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Dynamics of Star Clusters and the Milky Way

Abstracts of Talks and Posters presented at the International Conference of the Astronomische Gesellschaft at Heidelberg, March 20–24, 2000

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Talks

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T 01

Internal Motions in Globular Clusters

Ivan King and Jay Anderson
(Astronomy Department, University of California, Berkeley, CA 94720, USA)

Recent advances in astrometric techniques now make it possible to use HST WFPC2 images to measure proper motions of individual stars in many globular clusters. These proper motions have an important impact both on the dynamics of the clusters and on their distance scale.

Previously, only radial velocities were available. From them two of the three components of the cluster's rotation can be measured, and anisotropy of the velocity ellipsoid of the brighter stars can be estimated from a comparison of observed velocity dispersions with those predicted by a model that is based on isotropic velocities. From proper motions, however, anisotropy can be measured directly by comparing proper-motion dispersions in the radial and transverse directions. Moreover, such measurements can be extended to low-mass stars for which anisotropy measurements have not previously been possible. Radial variations of the radial-direction dispersion also offer a further check on the modeling. Finally, measurement of the mean velocity of cluster stars with respect to distant background objects gives the plane-of-the-sky component of cluster rotation.

The most valuable by-products of proper-motion measurements in globular clusters lie outside the scope of this conference. First among them is the measurement of cluster distances by comparison of the dispersion of proper motions with that of radial velocities, which are now becoming available by the thousands from Fabry–Perot observations. Also of value is the separation of cluster stars from field stars, which now allows tracing cluster main sequences almost to the hydrogen-burning limit.

T 02

Mass Loss from Globular Clusters

Douglas C. Heggie (University of Edinburgh, Department of Mathematics and Statistics, King's Buildings, Mayfield Road, Edinburgh EH9 3JZ, UK)

Study of the escape rate from star clusters is a long-standing theoretical problem, which has been approached with both analytical and numerical methods. In recent years a small body of direct observational evidence has also accummulated. This talk reviews all three aspects of the problem.

Even in the simplest cases of equal-mass systems in isolation, some fundamental theoretical issues remain unresolved at the present day. The inclusion of tidal effects changes the problem qualitatively, in relation to the definition of escape, escape criteria, the time scale of escape, the role of relaxation in the escape rate, and the self-consistency requirements of tidal boundary conditions. Inclusion of mass loss by stellar evolution appears to separate cluster evolution into two rather separate regimes, depending on the relative rates of relaxation and stellar evolution.

The precise formulation of the boundary conditions requires care, even for a cluster on a circular galactic orbit, which is a highly idealised case. Our theoretical understanding of these issues for clusters on realistic (elliptic) galactic orbits is extremely limited, but progress is needed for the purpose of interpretation of observations.

T 03

Monte Carlo Simulations of Star Clusters

M. Giersz (N. Copernicus Astronomical Center, Polish Academy of Sciences, ul. Bartycka 18, 00–716 Warsaw, Poland)

A revision of Stodółkiewicz's Monte Carlo code is used to simulate evolution of large star clusters. The new method treats each *superstar* as a single star and follows the evolution and motion of all individual stellar objects. The first calculations, for multi-mass systems influenced by the tidal field of a parent galaxy and with stellar evolution are presented. The process of energy generation was realised by means of an appropriately modified Spitzer's formula for the interaction cross section between binaries and field stars. The setup of the initial model was analogous to the one accepted for the collaborative experiment (Heggie *et al* 1998): $M = 60000 M_{\odot}$, $\alpha = -2.35$, $m_{min} = 0.1 M_{\odot}$, $m_{max} = 15.0 M_{\odot}$, $r_{tid} = 30 pc$, except the initial concentration. Models with $W_0 = 3, 5, 7$ and Plummer model were simulated.

The first results are in a good agreement with the theoretical expectation. The initial rapid mass loss, due to stellar evolution of most massive stars, causes expansion of the whole cluster and eventually leads to disruption of the less bound system ($W_0 = 3$). Models with larger W_0 survive this phase of evolution and then undergo core collapse and subsequent post-collapse expansion, as for isolated models. The expansion phase is eventually reserved when tidal limitation becomes important. As in isolated models, mass segregation almost stops by the end of the core collapse (except $W_0 = 3$); after a core bounce there is a substantial increase in the mean mass, caused by the preferential escape of stars of low mass and tidal effects. Models with $W_0 > 5$ show modest initial build up of anisotropy in the outer parts of the system. As the tidal stripping exposes inner parts of the system, anisotropy gradually decreases and eventually becomes slightly negative.

T 04

Formation and Early Evolution of Star Clusters

Christian Boily
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

I discuss how initial conditions imprint the early evolution of stellar clusters using numerical N-body simulations. I limit the discussion to Newtonian gravitation and neglect mass loss due to stellar evolution. As star cluster profiles are well fitted with King models but suffer much two-body relaxation, I ask how much freedom is allowed in the initial conditions for them to show the degree of symmetry they have, by concentrating on the regime where two-body effects are small. I investigate the effects of morphology, rotation and tides in particular, and emphasise the rôle of radial orbit instability.

T 05

Rotation and Relaxation in Dense Star Clusters and Galactic Nuclei

R. Spurzem
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

The concept of two-body relaxation in systems consisting of initially uncorrelated point masses, which drives core collapse and gravothermal core oscillations in (globular) star clusters and generates steady-state density cusps around massive black holes in galactic nuclei is a simple, traditional but very successful concept to understand the physical behaviour of many gravitating N-body systems, despite of its obvious lack of realism (finite size of stars, dynamics coupled to stellar evolution processes, primordial binaries). It is shown how a moderate amount of initial rotation and a certain initial fraction of binaries ("primordial binaries") change the standard evolutionary features even on that fundamental theoretical level. Two-dimensional projected profiles of densities, velocity dispersions, and rotational velocities can be deduced from our self-consistent evolutionary models. For the first time self-consistent distributions of a large number of primordial binaries, evolving self-consistently in and with a surrounding star cluster are presented. A review of further refinements of star cluster models from other work in the field will be given, which are necessary steps on the road to realistic astrophysical star cluster simulations, with a comparative assessment of the different physical models used in the field.

T 06

The Formation of Hierarchical Systems in Star Clusters

S. J. Aarseth
(Institute of Astronomy, Cambridge, UK)

Results of star cluster simulations on HARP show that hierarchical systems play an important role for the overall dynamics. Models with 8000 single stars and 2000 primordial binaries reveal a gradual build-up and more than 20 such systems may exist during the later stages of evolution. We concentrate on the formation of hierarchies and their stability. This analysis is facilitated by the use of chain regularization which provides a natural tool for investigating the formation mechanism. Although hierarchies can be considered as newly formed binaries, their mode of formation often leads directly to hard binding energies. Most of these systems are formed by close two-body encounters between binaries, whereas standard binaries form by the classical three-body process and their appearance is therefore coinsiderably less pronounced. Finally, we discuss the implications of persistent higher-order systems for direct N-body simulations of globular clusters.

T 07

Dynamics of Black-Hole Nuclei

D. Merritt
(Rutgers University, New Brunswick, NJ)

The stellar dynamics of galactic nuclei containing supermassive black holes is reviewed. Topics include: Observational constraints on nuclear dynamics; stellar dynamical limits on the shapes of nuclei; and formation and evolution of black-hole binaries.

T 08

Stellar Collisions in the Galactic Centre

M. B. Davies
(University of Leicester, UK)

We consider the destructive effects of encounters between binaries and red-giant stars in the galactic centre. Such encounters may explain the observed depletion of luminous red giants within the central 0.2 pc of the galaxy. We consider encounters involving $2M_{\odot}$ and $8M_{\odot}$ red giants, and thus span the range of stellar masses contributing to the most luminous red giants observed in the galactic centre. To explore the phase space of encounters thoroughly, we simulate 18×10^3 encounters using a modified four-body code where the red-giant core and components of the binary are treated as point masses, and where the envelope configuration is assumed to remain static throughout the encounter. We then rerun a small number of encounters with a smoothed particle hydrodynamics (SPH) code to confirm the reliability of conclusions drawn from the four-body runs. We see two possible pathways to red-giant destruction. A large fraction of encounters lead to the formation of common-envelope systems, where two compact objects (drawn from the red-giant core and the components of the original binary) form a binary within a common gaseous envelope, whilst the third body is ejected. The destruction of the red giant will then follow when the envelope is ejected as the binary hardens. In a smaller number of encounters, the intruding binary passes through the star and ejects the red-giant core from the envelope. The red-giant envelope will then disperse on short time-scales. We compute the time-scales for both of these processes to occur in the galactic centre for a variety of binary populations.

T 09

Instabilities in the Spherical Phase Models of Collapsing Galaxies

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One of the main goals of this paper is the development condition determination of some instabilities on the background of collapsing self-gravitating spherical systems. Early it was constructed two non-linearly non-stationary models of collapsing system. As one-multiplely collapsing model has weak power-degree instability we constructed pulsating models.

Here it will presented basic results of the stability analysis of these non-linear models. We considered large-seale and small-scale modes of oscillations on the background of the non-linear model. In particular, some results were applied to the formation problem of the globular cluster system.

T 10

The Galactic Potential in the Solar Neighbourhood

O. Bienaymé
(Observatoire Astronomique de Strasbourg, France)

Hipparcos data provide the first, volume limited and absolute magnitude limited homogeneous tracer of stellar density and velocity distributions in the solar neighbourhood. The density of A-type stars more luminous than $M_v = 2.5$ can be accurately mapped within a sphere of 125 pc radius, while proper motions in galactic latitude provide the vertical velocity distribution near the galactic plane. The potential well across the galactic plane is traced practically hypothesis-free and model-free. The local dynamical density comes out as $\rho_0 = 0.076 \pm 0.015\ M_\odot \mathrm{pc}^{-3}$ a value well below all previous determinations leaving no room for any disk shaped component of dark matter.

T 11

The Initial Mass Function of Stars

Pavel Kroupa
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The observational surveys and methods aimed at constraining the distribution function of stellar masses can be subdivided into three broad mass regimes, each of which has its own peculiar difficulties and biases: massive stars ($m > 5\,M_\odot$ approximately), low-mass stars ($0.8 - 0.1\,M_\odot$) and brown dwarfs ($0.08 - 0.01\,M_\odot$). Taking account of biases through unresolved multiple systems, incompleteness and dynamical effects, such as mass segregation and ejection of massive stars from clusters, and assuming the IMF is continuous, I show that it can be approximated by the following three-part power-law form for population I stars (Salpeter: $\alpha = 2.35$):

$$\alpha(m) = \begin{cases} +0.3 & , \quad 0.01 \leq m/M_\odot < 0.08, \\ +1.3 & , \quad 0.08 \leq m/M_\odot < 0.5, \\ +2.3 & , \quad 0.5 \leq m/M_\odot, \end{cases} \tag{1}$$

where $\xi(m)dm$ is the number of stars in the mass interval m to $m + dm$, and $\xi(m) \propto m^{-\alpha}$. The IMF is well constrained in the mass range $0.1 - 0.8\,M_\odot$, where it cannot be approximated by a single power-law. The uncertainty in α in this mass range is $\delta\alpha \approx 0.2$. Below the hydrogen burning mass limit, α remains rather uncertain, with values between about $\alpha = 0$ and 1.0. The data show evidence for two changes of the power-law index only, namely near $0.5\,M_\odot$ and $0.08\,M_\odot$. In addition, the various surveys of OB associations and young clusters lead to a *constant* scatter of $\delta\alpha \approx 0.5$ in the range $\approx 1 - 100\,M_\odot$. Massive stars have a high multiplicity fraction, and correction for this may systematically steepen the IMF further to $\alpha \approx 2.5 - 2.7$ for $m > 1\,M_\odot$.

T 12

Stellar Moving Groups in the Solar Neigbourhood via HIPPARCOS Data

A. Mülläri, C. Flynn (Tuorla Observatory, University of Turku, Finland)
V. Orlov (Astronomical Institute, St. Petersburg State University, Russia)

The existence of the moving groups is known for a long time. However, the absence of high accuracy observational data for large samples of stars did not allow the search for the moving groups on a large scale. Now such an opportunity exists due to the HIPPARCOS Catalogue. We consider a sub-sample of stars from the solar neigbourhood of 75 pc with known radial velocities. There are 5377 such stars in this catalogue.

The goal of our study is to compile a preliminary list of candidates to the moving groups as places of concentrations of the stars in the (three-dimensional) velocity space. Using hierarchical cluster analysis we revealed 25 moving groups. Most of the moving groups follow two large streams in the velocity space. These streams correspond to the well-known Hyades and Sirius superclusters. The velocity dispersions of the moving groups increase with age. This confirms the heating of the older stars due to interactions with spiral arms, giant molecular clouds, etc.

T 13

The Evolution of the Milky Way Monitored in the Solar Neighbourhood

B. Fuchs
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

In this review I concentrate on the dynamical evolution of the Milky Way disk as monitored in the solar neighbourhood. I present the relevant data sets and discuss the material. Next I review the various mechanisms, which drive the dynamical evoltion. Finally I dsicuss briefly some data on the kinematics of nearby subdwarfs.

T 14

DIVA, the Next Global Astrometry and Photometry Mission

S. Röser, U. Bastian
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The small German satellite DIVA is intended to provide highest-quality astrometric and multi-band spectrophotometric data for a complete sky survey of about 35 million stars. The satellite is planned to operate for two years, starting early 2004. Final results will be generally available in 2008.

With about 300 times as many stars as Hipparcos, typically five times the astrometric precision, and the provision of multi-colour photometry in several dozen optical and near-UV bands, DIVA will be the next milestone in the series of global astrometric data sets that started with the Hipparcos Catalogue in 1997 and which will culminate in the GAIA data products around 2018.

The talk will present a brief description of the project and its planned products. DIVA's scientific potential for galactic astronomy and stellar astrophysics will be outlined by examples from different fields of research. DIVA's applications will generally cover similar areas as those of Hipparcos, but at a greatly increased scale. While Hipparcos provided about 20 000 parallaxes of 10 percent relative precision (out to about 100 pc), DIVA will yield about 250 000 of them, out to about 600 pc. Proper motions will have precisions up to 0.1 milli-arcsec/year, corresponding to a tangential velocity of 1 km/s at a distance of 2 kpc. The multi-colour photometry will give a fairly clear physical characterization of a large proportion of the observed stars, largely eliminating the need of extensive ground-based parallel observation campaigns for the selection of specific stellar samples within the DIVA data.

T 15

The Dynamics of the Galaxy's Satellites

James Binney
(Physics Department, Oxford University, 1 Keble Road, Oxford OX1 3NP, England)

Two questions will be addressed: (i) what constraints do the Galaxy's satellites place on the extent and mass of the Milky Way? (ii) what do observations of the Magellanic Clouds and the Sagittarius dwarf galaxy imply for the rate at which the Galaxy is accreting mass and off-axis angular momentum?

T 16

The Nuclear Star Cluster and the Massive Black Hole at the Centre of the Milky Way

R. Genzel
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I discuss high resolution near-infrared imaging and spectroscopy of the central parsec of the Galaxy. The observations give detailed information about the structure and composition of the dense stellar cluster at the centre of the Galaxy. I review the star formation history, dynamics, and evolution of this unique 'stellar cluster', as well as the current evidence the stellar motions provide for the presence of a massive central black hole.

T 17

The Stellar Age Distribution and the Vertical Structure of Galactic Disks

A. Just
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

The velocity dispersion and as a consequence the scale height of the stellar populations of galactic disks increase with age. We compute self-consistent models for the present day vertical structure of the stellar disk including self-gravity, and the gravitation of the gas component and of the dark halo. We start with a star formation rate history corrected for the effect of mass loss due to stellar evolution and a dynamical heating function. As a result we find the vertical density profile, the age distribution of the stars, and also the velocity distribution function of different types of stars assuming isothermal subcomponents for each age.

For the solar cylinder we find a model to fit the velocity distribution functions for different samples of stars and reproduce the observed heating function. We get the local age distribution of the stars and derive the scale height as a function of age. From that we can compute the mean scale height for different types of stars. This can be used to determine the IMF from the local mass or luminosity function. Since the mass loss of the stellar component depends on the IMF, the star formation rate history can be computed from the present day age distribution as a last step.

These self-consistent disk models show that the determination of the IMF and the star formation rate history depend in a complicated way on the local age distribution and the dynamical heating function. The high mass end is much more affected than the low mass end of the IMF.

T 18

Evolution of Globular Cluster Systems

E. Vesperini
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The evolution of the main properties of globular cluster systems (mass function, spatial distribution, specific frequency) in the Galaxy and in elliptical galaxies and their variation with the galactocentric distance is thoroughly investigated. The effects of stellar evolution, two-body relaxation and dynamical friction on the evolution of individual globular clusters are considered.

The dependence of the evolution of globular cluster systems on their initial mass function and on the properties of the host galaxy will be discussed; in particular I will discuss the results of a survey over a large number of different initial conditions showing the variation, due to the effects of dynamical evolution, in the fraction of surviving clusters and in the properties of their mass function for different host galaxies; host galaxies ranging from dwarf to giant ellipticals are considered.

The results will be compared with the observational data available for galactic and extragalactic globular cluster systems.

T 19

OGLE Survey – Microlensing in the Milky Way

M. Szymański
A. Udalski, M. Kubiak, G. Pietrzyński, I. Soszyński, P. Woźniak, K. Żebruń
(Warsaw University Observatory, Poland)

Optical Gravitational Lensing Experiment (OGLE) is a long-term project dedicated to the search for microlensing phenomena. The observations are performed at the Las Campanas Observatory, Chile, operated by the Carnegie Institution of Washington, using 1-meter Swope telescope (1992-1995, OGLE-I phase) and then 1.3-meter dedicated Warsaw telescope (from 1997, OGLE-II phase). Based on the massive photometry of the dense star fields in the Galactic Bulge, Galactic Disk and the Magellanic Clouds, OGLE survey resulted in discovery of the first ever detected microlensing event in the Galactic Bulge, followed by over 200 events found to date. The optical depth to microlensing was first estimated to be larger than $(3.3 \pm 1.2) \times 10^{-6}$ (1994), in excess of current theoretical estimates. The preliminary analysis of much larger data set (1999) confirms this result.

The huge photometric database of OGLE experiment allows many side projects to be done. These include also some interesting results in the field of our Galaxy exploration: evidences for existence of a bar in the Galaxy, publication of extinction maps towards the Galactic Bulge, catalog of periodic variable stars in the Galactic Center, photometry of globular clusters ω Cen and 47 Tuc, *etc.* The OGLE real-time system of detection of ongoing microlensing events (EWS) allows other collaborations (PLANET, MPS) to search for extrasolar planets orbiting lensed stars.

T 20

Halo Debris Streams as Relicts from the Formation of the Milky Way

A. Helmi (Leiden Observatory, The Netherlands)
S. White (Max-Planck-Institut für Astrophysik, Germany)

We study numerical simulations of satellite galaxy disruption in a Galactic potential and in a scaled-down high resolution N-body simulation of the formation of a cluster in a ΛCDM cosmology. Our goal is to assess whether a merger origin for the stellar halo would leave observable fossil structure in the phase-space distribution of nearby stars. Although after 10 billion years few asymmetries remain in the distribution of particles in configuration space, strong correlations are still present in velocity space. We find that if the whole stellar halo were built by disrupted satellites, it should consist locally of 300-500 kinematically cold streams.

We also use kinematic data from the HIPPARCOS satellite and demonstrate the existence of debris streams in the solar neigbourhood originating in a single coherent object (probably resembling the Fornax dSph) disrupted during or very soon after the Milky Way's formation. These ghostly streams may be the first fossil evidence showing directly that our own Galaxy was put together from smaller building blocks.

P

Poster

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P 01

Finding out the Velocity Anisotropy Parameter for Some Globular Clusters

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The dynamical evolution problems of globular clusters often request determination of the some kinematic characters of these clusters from observations. One of them is a anisotropy parameter. It characterizes a velocity distribution in stellar systems and in general case it depends on radial distance and time (R. Spurzem, IAU Symp. 174). In this paper we are considering the problem of determination of the velocity distribution character in globular clusters using observation data. For these calculations we used density profiles from star counts. Minimizing the sum of the squares of the difference between theoretical and observational surface densities we determined the value of the anisotropy parameter A for 10 globular clusters. Here we decided to consider the case of $A = \text{const}$ along radius. The results show that for some clusters A > 1, i. e. the velocity distribution is radially elongated. This means the presence of some nonstationary processes in these clusters (e. g. star-accreting central massive object et al.). Also we analysed a dependence of anisotropy parameter from others.

P 02

Lifetimes of Star Clusters and Dynamical Relaxation

H. Baumgardt (University of Edinburgh, Department of Mathematics and Statistics, King's Buildings, Edinburgh EH9 3JZ, UK)

We report results of collisional N-body simulations aimed to study the dynamical evolution of star clusters. Our clusters consist of equal-mass stars and are in virial equilibrium. Clusters moving in external tidal fields and clusters limited by a cut-off radius are simulated. Our main focus is to study the scaling of the lifetimes of the clusters with the particle number.

We find that star clusters in external tidal fields exhibit a scaling problem in the sense that their lifetimes do not scale with the relaxation time. Isolated clusters show a similar problem if stars are removed only after their distance to the cluster centre exceeds the cut-off radius. If stars are removed immediately after their energy exceeds the energy necessary for escape, the scaling problem disappears.

We show that some stars which gain the energy necessary for escape are scattered to lower energies before they can leave the cluster. Since the efficiciency of this process decreases with increasing particle number, it causes the lifetimes not to scale with the relaxation time. A toy model is constructed which reproduces the scaling of the lifetimes in the different cases.

P 03

Spatial and Kinematic Structure of the Per OB2 Association Region

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E. Schilbach, R.-D. Scholz
(Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany)

We have investigated the spatial and kinematic structure of the nearby region of star formation with a radius of 10°, centered at the Per OB2 association. The region has complex structure: it includes dark and dense clouds, young stellar groups and OB stars. A compiled catalogue of about 12000 stars has been constructed. It is based on the Hipparcos and Tycho catalogues and includes other relevant data like the PPM and CMC11 catalogues, data from the Simbad database and from a number of other published catalogues. The catalogue is complete down to $V = 10.6$, and has a limiting magnitude of $V = 15$. In some especially interesting regions (IC 348 region) it is complete down to $V = 18.6$, and has a limiting magnitude of $V = 21.2$. Here we report results on the overall structure of the region. As the analysis of spatial velocities, available parallaxes and color-magnitude diagrams has shown, the stellar population can be divided into two major groups, whose members have common spatial, kinematic and evolutionary parameters. The first group of stars belonging to the relatively small core of the association with a radius of about 5 pc, is located at a distance of 370 ± 24 pc from the Sun, whereas the second group or the "association front shell" at 3° to the south of the association center, is located between the core and the Sun (at a distance of 275 pc along the line of sight). This group consists of early type stars, dark clouds, and young stellar groups (like the IC 348 and NGC 1333 clusters).

P 04

Determining Hard Binary Populations of Globular Clusters with Gravitational Radiation

M. Benacquista
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The recent discovery of nine new millisecond pulsars in 47 Tucanae brings the number of known pulsars in that globular cluster to twenty. The scenarios for the formation and evolution of recycled pulsars in globular clusters include tidal capture of low-mass main-sequence stars by neutron stars and exchange interactions with primordial binaries. These scenarios generally involve mass transfer between a main-sequence or evolved star and the neutron star, resulting in a short-period binary system consisting of a neutron star and a low-mass degenerate object ($M \leq 0.2 M_{\odot}$). These systems will produce signals of continuous gravitational radiation which should be detectable by space-based gravitational radiation detectors such as LISA. The angular resolution of LISA is such that sources with orbital period of about 2000 s can be located to within the angular size of 47 Tucanae. Thus, gravitational radiation can be used to measure the population of hard binaries which is expected to arise from the scenario nario which produces the millisecond pulsars. Since these scenarios differ significantly in the expected hard binary population, gravitational radiation observations can be used to distinguish between them.

P 05

Dynamical SPH + N-body Code for Chemo-photometric Evolution of Disk Galaxies

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The chemical and photometric evolution of star forming disk galaxy is investigated using the dynamical SPH + N-body code. The hydrodynamical simulations are based on our own code of the Chemo-Dynamical Smoothed Particle Hydrodynamics (CD – SPH) approach, including feedback through star formation. The dynamics of the "star" component is treated in the frame of a standard N-body approach. Thus, the galaxy consists of gas and "star" particles. The star formation (SF) process, SNII, SNIa and PN events as well as chemical enrichment of gas have been considered within the framework of model proposed in Berczik P., 1999, A&A, 348, 371.

The code is slightly modified for the present problem so as to include the photometric evolution of each "star" particle, based on the idea of the Single Stellar Population (SSP) Tantalo R., Chiosi C., Bressan A. & Fagotto F., 1996, A&A, 311, 361. At each time-step, absolute magnitudes: M_U, M_B, M_V, M_R, M_I, M_K, M_M and M_{bol} are defined separately for each "star" particle. The spectro-photometric evolution of the overall ensemble of the "star" particles forms the Spectral Energy Distribution (SED) of the galaxy.

As a first application, the model is used to describe the chemical and photometric evolution of the Milky Way – like disk galaxy.

P 06

Tracing Spiral Structure in the Milky Way

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Ortwin Gerhard,
(Astronomisches Institut der Universität Basel)

We present a new model for the 3D light distribution of the Milky Way derived with a new non-parametric deprojection technique algorithm that supplements the Richardson-Lucy method and is more flexible in model constraints. The method is based on the penalised maximum likelihood technique. Our new models include the spiral structure of the Milky Way and are constrained by the distribution of clump giants along certain lines-of-sight towards the bulge in addition to the COBE/DIRBE L-band data. They reproduce the tangent points of the spiral arms and the asymmetry in the clump giant distribution.

P 07

The Inner and Outer Cluster Blue Horizontal Branches of M92, M3 and M13

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A. Shearer (Information Technology Centre, National University of Ireland, Galway)

We compare the following blue horizontal branch (BHB) properties of the inner (r < 40 arc sec) and outer regions of three globular clusters (M92, M3 and M13) using independently reduced archive HST/WFPC-2 V, U data and published outer cluster B, V data: (a) V magnitude extension and (b) location of BHB gap minima in V. We keep low number statistics in mind, and ask the following for each GC: Are the inner and outer cluster BHB star populations consistent with being drawn from the same distribution of star properties?

P 08

The Dynamical Evolution of Globular Cluster Systems in Triaxial Galaxies

R. Capuzzo-Dolcetta
(Institute of Astronomy, University La Sapienza, Roma)

The presence of the popolous family of box orbits in triaxial galaxies makes them a place where the evolution of the globular cluster system (GCS) is expected to be much more relevant than in axisymmetric galaxies. Actually, the effect of dynamical friction is significantly enhanced, as well as tidal interaction with the compact central region.

We have integrated a set of orbits (in a huge range of initial conditions and of galactic models) of globular clusters moving in self-consistent triaxial potentials, in order to deepen the study of the importance of dynamical friction on the individual and global characteristics. The results confirm that the difference between the radial distribution of the halo-bulge stellar component and the one of the GCS (clearly shown by many observations of elliptical galaxies) may be explained by the GCS evolution. Moreover, the GCS evolution may lead to loss of matter (in form of tidally stripped stars) to the galactic centre, helping the formation and subsequent accretion of a massive object therein.

P 09

Galactovertical Oscillations of Blue Supergiants as a Test of the Theories of Stellar Evolution

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The absolute magnitudes, intrinsic colours, and distances are inferred for 619 Galactic blue supergiants using published UBV or $uvby$ and Hβ photometry and absolute-magnitude and intrinsic-colour calibrations by Dambis (1990, 1991). The individual ages are determined for all stars based on different isochrone grids both classical and those including mass loss and overshooting. The vertical scale height of the subsample of blue supergiants located within 1.5 kpc of the Sun (a total of 226 stars) is found to decrease with the age from $\sim$ 60 pc for the youngest stars down to $\sim$ 20 pc for the oldest ones. The time scale of this decrease is known to be related to the period of galactovertical oscillations in the solar neighbourhood (M. Joeveer, Tartu Publ., 1974, vol. 47, p. 35). The latter can be independently inferred from the known mean density in the solar neighbourhood and Oort's constants and then compared with the values implied by the analysis of the evolution of the Galactovertical distribution of blue supergiants in terms of variuous isochrone grids in order to test the underlying theories of stellar evolution.

Our results provide strong evidence in favor of classical theories of stellar evolution without overshooting and intense mass loss.

P 10

The Equilibrium after the Violent Relaxation in the Numerical Dynamical Models of the Open Star Clusters

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During the time of violent relaxation τ_{vr} the virial equilibrium does not attain in considered models of the open stellar clusters, but the equilibrium distribution of stars is formed in some physical spaces. This distribution of stars is only a little varied with the time t when $t > \tau_{vr}$. The analytical form for such equilibrium distribution of stars is obtained. The distribution of stars in the phase space and the regular potential of such equilibrium cluster model are strongly varying periodically (or near periodically) with the time.

The local relaxation times for the cluster model during the violent relaxation are estimated by the results of the investigation of the instability of the phase-space density functions of the cluster model relatively to the small perturbations in the initial phase-space coordinates of stars.

P 11

Intermediate-mass X-ray Binaries and their role in Producing Millisecond Pulsars in Globular Clusters

M. B. Davies
(University of Leicester, UK)

We investigate the conditions by which neutron star retention in globular clusters is favoured. We find that neutron stars formed in massive binaries are far more likely to be retained. Such binaries are likely to then evolve into contact before encountering other stars, possibly producing a single neutron star after a common envelope phase. A large fraction of the single neutron stars in globular clusters are then likely to exchange into binaries containing moderate-mass main-sequence stars, replacing the lower-mass components of the original systems. These binaries will become intermediate-mass X-ray binaries (IMXBs), once the moderate-mass star evolves off the main-sequence, as mass is transferred onto the neutron star possibly spinning it up in the process. Such systems may be responsible for the population of millisecond pulsars (MSPs) that has been observed in globular clusters. Additionally, the period of mass-transfer (and thus X-ray visibility) in the vast majority of such systems will have occurred 5–10 Gyr ago thus explaining the observed relative paucity of X-ray binaries today, given the MSP population.

P 12

Stellar Velocity Field in the Bar of the Galaxy Revealed from SiO Maser Observations

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A large survey has been made in the SiO J=1–0, v=1 and 2 transitions ($\sim$ 43 GHz) for the color-selected IRAS sources in the central part of the Galaxy, $-10^\circ < l < 40^\circ$ and $|b| \leq 3^\circ$ with the Nobeyama 45-m telescope. We have detected 338 out of 622 observed sources in SiO masers; most of them are new detections (not observed previously in OH). Distances to the sources range approximately from 2 kpc to 13 kpc (estimated from the IRAS 12 and 25 μm flux densities) and radial velocities of the sources spread between -310 km s^{-1} and 300 km $^{-1}$. The average rotational motion and velocity dispersion of the bulge stars agree well with the 3-D steady-state model of the triaxial bulge. We found that the subsets of sources in $-10^\circ < l < 15^\circ$, which are divided by distance, exhibit a systematic velocity shift in front of and behind the galactic center, suggesting evidence of streaming motions of stars along the bulge bar.

P 13

Multi-mass Gaseous Models of Globular Clusters with Stellar Evolution

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Gaseous models have proven to be a computationally cheap and reliable tool to investigate the dynamical behaviour of globular clusters in great detail. But to compete with other approaches for modelling the evolution of star clusters they need to be brought up to date with respect to the effects of a stellar mass spectrum, stellar evolution, and a consistent treatment of the tidal field of the galaxy. Here we want to report on the effects of a mass spectrum and stellar evolution on the dynamical evolution of the cluster.

By subdividing our model in several dynamical components – each with different stellar mass, whose stellar evolution is followed in a parameterised way – we can simulate the effects of the evolution of stars of different masses in the cluster. Even first tests with a rather simple way of modelling the mass loss due to stellar evolution showed how only small changes in the mass loss rate can change the internal dynamics of the cluster dramatically. We now want to report on the results of a more detailed description of the mass loss in our models and plan to show first results of models with a more discretized mass spectrum.

P 14

When Expanding Shells Fragment?

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The contribution deals with the star formation induced in walls of expanding HI shells. We are interested in the influence of external conditions, like the thickness of the galactic gaseous disk, the density of the gas and its temperature; and also in the influence of the type of the energy source (continuous or instantenous release of the energy) and the total amount of energy.

The evolution of expanding shells is calculated numerically by the 3D code based on the thin shell approximation. The stability of shells is studied using the linear perturbation theory.

P 15

SUPERBOX – An Efficient Code for the Self-Consistent Computation of the Dynamics of Collision-less Stellar Systems

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We present SUPERBOX, a particle-mesh code with high resolution sub-grids and a higher order NGP (nearest grid point) force-calculation scheme based on the second derivatives of the potential to accurately evaluate the accelerations. With this code a large number of galaxies can be modelled self-consistently. The sub-grids follow the trajectories of individual galaxies and allow a highly resolved treatment of galaxy interactions. SUPERBOX is a fast and low storage algorithm, giving the possibility to work with millions of particles on standard desk-top computers. Energy and angular momentum are conserved within a few tenths of a per cent. The effects of relaxation are negligible, even if the calculation covers a time-span longer than a Hubble-time.

P 16

Could Merged Star-clusters Build up a Small Galaxy?

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We investigate the behaviour of a cluster of young massive star clusters (hereafter super-cluster) in the tidal field of a host galaxy with a high-resolution particle-mesh code, *Super-box*. Specifically we want to establish if and how such super star-clusters merge and carry out a detailed study of the resulting merger-object. This merger-object shows either the elongated ('fluffy') shape of dSph-galaxies or the properties of a compact spherical object which devellops later on to a dSph-like object depending on the initial concentration and the orbit of the super-cluster.

P 17

The Reality of Old Moving Groups after Hipparcos – HR1614

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It was Olin Eggen who first introduced the concept of moving groups, most famous is maybe the Hyades. The basic idea is that stars form in clusters and thus with similar space motion, on top of which the random motions of single stars are added, resulting in a modest velocity dispersion. Through the orbital motion in the galactic potential the group will stretch out into a tube-like structure and finally dissolve. The stars will appear, if the Sun happens to be inside the tube, all over the sky but may be identified as a group through their common space velocities. Thus the moving groups may provide the essential, and so far largely un-utilized, link between cluster and field stars. A large stumbling block for the study of the reality of moving groups has been the lack of reliable parallaxes. This has now been largely overcome by the observations by the Hipparcos satellite (ESA, 1997).

Using the new parallaxes and recent radial velocities we perform, for the first time, an unbiased search in the UV-plane for the moving group HR1614. Combining the velocity data with high-quality photometric metallicities we find a concentration of stars with super-solar metallicities centered roughly on the UV-velocities of the star HR1614. Supported by dynamical simulations of the evolution of this moving group in the UV-plane of the member stars we confirm its existence and derive a new age from our new, well-defined, sample of member stars. The stars will provide the basis for future investigations of the abundance profile of the moving group. If field stars originate in clusters then the abundance ratios for stars in moving group should be identical to those of field stars in the solar neighbourghood. If the moving groups are not the source of the field stars then it is most likely that their star formation rate was different and the abundance ratios will be different. This is testable, in particular for metal-rich moving groups, such as HR1614.

P 18

Environment and Stellar Evolution in Globular Clusters: the Cases of M80 and ω Cen

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The Color Magnitude Diagram of two Galactic Globular Clusters (GGC) in which anomalous evolutive sequences have been detected are presented and discussed:

M80 – Using UV HST-WFPC2 observations of the core of the high density cluster M80 we discovered the largest and most concentrated population of BSS ever found in a Galctic Cluster. Since M80 has the highest central density of any GGC which has shown no previous evidence of core collapse, this discovery could represents the first direct confirmation that stellar collision could indeed be effective in delaying the core collapse.

ω Cen – The presence of an anomalous Red Giant Branch (RGB) well separated by the bulk of the "normal" RGB stars has been discovered in ω Cen using a new wide field and wide color baseline photometry. This population represents the extreme metal rich extension of the stellar content in ω Cen. The spatial distribution of stars along this branch seems to define sub-structures which can be interpreted as a *fossil* record of the tidal disruption of a merged subsystem.

P 19

Monte Carlo Simulations of Dense Galactic Nuclei

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The presence of massive black holes (BHs) in the center of many galaxies appears as an inescapable conclusion of recent high-resolution observations. This fact revives much interest in the study of the joint evolution of the central BH and its surrounding stellar cluster. In particular, in systems with high stellar densities, bright accretion flares are bound to occur when stars are destroyed by the BH's tidal forces or through collisions with other stars.

In order to predict the rate and characteristics of these disruptive events, self-consistent stellar dynamical simulations of the galactic nucleus have to be carried out. The physics to be taken into account includes overall self-gravity, 2-body relaxation, stellar collisions, tidal disruptions, BH growth and stellar evolution. We developed a new code based on Hénon's Monte Carlo scheme which proved so successful in the realm of globular cluster studies.

Except for stellar evolution, to be added at a future development stage, other key ingredients are all included in our simulations. In particular, the outcome of stellar collisions is determined through a huge set (> 10000) of realistic SPH (Smoothed Particles Hydrodynamics) simulations.

P 20

Star Clusters Simulations Using GRAPE-5

Toshiyuki Fukushige (Department of General Systems Studies, College of Arts and Sciences, University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153, Japan)

We discuss simulations of star cluster, such as globular cluster, galaxy, and galaxy cluster, using GRAPE(GRAvity PipE)-5.

GRAPE-5 is a new version of special-purpose computer for many-body simulation, GRAPE. GRAPE-5 has eight custum pipeline LSI (G5 chip) per board, and its peak performance is 38.4 Gflops. GRAPE-5 is different from its predecessor, GRAPE-3, regarding four points: a) the calculation speed per chip is 8 time faster, b) the PCI bus is adapted as an inteface between host computer and GRAPE-5, and, therefore, the communication speed is order of magnitude faster, c) in addition to the pure 1/r potential, GRAPE-5 can calculate force with arbitrary cutoff function so that it can be applied to the Ewald or P^3M methods, and d) the pair wise force calculated on GRAPE-5 is about 10 times more accurate. Using the GRAPE-5 system with Barnes-Hut tree algorithm, we can complete force calculations for one timestep in $10(N/10^6)$ seconds.

This speed enables us to perform a pre-collapse globular cluster simulation with real number of particles, and a galaxy simulation with more than 1 million particles, within several days. We also present some results of star cluster simulations using the GRAPE-5 system.

P 21

Order and Chaos in the Local Disc Stellar Kinematics

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The effects of the Galactic bar on the velocity distribution of old disc stars in the Solar neighbourhood are investigated using high-resolution test particle and N-body simulations. A detailed orbital analysis reveals that the structure of the $U-V$ distribution is closely related to the phase-space extent of regular and chaotic orbits. At low angular momentum and for a sufficiently strong bar, stars mainly follow chaotic orbits which may enter and be temporarily locked inside the corotation radius, and the $U-V$ contours follow lines of constant Jacobi's integral except near the regions occupied by weakly populated eccentric regular orbits. These properties can naturally account for the observed outward motion of the local low-V stars.

P 22

Towards Complete Stellar Orbits around the Galaxy's Central Black Hole: The First Acceleration Measurements

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Five years ago, we initiated a proper motion study of the Galaxy's central stellar cluster using diffraction-limited K[2.2 micron]-band images obtained with the W. M. Keck I 10-m telscope. With relative positional accuracies of $\sim$3 milliarcsec, we have been able to measure stars moving with velocities up to 1400 km/s and, for the first time ever, accelerations of 2.7 mas/yr^2 (0.33 cm/s^2) at projected distances from the apparent radio counterpart of the black hole, Sgr A*, of 0.004 pc (0.1 arcsec). These measurements have not only provided us with direct dynamical evidence for a $2.6 \times 10^6 M_\odot$ central black hole, but have also permitted us to begin to constrain the orbits of these stars, which appear to be bound to the central mass. Continued study of these orbits (which possibly have periods as short as 10 years) will allow us to infer the radial distribution of dark matter within a few hundredths of a parsec around the black hole.

P 23

Resonant Excitation of Spiral Density Waves in Galactic Disks of Stars

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Linear kinetic theory is developed to describe the resonant Landau-type excitation of spiral density waves in a self-gravitating, rapidly and nonuniformly rotating, spatially inhomogeneous, and practically collisionless stellar disk of flat galaxies. The system is treated by employing the well elaborated mathematical formalisms from plasma perturbation theory using normal-mode kinetic analysis. It is shown that the wave-star interaction at the corotation resonance in a hydrodynamically stable nonuniformly rotating self-gravitating disk of particles resembles a Cherenkov emission of electromagnetic waves (light) with continuous spectrum and specific angular distribution by an electric charge moving in a medium at a constant velocity. This Landau excitation of spiral density waves is suggested as a mechanism for the formation of observable structural features such as spiral arms, and the slow on a Hubble time dynamical relaxation of disk-shaped galaxies, in a parameter regime of classical 'hydrodynamical' Jeans stability. A separate investigation based on extensive N-body computer simulations is described to determine experimentally these Landau-growing, oscillatory propagating modes of oscillations.

P 24

Direct N-body Simulations of the Stellar Velocity Dispersion

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Already in the 1950's it was observed that in the Solar neighborhood older star populations have a higher velocity dispersion than younger ones. During the years several mechanisms have been proposed to explain the growth of the velocity dispersion: encounters of stars with giant molecular clouds, heating of the galactic disc by transient spiral waves, and heating by proposed black holes in the Galactic dark halo etc. To date a convincing mechanism to explain the observed amount of the disc heating has not been found.

We are tackling this problem with direct 3D N-body simulations. We simulate a local patch of the galactic disc employing linearized equations of motion and periodic boundary conditions. Perturbers, so far we have simulated giant molecular clouds (GMCs), are treated as mass points. A softening parameter is utilized in direct force calculations, typically 50 pc for a GMC of 10^6 Solar masses.

According to our preliminary results stellar encounters with GMCs can not explain the observed amount heating of the stellar disc even if much higher number density of GMCs is used than observed presently in the Solar neighborhood.

By the time of the meeting we hope to be able to present more detailed results and to be able to compare different plausible mechanisms that might be responsible for the evolution of stellar velocity dispersion.

P 25

A Molecular Face-On View of the Galactic Center – Molecular Bar and Its Kinematics

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We have successfully constructed a face-on view of the molecular gas distribution in the central kiloparsecs of the Milky Way galaxy. The method detailed in a separate paper (Sawada et al., this conference) is based on the comparison of the 2.6-mm CO emission and 18-cm OH absorption line intensities. It does not require any knowledge of the kinematics of the region, and offers an independent test for the dynamical models of the inner Galaxy. The resultant face-on view shows the following characteristics:

1. The central condensation – This bright elongated structure of dense molecular gas is 500 pc long and is oriented 65 ± 10 degrees away from end-on perspective with the positive longitude side closer to us.

2. Molecular lanes – A pair of fainter narrow emission structures originate from the ends of the central condensation in the direction almost parallel to our line of sight.

3. Gas kinematics – The face-on view of the velocity field shows the pattern characteristic of the central regions of barred spiral galaxies. The molecular lanes exhibit large ($\sim$ 100 km s^{-1}) linewidths indicative of violent dynamical processes such as shocks and cloud collisions.

P 26

Studying the Milky Way Galaxy with VERA (VLBI Exploration of Radio Astrometry)

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VERA (VLBI Exploration of Radio Astrometry), being promoted by National Astronomical Observatory of Japan in collaboration with several Japanese universities, is a new VLBI array of four 20 m antennas approved to start its construction in 2000. VERA, the first VLBI array dedicated to differential VLBI, has a dual beam antenna system which enables us to observe a Galactic maser source and a nearby reference source simultaneously to remove the atmospheric fluctuation, aiming at measuring the position of Galactic masers relative to reference sources (QSOs and radio galaxies) with 10 microarcsec level accuracy.

With that accuracy, VERA will be able to determine the distance to a Galactic object D kpc away from the Sun with an accuracy of D %, and the transverse velocity with an accuracy of 0.05 D km/s. Such a high accuracy enables us for the first time to measure the trigonometric parallax in the whole Galaxy. Hence, VERA will be one of the most powerful tools to study the structure and dynamics of the Galaxy without assuming distances and/or transverse velocities. The major science targets of VERA will be the 3D structure of the Galaxy and the distribution of dark matter, physics of outflow in star forming regions and stellar envelopes, maser physics in star forming regions and late type stars, precise calibration of the period-luminosity relation of Mira-type stars, structure and evolution of QSOs and radio galaxies, and so on. In this presentation, we will discuss the science targets with VERA, especially the structure and dynamics of the Milky Way Galaxy with 10 microarcsec level astrometry.

P 27

Thick disk Properties from Galactic Chemical Evolution Model

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The Milky Way is composed of four components: buldge, halo, think and thin disk. A good knowledge of the physical properties of each part, such as scale length and height, density profile, metallicity distribution, kinematic, are essential towards understanding the formation and evolution of the Galaxy. Among which, the thick disk may play an important role. Attemps to deduce its basic characters normally include remote star counts and field star survey (Gilmore, Ried and Hewett 1985, Buser, Rong and Karaali, 1998). But the results are still quite uncertain. Furthermore, how the think disk forms is also an open question.

Based on the two accretion episodes idea, which was first introduced by Parti et al. (1995) and Chiappini et al. (1997) in modeling the chemical evolution of the Galaxy, we have established a two-component galactic chemical evolution model with radial dependent SFR and Gaussian infall(Chang et al. 1999). In the modle, the present day local surface density of the thick disk has been chosen to be one of the free parameters, which enables us to discuss the density profile of the thick disk as well as its formation time scale by comparing model predictions with most recent observational constraints which include newest G-dwarf metallicity distribution in the solar neighborhood (Hou et al. 1998).

The predicated present-day local density of the thick disk is about 14 and 10 $M_{\odot}\,pc^{-2}$ in the case of pre- and post-thin scenarios, respectively. In the pre-thin case, the formation of thick disk precedes that of the thin disk, while in the post-thin situation, the thick disk forms from some action on or by the thin disk. Comparing with other results of star

P 28

On the Road to Realistic Globular Cluster Models

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The resolution provided by the HST is generating a wealth of high-quality observations of the stellar populations in both Galactic and Magellanic Cloud clusters. Combined with recent advances in computing efficiency this means that the time is ripe for a thorough confrontation of cluster models with observations. We have been working to produce a state-of-the-art N-body code incorporating a complete model of stellar evolution and binary interaction. This enables us to provide realistic cluster models for comparison with observed cluster populations of any metallicity.

As a pilot study we have investigated the incidence and distribution of blue straggler stars in the old open cluster M67. The results of semi-direct N-body simulations have constrained the nature and extent of the M67 primordial binary population. Future work in this area will revolve around an extensive HST project (#7307) which has produced detailed observations of eight rich star clusters in the LMC. This is an ongoing project to explore the complex dynamical evolution of N-body systems and their stellar populations.

P 29

Time Evolution of Galactic Warps in Prolate Halos

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A recent observation with the *Hipparcos* satellite and some numerical simulations imply that the interaction between an oblate halo and a disk is inappropriate for the persistence of galactic warps. Then, we have compared the time evolution of galactic warps in a prolate halo with that in an oblate halo. The halos were approximated as fixed potentials, while the disks were represented by N-body particles. We have found that the warping in the oblate halo continues to wind up, and finally disappears. On the other hand, for the prolate halo model, the precession rate of the outer disk increases when the precession of the outer disk recedes from that of the inner disk, and vice versa. Consequently, the warping in the prolate halo persisted to the end of the simulation by retaining the alignment of the line of nodes of the warped disk. Therefore, our results suggest that prolate halos could sustain galactic warps. The physical mechanism of the persistence of warp is discussed on the basis of the torque between a halo and a disk and that between the inner and outer regions of the disk.

P 30

Galactic Mergers: A Search for Chemical Signatures

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Luisa de Almeida (University of North Carolina at Chapel Hill)
Chris Sneden (University of Texas at Austin)

Recent kinematic and photometric evidence depicts an increasingly complicated picture of early galaxy formation, and of stellar debris left behind by an unknown number of passages and mergers by satellite systems of the Milky Way. In addition to kinematic similarites, chemical "signatures" may identify these merger/accretion events. A number of very high-velocity metal-poor field stars have been discovered that possess very unusual abundance ratios of alpha-elements to iron. The stars discovered to date all have large apogalacticon distances – these stars may have originated within a satellite galaxy or galaxies that experienced a different nucleosynthetic chemical evolution history than the Milky Way and which were later accreted by it.

We have gathered high resolution echelle spectra for more than two dozen high-velocity metal-poor field stars, including BD+80 245, a star previously known to have extremely low [alpha/Fe] abundances, as well as G4–36, a new low [alpha/Fe] star with unusually large [Ni/Fe]. In addition to deriving the alpha-element abundances, we have also analysed iron-group and s-process elements. For stars in common with those in the literature, our abundances are in accord. We are now able to start exploring the following question: What nucleosynthesis history is required to produce the unusual [alpha/Fe] and [Ni/Fe] ratios?

P 31

Dark Matter Distribution in the Milky Way

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We model the dark matter distribution of the Milky Way and determine the local dynamical mass density and the gravitational acceleration K_z. Our approach is based on a bimodal dark matter model. a) Baryonic dark matter has a radial distribution similar to that of the gaseous disk and dominates the observable rotation curve. b) The non-baryonic dark matter is distributed on scales significantly larger than the Galactic disk.

Our concern is the baryonic dark matter component, as traced by the gaseous Milky Way halo with a scale height of $h_z \sim 4.4$ kpc. Considering 3 different models for the stellar distribution, we derive in all cases a baryonic dark matter distribution which is within the observational uncertainties indistinguishable from the 3-D distribution of the gaseous halo. Baryonic dark matter and gas are closely related to each other.

For a Solar radius $R_\odot = 8.5$ kpc and a rotation velocity $v_\odot = 220 \mathrm{km\,s^{-1}}$ we derive a local gravitational acceleration perpendicular to the Galactic plane, K_z, which is in close agreement with the results of Kuijken & Gilmore (1989) and Bienaymé et al. (1987). The local surface mass density for $|z| < 1.1$ kpc is consistent with the determination by Kuijken & Gilmore. Also the derived Oort limit of $\rho_\odot \sim 0.09\ M_\odot \mathrm{pc}^{-3}$ agrees with recent determinations using HIPPARCOS. The Galactic mass distribution derived by us is consistent with a large scale co-rotation between disk and halo as observed for the gas.

P 32

On the General Features of Particle Periodic Motions in an Annular Distribution of N Bodies

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One of the most important modern trends in stellar dynamics, is the simulation of the N-body systems. It is well-known how difficult it is the investigation of the behavior of complex dynamical systems, although high speed computers and delicate techniques are used nowadays. However, it is often useful to approach these systems by means of simple N body geometric configurations. Recently, there has been proposed the ring problem of N+1 bodies consisting of N coplanar major bodies in an annular arrangement and a minor body which moves in their neighborhood under their resultant gravitational attraction. What may seem useful and important as well, is the product of the synthesis of information gathered little by little and step by step. Therefore, we strongly believe that the detailed and systematic study of this model will contribute in the investigation of the real celestial multi-body systems. As a first step in this direction, we focused our interest on the periodic solutions, since this kind of solutions is of great importance as a conceptual tool in the effort to penetrate into the complexity of the problem. From the material collected up to now, we are able to reach a basic understanding of all possible motions, thus acquiring a deeper knowledge of the mechanism of similar dynamical systems. In this article we expose the general features of the structure of the periodic solutions, simple and multiple and we give some illustrated examples.

P 33

A Search for Mass Segregation in Four Young Magellanic Cloud Clusters

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We present the results of our search for mass segregation within four young populous clusters in the Magellanic Clouds using HST/WFPC2 photometry. We find two clusters of this sample possess significant mass segregation. Our results indicate that the degree of mass segregation is inversely related to the cluster central density. This result is at odds with that expected from a two-body relaxation mechanism. We discuss the implications of our findings on the initial star formation process.

P 34

X-ray Astronomy: XMM, a New Tool to Investigate the Galactic Interstellar Medium

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Imaging X-ray telescopes open an entirely new window to the Milky Way. Their data allow to evaluate the soft X-ray radiation transfer quantitatively. Individual clouds can be studied in detail with respect to their small-scale density distribution (≤ 15") with a sensitivity level nearly an order of magnitude higher than radio astronomical observations.

ROSAT established the existence of X-ray emitting gas outside the galactic H sc i and H^+ layer. It was possible to discover soft X-ray shadows of individual clouds with the *ROSAT* data. These X-ray shadows contain a wealth of information on the plasma temperature, electron density and pressure infront and beyond the shadowing clouds. Moreover, it is possible to search for "hidden" molecular gas (in particular H_2) which is not traced quantitatively by $^{12}CO(1\rightarrow0)$ emission.

XMM will strongly push forward or knowledge on the composition of the interstellar medium because of its huge collecting area and high energy resolution provided by the new generation X-ray detectors. We will present our observation *XMM* campaign aimed to study X-ray shadows of local (D $<$ 100 pc), intermediate (D $<$ 1000 pc) and distant neutral clouds (D $>$ 3000 pc). These observations will give information on the 3-D structure and on the physical conditions of the galactic interstellar medium.

P 35

Mass Segregation in Star Clusters with Two Mass Populations

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Massive stars in a newly formed cluster are often found near its centre, indicating a mass segregation which can be explained by two different physical mechanisms: either these stars acquire their mass by subsequent accretion during the forming process near their place of birth already in the central regions, or they form elsewhere and sink to the bottom of the potential well through two-body relaxation. Both possibilities should differ in their time scales until the cluster achieves its observed radial mass stratification.

We present high-accuracy N body-simulations of isolated star clusters consisting of two distinct masses, m_1 and m_2 ($m_2 > m_1$), and determine the average star mass within a fixed "shell". The gradient of the average particle mass demonstrates the degree of mass segregation. We study the effect of varying both the number ratio between the two mass species n_2/n_1, and the mass ratio m_2/m_1. We also examine the evolution of other cluster properties like formation of binaries, their binding energies, and escapers.

P 36

Vertical Diffusion of Stars in the Inner Galactic Bulge

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Star formation in the inner few hundred pc of the Galactic bulge occurs in a flattened molecular layer called the central molecular zone (CMZ). Serabyn & Morris (1996) have suggested that the star formation in the CMZ has been sustained for the lifetime of the Galaxy, and the resulting agglomeration of stars formed in the CMZ is the "central r^{-2} density profile region", which is a prominent stellar density cusp at the Galactic center having about the same physical extent as the CMZ. This "central cusp" is somewhat less flat than the CMZ; thus the population of stars formed in the CMZ appears to have diffused out to larger latitudes. We hypothesize that such vertical diffusion is driven by the scattering of stars off the giant molecular clouds (GMC) in the CMZ, and perform Monte Carlo simulations of the scattering between stars and GMC's in the presence of the non-axisymmetric background potential. The simulation results show that the evolution of the aspect ratio of the stellar distribution formed by such scattering is consistent with the observed OH/IR star distribution.

P 37

The Galactic Circular Velocity (V_c) at the Solar distance

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Two methods of determining V_c are discussed. The first was proposed by Carlberg & Innanen (1987) who showed that in a local sample of high velocity dispersion disk stars, there should be an apparent deficiency of very low angular momentum stars whose orbits pass near the Galactic nucleus and which are scattered into the halo. They identified this deficiency (half width 40 km/s) in their sample and deduced a model-free V_c at the Sun in the range 225 to 245 km/s. Such "scattered" stars can be found among nearby halo stars whose highly eccentric chaotic orbits pass within 1 kpc of the Galactic Center and which reach more than 4 kpc from plane. Their well-defined mean V motion gives a model-independent V_c that depends systematically on the distances (and hence M_v) that have been assumed for the halo stars.

The second method follows Majewski (1992) and derives V_c from the proper motions of halo stars near the North Galactic Pole. Proper motions for the new sample of BHB and RR Lyrae stars were taken from the GSC2 catalogue; these are on an extragalactic reference frame. Their zero-point was checked from the proper motions of compact extragalactic objects of similar magnitude and colour and in the same field as the halo stars. The derived V_c here depends directly on the assumed distances of the halo stars (and hence on their assumed M_v). Both methods suggest that the most likely value of V_c exceeds the currently used value of 220 km/s.

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P 38

HIPPARCOS and the Spectroscopic Distance to Local Halo Stars

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We are currently extending the study of *Nearby stars of the Galactic disk and halo I & II* (Fuhrmann 1998 & 2000) to a sample of metal-poor halo stars out to about 500 pc. Our ultimate aim is to derive spectroscopic ages for these stars.

The basis of our analysis are spectra with R between 40,000 and 60,000 and signal-to-noise ratios (after co-addition) above 200 at Hα. These spectra were aquired using FOCES on the 2.2 m telescope at Calar Alto in 1999.

Some of the brighter halo stars have significant HIPPARCOS parallaxes against which we can cross-check our method of gravity determination. For halo stars down to $[m/\mathrm{H}] \sim -2$ (to which the *strong line method* is applicable) the resulting gravities are practically free of systematics when compared to HIPPARCOS. From 150 pc outward, the spectroscopic uncertainty in distance is *smaller* than the astrometric one.

The question of whether or not metal-poor stars require a temperature label and/or temperature-depth structure different from that of the Sun and solar-metallicity stars may be addressed in the context of non-LTE ionization equilibria of e. g. iron or calcium.

P 39

On the Dynamics Peculiar Motion of Galaxies

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We carried out the analysis of dynamics of discrete self-gravitating systems – such as galaxies and their clusters and derived for them the equation of peculiar motion connected energy with the potential energy of inhomogeneously distributed masses in expanding substratum. The dynamics of this gravitating systems embedded in a smooth expanding background is investigated on basis above mentioned equation of energy. We obtained the exact equation for the kinetic energy of peculiar motion and the potential energy of galaxies systems with consideration influence background matter of expanding medium. It is the estimated time during which gravitating bound clusters transit to the equilibrium state from state of violent relaxation on the cosmological background. This background has the equation of state similar to that of radiation.

P 40

Kinematics and Galactic Orbits of Globular Clusters

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Line-of-sight-velocities and proper motions compiled by Dauphole *et al.* (1996) and derived from Hipparcos (Odenkirchen *et al.*, 1997) were used for studying kinematics and orbits of globular clusters.

Rotation and average velocity ellipsoid were found for our sample oclusters and for clusters with variuos metallicities and belonging to various groups according to Mironov, Rastorguev & Samus' and Borkova & Marsakov.

Galactic orbits of clusters were calculated in the two-component Galaxy model of Kutuzov & Ossipkov (1989). Also, calculations with various sets of proper motions, line-of-sight velocities and distances were performed. All orbits were found to be ordered, mainly, of box type (according to Ollongren's terminology). A preliminary morphological classification of boxes is suggested.

Correlations between orbital elements and metallicities were discussed. Various groups of clusters were considered separetely.

The way of estimating orbital elements from line-of-sight velocities only is proposed, and some illustrations are given.

The kinematics of globular cluster subsystem from line-of-sight velocities only is dicussed in connection with the problem of estimating local galactic parameters.

P 41

Galaxy Modelling by Equipotential Method

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Authors develop the equipotential method for constructing galactic models. The method allows to find both potential and density laws in analytical form with a finite set of free parameters. The method can be applied in various cases of symmetry, including triaxial and axisymmetric models. Also, it allows the existence of a disk embedded into a halo.

To apply the method it is necessary to know two functions, namely, the potential law that can be taken by analogy with spherical models and the equation of equipotential surfaces. A general theory of quartic equipotentials was developed for axisymmetric systems. Equipotentials of well-known models by Kuzmin, Lynden-Bell, Miyamoto & Nagai and Sato are special cases of such equipotentials.

As for the potential law, we worked mainly with the potential of Kuzmin & Malasidze, that incledes Plummer's and isochrone ones as special cases and contains also the "limiting" model of Kuzmin & Veltmann (later found by Hernquist). A more general family of potentials suggested by Kuzmin, Tenjes & Veltmann includes so-called "γ–models". Also, we considered models with the potential that gives Brandt's rotation law and models with Velmann's family of potentials that includes Zhao's "β–models".

Ten years ago we suggested a two-component model of our Galaxy constructed by the equipotential method. Now we discuss constructing the three-component model taking into account new observational data.

P 42

The Helium Stars in the Galactic Center Revisited

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Integral field spectroscopy of the central parsec of the Galactic Center has been obtained using BEAR, an imaging Fourier Transform Spectrometer. Sixteen stars are identified as Helium stars from the detection of the 2.058 μm line in emission, providing an homogeneous set of fully resolved line profiles at a spectral resolution of 74 km s^{-1}. These observations are allowing us to revise all the earlier detections of HeI stars in the central cluster, to discard some wrong identifications and to add three new stars. Two sub-classes of almost equal number are clearly identified from the brightness of their continuum and from their line profile. One class of faint stars shows very broad line profiles (FWHM $\simeq$ 1000 km s^{-1}) while the other one is made of stars 10 times brighter in the average with a much narrower emission component of $\simeq$ 200 km s^{-1}. All these profiles exhibit a more or less pronounced P Cyg profile, which confirm the presence of two categories of very hot stars with a fast expanding envelope. The fitting of the velocity line profiles do not indicate any common motion but only a large dispersion of velocity over 800 km s^{-1}. In addition, the bright stars form a cluster, mainly members of the IRS 16 cluster while the faint stars are randomly distributed at the periphery of the field, indicative of two distinct starburst events. The Brγ line profile for the same stars when present has been also obtained, allowing a determination of the He I/H ratio. Streamers of hydrogen and of helium gas, distributed over a velocity range of 800 km s^{-1}, following the main arms of the mini-spiral are also mapped. Finally, the nature of the HeI stars and their link with the gas streamers are discussed.

P 43

Non-linear Oscillations of Self-gravitating Ellipsoids and Formation of Star Clusters

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In spite of remarkable advance in the study of the shape evolution of star clusters during dissipationless collapse, there is some lack of understanding of that process. The analytical and numerical approaches have been used for investigation of the phenomenon and both of them point to the instability of a collapsing sphere with respect to the ellipsoid deformation when the virial ratio is less than 0.1. The details of the shape evolution and its dependency on angular momentum appeared in numerical experiments are complicated to investigate them analytically. Indeed, there is the only phase model of a non - stationary rotating spheroid with any possible angular momentum built by the author in 1986 y. and it has rather exotic velocity distribution. Fortunately, the behavior of large-scale modes does not depend on high order momenta and can be described by the 18-th order system of ordinary differential equations. These equations permit us to investigate the oscillations of collisionless ellipsoids with different large-scale initial parameters. The case of the non-rotating spheroid oscillations was studied by Malkov & Omarov (1998) who described the phase portrait changes along the virial ratio parameter.

This paper consists of the short review of results on the shape evolution obtained by analytical methods and the presentation of the new investigations of ellipsoid oscillations, the rotating triaxial ellipsoids with internal streams being considered.

Malkov, E. A., Omarov, Ch. T.: 1998, in *Abstracts of the Joint European and National Astronomical Meeting for 1998. 9–12 September 1998, Prague, Czech Republic*

P 44

Searching for Tidal Tails in Galactic Dwarf Spheroidal Galaxies

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The formation of the Galactic halo is currently best explained by the combination of two scenarios which previously were regarded as competing models. Based on the kinematics of metal-poor halo field stars, Eggen, Lynden-Bell & Sandage (ELS, 1962) proposed that the halo formed during a rapid, smooth collapse from a homogeneous primordial medium. Searle & Zinn (SZ, 1978) argued a halo formation via the gradual merging of many subgalactic fragments. The SZ scenario has been strengthened by the observational evidence accumulated during the past decade. The discovery of the Sagittarius dwarf galaxy (Ibata, Gilmore & Irwin 1994), in a process of dissolving into the Galactic halo, argued in favour that accretion events can take place in the Milky Way. The possibility that accretion events may leave observable fossil records in the halo is also supported by theoretical models of tidally disrupted dSph satellites (Johnston, Spergel & Hernquist 1995; Oh, Lin & Aarseth 1995; Piatek & Pryor 1995).

We present our preliminary results of a long-term project to investigate the process of accretion and tidal disruption of dSph satellites in the Galactic halo and, in particular, to search for new tidal tails in a sample of nearby dSph satellites of the Milky Way. The presence of a possible tidal debris in Ursa Minor and Sculptor dSphs and the results of our survey for a tidal extension along the NW semimajor axis of Saggitarius is discussed.

P 45

Viscous Models for the Long-term Evolution of the Galactic Disk Based on Dynamical Instabilities

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We discuss a basic family of models for the long-term evolution of the Galactic disk including the following fundamental ideas: (i) Star formation is driven by local dynamic instabilities of the disk. Following Wang & Silk (1994), the local star formation timescale is intimately linked to the local growth rate of gravitational instabilities and is described in terms of the stability parameter Q. (ii) Radial gas flows within the disk are induced by a (hypothetical) viscosity of the interstellar medium. It is assumed that viscous gas transport and star formation are linked to the same causes and that the characteristic timescales of these both processes are therefore equivalent (Lin-Pringle condition). (iii) Secular infall of external gas, as indicated e.g. by high-velocity H I clouds, strongly affects the long-term evolution of the disk. We adopt total mass fractions for the infalling gas as high as 50 % up to 95 %. Infall onto the disk may induce further radial gas streaming within the disk. (iv). The abundance evolution of the elements iron and oxygen is driven by supernovae of type II and type Ia. The modelling of the chemical evolution does not make use of the instantaneous recycling approximation.

The models are compared with relevant observations concerning the solar neighbourhood and the radial profiles of the Galactic disk. Good agreement is found with most of the constraints. Moreover, the models predict a bimodal Schmidt law for the star formation rate, in qualitative agreement with what is found for nearby spiral galaxies. Applications of our results to high-z damped Lyα QSO absorbers are briefly discussed.

P 46

A Proper Motion Search for Stars Escaping from Globular Clusters with High Velocities

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The dynamical evolution of globular clusters, in particular during the late phases, may be strongly influenced by the energy transfer from binaries to passing stars. As a by-product of this process, stars with high velocities are expected, perhaps high enough to escape from the cluster. Accurate proper motions are the only suitable tool to identify candidates for such high-velocity cluster stars. In order to perform such a search, we use a catalogue of absolute proper motions and UBV magnitudes for about 10^4 stars with $B < 20$ in a field of 10 square degrees centered on the globular cluster M3. The data were derived from more than 80 photographic plates taken between 1965 and 1995 with the Tautenburg Schmidt telescope and measured by means of the APM facility, Cambridge. The stellar sample is complete to $B = 18.5$ and comprises nearly all post-main-sequence stars in the halo of M3 and its surrounding. The proper motions are of Hipparcos-like accuracy (median error 1 mas/yr) in this magnitude range. We find several dozens of candidates, distributed over the whole field, with proper motions and colours consistent with the assumption of their origin from the cluster. Further conclusions can be drawn only on the basis of radial velocity measurements for the candidates and of estimates for the field-star contamination by means of simulations of the Galactic structure and kinematics in this field.

P 47

Dynamical Evolution of Globular Clusters Moving within the Galactic Central Regions

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The decaying of globular clusters towards galactic nuclei can be an efficient dynamical mechanism to concentrate high amounts of stellar matter in the very inner galactic regions, so to contribute significantly to the accretion and feeding of a central massive black hole. Such decaying is made possible by the *dynamical friction* which dissipates the cluster orbital kinetic energy in a reasonably short time. Quantitative indications that this mechanism is capable to sustain the observed AGN luminosities have been already given.

However, there is need of a more refined numerical approach. In particular, while in normal conditions dynamical friction is well understood and its effects sufficiently well described, it is not clear what happens when a cluster decays into a region which "encloses" a bulge mass comparable with that of the cluster itself. In this case the gravitational feedback of the cluster on the bulge is very important and cannot be neglected. Moreover, it is quite difficult to predict, by just analytical means, the tidal effects due to the presence of the massive black hole on clusters' dynamics.

We want to show the results obtained by our simulations in this context. The simulations have been performed both with a serial and a parallel 'tree-code' (on a CRAY T3E), using a leap-frog scheme for the integration of particles' trajectories, with individual and variable time steps. A completely self-consistent particle representation has been used, not only for the globular cluster but also for the nuclear region of the bulge and for the massive black hole.

P 48

On the Non-linear Non-radial Oscillations of a Disc-like Model with Passive Halo

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We study the evolution of non-radial oscillations of the non-equilibrium flat model. This model non-linearly pulsates with the arbitrary amplitude in own plane in the presence of the passive ellipsoidal halo of uniform density.

The non-linear evolution is described by the system of ten equations written in matrix form. The results are presented as the dependences of oscillation period on the amplitude and the parameter of rotation.

P 49

A Determination of Galactic Radial Gradients of Velocity Dispersion from a Local Sample of F, G and K Stars

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We present the preliminary results of a kinematic study focused on the determination of local variations of velocity dispersions σ_U and σ_W in the galactic radial direction from local stellar samples, following a original method developed by Mayor & Oblak (1985).

The method is applied to well defined local samples (distance less than 25 pc) of F, G and K main-sequence stars, selected from the Hipparcos catalogue. Accurate Coravel radial velocities have been used.

We transform the observed residual velocity distribution to a local distribution of orbital parameters (eccentrictiy, mean orbital radius and orbital plane inclination). The free parameters of the distribution, related with the large scale velocity gradients, are adjusted to fit at best the locally observed distribution. We use a method based on the maximum likelihood and the Mote Carlo method in order to solve the nonlinear system of equations obtained (Oblak, 1983; Moreno, 1996).

The results are interpreted in terms of stability and galactic length s cale of the Galaxy.

P 50

Structure of the Milky Way: Selected Directions and Possible Double and Multiple Open Clusters

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We study the selected direction structure of the disc of our Galaxy. At present we have a complex programme partly based on the study of the plates obtained using the Kitab Double Zeiss Astrograph (F = 3000 mm, D = 400 mm) with the epoch difference over 20 years. We have the plates of a number of unique regions. For example, one can find more than 15 open star clusters (OSC) on the plate with the center $\alpha = 0^h 29^m$, $\delta = 62^0$. We also put emphasis on some unique double and multiple OSC.

The Galaxy OSC are near the galactic plane, many of them being located in the spiral arms. It is reasonable to search for double OSC first of all in the star complexes (Efremov,1986) and in the regions with optically multiple OSC.

P 51

New Non-linear Phase Models of the Non-stationary Galaxy Disk

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In this paper new two radial oscillating phase models are constucted. The models have the velocity anisotropic diagram.

Basic physical characters of these models are found. The phase model stability is also studied.

P 52

Ground-based Infrared Imaging Search for Planetary Companions Next to Young Nearby Stars

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We report first results from our ground-based infrared imaging search for sub-stellar companions (brown dwarfs and giant planets) of young (up to 100 Myrs) nearby (up to 75 pc) stars, where companions should be well separated from the central stars and still relatively bright due to ongoing accretion and/or contraction. Among our targets are all members of the TW Hya association, as well as other binary and single young stars either discovered recently among ROSAT sources (some of which as yet unpublished) or known before. Our observations are performed mainly with SOFI and SHARP at the ESO 3.5 m NTT on La Silla and with ISAAC at the ESO 8.2 m ANTU (VLT-UT1) on Cerro Paranal, all in the H- and K-bands. We present direct imaging data of a faint object detected next to TWA-7 which, if at the same age and distance as the central star, could be an object with only a few Jupiter masses.

P 53

Gross-Dynamics of Star Clusters in the Galaxy

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A cluster moving along a circular orbit in the axisymmetric steady Galaxy is considered. A linear (tidal) approximation of the galactic potential was adopted.

The hierarchy of gross-dynamics equations was deduced from the kinetic equations. They generalize the tensor Lagrange-Jacobi's equations. Chandasekhar's integrals are consequences of these equations. A problem of closing the gross-dynamics equations is discussed and the concept of quasi-homologicity is developed. We say that models belong to the same quasi-homologicity class if they follow the same relation between tensors of inertia and potential energy (with the same numerical values of coefficients). The existence of such classes is proved.

A generalization of Mineur's equilibrium ellipsoids is found for non-uniform models with anisotropic velocity distribution.

A theory of tidal disruption of clusters is outlined.

Small "virial" oscillations relative the equilibrium were studied. Eigen-frequences of such oscillations were found.

Gross-dynamics equations for clusters moving along epiciclic orbits were deduced also.

P 54

Motion and Formation Places of Young Stars in the Solar Neighborhood

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The motion of OB stars closer than 2 kpc from the Sun will be discussed using positions and proper motions from the Hipparcos catalogue. Only stars with the Strömgren photometry and radial velocities are selected, for which individual distances and ages are derived. Individual orbits in the Milky Way are analyzed. Formation places show a large scale shape of a sheet-like region in the galactic plane. We shall speculate about possible origins of this configuration.

P 55

Analytical Results for Distibutions Functions and Gravitationnal Potential for 3D and 2D Stellar Systems

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After general considerations on the properties of distribution functions (DF) for steady state stellar systems, I will talk about the choice of the DF. In the 3D gravitationnal context, I deal with a very old Chandrasekhar's conjecture (1942): What are the properties of a stellar system which DF depends only on the mean particle energy E (The inverse but unphysical problem is trivial), and I will use a rigourous theorem from Gidas, Ni and Nirenberg, 1981 to answer. In the 2D gravitational context, I will present a recent work (Aly and Perez, 1999) in which we obtain DF and gravitationnal potential for an unbounded system from thermodynamical consideration. An application of such a potential to orbits in thin stellars disks will be presented.

P 56

Halo Structure and Kinematics from SDSS-selected HB Stars

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SDSS Collaboration

The Sloan Digital Sky Survey (SDSS) surveyed several hundred degrees of the sky during its engineering/commissioning phase (mid-1998 through 1999). Several hundred field Blue Horizontal Branch (BHB) and RR Lyrae star candidates have been identified from the early data and modest resolution (R1800) spectra have been obtained for over 100.

The Survey is scheduled to begin normal operations this spring. Horizontal Branch (HB) stars are one of the primary stellar targets for spectroscopy and we expect to obtain velocities for roughly 10,000 HB stars over the Survey area (approximately 10,000 square degrees in the Northern Galactic Cap).

Early indications are that (1) there are more field HB stars than earlier, naive, models predicted; (2) the fall-off from the Galactic Center is shallower than earlier models predicted; and (3) there is evidence for clumpiness in the spatial distribution. We will present these and other results from the early data and will discuss the prospects for more comprehensive results for understanding the structure and kinematics of the halo from HB stars found in the SDSS.

P 57

OB Associations as Sources of Galactic Radioactivity

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Recent investigations of the COMPTEL ^{26}Al sky map have shown massive stars and their subsequent core-collapse supernovae to be the most promising source candidates for interstellar ^{26}Al. In correlated star formation massive stars are expected to form OB associations, which are considered as main source regions for the observed 1.8 MeV emission.

Our analysis exploits a detailed, analytical population synthesis model, which is presented in an updated version. This code allows modelling of the ^{26}Al, ^{60}Fe, kinetic energy, and extreme ultra-violet emission characteristics of OB associations. We present a consistency check with results of a standard starburst model (STARBURST99), which was modified by our group to also include the ^{26}Al nucleosynthesis. Furthermore we started to investigate the impacts of statistical fluctuations on the modelled parameters by exploiting Monte Carlo simulations.

We present results of an application of our model to OB associations in the Cygnus region. This analysis is based on updated measurements in the optical, radio and X-ray regime. We furthermore discuss other candidate regions as test objects for our model, and present some predictions of possible detections with the up-coming ESA satellite INTEGRAL.

P 58

New Constrains for the Edge of the Galactic Disk

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Structural parameters of galactic disks are of fundamental importance to address the formation and evolution of spiral galaxies. One of these parameters is the *cut-off radius* R_{co}, corresponding to a sharp radial truncation of the old stellar disk, first observed in nearby edge-on spirals. It is now well accepted that the galactic disk as well exhibits such an edge. Robin et al. (1992) determine the galactic disk structure with a synthetic stellar population model using optical star-counts and confirm a sharp truncation of the old stellar disk at 14±0.5 kpc. Using NIR star-counts instead Ruphy et al. (1996) find 15±2 kpc. Freudenreich (1998) fits a model for the old galactic disk to the *COBE*-DIRBE NIR data also confirming an outer truncation at 12.4±0.1 kpc. In contrast to former investigations (van der Kruit 1986, Lewis & Freeman 1989, Nikolaev & Weinberg 1997) placing the Milky Way scalelength around 4−5.5 kpc, they quote significantly lower scalelengths of 2.5±0.3 kpc, 2.3±0.1 kpc, and 2.59±0.02 kpc, respectively. In combination this results to 5.6±0.5, 6.5±1.2, and 4.8±0.1 for the ratio of R_{co}/h. This should be reviewed in context to our survey of 31 nearby edge-on spiral galaxies, where we find a mean value of the distance independent ratio $R_{co}/h = 2.9 \pm 0.7$, by fitting a three-dimensional single component disk model. Whereas the first two values are significantly higher than any value found in our sample (even the highest ever measured value of van der Kruit & Searle (1982) is only 5.3) the latter determination by Freudenreich is consistent with our highest values of 4.4 within the errors. If the Milky Way should be a 'typical' galaxy according to our data with $R_{co}/h = 2.9$ the scalelength is expected to be $h \geq 4.1$ kpc for $R_{co} \geq 12$ kpc.

P 59

The Galactic Spheroid Density Law

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Microlensing events towards the Magellanic Clouds from EROS and MACHO experiments imply that a significant part of the dark matter halo is made of stellar objects. Since one expect that a dark matter halo have a density law close to a power law with index of –2 in order to make the rotation curve flat, one should also think of a stellar spheroid of a similar shape. Some previous analyses of the spheroid density law gave rather steeper slopes, although being based on rather small samples of well identified tracers and with unpublished uncertainties.

In order to find new constraints on the spheroid density law, we have undertaken an analysis of deep photometric star counts in 15 high and intermediate latitude fields. Such counts contain large number of halo dwarfs easily distinguishable from thick disc dwarfs by their colours if the counts are deep enough (V>20).

Assuming a power law density we use a population synthesis model to simulate catalogues in each field. Model predicted counts are then compared with observations using a maximum likelihood test. We explore a wide range of galactocentric radius from 5 to 30 kpc. The absolute magnitudes of selected stars range between 4. and 10. We show that this part of the luminosity function does not strongly depend on the assumed initial mass function. The fit depends mostly on the local density of the spheroid, on the axis ratio and on the power law index. We also use complementary constraints on the local density of halo giants and dwarfs. The likelihood test gives its maximum for a spheroid density law with an axis ratio of 0.7 and a power law index of 2.6 ±0.3. The error bar accounts for the uncertainty on the local density of this population which is $4.7 \pm 1.2 \times 10^{-5}$ $M_\odot$ pc^{-3}. We observe a slight degeneracy between the flattening and the power law index. With a flattening

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From Hipparcos to DIVA: A more Detailed Look at the Galaxy

S. Röser
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

The talk will give a very short description of the planned small astrometric satellite DIVA and its mission. The main part of the talk will present and discuss possible scientific applications of the DIVA data for galactic research.

DIVA intends to provide positions, proper motions, parallaxes and multicolour photometry for about 35 million stars, i. e. for 300 times as many stars as Hipparcos. At a given magnitude, the DIVA measurements will be about a factor of 5 more precise than those of Hipparcos. DIVA is to be launched in 2003 or 2004. After a two-year mission and two more years to complete the data reduction, final results will be produced in about 2008 – at least 10 years before the data from the future great ESA mission GAIA will become available.

The DIVA data will enormously widen and deepen the new view of the Galaxy that Hipparcos has started to give us. In addition to the greatly increased number of stars and the improved precision of the astrometric data, the precise multicolour photometry will give a qualitatively new aspect as compared to Hipparcos: The stars will be physically characterized by the very same instrument that provides their spatial and kinematic location in the Galaxy.

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Dynamics of the Sgr A* Cluster

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We model the dynamics of the star cluster around Sgr A* using a spherical potential and an arbitrary two-integral distribution function in order to fully include the uncertainties created by orbital anisotropy. Given spatial and kinematical data for the stars, we find the best-fit parameters of the mass distribution, assuming a point mass embedded in a singular isothermal sphere. We also determine the distance to the Galactic center using statistical parallax.

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A Molecular Face-On View of the Galactic Center – Method and Its Reliability

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We present a method to derive positions of molecular clouds along the lines of sight from a comparison of the 2.6 mm emission line and the 18 cm absorption line. This method is applied to the central kiloparsecs of the Milky Way to derive a face-on distribution of the molecular gas (Hasegawa et al., this conference). To the first order, CO emission measures the amount of molecular gas, while the OH absorption measures the molecular gas in front of the continuum source. As the continuum source at 18 cm is diffuse and distributed in the Galactic center region, OH/CO line intensity ratio bears information of the location of the molecular gas in the region along the line of sight.

In deriving the face-on view, we have made following assumptions: (1) clouds are not overlapping with each other, (2) the OH opacity $\tau_{\rm OH}$ is proportional to the CO intensity $T_{\rm CO}$, (3) the excitation temperature of OH $T_{\rm ex}$(OH) is uniform, and (4) the continuum emissivity $j_{\rm cont}$ is described as a sum of axisymmetric Gaussians. Some of these assumptions (uniform $T_{\rm ex}$(OH), axisymmetric $j_{\rm cont}$) and used parameters ($T_{\rm CO}$ to $\tau_{\rm OH}$ coefficient, $T_{\rm ex}$(OH)) are inevitably crude and can be inadequate. We examine their possible effects and discuss the reliability of the resultant face-on view.

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A 3-D Survey of the Solar Neighborhood with DIVA

R.-D. Scholz, E. Schilbach, S. Hirte
(Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany)
U. Bastian, S. Röser, H. Jahreiß
(Astronomisches Rechen-Institut, Mönchhofstraße 12–14, D-69120 Heidelberg, Germany)

Our knowledge on stars in the Solar neighborhood is one of the main starting points for investigations of the stellar luminosity function, the initial mass function as well as for the search for planetary systems. Future missions for the detection of extrasolar planets (SIM, TPF, DARWIN) will (have to) concentrate on very nearby stars ($d < 10$ pc) in order to be able to reveal not only Jupiter-class but also Earth-like planets. The number of missing stars (mainly cool dwarfs are expected) within this distance limit was estimated as 130 systems compared to 234 known ones (Henry et al. 1997).

DIVA (Double Interferometer for Visual Astrometry) is a small satellite planned for launch in 2003. It will measure positions, proper motions and parallaxes, magnitudes and colours of 30 to 40 million stars, i. e. observe several hundred times as many stars as Hipparcos, at typically four times the precision of Hipparcos. For >250,000 stars, parallaxes will be provided with relative accuracy better than 10 %. Due to high sensitivity of the DIVA detectors between 600 nm and 900 nm, and because of the automatic detection on board, red stars and brown dwarfs are preferred objects in the DIVA survey. A representative sample of late-M and L dwarf spectra has been used for the simulation of DIVA raw data (dispersed and undispersed interferometric fringes) in order to estimate the limiting magnitude and accuracy which can be reached for these objects. Whereas most known nearby stars were found by their large proper motions, DIVA will provide an unbiased survey via direct distance measurements. Statistical properties of the survey are described.

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The Dynamical Evolution of Globular Clusters and the Stellar Initial Mass Function

K. Takahashi
(Department of Astronomy, University of Tokyo, Tokyo, Japan)

The stellar initial mass function (IMF) is one of the important factors which affects the dynamical evolution of globular clusters. First, the IMF determines the amount of mass lost from clusters via stellar evolution. This mass loss plays an important role in the early evolution of clusters. If the fraction of massive stars is significantly large, the clusters are easily disrupted during the early stage. Second, the IMF also affects the long-term evolution of globular clusters driven by two-body relaxation, since the two-body relaxation process depends on the stellar mass.

Recent observations indicate that the present-day mass function (PDMF) in many globular clusters is much flatter than the Salpeter IMF. Theoretically it is well known that the global mass function becomes flatter as the cluster loses mass from the tidal boundary. Therefore the PDMF might be significantly different from the IMF. However the observations of the PDMF should give a strong constraint on the IMF of low mass stars in any case.

Using Fokker-Planck models we carry out numerical simulations of the evolution of globular clusters over a wide range of initial conditions. Our simulations include the effects of the tidal field of the galaxy and of mass loss due to stellar evolution. We find that the lifetimes of clusters rather sensitively depend on the IMF.

From the constraint that globular clusters must survive today and have the mass function similar to the observed PDMF, we discuss possible forms of the IMF.

P 65

How to Form Twin Globular Clusters?

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In the last decade several scenarios for the formation of globular cluster have been suggested, e. g. the collapse of molecular clouds which are stabilized by UV-photons at a temperature T=10^4 K leading to a Jeans mass of $10^6 M_\odot$ or the collapse of the cores of supergiant molecular clouds that are stabilized magnetically which gives enough time for a homogenization of the metal distribution in the protocluster. However, these scenarios suffer from short formation timescales and unusually high star formation efficiencies. An alternative model starts with an OB-association exploding near the center of a molecular cloud: The expanding shell sweeps up the cloud material and in a later stage the expansion might be decelerated or stopped by the external pressure of the ambient hot gas. The shell itself might fragment into stars and, if the total energy of these stars is negative, they will recollapse and eventually form a globular cluster.

In order to compare the early evolution of a globular cluster in these scenarios, the collapse of a thin shell has been studied by means of N-body simulations and compared with the evolution of initially smoother mass distributions. It is shown that in the framework of the shell scenario it is easy to form twin or multiple stellar systems, whereas smoother configurations typically end either in a single stellar system or in complete disruption. This difference might allow for a discrimination between different formation scenarios.

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What Happens to the Gas in Globular Clusters?

A. Thoul
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E. Jehin, P. Magain, A. Noels, G. Parmentier

Observations of globular clusters show that they contain much too little gas or dust, compared to what should be present due to the mass-losing stars in the cluster. Many authors have been intrigued by the fate of the gas in globular clusters. They have suggested various mechanisms by which the gas could escape from the cluster, such as stellar UV radiation, cluster winds driven by X-ray bursters, novae, or flare-stars, relativistic winds from millisecond pulsars, condensation into stars, accretion processes drawing upon a central gas reservoir, continuous sweeping of the cluster gas by the gaseous medium of the Galactic halo ...

Recent results also show that globular cluster stars show many abundance anomalies. Accretion of interstellar gas by the cluster stars has been suggested as a plausible mechanism to explain these anomalies. It is also a major ingredient of the EASE scenario linking halo field stars to globular clusters, which we have recently developed to explain strong r-and s-elements correlations in halo field dwarf stars.

Here we will briefly review the status of gas and dust detection in globular clusters, as well as the possible gas removal mechanisms. We will explore in more details the gas and dust accretion processes onto main sequence stars. In particular, we will study the efficiency of this mechanism in removing gas from the globular clusters interstellar medium.

P 67

The Rotation of the Galactic Bulge

A. Winnberg (Onsala Space Observatory, SE-439 92 Onsala, Sweden)

OH/IR stars are well suited as probes of the dynamics in the central parts of the Galaxy. It is believed that most stars go through this short phase in their late evolution, and as such stars, their motions are governed by gravity only. Moreover their maser-amplified OH emission is very strong making it possible to detect these stars throughout the Galaxy.

In the present study, data from 5 different surveys for OH/IR stars covering the Galactic bulge region of the sky ($|l| \leq 30\,^\circ, |b| \leq 30\,^\circ$) were combined. Within this region there are about 550 OH/IR stars detected in these surveys. The probability of 'contamination' by stars belonging to the Galactic disk is discussed.

The principle tool in the dynamical analysis of OH/IR stars is the so called $l - v$ diagram: radial velocity as a function of Galactic longitude. It is demonstrated that every such $l - v$ diagram is a superposition of an ensemble of $l - v$ diagrams with regression line slopes which are decreasing with increasing area of sky around the Galactic centre. The conclusion is that the Galactic bulge has a differential rotation. This is in contrast to all other studies of the bulge which have either pointed to solid-body rotation or to no rotation at all.

Assuming that the distance to the Galactic centre is 8.5 kpc and that the orbital velocity of the Sun is 220 km s^{-1}, the mean streaming velocity and the *rms* velocity spread both start out at about 50 km s^{-1} at 10 pc from the centre and rapidly climb to about 100 km s^{-1} at about 200–300 pc and then hover at that order of magnitude out to 3–4 kpc. Assuming further that the bulge is rotationally symmetric – and there is no evidence in these data of any asymmetry – and that the velocity spread is isotropic, the enclosed mass and circular rotation velocity can be calculated.

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Expanding Shells: Instability with Nonlinear Terms

Richard Wünsch and Jan Palouš
(Astronomical Institute, Boční II 1401, 141 31 Praha 4, Czech Republic)

A model of the thin shell expanding into uniform ambient medium is developed. Density perturbations are described using equations with linear and quadratic terms. Linear and nonlinear solutions are compared and the interaction of modes on the shell surface is discussed. The numerical solution defines the time when the fragments are formed.

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Deep BV CCD Photometry of the Metal-Rich Globular Cluster M71

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Deep BV photometry for about 15,000 stars in the globular cluster M71 has been obtained from the 2.2 m University Hawaii Telescope using 2k CCD. The frames cover a $7.5' \times 7.5'$ region of the cluster center through $220''$ (about 7 core radii). A complete color-magnitude diagram(CMD) from the upper red-giant branch to the lower main sequence($V_{limit} \sim 22$; approximately 5 mag below the main-sequence turnoff) has been constructed.

From the fitting of the CMD fiducial sequence to the New Yale Isochrone and the similar metallicity globular cluster 47 Tuc, we estimated the absolute and relative ages of this "disk population" globluar cluster.

A luminosity function to $M_v \sim 8.3$ for the cluster main-sequence has been derived. Applying several theoritical mass-luminosity relations, we derived mass function of M71. We discuss the implications of this on recent HST results about low mass main-sequence stars' lumisoty function and on dynamical evolution of the globular cluster.

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UCAC1: New Proper Motions for 27 Million Stars on the Southern Hemisphere

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D. G. Monet (Naval Observatory, Flagstaff Station)
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G. L. Wycoff
M. I. Zacharias
T. J. Rafferty

The big impact of UCAC on galactic kinematics and dynamics studies will be outlined. The USNO CCD Astrograph (UCA) started an astrometric sky survey in February 1998 at Cerro Tololo, Chile. By January 2000 about 90 % of the Southern Hemisphere has been observed and full sky coverage is expected by early 2003. In addition, calibration fields around extragalactic reference frame sources and selected open clusters are observed frequently. The UCAC project is a huge dedicated astrometric survey similar to the AGK2 and AGK3 projects but vastly exceeding those with respect to higher accuracy, limiting magnitude (16th) and full sky coverage.

A first catalog (UCAC1) is being published in early 2000 for 27 million stars. Stars in the range of 9 to 14th magnitude have a positional precision of 20 mas. The UCAC1 will utilize positions from the USNO A2.0 catalog for determining proper motions, which are expected to be about 8 mas/yr for this initial release. Higher precision proper motions, expected to be in the 3 to 4 mas/yr range, will be derived utilizing a variety of early epoch data, including re-measuring of the Southern Proper Motion (SPM) survey first epoch plates.

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WFI Imaging of Tidal Tails in Galactic Globular Clusters

S. Zaggia
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We will present first results on deep and wide field imaging of Tidal Tails of some Galactic Globular Clusters obtained with the Wide Field Imager of the ESO/MPI 2.2 m La Silla telescope.

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Astronomical Instruments and Methods at the Turn of the 21st Century

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Reviews in Modern Astronomy 13

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