Australia's National
Science Agency

SDHDF: Formal Definition

Formal definition for Single Dish Hierarchical Data Format – a file format for spectral line and continuum data from single dish radio telescopes

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V2.1 (July 31st 2021)

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The SDHDF Definition (v2.1)

SDHDF Definition Overview		
SDHDF Definition Version: 2.1		
Author: Lawrence Toomey		
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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_N
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, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	data
NORMALISATION_FACTOR	Attribute	The factor by which the number of samples integrated into each output sample are normalised
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/astronomy_data/frequency	Dataset	-
CLASS	Attribute	DIMENSION_SCALE

DESCRIPTION	Attribute	Weighted mean of channel centre frequencies
FRAME	Attribute	topocentric
NAME	Attribute	frequency
REFERENCE_LIST	Attribute	HDF5 object reference
SDHDF_CLASS	Attribute	sdhdf_frequency
UNIT	Attribute	MHz
/beam_N/band_N/astronomy_data/data_weights	Dataset	-
DESCRIPTION	Attribute	Product of the channel bandwidth (Hz) and integration time (s)
NAME	Attribute	data_weights
SDHDF_CLASS	Attribute	sdhdf_weights
/beam_N/band_N/astronomy_data/data_flags	Dataset	-
DESCRIPTION	Attribute	Flag applied to a frequency channel (boolean)
NAME	Attribute	data_flags
SDHDF_CLASS	Attribute	sdhdf_flags
/beam_N/band_N/calibrator_data/cal32_data	Dataset	-
DESCRIPTION	Attribute	SDHDF calibration dataset (calibrator signal 32 bins)
DIMENSION_LABELS	Attribute	time, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	cal32_data
NORMALISATION_FACTOR	Attribute	The factor by which the number of samples integrated into each output bin are normalised
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/calibrator_data/cal_data_off	Dataset	-
DESCRIPTION	Attribute	SDHDF calibration dataset (calibrator signal off)
DIMENSION_LABELS	Attribute	time, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	cal_data_off
NORMALISATION_FACTOR	Attribute	The factor by which the number of samples integrated into each output bin are normalised
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, polarization, frequency, bin
DIMENSION_LIST	Attribute	List of dimension objects
NAME	Attribute	cal_data_on
NORMALISATION_FACTOR	Attribute	The factor by which the number of samples integrated into each output bin are normalised
SDHDF_CLASS	Attribute	sdhdf_waterfall
UNIT	Attribute	counts
/beam_N/band_N/calibrator_data/cal_frequency	Dataset	-
CLASS	Attribute	DIMENSION_SCALE
DESCRIPTION	Attribute	Weighted mean of channel centre frequencies
FRAME	Attribute	topocentric
NAME	Attribute	cal_frequency
REFERENCE_LIST	Attribute	HDF5 object reference
SDHDF_CLASS	Attribute	sdhdf_frequency
UNIT	Attribute	MHz
/beam_N/band_N/calibrator_data/cal_data_weights	Dataset	-
DESCRIPTION	Attribute	Product of the channel bandwidth (Hz) and integration time (s)
NAME	Attribute	cal_data_weights
SDHDF_CLASS	Attribute	sdhdf_weights
/beam_N/band_N/calibrator_data/cal_data_flags	Dataset	-
DESCRIPTION	Attribute	Flag applied to a frequency channel (boolean)
NAME	Attribute	cal_data_flags
SDHDF_CLASS	Attribute	sdhdf_flags
/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 arguments
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/schedule	Dataset	-
DATE	Attribute	Date (UTC YYYY-MM-DD-hh:mm:ss)
DESCRIPTION	Attribute	Metadata specific to the scheduling of the observation
NAME	Attribute	schedule
SCHED_BLOCK	Attribute	Schedule block contents
SCHED_HOST	Attribute	Schedule host machine
SCHED_VERSION	Attribute	Schedule template version
SDHDF_CLASS	Attribute	sdhdf_table
/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 v2.1 (Latest: July 31st 2021)

- Fix frequency dataset bandwidth bug (where nchan-1 should be nchan), and define as channel centre not channel start
- Update data weights definition
- Add data flags definition for RFI flagging
- Add parsing of normalisation flags from the telescope backend
- Remove redundant beam dimension from astronomy and calibrator datasets
- Minor small fixes and attribute updates

SDHDF v2.0

- Implement configuration file for use by any telescope
- Add weights group to definition
- Enable metadata copy if existing, to prevent unnecessary database query duplication
- Metadata for wind direction and wind speed parameters are now the right way around
- Enable splitting observation by frequency band
- Fix metadata query string not making it into history table
- Replace deprecated H5py create_scale with make_scale

SDHDF v1.9.2

- Incorporate 32-bin calibrator dataset
- Fix missing PROC_ARGS in history dataset
- Add metadata query string to history dataset
- Fix missing reference to InfluxDB in software_versions dataset
- Minor additions/fixes to modules and metadata

SDHDF v1.9.1

- Fix OBS_TYPE
- Minor additions/fixes to modules and metadata

SDHDF v1.9

- 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 metadata
- 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 metadata
- 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 metadata

SDHDF v1.1

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

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 metadata

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