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The 1 Jy class radio transients in Nasu 1.4 GHz wide-field survey

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We present the detection of radio transients in Nasu 1.4 GHz wide-field survey. The survey started at Nasu observatory, Japan, in 2003. In the survey, we use four pairs of two element interferometers aligned east-west and simultaneously survey the region at +32 degree < declination < +42 degree in drift scanning. In the observation at the declination of +41.5 degree in 2005, we detected two transient bursts which brightened to 1 Jy-2 Jy and faded within 2 days. While one was in low Galactic region, the other was in high Galactic region and the high Galactic one has possible counterparts only in gamma-ray databases. But such a powerful radio afterglow of a gamma-ray burst has never been known. Considering that the transient has no counterpart in x-ray wavelengths, it could be a member of a new class of highly energetic radio transients unless it is an exotic source with Doppler boosting. To study such one-time transients in more detail, observations in optical, radio, x-ray, and gamma-ray wavelengths are necessary. We also present a plan for an alert system of radio transients to collaborate with other observatories in the world.

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1. Introduction

Triggered by the discovery of variable compact radio sources [2], radio survey programs for time-variable and transient sources started. In the survey program of the galaxy plane, Gregory and Taylor have detected the variability of LSI+61303 [5]. Recently, Rotating Radio Transients were discovered in a survey using the Parkes radio telescope [10] and a 1 Jy radio transient was found in a monitoring observation of the Galactic Center region using the Very Large Array telescope [6]. These observational results are the triggers of the wide-field survey projects being constructed.

In Japan, we started a 1.4 GHz wide-field survey at Nasu observatory in 2003. We suppose our universe would be more dynamic than expected and the survey is aimed to detect transient and time-variable radio sources such as Cygnus X-3 [12]. To detect such phenomena, we intend to achieve large field of view rather than high spatial resolution, and we use four pairs of two element interferometer in drift scanning to monitor the wide-field of the sky. As a result, we have detected several 1 Jy radio transients [7] [11].

In this paper the detection of two radio transients in 2005 [9] is shown. The two transients appeared on only a single day in a 27 days continuous observation. In section 2, we describe the observation in the survey program. The data analysis is shown in section 3. The results and the discussion of the transient radio bursts are shown in section 4. In section 5, we show the plan to construct an alert system for the future collaboration with other observatories in the world, and in section 6, we remark our conclusion.

2. Observation

At Nasu observatory, the wide-field survey is performed at 1.4 GHz with bandwidth of 10 MHz. We use the eight element interferometer, east-west aligned at even intervals. Each element has a spherical main dish that is 20 m in diameter and a pair of a sub-reflector and a feed-horn antenna. To achieve large field of view, we use four pairs of two element interferometers. The antenna baseline of one pair is 84 m and the HPBW is about 1.0 degree. By using the four beams in drift scanning, we monitor four different declination lines in the sky at a time.

One survey is composed of several observational units and one unit usually lasts for two weeks with the four beams fixed to their observing declination lines. We change the directions of the beams by 0.5 degree intervals at declination when one unit finishes. Thus we need 5 units to cover our observational region between +32 degree and +42 degree at declination, and it takes about 3 months, that is 10 weeks and several days for maintenance of the observational system (Fig. 1). Since our survey is aimed to detect time-variable sources and transient sources which we cannot tell when they appear, we need to monitor the same region of the sky as long as possible. Therefore, we perform the 3 months survey simultaneously and one declination line is monitored for 8 weeks per year, i.e. in 4 observational units of 2 weeks duration.

The received signals from two elements are added and sampled by A/D for 24 hours. The receivers of each element are not cooled and the average system temperature is 100 K. The received intensities of sources are decided by the peak-to-peak power and the flux densities are determined by comparison with powerful calibrators, which are near the detected sources. The error on flux density is determined as 1 sigma of noise in the data. It is between 200 mJy and 500 mJy, depending on the observational conditions. The positions are determined by phase calibration using the calibrators. The positional error on declination is decided by the HPBW of the fringe beam because the survey is performed in drift scanning. The positional error on right ascension is 10 arc-minute.

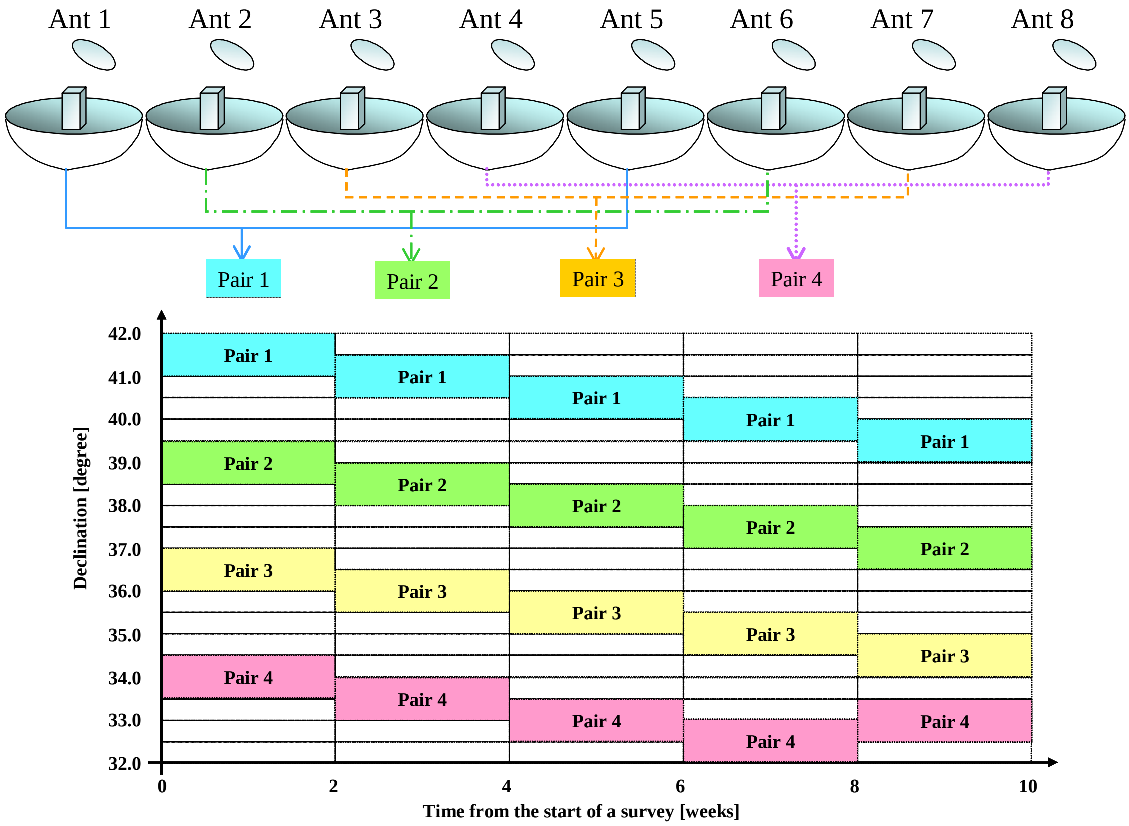

Figure 1: An observational schedule and the projection on the sky in a three months survey.

We performed a 27 days continuous observation at declination of +41.5 degree from 2004 Dec 28 to 2005 Jan 23. In the observational period, the detection limit was on average about 400 mJy. In the 27 days observational data, we detected two transient fringes, both of which appeared one day and faded in the next day.

3. Data Analysis

In the fringe data analysis, we use the spectrum analysis and the periodic analysis, because a theoretical fringe frequency is determined by the antenna baseline and the declination observed in a drift scanning type two element interferometer aligned east-west. In the first step of the analysis, we perform the Fringe Band Pass Filter (FBPF) method we developed [8]. In the observational data of a drift scanning two element interferometer aligned east-west, the observed fringe of a celestial object has a narrow band feature in the spectrum. The frequency components lower than the theoretical fringe frequency distort the baseline of the fringe data and the higher ones are the noise components which decrease the signal-to-noise ratio. Thus, in the FBPF method, we Fourier Transform the observational temporal fringe data to frequency domain and Inverse Fourier Transform using the celestial fringe frequency components to extract the fringe waveform without noise components.

In the next step, we perform autocorrelation to the filtered temporal fringe waveform to search its fringe period. The fringe period of the observed celestial fringe coincides with the theoretical fringe period at the declination observed. This coincidence of the fringe period is the strong evidence that the observed fringe has celestial origin.

Transient name	bII (degrees)	Flux density (Jy)	Counterpart	
WJN J0445+4130	-2	1.8	1RXS J044434.9+410331	x-ray
			4B 950523-	gamma-ray
			4B 931016-	gamma-ray
			4B 910912	gamma-ray
			NVSS J044424+414005	1.4 GHz
WJN J1043+4130	+60	1.7	4B 940504	gamma-ray
			4B 960803	gamma-ray

Table1: Profiles and counterparts of two radio transients. The x-ray source is in the ROSAT All-Sky Survey Faint Source Catalogue [13]. The gamma-ray sources are in the CGRO BATSE catalog in Paciesas et al. and the BATSE Gamma-Ray Burst Catalog (http://gammaray.msfc.nasa.gov/batse/grb/catalog/current/). The 1.4 GHz source is in the NVSS catalog [1] and the flux is 76.3 mJy.

4. Results and discussion

We analyzed the observational data from 2004 Dec 28 to 2005 Jan 23 in the manner described in section 3 and detected two transient fringes of celestial origin. They are one-day transients which appeared one day and disappeared in the next day. We named them WJN J0445+4130 and WJN J1043+4130, where WJN is our catalogue name. Table 1 shows their Galactic latitudes, flux densities, and counterparts searched in the NASA Extragalactic Database and the HEASARC database.

Here, we consider whether the two transients were affected by the well-known source-extrinsic effect, the Interstellar Scintillation (ISS). There are many reports that the flux densities of compact flat spectrum sources increase or decrease by ISS. The known increases of flux

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densities are usually several tens of percent of the averaged flux and at most double. However the transients we detected had flux of 1 Jy to 2 Jy with the signal-to-noise ratio much more than 3 sigma. Thus, the interpretation that these transients were the results of ISS is not sufficient to explain the observed variations.

WJN J0445+4130 was detected in a low Galactic latitude. As shown in table 1, this source has counterparts in radio, x-ray and gamma-ray databases. Considering the low Galactic latitude, this type of source would be an active galactic one, such as a microquasar. GRS1915+105 is a well-studied microquasar in radio, x-ray and gamma-ray wavelengths and significant flares before its plateau state were detected [3] [4]. WJN 0445+4130 might be such a flare due to the outflow of relativistic electrons.

Meanwhile, WJN J1043+4130 was detected in a high Galactic latitude and it has counterparts only in gamma-ray wavelengths. But we consider that the interpretation of this transient as a radio afterglow of a gamma-ray burst is not appropriate, because such a powerful afterglow has never been found. Then, considering the high Galactic latitude, the plausible types are AGNs such as blazars and magnetars. The association between AGNs and x-ray emissions are well known, however, no counterparts in x-ray have been found. Therefore, we consider that this transient is faint and quiet in x-ray and we detected its transient 1 Jy burst in radio. Although this source could be an exotic radio transient with Doppler boosting, it might be one of a new class of highly energetic radio transient sources.

5. The alert system of radio transients

Since we started the survey program at Nasu observatory, we have detected 10 radio transients. 4 transients are in published papers and papers on other transients are now in preparation. Since the transients are widely distributed in both low Galactic and high Galactic regions, the long-time and wide-field survey is necessary to detect such transients. The wide-field radio observatories such as LOFAR, LWA and SKA will start to operate in a few years and we suppose that transient and time-variable phenomena more than expected would be detected.

Now we have a new 30 m diameter antenna which can be used for follow-up observations of the transients. But, for more detailed study, observations in optical, radio, and other wavelengths are necessary and we are planning to collaborate with other observatories in the world. One of the plans is follow-up observations on other telescopes triggered by our alert of the detection of transient events. In the follow-up observations, we would not need very high resolution but would need an observational method in which the sky within the error box of a transient is scanned with moderately wide beam, because the positional error on declination in our interferometers is about 1 degree. Moreover, in radio wavelengths, it would be desirable that several frequencies including 1.4 GHz are used.

Considering that the flux densities of the transients detected at Nasu decay from Jy level to mJy level during 1 day, the immediacy of the alert is most important. Thus, we are developing an alert system which includes a new data sampling system that shortens the data sampling time from 24 hours in the present system to 1 hour. We installed the alert system at Nasu observatory

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in 2007 and we are now testing it. With the new system, the alert will be sent to the world within a few hours after detecting transient events.

6. Conclusion

We have detected two radio transients, WJN J0445+4130 at a low Galactic latitude and WJN J1043+4130 at a high Galactic latitude, in a survey at Nasu observatory in 2005. We consider that the transients were due to 1 Jy class radio bursts. Especially, WJN J1043+4130 has counterparts only in gamma-ray databases. The transient is probably one of the AGNs that are very faint and quiet in x-ray and radio wavelengths. Though it might be an exotic source with Doppler boosting, it could also be a member of a new class of highly energetic transients.

To study the one-time transients as we detected in more detail, observations in radio, x-ray, and other wavelengths are necessary. For future collaboration with other observatories, we are developing an alert system to alert the detection of radio transients. This system includes our new data sampling system in which the sampling time will be shortened to improve the immediacy of the observational data. With the alert system, we will continue the wide-field survey and hope to cooperate with other observatories in the world, to uncover the nature of the dynamic radio sky.

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