The Messenger continues its publication of reports from the Chilean astronomical community with the Panorama of Chilean Astronomy by Professor Leonardo Bronfman, President of the Sociedad Chilena de Astronomía, followed by an article by A. Reisenegger et al. on the on-going investigation of the Shapley supercluster.

A Panorama of Chilean Astronomy

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Chile is becoming the astronomical capital of the world. The Atacama desert encompasses the best locations on Earth to build astronomical observatories. Paranal, Las Campanas, Tololo, Pachón, and La Silla are well-known places that contain top-quality optical astronomical facilities open to Chilean astronomers. In the last few years a new generation of astronomical facilities, the mega-telescopes, have been constructed in those sites: VLT, Magellan, and Gemini. In addition, there will be near San Pedro de Atacama at a height of 5000 m, the most powerful radio synthesis telescope of the world: the Atacama Large Millimetre Array (ALMA). This telescope will open up a new, unexplored, window of the electromagnetic spectrum for astrophysical studies. It will operate in an spectral range where clouds of cold gas which are the placental material of mostly every object we know in the universe, have their characteristic spectral signatures.

The privileged access of Chilean astronomers to this unparalleled suite of instruments provides them with a unique opportunity to address some of the most fundamental problems in modern astrophysics. In a time span of a few years ALMA will permit them to investigate the origins of celestial objects. To face these new challenges in the best possible way it has become necessary that the nation provides the astronomers with the proper environment and tools to undertake the research which should put them at the frontiers of astrophysics.

I. Recent Developments

The Chilean CONICYT (Consejo Nacional de Ciencia y Tecnología) recently approved a Centre of Excellence in Astronomy, within the FONDAP (Fondo Nacional de Desarrollo de Areas Prioritarias) programme. This Centre constitutes a new approach among astronomers to generate the conditions to boost Chilean astrophysics, and place it among the world leaders in the area. The Centre members will tackle, through the use of the currently available mega-telescopes, various problems of fundamental scientific importance, covering the origins of a broad range of objects. They will investigate origins from the largest scales, by studying aspects of galaxy formation and evolution, to the smallest scales, by studying aspects of the collapse of an individual star, facing candent problems such as: What did the universe look like 10 billion years ago? How do galaxies form? How do low-mass and high-mass stars form? Where do planets, complex molecules and the beginnings of life came from? Significant progress toward the main scientific goals of the Centre will only be achieved if individuals studying different aspects of origins in astrophysics are brought together for the fruitful and much needed interchange of different views and ideas.

The Centre's mission is to pave the way, through the research of their members and the education of the new generations of astronomers, for identifying and setting up the basis of the new problems to be tackled with the new generation of instruments to be set in Chile, in particular with ALMA. This world's largest array will produce some of the most exciting science in astronomy over the following 10–20 years. It will be the best instrument for detecting proto-galaxies at very high redshifts in the early Universe, as well as both protostars and proto-planetary disks in nearby star-forming clouds. With a resolution higher than the Hubble telescope, and a sensitivity 10 times larger than anything else currently in existence, it will be the largest and most powerful millimetre array in the world.

To accomplish its mission, the FONDAP excellence centre has set for itself the following strategic objectives in science, education, and outreach:

1. Transform the nature of Chilean astrophysics from individual research efforts into a coherent, co-ordinated and collaborative endeavour in science and education.
2. Place Chilean astrophysics in an internationally highly competitive position in several major areas of current interest.
3. Educate and train a new generation of young astronomers to take full advantage of the unique opportunities available in Chile to carry out world-class research, and help create career opportunities for young astronomers in Chilean institutions.
4. Make the Chilean public highly aware of work and discoveries by national astrophysicists and use astrophysical research as a model to promote national pride.

The Centre will be hosted by the Universidad de Chile at its Astronomy Department in Cerro Calán, and will have as associated organizations the Astronomy Department of the Pontificia Universidad Católica and the Physics Department of the Universidad de Concepción. In the next section I describe the present status of Astronomy in these institutions, as well as other recent centres.

II. Existing Institutes

Universidad de Chile

Astronomy is one of the scientific disciplines with the longest tradition at the Universidad de Chile. It began in 1852, when the Chilean Government established the National Observatory in association with the Universidad de Chile. During the early 60's the build up of modern international observatories (Cerro Tololo, Cerro La Silla, and Cerro Las Campanas) prompted the Universidad de Chile to create the Astronomy Department at the Observatorio Nacional, starting up the first programme of *Licenciatura en Astronomía* in 1966 and a decade later the current Magister in Astronomy programme. Many graduates of these programmes went to obtain their Ph.D. degrees in USA, Canada, and Europe, returning in the early 80's to the Department, making a deep impact in astrophysical research and teaching. Two of these early graduates, M.T. Ruiz and J. Maza, have obtained the National Science Prize. The present staff of the Astronomy Department includes 14 faculty members: M.T. Ruiz (Chair), H. Alvarez, L. Bronfman, L. Campusano, S. Casassus, E. Costa, G. Garay, P. Lira, S. López, J. May, J. Maza, D. Mardones, F. Noël, and M. Rubio, as well as 5 postdoctoral fellows. The Astronomy Department is part of the Facultad de Ciencias Físicas y Matemáticas, which attracts a freshman class of 500 from the top 2% of all graduating high school students, a most important asset. It is located at Cerro Calán, Santiago, in a large building with adequate teaching and research facilities, as well as the oldest and most complete astronomical library in the country.

The Universidad de Chile created in 1999, with support from Fundación Andes, the first Ph.D. programme in astronomy in the country. The programme has currently 8 students enrolled, and is expected to significantly increase the number of young scientists starting a career in Astronomy. To strengthen the areas of astrophysics not currently covered by the members of the Department, during the first few years of the programme part of the teaching is done in association with Yale University. It is expected that the programme will timely change its centre of gravity to the Universidad de Chile. A key for such change will be the incorporation to the staff of theoretical astrophysicists in the next two years, through a joint programme of the Physics and Astronomy Departments, with support of the Comité Mixto ESO-Chile. The Ph.D. programme was recently awarded an important grant from the Ministry of Education, through a MECESUP project, to hire new faculty and fund student fellowships over the next 3 years.

Research is carried on in a number of areas, including Quasars and AGNs (evolution of galactic nuclear regions and the formation of massive black holes); Large-Scale Structure and Cosmology; Starburst Galaxies (dwarf systems, metal-poor galaxies) ; High-Mass and Low-Mass Star Formation (galactic distribution, hot molecular cores, bipolar outflows, gas kinematics at high densities, embedded pre-main sequence stars); Supernovae; Faint Stellar Objects (faint white dwarfs, brown dwarfs, extrasolar planets, baryonic dark matter); ISM in the Galaxy and the Magellanic Clouds; Red Giants; Planetary Nebulae; and Solar Astrometry. Some research highlights are: (i) the discovery of the first free floating brown dwarf (Ruiz et al. 1997, *AJ* 491, 107); (ii) the Calán-Tololo supernovae survey (Hamuy et al. 1995, *AJ* 109, 1), which provided the first calibration of the relationship between the absolute magnitude of type Ia SNe at maximum and their rate of decline, and is the basis for studies of the expansion of the Universe; (iii) the first derivation of the mass and distribution of H_2 in the Galaxy using a complete CO survey (Bronfman et al. 1988, *ApJ* 324, 248); (iv) the first complete CO survey of the LMC (Cohen et al. 1988, *ApJ* 331, 95); (v) recent searches for infall motions toward young stellar objects (Mardones et al. 1997, *ApJ* 489, 719); and (vi) a thorough review on the environment and formation of massive stars (Garay and Lizano 1999, *PASP* 111, 1049).

The Astronomy Department is actively engaged in collaboration with a number of international institutions, presently holding agreements with the Association of Universities for Research in Astronomy (AURA), the Carnegie Southern Observatory (CARSO), the University of Florida, the National Radio Astronomy Observatory (NRAO), CalTech, the National Astronomical Observatory of Japan (NAOJ), and the Instituto Astrofísico de Canarias (IAC). A 45-cm telescope donated by the government of Japan, with a CCD camera 1k × 1k, will arrive at Cerro Calán in 2002, to be used for public outreach and student training. The Department operates the *Estación Astronómica Cerro El Roble*, with a 90-cm Maksutov telescope.

Pontificia Universidad Católica de Chile

The Departamento de Astronomía y Astrofísica (DAA) is part of the Physics Faculty of the Pontificia Universidad Católica de Chile (PUC). Astronomy at the PUC started in 1929 when the University received, as a donation, a 36-inch Mills telescope located then at the Observatorio Manuel Foster on the Cerro San Cristóbal in Santiago. The Institute for Physics and Astrophysics was founded to teach in these areas; the Institute later gave rise to the present Faculty of Physics. The Department of Astronomy and Astrophysics was created in 1996, and operates at the Campus San Joaquín in Santiago. The PUC is promoting the growth of astrophysics by the creation of faculty and postdoctoral positions, as well as undergraduate and graduate programmes of study: a *Certificado Académico* (minor), a *Licenciatura* (B.Sc.), a M.Sc., and a Ph.D in Exact Sciences.

The University, recognizing the major comparative advantages, has given high priority to astronomy. Since 1995 the number of members at the DAA has increased steadily. Currently, working at the DAA there are 8 faculties: L. Infante (chair), F. Barrientos, M. Catelan, A. Clocchiatti, G. Galaz, D. Minniti, H. Quintana and A. Reisenegger, as well as 8 postdoctoral fellows. All members at the DAA are heavily involved in research and teaching, both astronomy and physics. There are 8 graduate students and of the order of 100 undergraduate students. The DAA carries out research in both observational and theoretical astrophysics. Most of the research is based on observations at the telescopes of the international observatories operating in Northern Chile. A significant fraction of the Department's research projects involves collaborations with European, North American, Australian and other Latin American astronomers, with funding from several international agencies (NASA, NSF, etc).

The main areas of research are: Planetary Astronomy (search for extrasolar planets); Stellar Astronomy (supernovae, Be stars, Cepheid and RR Lyrae variables; distances, ages, and metallicities of clusters in the Galaxy and the Magellanic Clouds); Extragalactic Astronomy (dynamics of groups and clusters of galaxies, evolution and structure of Dumbell galaxies, structure and dynamics of superclusters, faint and low-surface brightness galaxies, gravitational lenses in clusters of galaxies, quasars, large-scale structure and cosmology); and Theoretical Astrophysics (stellar evolution, compact objects, extragalactic astrophysics and cosmology, hot gas and metals in clusters of galaxies, formation of structure in the Universe). DAA members have had important participation in the discovery of the accelerated expansion of the Universe; the disclosure of Ultra Compact Galaxies in clusters; the discovery and understanding of MACHOS; the detection of the overall collapse of the Shapley Superclusters; the strong clustering of galaxies in pairs and in small groups.

With the support of Fundación Andes, who also funds several fellowships, the DAA is involved in a partnership programme with the Department of Astrophysical Sciences of Princeton University (USA). This programme includes a joint postdoctoral prize fellowship in observational astronomy, faculty and graduate student exchange, joint organisation of international meetings in astrophysical areas of common interest, and the construction of an observatory in the outskirts of Santiago for student training. The PUC is one of four international affiliate members of AURA (Association of Universities for Research in Astronomy), and has built a number of partnerships with several academic institutions in Chile and abroad.

Universidad de Concepción

The astronomy group was created in 1995, as part of the Physics Department. Its current staff includes Douglas Geisler, Wolfgang Gieren, Ronald Mennickent, and recently Tom Richtler. There are 4 postdocs funded by the Comité

Mixto ESO-Chile, the Alexander Von Humboldt Foundation, and a NASA project. Research is funded mostly by FONDECYT, as well as by Fundación Andes and several international agencies.

Current fields of research include: Star clusters (galactic and extragalactic); Stellar populations (in the local group and other nearby groups of galaxies); Distance scale calibration (Cepheids, RR Lyraes, red clump stars, blue supergiants, PNLF, GCLF, SN Ia); Physics of stellar standard candles; Cataclysmic variables and accretion disks; Dwarf novae and long-term variables; Close binary evolution and brown dwarfs in binary systems; Old giants in the galactic halo; Galactic structure. A full account of the ongoing work can be found in Gieren et al. 2002 (*The Messenger* 106, 15)

The Universidad de Concepción recently created a Doctoral programme in physics, including astronomy. Presently there is one student enrolled in astronomy and several more are expected to enter the programme in 2002. In 2003 a *Licenciatura en Física con Mención en Astronomía* will begin.

Universidad Católica del Norte in Antofagasta

The Instituto de Astronomía at the Universidad Católica del Norte, of recent formation, operates the Observatorio Cerro Armazones, with two telescopes of 84 cm and 41 cm. In 2002, with the support of the Physics Department also from the Facultad de Ciencias, an undergraduate programme, *Licenciatura en Física con mención en Astronomía*, will start. The Institute operates, with the help of ESO, an important outreach centre, the *Centro de Divulgación de la Astronomía*, serving the northern Chile community. There is presently one full-time staff member, L. Barrera, and another one will be appointed this year with the help of the Comité Mixto ESO-Chile. The research carried on at the Institute includes Ground Support for Space Missions; Quasar Monitoring; Trans-Neptunian Objects; Craters and Meteorites in the II Region of Chile.

Universidad de La Serena

The Universidad de La Serena has created a new astronomy group at the Physics Department, with two staff members, A. Ramírez and H. Cuevas. Another one will be hired with the help of the Comité Mixto ESO-Chile. The Physics Department, traditionally devoted to teaching, is presently strongly supporting the development of research in astronomy. The group has further impact over the IV Region of Chile by providing the possibility of starting a career in astronomy to local students unable to move away from the region. Research is mostly oriented to Extragalactic Astronomy (intermediate red-shift clusters, X-Ray clusters).

III. The Next Decade

The FONDAP Centre of Excellence is expected to play a major role supporting the formation of human resources in astrophysics at different universities in Chile. The Ph.D., M.Sc., and/or B.Sc. programmes in astronomy at the Universidad de Chile, Pontificia Universidad Católica, and Universidad de Concepción will benefit strongly from the efforts of the astronomers associated with the Centre. They will offer graduate courses jointly to students of all institutions, supervise students from any institution, and visiting professors will be encouraged to have stays at more than one site. The Centre will also support and be involved in summer schools to attract the young, science-oriented minds, to astrophysics. The Centre is expected to become, in a ten-year frame, a world-wide recognised institution that provides graduate student training at the highest level of excellence and performs frontier research in astrophysics.

The Centre will encourage members to perform and be involved in the execution of large surveys. Chilean astronomers are in a unique position to do prominent surveys, maximising telescope time and fostering cross collaborations. This can be achieved by organising the Chilean community, and dedicating a fraction of the available (human and technical) resources. These surveys, along with the solid doctoral programmes at Chilean Universities, would perhaps become the long-lasting legacy of the new Centre. Its present members are G. Garay (Director), M.T. Ruiz (Subdirector), L. Bronfman, D. Geisler, W. Gieren, L. Infante, D. Mardones, J. Maza, D. Minniti, H. Quintana, and M. Rubio.

The first goal of the Centre is to broaden the research base in each astronomy site within the country, giving a particular emphasis to the development of research areas related to the study of the *origins* of celestial objects. The second, and equally important, goal of the Centre is to strengthen the teaching of theoretical astrophysics in all astronomy Ph.D. programmes in the country so that they will be fully conducted by Chilean universities.

There will be five main areas of astrophysics to be cultivated at the Centre. All of them have a distinct integrator: *The study of origins of celestial objects* ; and a common window for future progress: *Sub-millimetre wavelength observations with ALMA*. The advance in knowledge in any of these areas will have an immediate impact in the understanding of the others. Each of the areas will be led by a Principal Investigator (P.I.) which will be responsible for the proper advance to achieve the goals expected in his/her area of research. In what follows we shortly summarise the research areas, putting emphasis in the connectivity between them.

1. Birth and Evolution of Structures in the Universe (P.I.: L. Infante)

One of the greatest challenges in extragalactic astrophysics is to understand the formation and evolution of galaxies. Understanding the physics underlying the processes by which these structures formed and evolved is the main thrust of modern cosmology. To reconstruct the star-formation history of the Universe beginning with the early epochs of galaxy formation and reaching the present is one of the key questions in astrophysics. The Centre will carry out studies in the following topics:

• *Primeval galaxies*. – How, at the earliest epochs, the seeds observed in the cosmic microwave background radiation lead to the formation of the first galaxies (and stars), and how these primordial low-mass galaxies merge to produce the more massive systems we see today.

• *Galaxy clusters as tracers of Large-Scale Structure*. – Galaxies cluster on all scales by gravitational forces and this clustering evolves with time. As galaxies cluster on smaller scales, they interact more and more, leading to their growth via a merging process. How, during early times, clustering processes assemble larger galaxies by mergers of smaller or not fully developed ones, leading to the present-day large galaxies; and how gas with a mass an order of magnitude larger than those in galaxies, is trapped in the growing gravitational potential wells.

• *Starburst galaxies*. – The current generation of mega-telescopes and unique instrumentation will make possible the identification of hundreds of extreme star-forming galaxies at redshifts ~ 3 and higher, thereby initiating detailed studies of star-forming galaxies when the Universe was still young. These studies will permit to characterise and trace the evolution of starburst galaxies on a firm statistical basis and, in particular, to determine the peak epoch of star formation activity, helping to constrain structure formation models.

• *Globular Clusters and Galaxy Formation*. – Being the living probes of the earliest epoch when most galaxies formed, globular clusters (GCs) are an ideal tool for the study of galaxy formation. Centre members plan to obtain reliable age, chemical abundance, and kinematic information for globular cluster systems, which will provide critical clues to reveal the formation and chemical evolution history of galaxies, and will help to tightly constrain galaxy formation models.

• *Nearby galaxies*. – The nearest galaxies are key in the understanding of galaxy evolution, since they are the only galaxies that can be studied consistently on a star-by-star basis, providing direct information on the distribution of ages and metallicities. Their studies will help us to constrain the integrated-light population synthesis models used in the interpretation of distant galaxies not resolved into stars.

• *The Milky Way*. – Our own galaxy, the Milky Way, is a unique place to study in great detail the formation and evolution of galaxies. We can determine with exceeding resolution the interplay between its stellar, molecular, and neutral components, which should be representative of similar galaxies. Centre members are involved in the determination of the large-scale distribution of massive star formation in our own Galaxy, aiming to derive the best rendition of the spiral structure of the Milky Way, using the most adequate tracers, which will become a key stone for future comparison with the distribution in external galaxies at the scale of spiral arms.

2. Quasars and Active Galactic Nuclei (P.I.: J. Maza)

Being the most luminous objects of the Universe, quasars and active galactic nuclei are splendid, but puzzling, probes of the earlier stages of cosmic evolution. Members of the Centre will carry out research in three main topics of this fascinating area of astrophysics. They will seek to understand how the luminosity function for quasars evolves with time (or redshift), which is of paramount importance in order to understand how massive black holes can develop in galactic centres and how they become bright quasars. They will also investigate the mechanism of the enormous energy production in compact objects, including quasars, nuclei of giant elliptical galaxies, BL Lac objects, and cores of radio galaxies. In addition, they will undertake observations to determine the metal abundance of the faintest population of starburst galaxies, a project of utmost importance since it will permit to obtain the most accurate value of the primordial Helium abundance, a basic cosmological parameter. Once ALMA comes on line, the researchers in this field will get accurate measurements of the sub-millimetre emission from quasars and active galactic nuclei to clarify the relationship between these enormously energetic objects and to learn about the mechanism of their energy production. These measurements would be crucial to distinguish between the mechanisms leading to "radio-loud" and "radio-quiet" quasars.

3. The Extragalactic Distance Scale (P.I.: W. Gieren)

• *Cepheid variables as standard candles*. – Cepheid variables are thought to be one of the most reliable standard candles, and hence one of the most powerful distance indicators. There are, however, uncertainties, in particular the effect of metallicity on the Cepheid fundamental physical parameters and on their pulsation properties. To determine the effect of metallicity on Cepheid properties, Centre members will carry out a programme to discover Cepheid variables in nearby galaxies with steep metallicity gradients in their disk, and then calibrate the metallicity effect on the period-luminosity relationship. This programme is expected to lead to the first truly accurate empirical determination of the effect of metallicity on Cepheid-based galaxy distances.

• *The distance to the LMC*. – Although the knowledge of the distance to the Large Magellanic Cloud (LMC) is a key step in the determination of the distance ladder, its value is still a matter of debate. Centre members will employ the surface brightness technique calibrated on Cepheid variables, and at infrared wavelengths to minimise problems with interstellar absorption and metallicity to obtain the distance with a precision of 3%. Such a precision will mean a big leap forward in the calibration of the distance scale, and the Hubble constant.

4. Star Formation (P.I.: G. Garay)

A comprehensive theory of both high- and low-mass star formation is an essential requirement if we are to understand galaxy formation and evolution and the formation of Sun-like stars and planets. However, our knowledge of how stars form is still rudimentary. Several questions of a basic nature remain unanswered: (a) What motions occur before and during the gravitational collapse of a molecular cloud core to form stars? (b) How do stars acquire their main-sequence mass, or how does the collapse and accretion stop? and (c) What is the role of disk-like structures in the formation of single stars, binary stars, and planets? (d) How are high-velocity bipolar jets driven away from the central protostar? To address these questions, Centre members have identified 850 individual regions of massive star formation in the Milky Way, the most complete sample presently available.

• *Infall*. – Members of the Centre will study, at sub-millimetre wavelengths, the long-sought evidence of gravitational infall onto very young stars, to get a comprehensive view of the infall processes leading to either the formation of an isolated low-mass star, as seen in dark globules, or to the formation of a cluster of massive stars, as seen in dense molecular cores. Do low- and high-mass stars form in a self-similar way? or do they follow a different formation path, possibly due to differences in the initial conditions of the parental gas? In the latter case, which is the determinant physical parameter of the ambient gas that establishes the different modes of collapse? With ALMA they will study the kinematic of the infalling gas close to the forming star, the structure and kinematics of protostellar disks, and their role in the formation of binary stars and planets.

• *Outflows*. – One of the major astronomical results of the last two decades has been the discovery that star formation is accompanied by energetic, collimated mass outflow. The outflow mechanism is unknown and requires study on scales as close to the star as possible. High-velocity flows from recently formed stars will be observed with unprecedented sensitivity, helping to elucidate the mechanism that drives the outflow and its influence in limiting the growth of a star. They will also investigate how the outflow phenomena that appear in the earliest stages of star formation affect the physical and chemical properties of the environment.

• Star formation in the Magellanic Clouds. – The Large and Small Magellanic Clouds (LMC, SMC), being the two nearest external galaxies, provide the best opportunity for a detailed study of the stellar and interstellar matter component of any external galaxy. Understanding the process of formation of stars, their interaction with the surrounding gas and dust, the chemical enrichment, as well as the older population of stars in these galaxies, is the link between the knowledge in our Galaxy and the rest of the Universe.

5. Brown Dwarfs and Planetary System Studies (P.I.: M.T. Ruiz)

• *Brown Dwarfs*. – Sub-stellar objects, like brown dwarfs, are likely to provide unique information on the fragmentation processes that accompany the formation of a single star or a cluster of stars. Although the first free floating brown dwarf was discovered only five years ago, current surveys are showing that there are plenty of these objects, implying that we might be immersed in a sea of small dark bodies. How many and how massive are they? The answer to these questions will have an impact on the theory of stellar formation and might have some dynamical consequences for the galaxy as a whole. Using the new optical/IR mega-telescopes and their IR instrumentation it will be possible to investigate the physical characteristics of these objects, particularly those in orbit around nearby stars which will allow us to obtain their masses. ALMA will be a perfect instrument for the follow-up studies of brown dwarfs found in these studies.

• *Extrasolar planets and proto-planetary disks*. – One of the great appeals of astronomy is undoubtedly its potential to help us understand the origin of our planet. The Centre will foster the development of the area of planetary science, currently non-existent in the country, starting from available human resources. This would be accomplished by joining and developing searches for extrasolar planetary systems using modern techniques such as radial velocities, planetary occultations (transits) and micro-lensing. Once ALMA is available we will be able to undertake molecular line observations of the atmospheres of planets and other bodies which will give new knowledge of planetary "weather", the structure of atmospheric wind and the variations in chemical constituents. Studies of proto-planetary disks will be carried out using the recently available IR facilities. ALMA, with its sensitivity and resolving power, will be the ideal instrument to provide definite answers regarding the formation and evolution of proto-planetary disks. Their images will have enough detail to allow astronomers to see chemical variations in proto-planetary systems and to permit them to compare such systems with evolutionary models of our own solar system.

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Dynamics and Mass of the Shapley Supercluster, the Largest Bound Structure in the Local Universe

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Introduction

The Shapley Supercluster is the largest bound structure identified in the local Universe ($z < 0.1$). In this article, we discuss the role of superclusters as present-day "turning points" in the growth of structure in the Universe. We review observations of the Shapley Supercluster and their interpretation, particularly with regard to its dynamics and the determination of its mass, much of which has been done by our group, centred at Pontificia Universidad Católica de Chile. Finally, we describe our recent application of a spherical collapse model to the supercluster, and discuss possibilities of future progress.

1. Cosmological Structure Formation and Superclusters

Observations of the cosmic microwave background radiation show matter in the early Universe to be very uniformly distributed, with large-scale density perturbations as small as 1 part in 10^5 (Smoot et al. 1992). This is in strong contrast with the present-day Universe and its highly overdense condensations, such as galaxies and clusters of galaxies. A natural and widely accepted explanation for the growth of the density perturbations is that initially slightly overdense regions attract the surrounding matter more strongly than underdense regions. Therefore, the expansion of overdense regions is slowed down with respect to underdense regions, and the density contrast grows. Eventually, regions of large enough overdensity can stop their expansion altogether and start recontracting. Their collapse is then followed by a process of relaxation or "virialisation", after which the resulting object is in an approximate equilibrium state, in which its structure is only occasionally perturbed by merging with other objects. This state is well described by the *virial theorem* of classical mechanics, which states that in such an equilibrium state the gravitational potential energy of the object is proportional to the total kinetic energy of the smaller objects randomly moving inside it (stars in a galaxy, galaxies in a cluster of galaxies). This theorem allows to infer the mass of the object (which determines the gravitational potential) from the measured velocity dispersion and size of the collapsed structure.

Inflationary models for the early Universe predict a well-defined relation between the amplitude of the "initial" density fluctuations on different spatial scales. The prediction, corroborated by several sets of observations, implies that the fluctuations are largest on the smallest scales. Since fluctuations on all significant scales grow at the same rate, those on the smallest scales will first reach turnaround and virialisation. Thus, the chronological order of formation of objects proceeds from small to large, i.e., from globular clusters[1] to galaxies, groups of galaxies, and finally to galaxy clusters, the largest virialised known structures at present. The next larger objects, namely groupings of clusters of galaxies, or *superclusters,* should presently be undergoing gravitational collapse, whereas even larger structures should still be expanding and only slightly denser than average.

On the largest scales, the Universe is still undergoing a nearly uniform expansion. For a very distant galaxy, its *redshift factor* $1 + z$, defined as the ratio of the *observed* wavelength of a given line in the spectrum to the wavelength of the same line *at its emission,* is a good approximation to the factor by which the Universe expanded in all spatial directions while the radiation was travelling through it. From a Newtonian point of view, applicable to regions much smaller than the Hubble length[2], this is

[1]Structures much smaller than globular clusters cannot collapse spontaneously, since their gravitational attraction is not strong enough to overcome the pressure of the intergalactic gas. Therefore, stars are formed only within collapsing or already collapsed larger structures.