Australia's National
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SDHDF: Single Dish Hierarchical Data Format

A defined file format for spectral line and continuum data from single dish radio telescopes

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1 Introduction

Single Dish Hierarchical Data Format[1] (SDHDF) is a new file format for radio astronomy spectral line and continuum data from single dish telescopes, based on the Hierarchical Data Format[2] (HDF).

With ever increasing instantaneous bandwidth and higher data volumes output from new receivers both existing, such as the Ultra-Wide-Bandwidth Low Frequency (UWL, Hobbs et al. 2020) receiver at Parkes and planned (for example the cryo-PAF receiver at Parkes) , there is a need for agreement on a new data format capable of meeting future requirements.

The use of HDF as a file format for Parkes spectral line data was first introduced specifically for the HI-Pulsar 'HIPSR' digital backend (Price et al. 2016) of the 21cm Multibeam receiver, as a replacement to the more traditional format amongst the astronomical fraternity, FITS (Pence et al. 2010).

Consequently we explored the use of HDF for all spectral line data products from the UWL, converging on the SDHDF model as the formal convention due to the following:

- The data model is based on HDF version 5 (HDF5), a well-defined format
- It is capable of storing comprehensive data and metadata products in a nested hierarchical structure suitable for telescopes with multiple beams
- It is extensible and portable, with long-term development support
- The format can be parsed by modern and conventional computer languages, as well as by open source tools and graphical user interfaces (GUIs)
- Data products are suitable for ingest into CSIRO's Australia Telescope Online Archive[3] (ATOA)
- The FITS format was found to have limitations for use with high-volume data products, including I/O speed and the ability to be highly parallelised (Price et al. 2015)

In this document, we introduce the SDHDF format and definition in Section 2, describe a suite of tools for interrogating the format in Section 3, and present SDHDF data reduction tools in Section 4.

The full detailed definition is laid out in Appendix A, with version information presented in Appendix B.

[1] The formal 'SDHDF' definition is in Toomey et. al 2020 (in prep.)

[2] https://www.hdfgroup.org/

[3] https://atoa.atnf.csiro.au/

2 SDHDF Overview

The SDHDF format can be thought of as a tree-like structure of 'group' and 'dataset' binary objects, containing the raw data, observation metadata, and time, frequency and polarisation information, and conforms to the HDF definition (HDF5 v3.0[4]) at the time of writing.

An SDHDF file can be a combination of many input data streams, associated metadata for both astronomy and calibration data products, and observation metadata, but may also be a product of post-processing from any number of other SDHDF data and metadata products structured according to the definition - such is the flexible nature of the format.

The data and metadata structure, descriptions, units and values, are implemented in a template SDHDF file for a specific observation. The template structure is then populated by the raw data and metadata to form the final data product.

The metadata are stored in HDF 'attributes', small objects directly describing the dataset or group object they are attached to.

The configuration may be adapted to suit a particular set of parameters for a specific part of the hardware and software chains. This flexibility allows uptake by multiple radio astronomy institutions, whilst the implementation of the template ensures that all data products adhere strictly to the file format definition, thereby enhancing data provenance.

Full details and structure of the SDHDF definition can be found in Appendix A, with version history detailed in Appendix B.

3 Viewing File Contents

The HDF group provides basic command-line tools that can be installed on Unix/Linux systems, such as *h5ls* and *h5dump*.

There are also open source GUIs available, for example *h5pyViewer*[5]*, HDFView*[6] and *Panoply*[7].

Pythonic interfaces and modules are also available, such as *h5py*[8].

[4] https://portal.hdfgroup.org/display/HDF5/File+Format+Specification

[5] https://pypi.org/project/h5pyViewer/

[6] https://www.hdfgroup.org/downloads/hdfview/

[7] https://www.giss.nasa.gov/tools/panoply/

[8] https://www.h5py.org/

3.1 Command-line HDF tools

In this section we will describe how to access the contents of an SDHDF file with command-line HDF tools such as *h5ls* and *h5dump*.

3.1.1 Example: Using h5ls and h5dump

In this example, the structure of the top level of an SDHDF file can be viewed with:

```
% h5ls uwl_191208_055418.hdf
```

Where the output may be similar to:

```
beam_0                   Group
config                   Group
metadata                 Group
```

A detailed look at the structure can be viewed with:

```
% h5dump -n uwl_191208_055418.hdf
```

Where the output may be similar to:

```
HDF5 "uwl_191208_055418.hdf" {
FILE_CONTENTS {
 group      /
 group      /beam_0
 group      /beam_0/band_SB7
 group      /beam_0/band_SB7/astronomy_data
 dataset    /beam_0/band_SB7/astronomy_data/data
 dataset    /beam_0/band_SB7/astronomy_data/frequency
 group      /beam_0/band_SB7/calibrator_data
 dataset    /beam_0/band_SB7/calibrator_data/cal_data_off
 dataset    /beam_0/band_SB7/calibrator_data/cal_data_on
 dataset    /beam_0/band_SB7/calibrator_data/cal_frequency
 group      /beam_0/band_SB7/metadata
 dataset    /beam_0/band_SB7/metadata/cal_obs_params
 dataset    /beam_0/band_SB7/metadata/obs_params
 group      /beam_0/band_SB8
 group      /beam_0/band_SB8/astronomy_data
 dataset    /beam_0/band_SB8/astronomy_data/data
 dataset    /beam_0/band_SB8/astronomy_data/frequency
 group      /beam_0/band_SB8/calibrator_data
 dataset    /beam_0/band_SB8/calibrator_data/cal_data_off
 dataset    /beam_0/band_SB8/calibrator_data/cal_data_on
 dataset    /beam_0/band_SB8/calibrator_data/cal_frequency
 group      /beam_0/band_SB8/metadata
 dataset    /beam_0/band_SB8/metadata/cal_obs_params
 dataset    /beam_0/band_SB8/metadata/obs_params
 group      /beam_0/metadata
 dataset    /beam_0/metadata/band_params
 dataset    /beam_0/metadata/cal_band_params
 group      /config
 dataset    /config/backend_config
 dataset    /config/cal_backend_config
 group      /metadata
 dataset    /metadata/beam_params
 dataset    /metadata/history
 dataset    /metadata/primary_header
 dataset    /metadata/software_versions
 }
}
```

An observation can have one or many ‘beam’ groups (one for a single pixel feed). A beam group may have many ‘band’ groups depending on the receiver frequency range configuration. A ‘band’ group contains astronomy data, calibrator data and associated metadata.

The following command shows the content of the astronomy data group:

```
% h5ls uwl_191208_055418.hdf/beam_0/band_SB7/astronomy_data
```

Where the output may be similar to:

```
data                     Dataset {182, 1, 4, 262144, 1}
frequency                Dataset {262144}
```

In the above example, the dimensions of the data arrays are shown in the curly brackets.

3.2 Graphical user interfaces

In this section we show how to view SDHDF file contents using open source GUIs.

3.2.1 Example: HDFView

In this example, we demonstrate how HDFView can be used to display available data and meta-data in an SDHDF file. Load the file with:

```
% hdfview uwl_191208_055418.hdf
```

Click on an HDF object in the side pane to display the HDF attributes and meta-data, and double-click to display the data (see Figure 1).

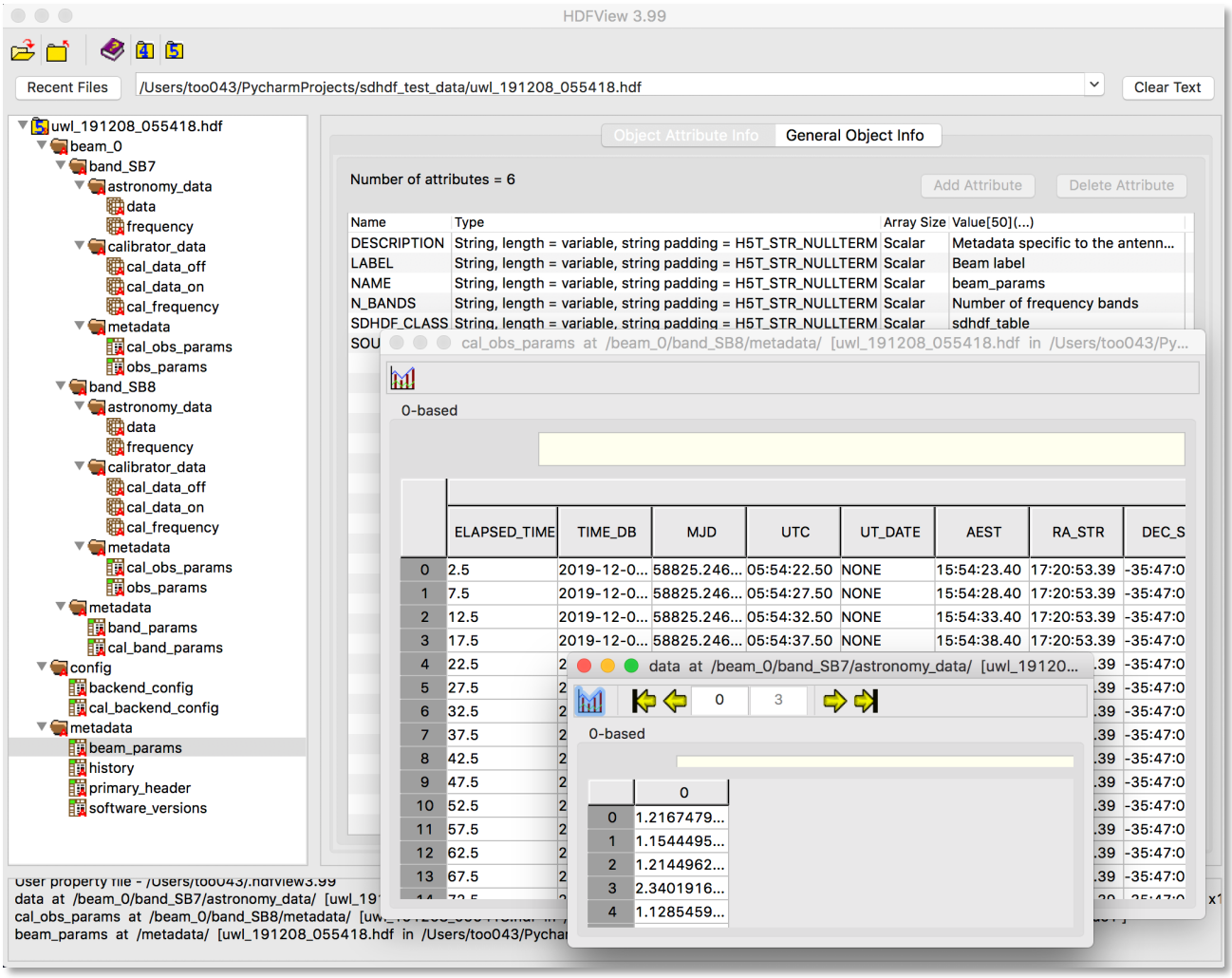


Figure 1: HDFView display panels

3.3 Python interfaces

H5py is a powerful python interface to view and manipulate HDF files, and is the module used to write the SDHDF data products.

Additional python modules are available for viewing data and metadata, and can be found in the SDHDF tools repository[9].

[9] https://bitbucket.csiro.au/projects/CPDA/repos/sdhdf_tools/browse

3.3.1 Viewing metadata

A basic implementation of this interface can be found in the *read_sdhdf_header.py* module that describes the file contents, for example:

```
% python read_sdhdf_header.py --filename uwl_191208_055418.hdf
```

Where the output may be similar to:

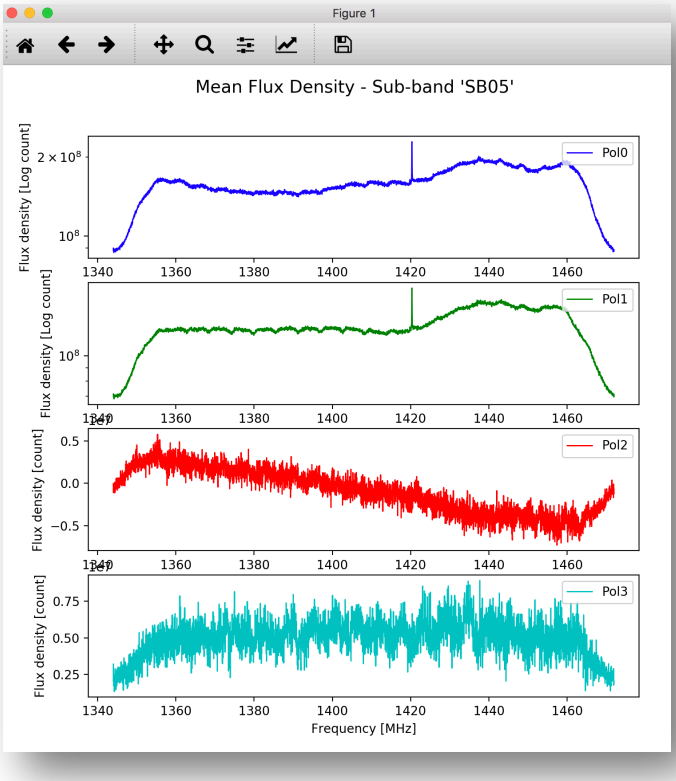
```
Displaying primary header for file:
uwl_190531_092815.hdf

               -- Key --           -- Value --
0                   DATE  2020-02-03-10:25:11
1               HDR_DEFN                SDHDF
2       HDR_DEFN_VERSION                  1.9
3            FILE_FORMAT                  HDF
4    FILE_FORMAT_VERSION                  5.0
5         SCHED_BLOCK_ID                 6183
6               CAL_MODE                   ON
7             INSTRUMENT               Medusa
8               OBSERVER               gre469
9                    PID                 P737
10              RECEIVER                  UWL
11             TELESCOPE               Parkes
12             UTC_START  2019-12-08-05:54:18
13               N_BEAMS                    1
```

3.3.2 Plotting spectra

The *plot_sdhdf.py* module can display the spectrum for individual sub-bands. Example usage is:

```
% python plot_sdhdf.py --filename uwl_190531_092815.hdf
```

Where the output may be similar to those in Figure 2.



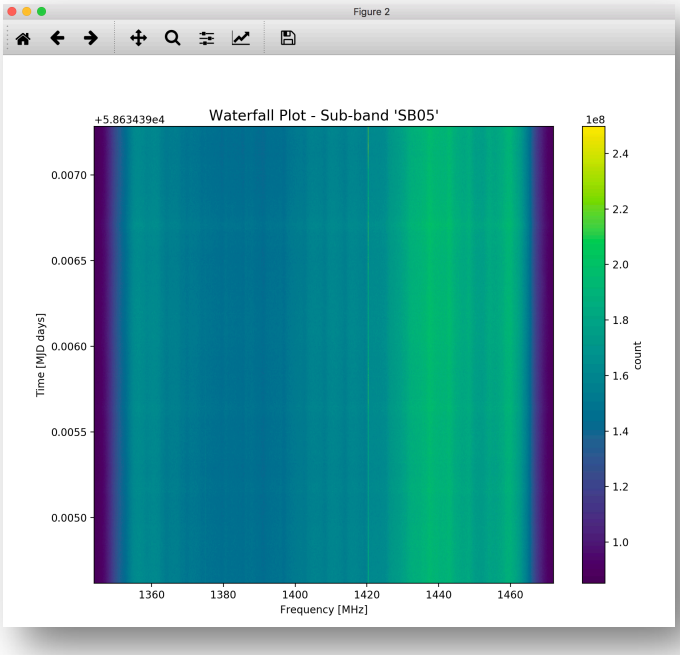


Figure 2: A plot of the spectrum (top) and waterfall data from an example SDHDF file

4 Processing an SDHDF File

A suite of routines '*sdhdfProc*', written in C, for the interrogation, processing and calibration of SDHDF data are also available from the SDHDF tools repository[10]. The suite comes with substantial documentation on the usage of *sdhdfProc* and examples of use cases.

In Figure 3, an example from the documentation, the *sdhdf_plotSpectrum* routine is used to plot a region of the spectrum around an OH maser, and then convert the frequency axis into velocity at the Local Standard of Rest using *sdhdf_modify*.

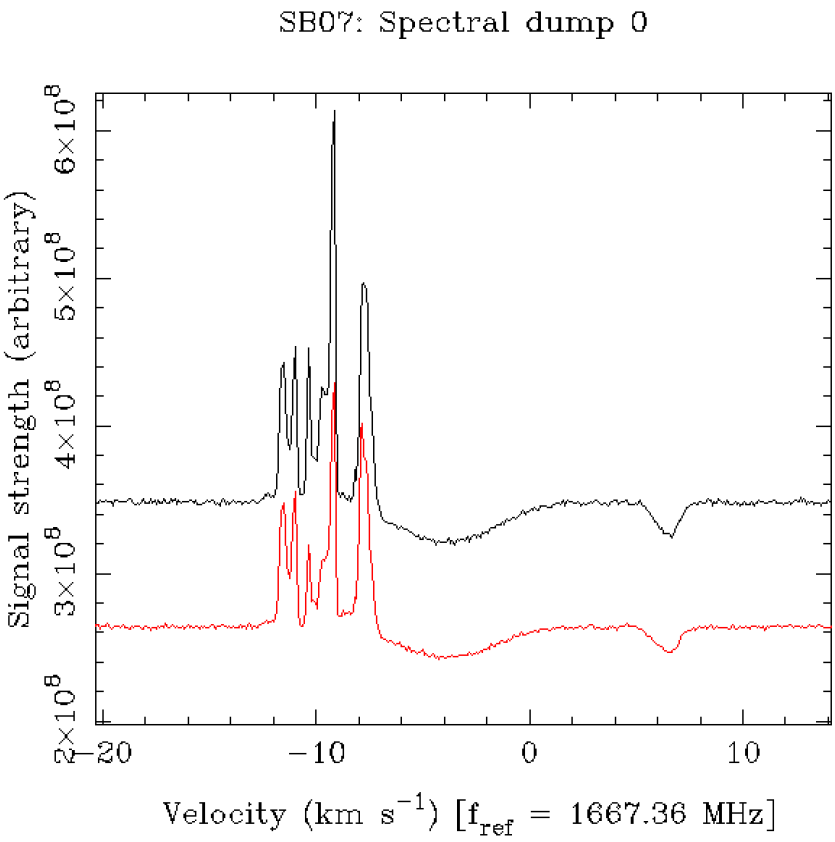


Figure 3: An OH maser at LSR formed by the *sdhdfProc* package

For further information on *sdhdfProc*, please contact george.hobbs@csiro.au.

[10] https://bitbucket.csiro.au/projects/CPDA/repos/sdhdf_tools/browse

5 Conclusion

In this document we have presented a new file format, SDHDF, for spectral line radio astronomy data, a format flexible enough to handle current and high data volumes expected from an era of large telescopes with single pixel or multi-beam receivers.

The Parkes radio telescope is the first to use the format natively for spectral line and continuum observations, since late 2018, and we encourage other institutions to adopt this as their primary format because of its flexible nested structure and comprehensive metadata capture.

The SDHDF definition will be formerly published in a refereed journal shortly, and we have provided details in this document on how to access SDHDF data reduction packages.

Appendix A: The SDHDF Definition (v1.9)

SDHDF Definition Overview		
SDHDF Definition Version: 1.9		
Author: Lawrence Toomey		
Copyright: CSIRO 2020		
SDHDF File Overview		
HDF_Object_Name	*HDF_Object_Type*	*Value*
file.hdf	File	SDHDF format file
SDHDF Structure Overview		
HDF_Object_Name	*HDF_Object_Type*	*Value*
/beam_N	Group	-
DESCRIPTION	Attribute	SDHDF group containing data products specific to the antenna beam
NAME	Attribute	beam_N
SDHDF_CLASS	Attribute	sdhdf_beam
/beam_N/band_N	Group	
DESCRIPTION	Attribute	SDHDF group containing data products specific to the frequency band
NAME	Attribute	band_SB0
SDHDF_CLASS	Attribute	sdhdf_band
/beam_N/band_N/astronomy_data	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation data
NAME	Attribute	astronomy_data
SDHDF_CLASS	Attribute	sdhdf_data
/beam_N/band_N/astronomy_data/data	Dataset	-
DESCRIPTION	Attribute	SDHDF astronomy data
DIMENSION_LABELS	Attribute	time, beam, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	data
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/astronomy_data/frequency	Dataset	-
CLASS	Attribute	DIMENSION_SCALE
DESCRIPTION	Attribute	SDHDF frequency data (default reference frame: topocentric)
FRAME	Attribute	topocentric

NAME	Attribute	frequency
REFERENCE_LIST	Attribute	HDF5 object reference
SDHDF_CLASS	Attribute	sdhdf_frequency
UNIT	Attribute	MHz
/beam_N/band_N/calibrator_data	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation data (calibrator)
NAME	Attribute	calibrator_data
SDHDF_CLASS	Attribute	sdhdf_data
/beam_N/band_N/calibrator_data/cal_data_off	Dataset	-
DESCRIPTION	Attribute	SDHDF calibration dataset (calibrator signal off)
DIMENSION_LABELS	Attribute	time, beam, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	cal_data_off
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/calibrator_data/cal_data_on	Dataset	-
DESCRIPTION	Attribute	SDHDF calibration dataset (calibrator signal on)
DIMENSION_LABELS	Attribute	time, beam, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	cal_data_on
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/calibrator_data/cal_frequency	Dataset	-
CLASS	Attribute	DIMENSION_SCALE
DESCRIPTION	Attribute	SDHDF frequency data (default reference frame: topocentric)
FRAME	Attribute	topocentric
NAME	Attribute	None
REFERENCE_LIST	Attribute	HDF5 object reference
SDHDF_CLASS	Attribute	sdhdf_frequency
UNIT	Attribute	MHz
/beam_N/band_N/metadata	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation metadata
NAME	Attribute	metadata
SDHDF_CLASS	Attribute	sdhdf_meta

/beam_N/band_N/metadata/cal_obs_params	Dataset	-
AEST	Attribute	Australian Eastern Standard Time (HH:MM:SS.s)
AEST_UNIT	Attribute	hours
AZ_OFFSET	Attribute	J2000 Ax (Cross-El) offset
AZ_OFFSET_UNIT	Attribute	arc-sec
AZ	Attribute	Antenna azimuth angle
AZ_DRIVE_RATE	Attribute	Azimuth drive rate
AZ_DRIVE_RATE_UNIT	Attribute	degrees/min
AZ_UNIT	Attribute	degrees
DEC_DEG	Attribute	J2000 declination
DEC_DEG_UNIT	Attribute	degrees
DEC_OFFSET	Attribute	J2000 DEC offset
DEC_OFFSET_UNIT	Attribute	arc-sec
DEC_STR	Attribute	J2000 declination
DEC_STR_UNIT	Attribute	DD:MM:SS.s
DESCRIPTION	Attribute	Metadata specific to the integrations of the observation
EL	Attribute	Antenna elevation angle
ELAPSED_TIME	Attribute	Time since integration start
ELAPSED_TIME_UNIT	Attribute	s
EL_OFFSET	Attribute	J2000 El offset
EL_OFFSET_UNIT	Attribute	arc-sec
EL_UNIT	Attribute	degrees
GB	Attribute	Galactic latitude
GB_UNIT	Attribute	degrees
GL	Attribute	Galactic longitude
GL_UNIT	Attribute	degrees
HOUR_ANGLE	Attribute	Hour angle
HOUR_ANGLE_UNIT	Attribute	degrees
MJD	Attribute	Timestamp at integration midpoint (MJD)
MJD_UNIT	Attribute	days
NAME	Attribute	cal_obs_params
PARA_ANGLE	Attribute	Parallactic angle
PARA_ANGLE_UNIT	Attribute	degrees
RA_DEG	Attribute	J2000 right ascension
RA_DEG_UNIT	Attribute	degrees
RA_OFFSET	Attribute	J2000 RA offset
RA_OFFSET_UNIT	Attribute	s
RA_STR	Attribute	J2000 right ascension
RA_STR_UNIT	Attribute	HH:MM:SS.s
SDHDF_CLASS	Attribute	sdhdf_table
TIME_DB	Attribute	Database Universal Coordinated Time (HH:MM:SS.s)
TIME_DB_UNIT	Attribute	hours

UTC	Attribute	Timestamp at integration midpoint (UTC)
UTC_UNIT	Attribute	hours
UT_DATE	Attribute	Date at integration midpoint (UTC YYYY-MM-DD-hh:mm:ss)
WIND_DIR	Attribute	Wind direction
WIND_DIR_UNIT	Attribute	degrees
WIND_SPD	Attribute	Wind speed
WIND_SPD_UNIT	Attribute	km/hr
ZE	Attribute	Antenna zenith angle
ZE_DRIVE_RATE	Attribute	Zenith drive rate
ZE_DRIVE_RATE_UNIT	Attribute	degrees/min
ZE_UNIT	Attribute	degrees
/beam_N/band_N/metadata/obs_params	Dataset	-
AEST	Attribute	Australian Eastern Standard Time (HH:MM:SS.s)
AEST_UNIT	Attribute	hours
AZ_OFFSET	Attribute	J2000 Ax (Cross-El) offset
AZ_OFFSET_UNIT	Attribute	arc-sec
AZ	Attribute	Antenna azimuth angle
AZ_DRIVE_RATE	Attribute	Azimuth drive rate
AZ_DRIVE_RATE_UNIT	Attribute	degrees/min
AZ_UNIT	Attribute	degrees
DEC_DEG	Attribute	J2000 declination
DEC_DEG_UNIT	Attribute	degrees
DEC_OFFSET	Attribute	J2000 DEC offset
DEC_OFFSET_UNIT	Attribute	arc-sec
DEC_STR	Attribute	J2000 declination
DEC_STR_UNIT	Attribute	DD:MM:SS.s
DESCRIPTION	Attribute	Metadata specific to the integrations of the observation
EL	Attribute	Antenna elevation angle
ELAPSED_TIME	Attribute	Time since integration start
ELAPSED_TIME_UNIT	Attribute	s
EL_OFFSET	Attribute	J2000 El offset
EL_OFFSET_UNIT	Attribute	arc-sec
EL_UNIT	Attribute	degrees
GB	Attribute	Galactic latitude
GB_UNIT	Attribute	degrees
GL	Attribute	Galactic longitude
GL_UNIT	Attribute	degrees
HOUR_ANGLE	Attribute	Hour angle
HOUR_ANGLE_UNIT	Attribute	degrees
MJD	Attribute	Timestamp at integration midpoint (MJD)

MJD_UNIT	Attribute	days
NAME	Attribute	obs_params
PARA_ANGLE	Attribute	Parallactic angle
PARA_ANGLE_UNIT	Attribute	degrees
RA_DEG	Attribute	J2000 right ascension
RA_DEG_UNIT	Attribute	degrees
RA_OFFSET	Attribute	J2000 RA offset
RA_OFFSET_UNIT	Attribute	s
RA_STR	Attribute	J2000 right ascension
RA_STR_UNIT	Attribute	HH:MM:SS.s
SDHDF_CLASS	Attribute	sdhdf_table
TIME_DB	Attribute	Database Universal Coordinated Time (HH:MM:SS.s)
TIME_DB_UNIT	Attribute	hours
UTC	Attribute	Timestamp at integration midpoint (UTC)
UTC_UNIT	Attribute	hours
UT_DATE	Attribute	Date at integration midpoint (UTC YYYY-MM-DD-hh:mm:ss)
WIND_DIR	Attribute	Wind direction
WIND_DIR_UNIT	Attribute	degrees
WIND_SPD	Attribute	Wind speed
WIND_SPD_UNIT	Attribute	km/hr
ZE	Attribute	Antenna zenith angle
ZE_DRIVE_RATE	Attribute	Zenith drive rate
ZE_DRIVE_RATE_UNIT	Attribute	degrees/min
ZE_UNIT	Attribute	degrees
/beam_N/metadata	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation metadata
NAME	Attribute	metadata
SDHDF_CLASS	Attribute	sdhdf_meta
/beam_N/metadata/band_params	Dataset	-
CENTRE_FREQ	Attribute	Band centre frequency
CENTRE_FREQ_UNIT	Attribute	MHz
DESCRIPTION	Attribute	Metadata specific to the frequency bands of the antenna beam
DUMP_TIME	Attribute	Band dump time
DUMP_TIME_UNIT	Attribute	s
HIGH_FREQ	Attribute	Band range high frequency
HIGH_FREQ_UNIT	Attribute	MHz
LABEL	Attribute	Band label
LOW_FREQ	Attribute	Band range low frequency
LOW_FREQ_UNIT	Attribute	MHz

NAME	Attribute	band_params
N_CHANS	Attribute	Number of channels in band
N_DUMPS	Attribute	Number of spectral data dumps in band
N_POLS	Attribute	Number of polarisations (1, 2, 4)
POL_TYPE	Attribute	Polarisation type (AABBCRCI for 4 pol coherence data where AA and BB are the direct products of the two input channels A and B and CR and CI are the real and imaginary parts of the cross product A* B; AA+BB for 1 pol data with summed orthogonal products; AABB for 2 pol data)
SDHDF_CLASS	Attribute	sdhdf_table
/beam_N/metadata/cal_band_params	Dataset	-
CENTRE_FREQ	Attribute	Band centre frequency
CENTRE_FREQ_UNIT	Attribute	MHz
DESCRIPTION	Attribute	Metadata specific to the frequency bands of the antenna beam
DUMP_TIME	Attribute	Band dump time
DUMP_TIME_UNIT	Attribute	s
HIGH_FREQ	Attribute	Band range high frequency
HIGH_FREQ_UNIT	Attribute	MHz
LABEL	Attribute	Band label
LOW_FREQ	Attribute	Band range low frequency
LOW_FREQ_UNIT	Attribute	MHz
NAME	Attribute	band_params
N_CHANS	Attribute	Number of channels in band
N_DUMPS	Attribute	Number of spectral data dumps in band
N_POLS	Attribute	Number of polarisations (1, 2, 4)
POL_TYPE	Attribute	Polarisation type (AABBCRCI for 4 pol coherence data where AA and BB are the direct products of the two input channels A and B and CR and CI are the real and imaginary parts of the cross product A* B; AA+BB for 1 pol data with summed orthogonal products; AABB for 2 pol data)
SDHDF_CLASS	Attribute	sdhdf_table
/config	Group	-
DESCRIPTION	Attribute	SDHDF group containing configuration parameters as defined at the time of the observation
NAME	Attribute	config
SDHDF_CLASS	Attribute	sdhdf_config

/config/backend_config	Dataset	-
DESCRIPTION	Attribute	Astronomy backend configuration
NAME	Attribute	backend_config
SDHDF_CLASS	Attribute	sdhdf_table
/config/cal_backend_config	Dataset	-
DESCRIPTION	Attribute	Astronomy backend configuration (calibration)
NAME	Attribute	backend_config
SDHDF_CLASS	Attribute	sdhdf_table
/metadata	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation metadata
NAME	Attribute	metadata
SDHDF_CLASS	Attribute	sdhdf_meta
/metadata/beam_params	Dataset	-
DESCRIPTION	Attribute	Metadata specific to the antenna beam
LABEL	Attribute	Beam label
NAME	Attribute	beam_params
N_BANDS	Attribute	Number of frequency bands
SDHDF_CLASS	Attribute	sdhdf_table
SOURCE	Attribute	Source name
/metadata/history	Dataset	-
DATE	Attribute	Date (UTC YYYY-MM-DD-hh:mm:ss)
DESCRIPTION	Attribute	Metadata specific to the processing history of the file
NAME	Attribute	history
PROC	Attribute	Process name
PROC_ARGS	Attribute	Process command
PROC_DESCR	Attribute	Process description
PROC_HOST	Attribute	Host machine running the process
SDHDF_CLASS	Attribute	sdhdf_table
/metadata/primary_header	Dataset	-
CAL_MODE	Attribute	Calibration mode (ON | OFF)
DATE	Attribute	File creation date (UTC YYYY-MM-DD-hh:mm:ss)
DESCRIPTION	Attribute	General observation metadata
FILE_FORMAT	Attribute	File format
FILE_FORMAT_VERSION	Attribute	File format version
HDR_DEFN	Attribute	File format definition
HDR_DEFN_VERSION	Attribute	File format definition version

INSTRUMENT	Attribute	Backend instrument name
NAME	Attribute	primary_header
N_BEAMS	Attribute	Number of beams
OBSERVER	Attribute	Observer name
OBS_TYPE	Attribute	Observation type (TRACK|SCAN)
PID	Attribute	Project ID
RECEIVER	Attribute	Receiver name
SCHED_BLOCK_ID	Attribute	Schedule block ID
SDHDF_CLASS	Attribute	sdhdf_table
TELESCOPE	Attribute	Telescope name
UTC_START	Attribute	Observation start (UTC YYYY-MM-DD-hh:mm:ss)
/metadata/software_versions	Dataset	-
DESCRIPTION	Attribute	Metadata specific to software packages used for creating or processing the file
NAME	Attribute	software_versions
PROC	Attribute	Process name
SDHDF_CLASS	Attribute	sdhdf_table
SOFTWARE	Attribute	Software package
SOFTWARE_DESCR	Attribute	Software package description
SOFTWARE_VERSION	Attribute	Software package version
/metadata	Group	-
DESCRIPTION	Attribute	SDHDF group containing observation metadata
NAME	Attribute	metadata
SDHDF_CLASS	Attribute	sdhdf_meta
/metadata/beam_params	Dataset	-
DESCRIPTION	Attribute	Metadata specific to the antenna beam
LABEL	Attribute	Beam label
NAME	Attribute	beam_params
N_BANDS	Attribute	Number of frequency bands
SDHDF_CLASS	Attribute	sdhdf_table
SOURCE	Attribute	Source name
/metadata/history	Dataset	-
DATE	Attribute	Date (UTC YYYY-MM-DD-hh:mm:ss)
DESCRIPTION	Attribute	Metadata specific to the processing history of the file
NAME	Attribute	history
PROC	Attribute	Process name
PROC_ARGS	Attribute	Process command
PROC_DESCR	Attribute	Process description

PROC_HOST	Attribute	Host machine running the process
SDHDF_CLASS	Attribute	sdhdf_table
/metadata/primary_header	Dataset	-
CAL_MODE	Attribute	Calibration mode (ON | OFF)
DATE	Attribute	File creation date (UTC YYYY-MM-DD-hh:mm:ss)
DESCRIPTION	Attribute	General observation metadata
FILE_FORMAT	Attribute	File format
FILE_FORMAT_VERSION	Attribute	File format version
HDR_DEFN	Attribute	File format definition
HDR_DEFN_VERSION	Attribute	File format definition version
INSTRUMENT	Attribute	Backend instrument name
NAME	Attribute	primary_header
N_BEAMS	Attribute	Number of beams
OBSERVER	Attribute	Observer name
PID	Attribute	Project ID
RECEIVER	Attribute	Receiver name
SCHED_BLOCK_ID	Attribute	Schedule block ID
SDHDF_CLASS	Attribute	sdhdf_table
TELESCOPE	Attribute	Telescope name
UTC_START	Attribute	Observation start (UTC YYYY-MM-DD-hh:mm:ss)
/metadata/software_versions	Dataset	-
DESCRIPTION	Attribute	Metadata specific to software packages used for creating or processing the file
NAME	Attribute	software_versions
PROC	Attribute	Process name
SDHDF_CLASS	Attribute	sdhdf_table
SOFTWARE	Attribute	Software package
SOFTWARE_DESCR	Attribute	Software package description
SOFTWARE_VERSION	Attribute	Software package version

Appendix B: SDHDF Version History

SDHDF Versions

SDHDF v1.9 (Latest: April 22rd 2020)

- Added OBS_TYPE to primary_header dataset
- Hierarchical structure updated to allow for multiple beams
- Add position offsets to obs_params datasets
- Minor additions/fixes to modules and metadata

SDHDF v1.8

- Incorporated an interpolation routine for InfluxDB output
- Added telescope config class
- InfluxDB observation metadata (including pointing) are accurate to within +/-1 second of time
- Minor additions/fixes to modules and metadata

SDHDF v1.7

- Re-processed observations from and including UTC_START: 2018-12-19-07:40:30
- InfluxDB observation metadata (including pointing) are accurate to within +/-5 seconds of time
- Metadata comprises the SDHDF definition by default
- Added 'history', 'rfi_excision', 'software_versions', 'weights' and 'cal_weights' datasets

SDHDF v1.6

- 'time' and 'cal_time' datasets changed to 'obs_params' and 'cal_obs_params', now incorporating time and observation metadata from InfluxDB
- 'obs_params' and 'cal_obs_params' dataset values now all refer to the timestamp at the start of the integration
- Enabled data from partial integrations to be incorporated
- Minor fixes to unit datasets
- Implemented header metadata comparison with input data file contents (header does not necessarily reflect contents)
- Added 'band_header' dataset for sub-/zoom-band metadata
- Added extra parameters to 'primary_header' dataset

SDHDF v1.5

- Updated time axis method to fix intervals, add integration index and time since start columns to time datasets, and set MJD to integration mid-point
- Minor fixes to array shapes
- Updated SDHDF definition with backend header descriptions
- Fixed missing dimension scales
- Fixed incorrect cal-on cal-off bin ordering
- No InfluxDB metadata
- Processed observations from UTC_START: 2019-04-09*

SDHDF v1.4

- Implemented fix to correctly order integrations in time
- Implemented separate datasets for cal-on and cal-off
- No InfluxDB meta-data
- Processed observations from and including UTC_START: 2019-04-02-01:25:28

SDHDF v1.3

- First official complete run with real data
- Medusa calibration (preproc) data included
- Implemented independent frequency datasets to allow for sub-bands with different frequency resolutions
- Primary header intact but not finalised
- No InfluxDB meta-data
- Processed observations from and including UTC_START: 2018-12-19-07:40:30

SDHDF v1.2

- Data from second commissioning run (P737)
- Incorrect and/or missing header information
- Medusa calibration (preproc) data included
- No InfluxDB meta-data

SDHDF v1.1

- Data from first commissioning run (BL, P737)
- Incorrect and/or missing header information
- No calibration (preproc) data
- No InfluxDB meta-data

SDHDF v1.0

- Data from first commissioning run (P737)
- Incorrect and/or missing header information
- Preliminary SDHDF structure
- Draft naming scheme implemented
- No Medusa calibration (preproc) data
- No InfluxDB meta-data

References

Hobbs, G., et al., 2020. *An ultra-wide bandwidth (704 to 4032 MHz) receiver for the Parkes radio telescope*. Publications of the Astronomical Society of Australia, Volume 37, article id. e012

Pence, W.D., et al., 2010. *Definition of the Flexible Image Transport System (FITS), version 3.0*. A&A 524, 42.

Price, D., et al., 2015. *HDFITS: porting the FITS data model to HDF5*.

https://arxiv.org/abs/1505.06421

Price, D., et al., 2016. *HIPSR: A Digital Signal Processor for the Parkes 21-cm Multibeam Receiver*

https://arxiv.org/abs/1702.00443

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