ORN NDA/NewRoutine Jupiter EDR FITS Dataset Specification, version 1.1

Alexia Duchêne[3], Laurent Lamy[1,2,3], Alan Loh[1,2],
Baptiste Cecconi[1,2], Cédric Viou[2], Patrice Renaud [2]

[1] LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université Paris Cité, Meudon, France
[2] Observatoire de Radioastronomie de Nancay, Observatoire de Paris, Université PSL, CNRS, Université Orléans, Nancay, France
[3] Aix-Marseille Université, CNRS, CNES, LAM, Pythéas, Marseille, France

Citation: A.Duchêne, L.Lamy, A.Loh, B.Cecconi, C.Viou, P.Renaud, *ORN NDA / Newroutine Jupiter EDR FITS Dataset Specification*, version 1.1 (2022)

Version History:

Date	Version	Change record	Authors
2022-05-11	0.1	First Release	A.Duchêne
2022-06-13	0.2	Update metadata keys	A.Duchêne
2022-06-15	0.3	Update Data acquisition	L.Lamy
2022-08-08	1.0	Revision and page layout	A.Duchêne
2022-08-23	1.1	Revision	L.Lamy

1 Data acquisition

The Nançay Decameter Array (NDA) hosted at the Observatoire Radioastronomique de Nançay (ORN) in the Sologne forest (France) is a phased array of 144 « Teepee » helicoidal antenna, composed of two sub-arrays of 72 antenna each, sensitive to Right Handed (RH) and Left Handed (LH) circular polarization, respectively. Since January 1978, the NDA has been acquiring quasi-daily decametric observations of Jupiter (typically within 10-40 MHz) and the Sun (typically within 10-80 MHz), together with punctual transit observations of intense radiosources for calibration purposes, with several analog (<1990) and digital (>1990) receivers. [1] [2] [3]

The *NewRoutine* receiver is operational since Nov. 2012. This digital receiver, based on a FPGA architecture, can record data on 4 channels simultaneously, sensing the auto-correlations on both RH and LH sub-arrays and the real and imaginary parts of the cross-correlation between RH and LH sub-arrays. This receiver benefits a large dynamics (14-bits ADC) and continuously samples the signal over a 100 MHz band at a 200 Msamples/second cadence. 2048 channels Transforms provide instantaneous spectra with a fixed spectral step of 48.828 kHz at a $>$ 1 msec, adjustable, temporal cadence. For standard daily observations, N successive spectra are averaged together, yielding an effective temporal cadence of $\sim$ 500 msec. When compared to *Routine* (swept-frequency) observations, *NewRoutine* standard observations of RH/LH autocorrelations display better signal-to-noise ratios, typically larger by factor of ~ 30, while sampling instantaneously the full spectral range.

The standard configuration used for *NewRoutine* observations of Jupiter is the following. The recorded data corresponds to 4 channels (LH/RH auto- and cross- correlations), sampling the 10.01-39.99 MHz range with 615 frequency channels. N = 24156, so that the final temporal cadence is 494.715 msec.

As for the other receivers, *NewRoutine* observations include hourly calibration sequences. In practice, such calibration sequences are executed as follows. The signal summed up over each bloc of 8 antennas is replaced by the signal of a reference noise diode which delivers a fixed power of 42 dB ENR (or -72 dBm/MHz). This signal is then attenuated by 30 dB, 20 dB, 10 dB and 0 dB and measured over 10 s long exposures for each attenuation factor. The 30 dB attenuation factor approximately corresponds to the mean sky level. These calibration sequences can in turn be used to calibrate the RH/LH flux densities. Alternately, NDA/*NewRoutine* transit observations of powerful radiosources are acquired regularly and provide another way to calibrate RH/LH flux densities.

2 General structure of the dataset

The *ORN NDA / NewRoutine Jupiter EDR Dataset* [4] provides uncalibrated experiment data record (EDR), together with time series of pointing and instrumental parameters. The data are distributed in the FITS (Flexible Image Transport System) format. A FITS datafile is composed of a primary Header and Data Unit (HDU), and of 3 additional extensions [5]. Documents and links introducing to FITS are available at NASA/GSFC (Goddard Space Flight Center).

The primary header is made of three sections, describing the data, the instrumental configuration and providing relevant physical ephemeris. It also contain the required metadata to be compliant with ISTP (International Solar Terrestrial Program), the PDS4 (NASA Planetary Data System version 4) , and the EPNcore data model used by the VESPA project for its data distribution protocol EPN-TAP [6]. The primary HDU does not contain data. The exact content of the primary header is detailed in section 3.

The 3 additional extensions, each associated to a specific header, provide setup, science and acquisition data, respectively. More precisely :

- Extension # 1 (see section 4 for details) provides the frequency channels;
- Extension # 2 (see section 5 for details) provides the data epoch time series and the scientific data (in V^2/Hz). When transposed to decibels and compared to *Routine* data, the background level of *NewRoutine* RH/LH autocorrelation data is typically $\sim$ 4dB larger;
- Extension # 3 (see section 6 for details) provide time series of the NDA pointing, of the NDA filters in use and of the attenuation factors corresponding to calibration sequences.

3 Primary Header

This section lists the metadata stored in the primary header. Keywords, and their associated value and comment are presented as written in the FITS file, with some additional information provided whenever useful.

DATA DESCRIPTION

TITLE	value: `ORN NDA newroutine JUPITER EDR Dataset` comment: `Title of the dataset`
ORIGIN	value: `ORN` comment: `Observatoire Radioastronomique de Nancay`

Identifies the organization or institution responsible for creating the FITS file [5].

CONTACT	value: `contact_nda at obs-nancay.fr` comment: `Contact email address`

For any questions and/or collaborative purposes, the ORN/NDA team can be contacted at the contact email address.

PI_NAME	value: `L.Lamy` comment: `Principal Investigator`
PUBLISHE	value: `Obs. Paris/ORN/PADC` comment: `Publisher of the dataset`

Identifies the organization or institution responsible for the publishing of the data set, here being Observatoire de Paris, Observatoire Radioastronomique de Nancay, and Paris Astronomical Data Center.

OBJECT	value: `Jupiter` comment: `Target observed`

Identifies the object observed [5].

DATE	value: *Updated by script* comment: `Date of file creation`

Date on which the HDU was created, written as `YYYY-MM-DD` [5].

FILENAME	value: *Updated by script*

File name of the FITS file. The convention filing name is `orn_nda_newroutine_jup_edr_yyyymmddhhmm _yyyymmddhhmm_VX-X-X,` containing the date (yyyy-mm-dd) and time (hh:mm) of the start and end of the observation, as well than the version of the file as a triple digit `X-X-X`.

OBSRVTRY	value: `ORN` comment: `Observatoire Radioastronomique de Nancay`

Name of the observatory [7].

TELESCOP	value: `NDA` comment: `Nancay Decameter Array`

Identifies the telescope used to acquire the data associated with the header [5].

OBSGEO-L	value: *47.380510* comment: `Geographic longitude of ORN/NDA in deg`

Defines the longitude in the ITRS Cartesian coordinates [8].

OBSGEO-B	value: *2.193226* comment: `Geographic latitude of ORN/NDA in deg`

Defines the latitude in the ITRS Cartesian coordinates [8].

OBSGEO-H	value: *135* comment: `Geographic altitude of ORN/NDA in meters`

Defines the altitude in the ITRS Cartesian coordinates [8].

INSTRUME	value: `newroutine` comment: `Receiver`

Identifies the instrument used to acquire the data associated with the header [5].

DATE-BEG	value: *Updated by script* comment: `Begin date of observation`

Identifies the date of the start of the data acquisition in the `UTC` time system by default [7]. The date is written as `YYYY-MM-DD`.

DATE-END	value: *Updated by script* comment: `End date of observation`

Identifies the date of the end of the data acquisition in the `UTC` time system by default [7]. The date is written as `YYYY-MM-DD`.

TSTART	value: *Updated by script* comment: `Begin time of observation`

Identifies the time of the start of the data acquisition in the `UTC` time system by default [8]. The time is written as `hh:mm:ss.sss`.

TSTOP	value: *Updated by script* comment: End time of observation

Identifies the time of the end of the data acquisition in the `UTC` time system by default [8]. The time is written as `hh:mm:ss.sss`.

OBS_MODE	value: Spectroscopy comment: Observation technique
SUBJECT	value: Planetary science comment: Science discipline
DATATYPE	value: EDR comment: Experiment Data Record
VERSION	value: *Updated by script* comment: Version number of dataset

Identifies the version of particular FITS data file. The version is a number on 3 digits, incremented every time the file is updated.

INFO-URL	value: `http://www.obs-nancay.fr` comment: `Data Website`
REFERENC	value: `https://doi.org/10.1553/PRE8 s455` comment: `Reference article`

Citing the reference where the data associated with the header are published [5].

REFDATA	value: `http://www.obs-nancay.fr` comment: `Reference dataset`
REFSPEC	value: `http://www.obs-nancay.fr` comment: `Reference data description`

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INSTRUMENTAL CONFIGURATION
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DATE-MER	value: *Updated by script* comment: Date of passage of the object at meridian

The date is written as `YYYY-MM-DD`.

`TIME-MER`	value: *`Update by script`* comment: `Time of passage of the object at meridian`

The time is written as `hh:mm:ss.sss`

`ACC`	value: *`Update by script`* comment: `Accumulation factor`

The number N of successive spectra averaged together.

`FREQMIN`	value: *Updated by script* comment: `Minimum frequency in MHz`
`FREQMAX`	value: *Updated by script* comment: `Maximum frequency in MHz`
`DF`	value: *Updated by script* comment: `Frequency resolution in MHz`
`DT`	value: *Updated by script* comment: `Time resolution in seconds`
`CHANNEL1`	value: `LL` comment: `Left-Handed (LH) sub-array Autocorrelation`

Channel 1 withhold the data from the autocorrelation measured on the Left-Handed (LH) sub-array in V^2/Hz.

`CHANNEL2`	value: `RR` comment: `Right-Handed (RH) sub-array Autocorrelation`

Channel 2 withhold the data from the autocorrelation measured on the Right-Handed (RH) sub-array in V^2/Hz.

`CHANNEL3`	value: `LR_RE` comment: `Real part of LH/RH Crosscorrelation`

Channel 3 withhold the real part data from the crosscorrelation between the Left-Handed (LH) and the Right-Handed (RH) sub-arrays in V^2/Hz.

`CHANNEL4`	value: `LR_IM` comment: `Imaginary part of LH/RH Crosscorrelation`

Channel 4 withhold the imaginary part data from the crosscorrelation between the Left-Handed (LH) and the Right-Handed (RH) sub-arrays in V^2/Hz.

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VIRTUAL OBSERVATORY COMPLIANCE
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DSCPLN	value: `Planetary Physics>Waves` comment: `ISTP attribute`

Science discipline and sub-discipline [**cecconi2020jup**].

DSCRTR	value: `NewRoutine_Jupiter` comment: `ISTP attribute`

Identifies the name of the instrument/sensor that collected the data [**cecconi2020jup**].

INS-TYPE	value: `Radio Telescope` comment: `ISTP attribute`

Instrument type to facilitate the choice through CDA Web (Coordinated Data Analysis) [**cecconi2020jup**].

MODS	value: *Updated by script* comment: `ISTP attribute`

Denote the history of modifications made to the dataset [**cecconi2020jup**], which is a standard global attribute of NSSDCA. If the value is set to `None`, the data file has been through no modifications.

PARENTS	value: *Updated by script* comment: `ISTP attribute`

List of the parent FITS for files of derived and merged data sets [**cecconi2020jup**]. If the value is set to `Original File` , the data file is itself the parent file.

RULE-USE	value: `http://www.obs-nancay.fr` comment: `ISTP attribute`

The link contain the information on citability and PI access restrictions, referring to this specification document. [**cecconi2020jup**]

ORN/NDA observations in open access can be freely used for scientific purposes. Their acquisition, processing and distribution is ensured by the ORN/NDA team, which can be contacted for any questions and/or collaborative purposes at the contact email address (contact.nda@obs-nancay.fr). We kindly request the authors of any communications and publications using the data to let us know about them, include minimal citation to the reference, and appropriate acknowledgments whenever needed.

SFW-LANG	value: `python3` comment: `ISTP attribute`

Software language used for the processing [**cecconi2020jup**].

PDS_TYPE	value: `Radio` comment: `PDS attribute`

Identifies the observation type [**cecconi2020jup**].

VES-TYPE	value: `DS>Dynamic Spectrum` comment: `VESPA attribute`

Identifies the organization of the data product from an enumerated list [6].

OBJ-CLAS	value: `planet` comment: `VESPA attribute`

Identifies the target type from an enumerated list [6].

OBJ-REGN	value: `Aurora, Magnetosphere` comment: `VESPA attribute`

Identifies the type of region of interest [**cecconi2020jup**].

FEA-NAME	value: `Decametric radio emmissions (DAM)` comment: `VESPA attribute`

Identifies the secondary name, can be the standard name of region os interest [**cecconi2020jup**].

MSR-TYPE	value: `phys.flux.density; em.radio; phys.polarization` comment: `VESPA attribute`

Identifies a physical characterization of the data [**cecconi2020jup**], using UCD (Unified Content Descriptor) as defined by IVOA (International Virtual Observatory Alliance).

ACC-FORM	value: `application/fits` comment: `VESPA attribute`

Identifies the format type using the MIME (Media) type in a two-part identifier [**cecconi2020jup**].

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ASTRONOMICAL EPHEMERIS
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DECOBJ-B	value: *`Updated by script`* comment: `Object declination at start of acquisition`
DECOBJ-E	value: *`Updated by script`* comment: `Object declination at end of acquisition`
RAOBJ-B	value: *`Updated by script`* comment: `Object right ascension at start of acquisition`

RAOBJ-E	value: *Updated by script* comment: Object right ascension at end of acquisition
DISTE-B	value: *Updated by script* comment: Earth-target distance in AU at start
DISTE-E	value: *Updated by script* comment: Earth-target distance in AU at end
DISTE-1	value: *Updated by script* comment: Minimum Earth-target distance in AU
DISTE-2	value: *Updated by script* comment: Maximum Earth-target distance in AU
SUBELATB	value: *Updated by script* comment: Sub-terrestrial latitude in deg at start
SUBELATE	value: *Updated by script* comment: Sub-terrestrial latitude in deg at end
SUBELAT1	value: *Updated by script* comment: Minimum Sub-terrestrial latitude in deg
SUBELAT2	value: *Updated by script* comment: Maximum Sub-terrestrial latitude in deg
SUBELONB	value: *Updated by script* comment: Central Meridian Longitude in deg at start
SUBELONE	value: *Updated by script* comment: Central Meridian Longitude in deg at end
CARROT-B	value: *Updated by script* comment: Carrington Rotation number at start
CARROT-E	value: *Updated by script* comment: Carrington Rotation number at end
DISTS-B	value: *Updated by script* comment: Sun-target distance in AU at start
DISTS-E	value: *Updated by script* comment: Sun-target distance in AU at end
DISTS-1	value: *Updated by script* comment: Minimum Sun-target distance in AU
DISTS-2	value: *Updated by script* comment: Maximum Sun-target distance in AU

For the following keywords, `XX` represents the two first letters of Jupiter's natural satellites : as `IO` for Io, `GA` for Ganymede, `CA` for Callisto, `EU` for Europa, and `AM` for Amalthee.

`LT_XX-B`	value: *Updated by script* comment: `(Satellite Name) Local Time in hours at start`
`LT_XX-E`	value: *Updated by script* comment: `(Satellite Name) Local Time in hours at end`
`LT_XX-1`	value: *Updated by script* comment: `Minimum (Satellite Name) Local Time in hours`
`LT_XX-2`	value: *Updated by script* comment: `Maximum (Satellite Name) Local Time in hours`
`LON_XX-B`	value: *Updated by script* comment: `(Satellite Name) SIII longitude in deg at start`
`LON_XX-E`	value: *Updated by script* comment: `(Satellite Name) SIII longitude in deg at end`
`MLATXX-B`	value: *Updated by script* comment: `(Satellite Name) Magnetic Latitude in deg at start`
`MLATXX-E`	value: *Updated by script* comment: `(Satellite Name) Magnetic Latitude in deg at end`
`MLATXX-1`	value: *Updated by script* comment: `Minimum (Satellite Name) Magnetic Latitude in deg`
`MLATXX-2`	value: *Updated by script* comment: `Maximum (Satellite Name) Magnetic Latitude in deg`
`RJ_XX-B`	value: *Updated by script* comment: `(Satellite Name) distance in jovian radii at start`
`RJ_XX-E`	value: *Updated by script* comment: `(Satellite Name) distance in jovian radii at end`
`RJ_XX-1`	value: *Updated by script* comment: `Minimum (Satellite Name) distance in jovian radii`
`RJ_XX-2`	value: *Updated by script* comment: `Maximum (Satellite Name) distance in jovian radii`

4 Extension 1: Setup data

The extension named `'SETUP'` (extension #1) contains the 1D array of frequencies (`'frq'` extension). Those are provided in MHz, and recorded as single-precision floating points.

5 Extension 2: Science data

The extension named `'SCIENCE'` (extension #2) contains the 1D array of observing times and time-frequency 4D data arrays.

- The observing times (`'jd'` extension) are given in julian days, and recorded as double-precision floating points ;
- The data arrays (`'data'` extension) are provided in V^2/Hz, and recorded as single-precision floating points. They are provided in the order given in the main header (keywords `CHANNEL1, CHANNEL2, CHANNEL3, CHANNEL4`).

6 Extension 3: Acquisition data

The extension named `'ACQUISITION'` (extension #3) contains tracking and instrumental informations as a function of (pointing) time.

The pointing times (`'time'` extension) are given in julian days, and recorded as double-precision floating points. Contrary to the observing times, they are sampled every 10 sec or more (the sampling can be irregular).

The sky pointing coordinates are provided in two different systems, both expressed in degrees as single-precision floating points :

- azimuth and altitude (`'azimuth'` and `'altitude'` extensions):
  horizontal coordinate system ;
- right ascension and declination (`'right_ascension'` and `'declination'` extensions):
  equatorial coordinate system.

The provided instrumental parameters are the following ones :

- the field bandpass filter in use defined by two limit frequencies (`'filter_min_field` and `'filter_max_field'` extensions) : integer values expressed in MHz ;
- the laboratory high-pass filter defined by a cutoff frequency (`'filter_lab'` extension) : integer value expressed in MHz ;
- the attenuation factor for calibration sequences (`'at'` extension) : integer value in dB (30, 20, 10, 0 during calibration sequences, -1 elsewhere).

References

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