Annual Report 2016
Jaan Einasto
and Tartu Observatory cosmology group

1 Research

Einasto et al. (2016a) performed a study to understand how the lack of galaxy formation in voids influences geometrical properties of the cosmic web. We calculate the density field of the SDSS main sample of galaxies and of a ΛCDM model, and use variable threshold density levels to divide the space into high- and low-density regions (clusters and voids). We define the clustered matter model as a sample of particles associated with galaxies, it includes only particles of density above the mean density. To characterise geometrical properties of the cosmic web we find the largest clusters and voids, and calculate their lengths, filling factors and numbers as functions of the threshold density. We call these statistics geometrical curves. Geometrical curves for clusters of dark matter models, clustered matter models and SDSS samples are similar. Geometrical curves for voids of dark matter models vs. clustered matter and SDSS samples are very different. SDSS and clustered matter model samples have only one large percolating void. Dark matter models have at small threshold densities numerous tiny voids, surrounded by percolating clusters. The geometry of the cosmic web is complex, and geometrical curves of clusters and voids yield additional information of properties of the cosmic web. Geometrical curves for voids of SDSS and clustered matter models are very asymmetrical. The density field of the luminous matter is non-Gaussian by a large margin.

Signatures of the processes in the early Universe are imprinted in the cosmic web (Einasto et al., 2016b). Some of them may define shell-like structures characterised by typical scales. Examples of such structures are shell-like systems of galaxies, which are interpreted as a signatures of the baryon acoustic oscillations. Our results confirm that shell-like structures can be found in the distribution of nearby galaxies and their systems. The radii of the possible shells are larger than expected for a baryonic acoustic oscillations (BAO) shell ($\approx\ 109\ h^{-1}$ Mpc versus $\approx 120 - 130\ h^{-1}$ Mpc), and they are determined by very rich galaxy clusters and superclusters. In contrast, BAO shells are barely seen in the galaxy distribution. We discuss possible consequences of these differences.

Together with Maret Einasto and collaborators we studied the cosmic web, where galaxy superclusters or their high-density cores are the largest objects that may collapse at present or during the future evolution (Einasto et al., 2016c). We studied the dynamical state and possible future evolution of galaxy superclusters from the Sloan Great Wall (SGW), the richest galaxy system in the nearby Universe. We calculated supercluster masses using dynamical masses of galaxy groups and stellar masses of galaxies. We employed normal mixture modelling to study the structure of rich SGW superclusters and search for components (cores) in superclusters. We analysed the radial mass distribution in the high-density cores of superclusters centred approximately at rich clusters and used the spherical collapse model to study their dynamical state. We found that the lower limit of the total mass of the SGW is approximately $M = 2.5\times\ 10^{16}h^{-1}M_{\odot}$. Different mass estimators of superclusters agree well, the main uncertainties in masses of superclusters come from missing groups and clusters. We detected three high-density cores in the richest SGW supercluster (SCl 027) and two in the second richest supercluster (SCl 019). They have masses of $1.2 - 5.9\times\ 10^{15}h^{-1}M_{\odot}$ and sizes of up to $\approx 60\ h^{-1}$ Mpc. The high-density cores of superclusters are very elongated, flattened perpendicularly to the line of sight. The comparison of the radial mass distribution in the high-density cores with the predictions of spherical collapse model suggests that their central regions with radii smaller than $8h^{-1}$Mpc and masses of up to $M = 2\times\ 10^{15}h^{-1}M_\odot$ may be collapsing. The rich SGW superclusters with their high-density cores represent dynamically evolving environments for studies of the properties of galaxies and galaxy systems.

2 Lectures

• June 20, Conference “All-wave astronomy. Shklovsky-100”; talk “Evolution of Superclusters and Dark Energy”;
• September 08, lecture in seminar of Tartu Observatory: “Evolution of the Cosmic Web”;
• September 20, Erevan, Armenia, “Conference dedicated to 70th anniversary of Byurakan Observatory”, talk “Evolution of the Cosmic Web” (read by T. Viik).

3 Visits

• June 19 – June 23, Moscow University, Conference “All-wave astronomy. Shklovsky-100”.

4 Scientific organisations, awards

I am member of the International Astronomical Union (1961), Estonian Academy of Sciences (1981), American Astronomical Society (1981), European Astronomical Society (1990), Academia Europaea (1990), Royal Astronomical Society (1994).

I have Estonian Science Prizes (1982, 1998, 2003, 2007), Gauss Professor of the Göttingen University (1993), The Estonian Order of the National Coat of Arms (1998), Marcel Grossmann Award (2009), honorary Doctor of Tartu University (2010), Viktor Ambartsumian International Prize (2012), Doctor Honoris Causa degree of the Turku University (2013), Gruber International Cosmology Award (2014).

5 Research – Tartu Observatory cosmology group

In this Section the work is described done in Tartu Observatory cosmology group, in addition to the work described in Section 1. This overview is based on abstracts written by authors of respective papers.

Einasto (2015) studied the relations between the multimodality of galaxy clusters drawn from the SDSS DR8 and the environment where they reside. We find that multimodal clusters reside in higher density environment than unimodal clusters. We determine morphological types of superclusters and show that clusters in superclusters of spider morphology have higher probabilities to have substructure and larger peculiar velocities of their main galaxies than clusters in superclusters of filament morphology. Our study shows the importance of the role of superclusters as high density environment which affects the properties of galaxy systems in them.

Lietzen et al. (2016) investigated superclusters as the largest relatively isolated systems in the cosmic web. Using the SDSS BOSS survey, we search for the largest superclusters in the redshift range $0.43 < z < 0.71$. Methods: We generate a luminosity-density field smoothed over 8 h^{-1} Mpc to detect the large-scale over-density regions. Each individual over-density region is defined as single supercluster in the survey. We define the superclusters so that they are comparable to the superclusters found in the SDSS main survey. Results: We find a system that we call the BOSS Great Wall (BGW), which consists of two walls with diameters 186 and 173 h^{-1} Mpc and two other major superclusters with diameters of 64 and 91 h^{-1} Mpc. As a whole, this system consists of 830 galaxies with the mean redshift 0.47. We estimate the total mass to be approximately $2 \times 10^{17} h^{-1} M_{\odot}$. The morphology of the superclusters in the BGW system is similar to the morphology of the superclusters in the Sloan Great Wall region. The BGW is one of the most extended and massive systems of superclusters found so far in the Universe.

Groups form the most abundant class of galaxy systems (Tempel et al., 2016a). They act as the principal drivers of galaxy evolution and can be used as tracers of the large-scale structure and the underlying cosmology. However, the detection of galaxy groups from galaxy redshift survey data is hampered by several observational limitations. We improve the widely used friends-of-friends (FoF) group finding algorithm with membership refinement procedures and apply the method to a combined dataset of galaxies in the local Universe. A major aim of the refinement is to detect subgroups within the FoF groups, enabling a more reliable suppression of the fingers-of-God effect. The FoF algorithm is often suspected of leaving subsystems of groups and clusters undetected. We used a galaxy sample built of the 2MRS, CF2, and 2M++ survey data comprising nearly 80 000 galaxies within the local volume of 430 Mpc radius to detect FoF groups. We conducted a multimodality check on the detected groups in search for subgroups. We furthermore refined group membership using the group virial radius and escape velocity to expose unbound galaxies. We used the virial theorem to estimate group masses. The analysis results in a catalogue of 6282 galaxy groups in the 2MRS sample with two or more members, together with their mass estimates. About half of the initial FoF groups with ten or more members were split into smaller systems with the multimodality check. An interesting comparison to our detected groups is provided by another group catalogue that is based on similar data but a completely different methodology. Two thirds of the groups are identical or very similar. Differences mostly concern the smallest and largest of these other groups, the former sometimes missing and the latter being divided into subsystems in our catalogue. The catalogues are available at the CDS (Tempel et al., 2016b).

The distribution of smaller satellite galaxies around large central galaxies has attracted attention because peculiar spatial and kinematic configurations have been detected in some systems (Libeskind et al., 2016). A particularly striking example of such behavior is seen in the satellite system of the Andromeda galaxy, where around 80% are on the near side of that galaxy, facing the Milky Way. Motivated by this departure from anisotropy, we examined the spatial distribution of satellites around pairs of galaxies in the Sloan Digital Sky Survey. By stacking tens of thousands of satellites around galaxy pairs, we found that satellites tend to bulge toward the other central galaxy, preferably occupying the space between the pair, rather than being spherically or axis-symmetrically distributed around each host. The bulging is a function of the opening angle examined and is fairly strong — there are up to $\sim 10\%$ more satellites in the space between the pair than expected from uniform. Consequently, it is a statistically very strong signal, being inconsistent with a uniform distribution at the 5σ level. The possibility that the observed signal is the result of the overlap of two halos with extended satellite distributions is ruled out by testing this hypothesis by performing the same tests on isolated galaxies (and their satellites) artificially placed at similar separations. These findings highlight the unrelaxed and interacting nature of galaxies in pairs.

Because of the 3D nature of galaxies, an algorithm for constructing spatial density distribution models of galaxies on the basis of galaxy images has many advantages over approximations of the surface density distribution (Tempel et al., 2015). We present a method for deriving the spatial structure and overall parameters of galaxies from images and estimate its accuracy and derived parameter degeneracies on a sample of idealised model galaxies. The test galaxies consist of a disc-like component and a spheroidal component with varying proportions and properties. Both components are assumed to be axially symmetric and coplanar. We simulate these test galaxies as if they had been observed in the SDSS project through ugriz filters, thus gaining a set of realistically imperfect images of galaxies with known intrinsic properties. These artificial SDSS galaxies were thereafter remodelled by approximating the surface brightness distribution with a 2D projection of a bulge+disc spatial distribution model and the restored parameters were compared to the initial ones. Down to the r-band limiting magnitude of 18, errors in the restored integral luminosities and colour indices remain within 0.05 mag and errors in the luminosities of individual components within 0.2 mag. Accuracy of the restored bulge-to-disc luminosity ratio (B/D) is within 40% in most cases, and becomes worse for galaxies with low B/D, but the general balance between bulges and discs is not shifted systematically. Assuming that the intrinsic disc axial ratio is < 0.3, then the inclination angles can be estimated with errors $< 5°$ for most of the galaxies with B/D < 2 and with errors $< 15°$ up to B/D $= 6$. Errors in the recovered sizes of the galactic components are below 10% in most cases. The axial ratios and the shape parameter N of Einasto's distribution (similar to the Sersic index) are relatively inaccurate, but can provide statistical estimates for large samples. In general, models of disc components are more accurate than models of spheroidal components for geometrical reasons.

The radiation of stars heats dust grains in the diffuse interstellar medium and in star-forming regions in galaxies (Viaene et al., 2016). Modelling this interaction provides information on dust in galaxies, a vital ingredient for their evolution. It is not straightforward to identify the stellar populations heating the dust, and to link attenuation to emission on a sub-galactic scale. Radiative transfer models are able to simulate this dust-starlight interaction in a realistic, three-dimensional setting. We investigate the dust heating mechanisms on a local and global galactic scale, using the Andromeda galaxy (M31) as our laboratory. We perform a series of panchromatic radiative transfer simulations of Andromeda with our code SKIRT. The high inclination angle of M31 complicates the 3D modelling and causes projection effects. However, the observed morphology and flux density are reproduced fairly well from UV to sub-millimeters wavelengths. Our model reveals a realistic attenuation curve, compatible with previous, observational estimates. We find that the dust in M31 is mainly (91 % of the absorbed luminosity) heated by the evolved stellar populations. The bright bulge produces a strong radiation field and induces non-local heating up to the main star-forming ring at 10 kpc. The relative contribution of unevolved stellar populations to the dust heating varies strongly with wavelength and with galactocentric distance.The dust heating fraction of unevolved stellar populations correlates strongly with NUV-r colour and specific star formation rate. These two related parameters are promising probes for the dust heating sources at a local scale.

Kipper et al. (2016c) probed the feasibility of describing the structure of a multicomponent axisymmetric galaxy with a dynamical model based on the Jeans equations while taking into account a third integral of motion. We demonstrate that using the third integral in the form derived by G. Kuzmin, it is possible to calculate the stellar kinematics of a galaxy from the Jeans equations by integrating the equations along certain characteristic curves. In the cases where the third integral of motion does not describe the system exactly, the derived kinematics would describe the galaxy only approximately. We apply our method to the Andromeda galaxy, for which the mass distribution is relatively firmly known. We are able to reproduce the observed stellar kinematics of the galaxy rather well. The calculated model suggests that the velocity dispersion ratios σ_z^2/σ_R^2 of M31 decrease with increasing R. Moving away from the galactic plane, σ_z^2/σ_R^2 remains the same. The velocity dispersions σ_θ^2 and σ_R^2 are roughly equal in the galactic plane.

Tempel & Stoica (2015); Tempel et al. (2016c) argued that the cosmic web is a highly complex geometrical pattern, with galaxy clusters at the intersection of filaments and filaments at the intersection of walls. Identifying and describing the filamentary network is not a trivial task due to the overwhelming complexity of the structure, its connectivity and the intrinsic hierarchical nature. To detect and quantify galactic filaments we use the Bisous model, which is a marked point process built to model multi-dimensional patterns. The Bisous filament finder works directly with the galaxy distribution data and the model intrinsically takes into account the connectivity of the filamentary network. The Bisous model generates the visit map (the probability to find a filament at a given point) together with the filament orientation field. Using these two fields, we can extract filament spines from the data. Together with this paper we publish the computer code for the Bisous model that is made available in GitHub. The Bisous filament finder has been successfully used in several cosmological applications and further development of the model will allow to detect the filamentary network also in photometric redshift surveys, using the full redshift posterior. We also want to encourage the astro-statistical community to use the model and to connect it with all other existing methods for filamentary pattern detection and characterisation.

Tidal torque theory suggests that galaxies gain angular momentum in the linear stage of structure formation (Pahwa et al., 2016). Such a theory predicts alignments between the spin of haloes and tidal shear field. However, non-linear evolution and angular momentum acquisition may alter this prediction significantly. In this paper, we use a reconstruction of the cosmic shear field from observed peculiar velocities combined with spin axes extracted from galaxies within 115 Mpc (8000 km/s) from 2MASS Redshift Survey (2MRS) catalogue to test whether or not galaxies appear aligned with principal axes of shear field. Although linear reconstructions of the tidal field have looked at similar issues, this is the first such study to examine galaxy alignments with velocity shear field. Ellipticals in the 2MRS sample show a statistically significant alignment with two of the principal axes of the shear field. In general, elliptical galaxies have their short axis aligned with the axis of greatest compression and perpendicular to the axis of slowest compression. Spiral galaxies show no signal. Such an alignment is significantly strengthened when considering only those galaxies that are used in velocity field reconstruction. When examining such a subsample, a weak alignment with the axis of greatest compression emerges for spiral galaxies as well. This result indicates that although velocity field reconstructions still rely on fairly noisy and sparse data, the underlying alignment with shear field is strong enough to be visible even when small numbers of galaxies are considered - especially if those galaxies are used as constraints in the reconstruction.

The nature versus nurture scenario in galaxy and group evolution is a long-standing problem not yet fully understood on cosmological scales (Poudel et al., 2016b). We study the properties of groups and their central galaxies in different large-scale environments defined by the luminosity density field and the cosmic web filaments. We use the luminosity density field constructed using 8 Mpc/h smoothing to characterize the large-scale environments and the Bisous model to extract the filamentary structures in different large-scale environments. We find differences in the properties of central galaxies and their groups in and outside of filaments at fixed halo and large-scale environments. In high-density environments, the group mass function has higher number densities in filaments compared to that outside of filaments towards the massive end. The relation is opposite in low-density environments. At fixed group mass and large-scale luminosity density, groups in filaments are slightly more luminous and their central galaxies have redder colors, higher stellar masses, and lower specific star formation rates than those outside of filaments. However, the differences in central galaxy and group properties in and outside of filaments are not clear in some group mass bins. We show that the differences in central galaxy properties are due to the higher abundances of elliptical galaxies in filaments. Filamentary structures in the cosmic web are not simply visual associations of galaxies, but rather play an important role in shaping the properties of groups and their central galaxies. The differences in central galaxy and group properties in and outside of cosmic web filaments are not simple effects related to large-scale environmental density. The results point towards an efficient mechanism in cosmic web filaments which quench star formation and transform central galaxy morphology from late to early types.

To understand the role of the environment in galaxy formation, evolution, and present-day properties, it is essential to study the multifrequency behavior of different galaxy populations under various environmental conditions (Poudel et al., 2016a). Authors study the stellar mass functions of different galaxy populations in groups as a function of their large-scale environments using multifrequency observations. We cross-matched the SDSS DR10 group catalog with GAMA Data Release 2 and Wide-field Survey Explorer (WISE) data to construct a catalog of 1651 groups and 11.436 galaxies containing photometric information in 15 different wavebands ranging from ultraviolet (0.152 μm) to mid-infrared (22 μm). We performed the spectral energy distribution (SED) fitting of galaxies using the MAGPHYS code and estimate the rest-frame luminosities and stellar masses. We used the $1/V_{max}$ method to estimate the galaxy stellar mass and luminosity functions, and the luminosity density field of galaxies to define the large-scale environment of galaxies. The stellar mass functions of both central and satellite galaxies in groups are different in low- and high-density, large-scale environments. Satellite galaxies in high-density environments have a steeper low-mass end slope compared to low-density environments, independent of the galaxy morphology. Central galaxies in low-density environments have a steeper low-mass end slope, but the difference disappears for fixed galaxy morphology. The characteristic stellar mass of satellite galaxies is higher in high-density environments and the difference exists only for galaxies with elliptical morphologies. Galaxy formation in groups is more efficient in high-density, large-scale environments. Groups in high-density environments have higher abundances of satellite galaxies, irrespective of the satellite galaxy morphology. The elliptical satellite galaxies are generally more massive in high-density environments. The stellar masses of spiral satellite galaxies show no dependence on the large-scale environment.

Stoica et al. (2016) described several applications in astronomy and cosmology that are addressed using probabilistic modelling and statistical inference.

The Bisous model is a marked point process that models multi-dimensional patterns (Tempel & Stoica, 2015). The Bisous filament finder works directly with galaxy distribution data and the model intrinsically takes into account the connectivity of the filamentary network. The Bisous model generates the visit map (the probability to find a filament at a given point) together with the filament orientation field; these two fields are used to extract filament spines from the data.

Arnalte-Mur et al. (2016) presented a full description of the N-probability density function of the galaxy number density fluctuations. This $N - pdf$ is given in terms, on the one hand, of the cold dark matter correlations and, on the other hand, of the galaxy bias parameter. The method relies on the assumption commonly adopted that the dark matter density fluctuations follow a local non-linear transformation of the initial energy density perturbations. The N-pdf of the galaxy number density fluctuations allows for an optimal estimation of the bias parameter (e.g., via maximum-likelihood estimation, or Bayesian inference if there exists any a priori information on the bias parameter), and of those parameters defining the dark matter correlations, in particular its amplitude (σ_8). It also provides the proper framework to perform model selection between two competitive hypotheses. The parameters estimation capabilities of the $N - pdf$ are proved by SDSS-like simulations (both, ideal log-normal simulations and mocks obtained from Las Damas simulations), showing that our estimator is unbiased. We apply our formalism to the 7th release of the SDSS main sample (for a volume-limited subset with absolute magnitudes $M_r \leq -20$). We obtain hat $b = 1.193 \pm 0.074$ and $\sigma_8 = 0.862 \pm 0.080$, for galaxy number density fluctuations in cells of the size of 30 h^{-1} Mpc. Different model selection criteria show that galaxy biasing is clearly favoured.

Sepp et al. (2016) presented the results of N-body/smoothed particle hydrodynamics simulations of galaxy cluster collisions with a two component model of dark matter, which is assumed to consist of a predominant non-interacting dark matter component and a 20 percent mass fraction of dark plasma. Dark plasma is an intriguing form of interacting dark matter with an effective fluid-like behavior, which is well motivated by various theoretical particle physics models. We find that by choosing suitable simulation parameters, the observed distributions of dark matter in both the Bullet Cluster (1E 0657-558) and Abell 520 (MS 0451.5+0250) can be qualitatively reproduced. In particular, it is found that dark plasma forms an isolated mass clump in the Abell 520 system which cannot be explained by traditional models of dark matter, but has been detected in weak lensing observations.

Deshev et al. (2016) present the first, preliminary results from our ongoing survey of galaxies residing in Abell 520 ($z = 0.2$), a cluster in the process of formation at the crossing of three large-scale structure filaments. We use spectroscopy for 682 galaxies, 317 of which reside within the cluster, to search for signs of transformation in the galaxies in this extreme environment. We apply classical definitions of local and global environment to find that both contribute to the quenching of star-formation as measured by the fraction of galaxies with emission lines.

In a hierarchical Universe clusters grow via the accretion of galaxies from the field, groups and even other clusters (Jaffé et al., 2016). As this happens, galaxies can lose and/or consume their gas reservoirs via different mechanisms, eventually quenching their star formation. We explore the diverse environmental histories of galaxies through a multiwavelength study of the combined effect of ram-pressure stripping and group "processing" in Abell 963, a massive growing cluster at $z = 0.2$ from the Blind Ultra Deep H I Environmental Survey (BUDHIES). We incorporate hundreds of new optical redshifts (giving a total of 566 cluster members), as well as Subaru and XMM-Newton data from LoCuSS, to identify substructures and evaluate galaxy morphology, star formation activity, and H I content (via H I deficiencies and stacking) out to $3 \times R200$. We find that Abell 963 is being fed by at least seven groups, that contribute to the large number of passive galaxies outside the cluster core. More massive groups have a higher fraction of passive and H I-poor galaxies, while low-mass groups host younger (often interacting) galaxies. For cluster galaxies not associated with groups we corroborate our previous finding that H I gas (if any) is significantly stripped via ram-pressure during their first passage through the intracluster medium, and find mild evidence for a starburst associated with this event. In addition, we find an overabundance of morphologically peculiar and/or star-forming galaxies near the cluster core. We speculate that these arise from the effect of groups passing through the cluster (post-processing). Our study highlights the importance of environmental quenching and the complexity added by evolving environments.

Bonamente et al. (2016) analysed Chandra low energy transmission grating and XMM-Newton Reflection Grating Spectrometer (RGS) spectra towards the $z = 0.177$ quasar PG 1116+215, a sightline that is rendered particularly interesting by the Hubble Space Telescope (HST) detection of several O VI and H I broad Lymanα absorption (BLA) lines that may be associated with the warm-hot intergalactic medium (WHIM). We performed a search for resonance K absorption lines from O VII and O VIII at the redshifts of the detected far-ultraviolet lines. We detected an absorption line in the Chandra spectra at the 5.2σ confidence level at wavelengths corresponding to O VIII Kα at $z = 0.0911 \pm 0.0004 \pm 0.0005$ (statistical followed by systematic error). This redshift is within 3σ of that of an H I broad Lymanα of $b \sim 130$ km s^{-1} (corresponding to a temperature of $\log T(K) \approx 6.1$) at $z = 0.09279 \pm 0.00005$. We have also analysed the available XMM-Newton RGS data towards PG 1116+215. Unfortunately, the XMM-Newton data are not suitable to investigate this line because of instrumental features at the wavelengths of interest. At the same redshift, the Chandra and XMM-Newton spectra have O VII Kα absorption-line features of significance 1.5σ and 1.8σ, respectively. We also analysed the available Sloan Digital Sky Survey (SDSS) spectroscopic galaxy survey data towards PG 1116+215 in the redshift range of interest. We found evidence for a galaxy filament that intersect the PG 1116+215 sightline and additional galaxy structures that may host WHIM. The H I BLA and the O VIII Kα absorbers are within a few Mpc of the filament (assuming that redshifts track Hubble flow distances) or consistent with gas accreting on to the filament from either direction relative to the sightline with velocities of a few times 100 km s-1. The combination of HST, Chandra, XMM-Newton and SDSS data indicates that we have likely detected a multi-temperature WHIM at $z0.091 - 0.093$ towards PG 1116+215. The O VIII Kα absorption line indicates gas at high temperature, $\log T(K) \geq 6.4$, with a total column density of the order of $\log NH(\mathrm{cm}2) \geq 204$ and a baryon overdensity $\delta b \sim 100 - 1000$ for sightline lengths of $L = 1 - 10$ Mpc. This detection highlights the importance of BLA absorption lines as possible signposts of high-temperature WHIM filaments.

An understanding of the mass build-up in galaxies over time necessitates tracing the evolution of cold gas (molecular and atomic) in galaxies (Cybulski et al., 2016). To that end, we have conducted a pilot study called CO Observations with the LMT of the Blind Ultra-Deep H I Environment Survey (COOL BUDHIES). We have observed 23 galaxies in and around the two clusters Abell 2192 ($z = 0.188$) and Abell 963 ($z = 0.206$), where 12 are cluster members and 11 are slightly in the foreground or background, using about 28 total hours on the Redshift Search Receiver on the Large Millimeter Telescope (LMT) to measure the 12CO $J = 1 \rightarrow 0$ emission line and obtain molecular gas masses. These new observations provide a unique opportunity to probe both the molecular and atomic components of galaxies as a function of environment beyond the local Universe. For our sample of 23 galaxies, nine have reliable detections ($S/N \geq 3.6$) of the 12CO line, and another six have marginal detections ($2.0 < S/N < 3.6$). For the remaining eight targets we can place upper limits on molecular gas masses roughly between 10^9 and $10^{10} M_\odot$. Comparing our results to other studies of molecular gas, we find that our sample is significantly more abundant in molecular gas overall, when compared to the stellar and the atomic gas component, and our median molecular gas fraction lies about 1 above the upper limits of proposed redshift evolution in earlier studies. We discuss possible reasons for this discrepancy, with the most likely conclusion being target selection and Eddington bias.

Fluctuations of the surface brightness of cosmic X-ray background (CXB) carry unique information about faint and low luminosity source populations, which is inaccessible for conventional large-scale structure (LSS) studies based on resolved sources (Kolodzig et al., 2016). We used Chandra data of the XBOOTES field ($\sim 9\,\mathrm{deg}^2$) to conduct the most accurate measurement to date of the power spectrum of fluctuations of the unresolved CXB on the angular scales of $\sim 3\,\mathrm{arcsec} \simeq 17\,\mathrm{arcmin}$. We find that at sub-arcmin angular scales, the power spectrum is consistent with the AGN shot noise, without much need for any significant contribution from their one-halo term. This is consistent with the theoretical expectation that low-luminosity AGN reside alone in their dark matter halos. However, at larger angular scales we detect a significant LSS signal above the AGN shot noise. Its power spectrum, obtained after subtracting the AGN shot noise, follows a power law with the slope of -0.8 ± 0.1 and its amplitude is much larger than what can be plausibly explained by the two-halo term of AGN. We demonstrate that the detected LSS signal is produced by unresolved clusters and groups of galaxies. For the flux limit of the XBOOTES survey, their flux-weighted mean redshift equals $\langle z\rangle \sim 0.3$, and the mean temperature of their intracluster medium (ICM), $\langle T\rangle \approx 1.4$ keV, corresponds to the mass of $M_{500} \sim 10^{13.5}\,\mathrm{M}_\odot$. The power spectrum of CXB fluctuations carries information about the redshift distribution of these objects and the spatial structure of their ICM on the linear scales of up to ~Mpc, i.e. of the order of the virial radius.

Song et al. (2016) studied the dependence of the number density and properties of quasars on the background galaxy density using the currently largest spectroscopic data sets of quasars and galaxies. We construct a galaxy number density field smoothed over the variable smoothing scale of between approximately 10 and 20 h^{-1} Mpc over the redshift range $0.46 < z < 0.59$ using the Sloan Digital Sky Survey (SDSS) Data Release 12 (DR12) Constant MASS galaxies. The quasar sample is prepared from the SDSS-I/II DR7. We examine the correlation of incidence of quasars with the large-scale background density and the dependence of quasar properties such as bolometric luminosity, black hole mass, and Eddington ratio on the large-scale density. We find a monotonic correlation between the quasar number density and large-scale galaxy number density, which is fitted well with a power-law relation, $nQ \propto (\rho)$ G0.618. We detect weak dependences of quasar properties on the large-scale density such as a positive correlation between black hole mass and density, and a negative correlation between luminosity and density. We discuss the possibility of using quasars as a tracer of large-scale structures at high redshifts, which may be useful for studies of the growth of structures in the high-redshift universe.

Vennik & Hopp (2015) analysed distribution, kinematics and star-formation (SF) properties of satellite galaxies in three different samples of nearby groups. We find that studied groups are generally well approximated by low-concentration NFW model, show a variety of LOS velocity dispersion profiles and signs of SF quenching in outskirts of dwarf satellite galaxies.

HI4PI Collaboration et al. (2016): Context. Measurement of the Galactic neutral atomic hydrogen (H I) column density, NH I, and brightness temperatures, TB, is of high scientific value for a broad range of astrophysical disciplines. In the past two decades, one of the most-used legacy H I datasets has been the Leiden/Argentine/Bonn Survey (LAB). Aims: We release the H I 4π survey (HI4PI), an all-sky database of Galactic H I, which supersedes the LAB survey. Methods: The HI4PI survey is based on data from the recently completed first coverage of the Effelsberg-Bonn H I Survey (EBHIS) and from the third revision of the Galactic All-Sky Survey (GASS). EBHIS and GASS share similar angular resolution and match well in sensitivity. Combined, they are ideally suited to be a successor to LAB. Results: The new HI4PI survey outperforms the LAB in angular resolution (FWHM = 16.2') and sensitivity (RMS= 43μK). Moreover, it has full spatial sampling and thus overcomes a major drawback of LAB, which severely undersamples the sky. We publish all-sky column density maps of the neutral atomic hydrogen in the Milky Way, along with full spectroscopic data, in several map projections including HEALPix. HI4PI datasets are only available at the CDS (Hi4PI Collaboration et al., 2016).

The Galactic All-Sky Survey (GASS) is a survey of Galactic atomic hydrogen (H i) emission in the southern sky observed with the Parkes 64-m Radio Telescope (Kalberla & Haud, 2015). The first data release (GASS I) concerned survey goals and observing techniques, the second release (GASS II) focused on stray radiation and instrumental corrections. Aims: We seek to remove the remaining instrumental effects and present a third data release. Methods: We use the HEALPix tessellation concept to grid the data on the sphere. Individual telescope records are compared with averages on the nearest grid position for significant deviations. All averages are also decomposed into Gaussian components with the aim of segregating unacceptable solutions. Improved priors are used for an iterative baseline fitting and cleaning. In the last step we generate 3D FITS data cubes and examine them for remaining problems. Results: We have removed weak, but systematic baseline offsets with an improved baseline fitting algorithm. We have unraveled correlator failures that cause time dependent oscillations; errors cause stripes in the scanning direction. The remaining problems from radio frequency interference (RFI) are spotted. Classifying the severeness of instrumental errors for each individual telescope record (dump) allows us to exclude bad data from averages. We derive parameters that allow us to discard dumps without compromising the noise of the resulting data products too much. All steps are reiterated several times: in each case, we check the Gaussian parameters for remaining problems and inspect 3D FITS data cubes visually. We find that in total 1.5% of the telescope dumps need to be discarded in addition to 0.5% of the spectral channels that were excluded in GASS II. Conclusions: The new data release (GASS III) facilitates data products with improved quality. A new web interface, compatible with the previous version, is available for download of GASS III FITS cubes and spectra.

Kalberla et al. (2016) investigate data from the Galactic Effelsberg-Bonn H i Survey, supplemented with data from the third release of the Galactic All Sky Survey (GASS III) observed at Parkes. We explore the all-sky distribution of the local Galactic H i gas with $|vLSR| < 25$ km s^{-1} on angular scales of $11° - 16°$. Unsharp masking is applied to extract small-scale features. We find cold filaments that are aligned with polarized dust emission and conclude that the cold neutral medium (CNM) is mostly organized in sheets that are, because of projection effects, observed as filaments. These filaments are associated with dust ridges, aligned with the magnetic field measured on the structures by Planck at 353 GHz. The CNM above latitudes $|b| > 20°$ is described by a log-normal distribution, with a median Doppler temperature TD = 223 K. Assuming that the CNM filaments are confined by magnetic pressure, we estimate a thickness of 0.09 pc; the median volume density is in the range $14 \leq n \leq 47$ cm^{-3}.

D'Onofrio et al. (2016a,b) published notes on the history of the development of modern cosmology. Opinions of individual astronomers on the history of 20th Century cosmology are presented. Editors remarked that "until recently the great majority of naturalists believed that species were immutable productions, and had been separately created. This view has been ably maintained by many authors. Some few naturalists, on the other hand, have believed that species undergo modification, and that the existing forms of life are the descendants by true generation of preexisting forms".

Proceedings of the IAU Symposium 308 "The Zeldovich Universe: Genesis and Growth of the Cosmic Web" were finally printed (van de Weygaert et al., 2016). Here reports of Tartu Observatory astronomers were published (Einasto, 2016b,a; Kipper et al., 2016b,a; Kuutma et al., 2016; Lietzen & Einasto, 2016; Nevalainen et al., 2016; Saar, 2016; Tamm et al., 2016; Tempel & Bussov, 2016).

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