New stage of the Suffa Submm Observatory in Uzbekistan Project

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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, sub millimeter waves, subTHz observatory, radiotelescope**

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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].

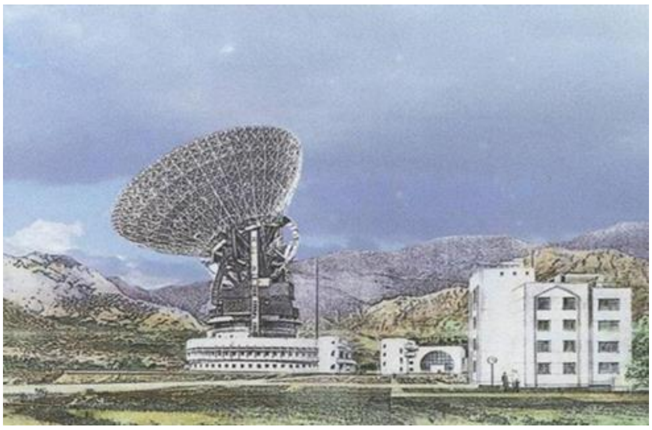

Fig.1. Suffa Project 1980-th

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.

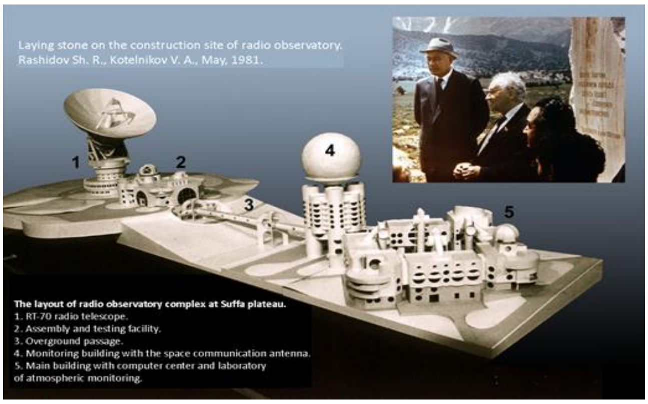

Fig.2. Suffa Project in 1981: formal opening.

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:*

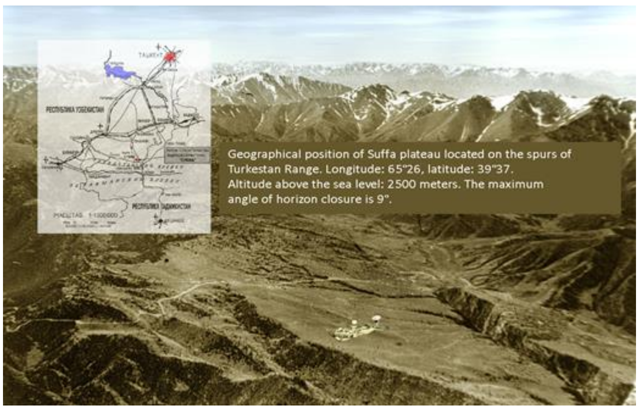

Fig.3 Location of Suffa

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 = l - 6cm)
Secondary mirror diameter, m 3 (5)

TABLE I
WORKING BANDS OF SUFFA RECEIVERS

Operating wavelength ranges (In priority: II, III, IV)	I	II	III	IV	V	VI	VII
Average wavelength, (mm)	0.87	1.2	1.9	3.3	7.5	13	61
Frequency range, (GHz)	275-373	211-275	125-211	67-116	26.5-50	18-26.6	4-8
Beam, 1.02(λ/D) (")at level of 0.5	2.6	3.5	5.6	9.7	22	38	180
Antenna effective area (m^2)	1350	1350	2000	2000	2700	2700	2700
Antenna aperture efficiency	0.3	0.4	0.5	0.6	0.7	0.7	0.7
Sensitivity (RMS) in µJy (integration time 1 minute /8 hours)	480/20	220/10	140/7	100/5	170/8	560/30	800/40
System noise temperature (K°) (with 3 mm of precipitated water)	380	230	190	160	110	80	60
Receiver noise temperature (K°)	100	100	100	100	50	30	10
Maximum receiver bandwidth (GHz)	30	30	30	30	10	2	0.1

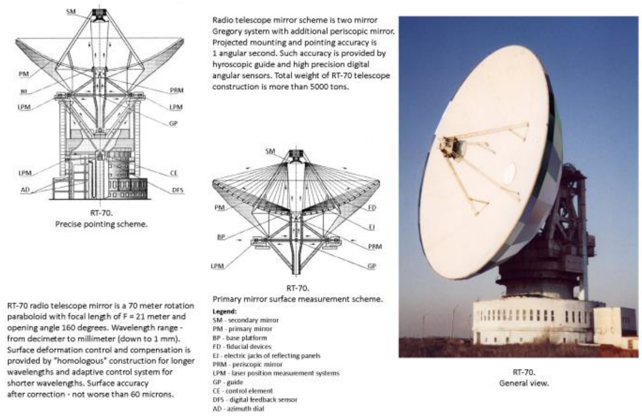

Fig. 4. Suffa RT-70 telescope

Geometric shape of the mirror surface: Ellipsoid of rotation

Inter focal distance of ellipsoid, m 242

Size of diagonal periscopic mirror, mm 600 mm

Equivalent focus of Gregory system, m 571 (345)

The method of the compensation of the main mirror weight deformation is a combination the homologous and active forms of adjustment (so-called “adaptive mirror”).

The standard deviation of the main mirror paraboloid from approximated shape, mm 0.062

Operating panel profile errors (RMS), mkm 50

Antenna installation type Full-circle

Base type Tower

Telescope mounting Azimuth, with mutually perpendicular non-intersecting axes,

Provided mounting and pointing accuracy at wavelength ranges: M, S, angular sec. <2– by detector «angle-code», 22 rank, <1 - by additional system using guide.

Elevation, m: 2,324.

Antenna installation type Full-circle.

The reflective surface of the radio telescope is formed by panels of trapezoidal shape with the maximum size of 2.5 by 2 meters; the total number of panels of 14 different sizes is 1,188. The panels have a special design that allows using pre-alignment of the reflective surface with on average 50 points, RMS better than 50 microns. To provide the operation of the radio telescope at short millimeter wavelength ranges, the shape of the reflecting surface (parabola) must be preserved during the observation under the action of gravity, wind and heat, with an accuracy of λ /D = 20, i.e., 50-70 microns. To ensure this, each panel is installed on special electrical jacks in its corners, which are mounted on the frame truss of the telescope. The total number of electrical jacks is 1,440. During the observation, the control system tracks the position of each panel and, if necessary, adjusts them by their relative position to create the optimal shape of the radio telescope reflecting surface (adaptive method). It is supposed that in the wavelength range of 6 cm to 8 mm the shape of the reflecting surface will be maintained through the use of the homologous method, and at shorter wavelengths by the adaptive method.

The secondary mirror with the diameter of 3 or 5 meters has 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 II
ZENITH ATMOSPHERE TRANSPARENCY (DAYS)

% absorbtion in zenit	Wavelength, (mm)				
	0.88	1.36	2.2	3.15	8
<10	-	-	9/18 Dec.-Feb.	46/68 all year	46/68 all year
<25	-	9/18 Dec.-Feb.	46/68 all year		
<50	2/4 Dec.-Feb.	34/57 Sept.-May			

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 Maidanak 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 of a careful analysis of available meteo- and direct transmission of atmosphere data. Making comparison between the Suffa and Maidanak 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 radiostronomical 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 is 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 (Evpatoria, 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

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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.

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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.

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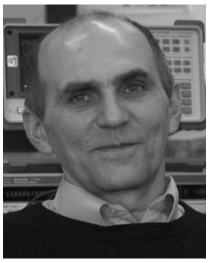

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