The HELAS Workpackage Asteroseismology

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What is the Workpackage Asteroseismology?

Outline: A collection of tools for the analysis of photometric and spectroscopic data of pulsating stars packed into a userfriendly interface (objective of NA5, head: Conny Aerts)

Focus on: Frequency analysis & Mode identification
(according to input from COROT community at CW9)

Target stars: all Main Sequence pulsators from Gamma Dor to Beta Cep stars

What is the Workpackage Asteroseismology?

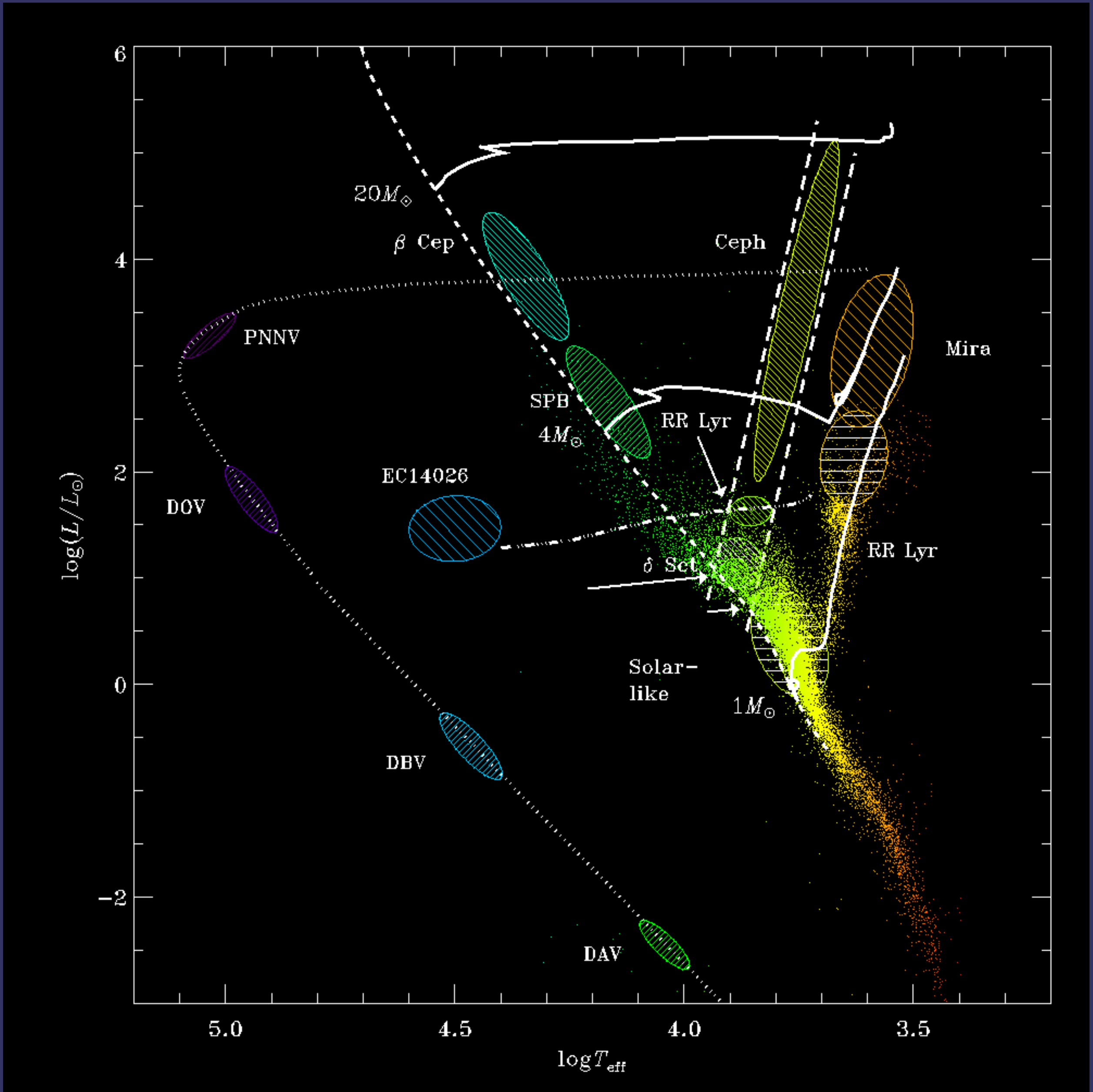

Figure by J. Christensen-Dalsgaard

What is the Workpackage Asteroseismology?

Outline: A collection of tools for the analysis of photometric and spectroscopic data of pulsating stars packed into a userfriendly interface.

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Target stars: All Main Sequence pulsators from Gamma Dor to Beta Cep stars

Objective: Spread knowledge and tools to the whole asteroseismic community

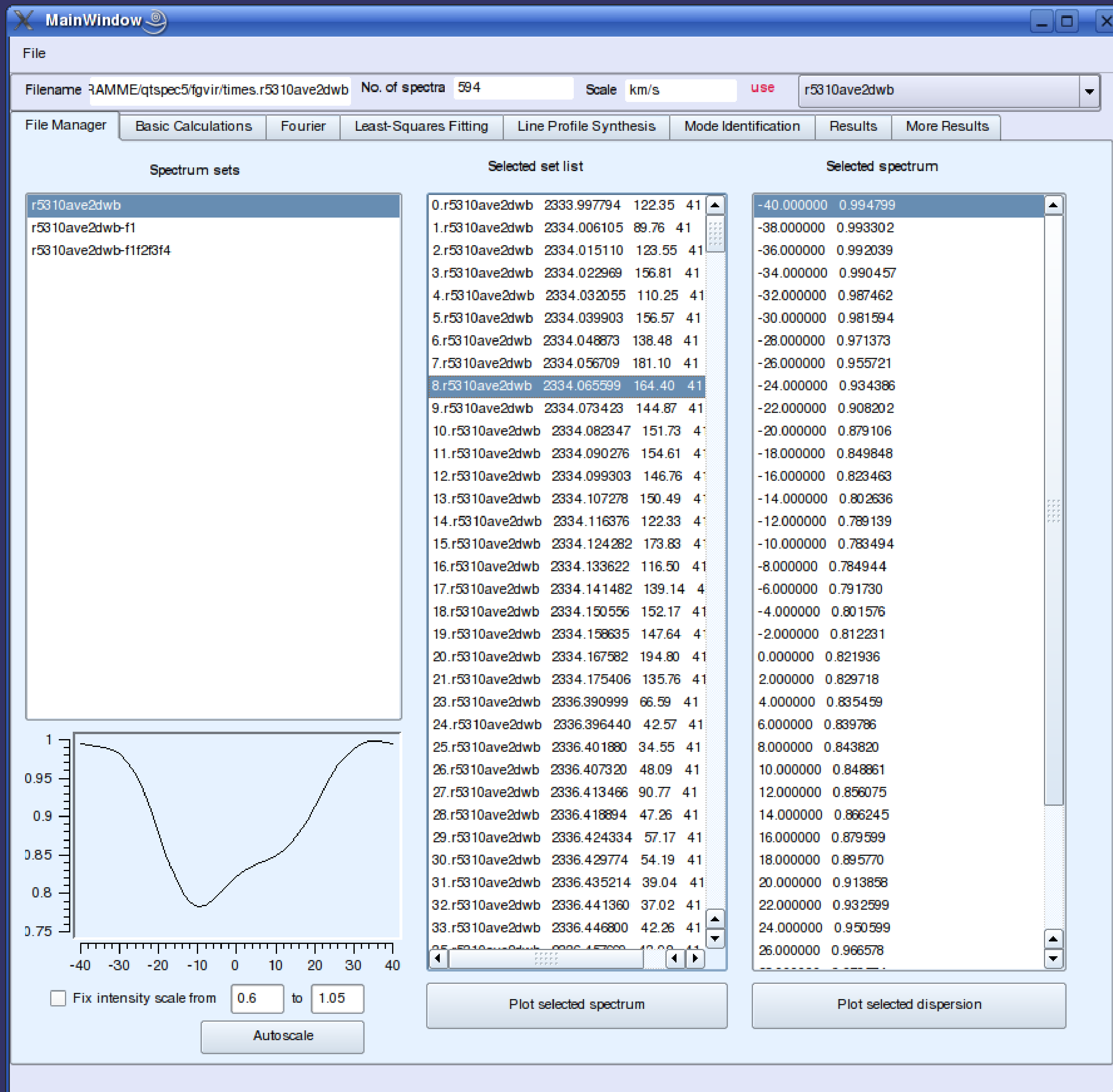
Planned first release: End, 2007

Concept of the WPA (1)

Spectroscopy:

- Analyze sets of time-resolved high-resolution spectroscopy
- Prepare data for analysis (select lines, statistics)
- Compute moments & equivalent width variations
- Fourier analysis (DFT) & least-squares fitting of moments and pixels across profile
- Mode identification methods: moment method (Briquet & Aerts 2003), Fourier parameter fit method (Zima 2006) and direct line profile fitting

  ⟹ l, m, intrinsic amplitude, inclination
- MIMs supported by genetic optimization (parallelization possible on multi-processor computers)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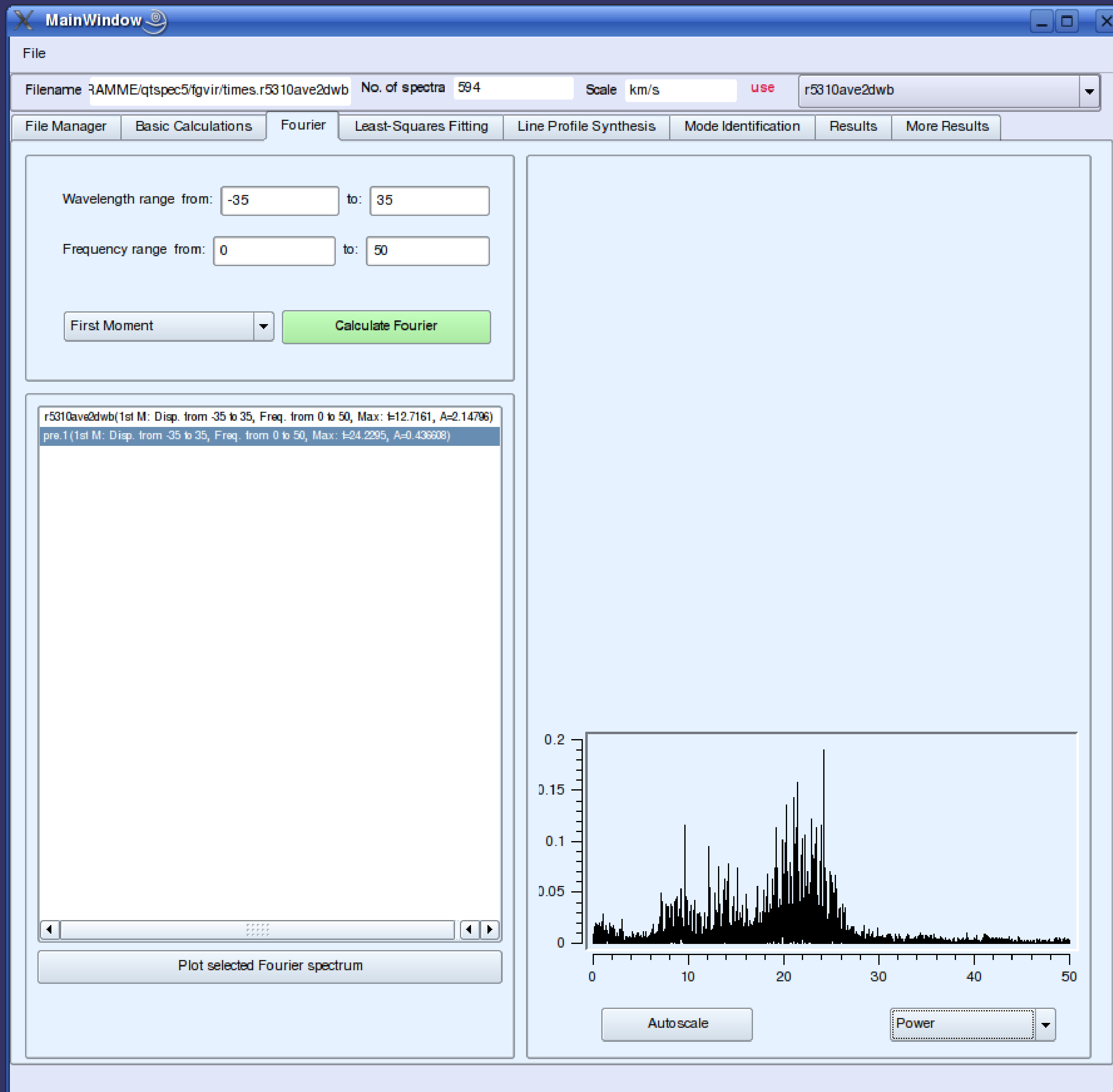
RAMME/qtspec5/fgvir/times.r5310ave2dwb
No. of spectra
594
Scale
km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
Line Profile Synthesis
Mode Identification
Results
More Results
Spectrum sets
r5310ave2dwb
r5310ave2dwb-f1
r5310ave2dwb-f1f2f3f4
Selected set list
0.r5310ave2dwb 2333.997794 122.35 41
1.r5310ave2dwb 2334.006105 89.76 41
2.r5310ave2dwb 2334.015110 123.55 41
3.r5310ave2dwb 2334.022969 156.81 41
4.r5310ave2dwb 2334.032055 110.25 41
5.r5310ave2dwb 2334.039903 156.57 41
6.r5310ave2dwb 2334.048873 138.48 41
7.r5310ave2dwb 2334.056709 181.10 41
8.r5310ave2dwb 2334.065599 164.40 41
9.r5310ave2dwb 2334.073423 144.87 41
10.r5310ave2dwb 2334.082347 151.73
11.r5310ave2dwb 2334.090276 154.61
12.r5310ave2dwb 2334.099303 146.76
13.r5310ave2dwb 2334.107278 150.49
14.r5310ave2dwb 2334.116376 122.33
15.r5310ave2dwb 2334.124282 173.83
16.r5310ave2dwb 2334.133622 116.50 41
17.r5310ave2dwb 2334.141482 139.14
18.r5310ave2dwb 2334.150556 152.17 41
19.r5310ave2dwb 2334.158635 147.64
20.r5310ave2dwb 2334.167582 194.80 41
21.r5310ave2dwb 2334.175406 135.76 41
23.r5310ave2dwb 2336.390999 66.59 41
24.r5310ave2dwb 2336.396440 42.57 41
25.r5310ave2dwb 2336.401880 34.55 41
26.r5310ave2dwb 2336.407320 48.09 41
27.r5310ave2dwb 2336.413466 90.77 41
28.r5310ave2dwb 2336.418894 47.26 41
29.r5310ave2dwb 2336.424334 57.17 41
30.r5310ave2dwb 2336.429774 54.19 41
31.r5310ave2dwb 2336.435214 39.04 41
32.r5310ave2dwb 2336.441360 37.02 41
33.r5310ave2dwb 2336.446800 42.26 41
Selected spectrum
-40.000000 0.994799
-38.000000 0.993302
-36.000000 0.992039
-34.000000 0.990457
-32.000000 0.987462
-30.000000 0.981594
-28.000000 0.971373
-26.000000 0.955721
-24.000000 0.934386
-22.000000 0.908202
-20.000000 0.879106
-18.000000 0.849848
-16.000000 0.823463
-14.000000 0.802636
-12.000000 0.789139
-10.000000 0.783494
-8.000000 0.784944
-6.000000 0.791730
-4.000000 0.801576
-2.000000 0.812231
0.000000 0.821936
2.000000 0.829718
4.000000 0.835459
6.000000 0.839786
8.000000 0.843820
10.000000 0.848861
12.000000 0.856075
14.000000 0.866245
16.000000 0.879599
18.000000 0.895770
20.000000 0.913858
22.000000 0.932599
24.000000 0.950599
26.000000 0.966578
1
0.95
0.9
0.85
0.8
0.75
-40 -30 -20 -10 0 10 20 30 40
Fix intensity scale from
0.6
to
1.05
Autoscale
Plot selected spectrum
Plot selected dispersion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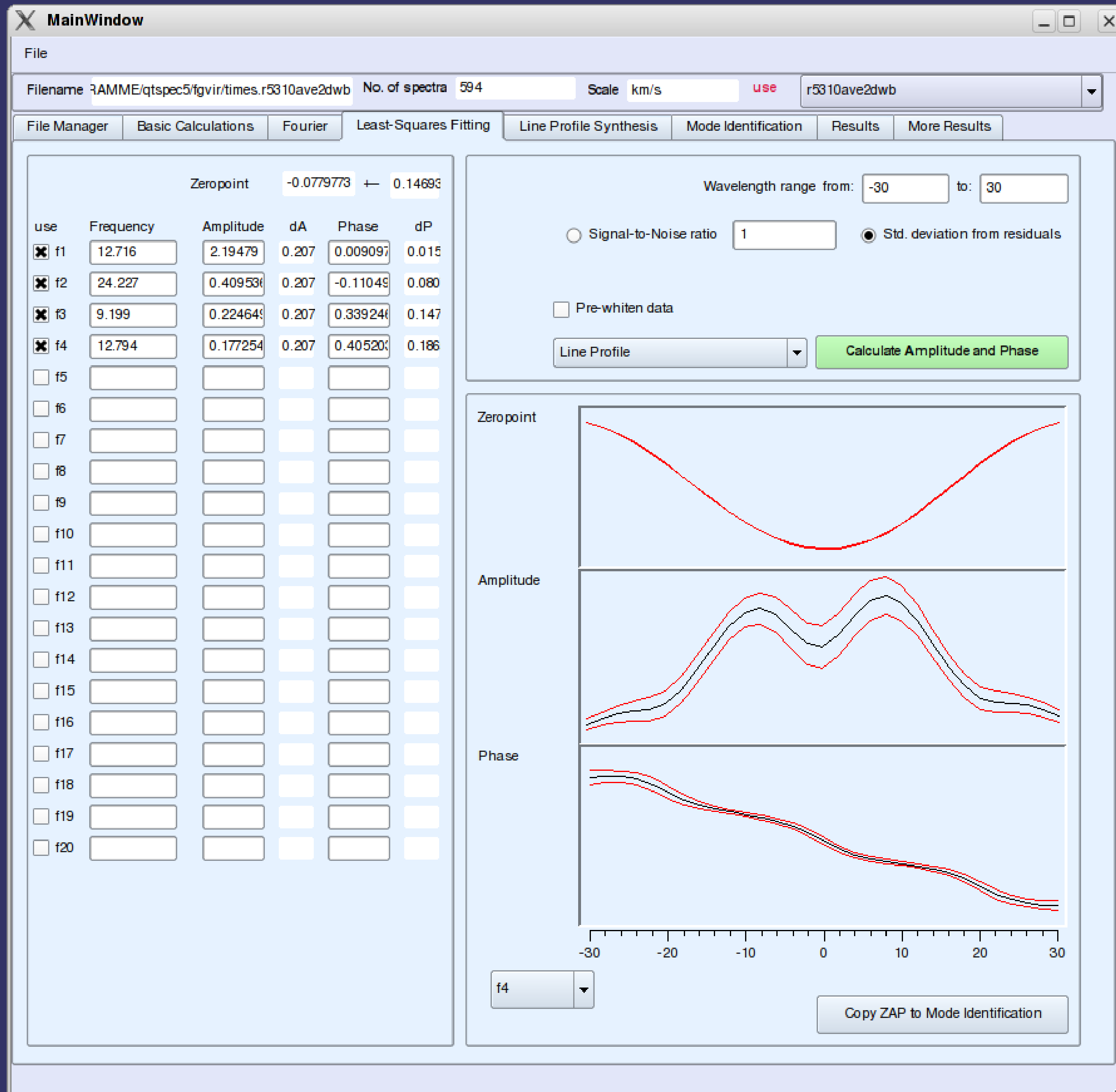
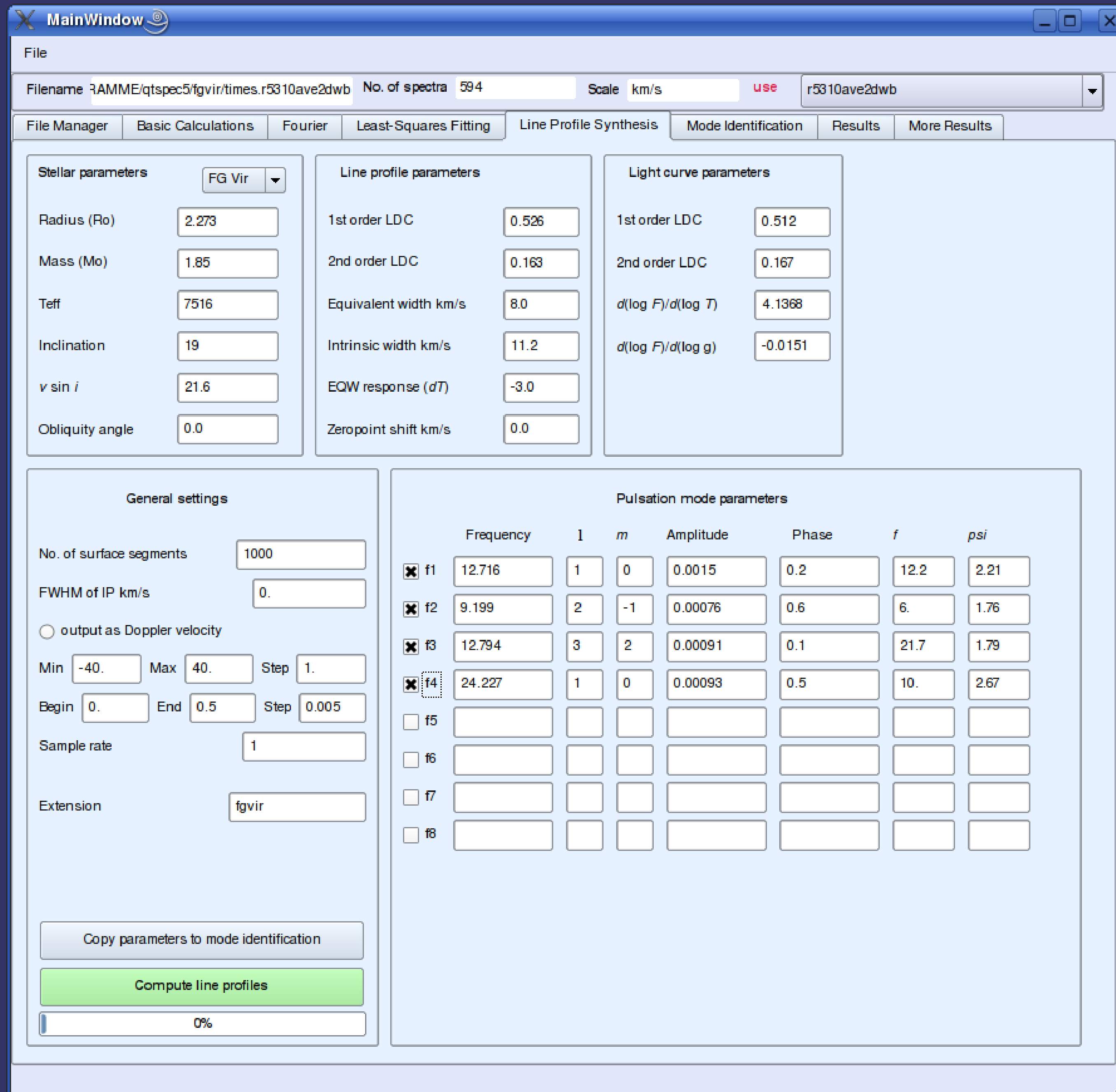
RAMME/qtspec5/fgvir/times.r5310ave2dwb
No. of spectra
594
Scale
km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
Line Profile Synthesis
Mode Identification
Results
More Results
Wavelength range from:
-35
to:
35
Frequency range from:
0
to:
50
First Moment
Calculate Fourier
r5310ave2dwb(1st M: Disp. from -35 to 35, Freq. from 0 to 50, Max: f=12.7161, A=2.14796)
pre.1 (1st M: Disp. from -35 to 35, Freq. from 0 to 50, Max: f=24.2295, A=0.436608)
Plot selected Fourier spectrum
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
Autoscale
Power


MainWindow
File
Filename
No. of spectra
594
Scale
km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
Line Profile Synthesis
Mode Identification
Results
More Results
Zeropoint
-0.0779773
0.14693
use
Frequency
Amplitude
dA
Phase
dP
f1
12.716
2.19479
0.207
0.009097
0.015
f2
24.227
0.207
0.080
f3
9.199
0.207
0.147
f4
12.794
0.177254
0.207
0.186
f5
f6
f7
f8
f9
f10
f11
f12
f13
f14
f15
f16
f17
f18
f19
f20
Wavelength range from:
-30
to:
30
Signal-to-Noise ratio
1
Std. deviation from residuals
Pre-whiten data
Line Profile
Calculate Amplitude and Phase
Zeropoint
Amplitude
Phase
-30
-20
-10
0
10
20
30
f4
Copy ZAP to Mode Identification


MainWindow
File
Filename RAMME/qtspec5/fgvir/times.r5310ave2dwb
No. of spectra 594
Scale km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
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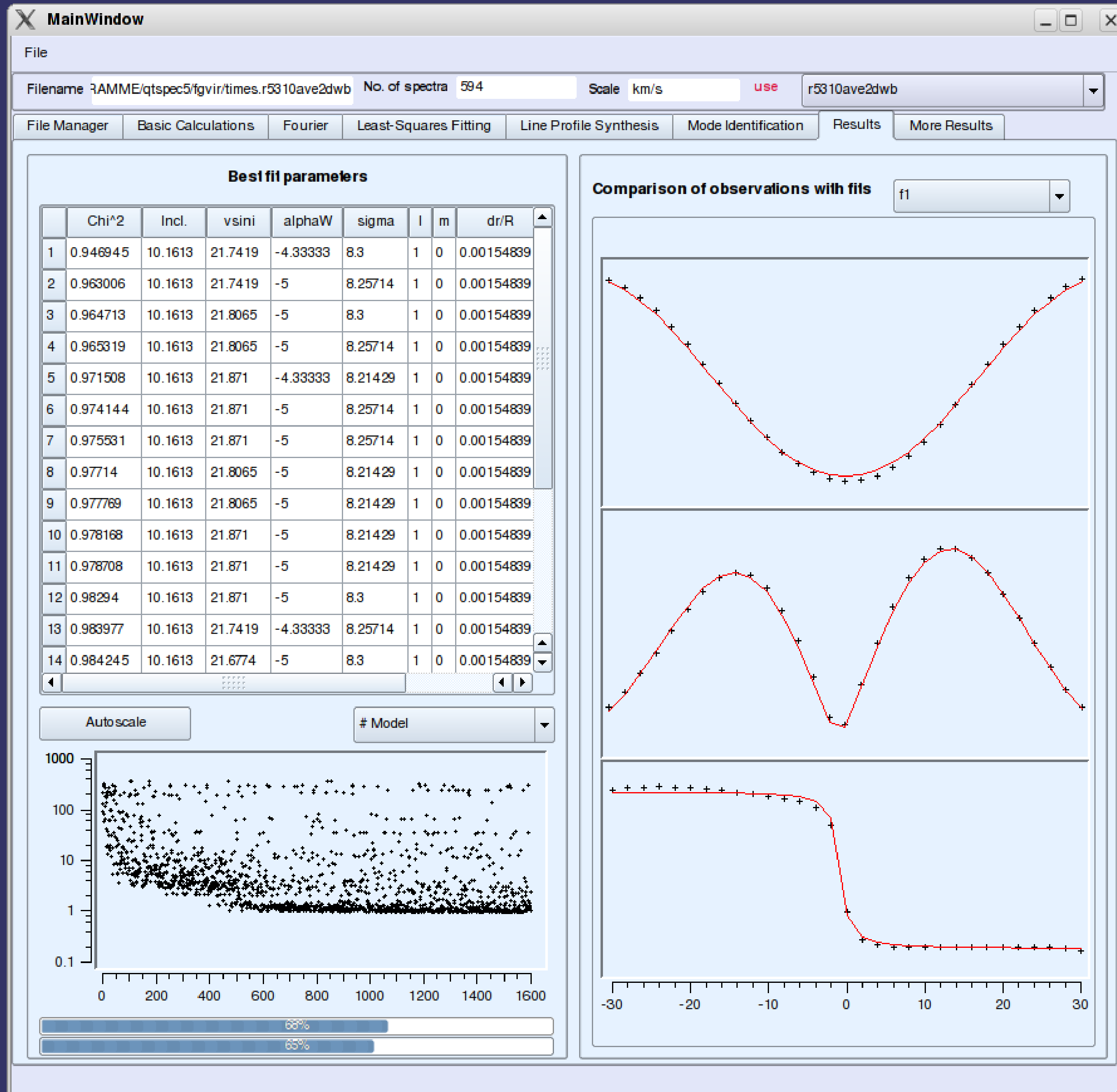
More Results
Stellar parameters
FG Vir
Radius (Ro) 2.273
Mass (Mo) 1.85
Teff 7516
Inclination 19
v sin i 21.6
Obliquity angle 0.0
Line profile parameters
1st order LDC 0.526
2nd order LDC 0.163
Equivalent width km/s 8.0
Intrinsic width km/s 11.2
EQW response (dT) -3.0
Zeropoint shift km/s 0.0
Light curve parameters
1st order LDC 0.512
2nd order LDC 0.167
d(log F)/d(log T) 4.1368
d(log F)/d(log g) -0.0151
General settings
No. of surface segments 1000
FWHM of IP km/s 0.
output as Doppler velocity
Min -40. Max 40. Step 1.
Begin 0. End 0.5 Step 0.005
Sample rate 1
Extension fgvir
Copy parameters to mode identification
Compute line profiles
0%
Pulsation mode parameters
Frequency l m Amplitude Phase f psi
f1 12.716 1 0 0.0015 0.2 12.2 2.21
f2 9.199 2 -1 0.00076 0.6 6. 1.76
f3 12.794 3 2 0.00091 0.1 21.7 1.79
f4 24.227 1 0 0.00093 0.5 10. 2.67
f5
f6
f7
f8


MainWindow
File
Filename RAMME/qtspec5/fgvir/times.r5310ave2dwb
No. of spectra 594
Scale km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
Line Profile Synthesis
Mode Identification
Results
More Results
Select global free parameters & range
No. of surface segments 1000
Min or const
Max
Step
Radius (Ro) 2.273
Mass (Mo) 1.85
Teff 7516
Inclination 5 85 5
v sin i 17 23 0.1
Obliquity angle 0.0
1st order LDC 0.526
2nd order LDC 0.163
Equivalent width km/s 8.082 15. 0.1
Intrinsic width km/s 9. 10 0.1
EQW response (dT) -5.0 5 1
Zeropoint shift km/s 0.0 4. 0.1
1st order LDC 0.512
2nd order LDC 0.167
d(log F)/d(log T) 4.1368
d(log F)/d(log g) -0.0151
Select mode free parameters & range
Import parameters
f1 (12.716)
Frequency 12.716
Min
Max
Step
Degree l 0 4 1
Order m -4 4 1
Amplitude 0. 0.003 0.0001
Phase 0.85 1 0.01
f 0. 20. 1.
psi 0. 3.1 0.1
Genetic optimization parameters
Population size 50
Fitness prop. selection
Max. generations 50
Gray coding except (l,m)
Crossover 0.5
Avoid crowding
Mutation 0.01
Auto
Emax 1.7
No. Elite 2
Reset optimization
l&m: free parameters
Default settings
FPF Method: Mono mode: fit zeropoint, amplitude & phase
Optimizing... Press to interrupt


MainWindow
File
Filename RAMME/qtspec5/fgvir/times.r5310ave2dwb
No. of spectra 594
Scale km/s
use
r5310ave2dwb
File Manager
Basic Calculations
Fourier
Least-Squares Fitting
Line Profile Synthesis
Mode Identification
Results
More Results
Best fit parameters
Chi^2 Incl. vsini alphaW sigma l m dr/R
1 0.946945 10.1613 21.7419 -4.33333 8.3 1 0 0.00154839
2 0.963006 10.1613 21.7419 -5 8.25714 1 0 0.00154839
3 0.964713 10.1613 21.8065 -5 8.3 1 0 0.00154839
4 0.965319 10.1613 21.8065 -5 8.25714 1 0 0.00154839
5 0.971508 10.1613 21.871 -4.33333 8.21429 1 0 0.00154839
6 0.974144 10.1613 21.871 -5 8.25714 1 0 0.00154839
7 0.975531 10.1613 21.871 -5 8.25714 1 0 0.00154839
8 0.97714 10.1613 21.8065 -5 8.21429 1 0 0.00154839
9 0.977769 10.1613 21.8065 -5 8.21429 1 0 0.00154839
10 0.978168 10.1613 21.871 -5 8.21429 1 0 0.00154839
11 0.978708 10.1613 21.871 -5 8.21429 1 0 0.00154839
12 0.98294 10.1613 21.871 -5 8.3 1 0 0.00154839
13 0.983977 10.1613 21.7419 -4.33333 8.25714 1 0 0.00154839
14 0.984245 10.1613 21.6774 -5 8.3 1 0 0.00154839
Autoscale
Model
1000
100
10
1
0.1
0
200
400
600
800
1000
1200
1400
1600
68%
65%
Comparison of observations with fits
f1
-30
-20
-10
0
10
20
30

Concept of the WPA (3)

Photometry:

- analyze light curves from different photometric passbands & systems
- Fourier analysis (FFT) and least-squares fitting (similar to Period04)
- import amplitude and phase values
- mode identification with the method of amplitude ratios and phase differences between different filters

require non-adiabatic photometric observables

Photometric Mode Identification

OBSERVATIONS
(from calibrations)
Teff, log g,
Metallicity,
Luminosity

Frequency

select all models in error box

SEISMIC STELLAR MODELS

Teff, log g, Mass, log L, Radius,
age, (X,Z), overshooting, convection

excited pulsation modes:
Frequency
(l, m)
$(f_T, \psi_T), (f_g, \psi_g)$

select mode with closest frequency

COMPUTE PHOTOMETRIC LIGHTVARIATIONS

$$\Delta m(\lambda) = 2.5 \log e\, a\, N_l^m P_l^{|m|}(\cos i)\, b_{l,\lambda} \left|(2+\ell)(1-\ell) + (\alpha_T+\beta_T) f_T e^{i\psi_T} + (\alpha_g+\beta_g) f_g e^{i\psi_g}\right|$$

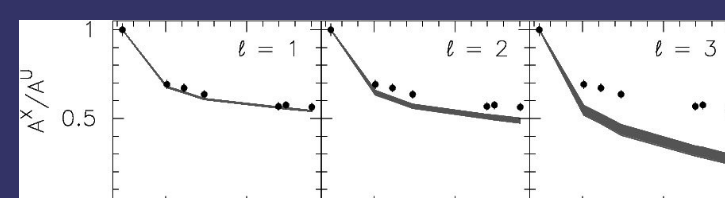
Static atmosphere
models

OBSERVED
Amplitude ratio
Phase difference

COMPARISON

THEORETICAL
Amplitude ratio
Phase difference

degree l



Definition of the non-adiabatic observables

$$\frac{\delta T_{eff}}{T_{eff}} = f_T e^{i\psi_T} \frac{\xi_r}{R}$$

$$\frac{\delta g}{g} = f_g e^{i\psi_g} \frac{\xi_r}{R}$$

f describes the relation between the radial displacement and temperature/log g variations

Photometric Mode Identification

OBSERVATIONS
(from calibrations)
Teff, log g,
Metallicity,
Luminosity

Frequency

select all models in error box

SEISMIC STELLAR MODELS

Teff, log g, Mass, log L, Radius,
age, (X,Z), overshooting, convection

excited pulsation modes:
Frequency
(l, m)
(f_T, ψ_T), (f_g, ψ_g)

select mode with closest frequency

COMPUTE PHOTOMETRIC LIGHTVARIATIONS

$$\Delta m(\lambda) = 2.5 \log e\, a N_l^m P_l^{|m|}(\cos i)\, b_{l,\lambda} \left| (2+\ell)(1-\ell) + (\alpha_T+\beta_T) f_T e^{i\psi_T} + (\alpha_g+\beta_g) f_g e^{i\psi_g} \right|$$

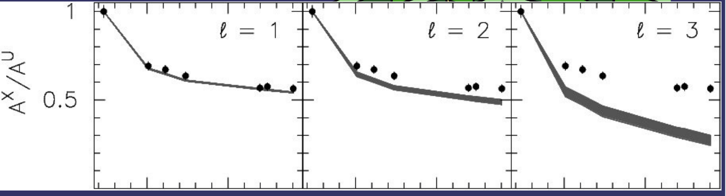
Static atmosphere
models

OBSERVED
Amplitude ratio
Phase difference

COMPARISON

THEORETICAL
Amplitude ratio
Phase difference

degree l



What we already have ...

- SPB and Beta Cep stars: grid of stellar models & non-adiabatic observables computed with CLES & MAD (Dupret 2003)
- -> (f_T, ψ_T), (f_g, ψ_g)
- calculation of amplitude ratios and phase diff. by using static Kurucz atmospheres

What we require ...

- Gamma Dor, Delta Sct & massive pulsators on MS
- Models from different research teams would be benefit
- Precomputed grid of f_T & ψ_T (if available f_g & ψ_g):
- only Main Sequence models
- abundances X,Y, Z: new solar values (?)
- Overshooting: different values!
- Convection, mixing length: different values

- Summer 2007

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