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OBSERVATIONS OF DECAMETER CARBON RADIO RECOMBINATION LINES IN SEVERAL GALACTIC DIRECTIONS. Part 1. EXPERIMENTAL STUDY

Subject and Purpose. *Since decameter carbon radio recombination lines (RRLs) were detected for the first time more than forty years ago, they have significantly extended our knowledge of the physics, kinematics and chemistry of the cold rarefied interstellar medium (ISM). A large number of these lines have been observed towards various Galactic radio sources. The present paper describes our studies of decameter carbon RRLs in such Galactic directions as the sight-lines to the S140 emission nebula and to the large volume of cold neutral hydrogen known as the GSH 139-03-69 super shell.*

Methods and Methodology. *Observations within a 1-MHz frequency band centered at 26 MHz were performed using the UTR-2 radio telescope and a multi-channel digital correlator. The UTR-2 is still the world largest and the most sensitive low-frequency radio telescope.*

Results. *We report the detection of decameter carbon RRL series C627α – C637α from the medium lying towards the S140 nebula. The extents of RRL forming regions have been estimated. It is suggested that RRLs in the S140 direction are formed in the local ISM lying along the line of sight. The RRL-forming region is probably associated with omnipresent diffuse neutral HI gas in the Galactic plane rather than with S140 nebula itself. Toward the GSH 139-03-69 super shell, decameter RRLs have been detected as well. Likewise, they apparently originate from the local medium lying along the sight-line. Yet, the spectrum contains a RRL component corresponding to the absorption of the cold gas of the GSH 139-03-69 itself in the ISM.*

Conclusions. *The obtained results indicate great possibilities of decameter carbon RRLs not only for cold ISM probing but also for making a good auxiliary tool for studying large complexes of extremely cold hydrogen HI in the Galaxy.*

Keywords: *cold rarefied gas, digital correlator, interstellar carbon, interstellar medium, radio recombination lines, radio telescope.*

Introduction

The interstellar medium (ISM) is an important research object in experimental radio spectroscopy. The ISM is a birthplace and nursery of stars and a repository of stellar ejections accompanying star evolutions. Due to a constant energy and matter exchange between stars and surrounding gas, the ISM is justifiably expected to simultaneously exist in different phases. The main physical parameters of the gas organized in a variety of different ISM phases clearly have a wide range of values [1]. Atoms in the ISM at relatively low temperatures and densities can be excited

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up to high quantum states. They are called Rydberg atoms and owe their states to the ion and electron recombination. After the electron is captured to a high atomic quantum level, it cascades down to less excited states. The transition is followed by the photon emission with energy corresponding to radio frequencies. The spectral lines originating from these transitions are called radio recombination lines (RRLs) [2].

High-frequency (over 1 GHz) RRLs are mainly used to trace the hot dense gas associated with HII regions. At the same time, low-frequency RRLs trace the relatively cold and rarefied diffuse gas. Many astrophysical processes run differently at high and low frequencies. Some features do not manifest themselves at high frequencies at all. These peculiarities make low-frequency RRLs a unique tool for ISM diagnostics. The discovery of the decameter RRL phenomenon owing to the radio telescope UTR-2 [3] provides new observational opportunities for ISM research.

The interstellar gas traced by low-frequency RRLs plays an important part in the cosmic matter evolution and energy processes and in the course of star formation. Ultraviolet (UV) photons, $912\ \text{Å} < \lambda < 1\,100\ \text{Å}$ released by HII regions (lying predominantly in the Galactic plane) can partially or completely ionize carbon. Thus, low-frequency carbon RRLs amplified by the stimulated emission whose contribution increases with the wavelength are formed. By using them, it is possible to explore more distant from hot stars and less dense ISM regions. As was already mentioned, low-frequency carbon RRLs in the decameter range were first detected owing to the UTR-2 radio telescope in the late 1970s [3]. At these frequencies, RRLs from hydrogen, the most abundant element in the ISM, are extremely faint because the ionization potential of hydrogen is higher than that of carbon, and UV photons fail to ionize hydrogen. The main source of hydrogen ionization at low frequencies are cosmic rays [2]. The EDA (Engineering Development Array, a single test station for Square Kilometre Array (SKA) precursor technology) was the first to detect low-frequency hydrogen RRLs below 100 MHz, specifically at 63 MHz [4]. Later on, a lower-frequency detection was made for decameter hydrogen RRLs at about 24 MHz towards Cassiopeia A (Cas A) through the UTR-2 radio telescope, and it still remains the lowest-frequency hydrogen line detection in the decameter range [5].

The line intensity and the line width are the main observational characteristics of RRLs. The line intensity is determined by the number of ions falling in the sight-line within the radio telescope beam. The line width depends on ion motions in a studied region, magnetic field influence, and obstacles met by protons when passing through the medium [2]. The low-frequencies measurements of these characteristics can shed light on how to attack such important astrophysical problems as the determination of: a) medium parameters, including electron temperature T_e, electron density N_e, emission measure *EM*, etc., b) chemical element abundance in the ISM, c) ionization and recombination mechanisms, d) distribution of Galactic matter, its structure and movements [6].

Depending on the level populations, low-frequency carbon RRLs are observed in emission (at frequencies above 200 MHz) or in absorption (at frequencies below 150 MHz) and originate from predominantly cold, rarefied gas residing in both surface shells of molecular clouds (where hydrogen changes its atomic form to a molecular one, carbon being completely in atomic form) and diffuse HI clouds.

With the UTR-2 radio telescope, decameter carbon RRLs have been widely explored both in sight-lines to discrete radio sources and in various Galactic plane directions [5, 6]. Taking into account the high level of radio frequency interference (RFI) and the faintness of received signals, the Perseus Arm medium lying in the sight-line to bright radio source Cas A is best suited for low-frequency radio spectroscopic studies. So far, a large amount of unique information has been obtained through observations in this direction [see 5, 7, 8, and references therein]. However, advances in radio astronomical equipment with continuing improvements in resolution and sensitivity of radio telescopes and receivers, the frequency bandwidth expansion, etc. enable more extended ISM regions, in particular, in Galactic plane directions to be explored in decameter carbon RRLs [see 9, 10 and references therein]. Here we will focus on the S140 nebula and the GSH 139-03-69 super shell directions.

The emission nebula S140 is situated near the edge of the molecular cloud L1204 located in the Galactic plane. This direction is of particular interest since the nebula S140 and the molecular cloud L1204 near it provide an example of closely spaced objects at

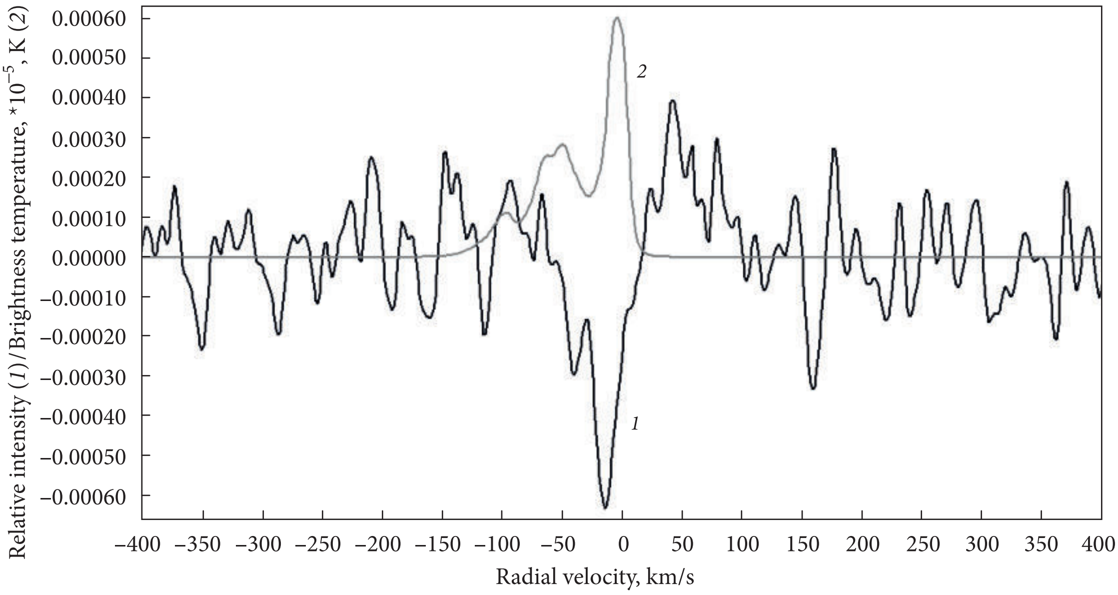

Fig. 1. Line *1* — averaged spectrum of C627α – C637α RRLs towards the S140; line *2* — synthesized spectrum of HI line towards the S140 (from [18], the angular resolution is $12 \times 12°$)

different stages of star formation. The sight-line to the complex S140/L1204 has been much investigated in various spectral lines including RRLs [11—15]. In [11, 12], the observations of high-frequency carbon RRLs towards the S140/L1204 complex are discussed, with an indirect assumption suggested that the line forming region (ionized carbon area, or CII region) may reside in this direction. The sight-line to the S140 was additionally examined in decameter carbon RRLs. Work [13] reports the first detection of the low-frequency carbon line C640α in the S140 direction near 25 MHz due to the decameter UTR-2 radio telescope. The size estimation of CII region responsible for the low-frequency RRL formation in the S140 direction is also given. Its linear and angular extents at a 1 kpc distance to the S140 are within 2 to 6 pc and 7 to 20′, respectively. The DKR-1000 radio telescope failed [14] to detect the C540α line at about 42 MHz in the S140 direction. No line was found in the obtained spectra. However, quite a large width of the line C640α measured in [13] was interpreted. In [14], the authors suggest that CII region of the observed decameter carbon RRL formation in the S140 direction is not associated with the S140 nebula itself. The observational data on the C640α line and HI line are compared in [14], showing a good agreement between them. Thus, both line profiles have their maxima at a radial velocity of about 0 km/s. Another point of agreement is that the decameter RRLs in the S140 direction are formed in multiple diffuse HI clouds in the sight-line. In [15], decameter carbon RRLs towards the S140 detected due to the UTR-2 telescope and a 4096-channel digital correlator are reported. It was preliminarily determined that CII region responsible for the low-frequency line formation is not spatially associated with the nebula S140 itself.

The other object of the study is the sight-line to the GSH 139-03-69 super shell in the Galactic plane. The super shell GSH 139-03-69 is a giant region of extremely cold HI gas spaced 9 kpc away from the Sun and 16 kpc away from the Galactic center. The size of the super shell is 2.8×1.6 kpc, which is comparable with giant molecular cloud complexes. A study of the GSH 139-03-69 in HI self-absorption line (at 1420 MHz) was carried out through the Synthesis Telescope of the Dominion Radio Astrophysical Observatory in Canada [16]. A northern border arc of a size >15° along galactic longitude and ~1° along galactic latitude was observed (Fig. 1 in [16]). The results unambiguously show a huge reservoir of cold atomic hydrogen with a large optical depth ($\tau \approx 1$), low brightness temperatures of the shell (~10÷20 K) and of the background HI gas (~15÷40 K).

The above-given facts encourage us to survey decameter carbon RRLs in different Galactic directions in an effort to refine the medium model and its physical parameter values and estimate extents of

CII regions responsible for the RRL formation. Decameter RRLs can not only provide us with details of physical conditions in CII regions but also confirm existence of cold HI gas complexes and independently estimate their extents, ionization states and other parameters. The detection of the decameter RRL component indicating the gas absorption in the GSH 139-03-69 super shell is important for understanding the vast reservoirs of neutral gas near the Galactic plane, their evolution, physical and kinematic characteristics.

Since the first detection of decameter carbon RRLs in the S140 direction through the UTR-2 radio telescope [17], the digital correlator (DC) has been upgraded [6, 15]. The increased bandwidth and a larger number of spectral channels added sensitivity to the radio spectroscopic studies. In this paper, we examine decameter carbon RRLs observed at about 26 MHz towards the S140 and the GSH 139-03-69 due to the Ukrainian UTR-2 radio telescope. The analysis of physical conditions in the line-forming regions and their association with other ISM components are left for the next paper.

1. Observational equipment and techniques

Observations of low-frequency carbon RRLs are really challenging. The detected lines exhibit very low intensities (about $10^{-3} \div 10^{-4}$ against the continuum level). High brightness temperatures of the Galactic background (~40 000 K at 25 MHz), high-level RFI and changeable ionospheric conditions further compound the observation problem. To resolve these difficulties and successfully observe low-frequency carbon RRLs, the equipment and techniques must meet a number of strict requirements. The radio telescope faces increasing demands for sensitivity as a reasonable combination of large effective area and high resolution. A broad frequency bandwidth, great efficiency, and high directivity are implied. The spectrometer must have a high resolution in frequency.

The discussed observations were carried out using the Ukrainian UTR-2 radio telescope [17] that fulfils all the mentioned requirements for high-sensitivity radio-spectroscopic observations. Specifically, a total effective area it provides is of about 140 000 m^2, its maximum angular resolution at 25 MHz is $\alpha \times \delta = 25' \times 25'$. This performance makes the UTR-2 the world largest low-frequency radio telescope on the one hand and the most sensitive instrument for low-frequency radio spectroscopy on the other. The operating frequency range of the UTR-2 is within 8 to 32 MHz. The antenna system consists of two mutually orthogonal phased antenna arrays "North — South" and "West — East" with a total of 2040 dipoles. Observations can be conducted both with each of the arrays individually, independently of each other and jointly, in modes of summation and multiplication of signals from these two arrays altogether. The beam steering is controlled electrically via discrete switching of the cable delay lines operating as phase shifters, which makes it possible to orient the beam in a wide field of view. Observations are possible both in single- and multi-beam modes. Multi-beam mode is designed so as to avoid signal distortions and refractions in the ionosphere. For this purpose, the beam is split into five independent beams spatially separated relative to declination.

The 4096-channel DC was used [6] as a spectrometer. This device is a most efficient tool for dealing with faint spectral lines. Its operating frequency bandwidth ranges up to 30 MHz. The frequency resolution is within 0.1 to 10 kHz. The time resolution is no worth than 100 milliseconds. The operating principle of this device lies in the determination of the autocorrelation function of the signal arriving from the antenna system. The obtained data feeds in the DC-coupled PC to be averaged over a specified time interval. Finally, the power energy spectrum is obtained through the Fourier transform.

The performance of the UTR-2 radio telescope enables decameter RRL observations with a high signal-to-noise ratio. At the same time, as the principal quantum number n increases, the distance $\Delta\nu$ between neighboring RRLs decreases as $\Delta\nu \sim 3\nu / n$, where ν is the frequency in kHz. In the case where the frequencies of spectrum series lines are known exactly, the lines within the series can be stacked. This is equivalent to the corresponding increase of integration time and measurement sensitivity by the factor $\sqrt{N}$, where N is the number of lines averaged simultaneously. By stacking transitions observed on the same antenna, we essentially increase the signal-to-noise ratio and improve the determination accuracy of RRL parameters (line intensity and line width).

In order to reduce exposure to the RFI, observations were made exclusively at night.

"North — South" array (1440 dipoles, effective area 100000 m^2, angular resolution $\alpha \times \delta = 12° \times 20'$) was employed, the central observational frequency was chosen to be 26 MHz. This choice warrants an optimum RFI situation during the observation period. The DC bandwidth was taken to cover 1 MHz so as to simultaneously observe eleven α-RRLs with the quantum numbers 627 to 637. The sampling frequency was 3.7 MHz. With a large number of DC channels, we have now a frequency resolution of about 1 kHz. Observations were conducted in night sessions lasting for 6 to 8 hours. For the details, see Tab. 1. The DC data fed in the PC are framed as four-minute samples. This choice of the integration time depends on the RFI situation and warrants that the data loss because of the broadband RFI is kept to a minimum.

The same as in [7], the four-minute samples that were affected by broadband RFI were discarded from the analysis. All the unaffected samples within a single session were averaged. Then the resulting averaged spectrum was cleared from the narrow-band RFI. Finally, the spectra of all single sessions were averaged. The baseline removal was accomplished through the third-order polynomial fitting. After that, all the eleven RRLs within the DC bandwidth were stacked, yielding the α-RRL spectra for each direction. The obtained results derived from the experimental studies in the S140 direction and its environs are similar to those described in [15]. The difference consists in the modified procedure of baseline removal and Gaussian fitting used to increase reliability of RRL characteristics. The improved polynomial fitting procedure produces a 20 percent improvement in relative intensity accuracy as against the older procedure. The older Gaussian fitting underestimates the line widths.

2. Results

S140

Until recently there is no hard data to clearly confirm or refute the association of CII region (which is responsible for the low-frequency RRL formation) with the S140 nebula itself. So, having more sensitivity from the upgraded DC, we continue on the way in an effort to estimate CII region extension and find out whether this region is associated with the S140/L1204 complex or not.

Fig. 1 shows the averaged spectrum series C627α – C637α of carbon RRLs measured towards the S140 nebula. From this Figure on, the RRL spectra for each sight-line are presented pairwise with the HI line spectra from the LAB Survey [18] synthesized for the beam width $12 \times 12°$ (relative to the larger size of "North — South" array beam). The line widths were obtained by Gaussian fitting of the line profiles. The obtained RRL characteristics are listed in Tab. 2.

Since an assumption was proposed in relevant earlier papers that CII regions responsible for the formation of low-frequency carbon RRLs might be associated with HI clouds, the RRLs and HI line deserve to be simultaneously examined in the S140 direction with its environs. The HI line spectra indicate that HI line is formed in the local ISM in a region spatially extended (up to 10° in size) in the S140 direction. Following the hypothesis that the line-forming regions of two line types are associated with each other, it is expected that the decameter RRLs detected in this direction are also formed in spatially extended local ISM structures which are not associated with the S140 nebula itself. To estimate the dimensions of CII region responsible for the formation of decameter RRLs towards the S140, observations through

Table 1. **Information about RRLs observations via the UTR-2 radio telescope**

Direction	Coordinates	Frequency, MHz	Integration time, hours	Year
S140	$l = 106.8°$, $b = +5.32°$	26	108	2003
G105.15+2.8	$l = 105.15°$, $b = +2.8°$	26	46.2	2003
G108.48+7.83	$l = 108.48°$, $b = +7.83°$	26	72	2003
G140.00+0.00	$l = 140.0°$, $b = 0.0°$	25	155	2005
GSH 139-03-69	$l = 137.0°$, $b = +2.1°$	26	340	2002
GSH 139-03-69	$l = 137.0°$, $b = +2.1°$	26	167	2003
G145.00+0.00	$l = 145.0°$, $b = 0.0°$	26	227	2002
G137.00-6.00	$l = 137.0°$, $b = -6.0°$	26	47	2002

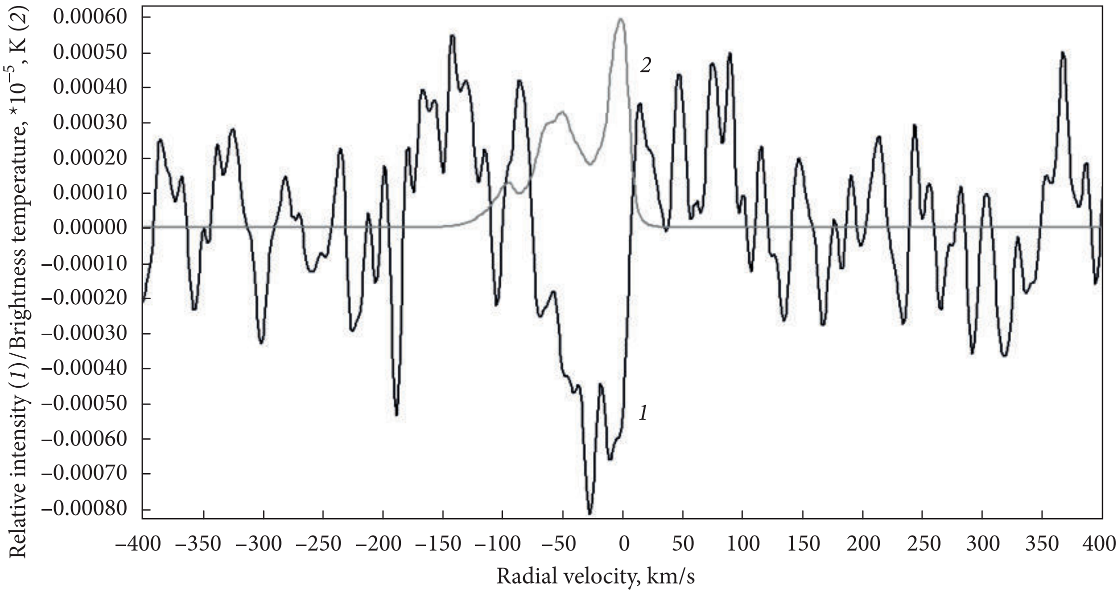

Fig. 2. Line *1* — averaged spectrum of C627α – C637α RRLs towards the G105.15+2.8 (deflection by 3° in declination from the S140 towards negative declinations); line *2* — synthesized spectrum of HI line towards the G105.15+2.8

Table 2. **The obtained low-frequency carbon RRL characteristics**

Direction	$\Delta T_L / T_C \times 10^{-4}$	V_{LSR}, km/s	$\Delta \nu$, kHz	ΔV, km/s	I_L, s^{-1}
S140	6.2	−16	2.0	23.06	−1.54
G105.15+2.8	8.1	−29	4.5	51.88	−2.92
G108.48+7.83	6.8	−16	1.75	20.17	−1.04
G140.00+0.00	4.3	−16	3.6	43.40	−1.07
GSH 139-03-69 (2002)	2.7	−32 (−7)	3.8	44.60	−0.78
GSH 139-03-69 (2003)	3.0	−19	3.12	36.03	−0.86
G145.00+0.00	3.4	0	4.5	51.88	−0.95
G137.00-6.00	—	—	—	—	—

the UTR-2 telescope were carried out in the directions shifted from the S140 sight-line by 3° relative to declination. The direction G105.15+2.8 corresponds to the shift from the S140 center towards negative declinations, and the direction G108.48+7.83 corresponds to the shift from the S140 center towards positive declinations. The spectra of the averaged RRL series C627α – C637α detected in these directions are plotted in Figs. 2 and 3, respectively. Compared to Fig. 1, the line intensities do not very change when the radio telescope beam shifts from the S140 center. A comparison of the RRL and HI spectra clearly shows a coincidence of the radial velocities of CII regions and HI clouds as well as the same character of the RRL intensity and the HI brightness temperature at three viewpoints. This argues for the hypothesis that carbon RRLs are formed in an extended group of HI clouds, where hydrogen is neutral and carbon is ionized by the background UV radiation released from HII regions. So, the hypothesis that the CII region is smaller than 20′ is not true. According to the standard model of the matter rotation in our Galaxy, the carbon RRL components with the radial velocities ~−50 to ~0 km/s match the gas that resides in the Perseus' and Orion's spiral arms.

GSH 139-03-69

Based on the results from the studies of HI self-absorption line, it is concluded that the observed line arises from the medium with a very low tempe-

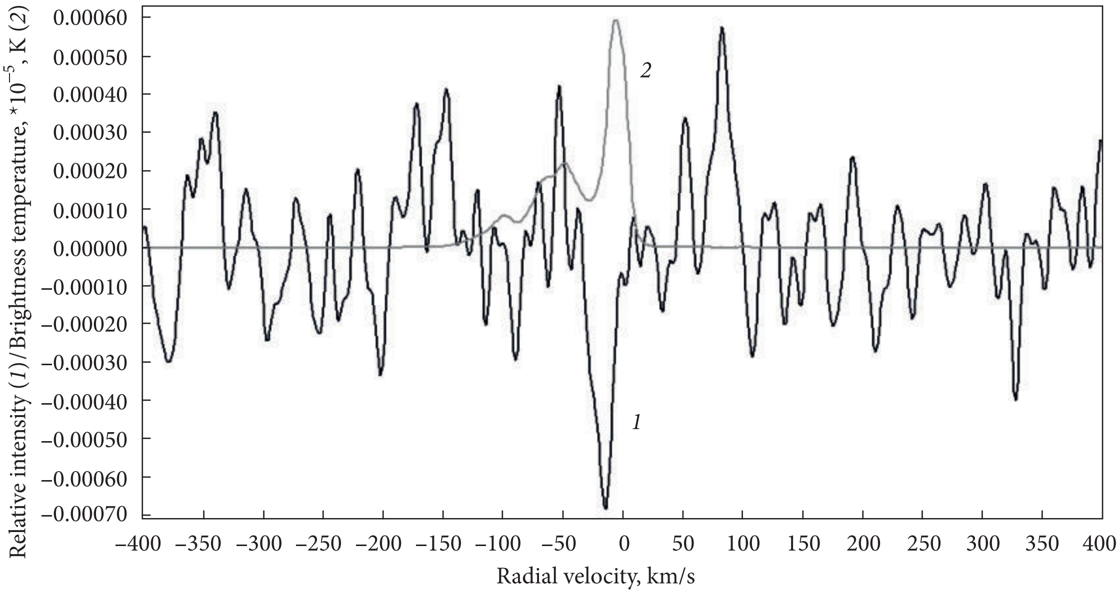

Fig. 3. Line *1* — averaged spectrum of C627α – C637α RRLs towards the G108.48+7.83 (deflection by 3° in declination from the S140 towards positive declinations); line *2* — synthesized spectrum of HI line towards the G108.48+7.83

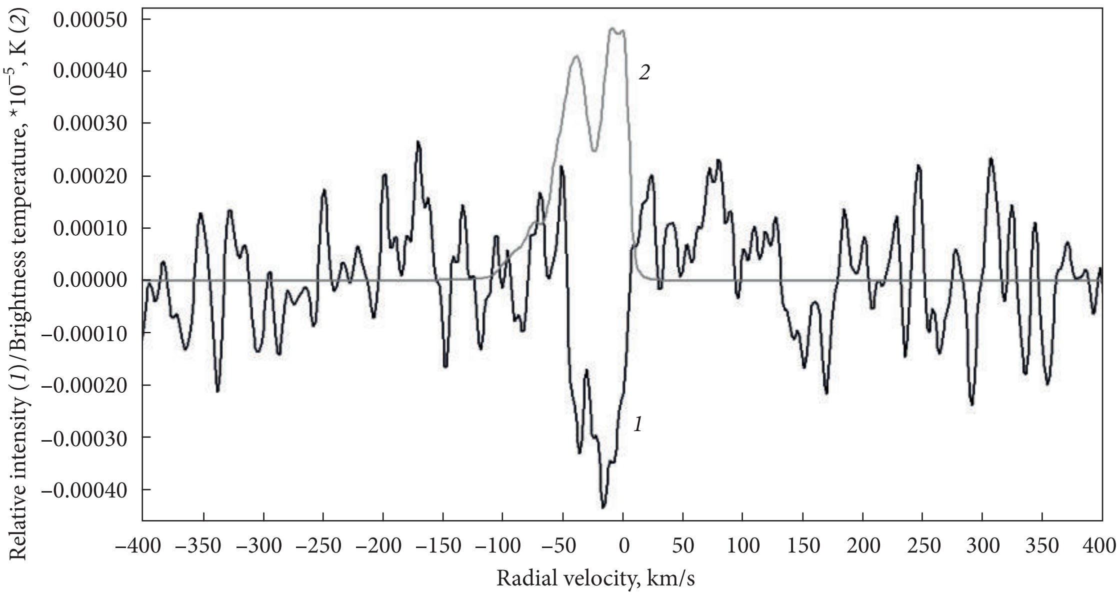

Fig. 4. Line *1* — averaged spectrum of C635α – C645α RRLs (25 MHz) towards the G140+0.00; line *2* — synthesized spectrum of HI line towards the G140+0.00

rature (~10 K). Since CII region responsible for the decameter RRL formation is assumed to be associated with HI cloud, the observation of decameter lines towards the GSH 139-03-69 is another way to confirm existence of the cold neutral atomic hydrogen reservoir in the Galactic plane. To test the hypothesis that CII regions are associated with HI clouds, the RRLs spectra detected with the UTR-2 are compared with the HI line spectra from the LAB Survey. The data refers to the several Galactic plane directions $l = 70 \div 150°$, $b = 0°$. Fig. 4 compares the spectra of decameter RRLs and HI line at the point $l = 140°$, $b = 0°$ and illustrates a good agreement between the radial velocities for both types of spectral lines, suggesting that these two types of lines might have been formed in the same gas.

A search for decameter carbon RRLs in the GSH 139-03-69 direction was carried out by means

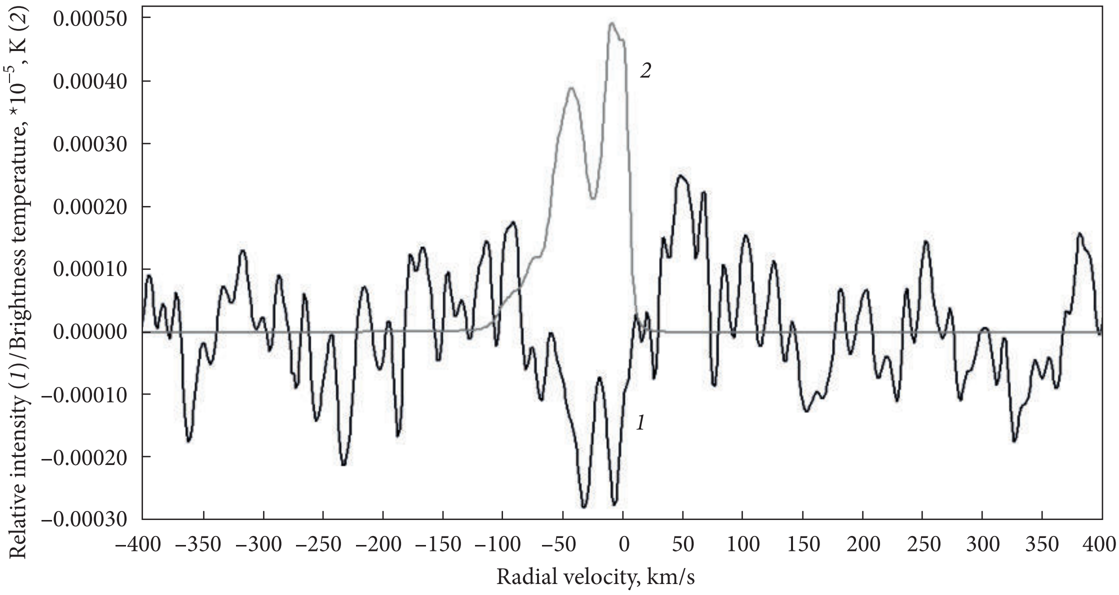

Fig. 5. Line *1* — averaged spectrum of C627α – C637α RRLs obtained towards the GSH 139-03-69 in 2002; line *2* — synthesized spectrum of HI line toward the GSH 139-03-69

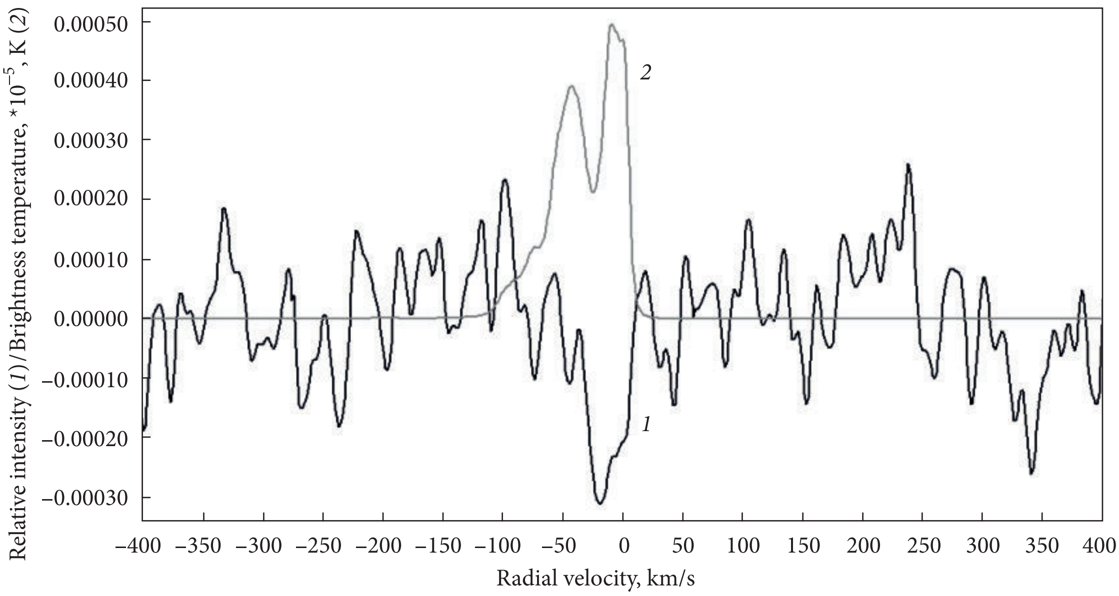

Fig. 6. Line *1* — averaged spectrum of C627α – C637α RRLs obtained towards the GSH 139-03-69 in 2003; line *2* — synthesized spectrum of HI line towards the GSH 139-03-69

of the UTR-2 in 2002—2003. The spectra of the averaged carbon RRL series discovered in this direction in 2002 and 2003 are shown in Figs. 5 and 6, respectively. In addition to the components with the radial velocities −50 and 0 km/s corresponding to The Perseus Arms and The Orion Arms, both spectra exhibit in addition a weak component with the radial velocity near −80 km/s corresponding to the outer Galactic arm. At the same radial velocity, one can also see HI self-absorption line in the GHS 139-03-69 direction.

To estimate the size of CII region responsible for decameter carbon RRL formation towards the GSH 139-03-69, the direction $l = 145°$, $b = 0°$ was also examined. The UTR-2 beam was deflected by 8° in galactic longitude from the GSH 139-03-69 sight-line to estimate the CII region extent in longitude. The corresponding spectrum with the averaged

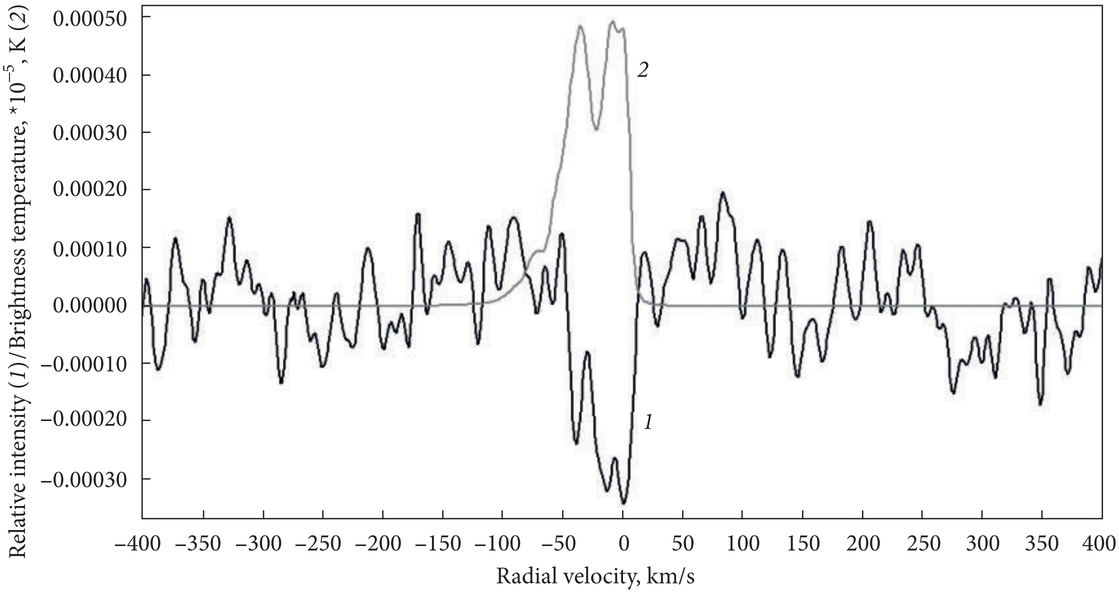

Fig. 7. Line *1* — averaged spectrum of C627α – C637α RRLs towards the G145.00+0.00; line *2* — synthesized spectrum of HI line towards G145.00+0.00

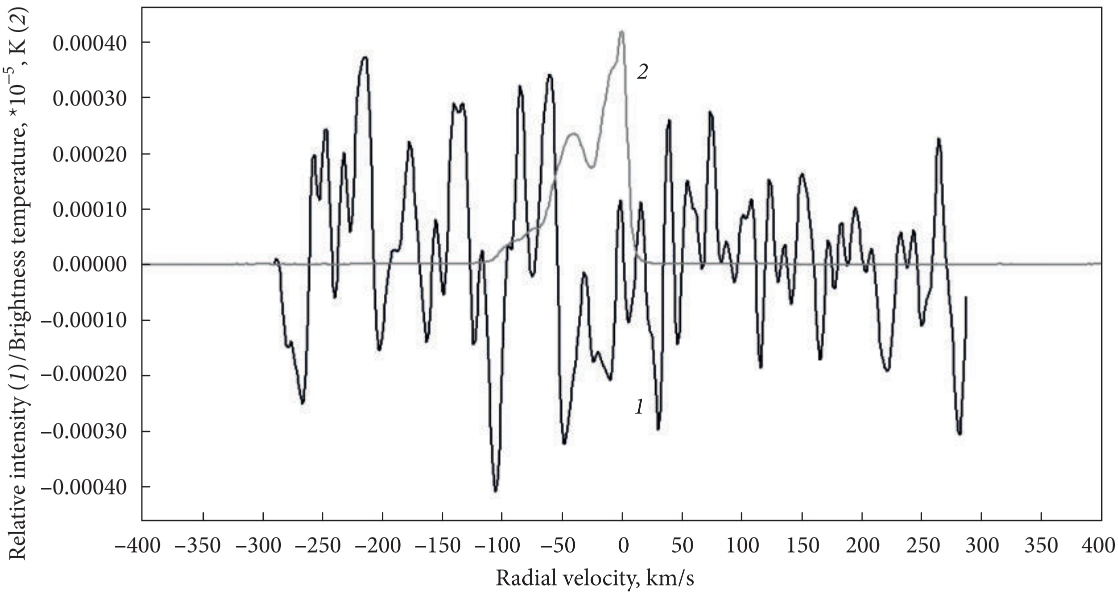

Fig. 8. Line *1* — averaged C635α – C645α spectrum towards the G137.00-6.00, with RRLs being absent; line *2* — synthesized spectrum of HI line towards the G137.00-6.00

decameter carbon RRL series is displayed in Fig. 7. In this direction, there is no component with the radial velocity –80 km/s, and there is no HI self-absorption line either.

Shown in Fig. 8 is the spectrum measured in the direction deflected by 8° along galactic latitude (towards negative galactic latitudes) from the GSH 139-03-69 line of sight. The spectrum was obtained in order to estimate the CII region extension by latitude (southern edge of super shell, Fig. 1 in [16]). No RRLs were detected in this direction.

Conclusions

This paper describes studies of decameter carbon RRLs towards the S140 nebula and the GSH 139-03-69 super shell. The studies were performed at about 26 MHz with the use of the UTR-2 radio telescope and a 4096-channel DC as a spectrometer. The

UTR-2 has a large effective area and enables high-sensitivity observations.

The lines of sight to the S140 emission nebula and to the GSH 139-03-69 super shell located near the Galactic plane were surveyed with "North — South" array of the UTR-2 in 2002 and 2003. Large integration times were realized for each line of sight. The detected lines had intensities of order 10^{-4} with respect to the background level and line widths within 20 to 52 km/s. The radial velocities indicate that the observed RRLs were formed in the gas corresponding to the Perseus' and Orion's spiral arms.

A comparison of the line characteristics obtained in the S140 direction and its vicinity suggests that the line-forming region is spatially extended (more than 6° by declination) and is most likely associated with HI clouds rather than the nebula S140 itself. Towards the GSH 139-03-69, decameter carbon RRLs with radial velocities of about −50 to 0 km/s were detected. These radial velocities suggest that the lines might have been formed in the Galactic plane in the local HI gas that resides in the Perseus' and Orion's spiral arms. A line component near −80 km/s is clearly traced in the spectra. It corresponds to the very cold gas far away from the outer Galactic spiral arm and seems to be related to the GSH 139-03-69 super shell itself. But the intensity of this component is very low and hampers analysis. The further studies of large masses of the extremely cold atomic hydrogen with temperatures near 10 K in our Galaxy will provide a substantially better interpretation of spectral observations of the ISM matter with the use of decameter carbon RRLs.

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СПОСТЕРЕЖЕННЯ ДЕКАМЕТРОВИХ
РЕКОМБІНАЦІЙНИХ РАДІОЛІНІЙ ВУГЛЕЦЮ
В ДЕЯКИХ НАПРЯМКАХ ГАЛАКТИКИ.
Частина 1. ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ

Предмет і мета роботи. Декаметрові рекомбінаційні радіолінії (РРЛ) вуглецю було вперше виявлено більше сорока років тому. За цей час дослідження РРЛ значно розширили наші знання відносно фізики, кінематики і хімічних властивостей холодного розрідженого міжзоряного середовища (МЗС). Велика кількість цих ліній спостерігалась у напрямках різних галактичних радіоджерел. У цій статті описано наші дослідження декаметрових РРЛ вуглецю в напрямках емісійної туманності S140 і гігантської оболонки холодного нейтрального водню GSH 139-03-69.

Методи і методологія. Спостереження було проведено на радіотелескопі УТР-2 за допомогою багатоканального цифрового корелометра в смузі аналізу 1 МГц відносно центральної частоти 26 МГц. УТР-2 є найбільшим у світі та найчутливішим низькочастотним радіотелескопом.

Результати. Серії декаметрових РРЛ вуглецю C627α – C637α було виявлено в середовищі, що лежить у напрямку S140. Було оцінено розміри областей формування ліній. Передбачається, що лінії в напрямку S140 утворюються в місцевому МЗС, який лежить на промені зору. Область формування ліній, ймовірно, пов'язана із широко розповсюдженим дифузним газом HI, що лежить в Галактичній площині, і не пов'язана із самою туманністю S140. Декаметрові лінії також було виявлено й у напрямку гігантської оболонки GSH 139-03-69. Вони, судячи з усього, також утворилися в місцевому середовищі, що лежить уздовж променя зору. Однак у спектрі присутній також і компонент лінії, який відповідає поглинанню холодного газу самої GSH 139-03-69 у МЗС.

Висновки. Отримані результати свідчать про високі можливості декаметрових РРЛ вуглецю не тільки для зондування холодного МЗС, а й як допоміжного інструменту при вивченні великих комплексів надзвичайно холодного водню HI в Галактиці.

Ключові слова: *міжзоряний вуглець, міжзоряне середовище, радіотелескоп, рекомбінаційні радіолінії, холодний розріджений газ, цифровий корелометр.*