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Resolving the Disk-Halo Degeneracy: A look at NGC 628

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The decomposition of the 21 cm rotation curve of galaxies into the disk and dark halo remains uncertain and depends on the adopted mass to light ratio (M/L) of the disk. Given the vertical velocity dispersion of stars in the disk and its scale height, the disk surface density and hence the M/L can be estimated. Earlier works (eg: Herrmann & Ciardullo, 2009) have used planetary nebulae (PNe) as probes to conclude that galaxy disks are submaximal. However, we aim to address an important conceptual problem that has previously not been included in the velocity dispersion estimates.

Measuring the surface density of the disk requires dispersion and a disk scale height but they must be for the same population of the tracers. Disks of spirals contain PNe of all ages. The younger PNe (ages < 2 Gyr) have relatively smaller scale height and velocity dispersion, compared to the older, kinematically hotter PNe. Since it is not possible to measure the scale height directly in face-on disks, we need to estimate it using the extensive I-band and near-IR photometric data for the old disks of edge-on galaxies. The spectra of the integrated light of the disk, which we use to measure the vertical velocity dispersion, comes from the luminosity-weighted stellar population of the disk and contains a considerable contribution from the kinematically colder, younger disk population. Combining the (single) measured velocity dispersion of the total young + old disk population with the scale height estimated for the older population would underestimate the disk surface density. Such a disk would have a peak rotational velocity that is less than that for the maximal disk, thus making it appear submaximal.

We present an analysis of NGC 628, a nearby face-on disk galaxy, using planetary nebulae (PNe) as tracers. We extend out to > 4 disk scale lengths and demonstrate the presence of a young, kinematically colder population of PNe and its effect on the disk-halo decomposition in this galaxy.

[1] K. A. Herrmann, R. Ciardullo, The Astrophysical Journal, 705, 1686-1703 (2009).

Phase space reconstruction of the dark matter density field with CMASS galaxies in Data Release 12

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We present a Bayesian phase space reconstruction of the cosmic matter density and velocity field from the SDSS-III Baryon Oscillations Spectroscopic Survey Data Release 12 (BOSS DR12) CMASS galaxy clustering catalogue in a cubical volume of 1250 h^{-1} Mpc side.

In particular, we use a Gibbs sampling approach, implemented in the ARGO code, to iteratively reconstruct the dark matter density field and the coherent peculiar velocities of individual galaxies. In each iteration we obtain distance estimates for each galaxy correcting for coherent redshift space distortions (RSD). This permits us to assume an isotropic power spectrum in the real-space cosmic density field reconstruction. This is done using Hamiltonian sampling assuming a lognormal prior and the negative binomial probability distribution function.

In this way we account for the galaxy bias model relating the dark matter field to the expected number counts of galaxies per volume element. As a crucial improvement we consider the completeness dependence of the lognormal renormalisation field.

Cosmic evolution is taken into account in the growth of structures, a redshift dependent galaxy bias and velocity field.

Including all the above mentioned ingredients we obtain unbiased power spectra of the nonlinear density field up to $k\sim0.3 h$ Mpc^{-1}, as compared to the N-body based emulators.

Our tests relying on accurate N-body based mock galaxy catalogues, demonstrate that we recover the real-space quadrupole, obtaining isotropic density field reconstructions.

Complete mapping of the local and more remote Universe – current status, future prospects

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I will discuss the current status and near-future prospects of low-redshift ($z<0.1$) as well as deeper (up to $z<0.5$) galaxy redshift surveys covering very large angular scales. So far, these have been mostly based on 2MASS data as well as on WISE. The large-scale structure up to $z<0.05$ is well mapped with spectroscopic redshifts (2MRS, 6dFGS) while higher redshifts on the full extragalactic sky are currently accessible only with the photometric approach (2MPZ, 2MASS PSC x WISE and WISE x SuperCOSMOS cross-matches). The situation is however going to improve in the coming years thanks to the TAIPAN survey starting later this year, as well as the LoRCA proposal; these two combined should provide complete spectroscopic mapping of 2MASS galaxies outside of the Zone of Avoidance. As far as the ZoA is concerned, the LSS behind it starts now to be comprehensively revealed thanks to HI surveys, such as HIZOA, with a promise of a more complete census with the SKA precursors ASKAP and APERTIF. The latter can eventually lead to alternative 3D mapping of the 4pi LSS, they will however still require optical and IR counterparts, provided beyond 2MASS by such surveys as WISE, VHS, as well as DES and KiDS on smaller angular scales.

Simulated thin Planes of Satellites in ΛCDM are not kinematically coherent

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A large fraction of the dwarf satellite galaxies orbiting the Andromeda galaxy are surprisingly aligned in a thin, extended and seemingly kinematically coherent planar structure. Such a structure is not easily found in simulations based on the Cold Dark Matter with Dark Energy model (ΛCDM). Using 21 high resolution cosmological simulations based on this model we propose a formation scenario for thin planes of satellites via the accretion of satellites along filaments in early forming haloes at higher redshift [1]. This formation scenario is able to naturally explaining the rareness of the planes and the fact that until now no difference in satellite properties between satellites in and off the plane is found [2]. We analyse the kinematical structure of planes of satellites resembling the one observed around Andromeda when co-rotation is characterized by the line-of-sight velocity. Investigation of the kinematics of the satellites in the plane reveals that the number of co-rotating satellites varies by 2 to 5 depending on the viewing angle. These variations are consistent with that obtained from a sample with random velocities. Using instead the clustering of angular momentum vectors of the satellites in the plane as a proxy for their co-rotation results in a better measure of the kinematic coherence. Thus we conclude that the line-of-sight velocity as a proxy for the kinematical coherence of the plane seems to be not a robust measure. Detailed analysis of the kinematics of our planes shows that they consist of ~30% chance aligned satellites. Tracking the satellites in the plane back in time reveals that the planes appear to be a transient feature and not kinematically coherent as would appear at first sight. Thus, if our simulations really resemble the plane of satellites around Andromeda, we predict some of the satellites in this plane to have a high velocity perpendicular to the plane.

[1] T. Buck et al., ApJ, Volume 809, Issue 1, article id 49, 6 pp. (2015)
[2] M. Collins et al., ApJL, Volume 799, Issue 1, article id L13, 6 pp. (2015)

The Local Group Factory

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The Local Group Factory is a pipeline designed to produce and simulate isolated halo pairs, with properties broadly compatible with those of MW and M31, within a large scale environment compatible with the observed one.

The properties of the simulated filament and Virgo are studied, to show that the method is able to consistently reproduce the observations while at the same time producing LG-like objects at a substantial rate [1].

As an example of the possible applications, it will be discussed how large samples of simulated LGs can be used to derive predictions for the tangential velocity of M31 [2]. This allows to test the degree of compatiblity of two conflicting estimates of this quantity ([3] and [4]) and to determine whether the standard cosmological model is at odds with any of them.

[1] E. Carlesi et al., in print, MNRAS, 2016

[2] E. Carlesi et al., submitted to MNRAS, 2016

[3] R.P. van der Marel et al., ApJ, 753, 8, 2012

[4] J.B. Salomon et al., MNRAS, 456, 4432, 2016

The Local Group planes of satellite galaxies

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One of the many puzzling aspects of the Local Group are the planes of satellite galaxies observed around the Milky Way and Andromeda. These are satellite configurations that are spatially thin and that show a large degree of coherent motion. Despite previous claims, I will discuss why there is no compelling evidence that these satellite planes pose a problem to LCDM. The planes are a common prediction of the LCDM model, with roughly 10% of haloes having satellite configurations that are even more prominent than the Local Group ones. While ubiquitous, the satellite planes show a large diversity in their properties. This precludes using one or two systems as small-scale probes of cosmology, since a large sample of such systems is needed to obtain a good measure of the object-to-object variation. This very diversity has been misinterpreted as a discrepancy between the satellite planes observed in the Local Group and LCDM predictions. A more promising avenue is to use these satellite configurations to infer their formation and accretion history and also that of their host halo. For example, the preferential directions of the halo can be significantly better constrained by using the satellite system in conjunction with the central galaxy.

Navigating the Universe ***Cosmic Flows program tenth year***

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We shall discuss the evolution of the “Cosmic Flows” program spanning ten years of research since its inception [2006-2016]. From CF1 to the latest CF3 data-set, an order of magnitude in the number of observational galaxy distances is gained, meanwhile the cosmographied volume is multiplied by 150. We shall further present the theoretical framework that has been developed so as to accommodate and analyze the data. This includes the Bayesian reconstruction tools of the Wiener filter and constrained realizations, constrained simulations of the local universe, visualization tools of the 3D large scale structure, the correction of the Malmquist bias & the analysis, and the cosmic web by means of the V(velocity)-web. Some specific topics that will be presented include advances in cosmography (the Laniakea and Arrowheads superclusters), the characterization of the flow by the dipole (bulk flow) and quadrupole (shear tensor) moments and constrained cosmological simulations.
The talk will conclude with a new major throughput in knowledge concerning the cosmic V-web.

How the first stars helped dwarf galaxies through reionization

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The number density of fain isolated late-type dwarfs is estimated to be roughly equal to that of corresponding dark-matter halos (Tollerud et al. 2015). Despite having circular velocities as low as 15 km/s, they have "survived" the reionization era. At this circular velocity, simulations predict over 90% of all halos to be dark because of the combined effects of supernova explosions and the cosmic ultraviolet background (Sawala et al. 2014). Only a small minority of the Local Group dwarfs shows evidence for their star formation to have been cut short by reionization (Hidalgo et al. 2013, Weisz et al. 2014). Thus, theorists are faced with the challenge of having low-mass dwarf galaxies retain their gas through the reionization era without them forming too many stars from this gas. Given the self-regulating nature of star formation, this has proven to be exceedingly difficult. Using new numerical simulations, we show that this dilemma can be effectively resolved by taking into account the impact of the ultraviolet radiation of Pop III stars on a dwarf's star formation rate while otherwise staying within the standard cosmological paradigm for structure formation (Verbeke et al. 2015).

This Pop III feedback is crucial for suppressing the star-formation rate in a dwarf's progenitors and thus delaying its star-formation history. This not only agrees with the delayed star-formation histories of observed dwarfs (Weisz et al. 2014) but is also key to having gas-rich dwarfs survive reionization. For the first time, these simulations produce isolated faint, neutral-gas dominated, star-forming dwarf galaxies that lie on the baryonic Tully-Fisher relation, and that, over a luminosity range of 10 magnitudes, reproduce a very broad range of chemical, kinematical, and structural observables of real dwarf galaxies.

In short, we have used detailed simulations to show that Pop III stars, while they were born over 10 billion years ago, had a lasting impact on their host galaxy and its progenitors and are an essential ingredient of realistic dwarf galaxy evolution simulations.

What can Andromeda II and Fornax dSphs tell us about their past?

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The Fornax and Andromeda II dwarf spheroidal galaxies are among the most conspicuous dwarfs in the Local Group. Fornax shows strong asymmetries in the spatial distribution of its stars. On the other hand, Andromeda II rotates mainly about its optical major axis. Using the deepest ground-based Color-Magnitude Diagrams available to date, deep HST photometry and spectroscopy of ~3000 stars, we present a comprehensive study of their resolved stellar populations, including their detailed star formation histories, both age and metallicity-dependent spatial distribution maps and their rotation patterns. Our results demonstrate that both systems are complex and rare, showing features suggesting a tumultuous past. We study the mechanisms that may have affected their evolution and propose different merger scenarios to explain their properties using, in the case of Andromeda II, N-Body simulations.

[1] del Pino, A. et al. 2013, MNRAS, 433, 1505

[2] Łokas, E. L. et al. 2014, MNRAS, 445, 6

[3] del Pino, A. Aparicio, A., and Hidalgo, S. L. 2015, MNRAS, 454, 3996

Stars in EMMA

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The apparition of the first stars radically changed the state of the gas in the Universe. With their highly energetic radiation, they heat up and ionize the surrounding gas. Moreover, at the end of their life, stars explode in supernovae, which create swirl in the gas around them. But this gas is also the main material used to grow the next generation of stars, and a change in his state could have consequence on the star formation rate of the futures generations. To study this period of intense change, induced by a complex coupling into different physics, we use numerical simulations.

I'm working with EMMA [1], an AMR cosmological code with fully coupled radiative hydrodynamics, in which one I've implement a star formation recipe and different types of supernovae feedback.

Historically, first models of supernovae, used a thermal way to inject energy in the gas, but this model is now known to be inefficient, as the gas can cool really fast compared to the dynamical time scale. To avoid this, some tricks has been developed, like using a kinetic form of feedback, or using a delayed cooling method. Depending of the chosen method, and with still the same amount of energy injected, the response of the gas can be really different. There is still no consensus about wich method to use.

Now, with the introduction of radiation in simulations, it seams that we are observing the same behavior, when injecting radiative energy from stars. I observe that the way photons are puts in the medium drastically change the reionization history, while the total number of emitted photons is conserved.

Understanding this behavior is crucial for a good interpretation of simulations results.

[1] Dominique Aubert, Nicolas Deparis, Pierre Ocvirk. EMMA: an AMR cosmological simulation code with radiative transfer.

Reionization and the Local Group

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The ultraviolet background (UVB) and its evolution affect galaxy formation, including that of the Milky Way (MW). The reionization of hydrogen, resulting from the first stars and galaxies, is an important driver of the evolution and character of the UVB above z = 6. In turn, the growing UVB can suppress star formation, which delays reionization either locally or globally. The MW resides in the Local Group, which resides in a particular place in the Universe. This configuration matters for the reionization history of the Local Group. To understand the progression of reionization, we perform full radiative transfer on the dark matter fields from a 64 Mpc/h constrained simulation. We calculate the reionization history of the MW and its satellites. We address whether the LG reionizes from the inside-out or outside-in. We also estimate the star formation that occurs in the MW satellites before the end of reionization. Since the exact nature of radiative feedback on ionizing sources is unknown, we explore several source models.

A reconciliation scenario for the origin of the disk of satellites

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The origin of the vast disk of satellites (DoSs) found around the Milky Way, Andromeda and possibly more distant galaxies, remains elusive. One reason for that is that the dwarf galaxies within the DoSs share at the same time properties expected for tidal dwarf galaxies formed in situ (spatial distribution, velocities with respect to the host) and those for classical accreted dwarf galaxies (Stellar populations, structure, high M/L). I will present, based on ultra deep optical images of old mergers, and idealized simulations of galaxy collisions, a possible scenario to reconcile the intriguing properties of the satellite galaxies with both the tidal and cosmological accretion scenarios [1].

[1] B Smith, P.-A. Duc et al., 2015, ApJ 818, 11 .

Reconciling the conflict between LCDM predictions

and the circular velocities of nearby field galaxies

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We compare the half-light circular velocities, $V_{1/2}$, of dwarf galaxies in the Local Group to the predicted circular velocity curves of galaxies in the NIHAO suite of ΛCDM simulations. We use a subset of 34 simulations in which the central galaxy has a stellar mass in the range $10^5 < M_{\rm star}/M_\odot < 10^8$. The NIHAO galaxy simulations reproduce the relation between stellar mass and halo mass from abundance matching, as well as the observed half-light size vs luminosity relation. The corresponding dissipationless simulations over-predict the half-light circular velocities, recovering the problem known as too big to fail (TBTF). By contrast, the NIHAO simulations have expanded dark matter haloes, and provide an excellent match to the distribution of $V_{1/2}$ for galaxies with $L_V > 2\times10^6\, L_\odot$. For lower luminosities our simulations predict very little halo response, and tend to over predict the observed circular velocities. In the context of ΛCDM, this could signal the increased stochasticity of star formation in haloes below $M_{\rm halo} \sim 10^{10}\, M_\odot$, or the role of environmental effects. Thus, haloes that are "too big to fail", do not fail ΛCDM, but haloes that are "too small to pass" (the galaxy formation threshold) provide a future test of ΛCDM. [1]

[1] A. A. Dutton, A.V. Macciò, Jonas Frings, et al., MNRAS, 457L, 74 (2016).

The APOSTLE project: mass of the Milky Way satellites and the too-big-to-fail problem

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The consistency of the observed mass distribution in the inner region of dwarf galaxies and LCDM predictions is debated. The cusp-core and too-big-to-fail problems are studied almost exclusively using dwarf galaxies in and around the Local Group. We use the APOSTLE project [1,2], a suite of state-of-the-art high resolution hydrodynamical zoom-in simulations of regions selected from a cosmological volume to resemble the Local Group, to study the inner mass distribution of Local Group dwarfs. We particuarly look at the dynamical mass estimates for the Milky Way dwarf satellites within their half-light radii while considering all the observational and systematic errors, and compare them with the predictions of the simulations. Statistical anslysis of the mass distributions reveals consistent results amongst observed and simulated Milky Way satellites. We revisit the too-big-to-fail problem with the new mass estimates for the Milky Way satellites, and confirm findings of [1] that there is no such problem in APOSTLE simulations.

[1] Sawala, T., et al., MNRAS, 457, 1931 (2016).

[2] Fattahi, A., et al., MNRAS, 457, 844 (2016)

Modeling the kinematics and star formation history of Andromeda II by a gas-rich major merger of dwarf galaxies

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We present an evolutionary model for the origin of Andromeda II, a dSph satellite of M31. The model is an extension of the scenario proposed by [1] involving a major merger between two gas-rich disky dwarf galaxies.

The simulation traces the evolution of two initially gas-rich disky dwarfs galaxies, placed on a radial orbit towards each other with their angular momenta inclined by 90 deg. After a few Gyr the merger remnant forms a stable triaxial galaxy with rotation mainly around the longest axis. This explains the origin of prolate rotation recently detected in the kinematic data for And II.

The merger triggers the formation of new stars, mainly in the center of the dwarf galaxy where the gas density is the highest. Thus the model successfully explains the origin of two stellar populations in And II, the observed excess of stars in the central stellar density profile of And II and the And II star formation history.

We also take into account the interaction between the remnant of the merger and M31. This could explain the lack of gas in And II and the sudden stop of the star formation 5 Gyr ago.

[1] E. Łokas, I. Ebrová, A. del Pino, M. Semczuk, MNRAS 445 L6 (2014)

Tidally induced bars in dwarf galaxies

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One of the possible explanations for the morphology-density relation in the Local Group is the tidal stirring scenario, where an initially disky dwarf is accreted by a large galaxy and then gradually transformed into a spheroid via tidal interaction with the host. An intermediate stage of this process involves the formation of a bar in the disk of the dwarf. Such tidally induced bars may be present in some of the Milky Way satellites, like the Sagittarius dwarf, Ursa Minor or Hercules. I will present the analysis of N-body simulations of dwarf galaxies orbiting a Milky Way-like host focusing on the evolution of the shape and kinematics of the bar. I will demonstrate that due to the interaction with the host galaxy the bar is weakened and slows down on the time scale of a few Gyr, but the pattern speed exhibits some variation. The final outcome of the evolution depends on the initial orientation of the dwarf's disk with respect to the orbit resulting in significant differences between the properties of the bar formed on exactly prograde and inclined orbits. Results concerning the orbital structure of tidally induced bars will also be discussed. In the inner part of the bar, the orbits have mainly boxy shapes and only small fraction have shapes similar to classical periodic x_1 orbits.

Vast Plane of Satellites in CLUES: from the reionization to satellite populations.

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The plane of satellites problem is one of the small scale challenges of the cosmological standard model Lambda-CDM. We investigate Vast Plane of Satellites in a high resolution hydrodynamics simulation of the Local Group performed by the CLUES project. This study is the continuation of the analyze of Andromeda like planar structures in the set of CLUES simulations.

We use in this study a well constrained Local Group particularly in term of mass of the Milky Way and Andromeda, which are more massive than the precedent simulation and in the high part of the observed estimations. It will permits to explore the influence of the host's mass on the satellite populations and the probability to find a planar structure. We also perform a realistic simulation of the reionization that permit to probe and compare different models of satellite populations with the observations.

In this study we find planes similar to the observed one but none of the detections can quantitatively reach a significance as strong as the observations.

Near field cosmology with constrained simulations: the CLUES project

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Numerical simulations are the driving force behind much of the theoretical progress in our understanding of the formation of structure in the universe. Cosmological simulations must cover a large dynamical and mass range. A representative volume of the universe should be large, but this comes at the expense of the resolution. To overcome this problem a new approach has been developed which consists of using observations of the nearby universe as constraints imposed on the initial conditions of the simulations.

The resulting constrained simulations successfully reproduce the observed structure within a few tens of megaparsecs around the Milky Way including the nearby well-known clusters of galaxies. Zoomed high-resolution gas-dynamical simulations allow to study the formation of the Local Group in the right large scale environment. We have performed such simulations within the CLUES project (Constrained Local UniversE simulations, http://www.clues-project.org). I will review briefly the progress made over the last decade and give an outlook to new projects.

Push it to the limit: Local Group constraints on high-redshift stellar mass functions for $M_\star \geq 10^5\,M_\odot$

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We constrain the evolution of the galaxy stellar mass function from $2 < z < 5$ for galaxies with stellar masses as low as $10^5\ M_\odot$ by combining star formation histories of Milky Way satellite galaxies derived from deep Hubble Space Telescope observations with merger trees from the `ELVIS` suite of N-body simulations. This approach extends our understanding more than two orders of magnitude lower in stellar mass than is currently possible by direct imaging. We find the faint end slopes of the mass functions to be $\alpha = 1.42^{+0.07}_{-0.05}$ at $z = 2$ and $\alpha = 1.57^{+0.06}_{-0.06}$ at $z = 5$, and show the slope only weakly evolves from $z = 5$ to $z = 0$. Our findings are in stark contrast to a number of direct detection studies that suggest slopes as steep as $\alpha =$ -1.9 at these epochs. Such a steep slope would result in an order of magnitude too many luminous Milky Way satellites in a mass regime that is observationally complete ($M_\star > 2 \times 10^5 M_\odot$ at $z = 0$). The most recent studies from ZFOURGE and CANDELS also suggest flatter faint end slopes that are consistent with our results, but with a lower degree of precision. This work illustrates the strong connections between low and high-z observations when viewed through the lens of ΛCDM numerical simulations.

The Magellanic Stream: two ram-pressure tails and the relics of the collision between the Magellanic Clouds

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The Magellanic Stream: two ram-pressure tails and the relics of the collision between the Magellanic Clouds [1]

Abstract: We have analysed the Magellanic Stream (MS) using GASS, which is the deepest and the most resolved HI survey of the Southern Hemisphere. Along all its length, the Stream is structured into two filaments suggesting two ram-pressure tails lagging behind the Magellanic Clouds (MCs). The past motions of the Clouds appear imprinted in them, implying almost parallel initial orbits, and then a radical change after their passage near the N(HI) peak of the MS. This is consistent with a recent collision between the MCs, 200-300 Myr ago, which has stripped further their gas into small clouds, spreading them out along a gigantic bow-shock, perpendicular to the MS.

The corresponding hydrodynamical modelling reproduces the MS morphological distribution, its velocity and column density. It is consistent with a Milky Way (MW) halo hot gas of n_h= 10^{-4} cm^{-3} at 50-70 kpc, a value necessary for explaining the MS multiphase HVCs. The Stream filamentary structure is expected to survive KH instabilities. The 'ram-pressure plus collision' scenario requires tidal dwarf galaxies, which are assumed to be the Cloud and dSph progenitors, to have left imprints in the MS and the Leading Arm, respectively.

[1] F. Hammer, Y. B. Yang, H. Flores, M. Puech and S. Fouquet, Astrophys. J. 813, 110 (2015).

Cosmic velocity fields as probes of the nature of gravity

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Peculiar velocities of galaxies reflect continued action of gravity working throughout the whole cosmic expansion history. This indicates that velocity-based probes and observational statistics are, in principle, very well posed to be sensitive to even very moderate modifications to the standard force-law of General Relativity. Whether it be a theory of modified gravity, or a model of an interacting Dark Energy, the cosmic galaxy velocity field should be sensitive to induced deviations from the standard growth of structures scenario. I am going to present a class of velocity-based observational statistics that can be used to test GR on intermediate cosmological scales. I will also discuss weak and strong points of various probes and give some prospects for the future.

N-Body Time Machine

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I'll present an algorithm to calculate cosmological initial conditions that lead to some desired final particle configuration when evolved forward in time. It is a time machine in the sense that under certain constraints we can use galactic surveys as input, and the algorithm will find the appropriate initial conditions at high redshift. These initial conditions, when evolved forward in time using any N-Body code (e.g. Gadget2) will give the exact configuration observed in the galactic survey used as input

Orbit anisotropy of dark matter haloes with Schwarzschild modeling

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Using mock data obtained from four numerical realizations of dark matter haloes differing in the orbit anisotropy, we investigate the reliability of recovering the underlying anisotropy parameter profiles using the Schwarzschild orbit superposition method. Our data sets contain interesting models of both constant and varying (growing or decreasing) profiles of anisotropy. We also explore the effect of small samples of tracing particles and the sampling errors in order to apply the method to dwarf galaxies of the Local Group.

A **Bound Violation on the Galaxy Group Scale: The Turn-Around Radius of NGC 5353/4**

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The following abstract is extracted from Lee et al. (2015, ApJ, 815, 43) : The first observational evidence for the violation of the maximum turn-around radius on the galaxy group scale is presented. The NGC 5353/4 group is chosen as an ideal target for our investigation of the bound-violation because of its proximity, low-density environment, optimal mass scale, and existence of a nearby thin straight filament. Using the observational data on the line-of-sight velocities and three-dimensional distances of the filament galaxies located in the bound zone of the NGC 5353/4 group, we construct their radial velocity profile as a function of separation distance from the group center and then compare it to the analytic formula obtained empirically by Falco et al. (2014) to find the best-fit value of an adjustable parameter with the help of the maximum likelihood method. The turn-around radius of NGC 5353/4 is determined to be the separation distance where the adjusted analytic formula for the radial velocity profile yields zero. The estimated turn-around radius of NGC 5353/4 turns out to substantially exceed the upper limit predicted by the spherical model based on the LambdaCDM cosmology. Even when the restrictive condition of spherical symmetry is released, the estimated value is found to be only marginally consistent with the LambdaCDM expectation.

[1] Lee, J., Kim, S. & Rey, S.-C. 2015, ApJ, 815, 43

[2] Falco, M., Hansen, S.H., Wojtak, R., et al. 2014, MNRAS, 442, 1887

Planes of Satellites in the Local Universe:

Interactions, Dark Matter & Long Term Stability

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Both the Milky Way and Andromeda possess thin planes of satellite galaxies, structures at odds with models of galaxy formation and evolution. But are these transient features, or long-term structures? In this talk, I will review recent work on the stability of coherent satellite planes within galactic halos, considering the impact of halo triaxiality, other orbiting satellites, and the presence of dark matter subhalos. We find that these features can significantly impact the survivability of satellite planes, with significant implications for the nature of dark matter, the shape of the dark matter halo, and the formation of planes of satellites.

Planes of dwarfs

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Recent observational studies have demonstrated that the majority of satellite galaxies tend to orbit their hosts on highly flattened, vast, possibly co-rotating planes. Two nearly parallel planes of satellites have been confirmed around the M31 galaxy and around the Centaurus A galaxy, while the Milky Way also sports a plane of satellites. It has been argued that such an alignment of satellites on vast planes is unexpected in the standard (LCDM) model of cosmology if not even in contradiction to its generic predictions. Guided by LCDM numerical simulations, which suggest that satellites are channeled towards hosts along the axis of the slowest collapse as dictated by the ambient velocity shear tensor, we re-examine the planes of local satellites systems within the framework of the local shear tensor derived from the Cosmic dataset. The analysis reveals that the Local Group and Centaurus A reside in a filament stretched by the Virgo cluster and compressed by the expansion of the Local Void. Four out of _ve thin planes of satellite galaxies are indeed closely aligned with the axis of compression induced by the Local Void. Being the less massive system, the moderate misalignment of the Milky Way's satellite plane can likely be ascribed to its greater susceptibility to tidal torques, as suggested by numerical simulations. The alignment of satellite systems in the local universe with the ambient shear field is thus in general agreement with predictions of the LCDM model.

[1] Libeskind et al MNRAS, 452, 1052 (2015)

Cosmic Flows via an all-sky sample of NIR FP Cluster Distances

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Fundamental plane (FP) distances and peculiar velocities have been determined for an all-sky set of 88 nearby clusters ($0.020 < z < 0.055$). This dataset was constructed by adopting velocity dispersion measurements from the published surveys and deriving photometric parameters (effective radii and surface brightnesses) from 2MASS J-band image tiles. Cluster distances were determined using the "inverse" FP relation which resulted in a distance error per galaxy of 19%. The FP galaxies used per cluster range from 15 to 100 which resulted in a mean cluster distance error of ~4%. In the CMB frame the cluster sample has a small bulk flow amplitude, i.e. less than 170 km/s with an uncertainty of 120 km/s. We recover the expected Local Group motion with respect to the CMB.

Stellar photometry of unusual void galaxy DDO68

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DDO68 (UGC5340) is an unusual dwarf galaxy with the record-low gas metallicity (12 + log(O/H) = 7.14) residing in the nearby Lynx-Cancer void. Despite its apparent isolation, both the optical and Hi morphology evidence for the strong tidal disturbance. Here we study the resolved stellar populations of DDO68 using deep images from the HST archive. We determined the distance of 12.75±0.41Mpc using the tip of the red giant branch (TRGB). The star formation history reconstruction reveals that about 60 per cent of stars have been formed during the initial period of star formation about 12–14 Gyr ago. During the next 10 Gyr DDO68 was in the quenched state with only slight traces of star formation from 1 to 12 Gyr. The onset of the most resent burst of star formation have occurred about 300 Myr ago. We find that the young population with ages of several million to a few hundred million years is widespread over various parts of DDO68, indicating an intense star formation episode with the high mean rate of 0.15 $M_\odot$/yr. The major fraction of visible stars in the whole system (~ 80 per cent) has the low metallicity: $Z = Z_\odot/50$–$Z_\odot/20$. The properties of the northern periphery of DDO68 can be explained by an ongoing burst of star formation induced by a minor-merger of a small gas-rich extremely metal-poor galaxy with a more typical dwarf galaxy. The current TRGB-based distance of DDO68 implies its total negative peculiar velocity of ≈ 500 km/s.

Andromeda XVIII and other nearby isolated dwarf spheroidals: clues on evolution and stellar populations

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We present photometric study of the Andromeda XVIII dwarf spheroidal galaxy associated with the M31 giant spiral galaxy, and situated well outside of the virial radius of the M31 group. The galaxy was resolved into stars with Hubble Space Telescope/Advanced Camera for Surveys including old red giant branch and red clump. With the new observational data we measured Andromeda XVIII distance of $1.33^{+0.06}_{-0.09}$ Mpc using the tip of red giant branch method. Thus, the dwarf is situated at the distance of 579 kpc from the M31 galaxy. We model star formation history of Andromeda XVIII from the stellar photometry results and Padova theoretical stellar isochrones. According to our calculation, the ancient burst of star formation has occurred 12-14 Gyr ago. There are also indications of continuous star formation from 1.5 to 8 Gyr ago. There is no signs of recent/ongoing star formation in the last 1.5 Gyr of the Andromeda XVIII's life. The mass fraction of the ancient and intermediate age stars is 34 and 66 per cent, respectively. The total stellar mass of Andromeda XVIII is estimated as $4x10^{6}$ M_sun. There is some evidence that the galaxy did not experienced any interaction in the past. It is highly possible, that star formation processes were going in this dwarf spheroidal galaxy without influence of an interaction with the giant spiral M31. We also discuss star formation processes and possible evolution scenarios of dSphs KKR25,KKs03, as well as dTr KK258. Their star formation histories were uniformly measured by us from HST/ACS observations. All the galaxies are situated well beyond the Local group virial radius, and two unique dSphs KKR25 and KKs03 are extremely isolated. It should be expected, that the evolution of all these objects was run without any external influence.

The connection between Galaxies and their Dark Matter haloes from Large-scale Structure to Dwarfs

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Semi-empirical galaxy formation models provide a unique and direct link between galaxies and dark matter haloes, and do not depend on model assumptions on unresolved physics. On large scales they have been very successful in explaining the clustering of galaxies. However, on small scales and for low mass galaxies, this galaxy-dark matter connection is not yet understood well, and often extrapolated from more massive galaxies. I will present the next generation of semi-empirical galaxy formation models that take into account the assembly history of the dark matter haloes. While previous models determined galaxy quantities only as an average for a given halo mass, the new models can predict stellar mass, star formation rate, gas mass, and colour for individual systems based on their formation history. I will discuss how this model can be extended to the dwarf galaxy regime using the latest observations, and how it can be used to study the formation of the Local Group. Furthermore I will present star formation histories for quenched and star-forming galaxies and their correlation with the cosmic web. In this context I will discuss the newest results on galactic conformity, i.e. quenched galaxies typically residing in quenched neighbourhoods, and how this can help us to understand galaxy formation.

Shooting Centaurus: new dwarf galaxies in multipacks

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We report on the first results of a large-scale survey of the southern Centaurus and Sculptor groups with the wide-field cameras of the Dark Energy Survey (DECam) and the australian SkyMapper telescope. The aim of the survey is to push down the completeness limit of the Centaurus and Sculptor galaxy populations down to absolute magnitudes of -10, allowing a systematic study of the abundance and distribution of dwarf galaxies in group environments beyond the Local Group. Are the dwarf satellites underabundant and distributed in planar structures in these groups (and probably elsewhere) as well, or are these strange features a local phenomenon confined to the LG? This is a key question for models of structure formation and the problem of dark matter. So far we have imaged an area of roughly 600 square degrees in Centaurus with DECam covering both subgroups around M83 and CenA. About 50 new (unresoved) dwarf candidates have been discovered. Their photometric parameters suggest Cen group membership. Distance measurements for part of the galaxies are underway. Asymmetries in the dwarf distribution (aside from those suggested by Tully et al. [1]) are clearly present.

[1] Tully et al. ApJ 802L, 25T (2015).

Dynamics in the nearest Mpcs

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A dynamical analysis of the motion of galaxies within 5Mpc will be presented in detail. In particular, reconstructing the past orbit of the Local Group galaxies using Peebles' least action method provides masses of M31 and MW. Although smaller galaxies are not important dynamically, their kinematic information will break the mass degeneracy inherent in the classical timing argument of two body system.

The reionization of the local group in the Cosmic Dawn simulation

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The Cosmic Dawn simulation is a massive, fully coupled radiation-hydrodynamics simulation of the reionization of the local Universe. Thanks to the carefully constructed initial conditions provided by the CLUES collaboration, it contains a Milky Way - M31 galaxy pair, embedded in a realistic environment, up to the Virgo and Fornax clusters. I will shortly introduce the simulation, and use it to illustrate the reionization of the local group of galaxies, and discuss the internal versus external nature of the process.

Missing dark matter in nearby dwarf galaxies?

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We use cosmological hydrodynamical simulations of the APOSTLE project to examine the fraction of baryons in ΛCDM haloes that collect into galaxies. This `galaxy formation efficiency' correlates strongly and with little scatter with halo mass, dropping steadily towards dwarf galaxies. The baryonic mass of a galaxy may thus be used to place a lower limit on total halo mass and, consequently, on its asymptotic maximum circular velocity. A number of dwarfs seem to violate this constraint, having baryonic masses up to ten times higher than expected from their rotation speeds, or, alternatively, rotating at only half the speed expected for their mass. Taking the data at face value, either these systems have formed galaxies with extraordinary efficiency – highly unlikely given their shallow potential wells – or they inhabit haloes with extreme deficits in their dark matter content. This `missing dark matter' is reminiscent of the inner mass deficits of galaxies with slowly-rising rotation curves, but extends to regions larger than the luminous galaxies themselves, disfavouring explanations based on star formation-induced `cores' in the dark matter. An alternative could be that galaxy inclination errors have been underestimated, and that these are just systems where inferred mass profiles have been compromised by systematic uncertainties in interpreting the velocity field. This should be investigated further, since it might provide a simple explanation not only for missing-dark-matter galaxies but also for other challenges to our understanding of the inner structure of cold dark matter haloes.

The too-big-to-fail problem is too-persistent-to-die:

new constraints from nearby field dwarfs

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The "too big to fail" (TBTF) problem is a pressing observational challenge to the standard cosmological model at small scales. Put simply, it refers to the fact that it is very challenging to explain both the internal kinematics and the observed number density of dwarfs in the ΛCDM context. Even though the problem was first identified in the context of the Milky Way satellites, it has now become clear that it concerns dwarf galaxies in general. In this talk, I first plan to give an overview of the observational evidence that supports the statements above. I then plan to give a brief overview of the most promising solution to the problem, which is a "baryonic" solution within ΛCDM. I will conclude by showing how present and future observations of HI in nearby field dwarfs can help us distinguish between a cosmological and an astrophysical solution for TBTF.

The Satellite Galaxy Plane Problem: Biases and Baryons

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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 appear to 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 ΛCDM. However, the current debate on this topic is highly controversial. Claims range from rejecting that there is significant evidence for the existence of satellite planes, over them being natural in cosmological simulations (despite not having been predicted), to them being catastrophic failures of ΛCDM cosmology itself. A major difficulty in comparing current studies is that they are based on different assumptions and often do not take observational biases into account. I will argue that a statistically robust comparison requires great care, in particular the mock observation of sub-halo satellites from the simulations need to apply similar selection functions as present for the observational data and spatial effects need to be controlled for when searching for correlations between satellite planes and their host halos' properties. I will also discuss 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 address whether there is evidence that baryonic physics has an effect on the frequency and properties of satellite galaxy planes in cosmological simulations.

How massive is the LMC?

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Although the Large Magellanic Cloud (LMC) is the most luminous satellite galaxy of the Milky Way its mass remains largely unconstrained. In this talk I will show that the observed dynamics of galaxies in the local Hubble flow (<3 Mpc) can be used to weigh the LMC. The resulting bounds are consistent with abundance-matching constraints, suggesting that the LMC is embedded in an extended dark matter halo adding support to the scenario where this galaxy was accreted onto the Milky Way only recently. I will discuss the implications of a large LMC on the Galactic potential in the era of Gaia.

[1] Pe{\~n}arrubia, J., G{\'o}mez, F.~A., Besla, G., Erkal, D., \& Ma, Y.-Z.\ 2016, MNRAS, 456, L54

Ginnungagap – a cosmological initial conditions generator

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Ginnungagap is a code for generating cosmological initial conditions. It is aimed at high scalability and ease of use. Its features include refinement of low resolution initial conditions to a higher resolution, zoom-in technique, it also can use white noise fields prepared by other programs (e.g. constrained realizations) and it is fully MPI-parallel. These features can be used to effectively prepare initial conditions for the new generation of Constrained Local UniversE Simulations.

Identifying connections between large-scale structure and galaxy evolution – views on dynamically active cluster systems and cluster disk galaxies at low redshift

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Over the last decade, using numerical simulations and large observational surveys, substantial effort has been made to answer one of the main open questions of observational cosmology, that is the connection between the evolution of galaxies and the properties of their host haloes. At low redshifts, the physics behind these connections can be directly investigated, thanks to high-quality observational data. In this talk, the results of two research projects investigating the interplay between galaxy properties and properties of their large-scale hosts (galaxy groups and clusters) will be discussed. In addition, an outlook to project follow-ups and a brief discussion of their expected results for improving current models of galaxy evolution at low redshift will be presented.

In a first project, we investigated the properties of galaxies hosted by two comparable low-redshift clusters with different dynamical states, using XMM-EPIC X-ray data, 2dF and EFOSC2 multi-object spectroscopy and ESO 2.2m WFI multi band imaging. We detected imprints of ongoing cluster- and group-mergers on the galaxy populations in terms of SF-activity, galaxy morphology and colour. Quality and intensity of these imprints appear to depend on the dynamical state of the clusters.

In the second project, we analysed surface brightness profiles, colours and morphologies for a sample of 180 low-redshift field and cluster galaxies selected from the NYU-VAGC. Based on the results of this work, we suggest a new scheme for environment-driven galaxy evolution for the regime of disk galaxies at low redshift.

Connecting the Cosmic Infrared Background, the Dark Matter Particle, and the Old Local Stellar Population

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Redshifted UV emission from reionization era galaxies is expected to contribute to the cosmic infrared background (CIB). A warm dark matter universe should have a lower CIB than a cold dark matter universe due to the suppression of low mass halos. If we live in a warm dark matter universe, future deep surveys should be able to "resolve away" the contribution of high redshift galaxies to the diffuse CIB. However, if we live in a CDM universe, some diffuse background from stars in faint galaxies lying in small high redshift halos should remain unresolvable. Recent measurements derived from spatial fluctuations of the diffuse CIB [1] suggest a large contribution from redshift 10 galaxies, which, if correct, would be difficult to reconcile not only in WDM, but also in CDM. We consider the old stellar population in local dwarfs and larger galaxies that would be expected to have descended from a CIB made of unresolved high redshift galaxies.

[1] K. Mitchell-Wynne, et al., Nature Communications, 6, 7945 (2015).

MUSE crowded field 3D spectroscopy in nearby galaxies: first results from NGC300

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We present first results from crowded field 3D spectroscopy with MUSE in the Sculptor group galaxy NGC300. We show that under conditions of excellent seeing, and using a novel PSF-fitting technique, we are able to extract hundreds of spectra per field that provide sufficient signal-to-noise to classify spectral types for stars of luminosity class I-III, and thus to distinguish blue/red supergiants, carbon and oxygen rich AGB stars, WR stars, and other massive stars. Thanks to the unique sensitivity and image quality of MUSE we also measure the unresolved background of faint stars and detect emission line objects (compact HII regions, planetary nebulae, supernova remnants, and the diffuse ISM) down to unprecedented faint flux levels. We discuss the potential of this new technique for extragalactic archeology and prospects towards the future E-ELT.

The Apostle Simulations: Solutions to the Local Group's Cosmic Puzzles

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The dwarf galaxies of the Local Group represent some of the most discriminating tests of structure formation on small scales, and of the Lambda-CDM cosmological model. Based on results from the APOSTLE suite of cosmological hydrodynamic simulations of the Local Group [1], I will discuss how the impact of baryonic physics affects the relation between the observed galaxies and the underlying dark matter structures. In particular, I will show that many of the apparent small-scale failures of Lambda-CDM can be resolved when radiation processes including supernova feedback and reionisation are taken into account, resulting in a Local Group dwarf galaxy population that matches the observed one.

[1] Sawala et al., MNRAS, 2016, volume 457, pages 1931-1943

Formation and evolution of spiral arms in galaxies orbiting a Virgo-like cluster

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The observed morphology-density relation places spiral galaxies in regions of low density: the field or outskirts of clusters. While reasons for this arrangement are more or less known, the origin of spiral structure in galactic disks still remains a mystery. One of the propable scenarios for the creation of two-armed, grand-design spiral arms involves tidal interactions with external objects. We use N-body simulations to study the evolution of a Milky-Way size galaxy in the a Virgo-like cluster. The galaxy is placed on a few orbits of different size but similar eccentricity. We find that grand-design spiral arms form on each of them, but are most pronounced for the most extended orbit where tidal forces are relatively mild. We measure the properties of the arms, such as the pitch angle, the strength and the pattern speed as a function of time. The arms found in simulations are approximately logarithmic, but are also dynamic, transient and recurrent. They are triggered by pericenter passages and after that they wind up and dissipate. We interpret the results in the context of the Hubble sequence.

Studying the Milky Way with RR Lyrae Stars in the Era of Pan-STARRS1, GAIA, and LSST

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RR Lyrae stars are high-precision, high-contrast tracers of Galactic structure, substructure, and kinematics whose usefulness will only increase once GAIA data become available in the near future. In my talk, I will describe some exciting science cases that can be tackled using the largest (56,000 stars), widest (covering 3/4 of the sky), and deepest (up to 120 kpc) sample of RR Lyrae stars selected from the Pan-STARRS1 survey. These science cases include a search for faintest Milky Way satellites, constraining the Galactic potential, and mapping the structure of the ancient Galactic disk. I will also emphasize the importance of tools and approaches, such as machine learning and forward modeling, that we should employ when dealing with future large data sets.

[1] B. Sesar, S. R. Banholzer, J. G. Cohen, et al., ApJ, 793, 135 (2014)

[2] B. Sesar, J. Bovy, E. J. Bernard, et al., ApJ, 809, 59 (2015)

[3] N. Hernitschek, E. F. Schlafly, B. Sesar, et al., ApJ, 817, 73 (2016)

Unveiling the cosmic web through intensity mapping of IGM filaments

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Most of the baryons in the Universe are located in filaments in the intergalactic medium, however the low surface brightness of these filaments has not yet allowed their direct detections except in very special regions in the circum-galactic medium.

I will show estimates for the intensity and spatial fluctuations of Lyman Alpha emission from IGM filaments illuminated by the UV background and discuss the prospects for the next generation of UV space based instruments to detect this signal from the local Universe to the epoch of peak star formation activity. By mapping the emission from these filaments we will be able to probe the non-linear regime of structure formation which can be used to test key predictions from the LCDM cosmological model.

I will also discuss possible cross correlations between IGM Lyman alpha emission and galaxy HI 21 cm emission.

How did the local Large Scale Structure Form?

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Our Local Universe, the best-observed volume of the Universe, provides excellent data with which we can attempt to understand the formation and evolution of our cosmological neighborhood. Using positions and peculiar velocities from Cosmicflows catalogs, we are able to reproduce in Constrained Local Universe Simulations the observed nearby large-scale structure with an accuracy of a few megaparsecs. The formation of nearby objects can be studied in great details. Taking the nearest cluster, we will answer the question ‘‘How did the Virgo cluster form?’’.

Dark Influences: structural characterization of minor mergers of dwarf galaxies with dark satellites

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In the current concordance cosmology small halos are expected to be completely dark. Nevertheless, they can significantly perturb low-mass galaxies during minor merger interactions, and these interactions may well contribute to the diversity of the dwarf galaxy population. Moreover, dwarf galaxies in the field are often observed to have peculiarities in their structure, morphology, and kinematics as well as strong bursts of star formation without apparent cause.

We explore and quantify a variety of structural, morphological, and kinematic indicators of merging dwarf galaxies and dwarf galaxy merger remnants, using a large suite of controlled hydrodynamical simulations. We compare our results to observational data from the literature, and characterize the signatures of minor mergers of dwarf galaxies with dark satellites to aid their observational identification.

The most sensitive indicators of mergers with dark satellites are large asymmetries in the gaseous and stellar distributions, enhanced central surface brightness and starbursts, and velocity offsets and misalignments between the cold gas and stellar components. In general merging systems span a wide range of values of the most commonly used indicators, while isolated objects tend to have more confined values. Interestingly, we find in our simulations that a significantly off-centered burst of star formation can pinpoint the location of the dark satellite. Observational systems with such characteristics are perhaps the most promising for unveiling the presence of the hitherto, missing satellites.

Structure and formation of the Milky Way as seen by large spectroscopic surveys

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The Milky Way is the galaxy which in principle can be observed the best as it can be resolved into individual stars of which we can measure their 6D phase space coordinates as well as their chemical abundances. This allows us to disentangle the convoluted formation history of the Galaxy in terms of chemical as well as kinematical evolution. Practical studies have however been hindered by the fact that the Sun is sitting inside of the Milky Way; a complete census thus requires all sky surveys. In the past decade, several massive spectroscopic wide-area observing campaigns such as the RAVE, SEGUE, LAMOST and APOGEE surveys have been initiated (and some of them even completed) providing us for a first time a systematic census of the stellar content of our Galaxy. I will present some of the results of these campaigns on the chemo-dynamical evolution of the Milky Way and conclusions we can draw on the formation of galaxies in general. I will provide an outlook on what the Gaia astrometric campaign will be able to achieve, in particular when combined with the next generation of spectroscopic surveys such as WEAVE and 4MOST.

Cosmic web in the local Universe

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We present an analysis of the cosmic web in the local Universe. First, we use the improved friends-of-friends group finder [1] to detect galaxy groups and to suppress the fingers-of-God redshift-space distortions in 2MRS survey. The corrected distribution of galaxies is thereafter used to extract galaxy filaments using the Bisous model [2]. We compare the filaments detected in galaxy distribution with the underlying velocity field reconstructed from the peculiar velocities of galaxies [3]. We find a good agreement between the two methods.

[1] E. Tempel, R. Kipper, A. Tamm and et al. Friends-of-friends galaxy group finder with membership refinement. Application to the local Universe, (2016) A&A, 588, A14 [arXiv:1601.01117].

[2] E. Tempel, R. S. Stoica, V. J. Martınez and et al. Detecting filamentary pattern in the cosmic web: a catalogue of filaments for the SDSS, (2014) MNRAS, 438, 3465 [arXiv:1308.2533].

[3] N. Libeskind, E. Tempel, Y. Hoffman, R. B. Tully and H. Courtois, Filaments from the galaxy distribution and from the velocity field in the local universe, (2015) MNRAS, 453, L108 [arXiv:1505.07454].

Unraveling the history of the Milky Way disk through chemical tagging

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Elemental abundance patterns of stars hold essential clues not only to their formation but also to the assembly histories of galaxies. One exciting possibility in near-field cosmology is the use of stellar abundance patterns as “chemical tags” to identify stars that were born together. My talk consists of three parts: (1) by generating models of the Milky Way tailored to predict observations from on-going chemical tagging surveys, we showed that different stellar cluster mass functions imprint varying degrees of clumpiness in chemical space. These differences provide the opportunity to statistically reconstruct the cluster mass function of the Milky Way disk in the past.; (2) applying this idea to the APOGEE survey, we put a first abundance-based constraint on the cluster mass function. We showed that the Milky Way old disk has not formed star clusters more massive than 3x10^7 solar masses; (3) our models showed that the current measurement precision of elemental abundances might not be sufficient to separate individual star clusters in chemical space. To deliver better precision, we devise a new adaptive grid/generative model based method to generate stellar synthetic libraries. This approach reduces the exponential growth of models needed in rectilinear grid interpolation to a quadratic growth. This enormous speed-up enables the simultaneous many-label fitting of spectra and exploiting information in the blended lines, and so should deliver more precise elemental abundances and potentially enables chemical tagging.

[1] Y.-S. Ting, C. Conroy, A. Goodman, ApJ, 807, 104 (2015).

[1] Y.-S. Ting, C. Conroy, H.-W. Rix, ApJ, 816, 10 (2016).

[1] Y.-S. Ting, C. Conroy, H.-W. Rix, arXiv-eprint: 1602.06947.

[1] H.-W. Rix, Y.-S. Ting, C. Conroy, D. W. Hogg, arXiv-eprint.

The impact of reionization and feedback on the observed abundance of structures in the Local Volume

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No complete theoretical prediction exists so far to explain the observed dearth of dwarf galaxies in the Local Volume compared to the large number of dark matter halos in CDM. By means of high-resolution gasdynamics cosmological simulations we investigate the role of gas heating due to reionization and other energy sources on the formation of the smallest dwarf galaxies. We assess the impact that the uncertainty in the IGM temperature at $z > 6$ has on the use of dwarf galaxies as cosmological probes. We find that despite the importance of reionization, extreme feedback from stars is essential to reproduce the abundance of dwarfs in the Local Volume. However, invoking stellar feedback as a solution may result in tensions with other observational constraints including the abundance of star-forming dwarfs, the number of satellites around the MW and M31, and the stellar content of massive galaxies.

Cosmicflows-3

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Cosmicflows-3 is a database of 17,669 galaxy distances, more than double the number in the previous edition. The new catalog adds 2,257 distances based on the correlation between galaxy rotation and luminosity using Spitzer 3.6 micron photometry, 8,885 Fundamental Plane distances provided by the 6dFGS collaboration, and 25-30% augmentations of the samples provided by the Tip of the Red Giant Branch and Type Ia supernova techniques. The zero point calibration is consistent with H_0=75-76 km/s/Mpc and the ensemble seriously challenges claims of H_0 below 70.

Sweating the small stuff: simulating dwarf galaxies, ultra-faint dwarf galaxies, and their own tiny satellites

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If LCDM is correct, then all dark matter halos hosting galaxies are filled with abundant substructure down to very low mass scales ($<< 10^9$ $M_\odot$). Specifically, even the dark matter halos of Local Group field dwarfs should be filled with subhalos ($\sim 10^8$ $M_\odot$), and thus are potential targets for hosting small (ultrafaint) galaxies. Here we make predictions for the existence of ultrafaint satellites of dwarf galaxies using the highest resolution cosmological dwarf simulations yet run ($m_{gas} \sim 250$ $M_\odot$). We simulate four dwarf halos (10^9 $M_\odot$ < $M_{vir} < 10^{10}$ $M_\odot$) down to z = 0 using the Gizmo/FIRE [1] code. We predict that ultrafaint galaxies ($M_\star \sim 3,000$ $M_\odot$) should exist as satellites around more massive dwarf galaxies ($M_\star$] $\sim 10^6$ $M_\odot$) in the Local Group. These tiny satellites, as well as the two isolated ultrafaints, have uniformly ancient stellar population (> 10 Gyr) owing to reionization-related quenching. This is independent of whether they are satellites or centrals, or when they fell into their host galaxies. Additionally, we show that the kinematics and ellipticities of isolated simulated dwarf centrals are consistent with observed dSphs satellites without the need for harassment from a massive host. We further show that most (but not all) observed isolated* dIrrs in the Local Volume also have dispersion-supported stellar populations, contradicting the previous view that these objects are rotating. Finally, we investigate the stellar age gradients in dwarfs showing that early mergers and strong feedback can create an inverted gradient, with the older stars occupying larger galactocentric radii.

These results offer an interesting direction in testing models that attempt to solve dark matter problems via explosive feedback episodes. Can the same models that create large cores in simulated dwarfs preserve the mild stellar rotation that is seen in a minority of isolated dwarfs? Can the same bursty star formation that created a dark matter core also match observed stellar gradients in low mass galaxies? Comparisons between our simulations and observed dwarfs will hopefully provide an important benchmark for this question going forward.

[1] Hopkins P. F., Keres D., Oñorbe J., Faucher-Giguere C.-A., Quataert E., Murray N., Bullock J. S., 2014, MNRAS, 445, 581

The Multidark Simulation Project:

Large Volume simulations for Near Field Cosmology

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Abstract

Large volume cosmological N-body simulations are an indispensable tool to compare the predictions from different cosmological models with the upcoming observational results from the different galaxy redshift survey projects such as BOSS, DES, DESI, 4MOST, JPAS, EUCLID, LSST, etc. These surveys will probe tens of cubic gigaparsec and therefore the numerical experiments must be done in computational volumes of similar size, with enough resolution to resolve the halos hosting the same galaxies detected by the different surveys. The MultiDark simulation project consists of a series of N-body simulations with a large number of particles, around 60 billion each, in different computational boxes , ranging from 160 Mpc to 4 Gigaparsec on a side and using the most up to date cosmological parameters consistent with the latest results from Planck Collaboration. From the largest volumes, one can extract mock Luminous Red Galaxy catalogs that can be compared with the clustering results from BOSS, the most recent spectroscopic redshift survey. At the same time, due to the large dynamical range of the MultiDArk simulation suite, it can be used also for Near Field cosmology studies. In particular, they can be used to estimate how common our Local Group is in the Universe and investigate the effects of environment on the formation and evolution of Local group candidates by searching for them in the huge database of dark matter halos (more than 60 billion) identified in these simulations.