International
Virtual
Observatory
Alliance

Pulsar and FRB Radio Data Discovery and Access

Version 1.0

IVOA Note 2022-09-22

Working group
DAL
This version
https://www.ivoa.net/documents/PulsarRadioDataAccess/20220922
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Abstract

This document presents the issues of Discovery and Access for time dependant radio data, specially dedicated to point sources such as pulsars or FRB. The Discovery phase may follow different modes, including ObsTap discovery. Proposal are made for mapping of PSRFITS and filterbank keywords to ObsCore. Extensions are proposed when needed. Usage of IVOA provenance metadata and Access using SODA interface is also presented.

Status of this document

This is an IVOA Note expressing suggestions from and opinions of the authors. It is intended to share best practices, possible approaches, or other perspectives on interoperability with the Virtual Observatory. It should not be referenced or otherwise interpreted as a standard specification.

A list of current IVOA Recommendations and other technical documents can be found at https://www.ivoa.net/documents/.

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Acknowledgments

The authors would like to thank all the discussions participants in RadioIG, TDIG, DAL and DM working groups for their ideas and critical reviews on these matters.

1 Introduction

Radioastronomy faces at least two categories of objects where the signal varies with time = pulsars and FRB. Although very different in nature these two categories of objects require that time of recording is registered during observations. They also are pointed observations related to specific sources.

Two main formats are available for that : PSRFITS and filterbank. PSRFITS[1] is a FITS extension flavor defining some specific rules on the way data are to be organized into specific HDUs and metadata are to be expressed in the headers. PSRFITS contains the observed data themselves, but also additional auxiliary data.

Filterbank[2] is made of a header followed by a binary table.

For pulsars the so called search mode of PSR fits can be compared to filterbank in such a way that it's a simple TimeSeries. But as pulsars are periodic variable objects PSR fits can also give phased data after determination of the pulsar period (giving mean measurements for each phase in the period) this is called the folded mode.

2 How these data can be discovered ?

We can imagine 3 modes of discovery according to "TimeSeriesDiscovery and access" IVOA note[3][4]

- We have catalogs of pulsars or FRB (in Vizier or any tap service) and we simply link the datafile to the source by using some link (column with URL, LINK feature or DataLink) These are some example of such catalogs:
  - ATNF Pulsar Catalogue (Manchester+, 2005)
  - Pulsar subpulse modulation properties at 21cm (Weltevrede+, 2006)
  - First CHIME/FRB Fast Radio Burst Catalog (CHIME/FRB Col.+, 2021)
  - FRBCAT: The Fast Radio Burst (FRB) Catalog (Petroff+, 2016)
- We have an archive of observation which may be related to objects (or not) . We want astronomers to discover them. These data have to be discovered using ObsCore metadata (Louys and Tody et al., 2017) describing them. See Nebot et al, 2018[5] and Louys et al, 2022[6]for a list of additional metadata which could be needed for time series Discovery.

  The Astron ARTS Simple cone search service may be seen as a variant of that approach with less standardisation of the dataset description.

[1] https://www.atnf.csiro.au/research/pulsar/psrfits_definition/PsrfitsDocumentation.html
[2] https://sigproc.sourceforge.net/sigproc.pdf
[3] https://ivoa.net/documents/Notes/TimeSeriesDiscoveryAndAccess/20180722/index.html
[4] new version: https://github.com/ivoa/TimeSeriesDiscoveryAndAccess/releases/download/auto-pdf-preview/TimeSeriesDiscoveryAndAccess-draft.pdf
[5] https://volute.g-vo.org/svn/trunk/projects/time-domain/time- series/note/TSSerializationNote.pdf
[6] https://wiki.ivoa.net/internal/IVOA/JointRIG-TDIGVirtualMeeting/ObscoreExtensionforTimeandFreq-MLouys.pdf

- We store in the same service catalog of objects and catalog of datasets metadata. We can set constraints on both type of parameters on joins of the two tables.

These are a couple of example queries a user may like to send:

- Give me the link of available radio datasets for pulsar "so and so"
- Give me back the descriptions of datasets available where the direction is around "blah" the wavelength is inside the range "blah,blah" , the cadence is smaller than 1 mas and the original timescale is UTC with refposition provided.
- From this PSRFITS that your service describe I want to retrieve a dynamical spectrum in FITS image format in time range "blah,blah" and spectral range "blah,blah"

3 Proposed mapping between ObsCore and PSRFITS

Among us we can distinguish the Nançay group (BC,JMG,AL) and the INAF group (VG,AZ). Both made an attempt to map PSRFITS to ObsCore. Results are presented in table 1 For each obscore parameter two formulae are proposed using PSRFITS keywords value. A last column add some comments comparing the two approaches.

4 Proposed mapping between ObsCore Extensions and PSRFITS

Some useful metadata for discovery cannot be mapped onto main ObsCore. Recently two extensions of ObsCore have been proposed, one for radio[7] and the other one for time[8]. Our mapping proposal can be found in table 2. This table again contains a comment column to explain the rationale of our choices.

5 Provenance metadata and ancillary data

Some keywords in the main header and the whole HISTORY HDU contains provenance metadata. Telescope and instrument name belong to ObsCore

[7] https://github.com/ivoa/ObsCoreExtensionForVisibilityData/releases/download/auto-pdf-preview/ObsCoreExtensionForVisibilityData-draft.pdf

[8] https://wiki.ivoa.net/internal/IVOA/JointRIG-TDIGVirtualMeeting/ObscoreExtensionforTimeandFreq-MLouys.pdf

although they could be tackled within the scope of the IVOA Provenance data model (Servillat and Riebe et al., 2020).

Moreover, observation is a special "type" of Activity from which datasets are "derived". Observation makes "use" of entities of type device such as "telescopes" "instruments". Different observations modes (such as tracking modes of pulsar observations) can be managed as "tracking" parameter values of the activity description.

Configuration of telescope or instrument are entities "used" by the observation as well.

The processing phase as presented in the history HDU can be described as a succession of activities or workflow with its parameters and configuration.

Some PSRFITS HDU also contain ancillary metadata useful for analysis or resulting of previous analysis such as "Digitiser statistics binary table" or "Digitiser counts binary table". The DataLink (Dowler, Bonnarel, Michel and Demleitner, 2015) links facility allows to link various resources to a single record (dataset description) in a discovery service query response. It is possible to link the ancillary data as well as the main obervation data to the dataset record this way. URL with fragments are allowed, a feature permitting to address the right HDU in a full PSRFITS dataset.

6 Mapping filterbank keywords to ObsCore and extensions

Table 3 is an attempt of such a mapping. A lot of obscore parameters are still missing.

7 More on discovery and Access

As currently discussed in the DAL working group, the simple image access protocol (Dowler, Bonnarel and Tody, 2015) is going to be upgraded into a "dataset access protocol" a server parameter based access to Obscore databases. This could be very useful to discover dynamic spectra in PSRFITS or filterbank format.

Full retrieval of datasets may be provided by the access_url field content of the ObsCore table or via the DataLinklinks response. More sophisticated access methods should use the SODA interface (Bonnarel and Dowler et al., 2017).

SODA is the IVOA cutout facility protocol for data "cubes". It can be used to extract subparts of the datasets by limitation of ranges on the physical axes. It can also be used to change the datasets output format dynamically. DAL working group currently manages discusions for evolution of this standard in order to integrate interfaces to resampling facility and

product type transformations. These evolution would be very useful to allow standardization of light curve or spectra extractions or changes in spectral quantity or time scales.

SODA endpoints for specific datasets can be accessed directly from the discovery service response or via DataLink links endpoint using the "service descriptor" features of the DataLink specification.

obscore column name	Nançay	INAF	comment
t_obs_mjd	STT_IMJD+ (STT_SMJD+ STT_OFFS)/86400	....	....
t_min	t_obs_mjd+ (OFFS_SUB[0]- TSUBINT[0]/2) /86make400	UTC_To_MJD(DATE_OBS)	Nançay computation is very accurate. Is not INAF proposal enough? Or t_obs_mjd?
t_max	t_obs_mjd+ (OFFS_SUB[-1] -TSUBINT[-1]/2) /86400	.....	Nançay computation. Nothing simpler
t_exptime	(t_max - t_min)*86400	SCANLEN	SCANLEN is a requested exposure time. May be shorter in reality
t_resolution	OFFS_SUB[1]	TBIN	mean(TSUBINT) approaches more t_resolution definition. OFFS_SUB and TBIN are more about sampling.

t_xel			NBIN (fold mode) or int(NSTOT/NDBLK) (search mode) no NROWS in search mode ?
s_ra	RA	RA_RAD*180/PI	.....
s_dec	DEC	DEC_RAD*180/PI	.....
s_fov	2.07 for LOFAR	19.7/(OBSFREQ-OBSBW/2) /1000/6	It depends actually on the diameter of the antenna and the wavelength. Can we find a generic formula 1.22*lambda/D Should be 19.7/OBSFEQ/1000/60
s_region		CIRCLE('ICRS', s_ra, s_dec, s_fov/2.0)	....
s_xel1			actually 1. No sampling
s_xel2			actually 1. no sampling
s_resolution			doesn't make sense or equal to s_fov (no source separation inside this range)

em_min	c/ (min(DAT_FREQ)*1e6)	c/ ((OBSFREQ -OBSBW/2)*1e6)	is simpler INAF formula sufficiently accurate ?
em_max	c/ (max(DAT_FREQ)*1e6)	c/ ((OBSFREQ +OBSBW/2)*1e6)	is simpler INAF formula sufficiently accurate ?
em_xel	-	OBSNCHAN	
o_ucd	phot.flux.density	phot.flux.density	
pol_states	-	depending on NPOL	not only also FD_POLN
pol_xel	-	NPOL	
data_product_type	cube	-	dynamic spectrum
facility_name	mapping from TELESCOP	TELESCOP	
instrument_name	TELESCOP	FRONTEND, BACKEND	probably FRONTEND. BACKEND belongs to processiong tackled by provenance
target_name	SRC_NAME	SRC_NAME	
target_class	pulsar	regular expression ?	
calib_level	1	0 or 1	

Table 1: ObsCore parameters for PSRFITS datasets

ObsCore extension column name	origin	PSRFITS mapping	comment
t_delt	time extension	TBIN	or mean(OFF_SUB[n+1]-OFF_SUB[n])
t_delt_min	time extension	TBIN	or min(OFF_SUB[n+1]-OFF_SUB[n])
t_delt_max	time extension	TBIN	or max(OFF_SUB[n+1]-OFF_SUB[n])
t_res_min	time extension	min(TSUBINT)	TSUBINT more appropriate than TBIN
t_res_max	time extension	max(TSUBINT)	TSUBINT more appropriate than TBIN
t_mode		folded/search	
t_fold_period			NULL for search mode
t_scale	time extension	TAI, TT, UTC, ...	any of IVOA timescale vocabulary[9] not available in PSRFITS metadata

[9]https://www.ivoa.net/rdf/timescale/2019-03-15/timescale.html

t_refPosition	time extension	time measured at this position	not availbale in PSR-FITS metadata
t_origin	time extension	origin of relative time	not availbale in PSR-FITS metadata
t_refDirection	time extension	should be position of source in sky	not availbale in PSR-FITS metadata
t_format	time extension	ISO, JD, MJD, julian year, ...	not available in PSR-FITS metadata
s_fov_min	radio extension	1.22 * em_min/D	where is D antenna diameter ?
s_fov_max	radio extension	1.22 * em_max/D	where is D, antenna diameter
s_resolution_min	radio extension	1.22 * em_min/D	doesn't make sense or equal to s_fov (no source separation inside this range)
s_resolution_max	radio extension	1.22 * em_max/D	doesn't make sense or equal to s_fov (no source separation inside this range)

f_resolution	radio extension	mean(DATA_FREQ[n+1]-DATA_FREQ[n])	Proposed by INAF because em_res_power changes too much along the spectral band
f_max	radio extension	c / em_min	Radio astronomers prefer frequencies
f_min	radio extension	c / em_max	Radio astronomers prefer frequencies

Table 2: ObsCore extension mapping proposal for PSRFITS datasets

obscore column name	filterbank keyword	comment
t_min	tsart	
t_max	tstart + tsamp * nsamples	
t_exptime	tsamp * nsamples	assuming there is no interruption during observation
t_delt	tsamp	tsamp looks more a cadence than a resolution
t_resolution	tsamp ???	tsamp looks more a cadence than a resolution
t_mode	folded/search	
t_fold_period	period	
s_ra	src_raj	
s_dec	src_dec	
s_fov	?	depends from telescope and frequency
em_min	c/(fch1+foff*nchans)/10e6	
em_max	c/fch1/10e6	
f_max	(fch1+foff*nchans)*10e6	radioastronomers prefer frequencies
f_min	fch1*10e6	radio astronomers prefer frequencies
f_resolution	foff	sampling, resolution or both ?

pol_xel	nifs	
pol_states	?	doesn't appear in keywords ?
o_ucd	phot.flux.density	is that always true for filterbank ?
dataproduct_type	data_type	filterbank is dynamic spectrum ? otherwise lightcurve , spectrum ?
facility_name	inferred from telescope_id value	
instrument_name	inferred from machine_id value	
target_name	source_name	
calib_level	1	

Table 3: ObsCore and Onscore extension mapping proposal for filterbank datasets

A Changes from Previous Versions

A.1 Creation-1.0-2022-09-23

This is the initial document version.

References

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