Cosmology & Galaxies

Andromeda Galaxy — NASA, Hubble Telescope

11th Great Lakes Cosmology Workshop

June 19 - 22, 2016

Hamilton, Ontario

McMaster University

Origins Institute

CITA ICAT Canadian Institute for Theoretical Astrophysics L'institut canadien d'astrophysique theorique

PERIMETER PI INSTITUTE FOR THEORETICAL PHYSICS

*see below

Schedule

	Sunday	Monday	Tuesday	Wednesday
09:00:00 AM		*Simon White*	*Arianna Di Cintio*	*Mike Hudson*
09:25:00 AM		Contributed Talks	Contributed Talks	Contributed Talks
09:40:00 AM				
09:55:00 AM				
10:10:00 AM				
10:25:00 AM				
10:40:00 AM		**COFFEE**	**COFFEE**	**COFFEE**
11:10:00 AM		Contributed Talks	Contributed Talks	Contributed Talks
11:25:00 AM				
11:40:00 AM				
11:55:00 AM				
12:10:00 PM				
12:25:00 PM				
12:40:00 PM		**LUNCH**	**LUNCH**	**LUNCH**
02:00:00 PM	**Python Workshop**			
02:30:00 PM		*Erik Bell*	*James Taylor*	*Matthew Johnson*
02:55:00 PM		Contributed Talks	Contributed Talks	Contributed Talks
03:10:00 PM				
03:25:00 PM				
03:40:00 PM				
03:55:00 PM				**COFFEE**
04:10:00 PM		**COFFEE**	**COFFEE**	
04:25:00 PM				Contributed Talks
04:40:00 PM		Contributed Talks	Contributed Talks	
04:55:00 PM				
05:10:00 PM				
05:25:00 PM				
05:40:00 PM				(end)
05:55:00 PM				
06:10:00 PM		(end)	(end)	
07:00:00 PM	**Reception @ Ye Olde Squire (875 Main St. West)**	**Banquet @ Radius (151 James St. S)**		
08:00:00 PM			**Origins Public Lecture (MDCL 1105)** *Simon White*	

*Godzilla has been the official mascot of the Great Lakes Workshop for a long time. In honour of this 11th Great Lakes Workshop, Godzilla makes eleven appearances throughout the program. Congratulations, you've already found one Godzilla— only ten left!

Monday June 20, 2016

9:00 Simon White

The baryon content of dark halos

In the most massive dark matter halos (rich galaxy clusters) the observed fraction of baryons is close to the cosmic mean and is predominantly in the form of hot gas. On galaxy scales the directly observed baryon fraction is substantially lower, maximising at about 25%, and is primarily in the form of stars in the central galaxy. Stacking large numbers of galaxies allows the missing baryons to be identified as hot gas with a more extended distribution than the dark matter, a likely consequence of feedback effects. Gravitational lensing allows the scaling relations between galaxy halos and their stellar and hot gas content to be explored directly, demonstrating that these relations depend on properties of the central galaxy other than just its mass.

9:25 Alex Richings

Non-equilibrium chemistry in simulations of galaxy formation

Simulations of galaxies often assume chemical equilibrium, where the chemical reactions between ions and molecules have reached a steady state. However, this assumption may not be valid if the physical conditions of the gas are evolving rapidly. I will present a chemical model that we have developed to follow the non-equilibrium evolution of ions and molecules, which we have incorporated into hydrodynamic simulations of galaxies. We applied this model to simulations of isolated disc galaxies with different metallicities and UV radiation fields, and compared these to simulations that assume chemical equilibrium. We found that the total star formation rate is higher at higher metallicity and for weaker radiation fields. In contrast, non-equilibrium chemistry does not strongly influence the total star formation rate or outflow properties of the galaxy. However, it does affect the abundances of individual chemical species, for example in molecular outflows.

9:40 Nathan Goldbaum

Mass Transport and ISM Phase Balance in Simulations of Gravitationally Unstable Disk Galaxies

Both self-gravity and star formation feedback are capable of transporting mass and driving turbulent motions in the gas of disk galaxies. Understanding how the interplay between these two processes influence galactic structure requires high resolution numerical simulations. In this talk, we present a suite of Enzo AMR simulations of isolated disk galaxies at 20 parsec spatial resolution. The simulations include a live dark matter halo and were run for several galactic dynamical times under the influence of realistic cooling, self-gravity, and star formation feedback, including supernova blastwaves. We describe the qualitative outcome of the simulations and examine the rate of mass transport in the gas as well as the phase balance maintained by the simulated ISM in detail. The simulation code, analysis code as well as 12 TB or simulation data and ancillary postprocessed data used for this work are publicly available. Interested parties are invited to build on these simulations and extract novel insights from the simulations.

9:55 Samantha Benincasa

Pressure-driven regulation of star formation in simulated galaxies

We explore the regulation of star formation in star-forming spiral galaxies through a suite of high-resolution isolated galaxy simulations. Our simulations include photoelectric heating and produce a two-phase ISM. Representative star formation and feedback sub-grid models create a weak, sub-linear dependence between the amount of star formation and parameter changes. We incorporate these sub-grid models into both an equilibrium and dynamic pressure-driven regulation framework and show the sub-linear scaling is a consequence of the non-linear relationship between effective pressure and scale-height.

10:10 Hui Li

Star cluster formation in cosmological simulations

Stars are mainly formed in cluster environment and star clusters are the building blocks of the stellar component of galaxies. In this talk, I will present a new method of modeling star cluster formation in cosmological simulation by treating star particles as individual star clusters. I will talk about the details of the continuous cluster formation method and show some recent results on various properties of model star clusters. The cluster initial mass function can be best fitted by Schechter function with a power-law slope that is consistent with observations. The cutoff mass from the fit shows a strong positive correlation with the global star formation rate of the host galaxies. The formation of massive star clusters are preferred during starburst activities that are triggered by major merger events. Giving that these young massive clusters can be considered as the progenitors of the globular clusters at present, our simulations provide some interesting implications on the origin of globular clusters.

10:25 Brian Devour

Measuring Dust and Inclination Effects on the Luminosities and Structures of Galaxies

Many common measurements of galaxy properties suffer from biases with inclination, with differing values reported for identical galaxies viewed at different angles. These effects can be due both to dust attenuation and to purely geometric limitations in photometry or structural measurements, and are not easy to quantify using only (dust-affected) optical observations. We use a set of IR-based metrics carefully selected to be dust and inclination-independent to match samples of intrinsically similar galaxies, in order to quantify the variation in their observed optical properties with inclination. We find that dust attenuation varies with both stellar mass and specific star formation rate, reaching a maximum for the most strongly star-forming galaxies at intermediate masses, and that optical structural measurements show strong biases with inclination, and in the case of Sérsic index, even for quiescent galaxies without significant dust attenuation.

10:40 COFFEE

11:10 Stephane Courteau

Understanding the Tight Scatter in Galaxy Scaling Relations

Galaxies like our Milky Way can be described in terms of their structure, dynamics, and stellar populations. Some very robust correlations between galaxy structural properties, such as total luminosity, maximum circular velocity, and size show rather small scatter, hinting at well-regulated galaxy formation processes. A major challenge to understanding these scaling relations, their tight scatter, and ultimately galaxy formation and evolution, is the elusive interplay between visible and dark matter. I will discuss the latest constraints to galaxy scaling relations and their link with modern cosmological models.

11:25 Federico Lelli

Structure and Dynamics of Nearby Galaxies from SPARC

Galaxies follow tight scaling relations linking their baryonic content to their dynamical properties. We study these dynamical relations using SPARC (Spitzer Photometry and Accurate Rotation Curves): a sample of 176 disk galaxies with new photometry at 3.6 um, tracing the stellar mass distribution, and extended HI rotation curves, tracing the gravitational potential out to large radii. SPARC spans a broad range of galaxy types (S0 to Irr), luminosities (5 dex), and surface brightnesses (4 dex). We find that the baryonic Tully-Fisher relation (BTFR) is extremely tight: its intrinsic scatter (of only 0.1 dex) is below general expectations in LCDM and represents an open challenge for galaxy formation models. We also study a local version of the BTFR, which relates the baryonic gravitational force to the total gravitational force at every galactic radius. This empirical relation expresses a local coupling between baryons and dark matter in galaxies, which remains to be understood in LCDM.

11:40 Daniela Carollo

The Age Structure of the Milky Way's Halo

I will present the first high-resolution chronographic (age) map of the Milky Way's halo, based on the inferred ages of ~130,000 field blue horizontal-branch (BHB) stars with photometry from the Sloan Digital Sky Survey. The map exhibits a strong central concentration of BHB stars with ages greater than 12 Gyr, extending up to ~15 kpc from the Galactic center (reaching close to the solar vicinity), and a decrease in the mean ages of field stars with distance by 1-1.5 Gyr out to ~45-50 kpc, along with an apparent increase of the dispersion of stellar ages, and numerous known (and previously unknown) resolved over-densities and debris streams, including the Sagittarius Stream. These results agree with expectations from modern ΛCDM cosmological simulations, and support the existence of a dual (inner/outer) halo system, punctuated by the presence of over-densities and debris streams that have not yet completely phase-space mixed.

11:55 Ashley Bemis

Investigating Dense Gas and Star Formation in the Antennae Galaxies (NGC 4038/39) using ALMA

The Antennae are a system of nearby (22 Mpc) interacting galaxies that show evidence of recent star formation. We study the relationship between dense gas and star formation in the Antennae galaxies by comparing emission of dense gas tracers, HCN, HCO+, and HNC, from high-resolution ALMA observations to 70 micron infrared observations taken with Herschel PACS. A recent study of the Antennae by Bigiel et al. 2015 compares the emission of these dense gas tracers in the brightest regions of the overlap region and two nuclei using CARMA observations. With the higher sensitivity of ALMA, we are able to probe regions of weaker emission and compare the total recovered flux of these two studies. Additionally, we use OVRO CO data to derive the star formation efficiencies and compare with dense gas fraction and dense gas star formation efficiencies.

12:10 Angus Mok

Comparing the ISM and Star Formation Properties of Nearby Spiral Galaxies in Different Environments

Using a sample of gas-rich spiral galaxies from the Nearby Galaxies Legacy Survey (NGLS), we explore the effects of environment on their distribution of atomic gas, molecular gas, and star formation. Integrated results show that molecular gas is enhanced for the galaxies in the Virgo Cluster, along with a reduction in the star formation efficiency. We use CO(3-2) data from the JCMT and VLA 21 cm observations to determine radial trends in both their molecular and atomic gas surface densities. We find no signs of a significant truncation in their molecular gas disks, in contrast to their atomic gas distributions. We also combine the CO(3-2) data with Hα-derived star formation rate maps to constrain variations in gas depletion times.

12:25 Traci Johnson

Resolving the physical scale of star formation in a lensed galaxy at z=2.5

Clumpy substructure in galaxies $1<z<3$ is prevalent and forms from gravitational instabilities in the disk as cold gas accretes from the intergalactic medium. These clumps are the launching points of outflows from massive stars, and will merge over time to build up the exponential disks of today's galaxies. Even with HST, the highest spatial resolution we can achieve at these redshifts is ~1 kpc, and we expect much of the substructure is unresolved. Gravitational lensing breaks down this observational barrier by amplifying the observed sizes of galaxies. I will be presenting my work using the combined power of HST and lensing to resolve the structure of SGAS J1110+6459, a clumpy star-forming galaxy at z=2.481 lensed by a galaxy cluster at z=0.659. We have developed an innovative forward-modeling technique to model the clumpy structure of the galaxy in the source plane, which allows us to effectively deconvolve the source galaxy with the so-called "lensing PSF" arising from asymmetric shear and the instrument PSF. We are able to resolve scales for star forming clumps on the order of 100 pc (FWHM) and recover clumps as small as 30 pc. With our model and exquisite HST imaging, we will be able to measure precise star formation rates on a clump-by-clump basis, work that has only ever been accomplished for nearby galaxies.

12:40 LUNCH 

2:30 Eric Bell

Supermassive black holes as the regulators of star formation in galaxies

Using the Henriques et al. (2015) semi-analytic model, Terrazas et al. (2016) found that quiescence is primarily a function of black hole mass, where central galaxies become quiescent when heating from their active galactic nuclei becomes sufficient to offset the cooling rate. We present an analysis of observational data of local central galaxies with directly-detected black hole mass measurements in order to test this correlation and determine the main physical drivers of quiescence. We find that the specific star formation rate is a smooth and tight function of the black hole mass-stellar mass ratio, or what we call the black hole prominence, for all galaxies of different morphological types. As a result, partially-quiescent galaxies - which have generally been thought of as transitory stages towards complete quiescence - are found to be stable systems with intermediate black hole prominence. Further, we compare our observational data with four state-of-the-art galaxy formation models. We find that models that balance gas cooling with AGN heating in order to grow the quiescent population show the best agreement with observational trends that relate black hole mass, stellar mass, and star formation rate. Our results provide strong evidence that the black hole has an increasingly suppressing, smoothly varying effect on the star formation occurring within central galaxies, giving credence to the AGN feedback paradigm.

2:55 Michael Tremmel

Dancing to ChaNGa: Supermassive Black Hole Mergers in Romulus

We predict the rate and characteristics of supermassive black hole (SMBH) mergers across cosmic time using a new set of high resolution cosmological simulations called Romulus, which emphasize a novel approach to improving the sub-grid physics of SMBHs, including their dynamics (Tremmel+ 2016, in prep). By modeling the unresolved dynamical friction acting on SMBHs, we are for the first time able to accurately track SMBH orbits to an accuracy of < 1 kpc (Tremmel+ 2015) while making no assumptions as to the sinking times or positions of SMBHs within their host galaxy. Utilizing this accurate representation of SMBH dynamics, we analyze the population of SMBH mergers, predicting how the population changes over cosmic time not only in terms of the black hole properties, but also in terms of the galaxies that host these events. We make predictions for the detection of SMBH mergers with eLISA and predict the population of galaxies likely to host SMBH mergers across cosmic time.

3:10 Ben Keller

Superbubbles, Supernovae, and Deregulating Galaxies: Too Big Not to Fail

M* galaxies, with halo masses ~10^{12} Msun, live in an interesting part of parameter space. Not only are they the “turnover” in the galaxy mass Schecter function, they also have the highest stellar mass (and baryon) fraction, very low bulge-to-disk ratios, and dominate the star formation of the epoch they live in. In this talk I will present the results of a sample of 18 cosmological M* galaxies, simulated using the state-of-the-art superbubble method for handling feedback from Type II Supernovae. I will show that the key to obtaining a realistic stellar mass to halo mass relation (SMHMR) is preventing the runaway growth of a massive bulge by driving outflows with large mass-loadings. If this happens, SN feedback alone can no longer effectively drive outflows from the galaxy, and star formation becomes unregulated. This is a key piece of evidence that the peak of the SMHMR is due to the shut down of SN regulation and the beginning of AGN regulation in more massive halos. I will also show how the interaction between hot outflows and the disk ISM, together with the potential well they live within, sets how much mass is entrained in a galactic wind/fountain, and how this can halt SN-driven winds in high-mass galaxies.

3:25 Chad Bustard

A Versatile Family of Galactic Wind Models

Current models of galaxy formation overestimate the number of low-mass galaxies and their stellar ages. A possible solution is efficient galactic wind feedback that limits star formation at high redshift in low-mass galaxies. Unfortunately, the processes governing wind feedback are typically at too small scales to be properly accounted for in galaxy formation simulations. I will present a new model of galactic winds aimed at bridging this gap between physically motivated outflow models and cosmological simulations of galaxy formation. The Chevalier and Clegg (1985) galactic wind model is upgraded to include radiative losses, a gravitational potential from an extended mass distribution, and nonuniform mass and energy sources. I will show which wind solutions are most efficient in expelling mass from a galaxy, the abundance of low-temperature high velocity outflows, and the ability of our model, unlike the Chevalier and Clegg model, to reproduce the observed linear relationship between galaxy X-ray luminosity and star formation rate. Additionally, constraining our model to fit this linear trend leads to an inverse relationship between possible wind mass-loading factors and star formation rate. When employed in galaxy formation simulations, this relationship may lead to a better fit to the observed galaxy stellar mass function. Finally, I will address the effects of an extended halo potential on the escape or fall-back of various wind solutions, as well as possible consequences of galactic wind termination shocks in the intergalactic medium.

3:40 Miao Li

How do Supernovae Launch Galactic Winds?

Galactic winds are ubiquitously observed in star forming galaxies, and are essential for galaxy formation, but it remains a puzzle how the winds are launched. I will introduce our hydrodynamic simulations on how supernovae (SN) collectively shape the ISM in different environments. We find the criteria when a steady state ISM is no longer feasible and outflows are inevitable. I will discuss the key factors that affect the mass outflow rate and the multiphase structure of the winds.

3:55 Robbert Verbeke

Realistic dwarf galaxy simulations with Pop III feedback and how to "observe" them

Dwarf galaxies occupy the faint end of the galaxy mass function and their properties are often regarded as strong tests for cosmological and galaxy evolution models. Indeed, their shallow gravitational potential makes them very susceptible to both external and internal processes, such as ram-pressure stripping and supernova feedback. Using computer simulations, the effects of such processes can be tested (e.g. Mayer et al. 2006, Governato et al. 2010). To do this, the properties of the simulated galaxies need to be closely compared to a broad range of observed galaxy properties and scaling relations. We present the results of N-body/SPH simulations including radiative cooling, star formation, chemical enrichment, stellar feedback, heating by the cosmic UV background, and feedback from Population III stars (Verbeke et al. 2015) and show that these compare very well to observed galaxies over the entire dwarf galaxy regime, unlike simulations without Population III feedback. We therefore conclude that Population III stars played a crucial role in the evolution of (dwarf) galaxies. Furthermore, we stress the importance of the way simulations are analyzed. The more in line these mock observations are with real observational techniques, the more reliable the comparison. Obtaining for example the rotational velocity from HI kinematics, metallicities from RGB stars (Kirby et al. 2013), and star formation histories from colour-magnitude diagrams (Monelli et al. 2008) or unresolved stellar spectra (Koleva et al. 2009) are thus very important and can greatly affect the interpretation of the simulations. Lastly, we discuss how the different assembly histories of the galaxies are reflected in the scatter on observed scaling relations.

4:10 COFFEE

4:40 Gwendolyn Eadie

A Hierarchical Bayesian Method for Determining the Galactic Mass Profile

We have developed a hierarchical Bayesian method that estimates the mass profile M(r) of the Milky Way using the kinematic information of tracer objects such as globular clusters and dwarf galaxies. There are two main advantages of this method: 1) we make the most of the available kinematic data, even when some of these data are unknown (e.g. missing proper motion measurements) and 2) we incorporate measurement uncertainties in a meaningful way. The former is a step forward from traditional tracer mass estimators that use incomplete data (radial velocities only) or complete data (radial and tangential velocities) separately, and the latter leads to revised estimates for the positions and velocities of the tracer objects. In this talk, I will describe how the hierarchical Bayesian method works and present an example application to the Milky Way. I will also discuss how this powerful approach may be applied to other galaxies.

4:55 Nicole Drakos

Energy truncation of NFW profiles as a possible explanation for tidally stripped halo density profiles

To study the dynamics of halo mergers, it is necessary to simulate stable isolated halos; however, the commonly used Navarro-Frenk-White (NFW) profile cannot be fully simulated due to its infinite mass. One solution to this problem is to exponentially truncate the density profile outside some cut-off radius (e.g. Kazantzidis et al, 2004). However, we suggest an alternate, physically motivated truncation based on energy. Our truncation yields a profile that looks similar to tidally stripped halos (Hayashi et al., 2003). Thus, we also provide a possible physical explanation for the density profile of tidally stripped halos.

5:10 Stephen Pardy

Tidal Interaction between the Magellanic Clouds: A Challenge for their Past Orbits

The Large Magellanic Cloud (LMC) is part of a class of dwarf galaxies showing pronounced asymmetries, such as off-center bars and one-armed features. Through high-resolution numerical simulations, we show that the dwarf-dwarf gravitational interactions between the LMC and the Small Magellanic Cloud produce long-lived asymmetries in the LMC disk which are wrongly interpreted as an offset bar. However, the Milky Way gravitational potential and the presence of a hot corona highly affect the orbits of the Clouds. Here we explore different orbital configurations in the gravitational interaction between the Magellanic Clouds and the Milky Way to show how a first or second passage around our Galaxy greatly influences the effects of such dwarf-dwarf interactions in producing the observed Magellanic System. This result has implications for the internal structure of the Magellanic Clouds, the Magellanic Stream, and for gas funneling into the Milky Way.

5:25 Marcel S. Pawlowski

The Satellite Galaxy Plane Problem: Biases and Baryons

The observed satellite galaxies of the Milky Way (MW) and Andromeda are preferentially distributed in highly flattened configurations. In addition, the velocities of the dwarf galaxies within these satellite planes are surprising correlated, they mostly co-orbit within the planes. A straightforward comparison of the observed satellite planes with distributions of sub-halos in cosmological simulations indicates that these structures should be extremely rare, giving rise to the satellite plane problem of LCDM. However, the current debate on this topic is highly controversial. Claims about the satellite galaxy planes range from rejecting that there is significant evidence for their existence, over them being natural in cosmological simulations (despite not having been predicted), to them being catastrophic failures of LCDM cosmology itself. A major difficulty in comparing current studies is that they are based on different assumptions and often do not take observational biases such as uncertainties in measured phase-space coordinates and survey footprint shapes into account. I will argue that a statistically robust comparison requires a careful comparison between simulations and the observed satellite systems, in particular the selection (or mock observation) of sub-halo satellites from the simulations need to apply similar selection functions as implied present in the observational data. I will also discuss the effects of observational biases such as whether the SDSS survey footprint biases satellites discovered by it to align with the plane defined by the more luminous, classical MW satellites. Finally, I will discuss whether there is evidence that baryonic physics relevant for the formation of luminous galaxies within dark matter halos can be claimed to have an effect on the frequency and properties of satellitegalaxy planes in cosmological simulations.

5:40 Catherine Fielder

Spin Correlation within Milky Way Satellites

The stellar disk of the Milky Way has a shorter scale length by roughly a factor of two compared to what would be expected given its luminosity and rotation speed. In simple models of galaxy evolution, having a smaller disk indicates that the Milky Way would also have lower average rotational angular momentum, which we parameterize by the spin parameter (λ). In this work, we test whether a halo's spin parameter correlates with properties of its satellite population, as one might expect given the relationship of each one to merger history. We present results from a new suite of zoom-in Milky Way-mass halo simulations, finding that Milky Way mass-halos with lower angular momenta also exhibit less substructure. This suggests that the short disk scale length of the Milky Way and the 'missing satellites' problem may have a common origin, likely connected to the Milky Way's quiet accretion history.

5:55 Jacob Bauer

Growing Disks in Cosmologial Zoom-in Simulations

We present a scheme for embedding a nearly equilibrium stellar disk in a cosmological dark halo. The resulting self-consistent disk-halo system provides initial conditions for numerical simulations that study the influence of halo substructure on bar formation, the generation of bending and breathing modes in stellar disks, and the origin of warps. As with earlier attempts, we first adiabatically grow a rigid disk in a live halo and then replace the rigid disk with a live one at some suitable redshift (typically $z=1$). However, our method makes several improvements over previous attempts. The orientation of the disk is dynamically modeled over the growth phase by sampling the local torque field and evolving equations for the Euler angles of a rigid disk. The final inserted disk is then generated from a semi-analytic distribution function with three integrals of motion. Our method can be easily extended to include gas physics through SPH, allowing future work in the study of how gas physics is influenced by the local environment of the galaxy.

Tuesday June 21, 2016

9:00 Arianna Di Cintio

Is LCDM dead?The vital role of baryon physics in understanding our Universe

Several problems affects the LCDM paradigm at small scales. I will review these issues and show that they can be self-consistently reconciled within a LCDM framework by taking into account the effect of baryonic feedback on the distribution of dark matter within galaxies. The formation of a dark matter core at a particular mass scale is the key to reconcile observations and simulations.

9:25 Michael Petersen

Dark Matter Trapping by Stellar Bars: The Shadow Bar

I present an investigation into the complex interactions between the baryonic (stellar) disc and the dark-matter halo during bar formation and evolution using N-body simulations, revealing that the forming stellar bar traps dark matter in the vicinity of the stellar bar into bar-supporting orbits--the shadow bar. The shadow bar modifies both the location and magnitude of the angular momentum transfer between the disc and dark matter halo and adds 10% to the mass of the stellar bar over 4 Gyr. The (potentially) observable consequences of the shadow bar, its density and velocity signature in spheroid stars, are presented. Numerical tests demonstrate that the shadow bar can diminish the rate of angular momentum transport from the bar to the dark matter halo by more than a factor of three over the naive dynamical friction prediction, and thus provides a possible physical explanation for the observed prevalence of fast bars in nature.

9:40 Tim Haines

Detecting the Presence of Dark Matter in a Wobbling Disk

The Milky Way is not in perfect isolation; accretions of small satellites like the Sagittarius dwarf spheroidal galaxy have been occurring over its entire lifetime. Modern simulations of such interactions have shown that these accretion events induce a vertical wobbling of the disk. However, this wobbling has not been accounted for in recent attempts to observationally constrain the dark matter content in the Galactic disk near the Sun. Indeed, since the earliest measurements of the dynamics of local stars, astronomers have assumed the Galactic stellar disk has been unaffected by these accretion events. Under these assumptions, a discrepancy between the local baryonic density and the total matter density inferred from the dynamics of local stars has been identified. This difference, known as the Oort Limit, has been attributed to the presence of dark matter near the solar neighborhood. Using high-resolution simulations, we analyze the effects that accretion events like the Sagittarius dwarf have on the dynamics of the Milky Way's disk. In particular, we explore the consequences that these dynamics have on the latest observational evidence for dark matter in the Galactic disk.

9:55 Jonathan D. Sloane

Using Galaxy Simulations to Quantify the Uncertainty in Direct Detection of Dark Matter

Experiments that will directly detect dark matter are strongly dependent on the velocity of the dark matter particle. These experiments use different elements as target nuclei, have different energy thresholds, and so probe different portions of the dark matter velocity distribution. Heavier target nuclei are only sensitive to higher impact velocities, assuming equal detector thresholds. The velocity of the dark matter is set by astrophysics. To date, all direct detection experiments assume that the dark matter in the Milky Way follows the Standard Halo Model (SHM), a Maxwellian velocity distribution with peak velocity of 220 km/s. N-Body simulations that include only dark matter have long shown that this assumption is incorrect, but the effect of baryons has not been explored in detail. In this work, we use high resolution cosmological simulations of Milky Way-mass galaxies that include dark matter, gas, and stellar physics, in order to explore the additional effect of baryons on the velocity distribution of dark matter in the solar neighborhood. These simulations have a spline gravitational softening length of 174 pc. The mass resolution is 1.5 $\times 10^5 M_{sun}$ for dark matter. Gas particles begin with a mass of 2.7 $\times 10^4 M_{sun}$ and stars are born with 30% of the parent gas particle's mass. We show that the baryons have a significant impact, altering the predictions from the dark matter-only case, leading to a distribution that is closer to Maxwellian. We find that Standard Halo Model assumption in direct detection searches leads to overly optimistic exclusion bounds on the scattering cross section at lower dark matter masses.

10:10 Dan Taranu

Modelling and simulating galaxies with SAMI

The SAMI integral field galaxy survey has measured spatially-resolved kinematics for ~1400 galaxies over a wide range of masses and environments. With deep imaging and ~300 HI detections, SAMI data - combined with novel modeling and simulations - can provide strong constraints on the structure of z~0 galaxies and therefore on galaxy formation models. We have developed a new method for bulge-disk-halo decomposition of spiral galaxies using self-consistent 3D models. By simultaneously modelling deep photometry and kinematics, the method robustly constrains the underlying parameters of spiral bulges and disks, and even the inner dark matter halo profile - a vast improvement over existing 2D methods. I will also present results from the new Romulus cosmological simulation, a high-resolution $(25\mathrm{Mpc})^3$ volume with novel treatment of black hole physics. By creating a mock SAMI survey with realistic synthetic observations of Romulus galaxies, we are able to directly compare predicted and observed galaxy scaling relations with minimal systematics. Finally, I will outline how these projects - combined with $z\sim1$ data from KMOS - will significantly enhance our understanding of how spiral galaxies form and evolve.

10:25 Lindsay Holmes

Non-Parametric Fitting of Disk Galaxy Photometry for a Sub-set of CALIFA Galaxies

Disentangling the disk and bar components of nearby spiral galaxies can be difficult with standard image or velocity decomposition techniques that either rely on fitting a single set of ellipses or imposing functional forms. The publicly available software “DiskFit” can extract non-parametric disk and bar components from either photometric images or emission-line velocity fields, making it a unique tool for understanding spiral galaxy structure and dynamics. By applying DiskFit to almost 50 Halpha velocity fields produced from Calar Alto Legacy Integral Field spectroscopy Area survey (CALIFA) DR1 data, we have demonstrated that it can faithfully recover disk geometries and rotation velocities in equilibrium disks, as well as detect non-circular motions consistent with bar-like flows. We have since performed additional extensive testing of DiskFit’s kinematic fitting algorithm using simulated velocity fields to determine the ranges of parameters for which DiskFit is able to identify bars (e.g. inclination, position angle, and bar angle) and to better refine the amplitudes of non-circular motions that can be detected. We have used these parameters to model the Ha velocity fields for the spiral galaxies observed in the complete CALIFA sample. Using the DiskFit models of CALIFA galaxies in combination with simulated galaxies allows us to better classify both detections and non-detections of bar-like non-circular flows as they relate to the galaxy and bar properties. The incidence of non-circular flows found within this sample of galaxies is also compared with photometric bar classifications.

10:40 COFFEE 

11:10 Andrew Pontzen

Understanding quenching using a new approach to galaxy formation simulations

In the ΛCDM paradigm, galaxy evolution is dictated by the interaction between cosmological environment and internal processes such as stellar and AGN feedback. For simulators, maintaining sufficient resolution to meaningfully resolve these feedback processes while also studying a representative range of accretion histories is a fundamental challenge, tensioning cosmological volume against resolution. I will show the first results from a new approach which circumvents the need for large volumes by making carefully controlled modifications to an individual merger history within a ΛCDM zoom simulation. In contrast to fully idealised runs, these simulations allow controlled experiments within a fully cosmological environment. I will discuss the first applications of this technique, coupled to a state-of-the-art black hole implementation, to show why some galaxies quench for indefinite periods following a merger, while others rapidly regain a star-forming disk.

11:25 Azi Fattahi

The cold dark matter content of Galactic dwarf spheroidals: no cores, no problem

We examine the dark matter content of satellite galaxies in LCDM cosmological simulations of the Local Group from APOSTLE project. We find excellent agreement between the simulation results and estimates for Galactic dwarf spheroidals (dSphs) derived from their stellar velocity dispersions and half-light radii. Our simulations thus show no sign of the "too-big-to-fail" problem that has plagued earlier work. The resolution of this problem does not require "cores" in the dark mass profiles, but, rather, relies on correcting biases and inaccuracies in the theoretical modelling and in the interpretation of observational data. In particular, we find that (i) the halo mass-galaxy mass relation deviates systematically and substantially from simple abundance-matching estimates, a deviation that is exacerbated when considering satellite galaxies; that (ii) uncertainties in observational estimates of the dark matter content of individual dwarfs have been underestimated, at times substantially; and that (iii) the number of massive subhaloes correlate strongly with assumed Milky Way halo mass, but there is also considerable scatter about the mean trend.

11:40 David Williamson

Chemodynamical Evolution of Dwarf Galaxies in a Tidal Field

We present results of chemodynamical simulations of dwarf galaxies under the influence of an external tidal field, examining the distribution and abundances of metals, and the effects of tides on star formation.

11:55 Isabel Santos-Santos

Dust emission in simulated dwarf galaxies using GRASIL3D

The submillimeter to far-infrared wavelength range of galaxy spectra, now available thanks to instruments like Herschel, has gained special importance as it gives information on the dust-reprocessed light emitted by young stars. In particular, this spectral range allows us to further study low mass-low metallicity galaxies, a challenging piece within the puzzle of galaxy formation in the near Universe, for which the amount of data is increasing in the last years. Their spectral energy distributions (SEDs) show some particular features -as compared to normal, larger galaxies- that cannot be explained with the current models. In summary these are: 1.An excess of emission in the submm (~500 um), causing a flattening of the submm/FIR slope; 2.Broadening of the IR peak of the SED, implying the presence of warmer dust; 3.Less PAH emission lines. In order to fit the data, observers add new ad hoc extra dust components to their modelling, like modified black-bodies, with whatever properties provide the best match. In this work, the SEDs of a sample of 27 simulated dwarf galaxies have been calculated using the GRASIL-3D radiation transfer code. This code has the particularity that it separately treats the radiative transfer in dust grains from molecular clouds and cirruses, the respectively dense and diffuse components of the gas phase. The simulated galaxies have masses ranging from 10^6-10^9 Msol, and have been identified in a hydrodynamical cosmological simulation with initial conditions from the CLUES project and run with GASOLINE. We report on a careful study of their IRAS, Spitzer and Herschel bands luminosities, as well as of their SFRs, dust and gas (HI & H2) mass contents. The results have been compared with observational data and a satisfactory agreement has been found, with GRASIL-3D reproducing naturally the particular spectral features mentioned above. We conclude that the GASOLINE code produces realistic galaxies and that the GRASIL-3D two-component model gives a physical interpretation to the emission of low mass-low metallicity galaxies, with molecular clouds (cirruses) as the warm (cold) dust components needed to recover observations.

12:10 Aaron E. Watkins

Testing galaxy evolution through deep imaging

I present deep broadband and narrowband imaging of several nearby galaxies, done with the Burrell Schmidt telescope at KPNO. We find few tidal features -- even in the bound Leo I Group -- implying inactive merger histories: odd in a merger-driven galaxy evolution paradigm like LCDM. Additionally, we find mostly outer disks dominated by old stars and lacking any spiral structure; within LCDM, dynamical processes such as radial migration can build such old outer disks, however they require resonant structures such as spiral arms to proceed. Finally, the only example of extended star formation we do find, in the interacting system M101, shows relatively little Halpha flux tracing instantaneous star formation. This implies a fading starburst, rather than continuous star formation as might be expected in an inside-out disk formation scenario. All told, for these galaxies, local environment (within the virial radius) coupling to internal dynamics seems the primary evolutionary driver.

12:25 Bert Vandenbroucke

Shadowfax: a public moving-mesh code

Current large scale cosmological simulations lack the resolution to distinguish between cosmological models containing a cold dark matter (CDM) component and models containing weakly self-interacting dark matter. To falsify CDM, we need detailed, high-resolution simulations of dwarf galaxies. These systems have low masses, and their evolution is sensitive to small changes in their gravitational potential. However, as the best observations of dwarf galaxies are limited to satellites in our own Local Group, making model predictions that can directly be compared to observations requires a full modelling of both a Milky Way size parent halo, and a system of dwarf satellites, both at high resolutions. Furthermore, these simulations require an accurate treatment of the interstellar and intergalactic medium, to achieve a self-consistent modelling of the baryonic content of the satellite galaxies. We present the public moving-mesh code Shadowfax, which can be used to evolve a mixture of a fluid and a colisionless component, i.e. stars and dark matter, subject to the laws of hydrodynamics and gravity. We focus on a comparison between Shadowfax and a number of other state of the art codes, like the AMR code MPI-AMRVAC, and the SPH and mesh-free hydrodynamical modules of the simulation code SWIFT. We further discuss problems with the scalability of our current approach, and illustrate an experimental task-based parallel version of Shadowfax built on top of SWIFT. This research paves the way for future high-resolution simulations of Local Group dwarf galaxy satellites.

12:40 LUNCH

2:30 James Taylor

The Galaxy-Subhalo Connection

Dark Matter is now a well-established framework for structure formation, and great progress has been made matching observed field or central galaxies to simulated dark matter halos. I will discuss the next challenge, matching satellite galaxies to subhalos. In particular, matching the stellar mass function in the core of the Virgo cluster, as recently determined by the Next Generation Virgo Survey, to simulations of halo substructure, we have found evidence for a simple pattern in the efficiency of galaxy formation at the lowest masses. In ongoing work, we are now extending this approach to the entire cluster, although there are a few numerical challenges along the way.

2:55 Joel Roediger

A Newfound Behaviour in the Red Sequence Towards Low Galaxy Masses

Star-forming galaxies are known to be quenched by their environments once they are accreted into galaxy clusters. A number of processes have been proposed to effect this transformation [e.g. ram pressure stripping, strangulation] but their efficiencies as a function of infall time, galaxy mass, and orbital parameters remain poorly known. Constraining the predominant quenching mechanism(s) at early epochs and over an extensive range of mass may be achieved by surveying the cores of nearby galaxy clusters. Deep optical imaging from the Next Generation Virgo Cluster Survey [NGVS] has unveiled the galaxy population within the innermost ~300 kpc of this benchmark cluster down to a limiting mass of $M_* \sim 10^6$ M_{sol}, reaching the scale of classical satellites in the Local Group. Using isophotal photometry from the NGVS, we have studied the red sequence in this region, spanning an unprecedented ~13 mags in luminosity. While the red sequence is known to flatten at its bright end, our analysis reveals that a similar behaviour occurs at its faint end too, in all colors, beginning at $M_g \sim -14$. This newfound flattening is especially pronounced in u-band colors, suggesting that it is largely driven by a constant mean age amongst low-mass dwarfs. The implication of these results may be that the early environments of today's rich clusters were very efficient in quenching dwarf galaxies across a wide mass range. Whatever the case, current models of galaxy formation do not reproduce the shape of the red sequence in Virgo in many respects, pointing to deficiencies in their treatment of environmental effects, as well as chemical evolution. Our results should assist in improving future generations of these models and spur new insights into galaxy transformations at the intersection of low galaxy mass and dense environment.

3:10 Gandhali Joshi

Hidden in plain sight: Mass segregation using galaxy analogues in simulations

We use high resolution DM-only simulations to explore the mass functions and radial distributions of subhalos in group and cluster halos with two popular halo finders – the Amiga Halo Finder (AHF) and ROCKSTAR. There are significant differences in the subhalo radial distributions, due in large part to differing subhalo hierarchies. Instead of looking strictly at subhalo populations, we identify a sample of 'galaxy analogues' and show that the radial distribution of these analogues agree well at large halo-centric radii, but still show significant differences at small separations from the host halo centre where phase-space information becomes important for disentangling the analogues from the dense host mass distribution. The extent to which galaxies are segregated by mass within their parent halos is a currently unresolved topic that could shed light on environmentally-driven mechanisms of galaxy evolution. We explore mass segregation in our parent halo population using the identified galaxy analogues. Like some previous work, we see evidence for mild mass segregation at small radii (within $0.5R_{vir}$) with average galaxy analogue mass decreasing with radius. We also see evidence that beyond a virial radius, the average galaxy analogue mass tends to increase with radius. These mass segregation trends show a further dependence on halo mass with the trends becoming weaker in more massive halos. Our findings suggest that the observed mass segregation trends are likely dominated by the accretion history of the subhalos rather than dynamical friction, particularly in massive clusters. We are currently extending this study with SPH group and cluster simulations.

3:25 Emmet Golden-Marx

The High-Redshift COBRA Galaxy Cluster Survey

Galaxy clusters offer a unique laboratory for studying galaxy evolution from early in the universe to the present day. However, since traditional cluster detection methods — including optical overdensity and X-ray searches — are limited due to foreground contamination and surface brightness dimming, few high-z, spectroscopically confirmed galaxy clusters are known. Recent techniques including infrared overdensity searches and AGN targeting show promising results. Here, we present results from the Clusters Occupied by Bent Radio AGN (COBRA) Survey of high-z galaxy clusters, which uses these techniques. The COBRA survey consists of 646 bent, double-lobed radio sources from the VLA FIRST Survey and spans $0.5 < z < 3.0$. The bent radio morphology results from interactions between the AGN host galaxy and the surrounding intracluster medium – the relative motion results in ram pressure on the lobes, bending them. Since low-z bent, double-lobed radio sources are found to frequently reside in clusters and the radio emission is easily detected at high-z, these sources are ideal tracers for high-z clusters. Using our Spitzer observations we measure infrared galaxy overdensities, finding that ~50% of our sources are cluster candidates. We have followed these sources up with optical observations at the Discovery Channel Telescope. Here, we present initial estimates of optical overdensities and photometric redshifts, found by matching the host galaxy's color to galaxy evolution models. Additionally, we use multi-band color cuts to examine red sequence populations and overdensities for a subset of the clusters in our sample.

3:40 Rachel Paterno-Mahler

Swift Initial Characterization of a Strong Lens Cluster Sample

We present the results from the Michigan Swift X-ray observations of the Sloan Giant Arcs Survey (SGAS). These clusters were selected because of the presence of a giant arc visible in the SDSS survey. We characterize the morphology of the sample, and discuss the offset between the X-ray centroid, the mass centroid as determined by strong lensing analysis, and the BCG position. We also present scaling relations such as Lx-T and compare them to self-similarity.

3:55 Jesse Golden-Marx

The Impact of Environment on the Stellar Mass - Halo Mass Relation

We present the Stellar Mass - Halo Mass (SMHM) relation for the Brightest Cluster Galaxies (BCGs) in the low-redshift SDSS-C4 cluster sample. For each cluster, we identify the BCG and correct the SDSS light profile for biases resulting from background over-subtraction. To construct our SMHM relation, we obtain stellar masses using SED modeling, in which we account for reddening and star formation in individual galaxies. We find that 64% of our BCGs can be best fit by a model consisting of a single stellar population and passive evolution. We also find that the SMHM relation shows a clear stratification with magnitude gap; clusters with the highest gaps sit atop the SMHM relation while those with the lowest gaps sit at the bottom. The magnitude gap is an indicator of the cluster age and the BCG growth history and we measure it between the first and fourth brightest galaxies. This gap acts as a significant third parameter in the SMHM relation. We find that this stratification is also present in semi-analytic representations of low-redshift galaxies using the prescription of Guo et al. (2010) and the MILLENNIUM simulation, indicating that its primary cause is the hierarchical growth of the BCG. We conclude that the environment and growth history of BCGs plays an important role in the characterization of the high-mass end of the SMHM relation.

4:10 COFFEE

4:40 Harisah Mehmood

Morphological changes in galaxies within cluster environments

It is well known that cluster environments favor early-type galaxies over late-type. However, the physical origin of the correlation remains uncertain. We focus specifically on the external environmental mechanisms responsible for morphological transformation. All the external processes have one factor in common which is the orbital path taken by the galaxy through the cluster. While the orbital history is not directly observable, using simulations it is possible to statistically access galaxies orbital histories based on their current phase-space coordinates. I will show results obtained from comparing morphologies of SDSS galaxies in clusters to predictions from orbital libraries that allow us to determine when and where in the orbit, the galaxy morphology is transformed.

4:55 Susmita Adhikari

Splashback in accreting dark matter halos

Recent work has shown that density profiles in the outskirts of dark matter halos can become extremely steep over a narrow range of radius. This behavior is produced by splashback material on its first apocentric passage after accretion. The location of this splashback feature may be understood quite simply, from first principles. I present a simple model, based on spherical collapse, that accurately predicts the location of splashback without any free parameters. I will talk about how the location of the feature can be used as a robust probe of the accretion rate of halos in different cosmologies like DGP and f(R) and also how this feature can be used to probe dynamical friction of subhalos in cluster environments.

5:10 Sandrine Codis

Galaxy clustering in the large-deviation regime

In this talk, I will show how to implement a large-deviation principle to study the time-evolution of the large-scale structure of the Universe. This approach allows for analytical predictions in the mildly non-linear regime, beyond what is commonly achievable via other statistics such as correlation functions. The idea is to measure the mean cosmic densities within concentric spheres and study their joint statistics.The spherical symmetry then leads to surprisingly accurate predictions where standard PT calculations usually break down. I will show results for the one and two-point density statistics and discuss implications for future large galaxy surveys like Eulid.

5:25 Anastasia Kasparova

Dark matter - dark methods

The features of the dark matter distribution in galaxies determine largely the evolution of visible matter. We examined the reliability of estimates of pseudoisothermal, Burkert and NFW dark halo parameters for the methods based on the mass-modelling of the rotation curves. We showed that in a half of considered galaxies the best-fitting results are questionable. The trustworthiness of the results depends on the shape and the extension of rotation curve and on the availability of detailed data for the central parts of rotation curves. To reproduce the possible features of the observations we made tests showing how the parameters of the three halo types change in the cases of a lack of kinematic data in the central or peripheral areas and for different spatial resolutions. The central densities and the characteristic radial scales of dark haloes appear to be quite uncertain. In contrast, the estimates of dark halo mass within optical borders are much more reliable.

5:40 Marcel van Daalen

Constraining Galaxy Formation Through Clustering

I will introduce a method that can be used to estimate the projected two-point correlation function of galaxies in a large semi-analytic simulation to better than ~10% using only a very small subsample of the subhalo merger trees. This allows measured correlations to be used as constraints in a Monte Carlo Markov Chain exploration of the astrophysical and cosmological parameter space. An important part of our scheme is an analytic profile which captures the simulated satellite distribution extremely well out to several halo virial radii. This is essential to reproduce the correlation properties of the full simulation at intermediate separations. Our methods allow multi-epoch data on galaxy clustering and abundance to be used as joint constraints on galaxy formation.

5:55 Meagan Lang

The Non-parametric Concentration of Dark Matter Halos in Cosmological N-body Simulations

A wealth of information on the evolution of structure in the universe can be gained by measuring how the properties of dark matter halos in numerical simulations evolve over time. However, the techniques commonly used to measure halo properties often make assumptions about a halo's structure that are not strictly true, resulting in systematically biased results. TesseRACt, a non-parametric tessellation-based technique for measuring halo concentration in N-body simulations, does not make any assumptions about the halo structure, allowing for halos to be axisymmetric, triaxial, contain substructure, and have ill-defined centers. Preliminary results are presented using TesseRACt to measure the concentration of dark matter halos in cosmological N-body simulations.

Origins Institute Public Lecture

WHEN:
8:00PM Tuesday June 21, 2016

WHERE:
MDCL 1105 McMaster University

Origins
INSTITUTE

WHO:

Professor Simon White

Director at the Max-Planck-Institute
for Astrophysics in Garching, Germany

TUESDAY JUNE 21

TITLE & ABSTRACT:

ALL FROM NOTHING:
THE STRUCTURING OF OUR UNIVERSE

Telescopes are time-machines. They allow us to see into the distant past. Our deepest images show the Universe not as it is today, but as it was just 400,000 years after the Big Bang. At that time there were no galaxies, no stars, no planets, no people, no familiar elements other than hydrogen and helium. The cosmos contained nothing but weak sound waves in a near-uniform fog. Supercomputers can compress thirteen billion years of cosmic evolution into a few months of calculation to show how these sound waves developed into the rich structure we see around us today. A study of their harmonic content gives clues to their origin. They appear to be an echo of quantum zero-point fluctuations occurring a tiny fraction of a second after the Big Bang. Thus our entire world may be a consequence of the nature of this early vacuum. In a very real sense, everything may have come from nothing.

Wednesday June 22, 2016

9:00 Mike Hudson

Dark matter halos and large-scale filaments from weak gravitational lensing

Weak gravitational lensing allows a statistical measurement of the dark matter (DM) distribution around and between galaxies. I will discuss recent results from the CFHTLenS analysis of the CFHT Legacy survey. These data allow us to measure the evolution of the DM halos of galaxies as a function of cosmic time and stellar mass. They also allow us to directly detect the tidal stripping of DM halos in dense environments, and the DM filaments of the cosmic web between groups and clusters.

9:25 Claes-Erik Rydberg

The search for high-redshift primordial objects

The potential for detection and identification of primordial stars, galaxies, and supernovae at high redshift will be presented. Simulations indicate that the first Population III stars should appear in minihalos of mass $M = 105{-}106\ M_{sun}$ at $z \approx 10{-}30$. We assess the plausibility of detection with the upcoming James Webb Space Telescope (JWST), using the gravitational lensing provided by the galaxy cluster MACSJ0717.5+3745. The conclusion is that the detection of these objects is highly improbable but not impossible. Population III galaxies are predicted to exist at high redshifts and may be rendered sufficiently bright for detection with current telescopes when gravitationally lensed by a foreground galaxy cluster. Lyα emitters (LAE) with very high Lyα equivalent, EW(Lyα) >150 Å, potentially Population III galaxies, should furthermore be identifiable from broadband photometry because of their unusual colors. The results of a search for such objects at z > 6 in the imaging data from the Cluster Lensing and Supernova survey with Hubble (CLASH), covering 25 galaxy clusters in 16 filters is presented. The selection algorithm returns five singly-imaged objects with Lyα-like color signatures at z between 6.8 and 8.8, for which ground-based spectroscopy with current 8–10 m class telescopes should be able to test the predicted strength of the Lyα line. None of these five objects have been included in previous CLASH compilations of high-redshift galaxy candidates. However, only two of these objects are significantly better fitted by Population III models than by more mundane, low-metallicity stellar populations. The algorithm also identified two likely gravitationally lensed images of a single LAE candidate behind the Abell 2261 (z = 0.225) cluster. The object has substructure and could be a merger or two galaxies interacting. Model fits to the CLASH broadband photometry suggest strong intrinsic Lyα emission, rest-frame Lyα equivalent width EW(Lyα) > 150 Å, at a redshift of z ≈ 6.2. While Population III galaxy models formally provide the best fits, Population I/II models with un-

usually strong Lyα emission can also reproduce the observations. Finally, we propose to model how gravitational lensing by galaxies/ galaxy clusters can reveal the first supernovae (SNe) in the universe in two, parallel simulation lines. First, we will predict the number of SNe and protogalaxies that will appear in dedicated surveys of individual cluster lenses such as CLASH, Frontier Fields and GLASS, which have narrower fields but higher magnification factors. Second, we will estimate the number of lensed SNe and protogalaxies that will be found in future wide-field near infrared (NIR) and optical surveys by Euclid, WFIRST and LSST. These surveys will have lower average magnifications but much larger areas that could harvest far more events.

9:40 Paul Charlton

Dark Matter Halos and Galaxy Morphology

Weak gravitational lensing gives us an observational method to examine dark matter halos and their dependence on galaxy properties. Using CFHTLenS, we investigate the relationship between the morphology of the stars and dark matter by using single Sersic profiles to model the distribution of luminous matter and weak lensing to model the profile of dark matter. Using galaxies within the AEGIS survey we show that, for our purposes, ground-based imaging can recover similar galaxy mass-radius relationships as space-based imaging. We also include preliminary lensing results showing halo properties for different galaxy sizes.

9:55 Chiamaka Okoli

Concentration, ellipsoidal collapse, and the densest dark matter haloes

The smallest dark matter haloes are the first objects to form in the hierarchical structure formation of cold dark matter (CDM) cosmology and are expected to be the densest and most fundamental building blocks of CDM structures in our Universe. Nevertheless, the physical characteristics of these haloes have stayed illusive, as they remain well beyond the current resolution of N-body simulations (at redshift zero). However, they dominate the predictions (and uncertainty) in expected dark matter annihilation signal, amongst other astrophysical observables. Using the conservation of total energy and the ellipsoidal collapse framework, we analytically find the mean and scatter of concentration of haloes of different virial mass M_{200}. Our results are in good agreement with numerical results within the regime probed by simulations slowly decreasing functions of mass that approach constant values at large masses. However, we find that current extrapolations from simulations to smallest CDM haloes dramatically depend on the assumed profile (e.g. NFW vs. Einasto) and fitting function, which is why theoretical considerations, such as the one presented here, can significantly constrain the range of feasible predictions.

10:10 Elisabetta Valiante

The Herschel-ATLAS survey: main results and data release

I describe the first major data release of the largest single key-project carried out in open time with the Herschel Space Observatory. The Herschel Astrophysical Terahertz Large Area Survey (H-ATLAS) was a survey of 50 deg^2 in five photometric bands: 100, 160, 250, 350 and 500 micron. In this talk I will show some of the results of the survey: 1) the development of a technique to select lensed objects with 100% efficiency, 2) how to select up to 1000 lensed sources, 3) the development of a technique to select very high redshift galaxies, 4) the discover of a high-redshift proto-cluster, 5) the definition of the local far-ir luminosity function, 6) dust properties of nearby galaxies. Moreover, I will describe images and catalogues of the three fields on the celestial equator previously observed in the Galaxy and Mass Assembly (GAMA) redshift survey, which cover a total area of 161.6 deg^2. These data will be released and made available to the public during 2016. Our catalogues include ~$3x10^5$ sources detected at 5 sigma at 250, 350 and 500 micron, respectively. I will describe a detailed analysis of the effects of instrumental noise and source confusion on he images and the catalogues, as well as other simulations which will aid the interpretation of the H-ATLAS data by the astronomical community.

10:25 Kazuyuki Ogura

A survey for over-density regions through high-z DLAs

The over-density region is a key component to understanding the structure formation in the Universe. So far, many survey for high-z over-density regions have been performed focusing on the number excess of LBGs or LAEs. Massive objects, such as quasars of radio galaxies, are often used as the tracer of over-density regions. It should be noted that these surveys need emissions from galaxies. However, in the high-z Universe, large fraction of baryons in galaxies could be in the gas phase and thus could be missed in previous surveys. To study about gases at high-z, we are focusing on the DLA (Damped Lyman-alpha Absorption system). The DLA is a class of quasar absorption-line systems with $N_{HI} > 10^{20.3}$ cm^{-2}. Since DLA can be recognized as by their HI column densities regardless of their luminosities, we can effectively investigate the nature of gases in the high-z Universe through the DLAs. We are now working to examine the nature of the DLAs and their environments. Based on the BOSS DLA catalog, we investigated the spatial and redshift distribution of DLAs and found some possible “DLA clusters” where some DLAs distribute in very narrow regions. To examine whether those possible DLA clusters corresponds to over-density regions or not, narrow-band imaging observations are useful. In this talk, we report the results of our Subaru/Suprime Cam narrowband observation for line-emitting galaxies around some possible DLA clusters.

10:40 COFFEE

11:10 Jacobo Asorey Barreiro

Measuring Large Scale Structure with photometric surveys using angular correlations

Photometric surveys provide us with a huge amount of information regarding the late time expansion of the Universe. Large Scale Structure studies are usually affected by the uncertainty on the determination of photometric redshifts. To study the redshift evolution of the galaxy density field we usually divide survey catalogues in tomographic bins. We show that we can recover three dimensional clustering information by using angular cross-correlations and we also address the perspective of using multiple density tracers to measure the growth rate of structure by considering redshift space distortions with no sample variance, using the cross correlation of photometric samples. We show that if we weigh the galaxy number counts in each tomographic redshift bin by the photometric redshift probability of each galaxy to belong to the corresponding shell we can reduce the measurement biases on the parameters due to photometric uncertainties.

11:25 Stephen Turnbull

Peculiar Velocities as probes of gravity, and growth of structure

I will give a brief overview of how observed departures of galaxy velocities from the smooth Hubble flow, known as peculiar velocities, may be used to obtain meaningful measurements of the cosmological parameters and of the power spectrum of gravitating masses. Specifically, in linear theory, peculiar velocities result from gravitational acceleration towards massive bodies. By comparing a catalogue of measured peculiar velocities to predictions derived from a full sky galaxy redshift survey density field, we obtain tight constraints on cosmological parameters. The mean bulk motion on largest scales can also be used to constrain the matter power spectrum on the largest observable scales. Combining results from multiple such surveys at different redshifts we can, measure how matter fluctuations grow relative to dark matter fluctuations over cosmological time. The observed evolution of which can rule out certain classes of alternate gravity models.

11:40 Dritan Kodra

Statistical methods for photo-z improvements with CANDELS

In this talk, I will describe tests of methods for combining photometric redshift probability distributions produced by members of the CANDELS team and test their accuracy by comparison with spectroscopic measurements (spec-z's). These methods have included the Hierarchical Bayesian and the minimum Frechet Distance approach. The former creates a new distribution from the participiting ones by taking into account the possibility of some measurements being wrong. The latter choses one of the participating distributions as being the most similar to the others, thus corresponding to a 'median' of curves. We aim to achieve probability distributions that are more accurate at predicting true redshifts and properly describe redshift uncertainties. We have also explored methods of mitigating errors in the shapes of the photo-z probability distributions from individual participants, resulting in modest improvements."

11:55 Marcelo Alvarez

A Fast Pipeline for Full Sky Mock Observations

I will present mock observations in the radio to optical created with our newly developed full sky pipeline. The new pipeline allows for realistic observations over a broad range of wavelengths to be created from the same realization of initial fluctuations and cosmological background model in a fraction of the time taken by more traditional N-body approaches. First applications of our method, to the Sunyaev-Zel'dovich affect from groups and clusters of galaxies, illustrate the efficiency and power of the approach.

12:10 George Stein

Primordial non-Gaussianity with Large Scale Structure

We explore the detectability of different types of primordial non-Gaussianity in future 3D large scale structure surveys. For both the intermittent (spatially sporadic) and the conventional perturbative variety of non-Gaussianity we find characteristic signatures not only in the scale dependent bias on large scales, as is usually discussed, but that intermittent non-Gaussian models may have a much more unique signal which is strongest in cluster abundances and even single cluster statistics. These forecasts are promising for near-future surveys such as CHIME and SPHEREx if systematics are well controlled.

12:25 Philippe Berger

Simulating cosmic 21 cm emission below the resolution scale

The 21 cm signal should receive a large contribution from dark matter halos which are typically well below the mass resolution of N-body or mock galaxy catalog full-sky simulation schemes. We present a sub-resolution algorithm, designed to reproduce dark matter halo abundances and large scale clustering, which allows for the extension of mock catalogs to the grid size of the simulation and below. Combined with the Peak Patch algorithm of Bond & Myers (1996) in a hybrid scheme, we produce Monte Carlo full-sky large volume simulations of cosmic neutral hydrogen (HI). We study the effect of this sub-resolution contribution on the BAO and trans-linear regimes. This technique is necessary for accurate modelling of existing and future large area HI intensity mapping surveys such as the CHIME telescope, currently under construction in Pentiction, B.C.

12:40 LUNCH

2:30 Matthew Johnson

Constraining cosmological ultra-large scale structure using numerical relativity

Cosmic inflation, a period of accelerated expansion in the early universe, can give rise to large amplitude ultra-large scale inhomogeneities on distance scales comparable to or larger than the observable universe. The cosmic microwave background (CMB) anisotropy on the largest angular scales is sensitive to such inhomogeneities and can be used to constrain the presence of ultra-large scale structure (ULSS). We numerically evolve nonlinear inhomogeneities present at the beginning of inflation in full General Relativity to assess the CMB quadrupole constraint on the amplitude of the initial fluctuations and the size of the observable universe relative to a length scale characterizing the ULSS. To obtain a statistically significant number of simulations, we adopt a toy model in which inhomogeneities are injected along a preferred direction. We compute the likelihood function for the CMB quadrupole including both ULSS and the standard quantum fluctuations produced during inflation. We compute the posterior given the observed CMB quadrupole, finding that when including gravitational nonlinearities, ULSS curvature perturbations of order unity are allowed by the data, even on length scales not too much larger than the size of the observable universe. Our results illustrate the utility and importance of numerical relativity for constraining early universe cosmology.

2:55 Zimu Khakhaleva-Li

Cosmic Reionization on Computers. Ultraviolet Contimuum Slopes and Dust Opacities in High Redshift Galaxies

We compare the properties of stellar populations of model galaxies from the Cosmic Reionization On Computers (CROC) project with the exiting UV and IR data. Since CROC simulations do not follow cosmic dust directly, we adopt two variants of the dust-follows-metals ansatz to populate model galaxies with dust. Using the dust radiative transfer code Hyperion, we compute synthetic stellar spectra, UV continuum slopes, and IR fluxes for simulated galaxies. We find that the simulation results generally match observational measurements, but, perhaps, not in full detail. The differences seem to indicate that our adopted dust-follows-metals ansatzes are not fully sufficient. While the discrepancies with the exiting data are marginal, the future JWST data will be of much higher precision, rendering highly significant any tentative difference between theory and observations. It is, therefore, likely, that in order to fully utilize the precision of JWST observations, fully dynamical modeling of dust formation, evolution, and destruction may be required.

3:10 Rongpu Zhou

Devloping photo-z testbed data for LSST

Measurement of galaxy redshift is very important in cosmology. Redshifts measured from spectroscopy (spectro-z's) are usually very accurate, but they are expensive and are limited to relatively bright objects. Photometric redshifts (photo-z's) - redshifts obtained from the brightness from a few broad passbands - provide a much cheaper alternative, and they are crucial in on-going and future imaging surveys such as LSST. To test and improve photo-z algorithms, datasets with spectro-z's and well-calibrated photometry are needed. Here I present such testbed data in the Extended Groth Strip which combines CFHTLS photometry and DEEP2/3 spectroscopy. I will describe the calibration of photometry in the ugriz bands from CFHTLS and y-band photometry obtained from the Subaru telescope. I will also describe a method to produce corrected aperture photometry, which has improved random and systematic error. This dataset will be especially useful for LSST photo-z studies.

3:25 Niayesh Afshordi

Probing Dark Matter Nanostructure

I will discuss complementary theoretical and observational efforts to probe dark matter nanostructure on smallest astrophysical scales.

3:40 James Mertens

Computing Observables in an Inhomogeneous Universe using Numerical Relativity

While numerical general relativity is widely used to modeling astrophysical phenomena and compact objects, new windows are opening for cosmological applications. Here, we examine departures from the FLRW cosmological model by examining the behavior of photons traversing an inhomogeneous spacetime. We use the BSSN formalism in numerical relativity to evolve the full, unconstrained Einstein field equations, and integrate the optical scalar equations through this numerical spacetime. The universe that emerges exhibits an average FLRW behavior, but locally inhomogeneous structure contributes to deviations in observables along particular paths. This departure from FLRW is an important path-dependent effect with implications for computing observables in an inhomogeneous universe.

3:55 COFFEE

4:25 J Richard Bond

Polarization at Low Multipoles from the Planck HFI Instrument and the Reionization Epoch of the Universe

One of the hardest quantities to determine well in cosmology is the Compton depth τC to electron scattering of CMB photons, which is directly related to the redshift zreion when light from the first stars in primeval galaxies reionized the post-recombination neutral atoms. τC and zreion rely on accuracy in the first dozen E polarization multipoles cleaned of systematics and foregrounds. I will report on our Planck 2016 use of the High Frequency Instrument channels to considerably refine (and lower) the prior WMAP9 and Planck 2015 estimates, and its implications for zreion and galaxy formation.

4:40 Duncan Watts

Measuring the Largest Angular Scale CMB B-mode Polarization with Galactic Foregrounds on a Cut Sky

We consider the effectiveness of foreground cleaning in the recovery of Cosmic Microwave Background (CMB) polarization sourced by gravitational waves for tensor-to-scalar ratios in the range $0<r<0.10$. Using the planned survey area, frequency bands, and sensitivity of the Cosmology Large Angular Scale Surveyor (CLASS), we simulate maps of Stokes Q and U parameters at 40, 90, 150, and 220 GHz, including realistic models of the CMB, diffuse Galactic thermal dust and synchrotron foregrounds, and Gaussian white noise. We use linear combinations (LCs) of the simulated multifrequency data to obtain maximum likelihood estimates of r, the relative scalar amplitude s, and LC coefficients. We find that for 10,000 simulations of a CLASS-like experiment using only measurements of the reionization peak ($l \leq 23$), there is a 95% C.L. upper limit of r<0.017 in the case of no primordial gravitational waves. For simulations with r=0.01, we recover at 68% C.L. $r=0.012^{+0.011}_{-0.006}$. The reionization peak corresponds to a fraction of the multipole moments probed by CLASS, and simulations including 30â□€â□□â□€100 further improve our upper limits to r<0.008 at 95% C.L. (r=0.01 ± 0.004 for primordial gravitational waves with r=0.01). In addition to decreasing the current upper bound on r by an order of magnitude, these foreground-cleaned low multipole data will achieve a cosmic variance limited measurement of the E-mode polarization's reionization peak.

4:55 Arka Banerjee

Cosmological Simulations with "Hot" Particles

N-body simulations have been the main tool for doing non-linear structure formation calculations for three decades, with spectacular success for the Lambda-CDM cosmology. However, it is known to be less accurate for some other cosmologies of interest - for example ones with Warm Dark Matter and neutrinos, where particles have finite thermal dispersions. In this talk, I will describe a new method we have developed to study these cosmologies, which is extremely efficient at removing the effects of shot noise which plague N-body simulations. I will also talk about a new effect which can be studied using this method - namely, a strong scale dependence in the biasing of voids in cosmologies with massive neutrinos.

5:10 Derek Inman

Cold Dark Matter-Neutrino dipole in N-body simulations

Due to their relativistic origins, neutrinos have a bulk velocity significantly different from the cold dark matter in the Universe. This leads to downstream neutrino distortions in the direction of the relative flow. Such an effect is unique to neutrinos and potentially observable in a dipole measurement. I will discuss this effect both in linear theory and in N-body simulations containing cold dark matter and neutrino particles.

5:25 Haoran Yu

Differential Neutrino Condensation onto Cosmic Structure

Astrophysical techniques have pioneered the discovery of neutrino mass properties. Current cosmological observations give an upper bound on neutrino masses by attempting to disentangle the small neutrino contribution from the sum of all matter using precise theoretical models. We discover the differential neutrino condensation effect in our TianNu N-body simulation. The neutrino masses can be measured using this effect by comparing galaxy properties in regions of the universe with different neutrino relative abundance (i.e. the local neutrino to cold dark matter density ratio). In neutrino-rich regions, more neutrinos can be captured by massive halos compared to neutrino-poor regions. This effect differentially skews the luminosity functions of galaxies and opens up the path to independent neutrino mass measurements in current or future galaxy surveys.

Adam Smercina

The Resolved Stellar Halo of M81: Insights from Subaru

In the current paradigm for galaxy evolution and formation, baryonic matter is funneled into the potential wells of dark matter halos in the early universe. These newly formed galaxies grow hierarchically, through frequent mergers and the accretion of lower-mass galaxies. As a result, galaxies are subject to complex physical and chemical processes, which provide a wealth of information for understanding short-term galaxy evolution, but also completely eradicate most of the information regarding their formation and long-term evolution. However, the stellar halo remains as a remnant of these ancient interactions. Towards the goal of understanding the merger and accretion histories of nearby MW-mass galaxies, the stellar halo is one of our most powerful observational probes. We present Subaru Hyper Suprime-Cam gri imaging of the stellar halo of M81. The result is an impressive combination of surface brightness sensitivity and large FOV. We have resolved the halo into individual RGB stars in an effort to probe the diffuse stellar components, which are virtually unobservable through integrated light techniques. These observations will help to provide crucial constraints on models of galaxy formation, leading to a more robust understanding of how MW-mass galaxies assemble their mass.

Ananthan Karunakaran

HI observations of NGC 3109's Satellites: Connecting to Cosmology

The Local Volume is an ideal environment in which to study the mechanisms that drive the evolution of the faintest known dwarf galaxies. More specifically, the atomic gas(HI) content of these dwarfs place important constraints on their evolutionary histories, shedding light on their orbital histories and the dark matter subhalos in which the reside. With respect to the Milky Way, dwarfs within the virial radius are gas-poor, while those beyond the virial radius are gas-rich. This strong environmental dependence likely arises from the combined effects of satellite infall times and ram pressure stripping. However, it is unclear whether these trends extend to satellite systems of lower mass hosts. From an optical imaging survey using the CTIO-4m+DECam around NGC 3109, itself a dwarf irregular, a set of candidate ultra-faint dwarf satellites were found that can be compared to those around the Milky Way. Using the Green Bank Telescope we have studied the HI content of these dwarf satellite candidates; these findings will be presented and their cosmological implications will be discussed.

Fraser Evans

Red Misfits in the Sloan Digital Sky Survey

It has long been known that many properties of galaxies depend strongly on their host environment; red passively-evolving galaxies dominate dense environments and blue star-forming galaxies dominate low density environments. ~90 percent of the galaxies in the universe can be described this way, as either blue and active or red and passive. In a large sample of galaxies from the Sloan Digital Sky Survey we study the remaining ~10 percent of galaxies which defy this trend, galaxies which exhibit red colours but are actively star-forming. These “red misfits” galaxies are a population physically distinct from blue active and red passive galaxies. They have intermediate morphologies, they are the preferred hosts of AGN and their abundance does not seem to depend on environment in any obvious way. I will discuss the peculiar properties of red misfits as well as their implications for both environmental and secular galaxy evolution in the low-redshift universe.

Ian Roberts

A Product of their Halo Environment: How galaxy properties depend on group X-ray luminosity and dynamical state

Star formation rates and morphologies of galaxies, particularly low-mass galaxies, are strongly linked to the properties of their environment. Using a large sample of galaxies in SDSS groups, we investigate the dependence of star formation and morphology on host properties such as the X-ray luminosity and dynamical state, while controlling for stellar and halo mass. We find that galaxy populations in groups with strong X-ray emission have preferentially low star-forming and disc fractions, both within and beyond the radius associated with the X-ray emission. Additionally, we consider the effect of group dynamics on the properties of member galaxies and the infalling galaxy population separately. We show that the fraction of both star-forming and disc galaxies are independent of dynamical state for infalling galaxies, while galaxies within the virial radius are sensitive to the dynamical state of their host group. Specifically, low-mass galaxies in unrelaxed groups show higher star-forming and disc fractions. Together these findings help constrain the mechanisms at play in environmentally driven galaxy evolution.

Jay Franck

The Candidate Cluster and Protocluster Catalog (CCPC): Spectroscopically Identified Structures Spanning 2<z<6.6

We identify 218 candidate clusters and protoclusters at redshifts z>2 by mining lists of galaxies with spectroscopic redshifts. The selection criteria requires that systems exhibit an overdensity with respect to the field within a radius of R<20 comoving Mpc (cMpc). We demonstrate that these high redshift overdensities are real, physical associations, and not chance projections. At redshifts of z>4, we have found 42 protocluster candidates, including the most distant spectroscopically confirmed association known to date at z=6.56. There is also tantalizing evidence that some of these overdense systems belong to (proto)superclusters with lengths greater than 100 cMpc. The median velocity dispersion of the overdensities are a factor of 1.5 times larger than simulated N-body dispersions of the highest mass systems in the universe at these epochs.

Matthew Young

Constraining cosmological temperature evolution with Advanced ACTpol

In an adiabatically expanding universe, the temperature of the Cosmic Microwave Background (CMB) evolves with redshift z as a simple power law. This temperature evolution is commonly parameterized as $T_{CMB}(z) = T_0(1+z)^{1-\alpha}$, where deviations from the standard cosmological model (α=0) can suggest alternative physics at play. With the next generation of CMB experiments coming online in the near future (such as Advanced ACTpol), we can predict new constraints on α using expected survey parameters. Simulated thermal Sunyaev-Zel'dovich (tSZ) anisotropy maps will be used to quantify the survey's ability to locate galaxy clusters, mapping T(z) over the low redshift range ($z \leq 1$) and placing constraints on α. This method also enables limits to be placed on the noise and resolution requirements of CMB-S4 in constraining α to a set confidence level.

Michael Foley

Revised Uncertainties in Big Bang Nucleosynthesis

Big Bang Nucleosynthesis (BBN) explores the first few minutes of nuclei formation after the Big Bang. We present updates that result in new constraints at the 2σ level for the abundances of the four primary light nuclides - D,3He,4He, and 7Li - in BBN. The standard BBN code modified by Kawano is used in a Monte Carlo analysis of abundance formation at different baryon-to-photon ratios. Additionally, reaction rates have been updated to those of NACRE, REACLIB, and Descouvemont et al. Further the neutron lifetime has also been updated to 880.3 ± 1.1 from Particle Data Group 2014. We find strong agreement with recent observational constraints from A. Coc for Yp, D/H, and He3. However, we also find the lithium problem persists as our theoretical mean abundance value is a factor of 3.4 greater than the observational mean. We also discuss the possibility of new physics as a solution to this problem.

Nandan Roy

Dynamical Systems Analysis of Chameleon Cosmology Models

In this work we use dynamical systems analysis to find qualitative behaviour of chameleon cosmology models. In chameleon models the scalar field is coupled to matter Lagrangian in such a way that the mass of the scalar field is proportional to ambient matter density. We gave a complete diagnostic of fixed point and their stabity of all kind of combination of coupling constant and potential. The advantage of this kind of analysis is that with out finding an exact solution we can find the models which are more favourable.

Nathan Brunetti

An ALMA Archival Study of the Core Mass Function in the LMC

I present preliminary results of an ALMA archival study that combines data from two separate projects to build a large sample of clouds and cores in the Large Magellanic Cloud (LMC). These projects contain continuum and spectral line data of 30 Doradus, N159E and N159W over a combined area of ~10.1 square arcminutes in Bands 3 and 6 (~95 and ~228 GHz respectively). I focus on using the continuum data to estimate dust masses for these sources as well as an analysis of the cloud/clump properties to construct a clump mass function (CMF). The lower metallicity in the LMC will be used in comparison with galactic studies to explore the effects of metallicity on the CMF. I will also discuss the wider continuum and eventually spectral line archival studies that will be enabled by this data gathering approach. I plan to include N166, GMC 225, PCC 11546, N113 and potentially several Small Magellanic Cloud and Magellanic Bridge objects to build a data set with substantially improved statistics compared to any single ALMA project.

Ryan Plestid

The Role of Sterile Neutrino Dark Matter in Neutrino Oscillations

Sterile neutrinos are a viable dark matter candidate for masses in the 1-100 keV range. The strongest constraints on models with sterile neutrino dark matter (SNDM) tend to come from X-ray telescopes. These measurements constrain the mixing between sterile and active neutrinos; this can be parameterized by a mixing angle, . Sterile neutrinos can also induce neutrino masses, which have been observed, and represent the strongest evidence that the Standard Model is not complete. These masses are intimately linked to the aforementioned mixing angle. In this work we consider the possibility of SNDM significantly influencing neutrino oscillation phenomenology. We use X-ray data and a simple parametric relation to find a SNDM candidate's contribution to neutrino masses.

Ryley Hill

The spectrum of the Universe

The energy density of extragalactic background radiation, from radio waves to gamma-rays, carries information about the source of that energy. I describe this spectral energy distribution of the entire Universe using a complication of current data and explain what it tells us about the origin of these photons. Although most of this spectrum is "continuum", I will also show what the global line spectrum might look like. Considering this cosmic SED as the monopole mode of the sky distribution, it is clear how we could generalise to the the spectrum of variations on different angular scales – a datacube statistically describing the entire history of photon emission.

Workshop Attendees

Aaron E. Watkins	Case Western Reserve University
Aaron Ludlow	ICC, Durham University
Abdul Basit	Aligarh Muslim University
Adam Smercina	University of Michigan
Alex Richings	Northwestern University
Amandine Le Brun	CEA Saclay Service d'Astrophysique
Ameek Kaur Sidhu	Student
Ananthan Karunakaran	Queen's University
Anastasia Kasparova	Sternberg Astronomical Institute, Moscow State University
Andreas Schmidt	Max Planck Institute for Astrophysics (MPA)
Andrew Pontzen	University College London
Angus Mok	McMaster University
Anita Bahmanyar	Department of Astronomy and Astrophysics at University of Toronto
Arianna di cintio	DARK cosmology centre
Arka Banerjee	University of Illinois, Urbana-Champaign
Arya Farahi	University of Michigan - Ann Arbor
Ashley Bemis	McMaster University
Azi Fattahi	University of Victoria, Victoria, BC
Bekir Baytas	The Pennsylvania State University
Ben Keller	McMaster University
Bert Vandenbroucke	Ghent University
Boris Kriger	Independent Scientific Writer
Brian Devour	University of Michigan Astronomy Department
Catherine Fielder	University of Pittsburgh
Chad Bustard	University of Wisconsin - Madison
Chengyu Xi	University of Waterloo
Chiamaka Okoli	University of Waterloo/ Perimeter Institute
Chris Wilson	McMaster University
Christina Peters	Drexel University
Chukwuemeka Asogwa	University of Waterloo
Claes-Erik Rydberg	Heidelberg University
Dan Taranu	ICRAR/UWA
Daniela Carollo	Dept. of Physics and JINA Center for the Evolution of the Elements - University of Notre Dame - USA
David Williamson	Universite Laval
Derek Inman	University of Toronto
Dritan Kodra	University of Pittsburgh
Duncan Watts	Johns Hopkins University
Elisabetta Valiante	Cardiff University
Emmet Golden-Marx	Boston University Astronomy Department
Eric Bell	University of Michigan Astronomy
Facundo Rodriguez	Instituto de AstronomÃa TeÃ³rico y Experimental (IATE)
Federico Lelli	Case Western Reserve University
Fraser Evans	McMaster University

ATTENDEES

Gandhali Joshi	McMaster University
George Stein	CITA, University of Toronto
Gwendolyn Eadie	McMaster University
Haoran	Canadian Institute for Theoretical Astrophysics
Harisah Mehmood	University of Waterloo
He Hao	McMaster University
Honey M	Indian Institute of Astrophysics, Bangalore, India
Hugo Martel	Université Laval
Hui Li	University of Michigan
Ian Roberts	McMaster University
Isabel Santos-Santos	Dept. Fisica Teorica, Universidad Autonoma de Madrid, España
J Richard Bond	CITA Univ of Toronto
Jacob Bauer	Queen's University
Jacobo Asorey	University of Illinois at Urbana-Champaign
James Mertens	Case Western Reserve University
James Taylor	University of Waterloo
James Wadsley	McMaster University
Jay Franck	Case Western Reserve University
Jesse Golden-Marx	University of Michigan, Department of Astronomy
Joel Roediger	NRC Herzberg Astronomy & Astrophysics
Joey Rucska	McMaster University
Jonathan D Sloane	Rutgers University
Kamal Barghout	Prince Mohammad Bin Fahd University
Karim Jaffer	John Abbott College, Bishop's University
Kazuyuki Ogura	Ehime University (Japan)
Ke-Jung Chen	National Observatory of Japan
Laura Parker	McMaster University
Laura S. Chajet	York University
Lindsay Holmes	RMC
Mansour Karami	University of Waterloo
Marcel S. Pawlowski	Case Western Reserve University
Marcel van Daalen	UC Berkeley/LBL
Marcelo Alvarez	CITA
Matthew Johnson	York University and Perimeter Institute
Matthew Young	Dunlap Institute
Meagan Lang	NCSA, University of Illinois, Urbana-Champaign
Miao Li	Columbia University, Astronomy Department
Michael De Robertis	York University
Michael Foley	University of Notre Dame
Michael Petersen	University of Massachusetts at Amherst
Michael Tremmel	University of Washington
Mike Hudson	University of Waterloo
Miles Cranmer	McGill Space Institute

Nandan Roy	Harish-Chandra Research Institute
Natacha Altamirano	University of Waterloo/Perimeter Institute
Nathan Brunetti	McMaster University
Nathan Goldbaum	University of Illinois at Urbana-Champaign
Niayesh Afshordi	University of Waterloo and Perimeter Institute
Nicole Drakos	University of Waterloo
Niloufar Javid Khalili	McMaster University
Nishanth Sasankan	University Of Notre Dame
Noelia Jimenez	University of St Andrews, UK
Oindree Banerjee	Ohio State University
Oladotun Akinfolajimi	University of Cergy Pontoise, France
Paul Charlton	University of Waterloo
Philippe Berger	CITA
Prakriti Pal Choudhury	Department of Physics (Astrophysics), Indian Institute of Science, Bangalore, India
Pritpal Kaur Sandhu	Indian Institute of Technology Indore
Rachel Paterno-Mahler	University of Michigan
Reju Sam John	PEC, Pondicherry University, India
Rhea Kapoor	PESH, Plano, TX
Robbert Verbeke	Ghent University
Rongpu Zhou	University of Pittsburgh
Ryan Plestid	McMaster University & Perimeter Institute
Ryley Hill	University of British Columbia
Samantha Benincasa	McMaster University
Sandrine Codis	CITA
shahram khosravi	Alumus (PhD in physics) of Texas A&M University
Sijing Shen	University of Cambridge
Sownak Bose	Institute for Computational Cosmology
Stephane Courteau	Queen's University
Stephen Pardy	University of Wisconsin - Madison
Stephen Turnbull	University of Waterloo
Sukhdeep Singh	Carnegie Mellon University, USA
Susmita Adhikari	UIUC
Tetyana Nykytyuk	Main Astronomical Observatory NAS Ukraine
Thomas Mudway	McMaster University
Thomas Quinn	University of Washington
Tim Haines	University of Wisconsin-Madison
Traci Johnson	University of Michigan
Tuyets Cantlebury	PA
Varsha Kulkarni	University of South Carolina
Xin Wang	CITA
Zhengxiang Li	Beijing Normal University
Zimu Khakhaleva-Li	University of Chicago