New stage of the Suffa Submm Observatory in Uzbekistan Project


Abstract—The International Radio Astronomy Observatory (IRAO) is the project carried out by an international collaboration led by the Astro Space Center of the Lebedev Physical Institute of the Russian Academy of Sciences [1] to provide fundamental and applied astrophysical, geophysical and space research in the centimeter, millimeter and submillimeter wavelengths. The main instrument of the observatory is the radio telescope RT-70 of the centimeter wave band with a mirror of 70 meters in diameter - the only large radio telescope in the Eastern hemisphere located in the center of the Eurasian continent in Uzbekistan already built to at least of 50% readiness. It is able of highly effective long-duration operations due to its location at the altitude of 2,500 m and the unique astroclimate of the Suffa Plateau. Since 2018 the new stage of the project started following the three visits of the RAS President A. Sergeev to Uzbekistan and the Road Map of the Suffa project signed.

Index Terms — radio astronomy, millimeter waves, submillimeter waves, subTHz observatory, radiotelescope

I. INTRODUCTION

A new stage of a rather old project of the SubMM observatory has been presented (Fig. 1). It will be an extremely important tool in ground-based and terrestrial VLBI observations with the prospect of adding mm wavelengths [2]. In these studies, the RT-70 will provide the highest sensitivity and angular resolution as concerns continuous spectrum observations, spectral lines observations, polarization measurements and the study of rapidly varying processes occurring in the Universe. Instrumentation of the Suffa Observatory will be extended by relatively small (10-15 m of diameter) telescope working in Submm waves and installed near the main mirror no later then 2024. Radioastronomical observations in atmospheric windows around 1.3 and 0.8 mm will become possible. First results of atmospheric opacity measurements provided some data presented here which give some grounds to moderate optimism. Both the telescopes will be equipped by extremely high sensitive cryogenically cooled receivers [3].
II. HISTORICAL AND GEOGRAPHICAL REVIEW

The Suffa project (Fig.1) started in the early 80’s as the formal opening ceremony of construction took place on the Suffa plateau with the leader of the Uzbek Republic Sh. Rashidov and Vice-President of the Academy V. Kotelnikov present (Fig.2). In 10 years when more than a half of the project had been fulfilled following the disintegration of the USSR the project was frozen.

Fig.2. Suffa Project in 1981: formal opening.

In 2005 Uzbek and Russian authorities decided that the project should continue and be finalized [2]. Since the appearance of the first publications concerning the Suffa observatory, 10 years have passed without any visible progress. Only in 2018 thanks to the initiative of the Russian Academy of Sciences and the National Academy of the Republic of Uzbekistan significant progress was made in promoting the project, including the promise of some substantial financing starting from 2019. The current status of the project and results of the project development in 2018 as well as some plans for 2019/20 are being presented in this paper.

A. Suffa plateau, pic.1:

Fig.3 Location of Suffa
Geographic coordinates: 39°37’28.46”N 68°26’54.16”E;
Measurements period: permanently since 2012;
Altitude above sea level: 2400m
Climate zone: Dry sharply continental

B. Nearest mountains for small mirror to be installed
Altitude above sea level: 3200m

C. Maidanak is the place of the Uzbek national optical observatory as the alternative place for the small SubTHz mirror Main Performances

Main specifications of the projected 70 m telescope are listed below:
Main mirror diameter, m 70
Surface geometrical shape Paraboloid of rotation
Focal length, m 21
Opening angle, deg. 160
Optical scheme Gregory two mirror system with periscopic mirror
Wavelength range, λ S - millimeter (λ= 0.87 - 10 mm)
M- centimeter (λ = 1 - 6cm)
Secondary mirror diameter, m 3 (5)

<table>
<thead>
<tr>
<th>TABLE</th>
<th>WORKING BANDS OF SUFFA RECEIVERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating wavelength ranges (In priority: II, III, IV)</td>
<td>I</td>
</tr>
<tr>
<td>Average wavelength, (mm)</td>
<td>0.87</td>
</tr>
<tr>
<td>Frequency range, (GHz)</td>
<td>275-373</td>
</tr>
<tr>
<td>Beam, 1.02(λ/D) (”) at level of 0.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Antenna effective area (m²)</td>
<td>1350</td>
</tr>
<tr>
<td>Antenna aperture efficiency</td>
<td>0.3</td>
</tr>
<tr>
<td>Sensitivity (RMS) in μJy (integration time 1 minute /8 hours)</td>
<td>480/20</td>
</tr>
<tr>
<td>System noise temperature (Ko) (with 3 mm of precipitated water)</td>
<td>380</td>
</tr>
<tr>
<td>Receiver noise temperature (Ko)</td>
<td>100</td>
</tr>
<tr>
<td>Maximum receiver bandwidth (GHz)</td>
<td>30</td>
</tr>
</tbody>
</table>
The shape of an ellipsoid of rotation with five degrees of freedom of movement in space. Depending on the diameter it is either a one-piece mirror (3 meters) or collected of individual panels on the frame (5 meters). The mirror position is controlled by the computation and control complex.

The periscope (diagonal) mirror has a flat elliptical shape. The major axis is 600 mm. The mirror has four degrees of freedom. Subsequently, it can be made adaptive. The telescope control system consists of the electric drive of the traditional for radio astronomy antennas scheme, and the precision-pointing contour, providing operation at the millimeter wavelength range. The electric drive provides pointing at the source and its tracking with required accuracy and speed. It uses a computation and control complex and digital 22-bit (0.3) feedback sensors, installed on the elevation and azimuth axes, and provides pointing at the source within the RMS of 1 arc seconds with allowance for the errors in the drive mechanisms etc. At 1 mm wavelength, the calculated radiation pattern of the radio telescope is 3 arc seconds. There is a special high-precision pointing system of the electrical axis of the antenna aimed at the source under observation which has a range of angles of ±10" from the current direction determined by the feedback sensors of the electric drive, and provides pointing accuracy of at least 0.3 arc seconds.

Table 2 shows the operating frequency ranges of the radio telescope. Radiometers will be placed at the primary and secondary focus. In the primary focus the change of radiometers will be done using a fixed service tower, in the secondary 7 radiometers with the fixed mounting and beam switching is done by periscopic mirror. The set of radiometers and its radiophysical characteristics are determined by specific scientific tasks of observations cycle. The preferences are the short-wave part of the millimeter range, the search of weak sources and deep surveys in the continuous spectrum, polarimetry of cosmological background (CMB), molecular radiospectroscopy, and rapidly changing processes. Within this range bolometers are mainly used (or bolometer arrays) which are cooled down to 4 - 0.3 K. The super heterodyne receivers are also cooled down to 4 - 20 K.

The Gregory telescope optical system has a field of view in the secondary focus of 15°–40°, depending on the diameter of the secondary mirror (5 or 3 m). With the radiation pattern of the 3°, 1,000-element (bolometers or mixer receivers) or more cooled matrix can be placed in the focus.

### III. ASTROCLIMAT

Since 1981, we have carried out astroclimate monitoring as presented in pic.66. We can see that observations are possible even in atmospheric windows 1.3 and 0.8. However, for 0.8 mm there are only some dozens of days from December till March when the zenith absorption is less than 50%. See table 2.

At present, some results of direct SubTHz measurements (λ = 2 & 3 mm) made over past 6 years added to our optimism. These are presented here by G.Bubnov at al [4].

Definitely, direct 1.3 and 0.8 mm (similar to presented in [4] 2 and 3 mm measurements) measurements should be
fulfilled before the adjustment of 70-m mirror is started for operation in these wavebands.

<table>
<thead>
<tr>
<th>% absorption in zenith</th>
<th>Wavelength, (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.88</td>
</tr>
<tr>
<td>&lt;10</td>
<td>-</td>
</tr>
<tr>
<td>&lt;25</td>
<td>-</td>
</tr>
<tr>
<td>&lt;50</td>
<td>2/4</td>
</tr>
</tbody>
</table>

IV. FUNDAMENTAL QUESTIONS TO BE ANSWERED

Despite the optimistic new status of the Project, revival of the Observatory construction in the previous year and the results of astroclimate research presented above, there are still many problems and fundamental question (FQ) to be solved as soon as possible.

A. FQ1: Will the RT-70 operating at wavelengths down to 0.8 mm (RT-70-mm) be interesting from the scientific point of view?

The answer that could be heard from astronomers at the 1st International workshop “Present Status and Future Prospects of the Radioobservatory at Plateau Suffa in Uzbekistan” in Tashkent, Uzbekistan, August 27-29, 2018 was definitely YES [5].

B. FQ2 Does the Suffa plateau enjoy the conditions for transmission good enough for 0.8 mm observations, "good enough" being the key word?

The current answer is: This is not quite clear at the moment. The answer will be extremely important and will have huge consequences. There are rumors that the Maidenak site (also in Uzbekistan, 250 km S-W direction) is much better. It should be (and will be) proved by direct measurements soon.

Action required: Carrying out a careful analysis of available meteo- and direct transmission of atmosphere data. Making comparison between the Suffa and Maidenak sites. Do we have enough data on water vapor for the final decision? If not, let’s get more (through measuring, meteo sats; etc.)

C. FQ3. Are we sure that a completed RT-70-mm structure design can be made to operate well at 0.8 mm?

Answer: Probably yes. Sooner or later this instrument will work at 0.8 mm, but definitely the Suffa observatory should be extended by addition of a 12-15 m SubMM to the main 70-meter telescope. Following the ALMA path (Pathfinder telescope) making a small mirror commercially available a smaller telescope will be built much sooner than the 70-m one and will provide short mm radioastronomical observations rather soon. Now EIE group (Italy) and Vertex (Germany) are actively involved into preparation of this part of the project and there are no doubts that such kind of pathfinder will be in an operational condition before the 2024.

D. FQ4. Is the present RT-70 Suffa structure at the Suffa plateau still usable and is completion of the antenna worthwhile to be carried out?

Answer: yes. Start-up telescope: a 12-15-meter 0.8 mm antenna with receivers and equipment for bands ALMA 2-3, 6, 7 equipment for VLBI observations with Vertex (Germany) or another winner of a further tender.

Main requirements for the tender are: Establishing an error budget for a 0.8 mm telescope wavefront performance: Overall 60 microns (1/13 lambda), panels 30-micron rms, (secondary 15microns), structure (including secondary support) 40 microns, wind loads 30 microns.

The current RT-70 status of the antenna design for a 70-meter diameter antenna, "existing" design of two similar telescopes already built (Evpatovia, Ussuriysk), and lots of critical details mainly connected with the adaptive surface should be considered to provide transition from RT-70 as the CM telescope to RT-70 as the MM (with SubMM) telescope.

The new concept of instrumentation should be developed on the ALMA++ ideology based on wide international collaboration. It is part of the answer to FQ5.

E. FQ5: Are the Suffa Observatory team ready to undertake a mm astronomy project of world-class size and scale? Do they have the expertise?

The current answer: Not yet, but there are special items in the Road Map aimed at this specific problem. The new extended team should be collected around the project, and new staff trained.

V. CONCLUSION

We must say that the Suffa project has been restarted now and the new stage of it is in progress. There are no doubts that it will be fulfilled thanks to worldwide cooperation. There are still lots of problems and fundamental questions to be solved and results will depend on solutions and answers to them.

ACKNOWLEDGMENT

Authors are very obliged to the team of the RT-70 observatory for their support of the project over 25 years, and to presidents of two national Academies, Uzbek and Russian, B. Yuldashev and A. Sergeev, for their initiative in revival of the project.

REFERENCES

Yury Yu. Balega was born on January 8, 1953, in the Kolchyno village of the Mukachevo district, Transcarpathian region. Since 1975, he has held a research position in the Special Astrophysical Observatory of the Russian Academy of Sciences. He received the Ph.D. degree in 1985 and the Doctor of Science degree in 1996. In 1993, he was elected Director of the Observatory. In 1997 he was elected as the Corresponding Member of the Russian Academy of Sciences in the Department of General Physics and Astronomy. He holds a chair of Professor in several universities. His field of scientific interests includes registration and processing of astronomical images in the visible and infrared, interferometry methods in astronomy, study of the fundamental properties, origin and evolution of multiple stellar systems, and study of the gas/dust shells around stars at late evolution stages. In 1991, Dr. Balega received the USSR State Award in Science and Technology, and in 2003, the State Award of Ukraine.

Andrey M. Baryshev received the M.S. degree (summa cum laude) in physical quantum electronics from the Moscow Physical Technical institute, Moscow, Russia, in 1993, and the Ph.D. degree in superconducting integrated receiver combining SIS mixer and flux flow oscillator into one chip from the Technical University of Delft, Delft, The Netherlands, in 2005. He is currently an Associate Professor with the Kapteyn Astronomical Institute, University of Groningen, Groningen, The Netherlands. He was previously a Senior Instrument Scientist with SRON—Low Energy Astrophysics Division, Groningen, The Netherlands, from 1998 to 2017. In 1993, he was an Instrument Scientist with the Institute of Radio Engineering and Electronics, Moscow, Russia, involved in the field of sensitive superconducting heterodyne detectors. In 2000, he joined an effort to develop an SIS receiver (600–720 GHz) for the Atacama Large Millimeter Array, where he designed the SIS mixer, quasi-optical system, and contributed to a system design. His current main research interests include application heterodyne and direct detectors for large focal plane arrays in terahertz frequencies and quasi-optical systems design and experimental verification. Dr. Baryshev was the recipient of the NOW-VENI Grant for his research on heterodyne focal plan arrays technology in 2008 and, in 2009, he was the recipient of the EU commission Starting Researcher Grant for his research on focal plane arrays of direct detectors. (Based on document published on 19 September 2018).

Grigoriy M. Bubnov (IEEE Member’ 2016) was born 29.10.1989 in Gorky (now Nizhny Novgorod), Russia. Graduated from Nizhny Novgorod State Technical University (NNSTU) in 2013 with master-engineer’s degree of Radiotechnics. The theme of master’s thesis is ”MM-wave radiometer for atmospheric absorption measurements”. Finished the postgraduate school of NNSTU in 2017. The field of scientific interests includes methods and techniques of millimeter-submillimeter wave spectroscopy and atmospheric radiometry, laboratory and field investigations of atmospheric absorption. Took part and organized a several expeditions of astroclimate research. Project leader of two grants on astroclimate research. Since 2011 to the present time works at the Institute of Applied Physics RAS. Current position is Junior Researcher.

Nikolay S. Kardashev graduated from Moscow State University in 1955, following up at Sternberg Astronomical Institute. He studied under Shklovskii and finished his PhD in 1962. In 1963 Kardashev examined quasar CTA-102, the first Soviet effort in the search for extraterrestrial intelligence (SETI). In this work he came up with the idea that some galactic civilizations would be perhaps millions or billions of years ahead of us, and created the Kardashev classification scheme to rank such civilizations. Kardashev defined three levels of civilizations, based on energy consumption: Type I with "technological level close to the level presently attained on earth, with energy consumption at ≈4×1019 erg/sec (4 × 1012 watts)". Type II, "a civilization capable of harnessing the energy radiated by its own star", and Type III, "a civilization in possession of energy on the scale of its own galaxy". [2] Serious Russian efforts in SETI predate similar programs in the US by some years. Other notable experts in the USSR were Vsevolod Troitskii and Iosif Samuilovich Shklovskii (Kardashev's former professor). Kardashev became a corresponding (associate) member of the USSR Academy of Sciences, Division of General Physics and Astronomy on December 12, 1976. He became a full member of the Russian Academy of Sciences on March 21, 1994 and was awarded the Demidov Prize in 2014.

Thijs M. de Graauw studied astronomy at Utrecht University and received there his Ph.D. in 1975 under H. van Buren with a dissertation on heterodyne instrumentation applied to infrared observations. From 1975 to 1983 he worked as a scientist for the Space Science Department of ESA (European Space Agency). At ESA's largest facility, ESTEC in Noordwijk, he worked on the development of microwave receivers. In 1983 he became the director of the Groningen branch of SRON (Stichting Ruimte Onderzoek Nederland). [3] From 2008 to 2013 he was the director of the Atacama Large Millimeter/submillimeter Array (ALMA). In 2012 he won the Joseph Weber Award for his work on the
Shukhrat A. Eghamberdiev

Shukhrat Abdumannapovich Eghamberdiev was born in Tashkent, on December 18, 1953, and graduated from the Astronomy Department of the Physics Faculty of Moscow State University (MSU) in 1977. Five years later, in 1982, he successfully defended his thesis “The Study of Solar X-ray Bright Points” for the degree of Candidate of Physical and Mathematical Sciences (Ph.D. equivalent) at Moscow State University. In 1994, Shukhrat Eghamberdiev at Moscow State University successfully defended his thesis for the degree of Doctor of Physical and Mathematical Sciences. In 2000, Professor Eghamberdiev was elected Chief Scientific Secretary of the Academy of Sciences of Uzbekistan. In 2003-2005, he was appointed Deputy Adviser to the President of Uzbekistan for Science, Education and Health.

Valery P. Koshelets

Valery P. Koshelets received the M.S. degree in physics from Lomonosov Moscow State University, Moscow, Russia, in 1973, and the Ph.D. degree in radio physics and D.Sc. (Habilitation) degree in physical electronics from the Kotel’nikov Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Moscow, in 1978 and 1990, respectively. Since 1973, he has been with the Kotel’nikov Institute of Radio Engineering and Electronics, Russian Academy of Sciences, Moscow, Russia, where he is currently the head of the Laboratory of superconducting devices for signal detection and processing. (Based on document published on 24 December 2015).

Gerbert Lagerweij

Vyacheslav F. Vdovin

Ilya V. Lesnov received the M.S. and Ph.D. degrees from Nizhny Novgorod State Technical University n.a. R.E. Alekseev in 2009 and 2017 respectively. Since 2012, he has been with the Institute of Applied Physics of the Russian Academy of Sciences in positions from Junior Research Fellow up to Researcher. His research interests include cryogenics, THz communication systems and experiment automation.


Igor Y.Zinchenko was born in Gorky (now Nizhny Novgorod), Russia, in 1950. He received an equivalent of the M.S. degree in radio physics from the Lobachevsky University of Nizhny Novgorod in 1972, the Candidate of Science (Ph.D.) degree in astrophysics and radio astronomy from the Radiophysical Research Institute (Nizhny Novgorod) in 1982, and the Doctor of Science degree in the same field in 1998. From 1972 to 1977, he was a junior researcher at the Radiophysical Research Institute. Since 1987, he has been Head of Division of Millimeter Wave Astronomy and Radio Engineering at the Institute of Applied Physics of the Russian Academy of Sciences. Since 2002, he has also been a Professor at the Lobachevsky University of Nizhny Novgorod. He is an author of more than 100 articles. His research interests include millimeter and submillimeter wave radio astronomy, physics of the interstellar medium, star formation, and radio waves propagation in atmosphere. Prof. Zinchenko is a member of the International Astronomical Union (IAU), European Astronomical Society (EAS), Euro-Asian Astronomical Society (EAAS), and International Union of Radio Science (URSI). (Based on document published on 14 January 2015).

Scope of professional interest: Radio physics, a radio engineering of low temperatures, development of high-sensitivity cryogenically cooled receivers for millimeter and submillimeter frequency ranges for spectral astronomical researches, and purposes of atmospheric spectroscopy, medical and biologic researches and other applications. Since 1978 on the present with Institute of applied physics: Since 2008 on the present – collaboration with Astrospace Centre of FIAN. Since 2010 professor of Nizhniy Novgorod State Technical University, head of the Center of Cryogenic Nanoelectronics of NNSTU. Vice-president of the World federation of science workers (WFSW), Member of the Cryogenic Society of America (CSA).