Large Radio Astronomy: next 70 Years Step

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Abstract

Some attempts to predict the very distant future of Radio Astronomy are given. It is not easy to predict a list of the first priority problems which may appear, but the facilities potential is more predictable. It is suggested, that in addition to the "dedicated for Radio Astronomy", facilities may be extended greatly by integration with the next generation living standards facilities, connected with People-to-People communications through the global networks and by incorporating of the "Natural facilities", such as grav. lensing, maser amplification in the ISM etc. As an examples of the extreme cases of the $10^9m^2$ class of the new generation Radio Telescopes, utilization of the personal dipole size communication facilities by SKA type instrument, and array from the asteroids first "Frehnel zones" will be mentioned. Radio Astronomy from the secondary to optical facilities tool will be the only tool in the exploration of the $z > 10$ Universe. The reality of all predictions depend mostly on the way, the Civilization will prefer: "Ahead, to HOMO SAPIENCE" or "BACK TO PRIMATES".

1 Introduction

Looking back, we can better predict our future. Few historical remarks. In Russian tradition, we divide the Radio history into Radio as a tool for "People-to People" communication and Radio as a tool for "People-to Nature" communication. Loomis (USA, 1876) had the first patent on wireless

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telegraph, much before Marconi and Popov, but Popov with his patent on "Thunderstorm marker" was the first in "People-to Nature" communication (Russia, 1897). During the last 100 years, Radio Astronomy made the really big step – from the atmospherics lightning to the Big Bang... It was demonstrated by many radio astronomers, that, by averaging of the small steps in the 5-10 Years intervals, practically all important parameters are improving exponentially during the whole history of Radio Astronomy (Popov point is on the same line).

Such big progress in Radio Astronomy tools, comparable only with computers science, resulted in transformation of "Quantitative changes" into the "Qualitative changes". Below we suggest few examples.

1. From Milky Way to the End of the luminous Universe
2. From the "FINAL PRODUCT" of the Universe activity (nearby objects) to the "Initial Conditions", (Inflation etc).
3. From "Objects" to "Proto objects" (CMB anisotropy)
4. From small addition to the Optical Astronomy to the "Only Window" to the Early Universe, \( z > 10 \).

In instrumentation:

1. From "Receiver noise limited" devices to the "Natural limited" devices (Galaxy and Metagalaxy noise, CMB anisotropy noise etc)
2. From Telescope dimension limits to the "Natural limits" sets by physical size of objects (Compton T_b limit, e.g).

Both lists may be extended greatly.

It is not easy to predict the main scientific targets of interest for future Radio Astronomy. There was nice case with attempt to predict Physical science targets by M.A.Markov (later- famous theorists in Russian Academy of Science). He made the list of predictions, compiled after direct interview with world best experts in Physics of the first quarter of 20th century (including Einstein, Planck, Bohr, and many others) and checked these predictions 25 years later- NO ONE PREDICTION WAS CONFIRMED.

New unsolved problems with DARK Energy, Dark matter, Dark Ages and HE Physics will be as a long time scale targets, but we are going to talk here about possible revolution in the FACILITIES. Few remarks.

1. We shall begin with the new frequency domain, connected with deepest observations. Human main facilities in optical domain(eye, telescope) where adjusted nicely to the maximum emission of the Sun and to the atmospheric window (which again was adjusted by LORD to the Sun emission). For future civilization we have CMB emission as a major source of energy in the
Figure 1: RATAN-600 new data on the window to the Early Universe on the "Scale – Frequency plane". The high frequency boundary depends on the instrument parameters and on the total sky surface covered by the extended radio sources (Ken I. Kellermann limit, marked as "KIK").

We see, that sub-microK experiments are possible in the future.

2. Phase disturbance in the wavefront, introduced by the medium between the source under exploration and observer, strongly affect the information. 50 years ago we believed, that atmospheric phase screen set absolute limit on the resolving power of the instruments. In Radio, we realized in 60th, that it is not the case, and wavefront restoration is possible. Later, it was demonstrated, that in optical domain it is possible also (Palomar experiment with non-redundant array of the holes in the aperture screen). Interplanetary
scattering was removed also in the properly organized observation. Recently, gravitational lensing effects were corrected, and undisturbed map of the radio source was found. It is very interesting, how far we can go in this way.

3. Change the targets, from "Objects" to "Protoobjects", results in the drastically change in requirements to the facilities. Instead of standard one (resolution, collecting surface etc) we need now in "temperature resolution". Up to now, there are no project which can work as deep as the Nature suggests. The main problem – even with no noise receiver – the integration time should be hundreds and thousands Years. One of the possible solution – next generation multi-elements array should be prepared not only to the registration $E_i \cdot E_j$ products, but also for $(E_i)^2$, that is, to the total power mode. Looking at the same sky pixel, it is possible to reduce the integration time by factor N (number of elements). Another way, which we try to test with the world greatest reflector RATAN-600 with giant unaberration field – multi-element focal plane array. Up to few thousands receivers may be put in the focal plane, each looking at the same pixel on the sky (see fig.3) ([5], and "Cosmological Gene" project in www.sao.ru)

3. Up to now, the biggest in the collecting surface ground based project

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**Figure 2:** New limit on the Galaxy noise at $l=2000$ scale. Upper curve –old version, lower curve – new, data for synchrotron component.
Figure 3: If an unaberration field is smaller than the sky pixel size of interest all focal plane receivers will see the same sky pixel

was suggested in 1964 to the IAU meeting (Hamburg) by Pulkovo radioastronomers (5 \(10^6m^2\) ring reflector array, [1]). It was too early, but now several well documented projects with close collecting surface and with modern phase imaging concept are under discussion. Here we want to stress, that using simple extrapolation low, we should be ready to the \(10^8m^2 - 10^9m^2\) Radio telescopes in the middle of the 21 century. Up to now, there are no suggestions for this Radio telescopes class. Here we suggest two unusual (but possible) ways of realization of \(10^9m^2\) project.

a) From ”dedicated” to ”private” facilities.

Even if someone is not interested in the science, but just has switched on his personal ”People-to People” device with omnidirectional antenna (dipole, e.g.), he receives (see in TV mode, listening in the audio mode) all cosmic radiation above the horizon, including discrete objects and CMB. The level of this radiation may be from few percent to almost 100% of the personal equipment noise.

As is stated by the most powerful companies, in the distant future practically all Earth population will use personal People-to-People broad band communication facilities, interconnected through the global communication systems. With predicted 10-20 billion population, the collecting surface of the personal dipole type antenna will be not very far from \(10^9m^2\), see fig.4.
Phase adjustments may be properly introduced to the communication signals, and all population may be organized as an giant phased array with big collecting surface, VLBI type resolution and better than VLA image quality ([2]).

b) Solar System resources.

As was discovered by the first generation Radar exploration of the Moon, the first Fresnel zone is well visible in the reflected signal. The same was found in other cases- from all Earth type planets to about 100 minor planets (asteroids). The size of the first zone is about \((R \ast \lambda)^{1/2}\) and even for minor planets it has about 1000 \(m^2\) surface. The reflection is not ideal, only few percent, but it was found recently through SDSS survey, that number of asteroids with size more than 50 km increases now to 57000. They are scattered in the solar system inside the about 10 a.e. radius,see fig.5. It is suggested, that the real number may as big as \(10^8\). It means, that the total reflecting surface of these flying radio telescopes is much bigger, than SKA ([2]). It is important, that this array has nano-arcsecond resolution, about billion \(m^2\) surface, and also the whole sky field of view. With big dedicated radio telescope we can put first Fresnel zone into the near field zone, and
collect the signals without distance-dependent losses.

c) From uv- to uvw synthesis.

With item b) type array all, deviations from the plane wavefront of radiation, coming from point source at $c/H_0$ ($c$- light velocity, $H_0$- Hubble constant) distance may be comparable with wavelength, that is the whole Universe will be in the near field zone of ecliptic array. It means, that cosmological parallaxes may be measured, and 3-dimensional aperture synthesis may be realized ([3]).

d) From single pixel Radio Telescopes to the All Sky field of view with the same pixel sensitivity.

It is well known, that ideal instrument should read all information available in the Wolf Coherent function, $W(r, \tau)$, where $r$ is the space distance between two points on the collecting surface and $\tau$ is the time lag between these signals. Space structure and frequency spectrum may be collected from this function. The problem is, that reflectors can solve this problem only at the optical axes, that is ONE PIXEL solution may be found. Aperture synthesis array are better, but just $1/GAIN$ field of view may be realized ($GAIN=$Physical array element surface/$(4\pi\lambda^2)$. We hope, that by some way the field of view problem will be solved, and all sky may be mapped with greater sensitivity than achieved now with VLA in the one-arcmin. field.
2 Conclusion

We predict the "Second Birth" of the Radio Astronomy, and not only due to expected e-fold increase of the facilities potential, but also due to drastically change in the role it will play in the future; from secondary (to optical domain) to the "prima ballerina" role at $z > 10$

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