

フェラーリF300について

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コラボレーター

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- INAF G.Tuccari
- 宇宙線研究所 三上涼
- ISAS/JAXA 竹内央

フェラーリF300



Low frequency VLBI



Japan

東北大学飯館観測所

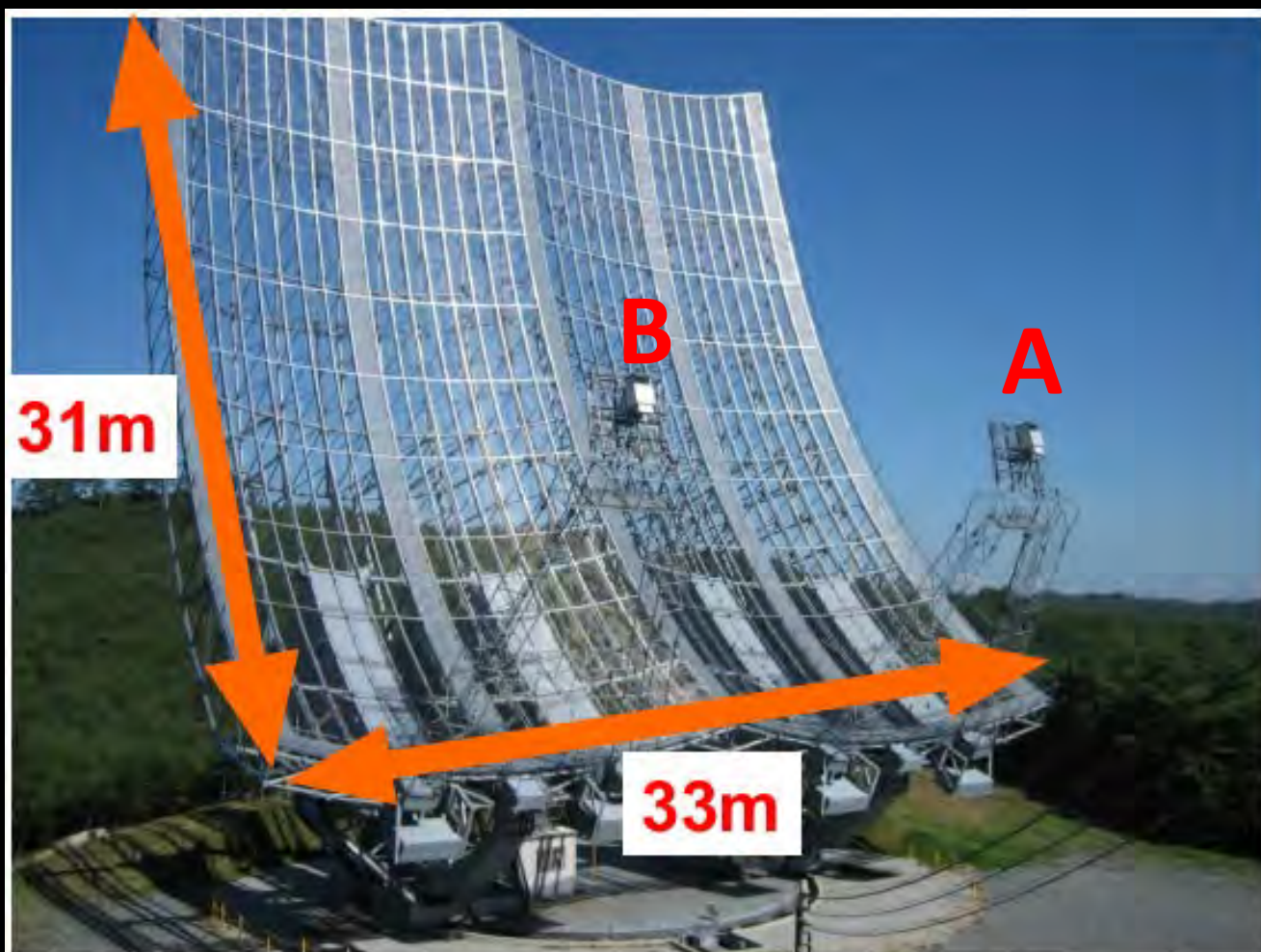


Fig. 5 litate planetary radio telescope (IPRT)

開口面積1000m²以上～高感度観測



受信システム

- 300MHz帯：太陽、木星
- 700MHz帯：太陽、木星
- 100-500MHz：広帯域系

名古屋大学STE研

Tokumaru et al Radio Science 2011

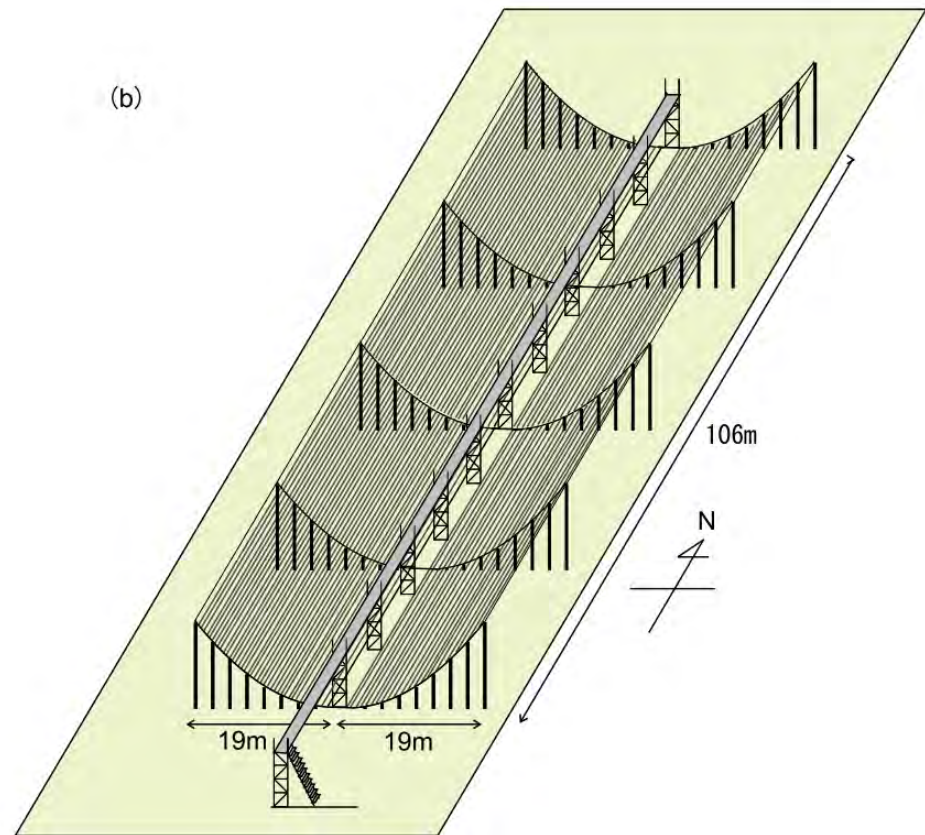


Figure 1. (a) Overall view of the SWIFT at the Toyo mounted at the focal line of the SWIFT.

豊川観測所 108mのシリンドリカルアンテナ
192エレメント、天頂付近にビーム

4 大施設

Table 1. System Noise Temperature T_{sys} , Effective Aperture Area A_e and Minimum Detectable Flux Density ΔS_{min} of the Radiotelescope at Each Station

現在はアンプを交換してさらに性能が向上している

Station	T_{sys} (K)	A_e (m ²)	ΔS_{min} (J)
Toyokawa	334	1013	0.91
Fuji	151	1500	0.28
Sugadaira	229	1120	0.58
Kiso	221	1409	0.43

Tokumaru et al Radio Science 2011

あと、京大生存圏の信楽MULレーダー、
NICT 山川太陽電波観測所も使えるかも

Italy

AntArr

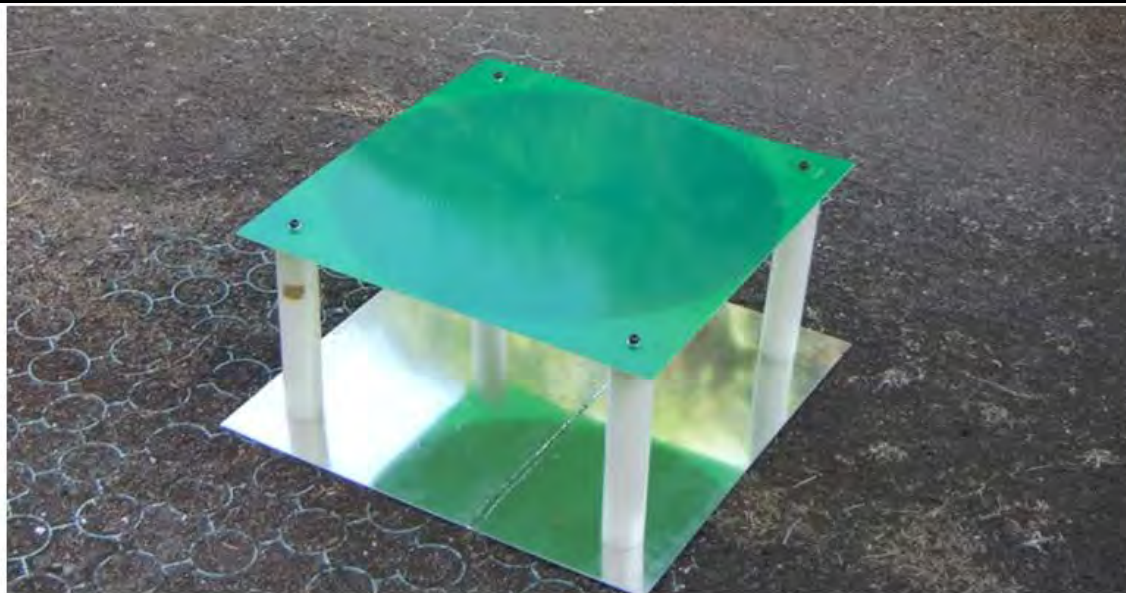


Fig. 2: Prototype of the low-frequency antenna

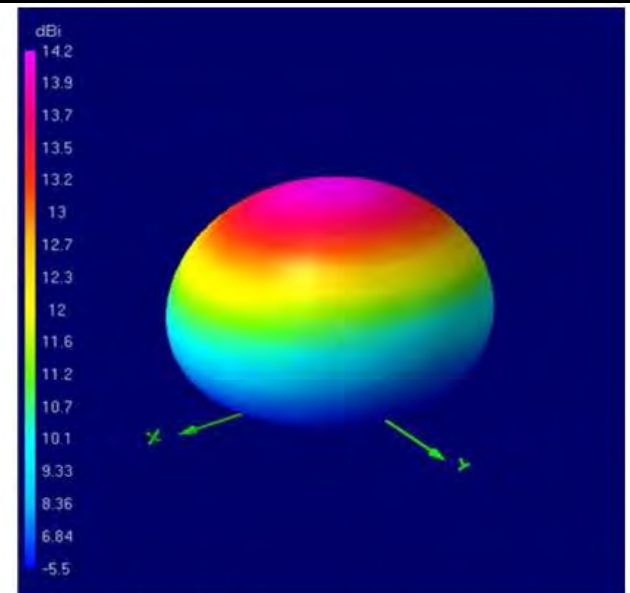
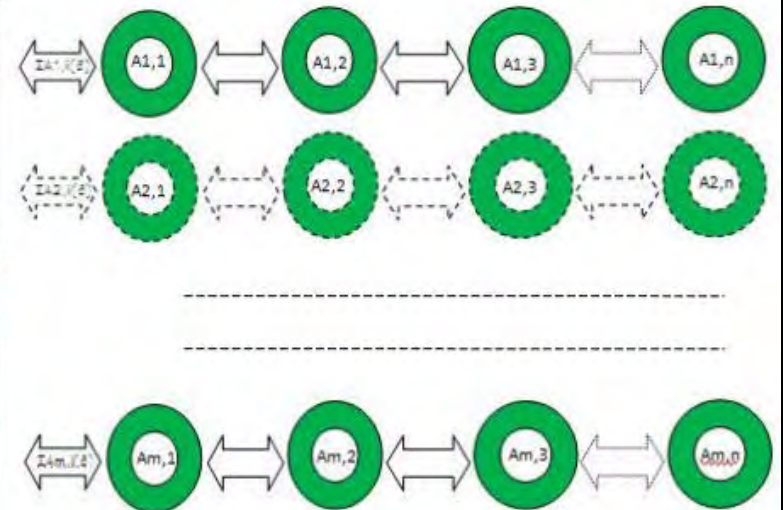


Fig. 3: Antenna beam



Tuccari et al, Proc of EVN2014

将来的に1024エレメント

- Frequency range: 10 - 1000 MHz
(128MHzBw)
- Number of antennas in a single arm: 32
- Number of arms in a single DBBC3L: 32
- Analogue delay compensation digitally controlled at every antenna
- Analogue summation for each arm at every antenna

低周波帯VLBI フェラーリF300 プロジェクト

日本ラウンド

飯館アンテナ + 豊川アンテナ (300MHz)
大学VLBI連携??

イタリアラウンド

飯館アンテナ + AntArr
300MHz帯、100-500MHz帯 (uvが一気に埋まる?)
低周波では世界最長クラスの基線長

インドラウンド? フェラーリF300 + GMRT

オーストラリアラウンド? フェラーリF300 + SKA

月面グランプリ? フェラーリF300 on Moon

Motivation

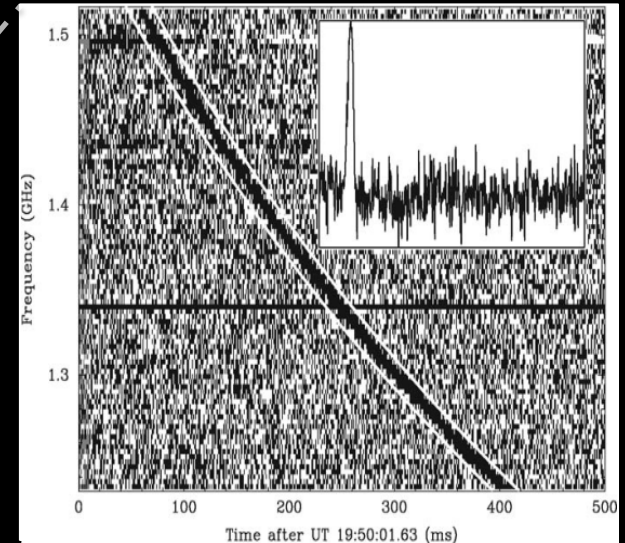
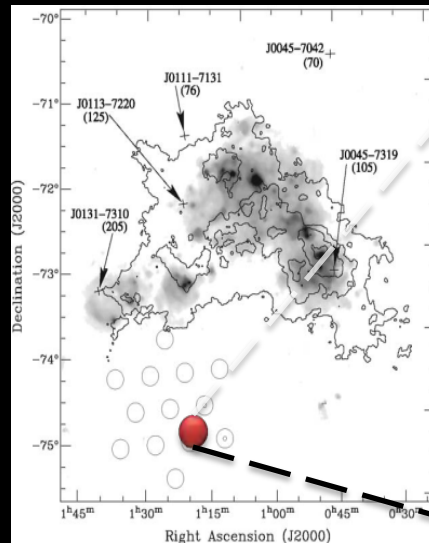
- 技術的挑戦
 - 電離層がひどいらしい
 - 水素メーザーが（たぶん）必要ない
 - ある程度は相関処理でカバー
 - in beam & multi phase center の応用
- サイエンス
 - 300MHz帯での最長基線観測
 - 微弱クエーサー
 - 系内コンパクト天体
 - パルサー、FRB

Fast Radio Burst (FRB)

- Lorimer+ 2007
 - Duration ~ 5 ms
 - Flux ~ 30 Jy
 - Index ~ -4
 - $DM \sim 375 \text{ cm}^3$
(too large)
 - $b = -41.8$ (predicted
 $DM = 25 \text{ cm}^3$).

Brightness temp.: $\sim 10^{34} (D_{500 \text{ Mpc}} / W_{5 \text{ ms}})^2 \text{ K}$

Energy: $\sim 10^{33} (D_{500}^2 \times W_{5 \text{ ms}}) \text{ J}$



Arecibo

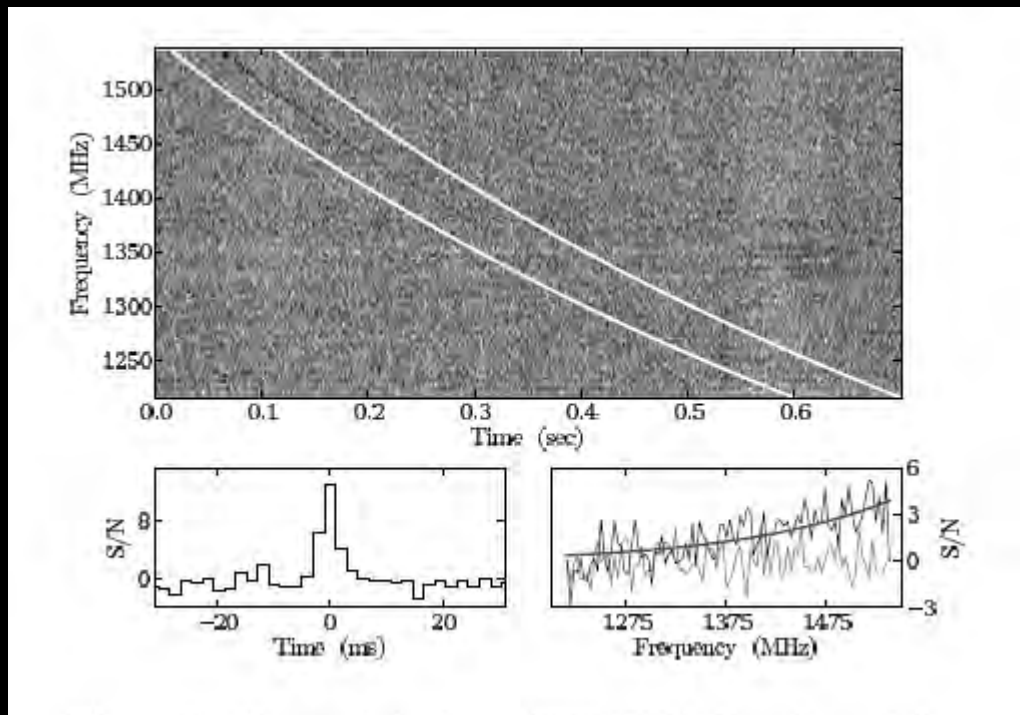


Table 1
Observational Parameters of FRB 121102

Parameter	Value
Date	2012 Nov 02
Time	06:35:53 UT
MJD arrival time ^a	56233.27492180
Right Ascension ^b	05 ^h 32 ^m 09.6 ^s
Declination ^b	33°05'13.4"
Gal. long. ^b	174.95°
Gal. lat. ^b	-0.223°
DM (pc cm ⁻³)	557.4 ± 2.0
DM _{NE2001,max} (pc cm ⁻³)	188
Dispersion index ^c	-2.01 ± 0.05
Pulse width (ms)	3.0 ± 0.5
Pulse broadening (ms) ^d	< 1.5
Flux density (Jy) ^e	0.4 ^{+0.4} _{-0.1}
Spectral index range(α) ^f	7 to 11

^a Barycentered arrival time referenced to infinite frequency.

^b The J2000 position of the center of beam 4.

^c $DM \propto \nu^\beta$

^d Flux density at 1 GHz

^e Flux estimation at 1.4 GHz assumes a side-lobe detection and a corresponding gain of 0.7 ± 0.3 K Jy⁻¹.

^f $S(\nu) \propto \nu^\alpha$

A Repeating Fast Radio Burst

L. G. Spitler¹, P. Scholz², J. W. T. Hessels^{3,4}, S. Bogdanov⁵, A. Brazier^{6,7}, F. Camilo^{5,8}, S. Chatterjee⁶, J. M. Cordes⁶, F. Crawford⁹, J. Deneva¹⁰, R. D. Ferdman², P. C. C. Freire¹, V. M. Kaspi², P. Lazarus¹, R. Lynch^{11,12}, E. C. Madsen², M. A. McLaughlin¹², C. Patel², S. M. Ransom¹³, A. Seymour¹⁴, I. H. Stairs^{15,2}, B. W. Stappers¹⁶, J. van Leeuwen^{3,4} & W. W. Zhu¹

Table 1: Properties of detected bursts. Uncertainties are the 68% confidence interval, unless otherwise stated.

No.	Barycentric Peak Time (MJD) ^a	Peak Flux Density (Jy) ^b	Fluence (Jy ms) ^b	Gaussian Width ^c (ms)	Spectral Index ^d	DM (pc cm ⁻³) ^e
1	56233.282837008	0.04	0.1	3.3±0.3	8.8±1.9	553±5±2
2	57159.737600835	0.03	0.1	3.8±0.4	2.5±1.7	560±2±2
3	57159.744223619	0.03	0.1	3.3±0.4	0.9±2.0	566±5±2
4	57175.693143232	0.04	0.2	4.6±0.3	5.8±1.4	555±1±2
5	57175.699727826	0.02	0.09	8.7±1.5	1.6±2.5	558±6±4
6	57175.742576706	0.02	0.06	2.8±0.4		559±9±1
7	57175.742833337	0.02	0.06	2.1±0.4	-3.7±1.8	
8	57175.743510138	0.14	0.9	0.6±0.1		556.5±0.7±2
9	57175.745665132	0.05	0.3	6.0±0.3	-10.4±1.1	558.4±0.7±3
10	57175.747624151	0.05	0.2	8.0±0.5		558.7±0.9±4
11	57175.748287265	0.31	1.0	3.06±0.04	13.6±0.4	556.5±0.1±1

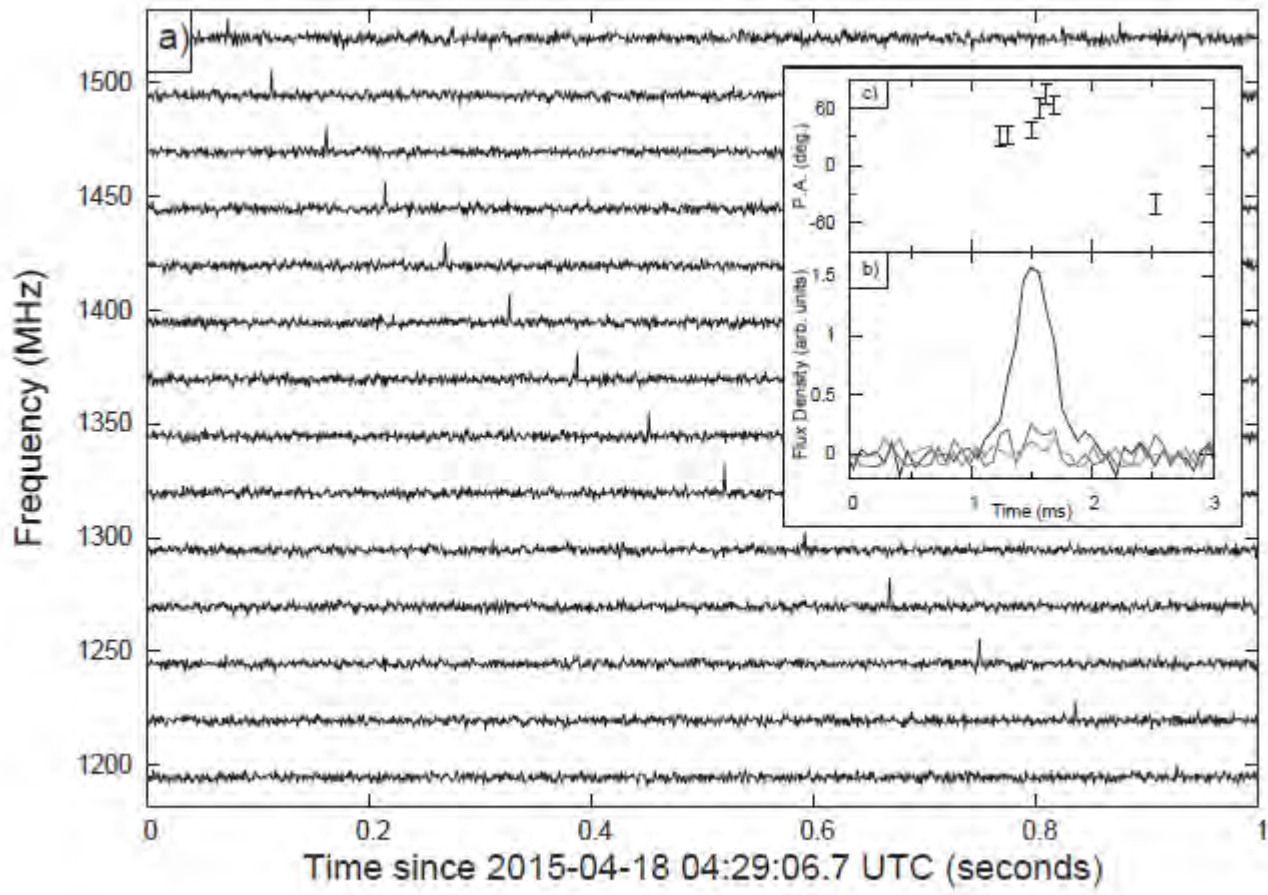
^a Arrival time corrected to the solar-system barycentre and referenced to infinite frequency (i.e. the time delay due to dispersion is removed).

^b Lower limit since it assumes burst is detected at the centre of the beam (i.e. an assumed gain of 10 K/Jy yielding a system equivalent flux density of 3 Jy).

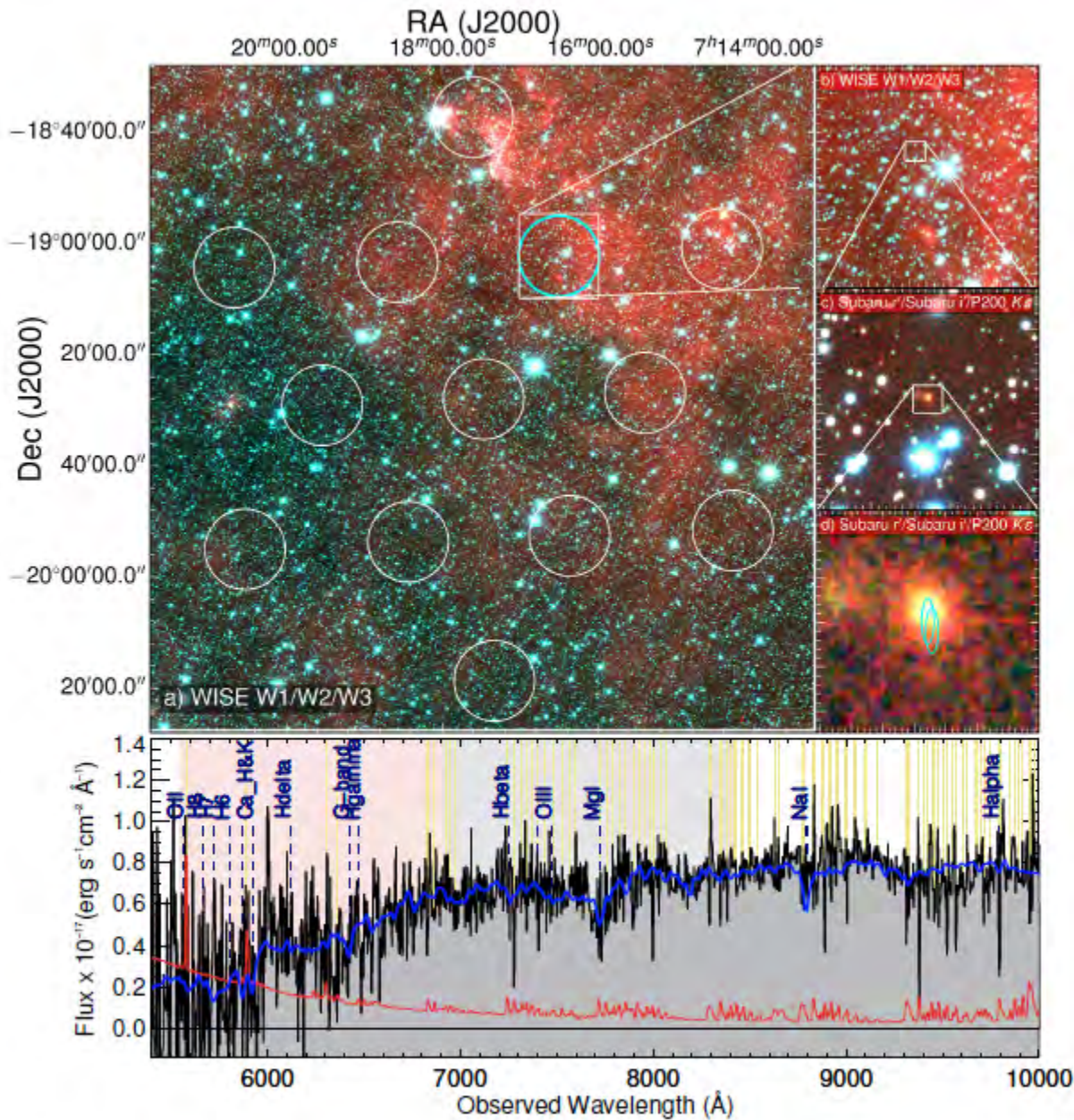
^c Widths are the full-width at half maximum.

^d Bursts 8 and 10 are not well-fit by a power-law model. Burst 6 is too corrupted by RFI to include.

^e Quoted errors are, in order, statistical and systematic (see Methods). Burst 7 was too weak and corrupted by RFI to include.



FRB150418 Keane et al, Nature 2016



Subaruで
 ホスト銀河の特定？
 ATCAでアフターグロー
 検出？

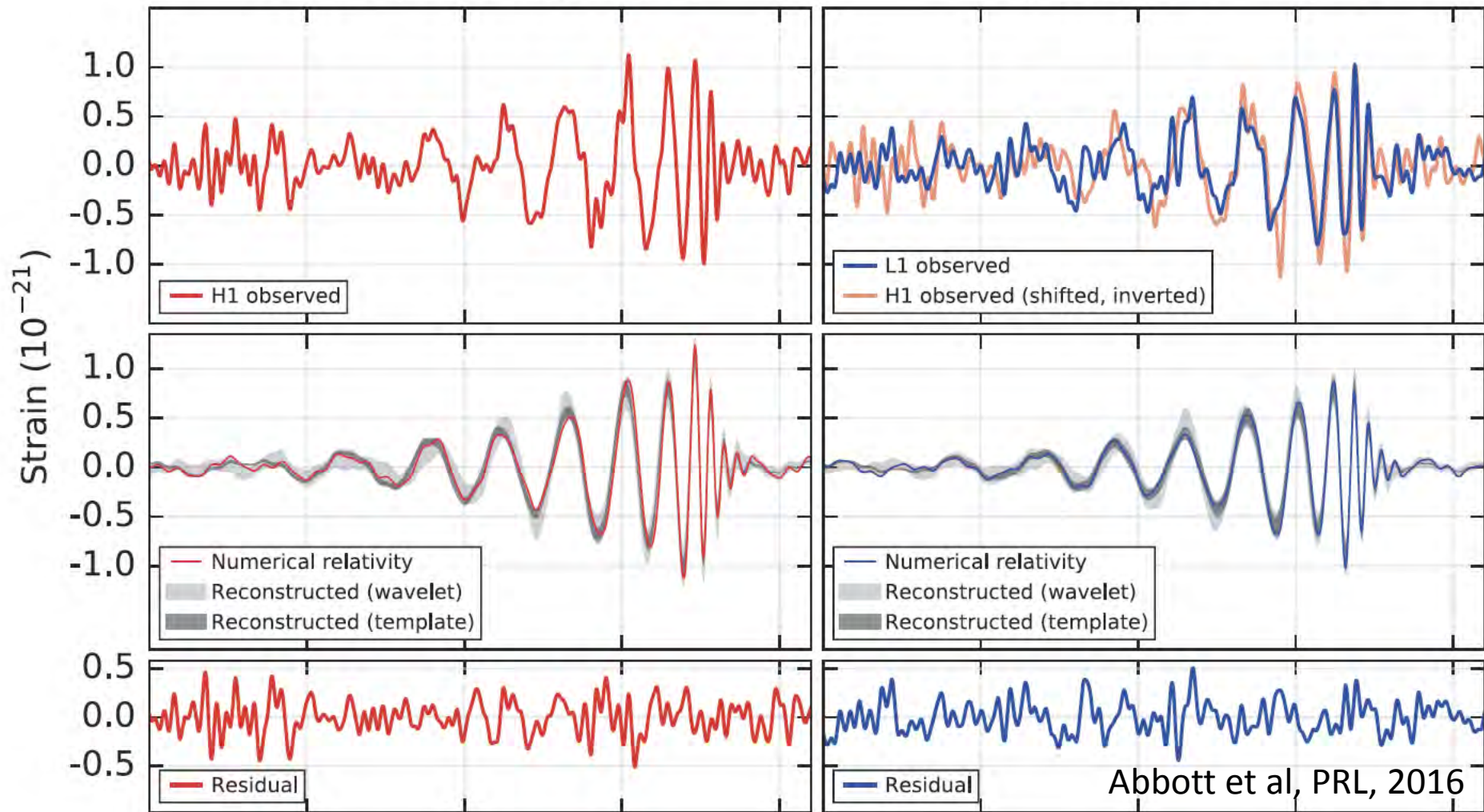
FAST RADIO TRANSIENT

- Detected by Parkes, GBT, and Arecibo
- Not yet detected by low frequency observatory of LOFAR and MWA?
- Keaneへの反論
 - ただのシンチレーションでは？Akiyama&Johnson 2016

一方、

Hanford, Washington (H1)

Livingston, Louisiana (L1)



GW150914: 2局で証明だっぺ!

Could FRB detect by VLBI?

Giant radio pulse observation by VLBI (Takefuji+ 2016)



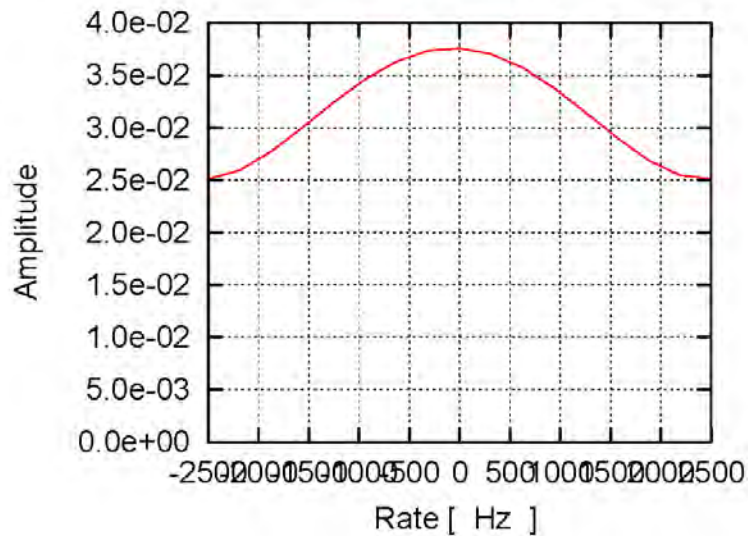
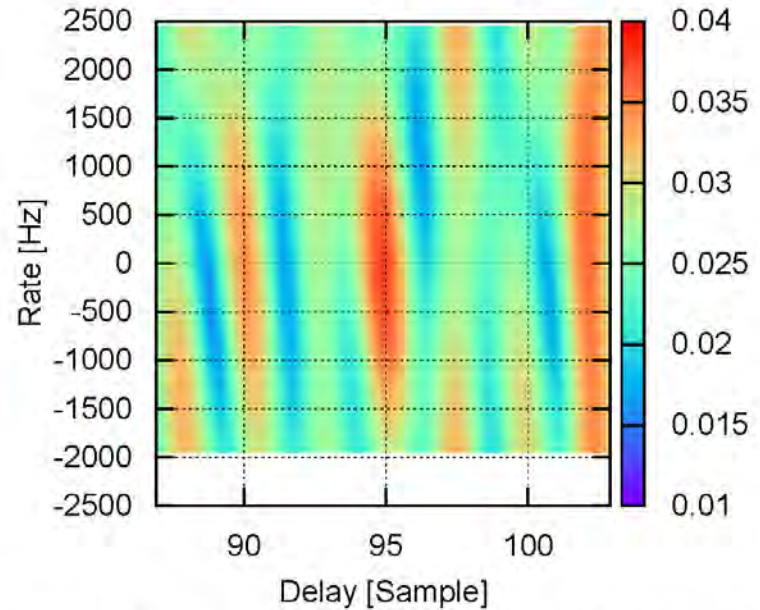
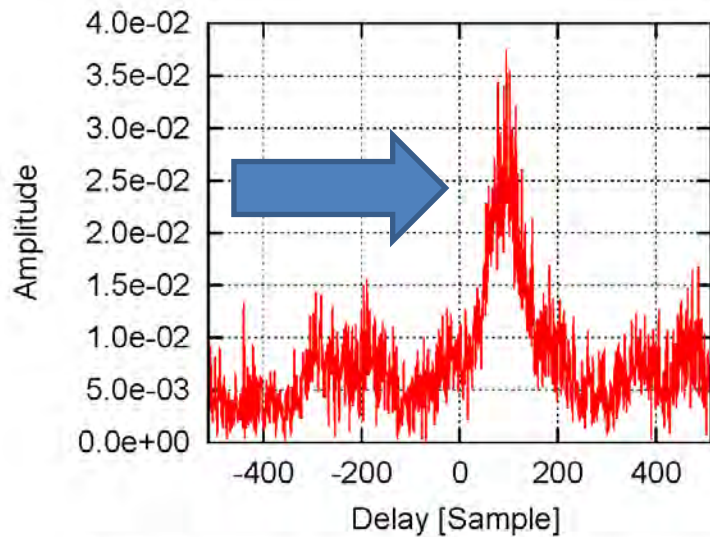
Kashima 34m



Usuta 64m

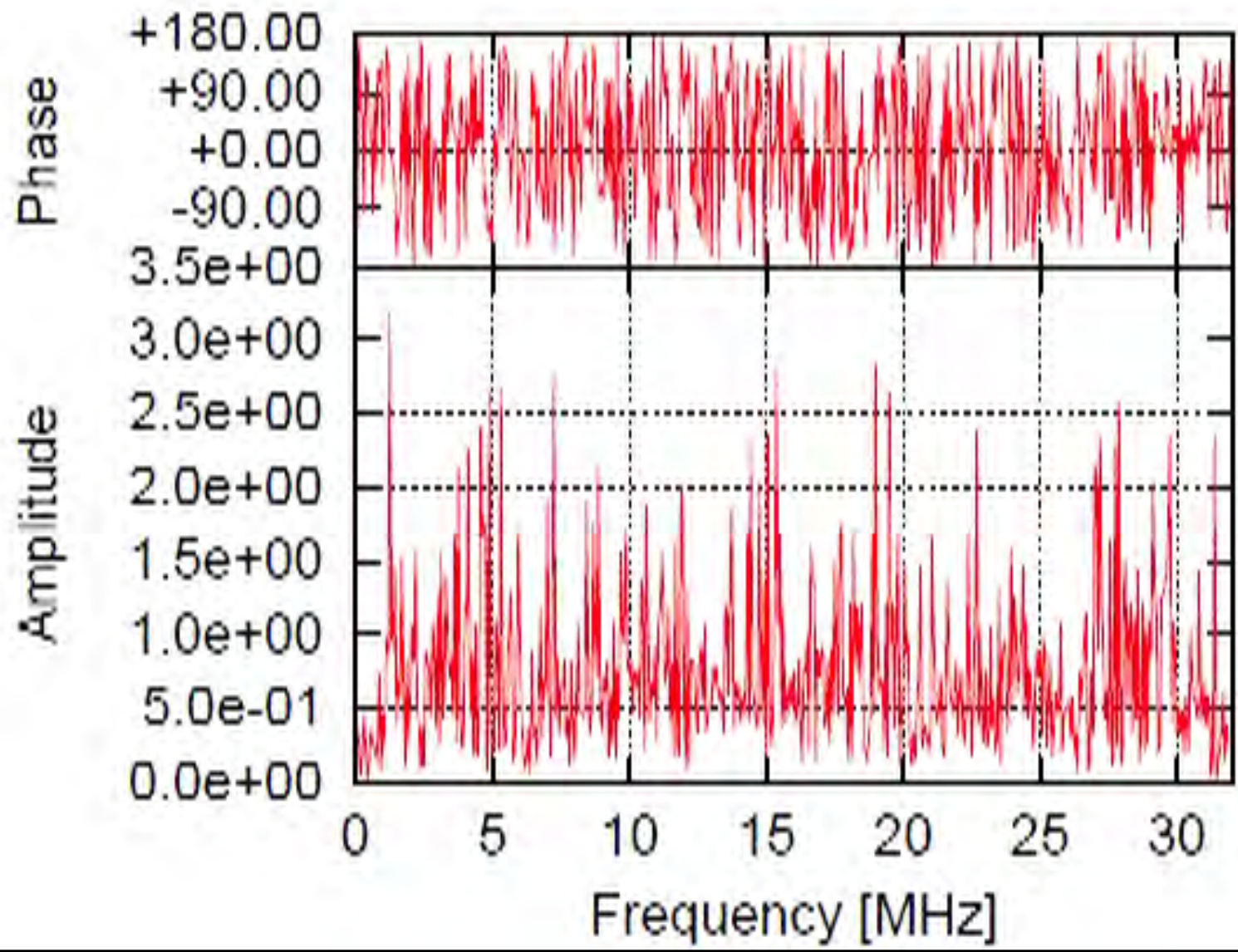
VLBI observation

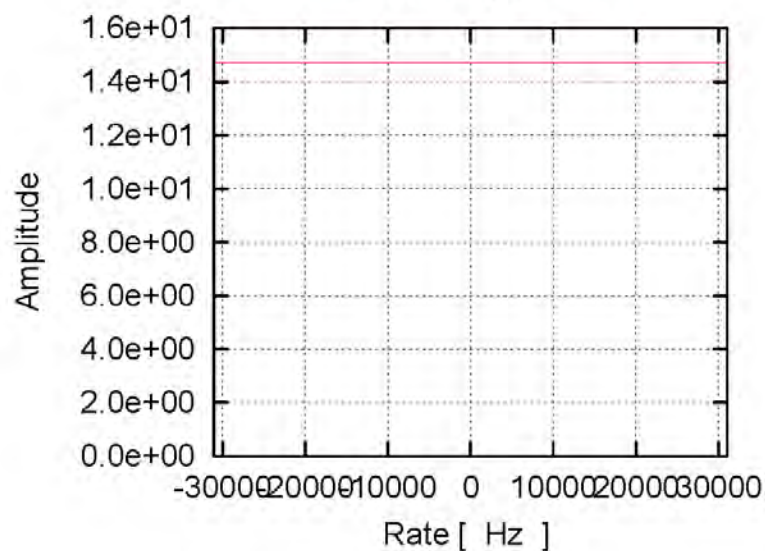
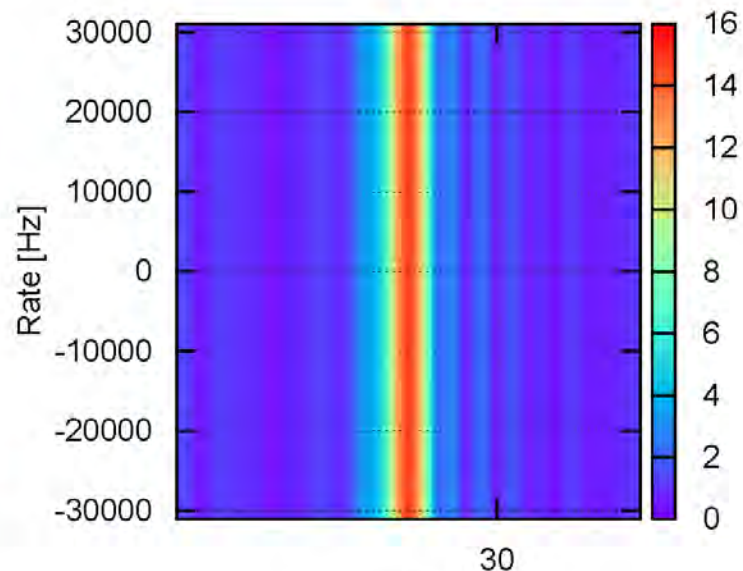
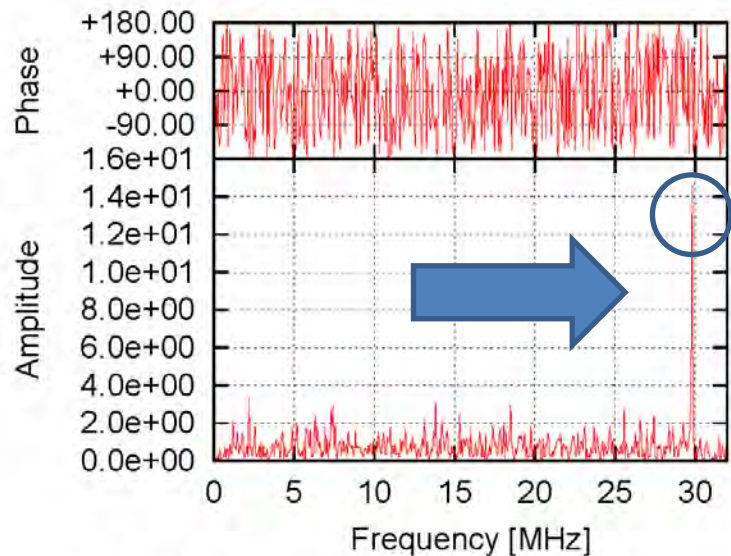
- 2014/206 23:00:00-24:00:00
- L-band observation 1400~1700 MHz
- 0552+398 for delay determination



```

Epoch      : 2014/206 23:31:22
Station-1  : KAS34
Station-2  : USU64
Source     : taua
Length     : 0.000400 [sec]
Sampling   : 64000000 [sps]
Frequency  : +1666.000000 [MHz]
Peak Amp   : 3.760852 [%]
Peak Phs   : -19.336714 [deg]
Delay      : +94.900162 [spl]
Rate       : -64163.538869 [mHz]
SNR        : 4.822303
  
```

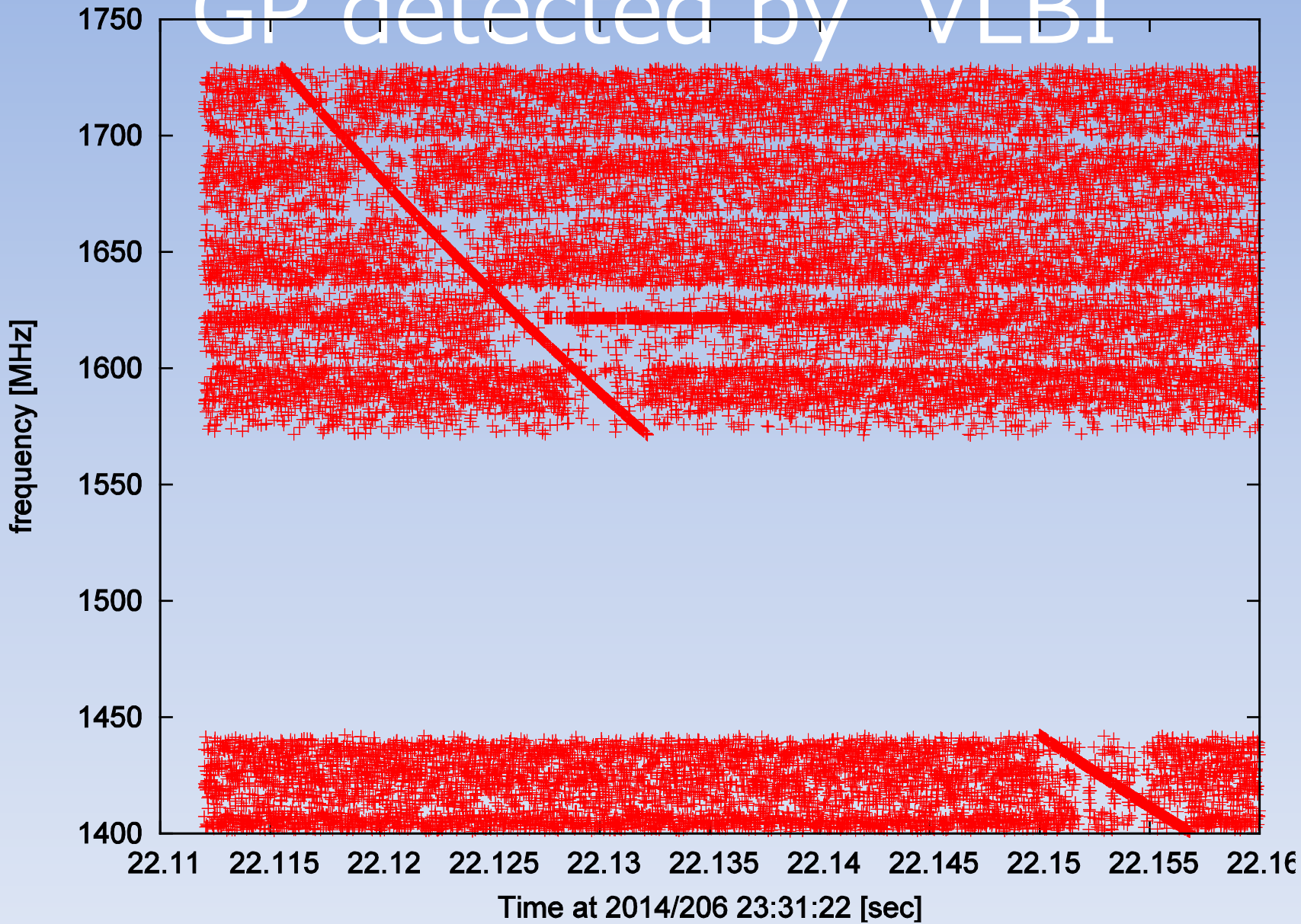




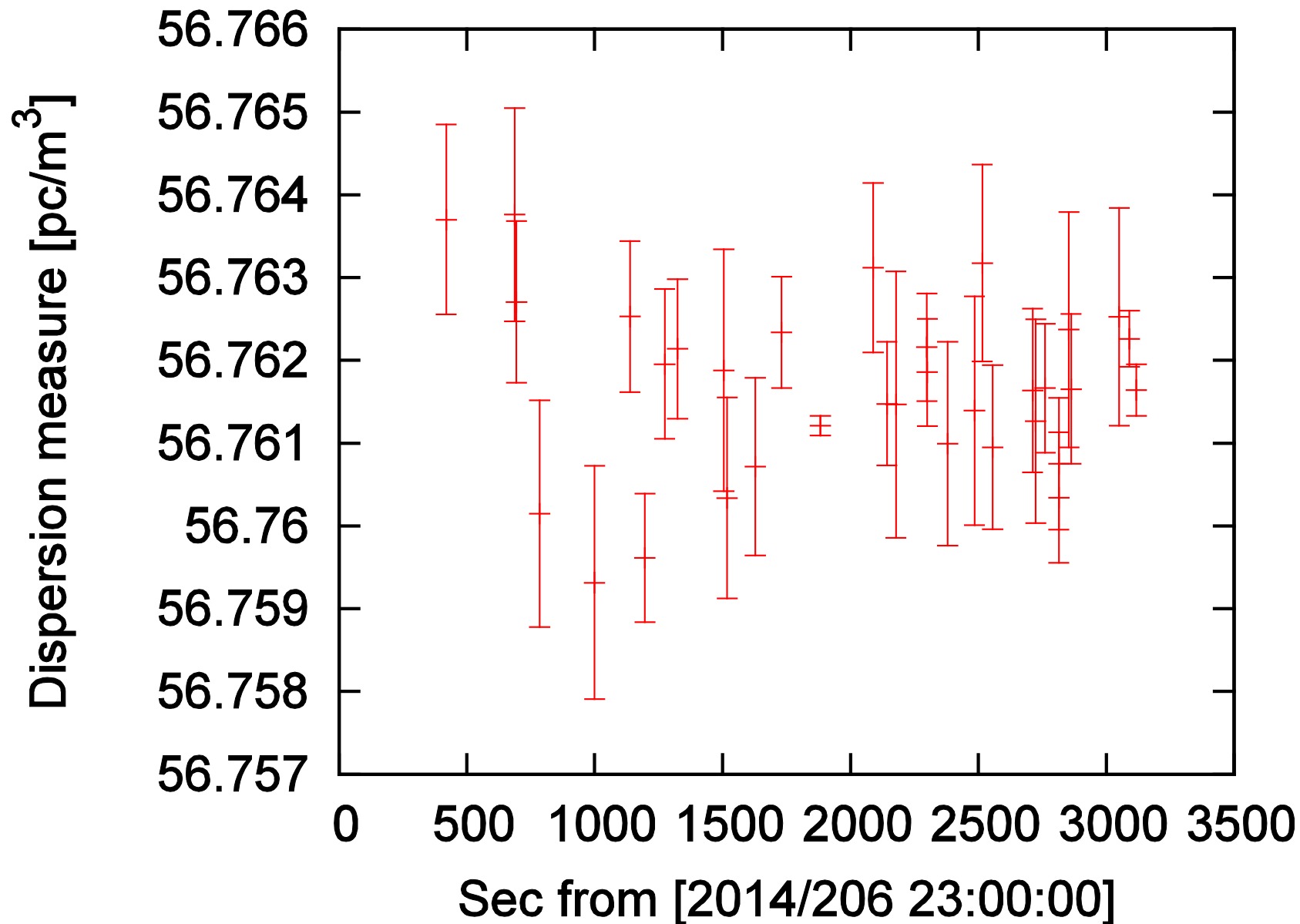
```

Epoch      : 2014/206 23:31:22
Station-1  : KAS34
Station-2  : USU64
Source     : taua
Length     : 0.000016 [sec]
Sampling   : 64000000 [sps]
Frequency  : +1666.000000 [MHz]
Peak Amp   : 1469.277240 [%]
Peak Phs   : 114.673039 [deg]
Peak Freq  : +29.808907 [MHz]
Rate       : +0.000000 [mHz]
SNR        : 36.107637
  
```

GP detected by VLBI



35GPs



FRB探索

シングルディッシュでもOK

- 処理対象がクロススペクトルからオートスペクトルになるだけ

Single dish と VLBI 比較

- Count GRP residuals

	Only Kashima	Only Usuta	VLBI
#1 23:31:22	945	1008	1778
#2 23:51:30	471	549	732
#3 23:51:58	581	701	922
#4 23:28:50	251	241	391

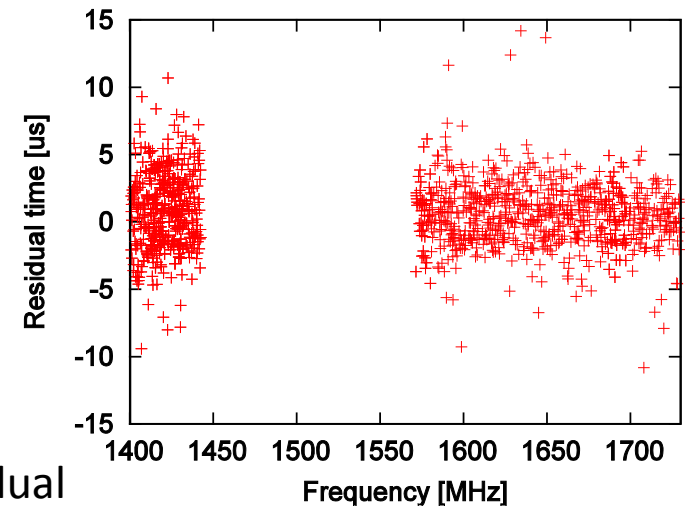


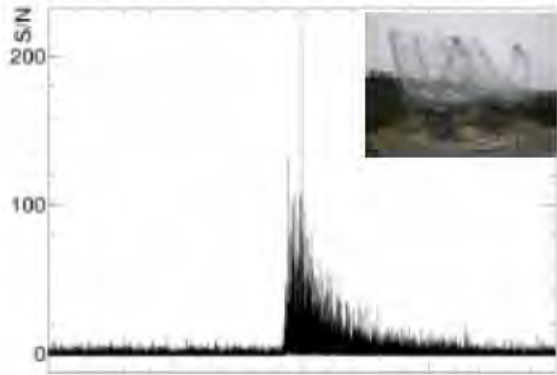
Figure of the residual

FRB探索

多周波観測でもOK

東北大

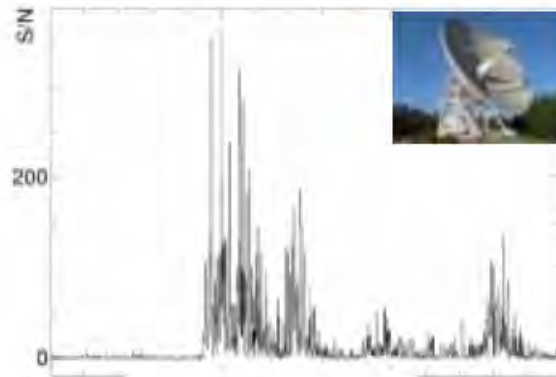
惑星圏飯館観測所
(323.1-327.1MHz)



← 4ms →

NICT鹿島

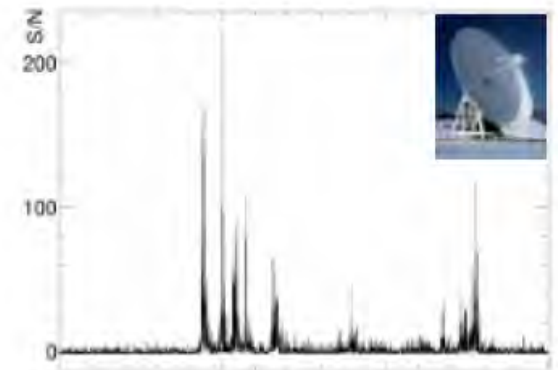
(1400-1443MHz)



← 20 μ s →

JAXA臼田

(2182-2344MHz)



← 20 μ s →

まとめ

- 安くて、易くて、うまい 低周波！
- 将来的に低周波アレーを日本で！
- FRB を VLBIで受信できるかも！
- Beginning of FRB-GW-GRB astronomy !!