Annual Report 2015
Jaan Einasto
and Tartu Observatory cosmology group

1 Research

Together with Maret Einasto and collaborators we studied the distribution, masses, and dynamical properties of galaxy groups in the A2142 supercluster (Einasto et al., 2015a). We found galaxy groups and filaments in this region, calculated their masses and mass-to-light ratios, and analysed their dynamical state. We found that in the A2142 supercluster rich groups and clusters lie along an almost straight line forming the 50 h^{-1} Mpc long main body of the supercluster. The A2142 supercluster has a very high density core surrounded by lower-density outskirts. The total estimated mass of the supercluster is $M_{est} = 6.2 \times 10^{15} M_{\odot}$. More than a half of groups with at least ten member galaxies in the supercluster lie in the high-density core of the supercluster, centred at the X-ray cluster A2142. Most of the groups in the core region are multimodal. The orientation of the axis of the cluster A2142 follows the orientations of its X-ray substructures and radio halo, and is aligned along the supercluster axis.

We studied characteristic density contrasts in the spherical collapse model for several epochs in the supercluster evolution and their dynamical state (Gramann et al., 2015). We analysed the density contrasts for the turnaround, future collapse, and zero gravity in different ΛCDM models, and applied them to study the dynamical state of the supercluster A2142. We presented characteristic density contrasts in the spherical collapse model for different cosmological parameters. The analysis of the supercluster A2142 shows that its high-density core has already started to collapse. The zero-gravity line outlines the outer region of the main body of the supercluster. In the course of future evolution, the supercluster may split into several collapsing systems. The various density contrasts presented in our study and applied to the supercluster A2142 offer a promising way to characterise the dynamical state and expected future evolution of galaxy superclusters.

We searched for shell-like structures in the distribution of nearby rich clusters of galaxies drawn from the SDSS DR8 (Einasto et al., 2015b). We found a maximum in the distribution of distances from rich galaxy clusters to other groups and clusters at distance of about 120 h^{-1} Mpc, suggesting the presence of a density enhancement at this distance from rich clusters. The rich cluster A1795 (the central cluster of the Bootes supercluster) has the highest maximum in the distance distribution of other groups and clusters around them at distance of about 120 h^{-1} Mpc, another maximum is at a distance of about 240 h^{-1} Mpc. The Sloan Great Wall, the Corona Borealis supercluster and the Ursa Major supercluster are main elements of the shell around A1795. The radii of possible shells are larger than expected for a BAO shell (approximately 109 h^{-1} Mpc), and they are determined by very rich galaxy clusters and superclusters with high density contrast, while BAO shells are barely seen in the galaxy distribution.

2 Research – Tartu Observatory cosmology group

Elmo Tempel with collaborators studied cosmic filaments (Guo et al., 2015; Libeskind et al., 2015; Tempel & Tamm, 2015; Tempel et al., 2015). The accretion of satellites on to central galaxies along cosmic filaments is an apparent outcome of the anisotropic collapse of structure in our Universe. Numerical calculations indicate that satellites are beamed towards hosts along preferred directions imprinted by the velocity shear field. Tempel et al. (2015) used the Sloan Digital Sky Survey to observationally test this claim. They constructed 3D filaments and sheets and examined the relative position of satellite galaxies. A statistically significant alignment between satellite galaxy position and filament axis is confirmed.

Libeskind et al. (2015) compared two methods to characterise large-scale structure, using point process algorithms to extract filaments, and reconstruction of the velocity field to decompose the web into voids, sheets, filaments and knots. Both methods are in good agreements when applied to local Universe within 100 h^{-1} Mpc. This is remarkable, given that the two methods are radically different in ideology and applied to completely independent and different data sets.

Guo et al. (2015) investigated the satellite luminosity function of primary galaxies in the Sloan Digital Sky Survey (SDSS), and looked whether the luminosity function depends on the position of host galaxy in a filament or not. Authors found that galaxies in filaments have more satellites. Gravitational collapse theory and numerical simulations suggest that the velocity field within large-scale galaxy filaments is dominated by motions along the filaments. The alignment analysis shows that the orientation of galaxy pairs correlates strongly with their host filaments (Tempel & Tamm, 2015).

Park et al. (2015) used a volume-limited sample of quasars in the Sloan Digital Sky Survey DR7 quasar catalog to identify quasar groups and to address their statistical significance. This quasar sample has a uniform selection function on the sky, and forms nearly a maximum possible contiguous volume that can be drawn from the DR7 catalog. Quasar groups are identified by using the Friend-of-Friend algorithm with a set of fixed comoving linking lengths. We find that the richness distribution of the richest 100 quasar groups or the size distribution of the largest 100 groups are statistically equivalent with those of randomly-distributed points with the same number density and sky coverage when groups are identified with the linking length of 70 h^{-1} Mpc. It is shown that the large-scale structures like the huge Large Quasar Group (U1.27) reported by Clowes et al. (2013) can be found with high probability even if quasars have no physical clustering, and does not challenge the initially homogeneous cosmological models.

Nevalainen et al. (2015) investigated the problem of missing baryons, based on the assumption that the missing baryons are in the form of warm hot intergalactic medium (WHIM), and that the galaxy luminosity density can be used as a tracer of the WHIM. Authors applied their procedure to the line of sight towards the blazar H2356-309, and found evidence of WHIM that corresponds to the Sculptor and Pisces-Cetus superclusters, in agreement with the redshifts and column densities of the X-ray absorbers. This agreement indicates that the galaxy luminosity density and galactic filaments are reliable signposts for the WHIM.

Israel et al. (2015); Schellenberger et al. (2015) calibrated X-ray temperature measurements of the intracluster medium, made by XMM-Newton and Chandra satellites. XMM-Newton temperatures are on average 23 % lower than Chandra temperatures. Authors conclude that using XMM-Newton instead of Chandra to derive full energy band temperature profiles for cluster mass determination results in an 8 % shift toward lower Ω_M values and < 1 % change of σ_8 values in a cosmological analysis of a complete sample of galaxy clusters. Such a shift is insufficient to remove the tension between Planck CMB primary anisotropies and Sunyaev-Zeldovich-plus-XMM-Newton cosmological constraints.

Old et al. (2015b,a) performed a comparison of various cluster mass estimation techniques that utilize the positions, velocities and colours of galaxies. Analysing 968 clusters, authors find a wide range in the rms errors in log M200c delivered by the different methods (a factor of $\sim 1.5 - 12$), with abundance-matching and richness methods providing the best results.

Certain methods produce a significant number of catastrophic cases where the mass is under- or overestimated by a factor greater than 10.

Kanemaru et al. (2015) investigated the potential of the higher multipole power spectra of the galaxy distribution in redshift space as a cosmological probe on halo scales.

Theories where the Planck scale is dynamically generated from dimensionless interactions provide predictive inflationary potentials and super-Planckian field variations. Kannike et al. (2015) studied the minimal single-field realisation in the low-energy effective field theory limit, finding the predictions $n_s \approx 0.96$ for the spectral index and $r \approx 0.13$ for the tensor-to-scalar ratio, which can be reduced down to ≈ 0.04 in presence of large couplings.

Kolodzig et al. (2015b,a) discussed possibilities of the Spektrum-Roentgen-Gamma (SRG) satellite, which is expected to detect about 3 million active galactic nuclei (AGN) with a median redshift of $z \sim 1$ during the four-year X-ray All-Sky Survey. Authors demonstrate that this unprecedented AGN sample, complemented with redshift information, will supply us with outstanding opportunities for large-scale structure studies. Authors show that with this sample of X-ray selected AGN, it will become possible for the first time to perform detailed redshift- and luminosity-resolved studies of the AGN clustering. This enable us to put strong constraints on different AGN triggering/fueling models as a function of AGN environment, which will dramatically improve our understanding of super-massive black hole growth and its correlation with the co-evolving cosmic web. Further, the eRASS AGN sample will become a powerful cosmological probe.

Laur et al. (2015) used own photometric observations as well as archival data to search for variations in orbital periods of seven massive eclipsing binary systems in the Cygnus OB2 association, and estimated their mass-loss rates and stellar parameters. Authors used a Bayesian parameter estimation method to simultaneously fit the period and period change to all available data and a stellar modelling tool to model the binary parameters from photometric and radial-velocity data. Four out of the seven selected binaries show non-zero period change values at two-sigma confidence level.

Teerikorpi et al. (2015) constructed a graph to characterize the relative importance of uniform and constant dark energy, as given by the Λ term in the standard ΛCDM cosmology, in galaxy systems of different scales from groups to superclusters. Here the matter-DE density ratio ($\varrho_M/\varrho_\Lambda$) for different galaxy systems is plotted against the radius R. This presents gravitation- and DE-dominated regions and directly shows the zero velocity radius, the zero-gravity radius, and the Einstein-Straus radius for any fixed value of mass. Example galaxy groups and clusters from the local universe illustrate the use of the Λ significance graph. These are generally located deep in the gravity-dominated region ($\varrho_M/\varrho_\Lambda > 2$), and are virialized. Extended clusters and main bodies of superclusters can reach down near the borderline between the gravity-dominated and the DE-dominated regions.

Arnalte-Mur et al. (2015) 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 commonly adopted assumption 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).

Stoica et al. (2015) described several applications in astronomy and cosmology that are addressed using probabilistic modelling and statistical inference.

Kalberla & Haud (2015) removed the remaining instrumental effects and presented a third data release of the Galactic All-Sky Survey (GASS) — a survey of Galactic atomic hydrogen (H i) emission in the southern sky, observed with the Parkes 64-m Radio Telescope. 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.

Shvelidze & Malyuto (2015) performed quantitative spectral classification of F, G and K stars with the 70-cm telescope of the Ambastumani Astrophysical Observatory in areas of the main meridional section of the Galaxy, for which proper motion data are available. Fundamental parameters have been obtained for several hundred stars. Space densities of stars of different spectral types, the stellar luminosity function and the relationships between the kinematics and metallicity of stars have been studied.

Grziwa et al. (2015) reported the discovery of EPIC 204129699b, the first confirmed transiting hot Jupiter detected by the K2 space mission. Authors combined K2 photometry with FastCam lucky imaging and FIES and HARPS high-resolution spectroscopy to confirm the planetary nature of the transiting object and derived the system parameters. EPIC 204129699b is a 1.8-Jupiter-mass planet on an 1.26-day-orbit around a G7V star.

3 Lectures

• January 08, lecture in the Saaremaa Campus of Tartu University: “The Development of the Modern Cosmology Paradigm”;
• June 20, Oxbridge Club, Tallinn, talk “Dark Matter, Cosmic Web and Cambridge”;
• July 07, Aix en Provence, talk on conference “Drifting through the Cosmic Web: the Evolution of Galaxies within the Large Scale Structure” – “The Formation and Evolution of the Cosmic Web”.

4 Visits

• January 07 – January 09, Tartu University Saaremaa Campus;
• June 19 – June 20, Estonian Academy of Sciences, Tallinn, Oxbridge Club;
• July 05 – July 11, Aix en Provence, conference “Drifting through the Cosmic Web: the Evolution of Galaxies within the Large Scale Structure”;
• September 22 – September 25, Kubija, Estonia, Tartu-Tuorla Cosmology Workshop “Always Look on the Bright Side of Space”.

5 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), 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).

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