Radio Telescopes ; the EM-Wave Application which Show Us Invisible Light from Space.

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***Abstract* — I choose 'Radio Astronomy' as my topic, because I think that students who specialized in electrical and electronical engineering, are farmilier with other topics(several communications using EM wave, microwave oven, vision, GPS, radar and etc). Then, I did want to challenge somewhat fresh topic.**

Stars radiate not only visible light but also light of invisible wavelength region. Then, we can get more information about stars from these invisible light by radio telescopes. For that reason, I will approach the topic 'Radio Astronomy' with radio telescopes.

I. INTRODUCTION

We usually think that radio-wave is a way of communication. Whenever an event happens in space, for example, the explosion of stars, the collision with galaxies and so on, not only visible light but also EM-waves of various wavelength region; ultraviolet rays, infrared rays, X-ray, radio-wave and so on, are radiated. Then, EM-waves from space contain these event's information. Therefore, we can 'look' space with radio-wave.[1]

In. this paper, I present useful EM-wave characteristics of radio-wave for observation, the antenna of radio telescopes as EM-wave device, current and planned radio telescopes and etc..

II. THE REASON OF USING RADIO TELESCOPES

Why we use 'radio telescopes' for observing space? Because space radiate EM-waves of various wavelength, we can get more information from all possible wavelength region light for observation than only visible light. The wavelength regions which can pass earth's atmosphere, are visible light and radio-wave. EM-waves of Other wavelength regions are almost absorbed by earth's atmosphere. Accordingly, they can't reach us. Then, we should observe radio-wave for getting information which is not obtained by observing visible light. Because human can't look radio-wave, we need radio telescopes for observing radio-wave.

III. THE ORIGIN OF RADIO-WAVES FROM SPACE & USEFUL EM-WAVE CHARACTERISTICS OF THESE

The radio-waves from space are grouped into thermal radio-waves which are caused by ionized gas, and nonthermal radio-waves which are caused by synchrotron radiation or plasma vibration.

The nebula around the star in high temperature, is ionized by short wavelength light, which has Lyman continuous spectrum and are radiated from the star. Then, the electron from ionized nebula, is deflected by other positive ions. The electron's deflection means the electron is moving with acceleration. The accelerated electric charge radiates some EM-wave which wavelength region is radio-wave in this case. The radio-wave generated by this process, is called thermal radio-wave. The radio-wave's intensity is proportional to both the surface area of the nebula and the temperature of it. When we knew the surface area of the nebula already, we can also know the temperature of the nebula by measuring the intensity of radio-wave radiated from the nebula.[2]

In space, very weak magnetic field exists. In the nebula which is generated by a violent explosion of a star or a galaxy, there are many electrons of sublight speed. In other words, many electrons of very high speed are moving on a magnetic field. In that case, the electrons do circular motion. At this time, the radio-wave is radiated by synchrotron radiation. As stated above, the nonthermal radio-wave is a evidence of the active nebula.[2]

A useful characteristic of nonthermal radio-wave is polarization. As the electrons do circular motion on a magnetic field, the vibration of the electron is orthogonal to the direction of the magnetic field. If the result has a certain polarization when we measure the radio-wave, we can know the direction of magnetic field of observation target.[2]

By this time, I state the radio-waves which have continuous spectrum. Frequently, we can receive the radio-waves which have line spectrum. Because the spectrum corresponding to a certain material is already known, we can know the kinds of existent materials of the line spectrum source. If the received line spectrum has redshift or blueshift when it compare with the line spectrum of the material supposed to exist in the observation target, we can know the relative speed of target to us. Moreover, we can know the quantities of the existent materials by line spectrum, because intensity of line spectrum corresponding to a material is proportional to the quantity of the material. In practical, the intensity of line spectrum is influenced by not only the quantity of corresponding to the material but also the temperature and the pressure of line spectrum source. If we knew the quantities of the existent materials already, we can know the temperature and the pressure of source.[2]

When the electron from ionized nebula is deflected by other positive ions, thermal radio-wave is radiated. On the other hand, the electron can be captured by positive ions, too. As captured, a certain line spectrum called recombination lines is radiated. Its intensity is proportional to the square of density of ions as thermal radio-wave. Accordingly, we can know the temperature of nebula by comparison with the intensity of its thermal radio-wave and recombination lines.[2]

IV. Some radio-wave observation results using it's EM-wave characteristics

We can get the result that space between galaxies is not absolute vacuum, with Faraday rotation. Faraday rotation is the changing the direction of polarization when the radio-wave transmits into the plasma which has magnetic field. The quantity of changing polarization is proportional to both the quantity of the plasma and the intensity of the magnetic field. Therefore, if either the quantity of the plasma or the intensity of the magnetic field is zero, Faraday rotation does not happen. When we measure the quantity of Faraday rotation of nonthermal radio-wave source out of our galaxy, the result is always not zero and proportional to distance between the target and us. This is an evidence that the plasma having magnetic field exists in the space between galaxies.[2]

In addition, we can know what our galaxy's shape is, with Doffler effect and 21cm wavelength radio-wave which is radiated from neutral hydrogen atoms. The radio-wave of 21cm wavelength can transmit without interruption of interstellar matter. While the density of neutral hydrogen atoms in galaxy is high, that in interstellar is very low. Accordingly, when we measure the intensity of 21cm wavelength radio-wave from many directions, we can know where our galaxy exists and guess our galaxy's shape also. When we receive 21cm wavelength radio-wave from the direction of the Milky Way, we can get the result that there are an exact 21cm wavelength radio-wave and two blueshifted 21cm wavelength radio-waves, shown in Fig. 1.. Because source #2 in Fig. 2. has the fastest relative speed to us, the quantity of blueshift is the largest(B in Fig. 1.). Since source #3 and source #1 in Fig. 2. have the same relative speed to us, the quantities of blueshift are the same(A in Fig. 1.). As source #4 in Fig. 2. has no relative speed to us, the quantity of blueshift is zero(S in Fig. 1.). With these processes to every directions, we can guess our galaxy is one of spiral galaxy which has 4 arms.[3]

V. Antenna of radio telescopes

A radio telescope consists of antenna, receiver, equipment for calculation and etc.. The antenna concentrates the radio-waves from space on focus where receiver is placed. The radio-waves from space are as weak as the antenna of the earth's revolution orbit size, is needed for lighting a miniature bulb by only energy of radio-waves from space. Therefore, the antenna capability of a radio telescope is determined by aperture gain and resolution.

The antenna is, as we have seen, an arrangement intended to intercept a certain flux of radio energy[in this paper, from space especially] and to transform it into an electric current propagating on a transmission line. If S is the density of the incident flux, the available power at the terminals of the antenna has a value P such that P = AS. The quantity A, which has the dimensions of area, is the collecting area.[4] For that reason, the aperture gain is proportional to the area of antenna.

The resolution of an antenna depends essentially on its dimensions reckoned in wavelengths. In a given plane, the angular resolution in radians is given approximately by (wavelength / length of antenna).[4] Accordingly, We can increase the resolution of the antenna in proportion to its length.

VI. Current radio telescopes

The world's largest antenna of radio telescope is a 305-meter fixed dish built into a valley in the hills at Arecibo, Puerto Roco. The largest fully steerable radio telescope' are about 100meter in diameter.

As stated above, if the size of antenna of radio telescopes is increased, the aperture gain and the resolution are also increased. However, there are the limitations of increasing its size practically. Because the concentration error determined by the smoothness of antenna surface is not good when the size of antenna is increased simply. For example, if the error is 3mm, we can observe the radio-wave above 6cm wavelength without difficulty and we can't observe the radio-wave under 3cm wavelength. For overcoming this limitation, we use aperture synthesis which combine observations from two or more radio telescopes, or interferometers which are linked electronically with computers to achieve the resolution of one giant antenna.[2]

The Very Large Array(VLA) is the primary aperture synthesis facility of the National Radio Astronomy Observatory, located at a 2100meter high site in New Mexico, U.S. The VLA consists of 27 movable 25-meter radio antennas that can be used in different configurations to simulate the performance of a fully steerable radio antennas 34km in diameter. They planed 8 radio antennas is added with 140 million dollars.

Very long baseline interferometry(VLBI) gives the best resolution. Data are recorded on magnetic tape from coordinated observations of a specific radio source by two or more antennas continents apart. The data can be correlated by computer to simulate one dish as big as the earth.

The Very Long Baseline Array(VLBA) consists of 10 automated 25-meter radio telescopes distributed across the U.S. from Hawaii to St. Croix, Virgin Islands. Each antenna operates automatically under control from the operations center in New Mexico. Computer processing of the recorded data from all 10 antennas subsequently can synthesize a single radio telescope 8000km in diameter.

The resolution is maximized by using a VLBI with Earth-orbiting radio telescopes. The HALCA/VSOP consists of EVN which consists of 18 radio telescopes in Europe, VLBA and HALCA which is a satellite made by Japan in 1997.

VII. Planned radio telescopes

The RadioAStron of the Russian Space Agency and the ARISE of NASA are planned, which are VLBI with Earth-orbiting radio telescopes, too.

The ALMA is an international collaboration between Europe and the North America to build a synthesis radio telescope that will operate at millimeter and submillimeter wavelengths. Japan may also become a partner, making this a truly global collaboration.[5]

The SKA is a centimeter wavelength radio telescope, with a proposed collecting area at low frequencies (150Mhz to 1.5GHz) of roughly 1 square kilometer. The SKA project involves collaborative strategic research with partners from The Netherlands, Canada, India and the U.S..[6]

The Korea Astronomy Observatory planned the Korean VLBI Network(KVN) consisting of 20-meter diameter radio antennas in Seoul, Ulsan, and Jeju island in Korea. This will give a resolving power equivalent to a 500km diameter telescope. The KVN aims to complete construction in 2007 and will be the first millimeter wavelength dedicated VLBI system in the world. The KVN will be a national basic research infrastructure to carry out studies of the fine details of structures in the Universe, such as active galactic nuclei – as well as the detection of small tectonic movement of Korean peninsula.[7]

VIII. Conclusion

Radio astronomy began in 1931 when U.S. engineer Karl G. Jansky(1905-1950) discovered radio-waves coming from the Milky Way. Radio astronomy has helped astronomy to develop because invisible radio-wave source of importance like as a quasar, a pulsa and etc. can be observed by only radio telescopes. Therefore, the primary field of astronomy at present is radio astronomy.

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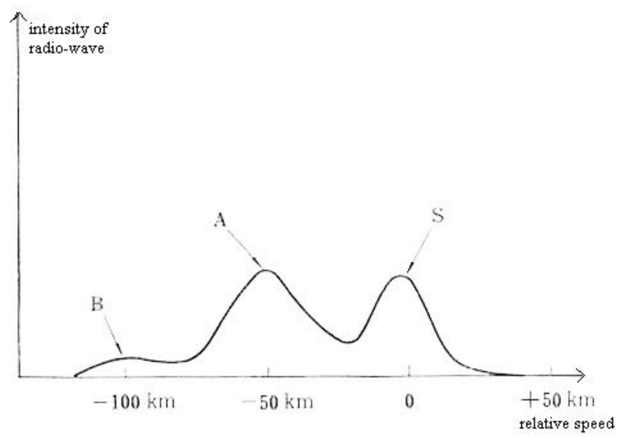

Fig. 1. The intensity of 21cm radio-wave from our galaxy.

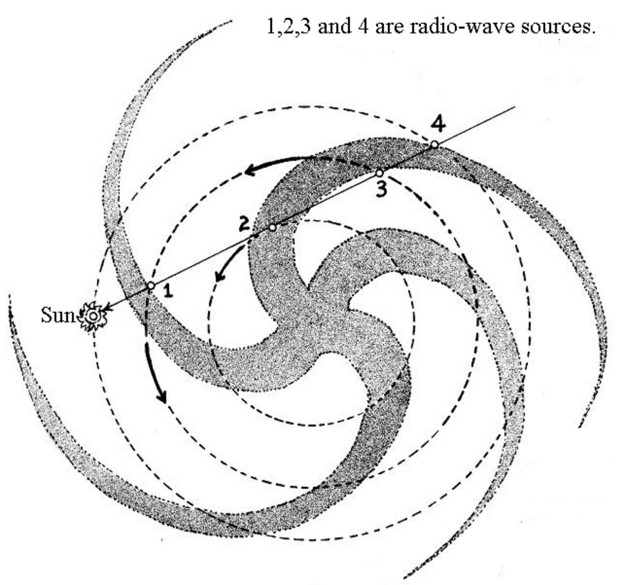

Fig. 2. The bird's-eye view of our galaxy.