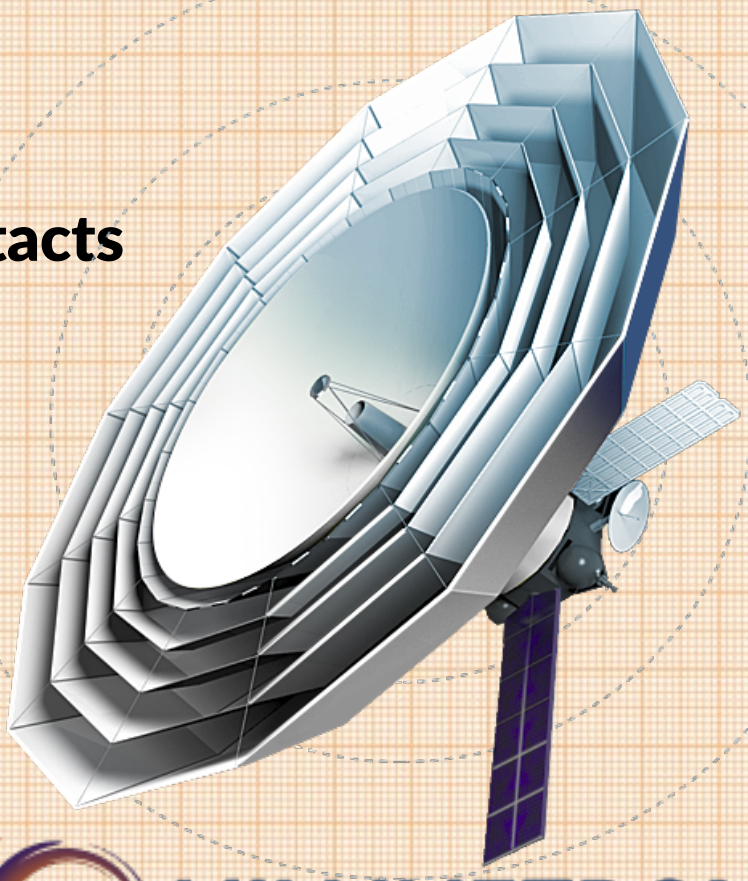
Russian Academy of Sciences — RAS
Lebedev Physical Institute — LPI
Astrospace Center — ASC

First Moscow International Conference Submillimeter and Millimeter Astronomy: Objectives and Instruments

AstroSpaceCenter, Moscow
12—16 April 2021

Programme & Abstacts



Moscow 2021

MILLIMETRON
SPACE OBSERVATORY

Motivation

Millimeter and submillimeter astronomy has been developing for about 60 years. During this time, not only our ideas about the "cold" part of the Universe associated with CMB radiation, molecular gas and dust in the interstellar medium of galaxies have undergone revolutionary changes. Most of what commonly referred to as "hot" high-energy objects, such as bursts of star formation and active galactic nuclei with supermassive black holes, turned out to be hidden by dense clouds of gas and dust, and manifests itself only in the millimeter and submillimeter spectral range. Thanks to this, our nowadays understanding of the Universe has become fundamentally different from the one of a few years ago.

Currently, Russia is developing two large projects in the mm and submm range: the Spektr-M space project to create the Millimetron space observatory (operating range 70 μm - 3 mm) and the related project of the Suffa International Radio Astronomy Observatory implemented within the framework of an intergovernmental agreement between Russia and Uzbekistan (the initially planned working range was 0.8-10 mm). In addition, a program of establishing in Russia its own interferometric network consisting primarily of 2 mm-wave telescopes is currently being discussed.

The primary purpose of this conference is to discuss science related to mm/submm astronomy, as well as the main aspects of technological problems and the prospects of their development.

Topics

A. Scientific targets of MM and SubMM astronomy

1) Relativistic astrophysics: supermassive black holes in our and other galaxies, measurements of the space-time metric, plasma properties in strong gravitational fields, electromagnetic afterglow of gravitational waves, fast bursts (time domain) in mm and submm;
2) Cosmology: spectral distortions of the CMB, problem of H_0 (Hubble tension), early objects in the Universe, evolution of the luminosity function of galaxies at cosmological times;
3) Interstellar medium: molecular clouds and star formation, astrochemistry, the origin of dust, features of the dust emission of various objects, the circulation of dust in galaxies;
4) The origin of life in the Universe: water in the interstellar medium, complex organic molecules in the ISM, protoplanetary disks, exoplanets, brown dwarfs, Solar system;
5) Galaxies: luminous infrared galaxies, active galactic nuclei obscured by dust.

B. Instruments

1) Ground-based mm/submm astronomy: astroclimate research, site selection, antennas, receivers.
2) Balloon and aircraft mm/submm experiments: Olimpo, SOFIA, and others.
3) Space projects: Millimetron, OST.

Organizing Commitee

Yuri Artemenko;
Roman Cherny;
Evgeny Golubev;
Tatiana Larchenkova;
Sergey Likhachev;
Igor Novikov;
Alexei Rudnitskiy;
Yuri Shchekinov (chair)
Evgenii Vasiliev;
Vyacheslav Vdovin;
Igor Zinchenko;

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Programme

April 12th Monday | General aspects of mm/submm astronomy, sites, instruments

Chair: **Yuri Shchekinov**

10:00 **Nikolay Kolachevsky** (Director of Lebedev Physical Institute RAS), Welcome
10:10 **Yuri Balega** (Vice-President RAS), The future of the millimeter range astronomy in Russia
10:40 **Sergey Likhachev** (Head of ASC LPI, PI of the Millimetron project), Introduction to Milllimetron

11:10 Coffee

11:30 **Vladimir Soglasnov**, On the early history of millimeter and submillimeter astronomy in Russia
12:00 **Vyacheslav Vdovin**, Experimental mirowave astroclimate research for development of subTHz astronomy
12:30 **Marat Mingaliev**, Millimeter astronomy in Russia: what, where and when?

13:00 Lunch

Chair: **Vyacheslav Vdovin**

14:00 **Thijs de Graauw**, Submillimeter and Millimeter Astronomy: Evolution and Future Perspectives
14:40 **Massimiliano Tordi & Mattia Scomparin**, On the development of radio-antennas for mm/sub-mm observations: an industrial perspective
15:10 **Taehyun Jung**, (E)KVN: Simultaneous Multi-Frequency (18 - 150 and 230GHz) VLBI System
15:40 **Vladimir Khaikin**, On the projects of ground-based MM and SubMM telescopes and the development of the concept of the ESMT project

16:10 Coffee

16:25 **Aleksander Lapinov**, On the advantages of the Eastern Pamirs for sub-mm astronomy
16:55 **Tatiana Khabarova**, Study of best sites for ground based mm-wave radio telescopes
17:10 **Artem Shikhovtsev**, Astroclimatic characteristics of the Sayan Solar Observatory and the Special Astrophysical Observatory sites for ground-based mm/submm astronomy

17:40 Discussion (Chair – Andrey Khudchenko): sites, instruments & wine, dancing, singing etc … on-line

April 13th Tuesday | Instruments

Chair: **Igor Zinchenko**

09:00 **Maria Salatino**, mm-astronomy from the Tibetan plateau: the AliCPT-1 telescope
09:30 **Andrey Khudchenko**, SIS Receivers for Radio Astronomy – overview of existing instrumentation
10:00 **Grigorii Goltsma**n, Development and application of terahertz hot electron bolometers
10:30 **Valery Koshelets**, Superconducting sub-THz receivers for space and ground-based radio astronomy

11:00 Coffee

11:15 **Ivan Tret'yakov**, HEB mixer based THz astronomical instruments
11:45 **Andrey Baryshev**, Direct Detectors for Radio Astronomy
12:15 **Mikhail Tarasov**, SINIS detector arrays for radioastronomy
12:45 **Alexander Sobolev**, 2D arrays of Cold Electron Bolometrers based on SINIS structures

13:00 Lunch & Posters

Kirill Maslennikov, Shorbulak (Eastern Pamirs) vs Chajnantor Plateau (Chilean Andes, Atacama Desert): a brief astroclimatic comparison
Aleksandr Malinovsky, Catalog of supermassive black holes for interferometric observations
Petr Zemlyanukha, Prospects for 3D printing of quasi-optical and waveguide systems

Chair: **Vyacheslav Vdovin**

14:00 **Alexey Rudnitsky**, Capabilities and geometry of VLBI mode in Millimetron Mission
14:30 **Roman Cherny**, Onboard electronic complex
15:00 **Evgeny Golubev,** Millimetron payload module design
15:30 **Viktor Bujaka**s, New Precise Petal-type Reflector for Space Radio Astronomy

15:45 Coffee

Chair: **Andrey Khudchenko**

16:00 **Alexander Shurakov**, Status of THz Schottky diode technology for radio astronomy in Russia and worldwide
16:20 **Leonid Kuzmin**, Multifrequency receiving systems based on planar slot antennas with cold-electron bolometers for radio telescopes COrE and LSPE
16:40 **Andrey Pankratov**, Cold-Electron Bolometers for Radio Astronomy Missions
16:55 **Igor Bubukin**, Comparative analysis of the propagation conditions of millimeter radio waves at the NIRFI NNSU "Karadag" site (southeastern Crimea), the "Suffa" plateau (southern Uzbekistan) and three IAA RAS test sites located in different climatic zones of the Russian Federation
17:10 **Igor Rakut'**, Microwave meteorological station to determine the integral humidity of the atmosphere sites

17:25 – 19:00 Discussion (Chair – Andrey Baryshev): Instruments & wine, dancing, singing etc … on-line

April 14th Wednesday | Cosmology

Chair: **Dmitrii Novikov**

09:00 **Sergey Pilipenko**, Unveiling the obscured high-redshift Universe with Millimetron
09:30 **Biman Nath**, The enigmatic star forming galaxy at z=11
10:00 **Evgenii Vasiliev**, FIR from high-z SMBHs
10:30 **Igor Novikov Jn**, Shock-excited Infrared signatures in ULIRGs

10:45 Coffee

11:00 **Paolo de Bernardis**, Millimetron, Galaxy Clusters and the Large-Scale Structure of the Universe
11:30 **Dmitry Novikov**, Anisotropic SZ effect and independent estimation of the CMB anisotropy low multipoles
12:00 **Gemma Luzzi**, Cosmology with the SZ spectrum: measuring the Universe's temperature and expansion with galaxy clusters
12:30 **James Creswell**, Asymmetry of the CMB map: local and global anomalies

13:00 Lunch

Chair: **Alexey Rudnitsky**

14:00 **Andrea Ferrara**, Dusty Galaxies in the Epoch of Reionization
14:40 **Sergey Balashev**, Outflows from the type I quasar at high-z: molecular gas in the host galaxies
15:10 **Luca Graziani**, The assembly of dusty galaxies at z>4

15:40 Coffee

16:00 **Carlotta Gruppioni**, Obscured Star-Formation in the Early Universe
16:20 **Laura Bisigello**, Simulating the infrared sky with a SPRITZ
16:40 **Luigi Spinoglio**, Galaxy Evolution studies in the IR and submm from the space
17:00 **Francesco Salvestrini**, Unveiling the AGN intrinsic power and its effect on the host-galaxy ISM
17:20 **Sergey Drozdov**, Emission from hot bubbles by a quiescent star formation

17:35 – 19:00 Discussion (Chair – Yuri Shchekinov): Cosmology & wine, dancing, singing etc … on-line

April 15th Thursday | Relativistic Astrophysics

Chair: **Yuri Shchekinov**

09:00 **Andrey Andrianov**, Simulations of M87 and Sgr A∗ imaging with the Millimetron Space Observatory on near-Earth orbits
09:30 **Sergey Chernov**, MHD modeling of shadows and rings from black holes. Problems and it's solutions
10:00 **Evgeniya Kravchenko**, Polarimetry of active galactic nuclei in ground and space VLBI observations
10:30 **Yuri Kovalev**, Probing the event horizon scales with multi-frequency polarization Space VLBI visibility tracking

11:00 Coffee

11:15 **Gabriele Giovaninni**, High resolution – high frequency properties of relativistic jets in AGN
11:45 **José Gómez,** Accretion onto supermassive black holes and jet formation: prospects for future ngEHT and space mm-VLBI observations
12:15 **Andrey Lobanov**, Millimetre VLBI probes of physics down to the event horizon scale
12:45 **Elena Mikheeva**, Black Hole Shadow Observations with Space-Ground Interferometers

13:00 Lunch

Chair: **Sergey Pilipenko**

14:00 **Tatiana Larchenkova**, Gravitational lensing and Hubble tension problem with Millimetron
14:30 **Andrei Doroshkevich**, Lyman-alpha emitters and first galaxies with Millimetron
15:00 **Arina Morgunova**, Investigation of the Hubble tension problem in the case of a time-dependent dark energy parameter
15:15 **George Bendo**, The Millimeter Valley Between Dust and Synchrotron Emission in Nearby Galaxies

15:45 Coffee

16:00 **Vyacheslav Dokuchaev**, Images of black holes
16:30 **Alexander Zakharov**, Orbits of bright stars near the Galactic Center as a tool to test gravity theories
16:50 **Maxim Pshirkov**, Radio transients: current status
17:20 **AndreyErmash**, Sources of confusion noise of the Millimetron Mission

17:35 – 19:00 Discussion (Chair – Andrey Baryshev): Relativistic Astrophysics & wine, dancing, singing etc … on-line

April 16th Friday | ISM & Water

Chair: **Valery Shematovich**

09:00 **Anna Punanova**, Water trail with Millimetron
09:30 **Dmitrii Wiebe**, (Sub)millimeter observations of organic molecules
10:00 **Sergey Kalensky**, Images of Class I methanol masers in the regions of low-mass star formation
10:30 **Maxim Voronkov**, Millimetre facilities and maser surveys in Australia

11:00 Coffee

11:15 **Philippe Andre**, Filamentary star formation and the role of magnetic fields on various scales
11:45 **Lev Pirogov**, Kinematics of filaments and cores associated with regions high-mass star formation
12:15 **Maria Kirsanova**, Non-stationary photodissociation regions around young massive stars
12:30 **Alisher Hojaev**, Scientific tasks for studies of galactic molecular clouds with RT-70
12:45 **Ilya Kovalenko**, Turbulence in gas-dust optically thick interstellar clouds: radiation-convective model

13:00 Lunch

Chair: **Evgenia Kravchenko**

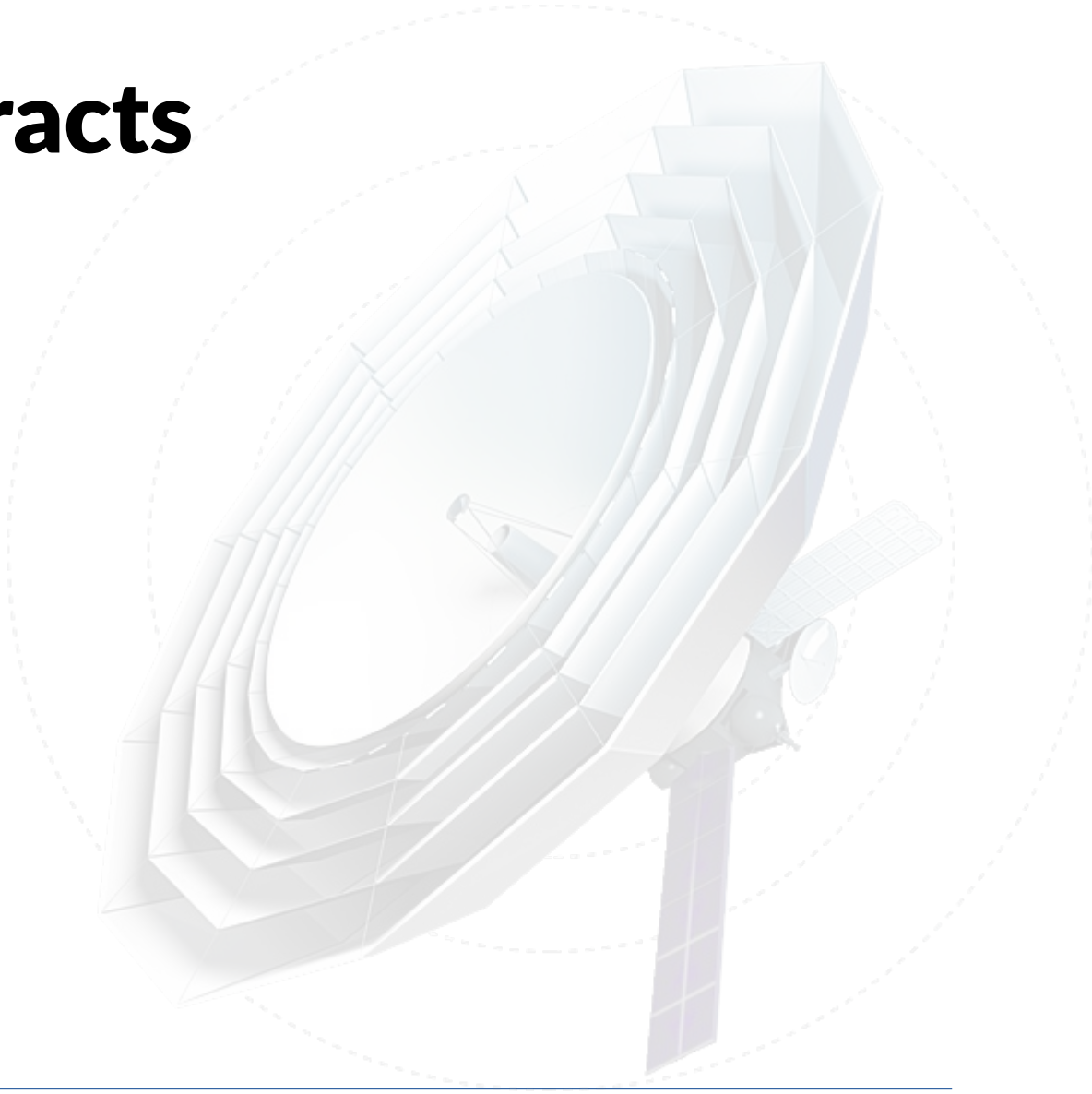
14:00 **Valery Shematovich**, Studies of the ocean worlds in the Solar and exosolar planetary systems in the MM and subMM astronomy
14:30 **Dmitrii Sokoloff**, Symmetries of Magnetic Fields Driven by Spherical Dynamos of Exoplanets and Their Host Stars
15:00 **Maria Pashentseva**, Modeling magnetic fields in accretion discs, taking into account convective flows
15:15 **Natalya Kargaltseva**, Primary disks and their observational appearance in collapsing magnetic rotating protostellar clouds
15:30 **Sergey Khaibrakhmanov**, Physical and chemical vertical structure of the magnetostatic accretion disks of young stars
15:45 **Dmitrii Ladeyschikov**, Relation between star formation traced by water masers and physical parameters of dust clumps in the submillimeter wavelength range

16:00 Coffee

16:15 **Igor Zinchenko**, Ground-based and space-borne mm/submm astronomy in studies of ISM
16:45 **Andrey Sobolev**, Millimeter and submillimeter transient events in star formation
17:15 **Nadezhda Shakhvorostova**, Probing star-formation in Infrared Dark Clouds with mm-wave masers using Onsala 20-m RT
17:35 **Lucero Uscanga**, Millimeter observations of maser-emitting planetary nebulae

18:00 – 20:00 Discussion (Chair – Dmirii Wiebe): Water, complex molecules, disks & wine, dancing, singing etc … on-line

Abstracts



A

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Simulations of M87 and Sgr A∗ imaging with the Millimetron Space Observatory on near-Earth orbits

High-resolution imaging of supermassive black hole shadows is a direct way to verify the theory of general relativity under extreme gravity conditions. Very Long Baseline Interferometry (VLBI) observations at millimetre/submillimetre wavelengths can provide such angular resolution for the supermassive black holes located in Sgr A∗ and M87. Recent VLBI observations of M87 with the Event Horizon Telescope (EHT) have shown such capabilities. The maximum obtainable spatial resolution of the EHT is limited by the Earth's diameter and atmospheric phase variations. In order to improve the image resolution, longer baselines are required. The Radioastron space mission successfully demonstrated the capabilities of space–Earth VLBI with baselines much longer than the Earth's diameter. Millimetron is the next space mission of the Russian Space Agency and will operate at millimetre wavelengths. The nominal orbit of the observatory will be located around the Lagrangian L2 point of the Sun–Earth system. In order to optimize the VLBI mode, we consider a possible second stage of the mission that could use a near-Earth high elliptical orbit (HEO). In this paper, a set of near-Earth orbits is used for synthetic space–Earth VLBI observations of Sgr A∗ and M87 in a joint Millimetron and EHT configuration. General relativistic magnetohydrodynamic models for the supermassive black hole environments of Sgr A∗ and M87 are used for static and dynamic imaging simulations at 230 GHz. A comparison preformed between ground and space–Earth baselines demonstrates that joint observations with Millimetron and EHT significantly improve the image resolution and allow the EHT + Millimetron to obtain snapshot images of Sgr A∗, probing the dynamics at fast time-scales.

B

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Outflows from the type I quasar at high-z: molecular gas in the host galaxies

There is accumulating evidence for a strong link between the evolution of massive galaxies and the super-massive black hole (SMBH) that they generally host in their centre. A key element of this mutual dependence is a powerful AGN wind that is triggered by the intense accretion. Recently, we show that identification of the molecular hydrogen absorption systems with leaking Ly-alpha emission using SDSS spectra allow us to pre-select type I quasars with active multiphase outflows. In this talk I will present the result of the follow-up observations of one of such quasars J0015+1842 with redshift z=2.631. In particular, 3-mm observations of this system with the NOrthern Extended Millimeter Array (NOEMA) reveals a large amount of the molecular gas MH2 ≈ (3–17) ×10^{10} M_{\odot}, traced via CO(3-2) line. J0015+1842 is located in the molecular gas-rich region in the IR vs CO line luminosity diagram, in-between the main locus of main-sequence and sub-millimeter galaxies and that of most luminous AGNs targeted so far for CO measurements. The large observed velocity dispersion of the CO line (FWHM = 1000±100 km s^{−1}) suggests a post-merger system, while J0015+1842 is observed to be a regular, only very moderately dust-reddened (AV ∼ 0.3–0.4) type-I quasar from its UV-optica spectrum. We suggest that J0015+1842 is observed at a galaxy evolutionary stage where a massive merger has brought significant amounts of gas towards an actively accreting super-massive black hole (quasar) that already cleared the way in the circum-nuclear region towards the observer through powerful winds, while the host still contains a large amount of dust and molecular gas with high velocity dispersion. Observations of a sample of similar systems should help determining better the respective importance of evolution and orientation in the appearance of quasars and their host galaxies and have the potential to investigate early feedback and star-formation processes in galaxies in their quasar phases

B

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The future of the millimeter range astronomy in Russia

After the commissioning of the ALMA array of millimeter and submillimeter telescopes of the European Southern Observatory and its partners in 2013, the coldest objects in the Universe became available for study: giant clouds of gas and dust in interstellar space, from which stars, planets and the first galaxies are born. Although observations in the millimeter wave range have been carried out in the past in other observatories, the ALMA project has revolutionized research in this range of electromagnetic radiation.
In our country, the largest millimeter-wave project has become the MILLIMETRON project, which has no analogues in the world. The most important object of the ground part of this project was to be the RT-70 telescope on the Suffa plateau in Uzbekistan. Its construction was stopped after the collapse of the USSR. At present, thanks to the development of cooperation between Russia and Uzbekistan and the attention shown to the project by the leaders of the two countries, there is every chance to complete the creation of this instrument. However, today, almost 40 years after the start of work on the project, it is necessary to carefully analyze the relevance of the scientific problems that were posed at that time and revise the technical ideas that formed the basis of the project. The limitations of observing capabilities due to climatic conditions on the Suffa Plateau should also be carefully considered. After a representative delegation visited the Suffa observatory in 2018 with the participation of the presidents of two academies, the Russian and the Uzbek, the possibility of installing an instrument of a smaller diameter on the plateau began to be considered. Relatively small (10-12 m) antennas for observations in the millimeter wave range can be purchased from well-known European suppliers: EIE (Italy) and Vertex (Germany). However, in conditions of significant absorption of radiation at an altitude of 2600 m, they will only be able to register signals from bright sources. To work on a wide range of scientific problems, collecting surfaces with a diameter of at least 20 m are required. Such antennas can be built by domestic industry by ROSTECH enterprises. For example, consider designing antennas with active composite mirrors made of aluminum or silicon carbide as the bearing surface. Examination of the design of the RT-70 telescope, and then the completion of its construction, should be carried out in parallel with the creation of smaller instruments. A separate problem is the development of highly efficient receivers for the sub-terahertz range. Given the current state of development in this area, we will be forced to develop broad international cooperation if receivers are needed in the next 5-10 years. An interesting development of the project, and, possibly, its only implementation that is significant for modern science is the creation of a long-base interferometer, which could be included in a system such as the Event Horizon Telescope. It is quite obvious that the second antenna of the interferometer arm should be installed on the territory of Russia, possibly in one of the observatories in the North Caucasus. This will allow working out technologies for creating and controlling antennas for sub-terahertz waves, radiation detectors, and training a sufficient number of specialists that we do not have now.

B

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Direct Detectors for Radio Astronomy

Incoherent, direct detectors are used in astronomical instrumentation which does not require extreme spectral resolution or radio interferometric observations. This technology does not have a principal quantum sensitivity limit, which makes it especially attractive to use in telescope with very low parasitic background, such as Millimetron Space mission. Direct detectors are used in large scale focal plane arrays both in space and ground due to their large multiplexing ratios. Another applications for this technology is low-medium spectrometer instruments, based on Grating, Fabry Perot resonator or Fourier Transform Interferometer principles.
We will discuss the principle and current status of major direct detector technologies such as microwave kinetic Inductance detectors, transition edge censors, quantum capacitance detectors and bolometers on cold electors. We will overview achieved multiplexing factors, arrays sizes, raw sensitivities, bandwidth coverage and saturation effects. We will discuss impact of detector sensitivity on actual performance of low background space mission such as 10K 10m diameter telescope of Millimetron space mission.

B

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The Millimeter Valley Between Dust and Synchrotron Emission in Nearby Galaxies

With the recent advancements in millimeter and submillimeter instrumentation, work has been ongoing to examine this part of the spectral energy distribution in galaxies, which covers the transition from dust emission at shorter wavelengths through free-free emission to synchrotron emission at longer wavelengths. However, this part of the spectral energy distribution still remains poorly characterized. I will discuss what has been found so far in these wavebands, including mentioning some rather unusual sources of continuum emission, and also set out some challenges for future research. I also describe the possibilities for measuring star formation at submillimeter and millimeter wavelengths and the opportunities for probing nearby galaxies' nuclei with Millimetron.

B

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Simulating the infrared sky with a SPRITZ

Current hydrodynamical and semi-empirical simulations of galaxy formation and evolution have difficulties in reproducing the number densities of IR-detected galaxies. Therefore, a versatile, phenomenological new simulation tool is necessary to reproduce current and predict future observations at IR wavelengths. In this talk I will introduce the new SPRITZ (spectro-photometric realisations of infrared-selected targets at all-z) simulation which starts from the Herschel infrared luminosity functions and contains both galaxies and active galactic nuclei. I will show that the SPRITZ simulation well reproduces a large set of available observations and it can be used to obtain, in a fully consistent way, simulated observations for a broad set of current and future IR facilities with photometric capabilities as well as low-resolution spectroscopy.

B

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New Precise Petal-type Reflector for Space Radio Astronomy

The possibility to create mm-band space radio telescope without adaption of reflecting surface of main mirror antenna is considered A new design and a new scheme for petal antenna deployment are proposed. A mathematical model of deployment kinematics is built. The results of computer and physical modeling of a new technical solution are presented.
The work was partly supported by RFBR grant № 17-29-10039.

C

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MHD modeling of shadows and rings from black holes. Problems and it's solutions

The report is devoted to the problems of MHD modeling of shadows and rings from black holes. It will be shown by the example of Sagittarius that the images from black holes are strongly model-dependent and that the polarization strongly restricts the parameters of the model.

C

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Onboard electronic complex

The onboard electronic complex is designed to provide radio-astronomy observations in the modes of a single telescope and a terrestrial space interferometer, collecting and storing the scientific information of the specified format and subsequent transmission through a highly informative radio complex.

C

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Asymmetry of the CMB map: local and global anomalies

The low-multipole anomalies of the CMB include the parity asymmetry, the dipole modulation, and the quadrupole-octupole alignment. We investigate these anomalies in the pixel domain and find them concentrated in a "ring of attraction" orthogonal to the kinematic dipole of the CMB, and we analyze the interaction of the low multipoles with this ring.

D

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Images of black holes

Shapes of black hole images, viewed by a distant observer, depend on the distribution of emitting matter around black holes. There are two distinctive astrophysical cases: (1) Luminous stationary background behind the black hole (emission of photons outside the photon spheres). In this case the dark classical black hole shadow is viewed, which is a capture photon cross-section in the black hole gravitational field. (2) Luminous accretion inflow near the black hole event horizon (emission of photons inside the photon spheres). In this case the dark event horizon shadow is viewed, which is a lensed image of the event horizon globe. This event horizon shadow is projected at the celestial sky within the possible position of the classical black hole shadow. The Blandford-Znajek process is a suitable model for the General Relativistic Magnetohydrodynamics (GRMHD) accretion onto black holes, in which the inflowing plasma is strongly heated even in the vicinity of event horizon by the radial electric current. Nowadays the GRMHD numerical simulations confirm this model. In particular, the dark silhouette of the event horizon shadow (rather than the classical black hole shadow) is viewed at the image of supermassive black hole M87* obtained by the Event Horizon Telescope collaboration. The classical black hole shadow is very difficult to observe by VLBI methods in view of the insufficiently strong brightness of the standard astrophysical backgrounds (extended hot gas clouds or stars). Meanwhile, the brightness of accretion inflow may far exceeds the corresponding one from extended hot gas clouds or stars. The unique information for the verification of gravitation theories in the strong field limit will be provided by the detailed observations of the black hole images by using the Millimetron Space Observatory.

D

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Emission from hot bubbles by a quiescent star formation

A relatively weak star formation in the central regions of galaxies is believed to form hot extended bubbles rising to heights of several to tens of kiloparsecs above the galactic midplane. Such structures are observed both in several local edge-on galaxies and in our galaxy. We follow numerically the evolution of such bubbles and study their emissivities in various energy ranges. We find a relatively tight correlation between IR emission produced by dust grains and X-rays from hot gas. We discuss possible destruction of dust grains in a warm-hot gas inside such bubbles.

E

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Sources of confusion noise of the Millimetron Mission

Sensitivity of future far infrared 10m class space telescopes will be limited by a confusion noise created by distant galaxies. Here we use the definition of the confusion noise as the FWHM of the left side of the pixel histogram. With help of previously developed model of extragalactic background we considered various factors that influence the estimations of the confusion noise.
We show that:
(1) The presence of the Large Scale Structure is crucial to the estimations of the confusion noise;
(2) The effects of gravitational lensing play negligible role;
(3) We came to the following conclusion about the redshift interval of objects that create the confusion noise.
The minimum redshift z_min does not significantly depend on the wavelength and is about 0.5-0.6, the maximum redshift gradually changes from ~4 to ~3 from 70um to 2000um.
(4) On short wavebands the main bulk of the confusion noise is created by galaxies with luminosities in range 10^7L_\odot — 10^9L_\odot, while at longer wavelengths galaxies with L\geq10^{10}L_\odot give the most contribution.
(5) On short wavebands the confusion noise is created by objects that contribute significantly to the confusion in the closest longer waveband and give relatively small contribution to the adjacent short waveband.
Towards longer wavelengths the situation gradually changes to the opposite.

F

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Dusty Galaxies in the Epoch of Reionization

When did dust first appear on the cosmic scene? What were the sources that enable a fast dust enrichment of the interstellar medium of galaxies? At a time in which ALMA (and soon JWST) begins to scratch the surface of these problems, it is crucial and timely to consider what these amazing data can bring to these important and yet unknown aspects of early galaxy formation and evolution. Dust could not only affect the physical properties and the star formation history of pristine systems; it might at the same time affect their visibility and infrared emission. In addition, it might be also responsible for the transition from metal-free (Pop III) stars to the most common ones seen today. These problems need to be solved in the framework of studies that combine cosmological simulations and the most advanced IR/sub-mm observations. I will review in detail the present status of this blossoming field.

G

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High resolution – high frequency properties of relativistic jets in AGN

In recent years sensitivity VLBI imaging at high frequencies and high resolution has become possible. Wide banding observing and more available telescopes provide important results on jet starting regions and jet properties. After a short review of available arrays I will show recent results on selected radio galaxies and I will highlight obtained results. I will focus on results obtained at 7, 3 and 1 mm thanks also to the EHT. I will conclude discussing the large improvement provided by future possible space VLBI observations with Millimetron.

G

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Development and application of terahertz hot electron bolometers

The development of techniques and technologies for the deposition of ultrathin superconducting films, the creation of superconducting structures on a nanometer scale is the basis of significant progress in the field of superconducting receiving systems. Ultrathin NbN films are the basis for a wide range of record-breaking hot electron devices: direct and heterodyne terahertz detectors. Terahertz receivers are especially in demand in high-resolution spectroscopy for astronomical, atmospheric, and medical research.
HEB receivers are widely used in terahertz radio astronomy. For example, the Dutch SRON Institute is preparing a project for the GUSTO hot air balloon telescope with a HEB mixer array at 1.4 THz and 1.9 THz. A 5-meter Chinese terahertz telescope DATE5 with HEB mixers at 1.4 THz is installed at the South Pole. The Stratospheric Observatory (SOFIA) uses HEB mixer matrices in the GREAT instrument operating in the 1.2 - 4.7 THz range. It is planned to implement the international project Origins Space Telescope (OST) in the far infrared region based on HEB receivers. The Japanese project Smiles-2 will allow measurements at 1.8 THz in the upper layers of the stratosphere and mesosphere. The development of the Millimetron space observatory continues in Russia.

G

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Millimetron payload module design

Millimentron Space Observatory is a mission of large-sized cryogenic telescope with a 10-m diameter deployable primary mirror for operation in the submillimeter and far-infrared wavelength ranges. The primary mirror consists of a 3-meter diameter solid central part surrounded by 24 deployable petals. The deployment concept is based on the previously implemented structure in the Radioastron project. In order to achieve the required high surface accuracy of the primary mirror after the deployment and compensate reflecting surface distortions under the action of space environment factors, each petal is composed of a supporting spatial frame and three independent reflecting panels. The panels are mounted on the supporting frame via precise cryogenic actuators to adjust their reflecting surface. An active surface control system is used to control all reflecting panels of the mirror by using wave-front sensing. Additionally, providing a lightweight structure with high thermal stability, a high modulus carbon fibre reinforced plastic (CFRP) has been chosen for the material of the primary mirror.
The Millimetron mission will be launched into a halo orbit around the second Lagrange Point (L2) in the Sun-Earth system to obtain a stable thermal environment, which allows us to use effective radiative cooling in combination with a mechanical cooling system. Therefore, the telescope is equipped with large thermal shields to cool the telescope passively to temperature of 40 - 60K. Besides, there is the nearest to primary mirror cryogenic shield, which should be actively cooled to 20K. The thermal shield subsystem and the payload module basic structure with low thermal conductance separate the observatory into a warm sun-side part and a cold part.
This report introduces details of the Millimetron payload module design, focusing on the incremental development efforts for the antenna and thermal design.

G

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Accretion onto supermassive black holes and jet formation: prospects for future ngEHT and space mm-VLBI observations

The processes that determine the formation, acceleration, and collimation of powerful relativistic jets in AGN and X-ray binaries are a long-standing mystery in black hole physics. VLBI observations at progressively shorter wavelengths, and the addition of orbing antennas such as Russian's space VLBI mission RadioAstron, have made it possible to probe the jet formation regions with unmatched angular resolutions. The unprecedented ground-based coverage that the ngEHT will provide and the possibility to perform space VLBI observations with future mm-wave orbiting antennas, such as Millimetron, opens up for the first time the possibility to determine how jets are powered and launched, to test the Kerr metric in SgrA* and M87, to determine black hole spins, and to study supermassive binary black holes in connection with future space-based GW detectors, among other key science projects.

G

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Submillimeter and Millimeter Astronomy: Evolution and Future Perspectives

Topics that will be addressed are:
- Characteristics of the FIR/submm wavelength region and relevance for astronomy and astrophysics
- Past and present submm/mm observing facilities and associated science highlights
- Evolution in submm/mm technology and astronomy: technology and science, a cybernetic unity in the early development phase
- Significance of achieved science results
- Requirements and desirables for future submm/mm projects/missions
- Future Projects/Space Missions
- Preliminary Conclusions

G

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The assembly of dusty galaxies at z>4

The existence of high redshift (z>4) dusty galaxies is nowadays confirmed by a robust series of observations demonstrating that dusty, star forming objects are evolving within the Epoch of Reionization (EoR, z>6) when the universe was only 1 Gyr old. As more observations are about to come thanks to ALMA and future observational facilities (e.g. JWST), present theoretical models of galaxy formation and evolution require significant updates in order to predict the properties of the interstellar medium of these objects. In this talk I will discuss the results of a new generation of hydrodynamical simulations performed with the dustyGadget code (Graziani 2020 MNRAS), combined with detailed multi-frequency-band radiative transfer simulations. I will show our predictions on high redshift scaling relations, updated estimates of the mass of dust, the chemical composition of grains, their temperature and charge in different phase of the ISM and how they evolve during the process of galaxy assembly, all the way down to z=4 where robust constraints are provided by the recent ALPINE survey. Prediction on the galaxy spectral energy distributions are also discussed and compared with recent observations. Finally, the impact of dust on the process of Reionization and Metal Enrichement of the surrounding Intergalactic medium is addressed by showing the properties of their HII dusty regions at the extragalactic scale.

G

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Obscured Star-Formation in the Early Universe

Although a substantial fraction of the star formation in the Universe is heavily enshrouded by dust, our current knowledge of the cosmic star formation rate density (SFRD) at high redshift (z > 3) is based mostly on galaxy samples selected in the UV rest frame. This has long been an obstacle to our capacity of obtaining a complete picture of galaxy evolution. The Atacama Large Millimetre/submillimetre Array (ALMA) has now opened a gap in the wall, allowing us to refine our understanding of dusty galaxies at high redshifts by unveiling normal galaxies and heavily obscured ones (e.g., HST-dark galaxies). There is increasing evidence that the SFRD at z>3 remains as high as at cosmic noon over at least up to z~6. These new discoveries, having important implications for our understanding of the formation and evolution of galaxies and the overall star formation history of the Universe, show that our current knowledge of the high-z SFRD is still far to be complete. A complete understanding of how galaxies form and evolve requires investigating, on one hand, the constituents of galaxies (i.e., gas, stars, dust, supermassive black holes) and, on the other hand, the mutual interactions and relations which concur to the so-called baryon cycle. Only a sensitive spectroscopic facility in the mid-IR-to-mm range will provide a clear understanding of how cosmic star-formation, accretion, and galactic outflows relate to the physical conditions in galaxies. Here I will present the recent results obtained by the ALMA large programme ALPINE and discuss the badly need for future facilities in the IR/mm domain.

H

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Scientific tasks for studies of galactic molecular clouds with RT-70

We present the parameters and descriptions of promising objects for observation by the RT-70 millimeter-wave radio telescope being under construction on the Suffa plateau (Uzbekistan). Assessments of what can be done with the RT-70 and their analysis have been made. Some items related to the scientific program for the RT-70-Suffa radio telescope are also discussed.

J

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(E)KVN: Simultaneous Multi-Frequency (18 - 150 and 230GHz) VLBI System

The Korean VLBI Network (KVN) consists of three 21m radio telescopes in Korea with the world's first 4-channel receiver that can observe four different frequencies (e.g., 22, 43, 86, 129 GHz) simultaneously. This receiving system of KVN is particularly effective in millimeter-wavelength VLBI (mm-VLBI) observations by compensating fast atmospheric fluctuations effectively. This technology is now being enhanced with a compact triple-band receiver, which can be easily implemented in reduced size. Thus, there are a growing number of radio telescopes to introduce it. In 2020, the construction of a new KVN telescope was approved and is currently underway. The new telescope is almost identical to the current KVN telescope, but it will have better surface accuracy to extend operation frequency up to 230 GHz. Together with on-going development of a wideband receiving system, the (E)KVN is highly expected to explore the wider and more fundamental issues of science in millimeter wavelengths.

K

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Images of Class I methanol masers in the regions of low-mass star formation

In the past few years several Class I methanol masers (MMIs) were found in nearby low-mass star formation regions They were detected in Class I lines 4_{-1}-3_0E at 36~GHz, 7_0-6_1A+ at 44~GHz, 8_0-7_1A+ at 95 GHz, and 6_{-1}-5_0E at 132 GHz. The main properties of these masers (LMMIs) proved to be similar to those of masers in the regions of massive star formation (HMMIs), showing that LMMIs are an extension of HMMI population toward low luminosities of both the masers and associated YSOs. Exploration of LMMIs might be more straightforward compared to that of HMMIs. Below we present the results of the observations of three maser sources performed at 44~GHz with the EVLA and the results of CARMA observations of thermal methanol lines 5_K-4_K at 241 GHz toward one of the masers, L1157. Deconvolved maser spot sizes fall within the range 0.10" - 0.3" (30-90 AU, respectively). The brightness temperatures of the strongest spots are as high as ~10^5 K. Maser spots often consist of two or three closely spaced components. Most likely, these masers are unsaturated. The turbulence model of Sobolev et al. (1998) poorly agrees with our observations. Probably the masers arise in vortices with the axes parallel to the line of sight.

K

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Primary disks and their observational appearance in collapsing magnetic rotating protostellar clouds

We present numerical simulations of the collapse of magnetic rotating protostellar clouds, performed using the modified two-dimensional MHD code Enlil. The simulations are performed taking into account the formation of the first hydrostatic core. The main attention is paid to the formation and properties of quasi-magnetostatic primary disks formed at the initial stage of collapse. The mass, size, angular momentum, magnetic flux and lifetime of the primary disks are determined depending on the initial parameters of the cloud. Possible observational features of the primary disks, including those in the submillimeter range, are discussed.
This work was financially supported by the Russian Science Foundation (project 19-72-10012)

K

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Physical and chemical vertical structure of the magnetostatic accretion disks of young stars

Physical and chemical vertical structure of the magnetostatic accretion disks of young stars We investigate vertical structure of the accretion disks of young stars with fossil large-scale magnetic field. To simulate the vertical structure of the accretion disk, we solve the equation of magnetostatic equilibrium taking into account stellar gravity, gradients of gas and magnetic pressure. Thermal structure of the disk is calculated from the equation of heat transfer including effects of heating by turbulence and stellar radiation, as well as radiative cooling. Ordinary differential equations of the model are solved with the Runge-Kutta scheme of the 4th order. Radial structure of the disk is calculated with the help of the model of the accretion disks developed by Dudorov and Khaibrakhmanov. Simulated physical structure of the disk is used to model its chemical structure using the MONACO code. On the basis of the chemical modelling results, we analyze features of spatial distribution of CN molecules, which are the promising tool to measure the disk's magnetic field strength by detection of circular polarization due to the Zeeman splitting of the molecular lines.
The work is supported by the Russian Science Foundation (project No 19-72-10012).

K

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On the projects of ground-based MM and SubMM telescopes and the development of the concept of the ESMT project

New problems in submillimeter astronomy require the creation of instruments that combine high sensitivity, angular resolution, wide field of view, and multi-wavelength (multicolor) spectral range. The appearance of large mm / submm telescopes in Eurasia is long overdue; in recent decades, the astroclimate of possible sites for placing an MM / subMM telescope in the Russian Federation and the development of sub-THz receiving technologies have been actively studied [1]. An overview of existing large MM / subMM telescopes is given, projects of large ground-based instruments of the sub THz range, conditions and possibilities of their implementation are considered. The results of the development of the concept of the ESMT project [2] are presented from the point of view of methods for studying the astroclimate, optimizing the optical scheme, FOV, image field, achieving the required accuracy parameters, using active optics, multicolor receiving cameras of extreme sensitivity with a large number of detectors (10^4-10^5). An assessment of the possibility of using classical methods for measuring and suppressing atmospheric fluctuations such as WVR, wobbling, EKH, reference object method, Fast Scanning, as well as adaptive optics methods for studying the statistics of wavefront tilt variability and improving image quality in «tip-tilt correction» and «smart wobbling» modes are given.

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K

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SIS Receivers for Radio Astronomy – overview of existing instrumentation

Receivers based on superconductor-insulator-superconductor (SIS) mixers are known to be the most sensitive high resolution ($R>10^6$) instruments in the wavelength range 0.3-3 mm (100 - 1000 GHz). As result, they are widely used at astronomical telescopes and observatories. This report presents an overview of existing heterodyne instruments based on SIS receivers and review the observatories utilizing them. The observatories include existing ground based single dish telescopes (APEX, JCMT, LMT, GLT, IRAM and others) and interferometers (ALMA, NOEMA, SMA, CARMA, Nobeyama). Additional attention will be dedicated to the planed onboard instrumentation for space mission Milllimetron. Another possible future facilities like Origin Space Telescope (OST) and ground based telescope AtLaST will be mentioned as well.

K

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Non-stationary photodissociation regions around young massive stars

Massive O and B-stars reveal the places of their birth by powerful UV radiation and stellar winds, which ionizes hydrogen atoms and leads to the formation of non-stationary HII regions and wind-blown bubbles. They are surrounded by photodissociation regions (PDRs), where the physical, chemical conditions in gas and dust, as well as their dynamics are defined by absorption of FUV photons of 6-11 eV. Therefore, the heating and mechanical feedback from the massive stars are transferred into the interstellar medium in PDRs. The PDRs can be observed with the main cooling lines as [CII] at 158 and [OI] at 63 micron, but these lines are optically thick, because they are formed not only in the PDRs but also in foreground cold neutral medium. We combined several optically thin and thick lines of atomic and molecular species in far-IR, submm and mm wavelengths to study expanding HII regions in different evolutionary stages from young and compact to old and extended. We found low expansion velocities about 1-2 kms(-1) which are in agreement with theoretical models.

K

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Superconducting sub-THz receivers for space and ground-based radio astronomy

no abstract

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Turbulence in gas-dust optically thick interstellar clouds: radiation-convective model

The results of numerical two-dimensional modeling by methods of radiation hydrodynamics of convective instability developing in an optically thick gas-dust cloud are presented. Axisymmetric models are considered, which take into account radial radiation transfer, self-gravity of the medium, and polydispersity of dust. The radiation source located in the center of the cloud creates an inverse distribution of temperature and density due to inhomogeneous heating of the cloud along the radius due to scattering and absorption of radiation by the dust. The conditions for the development of instability first arise in a thin inverted layer, and then the development of convection leads to turbulization of the cloud throughout the entire thickness. The vortices grow over time in sizes from hundredths to several tenths of the Jeans length, which determines the characteristic size of the cloud. The advanced stage of turbulence takes on a transonic character with Mach numbers up to 1.2; however, supersonic regions occupy a small part of the cloud volume. Modeling shows that the proposed mechanism for the formation of thermal turbulence in a stratified optically thick medium can explain the presence of transonic turbulence observed in clouds on parsec and subparsec scales.
The reported study was funded by RFBR, project number 20-02-00913_a, and by RFBR and the government of Volgograd region according to the research project 19-42-343005-r_mol_a.

K

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Probing the event horizon scales with multi-frequency polarization Space VLBI visibility tracking

In this report we discuss prospects of the Space VLBI capability of the very sensitive Millimetron space dish to study properties of black holes in our and other galaxies. In particular, the subrings produce significant interferometric signatures on the extraordinarily fine scales that ground-to-Millimetron baselines will probe, and the simplicity of these signatures will allow measurements of the black hole's mass and spin with a single baseline as well as tests of general relativity. We will also discuss selected results of the RadioAstron AGN survey which affect planning of these future total and polarized visibility-based millimeter SVLBI experiments.

K

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Polarimetry of active galactic nuclei in ground and space VLBI observations

In our current understanding, powerful relativistic jets in active galactic nuclei (AGN) are produced by dynamically important magnetic fields, which can be best studied in polarimetric observations. Moreover, ground and space VLBI observations in cm-and mm-wavelength ranges allow us obtaining the highest angular resolution and resolving the innermost regions of AGN jets and vicinity of super massive black holes (SMBH). The feasibility of space-VLBI polarimetric imaging was successfully demonstrated in observations with satellite antennas of the VSOP (Japan) and RadioAstron (Russia) projects. The results of these missions show that existing methods for estimating instrumental polarization are not only applicable in space-VLBI, but also provide the high accuracy required for such kind of studies.
In this talk, I will summarize the results of the RadioAstron polarization observations, which were carried out in the framework of the key science program on the polarization imaging of AGNs in 2012-2018. The most important results include the highest angular resolution ever achieved for sources at cm-frequencies, and the most detailed radio polarimetric images of AGN jets, providing the ground for our better understanding of nature and physics of AGN jets and vicinities of SMBH.
Besides, these new polarimetric results show importance and feasibility of further polarimetric studies in in future ground and space-VLBI missions. For example, one of the promising methods to probe polarized structure of AGN jets is Faraday rotation and Faraday synthesis at short wavelengths (mm and submm). Due to low depolarization within the receiving band, and an absence of synchrotron absorption, it is an ideal tool for tracing AGN magnetic fields in the vicinites of SMBHs, and is a useful diagnostic in probing of accretion rates and even physics of wormholes, while Faraday rotation delivers the least model dependent information on these physical properties.

K

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Multifrequency receiving systems based on planar slot antennas with cold-electron bolometers for radio telescopes COrE and LSPE

Multifrequency receiving systems based on cold-electron bolometers (CEB) for radioastronomy telescopes LSPE and COrE have been developed. Receiving systems are based on planar slot antennas. In the course of the research, numerical modeling, sample fabrication and measurement of the frequency response of receiving systems with CEB were carried out. The frequency response of a planar concentric shell-type antenna system with CEB, developed for use in the COrE orbital radiotelescope of the European Space Agency, was studied numerically and experimentally. The formation of a resonant frequency response in a system with a kinetic inductance [1] and using the resonant properties of a slot antenna with a coplanar line [2] for channels 75 and 105 GHz is demonstrated. Numerical modeling of a single receiving cell and a matrix of receiving antennas of auxiliary frequency channels 220 and 240 GHz for the LSPE project was carried out [3]. The presence of narrow resonances with a width of about 5% at the operating frequencies of the system is shown, which meets the LSPE requirements for the bandwidth of the auxiliary frequency channels. A technique has been developed for studying the amplitude-frequency characteristics of bolometric structures using a Josephson traveling wave generator based on an HTC YBCO film, located in the same cryostat as the bolometric receiver [4]. A numerical and experimental study of the frequency response of a single receiving cell of the LSPE project at 220 and 240 GHz has been carried out. The AFC was measured by irradiating the structure under study with a Josephson traveling wave generator based on an HTC YBCO film [5]. The correspondence of experimental data and simulation results is shown. The developed technique with concentric antennas and CEB makes it possible to create multifrequency systems with an unlimited number of channels. For example, the 90/145/220 GHz system, which is popular with radioastronomers, can be developed to study the Sunyaev-Zeldovich effect.
This work was carried out with financial support from the Russian Science Foundation (Grant No. 21-79-20227).

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L

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Relation between star formation traced by water masers and physical parameters of dust clumps in the submillimeter wavelength range

This work investigates the relationship between the star formation process and the physical parameters of dust clumps from the ATLASGAL submillimeter survey at 870 μm. The emission of a water maser was used as an indicator of star formation. A generalized linear model is used to determine which physical parameters of ATLASGAL clumps are most sensitive to the early phase of star formation, which manifests itself through a water maser's emission. These parameters are dust temperature (Tdust), bolometric luminosity (Lbol), mass (M), and gas concentration (n). The generalized linear model allows determining the probability of detecting a water maser in a dust clump, depending solely on its ATLASGAL physical parameters. The model prediction accuracy was found to be 70%. For bright water masers (> 6 Jy), using the detection probability threshold of 0.98, the model accuracy was as high as 93%. One compared the prediction accuracy using the generalized linear model with the prediction accuracy using the neural network analysis on the same training dataset. The prediction accuracy for neural networks (70%) is the same as the generalized linear model's (70%). Thus, the found model makes it possible to quickly estimate the early star formation phase's onset probability in dust clumps, which manifests itself through a water maser's emission. The used parameters for prediction are the dust clumps physical parameters in the submillimeter wavelength range. One can use this result to analyze new data from the Millimetron space telescope.
This work was supported by the Russian Science Foundation grant No. 20-72-00137.

L

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On the advantages of the Eastern Pamirs for sub-mm astronomy

Thanks to the first mm studies on the territory of the former USSR in the early 1960s and succeeding sub-mm measurements in the 1970s – early 1980s at wavelengths up to 0.34 mm, a completely unique astroclimate was revealed in the Eastern Pamirs, only slightly inferior to the available conditions on the Chajnantor plateau in Chile and Mauna Kea. Due to its high plateau altitude (4300 – 4500 m) surrounded from all sides by high (~7000 m) air-drying icy mountains and remoteness from oceans this area has the lowest relative humidity in the former USSR and extremely high atmospheric stability. In particular, direct measurements of precipitated water vapor in the winter months showed typical pwv=0.8 – 0.9 mm with sometimes 0.27 mm. To validate previous studies and to compare them with results for other similar regions we performed opacity calculations at mm – sub-mm wavelengths for different sites in the Eastern Pamirs, Tibet, Indian Himalayas, APEX, ALMA, JCM, LMT and many others. To do this we integrate radiative transfer equations using the output of NASA Global Modeling and Assimilation Office model GEOS-FPIT for more than 12 years. We confirm previous conclusions about exceptionally good astroclimate in the Eastern Pamirs. Due to its geographical location, small infrastructure and the absence of any interference in radio and optical bands, this makes the Eastern Pamirs the best place in the Eastern Hemisphere for both optical and sub-mm astronomy. Taking into account the observing experience, the criteria for choosing the best sites for submm measurements are given, which are the determining factors for the successful research.
The research was carried out within the IAP RAS state program 0030-2021-0005.

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Study of best sites for ground based mm-wave radio telescopes

Nowadays, thanks to the development of the modern telescopes, active monitoring of their surfaces, and high sensitivity radiometers, a significant progress is observed in a ground-based mm radio astronomy including commissioning of such instruments as QTT, SRT, TNRT, KVN, ngVLA, etc. In order to assess the potential of the domestic astronomy, to select the best places for new mm-wave radio telescopes, we carried out the astro climate studies in a wide range of wavelengths from 17 to 2 mm. To do this we integrated radiative transfer equations using the output of NASA Global Modeling and Assimilation Office model GEOS-FPIT for more than 12 years for different sites in the middle part of Russia, Crimea, Siberia and Caucasus. Additionally we analysed the domestic weather archives. Finally, the obtained results were compared with our calculations for Effelberg, Onsala, GBT, Nobeyama, KVN and some others. The conclusions were made for a choice of new sites and to upgrade the existing instruments.
The research was carried out within the IAP RAS state program 0030-2021-0005 and the Russian

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Gravitational lensing and Hubble tension problem with Millimetron

The prospects of observation of gravitationally lensed sources in far-infrared and submillimeter wavelength ranges by MSO are discussed. The possibility of solving some important cosmological and astrophysical scientific problems, including the problem of the Hubble tension, by observing gravitationally lensed sources is considered.

L

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Millimetre VLBI probes of physics down to the event horizon scale

Ground and space VLBI observations made at millimetre wavelengths provide arguably the best tool for making accurate measurements of brightness temperature, polarization, and opacity of radio emission on scales approaching to the very vicinity of the event horizon scale in compact relativistic radio sources. Combining together these measurements will enable the most accurate reconstruction of the magnetic field properties to be made and used for investigating the physical nature of black holes and their exotic "mimickers" such as wormholes and gravastars. A brief review of current results and future prospects in this area of study will be presented.

L

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Cosmology with the SZ spectrum: measuring the Universe's temperature and expansion with galaxy clusters

The Millimetron space telescope has among its main scientific goals that of checking the limits of applicability of modern cosmological theory. In this context we focus on what can be learned on the temperature evolution and expansion history of the Universe by using low-resolution spectroscopy of the SZ effect.

M

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Shorbulak (Eastern Pamirs) vs Chajnantor Plateau (Chilean Andes, Atacama Desert): a brief astroclimatic comparison

Shorbulak, at Eastern Pamirs, a former astronomical point of Pulkovo Observatory (currently, under the guidance of Institute of Astrophysics, The National Academy of Science of Tajikistan), at the altitude of 4350 meters above the sea level, is one of the most promising sites on the globe for millimeter and submilieter observations.

M

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On the development of radio-antennas for mm/sub-mm observations: an industrial perspective

The application of radio-technologies to astronomy has greatly expanded our understanding of both the astrophysical and cosmological universe. Despite this, new and unexpected challenges, like H0 tension, CMB anomalies, and DM modeling, are burning some of the fundamental theories of modern cosmology and astrophysics. Under this perspective, innovative high sensitive radio-telescopes combining good angular resolution, wide field of view, and multi-wavelength observational range could mark a significant turning point. Starting from the experience gained in the framework of the Atacama Large Millimeter Array, where EIE GROUP led the design and manufacturing of the prototype and of the serial production of the 25 European units, the aim of the paper is to provide an engineering and managerial perspective on the main issues encountered during the development of mm / sub-mm antennas, from the development of the engineering requirements, to the commissioning of the system. The main topics will be discussed and a possible roadmap for the development of complex scientific infrastructure is proposed, from the definition of the early conceptual design to the construction phases.

M

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Black Hole Shadow Observations with Space-Ground Interferometers

The study explores black hole (BH) shadow images which can be restored by data processing and image recovery procedures during space Very Large Baseline Interferometry (VLBI) missions in the future. For Kerr BHs with masses and coordinates of SgrA*, M87*, and M31*, all illuminated by a light source behind them, three kinds of observation are considered: the ground-based interferometer (similar to the Event Horizon Telescope), space-ground interferometer with a satellite in geocentric orbit, and spaceground interferometer with a satellite located in Lagrange point L2. The significant difference between the images produced by the ground-based telescope alone and ones from the space VLBI with an added low-orbit satellite is caused by both the increased baseline and the improved (u,v) coverage. The near-Earth configuration of the radio interferometer for BH shadow observations is the most preferable among the considered cases. As the orbit radius increases up to the Lagrange point L2, the density of the (u,v) filling decreases and the results appear less reliable. Model images for all the cases are presented.

M

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Catalog of supermassive black holes for interferometric observations

We present a catalog of supermassive black holes (SMBHs) sharpened for interferometric observations at millimeter and submillimeter wavelengths, based on open sources. The catalog includes the object's name, coordinates, angular size, and mass, the angular size of the gravitational radius of the SMBH, and the integrated radio flux associated with the radiosource concluding the SMBH at 20–900 GHz, planned for the Event Horizon Telescope, the future space mission Millimetron, and others. The catalog is intended for use during planning of interferometric observations of SMBH shadows.

M

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Millimeter astronomy in Russia: what, where and when?

Millimeter and sub-millimeter astronomy has opened a new window in the study of the universe in almost all areas of astrophysics. As a result, the transition to shorter wavelengths has significantly improved the angular resolution of ground instruments, allowing them to explore objects with even greater detail. Unfortunately, Russia has little or no involvement in this process. In the last few years there have been various discussions about the development of millimeter and sub-millimeter astronomy. The report will address:

1) Today's state in Russia;
2) Overview of leading foreign (international) observatories;
3) Offers to choose an antenna;
4) Proposals for choosing the location of the radio telescope installation.

N

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Anisotropic SZ effect and independent estimation of the CMB anisotropy low multipoles

Stokes parameters frequency spectral distortions arising due to Compton scattering of the anisotropic CMB radiation towards clusters of galaxies gives us an opportunity for an independent estimation of the low multipole angular CMB anisotropies: dipole, quadrupole and octupole. Using distorted signal from nearby and distant clusters one can also distinguish between the Sachs-Wolfe and the Integrated Sachs-Wolfe effects.

N

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Shock-excited Infrared signatures in ULIRGs

We initiate a systematic study of collimated fast wind on a galactic scale as well as accurately track the formation of H2 in the cooling regions to see how it may affect the molecular content for star formation in ULIRGs.

P

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Cold-Electron Bolometers for Radio Astronomy Missions

The cosmic microwave background (CMB) radiation is the only observed radiation that allows the study of the earliest stages of the Universe. Space-based radio astronomy instruments for the study of CMB require low operating temperatures of about 0.1 K to obtain the required sensitivity. Electron cooling in cold-electron bolometers (CEB) [1, 2] using NIS tunnel junctions (normal metal - insulator - superconductor) is one of the promising methods of cooling in space at temperatures below 0.3 K. Such restriction of 0.3K appears due to the fact that standard dilution refrigerators cannot operate in zero gravity, but simple refrigerators based on the evaporation of 3He are widespread. NIS junctions can cool conduction electrons in normal metals below the phonon temperature (refrigerator temperature) due to selective tunneling of hot electrons. In metals at low temperatures, the electron-phonon relaxation becomes orders of magnitude slower than the electron-electron relaxation. As a result, the electron and phonon subsystems can coexist at different but well-defined temperatures.
A bolometer for space missions has been created, consisting of an array of 192 antennas at a frequency of 350 GHz, each including a cold-electron nanobolometer [1, 2]. The bolometer noise reached the limiting level of the photon noise of the received signal at a cryostat temperature of 310 mK, due to the self-cooling of the nanoabsorbers. Direct electron cooling of the nanoabsorber through the "metal - insulator - superconductor" junction has a high efficiency due to the low electron-phonon conductivity, which serves as a good thermal insulation. An electronic temperature of 120 mK was achieved without optical load and 225 mK at a load of 60 pW with the intrinsic noise of the nanobolometer below 8×10-18 Вт/√Гц.
In a modified design of the receiving pixel [1, 2] based on cold-electron bolometers, at a phonon temperature of 300 mK, it was possible to experimentally achieve a theoretical minimum of electron temperature of 65 mK [3]. 300 mK is an important threshold temperature since it can be achieved in 3He refrigerators. Electronic cooling was also demonstrated from 256 mK (which can be achieved in two-stage 3He cryostats) to 48 mK, i.e. the electronic temperature has been reduced by more than a factor of five. This result was achieved by introducing a hybrid nanosabsorber based on a superconductor/ ferromagnet film instead of a normal metal nanosabsorber, improving the geometry of the electrodes of tunnel junctions, and adding specially designed normal metal traps for nonequilibrium quasiparticles in direct contact with superconducting electrodes. Deep electron cooling, demonstrated in [3], gives cold-electron bolometers a record sensitivity, which makes them promising as receivers for future space and balloon missions. Optimized receiver designs have now been developed to improve sensitivity, and samples of new designs have begun to be fabricated.
This work was supported by the Russian Science Foundation (projects 16-19-10468 and 21-79-20227).

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P

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Modeling magnetic fields in accretion discs, taking into account convective flows

Magnetic fields take place in different astrophysical objects such as the Sun, other stars, galaxies, planets etc. As for large amount of these objects their generation is connected with the dynamo action. There have been developed different models, which describe this effect, taking into account specific features of concrete objects. The magnetic fields are also thought to exist in accretion disks surrounding massive astrophysical objects such as neutron stars, black holes and white dwarfs. They can explain the transition of angular momentum between different parts of the disk. The magnetic field generation in accretion disk can be connected with the dynamo mechanism, too. It is quite convenient to use for studying it modified no-z approximation, which firstly was developed for the galactic disks. It is also necessary to take into account vertical motions, which can be connected with convection and other effects. Here we present the results of modelling magnetic fields, taking into account vertical flows.

P

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Unveiling the obscured high-redshift Universe with Millimetron

This talk summarizes various proposals concerning observations of high-redshift Universe with Millimetron: the build-up of supermassive black holes, the origin of dust, the searches for the first galaxies and others.

P

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Kinematics of filaments and cores associated with regions high-mass star formation

Kinematics of several filamentary molecular clouds and cores associated with regions high-mass star formation is studied using molecular line data. Velocity gradients and oscillations along the filaments are found. They can be associated with the star formation and fragmentation processes. An analysis with the velocity structure function is used to estimate linear scales of turbulence in the clouds. Also, with an algorithm for fitting model spectral maps into observed ones the radial profiles of turbulent and systematic velocities of the L1287 dense contracting core are derived.

P

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Radio transients: current status

The talk is a brief review of the current status of radio wavelength transient studies. The transient objects belong to different classes: from neighbouring flaring stars and Galactic pulsars to fast radio bursts (FRBs), originating at cosmological distances. Most of the talk would be dedicated to FRBs which are one of the major astrophysical puzzles now. There is considerable progress in our understanding of this phenomenon as fast increase in number of detections brings new exciting results at a very high rate.

P

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Water trail with Millimetron

Water molecules are the simplest and yet the most important for life as we know it - the life based on carbon chains, proteins and nucleic acids. Water forms early in star-forming molecular clouds and primarily stays in dust icy mantles until a newborn protostar heats up the surrounding material and returns water to the gas-phase by thermal desorption, leaving the primordial water only beyond the water snow line. Studying water at all stages of star formation is essential to understand the origins of planetary and cometary water, the origins of water on Earth. However, the most important ground-state water lines are blocked for ground-based observations by the atmosphere. The first water studies were performed with the space-based observatories ISO, Spitzer, and Herschel. Millimetron will perform a brand new, complete water trail survey, standing on the shoulders of Giants.

R

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Microwave meteorological station to determine the integral humidity of the atmosphere

From mid-2017 to the present in RRI at the Karadag Polygon (Republic of Crimea), there are studies of integral moisture content, determined by the measurements of atmospheric absorption in the wavelength range of 2 mm, 3 mm and 8 mm. In the process of research, the structural elements of the measuring system are being worked out for solving a number of scientific and applied tasks. At the moment, a module of the full-scale of the microwave meteorological system for determining the integral humidity of the atmosphere has been developed [1]. On the basis of naturale experiments, its main structural, frequency characteristics, methods of controlling the complex, system of collecting and processing data were determined. In the central part of the complex there is a rotary module (RM) with two flat reflectors for setting the position of the radiation patterns of the horn antennas of radiometers located at the edges of the RM. The antennas of the modulation radiometric receivers of the 3 mm and 8 mm range are directed strictly towards each other and look at two flat mutually perpendicular elliptical reflectors in the RM. The reflectors are mounted at a 45-degree angle on a shaft that is rotated through the gears by a stepper motor. The RM housing also has transparency windows made of fluoroplast plates. Through these windows, according to the complex control program, in accordance with the angle of rotation of the reflectors, the radiometers receive atmospheric radiation in the range of angles from the horizon to the zenith. The data collected using the cross-section method [2] for the plane-layer model of the atmosphere allows us to determine the integral atmospheric humidity at both frequencies. The measuring module is installed on the roof of the laboratory house of the landfill at an altitude of 105 m from sea level. Measurements of the brightness temperatures of the atmosphere are carried out in the south direction in the vertical plane (when counting from the zenith) at the angles of 0°, 10°, 22.53°, 30°, 40°, 50°, 59.35°, 66.63°, 70°, 75°, 80 ° through an open area of space. Also, at an angle of 90°, radiation is received from the vegetation-covered peaks of the hills located at a distance of about 2 km. The value of this radiation is used in the calculation [2] as the reference area of the "blackbody" emitter located in the far zone of the antenna with a radiation coefficient close to one. To study the variation of the radiation coefficient of surfaces in the measurement area under varying weather conditions, radiation at an angle of 103° also we are measured , coming from the slope of these hills and partly from the flat part at their foot. The moist component of the atmosphere is variable, and absorption of the atmospheric in the windows of transparency of 8 mm, 3 mm and 2 mm in a cloudless atmosphere allows us to determine the same value - the integral water vapor content in the direction of observation. The absorption in the cloud from the droplet fraction and water vapor have different frequency dependences, which makes it possible to separate the contribution of clouds and cloudless atmosphere to the absorption in the transparency windows. Usually 13.5 mm and 8 mm wavelengths with a wavelength ratio of 1.7 are used in atmospheric diagnostic channels. It seems to us more promising to use 8 mm and 3 mm wavelengths. The radiometers corresponding to these wavelengths were installed during the present measurement period to accumulate statistical data. In some periods of measurements, a pair of radiometric receivers at wavelengths of 2 mm and 3 mm was used in the experiments, which was subsequently replaced by a pair at wavelengths of 3 mm and 8 mm. This circumstance explains the mentioning of three frequencies of the millimeter range in this work. The complex is controlled by a program developed in 2018 based on a general software package in Python language. For year-round temperature maintenance inside the complex under various weather conditions, the system of thermal stabilization of different elements of the complex is applied and is being finalized. Due to the fact that the methodology of measurements and data processing used is designed for a flat-layered model of the atmosphere, meteorological situations with clouds and precipitation are so far excluded from consideration. However, all received data are additionally analyzed in order to determine extended information about cloud characteristics of different configuration, its density, amount of water content, crystalline fraction and electrical activity. Together with the microwave weather station data, data from a standard Davis Vantage Pro 2 handheld weather station is synchronously recorded, allowing for real-time comparison and analysis of an expanded set of meteorological data.

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R

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Capabilities and geometry of VLBI mode in Millimetron Mission

VLBI method is a unique technique that allows to perform the observations of the most compact astronomical objects with high angular resolution. In this contribution we will demonstrate the capabilities of Millimetron VLBI mode regarding the tasks of two-dimensional imaging of the black hole shadows and observing compact structures around. Attention is paid not only to the sensitivity and frequency configuration of space-ground interferometer, but also to it geometry, namely possible orbital configurations of Millimetron observatory and its capabilities.

S

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MM-astronomy from the Tibetan plateau: the AliCPT-1 telescope

Nowadays, ground-based CMB telescopes have mainly been developed in the Southern Hemisphere (i.e. the Atacama Desert and Antarctica) for years. Recently, ground-based observation from the Northern Hemisphere has attracted a lot of attention, especially after the Planck satellite mission. The new observatory in Ali region, Tibet, will contribute to ongoing efforts in expanding and deepening sky observation in the microwave range from the Northern Hemisphere. The Ali CMB polarization telescope (AliCPT-1), an ambitious ground-based millimeter telescope to be deployed on the Tibetan Plateau at 5,250 m above sea level, will provide a unique opportunity for deep observations of the Cosmic Microwave Background at 90 and 150 GHz in a low galactic emission patch of the Northern sky.
The receiver, a 72 cm aperture, two-lens refracting telescope cooled down to 4K, is designed to operate up to 32,376 dichroic polarization-sensitive Transition-Edge Sensors (TESes). AliCPT-1 is currently being constructed and tested by the AliCPT collaboration.
In this talk, I will present AliCPT-1, its science targets, the receiver design and its current status.

S

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Unveiling the AGN intrinsic power and its effect on the host-galaxy ISM

In this work, we determine the intrinsic emission of obscured AGN though X-ray spectral analysis, and assess its effect on the host-galaxy ISM properties and star formation activity in a sample of 33 local Seyfert 2 galaxies. From the analysis of X-ray (NuSTAR) observations we found: i) the first accurate determination of the intrinsic power (LX) and column density (NH) of the obscuring material; ii) the comparison of the column density (NH) obtained from the obscuration in the X-rays with that derived in the mid-IR, associated to the optical depth of the 9.7μm absorption feature. Then, we compared the molecular gas content (derived with new and archival single-dish CO spectroscopy) and the PAH emission between the Seyfert 2 and a control sample of normal SF galaxies (SFGs). We found that: i) local AGN and SFGs show similar molecular gas masses and depletion times; ii) PAH emission is suppressed in AGN with respect to SFGs.

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Probing star-formation in Infrared Dark Clouds with mm-wave masers using Onsala 20-m RT

Astronomical masers are excellent tools for probing different structures in the interstellar medium. Many maser surveys were performed toward different types of objects, mainly in the direction of star formation regions. Class I methanol masers (cIMM), the brightest among mm wave methanol masers in the interstellar medium, are believed to be tracers of interstellar shocked gas. However, they receive less attention due to their low luminosity and more distant location from other sites of star-formation activity. Search for cIMMs is a task of current interest for observers. The aim of this study is to search for cIMMs in molecular cores in Infrared Dark Clouds (IRDC). IRDCs are considered to be precursors to star clusters and represent the earliest stage of high-mass star formation. We aimed to probe which type of cores (active, intermediate or quiescent) is more probable to contain cIMM. Using the 20-m Onsala radio telescope we have observed a sample of 42 molecular cores in class I methanol line 7_0−6_1 A+ at 44 GHz. The sample contains cores at early stages of star formation, but in different state of activity: from quiet state without any IR-signature to active state with pronounced maser activity. Methanol emission at 44 GHz was detected in 29 of 42 sources. Class I methanol masers were newly discovered in 4 sources and firstly detected at 44 GHz in 11 sources containing cIMM at other frequencies. Both active and intermediate molecular cores in our sample exhibit cIMM at 44 GHz with the same probability. All cores in quiescent state are undetected. We conclude that for further searches it will be more perspective to observe molecular cores exhibiting mid-IR signatures rather than quiescent cores. Our results support the observational fact that cIMM are likely to appear in regions with signs of current star-forming activity.

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Criteria for Fast MM/SubMM transients

Conditions and environments for fast transients in mm/submm range are discussed.

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Studies of the ocean worlds in the Solar and exosolar planetary systems in the MM and subMM astronomy

no abstract

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Comparison of the parameters of turbulence and phase fluctuations of the atmosphere in the optical and sub-mm ranges: evaluation of the possibilities of using adaptive optics methods for measuring and correcting the tip-tilt of the wave front on the ESMT

The paper considers adaptive optics (AO) methods used on large ground-based optical telescopes [1]. It is proposed to adapt and apply the AO methods to study the statistical variability the tip-tilt of the wave front (WF) at the promising sites of Eurasian SubMM Telescopes (ESMT)[1] and to assess the possibility of correcting the tip-tilt or using smart beam scanning of observed objects to suppress atmospheric fluctuations (smart wobbling). The specificity of the sub-mm range consists in the dominant influence of the wet component of the refractive index of the atmosphere, both non-dispersive and dispersive, in comparison with the optical range, where the dry non-dispersive component of the refractive index of the atmosphere dominates. The associated small-scale and large-scale phase fluctuations cause the images to blur and shake, and the high-altitude ones also cause the images to flicker. Estimates of atmospheric turbulence parameters in the sub-mm range for ESMT are given for the Mondy site (East Sayan) based on turbulence models based on reanalysis data. The estimated water vapor component and the associated phase fluctuations are calculated. The obtained estimates indicate the possible dominance of the tip-tilt wave front fluctuations, which lead to the effect of image jitter on the ESMT with a frequency of no more than 1 Hz. It is proposed to use several small optical telescopes with a diameter of up to 300mm, spaced within the aperture of the radio telescope, to determine the tip-tilt statistics. As a WF sensor, it is advisable to use commercially available optical Shack-Hartmann WF sensor with the minimum number of subapertures (3x3) and a broadband CMOS matrix of high quantum efficiency up to the first significant line of water vapor absorption in the near-IR range (940 nm). It is proposed to use optical stars of all spectral classes as reference objects for the application of AO methods on a radio telescope, and not only IR stars of late spectral classes with low brightness. Our preliminary estimates show that high-brightness stars (5m-6m) as reference stars can be observed in mountainous conditions (above 3000 m) at night, at evening twilight, and in the morning when using a band-pass filter to suppress sky illumination. At this time, the ESMT is operation in the short-wave range will be most effective.

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Astroclimatic characteristics of the Sayan Solar Observatory and the Special Astrophysical Observatory sites for ground-based mm/submm astronomy

The necessity for large mm/submm telescopes in Eurasia is long overdue since an appropriate expansion of the existing (EHT) and the future VLBI networks would significantly improve observational capabilities and the quality of the images obtained. The study of the astroclimate of possible sites for the sub-MM telescope in Russia and the development of sub-THz receiving technologies is relevant [1]. The most important atmospheric transmittance characteristic, which is used to determine the possible suitability of a site for mm/submm observations, is the precipitable water vapor (PWV) and its variations (dPWV). Image quality and astroclimate are determined by the amplitude-phase and phase characteristics of the beam along its path in the atmosphere at the telescope aperture. To estimate these characteristics, knowledge of the variations in the vertical profile of refractive index fluctuations, the structural function and the structural coefficient of the integral refractive index of the atmosphere as well as the characteristics of fluctuations in the wavefront slopes is necessary [2,3]. This report presents the results of studies of the astroclimate at the Sayan Solar Observatory (ISTP SB RAS) and the Special Astrophysical Observatory (SAO RAS) including PWV and dPWV analysis. Based on high spatial resolution ERA-5 reanalysis database PWV and dPWV values averaged over long time intervals were calculated for individual regions of the Eastern Sayan and Northern Caucasus. The obtained distributions of PWV values over the territory as well as distributions of PWV repeatability allowed us to select sites in the considered regions for ESMT telescope [4]. The repeatability of conditions with extremely low PWV values < 1 mm, in which observations at 230 GHz become possible and effective, was estimated. The obtained statistics of PWV are compared with the results of PWV studies at the best astronomical observatories of the world.

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S

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Status of THz Schottky diode technology for radio astronomy in Russia and worldwide

THz technology gradually increases its impact on human society. Nowadays, Schottky diodes are widely used as frequency conversion devices in the microwave, mm and THz bands of EM spectrum. Both whisker contacted and planar Schottky diodes can effectively act as part of coherent and direct detection THz receivers. Among those, an important role is played by remote sensors for the needs of radio astronomy, planetary and atmospheric sciences.
The state-of-the-art THz planar Schottky diode technologies available in Europe and the United States reveal their capabilities in the development of heterodyne receivers for the Submillimetre Wave Instrument (enables observations at 530-601 and 1080-1275 GHz) on board of the Jupiter Icy Moons Explorer scheduled for launch in 2022 and the Microwave Sounder (utilizes 24 channels operational from 23.8 up to 229 GHz) on board of the MetOp Second Generation satellite, whose launch is scheduled for 2024. Both the sources and detectors of THz radiation relying on the planar Schottky diode technology are commercially available worldwide, e.g. from VDI Inc., Teratech Components Ltd., RPG and ACST GmbH. Numerous foreign scientific laboratories and academic institutions (including JPL, LERMA, RAL, Chalmers University of Technology etc.) also contribute to research and development in the area significantly.
Despite vast heritage in the development of Schottky diode based receivers for the microwave and mm bands in Russia (NIIPP, TUSUR, Micran), recent trends in mastering even higher frequencies do not follow those observed in the world. Yet, there is a number of domestic developers with the technologies suitable for THz applications. This report is to review their capabilities in terms of the instrumentation for radio astronomy.

S

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2D arrays of Cold Electron Bolometrers based on SINIS structures

In this report we present concepts of periodic arrays of cold-electron bolometers (CEBs) for cosmology experiments based on superconductor-insulator-normal metal - insulator - superconductor nanostructures. These arrays are designed in the framework of periodic approximation, when the entire array is represented by a unite cell with periodic boundary conditions and the Floquet port. Such an approach is widely used for design and optimization of quasioptical filters, when only reflection and transmission parameters are engineered. However, the unit cell of the lossy bolometric array is designed to provide both absorption of incident submm radiation and optimal DC-biasing for all the bolometers. Arrays with different unit cell sizes will be considered: narrowband arrays with the period comparable to the wavelength and ultrawideband miltioctave arrays with the unit cell siza as small as one tenth of a wavelength.

S

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Millimeter and submillimeter transient events in star formation

Surveys in the optics and near infrared have established the ubiquity of variability in the young stars visible in these ranges. However, objects at the earliest stages of protostellar growth are normally deeply embedded and can be observed only in the far infrared, submillimeter and millimeter ranges. Another advantage of the variability studies in these ranges is that such studies provide information on the luminosity changes rather than opacity effects. Monitoring of the low-mass-star forming regions within JCMT Transient Survey at 850 mkm have established that there are ubiquitous changes on the time scales of months and years which are attributed to the changes in accretion rates. Stochastic accretion variability is also detected. This is very valuable information for the studies of accretion phenomena. JCMT Transient Survey has also discovered a very short-term non-thermal variability event which was associated with magnetic field reconnection. Studies of such events are potential tool to study physical processes in the scale of the inner accretion disk to the stellar surface. Last few years are marked by exciting discoveries of the bright accretion bursts in the high-mass young stellar objects in S255IR, NGC6334I and G358.931-0.030. Remarkably, these events were accompanied by the maser emission, in submillimeter and millimeter ranges as well. Maser Monitoring Organisation (M2O) plays a big role in these complex studies. These are some of obtained results: Observations show that the structure of the circumstellar disks of massive young stellar objects is significantly inhomogeneous. These disks contain coherent structures up to 1000 AU in size. Accretion of matter onto a young star occurs along some structures; these structures can be in the form of spirals. The material of accretion structures consists of clumps, the fallout of which on a young star leads to accretion bursts of various intensities A large amount of high density material is present in the structure of the disc, leading to a significant slowing-down in the propagation of light. After an accretion burst, the physico-chemical state of the disk matter changes and does not return to its previous state. These bursts sometimes can be revealed only in the submillimeter and millimeter ranges.

S

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On the early history of millimeter and submillimeter astronomy in Russia

A brief overview of the activities of the submillimeter astronomy group, created at the end of the 60s of the last century in the Shklovsky department (SAI/ IKI / ASC), and continued already in our century, is given. It was pioneering work, they have launched a real astronomical observations in the millimeter and submillimeter range. Many of their results are a priority.

S

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Symmetries of Magnetic Fields Driven by Spherical Dynamos of Exoplanets and Their Host Stars

Observations of exoplanets open a new area of scientific activity, and the structure of exoplanet magnetospheres is an important part of this area. Here we use symmetry arguments and experiences in spherical dynamo modeling to obtain the set of possible magnetic configurationsfor exoplanets and their corresponding host stars. The main part of our results is that the possible choice is much richer than the basic dipole magnetic field of both exoplanets and stars. Other options, for example, are quadrupole configurations or mixed parity solutions. Expected configurations of current sheets for the above mentioned exoplanet host star systems are presented as well.

S

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Galaxy Evolution studies in the IR and submm from the space

The evolution of galaxies at Cosmic Noon (redshift 1<z<3) passed through a dust-obscured phase, during which most stars formed and black holes in galactic nuclei started to shine, which cannot be seen in the optical and UV, but it needs rest frame mid-to-far IR spectroscopy to be unveiled. At these frequencies, dust extinction is minimal and a variety of atomic and molecular transitions, tracing most astrophysical domains, occur. Only through future IR/submm space telescope missions, such as Millimetron and Origin Space Telescope, to give two examples, we will be able provide for the first time a 3-dimensional spectroscopic view of the hidden side of star formation and black hole accretion in all environments, from voids to cluster cores over 90% of cosmic time. Here we outline what an IR/Submm telescope will do in galaxy evolution studies.

T

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SINIS detector arrays for radioastronomy

We consider application of SINIS detectors for two separate instruments: broadband photometer and medium resolution spectrometer. For multipixel imaging array of broadband photometers we develop two options with feedhorn-coupled matrices of electrically small antennas connected in series and matched to JFET readout and connected in parallel and matched to SQUID readout. The first option can operate even in post-cryogenic stage when SINIS operate as NININ detector with reduced, but still reasonable sensitivity. The multipixel instrument is arranged for Frequency Domain Multiplexing (FDM). In this case each pixel comprising coplanar resonator and coupler is read out by Josephson Travelling Wave Parametric Amplifier (JTWPA). Such schematics provide fast readout via one coaxial output line instead of hundreds wires and amplifiers in conventional configuration. All listed above devices are fabricated using direct-write e-beam lithography and magnetron sputtering. Devices were tested using He3 sorption cooler at 280 mK and at 100 mK using dilution He3-He4 cryostat.

T

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HEB mixer based THz astronomical instruments

The THz range of frequencies (0.3 to 10 THz) is rich in astronomically important fine molecular and atomic lines. The using of high resolution spectroscopic techniques makes it possible to determine parameters such as density, temperature and velocity that can help in understanding of the dynamics and chemical processes courses in star forming regions. Currently, NbN HEBs are one the most suitable mixers for high resolution spectroscopic terahertz astronomy at frequencies above 1 THz. High sensitivity and low LO power requirement make them unique at terahertz frequencies. The HEBs have been used in a wide range of astronomical observatories in order to observe different THz lines [1]–[4]. In this report we will overview HEBs based actual astronomical instruments such as airborne (SOFIA), balloon borne (STO-2, GUSTO) and future satellite (Millimetron and Origin space telescope) THz observatories.

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Millimeter observations of maser-emitting planetary nebulae

Observations in the mm bands of maser-emitting planetary nebulae (PNe) are crucial to study their circumstellar molecular gas at the beginning of the PN phase. Maser-emitting PNe are in the earliest phases of PN formation, therefore these sources are key objects to study the molecular content during the early evolution of PNe. These circumstellar envelopes are active sites for the production of molecules. Up to 2017, over 20 molecular species have been discovered in PNe. I will present preliminary results of our mm observations with the IRAM 30m telescope toward a sample of five maser emitting PNe, we detect 12CO and 13CO lines in both 1-0 and 2-1 transitions, as well as HCO+ and HCN lines in both 3-2 and 1-0 transitions in a few of them. We are working in the analysis and interpretation of these observations.

V

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FIR from high-z SMBHs

During last decade many super-massive black holes (SMBH) have been discovered at redshifts higher 6. We discuss how SMBH can be studied in far-infrared (FIR) line and continuum emission.

V

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Laboratory studies of astrochemically relevant processes

Development of observational facilities operating in submillimeter and infrared wavelength during last decades resulted in rapid accumulation of knowledge on chemical composition of interstellar medium (ISM) in our Galaxy. Since 1970s, roughly four to five molecules are discovered in the ISM annually. To date, census of interstellar molecules includes about two hundreds species that range from simple diatomic to complex organic and prebiotic molecules. Given that new generation of observational facilities such as JWST, Millimetron and Suffa to become operational in the near future, the pace of progress in astrochemistry is expected to remain high. The observed chemical diversity develops thanks to a number of phyiscal and chemical processes that occur both in the gas phase and on the icy mantles of interstellar dust grains. Chemistry on grains plays the key role in the formation of complex organic molecules. Yet, it is still poorly understood. In the talk, we will discuss the prospects of experimental laboratory studies of astrochemically relevant chemical processes under the condition similar to interstellar medium in star- and planet-forming regions. The ultra-high vacuum cryogenic setup of Research Laboratory for Astrochemistry at the Ural Federal University will be presented. General directions of future research aimed at conjunction of experiments, numerical modeling and observations will be discussed.

V

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Experimental mirowave astroclimate research for development of subTHz astronomy

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V

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Millimetre facilities and maser surveys in Australia

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) msanages Australia's leading facilities for radio astronomy, which are collectively known as the Australia Telescope National Facility, or ATNF. The Australia Telescope Compact Array (ATCA) was the first interferometer operating at millimetre wavelengths in the Southern Hemisphere thanks to the high-frequency upgrades done in early 2000s. Together with the Mopra single-dish, which was often used as an engineering prototype for the receiver and backend development, these instruments both proved to be powerful and flexible survey machines. I will review the capabilities and the history of events leading to both success and shortcomings based on my own experience with commissioning and as an active scientific user afterwards. The science examples will focus on the projects in my own area of maser surveys and, more broadly, molecular spectroscopy and star-formation.

W

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(Sub)millimeter observations of organic molecules

A (sub)millimeter range is rich in various molecular lines. I will present our current understanding of formation and destruction pathways for organic molecules in various objects including molecular clouds, hot cores, and protoplanetary disks. Also, outlooks of their studies with prospective instruments will be discussed.

Z

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Orbits of bright stars near the Galactic Center as a tool to test gravity theories

Observations of bright stars near the Galactic Center demonstrated that the preferable model for the Galactic Center is the supermassive black hole. These observations of VLT and Keck telescopes got a high recognition among a scientific community and R. Genzel (VLT) and A. Ghez (Keck) were awarded the Nobel prize in physics in 2020. We discuss opportunities to evaluate parameters of the supermassive black hole and extended mass distribution from these observations. Similarly, these observations give a possibility to find constraints on alternative theories of gravity such as f(R) theory, Yukawa gravity and theories with massive graviton. Graviton mass limits found with the approach is comparable constraints obtained with other techniques including gravitational wave observations with LIGO—Virgo detectors.

Z

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Prospects for 3D printing of quasi-optical and waveguide systems

The report will provide an overview of the additive technologies used for the production of microwave equipment and the future prospects. Both metal printing technologies and the application of a conductive coating on plastic with subsequent removal of the dielectric will be discussed. Special attention will be accounted to the technologies based on photovoltaic electroplating, which are being developed at the IAP RAS.

Z

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Ground-based and space-borne mm/submm astronomy in studies of ISM

We discuss advantages and limitations of ground-based and space-borne mm/submm observations in studies of interstellar medium. Preferred tasks for ground-based and space-borne instruments are described. Examples of the ISM studies with different instruments are presented.