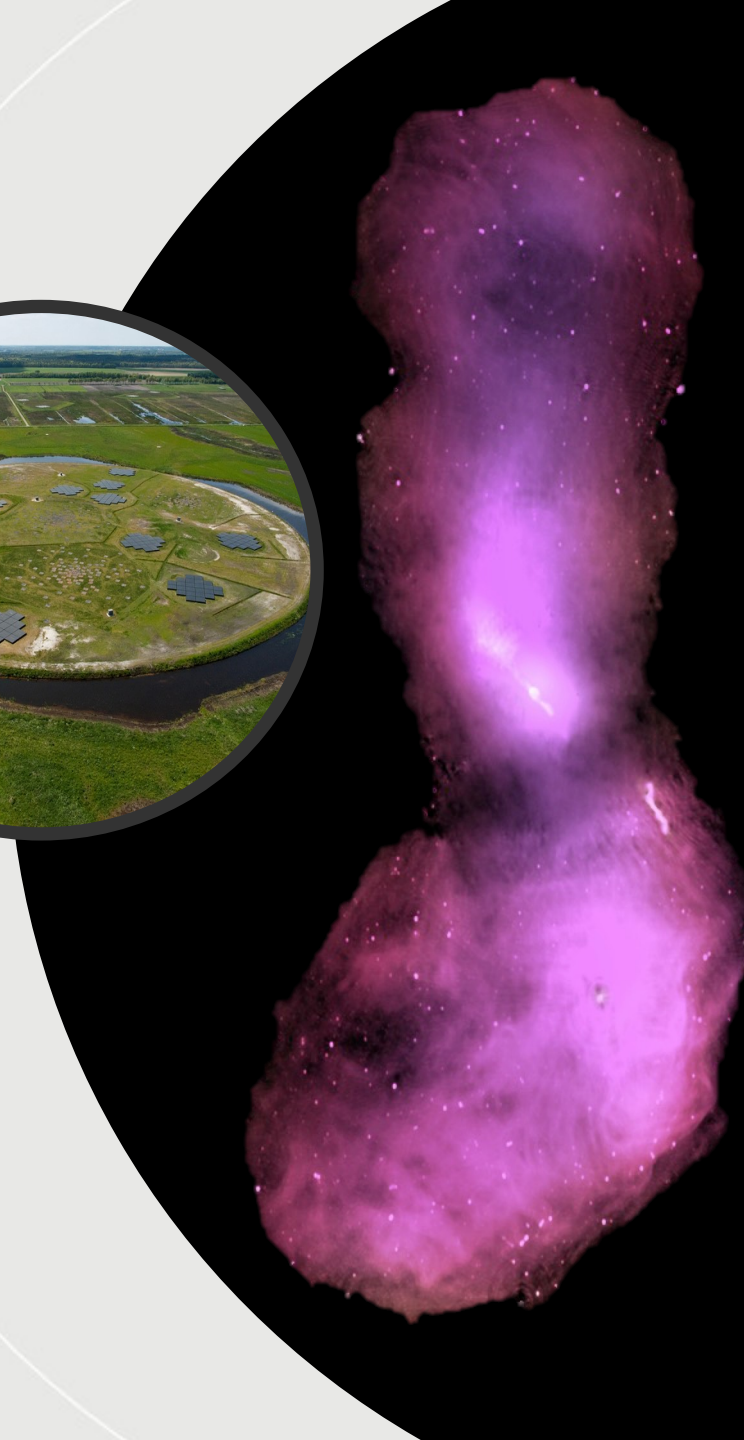
ASTRON

Flagging why it is important to get the most boring step right



Joe Callingham (ASTRON)

Botswana Radio Astronomy School,
Palapye, Botswana
5th of July 2019

Thanks to Andre Offringa

DARA
DEVELOPMENT IN AFRICA WITH RADIO ASTRONOMY

Data Inspection and Flagging

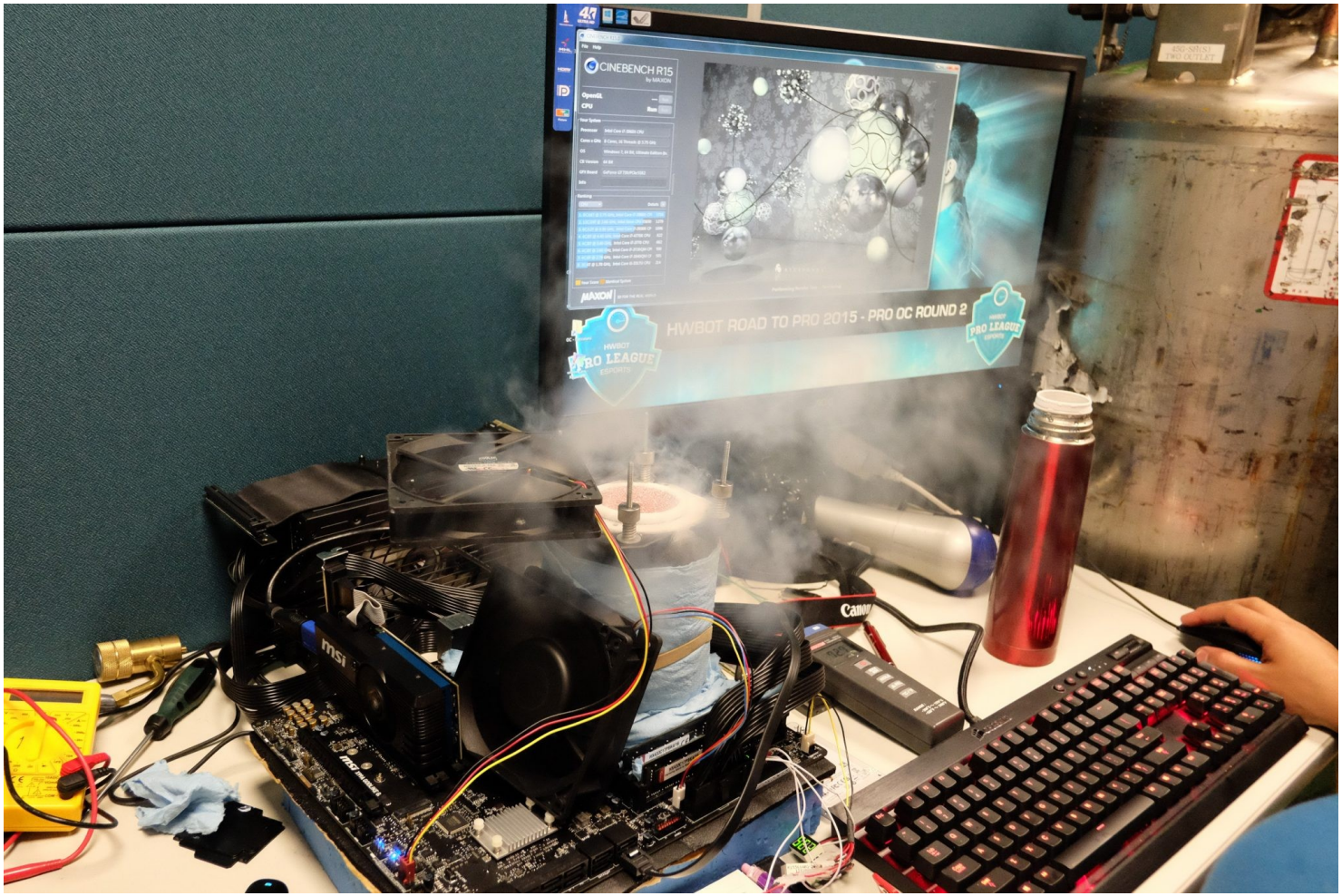
› Broken Elements

Why data editing?

› Broken Elements
› Antenna Shadowing

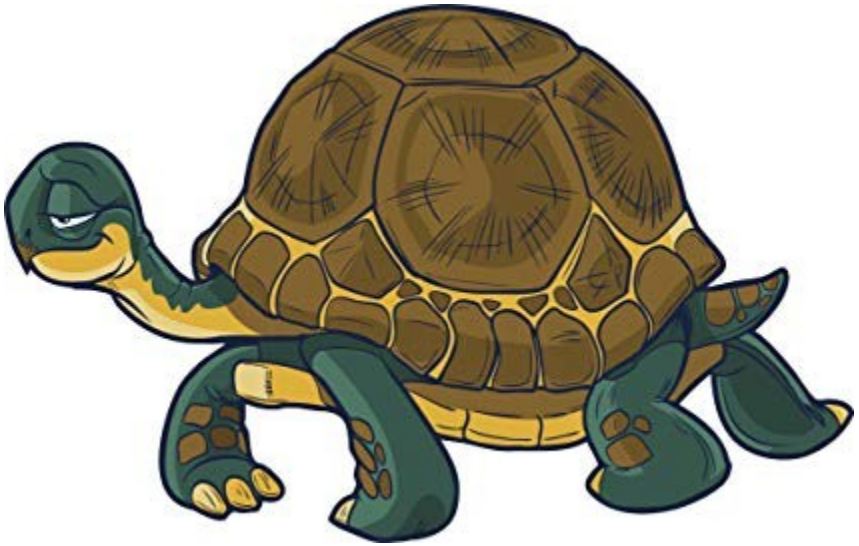
Why data editing?

› Broken Elements
› Antenna Shadowing
› Correlator malfunctions



Why data editing?

- Broken Elements
- Antenna Shadowing
- Correlator malfunctions
- Initial pointing delay



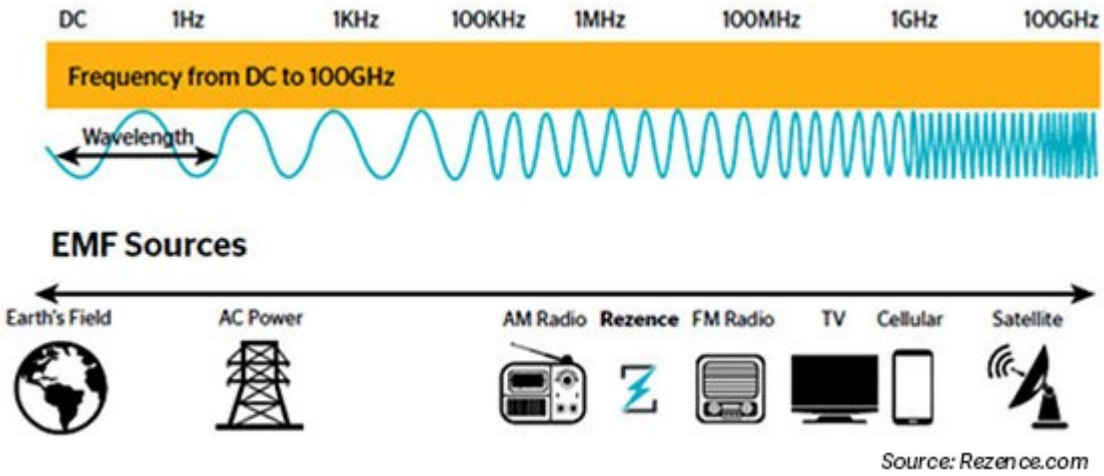
Why data editing?

› Broken Elements
› Antenna Shadowing
› Correlator malfunctions
› Initial pointing delay

› Bandpass issues
› Low elevation for some antennas
› Correlated noise on some baselines

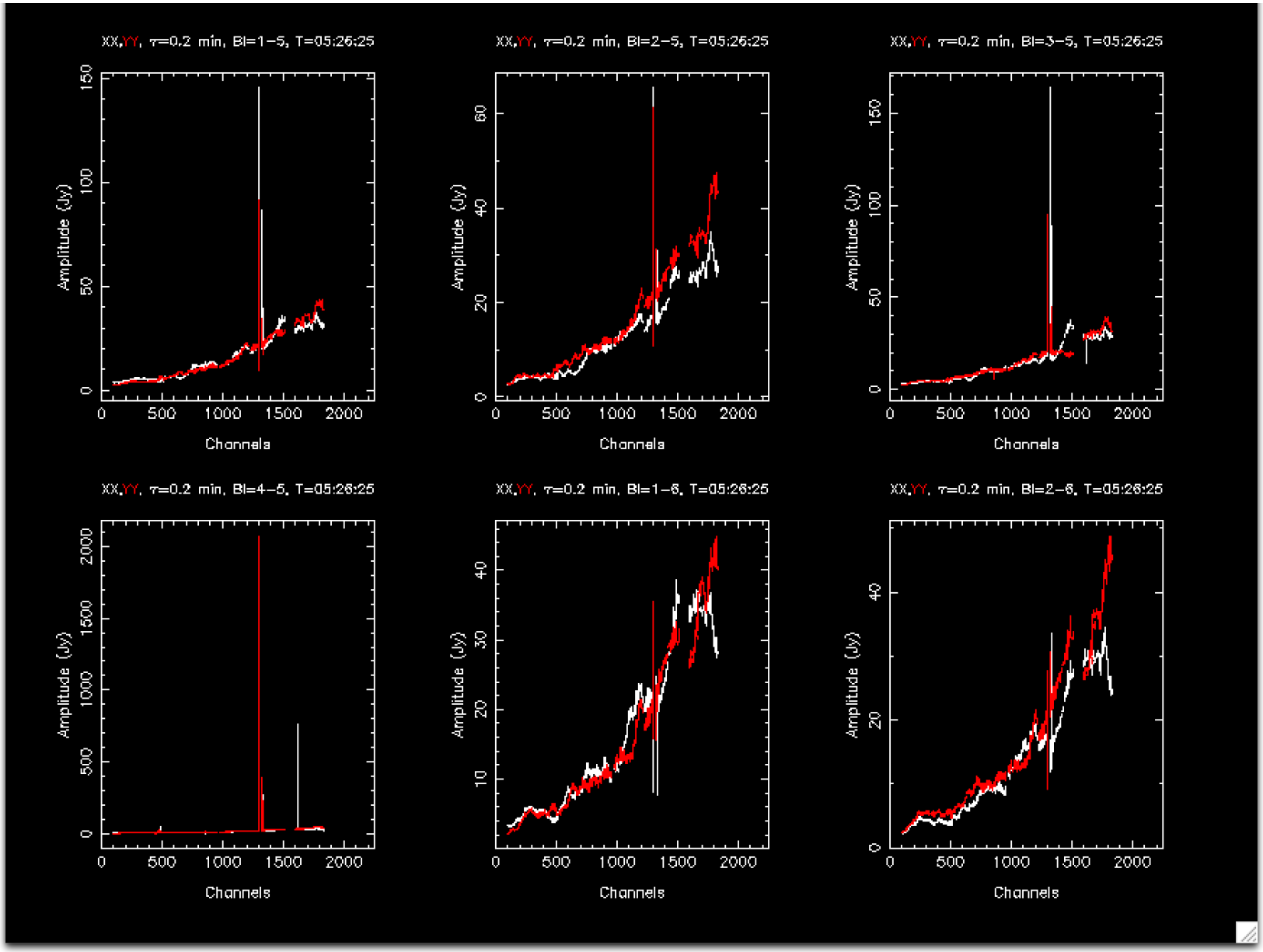
Radio Frequency Interference – a radio astronomers worst enemy (most of the time)

› Discrete bands

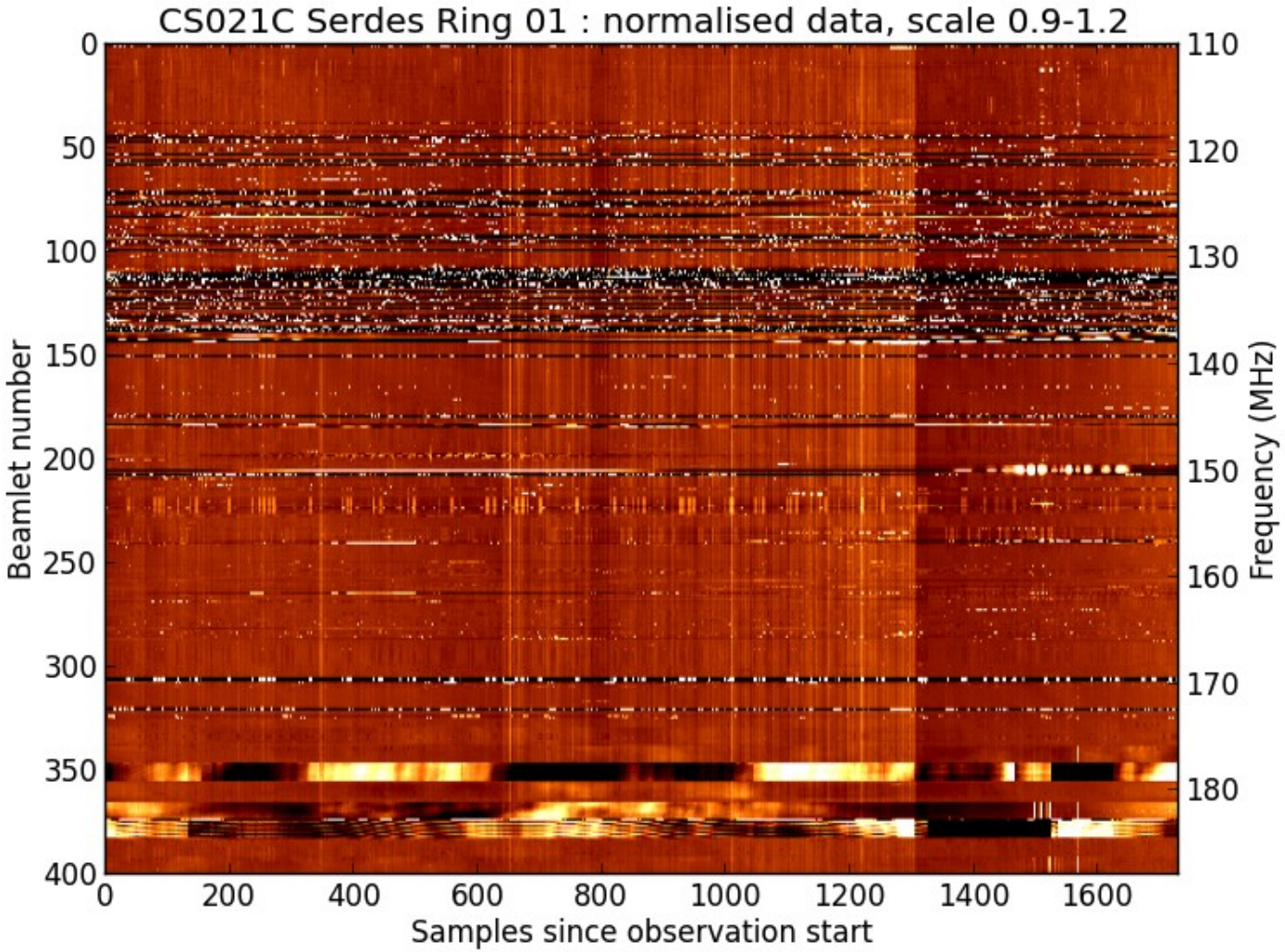


› Broadband

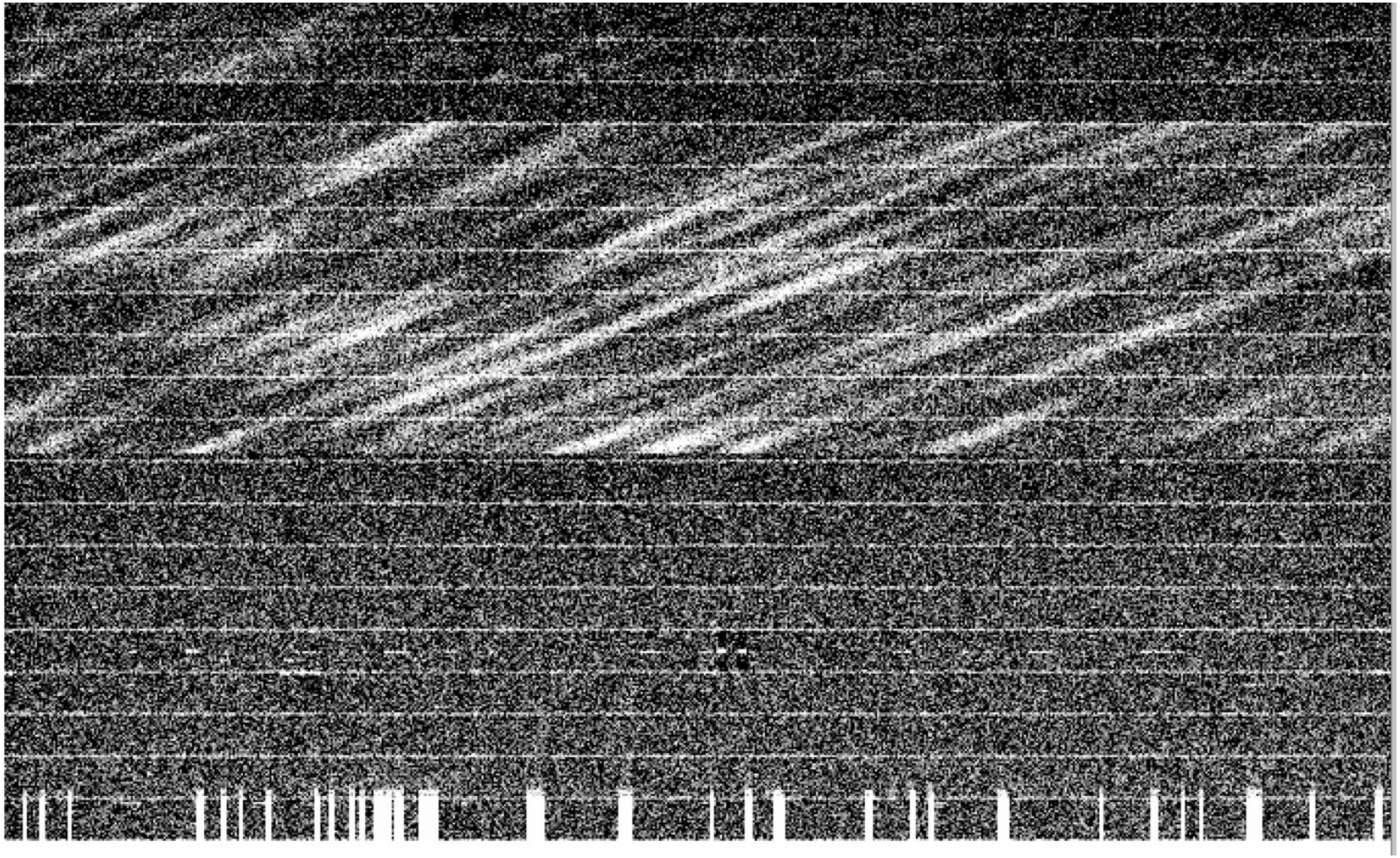
What can RFI look like?



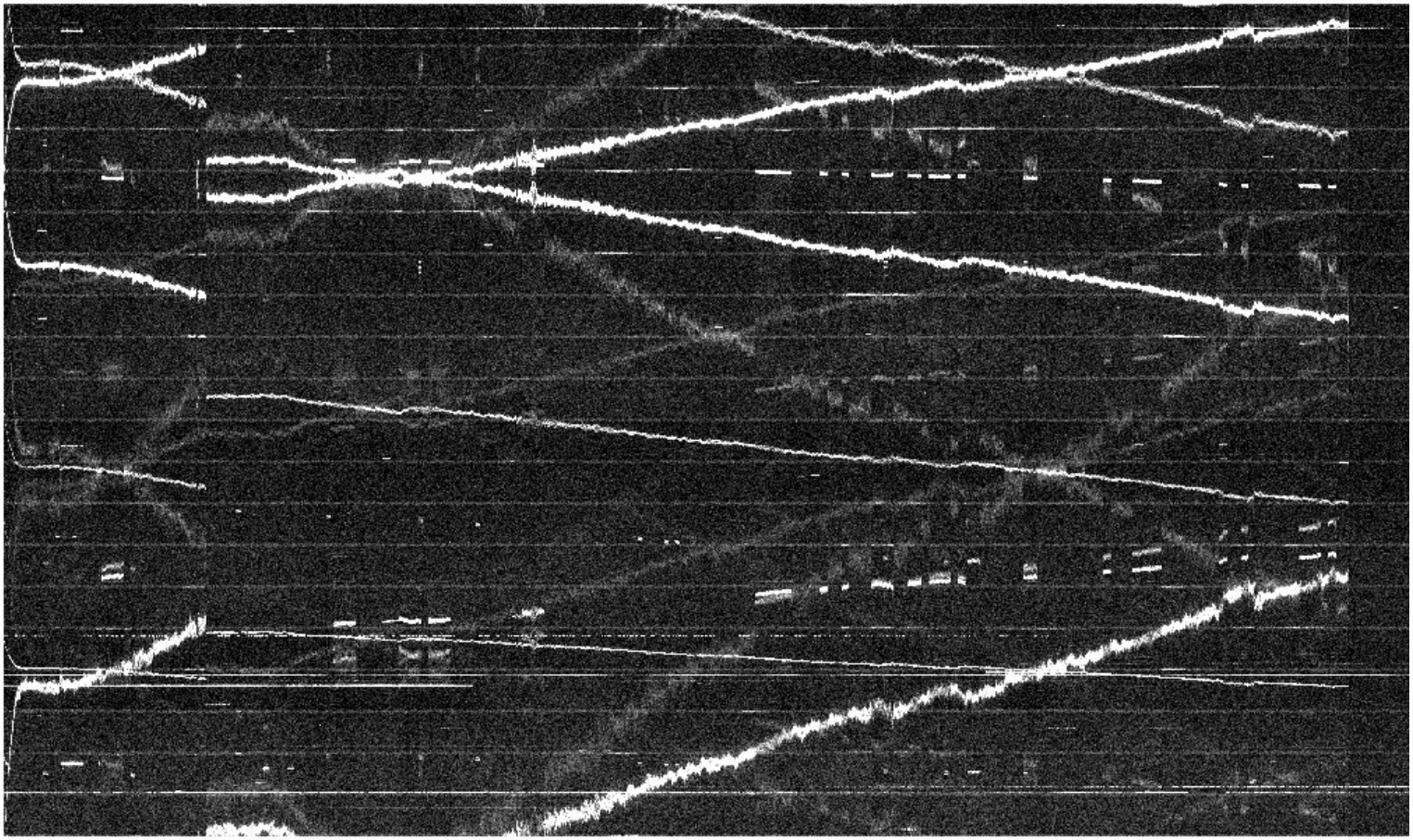
What can RFI look like?



What can RFI look like?



What can RFI look like?

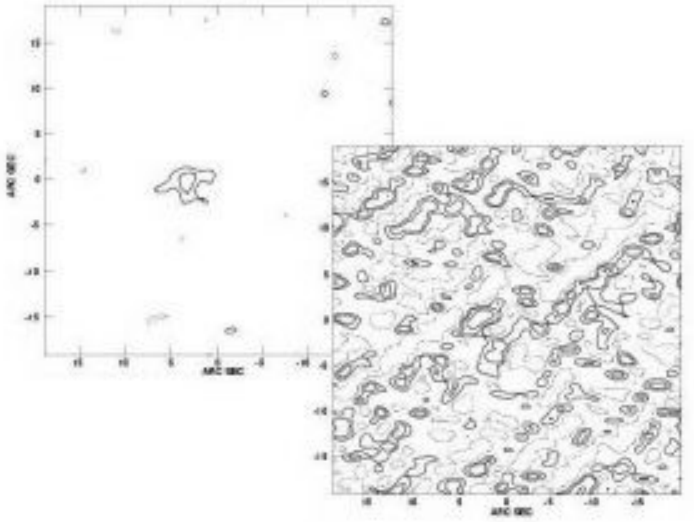


What if you do not flag?

› Probably will not be able to derive sensible calibration solutions (e.g. delay or phase solutions in particular)

› If you can make an image, it will be noiser and (depending on the brightness of your target), you will not be able to see your target

› Remember RFI is not constant in time. So you have to flag all calibrators and targets seperately.



How can we fix this in one slide…

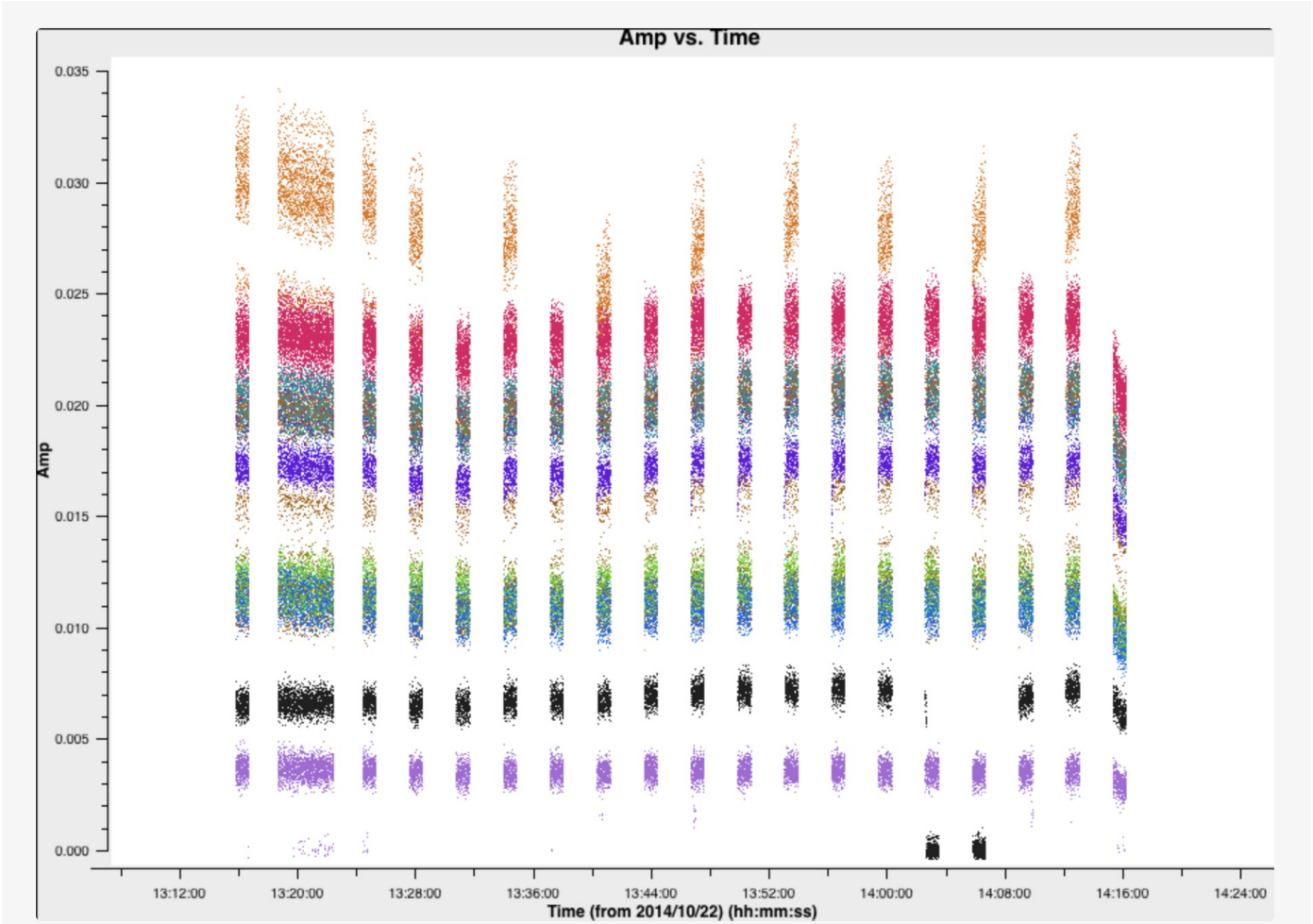
- Broken elements → **remove antennas**
- Correlator malfunctions → **remove timesteps**
- Shadowing → **remove antennas in time range**
- Initial pointing delay → **remove first timesteps**
- Bandpass issues → **remove channels**

- Low elevation → **remove antennas with low elevation**
- Correlated noise on some baselines (e.g. LOFAR split stations) → **Flag baselines**
- RFI→ **remove antennas, timestep, frequencies or baselines...**

You have already seen how to do this in casa

› Inspecting and find - look at antennas, frequency and time, phase and amp.

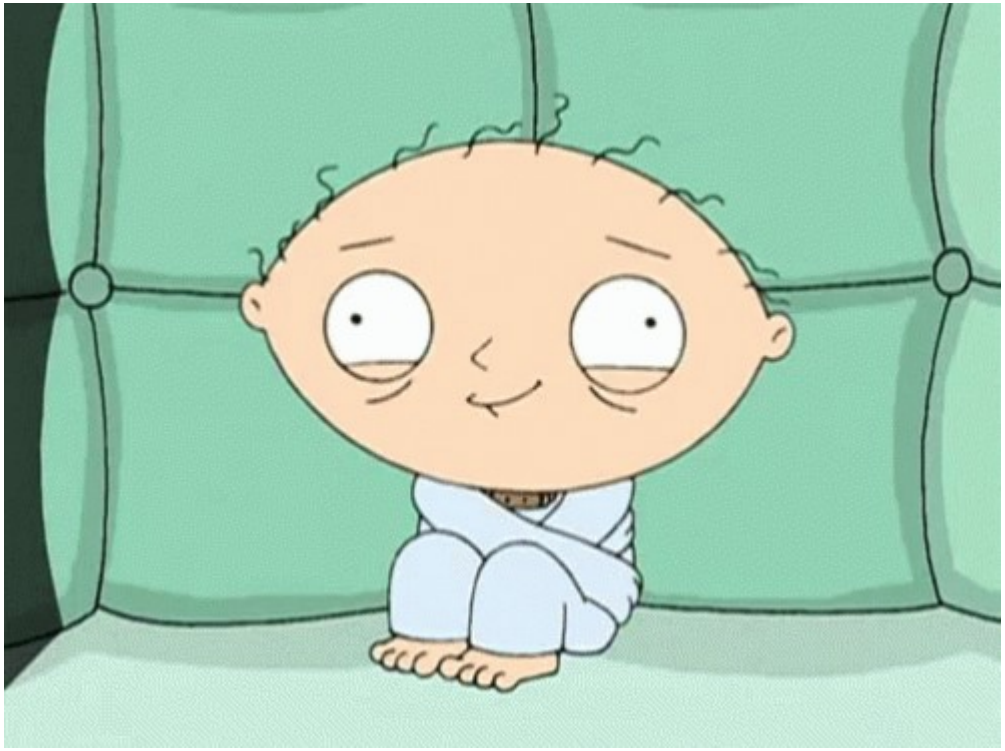
› A little bit easier in VLBI as you correlate the RFI away



Flagging data does not mean deleting

Modern ways to flag can not be manual

› For example, LOFAR has 44 stations (including international stations). That means there are N(N-1)/2 = **946 baselines**



› **Far too many to inspect manually**

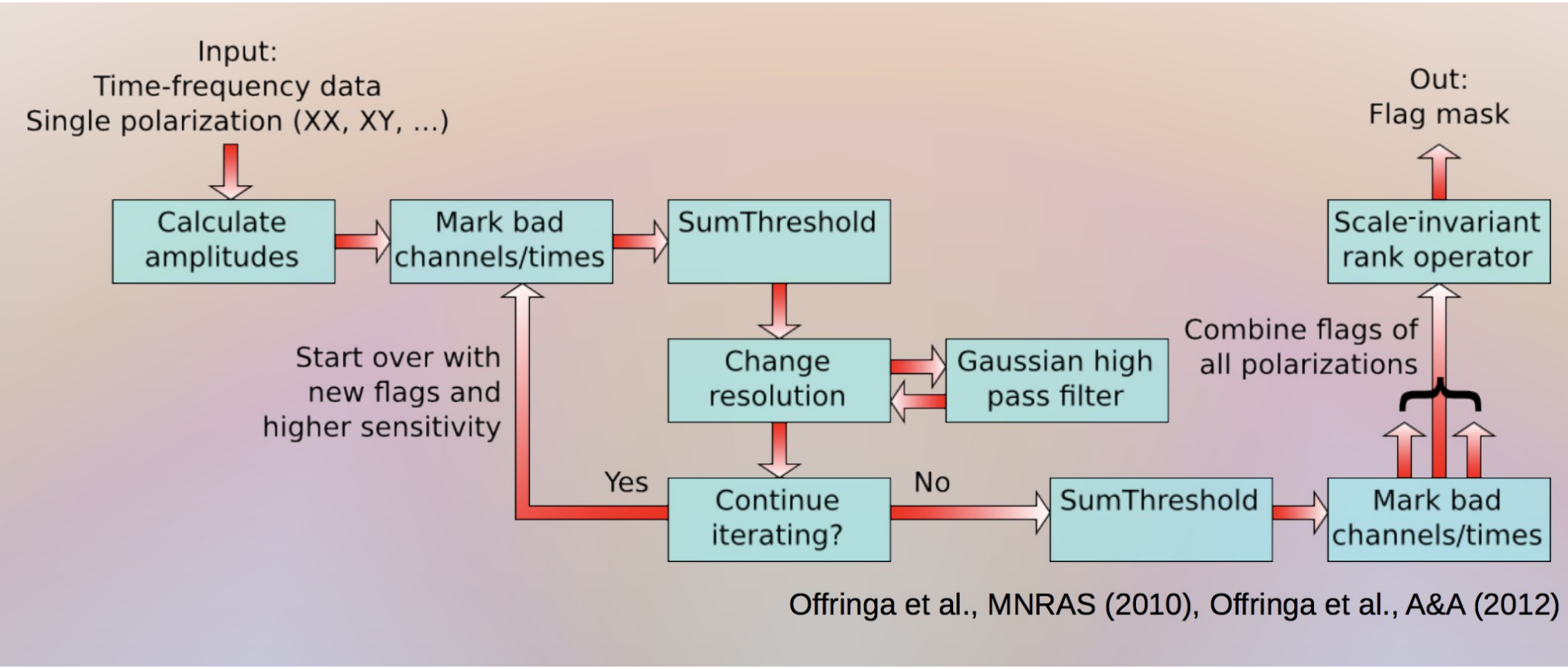
Other more automated/modern ways to flag

- **Two classes of RFI excision methods:**
  - **Detection: find & throw away affected data**
  - **Filtering or subtracting: estimate RFI contribution and restore affected data**

- Detection methods (“flagging”) commonly used
  - Some specialized pipelines for surveys or instruments

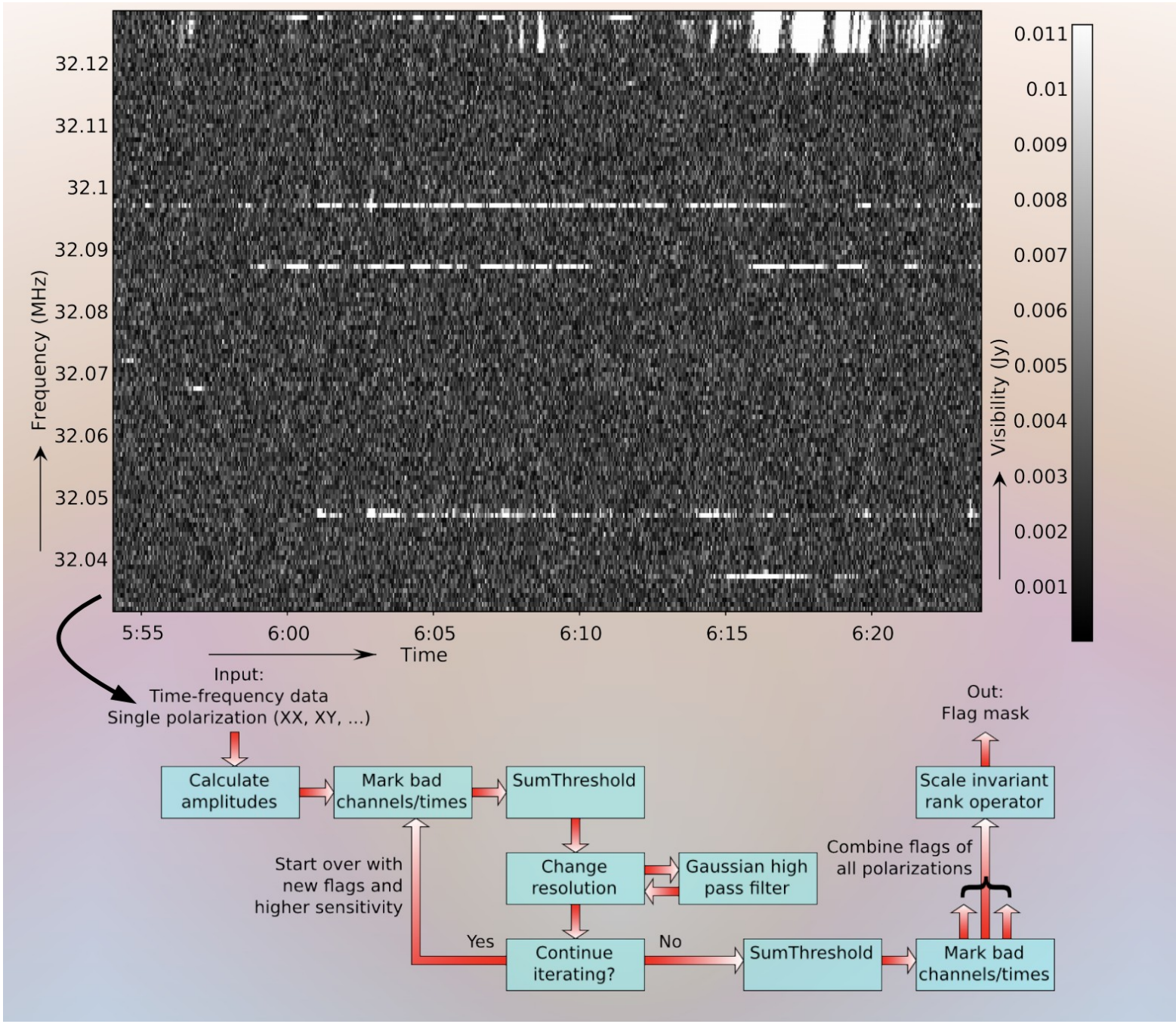
- Filtering RFI is harder
  - Resulting data quality is not well understood
  - Requires more resources
  - Lack of full (automated) filtering pipelines

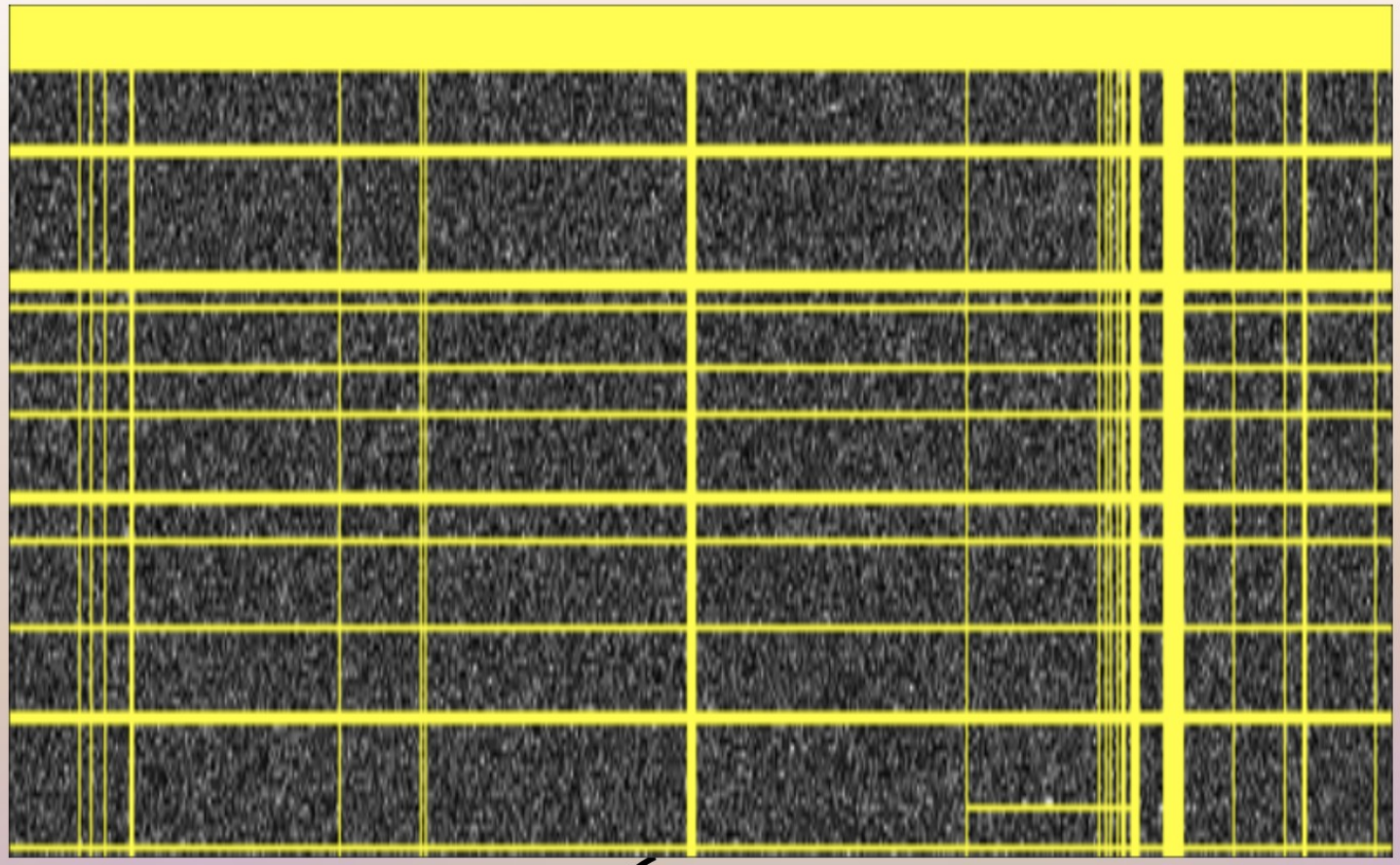
AOFlagger

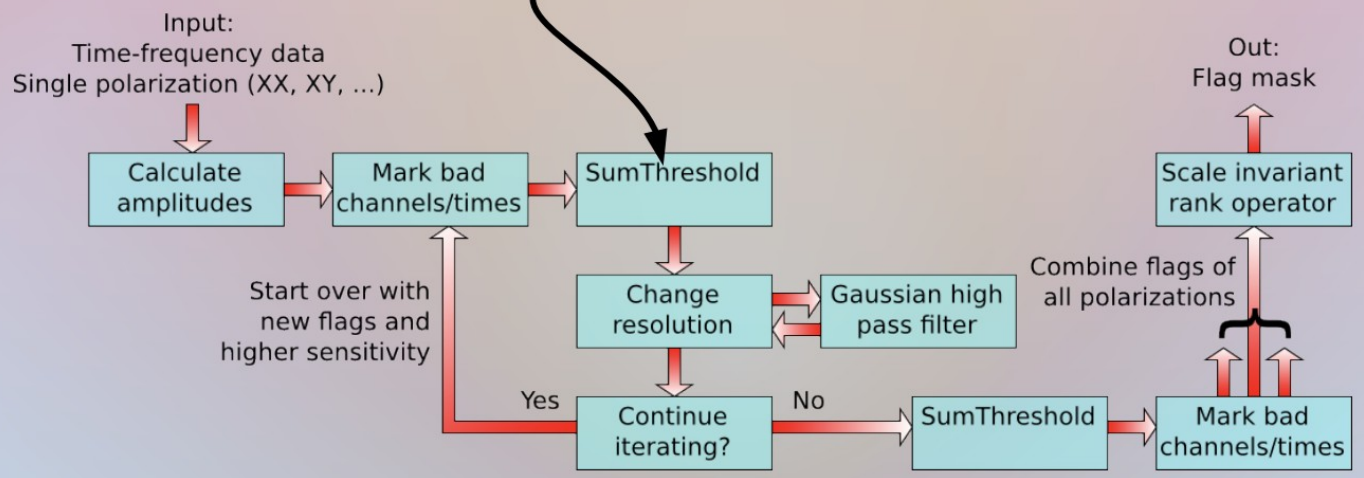


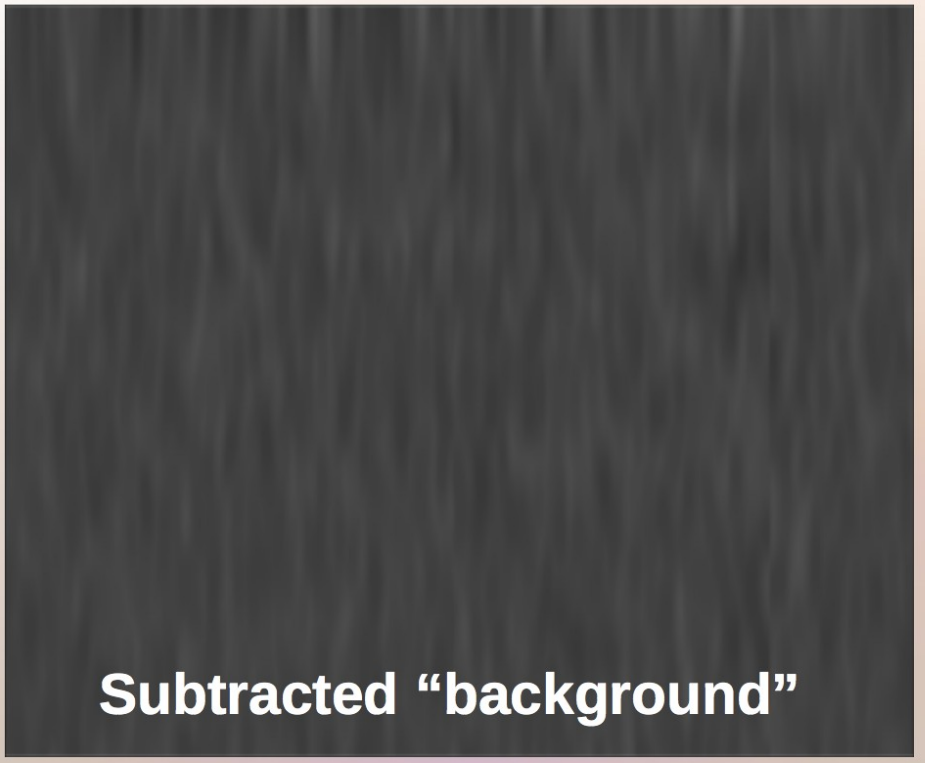
Offringa et al., MNRAS (2010), Offringa et al., A&A (2012)

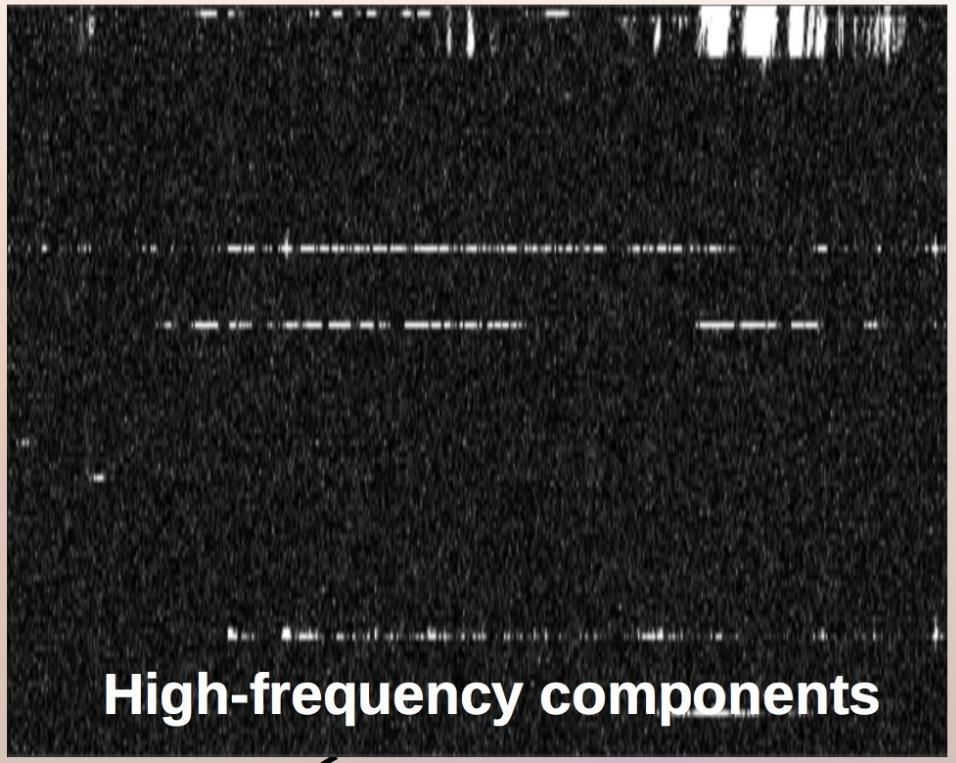
AOFlagger

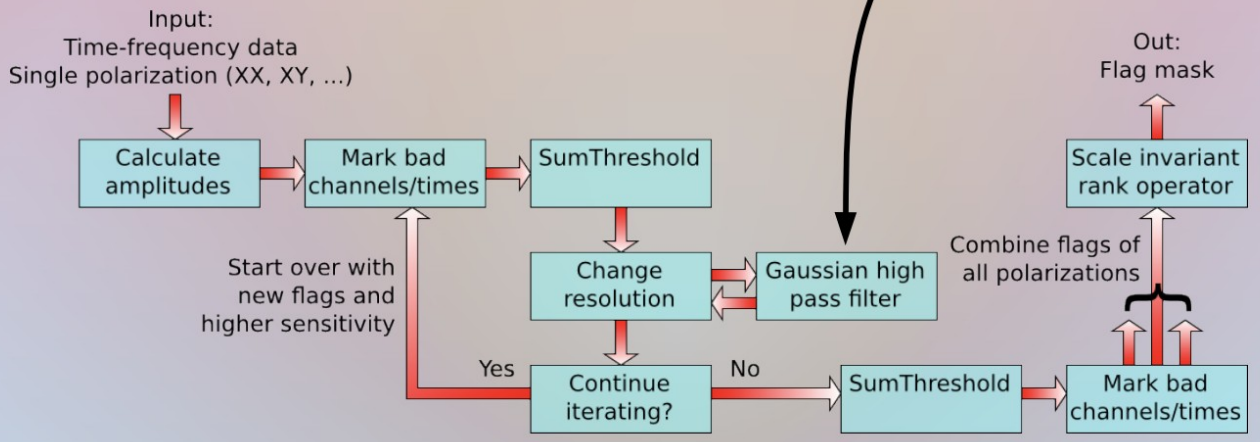

32.12
32.11
32.1
32.09
32.08
32.07
32.06
32.05
32.04
Frequency (MHz)
5:55
6:00
6:05
6:10
6:15
6:20
Time
0.011
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Visibility (Jy)
Input:
Time-frequency data
Single polarization (XX, XY, ...)
Calculate amplitudes
Mark bad channels/times
SumThreshold
Change resolution
Gaussian high pass filter
Start over with new flags and higher sensitivity
Yes
Continue iterating?
No
SumThreshold
Mark bad channels/times
Combine flags of all polarizations
Scale invariant rank operator
Out:
Flag mask

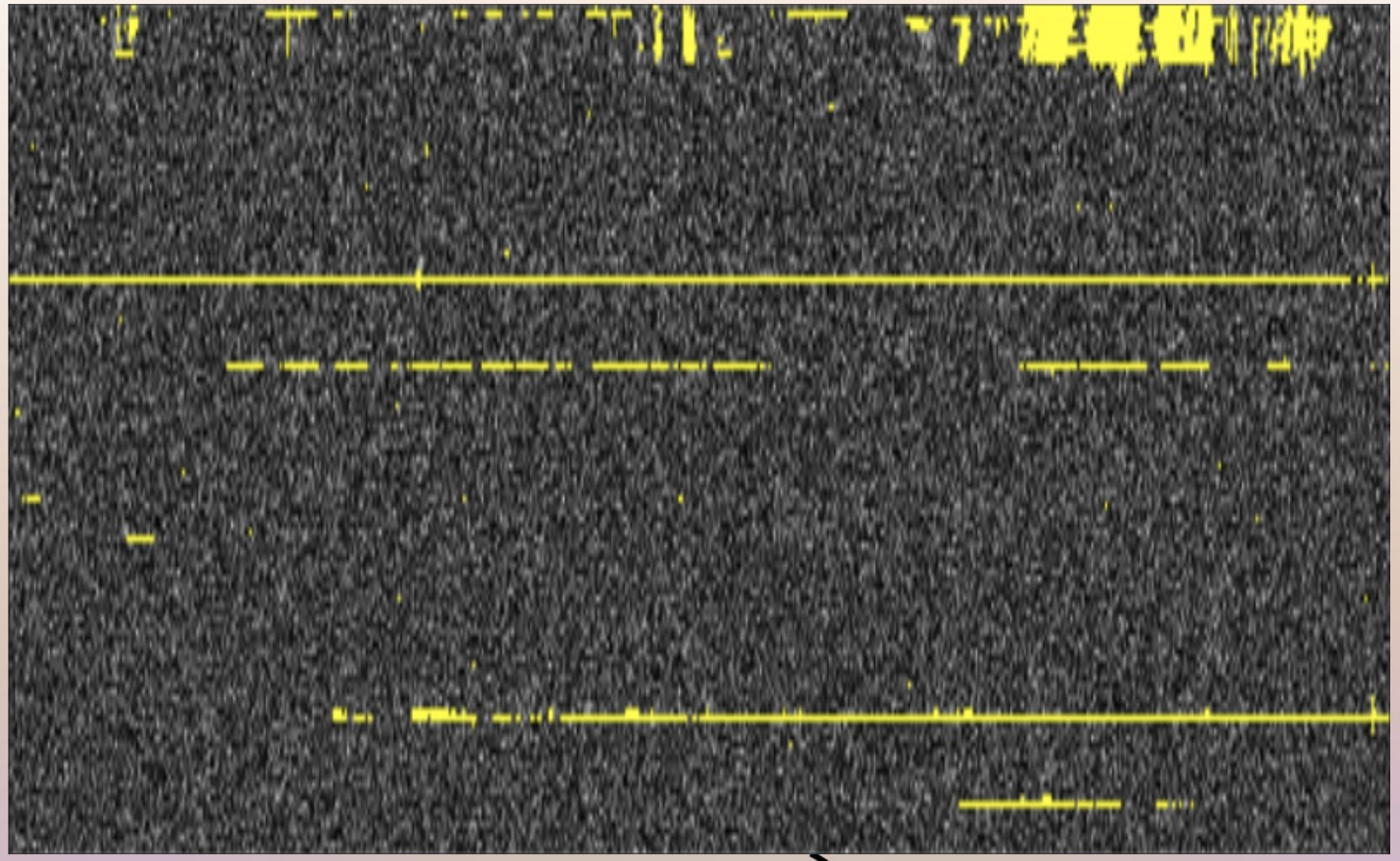


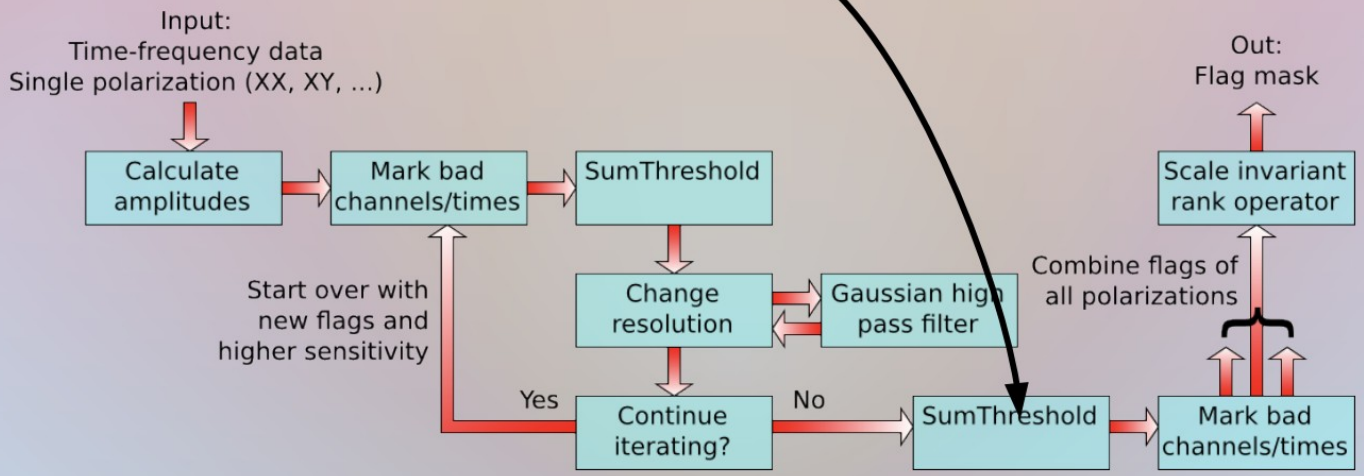

Input:
Time-frequency data
Single polarization (XX, XY, ...)
Calculate amplitudes
Mark bad channels/times
SumThreshold
Change resolution
Gaussian high pass filter
Start over with new flags and higher sensitivity
Yes
Continue iterating?
No
SumThreshold
Mark bad channels/times
Combine flags of all polarizations
Scale invariant rank operator
Out:
Flag mask

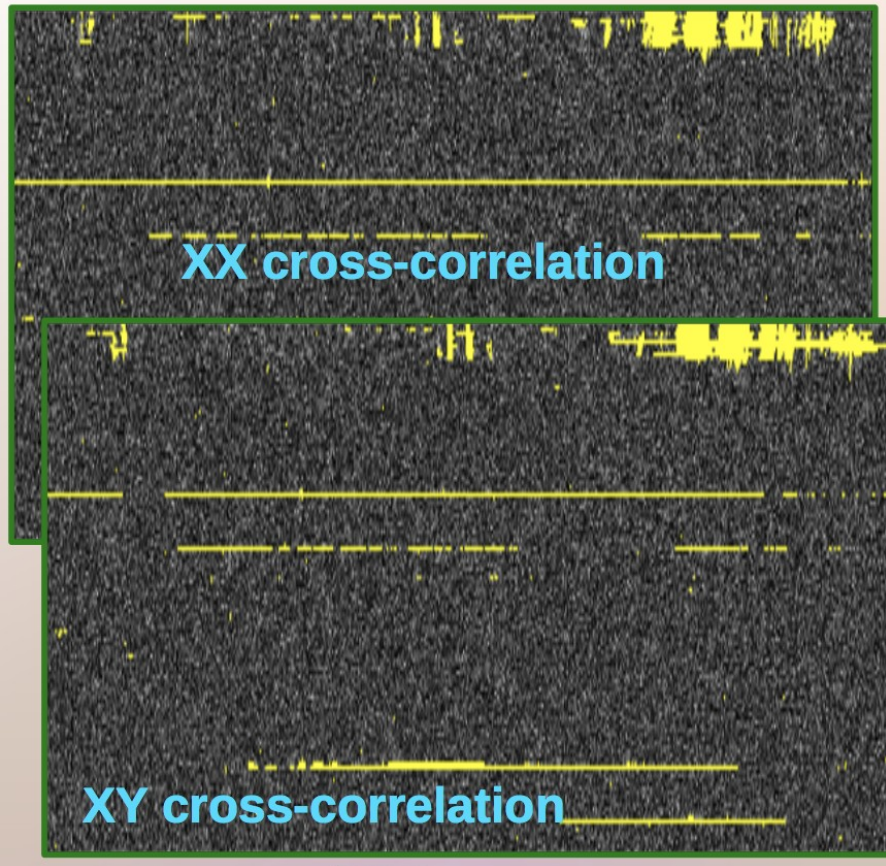

Subtracted “background”

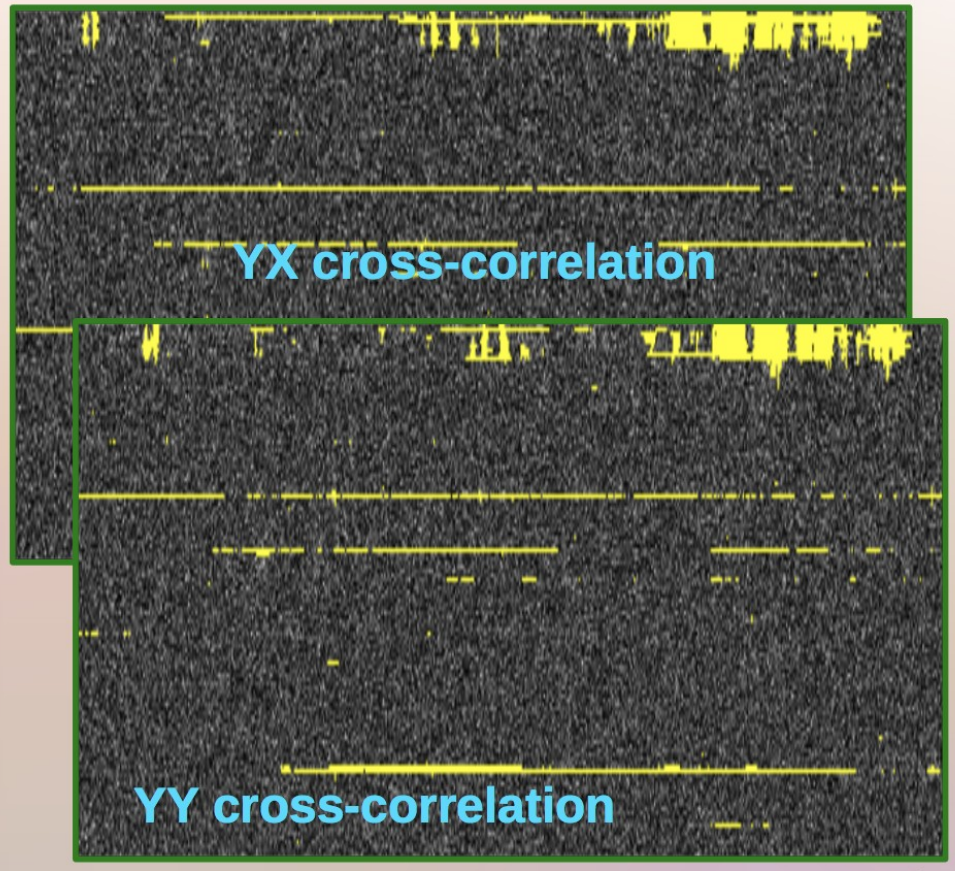

High-frequency components

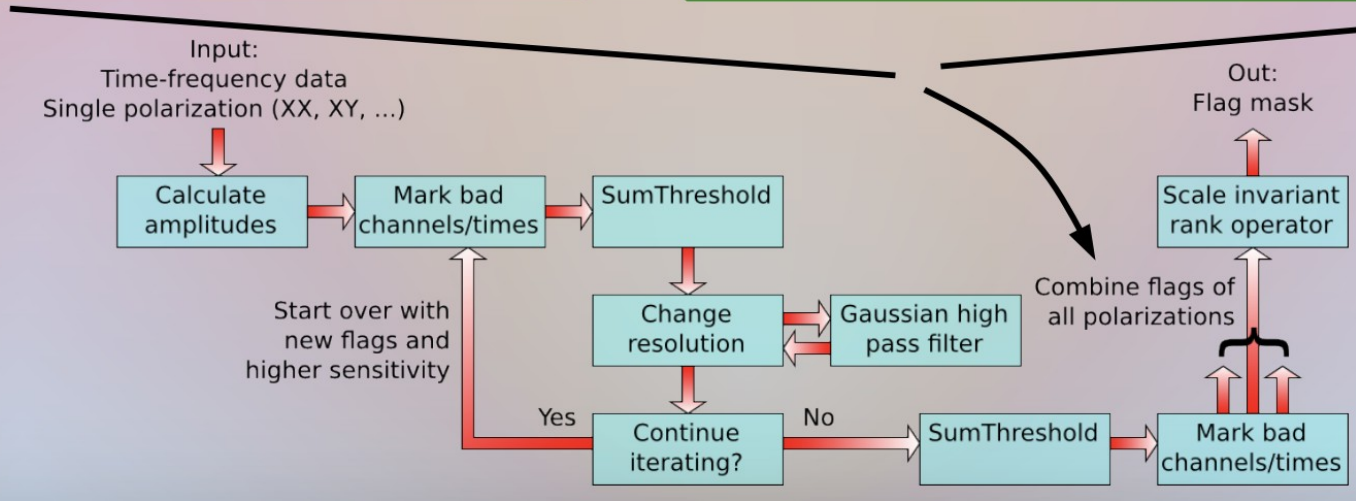

Input:
Time-frequency data
Single polarization (XX, XY, ...)
Calculate amplitudes
Mark bad channels/times
SumThreshold
Change resolution
Gaussian high pass filter
Start over with new flags and higher sensitivity
Yes
Continue iterating?
No
SumThreshold
Mark bad channels/times
Combine flags of all polarizations
Scale invariant rank operator
Out:
Flag mask




Input:
Time-frequency data
Single polarization (XX, XY, ...)
Calculate amplitudes
Mark bad channels/times
SumThreshold
Change resolution
Gaussian high pass filter
Start over with new flags and higher sensitivity
Yes
Continue iterating?
No
SumThreshold
Mark bad channels/times
Combine flags of all polarizations
Scale invariant rank operator
Out:
Flag mask


XX cross-correlation
XY cross-correlation

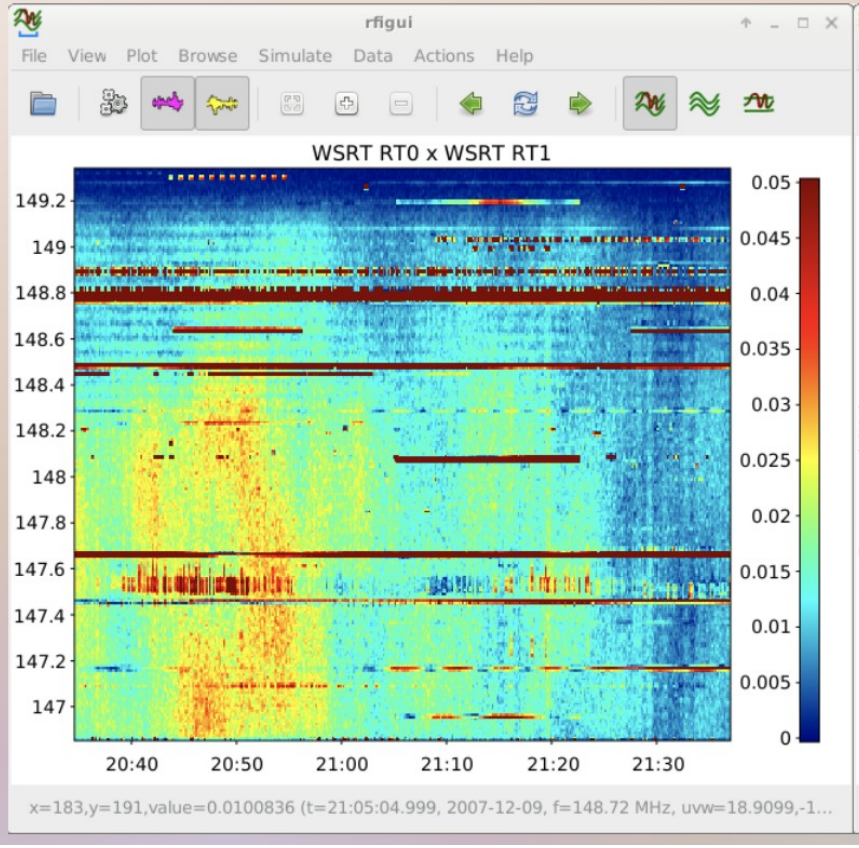

YX cross-correlation
YY cross-correlation


Input:
Time-frequency data
Single polarization (XX, XY, ...)
Calculate amplitudes
Mark bad channels/times
SumThreshold
Change resolution
Gaussian high pass filter
Start over with new flags and higher sensitivity
Yes
Continue iterating?
No
SumThreshold
Mark bad channels/times
Combine flags of all polarizations
Scale invariant rank operator
Out:
Flag mask

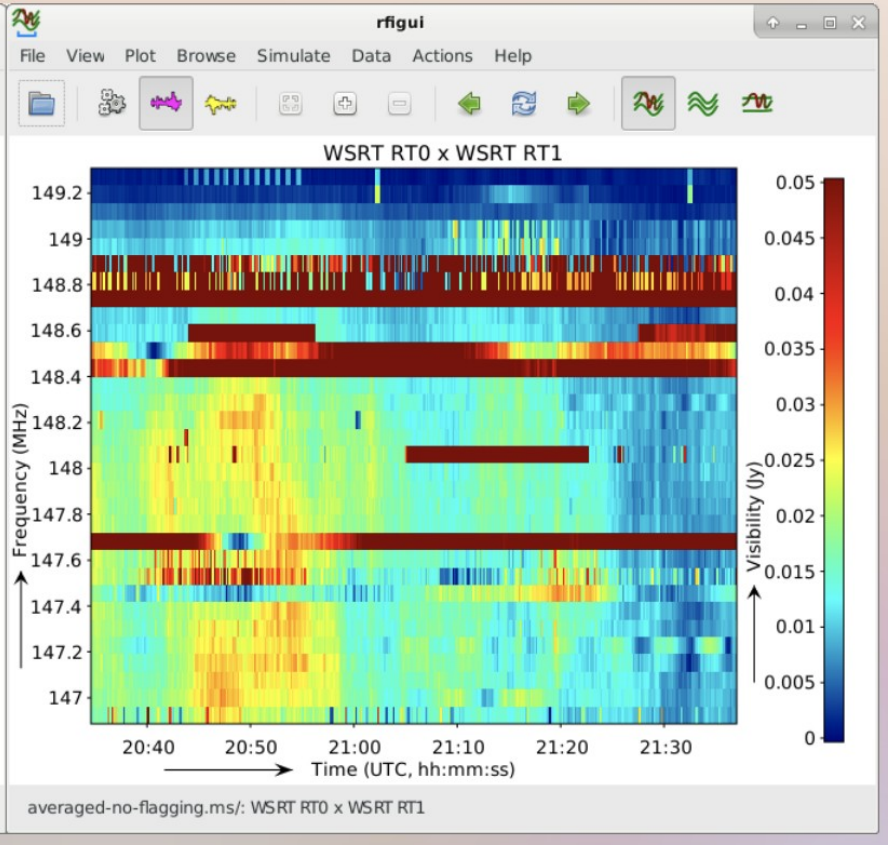
AOFlagger

› Always flag (first) at highest possible resolution

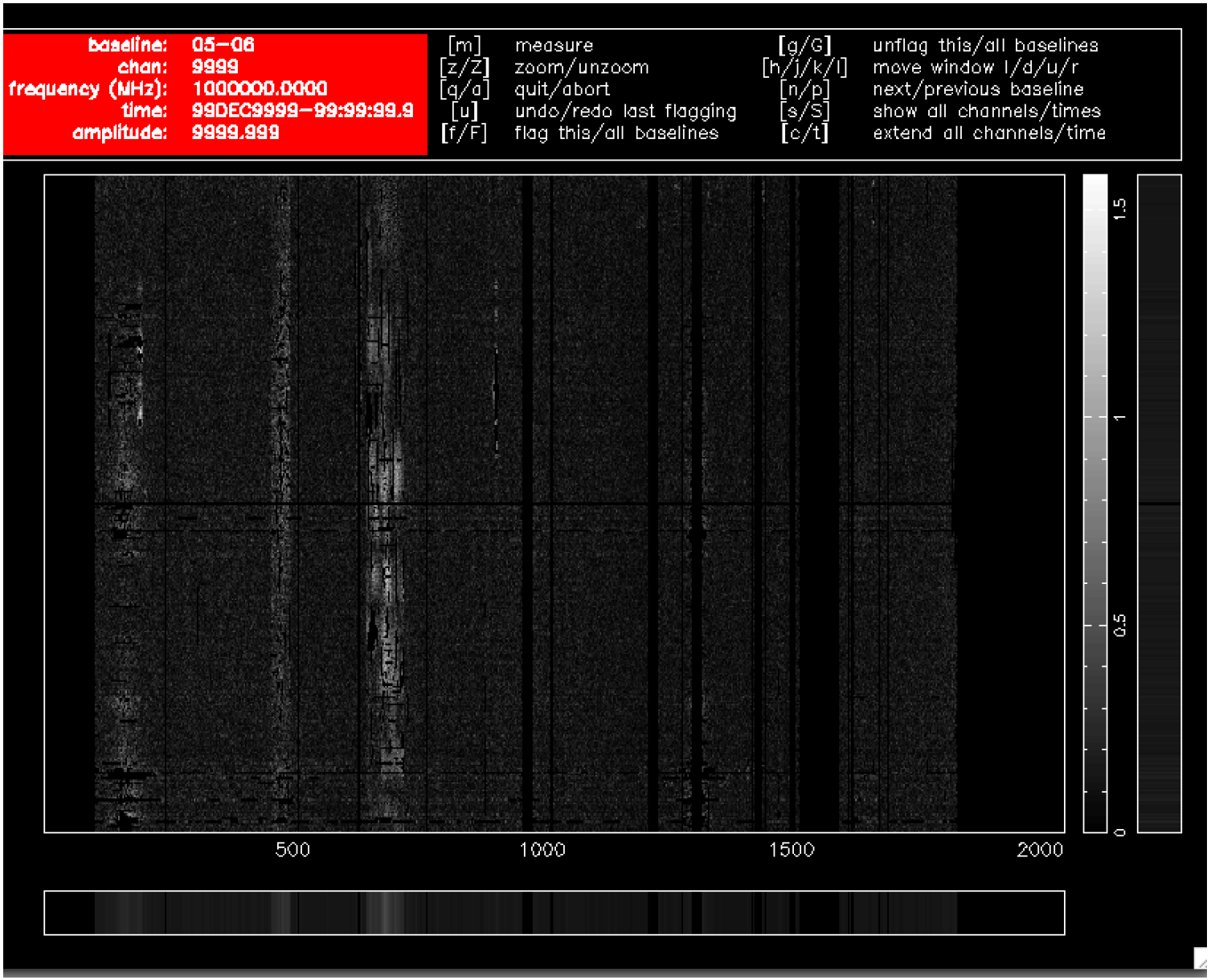
Highest resolution:



Averaged without RFI detection:



Flagging is often iterative with calibration



Conclusion

- First step in data processing is data inspection
- Then flagging (making sure you back up your data!)
- Flagging in VLBI can be quite manual but most other flagging routines are automative
- Remember: Better to have less data that is good than more data that has bad components.