Simulating Dense Star-Gas Systems in Galactic Nuclei Using Special Hardware

Astrophysics in Kazakhstan
and
STARDISK Collaboration on Active Galactic Nuclei Disks in dense stellar systems

Chingis Omarov[1], Rainer Spurzem[2,3,4], Andreas Just[2], Emmanuil Vilkoviskij[1], Maxim Makukov[1,2], Denis Yurin[1,2], Peter Berczik[2,3,5]

[1] *Fesenkov Astrophysical Institute, National Centre of Space Research and Technology of the Republic of Kazakhstan, Observatory 20, Kamenskoe Plato, Almaty 050020, Kazakhstan*
[2] *Astronomisches Rechen-Institut, Zentrum für Astronomie, Univ. Heidelberg, Mönchhofstr. 12-14, 69120 Heidelberg, Germany*
[3] *National Astronomical Observatories, Chinese Academy of Sciences, 20A Datun Rd., Chaoyang Distr., Beijing 100012, China*
[4] *Kavli Institute for Astronomy and Astrophysics, Peking University, 5 Yiheyuan Rd., Haidian Dist., Beijing 100087, China*
[5] *Main Astronomical Observatory, National Academy of Sciences of Ukraine (NASU), Akademika Zabolotnoho 27, 03680 Kyiv, Ukraine*

Abstract

Some hundred billion stars bound by gravitational forces form our Galaxy, the Milky Way. Many of them have planetary systems similar to our own Solar System and (what is not yet known) may harbour extraterrestrial life. However, deep in the gravitational centre of the Milky Way a Supermassive Black Hole has formed. The Black Hole, predicted by Einstein's Theory of Relativity, is invisible itself. But its existence is revealed through a dense cluster of stars orbiting around it with very high velocities. Such an environment is very hostile to the formation of a stable long-lived planetary systems, as it is necessary to form life. Through direct observation of stellar motions in the Galactic Center and with Kepler's 3rd law the mass of the black hole is determined in a straightforward way to be about three million times the mass of the sun.
Modern cosmology has provided strong evidence in recent years that our entire universe has been created from a very dense and hot initial state (the Big Bang), structured by forces of gravity which form billions of galaxies, and nearly every of these galaxies contains a supermassive black hole in the centre, surrounded by a dense cluster of stars, similar to our own galaxy (but with a considerable variation in the mass and size of black holes and galactic centers).
In this project we study the combined evolution of black holes, gas and stars in the dense centres of galaxies. We also use the occasion here to provide some information about the new structure and research topics at the Fesenkov Institute of Astrophysics in Almaty, which is now part of the National Center for Space Research and Technology of the Republic of Kazakhstan.

National Center for Space Research and Technology, Fessenkov Astrophysical Department (former APHIF)

Fessenkov Astrophysical Department situated in Almaty, Kazakhstan. It was founded in 1950.

Its scientific scope includes researches of Earth and other planets' atmospheres, Sun, minor bodies of the solar system, stars, interstellar medium and galaxies as well as Earth satellites.

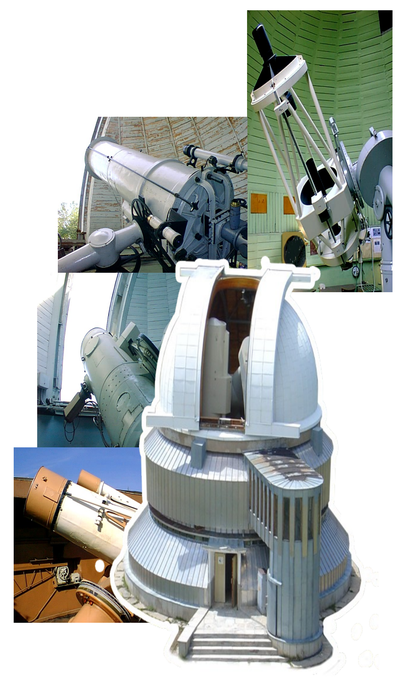
The institute has three observatories:
Assy-Turgen Plateau Observatory (2750 m above sea-level)
Kamenskoe Plateau Observatory (1450 m above sea-level)
Tyan-Shan Observatory (2600 m above sea-level)

Partners of the institute: ARI (Heidelberg, Germany), Institute for Theoretical Astrophysics (Moscow, Russia)

The institute is traditionally involved in observational as well as in theoretical and numerical researches.

World space Observatory/UV at APHI

APHI takes part in the International project of Ultraviolet Space Telescope "WSO/UV". This project has capabilities analogous to those of the Hubble Space Telescope. The main mirror's diameter is 170 cm, operational range is 90-320 nm. The launch is expected in 2012. APHI provides parallel ground-based tracking with its observatories. Also it plans to participate in the research program development for the WSO/UV telescope.

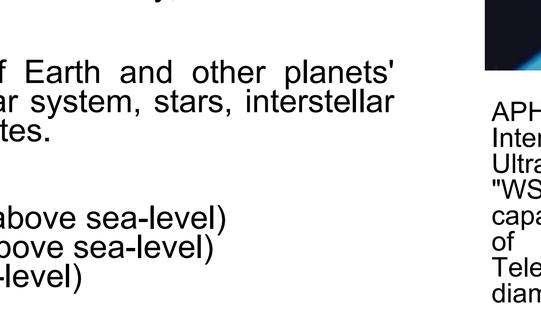


VolkswagenStiftung

STARDISK

N-body simulations of AGN consisting of Black Hole, Compact Stellar Cluster, and Gas Disk subsystems.

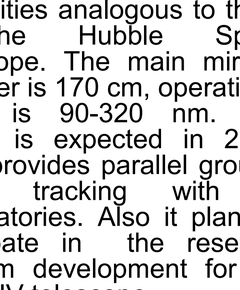
In our project, named “STARDISK”, we study by large computer simulations how supermassive black holes grow in nuclei of galaxies and how they influence their environment of stars and a gaseous disk around them. Our simulations use only basic laws of physics, like e.g. Newtonian gravity for the stars, with relativistic corrections for the black holes; we follow the dynamical evolution over several hundred million years by a typical computer model, because the equations of motion of many particles cannot be solved analytically.
In computational astrophysics such computer simulations play the role of experiments and improve observational work with astrophysical telescopes. Modern astrophysical telescopes like Hubble Space telescope or European VLT, or the planned Russian/Kazakh/Chinese/and others World Space Observatory (WSO/UV) can produce excellent and detailed images and spectral information, but none of them helps us like a computer simulation to learn about the evolution of astrophysical objects over millions or billions of years. Computer simulation is really the only way astrophysicists can do experiments like physicists in the laboratory.
Our groups at the Fesenkov Astrophysical Institute in Almaty, Kazakhstan and at the University of Heidelberg in Germany both work for a long time together in this subject, and collaborate since 1990. The project “STARDISK” funded by Volkswagen Foundation supports the exchange of students and scientists between Kazakhstan and Germany and the first use of special accelerated many-core computing device (GRAPE special purpose computers for gravitational many-body simulations, developed in Japan) in Central Asia. The project has supported Computational Astrophysics in Almaty and will inspired new projects using graphics cards (GPU's) for general purpose computing.



A result of the n-body simulations of the system, including SMBH + Accretion disk + star cluster.
Left – in the beginning,
Right – after the "dissipative evolution time".

Computational facilities used in the STARDISK project. GRAPE cards are the hardware accelerators designed specially for direct integration of N-body systems. However, recent advent of GPGPU technique allowed usage of non-specialized GPU hardware with even more efficiency. Both GRAPEs and GPUs are used to equip computer clusters so parallelization of the task further speeds up the calculations.

Video card



The computer cluster in Almaty

The computer cluster in Heidelberg

Contact R. Spurzem, spurzem@ari.uni-heidelberg.de, Astron. Rechen-Inst., ZAH, Univ. Heidelberg,
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