Key Program for NenuFAR

« Exoplanets, Stars, and their Plasma Interactions »

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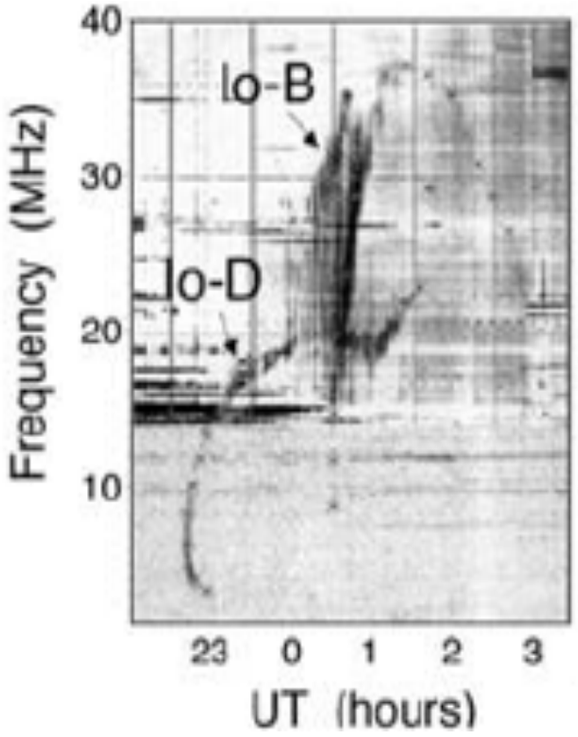
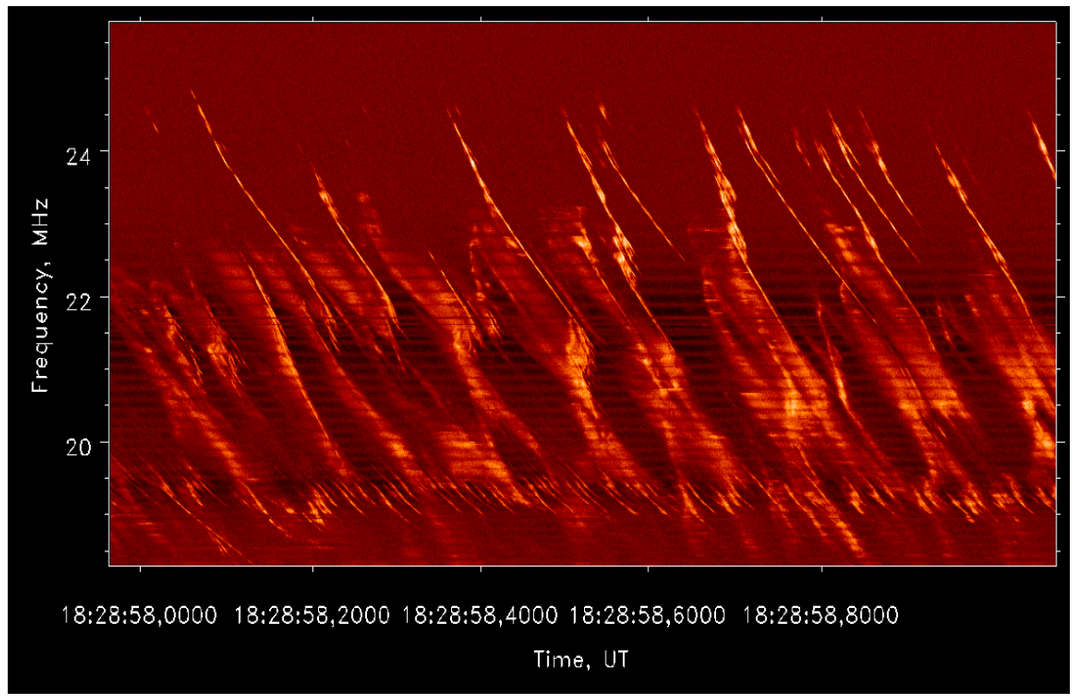
Solar system magnetospheric radio emissions ...

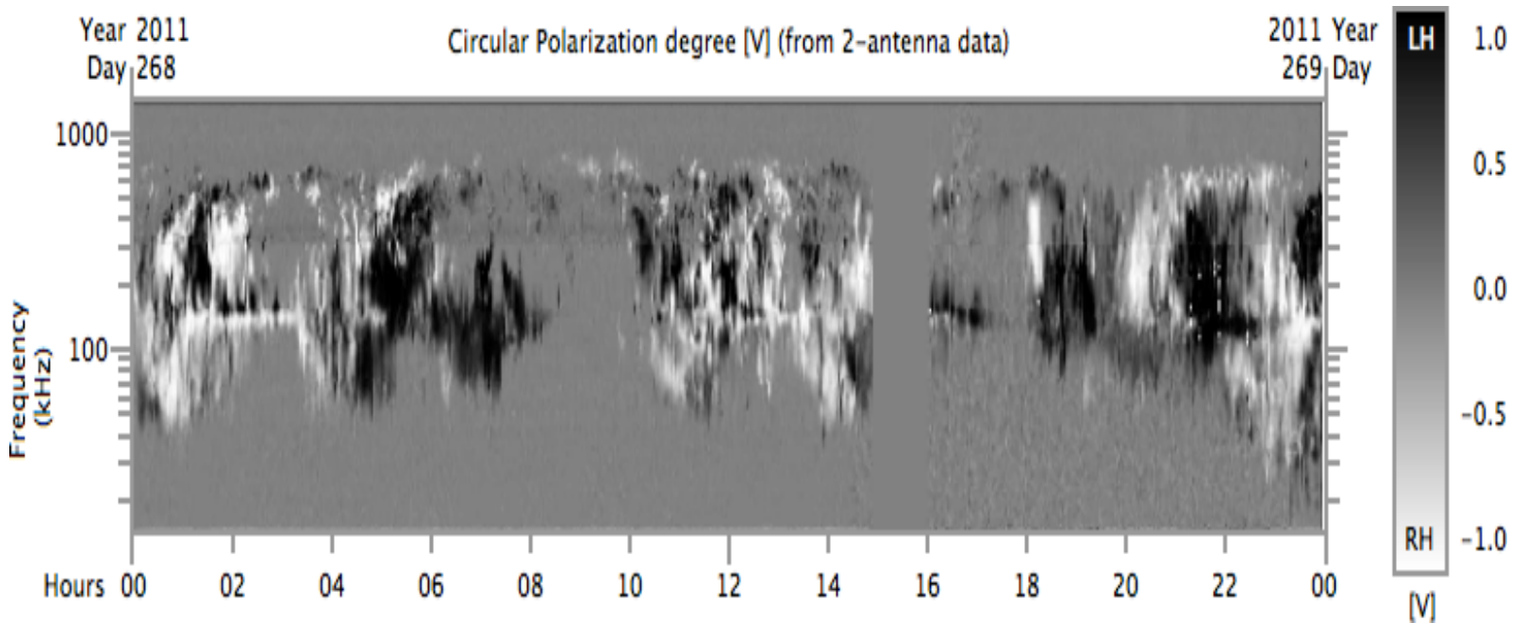
Jupiter





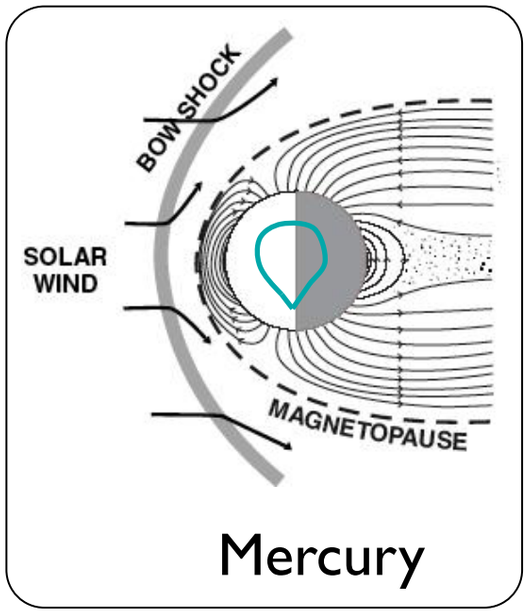
[Queinnec & Zarka, 1998; Hess et al., 2008; Ryabov et al., 2014]

Saturn

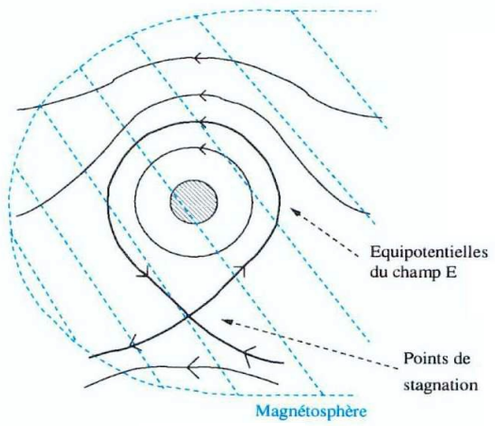


[Lamy et al., 2008]

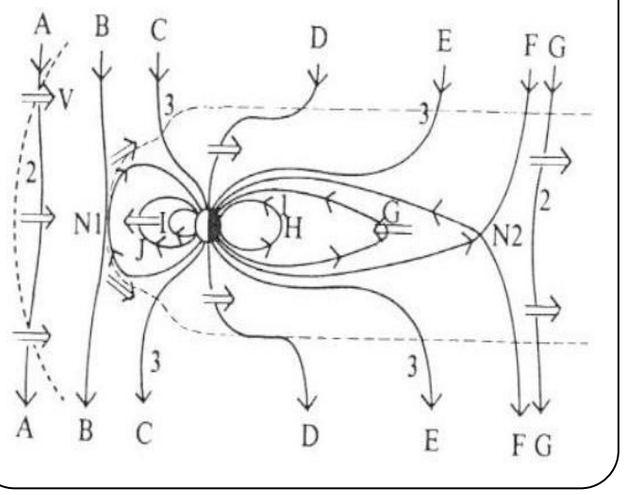
Structure & dynamics of all magnetospheres strongly different

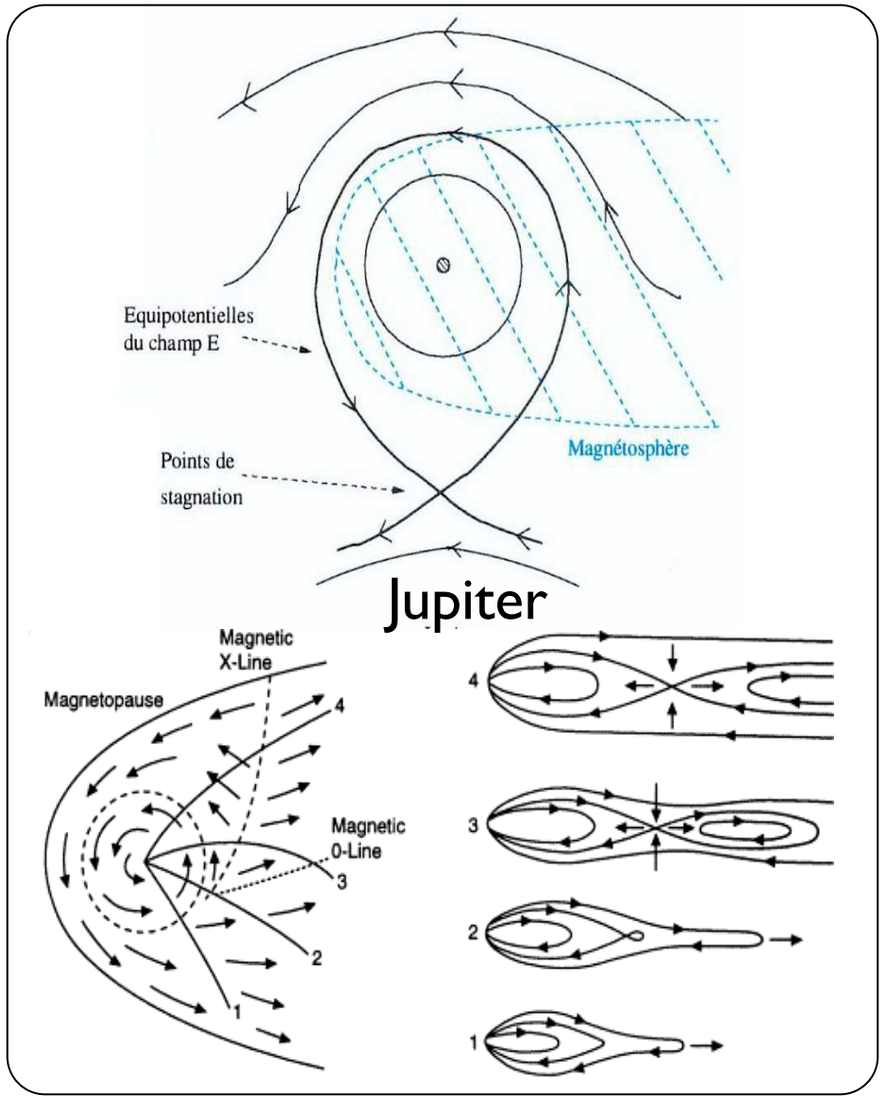


Mercury

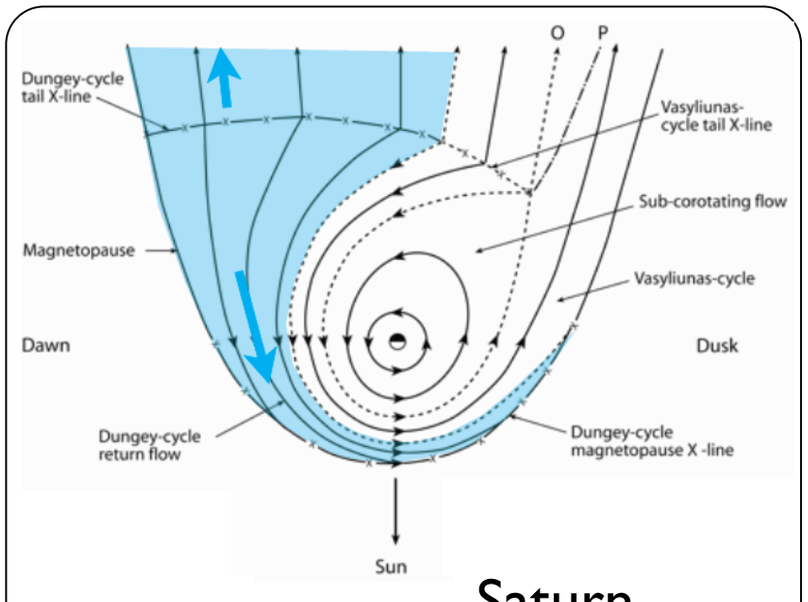


Earth

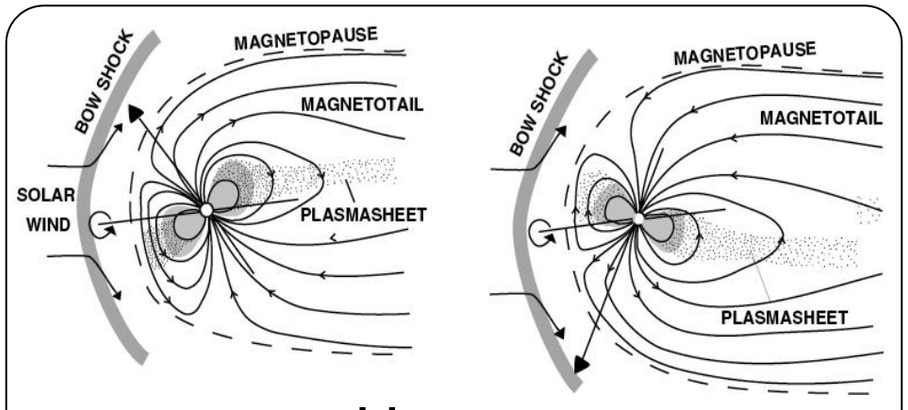




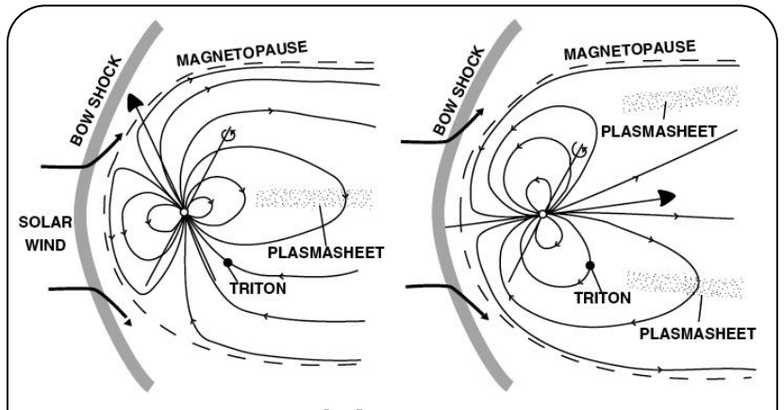
Jupiter



Saturn



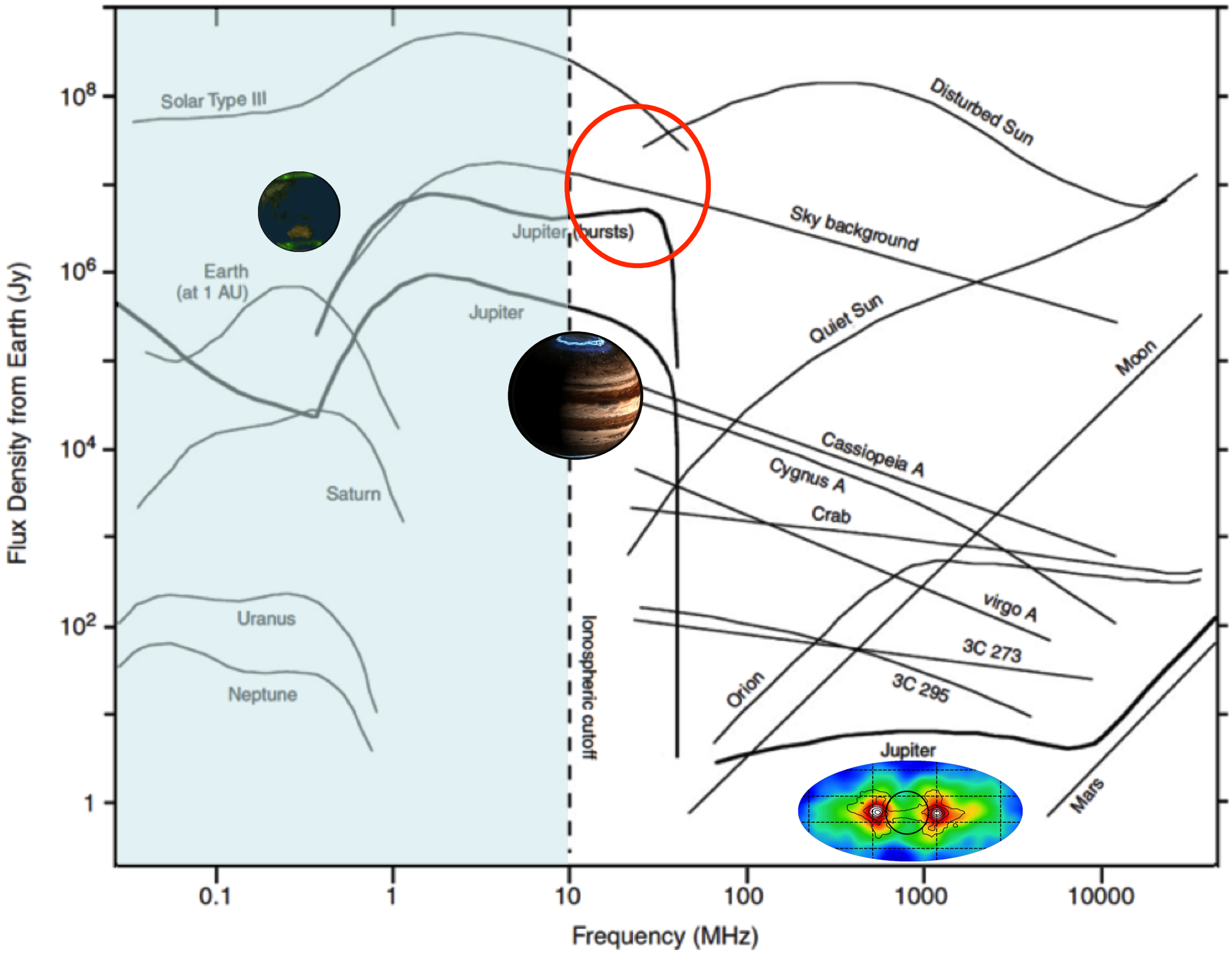
Uranus



Neptune

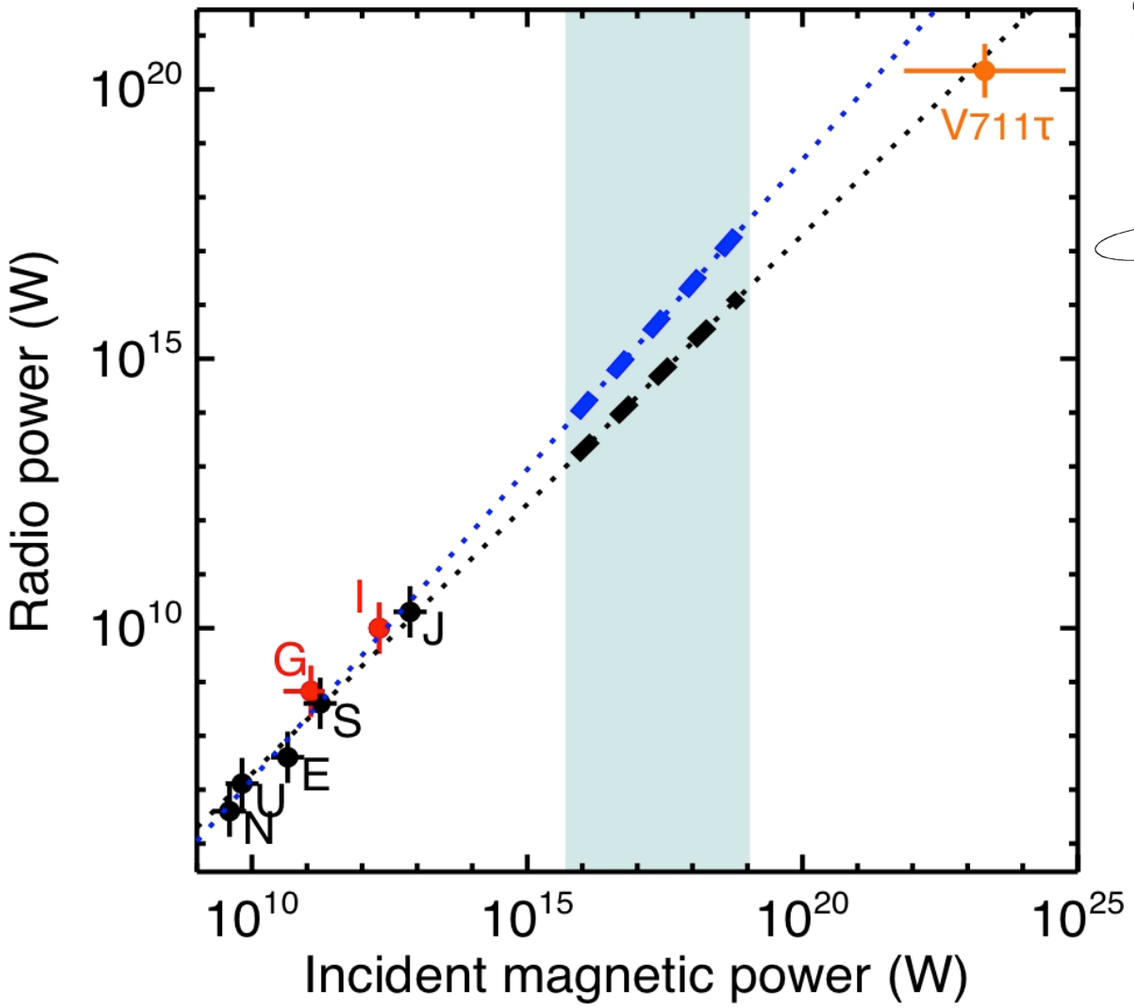
→ need for comparative exo-magnetospheric physics

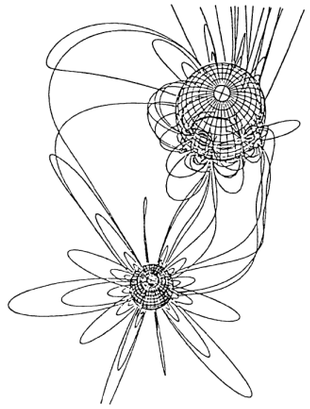
All magnetospheres produce intense non-thermal radio emissions



- detectable from exoplanets ? → Jupiter at ≤ 0.2 pc with LOFAR

Predicted intensities : radio-magnetic scaling law



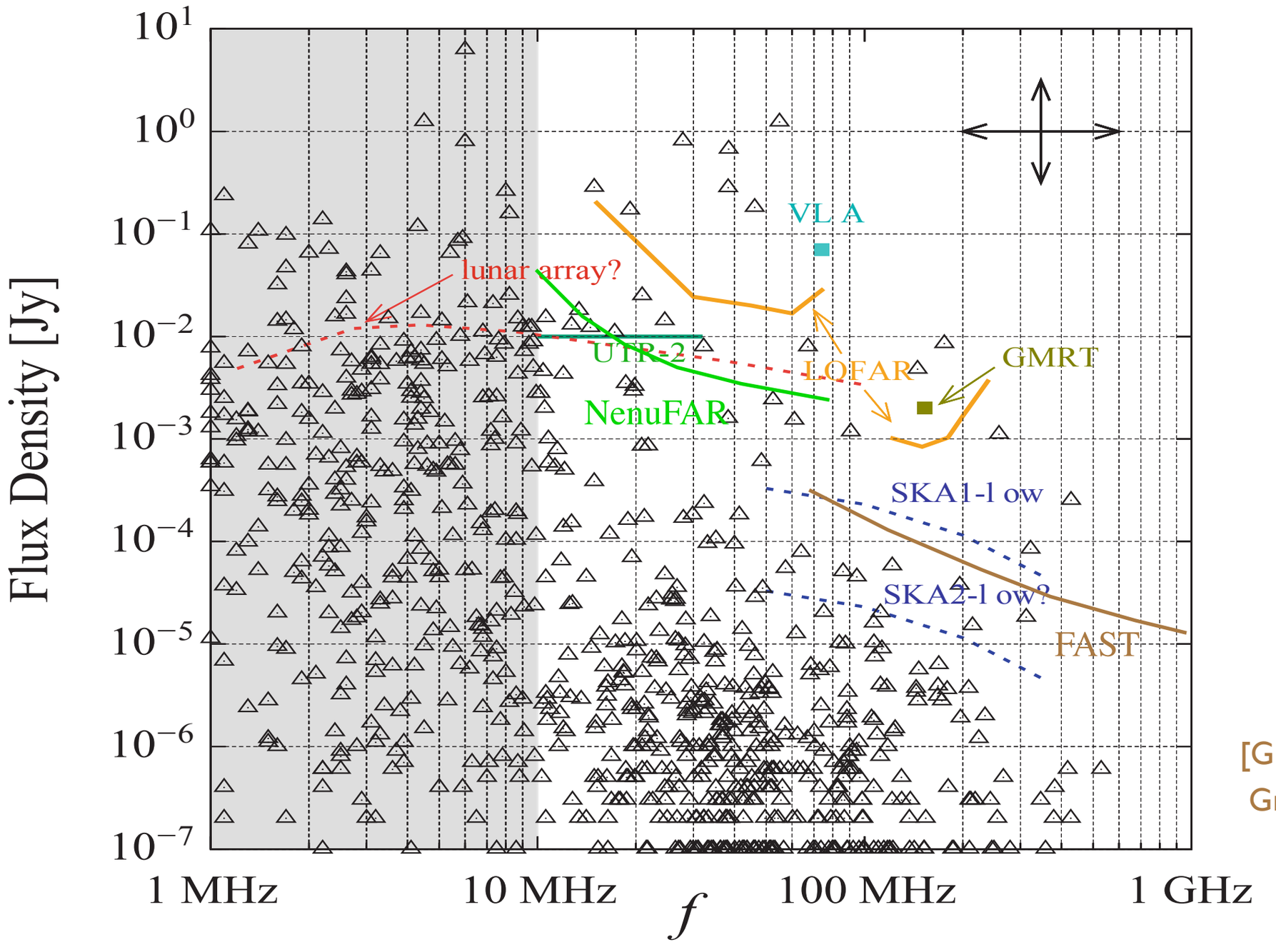


[Zarka et al., 2001 ; Zarka, 2007, 2010, 2018]

hot Jupiters : magnetospheric emission and Io-induced emission

+ other predictions

Application to known exoplanets : candidates detectable by present/future large radiotelescopes



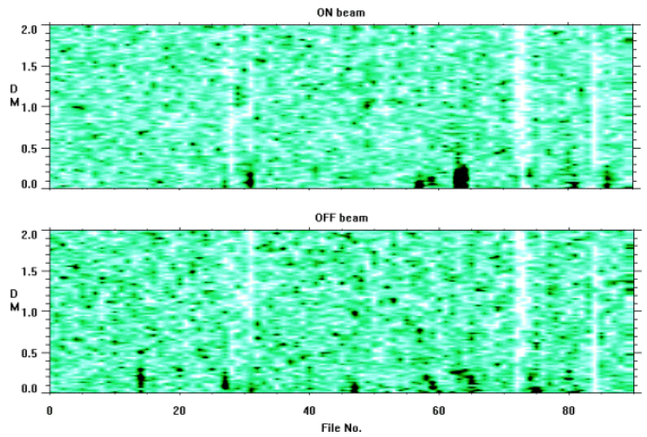
[Grießmeier et al., 2011; Grießmeier, 2018]

→ Detectable candidates predicted

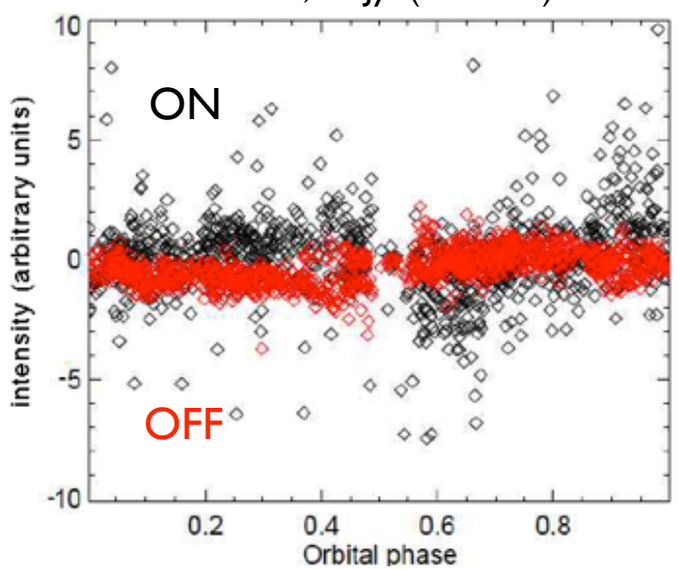
Previous observations

UTR-2 10-32 MHz

ρ Cr, 160 mJy (On / Off)



Corot 7, ~1 Jy (On / Off)

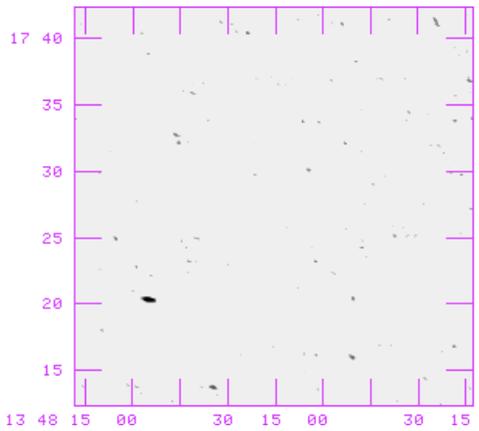


[Ryabov et al., 20 4 ; Vasylieva et al., 2016]

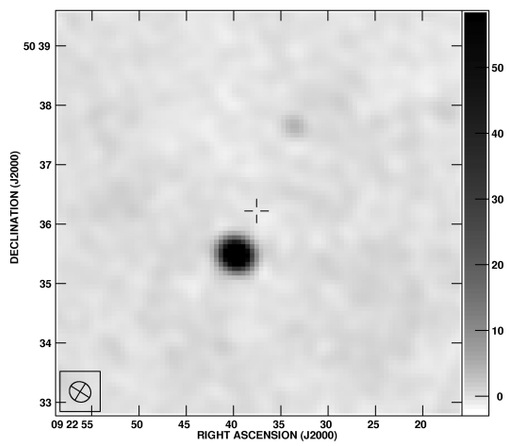
?

VLA 74 MHz

τ Boo, 74 MHz, 100 mJy



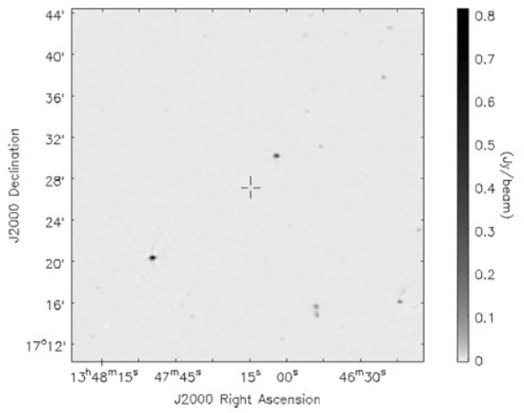
HD80606, 330 MHz, 1.7 mJy

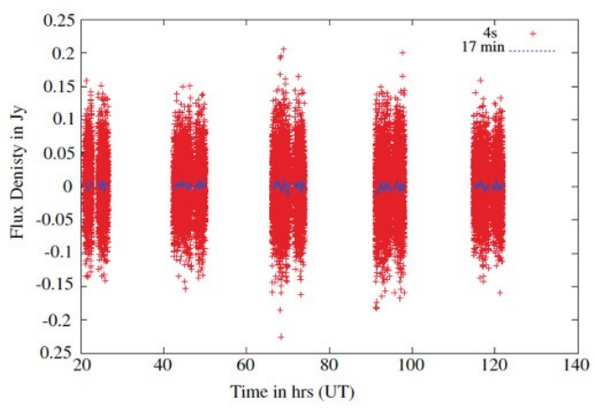


[Farrell et al., 2003, 2004 ; Lazio & Farrell, 2007]

GMRT 150 MHz

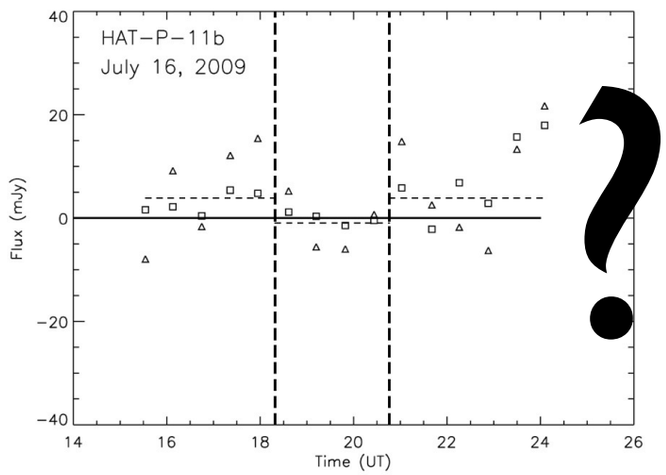
τ Boo, 150 MHz, 1 mJy





[Hallinan et al., 2013]

Hat-P-11, 150 MHz, 3.9 mJy



?

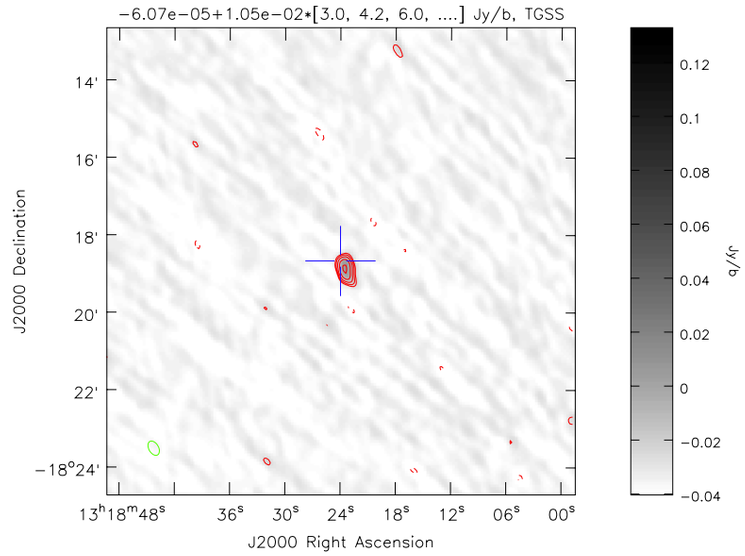
[Lecavelier et al., 2013]

Previous observations

GMRT 150 MHz

TGSS → 4 candidates out of 175 exoplanetary systems, ~ 18-120 mJy

[Sirothia, et al., 2014]



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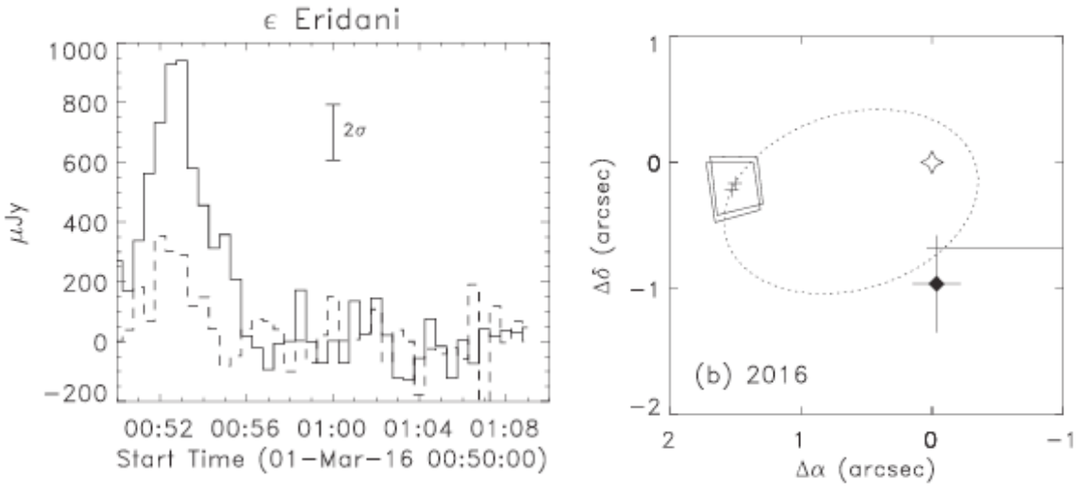
VLA 2-4 GHz



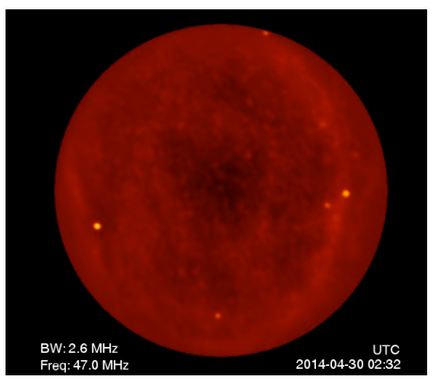
[Bastian et al., 2018]

?

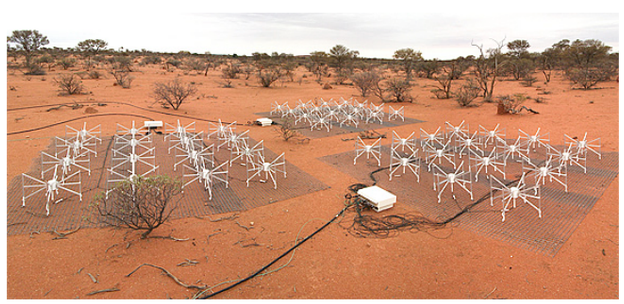
LWA (+ OLWA?) 10-88 MHz

~5000+ h on ~12 Hot Jupiters

[Hartman, Hallinan, et al.]



MWA 163-231 MHz



Proxima Centauri, V, 18 mJy ?

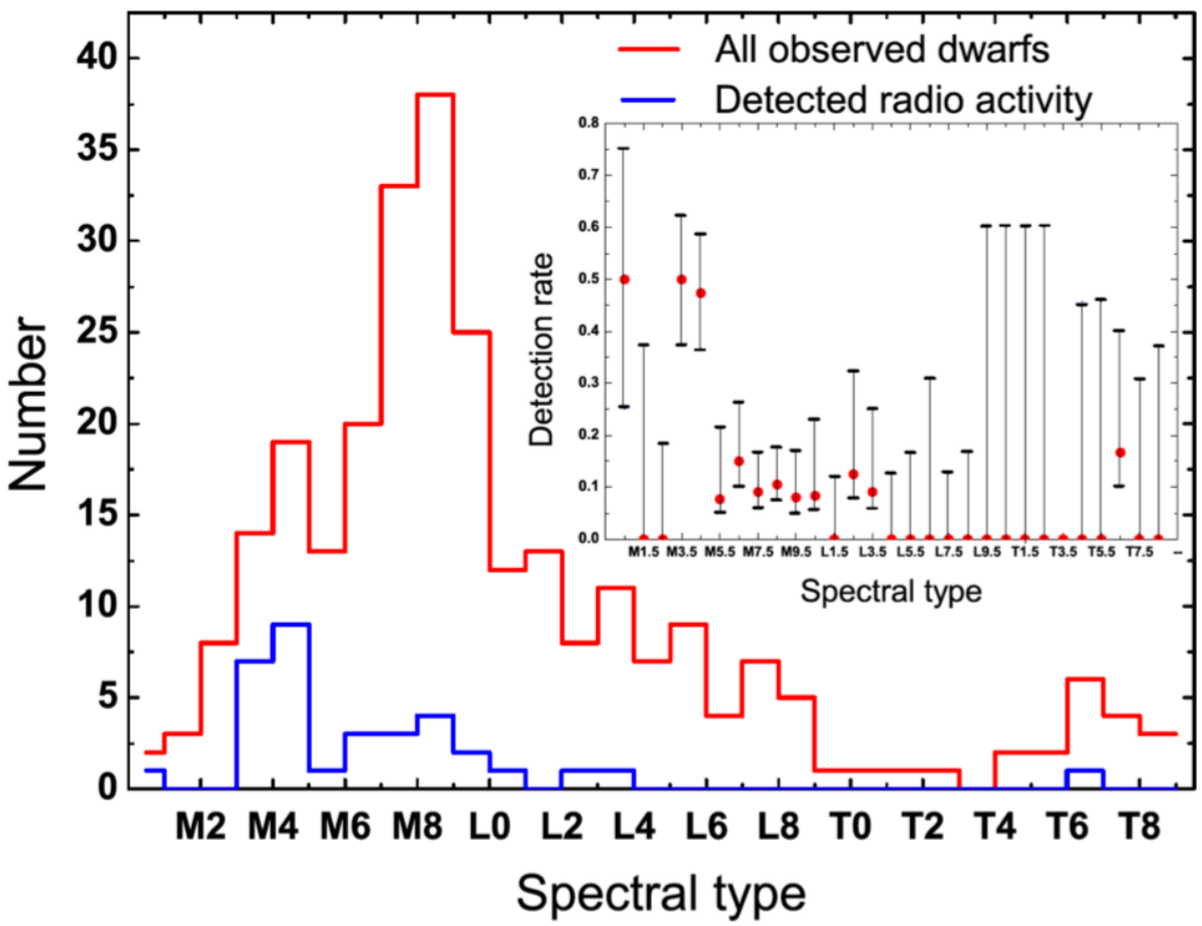
[Lenc et al., 2018]

?

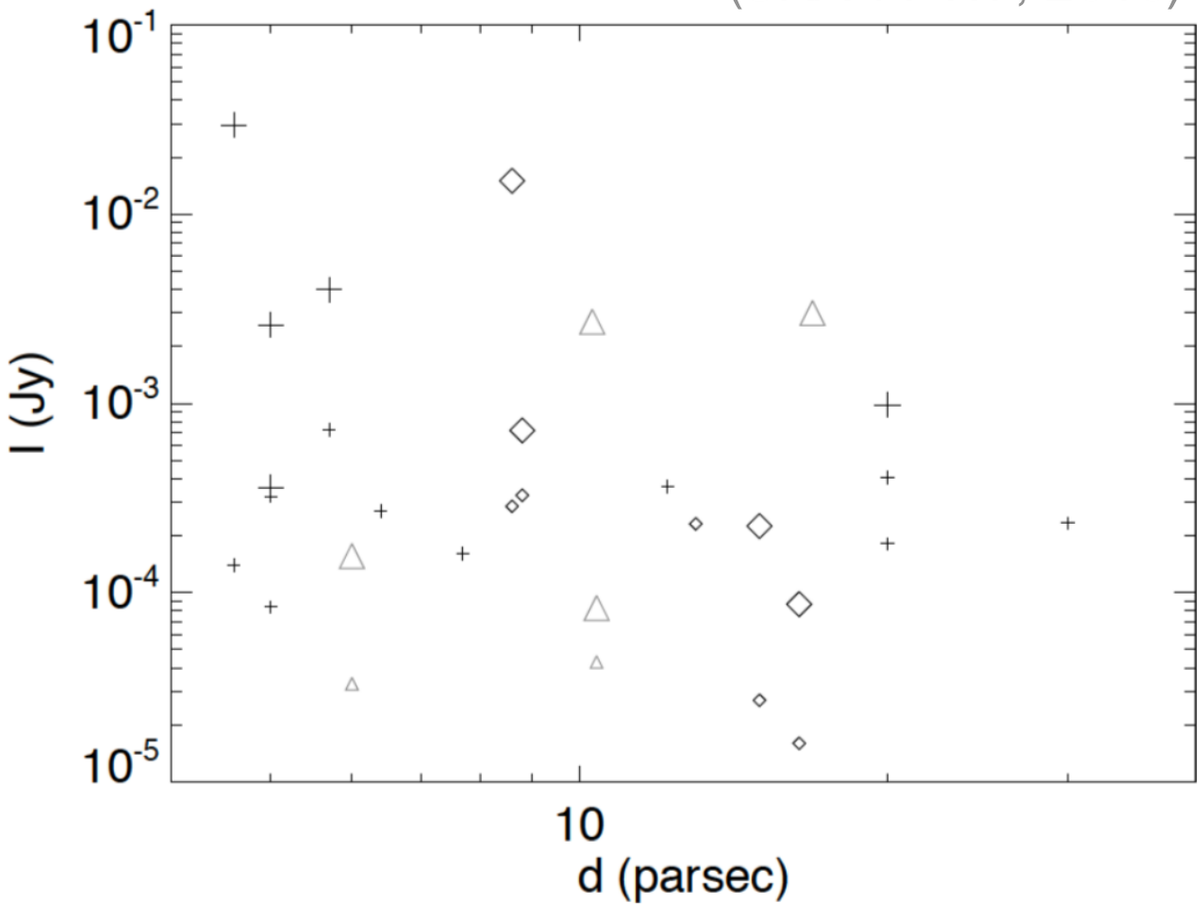
Search for ultracool dwarfs/stars with NenuFAR

Ultracool dwarfs (UCDs) : very low mass stars + brown dwarfs (late > M7 type)
~ 25 detections of M-L-T bodies >1GHz up to a few mJy (Williams, HoE, 2017)
- Radio window : unique probe of UCDs, fast rotation, planet-type magnetism (kG)
    (1) Unpolarized smooth emission : attributed to gyrosynchrotron
    (2) Circularly polarized transient emission : attributed to CMI <=> Exoplanets

(Antononova,, A&A 2013)



(SKA-Fr WP, 2018)



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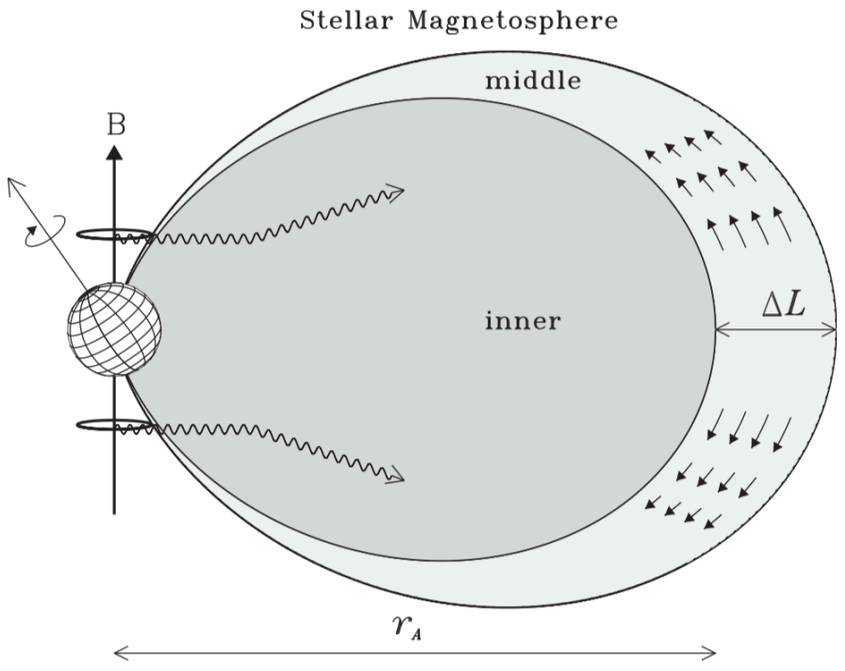
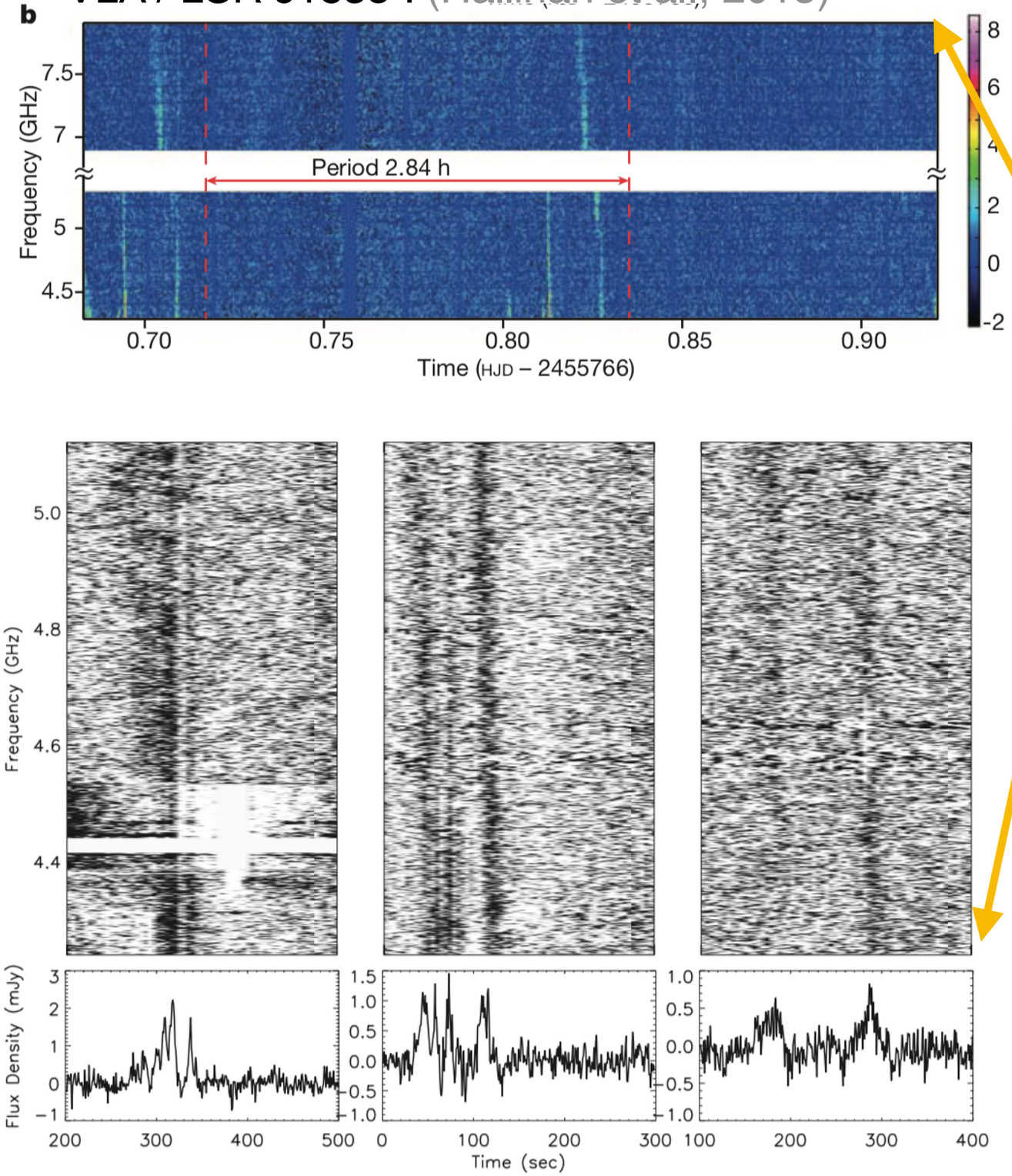
Stars :
- Star-Planet CMI-driven radio emissions = radio emission from the host star
- Magnetic Chemically Peculiar (MCP) stars : A/B early-type stars, radiatively-driven stellar wind (Leto et al., 2017) + M flaring stars (Villadsen & Hallinan, 2018) :
=> radio bursts seen >200MHz up to a 100-200 mJy : (1) and/or (2)



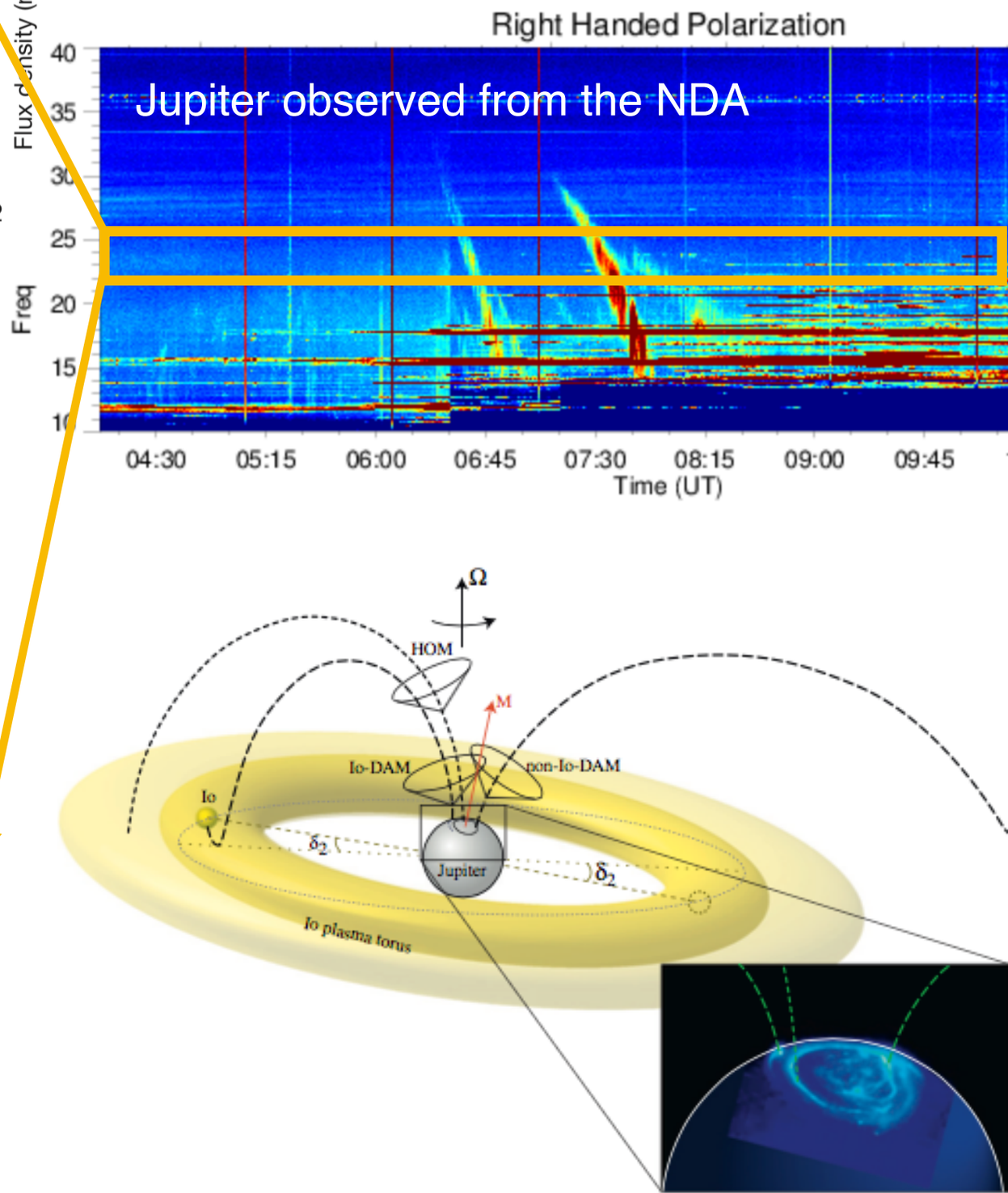
Oblique rotator model
(Leto et al., 2016)

Examples of radio-active UCDs

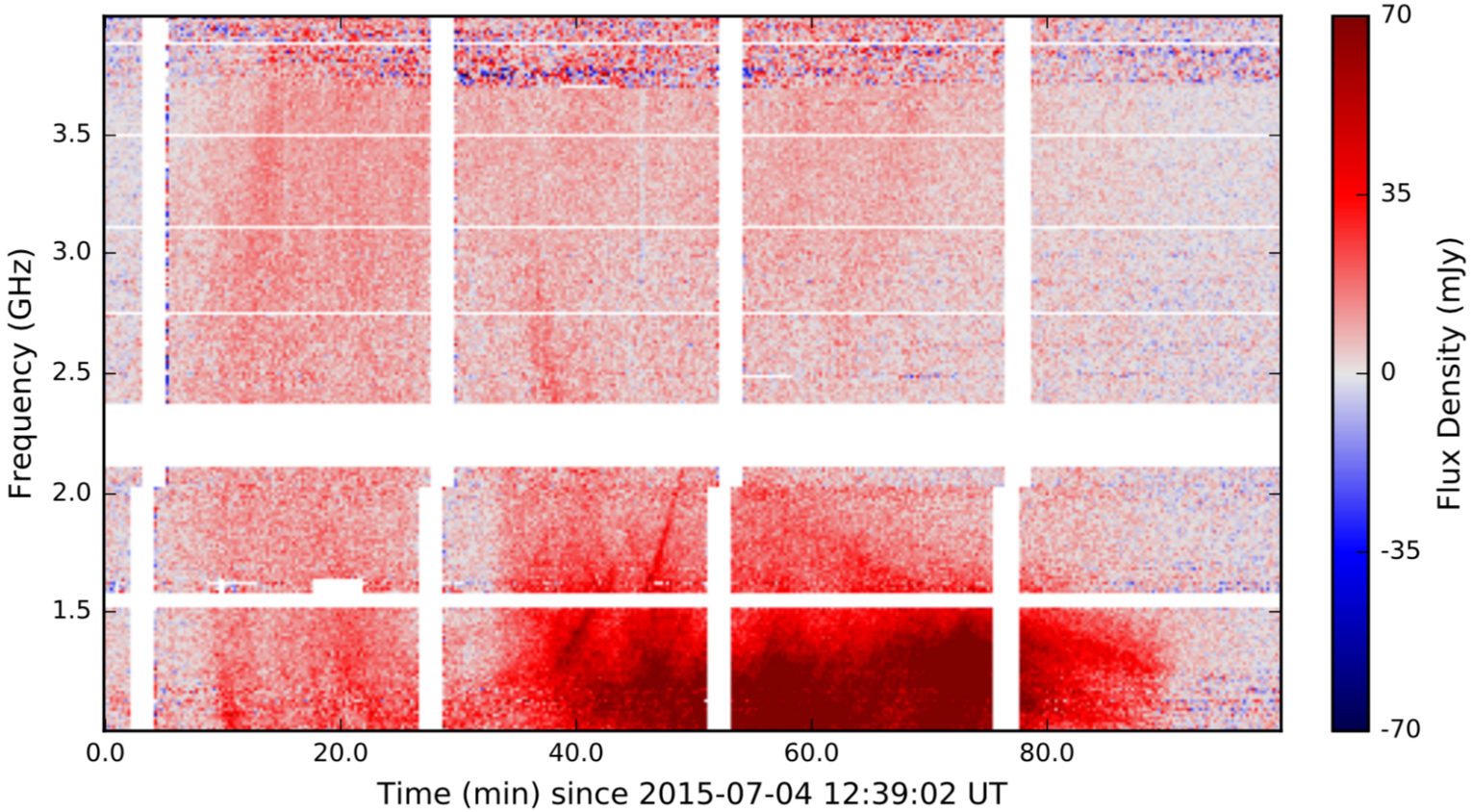
VLA / LSR J1835 : (Hallinan et al., 2015)



Arecibo / 2MASS J1047 : (Route et al., 2012)



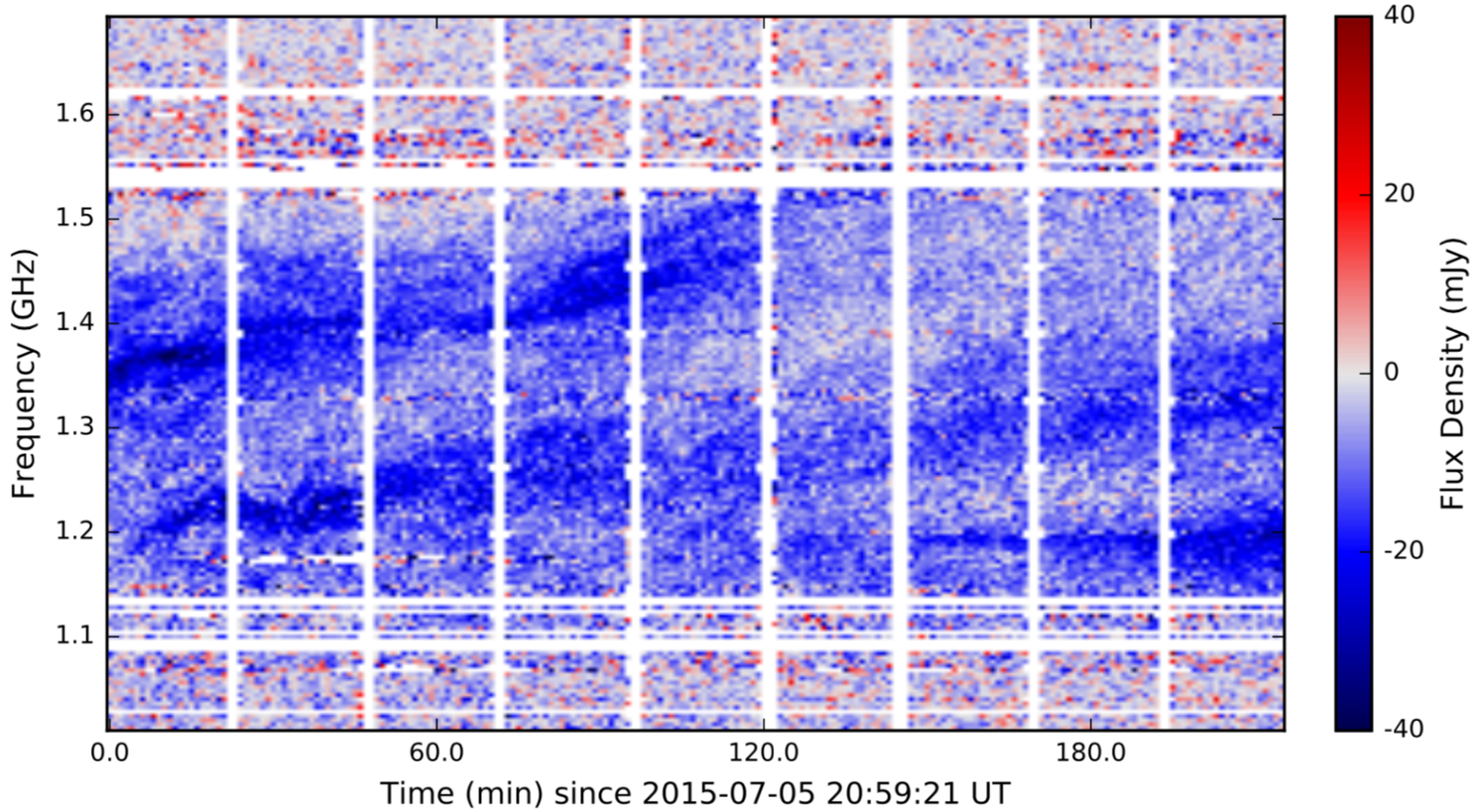
Examples of radio-active stars



Recent 58h-long VLA survey :
(Villadsen & Hallinan, A&A, 2018)

UV Ceti : M6.5, ~2pc
P_{rot} ~ 6h
seen @ 157 MHz, 1-4GHz

AD Leo : M3.5, ~5pc
P_{rot} ~ 2.3d
seen @ 1-4GHz



Search for ultracool dwarfs/stars with NenuFAR

Sources :

- List of detected UCDs : (Williams, HoExop, 2017)
NB : 50% visible from Nançay
- Exhaustive lists of UCDs : (Gagné, 2014)
- List of new BDs from Gaia : (Reylé, A&A, 2018)
- List of variable stars : Gaia DR2 etc.

Source name	Other name	SpT	Var?	First radio detection
2MASS J09522188−1924319 AB		M7*		McLean et al. (2012)
2MASS J13142039+1320011 B	NLTT 33370 B	M7	Y	McLean et al. (2011)
2MASS J14563831−2809473		M7		Burgasser & Putman (2005)
2MASS J00275592+2219328 AB	LP 349–25 AB	M8*	N	Phan-Bao et al. (2007)
2MASS J15010818+2250020	TVLM 513–46546	M8.5	Y	Berger (2002)
2MASS J18353790+3259545	LSR J1835+3259	M8.5	Y	Berger (2006)
2MASS J10481463−3956062	DENIS J...	M9	Y	Burgasser & Putman (2005)
2MASS J00242463−0158201	BRI B0021−0214	M9.5	Y	Berger (2002)
2MASS J03393521−3525440	LP 944–20	M9.5	Y	Berger et al. (2001)
2MASS J07200325−0846499 AB		M9.5+T5	Y	Burgasser et al. (2015)
2MASS J07464256+2000321 B		L1.5	Y	Berger et al. (2009)
2MASS J19064801+4011089	WISE J...	L1		Gizis et al. (2013)
2MASS J05233822−1403022		L2.5		Berger (2006)
2MASS J00361617+1821104		L3.5	Y	Berger (2002)
2MASS J13153094−2649513 AB		L3.5+T7		Burgasser et al. (2013)
2MASS J00043484−4044058 AB		L5+L5		Lynch et al. (2016)
2MASS J04234858−0414035	SDSS J...	L7.5	Y	Kao et al. (2016)
2MASS J10430758+2225236		L8	Y	Kao et al. (2016)
2MASS J06073908+2429574	WISE J...	L9		Gizis et al. (2016)
2MASS J01365662+0933473	SIMP J...	T2.5	Y	Kao et al. (2016)
WISEP J112254.73+255021.5		T6	Y	Route & Wolszczan (2016)
2MASS J10475385+2124234		T6.5	Y	Route & Wolszczan (2012)
2MASS J12373919+6526148		T6.5	Y	Kao et al. (2016)

Table 1: The twenty-three radio-detected UCDs as of mid-2017. "SpT" shows a spectral type from SIMBAD; UCD spectral typing is challenging and subtle (e.g., Kirkpatrick et al. 2012), but to conserve space we omit details and references. Spectral types with asterisks (*) are known to come from the blended spectra of more than one object. "Var?" indicates whether the source has been confirmed to have radio emission that varies on short ($\lesssim$1 hr) time scales. This is the case for all well-studied UCDs except LP 349–25 AB (Osten et al. 2009).

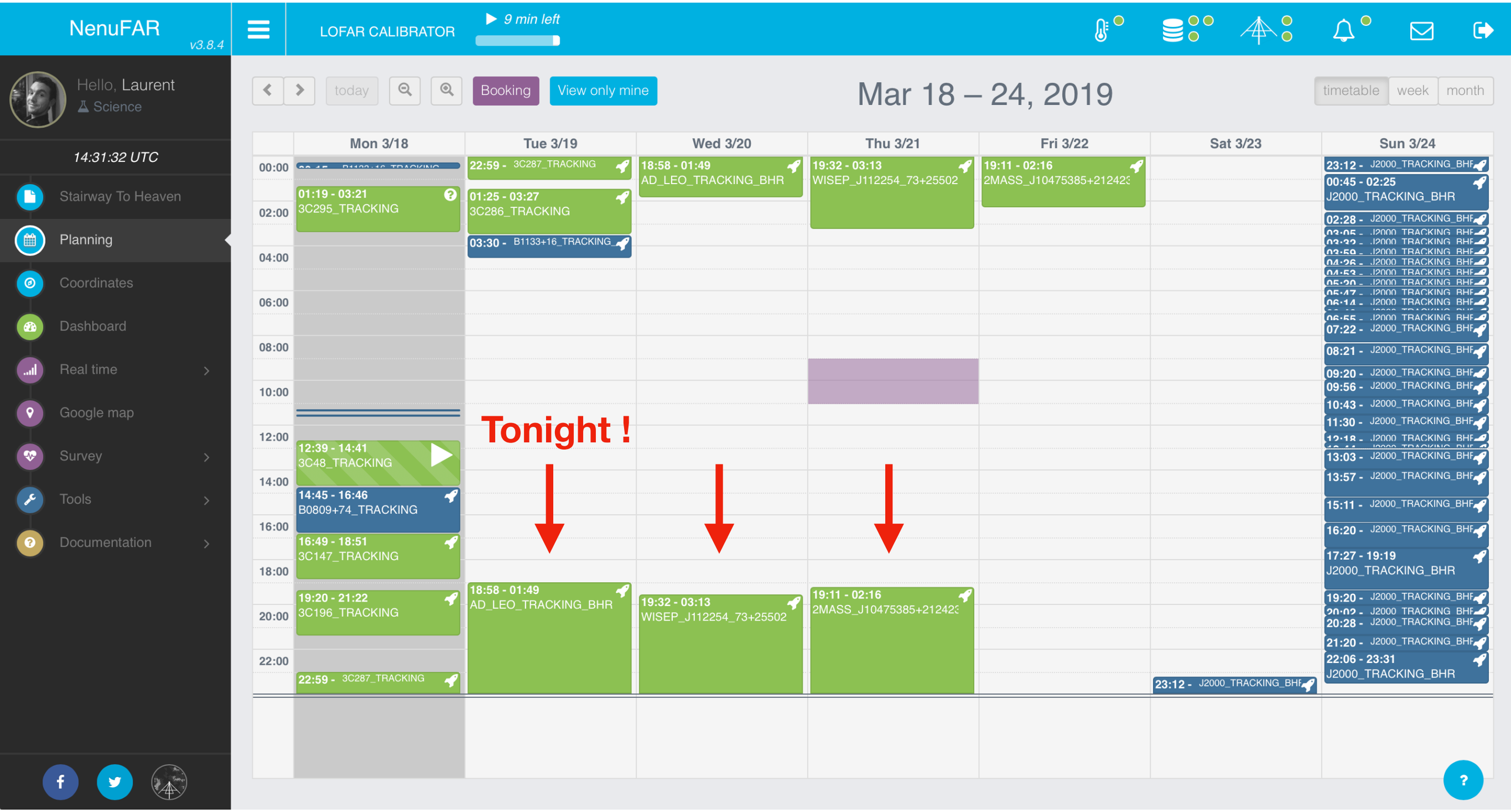
Methodology :

- time-frequency observations of Stokes (I,V) => Undysputed beamformed
- survey approach aimed at a systematic search

Search for ultracool dwarfs/stars with NenuFAR

Commissioning tests :

- Early LANewBa/BST observations in Nov. 2018 coordinated with NRT
- Undysputed/DynSpec observations planned in the coming days



Proposed observations

- ~10 targets short term (1st semester), ~100 targets (2 years), ~1000 targets (long-term) [tracking RA, δ]
- Known exoplanets / stars with hints of previous detection or high predicted flux
- First targets will include : Tau Bootes [Zarka et al., in preparation], Proxima Centauri [Lenc et al., MNRAS, 2018], UV Ceti & AD Leo [Villadsen & Hallinan, astro.ph, 2018], Corot-7b [Vasylieva, PhD thesis, 2015]…
- ~200 h on first 10 targets, by 1-2 hours chunks, covering ≠ orbital phases (E R C proposal PZ, 500h / semester, response ≤8/4/2019)
- Preferably night-time, low-frequencies, close to meridian transit
- Multi-beam UnDySPuTeD-tf, with up to 3-4 interesting targets per analog beam
- 2 Off digital beams (selected from MSSS or LoTSS) simultaneously in analog beam
- Same SB in all digital beams, selected from RFI occupancy statistics for min. RFI probability
- 4 Stokes, 3 kHz x 10 - 20 msec per spectrum

Processing

- RFI mitigation
- Integration / t,f
- Detection in Stokes V

→ pipeline (RFI mitigation + detection) developed with J. Turner, J.-M. Grießmeier and I. Vasylieva

[Vasylieva, PhD thesis, 2015; Turner et al., PREVII 2017; Turner et al., A&A 2019]

well adapted to NenuFAR beamformed data.

The team

P.I.s : P. Zarka (exoplanets & SPI), L. Lamy (stars)

Members: J.-M. Grießmeier, J. Turner, A. Loh, J. Girard

plus TBC: B. Cecconi, C. Briand, H. Krishnan, ...