FRB detection in the presence of coloured noise

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Content

Introduction

Detection statistics

Summary

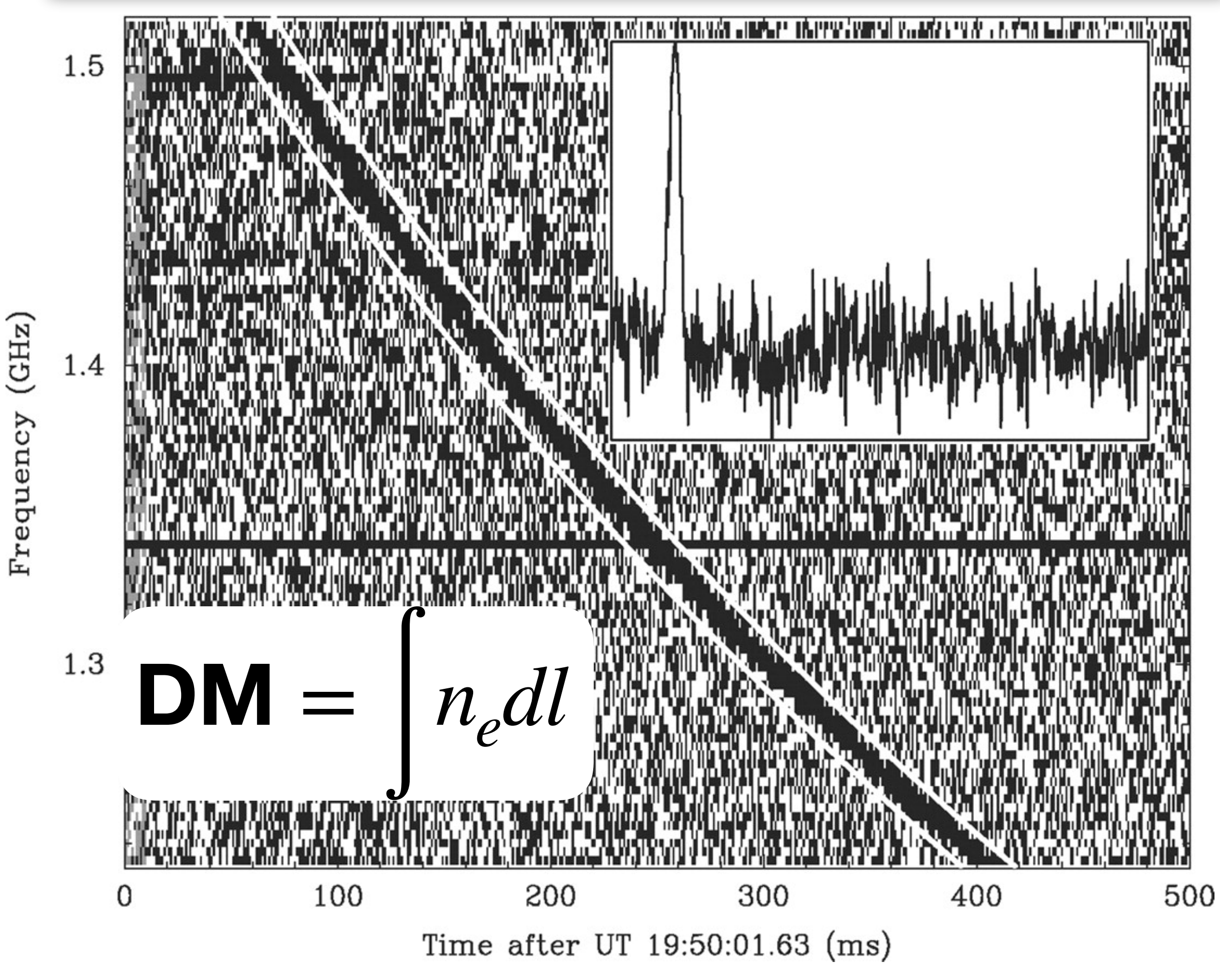
What is FRB (Fast Radio Burst)

A Bright Millisecond Radio Burst of Extragalactic Origin

D. R. Lorimer,[1,2]* M. Bailes,[3] M. A. McLaughlin,[1,2] D. J. Narkevic,[1] F. Crawford[4]

Pulsar surveys offer a rare opportunity to monitor the radio sky for impulsive burst-like events with millisecond durations. We analyzed archival survey data and found a 30-jansky dispersed burst, less than 5 milliseconds in duration, located 3° from the Small Magellanic Cloud. The burst properties argue against a physical association with our Galaxy or the Small Magellanic Cloud. Current models for the free electron content in the universe imply that the burst is less than 1 gigaparsec distant. No further bursts were seen in 90 hours of additional observations, which implies that it was a singular event such as a supernova or coalescence of relativistic objects. Hundreds of similar events could occur every day and, if detected, could serve as cosmological probes.

- ✓ Short duration (ms) --> must be compact
- ✓ Mostly found around 1GHz
- ✓ Bright --> 1e38 erg
- ✓ High DispersionMeasure (Greater than local Galaxy values)
- ✓ Maybe two types
    - repetitive vs non repetitive
- ✓ Mystery origins



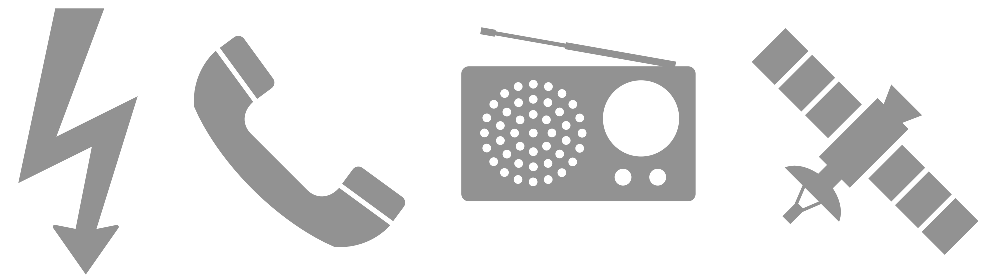
$$\mathbf{DM} = \int n_e dl$$

$$\Delta t = 4.15\,\mathrm{ms} \times \mathrm{DM}(\nu_{\mathrm{low,GHz}}^{-2} - \nu_{\mathrm{high,GHz}}^{-2})$$

D. R. Lorimer et al. Science 2007;318:777-780

FRB Search

De-disperse → Remove RFI → Single pulse



- ✓ HEIMDALL

  Andew Jameson &Ben Barsdell

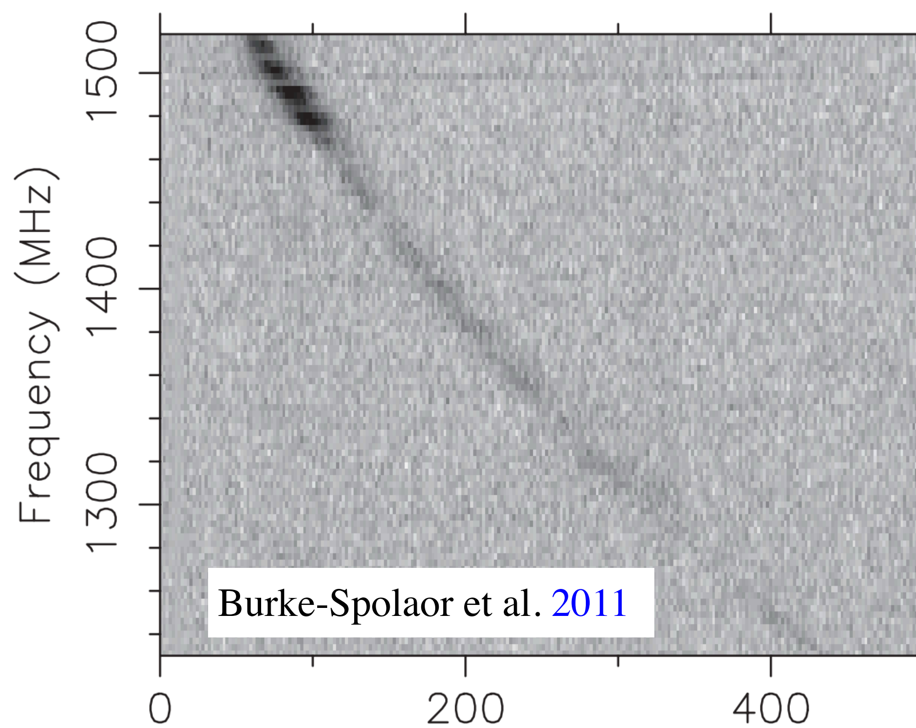
- ✓ BEAR

  (Men et al. 2019)

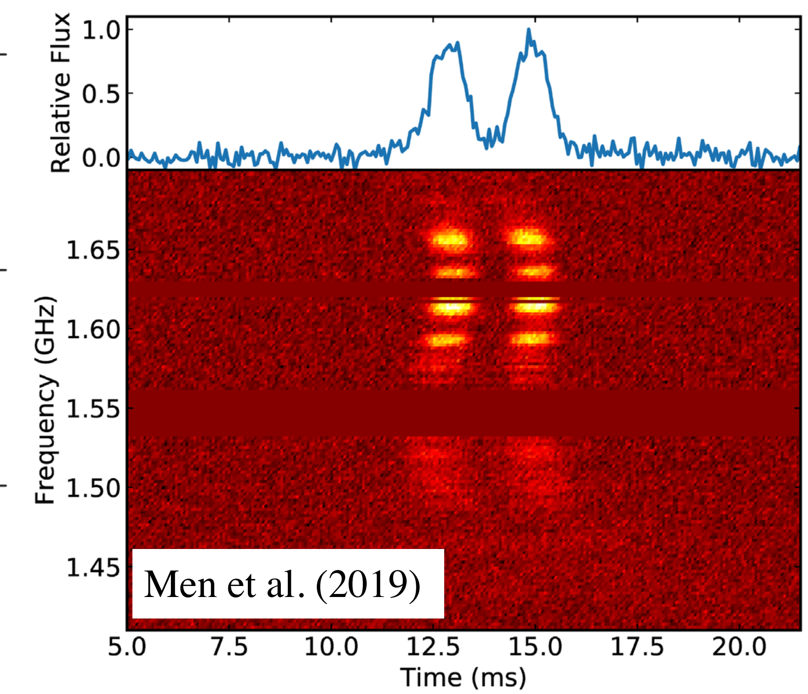
- ✓ Presto

  Scottransom

……



Burke-Spolaor et al. 2011



Men et al. (2019)

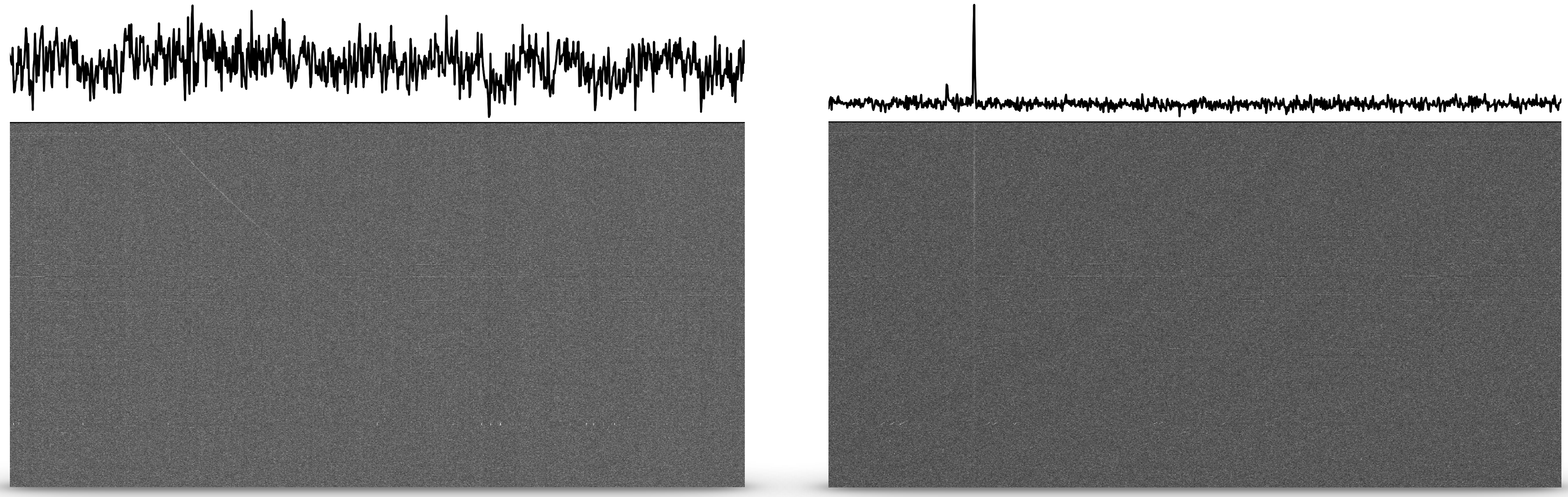
✦Strong RFIs

➡Remove

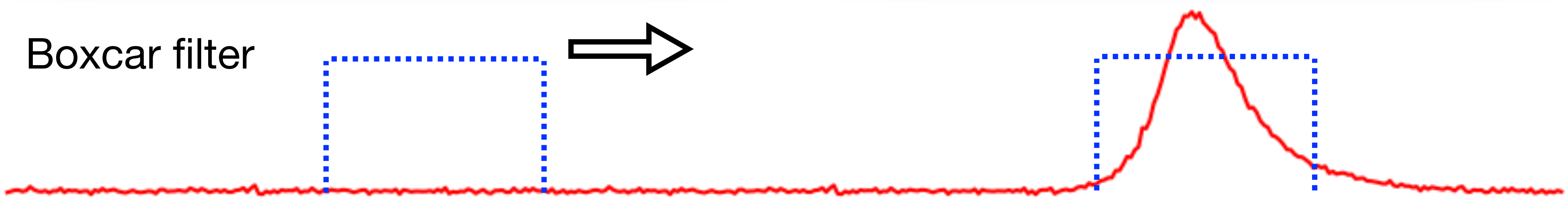
✦Weak RFIs

➡Colored noise

Detection Statistics



Boxcar filter



$$S = \frac{1}{N_{\mathrm{box}}\sigma^2}\left(\sum_{|t-t_0|<w} s_i\right)^2$$

$$= \mathrm{SNR}^2$$

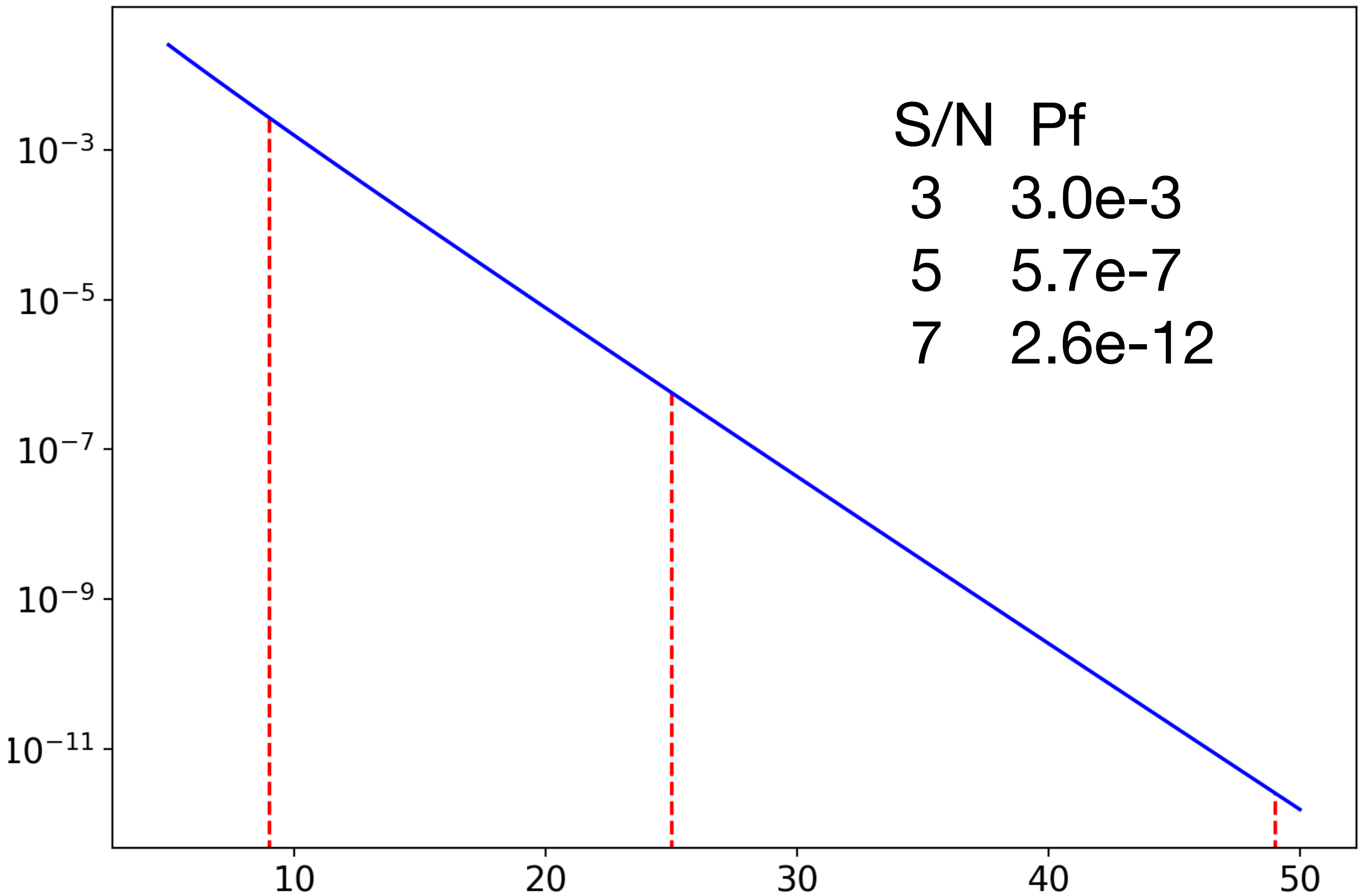
Van der Vaart 2000

$$S = S(t, W, \mathrm{DM})$$

$S > S_0$ → **Candidate detection**

Detection Statistics

- **False alarm probability** $P_f(S \geq S_0) = \text{erfc}(\sqrt{S_0/2}).$



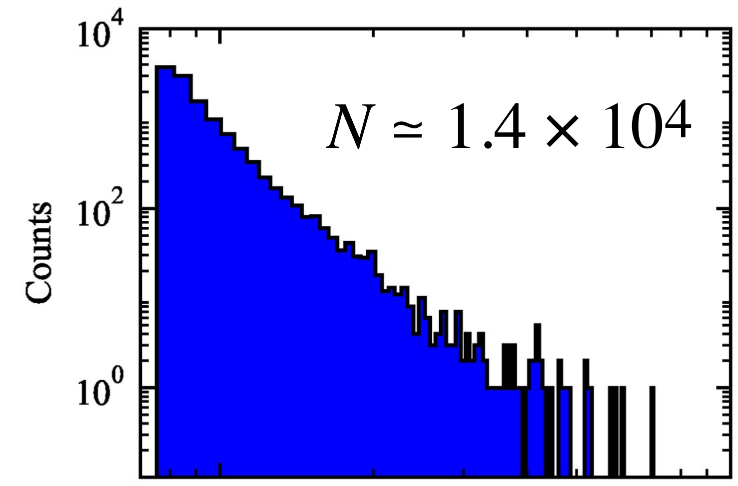
南山26米射电望远镜@XAO

- Fasle positives $N \simeq 3.6 \times 10^{-4}(P_f/10^{-12})(T/100\text{h})(w/\text{ms})^{-1}$

However…

Telescope	BW MHz	$f_{central}$ [1] MHz	f_{ch} [2] MHz	Gain K Jy^{-1}	T_{sys} [3] K	Δt [4] μs	T_{obs} h
NS26m	320	1560	0.97	0.1	25	65	55

Detection Statistics

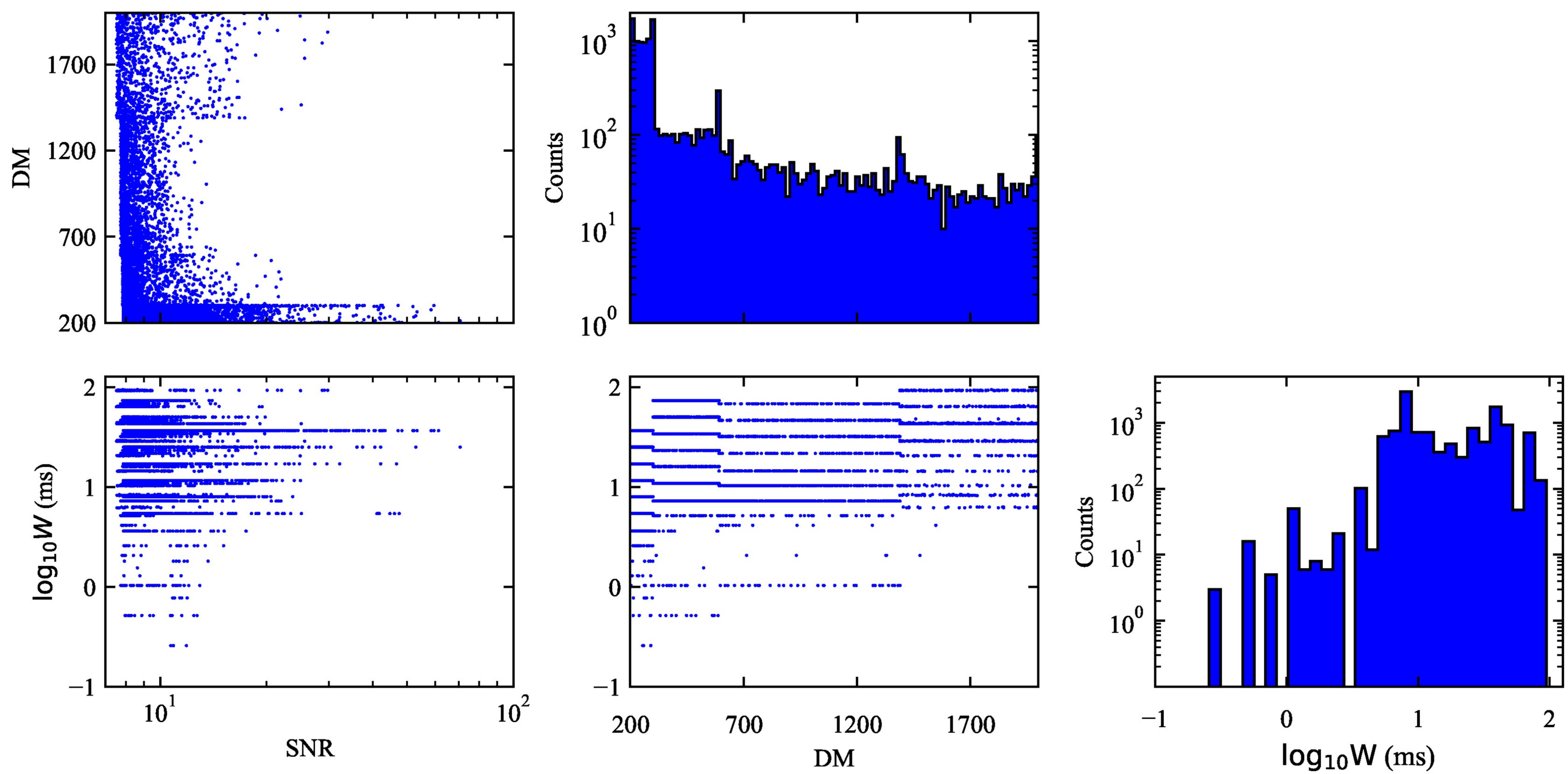


1) the candidate number is much larger than expected;

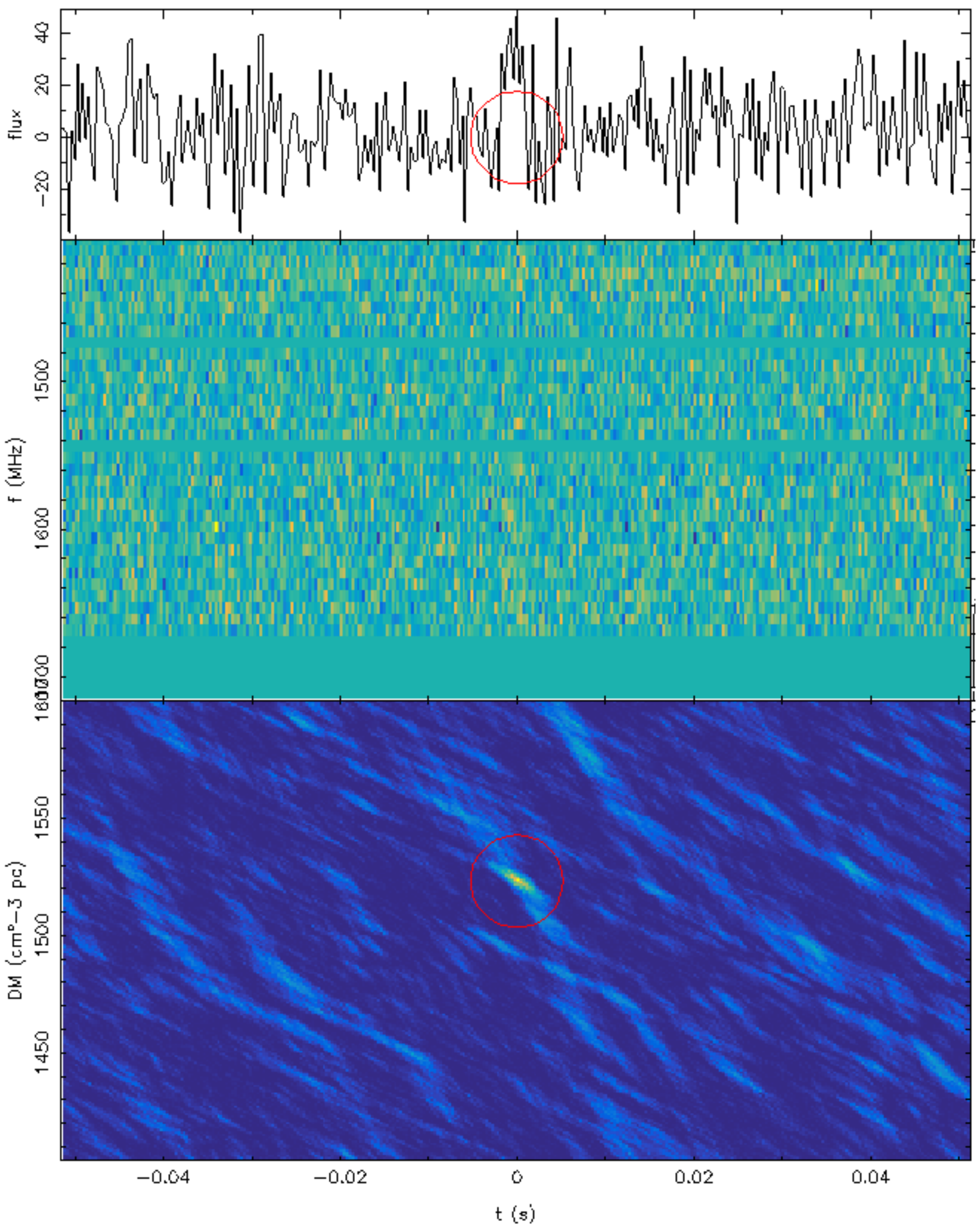
2) the candidate S/N distribution shows long-tailed feature;

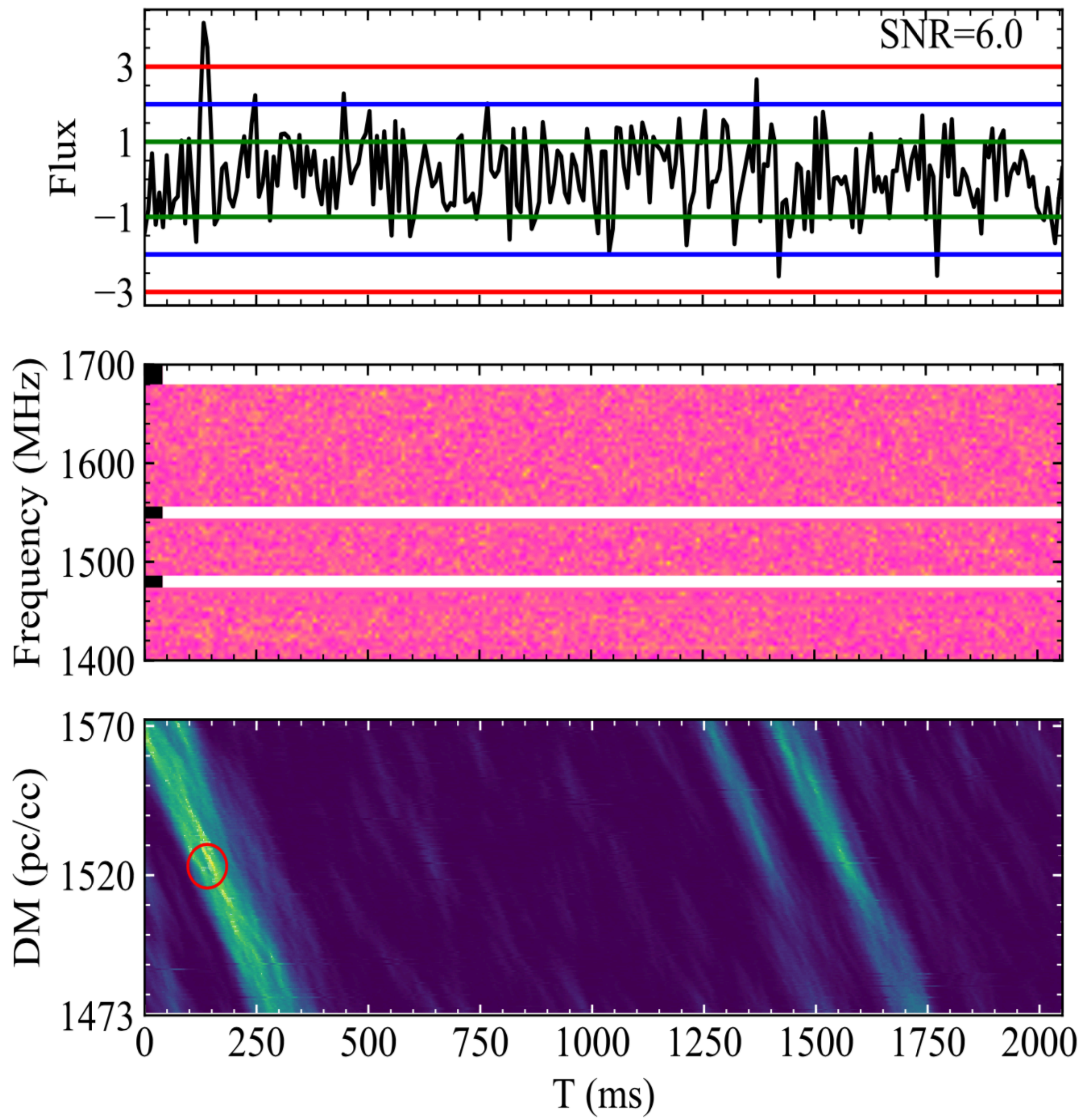
3) S/N correlates with the pulse width.

4) candidate counts correlate with the pulse width;

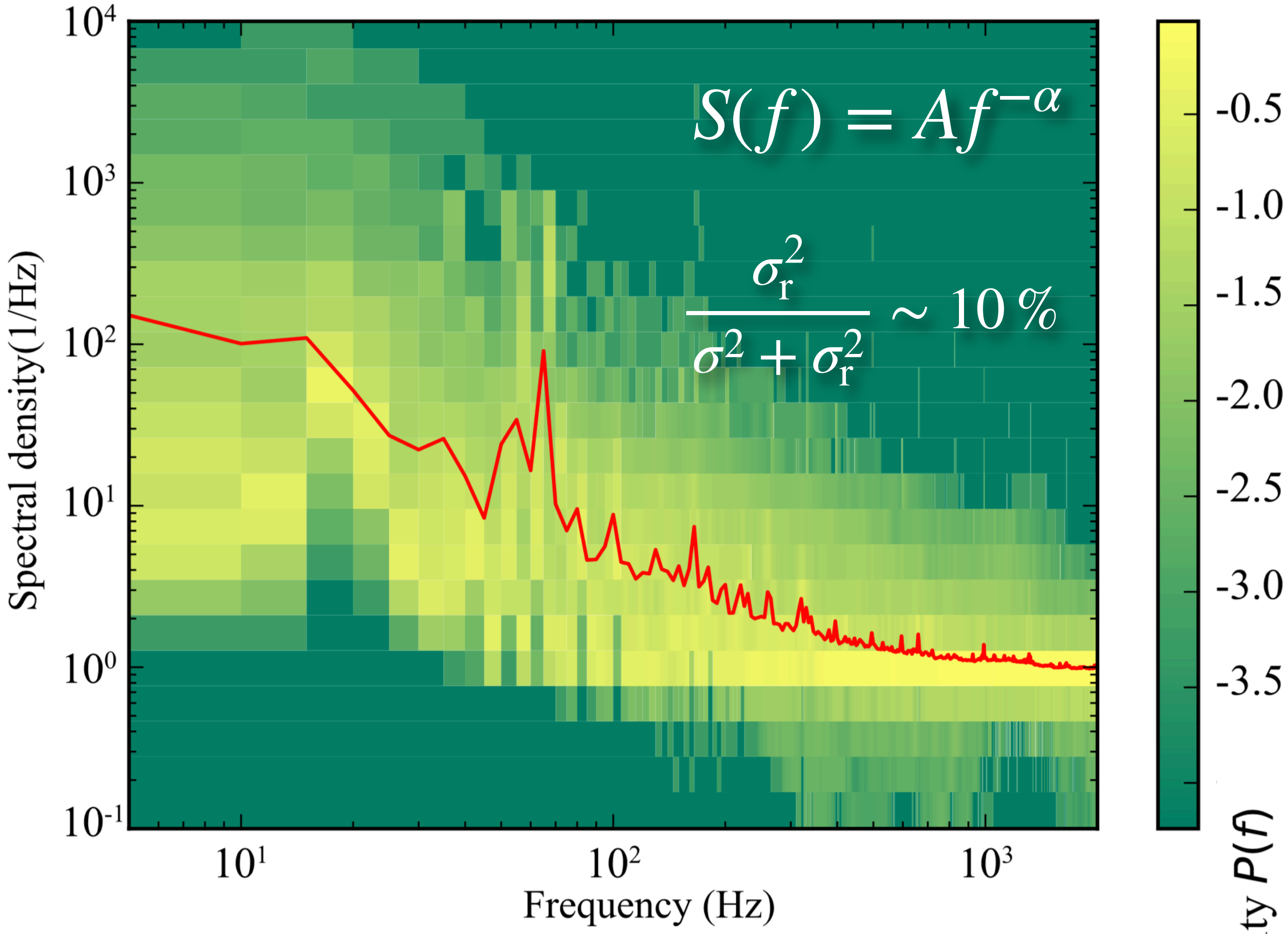


Detection Statistics





Detection Statistics



$$S = \frac{1}{N_{\mathrm{box}}\sigma^2}\left(\sum_{|t-t_0|<w} s_i\right)^2$$

$$S' = \eta S$$

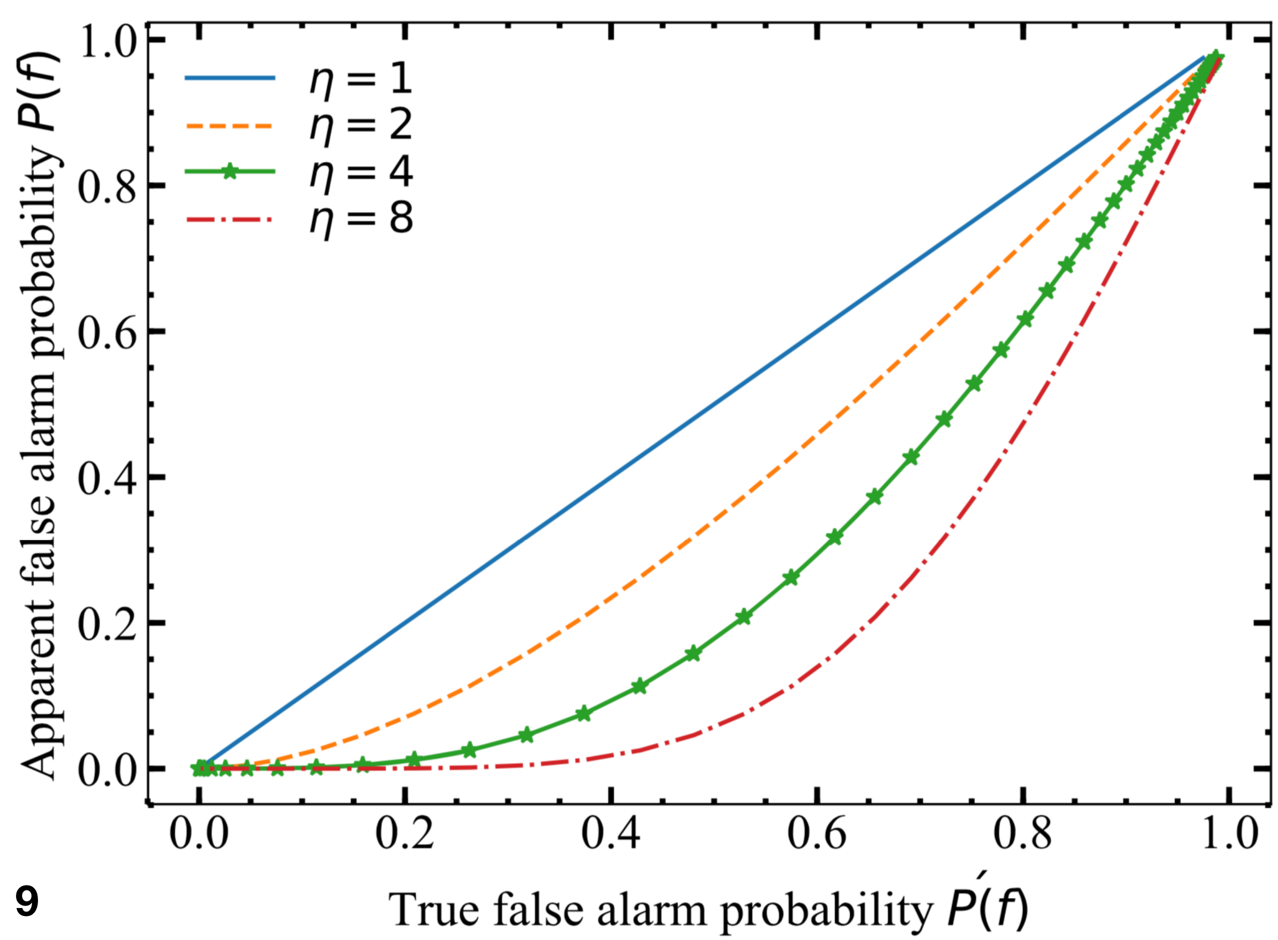
$$P_{\mathrm{f}}(S \geq S_0) = \mathrm{erfc}(\sqrt{S_0/2})$$

$$P'_{\mathrm{f}}(S \geq S_0\,|\,\eta) = \mathrm{erfc}(\sqrt{S_0/2\eta})$$

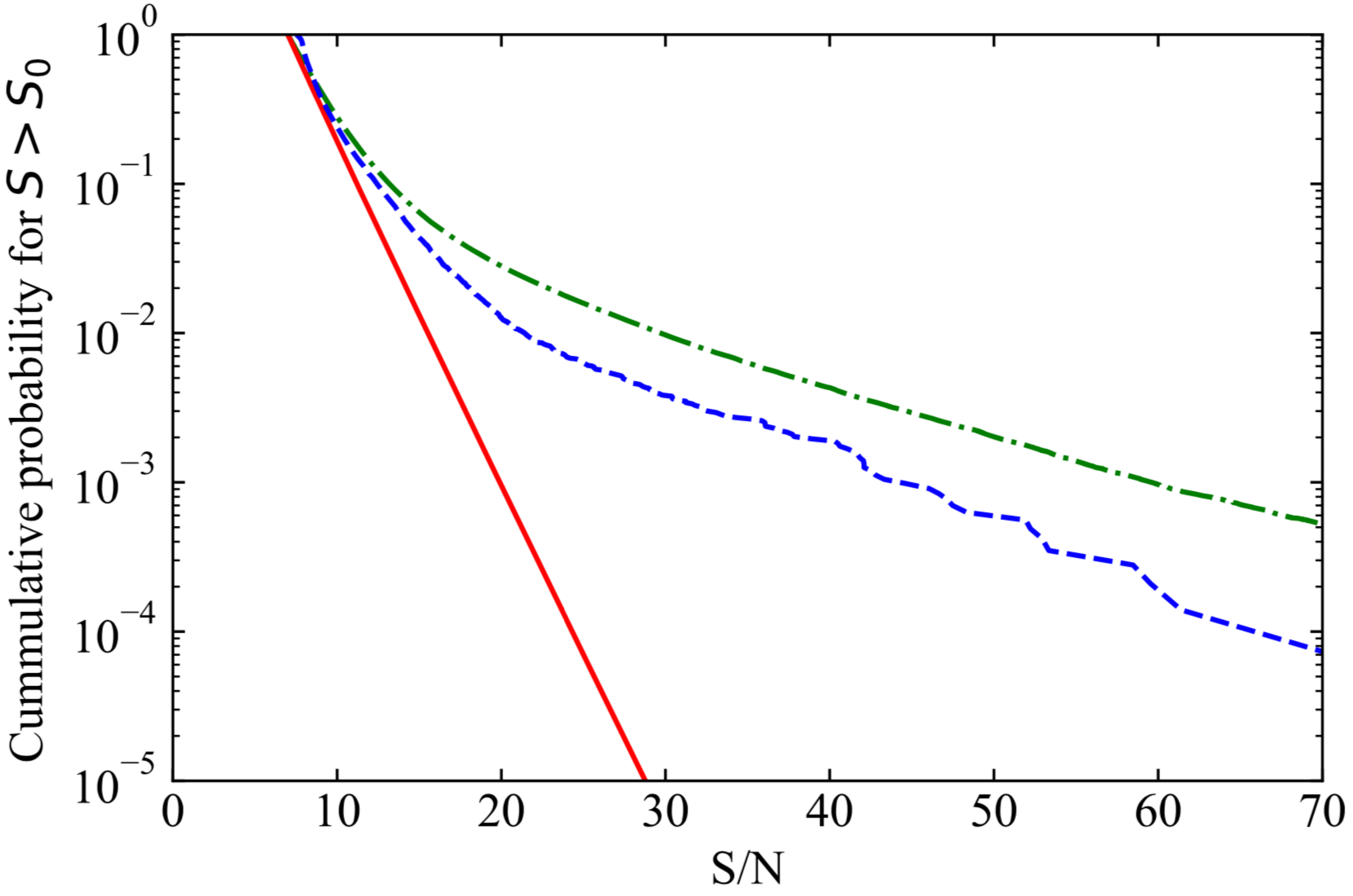
$$\eta = 1 + N_{\mathrm{box}}\kappa\frac{\sigma_r^2}{\sigma^2+\sigma_r^2}$$

$$N_{\mathrm{box}} \sim 10 - 10^2 \quad \kappa \simeq 0.01$$

$$P'_{\mathrm{f}}(S \geq s_0) = \int P'_{\mathrm{f}}(s \geq s_0\,|\,\eta) f_\eta(\eta) d\eta$$



Detection Statistics



✔ $N_c = \sum_{w_i} P'_f(S \geq 7 \,|\, \eta(w_i)) \frac{T}{w_i}$

$\simeq 1.5 \times 10^4$

✔ S/N distribution shows long-tailed feature

$$P'_f(S \geq s_0) = \int P'_f(s \geq s_0 \,|\, \eta) f_\eta(\eta) d\eta$$

✔ S/N correlates with the pulse width.

$$S' = \eta S \qquad \eta = 1 + N_{box} \kappa \frac{\sigma_r^2}{\sigma^2 + \sigma_r^2}$$

✔ Candidate counts correlate with the pulse width;

Summary

✓RFIs introduce correlated noise;

✓The correlated noise significantly **increases** the false alarm probability;

✓The signal-to-noise ratios (S/N) of the false positives become **higher.**

Thank you!