.

Academy of Athens
Research Center for Astronomy

Galaxies and Chaos Theory and Observations

Athens, September 16-19, 2002

Book of Abstracts

Monday

08:30	*Registration*	
09:00	*Welcoming Addresses and Conference Opening.*	
10:00	*Coffee break*	
10:30	**G. Contopoulos**	*Order and Chaos in Astronomy*
11:20	**D. Lynden-Bell**	*Critical Ergos Curves and Chaos at Co-rotation*
12:10	*Short break*	
12:20	**P.A. Patsis**	*Nonlinear Phenomena in Disk Galaxies*
12:45	**T. Bountis**	*Localized Oscillations in Multi Degree of Freedom Hamiltonian Systems.*
13:30	*Lunch break*	
15:30	**P.O. Lindblad**	*Observational Determination of the Gravitational Potential and Pattern Velocity in Strongly Barred Galaxies.*
16:20	**A. Fridman**	*Observational Manifestation of Chaos in Grand Design Spiral Galaxies.*
17:10	**E. Polyachenko**	*Quarter-turn Spirals just beyond the Principal Arms of Galaxies*
17:35	*Coffee break - Poster Session*	
18:00	**A. Bosma**	*Dark Matter in Galaxies*
18:50	**P. Grosbol**	*Observing Chaos in Galaxies*
19:40	**E. Griv**	*Nonlinear Theory of Gravity Instabilities and Dynamical Evolution of Rapidly Rotating Disk-shaped Galaxies*
20:05-21:00	*Poster session*	

- **Talk: A1**

Order and Chaos in Astronomy

G. Contopoulos

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We give a classification of chaotic systems, and various applications of order and chaos in Astronomy.
(1.) In celestial mechanics chaos has been found in the rotation of certain satellites and in the orbits of asteroids and of some of the planets, like Pluto.
(2.) In galactic dynamics ordered orbits are described by formal integrals, of the "third integral" type. Chaotic orbits appear mainly near the center, near corotation and in the transition region between box and tube orbits.
(3.)There are two types of diffusion of galactic orbits, namely Arnold diffusion and resonance overlap diffusion.
(4.)When the energy becomes larger than the escape energy most chaotic orbits escape to infinity. The escape rates seem to follow a universal law.
(5.)The gas in a galaxy follows the dynamics of dissipative systems. Many dissipative systems have strange attractors.
(6.)Chaos appears also in relativity (e.g. in the case of two fixed black holes) and in cosmology (e.g. the mixmaster model).
(7.)The stellar pulsations may be either regular or chaotic.
(8.)The solar activity is another example where chaos is important (sunspots and flares).

- **Talk: A2**

Critical Ergos Curves and Chaos at Co-rotation

D. Lynden-Bell

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The theory of adiabatic invariants is developed to cover the gyration of a star about a nearly equipotential orbit in a galaxy with a strong bar. The guiding centres for such orbits follow curves of constant Ergos. Critical Ergos curves have a pair of X-type gravitational neutral points which provide switches between trajectories that have the star circulating forward relative to the corotating frame of the bar and those that turn back to remain on one side of the galaxy's centre. An attempt to discover the dynamical basis of the apparently random swiching, that has been observed in computations of orbits with finite amplitudes of gyration, FAILS to find any such chaos at small gyration amplitudes, where Ergos curves give a good description of guiding centre motion.

- **Talk: A3**

Nonlinear Phenomena in Disk Galaxies

P.A. Patsis

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A summary of non-linear phenomena which are related with the morphology of disk galaxies is presented. These phenomena reflect the dynamical behaviour encountered in 2D and 3D models and explain observed structures. In particular I will refer to

- the end of the symmetric part of spiral patterns as observed in the near infrared, and
- the boxiness of the outer isophotes of early-type bars.

The general conclusion is that although the observed overall morphology is due to order, chaos and non-linear phenomena are present and play an essential role in the dynamics of galactic disks.

- **Talk: A4**

Localized Oscillations in Multi Degree of Freedom Hamiltonian Systems

T. Bountis

Department of Mathematics and Center for Research and Applications of Nonlinear Systems University of Patras, Patras GREECE

In recent years, there has been great interest in the study of localized oscillations (known as breathers) in 1-dimensional nonlinear lattices. Even though breathers are described by Hamiltonians of infinitely many degrees of freedom, they are also observed in N - degree of freedom systems, for N finite but large enough. These oscillations are often stable and hence of particular importance regarding properties like transfer of energy. In this lecture, we shall show how breathers can be accurately constructed using the theory of homoclinic orbits of 2-(and higher-) dimensional mappings. Furthermore, we will describe how homoclinic tangles can can be used to predict the existence of localized oscillations of increasing spatial complexity called multibreathers. These oscillations, however, are generally unstable and lead to the occurrence of spatio-temporal chaos, which restores the expected equipartition of energy among all available degrees of freedom.

- **Talk: A5**

Observational Determination of the Gravitational Potential and Pattern Velocity in Strongly Barred Galaxies

Per A.B. Lindblad and Per Olof Lindblad

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In order to compute stellar orbits in spiral galaxies the gravitational potential and its pattern velocity field, i.e. the angular velocities of the non-axisymmetric perturbations of the axisymmetric density distribution, must be known. Observationally, these parameters are difficult to determine. We will illustrate the case of strongly barred galaxies, where the problem has been approached by numerical gasdynamical simulations.

- **Talk: A6**

Observational Manifestation of Chaos in Grand Design Spiral Galaxies.

A. M. Fridman[1], O. V. Khoruzhii[2] and E. V. Polyachenko[3]

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[3]*Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya 48, Moscow 109017, RUSSIA*

The main goal of the contribution is to demonstrate the presence of chaotic trajectories in the gaseous disk of a real spiral galaxies. As an example we have chosen NGC 3631. We present additional arguments in favour of the stationarity of the 3D velocity field restored from the observed line-of-sight velocity field of the gaseous disk. The presence of the stationarity allows to analyse the behaviour of the trajectories of the fluid particles (gas clouds) in the disk, calculating the corresponding observed streamlines. We estimate the Lyapunov characteristic numbers (LCN) using their independence of the metrics. The LCN turn out positive in the vicinity of the saddle points and outside of the vortices which are present in the velocity field. Related spectra of the stretching numbers for some trajectories are also calculated. We show that unlike the LCN the spectra depend on the metrics.

- **Talk: A7**

Quarter-turn Spirals just beyond the Principal Arms of Galaxies

E. Polyachenko

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Observations in the optical show that grand design spirals consist of a set of principle arms and characteristic near-circular extensions that can be described as quarter-turn spirals. Arguments are presented in favor of the idea that the latter set of spirals is merely caused by the response of the material of the disk to the gravitational potential of the main spiral arms.

- **Talk: A8**

Dark Matter in Galaxies

A. Bosma

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I will review the current status of the dark matter problem in galaxies. Special attention will be given to the discrepancies between the slopes of the halo density profiles derived from observations of low surface brightness galaxies and those predicted from cosmological numerical simulations based on the cold dark matter model. I will also discuss recent observations of spiral galaxies, and their impact on the dark matter problem.

- **Talk: A9**

Observing Chaos in Disk Galaxies

Preben Grosbøl

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The regions in disk galaxies where one would expect to find chaotic behavior are reviewed. Different observational techniques (e.g. surface photometry and integral field spectroscopy to obtain line-of-sight velocity profiles) are discussed in terms of their ability to identify regions with chaos in galaxies. Finally, the feasibility of performing such observations with current state-of-the-art facilities such as the VLT is considered.

- **Talk: A10**

Nonlinear Theory of Gravity Instabilities and Dynamical Evolution of Rapidly Rotating, Disk-Shaped Galaxies

E. Griv, M. Gedalin, E. Liverts

Department of Physics, Ben-Gurion University of Negev, POB 653, Beer-Sheva 84105, ISRAEL

The theory of spiral structure (and dynamical evolution) of rotationally supported galaxies has a long history, but, as we emphasize here, is not yet complete. Even though no definitive answer can be given at the present time, the majority of experts in the field is yielded to opinion that the study of the stability of collective vibrations in disk galaxies of stars is the first step towards an understanding of the phenomenon. This is because the bulk of the total optical mass in the Milky Way and other flat galaxies is in stars. (Recent measurements of the local dynamic density by Hipparcos rule out any disk-shaped dark matter [e.g., Creze et al. 1998]. Hipparcos data indicate a moderate contribution of unseen matter to the local potential [Haywood et al. 1997]). We analyze the reaction between growing (unstable) collective-type gravity perturbations and stars of a rotating and spatially inhomogeneous disk of flat galaxies. A mathematical formalism in the approximation of weak turbulence (a quasi-linearization of the Boltzmann collisionless kinetic equation) is developed, which is a direct analogy with the plasma weakly nonlinear formalism. A diffusion equation in configuration space is derived which describes the change in the main body of equilibrium distribution of stars. The distortion in phase space resulting from such a wave-star interaction is studied. The theory is tested by our own N-body computer simulations. Certain applications of the theory to actual disk-shaped galaxies are explored as well. In particular, the theory, applied to the solar neighborhood, accounts for the observed Schwarzschild shape of the velocity ellipsoid, the increase in the random stellar velocities with age, the exponential surface density distribution, and the essential radial migration of the Sun from its birth-place in the inner part of the Galaxy outwards during its lifetime.

Tuesday

09:00	**E. Athanassoula**	*Bars as Engines of Galactic Evolution*
09:50	**O. Gerhard**	*Dynamics of the Milky Way Galaxy*
10:40	**W. Maciejewski**	*Chaos and Order in Double Barred Galaxies.*
11:05	*Coffee break - Poster Session*	
11:30	**C. Hunter**	*Orbits in Kuzmin-like Potentials*
12:20	**N. Voglis**	*Waves from Galactic Orbits. Solitons and Breathers*
13:10	**O.V. Khoruzhii**	*Nonlinear Collective Phenomena in Astrophysical Disks caused by Density Waves*
13:35	*Lunch break*	
15:30	**R. Miller**	*Motions of a Black Hole Near the Center of a Galaxy*
16:20	**A. Burkert**	*Formation of Elliptical Galaxies*
17:10	**T. Nikityuk**	*A Formation of the Halo Stellar Population in Spiral and Elliptical Galaxies.*
17:35	*Coffee break - Poster Session*	
18:00	**H. Kandrup**	*Experimental Tests of Galactic Dynamics.*
18:50	**H. G. Gonzalez-Hernadez**	*CHAOSTIN: A Chaotic Dynamics Analyzer.*
19:10	**E. Verolme**	*Dynamical Models of Early type Galaxies. Constraining Intrinsic Properties by Using Integral-Field Data.*
19:30	**G. Van De Ven**	*Using the Jeans Equations to study Triaxial Models with Separable Potentials.*
19:50-21:00	*Poster Session*	

- **Talk: B1**

Dynamical Evolution of Disk Galaxies

E. Athanassoula

Observatoire de Marseille, 2 Place Le Verrier, Marseille, FRANCE

Bars or ovals can be found in more than half the disc galaxies and also form naturally in N-body simulations of galactic discs. I will use such simulations as tools to explain the formations and evolution of bars. I will then compare the morphological, photometrical and kinematical properties of N-body bars with those of their galactic counterparts. Evolution is due to the exchange of energy and angular momentum between resonant particles in the inner disc and resonant particles in the outer disc and halo. I will discuss what determines this exchange and how it influences fundamental bar properties, like its strength and pattern speed. Material is also redistributed during the evolution and discs can evolve from sub-maximum to maximum.

- **Talk: B2**

Dynamics of the Milky Way Galaxy

O. Gerhard

Observatory of Basel, Astronomisches Institut, Venusstrasse 7, 4102 Binningen, SWITZERLAND

In this talk I discuss the structure of the Milky Way bar and disk from NIR observations, and the dynamics inferred from gas-dynamical calculations. Models which include massive spiral arms clearly match the observed ^{12}CO lv-diagram better than if the potential does not include spiral structure, and models with four massive spiral arms are better fits than two-armed models. In addition, there is evidence from the ^{12}CO data that the bar and spiral arms rotate with separate pattern speeds. This will have interesting implications also for the stellar orbits.

- **Talk: B3**

Chaos and Order in Double Barred Galaxies?

W. Maciejewski

Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, 50125, Firenze, ITALY

Bars in galaxies are mainly supported by particles trapped around closed periodic orbits; these respond to the bar's forcing frequency only and jack free oscillations. We show that a similar situation takes place in double bars; particles get trapped around orbits which only respond to the forcing from the two bars and lack free oscillations. We find that writing the position of a particle on such an orbit every time the bars align generates a closed curve, which we call a loop. Loops allow us to search the phase-space in double bars in order to determine the fraction occupied by ordered motions.

- **Talk: B4**

Orbits in Kuzmin-like Potentials

C. Hunter

Florida State University, Tallahassee, Florida 32306-4510, U.S.A.

Many galaxies, normal spirals and S0s for example, have both a disk component and one or more other components which are much less flattened. Orbits of stars belonging to a less-flattened component will cross back and forth through the disk. As they do, they will experience a fairly abrupt change in the gravitational force field. We will discuss the effects that these repeated changes have on orbits, on the resonances which they can cause, and on the extent to which they can induce chaos. We will discuss the possible astrophysical relevance of these.
This work has been supported by NSF through grant DMS-0104751.

- **Talk: B5**

Waves derived from galactic orbits. Solitons and Breathers

N. Voglis

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We show how Partial Differential Equations (PDEs) can be derived from a Third Integral of motion of galactic orbits. In the case of orbits near the Inner Lindblad Resonance, a Sine-Gordon equation is derived. This equation admits kink or anti-kink soliton solutions. By applying the Third Integral on a string of stars having as initial conditions the successive consequents of an orbit on a Poincaré surface of section a Frenkel-Kontorova Hamiltonian is constructed. The corresponding equations of motion constitute an infinite set of discrete Sine-Gordon equations. These equations admit solutions that represent localized oscillations on a grid. Such solutions are known in the Non-linear Dynamics as Discrete Breathers.

- **Talk: B6**

Nonlinear collective phenomena in astrophysical disks caused by density waves.

O. Khoruzhii

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The talk presents the results of analysis of nonlinear effects in gaseous astrophysical disks arising in response to propagation of the density wave with finite amplitude. The effects include a kind of "high-frequency" pressure, the correspondent corrections to the rotation curve and several kinds of radial flows. The special emphasize is given to the influence of the real 3D structure of the disk and the density wave on the character and amplitude of the disk response.

- **Talk: B7**

Motions of a Black Hole near the Center of a Galaxy

R. H. Miller

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Some years ago we published an account of experiments which indicated that the nucleus of a galaxy orbits around the mass centroid. This can be viewed as an orbiting density wave which grows near the center in a galaxy model that starts without such motions. While these experiments were run without a massive particle, we suggested that similar physical effects might cause a massive particle near the center to oscillate with larger amplitudes than indicated by simple Brownian motion arguments. Results from recent experiments will be reported to clarify some of the issues raised by a massive particle (a black hole) near the center.

- **Talk: B8**

The Formation of Elliptical Galaxies

A. Burkert, Th. Naab, S. Khochfar

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Within the framework of cosmological structure formation galaxies are assumed to form as a result of mergers of smaller substructures. Whereas spiral galaxies result from minor and gas-rich mergers, elliptical galaxies are assumed to have formed by major merger events.
We will present new results which support the major merger scenario of elliptical galaxy formation. Using numerical simulations we demonstrate that the observed correlation between isophotal shape and anisotropy parameter requires ellipticals to have formed by a major merger event instead of multiple minor stellar mergers. We find strong evidence for additional disk components in all rotating ellipticals, independent of whether they are boxy and disky. Our results also indicate that the more massive ellipticals formed through major mergers of early-type systems whereas low-mass ellipticals formed as a result of spiral-spiral mergers.
Finally, current problems and predictions of the major merger scenario will be discussed which require additional observational data.

- **Talk: B9**

A Formation of the Halo Stellar Population in Spiral and Elliptical Galaxies

T. Nikityuk

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A scenario of the galactic formation through merger of fragments has been considered. In a frame work of the scenario a sets of fragments have been obtained whose stellar populations reproduce the observed stellar metallicity distribution function of the Milky Way Galaxy and some other galaxies. Our results allow to conclude that i)formation of the halo globular clusters goes through the merger of fragments in spirals; in ellipticals a role of the merger of fragments in the halo globular cluster formation is still unknown ii)in the Milky Way Galaxy the formation of the majority of halo stars and the halo globular clusters took place in a metal-poor fragments; the formation of the halo field stars could be associated with the formation of halo globular clusters in MWG iii)the formation of bulk of halo field stars of M31 and NGC 5128 could take place in a massive fragments and perhaps don't associate with formation of the halo globular clusters in these galaxies.

- **Talk: B10**

Experimental Tests of Galactic Dynamics

H.E. Kandrup

Department of Astronomy, Department of Physics and Institute for Fundamental Theory, University of Florida, Gainesville, Florida 32611, U.S.A.

This talk discusses three features associated with nearly collisionless systems of bodies interacting via long range $1/r^2$ forces, a class of systems that includes *inter alia* both galaxies and charged particle beams:

1. The bulk potential typically changes in time as the bulk mass distribution evolves. To the extent, however, that this time-dependence involves large amplitude oscillations, resonant interactions can trigger an epoch of *transient chaos* during which – even if the initial and final states correspond to an integrable potential – individual orbits in the bulk potential experience exponential sensitivity and, hence, can exhibit chaotic phase mixing. This has obvious implications for collisionless relaxation.

2. The form of the bulk potential is (at least in part) determined self-consistently by the bulk mass distribution, rather than being imposed externally. It is thus important to determine whether systems in or near a collisionless equilibrium tend to be characterised by a bulk potential that admits large measures of chaos and/or whether systems tend to evolve in such a fashion as to minimise the amount of chaos.

3. Two distinct sources of chaos can be identified, namely *microchaos* reflecting close encounters between individual bodies, which is generic to the N-body problem, and *macrochaos* reflecting properties of the bulk potential, which may or may not be present. Microchaos becomes progressively less important as the number of bodies increases (although, as defined in the usual way, the trajectories of individual bodies appear to become *more chaotic*!), but can prove more important than might be expected on dimensional grounds, especially if macrochaos is also present.

These three effects arise independent of the sign of the two-body interaction, requiring only a many-body system interacting via long range forces, so that, to a considerable degree, predictions made regarding galaxies also apply to systems like charged particle beams. Unlike the case of galaxies, however, predictions regarding beams can be tested in the laboratory. A University of Florida - Fermilab/Northern Illinois University - University of Maryland collaobration is currently planning experiments to look for manifestations of chaos in charged particle beams, both as a tool towards the development of more stable beams (by controlling undesirable emittance growth) and as a Laboratory for Galactic Dynamics.

This work, based largely on collaborations with Ioannis V. Sideris, was supported in part by NSF AST-0070809.

- **Talk: B11**

CHAOSTIN: A Chaotic Dynamics Analyzer

H. G. Gonzalez-Hernadez

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Chaotic phenomena has been observed in many different situations in nonlinear systems such as turbulence, brain activity and astronomy. However, there is a lack of a unified technique for the analysis of systems evolving chaotically; different situations arise according to different system's nature, sometimes a sufficiently accurate model is available and some other times just a measurement of one of the system variables is available. The authors developed a tool that includes several different techniques in one software. This software can handle analysis of systems described by ordinary differential equations, difference equations and time series; features 3D plots, Poincare Maps, n-Return Maps, Lyapunov exponents, fractal dimensions, bifurcation diagrams and attractor reconstruction among other analysis techniques.

- **Talk: B12**

Dynamical Models of Early-type Galaxies: Constraining Intrinsic Properties by Using Integral-field Data

E. Verolme

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We present dynamical models for axisymmetric and triaxial early-type galaxies. Our method is based upon Schwarzschild's orbit superposition method and combines a general density parametrisation with all available kinematical observations. This includes high resolution HST observations and two-dimensional kinematical data obtained with the panoramic integral-field spectrograph SAURON. We show that, by doing this, the method allows us to identify distinct structures in phase-space, such as counterrotating or kinematically decoupled components and thick disks. This has interesting implications on their formation scenario. Furthermore, we discuss the role of chaotic motion and present some results from our models.

- **Talk: B13**

Using the Jeans Equations to Study Triaxial Galaxy Models with Separable Potentials

G. Van De Ven

Sterrewacht Leiden, Postbus 9513, 2300 RA Leiden, THE NETHERLANDS

We have solved the Jeans equations for triaxial galaxies with a potential of Staeckel form. In an initial application, we use the solution, together with Statler's formalism for the mean-streaming motion, to study the properties of the observed velocity and dispersion fields of triaxial galaxies. Staeckel models only harbour regular motion and have cores rather than central density cusps. Even so, they exhibit much of the rich internal dynamics of large elliptical galaxies. For these galaxies we expect to reproduce the observed two-dimensional kinematical features and constrain global properties, such as the M/L ratio and viewing angles.

Wednesday

09:00	**H. Dejonghe**	*Dynamics of Galaxies: From Observations to Distribution Functions*
09:50	**D. Pfenniger**	*Limits of N-body simulations*
10:40	**C. Efthymiopoulos**	*Spherical Shell Models of the Distribution Function of Collisionless N-Body Systems.*
11:05	*Coffee break - Poster Session*	
11:30	**B. Jones**	*Cosmic Structure: The Growth of Order to Chaos*
12:20	**R. Weygaert**	*Foamlike Patterns and Gravitational Structure Formation*
13:10	**M. Harsoula**	*Direct vs Merger Mechanism Forming Counterrotating Galaxies*
13:35	*Lunch break*	
15:30	**J. Hadjidemetriou**	*On the Stability of Extrasolar Planetary Systems: Chaotic and Ordered Motion.*
16:00	**H. Skokos**	*Detecting Ordered or Chaotic Motion in Hamiltonian Systems by the Smaller Alignment Index (SALI) Method*
16:25	**E. Liverts**	*Nonlinear Response of Supersonic Interstellar Gas Flow to Galactic Spiral Density Waves.*
16:45	*Coffee break - Poster Session*	
17:05	**R. Dvorak**	*Chaos in the Solar System Dynamics*
17:55	**H. Varvoglis**	*The "Third" Integral in the Restricted Three-Body Problem Revisited*
	Guest speaker:	
18:25	**B. Papazachos**	*Chaos in Seismology and Earthquake Prediction.*

- **Talk: C1**

The Determination of Distribution Functions for Stellar Systems.

H. Dejonghe

University of Ghent, Astronomical Observatory, Krijgslaan 281, S9,B 9000 Gent, BELGIUM

We review various methods to determine distribution functions for stellar systems. We pay attention to both parametric and non-parametric methods, and discuss briefly the underlying statistical mechanics, where appropriate. We touch upon the complicated issue of the determination of the gravitational potential. From the observational side, we discuss the difficulties connected with a reliable determination of kinematic data, which is our most critical source of information on the dynamical state of a stellar system.

- **Talk: C2**

Limits of N-body Simulations

D. Pfenniger

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N-body systems are strongly chaotic and the only rational way to interpret typical N-body simulations is of statistical order. Classical statistical mechanics tools can not be applied to gravitational systems blindly due to their non-extensive properties. Illustrated by a series of N-body experiments, commonly encountered situations in simulations of collisionless or SPH N-body systems will be discussed, where the effect of the standard softening acts to reverse the heat capacity sign. This implies a drastic misrepresentation of the physical system intended to be simulated.

- **Talk: C3**

Spherical Shell Models of the Distribution Function of Collisionless N-Body Systems

C. Efthymiopoulos[1,2] and N. Voglis[1]

[1] *Center for Astronomy, Academy of Athens*
[2] *Department of Statistics, University of the Aegean*

We study the distribution function of collisionless N-Body systems in equilibrium after a violent relaxation from cosmological initial conditions. A system is decomposed in a number of spherical shells. Thermodynamical quantities (e.g. temperatures) are defined within each shell of radius r, in a way that their values vary smoothly with r. Models of the coarse grained distribution function are built based on the statistical regularity of the number density function $\nu(\mathcal{E}, L^2, r)$ within each shell of radius r. The models can take the form of modified Stiavelli-Bertin (1987) models. The main modification is that the Lagrange multipliers appearing in the distribution function have values that are functions of the radius. These models are derived from the orbital dynamics of only the monopole component of the potential expansion, but they are found to fit nicely the observable profiles of triaxial N-Body systems as well.

- **Talk: C4**

Cosmic Structure - The Growth of Order out of Chaos

B. Jones

Copenhagen University Observatory

The Universe we observe today is rich in structure. Not only do we see galaxies and clusters of galaxies: we see the organisation of cosmic structure on vast scales in the form of filaments and sheets of galaxies surrounding vast voids. Yet the Universe is thought to be born from random initial conditions determined by physical processes taking place shortly after the big bang. This hypothesis has received strong support from recent measurements of the anisotropy of the cosmic microwave background radiation.

The question arises as to how the observed grand organization emerged from the primordial chaos. We know that gravity acting on large scales was the driving force. We would like to understand how gravity produced the structures we see. In particular, we would like to understand the origin of the approximately lognormal distribution of the density field, the scaling of the two-point and higher correlation functions, and the fact that the random component of the cosmic velocity field is Gaussian, despite extreme nonlinearity in the density field.

I will outline how this structure is described quantitatively in a dynamically relevant way by use of fractal scaling techniques and present a dynamical model that provides a basis for understanding the emergence of this remarkable structure.

- **Talk: C5**

Foamlike Patterns and Gravitational Structure Formation

R V.d. Weygaert

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In a great many physical systems, the spatial organization of matter is one of the most readily observable manifestations of the forces and processes forming and moulding them. Richly structured morphologies are usually the consequence of the complex and nonlinear collective action of basic physical processes. Their rich morphology is therefore a rich source of information on the combination of physical forces at work and the conditions from which the systems evolved. In many branches of science the study of geometric patterns has therefore developed into a major industry for exploring and uncovering the underlying physics.

The interior of the Universe is permeated by a tenuous space-filling frothy network. Welded into a distinctive foamy pattern, galaxies accumulate in walls, filaments and dense compact clusters surrounding large near-empty void regions. This vast Megaparsec cosmic web is undoubtedly one of the most striking examples of complex geometric patterns found in nature. In its own right, its vast dimensions and intricate composition make the cosmic web one of the most imposing and intriguing patterns existing in the Universe.

The wide-ranging importance of the cosmic foam stems from its status as a cosmic fossil. As borne out by a large sequence of computer experiments, such weblike patterns in the overall cosmic matter distribution do represent a universal but possibly transient phase in the gravitationally propelled emergence and evolution of cosmic structure. We discuss the properties of this striking and intriguing pattern, describing its observational appearance, seeking to elucidate its dynamical origin and nature and attempting to frame a geometrical framework for a systematic evaluation of its fossil content of information on the cosmic structure formation process. Special attention is put on a geometrical and stochastic framework for a systematic evaluation of its fossil information content on the cosmic structure formation process. Its distinct geometric character and the stochastic nature provides the cosmic web with some unique and at first unexpected properties. The implications for galaxy clustering are discussed on the basis of its relevant branch of mathematics, stochastic geometry. Central within this context are Voronoi tessellations, which have been found to represent a surprisingly versatile model for spatial cellular distributions.

- **Talk: C6**

Direct vs Merger Mechanism Forming Counterrotating Galaxies

N. Voglis and M. Harsoula

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We investigate the formation of counterrotating elliptical galaxies, using N-body simulations in two alternative scenarios: a) The scenario of a dissipationless merger of a primary galaxy and a satellite and b) the direct scenario, in which counterrotating galaxies are formed primordially, from cosmological initial conditions. In the merger scenario, a large number of initial parameters must be fixed inside a certain range of values, for the creation of counterrotating remnant galaxies. In the direct scenario, counterrotation appears as a spontaneous result of the cosmological tidal interaction between a bound system, formed by a bar-like density excess in the early post-decoupling Universe, and the density perturbations of the environment. The parameter space here is much more simple. Although our simulations have shown that both scenarios are possible, the large number of counterrotating galaxies (almost 1/3 of the observed elliptical galaxies) makes the direct scenario more probable.

- **Talk: C7**

On the Stability of Extrasolar Planetary Systems: Chaotic and Ordered Motion.

J. D. Hadjidemetriou and D. Psychogiou

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The stability of planetary systems with two planets is studied, taking into account the masses of the planets, their eccentricity and their relative position in their orbits. The results are compared with several extrasolar planetary systems that have been observed recently, with two relatively large planets, and in some cases large eccentricties. It is proved that extrasolar planetary systems, even with large masses and eccentricities, can be stable, provided that they are close to stable resonant periodic orbits. Indeed, all the extrasolar planetary systems with large eccentricities that have been observed, are close to a resonance. In particular, we study the 2/1, 5/1 and 5/2 resonant cases, and we find that stable families of resonant periodic orbits exist. On the other hand, it is proved that the phase (relative position of the two planets in their orbits) plays a crucial role in the stability of the system, and that for the same resonance and the same eccentricities chaotic motion appears, if the initial phase is changed, resulting to a quick disruption of the planetary system. On the other hand, a phase protection mechanism appears for suitable initial phase of the two planets, resulting to stable, ordered, motion. An application of the above results to observed extrasolar planetary systems is made, by the method of the Poincare map on a surface of section.

- **Talk: C8**

Detecting ordered or chaotic motion in Hamiltonian systems by the Smaller Alignment Index (SALI) method

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We apply the recently introduced method of the Smaller Alignment Index (SALI) for determining the ordered or chaotic nature of orbits, on some examples of Hamiltonian systems and symplectic maps. One of the main advantages of the SALI is that it can be computed easily. For a given orbit we follow the evolution in time of two different initial displacement vectors. In every time step we compute the norms of the difference (parallel alignment index) and the addition (antiparallel alignment index) of the two normalized vectors. The time evolution of the smaller alignment index (SALI) reflects clearly the chaotic or ordered nature of the orbit. In general the SALI tends to zero for chaotic orbits, while it fluctuates around non-zero values for ordered orbits. The computation of the SALI for a sample of initial conditions allows us to distinguish easily between regions in the phase space where ordered or chaotic motion occurs. The relationship of this index with the Lyapunov exponent is also discussed.

- **Talk: C9**

Nonlinear Response of Supersonic Interstellar Gas Flow to Galactic Spiral Density Waves

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Supersonic nonlinear gas behavior is studied to describe the gas flow in the galactic spiral density waves. It was shown that $4\pi, and\ \ 6\pi$ periodic solutions may exist if the nonlinear effect is taken into account. This analytical study of the properties of nonlinear flows yields results that are qualitatively similar to those found numerically for fully nonlinear flows Shu *et al* (1973). It is demonstrated that a certain range of values for the intrinsic frequency of the waves gives rise to combined ultra harmonic and parametric resonance response which can introduce a secondary compressions of the interstellar gas. This result may relate directly to the phenomena of filamentation of the arms if certain conditions are fulfilled on galactic disc scale, as well as to small scale structures like feathers, and thorns if the conditions are fulfilled locally.

- **Talk: C10**

Chaos in the Solar System Dynamics

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With the discovery of exosolar systems the dynamical evolution of our Solar System is seen in a new light, because it serves as a model for any new discovered planetary system. As far as we know our planets are moving in stable orbits for billions of years. Chaotic motion is evidently governing the motion of the small bodies in our system making their dynamical history rather turbulent: comets coming from the Oort cloud and the Kuiper belt may collide with planets (e.g. SL9) or may become Sungrazers and the asteroid population close to the Earth is now recognized as being of potential danger for the Earth. In this lecture we discuss the long term evolution of the planetary orbits, which is now fairly well understood, then we will discuss the nature of dynamical chaos acting on the inner and the outer planets and the limits of predictability of their orbits. We also report the stages of dynamical evolution of the comets, which is mainly determined by the giant planet Jupiter and then we will review our knowledge of the dynamics of the different asteroid populations: from the Kuiper-belt objects, the Centaurs between Neptune and Jupiter, the classical Trojans and the main-belt asteroids with its gaps to the Near Earth Asteroids mentioned already above. Due to extensive numerical integrations of the equations of motion via more or less complicated new and old methods and the analytical work of theoreticians our knowledge for the cause of the chaotic behaviour has been improved a lot and we understand the fundamental role of the different sorts of resonances respectively resonance overlapping acting on the motion of Solar System bodies.

- **Talk: C11**

The "Third" Integral in the Restricted Three-Body Problem Revisited

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Some forty years ago G. Contopoulos, aiming at the interaction and cross-fertilization between Galactic Dynamics and Celestial Mechanics, organized in Thessaloniki a IAU symposium devoted to the theory of orbits. In this meeting V. Szebehely and G. Bozis presented the first numerical results, indicating the existence of a "new" local integral of motion in the restricted three-body problem. The first terms of an asymptotic expansion of this integral were later calculated by Bozis (1966), who used a method devised by Contopoulos (1960) in his pioneering work on the "third" integral in Galactic Dynamics. Since then the Celestial Mechanics astronomical community developed a very successful theory on local integrals of motion in the restricted three body, which however in the jargon of this field are called "proper elements" (Yuasa, 1973; Milani and Knezevic, 1990). This theory is based on the implicit assumption that the orbit traced by a planet (major or minor) is regular. Here we show that the method can be applied, albeit partly, in the case of a special class of chaotic motion in the Solar System, known as "stable chaos". The existence of an additional non-isolating (local) integral of motion in the elliptical restricted three-body problem is responsible for the phenomenon of stable chaos, while its absence is closely related to the creation of the Kirkwood gaps.

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- **Talk: C12**

Chaos in Seismology and Earthquake Prediction

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The theory of chaos, as an emerging discipline, has affected much seismological research during the last decade. It contributed to a better understanding of the physical process of earthquake generation and to the improvement of the capability for earthquake prediction. This theory motivated the introduction in seismological research older and new concepts (self-organized criticality, deterministic chaos, critical point), terms (power laws, fractals, self similarity, scale invariance), physical models (slider block model, sand pile model, forest fire model, percolation model) and numerical procedures (cellular automata models, hierarchical models, renormalization group procedures). It is shown in this article that the concepts of: self-organized criticality explains properties of distributed and induced seismicity, deterministic chaos interprets the sensitive dependence of a future mainshock on the rupture properties of the previous past mainshock and the critical point concept explains accelerating seismicity. It is further shown, based on the chaos theory, that very long term earthquake prediction is inherently very difficult, long term statistical prediction is practically applicable, intermediate term prediction is possible but it needs further testing and short term earthquake prediction is not possible at present.

Thursday

09:00	**G. Bertin**	*Weak Homology of Elliptical Galaxies*
09:50	**V. J. Martinez**	*Lacunarity in the Galaxy Distribution.*
10:15	**A. Del Popolo**	*Mass Function of Dark Matter Haloes*
10:35	**M. Barkov**	*Model of Ejection of Matter from Nonstationary Dense Stellar Clusters and Chaotic Motion of Gravitational Shells.*
10:55	*Coffee break - Poster Session*		
11:20	**L. Galgani**	*An Analogy between the "Nonclassical" Statistical Distributions of Molecular Dynamics and those of Stellar Dynamics.*
12:05	**A. El-Zant**	*Bar Survival in Mildly Triaxial Halos*
12:30	**C. Skiadas**	*Chaotic Dynamics in Simple Rotation-Reflection Models*
	Conclusions	
12:50	**G. Contopoulos**	*Workshop Review and Discussion.*
13:40	*Lunch break*		

- **Talk: D1**

Weak Homology of Elliptical Galaxies

G. Bertin

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Studies of the Fundamental Plane of early-type galaxies, from small to intermediate redshifts, are often carried out under the guiding principle that the Fundamental Plane reflects the existence of an underlying mass-luminosity relation for such galaxies, in a scenario where elliptical galaxies are homologous systems in dynamical equilibrium. Here I will re-examine the issue of whether empirical evidence supports the view that significant systematic deviations from strict homology occur in the structure and dynamics of bright elliptical galaxies. In addition, I will discuss possible mechanisms of dynamical evolution for these systems, in the light of some classical thermodynamical arguments and of recent N-body simulations for stellar systems under the influence of weak collisionality.

- **Talk: D2**

Lacunarity in the Galaxy Distribution

Vicent J. Martinez[1] and Enn Saar[2]

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The large-scale distribution of galaxies in the universe shows remarkable patterns in which big regions of the space, nearly devoid of galaxies, are surrounded by filamentary and sheet-like structures where the galaxies lie. The description of this clumpy distribution and its relation with the matter density field is one of the main goals of modern cosmology. While at small scale the distribution is fractal, at larger scales the analysis of the deep redshift surveys shows unambiguously a gradual transition to homogeneity. This view has been recently reinforced by the galaxy maps displayed by huge ongoing datasets as the 2dF and the SDSS redshift surveys. Within the fractal regime, the distribution cannot be completely described by its fractal dimension. In fact, several distributions showing different patterns may perfectly have the same fractal dimension. In this letter we make use of a measure called lacunarity as defined by Mandelbrot to characterize the cosmic texture. Lacunarity is a property related with the presence of empty regions of different size that measures how a set deviates from being transactional invariant.

- **Talk: D3**

Mass Function of Dark Matter Haloes

A. Del Popolo

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I use the extension of the excursion set model of Sheth & Tormen (2002) and the barrier shape obtained in Del Popolo & Gambera (1998) to calculate the unconditional halo mass function, and the conditional mass function in several cosmological models. I show that the barrier obtained in Del Popolo & Gambera (1998), which takes account of tidal interaction between proto-haloes, is a better description of the mass functions than the spherical collapse and is in good agreement with numerical simulations (Tozzi & Governato 1998, and Governato et al. 1999).
The results are also in good agreement with those obtained by Sheth & Tormen (2002), only slight differences are observed expecially at the low mass end. I moreover calculate, and compare with simulations, the temperature function obtained by means of the mass functions previously calculated and also using an improved version of the M-T relation, which accounts for the fact that massive clusters accrete matter quasi-continuously, and finally taking account of the tidal interaction with neighboring clusters. Even in this case the discrepancy between the Press-Schecter predictions and simulations is considerably reduced.

- **Talk: D4**

Model of Ejection of Matter from Nonstationary Dense Stellar Clusters and Chaotic Motion of Gravitational Shells

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It is shown that during the motion of two initially gravitationally bound spherical shells, consisting of point particles moving along ballistic trajectories, one of the shell may be expelled to infinity at subrelativistic speed V ¡= 0.25 c. The problem is solved in Newtonian gravity and GR. Motion of two intersecting shells in the case when they do not runaway shows a chaotic behaviour. We hope that this toy and oversimplified model can give nevertheless a qualitative idea of the nature of the mechanism of matter outbursts from the dense solar clusters.

- **Talk: D5**

An Analogy between the ”Nonclassical” Statistical Distributions of Molecular Dynamics and those of Stellar Dynamics

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Since the years 70's it was observed that in molecular dynamics, inparticular in the Fermi-Pasta-Ulam problem, one meets with statistical distributions different from that of Maxwell-Boltzmann. This clearly presents an analogy with some nonclassical distributions, as that of Lynden-Bell, met in stellar dynamics. Here it is pointed out that the analogy is even stronger, because it was recently observedthat the nonclassical distributions of molecular dynamics describe a kind a metaequilibrium, which on longer and longer times tends to the classical situation, as is known to be the case in stellar dynamics.It turns out that also the use of a kind of ”third integral” has many similarities in the two cases. Finally some recent results on the dynamical foundations for the nonclassical distributions of molecular dynamics are illustrated, which are related to the presence of the so called Levy flights. Whether something analogous might occur in stellar dynamics is presently unclear.

- **Talk: D6**

Bar Survival in Mildly Triaxial Halos

A. El-Zant

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We study the orbital stucture of barred galactic systems embedded in mildly non-axisymmetric extended dark matter halos. We find stong correlation between the stability properties of the trajectories, as measured by standard diagnostics such as Liapunov exponets and their configuration space structures. Both these measures indicate that centrally concentrated halos that are even mildly trixial (even 1% deviation in the potenital axis ratio from non-axisymmetry may be sufficent) are unlikely to envelop barred galaxies. The implications for both structure formation and galactic structure are discussed.

- **Talk: D7**

Chaotic Dynamics in Simple Rotation-Reflection Models

C. Skiadas

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In chaotic dynamics the main effort is usually centered on the formulation of relatively simple models with only few chaotic parameters. If the main characteristics of the phenomenon are included in the final model the chaotic character of many phenomena in nature could be well expressed. Chaotic formation in Galaxies could appear when rotation, reflections and translations (axial movements) are present along with the influence of gravitational forces that play an important role. In this paper we present simple iterative models, perhaps the simplest ones, which can include rotation, reflection, translation and the influence of gravitational forces in the angle of rotation. The models give interesting aspects that are studied analytically and are presented in several graphs after the simulation. A simple spherical form appears when no translation (axial movement) is present, by means that there are no asymmetries. When the axial movement (translation) is larger and larger first a spiral form is present, it continues until a double connected formation appear and finally leads in two separated spiral forms. Several spiral forms of various formations can be modeled by changing the parameters of the models. The formulation of the paper follows a geometric analytic approach in an Euclidean space. Chaotic attractors are classified according to their rotation-reflection form.

Posters

F-A. Balderas	*Photometric Properties of Karachentsev's Mixed Pairs of Galaxies*
S. Dikova	*Virtual Causality*
D. Docenko and K. Berzins	*Spline Histogram Method for Reconstruction of Galaxy Cluster Probability Distribution Function*
S. Hozumi	*Pitch Angle of Spiral Galaxies as Viewed from Global Instabilities of Flat Stellar Disks*
M. Iyer et al.	*Arp 158: A study of the HI*
M. Kostina	*Metal Enrichment of the Intergalactic Medium at High Redshifts*
I. Livadiotis and N. Voglis	*Properties of N-coupled Standard Maps and their Dynamical Spectra of Stretching Numbers*
E. Liverts et al.	*Dynamical Evolution of Galaxies: Supercomputer N-body Simulations*
A. Mathieu	*From Kinematics to Dynamics in Stellar Systems*
N. Mouawad and A. Eckart	*Stellar Orbits at the Center of the Milky Way*
V. Muccione and L. Ciotti	*N-body Simulations of Elliptical Galaxies interacting with the Cluster Tidal Field: Origin of the Intracluster Stellar Population*
E. Rassia	*Deep Wide Search for Emission Line Galaxies at the MPG/ESO 2.2m Telescope*
P. Tarakanov	*Abnormal Fractal Diffusion in Interstellar Medium of Galaxy*
B. Terzic	*Building Self-Consistent Triaxial Galaxy Models using Schwarzschild's Method*
N. Voglis, C. Kalapotharakos et al.	*Level of Chaos in N-body Models of Elliptical Galaxies*
G. Voyatzis	*A Low Frequency Spectral Indicator and Classification of Trajectories in Hamiltonian Systems*

- **Poster: No. 1**

Photometric Properties of Karachentsev's Mixed Pairs of Galaxies

A-F. Balderas

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The theoretical and observational studies related to evolution of galaxies indicate that they do not finish forming at high redshift, as a result of a fast collapse of the protogalactic cloud. The collisions and mergers continue during all the history of galaxies. Studies of Spiral-Elliptical pairs (E+S) in the North Hemisphere show that they have an excess of emission in optical and FIR wavelengths (Sulentic, 1989; Xu and Sulentic 1991; Hernadez-Toledo et al. 1999, 2000). This phenomenon has been explained as a result of an accelerated process of induced stellar formation in the spiral component which is tidally induced by the presence of the elliptical component. We report photometric evidence of morphological disturbance in E+S pairs.

- **Poster: No. 2**

Virtual Causality

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The aim of the present research is to explore the ways in which Deterministic Chaos affects the Principle of Causality in modern Physics. The main idea consists in understanding that returning to interdisciplinary thinking may hold the key to various open problems in Science. I suppose a thesis, according to which Deterministic Chaos encourages us to separate total predictability from Determinism and permits us to define a new principle of causality in the light of the new paradigm. I define the term "virtual causality" and investigate the consequences from the elucidation of time paradox by the Complex Spectral Analysis developed by the Brussels-Austin groups directed by Nobel Prise laureate Prof. Ilya Prigogine.

• **Poster: No. 3**

Spline Histogram Method for Reconstruction of Galaxy Cluster Probability Distribution Function

D. Docenko[1] and K. Berzins[2]

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We present a new realization of spline histogram method [1] for reconstruction of ID galaxy probability distribution function (PDF) underlying a galaxy cluster. In this method one uses intermediate construction of cubic spline interpolating the cumulative distribution function (CDF). Spline is drawn precisely through data points. PDF is then obtained by taking analytical derivative of CDF. New algorithm TCSplin [2], realized in FORTRAN language, uses tensioned cubic splines for interpolation of CDF, and digital Savitzky-Golay filters [5] for smoothing of PDF. This smoothing is necessary to diminish the role of shot noise in PDF. Smoothing filter size is defined automatically by minimizing the integrated square error (ISE) function (cf. [4]). Special algorithm is used to completely exclude extrema from CDF. Both the spline histogram algorithm and the smoothing algorithm are objective, and they do not make any assumptions about dataset distribution function (except that PDF exists and it is a smooth function). Savitzky-Golay filters were chosen because they minimally distort the distribution by conserving its first moments locally. This algorithm is suitable not only for galaxy cluster analysis, but also for any statistical selection purposes. The following tests of the algorithm were performed. The random selections were taken from several model distributions - single Gaussian and two partially overlapping Gaussians with different dispersions (with gap height at half maxima height). Results have shown visual obvious separation of two gaussians if volume of selection exceeded 50 points. Width of smoothing filter has shown to behave correctly with changing of volume of the selection. The algorithm was tested on data sets of several real galaxy clusters including the Centaurus cluster A3526 shown here as example. The spline histogram of the central part of A3526 is shown in Fig.1. It has a well-defined multimodal radial velocity distribution function as it can be well seen from the generated PDFs. The previous studies of this cluster has found two subclusters CenSO and Cen45 and group around 9000 km sec^{-1} (cf. [3] and [4]). Using the same dataset as [4], besides the three known subgroups a new small (about 8 galaxies) foreground group, merging with the main subcluster CenSO, was detected using the spline histogram. Possibly it is a redshift space caustics infalling in the cluster from the background side in the real space. We conclude that the spline histogram algorithm is widely applicable in structure analysis of galaxy clusters and statistical selections in general. The more detailed discussion of the spline histogram method will be given in our upcoming paper (in preparation).

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- **Poster: No. 4**

Pitch Angle of Spiral Galaxies as Viewed from Global Instabilities of Flat Stellar Disks

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We study what controls the pitch angle of spiral galaxies when spiral structure is viewed as a manifestation of the unstable modes caused by global instabilities of infinitesimally thin stellar disks. Two series of disk models are constructed: one is that the radial velocity dispersion profile remains unchanged from model to model, and the other is that the distribution of the Toomre stability parameter Q is the same for all models. The fastest growing global modes are obtained by numerically solving the linearized collisionless Boltzmann equation. We have found that the pitch angle increases as the surface density decreases for the same radial velocity dispersion profile models, while this relation is made inverted for the same Q distribution models. These results can be explained qualitatively by the local dispersion relation derived from the density wave theory. Finally, we can show that the difference in pitch angle from galaxy to galaxy originates from the difference in the ratio of the square of the radial velocity dispersion to the surface density, provided that the total mass profile is invariable. Our finding suggests that the Hubble sequence would represent an increasing sequence of this ratio from Sa to Sc.

- **Poster: No. 5**

Arp 158: A study of the HI

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According to the evolutionary sequence described by Hibbard et al. (1986), Arp 158 appears to be an intermediate stage merger. There seems to be 2 distinct knots connected by a bar embedded in luminous material. There is also a diffuse spray to the southeast. As noted by A. Toomre (Chincarini and Heckathorn, 1973, PASP, 85, 568), there is a certain similarity between Arp 157 (NGC 520) and Arp 158. We present high sensitivity 21cm observations of the Arp 158 system. The distribution of HI in both these systems is however, rather dissimilar. In Arp 157, the distribution of the HI is very disc-like. Although Arp 158 contains a large amount of HI, its appearance is not very disc-like. The HI is spread out far beyond the optical system, indicative of an interaction or a merger. HI observations also reveal the presence of three different systems with distinct kinematics. One of these systems has no apparent optical counterpart. There is also a difference of 400 km/sec between the other two systems with a distinct discontinuity between them. We have performed a study of the HI dynamics which will help us understand the overall formation and evolution of this system and its role in galaxy evolution.

- **Poster: No. 6**

Metal Enrichment of the Intergalactic Medium at High Redshifts

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Simple model of the metal enrichment of the intergalactic medium (IGM) is considered. Dependence of heavy elements abundance on galaxies and stars formation processes and mechanisms of galaxies mass loss is investigated. Results of simulations and observational data of L_alpha-clouds abundance are compared.

- **Poster: No. 7**

Properties of N-coupled Standard Maps and their Dynamical Spectra of Stretching Numbers

G. Livadiotis[1,2] and N. Voglis[1]

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[2] *University of Athens Department of Physics, Section of Astrophysics*

The dynamical spectra of stretching numbers in N coupled Standard maps have a fast convergence, almost independent of N, to particular invariants forms. We examine the role of the unstable Manifold with the Maximum eigen value λ that we call MML. We show how MML is responsible for the fast convergence of the Dynamical Spectra in such systems.
The role of the coupling constant is also examined. We find that there is a critical value separating the weak from the strong coupling. Orbits starting on the MML present limited diffusion around this manifold, which depends on the coupling constant.
If all the coupled Standard Maps have the same non-linearity constant, a number of symmetries are found that simplify the study of such systems. The method of finding symmetries is general independent of the particular form of the coupled maps. In the case of different non-linearity constants the Dynamical Spectra still have a fast convergence that is obtained by a similar mechanism, but with a more complicated geometry.

- **Poster: No. 8**

Dynamical Evolution of Galaxies: Supercomputer N-body Simulations

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The time evolution of initially balanced, rapidly rotating models for an isolated disk of highly flattened galaxies of stars is calculated. The method of direct integration of the Newtonian equations of motion of stars over a time span of many galactic rotations is applied. Use of modern concurrent supercomputers has enabled us to make long simulation runs using a sufficiently large number of particles N= 100,000. One of the goals of the present simulation is to test the validities of a modified local criterion for stability of Jeans-type gravity perturbations (e.g. those produced by a barlike structure, a spontaneous perturbation and/or a companion galaxy) in a self-gravitating, infinitesimally thin and collisionless disk. In addition to the local criterion we are interested in how model particles diffuse in velocity. This is of considerable interest in the kinetic theory of stellar disks. Certain astronomical implications of the simulations to actual disk-shaped (i.e. rapidly rotating) galaxies are explored. The weakly nonlinear, or quasi-linear kinetic theory of the Jeans instability in disk galaxies of stars is described as well.

- **Poster: No. 9**

From Kinematics to Dynamics in Stellar Systems

A. Mathieu

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I will present a review of current methods to solve the fundamental problem of galactic dynamics, i.e. finding the dynamics of stellar systems from their observables.

- **Poster: No. 10**

Stellar Orbits at the Center of the Milky Way

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The combined SHARP and Keck data base now contains stellar proper motion information over 10 years. For the central high velocity stars this allows us to measure orbital accelerations or to derive upper limits on these quantity. Not only can the accelerations be used to obtain an improved estimate of the enclosed mass,they also allow to us to derive estimates on the central number density distribution of the stars in the vicinity of SgrA*. We also discuss the importance of relativistic and Newtonian periastron shifts for stellar orbits in the central cluster and how future observations with infrared interferometers (LBT, VLTI, Keck) will help to improve our understanding of the dynamics and distribution of the stars in this region.

- **Poster: No. 11**

N-Body Simulations of Elliptical Galaxies Interacting with the Cluster Tidal Field: Origin of the Intracluster Stellar Population

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We describe the evolution of stellar orbits in cluster elliptical galaxies, under the effect of the cluster tidal field.By performing Monte-Carlo simulations of several hundred thousand orbits on the parallel supercomputer "GRAVITOR" at the Geneva Observatory, we explore the possibility that collisionless stellar evaporation from elliptical galaxies is an effective mechanism for the production of the recently discovered intracluster stellar population(ISP).

- **Poster: No. 12**

Deep Wide Search for Emission Line Galaxies at the MPG/ESO 2.2m Telescope

E. Rassia

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A lot can be derived from the study of emission line galaxies, since not only do they include a wide range of phenomena, interesting for individual study, but also they host, in many cases, some of the most energetic ones known in the Universe. Therefore, a study of their distribution can also provide information about galaxy formation and evolution and large scale structures. In order to conduct a deep search for them, there is a need for a combination of a wide field and a large collecting area. These characteristics are uniquely provided in the southern hemisphere by the Wide Field Imager (WFI) mounted on the- 2.2m MPG/ESO telescope in La Silla. Our survey is based on imaging and slitless spectroscopy using this instrument. We more particularly concentrate on HII and star forming galaxies, low metallicity dwarf galaxies and type 2 AGNs, by a means of a search sensitive to Ha, HJ3, [Oil], [OIII] lines in the redshift ranges of 0.02 and 0.44. Data reduction techniques and primary results will be presented.

- **Poster: No. 13**

Abnormal Fractal Diffusion in Interstellar Medium of Galaxy

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As show observations, the molecular clouds in ISM are fractals with fractal dimension about 2.35. The model of formation of a cloud is considered by "cloudlets" aggregation, thrown out from stars. Is shown, that the driving of a cloudlet in the interstellar medium is well described within the framework of model of a generalized Brownian motion and, hence, generatored thus cloud should have fractal structure. It is known, that for cloudy structures of various types (including atmospheric clouds and L-alpha forest clouds) the fractal dimension also is close by 2.35. The hypothesis is expressed, that the value of fractal dimension of a cloud is completely determined by cloudlet mass modification character, and the constancy of fractal dimension for clouds of various types is stipulated by proximity of the mass increment laws of at clouds formation. By reviewing all population of cloudlets the "microscopic" exposition of moving is unsuitable. It is possible to describe a generalized Brownian motion of an ensemble of particles as generalized diffusion process with a time-dependent factor - the abnormal diffusion. The connection of the law of cloudlet mass increase, process of the abnormal diffusion of cloudlets properties and fractal dimension of structures obtaining as a result of such process is considered. Is shown, that the fractal dimensionality of formed clouds corresponds to the "natural" mass increment law following from the supposition about stochastic collisions of cloudlets.

- **Poster: No. 14**

Building Self-Consistent Triaxial Galaxy Models using Schwarzschild's Method

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Our findings strongly suggest that strengthening the central density cusp increases its ability to efficiently scatter centrophilic orbits and render them chaotic, which is in agreement with earlier studies of cuspy potentials. This chaotic scattering rids models of regular box-like orbits necessary to reproduce flattened triaxial shapes, thus rendering them non-self-consistent. We also demonstrate that strengthening the central density cusp stabilizes of the centrophobic tube orbits. Delineating self-consistent and non-self-consistent regions of the axis-ratio space enables us to quantify how and to what extent can triaxiality and central density cusps coexist. The self-consistent solutions of the weak-cusped galaxies are found for the full range of triaxial shapes, while in the case of the strong cusps the self-consistent region of the axis-ratio space is limited to nearly axisymmetric, mildly triaxial, regions near the prolate and oblate boundaries. This establishes gravitational scattering as the key factor in restricting the shapes of elliptical galaxies.

- **Poster: No. 15**

The Level of Chaos in N-Body Models of Elliptical Galaxies

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We study the level of chaos (proportion of particles in chaotic orbits) in four different self-consistent N-Body models of elliptical galaxies in equilibrium.
Two of the N-Body systems (Q model and C model) are produced from quiet and clumpy cosmological initial conditions. These models are non-rotating and they have a smooth density profile at the center. The other two models (QB1 and QB2) are produced from the Q model by adding a point mass (black hole) at the center, with a mass equal to 0.1% and 1% of the total galactic mass respectively. All the models are triaxial, but the Q and QB models are more elliptical than the C-model.
We propose a methodology to obtain reliable estimates of the level of chaos (proportion of chaotic orbits) in a self-consistent galactic system. This methodology combines three different numerical methods known in the literature. The combined use of the three methods provides a solution to the problem of estimation of Lyapunov times despite the very different periods of particular orbits within a galactic system.
The models Q and C (with smooth central density profiles) have chaotic orbits only at relatively low absolute energies, i.e. at energy levels exceeding the deepest 30% of the potential well. Below this level most orbits are regular boxes or box-like. In the Q model, the detected chaotic part is about 30% of the total mass. This part has a nearly spherical distribution. It imposes limitations on the maximum ellipticity of the system, in spite the fact that only a part less than about 8% of the total mass moves in chaotic orbits able to develop chaotic diffusion within a Hubble time. In the C model, the detected chaotic part is about 25% of the total mass, but only less than 2% can develop chaotic diffusion within a Hubble time. Chaos is much more pronounced in the QB models with the central black holes, and it extends to energies down to the minimum of the potential well. This has implications on the number of particles in box or 1:1 tube orbits, and it affects the ellipticity of the systems. The overall proportion of particles in chaotic orbits reaches as much as 70% in the QB models. Notice that no Lyapunov numbers larger than 10^{-1} appear except of a relatively small fraction of mass in the case of QB2 that Lyapunov numbers can reach values of about 3×10^{-1}.
In all the systems, the chaotic components produce different surface density profiles than the profiles of the rest of the mass. The combination of the two profiles produces observable signatures in the total profile.

- **Poster: No. 16**

A Low Frequency Spectral Indicator and Classification of Trajectories in Hamiltonian Systems

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We consider the problem of trajectory classification (as regular or chaotic) in Hamiltonian systems. A new indicator is presented based on the low frequency spectral properties of trajectories. The indicator "measures" the effect of small denominators in the destruction of invariant tori under small perturbations. It is extracted directly from a single trajectory segment and it shows a remarkable similarity with the maximum LCE.