CASSINI-RPWS-HFR LESIA/Kronos Database at Obs.Paris-PSL (Meudon)

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1. DATA ACCESS, ORGANIZATION & STRUCTURE

1.1 DATA ACCESS

Data and products are available from the web server
http://www.lesia.obspm.fr/kronos
(Authentication required)

The web page contains:
- "HFR Data Access": the list of all files available in the data base, sorted with 3 months periods and with data level (see section 1.3).
- "Browse HFR Data": a data browser built from the summary plots
- "HFR OpMode Database Search": a tool to search a into the operating mode of the HFR.
- "HFR Routines": list of routines (to be done)
- "HFR Documentation": list of documentation files and papers related to the HFR data.

It is also possible navigate directly (**no authentication**) in the data directories using that link:
http://www.lesia.obspm.fr/kronos/data

1.2 DATA ORGANIZATION

Data and products are organized in directories `yyyy_ddb_dde/` where

`yyyy` is the year
`ddb` is the beginning day of the period (included)
`dde` is the ending day of the period (included)

Each directory contains a trimester of data and products. A year `yyyy` is divided in 4 directories:
`yyyy_001_090/`
`yyyy_091_180/`
`yyyy_181_270/`
`yyyy_271_366/` (NB: even if only 365 days)

Each directory `yyyy_ddb_dde/` contains the following subdirectories:

`bg/`	background files
`ephem/`	1 min resolution ephemeris+attitude files per source (Jupiter, Sun, Saturn, Earth … from team page tools, depending on the period studied)
`k/`	kronos files retrieved from Iowa

`lis/`	mode lists (files `yyyyddd.lis` - see DescrModesLis.doc)
`n1/`	raw data products (level 1)
`n2/`	calibrated data products (level 2)
`n3/`	(not implemented)
`n3a/`	(not implemented)
`n3b/`	goniopolarimetric data products on 3 antenna (level 3)
`n3c/`	goniopolarimetric data products on 3 antenna (U=Q=0) (level 3)
`n3d/`	goniopolarimetric data products on 2 antenna (fixed θ, ϕ) (level 3)
`n3e/`	goniopolarimetric data products on 2 antenna (U=Q=0) (level 3)
`n3f/`	(not implemented)
`n3g/`	galactic calibration data products (level 3), flux density only
`index/`	source index data products (level 4)
`loc/`	source location data products (level 4)
`pdf/`	summary plots in pdf
`skr/`	skr data products (level 4)
`temp/`	temporary files

Other data directories for limited periods corresponding to specific events in the Cassini lifetime include:

`Turn_on/`	data from instrument post-launch turn-on: 1997298 to 1997299
`Venus1/`	data from first Venus flyby: 1998116
`Ico_m14/`	data from first test period (launch+14 months): 1998364 to 1999005
`Venus2/`	data from second Venus flyby: 1999175
`Earth/`	data from Earth flyby: 1999227 to 1999257

These directories have the same subdirectory structure as above.

1.3 DATA STRUCTURE

The Cassini/RPWS/HFR instrument is a sweeping frequency receiver, observing from 3.5 kHz to 16.1 MHz. The instrument is recording the data as sweeps with increasing frequencies, with various receivers (A, B, C, H1 and H2, see, Gurnett et al. 2004). Each sweep is composed of a series of records, with identical structure. Each record is results from a measurement on the pair of selected antenna at the time of the measurement, and contains 4 quantities: 2 autocorrelations of the radio electric power measured on each of the 2 antenna; and the real and imaginary part of the cross-correlation of the radio electric signals measured on each antenna.

The data is available as hourly or daily files (depending on the data level). In order to keep of the recorded data sweeps from being split into different files, the time of each record is set to that of beginning of the sweep. A function is available to recompute the accurate time of each individual record within a sweep. In the case of the last sweep of the file, it may occur that the actual accurate record times are beyond the file time range.

All data products saved in binary files, fixed length records, little endian.

Some N3a-f files might be empty (zero bytes long) in case of no ephemeris data for the concerned period.

`k/` raw data (hourly files)

Raw data **`k`** files are retrieved from the PI institute (University of Iowa). They are extracted from telemetry RPWS files and decompressed (meander lossless compression). The raw data **k** files are hourly files with nomenclature « Kyyyyddd.hh » corresponding to year yyyy, day of year ddd, time [hh, hh+1[.

Estimated single file size: 100-1000 KB.

n1/ level 1 products (hourly files)

The **n1** data result from reading, decoding and sorting K files (structure adapted from the output of LIT_HFR.pro & EXTRAIT_HFR.pro).

Structure of one record of **n1** data:

```
N1 = {ydh: 0L, $     ;    yyyydddhh of current file
      num: 0L  $     ;    index of record in current file
       ti: 0L, $     ;    time index
       fi: 0L, $     ;    frequency index
       dt: 0,  $     ;    integration time (msec)
        c: 0B, $     ;    hundreds of second
      ant: 0B, $     ;    antenna selection: 0-3=NoDF
                     ;    (Ex=Off,+X,-X,D), 11=DF/+X, 12=DF/-X
     agc1: 255B,    $    ;    agc 'X'
     agc2: 255B,    $    ;    agc 'Z'
    auto1: 255B,    $    ;    auto-correlation 'X'
    auto2: 255B,    $    ;    auto-correlation 'Z'
   cross1: -999,    $    ;    cross-correlation (real)
   cross2: -999 }    ;    cross-correlation (Imaginary)
```

Structure: 13 tags,
Data length: 28 bytes.

Notes:

- ydh (same for all records of a given file) & num (0 to n-1) indices uniquely define each data. They are repeated in all level > 1 products for traceability.
- time & frequency indices (ti and fi) uniquely define each data status.
- dt = integration time: 125-1000 msec in bands ABC, 20-160 msec in H1, 10-80 msec in H2.
- c = hundreds of second to be added to ti for exact time of start of packet.
- agc, auto and cross values remain at initialized values if corresponding measurement does not exist (e.g., when antenna 2 = OFF).

Time index definition: yydddsssss
with yy = year - 1996 (1997=1, 1998=2 ...)
ddd = day of year (1 - 366)
sssss = second of day (0 - 86400)

Frequency index definition: bcccffnn
with b = band (0=A, 1=B, 2=C, 3=H1, 4=H2)
ccc = synthéziser position in H1 & H2 bands (kHz/25), 0 in ABC bands
ff = number of filters per band (1,2,4,8,16,32)
nn = rank of filter in the band (0 - 31)

The **n1** data are archived at CNES, with nomenclature « `Ryyyyddd.hh` ».

Estimated single file size: ~ 5.5 KB

n2/ level 2 products (hourly files)

The **n2** data are calibrated values (V^2/Hz).

Structure of one record of **n2** data:

```
N2 = {ydh: 0L,  $   ;    yyyydddhh of current file
      num: 0L   $   ;    index of record in current file
      t97: 0.d0,$   ;    time (decimal days, epoch = 1997.0)
        f: 0.,  $   ;    frequency (kHz)
       dt: 0.,  $   ;    effective integration time (msec)
       df: 0.,  $   ;    effective bandwidth (kHz)
    autoX: 0.,  $   ;    auto-correlation 'X' (V2/Hz)
    autoZ: 0.,  $   ;    auto-correlation 'Z' (V2/Hz)
   crossR: -999., $ ;    cross-correlation (real)
   crossI: -999., $ ;    cross-correlation (Imaginary)
      ant: 0B }     ;    antenna selection: 0-3=NoDF
                    ;    (Ex=Off,+X,-X,D), 11=DF/+X, 12=DF/-X
```

Structure: 11 tags
Data length: 45 bytes

Notes:

- `ydh`, `num` & `ant` identical to `n1` data. One-to-one correspondence between N1 and N2 records.
- `t97` is the time of sweep start.
- `dt` and `df` are effective quantities computed for the current measurement.
- `auto` and `cross` values values remain at initialized values if corresponding measurement does not exist (e.g., when antenna 2 = OFF). Cross-correlation values are normalized and corrected for the phase shift introduced by the instrument.

The **n2** data are archived at CNES, with nomenclature « `Pyyyyddd.hh` ».

Estimated single file size: ~ 9 KB

n3/ final level 3 products (hourly files)

Warning: this dataset is not available

The **n3** data (S,Q,U,V,θ,ϕ,χ^2,Zr,SNR,…) will result from comparison, validation and merging of n3a-f… products.

Expected single file size: ~ 6 KB

n3a/ level 3 products (hourly files)

Warning: this dataset is not available.

The **n3a** data are GP results from Powell method applied to 3 antenna measurements *(cf. Vogl et al., 2004)*.

```
Structure of one record of n3a data:
N3a = {ydh: 0L,      $    ;    yyyydddhh of current file
       num: 0L,      $    ;    index of record in current file
         S: 0.,      $    ;    Intensity (V2m-2Hz-1)
         q: 0.,      $    ;    Normalized linear polarization
         u: 0.,      $    ;    parameters Q & U
         v: 0.,      $    ;    Normalized circular polar. V
        th: 0.,      $    ;    Source colatitude ( in S/C frame)
        ph: 0.,      $    ;    Source azimuth    ( in S/C frame)
       chi: 0.,      $    ;    chi-square residual
        zr: 0.,      $    ;    ratio of 2 Azz val.
                                    (Azz+-Azz-)/(Azz++Azz-)
        sn: fltarr(4)}    ;    S/N ratio on autocorrel. values
```

Structure: 11 tags,
Data length: 56 bytes.

Notes:

- ydh & num identical to n1 data. N3a records correspond to a subset of N1 and N2 records.
- S is an intensity multiplied by the h_z antenna squared length. The h_z antenna length is supposed to be 1 here. Use Zarka et al. JGR 2004 to obtain a calibrated intensity in $Wm^{-2}Hz^{-1}$.

The **n3a** files nomenclature « N3a_XYY_yyyyddd.hh »
where

X = 1-character code defining the antenna parameter set used:

- r for rheometry,
- j for Jupiter-Cal
- d for December 2004 calibration

YY = 2-character code defining the radiosource of reference:

su=Sun, ea=Earth, ju=Jupiter, sc=Saturn's center, sn=Saturn_North, ss=Saturn_South

Estimated single file size: ~ 5.5 KB

n3b/ level 3 products (hourly files)

The **n3b** data are GP results from Direct Inversion (DI) method applied to 3 antenna measurements *(cf. Cecconi & Zarka, 2004)*.

Structure of one record of n3b data:

```
N3b = {ydh: 0L,      $    ;    yyyydddhh of current file
       num: lonarr(2),$   ;    indices of record in current file
         s: fltarr(2),$   ;    Intensity (V2m-2Hz-1)
```

```
          q: fltarr(2),$  ;    Normalized linear polarization
          u: fltarr(2),$  ;    parameters Q & U
          v: fltarr(2),$  ;    Normalized circular polar. V
         th: 0.,      $   ;    Source colat ( in S/C frame)
         ph: 0.,      $   ;    Source azimuth ( in S/C frame)
         zr: 0.,      $   ;    ratio of 2 Azz val.
                                    (Azz+-Azz-)/(Azz++Azz-)
         sn: fltarr(4)}   ;    S/N ratio on autocorrel. values
```

Structure: 10 tags,
Data length: 72 bytes.

Notes:

- S, Q, U, V are computed separately for each pair of antennas in the 3 antenna set. If Q, U, V are all = 0, then a specific inversion is used instead (see n3c).
- S is an intensity multiplied by the h_z antenna squared length. The h_z antenna length is supposed to be 1 here. Use Zarka et al. JGR 2004 to obtain a calibrated intensity in $Wm^{-2}Hz^{-1}$.

The **n3b** files nomenclature « N3b_XYY_yyyyddd.hh » with same conventions as N3a

Estimated single file size: ~ 6.5 KB

n3c/ level 3 products (hourly files)

The **n3c** data are GP(V only) results from Direct Inversion (DI) method applied to 3 antenna measurements, with U=Q=0 *(cf. Cecconi & Zarka, 2004)*.

Structure of one record of n3c data:

```
N3c = {ydh: 0L,      $    ;    yyyydddhh of current file
       num: lonarr(2),$   ;    indices of record in current file
          s: 0.,      $   ;    Intensity (V2m-2Hz-1)
          q: 0.,      $   ;    Normalized linear polarization
          u: 0.,      $   ;    parameters Q & U
          v: fltarr(2),$  ;    Normalized circular polar. V
         th: fltarr(2),$  ;    Source colat.  (in S/C frame)
         ph: fltarr(2),$  ;    Source azimuth (in S/C frame)
         zr: 0.,      $   ;    ratio of 2 Azz val.
                                    (Azz+-Azz-)/(Azz++Azz-)
         sn: fltarr(4)}   ;    S/N ratio on autocorrel. values
```

Structure: 10 tags
Data length: 68 bytes.

Notes:

- S is an intensity multiplied by the h_z antenna squared length. The h_z antenna length is supposed to be 1 here. Use Zarka et al. JGR 2004 to obtain a calibrated intensity in $Wm^{-2}Hz^{-1}$.

The **n3c** files nomenclature « N3c_XYY_yyyyddd.hh » with same conventions as N3a

Estimated single file size: ~ 6 KB

`n3d/` level 3 products (hourly files)

The **`n3d`** data are Polarization results from Direct Inversion (DI) method applied to 2 antenna measurements, with a selected source direction ***(cf. Cecconi & Zarka, 2004)***.

Structure of one record of **n3d** data:

```
N3d = {ydh: 0L,      $    ;    yyyydddhh of current file
       num: 0L,      $    ;    index of record in current file
         s: 0.,      $    ;    Intensity (V²m⁻²Hz⁻¹)
         q: 0.,      $    ;    Normalized linear polarization
         u: 0.,      $    ;    parameters Q & U
         v: 0.,      $    ;    Normalized circular polar. V
        th: 0.,      $    ;    Source colatitude ( in S/C frame)
        ph: 0.,      $    ;    Source azimuth    ( in S/C frame)
        sn: fltarr(2)}    ;    S/N ratio on autocorrel. values
```

Structure: 9 tags
Data length: 40 bytes.

Notes:

- `S` is an intensity multiplied by the h_z antenna squared length. The h_z antenna length is supposed to be 1 here. Use Zarka et al. (2004) to obtain a calibrated intensity in $Wm^{-2}Hz^{-1}$.

The **`n3d`** files nomenclature « `N3d_XYY_yyyyddd.hh` » with same conventions as N3a

Estimated single file size: ~ 8 KB

`n3e/` level 3 products (hourly files)

The **`n3e`** data are GP (V) results from Direct Inversion (DI) method applied to 2 antenna measurements, with U=Q=0 ***(cf. Cecconi & Zarka, 2004)***.

Structure of one record of **n3e** data: ***identical to N3d***

```
N3e = {ydh: 0L,      $    ;    yyyydddhh of current file
       num: 0L,      $    ;    index of record in current file
         s: 0.,      $    ;    Intensity (V²m⁻²Hz⁻¹)
         q: 0.,      $    ;    Normalized linear polarization
         u: 0.,      $    ;    parameters Q & U
         v: 0.,      $    ;    Normalized circular polar. V
        th: 0.,      $    ;    Source colatitude ( in S/C frame)
        ph: 0.,      $    ;    Source azimuth    ( in S/C frame)
        sn: fltarr(2)}    ;    S/N ratio on autocorrel. values
```

Structure: 9 tags
Data length: 40 bytes.

Notes:

- `S` is an intensity multiplied by the h_z antenna squared length. The h_z antenna length is supposed to be 1 here. Use Zarka et al. JGR 2004 to obtain a calibrated intensity in $Wm^{-2}Hz^{-1}$.

The **`n3e`** files nomenclature « `N3e_XYY_yyyyddd.hh` » with same conventions as N3a

Estimated single file size: ~ 8 KB

`n3f/` level 3 products (hourly files)

Warning: this dataset is not available

The **`n3f`** data are GP results from SVD method applied to 3 antenna measurements *(cf. Ladreiter et al., 1995)*.

`n3g/` level 3 products (hourly files)

The **`n3g`** data are flux densities calibrated with short dipole (f ≤ 2 MHz) and/or Galaxy (f ≥ 1 MHz) *(cf. Zarka et al., 2004)*.

Structure of one record of n3g data:

```
N3g = {ydh: 0L,      $    ;    yyyydddhh of current file
        num: 0L,      $    ;    index of record in current file
      fluxX: 0.,      $    ;    flux density 'X' (W/m2/Hz)
      fluxZ: 0.}      $    ;    flux density 'Z' (W/m2/Hz)
```

Structure: 4 tags
Data length: 16 bytes.

Notes:

- One-to-one correspondence between `n3g` and `n1`/`n2` records.

The `n3g` files nomenclature « `Fyyyyddd.hh` »

Estimated single file size: ~ 3 KB

`index/` source index data products (hourly files)

The **`index`** data are derived from **`n3b`** or **`n3e`** data products, after comparing the direction of arrival and Saturn's location. This dataset has been used in panel c of Fig. 2 of *Cecconi et al. (2009)*.

Structure of one record of **index** data:

```
Index = {ydh: 0L,   $    ;    yyyydddhh of current file
         num: 0L,   $    ;    index of record in current file
         ind: 0.,   $    ;    Index value (from -1 to 10)
          tl: 0.,   $    ;    local Time
          rr: 0.,   $    ;    Distance from S/C to Saturn (Rs)
          zz: 0.,   $    ;    Altitude of S/C above ring-plane (Rs)
         ydf: 0.,   $    ;    Horizontal source direction location
```

```
zdf: 0.}        ;     Vertical source direction location
```

Structure: 8 tags
Data length: 32 bytes.

The **`index`** files nomenclature « `INDEX_yyyyddd.hh` » (for **`n3e`** derived data products)or « `INDEX_3A_yyyyddd.hh` » (for **`n3b`** derived data products).

• **`n3e`** derived **`index`** products:

The data index values are as presented below, and on figure 1.

Index	SNR selection	Circular Polarization		Region
0	Stokes S = 0	No selection		
1	Both SNR > SNR_min	RH	|V| in [V_min, V_max] & V < 0	North
2	Both SNR > SNR_min	LH	|V| in [V_min, V_max] & V > 0	North
3	Both SNR > SNR_min	RH	|V| in [V_min, V_max] & V < 0	South
4	Both SNR > SNR_min	LH	|V| in [V_min, V_max] & V > 0	South
5	Both SNR > SNR_min	RH	|V| in [V_min, V_max] & V < 0	Equator
6	Both SNR > SNR_min	LH	|V| in [V_min, V_max] & V > 0	Equator
7	Both SNR > SNR_min	RH	|V| in [V_min, V_max] & V < 0	Outer North
8	Both SNR > SNR_min	LH	|V| in [V_min, V_max] & V > 0	Outer North
9	Both SNR > SNR_min	RH	|V| in [V_min, V_max] & V < 0	Outer South
10	Both SNR > SNR_min	LH	|V| in [V_min, V_max] & V > 0	Outer South
255	All other data samples			

Fig. 1. Index values for n3e data with selections on direction of arrival. Angles Lat_min and Lat_max correspond respectively to the minimal and maximal latitudes. The **ydf** and **zdf** parameters of the **index** structure are respectively Azimuth and Latitude in Rs.

The N3e data selection criteria in use are:

- `Vmin = 0.2      ; Minimum valid circular polarization degree`
- `Vmax = 1.1      ; Maximum valid circular polarization degree`
- `altmin = 0.     ; Minimum altitude of source above equator`
- `altmax = 10.    ; Maximum altitude of source above equator`
- `SNRmin = 10.    ; Minimum SNR in decibel`

Lat_min and Lat_max are defined as:

- `Lat_min = rr*tan(atan(altmin/rr)+th_err)`
- `Lat_max = rr*tan(atan(altmax/rr)+th_err)`

with the value of `th_err` set to 5° (corresponding to an upper limit of the direction of arrival determination uncertainly).

• **`n3b`** derived **`index`** products:

The data index values are as presented below, and on figure 1.

Index	SNR selection	Circular Polarization	Region

0	Any SNR < SNR_min	No selection	
1	Both SNR > SNR_min	No selection	North
2	Both SNR > SNR_min	No selection	South
3	Both SNR > SNR_min	No selection	Equator
4	Both SNR > SNR_min	No selection	Remote North
5	Both SNR > SNR_min	No selection	Remote South
255	All other data samples		

Fig. 2. Index values for n3b data with selections on direction of arrival. See Fig. 1 for more details.

The N3b data selection criteria in use are:

- `altmin = 0.    ; Minimum altitude of source above equator`
- `altmax = 10.   ; Maximum altitude of source above equator`
- `SNRmin = 10.   ; Minimum SNR in decibel`

`Lat_min` and `Lat_max` are defined as in the **`n3e`** derived **`index`** products.

`loc/` radio source location data products (hourly files)

The **`loc`** data are derived from **`n3b`** or **`n3e`** data products. The radio source location and characterization algorithm is described in Appendix B of *Cecconi et al. (2009)*. In short, we assume that the radio source emission frequency is the local electron cyclotron frequency (according to the Cyclotron Maser Instability). We use the direction of arrival provided in **n3b** or **n3e** data collections and compute cyclotron frequency all along the line of sight, using a magnetic field model[1]. We then locate the radio source where the cyclotron frequency is the observation frequency. This position is provided in the *xyz* element of the **loc** structure. Given the radio source location and that of the observer, we can compute the observed source beaming angle knowing the magnetic field vector direction in the radio source (*beam* element). Following the magnetic field line bearing the radio source, we can derive the magnetic footprint[2]. This footprint is available in the *foot* element of the **loc** structure

Structure of one record of **loc** data:

```
Loc = {ydh:  0L,      $    ;    yyyydddhh of current file
        num:  0L,      $    ;    index of record in current file
       foot:  fltarr(3),$   ;    Magnetic footprint location in
                            ;    spherical units (r,θ,φ).
        xyz:  fltarr(3),$   ;    Radio source location in cartesian
                            ;    units (x,y,z)
       beam:  0.,      $    ;    Beaming angle (radians)
       dist:  0.}           ;    Distance from the source to iso-fc (Rs)
```

Structure: 6 tags
Data length: 40 bytes.

The **`loc`** files nomenclature « `loc_SPV_yyyyddd.hh` » (for **`n3e`** derived data products) or « `loc_3A_SPV_yyyyddd.hh` » (for **`n3b`** derived data products). The "SPV" element refers to

[1] We use the SPV (Saturn-Pioneer-Voyager) model, as described in Davis and Smith (1990)
[2] The footprint altitude is classically defined by the 1-bar atmospheric altitude.

the magnetic field model in use.
NB:

- Due to the uncertainty on the direction of arrival estimation, as well as to the assumption of straight line propagation, the algorithm may not find a proper radio source location. The way these cases are processed is explained in Appendix B1 of Cecconi et al. (2009).
- The locations of the radio source and its magnetic footprint are provided in the SSQ (Saturn Solar Equatorial) frame.
- The *dist* element is a tracking the fact that a radio source has been found along the line of sight (*dist=0*). If the line of sight doesn't intercept the $f_{obs}=f_c$ surface, the *dist* value is non zero, and provides the closest distance from the line of sight to that surface, in Rs. This parameter can then be use to select data samples for analysis.
- We use the cyclotron frequency f_{ce} for the source location determination, instead of the R-X mode cutoff frequency f_X, which is defined as $(f_p^2+f_{ce}^2/4)^{1/2}+f_{ce}/2$, where f_p is the plasma frequency. However, in the radio source regions (at high latitude), and taking into account the uncertainties on the direction of arrival, this assumption is considered valid, as discussed in Cecconi et al. (2009)

An associated of **`loc`** files is available and is named **`loc_err`** , with the nomenclature as follows: « `loc_err_SPV_n08_yyyyddd.hh` » (for **`n3e`** derived data products) or « `loc_err_3A_SPV_08_yyyyddd.hh` » (for **`n3b`** derived data products) files. Those files contains data which can be used to estimate of the radio source parameters uncertainty. For each element of the **`loc`** dataset, a set of 8 (as stated in the "`_08_`" section of the file name) directions of arrivals are modeled, along a 2° half-angle cone centered on the measured direction of arrival (from **n3b** or **n3e** dataset). Such dataset has been used to prepare the left hand panels of Figure 6, 8 and 12 of Cecconi et al. (2009). The **`loc_err`** files thus have 8 times more records than the corresponding **`loc`** file.

`pdf/` & `lis/` summary plots & mode lists (daily files)

- Summary plots « `yyyyddd.pdf` » : 2 dynamic spectra displayed (with/without background subtraction), with graphical indication of Df 'on' in ABC, H1, H2 bands.
  Volume ≤ 200 Kbytes / day.
- Mode lists « `yyyyddd.lis` » (compact format) : see detailed description in DescrModesLis.doc
  Volume ≤ 50 Kbytes / day.

2. DATA PROCESSING

The whole data set is available on the web, on a password protected web page (http://www.lesia.obspm.fr/kronos).

2.1 RPWS-Kronos SOFTWARE

The Kronos software has been developed in IDL and is available here:
https://lesia.obspm.fr/kronos/routines/
(no authentication)

The Kronos IDL library is distributed under MIT license (although not stated in the software files).

Further documentation and other languages (Python) is under development.

2.2 RETRIEVING AND PROCESSING RPWS DATA

The **`k`** files as well as the ephemeris and attitude data are retrieved from a web server at University of Iowa. The `n1`, `n2`, `n3a-g`, `pdf`, and `lis` files are produced and archived on a regular basis.

All data products (`n1`, `n2`, `n3a-g`) consist of hourly files.

Summary plots (`pdf`) and mode lists (`lis`) are daily files.
⇒ Use `summary.pro` to produce `pdf` files.
⇒ Use `make_lis_files.pro` to produce `lis` files

Data products are written as binary files, each containing N "records" of data (unformatted read/write). Each record can be written/read as an IDL structure (fixed length, little endian). The ratio `file_size / record_length` gives the number of records to be read.
⇒ Use `make_n1_files.pro` to produce `n1` files.
⇒ Use `make_n2_files.pro` to produce `n2` files.
⇒ Use `make_n3b_files.pro` to produce `n3b` files.
⇒ Use `make_n3c_files.pro` to produce `n3c` files.
⇒ Use `make_n3d_files.pro` to produce `n3d` files.
⇒ Use `make_n3e_files.pro` to produce `n3e` files.
⇒ Use `make_n3g_files.pro` to produce `n3g` files.
⇒ Use `read_data_binary.pro` to read files.

Level `n3a-f` data result from GP analyses. Several methods are used, producing corresponding data sets `n3a-f`:

`n3a` GP Powell 3 antennas ***(Vogl et al., 2004)***
`n3b` GP Direct Inversion (DI) 3 antennas (Cecconi & Zarka, 2004)
`n3c` GP (V only) DI 3 antennas, U=Q=0 ***(C&Z, 2004)***
`n3d` Polar. DI 2 antennas, , fixed ***(C&Z, 2004)***
`n3e` GP (V only) DI 2 antennas, U=Q=0 ***(C&Z, 2004)***
`n3f` GP SVD 3 antennas ***(Ladreiter et al., 1995)***

Level `n3a-f` data are computed from level `n2` + background subtraction, S/N computation, data selection (2 or 3 antennas, max. frequency…).
Computation also requires in input :

- a reference antenna set (3 antenna effective height vectors defining the electrical equivalent dipoles): available sets include rheometry ***(Rucker et al., 1996)***, Jupiter-calibration ***(Vogl et al., 2004)***.
- spacecraft attitude information (position of the source of interest in the spacecraft frame, used both for initialization and final check of DF results concerning the wave **k**-vector)

Level `n3g` data are flux densities calibrated with short dipole (f ≤ 2 MHz) and/or Galaxy (f ≥ 1 MHz) ***(cf. Zarka et al., 2004)***.

bg/ background (quarterly files)

Background data is computed from histograms of intensities per frequency and recorded as binary files.

The **bg** file nomenclature (in `yyyy_ddb_dde/bg/`) is :

`bg_yyyy_ddb_dde`	(whole interval)
`bg_yyyyddb_hb_yyyydde_he`	(selection)

⇒ Use `make_bg_files.pro` to produce `bg` files.

Structure of **bg** data (one record per frequency):

```
bg = {h: lonarr(1601,4),$ ; 1601 bins x 0.05 dB
                          ; in [-170,-90] dB range
                          ; 0=Z, 1=+X, 2=-X, 3=D
     bt: fltarr(4), $     ;    <df*dt> per antenna
                          ;    over the period studied
    nbt: fltarr(4), $     ;    N values for bt computation
     fi: 0L,        $     ;    Frequency Index (see n2 data)
     xf: 0.,        $     ;    Frequency (kHz)
    sig: fltarr(4), $     ;    RMS on fon(4)
    fon: fltarr(4), $     ;    mode of histogram of intensities
   fon5: fltarr(4), $     ;    5% level of histogram
  fon10: fltarr(4)}       ;    10% level of histogram
```

The background data can be computed with various number of histogram bins (from 320 to 3200 bins), but the available dataset has been computed with 1600 bins.

ant/ Antenna parameter

Antenna paramters sets are available from:
https://lesia.obspm.fr/kronos/data/rpws/ant/

Most of the available data have been computed using the Dec04 calibration files (`calDec04_ABC.ant` and `calDec04_H12.ant`), which define a slightly different set of antenna for A, B and C receivers, and H1 and H2 ones.

Antenna parameter list:

The list of antenna valid files is described in
https://lesia.obspm.fr/kronos/data/rpws/pro/ant_list.txt

The file contains 1 row per antenna parameter, as 'colon' separated values. The first field is the antenna set name, while the second is the file name to be used (where the `.ant` extension is optional). Lines starting with # are comment lines.

ephem/ Ephemeris and Attitude

The ephemeris and attitude data are retrieved from a web server of University of Iowa as ASCII tables.

The binary ephemeris and attitude files are then computed for each source of interest (Sun, Earth, Jupiter, Saturn). Files contain (x, y, z, θ, φ) sets with 1 min resolution, with (x, y, z) = position of

Cassini in the selected frame coordinates and in km, and (θ, ϕ) = position of source in Cassini frame (radians). The attitude data is stored in the form of quaternion that are used to transform the coordinates from the spacecraft frame to the another. Depending on the science case, various source ephemeris and coordinate frames can be used.

The ephemeris (positional) data file nomenclature is `YYYYDDD.vTTT`, where `TTT` is the short name for the selected target source. The attitude (orientation) data file nomenclature is `YYYYDDD.qFFF`, where `FFF` is the short name for the selected coordinate system. The `TTT` and FFF shorts names are defined in the source list file.

⇒ Use `make_ephem_files.pro` to produce ephemeris and attitude files.

Source list

The list of valid sources files is described in
https://lesia.obspm.fr/kronos/data/rpws/pro/src_list.txt
As for the antenna parameter list file (see previous sub-section), the data is stored as a `colon` separated table. The file header (commented section) describes the various fields.

During the Saturn orbital mission, most of the GP data have been computed using the `sq` setup (as found in their file name). The source list file shows that it corresponds to Saturn's center ephemeris (`.vsat` files) and Saturn Solar Equatorial coordinate system (`.qssq` files).

Data selection before GP.

All the records available in `n1` data files are not processed. The computation is done using the following criteria :

- auto-correlations all > 0 (after background subtraction)
- |cross-correlations| ≤1
- ephemeris / attitude available.

Data not meeting these criteria are either eliminated or set to the max/min acceptable value.
In output, S/N ≥ threshold (dB), and (autoZ) < n% within 3 antenna data set, allow for further selection.
Angular distance between DF results (θ, ϕ) and the selected source can be recomputed from GP results and interpolated data from the ephemeris file.

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