Proposed triggered GW search associated with WJN radio transients

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Collaborating with radio astronomers :

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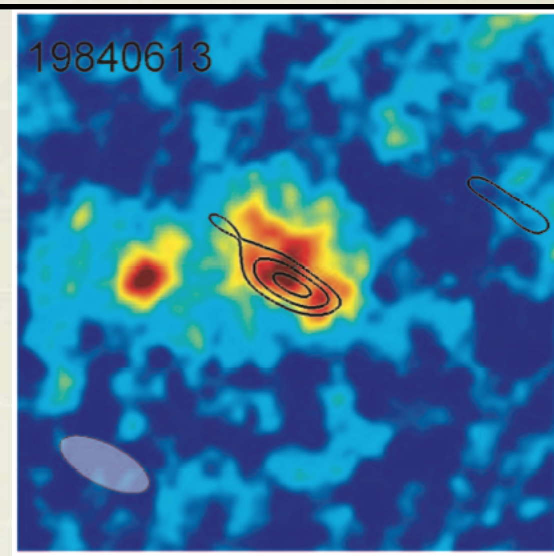
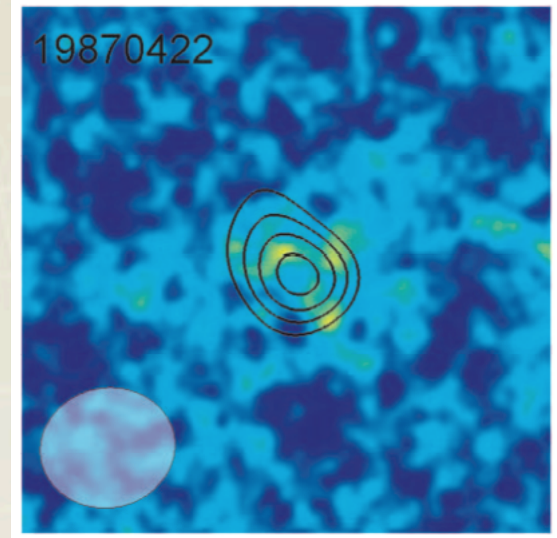
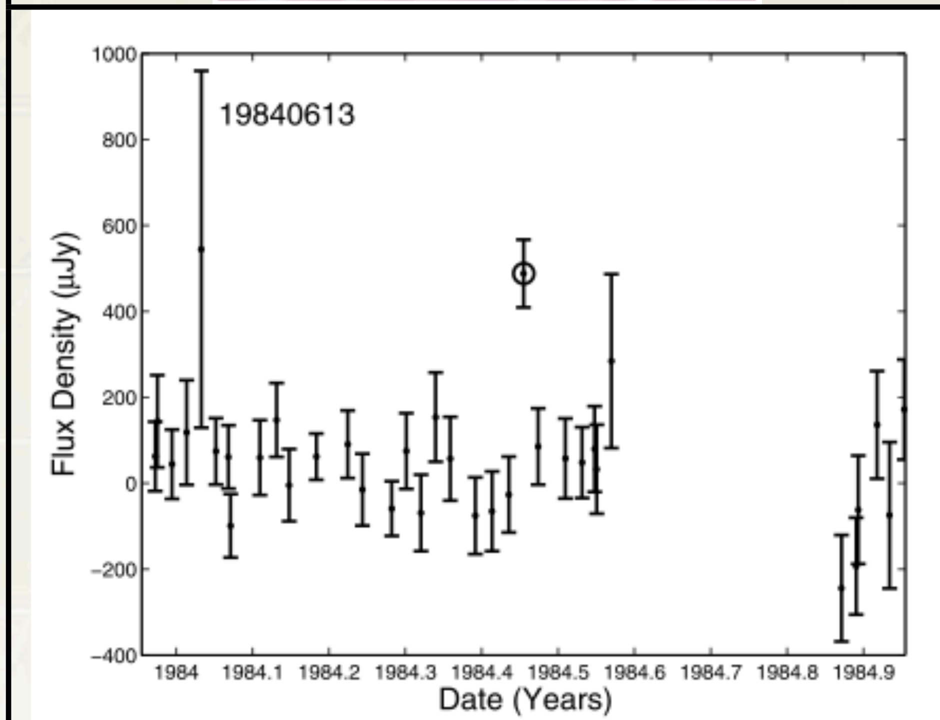
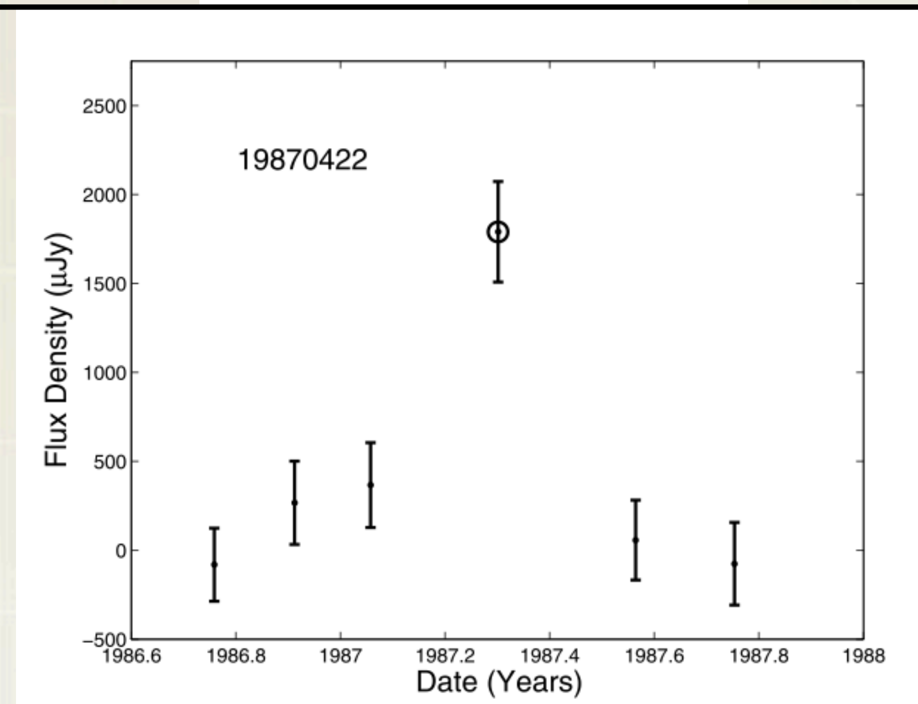
The WJN catalog is named for Waseda University, Jiyu Gakuen, and Nasu Observatory.

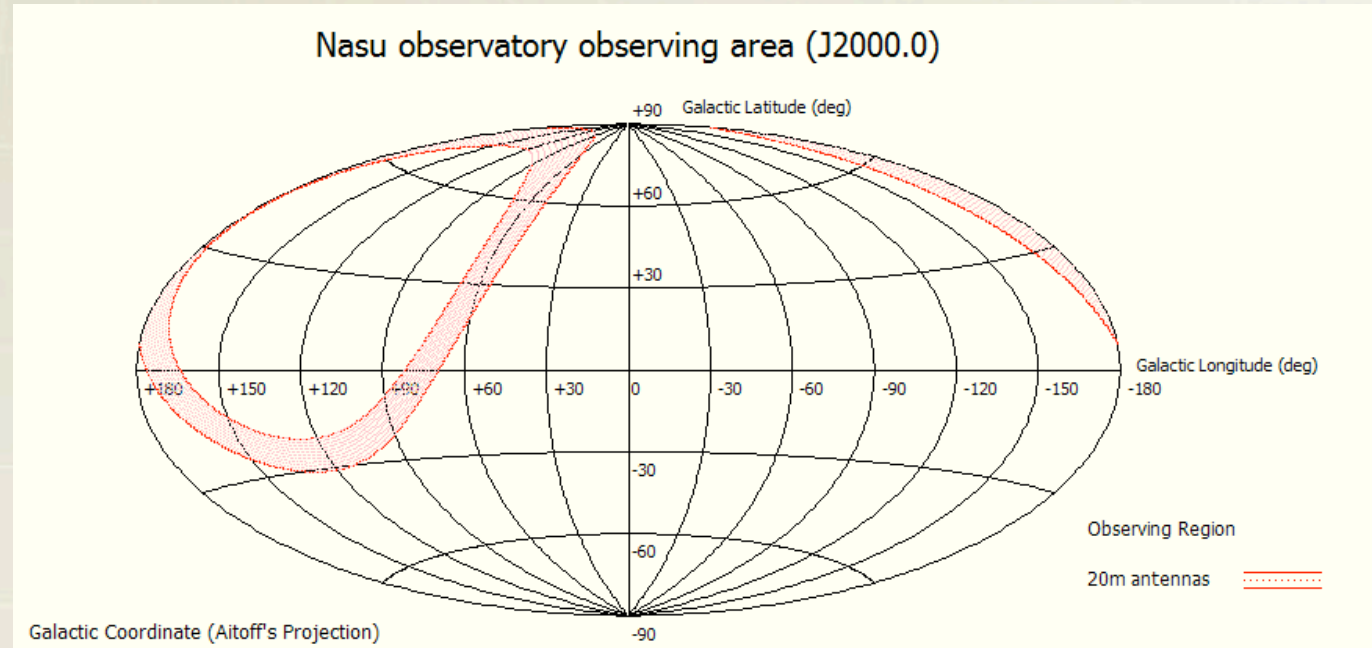
Radio afterglow of CBC

- **Last year, a paper titled**
  "Detectable radio flares following gravitational waves from mergers of binary neutron stars"
  E. Nakar, T. Piran, Nature 478, 82–84 (06 October 2011)
  http://www.nature.com/nature/journal/v478/n7367/full/nature10365.html
  http://arxiv.org/abs/1102.1020
  has been published.
- **In abstract,** ***"Numerical simulations have demonstrated that these mergers eject energetic sub-relativistic (or even relativistic) outflows. This is certainly the case if the mergers produce short GRBs, but even if not, significant outflows are expected. The interaction of such outflows with the surround matter inevitably leads to a long lasting radio signal."***
- **The optimal search will take place around 1.4GHz.**
- **The signal may be a few 100 micro Jy at a few 100 Mpc, lasting a few weeks.**
- **The radio transients appear weeks to years after the merger.**
- **Other possible 1.4GHz sources with similar properties are radio NSe, but one can filter them by three ways: SN optical light, optically thick spectrum, luminosity-time scale relation (rSNe emission is longer&fainter)**

Possible candidates

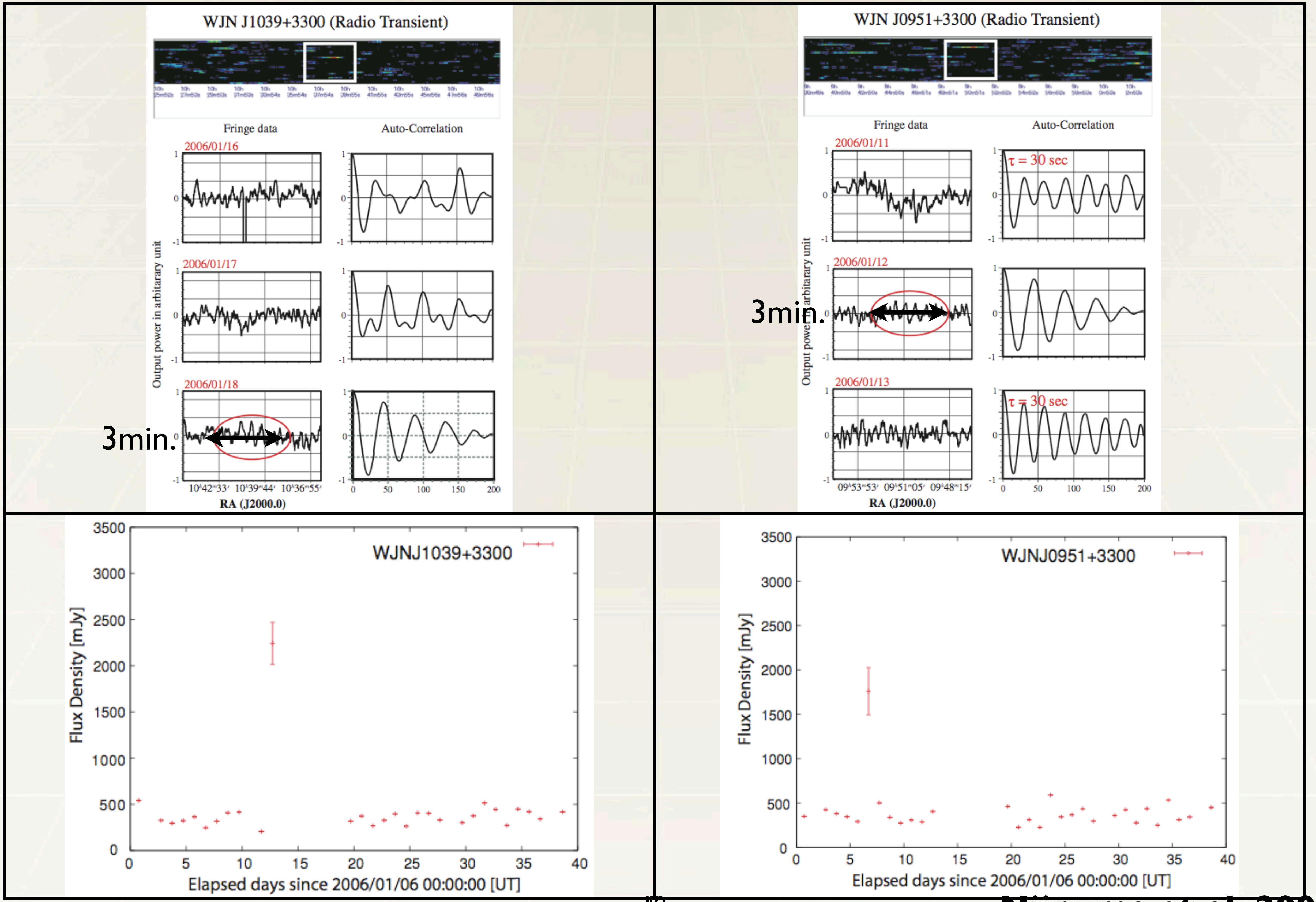
	
	
o flux: 0.4-0.6mJy at 140Mpc o duration: < 7days o event rate: 6000-150000$Gpc^{-3}yr^{-1}$ (consistent with estimated CBC rate)	o flux: 1.5-2.0mJy at 1.05Gpc o duration: ~2months o event rate: 80-20000$Gpc^{-3}yr^{-1}$ (consistent with estimated CBC rate)

NASU radio observatory



Purpose	Radio Interferometers for Wide Field Survey Eight 20 m diameter spherical dish antennas+ A 30 m diameter spherical dish antenna
System Noise Temperature	Appoximately 80K
Observing frequency	1.42 GHz
Bandwidth	20 MHz
Site	Nasu-Shiobara, Tochigi prefecture
Target	Radio Transients, Radio counterparts of EGRET un-id sources, Pulsars
Sensitivity	Several hundred mJy (1 sec integration)

WJN radio transients



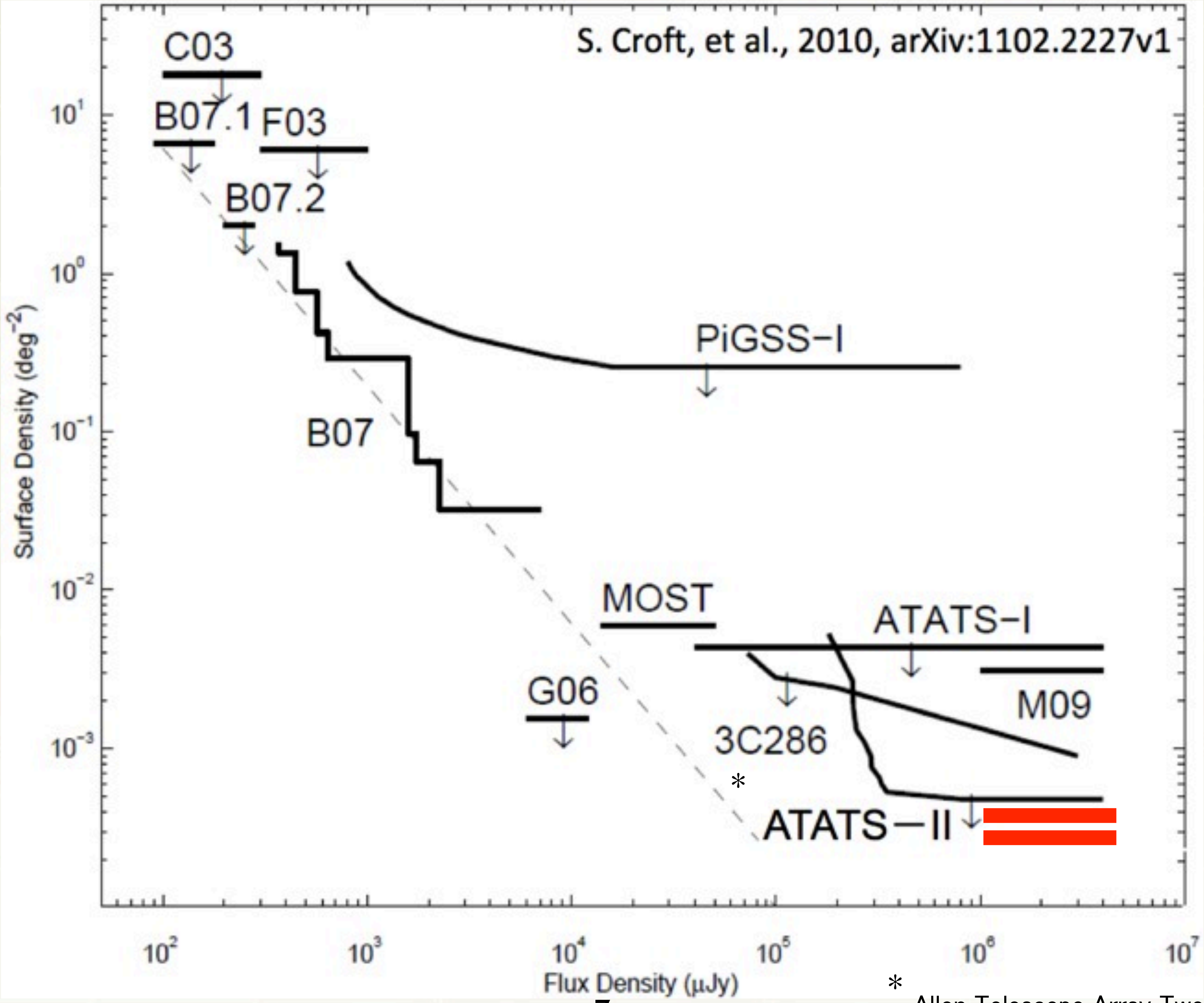
Niinuma et al. 2009

WJN radio transients in 2004-2006

Name	δ (J2000.0)	b (J2000.0)	Flux Density	Detection Date	Paper
WJN J0200+4142	41°42’	~-19°	~2.7±0.5Jy	2005Feb10	Matsumura et al.(2009)
WJN J0202+4142	41°42’	~-19°	~4.1±0.9Jy	2006Dec24	
WJN J0205+4142	41°42’	~-19°	~4.3±0.6Jy	2006Dec26	
WJN J0445+4130	41°30’	~-3°	~1.8±0.2Jy	2005Jan10	Matsumura et al.(2007)
WJN J0645+3200	32°00’	~+13°	~1.2Jy	2005Mar24	Kida et al.(2008)
WJN J0951+3300	33°00’	~+51°	~1.8±0.3Jy	2006Jan12	Niinuma et al.(2009)
WJN J1039+3200	32°00’	~+61°	~1.7Jy	2005Mar 4	Kida et al.(2008)
WJN J1039+3300	33°00’	~+61°	~2.2±0.2Jy	2006Jan18	Niinuma et al.(2009)
WJN J1043+4130	41°30’	~+60°	~1.7±0.2Jy	2005Jan 2	Matsumura et al.(2007)
WJN J1443+3439	34°39’	~+65°	~1.5±0.3Jy ~3.0±0.3Jy	2005Feb13 2005Feb14	Niinuma el al.(2007)
WJN J1737+3808	38°08’	~+30°	~1.6±0.2Jy	2004May20	Kuniyoshi et al.(2007)

Source density

- **For now The surface density of the WJN transients was calculated using subset of observation data for some reason. The density should be lower if we use all observation data.**



* Allen Telescope Array Twenty−centimeter Survey

2012年5月15日火曜日

Some errors ...

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LONG-DURATION RADIO TRANSIENTS LACKING OPTICAL COUNTERPARTS ARE POSSIBLY GALACTIC NEUTRON STARS

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ABSTRACT

Recently, a new class of radio transients in the 5 GHz band and with durations of the order of hours to days, lacking any visible-light counterparts, was detected by Bower and collaborators. We present new deep near-infrared (IR) observations of the field containing these transients, and find no counterparts down to a limiting magnitude of $K = 20.4$ mag. We argue that the bright (>1 Jy) radio transients recently reported by Kida et al. are consistent with being additional examples of the Bower et al. transients. We refer to these groups of events as "long-duration radio transients." The main characteristics of this population are: timescales longer than 30 minutes but shorter than several days; very large rate, $\sim 10^3$ deg^{-2} yr^{-1}; progenitor's sky surface density of >60 deg^{-2} (at 95%

Not correct ...

Detectors in science mode around WJN events

WJN J 1039+3300

- **GPS: 821639626, (RA[deg],DEC[deg])=(159.86,+33)**
- **H1,H2 were in science mode in 10000[s] around the events**

WJN J 0951+3300

- **GPS: 821119786, (RA[deg],DEC[deg])=(147.84,+33)**
- **Part of H1,H2,L1 data were in science mode in 10000[s] around the events**

WJN J0205+4142

- **GPS: 819627463, (RA[deg],DEC[deg])=(30.946,+41.7)**
- **H1,H2,L1 were in science mode in 10000[s] around the events**

WJN J0202+4142

- **GPS: 850991014, (RA[deg],DEC[deg])=(30.275,+41.7)**
- **H1,H2,L1 were in science mode in 10000[s] around the events**

Search type

- The most interesting search is CBC associated with the radio transients and set constraint on model parameters proposed by Nakar&Piran.
- Other interesting search is burst search. We did some test analyses using X-pipeline in 2010.
https://dcc.ligo.org/cgi-bin/private/DocDB/ShowDocument?docid=8990
(Next page)

Application of X-pipeline to LIGO data around the radio transients

WJN J0202+4142

Data: H1,H2,L1, Off-source:10800[s] around the event

https://atlas1.atlas.aei.uni-hannover.de/~kazu/LSC/WJNJ0202+4142_WJNJ0202+4142/WJNJ0202+4142_WJNJ0202+4142_closedbox.shtml

WJN J0205+4142

Data: H1,H2,L1, Off-source:10800[s] around the event

https://atlas1.atlas.aei.uni-hannover.de/~kazu/LSC/WJNJ0205+4142_WJNJ0205+4142/WJNJ0205+4142_WJNJ0205+4142_closedbox.shtml

WJN J 1039+3300

Data: H1,H2

```
Writing on-source event file ...
Calling xchooseskylocations2 to generate  input/sky_positions_trigger_time.txt
xchooseskylocations2 159.86 33.0 821639626.0 3.0 3 H 5e-4 input/sky_positions_trigger_time.txt
0
Warning: Duplicate directory name: /archive/home/kazu/matapps/SDE.
??? Error using ==> xchooseskylocations2 at 86
We can only handle 2 or 3 sites at present
```

WJN J 0951+3300

Data around the event is missing, analysis not possible

Summary

- Some types of radio transients may be radio remnants of compact binary mergers.
- The peak frequency of the resulting radio transients is 1.4GHz.
- The radio remnant appears weeks to years after the mergers and lasting a similar time. (depends on parameters, of course)
- We propose ...

Bonus slides

Overview of Nasu radio transients monitoring array

NAOJ LSC

Transients monitoring array is chiefly composed of eight spherical dish antennas. In order to search for radio transients or to monitor a radio variability of AGNs, we have utilized these antennas as four pairs of interferometers with 84m baseline length. Four different declinations are monitored with four fringe beams simultaneously.

The specification of each antenna:

- **20m in diameter and primary dish are fixed on the ground**
- **Only (the earth rotation based) drift-scan observation is available**
- **It is possible to observe any direction within +/- 5deg from the zenith (Dec. +32deg ~ +42deg) by moving a symmetrical Gregorian sub-reflector.**
- **The half-power beam width is approximately 0.8deg (200sec) and the fringe spacing is approximately 10~11.5arcmin (40sec ~ 46sec : depending on the declination and the projected baseline length)**
- **FoV is 0.8 deg (in RA direction) x 3.2 deg (in Decl. direction)**
- **Observing frequency: 1.42 +/- 0.01 GHz**

Detection method of radio transients

If a point source passes through fringe beam of the Nasu interferometer, the beam pattern that is defined as multiplication of primary beam (HPBW~0.8deg) and fringe pattern (spacing of 40~46sec), appears in data (see, figure 2 left).

Basically, even if we search for radio transients, it is same as case of normal radio sources. We determine that the fringe signal is derived from transient objects if beam pattern appears clearly. So the duration of all the radio transients we have published is ~4min at least.

Also, using auto-correlation function, we calculate the fringe cycle (spacing) that is one of the evidence that the signal originated from celestial objects (figure 2 right)

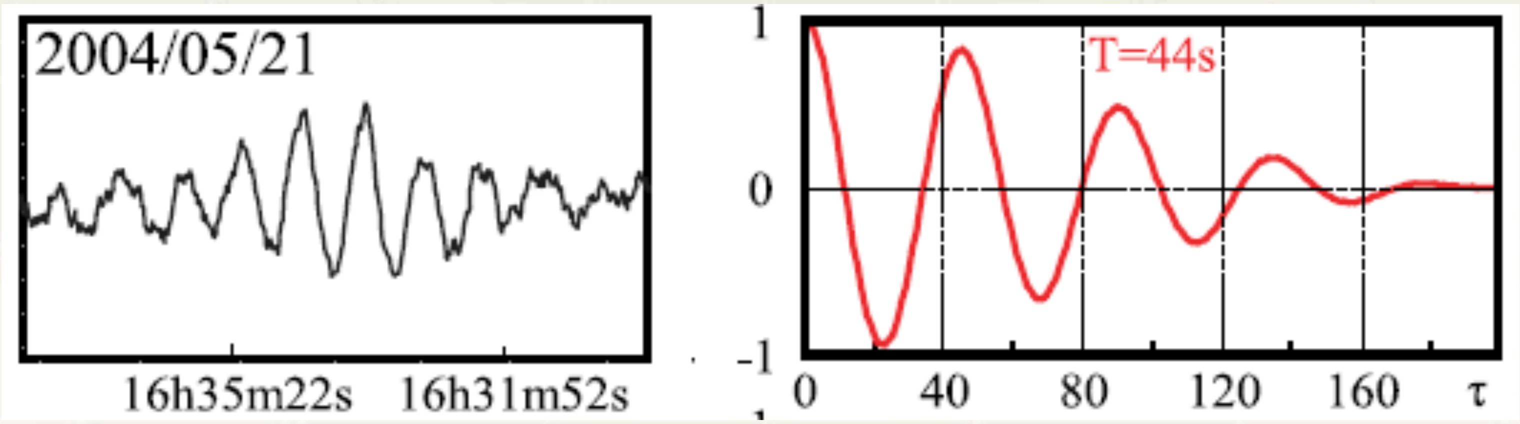

Figure 2

Accuracy of parameters of radio transients

- **Position**: within +/- 20sec (+/-5arcmin) in RA direction, 0.8 deg in DEC direction. Briefly, within 1 deg at most.
- **Time of detection**: within +/- 20sec (In our report, we have defined the detection time as center of obtained beam pattern of transients. However, transients we already found were lasting during detection time +/- 100sec at least. So I feel that err of detection time has no meaning.
- **Energy**: We can't determine the energy of it, because the distance to the target can't be measured. However, we can determine the flux density of them with an accuracy of 1σ noise level (~300mJy).
- **Possibility that the transient signal originated from "astronomical phenomenon"**: If human-generated radio frequency interference (RFI) around the antennas produced transient signal accidentally, the other antennas observing other declinations also should have caught same signal.Also, if these transient signals had been caused by a satellite or airplane, neither a fringe nor a fringe cycle from such sources would appear in a drift-scanning observation. Therefore, it is thought that these transient signals must be derived from objects on the celestial sphere.
- **Duration**: When we follow our policy to analyze the data, duration of the lower limit is approximately 4min at least. If transient is detected in just one day, the duration of this transient will be estimated between 4min and 48hr1.

Prospects of Nasu

In Daishido laboratory, the spatial FFT observing system for direct imaging observation was developed, and we have been carrying out the test observation with this system at the Nasu observatory (Asuma et al., 2010 in prep). When it becomes possible to carry out a stable observation, it will be possible

- **to obtain the dispersion measure within the bandwidth of 20 MHz → We can estimate the distance to the origin by assuming the column density of the electrons.**
- **to detect radio sources with the time resolution of 50 micro sec to observe same object eight times every about 25 sec in a day (to observe it once a day now)**

Also, although the FoV will become 1/4, the detection sensitivity will be 4 times of current observation system. That is, it will be possible to detect radio transients that are weaker than the ones that have been already detected.

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