Titles & Abstracts

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ORAL PRESENTATIONS

(R—Invited Reviews, IT—Invited Talk)
Hidden galaxies: but not for long

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Because the local sky is ten thousand times brighter than it is in Intergalactic Space it is almost impossible for us to see much of the Low Surface Brightness Universe. But Surface Brightness selection effects, at both ends of the SB range, are so very dramatic and non-intuitive that most astronomers, especially seasoned observers, struggle to believe them. I will try to make those effects seem plausible and then show why galaxy clustering has misled so many 21-cm. and QSOAL astronomers into misidentifying truly LSBGs with other more spectacular sources such as L star galaxies. But once one compounds all the conflicting evidence together it is possible to argue that the odds on Hidden Galaxies significantly outnumbering the visible ones are as high as a million to one. There are ways to unveil this Hidden Universe, but it won’t be easy.
The Renaissance of LSB galaxies

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LSB galaxies come in many different flavors ranging from massive, giant galaxies to extremely low-mass objects, and from gas-rich galaxies with low-level star formation to gas-deficient, quiescent ones. In our own Local Group, LSB dwarfs have experienced a renaissance during the past two decades when their numbers were more than tripled thanks to deep imaging surveys. These surveys led to the discovery of the least luminous, least massive, most dark-matter-dominated galaxies known - ultrafaint dwarf spheroidal galaxies - which hold important clues to the conditions of early star formation in small dark matter halos. In galaxy clusters, the recent re-discovery of extended ultra-diffuse galaxies (UDGs) triggered numerous extensive surveys. Meanwhile UDGs are being routinely detected and have also been found in galaxy groups and in the field, and radio surveys are revealing gas-rich UDGs. Are UDGs "failed" Milky-Way-type galaxies quenched by cluster environments? Are they highly dark-matter-dominated dwarfs? Is their evolution regulated by internal or by external effects? Are they indeed a new class of galaxies or just the tail of the LSB galaxy population? The intensified research during just the last four years has revealed a number of intriguing and varied properties that suggest multiple formation pathways.
Session 1A: State-of-the-art in current and future ground-based instrumentation
Over the past few decades, advances in telescope/detector technologies and deep imaging techniques have pushed surface brightness limits to ever fainter levels. We can now both detect and measure the diffuse, extended starlight that surrounds galaxies and permeates galaxy clusters, enabling the study of galaxy halos, tidal streams, LSB galaxy populations, and the assembly history of galaxies and clusters. With successes come new challenges, however, and pushing even deeper will require careful attention to systematic sources of error. In this review I highlight recent technical and scientific advances in the study of diffuse starlight in galaxies, and discuss the challenges faced by the next generation of deep imaging studies.
Galaxies have both extended gas disks and gas-rich circum-galactic media. These galactic components have been historically probed by HI observations and through quasar absorption line studies from low to high redshifts. With few exceptions, diffuse and dense molecular gas has been largely undetectable. I discuss our on-going work to detect and characterize molecular gas in both extended disks and the circum-galactic medium of high redshift galaxies with the ATCA and ALMA. I discuss several ideas how this multiphase gas arises in galaxies and its importance for obtaining a complete view of the low surface brightness emission in and around galaxies.
Ultra-deep imaging with amateur telescopes

R David Martínez Delgado  
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In the last decade, ultra-deep, wide-field imaging of nearby galaxies obtained with small robotic telescopes (0.1-0.5 meter aperture) has provided unprecedented views of nearby galaxies and new insights on galaxy formation and evolution in the local Universe. In this talk, I review the methodology and the contribution of this collaboration with high-class astrophotographers to this research topic, including: i) a deep probe of the Magellanic Clouds interaction using telephoto lens; ii) the search for stellar tidal streams around Milky Way-like galaxies; iii) the search for "missing" dwarf satellites around nearby spirals; iv) the detection of huge clouds of ionized gas in some halos; and v) the discovery of a new isolated galaxy around the Local Group and some ultra-diffuse galaxies in the field.
A 100h Imaging Of M101 With A Small Telescope: Reaching The Limits Of Amateur Telescopes For Low Surface Brightness Science

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While a lot of time and effort is spent by amateur astronomers to obtain visual appealing images of astronomical objects, only few data is taken in such a way that can be used for real science. In this contribution we will present the results of an ongoing experiment showing the benefits of the collaboration between amateur and professional astronomers. We will show which are the current limits of amateur technology for doing low surface brightness science when a proper observation strategy and data reduction is carried out. The presentation will be divided in two parts, first Aleix Roig (amateur astronomer) will describe the observatory and telescope characteristics. The second part will be presented by Raul Infante-Sainz (professional astronomer) and it will consist in how data is reduced and treated in order to correct all systematic biases. With M101 galaxy as the main target for this project, we will show that current amateur astronomy can compete in depth with professional telescopes.
Session 1B: State-of-the-art in current and future space-based instrumentation
LSST and the LSB universe

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I will present a review of current ground- and space-based facilities available for low surface brightness observations, as well as a look at the next-generation of facilities that are under development or being proposed.
Going Towards Wide-Area Ultra-Deep Imaging Surveys

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In the coming years a number of surveys, including Euclid and LSST, will start to produce image sets of unprecedented size as well as depth. These images will open new avenues for low surface brightness science, mainly by allowing the study of huge samples of objects, but the images from such surveys will be affected by systematic effects that we have come to know from smaller or pilot studies. These effects include background subtraction, adequate masking, scattered light, and Galactic cirrus. I will summarise the potential problems and illustrate from recent work how they can be overcome, and then explore the possibilities offered by the upcoming surveys, concentrating on the physics of the outskirts of galaxies.
The Huntsman Telescope

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The Huntsman Telescope is a new Canon telephoto array located at Siding Spring Observatory in Australia. Based upon the Dragonfly Telephoto Array, it is designed to detect low surface brightness structures in the Southern Skies. I will outline the main science aims of the facility, including synergies with Square Kilometer Array precursor HI surveys. A particular focus will be placed on early results highlighting side-by-side comparisons on LSB performance with a reflecting telescope. I will also provide an update on SkyHopper, an Australian LSB-optimized space telescope CubeSat mission designed to measure the cosmic infrared background.
The Canada-France Imaging Survey As A Euclid Precursor: Blind All-Sky Low Surface Brightness Survey Of The Northern Sky

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The Canada-France Imaging Survey (CFIS) is a legacy survey that aims at some fundamental questions in astronomy: the properties of dark matter and dark energy, the growth of structure in the Universe from Galactic to cluster scales, and the assembly of the Milky Way. While tailored for point source science using MegaCam on CFHT, the observing and data processing strategy are designed to further enhance the scientific potential of the survey by also enabling the detection of low surface brightness features down to r=28 magnitude per square arcsecond over the 5000 square degrees of the footprint. This r-band component of the CFIS is motivated in part by the ESA Euclid space mission which will also offer a similar blind low surface brightness optical survey over 15000 square degrees to greater LSB depths (30+) as a consequence of the ultra low background at L2, and its off-axis optical design with enhanced baffling aimed at delivering a pristine PSF for gravitational lensing. CFIS is in various ways an exploratory precursor to Euclid. This talk will present the status and LSB performance of the CFIS, which started early 2017, and an overview of the Euclid survey.
The S-class MESSIER satellite has been designed to explore the extremely-low surface brightness universe at UV and optical wavelengths. The two driving science cases target the mildly- and highly non-linear regimes of structure formation to test two key predictions of the LCDM scenario: (1) the detection of the putative large number of galaxy satellites, and (2) the identification of baryonic filaments in the cosmic web. The science requirements imply challenging instrumentation issues which have only recently been solved. The satellite will drift scan the entire sky in 6 bands covering the 200-1000 nm wavelength range to reach the unprecedented surface brightness levels of 34 mag/arcsec\(^2\) in the optical and 37 mag/arcsec\(^2\) in the UV. As usual when uncovering new volumes in parameter space, many important secondary science cases will also result as free by-products and will be discussed in some detail: the actual luminosity function of galaxies, the contribution and role of intracluster light, the fluctuations of the cosmological background radiation at UV and optical wavelengths, the warm molecular hydrogen content of galaxies at z=0.25, time-domain studies of supernovae and tidal disruption events, the chemical enrichment of the interstellar medium through mass loss of red giant stars and the accurate measure of the BAO scale at z=0.7 with over 30 million galaxies detected in Lyman-alpha at this redshift. It will provide the first space-based reference UV-optical photometric catalogue of the entire sky.
FIREBall-2 : The First Stratospheric Balloon Coupled To A Multi Object Spectrograph To Reveal CGM At $z \sim 0.7$

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Observing the circumgalactic medium (CGM) represents an important challenge for understanding how galaxies evolve as it hosts important mechanisms regulating their replenishment through inflows and outflows. Despite its complex nature (compact/diffuse emission, multiple energy sources and resonant lines inherent difficulties) the Ly$\alpha$ line ($\lambda=1216\text{Å}$, H 2→1 electronic transition) remains an essential tracer for accessing CGM properties (extension, accretion/ejection phenomena, energy budget) due to the proliferation of observations at all redshifts and the improvements of numerical simulations. Observations at low redshift (LARS) and higher redshift (MUSE, CWI) of Ly$\alpha$ halos suggest an important evolution of the CGM gas content between $z \sim 0$ and $z > 3$ which is still unexplored due to the difficulties of vacuum UV observation. At this intermediate redshift, simulations predict that Ly$\alpha$ emission of the CGM should be detectable by space based spectrographs with relatively low acquisition time ($\sim 105$ seconds) for bright galaxies (MagNUV<20). This is exactly the goal of the FIREBall-2 path-finder: help fill the gap between low and high redshift CGM observations and pave the way to more ambitious orbital projects aiming to image the UV low surface brightness universe. This balloon-borne one meter telescope coupled to a UV Multi-Object Spectrograph (MOS) is designed to image the CGM in emission via Ly$\alpha$ resonant line redshifted at $\sim 200\text{nm}$ and flew for the first time from the CSBF NASA facility in New Mexico, USA in September 2018. Given its wide field of view (FOV) of $20 \times 40$ arcmin$^2$, its angular resolution of $\sim 6$ arcsec and spectral resolution above 1000, FIREBall-2 has the potential to bring important insights about the gas distribution in the CGM and velocity/temperature fields. This $\sim 15\text{M}\$ and 10 years of development science explorer, jointly funded by CNES and NASA, is also a technology demonstrator that incorporates a high efficiency UV emCCD coated and delta dopped by the JPL, the best sub-arcescond balloon-dedicated CNES pointing system and a low cost aspherized grating, which all became flight-tested for the first time. After describing the instrument design and its scientific performances we will present the flight data processing and analysis. Due to flight degraded conditions (less than an hour at nominal altitude instead of a full 8hour night) we will focus on the proof of performance of this first time ever multi object acquisition by a MOS in space, the determination of the upper limit on the average signal for NUV bright galaxies and the implication on the intermediate-z Ly$\alpha$ emission.

As simulations and flight data show that in nominal flight conditions and with minor instrumental improvements, the CQM and the CGM of bright galaxies should be spectrally detected, a 2020 flight is deeply considered.
AMUSS – Astrophysics Miniaturized UV Spatial Spectrometer  
For Spectroscopic Studies Of Diffuse Astrophysical Objects

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It has been extremely challenging to probe the physical properties of several important classes of astrophysical objects in our galaxy and beyond, that, by their nature, are faint, extended and diffuse. These classes include the astrospheres around dying stars, the interstellar medium of our Galaxy, supernova remnants, and the circumgalactic medium around nearby galaxies. Traditional slit spectrographs lack the sensitivity for detecting the faint UV emission that can be used to characterize the diffuse, hot gas in these objects. We describe a novel spectroscopic instrument, called the Spatial Heterodyne Spectrometer (SHS), which provides significant gains in sensitivity over a slit-spectrograph. SHS is a miniature, all-reflective two-beam cyclical interferometer that modulates and beats the photons (collected from large angular regions on the sky, ∼1 arcmin) against themselves efficiently, enabling spectroscopy from targeted spectral lines at high spectral resolution (R∼100,000). The extremely compact design of the SHS makes it the instrument of choice for CubeSat/SmallSat missions with small-aperture telescopes, that can be used to study important UV lines with high-spectral resolution, in order to probe the diffuse gas in these objects.
Session 2: Data analysis in LSB imaging
The low-surface-brightness universe: the new frontier in the study of galaxy evolution

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The low-surface-brightness (LSB) Universe represents one of the last unexplored frontiers in modern cosmology. Not only does the vast majority of the galaxy population (down to e.g. stellar masses of $10^7 \, M_\odot$) inhabit this regime, the LSB Universe contains largely unexplored structures that can provide key constraints on our theoretical paradigm — two examples are LSB tidal features that encode the assembly histories of galaxies and intra-cluster light which hosts a significant fraction of baryons in clusters. Using predictions from simulations, I will outline the properties of galaxies in the LSB regime, and the LSB structures above, that can be tested using the next generation of datasets. I will then explore how forthcoming surveys, such as LSST, can be used to test these predictions, potentially revolutionizing our current understanding of how the observable Universe forms and evolves over cosmic time.
Signal from the low surface brightness universe is often buried deep in the dataset’s noise and thus requires deep (many exposures) observations. The low signal-to-noise ratio of this signal per pixel, makes these targets particularly susceptible to systematic biases in the preparation of the deeper datasets. In order to study such regions, the accuracy and precision of the reduction steps needs to be studied and understood to improve their usefulness for accurate low surface brightness studies. Given the large volume of data already in surveys like HSC and DES (which will increase dramatically with LSST), and the many configuration options (parameters to all the software used, software versions, and their operating environment), it is becoming harder to test new configurations, methods or software and thus understand the limits of the final choice in the low signal-to-noise regime. This is a major hurdle in using such studies for the low surface brightness universe. Such tests can be facilitated/encouraged in a design where previous results can be exactly reproduced, on different machines, independent of the host operating system. In this talk, I will report on our progress in this front and how we are using it to better understand/constrain our systematics in studying the low surface brightness universe.
Reproducibility In Ultra-Deep Imaging

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In an era where ultra-deep optical imaging are crossing the 30 mag/arcsec$^2$ surface brightness frontier, a natural question is how reliable are the faintest features we see in those images. Most of the images at such depth are unique (as the time investment for getting them is enormous) and consequently hardly reproducible by other teams. In this contribution, we will show the results of a program where we have studied the same galaxy using different telescopes. We explore the repeatability of the faintest surface brightness features on those images. We will show that current technology allow us to safely recover features on the 30-31 mag/arcsec$^2$ regime.
Brightness Overestimation Due To PSF In Very Faint Galaxy Structures: The Thick Disc’s Case

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Our understanding of the evolution of galaxies within their optical radius has made great advances in the last decades. These have been achieved by analysing in detail the internal secular processes, the star formation history, and the Interstellar medium. However, the study of galaxy outskirts, so-called low surface brightness science, is still in its infancy. In this talk, I will explain how we use ultra-deep data to study the formation and evolution of very faint galaxy structures, in particular, their thick discs, in unprecedented detail. Thick discs can give invaluable information on the formation and evolution history of galaxies as most if not all, disc galaxies have a thin (classical) disc and a thick disc. We study the structure of thick discs in extraordinary depth by reaching a surface brightness limit of $\mu_{\text{r,deep}} \sim 28.5-29$ mag arcsec$^{-2}$ ($3\sigma$, 10x10 arcsec boxes) with combined g, r, i bands images from the IAC Stripe 82 Legacy Project. I will show how we can derive reliable thick disc profiles well above the galaxies mid-plane by fitting the disc components to a 2D galaxy PSF-deconvolved model, considering that the thin and thick discs are two stellar fluids in hydrostatic equilibrium. After a careful PSF treatment, we find that scattered light significantly affects the galaxy outskirts. If the PSF is ignored, the brightness of the galaxy thick discs, and thus, their mass, may be overestimated by up to a factor of $\sim 4$. Thus, proper PSF treatment is a very important issue to consider when dealing with ultra-deep surveys, including Euclid and LSST.
New Limits To Low Surface Brightness Details: The Hubble Ultra Deep Field Even Deeper

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In this contribution we present a fresh view of what - up to now - had been the deepest image of the Universe from the Hubble Space Telescope. Using a suite of special reduction algorithms, specifically designed to minimize the systematic effects which dominate the low surface brightness regime we will show surface brightness details down to an unprecedented depth ($\mu_{lim} \sim 33$ mag arcsec$^{-2}$, $3\sigma$, 10x10 arcsec$^2$) using the near-infrared observations of WFC3/IR in the Hubble Ultra-Deep Field. The results of this work, published in Borla et al. (2019) show that all previous reductions of the HUDF severely over-subtracted the outer parts of the brightest galaxies. With our new treatment we successfully restore the outskirts of galaxies with unprecedented detail, increasing the depth of the HUDF by reducing the systematic biases. We will show how our new methodology will be fundamental for future space missions such as JWST and Euclid if we want to exploit these telescopes to their limit.
Session 3: Dust particles and grains: from the Zodiacal light to the ISM cirri
Progress in zodiacal light understanding: Significance for observations of faint extended sources, properties and sources of interplanetary dust, and clues to Solar System evolution

R Anny-Chantal Levasseur-Regourd

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The zodiacal light, nowadays difficult to detect because of light pollution, is a major source of the natural background radiation and a topic of interest for the evolution of our Solar System. From the 18th century to the first half of the 20th century, it was progressively understood that zodiacal light comes from solar light scattered by a cloud of dust particles (the interplanetary dust cloud), the concentration of which increases towards the ecliptic and the Sun. The Space Age has then triggered many observations, typically under the auspices of the past IAU commission 21 (Light of the night sky), leading to tables and maps of the zodiacal light brightness and partial linear polarization, and of its thermal emission. While some questions about possible fluctuations were soon closed, the seasonal effects induced by the slight inclination of the symmetry surface of the cloud upon the ecliptic were pointed out. Asteroidal bands and cometary trails have been detected, and new meteoroid streams identified. Nevertheless, further observations from Earth’s orbit of the zodiacal light brightness and polarization, at least in the visible and near infrared domains, are still mandatory. Inversion techniques (e.g. with the node of lesser uncertainties approach) have provided key results on local properties of dust particles near the ecliptic, from \( \approx 0.1 \) to \( 1.5 \) au solar distance. Recent interpretations, through theoretical and experimental methods, provide clues to the physical properties of the dust and to the gradual sublimation of complex organic molecules while they spiral towards the Sun. Besides, zodiacal light modelling, dynamical studies, and IR emission studies, presently indicate that most of the near-Earth interplanetary dust is of cometary origin, with \( \approx 85\% \) of the total mass influx at 1 au expected to come from Jupiter Family Comets. The flux of interplanetary dust entering the Earth atmosphere is estimated to be about \( (30 \pm 20) \) kg/yr, with at least 12\% reaching the Earth’s surface without melting. The ground-truth provided by Rosetta long-duration rendezvous with comet 67P/Churyumov-Gerasimenko establishes that its dust particles i) consist about equally of minerals and complex organics in volume, ii) are more or less porous aggregates with a likely fractal structure from the nm to the mm scale, and iii) present significant similarities with zodiacal dust particles, collected within the stratosphere (CP-IDPs) or the Antarctica snows (UCAMMs) after their atmospheric entry. Such results do not only indicate that cometary nuclei were agglomerated in the protosolar nebula, but may suggest that, while the zodiacal cloud was much denser and brighter than nowadays at the LHB epoch, it could have brought a significant amount of pristine carbonaceous compounds to the surface of telluric planets.
Interpreting the zodiacal light observations from the properties of interplanetary and cometary dust particles

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Remote observations of the zodiacal light give us information on the physical properties of the interplanetary dust in the near-ecliptic symmetry surface. These include their local polarization, temperature, and composition, together with their heliocentric variations. Numerical and laboratory models of the interplanetary dust particles have been developed based on in situ measurements to interpret the remote observations of scattered and emitted light. We show that a numerical model of solid particles constituted by spheroidal grains and aggregates thereof can reproduce the equilibrium temperature and light scattering properties of the interplanetary dust cloud. A good fit of the local polarization phase curve near 1.5 AU from the Sun is obtained for a mixture of silicates and more absorbing organic material (approximately 40% in mass) and for a realistic size distribution typical of the interplanetary dust particles in the 0.2 μm to 200 μm size range. The heliocentric dependence of the polarization value at 90 degrees of phase angle is interpreted as a progressive disappearance of solid organic (such as HCN polymers or amorphous carbon) towards the Sun. Furthermore, measurements on analog dust particles lifted in microgravity conditions with the PROGRA2 light scattering experiment also reproduce such properties. The analogue particles correspond to a mixture of previously determined analogs for cometary and asteroid dust particles, including fluffy aggregates and compact particles. Five different organics to silicates ratios were generated confirming the interpretation of the heliocentric dependence of the polarization values. The best analog for the zodiacal light observations corresponds to a distribution of particles following a power-law with coefficients of ($-3 \pm 0.5$) for a size range of 10–100 μm and ($-4.4 \pm 0.6$) for a size range of 100–200 μm, with a constant ratio of (35 ± 10) % in mass of fluffy aggregates versus compact particles and a decreasing content in organics with decreasing solar distance. The results are then further discussed in the context of recent in situ measurements on cometary dust particles from the Rosetta space mission at 67P/Churyumov-Gerasimenko to assess the potential contribution of cometary dust to the interplanetary dust cloud.
Diffuse light from interstellar cirrus clouds across the electromagnetic spectrum

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Interstellar cirrus clouds are an ubiquitous component of the low-brightness sky across the electromagnetic spectrum. For us working on the physics of interstellar medium, cirrus observations reveal the intricate, scale-invariant, structure of the interstellar medium and bear unique information on the nature of interstellar dust. An additional perspective was recently opened by observations in polarized light, from Planck and from low-frequency radio observatories such as LOFAR, which are revealing the structure of interstellar magnetic fields. Much of the research on interstellar cirrus connects to extragalactic and cosmological observations, because it is a main foreground veil over the extragalactic sky. Today, interstellar cirrus is a main hindrance in the analysis of cosmological data for e.g. the Cosmic Microwave Background, the HI 21cm signal from the Epoch of Reionization and lensing surveys in the optical. In each context, cosmology is tied to interstellar physics, and from a methodological point of view, to mathematics, because novel methods are required to model the statistical properties of the Galactic foreground. I will review these various perspectives on this diverse research field.
Deriving diffuse dust properties from UV and optical observations

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Interstellar dust shapes the appearance of galaxies from the UV and optical to the millimeter domain. Observations at shorter wavelengths have the highest resolution and sensitivity, allowing the most detailed maps of diffuse dust in galaxies. As UV and optical starlight travels towards an observer, it gets scattered or absorbed by dust grains. The properties of these grains get imprinted on the processed light. Decoding these effects is hard, but rewarding if one wants to learn about the composition and evolution of dust grains in the diffuse interstellar medium and if one wants to provide realistic dust corrections. The latter will then yield more accurate estimates of the stellar population properties. In this talk I will discuss the relevant methods to derive dust grain properties from UV and optical observations. I will focus on data-driven methods ranging from pure empirical diagnostics to continuum radiative transfer modeling. It is now possible to probe the grain composition and properties of diffuse dust beyond the Local group. The first comparisons of these measurements with Milky Way cirrus dust are reviving interest in the evolution and diversity of dust in galaxies.
Deep optical imaging reveals a plethora of diffuse light associated with reflected starlight from dust particles of the Milky Way: the Galactic cirri. This diffuse light represents a strong source of confusion for the detection of extremely low surface brightness extragalactic features, becoming a major challenge for the current generation of deep optical observations. We have obtained the optical colors of the Galactic cirri using g, r, i and z SDSS bands in the Stripe82 region. Through comprehensive image processing techniques, including the modeling and removal of the scattered light by stars, we manage to isolate the extremely faint optical diffuse emission of the Galactic cirri, finding an excellent correlation with far IR emission from Herschel and IRAS data. Cirri colors are driven by the dust column density. We found a strong correlation between the optical colors and the 100μm emission, being this correlation steeper for colors using the bluer bands. Galactic cirri have optical colors different from those of the galaxies in the background, confirming the use of multi-band optical photometry as a good approach for the detection of high resolution cirri features. Finally, we suggest the extraordinary potential of the future LSST in the study of the Galactic foreground dust.
Section 4: The LSB circumstellar medium and orphan stars
Most stars in the Universe that evolve in a Hubble time (~1-8 Msun) undergo extraordinary deaths, losing half or more of their mass as they ascend the Asymptotic Giant Branch (AGB) in the H-R diagram. They enrich the ISM with the products of nucleosynthesis (including the biogenic elements C and N) and seed it with dust grains that eventually play a role in the formation of new solar systems like our own. But because emission from the usual tracers of gas in the ejecta (CO) becomes undetectable at distances typically a few × 10^{17} cm from the central star, we have only been able to probe a very small fraction of these ejecta. The unexpected discovery of ~10 times larger circumstellar structures in GALEX FUV images has now allowed us to probe the full extent and mass of the ejecta in a few objects; similar structures have been found via dust emission in the far-infrared as well. These emissions arise in an astrosphere resulting from the stellar ejecta interacting with the ISM. The FUV emission is inferred to be H2 line emission collisionally excited by hot electrons in shocked gas. We discuss examples of such astrospheres, and how their properties can be directly probed using a novel instrument (Spatial Heterodyne Spectrometer or SHS).
The Tale of the Lost Mass

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As stars evolve they return the by-products of stellar nucleosynthesis to the ISM. Either via heavy mass-loss or explosive events the stars shred their envelopes to end their lives as compact objects. In the low surface brightness (LSB) features formed is written the history of the physics that took place. In this review I will summarize what can we learn from the study of LSB structures around stars regarding mass-loss processes, timescales of evolution, shocks, initial-to-final mass relations, stellar dynamics and stars-ISM interactions.
Multi-Wavelength Observations Of Orphan SN And Other Transients As Signposts For Very Low Surface Brightness Structures

IT Dominik J. Bomans

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A basic problem to detect and study low surface brightness emission is the always present background, for ground-based observations, but also in space. A complementary approach for detecting low surface brightness structures, like (very) low surface brightness galaxies, ultra diffuse galaxies, and tidal debris could be the use of bright transients. These more easily detected point sources could pinpoint the location underlying, not so easily detected diffuse emission. Still, there are limits imposed by the different transient populations used, and the needed follow-up observations. In this talk, I will give a short introduction of the underlying principles, and discuss pro and cons of potential transient populations (like orphaned supernovae of different types, Gamma Ray Burster, X-ray transients, and Fast Radio Transients). Then I will review the properties of the low surface brightness objects detected by this approach and the implied limits for the local baryon content in low surface brightness objects. Finally I will discuss limitations of the approach and the promise of current and upcoming survey projects, like e.g. LSST, and EUCLID.
I will introduce a galaxy sample selection method using core-collapse supernovae (CCSNe). Using a complete sample of \( \sim 900 \ z<0.2 \) CCSNe, identified from the SDSS-II Supernova Survey, as pointers towards their host galaxies, we find 140 new low surface brightness galaxies whilst identifying the hosts. Selecting star-forming galaxies using CCSNe leads to the removal of surface brightness and mass biases. I will demonstrate how CCSN-rates as a function of galaxy stellar mass can be used to trace both star-formation rates and the form of the galaxy stellar mass function. Resultant number densities are well-constrained deep into the dwarf regime and are found to increase following a power-law with decreasing mass down to the low mass limit of \( \sim 10^{6.4} \ M_\odot \), well represented by a single Schechter function with a faint-end slope of \( \alpha = -1.41 \). This lack of downturn to galaxy number densities down to the low mass limit implies that overcoming surface brightness and stellar mass biases is important for an assessment of the sub-structure problem.
Session 5A: Low surface brightness features around and within galaxies
I will give an overview on how the discovery of low surface brightness features, including recent accretion events as well as the faintest among dwarf galaxies, have revolutionized near-field cosmology in the past two decades. I will review deep, wide-field surveys both within the Local Group as well as for nearby groups of galaxies, and summarise how these can be compared to state-of-the-art theoretical predictions in order to improve our understanding of galaxy formation and evolution.
A Survey Of Observed And Simulated Stellar Halos Around Milky Way-Like Galaxies In The Nearby Universe

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The recent increase in the quality and availability of deep observations and simulations of the stellar halos of nearby galaxies alike has prompted with increased urgency the question of how well the two agree with one another. The key impediment at this stage seems to be the difficulty in carrying out robust, ‘apples-to-apples’ comparisons between observed and simulated data. To address this, we selected disk galaxies from the Illustris-TNG100 cosmological magnetohydrodynamic simulations that are matched in stellar mass with a sample of spiral galaxies observed to extremely low surface brightness limits (30-32 mag arcsec$^{-2}$) as part of the newly-updated Dragonfly Nearby Galaxies Survey. We show that the low surface brightness outskirts of TNG100 galaxies are systematically more massive and extended than their observational counterparts, and that this discrepancy is greater than what we expect from observational uncertainties alone. Finally, we present initial findings from tracking individual particles that are currently found in the outskirts of galaxies across the entire simulation (20$\geq$ z $\geq$ 0), and discuss several possible explanations for these overly massive simulated stellar halos.
Forming Low Surface Brightness Objects In Simulations

Chris Brook

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We use cosmological hydrodynamical galaxy formation simulations to explore the formation of low surface brightness galaxies, and compare their formation to those of lower mass Ultra diffuse galaxies. We look for observational signatures that may accompany different formation scenarios.
I will present a review of HI 21-cm observations of extended low surface brightness (LSB) structures in the local Universe. Typically found in galaxy groups and clusters, HI features outside galaxies can span many hundreds of kpc, tracing gravitational interactions between galaxies and ram pressure forces by moving through the intra-group/cluster medium. Upcoming large HI surveys, e.g. with the wide-field (FOV = 30 square degrees) Phased Array Feeds on the Australian SKA Pathfinder (ASKAP), will provide a census of LSB structures in the Local Universe. I will include the latest results from our ASKAP HI observations in my talk.
MATLAS: An Investigation Of The Mass Assembly Of Galaxies With Their Fine Structures, Satellite And Globular Cluster Populations

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Multiple explorations of the low surface brightness (nearby) universe with deep imaging are currently on-going. The originality of the MATLAS survey lies in the size of the galaxy sample that has been studied with multiple broad-band CFHT images - several hundreds of galaxies -, and exclusive image quality of the MegaCam images, allowing us to detect with the same exposures the LSB structures (tidal features, extended halos, faint satellites and UDGs but also cirrus) and compact barely resolved objects (GCs, UCDs) in the field. The latter provide further clues on the properties and history of their host galaxies. I will present the current on-going projects using the MATLAS data, with a special emphasis on the complete survey of the LSB dwarf satellites together with their GC population that has recently been completed (Habas et al. submitted).
Detecting Thin Stellar Streams in External Galaxies: Resolved Stars & Integrated Light

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Thin stellar streams emerging from globular clusters can be used in the quest for the nature of the dark matter particle, as gravitational interactions with dark matter subhalos leave behind specific morphological and kinematic signatures in the streams. In this talk, I present results on current and future prospects for detecting low surface brightness globular cluster streams in external galaxies in both resolved stars (e.g. with WFIRST) and in integrated light (e.g. with HSC and LSST). In particular, I inject mock-streams to data from the PAndAS M31 survey and create simulated M31 backgrounds mimicking what WFIRST will observe in M31, given WFIRST’s deeper limiting magnitudes. Additionally, I estimate the distance limit to which globular cluster streams will be reported the detection of a globular cluster stream. WFIRST, however, should easily detect a PAl 5 like a stream in resolved stars for galaxies out distances of several Mpc. Using integrated light, I predict we will be able to observe thin streams out to ~100 Mpc, depending on the stream location and properties of the host galaxies.
The size of galaxies in an era of ultra-deep imaging

Nushkia Chamba, Ignacio Trujillo, Johan Knapen
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The traditional measurement of the size of galaxies, the effective radius, is a relic of the epoch when shallow imaging was unable to capture the full extension of astronomical sources. However, current deep imaging surveys have revolutionised our view of these objects, allowing us to regard critically our own conventions. In this sense, it is time to move from a definition of the light concentration of galaxies, the effective radius, to a definition that intuitively captures the concept of the size of galaxies, such as its edge or boundary. In this contribution, we introduce a new definition of the size of a galaxy based on the gas density threshold value for star formation in galaxies. Remarkably, our new size definition not only captures what the human visual system identifies as the edge of a galaxy, but also dramatically decreases the scatter in the stellar mass-size relation by more than a factor of 2. What’s even more unique is that our size parameter unifies galaxies spanning 5 orders of magnitude in stellar mass on a single mass-size relationship. To place our discovery in the context of galaxy formation, we discuss its application in two scientific cases: the nature of ultra-diffuse galaxies and the location of the onset of the stellar halo of a galaxy.
Signatures Of On-Going Interactions At The M81 Group Centre In The Low Surface Brightness Features

Sakurako Okamoto
Subaru Telescope, NAOJ, Hilo, USA

We present the photometric properties of dwarf galaxies and young stellar systems at the centre of the M81 group from the wide-field survey that we are conducting with Hyper Suprime-Cam on Subaru Telescope. One of the famous triplets, NGC3077 shows the diffuse stellar halo which extends towards north and south in S-shape structures, while other early-type dwarfs show no obvious features of the tidal effect from the recent interactions among M81, M82, and NGC3077. The outlying young stellar systems around these galaxies show their continuous star formation period in the recent past. No old stars are associated with these young objects, implying that they are genuine new stellar systems formed as a result of the recent encounters of M81, M82, and NGC3077. We also introduce our ongoing photometric survey for nearby galaxies.
Hunting For Low-Surface Brightness Features In Nearby Galaxy Groups

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Hunting For Low-Surface Brightness Features In Nearby Groups Dwarf galaxies are powerful testbeds to study cosmology on small-scales. In the Local Group, several discrepancies between theoretical predictions and observations of dwarfs have been identified and dubbed as a small-scale crisis. To extend these studies, we have conducted several surveys with different telescopes (DECam, SDSS, VLT, and the Jeanne Rich telescope) to probe other nearby galaxy groups and search for dwarf galaxies, ultra-diffuse galaxies, and tidal features. In my talk, I will provide evidence that the small-scale problems persist in other galaxy groups, most notably in the Centaurus A group. And more, I will present how a recently developed Max-Tree based method – MTO – can help us discover low-surface brightness features in astronomical images and can be used to process large ongoing and upcoming surveys.
Galaxy interactions should be easier to investigate in regions of high galaxy densities. However in galaxy clusters it is difficult to disentangle the real interactors among the many galaxies. This discrimination of interactors should be much easier in regions that have, on the one hand, a high density of galaxies and, on the other hand, contain only a small number of objects. We imaged some Hickson Compact Groups to detect extended LSB features that would hint on the evolution mechanisms in such dense environments and present results from deep imaging that reach surface magnitudes of 28-30 mag/square arcsec. The observations were obtained in a wide red spectral band with a fast-focus 28-inch telescope at the Wise Observatory. We show some outstanding systems with clear signs of interaction that, at very low surface brightness levels, allow the discovery of new phenomena and a better understanding, in cases of dry or wet mergers, of such systems.
The Reports Of Thick Discs’ Death Are Greatly Exaggerated: Thick Discs Are NOT Artefacts Caused By Diffuse Scattered Light

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Recent studies have made the community aware of the importance of accounting for scattered light when examining low surface brightness galaxy features such as thick discs. In past studies on thick discs of edge-on galaxies the point spread function (PSF) effects were not taken into account or were modelled with a Gaussian kernel. We have re-examined results on photometric decompositions of discs in the Spitzer Survey of Stellar Structure of Galaxies (S4G) using a revised PSF model that accounts for extended wings out to more than 2.5 arcminutes. We studied 141 edge-on galaxies. This is the largest sample of extragalactic thick discs studied so far. The main difference between our current fits and those presented in the past is that now the scattered light from the thin disc dominates the surface brightness at levels below 26 mag arcsec⁻². This change, however, does not affect drastically any of our previously presented results: - Thick discs are nearly ubiquitous. They are not an artefact caused by scattered light as has been suggested elsewhere. - Thick discs have masses comparable to those of thin discs in low-mass galaxies (with circular velocities vc<120 km s⁻²) whereas they are typically less massive than the thin discs in high-mass galaxies. - Thick discs and central mass concentrations seem to have formed at the same epoch from a common material reservoir. We conclude that the mass of the thick discs has not been overestimated due to an incorrect PSF description. They are confirmed to contain a large fraction of the baryons in galaxies. Because they contain some of the oldest stars in galaxies and because of their large mass understanding them is of fundamental importance to understand how galaxies themselves form.
Session 5B: Low-surface-brightness features around and within galaxies
Early Photographic Detection of LSB Features

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For nearly 100 years, classical, silver-based photography was the only useful detector for revealing large-scale low surface brightness features in the night sky. That changed rapidly in the early 1990s with the photographic introduction of large format digital detectors. Here I review the last two decades of the era, which were remarkably productive in this context. New photographic techniques were developed which lead to the discovery of many new LSB features of bright galaxies and a new variety of fainter ones, casting new light on the variety of galaxy interactions.
Dark matter and chemical enrichment in the low surface brightness outskirts of galaxies

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I will present the latest results from the HALO7D survey of MSTO stars in the remote Milky Way (MW) halo, the PHAT and SPLASH surveys of the stellar halo and stellar disk/halo interface of M31 and M33, the PISCeS project targeting the stellar halos of MW-like galaxies in the Local Volume (Sculptor Group, Centaurus A group, M81 group), and the NGVS survey of low surface brightness galaxies and intra-cluster light in the Virgo cluster. The findings are based on deep spectroscopy of resolved and partially resolved stellar populations and globular clusters obtained using the Keck II 10-meter telescope and DEIMOS spectrograph, supplemented by deep wide-field groundbased imaging and HST imaging. These results, together with state-of-the-art Lambda-CDM simulations, present a coherent picture of galaxy assembly, chemical enrichment, and star-formation history in the sparse outer regions of massive and low mass galaxies.
Tracing The Extended Stellar Outskirts Of Low-Mass Disk Galaxies

In Sung Jang, Roelof De Jong

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The low surface brightness features around galaxies are believed to hold a key to the understanding of the early galaxy formation. With the advent of deep imaging and high-precision resolved stellar photometry, our knowledge on the galaxy outskirts has been greatly improved. Now we know that massive disk galaxies do have stellar halos and their halo properties are diverse in terms of mass, mass fraction, and mean metallicity. For low-mass disk galaxies, however, our knowledge is still limited, mainly due to the even fainter stellar structures around the galaxies. In this talk, we present faint stellar outskirts of two low-mass disk galaxies, NGC 300 and NGC 7793, in the Sculptor group using the image data taken from the Hubble Space Telescope. We detect a significant population of old and metal-poor RGB stars, which extend out to ∼15 disk scale lengths and remained undetected in previous studies. The star count profiles of both galaxies show a clear break at R ∼ 7 disk scale lengths, deviating from the pure exponential distribution. Beyond this break radius, the profiles become significantly flatter than those of the inner region, suggesting that the two low-mass galaxies have extended stellar envelopes. We compare our findings with model predictions and discuss its implications.
Census Of Tidal Features In Nearby Early-Type Galaxies

Michal Bilek, Pierre-Alain Duc
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MATLAS is a volume limited deep imaging survey of nearby early-type galaxies (ETGs) carried out with the MegaCam camera at the 3.6m Canada-France Hawaii Telescope. The survey reaches the typical surface-brightness limit of 28.5-29 mag/arcsec$^2$ in g while keeping excellent image quality. Various scientific topics are being addressed in this project. We will present here the efforts made at detecting and characterizing tidal features, the photometric irregularities in galaxies caused by galaxy interactions. Tidal features can survive for several Gyr. Their morphology depends on the orbital geometry of the encounter and the properties of the galaxies such as their masses or the degree of rotational support. Tidal features are thus keepers of the assembly history of galaxies. We will present our method to identify collisional debris and results regarding how the frequency of individual types of tidal features depends on the properties of the host galaxy. The astrophysical implications will be discussed.
Deep HST or future JWST imaging, intended to investigate the high-z Universe, are "contaminated" by a number of extended galaxies. They are either massive and/or low-z galaxies. Similarly, synoptic surveys like Euclid or LSST will commonly find such objects. We started their analysis with the study of the six most massive (>$5\times10^{10}$ $M_\odot$) galaxies at $z<1$ in the Hubble Ultra Deep Field. The outer ($10<R/{\rm Kpc}<50$) parts of these early-type galaxies host 5-20% of their stellar mass, at variance with what happens for same-mass late types ($<5\%$). This is key to explain the inside-out growth of massive galaxies, being these outer envelopes progressively created by the continuous merging with surrounding satellites, and therefore being in their own right stellar haloes detected in our sample at a median redshift $z=0.65$! We are extending our analysis to similar galaxies in all HST CANDELS fields and I will show how to deal with these large galaxies in order to retrieve accurate masses and structural parameters. Additionally, only a good characterization of their light could unveil the properties of their minor galaxy neighbours. Finally, our experience enables us to explore extreme objects such as IC1101, the largest galaxy ever detected, for which I will provide updated sizes, surface brightness profiles and for the first time a stellar mass based on HST and dedicated data.
Low Surface Brightness Features In The Local Universe: Viewed From Subaru Prime Focus

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One of the unique features of the Subaru Telescope among 8-10 meter telescopes is that it equips with the prime focus. The fast F-ratio of the prime focus enables us to survey wide field efficiently and is also favorable for detecting low surface brightness features. Furthermore, the good image quality realized at Maunakea enables us to investigate their detailed structures. Therefore, Subaru prime focus is one of the best facilities to explore the low surface brightness universe. In this presentation, we focused on the low surface brightness features found in the local universe, that are (1) diffuse HII regions in the Local Group dwarf irregular galaxy NGC 6822, (2) diffuse intracluster Halpha filaments in the Coma cluster.
Session 6A: The nature of ultra-diffuse galaxies and other LSB galaxies
On The Nature Of The Ghostly Ultra-Diffuse Galaxies In The Coma Custer

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Ultra-diffuse galaxies (UDGs) have been one of the latest hypes in the extragalactic community. Although discovered a few decades ago, only recently we have had the opportunity to start grasping their nature thanks to deep photometric observations. With the sizes and stellar masses of the Milky Way but only 1% of its light, they have been found in clusters by the hundreds. With some unexpected and intriguing properties, their origin is still under debate. Altogether, this means that we have been neglecting their role into the galaxy census. In this talk I will present the largest spectroscopic sample of UDGs in Coma, complemented by new Perseus and field UDG data. Analysing the stellar populations and star formation histories of these different UDGs, I will compare their properties with the different formation scenarios, revealing the nature of UDGs and the role they play in the broader picture of galaxy evolution.
The Stellar Content In Ultra Diffuse Galaxies: Contrasting The Galaxy “Lacking” Dark Matter With Other Coma Cluster UDGs

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Understanding the peculiar properties of Ultra Diffuse Galaxies (UDGs) via spectroscopic analysis is a challenging task that is now becoming feasible. Improvements in observing techniques together with advances in the modelling of stellar populations are allowing the recovery of the stellar content shaping these faint objects with unprecedented reliability. In this talk we report on the extensive comparison between the star formation histories (SFH) recovered through the analysis of deep CMDs and high-quality integrated spectra (STECKMAP). Given the outstanding performance of STECKMAP at recovering SFH, we exploit its capabilities to perform one of the most complete and reliable characterisations of the stellar component of UDGs to date using deep spectroscopic data. We find that the SFHs of the UDG (located in the Coma cluster) are dominated by old ($\sim 7$ Gyr), metal-poor ($[\text{M/H}] \sim -1.1$) and alpha-enhanced ($[\text{Mg/Fe}] \sim 0.4$) populations followed by a smooth or episodic decline which halted $\sim 2$ Gyr ago, possibly a sign of cluster-induced quenching. We conclude that these UDGs are extended dwarfs whose properties are likely the outcome of both internal processes, such as bursty SFHs and/or high-spin haloes, as well as environmental effects within the Coma cluster. We also study [KKS2000]04, the galaxy “lacking” dark matter, to find that it has nothing peculiar when comparing its stellar content with other UDGs in Coma. In addition, we find 2 new PNe candidates as well as confirm membership of 5 GCs. Although its origin as a tidal dwarf is disfavoured, the recovered lack of a population gradient (age and metallicity) in this galaxy allows us to argue that interactions might have played a major role in shaping this galaxy in the past. This kind of spectroscopic works shows that significant changes in the observing strategy and data reduction is needed to study such faint objects in the future.
The Formation of Ultra-Diffuse Galaxies: Observational Evidence

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The existence of ultra diffuse galaxies (UDGs) is now a well known phenomenon, with a variety of formation mechanisms proposed. However, it is still not clear which process is dominant and how this varies as a function of environmental density. In my talk, I will put UDGs into perspective with smaller low surface brightness galaxies, referencing halo mass estimates derived from the globular cluster abundances of 175 LSB galaxies in the Fornax cluster. In the second part of the talk, I will discuss how the properties of UDGs in the field allow us to put constraints on the efficiency of secular evolution processes using an empirical UDG model. Finally, I will provide a summary of the relative importances of UDG formation scenarios from an observational perspective.
In the present work, we build a volume-limited sample of galaxies derived from the SDSS-DR7 to characterize the environment of LSB galaxies at different scales, finding that the large scale structures have a lower impact in the galaxy properties than local environment. Using an observational proxy for the assembly time, we found that LSB galaxies assembly half of their total halo mass later than HSB ones, reinforcing the idea of them being unevolved systems. We use 5 different methods to estimate the total halo mass, finding that the stellar-to-halo mass ratio is up to 22% lower in LSB galaxies. Finally, in order to estimate the spin parameter $\lambda$, we use a bulge-disk decomposition to obtain the specific angular momentum $j^*$ of the galaxy. We also consider a Tully-Fisher relation to estimate the rotation velocity of the disk, to calculate the spin parameter considering the 5 estimations of the halo mass, as well as a halo mass independent expression, finding that the spin of LSB galaxies is between 1.2 to 2 times larger than for HSB ones. We compare these results with a control sample that includes kinematic information, taken from the ALFALFA $\alpha$.100 galaxy catalog, allowing us to measure directly the rotation velocity of the disk. The trends in the values of $j^*$ and $\lambda$ are similar to the volume limited-sample. These differences could be due not only to the intrinsic spin distribution, but also due to the fact that HSB galaxies retain less angular momentum than LSB ones, as shown by different studies, where galaxies with lower B/D ratio retain angular momentum efficiently.
Session 6B: The nature of ultra-diffuse galaxies and other LSB galaxies
I will discuss the status of the SMUDGes survey, including the results of follow-up observations in the UV, optical, and radio wavelengths. Large surveys, like SMUDGes, enable the search for rare objects and provide large enough samples for statistical treatments.
Ultra Diffuse And Low Surface Brightness Galaxies In The Virgo Cluster: Constraints From The VESTIGE And GUViCS Surveys, And Simple Models

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In the recent years, UDGs have been found in large numbers first in clusters (Koda et al. 2015), and then also in the field, with a wide range of properties. The Virgo cluster being both nearby, and deeply observed at all wavelength, it is a prime target to search and study such galaxies in the cluster environment. Recently, the NGVS has allowed the characterisation of thousands of galaxies in Virgo, and to find more than 100 UDGs or LSB galaxies. I will present some on-going work concerning their study, focusing on measurements from GALEX in the UV and VESTIGE in H-alpha. Finally, I will show that simple models of galaxy evolution can allow us to test the effect of ram-pressure stripping on the star formation history of galaxies that would be “usual” in its absence. UDGs may be affected by a combination of effects but simple models allow us to study the role of an effect that SHOULD be present in the cluster environment.
Unavoidable Questions About Giant Low Surface Brightness Galaxies

Gaspar Galaz

Istituto de Astrofisica, PUC, Santiago, Chile

I summarize fundamental issues still pending in the field of study of giant low surface brightness galaxies. I discuss some clues that can illuminate the answers, as well as recent results that solve some of them, but also open new questions.
Giant low surface brightness galaxies (gLSB) with discs as large as 150 kpc challenge galaxy formation scenarios and it is still not well understood how they form and evolve through the cosmic time. Here we present analysis of deep long-slit spectroscopic observations of a sample of five out of seven known gLSBs obtained with the Russian 6-m telescope: UGC 1922, Malin 2, UGC 6614, NGC 7589 and UGC 1378. We derived spatially resolved properties of stellar and ionized gas kinematics and characteristics of stellar populations and interstellar medium. The stars in the central regions are old and metal rich for most of the galaxies. We revealed the presence of a kinematically decoupled central component in the inner regions of UGC1922 and UGC6614, where we detected counter-rotating kinematical components. There seems to be a need for diversity of gLSBs formation scenarios: (i) some of them could have formed by in-plane mergers of massive galaxies; (ii) for some others the major merger scenario is excluded by our data. We revealed that most of gLSBs are situated in low-density environment which possibly helped to preserve the giant discs. At the same time at some point of the formation history of these systems there should exist a reservoir of gas from which the massive discs were formed. Future observations and detailed comparison with numerical simulations of galaxy formation in the cosmological contest will help to clarify which gLSB formation channel is more important.
Hunting Distant UDGs In Very Massive Galaxy Clusters With HST

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Ultra-diﬀuse galaxies (UDGs) have extremely large sizes in the realm of low surface brightness (LSB) galaxies. Understanding of these interesting galaxies has been improved by recent studies which found hundreds of UDGs in galaxy groups or clusters. However, our knowledge of UDGs in more massive hosts than the Coma cluster is still limited, because most previous studies searched for UDGs in host systems in the local universe. In this study, we report our search and analysis of UDGs in three very massive clusters (M_{200} > 10^{15} M_{\odot}) of the Hubble Frontier Fields: Abell 2744 (z=0.308), Abell S1063 (z=0.348), and Abell 370 (z=0.375). To date, these clusters are the most massive hosts of UDGs. We found 134 UDGs in these three clusters. Most UDGs show a color-magnitude relation consistent with the red sequence of cluster members. This means that these UDGs are mainly composed of old stars. However, we found a few blue UDGs in the central ﬁelds of these clusters. They are intriguing because previously known blue UDGs were found in much lower density environments. The radial number density proﬁles of bright galaxies and UDGs show a signiﬁcant discrepancy in the central region of the clusters. The proﬁles of UDGs show a drop or a ﬂattening as the cluster-centric distance decreases, while that of bright galaxies shows a continuous increase. This implies that a signiﬁcant amount of UDGs was tidally disrupted in the central region of the clusters. We indirectly estimated the dynamical masses of UDGs, using the fundamental manifolds. Most UDGs show similar masses to those of dwarf galaxies (M_{200} < 10^{11} M_{\odot}), but a few large UDGs show L* -like masses (M_{200} > 10^{11} M_{\odot}). We found a tight power-law relation between the abundance of UDGs (N(UDG)) and the virial masses (M_{200}) of their hosts: M_{200} \sim N(UDG)^{(1.01 \pm 0.05)}. This power-law index is nearly one, implying that the survival eﬃciency of UDGs depends little on the masses of their host environments. In conclusion, distant UDGs in massive clusters have similar properties to nearby UDGs.
I first clarify the distinction between high and low (+ very low) surface brightness, as well as giant vs dwarf, galaxies based on structural and dynamical measurements and the scaling relations that these define. Formation models for these galaxy types are reviewed and I present evidence for any dependence of LSB properties on various in-situ (IMF/feedback) and environmental properties. A related question is whether the observed Local Group and simulated LG analogs provide representative environments for the global study of LSBs. I will stress the importance, and discuss the future, of dynamical measurements of LSB galaxies in constraining their formation and evolution.
Internal Dynamics And Stellar Content Of Ultra-Diffuse Galaxies In The Coma Cluster Prove Their Evolutionary Link With Dwarf Early-Type Galaxies

Igor Chilingarian\textsuperscript{1}, Anton Afanasiev\textsuperscript{2}, Kirill Grishin\textsuperscript{2}, Daniel Fabricant\textsuperscript{1}, Sean Moran\textsuperscript{1}

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Ultra-diffuse galaxies (UDGs) are spatially extended low surface brightness stellar systems with regular elliptical-like morphology. They are found in large numbers in galaxy clusters and groups, but their formation and evolution remain poorly understood because their low surface brightnesses have made studies of their internal dynamics and dark matter content challenging. Here we present spatially resolved velocity profiles, stellar velocity dispersions, ages and metallicities of 8 UDGs in the Coma cluster and cluster membership confirmation for another 10 UDGs. We use intermediate-resolution spectra obtained with Binospec, the MMT’s new high-throughput optical spectrograph and complement it with multi-wavelength photometric data from GALEX, Spitzer, and Subaru. We derive dark matter fractions between 50\% and 90\% within the half-light radius using Jeans dynamical models. Two galaxies exhibit major axis rotation, two others have highly anisotropic stellar orbits, and one shows signs of triaxiality. In the Faber–Jackson and mass–metallicity relations and on the Fundamental Plane, the 8 UDGs fill the gap between cluster dwarf elliptical (dE) and fainter dwarf spheroidal (dSph) galaxies. Overall, observed properties of all UDGs can be explained by a combination of internal processes (supernovae feedback) and environmental effects (ram-pressure stripping, interaction with neighbors). These observations suggest that UDGs and dEs are members of the same galaxy population.
Optically Dark Hydrogen Clouds From The Arecibo Galaxy Environment Survey : Dark Galaxies Or Debris ?

Rhys Taylor  
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I will review the optically dim and dark HI features uncovered by the Arecibo Galaxy Environment Survey. In the Virgo cluster, we discovered 8 isolated HI clouds (more than 100 kpc from the nearest galaxy) with no optical counterparts and line widths up to 180 km/s. I will describe the results of a series of numerical simulations showing that these are unlikely to be produced by tidal encounters - such debris is not expected to remain detectable so far from its parent galaxies, whereas the survival of the clouds is greatly enhanced if they have a significant dark matter component. I will discuss the possible connection to low surface brightness galaxies detected in the cluster and elsewhere. In particular, we have recently detected 3 ultra diffuse galaxies in the Pegasus cluster which have 100 times as much HI as the Virgo clouds, similar line widths, little or no star formation and little molecular gas (based on observations with the IRAM 30 m telescope). I will discuss whether such objects may relate to the Virgo clouds or if a different formation mechanism is more probable.
The Startling Dynamics Of HI-Rich Ultra Diffuse Galaxies

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2. ASTRON, Groningen, The Netherlands

In this talk I will present our main discoveries regarding the dynamics of HI-rich ultra diffuse galaxies (UDGs). Using a set of interferometric observations and a state-of-the-art 3D fitting technique we derive reliable rotation velocities for a sample of seven isolated UDGs. Surprisingly, these galaxies have very low rotation velocities given their baryonic masses, which makes them shift off from the Baryonic Tully-Fisher relation (BTFR), suggesting fundamental differences between the formation of HI-rich UDGs and other disc galaxies. Moreover, their position in the BTFR matches the expectations of galaxies with a baryon fraction equal to the cosmological value, making these galaxies compatible with having no missing baryons, which sets important constraints on feedback processes at dwarf-scales. The rotation velocities we derive also allow us to make an estimation of the dynamical mass of our HI-rich UDGs, revealing (as glimpsed by their low rotation velocities but high baryonic fractions) their low dark matter content.
Dispersion vs Rotation Support In Ultra-Diffuse And Low Surface Brightness Galaxies

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We analyze numerical simulations from the NIHAO project to study in detail the rotation vs pressure support of simulated Low Surface Brightness (LSB) and Ultra-Diffuse Galaxies (UDGs). We show that while LSBs are consistently rotation supported, UDGs appear to be both rotation and dispersion supported. The different behaviours are connected with different formation scenarios: the LSBs rotation is connected to their dark matter halo spin and acquisition of angular momentum during mergers, whereas the kinematics of UDGs is independent of halo spin and mostly due to internal processes, i.e. powerful supernova feedback. Furthermore, we found that in UDGs the rotation is related to the amount of HI gas: UDGs with lower HI fractions are pressure supported while HI dominated-UDGs are rotation supported. We explore the reasons for these differences and offer observational predictions.
**Internal Dynamics Of The Extended Dwarf Spheroidal Galaxy KDG64: Bridging The Gap Between Ultra-Diffuse Galaxies And Dwarf Spheroidals**

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KDG64 (UGC5442) is a relatively large (Reff = 1.05 kpc) and luminous (MV = -13.6 mag) dwarf spheroidal galaxy residing in the M81 group that bridges the dE and dSph classes in terms of size and mass. With recent advances in studies of ultra-diﬀuse galaxies in Coma cluster it became a promising target as one of the closest analogues to UDGs in the Local Volume. Here we present spatially resolved velocity and velocity dispersion profiles along both major and minor axes of KDG64 from deep intermediate-resolution integrated-light spectra obtained with Binospec, the MMT’s new high-throughput optical spectrograph. We derive dark matter fraction within the half-light radius of about 90\% and high level of the vertical orbital anisotropy (beta_z = 0.75) using axisymmetric Jeans dynamical models, which is consistent with some of the Coma UDGs. The shape of the dispersion profile with central elevation cannot be precisely described by a constant M/L model, which may be explained using a cuspy dark matter profile. While the exact shape of DM halo is beyond our grasp, we could still put some limitations to address the cusp/core issue in dwarf spheroidals. KDG64 sits on the mass metallicity relation formed by somewhat fainter dSphs in the Local Group and more luminous UDGs and dEs in clusters and its internal dynamics also bridges the gap between them. Overall, there seems to be a continuum of structural and dynamical properties including dark matter contents for dEs, UDGs, and dSphs, hence we should think how to build a general scenario of dwarf galaxy formation and evolution that explains the full variety of observed characteristics.
Session 7: The circumgalactic medium of low- and high-redshift galaxies
Illuminating The Cosmic Web And The Circumgalactic Medium With Fluorescent Lyman-Alpha Emission

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Our standard cosmological model predicts that most of the matter in the universe is distributed into a network of filaments - the Cosmic Web - in which galaxies form and evolve. Because most of this material is too diffuse to form stars, its direct detection has remained elusive for several decades leaving fundamental questions still open, including: How are galaxies linked to each other? What are the morphological and physical properties of the Cosmic Web and Circumgalactic gas on both large and small scales? How do galaxies accrete gas from the Cosmic Web and from their Circumgalactic Medium? In this talk, I will review recent studies that tackle these questions by directly detecting high-redshift cosmic gas in emission using bright quasars and galaxies as external “sources of illumination”. In particular, I will show results from ultra-deep narrow-band imaging and integral-field-spectroscopy with both MUSE/VLT and the Keck Cosmic Web Imager (KCWI) that revealed numerous giant Lyman-alpha emitting haloes and filaments extending up to several hundred kpc around quasars and bright galaxies. I will discuss how the unexpectedly high luminosities of these systems, together with the constraints from Helium and metal extended emission, represent a challenge for our current understanding of cosmological structure formation. In particular, I will show that current observations suggest that intergalactic gas around high-redshift galaxies and quasars has a much broader density distribution of cold material than expected from cosmological simulations and I will present our first attempts to understand the origin and nature of these structures using high-resolution hydrodynamical models.
The circumgalactic medium of low-redshift galaxies, probed by emission lines at low surface brightness

**Matthew Hayes**  
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The Circumgalactic Medium (CGM) is the gaseous interface between interstellar gas and intergalactic space. It acts as the exchange medium to where feedback expels hot gas, and the region that inflowing gas from the IGM must traverse or order to supply galaxies with fresh gas. As such, the CGM acts as the driver and regulator of galaxy formation. Unfortunately the CGM is also a very tenuous medium, and the light that it does emit will be found at very low surface brightness. I will present the results of endeavours to measure properties of circumgalactic gas of low redshift galaxies, using imaging techniques. My talk will focus on two wavelength regimes: the far ultraviolet and the optical. In the UV we study extended photoionized gas using (possibly scattered) HI Lyman-alpha emission, and emission from highly ionized oxygen (O VI). Capturing the same gas in emission and absorption allows unique constraints to be on the volume density and column length, without the use of simulations. In the optical we measure extended line emission and map its distribution, ionization levels, and dynamical properties, showing that the CGM of low-z starbursts is a chaotic, multiphase environment. I will close by presenting some perspectives on the future, and outlining some of the key requirements for future observatories.
Direct Detection Of The Circumgalactic Medium Using Dragonfly

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2. Yale University, New Haven, USA

We describe a new approach to studying the intergalactic and circumgalactic medium in the local Universe: direct imaging. We have modified the Dragonfly Telephoto Array to turn it into an ultra-sensitive line emission mapper. This upgrade is designed to target the extremely low surface brightness visible-wavelength line emission from gas in the cosmic web. Using hydrodynamical cosmological simulations (EAGLE) we investigate the expected brightness of this emission at low redshift (z < 0.2) and find that H-alpha emission in extended halos of galaxies (analogous to the extended Ly-alpha halos/blobs detected around galaxies at high redshifts) and the fluorescent ‘skin’ of local ‘dark’ HI clouds could be directly imaged in exposure times of ∼10 hours. We will present first results from our prototype and speculate on the ultimate limits of an upgraded array.
GTC-Based Search For Diffuse Gas Around Local Gas-Accreting Galaxies

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According to the cosmological numerical simulations of galaxy formation, cosmic gas accretion sets the rate of galaxy growth. This ingredient is both central to the theory of galaxy formation and extremely elusive observationally. The accreted gas is expected to coexist with winds driven by the ensuing star-formation. Cosmic accretion is particularly important in low-mass dark-matter haloes, i.e., in galaxies of the early universe, but also in isolated dwarf galaxies of the local universe. We identified a number of local galaxies that seem to have gone through a recent gas accretion event (SA+15. ApJ). Using them as targets, we have been trying to detect the Ha emission of the gas predicted by the models. I will report on a very deep GTC observation of the circum-galactic medium around UM260, which shows both diffuse emission and discrete clumps at the level of $10^{-18}$ erg/s/km$^2$/arcsec$^2$. I will also present follow up observations using GTC-OSIRIS to confirm redshifts and to infer physical properties for the Ha emitting clumps.
Galaxies are intimately connected to the environments they live in: they grow by accreting gas from the circumgalactic medium (CGM) and they heat and enrich the CGM through galactic outflows. Even though the CGM is diffuse and faint, it has been observed in both absorption and emission. With the advent of new and upcoming instrumentation, such as ALMA, SKA, MUSE, and Athena+, the complex, multiphase gaseous haloes will be observed in three dimensions. This will significantly enhance our current knowledge of the role the CGM plays in galaxy formation, especially when combined with state-of-the-art simulations. However, most cosmological, hydrodynamical simulations focus their computational effort on the galaxies themselves and treat the CGM more coarsely, which means that small-scale structure cannot be resolved. I will discuss how we get around this issue by running zoom-in simulations of a Milky Way-mass galaxy with uniform 0.5 kpc resolution within the virial radius (out to about 200 kpc). The improved spatial resolution does not strongly impact the central galaxy or the average density of the CGM. However, it samples strong overdensities (and underdensities) much better and therefore drastically changes certain observables. Additionally, I will show that metals are mixed less efficiently, reducing the average metallicity of the (ionized) CGM. I will therefore conclude that some of the properties of the simulated CGM are strongly resolution dependent, while others are more robust. This is especially important to keep in mind when using simulations to predict or interpret observations of the CGM or of the intergalactic medium.
Surprising Existence Of Circumgalactic Molecular Medium In A Galaxy Protocluster At \( z=2.2 \)

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We know that environment has a critical impact on galaxy growth and evolution. What we do not know is when it starts to have an impact and how it does it. We are using the radio interferometers the Australian Telescope Compact Array (ATCA) and ALMA to study the role of environment on the molecular gas content, the fuel of star formation, of distant star-forming galaxies. From our pilot study to search for low-surface brightness cold CO(1-0) molecular gas emission, I present the discovery of massive extended CO gas reservoirs in these star-forming galaxies that are located in the galaxy protocluster surrounding the radio galaxy, MRC1138-262 at \( z=2.2 \). The discovery of circumgalactic molecular medium is unexpected as gas truncation and stripping was predicted. Our results alter our view of the important topics of the development and gas phase distribution of the proto-intracluster medium: how ram-pressure stripping may operate in galaxy protoclusters, how the galaxies may contribute to enriching and heating the proto-intracluster medium, and how their star formation may be limited by their internal dynamics. Furthermore, I will present results of our on-going ATCA Large Program ‘CO ATCA Legacy Archive of Star-Forming Galaxies (COALAS)’ based on our successful pilot study. This survey significantly extends our study of how environment impacts the cold molecular gas content in cluster and field galaxies in the early universe.
Understanding The Cool Circumgalactic Medium Of Passive Galaxies

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The circumgalactic medium (CGM) of galaxies consists of a multiphase gas with components at very different temperatures, from $10^4$ K to $10^7$ K. One of the greatest puzzle about this medium is the presence of a large amount of low-temperature (T~$10^4$ K) gas around quiescent early-type galaxies (ETGs). Using semi-analytical parametric models, we describe the cool CGM around massive, low-redshift ETGs as the cosmological accretion of gas into their dark matter halos, resulting in an inflow of clouds from the external parts of the halos to the central galaxies. We compare our predictions with the observations of the COS-LRG collaboration. We find that inflow models can successfully reproduce the observed kinematics, the number of absorbers and the column densities of the cool gas. Our MCMC fit returns masses of the cool clouds of about $10^5$ solar masses and shows that they must evaporate during their journey due to hydrodynamic interactions with the hot gas. We conclude that the cool gas present in the halos of ETGs likely cannot reach the central regions and feed the galaxy star formation, thus explaining why these passive objects are no longer forming stars.
Session 8: The intracluster light and its role in galaxy evolution in clusters
Galaxies in clusters interact among each other. During these interactions, stars are stripped from their galaxies and end up forming a diffuse light called intracluster light (ICL). In this talk, I will review the history of the ICL, its role as fossil record of the accretion history of the cluster and the observational challenges needed to accurately measure this component of galaxy clusters.
Intra-Cluster Light: its formation and main properties

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We study the formation of the Intra-Cluster Light (ICL) using a semi-analytic model of galaxy formation, coupled to merger trees extracted from N-body simulations of groups and clusters. We assume that the ICL forms by (1) stellar stripping of satellite galaxies and (2) relaxation processes that take place during galaxy mergers. The fraction of ICL in groups and clusters predicted by our models ranges between 10 and 40 per cent, with a large halo-to-halo scatter and no halo mass dependence. On cluster scale, large part of the scatter is due to a range of dynamical histories, while on smaller scale it is driven by individual accretion events and stripping of very massive satellites, $M > 10^{10.5} M_\odot$, that we find to be the major contributors to the ICL. The ICL in our model forms very late ($z < 1$), and a fraction varying between 5 and 25 per cent of it has been accreted during the hierarchical growth of haloes. In agreement with recent observational measurements, we find the ICL to be made of stars covering a relatively large range of metallicity, with the bulk of them being sub-solar.
Stellar Halos From Deep VST Surveys: Comparing Observations And Theory

Marilena Spavone

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In the recent years, a big effort was made to develop deep photometric surveys aimed at studying galaxy structures down to the faintest levels of surface brightness of $\mu_g \sim 27-30$ mag/arcsec$^2$. In this context, the VST Early-type GAlaxies Survey (VEGAS) is producing competitive results. They confirm the feasibility of such a survey to reach the faint surface brightness levels of 27 - 30 mag/arcsec$^2$ in the g band, out to about 10 Re. Therefore, taking advantage of the deep photometry, we can address the build up history of the stellar halo by comparing the surface brightness profile and the stellar mass fraction with the prediction of cosmological galaxy formation. One of the priority science goals of VEGAS is to study the faint outer regions of the massive galaxies in groups and clusters. The large mosaics obtained with the 1 square degree field-of-view pointings of OmegaCam at VST, plus the high angular resolution of 0.21 arcsec per pixel and the large integration time allow us to study, on the cluster scale, the galaxy structure from the brightest inner regions to the faint outskirts, where the stellar envelope merges into the intracluster light. The deep observations can be directly compared with the predictions from the up-to-date theories for the stellar halo formation and the relation with the galaxy environment. In this talk, I will present the VEGAS survey and I will review the main results on the study of galaxy stellar halos.
Intracluster Light As A Proxy For Host Cluster Properties

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In this project, a multi-stage image processing pipeline for the efficient recovery of low surface brightness (LSB) emission from galaxy clusters will be defined. Within a galaxy cluster the tidal gravitational interaction between the galaxies causes stars to be stripped from the galaxy’s outskirts. Over time this stripping mechanism forms a diffuse component throughout the cluster known as intra-cluster light (ICL). In observational data, LSB structures are notoriously difficult to detect, extract and measure. The purpose of this work is to define an efficient automated pipeline to extract the ICL from cluster images. By accounting for the point-spread function (PSF) in greater depth than previous works, applying novel segmentation techniques by comparison with simulations, masking secondary sources, and applying the techniques to a large sample of clusters across multiple telescopes and surveys this work aims to provide a new window onto the LSB components of the largest gravitationally bound structures in the universe. A key feature of the pipeline is the initial sky estimation, since this is typically the point in the process at which traditional sky estimation methods overestimate and remove LSB features from the data completely. As for extracting the ICL, the method employed in this work utilises averaged values taken in concentric elliptic annuli from the Brightest Cluster Galaxy (BCG) at the center of the cluster. Plotting these averaged values for brightness against distance form the centre of the cluster gives a robust profile of the BCG out to the outer edges of the ICL. Once this method of profile extraction has been applied to the cluster sample the profiles may be stacked, providing one averaged profile. The advantage of this method is that rather than focusing on specific cases, it allows the study of the general properties of the ICL. A further benefit of this method is that the separate profiles may be stacked by cluster property. In this way it becomes possible to study the effect of, for example, cluster mass on the ICL profile. Cluster richness, redshift, colour and BCG morphology may all also be tested in this way, and may pave the way towards ICL profiles being used as a proxy for these features.
Intracluster Light And Its Influence On Galaxy Evolution In Clusters

IT Florence Durret
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Though its detection is still difficult, intracluster light is important to trace cluster formation as well as the evolution of galaxies in clusters. I will review the recent advances of our team on this topic, from nearby clusters to more distant ones (z~0.8).
Unveiling The Dynamical Stage Of Massive Clusters Through The Study Of The Intracluster Light

Yolanda Jimenez Teja, Renato Dupke
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The intracluster light (ICL) is defined as the luminous component of the galaxy clusters formed by stars that are gravitationally bound to the cluster potential but not to any individual galaxy of the system. Its study can give insights on the cluster formation and evolution, since its origin is thought to be mainly linked to the BCG formation and/or to the dynamical stripping of stars of member galaxies. In Jiménez-teja & Dupke (2016) we developed a precise technique to measure the ICL fraction (defined as the ratio of intracluster light to the total luminosity of the clusters) called CHEFs Intracluster Light Estimator (CICLE). CICLE showed a remarkable performance analyzing HST data of clusters in the redshift range \(0.18 < z < 0.55\) at three different optical bands (F435W, F606W, and F814W) (Jiménez-Teja et al. 201, and proved that the ICL fraction can be used as indicative of the dynamical state of the clusters. The ICL fraction of relaxed clusters was found to be nearly constant at all wavelengths, while we detected an excess on the ICL fraction measured in the F606W filter for merging systems. This was interpreted as a higher amount of younger/lower-metallicity stars in the ICL compared to the cluster members, which might have been stripped from the outskirts of infalling galaxies during the merger. We later expanded our study to lower redshifts using J-PLUS data of the Coma cluster. We observed again an excess in the ICL fraction measured at certain blue filters and at the same time the use of the J-PLUS narrow filters let us understand better the dynamics in Coma.
The Deep (Photometric And Spectroscopic) Surveys Of The Fornax Cluster: Exploring The Faintest Regions Of The Bright ETGs Inside The Virial Radius

Enrichetta Iodice

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The Fornax cluster provides a uniquely compact laboratory in which to study the detailed history of early-type galaxies and the role played by the environment in driving their evolution and their transformation from late-type galaxies. In this talk I would like to present the complexity of the nearby Fornax cluster as result from the Fornax Deep Survey (FDS), performed with the VST, and the high-quality integral-field data obtained with MUSE@VLT from the Fornax3D project. Both surveys map the Fornax cluster out to its virial radius. The analysis of the deep images from FDS suggests that the Fornax cluster is not completely relaxed inside the virial radius. The bulk of the gravitational interactions between galaxies happens in the W-NW core region of the cluster, where most of the bright early-type galaxies are located and where the intra-cluster baryons (diffuse light and globular clusters) are found. We suggest that the W-NW sub-clump of galaxies results from an infalling group onto the cluster, which has modified the structure of the galaxy outskirts (making asymmetric stellar halos) and has produced the intra-cluster baryons (ICL and GCs), concentrated in this region of the cluster. The Fornax3D project provides the stellar and ionised-gas kinematics for all galaxies in the Fornax3D sample. Furthermore, for the ETGs in Fornax3D we also obtain average stellar population properties from measurements of absorption line-strength indices. The galaxies have been mapped in high resolution from the brightest central regions to the outskirts, where the surface brightness $\mu_B \sim 25$ mag/arcsec$^2$, and out to $2-3$ Re for the 23 early-type galaxies and 1-2 Re for the 10 late-type galaxies in the sample. The results provide insight into the mass assembly in the high density region of the cluster and on the structure and formation of the Fornax cluster. These studies could be considered as a benchmark for (simulations of) the assembly and evolution of galaxies in a cluster environment.
Recently, using observations taken by the Hubble Space Telescope, it has been found that the star distribution closely follows the total matter distribution inside the intra-cluster space. The stars were detected as a faint glow (the intra-cluster light, ICL) and the matter distribution was extracted from gravitational lensing. In this work, we aim to test these observations using the set of Cluster-EAGLE simulations, comparing the projected density distributions inferred directly from the particles information. We compare the iso-density contours using the same procedure as in Montes & Trujillo (2019), and found that the stars follow the matter distribution closer than observed. In addition, we study the ratio between the star and total matter density profiles in circular apertures and found that it shows a slope close to -1, with a small dependence on the cluster’s total mass.
Evidence for the existence of intracluster light $\sim$5 billion years after the Big Bang

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We present a ICL study of MOO J1014+0038 at $z=1.24$, using high-quality HST/WFC3 near-IR imaging data that enables us to reach a very low surface brightness threshold ($\sim$29 mag arcsec$^{-2}$) and obtain a clear two-dimensional ICL map out to $\sim$200 kpc from the center of the cluster. We find that the ICL color is consistent with that of the bright, red cluster galaxies. However, unlike the radial color variation of galaxies, we do not detect any significant radial dependence of the ICL color. Using simple stellar population synthesis with an exponentially decaying star formation model, we estimate that the ICL stars had formed at $z \sim 2$ or earlier. Despite our conservative analysis, the ICL fraction still exceeds $\sim$10% of the total cluster light at $r<200$ kpc. These results strongly support that intracluster stars might have formed during a short period and early in the history of the Virgo-like massive cluster formation and might be concurrent with the formation of the brightest cluster galaxy.
Sourcerer*: A Robust, Multi-Scale Source Extraction Tool Suitable For Faint And Diffuse Objects

Michael Wilkinson¹, Caroline Haigh¹, Simon Gazagnes¹, Paul Teeninga¹, Nushkia Chamba², Thanh Xuan Nguyen³, Laurent Najman³, Benjamin Perret³, Giovanni Chierchia³, Aku Venhola⁴, Reynier Peletier¹

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Finding faint, diffuse objects reliably and reproducibly is a difficult challenge. To tackle this challenge, we present Sourcerer*, a new source extraction tool for the detection of very low surface brightness and diffuse sources in astronomical images, under development within the SUNDIAL ITN. It is based on the previous Max-Tree Objects (MTObjects) [1], which we recently compared to three other source extraction tools: Source Extractor, Profound, and NoiseChisel + Segment. These tests showed that MTObjects outperformed the others in terms of F1 score and segmentation error on synthetic images. A separate study compared Source Extractor to MTObjects on the Fornax Deep Survey supported these findings through visual evaluation. Three key strengths of our tool are a low number of false positives, consistent performance over different data sets, and ease of use due to the small number of parameters to set. What is new in this tool is its ability to detect nested objects, effectively allowing the separation of light from diffuse sources with more compact ones superimposed. It does this using a so-called Max-Tree, which stores all connected components of all threshold sets of the image efficiently. This tree is used to compute variable, hierarchical detection thresholds which depend on the areas of the sources, using a statistical test to judge whether connected structures can be explained by noise statistics. As such, diffuse structures can be detected at levels over 10 times fainter than Source Extractor without creating a large number of false positives. In this contribution, we will present our source finding tool and ongoing efforts to improve and include additional modules to the program to achieve faster execution through parallel max-tree algorithms [2], smoother boundaries of detected objects, compute different trees or graphs for handling multi-band images, support various other statistical tests for source detection, better source deblending, different background estimation methods, and the ability to extract various features from the detected astronomical objects. Ultimately, we aim to add an object classification scheme to the package that could be directly applied to upcoming deep and large surveys such as LSST and Euclid.

References:
Session 9: The cosmic web of large-scale filaments
Line Intensity Mapping: A “novel” Window To The Cosmic Web

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Intensity mapping has been attracting an increasing interest as a way to include the faint universe in our understanding of galaxies evolution and the large scale structure of the Universe. We will start by introducing the concept of line-intensity mapping (IM). After enumerating the most prominent emission lines for IM we will discuss its science cases. These range from the history of star formation to BAO and the fundamental physics. We will then review the current experimental landscape as well as reported detections. IM measures the statistics of surface brightness as a function of frequency, and therefore, one needs to model both the target line luminosity and any other source that emits radiation in such frequency. Several approaches to modeling these signal have been discussed in the literature. We will briefly discuss them as well as the techniques to deal with foreground and background contamination. In this review we will focus on the post-reionization universe.
The diffuse gas in the filaments of the cosmic web acts both as an emitter and absorber of Lyman-alpha radiation. Using cosmological hydrodynamical simulations, we predict the Lyman-alpha emission properties and discuss the prospects of directly observing emission from filaments in the Lyman-alpha line. We also present new results from Lyman-alpha absorption studies and their implications for cosmic reionization and dark matter free streaming.
Looking For A WHIM In The Large-Scale Filaments Of The Cosmic Web

**IT Nicolas Tejos**  
*PUCV, Valparaiso, Chile*

I will present recent results aimed to detect the warm-hot intergalactic medium (WHIM) in large-scale filaments of the cosmic web. The WHIM is thought to host a significant fraction of the so-called ‘missing baryons’ at low redshifts ($z<1$), as predicted by cosmological hydrodynamical simulations. The expected densities of a few times the critical density of the Universe, and temperatures between $10^5$-$10^7$ K, makes the direct observation of the WHIM extremely challenging with current technology although some efforts exist. I will focus the talk on a particular approach that uses UV spectroscopic observations of targeted UV-bright QSOs with sightlines intersecting multiple inter-cluster filaments, with the idea to detect this WHIM through the relative comparison between broad and narrow HI absorption at the inter-cluster redshifts.
Session 10: The UV / optical / IR cosmological background radiation
The UV And Optical Sky Background

R Jayant Murthy  
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The diffuse ultraviolet/optical sky is comprised of many components ranging from dark count in the instrument through airglow and zodiacal light to dust scattered starlight and extragalactic radiation. Traditionally, the diffuse radiation has been difficult to observe and model because of limitations in the instrumentation and in the modeling but the situation has changed dramatically in the UV due to the all-sky GALEX survey and with new observations from Nw Horizons in the optical. I will review the current state of our knowledge of the diffuse UV/Optical radiation and will describe some ideas we have for further instrumentation.
The light emitted by all galaxies across the history of the Universe is encoded in the intensity of the extragalactic background light (EBL), the diffuse cosmic radiation field at ultraviolet, optical, and infrared wavelengths. The EBL is a source of opacity for high-energy gamma rays via pair production, leaving a characteristic attenuation imprint in the spectra of distant gamma-ray sources. In this talk, I will report on a new measurement of the EBL using gamma-ray data from both the Large Area Telescope on board the Fermi Gamma-ray Space Telescope and ground-based Imaging Atmospheric Cherenkov Telescopes. This unprecedented measurement has allowed us to derive the cosmic star-formation history, the number density of faint galaxies during the re-ionization epoch, and also the expansion rate of the Universe and its matter content, all of this using independent and complementary methodologies to existing ones.
Measuring Energy Production In The Universe Over All Wave-lengths And All Time

IT Simon Peter Driver

University of Western Australia, Perth, Australia

With recent and upcoming advances in deep multi-wavelength ground-based and space-based astronomy it is becoming possible to map energy production in the Universe from x-ray to radio wavelengths. Even more important is its subdivision into time intervals from the very high to very low Universe. Encoded in these data is the rich history of galaxy formation and the evolution of the baryons as they are processed from one form to another. In this talk we will describe recent progress in measuring the extra-galactic background light, its subdivision into the cosmic spectral energy distribution, and attempts to model it from simple toy models to more detailed numerical simulations. We note that a key portion of the spectrum not well measured nor modelled is in the extreme ultra-violet and advocate the need for a future mission in this wavelength regime. If time permits the talk will include how the EBL and CSED could be used to constrain decaying dark matter models.
Role Of Environment On AGN Activity

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Motivated by the apparently conflicting results reported in the literature on the effect of environment on nuclear activity, we have carried out a new analysis by comparing the fraction of galaxies hosting active galactic nuclei (AGNs) in the most overdense regions (rich galaxy clusters) and the most underdense ones (voids) in the local universe. Exploiting the classical BPT diagnostics, we have extracted volume limited samples of star forming and AGN galaxies. We find that, at variance with star-forming galaxies, AGN galaxies have similar distributions of specific star formation rates and of galactic ages (as indicated by the Dn4000 parameter) both in clusters and in voids. In both environments galaxies hosting AGNs are generally old, with low star formation activity. The AGN fraction increases faster with stellar mass in clusters than in voids, especially above $10^{10.2} M_\odot$. Our results indicate that, in the local universe, the nuclear activity correlates with stellar mass and galaxy morphology and is weakly, if at all, affected by the local galaxy density.
The M101 Satellite Luminosity Function And The Halo To Halo Scatter Among Milky Way Analogues

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\textsuperscript{3}. The University of Tampa, Tampa, United States

The Lambda Cold Dark Matter model for structure formation has been very successful at reproducing observations of large scale structures; however challenges emerge at sub-galactic scales. Observations of the faint end of galaxy satellite luminosity functions are important in reconciling the differences at these smaller scales. This is crucial to constrain the physics governing galaxy formation and evolution and will also allow us to understand the relation between the stellar content and dark matter halo in dwarf galaxies. As part of a wider survey for low surface brightness galaxies in the Canada-France-Hawaii-Telescope Legacy Survey (CFHTLS), we have examined the M101 group in detail discovering 37 new diffuse dwarf candidates in the vicinity of M101. Examination of 19 of these dwarfs with the Hubble Space Telescope has allowed us to explore the satellite luminosity function of M101 and compare it to other Milky Way analogues. We will also report on the results of the wider CFHTLS survey.
Origin Of Tidal Structures In Modified Gravity

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Modified Newtonian Dynamics (aka MOND) is the leading alternative to the dark matter hypothesis suggesting a modification of the laws of physics at low accelerations. It explains many galaxy properties. Comparative simulations of interacting galaxies in MOND and Newtonian gravity with dark matter revealed two principal differences: 1) galaxies can have close flybys without ending in mergers in MOND because of weaker dynamical friction, and 2) tidal dwarf galaxies form very easily in MOND. When this is combined with the fact that many interacting galaxies are observed at high redshift, we obtain a new perspective on tidal features: they are often formed by non-merging encounters and tidal disruptions of tidal dwarf galaxies. I will present our reconstruction of the Local Group history using a MOND N-body simulation. It showed that the Milky Way and Andromeda galaxy had a close encounter 7-11 Gyr ago that left its signatures. These signatures resemble the observed peculiarities in the Local Group such as the stellar streams, the warp in the Milky Way disk or the disks of satellites.
We classify galaxies of the GALEX/S4G sample comprising 1931 nearby galaxies ($z < 0.01$) into two types of extended ultraviolet (XUV) disk galaxies. Galaxies that have extended outer structures in galactocentric distances, several times farther than their optical disk when seen in the far and near-ultraviolet (GALEX FUV and NUV) images, are classified as Type 1. Galaxies that have large and blue color disks are classified as Type 2, that is, galaxies with a recently star-forming low-surface brightness (LSB) disk component as seen in the UV compared to the underlying low-mass, and presumably older, stellar population disk component as seen in the IR.

Type 1 and Type 2 are independent classifications which are not mutually exclusive, hence, we also obtain a small subsample of Type 1+2 galaxies that have the properties of both. These criteria are similar to those used by Thilker et al. (2007) but adapted to the use of deeper near-IR IRAC data. Understanding how XUVs form and knowing their fraction will help in putting constraints on certain star formation mechanism over others.

Using our criteria, we find 217 Type 1 and 156 Type 2 galaxies of which 24 are Type 1+2. These numbers represent a six-fold increase over previously known samples. All XUV-disk galaxies are found in the so-called GALEX Blue Sequence (GBS) of star-forming galaxies in the (FUV – NUV) versus (NUV – [3.6]) color-color diagram (Bouquin et al. 2015, 2018), but are not especially different, in terms of colors, from other galaxies found in the GBS.
Searching For Accretion Traces Near Edge-On Disks

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The prevailing opinion is that galaxies evolve by interactions with their surroundings, e.g. by accreting dwarf galaxies. Such accretion events should leave visible signatures. The interaction signatures should be easier to detect against the clear sky, and not against the galaxy’s own background. We present preliminary results from an imaging survey of 123 disks seen edge-on obtained in a wide-red spectral band with a 28-inch telescope at the Wise Observatory where we searched for stellar streams, vertical deformations of the disks, etc. This sample includes disk galaxies above declination -30° and with major axes larger than 2 arcmin, irrespective of redshift or brightness. We describe the tools that allow us to reach surface magnitudes of 28-30 mag/arcsec² and present preliminary conclusions about the detection of out-of-the-plane extended features. We describe disk extensions and morphological peculiarities that become apparent only at very low surface brightness levels.
Rings And Spiral Arms Are Not Strongly Coupled With Stellar Bars

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We study the pitch angles of spiral arms and the frequency and dimensions of inner and outer rings as a function of disk parameters and the amplitude of non-axisymmetries. We use 1320 not-highly inclined disk galaxies from the S⁴G survey.

The ring fraction increases with bar Fourier density amplitude: this can be interpreted as evidence for the role of bars in ring formation. The sizes of inner rings are positively correlated with bar strength: this can be linked to the radial displacement of the 1/4 ultra-harmonic resonance while the bar grows and the pattern speed decreases. The ring intrinsic ellipticity is weakly controlled by the non-axisymmetric perturbation strength: this relation is not as strong as expected from simulations. The ratio of outer-to-inner ring semi-major axes and the pitch angle are uncorrelated with bar strength: this questions the manifold origin of rings and spiral arms. On average, the dimensions of rings and the pitch angles of spiral arms are roughly the same for barred and non-barred galaxies. We confirm that the fraction of rings is larger in barred galaxies than in their non-barred counterparts, but approximately 1/3 (1/4) of the galaxies hosting inner (outer) rings are not barred. In addition, we show that pitch angles cannot be used to make constraints on the masses of supermassive black holes or dark matter halos in the S⁴G. Finally, we apply unsupervised machine learning (Self Organizing Maps) to confirm that rings are mainly hosted by red, massive, gas-deficient, dark-matter poor, and centrally concentrated galaxies. We conclude that the present-day coupling of rings, spiral arms, and bars is not as robust as predicted by numerical models.
Utilizing Shell Galaxies

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Shell galaxies constitute at least 10\% of early-type galaxies and a small portion of spirals. Stellar shells are low surface brightness features in the form of open, concentric arcs, formed in close-to-radial collisions of galaxies. Recently, the view concerning their origin has been shifting from minor to intermediate-mass or even major mergers. The unique kinematics of shells carry valuable information about their host galaxies. We will discuss a method using measurements of the number and distribution of shells to estimate the mass distribution of the galaxies and the time since the merger. We will demonstrate the application of this method on NGC 4993 - a galaxy hosting the electromagnetic counterpart of the recent gravitational wave event GW170817. We used analytical calculations and particle simulations to show that, in special cases, when kinematic data are available, further constraints on mass distribution and merger time can be derived. Lastly, we will discuss an ongoing project of testing the feasibility of the proposed methods on a large representative set of simulated shell galaxies from a large-scale cosmological hydrodynamical simulation Illustris. Applying the methods on the rapidly growing sample of known shell galaxies will constrain the dark-matter content in the galaxies and reveal detailed information on the recent merger history of the Universe.
The Intracluster light (ICL) is a diffuse component of galaxy clusters or groups in the visible and NIR wavelengths. It is composed of stars that do not belong to any specific galaxy, but that are more related to the global gravitational potential of their cluster/group. The very low surface brightness of this diffuse component (few percent of the sky background) and the various sources of contamination (scattered light in the detector, blending into galaxy light profiles...) make its detection a challenge. Here we choose a multiscale approach to the problem and create DAWIS, a Detection Algorithm with Wavelets for Intracluster light Surveys. We apply it to the core of MACSJ0717, a massive galaxy cluster which is part of the Hubble Frontier Field, and to its south-east cosmic filament.
Diffuse Extended Post-Starburst Galaxies: Ultra-Diffuse Galaxies Caught Being Young

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Studies of quiescent low-surface brightness galaxies observationally is very challenging and one has to work on the limit of sensitivity of currently available instrumentation. One of the best ways to probe internal dynamics and stellar content of such dim objects is to spot them during a phase of their life when a large fraction of stars in them is still young and, hence, galaxies have much higher surface brightnesses than their old counterparts. Using multi-wavelength spectrophometric information from the Reference Catalogue of Spectral Energy Distribution of galaxies (RCSED) we have identified a sample of 13 low-mass diffuse extended (10kpc) galaxies residing in two galaxy clusters (Coma and Abell 2147) and one compact group. All of them exhibit young mean stellar ages and for a few of them we see clear signs of ram-pressure stripping in a form of tails. We followed them up using a new high-throughput Binospec spectrograph at the 6.5m MMT in Arizona. With our deep spectroscopic data we tried to unveil how stars were formed in these galaxies in the past, and what will happen with their stellar content in the future. Using simple stellar populations models, we have computed a grid of model spectra to reproduce probable evolutionary scenario of post-starburst galaxies. The scenario includes a truncated constant star formation history and the final starburst induced by ram-pressure stripping. The chemical evolution with delayed enrichment from supernovae Ia is accounted for using the “leaky box” approach. By fitting the MMT spectra against a grid of our stellar population models we estimated (i) stellar mass formed prior to ram-pressure stripping moment, (ii) stellar mass, formed in the burst induced by ram-pressure stripping, (iii) the age of ram-pressure stripping and the (vi) outflow parameter controlling galactic winds. We conclude that because all gas has been stripped, these galaxies will not be able to form new stars anymore, and they will get fainter by a factor of 20 in 5 Gyr and resemble present-day ultra-diffuse galaxies. Thus, ram-pressure stripping is at least one channel responsible for formation of UDGs.

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Recovering the star formation and chemical evolution history (SFH & CEH, respectively) are essential for studying local and distant galaxies in the Universe. However, it is still an enigma how the stellar population properties of low surface brightness (LSB) galaxies compare to normal ones. For instance, spectral synthesis applied to these objects is extremely challenging because the typical signal-to-noise (S/N) ratio at the continuum level is in general insufficient to retrieve reliable information regarding their physical properties, such as the total stellar mass, mean stellar age and metallicity. In addition to this, despite significant progress over the past decades, state-of-the-art population synthesis (PS) codes suffer from severe deficiencies limiting their potential of gaining sharp insights into the SFH and CEH of galaxies, i.e. the neglect of nebular continuum and, the lack of a mechanism to ensure consistency between the best-fitting SFH and the observed nebular characteristics (e.g., Balmer-lines, Balmer/Paschen jumps). These introduce non-negligible biases in their recovered physical properties (stellar mass M* and specific star formation rate) as demonstrated in Cardoso, Gomes & Papaderos (2019). We present FADO (Fitting Analysis using Differential evolution Optimization - Gomes & Papaderos 2017) a novel self-consistent PS code employing genetic optimization, publicly available at http://www.spectralsynthesis.org, capable of identifying the SFH & CEH that best reproduce the observed nebular characteristics of a galaxy, alleviating degeneracies in the spectral fits. Even when the S/N level of the underlying continuum is low (\(<5\)), FADO can recover the physical and evolutionary properties of galaxies due to the additional constraints from the emission lines. The retrieved M* and mean age/metallicity are with an accuracy significantly better (\(~0.2\) dex) than purely-stellar codes. An outline of FADO and applications to local and higher-z galaxies will be presented. Special emphasis on results for LSB galaxies from SDSS will be given. Additionally, we will discuss applications of FADO to SDSS ultra diffuse galaxies and future prospects.
Unveiling The Formation And Evolution Of Low Surface Brightness Galaxies Through Studying Dwarf Galaxies In Local Group

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Due to observational constraints, our detailed knowledge of stellar populations, formation and evolution of low surface brightness galaxies is limited to few dozen galaxies located in Local Group. The local Group of galaxies offers a superb near-field cosmology site. Here, we can construct the formation histories, and probe the structure and dynamics of many dwarf galaxies surrounding the Milky Way and Andromeda, and of isolated dwarf galaxies. Surveying an entire satellite system enables us to determine variations among satellites due to their infall histories, cosmic reionization, and internal processes, and to examine how these variations depend on their structural properties such as total mass, gas mass, and distance to their galaxy host. To this aim, we have conducted an optical monitoring survey of pulsating giant stars at the Isaac Newton Telescope (INT) of majority of dwarf galaxies in the Local Group. We have identified long period variable stars (LPVs) and used them to probe the star formation history (SFH) and dust production rate in these galaxies. In this paper, first I will present the results we obtained for SFH and dust production rate in individual dwarf galaxies separately to answer how different types of dwarf galaxies have been formed and evolved over cosmic time. Then, I will discuss whether the mass return from dusty evolved stars can provide enough gas reservoirs to sustain the star formation or even rejuvenate the dwarf galaxy, as some seem to harbour relatively young stars. Finally, I will compare the SFHs of different types of dwarf galaxies found in different environments to achieve a comprehensive picture of galaxy evolution in the Local Group.
First Study Of The Rotation Curve And Star Formation Rate Of Malin 1 From Emission Line Spectroscopy

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Low Surface Brightness galaxies (LSBs) represent a significant fraction of galaxies in the nearby universe (up to 50% according to O’Neil & Bothun 2000; 40% for Galaz et al. 2011). Despite this large fraction the structure and origin of this class of galaxies is still poorly understood, especially due to the lack of high-resolution kinematics and spectroscopy. Malin 1 is the largest known low surface brightness galaxy to date, the archetype of so-called giant LSBs. I will present new results based on spectroscopic observations of Malin 1, using the Hα emission line in order to bring new constraints on the dynamics and star formation of this galaxy. We have extracted a total of 12 spectra from different regions of Malin 1 and calculated the inner rotational velocities and estimated the star formation rate order of magnitudes from the observed Hα emission line fluxes. I will show for the first time a steep rise in the rotation curve of Malin 1 up to \~ \sim 370 \text{ km/s} (within r < 10 \text{ kpc}), which had not been observed in any of the previous works on this galaxy. I will discuss the implications of this result for a new mass model. I will also show that the Hα fluxes provide star formation rate estimates consistent with an early-type disk for the inner galaxy, and with the level found in extended UV galaxies in a region detected at about 26 \text{ kpc} from the center of the galaxy. This work provide new constraints for models of Malin 1-like galaxies (e.g. Zhu et al. 2018) or LSBs in general (e.g. Di Cintio et al. 2019; Martin et al. 2019).
#P13

**Low Surface Brightness Filaments Between Stephan’S Quintet And NGC 7331**

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We present new deep optical observations of faint emission in the region between Stephan’s Quintet and NGC 7331, mentioned by Arp & Lorre (1976). We found that filaments A and B have an infrared counterpart (12 μm) and are most probably galactic cirrus. Filament C isn’t a continuous structure as described by Arp & Lorre, and we suggest it is a Galactic feature. Filament H is directly related with the stars inside it and it is possibly a reflection nebula. Finally, we include estimates of colour of the filaments.
I present a review of recent projects by our group concerning faint extended haloes and filaments in galaxies. We find some evidence for the previously-reported enormous halo around A1413 by co-adding different fields along the major axis. We have investigated the filamentary features found between NGC 7331 and Stephan’s Quintet in new CCD images. Longslit spectroscopy of the halo of NGC 6086 in A2162 shows a more complicated central velocity structure than previously reported. NGC 4488 in Virgo looks like a face-on bar with faint spiral arms attached, but may be a merger remnant.
Observing The Low-Surface Brightness Cosmos With WIYN And The One Degree Imager

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The One Degree Imager on the 3.5m WIYN telescope uses a total of 30 Orthogonal Transfer Array Detectors, each consisting of a chess-board pattern of 64 active CCDs. While wide fields and fast readouts are useful for LSB measurements, the resulting configuration of >1900 individual CCDs, each with their own detector characteristics (gain, flatfield response, etc) and the associated pattern of gaps between detectors and cells does not automatically lend itself for detailed studies of low-surface brightness features. With ODI large-scale flatfielding, variations in CCD properties, and pupil ghost removal present particular challenges. In this talk I will present a summary of data processing techniques that successfully mitigate these disadvantages. As a result ODI is effective for a variety of LSB observations. For example, time-domain observations of comets and active asteroids present the particular challenge of showing variability on both small angular scales and time intervals. Deep multi-band imaging of galaxy outskirts in galaxy groups has the potential to serve as evolutionary clock to reconstruct galaxy transformation processes and in particular pre-processing in medium density environments before galaxies enter the high-density regime near or within galaxy clusters. As a third example, deep studies of LSB dwarf galaxies in clusters allow us to study the interplay between dwarfs and giants to constrain their formation processes and thus the growth history of the cluster at large, and I will review results for the Perseus galaxy cluster combining data from WIYN, WHT, and Subaru. Most of the tools developed for ODI can easily be adapted to also work with other imagers. In particular multi-detector arrays, including both HyperSuprimeCam and the LSST camera, and thus help push the limits of low-surface brightness photometry over the next decade.
Ultra-di
ffuse galaxies (UDGs) have luminosities similar to dwarf galaxies, but sizes akin to
giant galaxies. Quiescent UDGs are found in all environments from cluster to isolated, and it
is clear from their diverse properties (dark matter, globular clusters, etc.) that they have mul-
tiple origins. Stellar populations provide a key diagnostic, but spectroscopy at such low surface
brightnesses is time consuming. A key alternative is provided by spectral energy distribution
(SED) fitting from UV through visible light to the near-infrared. Here we present first results
from a survey of UDGs using Spitzer and visual photometry combined with SED fitting with
“Prospector,” to estimate ages and metallicities, and to provide implications for UDG formation
histories in various environments.
Resolved Stellar Populations In The Local Low Surface Brightness Universe

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Deep images show fascinating features of integrated stellar light in the diverse low surface brightness (LSB) systems located around dwarf to giant galaxies, intragroup regions, and intracluster regions. Nearby LSB systems are an ideal laboratory to investigate the nature of these features. We present a photometric study of resolved stellar populations in the LSB systems in massive galaxy halos and intracluster regions. The resolved stars in these LSB systems show a diverse metallicity distribution, indicating that their progenitors have a large range of mass. We discuss the origin of galaxy halos and intracluster light in relation with their progenitor galaxies.
Improvements Of The ICMOS (Intensified CMOS) Sensors For LSB Observations

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We introduce new technologies improving the PLD (Pulsed Laser Deposition) method to fabricate visible (370 ~ 600 nm) and NUV (Near Ultraviolet, 185 ~ 320 nm) photocathodes for IIT (Image Intensifier Tube) sensors. The multi-purpose PLD VC (Vacuum Chamber) by utilizing optical window viewports and a couple of internal carousels can do the whole process of the laser deposition of various alkalis, including the measurement the QE (Quantum Efficiency) in-situ, for multiple photocathode targets. Then, we have integrated a Load/Degassing/Assembly (LDA) VC to the PLD VC, to prepare, load, degas, and assemble the alkali targets and the photocathode substrates. With these facilities, we have manufactured high QE photocathodes free from oxidation and water vapor contamination during the process. In this paper, we describe detail procedures of our new technologies to make S20 and CsTe photocathodes for visual and NUV wavelengths respectively, and discuss about the test results of the IIT products for LSB (Low Surface Brightness) observations.
Correlation Of Outer Features Of Galaxies With Their Physical Properties

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Utilizing wide and deep coverage of Stripe-82, we have selected a sample of ~10000 galaxies which have imaging and spectra from Far-IR (HerS) to UV (GALEX), in addition to optical (IAC, at 28.5 mag/arcsec$^2$ limit). Using this wealth of data and our new-developed techniques, we have computed their cold gas mass converted from cold dust mass, in addition to stellar mass and star formation rates. Using their images in near-IR from VICS82 at unprecedented resolution (0.3″/pixel), we are also in the process of computing their bulge, disc and bar parameters, using GALFIT in the most accurate manner. Our method is to subtract the main galaxy model to extract the outer interaction features from the residual images. Furthermore, we are also attempting to quantify these features through non-parametric measures and fitting Fourier modes. The role that galaxy interaction plays in transforming its morphology and stellar activity is still under debate. Our aim is to correlate the outer tidal features in all galaxies with their stellar and gas properties. Using the representative sample of 10k galaxies with wide and deep coverage will enable us to obtain significant insight on the role of environment in evolution of galaxies.
Intracluster Light Evolution And Impact On Galaxy Cluster Dynamics

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Intracluster light (ICL) has attracted significant attention in recent years because of its ability to provide some guidance on the processes that drive the evolution of galaxy clusters. In this sense, we sought to determine the dynamic stages of two clusters of galaxies observed through the Hubble Space Telescope in the Frontier Fields project, Abell 370 and Abell S1063. We analyzed the physical properties of ICL and its evolutionary processes for both clusters. We used a free assumption algorithm based on the Chebyshev-Fourier functions, the CICLE, which is a mathematical tool specially designed to model the luminous distribution of galaxies and some parameters of Differential Geometry. It has proven to be an unbiased and accurate method to study ICL and consequently the dynamics of galaxy clusters.
The Study Of Bars And Bulges In Low Surface Brightness Galaxies

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We present the results of our study of bars and bulges in barred giant Low Surface Brightness Galaxies (LSBGs). The LSBGs are optically dim galaxies that are HI rich and dominated by dark matter content. The barred galaxy fraction amongst LSBGs is found to be very low (8.3%) compared to normal high surface brightness (HSB) galaxies. The barred LSB galaxies were imaged in the NIR bands and the bar properties obtained were similar to properties of bars in the normal galaxies. Our study shows that halo dominated galaxies can host strong bars and the bars have only a small effect on galaxy color. We have also done two-dimensional disk decomposition of barred LSBGs using SDSS i-band images. Our results indicate that bars are present in LSBGs that are both bulgeless and have bulges in their disks. We found that the LSBG bulges are classical in nature according to the Kormendy relation. Using the SDSS optical spectra of the sample LSBGs we derived the central velocities as well as the Dn(4000) spectral break index. Our results indicate that the major fraction of bulges in LSBGs are classical in nature and composed of an older stellar population. All these facts show that the barred LSBGs have evolved bulges. We also discuss the properties of bulges in non-barred LSBGs and how it differs from the bulges in barred LSBGs.
Shells are fine stellar structures identified by their arc-like shapes present around a galaxy and currently thought to be vestiges of galaxy interactions. Several samples with advanced observational techniques have allowed us to distinguish numerous astonishing shells surrounding early-type galaxies, like the case of NGC 0474 and NGC 3619 or more complex systems like Centaurus A and Arp 230. Big efforts have made in multiple models in order to reproduce them, but its origin has not yet completely understood. Although different type of interactions could generate them, the observations indicate that they are result of intermediate-mass mergers. On the other hand, numerical simulations have proposed a shell formation mechanism through phase wrapping (Hernquist & Quinn 1989, Dupraz & Combes 1987). However, HI observations have revealed neutral gas associated with shells but the gas is expecting to be driven quickly to the center if it is located on nearly radial orbits. Then, shells could be either phase-wrapped or space-wrapped structures, and the dynamical fate of the gas as well as their consumption through star formation would be different. Molecular gas has been already detected in the shells of Centaurus A (Charmandaris et al. 2000) and a dynamical model to account for the presence of gas in shells was proposed (Combes & Charmandaris 2000, Salome et al. 2016). Hence, with the aim to test the models and improve our knowledge of their gas content and dynamics, we performed CO observations in a sample of four galaxies with stellar and gaseous shells. We have detected CO mass in several shells of one galaxy en we computed the upper limits for the rest of our sample.
The semi-empirical galaxy-halo connection: UDG’s and LSB galaxies.

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According to the current cosmological paradigm, which is summarized in the model called \( \Lambda \) Cold Dark Matter (\( \Lambda \)CDM), galaxies form and evolve within the gravitational potential of growing dark matter halos. Big effort has been done in order to obtain the galaxy-halo connection along the whole mass spectrum of galaxies. Using semi-empirical models have been possible to constrain this connection through the generation of large and complete mock catalogs of local galaxies. The projection of a semi-empirical galaxy-halo connection towards to the structural-dynamic properties of galaxies allow us to make a complete demographic description of the observed galaxies and their dark halos. This semi-empirical description is mainly based in large massive surveys like the SDSS. Nonetheless, this kind of surveys are biased in terms of the surface brightness, since they are missing particular galaxy subpopulations like those with low surface brightness. In this project we extend the approach to make predictions on the correlations and distributions about the recently discovered population of UDGs and LSB galaxies. Specifically, we explore their distribution in both the low- and high-mass side of the galaxy stellar mass function. We make predictions on the distribution of effective radius, Re, (stellar and gaseous) surface density as a function of mass, type and environment. We study other scaling relations like Tully-Fisher, bulge-to disk mass ratio and the evolution with the luminosity and surface brightness. Thus, with this analysis we go further on the key constric- tions of the galaxy formation paradigm.
Molecular gas content in Ultra-Diffuse Galaxies

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One of the most spectacular discoveries over the past years in extragalactic astronomy is the detection of a new type of galaxies named Ultra Diffuse Galaxies (UDGs). These galaxies are characterized by their very low central surface brightness and large effective radii. They appear to be more numerous than the galaxy population of higher surface brightness, and span a wide range of environments (from clusters to filaments). Their stellar mass densities are very low and constitute a challenge for galaxy formation models. Undoubtedly, UDGs are one of the most suitable laboratories to understand star formation in the low density regime. The detection of cold atomic or molecular gas is crucial for the comprehension of the nature and origin of this new type of galaxy population, since it has wide implications for star formation efficiency in galaxy evolution. Thus, in order to quantify the molecular gas content of this new kind of galaxies, we have performed several CO spectroscopy surveys. Our samples are conformed by sources from several environments and different properties. We include objects like the very red galaxies Dragonfly 44 and DGSAT I, those with blue colors and Hα emission UDGs recently observed with Arecibo, as well as two brightest UDGs observed by the Hyper Suprime-Cam Subaru Strategic Program, which show high gas-phase metallicities. Until now we have obtained unprecedented upper limits of their CO mass (few $10^6$–7 solar masses).
Probing The Merger History Of Red Early-Type Galaxies With Their LSB Substructures

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Sophisticated observations at CFHT have revealed prominent LSB fine structures that change the apparent morphology of galaxies. Several optimized surveys have developed observational techniques which exploit the diffuse light detected in the external regions of galaxies. In this study, the outer regions have been identified and classified like tidal tails, stellar streams and shells. These structures are tracers of merging events and they keep a memory of the mass assembly of galaxies. Their detection depends on several factors like the orientation and the surface brightness limit. Cosmological numerical simulations are needed to estimate their visibility time in order to reconstruct the past merger history of galaxies. In this project, we analyzed a hydrodynamical numerical simulation to make a comprehensive interpretation of the properties of fine structures. We make a census of several types of LSB fine structures by visual inspection. We reconstructed the evolution of the number of fine structures detected around an early-type galaxy and we compared with the merger history of the galaxy. We found that shells and streams remain visible around 4 Gyr and they are mainly associated to minor mergers and a continuous diffuse gas accretion, while tidal tails have a durability time of around 1 Gyr and are correlated with major merger events.
The Importance Of Finding RR Lyrae Stars In Ultra-Faint Dwarf Galaxies

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In the last decade, wide-field surveys such as SDSS, ATLAS, DES, and MagLites have contributed to the discovery of more than 20 ultra-faint dwarf galaxies (UFD, MV > −8 mag), satellites of the Milky Way, which were undetectable in the past. Because these systems are faint and the evolutionary stages of the stars are not so clearly marked in the Color-Magnitude diagram, the determination of the distance using the isochrone fitting technique is a very difficult task. The main challenge is the scarcity of stars and the large contamination by field stars. Although the presence of RR Lyrae stars in systems with MV > −3.5 mag is expected to be 1±1 stars, the detection of at least one of these offers independent and accurate distances to the host. In addition, their presence will confirm the existence of old stellar populations in these galaxies. This can also provide clues about the contribution of UFDs in the formation of the halo of the Milky Way and disentangle the mysteries about the hierarchic architecture of Galaxy Formation and Evolution theories. All this and our group’s on-going efforts in completing the census of RR Lyrae stars in UFDs will be discussed in this talk.
An Introduction To INO-LA, Iranian National Observatory’s Lens Array Observing Facility

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We present the technical details of the INO Lens Array (INOLA), constructed by the INO Technology Development Division (TDD) team to study ultra-low surface brightness systems at visible wavelengths. INOLA has been already installed at mount Gargesh at an altitude of 3600m above the sea level, where will host the main 3.4 m telescope. INOLA is initially made up of three Canon 400mm lenses with fantastic nano-fabricated coatings, particularly designed to reveal faint structures by greatly reducing scattered light and internal reflections within its optics. The main scientific goals envisioned for the INOLA include observing faint galaxies and ultra-low surface brightness dwarfs. Observations of stellar halos and substructures, tidal debris around galaxies, intra-cluster light, variable stars and transiting exoplanets are other objectives. The array will work in three observation modes in order to fulfill diverse scientific goals. Since the time sensitivity of transient events like supernovae and cataclysmic variable star outbursts requires prompt response by observers, these targets will have the highest priority. Queue mode is the second observing fashion where the observation will be performed based on the rank of the observation program, the priority of the target, observing conditions (seeing, moon phase, moon distance, airmass, etc.). The final observing mode is the survey mode in which the array will observe wider areas of the sky and longer exposure times will be desired. INOLA is equipped with a dedicated instrumental and environmental controlling system which remotely performs all pre-observing tasks, as well as the main observing process and data transmissions and is responsible for the safety of INOLA instruments and data. LA has received first light on August 2018 and an important phase of commissioning started. Technical and scientific evaluation of the system is now in progress. According to first results we are optimistic to get qualified observations of very faint objects to participate effectively in a quite new era of low surface brightness astronomy.
We present results from a photometric study of low surface brightness (LSB) galaxies and their host NGC 3585 group, where these LSB galaxies are newly discovered from the KMT-Net Supernova Program (KSP). The main science of the KSP is to study early evolution of supernovae using multi-color (BVI) and wide-field (2 deg × 2 deg) images from three identical 1.6-m telescopes located at CTIO, SAAO, and SSO. Stacked images of several hundred images obtained from the time domain observations of the KSP have been used for the search of LSB galaxies reaching $\mu(BVI) \approx 28$ mag arcsec$^{-2}$. Especially, the KSP observations on several dozens of nearby (<20 Mpc) galaxy groups make it possible to study detailed and homogeneous properties of faint dwarf galaxies in galaxy groups. Using deep stack images of the NGC 3585 group, one of our target fields, we recently discovered 46 candidates of faint dwarf galaxies distributed in 7 square degree field. Unusually, there is no indication of a change of color or brightness in the dwarfs with projected distance from the group center. There are also eight nucleated dwarf galaxies, which show no radial dependence on the incidence of nucleation. However, four ultra-diffuse galaxy (UDG) candidates identified in the NGC 3585 group are all within the central region of the group. These spatial properties suggest that the NGC 3585 group is dynamically younger than the typical group. Additionally, a value of 4 UDGs in a group system with a small velocity dispersion, causes a flattening of the relationship between the UDG number abundance and system mass. This may indicate that UDGs form preferentially in groups or are less effectively destroyed. More results from the LSB galaxies in the NGC 3585 group and other groups will be showed and discussed in this presentation.
We present the serendipitous discovery using GTC of a large and luminous Lyman alpha nebula at $z = 3.326$. Medium-band imaging in SHARDS filters and long-slit spectroscopic observations with OSIRIS reveal extended emission in the Lyman alpha, C IV 1550, and He II 1640 lines over 110 kpc, and a total Lyman alpha luminosity of $6.4 \times 10^{44}$ erg/s. The nuclear spectrum show line ratios characteristic of a type-II active galactic nucleus. The Lyman alpha nebula presents an elongated morphology aligned with two faint radio sources seen in the inner 8 kpc of the nebula. The continuum emission at short wavelengths is, however, likely dominated by stellar emission of a very massive host galaxy. Compared with other Lyman alpha nebulae, this one shows in the central regions extreme line ratios of Lyman alpha/CIV and Lyman alpha/HeII, well above the standard values of photoionization models and very unusual in Ly alpha nebulae. We will compare the properties of this object with other Lyman alpha emission nebulae and discuss the results using recent theoretical models of the excitation of the circumgalactic medium of high-redshift galaxies.
Radial Metallicity Gradients And Velocities In A2162

Ernesto Perez Hernandez, Simon Kemp, Alberto Nigoche

*University of Guadalajara, Zapopan, Mexico*

cD galaxies have two components, one has a light profile similar to the de Vaucouleurs law (n=4) while there is also a component from an extended luminous envelope. D and cD galaxies are usually brightest cluster members (BCM) and, while there are many ways of forming the extended luminous envelope, it is not clear why not all BCMs have one. We present a study of optical long-slit spectroscopy of A2162 (NGC 6086) cD galaxy with 8 hours of exposure using the Boller & Chivens spectrograph at the 2.1 m San Pedro Mártir telescope and data, using the OSIRIS spectrograph at the 10.4 m GTC telescope in minor and major axis respectively, to find gradients in age and metallicity, plus one run of photometry with the 2.1m telescope looking for radial color gradients, radial velocities, 2d component decomposition with Galfit and SSP. Preliminary results shows more complex kinematics than previous reported.
I present results from high-resolution, “genetically modified” cosmological simulations of ultra-faint dwarf galaxies. Ultra-faint dwarfs galaxies are the smallest galaxies in the Universe; their stellar masses are highly sensitive to the interaction between halo mass and feedback. This sensitivity makes ultra-faints an ideal laboratory for testing galaxy formation models, while potentially generating significant scatter in their structural properties. Quantifying the expected scatter will be essential to interpret findings in the next generation of low-surface brightness observations. To begin this quantification, I present an application of “genetic modifications” (Roth et al. 2016, Rey et al. 2018) to cosmological high-resolution, zoom simulations. Genetic modification allows us to generate different versions of the same dwarf galaxy, each version with a targeted change to its mass assembly history. In addition, each simulation is able to resolve the effects of individual supernovae on the interstellar medium and we further explore uncertainties in the feedback implementation at this resolution. This unique combination of abilities provides a complete overview of the interaction between feedback and assembly in these systems. I will show how this interplay generates diversity in the stellar masses and inner density profiles of dwarf galaxies.
The Survey of Centaurus A’s Baryonic Structures (SCABS). V. Characterization of the Dwarf Galaxy Population in the Centaurus A Environment

Karen Ribbeck, Thomas H Puzia, Matthew A Taylor, Paul Eigenthaler, Roberto P Muñoz, Yasna Ordenes-Briceño, Linda C Watson
Pontificia Universidad Católica de Chile - Institute of Astrophysics, Santiago De Chile, Chile

$R_{25}$ $\geq$ 4.5, which extend the size-luminosity relation toward fainter luminosities and smaller sizes for known dwarf galaxies outside the Local Group (LG), and are consistent with properties of nearby dwarf spheroidal galaxies.
Dusty Pulsating Giant Stars In The M31 Dwarf Spheroidal Galaxy Andromeda I

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1. School of Astronomy, Tehran, Iran
2. Institute for Research in Fundamental Sciences (IPM), Tehran, Iran
3. Keele University, Staffordshire, United Kingdom

We have conducted an optical monitoring survey at the Isaac Newton Telescope (INT), of the majority of the Local Group dwarf galaxies in more than two years. The main aim is to identify the pulsating Asymptotic Giant Branch (AGB) stars in the very final stages of their evolution which are the main sources of dust and thus have a strong influence on the global properties of a galaxy. In this paper, we present the first census of these stars in Andromeda I (And I) dwarf galaxy and measure the dust production and rates of mass loss among the dustiest ones. And I is a strongly disrupted satellite of M 31 with a metallicity of [Fe/H] = -1.45 ± 0.04 and a distance modulus of 24.49 ± 0.12 mag. We have detected 100 candidates of pulsating AGB stars in a 0.07 square degree field of And I among over 15,000 stars. Our data were matched to mid-infrared photometry from the Spitzer Space Telescope (DUSTiNGS project); while DUSTiNGS has only detected four dust-producing AGB stars in And I, we have found 15 dusty pulsating stars with large amplitudes and the reddest colours. We have modelled the spectral energy distributions of all identified dusty variable stars with measurements in i and V bands (filters used in our survey) and two mid-IR bands of Spitzer, with the publicly available dust radiative transfer code dusty (based on Ivezić & Elitzur 1997). The optical depth and mass loss rate of them have been calculated.
Commissioning The INOLA; Low Surface Brightness Universe With The Lens Array

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We report on the commissioning of a Lens Array system for the Iranian National Observatory. The main objective of the project is to study the low surface brightness objects. The system consists of a multi-lens array to make observations at the optical wavelength due to a great reduction of scattered light and internal reflections within its optics. The large field of view of the lens array enables us to observe the target with multiple apertures with a single filter for added signal-to-noise or at different filters simultaneously. To commission the system we use the system for observing dwarf galaxies around the NGC 6946 galaxy. This is a late-type spiral galaxy at a distance of 6.08 Mpc. The observations of this galaxy are challenging due to the fact that the object lies close to the plane of galactic and thus heavily obscured by dust. Although some of the studies claimed to be NGC 6946 located at the border of the local void, so far 18 dwarf galaxies have been discovered near this galaxy, though not so close. Most of these are dwarf Irregular (dIrr) galaxies within a radius of 1 Mpc of NGC 6946. Dfrr galaxies are the most attractive of dwarfs from the point of view of the gaseous content, recent star formation and presence in low-density regions of the sky. We report on the observations of the field of this galaxy using INOLA system.
Faint Structures in the CALIFA Survey - A Multi Color Analysis

Michael Stein

Ruhr Universität Bochum, Germany

In the recent years, many studies have shown that unfolding the secrets of the low surface brightness universe helps us to understand the nature and evolution of galaxies in far more detail than astronomers were capable to do before. Most of the studies concentrate on detecting even the faintest features of tidal streams or UDG’s and study the morphology in great detail (Duc et al., 2018; Trujillo and Fliri, 2016; Borlaff et al., 2019). Our approach in this project is to generate a sample of LSB structures around HSB galaxies, which are still bright enough to detect in stacked SDSS images, and then perform an spectral analysis in nine photometric bands (SDSS: ugriz; UKIDSS LAS: YJHK). We choose the CALIFA mother sample (MS) that is designed to represent the characteristics of the galaxies in the local universe and is derived by applying selection criteria onto the SDSS data set (Walcher et al., 2017). We build the sample of this project by applying a stacking method introduced by Miskolczi et al. (2011) and manually search for faint structures. We find that from a total of 937 galaxies of the MS, 179 clearly show features that hint to minor/major merger processes and tidal debris. Of these galaxies, we only choose the brightest features in order to detect flux in the single spectral band to perform our measurements.
Deep Observations Of The Ultra-Low Density Galaxy Crater II.

Alistair Walker¹, Clara Martinez-Vazquez¹, A. Katherina Vivas¹, Matteo Monelli², Gloria Andreuzzi³, Giuseppe Bono⁴

1. NOAO/CTIO, La Serena, Chile
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3. Departamento de Astrofísica, La Palma, Spain
4. Universidad de La Laguna, Rome, Italy

Crater II is a recently discovered dwarf satellite galaxy of the Milky Way located at a heliocentric distance of 115 kpc, characterized by its large size with half light radius ~1 Kpc, but very low stellar density corresponding to a surface brightness ~31 mag/arcsec. We have used deep observations made with the wide field (FoV ~3 sq. deg.) imager DECam on the CTIO 4m Blanco telescope in order to study the stellar content of the galaxy to well below the ancient main-sequence turnoff, and to further evaluate the properties of its variable star population (mainly RR Lyrae and Anomalous Cepheid stars). We study the star formation history and structure of Crater II; these results together with those for the possibly similar galaxy Antlia II should inform interpretation of the properties for more distant counterparts.
On The Varied Origins Of Up-Bending Breaks In Galaxy Disks

Aaron Emery Watkins¹, Jarkko Laine², Sébastien Comerón¹, Joachim Janz¹, Heikki Salo¹

1. University of Oulu, Oulu, Finland
2. University of Hamburg, Hamburg, Germany

Surface brightness profiles of disk galaxies, which encode the distribution of stellar mass throughout the disk, serve as an important clue to their formation history. Of the three flavors of disk galaxy profile – Type I, with a single exponential slope; Type II, with a downbending break in slope; and Type III, with an up-bending break – the least understood are of Type III, representing an excess of mass in the disk outskirts. We investigate the origins of this excess mass through a detailed re-examination of Type III break-hosting disks (as identified by Laine et al. 2016), including a revised, unbiased break-finding algorithm with which we uncover many previously unaccounted-for breaks. We carefully classify all identified breaks into subtypes based on their association with features in the disks, asymmetric isophotes, or outer spheroidal components, and examine populations of galaxies separated by the subtypes of their outermost breaks. The most common cause of Type III breaks in this sample is disk asymmetry; such breaks occur only because elliptical apertures are used to measure non-elliptical isophotes, hence these breaks potentially act as a significant source of contamination in disk break studies. Of Type III breaks related to disk features (e.g., spiral arms, rings, etc.), most occur at higher surface brightness than other break types, and they are frequently superseded by additional breaks at larger radius, including of Type II. This suggests that Type III breaks related to, e.g., spiral arms, may not persist and therefore do not necessarily constitute the host’s outer disk. Those with subtle Type II breaks at large radius occupy the lowest density environments in our sample, suggesting that such breaks cannot survive frequent interactions. Type III breaks associated with outer spheroids are the rarest, and show a dichotomy in their stellar populations: those with blue inner disks and red outer disks, and those with roughly flat, red color profiles. The hosts of this break type also occupy the highest density environments in our sample. This suggests that many of these galaxies may be quenching or quenched, thereby transitioning into early type galaxies through, e.g., galaxy harassment. All told, the origins of Type III breaks appear diverse; future disk break studies should therefore avoid broad categorizations into simply Type I, II, and III disks, which may risk obscuring already subtle trends or scaling relations that might be uncovered through study of disk breaks.
Although low surface brightness galaxies make up a significant fraction of the galaxy population, it is only within the last few years that they have been studied in large numbers. Consequently, the methods by which they form and evolve, as well as the extent to which these processes fit within the commonly accepted paradigms of galaxy evolution and cosmology, lack a consensus. In this talk, I will use the state-of-the-art cosmological simulations Romulus25 and RomulusC to examine the properties of low surface brightness galaxies. I will demonstrate that our simulated galaxies match observations and discuss their formation and evolution across a broad mass range and a variety of environments.
A Suprime Look At The Stellar Halos Of The M81 Group

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The state-of-the-art Hyper Suprime-Cam on the Subaru Telescope is providing some of the first wide-field views of stellar halos beyond the Local Group. I will present results from our ongoing M81 Group survey which uses resolved red giant branch stars as tracers of the stellar halos of M81, M82 and NGC3077. I will show the density and metallicity profiles of the halos and compare these to the results of the GHOSTS survey, which covers a smaller area, as well as results for the Milky Way and M31.
During the last years, Low Surface Brightness Galaxies (LSBs) have received renewed attention due to the contained information about formation and evolution of galaxies and new observation and data reduction techniques. Beside searching for Exoplanets, TESS will be a good instrument to hunt for those objects because of its sky coverage, large pixels (scale of 21 arcsec per pixel) and long exposure time. We used the TESS Full Frame Images of sector 1, camera 3, CCD 4 to create stacks up to 1278 images (~202h integration time). We showed that the background noise level gets down to 60 percent by stacking but is dominated by the detector read out noise for stacks with $n > 100$ images. Our measurements indicate a $3\sigma$ limiting surface brightness of 32.2 mag arcsec$^{-2}$. This is very close to the prediction derived by us in advance based on the simulated ETE-6 data (Jenkins et al., 2018) and the implied detection limit of Holwerda (2018) using the formula of Valls-Gabaud & MESSIER Collaboration (2017). As a first application of our stacking routine and TESS data we targeted the nearby late type galaxy NGC 1313. We detected a $\sim 27$ mag arcsec$^{-2}$ faint, very extended ($\sim 35'$) asymmetric “halo”, which is partly visible in ATCA HI data (Ryder et al., 1995), too. Therefore, TESS data will be a good hunting ground for large LSB galaxies.
MONDAY July 8th

09:00 Casiana Muñoz-Tuñón (Deputy Director, IAC, Spain)
   Welcome

09:15 David Valls-Gabaud (Obs. Paris, France)
   Introduction and overview

   Chairperson: Pierre-Alain Duc

09:30 R Michael Disney (Cardiff Univ., UK)
   Hidden galaxies: but not for long

10:00 R Eva Grebel (ARI, Germany)
   The renaissance of LSB galaxies

   10:30 Coffee break

Session 1A State-of-the-art in current and future ground-based instrumentation

11:00 R Christopher Mihos (CWRU, USA)
   Deep imaging of galaxies and clusters: successes and challenges

11:30 Matthew Lehnert (IAP, France)
   Low surface brightness molecular and atomic line emission in distant galaxies

11:45 R David Martínez Delgado (ARI, Germany)
   Ultra-deep imaging with amateur telescopes

12:15 Raúl Infante Sainz & Alex Roig (IAC; Astroprades, Spain)
   A 100h imaging of M101 with a small telescope: reaching the limits of amateur telescopes for low surface brightness science

12:30 Lunch
Session 1B  State-of-the-art in current and future space-based instrumentation

Chairperson: Noah Brosch

14:30 LT Sarah Brough (UNSW, Australia)
*LSST and the LSB universe*

14:55 LT Johan Knapen (IAC, Spain)
*Going towards wide-area ultra-deep imaging surveys*

15:20 Lee Spitler (Macquarie Univ., Australia)
*The Huntsman Telescope*

15:35 Jean-Charles Cuillandre (CEA, France)
*The Canada-France imaging survey as a Euclid precursor: blind all-sky low surface brightness survey of the northern sky*

15:50 LT Armando Gil de Paz (UCM, Spain)
*Darkness revealed: The MESSIER surveyor*

16:15 Vincent Picouet (LAM, France)
*FIREBall-2: The first stratospheric balloon coupled to a multi object spectrograph to reveal the CGM at z~0.7*

16:30 Sona Hosseini (JPL, USA)
*AMUSS – Astrophysics Miniaturized UV Spatial Spectrometer for spectroscopic studies of diffuse astrophysical objects*

16:45 Coffee Break

Session 2  Data analysis in LSB imaging

Chairperson: Lee Spitler

17:15 LT Sugata Kaviraj (Univ. Hertfordshire, UK)
*The low-surface-brightness universe: the new frontier in the study of galaxy evolution*

17:40 LT Mohammad Akhlaghi (IAC, Spain)
*Digging out the low-surface-brightness universe: understanding and constraining the limits of methods used*

18:05 Ignacio Trujillo (IAC, Spain)
*Reproducibility in ultra-deep imaging*

18:20 Cristina Martinez Lombilla (UNSW, Australia)
*Brightness overestimation due to PSF in very faint galaxy structures: the thick discs case*

18:35 Alejandro S. Borlaff (ESA, Spain)
*New limits to low surface brightness details: the Hubble Ultra Deep Field even deeper*

18:50 Poster presentations (#15 Kotulla, #18 Lee, #27 Mehrabani, #34 Sharbaf, #40 Weimann)
19:00 Welcome Reception
TUESDAY July 9th

Session 3  Dust particles and grains: from the Zodiacal light to the ISM cirri

Chairperson: Eva Villaver

09:00 R Anny-Chantal Levasseur-Regourd (LATMOS/IPSL, France)
  *Progress in Zodiacal light understanding: significance for observations of faint extended sources, properties and sources of interplanetary dust, and clues to Solar System evolution*

09:30 IT Jérémie Lasue (IRAP, France)
  *Interpreting the Zodiacal light observations from the properties of interplanetary and cometary dust particles*

09:55 R François Boulanger (ENS, France)
  *Diffuse light from interstellar cirrus clouds across the electromagnetic spectrum*

10:25 IT Sébastien Viaene (Ghent Univ., Belgium)
  *Deriving diffuse dust properties from UV and optical observations*

10:50 Javier Román (IAA, Spain)
  *Galactic cirri in deep optical imaging*

11:05 Coffee break

Session 4  The LSB circumstellar medium and orphan stars

Chairperson: Sarah Brough

11:35 R Raghvendra Sahai (JPL, USA)
  *Faint but not forgotten: astrospheres around dying stars*

12:05 R Eva Villaver (UAM, Spain)
  *The tale of the lost mass*

12:35 IT Dominik Bomans (Bochum, Germany)
  *Multi-wavelength observations of Orphan SN and other transients as signposts for very low surface brightness structures*

13:00 Thomas Sedgwick (LJMU, UK)
  *Low surface brightness galaxies & the galaxy stellar mass function from core-collapse supernovae*

13:15 Lunch
Session 5A  Low surface brightness features around and within galaxies

Chairperson: Gaspar Galaz

15:00  R Denija Crnojević (Univ. Tampa, USA)
Near-field cosmology with low surface brightness features

15:30  IT Allison Merritt (MPIA, Germany)
A survey of observed and simulated stellar halos around Milky Way-like galaxies in the nearby universe

15:55  IT Chris Brook (IAC, Spain)
Forming low surface brightness objects in simulations

16:20 Bärbel Koribalski (CSIRO, Australia)
Hydrogen tails, plumes, and filaments

16:35  Coffee break

17:05  IT Pierre-Alain Duc (Obs. Strasbourg, France)
MATLAS: An investigation of the mass assembly of galaxies with their fine structures, satellite and globular cluster populations

17:30 Sarah Pearson (FICCA, USA)
Detecting thin stellar streams in external galaxies: resolved stars and integrated light

17:45 Nushkia Chamba (IAC, Spain)
The size of the galaxies in the era of ultra-deep imaging

18:00 Sakurako Okamoto (Subaru, Japan)
Signatures of on-going interactions at M81 group centre in the low-surface-brightness features

18:15 Oliver Müller (Obs. Strasbourg, France)
Hunting for low-surface-brightness features in nearby galaxy groups

18:30 Noah Brosch (Tel Aviv, Israel)
Low-surface-brightness features in Hickson compact groups

18:45 Sébastien Comerón (U. Oulu, Finland)
The reports of thick discs’ death are greatly exaggerated: thick discs are not artefacts caused by diffuse scattered light

19:00 End of session
WEDNESDAY July 10th

Session 5B  Low-surface-brightness features around and within galaxies

Chairperson: Stéphane Courteau

09:00 R David F. Malin (AAO, Australia)
   Early photographic detection of LSB features

09:30 Raja Guhathakurta (UCSC, USA)
   Dark matter and chemical enrichment in the low-surface-brightness outskirts of galaxies

09:45 In Sung Jang (Postdam, Germany)
   Tracing the extended stellar outskirts of low-mass disk galaxies

10:00 Michal Bilek (Obs. Strasbourg, France)
   Census of tidal features in nearby early-type galaxies

10:15 Fernando Buitrago (IASS, Portugal)
   Why finding an extended galaxy in a high redshift survey is not an annoyance but a potential treasure trove

10:30 Yutaka Komiyama (NAOJ, Japan)
   Low-surface-brightness features in the Local Universe viewed from the Subaru Prime Focus

10:45 Coffee break

Session 6A  The nature of ultra-diffuse galaxies and other LSB galaxies

Chairperson: Fernando Buitrago

11:15 Anna Ferré-Mateu (ICCUB, Spain)
   On the nature of the ghostly ultra diffuse galaxies in the Coma cluster

11:30 Tomás Ruiz-Lara (IAC, Spain)
   The stellar content in ultra diffuse galaxies: contrasting the galaxy “lacking dark matter” with other Coma cluster UDGs

11:45 Daniel J. Prole (Cardiff Univ., UK)
   The formation of ultra diffuse galaxies: observational evidence

12:00 Luis E. Pérez Montaño (UNAM Morelia, Mexico)
   Halo Structural parameters of low surface brightness galaxies

12:15 Poster presentations (#26 Martínez-Vázquez, #33 Saremi, #09 Grishin, #11 Javadi, #13 Kemp, #28 Park, #32 Ribbeck, #36 Walker, #24 Mancillas, #05 Brosch, #14 Kemp, #35 Stein, #39 Zemaitis)

13:00 Lunch
Session 6B  The nature of ultra-diffuse galaxies and other LSB galaxies

Chairperson: Mireia Montes

15:00  R Dennis Zaritsky (U. Arizona, USA)
Searching for SMUDGes

15:30  Samuel Boissier (LAM, France)
Ultra-diffuse and low-surface-brightness galaxies in the Virgo cluster: constraints from the VESTIGE and GUViCS surveys, and simple models

15:45  Gaspar Galaz (PUC, Chile)
Unavoidable questions about giant low-surface-brightness galaxies

16:00  Anna Saburova (SAI, Russia)
Unveiling the origin of giant low surface brightness discs: results of the long-slit spectral observations

16:15  Jeong Hwan Lee (U. Seoul, South Korea)
Hunting distant UDGs in very massive clusters with HST

16:30  Coffee Break

17:00  Stéphane Courteau (Queen’s U., Canada)
Structural and dynamical properties of LSB galaxies

17:15  Igor Chilingarian (SAO, USA)
Internal dynamics and stellar content of ultra-diffuse galaxies in the Coma cluster prove their evolutionary link with dwarf early-type galaxies

17:30  Rhys Taylor (Prague, Czech Republic)
Optically dark hydrogen clouds from the Arecibo Galaxy Environment Survey: dark galaxies or debris?

17:45  Pavel Mancera-Piña (Kapteyn, The Netherlands)
The startling dynamics of HI-Rich ultra-diffuse galaxies

18:00  Salvador Cardona Barrero (IAC, Spain)
Dispersion vs rotation support in ultra-diffuse and low surface brightness galaxies

18:15  Anton Afanasiev (SAI, Russia)
Internal dynamics of the extended dwarf spheroidal galaxy KDG64: bridging the gap between ultra-diffuse galaxies and dwarf spheroidals

18:30  Poster presentations and discussions (#02 Bennet, #04 Bouquin, #19 Li, #06 Díaz-García, #21 Malayi, #31 Rey, #37 Watkins, #12 Junais, #16 Laine, #17 Lee, #10 Gomes)

19:00  End of session
THURSDAY July 11th

Session 7  The circumgalactic medium of low- and high-redshift galaxies

Chairperson: Matthew Lehnert

09:00 R Sebastiano Cantalupo (ETH, Switzerland)
   Illuminating the cosmic web and the circumgalactic medium with fluorescent Lyman-alpha emission

09:30 IT Matthew Hayes (Stockholm Univ., Sweden)
   The circumgalactic medium of low-redshift galaxies, probed by emission lines at low surface brightness

09:55 Deborah Lokhorst (Univ. Toronto, Canada)
   Direct detection of the circumgalactic medium using Dragonfly

10:10 Jorge Sánchez Almeida (IAC, Spain)
   GTC-based search for diffuse gas around local gas-accreting galaxies

10:25 Poster presentations and discussions (#29 Pérez-Fournon, #30 Pérez Hernandez)

11:00 Coffee break

11:30 IT Freeke van de Voort (MPA, Germany)
   Cosmological simulations of the CGM at sub-kpc resolution

11:55 Genoveva Micheva (AIP, Germany)
   Deep surface photometry of the Lyman Alpha Reference Sample (LARS)

12:10 Helmut Dannerbauer (IAC, Spain)
   Surprising existence of circumgalactic molecular medium in a galaxy protocluster at z=2.2

12:25 Andrea Afruni (Kapteyn, The Netherlands)
   Understanding the cool circumgalactic medium of passive galaxies

12:40 Poster presentations and discussions (#38 Wright, #23 Mancillas, #25 Mancillas, #03 Bilek, #01 Amiri, #20 De Oliveira)

13:00 Lunch
Session 8  The intracluster light and its role in galaxy evolution in clusters

Chairperson: Matthew Hayes

15:00 R Mireia Montes (UNSW, Australia)
*The intracluster light and its role in galaxy evolution in clusters*

15:30 IT Emmanuele Contini (Nanjing Univ., China)
*Intracluster light: its formation and main properties*

15:55 Marilena Spavone (Obs. Naples, Italy)
*Stellar haloes from deep VST surveys: comparing observations and theory*

16:10 Brandon Kelly (LJMU, UK)
*Intracluster light as a proxy for host cluster properties*

16:25 Coffee break

17:00 IT Florence Durret (IAP, France)
*Intracluster light and its influence on galaxy evolution in clusters*

17:25 IT Yolanda Jiménez-Teja (Obs. Rio de Janeiro, Brazil)
*Unveiling the dynamical stage of massive clusters through the study of the intracluster light*

17:50 Enrichetta Iodice (Obs. Capodimonte, Italy)
*The deep (photometric and spectroscopic) surveys of the Fornax cluster: exploring the faintest regions of the bright ETGs inside the virial radius*

18:05 Isaac Alonso Asensio (IAC, Spain)
*Similarity between stellar and total dark matter density distributions in the intra-cluster volume: a view from simulations*

18:20 Jongwan Ko (KASI, South Korea)
*Evidence for the existence of intracluster light ~5 billion years after the Big Bang*

18:35 Michael Wilkinson (U. Groningen, The Netherlands)
*Sourcerer*: a robust, multi-scale source extraction tool suitable for faint and diffuse objects

18:50 Poster presentations and discussions (#07 Ebrova, #22 Mancillas, #08 Ellien)

19:00 *End of session*

20:00 *Conference dinner (Hotel Mencey, Santa Cruz de Tenerife)*
FRIDAY July 12th

Session 9 The cosmic web of large-scale filaments

Chairperson: Simon Driver

09:00 R José Fonseca (U. Padova, Italy)
Line intensity mapping: a “novel” window to the cosmic web

09:30 IT Ewald Puchwein (AIP, Germany)
Lyman-alpha emission and absorption by the cosmic web

09:55 IT Nicolas Tejos (Univ. Valparaiso, Chile)
Looking for a WHIM in the large-scale filaments of the cosmic web

10:20 Coffee break

Session 10 The UV / optical / IR cosmological background radiation

Chairperson: Florence Durret

10:50 R Jayant Murthy (IIA, India)
The UV and optical sky background

11:20 IT Alberto Dominguez (UCM, Spain)
The extragalactic background light in the Fermi-LAT era

11:45 IT Simon Driver (UWA, Australia)
Measuring energy production in the Universe over all wavelengths and all time

12:10 Christopher Mihos (CWRU, USA)
Summary of the conference

12:40 End of conference

13:00 Lunch

14:15 Visit to Teide Observatory

20:30 Return from visit
Social Programme

- **Monday, July 8**
  19:00 Welcome Reception.
  Cafeteria of the Aulario Central, Guajara Campus, University of La Laguna (conference venue)

- **Thursday, July 11**
  20:00 Dinner at Hotel Iberostar Grand Mencey
  **Address:** Calle Doctor José Naveiras, 38, Santa Cruz de Tenerife, 38004
  **Tel:** +34 922-609-900
  **E-mail:** hotel.mencey@iberostar.com

- **Friday, July 12**
  14:15 to 20:00 Excursion to Teide Observatory in Tenerife
  Buses leave from Conference Venue at 14:15
  Return to the venue expected at 20:00
  (Google Maps link: Mirador observatorio del Teide)
  [https://goo.gl/maps/WZsS6jd5SFVqSMMr9](https://goo.gl/maps/WZsS6jd5SFVqSMMr9)

- **Saturday, July 13**
  08:00 to 19:30 Excursion to Roque de los Muchachos Observatory, La Palma
  **Flights:**
  NT 607 G 13JUL 6 TFNSPC HK15 0800 0830
  NT 638 G 13JUL 6 SPCTFN HK15 1900 1930
  **Visit of the Observatorio del Roque de los Muchachos (ORM)**
  (with guide from Starlight)
  11:00 Reception at ORM. Coffee + cakes!
  11:30 Visit to MAGIC
  12:30 Visit to GTC
  13:30 Lunch at ORM Residencia
  14:30 Visit to WHT