The Discovery of Terrestrial, Swept-frequency Emission that Mimics an Interstellar Dispersive Delay

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Abstract

We will detail the discovery of an anomalous terrestrial source of pulsed emission which exhibits a frequency-swept signal that closely mimics the frequency-dependent delay induced by dispersion in interstellar plasma. The signals were detected through the far sidelobes of Parkes Radio Telescope, appearing in all of the 13 independently-positioned receivers installed at the dish focus. The frequency-dependent delay and the sweep rates for most of the bursts are similar to those of a burst previously purported to be extragalactic. These bursts both call into question the extragalactic nature of that burst, and highlight the limitations of performing searches for one-off impulses with single dishes, in that they experience ambiguity in the positional localization of burst origins.

1 Rising prevalence of transient-emission searches

Astrophysical pulses can typically be discriminated from locally-generated emission by searching for pulses that exhibit a frequency-dependent delay that follows $\delta t \propto f^{-2}$. This property is expected from broad-band pulses that have undergone dispersion due to a frequency-dependent refractive index gradient in interstellar and intergalactic plasma.

Several single-pulse discoveries have been made over the past half-decade: isolated emission from "rotating radio transients" [1] and a single pulse with extragalactic spectral characteristics (the "Lorimer Burst") [2]. The success of these searches has caused searches of archival pulsar data for isolated pulses to become increasingly common, and experiments with the primary aim of detecting single pulses are underway or being developed [3-5]. Single-dish systems have primarily been used to perform transient-pulse searches. Until recently, the use of single-element detectors has not presented any hinderance to the searches; dispersion can typically separate astronomical emission from local emission, and the most common source of radio transients, pulsars, can always be confirmed by re-detecting the emission at the same sky location.

2 Terrestrial swept-frequency emission: complications arise

Recently, 16 swept-frequency pulses were reported that mimic an astronomical dispersion delay, however were shown to be of terrestrial origin [6]. The pulses were discovered in data taken with the 20cm Multibeam Receiver installed at Parkes Telescope, which has 13 beams at independent sky positions. The detection of all the pulses in 13 beams (Fig. 1) indicated that they were detected in far sidelobes. Their frequency-dependent modulation properties (see Fig. 2) indicated multi-path scattering and put limits on the pulse origin of $> 4\,\mathrm{km}$ from the Parkes dish. It has been indicated that the signals are likely to originate from either man-made satellite transmissions, or a natural atmospheric process [7;!!! see also paper #1703 submitted to commission G]. This class of pulses were subsequently labelled "Perytons" for want of a definitive physical description for their origin. Strikingly, the Perytons had sweep rates which clustered primarily around a dispersion measure (DM, which essentially indicates the magnitude of the $\delta t \propto f^{-2}$ sweep) of DM $= 380\,\mathrm{pc\,cm^{-3}}$; this is very similar to that of the Lorimer Burst, which exhibited a DM of $375\,\mathrm{pc\,cm^{-3}}$.

While the source of the Perytons is not yet known, they generate pertinent and timely warnings about using single-dish systems as transient detectors. The non-repeating nature of one-off transient sources inherently entails that one cannot confirm a candidate signal simply by re-observing the position at which the

978-1-4244-6051-9/11/$26.00

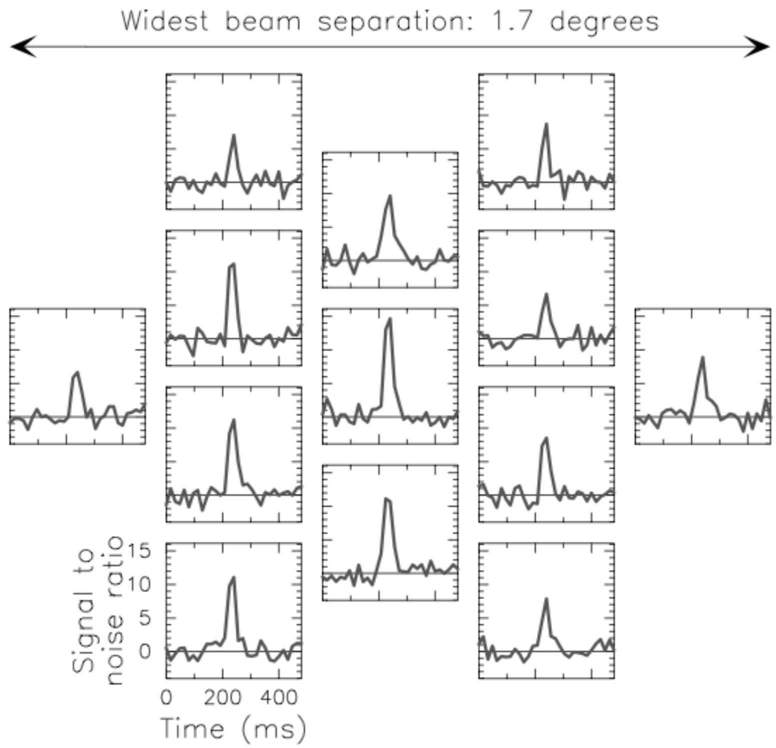

Figure 1: Here we show a time series for one Peryton as it appeared in the 13 beams of the multibeam receiver. The panels are laid out to reflect the relative beam positions on the sky. The time series in each beam has been corrected for a dispersion of $DM = 378\,\mathrm{pc\,cm^{-3}}$.

object was detected. Multibeam receivers like the one installed on Parkes Telescope do allow rough positional (∼several-arcminute) discrimination for objects focussed by the dish. However, as was one of the troubles in finding candidate host galaxies for the Lorimer Burst, these systems have insufficient resolving power to provide a manageable list of transient hosts. Thus, it becomes difficult for single dishes to provide precise localization (and subsequent classification) for both genuine extragalactic bursts, and for locally-generated transient signals.

3 Future designs for astronomical and terrestrial radio transient searches

The overarching difficulty with astronomical radio transient science is the singularity and (apparent) rarity of detectable transient events. It is imperative that as much information as possible be recorded from the data stream in the detection of such an event, while keeping a manageable data rate. Most current-generation instruments were not designed for single-event detection (nearly all sub-second radio transient discoveries have come out of archival or ongoing pulsar survey data), however as the next-generation transient-capable instruments are built, there are several aspects of capturing transient signals that need consideration. Due to the implied data-rate increase, many of these would only be possible with a real-time transient search that identified segments of interesting data to be recorded (a capability which, for wide-bandwidth systems up to high dispersion measure, currently can only function in real-time on Graphics Processing Units). Useful additions to current typical data-recording modes would include: 1) the recording of full-stokes polarization, which could potentially provide a potent discriminator between natural and man-made emission; 2) an increase in the recorded (though not necessarily searched) number of digitzation bits, which would provide significant dynamic range increases to detect e. g. modulation effects as seen in Fig. 2 as well as pulse-

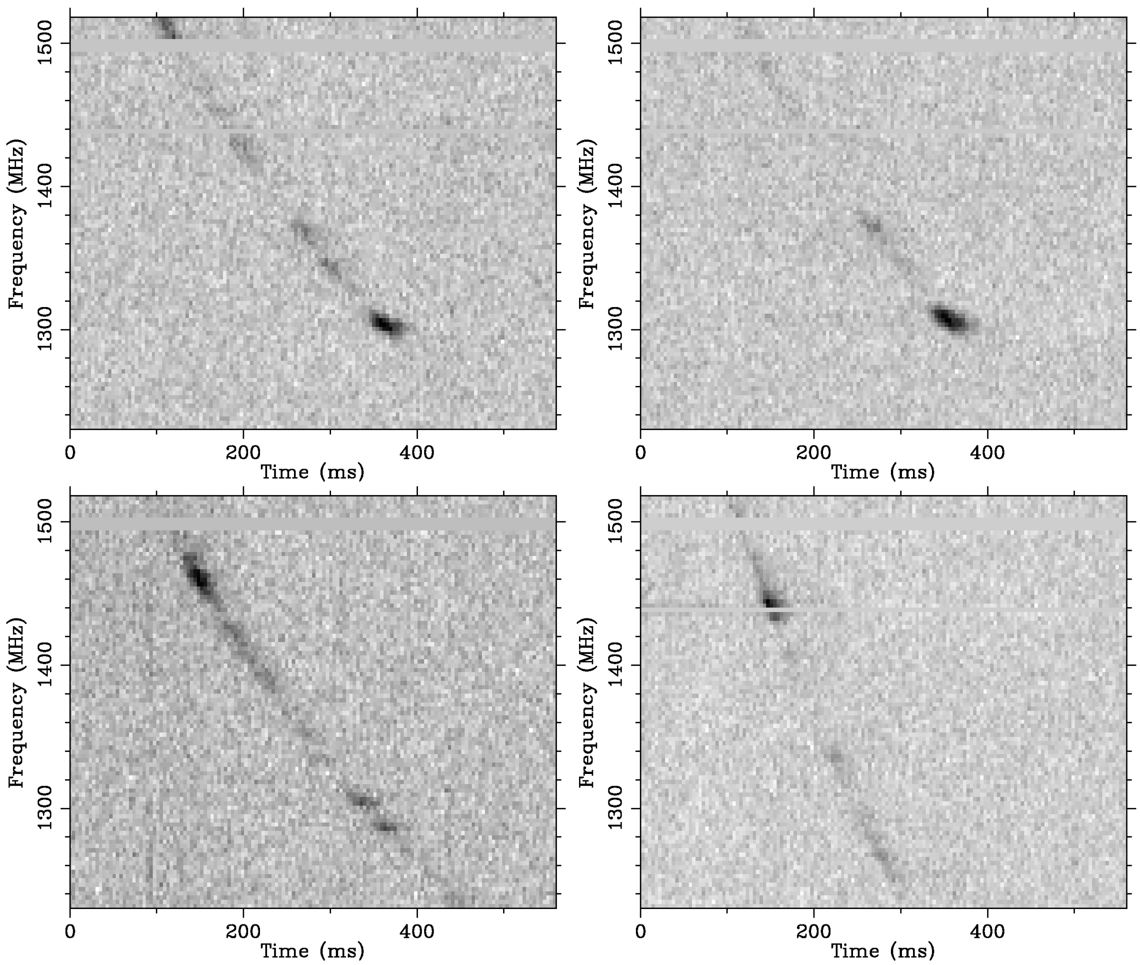

Figure 2: Examples of four Peryton spectrograms. Power is plotted in greyscale (black is higher power, white is lower power) as a function of frequency versus time. The frequency-dependent delays are clear, as are the modulation properties interpreted as a multi-path scattering effect [6].

shape features; 3) the prompt identification of events of interest and fast, co-ordinated response capability from observatories at other wavelengths, and finally, 4) a multi-element detector system capable of either high resolving power (i. e. widely-spaced elements, which would target extragalactic emission), or a large-field-of-view and capable of detecting the shape of a laterally-incident wavefront (i. e. discretely-positioned restricted-separation elements, which could target the origin of localized signals). It is the last of these enhancements that would provide the most powerful discriminator of Peryton and astronomical pulses, and which several groups are beginning to explore [3, 4, 8].

4 References

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