UNDERSTANDING THE ROLES OF ROTATION, PULSATION AND
CHEMICAL PECULIARITIES IN THE UPPER MAIN SEQUENCE

11th - 16th September 2016, Lake District, UK

UNBIASED ESTIMATION OF A MULTIFREQUENCY SOLUTION IN DELTA SCUTI STARS

Javier Pascual Granado, **Juan Carlos Suárez Yanes**,
Rafael Garrido Haba, and José Ramón Rodón

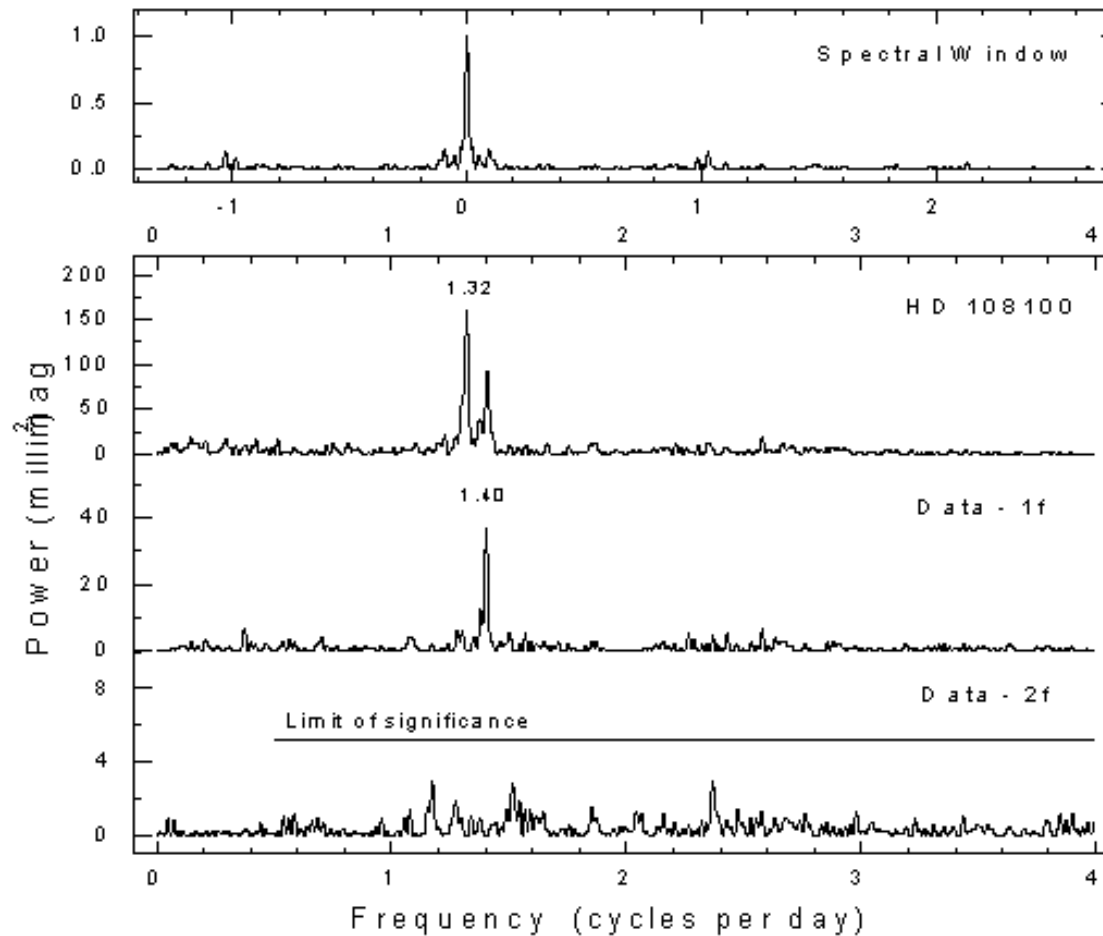# STANDARD ANALYSIS PROCEDURE IN ASTEROSEISMOLOGY

- Pre-processing: removal of systematics, outliers, de-trending, etc.

- Pre-whitening cascade – CLEAN method, SigSpec, etc.

- Filtering harmonics, combinations and/or spurious frequencies.

- Characterization of the spectrum: $\Delta\nu$, ν_{max}, σ
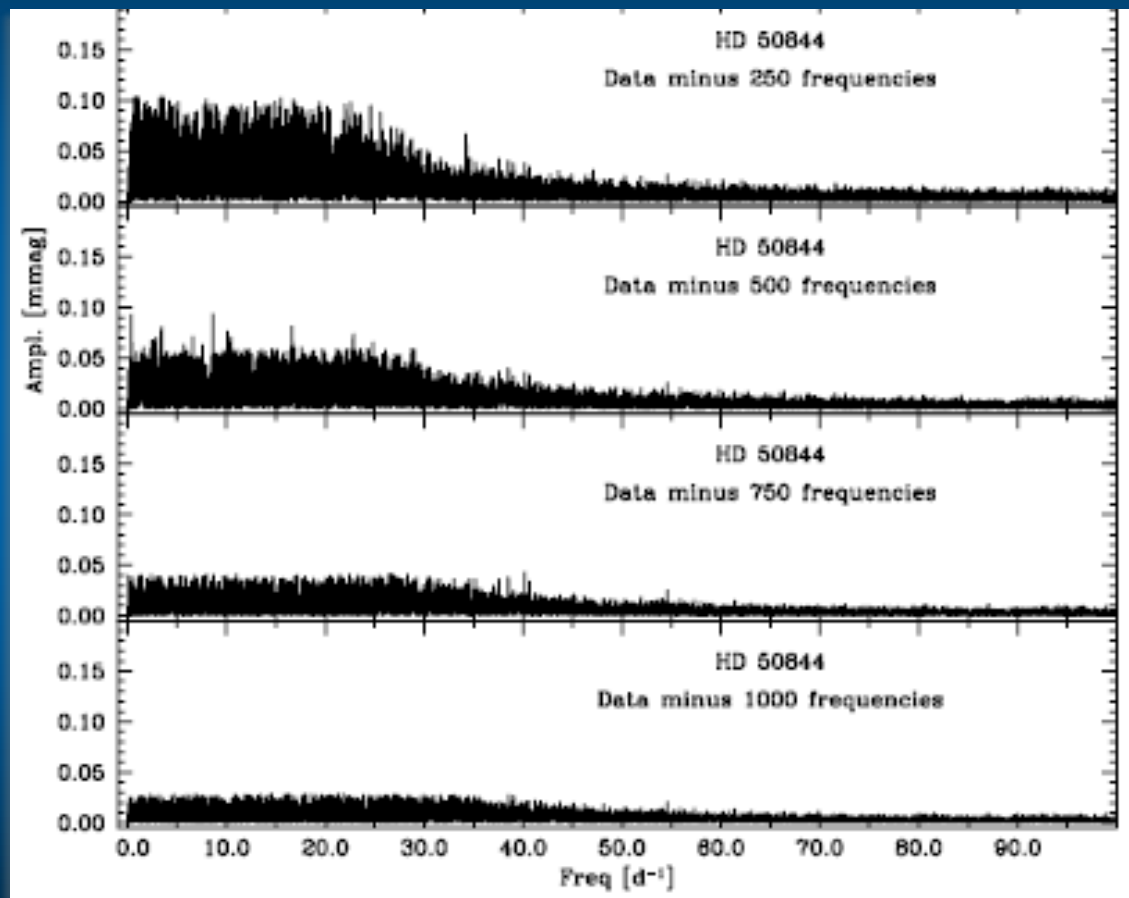
- Model fitting

PRE-WHITENING

PRE-WHITENING

Breger, M., Handler, G., Garrido, R., et al. 1996, DSN, 10, p.24

HD 50844: an interpretation challenge

Poretti et al. 2009, A&A, 506, 85-93

- More than a thousands of frequencies detected.

- The residuals of the prewhitening sequence are not white noise (plateau)

Also HD 50870, HD49434, …

AIMS

Impact of pre-whitening on frequency detection

➢ Gapped data

➢ ARMA interpolation: preserving the original frequency content

  Pascual-Granado, J., Garrido, R., and Suárez, J. C. 2015, A&A, 575, A78

➢ Linear interpolation: non-preserving the original frequency content

THE SAMPLE

CoRoT seismofield data. Why CoRoT?

CoRoT seismofield observations have
~twice the cadence of Kepler SC

Advantages of higher cadence data:

- increased sampling rate
- higher Nyquist frequency
- fewer low-frequency artefacts

- **reduced errors on frequency, amplitude and phase determinations in the Fourier spectrum**

Murphy, Simon J., 2012, MNRAS, 422 (1), 665-671

THE SAMPLE

Run	HD	ID	Star	SpT	mv	$\log T_{\text{eff}}$	V	$v \sin i$
IRa01	50844	123	A/F D Scu	A2	9.1	3,88	1,31	64
SRc01	174936	7613	A/F D Scu	A2	8.58	3,9	1,88	170
SRc01	174966	7528	A/F D Scu	A3	7.72	3,88	1,95	125
LRc01	181555	8669	A/F D Scu	A5 V	7.52	3,85	2,19	200
LRa01	49434	100	G Dor	F1 V	5.75	3,86	2,74	-
LRc02	172189	8170	A/F D Scu	A2	8.73	3,89	1	-
SRc02	174532	7655	A/F D Scu	A2	6.90	3,86	1,38	-
SRc02	174589	7663	A/F D Scu	F2 III	6.09	3,85	1,45	100
LRa02	51722	1022	A/F D Scu	A5	7.53	3,86	1,13	127
LRa02	51359	1320	A/F D Scu	A5	8.50	3,9	0,89	-
LRa02	50870	546	A/F D Scu	F0	8.88	3,88	1,67	17
LRc0506	170699	8301	A/F D Scu	A2	6,95	3,88	1,49	-
IRLRa04	GSC00144-03031	21960	A/F D Scu	A8	10,1	-	-	-
IRLRa05	41641	5685	A/F D Scu	A5	7,9	3,882	1,92	28
SRa05	48784	3619	A/F D Scu	F0	6,66	3,84	1,87	108

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(Gdor — annotation marked on LRa01 row, HD 49434)

9

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Binarity

THE SAMPLE

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AIMS

<u>Study of the impact of pre-whitening techniques used for frequency detection on asteroseismology</u>

Three datasets are used:

➢ Gapped data

➢ ARMA interpolation: preserving the original frequency content

   Pascual-Granado, J., Garrido, R., and Suárez, J. C. 2015, A&A, 575, A78

➢ Linear interpolation: non-preserving the original frequency content

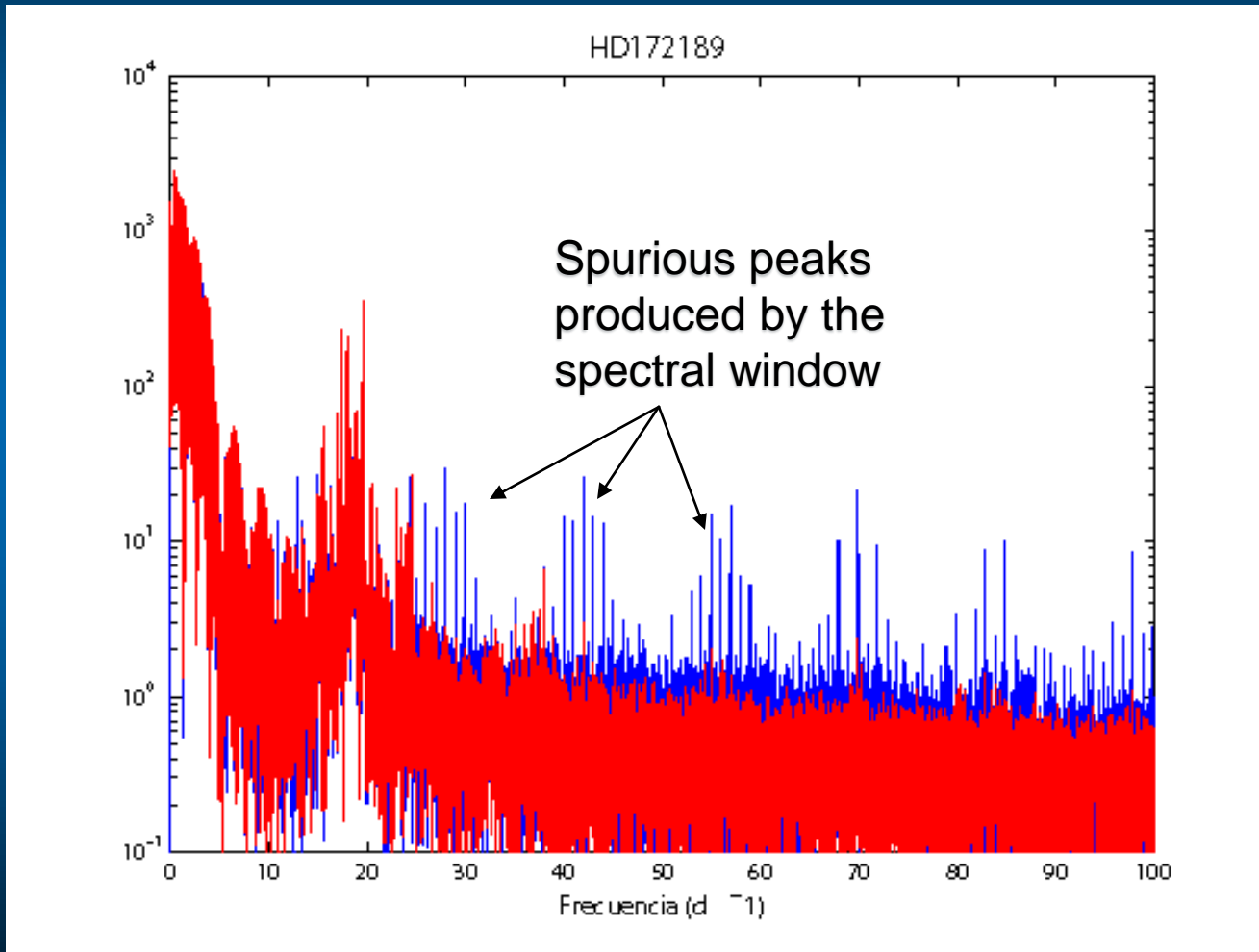# Wrong data produced by the South Atlantic Anomaly
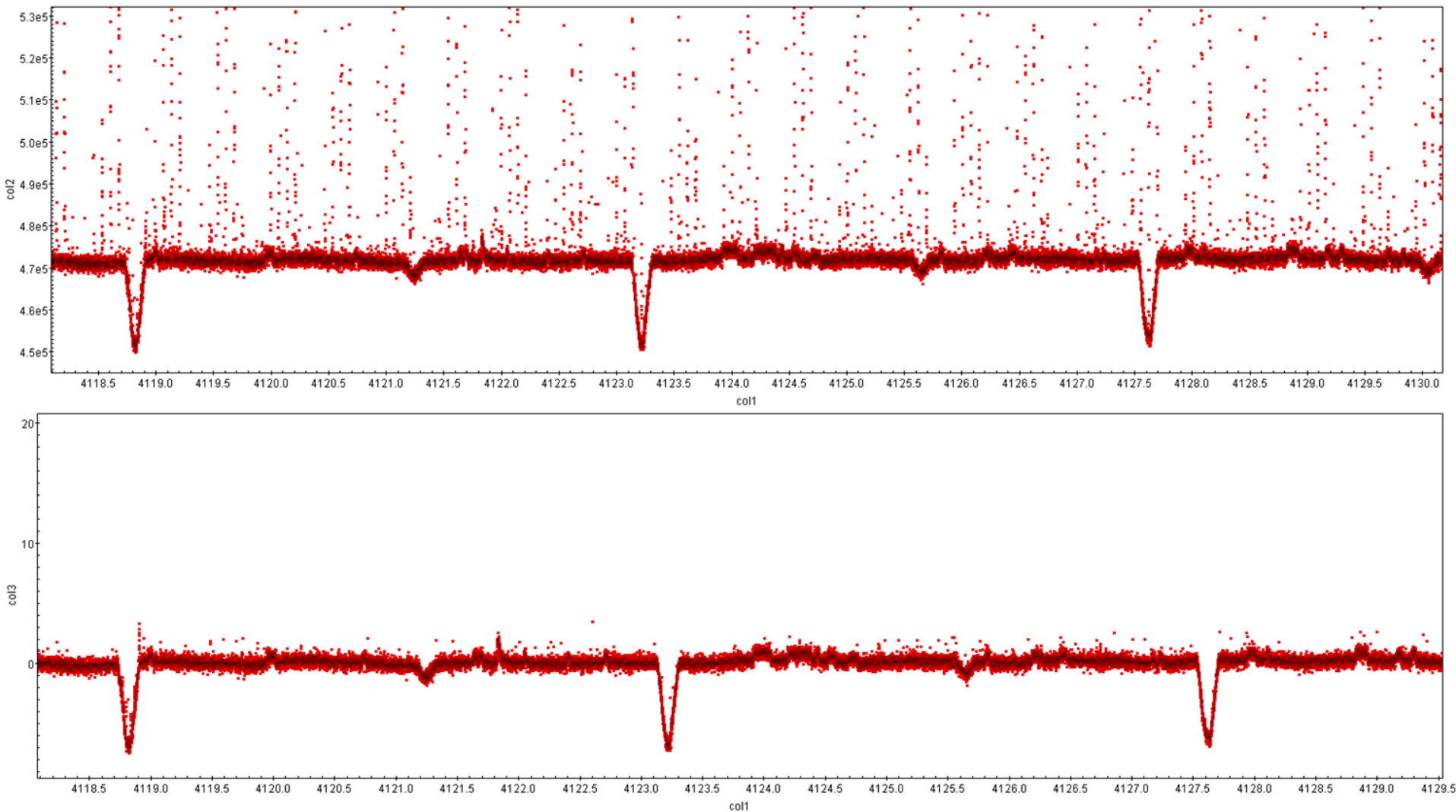
INTERPOLATION: HD170699
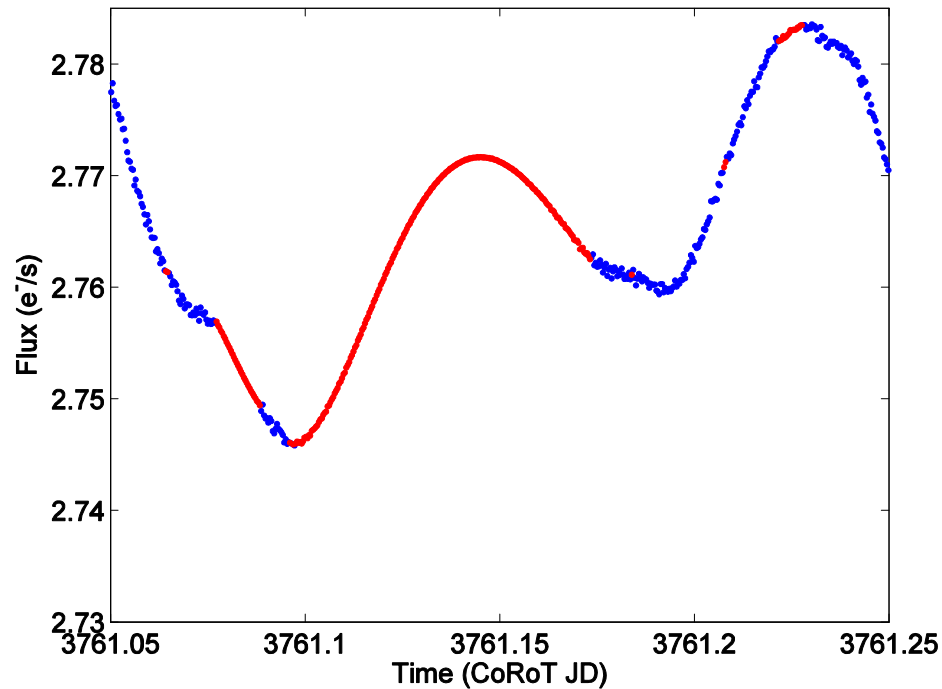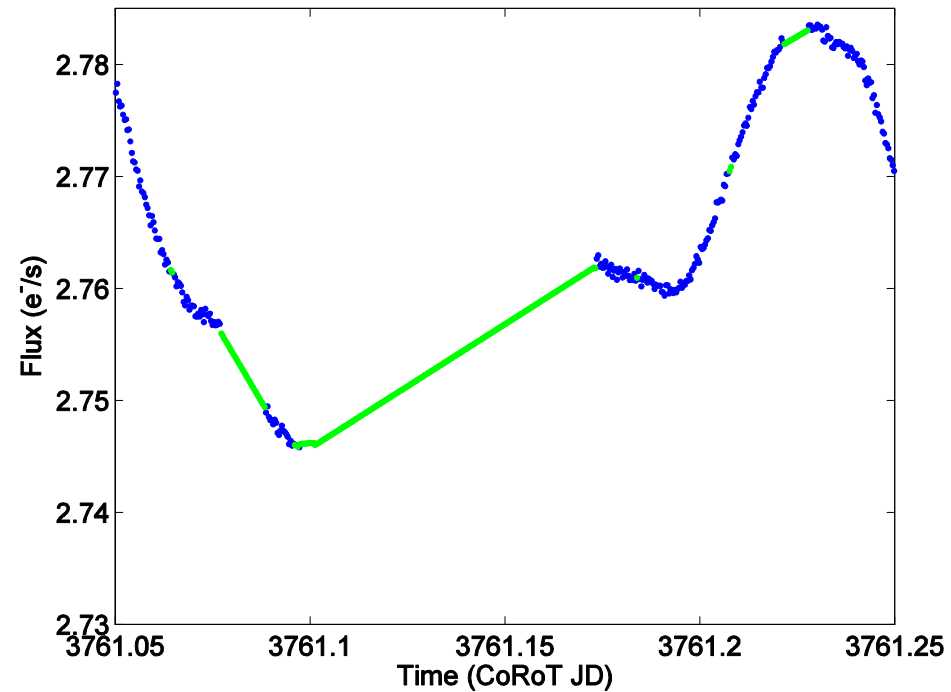
CoRoT passing through the SAA introduce spurious peaks

FREQUENCY DETECTION: SIGSPEC

Reegen, P. 2007, A&A, 467, pp.1353-1371

Iterative process consisting of four steps:

1. Computation of the significance spectrum.

2. Exact determination of the peak with maximum significance.

3. MultiSine least-squares fit of the frequencies, amplitudes and phases of all significant signal components detected so far.

4. Pre-whitening of the sinusoidal components. The residuals are used as input for the next iteration.

COMBINATIONS FILTERING

- The procedure followed is similar to

  García Hernández, A., Moya, A., Michel, E. et al. 2013, A&A, A63, 14

- Independent freqs. used to find combinations with Combine from Reegen, P.

  Reegen, P., 2011, CoAst, 163, p.119

- Harmonics and combinations up to 3rd order within a 1/Tobs interval.

- A set of 12 independent freqs. Is used, harmonics until the 5th order, and combinations $AF_a + BF_b$ being A, B = [1,3].

- Interactions with the satellite orbital freq. (f_s = 13.972 d^{-1}) for F1 to F4 and the 4 first harmonics of f_s.

- Sidelobes of the 1 d^{-1} alias around f_s and its harmonics.

RESULTS: HISTOGRAM OF FREQUENCIES
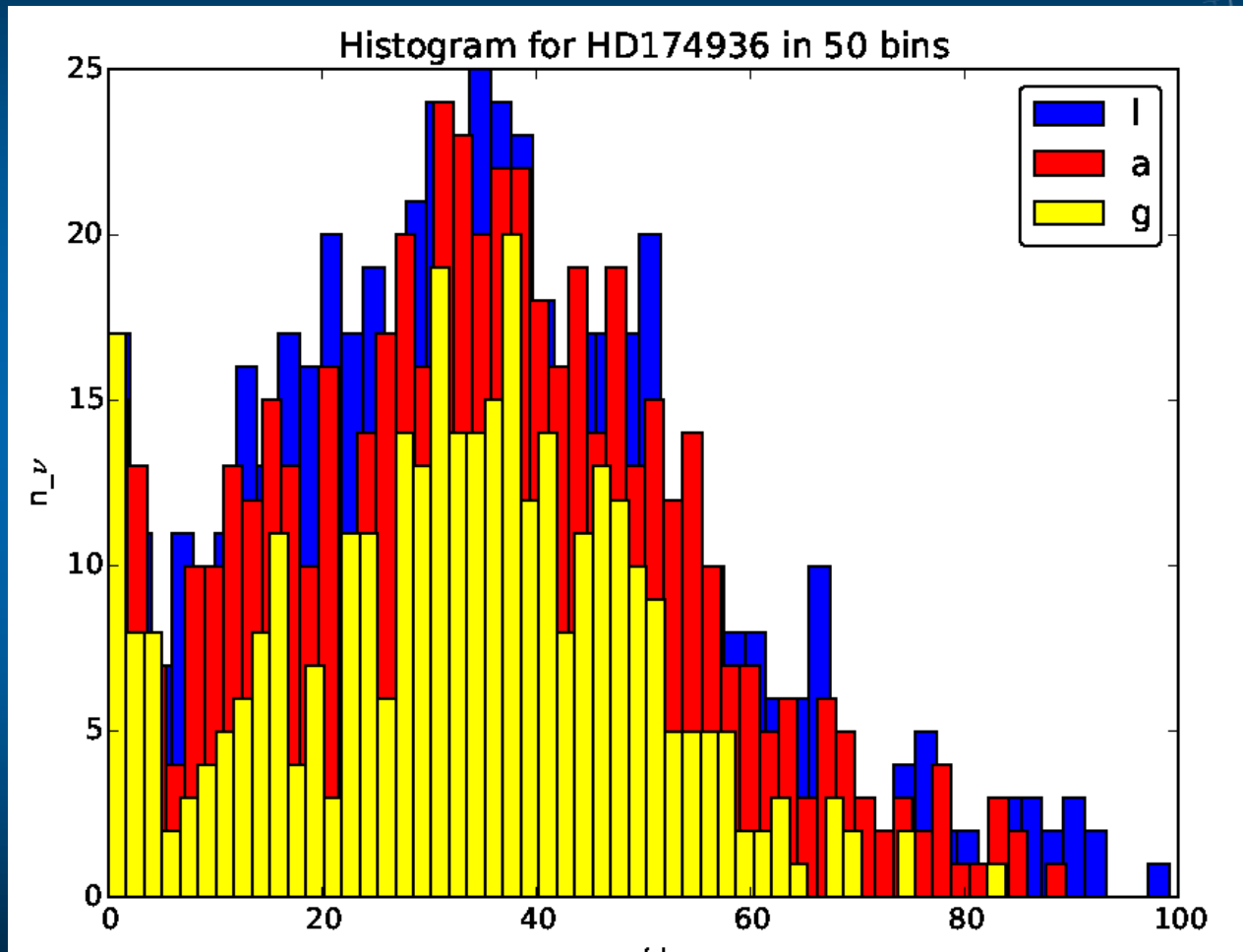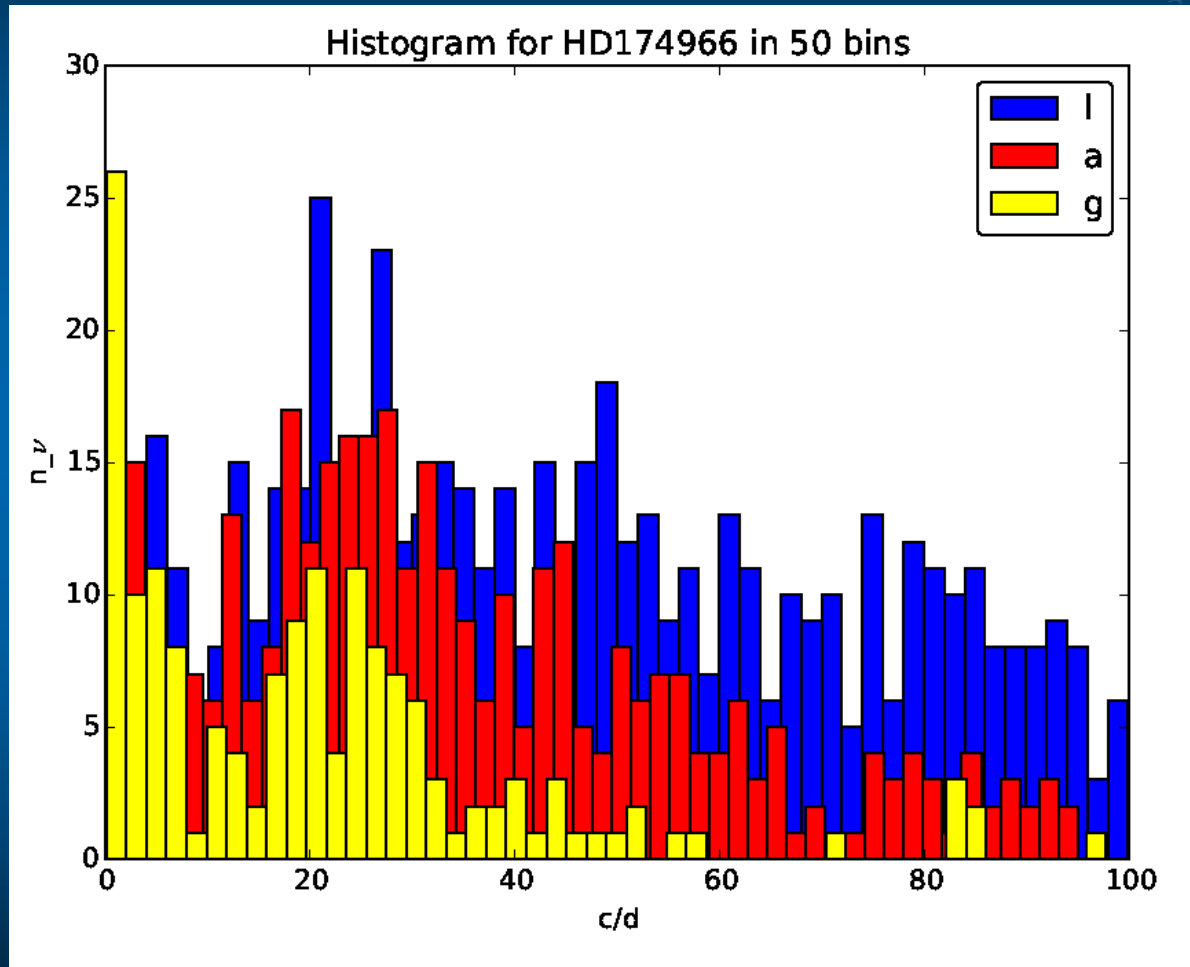
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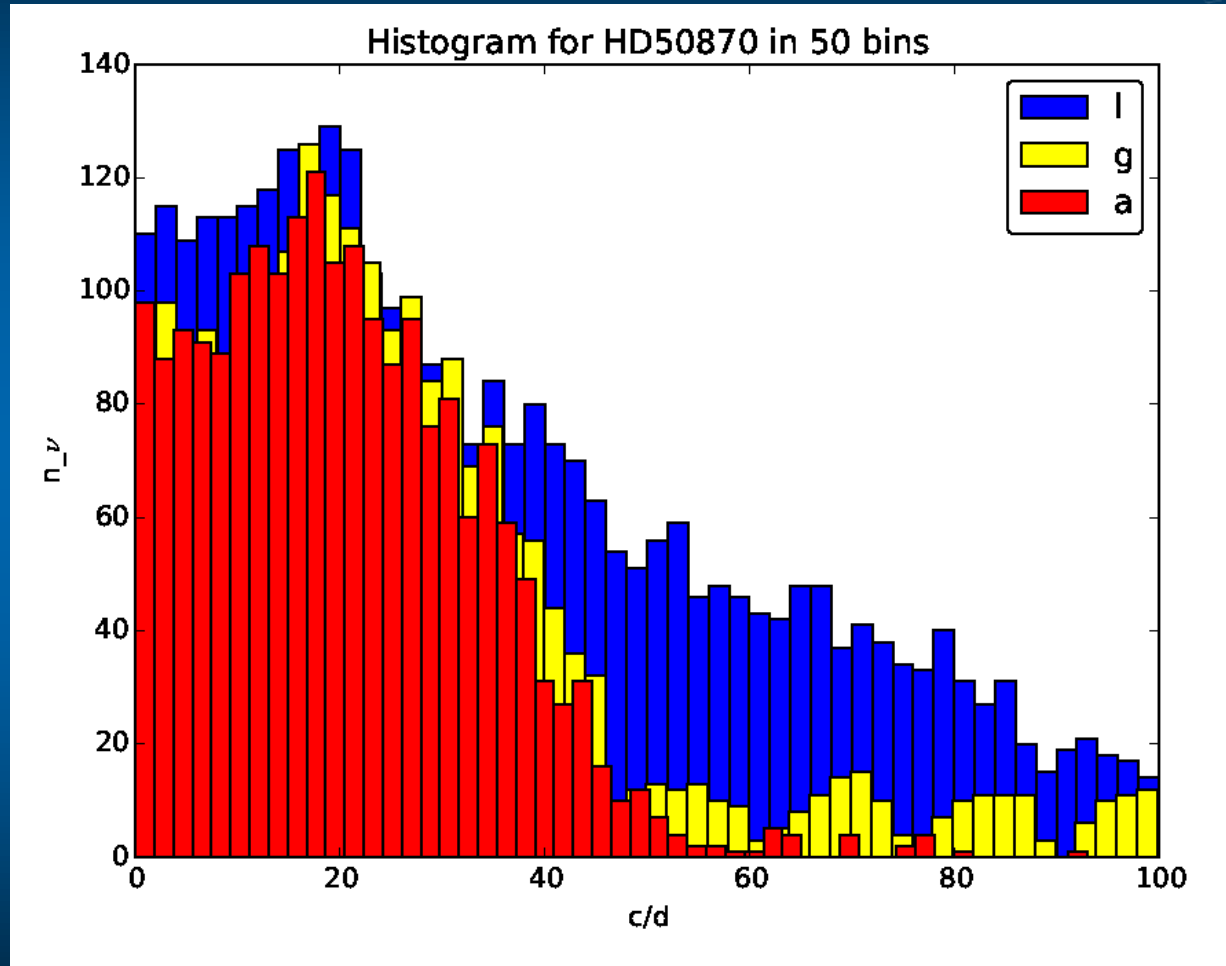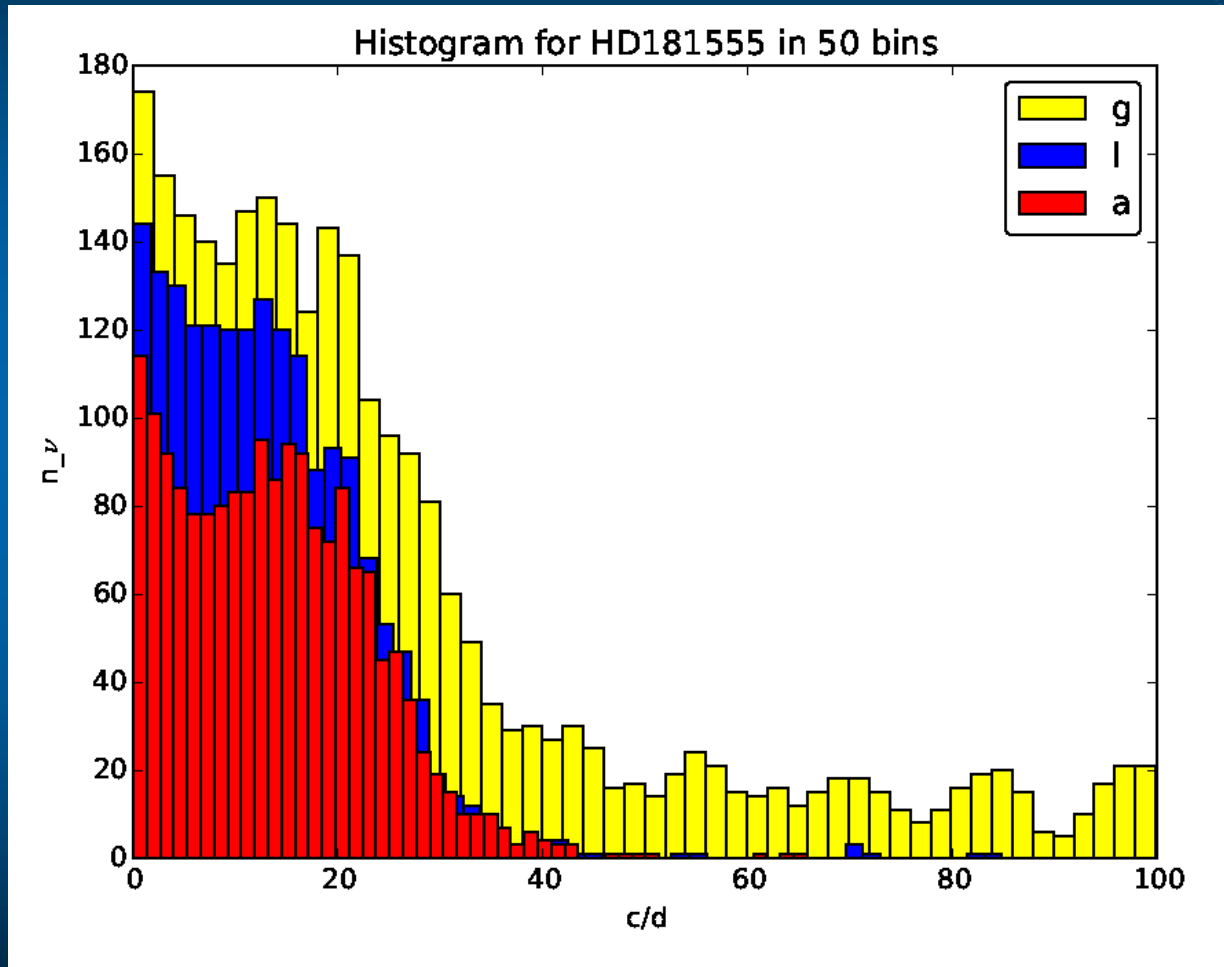

Histogram for HD174966 in 50 bins

RESULTS: HISTOGRAM OF FREQUENCIES

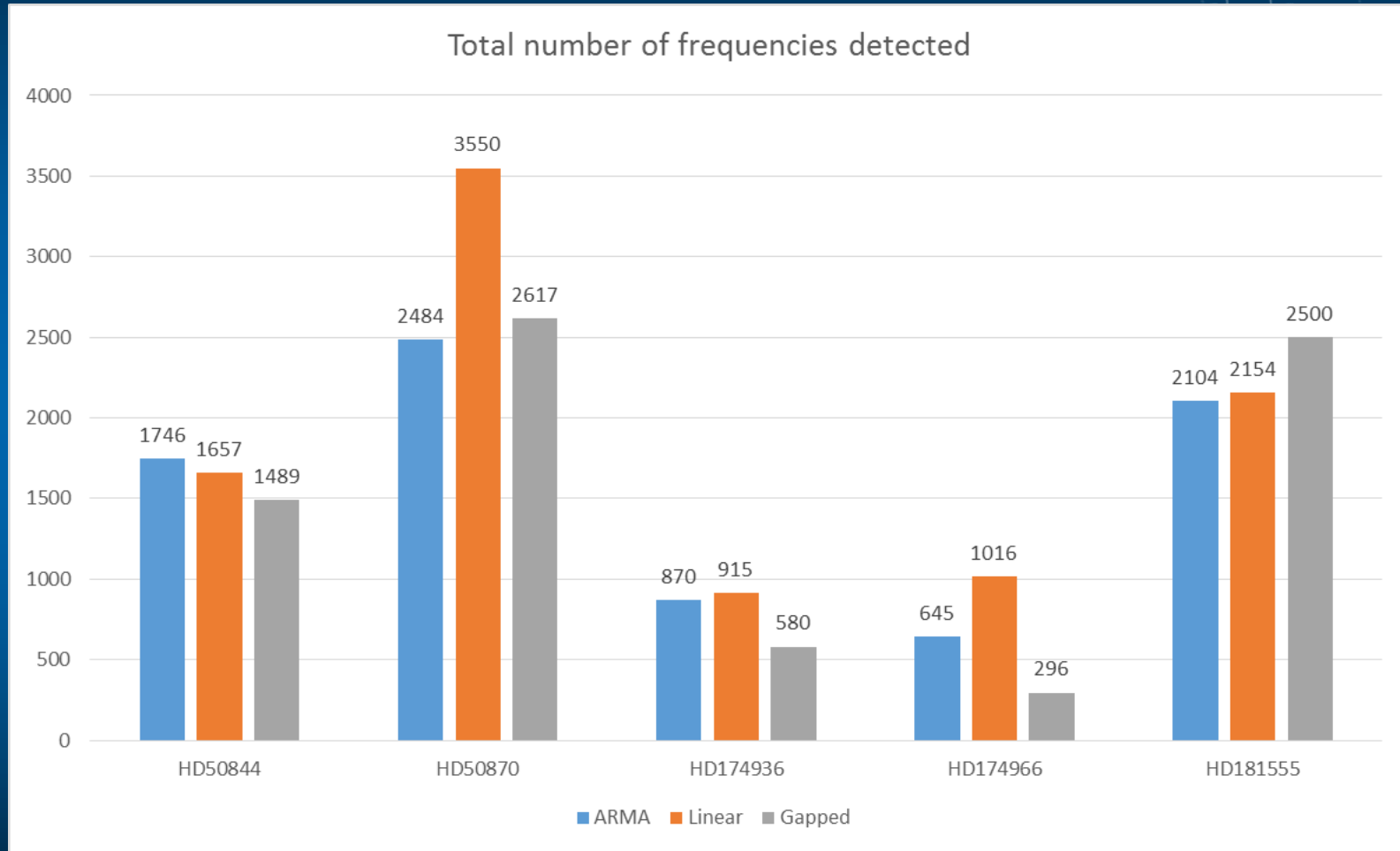# RESULTS: HISTOGRAM OF FREQUENCIES

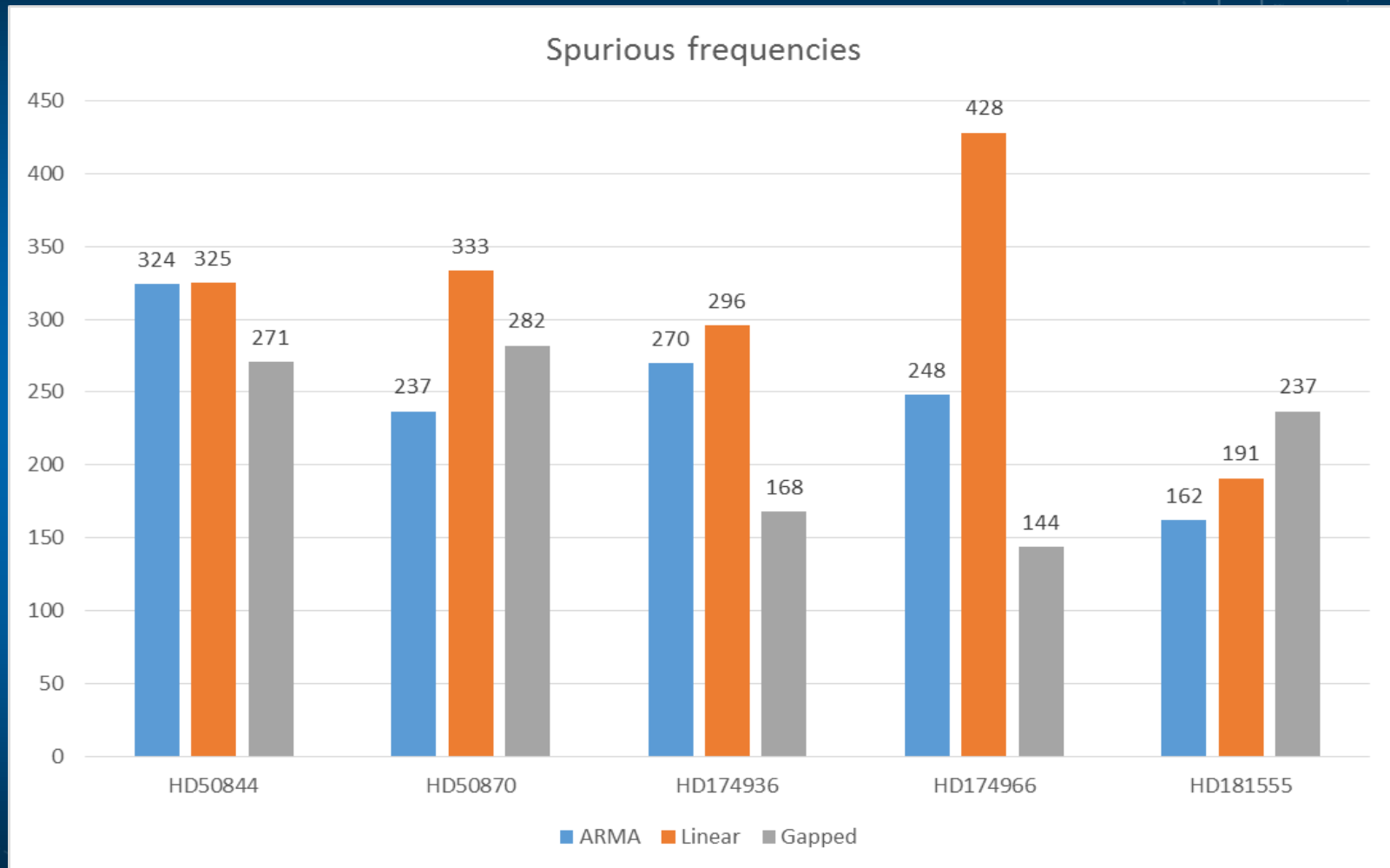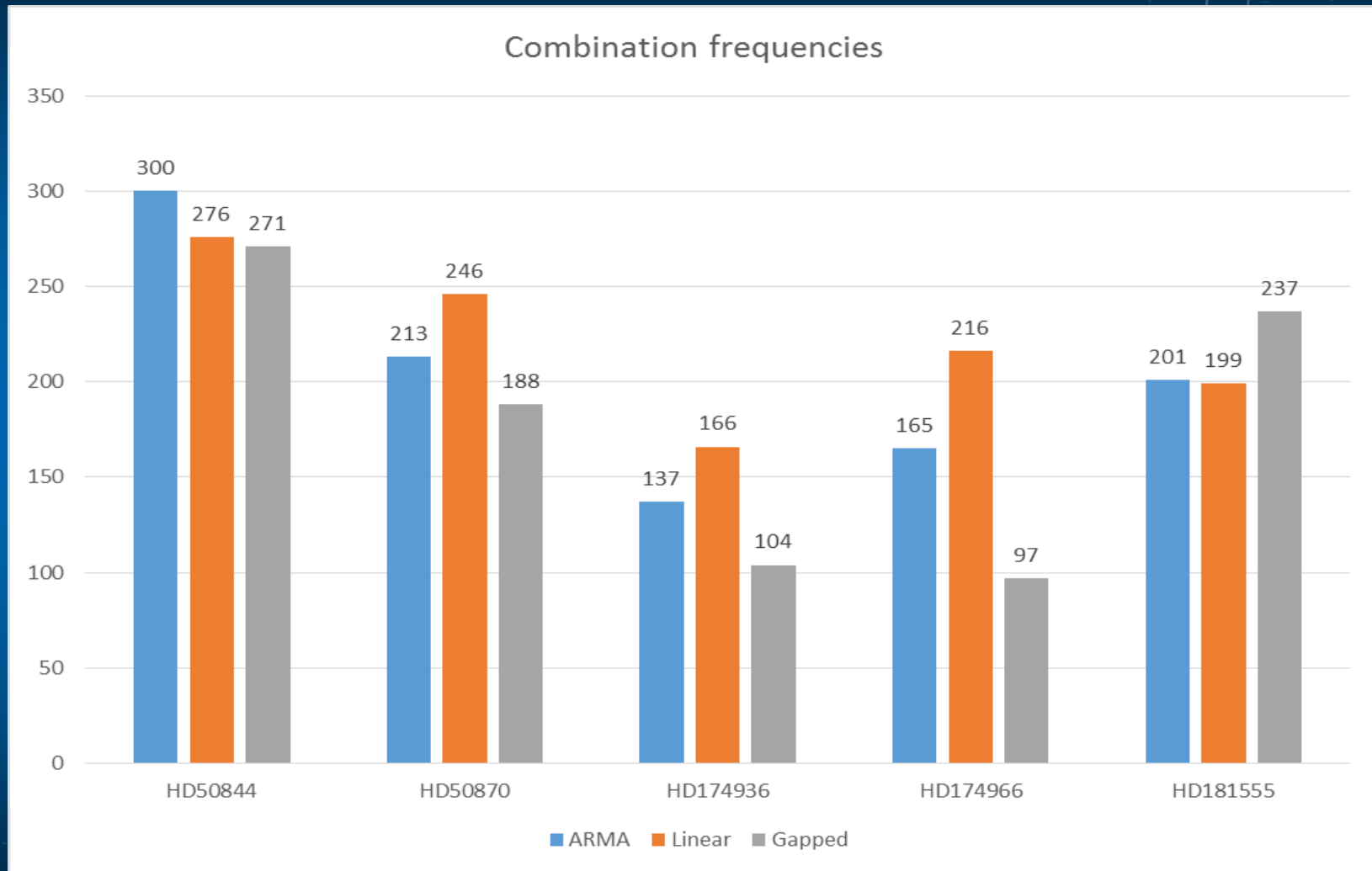# RESULTS: HISTOGRAM OF FREQUENCIES

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Total number of frequencies detected
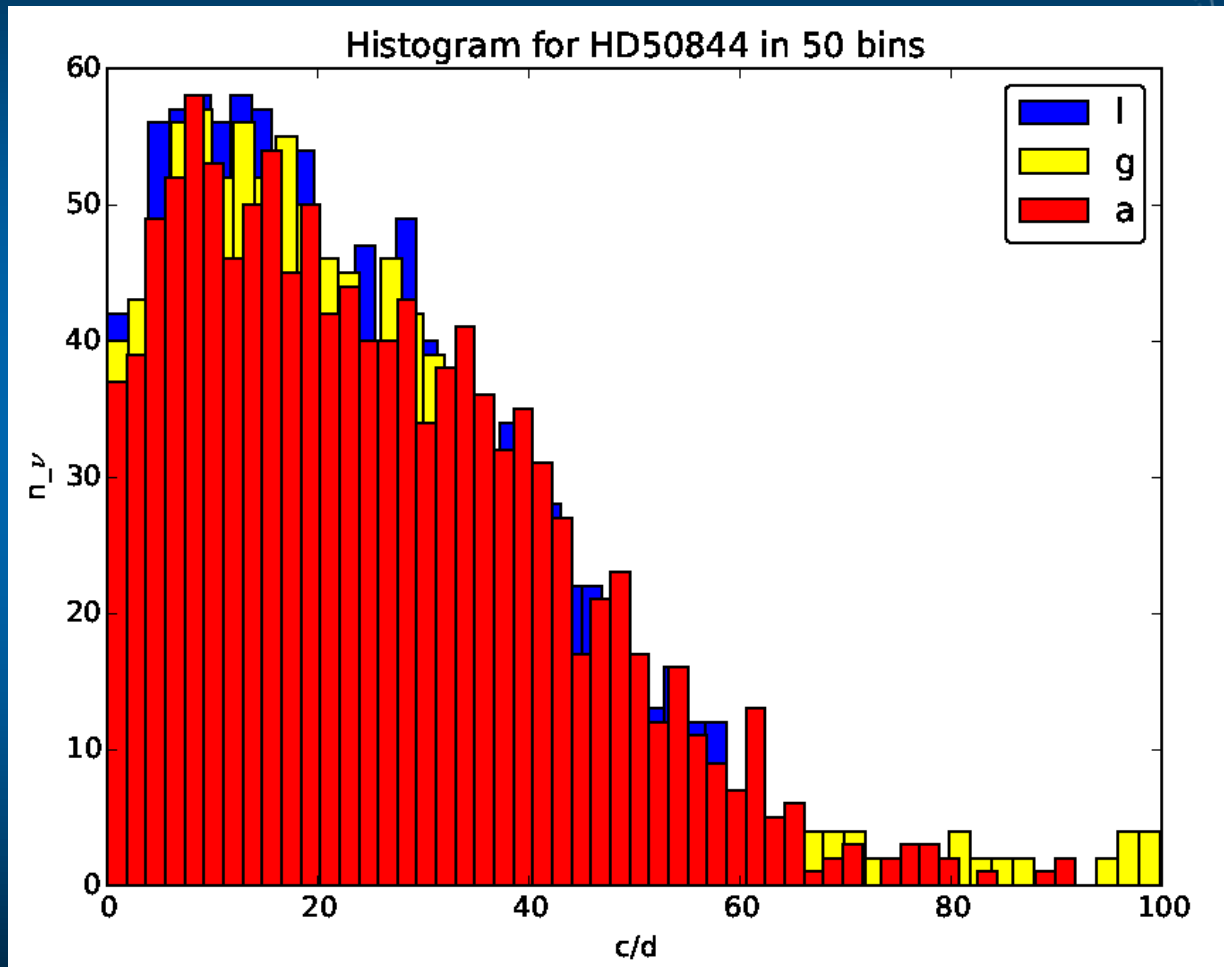
RESULTS: HISTOGRAM OF FREQUENCIES

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Combination frequencies

IN SUMMARY

Expectations from prewhitening

This is what actually happens

CONCLUSIONS

- Prewhitening techniques (CLEAN) are not always reliable.

- An unbiased estimator of the frequency spectrum is not guaranteed when classical prewhitening techniques are used.

More info on this:

Limits in the application of harmonic analysis to pulsating stars
Pascual-Granado, J., Garrido, R., Suárez, J. C., 2015, A&A, 581, A89