system is funded by Hong Kong Jockey Club Charities Trust and will be called Jockey Club Spectroscopy Survey System. I will present the design and development progress. The first light with the first two spectrographs will be in 2025.

A panoramic photograph of the Galactic bar from long period variables

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Knowledge of the Galactic bar is crucial to fully understanding the chemo-dynamical evolution of the Milky Way because the Galactic bar affects both the gravitational potential at the inner Galaxy and the ecosystem of the Milky Way. However, little discussion is devoted to the bar properties through direct observation of resolved stars in the bar due to the imprecise distances and heavy extinction. Thanks to the variables stars published from Gaia DR3, we can now shed light on the resolved stars in the Galactic bar. We use the low-amplitude, long-period variable (LA-LPV) stars from the Gaia DR3 LPV catalogue, which enable us to assign luminosity distances to these stars through the period-luminosity relation. We present an LA-LPV sample that covers the Galactic disc and bulge. A panoramic picture of the inner Galaxy is revealed in full 6D phase space on the near side and the far side of the bar. We constrain the kinematics field of the Galactic bar on both sides of the Galaxy and find consistency with N-body simulations. We provide a newly developed method to measure the dynamical length of the Galactic bar using purely kinematics. Meanwhile, we also estimate the pattern speed of the Milky Way bar using the continuity equation and yield a result of ~34.1 km/s/kpc. Further, we study the orbital families of the bar-supporting orbits and find a significant population of the “banana” orbits, which are the main building blocks of the Galactic X-shaped structure.

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