INTERNATIONAL WORKSHOP
MODEST-13

STAR CLUSTERS ACROSS COSMIC TIME

SCHOOL FOR YOUNG SCIENTISTS/STUDENTS

NEW TECHNIQUES OF MODELING AND OBSERVING – MODEST 13A

PROGRAM

ALMA-ATA HOTEL
ALMATY, KAZAKHSTAN
AUGUST 19-23, 2013

CONFERENCE ORGANIZERS

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Chingis Omarov (Fessenkov Astrophysical Institute, Almaty, Kazakhstan) – Co-chair

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WELCOME TO MODEST-13

Dear participants of MODEST-13,

Guests and Colleagues!

As a president of the JSC «National Center for Space Research and Technology», I am pleased to welcome you to this landmark international meeting MODEST-13 in Almaty hosted by Fesenkov Astrophysical Institute, which is a major division of the National Centre for Space Research and Technology in the National Space Agency of Republic of Kazakhstan.

This thirteenth workshop on the theme "Star Clusters across Cosmic Time" within the MODEST initiative is the first major international meeting on astrophysics in independent Republic of Kazakhstan. We hope that in the future we will have a lot of international meetings on astronomy.

We all know that MODEST workshops are held annually since 2001 in different countries. We are very excited that the MODEST-13 passes here in Kazakhstan. In this way we see that our Astrophysical Institute conducts scientific research in astronomy at the global level.

Fesenkov Astrophysical Institute which organizes this workshop is the largest Astrophysical Center in Kazakhstan. The Institute was founded in 1941 and has a great scientific history. Nowadays different areas including theoretical, observational and computational astrophysics are being successfully developed in our Institute.

Also, we are glad that this workshop is attended by leaders of this field of astronomy. I think that due to participation of these famous scientists this workshop will be successful and will give its good scientific results in research.

Thank you again for being part of this workshop. I hope you find it valuable and I look forward to hearing of new

discoveries and developments resulting from the wonderful work you all do.

I wish you all a scientifically rewarding unforgettable Workshop and a most enjoyable stay in Almaty.

Sincerely yours,

President of

National Center for Space Research and Technology

in National Space Agency of Republic of Kazakhstan

Zhumabek Zhantayev

ABOUT MODEST 13

The MODEST (Modeling Dense Stellar Clusters) collaboration is a loosely knit international collaboration between various groups working in stellar dynamics, stellar evolution, stellar hydrodynamics, and related research areas. One of the main activities of the collaboration is to provide a software framework for large-scale simulations of dense stellar systems, in which existing codes for dynamics, stellar evolution, and hydrodynamics can be easily coupled, and place them in the appropriate observational context.

Our present understanding of dense stellar systems and its subsystems has greatly evolved in the past years due to the development of new methods and approaches in computational astrophysics. Dense stellar systems not only occur in thousands of globular clusters around and among galaxies, but also at the lower end of scaling relations for black holes and galactic nuclei. And recent research reveals that their could be a continuous transition from dense stellar systems to small galaxies. Obviously, all these developments are connected with new high resolution observational data available today. Star Clusters are tracers and building blocks of galaxy formation, and their importance as gravitational wave sources through their stellar or intermediate mass black holes is getting into the focus.

In recent years, significant progress has been made in the fields of N-body dynamics, hydrodynamics, radiative transport, and stellar evolution, and powerful hardware (especially GPUs) has become available to vastly speed up simulations.

Understanding the formation and evolution of star clusters is a challenging task which requires the collaboration and the exchange of ideas of astronomers, physicists, and computer scientists with observational and theoretical expertise in galactic and extragalactic astronomy, stellar dynamics, hydrodynamics, stellar evolution, and software/hardware development.

MODEST-13 is the thirteenth workshop within the MODEST initiative, the first major MODEST meeting in central Asia, and the first in Kazakhstan.

Main topics of MODEST-13 workshop are:

1. Globular and dense clusters
2. Central clusters in galaxies
3. N-body simulations.

CONFERENCE PROGRAM

MONDAY

19 August (Topic: N-body simulations)

9:00 Registration

9:30 Welcome speeches

Invited speakers (Chairperson: Thijs Kouwenhoven**)**

10:00 Sverre Aarseth "Post-Newtonian N-Body simulations"

10:50 Coffee-break & Poster Session

11:40 Stephen McMillan "Simulating Star Clusters with AMUSE"

12:30 Rainer Spurzem "Astrophysical Supercomputing, Galactic Nuclei and Black Holes"

13:20 - Lunch

Contributors (Chairperson: Jarrod Hurley**)**

14:30 Peter Berczik "Galactic Star Cluster mass evolution. High performance star by star simulations"

14:50 Igor Zinchenko "High resolution N-body modeling of the Galactic disk radial motion and stability under the minor merger scenario"

15:10 Margarita Sobolenko "N-body modeling of galaxy mergers and the "mass deficit" effect"

15:30 Coffee-break

16:00 Denis Yurin "A New Iterative Method for the Construction of Equilibrium N-Body Models"

16:20 Inti Pelupessy "Cluster formation simulations with AMUSE"

TUESDAY

20 August (Topic: Globular clusters)

Invited speakers (Chairperson: Margarita Sobolenko**)**

10:00 Jarrod Hurley "The role of stellar mass black holes in globular clusters"

10:50 Coffee-break & Poster Session

11:40 Mirek Giersz "New IMBH formation scenario in dense star clusters"

12:30 Thijs Kouwenhoven "The dynamical evolution of multi-planet systems in star clusters"

13:20 – Lunch

Contributors (Chairperson: Stephen McMillan**)**

14:30 Yeong-Bok Bae "Compact Binaries ejected from Globular Clusters as GW Sources"

14:50 Jongsuk Hong "Black hole binaries in galactic nuclei and gravitational waves"

15:10 Gareth Kennedy "The role of three-body stability in tidally interacting globular clusters"

15:30 Coffee-break

16:00 Christoph Olczak "Mass segregation in young star clusters"

16:20 Andreas Ernst "The volume of star clusters"

16:40 Arkadiusz Hypki "Bimodal spatial distribution of blue stragglers as a tracer of star cluster dynamical state"

18:30 CONFERENCE DINNER

WEDNESDAY

21 August (Topic: Stellar dynamics, galactic centers)

Invited speakers (Chairperson: Leonid Chechin**)**

10:00 Leonid Ossipkov "Stochastization and dynamical evolution of gravitating systems"

10:50 Coffee-break & Poster Session

11:40 Stefan Gillessen "Stellar dynamics in the Galactic Center"

12:30 Holger Baumgardt "The origin of ultra-compact dwarf galaxies"

13:20 - Lunch

Contributors (Chairperson: Chingis Omarov**)**

14:30 Taras Panamarev "Comparative analysis of the dynamical action of the accretion disk models on the stellar component in galactic nuclei"

14:50 Emmanuil Vilkoviskij "AGN Numerical Modeling in Fesenkov Astrophysical Institute"

15:10 Tobias Cornelius Hinse "Observation & Dynamics of Circumbinary Exoplanets"

15:30 Coffee-break

16:00 Leonid Chechin "On the modern status of Universe rotation problem"

16:20 Gulya Avkhunbaeva "Gravitational lensing"

16:40 Maxim Krugov "View of development of mountain observatory of Assy-Turgen, as an international observation hub"

THURSDAY

22 August (Lectures)

09:30 – 12:30 **Stephen McMillan**

"Simulations of Dense Stellar Systems"

11:00 – 11:30 Coffee-break

12:30 – 14:30 **Lunch**

14:30 – 17:30 **Jarrod Hurley**

"Stellar Evolution"

16:00 – 16:30 Coffee-break

FRIDAY

23 August (Lectures)

09:30 – 12:30 **Rainer Spurzem**

"How to start CUDA programming on GPU; parallel programming and MODEST applications"

11:00 – 11:30 Coffee-break

12:30 – 14:30 **Lunch**

14:30 – 17:30 **Sverre Aarseth**

"Post-Newtonian Implementations"

16:00 – 16:30 Coffee-break

SOCIAL EVENTS

18 August

18:30 – Reception evening

Venue: Alma-Ata Hotel

20 August

18:30 – Conference dinner

Venue: Alma-Ata Hotel

24 August

09:30 – Excursions

Starting place: Alma-Ata Hotel

ABSTRACTS

Post-Newtonian N-body Simulations

Sverre Aarseth
Institute of Astronomy/University of Cambridge, UK

We report on fully consistent long-term simulations of small globular clusters containing a population of black holes (BHs) which are formed from evolving massive stars. The initial mass function is chosen in the range 0.2 – 50 M. Emerging neutron stars and BHs are assigned a velocity kick such that nearly half the population is retained. The resulting mass segregation is dominated by the BHs which eventually lead to the formation of stellar mass binaries. The subsequent evolution is characterized by ejection of the most massive BHs following sling-shot interactions in which the binaries also escape at high terminal velocity. This process appears to be an efficient mechanism for depleting the most massive BHs and thereby preventing the growth of a dominant central body. Depending on the initial conditions, post-Newtonian treatments of eccentric BH binaries is sometimes called for. A search for stellar disruptions due to close encounters with BHs reveals that such events are quite rare.

Gravitational lensing

Gulya Avkhunbaeva
Fesenkov Astrophysical Institute, Kazakhstan

The new models of two – component gravitational lens were discussed in the report. The focus of models is in the accounting both of baryonic and nonbaryonic (dark) matter and in considering case when contributions on the gravitational lensing of these components are comparable each other. It is shown that positions of images of lensing object depend on profiles of dark matter and baryonic matter.

The origin of ultra-compact dwarf galaxies

Holger Baumgardt
University of Queensland, Australia

Ultra-compact dwarf galaxies (UCDs) were discovered in the late 1990s in spectroscopic surveys of the Fornax galaxy cluster (Hilker et al. 1999, rinkwater et al. 2000) and have since then been found in several other nearby galaxy groups and clusters. UCDs are bright ($-11 < M_V < -13.5$) and compact ($7 < r_h < 100$ pc) stellar systems with ages of at least several Gyr and possibly up to 10 Gyr. One of the most remarkable properties of UCDs are their elevated mass-to-light ratios, which are on average about twice as large than those of globular clusters of comparable metallicity, and are larger than what one would expect based on simple stellar evolution models that assume a standard stellar initial mass function. In my talk I will give an overview of what is known about UCDs and discuss possible pathways to their formation.

Galactic Star Cluster mass evolution. High performance star by star simulations.

Peter Berczik [1,2], Andreas Just[2], Andreas Ernst[2], Rainer Spurzem[1,2]

1 National Astronomical Observatories of China, Chinese Academy of Sciences (NAOC/CAS) Beijing, China

2 Astronomisches Rechen-Institut, Zentrum fur Astronomie Univ. Heidelberg, Germany

We carry out the large set of Galactic Star Cluster simulations (up to 5e5 M_sol initial masses) using our high performance direct N-body code phi-GRAPE+GPU with the maximum possible numerical resolution (one particle one star) on the largest astrophysical GPU clusters. Our main goal was to investigate the cluster initial volume "filling" factor to the process of the cluster mass loss as well as the cluster whole lifetime. We also investigate the evolution of the present day Cluster Mass Function depending on the initial parameters of the clusters.

On the modern status of Universe rotation problem

Leonid Chechin
Fesenkov Astrophysical Institute, Kazakhstan

The brief modern review of the Universe rotation problem is presented. Also I argued the vacuum concept of the Universe rotation, found the galactic coordinates of the Universe rotation axis and described theoretically the concept of the deceleration parameter anisotropy.

An overview of LEGUE (LAMOST Experiment on Galactic Understanding and Expolration)

Licai Deng
National Astronomical Observatories of China/CAS, China

LAMOST (Large sky Area Multi-Object fiber Spectroscopic Telescope) is a Chinese national scientific research facility operated by National Astronomical Observatories, Chinese Academy of Sciences (NAOC). After two years of commissioning beginning in 2009, the telescope, instruments, software systems and operations are nearly ready to begin the main science survey. Through a spectral survey of millions of objects in much of the northern sky, LAMOST will enable research in a number of contemporary cutting edge topics in astrophysics, such as: discovery of the first generation stars in the Galaxy, pinning down the formation and evolution history of galaxies especially the Milky Way and its central massive black hole, looking for signatures of dark matter distribution and possible sub-structures in the Milky Way halo. To maximize the scientific potential of the facility, wide national participation and international collaboration has been em- phasized. The survey has two major components: the LAMOST ExtraGAlactic Survey (LEGAS), and the LAMOST Experiment for Galactic Understanding and Exploration (LEGUE). Until LAMOST reaches its full capability, the LEGUE portion of the survey will use the available observing time, starting in 2012. An overview of the LAMOST project and the survey that will be carried out in next five to six years is presented in this talk.

N-body simulation of the close binary system destruction in the field of super-massive BH

Dryomova G.N.[1], Dryomov V.V.[1], Tutukov A.V.[2]

[1]*Russian Federal Nuclear Centre, Snezhisk, Chelyabinsk region, Russia*

[2] *Institute of Astronomy, Russian Academy of Sciences, Moscow, Russia*

At the beginning of XXI-th century the new class of stars was opened known today as *Hypervelocity Stars*. For the first time these objects were predicted by Hills in 1988, who considered the problem of Close Binary System (CBS) in close neighborhood of Super-Massive Black Hole (SMBH). He estimated that the dynamical capture of one of CBS component by gravity field of SMBH results in the ejection of second CBS component with the velocity appreciably exceeding escape velocity for the Galaxy. Stars with high space velocity approaching to 1000 km/s are indeed discovered nowadays.

We also appeal to the scenario of close to SMBH passing of the binary star to estimate highest possible spatial velocities for the "runaway stars» as well as to find constraints to the destruction of CBS as gravitationally bound object and to formulate survival conditions of star-components. We propose two-stage approach including point-like and structured representation of CBS stars. On the first stage the three-body simulation was applied and the statistics of 10^4 chaotically oriented CBS orbits relative to SMBH is stored up.

The strategy for the processing of the results of three-body simulation is based on an assessment of the maximum specific total energy gained by one of CBS components when passing the SMBH pericentre. Cumulation of energy required to create a *Hypervelocity object* was estimated from the condition that the escaped star appears to be at infinity. The analysis of the

dependence of the maximum speed upon pericentre distance from SMBH allows to localize effective zone for the search conditions for energy cumulation. But point-like approximation faced the problem when it comes to the maximum possible acceleration of a real star – the problem of strong tidal effects. To obtain more realistic evaluation of maximum acceleration we must deal with the structural object.

So the results of three-body simulation were analyzed to select the most favorable for ejection initial orientations of CBS. These orbits were recalculated within the approach where the star was considered as a finite-size object in the framework of N-body problem.

Results of N-body simulation give us an unbiased view on the survival of components of close binary in the vicinity of massive black hole and allow to estimate the critical distance from SMBH where binary stars can still avoid fatal destruction and get the accelation needed to achieve the status of *Hypervelocity Stars*.

The volume of star clusters

Andreas Ernst
Astronomisches Rechen-Institut, Germany

Star clusters are usually embedded in the tidal field of a galaxy. In a realistic simulation, their formation and evolution should be calculated in the framework of a restricted three-body problem. In this framework the Roche volume arises as an immanent volume scale. The talk addresses the question to which extent star clusters fill the Roche volume and what the effect of different Roche volume filling factors is.

New IMBH formation scenario in dense star clusters

Mirek Giersz
Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences, Poland

I will discuss a new scenario for intermediate mass black hole (IMBH) formation in dense star clusters. In this scenario IMBH is formed as a result of dynamical interactions of a hard binary, containing a stellar mass black hole (BH), with other stars and binaries. The mass of the BH constantly increases due to mergers with incoming stars and mass transfer from companions. Interactions with other objects in the cluster make the binary harder, but before the final interaction can happen, in which the binary would be expelled from the system, the binary undergoes a total merger in which a single, more massive BH emerges. Then the massive BH forms quickly a binary in the three-body interaction, and the whole process of BH mass increase starts again. Finally this process leads to IMBH formation. I will discuss the necessary conditions to initiate the process of IMBH formation and dependence of the rate of IMBH mass increase on the global cluster properties.

Stellar dynamics in the Galactic Center

Stefan Gillessen
MPE/MPI, Germany

The Galactic Center is the closest galactic nucleus, allowing thus observations of the dense stellar system around a massive black hole in unprecedented detail. In the central 100 milli-parsec a population of surprisingly young B-type stars is found to obit the black hole on randomly oriented orbits. Further out, a population of even younger, extremely massive stars is present, the orbits of which are co-aligned for at least a third of the population. A third component accessible with observations are old, red giants. These stars show an unexpected surface density profile, since there is no cusp in the center. Overall, the Galactic Center system seems to be in a surprisingly complex state.

Observations & Dynamics of Circumbinary Extrasolar Planets

Tobias Cornelius Hinse
Korea Astronomy & Space Science Institute (KASI), South Korea

In recent years several single and multi-body extrasolar planets (aka circumbinary planets) have been announced to orbit short-period eclipsing binaries. Using ground-based measurements of the time of primary mid-eclipse the light-travel time effect can be used to detect additional companions. However, a dynamical analysis of these systems reveal that the derived best-fit orbital elements result in unstable orbits on short time scales. In this talk, I will shortly review the detected circumbinary planets from the Kepler space telescope and present results from modelling synthetic timing data set of stable circumbinary planetary systems. Results will be presented and their implications discussed.

Black Hole Binaries in Galactic Nuclei and Gravitational Waves

Jongsuk Hong, Hyung Mok Lee
Seoul National University, South Korea

The direct detection of gravitational waves (GWs) is now expected for the next-generation GW detectors such as advanced LIGO and Virgo which are planned or under construction. Stellar black hole (BH) binaries are one of the most promising GW sources for GW detection by the ground-based detectors. To investigate the formation and evolution of the BH-BH binaries in the dense stellar systems like the galactic nuclei, we have carried out the direct N-body simulations. Nuclear star clusters (NCs) located at the center of galaxies are known to have massive black holes (MBHs) and to be bounded a deep gravitational potential from other galactic building blocks like the bulge. This environment of NCs provides a good laboratory for the BH-BH binary formation by the gravitational radiation (GR) capture due to the high BH number density via the mass segregation and high velocity dispersion. We find that the overall formation rates for BH-BH binaries per NC is $\sim 10{-}10\mathrm{yr}{-}1$ for the Milky-Way-like galaxies and weakly dependent on the mass of MBH as $\Gamma \propto$ M3M/B28H. Because the merging time of these binaries is negligible compared to the cluster life time, the binary formation rates can be directly converted to the merger rates. The expected detection rates for the next-generation GW detectors can be obtained by the cosmological volume integration of the merger rates and MBH mass function up to the maximum horizon distance. We estimate the detection rate of 0.02-20yr−1 for advanced LIGO with uncertainties from several factors such as the dynamical evolution of the cluster, the variance of the number density of stars and the mass range of MBH.

The binary populations of simulated star clusters

Jarrod R. Hurley
Swinburne University of Technology, Australia

This talk will review the nature of the binary populations that arise in realistic simulations of star cluster evolution performed with the direct N-body code NBODY6. The incidence of various close binary types (e.g. X-ray binaries, cataclysmic variables, black hole binaries) and related products (e.g. blue stragglers, type Ia supernovae) will be discussed and compared to expectations from observations. General characteristics of the binary population will also be discussed, such as the binding energy distribution and binary fraction, as will the impact on cluster properties.

Bimodal spatial distribution of blue stragglers as a tracer of star cluster dynamical state

Arkadiusz Hypki
Nicolaus Copernicus Astronomical Center, Poland

Blue stragglers are defined as stars which are brighter and bluer (hotter) than the main sequence turn-off point. These stars lie along an extension of the main sequence in the Color-Magnitude Diagram and appear to be rejuvenated stellar population. Their mass is larger that the turn-off mass which suggests some stellar merger or a mass transfer scenario of their creation. They are essentially present in all globular cluster observed with decent photometric resolution. Radial distribution of blue stragglers in many clusters is bimodal. First discoveries of bimodal distributions were done for the M3 by Ferraro (1993, 1997) and by Zaggia (1997) for M55. Bimodal spatial distribution shows the maximum at the center of the cluster, a clear-cut dip in the intermediate region and again a rise of blue stragglers in the outer region of the cluster (but lower than the central value). Bimodal distribution of blue stragglers was later shown by other authors for other clusters like 47Tuc, NGC6752, M5. However, for some of them a flat distribution is found (e.g. NGC2419). Studying this phenomena can give important constraints on a link between the stellar and dynamical evolution of star clusters.

We report a detail study of bimodal spatial distributions of blue stragglers based on numerical simulations for star clusters with a variety of initial properties. We show how and when a bimodal spatial distribution is formed and how it depends on the half-mass relaxation times. Additionally, we show for which star clusters it cannot be formed. We discuss also whether lifetimes of blue stragglers have some influence on the bimodal spatial distribution formation. Simulations were done with the MOCCA code which is one of the most advanced codes for simulating real size star clusters.

The role of three-body stability in tidally interacting globular clusters

Gareth F. Kennedy
National Astronomical Observatories of China, Chinese Academy of Sciences, China

The role of stability in the general three-body problem is investigated with regard to the tidal radius of a globular cluster in a galactic potential.

A stability analysis, outlined in Mardling (2008), is used here to predict the occurrence of unstable stellar orbits in the outermost region of a globular cluster. Stars on unstable orbits will random walk in binding energy until their eventual escape from the cluster.

The timescale for this random walk is investigated using a high resolution N-body simulation of a tidally interacting star cluster on an orbit based on NGC 6341. This simulation is run for 1 Gyr and consists of over 10^5 particles, resolving each star in the cluster. During the random walk stage stars will have a different distribution of velocities when compared to stars in an isolated cluster. This manifests as a flattening of the velocity dispersion profile beyond the transition radius between stable and unstable orbits.

This transition radius is compared to observational data of the velocity dispersion for 8 Milky Way globular clusters with approximately known orbital parameters. We find that the transition radius predicts where the velocity dispersion flattens and that there is no need for any MOND type theories to explain the observations.

The dynamical evolution of multi-planet systems in star clusters

M.B.N. (Thijs) Kouwenhoven
Kavli Institute for Astronomy and Astrophysics at Peking University, China

Several hundreds of exoplanets have been found over the last decade, and thousands of exoplanet candidates have been identified. The immense variety of the orbital and physical properties of these newly discovered worlds have provided us with more questions than answers, and have prompted the development of sophisticated theories of planetary systems evolution, including interactions with the natal disk and with the host star, as well as planet-planet scattering, secular evolution of multi-planet systems, and interactions with the environment. As most stars are thought to form in star clusters, interactions with neighboring stars likely occurred more frequently during the early life of planetary systems. Close encounters with other stars are obviously disastrous for a system, but also the cumulative effect of weak, distant encounters can have dramatic effects. The latter is particularly important for relatively closely packed systems, in which a perturbed outer planet can induce orbital instabilities long after an encounter has happened, which could in turn result in planet-planet collisions, planet-star collisions, and ejections. This talk provides an overview of the recent work carried out on the dynamical evolution of planetary systems in star clusters, with a connection to recent observational results, such as the apparent scarcity of planets orbiting members of star clusters.

The investigation of two new eclipsing binary systems with an eccentric orbit V1176 CAS =GSC 4513 2537 and GSC4277 0586

V.S. Kozyreva[1], A.V. Kusakin[2]

[1]*Sternberg Astronomical Institute, Moscow, Russia*
[2]*Fesenkov Astrophysical Institute, Almaty, Kazakhstan*

We study new eclipsing binaries with an eccentric orbits were included in a list of "50 new eclipsing stars with elliptical orbits found in the ASAS, Hipparcos, and NSVS data based" by Otero et al. GSC 4487 0347 and GSC 4513 2537 are recently discovered binary systems with orbital periods 6.33 and 2.87 days. We carried out the photometric observations of these eclipsing binaries using CCD-array in 2009-2010 years at the Tien Shan Observatory, the Crimea Station of the Sternberg Astronomical Institute and the spectrophotometric observations at the Starlight Farm Observatory (Barnesville). We obtained the light curves of these stars , the photometric elements, apsidal periods and UBV-magnitudes.

View of development of mountain observatory of Assy-Turgen of Fesenkov Astrophysical Institute as an international observation hub with Remote Telescopes

Maxim Krugov, Chingis Omarov
Fesenkov Astrophysical Institute, Kazakhstan

The surface-based observation astronomy is currently developing in several directions.

1. Use of own observatories
2. Arrangement of international collaboration
3. Use of remote telescopes at international observatories

Each of these directions has its strengths and weaknesses.

Thus, the use of own observatories implies maintenance of facility infrastructure and labor costs for personnel in addition to capital construction costs. Development of joint observatories is in common practice as one of the options.

Arrangement of observations in the format of international teams represents a temporary organization with minimum initial costs, it requires a project supervisor, and however, it frequently competes with the observatory's owner's works by time. It is likely to experience nonconformity in equipment and standards applied.

In terms of operational costs, remote use of telescopes at surface-based observatories is more profitable than the option of the own observatory arrangement as renting area, infrastructure, and technical maintenance is much cheaper than independent maintenance of those functions. However, this option does not provide any synergy of global working groups that are focused on the task solution, which is a fundamental standard in the modern astrophysics.

One of the prospective directions is the option that unites strengths of international teams with the use of remote telescopes located at the observatories. Such work arrangement enables modern science to realize its potential through attracting leading scientists of global renown in the working groups. Obtaining data

from observatories with convenient longitudinal location that is required for the purpose of collection of continuous sequence of data when one target is being observed for several months from different observatories in the world, such as the Whole Earth Telescope (WET) project. It also enables to apply advantages by spectral window through installation of telescopes at mountain observatories. Moreover, in long-term strategy such direction lays the foundation for the use of the telescopes installed at the space facilities.

The presentation shows the option for arrangement of international observation platform with remote telescopes based on mountain observatory Assy Turgen. Based on the experience gained within the projects by V.G.Fesenkov Astrophysical Institute with the Whole Earth Telescope (WET) and the projects by National Astronomical Observatory of Japan, there is the analysis provided for electricity provision as well as communications and technical maintenance.

The impact of metallicity and dynamics on the evolution of dense young star clusters

Michela Mapelli
INAF-Osservatorio Astronomico di Padova, Italy

The early evolution of a dense young star cluster (SC) depends on an intricate connection between the stellar evolution of its members and the dramatic dynamical processes that take place at this stage. Thus, N-body simulations aimed to tackle this issue must account with sufficient accuracy for both dynamics and (metallicity-dependent) stellar evolution. In this talk, I present N-body simulations of intermediate-mass young SCs with three different metallicities (Z=0.01, 0.1 and 1 Zsun), including metallicity-dependent stellar evolution recipes and metallicity-dependent prescriptions for stellar winds and remnant formation. The core-collapse timescale of the simulated young SCs is comparable with the lifetime of massive stars. I show that mass-loss by stellar winds influences the reversal of core collapse and the expansion of the half-mass radius. In particular, the post-collapse re-expansion of the core is weaker for metal-poor SCs than for metal-rich SCs, because the former lose less mass (through stellar winds) than the latter. As a consequence, the half-mass radius expands faster in metal-poor SCs. The difference in the half-light radius between metal-poor SCs and metal-rich SCs is (up to a factor of two) larger than the difference in the half-mass radius. These results give us a clue to understand the early evolution of young SCs in environments with different metallicity.

Simulating Star Clusters with AMUSE

Stephen McMillan
Drexel University, USA

Dense stellar systems -- star forming regions, young star clusters, globular clusters, and galactic nuclei -- are complex environments in which many physical processes compete to control the dynamics and evolution of the system. Modeling these systems places stringent demands on both simulation software and computer hardware. As part of an ongoing effort to understand these systems, I will describe AMUSE, the Astrophysical MUltiphysics Software Environment, a general-purpose framework for combining multiple simulation modules within a homogeneous, unified interface. The framework is intrinsically parallel and allows automatic unit conversion, distributed execution within a cluster or grid, and orderly recovery from errors. It provides a platform both to combine existing simulation codes and to develop new solvers within a rich "ecosystem" of interchangeable modules. I will illustrate the capabilities of AMUSE by describing its application to simulations of various stages of cluster formation and evolution.

Mass segregation in young star clusters

Christoph Olczak[1,2,3], R. Spurzem[3,1,4], Th. Henning[2], J.Ziegel[5,1]
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As a consequence of energy equipartition, mass segregation evolves dynamically in any self-gravitating system that is composed of more than one mass component. The degree of mass segregation observed in star clusters at any given age is thus a key tracer of their dynamical history. Measuring mass segregation in star forming regions imposes constraints on the degree of primordial mass segregation and so on the star formation process itself.

Using numerical simulations of dynamical star clusters models I will show that high concentrations and cool initial conditions can significantly accelerate the dynamical evolution of mass segregation, and will further present the interesting effect of primordial binaries. As a final prove I will demonstrate the rapid segregation of massive stars in the Arches cluster from multi-epoch high-resolution observational data.

Stochasticity and Dynamical Evolution of Gravitating Systems

Leonid P. Ossipkov
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When considering dynamical evolution of gravitating systems we meet stochastic processes at any level of description.

The classical concept of binary relaxation must be revisited taking into account the influence of the smoothed gravitational field, and the effective relaxation time (the stochastization time) seems to be much shorter than the Jeans–Chandrasekhar one.

The evolution of the coarse-grained distribution function of collisionless systems is time-irreversible in general. Violent relaxation is a kind of phase-space mixings in such systems. A direction of evolution is governed by Antonov's quasientropy (H-functional by Tremaine, Hernon, Lynden-Bell).

Non-linear oscillations of collisionless systems generate a background for the coarse-grained irreversibility. Gross-dynamic equations provide a tool for revealing such oscillations that can be triggered by random external perturbations. Large-scale oscillations can generate the small-scale irreversible evolution of the distribution function as it was proposed by Chernin et al. Such evolutionary scenario must be checked by computer simulations.

Comparative analysis of the dynamical action of the accretion disk models on the stellar component in galactic nuclei

Panamarev T.[1], Shukirgaliyev B.[1], Berczik P.[2,4,5], Just A.[4], Makukov M.[1], Nurmukhanov O.[1], Omarov Ch.[1], Spurzem R.[2,3], Vilkoviskij E.[1]

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Recent work shows that gaseous disks in galactic centers around Super-massive Black Holes are important for the dynamics and the morphology of central regions of galaxies and for the evolution of single or multiple central black holes. We investigate the dynamical interaction of a central star cluster surrounding a super-massive black hole and a central accretion disk. The accretion disk is implemented with its density distribution in a full three-dimensional resolved structure and impact of accretion disk is treated by calculating the drag force acting on the stellar component. The dissipative force acting on stars in the disk leads to an enhanced mass flow towards the super-massive black hole. Here we focus on comparison of constant thickness of the accretion disk and linear thickness models with respect to disk radius. We show how these models affect the dynamical action of the accretion disk on the stellar component.

Cluster formation simulations with AMUSE

Inti Pelupessy, Simon Portegies Zwart
Leiden Observatory, the Netherlands

Our understanding of the relation between galactic stellar populations and the star formation process and the wider evolution of a galaxy depends on an understanding of the formation and early evolutionary stages of stellar clusters and associations. However, the evolution from a gaseous interstellar cloud to a gasless stellar cluster presents a formidable challenge to model, as these objects exhibit a complex interplay of stellar and gaseous dynamics, as well as stellar evolution and feedback processes such as UV irradiation and the mechanical luminosity from stellar winds and supernovae. We present the Astrophysical Multi-purpose Software Environment (AMUSE), which has been developed at Leiden Observatory to provide a flexible framework to examine such multi-physics problems. We will present applications of this framework towards the modelling of early cluster evolution, amongst which the results of simulations of embedded cluster evolution and our approach to modelling the stage before that, when a gaseous cloud starts to form proto-stellar objects.

N-body modelling of galaxy mergers and the mergers "mass deficit" effect

Sobolenko Margaryta, Igor Zinchenko and Peter Berczik
Main Astronomical Observatory/NASU, Ukraine

We present the second part of our work about linked evolution of the merging galaxies and black holes. We investigate the so call "dry" merging of two galactic masses objects in the conditions of the orbits close distance passing.

To carry out our N-body experiments using the parallel version of our own developed galactic dynamic TREE-GPU code. The code shows the excellent speed up (around x 100) compare to the similar CPU based programs. We investigate the wide range of parameters of the galaxies mass ratio q = 1 ... 0.1 and their orbital eccentricities e = 0.0 ... 0.99.

We was able to obtain the common picture of the mergers "mass deficit" evolution for the range of particle numbers N = 2x100k, 2x200k, 2x500k. Our main conclusion, from this set of runs, that the dependence of the merger "mass deficit" from the common mass to mass ratio is weak. Also we confirm, that the common galactic merging system lose mass more effectively at the circular orbits and when the objects hase minor mass to mass ratio.

Astrophysical Supercomputing, Galactic Nuclei and Black Holes

Rainer Spurzem
National Astronomical Observatories, Chinese Academy of Sciences, China
Kavli Institute for Astronomy and Astrophysics, Peking Univ., China
Astronomisches Rechen-Inst., ZAH, Univ. of Heidelberg, Germany

To use graphical processing units (GPU) for general purpose computations is becoming more and more ubiquitous on all scales - from user's desktops to the most powerful supercomputers. China has been in the past four years pioneering this field, running some very powerful GPU clusters, but recently the US have obtained the top GPU computing spot with the Oak Ridge Cray XK7 system (second fastest general system and largest GPU system). Notably the fastest computer in the world now again is in China and uses a new kind of accelerator, Intel Phi.

An overview of hardware and our application software and research with such clusters, mainly in China and Germany, is presented.

We discuss particle- and mesh-based algorithms for astrophysics using hundreds to thousands of GPUs (approaching a million GPU cores) for one single application run in a parallel message passing environment, some with detailed timing models. Future perspectives for GPU and FPGA accelerated computing towards Exaflop/s will be shown. We will also briefly highlight progress with our massively parallel N-body code NBODY6++ (for phiGPU see Peter Berczik's talk).

As an example one of our astrophysical applications - computer models of star clusters containing supermassive black holes - is explained in more detail. We use large high-order direct N-body simulations, parallelised with MPI across a large number of nodes and across many GPU thread processors on

each node. Our simulations typically proceed from a merger of two galaxies with central black holes to the complete relativistic merger of the black holes, including Post-Newtonian corrections to gravitational forces. The expected gravitational radiation from our model sources will be briefly reviewed. We discuss the relevance of this for current and future instruments to measure gravitational waves.

Binary black hole formation in globular clusters

Ataru Tanikawa
RIKEN Advanced Institute for Computational Science, Japan

Binaries consisting of two black holes (BHs), hereafter binary black holes (BBHs), are one of the most promising sources for next-generation gravitational wave (GW) observatories. BBHs formed dynamically in globular clusters (GCs) can contribute to GW detection rates. In order to estimate the GW detection rate of these BBHs, we have performed N-body simulations of GCs, and have followed the dynamical formation of BBHs. Most of BHs escape from the GCs, and one third of them are BBH components. We call these BBHs ``BBH escapers''. We have estimated how many BBH escapers are detected by the next-generation GW observatories. The detection rates are 0.5 -- 20 per year for BH retention fraction 0.5. Our results show that a part of BHs are retained in GCs at the present time.

Large scale speed and effectivity test of the parallel Bonsai N-body TREE-GPU code.

Veles O., Berczik P. and Liu Lei

Main Astronomical Observatory of the National Academy of Sciences of Ukraine

We investigate the recently publicly available high performance MPI paralell TREE-GPU code "bonsai2": http://castle.strw.leidenuniv.nl/software/bonsai-gpu-tree-code.html
performance on our GPU clusters with different NVIDIA GPU hardwares (Heidelberg, Kiev, Beijing) with the wide range of particle numbers (from 16K up to 16M) to find a range of optimal parameters for the code usage. We also compare this new code with our older TREE-GRAPE/GPU library (based on the original Fukushige tree code).
We see the very good MPI effectivity of the new code for the range of particles larger as 0.5M per single GPU. For the smaller particle number per GPU the scaling is quickly degradate.
In a future we plan to use these new dynamical tool for the Milky Way like disk galaxy (composed by Bulge, Disk and Halo) stability analysis with the maximum up to 128M number of particles.

AGN Numerical Modeling in Fesenkov Astrophysical Institute

Vilkoviskij E., Yefimov S., Makukov M., Omarov Ch.
Fesenkov Astrophysical Institute

The short review of numerical model calculations of AGN structure and dynamics (both radiation gas dynamics and n-body simulation models) in Fesenkov Astrophysical Institute (FAI) is presented. It is stressed that the second direction of research (n-body methods) became possible due to international collaboration of the scientific group from FAI with the foreign scientific groups headed by Prof. R. Spurzem.

Compact Binaries ejected from Globular Clusters as GW Sources

Bae Yeong-Bok, Chunglee Kim, and HyungMok Lee
Seoul National University, South Korea

Based on N-body simulations, we find out that significant fraction of dynamically formed BH-BH (10 $M_{\odot}$ each) and NS-NS (1.4 $M_{\odot}$ each) binaries are likely to be ejected from globular clusters. About 30 per cent of compact stars are ejected in the form of binary. The merging time of ejected binary depends on the velocity dispersion of globular clusters. Some of them have merging time-scales shorter than a Hubble time and are expected to produce gravitational waves that can be detectable by the advanced ground-based interferometers. The merger rate of ejected BH-BH and NS-NS binaries per globular cluster are estimated to be 2.5 and 0.27 per Gyr, respectively. Assuming the spatial density of globular clusters as 8.4 h^3 clusters Mpc^{-3} and extrapolating to the horizon distance of the advanced LIGO-Virgo network, we expect the detection rates solely attributed to BH-BH and NS-NS with cluster origin are to be 15 and 0.024 yr^{-1}, respectively. Besides, we find out that BH-NS binary ejection hardly occurs in globular clusters and dynamically formed compact binaries may possible be the source of short GRBs whose locations are far from host galaxies.

New Iterative Method for the Construction of Equilibrium N-Body Models

Yurin Denis
Heidelberg Institute for Theoretical Studies, Germany

We describe a new iterative method for the construction of equilibrium N-body systems with a given density distribution. Our method uses elements of the orbit-based and made-to-measure methods, but is based on a different principle. To minimize the Merit function, the method changes not the weights of the orbits but rather the orbits themselves. As a result, we have direct solutions without any need for sampling of the velocity distributions in post-processing. Furthermore, the velocities reconstructed with this method have very smooth distributions and do not require any artificial smoothing. The capabilities of our method are demonstrated by reproducing the exact solution for the Hernquist sphere. We address the main disadvantage of our method, the computation time, with hierarchical block step sizes, which allow us to avoid iterations that lead to insignificant changes of the orbits.

SMBH accreting stars in axisymmetric galactic nuclei

Shiyan Zhong, Peter Berczik, Rainer Spurzem

National Astronomical Observatories of China/CAS, China

We performed direct N-body simulations to investigate the behavior of SMBH in axisymmetric galactic nuclei. The stars are distributed following a rotating King model with W=6 and omega=0.3. We measured the tidal disruption(TD) rate in these systems, compared with that in spherical systems, and found a higher TD rate in axisymmetric systems. This can be explained by an extended loss-cone in phase space which is raised from the fact that angular momentum **J** is not conserved. We also found the distribution of the TD stars' origin, i.e. the last apocenter position, are peaked at the so called critical radius. Due to the 2-dimension nature of the system, inside the influence radius r_h, the origin of TD stars have angular dependence(zenith angle) -- they are concentrated around the equatorial plane; while outside of the influence radius this dependence is weak. Inside r_h, most of stars are moving on two families of regular orbit, called SAT and saucer orbits. We will show that these orbits are the key to explain the angular dependence of the TD stars' origin.

High resolution N-body modelling of the Galactic disk radial motion and stability under the minor merger scenario

Zinchenko Igor, P. Berczik, L. Pilyugin, E. Grebel and A. Just
Main Astronomical Observatory/NASU, Ukraine

We investigate the dynamical interaction and merging of Milky Way-like galaxy with low mass satellites. We use up to 4 million particles to study evolution of three component (Disc, Bulge and Halo) Milky Way-like galaxy and 1 million disc particles to study radial chemical abundance gradient disc stability under the minor merger scenario.

We suggest the exponential initial radial distribution of oxygen abundances (linear in 12+log(O/H) values) and using the own developed N-body TREE code that runs on the GPU. We simply evolve the dynamical system up to 2 Gyrs without including the effect of gas and star formation. Particles distribution in satellite galaxy have been reproduced by simple Plummer model.

By considering a network of satellite masses and initial positions we find:

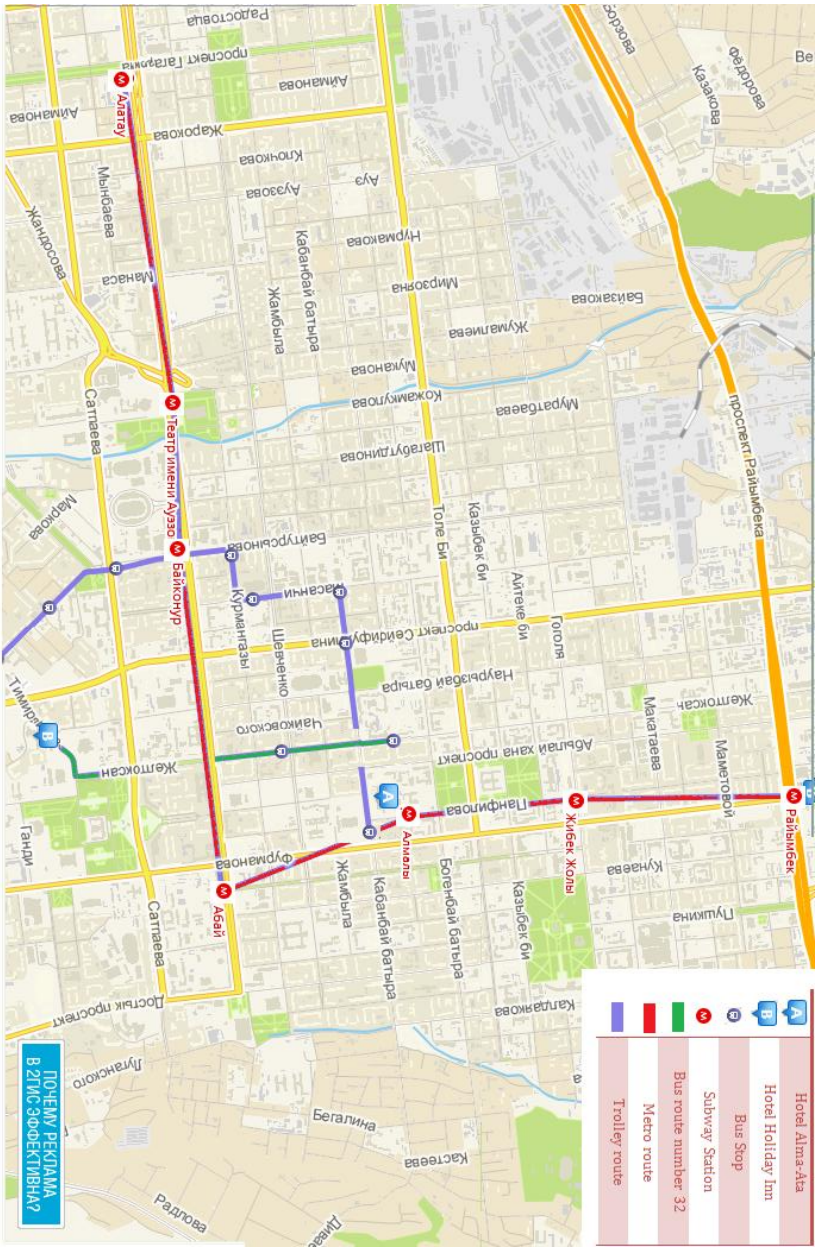
1) The radial chemical abundances gradient in inner region Milky Way-like galaxies weekly depends on merging satellites with all the masses up to M = 5 x 10^9 M_sol.

2) Radial distribution of chemical abundances in galactocentric distances larger then ~10 kpc shows increasing by more when 0.2 dex after the merging with satellites with the mass more than M = 2.5 x 10^9 M_sol.

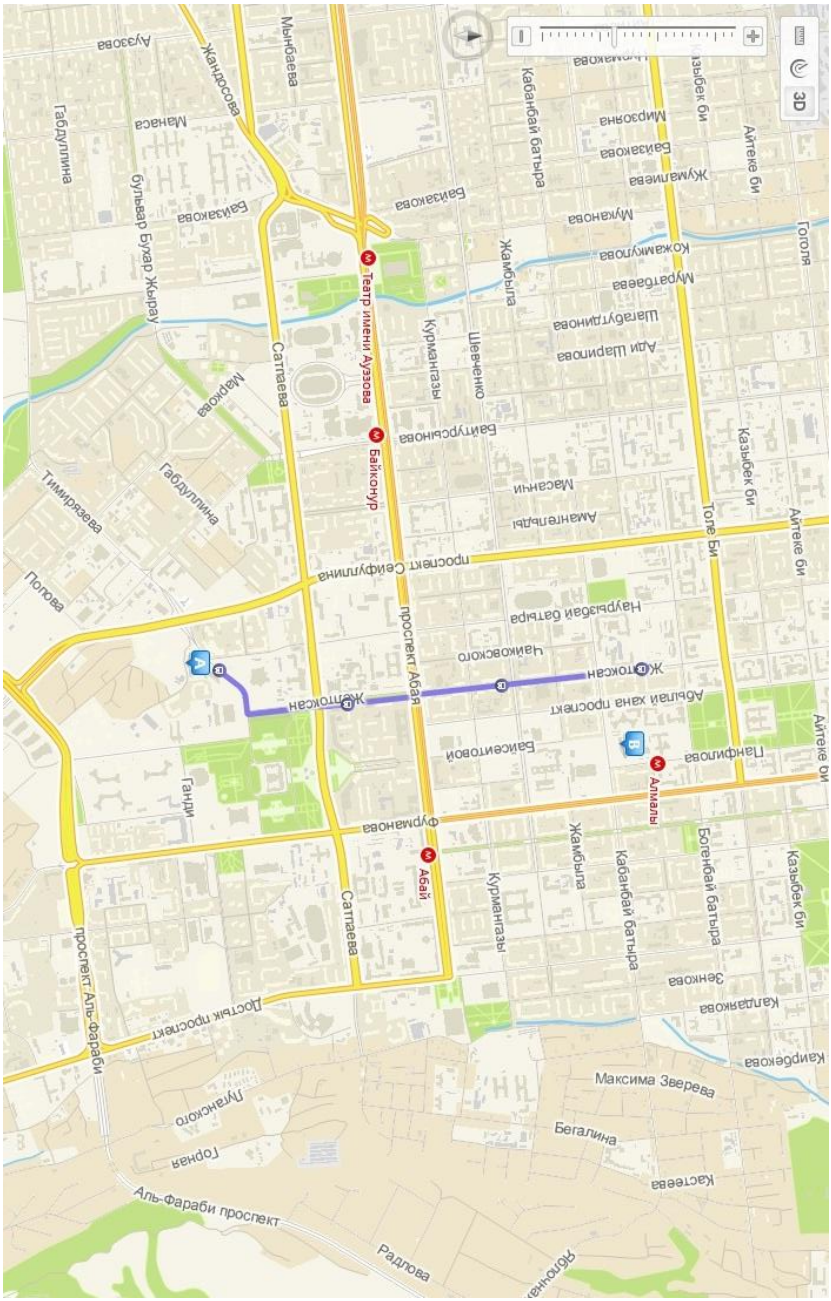
3) In the case of merging satellite with masses 1.0 x 10^9 M_sol there is no significant changes of chemical abundances in all considered range of galactocentric distances.

ADDITIONAL INFORMATION

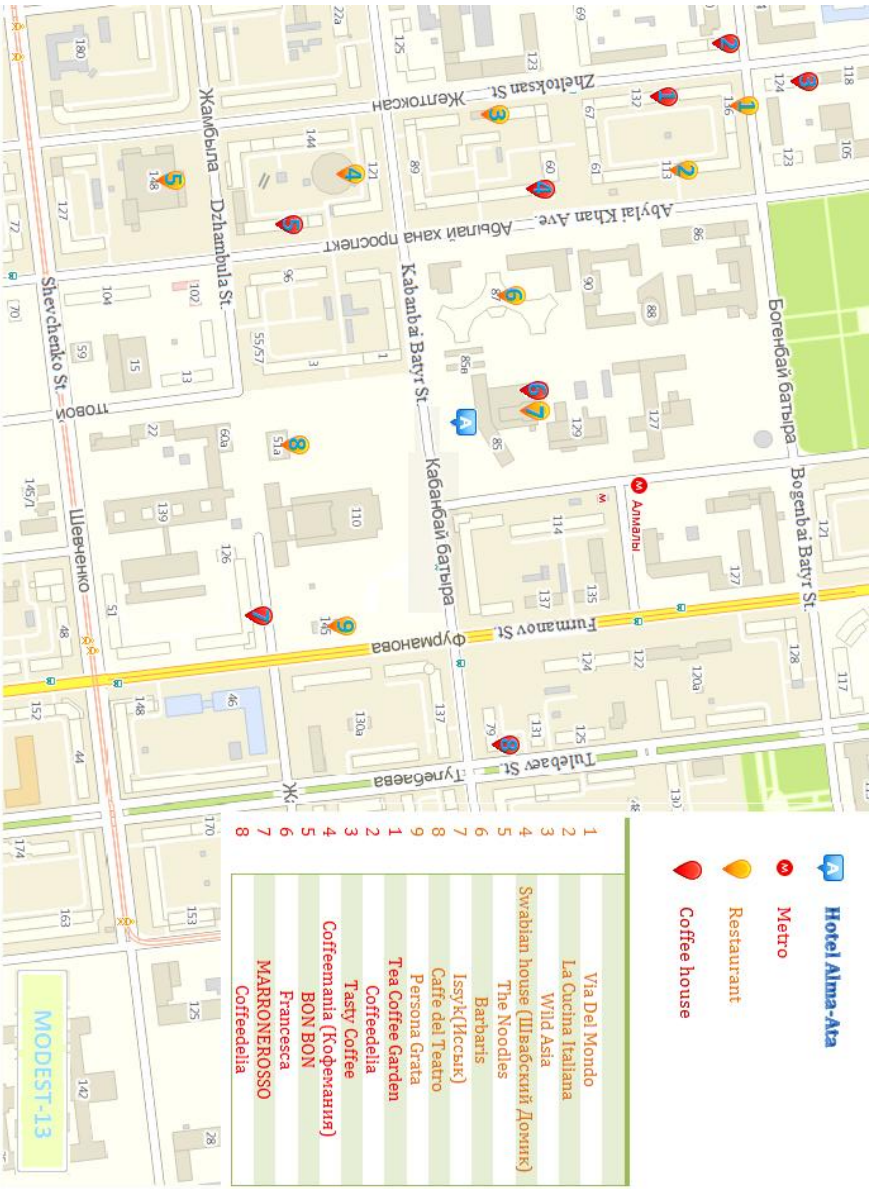
Almaty Downtown Map



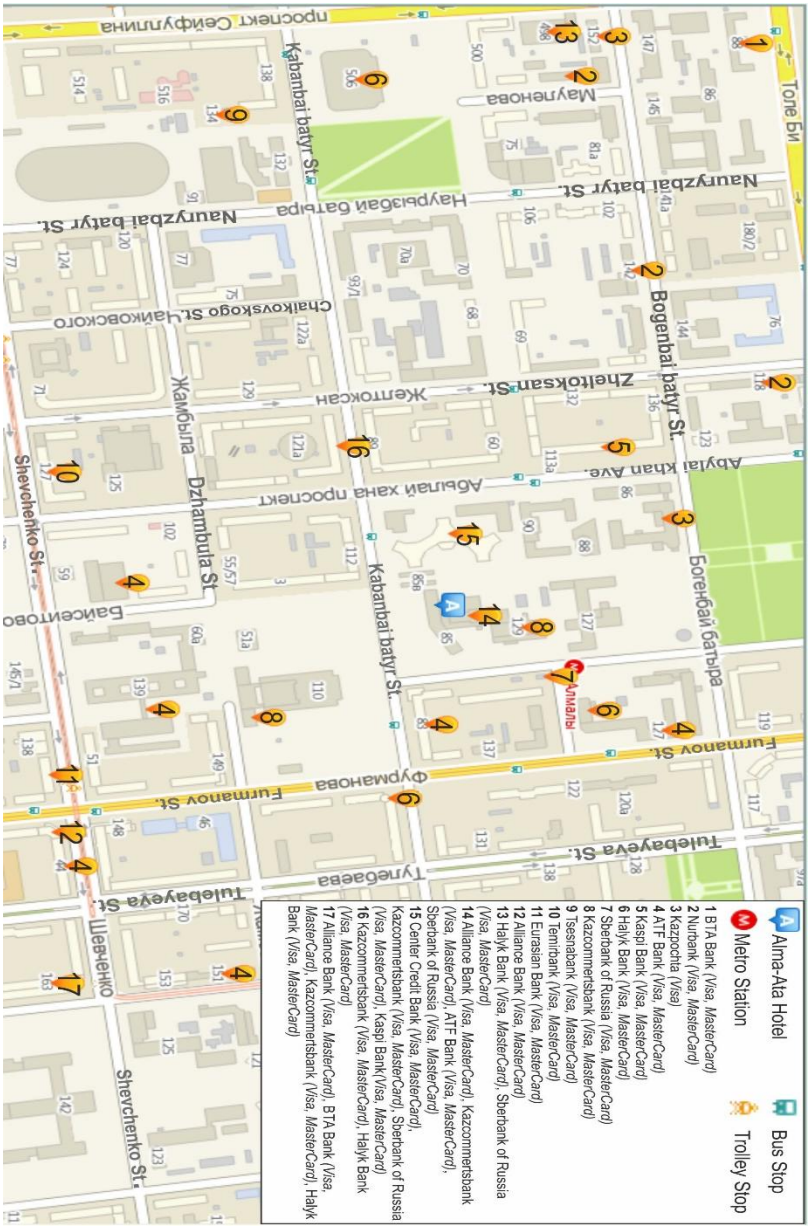
Holliday Inn– Alma-Ata Hotel route



LIST OF NEARBY RESTAURANTS



LIST OF NEARBY ATM AND BANKS



EXCURSIONS INFORMATION

There are three type of full day excursions are organized through travel agency:

- Combined tour: City Tour + Big Almaty Lake
- Grand Tour around Almaty + Shymbulak ski resort
- Charyn Canyon

The cost of excursion depends on the number of participants. If the number of participants in one excursion is less than 10 the excursion will not be held.

IMPORTANT

If you want to take part in excursions, please let us know which excursion you want to participate before 20 August.

PUBLIC TRANSPORT

In Almaty, the bus is the main means of transport for passengers who do not have their own transport. Payment of journey takes place in the bus at the exit or at movement. There are two kinds of payment: by "Validator" (machine to receive payment for travel) or to live conductor. Within the city travel on all buses costs 80 tenge (see info on Currency Exchange below).

Validators accept only coins (5, 10, 20, 50 and 100 tenge).

Don't forget to get a ticket after payment.

You can also move around the city by trolleybuses and trams. But trolleybuses and trams move rarely, because of their short routes. On all trams and trolleybuses the payment is accepted by the validator. The fare also 80 tenge (see Currency Exchange below).

If you want to take a taxi, you can call them or get a taxi at the street. But be careful if it is not official taxi. In downtown price for taxi is 500 tenge.

Call the taxi at the following numbers:

Econom taxi: 8 (727) 245-47-47, 8 (727) 390-54-10, 8 (702) 897-08-35, 8 (777) 022-00-12.

Almaty taxi: +7 (747) 775 55 55, or short number 158

CURRENCY EXCHANGE

by the National Bank of Kazakhstan on 15.08.2013

Currency	**Tenge**
Euro	202.72
US Dollar	152.85
Chinese Yuan	24.98
Russian Rouble	4.61

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