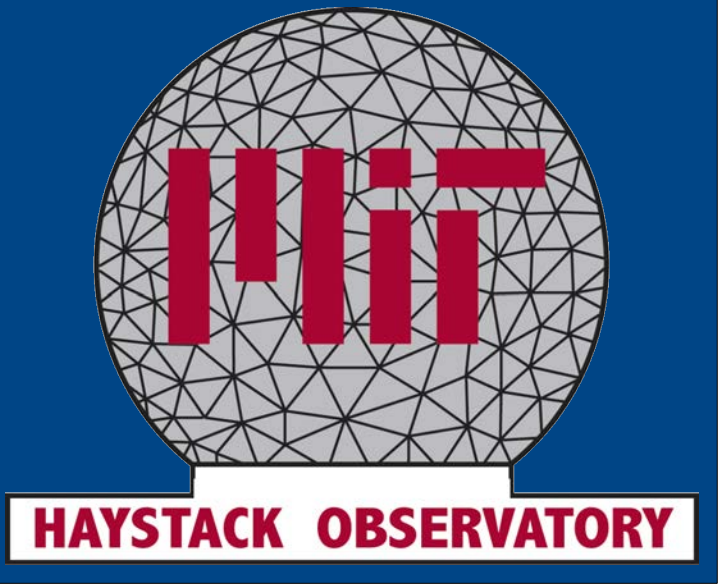
Solar Radio Event Detection with the MWA

Brian Timar	U. California Berkeley
Victor Pankratius	MIT Haystack Observatory
Colin Lonsdale	MIT Haystack Observatory

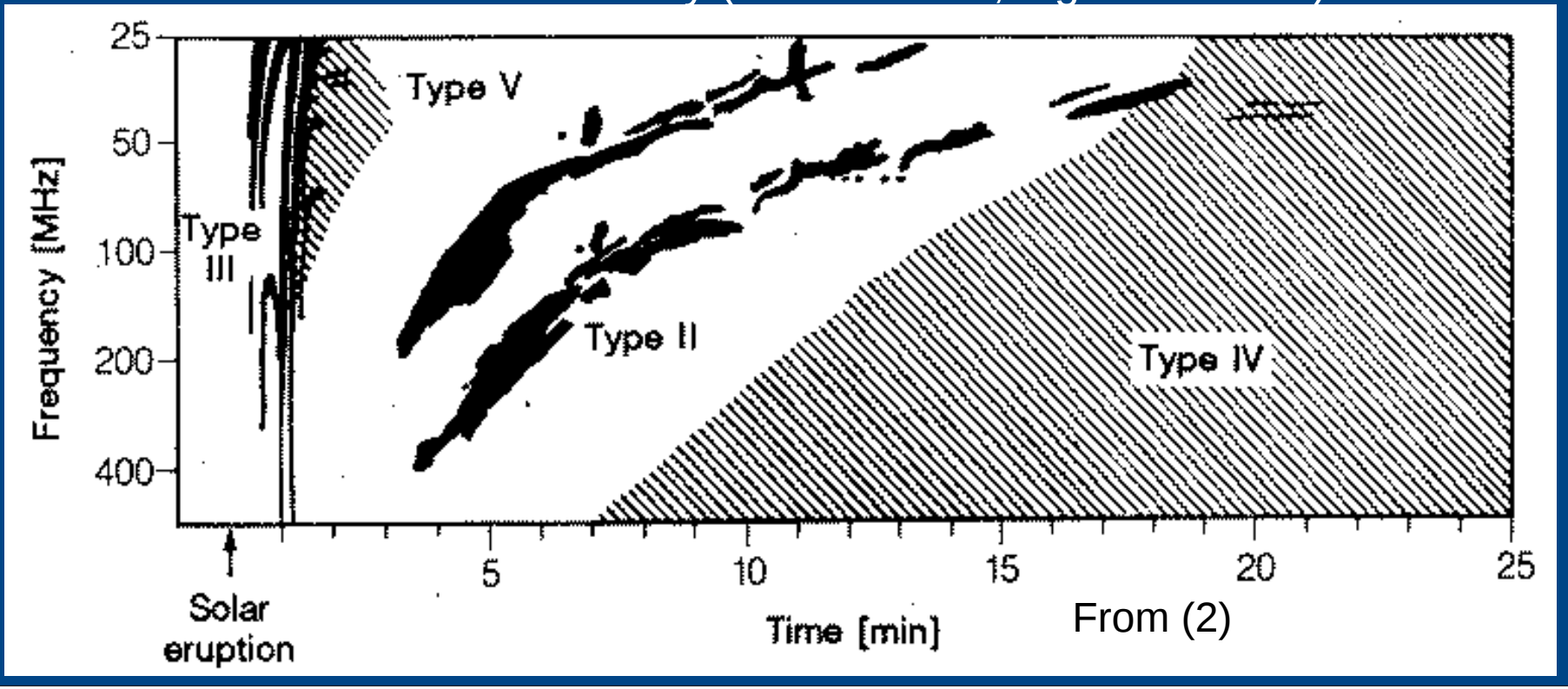


Intro: Coronal Radio Emissions

Coherent emission – at plasma frequency or 1st harmonic

Plasma frequency scales like square root of local electron # density

Goal: identify, extract and characterize previously unknown Type III-like radio events automatically (~1s duration, high drift rates).



From (2)

The Murchison Widefield Array

- Tile signals are quantized before being passed to correlator.

- 24 * 1.28 MHz coarse channels, out of 80-300 MHz. Work with contiguous data.

Single MWA tile

Van-Vleck Corrections

-Quantized correlation =/= Analog correlation at inputs

- For given autocorrelation statistics and quantization
levels, we can determine the relationship numerically

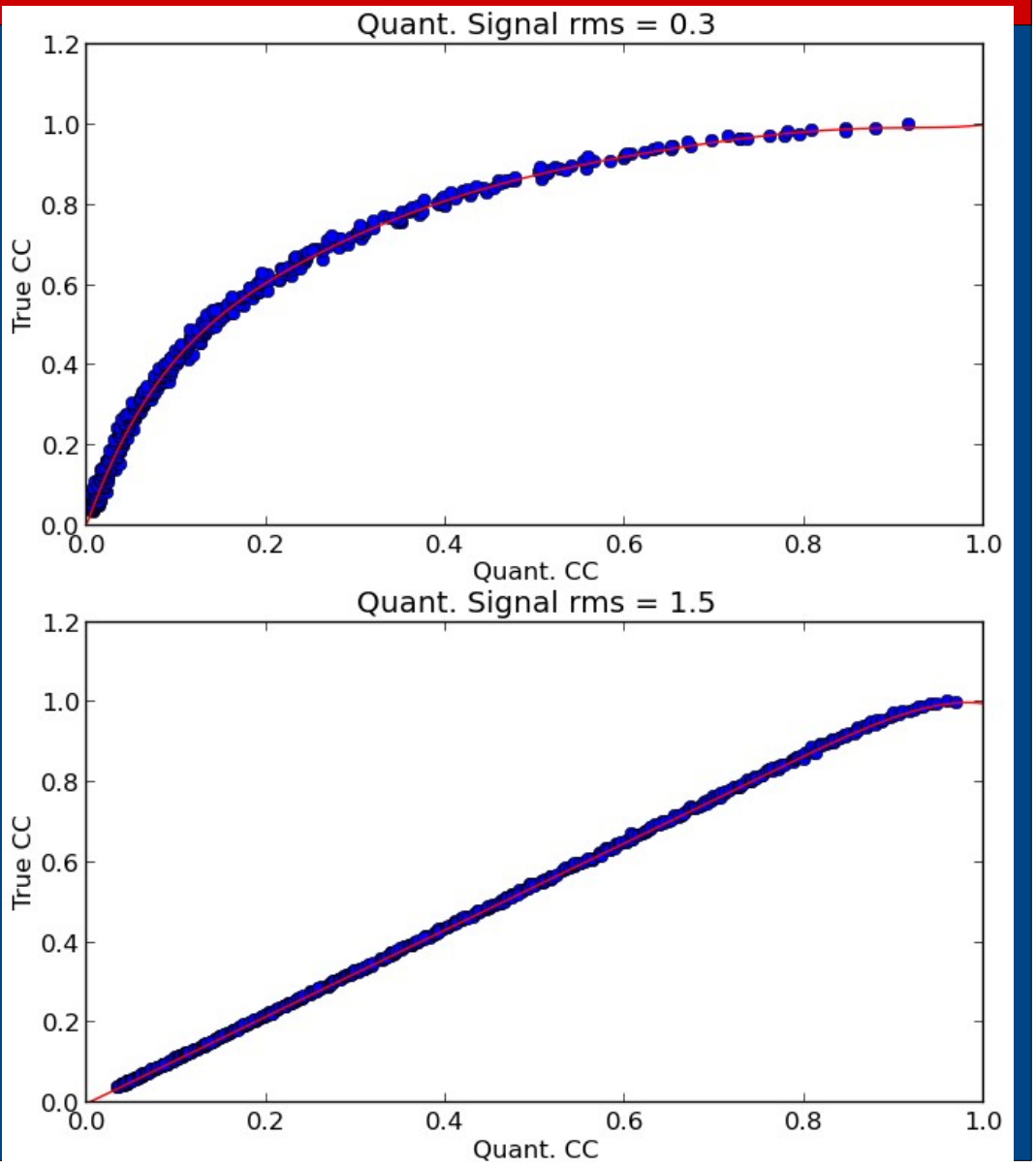
- *Nonlinear* – although approximately linear at
low correlations

-Measured autocorrelations are also affected

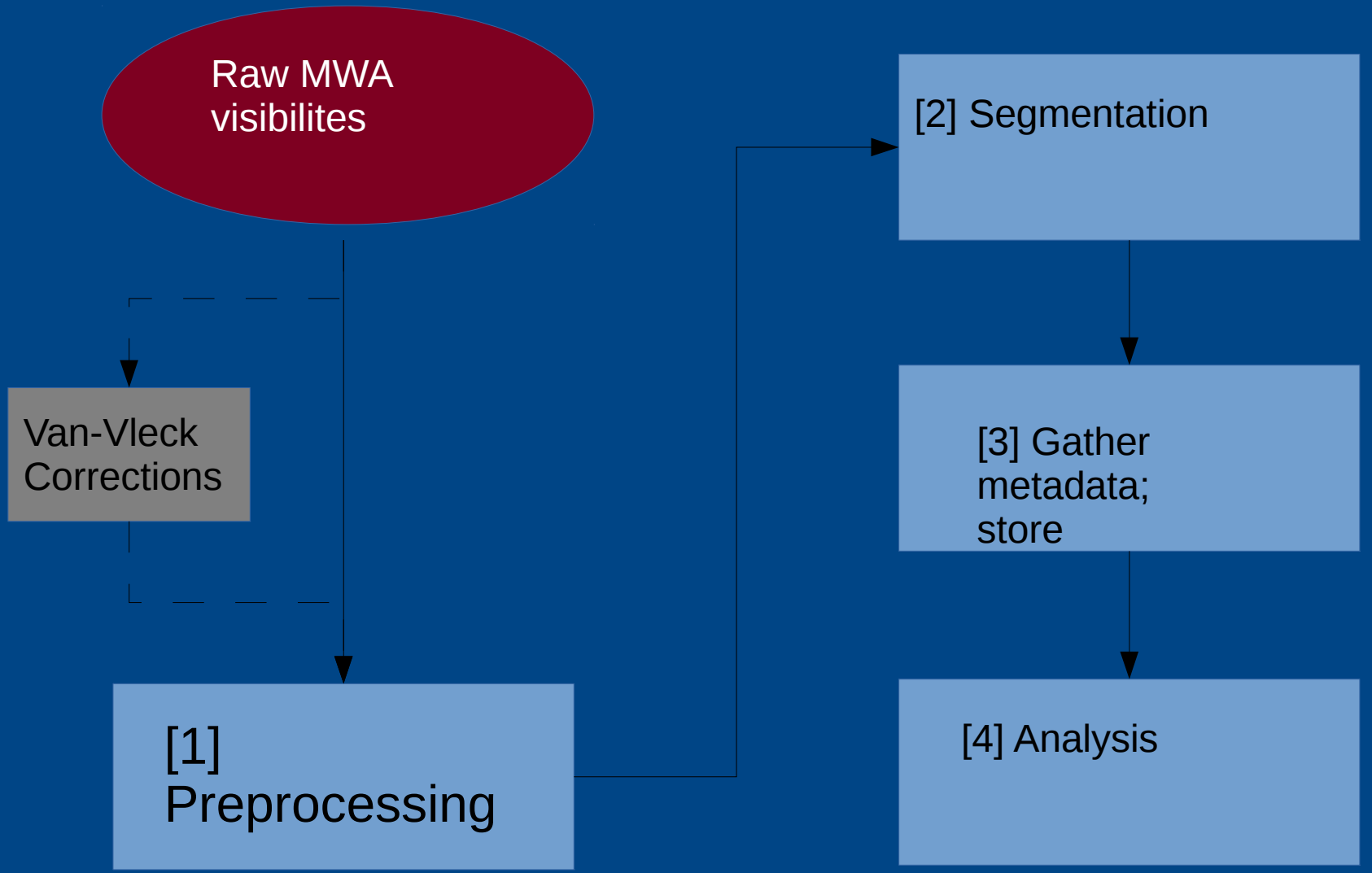
$$\rho = \frac{\mathrm{Cross}(s_1, s_2)}{\sqrt{\mathrm{Auto}(s_1) * \mathrm{Auto}(s_2)}}$$

$$\mathrm{Cross}(s_1, s_2) := \frac{1}{T}\int_0^T s_1^*(t)\, s_2(t) dt$$

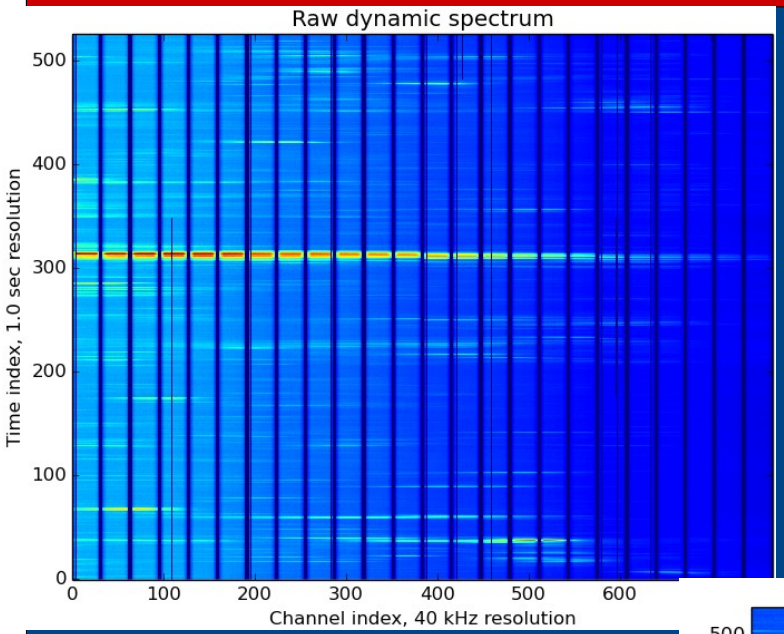
$$\mathrm{Auto}(s_1) := \frac{1}{T}\int_0^T |s_1(t)|^2 dt$$



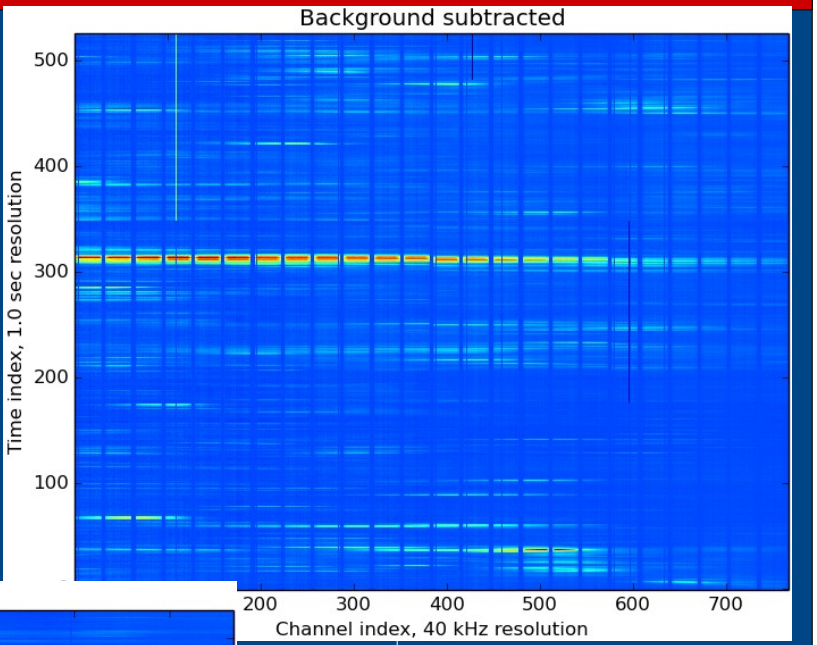
Pipeline


Raw MWA visibilites
Van-Vleck Corrections
[1] Preprocessing
[2] Segmentation
[3] Gather metadata; store
[4] Analysis

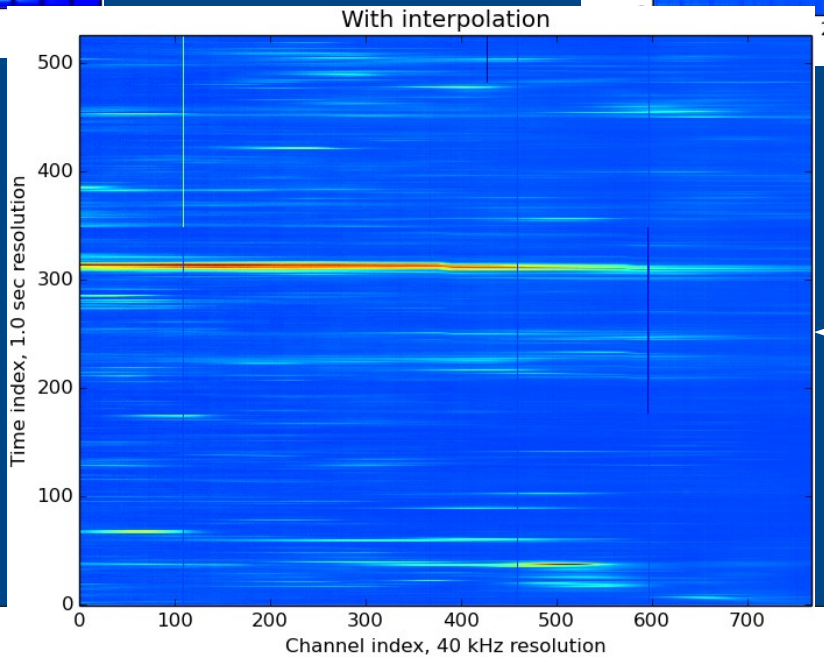
[1] Preprocessing



Pick ~10 timesteps to define background



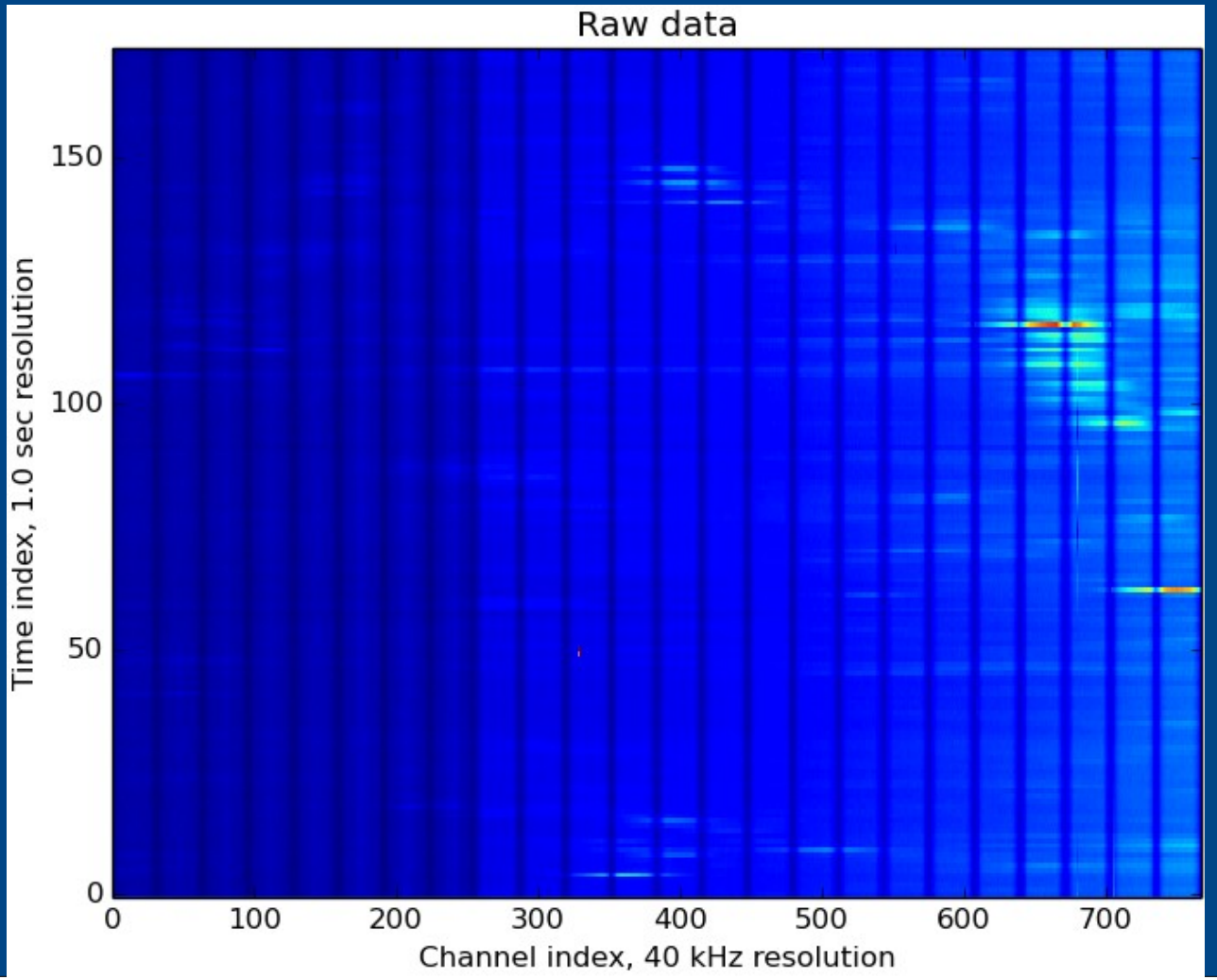
Data courtesy of L. Mattews. See (1)



Interpolate over channel gaps

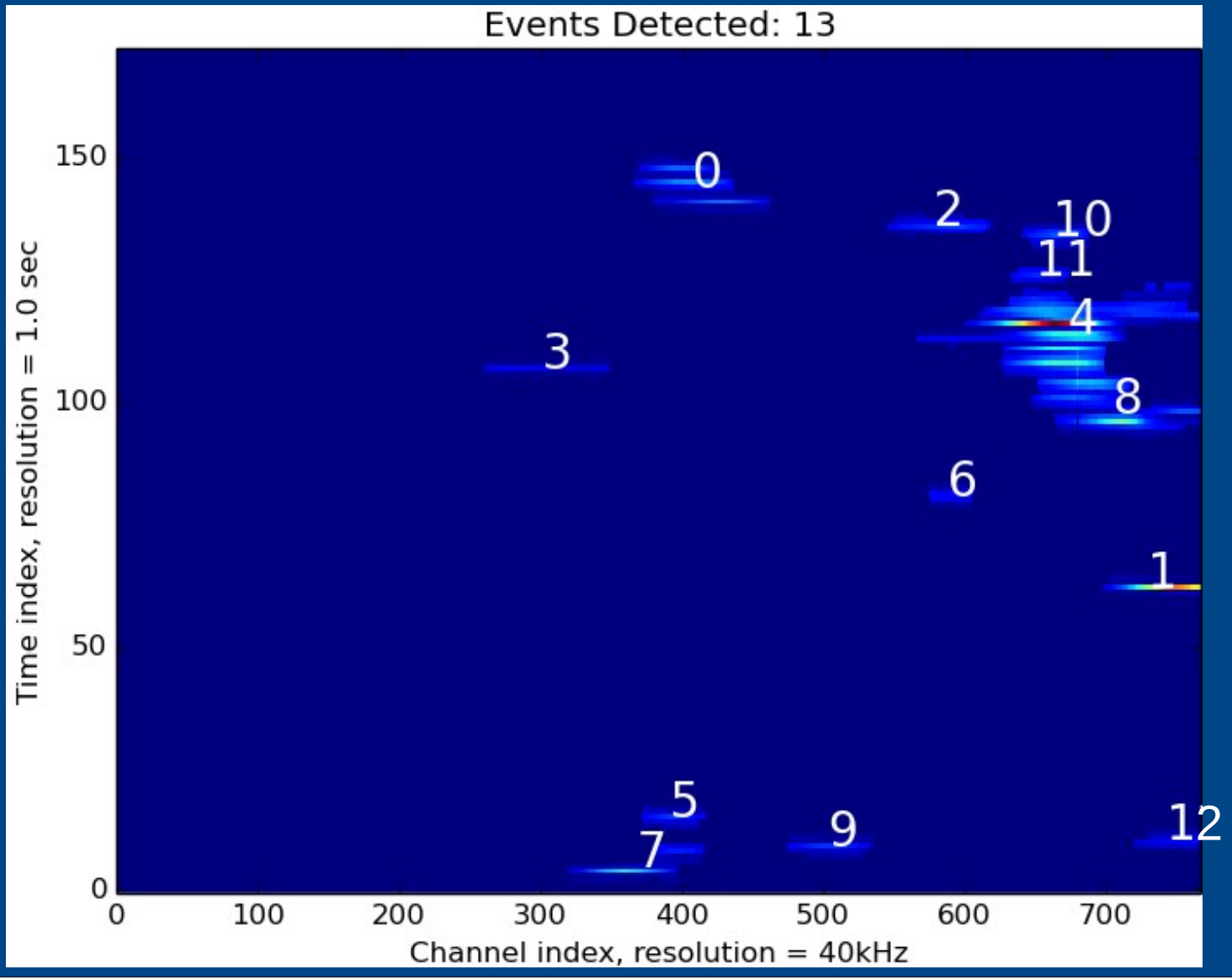
[2] Segmentation

- Retrieve subsets of image corresponding to events
- Focus on short timescales, high drift rates

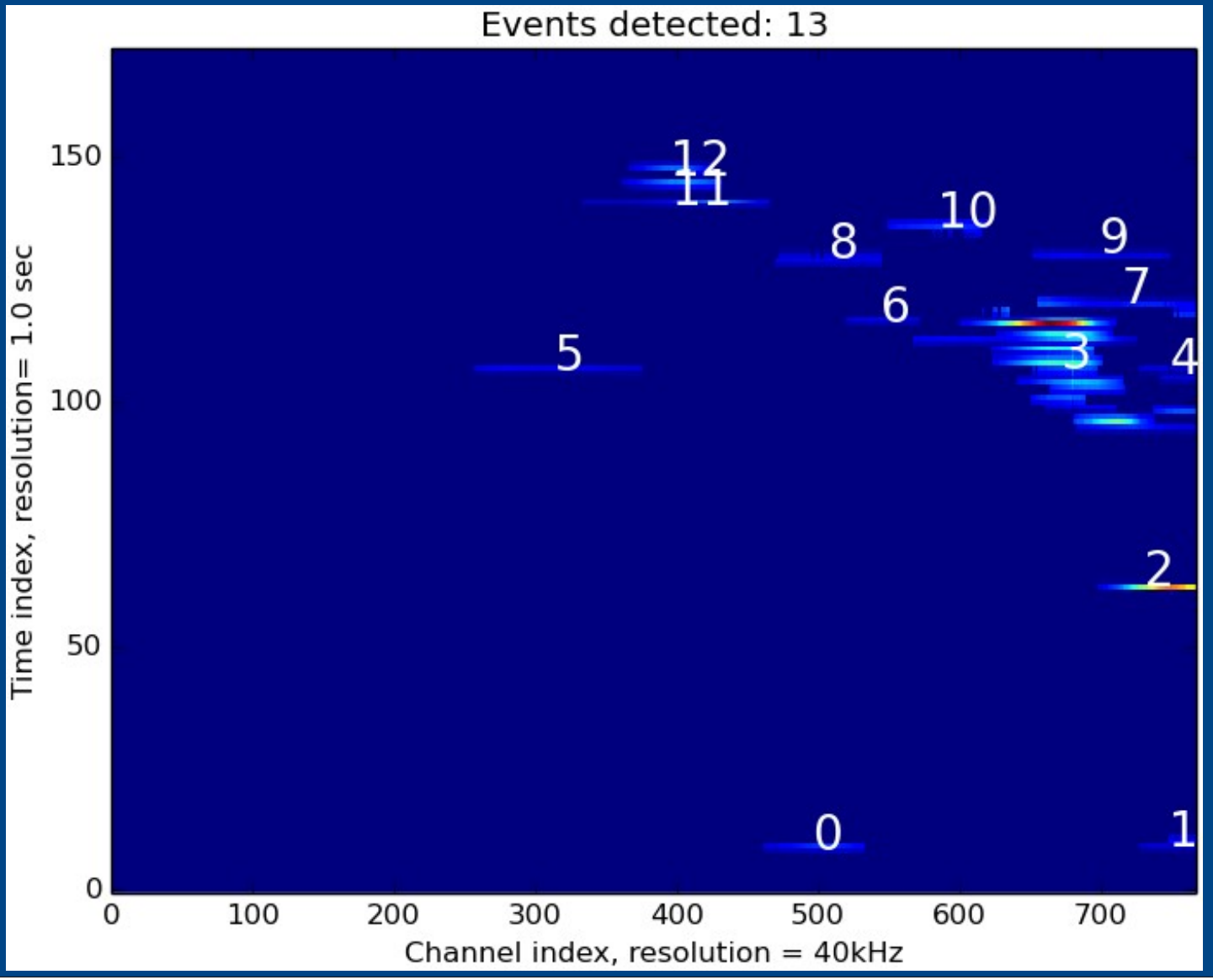


Data courtesy of D. Oberoi

[2a] Region Growing



[2b] Wavelet Decomposition



[3] Database

- Events characterized by time duration, bandwidth, max. intensity, etc.

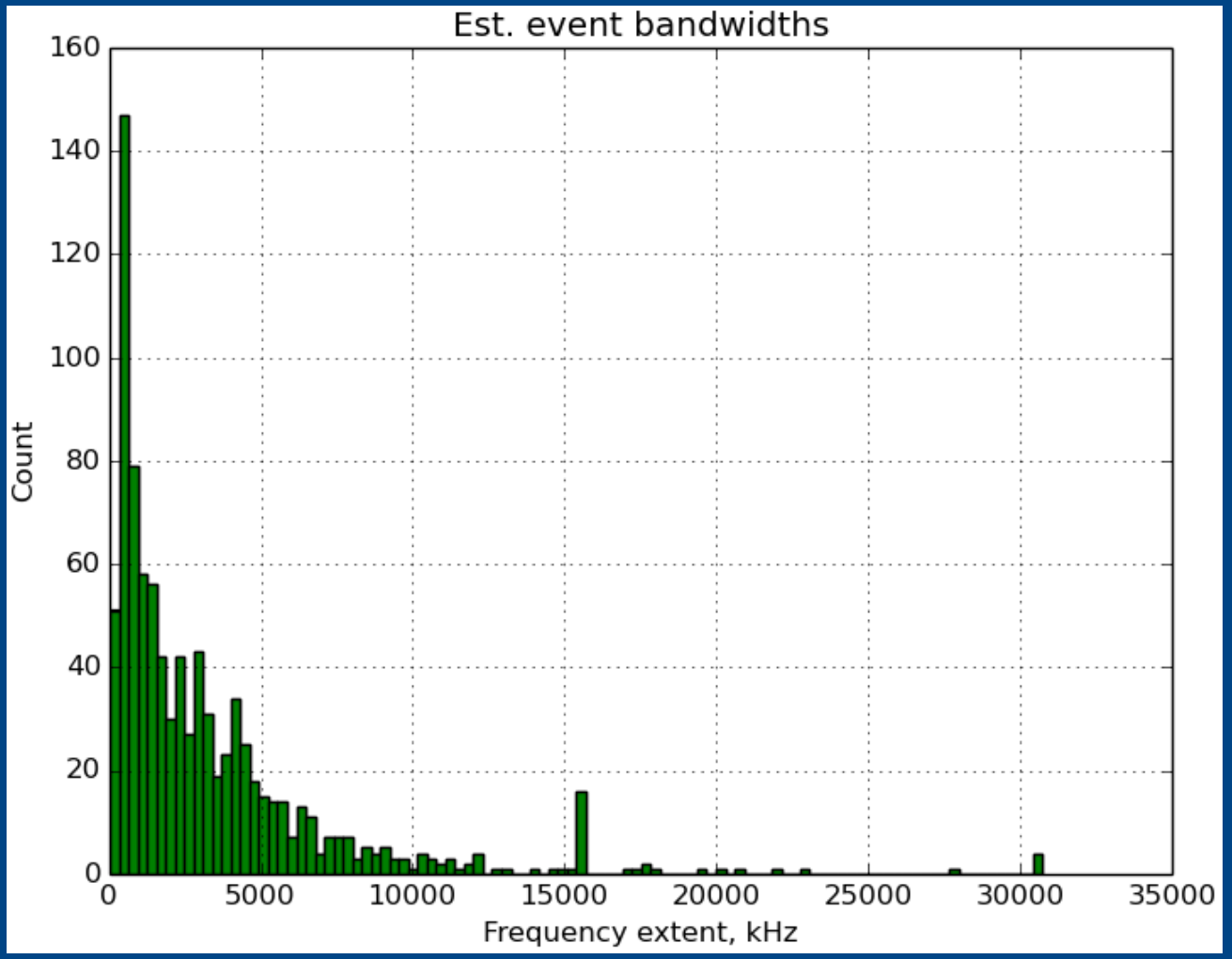
-Logged in query-based database for permanent storage

```
>>> df.head(5)
                      msname  cent_time  cent_freq  deltat   deltaf  \
0  1032149704-%b_T1-3.DS.dat.p  11.652542   0.024777      30  0.00017
1  1032149704-%b_T1-3.DS.dat.p  11.441176   0.030280      26  0.00009
2  1032149704-%b_T1-3.DS.dat.p  14.500000   0.030605      10  0.00021
3  1032149704-%b_T1-3.DS.dat.p  13.260563   0.021787       4  0.00043
4  1032149704-%b_T1-3.DS.dat.p  13.813433   0.023071       4  0.00022

   mean_intensity  max_intensity  freq_point1  freq_point2  freq_point3  \
0        0.023643       0.960097     0.599920     0.619785     0.592757
1       -0.019599       0.841422     0.593024     0.561744     0.554479
2       -0.016459       0.628802     0.542501     0.582737     0.529195
3        0.001167       0.570673     0.542352     0.403601     0.389365
4        0.004670       0.615377     0.545244     0.405549     0.440699

   freq_point4     slope class evindex  ant1  ant2 pol timestamp
0     0.602834  0.000034  None    None     1     3  XX      None
1     0.595576 -0.000018  None    None     1     3  XX      None
2     0.394268 -0.000567  None    None     1     3  XX      None
3     0.540622  0.000334  None    None     1     3  XX      None
4     0.586077 -0.000325  None    None     1     3  XX      None

[5 rows x 18 columns]
```

Compute correlations, other statistics on demand.

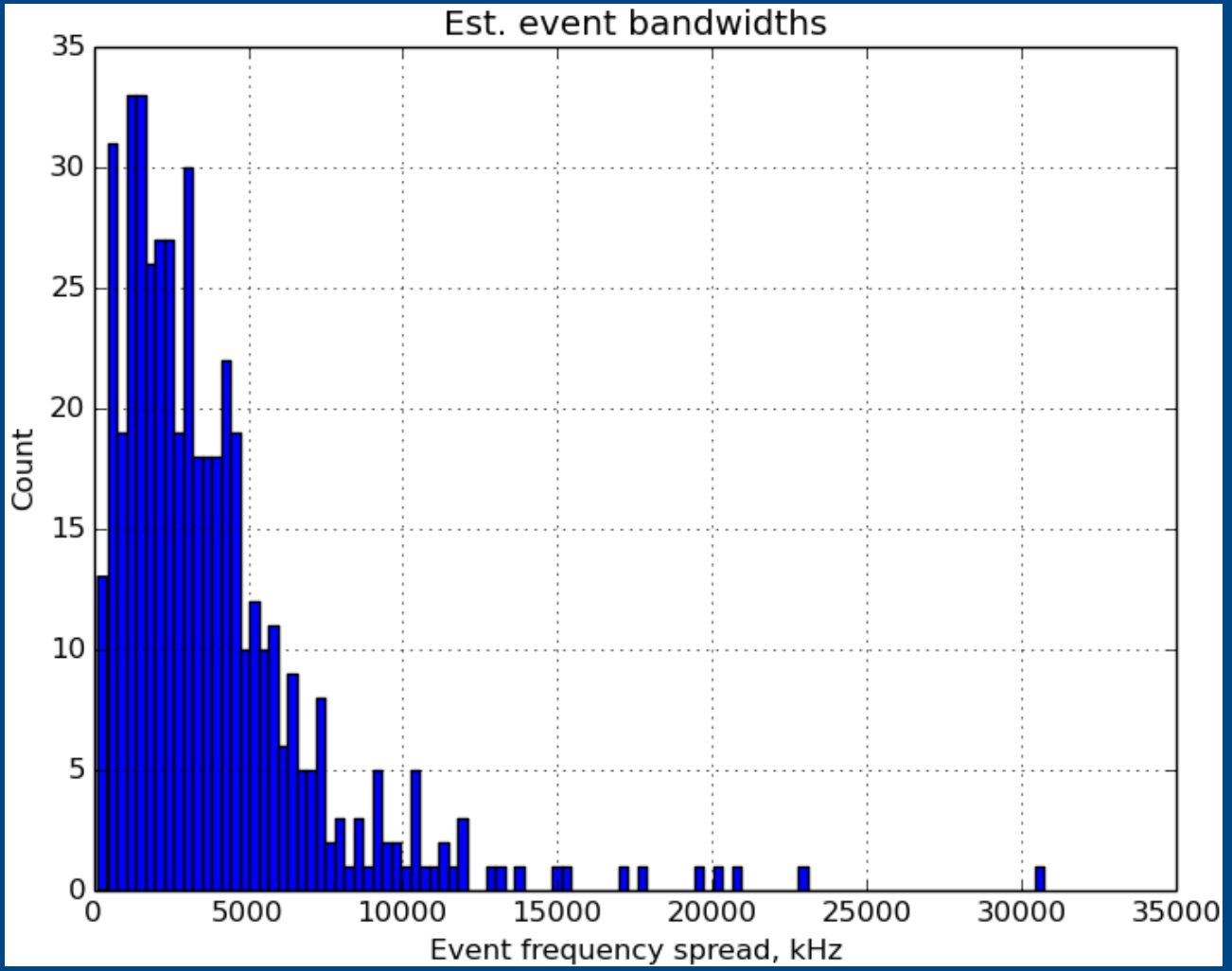
[4] Example: Alpha Commissioning

Region-growing on 53 Alpha sets



[4] Example: Alpha Commissioning

Wavelet decomposition on 73 Alpha sets:



Results

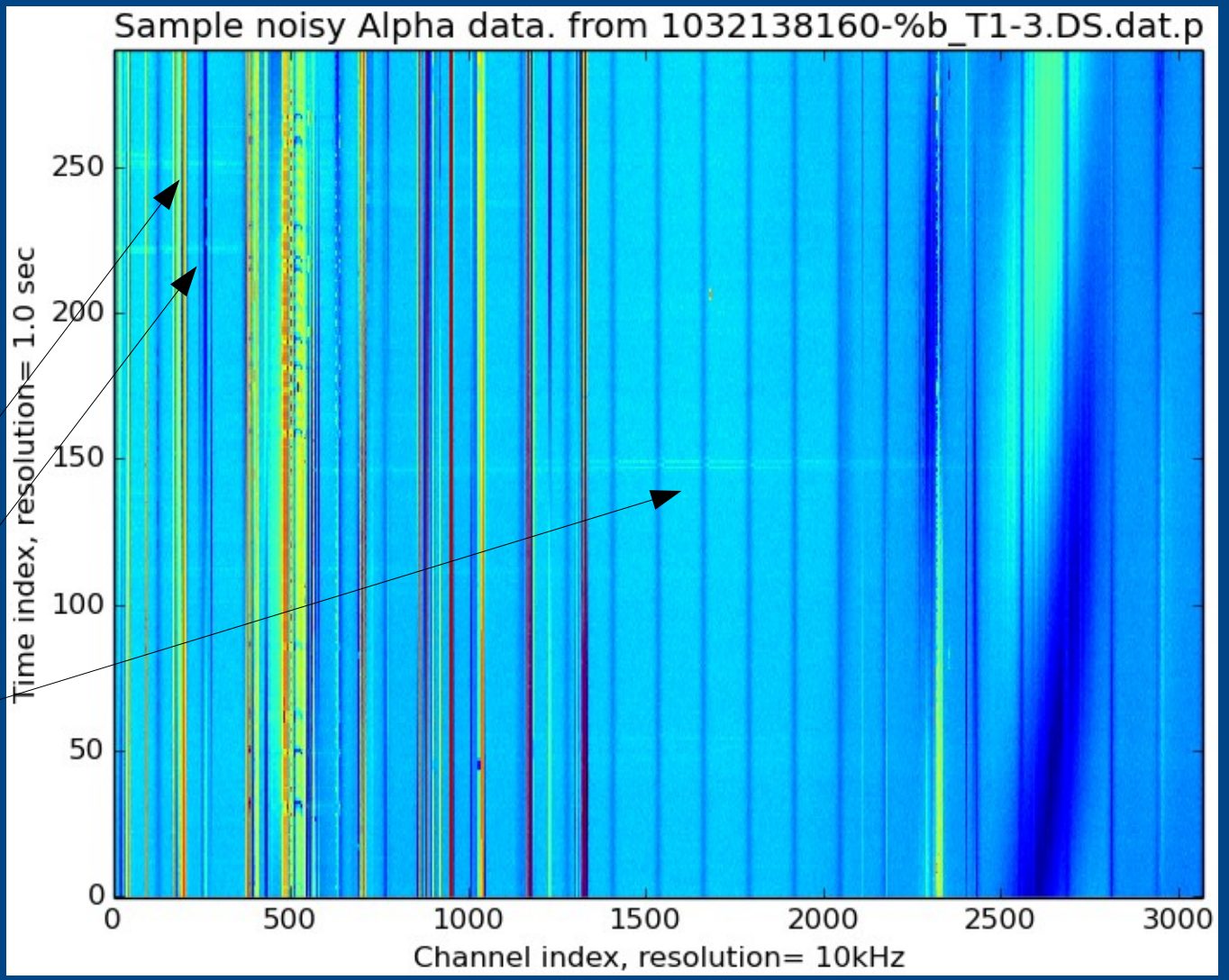
Out of 20 sample Alpha sets:

Alpha Commissioning Success Rates:

Segmentation Type	True Positives	False Positives	False Negatives
Region Growing	56	76	46
Wavelets	59	35	84

No significant correlations in parameters sampled.

Error sources



Significant events

Data courtesy of D. Oberoi

Conclusions

Automated event recording is feasible over a range of solar activity levels, but robust RFI removal is imperative

Segmentation strategies may differ based on activity levels

Future work:

- “Sampling in 4D” & imaging the solar disc
- Application of classification tools
- Robust autoflagging

Acknowledgements

Many thanks to:

- Victor Pankratius, Colin Lonsdale, Divya Oberoi, Roger Cappallo, Phil Erickson, Vincent Fish, Lynn Matthews, Tim Morin, Jason Soohoo, K.T. Paul, Heidi Johnson ...

+ all of Haystack!

-The N.S.F.

References

- (1) Oberoi et al. “First Spectroscopic Imaging Observations of the Sun at Low Radio Frequencies with the Murchison Widefield Array Prototype”. *Astrophysical Journal Letters.* Volume 728, Issue 2, article id. L27, 7 pp. (2011). [8]
- (2) Joachim Köppen @ Institut für Theoretische Physik und Astrophysik der Universität zu Kiel; Personal website.