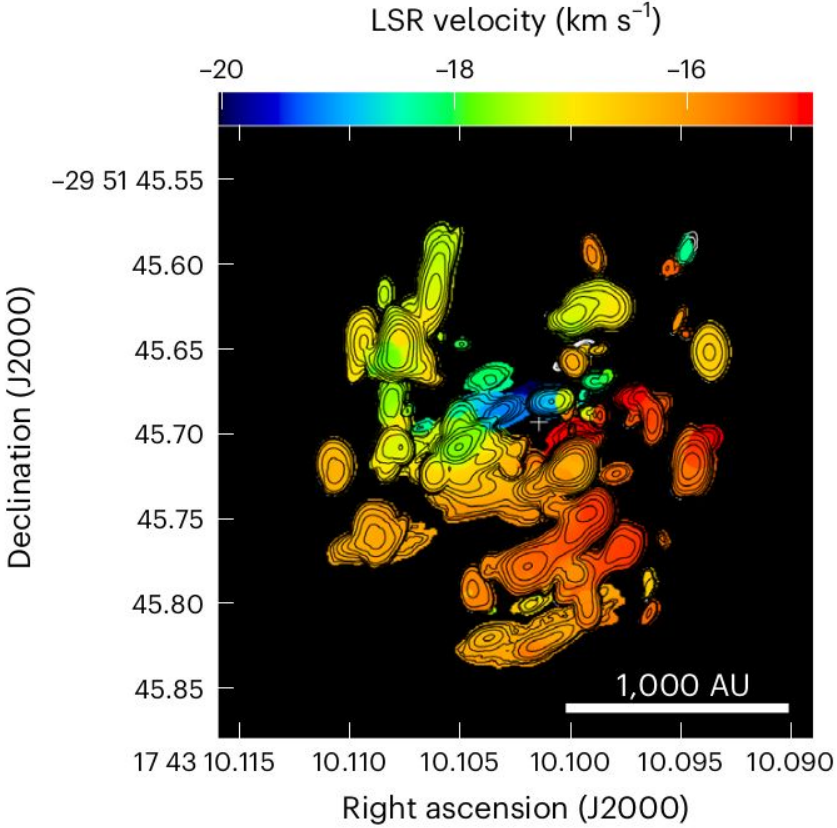


Lecture 9: Spectral line processing

Olga Bayandina

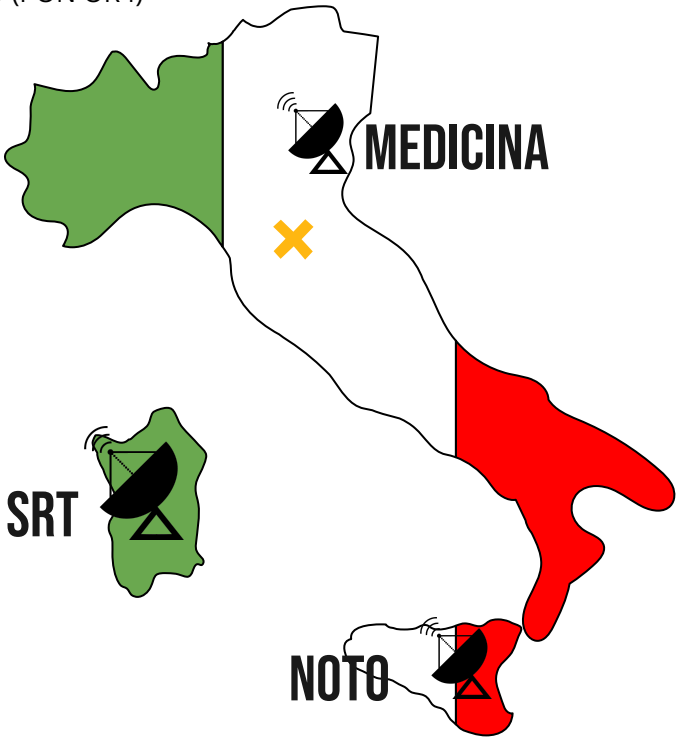
INAF
ISTITUTO NAZIONALE DI ASTROFISICA

JIVE

CASA
Common Astronomy Software Applications

CASA VLBI WORKSHOP 2023 (5-9 JUNE, JIVE, NL)

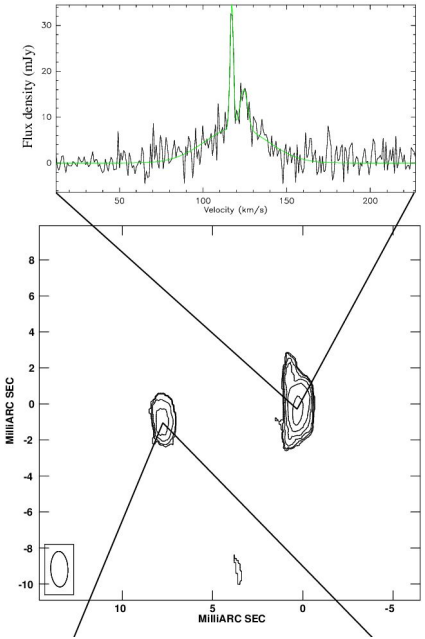
Installation of tri-band receivers to the INAF VLBI array (PON OR4)



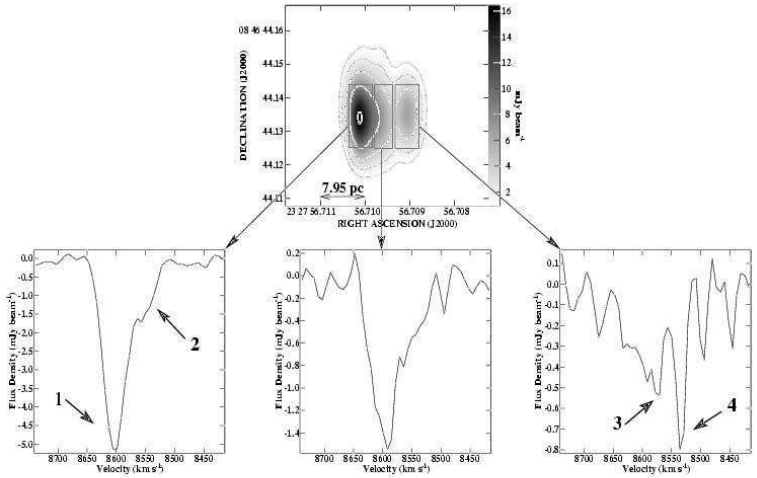
INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

OSSERVATORIO ASTROFISICO DI ARCETRI

Spectral line



Brunthaler+2009



Momjian+2003

Maser

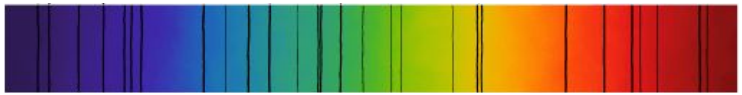
HI absorption

~1M ⊙

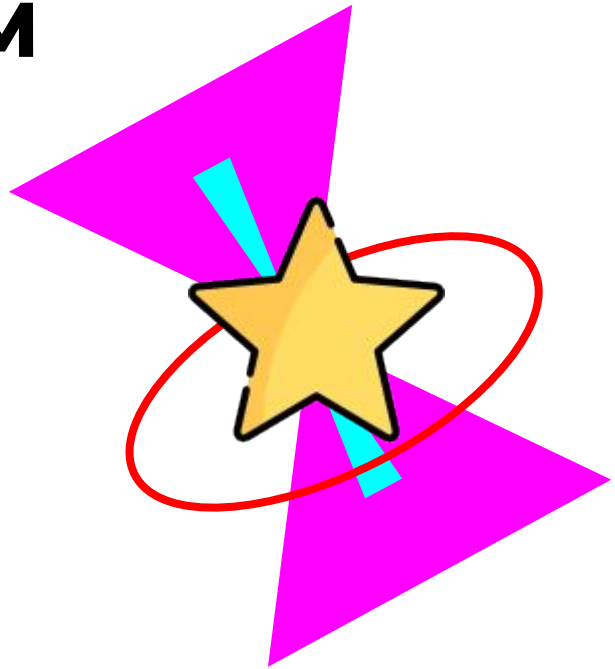
Ingredients: hydrogen, helium, oxygen, carbon, neon, iron

>8M ⊙

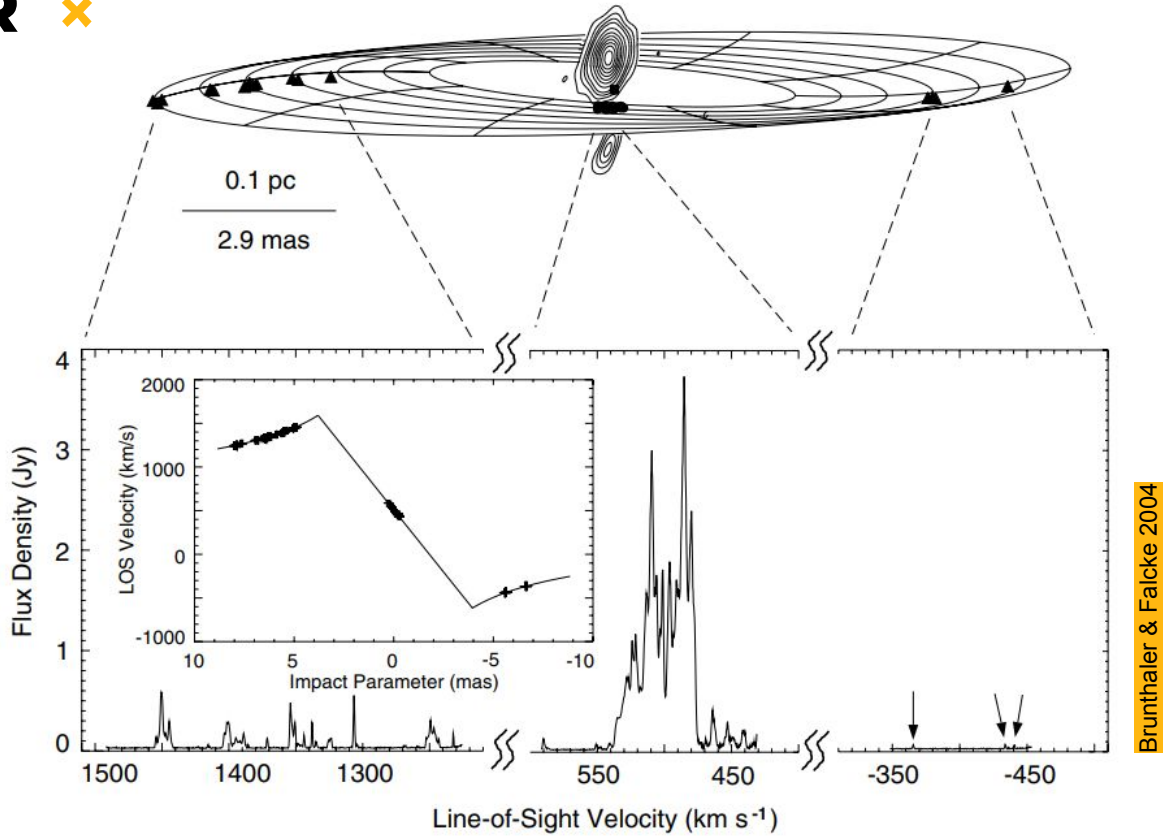
~1M$_\odot$



>8M$_\odot$

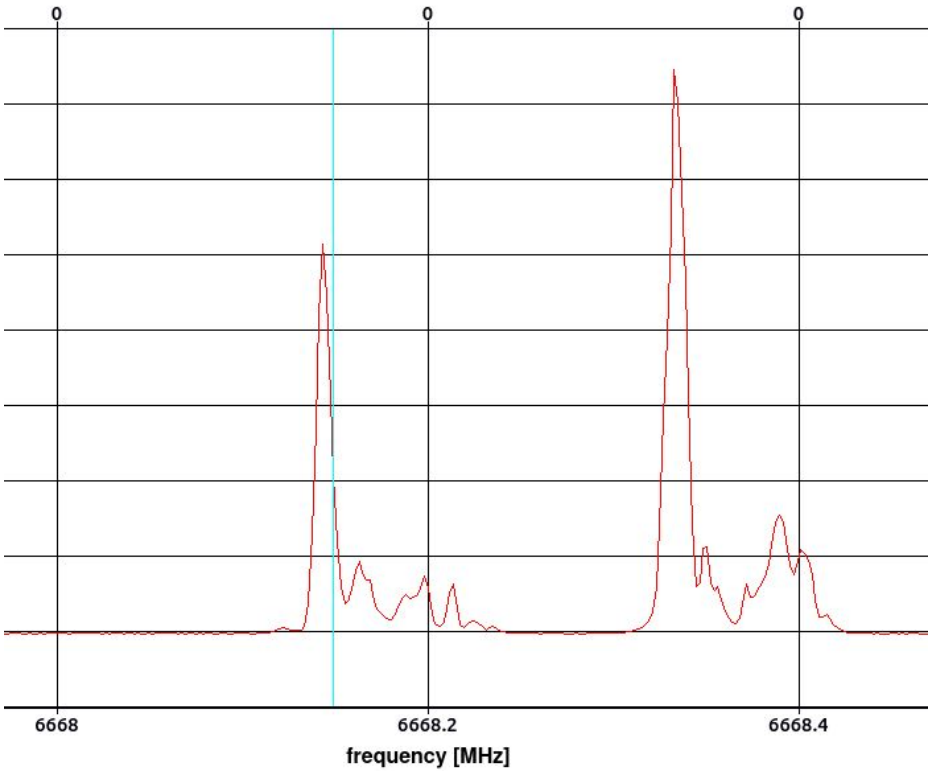


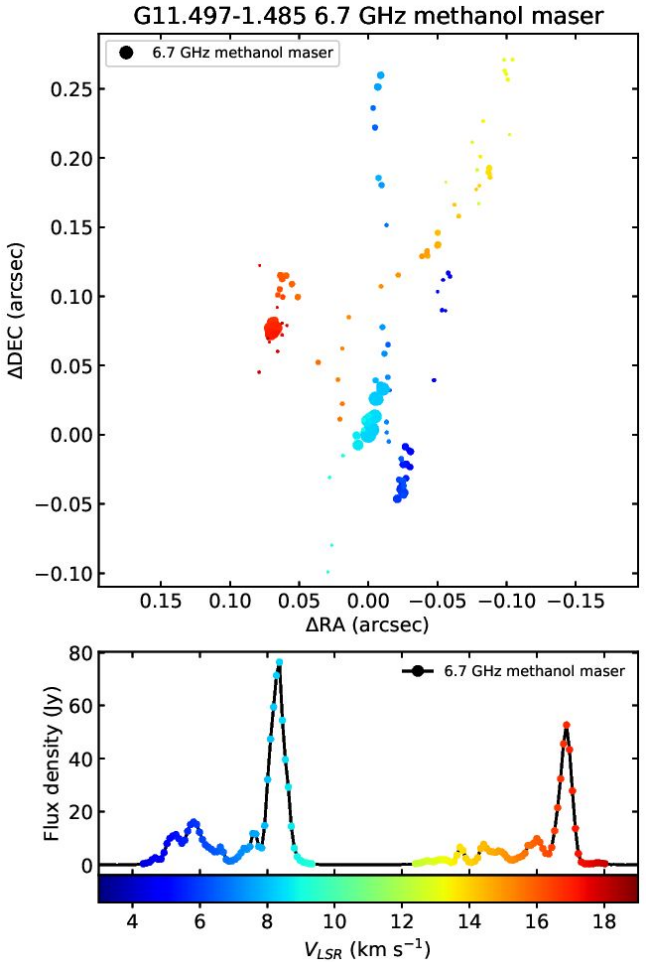
MASER ×



Brunthaler & Falcke 2004

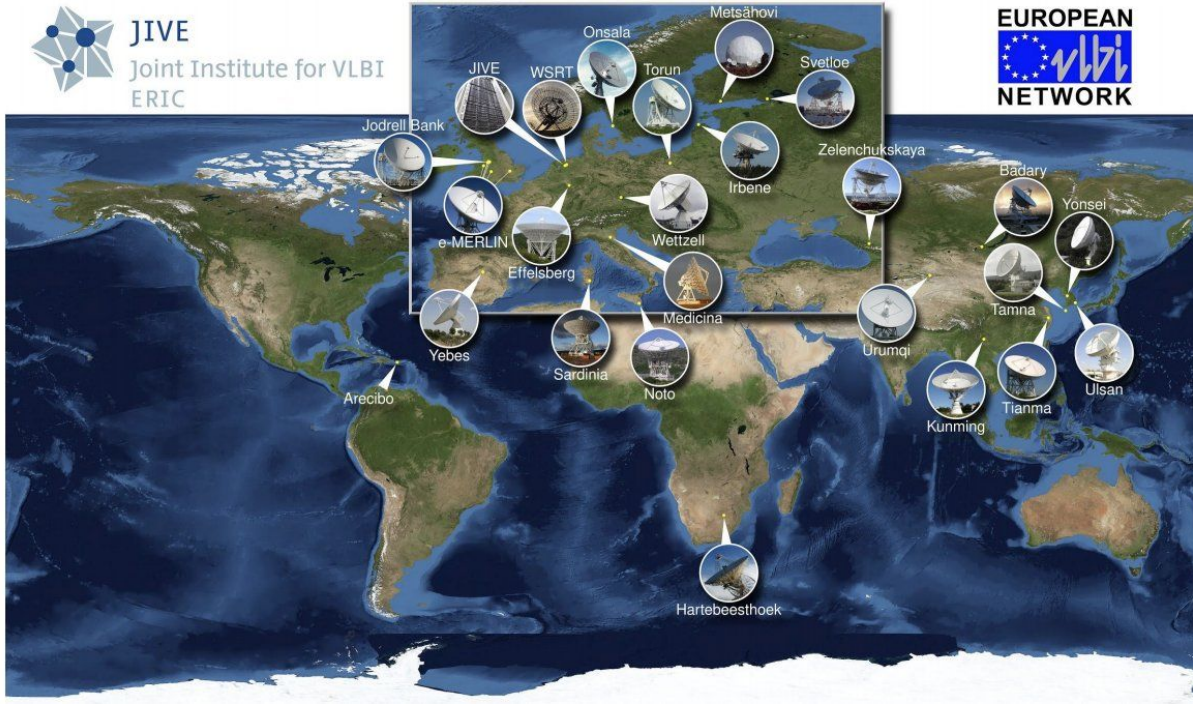
MASER





Bayandina+202? in prep.

00×

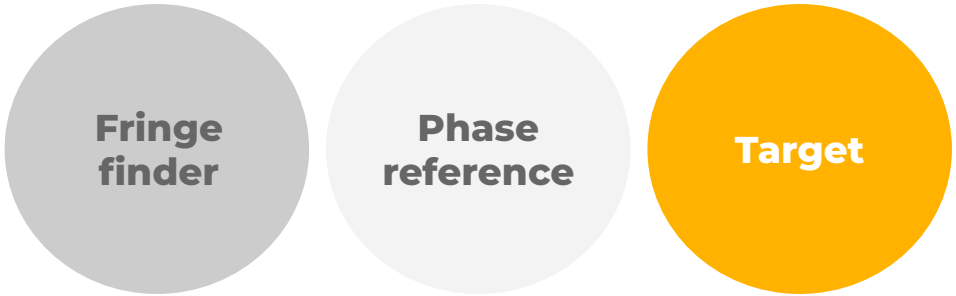


Observation

Scheduling

SCHEDULING

SOURCES

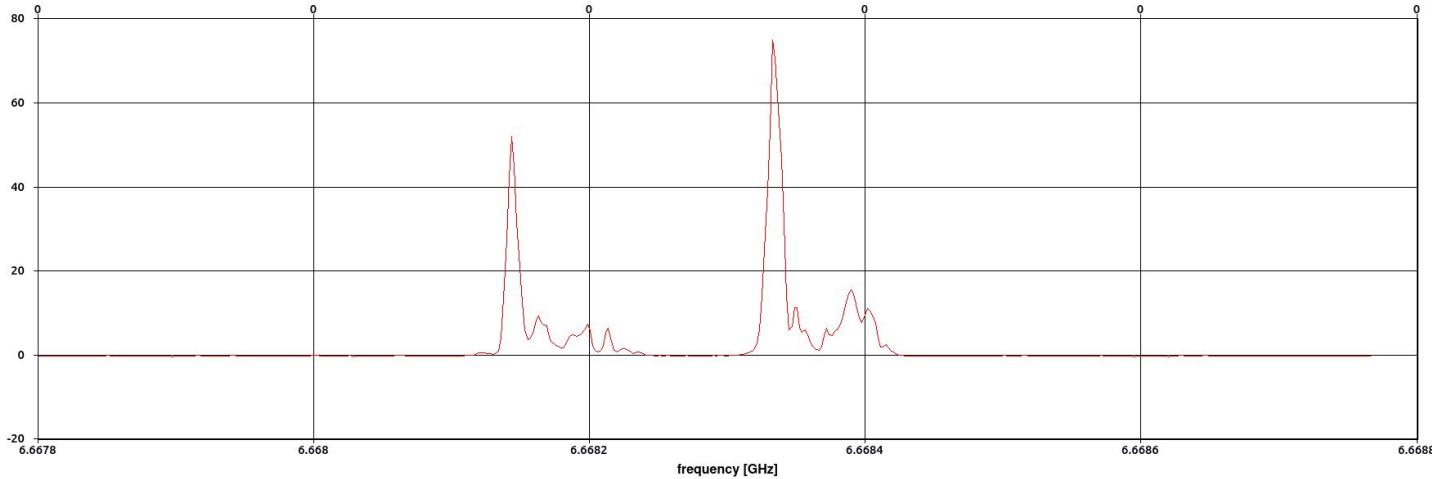


Continuum source

Continuum source

Maser source

SCHEDULING



Spectral resolution

Maser lines are narrow (at least 3 channels)

Central Frequency

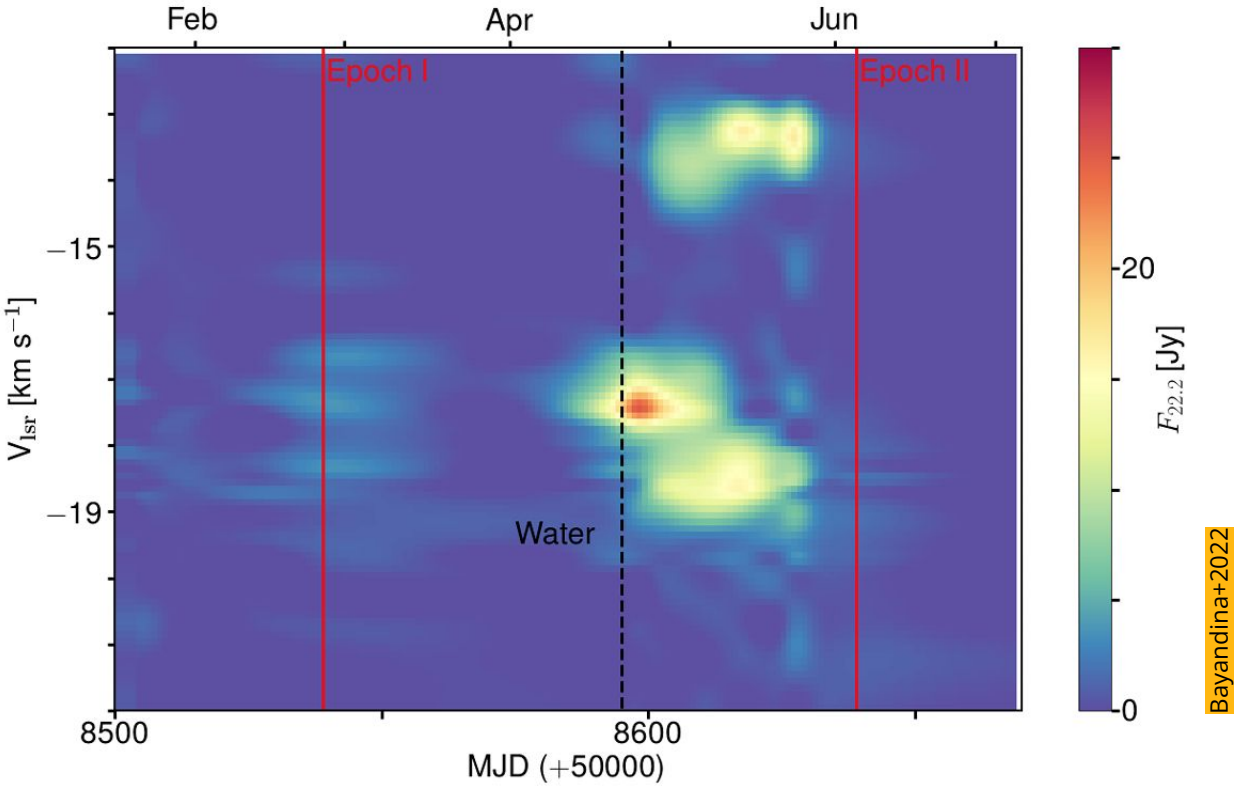
Rest frequency of a particular maser

Müller+2004

Bandwidth

To include all the spectral features

SCHEDULING

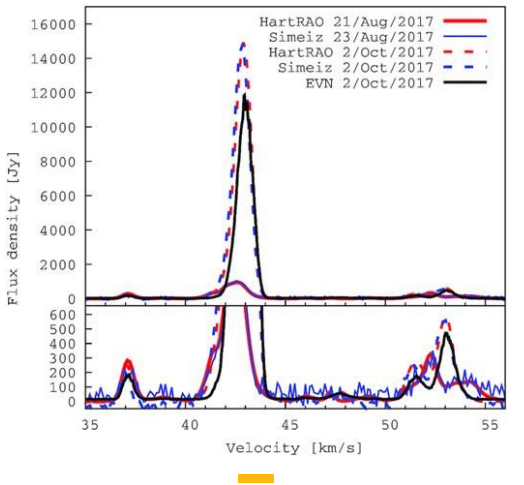


Bayandina+2022

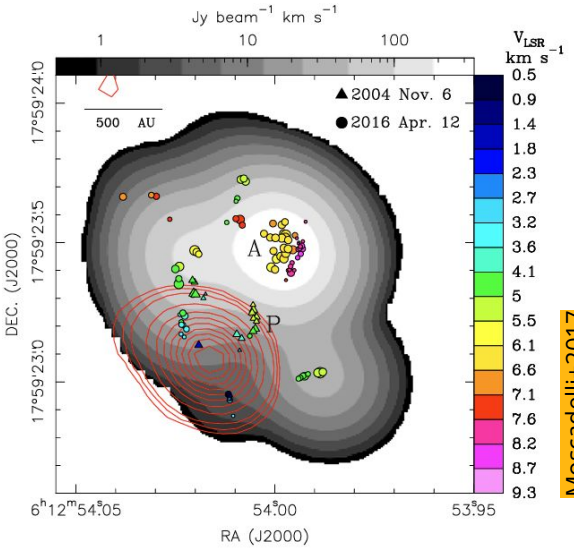
Flux density variability

Especially profound for water masers

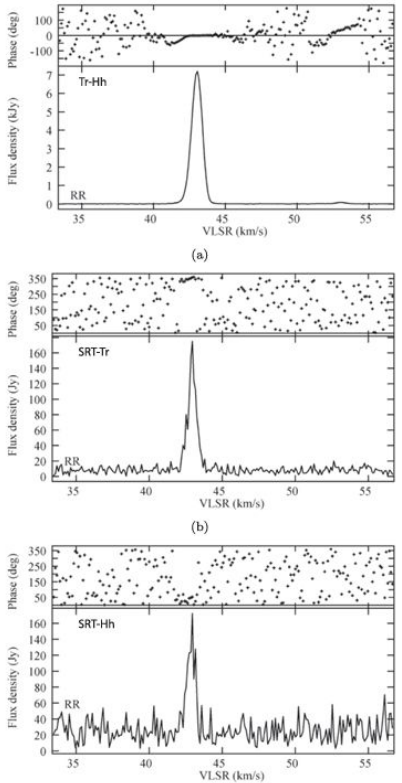
SCHEDULING



Burns+2019



Moscadelli+2017



Bayandina+2020

Extended vs Compact emission

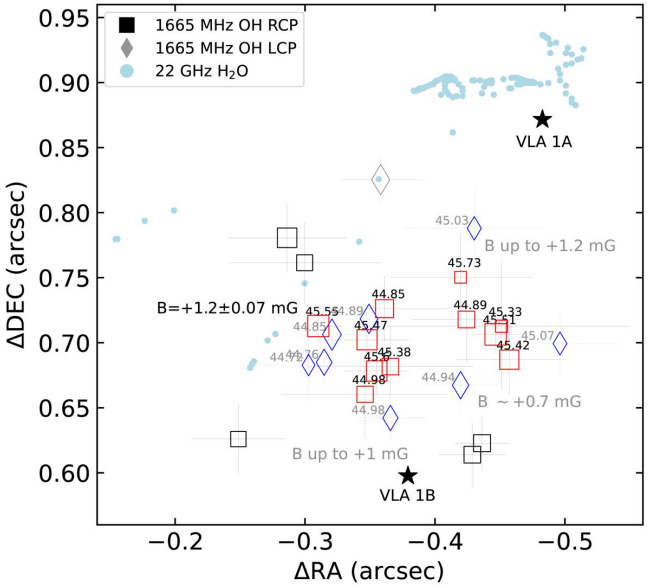
Masers consist of core+halo

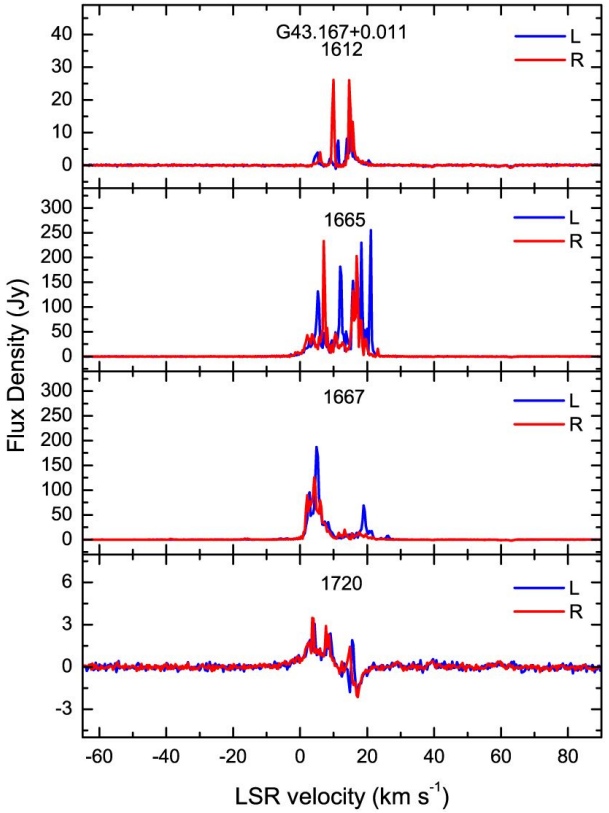
SCHEDULING

Polarization

Different flux density in RCP vs LCP

Bayandina+2023





Bayandina+2021

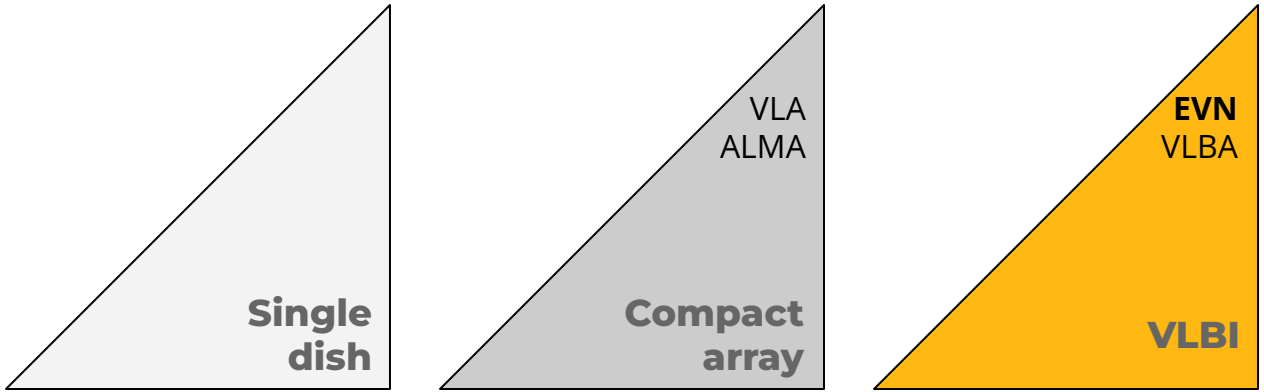
01 ×

DATA REDUCTION

Loading data...

DATA REDUCTION

All can observe spectral lines



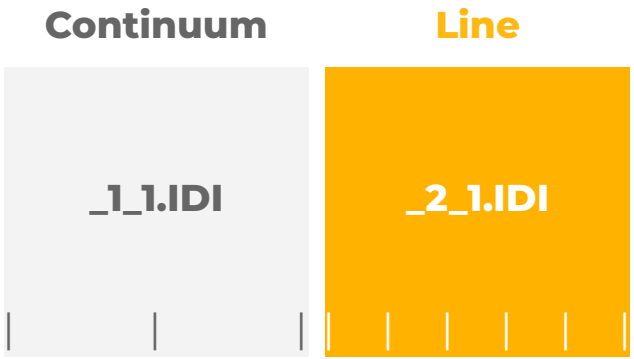
Only spectra | Science ready images | Manual calibration

But data reduction is different

DATA REDUCTION

EVN archive

- **Low spectral resolution** (e.g. 64 channels)
- Finge-finder + phase reference



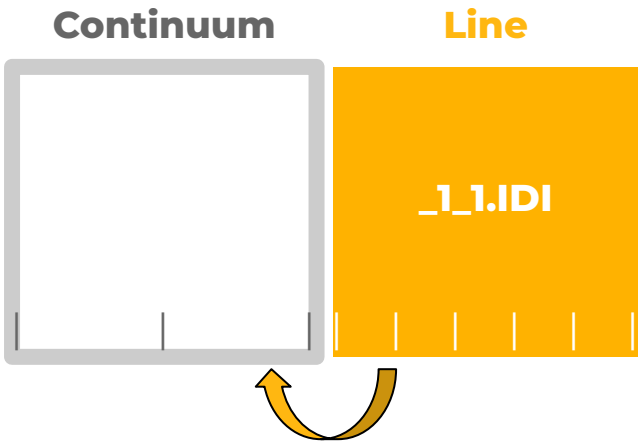
- **High spectral resolution** (e.g. 2048 channels)
- Target

Both contain
- all sources -
but with **different** spectral resolution

DATA REDUCTION

EVN archive

- **Low spectral resolution** (e.g. 64 channels)
- Finge-finder + phase reference



- **High spectral resolution** (e.g. 2048 channels)
- Target

SPLIT

width - N chan to average

02 ×

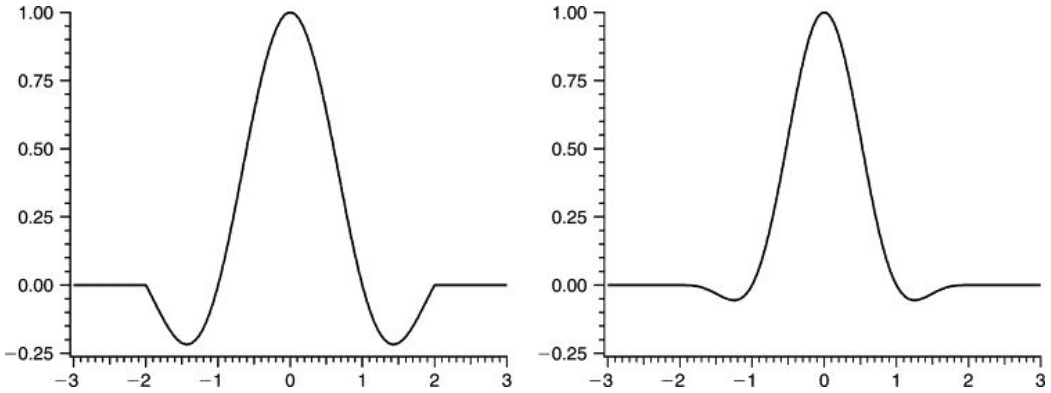
DATA REDUCTION

Data Inspection

DATA REDUCTION

- **Smoothing**

RFIs and strong spectral lines cause ringing across the frequency channels (the Gibbs phenomenon)



Thévenaz+2009

x2 lower spectral resolution

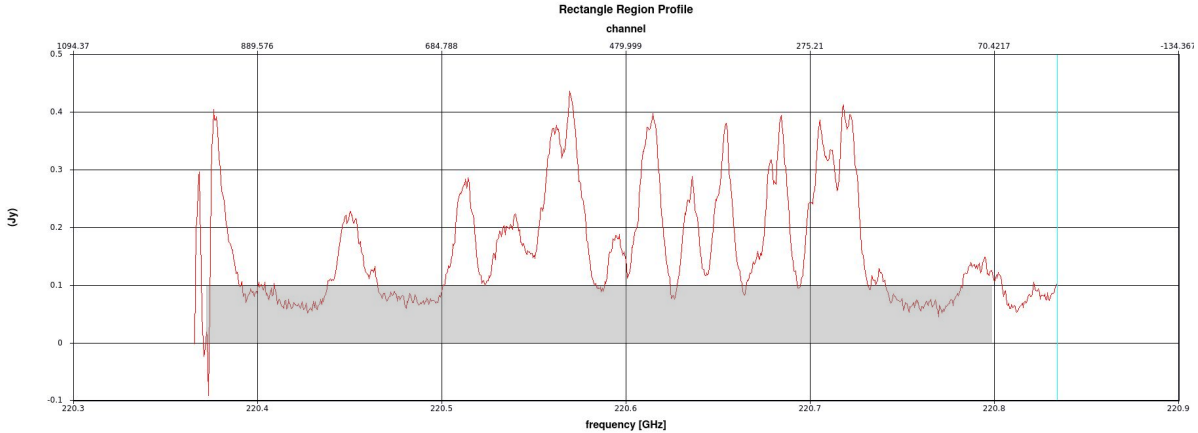
DATA REDUCTION

- **Continuum subtraction**

`imcontsub`

or

`uvcontsub`

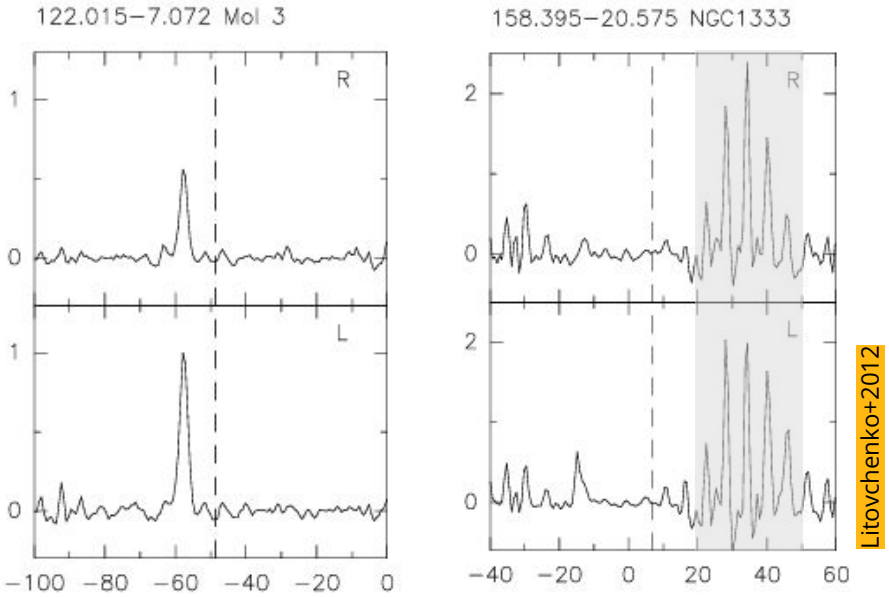


2 datasets =
1 continuum
+
1 spectral line

DATA REDUCTION

- **Flagging**

Strong and narrow spectral lines are confused with RFI by automatic flagging algorithms



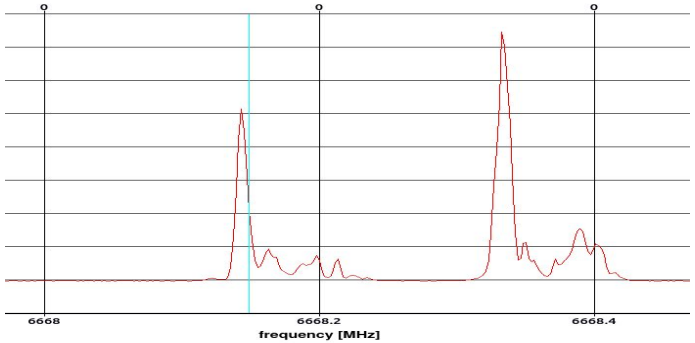
Litovchenko+2012

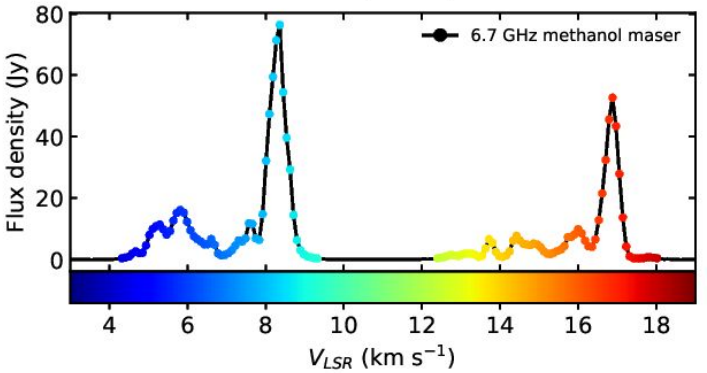
comb-type RFI

DATA REDUCTION

- **Frequency -> Velocity**

```
CVEL
field = 'target'
mode = 'velocity'
outframe= 'LSRK'
veltype= 'radio'
restfreq = XXX GHz
```





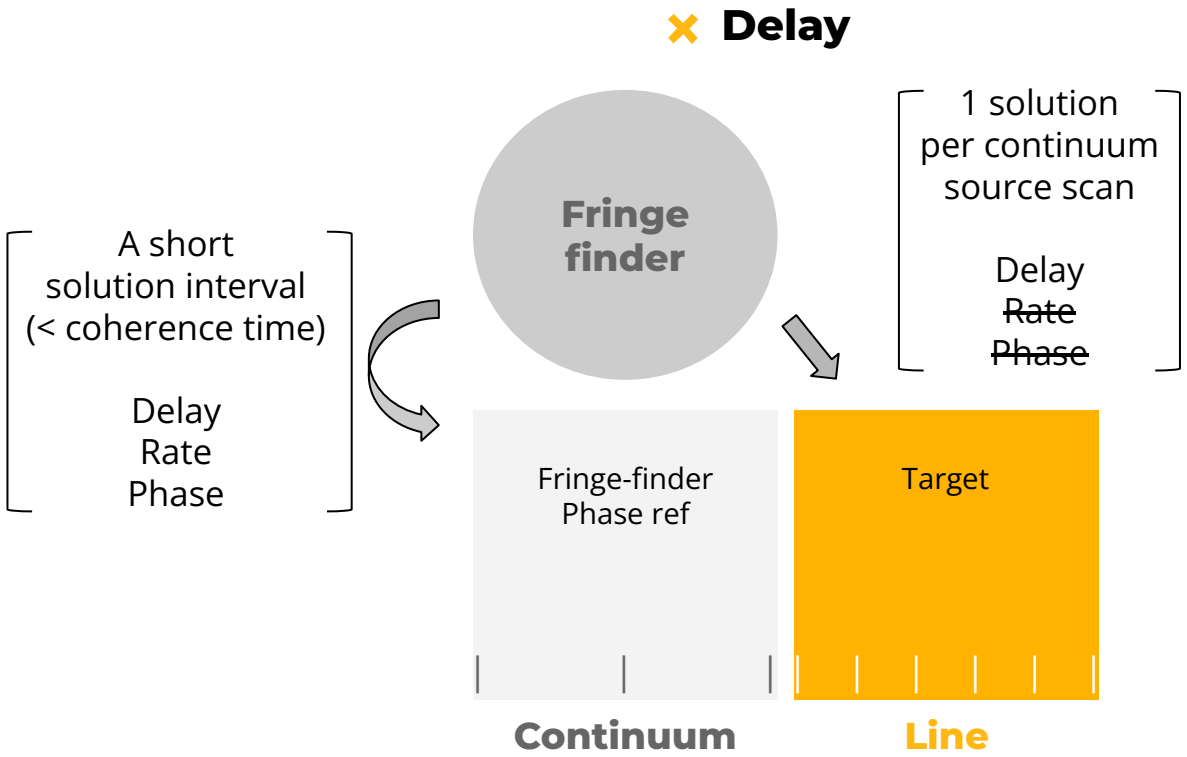
Bayandina+202? in prep.

03

DATA REDUCTION

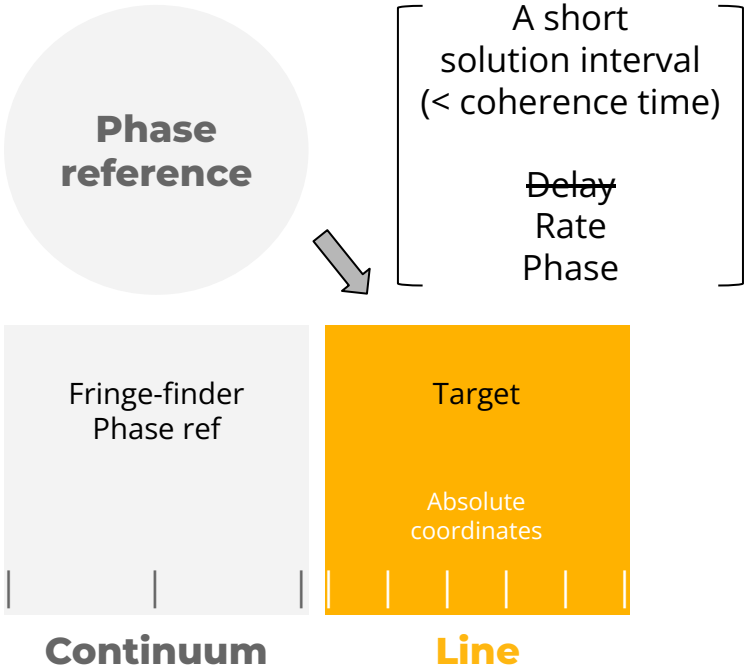
Calibration

DATA REDUCTION



DATA REDUCTION

× **Rate + Phase**

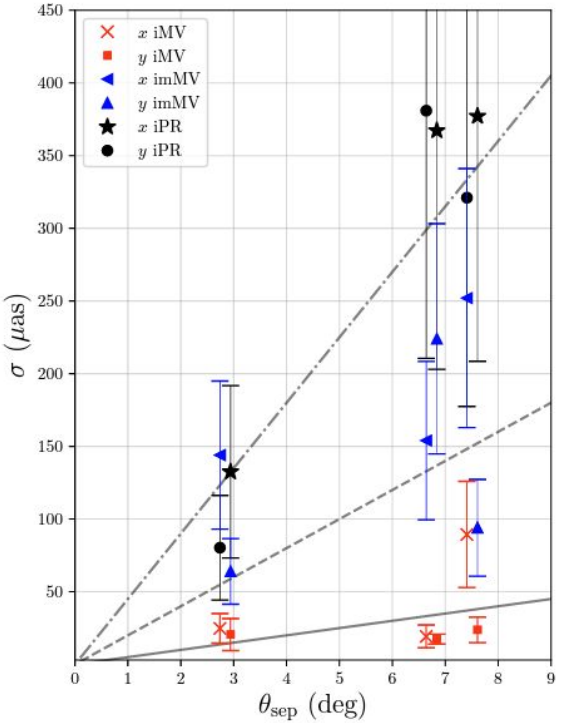


DATA REDUCTION

- **Phase**

Inverse phase referencing

- Target is strong but the phase reference calibrator is too weak
- The phase of the target is transferred to the calibrator (not other way around)
- The measured offset of the phase ref calibrator is used to determine the position of the target



Hyland+2023

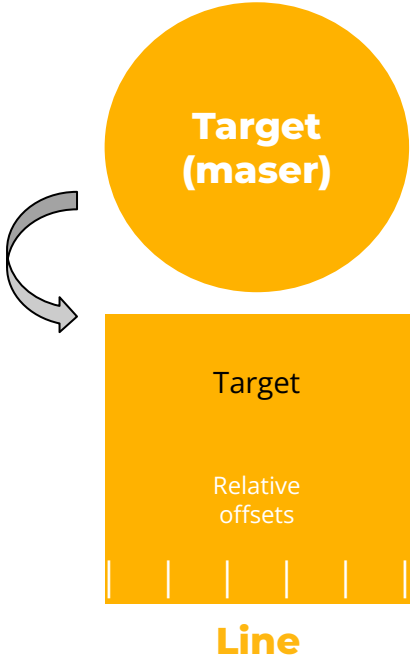
DATA REDUCTION

× Self-calibration

A short
solution interval
(< coherence time)

The strongest channel
(compact maser feature)

~~Delay~~
Rate
Phase



A few times
increase in flux
density

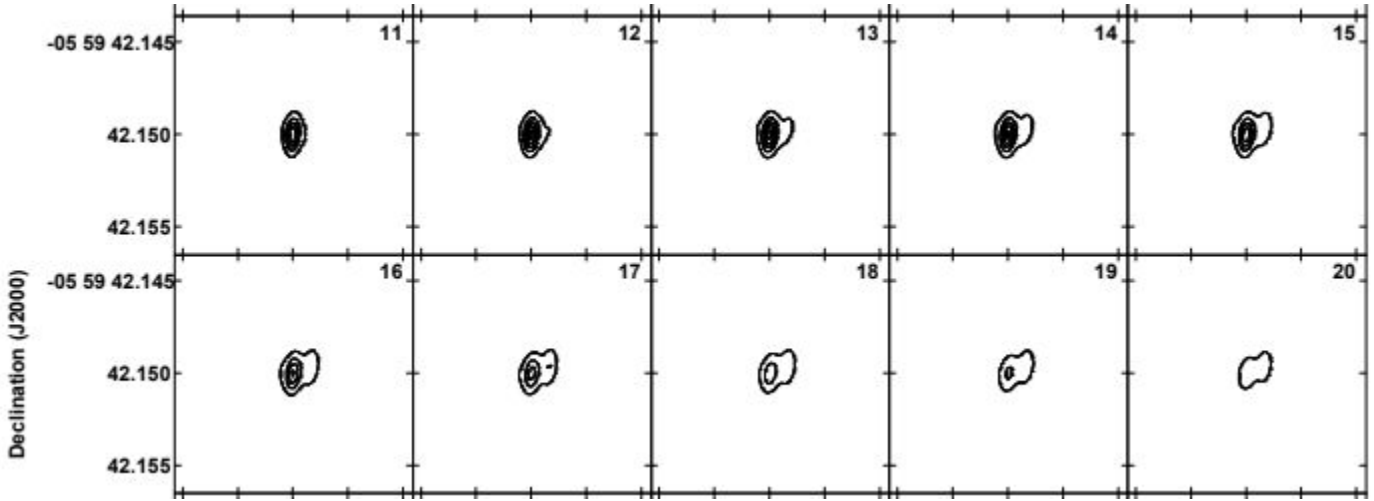
Keep an eye on
the beam size!

DATA REDUCTION

Self-calibration

The **self-calibration channel** must contain **a single point-like feature**

If the strongest channel shows double-structure, choose another channel
(but still a strong one!)



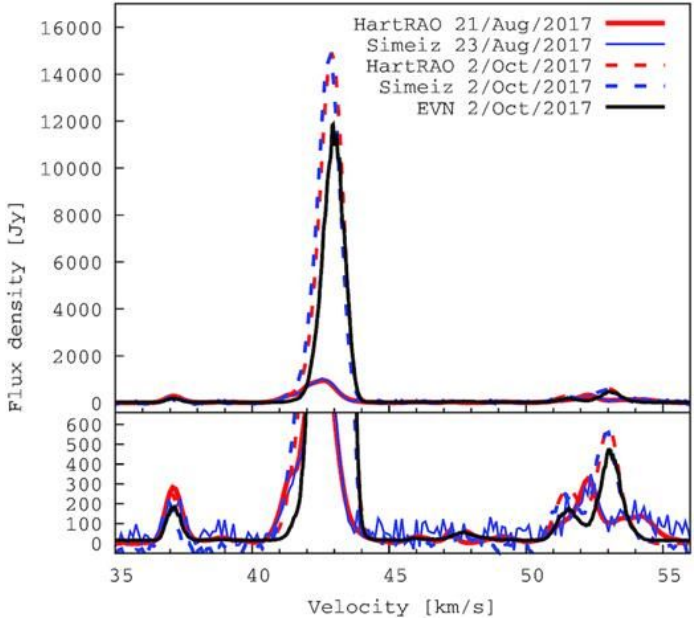
DATA REDUCTION

Bandpass

- Important for auto-correlation spectra

- Amplitude only (~~phase~~)
- Calibrated on
  fringe-finder (bright continuum source)
  or
  line-free channels of target source

Burns+2019



04×

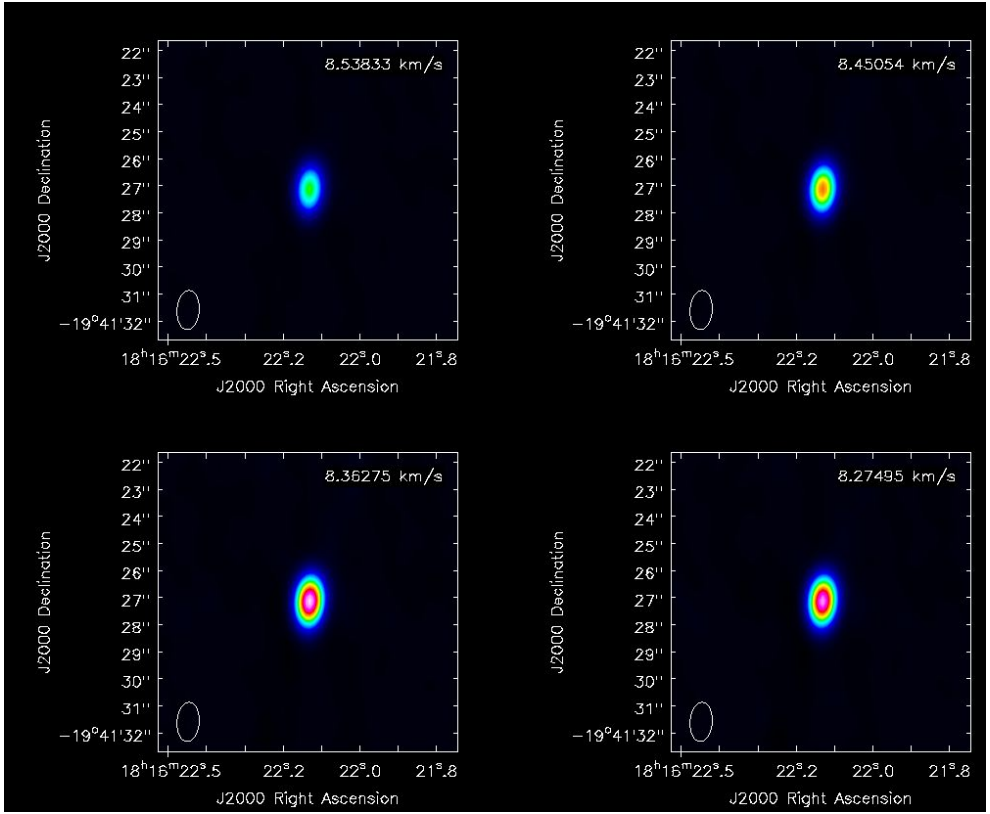
DATA REDUCTION

Imaging

DATA REDUCTION

Data cube

```
tclean
(vis='.ms',
 field='X',
 spw='X',
 specmode='cube',
 deconvolver='hogbom',
 start='0',
 nchan=XXX,
 outframe='LSRK',
 veltype='radio',
 restfreq='XXX MHz',
 imsize=[XXX],
 cell=['XXX'],
 weighting='briggs/natural',
 gridder='mosaic')
```



DATA REDUCTION

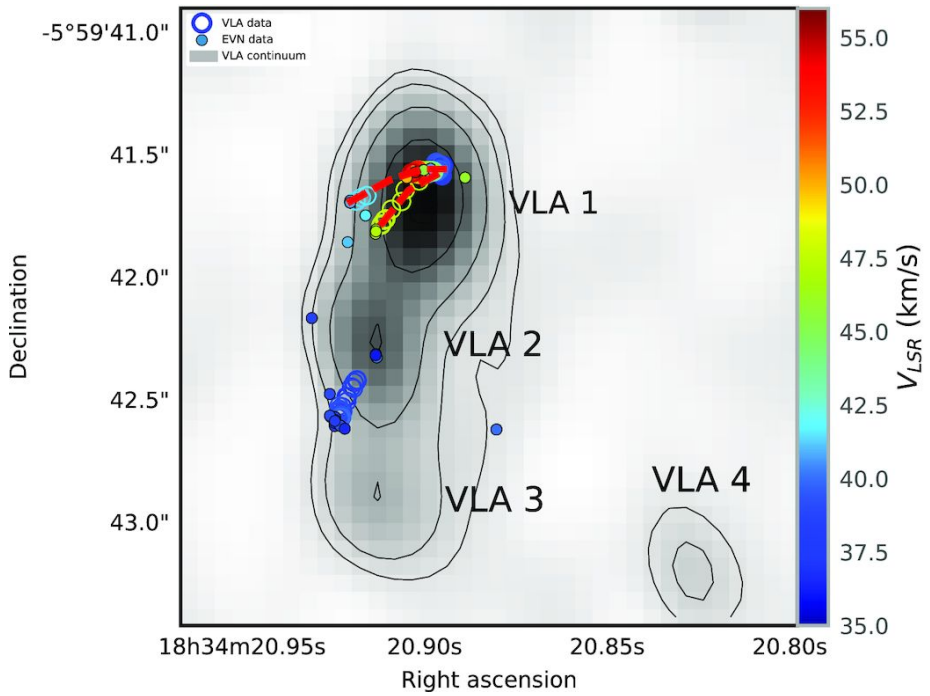
Spot map

```
image = raw_input("Enter image name:")
sch = int(raw_input("Enter 1st channel:"))
fch = int(raw_input("Enter last channel:"))
nfch = fch + 1

for iii in range(sch,nfch):

imfit(
     imagename = image,
     box = '',
     chans = str(iii),
     stokes = 'I',
     logfile = str(iii) + '.txt',
     append = False)
```

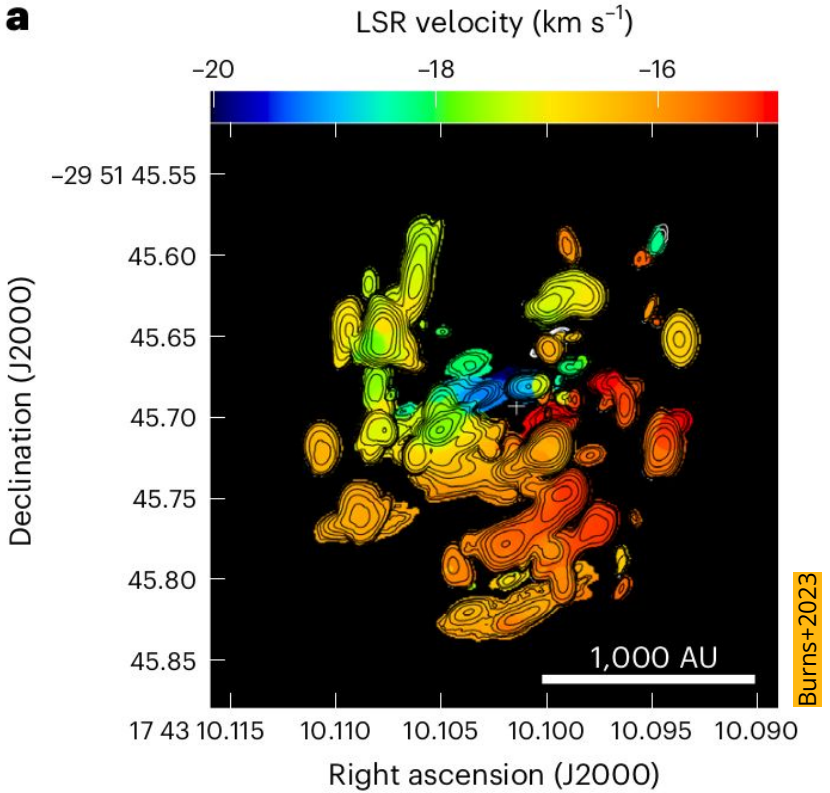
Burns+2019



DATA REDUCTION

- **Moments**

```
immoments
(imagename='',
moments=[0],
axis='spectral',
region='',
chans='XX~XX',
includepix=[XX,XX],
outfile='',
stretch=False)
```

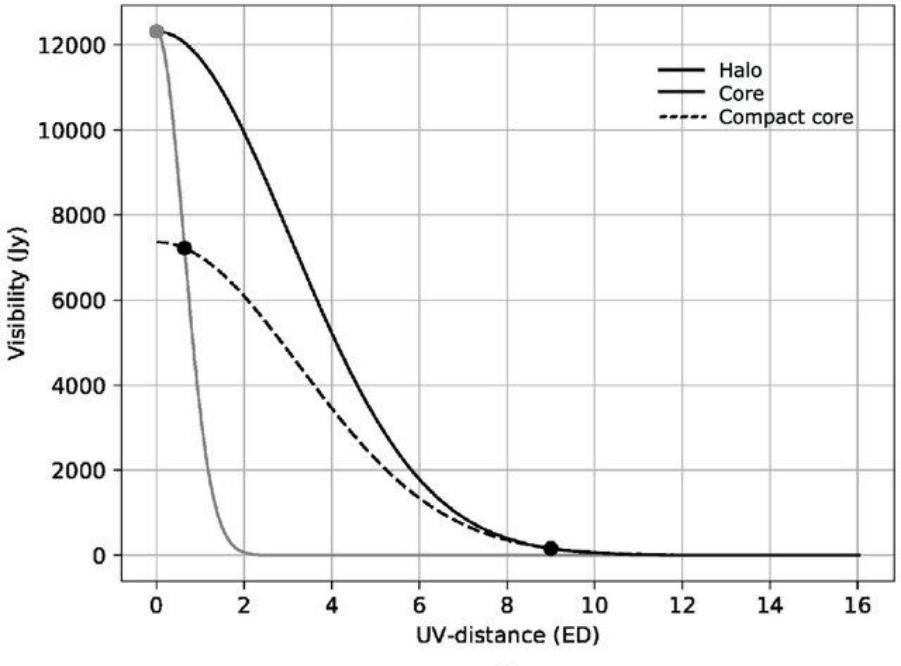


DATA REDUCTION

- **Poor uv coverage**

The size of the compact maser emission feature can be studied based on the angular resolution and recovered flux density

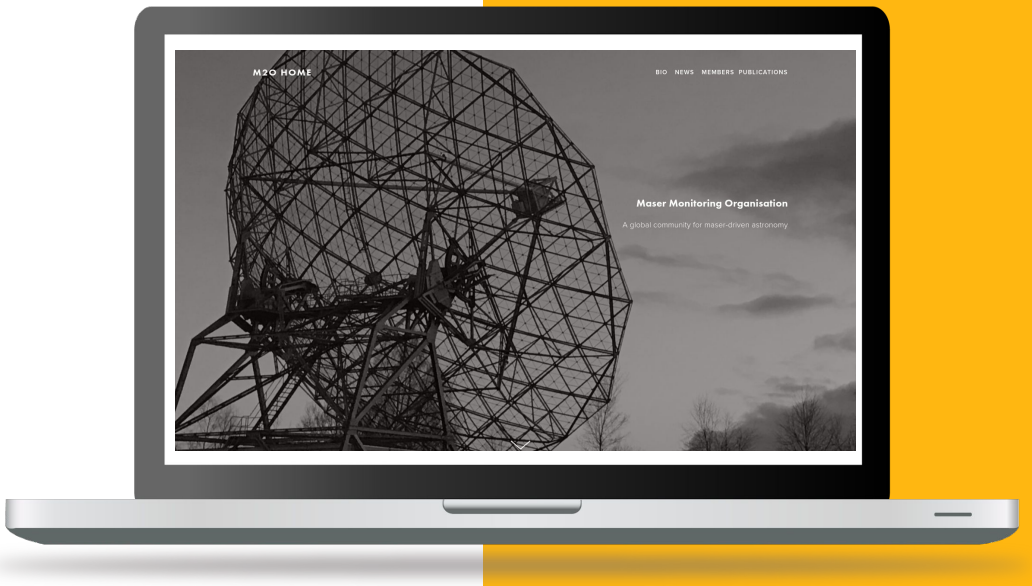
Bayandina+2020



05

RESOURCES

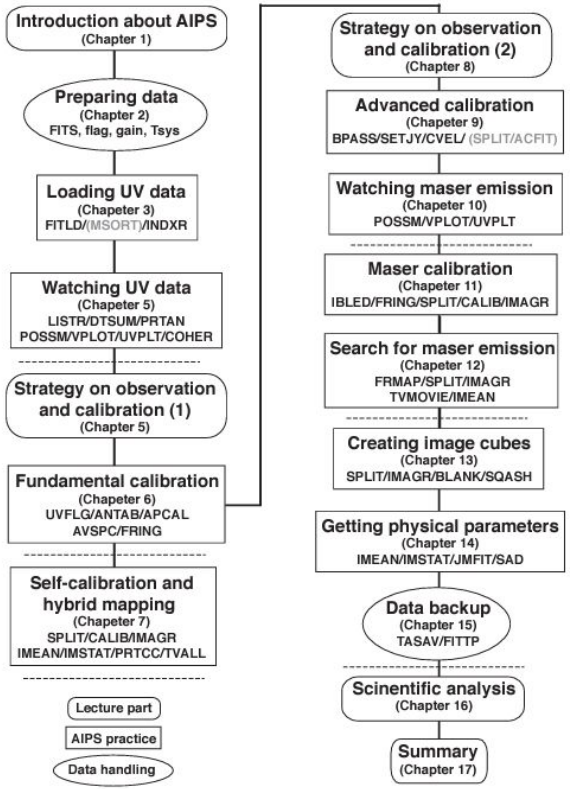
Some links to click



Tutorial AIPS(!)

AIPS Data Analysis Training

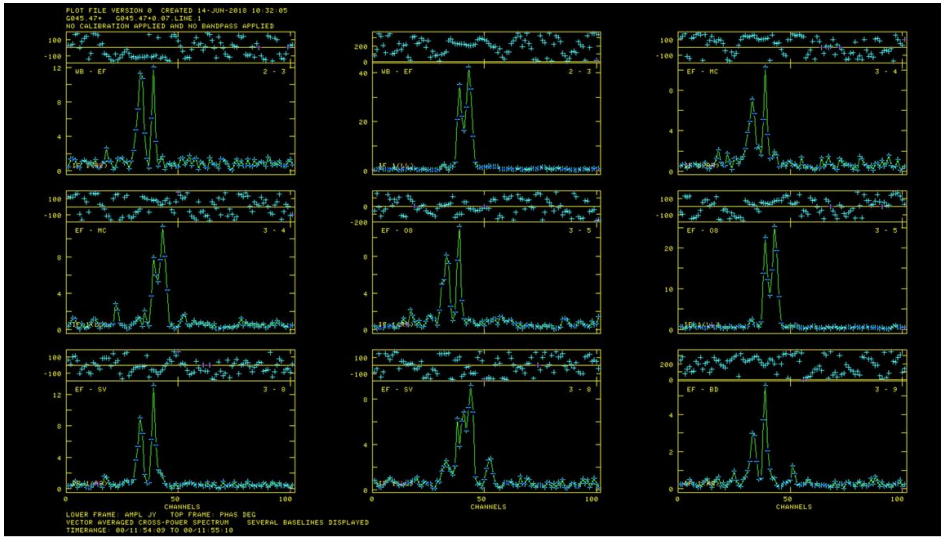
- Core philosophy of spectral line data reduction
- Can be translated to CASA with AIPS-CASA Dictionary



Tutorial AIPS(!)

Reducing EVN spectral line data

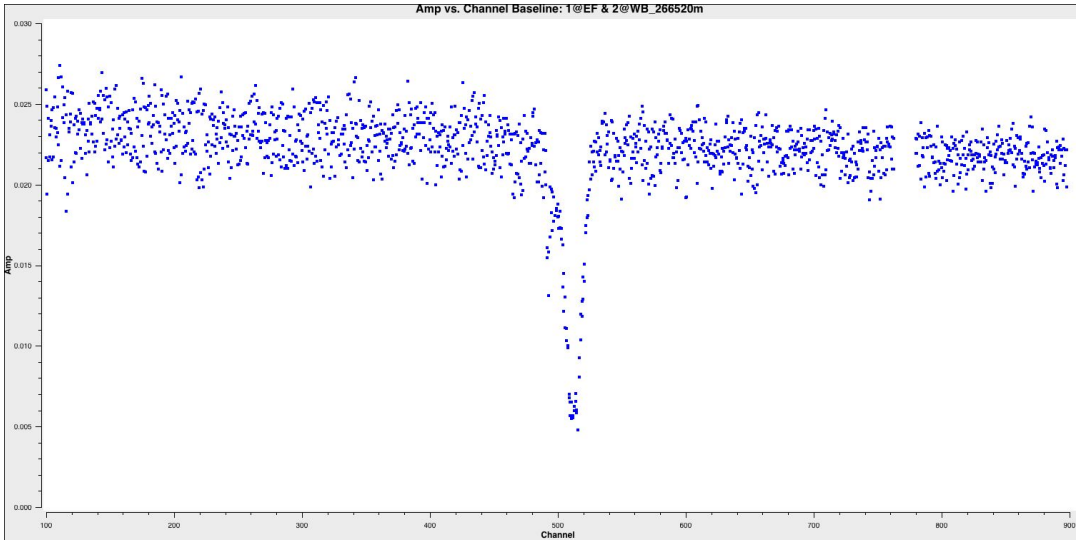
- Simple tutorial
- EVN OH maser data - EB063C



Tutorial CASA

EVN HI Spectral Line

- HI absorption data
- EVN data - NGC660.FITS



Tutorial CASA

ALMA guides

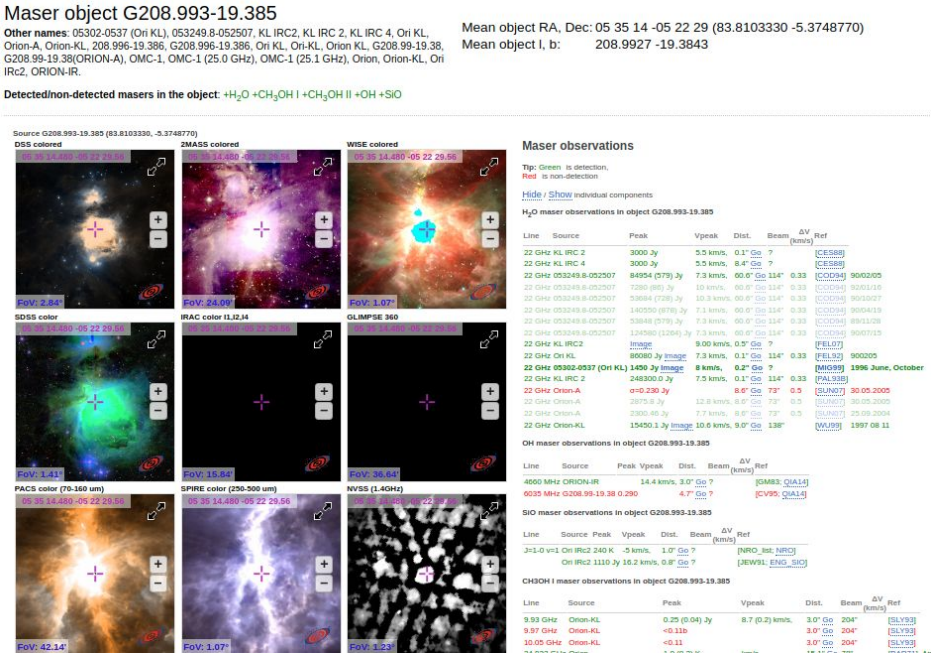
- Compact array!

+ Imaging of a spectral line
+ Moment creation and basic image analysis

Maser database

A database and multi-purpose tool for analyzing maser data

- Find your source!

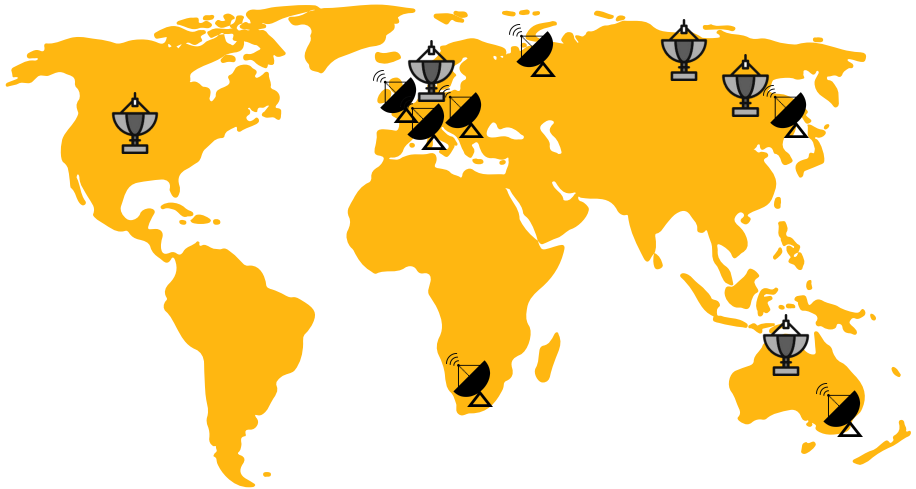


maserdb.net

M2O: Maser Monitoring Organisation

A global community for maser-driven astronomy

- monitoring stations report new maser flares ->
- confirmation by other radio observatories ->
- follow up VLBI and IR observations



Want to join?

masermonitoring.org

THANKS

Do you have any questions?

olga.bayandina@inaf.it
masermonitoring.com

This event has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004719.

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