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Radio Astronomy in Serbia: A Short Review

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Abstract. In this lecture, I presented a short review of: 1. the brief history of development of radio astronomy in Serbia, and 2. the present state of research and university teaching in Serbia on this interesting and modern field of astronomy. Since 1970's, the continuum observations at the lowest radio frequencies (e.g. 38 MHz) and the Galactic radio loops have been represented the topics of main research interest for the first radio astronomer in Serbia, prof. dr Jelena Milogradov-Turin. In 1983, she introduced Radio astronomy as two semester course at 4th year of studies at Department of astronomy, Faculty of Mathematics, University of Belgrade. In this moment we have radio astronomy group with 5 (mainly younger) researchers from Department of Astronomy and Belgrade Astronomical Observatory. The main fields of research interest are, as a part of tradition, the Galactic radio loops and additionally, the hydrodynamic and radio evolution of supernova remnants. Our future projects will be connected with radio evolution of nova remnants and planetary nebulae.

1 The Brief History of Radio Astronomy

Carl Jansky was the first man who detected radio waves which are non-terrestrial in its origin. He received radiation from the Galactic center region. This astronomy discipline was rapidly developed after Second World War due to transformation of radars to the radio telescopes (especially in Great Britain). In 1950's, the most of radio telescopes were mounted in Great Britain, Netherlands and USA. Therefore the most important discoveries in 1950's were established by radio astronomers from these states. The crucial reveal was detection of the neutral hydrogen line at wavelength of 21 cm. Due this, radio astronomy became the basic discipline of investigation on interstellar medium. The decades of great expansion of this discipline were 1960's and 1970's. In this dramatic period of development, quasars, microwave background, pulsars and binary pulsars represented only main reveals of radio astronomy. The best resolution, in 400 years long history of astronomical observations by telescopes, was reached by using radio interferometers in 1970's and 1980's. Also, radio astronomy represented the fundamental astronomical discipline over the last decade. The modern astronomy can not be imagined without radio astronomy. Therefore we can conclude that radio astronomy enters in its own "mature" age. As illustra-

tion, we emphasize that eleven astronomers won Nobel prizes for physics, and six of them are radio astronomers.

2 Radio Sky

The basic characteristics of radio sky are:

1. radio sky is not black,
2. ordinary stars are not visible,
3. Milky Way is very bright,
4. Sun, at low frequencies (if is not in active phase), is dark object on the sky,
5. the extended objects can be seen, mainly,
6. the spur structures are dominant in all sky radio surveys.

From these basic characteristics, we can conclude that radio sky is essentially different in comparison to sky at optical wavelengths. The non-thermal (synchrotron) processes efficiently provide radiation at radio frequencies. Therefore the thermal objects (stars) are not visible because they are typical black body emitters. Using radio observations, the interstellar medium (ISM), especially nebulae (denser part of ISM), can be observed and analyzed. Additionally, some high energy extragalactic objects are also strong radio emitters such as radio galaxies and radio loud quasars. Also, the microwave background radiation can be measured at the radio wavelengths in millimeter range.

3 In Serbia

In late 1960's and early 1970's J. Milogradov – Turin (the first Serbian radio-astronomer) was attended graduate studies at the University of Manchester. She observed with Jodrell Bank 76 m radio telescope. She made continuum sky survey at 38 MHz and she published results in 1973 [1]. In this period, her main research topics were:

1. determination of spectral index of the Galactic background radiation, and
2. structure and origin of the Galactic radio loops.

In 1983, prof. dr J. Milogradov-Turin introduced course Radio Astronomy at Department of Astronomy, Faculty of Mathematics, University of Belgrade. It is two semester course (4 hours per week) at 4th year of undergraduate studies of astrophysics. In this moment teaching of Radio Astronomy at University of Belgrade has 23 years long tradition. Additionally, the four different advanced Radio Astronomy courses our students can choose at PhD studies!

4 In Serbia, Now

In this moment, our radio astronomy research group consists of five scientists from Department of Astronomy, Astronomical Observatory and Vinča Institute in Belgrade. We intensively collaborate with scientists from CALTECH, University of New Mexico, Wayne State University, University of California, Berkeley, and Arecibo Observatory. All these institutions are located in USA.

The theoretical modelling of radio and hydrodynamic evolution of supernova remnants (SNRs) is the one of the main research topics of our group. We try to develop the radio surface brightness to diameter, so-called $\Sigma - D$ relation. This relation is very convenient for description of evolution and determination of distances to SNRs (e.g. [2], [3]). We are very interested for SNRs in the nearby galaxies and therefore we try to detect there as much as possible SNRs (e.g. [4]). In addition, we try to introduce the thermal radio emission as a significant part of the total radio emission of an SNR (e.g. [5]). Traditionally, the Galactic radio loops are in the focus of our research interest, too (e.g. [6], [7]).

As observational basis we use data obtained by the best radio telescopes/interferometers on the world, such as VLA, Arecibo telescope, etc. At the other side, for the better quality of our conclusions, we need the optical data, especially for SNRs in galaxies M81, M82 and M83. We will be very satisfied by observations at Rozhen Observatory. The technical characteristics of Rozhen 2 m telescope will be very convenient for such kind of observations.

5 Our Future Plans

We plan to extent our standard research on radio and hydrodynamical evolution of SNRs, to similar objects as:

1. nova remnants, and
2. planetary nebulae.

6 Instead of Conclusion

We want to call all colleges interested to these topics to join us and to work with us. Also, we call students, to learn Radio Astronomy and evolution of supernova remnants at the undergraduate and PhD studies in Belgrade!!!

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