simulateSearch

A software package for simulating high time-resolution radio data

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Historically, most of spectacular astronomical discoveries were serendipities. Different from the past, emerging mega facilities challenge us on how to find the unknown unknowns from data-intensive sciences. There have been some algorithms designed for anomaly detections. To investigate which algorithm is capable for doing this job, the prerequisite is to obtain the data that is flexible for parameter setting. Here we present a software package, ***simulateSearch***, which can be used to simulate high time-resolution data from radio telescopes or to inject fake signals into existing data sets.

Overview on the software utilities

In the code, we build the data environment for a mock radio telescope. The system noise and radio frequency interference can be simulated, including wide-band single pixel and multibeam receiver systems. For the astronomical signals, we developed algorithms for generating pulse profiles, emission spectrum, scattering and scintillation. Radio transient sources such as pulsars and fast radio bursts can therefore be simulated as realistically as possible. In particular, we provide an injection routine for various anomalous patterns, which can provide a good condition for developing or testing algorithms on anomaly detection. We demonstrate the practicability by simulating data for the cases of the Parkes (Murriyang), MeerKAT and FAST telescopes. Also, we validate the simulations by comparing a couple of representative real signals with the simulated ones.

The system of a mock radio telescope has been designed and modelled in our code, including the designs in frontend and backend that can impact on the collected radio data. In the system noise, we consider basic recipes as follows.

TELESCOPE SYSTEM	DESIGN	BUILT	MODELED
Receiver	Pointing	✅	Astronomical Coordinates
	Multibeam	✅	Beam layout and positions
	Bandwidth	✅	Frequency channeled
Backend	Digitisation	✅	1bit, 2bit, 4bit, 8bit
	Noise level setting	✅	Automated mean noise levels
	Coherent dedispersion	✅	Performed

Table 1: The recipes of a mock telescope system that are modeled in ***simulateSearch***

Radio Frequency Interference

In radio astronomy, radio frequency interference (RFI) is ubiquitous. RFI is usually produced by terrestrial electronic devices or space satellites. Here we provide the simulation examples on the two types of commonly seen RFI in time-domain data: persistent and impulsive RFI (Figure 1).

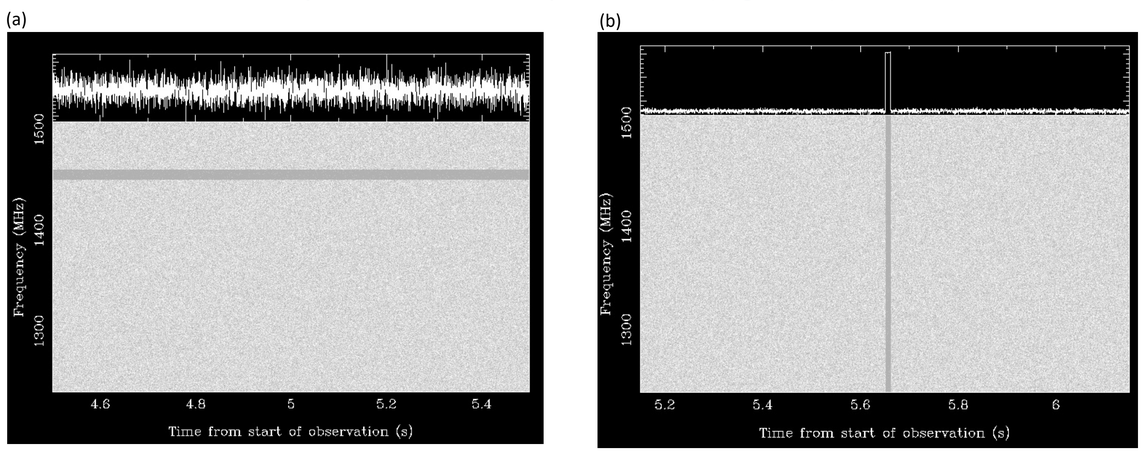

Figure 1: Two examples of common RFI: (a) Persistent narrowband RFI. (b) Impulsive broadband RFI.

Astronomical signals

There are two kinds of known radio transient signals in time-domain radio data, i.e. Pulsars and Fast Radio Bursts (FRBs). Observationally, pulsars are a series of periodic single pulses with different amplitudes, while FRB just exhibits a bright short-duration single pulse with significant dispersion.

We can simulate the artificial signals for these patterns as follows (Figure 2), which may be essentially useful for completeness tests on different pulsar or FRB searching pipelines.

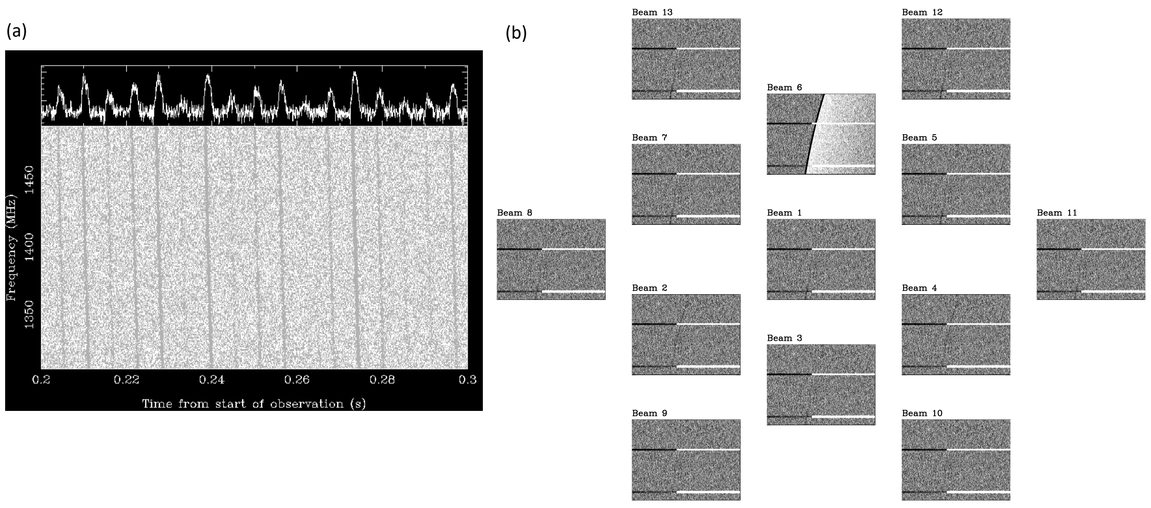

Figure 2: Two examples of simulations on the known astronomical signals: (a) A millisecond pulsar with variable emission intensities. (b) An FRB detected in the multibeam receiver, where the burst is detected in Beam 6.

Anomalous pattern injections

Our simulation code can be used to generate some anomalous signals that might exist in real data. Here we present two examples: splines and input images (see Figure 3). The spline pattern can be created by smoothing different points in the dynamic spectrum, and the input image requires we digitise the data in each pixel and then output to the samples in radio data.

These anomalous patterns can be injected to real data practically, which would be helpful for relevant algorithms tests on the outlier detections. We are looking forward to make new discoveries on the unknown unknowns in the future.

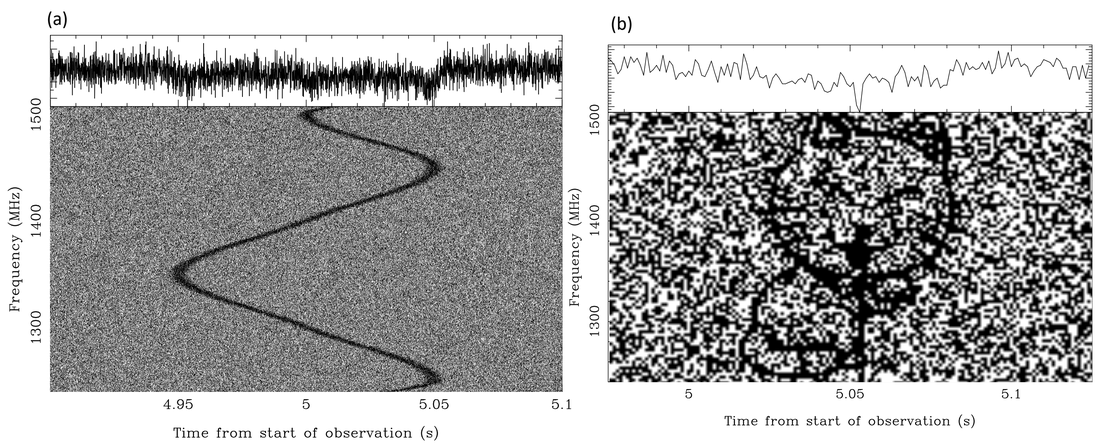

Figure 3: Two examples of simulations on the anomalous signals: (a) A bright spline. (b) An image of happy cat.

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FOR FURTHER INFORMATION
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REFERENCES

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