

# NenuFAR pulsar instrumentation overview

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# The first observation of pulsar



Jocelyn Bell, 1968

First pulsar discovered at  
81.5 MHz (Hewish et al. 1968).



The IPS array (Interplanetary Scintillation Array) near Cambridge

# Introduction: Pulsars

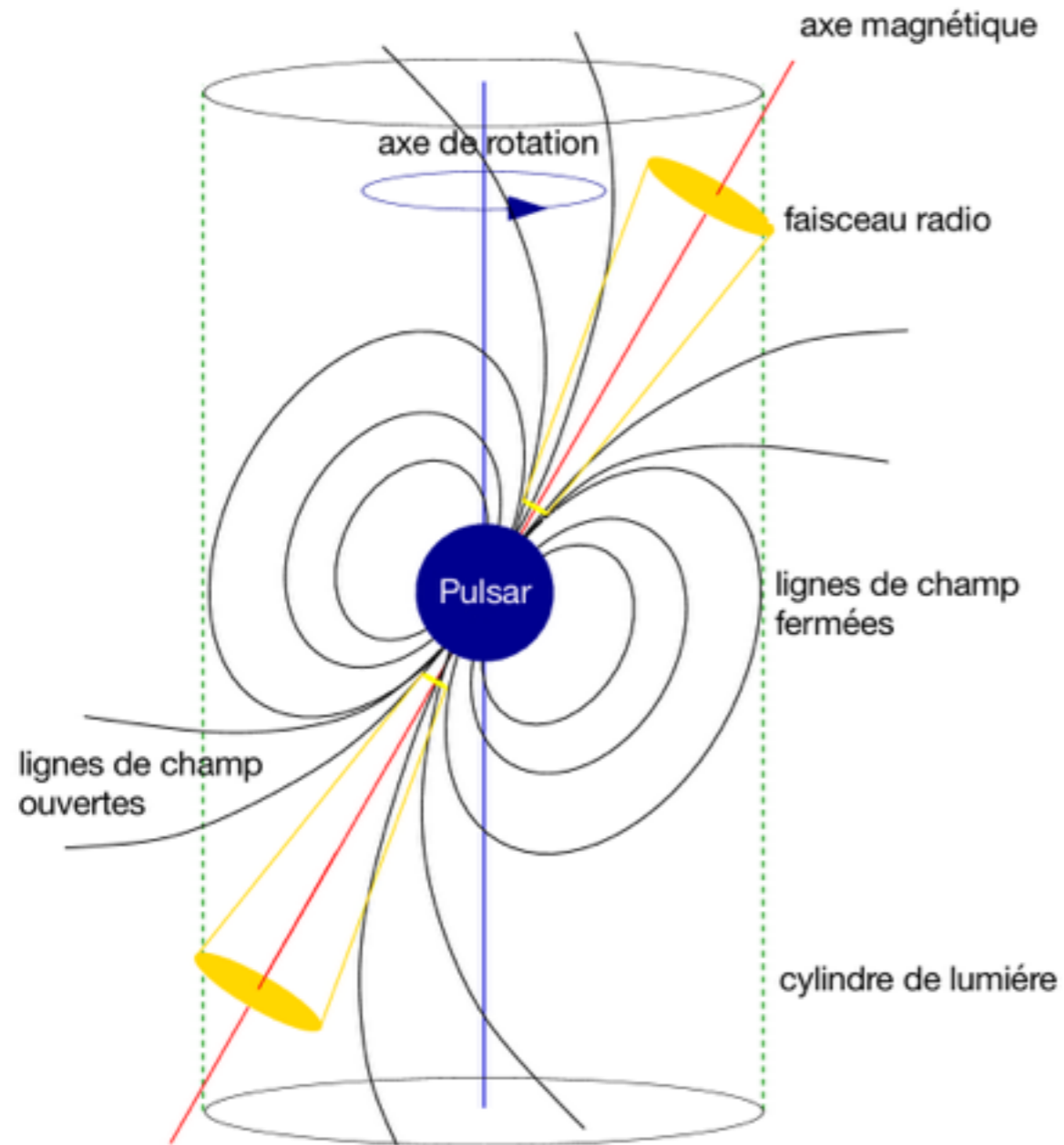
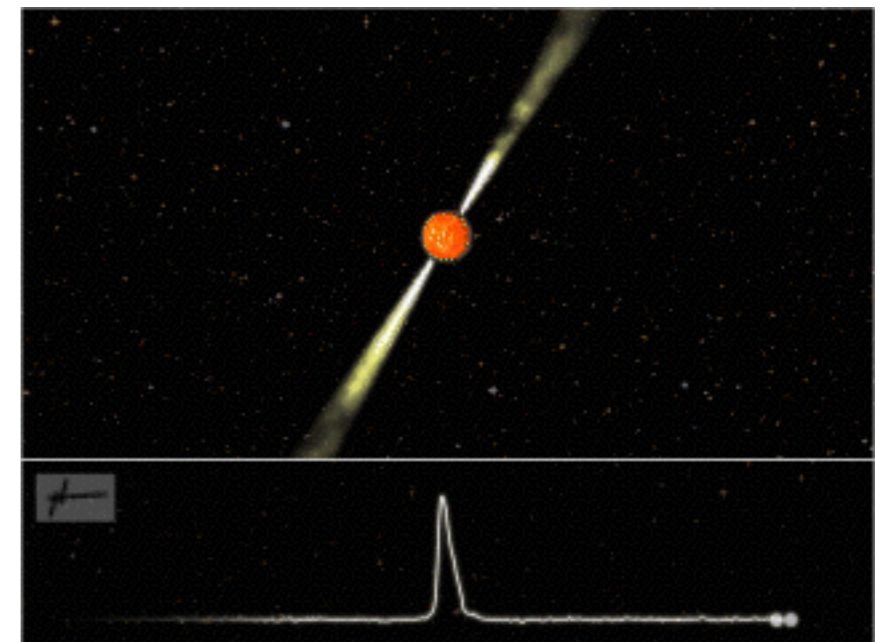


Diagram of a pulsar *Handbook of Pulsar Astronomy*  
D.Lorimer & M.Kramer.

- Rapidly rotating neutron star of  $\sim 1.4 M_{\odot}$  for a diameter of 20 km.
- Synchrotron Radiation from the magnetic poles.
  - generating a radio beam



1. Three modes for the observations
2. Observational limits
3. Examples



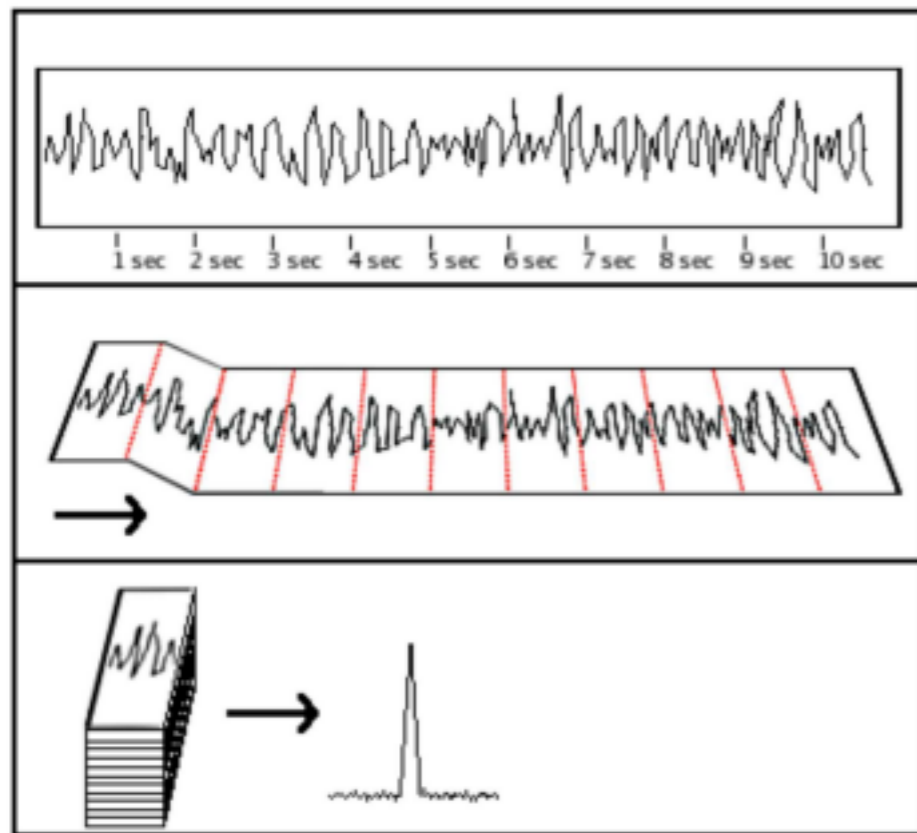
Three modes with different levels of compression:

1. folding
2. single pulse
3. waveform

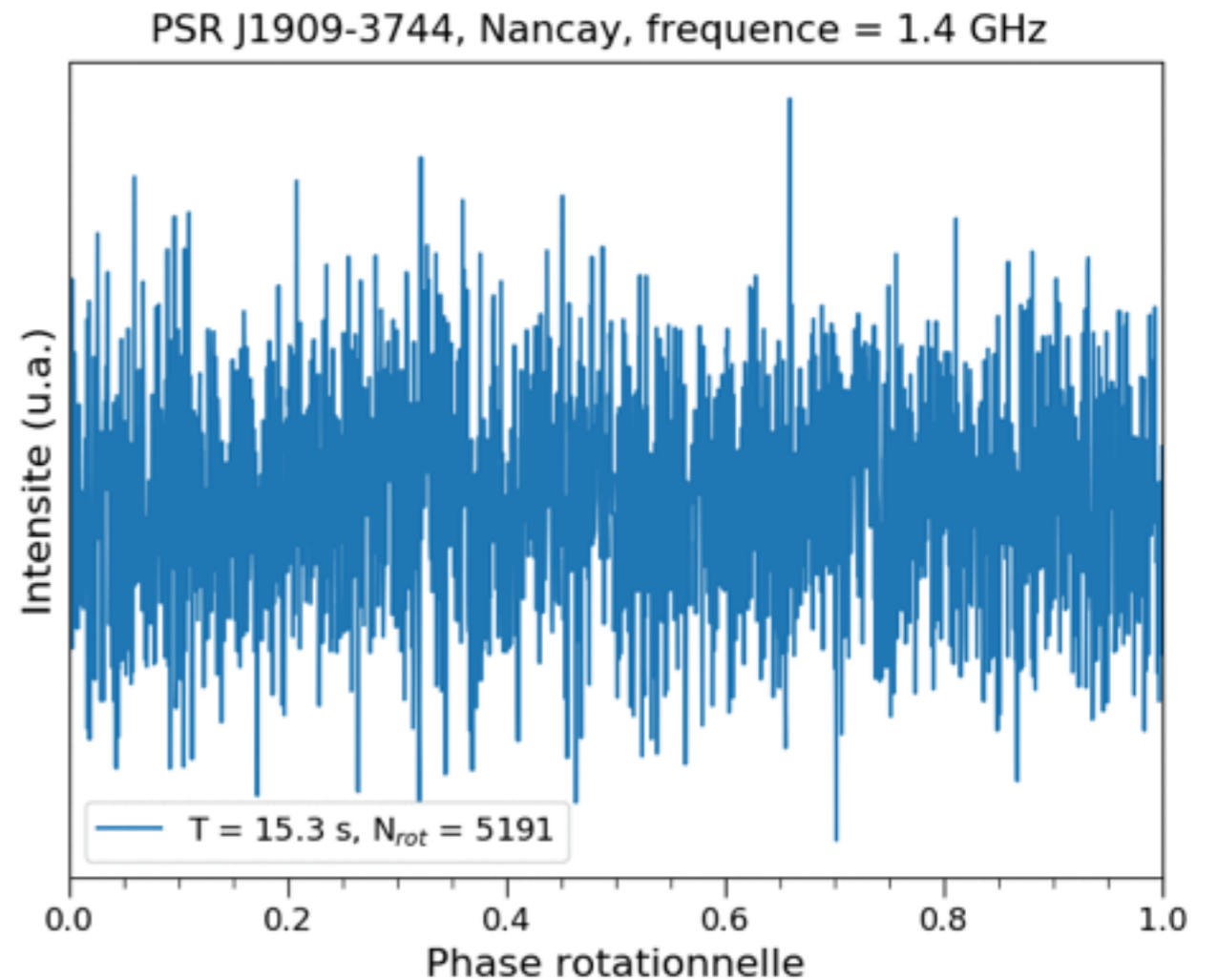


# Introduction: Pulsars

Folding of an observation:



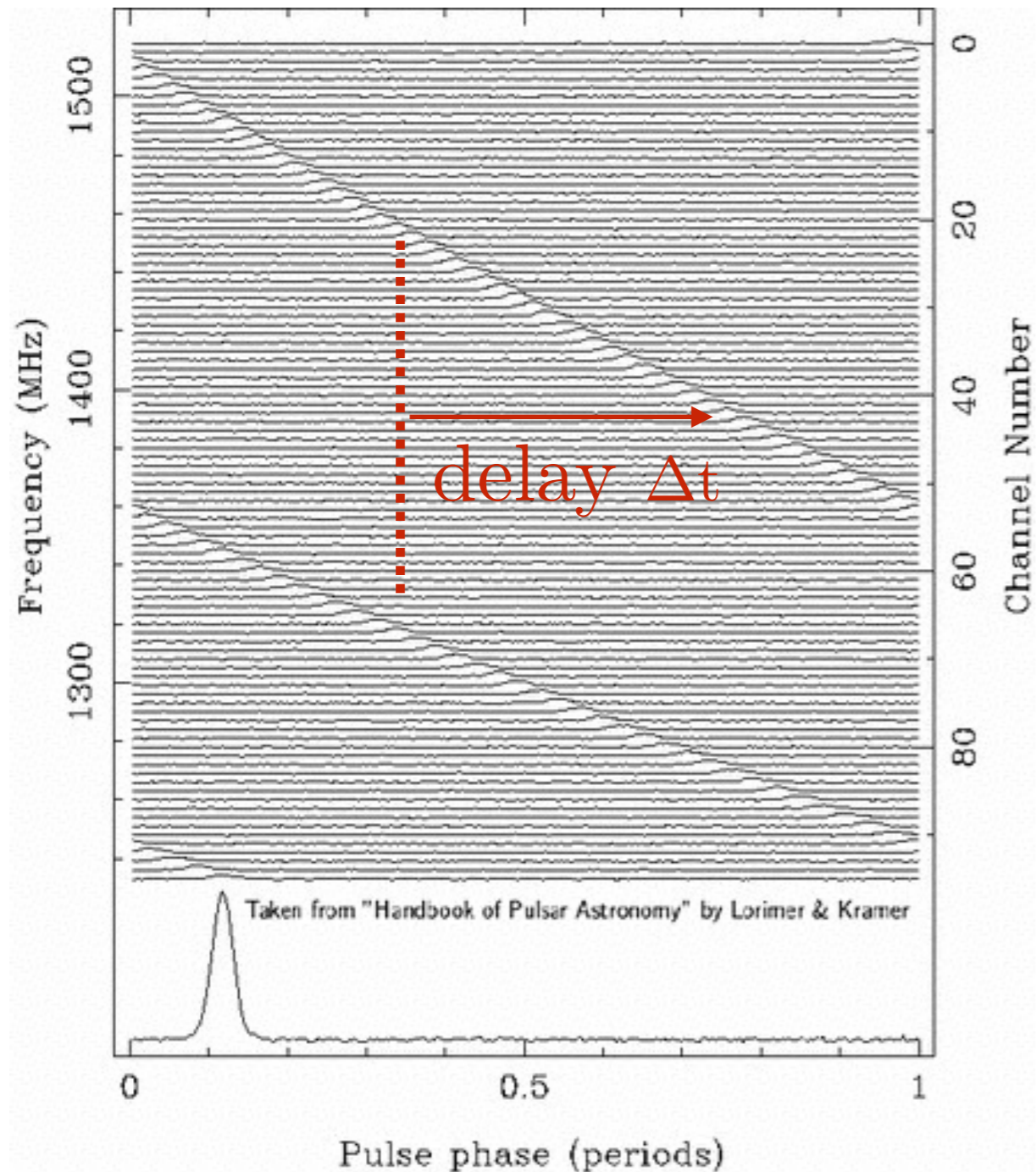
*Handbook of Pulsar Astronomy* D.Lorimer & M.Kramer.



*Animation folding of a pulsar L. Guillemot (LPC2E) using the nancay radio telescope*



## The dispersion



*Pulsar Astronomy* A. Lyne & F. Graham-Smith

- Delay due to the frequency-dependance of group velocity.

$$\Delta t \propto f^2$$



## Low frequency dedispersion

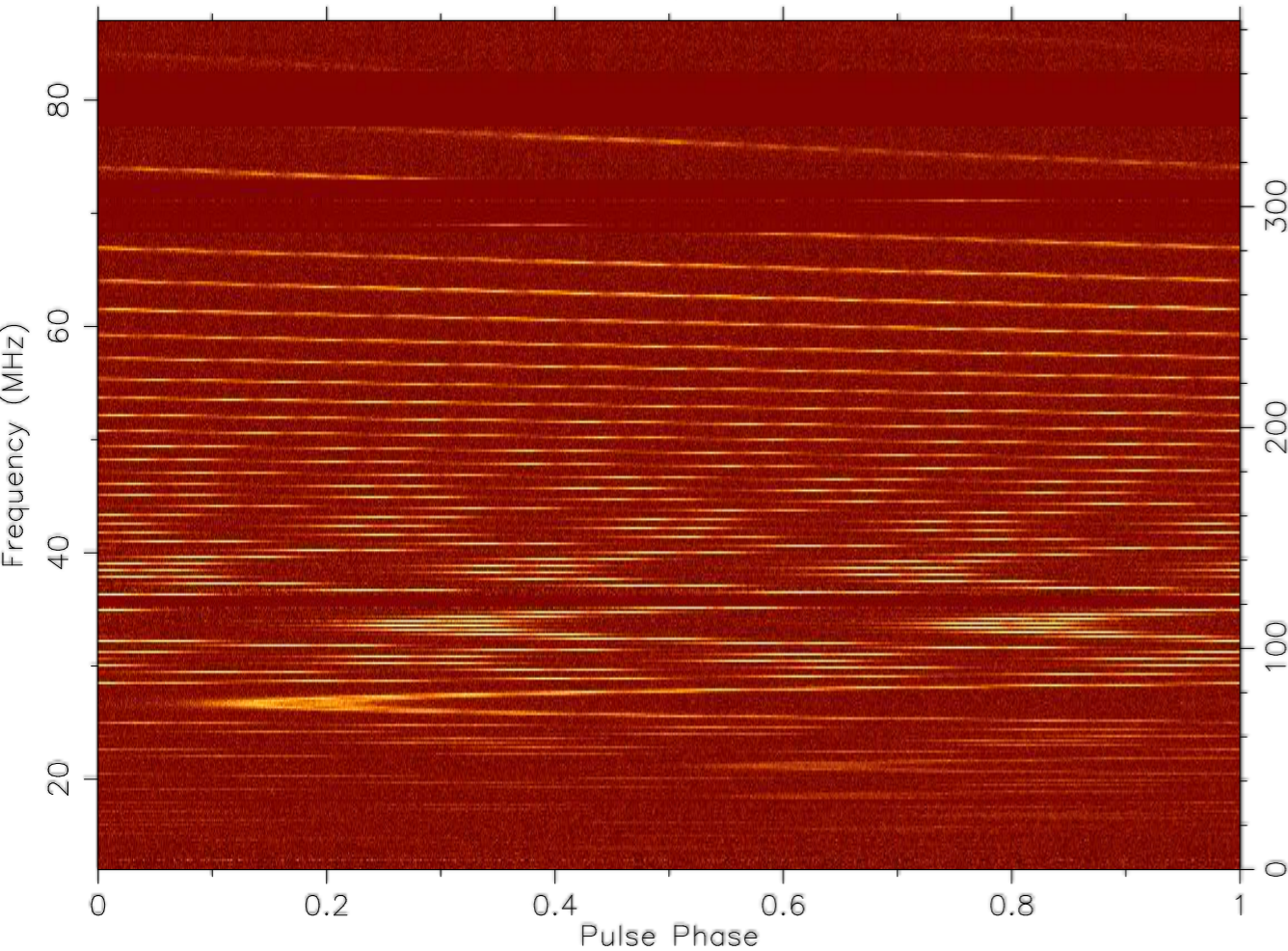
Dispersed

Pulsar backend

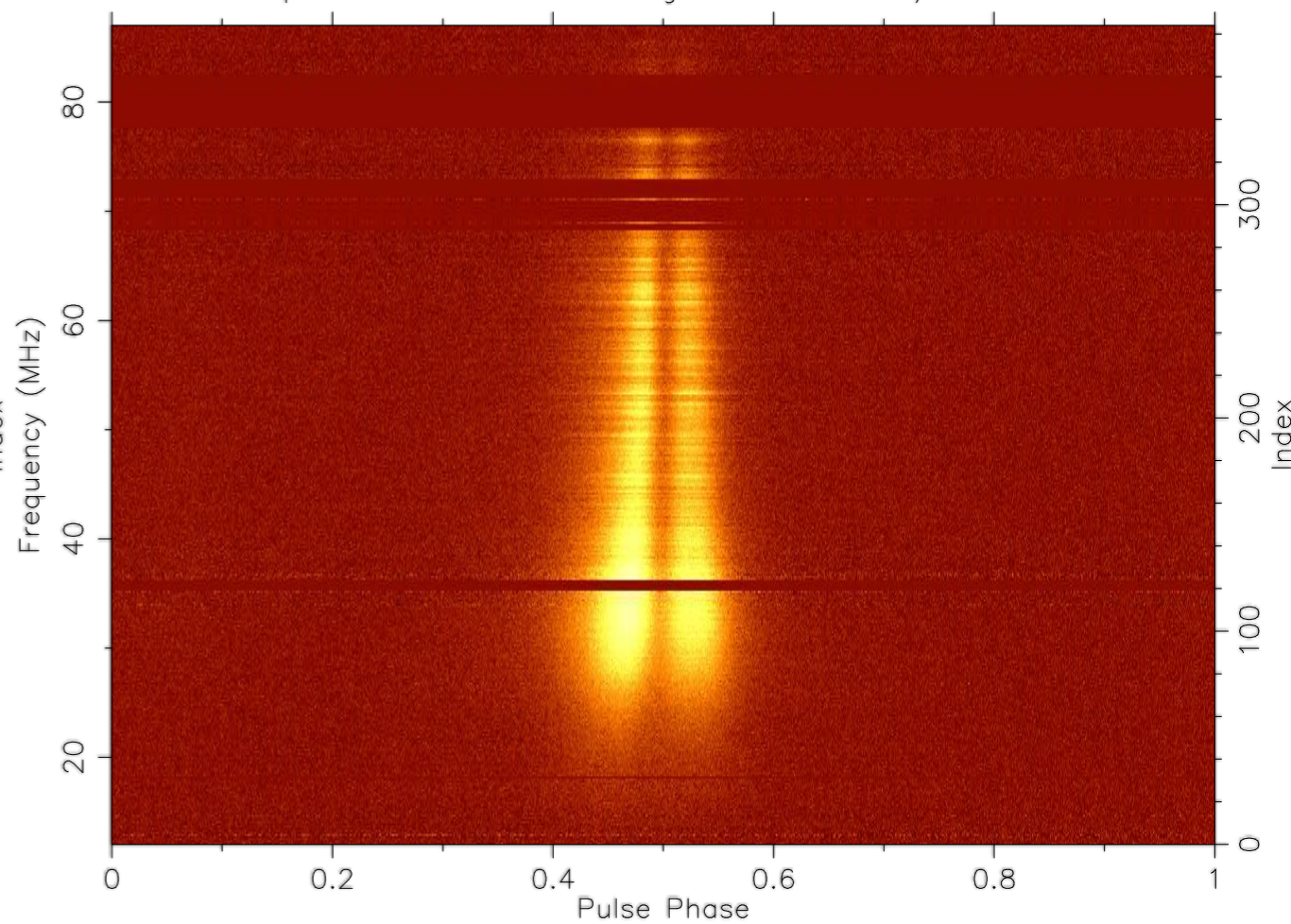


Dedispersed

B0950+08 test.ar  
Freq: 46.112 MHz BW: 75 Length: 15825.964 S/N: 1467.275



B0950+08 test.ar  
Freq: 49.512 MHz BW: 75 Length: 15825.964 S/N: 1467.276





# NenuFAR: Observation modes (folding)

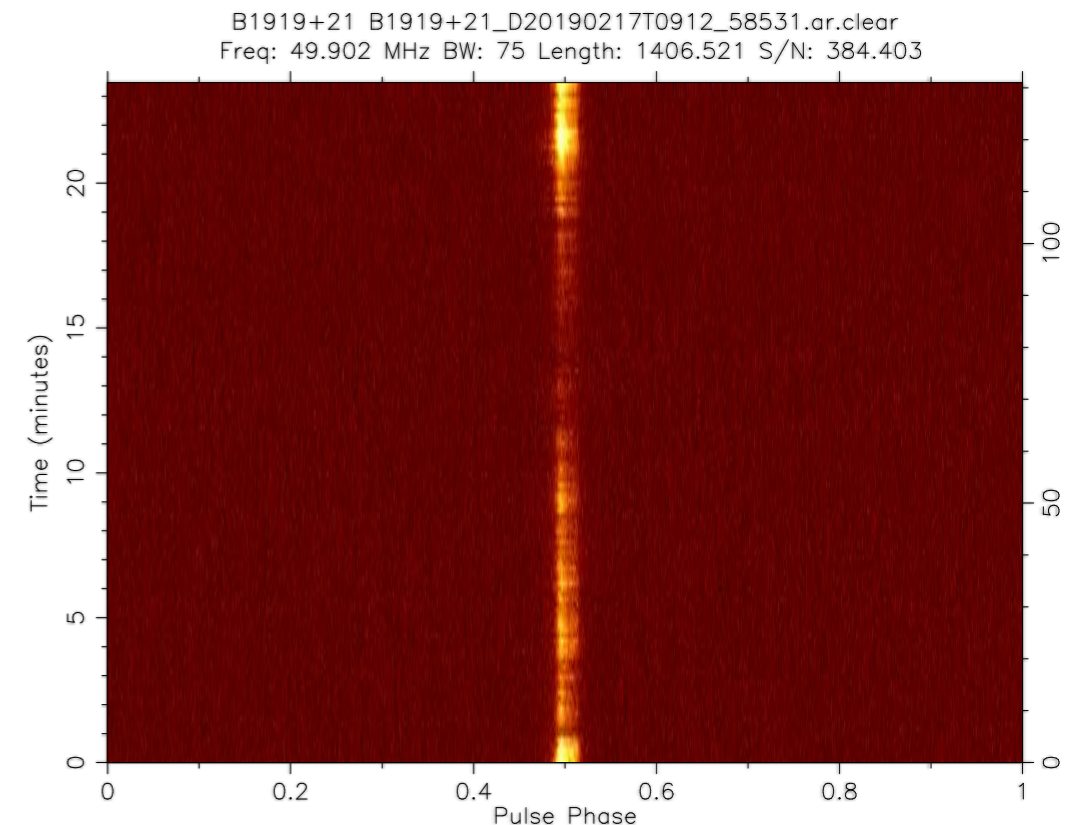
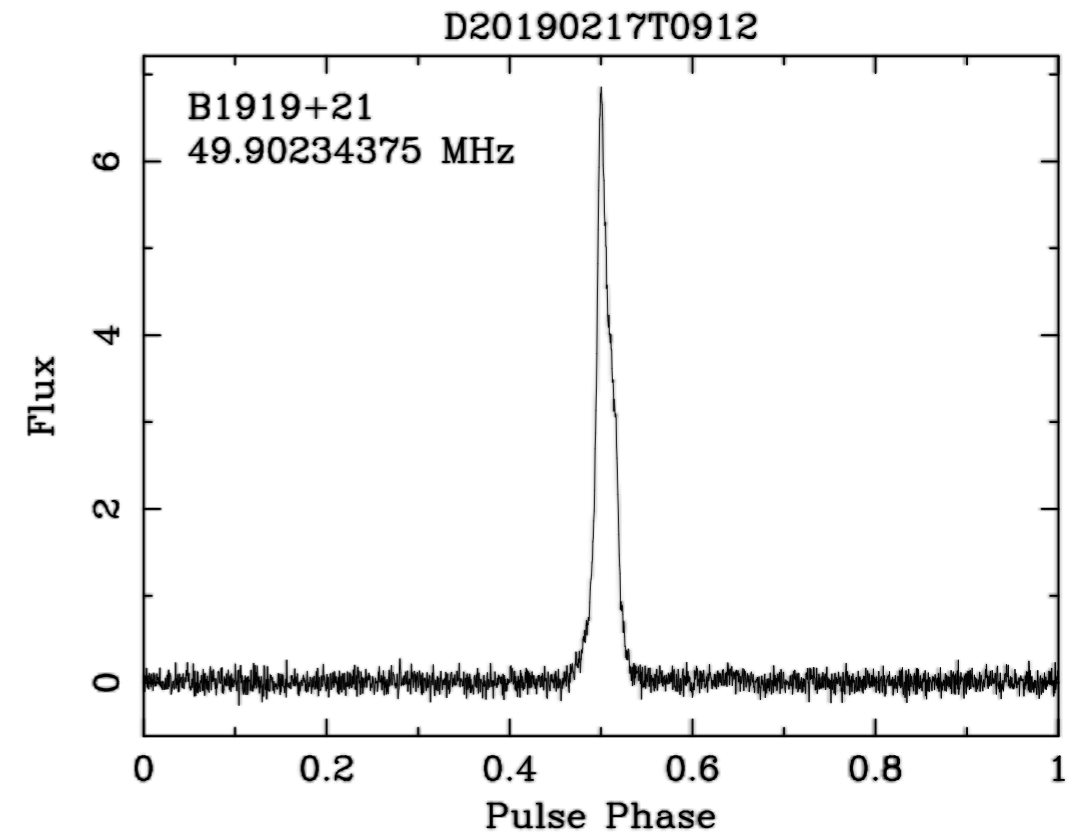
## Observation modes:

1. folding
2. single pulse
3. waveform

## folding mode:

- folding in real time
- dedispersion in real time
- single channel size fixed to 195 kHz
- low cost in disk space

produce 1 GB/h





# NenuFAR: Observation modes

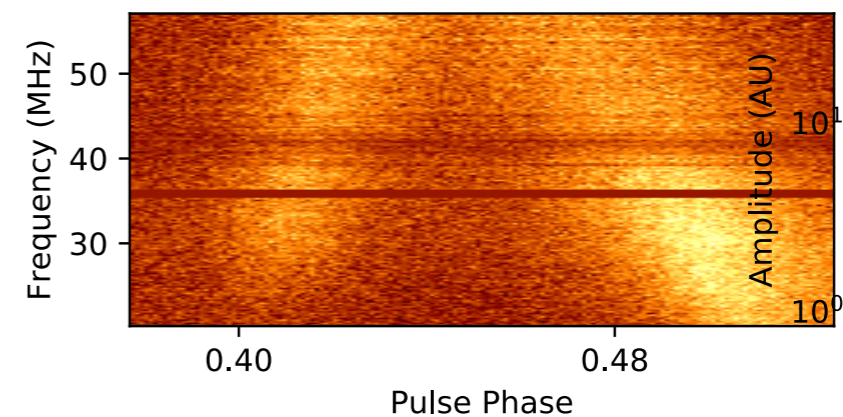
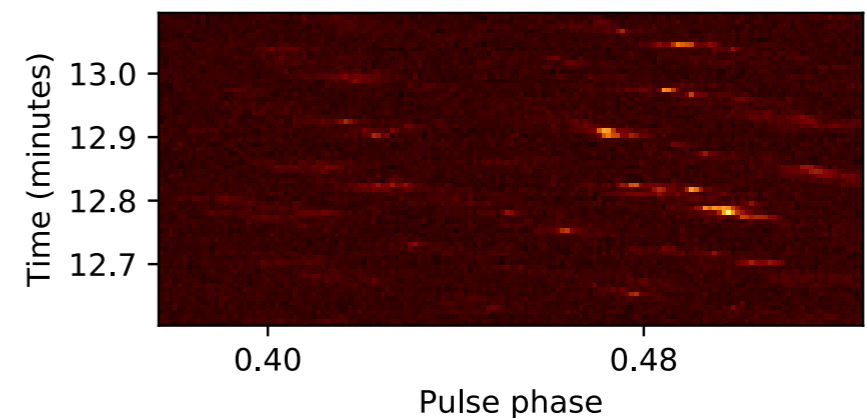
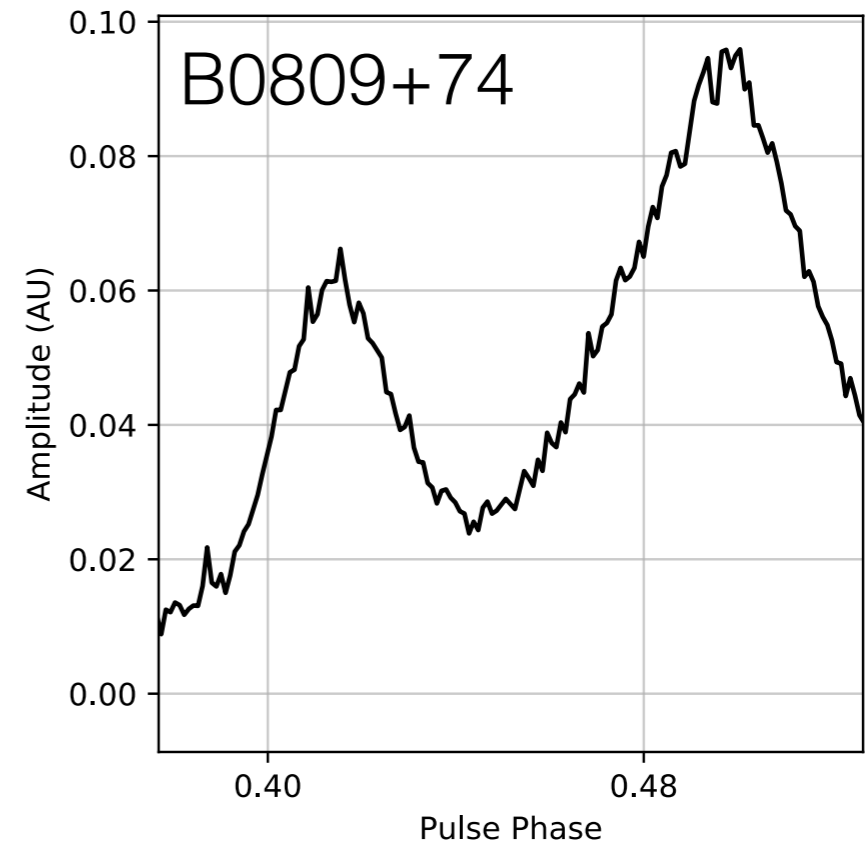
## Observation modes:

1. folding
2. single pulse
3. waveform

## single pulse mode:

- recorde each rotation independently
- dedispersion in real time
- single channel size fixed to 195 kHz
- medium cost in disk space

produce 10 GB/h



## Observation modes:

1. folding
2. single pulse
- ③ waveform

## waveform mode:

- no rule

produce 1 TB/h

- reprocessing
- folding / singlepulse
- rechannelization using dspsr
- no limit on dedispersion

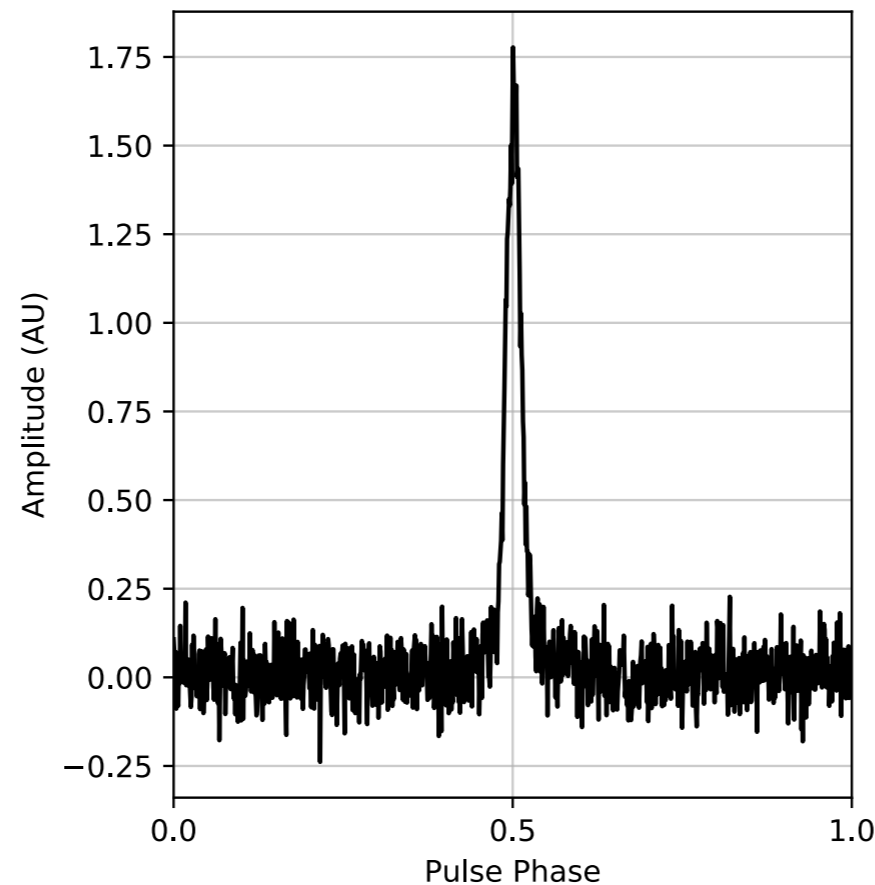


# NenuFAR: Observation modes

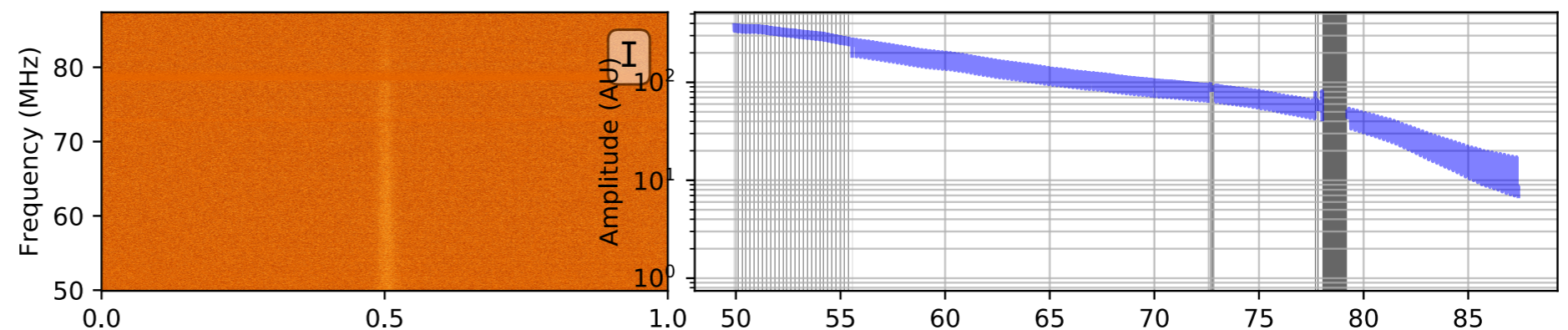
## Observation modes:

1. folding
2. single pulse
3. waveform

3072 channels



|             |  |                |
|-------------|--|----------------|
| name        | Source name                              | J0826+2637     |
| nbin        | Number of pulse phase bins               | 1024           |
| nchan       | Number of frequency channels             | 3072           |
| npol        | Number of polarizations                  | 1              |
| nsubint     | Number of sub-integrations               | 155            |
| length      | Observation duration (s)                 | 82.18861568    |
| dm          | Dispersion measure (pc/cm <sup>3</sup> ) | 19.4743003845  |
| period topo | Folding_period (s)                       | 0.530677407175 |
| type        | Observation type                         | Pulsar         |
| site        | Telescope name                           | nenufar        |
| coord ra    | Source coordinates (hms)                 | 08:26:51.384   |
| coord dec   | Source coordinates (dms)                 | +26:37:23.794  |
| freq        | Centre frequency (MHz)                   | 68.65234375    |
| bw          | Bandwidth (MHz)                          | 37.5           |
| rm          | Rotation measure (rad/m <sup>2</sup> )   | 0.0            |
| dmc         | Dispersion corrected                     | False          |
| rnc         | Faraday Rotation corrected               | False          |
| polc        | Polarization calibrated                  | False          |
| scale       | Data units                               | FluxDensity    |
| stat        | Data state                               | Intensity      |
| rcvr:name   | Receiver name                            | LaNewBa        |
| rcvr:basis  | Basis of receptors                       | Linear         |
| be:name     | Name of the backend instrument           | LUPPI          |
| MJDstart    | MJD of the first subintegration          | 58522.9854191  |
| SNR         | Signal noise ratio                       | 77.1519699097  |
| RFI         | Radio Frequency Interferency (/100)      | 7.52           |
| elevStart   | Elevation of the first subintegration    | 68.0811005606  |
| elevEnd     | Elevation of the last subintegration     | 67.995598701   |

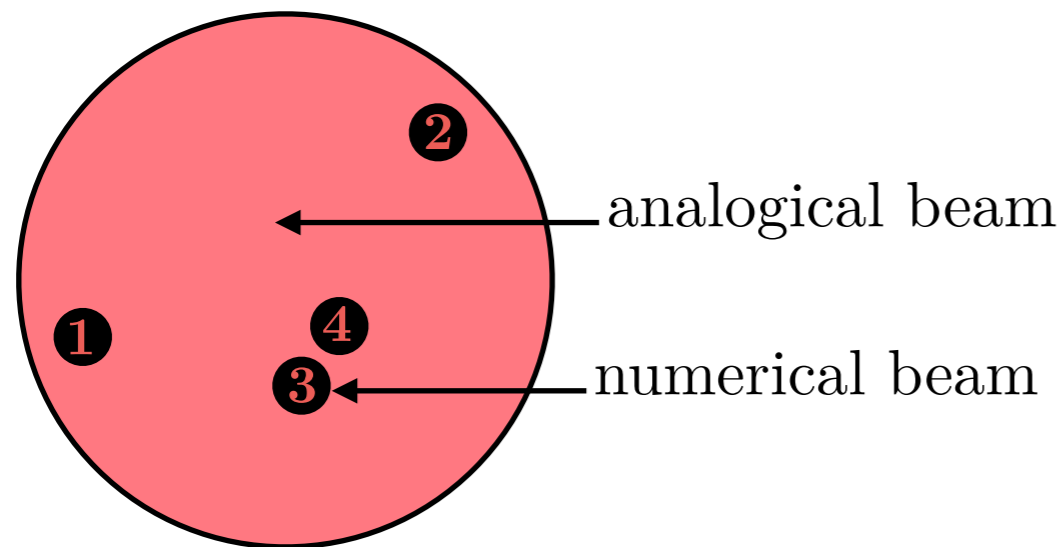


## Observation modes:

1. folding
2. single pulse
3. waveform

## 4 lanes of 37.5 MHz per observation

- total of 150 MHz of band width
- able to observed 4 pulsars simultaneously
- working with mode mixing
- compatible with Undisputed dynamique spectrum





## Observational limits:

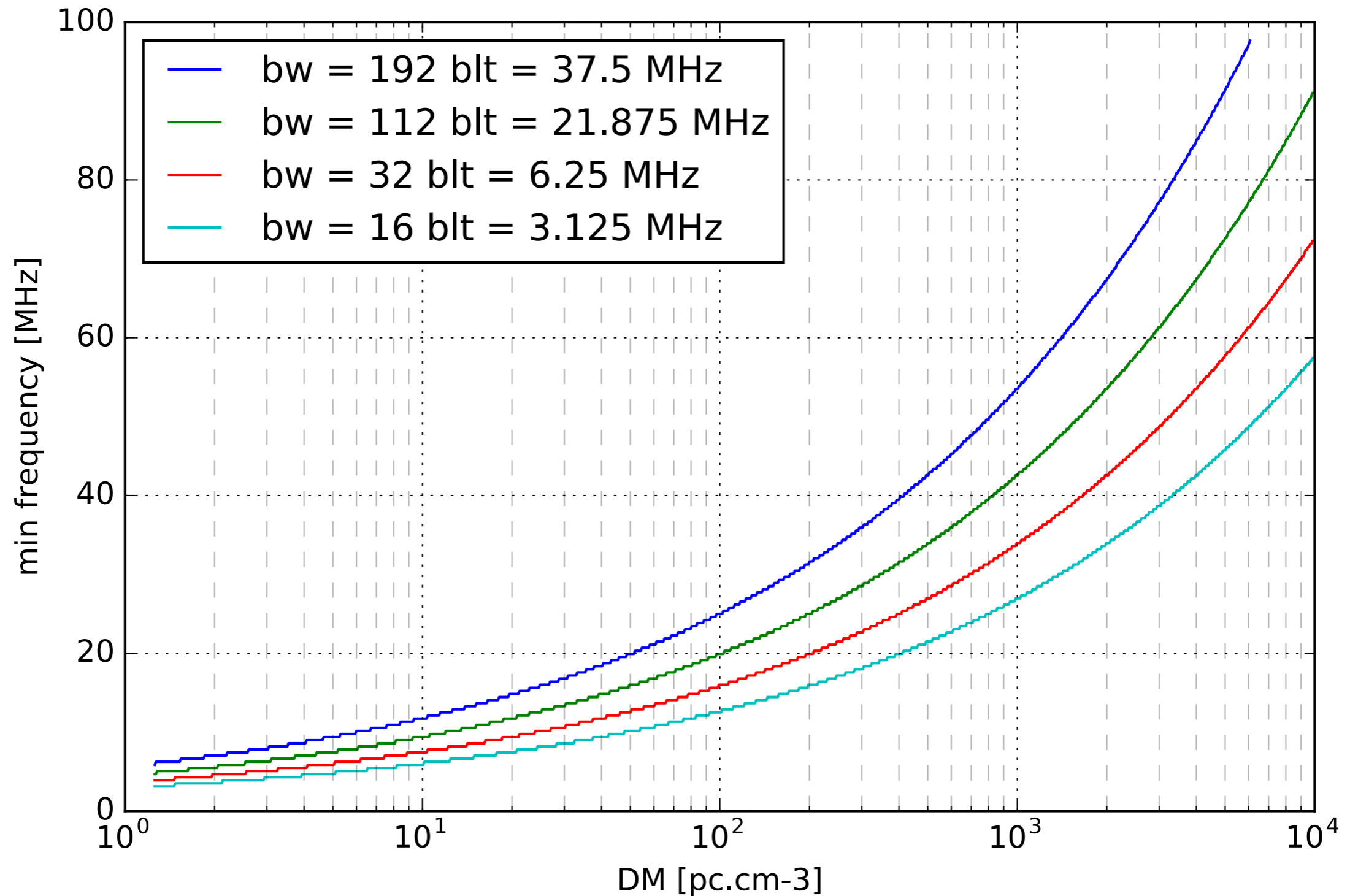
1. minimum frequency and DM
2. the Faraday rotation
3. calibrations (flux and polarization)

Limited by the size of the FFT in  
the Graphical Processing Units  
( 8 GB of memory)

# NenuFAR: Observational limits

## Observational limits:

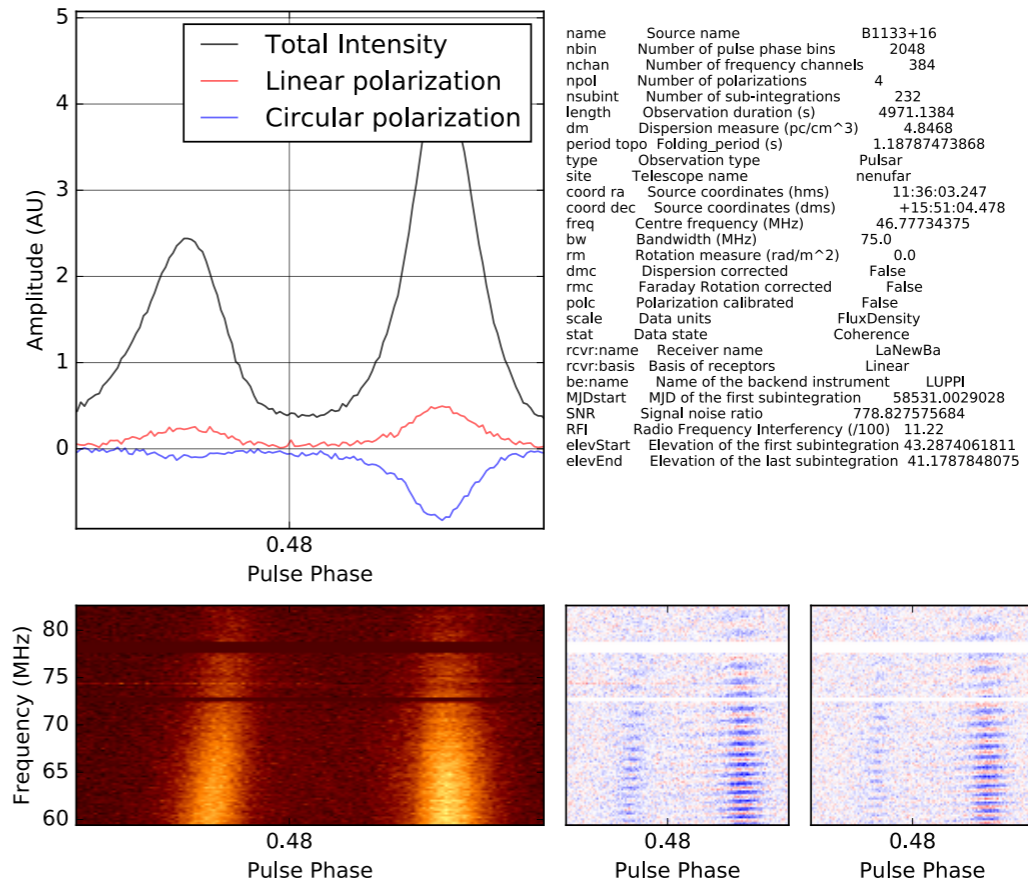
1. minimum frequency and DM





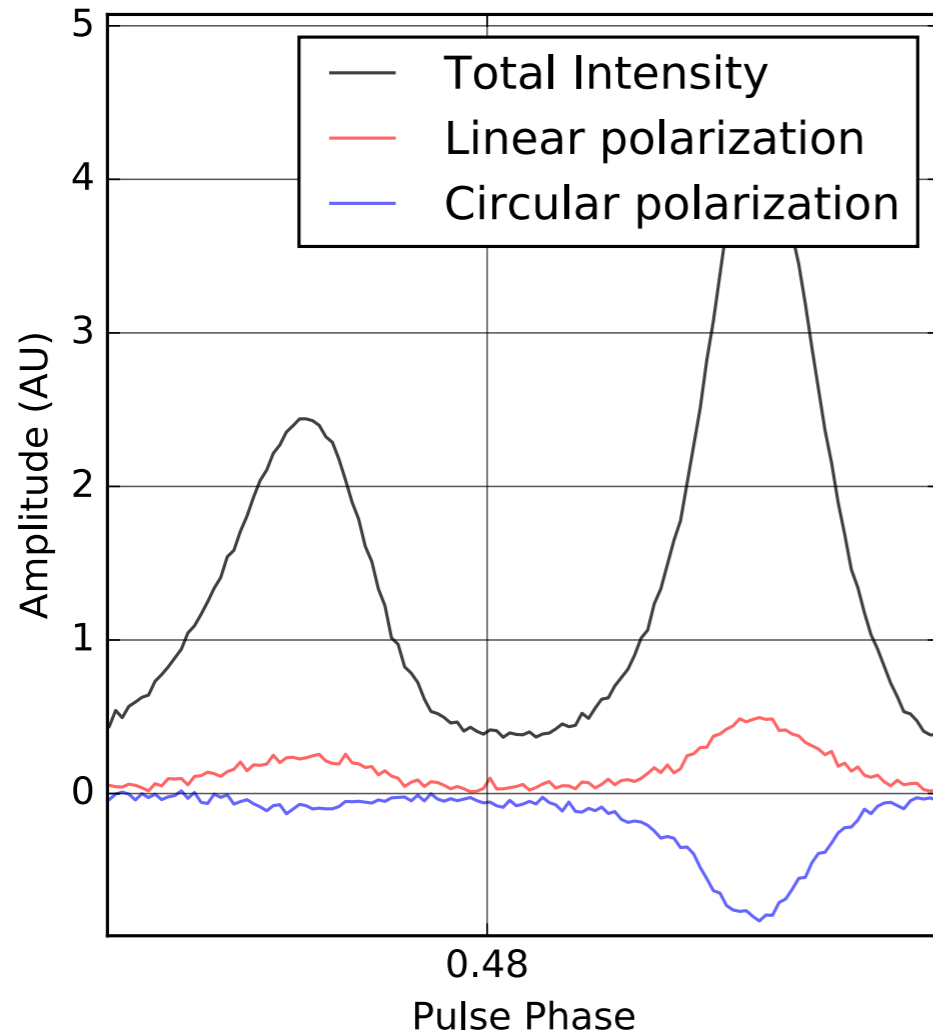
## Observational limits:

1. minimum frequency and DM
2. the Faraday rotation
3. flux calibration
4. polarisation calibration



Linear polarisation is affected by the  
Faraday rotation

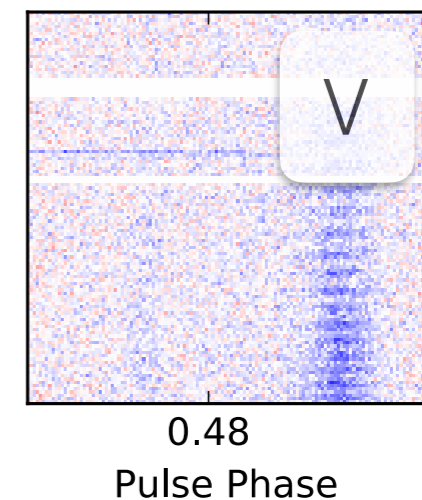
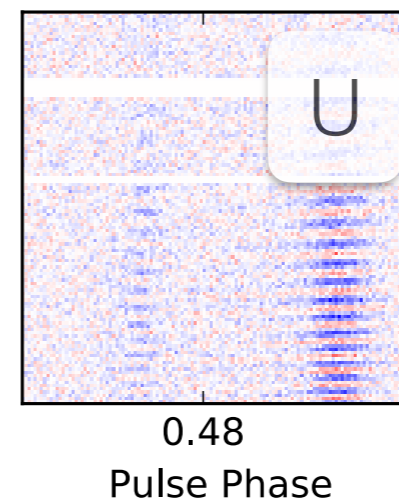
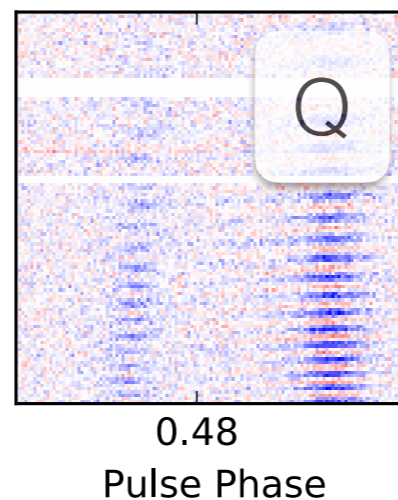
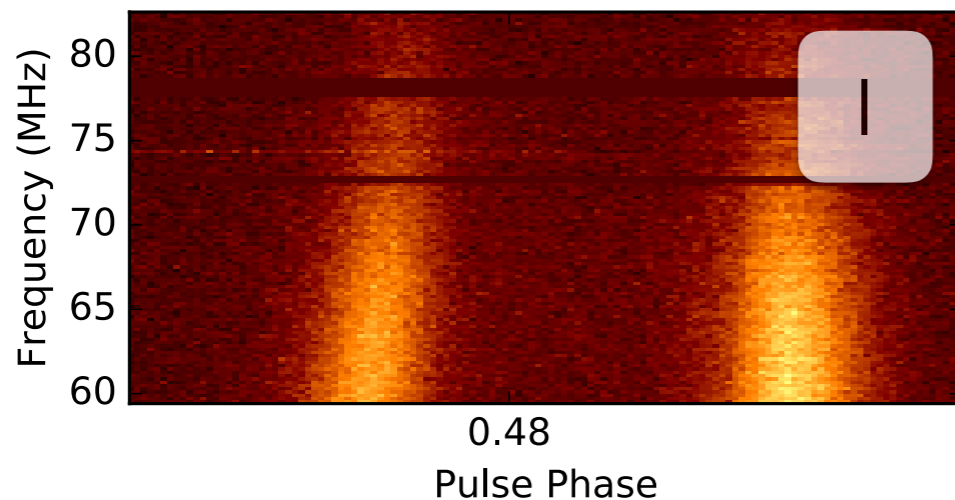
# NenuFAR: Observational limits



|             |  |               |
|-------------|--|---------------|
| name        | Source name                              | B1133+16      |
| nbin        | Number of pulse phase bins               | 2048          |
| nchan       | Number of frequency channels             | 384           |
| npol        | Number of polarizations                  | 4             |
| nsubint     | Number of sub-integrations               | 232           |
| length      | Observation duration (s)                 | 4971.1384     |
| dm          | Dispersion measure (pc/cm <sup>3</sup> ) | 4.8468        |
| period topo | Folding_period (s)                       | 1.18787473868 |
| type        | Observation type                         | Pulsar        |
| site        | Telescope name                           | nenufar       |
| coord ra    | Source coordinates (hms)                 | 11:36:03.247  |
| coord dec   | Source coordinates (dms)                 | +15:51:04.478 |
| freq        | Centre frequency (MHz)                   | 46.77734375   |
| bw          | Bandwidth (MHz)                          | 75.0          |
| rm          | Rotation measure (rad/m <sup>2</sup> )   | 0.0           |
| dmc         | Dispersion corrected                     | False         |
| rnc         | Faraday Rotation corrected               | False         |
| polc        | Polarization calibrated                  | False         |
| scale       | Data units                               | FluxDensity   |
| stat        | Data state                               | Coherence     |
| rcvr:name   | Receiver name                            | LaNewBa       |
| rcvr:basis  | Basis of receptors                       | Linear        |
| be:name     | Name of the backend instrument           | LUPPI         |
| MJDstart    | MJD of the first subintegration          | 58531.0029028 |
| SNR         | Signal noise ratio                       | 778.827575684 |
| RFI         | Radio Frequency Interferency (/100)      | 11.22         |
| elevStart   | Elevation of the first subintegration    | 43.2874061811 |
| elevEnd     | Elevation of the last subintegration     | 41.1787848075 |

$$RM = 3.97 \text{ rad.m}^{-2}$$

- It is the top of the band !!



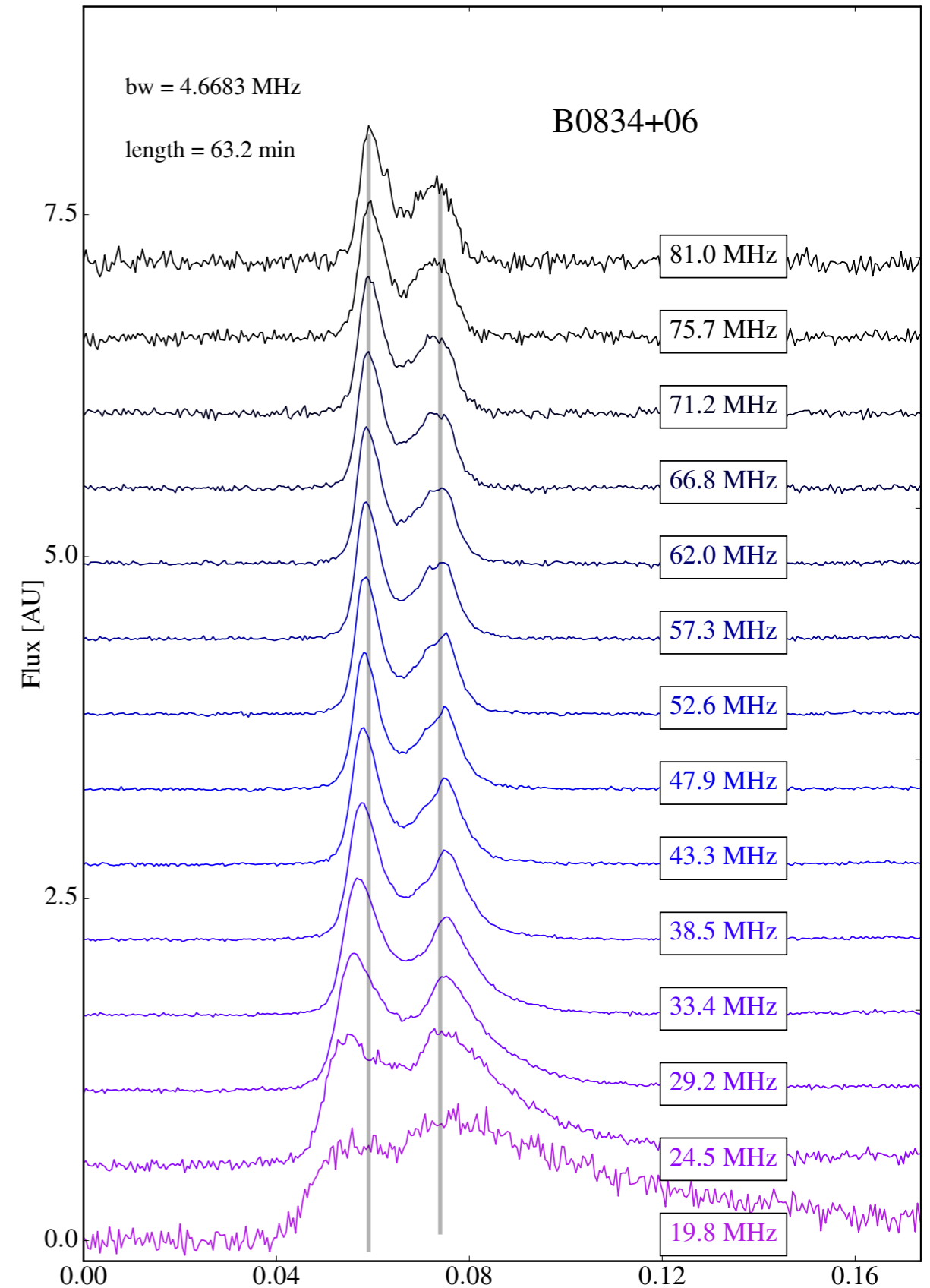
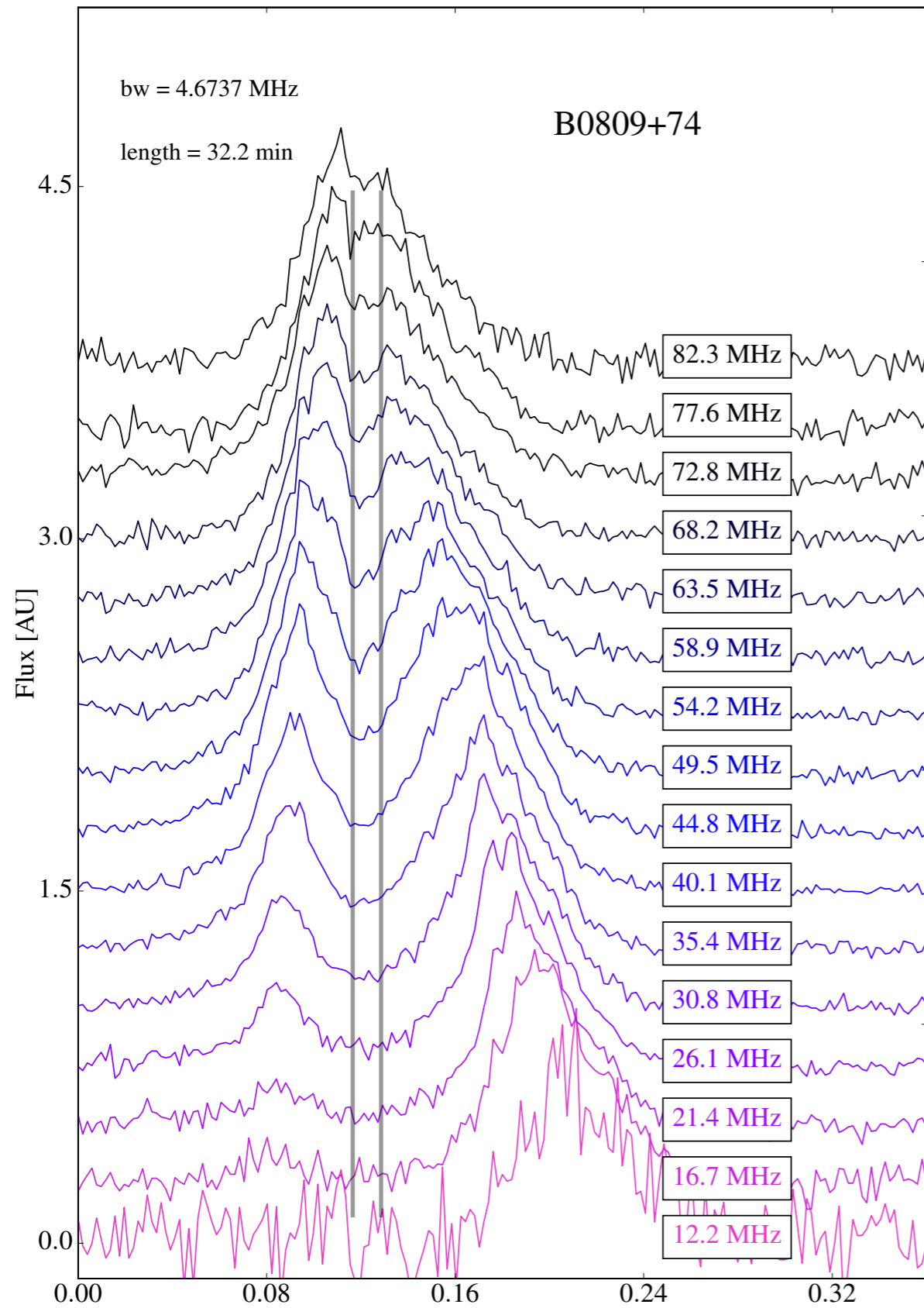


## Observational limits:

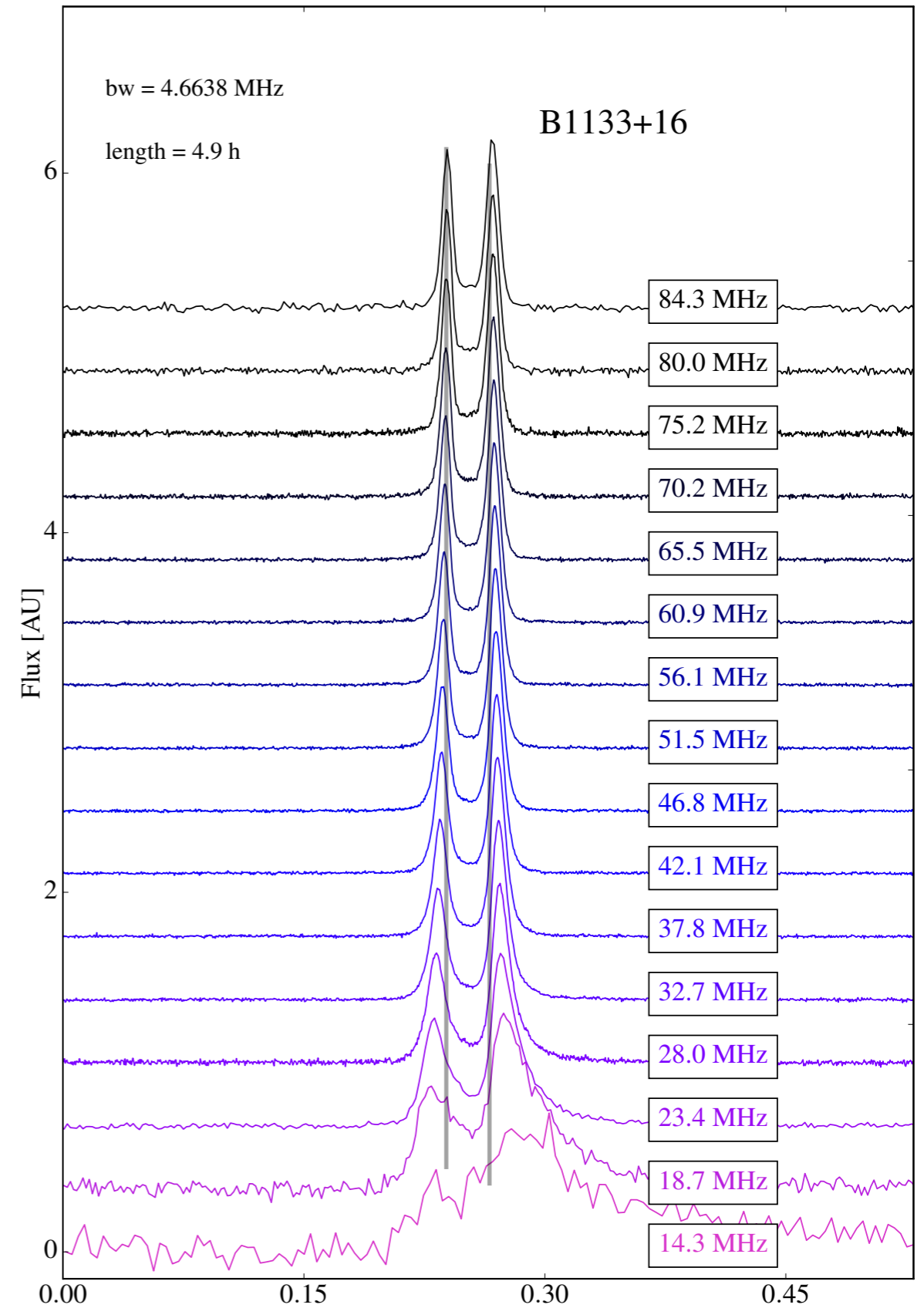
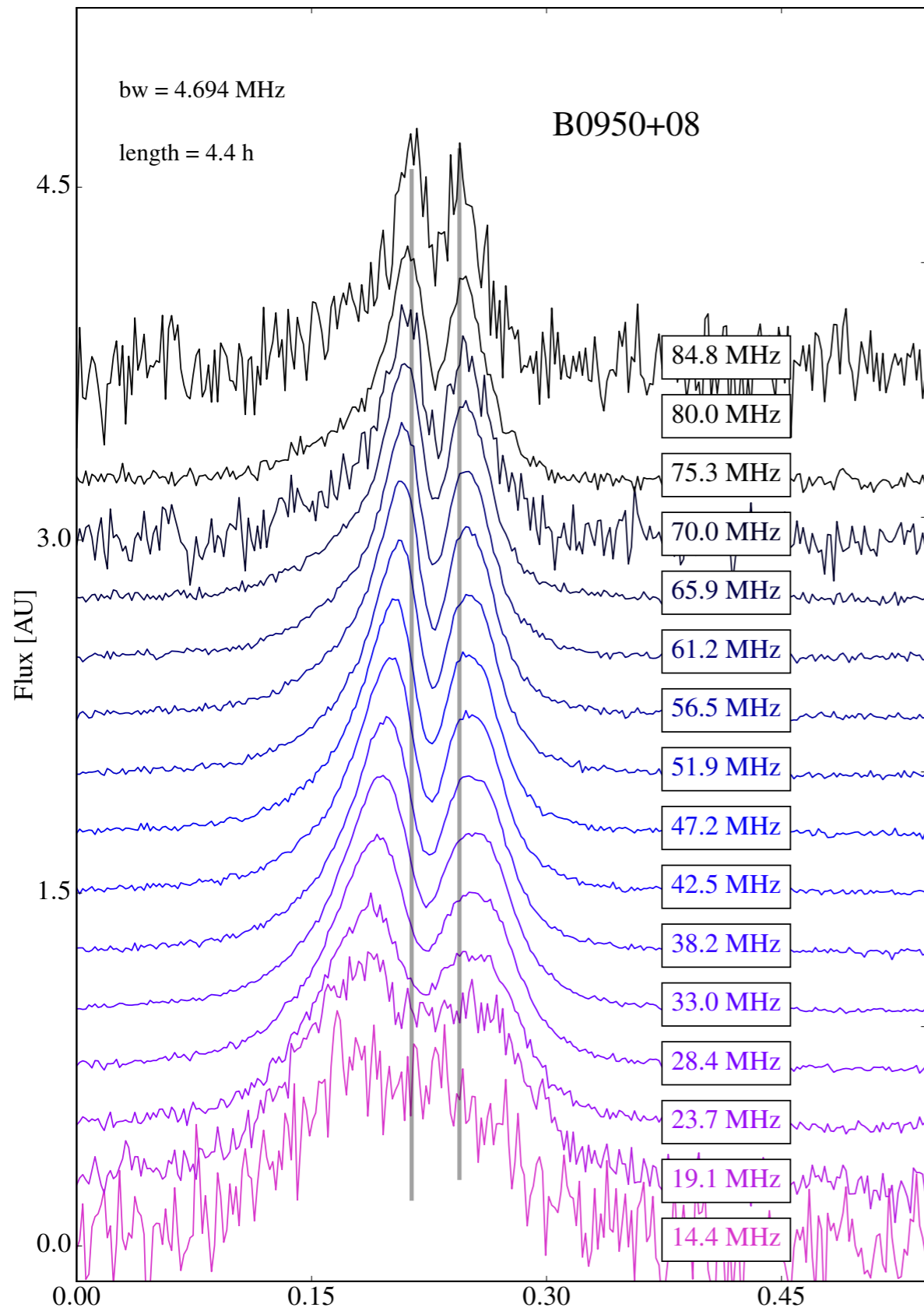
1. minimum frequency and DM
2. the Rotation Measure
3. calibrations (flux and polarization)

TODO !!

# NenuFAR: Results

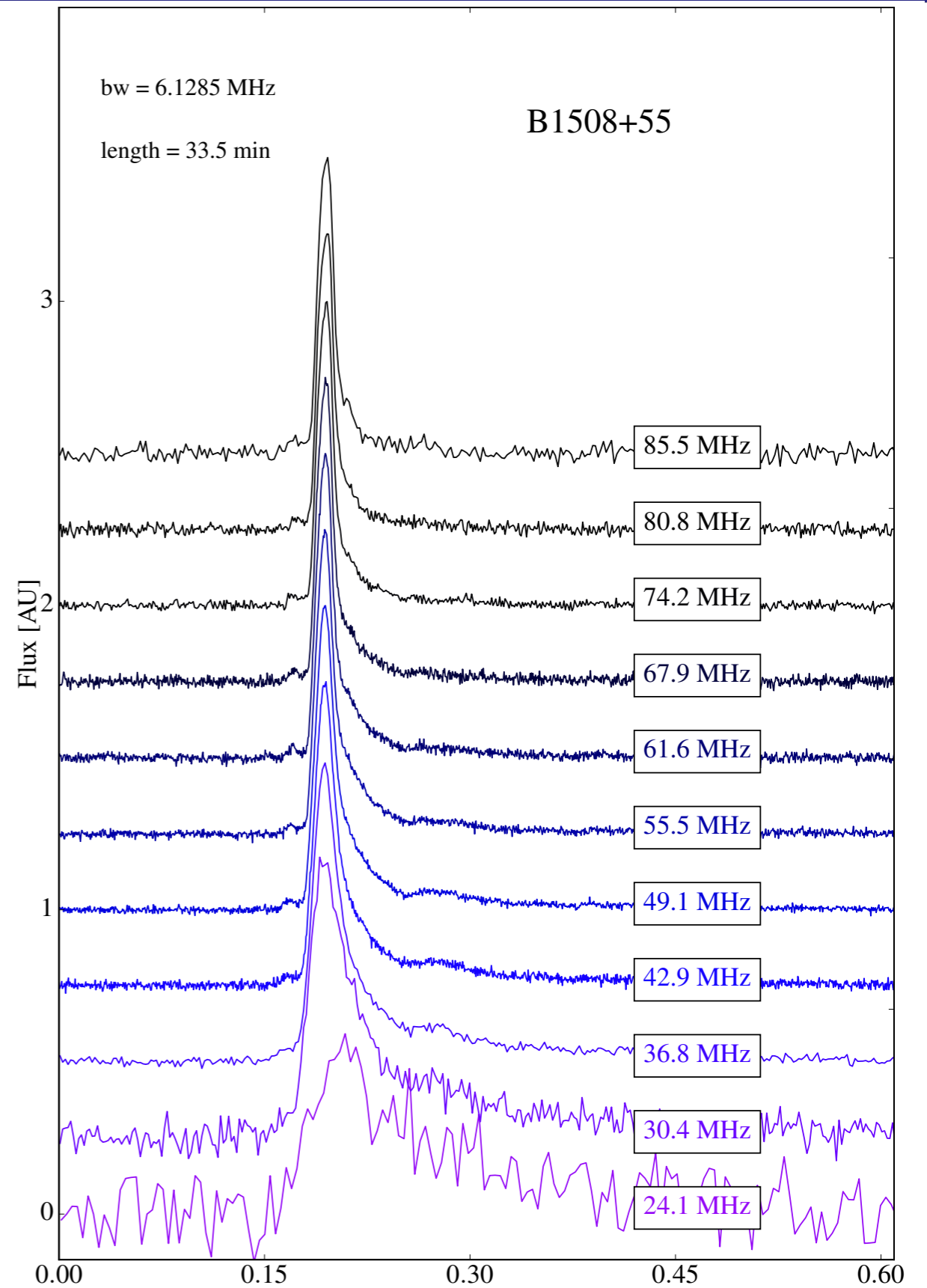
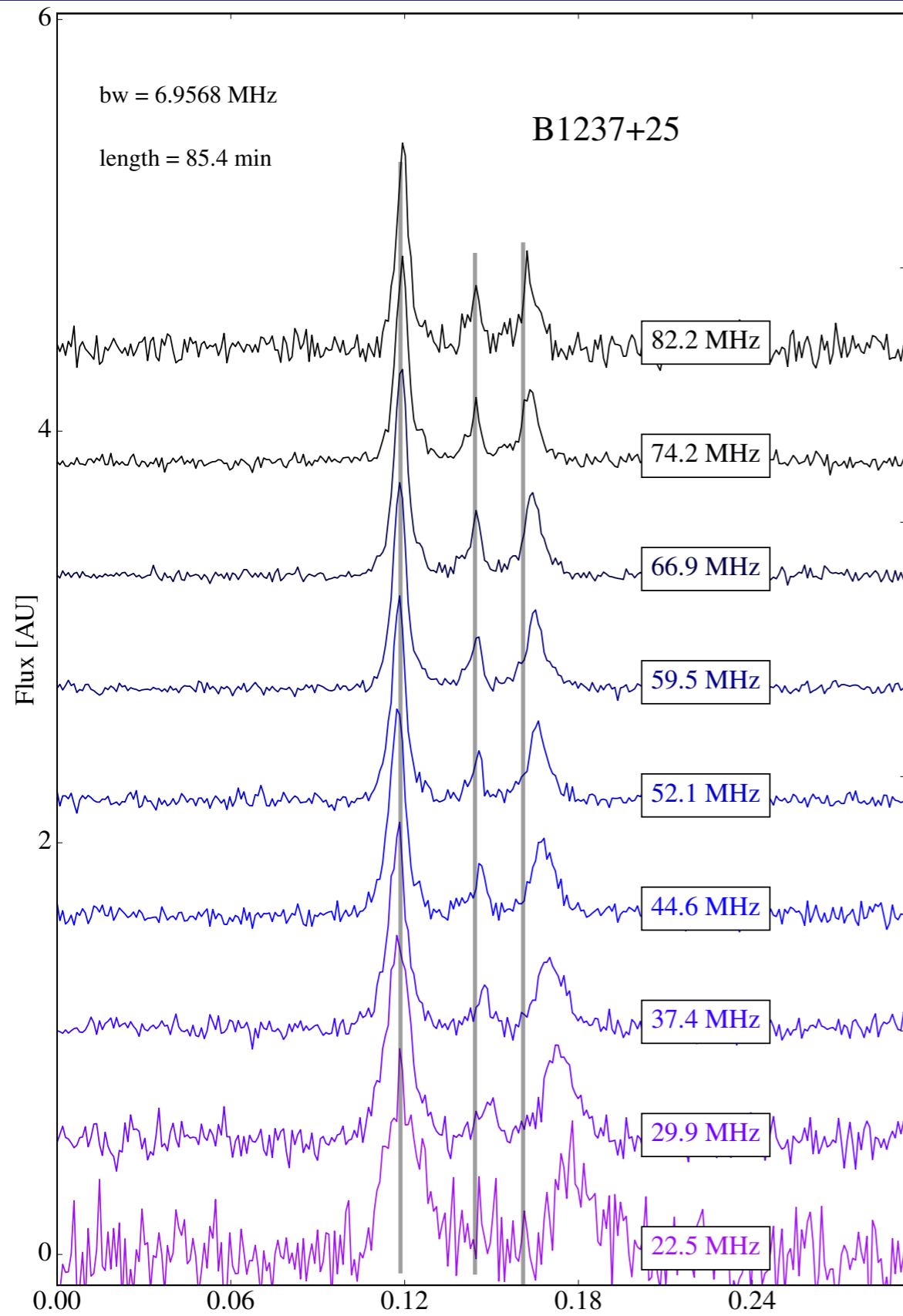


# NenuFAR: Results





# NenuFAR: Results



# NenuFAR: Results

