NOEMA spectral setups

Jeremie Boissier
Overview

Frontend

Astronomy

Backend

IF processing

Correlator

IF processing

Geometric delay

Frontend

Astronomy
Overview

Frontend

Astronomy

Backend

IF processing

Correlator

IF processing

Astronomy
NOEMA receivers

NOEMA antennas are equipped with heterodyne receivers

- Input: Radio frequency signal at ~mm wavelengths (~70-380GHz)
- Output: Slices of sky signal down converted to lower frequencies (~0-20GHz)

- Detecting devices are sensitive to narrow (~50-100 GHz) ranges of the spectrum
  - 4 receiver bands to cover 70 – 380 GHz range (i.e. 0.8 to 4.3 mm)
**NOEMA receivers**

**Heterodyne systems**

- Down-convert the spectrum from Radio Frequency ($50 < F_{RF} < 500$ GHz) to Intermediate Frequency ($F_{IF} < 20$ GHz)
NOEMA receivers

Heterodyne systems

- Down-convert the spectrum from Radio Frequency (50 < $F_{RF}$ < 500 GHz) to Intermediate Frequency ($F_{IF}$ < 20 GHz)
- Tuning the receiver = setting the FLO1 + optimizing some LO and Mixer parameters

Local Oscillator
Monochromatic signal
($F_{LO1}$)

229
237

$F_{IF} = F_{RF} - F_{LO}$

4
12

Radio Frequency (RF)

Intermediate Frequency (IF)
NOEMA receivers

Heterodyne systems

- Down-convert the spectrum from Radio Frequency ($50 < F_{RF} < 500$ GHz) to Intermediate Frequency ($F_{IF} < 20$ GHz)
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- Down-convert the spectrum from Radio Frequency ($50 < F_{RF} < 500$ GHz) to Intermediate Frequency ($F_{IF} < 20$ GHz)
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Local Oscillator Monochromatic signal ($F_{LO1}$)

213 LSB 221
229 USB 237

LSB/rejection 4 + USB 12

Single side band (SSB) output
NOEMA receivers

Heterodyne systems

- Down-convert the spectrum from Radio Frequency ($50 < F_{\text{RF}} < 500$ GHz) to Intermediate Frequency ($F_{\text{IF}} < 20$ GHz)
- Tuning the receiver = setting the FLO1 + optimizing some LO and Mixer parameters

Radio Frequency (RF)

Local Oscillator
Monochromatic signal
($F_{\text{LO1}}$)

2 side band (2SB) output

Intermediate Frequency (IF)
NOEMA receivers

Heterodyne systems

- Down-convert the spectrum from Radio Frequency (50 < \( F_{RF} \) < 500 GHz) to Intermediate Frequency (\( F_{IF} < 20 \) GHz)
- Tuning the receiver = setting the FLO1 + optimizing some LO and Mixer parameters

![Diagram showing the down-conversion process from RF to IF, including the Local Oscillator (F_{LO1}) and the USB/LSB signals.]

2 side band (2SB) output
NOEMA uses 2SB receivers
NOEMA receivers

Dual polarization

- 1 NOEMA receiving system detects 1 linear polarization
- Detecting 2 orthogonal polarization
  - Gain factor of 2 on observing time
  - Possibility to do polarimetry (provided some hard and soft changes)
- Each receiver band contains 2 receiving systems: Horizontal and Vertical polarization
  - Separation grid on the incident path
  - Each receiver band contains 2 mixer-blocks (H,V) made of 2 mixers (USB,LSB)
- Receiver band output contains 4 slices of spectrum:
  HLSB HUSB VLSB VUSB
  They are all brought to the correlator room through optic fibers
NOEMA receivers

Summary and nomenclature

- NOEMA antennas are equipped with 2SB, dual polarization, heterodyne receivers
  - Band 1: 72-116 GHz
  - Band 2: 127-179 GHz
  - Band 3: 200-276 GHz
  - Band 4: 275-373 GHz (2018)

- Tuning a receiver band = setting $F_{LO1} = F_{RF} \pm F_{IF}$

- Receiver output contains 4 slices of spectrum:
  - HLSB HUSB VLSB VUSB
  - Width= 8GHz
  - From 4 to 12 GHz in IF
Overview

Frontend

Astronomy

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Correlator

IF processing

Astronomy
NOEMA correlator PolyFix

Very simplified view of a correlator

Electric field from 12 Antennas
\[ E_i(t) \]

1 2 3... 12

CORRELATOR

1-2 1-3 2-3... 11-12

Visibility for 12*11/2 baselines
\[ V(u,v,v) \]
NOEMA correlator PolyFix

Less simplified view of a correlator (still much simpler than reality)

- Analog to Digital conversion
  - Correlator receives analogical signal from all the antennas
  - The wider the band, the higher the sampling rate, and the more difficult to implement
    - Converting 8 GHz bandwidth is challenging the best available ADC chips
      - Choice to split the input bandwidth into 2 parts of 4GHz
        - 0-4 GHz Basebands
- Correlation

Electric field from 12 Antennas
\[ E_i(t) \]

1 2 3... 12

A/D conversion
(= Sampling)

Correlation

Visibility for 12*11/2 baselines
\[ V(u,v,v) \]
NOEMA correlator PolyFix

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Electric field from 12 Antennas
E_i(t)
1 2 3... 12

Visibility for 12*11/2 baselines
V(u,v,v)
IF Processing

- Adapt the output of the receiver to the input of the correlator
  - 1 NOEMA receiver band delivers 4 x 8 GHz sidebands [4-12 GHz IF1]
  - 1 NOEMA correlator unit accepts 1 x 4 GHz [0-4 GHz IF2] x 12 antennas
- IF processor splits each sideband into 2 x 4GHz basebands
  - Downconversion to 0-4GHz IF2
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![Diagram of IF Processing](image)
IF Processing

- Adapt the output of the receiver to the input of the correlator
  - 1 NOEMA receiver band delivers 4 x 8 GHz sidebands [4-12 GHz IF1]
  - 1 NOEMA correlator unit accepts 1 x 4 GHz [0-4 GHz IF2] x 12 antennas
- IF processor splits each sideband into 2 x 4GHz basebands
  - Downconversion to 0-4GHz IF2
Nomenclature: Summary

8 Basebands (0-4 GHz IF2) feed 8 correlator units
NOEMA correlator PolyFix

Less less simplified view of a correlator (still simpler than reality)

Electric field $E_i(t)$ from 12 Antennas 4-12 GHz IF1

- IF Processor
  - Separate INNER and OUTER Basebands for the 4 receiver outputs (x12A)

- Analog to Digital conversion (ADC)

- Correlation

*Correlation*
NOEMA correlator PolyFix

Less less simplified view of a correlator (still simpler than reality)

- **Electric field** $E_i(t)$ from 12 Antennas 4-12 GHz IF1
  
  - **IF Processor**
    - Separate INNER and OUTER Basebands for the 4 receiver outputs (x12A)
  
  - **Analog to Digital conversion (ADC)**
  
- **Correlation**
  - **XF (e.g. widex)**
    1. Cross correlation (time domain)
    2. Then Fourier transform (frequency domain)
  - **FX (PolyFix)**
    1. Fourier transform (frequency domain)
    2. Cross spectrum (frequency domain)
      - Multiplication of the spectra of 2 antennas
NOEMA correlator: POLYFIX

8 identical and independent correlator units

- Input: 0-4 GHz baseband (x 12 antennas)
- Signal is digitized
- Baseband is split in 64 Chunks of 64 MHz on a fixed grid
  - “Overlapping Polyphase Filter Bank”
  - Last 3 chunks thrown away (antialiasing filter)
    Effective bandwidth=3872 MHz
NOEMA correlator: POLYFIX

8 identical and independent correlator units

- Input: 0-4 GHz baseband (x 12 antennas)
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- Baseband is split in **64 Chunks** of 64 MHz on a fixed grid
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    Effective bandwidth=3872 MHz
  - Confusion zone affecting first ~2 chunks
NOEMA correlator: POLYFIX

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- Input: 0-4 GHz baseband (x 12 antennas)
- Signal is digitalized
- Baseband is split in **64 Chunks** of 64 MHz on a fixed grid
  - “Overlapping Polyphase Filter Bank”
  - Last 3 chunks thrown away (antialiasing filter)
    - Effective bandwidth=3872 MHz
  - Confusion zone affecting first ~2 chunks
- Then Fourier Transforms and cross multiplication (FX)
  - Re-programmable: **Correlator modes**
  - Choice of the mode is done by correlator unit
    - i.e. different basebands can be processed using different modes
NOEMA correlator: POLYFIX

Correlator Modes:

- **Capabilities for a single unit**
- **Mode 1: Continuum + Lines**
  - 61 chunks at Low resolution (2MHz); total bandwidth 3872 MHz
  - [AND] 16 chunks at High resolution (62.5kHz); bandwidth 64 MHz each
  - Unique mode at delivery in 2017
- **Mode 2: Survey**
  - 61 chunks at 250 kHz; total bandwidth 3872 MHz
  - [Later]
- **Mode 3: Continuum and high resolution lines**
  - Similar to mode 1 with higher resolution in less chunks
  - [Even later]

<table>
<thead>
<tr>
<th></th>
<th>1 Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode 1 (2017):</strong></td>
<td>61 chunks (3872 MHz) at 2 MHz resolution AND</td>
</tr>
<tr>
<td>Continuum + Lines</td>
<td>16 chunks at 62.5 kHz resolution*</td>
</tr>
<tr>
<td></td>
<td>~16 GHz x 2 polar with 2 MHz channels AND</td>
</tr>
<tr>
<td></td>
<td>8 GHz with 62.5kHz channels*</td>
</tr>
<tr>
<td><strong>Mode 2:</strong></td>
<td>61 chunks (3872 MHz) at 250 kHz resolution</td>
</tr>
<tr>
<td>Survey</td>
<td>~16 GHz x 2 polar with 250 kHz channels</td>
</tr>
<tr>
<td><strong>Mode 3:</strong></td>
<td>&lt;61 chunks (3872 MHz) at 2 MHz resolution AND</td>
</tr>
<tr>
<td>Continuum + High</td>
<td>8/4/2 chunks at 31.25/15.625/7.8125 kHz resolution*</td>
</tr>
<tr>
<td>Resolution</td>
<td>&lt;16 GHz x 2 Polar with 2 MHz channels AND</td>
</tr>
<tr>
<td></td>
<td>4/2/1 GHz with 31.25/15.625/7.8125kHz channels*</td>
</tr>
</tbody>
</table>

*High resolution chunks chosen among the 61 of the fixed filter bank
Spectral windows

- The output of the correlator is a number of **spectral windows**
- In a given baseband, a **spectral window** is a set of contiguous chunks at the same spectral resolution
- With the default mode:
  - 1 Correlator Unit output is made of:
    - 1 low resolution spectral window (made of 61 chunks)
    - 1<n_{spw}<16 high resolution spectral windows (made of 16>n_{chls}>1 chunks)

1 low resolution SPW (3872 MHz wide, 2000 kHz channels)
1 high resolution SPW (1024 MHz wide, 62.5 kHz channels)
1 low resolution SPW (3872 MHz wide, 2000 kHz channels)
16 high resolution SPW (64 MHz wide each, 62.5 kHz channels)
1 low resolution SPW (3872 MHz wide, 2000 kHz channels)
4 high resolution SPW (widths: 384, 192, 320, 128 MHz, 62.5 kHz channels)
Overview

Frontend

Astronomy

Backend

Correlator

IF processing

Astronomy

IF processing
How to prepare NOEMA spectral observations

Use ASTRO in Gildas

```
$astro
OBSERVATORY NOEMA
TIME
```

Define a source (with a given velocity or redshift)

```
SOURCE
```

Define a receiver band tuning

```
TUNING
```

Select a/some baseband(s) + associated correlator mode

```
BASEBAND
```

Define flexible spectral windows (in the selected BB)

```
- Select the 16 high resolution chunks
  SPW
```

Examine my current settings

```
LIST
PLOT
```

Remove a spectral window

```
RESET
```

Get a final script

```
SETUP
```

Other useful commands:

- Get some help
  `HELP COMMAND`
- Show molecular lines on frequency plots
  `SET LINES ON`
- Choose line profile to be drawn
  `SET LINES GAUSS 100`
- Change the catalog of lines
  `CATALOG Myfile.lin /LINE`
- Choose the frequency axis
  `SET FREQUENCY Main Second`

Disclaimer:
Preparing NOEMA setups in ASTRO is a new functionnality
First release in GILDAS sep16b
All commands are likely to be modified. Plots are very likely to evolve.
Prepare the environment:

OBSERVATORY NOEMA

TIME 00:00:00.0 20–OCT–2016

SOURCE MySource EQ 2000 10:00:00.0 20:00:00.0 LSR 0

MySource Azimuth  -121.78699  Elevation  -2.75186
MySource V(S/OBS) =  -21.668 [S/LSR= 0.000,LSR/G= 4.952,G/OBS=-26.620]
MySource Redshift  0.000

! SOURCE must be entered to enable Doppler computations

SET LINES GAUSS 100

! Lines from the catalog will be indicated by a gaussian (width=100MHz)
Define the receiver tuning

**TUNING** ! Display the coverage of available receiver bands

! Nothing actually DONE, only plot

**I-TUNING**, Showing the coverage of NOEMA receiver bands
Define the receiver tuning

**TUNING** ! Display the coverage of available receiver bands

**TUNING** 230.538 LSB 6500 ! tune 230.538 REST at 6500 IF1 in LSB

I-TUNING, Resetting tuning
I-TUNING, Selecting the Band_3 band of the NOEMA receiver
I-TUNING, FRF = 230.55466 GHz
I-TUNING, FLO1 = 237.05466 GHz
I-TUNING, FLOTUNE = 237.03800 GHz
I-TUNING, Original tuning does not match the grid
I-TUNING, Tuning automatically shifted to the IF Frequency = 6462.000 MHz
I-TUNING, This corresponds to a shift of 38.000 MHz
I-TUNING, Actual command:
TUNING 230.538 LSB 6462.000
I-TUNING, Selecting the Band_3 band of the NOEMA receiver
I-TUNING, FRF = 230.55466 GHz
I-TUNING, FLO1 = 237.01666 GHz
I-TUNING, FLOTUNE = 237.00000 GHz
I-TUNING, Correlator input # 1 contains B3HUO
I-TUNING, Correlator input # 2 contains B3HUI
I-TUNING, Correlator input # 3 contains B3VUO
I-TUNING, Correlator input # 4 contains B3VUI
I-TUNING, Correlator input # 5 contains B3HLU
I-TUNING, Correlator input # 6 contains B3HLI
I-TUNING, Correlator input # 7 contains B3VLO
I-TUNING, Correlator input # 8 contains B3VLI
NOEMA setups in ASTRO

Define the receiver tuning

TUNING ! Display the coverage of available receiver bands
TUNING 230.538 LSB 6500 ! tune 230.538 REST at 6500 IF1 in LSB

I-TUNING, Resetting tuning
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I-TUNING, Correlator input # 5 contains B3HLO
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I-TUNING, Correlator input # 7 contains B3VLO
I-TUNING, Correlator input # 8 contains B3VLI
Define the receiver tuning

**TUNING** ! Display the coverage of available receiver bands

**TUNING 230.538 LSB 6500 /ZOOM** ! tune 230.538 REST at 6500 IF1 in LSB

I-TUNING,  Resetting tuning
I-TUNING,  Selecting the Band_3 band of the NOEMA receiver
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I-TUNING,  FLOTUNE :
I-TUNING,  Original :
I-TUNING,  Tuning autom :
I-TUNING,  This corre :
I-TUNING,  Actual corre :

**TUNING 230.538 LSB 6500 /ZOOM** ! tune 230.538 REST at 6500 IF1 in LSB

I-TUNING,  Selecting
I-TUNING,  FRF :
I-TUNING,  FLO1 :
I-TUNING,  FLOTUNE :
I-TUNING,  Correlato :
I-TUNING,  Correlato :
I-TUNING,  Correlato :
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I-TUNING,  Correlato :
I-TUNING,  Correlato :
I-TUNING,  Correlato :

I-TUNING,  Correlato :
NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

**BASEBAND Mode Selection Code**

! Mode not useful yet, omitted

! Selection code = baseband identification

combination of H/V, U/L, O/I

**BASEBAND** ! No selection: (H+V) x (U+L) x (O+I) = 8 basebands
Select a/some basebands and assign a correlator mode

**BASEBAND Mode Selection Code**

- ! Mode not useful yet, omitted
- ! Selection code = baseband identification combination of H/V, U/L, O/I

**BASEBAND**
- ! No selection: \((H+V) \times (U+L) \times (O+I) = 8\) basebands
- **BASEBAND H**
  - H polar selected: \(H \times (U+L) \times (O+I) = 4\) basebands
Select a/some basebands and assign a correlator mode

BASEBAND Mode Selection Code

! Mode not useful yet, omitted

! Selection code = baseband identification combination of H/V, U/L, O/I

BASEBAND ! No selection: (H+V) x (U+L) x (O+I) = 8 basebands
BASEBAND H ! H polar selected: H x (U+L) x (O+I) = 4 basebands
BASEBAND L ! Lower sideband: (H+V) x L x (O+I) = 4 basebands
NOEMA setups in ASTRO

Select a/some basebands and assign a correlator mode

BASEBAND Mode Selection Code
! Mode not useful yet, omitted
! Selection code = baseband identification combination of H/V,U/L,O/I

BASEBAND ! No selection: (H+V) x (U+L) x (O+I) = 8 basebands
BASEBAND H ! H polar selected: H x (U+L) x (O+I) = 4 basebands
BASEBAND L ! Lower sideband: (H+V) x L x (O+I) = 4 basebands
BASEBAND I ! Inner basebands: (H+V) x (U+L) x I = 4 basebands
Select a/some basebands and assign a correlator mode

**BASEBAND Mode Selection Code**

! Mode not useful yet, omitted

! Selection code = baseband identification combination of H/V,U/L,O/I

**BASEBAND** ! No selection: \((H+V) \times (U+L) \times (O+I) = 8 \) basebands

**BASEBAND H** ! H polar selected: \(H \times (U+L) \times (O+I) = 4 \) basebands

**BASEBAND L** ! Lower sideband: \((H+V) \times L \times (O+I) = 4 \) basebands

**BASEBAND I** ! Inner basebands: \((H+V) \times (U+L) \times I = 4 \) basebands

**BASEBAND UI** ! Upper SB, Inner BB: \((H+V) \times U \times I = 2 \) basebands
Select a/some basebands and assign a correlator mode

BASEBAND Mode Selection Code

! Mode not useful yet, omitted

! Selection code = baseband identification

combination of H/V,U/L,O/I

BASEBAND ! No selection: (H+V) x (U+L) x (O+I) = 8 basebands
BASEBAND H ! H polar selected: H x (U+L) x (O+I) = 4 basebands
BASEBAND L ! Lower sideband: (H+V) x L x (O+I) = 4 basebands
BASEBAND I ! Inner basebands: (H+V) x (U+L) x I = 4 basebands
BASEBAND UI ! Upper SB, Inner BB: (H+V) x U x I = 2 basebands
BASEBAND VUI ! V, Upper SB, Inner BB: V x U x I = 1 baseband

BASEBAND [H|V][U|L][O|I] /RESET

! Remove all existing spw from the selected baseband(s)
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND VUI

SPW /FREQUENCY 243.25 0.3

! 1 SPW covering a range centered at 243.25 with a width of 300 MHz

I-SPW, SPW fits in unit 4 B3VUI
I-SPW, Spectral window covers chunks 22 to 27
I-SPW, Unit B3VUI High_Res is used at 38%

LIST

I-LIST, 9 spectral windows defined:
SPW 1 in B3HLO: df = 2000.000 kHz, Chunks 1 to 61, REST 225384.37 to 229256.09 MHz

SPW 8 in B3VUO: df = 2000.000 kHz, Chunks 1 to 61, REST 244742.97 to 248614.69 MHz

SPW 9 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz

Nota Bene:
Actual coverage is not exactly 300 MHz
(6 x 64=384 MHz)
The system uses the chunks necessary to cover the requested range
Chunks are on a fixed grid, with a fix width
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND UI
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND UI

SPW /RANGE 241.6 242 ! SPW from 241.6 to 242 in H and V (2SPW)

I-SPW, SPW fits in unit 2 B3HUI
I-SPW, Spectral window covers chunks 44 to 50
I-SPW, Unit B3HUI High_Res is used at 44%
I-SPW, SPW fits in unit 4 B3VUI
I-SPW, Spectral window covers chunks 44 to 50
I-SPW, Unit B3VUI High_Res is used at 81%

LIST

I-LIST, 11 spectral windows defined:

[...]
SPW 1 in B3HLO: df = 2000.000 kHz, Chunks 1 to 61, REST 225384.37 to 229256.09 MHz
SPW 8 in B3VUO: df = 2000.000 kHz, Chunks 1 to 61, REST 244742.97 to 248614.69 MHz
SPW 9 in B3HUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz
SPW 10 in B3VUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz
SPW 11 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz

Nota Bene:

Actual SPW width is not exactly 400 MHz
(7 x 64 = 448 MHz)
Chunks are on a fixed grid, with a fix width
Define Spectral Windows

**BASEBAND UI**

**SPW /CHUNK 56 to 61** ! 2 SPW defined by chunk numbers

- I-SPW, Unit B3HUI High_Res is used at 81%
- I-SPW, Unit B3VUI High_Res is used at 119%
- W-SPW, You are using more resources than available

! Setup using more than 16 high res chunks in VUI

**Nota Bene:**

/CHUNK option available only when the baseband selection contains only 1 frequency range (eventually dual polars)
Define Spectral Windows

BASEBAND UI

SPW /CHUNK 56 to 61 ! 2 SPW defined by chunk numbers
  I-SPW, Unit B3HUI High_Res is used at 81%
  I-SPW, Unit B3VUI High_Res is used at 119%
  W-SPW, You are using more resources than available

! Setup using more than 16 high res chunks in VUI

RESET LAST

  I-RESET, Resetting Spectral Window # 10
  I-RESET, Resetting Spectral Window # 9
  I-LIST, 11 spectral windows defined:
  SPW 1 in B3HLO: df = 2000.000 kHz, Chunks 1 to 61, REST 225384.37 to 229256.09 MHz
  SPW 9 in B3HUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz
  SPW 10 in B3VUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz
  SPW 11 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND UI

SPW /CHUNK 42 to 45

I-SPW, Unit B3HUI High_Res is used at 56%
I-SPW, Unit B3VUI High_Res is used at 94%
W-SPW, SPW #9 uses conflicting chunk(s)
W-SPW, SPW #10 uses conflicting chunk(s)
W-SPW, SPW #11 uses conflicting chunk(s)
W-SPW, SPW #12 uses conflicting chunk(s)

! Setup using several times the same chunks
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND UI

SPW /CHUNK 42 to 45

! Setup using several times the same chunks

LIST

[...]

SPW 9 in B3HUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz !Conflict!
SPW 10 in B3VUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz !Conflict!
SPW 11 in B3HUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz !Conflict!
SPW 12 in B3VUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz !Conflict!
SPW 13 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz
Define Spectral Windows

BASEBAND UI

SPW /CHUNK 42 to 45

! Setup using several times the same chunks

LIST

[...]

SPW 9 in B3HUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz !Conflict!
SPW 10 in B3VUI: df = 62.500 kHz, Chunks 44 to 50, REST 241575.20 to 242023.17 MHz !Conflict!
SPW 11 in B3HUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz !Conflict!
SPW 12 in B3VUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz !Conflict!
SPW 13 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz

RESET 9 10

[...]

SPW 9 in B3HUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz
SPW 10 in B3VUI: df = 62.500 kHz, Chunks 42 to 45, REST 241895.18 to 242151.16 MHz
SPW 11 in B3VUI: df = 62.500 kHz, Chunks 22 to 27, REST 243047.10 to 243431.07 MHz
NOEMA setups in ASTRO

Visualize current state

PLOT
PLOT /RECEIVER
NOEMA setups in ASTRO

Visualize current state

```
PLOT
PLOT /RECEIVER
```
Define Spectral Windows

**BASEBAND**: All basebands selected
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND  | All basebands selected
SPW /FREQUENCY 230.538 0.4
SPW /RANGE 226.5 227.1
SPW /RANGE 227.3 227.6
SPW /FREQUENCY 245.6 0.4
NOEMA setups in ASTRO

Define Spectral Windows

BASEBAND ! All basebands selected
SPW /FREQUENCY 230.538 0.4
SPW /RANGE 226.5 227.1
SPW /RANGE 227.3 227.6
SPW /FREQUENCY 245.6 0.4
PLOT /RECEIVER
SETUP /FILE MyFile.astro

! write the minimal series of commands to come back to the current configuration and to set up the instrument
NOEMA spectral setups in ASTRO

Frequency axes

- All previous ASTRO plots were in REST frequency
- Actual frequency in the receiver is RF
- $F_{RF} = F_{REST} \times \text{DopplerFactor}$
  - Observatory contribution:
    + Earth rotation + revolution ($<30 \text{ km/s} \sim 10 \text{ MHz} @ 100 \text{ GHz}$)
      Varies with time
  - Source contribution:
    + LSR velocity ($\sim100 \text{ km/s} \sim 30 \text{ MHz} @ 100 \text{ GHz}$)
    + Redshift
      - $350\text{GHz REST} @ z=2.5$ observed at $\sim100 \text{ GHz}$ in RF
- Doppler corrections at NOEMA
  - Source LSR taken into account
    + $F_{\odot}$ is shifted
  - Earth Doppler corrected on real time (Doppler tracking)
    + $F_{\odot}$ changes with time
  - Redshift not corrected
    + Compute redshifted frequency and assume $z$ and LSR = 0
    + ASTRO can help ($\text{SET FREQUENCY [LSR|REST]}$)
Example with redshifted source

SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
Example with redshifted source

SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
Example with redshifted source

SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
NOEMA spectral setups in ASTRO

Example with redshifted source

```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
```
NOEMA spectral setups in ASTRO

Example with redshifted source

```
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U
SPW /FREQUENCY 98.8 0.7
```

Chunks 34 to 45
Example with redshifted source

```plaintext
SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Ouput in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U
SPW /FREQUENCY 98.8 0.7
    Chunks 34 to 45
RESET
SET FREQ REST LSR
BASEBAND U
```
Example with redshifted source

SET FREQUENCY REST LSR ! Main axis=REST, Secondary=LSR
! Main axis = Lower axis on plot + Input/Output in terminal
CATA CO.DAT /LINE ! Local file with only CO transitions
SET LINES GAUSS 500
SOURCE GAL EQ 2000 10 10 RED 2.5
TUNING
TUNING 350 USB 6500
SET FREQ LSR REST
TUNING
TUNING 100 USB 6500
BASEBAND U
SPW /FREQUENCY 98.8 0.7
Chunks 34 to 45
RESET
SET FREQ REST LSR
BASEBAND U
SPW /FREQ 345.8 2.45
! 98.8*3.5=345.8, 0.7*3.5=2.45
Chunks 34 to 45
Summary

2SB, dual polar, receivers

- 4-12 GHz IF1 split into 2 basebands (0-4GHz IF2)

8 Basebands (0-4GHz) feed 8 Correlator units

<table>
<thead>
<tr>
<th>Mode 1 (2017): Continuum + Lines</th>
<th>1 Unit</th>
<th>All Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 chunks (3872 MHz) at 2 MHz resolution AND 16 chunks at 62.5 kHz resolution*</td>
<td>~16 GHz x 2 polar with 2 MHz channels AND 8 GHz with 62.5kHz channels*</td>
<td></td>
</tr>
</tbody>
</table>

| Mode 2: Survey | 61 chunks (3872 MHz) at 250 kHz resolution | ~16 GHz x 2 polar with 250 kHz channels |

| Mode 3: Continuum + High Resolution | <61 chunks (3872 MHz) at 2 MHz resolution AND 8/4/2 chunks at 31.25/15.625/7.8125 kHz resolution* | <16 GHz x 2 Polar with 2 MHz channels AND 4/2/1 GHz with 31.25/15.625/7.8125kHz channels* |

*High resolution chunks chosen among the 61 of the fixed filter bank