

SETI with NenuFAR

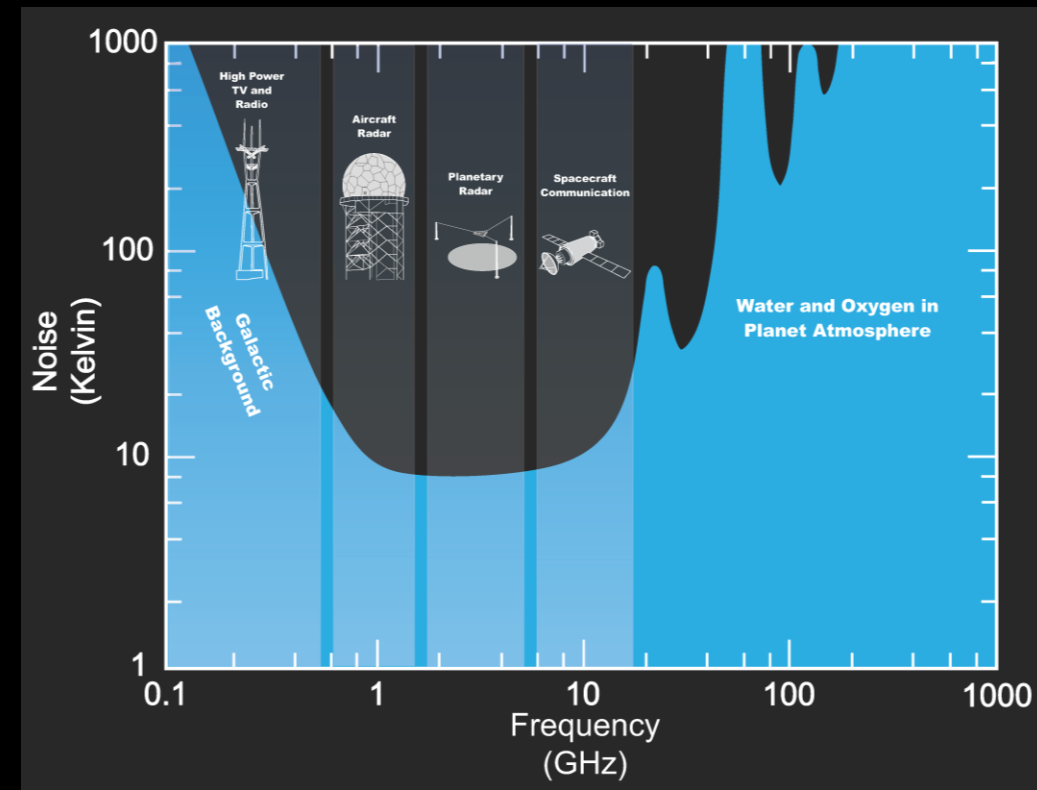
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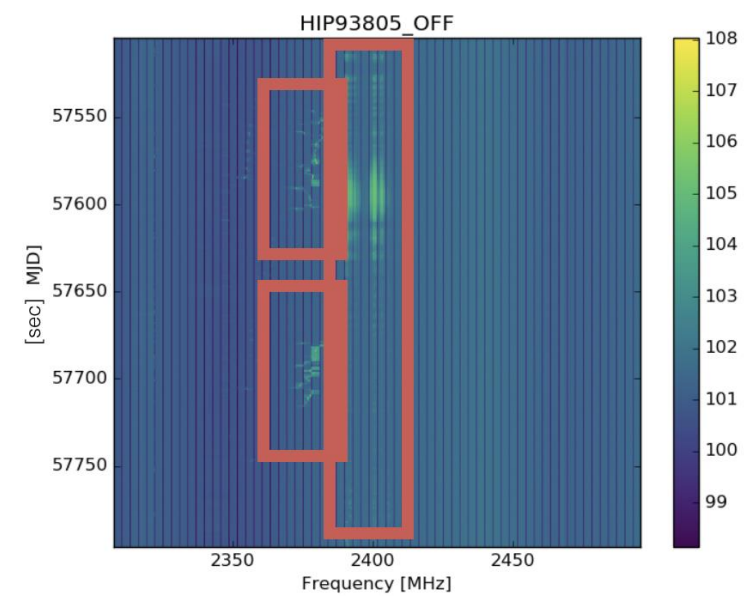
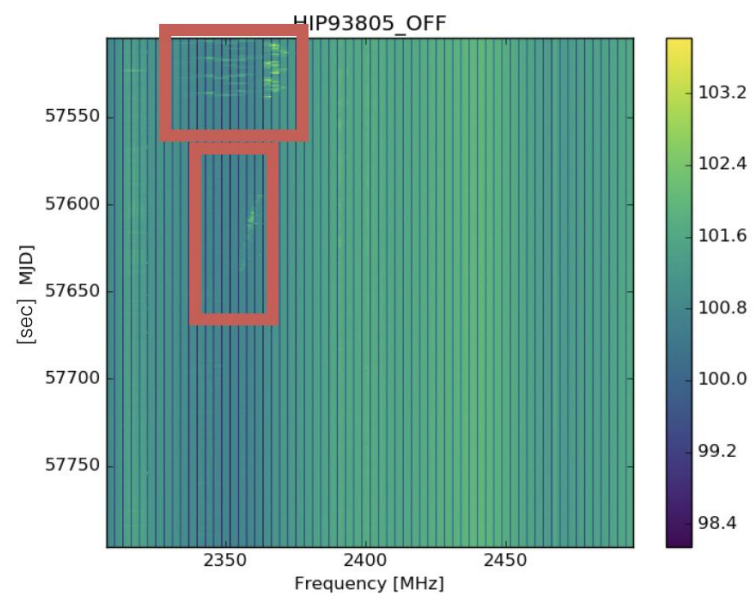
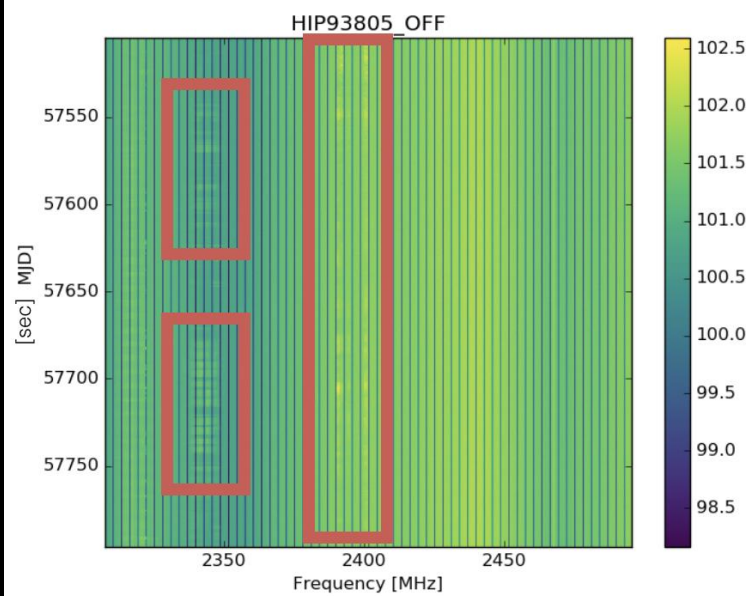
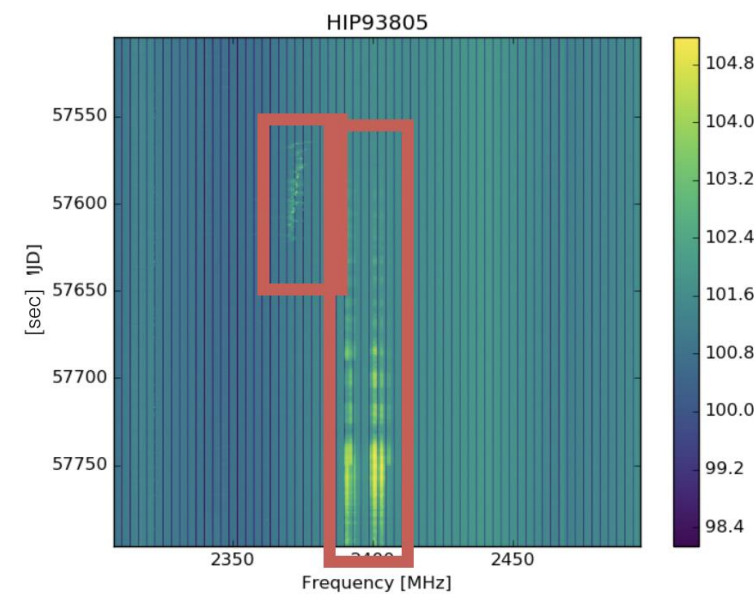
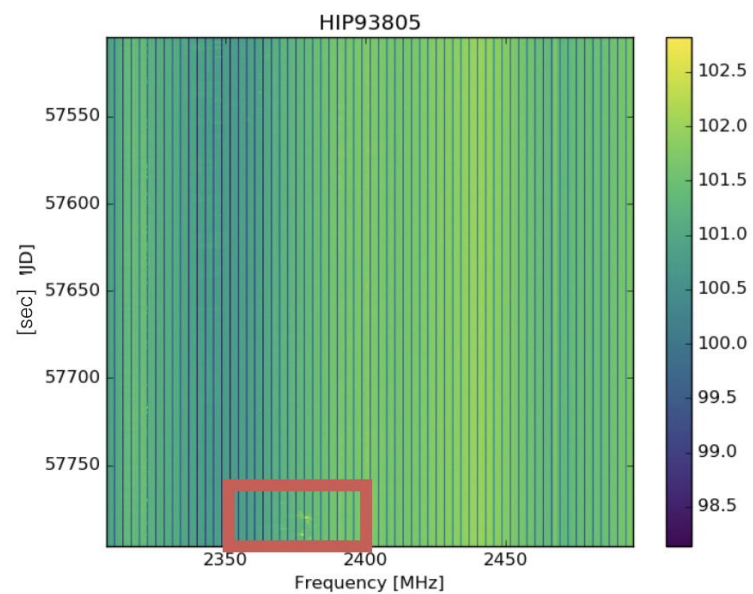
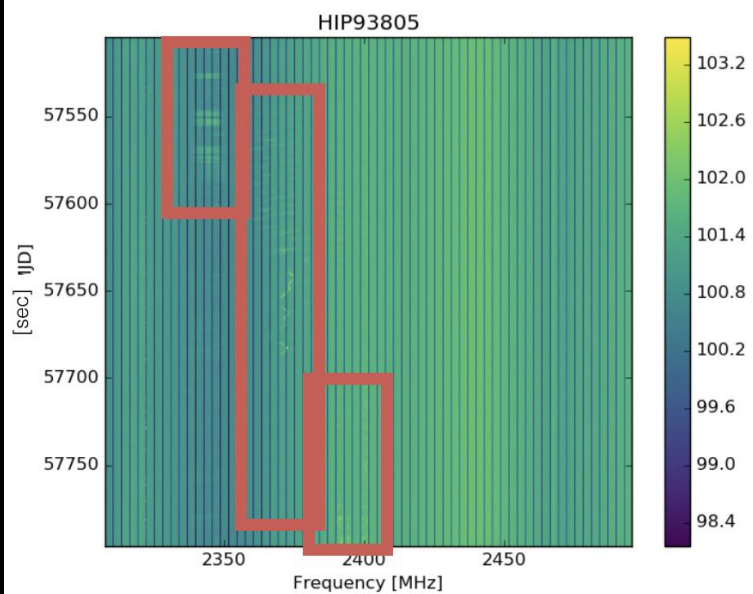
SETI : Search for ExtraTerrestrial Intelligence

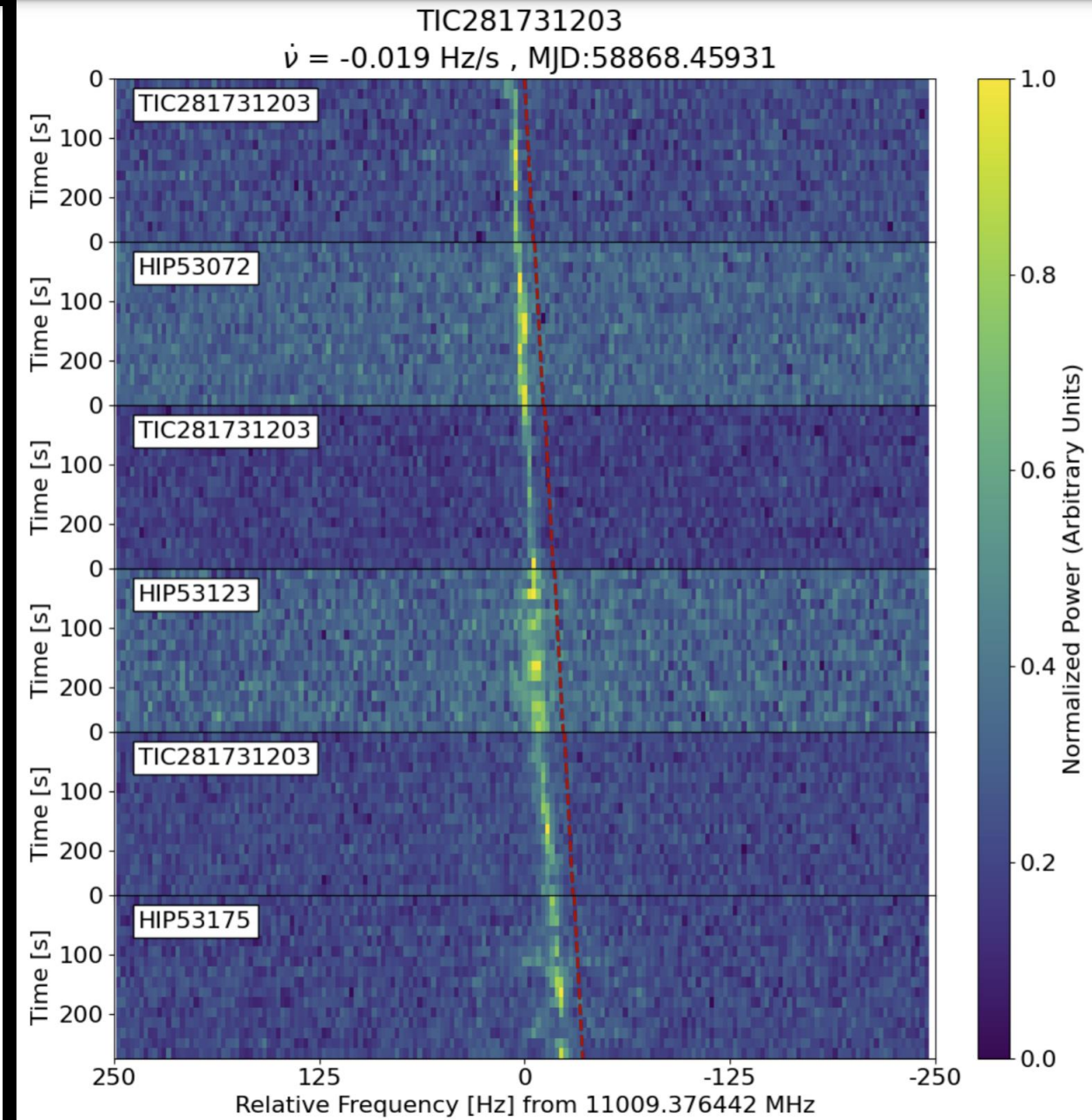
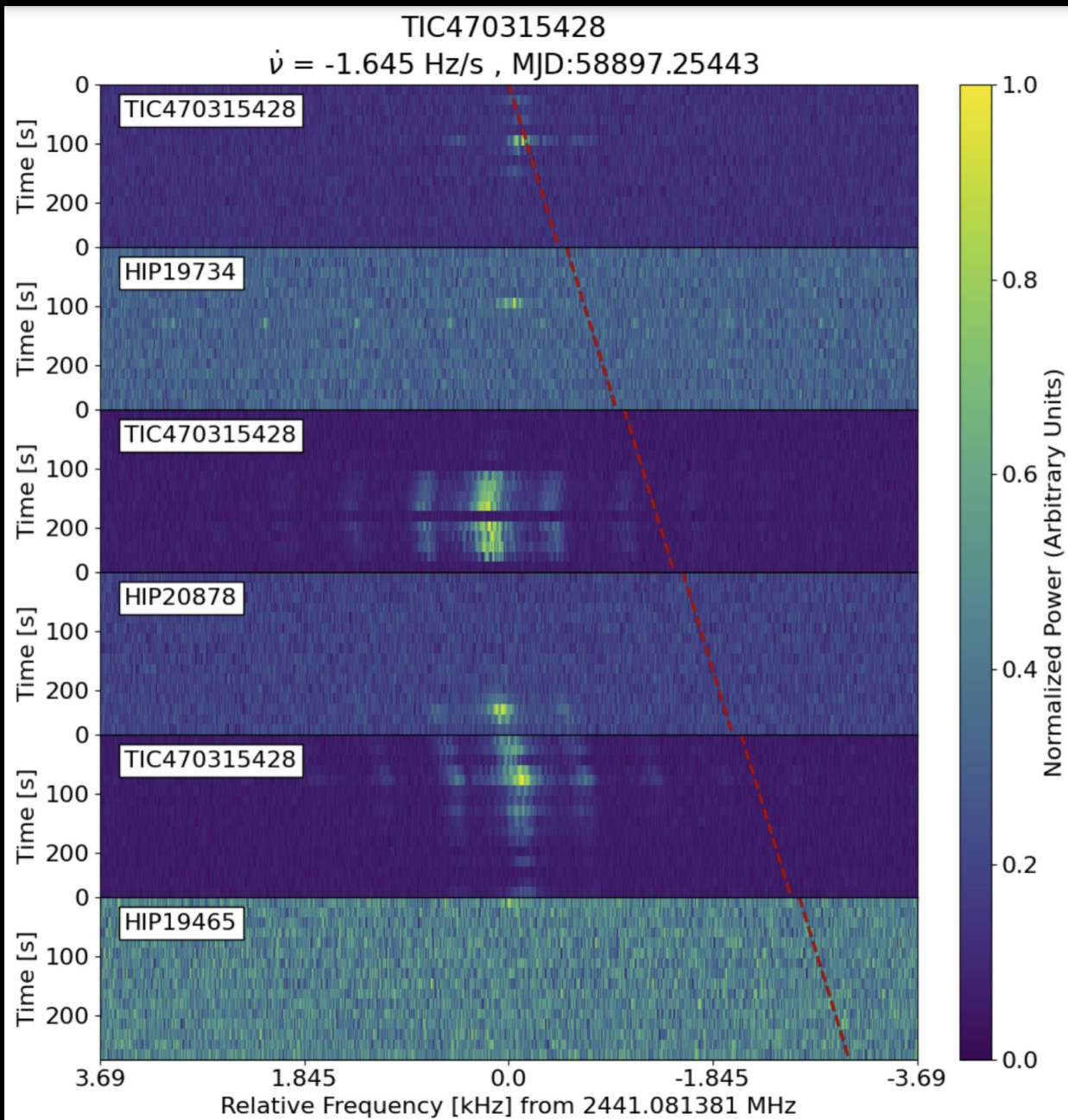
- Biosignatures vs. Technosignatures
- Radio signatures : deliberate vs. unintentional
- Most searches conducted at L-band
- Search for narrowband transmissions
 - Detectability vs energy efficiency optimum
 - Energy detection = easy implementation
- NenuFAR covers uncharted part of spectrum

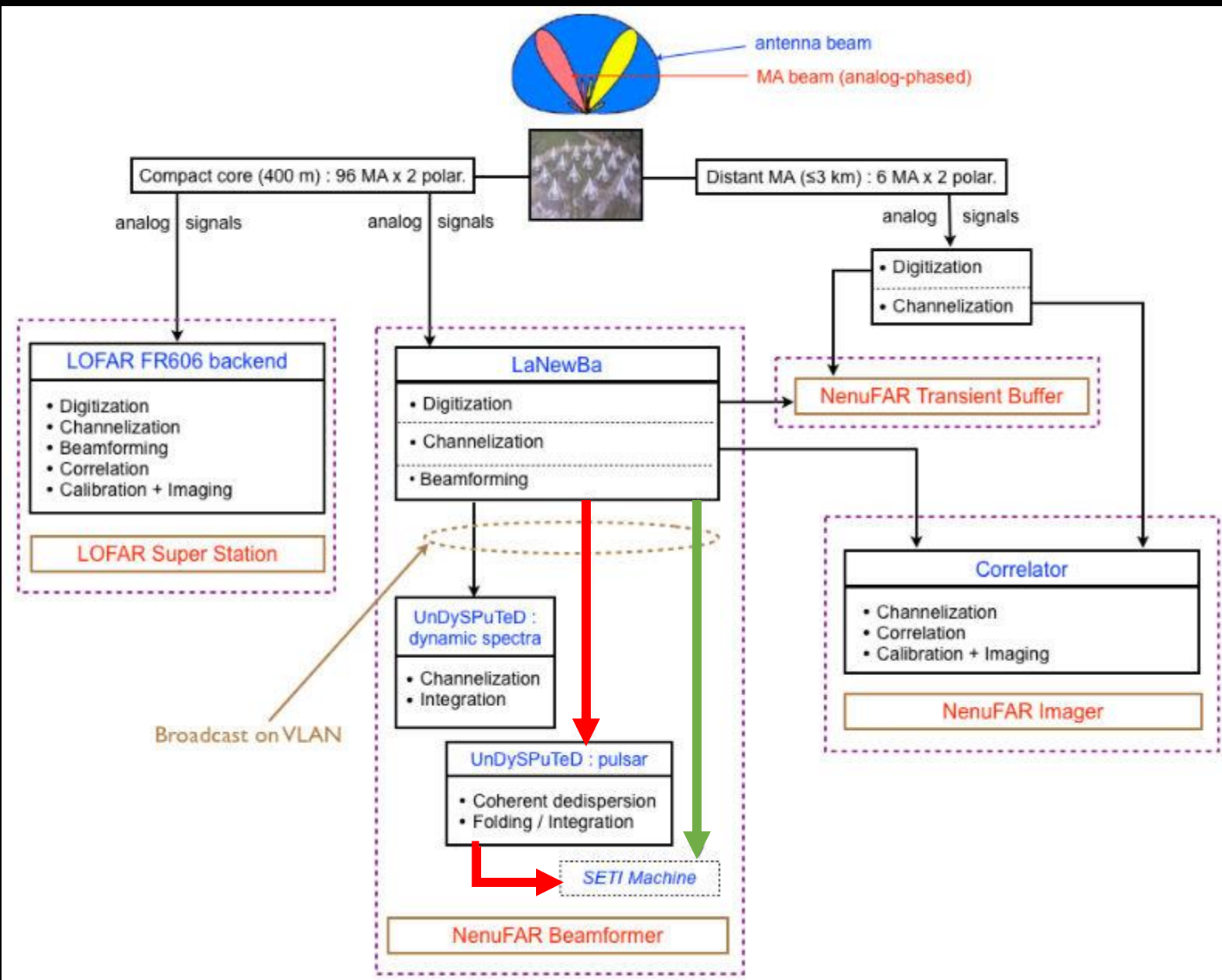


Targeted Radio Search for Technosignatures

- Search for radio transmissions from distant civilizations
- RFI mitigation (*needle in a needle stack*)
- Remove 'local' RFI (physically and satellites, ABACAD)
- Identification of Doppler effects (Local standard of rest)
- Identification of anomalies (RFI-like, ML-based approaches)
- Look for persistency
- Conduct independent observations







→ Current path

→ Commensal path

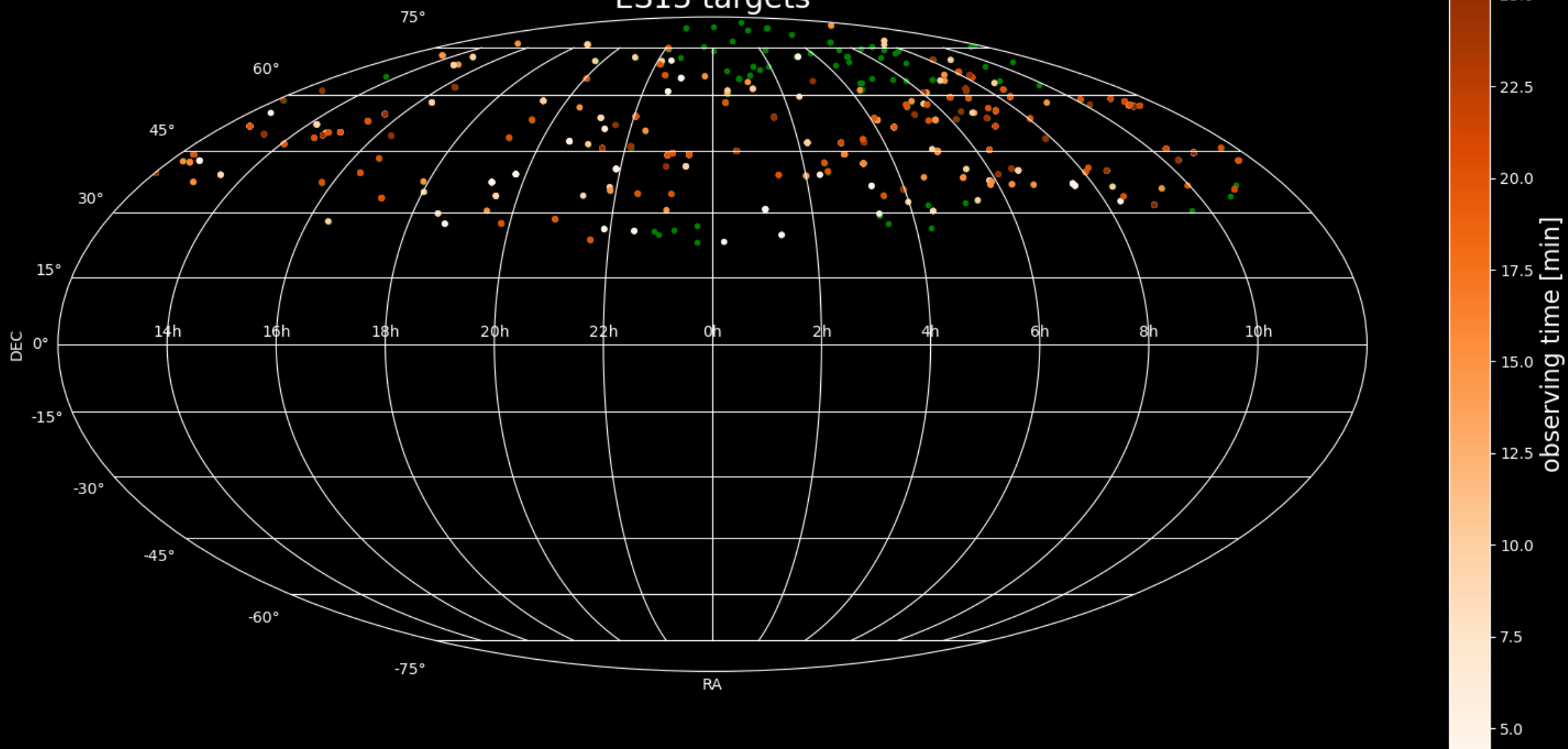
SETIBK – NenuFAR SETI back-end

- Obs de Paris + Breakthrough Listen (UC Berkeley)
- Purchased in July 2020
- 144 TB storage
- 1x RTX 2080 Ti GPU
- 2x Intel Xeon Silver 4210
- 96 GB DDR4
- ES13 : 164 telescope hours alloc btw 2019-07 and 2021-11

Observing time

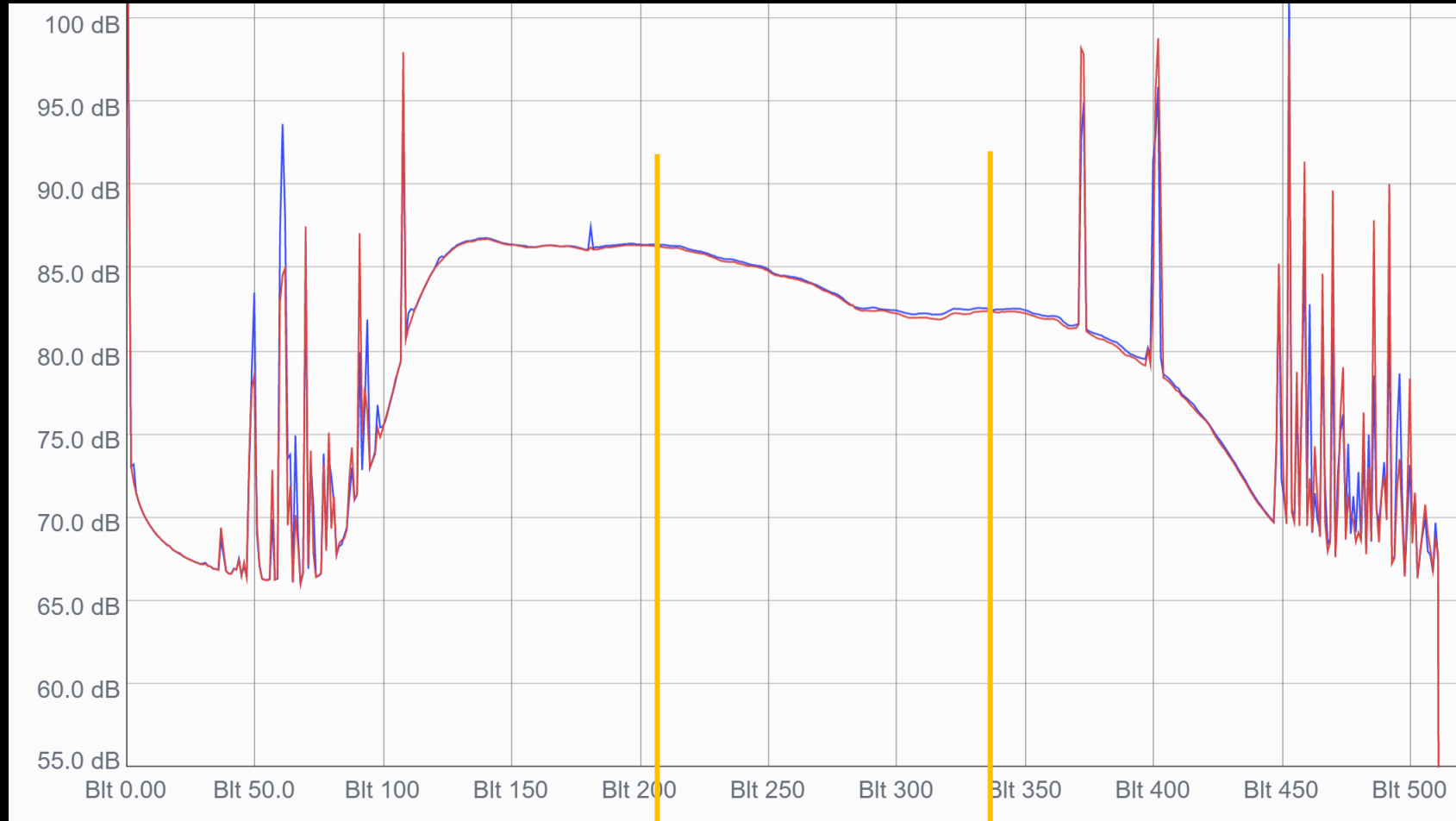
ES Semester	Dates	# of hours	Hours / slot	Targets
S1	2019/07-2019/12	12	12	Keppler
S2	2020/01-2020/06	48	12	Keppler
S3	2020/06-2020/11	36	2	Keppler
S4	2020/12-2021/05	36	2	TESS
S5	2021/06-2021/11	32	2	TESS
Total		164		
Total observed (incl. test time)		176		

ES13 targets



Total : 90 Kepler EP + 138 TESS EP + Moon tracking

● Unobserved

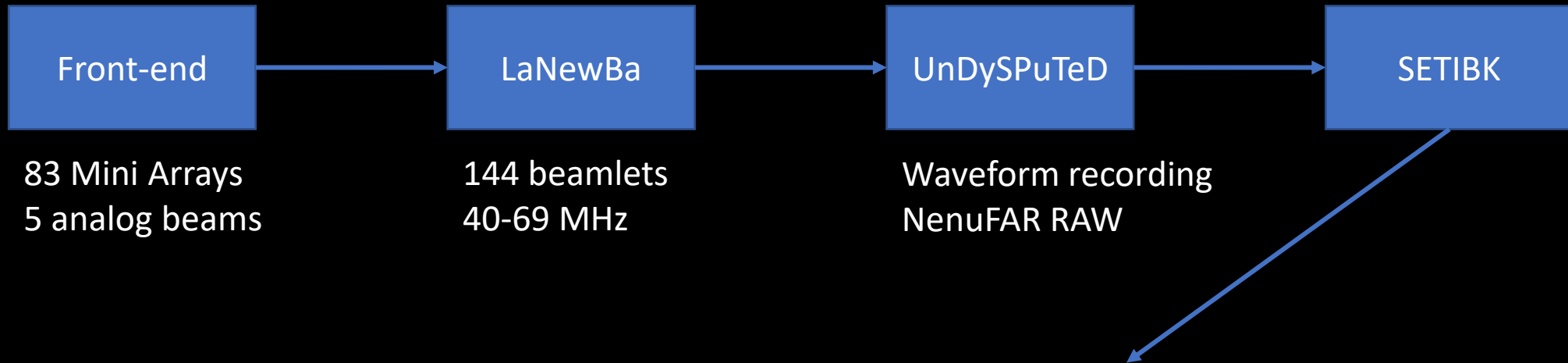


39.8 – 67.7 MHz

144 beamlets : 204 .. 347

30 MHz x 5 targets x 10 mins = 1.2 TB

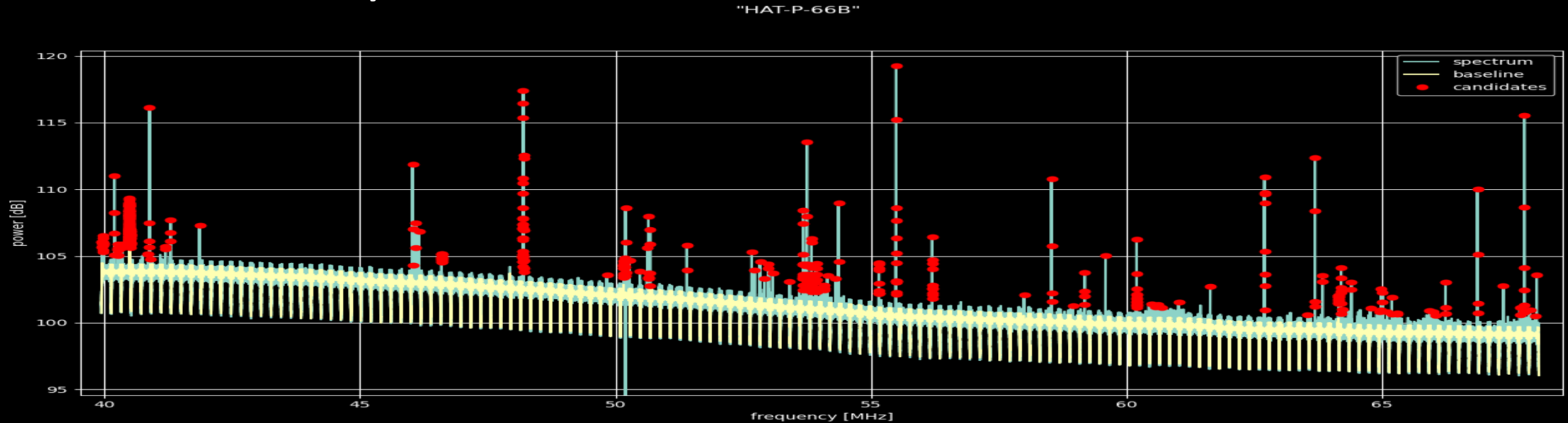
Processing pipeline



Python GPU offline pipeline:

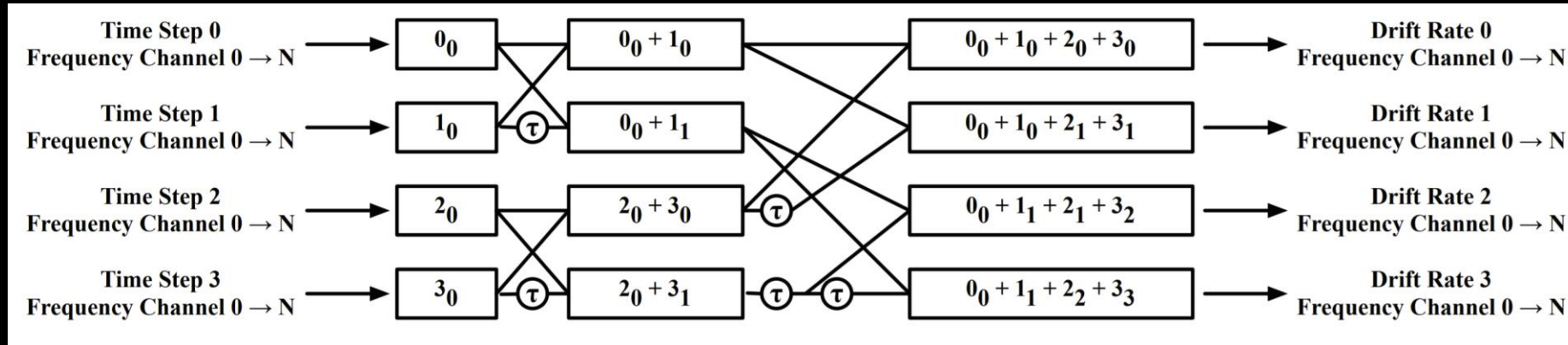
- Fine channelization + data integration : 1.49 Hz / 671 ms
- Total power
- Beamlets splicing
- Conversion to Filterbank File (60 GB / FIL)
- Raw files deletion

Data analysis



- Data integration
- Baseline estimation and subtraction (median filter)
- RMS estimation (MAD)
- Peak detection ($\geq 13.5 \sigma$)
- Data base

Doppler drift search



- UC Berkeley Blimpy / TurboSETI software
- GPU search for drifting signals
- Logical search between on-/off-target observations

SETI with NenuFAR

- Commensal observation option in progress
 - Data reduction pipeline requires further optimization
 - TESS survey to be completed in S7
 - SETI with NenuFAR paper expected in 2022
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- Open to collaborate with NenuFAR community

Acknowledgement : Philippe Zarka, Cedric Viou, Emmanuel Thetas, Christophe Taffoureau, Jean-Mathias GrieBmeier, NenuFAR team, CSN.