Stellar Halos Across the Cosmos

July 2-6, MPIA Heidelberg

Talk and Poster Abstracts

Lauren Anderson

Flatiron Institute

4D Cold Stream Detection

Gaia will measure the 6D phase space of 100s of millions of stars, but will measure positions on the sky and proper motions for billions of stars, and much most precisely. This 4D space is therefore an opportune parameter space to search for structures in the data. I will present work on looking for cold streams in the Milky Way halo in this 4D space, and using color and distance information for validation.

Felipe Ardila

UC Santa Cruz

A Consistent Comparison Between High Quality HSC data and Hydro Simulations

Hydrodynamic simulations of galaxies are commonly tuned to match the stellar mass functions (SMFs) of observed galaxies. However, there may be important differences in the way masses are measured in simulations and in data. We present a detailed comparison of the light profiles of massive galaxies in several hydrodynamic simulations (Illustris, TNG, BAHAMAS, MassiveBlack-II, and Horizon-AGN) with new high quality data from the Hyper Suprime-Cam (HSC) Survey. We focus on low redshift high mass galaxies with log(M*)>11.6 for which HSC can trace the light profiles of individual galaxies out to 100 kpc. We also examine the effects of projection angles, and the masking of satellites on the surface brightness profiles and mass measurements of these galaxies. Finally, we also compare the weak lensing signal around this massive galaxy sample with predictions from hydro simulations.

EDUARDO BALBINOT

UNIVERSITY OF SURREY

The Milky Way halo as seen by the Dark Energy Survey

I present a search for Galactic stellar streams in the Dark Energy Survey (DES), using three years of optical data taken across 5000 sq. degrees of the southern sky. The wide-field, uniform DES photometry provides unprecedented sensitivity to the stellar density field in the southern hemisphere, allowing for the detection of faint stellar populations. This work follows the “Field of Streams” procedure developed in the Sloan Digital Sky Survey (Belokurov et al., 2006) to identify stellar density features such as dwarf galaxies, globular clusters, and the stellar streams resulting from the tidal disruption of these objects. Improved analysis techniques applied to the DES data enable the discovery of more than a dozen new stellar streams, and provide added insight into the origin and stellar populations of previously identified objects. I will also discuss the ongoing efforts in modelling and spectroscopic follow-up of some of the most interesting streams and how these can offer opportunities to probe the growth of the Galaxy.

SARAH A. BIRD

SHANGHAI ASTRONOMICAL OBSERVATORY

Galactic Mass and Anisotropy Profile with Halo K-Giant Stars from LAMOST and Gaia

A major uncertainty in the determination of the mass profile of the Milky Way using stellar kinematics is the poorly determined anisotropy parameter, beta = 1 - ((sigma_T)**2 / (2 * (sigma_R)**2), where sigma_R is the Galactocentric radial velocity dispersion, and sigma_T is the tangential velocity dispersion. We use a sample of nearly 10,000 Galactic halo K giants from the LAMOST stellar spectroscopic survey, combined with parallaxes and proper motions from Gaia DR2, to measure beta(R) over a wide range of Galactocentric distances R from 5 to 80 kpc. We investigate the extent to which a much improved knowledge of beta influences the determination of the Galactic mass profile M(R) as a function of R.

Alina Boecker

MPIA Heidelberg

Recovering the Accretion History of Galaxies from Integrated Spectra

The relative contribution of in-situ star formation and ex-situ stars, originating from accretion of satellites, to a galaxy's total stellar mass budget is believed to lead to the large morphological and kinematic diversity observed in galaxies. Quantitative measures of ex-situ fractions are so far only conducted from surface brightness profiles of deep photometric observations of galactic halos. Therefore, we introduce a new method to derive a galaxy's accretion history and ex-situ mass fraction from the stellar population analysis of its integrated spectrum. We use a full spectral fitting routine as well as a calibrated and optimized regularization procedure in order to yield a galaxy's mass distribution in age and metallicity space, as opposed to typical average quantities. By exploiting the fact that ex-situ stars from low-mass accreted satellites will be more metal poor at fixed age, we use a flexible grid of empirically motivated, mass-dependent age-metallicity tracks to associate stellar population components in the spectrum to accreted galaxies of different masses. We validate this approach with mock observations of galaxies from the hydrodynamical cosmological EAGLE simulation. With this technique we can not only measure the total ex-situ mass fraction of a galaxy, but also the cumulative subhalo mass function of accreted satellite galaxies from a single integrated spectrum. Application of this method to deep spectroscopic observations of galaxy halos is currently being done to MUSE observations of the Fornax3D collaboration, which trace stellar halos of galaxies in the Fornax Cluster out to 25 mag/arcsec^2 in B-band. This will provide an excellent environment to verify our new method on observations, while disentangling the in-situ and ex-situ contribution of many different galaxies and gaining new insights into their different evolutionary pathways.

Ana Bonaca

Harvard University

What are the tidal streams constraining?

Cold stellar streams, remnants of tidally disrupted globular clusters, have been employed as tracers of dark matter in the Milky Way. Because of their different positions, different ages, and different levels of observational scrutiny, different streams tell us different things about the Galaxy. We employ a Cramer--Rao or Fisher-matrix approach to understand the quantitative information content in the known streams. In simple, static, analytic models of the Milky Way, streams on eccentric orbits contain the most information about the halo shape. For any individual stream, there are near-degeneracies between dark-matter halo properties and parameters describing the Galactic bulge, disk and the stream progenitor itself, but we find that simultaneous fitting of multiple streams ought to constrain all parameters to a precision of a few percent. At this level, simulated dark matter halos deviate from analytic parametrizations, so we chart the way forward with more flexible models of the Galaxy. Given enough model freedom, streams are most sensitive to the mass enclosed within their current position, and as an ensemble, they can resolve 10% differences in the acceleration field.

RODRIGO CAÑAS

ICRAR UNIVERSITY OF WESTERN AUSTRALIA

Diffuse stellar halos in state-of-the-art cosmological simulations of galaxy formation

Key information about the formation and evolution of galaxies can be obtained from the diffuse stellar component that surrounds galaxies and clusters, and recent studies (e.g., Morishita et al, 2017; Merritt et al, 2016), have provided some insight on the formation and evolution of these structures in different environments. However, conclusions are still limited by the surface brightness detection limit and the size of the samples in observations. Numerical simulations hence provide an excellent complementary tool to track the evolution of these structures in a cosmological context. Using a new, improved version of the 6-D halo finder VELOCIraptor, we measure and characterise the diffuse, Intra-Halo Stellar Component (IHSC) of halos in a wide dynamic range, from MW-like halo masses to galaxy clusters, in state-of-the-art simulations of galaxy formation (Horizon-AGN, EAGLE and Illustris). This is the first time that such measurement is possible in such a wide dynamic range. In this talk I will be presenting the simulation predictions throughout cosmic time and what we can learn of the build-up of galaxies and halos from their IHSC.

JEFF CARLIN

LSST

Near-Field Cosmology with Resolved Stellar Populations Around Local Volume LMC Stellar-Mass Galaxies

We discuss our ongoing observational program to comprehensively map the entire virial volumes of roughly LMC stellar mass galaxies at distances of ~2-4 Mpc. The MADCASH (Magellanic Analog Dwarf Companions And Stellar Halos) survey will deliver the first census of the dwarf satellite populations and stellar halo properties within LMC-like environments in the Local Volume. Our results will inform our understanding of the recent DES discoveries of dwarf satellites tentatively affiliated with the LMC/SMC system. This program has already yielded the discovery of the faintest known dwarf galaxy satellite of an LMC stellar-mass host beyond the Local Group, and at least two additional candidate satellites. MADCASH is primarily based on deep Subaru+HyperSuprimeCam imaging reaching ~2 magnitudes below the TRGB of the target galaxies. We will summarize the survey results and status to date, highlighting some challenges encountered and lessons learned as we process the data for this program through a prototype LSST pipeline. Our program will examine whether LMC stellar mass dwarfs have extended stellar halos, allowing us to assess the relative contributions of in-situ stars vs. merger debris to their stellar populations and halo density profiles. We outline the constraints on galaxy formation models that will be provided by our observations of low-mass galaxy halos and their satellites.

MARIUS CAUTUN

INSTITUTE FOR COMPUTATIONAL COSMOLOGY, DURHAM UNIVERSITY

The aftermath of the Great Collision between our Galaxy and the Large Magellanic Cloud

Recent observations indicate that the Milky Way (MW) is extremely atypical: it has an undersized supermassive black hole at its centre; it is surrounded by a very low mass, excessively metal-poor stellar halo; and it has an unusually large satellite, the Large Magellanic Cloud (\LMC) orbiting around it. I will discuss how the Large Magellanic Cloud (LMC) is on a collision course with the Milky Way (MW) with which it will merge in ~2.5 billion years. Using the EAGLE galaxy formation simulation, I discuss how, as a result of the merger, the central supermassive black hole will increase in mass up to a factor of 10. The Galactic stellar halo will also undergo an equally impressive transformation, becoming ~5 times more massive. The additional stars will come predominantly from the disrupted LMC but a sizeable number will be ejected onto the halo from the MW stellar disc. The post-merger stellar halo will have the median metallicity of the LMC, which is more typical of MW-mass galaxies. Furthermore, the disturbance to the MW's orbit due to the collision with the LMC will have the effect of delaying the next catastrophic encounter, this time with the Andromeda galaxy, which we now predict will not happen for at least 7 billion years.

Nushkia Chamba

Instituto de Astrofisica de Canarias

Stellar halos build-up as revealed by ultra-deep imaging

The currently favored cosmological model predicts an enormous amount of interactions around galaxies such as mergers and stellar accretion as a consequence of the hierarchical assembly of structures. These ongoing events are predicted to manifest themselves as a plethora of faint streams, shells and tidal features which are expected to eventually contribute to the build-up of stellar halos. To explore these halo mass assembly scenarios, we use the ultra-deep multi-wavelength imaging data from the IAC Stripe 82 Legacy Project. We select a complete volume limited sample of galaxies to characterize and quantify the amount of mass surrounding the host galaxies. Our sample consists of galaxies with stellar masses 10^9.5 Msun < Mstar < 10^11.6 Msun in the redshift range 0.01 < z < 0.08. We observe that the fraction of visually 'disturbed' galaxies is almost twice as high for stellar masses above 10^11 Msun than in the lower mass end of our sample. This trend is more significant for early-type galaxies. In this contribution, we will discuss our findings and how our estimations for the mass in the faint outskirts fit with the present-day cosmological paradigm. As part of the EU-funded SUNDIAL training network, this study will be used as a starting point for future deep learning-based automation of the process, to be applied to Euclid and LSST imaging of a much larger sample of galaxies.

Michelle Collins

University of Surrey

Tidal interactions as a means of forming ultra diffuse galaxies

The newly discovered ultra diffuse galaxies (UDGs) in the Coma cluster pose interesting questions for our understanding of galaxy evolution. Given their wide range of properties, it is almost certain that there are multiple formation channels for these objects. One such channel is that of tidal interactions (stripping, shocking, and harassment) between dwarf galaxies and more massive systems. In the nearby Universe, we already see a number of tidally affected dwarf galaxies whose surface brightness and size fall into the regime occupied by the Coma UDGs. In this contribution, I will summarise our findings for several nearby systems (including the extreme UDG, Andromeda XIX), and discuss the difficulties in identifying signs of tidal interactions in the more distant UDG population.

DENIJA CRNOJEVIC

TEXAS TECH UNIVERSITY

Resolving the extended stellar halos of nearby galaxies: the wide-field PISCeS survey

I will present results from the wide-field Panoramic Imaging Survey of Centaurus and Sculptor (PISCeS): the resolved stellar halos of two nearby galaxies (the spiral NGC253 and the elliptical Centaurus A, D~3.7 Mpc) are investigated with Magellan/Megacam. The survey pushes the limits of near-field cosmology beyond the Local Group, by characterizing the stellar content (ages, metallicities, gradients) of extended halos and their substructures (down to surface brightness limits of ~32 mag/arcsec^2) in two environments substantially different from the Local Group. The unique strength of PISCeS is the exquisite synergy between the wide-field, ground-based survey and its extensive imaging and spectroscopic follow-up (HST, Keck, VLT, Magellan, AAT). Our observational campaign provides not only crucial constraints to quantitatively inform theoretical models of galaxy assembly and evolution, but it also represents a necessary testbed in preparation for the next generation of ground-based (LSST, GMT, TMT) as well as space-borne (JWST, WFIRST) telescopes.

EMILY CUNNINGHAM

UC SANTA CRUZ

HALO7D: Disentangling the Milky Way Accretion History with Observations in 7 Dimensions

The Milky Way (MW) is shrouded in a faint metal-poor stellar halo. Its structure and kinematics provide a unique archaeological record of the MW's formation, past evolution, and accretion history. However, studies of the MW stellar halo are hindered by observational constraints. Beyond D~10 kpc, our knowledge of the MW halo is limited to line of sight (LOS) velocities and rare tracer populations (blue horizontal branch and red giant branch stars). We aim to address these limitations with the HALO7D survey. The HALO7D dataset consists of highly accurate HST-measured proper motions (PMs) and very deep (8-24 hour integrations) Keck DEIMOS spectroscopy of MW main sequence turn-off stars in the CANDELS fields. This project provides the first opportunity to measure 6D phase-space information plus chemical abundances (7 "Dimensions") for distant halo main sequence stars. I will present the first kinematic results from this survey. We use the HALO7D dataset to estimate the parameters of the halo velocity ellipsoid, and explore how the velocity distributions and anisotropy vary across survey fields and as a function of distance. This survey, which is unique even in the era of Gaia, will vastly improve our understanding of the Milky Way structure, evolution and mass in a way that neither the HST proper motions nor Keck spectroscopy can do on their own.

RICHARD D'SOUZA

UNIVERSITY OF MICHIGAN

Unravelling M31's accretion history

M31, our nearest large galactic neighbour, offers a unique opportunity to test how mergers affect galaxy properties. M31's stellar halo caused by the tidal disruption of satellite galaxies is the best tracer of the galaxy's accretion history. Here we use cosmological models of galaxy formation to show that M31's massive and metal-rich stellar halo containing intermediate age stars implies that it merged with a large (M* ~ 2.5 x 10^10 M_sun) galaxy ~2 Gyr ago. The simulated properties of the merger debris help to interpret a broader set of observations of M31's stellar halo and satellites than previously considered: its compact and metal-rich satellite M32 is the tidally-stripped core of the disrupted galaxy, M31's rotating and flattened inner stellar halo contains most of the merger debris, and the giant stellar stream is likely to have been thrown out during the merger. This merger may explain the global burst of star formation ~2 Gyr ago in the disk of M31 in which ~1/5 of its stars were formed. Moreover, M31's disk and bulge were already in place before its most important merger, suggesting that mergers of this magnitude do not dramatically affect galaxy structure.

AZADEH FATTAHI

INSTITUTE FOR COMPUTATIONAL COSMOLOGY, DURHAM UNIVERSITY

The origin of the Galactic stellar halo anisotropy

Recent observations, based on the 6D phase-space measurements available through Gaia+SDSS, have shown that kinematic properties of the inner stellar halo strongly depend on metallicity (Belokurov et al. 2018). The higher metallicity component of the stellar halo is shown to be highly anisotropic, which is inconsistent with the accretion of a large number of dwarf galaxies. I use the AURIGA high resolution, hydrodynamical simulations of Milky Way analogs to study the kinematics of their stellar halos. I find that the velocity ellipsoid of the inner stellar halo in a number of AURIGA galaxies show similar behavior to observations. I discuss the plausible origins of a highly anisotropic component of the stellar halo - in particular investigating whether this component is coming from the accretion of a single massive satellite, as previously suggested.

Emma Fernández-Alvar

Observatoire de la Côte d'Azur

The Characterization of the Stellar Halo with APOGEE

We present the analysis performed over halo stars within the APOGEE/APOGEE-2 database. The number of stars available, as well as the accuracy of the chemical abundance determinations, the radial velocities and the UCAC5/GAIA proper motions give us unprecedented quality tools to characterize the Galactic stellar halo. This analysis comprises the evaluation of the distribution of fourteen chemical abundances across the inner halo, as well as the kinematical and dynamical properties of the chemically distinct halo stellar populations as a function of distance. We evaluate the two different populations in terms of [alpha/Fe] trends with [Fe/H] detected and infer constrains for the initial mass function upper mass limit, and the star formation rate. We also compare the chemical trends observed with cosmological simulations and obtain the most suitable accretion history from our simulations.

Moritz Fischer

MPIA Heidelberg

A multi-dimensional atlas of in-situ vs. ex-situ stars from IllustrisTNG galaxies

We use the IllustrisTNG simulations to study the balance between in-situ and ex-situ stars in galaxies at z=0 ranging from Milky Way-like masses to the most massive galaxies at the centers of galaxy clusters.

By ex-situ stars, we mean those stars formed within galaxies other than the one under study and subsequently accreted via stripping or merging.

Being in situ or ex situ is a non observable property, so simulations represent a fundamental tool to provide guidance in interpreting observations.

The aim of this project is to build a quantitative tool which returns the probability for a star (with a given set of labels) residing in a galaxy (with a given set of properties) to be in situ or ex situ, relying on the galaxy physics model of IllustrisTNG and the hierarchical growth of structures.

In particular, we characterize our simulated stars by observable parameters like galactocentric distance, metallicity, age and circularity and we distinguish simulated galaxies by their stellar mass, host halo mass, and morphologies. In fact, we can further investigate the balance of in-situ to ex-situ stars across this multi-parameter space by taking into account non-observable properties like the accretion history of galaxies and the mass of the ex-situ progenitors. We find that such probabilities are a strong function of galaxy mass and that, for example, while at the Milky Way-mass scale, ex-situ stars have median metallicities about 0.3-0.4 dex lower than in-situ stars, this distinction disappears for massive cluster galaxies.

CARLOS FRENK

INSTITUTE FOR COMPUTATIONAL COSMOLOGY, DURHAM UNIVERSITY

The imprint of cosmic reionisation in the halo of the Milky Way

The (re)ionisation of hydrogen in the early universe has a profound effect on the formation of the first galaxies: by raising the gas temperature and pressure, it prevents gas from cooling into small haloes thus affecting the abundance of present-day small galaxies. Galaxy formation theory predicts that two key aspects of the reionisation process -- when reionisation took place and the characteristic scale below which it suppressed galaxy formation – are imprinted in the luminosity function of dwarf galaxies. The details of these two characteristic properties of reionisation determine the shape of the luminosity distribution of satellites in a unique way, and is largely independent of the other details of the galaxy formation model. Galaxy formation models generically predict a bimodality in the distribution of satellites as a function of luminosity: a population of faint satellites and population of bright satellites separated by a 'valley' forged by reionisation. I show that this bimodal distribution is present at high statistical significance in the combined satellite luminosity function of the Milky Way and M31. I will also present predictions for the expected number of satellites around LMC-mass dwarfs where the bimodality may also be measurable in future observational programmes.

NICOLAS GARAVITO-CAMARGO

UNIVERSITY OF ARIZONA, STEWARD OBSERVATORY

The interaction of the LMC and Milky Way: Effects on the stellar and dark matter halo of the Milky Way.

The Large Magellanic Cloud (LMC) is the most massive satellite galaxy of the Milky Way (MW) and is cosmologically expected to host ~10-20% of the total MW mass within its halo at infall. At 50 kpc, the LMC is thus the largest perturber to the dark matter density profile and potential of our Galaxy. To date, the impact of a high-mass LMC on the kinematics of halo tracers (stars, satellites and stellar streams) has not been quantified. I will present high-resolution, idealized N-body simulations of the recent passage of the LMC about the MW in a first infall scenario. The resulting combined potential of the MW+LMC system changes as both a function of time and radius over a 1 Gyr time-scale, comparable to the dynamical time of the halo. Using a stellar-tagging technique, I will further illustrate how the kinematics of both the dark matter and stellar halo are affected by the orbit of the LMC and outline a strategy to potentially detect the LMC's dark matter wake.

COLLEEN GILHULY

UNIVERSITY OF TORONTO

The Dragonfly Edge-on Galaxies Survey

Our observations of the overall shape and structure of stellar halos are few, largely due to scattered light backgrounds or field of view limitations. Even when dissecting a deep, azimuthally-averaged surface brightness profile, the interpretation of faint components apparently corresponding to stellar halos can be questioned for low inclinations. To alleviate this uncertainty, we have initiated a survey of nearby edge-on galaxies with the Dragonfly Telephoto Array in order to unambiguously identify and map their stellar halos (or lack thereof). Dragonfly's wide field of view and exquisite sensitivity to low surface brightnesses is perfectly suited for this task. Our sample comprises 33 edge-on and highly inclined (i > 80 degrees) spiral galaxies within 25 Mpc. The galaxies in our sample span 10e9 - 10e11 solar masses; we will be able to capture the diversity and correlations of stellar halo properties for the more massive galaxies while also beginning to probe the minimally explored regime towards dwarf galaxies (which is presently lacking both observationally and in simulations). Deep g-r colour profiles (~ 31-32 mag/arcsec^2) will enable measurements of stellar halo masses alongside parametrizations of their shape and (sub)structure. Focusing on edge-on galaxies will also enable better separation of thick discs and stellar halos. I will present our reduction and analysis methods, as well as first results from the survey.

JENNY GREENE

PRINCETON UNIVERSITY

Low Surface Brightness Galaxies with the Hyper Suprime-Camera Survey

The ongoing Hyper Suprime-Camera (HSC) Survey is revealing the low surface-brightness Universe over an unprecedented area. Here we discuss our ongoing efforts to characterize low surface brightness galaxies in all environments based on an automated search that has uncovered 800 galaxies thus far. These galaxies have typical distances of ~50 Mpc,

stellar masses of 10^7-10^8 Msun, and sizes of 1-5 kpc. They are roughly evenly divided into red and blue systems, but all are intrinsically round. We discuss the stellar populations, gas-phase metallicities, and relative environments of the red and blue populations. We also briefly highlight our new efforts to use HSC to characterize our own Milky Way halo, currently focused on the Sagittarius Stream.

MICHAEL GREGG

UC DAVIS

Drilling through the M31 Halo near Mayall-II/G1: Tidal Streams, Velocity Substructures, and Abundance Distributions

One of the most luminous and massive globular clusters in the local universe is G1 (Mayall II), a satellite of M31. Because it is quite massive, harbors a central black hole, and exhibits a wide metallicity spread, it has been speculated that G1 may instead be an ultra-compact dwarf (UCD) galaxy, the surviving nucleus of a dwarf elliptical stripped via tidal 'threshing' interactions with M31. As the nearest example of its class, G1 is key to understanding the origin of UCDs and the role that tidal destruction of dwarfs plays in the construction of luminous galaxy stellar halos over a Hubble time. Using DEIMOS at Keck Observatory, we have obtained about 1000 stellar spectra in a ~25'x25' area centered on G1, providing precision velocities and abundances. With these data, we have made the first detection of tidally stripped stars from G1. The velocity, spatial, and abundance correlations are beginning to shed light on the possible origins of this tidal debris as either from the present G1 core or a much larger dE envelope, now nearly completely stripped away. A faint extended envelope of stars would be strong evidence that G1 and the other over-luminous M31 globular clusters were once nuclei of dwarf ellipticals which have been stripped by their parent galaxy and accreted and blended into its halo. In addition, because the vast majority of our DEIMOS targets are representative M31 outer disk and halo RGB stars, our data provide a large statistical sample to search for velocity and abundance substructures by looking for departures from the expected component distributions. The velocity distribution of these M31 stars is decidedly non-Gaussian, perhaps indicating a turbulent, non-virialized component from a recent merger, completely unassociated with G1, another window on the continuing formation of luminous spiral haloes.

MENG GU

HARVARD UNIVERSITY

Hierarchical Assembly of Stellar Envelopes in Galaxy Clusters

Brightest Cluster Galaxies (BCGs) are shaped by complex merging processes. The study of stellar populations of the intracluster light (ICL) can shed light on the hierarchical assembly of galaxy clusters. In this talk I will present the stellar population properties of three ICL regions in the Coma cluster derived from modeling deep spectra obtained with SDSS/MaNGA, and discuss their implications on the build-up of the stellar envelopes. I will also present analysis of VLT/MUSE data of an on-going BCG assembly in a cluster at z~0.1. Our results reveal the coordinated assembly of BCGs: namely that the building blocks of BCGs are distinct from the general population low mass galaxies.

RAJA GUHATHAKURTA

UC SANTA CRUZ

Next Generation Virgo Cluster Survey: Globular clusters as tracers of the stellar halos of dwarf galaxies, ultra-diffuse galaxies, and the massive elliptical M87

I will present the latest results from the Next Generation Virgo Cluster Survey (NGVS), a wide field (104 square degree), multi-band (u, g, i, z, Ks), deep imaging survey using the 3.6-m Canada-France-Hawaii Telescope and MegaCam and WIRCAM instruments, supplemented by spectroscopy based on the Keck II 10-m telescope and DEIMOS spectrograph and the MMT 6.5-m telescope and Hectospec spectrograph, and data from other telescopes/instruments. My talk will focus on the study of globular cluster (GC) satellites of Virgo galaxies and will cover some or all of the following topics: (1) the use of GCs as dynamical tracers of the dark matter halos of dwarf elliptical galaxies and ultra-diffuse galaxies; (2) the angular momentum of GC satellite systems; (3) constraints on chemical enrichment and star formation history of the stellar halos of host galaxies from the co-added spectra of their GC satellites; (4) "orphan" GCs in the Virgo cluster; and (5) substructure in a remarkable new GC map of central few 100 kpc of the massive elliptical M87.

DAVID HENDEL

COLUMBIA UNIVERSITY

A machine vision algorithm for tidal debris classification

Faint tidal features in stellar halos retain information about the merger histories of galaxies for many Gyr and hold clues to their growth and assembly. In particular, the morphology of the features -- whether they appear as a stream or a shell -- is indicative of the progenitor satellite galaxies' orbit. The population statistics of debris may be used constrain the orbital infall distribution, a facet of galaxies' accretion histories that is not otherwise accessible. To date, all surveys of tidal features that consider the debris morphology have relied on visual identification. I will present a new machine vision technique to perform shell vs. stream classification that operates on resolved stellar population data. The backbone of this tool is the Subspace Constrained Mean Shift algorithm, which can identify a one-dimensional manifold of maximum density that conveniently traces both the arcs of tidal streams and the caustic edges of shells. Each location on the manifold can then be evaluated and classified as either shell-like or stream-like based on the properties of the underlying density distribution. I will show first results from applying this tool to a suite of controlled N-body simulations to evaluate its ability to match by-eye morphological classifications as well as correlations with the underlying physics of the merger interactions.

MEGHAN HUGHES

LIVERPOOL JOHN MOORES UNIVERSITY

Galactic Tidal Features and their star cluster populations in the context of E-MOSAICS

Many galaxies in the local universe, including our own galaxy and M31, present low surface brightness tidal features in the form of stellar streams. It is also known that many of these tidal features have associated star clusters.

We present the relationship between low surface brightness tidal features and their associated star clusters in cosmological, hydrodynamical simulations.

We use E-MOSAICS (MOdelling Star cluster system Assembly in Cosmological Simulations within EAGLE), which is the first work to model the formation and evolution of a galaxy and its star cluster population simultaneously.

The project includes high resolution zoom simulations of Milky Way like galaxies

which allow us to follow the evolution of 16 Milky Way like galaxies, locate their tidal features and then extract the properties of the star clusters which are associated with these tidal features.

The properties of these clusters are then scrutinised and compared to the properties of the star cluster population of the entire host galaxy.

We will show how a star cluster population can be used to trace the formation history of their host galaxy. We will particularly focus on how the sub-populations which are associated with tidal features differ from the overall population and how these particular star clusters can be used to trace the recent merger history of the galaxy.

We will compare the results of the simulations to observations of the Milky Way population and the PANDAS survey of M31, in order to shed light on some unexpected results from these surveys.

ENRICHETTA IODICE

INAF-ASTRONOMICAL OBSERVATORY OF CAPODIMONTE

Stellar halos and low surface brightness features from deep VST surveys

In the era of deep photometric surveys aimed at studying galaxy structures down to the faintest levels of surface brightness of mu_g~27-30 mag/arcsec^2, the VST survey of Early-type Galaxies in the Southern hemisphere (VEGAS, see http://www.na.astro.it/vegas/VEGAS/Welcome.html) is producing competitive results. First results have confirmed the feasibility of VEGAS to reach the faint surface brightness levels of 27 - 30~mag/arcsec^2 in the g band out to about 10 Re (Capaccioli et al. 2015; Spavone et al. 2017). Therefore, taking advantage of the deep photometry, we can address the build up history of the stellar halo by comparing the surface brightness profile and the stellar mass fraction with the prediction of cosmological galaxy formation.

As part of VEGAS, the Fornax Deep Survey (FDS) at VST aims to cover the Fornax cluster out to the virial radius (~0.7 Mpc), with an area of about 26 square degrees around the central galaxy NGC1399, and including the SW subgroup centred on FornaxA. FDS is a joint project based on VEGAS (P.I. E. Iodice) and the OmegaCam GTO (P.I. R. Peletier).

One of the priority science goals of VEGAS and FDS is to study the faint outer regions of the massive galaxies in groups and clusters. The large mosaics obtained with the 1 square degree field-of-view pointings of OmegaCam at VST, plus the high angular resolution of 0.21 arcsec/pixel and the large integration time allow us to study, on the cluster scale, the galaxy structure from the brightest inner regions to the faint outskirts, where the stellar envelope merges into the intracluster light. The deep observations can be directly compared with the predictions from the up-to-date theories for the stellar halo formation and the relation with the galaxy environment (Iodice et al. 2016, 2017a, 2017b).

Besides, the deep and multiband imaging of the VST surveys cited above allows us to derive the spatial distribution of candidate GCs (see D'Abrusco et al. 2016; Cantiello et al. 2017).

GIULIANO IORIO

INSTITUTE OF ASTRONOMY, UNIVERSITY OF CAMBRIDGE

A first Gaia all-sky look to the Galactic stellar halo

The detailed study of the smooth distribution of stars in the Galactic halo is fundamental to discern between different halo formation scenarios and to highlight halo substructures and streams. The easiest way to infer the spatial distribution of objects in the halo is counting the stars that are tracers of the halo population. Results of past work only roughly agree and are limited in the volume sampling of the halo by the footprint of the used survey. In this context, the advent of GAIA can offer a dramatic improvement.

We exploit the power of GAIA DR1 to present a first all-sky study of the distribution of RR Lyrae stars (RRL) in the inner halo ($R < 28$ kpc): we performed both parametric and non-parametric analysis, in particular, we have also tested halo properties that are usually not checked in the literature, as for example the presence of tilt and/or offset of the halo with respect to the Galactic disc. The results of both analysis nicely agree: the inner halo is well reproduced by a triaxial ellipsoid with a quite flattened distribution along the axis normal to the Galactic plane and a mild elongated distribution in the Galactic equatorial plane. The number density of stars follows a single power-law with exponent approximately equal to -3.

Neither significant tilt nor offset are needed to explain the spatial distribution of RRL in the inner halo. Finally, we discuss the possible extensions and improvements of this work that can be obtained with the future GAIA data releases.

In Sung Jang

Leibniz-Institut fur Astrophysik Potsdam

Quantifying the faint outskirts of M101 using resolved stars

Models of galaxy formation in a cosmological context predicts the hierarchical assembly of stellar and dark matter halos so that massive galaxies should have extended stellar envelopes. It is therefore, interesting that recent studies based on integrated light photometry reported several massive disk galaxies that have no detectable of stellar halos. We investigate the faint outskirt of one of these galaxies, M101, using resolved stars. We obtain deep image data taken with Hubble Space Telescope along the east and west sides of M101 and derive point source photometry. The outer regions of M101 are dominated by old and metal poor RGB stars, which extend out to R ~ 60 kpc. We combine radial density profiles of RGB stars with those of the integrated light and derive mass density profiles. The mass density profile for the west side of M101 shows a sign of upturn at the very outer region, while that of the east side does not. The stellar halo mass and the stellar halo mass fraction are derived from a disk + halo model. We compare the halo properties of M101 with those of the six GHOSTS survey galaxies as well as the Milky Way and M31 and find that M101 has an anemic stellar halo similar to the Milky Way.

Behnam Javanmardi

Institute for Research in Fundamental Sciences (IPM)

Dwarf Galaxy Survey with Amateur Telescopes (DGSAT)

The number, spatial distribution and physical properties of dwarf satellite galaxies can be used to study and test different galaxy formation scenarios. Recently, integrated-light surveys have proven to be a successful way to detect low surface brightness (LSB) features in the halo of galaxies beyond the Local Group. Here we present the Dwarf Galaxy Survey with Amateur Telescopes (DGSAT) that by using long exposure wide-field images obtained by amateur astronomers, aims at finding LSB galaxies in the field of Milky-Way-like galaxies within a distance of ~40 Mpc. So far, DGSAT has surveyed the surrounding of 8 Milky-Way-like galaxies, has discovered 13 new LSB galaxies, and has provided the observed properties of 20 more LSB galaxies down to a limiting surface brightness of around 28 mag/arcsec^2.

PRASHIN JETHWA

ESO GARCHING

Galaxy merger histories via integral of motion clusters

In the context of hierarchical structure growth, some fraction of a galaxy's globular cluster (GC) population likely originate in its satellite galaxies. By associating GCs with their progenitor satellites, we can therefore probe a galaxy's merger history and mass assembly. In the Milky Way, M31 and beyond, a minority of GCs cluster into distinct kinematic groupings, hinting at recent merger events. In order to uncover older events, however, which can phase mix into kinematic incoherence, requires that we label GCs with quantities which remain conserved even as they disperse throughout the halo. The integrals of motion - e.g. orbital energy and angular momentum - can be used as such labels. Here I will demonstrate that in external galaxies it is possible to statistically detect groupings of GCs in integral of motion space using data of existing quality, despite having access to only three of six phase space co-ordinates. The technique I will describe, applied to recent spectroscopic surveys of the GC populations of dozens of nearby galaxies, will allow us to statistically test hierarchical growth models and constrain galaxy mass assembly histories.

ERIN KADO-FONG

PRINCETON UNIVERSITY

Tidal Features in the Hyper Suprime-Cam Subaru Strategic Program: Demographics and Formation Events

Extended tidal features around external galaxies, a signpost of past interaction, are a window into individual galaxy assembly histories. The Hyper Suprime-Cam Subaru Strategic Program (HSC-SSP), which will cover more than 1400 sq. deg in five broadband filters (grizy) down to i~26 mag with a median i band seeing of 0.56”, offers an unprecedented view of the low surface brightness universe that is complementary to deep, targeted observations of nearby galaxies. I will present a multiscale detection algorithm that is suitable for finding galaxies that host tidal features in large area surveys such as HSC-SSP, and show the results of the algorithm on existing datasets. I will then discuss the demographics of galaxies that host streams versus those that host shells, as well as the nature of the tidal features observed in HSC-SSP. In particular, I will address observations of ongoing star formation in tidal features and the mass ratios of tidal feature formation events.

Jisu Kang

Seoul National University

Globular Cluster Systems in the Giant Halo of the Sombrero Galaxy

The Sombrero galaxy (M104) hosts a dominant stellar spheroid and a massive disk, and is considered as one of the nearest massive early-type galaxies. From the detailed structural analysis of a Spitzer image, it was suggested that a bulge of M104 is much smaller than that of previously known, and that there may exist an additional outer halo around this galaxy. Moreover, from the studies based on globular clusters (GCs) and resolved stars in massive galaxies, it was suggested that massive early-type galaxies host dual halos: a metal-rich inner halo and a metal-poor outer halo. Therefore it is expect that M104 may also host dual halos. Previous studies were limited to the central region of M104. In this study, we present the results of our search for an extended stellar halo in M104.

From deep and wide ugi imaging with CFHT/MegaCam, we detect a rich system of GC candidates with two clear sub-populations: blue metal-poor GCs and red metal-rich GCs. We also measure the radial velocity of these GC candidates from the spectra taken with MMT/Hectospec, and select the members of M104. The red GCs are centrally concentrated while the blue GCs are spread out to ~80 kpc from the galaxy center. From these results, we conclude that M104 hosts a giant metal-poor halo with a radius of ~80 kpc as well as an inner metal-rich halo. Additionally, we find some metal-rich sub-structures in the outer halo with infalling or receding speed of ~100 km/s. We will discuss these results with regard to the origin of these sub-structures and the formation of M104.

Chervin F. P. Laporte

University of Victoria

Stellar disc streams as probes of the Galactic potential and satellite impacts.

Stars aligned in thin stream-like features ("feathers"), with widths of 1 to 10 degrees and lengths as large as l~180 degrees, have been observed towards the Anticenter of our Galaxy and their properties mapped in abundances and phase-space. Long thought to be accreted components to the Milky Way's stellar halo, in this talk, I will discuss their in-situ disc origin by presenting similar features arising in an N-body simulation of a Galactic disc interacting with a Sagittarius-like dwarf spheroidal galaxy (Sgr). By following the orbits of the particles identified as contributing to feathers backwards in time, one can trace their excitation to one of Sgr's previous pericentric passages. These particles initially span a large range of phase-angles but a tight range of radii, suggesting they provide a probe of populations in distinct annuli in the outer Galactic disc. The structures are long lived and persist after multiple passages on timescales of ~4 Gyrs. On the sky, they exhibit oscillatory motion that can be traced with a single orbit over their full length and with amplitudes and gradients similar to those observed. I will demonstrate how these properties of feathers may be exploited to measure the Galactic potential, its flattening, as well as infer the strength of recent potential perturbations to the Galaxy with Gaia in combination with current and future spectroscopic surveys.

ALEXIE LEAUTHAUD

UC SANTA CRUZ

The Stellar Halos of Massive Galaxies

I will present new results from the Hyper Suprime Cam Survey (Huang et al. 2017, 2018) characterizing the light profiles of super massive galaxies (log(M*)>11.6). The depth of the HSC data enables us to measure surface mass density profiles to 100 kpc for individual galaxies without stacking. We show that more massive galaxies exhibit more extended outer profiles than smaller galaxies. When this extended light is not properly accounted for (because of shallow imaging and/or inadequate profile modelling), the derived stellar mass function can be significantly underestimated at the high-mass end. Using weak gravitational lensing, we also conclusively show that, at fixed stellar mass, the stellar profiles of massive galaxies depend on the masses of their dark matter haloes. Our results demonstrate that, with deep images from HSC, we can quantify the connection between halo mass and the outer stellar halo, which may provide new constraints on the assembly history of massive central galaxies.

MYUNG GYOON LEE

SEOUL NATIONAL UNIVERSITY

Resolved Stellar Populations in Stellar Halos and Formation of Massive Galaxies

Deep images of nearby massive galaxies show impressive features of stellar halos and intracluster/intragroup light. Photometry of resolved stars is an excellent tool to investigate the nature and origin of these stellar halos and to trace how massive galaxies formed. We present metallicity distribution functions (MDFs) of the resolved stars in nearby massive early-type galaxies as well as dwarf galaxies derived from deep images in the Hubble Space Telescope archive. The stellar halos in massive galaxies show often the presence of two distinct components (dual halos): a metal-rich one and a metal-poor one. In general the metal-poor halos are much more extended than the metal-rich halos. However, the contribution of metal-rich halos in and around massive galaxies are significantly wider than expected, and the contribution of the metal-poor halos is recognized even close to the central region of massive galaxies.

The MDFs of these stars are described remarkably well by the accreting gas model of chemical evolution with double components (a metal-rich one and a metal-poor one). These results support the dual halo mode scenario that massive galaxies form first in the metal-rich halo mode, and they grow in the metal-poor halo mode.

GERAINT LEWIS

SYDNEY INSTITUTE FOR ASTRONOMY

The Need for Speed: Escape velocity and dynamical mass measurements of the Andromeda galaxy

Our nearest large cosmological neighbour, the Andromeda galaxy (M31), is a dynamical system, and an accurate measurement of its total mass is central to our understanding of its assembly history, the life-cycles of its satellite galaxies, and its role in shaping the Local Group environment. Here, we apply a novel approach to determine the dynamical mass of M31 using high velocity Planetary Nebulae (PNe), establishing a hierarchical Bayesian model united with a scheme to capture potential outliers and marginalize over tracers unknown distances. With this, we derive the escape velocity run of M31 as a function of galacto-centric distance, with both parametric and non-parametric approaches. We determine the escape velocity of M31 to be 470±40 km s−1 at a galacto-centric distance of 15 kpc, and also, derive the total potential of M31, estimating the virial mass and radius of the galaxy to be 0.8±0.1×1012M⊙ and 240±10 kpc, respectively.

SUNGSOON LIM

PEKING UNIVERSITY

A New Study of Globular Cluster Populations in Coma Ultra-Diffuse Galaxies

Ultra-diffuse galaxies (UDGs) are unusual galaxies with faint luminosities similar to classical dwarf galaxies but have large sizes similar to the Milky Way. Several UDGs have large populations of globular clusters (GCs), which are unexpected in these low stellar density and low stellar mass galaxies. I will present a comprehensive Hubble Space Telescope (HST) study of GCs in both UDGs and classical dwarf galaxies in the Coma cluster. This study includes 49 UDGs across the Coma cluster, and 88 classical dwarfs in archival Coma Treasury Survey data. Among the 49 UDGs, we detect statistically significant GC systems in 30. The GC specific frequency of UDGs varies dramatically within our sample, and the mean GC specific frequency of UDGs is relatively higher than that of classical dwarf galaxies. I will also discuss relationships between GC specific frequency and host galaxy properties, and the implications of our results for UDG formation mechanisms.

SARAH LOEBMAN

UC DAVIS

Beta dips in the Gaia era: simulation predictions of the Galactic velocity anisotropy parameter (beta)

Milky Way (MW) science has entered a new era with the advent of Gaia. Combined with spectroscopic survey data, we have newfound access to full 6D phase space information for halo stars. Such data provides an invaluable opportunity to assess kinematic trends as a function of radius and confront simulations with these observations to draw insight about our merger history. I will discuss predictions for the velocity anisotropy parameter, beta, drawn from three suites of state-of-the-art cosmological N-body and N-body+SPH MW-like simulations. On average, all three suites predict a monotonically increasing value of beta that is radially biased, and beyond 10 kpc, beta > 0.5. I will also discuss beta as a function of time for individual simulated galaxies. I will highlight when "dips" in beta form, the severity (the rarity of beta < 0), origin (in situ versus accreted halo), and persistence of these dips. Thereby, I present a cohesive set of predictions of beta from simulations for comparison to forthcoming observations.

KHYATI MALHAN

OBSERVATOIRE ASTRONOMIQUE DE STRASBOURG

A new Substructure map of the Milky Way halo from Gaia DR2 using STREAMFINDER

STREAMFINDER is a new powerful algorithm that we have built to detect Milky Way stellar streams in an automated and systematic way in the ESA/Gaia catalogue. Our studies based on suite of simulations of mock Galactic survey data of similar quality to that expected from the Gaia mission showed that the algorithm is capable of detecting ultra-faint and distant halo stream structures containing as few as 15 members (equivalent surface brightness ~ 33.5 mag/arcsec2).

The application of our algorithm on the proper motion dataset of Pan-STARRS1 has also rendered some useful results, in particular discovery of a new stream-like structure that we found in the neighbouring region of the so called ``GD-1'' stream, that has marked the sanity and feasibility of the STREAMFINDER in handling real astrophysical datasets.

Given these results, the application of our algorithm onto Gaia DR2 should discover many new stellar stream structures in the Milky Way halo. Also, STREAMFINDER can be easily converted into a BLOBFINDER algorithm that can find very faint stellar clusters or faint dwarf galaxy like systems existing in our stellar halo. The final output of both the algorithms after processing Gaia DR2 should reveal a new map of the substructureness of the Milky Way halo unearthing various streams, star clusters and possibly other interesting objects (such as stream fanning structures).

Soon after Gaia DR2, scheduled for April 25 2018, we should obtain these intended, much awaited and interesting results that I would like to discuss during the presentation. STREAMFINDER naturally delivers the possible set of orbital solutions of the stream structures and thus gives a means of estimating the DF(x,v) of the detected Milky Way streams. This can be used to probe the nature and formation history of these star streams and the Galactic halo that together they span. I would also like to discuss these very useful results during the talk.

DAVID MARTINEZ DELGADO

ARI, UNIVERSITAT HEIDELBERG

Hidden Depths: A Search for Stellar Tidal Streams in the Local Universe with Deep Imaging Surveys

L- CDM simulations predict that the stellar halos of massive galaxies should contain a wide variety of diffuse structural features, such as stellar streams or shells, that result from interactions and mergers with dwarf satellites. The most spectacular cases of tidal debris are long, dynamically cold stellar streams, formed from a disrupted dwarf satellite, that wrap around the host galaxy's disk and roughly trace the orbit of the progenitor satellite. Although these fossil records disperse into amorphous clouds of debris in a few Gyr, these stellar streams may be detected nowadays, with sufficiently deep observations, in the outskirts of the majority of nearby massive galaxies. However, this aspect of galaxy formation has not yet been fully exploited, mainly because the stellar tidal streams are challenging to observe due to their extremely low surface brightness.

In this talk, I will summarize the observational effort in the last decade to compile a significant sample of stellar streams in the halos of Milky Way-like galaxies, including deep imaging with robotic amateur telescopes and more systematic searches of tidal features in shallower data from large -scale imaging surveys. I will also present the first results of our new search for tidal streams in deep images from the Legacy surveys. These new exquisite data allow the detection of striking tidal streams in the halos of massive galaxies situated up to distances of 150 Mpc, extending our search to stellar halos of a few thousands of massive galaxies. The significant sample of tidal structures resulting from our study will offer an unique opportunity to study in detail the apparently still dramatic last stages of galaxy assembly in the local universe and to probe the theoretical predictions of frequency and properties of tidal stellar features from the L-CDM paradigm.

KEVIN MCKINNON

UC SANTA CRUZ

The Ubiquity of Stellar Halos in Virgo Cluster Galaxies

Although feeble by light and mass, stellar halos encode important clues about galactic (sub-)structure and the connection between the host galaxy and its ambient intergalactic medium. We have used the deep Next Generation Virgo Survey (NGVS) for the study of faint stellar halos. The NGVS was designed to sample the light of Virgo cluster galaxies down to faint brightness levels, below 28.8 mag arcsec^{-2} in the g band. We have extracted 1D surface brightness profiles for 415 Virgo cluster galaxies from the deepest available NGVS g and i band images and compared to their Sloan Digital Sky Survey (SDSS) counterparts from the Spectroscopic and H-band Imaging of Virgo (SHIVir) catalogue to validate our methods. Model-independent parameters were derived from our profiles and compared to their model-dependent counterparts from the NGVS team based on 2D bulge-disk decompositions. We classify galaxies based on their 1D and 2D disk surface brightness profiles and find that about 1/3 of our well-behaved systems (those free of nearby contaminating neighbours: ~70% of galaxies) show a brightness upturn indicative of a putative stellar halo. Light profiles of halo-bearing candidate galaxies are then decomposed into bulge, disk, and halo components using various halo models (Sérsic, power law, exponential) to find the fraction of light emitted from the halo. The comparison of the observed halo light fraction with previous observations and models sets constraints on galaxy formation models.

ALLISON MERRITT

MPIA HEIDELBERG

Observing stellar halos around Milky Way-like galaxies in Illustris-TNG

The recent increase in the quality and availability of simulations and deep observations of the stellar halos of galaxies alike has prompted with increased urgency the question of how well the two agree with one another (as well as what can be learned from any discrepancies). The key impediment at this stage seems to be the difficulty in carrying out robust, apples-to-apples comparisons beween observed and simulated data. We have selected disk galaxies from the Illustris-TNG cosmological magnetohydrodynamic simulations that are matched in stellar mass with a sample of spiral galaxies observed to extremely low surface brightness limits (~30-32 mag arcsec^-2) as part of the Dragonfly Nearby Galaxies Survey (DNGS). I will discuss comparisons between the two datasets, focusing on both measurable properties which are derived directly from the data (eg the stellar mass maps and surface density profiles, both of which quantify the extent and degree of substructure in halos), and technique-dependent properties (eg stellar halo mass fractions) which bring an extra degree of uncertainty from the methodology itself.

MIREIA MONTES

UNSW SYDNEY

Intracluster light: a luminous tracer for dark matter in clusters of galaxies.

The vast majority of the mass in the Universe is expected to be in form of dark matter. Invisible as it is, it would be ideal to identify a luminous tracer that will mimic their spatial distribution. The distribution of stars within the galaxies is not a good tracer of the dark matter as they are originated in a dissipative process that locate most of the stars in the centre of the haloes. However, we expect that some stars whose spatial distribution results from the interactions of galaxies in the cluster follow the underlying dark matter distribution. These stars form the so called intracluster light (ICL). Here we compare the distribution of the dark matter mass in massive galaxy clusters (as traced by gravitational lensing models) with the distribution of ICL, using the exquisite data from the Hubble Frontier Fields. Using a shape matching measurement to assess the similarities, the Modified Hausdorff distance, we find an excellent agreement between the spatial distribution of the total mass and the intracluster light distribution. This gives us the first reliable luminous tracer of dark matter halos in galaxy clusters. Our finding opens the possibility to explore the dark matter distribution of galaxy clusters using only the low surface brightness light of such clusters.

LAMIYA MOWLA

YALE UNIVERSITY

Dragonfly Wide Field Survey: Intragroup Light

Intracluster light, intragroup light and stellar halos are created through stripping of stars during mergers and interactions and keep record of the assembly history of the galaxies they surround. They are large and diffuse structures with surface brightness many orders of magnitude fainter than the light of the central portion of the galaxies. Imaging this diffuse light requires depth > 29 mag/arcsec^2 and large field of view to provide panoramic image of the group/cluster of interest - requirements which are satisfied by the Dragonfly Telephoto array. Here we will present the progress of the Dragonfly Wide Field Survey, a 456 deg^2 imaging survey in g and r band, covering the SDSS Stripe 82 and the equatorial GAMA fields. The observing and data reduction of the survey is currently underway. By modeling and subtracting every bright object in the image, we will create a continuous map of only the diffuse stellar light of groups and clusters. Our survey area covers over fifty groups with a diverse range of halo mass, color, number of members and dynamical stage. This will be a comprehensive study of galaxy groups within D_L<100 Mpc which will reveal the presence of ultra-faint substructures, fraction of light contained in diffuse halos and place upper limits on the total stellar mass of galaxy groups.

JAMES NIGHTINGALE

DURHAM UNIVERSITY

The Stellar Halos of Massive Ellipticals, revealed with Strong Gravitational Lensing

The stellar halos of massive ellipticals are synonymously difficult to observe, because their low-surface brightness emission is outshone by the background sky and their visual appearance is strikingly similar to their central bulge. However, they constitute approximately half of the galaxy's stellar mass, meaning that whist their light cannot be seen, their presence in mass can be felt – a phenomenon which we demonstrate using a sample of four galaxy-scale strong gravitational lenses. With lensing, the bulge and stellar halo become easily separable, as their distinct mass distributions impart unique signatures into the lensing data. Lensing reveals that, within ~10 kpc, stellar halos are the dominant mass component in each system, outweighing each lens's bulge and host dark matter halo by factors of 1.5-3 and 2-4 respectively. They are highly flattened structures which are rotationally and centrally misaligned from their host galaxy's bulge. This supports a merger driven growth and evolution, provided that the bulge's formation at early times decouples its orientation from the surrounding large-scale environment. Thus, the rapid-size growth of elliptical galaxies may be explained by the hierarchical accretion of material onto their stellar halos, which the future analysis of 100 lenses can confirm.

PATRICK ALEXANDER ONDRATSCHEK

MPIA HEIDELBERG

Systematic uncertainties in the measures of the stellar halo density profiles

The 3D spherically symmetric or 2D projected stellar mass density profiles of galactic haloes can be in general well described by a simple power law rho = rho_0 *r^{alpha}. Therefore the powerlaw coefficient alpha (slope) can be used to characterise the distribution of the stellar material in the galaxy outskirts. With the galaxies from the IllustrisTNG simulations it can be shown that the stellar halo slopes yield information about their central galaxy and their dark matter host halo across an unprecedented range of galaxy masses and types. In particular, galaxies with lower halo masses have steeper stellar halo density profiles than the ones with higher halo masses (-5.5 <~ alpha_3D <~ 3), with increasing scatter in alpha towards the low-mass end. In this work, we used the simulated galaxies to provide quantitative estimations for the uncertainties in the measurement of the stellar halo slopes due to spatial features or inhomegenities of the halo as well as different choices in the adopted tracers. We provide predictions on the stellar halo slopes from the simulated galaxies across different radial ranges, in 3D vs. 2D projections, along different solid angles around a galaxy and for different stellar tracers, e.g. metal-poor vs. metal-rich halo stars and old vs. young halo stars. For Milky-Way like haloes, the metal-poor halo stars exhibit shallower density profiles than metal-rich stars, with a systematic difference in the inferred stellar halo slope which is larger than the galaxy-to-galaxy variation at fixed mass.

JOEL PFEFFER

LIVERPOOL JOHN MOORES UNIVERSITY

The E-MOSAICS project: simulating the formation and evolution of galaxies and their globular cluster systems across full cosmic history

We present the E-MOSAICS project (MOdelling Star cluster system Assembly In Cosmological Simulations in the context of EAGLE): a suite of cosmological, hydrodynamical simulations run with the EAGLE model that includes a subgrid model for star cluster formation and disruption. This is the first work to self-consistently model the formation and evolution of the entire star cluster population through cosmic history in fully cosmological, hydrodynamical simulations of galaxy formation. We will show how regular star cluster formation in the early universe results in the globular cluster populations observed today, and how globular cluster populations can be used to infer the formation and assembly of their host galaxy.

ANA-ROXANA POP

HARVARD UNIVERSITY

Shell Galaxies in a Cosmological Setting: Halo Shapes, Formation Processes and Metallicity Signatures

Shells are low surface brightness arcs of overdense stellar regions, situated on both sides of the galaxy center and extending to large galactocentric distances. In this talk, I will focus on their origin in a cosmological setting and on their influence on the shape of the stellar and dark matter halos of the host galaxy. We study the type of galaxy mergers that produce shells using a cosmological gravity+hydrodynamics simulation - Illustris. Out of the 220 galaxies (> 6e12 solar masses) in our sample, 18% exhibit shells. We identify the individual stars and progenitor galaxies responsible for forming shells by tracing their position, velocity and potential energy at key moments in their lifetime. Our results indicate that z=0 shells in massive ellipticals are the result of relatively major mergers, with progenitors accreted on low angular momentum orbits, between 4 and 8 Gyrs ago. Outer shells are often more metal-rich than the surrounding stellar material in the host halo, and in the case of galaxies with multiple shell-forming satellites, it is possible to detect significant differences in the metallicity of the shells produced by each progenitor. We investigate the shape of the stellar and dark matter halos for the shell galaxies in our sample, and we find that Type I shells are predominantly found in prolate halos. By separating the in-situ and ex-situ stellar components, we show that the stellar halos of many shell galaxies are oblate in the inner regions, which are dominated by in-situ stars, but become prolate or triaxial at larger radii where the shape is dictated by the presence of shells. We also investigate how the shape of the halos changes with redshift, particularly before and after the merger event that produced the shells.

ADRIAN PRICE-WHELAN

PRINCETON UNIVERSITY

Evidence for a disk origin for inner halo stellar structures

Diffuse stellar over-densities just beyond or above the disk of the Milky Way have been previously interpreted as tidal debris from ancient mergers. Recent observational evidence from kinematic, stellar population, and chemical abundance studies instead suggests that the stars in these structures were formed in the Galactic disk, despite their extreme positions. This suggests the existence of disk perturbations that can plausibly be traced all the way to asymmetries seen in the stellar velocity distribution around the Sun, likely as a result of interactions with Milky Way satellites like Sagittarius and the LMC. I will give an overview of observational evidence for this interpretation, but will focus on our groups efforts to study the nature of these structures.

CLAUDIA PULSONI

MAX-PLANCK-INSTITUT FÜR EXTRATERRESTRISCHE PHYSIK

The extended Planetary Nebula Spectrograph (ePN.S) early-type galaxy (ETG) survey - Kinematic diversity and angular momentum in the outer halos

We present two-dimensional velocity and velocity dispersion fields, specific and total angular momentum profiles for 33 ETGs into their outer halos (average 6 effective radii, Re). We use Planetary nebulae (PNe) to trace the kinematics to these very large radii where absorption line spectroscopy is no longer feasible. The ePN.S survey is the largest survey to-date of ETG kinematics with PNe, based on data from the Planetary Nebula Spectrograph (PN.S), counter-dispersed imaging, and high-resolution PN spectroscopy. We find that ETGs typically show a kinematic transition between inner regions and halo. Slow rotators have increased but still modest rotational support at large radii. Most of our fast rotators show a decrease in rotation, due to the fading of the stellar disk in the outer, more slowly rotating spheroid. 30% of these fast rotators are dominated by rotation also at large radii, 40% show kinematic twists, misalignments, or rotation along two axes, indicating a transition from oblate to triaxial in the halo. Estimated transition radii in units of effective radii are ~ 1-3 Re and anti-correlate with stellar mass. These results are consistent with cosmological simulations and support a two-phase formation scenario for ETGs.

RHEA-SILVIA REMUS

UNIVERSITY OBSERVATORY MUNICH (USM)

Connecting In-Situ and Accreted Populations to Global Stellar Halo Properties of Galaxies: Insights from the Magneticum Simulations

Only recently, hydrodynamical cosmological simulations reached resolutions high enough to resolve stellar halos of galaxies of different morphologies and over a broad mass range, from isolated Milky Way mass galaxies to brightest cluster galaxies. This allows to systematically study in a statistically relevant manner the connection between galaxy properties and their stellar halos, bridging the gap between isolated idealized merger simulations and observations. Using galaxies selected from the state-of-the-art cosmological hydrodynamical simulation set Magneticum, I will show how the formation pathways of galaxies of different masses and morphologies are connected to the shapes and radial profiles of their outer stellar halos, and how this evolves with redshift. I will demonstrate that the radial density profiles of these stellar halos can be universally described by an Einasto profile over a broad range of total halo masses,

and that the curvature of the profile is correlated to the accretion history of the galaxy. I will show that this can directly be connected to observations, and how this can be used as a diagnostic tool for obtaining total halo masses from measurements of outer stellar halo radial profiles and shapes. Finally, I will discuss how this is correlated to the in-situ and accreted stellar populations, and which role major and minor mergers play in the connection between the stellar halo and its central galaxy.

R. MICHAEL RICH

DEPARTMENT OF PHYSICS AND ASTRONOMY, UCLA

The Size of Galaxy Envelopes from the HERON Survey

The Halos and Environements of Nearby Galaxies (HERON) survey has undertaken an imaging survey of ~100 nearby galaxies in the Local Volume using a dedicated 0.7m telescope. We find a strong correlation between galaxy luminosity and the diameter of the stellar envelope of low surface brightness, with the largest (~100 kpc) envelopes occurring in the most luminous galaxies. The largest envelopes are found in elliptical galaxies and occur at the bright end of the red sequence. The faint end of the red sequence does not host substantially larger envelopes than the blue cloud at similar luminosity. We find that edge-on spiral galaxies show significantly larger low surface brightness envelopes than face-on spirals, and that S0 and spiral galaxies exhibit a similar range in envelope diameter.

JAVIER ROMÁN

INSTITUTO DE ASTROFÍSICA DE CANARIAS

Pushing the surface brightness limits: PSF and galactic cirrus characterization

Two are the main systematic effects preventing the full exploitation of ultra-deep imaging: the scatter light produced by the point spread function (PSF) and the curtains of dust also known as galactic cirri. Without addressing these phenomena, our efforts for getting ultra-deep imaging of the sky result fruitless. Here we present how to produce star-free imaging of the sky by careful characterization of the PSF and the scatter light associated. We also show a detailed analysis of the photometric properties of the galactic cirri. Having such characterization done, we describe how to discern between the galactic cirri and the background galaxies. We will show how these new techniques are fundamental if we want to fully exploit the science contained in ultra-deep data imaging.

AARON ROMANOWSKY

SAN JOSE STATE UNIVERSITY

Chemo-dynamics and substructure in galaxy halos beyond the Local Group

Understanding the origins and evolution of galaxy halos, shells, and streams ultimately requires spectroscopy to recover their composition and dynamics. This presents a severe observational challenge for galaxies beyond the Milky Way, which can be addressed through the use of globular clusters and planetary nebulae as discrete halo tracers, and now through integrated starlight using the Keck Cosmic Web Integer integral-field unit. I will present examples of halo streams in dwarf and spiral galaxies, and measurements in giant elliptical galaxy halos of chemodynamical transitions, substructures, and dynamical analyses that provide both evidence for accretion events as well as puzzles about their orbital structures.

RAÚL INFANTE SÁINZ

INSTITUTO DE ASTROFÍSICA DE CANARIAS

A crucial test in stellar halo physics: star counting versus integrated photometry techniques

Forgotten for many years, the low surface brightness Universe is undergoing a revolution due to the emergence of new facilities for observing the faintest and extended features in the sky. Astronomers are now starting to uncover structures as faint as 31 mag/arcsec2 using integrated photometry. However, all these discoveries are called into question due to the many technical difficulties associated with pushing the current capabilities to their limits. A way of robustly calibrate where are the present-day observational limits is to test, with an independent method, the detection of the faintest structures on the sky. This is what we have done here. We have obtained ultra-deep imaging of the stellar halo of the galaxy NGC 4565 with PAUCam at the William Herschel Telescope using the g, r and i bands. This object has been also explored with the HST (GHOSTS Survey) and its faintest (>30 mag/arcsec2) structures unveiled using the star counting technique. We have probed whether ultra-deep imaging is able to recover such structures. In this contribution we show the results of this analysis, the pros and cons of each of the two methods, and the prospects for using the integrated photometry analysis in galaxies where the star counting technique is infeasible.

JASON SANDERS

INSTITUTE OF ASTRONOMY, CAMBRIDGE UNIVERSITY

Tidal disruption of dwarf galaxies

With Gaia data we can link the orbital history of the dwarf spheroidal galaxies (dSphs) with their internal dynamical properties. Several dSphs display properties consistent with heavy tidal disruption through their shapes or suppression of their velocity dispersion (indicative of heavy mass loss). I will discuss numerical simulations of the tidal disruption of dSphs, focussing in particular on the interesting case of Crater II that has a highly suppressed velocity dispersion given its observed size. I will discuss the impact of tidal disruption on the shapes of dSphs and their alignments with the host halo. The competing effects of tidal shocking and tidal distortion leads to rounder central regions with more prolate radially-aligned outskirts. I will demonstrate that fitting Crater II within standard galaxy formation theory requires heavy tidal disruption putting constraints on its proper motion testable with Gaia. Furthermore, I will discuss Made-to-measure models of dSphs that account for observed on-sky flattening focussing on how proper motion data may be used to put constraints on anisotropy and flattening along the line-of-sight.

ROBYN SANDERSON

CALTECH

Science from synthetic stellar surveys

A new generation of observational projects is poised to revolutionize our understanding of the resolved stellar populations of Milky-Way-like galaxies at an unprecedented level of detail, ushering in an era of precision studies of galaxy formation. In the Milky Way itself, astrometric, spectroscopic and photometric surveys will measure three-dimensional positions and velocities and numerous chemical abundances for stars from the disk to the halo, as well as for many satellite dwarf galaxies. In the Local Group and beyond, HST, JWST and eventually WFIRST will deliver pristine views of resolved stars. The groundbreaking scale and dimensionality of this new view of resolved stellar populations in galaxies challenge us to develop new theoretical tools to robustly compare these surveys to simulated galaxies, in order to take full advantage of our new ability to make detailed predictions for stellar populations within a cosmological context. I will describe a framework for generating realistic synthetic star catalogs and mock surveys from state-of-the-art cosmological-hydrodynamical simulations, and present several early scientific results from, and predictions for, resolved stellar surveys of our Galaxy and its neighbors.

FELIX SCHULZE

MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS

Connecting Outer Stellar Halo Kinematics to the Formation Histories of Early-Type Galaxies

Several recent studies, using integral-field spectroscopy, suggest that the formation history of galaxies, and especially their in- and outflow history, is encoded in the stellar kinematics. We use a sample of well resolved galaxies extracted from the hydrodynamical cosmological simulation Magneticum to investigate their stellar kinematics out to five half-mass radii. We present extended radial angular momentum profiles, and discuss the relation between their shapes and the formation histories of the individual galaxies. Furthermore, we present results on the correlation of the profile shapes with observable quantities such as sersic index, stellar mass and specific angular momentum. Finally, we apply our results to recent observations, providing insights into the formation histories of the observed galaxies.

CHRISTINE SIMPSON

HITS

Progenitors of the stellar halo in the Auriga simulations

I will discuss results from the Auriga simulations, a set of cosmological, hydrodynamical simulations of Milky Way-like galaxies, on the properties of the progenitors of the Galactic stellar halo. The Galactic stellar halo is observed to have different chemical abundance patterns from surviving dwarf satellite galaxies, indicating a different formation channel for these stars that otherwise have similar low metallicities. A lingering question from this comparison is how similar (or different) were the ancient satellite galaxies that contributed to the stellar halo to the present day survivors. The Auriga simulations are some of the first simulations able to make predictions for the properties of these systems because of their high resolution and baryonic physics model in a cosmological context. I will discuss these results and touch on what remains of the debris of these systems in mock-GAIA catalogs constructed from the Auriga simulations.

ADAM SMERCINA

UNIVERSITY OF MICHIGAN

The Stellar Halo and Sparse Satellite Population of the 'Lonely Giant' M94: A Challenge to Galaxy Formation Models?

The stellar halos and dwarf satellites of Milky Way-mass galaxies are important relics of galaxy formation. Stellar halos provide information about the assembly of the massive centrals, while their satellites probe the lowest-mass dark matter halos, which simulations predict are found in abundance around galaxies like the MW. Recent advances have begun to allow us to place our own Milky Way's halo and satellites in context with other galaxies. We have conducted a deep Subaru Hyper Suprime Cam survey of the stellar halo and satellite population of the MW-mass galaxy M94. Our deep three-band photometry, reaching down to point source depths of r > 28, extends out to ~100 kpc to the East of M94 --- one of the deepest wide-field surveys of resolved stellar populations ever conducted. Our satellite search extends to 150 kpc in every direction in g-band. Surprisingly, we find that M94 hosts a satellite population unlike any other known galaxy: it possesses only two low-mass satellites, both <10^6 M_sun. Using 'standard' halo occupation, such a sparse satellite population occurs in <0.1% of MW-mass systems in the Millennium-II simulation. In order to produce an M94-like system more frequently we find that satellite galaxy formation must be much more stochastic than is currently predicted, requiring a dramatic increase to the slope and scatter of the SMHM relation. Surprisingly, the SMHM relation must even be altered above the ‘too big to fail’ mass. The sparse satellite population of M94 thus advocates for a major modification to ideas of how the satellites around MW-mass galaxies form.

GUILLAUME THOMAS

NRC HERZBERG ASTRONOMY & ASTROPHYSICS

Tracing the smooth stellar halo with BHBs

Using the Canada France Imaging Survey (CFIS), an ongoing CFHT Large Program that will map 10,000deg2 of the northern sky in the u-band to a depth 2.7 mag greater than SDSS, combined with Pan-STARRS1 griz bands, we are able to trace the shape of the smooth stellar halo out to ~ 110 kpc in a large fraction of the Northern sky. During this talk, I will present our method to identify the BHBs with respect to other A-type stars. Since they are good tracers of distance, this enables the study of the shape of the stellar halo through their radial distribution, and also the clumpiness through the clustering of the BHBs stars. I will also discuss the impact of our recent study on the shape of the dark matter halo using the BHBs and Gaia proper motion.

Daniel Thomas

Institute of Cosmology and Gravitation, University of Portsmouth

Stellar populations in galaxy haloes with SDSS-IV/MaNGA

CALIFA and SDSS-IV/MaNGA have initiated a new era of large Integral Field Unit galaxy surveys providing maps of the internal structures of galaxies for large statistical samples. At the same time large-scale hydrodynamical simulations of galaxy formation like EAGLE and Illustris are now in the position to make predictions of galaxy properties at similar spatial resolution for realistic galaxy populations within a cosmological framework (Pillepich et al 2014; Cook et al 2015). Massive galaxies are predicted to form in a two-phase scenario with an early phase of dissipative collapse producing the in-situ population and a subsequent phase of stellar accretion giving rise to the ex-situ component. A major issue is how this two-phase mechanism applies across galaxies of different masses and types and hence how many stars were formed in-situ relative to stars that were formed ex-situ. Analysing MaNGA data we find that the inner metallicity gradient is significantly steeper in disc galaxies than in spheroids and steepens significantly with increasing galaxy mass (Goddard et al 2017). Such flatter metallicity gradients of massive galaxies can be associated with low in-situ fractions. But also stellar age provides a very direct probe of the presence of accreted populations. Accreted stars are expected to be older than stars formed from internal or accreted gas (Hirschmann et al 2015). An analysis of late-type galaxies in the MaNGA secondary sample covering the outer galaxy component shows a dip in the age profile at about 1.5 half-light radii. This suggests a possible dependence on galaxy mass with increasingly older ages and steeper positive age gradients toward the stellar halo of more massive galaxies. This again could be a signature of stellar accretion through minor mergers, as predicted by galaxy formation simulations.

Erik Tollerud

Space Telescope Science Institute

HI & Stars in Local Group Dwarfs: Is There a Missing dIrr Problem?

I will present an approach for comparing HI surveys cross-matched with optical observations to LCDM simulations of the Local Group. When applied to the GALFA-HI survey and the ELVIS simulations, this technique reveals an apparent dearth of gas-rich dwarf galaxies. The impacts of reionization provide a plausible explanation for these observations, which thus provide significant constraints on the mass scales at which reionization must impact Local Group dwarf galaxies. Such constraints have direct impacts on halos because they set the lowest-mass dwarf galaxies that can be progenitors of the dwarf satellites in the Local Group and the gaseous and stellar components of the halo.

Elisa Toloba

University of the Pacific

Internal dynamics and dark matter halos of ultra-diffuse galaxies

In this talk, I will present Keck/DEIMOS spectroscopy of globular clusters (GCs) around three UDGs (VLSB-B, VLSB-D, and VCC615) in the core of the Virgo cluster. We have identified posible evidence for rotation along the stellar major axis of VLSB-D. These findings, in addition to its elongated shape and off-centered nucleus suggest that it may be tidally perturbed. On the contrary, VLSB-B and VCC615 show no signals of tidal deformation. The internal dynamics of VLSB-D suggest that it has a less massive dark matter halo than expected for its stellar mass, but VLSB-B and VCC615 are consistent with Milky Way-like dark matter halos. These results suggest that UDGs may be a diverse population, with their low surface brightnesses being the result of a very early formation, tidal disruption, or a combination of the two.

In this talk, I will open a discussion about the origin of UDGs based on these results (Toloba et al., 2018 ApJL in press), their connection to the growth of the stellar halos where they are found, the role these host stellar halos play in their evolution, and lastly, I will present the efforts our team is doing to answer these questions by analyzing the spatially resolved internal dynamics of other Virgo UDGs and UDGs we have discovered in lower density environments, such as the halo of the Milky Way-like galaxy NGC254 located at ~4Mpc from us.

Christopher Usher

Liverpool John Moores University

Exploring Galaxy Formation Histories with Globular Cluster Stellar Populations

Globular clusters provide a powerful method to study the assembly history of galaxies and their halos. Recent theoretical work has show that the distribution of globular clusters in age-metallicity space provides strong constants on their host galaxy's formation history. We use globular cluster colours and spectroscopic metallicities from the SLUGGS survey of massive early-type galaxies to provide metallicities and relative ages. By comparing these observed age-metallicity distributions with the predictions of the E-MOSAICS cosmological simulations of globular cluster system formation and evolution, we can constrain the formation histories of each of our galaxies. We will also discuss the connection between our inferred assembly histories and the global properties of our observed galaxies.

Asher Wasserman

UC Santa Cruz

Globular Clusters as Observational Probes of the Stellar and Dark Halos of Elliptical Galaxies

Observations of stellar halos can constrain the accretion history of galaxies, yet are hindered by the difficulty of measuring low surface brightness features. The globular cluster (GC) populations of nearby galaxies offer a complementary probe of the stellar halos of galaxies out to a radial range of ~8 Re. Massive elliptical galaxies can have thousands of GCs spread throughout their stellar halos, and these GC populations are almost always found to have a bimodal color distribution. While the exact formation mechanism of GCs is largely unknown, the redder subpopulation is usually attributed to both a metal-rich in-situ component and accretion from massive satellites, while the bluer, metal-poor subpopulation is claimed to have been built up by the accretion of low-mass satellites. Studying the dynamics of these two subpopulations thus provides an opportunity to probe different accretion histories from different progenitor masses. I present the results of the simultaneous dynamical modeling of these GC subpopulations in galaxies from the SLUGGS survey. In addition to deriving robust constraints on the dark matter distribution, I show that the color bimodality in GC populations is often matched by a difference in the orbital anisotropy of these two tracer populations. In particular for NGC 1407, the metal-poor GC subpopulation is observed to have tangentially-biased orbits, in contrast with simulations of galaxy mergers which predict radially-biased orbits.

Aaron Emery Watkins

University of Oulu

The Stellar and Gaseous Halo of M51

I present the results of deep broadband and narrow-band imaging of M51, done with the Burrell Schmidt Telescope at Kitt Peak National Observatory. M51 is a poster child for tidal interactions, having served as the basis for many iconic N-body and hydrodynamic simulations. The strength of the interaction has led to the formation of numerous highly extended tidal streams, including an HI tail with a projected length of nearly 100 kpc. It is perhaps no surprise, then, that the deeper one probes this system, the more structures one finds. Our deep broadband imaging showcases its extended stellar halo to a limiting surface brightness of 30 magnitudes per square arcsecond, uncovering two new tidal streams and constraining the integrated stellar populations of those previously known. Additionally, our deep narrow-band imaging has uncovered an extended cloud

of diffuse Halpha emission far north (32 kpc in projection) of the system, a possible relic of past AGN activity, past starburst induced superwinds, or interaction-induced shocking of one or both galaxies' ISM. Together, these data shed light on not only the capability of strong tidal interactions to populate the stellar halo, but also on their capability of influencing the IGM through gas stripping and feedback processes.

Kris Youakim

Leibniz-Institut für Astrophysik Potsdam

A large-scale clustering analysis of substructure in the Milky Way halo

The Milky Way halo is full of substructures made largely from dwarf galaxies and their disrupted remnants. Therefore, its clumpy nature can reveal much about the formation of the Milky Way stellar halo and its build-up through the accretion of dwarf galaxies.

Here, we present an analysis of the substructure in the Milky Way Halo using data from the Pristine survey, a narrow-band photometric survey which provides reliable metallicity information down to unprecedented levels at the low-metallicity end. This provides an added dimension for searching for and characterizing substructure, even in the era of the Gaia-satellite. We can use this data to separate the Halo in metallicity space, and due to a large sky coverage (currently 2500 deg2) we can then compare the substructure content between various Halo environments.

We demonstrate how a large-scale clustering analysis can be used to quantify the typical scale, and amount of substructure present at different metallicities. We then compare those results directly to cosmological simulations of Milky Way-size galaxies to reveal important clues on the formation and evolution of the Milky Way Halo.

LISA-MARIE ZESSNER

MPIA HEIDELBERG

Inputs from IllustrisTNG stellar halos on the relation between metallicity gradients and assembly history

Stellar halos can provide quantitative information about the assembly history of galaxies. The aim of this work is to analyze the correlation between stellar metallicity gradients, stellar mass and ex-situ mass fraction for a statistically significant sample of simulated galaxies. To this aim we use the simulations of the IllustrisTNG project. Metallicity gradients are measured in spherically symmetry at radial distances of 2-4 and 4-10 stellar halfmass radii for galaxies with Mstars > 10^9 Msun up to the most massive galaxies in 10^15 Msun halos. The results show that high mass galaxies (Mstars~10^12 Msun) have higher ex-situ fractions (>~ 60 %) and flatter metallicity profiles (slope ~ -0.5) than lower mass galaxies (slope ~ -1 at Mstars~10^10 Msun). For fixed stellar mass, metallicity profiles in the 4-10 stellar halfmass radii spatial range are steeper than in 2-4 halfmass radii. Finally, the correlation between metallicity gradients and stellar ex-situ fraction is stronger at larger galactocentric distances, showing that stellar halos contain information about the assembly history.

LING ZHU

MPIA HEIDELBERG

A discrete chemo-dynamical model: dark matter fraction, internal rotation and velocity anisotropy from inner to outer halo

Discrete point sources, bright stars, planetary nebulae or globular clusters, are important tracers of the halo. They usually have multiple populations with different spatial distributions and kinematic properties, which is a fossil record of galaxy formation history.

Here we introduce an axisymmetric discrete chemo-dynamical model within which, (1) potential is flexible enough to include contributions of BH, stars and dark matter, (2) discrete data points are modelled directly without binning, and (3) multiple populations are modelled simultaneously, each population is allowed to have its own rotation and velocity anisotropy.

This method has been successfully applied in modelling two stellar populations of the dwarf spheroid Sculptor, two populations of GCs + planetary nebulae + central IFU stellar kinematics of giant elliptical galaxies NGC 5846 and M87. For all these systems, we have been able to constrain the mass profiles at all scales, thus providing DM fractions from inner (~0.01effective radii) to outer (6-20 effective radii) regions. We are robust in finding out weak rotations of each tracer population, and breaking the mass-anisotropy degeneracy of dynamical models. The different rotations and velocity anisotropy profiles we found for PNe, red GCs and blue GCs in NGC 5846 and M87 tell us the multiple formation paths of the halo.

Our method is also flexible for modelling the multiple stellar populations of Milky Way smooth halo.