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Mysteries of a Variable Star: β Cas, a Time-series Spectroscopical Analysis

Ana-Maria Stanciu
Under the supervision of Prof. Dr. Konstanze Zwintz
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Beta Cas

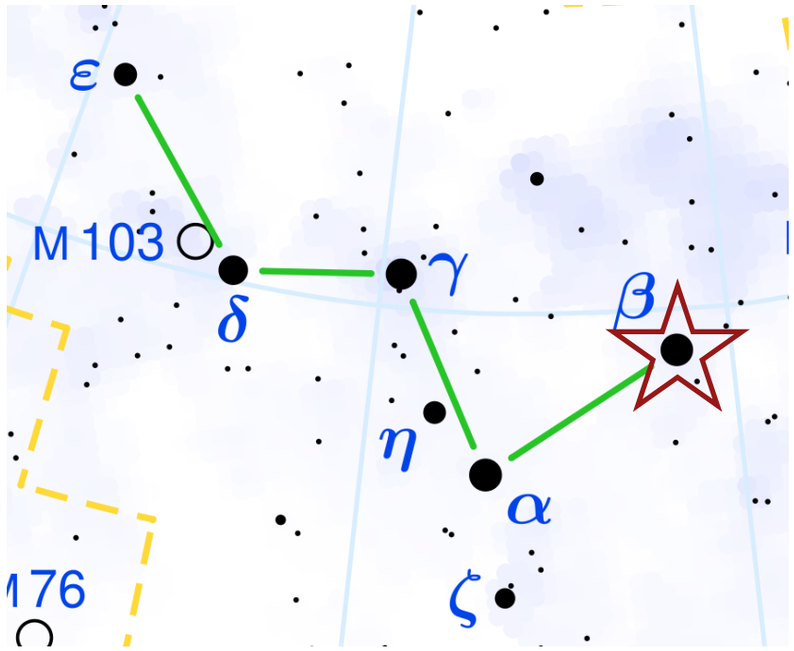

Fig. 1: Cassiopeia constellation

- Spectral type: F2
  (end of main sequence lifetime);
- Retired main sequence A type star;
- Initially: monoperiodic pulsator;
- Extremely fast rotator: 92% of critical speed

Parameter		err_1	err_2	Che et al. (2011)		Gray et al. (2003)
				Model 1	Model 2	
$T_{\rm eff}$ [K]	6920	35	140	6825	6897	6915
$\log g$ [dex]	3.53	0.16	0.58	3.57	3.59	3.49
$[M/H]$	−0.11	0.04	0.12			−0.02
$\upsilon_{\rm e} \sin i$ [km s^{-1}]	73.6	8.1	7.0	72.4	79.8	
$\upsilon_{\rm mic}$ [km s^{-1}]	4.1	0.4	0.5			3.1

Fig. 2: Beta Cas stellar parameters, Zwintz et al., 2020

Beta Cas

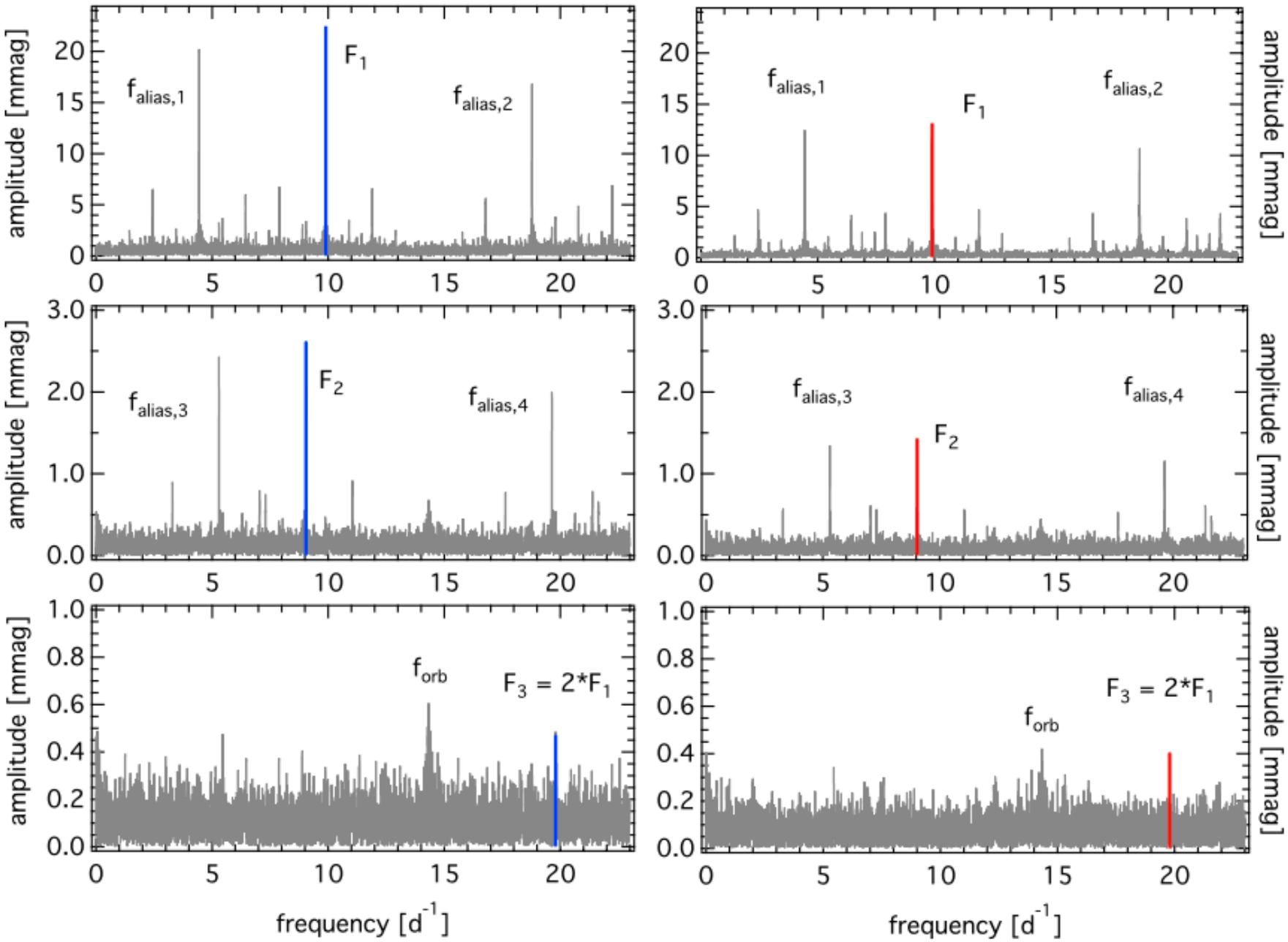

Fig. 3: BRITE frequencies of Beta Cas, Zwintz et al., 2020

Beta Cas

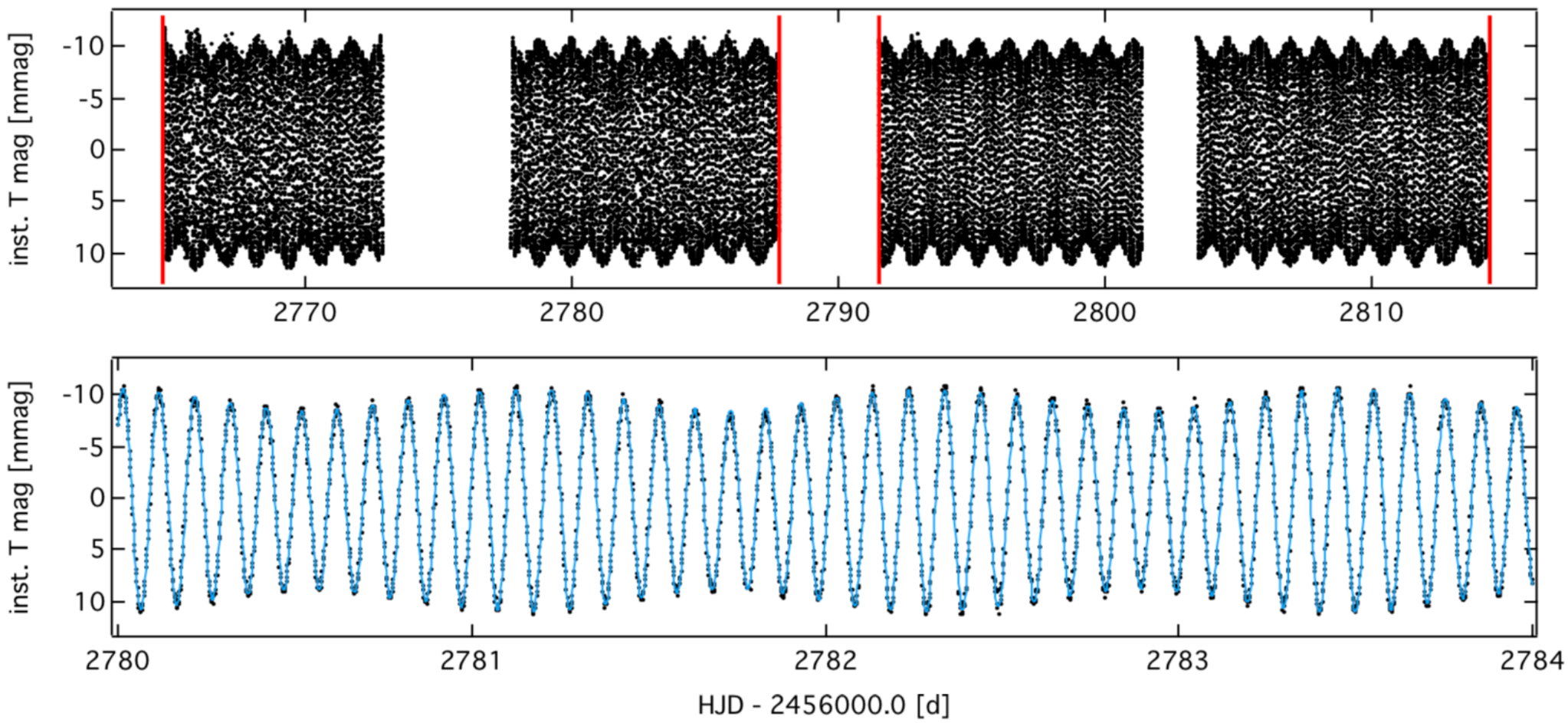

Fig. 4: TESS light curve of Beta Cas, Zwintz et al., 2020

Beta Cas

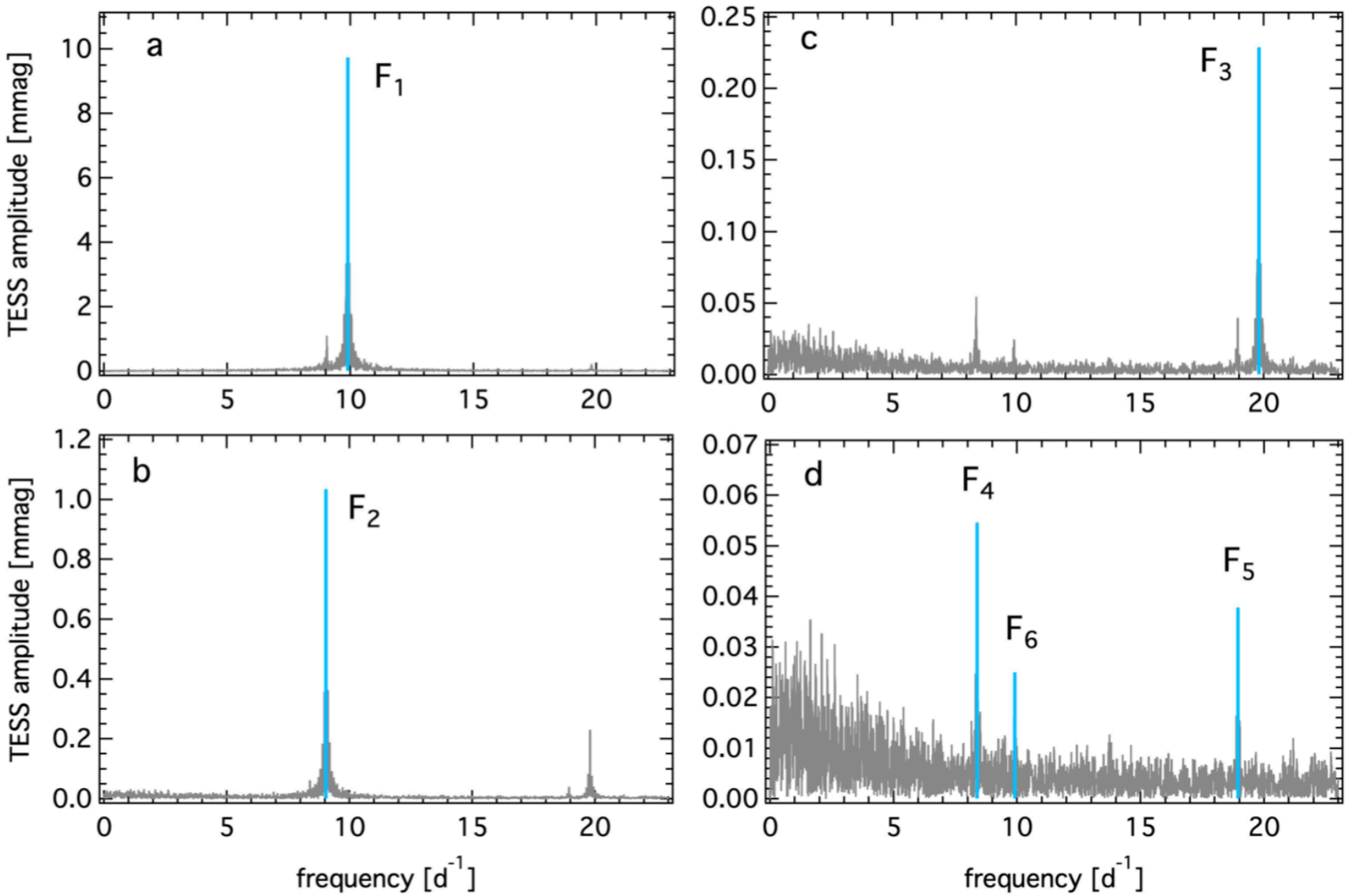

Fig. 5: TESS frequencies of Beta Cas, Zwintz et al., 2020

Beta Cas

- Data obtained through the BRITE spectropolarimetry survey;
- Zeeman-Doppler Imaging technique, on data from Narval;
- Poloidal magnetic field (65% of the energy is in poloidal modes);
- Rotational period: 0.868 d.

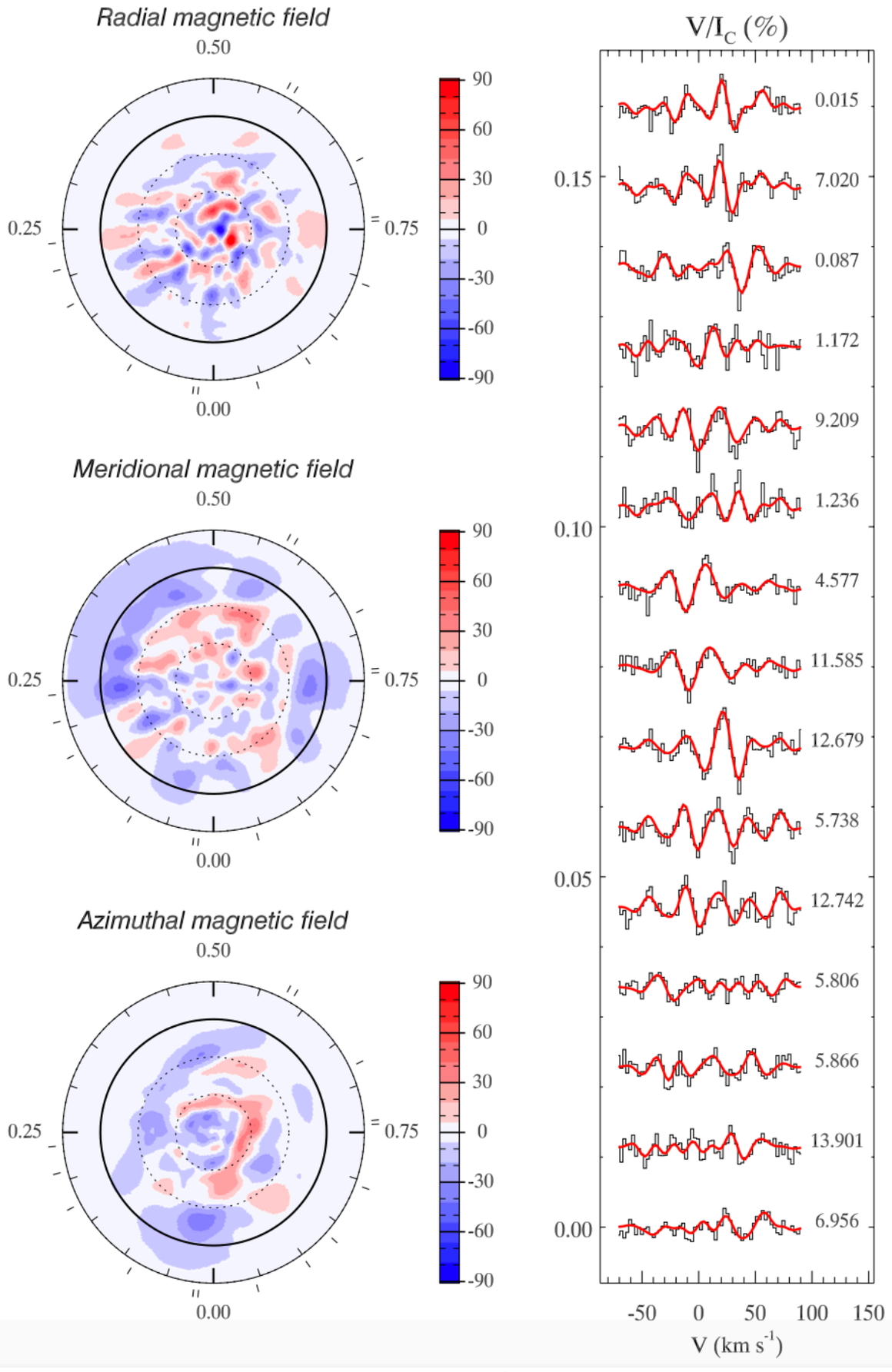

Fig. 6: Magnetic field maps of Beta Cas, Zwintz et al., 2020

SONG observations

- SONG telescope @ Tenerife (Proposal by Beck, Zwintz et al. 2018)

- 497 spectra obtained from Nov. 16th to Nov. 30, 2018

- Total time base: 15 days;

- Range of observations: 4350 Å to 6850 Å.

Spectroscopical Point of View

Mode ID, ideal scenario:

- Deep, narrow lines;
- Unblended lines, but no H or He;
- SNR > 200;
- R > 40000.

Mode ID, β Cas scenario:

- Wide, shallow lines; ✗
- Unblended Ca I & Fe I; ✓
- SNR > 200; ✓
- R > 40000. ✓

Spectroscopical Point of View

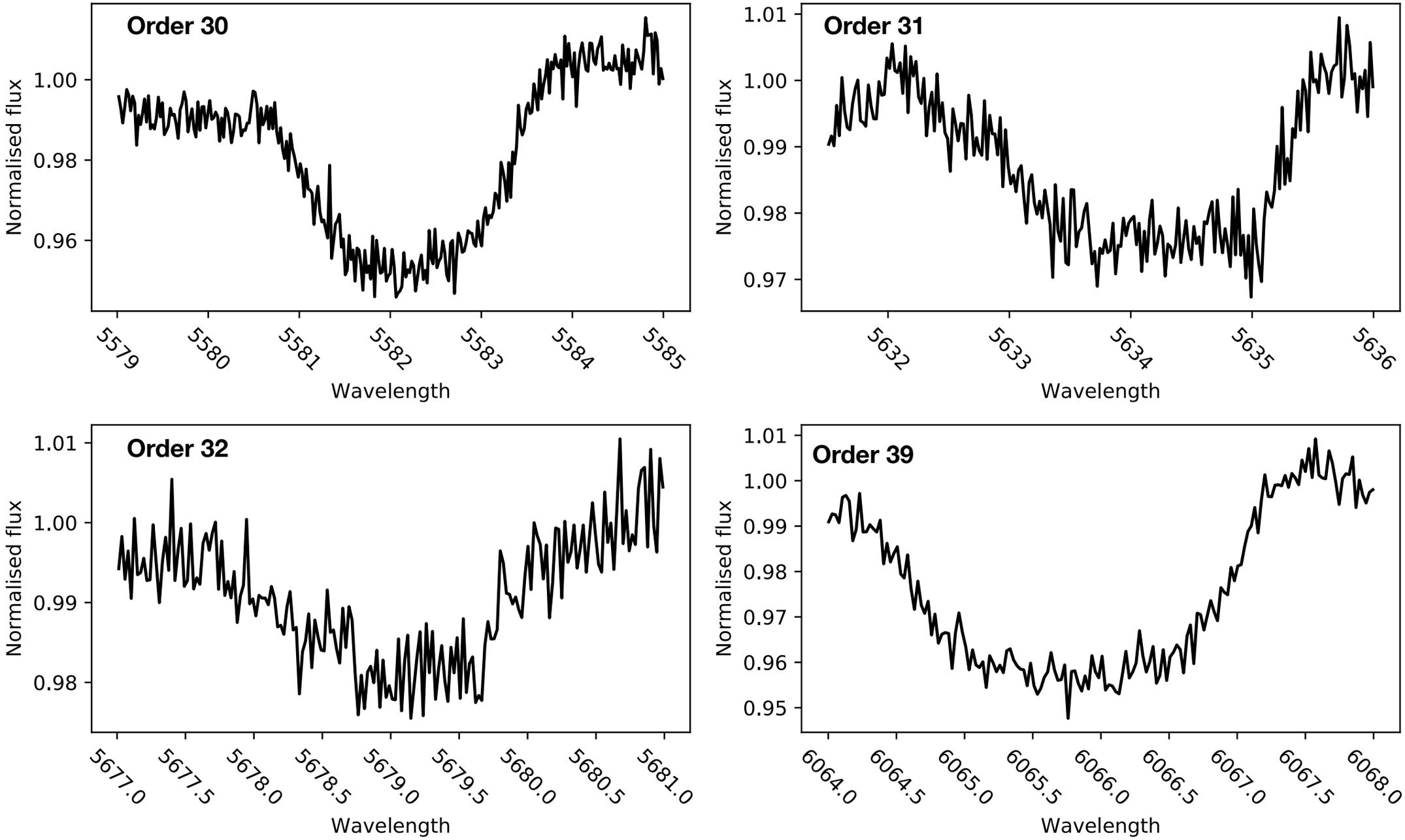

Fig. 7: Cut-out spectral lines

FAMIAS Analysis

- Search for periodicities: Fourier Parameter Fit method (Zima, 2006) and Moment method (Aerts & Briquet, 2003);

- FPF - moderate to fast rotators (vsini > 40 kms^{-1});

- MM - slow rotators (vsini < 40 kms^{-1});

- Frequencies are taken into account ONLY if the SNR > 4, for each of the found peaks (3.5 for harmonics or combinations);

- The found prominent frequency peaks will then be subjected to a LSF algorithm, which allows the improvement of amplitude, phase and, for the line profiles, the frequency, as well.

FAMIAS Analysis - MM

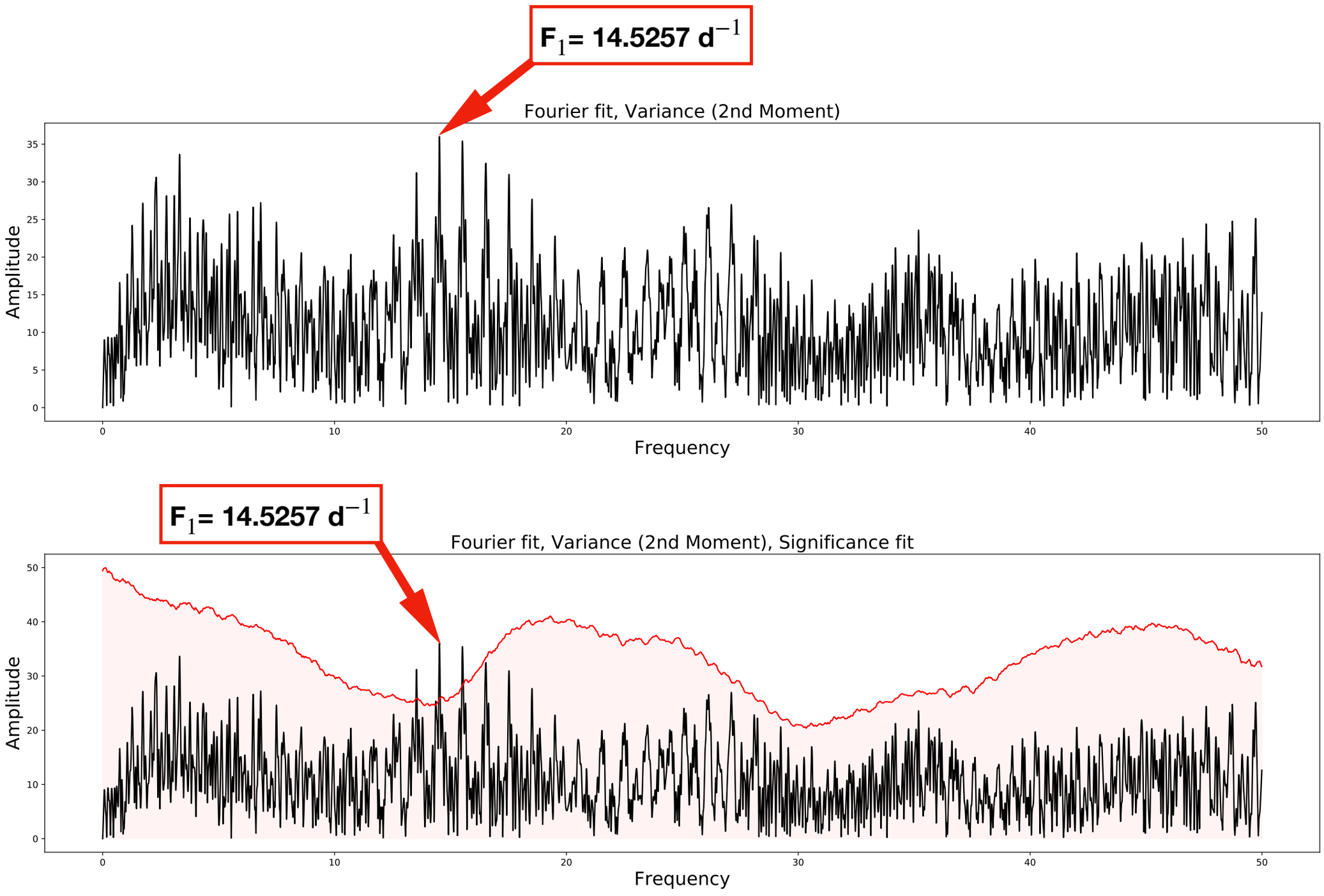

Fig. 8&9: Line moments Fourier fit, order 32

FAMIAS Analysis - Mode ID

Line	Frequency	l	m
Ca I ($\lambda_c = 5581{,}965\text{Å}$)	16.5026d^{-1}	0,1,2,3	-2,-1,0,3
Fe I ($\lambda_c = 5579{,}023\text{Å}$)	38.9769d^{-1}	0,1,2,3	[-3,3]
Fe I ($\lambda_c = 5579{,}023\text{Å}$)	14.5257*d^{-1}	0,1,2,3	[-3,3]
Fe I ($\lambda_c = 6065{,}48\text{Å}$)	-	-	-

FAMIAS Analysis - Conclusions

- Che et al. (2011) determined the inclination angle of β Cas as $19.9^{+1.9}_{-1.9}$ degrees;
    - Beta Cas is seen nearly pole-on;
- Rotational broadening complicates spectroscopic analysis of pulsation frequencies;
- A longer data set might expose more of the star's behaviour (?).

FAMIAS Analysis - Conclusions

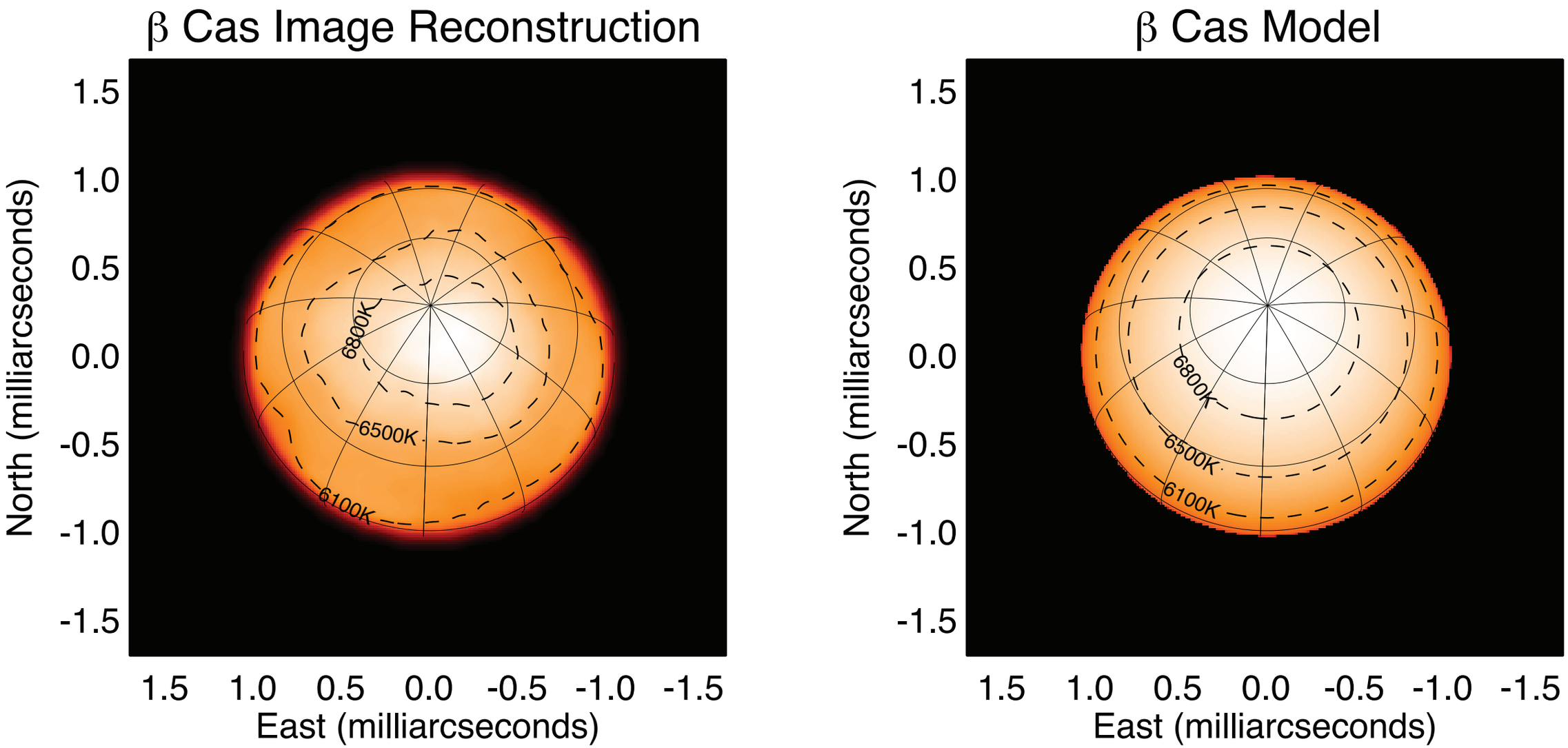

Fig. 10: Beta Cas, interferometry imaging (Che et al., 2011)

Thank you!

FAMIAS Analysis - FPF

- Computes the intensity of each wavelength bin across the line profile;
- No upper limit for mode ID;
- Fit done with synthetic line profiles;
- Computes the “goodness of fit” through a χ^2 statistical test;
- Relies on the pixel-by-pixel method.

FAMIAS Analysis - FPF

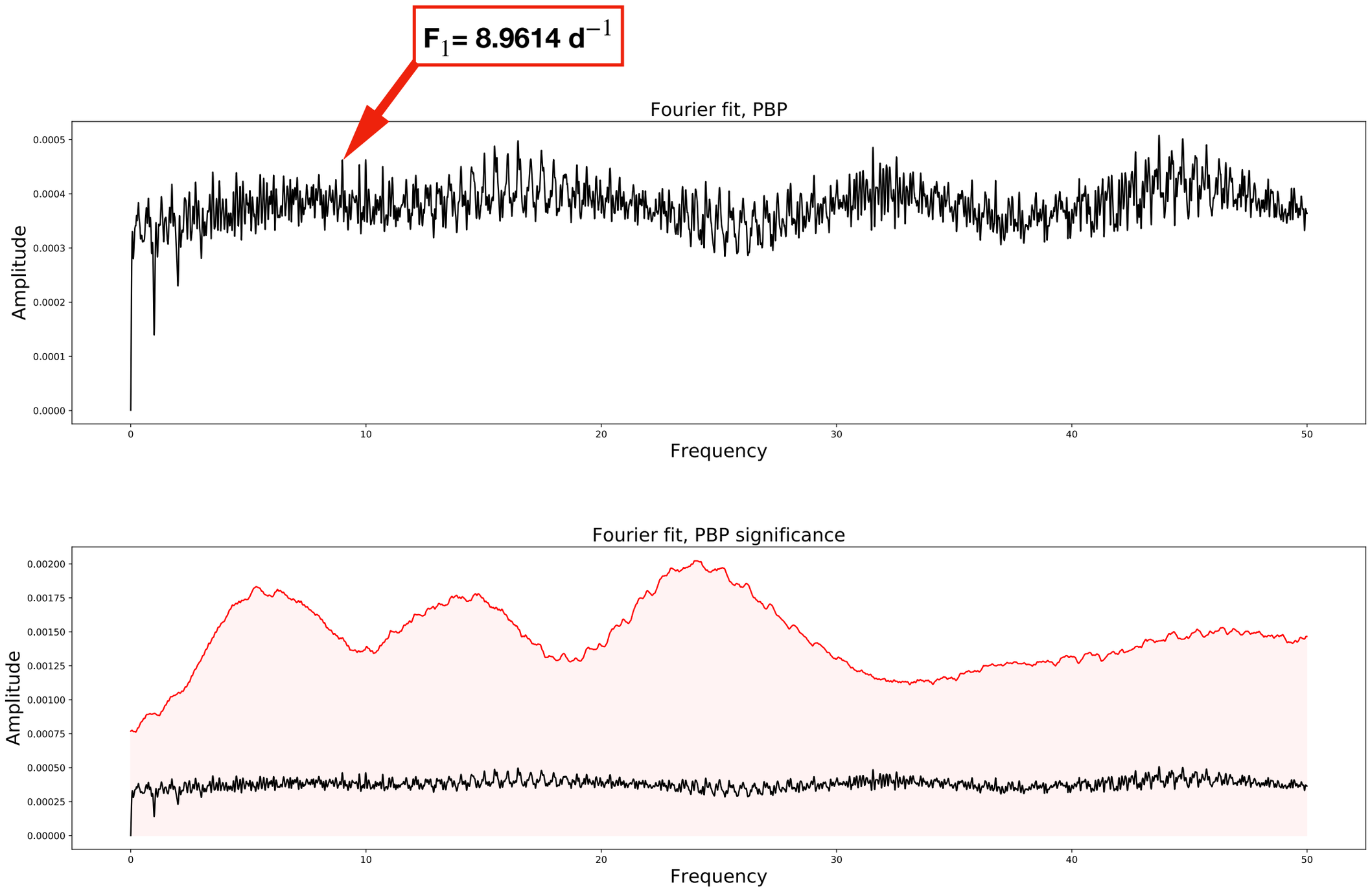

Fig. 8&9: Pixel-by-pixel Fourier fit, order 32

FAMIAS Analysis - MM

- Better suited for slower rotating stars;
- Uses a discriminant, computing the mode ID using information from the 1st (radial velocity) and 2nd (line width) line moments;
- The MM fitting in FAMIAS is done using existing theoretical models;
- Uses a χ^2 fit to determine the significance of the mode ID.

FAMIAS Analysis - MM

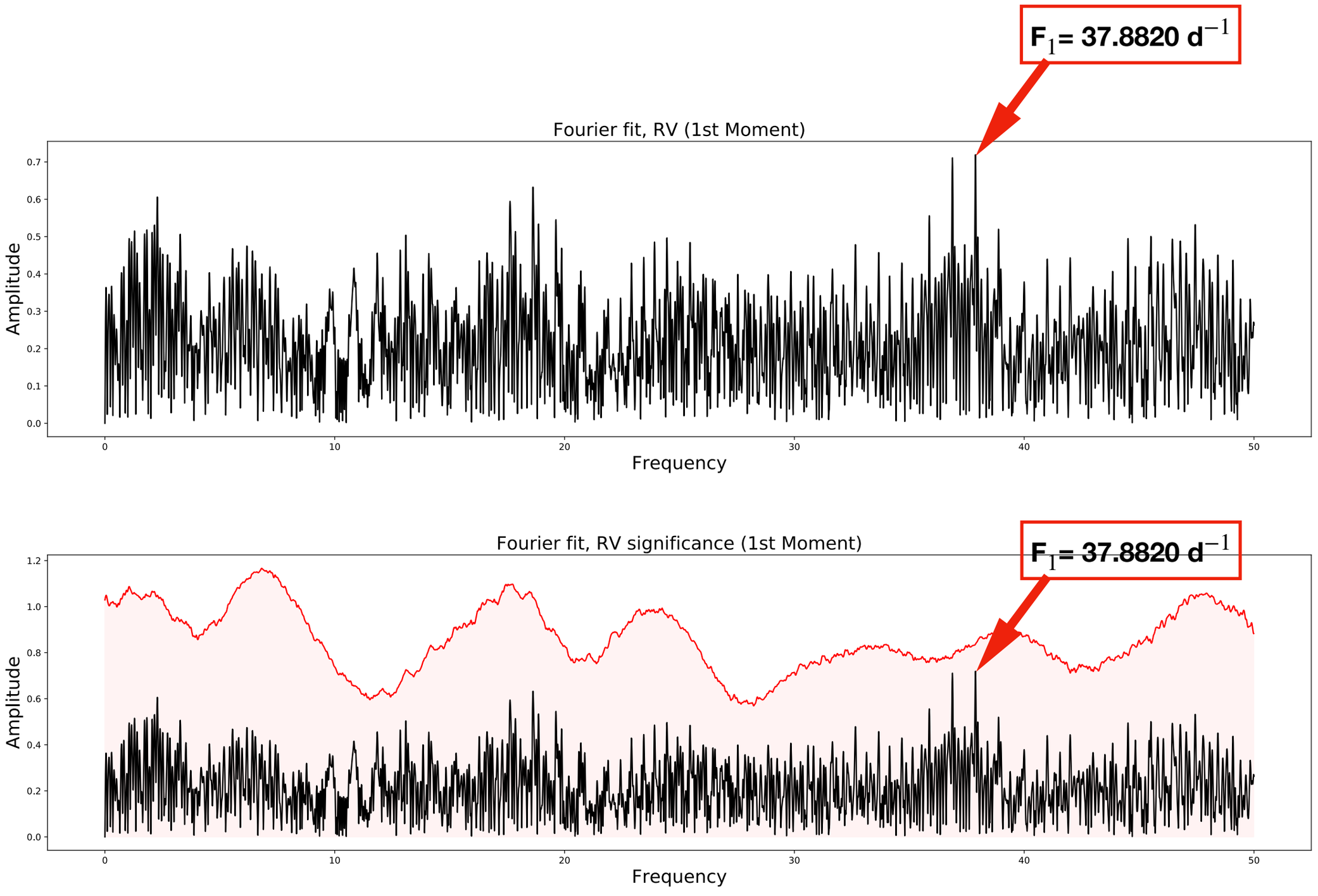

Fig. 10&11: Line moments Fourier fit, order 32

FAMIAS Analysis - MM

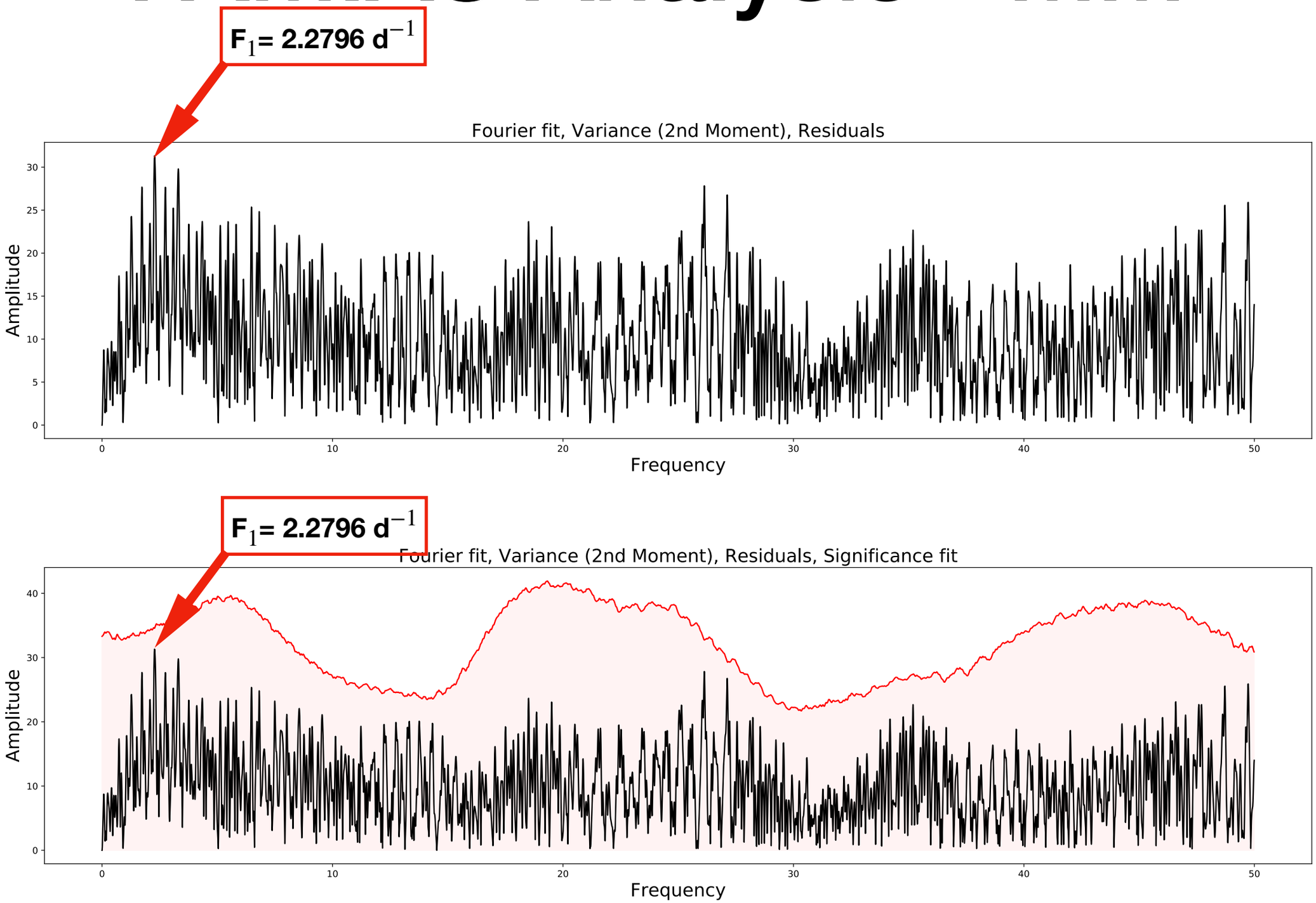

Fig. 14&15: Line moments residual data set, Fourier fit, order 32

FAMIAS Analysis

Order	Line Element	FPF (PBP) Analysis	Significant frequencies	Insignificant frequencies	MM (LPV) Analysis	Significant* frequencies	Insignificant frequencies
30	**Ca I**	**yes**	none	yes	**yes**	$16.5026 d^{-1}$ $38.9769 d^{-1}$	yes
31	**Fe I**	**yes**	none	yes	**yes**	none	yes
32	**Fe I**	**yes**	none	$8.9614 d^{-1}$	**yes**	$14.5257 d^{-1}$	yes
39	**Fe I**	**yes**	none	yes	**none**	none	yes

* - the frequency is, first of all, significant when it comes to its SNR(> 3.5) and discovered in the 1st of 2nd line moment.