A CONSOLIDATED CATALOGUE OF JOVIAN DECAMETRIC RADIO OBSERVATIONS OBSERVED IN NANÇAY FROM JANUARY 1978 TO DECEMBER 1990

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Abstract

A series of five Jovian decametric radio emission catalogues covering 13 years of observations (1978 to 1990) and published between 1981 and 1993 has been compiled after a digitisation process. The new catalogue has been validated and is provided in a standardised and interoperable format. In addition to the well-known Io–controlled Jovian radio emissions components, the catalogue statistically confirms the control by Ganymede.

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1 Introduction

Discovered by Burke & Franklin (1955) at 22.2 MHz, the Jovian low frequency radio emissions are produced by energetic particles traveling in the Jovian magnetospheric polar regions (Zarka, 2004). The current knowledge on the Jovian radio emissions physics is built upon decades of observation and monitoring, with ground and space instruments, such as the Nançay Decameter Array (NDA), in Nançay, France (Lecacheux, 2000; Lamy et al., 2017), the Planetary Radio Astronomy experiment onboard the Voyager-1 and Voyager-2 spacecraft (Warwick et al., 1977), or more recently, the Waves instrument onboard the Juno mission (Kurth et al., 2017). The Voyager mission was the first planetary probe with a low frequency radio receiver exploring the Jovian system, with Voyager-1 flying by Jupiter in March 1979 and Voyager-2 in July 1979. Supporting observations were conducted with ground-based low frequency observatories (e.g., with the NDA) and many publications resulted from those observations (see, e.g., Leblanc et al., 1980a,b; Genova & Leblanc, 1981; Leblanc et al., 1981, 1983, 1989a,b; Leblanc, 1990; Leblanc et al., 1990, 1993).

In 2018, the NDA initiated a project[1] aiming at digitising, consolidating, preserving and sharing the instrument's archives, which were only available on physical media such as paper, film rolls, etc. (Lamy et al., 2017; Lamy et al., 2023; Cecconi et al., 2018). This paper presents one of the outcomes of this project, focussing on the digitisation of radio emission catalogues, published by Yolande *Leblanc et al.* from 1981 to 1993 (Leblanc et al., 1981, 1983, 1989a, 1990, 1993), hereafter referred to as *Leblanc et al.* catalogues, with events spanning over 13 years of daily observations (from January 1978 to December 1990).

2 Materials and methods

The compiled catalogue is built from the *Leblanc et al.* catalogues, which have been digitised and validated. The resulting catalogue includes additional metadata related to the observational context in the Jovian system.

2.1 Original catalogues

Five published catalogues have been processed to build this data collection. The initial original data is available as PDF formatted raster scans from NASA/ADS (Astrophysics Data System). Table 1 provides the list of URLs for the PDF files of each catalogue. Figure 1 shows the first page of the first catalogue (Leblanc et al., 1981), as available from NASA/ADS.

The original catalogues provide, for each observation, the calendar date, the temporal coverage (time interval in UT, Universal Time), the spectral coverage in MHz as well as ephemeris parameters related to the Jovian planetary system. The same information is

[1] See `https://archives-decametriques.obspm.fr/?lang=en` for details.

TABLE I. — *Catalogue.*

DATE YY/MM/DD	DOY JJJ	OBSERVATIONS TIME UT HHMM - HHMM	CML III (1965.0)	IO PHASE	WIDTH MHZ	EMISSIONS TIME UT HHMM - HHMM	CML III (1965.0)	IO PHASE	WIDTH MHZ
78/ 1/ 3	3	1930 - 24 0	248 - 51	119 - 157	10 - 50	2054 - 2156	299 - 336	131 - 139	10 - 30
78/ 1/ 4	4	0 0 - 230	51 - 142	157 - 178	10 - 50				
78/ 1/ 4	4	1930 - 24 0	39 - 202	322 - 1	10 - 50				
78/ 1/ 5	5	0 0 - 230	202 - 293	1 - 22	10 - 50				
78/ 1/ 5	5	1930 - 24 0	189 - 353	166 - 204	10 - 30	1959 - 2320	207 - 328	170 - 198	10 - 28
78/ 1/ 6	6	0 0 - 146	353 - 57	204 - 219	10 - 30				
78/ 1/ 6	6	19 0 - 24 0	322 - 143	5 - 48	10 - 40	22 9 - 24 0	76 - 143	32 - 48	10 - 20
78/ 1/ 7	7	0 0 - 2 0	143 - 216	48 - 65	10 - 40	0 0 - 039	143 - 167	48 - 53	10 - 20
78/ 1/ 7	7	19 0 - 24 0	113 - 294	209 - 251	10 - 40	1941 - 2013	137 - 157	215 - 219	10 - 35
						2117 - 24 0	195 - 294	228 - 251	10 - 35
78/ 1/ 8	8	0 0 - 056	294 - 328	251 - 259	10 - 40	0 0 - 056	294 - 328	251 - 259	10 - 35
78/ 1/ 9	9	1930 - 24 0	72 - 235	260 - 299	10 - 50				
78/ 1/10	10	0 0 - 230	235 - 326	299 - 320	10 - 50	010 - 219	241 - 319	300 - 318	10 - 20
78/ 1/10	10	1930 - 24 0	223 - 26	104 - 142	10 - 50	20 6 - 20 8	244 - 246	109 - 109	10 - 13
						2036 - 2242	262 - 339	113 - 131	10 - 20
78/ 1/11	11	0 0 - 230	26 - 116	142 - 163	10 - 50				
78/ 1/11	11	1930 - 24 0	13 - 176	308 - 346	10 - 50	2320 - 2330	152 - 158	340 - 341	10 - 15
78/ 1/12	12	0 0 - 138	176 - 236	346 - 0	10 - 50				
78/ 1/12	12	1845 - 24 0	137 - 327	145 - 189	10 - 40	2037 - 24 0	204 - 327	161 - 189	10 - 28
78/ 1/13	13	0 0 - 2 0	327 - 40	189 - 206	10 - 40	0 0 - 036	327 - 349	189 - 194	10 - 28
78/ 1/13	13	19 0 - 24 0	296 - 118	351 - 33	10 - 40	1933 - 2018	316 - 343	355 - 2	12 - 15
						2248 - 23 9	74 - 87	23 - 26	10 - 15
						2325 - 24 0	96 - 118	28 - 33	10 - 30
78/ 1/14	14	0 0 - 1 0	118 - 154	33 - 41	10 - 40	0 0 - 057	118 - 152	33 - 41	10 - 30
78/ 1/14	14	1845 - 24 0	78 - 268	192 - 237	10 - 40				
78/ 1/15	15	0 0 - 2 0	268 - 341	237 - 253	10 - 40				
78/ 1/15	15	19 0 - 24 0	237 - 59	38 - 80	10 - 40				
78/ 1/16	16	0 0 - 1 0	59 - 95	80 - 89	10 - 40				
78/ 1/16	16	19 0 - 24 0	28 - 209	241 - 284	10 - 40				
78/ 1/17	17	0 0 - 2 0	209 - 282	284 - 301	10 - 40				
78/ 1/17	17	1745 - 2153	133 - 283	74 - 109	10 - 40	1930 - 2153	197 - 283	89 - 109	10 - 27
78/ 1/18	18	1745 - 24 0	284 - 151	278 - 331	10 - 40	18 8 - 1911	298 - 336	281 - 290	10 - 23
78/ 1/19	19	0 0 - 2 0	151 - 223	331 - 348	10 - 40				
78/ 1/19	19	1730 - 2255	65 - 262	119 - 165	10 - 40	1839 - 2028	107 - 173	129 - 144	10 - 22
						22 8 - 2253	234 - 261	159 - 165	10 - 27
78/ 1/20	20	1730 - 24 0	216 - 92	323 - 18	10 - 40	18 6 - 1849	238 - 264	328 - 334	15 - 20
						2318 - 24 0	66 - 92	12 - 18	10 - 25
78/ 1/21	21	0 0 - 2 0	92 - 164	18 - 35	10 - 40	0 0 - 152	92 - 160	18 - 34	10 - 25
78/ 1/21	21	1730 - 24 0	7 - 242	166 - 222	10 - 40				
78/ 1/22	22	0 0 - 2 0	242 - 315	222 - 239	10 - 40				
78/ 1/22	22	1715 - 24 0	148 - 33	8 - 65	10 - 40	1859 - 22 8	211 - 325	23 - 49	10 - 30
78/ 1/23	23	0 0 - 2 0	33 - 106	65 - 82	10 - 40	1 5 - 157	72 - 104	74 - 82	15 - 25
78/ 1/23	23	17 0 - 24 0	290 - 184	209 - 269	10 - 30	2129 - 2130	92 - 93	247 - 248	17 - 20
78/ 1/24	24	0 0 - 2 0	184 - 256	269 - 286	10 - 30	136 - 149	242 - 250	282 - 284	10 - 25
78/ 1/24	24	17 0 - 1910	80 - 159	53 - 71	20 - 40				
78/ 1/24	24	1910 - 24 0	159 - 334	71 - 112	13 - 33				
78/ 1/25	25	0 0 - 2 0	334 - 47	112 - 129	13 - 33				
78/ 1/25	25	17 0 - 24 0	231 - 125	256 - 316	10 - 40	17 1 - 1750	231 - 261	257 - 264	20 - 24
78/ 1/26	26	0 0 - 2 0	125 - 197	316 - 333	10 - 40				
78/ 1/26	26	17 0 - 24 0	21 - 275	100 - 159	10 - 40	1935 - 1948	115 - 123	122 - 124	15 - 30
						2059 - 2110	166 - 173	134 - 135	10 - 20
						2338 - 2339	262 - 263	156 - 156	14 - 17
78/ 1/27	27	0 0 - 2 0	275 - 348	159 - 176	10 - 40				
78/ 1/27	27	17 0 - 24 0	172 - 66	304 - 3	10 - 40	1827 - 20 8	225 - 286	316 - 330	15 - 25
						2119 - 2135	329 - 338	340 - 342	10 - 15
78/ 1/28	28	0 0 - 2 0	66 - 138	3 - 20	10 - 40	029 - 035	83 - 87	7 - 8	15 - 25
78/ 1/28	28	17 0 - 24 0	323 - 216	147 - 207	10 - 40	2048 - 21 5	100 - 111	179 - 182	15 - 25

DATE YY/MM/DD	DOY JJJ	OBSERVATIONS TIME UT HHMM - HHMM	CML III (1965.0)	IO PHASE	WIDTH MHZ	EMISSIONS TIME UT HHMM - HHMM	CML III (1965.0)	IO PHASE	WIDTH MHZ
						2155 - 2226	141 - 160	189 - 193	15 - 25
						2259 - 24 0	180 - 216	198 - 207	10 - 30
78/ 1/29	29	0 0 - 2 0	216 - 289	207 - 223	10 - 40	0 0 - 144	216 - 279	207 - 221	10 - 30
78/ 1/29	29	1645 - 24 0	104 - 7	349 - 50	10 - 40	20 8 - 2145	227 - 285	17 - 31	10 - 31
						2229 - 2230	312 - 313	37 - 37	13 - 17
						2336 - 2338	352 - 354	47 - 47	10 - 13
78/ 1/30	30	0 0 - 130	7 - 61	50 - 63	10 - 40	0 3 - 110	9 - 49	50 - 60	10 - 20
78/ 1/30	30	1645 - 24 0	255 - 158	192 - 254	10 - 40				
78/ 1/31	31	0 0 - 2 0	158 - 230	254 - 271	10 - 40				
78/ 1/31	31	1645 - 19 6	45 - 130	36 - 56	15 - 35	18 5 - 1838	93 - 113	47 - 52	15 - 25
						20 4 - 2030	165 - 181	64 - 67	15 - 18
						22 8 - 24 0	240 - 308	81 - 97	15 - 25
						0 0 - 038	308 - 331	97 - 103	15 - 25
78/ 2/ 1	32	1630 - 24 0	187 - 99	237 - 301	10 - 40				
78/ 2/ 2	33	0 0 - 1 0	99 - 135	301 - 309	10 - 40				
78/ 2/ 2	33	1845 - 24 0	59 - 249	100 - 144	10 - 40	21 8 - 2114	145 - 149	120 - 121	20 - 23
						2338 - 24 0	236 - 249	141 - 144	10 - 23
78/ 2/ 3	34	0 0 - 1 0	249 - 285	144 - 153	10 - 40	0 0 - 046	249 - 277	144 - 151	10 - 23
78/ 2/ 3	34	1617 - 24 0	120 - 40	282 - 348	10 - 40	1954 - 2217	251 - 337	313 - 333	10 - 22
78/ 2/ 4	35	0 0 - 1 0	40 - 76	348 - 356	10 - 40				
78/ 2/ 4	35	1630 - 24 0	278 - 190	128 - 191	10 - 40	2223 - 2250	132 - 148	178 - 181	15 - 22
78/ 2/ 5	36	0 0 - 1 0	190 - 226	191 - 200	10 - 40	016 - 054	200 - 223	194 - 199	13 - 27
78/ 2/ 5	36	1612 - 24 0	58 - 341	329 - 35	10 - 40	1833 - 1921	143 - 172	349 - 355	11 - 22
						2112 - 2212	239 - 275	11 - 20	10 - 25
						23 2 - 2330	306 - 323	27 - 31	15 - 25
78/ 2/ 6	37	0 0 - 1 0	341 - 17	35 - 43	10 - 40				
78/ 2/ 6	37	1558 - 24 0	200 - 131	170 - 238	10 - 40	1839 - 19 9	297 - 315	193 - 197	15 - 23
						1958 - 1959	345 - 346	204 - 204	15 - 20
78/ 2/ 7	38	0 0 - 1 0	131 - 168	238 - 247	10 - 40				
78/ 2/ 7	38	1550 - 24 0	346 - 282	13 - 82	10 - 40	1847 - 19 7	93 - 105	38 - 40	20 - 28
78/ 2/ 8	39	0 0 - 1 0	282 - 318	82 - 90	10 - 40				
78/ 2/ 8	39	1620 - 24 0	154 - 72	220 - 285	10 - 40	1735 - 2019	200 - 299	231 - 254	10 - 34
78/ 2/ 9	40	0 0 - 020	72 - 84	285 - 288	10 - 40				
78/ 2/ 9	40	1715 - 24 0	338 - 223	72 - 129	15 - 35	1743 - 1744	355 - 356	76 - 76	25 - 35
						20 8 - 2012	83 - 85	96 - 97	15 - 30
						2059 - 21 1	113 - 115	103 - 104	28 - 35
						2335 - 24 0	208 - 223	125 - 129	15 - 22
78/ 2/10	41	0 0 - 018	223 - 234	129 - 131	15 - 35	0 0 - 018	223 - 234	129 - 131	15 - 22
78/ 2/10	41	16 5 - 22 5	86 - 304	265 - 316	10 - 40	2027 - 2129	245 - 282	302 - 311	15 - 25
78/ 2/11	42	16 8 - 24 0	238 - 164	109 - 176	10 - 40	1626 - 1635	249 - 255	112 - 113	20 - 25
						1824 - 1834	321 - 327	128 - 130	15 - 20
						2235 - 2353	112 - 160	164 - 175	10 - 20
78/ 2/12	43	0 0 - 0 6	164 - 169	176 - 177	10 - 40				
78/ 2/12	43	16 4 - 24 0	27 - 374	312 - 19	10 - 40	2217 - 2251	252 - 273	5 - 10	10 - 20
78/ 2/13	44	0 0 - 0 4	314 - 317	19 - 20	10 - 40				
78/ 2/13	44	1557 - 24 0	173 - 105	155 - 223	10 - 40				
78/ 2/14	45	0 0 - 030	105 - 123	223 - 227	10 - 40				
78/ 2/14	45	1546 - 24 0	317 - 255	357 - 66	10 - 40	2027 - 2045	127 - 137	36 - 39	15 - 27
						2255 - 24 0	216 - 255	57 - 66	13 - 25
78/ 2/15	46	0 0 - 030	255 - 273	66 - 71	10 - 40	0 0 - 028	255 - 272	66 - 70	13 - 25
78/ 2/15	46	1546 - 24 0	107 - 46	200 - 270	10 - 40	1811 - 2129	195 - 314	221 - 249	15 - 26
78/ 2/16	47	0 0 - 030	46 - 64	270 - 274	10 - 40				
78/ 2/16	47	1543 - 24 0	256 - 196	43 - 113	15 - 35	2047 - 22 2	80 - 125	86 - 97	17 - 35
78/ 2/17	48	0 0 - 030	196 - 214	113 - 118	15 - 35				
78/ 2/17	48	1542 - 24 0	46 - 347	246 - 317	10 - 40	2020 - 22 4	214 - 277	286 - 300	15 - 25
78/ 2/18	49	0 0 - 030	347 - 5	317 - 321	10 - 40				
78/ 2/18	49	1640 - 1819	231 - 291	98 - 112	10 - 40				

Figure 1: *First page of Leblanc et al. (1981) available from NASA/ADS.*

Table 1: *Catalogue papers, with links to PDF files, containing the raw raster scans for each catalogue used in this collection. We provide the page number range where the catalogue section is located in the PDF file, as well as the number of table rows (including 4 lines of table header for each table).*

Reference	**NASA/ADS Bibcode (and File)**	**Size**	**Pages**	**Rows**
Leblanc et al., A&AS, 1981	`1981A&AS...46..135L` (PDF File)	10 pages	138–147	1021
Leblanc et al., A&AS, 1983	`1983A&AS...54..135L` (PDF File)	10 pages	137–146	966
Leblanc et al., A&AS, 1989	`1989A&AS...77..425L` (PDF File)	11 pages	427–437	1148
Leblanc et al., A&AS, 1990	`1990A&AS...86..191L` (PDF File)	13 pages	193–205	1343
Leblanc et al., A&AS, 1993	`1993A&AS...98..529L` (PDF File)	13 pages	534–546	1340

Table 2: *Columns of the published catalogue tables. The examples are provided for the first row of the first catalogue. The whitespace present in each fields are shown with the "␣" symbol.*

	Group	**Header**	**Description**	**Unit**	**Example**
1	Date	DATE YY/MM/DD	Abbreviated calendar date	—	`78/␣1/␣1`
2	Date	DOY JJJ	Day of current year	day	`␣␣1`
3	Observations	TIME UT (HHMM - HHMM)	Time interval	—	`1930␣-␣24␣0`
4	Observations	CML III (1965.0)	Central Meridian Longitude range	degrees	`248␣-␣␣51`
5	Observations	IO PHASE	Range of the apparent phase of Io	degrees	`119␣-␣157`
6	Observations	WIDTH	Spectral range	MHz	`10␣-␣50`
7	Emissions	TIME UT (HHMM - HHMM)	Time interval	—	`2054␣-␣2156`
8	Emissions	CML III (1965.0)	Central Meridian Longitude range	degrees	`299␣-␣336`
9	Emissions	IO PHASE	Range of the apparent phase of Io	degrees	`131␣-␣139`
10	Emissions	WIDTH	Spectral range	MHz	`10␣-␣30`

also available for each observed emission. The available ephemeris parameters are: (a) the observer's Central Meridian Longitude (CML) at the start and end of the interval; and (b) the apparent phase of Io, relative to the observer, at the start and end of the interval. The CML is the longitude of the observer, provided here in the *Jovian System III (1965.0)* longitude system (Fränz & Harper, 2002). The CML and the Io phase are geometric parameters linked to the physics of the Jovian radio emissions (see, e.g., Figure 2 of Louis et al., 2019, and references therein).

All tables are identically formatted, with 10 columns, which can be grouped as: the current date information (2 columns), the observation coverage (4 columns) and the observed emission coverage (4 columns). The detailed content of the columns is presented in Table 2.

The 57 pages of printed catalogue tables have been collected and processed using a free online OCR (Optical Character Recognition) tool, the OnlineOCR.net. As listed in Table 1, the full set of catalogues covers a total of more than 5800 lines of text. Submitting cropped sections of the tables (about 20 rows at a time) provided better results than submitting the full page at once, especially when the scanned page was not correctly aligned (see, e.g., p. 427 of Leblanc et al., 1989a). Each digitised table section is then manually edited to fit the original fixed column format. The edited fields for dates and times are using a zero-padded format.

2.2 Compiled catalogue

The compiled catalogue was built from the digitised *Leblanc et al.* catalogues, and is available in TFCat format (Cecconi et al., 2021b; Cecconi et al., 2023a). The observational

Table 3: *Context metadata in the compiled catalogue, exposed in the* `properties` *section of each TFCat feature. The last column presents the UCD (Unified Content Descriptor, Cecconi et al., 2021a) for each property.*

Name	Description	Unit	UCD
`obs_id`	Unique identifier in catalogue	—	`meta.code.id`
`cml_beg`	CML at observation start	deg	`pos.bodyrc.lon;time.start`
`cml_end`	CML at observation end	deg	`pos.bodyrc.lon;time.end`
`meridian_transit`	Jupiter local meridian transit time	ISO 8601	`time.epoch;obs.transit`
`am_phase_beg`	Amalthea phase at observation start	deg	`pos.angDistance;time.start`
`am_phase_end`	Amalthea phase at observation end	deg	`pos.angDistance;time.end`
`io_phase_beg`	Io phase at observation start	deg	`pos.angDistance;time.start`
`io_phase_end`	Io phase at observation end	deg	`pos.angDistance;time.end`
`eu_phase_beg`	Europa phase at observation start	deg	`pos.angDistance;time.start`
`eu_phase_end`	Europa phase at observation end	deg	`pos.angDistance;time.end`
`ga_phase_beg`	Ganymede phase at observation start	deg	`pos.angDistance;time.start`
`ga_phase_end`	Ganymede phase at observation end	deg	`pos.angDistance;time.end`
`ca_phase_beg`	Callisto phase at observation start	deg	`pos.angDistance;time.start`
`ca_phase_end`	Callisto phase at observation end	deg	`pos.angDistance;time.end`

context metadata included in the compiled catalogue is presented in Table 3, and cover the ephemeris of the Jovian moons known or suspected to have an effect on Jovian radio emissions (Zarka, 2004). The ephemeris data have been computed using SPICE kernels (Acton, 1996), accessed through a WebGeoCalc (Acton et al., 2018) instance installed at the Observatoire de Paris. The ephemeris stored in the compiled catalogue are taking into account the light travel time between the Jovian system and the observer.

3 First results

Using this metadata, we can rebuilt the Io–CML phase diagram presented in Figure 2 of Leblanc et al. (1993). This is shown in Figure 2, where the full interval (13 years of observations) is included. It can also be compared to Figure 6 of Marques et al. (2017) (see also Figure B.1), which were produced from the data acquired from 1990 to 2015, using NDA data acquired with a digital receiver installed in 1990.

Such phase–CML plots are very useful to identify Jovian decametric emissions induced by moons, and serve as a reference for the Jupiter online probability tool recently released by the NDA team[2] (Aicardi et al., 2022; Cecconi et al., 2023b).

3.1 Io–controlled components

The distribution shown in Figure 2 is very similar to Figure 6 of Marques et al. (2017), with the following exception: The so-called Io-D emissions are missing, and the Io-C ones are less prominent.

In order to examine why the Io-C and Io-D emissions are observed with a lower occurrence in the *Leblanc et al.* catalogue than in that of Marques et al. (2017), we have statistically

[2] https://jupiter-probability-tool.obspm.fr

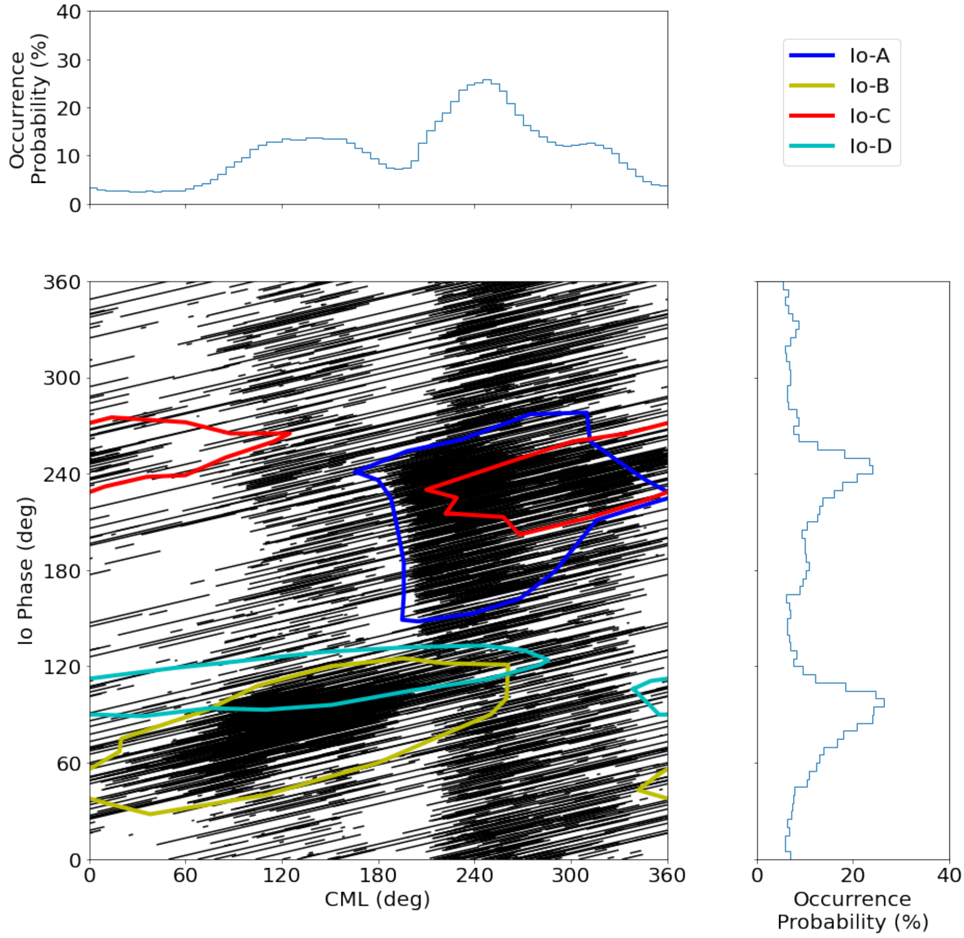

Figure 2: *Io phase–CML diagram for the 13 years of observations. The upper and right-hand side histograms are showing the occurrence probability (counts of observed emissions normalised by the count of observations in each bin). The coloured contours show the locus of the Io-A, -B, -C and -D emissions. They are derived from Marques et al. (2017), and are described in Appendix B.*

studied the upper frequency limit of the various Jovian radio components. For the catalogue published by Marques et al. (2017), we sorted the radio components according to the *emission type* annotation of that catalogue. For the *Leblanc et al.* catalogue, we used the selection method detailed in Appendix B.

Figure 3 shows stacked histograms of occurrence for the upper frequency limit of the various Jovian radio components. The two plots are strickingly similar, considering the rough selection method applied to select the Io–controlled emissions from *Leblanc et al.* catalogue. The Io-C and Io-D components have an upper frequency limit reaching ∼25 MHz, and many such events display a much lower spectral upper limit. This is also clear from Figure B.2 of Marques et al. (2017).

From 1978 to 1989, the radio receivers used with the NDA were storing information on film rolls (Lamy et al., 2017; Lamy et al., 2023). There is no explicit description of how the Jovian components were identified in the papers by *Leblanc et al.*, except for Figure 1 of Leblanc et al. (1989a), which shows a dynamic spectrum reproduced from the film roll. From that figure, it is clear that the identification of radio components below 25 MHz is

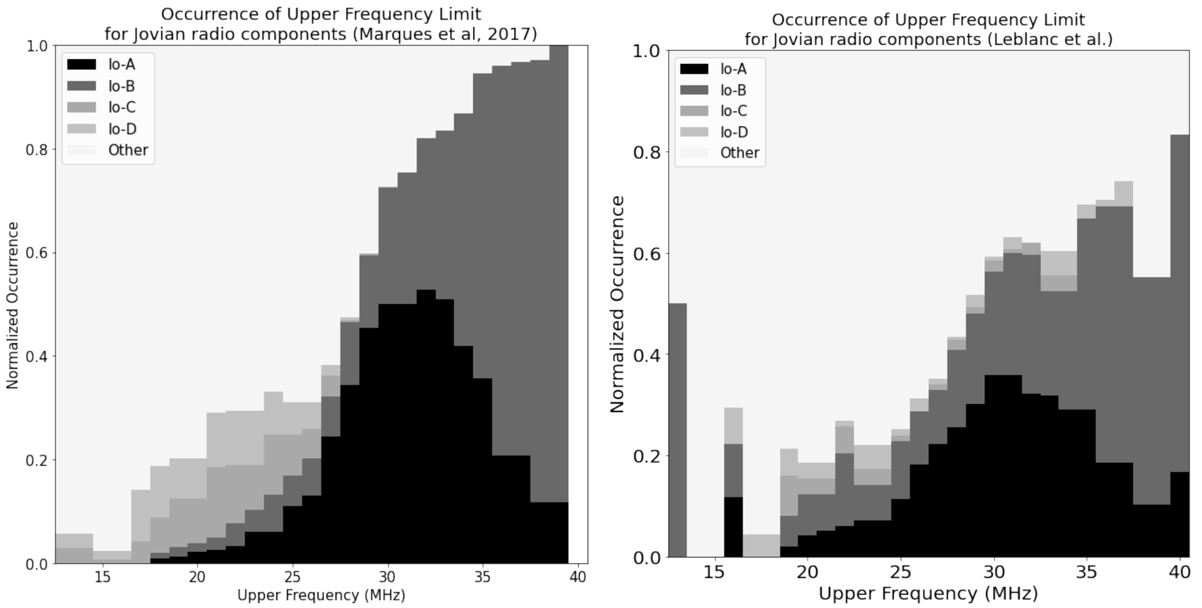

Figure 3: *Occurrence of upper frequency limit for the various Jovian radio components (Io-A, Io-B, Io-C Io-D and Other). The left-hand side plot is computed from Marques et al. (2017) catalogue, while the right-hand side one is derived from the* Leblanc et al. *catalogue.*

challenging without advanced data processing software. This fact can easily explain why the Io-C and Io-D component have a lower occurrence in the *Leblanc et al.* catalogue.

3.2 Ganymede–controlled components

The Ganymede control on the Jovian decametric radio emissions has been reported by Hospodarsky et al. (2001); Zarka et al. (2017); Zarka et al. (2018); Louis et al. (2020). Using the phase–CML locus of the Io–related emissions, as shown in Figure 2, we can select out the Io–related emissions from the catalogue and display the remaining elements in a Ganymede phase–CML diagram, as shown in Figure 4. The upper histogram of that figure shows the expected CML variation of occurrence probability, while that on the right-hand side shows a slight increase in probability around a Ganymede phase of 90°. Similarly to the processing applied in Figure 4 of Zarka et al. (2017), Figure 5 shows the Ganymede phase–CML diagram removing emissions with CML $> 200°$. The Ganymede–phase occurence probability histogram clearly shows two increased probability regions around Ganymede phase of $\sim$90° and $\sim$260°, consistent with the result of Zarka et al. (2017). This observation is a new evidence of Ganymede control on Jovian decametric emissions using an older dataset than the previously published results.

4 Quality and validation

The OCR tool provided us with sets of text containing most of the table content in a state that allowed us to reconstruct the original content, requiring however thorough manual

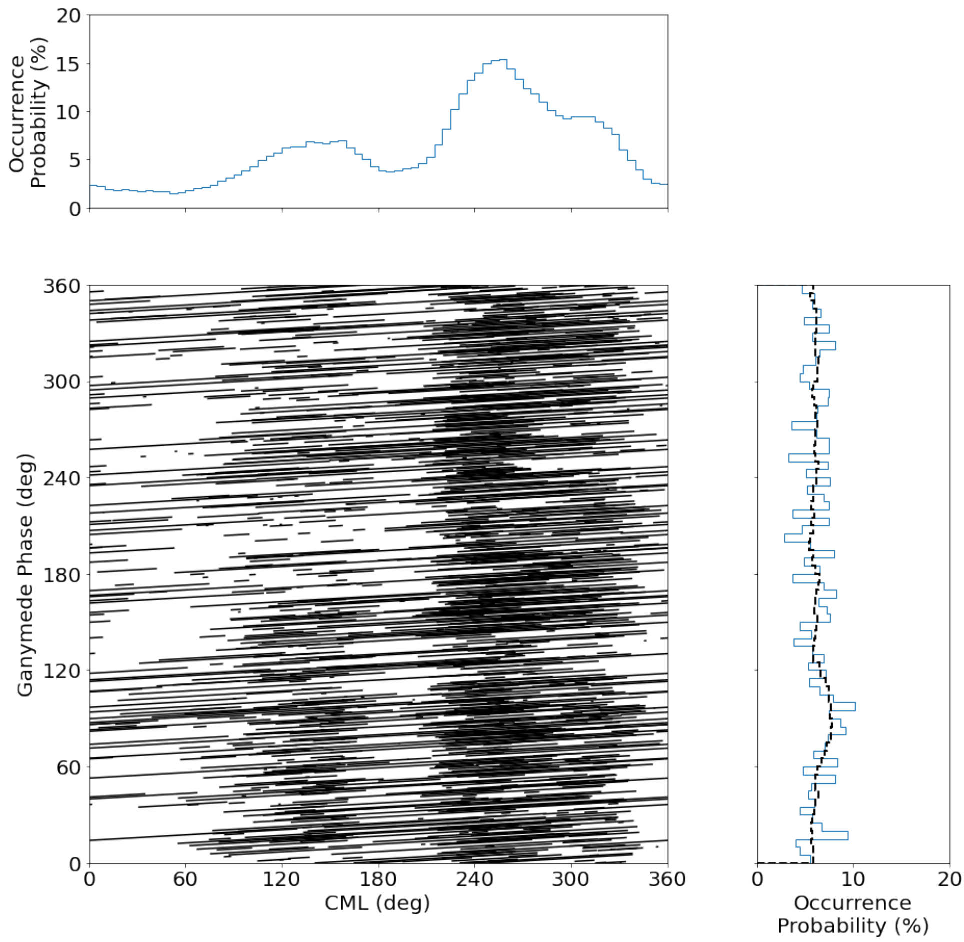

Figure 4: *Ganymede phase–CML diagram for the 13 years of observations, after removal of the Io–controlled events, as described in Appendix B. The side histograms are showing the occurrence probability (counts of observed emissions normalised by the count of observations in each bin). On the right-hand side histogram, the dashed line is an displaying a running average on 10 consecutive bins.*

editing to obtain scientifically validated content. The average quality of the input scanned images induced a series of typical errors, such as confusion between characters: `8` for `3`, or `I` for `1`. After the manual reformatting step, during which most of the obvious errors were fixed (e.g., the resulting lines should only contain numerical characters), a series of quality validation scripts were written in order to check the consistency of each column (e.g., the day of year value (column 2) must be strictly increasing except at the turn of each year).

The quality validation step also allowed us to fix a few typos and inconsistencies published in the original catalogues. We found rows with inconsistent time intervals, such as, e.g., on page 195 of (Leblanc et al., 1990): the second row corresponding to date `85/08/18` should be split into two rows, since the time interval crosses midnight. Duplicate observation rows have also been identified, and has been fixed, see e.g., on page 431 of (Leblanc et al., 1989a): the observation covering the night of March 30th to 31st is duplicated, with one emission each. Figure 6 shows the printed version and the corrected one.

The catalogues conversion process was managed using a git repository (hosted on the Git-

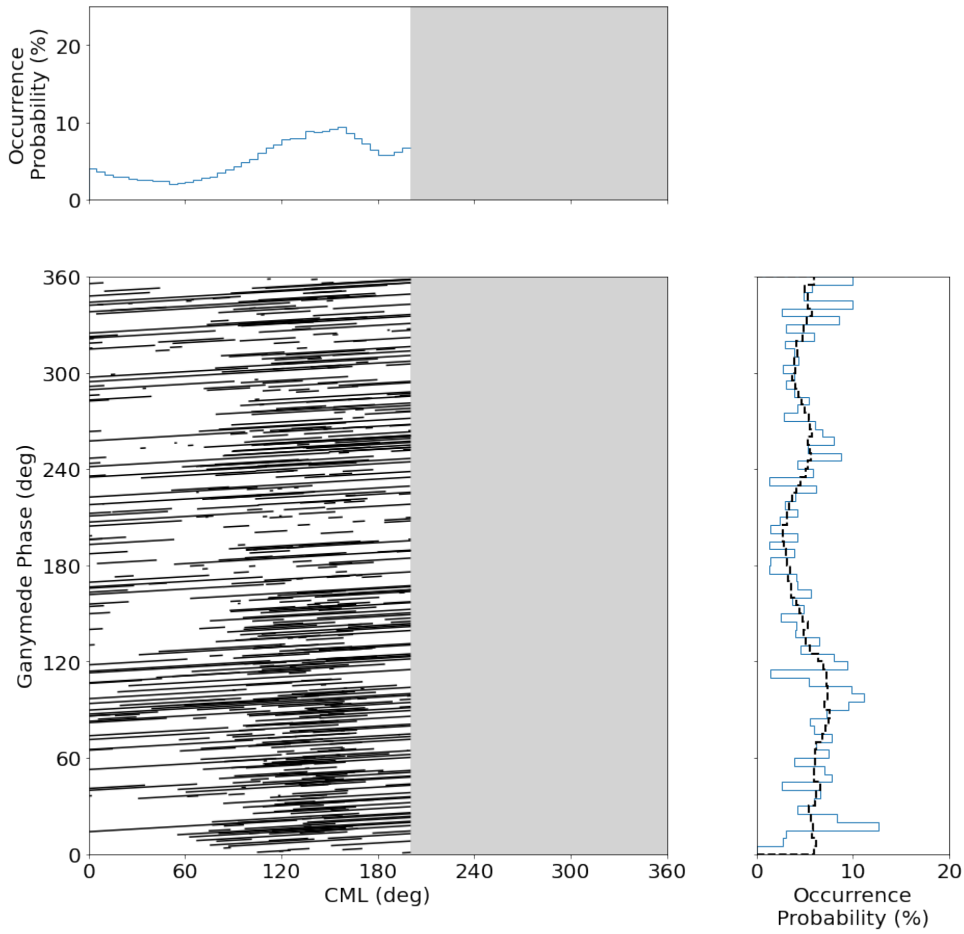

Figure 5: *Same as Figure 4 but removing all emissions with CML* $> 200°$.

Original print version:

83/ 3/3Ø	89	235Ø - 24 Ø	66 - 72	265 - 266	13 - 4Ø				
83/ 3/31	9Ø	Ø Ø - 8 5	72 - 5	266 - 334	13 - 4Ø	115 - 21Ø	117 - 15Ø	277 - 284	13 - 26
83/ 3/3Ø	89	235Ø - 24 Ø	66 - 72	265 - 266	13 - 4Ø				
83/ 3/31	9Ø	Ø Ø - 8 5	72 - 5	266 - 334	13 - 4Ø	43Ø - 537	235 - 275	3Ø4 - 314	13 - 26

Fixed processed version:

83/03/30	89	2350 - 2400	66 - 72	265 - 266	13 - 40				
83/03/31	90	0000 - 0805	72 - 5	266 - 334	13 - 40	0115 - 0210	117 - 150	277 - 284	13 - 26
						0430 - 0537	235 - 275	304 - 314	13 - 26

Figure 6: *Duplicated observation in Leblanc et al. (1989a), with the original printed version (top) and the processed (and fixed) version (bottom).*

lab server provided by the Observatoire de Paris), in order to keep track of the corrections and modifications. During the validation phase, all issues raised on the digitised content (mostly errors in the OCR process), or in the original printed catalogues were tracked using the “issues” feature of the Gitlab repository.

The digitised catalogues have also been ingested into the Vizier service at CDS (Centre de Données de Strasbourg), under reference VI/158. Thanks to the quality process in place at CDS, a set of extra typos were fixed.

5 Conclusion and perspectives

The *Leblanc et al.* catalogues have been digitised, processed and merged into an open access catalogue of events following the TFCat standard. The consolidated catalogue contains new observational and contextual metadata, corresponding to the current known and suspected physical dependencies of the observed radio emissions. In addition to the validation and quality control described in Section 4, the phase–CML diagrams presented in Figures 2, 4 and 5 also validates the quality of the digitised catalogue by confirming a recent result derived from an independent dataset. Further analysis of this catalogue will be possible thanks to the recent digitisation of the historic NDA film rolls (Lamy et al., 2023), which are the orginal source of the *Leblanc et al.* catalogues.

Other catalogues have been identified and will be converted in the future by the MASER team (Leblanc et al., 1980b; Barrow, 1981; Aubier & Genova, 1985).

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A Data and software availability

The source data are available from NASA/ADS, as presented in Table 1.

The resulting raw digitised tables are available in two forms: (a) with the original fixed column-width formatting, in a raw ASCII tabular file (Leblanc et al., 2020a,b,c,d,e); and (b) a merged version of the original catalogue in the Vizier service at CDS, under reference VI/158 (Leblanc et al., 2023).

The output data collection (Cecconi et al., 2021c) is citable and accessible using its registered DOI (https://doi.org/10.25935/1fqm-fs07). The landing page of the data collection

[3] `https://webgeocalc.readthedocs.io/en/latest/`

provides access to both available formats, with individual links. The use of TFCat formatted file allows to share the data collection using interoperable interfaces, such as a TAP (Table Access Protocol) (Dowler et al., 2019), as described on the data collection landing page.

B Selection of Io–controlled emissions

The Io-A, -B, -C and -D contours displayed in Figure 2 have been manually outlined from Figure 7a of Marques et al. (2017). Figure B.1 shows these contours overlayed on top of it.

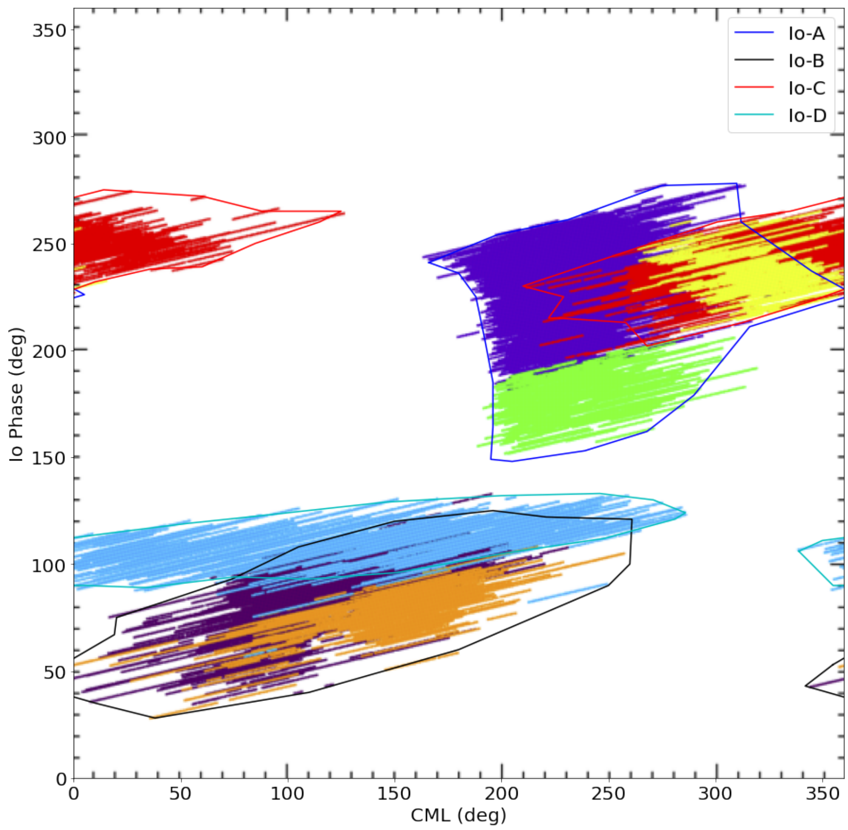

Figure B.1: *Io phase–CML diagram figure extracted from Marques et al. (2017), with superimposed Io-A, -B, -C and -D regions used for selection in this paper.*

Contrary to the catalogue of Marques et al. (2017), the digitised catalogue does not include a classification of the detected features. The contour have thus been used to exclude features, which are statistically Io controlled. The feature selection rule is: *any phase–CML segment fully inside the region formed by union of the contour polygons is considered as Io–controlled*. Figure B.2 shows the resulting features in an Io and Ganymede phase–CML.

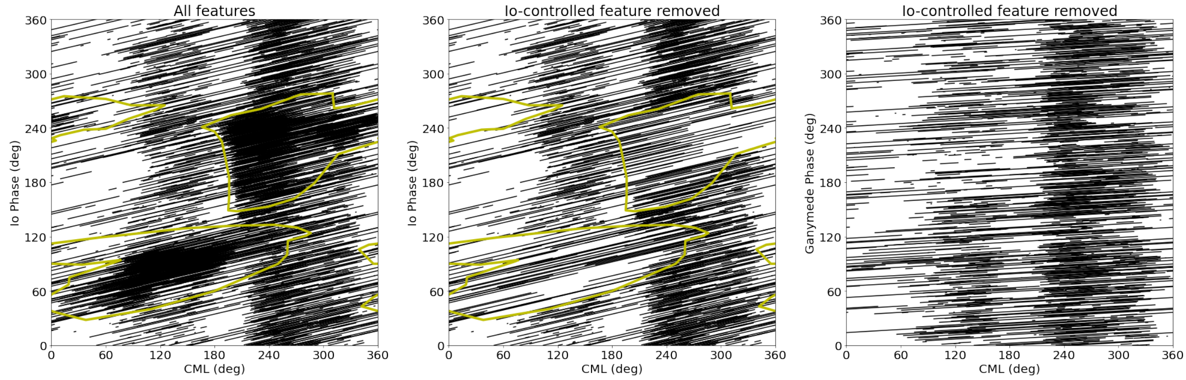

Figure B.2: *Phase–CML diagram of* Leblanc et al. *catalogue features, after filtering Io controlled events. The left-hand side plot shows the Io phase–CML diagram with all data (same as in Figure 2). The middle plot shows the Io phase–CML diagram, after removal of the Io-controlled emissions, as described in this section. On left-hand side and middle plots, the union of Io-controlled regions is shown as a set of yellow polygon. The right-hand side plot shows the same series of features, in a Ganymede phase–CML diagram. The latter is the same diagram as in Figure 4.*

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