# Programme and Book of Abstracts

INTERNATIONAL WORKSHOP MEETING

# Dynamics and Physics of Asteroids, TNOs and Natural Satellites in the New Era of Gaia Data

ANTALYA • TURKEY

SEPTEMBER 4-6 • 2019

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# About

## Welcome

Welcome to the international workshop meeting "Dynamics and Physics of Asteroids, TNOs and Natural Satellites in the New Era of Gaia Data" in Antalya. The workshop topics belong to the Planetary Sciences domain which joins both fundamental and applied sciences in research of Solar System bodies. Small Solar System bodies by the fact of their existence, variety of their orbits and physical properties are a necessary constrain for developing our knowledge on the origin and evolution of the Earth and our life on it.

Asteroids and trans-Neptunian objects (TNO) are the most numerous in number class of Solar System objects which counts today for 790 thousands of bodies, and this number is constantly growing due to newly discovered ones. The near-Earth asteroids (NEA) and potentially hazardous asteroids (PHA) make sequential subclasses to the asteroid's population. The latter objects are already the targets of space research and experiments today and are considered as the natural resources in the closest future.

The physical properties of the asteroids are highly variable that makes different the role of non-gravitational forces in their dynamics. Thus, propagation of their future trajectories even at small timescales requires consideration of their physical properties. This is especially important for predicting future close encounters of the potentially hazardous asteroids with the Earth.

Active experiments using space missions to asteroids do not belong anymore to science fiction. In 2018 the space-probe OSIRIS-REx (NASA) reached the asteroid (101955) Bennu, and the space-probe Hayabusa2 (Japanese Space Agency) rendezvoused the asteroid (162173) Ryugu.

The follow-up programs by the small ground-based telescopes can be beneficial for enlarging the number of objects characterized by space missions or large telescopes programs, calibrating the methods used. The Gaia catalog which is a joint effort of the European Space Agency space mission Gaia and the consortium of the universities provides access to 2 milliards of stars with proper motions, parallaxes, three color magnitudes beneficial for highly-accurate astrometry and photometry of asteroids. The Large Synoptic Survey Telescope (LSST) will provide 1.3 petabytes of data per year in the closest future, far more than can be reviewed by humans.

The international workshop meeting aims to bring together theoretical and experimental researchers working on the state of the art in the field of small Solar System bodies, data and methods used, exposing possibilities for follow up programs with the ground-based telescopes, establishing and enforcing collaboration between different research teams.

We would like to express our gratitude to the organizing committees for the enthusiastic work that made the workshop possible.

Thank you for coming to the meeting in Antalya. We hope you will have fruitful discussions, meet new collaborators and enjoy the meeting.

Anatoliy Ivantsov, Ph.D.,
Daniel Hestroffer, Prof. Ph.D.,
Zeki Eker, Prof. Ph.D.

# Scientific Organizing Committee

Anatoliy Ivantsov, Ph.D. (Akdeniz University, Turkey, chair)
Daniel Hestroffer, Prof. Ph.D. (IMCCE, Paris Observatory, France, co-chair)
Volkan Bakış, Prof. Ph.D. (Akdeniz University, Turkey)
Alberto Cellino, Prof. (Astrophysical Observatory of Torino, INAF, Italy)
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Christoph Lhotka, Ph.D. (Space Research Institute, Austrian Acad. of Sciences, Austria)
Paolo Tanga, Ph.D. (Côte d'Azur Observatory, France)
William Thuillot, Ph.D. (IMCCE, Paris Observatory, France)

# Local Organizing Committee

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Murat Kaplan, Ph.D. (Akdeniz University)
Gürkan Aslan (Akdeniz University)
Muhammed Fatih Dartıcı (Akdeniz University)
Gökhan Yücel (Akdeniz University)

# Programme

CT: Contributed Talk, IS: Invited Speaker, KL: Keynote Lecture.

## Wednesday, 4 of September

| | | | |
|---|---|---|---|
| 8:30–9:00 | **Registration** | | |
| 9:00–9:20 | **Welcome addresses** | | |
| **Session “Dynamics of Small Bodies” (Section I)** | | | |
| **Chairman: Daniel Hestroffer** | | | |
| 9:20–10:05 | KL | **Christoph Lhotka**<br>Graz, Austria | Dynamics of Charged Dust in the Solar System |
| 10:05–10:30 | IS | **Vladislav Sidorenko**<br>Moscow, Russia | More on Properties of Retrograde 1:1 Mean Motion Resonance (I) |
| 10:30–11:00 | **Coffee** | | |
| 11:00–11:20 | CT | **Sergey Efimov**<br>Dolgoprudny, Russia | Secular Dynamics of Resonant Kuiper Belt Objects: Lidov-Kozai Cycles and Adiabatic Chaos |
| 11:20–11:45 | IS | **Vladislav Sidorenko**<br>Moscow, Russia | More on Properties of Retrograde 1:1 Mean Motion Resonance (II) |
| 11:45–13:30 | **Lunch** | | |
| **Session “Dynamics of Small Bodies” (Section II)** | | | |
| **Chairman: Siegfried Eggl** | | | |
| 13:30–14:00 | CT | **Dmitrii Vavilov**<br>St. Petersburg, Russia | Interstellar Dust Erosion Made ’Oumuamua Elongated |
| 14:00–14:30 | CT | **Rudolf Dvorak**<br>Vienna, Austria | Families of comets in extra-solar planetary systems |
| 14:30–15:00 | CT | **Dmitrii Vavilov**<br>St. Petersburg, Russia | Why are so many comets shaped like peanuts? |
| 15:00–15:30 | **Coffee** | | |
| 15:30–15:55 | CT | **Anatoliy Ivantsov**<br>Antalya, Turkey | Prediction Accuracy of PHA’s Close Approaches with the Earth |
| 15:55–16:20 | CT | **Dmitrii Vavilov**<br>St. Petersburg, Russia | The Partial Banana Mapping Method for Impact Probability Computation |
| 16:25–19:00 | **Optional excursion to the Düden waterfalls in Antalya** | | |

# Thursday, 5 of September

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|---|---|---|---|
| **Session "Sky Surveys from Space and from the Ground"** | | | |
| **Chairman: Anatoliy Ivantsov** | | | |
| 9:00-9:45 | KL | **Daniel Hestroffer**<br>Paris, France | Gaia Mission General News and Science of Solar System Objects |
| 9:45-10:30 | KL | **Siegfried Eggl**<br>Seattle, the USA | Taking Inventory of the Solar System with the LSST |
| 10:30–11:00 | **Coffee** | | |
| 11:00–11:45 | IS | **William Thuillot**<br>Paris, France | The New Asteroids Detected by Gaia |
| 11:45–13:30 | **Lunch** | | |
| **Session "Observations of Small Bodies" (Section I)** | | | |
| **Chairman: Christoph Lhotka** | | | |
| 13:30–14:15 | KL | **Alberto Cellino**<br>Pino Torinese, Italy | Asteroid Polarimetry: Recent Achievements and Open Problems |
| 14:15–14:40 | CT | **Irek Khamitov**<br>Antalya, Turkey | Spectroscopic and Polarimetric Investigations of NEAs at RTT150 |
| 14:40–15:00 | CT | **Xiaoguang Yu**<br>Kunming, China | A Method of Improving the Quality and Efficiency of Spectral Observation |
| 15:00–15:30 | **Coffee** | | |
| 15:40–18:30 | **Optional excursion to the Antalya museum or Antalya aquarium** | | |
| 18:30 | **Workshop dinner** | | |

## Friday, 6 of September

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|---|---|---|---|
| Session "Observations of Small Bodies" (Section II) | | | |
| Chairman: Alberto Cellino | | | |
| 9:00 – 9:30 | CT | **Volkan Bakış** Antalya, Turkey | Performance of Akdeniz University Telescopes |
| 9:30–10:00 | CT | **Xiangming Cheng** Kunming, China | The Asteroid Observation System in Daocheng |
| 10:00–10:30 | CT | **Yigong Zhang** Kunming, China | Astrometric Observations of the NEAs Using Image Shifting and Stacking Method |
| 10:30–11:00 | **Coffee** | | |
| 11:00-11:20 | CT | **Oleksandr Kozhukhov** Kyiv, Ukraine | Observations of NEOs at the Facilities of State Space Agency of Ukraine |
| 11:20–11:45 | CT | **Anton Pomazan** Shanghai, China | Research Objectives and Observational Possibilities for Fast Moving Near-Earth Asteroids |
| 11:45–13:30 | **Lunch** | | |
| Session "Observations of Small Bodies" (Section III) | | | |
| Chairman: William Thuillot | | | |
| 13:30-14:00 | CT | **Na Wang** Guangzhou, China | A Distortion Solution of the Bok Telescope |
| 14:00–14:30 | CT | **Yücel Kılıç** Antalya, Turkey | A-Track: a Tool for Detecting Moving Objects from Astronomical Images |
| 14:30-15:00 | CT | **Zhenjun Zhang** Kunming, China | A Fast Point-Pattern Matching Algorithm Based on a Statistical Method |
| 15:00–15:30 | **Coffee** | | |
| 15:30–16:00 | General discussion & workshop closure | | |
| 16:00 | Optional excursion by cableway to the Tünek mountain summit | | |

# List of Abstracts

## Wednesday 4th

### Dynamics of Charged Dust in the Solar System

**Christoph Lhotka**[1], **Cătălin Galeş**[2]

[1] Space Research Institute, Austrian Academy of Sciences, Graz, Austria
[2] Faculty of Mathematics, Al. I. Cuza University of Iași, Iași, Romania

We investigate the dynamics of charged dust released by asteroids and comets close to outer mean-motion resonances with planet Jupiter. The importance of the interplanetary magnetic field on the orbital evolution of dust is clearly demonstrated. New dynamical phenomena are found that do not exist in the classical problem of uncharged dust. We find important changes in the orientation of the orbital planes of dust particles, an increased amount of chaotic kinds of orbital motions, sudden ‘jumps’ in the resonant argument, and a decrease in time of temporary capture due to Lorentz force.

## More on Properties of Retrograde 1:1 Mean Motion Resonance

**Vladislav Sidorenko**

Keldysh Institute of Applied Mathematics of Russian Academy of Sciences, Moscow, Russian Federation

Most of objects in the Solar System move around the Sun in the anticlockwise manner when seen from above the north ecliptic pole. And only a small number of celestial bodies move in opposite direction [1, 2]. Similar to prograde motion, the retrograde motion of a celestial body can also be in resonance with one of the major planets. For example, the asteroid 2015 BZ509 is in retrograde 1:1 mean motion resonance with Jupiter [3]. Theoretical studies demonstrated that such resonance can prevent collision of asteroid and planet in the case of co-orbital motion [4, 5]. The aim of our investigation is to obtain more information about the properties of this resonance. Similar to other MMR three dynamical processes can be distinguished in the case under consideration: "fast" process corresponds to planet and asteroid motions in orbit, "semi-fast" process is variation of the resonance argument (which describes the relative position of the planet and the asteroid in their orbital motions), and, finally, "slow" process is the secular evolution of the orbit shape (characterized by the eccentricity) and orientation (which depends on the ascending node longitude, inclination and argument of pericenter). With the use of double numerical averaging we construct evolutionary equations that describe the long-term behavior of asteroid's orbital elements (the "slow" process). Special attention is paid to possible transitions between different types of orbits existing at retrograde 1:1 resonance.

The author acknowledges the financial support from the Russian Ministry of Education and Science (Project KP19–270 "Questions of the origin and evolution of the Universe").

### References

[1] Gladman, B., Kavelaars, J., Petit, J.-M., Ashby, M. L. N., Parker, J., Coffey, J., Jones, R. L., Rousselot, P., Mousis, O.: Discovery of the first retrograde transneptunian object. *Astrophys. J.*, vol. 697, pp. L91–L94, 2009.

[2] Kankiewicz, P., Wlodarczyk, I.: How long will asteroids on retrograde orbits survive? *Planet. Space Sci.*, vol. 154, pp. 72–76, 2018.

[3] Wiegert, P., Connors, M., Veillet, C.: A retrograde co-orbital asteroid of Jupiter. *Nature*, vol. 543, pp. 687–689, 2017.

[4] Morais, M. H. M., Namouni, F.: A numerical investigation of coorbital stability and libration in three dimensions. *Cel. Mech. Dyn. Astron.*, vol. 125, pp. 91–106, 2016.

[5] Huang, Y., Li, M., Li, J., Gong, S.: Dynamic portrait of the retrograde 1:1 mean motion resonance. *Astron. J.*, vol. 155, article id. 262, 6 pp., 2018.

# Secular Dynamics of Resonant Kuiper Belt Objects: Lidov-Kozai Cycles and Adiabatic Chaos

**Sergey Efimov**[1], **Vladislav Sidorenko**[2]

[1] Moscow Institute of Physics and Technology, Dolgoprudny, Russian Federation
[2] Keldysh Institute of Applied Mathematics of Russian Academy of Sciences, Moscow, Russian Federation

A lot of Kuiper belt objects (KBOs) reside in mean motion resonance (MMR) with Neptune, most notably 1:2 MMR (twotino) and 2:3 MMR (plutino). We study the secular dynamics of such objects combining Wisdom's (1985) approach and numerical averaging of disturbing function. The results reveal possible scenarios of secular evolution, including a variety of Lidov-Kozai cycles, some of which appear to be new and unique, as well as couple key differences from the evolution in non-resonance case (Thomas and Morbidelli, 1996). Firstly, in MMR other planets than Neptune can substantially change secular evolution of KBO at relatively low eccentricities (e$\sim$0.2), creating wide Lidov-Kozai resonance islands. This is unlike non-resonant case where the influence of the inner giant planets only noticeable for objects with the eccentricity large enough to cross the planets' orbits. Moreover, the magnitudes of perturbation by Jupiter, Saturn and Uranus turn out to be very close to each other, which means that the dynamics of certain KBOs can be adequately described only by no less than six-body models. Secondly, evolution in MMR becomes stochastic with the appearance of the so-called adiabatic chaos (Neishtadt, 1987). In certain cases, it can raise eccentricities of KBOs starting from very low values, while for KBOs outside MMR small eccentricities always remain small (Thomas and Morbidelli, 1996).

## Interstellar Dust Erosion Made ‘Oumuamua Elongated

**Dmitrii Vavilov, Yurii Medvedev**

Institute of Applied Astronomy of the Russian Academy of Sciences, St. Petersburg, Russian Federation

‘Oumuamua became the first asteroid the orbit of which is determined as a reliable hyperbola (the eccentricity e=1.2). That means that the object came to the Solar system from the interstellar space. However, it paid huge attention of the scientific community for having an extremely elongated shape as well. The asteroid’s light curve implies that the object looks like an ellipsoid of revolution with the major axis 230 m and minor axis 35 m. The origin of such an elongated shape is a target of debates. In its journey in the interstellar space, the surface of the asteroid could suffer from erosion by gas or dust particles. Supposing the isotropic erosion ‘Oumuamua could have looked like a “normal” asteroid being about 500×300 m in size. In this work, we estimate the amount of interstellar gas and dust necessary to erode 125 meters of asteroid material. How fast asteroid surface material is stripped off depends on the asteroid’s physical properties as well as the relative speeds with respect to the gas and dust. From our simulations, the amount of gas ‘Oumuamua should have encountered with is at least 8 orders of magnitude higher than the estimated mass of dust making gas erosion negligible for the asteroid’s shape changes. The estimated mass of dust falling on a 1 $cm^2$ asteroid’s surface area required for this ablation ranges from $10^{-5}$ to $10^{-3}$ grams depending on the ‘Oumuamua’s physical parameters and the relative speed with respect to dust. These results correspond to traveling through the interstellar medium from millions to a couple of billion years. Passing through a 10 pc dust cloud with dust density from $10^{-22}$ to $10^{-24}$ $g/cm^3$ would have had a similar effect.

## Families of comets in extra-solar planetary systems

**Rudolf Dvorak**[1], **Birgit Loibnegger**[1], **Manfred Cuntz**[2], **Mattia Galiazzo**[1]

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[2] University of Texas, Arlington, USA

Since very recently, we acquired knowledge on the existence of comets in extrasolar planetary systems. The formation of comets together with planets around host stars now seems evident. As stars are often born in clusters of interstellar clouds, the interaction between the systems will lead to the exchange of material at the edge of the clouds. Therefore, almost every planetary system should have leftover remnants as a result of planetary formation in form of comets at the edges of those systems. These Oort clouds around stars are often disturbed by different processes (e.g., galactic tides, passing stars, etc.), which consequently scatter bodies from the distant clouds into the system close to the host star. Regarding the Solar System, we observe this outcome in form of cometary families. This knowledge supports the assumption of the existence of comets around other stars. We study the orbital dynamics of hypothetical exocomets in three star-planet systems, which are: HD 10180, 47 UMa, and HD 141399. These systems host one or more Jupiter-like planets, which change the orbits of the incoming comets in characteristic ways. We specially deal with the planetary system 55 Cancri which looks quite similiar to our Solar System in different aspects: the Jupiter like planet in about 6 au around the host star and 4 smaller planets in distances between 0.015 and 0.77 au. We put the family of all Jupiter comets into this system and compute the lifetimes of 100 different mean longitudes ($\delta$=3.6°) for every of the 580 comets. For some special ones (like the comet Tempel 1) we compare in detail close encounters with the planets and compute also the Tisserand value. In addition, because of the possibility that there may exist a terrestrial planet in the habitable zone, we added a hypothetical earth into 55 Cancri and compared the results for possible collisions of this Jupiter family comet Tempel 1 with the planets with the respective collisions in our Solar System.

## Why are so many comets shaped like peanuts?

**Dmitrii Vavilov**[1], **Siegfried Eggl**[2], **Yurii Medvedev**[1], **Pavel Zatitskiy**[3]

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The Rosetta mission showed that the comet 67P/Churyumov-Gerasimenko has a bi-lobed core. Five of the seven comets that have been imaged so far are bilobate, i.e. they consist of two lobes connected by a “neck”. It is known that short-period comets entering the inner Solar System experience significant mass loss as a result of sublimation and outgassing. It is, therefore, not surprising that sublimation caused by solar radiation has been proposed as a mechanism to change the shape of the nucleus over time. Our hypothesis suggests that the peculiar shape of comets is indeed caused by the interaction of an inhomogeneous nucleus with the subsequent differential sublimation of the material under the influence of sunlight. We derived a mathematical framework for describing changes in morphology as a result of inhomogeneous insolation during the spin-orbital evolution of the nucleus. The obtained partial differential equations are solved analytically for simple geometries, and numerically for more general configurations. The proposed mechanism explains the variety of shapes of currently observable comets, which largely depends on the spin evolution of the nucleus of the comet.

## Prediction Accuracy of PHA's Close Approaches with the Earth

**Anatoliy Ivantsov**[1,2], **Daniel Hestroffer**[2], **William Thuillot**[2], **Josselin Desmars**[3], **Pédro David**[2]

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[3] LESIA, Paris Observatory, PSL Univ., CNRS, Sorbonne Univ., Lille Univ., Paris, France

Prediction of epochs and distances of close encounters of asteroids with the Earth allows us to identify potentially hazardous asteroids (PHA) and estimate their future collisional risks. We report on the differences found in the prediction of the moments and distances of close encounters of asteroids with the Earth by four world ephemeride services. While the services are generally using the same measurement data collected at the IAU Minor Planet Center, the cross-identification of the close encounters provides an agreement in one-third part only between the lists of events within one year. The high sensitivity of the predictions results from the application of several algorithms: search of close encounters while the orbital data is available, dynamical models of motion, the weighting of measurements at the orbital fitting process, etc. Any inconsistencies in the algorithms or a subjective choice of the weights will change the orbital fitting and, thus, the future prediction of close approaches for PHA. As far as no ephemeride can be guaranteed, the additional observations of potentially hazardous asteroids at the moments of close encounters can be used for improving these predictions.

## The Partial Banana Mapping Method for Impact Probability Computation

**Dmitrii Vavilov**

Institute of Applied Astronomy of the Russian Academy of Sciences, St. Petersburg, Russian Federation

Since observations of small bodies of the Solar System are subject to errors the orbits of asteroids and comets are not obtained precisely. For an asteroid, there is a set of possible orbits, the so-called 'virtual asteroids', some of which can collide with the Earth producing impact probabilities. In space virtual asteroids are close to each other at the epoch of observations but over time they are getting more distant from each other. A full set of virtual asteroids define a region of possible positions of the asteroid, the confidence region. With time this stretches mainly along the nominal orbit and can reach several orbital revolutions. Here the new method for impact probability estimation is presented, which takes into account the curvature nature of the confidence region, while the classical target plane method can not. The method is linear, which means it requires propagation of only the nominal asteroid orbit unlike the Monte-Carlo method and LOV method. A collision can happen when the Earth comes close to the asteroid's orbit. At the time when the Earth is in the MOID point to the asteroid's orbit, on the main axis of the curvilinear confidence region one finds the virtual asteroid, which is closest to the Earth. The impact probability is calculated as the probability of the asteroid being in the region of the found virtual asteroid multiplied by the probability of a collision of the found virtual asteroid. The results show that the new approach is much more robust than the target plane method while the computational speed is practically the same.

# Thursday 5th

## Gaia Mission General News and Science of Solar System Objects

**Daniel Hestroffer**

IMCCE, Paris Observatory, PSL Univ., CNRS, Sorbonne Univ., Lille Univ., Paris, France

The Gaia ESA space mission provided its first harvest in 2016, with the DR1 catalogue release; yielding improved astrometry from classical ground-based observations of Solar System Objects (SSOs). Albeit of high interest, the DR1 data release has been largely surpassed by the DR2 release. Indeed, the Gaia DR2 is a major step in the Gaia mission by providing the very first full stellar catalogue, that includes all astrometric parameters (positions, parallaxes, and proper motions) at unprecedented precision, and this for more than 1 billion stars. All these positions are given in an absolute reference frame - to become the optical ICRF. Moreover, Gaia DR2 did provide for the first time astrometry of SSOs, more precisely, epoch positions of about 14,000 asteroids distributed from inner to outer regions of the Solar System, from the direct observations by the satellite down to magnitude V≈20.7. I will present the generalities of the Gaia surveying mission, and current status. I will then discuss the improvement brought by Gaia over its 5 years and more of mission — starting with DR1 — for the science of asteroids and other SSOs; and focusing especially on the astrometry and dynamics of asteroids. After reminding generalities on SSO observations by Gaia - and some of their peculiarities, we present some of the advances obtained from the use of the Gaia catalogues for the calibration and reduction of SSO astrometry. We also illustrate some ground-based activity for science alerts, and will also present advances in observations of stellar occultations, and studies of asteroids' dynamic.

## Taking Inventory of the Solar System with the LSST

**Siegfried Eggl**[1], **Lynne Jones**[2], **Mario Jurić**[2]

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[2] University of Washington, Seattle, USA

Currently under construction at Cerro Pachón, Chile, the Large Synoptic Survey Telescope (LSST) is an 8 m-class observatory that is expected to increase the number of known solar system objects by an order of magnitude. Apart from millions of main belt asteroids and hundreds of thousands of TNOs roughly 60% of all near-Earth Objects (NEOs) with absolute magnitude H<22 mag are likely to be found. This is made possible by LSST's 9.6 square degree field of view, a 3.2 Gigapixel camera and a rapid observational cadence. During its 10-year survey starting in 2022 LSST will scan the entire accessible night sky roughly every 3-4 days to median 5-sigma depths of $24^{th}$ mag. Data products encompass a near real time alert stream to enable rapid follow-up as well as orbit catalogs exclusively based on LSST astrometry published on a yearly basis. The latter serve as valuable input for population debiasing and future survey simulation studies. I present a status update on the LSST project and recent results on the expected discovery yields for Solar System objects.

## The New Asteroids Detected by Gaia

**William Thuillot**[1], **Federica Spoto**[2], **Benoît Carry**[2], **Paolo Tanga**[2], **Pédro David**[1], **Rene Alejandro Mendez**[3], **Sébastien Bouquillon**[4], **Damya Souami**[4,5], **Gaia-FUN-SSO collaborators**

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[5] LESIA, Paris Observatory, PSL Univ., CNRS, Sorbonne Univ., Lille Univ., Paris, France

The space astrometry Gaia mission has been designed for the global objectives of mapping our Galaxy and measures astrophysical targets but Gaia is also an interesting tool for the detection and high accuracy positioning of Solar System Objects (SSO). On contrarily to the first data release which provided in 2016 only stellar data, the second data release (DR2) published in 2018 included astrometric data of more than 14000 known asteroids. Besides, since the end of 2016, more information on SSO are daily available under the format of Gaia alerts triggered after the detection in space of unknown moving objects. Since Gaia observing mode is constrained by a scanning law which makes impossible to have an internal follow-up after the detection of these new objects, ground-based confirmations and follow-up are required. This is the reason why the DPAC consortium in charge of the data processing and analysis has set up a specific task dedicated to the daily processing of Solar System Object data and the triggering of alerts. Therefore, we have set up a web page diffusing publicly these alerts at https://gaiafunsso.imcce.fr to foster these confirmation and follow-up. More than 4800 alerts have been triggered so far and led to the ground-based detection of more than 150 new objects the astrometry of which have been sent to the Minor Planet Center. The dynamical compliance between the ground and space measurements is systematically checked and has led to almost 90 validated detections. Different observatories have been used but a special mention must be done for the Las Cumbres Observatory Global Telescope network (LCOGT) which is particularly well adapted for this kind of observations. We will give some information about this activity and on the already data acquired.

Gaia-FUN-SSO collaborators: L. Abe (Côte d'Azur Obs., Nice, France), K. Baillié (IMCCE, Paris Obs., France), P. Bendjoya (Côte d'Azur Obs., Nice, France), M. Delbo (Côte d'Azur Obs., Nice, France), M. Dennefeld (IAP, Paris, France), V. Godunova (ICAMER Observatory, Kyiv, Ukraine), D. Hestroffer (IMCCE, Paris Obs., France), Y. N. Krugly (Kharkiv National Univ., Ukraine), J. P. Rivet (Côte d'Azur Obs., Nice, France), V. Robert (IMCCE, Paris Obs., France), F. Taris (SYRTE, Paris Obs., France), V. Troianskyi (Astron. Obs. of Odessa National Univ., Ukraine), D. Vernet (Côte d'Azur Obs., Nice, France).

## Asteroid Polarimetry: Recent Achievements and Open Problems

**Alberto Cellino**

KL

INAF – Torino Astrophysical Observatory, Pino Torinese, Italy

After decades of substantial stagnation, due to the poor availability of dedicated instruments and few teams working in the field, asteroid polarimetry has known in recent years a moment of renaissance. The traditional activities of measurement of the so-called phase-polarisation curves have produced better calibrations of some important relations between polarimetric parameters and physical properties including primarily the geometric albedo and the average size of surface regolith particles. Moreover, a new and totally unexpected class of asteroids exhibiting anomalous polarimetric properties, the so-called "Barbarians" has been discovered, and interpreted in terms of a composition strongly reminiscent of the conditions characterizing the very early phases of planetary growth. More recently, the possibility to identify among the asteroid population objects of a possible cometary origin by means of their polarimetric properties has achieved a strong confirmation from the in situ exploration of (101955) Bennu by the OSIRIS-REx space probe. Finally, we are possibly at the beginning of an era in which the technique of spectro-polarimetry could become a major tool to achieve information about the physical properties of the small bodies in our Solar System.

# Spectroscopic and Polarimetric Investigations of NEAs at RTT150

**Irek Khamitov**[1,2], **Rustem Gumerov**[2,3], **Ilfan Bikmaev**[2,3], **Sergey Melnikov**[2,3], **Eldar Irtuganov**[2,3], **Gizem Okuyan**[1], **Oğuzhan Okuyan**[1]

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[2] Kazan Federal University, Kazan, Russian Federation
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Spectroscopic and polarimetric observations of Near Earth Asteroids (NEAs) are carrying out on the RTT150 regularly since 2018 in frame of scientific project: "Studies of physical parameters and ephemeris refinement of kilometer sized NEAs by the RTT-150 telescope". An experimental study as full as possible sample of kilometer sized NEAs involves the estimations of physical parameters of the asteroids such as geometric albedo, brightness, taxonomic class and diameters of NEAs. The objects are observed in the period of their closest approach to the Earth with the apparent magnitudes brighter 18 mag. We present observational results of the project performed in 2018. In total, there were made 106 photometric, spectral and polarimetric observations for 34 asteroids. The polarimetric and spectral observations were performed for the first time for 25 of them. There were made 41 polarimetric and 41 photometric observations in the V filter of the Bessel photometric system. There were observed 26 NEAs, for 17 of them, polarimetric observations were made for the first time, that is, they are new and original. There were got 10 reflective spectra in the wavelength range from 3500 Å to 8500 Å for 8 NEAs. Since September 2018 we make spectral observations using a specially made slit, shifted relative to the center of the telescope's field of view. There were got 11 reflective spectra in the range from 4700 Å to 10000 Å for 8 NEAs. The spectral observations for these asteroids were got for the first time. There were analyzed polarimetric and photometric observations in the V filter for 32 NEAs observed at RTT150 during the period of their close approach to the Earth from August 2014 to June 2018. To determine the albedo of NEAs, we offer an original method based on a limited number of polarimetric observations of asteroids at large phase angles. We preselected asteroids greater than 1 km in size using diameter estimations made before. The asteroids are divided into two groups with low and moderate albedo, within each group the histogram of NEAs with respect to the perihelion distance was analyzed. We suspect a slight increase of moderate albedo NEAs with the perihelion distance. To eliminate the selection effect due to the small size of the sample, this feature will be investigated using the new observational data. The observations of kilometer-sized NEAs within the project are ongoing in 2019.

*Acknowledgements.* This work was supported by the Russian Foundation for Basic Research (project no. 18-02-00105 A). Authors thank TÜBİTAK, KFU, AST, and IKI for partial support in using RTT150 (the Russian-Turkish 1.5-m telescope in Antalya). This work was partially funded by the subsidy 3.6714.2017/8.9 allocated to Kazan Federal University for the state assignment in the sphere of scientific activities.

### A Method of Improving the Quality and Efficiency of Spectral Observation

**Xiaoguang Yu**

Yunnan Observatories, Chinese Academy of Sciences, Kunming, China

The traditional method of fixed exposure time spectrum observations is susceptible to weather conditions, parameters setting of telescope tracking, and instrument efficiency. For variable cloud cover, the SNR of data will be reduce compared to the clear sky during the period of observation. When the telescope tracking parameters setting is not appropriate or the telescope tracking error is happening, the target tracking may deviate from the slit. A design scheme of an adaptive exposure control system is proposed for solving above problem. The luminous flux of target is monitored during spectral observations, the status of the weather and telescope tracking can be obtained by the changing of luminous flux; at the same time, the spectral SNR can be measured in real time. Exposure will be terminated when the SNR of spectrums meets the requirements, or else the time of exposure will be increased. Above method can improve the quality of observation data and the observing efficiency of telescope. The hardware equipment of the system has been built in the high dispersion fiber spectrograph of Lijiang 2.4 m telescope. The experimental data shows the feasibility of this method, it will be helpful for the high dispersion fiber optic spectrograph of Lijiang 2.4 m telescope. This work may provide references for different spectrographs with similar requirements.

## Friday 6th

### Performance of Akdeniz University Telescopes

**Volkan Bakış, Anatoliy Ivantsov, Zeki Eker, Murat Kaplan, Gökhan Yücel, Gürkan Aslan, Muhammed Fatih Dartıcı**

Faculty of Science, Akdeniz University, Antalya, Turkey

We provide detailed descriptions of two telescopes of Akdeniz University, UBT60 (D=0.61 m, F=3.96 m) installed at the mountain site of the Tubitak National Observatory, Bakırlı Tepe, and AUT25 (D=0.25 m, F=2.0 m) installed at the university campus in Antalya. The UBT60 telescope was upgraded with a new CCD camera in 2019. We report on the first photometric and astrometric observations made at these telescopes.

## The Asteroid Observation System in Daocheng

**Xiangming Cheng, Tengfei Song, Yigong Zhang, Guanjun Zhang**

Yunnan Observatories, Chinese Academy of Sciences, Kunming, China

The Daocheng Observatory is located in Daocheng County, at the junction of Sichuan Province and Yunnan Province in southwest China, with an altitude of more than 4500 m. The Daocheng Observatory has good observation conditions, with an average annual observable days of about 250 days, a median seeing of about 0.9 angular seconds, an average atmospheric water vapor content of about 2.5 mm during the observable period, a light intensity of about 21.7 mag per square angular seconds at night, and a distance of about 50 km from the Daocheng Airport Observatory. We have established an asteroid observation system at the Daocheng Observatory, which has a 50 cm telescope, a filter system with BVRI band, and a FLI refrigerated CCD camera. The observing system is also equipped with a followable dome and a remote observing system. The time accuracy of the system is better than 0.1 s.

## Astrometric Observations of the NEAs Using Image Shifting and Stacking Method

**Yigong Zhang**

Yunnan Observatories, Chinese Academy of Sciences, Kunming, China

Astrometric observations of Solar System objects are very helpful to study the origin and evolution of the Solar system, asteroids and exoplanet detection. As part of solar system, near-Earth asteroids get wide attention because of their potential threats to Earth. But it is very difficult to predict the long-term orbit of NEAs, so it is necessary to make continuous and high-precision astrometric observations of NEAs to help monitor the changing of their orbits and give humans ample time to respond the potential threats. Using the traditional long exposure method to observe the faint NEAs which have fast motion will cause a long tail, which is not conducive to calculate the center coordinates of the NEAs and get high accuracy astrometric results. We present a method using CCD/CMOS detectors, getting a series of images contain both NEA and stars without any saturation. Firstly, observation images should be divided into two separate parts, one background stars images and one NEA images. Secondly, shifting and stacking all background images using one background image as reference image; shifting and stacking all NEA images using one NEA image as reference image. Finally, comparing with traditional long exposure observation, more background stars with higher SNR and better NEA image can be obtained. Above method can improve the precision of astrometric observations reduction results of NEAs.

# Observations of NEOs at the Facilities of State Space Agency of Ukraine

**<u>Oleksandr Kozhukhov</u>, Serhii Ryschenko, Timur Dementiev, Valentyn Pasatetskii, Taras Bezluschenko, Yaroslav Tanasiychuk, Dmytro Kozhukhov, Volodymyr Prysiazhnyi**

National Space Facilities Control and Test Center, State Space Agency of Ukraine, Kyiv, Ukraine

Optical observations of near-Earth objects (NEOs) at the facilities of the State Space Agency of Ukraine were done during two periods. During the first period in 2009-2013, the observations of NEOs were occasional and made at the AZT-8 telescope in Crimea (the Minor Planet Center code is 'B17'). The second period began with upgrading the AZT-28 telescope of the Center for Special Information Reception and Processing and Navigation Field Control of National Space Facilities Control and Test Center at the end of 2016. As a result, it became possible to observe different minor bodies of the Solar System, including NEOs. The new station has got the Minor Planet Center code 'L18'. The regular observations of NEOs were organized in 2019, including follow-up of the newly discovered objects. The report presents the results of the observations of NEOs from September 2009 to August 2019.

# Research Objectives and Observational Possibilities for Fast Moving Near-Earth Asteroids

**Anton Pomazan**[1], **Zheng-Hong Tang**[1], **Kai Tang**[1], **Nadiia Maigurova**[2], **Yong Yu**[1]

[1] Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai, China
[2] Research Institute "Mykolaiv Astronomical Observatory", Mykolaiv, Ukraine

Main research objectives for the Near-Earth space security and control are discoveries, confirmations and posterior orbits determinations of Near-Earth Objects (NEOs). Until now, more than 20,000 NEOs are known, including around 2,000 Potentially Hazardous Asteroids (PHAs). The vast majority of them are less than 1 km size and have faint apparent magnitudes enough (down to 17 mag) therefore high-aperture telescopes are required to their observations. That's why some of these asteroids have an insufficient number of accurate observations for reliable calculation of their orbits elements. Only at moment of close approach to the Earth these objects might increase their apparent magnitude to be observable most of ground-based telescopes. However, their apparent velocity is big enough to get pointed image which is needed to obtain their precise coordinates by the classical methods of observations. Here, we used modified Rotating-drift-scan CCD mode of observations at telescopes of ShAO and RI MAO for obtaining point NEAs images and classical mode for obtaining fields with reference stars. This technique can both increase limited magnitude and improve accuracy of the NEAs position since images of both objects and reference stars are pointed. The method of observations and astrometric reductions, object selection criteria and some positional accuracy statistics of fast moving NEAs' are presented. It is shown that using modified Rotating-drift-scan CCD mode of observations allow us to get positions with accuracy in range $0.2''-0.3''$ for objects apparent velocity of which substantially exceed FWHM for exposure time. It is shown, such observations increase amount of observations for newly discovered asteroids which can significantly improve the accuracy of determining their orbital elements and our impact predictions.

## A Distortion Solution of the Bok Telescope

**Na Wang**

Jinan University, Guangzhou, China

The Beijing-Arizona Sky Survey (BASS) is an imaging survey and uses the 2.3-m Bok telescope at Kitt Peak. In order to improve the astrometry of the BASS, we present an analytical geometric distortion solution that is quite different from our previous numerical geometric distortion solution. By using the analytical GD correction and an additional lookup table correction the astrometry of BASS is improved greatly. The results show that when the Gaia DR2 star catalogue is referred to the positional measurement accuracy of the suitable bright stars is estimated at about 20 mas or even better in each direction.

## A-Track: a Tool for Detecting Moving Objects from Astronomical Images

**Yücel Kılıç[1], Murat Kaplan[2], Orhan Erece[1]**

[1] TÜBİTAK National Observatory, Antalya, Turkey
[2] Faculty of Science, Akdeniz University, Antalya, Turkey

The detection of moving objects in astronomical images is of vital importance, especially in terms of discovering new solar system objects. For this purpose, we have developed a software called A-Track that can detect moving objects from serial FITS images. In this study, the MILD algorithm on which this software is based, the astrometric features that we added afterward, and various performance improvements are introduced.

## A Fast Point-Pattern Matching Algorithm Based on a Statistical Method

**Zhenjun Zhang, Yigong Zhang, Xiangming Cheng, Jie Su, Jiancheng Wang**

Yunnan Observatories, Chinese Academy of Sciences, Kunming, China

We propose a new pattern-matching algorithm for matching CCD images to a stellar catalog based statistical method in this paper. The method of constructing star pairs can greatly reduce the computational complexity compared with the triangle method. We use a sub-sample of the brightest objects from the image and reference catalog and find a coordinate transformation between the image and reference catalog based on the statistical information of star pairs. Then all the objects are matched based on the initial plate solution. The matching process can be accomplished in several milliseconds for the images acquired by 1 m telescope, operated by Yunnan observatories.

# Useful Information

**Talks** will be held at the **Seminar Auditorium** of the Science Faculty (B Block), Akdeniz University. It is located on the first floor.

**Coffee breaks** will be offered in the neighbourhood hall.

**Lunches** will be offered for free for all participants during the workshop days at the Guest House restaurant of the Akdeniz University.

Wi-Fi will be available during the conference. There is access to an eduroam network in each building of the Akdeniz University.

The **conference dinner** will be held at the “Gaziantep Restaurant”, Konyaaltı Cd. No: 6 Bahçelievler Mahallesi, Antalya 07050.

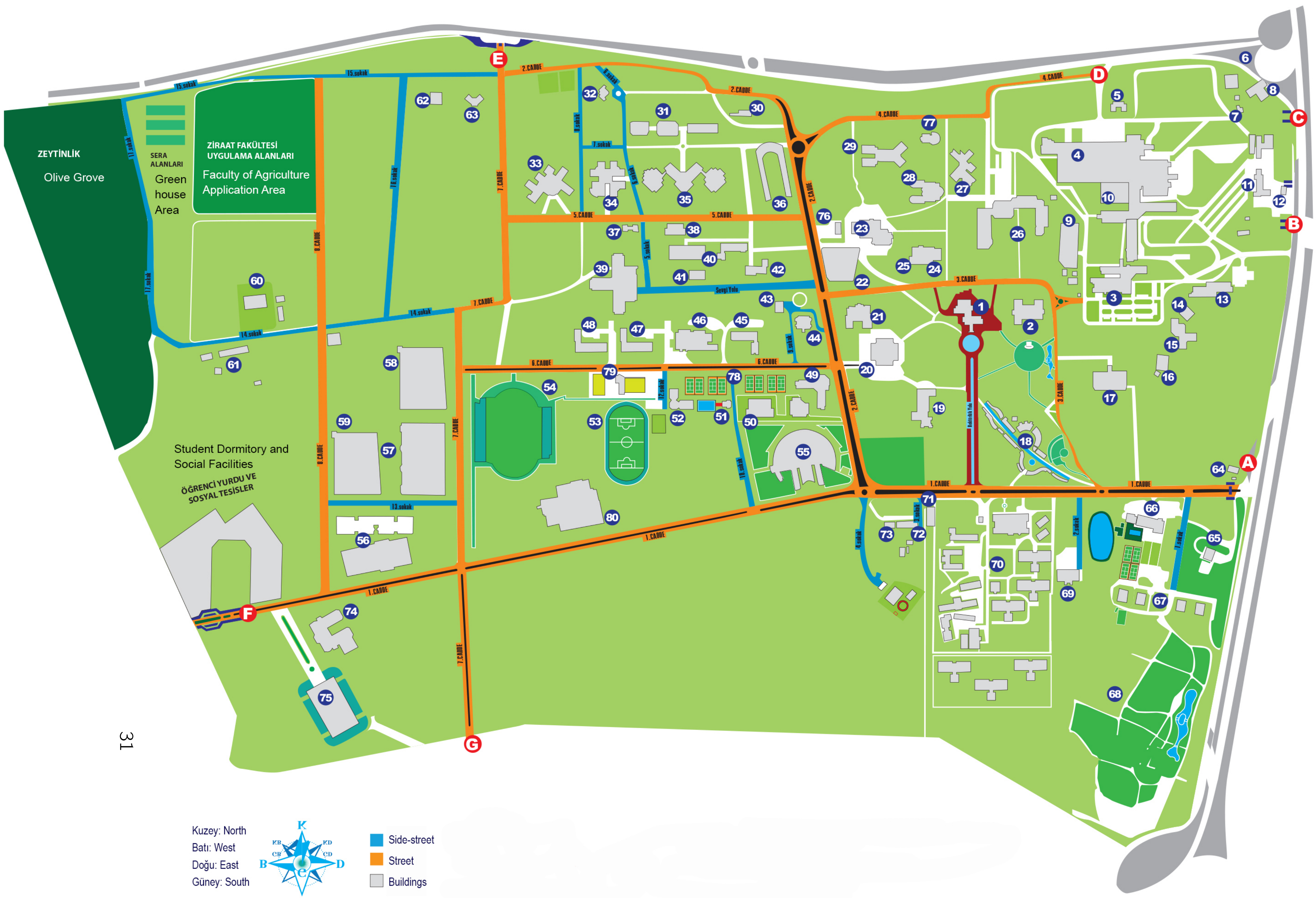
## How to get to the B Block of the Science Faculty, Akdeniz University?

The Akdeniz University can be accessed through different gates which are generally far from each other. The Science Faculty can be identified as “Fen Fakültesi” on different maps inside the University. The blocks A and B are located next to each other. Please, have at your hands your international passport or ID card to show to the University guardians at the gates (you can say: “Fen Fakültesi” that is in Turkish for “Science Faculty” to the guardians in case you are asked about your visit).

There are city buses coming inside the University campus. They are free of charge for transportation within the University campus for everyone; if a bus is going to leave the University campus, the driver will ask all the passengers to re-enter and charge their bus cards.

## Akdeniz University Campus

1 Rectorate
2 Library
3 Emergency Service
4 Research and Practical Hospital
5 Faculty of Dentistry
6 Heating Center
7 Organ Transplantation Center
8 AMATEM Building
9 Technical Center
10 Oncology Hospital
11 Kindergarten
12 Center for Selection & Placement
13 Physiotherapy Center
14 Outpatient Psychiatry Center
15 Mental Health Diagnosis Center
16 Open-Air Sculpture Workshop Area
17 Faculty of Fine Arts
18 Olbia
19 Faculty of Tourism
20 Central Cafeteria
21 Medical center for students
22 Rectorate Service Units
23 Atatürk Conference Hall
24 School of Foreign Languages
25 Central Auditoria
26 Faculty of Medicine
27 Faculty of Nursing
28 Faculty of Science, B Block
29 Faculty of Science, A Block
30 Cafeteria of the Faculty of Agriculture
31 Faculty of Agriculture
32 Incubation Center
33 Faculty of Fisheries
34 Food Research & Development
35 Faculty of Agriculture, Block 4
36 Yakut Food & Shopping Center
37 Faculty of Engineering
38 Nanotechnology EMUMAM Building
39 Faculty of Engineering
40 Technical Sciences School
41 Technical Sciences School
42 Faculty of Fisheries
43 Student Tent Meeting Point
44 Student Local Cafeteria
45 Faculty of Economics, A Block
46 Faculty of Economics, B Block
47 Faculty of Economics, C Block
48 Faculty of Communication
49 Physical Education & Sports School
50 Indoor Sports Hall
51 Swimming Pool
52 Physical Education & Sports School
53 Football Pitch
54 Athletics Track and Tribune
55 Faculty of Law
56 Faculty of Literature
57 Faculty of Education
58 Faculty of Communication
59 School of Foreign Languages
60 Faculty of Agriculture
61 Faculty of Agriculture
62 Technocity Block 1
63 Technocity Block 2
64 Security Center
65 Conservatory
66 Guest House
67 Staff Housing
68 Botanical Garden
69 Health Services School
70 Student Dormitories
71 Technical Sciences School
72 Workshop
73 Directorate of Parks and Gardens
74 Faculty of Theology
75 Mosque
76 Student Club Center
77 Gerontology Center
78 Tennis Courts
79 Football Pitch
80 Training Halls
81 Student Dormitories


ZEYTİNLİK
Olive Grove
SERA ALANLARI
Green house Area
ZİRAAT FAKÜLTESİ UYGULAMA ALANLARI
Faculty of Agriculture Application Area
Student Dormitory and Social Facilities
ÖĞRENCİ YURDU VE SOSYAL TESİSLER
Kuzey: North
Batı: West
Doğu: East
Güney: South
Side-street
Street
Buildings

# Notes

# Partner Institutions and Sponsors

The international workshop meeting is organized by Akdeniz University in Antalya, Turkey, with partial support from the Scientific and Technological Research Council of Turkey (TÜBİTAK) through the 1001-project "Astrometry of Potentially Hazardous Asteroids with Improved Accuracy" (118F036, PI Anatoliy Ivantsov). As well, partial support provided by the TÜBİTAK National Observatory, the Embassy of France in Turkey and the Turkish Astronomical Society is also acknowledged.

## Sponsors

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