Small Galaxies, Cosmic Questions - II
29th July – 2nd August, 2024

Conference Program

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Small Galaxies, Cosmic Questions — II

Monday, 29 July

9:30 AM – 10:30 AM

Invited Review: Dwarf galaxies beyond the Local Group

Shany Danieli
Princeton

Time: 9:30am

The Faint Satellite System of NGC253: Insights into Low-Density Environments and No Satellite Plane

Burcin Mutlu-Pakdil
Dartmouth College

Time: 10:00am

Local Group satellites have been the primary sample for understanding the astrophysics and cosmological implications of dwarf galaxies. However, there is a danger of 'overtailoring' the models to fit local observations. To fully test the ΛCDM model and its underlying astrophysics, studies of satellite systems beyond the Local Group are necessary to sample primary halos with a range of masses, morphologies, and environments. To address this fundamental need, we started PISCeS, a Magellan+Megacam survey to identify dwarfs and other substructures in resolved stellar light around Milky Way (MW)-mass galaxies outside the Local Group. We recently completed the survey around NGC253 (at 3.5 Mpc), the nearest MW-mass spiral galaxy in an isolated environment, providing us with a unique opportunity to extend the range of environments probed by the existing surveys.

We take a deeper look at the faint satellite system of NGC253, and find no convincing evidence for the presence of a plane of satellites surrounding NGC253. We construct its satellite luminosity function, and compare it to those calculated for other Local Volume galaxies. Exploring trends in satellite counts and star-forming fractions among satellite systems, we find relationships with host stellar mass, environment, and morphology, pointing to a complex picture of satellite formation, and a successful model has to reproduce all of these trends. In this talk, I will present these exciting PISCeS results, discuss complementary ongoing efforts, and conclude with a preview of what is possible with "big data" in the coming decade..

Satellites of dwarf galaxies with the MADCASH survey

Amandine Doliva-Dolinsky
University of Tampa; Dartmouth College

Time: 10:15am

Faint dwarf galaxies are powerful cosmological probes as their properties (number, size, luminosity, spatial distribution) can be used to test the cosmological model and, in particular, to constrain the dark matter particle mass. But, to use dwarf galaxies as such, it is absolutely crucial to accurately determine the dwarf galaxy detection limits so they can be accurately modeled into the dwarf galaxy system models. I will present the first such effort to fully characterize the dwarf galaxy system of 11 LMC-SMC type hosts in the Local Volume thanks to the first results of the Magellanic Analog Dwarf Companions And Stellar Halos (MADCASH) survey. This wide field imaging survey allows us to detect the very faint satellites of these systems, which are essential to constrain cosmology and the physics of galaxy formation & evolution.

Small Galaxies, Cosmic Questions — II

11:15 AM – 12:30 PM

An evolutionary continuum from nucleated dwarf galaxies to star clusters

Kaixiang Wang
Peking University

Time: 11:15am

Systematic studies have revealed hundreds of ultra-compact dwarf galaxies (UCDs) in the nearby Universe. With half-light radii r_h $10-100$ parsecs and stellar masses $M_* \sim 10^6$–10^8 solar masses, UCDs are among the densest known stellar systems. While similar in appearance to massive globular clusters, the detection of extended stellar envelopes, complex star formation histories, elevated mass-to-light ratio, and supermassive black holes suggest that some UCDs are remnant nuclear star clusters of tidally-stripped dwarf galaxies, or even ancient compact galaxies. However, only a few objects have been found in the transient stage of tidal stripping, and this assumed evolutionary path has never been fully traced by observations. Here we show that 106 galaxies in the Virgo cluster have morphologies that are intermediate between normal, nucleated dwarf galaxies and single-component UCDs, revealing a continuum that fully maps this morphological transition, and fills the "size gap" between star clusters and galaxies. Their spatial distribution and redder color are also consistent with stripped satellite galaxies on their first few pericentric passages around massive galaxies. The "ultra-diffuse" tidal features around several of these galaxies directly show how UCDs are forming through tidal stripping, and that this evolutionary path can include an early phase as a nucleated ultra-diffuse galaxy (UDG). These UCDs represent substantial visible fossil remnants of ancient dwarf galaxies in galaxy clusters, and more low-mass remnants likely remain to be found.

Pushing into the semi-resolved regime: A treasure trove of the lowest mass galaxies in isolation

Michael Jones
University of Arizona

Time: 11:30am

Our machine learning-aided search of the DESI legacy imaging surveys has identified dozens of previously unknown, extremely low mass galaxy candidates that are likely within a few Mpc. One such object is the Pavo galaxy, currently the lowest mass star-forming galaxy known in isolation. In this talk I will discuss the discovery of Pavo, its recent neutral gas observations, and a newly discovered close analogue, Corvus I, as well as our latest results concerning isolated quenched ultra-faint dwarf candidates. This discovery space has been made accessible by using machine learning to push into the semi-resolved regime where nearby low-mass galaxies are neither fully resolved into stars, nor smooth, continuous distributions of light. This regime has remained largely untapped by previous search algorithms, but offers a vital resource for identifying the lowest mass galaxies in isolation, beyond the influence of massive hosts. Furthermore, this technique is one of the few approaches that is able to straddle the threshold mass where reionization quenched galaxies, identifying both isolated quenched galaxies analogous to Tucana B and the lowest mass star-forming, such as Pavo. This offers a unique opportunity to connect these two populations and pin down where and how this transition occurs.

Satellite Galaxies around Low-Mass Hosts

Laura Congreve Hunter
Dartmouth College

Time: 11:45am

Dwarf galaxies are regarded as cosmological and astrophysical probes on small-scales, thus their discovery and characterization are among the most important goals in the field. Though much effort has been made in surveying Milky Way-mass galaxies and their satellite populations, the sample of satellites around lower-mass hosts is much less understood. I am presenting on the initial results of our ongoing campaign to establish a statistical sample of unresolved dwarf satellites around Large Magellanic Cloud and Small Magellanic Cloud mass ($10^8 \leq M_\star \leq 10^{10}$ $M_\odot$) hosts. As part of the systematic search of the virial volumes around over 30 nearby low-mass hosts (4<d<10 Mpc), we have identified hundreds of candidate satellite galaxies in the archival DECaLS imaging. The completed sample will provide quantitative constraints for galaxy formation physics and serve as an important benchmark for simulations to try and recover.

SAGA Survey: A Census of 101 Satellite Systems around Milky Way-like Galaxies

Yao-Yuan Mao
University of Utah

Time: 12:00pm

We present the main findings of the third Data Release (DR3) of the Satellites Around Galactic Analogs (SAGA) Survey, a spectroscopic survey characterizing satellite galaxies around Milky Way (MW)-mass galaxies. SAGA DR3 includes 378 satellites identified across 101 MW-mass systems in the distance range 25-40.75 Mpc, and an accompanying redshift catalog of background galaxies (including 46,000 taken by SAGA) in the SAGA footprint of 84.7 sq. deg. The number of confirmed satellites per system ranges from zero to 13, in the stellar mass range $10^6 - 10^10$ solar masses. Based on a detailed completeness model, this sample accounts for 94% of the true satellite population down to a stellar mass of $10^7.5$ solar masses. We find that the mass of the most massive satellite in SAGA systems is the strongest predictor of satellite abundance; one-third of the SAGA systems contain LMC-mass satellites, and they tend to have more satellites than the MW. The SAGA satellite radial distribution is less concentrated than the MW, and the SAGA quenched fraction below $10^8.5$ solar masses is lower than the MW, but in both cases, the MW is within 1-sigma of SAGA system-to-system scatter. We do not find a signal for corotation of SAGA satellites. Although the MW differs in many respects from the typical SAGA system, these differences can be reconciled if the MW is an older, slightly less massive host with a recently accreted LMC/SMC system.

The mass profiles of dwarf galaxies with weak lensing

Alexandra Amon
Princeton

Time: 12:15pm

Weak lensing provides a powerful avenue to measure the masses of dwarf galaxies, and constrain the shape of the full mass profile. I present a novel approach to extract a sample of dwarf galaxies from the entire footprint of photometric surveys in order to measure their average halo mass profile with weak lensing. The stellar mass and redshift distributions are characterized using a representative spectroscopic calibration sample. I demonstrate the viability of this approach using the $\sim 5000deg^2$ multi-band photometry from Dark Energy Survey and redshifts from the Satellites Around Galactic Analogs (SAGA) survey to select a sample of 100k dwarf galaxies spanning redshifts $z < 0.3$ and a median stellar mass of $\log_1 0(M * /Msun) \sim 8.5$ with an unsupervised machine learning method. I showcase measurements of their stacked excess surface mass density profiles using galaxy–galaxy lensing and constraints on the stellar-to-halo mass relation using a simulation-based forward-modelling approach to fit the measurements. The median halo mass of this sample is found to be $\log_1 0(Mhalo/Msun) \sim 10.7$. With spectra from the Dark Energy Spectroscopic Instrument and on the eve of Rubin Observatory's Legacy Survey of Space and Time, which will measure weak lensing with billions of galaxies, this work represents a pilot study to fully exploit these data to extract, characterise and measure the mass profiles of even lower mass dwarf galaxies.

2:00 PM – 3:30 PM

Invited Review: Dwarf satellite populations in the Local Group

Michelle Collins
University of Surrey

Time: 2:00pm

The HST Treasury Survey of the M31 satellite system

Alessandro Savino
U.C. Berkeley

Time: 2:30pm

Within the past decades, the exquisite observational characterization of the Milky Way (MW) satellite population has progressively anchored the framework of low-mass galaxy formation and small-scale structure growth in the Universe. However, the MW halo is a single environment, leading to questions of whether the MW satellites are broadly representative of L* galactic ecosystems. Due to its proximity, the Andromeda galaxy, and its satellite stellar systems, represent the best targets to study in detail the galactic environment in another massive spiral. In this talk, I will present new results from the HST Treasury survey of the M31 satellites, which has assembled deep HST imaging of virtually all known dwarf galaxies around M31, from ultra-faints (Mv= -6.0) to dwarf ellipticals (Mv= -16.8). I will provide an improved view on the 3D geometry of the M31 system, probing the existence of planar structures and asymmetries in the spatial distribution of the satellites. I will present homogeneously measured star formation histories for the whole satellite system of M31, highlighting similarities but also striking differences with respect to the MW satellites. I will also focus on the 6 ultra-faint dwarfs in our sample, showing how their star formation history paints a more nuanced picture of how reionization affects galaxy formation in low-mass halos.

Satellite group infall into the Milky Way: exploring the Crater-Leo case with new HST proper motions

Mariana P. Júlio
Leibniz Institute for Astrophysics Potsdam (AIP)

Time: 2:45pm

Within Λ Cold Dark Matter simulations, Milky Way-like galaxies accrete part of their satellite galaxies in small groups rather than individually. It was suggested that this might be the reason behind the origin of satellite planes and the galaxy pairs found in the Local Group, providing new insights on dwarf galaxy formation and evolution. Objects accreted in groups are expected to share similar specific total energy and angular momentum, and also identical orbital orientations. Looking at observations of Milky Way satellites, the dwarfs Leo II, IV, V, Crater II, and the star cluster Crater 1 were proposed to be a vestige of group infall. The suggested "Crater-Leo group" shows a monotonic distance gradient and all these objects align along a great circle. To further investigate this possibility, we use Gaia Data Release 3 and present new Hubble Space Telescope (HST) proper motions to derive accurate orbital properties for these objects. Assuming that satellites accreted as a group share similar specific angular momentum and total energy, we can identify possible associations and predict their proper motions. Leo II, Leo IV, and Crater 1 show orbital properties consistent with those we predict from assuming group infall. However, our results suggest that Crater II was not accreted with the rest of the objects. If confirmed with increasingly accurate proper motions in the future, the Crater-Leo objects appear to constitute the first identified case of a cosmologically expected, typical group infall event.

Eridanus III and DELVE 1: Carbon-rich Primordial Star Clusters or the Smallest Dwarf Galaxies?

Josh Simon
Carnegie Observatories

Time: 3:00pm

The boundary between ultra-faint dwarf galaxies and ultra-faint star clusters has become increasingly blurry in recent years. Are the Milky Way satellites with half-light radii < 20pc and extremely small stellar masses ($< 1000 M_{sun}$) dark matter-dominated but unusually compact dwarf galaxies, or the low-mass tail of the globular cluster population? I will discuss spectroscopy of the ultra-faint satellites Eridanus III (Eri III) and DELVE 1. Using eight member stars in each system, I place upper limits on their velocity and metallicity dispersions. The brightest star in each object is very metal-poor, at [Fe/H] = -3.1 for Eri III and [Fe/H] = -2.8 for DELVE 1. Both of these stars exhibit large overabundances of carbon and very low abundances of neutron-capture elements, classifying them as CEMP-no stars. Because their metallicities are well below those of the Milky Way globular cluster population, and because no CEMP-no stars have been identified in globular clusters, these chemical abundances could suggest that Eri III and DELVE 1 are dwarf galaxies. On the other hand, the two systems have half-light radii of 5-8 pc, which is more compact than any known dwarfs. Eri III and DELVE 1 are either the smallest dwarf galaxies yet discovered, or they are representatives of a new class of star clusters that underwent chemical evolution distinct from that of ordinary globular clusters. In the latter scenario, such objects are likely the most primordial star clusters surviving today.

Employing Dwarf Galaxies to Assess Star Formation Regulation on Galactic Scales

Erin Kado-Fong
Yale

Time: 3:15pm

Dwarf galaxies are exceptional probes of star formation physics due to the predominant role that star formation feedback plays in shaping their baryonic structure and to their status as extreme (low-density, low-metallicity) star-forming environments. For the same reason, the processes that regulate star formation in dwarfs must be understood in order to use these systems to test theories of dark matter or to explain the assembly of the low-mass galaxy population.

I will discuss two recent works that use low-mass galaxies to probe the processes that drive, halt, and regulate star formation. In particular, I will (i) show that contrary to what many cosmological simulations require, chemical evolution modeling of low-redshift galaxies implies that star formation in dwarfs is only moderately efficient at driving galactic winds (Kado-Fong et al. 2024), and (ii) present the existence of a quenched field dwarf below the self-quenching mass limit, demonstrating that interactions between dwarfs can temporarily halt star formation outside the influence of a massive host (Kado-Fong et al. 2023).

These works highlight both the utility of dwarfs in constraining the star formation cycle and the importance of star formation physics in explaining dwarf properties; such efforts will only expand in the coming years as new surveys assemble increasingly large and complete dwarf galaxy samples out to significant redshift.

Small Galaxies, Cosmic Questions — II

4:15 PM – 5:15 PM

New Proper Motion Constraints on the Structure and Dynamics of the Andromeda Dwarf Satellite System

Roeland Van Der Marel
Space Telescope Science Institute

Time: 4:15pm

The Milky Way (MW) dwarf satellite system is a key testing ground for understanding hierarchical structure formation and dark matter. However, the MW satellite system may not be representative, and indeed some of its key features differ from those of the second best studied dwarf satellite system, that of Andromeda (M31). However, detailed comparison of these satellite systems has been hampered by the lack of 3D velocity information for the Andromeda satellites, for which proper motions (PMs) are beyond the reach of Gaia. We report here on measurements of the PMs of ten M31 dwarf satellites using Hubble (HST), with a median accuracy of ~ 60 km/s. We also report new HST measurements of the PM of M31 itself, which further improve and complement existing shorter time baseline measurements by HST and Gaia. We combine the measurements with existing distance and line-of-sight velocity data to study the kinematics of the M31 satellite system and estimate the M31 virial mass. We assess the extent to which the new PMs support the assertion that many of the M31 satellites inhibit a thin rotating plane. Finally, we use the PM of M32 to study its orbit around M31, and what this tells us about the formation of this unusually compact dwarf elliptical.

Hints of a disrupted binary dwarf galaxy in the Sagittarius stream

Elliot Yarnell Davies
University of Cambridge

Time: 4:30pm

In this work, we look for evidence of a non-unity mass ratio binary dwarf galaxy merger in the Sagittarius stream. Simulations of such a merger show that, upon merging with a host, particles from the less-massive galaxy will often mostly be found in the extended stream and less-so in the central remnant. Motivated by these simulations, we use APOGEE DR17 chemical data from approximately 1100 stars in both the Sagittarius remnant and stream to look for evidence of contamination from a second dwarf galaxy. This search is initially justified by the idea that disrupted binary dwarf galaxies provide a possible explanation of the Sagittarius bifurcation, and the location of the massive, chemically peculiar globular cluster NGC 2419 found within the stream of Sagittarius. We separate the Sagittarius data into its remnant and stream and compare the [Mg/Fe] content of the two populations. In particular, we select [Mg/Fe] to search for hints of unique star formation histories among our sample stars. Comparing the stream and remnant populations, we find regions have distinct [Mg/Fe] distributions for fixed [Fe/H], in addition to distinct chemical tracks in [Mg/Fe] – [Fe/H] abundance space. We show that there are large regions of the tracks for which the probability of the two samples being drawn from the same distribution is very low ($p < 0.05$). Furthermore, we show that the two tracks can be fit with unique star formation histories using simple, one zone galactic chemical evolution models. While more work must be done to discern whether the hypothesis presented here is true, our work hints at the possibility that Sagittarius may consist of two dwarf galaxy progenitors.

Chemo-dynamical characterization of stellar populations and the dark matter halo of the Sculptor dwarf galaxy

José María Arroyo-Polonio
Instituto de astrofísica de Canarias

Time: 4:45pm

Satellite galaxies of the Milky Way (MW) lie in the faintest edge of the luminosity function and they are, according to the hierarchical model, the building blocks of the stellar halos of larger galaxies. Therefore, their understanding is crucial to shed light on the MW evolution itself. Moreover, they are the most dark-matter dominated galactic systems known, making them valuable proofs for cosmological models. In this work, we characterize the internal kinematics, metallicity properties and dark-matter density distribution of Sculptor, a "classical" dwarf spheroidal galaxy (dSph), satellite of the MW. We make use of a recent VLT/FLAMES data-set that provides high-precision velocities and metallicities for the largest number of reliable members. To compute the dark matter density profile, we perform an action-based dynamical modeling analysis, using highly flexible models capable of dealing with the presence of multiple populations and fitting the motion of individual stars. Among the scenarios proposed in the literature, we find that Sculptor is much better described by two populations than by one single population with a metallicity gradient. Furthermore, we find evidence for a third more extended and very metal-poor population, characterized by a systematic shift in the mean l.o.s. velocity. After considering various possible origins for this new population, we find a minor merger scenario to be the most likely one. Despite Sculptor being highly dark matter-dominated and having a relatively short star formation history, our study reveals a well-defined core in the dark matter density distribution of the galaxy.

The effect of binary stars on mass estimates for ultrafaint dwarf companions of the Milky Way

Amery Gration
University of Surrey

Time: 5:00pm

For the purposes of dynamical modelling galaxies are typically treated as populations of single stars moving within a static potential. But the presence of binary stars significantly modifies the distribution of stellar velocities. Binary-rich galaxies therefore have higher velocity dispersions than do binary-poor galaxies and a naive application of the virial theorem will result in spuriously large mass estimates for those galaxies. The modification of the velocity distribution in its entirety may be a particular problem for distribution function models of dwarf galaxies, which are sensitive to higher velocity moments in a way that Jeans models are not. We expand on the work of Minor et al. (2010), who outlined a theory for quantifying the effect of binary stars on observed line-of-sight velocities. We develop this theory in the context of distribution-function modelling and determine its significance for mass estimates for ultrafaint dwarf galaxies derived by fitting distribution-function models to single-epoch data. We bring it up to date by using the distributions of binary-star properties determined by Moe and Stefano (2017), which we then evolve under a range of star-formation histories. The distribution of binary-star properties outside the solar neighbourhood is very uncertain but we find that for any plausible scenario the effect of binary stars on observed LOS velocity distributions is minimal. We conclude with some thoughts on the possibility of recovering binary-population model parameters using distribution function modelling.

Tuesday, 30 July

9:00 AM – 10:30 AM

Invited Review: What can dwarf galaxies reveal about the nature of dark matter?

Ethan Nadler
USC & Carnegie Observatories

Time: 9:00am

High-fidelity cosmological simulations of the Local Group

Ewoud Wempe
Kapteyn Astronomical Institute, University of Groningen

Time: 9:30am

Cosmological simulations have proven essential to provide realistic models of structure formation in an ΛCDM paradigm. Several simulations that attempt to reproduce the Local Group have been created, but it has proven difficult to satisfy all our observational constraints on the Local Group, and moreover, to obtain an unbiased and fair sample of the posterior distribution of ΛCDM universes subject to the observational constraints of the Local Group. In this work, we extend the BORG algorithm (Bayesian Origin Reconstruction from Galaxies), that has already been used to model the Local Large-Scale Structure, to reconstruct the Local Group. Using this toolset, we perform a statistical inference on the history of the Local Group, following a ΛCDM prior on the cosmological initial conditions, and a likelihood that constrains local observational quantities, like the masses, positions, velocities of the Milky Way and M31 haloes, and the quiet local Hubble flow. We find a sample of initial conditions and simulations that successfully reproduce these properties, allowing our Local Group to be studied in greater simulated detail than ever before. This is particularly interesting in the context of dwarf galaxies, because we obtain the ΛCDM posterior distributions of the spatial and the dynamical properties of the Local Group's dwarf galaxies (e.g. spatial anisotropies, satellite planes, orbital clustering) as well as dark matter mass functions, given the exact configuration and environment of the Local Group's main galaxies. This enables us to put the Local Group's dwarf galaxies into a cosmological context.

LYRA dwarfs: the formation, growth and evolution of the smallest galaxies

Shaun Brown
ICC, Durham

Time: 9:45am

Dwarf galaxies offer a powerful probe of galaxy formation over a wide range of spatial and temporal scales. Their shallow potentials make them particularly sensitive to many forms of feedback, while their early formation histories provide a detailed view of star formation in the early universe. While these systems offer promising laboratories to test various galaxy formation models there is not yet a consensus on the key physical mechanisms necessary to produce a realistic population of these galaxies.

To address these questions I present a new simulation suite of over 40 dwarf galaxies run at an unprecedented resolution of 4 solar mass using the LYRA model which is able to fully resolve individual stars and their subsequent supernova. These systems are self consistently evolved in a fully cosmological context modelling the initial collapse of these structures, the formation of their first stars, their quenching due to reionisation and as well as dynamically evolving their stellar populations through to today. In this talk I will present some initial results of these new simulations, particularly focusing on why some of the smallest dark matter haloes are able to form start while others remain truly dark. The exquisite detail offered by these simulations make them an invaluable tool for further understanding the formation of both classical and ultra-faint dwarf galaxies, as well as making key predictions for both current and future surveys, such as DESI, LSST and Euclid.

How micro galaxies could help constrain the properties of dark matter

Raphael Errani
Carnegie Mellon University

Time: 10:00am

Guided by the recent discovery of the faint Milky Way satellite UMa3/UnionsI, in this talk I will present the results of our controlled high-resolution simulations to discuss how "micro galaxies" could be distinguished observationally from self-gravitating star clusters, and how such systems would help us to constrain both the properties of dark matter and the physical processes underlying the formation of the faintest of galaxies. Micro galaxies are a plausible prediction of Cold Dark Matter (CDM) cosmology: The centrally-divergent density cusps of CDM subhaloes render them remarkably resilient to tides. Heavily stripped tidal remnants of the Milky Way accretion may survive even in the strong tidal field of the inner regions of our Galaxy. Some of these tidal remnants may have been sufficiently massive in the past to allow for star formation within their potential wells, giving rise to a population of micro galaxies: co-moving groups of stars, gravitationally supported by the dark matter subhalo which surrounds them.

What's the Matter with Dwarf Galaxies?

Alyson Brooks
Rutgers University/CCA

Time: 10:15am

While Cold Dark Matter (CDM) was initially thought to have trouble reproducing the small scales of our Universe (dwarf galaxies and the central regions of galaxies like the Milky Way), it has generally become accepted in the last decade that a proper treatment of the gas and stars (baryonic matter) can alleviate those tensions. However, the models of energetic "feedback" from stars that have solved some of the tensions in CDM are now running into trouble solving new problems, specifically the "diversity of rotation curves" problem. Simultaneously, we are entering an era in which we will be able to detect and characterize hundreds of dwarf galaxies within the Local Volume. In this talk, I'll outline a campaign to simulate the largest suite of dwarf galaxies to date, in environments both near the Milky Way and further afield. This suite will be used to interpret upcoming observations. As an example of first results, I demonstrate that these galaxies predict a difference in the stellar-to-halo mass relation of dwarf galaxies as a function of distance from a Milky Way-mass galaxy, which naturally produces lower quenching rates, higher HI fractions, and bluer colors for more isolated dwarf galaxies. Additionally, the simulated dwarfs seem to show the full range of diversity in their rotation curves, even within CDM. I will highlight early results exploring the origin of diversity in CDM.

11:15 AM – 12:30 PM

Capture of stars by dark matter subhaloes

Jorge Peñarrubia
Royal Observatory of Edinburgh

Time: 11:15am

Dark Matter (DM) subhaloes travelling through a galaxy can capture nearby stars with small relative velocities onto temporarily bound orbits. The population of field stars trapped within a given subhalo reaches a steady state as the number of stars being captured equals that being tidally stripped. This talk will present N-body experiments that illustrate how small CDM subhaloes orbiting in a larger parent galaxy capture field stars. It will be shown that in some galactic environments ""dark"" subhaloes – too small to trigger in-situ star formation– can capture field stars and thus become ""luminous"". This talk will discuss estimates of the number and steady-state properties of these objects in different galaxies. I will show that these objects could be detectable as faint stellar overdensities with unusual kinematics and identical chemical composition as the host galaxy.

The true radial distribution of Galactic satellites

Isabel Santos-Santos
Institute for Computational Cosmology, Durham University

Time: 11:30am

The MW galaxy presents a larger number of satellite galaxies within ~ 30 kpc than predicted by cosmological simulations of MW-like halos. If we believe current simulation results, one implication is that halos as small as Vpeak 10 km/s should harbour galaxies, which is in contrast with the expectations of most galaxy formation models based on Hydrogen-cooling. However, recent works have highlighted that cosmological simulations suffer from artificial disruption of subhalos as a result of tidal stripping; and that, in the ideal situation of infinite numerical resolution, the cuspy NFW density profile of CDM halos never fully disrupts. We use the Aquarius cosmological simulations of MW-mass halos, combined with the GALFORM semi-analytical galaxy formation model, to account for these sub-resolution subhalos ("orphans"), and estimate the true radial distribution of satellite galaxies expected around the MW in LCDM. We carry out a convergence study of the number of orphans and surviving satellites by comparing 4 different resolution levels, and we characterize the population of orphans. Our unprecedented results evidence the crucial contribution of orphans to the population of MW ultrafaint satellites, which has been neglected in previous theoretical work. We give predictions for the radial distribution and orbital properties of these objects. Dozens of satellites should be observable within 30 kpc of the MW, awaiting discovery through deep imaging surveys like LSST.

Constraints on the properties of νMSM dark matter using the satellite galaxies of the Milky Way

Oliver Newton
Centre for Theoretical Physics, Polish Academy of Sciences

Time: 11:45am

Low-mass galaxies are powerful tools with which to investigate departures from the standard cosmological paradigm in models that suppress the abundance of small dark matter substructures. One of the simplest metrics that can be used to compare different models is the abundance of satellite galaxies in the Milky Way. Viable dark matter models must produce enough substructure to host the observed number of Galactic satellites. Here, we scrutinize the predictions of the neutrino Minimal Standard Model (νMSM), a well-motivated extension of the Standard Model of particle physics in which the production of sterile neutrino dark matter is resonantly enhanced by lepton asymmetry in the primordial plasma. This process enables the model to evade current constraints associated with non-resonantly produced dark matter. Independently of assumptions about galaxy formation physics we rule out, with at least 95 per cent confidence, all parametrizations of the νMSM with $Ms \leq 1$ keV, independently of other model parameters and of the Milky Way halo mass. Incorporating physically motivated prescriptions of baryonic processes and modelling the effects of reionization strengthens our constraints and we exclude all models with $Ms \leq 3$ keV. Unlike other literature, our fiducial constraints do not rule out the putative 3.55 keV X-ray line, if it is indeed produced by the decay of a sterile neutrino. In contrast with other work, we find that the constraints from satellite counts are substantially weaker than those reported from X-ray non-detections.

Confronting the diversity problem: the limits of rotation curves as a probe of dark matter in dwarf galaxies

Isabel Sands
California Institute of Technology

Time: 12:00pm

While galaxy rotation curves provide one of the most powerful methods of measuring dark matter profiles in the inner regions of galaxies, at the dwarf scale there are factors that can complicate rotation curve analysis. Given the expectation of a universal profile in dark matter-only simulations, the diversity of observed rotation curves has become an often-discussed issue in ΛCDM cosmology on galactic scales. In this talk, I show that, for a sample of Feedback in Realistic Environments (FIRE) dwarf galaxies simulated with cold dark matter and baryons, the inferred HI rotation curves can fail to map the true enclosed mass of the galaxies. For galaxies with well-ordered gaseous disks, the measured rotation curve may deviate from true circular velocity by roughly 10% or less within the radius of the disk. However, non-equilibrium behavior, non-circular motions, and non-thermal and non-kinetic stresses may cause much larger discrepancies, leading to measured rotation curves that differ from the underlying circular velocity profile by 50% or more. Most inferred rotation curves underestimate the true circular velocity, while some reconstructions transiently over-estimate it in the central few kiloparsecs due to dynamical phenomena. I further demonstrate that the features that contribute to these failures are not always visibly obvious in HI data. If such dwarf galaxies are included in galaxy catalogs, they can give rise to the appearance of ""artificial"" rotation curve diversity that does not reflect the true variation in underlying dark matter profiles.

What Determines the Extent of Baryon-Induced Dark Matter Core Formation?

Claudia Muni
University College London (UCL)

Time: 12:15pm

I will present analysis of the dark matter density profiles from the EDGE2 suite of state-of-the-art radiation-hydrodynamical simulations of dwarf galaxies. The suite covers the halo mass range $10^9 < Mhalo < 10^{10} Msol$ (stellar masses between $10^4 < M* < 10^8 Msol$). The response of dark matter to baryonic feedback must be better understood before we can use dwarf galaxy observations to place constraints on dark matter particle physics. For the last decade, the stellar-to-halo mass ratio (M* / Mhalo) has been widely regarded as the single most important quantity in determining the expected effect of most baryonic feedback models on cold dark matter halos at z=0. However, this talk will show that, in EDGE2, the M*/Mhalo ratio correlates only partially with dark matter core formation. We trace this result to the diversity of formation histories and their interaction with reionisation in faint dwarf galaxies. The talk will show how to predict the expected impact of baryonic feedback on dark matter halos, moving to a more precise formulation than M*/Mhalo. It will conclude with a preliminary discussion of how these new measures compare with constraints on star formation and dark matter distribution in observed dwarf galaxies.

2:00 PM – 3:30 PM

Invited Review: Dwarf galaxies at higher redshift, advances through JWST

Hakim Atek
IAP

Time: 2:00pm

The Nebular Structure of Faint Epoch of Reionization-Era Galaxies

John Chisholm
University of Texas at Austin

Time: 2:30pm

JWST observations have revealed that early faint galaxies had extremely different nebular properties than local galaxies. Here, we report on a high-resolution JWST NIRSpec program targeting 20 star-forming galaxies at redshifts greater than 4, many with stellar masses less than log(M*) = 8. These galaxies are characterized by extreme nebular conditions that cannot be reproduced by massive stars alone. We discuss the implications of high-ionization emission lines, non-stellar radiation sources, dense gas distributions, and fast galactic outflows on the interpretation of the ionization structure and metallicities of faint high-redshift galaxies. We suggest that accretion onto intermediate mass black holes may play a significant role in shaping faint galaxies during the Epoch of Reionization. Deep JWST NIRSpec observations are revealing the nebular structure of faint galaxies in the epoch of reionization and providing new clues for understanding the evolution of low-mass galaxies in the early universe.

Near-pristine DLAs: A window to the early chemical enrichment

Louise Welsh
INAF - Trieste

Time: 2:45pm

The properties of the first (Pop. III) stars remain a mystery. The chemistry of relic environments, enriched only by the supernovae of these first stars, offer an exciting avenue to study this population. Gaseous relics probe the chemistry of low density structures at early epochs ($z > 2$). I will discuss how these gas clouds can be used to understand early chemical evolution and structure formation. Particularly, I will focus on the most metal-poor DLAs found at $z \sim 3$ and the associated high-precision abundance determinations. This will include an updated view, provided by new data, on both the [O/Fe] enhancement seen at the lowest metallicities and the 12C/13C isotope ratio. Combined with a stochastic chemcial enrichment model, this isotope ratio can be used to probe the existence of low-mass (i.e. $1 M_s un$) Pop III stars as well as the enrichment timescale of these near-pristine DLAs. The current results tentatively indicate that these most metal-poor systems may have experienced a hiatus in star formation following the epoch of reionisation. We can further infer the total stellar and gas masses of these relics to investigate evolutionary relationships and search for their local descendants.

The Star Formation History of Leo P from Resolved Stars Imaged with JWST NIRCam

Kristen McQuinn
STScI; Rutgers University

Time: 3:00pm

In the early universe, at the lowest masses where gravity is in a tug-of-war with the energy injected by internal events (stellar feedback) and outside events (reionization, environmental effects), the dominant factors that govern the growth of the smallest structures are still speculative. Archeological studies of low-mass galaxies in the Local Group have striven to answer this question through detailed analyses of the oldest stars. Yet, the Local Group is, by definition, a complicated system and the history of its satellite galaxies are intertwined with their evolution in the shadow of their massive host. The only laboratory to truly measure how galaxies at the limit of structure formation grow is a very low-mass system that is isolated.

In this talk I will present the star formation history of the isolated, extremely low-mass ($M* \sim 10^5$ Msun), metal poor ($< 3\%$ Solar), gas-rich galaxy Leo P. The star formation history is derived from exquisite imaging of resolved stars obtained with JWST NIRCam that reaches a photometric depth below the oldest main sequence turn-off. This is the first such star formation history of a galaxy outside the Local Group and provides quintessential tests of theories of how the smallest structures in our universe survive and grow.

The resolved stellar population of the extremely metal-poor galaxy I Zw 18 with JWST.

Olivia Jones
UK Astronomy Technology Center

Time: 3:15pm

A James Webb Space Telescope (JWST) imaging survey of I Zw 18, an archetypal extremely metal-poor (XMP), star-forming blue compact dwarf (BCD) galaxy, has recently been conducted. With a metallicity of only $\sim$3% solar, I Zw 18 is an excellent analogue for galaxies at high redshift, including during the epoch of peak star formation. The study aims to understand the origins of dust and dust-production mechanisms in the metal-poor environments typical of the early Universe by characterizing its stellar populations. The JWST data provide a comprehensive infrared (IR) view of I Zw 18, utilizing eight NIRCam and MIRI photometry. The analysis reveals a recent starburst spatially concentrated in the northwest SF region, an intermediate-aged population of oxygen- and carbon-rich AGB stars spatially concentrated in the southeast SF region, and an older underlying population of red supergiant (RSG) stars populating the galaxy's halo. Additionally, we detect young stellar objects and pre-main sequence stars which trace the massive star formation taking place in I Zw 18, as well as evidence for a possible recent gravitational interaction with its companion system known as Component C. The results set the standard for future stellar population studies of XMP star-forming systems with JWST.

4:15 PM – 5:45 PM

Testing dark matter models with ultra-diffuse galaxies

Pavel E. Mancera Piña
Leiden Observatory

Time: 4:15pm

Ultra-diffuse galaxies (UDGs) are extreme systems with masses of dwarf galaxies but effective radii as extended as massive spirals. Some UDGs host large gas (HI) reservoirs, which has enabled the study of their gas dynamics over the last few years.

Some of these galaxies appear to challenge the cold dark matter (CDM) model since their rotation curves can only be explained by either the lack of dark matter or the presence of dark matter haloes with extremely low concentrations, unexpected in CDM. These claims, however, are primarily based on low-resolution HI data (limiting the constraining power of the rotation curves) and relatively faint optical imaging (not deep enough to provide independent estimates of the inclination of the galaxy, which normalizes the rotation curve).

I will present the results of a novel project conducting ultra-deep and ultra-sharp observations of a sample of 6 gas-rich UDGs. The observational campaign has obtained unprecedentedly deep optical imaging and high-resolution HI data exploiting the optical 10-m Gran Telescopio Canarias and the MeerKAT radio-interferometer. The new data allow us to constrain the inclination of the galaxies and obtain robust kinematic models. I will show that mass models obtained from rotation curve decomposition imply that the dark haloes of these UDGs have different structural parameters from those seen in CDM simulations. I will also present mass models in the context of self-interacting and fuzzy dark matter. I will highlight the aspects in which these theories better fit the dynamics of UDGs compared to CDM.

Are gas-rich UDGs and field dwarfs distinct?

Khadeejah Motiwala
Queen's University, Canada

Time: 4:30pm

The formation mechanisms of gas-rich Ultra-Diffuse Galaxies (UDGs) in low-density environments are not yet understood. For instance, some UDGs may be "failed" L* galaxies, while others appear to be the spatially extended tail of the low surface-brightness dwarf galaxy population. To constrain competing models, we explore the differences between UDG and dwarf galaxy populations using an extensive HI follow-up survey of optically-selected UDG candidates from the Systematically Measuring Ultra-Diffuse Galaxies (SMUDGes) catalogue. For each detection, the HI line provides distance (and therefore size) information that allows us to classify each SMUDGes candidate as either an actual UDG or a foreground dwarf. We also compare the SMUDGes observations with two state-of-the-art cosmological simulations: Numerical Investigation of a Hundred Astrophysical Objects (NIHAO), which forms UDGs through bursts of star formation at early times, and ROMULUS, which forms UDGs using major mergers at high redshift. Although formation scenarios for UDGs with these simulations are remarkably different, the present-day, global properties of the simulated galaxies are consistent with our observed sample. Furthermore, in both simulations and observations, we find that our UDG and dwarf samples follow similar scaling relations such as gas richness vs. optical size. Taken together, our results suggest that optically-selected, HI-rich field UDGs and dwarfs are not distinct galaxy populations in the present day Universe, either observationally or in simulations.

The Tale of Two Extreme Dwarfs: Elucidating Globular Cluster Formation and Dark Matter Haloes

Jonah Gannon
Swinburne University of Technology

Time: 4:45pm

Interest has been reignited in the study of large, low surface brightness dwarf galaxies with recent evidence suggesting that they may comprise as much as 7% of all galaxies across all environments. This suggests a large diversity in galaxy sizes in the dwarf regime. Beyond this, there is also a large diversity of globular cluster (GC) richness amongst these dwarfs, with some dwarfs known to host approximately half of the GC system of the Milky Way, despite having less than 10% of the stellar mass. In this talk, I will present a detailed differential study of two Virgo dwarf galaxies, VCC1448 and VCC9, using data from the Keck Cosmic Web Imager. These galaxies have similar, large half-light radii and stellar masses, yet very different GC system richness (99 vs. 25 GCs respectively). These galaxies are some of the first in the dwarf stellar mass regime to have deep, high spatial resolution kinematics measured. I will discuss how our measurements impact our understanding of their dark matter halo and its relationship to the formation of GCs. In particular, I will show how dwarf galaxies' kinematics may correlate with their GC-richness. This is expected under the theory that a galaxy's relative GC content is dependent on the natal gas properties of its formation. I will finish by presenting why these large, GC-rich dwarf galaxies are the perfect test bed for constraining dark matter particle properties. The future of this faint science is bright with the advent of upcoming deep wide-field imaging surveys.

Wednesday, 31 July

9:00 AM – 10:30 AM

Invited Review: The role of dwarf galaxies in the formation of Galactic halos

Amina Helmi
Groningen

Time: 9:00am

Confirmation of Stellar Halos Built By Accretion at the Dwarf Galaxy Scale

Catherine Fielder
University of Arizona

Time: 9:30am

I present deep optical observations of the stellar halo of NGC 300, an LMC-mass system, acquired through the Blanco DECam DELVE-DEEP sub-survey. Analysis reveals a significant discovery: a large, low surface brightness stellar stream extending more than 35 kpc from the galaxy's center, northward, in addition to other shell structures and a potential stream wrap. While it is well established that stellar halos and substructures reflective of accretion history exist at the Milky Way-mass scale, it remains unclear whether dwarf galaxies harbor similar structures and whether these halos form through accretion or in situ processes such as star formation-driven radial migration. These findings mark the first evidence supporting accretion as a viable mechanism for forming stellar halos in the LMC-mass range beyond the Local Group, shedding light on the intricate dynamics of dwarf galaxy evolution.

Searching for the building blocks of our Galaxy through the kinematics and metallicity distribution of accreted Halo stars

Alice Mori
University of Florence

Time: 9:45am

The standard cosmological scenario predicts a hierarchical formation for galaxies. Many accreted stars from dwarf galaxies have been found in the Galactic halo, usually identified as clumps in kinematic spaces. If they also feature different chemical properties, they are then associated to independent merger debris. To what extent can we couple kinematic characteristics and metallicities of stars in the Galactic halo to identify the building blocks of the Milky Way (MW)? In particular, different clumps in the energy-angular momentum space (E - Lz) with different metallicity distribution functions (MDF) should be associated to distinct accreted dwarfs? We analysed N-body simulations of a MW accreting a satellite, with different orbital parameters and metallicity gradients. We confirm that accreted stars from a massive merger redistribute in a wide range of E and Lz, thus not being associated to a single clump. Because satellite stars with different metallicities can be deposited in different regions of the E - Lz space (on average the more metal-rich ones end up more gravitationally bound to the MW), this implies that a single massive accretion can manifest with different MDFs. Groups of stars with different E, Lz and metallicities may be interpreted as originating from different accreted dwarf galaxies, but our analysis shows that these interpretations are not physically motivated. In fact, the coupling of kinematic information with MDFs to reconstruct the accretion history of the MW can bias the reconstructed merger tree towards increasing the number of past accretions and decreasing the masses of the progenitor galaxies.

Particle Tagging Simulations of Dwarf Galaxy Stellar Halos

Andrew Cooper
National Tsing Hua University

Time: 10:00am

Dwarf galaxies also accrete stars in mergers, but the phenomena associated with their accreted stars are somewhat different to those associated with the classical accreted stellar halos of more massive galaxies. I will present a suite of several thousand models of dwarf galaxy stellar halos (more precisely, accreted stellar components) obtained from the CoCo N-body simulation, using a particle-tagging technique in combination with the GALFORM semi-analytic model. The models span the mass range from MW satellites up to Milky Way analogues. I will show predictions for trends of stellar halo properties with stellar mass and halo mass across this volume-limited sample, relevant to ongoing and future low surface brightness surveys. The models also highlight several interesting points relevant to comparisons between the stellar halo of the Milky Way and the halos of apparent "Milky Way analogues". The models will be made public.

Signatures of Group Infall in the Milky Way Stellar Halo

Thomas Callingham
Kapteyn Institute, University of Groningen

Time: 10:15am

The Milky Way's accretion history is recorded in its stellar halo, where the mixed remains of consumed dwarf galaxies lie. Amidst a growing number of smaller substructures, it is often remarked that some stellar groups with similar dynamics could be attributed to a group infall of smaller satellites. Adhering to the hierarchical growth of LCDM, larger satellites are expected to have hosted populations of smaller satellites and dark subhalos before accretion—but do these companions follow the same fate? Using the Auriga simulations, we investigate the group infall of satellites onto MW-like galaxies. We study the population statistics of satellite groups at infall and follow their members' subsequent dynamical evolution. We find that some are destroyed along with their original host, but others can survive. Arriving at the present day, we investigate the dynamical distributions of the material accreted to the Galaxy's stellar halo and what dynamical coherence of the original group, if any, can remain. Finally, we return to our own Galaxy and apply our findings, attempting to identify the signatures of group infall in the MW's stellar halo.

11:15 AM – 12:30 PM

Tracing the Milky Way's ancient footsteps: Insights on low mass mergers from chemodynamical investigations of bright and distant metal-poor stars

Akshara Viswanathan
Kapteyn Astronomical Institute, University of Groningen

Time: 11:15am

Our Galactic halo hosts some of the most metal-poor stars. These are relics from the era of the smallest, earliest dwarf galaxies that merged into the Milky Way. I leverage large datasets including Gaia's precision astrometry, the Pristine survey's metallicity estimates for low-metallicity stars and my own spectroscopic follow-up observations to perform chemodynamical analyses of some of the most metal-poor stars in the Galaxy. Additionally, I delve into the outer galactic halo using the absence of well-measured parallax, a vital arena for deciphering the Milky Way's formation, despite its challenges, such as vast distances and the need for accurate metallicity measurements. From the first spectroscopic follow-up of 250 stars with predicted [Fe/H] ¡ -3.0 (extremely metal-poor, EMP), 75% of the stars have indeed [Fe/H] < -2.5, while all of them are very metal-poor ([Fe/H] < -2). This means a large improvement over the existing methods that search for EMP stars. Additionally, I probe further out into the uncharted outer galactic halo, between 30 kpc and 120 kpc. This resulted in the confirmation of three brightest members of the most metal-poor structure known in the universe, the C-19 stellar stream, one of which is 50 degrees away from the detected main body of the stream, allowing us to study the progenitor of this ancient stream. I also find the oldest stars in the Magellanic stellar stream, allowing us to decipher the LMC-SMC dwarf galaxy interaction history. Some of the EMP stars I discovered are on prograde disk-like orbits, which allow us to understand the MW disk formation at high redshift. Together, these works offer a fresh and comprehensive perspective on the low mass galaxies that made up the Milky Way in the distant past from a full chemodynamical analysis of the outer halo metal-poor stars.

The reports of the demise of the Planes of Satellite Galaxies Problem are greatly exaggerated

Marcel S. Pawlowski
Leibniz Institute for Astrophysics, Potsdam (AIP)

Time: 11:30am

Satellite galaxy systems of several nearby hosts show a pronounced flattening and kinematic correlation. The rarity of similar arrangements in cosmological simulations has given rise to the "planes of satellite galaxies problem". It has been posed as a major challenge to the ΛCDM model, but the tension has recently been claimed to be resolved. This success is, among others, attributed to new cosmological simulations, novel proper motion data, the influence of a massive Large Magellanic Cloud on the satellite galaxies, or based on employing alternative metrics to measure plane coherence. I will demonstrate some severe limitations of these explanations, including unrealistically compact simulated satellite systems and the effect of measurement uncertainties on the inferred satellite plane stability. Additionally, much of the debate remains focussed on just the Milky Way. Yet other hosts with established satellite structures (M31, Centaurus A) pose a similar challenge while eluding proposed solutions, and additional systems with strong coherence are being found at larger distances. An example is NGC 4490, which I will show represents a similar degree of tension to the better known cases. Taken together, this demonstrates that the satellite plane problem is far from solved. I will argue that to move forward, we will need to consider the issue statistically in a large sample of satellite systems, using unbiased metrics avoiding issues such as the look-elsewhere-effect. Time permitting, I will present our preliminary results of such efforts.

Prompt cusps and warm dark matter

M. Sten Delos
Carnegie Observatories

Time: 11:45am

Every dark matter halo and subhalo is expected to have a prompt $r^{-1.5}$ density cusp at its center, which is a relic of its condensation out of the smooth mass distribution of the early universe. The sizes of these prompt cusps are linked to the scales of the local maxima in the initial density field from which they formed. If the dark matter is warm, the smoothing scale set by free streaming of the dark matter can result in prompt cusps with masses of order 10^7 solar masses. I will present the basis for prompt cusps in simulations and theory, and I will discuss their observational implications. For warm dark matter, prompt cusps can detectably alter galactic kinematics, making the halos of small galaxies cuspier and more diverse.

The shape of dark matter at the EDGE of galaxy formation

Matthew Orkney
ICCUB (Universitat De Barcelona)

Time: 12:00pm

Results from collisionless cold dark matter-only simulations predict that dark matter haloes are highly prolate (cigar-shaped) in their centres, and increasingly triaxial towards their outskirts. This shape can then be modified by the introduction of baryonic physics, in which infalling gas clumps scatter dark matter particle orbits and lead to rounder halo shapes. It is unclear how efficient such processes are in the faintest dwarf galaxies, where baryon fractions are exceedingly low. Here, I present an investigation into the halo shapes of dwarf galaxies from the EDGE (Engineering Dwarfs at Galaxy formation's Edge) project, which involves cosmological zoom simulations of isolated dwarf galaxies. I find that the haloes with lower gas fractions are able to retain an unmodified prolate halo shape. Meanwhile, haloes with greater gas fractions experience non-negligible transformations in the shape of their dark matter within approximately ten half-light radii. In addition, the halo shape can be highly dependant upon its unique hierarchical assembly from the cosmological surroundings. I investigate the stellar velocity anisotropy profiles in these simulations, finding that they tend towards steeper radial slopes than the corresponding dark matter. I discuss the possible interpretations of these behaviours and the physical mechanisms acting behind them, and the implications they may have on the nature of dark matter, mass-modelling, and future observation.

Insights into Dwarf Galaxy Evolution: LYRA Simulation Perspectives

Joaquin Sureda
Durham University

Time: 12:15pm

In our understanding of galaxy evolution, dwarf galaxies represent a key ingredient, as these act as the building blocks of larger galaxies, and they can help us understand the early stages of the first galaxies in the Universe. In the context of simulations, the dwarf galaxy mass scale represents a challenge itself just to be able to resolve them within a cosmological box. State-of-the-art zoom-in simulations solve this issue but still rely on the chosen sub-grid physics model to account for the processes involved. For instance, supernova feedback is a fundamental process regulating the evolution of dwarf galaxies and, therefore, sensitive to the chosen model. LYRA is a new set of zoom-in cosmological hydrodynamical simulations designed to resolve with great detail the formation and evolution of dwarf galaxies. Having a baryonic mass of 4 Msun resolves individual stars above that mass, as well as supernovae shocks self-consistently, removing the need for sub-grid physics implementation of this process, and including new recipes for the chemical enrichment from Pop III stars. These simulations offer a promising avenue for advancing our understanding of the formation and assembly of dwarf galaxies, their stellar populations, and the influence of baryon physics in their assembly history. I will present some results from these simulations, particularly about the build-up of the stellar mass, the causes of the differences in their growth histories, and its impact on their host dark matter halos.

Small Galaxies, Cosmic Questions — II

Thursday, 1 August

9:00 AM – 10:30 AM

Invited Review: Star formation histories, metallicities and stellar populations in dwarf galaxies

Alex Ji
Chicago

Time: 9:00am

Mapping Chemical Evolution in UFD Galaxies with GHOULS (the GHost Ultra-faint dwarf galaxies Legacy Survey)

Kim Venn
University of Victoria

Time: 9:30am

In order to showcase two of the powerful capabilities of the Gemini-South GHOST spectrograph (namely, high-efficiency and high spectral resolution R 55,000), we have initiated the GHOULS survey to map the chemical abundances of all bright RGB stars (V < 18.5) in the southern ultra faint dwarf galaxies (DEC $< +30$, R$_{e}ll$ (half-light) < 3). The UFD galaxies are believed to be relics from the early Universe, and new Gaia-based target selection techniques have revealed additional stellar members that have no previous spectroscopic analyses. GHOST will be used to derive stellar parameters and elemental abundances to probe the chemical, dynamical, and orbital properties of these ancient systems. Early results from GHOST commissioning (June & Nov 2022) and from first results from the GHOULS program (starting May 2024) will be presented here. In addition, our new GHOST spectra will be shared publicly and integrated with previous results on the southern UFDs to increase the legacy value of the GHOULS program.

The First Alpha Abundances in Isolated Dwarf Galaxies Using JWST Spectroscopy

Katherine Sharpe
University of California, Berkeley

Time: 9:45am

I will present initial results from a JWST Cycle 2 program that is obtaining spectroscopy of ~ 200 resolved stars in three isolated Local Group dwarf galaxies: Leo A, Tucana, and IC 1613. These targets were selected as representative young, ancient, and intermediate age systems, respectively, which should have correspondingly diverse chemical enrichment histories. The majority of dwarf galaxy metallicities and abundances today come from the easily accessible Milky Way satellites. However, JWST's exquisite sensitivity and superior angular resolution makes it possible to measure large sets of [alpha/Fe] in galaxies at the edge of the Local Group and beyond, enabling studies of chemical enrichment in the absence of the environmental processes that affect satellite galaxies.

Here, I will summarize our program and highlight some of the unique technical challenges posed by JWST's spectroscopic set-up. I will present initial results (e.g., some of the first stellar spectra acquired by JWST at large distances, stellar chemistry in isolated dwarf galaxies) and preview prospects for the use of JWST in acquiring stellar abundance measurements outside of the Local Group.

Signatures of Extragalactic First Stars in the Large Magellanic Cloud

Anirudh Chiti
University of Chicago

Time: 10:00am

The Large Magellanic Cloud (LMC) is the most massive Milky Way satellite dwarf galaxy and is thought to have only recently (~ 2 Gyr ago) fallen into the Milky Way. This recent infall means that the LMC's lowest metallicity stars ([Fe/H]< -2.5) are unique windows into early star formation and nucleosynthesis by the first stars in a formerly distant, extragalactic region of the high-redshift universe. We present the detection and detailed chemical abundances of 10 stars between $-4.2 <$ [Fe/H] < -2.5 in the LMC, the lowest metallicity of which is 10x more metal-poor than any prior LMC star with detailed abundances. This star, with [Fe/H] $=$ -4.15, is the most metal-poor star known in any external galaxy, and is at sufficiently low metallicity to plausibly reflect enrichment from an individual supernova from an extragalactic first star. Intriguingly, this star is not a carbon-enhanced metal-poor star, in contrast to the lowest metallicity Milky Way halo stars where carbon-enhancement may be viewed as a characteristic signature. This, in addition to a few other trends, suggests that the proto-LMC may have experienced some diverging early enrichment or environmental effects relative to the early Milky Way. Broadly, we demonstrate that the very lowest metallicity stars exist in the LMC and are now detectable. Ongoing work to expand and comprehensively investigate this population will provide a novel avenue to test the universality of early enrichment and the properties of the first stars in diverse cosmic environments.

Detailed Views Into the Baryon Cycle of Dwarf Galaxies via HST Narrowband Imaging

Sal Fu
UC Berkeley

Time: 10:15am

I present hundreds of new stellar metallicities in faint, Local Group dwarf galaxies measured through a novel use of HST narrowband Ca H&K imaging. Our imaging includes 463 stars in 13 ultra-faint dwarf galaxies (UFDs) around the Milky Way, which effectively doubles the number of stellar metallicities in all known UFDs. It also includes 374 stellar metallicities in the quenched field dwarf galaxy Tucana, a factor of ~ 7 increase over literature spectroscopy. I will present highlights from the wide range of science cases enabled by our data, which include: 1) chemical evolution modeling to put novel constraints on the baryon cycle in UFDs, 2) new metallicity benchmarks for cosmological simulations of the faintest galaxies, 3) high-fidelity metallicity gradients that constrain stellar feedback and DM core formation models in dwarf galaxies. I conclude with a discussion on the immense scientific potential of using Ca H&K for stellar metallicities outside the LG.

Small Galaxies, Cosmic Questions — II

11:15 AM – 12:30 PM

Euclid's view of the star cluster systems in NGC 6822 and IC 10

Jess Howell
University of Edinburgh

Time: 11:15am

Star clusters probe galaxy evolution, encoding a record of star formation activity across time. Globular Clusters (GCs) originated during significant star formation episodes in the early Universe or subsequent major merger events. Consequently, GCs provide insights into the halos and formation histories of galaxies. Meanwhile, young clusters shed light on ongoing star formation rates and characteristics, such as the fraction of stars formed in clusters.
Euclid's arrival has provided an opportunity to enhance our understanding of previously studied cluster systems. The Euclid VIS instrument enables us to perform wide-field cluster searches to near-Hubble resolution, and the deep Near-Infrared imaging provides important constraints on the stellar ages and masses of the clusters. The Early Release Observations program imaged two dwarf irregular (dIrr) galaxies, which make ideal laboratories not only because they are common at high redshift and often isolated in the Local Group. IC 10, a starburst galaxy, provides a rich environment for studying young clusters, while NGC 6822 hosts an impressive GC system, including an example of an extended star cluster.
Euclid has increased the number of known clusters by $\sim 10\%$ in IC 10 and $\sim 20\%$ in NGC 6822. We perform aperture photometry to determine integrated magnitudes and empirical half-light radii of the new and previously identified clusters and SED-fitting to determine their ages and masses. We investigate their luminosity, mass and age distributions, producing a final catalogue with a consistent inventory of clusters spanning the entire halo of IC 10 and a significant portion of NGC 6822.

Do zeros count? Understanding the galaxy — globular cluster connection for the smallest galaxies

Samantha Berek
University of Toronto

Time: 11:30am

A remarkably tight scaling relation exists between galaxy masses and the number or combined mass of their globular cluster (GC) populations over many dex, alluding to a fundamental connection between the formation and evolution of galaxies and that of their most massive star clusters. This relation is least constrained for dwarf galaxies, and many of the lowest-mass galaxies lack GCs altogether. It is not well understood whether this is due to a fundamental difference in the formation and evolution of low-mass galaxies, or if they are simply the natural low-mass end of the normal scaling relation, too small to form very massive star clusters. In this talk, I will investigate this open question through the use of hurdle and zero-inflated count models to describe the GC populations of low-mass galaxies. Using these models, I find that there is significant intrinsic scatter, beyond just measurement uncertainties, present in galaxy-GC scaling relations, and that GC populations of nearby dwarf galaxies follow a more complex negative binomial distribution rather than a simple Poisson distribution. Using Bayesian predictive model comparison techniques, I also show for the first time that no additional model parameters are necessary to describe the population of low-mass galaxies that lack GCs. Taken together, these results suggest that a single formation and evolutionary process acts over all galaxy masses and that there does not appear to be anything unique about the lack of GCs in many low-mass galaxies. These results provide important constraints for simulations of GC formation and evolution in low-mass galaxies and inform conclusions from preliminary higher redshift GC data from telescopes like JWST, helping guide us toward a better understanding of GC formation and evolution across cosmic time.

Investigating the GC System-Halo Mass Relation In The Dwarf Regime

Veronika Dornan
McMaster University

Time: 11:45am

Globular star clusters are some of the oldest structures in galaxies, and can be excellent indicators of a galaxy's merger history and evolution. The strong, linear relationship between a galaxy's globular cluster system (GCS) mass and its dark matter halo mass has been known for several decades, and has been found to be consistent for nearly all galaxies which have been investigated. However, the data available for dwarf galaxies is significantly lacking compared to their higher-mass counterparts, and as such, the connection between their GCSs and dark matter halos is much less well-constrained in this low-mass regime. In this work we are adding standardized GCS masses from 19 dwarfs, determined from HST data, to better constrain the GCS - halo mass relation. In this talk I will discuss the relation for dwarfs, how it compares to the behaviour of the relation at other mass ranges, and how determining the intrinsic scatter in this relation for dwarfs can shed light into the origins of the GCS - halo connection.

The stellar content of NGC 6822 with JWST

Conor Nally
University of Edinburgh

Time: 12:00pm

We present the NGC 6822 GTO program, first results and combined NIRCam and MIRI CMDs. JWST MIRI and NIRCam imaging observations of the isolated metal-poor galaxy NGC 6822 were obtained in Cycle 1 (GTO Program ID 1234) producing an inventory of star formation and dust life cycles at high resolution. NGC 6822 is metal-poor ([Fe/H]=-1.2), making it a compelling target for studying stellar evolution as it is thought to have conditions similar to galaxies at the peak star formation epoch in the Universe. For the photometry, we use StarbugII which we developed for complex and crowded fields taken with JWST. With the high sensitivity instruments on JWST, we have deep spatially-resolved photometry of individual sources which are bright in the infrared, reaching 6 magnitudes deeper than any previous IR study of the galaxy. We detect to a depth just above the main sequence turn-off and see clear evidence for multiple aged populations within the post-main sequence stars and young stellar objects.
Of particular interest are the high dust producers - unlike our galaxy where low- and intermediate-mass stars provide substantial amounts of dust via mass loss during the Asymptotic Giant Branch (AGB) phase, high redshift galaxies simply lack the time to have ¡5 solar mass stars evolve onto the AGB and produce dust. As such, studying intermediate- to high-mass evolved stars in an isolated galaxy whose physical properties resemble those at z=2 may be key to understanding dust formation within galaxies as the universe evolves.

Chemodynamical Analyses of UFDs: Star Formation, Galactic Outflows, and Dark Matter Profiles

Nathan Sandford
University of Toronto

Time: 12:15pm

Ultra-faint dwarfs (UFDs) are the oldest, lowest mass, and most metal-poor galaxies in the Local Group, and their stellar populations encode a wide range of astrophysical insight on everything from the composition of dark matter to the physics of star formation, stellar evolution, and chemical enrichment in the early universe. While the intrinsic faintness of UFDs has historically precluded detailed study of their stellar populations, recent large observational investments, including wide-field stellar spectroscopic campaigns conducted by the Southern Stellar Stream Spectroscopic Survey (S5) and deep HST narrowband Ca H&K imaging have amassed ever-growing datasets of stellar chemistry and kinematics—enabling new statistical investigations of UFD formation and evolution. Here, I present results from chemodynamical analyses of these recent observations in two of the Milky Way's brightest UFDs, Eridanus II and Boötes I. Specifically, I demonstrate how a one-zone chemical evolution model can constrain key aspects of low-mass galaxy evolution from the UFD stellar metallicity distribution functions, including short, early, and inefficient star formation, and large galactic outflows. Using stellar kinematics measured out to large galactic radii, I also provide new constraints on the dark matter mass profile of Boötes I, its cuspiness, and the existence of multiple kinematic stellar populations. I conclude by discussing the prospects of future UFD chemodynamic studies as powerful new observing facilities, including JWST and 30-m class telescopes, allow us to characterize the stellar populations of fainter and more distant galaxies.

2:00 PM – 3:30 PM

Invited Review: The interplay between cosmic reionisation and the formation of dwarf galaxies

John Wise
Georgia Institute of Technology

Time: 2:00pm

DarkLight: The Impact of Reionization on the Stellar-Mass–Halo-Mass Relation for Dwarf Galaxies

Stacy Kim
Carnegie Observatories

Time: 2:30pm

One of the largest uncertainties in studies of dwarf galaxies is the connection between them and their dark matter halos, what is known as the stellar-mass–halo-mass (SMHM) relation. Studies differ by two orders of magnitude at halo masses $< 10^{10}$ Msun, and there is no consensus on the amount of scatter it exhibits. To address these uncertainties, I used high-resolution simulations of dwarfs from the Engineering Dwarfs at Galaxy formation's Edge (EDGE) Project to build a fast, light galaxy-halo model, DarkLight, that can accurately predict the stellar masses of dwarfs, uniquely including their dependence on accretion history. I show that the interplay between reionization and halo growth histories is key to shaping the slope, scatter, and shape of the SMHM relation. The scatter is small for low-mass halos at reionization, but grows as reionization quenching halts stellar mass growth, while the dark matter halos can freely grow. This decoupling, along with the large range in halo growth following reionization, accounts for the majority of the scatter in the SMHM. It also reproduces the increasing scatter observed in simulations at low halo masses. While we do not find a significant break in the slope of the SMHM, one can be introduced with earlier reionization. The timing of reionization controls the slope of the SMHM below the break, as well as the size of the scatter. Satellite halos can exhibit larger SMHM scatter due to environmental quenching.

Dancing in the Dark: Exploring the Impact of Binary Stars on Understanding the Properties of the Faintest Galaxies

Daniel Vaz
Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto

Time: 2:45pm

Ultra-Faint Dwarfs (UFDs) emerge as relics of the epoch of reionization, representing the oldest, least massive, least chemically evolved, and most dark matter dominated systems identified to date.

Precise measurement of the velocity dispersion of their stellar components is necessary for accurately determining their dynamical masses and to model their density profiles. A challenge to this lies in determining the contamination and impact of binary stars on these measurements. Although this concern has long been recognized, major studies have not been conducted, primarily due to the difficulty of observing these faint systems, where stars are lacking.

We propose to present the first measurements of the binary fraction for multiple faint and ultra-faint dwarf galaxies in the MUSE-Faint survey, utilising multi-epoch spectroscopic observations with the Multi-Unit Spectroscopic Explorer (MUSE) integral field spectrograph. We explore systems with multiple populations to show variations in binary fraction between young and old stars, such as observed in Leo T. Furthermore, we will discuss how binaries impact our velocity dispersion measurements and density profiles of these galaxies, exploring these results in the context of each galaxy's individual characteristics, including metallicity, magnitudes, stellar masses, and dark matter content.

In this contribution, we propose to discuss the role of binary stars in shaping our measurements and interpretations of the unique properties of UFDs that enable us to study the origins of the first galaxies and the behaviour of dark matter on small scales.

Small Galaxies, Cosmic Questions — II

Constraining Dark Matter through 3D dispersion profiles of Classical Dwarf Galaxies

Eduardo Vitral
Space Telescope Science Institute

Time: 3:00pm

Astrophysical evidence strongly supports that dark matter constitutes the majority of the Universe's matter. Its elusive nature remains a critical puzzle from cosmology to particle physics. Classical dwarf galaxies orbiting the Milky Way are pivotal for further progress. They are dark-matter dominated, and the kinematics of its many visible stars trace the gravitational potential, thus providing clues to the dark matter distribution. Traditional analyses of line-of-sight (LOS) velocities have led to the "cusp-core problem": a discrepancy between the steep density profiles predicted by simulations versus the flatter profiles observed. Resolving this requires analyzing transverse velocities or proper motions, necessitating long time-baseline observations (¿10 years) with high resolution observatories like the Hubble Space Telescope (HST). We present unprecedented radially-resolved 3D velocity dispersion profiles for the Draco dwarf spheroidal, that we obtained by combining four epochs of imaging over 18 years with LOS velocities from the literature. Using oblate axisymmetric Jeans equations, we infer radial velocity anisotropy along the symmetry axis, but tangential anisotropy on average. The analysis reveals that the galaxy's mass profile is consistent with ΛCDM predictions, suggesting that Draco's dark halo has remained largely unaffected by baryonic processes due to its low stellar mass and ancient star formation history. We discuss our ongoing efforts to now apply similar methods to other galaxies, specifically Ursa Minor and Sculptor, to elucidate the variation in dark matter distributions amongst galaxies. Moreover, we discuss our ongoing efforts to expand the HST proper motion analyses using JWST observations of additional fields and epochs.

Environmental differences in Dwarf Galaxy Growth: A Large Volume, High Resolution Exploration in GALFORM

Mac McMullan
Durham University

Time: 3:15pm

Due to the small size and relatively ancient nature of their stars, dwarf galaxies are excellent probes of early galaxy formation, and feedback effects from star formation. We have used the high-resolution DM-only simulation COCO combined with the GALFORM semi-analytic model to explore the dependance of stellar mass assemblies of dwarf galaxies (from $10^3 - 10^9$) on their environments. We explore different definitions of environment: morphological classifications of voids and nodes of the cosmic web, as well as a definition of environment based on local mass density. Our results show that galaxies in the densest environments assemble their mass first, and galaxies in the least dense environments have delayed assembly, and these trends are much stronger in satellite galaxies than in centrals. This is due to the significant difference in infall times of satellites between different areas of the cosmic web. Additionally, the smallest galaxies have their mass assembly halted early due to reionisation across all environments. Our research demonstrates the importance of galaxy environment in the assembly of stellar mass, while also situating it in the context of the more important factors: final day mass and the type of galaxy (satellite or central). This is the first exploration of this question extended to the ultra faint regime of dwarf galaxies.

4:15 PM – 5:45 PM

Using Cosmological Simulations to Explore the Stellar Age Gradients of Dwarf Galaxies

Claire Riggs
Rutgers, the State University of New Jersey

Time: 4:15pm

Dwarf galaxies across a large range of masses and environments tend to have their younger stars near their centers and their oldest stars near the outskirts, which is the exact opposite of the better-understood ""inside-out"" stellar age gradients observed in large, Milky Way-sized galaxies. While dwarf galaxies' stellar age gradients suggest an "outside-in" formation mechanism, we show that dwarf galaxies actually form inside-out, but a variety of mechanisms including dark matter core creation pushes the stars out over time, creating the outside-in stellar gradient observed in dwarf galaxies. Our sample of 73 simulated galaxies spans a stellar mass range of $10^6 - 10^9$ $M_\odot$ and contains halos in both satellite and field environments. We look at trends of star formation history, dark matter core creation, and merger history in order to determine how these processes interact with properties like mass and environment to create the stellar age gradients we observe in dwarfs.

Probing the star formation and metallicity in dwarf galaxies with JCSS

Renbin Yan
The Chinese University of Hong Kong

Time: 4:30pm

Local Gas-rich dwarf galaxies provide ideal samples to study star formation and feedback in very metal-poor environment, which are analogs of star formation in the early universe. We are building a large field, high spectral resolution integral field spectroscopy system that can study local group star-forming dwarf galaxies at 20pc or 100pc scales while covering them completely, including LMC, SMC, WLM, IC1613, etc.. It will provide R$\sim 15,000$ spectroscopy of the warm ionized gas in these galaxies, complementing HI studies for us to understand the star formation, feedback, metallicity distribution in these dwarf galaxies. The survey is called Jockey Club Spectroscopy Survey (JCSS), which is a prototype to the Affordable Multiple Aperture Spectroscopy Explorer (AMASE-P). The integral field spectrographs are underdevelopment and will be deployed to sites on both hemispheres. The first set of spectrographs, connected to a small telescope, is expected to have first light in 2025.

Morphology of Hα emission in bright dwarfs using the first Merian Survey data release

Abby Mintz
Princeton University

Time: 4:30pm

Dwarf galaxies are a particularly exciting demographic for testing our current theories of star formation; they are gas-rich, but inefficient at forming stars, bursty, and significantly more impacted by feedback and environment than their more massive counterparts. But due to observational limitations, the recent revolution in the study of spatially resolved star formation in Milky Way analog galaxies has not been extended to dwarfs. I will discuss early science results from the first data release of the optical medium-band Merian Survey – in particular, our use of the medium-band imaging to measure and map Hα emission and star formation in bright dwarfs at $0.06 < z < 0.1$. I will present the results of a morphological analysis of the Hα maps and the stellar continuum images, discussing trends with physical parameters. We find that the lowest mass galaxies with the highest SSFR have Hα emission that is consistently centralized and compact, indicating that high SSFRs in low mass galaxies likely result from dynamical instabilities triggered by accretion and interactions. Our results provide insight into the processes that lead to star bursts in low mass galaxies and demonstrate the power of the Merian Survey's new photometric catalog and imaging.

Friday, 2 August

9:00 AM – 10:30 AM

Invited Review: Upcoming surveys

Risa Wechsler
Stanford University

Time: 9:00am

The Stellar-to-Halo Mass Relation of Dwarf galaxies using galaxy clustering and galaxy-galaxy lensing in the DESI Y1 data

Zhiwei Shao
Shanghai Jiao Tong University

Time: 9:30am

Dwarf galaxies ($M* < 10^9$ Msol) are the key window to understanding stellar feedback, yet the stellar-to-halo mass relation (SHMR) of dwarfs is still poorly understood. Abundance matching alone would suffer strong degeneracy between the slope and scatter of SHMR at the low-mass end. We constrain the SHMR down to a few times 10^7 Msol by combining the clustering and weak lensing of galaxies from Bright Galaxy Survey (BGS) in the Dark Energy Spectroscopic Instrument (DESI) Year-1 release. Based on an improved Halo Occupation Distribution (HOD) formalism in previous work, we further use stellar mass function and cross-correlation between galaxies and groups to constrain the satellite contribution to the clustering and weak lensing of galaxies. These techniques together enable us to pin down the shape of the SHMR by breaking the degeneracy between its slope and scatter in the dwarf regime.

ELVES-Dwarf survey: Probing the satellite system of isolated low-mass galaxies in the Local Volume

Jiaxuan Li
Princeton University

Time: 9:45am

The satellite populations of Milky Way-mass systems have been extensively studied, significantly advancing our understanding of galaxy formation and dark matter physics. However, the satellites of lower-mass dwarf galaxies remain largely unexplored, despite the fact that the LCDM model provides testable predictions for the number and properties of these satellites. I will present the first results of the ELVES-Dwarf survey, which aims to statistically characterize the satellite population of isolated dwarf galaxies in the Local Volume (4¡D¡10 Mpc). We detect satellite candidates in integrated light using existing imaging survey data, and associate satellites to the hosts by measuring their surface brightness fluctuation (SBF) distances using deeper HSC and Magellan imaging. Compared to the resolved-star searches and distance measurements using TRGB, the SBF distance enables the efficient discovery of satellites in a much bigger volume. I will show our preliminary results from surveying 6 isolated dwarf hosts, which already doubles the sample size of surveyed dwarf hosts in the Local Volume. I will also present a comparison of the number of satellites with the prediction from semi-analytical models.

A new sample of gaseous dwarf satellites around nearby spirals in the south

Jingyao Zhu
Columbia University

Time: 10:00am

Dwarf galaxies that are satellites are extensively shaped by interactions with their hosts. In the Local Group, environmental effects like ram pressure and tidal stripping have effectively quenched most dwarf satellites, which is contrasted by a large diversity of satellite populations and quenched fractions in the extragalactic spiral analogs. We present a new sample of gaseous dwarf satellites around spiral galaxies beyond the Local Group with deep 21-cm HI data from two SKA-precursor surveys: MeerKAT MHONGOOSE and ASKAP WALLABY. We compare the properties of these gaseous dwarfs with existing studies with the ALFALFA survey and in the Local Group: the abundance of gaseous satellites, the kinematic distribution, and the degree of gas depletion. Where spatially resolved HI maps are available, we discuss the satellite morphology in contrast with isolated HI dwarf samples and the potential signs of gas stripping. Synergy with existing or future optical data from, e.g., Vera Rubin, will be key for quantifying the quenched fractions for these systems. Finally, we discuss our sample in the broader context of existing studies of satellites around spiral analogs.

Modeling the Chemical Abundances of Dwarf Galaxies in GRUMPY

Viraj Manwadkar
1) Department of Physics, Stanford University, 2) Kavli Institute of Particle Astrophysics and Cosmology (KIPAC), Stanford University

Time: 10:15am

In this upcoming decade, we will have an unprecedented wealth of observational data on dwarf galaxy properties. GRUMPY provides a framework under which these observations can be contextualized within galaxy formation physics. GRUMPY is a simple regulator-type model designed specifically for modeling dwarf galaxy formation and evolution. Despite its simplicity, when coupled with realistic mass accretion histories of haloes from simulations and reasonable choices for model parameter values, the framework can reproduce a remarkably broad range of observed properties of dwarf galaxies over seven orders of magnitude in stellar mass. GRUMPY, in combination with high-resolution Caterpillar zoom-in simulations, produces realistic Milky Way satellite galaxy populations that are consistent with the observed luminosity, radial and size distributions of MW satellites in the DES, PS1 and SDSS surveys. Furthermore, using the Simple Stellar Population modeling capabilities of 'Chempy', we extend the base GRUMPY model to allow for flexible chemical abundance modeling. This model gives predictions for the stellar mass-metallicity relationship, stellar metallicity distribution functions (MDFs), individual element abundance distributions and the effect of stochastic IMF and nucleosynthetic yields on these distributions. We show that this model predicts realistic looking MDFs for both classical, luminous dwarf galaxies and ultra-faint dwarf galaxies. We demonstrate how the distribution of [X/Fe] - [Fe/H] is sensitive to SNe Ia delay time distribution, nucleosynthetic yields etc. and how we can constrain them with our model.

Small Galaxies, Cosmic Questions — II

11:15 AM – 12:45 PM

Dwarf galaxies in Local Group analogues

Sarah Sweet
The University of Queensland

Time: 11:15am

Is our Local Group of galaxies unique? The LG serves naturally as a unique laboratory for studying galaxy formation and evolution over cosmic times, offering a first-hand view of ways in which myriad types of dwarf galaxies gravitationally come together and form larger galaxies like our Milky Way. However, in more distant groups, dwarf galaxies appear smaller and fainter, so are difficult to detect and select for comparable analyses. Determining the typicality of the Local Group's cosmic nature in terms of the absolute number of dwarf galaxies, their mass function, types and spatial distribution thus remains a significant challenge in astrophysics. We have recently commenced a study of dwarf galaxies in nearby Local Group analogues: a complete census down to low masses, a detailed demographic profile of the dwarfs, and the family trees of their evolutionary history. In this talk I will present the first results from our integral field spectroscopic survey of dwarfs in three Local Group analogues and our work towards equitable comparisons with dwarf galaxies around the Milky Way and Andromeda.

The Dragonfly Ultrawide Survey (DFUWS) - Design and Early Science

William Bowman
Yale University

Time: 11:30am

The low surface brightness universe encodes key information about galaxy formation and evolution, yet it is a challenging regime to study. The Dragonfly Telephoto Array is uniquely optimized for investigating low surface brightness phenomena, with its large (6 sq. deg.) field of view and relatively unobstructed light optical path, leading to significantly less scattered light compared to traditional telescope designs. We have recently completed the Dragonfly Ultrawide Survey (DFUWS), which covers roughly a quarter of the sky ($\sim 10,000$ sq. deg.) in g- and r-band imaging and overlaps with the entire SDSS footprint. The 30-minute integration times yield surface brightness limits below 29 mag/arcsec2 on 1x1' scales. The large survey footprint, combined with Dragonfly's unprecedented sensitivity to low surface brightness features and exquisite control over background systematics, enables us to explore key questions about the low surface brightness universe. The primary science of the Ultrawide survey is to detect the largest, nearest (d ¡ 20 Mpc) Ultra Diffuse Galaxies (UDGs). I will present an overview of the Dragonfly Ultrawide Survey and highlight the initial science results, including the search for as-yet undetected UDGs. The public release of the Dragonfly Ultrawide Survey is scheduled for the end of 2024. This rich data set can be mined to explore a variety of questions about dwarf galaxy formation and evolution.

The dwarf galaxy population as revealed by neutral hydrogen surveys

Betsey Adams
ASTRON

Time: 11:45am

Neutral hydrogen (HI) surveys offer an excellent way to identify gas-rich field 5.Dwarf galaxies beyond the Local Group. The ALFALFA HI survey set the stage for this, with the SHIELD sample of dwarf galaxies with HI masses $< 2x10^7$ Msun. Surveys with SKA pathfinders, such as MIGHTEE with MeerKAT and FASHI with FAST, are now providing even larger dwarf galaxy samples out to further distances. In this talk, I will discuss the low surface brightness dwarf galaxy population from the MIGHTEE Early Science data in the XMM-LSS field, showing that the HI data identifies low surface brightness galaxies missed in an optical selection and emphasizing how HI and optical surveys are complementary for identifying the full dwarf galaxy population. I will also highlight the identification of an optical counterpart to the FAST "dark" galaxy J0139+4328, revealing it to be a gas-rich dwarf galaxy with a stellar mass of 4×10^6 Msun.

Connecting ultra-diffuse galaxies to standard dwarfs with the Apertif HI surveys

Barbara Šiljeg
ASTRON and Kapteyn Institute

Time: 12:00pm

Recent studies on ultra-diffuse galaxies (UDGs), a subclass of dwarf galaxies with low surface brightness and large effective radii, have highlighted challenges for theoretical models in reproducing their observed properties. UDGs also seem to deviate from the baryonic Tully-Fisher relation (BTFR), raising questions about their origin and connection to the broader dwarf galaxy population.Apertif's non-targeted neutral hydrogen (HI) survey, offers powerful means to discover galaxies independently of their stellar content, obtaining a full diversity of gas-dominated dwarf galaxies. With such sample, we can explore connections between UDGs and standard dwarfs.

In this study, we select a sample of 24 dwarf galaxies, including 9 UDGs. When positioned in the BTFR, standard dwarfs follow the same BTFR as high-mass galaxies, whereas UDGs are slightly offset towards lower rotational velocities. This offset suggests a natural bridge between the extreme UDG population identified in previous studies and standard dwarfs, indicating that our sample occupies a previously unexplored range of low-mass galaxies.

Another significant finding concerns the presence of galaxy pairs. Dwarf galaxy interactions may have a strong impact in the evolution of dwarf galaxies, e.g. by igniting or temporarily suppressing star formation. However, the frequency of low-mass pairs is largely unconstrained. Having 3 pairs, our sample revealed 5 times higher fraction of dwarf pairs than predictions based on optical spectroscopic studies. This finding highlights the effectiveness of Apertif's non-targeted HI surveys in constraining the observed number of dwarf galaxy multiples, which we further explore by expanding the sample to all available Apertif detections.

Invited Review: Wrapping up: pressing questions and future prospects

Carlos Frenk
Durham

Time: 12:15pm