VOEvent Standard for Fast Radio Bursts

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ABSTRACT

Fast radio bursts are a new class of transient radio phenomena currently detected as millisecond radio pulses with anomalously high dispersion measures. As new radio surveys begin searching for FRBs a large population is expected to be detected in real-time, triggering a range of multi-wavelength and multi-messenger telescopes to search for repeating bursts and/or associated emission. Here we propose a method for disseminating FRB triggers using the Virtual Observatory Events (VOEvents) developed and used successfully for transient alerts across the electromagnetic spectrum and for multi-messenger signals such as gravitational waves. In this paper we outline a proposed VOEvent standard for FRBs including the essential parameters of the event and the structure of the event itself. We also discuss an additional advantage to the use of VOEvents for FRBs: new events can now be automatically ingested into the FRB Catalogue (FRBCAT) enabling real-time updates for public use. We welcome feedback from the community on the proposed standard outlined below and encourage those interested to join in the nascent working group forming around this topic.

Introduction

Fast radio bursts (FRBs) are one of the most exciting topics in modern astrophysics and their study is of intense interest to the transient astronomy community. FRBs are detected as millisecond radio pulses with a high dispersion measure, defined as

$$\mathrm{DM} = \int_0^D n_e d\ell \tag{1}$$

where D is the distance between the source and the observer along some path ℓ, and n_e is the electron column density. Dispersion is seen in pulses from Galactic pulsars but the DMs of FRBs are up to 70 times greater than the DM expected along the line of sight in the Milky Way leading to energetic extragalactic progenitor theories such as binary neutron star mergers[1], collapses of neutron stars to black holes[2], extremely active young pulsars in nearby galaxies[3], and hyperflares from magnetars[4], to name a few. The designation of a bright single pulse as an FRB (as opposed to a bright single pulse from a Galactic pulsar) has been based on its DM. All known FRBs have DMs in excess of the modeled electron density contribution from the Milky Way, and all but one[5] have DMs $> 1.5 \times \mathrm{DM}_{\mathrm{MW_N E2001}}$ where $\mathrm{DM}_{\mathrm{MW_N E2001}}$ is the electron density contribution along the line of sight modeled by NE2001[6].

The first FRB was discovered in 2007 by Lorimer et al.[7], FRB 010724[*], and since then progress has increased rapidly. Eighteen FRB sources have been published[†] and one source, FRB 121102, has been seen to repeat[8]. Interferometric observations

[*] FRBs currently follow the date-based naming conventions for gamma-ray burst and gravitational wave events: FRB YYMMDD.
[†] All publicly available FRBs are included in the FRB Catalogue (FRBCAT); http://www.astronomy.swin.edu.au/pulsar/frbcat/

of pulses from FRB 121102 provided positional accuracy capable of localizing the burst and pinpointing the host galaxy – a dwarf galaxy at a distance of $\sim$1 Gpc[9]. This detection confirms an extragalactic progenitor for this burst and a highly energetic production process for the radio pulses. The progenitors of FRBs, however, remain unknown. A repeating burst rules out a cataclysmic progenitor for FRB 121102; however, this source may not be representative of the full population of FRBs as it is the only FRB that has been seen to repeat[10]. Ultimately more FRBs need to be found, localized, and monitored to determine whether this observed behavior is common.

Recently, fast radio bursts have also been detected in real-time and followed-up with telescopes over radio, optical, X-ray, and γ-ray wavelengths and one search for multi-messenger signals from neutrinos[11–14]. Initial results have been inconclusive as the burst location within a large primary beam is unknown and association between the FRB and a multi-wavelength counterpart depends on detecting temporally coincident, distinctive transient emission. Some progenitor theories predict associated optical or X-ray transients and the search for possible counterparts remains essential.

As more telescopes begin to detect FRBs in real-time, a standard way to circulate new detections becomes necessary to enable efficient observing by telescopes wishing to follow-up FRBs. A structure for the dissemination of astronomical transients has been developed by the International Virtual Observatory Alliance (IVOA) which has been used to great effect for gamma-ray and supernova astronomy called a VOEvent. In this paper we describe the structure of a VOEvent for FRBs, including some information on the contents of the FRB VOEvent and practical uses. In the following sections we present some motivations for the development of a VOEvent standard, describe the VOEvent framework and why it is well-suited to FRB detections, describe the particulars of the FRB event structure, explain the automatic ingestion of FRB VOEvents into the FRB Catalogue[15], and present a sample FRB VOEvent.

Motivation

Many properties of FRBs remain unknown; a much larger population, with consistent monitoring and multi-wavelength follow-up will be needed to answer questions related to their origins and possible associated emission. A rapid increase in the FRB detection rate is expected in the next few years as more telescopes begin searching for FRBs and as new wide-field interferometers come on-line. Next generation synthesis radio telescopes such as the Aperture Tile In Focus (Apertif) upgrade to the Westerbork Telescope in the Netherlands, the Canadian Hydrogen Intensity Mapping Experiment (CHIME) in North America, and the Upgrade to the Molonglo Synthesis Telescope (UTMOST) in Australia are expected to detect hundreds of FRBs per year when up to full sensitivity.

Many FRB-finding experiments, such as the VLA realfast project[*], also plan to detect these bursts in real-time, issuing follow-up triggers upon robust detections. At the time of writing only a handful of FRBs have been detected in real-time, all from the Parkes telescope, and only three have reported multi-wavelength follow-up. The current triggereing procedure with detections at the Parkes telescope is to send an email with the relevant burst parameters to collaborators who then carry out observations. This process introduces considerable lag time between the discovery of an FRB and the first on-source observations with other telescopes. Efforts underway using the Effelsberg telescope and the Low Frequency Array (LOFAR) aim to capture the same burst in the bands of both telescopes. The large difference in observing frequency and the high DMs of FRBs allow for this detection, ensuring that the dispersed tail of a burst found with Effelsberg arrives seconds to minutes later in the LOFAR band. The ability to send triggers between the two telescopes on timescales of a few tenths of seconds is therefore essential for the project to succeed. Currently, a simple VOEvent network links the two telescopes, sending triggers between the observatories.

A faster and more standardized method of sending triggers must be implemented for FRBs in order to obtain broad and timely follow-up. Recent experiments have already shown that multi-wavelength follow-up may yield interesting results[16], such as the detection of variable radio sources in the fields of FRB 150418 and FRB 131104[12,13] and of a 380-s γ-ray transient temporally coincident with FRB 131104 in the field of the burst by the *Swift* telescope[17]. Additionally, recent observations of FRB 121102 have shown that at least this one FRB goes through phases of high activity when repeat pulses are more likely to be detected. For such a source a detection alert can be followed with extensive monitoring for repeated bright bursts by other radio telescopes.

The VOEvent structure provides a robust framework for sending and receiving triggers upon the detection of a new FRB. VOEvent triggers are already widely used for gamma-ray burst (GRB) and supernova detections and are beginning to be used for gravitational wave detections with the Laser Interferometer Gravitational-Wave Observatory (LIGO) and have many advantages over other trigger dissemination methods. Firstly, VOEvents are embedded within the larger Virtual Observatory framework, discussed in more detail in the next section. Tools for distributing and receiving VOEvents, as well as code for parsing individual event files, are freely available online and well documented. Secondly, a standardized event structure for FRBs used by radio telescopes searching for new bursts gives greater flexibility to any multi-wavelength or multi-messenger

[*] http://realfast.io

facility wishing to act upon FRB triggers. Thirdly, and finally for the purposes of this list, FRB VOEvents will be automatically added to the FRB Catalogue (FRBCAT) either as new entries upon detection or as updates to previously published bursts when additional detections are made. Details of this functionality are given in a separate section below. Our intention for this white paper is to provide the necessary background on the VOEvent structure and establish a template for FRB event triggers.

The VOEvent Framework

The IVOA is an organisation with the mission to facilitate the international astronomical community with the organizational structures necessary to make data, tools, and communication about these assets available for everyone within the community. By providing recommendations and standards for (meta)data structures, the goal is to make astronomical data so transparent that it's as if it is all the product of one Virtual Observatory (VO).

Due to technological advancements, the transients sky can be explored on ever shorter timescales, resulting in new and unknown astronomical events found across the entire electromagnetic spectrum and beyond. Reporting and keeping track of the discoveries of all these events is a growing challenge, one that the IVOA tried to tackle with the introduction of VOEvents in 2006. In their Sky Event Reporting Metadata Recommendation[†], they describe a standard format to structure metadata about any time-varying astronomical event using `xml` schemata. The data packet that contains this structured metadata is referred to as a *VOEvent* and the means to transport it to other facilities potentially interested in performing follow-up observations upon the reception of such an event is called the *VOEvent network*. The VOEvent semantics are intentionally kept broad, allowing the VOEvent network to be used for a wide range of applications. Consequently, VOEvents of a certain class are only interpretable by those receivers for which the event was intended. Users, those who send events (*authors*) and receive them (*subscribers*), have to agree on what information can be contained within a VOEvent, since only the way of structuring this information is specified by the IVOA recommendation. This white paper aims to tailor the use of VOEvents to the needs of the FRB community.

Key information about the VOEvents themselves are given in the IVOA identifiers. Every VOEvent must have a unique and valid International Virtual Observatory Resource Name (IVORN) in order to distinguish between events and to enable subscribers to find specific events or streams of events. An IVORN consists of an author ID, stream ID and a local ID unique to the event (see next section). VOEvent IVORNs are one of the means that subscribers can use to filter messages of interest from the many messages sent over the network. Events can also be filtered based on author, instrument, date, etc. through a scripted VOEvent parser[‡]. Through the IVORNs it is also possible to find who is responsible for sending a specific event or to create VOEvent archives in which specific events can be queried using the event's IVORN.

The IVORN of an event also plays an important role in its transmission over the VOEvent network. The network is designed according to the VOEvent Transport Protocol[§] and uses Transmission Control Protocol (TCP) connections to transfer a VOEvent error-free from an author to a subscriber. However, to ensure that the network is not flooded with identical events the TCP connections are relaid through a broker (a daemon tool maintained by an institute registered with the IVOA). Authors thus send their VOEvents to a broker that then re-transmits them to all its registered subscribers. The VOEvent network is built upon several interconnected brokers (the VOEvent Backbone) that have registered subscribers connected to one of the brokers and registered authors who are allowed to send VOEvents over the network, shown in Figure 1. The author-to-broker connections are temporal connections whereas the connections between brokers and subscribers are always open. Tools, like the software package Comet[18], have already been developed that can act as brokers or subscribers and take care of the technical requirements to keep the TCP connections alive. These tools make the VOEvent network reliable and easy to use, ideal for rapid transmission of events within a large collaboration or community.

No standard has currently been developed to register a new subscriber. If a facility or individual is interested in receiving VOEvents from a specific author or stream, the first step is to set up a local machine running Comet, or some similar tool, as a subscriber. The next step is to get the facility machine's IP address white-listed at the broker and implement the necessary filters to only receive events of interest. The same holds true for the registration of a new author. It is to be expected that this method of registration will change in the future when the network has progressed to later stages of its development.

The FRB VOEvent

The VOEvent standard defines an `xml` schema describing how an author should report on an astronomical event but not what should be reported. It is left to the author to decide the content and meaning of the event. If VOEvents are going to be used to report FRBs in the near future, a consensus should be reached about their content beforehand in order to facilitate interpretation

† http://www.ivoa.net/documents/VOEvent/
‡ https://github.com/timstaley/voevent-parse
§ http://www.ivoa.net/documents/VOEventTransport/

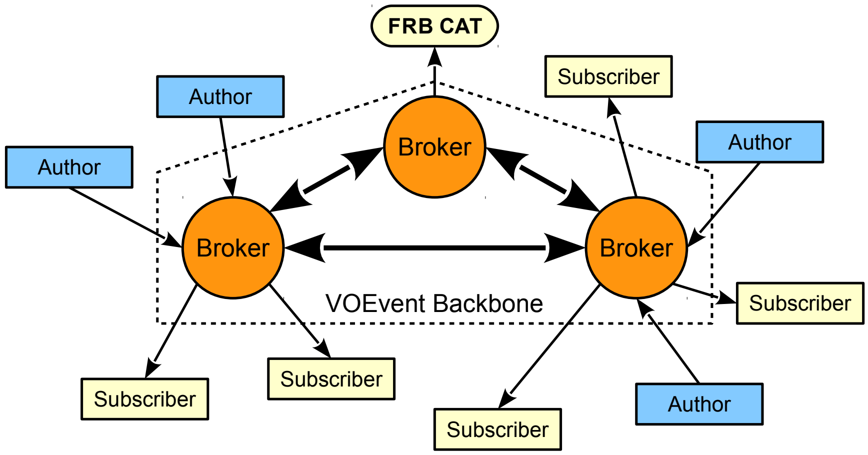

Figure 1. The VOEvent framework consists of connections between individual Brokers to which events can be pushed by Authors and received by Subscribers. The FRB Catalogue (FRBCAT) will automatically ingest events sent or received by a local broker.

by potential subscribers. Therefore we suggest a common usage of VOEvent elements when reporting new burst or improved FRB parameters. The usage may change if alternative designs are deemed to better accommodate the needs of the community.

Each FRB VOEvent is contained in a single `xml` **<VOEvent>** element with several of the sub-elements in the list below.

<Who> The <Who> element provides a subscriber with information about the author. Each facility should have a unique Author IVORN which refers to the institute issuing the event together with the date and time at which the event was created. This IVORN is typically in a reversed DNS format (i.e. `ivo://au.atnf.csiro/contact`). This element should also contain the contact details of the person responsible for the event within the issuing institute.

<What> What has been observed by the author. This element holds all the scientific parameters describing the observed FRB. A sample VOEvent is given at the end of this paper to show what parameters the authors believe can fully describe an FRB, but the community is encouraged to give feedback about the completeness of this list. Because the intended use of FRB VOEvents can trigger different responses at observatories the scientific parameters are grouped under the following three headers.

observatory parameters
All the relevant telescope and back-end parameters, like beam size, centre frequency and telescope gain.

event parameters
Only the essential, easy to extract FRB parameters are listed here, for instance the DM, width and signal-to-noise ratio of the detected burst. These parameters should allow for rapid follow-up observations with different instruments within seconds to minutes after the initial detection.

advanced parameters
Once the raw FRB data has gone through rigorous analysis and its characteristics are better known, these newly obtained or more detailed parameters go here. If they are known at the time of issuing the initial detection, they should also be included.

<WhereWhen> The IVOA Space-Time Coordinate (STC) specifications[¶] are used for this element to describe where on the celestial sky the event has happened and when.

<Why> This element gives a score between zero and one indicating how important the author considers the event to be for follow-up by the subscriber with zero being least important and one being most important for immediate follow-up. The importance element could also be considered as an assurance parameter.

<How> Optional element to provide a subscriber with more information on how the detection was made by providing a URL to a website with the back-end or system configuration, for instance. This element can also contain a description sub-element which gives information about DM excess of the observed FRB relative to the expected NE2001 DM along the line of sight.

[¶] http://www.ivoa.net/documents/latest/STC.html

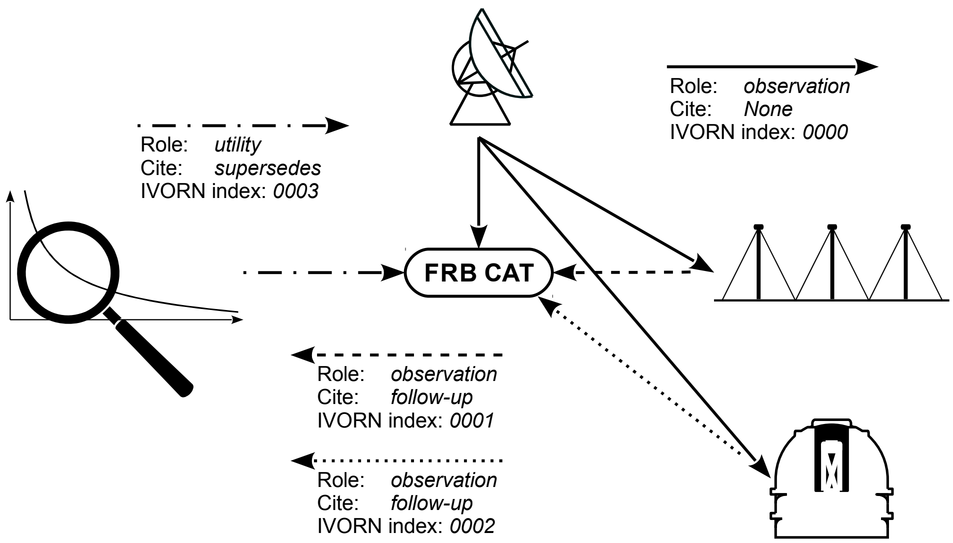

Figure 2. An example of a series of VOEvents issued concerning a particular FRB source. The source is first detected with a radio telescope and an *observation* event is issued with IVORN index 0000. If the source is observed with other telescopes they can report their findings using the *follow-up* keyword with a citation to the original detection and an IVORN index incremented by one (0001 and 0002). If detection facility makes further fits to the FRB and reports updated parameters to FRBCAT they use a *utility* VOEvent citing the original detection with the keyword *supersedes* and the next IVORN index in the series (0003).

<**Citations**> Optional element, but required when issuing an event that relates to a previous FRB VOEvent. In this case the author has to indicate the event's relation to the previously sent FRB VOEvent and provide the Event IVORN of the VOEvent to which it refers. Allowed event relations are *follow-up*, *supersedes* and *retraction*.

These sub-elements provide a subscriber with all the necessary scientific information to decide how to act upon an event, either by taking follow-up observations, updating the FRBCAT, or waiting for the next VOEvent. The main <VOEvent> element is the place holder for information about the VOEvent itself needed to properly parse the event. For instance, it specifies the version of the VOEvent standard used to structure the metadata in the event.

Furthermore, this element contains the "role" attribute that depicts the purpose of the event. If an author has a detection to which they want subscribers to respond, the FRB VOEvent should be sent with the "role" attribute *observation*. The "role" attribute can also be set to *test* if the FRB VOEvent was sent for testing purposes and no action is required by subscribers. The "role" *utility* is reserved for events whose main purpose is to provide updates or changes to an event in FRBCAT (see next section), again no action is required by other subscribers in the VOEvent network for these kind of VOEvents.

The final important component of the <VOEvent> element is the Event IVORN. As discussed above, the Event IVORN is a unique string used to identify a single FRB VOEvent. It should start with `ivo://` followed by an author ID, stream ID and a local ID with a similar reverse DNS format to the Author IVORN. With a large community potentially interested in sending many FRB VOEvents about the same FRB sources, especially if many are found to repeat, it is sensible to standardise the IVORN allocations for new events. In the case when VOEvents about the same FRB source but from different instruments are broadcast over the network and users would like to organise this information per FRB rather then per instrument this becomes particularly useful. We therefore propose to use the name of the institute issuing the FRB VOEvent as the author ID, the name of the instrument used to detect the FRB as the stream ID and the FRB name and a numeric index as the local ID. The full Event IVORN will then take the form `ivo://[institute]/[instrument]#FRB[YYMMDDhhmm]/[index]`. The first detection of a new FRB should be given the index count 0000 and every subsequent event published under the same FRB name should have a count raised by one. For example, a new detection at 12:00 on 29 March, 2017 using the Apertif instrument by ASTRON would have the IVORN `ivo://nl.astron/apertif#FRB1703291200/0000`. This enables the community to publish FRB VOEvents under the same FRB name, but gives a natural way to sequence the events. An example of the use of this indexing system is given in Figure 2. A sequential history of VOEvents for a given FRB and the appropriate index to use in the next event will be given in the FRB Catalogue, as discussed in the next section.

Connection with the FRB Catalogue

The FRB Catalogue has been upgraded to automatically ingest FRB VOEvents, parse them, and populate the catalogue in real-time as events are issued by authors. This functionality has been developed to provide a simple way to add bursts to the catalogue (until now this has been done manually) and to provide a centralised hub for information about new detections as a service for the community.

The FRB Catalogue will receive all events transmitted or received by the ASTRON Comet broker and will automatically place these in the catalogue. Upon notification of a new FRB (Event IVORN ending in 0000) a new page will be created in the catalogue for the source. Additional detections, all with the "role" *observation* citing the original FRB detection, will be added to the catalogue as new observations of an existing FRB. If new fits or updated parameters are available for an observed pulse after additional processing the best-fit parameters in the catalogue can be updated using another VOEvent; in this case the event should use the "role" *utility* citing the VOEvent containing the old parameters with the citation keyword *supersedes*. Events can also be removed from the catalogue using the "role" *utility* with the citation keyword *retraction*.

The catalogue will keep a VOEvent history for each FRB which will be visible on the detailed information page for an FRB source; however, VOEvents concerning retracted FRBs will not be kept on the catalogue webpage. We also plan to host a simple application program interface (API) on the catalogue webpage which will contain the IVORN identifier for each known FRB as well as the highest VOEvent index currently registered in the catalogue. If a facility wishes to distribute a new VOEvent concerning an existing FRB they can query this page to determine the appropriate index to be used. The API can be queried manually or via a script running at the facility issuing the VOEvent. In this way we hope that the catalogue will provide the necessary tools for standardisation across institutions issuing FRB VOEvents.

With regards to the FRB Catalogue we would like to conclude with a few notes on future-proofing as the FRB population grows and evolves. As more physical properties of FRB sources are understood, new parameters to describe FRBs may become necessary and new naming conventions may arise. The FRB Catalogue is not intended as a static resource but has been developed flexibly with the aim to add or remove parameters and provide functionality desired by the community. Continued feedback from users of the catalogue on the features they would like to see is welcomed and appreciated. It is the intention of the team responsible for this catalogue to implement viable new suggestions as quickly as possible and to adapt the catalogue to best capture the essential information for FRB science.

Discussion and Conclusions

In this paper we provide a proposed standard for FRB VOEvents – flexible, machine-parsable `xml` files used to disseminate astronomical triggers. VOEvents have been used successfully in the gamma-ray burst and supernova communities to notify facilities around the world of new transient phenomena and to facilitate rapid multi-wavelength follow-up. As new efforts commence to find FRBs with telescopes around the world, a large increase in the population is expected and real-time detections will become commonplace. The VOEvent framework is well suited to sending FRB triggers as the network infrastructure is already in place and is maintained by the International Virtual Observatory Alliance (IVOA). The structure of VOEvents themselves is extremely flexible and the standard contents of VOEvents sent about a certain source class must be defined by the community that intends to send and receive these events.

The VOEvent template provided with this white paper (and the examples located in the associated github repository) are intended to provide the community with a standard that can be used globally for FRB triggers. This standard is intended to be flexible, modular, and useful to the largest group possible to enable high impact, rapid response transient science. The standard presented here has been developed by a subset of the FRB community developing large surveys to detect FRBs, but the ultimate format and structure of FRB VOEvents should be decided on in collaboration with a majority of current users of such a system. As such, we encourage all users who are interested in this initiative to join this working group by contacting the authors of this white paper. We also welcome feedback on any aspect of this effort by members of the community as well as suggestions for changes or improvements that could be made to this model.

Code Repository

Some basic use cases for the FRB VOEvent as well as simple scripts will be included in a github repository as tools for the community [note: this isn't ready just yet]. Publicly available open-source code for parsing VOEvents is also available through `python` packages[‖].

‖ https://github.com/timstaley/voevent-parse

FRB VOEvent xml code

Here we present a template for the FRB VOEvent giving all possible parameters for an FRB with all values intentionally left blank. FRB VOEvents sent through the VOEvent Network do not need to include all the parameters presented here, and null values or blank values are also acceptable. Examples of an initial detection VOEvent and a VOEvent to update existing parameters in FRBCAT are also available on the github repository for this paper.

```
A Sample VOEvent
Emily Petroff & Leon Houben

<?xml version='1.0' encoding='UTF-8'?>
<voe:VOEvent xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:voe="http://www.ivoa.net/xml/VOEvent/v2.0" xsi:schemaLocation="http://www.ivoa.net/xml/VOEvent/v2.0 http://www.ivoa.net/xml/VOEvent/VOEvent-v2.0.xsd" version="2.0" role="[role]" ivorn="ivo://[institute]/[instrument]#FRB[YYMMDDhhmm]/[FRBcat index]">
  <Who>
    <AuthorIVORN>ivo://[institute]/contact</AuthorIVORN>
    <Date>[YYYY-MM-DDThh:mm:ss]</Date> <!-- Time of event creation -->
    <Author><contactEmail>[E-mail]</contactEmail><contactName>[Name]</contactName></Author>
  </Who>
  <What>
    <Group name="observatory parameters">
      <Param dataType="float" name="beam_semi-major_axis" ucd="instr.beam;pos.errorEllipse;phys.angSize.smajAxis" unit="MM" value=""/>
      <Param dataType="float" name="beam_semi-minor_axis" ucd="instr.beam;pos.errorEllipse;phys.angSize.sminAxis" unit="MM" value=""/>
      <Param dataType="float" name="beam_rotation_angle" ucd="instr.beam;pos.errorEllipse;instr.offset" unit="Degrees" value=""/>
      <Param dataType="float" name="sampling_time" ucd="time.resolution" unit="ms" value=""/>
      <Param dataType="float" name="bandwidth" ucd="instr.bandwidth" unit="MHz" value=""/>
      <Param dataType="float" name="centre_frequency" ucd="em.freq;instr" unit="MHz" value=""/>
      <Param dataType="int" name="npol" unit="-" value=""/>
      <Param dataType="int" name="bits_per_sample" unit="-" value=""/>
      <Param dataType="float" name="gain" unit="K/Jy" value=""/>
      <Param dataType="float" name="tsys" ucd="phot.antennaTemp" unit="K" value=""/>
      <Param name="backend" value=""/>
      <Param name="beam" value=""><Description>Detection beam number if backend is a multi beam receiver</Description></Param>
    </Group>
    <Group name="event parameters">
      <Param dataType="float" name="dm" ucd="phys.dispMeasure;em.radio.750-1500MHz" unit="pc/cm^3" value=""/>
      <Param dataType="float" name="dm_error" ucd="stat.error;phys.dispMeasure" unit="pc/cm^3" value=""/>
      <Param dataType="float" name="width" ucd="time.duration;src.var.pulse" unit="ms" value=""/>
      <Param dataType="float" name="snr" ucd="stat.snr" value=""/>
      <Param dataType="float" name="flux" ucd="phot.flux" unit="Jy" value=""/>
      <Param dataType="float" name="Broadening" ucd="time.duration;src.var.
```

```
pulse;spect.line.broadening" unit="ms" value="None"><Description>NOTE: if Broadening = None this means no evidence could be found for broadening or it has NOT been calculated</Description></Param>
    <Param dataType="float" name="gl" ucd="pos.galactic.lon" unit="Degrees" value=""/>
    <Param dataType="float" name="gb" ucd="pos.galactic.lat" unit="Degrees" value=""/>
</Group>
<Group name="advanced parameters">
    <Param dataType="float" name="ne2001_dm_limit" unit="pc/cm^3" value=""/>
    <Param dataType="float" name="redshift" ucd="src.redshift" unit="None" value=""><Description>Inferred redshift from DM excess</Description></Param>
    <Param dataType="float" name="dm_index" unit="None" value=""><Description>Dispersion measure index</Description></Param>
    <Param dataType="float" name="dm_index_error" unit="None" value=""><Description>Dispersion measure index error</Description></Param>
    <Param dataType="float" name="scattering" unit="None" value=""><Description>Scattering timescale at 1 GHz</Description></Param>
    <Param dataType="float" name="scatter_index" unit="None" value=""><Description>Scatter index</Description></Param>
    <Param dataType="float" name="scatter_index_error" unit="None" value=""><Description>Scatter index error</Description></Param>
    <Param dataType="float" name="spectral_index" unit="None" value=""><Description>Spectral index</Description></Param>
    <Param dataType="float" name="spectral_index_error" unit="None" value=""><Description>Spectral index error</Description></Param>
    <Param dataType="float" name="width_error_upper" ucd="stat.error;src.var.pulse;stat.max" unit="ms" value=""/>
    <Param dataType="float" name="width_error_lower" udc="stat.error;src.var.pulse;stat.min" unit="ms" value=""/>
    <Param dataType="float" name="flux_error_upper" ucd="stat.error;phot.flux;stat.max" unit="Jy" value=""/>
    <Param dataType="float" name="flux_error_lower" ucd="stat.error;phot.flux;stat.min" unit="Jy" value=""/>
    <Param dataType="float" name="fluence" ucd="phot.fluence" unit="Jy ms" value=""/>
    <Param dataType="float" name="fluence_error_upper" ucd="stat.error;phot.fluence;stat.max" unit="Jy ms" value=""/>
    <Param dataType="float" name="fluence_error_lower" ucd="stat.error;phot.fluence;stat.min" unit="Jy ms" value=""/>
    <Param dataType="float" name="linear_pol" ucd="phys.polarization.linear" unit="None" value=""/>
    <Param dataType="float" name="linear_pol_error" ucd="stat.error;phys.polarization.linear" unit="None" value=""/>
    <Param dataType="float" name="circular_pol" ucd="phys.polarization.circular" unit="None" value=""/>
    <Param dataType="float" name="circular_pol_error" ucd="stat.error;phys.polarization.circular" unit="None" value=""/>
    <Param dataType="float" name="rm" ucd="phys.polarization.rotMeasure" unit="rad/m^2" value=""/>
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    </What>
    <WhereWhen>
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                    ↪ ISOTime></TimeInstant></Time> <!-- Time FRB occured -->
                <Position2D unit="deg"><Name1>RA</Name1><Name2>Dec</Name2><Value2><
                    ↪ C1>[RA in degrees]</C1><C2>[DEC in degrees]</C2></Value2><
                    ↪ Error2Radius>[Position error in degrees]</Error2Radius></
                    ↪ Position2D>
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    <How>
        <Description>[Possible instrument details]</Description><Reference uri="[
            ↪ Link to external webpage about instrument]"/>
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            ↪ DM fraction in excess of NE2001 along this sightline -->
        </How>
        <Why importance="0.0">
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                ↪ Elaboration on flag criteria]</Description>
        </Why>
        </Why>
        <!--
        <Citations>
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                ↪ ]</EventIVORN>
            <Description>[Relation to the cited event]</Description>
        </Citations>
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</voe:VOEvent>
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