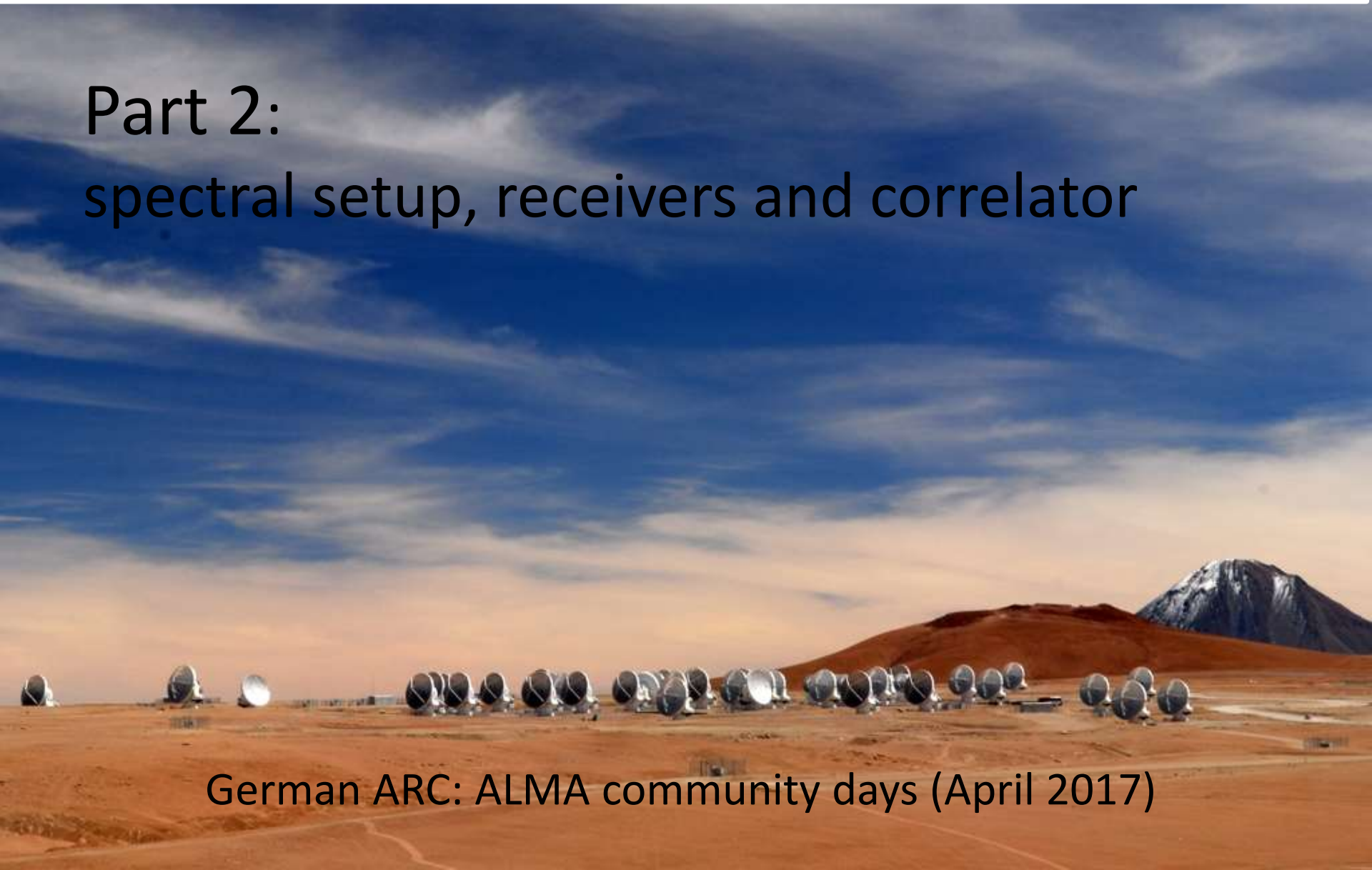




This presentation has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562 [RadioNet]

Part 2: spectral setup, receivers and correlator



German ARC: ALMA community days (April 2017)

Outline

Part 1: by L. Moser

- Introduction to aperture synthesis
- Interferometers: spatial filters

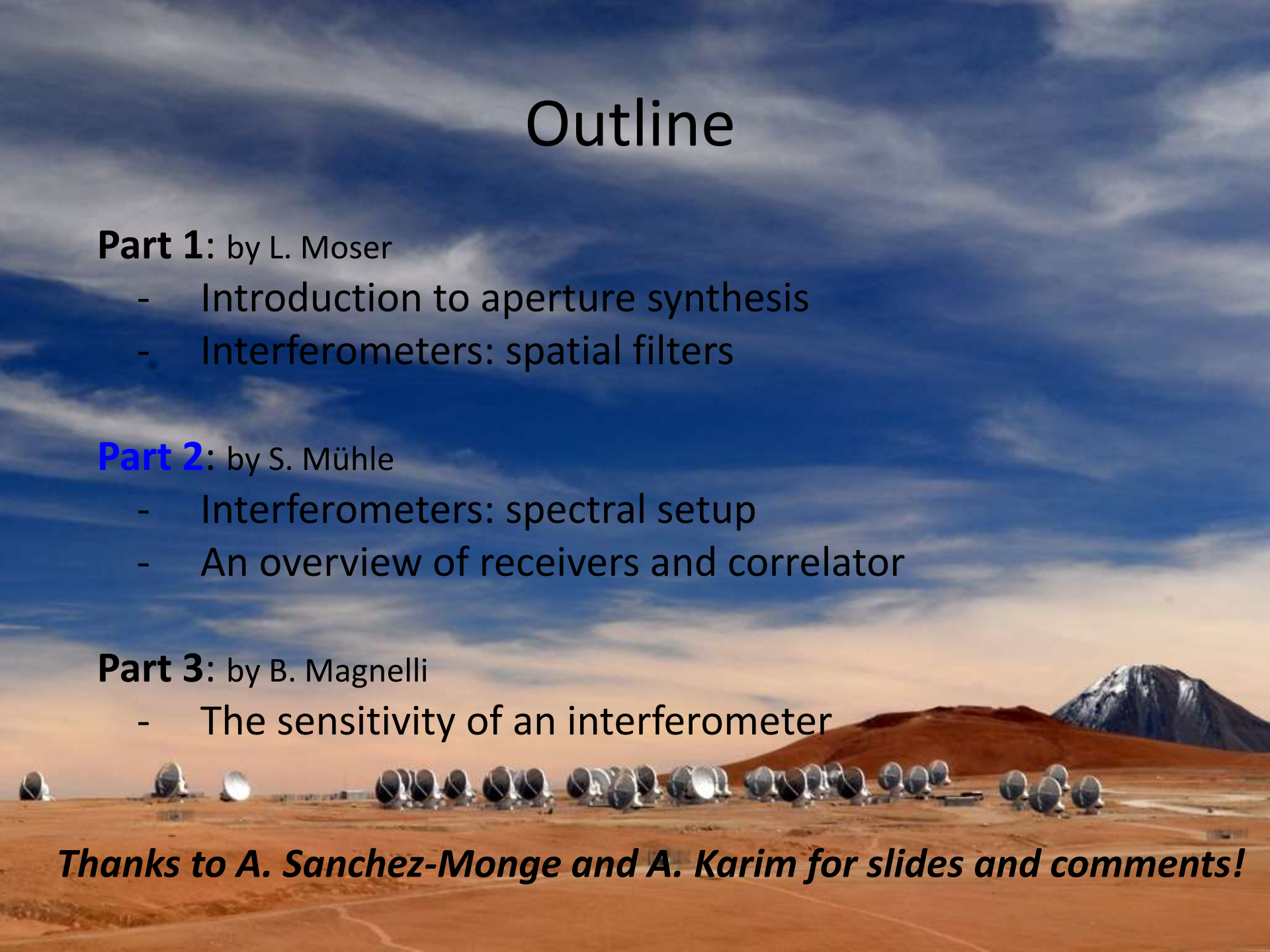
Part 2: by S. Mühle

- Interferometers: spectral setup
- An overview of receivers and correlator

Part 3: by B. Magnelli

- The sensitivity of an interferometer

Thanks to A. Sanchez-Monge and A. Karim for slides and comments!



Spectral setup in the almaOT

The screenshot displays the ALMA Observing Tool (Cycle5) interface. The title bar shows the application name and the current project: "ALMA Observing Tool (Cycle5) - Project". The system tray indicates the date and time as "Mon 27 Mar 09:50" and the user as "Alvaro Sanchez".

The interface is divided into several panels:

- Project Structure:** A tree view on the left showing the project hierarchy: Project > Proposal > Planned Observing > ScienceGoal (Science Goal) > Field Setup (selected).
- Editors:** A tabbed interface with "Spectral", "Spatial", and "Field Setup" tabs. The "Field Setup" tab is active.

The "Field Setup" tab contains the following configuration options:

Input source details and mapping info or use the Visual Editor on the spatial tab.
You must choose between checking 1 Rectangular Field on all sources or none.
Check 1 Rectangular Field on the first source before adding others to put rectangular mosaics around multiple sources.

SinglePoint

Source

Source Name: [Text Field] Resolve

Choose a Solar System Object? Name of object: Unspecified

System: ICRS Sexagesimal display? Parallax: 0.00000 mas

Source Coordinates: RA: 00:00:00.0000 PM RA: 0.00000 mas/yr
Dec: 00:00:00.0000 PM DEC: 0.00000 mas/yr

Source Radial Velocity: 0.000 km/s Isrk z: 0.000000000 Doppler Type: RADIO

Target Type: Individual Pointing(s) 1 Rectangular Field

Expected Source Properties

Peak Continuum Flux Density per Synthesized Beam: 0.00000 Jy

Continuum Polarization Percentage: 0.0 per cent

Peak Line Flux Density per Synthesized Beam: 0.00000 Jy

Line Width: 0.00000 km/s

Line Polarization Percentage: 0.0 per cent

Field Center Coordinates

Coord Type: Relative Absolute

Offset Unit: arcsec

#Pointings: 1

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5)

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Perspective

Project Structure

- Project
 - Proposal
 - Planned Observing
 - ScienceGoal (Science Goal)
 - General
 - Field Setup
 - Spectral Setup
 - Calibration Setup
 - Control and Performance
 - Technical Justification

Editors

Spectral Spatial Field Setup

Input source details and mapping info or use the Visual Editor on the spatial tab.
You must choose between checking 1 Rectangular Field on all sources or none.
Check 1 Rectangular Field on the first source before adding others to put rectangular mosaics around multiple sources.

SinglePoint

Source

Source Name

Choose a Solar System Object? Name of object Unspecified

System ICRS Sexagesimal display? Parallax 0.00000 m

Source Coordinates RA 00:00:00.0000 PM RA 0.00000 mas/y

Dec 00:00:00.000 PM DEC 0.00000 mas/y

Source Radial Velocity 0.000 km/s z 0.000000000 Doppler Type RADIO

Target Type Individual pointing(s) 1 Rectangular Field

Expected Source Properties

Peak Continuum Flux Density per Synthesized Beam 0.00000 Jy

Continuum Polarization Percentage 0.0 per cent

Peak Line Flux Density per Synthesized Beam 0.00000 Jy

Line Width 0.00000 km/s

Line Polarization Percentage 0.0 per cent

Field Center Coordinates

Coord Type Relative Absolute

Offset Unit arcsec

#Pointings 1

WE ALREADY KNOW HOW TO FILL THIS

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5)

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Perspective

Project Structure

Proposal Program

Project

Proposal

Planned Observing

ScienceGoal (Science Goal)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Technical Justification

Editors

Spectral Spatial Field Setup

Input source details and mapping info or use the Visual Editor on the spatial tab.
You must choose between checking 1 Rectangular Field on all sources or none.
Check 1 Rectangular Field on the first source before adding others to put rectangular mosaics around multiple sources.

SinglePoint

Source

Source Name

Choose a Solar System Object? Name of object Unspecified

System ICRS Sexagesimal display?

Source Coordinates

RA 00:00:00.0000 PM RA 0.00000

Dec 00:00:00.0000 PM DEC 0.00000

Source Radial Velocity 0.0000 km/s z 0.000000000 Doppler Type RADIO

Target Type Individual pointing(s) 1 Rectangular Field

Expected Source Properties

Peak Continuum Flux Density per Synthesized Beam 0.00000 Jy

Continuum Polarization Percentage 0.0 per cent

Peak Line Flux Density per Synthesized Beam 0.00000 Jy

Line Width 0.00000 km/s

Line Polarization Percentage 0.0 per cent

Field Center Coordinates

Coord Type Relative Absolute

Offset Unit arcsec

#Pointings 1

WE ALREADY KNOW HOW TO FILL THIS

SPECTRAL SETUP

Spectral setup in the almaOT

The screenshot displays the ALMA Observing Tool (Cycle5) interface. The title bar shows "ALMA Observing Tool (Cycle5) - Project" and the system tray includes the date "Mon 27 Mar 10:05" and the user name "Alvaro Sanchez". The menu bar contains "File", "Edit", "View", "Tool", "Search", and "Help".

The interface is divided into several panels:

- Project Structure:** A tree view on the left showing the project hierarchy: Project > Proposal > Planned Observing > ScienceGoal (Science Goal). Under ScienceGoal, several sub-items are listed: General, Field Setup, Spectral Setup (highlighted), Calibration Setup, Control and Performance, and Technical Justification.
- Editors:** A panel on the right with tabs for "Spectral", "Spatial", and "Spectral Setup". The "Spectral Setup" tab is active.

The "Spectral Setup" panel contains the following elements:

- Visualisation:** A plot showing "Observed Frequency" (top axis, 100,000 to 900,000) and "Rest Frequency" (bottom axis, 100,000 to 900,000). The plot displays several spectral lines and shaded regions representing receiver bands, labeled 03 through 10.
- Text:** A paragraph explaining the configuration: "In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3 to 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other." Below this, it says "Left/right click to zoom in/out, grab sliding bar to pan" and "Note: Moving LO1 here is for experimentation only - actual setup determined by the windows".
- Overlays:** A row of checkboxes: "Receiver Bands" (checked), "Transmission" (checked), "DSB Image" (checked), and "Spectral Lines" (unchecked). A button "Select Lines to Overlay" is to the right.
- Water Vapour Column Density:** A dropdown menu set to "Automatic Choice" and a text field containing "5.186mm (7th Octile)".
- Viewport:** Three buttons: "Pan to Spectral Window", "Zoom to Band", and "Reset".
- Spectral Type:** A section with radio buttons for "Spectral Line" (selected), "Single Continuum", and "Spectral Scan".

Spectral setup in the almaOT

The screenshot displays the ALMA Observing Tool (Cycle5) interface. The title bar shows "ALMA Observing Tool (Cycle5) - Project" and the system tray includes the date "Mon 27 Mar 10:05" and the user name "Alvaro Sanchez". The menu bar contains "File", "Edit", "View", "Tool", "Search", and "Help".

The interface is divided into two main panels:

- Project Structure:** A tree view on the left showing the project hierarchy: Project > Proposal > Planned Observing > ScienceGoal (Science Goal). Under "ScienceGoal", several sub-items are listed: General, Field Setup, **Spectral Setup** (highlighted), Calibration Setup, Control and Performance, and Technical Justification.
- Editors:** A panel on the right with tabs for "Spectral", "Spatial", and "Spectral Setup" (the active tab, circled in red). It contains a "Visualisation" section with text explaining spectral window configuration and a graph showing "Observed Frequency" and "Rest Frequency".

The "Visualisation" section includes the following text:

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3 to 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Left/right click to zoom in/out, grab sliding bar to pan
Note: Moving LO1 here is for experimentation only - actual setup determined by the windows

The graph shows two frequency axes: "Observed Frequency" (top) and "Rest Frequency" (bottom), both ranging from 100,000 to 900,000. Ten shaded rectangular regions represent spectral windows, labeled 03 through 10. Below the graph, there are controls for "Overlays" (Receiver Bands, Transmission, DSB Image, Spectral Lines), "Water Vapour Column Density" (Automatic Choice, Manual Choice), and "Viewport" (Pan to Spectral Window, Zoom to Band, Reset). At the bottom, "Spectral Type" options are listed: Spectral Line (selected), Single Continuum, and Spectral Scan.

Spectral setup in the almaOT

The screenshot displays the ALMA Observing Tool (Cycle5) interface. The main window is titled "ALMA Observing Tool (Cycle5) - Project" and shows the "Spectral Setup" configuration window. The left sidebar shows the project structure, with "Spectral Setup" selected under "Planned Observing" > "ScienceGoal (Science Goal)".

The "Spectral Setup" window contains the following information:

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Spectral Type: Spectral Line Single Continuum Spectral Scan

Produce image sidebands (Bands 9 and 10 only)

Polarization products desired: XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz, 0.0 GHz]

Spectral Line

Baseband-1	Fractio	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre
							Wi

Buttons: Add spectral window centred on a spectral line, Add spectral window manually, Delete, Show image spectral window

Baseband-2

Buttons: Add spectral window centred on a spectral line, Add spectral window manually, Delete, Show image spectral window

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Project Structure

- Project
 - Proposal
 - Planned Observing
 - ScienceGoal (Science Goal)
 - General
 - Field Setup
 - Spectral Setup
 - Calibration Setup
 - Control and Performance
 - Technical Justification

Editors

Spectral Spatial Spectral Setup

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Continuum or line ?

- Spectral Line
- Single Continuum
- Spectral Scan

Spectral Type

Produce image sidebands (Bands 9 and 10 only)

Polarization products desired XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz; 0.0 GHz]

Spectral Line

Baseband-1	Fractio	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre Wi

Add spectral window centred on a spectral line Add spectral window manually Delete Show image spectral window

Baseband-2

Baseband-2	Fractio	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre Wi

Add spectral window centred on a spectral line Add spectral window manually Delete Show image spectral window

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5)

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Perspective

Project Structure

Proposal Program

Project

Proposal

Planned Observing

ScienceGoal (Science Goal)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Technical Justification

Editors

Spectral Spatial Spectral Setup

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Continuum or line ?

Spectral Line

Single Continuum

Spectral Scan

Spectral Type

Polarization products ?

Produce image sidebands (Bands 9 and 10 only)

Polarization products desired

XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz, 0.0 GHz]

Spectral Line

Baseband-1

Fractio	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre W
---------	-------------------------	-----------------------	------------	----------------------------------	-----------	---------

Add spectral window centred on a spectral line

Add spectral window manually

Delete

Show image spectral window

Baseband-2

Fractio	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre W
---------	-------------------------	-----------------------	------------	----------------------------------	-----------	---------

Add spectral window centred on a spectral line

Add spectral window manually

Delete

Show image spectral window

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Project Structure

- Project
 - Proposal
 - Planned Observing
 - ScienceGoal (Science Goal)
 - General
 - Field Setup
 - Spectral Setup**
 - Calibration Setup
 - Control and Performance
 - Technical Justification

Editors

Spectral Spatial **Spectral Setup**

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Continuum or line ?

Spectral Line
 Single Continuum
 Spectral Scan

Polarization products ?

Produce image sidebands (Bands 9 and 10 only)
Polarization products desired
 XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz; 0.0 GHz]

Spectral Line

Baseband	Fraction	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg.	Repre W
Baseband-1							
Baseband-2							

Rest frequency ?

Add spectral window centred on a spectral line Add spectral window manually Delete Show image spectral window

Add spectral window centred on a spectral line Add spectral window manually Delete Show image spectral window

Spectral setup in the almaOT

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Project Structure

- Project
 - Proposal
 - Planned Observing
 - ScienceGoal (Science Goal)
 - General
 - Field Setup
 - Spectral Setup
 - Calibration Setup
 - Control and Performance
 - Technical Justification

Editors

Spectral Spatial Spectral Setup

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Continuum or line ?

Spectral Line
 Single Continuum
 Spectral Scan

Polarization products ?

Produce image sidebands (Bands 9 and 10 only)
Polarization products desired
 XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz; 0.0 GHz]

Spectral Line

Baseband	Fraction	Centre Freq (rest,lsrk)	Centre Freq (sky,bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg	Repre W
Baseband-1							
Baseband-2							

Rest frequency ?

Bandwidth, spectral resolution ?

Add spectral window centred on a spectral line Add spectral window manually Delete Show image spectral window

What do we need to know?

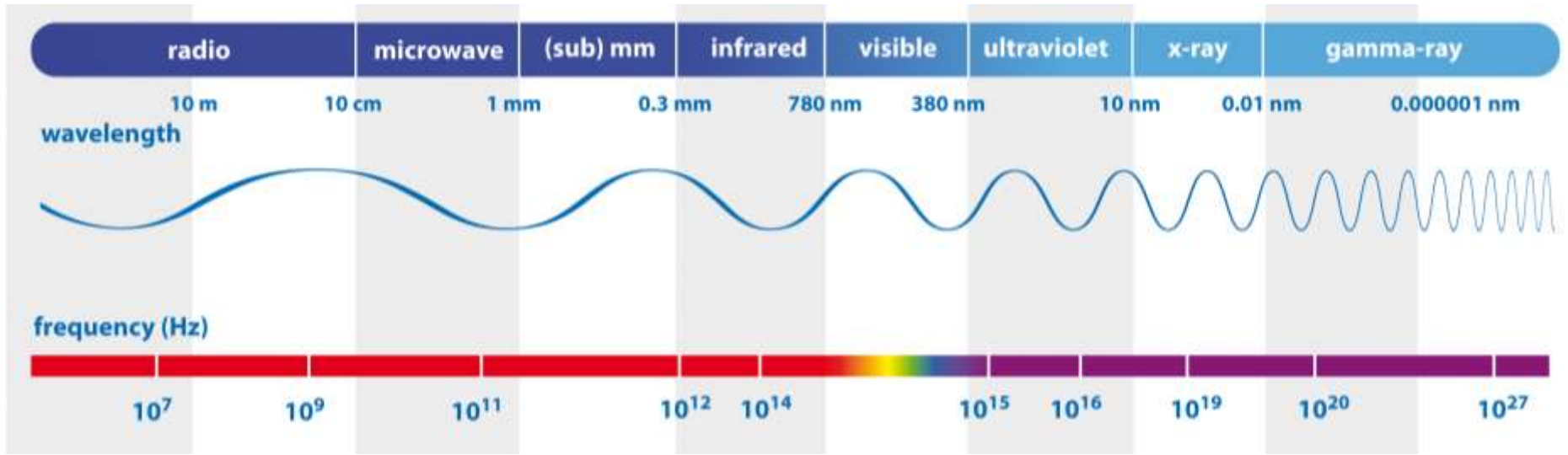
- continuum or line (both?)
- frequency of the lines to observe
- velocity / redshift of the source
- bandwidth / velocity coverage
- spectral resolution
- polarization products
- ...

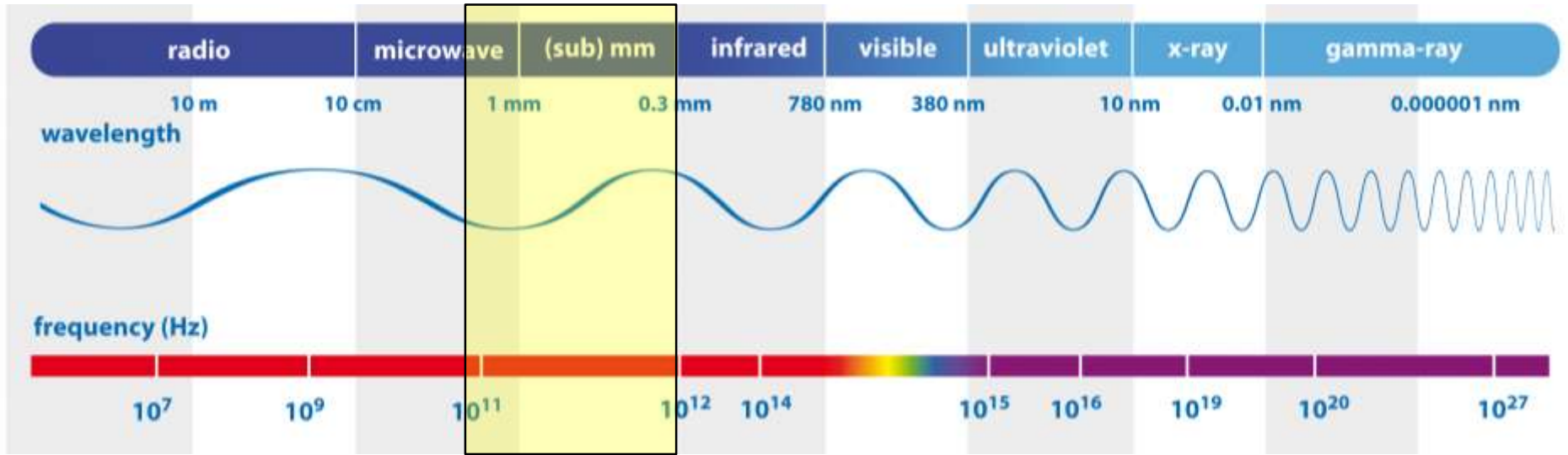


What do we need to know?

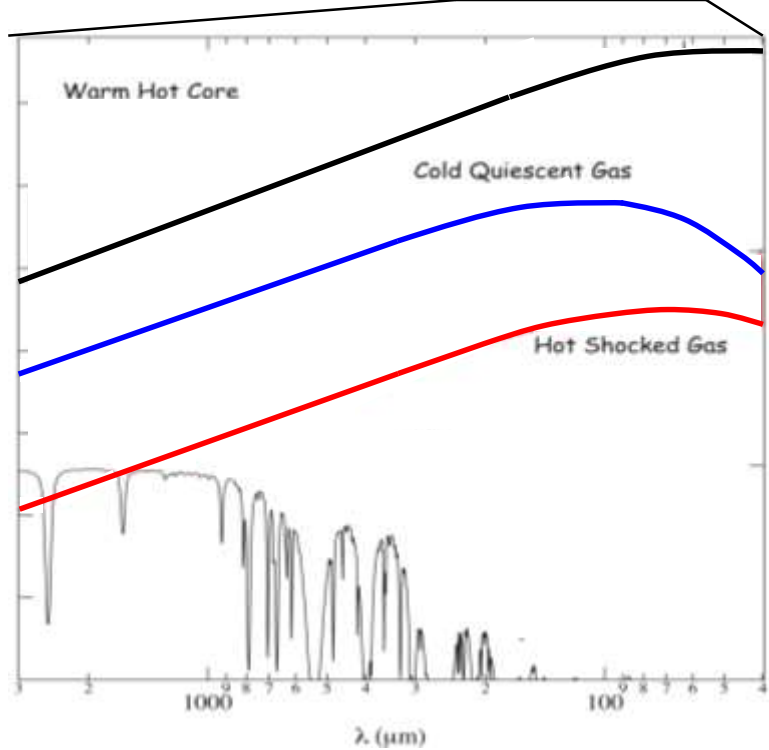
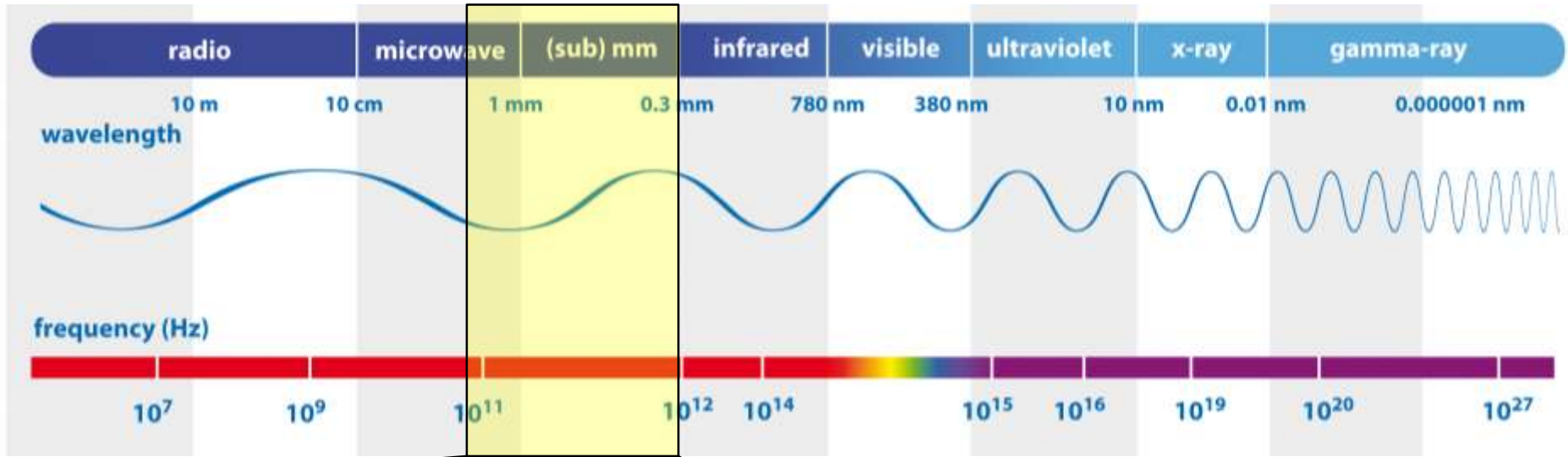
- **continuum or line (both?)**
- frequency of the lines to observe
- velocity / redshift of the source
- bandwidth / velocity coverage
- spectral resolution
- polarization products
- ...



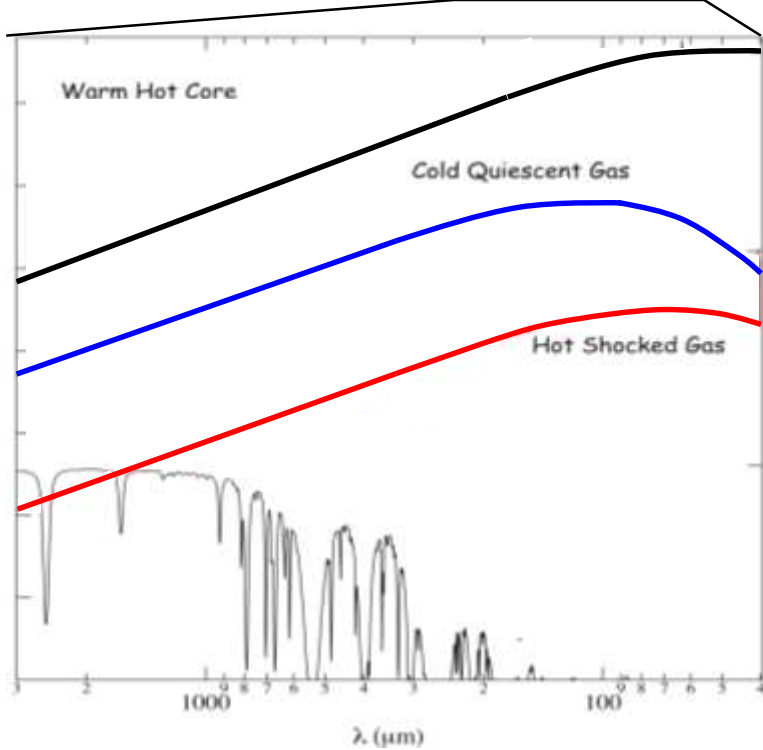
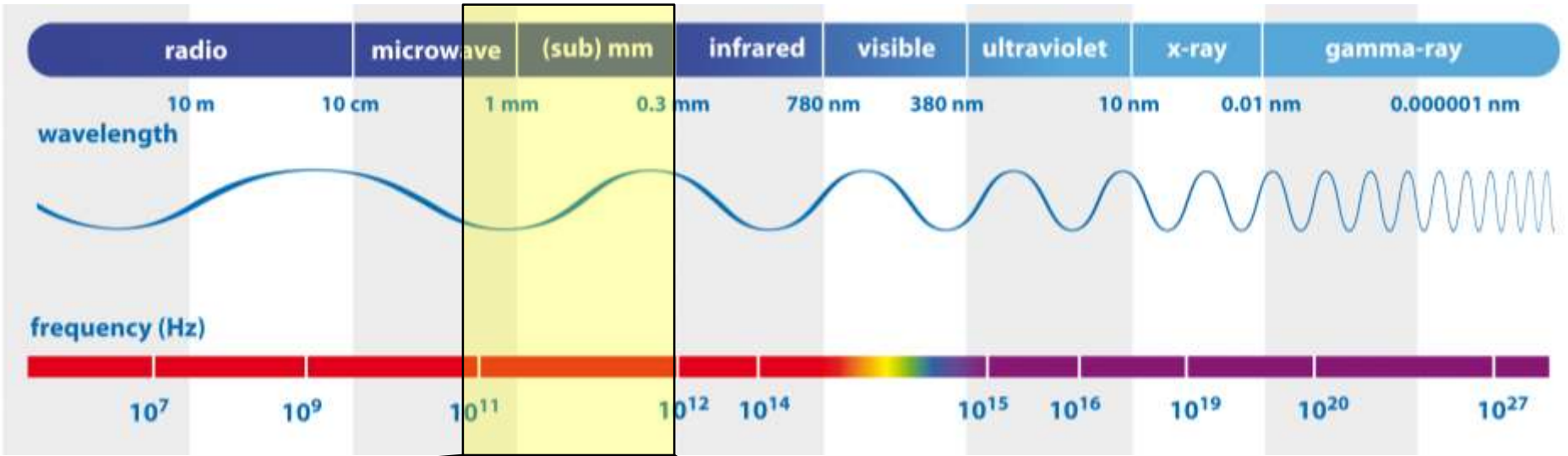




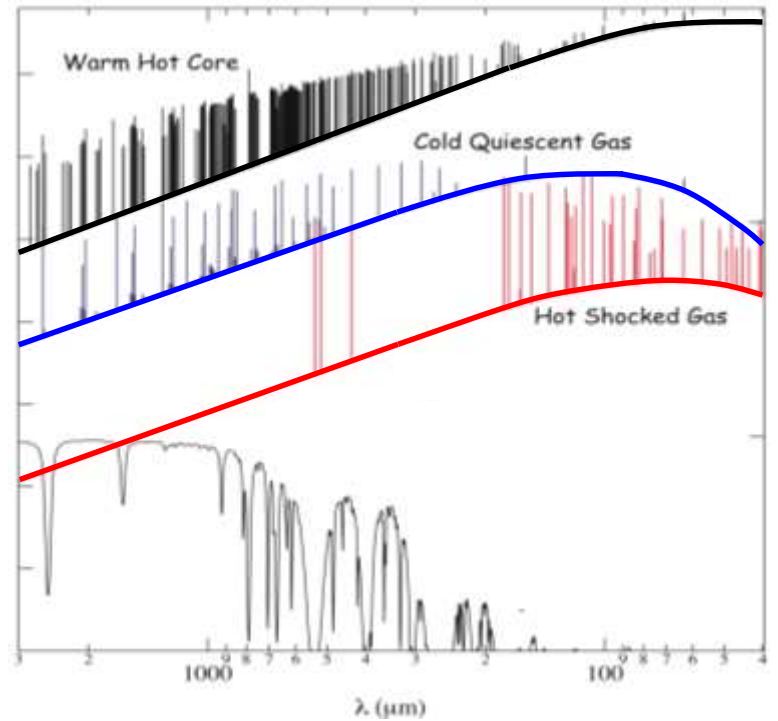
ALMA observable range
“Cold Universe”



continuum emission

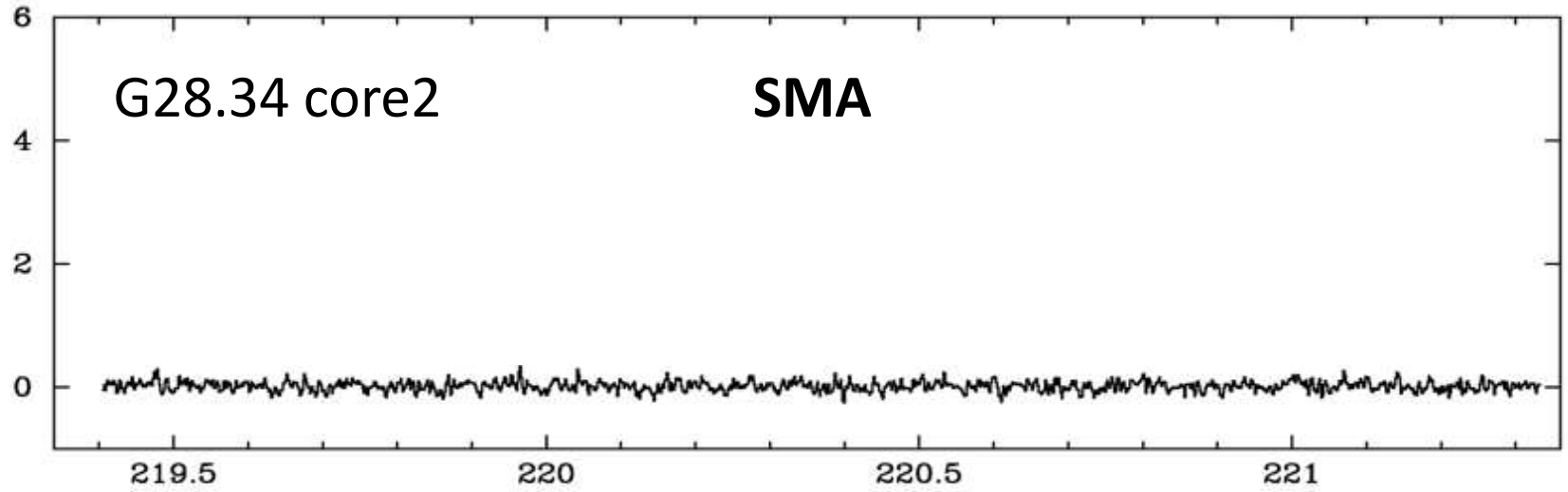


continuum emission



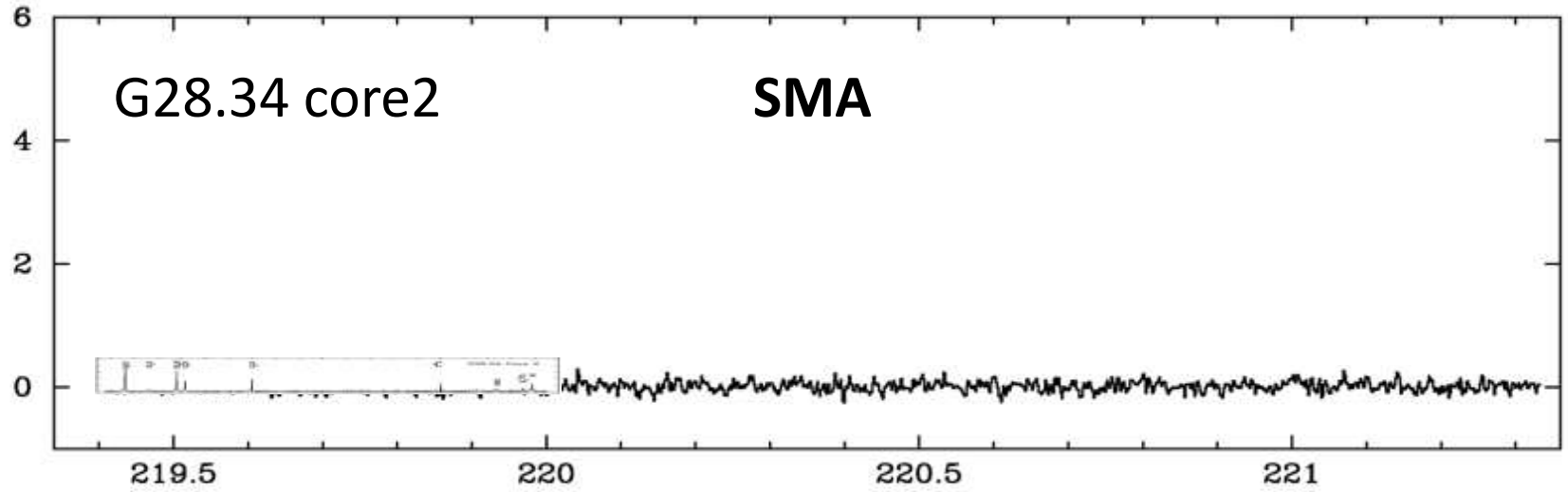
line emission

Can we detect spectral lines?

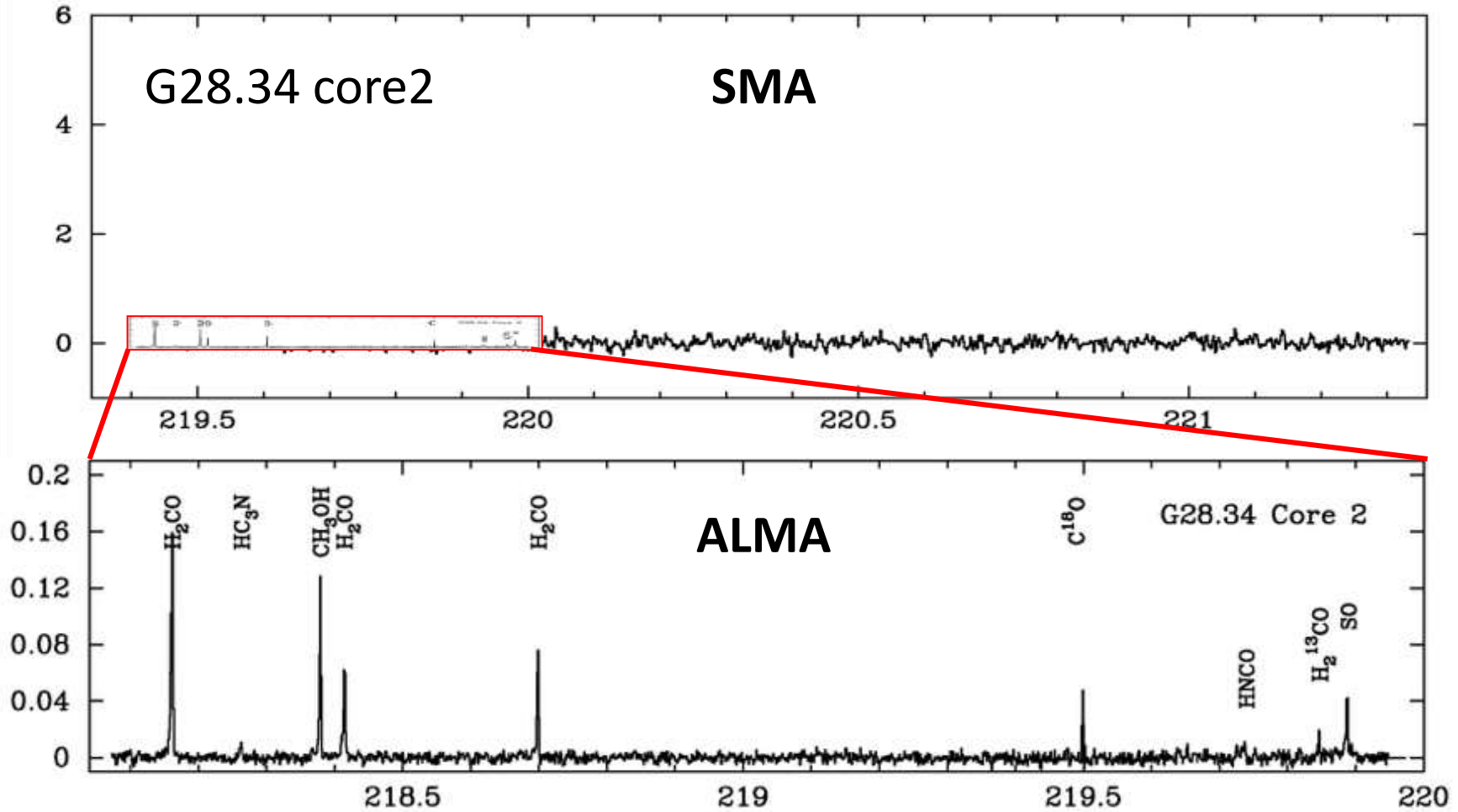


Zhang et al (2008)

Can we detect spectral lines?



Can we detect spectral lines?

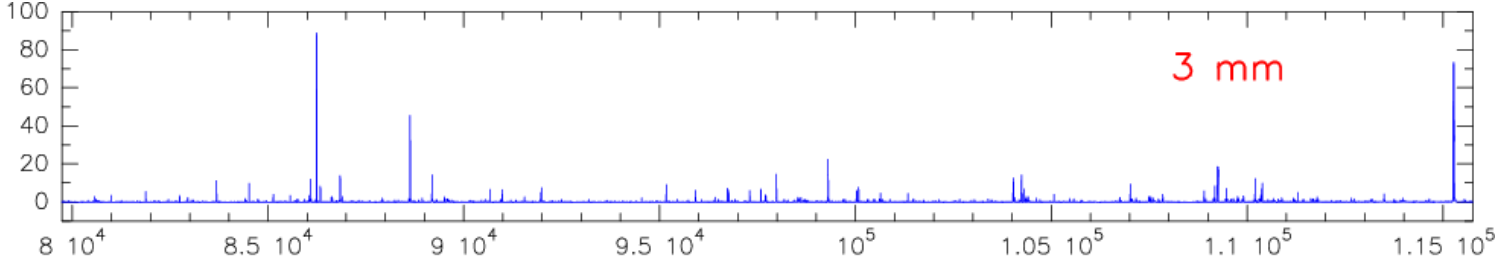


Zhang et al (2008)

Zhang et al (2014)

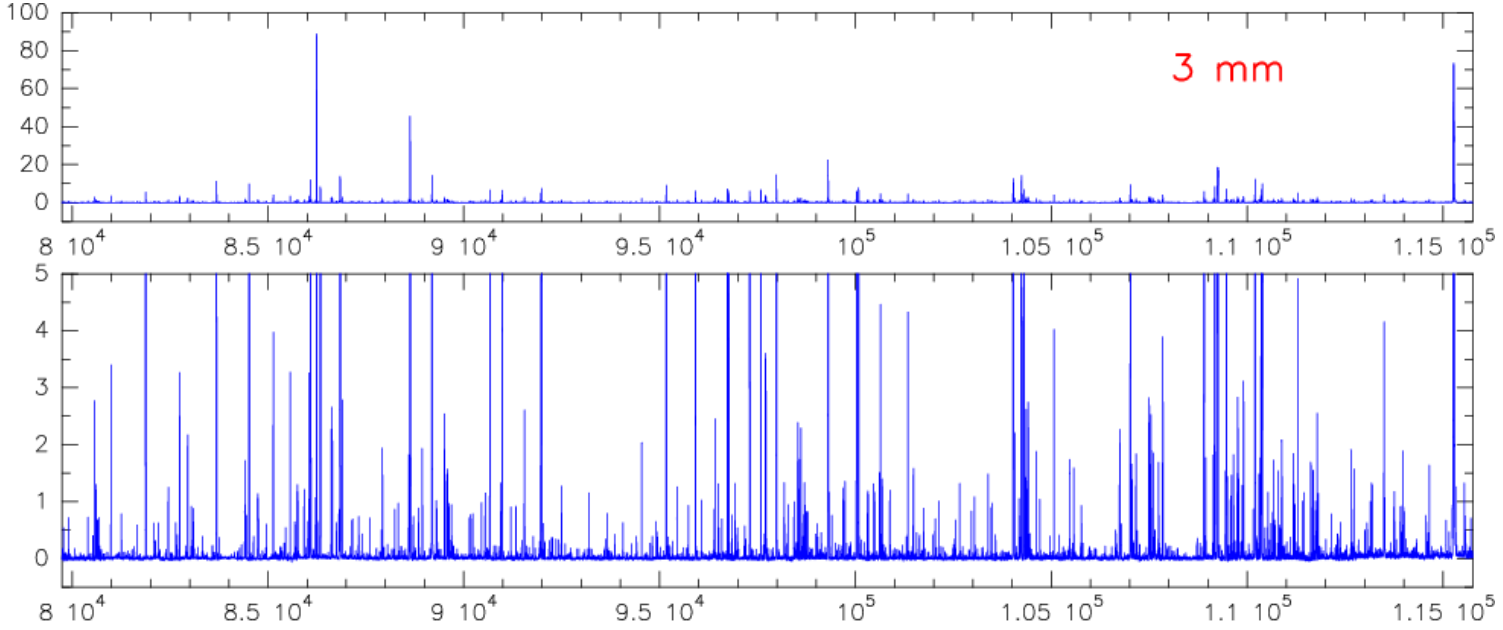
Can we detect spectral lines?

When sensitivity can be a problem
... entering the ALMA era



Can we detect spectral lines?

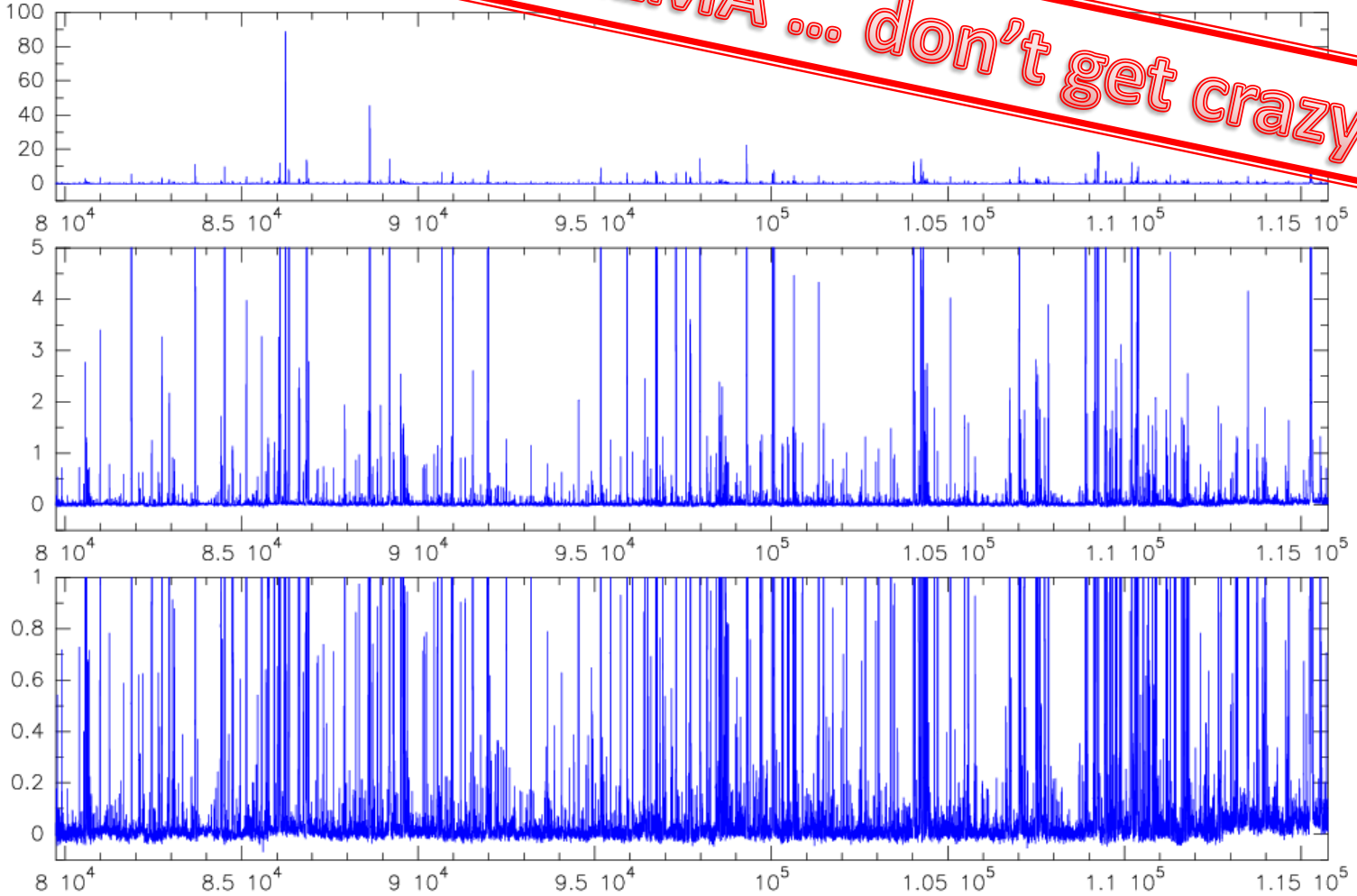
When sensitivity can be a problem
... entering the ALMA era



Can we detect spectral lines?

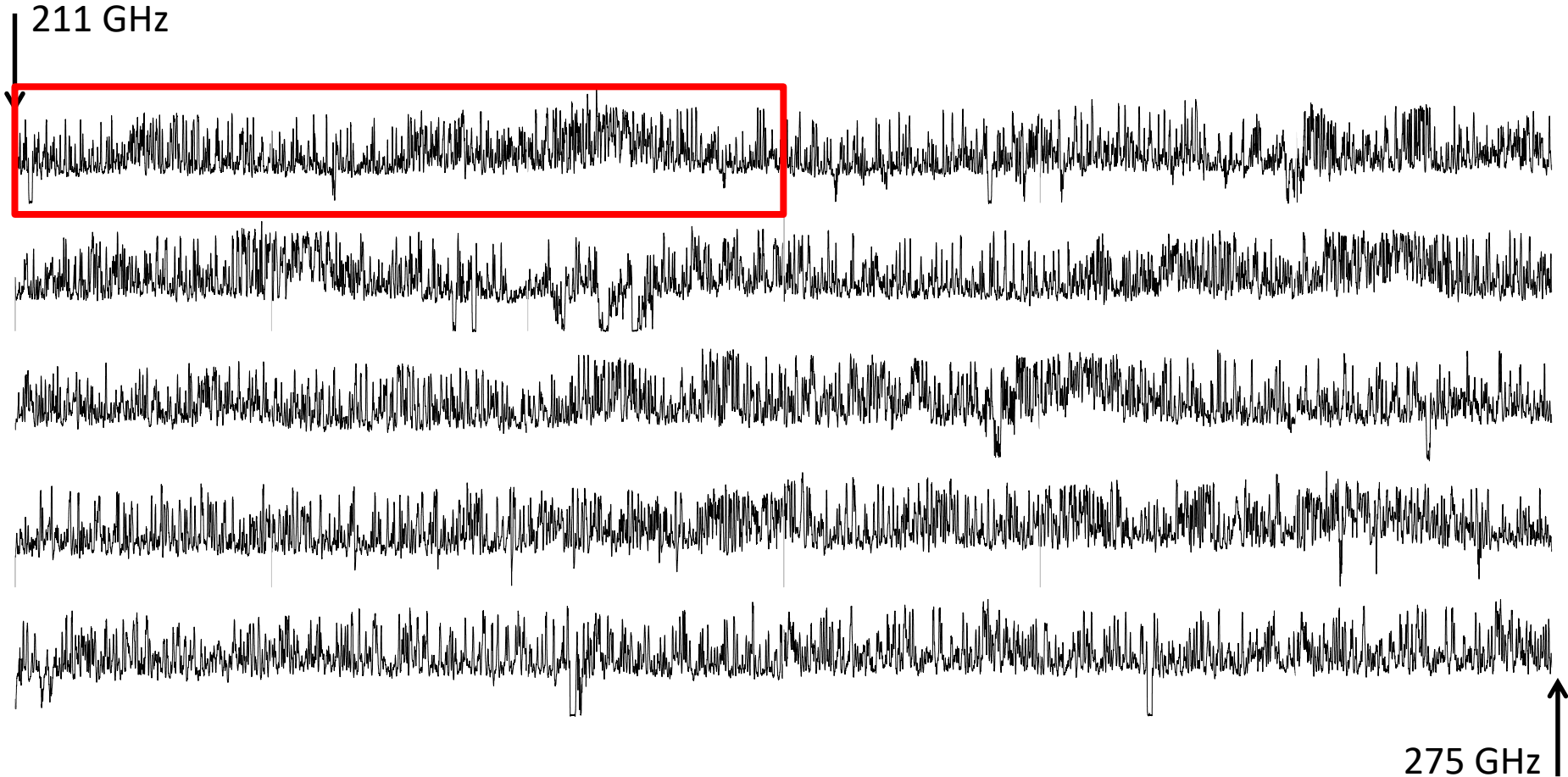
With ALMA ... don't get crazy!

When sensitivity can be a problem
... entering the ALMA era



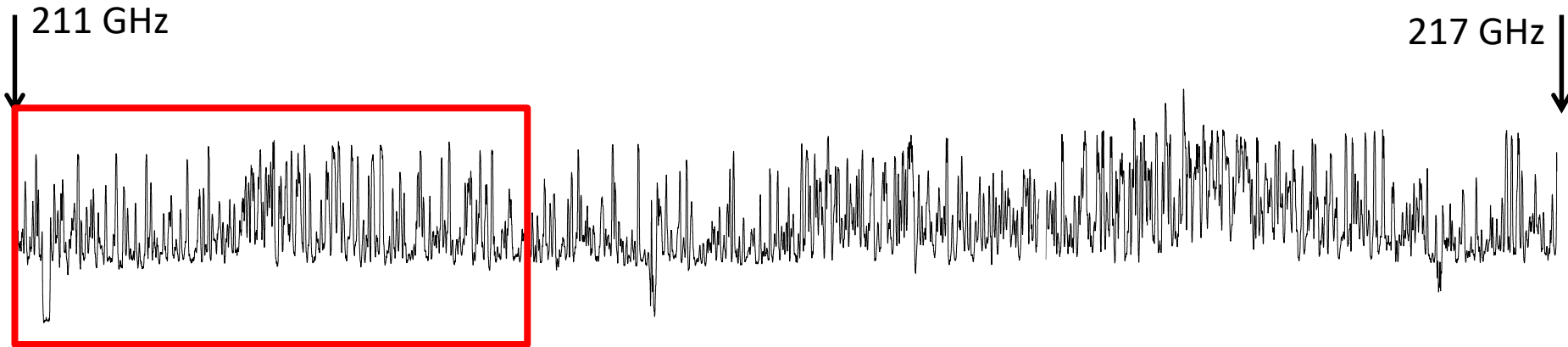
Can we detect spectral lines?

Spectrum (211-275 GHz) towards 1 single pixel



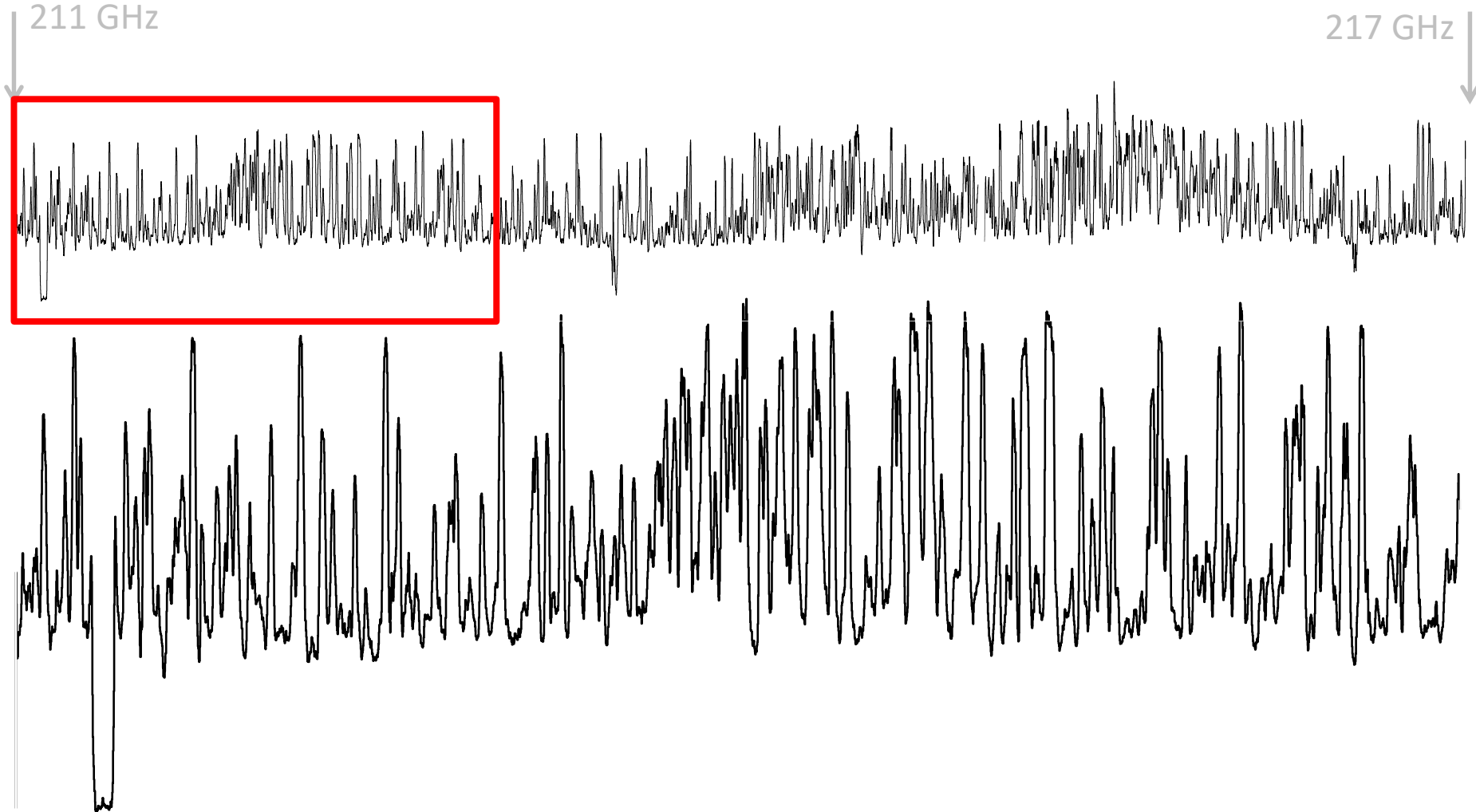
Can we detect spectral lines?

Spectrum (211-275 GHz) towards 1 single pixel

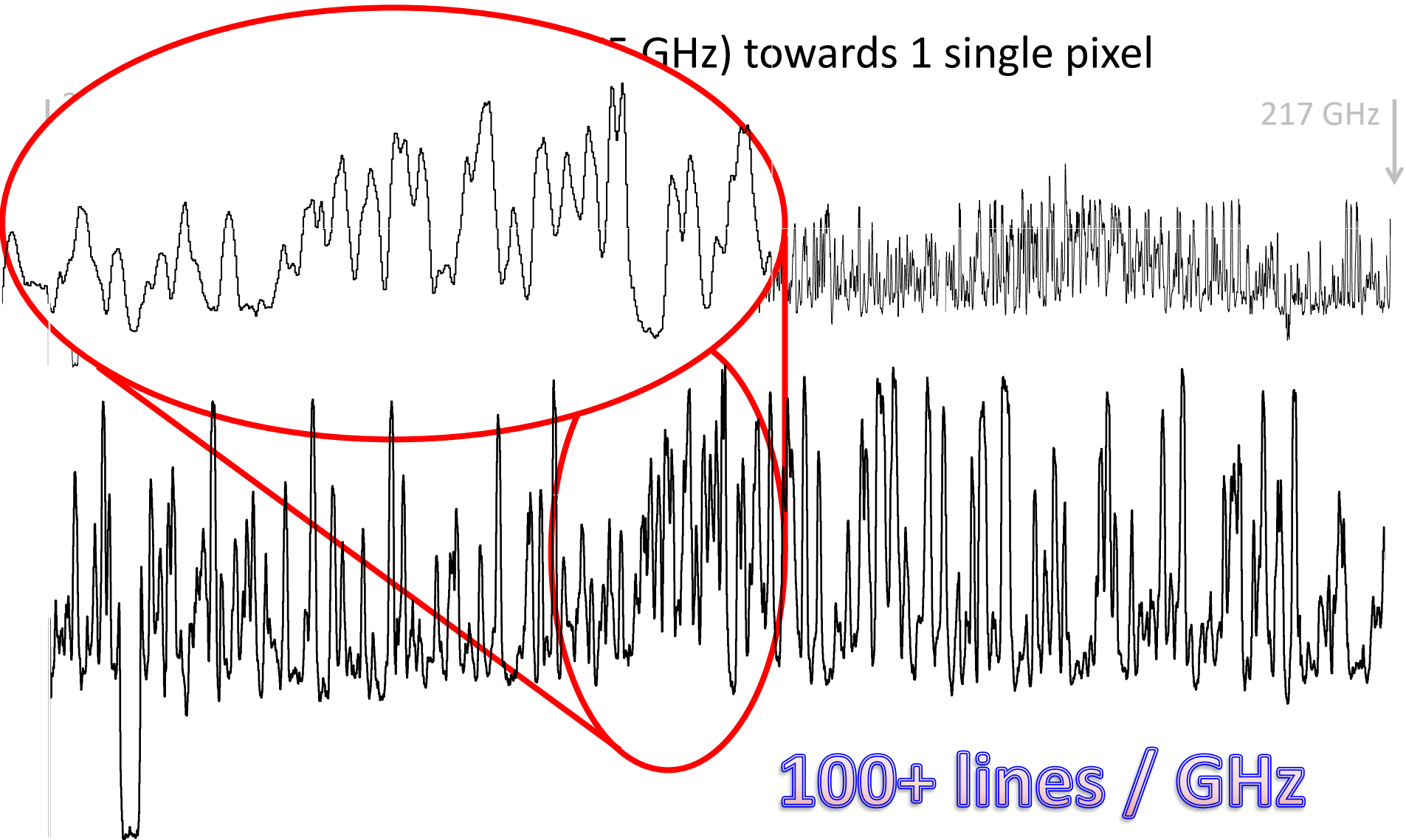


Can we detect spectral lines?

Spectrum (211-275 GHz) towards 1 single pixel



Can we detect spectral lines?



What do you want to observe?

continuum emission

line emission

both (continuum and line)

What do you want to observe?

continuum emission

which frequency/wavelength (**band**)

intensity of the source (**rms**) [see next Section]

spatial distribution (**beam, LAS**) [see previous Section]

line emission

both (continuum and line)

What do you want to observe?

continuum emission

which frequency/wavelength (**band**)

intensity of the source (**rms**) [see next Section]

spatial distribution (**beam, LAS**) [see previous Section]

line emission

which line (**frequency, band**)

intensity of the source (**rms**) [see next Section]

spatial distribution (**beam, LAS**) [see previous Section]

line shape (**bandwidth, spectral resolution**)

both (continuum and line)

What do we need to know?

- continuum or line (both?)
- **frequency of the lines to observe**
- velocity / redshift of the source
- bandwidth / velocity coverage
- spectral resolution
- polarization products
- ...



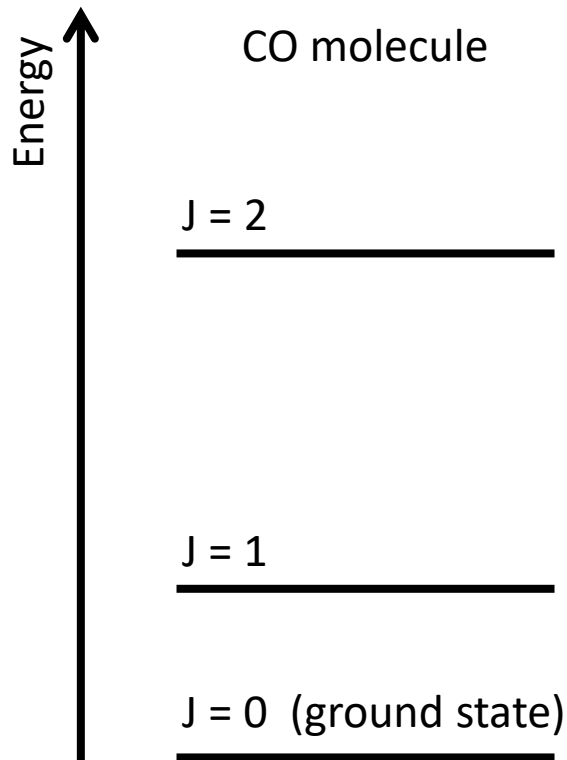
Basic concepts of spectral line observations

Rest frequency

Basic concepts of spectral line observations

Rest frequency

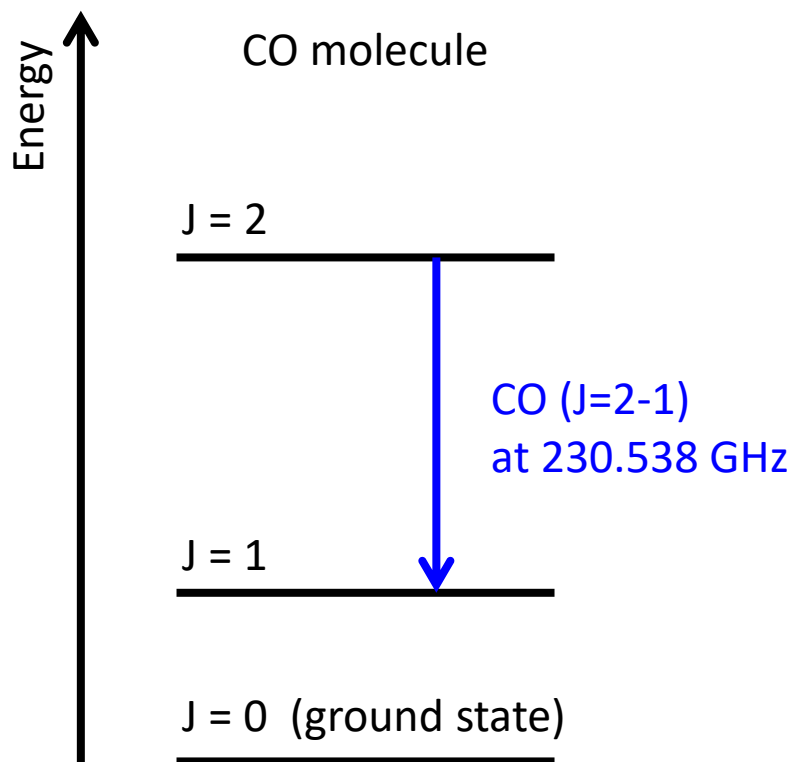
spectral line: transition between two different energy levels of a molecule, atom or ion



Basic concepts of spectral line observations

Rest frequency

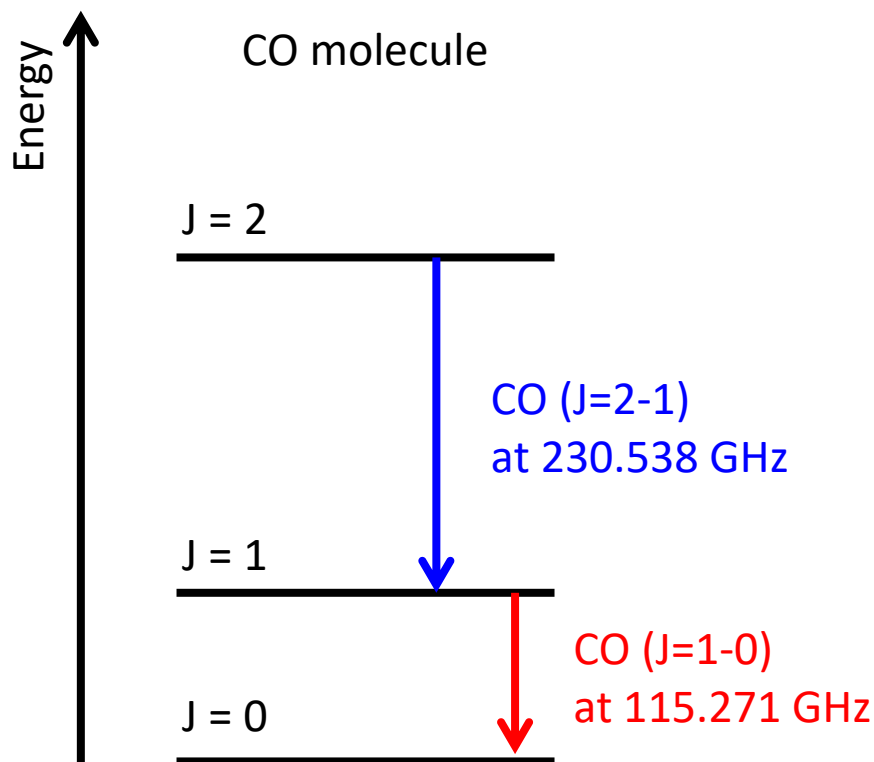
spectral line: transition between two different energy levels of a molecule, atom or ion



Basic concepts of spectral line observations

Rest frequency

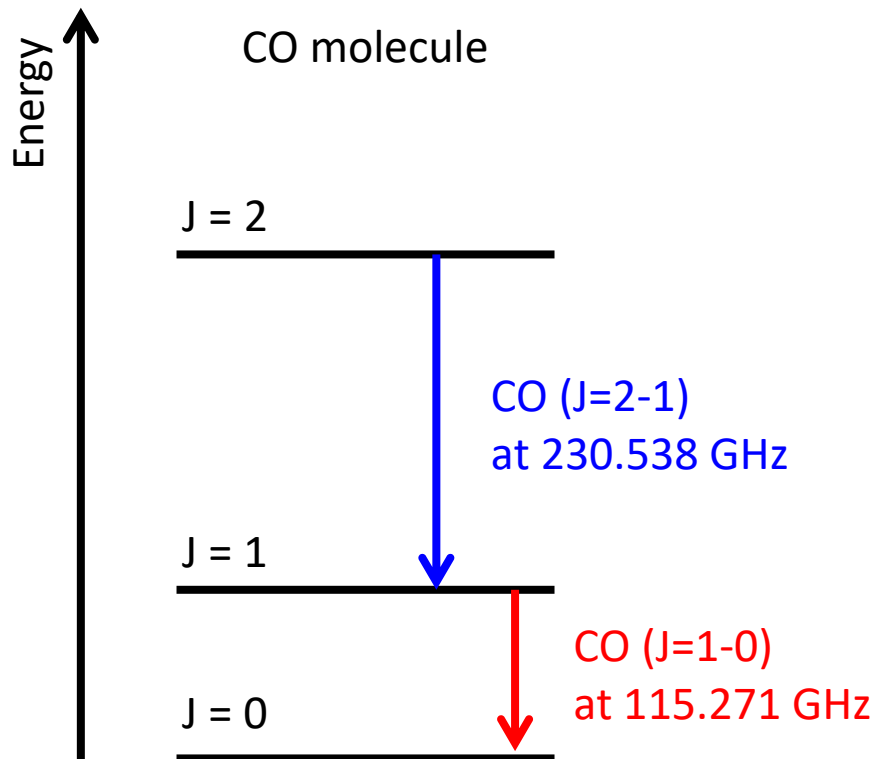
spectral line: transition between two different energy levels of a molecule, atom or ion



Basic concepts of spectral line observations

Rest frequency

spectral line: transition between two different energy levels of a molecule, atom or ion



Rest frequencies can be found in molecular databases:

CDMS

www.astro.uni-koeln.de/cdms

JPL

spec.jpl.nasa.gov

Splatalogue

www.splatalogue.net

What do we need to know?

- continuum or line (both?)
- frequency of the lines to observe
- **velocity / redshift of the source**
- bandwidth / velocity coverage
- spectral resolution
- polarization products
- ...



Basic concepts of spectral line observations

Velocity (V_{lsr}) / redshift (z)

Basic concepts of spectral line observations

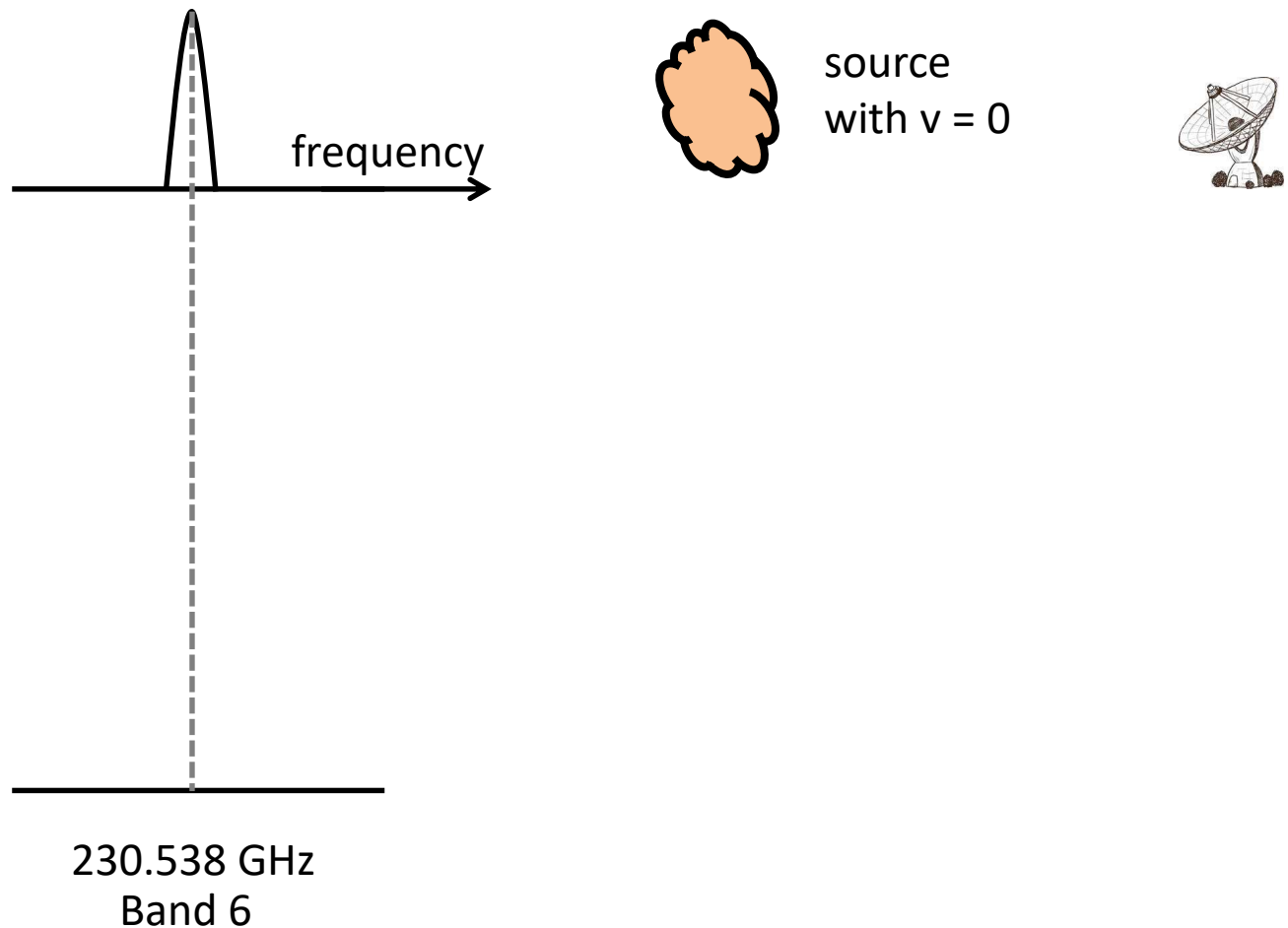
Velocity (V_{lsr}) / redshift (z)

... from rest to sky frequencies (“**doppler effect**”)

Basic concepts of spectral line observations

Velocity (V_{lsr}) / redshift (z)

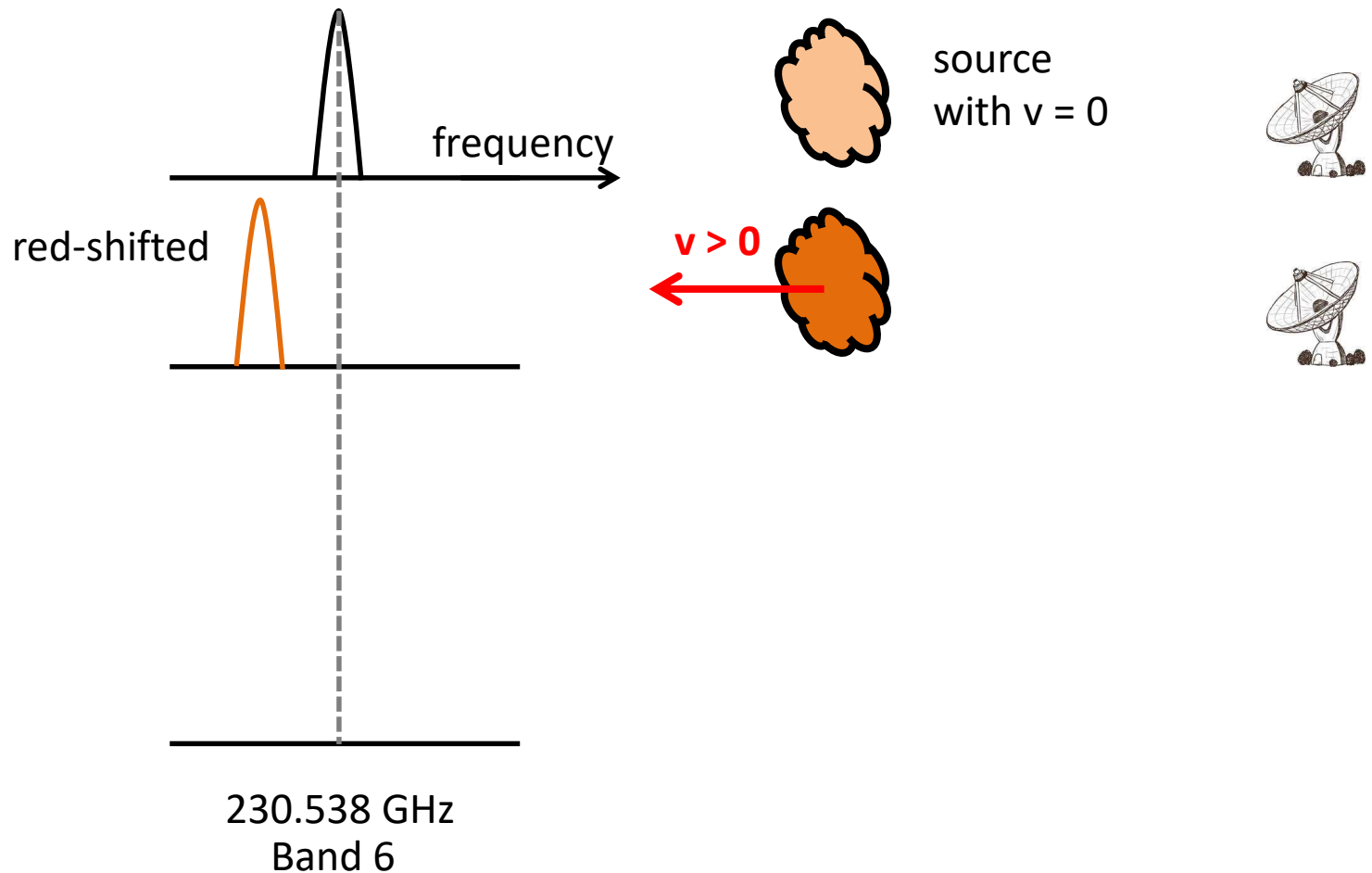
... from rest to sky frequencies ("**doppler effect**")



Basic concepts of spectral line observations

Velocity (V_{lsr}) / redshift (z)

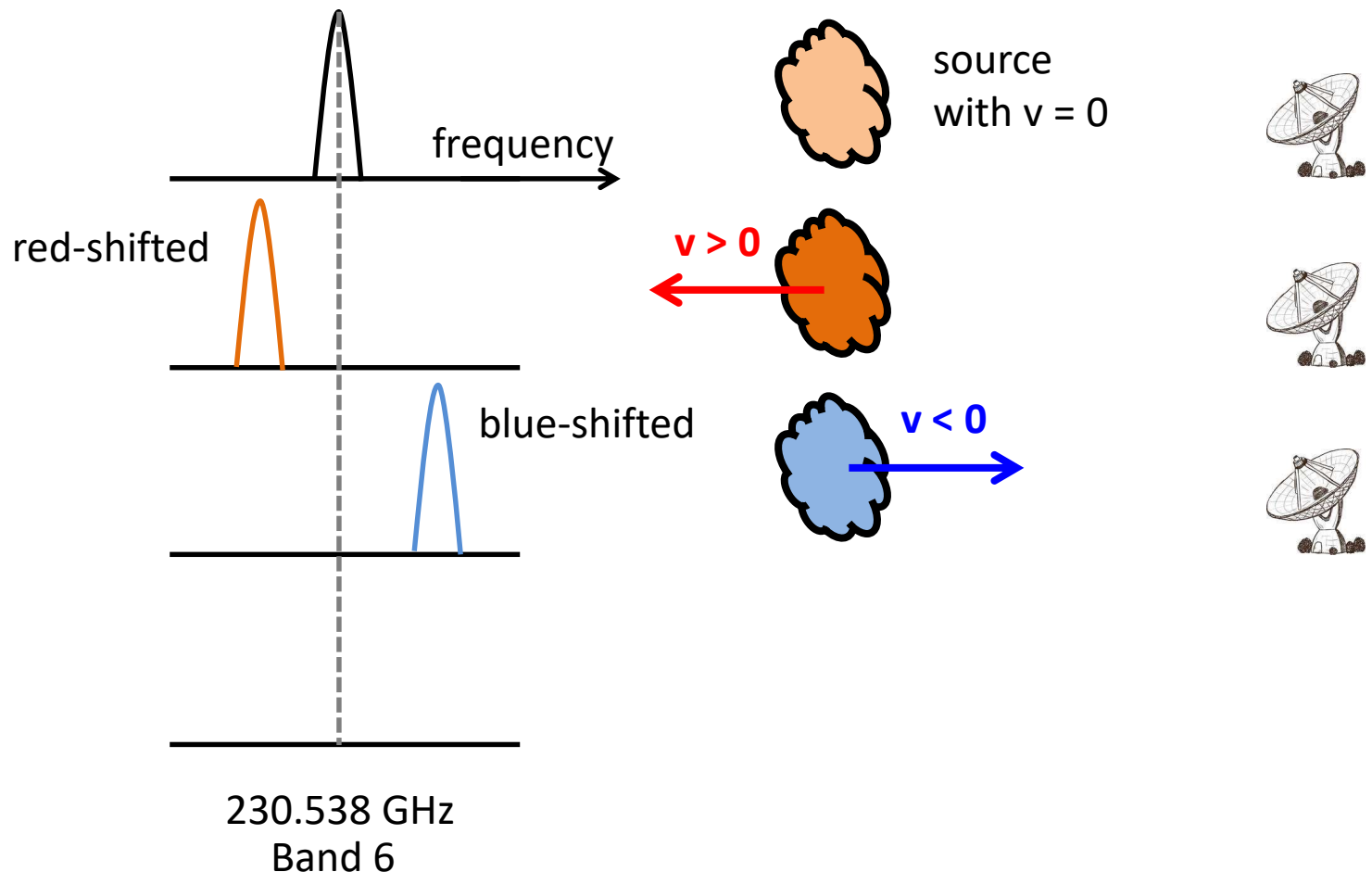
... from rest to sky frequencies (“**doppler effect**”)



Basic concepts of spectral line observations

Velocity (V_{lsr}) / redshift (z)

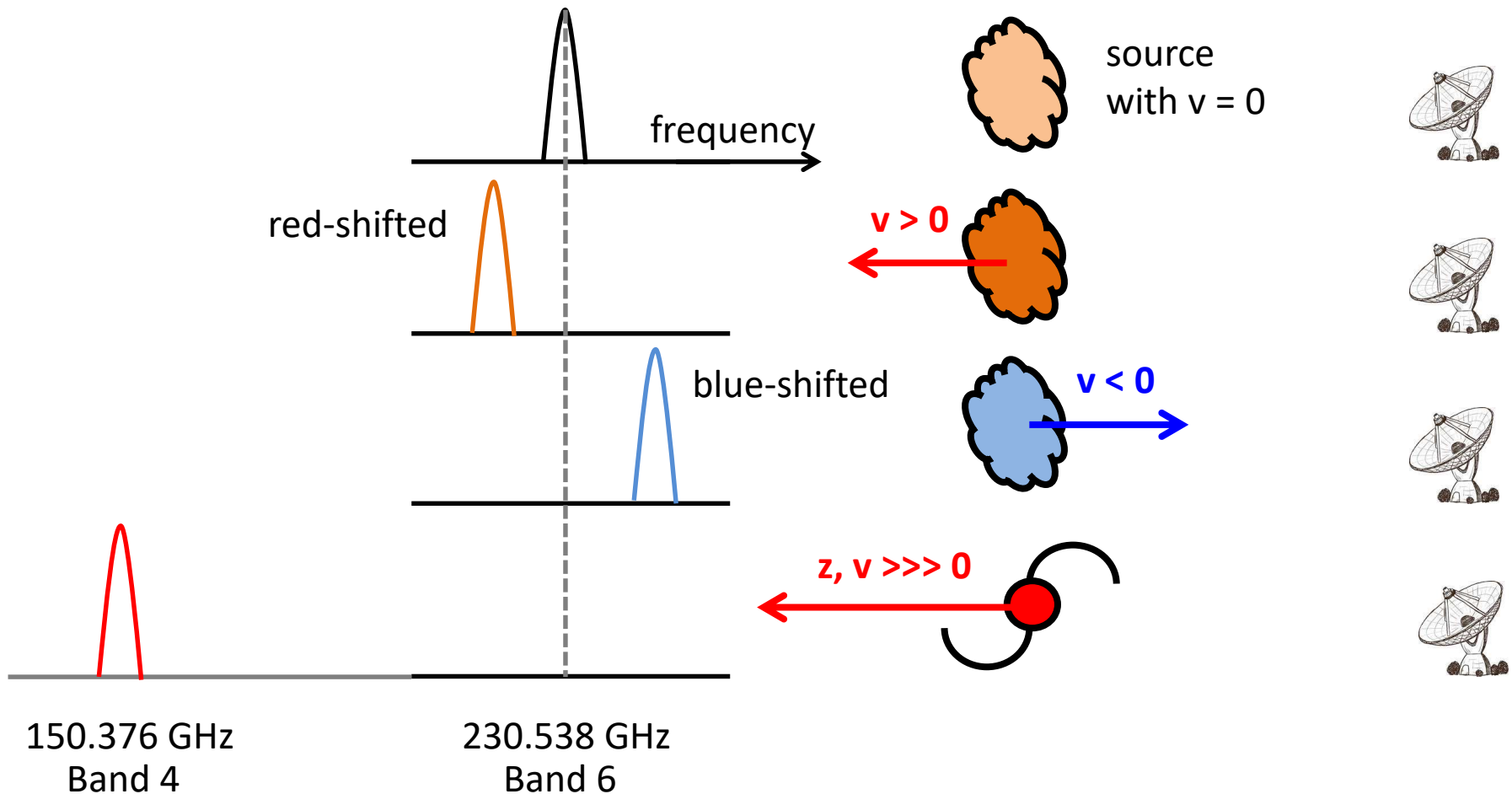
... from rest to sky frequencies (“**doppler effect**”)



Basic concepts of spectral line observations

Velocity (V_{lsr}) / redshift (z)

... from rest to sky frequencies (“**doppler effect**”)



What do we need to know?

- continuum or line (both?)
- frequency of the lines to observe
- velocity / redshift of the source
- **bandwidth / velocity coverage**
- spectral resolution
- polarization products
- ...



Basic concepts of spectral line observations

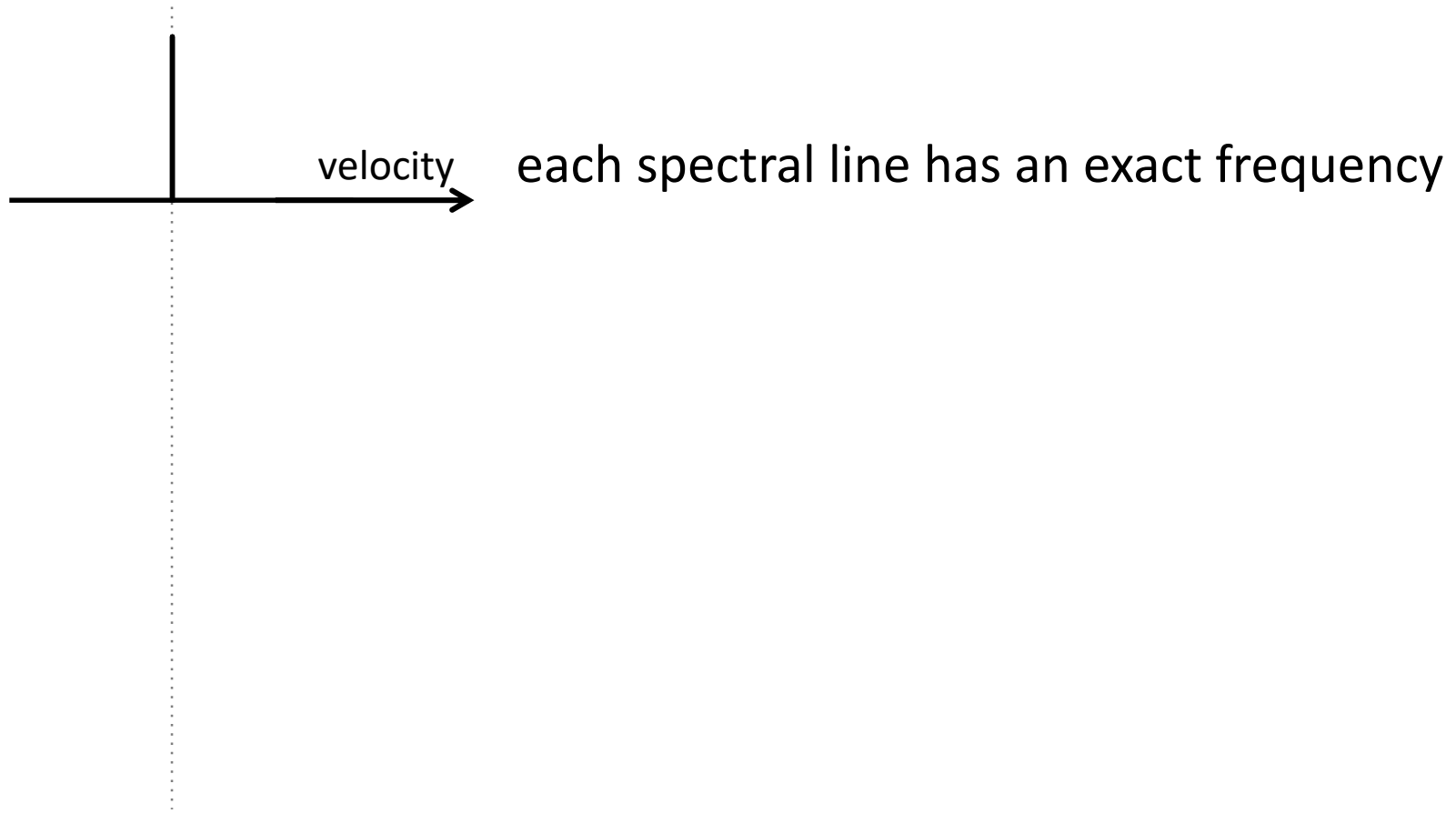
Linewidth ($\Delta\nu$)

the spectral line will have a width that depends on the properties of the object you are studying

Basic concepts of spectral line observations

Linewidth (Δv)

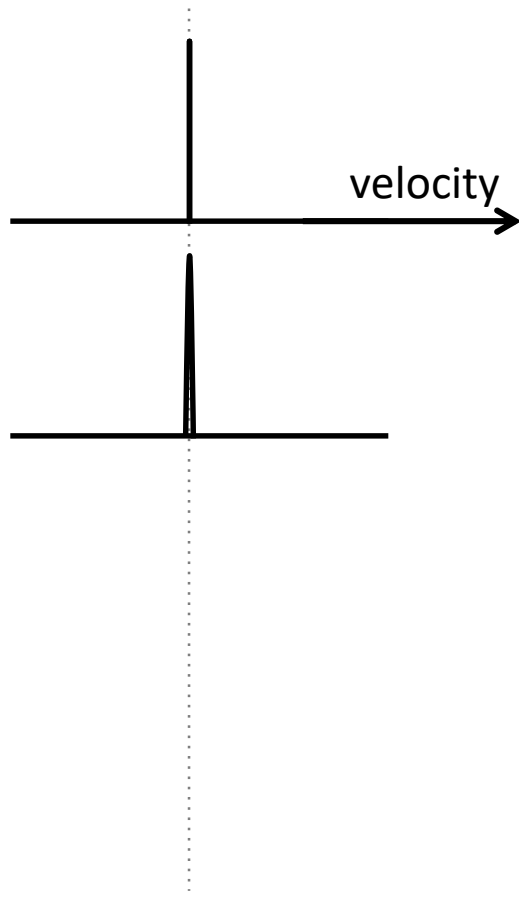
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Basic concepts of spectral line observations

Linewidth (Δv)

the spectral line will have a width that depends on the properties of the object you are studying



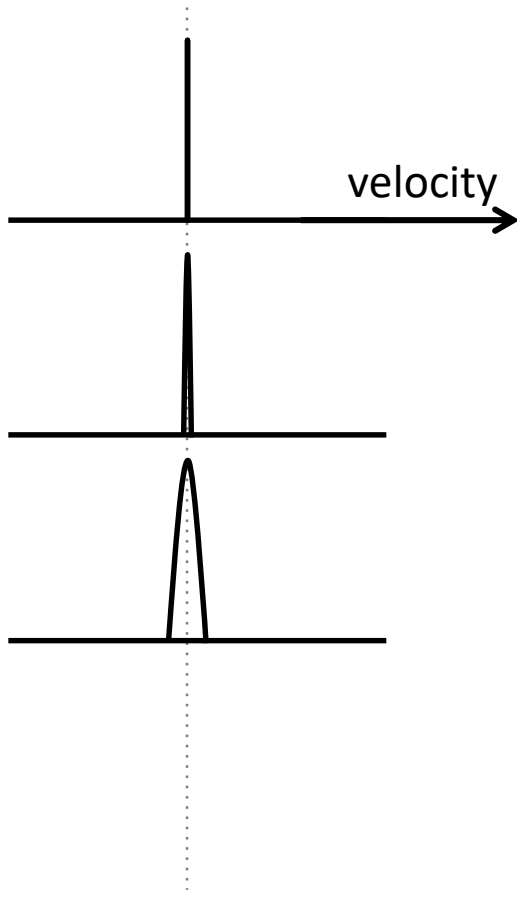
each spectral line has an exact frequency

natural broadening

Basic concepts of spectral line observations

Linewidth (Δv)

the spectral line will have a width that depends on the properties of the object you are studying



each spectral line has an exact frequency

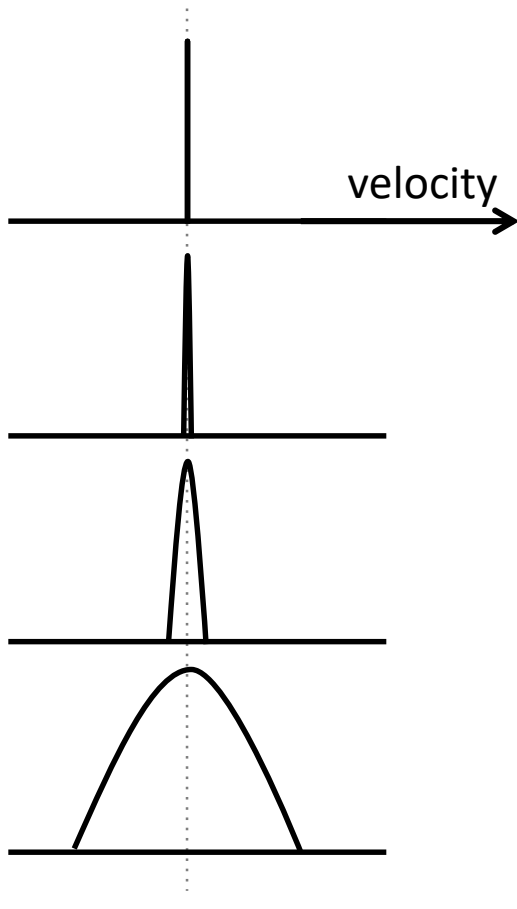
natural broadening

thermal, microturbulent, pressure broadening

Basic concepts of spectral line observations

Linewidth (Δv)

the spectral line will have a width that depends on the properties of the object you are studying



each spectral line has an exact frequency

natural broadening

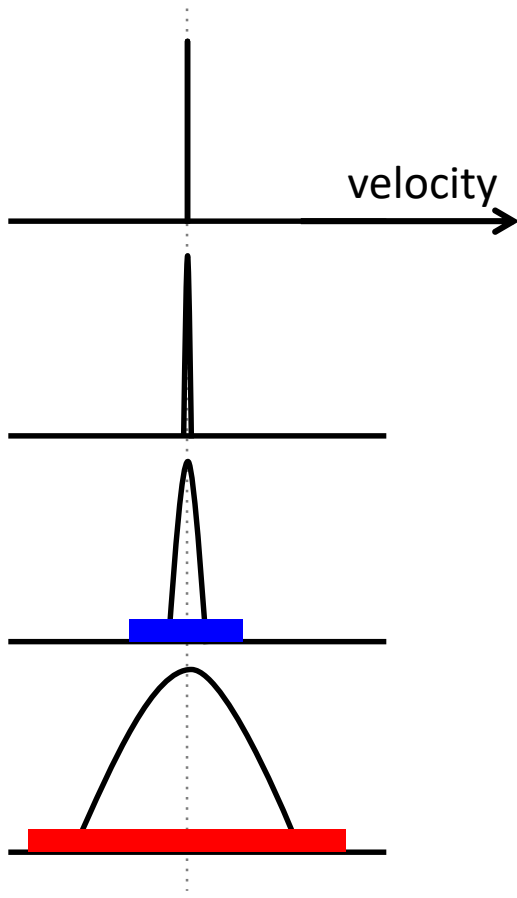
thermal, microturbulent, pressure broadening

large-scale motions broadening

Basic concepts of spectral line observations

Linewidth (Δv)

the spectral line will have a width that depends on the properties of the object you are studying

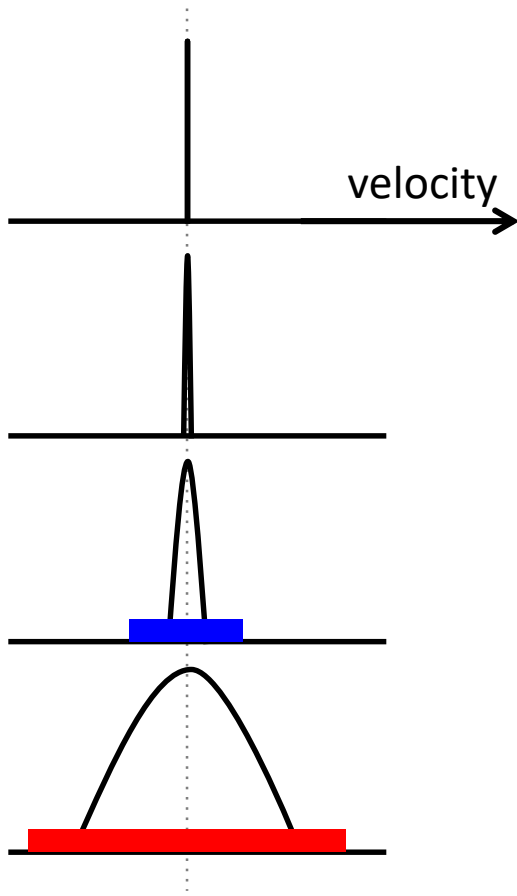


Depending on the linewidth of the line, you will cover a **narrower/broader** frequency (velocity) range

Basic concepts of spectral line observations

Linewidth (Δv)

the spectral line will have a width that depends on the properties of the object you are studying



velocity
linewidth
(km/s)

frequency
linewidth
(Hz)

$$\Delta V = -\Delta n \frac{c}{n_0}$$

Depending on the linewidth of the line,
you will cover a narrower/broader
frequency (*velocity*) range

Spectral setup in the almaOT

Project Structure

- Project
 - Proposal
 - Planned Observing
 - ScienceGoal (Science Goal)
 - General
 - Field Setup
 - Spectral Setup**
 - Calibration Setup
 - Control and Performance
 - Technical Justification

Editors

Spectral | Spatial | **Spectral Setup**

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Continuum or line ?

Spectral Type

Spectral Line
 Single Continuum
 Spectral Scan

Polarization products ?

Produce image sidebands (Bands 9 and 10 only)
Polarization products desired

XX DUAL FULL

Rest frequency ?

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz; 0.0 GHz]

Bandwidth, spectral resolution ?

Baseband	Fract	Centre Freq (rest, lsrk)	Centre Freq (sky, bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg	Repre Wi
Baseband-1							
Baseband-2							

Add spectral window centred on a spectral line | Add spectral window manually | Delete | Show image spectral window

What do we need to know?

- continuum or line (both?)
- frequency of the lines to observe
- velocity / redshift of the source
- bandwidth / velocity coverage
- spectral resolution
- polarization products
- ...



What do we need to know?

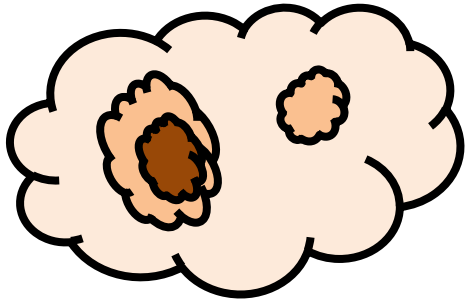
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- polarization products

Spectral observations in a radio-interferometer

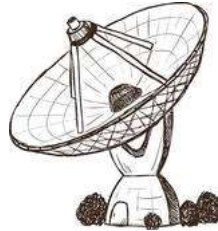
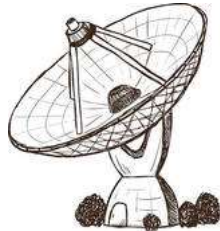
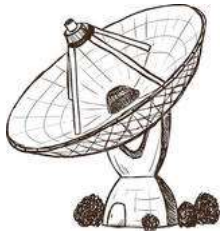
- frequency bands
- receivers
- correlator



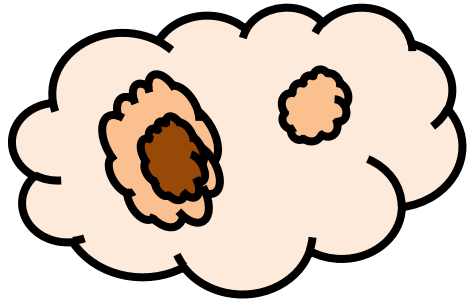
Scientific target



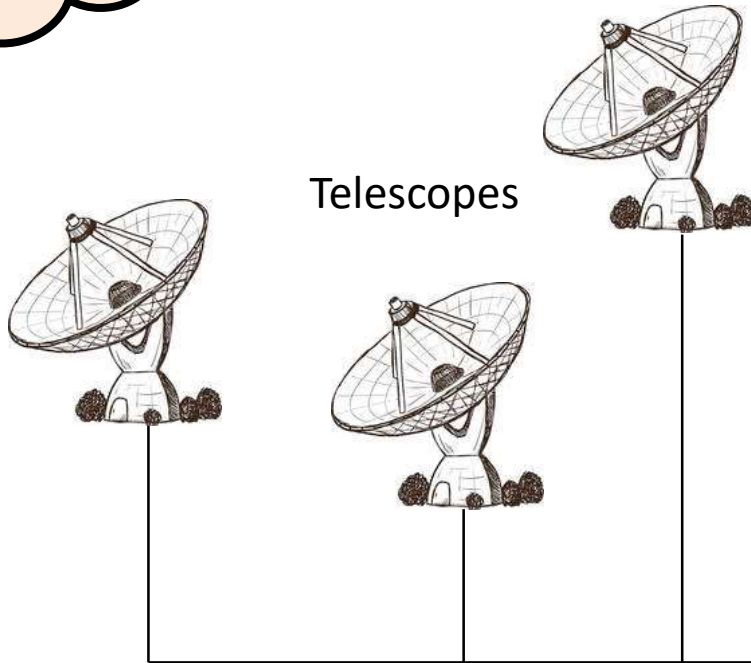
Telescopes



Scientific target



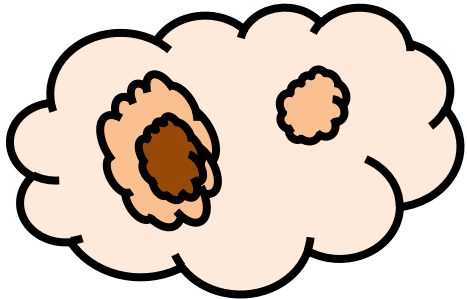
Telescopes



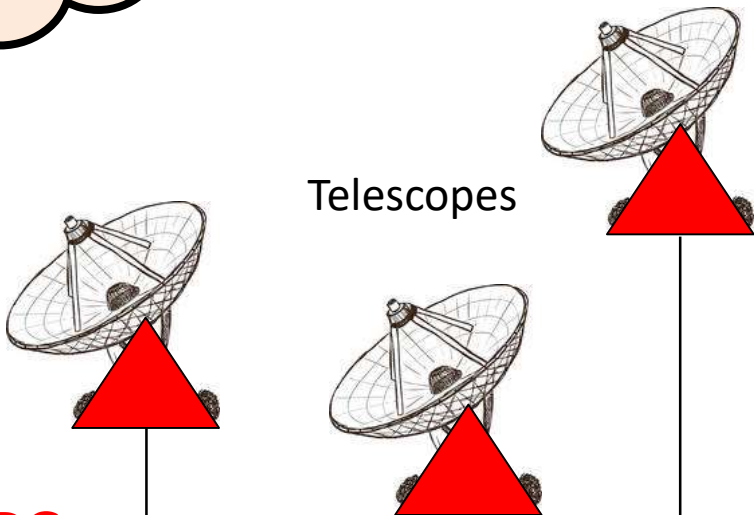
Control room



Scientific target



Telescopes

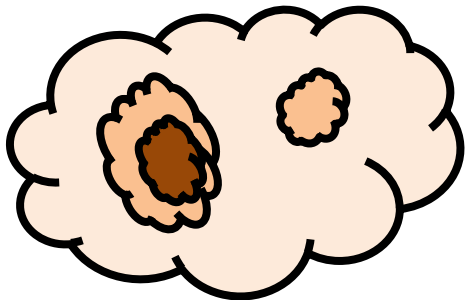


Control room

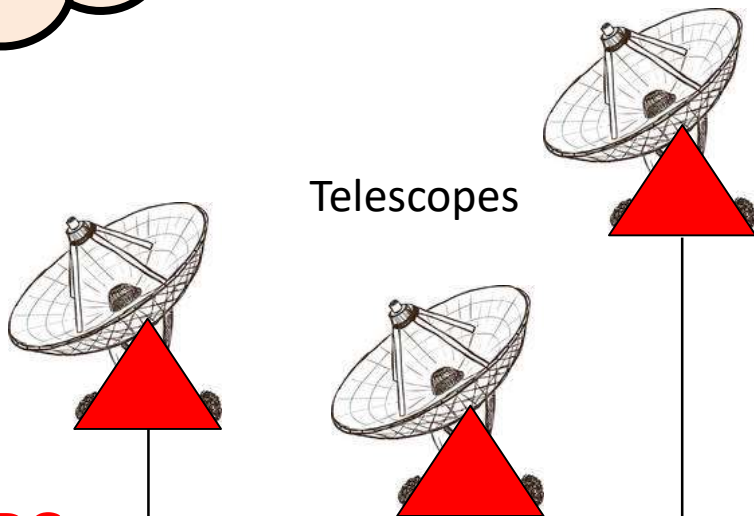
RECEIVERS

front-ends, bands

Scientific target

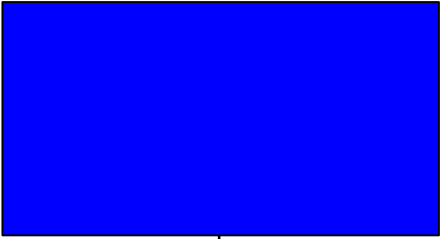


Telescopes



CORRELATOR
super-computer

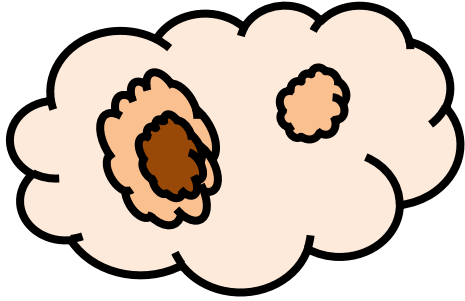
Control room



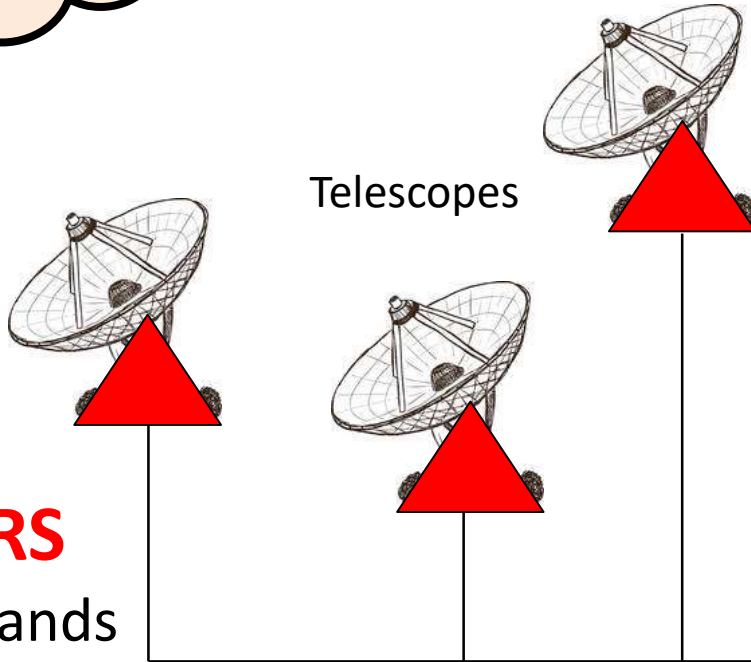
RECEIVERS

front-ends, bands

Scientific target

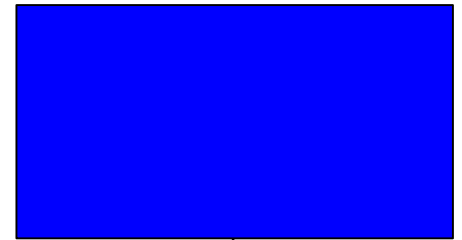


Telescopes



CORRELATOR
super-computer

Control room



RECEIVERS

front-ends, bands

WHAT frequencies do/can we observe?

HOW do/can we observe those frequencies?

What do we need to know?

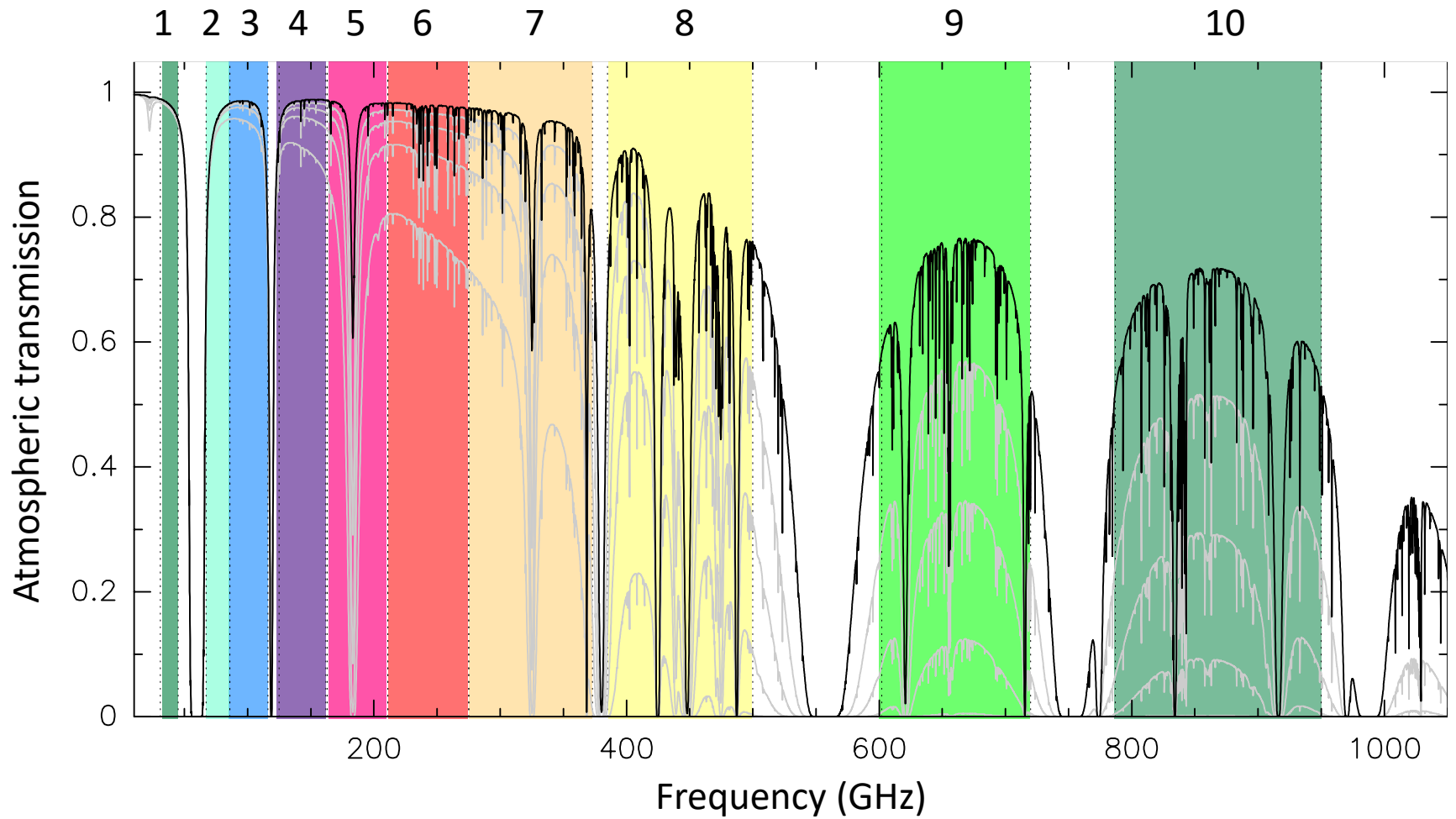
- continuum or line (both?)
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- bandwidth / velocity coverage
- spectral resolution
- polarization products

Spectral observations in a radio-interferometer

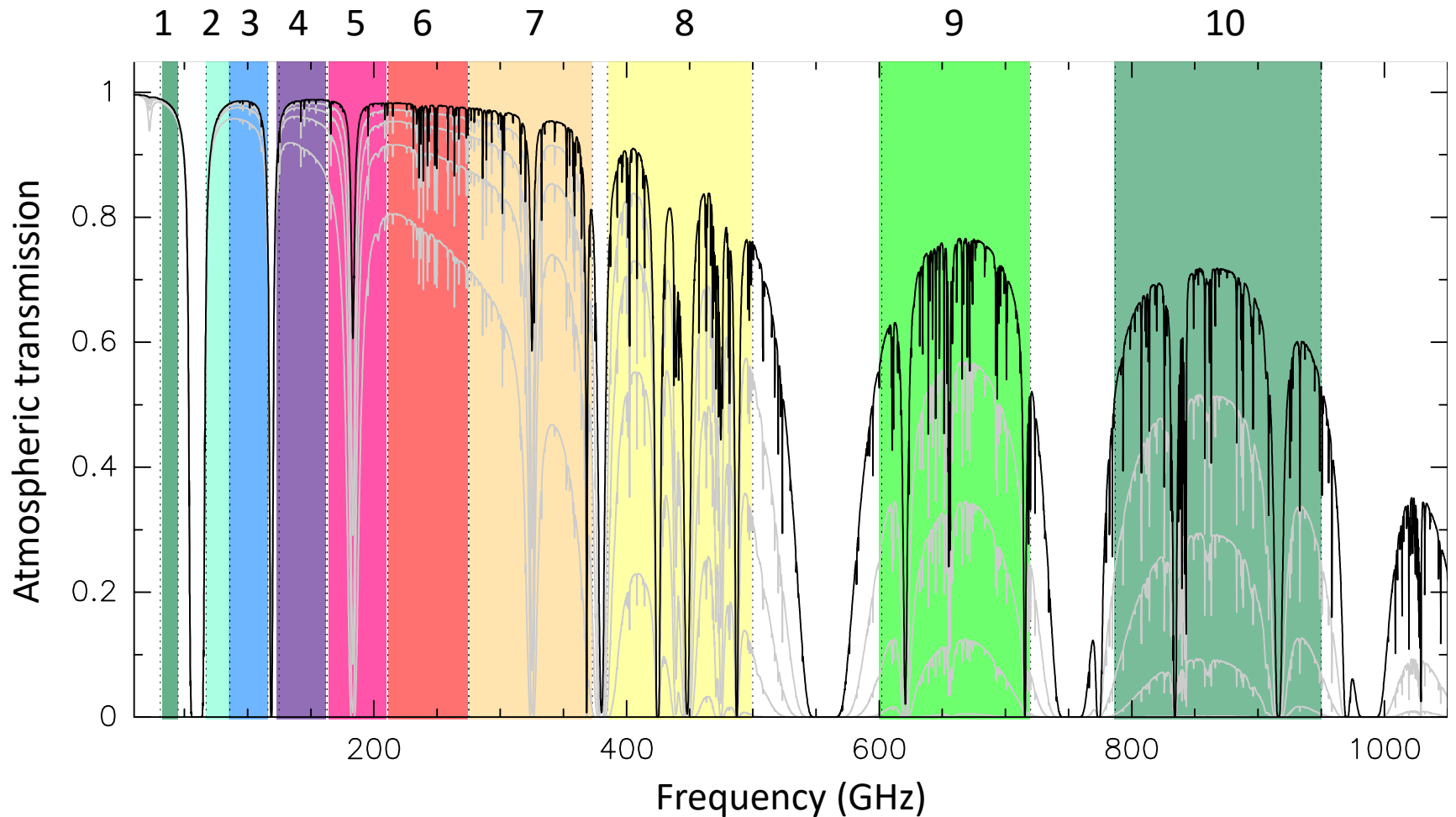
- **frequency bands**
- receivers
- correlator



ALMA frequency bands



ALMA frequency bands



Band 3: 84 – 116 GHz

Band 4: 125 – 163 GHz

Band 5: 159 – 211 GHz

Band 6: 211 – 275 GHz

Band 7/8: 275 – 373 GHz / 385 – 500 GHz

Band 9/10: 602 – 720 GHz / 787 – 950 GHz

What do we need to know?

- continuum or line (both?)
- frequency of the lines to observe
- velocity / redshift of the source
- bandwidth / velocity coverage
- spectral resolution
- polarization products

Spectral observations in a radio-interferometer

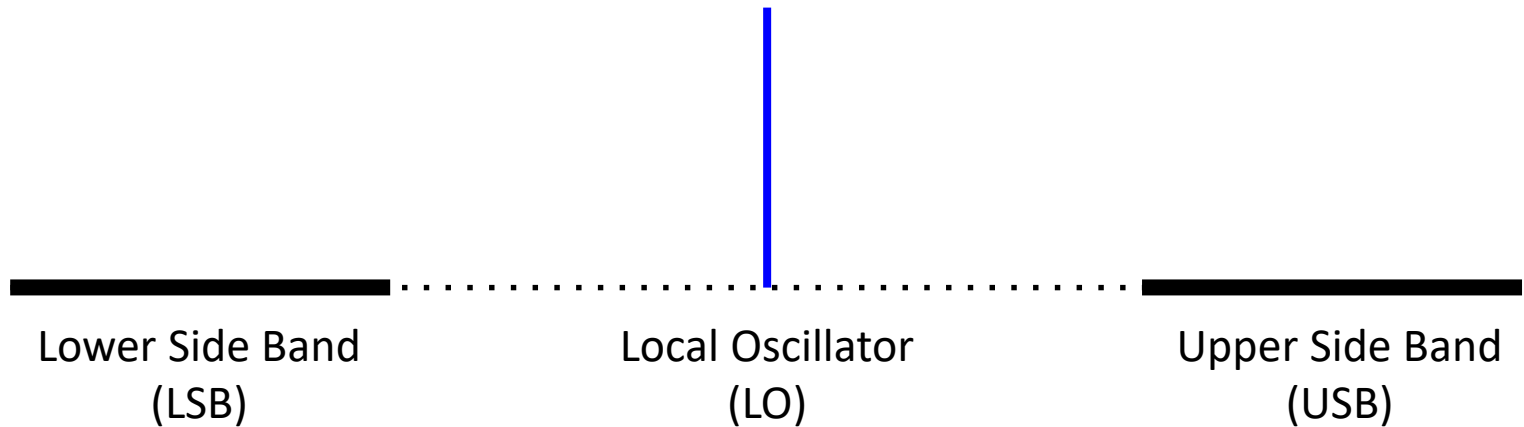
- frequency bands
- **receivers**
- correlator



ALMA receivers

Heterodyne receivers

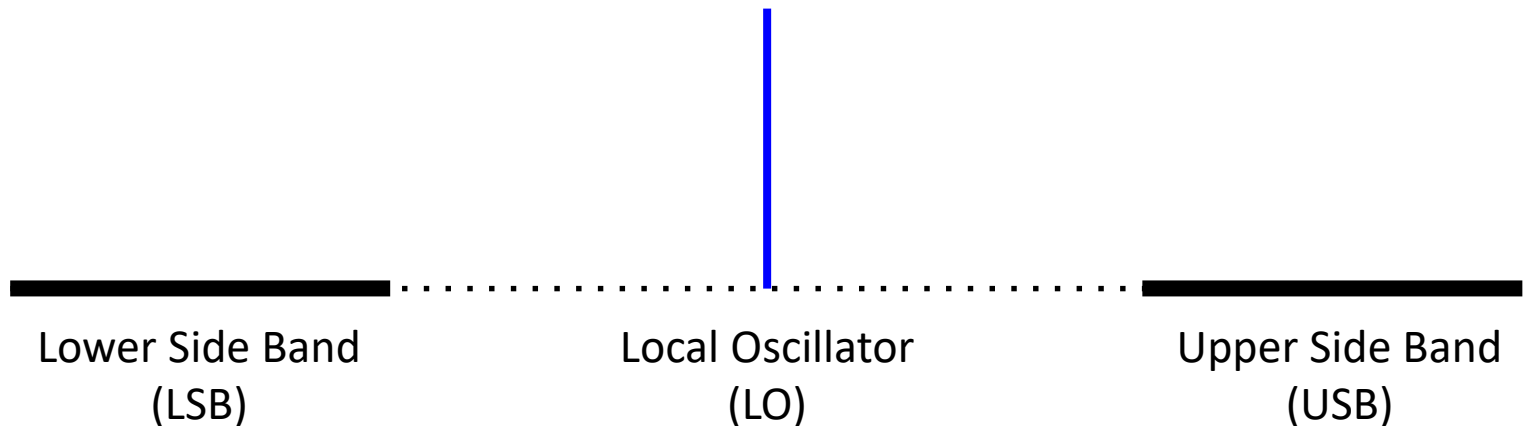
are sensitive to Lower Side Band (LSB) and Upper Side Band (USB)



ALMA receivers

Heterodyne receivers

are sensitive to Lower Side Band (LSB) and Upper Side Band (USB)



Heterodyne receivers can be:

SSB (single) outputs **LSB or USB**

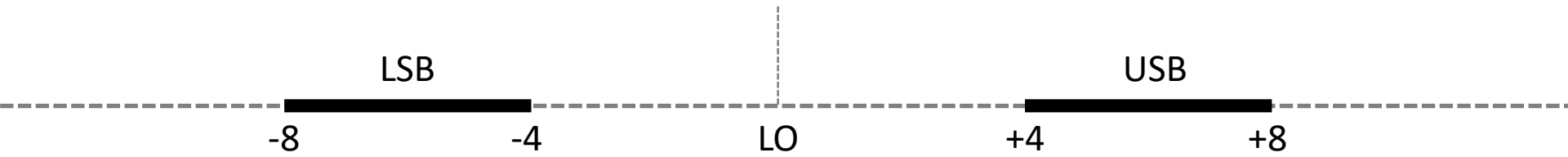
DSB (double) outputs the sum **LSB+USB** (separated in correlator)

2SB (two) outputs **LSB and USB** (separately)

ALMA receivers

ALMA B3 / B4 / B5 / B7 / B8

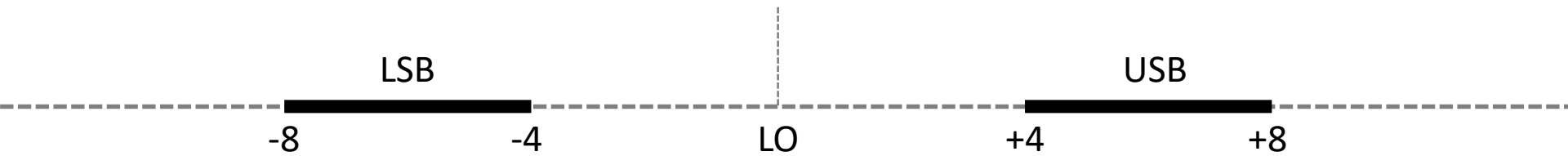
2SB receivers 4-8 GHz



ALMA receivers

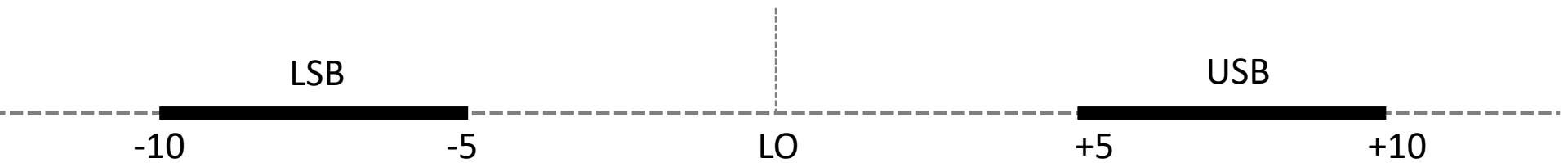
ALMA B3 / B4 / B5 / B7 / B8

2SB receivers 4-8 GHz



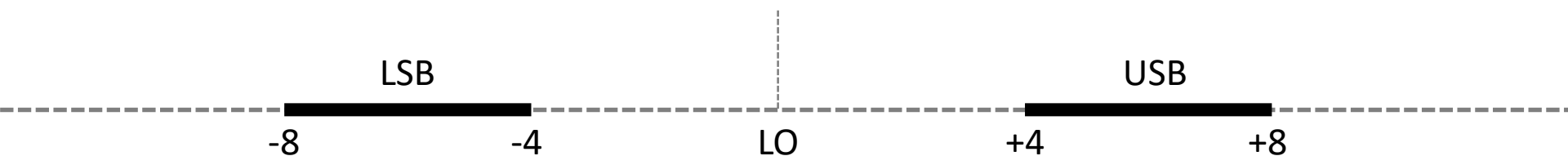
ALMA B6

2SB receivers 5-10 GHz

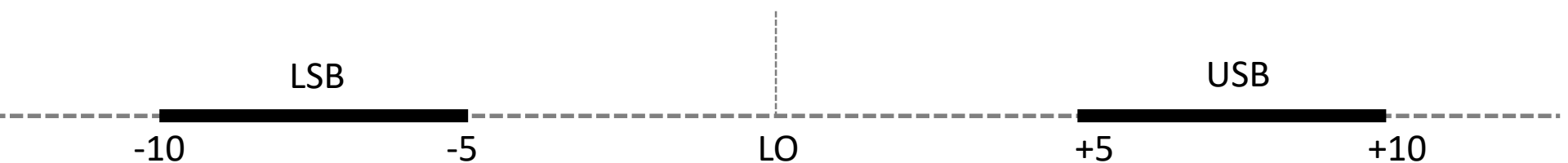


ALMA receivers

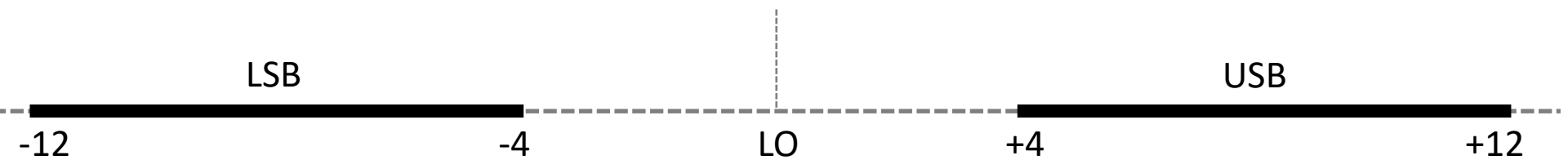
ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



ALMA B6 2SB receivers 5-10 GHz



ALMA B9 / B10 DSB receivers 4-12 GHz



ALMA frequency bands & receivers

Band 3: 84 – 116 GHz

Band 4: 125 – 163 GHz

Band 6: 211 – 275 GHz

Band 7: 275 – 373 GHz

Band 8: 385 – 500 GHz

Band 9/10: 602 – 720 GHz / 787 – 950 GHz

ALMA frequency bands & receivers

Band 3: 84 – 116 GHz

Band 4: 125 – 163 GHz

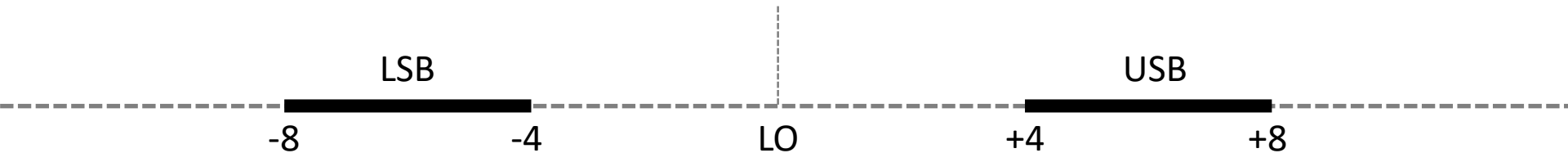
Band 6: 211 – 275 GHz

Band 7: 275 – 373 GHz

Band 8: 385 – 500 GHz

Band 9/10: 602 – 720 GHz / 787 – 950 GHz

ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



ALMA frequency bands & receivers

Band 3: 84 – 116 GHz

Band 7: 275 – 373 GHz

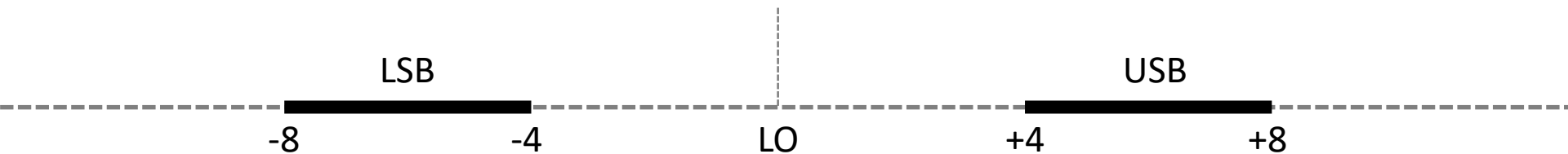
Band 4: 125 – 163 GHz

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ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



Band 3



ALMA frequency bands & receivers

Band 3: 84 – 116 GHz

Band 7: 275 – 373 GHz

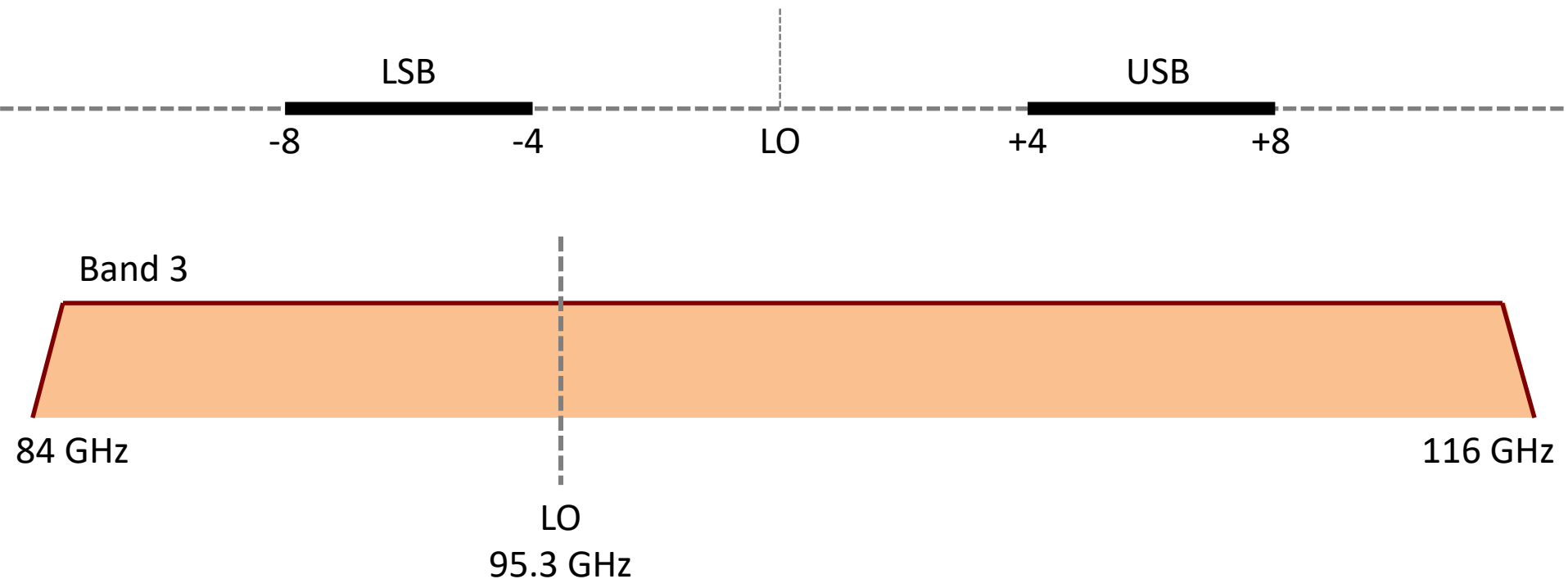
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ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



ALMA frequency bands & receivers

Band 3: 84 – 116 GHz

Band 7: 275 – 373 GHz

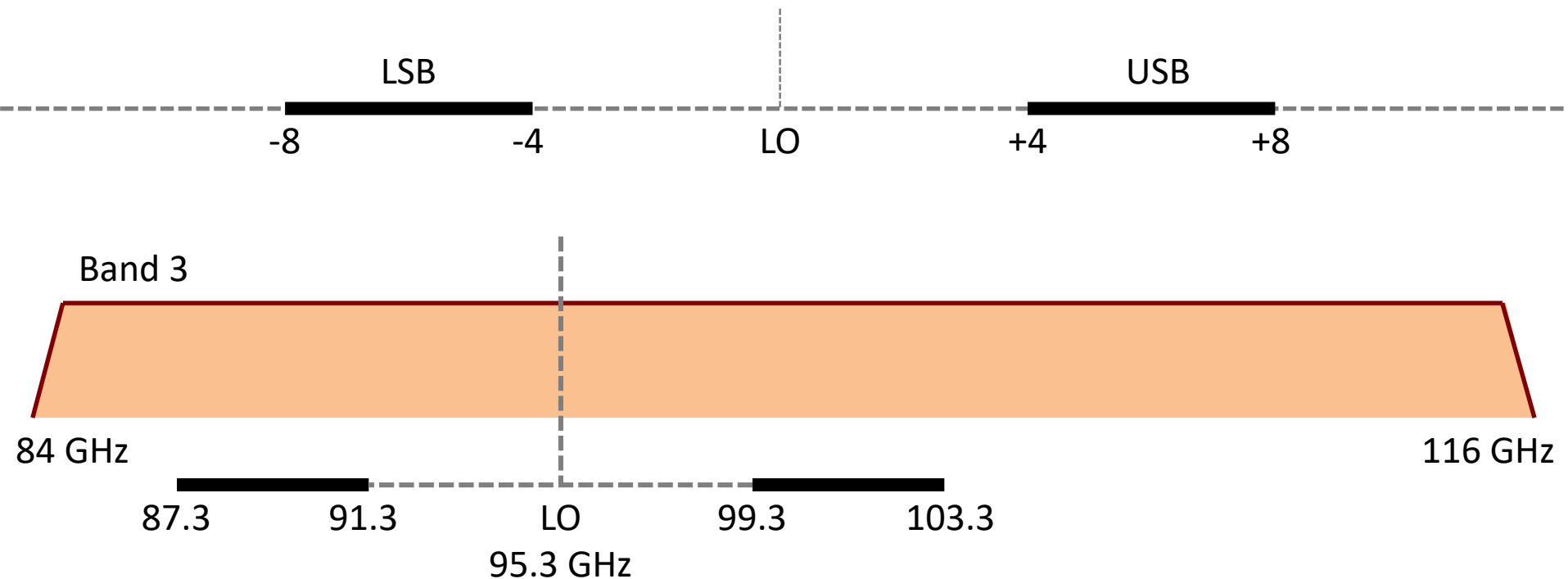
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ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



ALMA frequency bands & receivers

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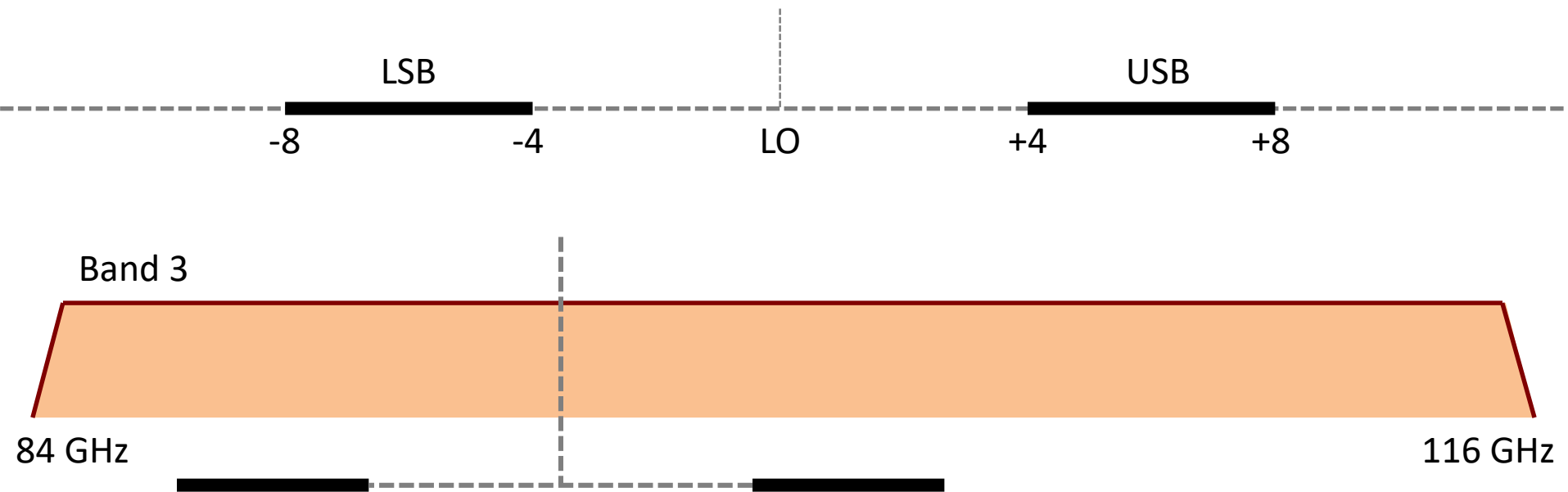
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ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



ALMA frequency bands & receivers

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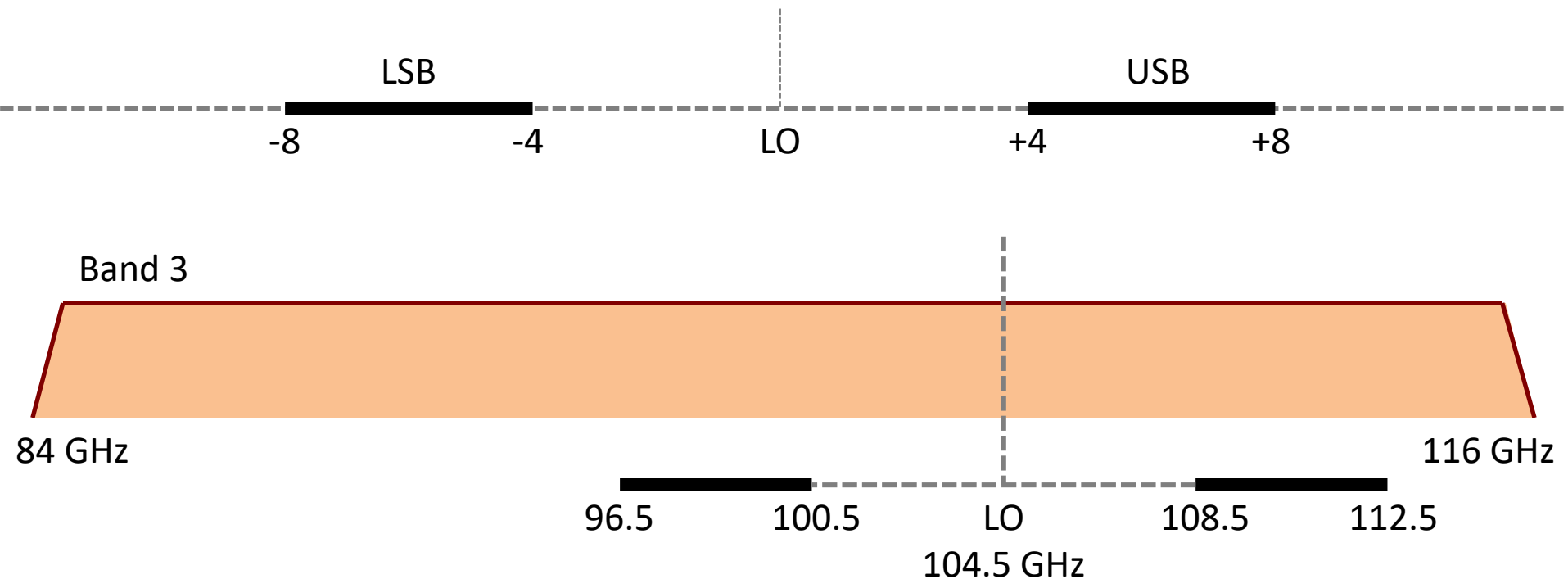
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ALMA B3 / B4 / B5 / B7 / B8 2SB receivers 4-8 GHz



What do we need to know?

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- bandwidth / velocity coverage
- spectral resolution
- polarization products

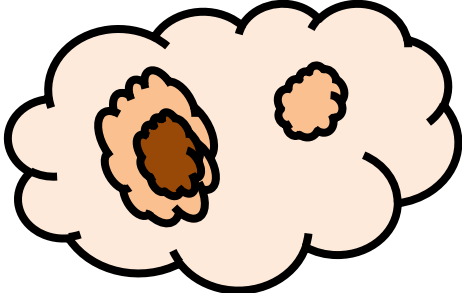
Spectral observations in a radio-interferometer

- frequency bands
- receivers
- **correlator**

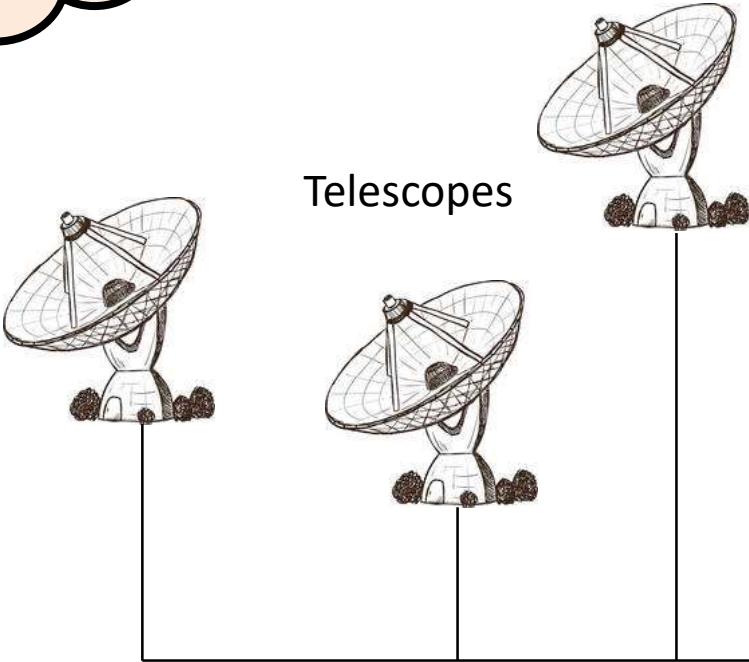


ALMA correlator

Scientific target



Telescopes

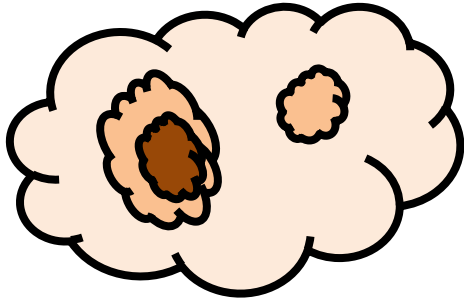


Control room

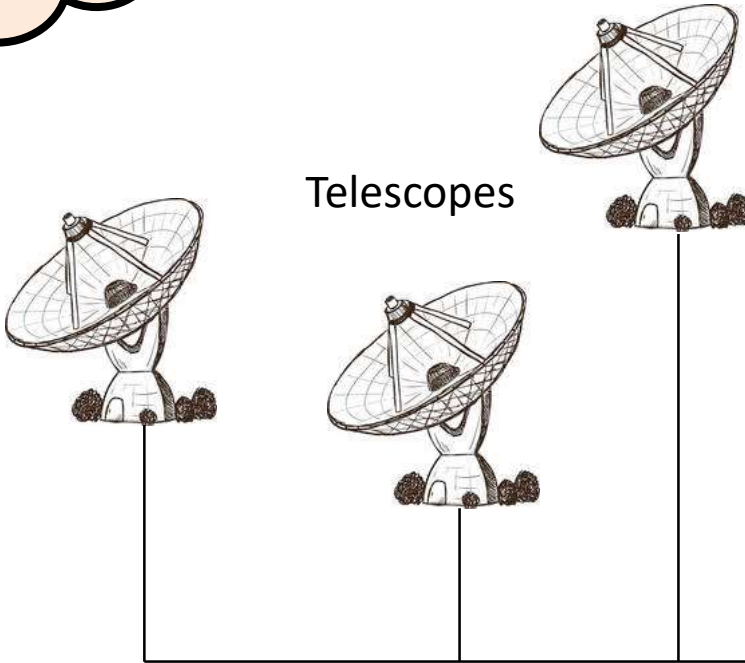


ALMA correlator

Scientific target



Telescopes

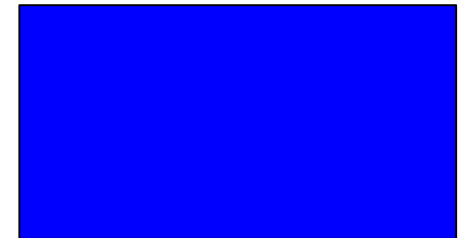


CORRELATOR:

Super-computer that accepts signals from element antennas, calculates **cross-correlation** of them, and produces **complex visibilities** that are used to synthesize images.

Keeps coherence in the complex visibilities, by providing delay and phase tracking to adjust wavefronts of received signals before correlation.

CORRELATOR



ALMA correlator



ALMA CORRELATOR:
one of the four 'quadrants' of the ALMA correlator

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CORRELATOR



ALMA correlator



ALMA CORRELATOR:
one of the four 'quadrants' of the ALMA correlator

Physically:

- 1 correlator = 4 quadrants
- 1 quadrant = 1 baseband

-ALMA correlator = 4 basebands

-Each baseband processes

- 64 antennas (2016 baselines)
- 2 polarizations
- **2 GHz** input

-Each baseband can be centered anywhere in the incoming 8 GHz

ALMA correlator / 4 basebands

basebands

information from 64 antennas

2 GHz input

up to 8192 channels

2 polarizations Horizontal / Vertical

up to 4 polarization products (HH, VV, HV, VH)

ALMA correlator / 4 basebands

basebands

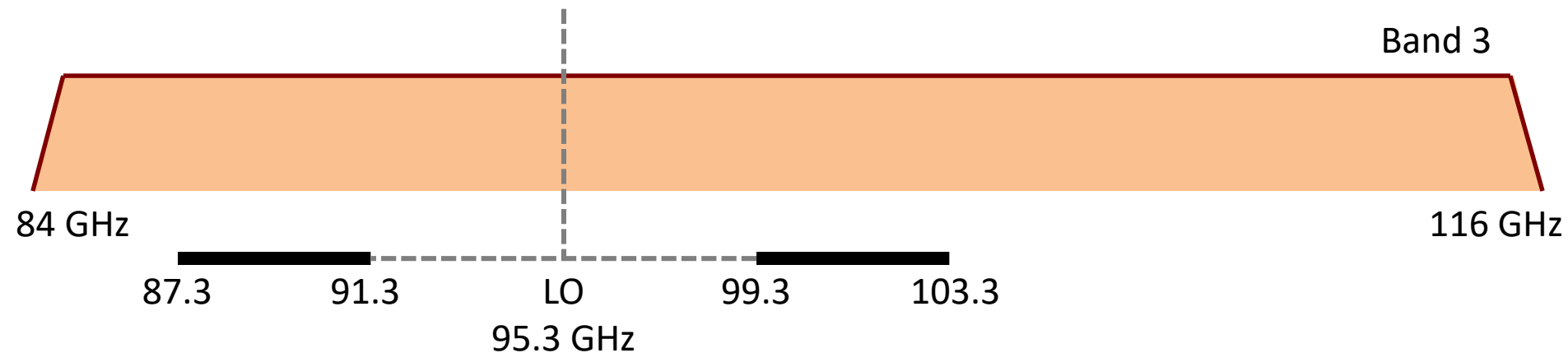
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ALMA correlator / 4 basebands

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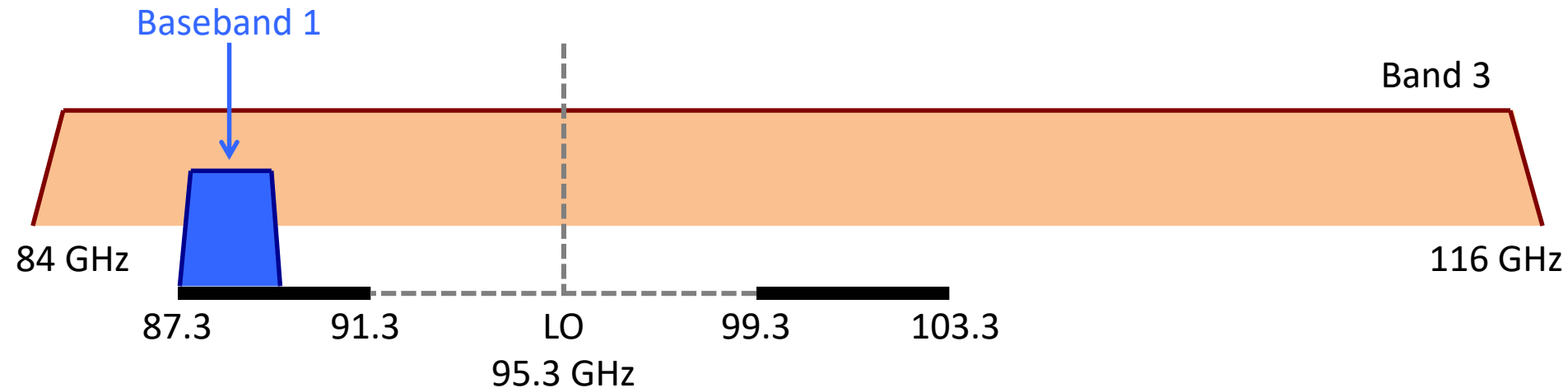
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ALMA correlator / 4 basebands

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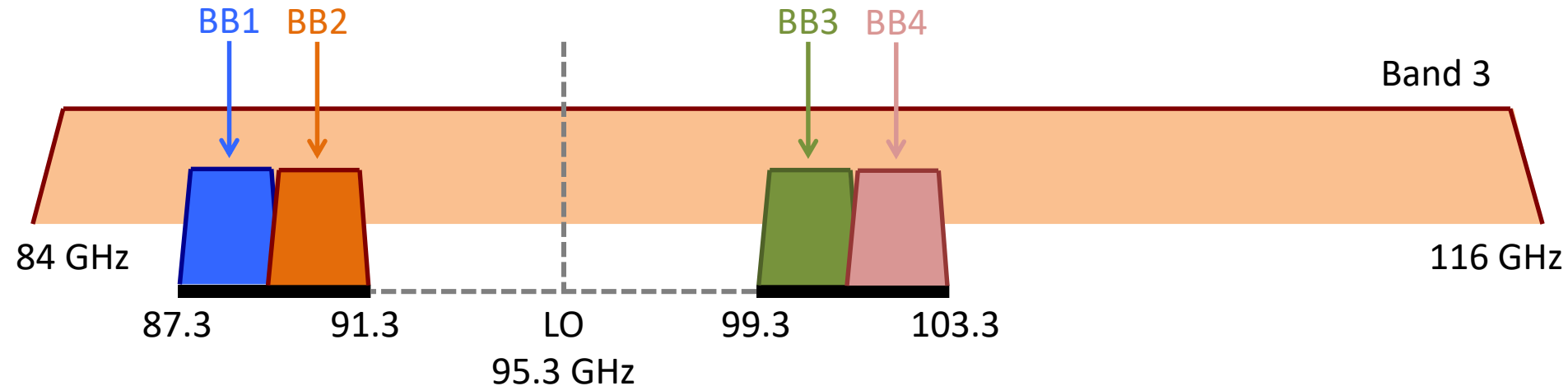
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ALMA correlator / 4 basebands

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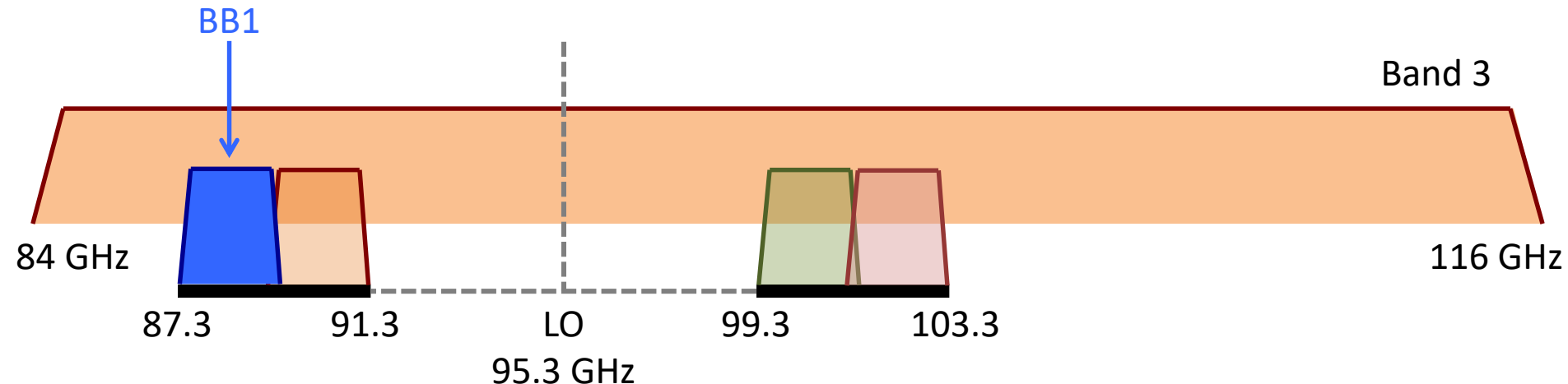
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ALMA correlator / **4 basebands**

basebands

information from 64 antennas

2 GHz input

up to 8192 channels

2 polarizations Horizontal / Vertical

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Baseband 1



87.3 GHz

89.3 GHz

ALMA correlator / **4 basebands**

basebands

information from 64 antennas

2 GHz input

up to **8192 channels**

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... up to 8192 channels

Baseband 1



87.3 GHz

89.3 GHz

ALMA correlator / 4 basebands

basebands

information from 64 antennas

2 GHz input

up to **8192 channels**

2 polarizations Horizontal / Vertical

up to 4 polarization products (HH, VV, HV, VH)

channel width (**spectral resolution**):

$$2 \text{ GHz} / 8192 = 244 \text{ kHz}$$



... up to 8192 channels

Baseband 1



87.3 GHz

89.3 GHz

ALMA correlator / 4 basebands

basebands

information from 64 antennas

2 GHz input

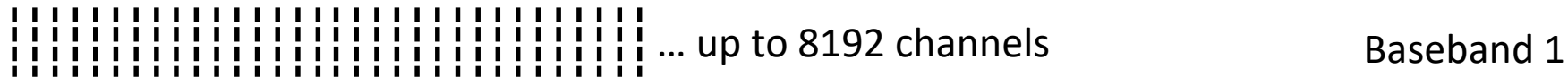
up to **8192 channels**

2 polarizations Horizontal / Vertical

up to 4 polarization products (HH, VV, HV, VH)

channel width (**spectral resolution**):

$$2 \text{ GHz} / 8192 = 244 \text{ kHz}$$



87.3 GHz

89.3 GHz

bandwidth = 2 GHz / resolution = 244 kHz ... **not fixed!**

ALMA correlator

Bandwidth – Spectral resolution

BW	2 GHz	8192 channels x 1 polz	244 kHz resol.
BW	1 GHz	8192 channels x 1 polz	122 kHz resol.
BW	500 MHz	8192 channels x 1 polz	61 kHz resol.
BW	250 MHz	8192 channels x 1 polz	30 kHz resol.
BW	125 MHz	8192 channels x 1 polz	15 kHz resol.
BW	64 MHz	8192 channels x 1 polz	7.5 kHz resol.
BW	32 MHz	8192 channels x 1 polz	3.8 kHz resol.
continuum mode		256 channels x 1 polz	7.5 MHz resol.

ALMA correlator

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... up to 8192 channels

Baseband 1



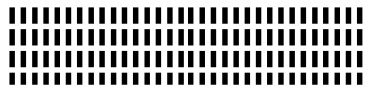
87.3 GHz

89.3 GHz

ALMA correlator

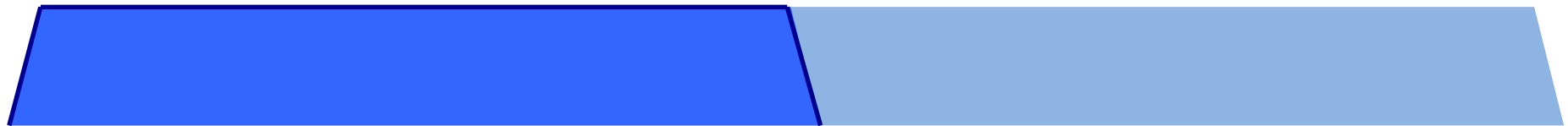
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... up to 8192 channels

Baseband 1



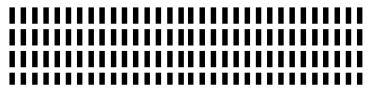
87.3 GHz

88.3 GHz

ALMA correlator

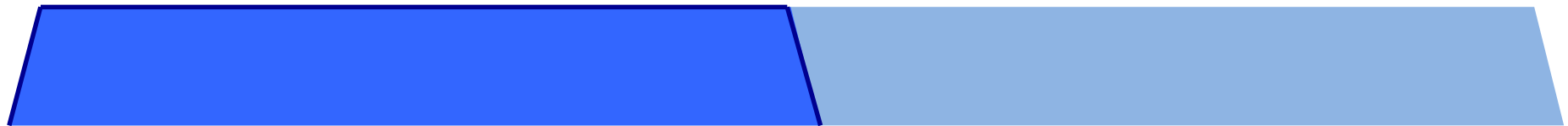
Bandwidth – Spectral resolution **1 polz (H or V)**

BW	2 GHz	8192 channels x 1 polz	244 kHz resol.
BW	1 GHz	8192 channels x 1 polz	122 kHz resol.
BW	500 MHz	8192 channels x 1 polz	61 kHz resol.
BW	250 MHz	8192 channels x 1 polz	30 kHz resol.
BW	125 MHz	8192 channels x 1 polz	15 kHz resol.
BW	64 MHz	8192 channels x 1 polz	7.5 kHz resol.
BW	32 MHz	8192 channels x 1 polz	3.8 kHz resol.
continuum mode		256 channels x 1 polz	7.5 MHz resol.



... up to 8192 channels

Baseband 1



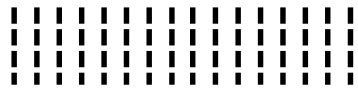
87.3 GHz

88.3 GHz

ALMA correlator

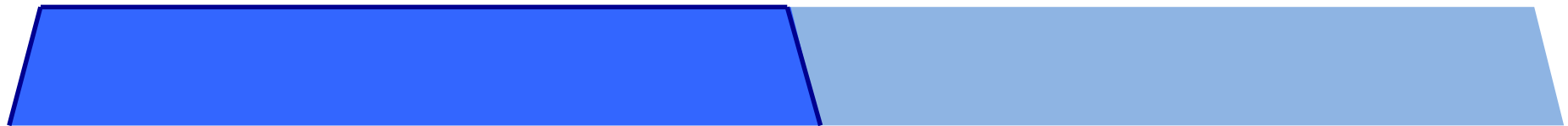
Bandwidth – Spectral resolution **2 polz (H and V)**

BW	2 GHz	4096 channels x 2 polz	488 kHz resol.
BW	1 GHz	4096 channels x 2 polz	244 kHz resol.
BW	500 MHz	4096 channels x 2 polz	122 kHz resol.
BW	250 MHz	4096 channels x 2 polz	61 kHz resol.
BW	125 MHz	4096 channels x 2 polz	30 kHz resol.
BW	64 MHz	4096 channels x 2 polz	15 kHz resol.
BW	32 MHz	4096 channels x 2 polz	7.5 kHz resol.
continuum mode		128 channels x 2 polz	15 MHz resol.



... up to **4096 channels**

Baseband 1



87.3 GHz

88.3 GHz

ALMA correlator

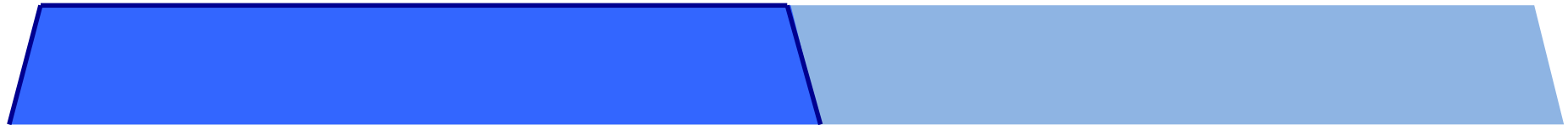
Bandwidth – Spectral resolution **4 polz (HH, VV, HV, VH)**

BW	2 GHz	2048 channels x 4 polz	976 kHz resol.
BW	1 GHz	2048 channels x 4 polz	488 kHz resol.
BW	500 MHz	2048 channels x 4 polz	244 kHz resol.
BW	250 MHz	2048 channels x 4 polz	122 kHz resol.
BW	125 MHz	2048 channels x 4 polz	61 kHz resol.
BW	64 MHz	2048 channels x 4 polz	30 kHz resol.
BW	32 MHz	2048 channels x 4 polz	15 kHz resol.
continuum mode		64 channels x 4 polz	31 MHz resol.



... up to **2048 channels**

Baseband 1



87.3 GHz

88.3 GHz

ALMA correlator

Polarization products (HH, VV, HV, VH)

the four are necessary for polarization studies

ALMA correlator

Polarization products (HH, VV, HV, VH)

the four are necessary for polarization studies

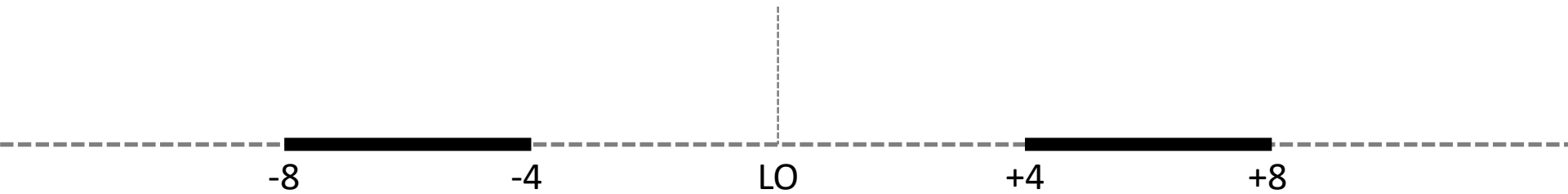
message to take home ...

	polarization	sensitivity	spectral resolution
1 polz product (HH or VV)	gray	red	green
2 polz products (HH and VV)	gray	green	orange
4 polz products (HH, VV, HV, VH)	green	green	red

ALMA correlator (examples)

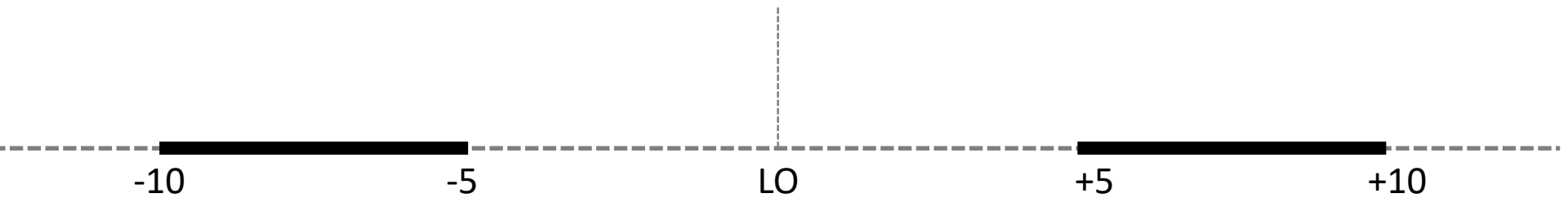
ALMA B3 / B4 / B5 / B7 / B8

2SB receivers 4-8 GHz



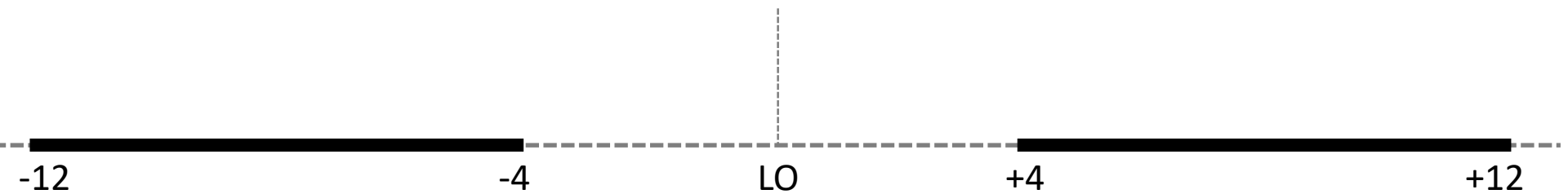
ALMA B6

2SB receivers 5-10 GHz



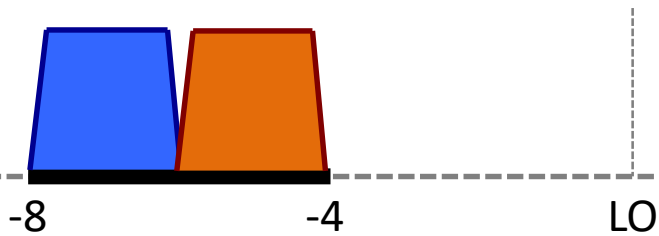
ALMA B9 / B10

DSB receivers 4-12 GHz

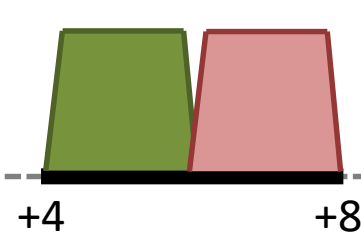


ALMA correlator (examples)

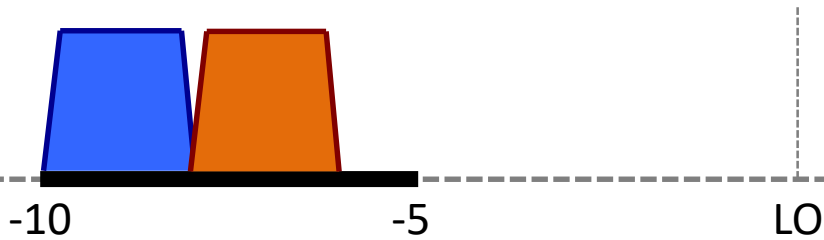
ALMA B3 / B4 / B5 / B7 / B8



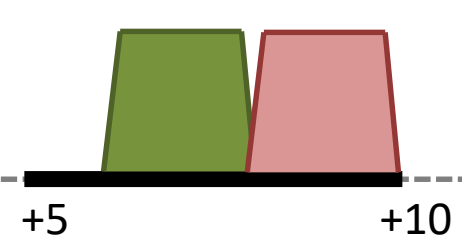
2SB receivers 4-8 GHz



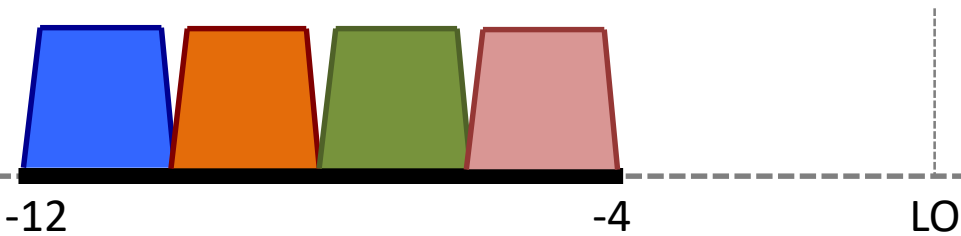
ALMA B6



2SB receivers 5-10 GHz



ALMA B9 / B10

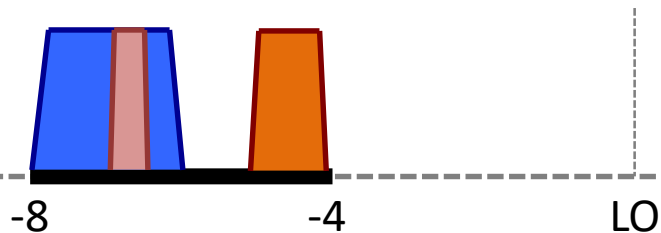


DSB receivers 4-12 GHz



ALMA correlator (examples)

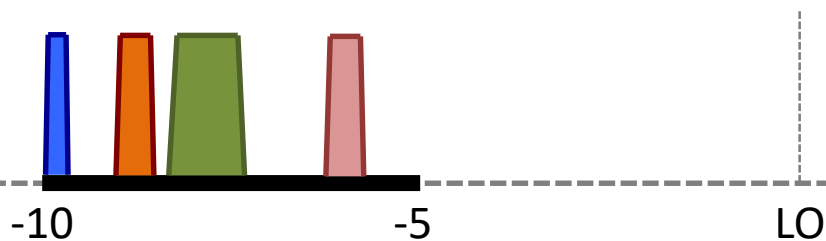
ALMA B3 / B4 / B5 / B7 / B8



2SB receivers 4-8 GHz



ALMA B6



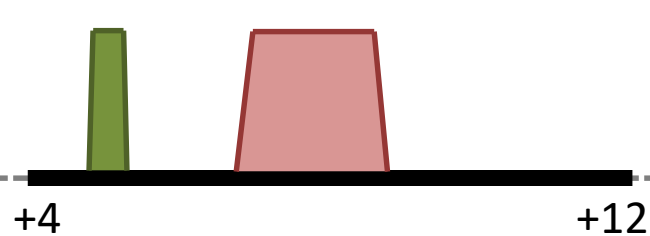
2SB receivers 5-10 GHz



ALMA B9 / B10



DSB receivers 4-12 GHz



Spectral setup in the almaOT

ALMA Observing Tool (Cycle5)

ALMA Observing Tool (Cycle5) - Project

File Edit View Tool Search Help

Perspective

Project Structure

Proposal Program

Project

Proposal

Planned Observing

ScienceGoal (Science Goal)

General

Field Setup

Spectral Setup

Calibration Setup

Control and Performance

Technical Justification

Editors

Spectral Spatial Spectral Setup

In the table below, it is possible to define up to 16 spectral windows, 4 per baseband as long as the total Fraction per baseband is no more than 1. Each baseband is 2GHz wide and can be separately configured i.e. each spectral window can have a different bandwidth and resolution. Note that for bands 3, 4, 6, 7 and 8, it is not possible to put 3 basebands in one sideband and the fourth one in the other.

Spectral Type

Continuum or line ?

Spectral Type

Spectral Line

Single Continuum

Spectral Scan

Polarization products ?

Produce image sidebands (Bands 9 and 10 only)

Polarization products desired

XX DUAL FULL

Spectral Setup Errors

No spectral window in the list. No suitable receiver band for the range :[0.0 GHz, 0.0 GHz]

Spectral Line

Baseband	Fraction	Centre Freq (rest, lsrk)	Centre Freq (sky, bar)	Transition	Bandwidth, Resolution (smoothed)	Spec Avg	Repre Wi
Baseband-1							
Baseband-2							

Add spectral window centred on a spectral line

Add spectral window manually

Delete

Show image spectral window

Rest frequency ?

Bandwidth, spectral resolution ?