Cosmology group of Tartu Observatory

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1.1 Science staff members

Jaan Einasto, Maret Einasto, Mirt Gramann, Urmas Haud, Gert Hutsi, Juhan Lauri Liivamägi, Valery Malyuto; Enn Saar, Ivan Suhhonenko, Erik Tago, Antti Tamm, Elmo Tempel, Peeter Tenjes, Jaan Vennik;

1.2 PhD student

Tiit Sepp

1.3 Technicians

Peeter Einasto, Triin Einasto, Margus Sisask.

2 Scientific studies

I will classify the results according to the project goals.

2.1 Testing the inflationary paradigm

In order to test the inflationary paradigm (the initial extremely fast expansion of the Universe) we studied the observational traces of baryon oscillations (BAO), predicted by inflation theories. Gert Hütsi discovered the traces of BAO in the power spectrum of the galaxy distribution, using the catalogue of the distant galaxy clusters of the Sloan Digital Sky Survey (SDSS). The paper has been accepted by 'Monthly Notices of the Royal Astronomical Society' (MNRAS).

Enn Saar, together with Ivan Suhhonenko and colleagues from the Valencia and Tuorla observatories demonstrated that photometric redshifts can be used to restore the matter correlation functions of deep lightcones. The paper has been published by MNRAS.

Gert Hütsi, together with colleagues from the Hiroshima University, studied the damping of BAO, and estimated the structure growth rate. One paper has been published (Physical Review), another submitted. Traces of BAO can be sought also in the correlation function of galaxies. Enn Saar and Elmo Tempel, together with colleagues from Valencia, found these. Enn Saar also solved the problem of bootstrap estimation of correlation function errors. The paper was published in 'Astrophysical Journal Letters'.

2.2 Dark energy

Dark energy determines the evolution of the large-scale structure; comparing theory with observations, we can set limits on dark energy. Gert Hütsi, together with colleagues from the Hiroshima University, estimated the structure growth rate from the velocity distortions of the SDSS; the paper was published in 'Progress of Theoretical Physics'.

Dark energy determines the formation and evolution of the largest elements of structure – galaxy superclusters and giant voids. Observational study of superclusters is the topic of the PhD work of Juhan Liivamägi; Maret Einasto, Erik Tago and Enn Saar helped. Comparing the properties of the observed superclusters with theory and numerical models allows us to check the dynamics of structure on large scales; the paper on the SDSS superclusters will be finished soon.

Enn Saar, together with his colleagues from the Tuorla Observatory and the Institute of Astrophysics of Canaries tested the chances to discover the warm supecluster gas in the future ESA Planck data; there is hope.

Together with Radu Stoica (University of Lille) and Vicent Martinez (Valencia University Observatory), Enn Saar developed an algorithm for searching for galaxy filaments in redshift surveys, found the filaments for the 2dFGRS North, and compared these with model filaments. The paper has been submitted.

Maret Einasto together with Enn Saar and other members of the cosmology group studied the morphology, substructure and galaxy populations of the richest superclusters, determined using the 2dFGRS data (the supercluster SCl126 in the Sloan Great Wall, and the supercluster SCl9, the Sculptor supercluster) using Minkowski functionals and shapefinders determined on the basis of Minkowski functionals. Using the SDSS data, we studied the morphology of the Sloan Great Wall and of individual superclusters in the Wall. In this study we gave a special attention to luminous red galaxies (LRG). The spatial distribution of these galaxies can be compared with that of the normal galaxies in SGW, but further out, LRG-s are the only supercluster members seen. We found several differences between the galaxy populations of these superclusters. Their overall morphology is also different. This all shows that the evolution of these superclusters has differed, although they have almost the same r! ichness (mass).

As we said already, limits on dark energy can be set by comparing the observed large-scale structure and its models. Jaan Einasto, together with Ivan Suhhonenko, Enn Saar, Elmo Tempel and Juhan Liivamägi calculated numerical models for the formation of galaxy systems. Together with Volker Müller (Potsdam) we have started to analyze the models. We have studied the influence of large-scale waves on the filament network, on the richness of superclusters and voids, and on the properties of voids. The first paper on this topic will be finished soon.

2.3 Dark matter

Gert Hütsi, together with Antti Hektor and Martti Raidal (Institute for Chemical and Biological Physics, Tallinn), found strong observational limits on the properties of leptonically annihilating dark matter (particle mass and the annihilation cross-section). This type of dark matter is one of the most attractive possibility to explain the unexpectedly large flow of energetic positrons from the Galactic centre direction. The paper was published in 'Astronomy and Astrophysics' (A&A) and was chosen as the best of the issue by the editors.

Erik Tago compiled several catalogues of galaxy groups and clusters, based on the final version of the SDSS. As the survey is finished, the main group catalogue is also final for a while; it includes 78,800 groups up to the distance of about 900 Mpc and covers a quarter of the sky. The paper is submitted to "Astronomy and Astrophysics".

Together with colleagues from Guanajato University, Mexico, Erik Tago studied the relative velocities of the main galaxies of rich galaxy clusters. They found that these velocities are in many cases too large, and that the standard dark matter picture needs updating. The paper has been published in 'Astronomical Journal'.

Gert Hütsi, together with Ofer Lahav (LondonUniversity College), studied the cross power spectrum of galaxy clusters and galaxies in the halo model. They found that the cross-correlation carries additional information and can be used to better estimate both the cosmological parameters and the parameters of the halo model.

Jaan Einasto was asked to write a survey of the discovery of dark matter for the international web-based science encyclopedia ('Encyclopedia of Life Support Systems'). Jaan Einasto was also awarded the 2009. Marcel Grossmann prize for the discovery of dark matter.

2.4 Formation and evolution of galaxies

An overall description of present-day galaxies and their evolution is given by their luminosity function (distribution of luminosities). Elmo Tempel, together with Jaan Einasto, Enn Saar, Maret Einasto, and Erik Tago determined the luminosity function for the 2dFGRS. We demonstrated that the galaxy luminosity function has a strong dependence on the galaxy environment. The paper has been published in 'A&A'. The same group, lead by Elmo Tempel, determined also the galaxy luminosity function of the final version (DR7) of the SDSS. This paper is close to be finished.

In a nearby region of the SDSS we can compare the locations and other properties of galaxies and quasars. At the present, quasars tend to avoid galaxies. This study was made together with our colleagues from Tuorla Observatory, and it was published in 'A&A'.

On the initiative of Maret Einasto, we made a detailed study of the luminous red galaxies (LRG) of the SDSS. We found that while LRG-s are considered the main galaxies of groups, a large number of LRG-s are satellite galaxies, and there are also isolated LRG-s. Using the visual tools created for the SDSS, we determined the morphology of about 1500 galaxies. We found that about one-third of nearby LRG-s are, in fact, spirals. The results on the studies of the SGW will be summed up in two papers; these are practically finished.

Enn Saar, together with his colleagues from Tuorla, studied isolated elliptical galaxies. We compared observational data with numerical galaxy formation models (merger trees), found three possible formation scenarios, and predicted a yet unobserved population of faint blue ellipticals. The paper has been submitted.

Jaan Vennik studied star formation in galaxies, located in groups of different mean density. He studied also the detailed structure of the members of a tight galaxy group NGC 6962, searched for traces of interactions and found them. Together with Ulrich Hopp (München) he continued to study the composition of nearby groups, using spectra of dwarf galaxies, obtained by the 11m Hobby-Eberly telescope (Texas). For the NGC 6962 group they found four new members; several other groups had also galaxies added. Two papers have been submitted.

Antti Tamm, Peeter Tenjes, and Elmo Tempel checked for internal absorption of starlight in the dust of our neighbour galaxy (Andromeda, M31) and found that it may be large, up to half a magnitude. This effect is important for other spiral galaxies, too, and we have already accounted for it in our luminosity function estimates. The paper has been submitted.

2.5 Our Galaxy

When studying the structure of the Galaxy, exact statistics of stellar surveys, stellar classification, is very important. This is the subject of study of Valeri Malyuto; he proposed, together with colleagues from the Odessa University, a new method for estimating the colour indices of supergiants. This will allow a precision mapping of the absorption by Galactic dust. When studying the structure of the Galaxy, exact statistics of stellar surveys, stellar classification, is very important. This is the subject of study of Valeri Malyuto; he analysed some available stellar catalogues of effective temperatures and used the results for producing a new preliminary homogenized catalogue of merged temperature data.

Apart from the stars, the Galaxy contains gas, both in hot star formation regions, and cold hydrogen far from them. Mapping the gas distribution, using radio data, is a difficult problem. Urmas Haud has continued to process the Leiden/Argentina/Bonn (LAB) survey data for that. He was able to find cold gas clouds in the data. As a result, he produced the map that shows the distribution of cold gas in the sky. The paper has been published in 'A&A'. Urmas Haud also discovered a chain of cold gas clouds, at a distance of 33-64 pc from the Sun. This chain is unique; he studied also other similar clouds. The paper has been submitted.

2.6 Publications

1. E. Tempel, J. Einasto, M. Einasto, E. Saar, E. Tago, "Anatomy of luminosity functions: the 2dFGRS example", Astr. Astrophys., 2009, Astr. Astrophys. 495, 37 – 51;

2. Lietzen, H., Heinämäki, P., Nurmi, P., Tago, E., Saar, E., Liivamägi, J., Tempel, E., Einasto, M., Einasto, J., Gramann, M. and Takalo, L. O., "Environments of nearby quasars in Sloan Digital Sky Survey", 2009, Astr. Astrophys., 501, 145 – 155;

3. Martínez, Vicent J.; Arnalte-Mur, Pablo; Saar, Enn; de la Cruz, Pablo; Pons-Bordería, María Jesús; Paredes, Silvestre; Fernández-Soto, Alberto; Tempel, Elmo, "Reliability of the Detection of the Baryon Acoustic Peak", 2009, ApJ, 696, L93;

4. Arnalte-Mur, Pablo; Fernández-Soto, Alberto; Martínez, Vicent J.; Saar, Enn; Heinämäki, Pekka; Suhhonenko, Ivan, "Recovering the real-space correlation function from photometric redshift surveys", 2009, MNRAS, 394, 1631;

5. J. Einasto, "Dark Matter", 2009, Encyclopedia, arXiv0901.0632E;

6. J. Einasto, "Large scale structure of the Universe", 2009, Zeldovich 95 Meeting, arXiv0906.5272E;

7. J. Einasto, "Two hundred years of galactic studies in Tartu Observatory", 2009, Marcel Grossmann Meeting 12;

8. Saar, E. "Multiscale methods", 2009, Lecture Notes in Physics, 665, 523;

9. Martinez, Vicent J.; Saar, Enn; Gonzales, Enrique Martinez; Pons-Borderia, Maria Jesus, "Data analysis in cosmology", 2009, Lecture Notes in Physics, 665;

10. Vennik, J. Hopp, U. "Testing of the dwarf galaxy content and the evolutionary status of nearby groups of galaxies", 2009, Astr. Nachr. 330, 998;

11. Hütsi, G.; Hektor, A.; Raidal, M., "Constraints on leptonically annihilating dark matter from reionization and extragalactic gamma background", 2009, Astr. Astrophys. 505, 999;

12. Nomura, Hidenori; Yamamoto, Kazuhiro; Hütsi, Gert; Nishimichi, Takahiro, "Confronting the damping of the baryon acoustic oscillations with observation", 2009, Physical Review D, vol. 79, Issue 6, id. 063512;

13. Hütsi, Gert, "Power spectrum of the maxBCG sample: detection of acoustic oscillations using galaxy clusters", 2009, MNRAS, Online Early, arXiv0910.0492;

14. Tamm, A.; Tempel, E.; Tenjes, P., "Luminous and dark matter in the Andromeda galaxy", 2009, IAUS 254, 73;

15. Guti-Errez, L.; Tamm, A.; Beckman, J. E.; Abrahamson, L.; Erwin, P.; Guittet, M., "Where have all the bulges gone?", 2009, IAUS 254, 24; arXiv:0810.2609;

16. R. Coziol, H. Andernach, C . A. Caretta, K. A. Alamo-Martinez, E.Tago, 2009, AJ, 137, 4795-4809. "The dynamical state of brightest cluster galaxies and the formation of clusters". ArXiv:0903.2360.

4. Visits

01.03.2009 – 01.04.2009 ICRAnet (J. Einasto);

19.04.2009 – 25.04.2009 Minsk University in Belorussia, Zeldovich Memorial Meeting (J. Einasto);

12.05.2009 – 15.05.2009 Galaxies in Isolation: Exploring Nature vs. Nurture, Granada, Hispaania (J. Vennik);

12.07.2009 – 19.07.2009 Paris, Marcel Grossmann 12th Meeting (J. Einasto, P. Einasto, E. Saar);

17.08.2009 - 28.08.2009 Rostov-on-Don, Rostov State University, joint work with V.Marsakov (V. Malyuto);

11.09.2009 – 12.10.2009 Astrophysics Institute Potsdam (J. Einasto, I. Suhhonenko, E. Tempel);

13.10.2009 – 12.12.2009 Valencia University, Spain (E. Saar, A. Tamm);

24.11.2009 – 27.11.2009 Tuorla Observatory (L. J. Liivamägi);

01.12.2009 – 17.12.2009 ICRAnet (J. Einasto).

2.7 Collaboration with other institutions

1) National Institute of Chemical Physics and Biophysics, group of elementary particle physics, head Martti Raidal – studies of dark matter and particle generation in early Universe;

2) Tartu University, Institute of Physics, Laboratory of Theoretical Physics – Piret Kuusk, Margus Saal, Laur Järv – theory of gravitation, physics of early Universe;

3) Estonian University of Life Sciences, Institute of Physics – Jaak Jaaniste – superclusters of galaxies; 4) Turku University, Tuorla Astronomical Observatory, Finland – Pekka Heinämäki, Pasi Nurmi – numerical simulations, properties of galaxy groups, participation in the Planck programme (WHIMm in superclusters;

5) Uppsala University, Astronomical Observatory, Sweden – Nils Bergvall – study of red haloes of galaxies;

6) Potsdam Institute for Astrophysics, Germany – Volker Müller, Stefan Gottlöber, Alexander Knebe – properties of superclusters of galaxies, numerical simukations;

7) ICRAnet, Italy — Remo Ruffini — formation and evolution of the structure of the universe;

8) University of Munich, Germany – Ulrich Hopp – study of galaxy groups and dwarf galaxies;

9) Bonn University, Argelander Astronomical Institute, Germany – Peter M.W. Kalberla – observations of the Galactic HI 21-cm radiation and their interpretation;

10) University College London, Astrophysics Group, Great Britain – Ofer Lahav – study of galaxy superclusters and of the initial epochs of the evolution of structure;

11) Valencia University, Astronomical Observatory, Spain – Vicent J. Martinez – statistics of the galaxy distribution, morphological studies;

12) CEA/Saclay, Astrophysics Service, France – Jean-Luc Starck – wavelet methods in data processing, morphology of structure;

13) Fermilab, U.S.A. – Douglas L. Tucker – properties of galaxy groups, superclusters of galaxies;

14) Stanford University, Department of Statistics, U.S.A. – David Donoho – wavelet methods in data processing;

15) Guanajato University, astronomy department, Mexico – Heinz Andernach – properties of rich galaxy clusters.