Interferometry & Asteroseismology of Delta Scuti Stars: 44 Tau and 29 Cyg

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Asteroseismology of Eclipsing Binaries

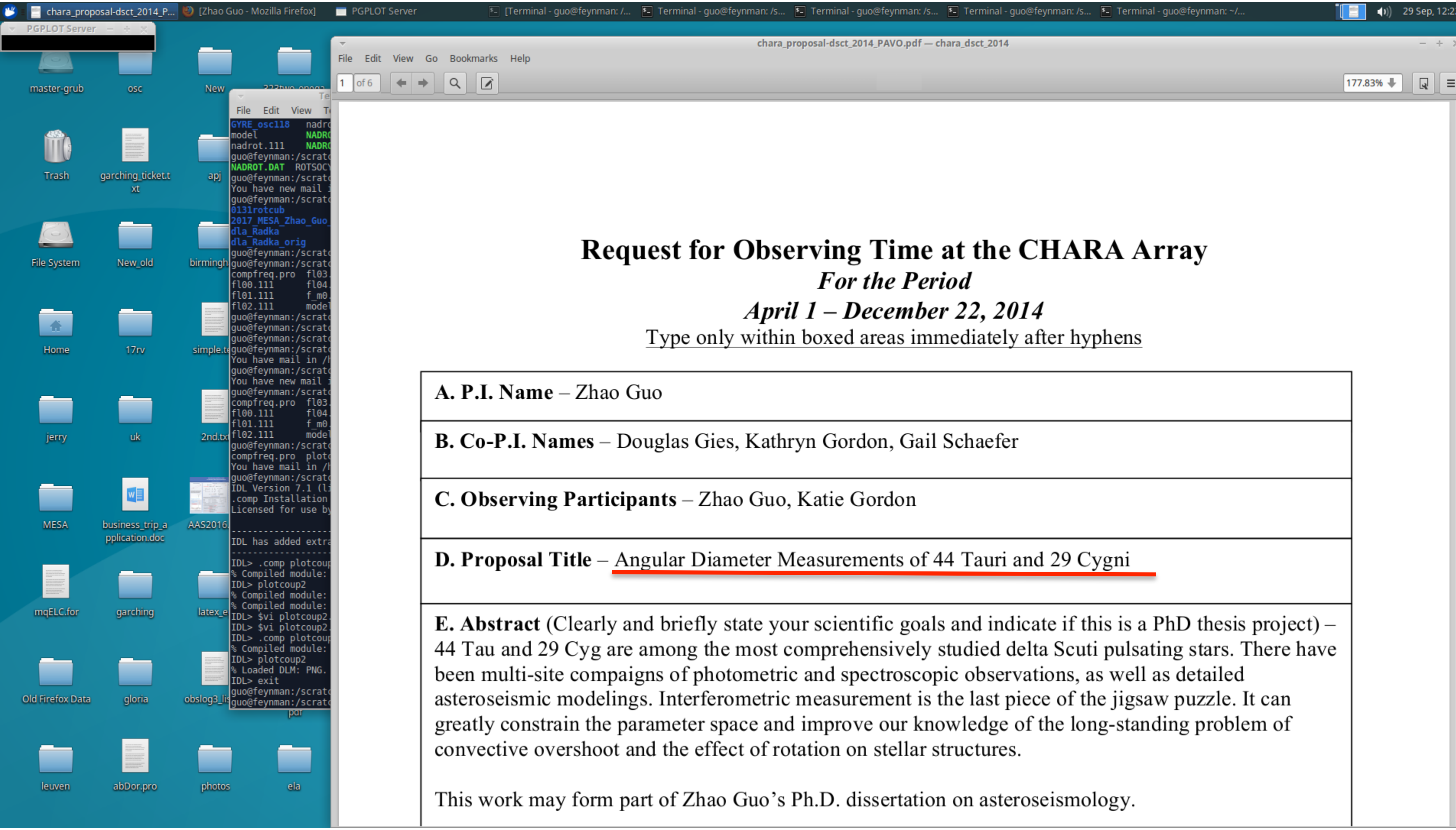
- **Gamma Dor stars**

  Guo, Gies, & Matson 2017, ApJ, in press.
- **Post-mass transfer Delta Scuti stars**

  Guo, Gies, Matson, et al. 2017, ApJ, 834, 59
- **Normal Delta Scuti stars**

  Guo, Gies, Matson, Garcia Hernandez. 2016, ApJ, 826, 69
- **Heartbeat stars with tidally excited oscillations**

  Guo, Gies, & Fuller 2017, ApJ, 837, 114



Request for Observing Time at the CHARA Array

For the Period

April 1 – December 22, 2014

Type only within boxed areas immediately after hyphens

A. P.I. Name – Zhao Guo
B. Co-P.I. Names – Douglas Gies, Kathryn Gordon, Gail Schaefer
C. Observing Participants – Zhao Guo, Katie Gordon
D. Proposal Title – Angular Diameter Measurements of 44 Tauri and 29 Cygni
E. Abstract (Clearly and briefly state your scientific goals and indicate if this is a PhD thesis project) – 44 Tau and 29 Cyg are among the most comprehensively studied delta Scuti pulsating stars. There have been multi-site compaigns of photometric and spectroscopic observations, as well as detailed asteroseismic modelings. Interferometric measurement is the last piece of the jigsaw puzzle. It can greatly constrain the parameter space and improve our knowledge of the long-standing problem of convective overshoot and the effect of rotation on stellar structures. This work may form part of Zhao Guo's Ph.D. dissertation on asteroseismology.

44 Tau

Spectroscopy,
mode ID: Zima 07

Multi-site photometry:
Rodler 03, Antoci 07

Seismic modeling:
Lenz 08,10

Interferometry

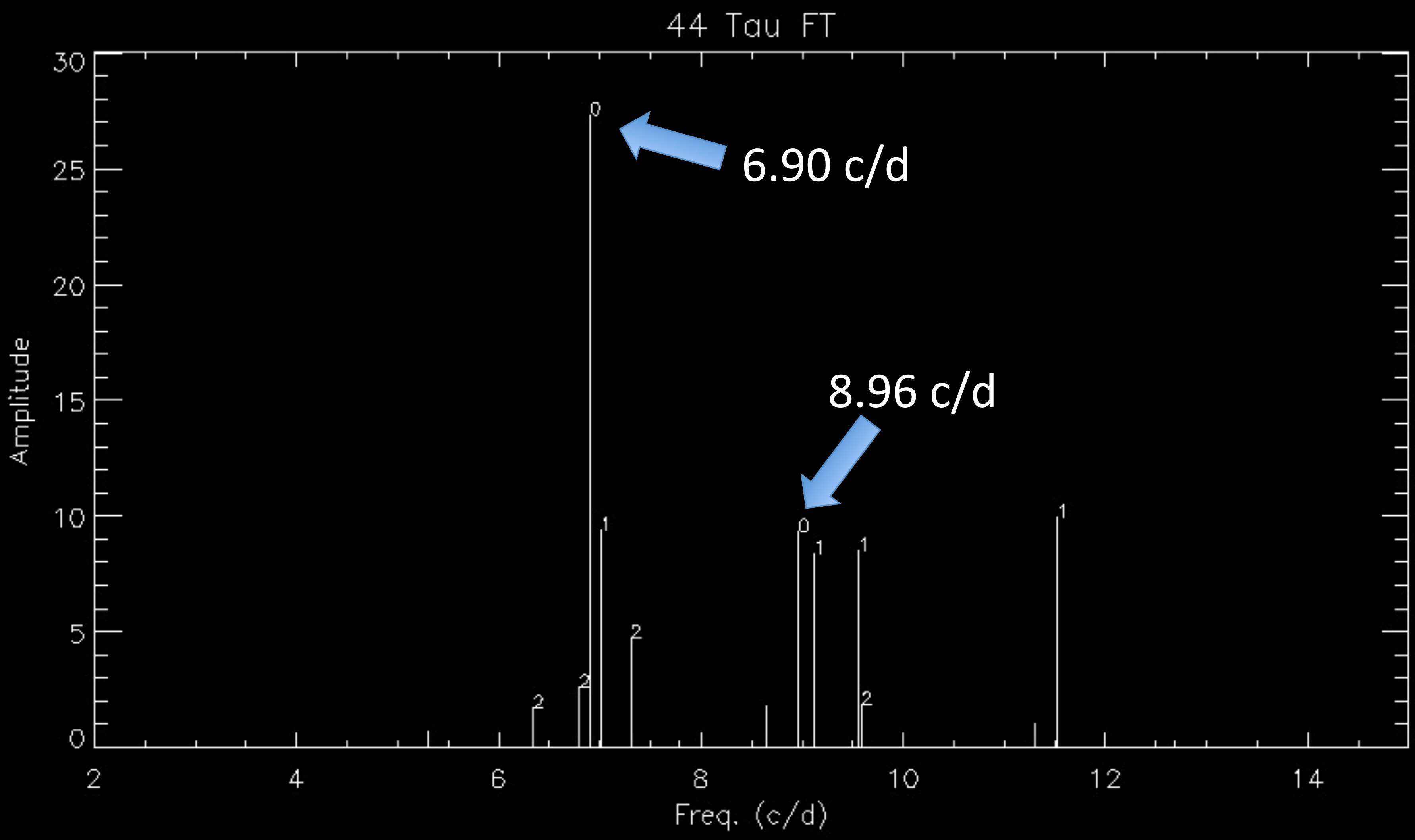
-> evolved

-> Intrinsic slow rotator: V_{eq} <= 5km/s   -> Non-rotating models OK

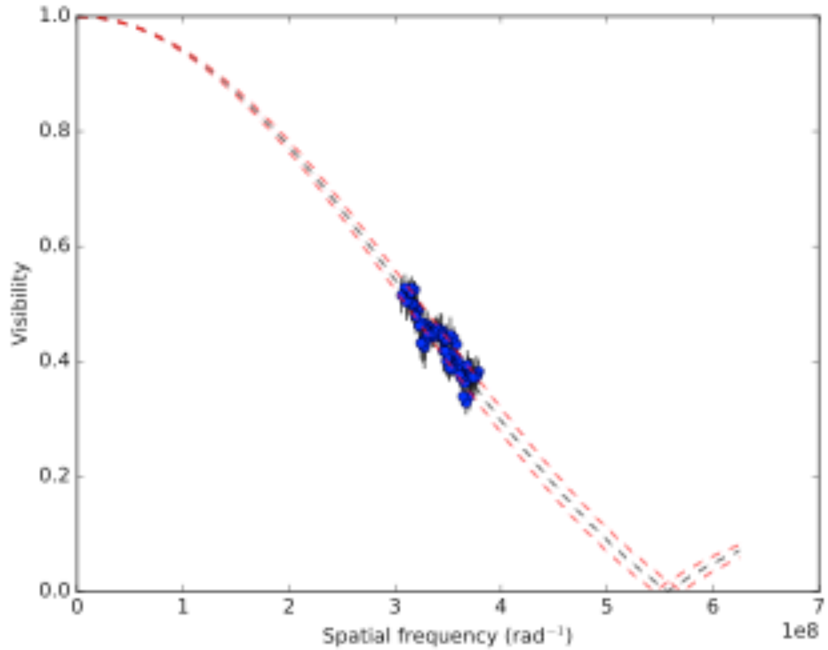
-> Solar metallicity

T_{eff}= 6900+/- 100K, log g=3.6 +/- 0.1

-> 15 frequencies, most with mode identification



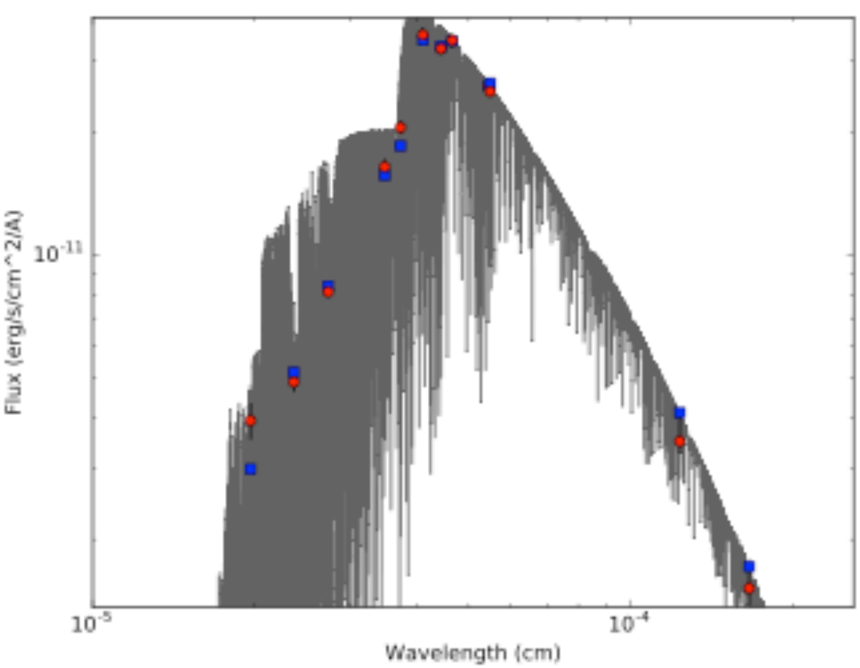
44 Tau FT
Amplitude
Freq. (c/d)
6.90 c/d
8.96 c/d
0
5
10
15
20
25
30
2
4
6
8
10
12
14



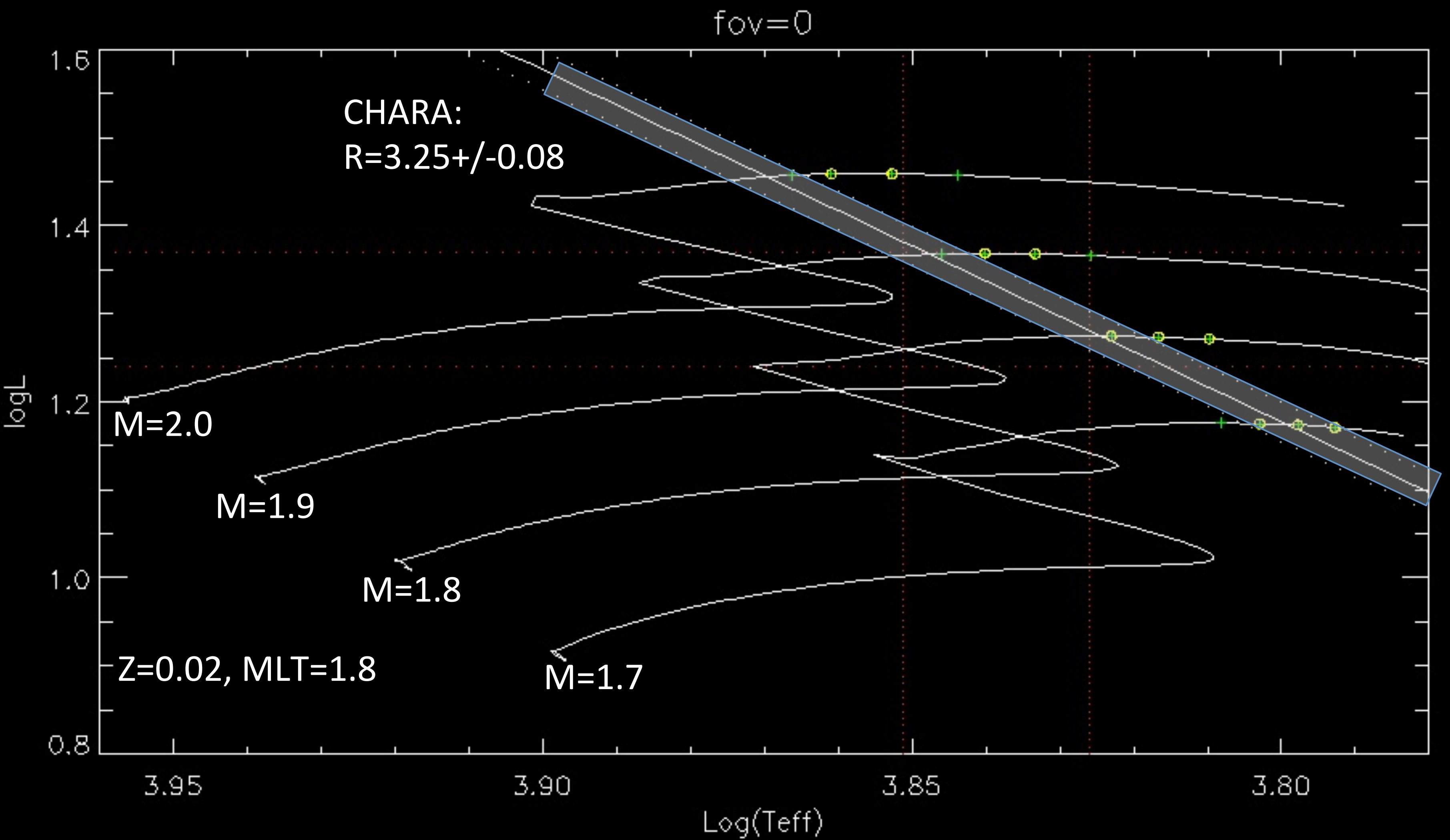
PAVO/CHARA K-band

Angular Diameter =
0.480 +/- 0.011 mas

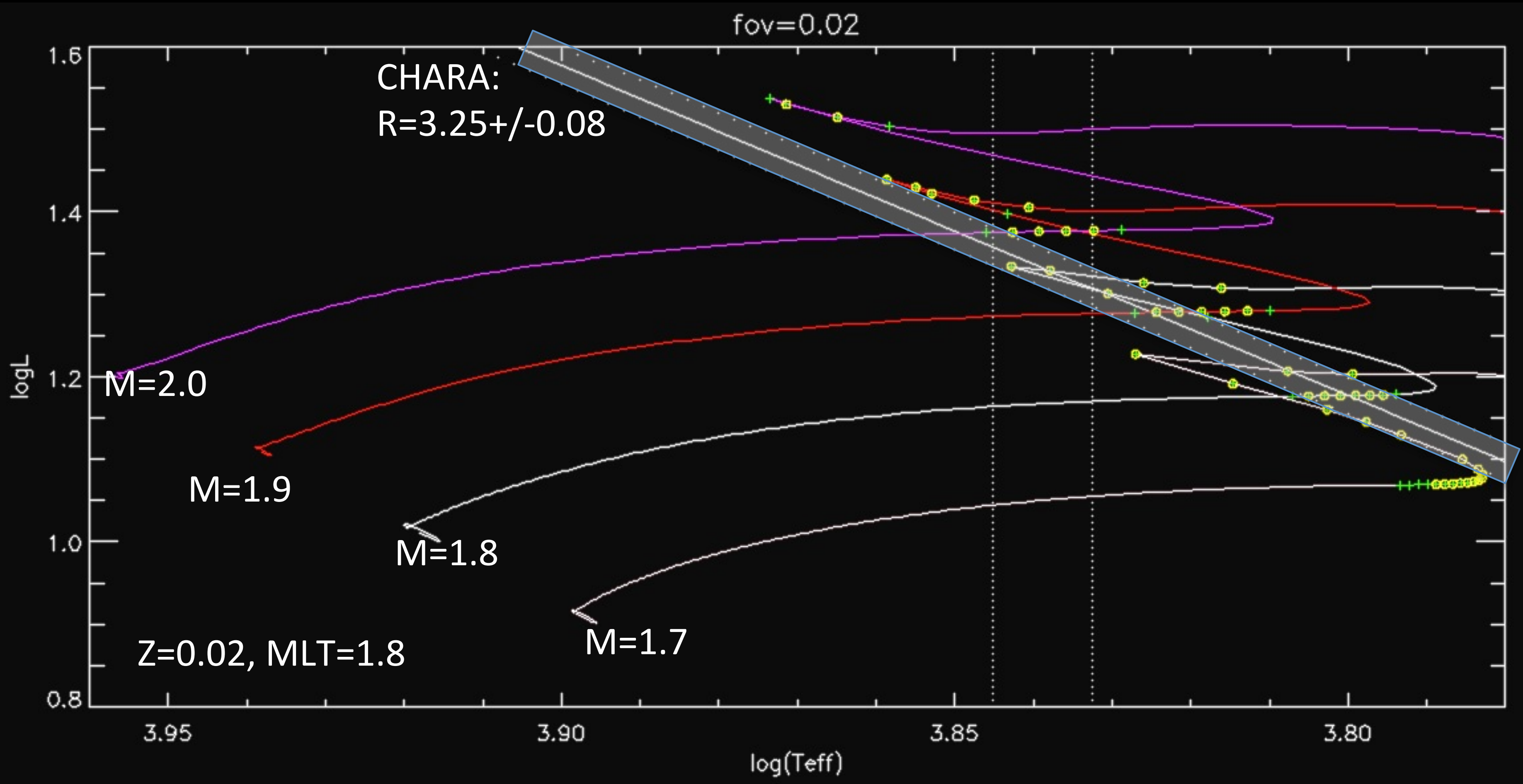
R=3.251+/- 0.083



Teff = 6768 +/- 94 K

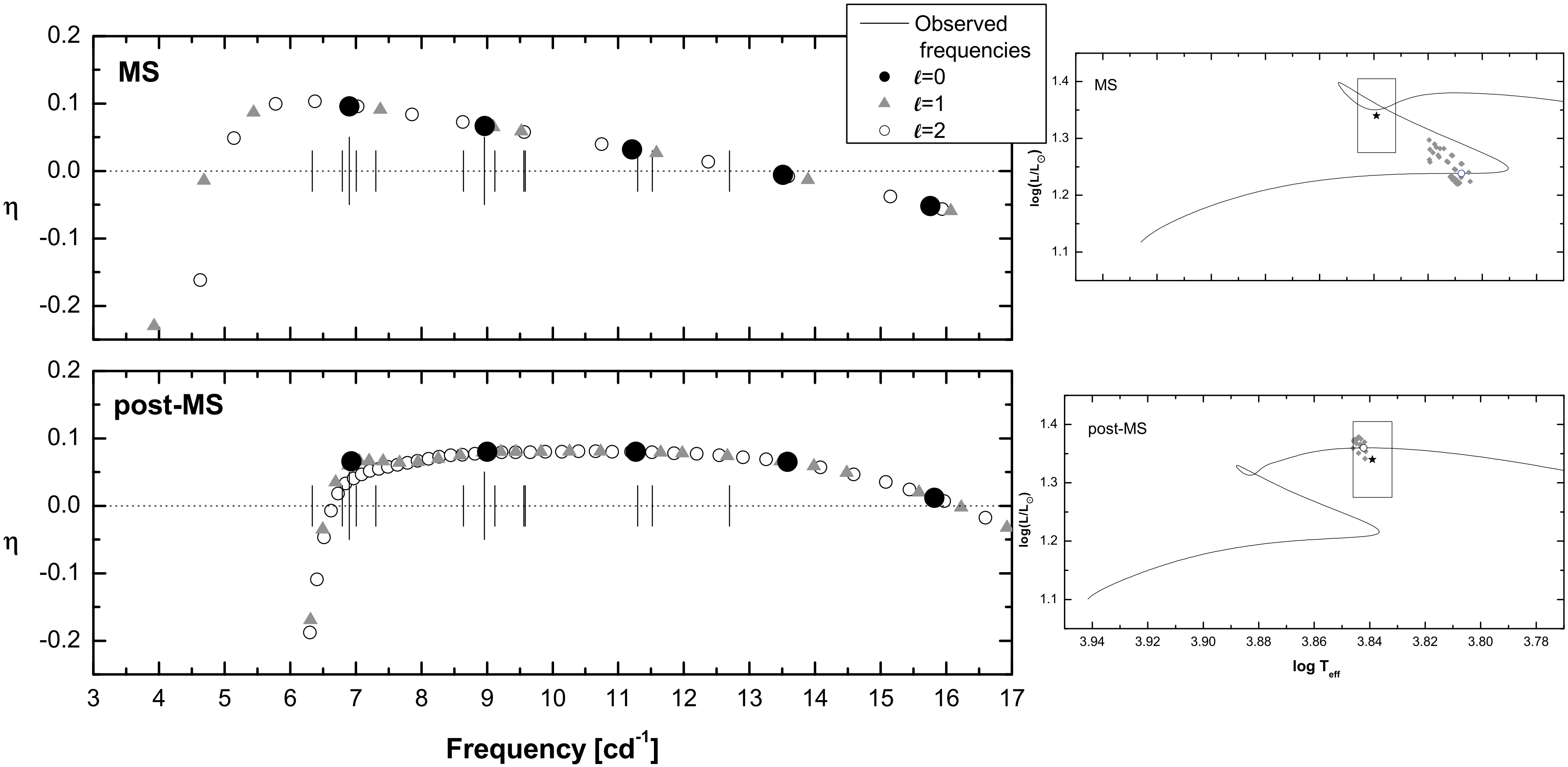


Fundamental radial mode= 6.90 +/- 0.10 (c/d)
1st overtone radial = 8.96 +/- 0.10 (c/d)

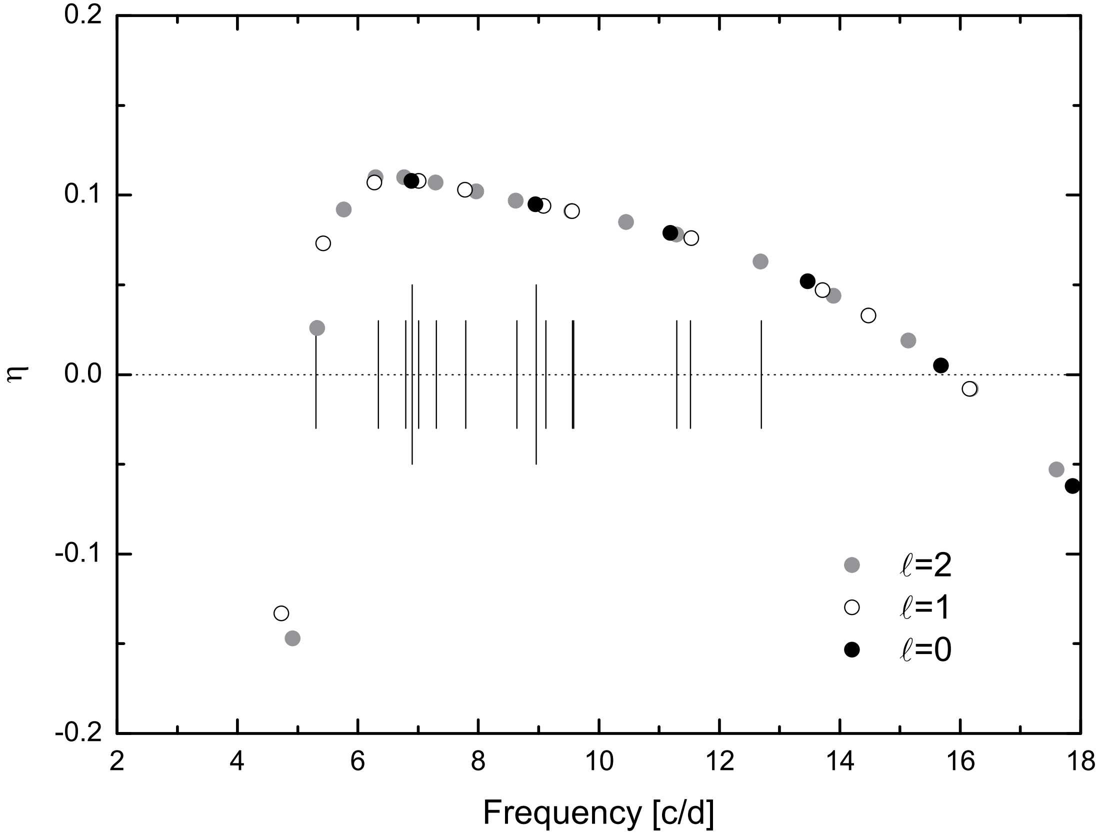


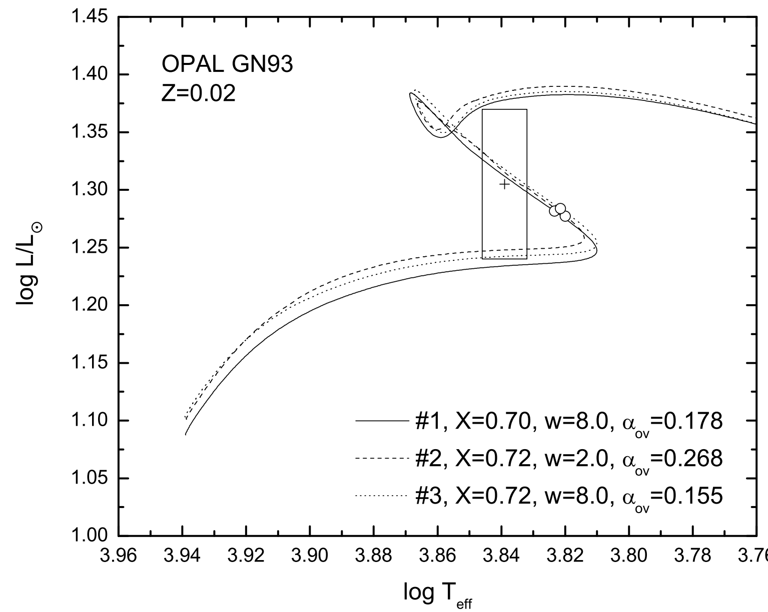
Fundamental radial mode= 6.90 +/- 0.10 (c/d)

1st overtone radial = 8.96 +/- 0.10 (c/d)



Lenz, Pamyatnykh et al. 2008





Lenz, Pamyatnykh et al. 2010

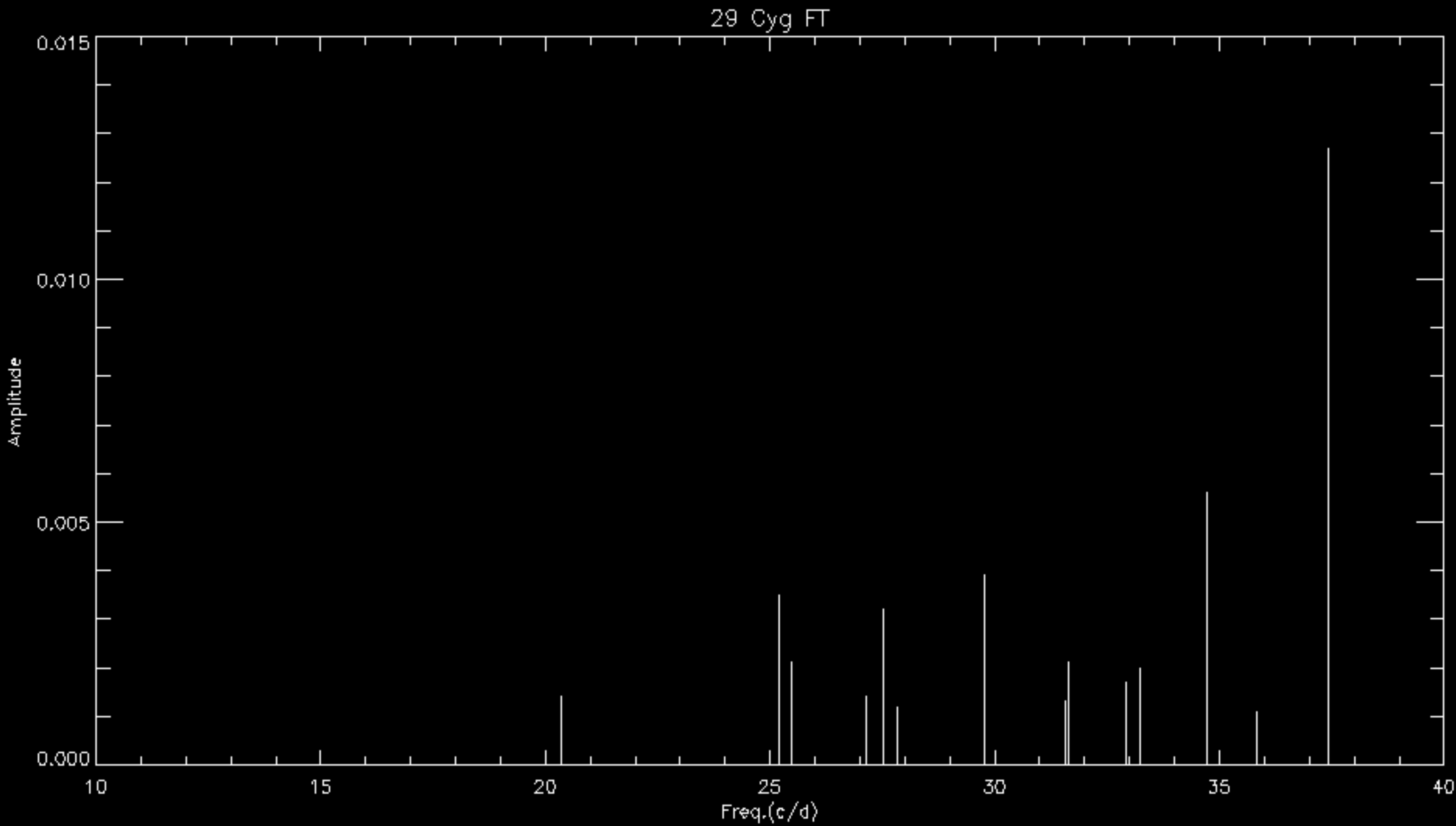
29 Cygni

- Vsini <= 80 km/s
- Main sequence, slightly evolved
- $\log T_{eff}$= 3.902+/- 0.009, log g=4.12+/-0.25
- Lambda Boo star

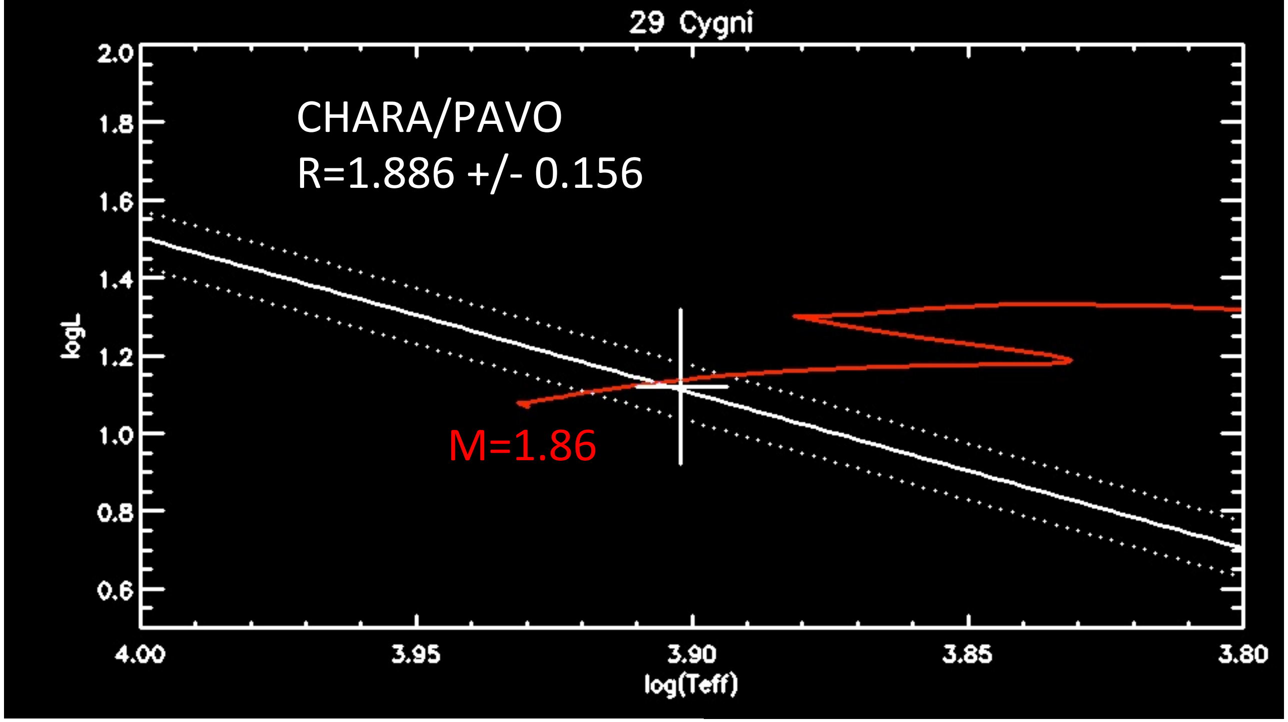
(unusually weak lines of iron-peak elements, whereas C,N,O and S have solar abundance)

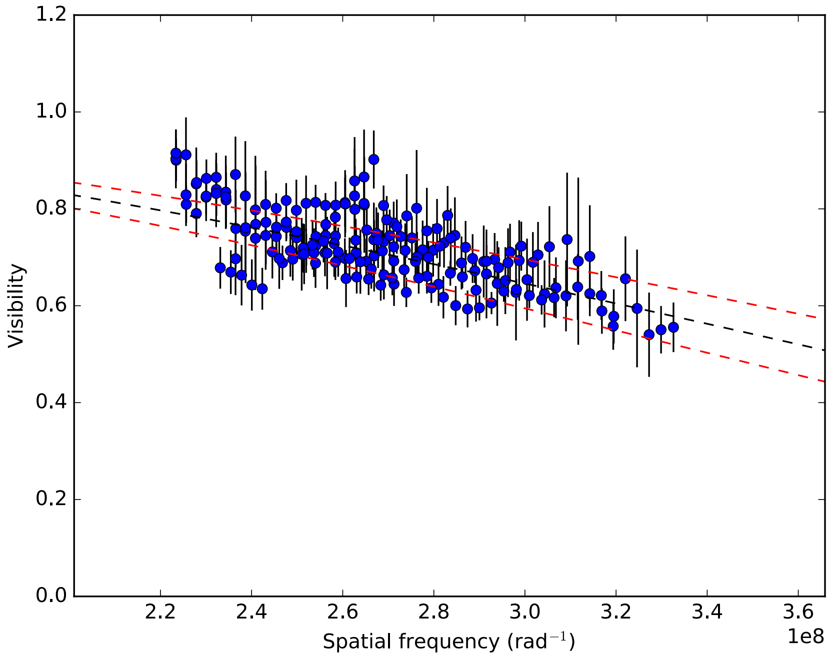
- 14 frequencies, multi-color photometry mode ID. & seismic modeling, Casas 09

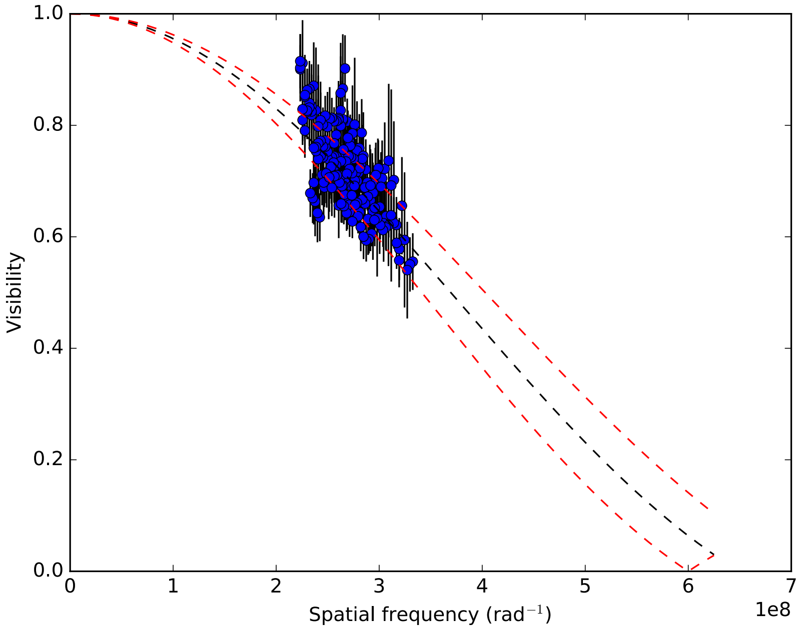
29 Cygni

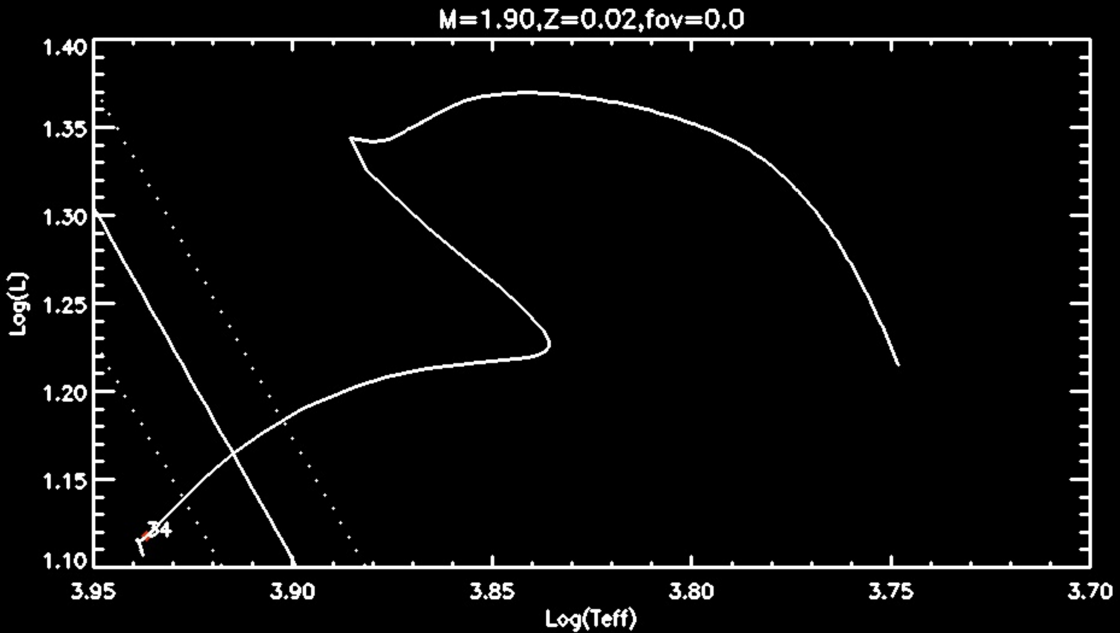


29 Cyg FT
0.015
0.010
0.005
0.000
Amplitude
10
15
20
25
30
35
40
Freq.(c/d)

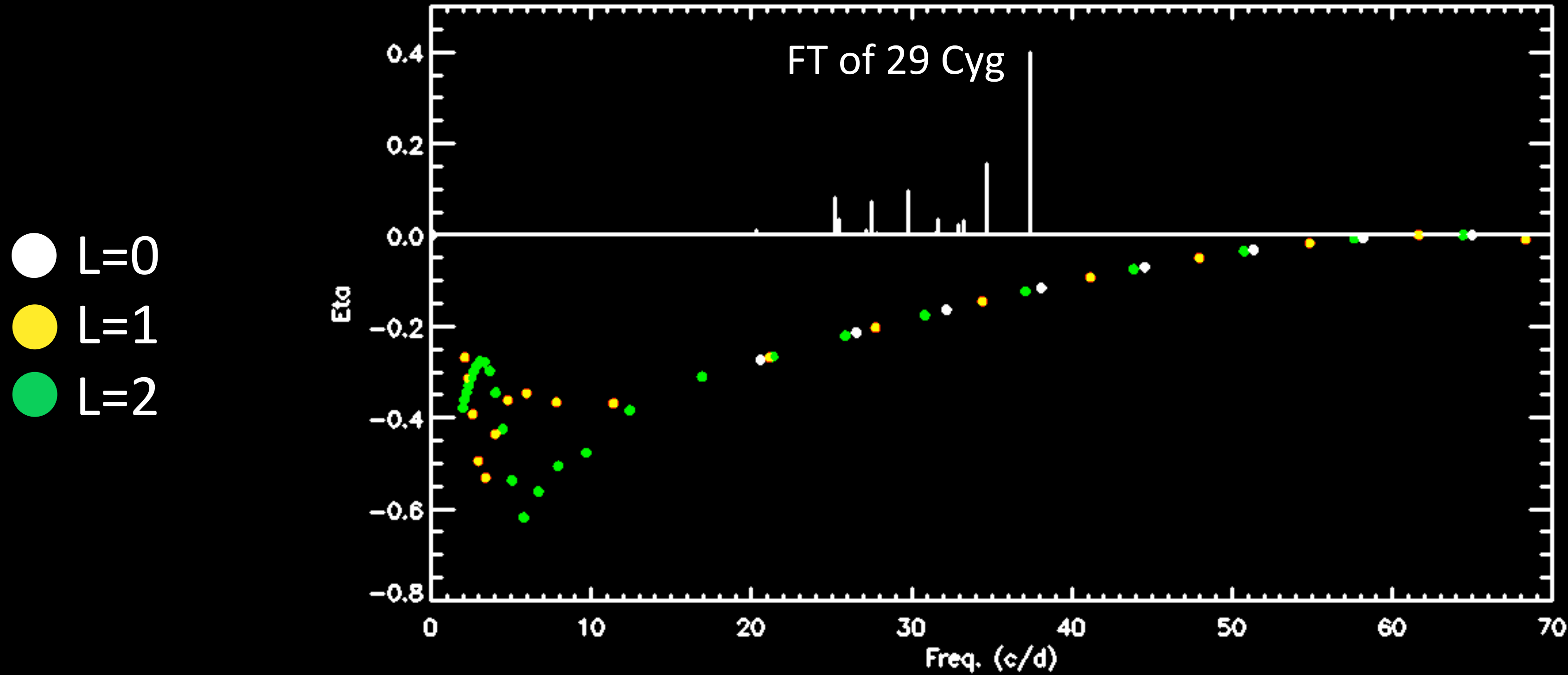

29 Cygni
CHARA/PAVO
R=1.886 +/- 0.156
M=1.86
logL
log(Teff)

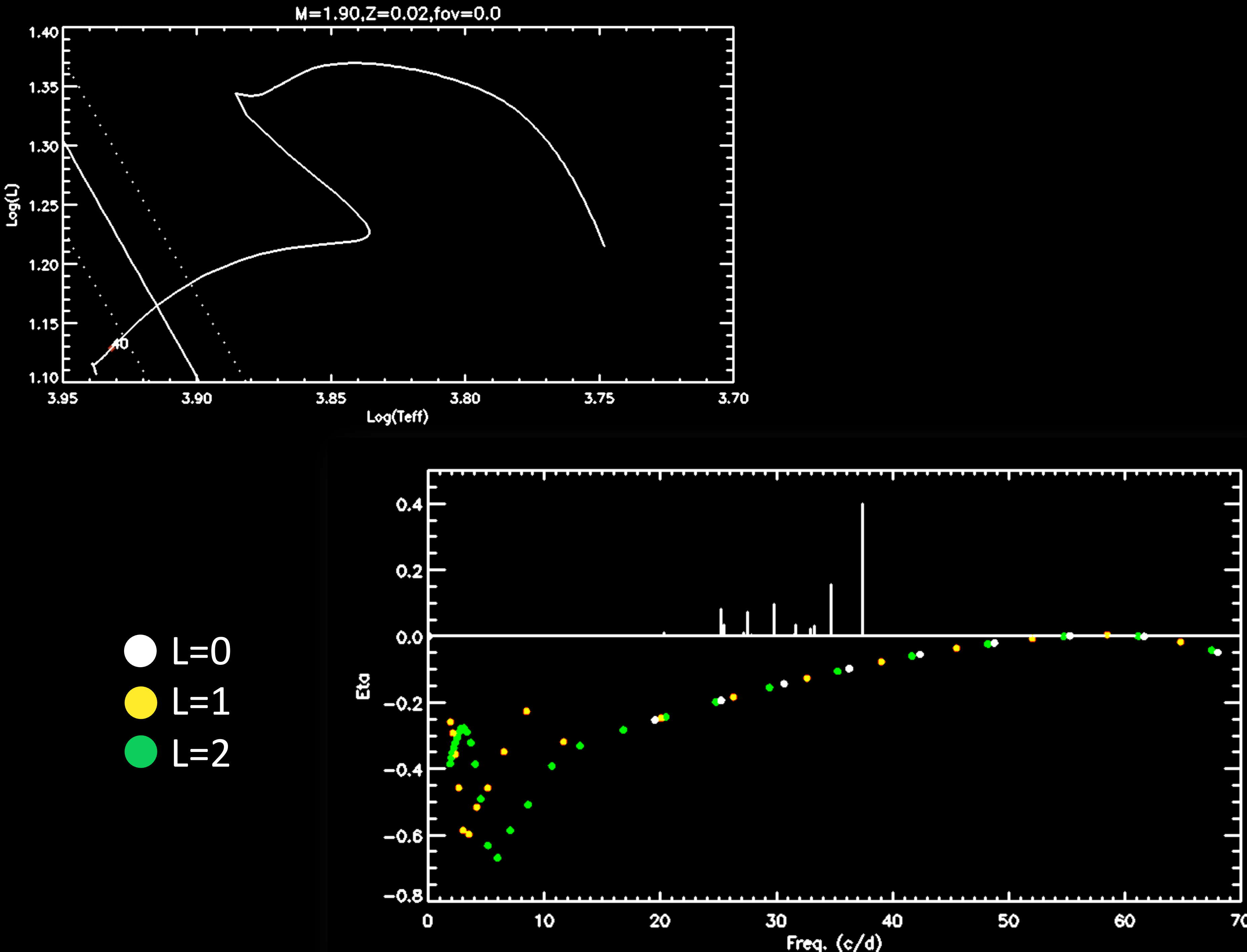

Visibility
Spatial frequency (rad^{-1})
1e8

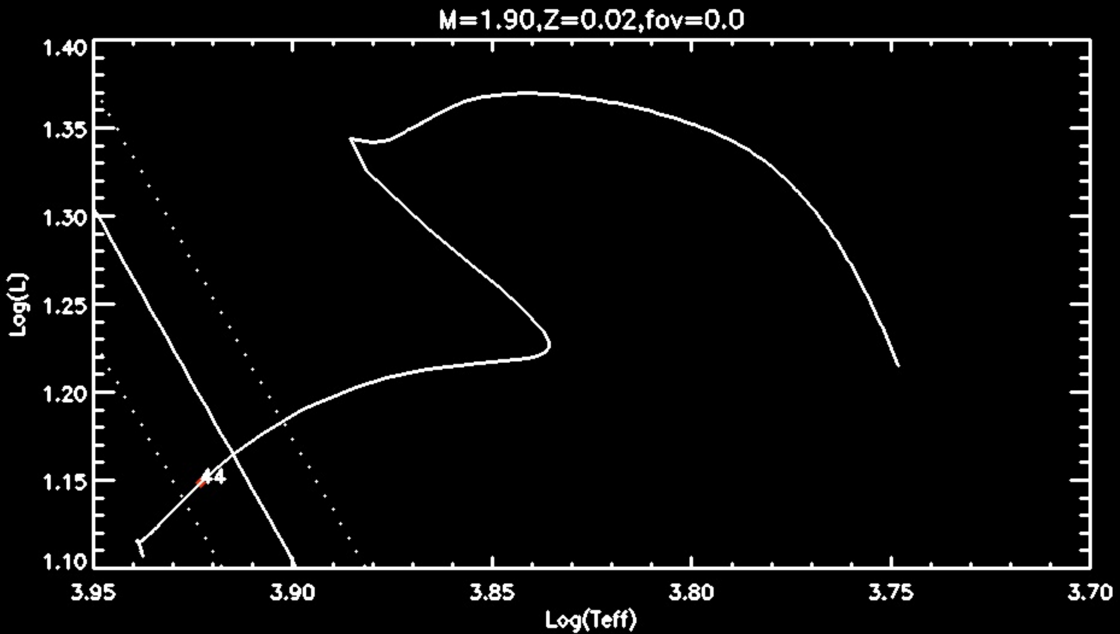

Visibility
Spatial frequency (rad^{-1})
1e8

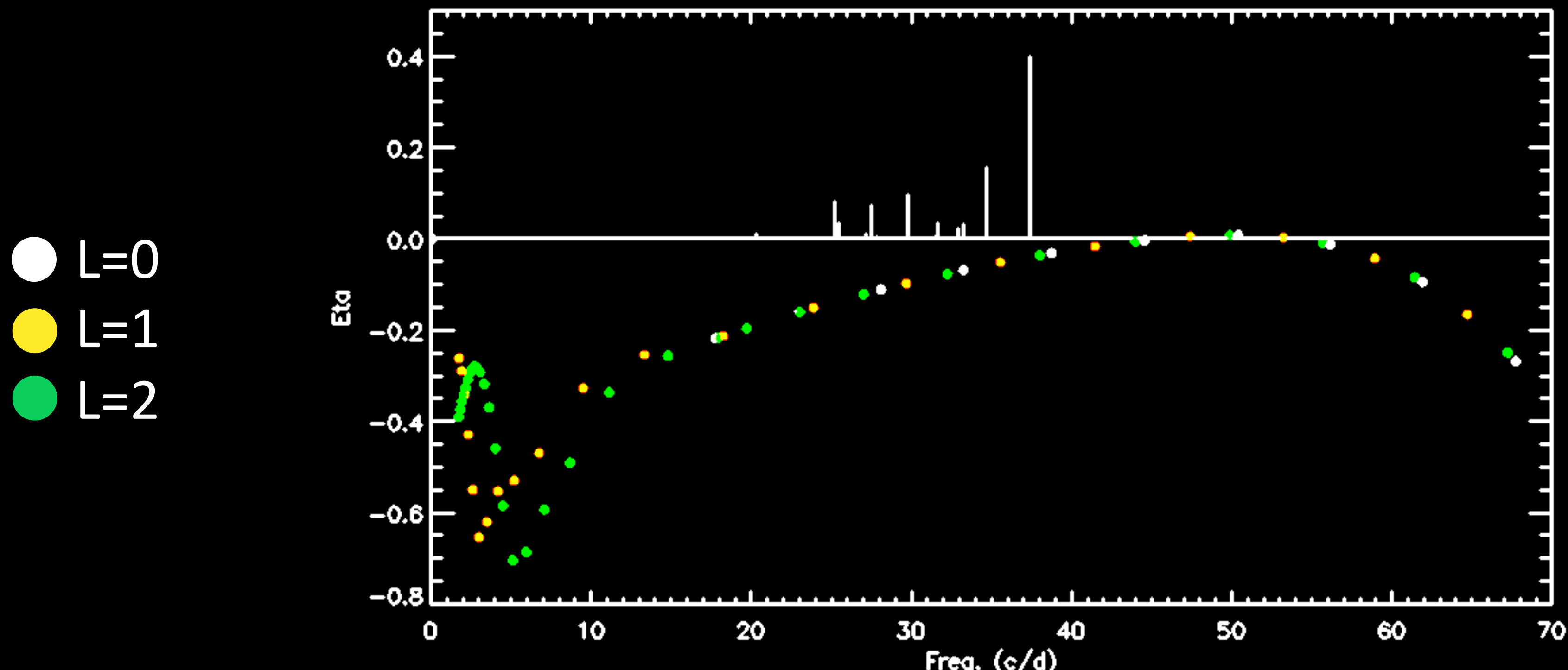


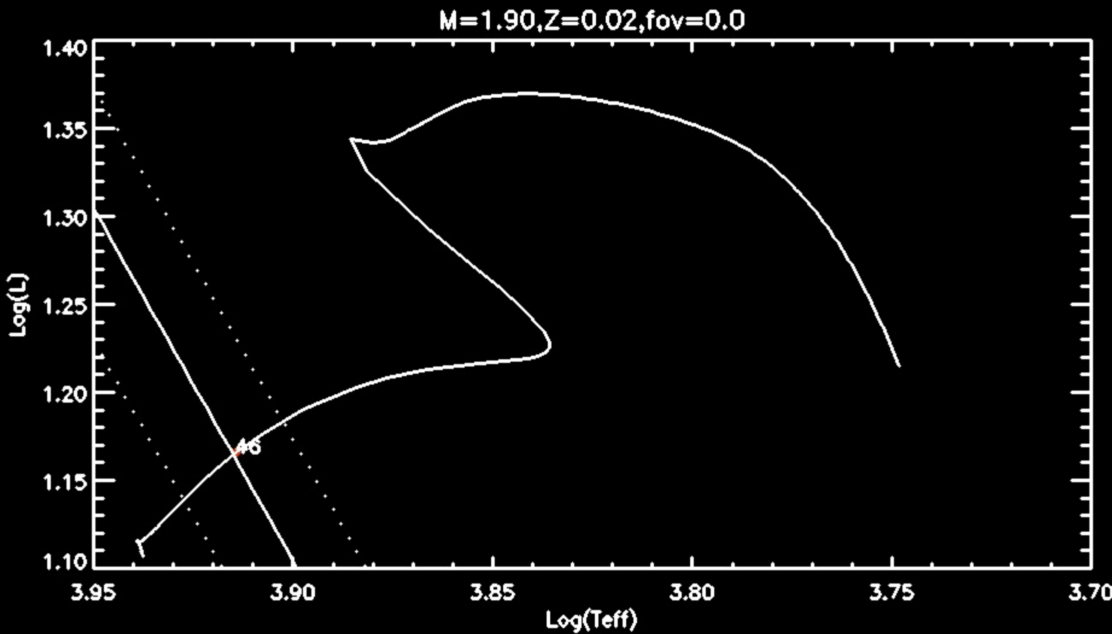
Evolution of frequencies and mode excitation

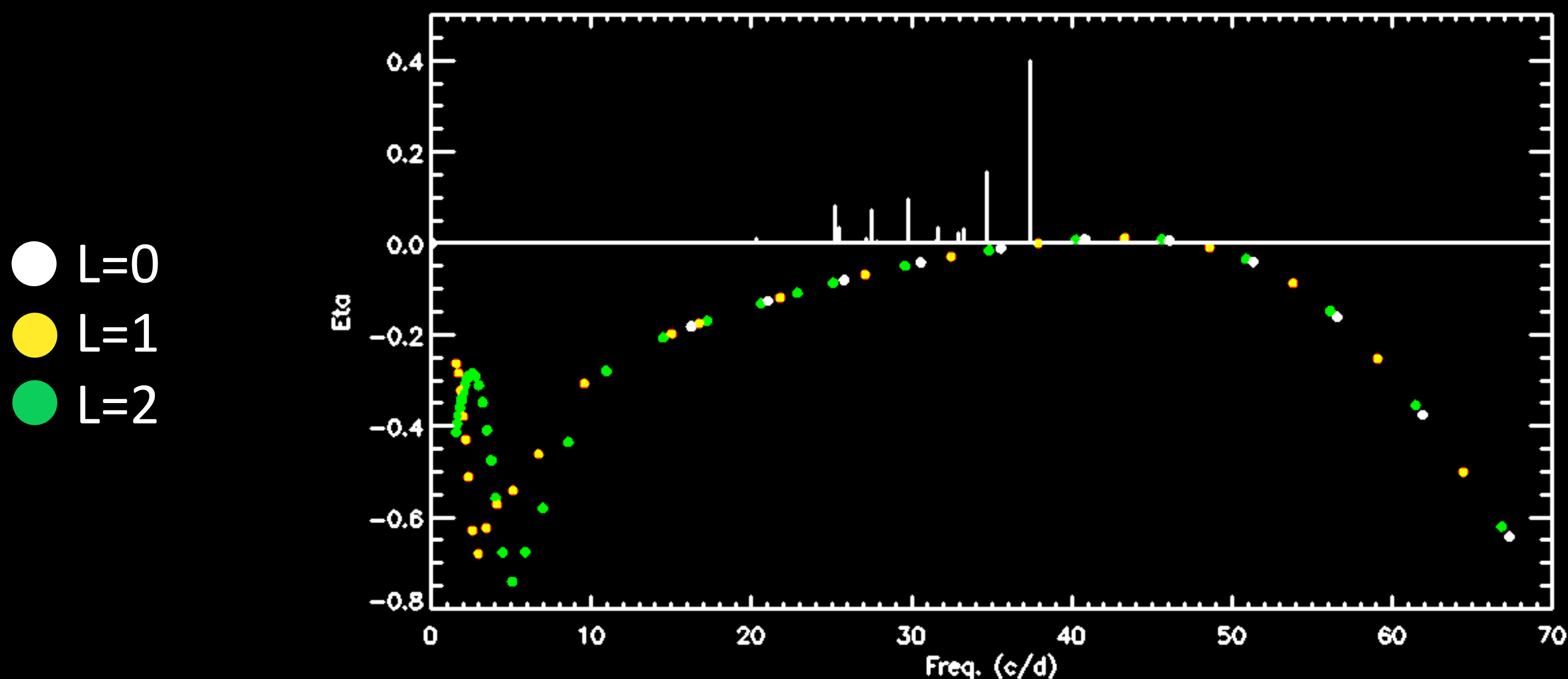


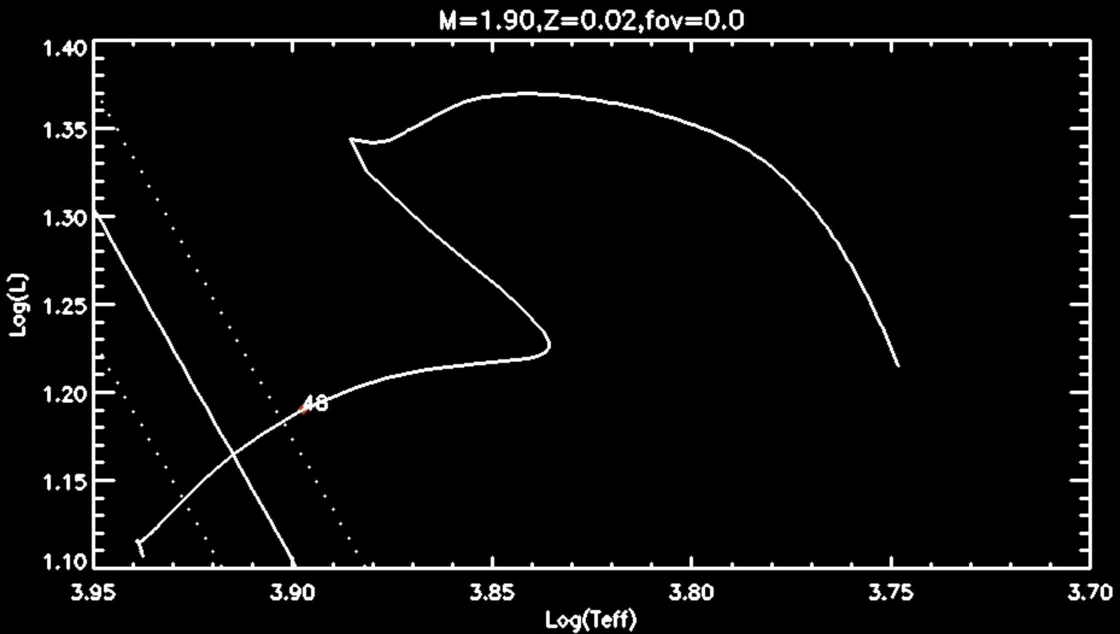

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
40
L=0
L=1
L=2
Eta
Freq. (c/d)

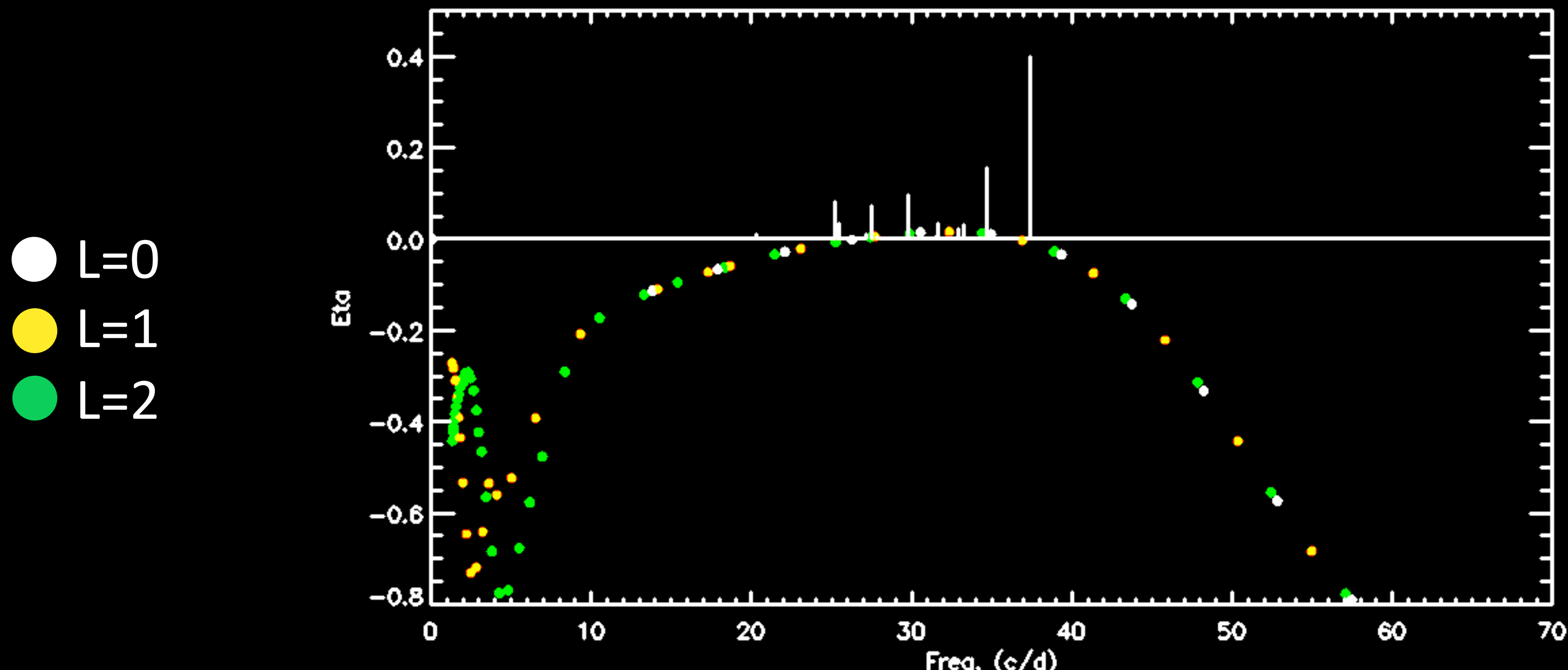

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
44

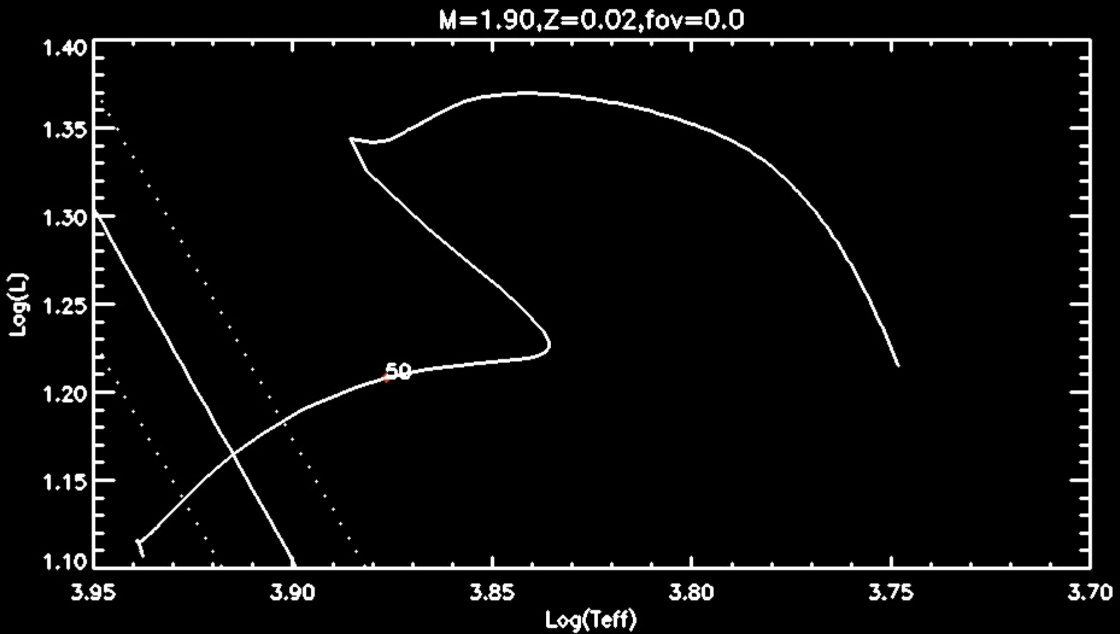

L=0
L=1
L=2
Eta
Freq. (c/d)


M=1.90,Z=0.02,fov=0.0
Log(L)
1.40
1.35
1.30
1.25
1.20
1.15
1.10
Log(Teff)
3.95
3.90
3.85
3.80
3.75
3.70
46

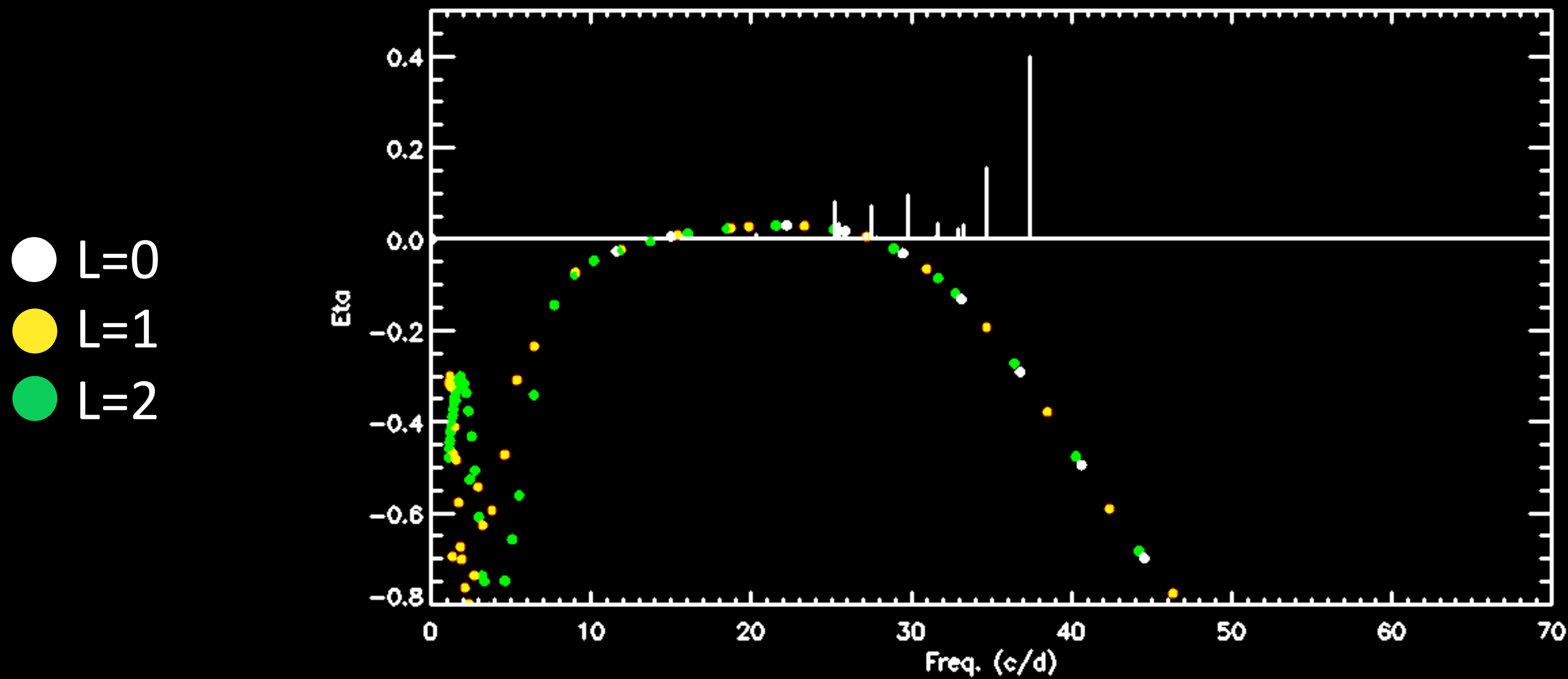

L=0
L=1
L=2
Eta
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
Freq. (c/d)
0
10
20
30
40
50
60
70


M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
48
1.40
1.35
1.30
1.25
1.20
1.15
1.10
3.95
3.90
3.85
3.80
3.75
3.70

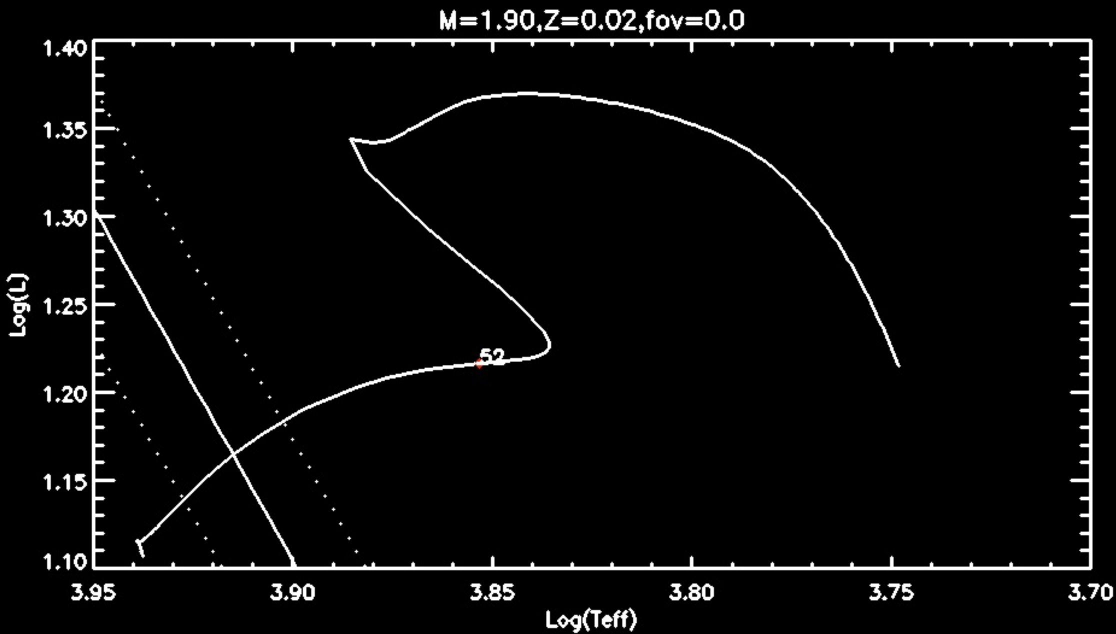

L=0
L=1
L=2
Eta
Freq. (c/d)
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
0
10
20
30
40
50
60
70

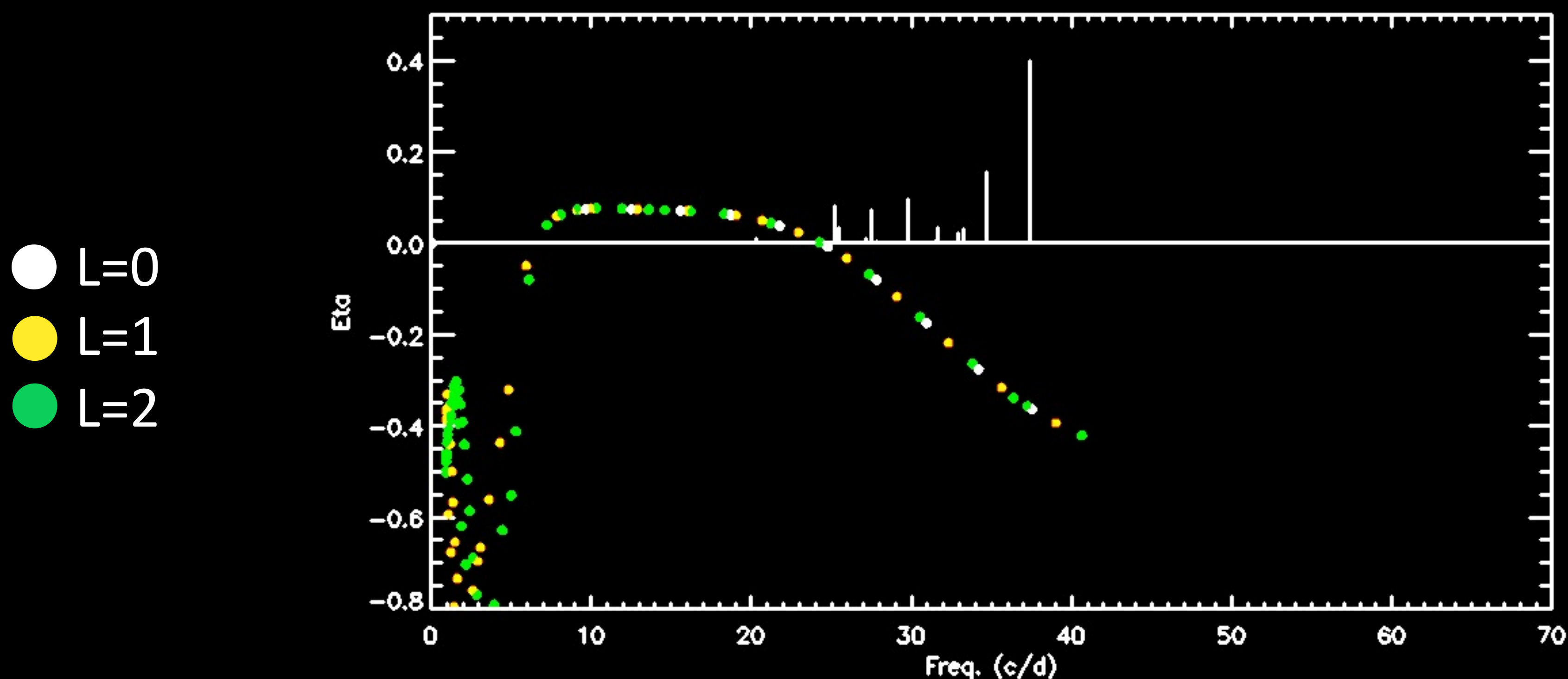


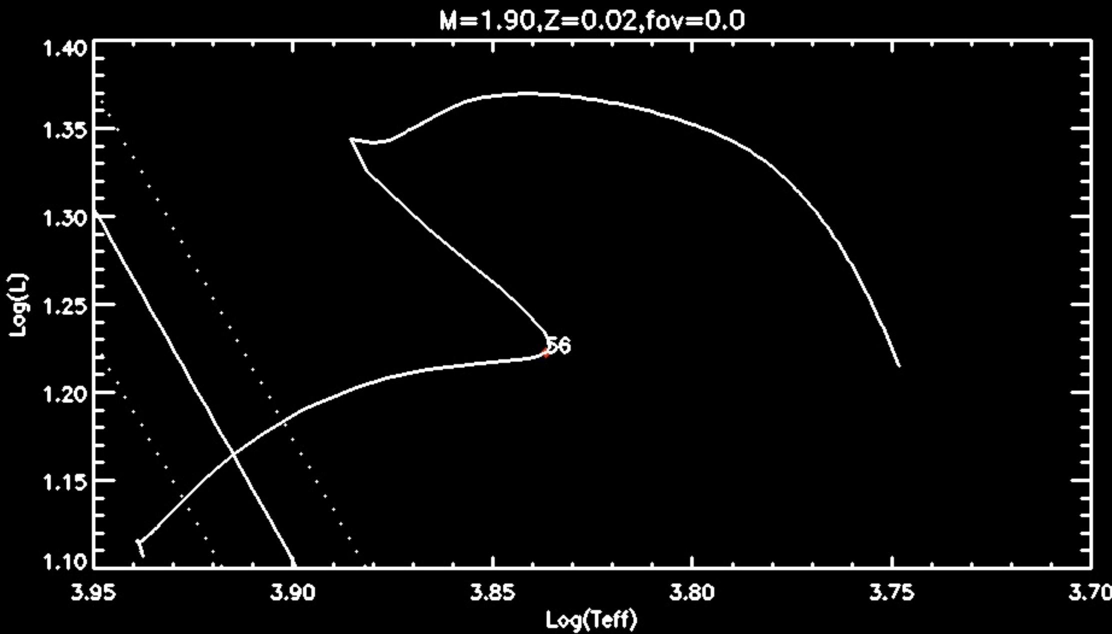
M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
50

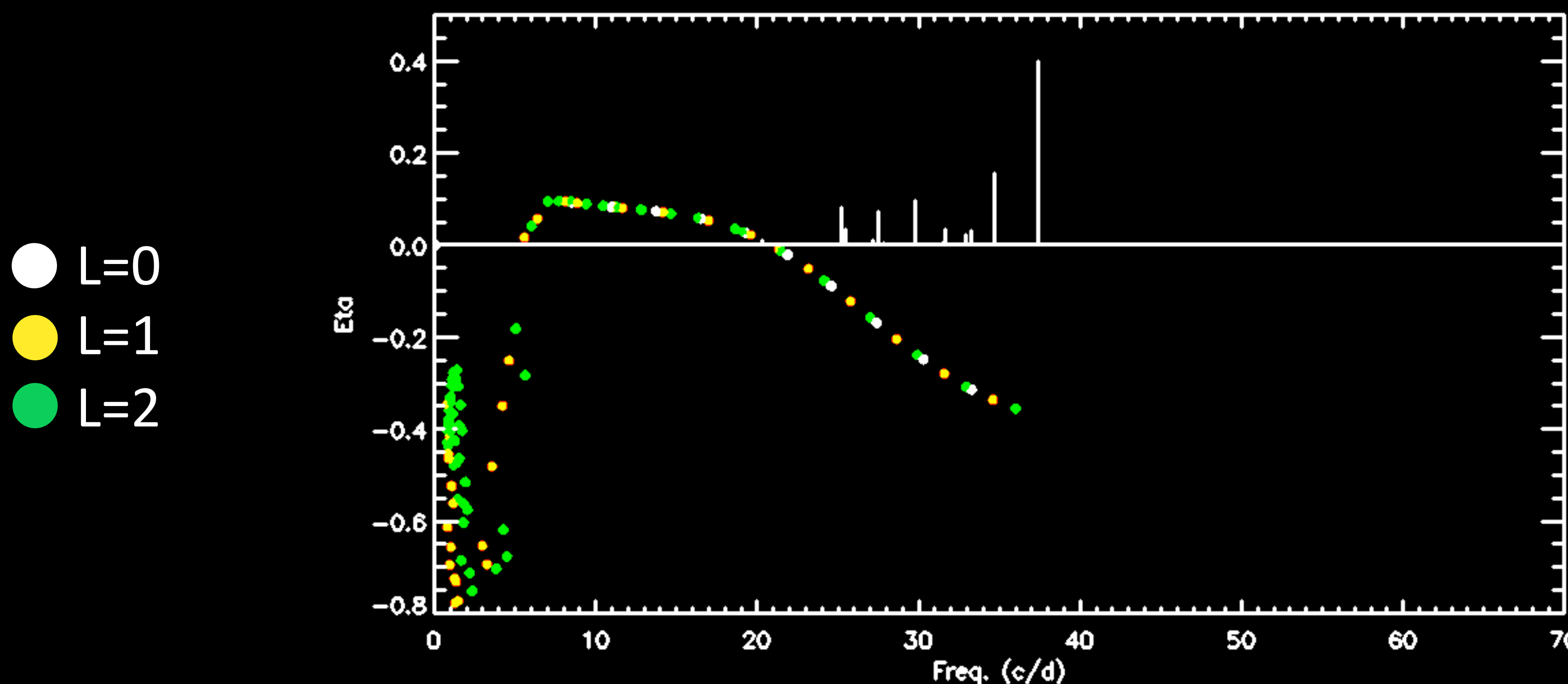


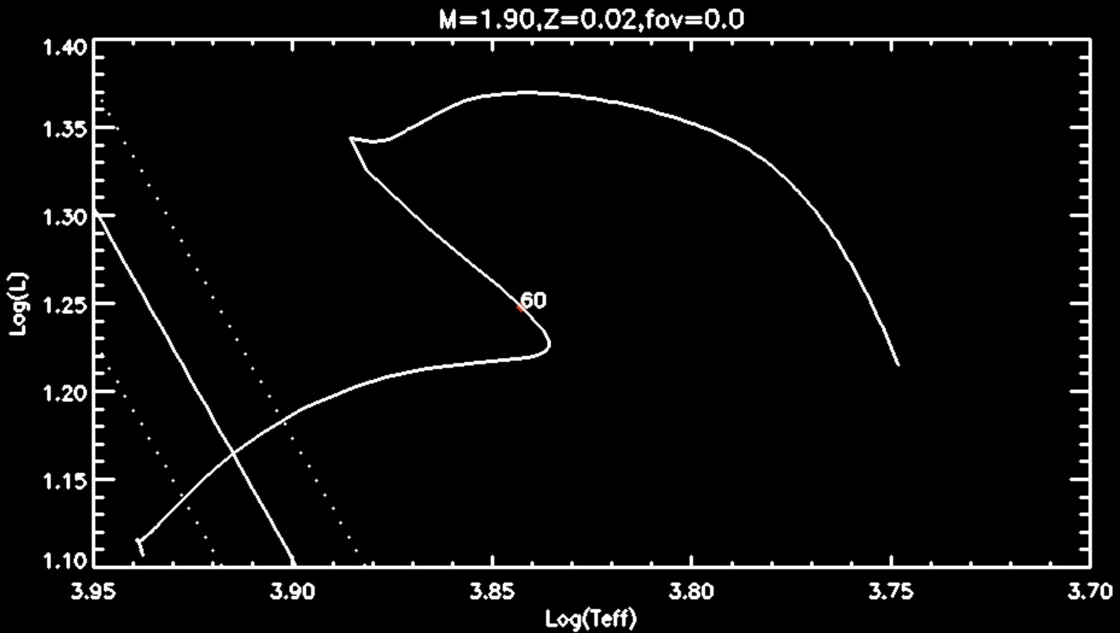
L=0
L=1
L=2
Eta
Freq. (c/d)

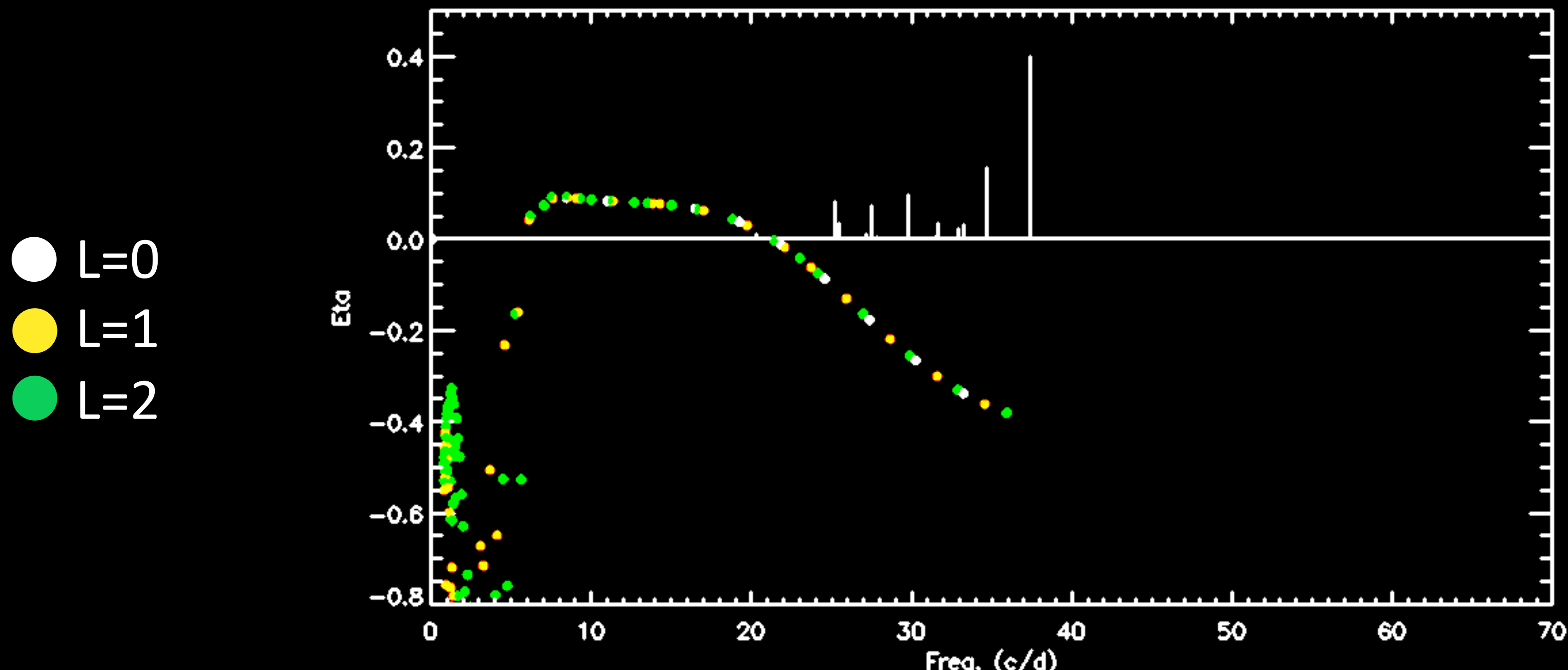

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
52
1.40
1.35
1.30
1.25
1.20
1.15
1.10
3.95
3.90
3.85
3.80
3.75
3.70

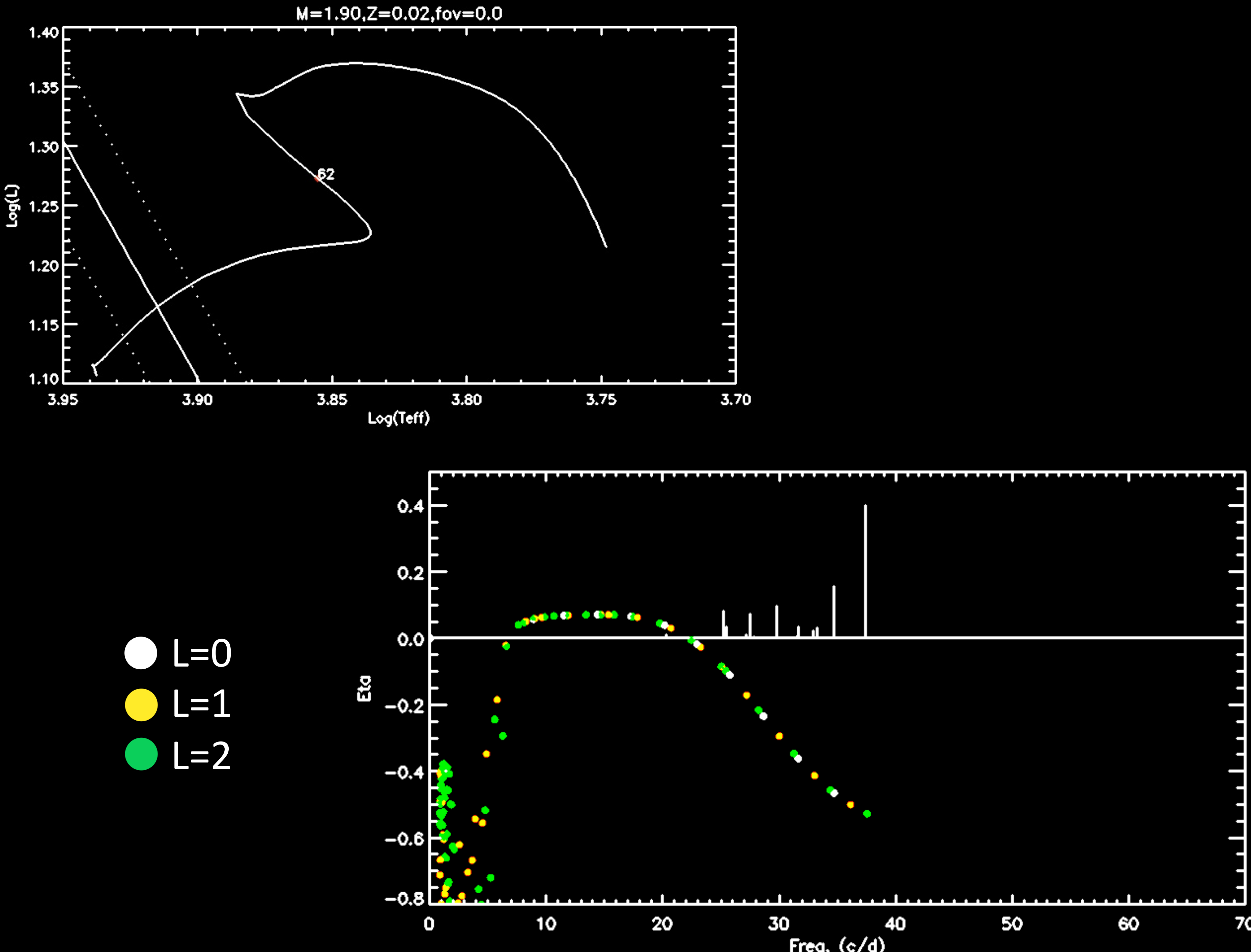

L=0
L=1
L=2
Eta
Freq. (c/d)
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
0
10
20
30
40
50
60
70

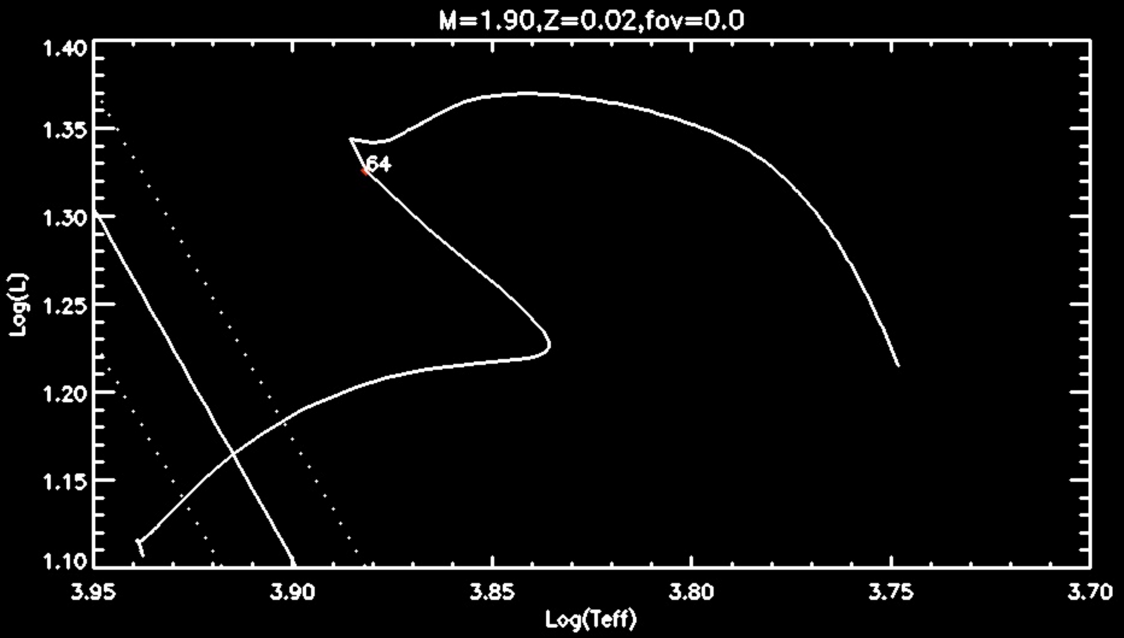

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
56

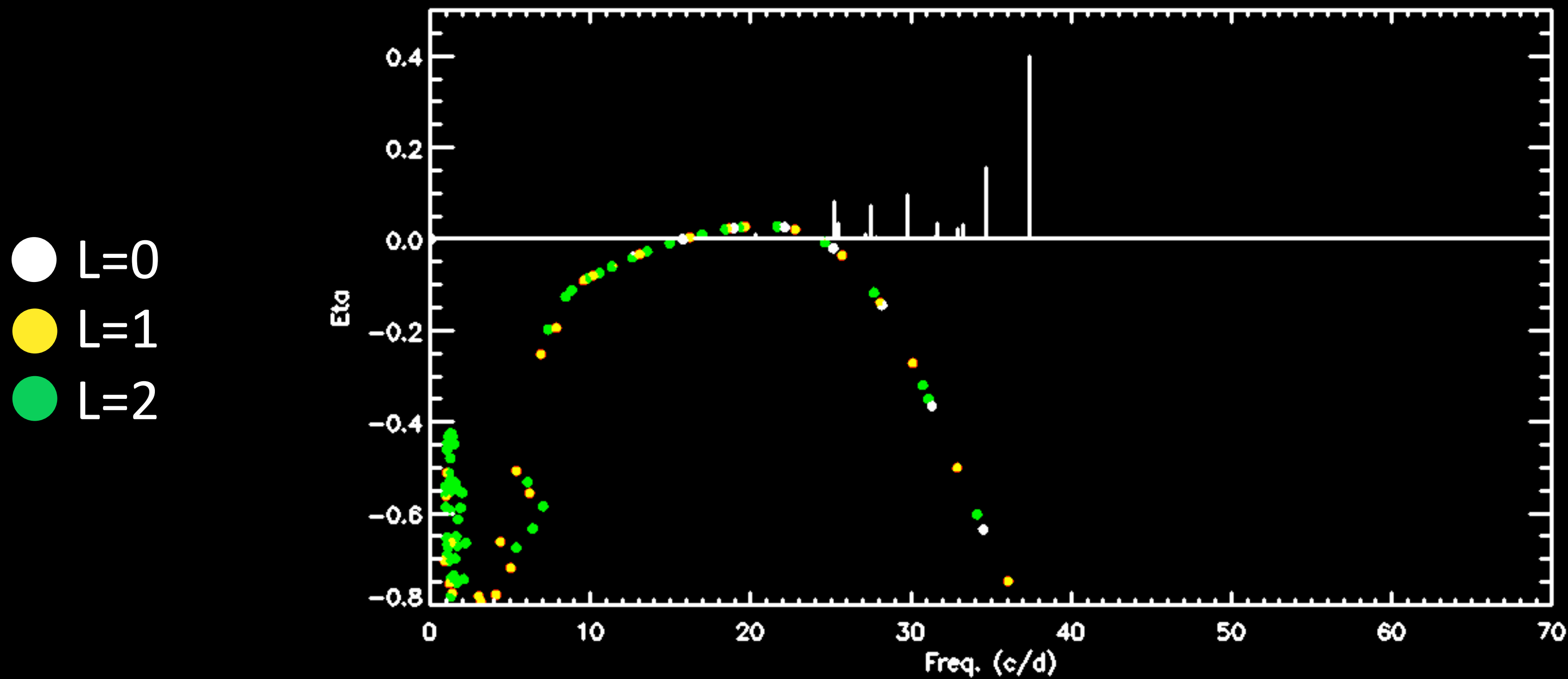

L=0
L=1
L=2
Eta
Freq. (c/d)

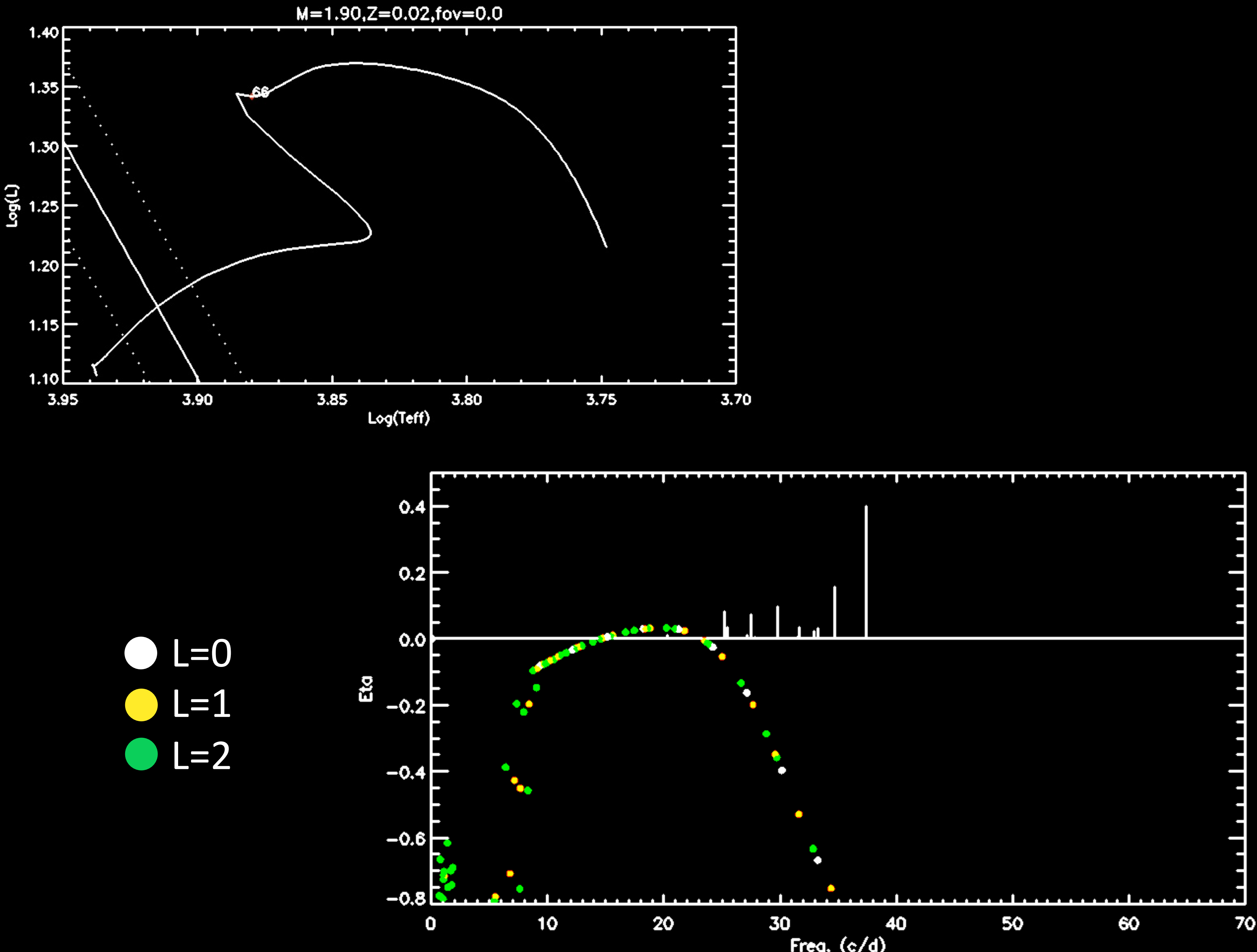

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
60
1.40
1.35
1.30
1.25
1.20
1.15
1.10
3.95
3.90
3.85
3.80
3.75
3.70


L=0
L=1
L=2
Eta
Freq. (c/d)
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
0
10
20
30
40
50
60
70

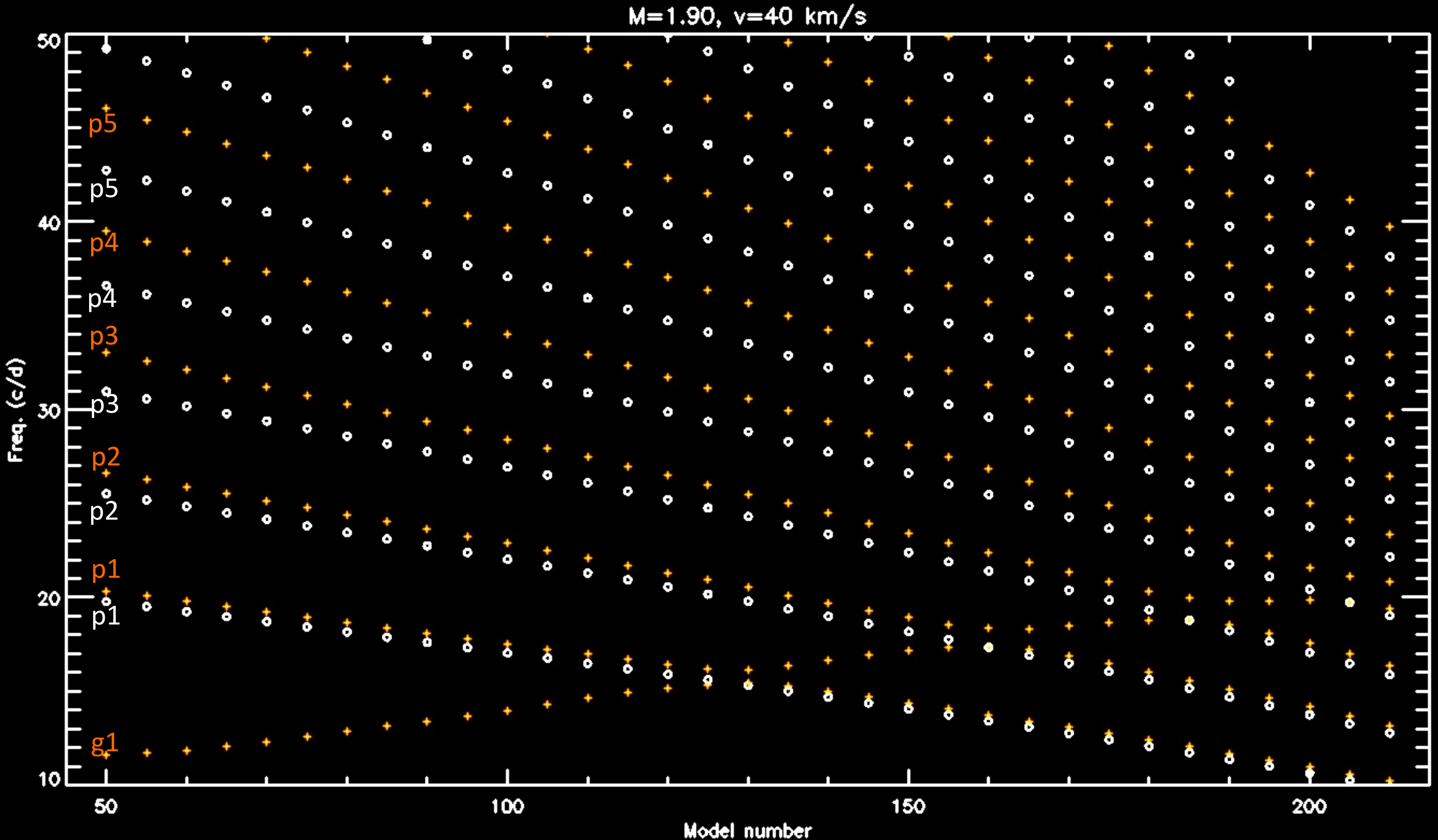

M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
62
1.40
1.35
1.30
1.25
1.20
1.15
1.10
3.95
3.90
3.85
3.80
3.75
3.70
L=0
L=1
L=2
Eta
Freq. (c/d)
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
0
10
20
30
40
50
60
70


M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
64


L=0
L=1
L=2
Eta
Freq. (c/d)

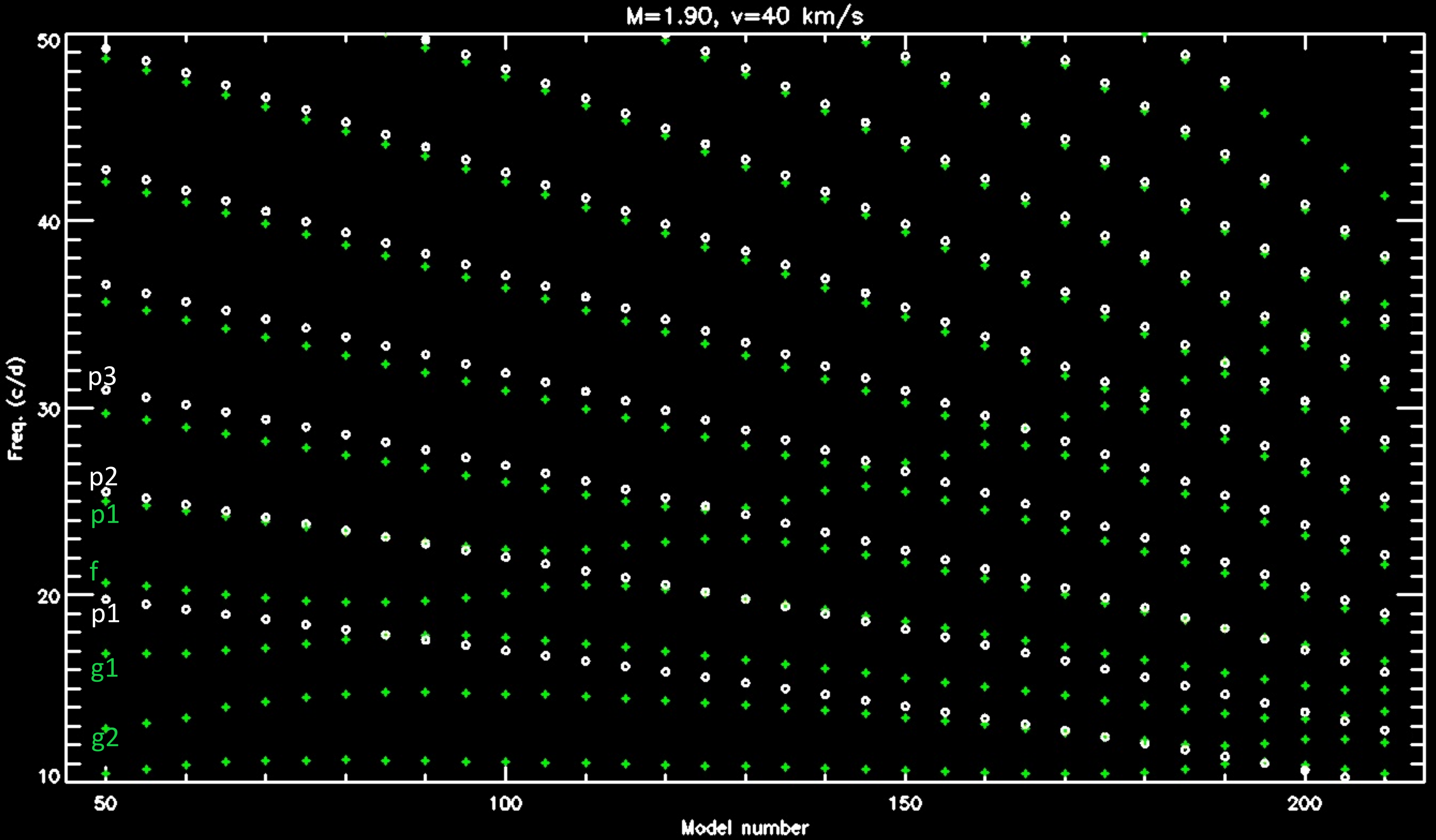


M=1.90,Z=0.02,fov=0.0
Log(L)
Log(Teff)
66
L=0
L=1
L=2
Eta
Freq. (c/d)



M=1.90, v=40 km/s
Freq. (c/d)
Model number
50
40
30
20
10
50
100
150
200
p5
p5
p4
p4
p3
p3
p2
p2
p1
p1
g1

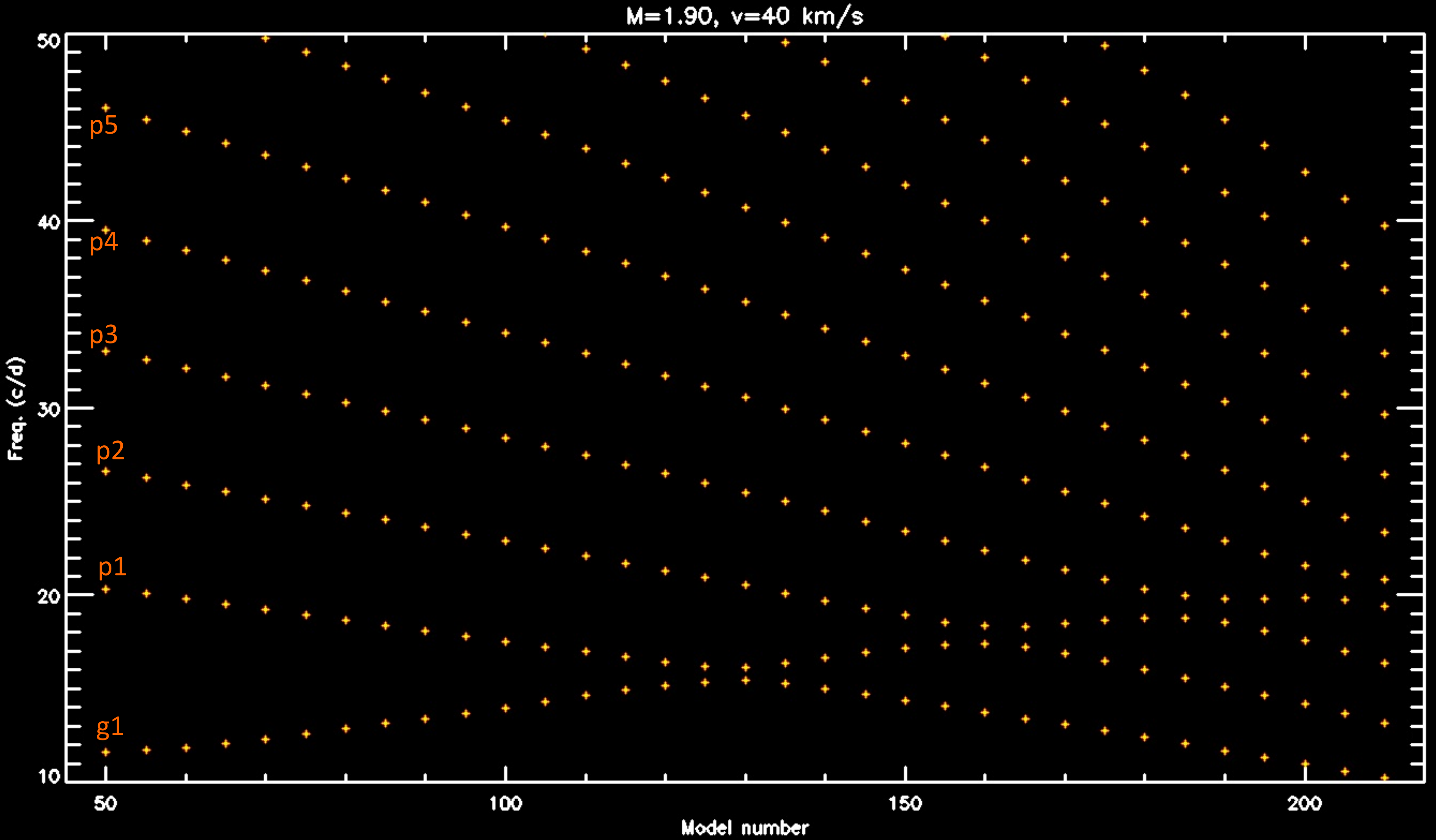
L=0
L=1, m=0



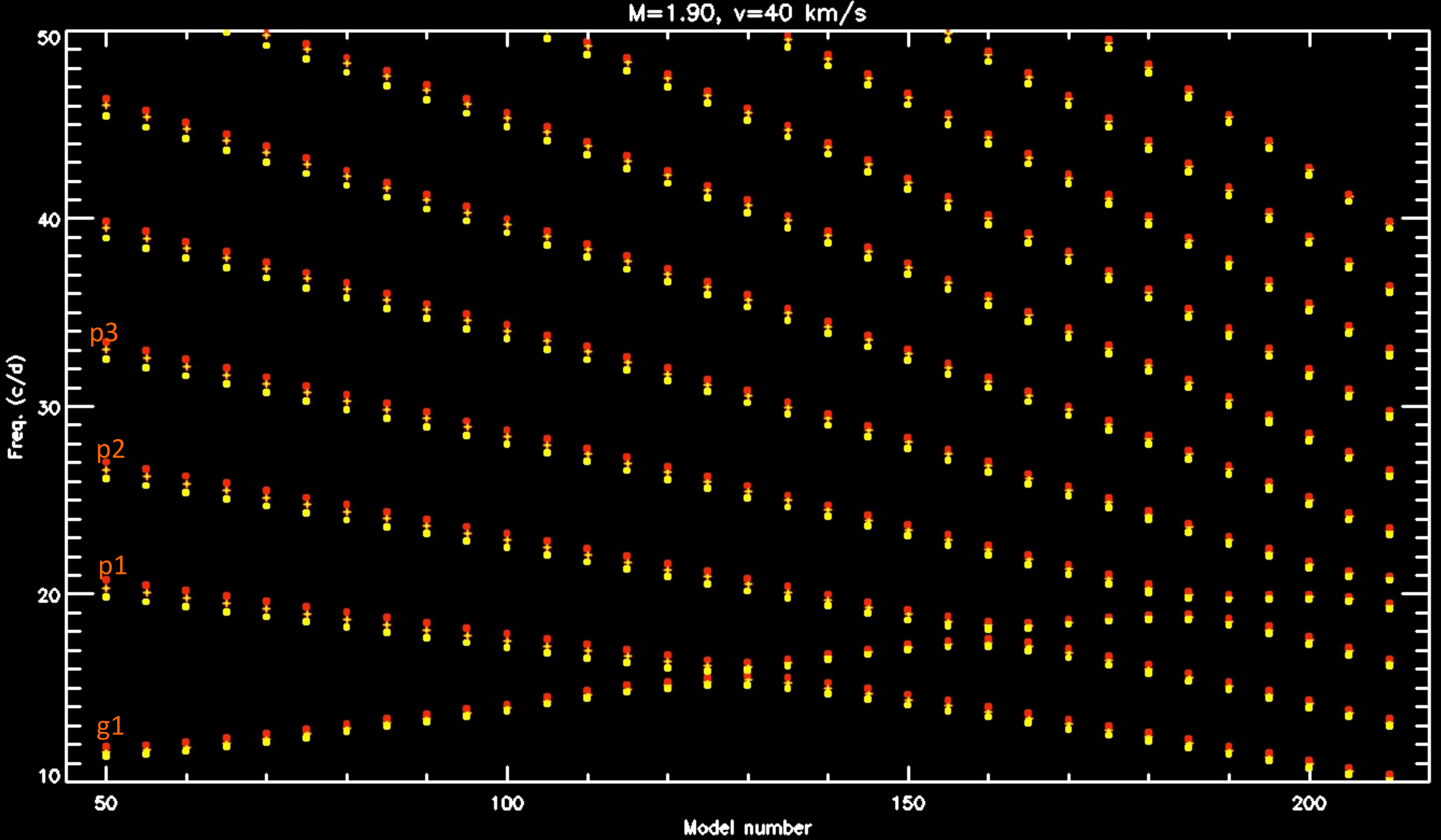
M=1.90, v=40 km/s
Freq. (c/d)
Model number
10
20
30
40
50
50
100
150
200
p3
p2
p1
f
p1
g1
g2

L=0

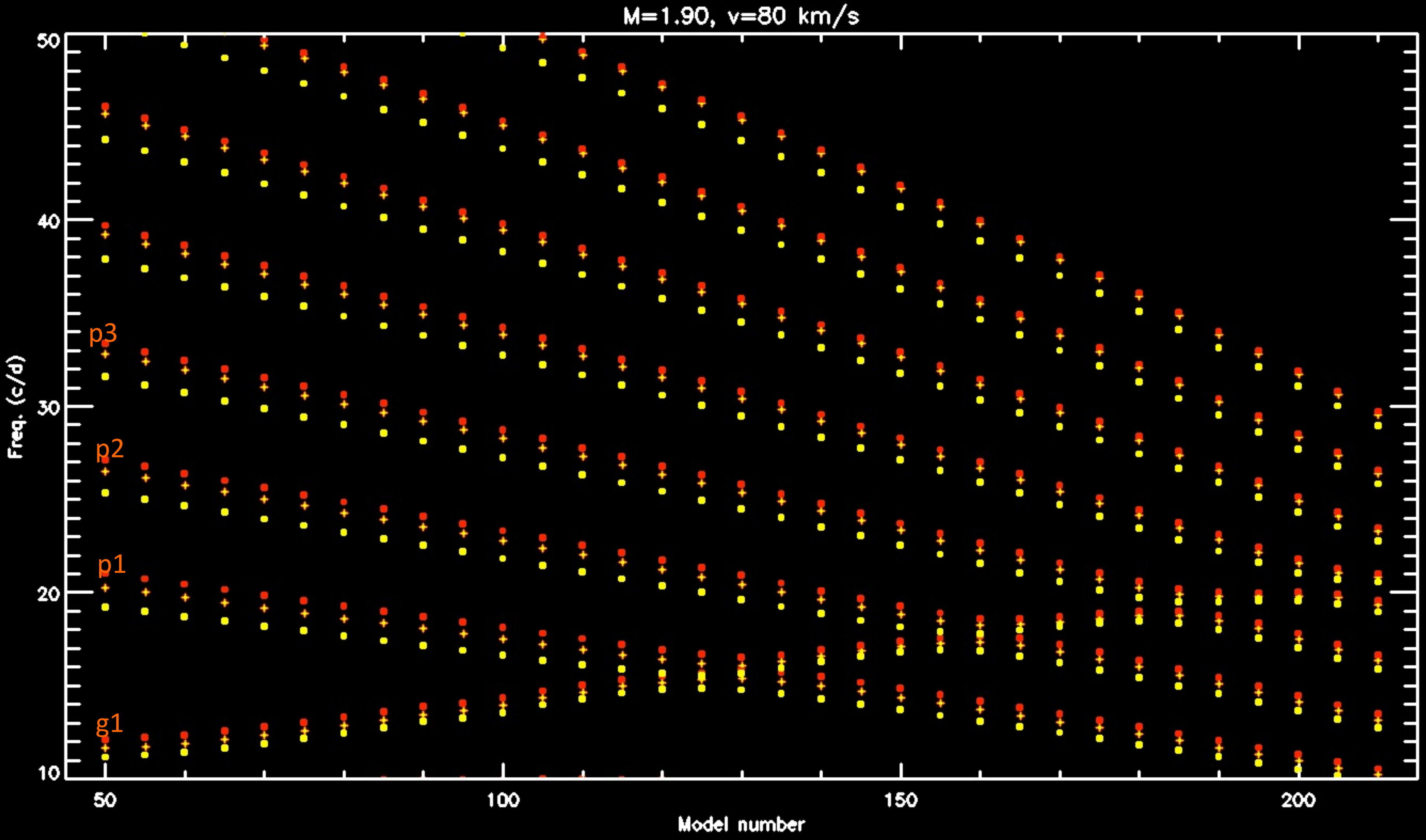
L=2, m=0


M=1.90, v=40 km/s
Freq. (c/d)
Model number
50
40
30
20
10
50
100
150
200
p5
p4
p3
p2
p1
g1

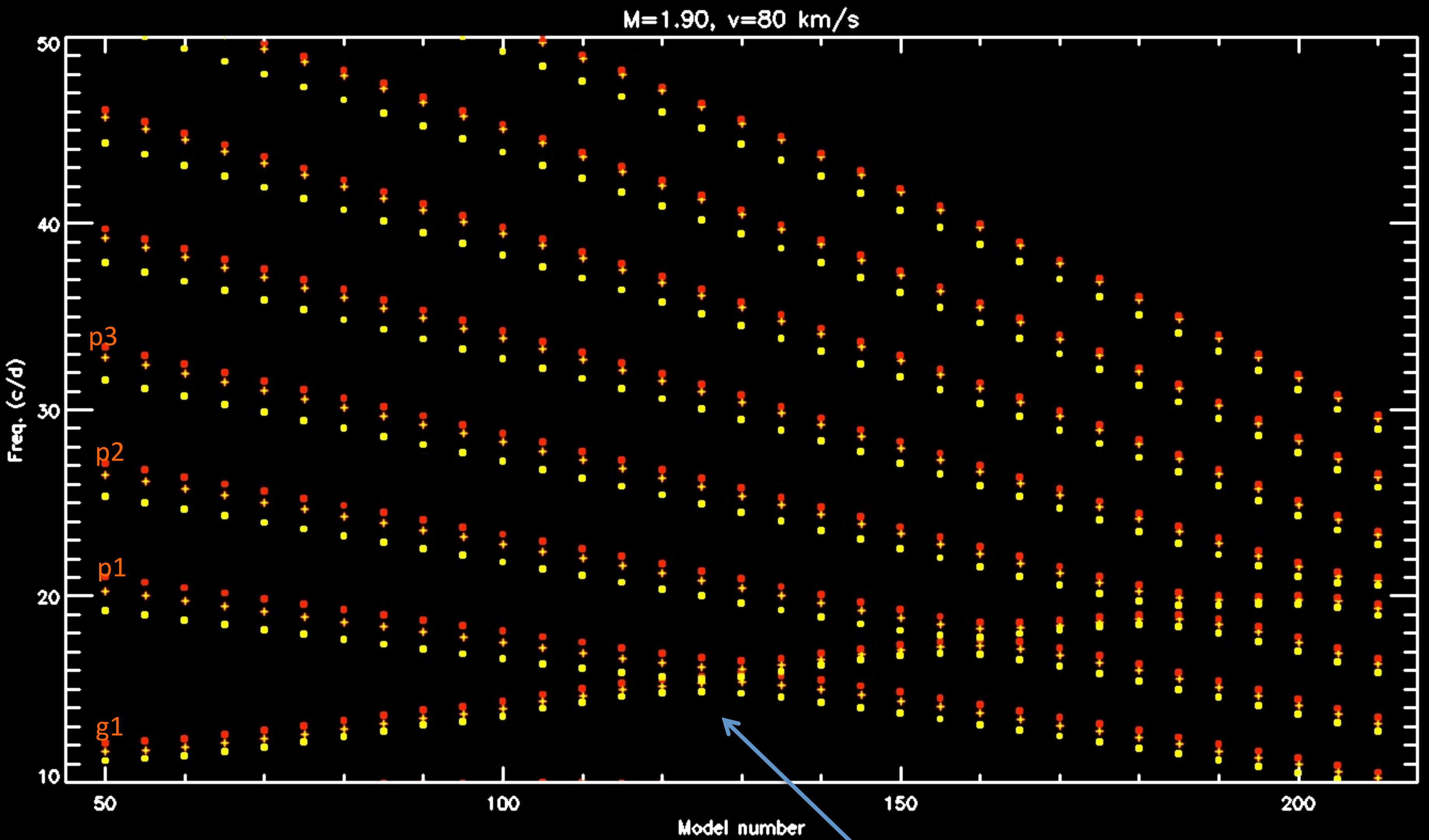
L=1, m=0


M=1.90, v=40 km/s
Freq. (c/d)
Model number
50
40
30
20
10
50
100
150
200
p3
p2
p1
g1

L=1, m=0, +1, -1

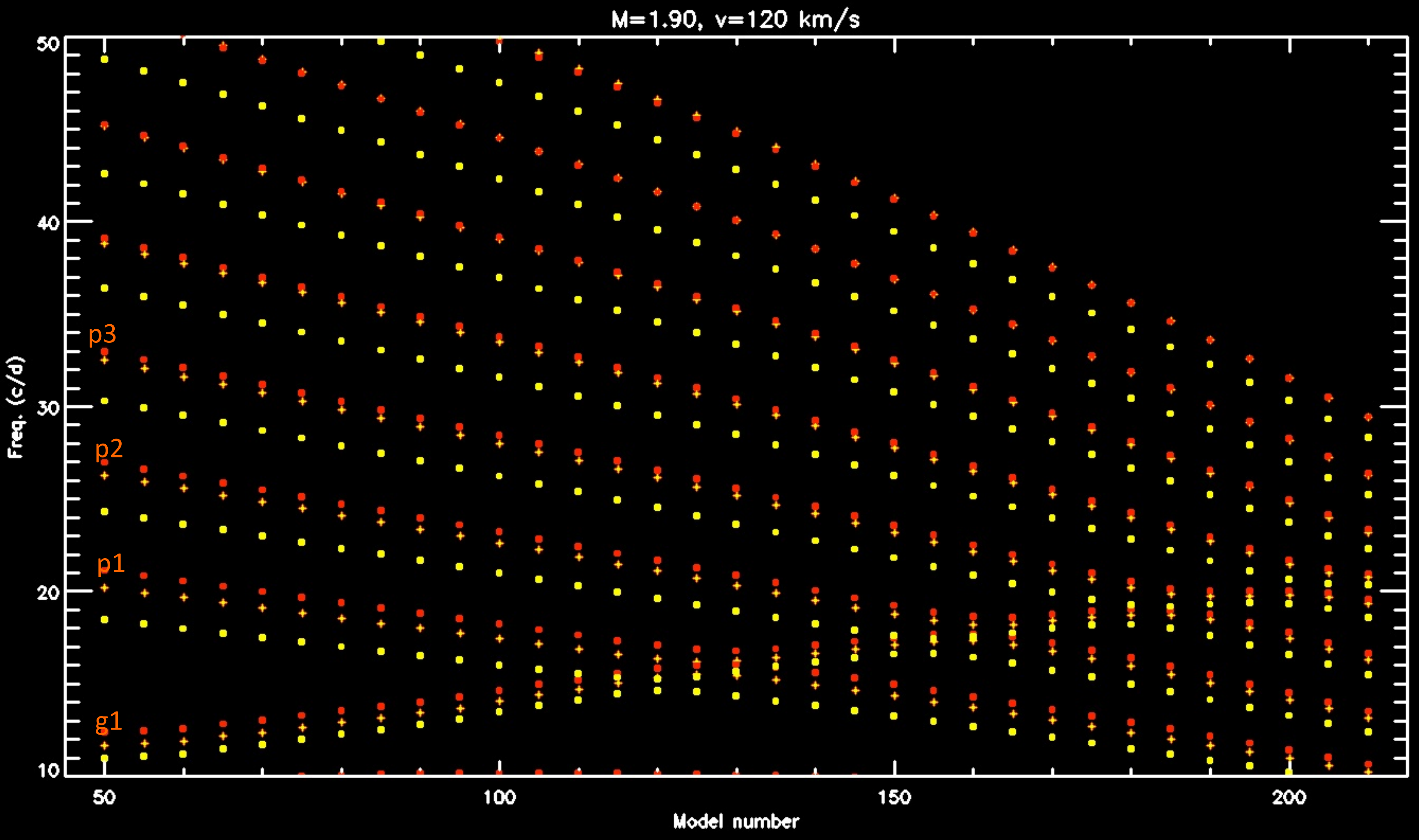

M=1.90, v=80 km/s
Freq. (c/d)
Model number
p3
p2
p1
g1
50
40
30
20
10
50
100
150
200

L=1, m=0, +1, -1



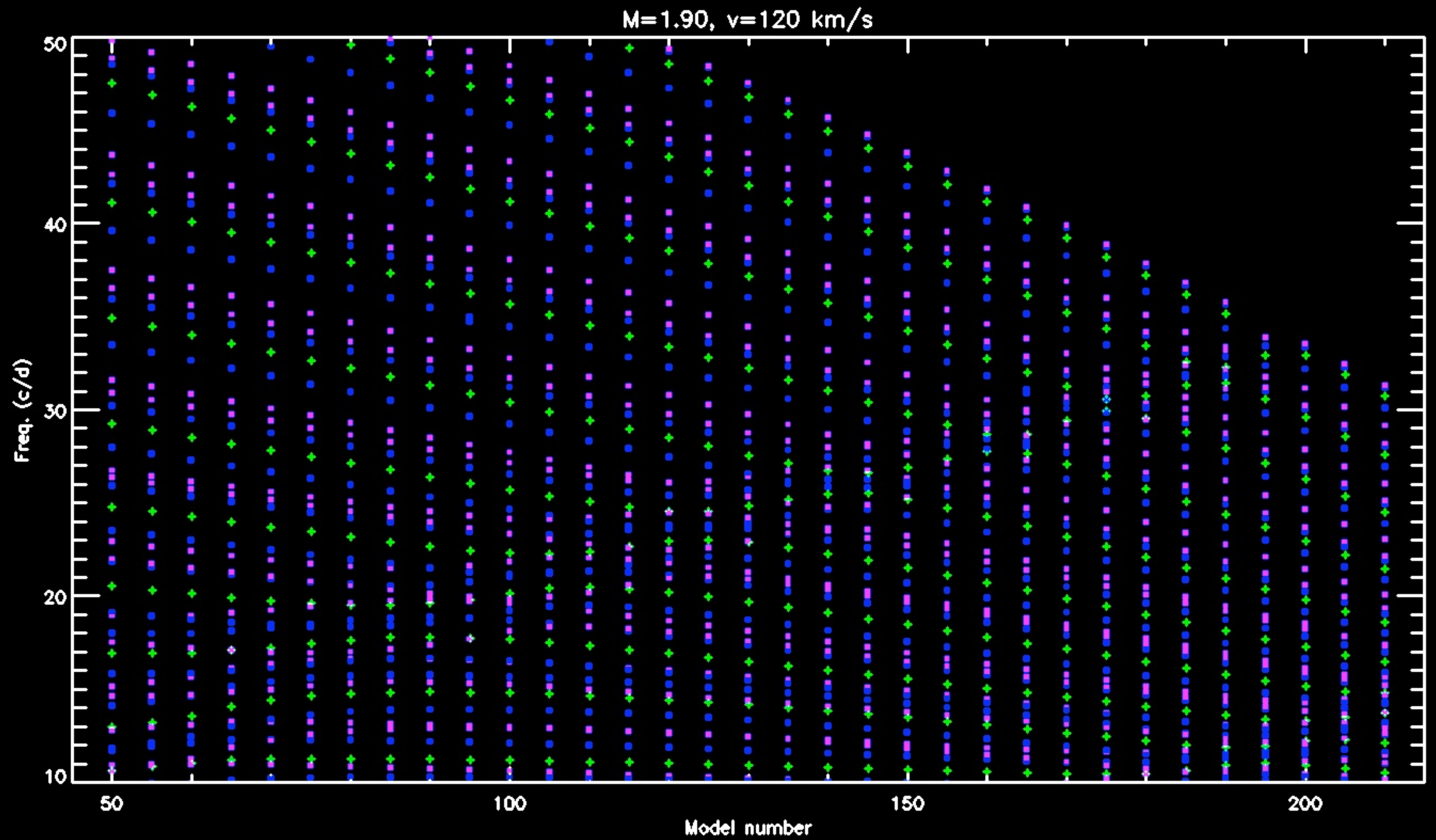
L=1, m=0, +1, -1

Avoided crossings
Mode changing properties, as revealed from their rotational splittings

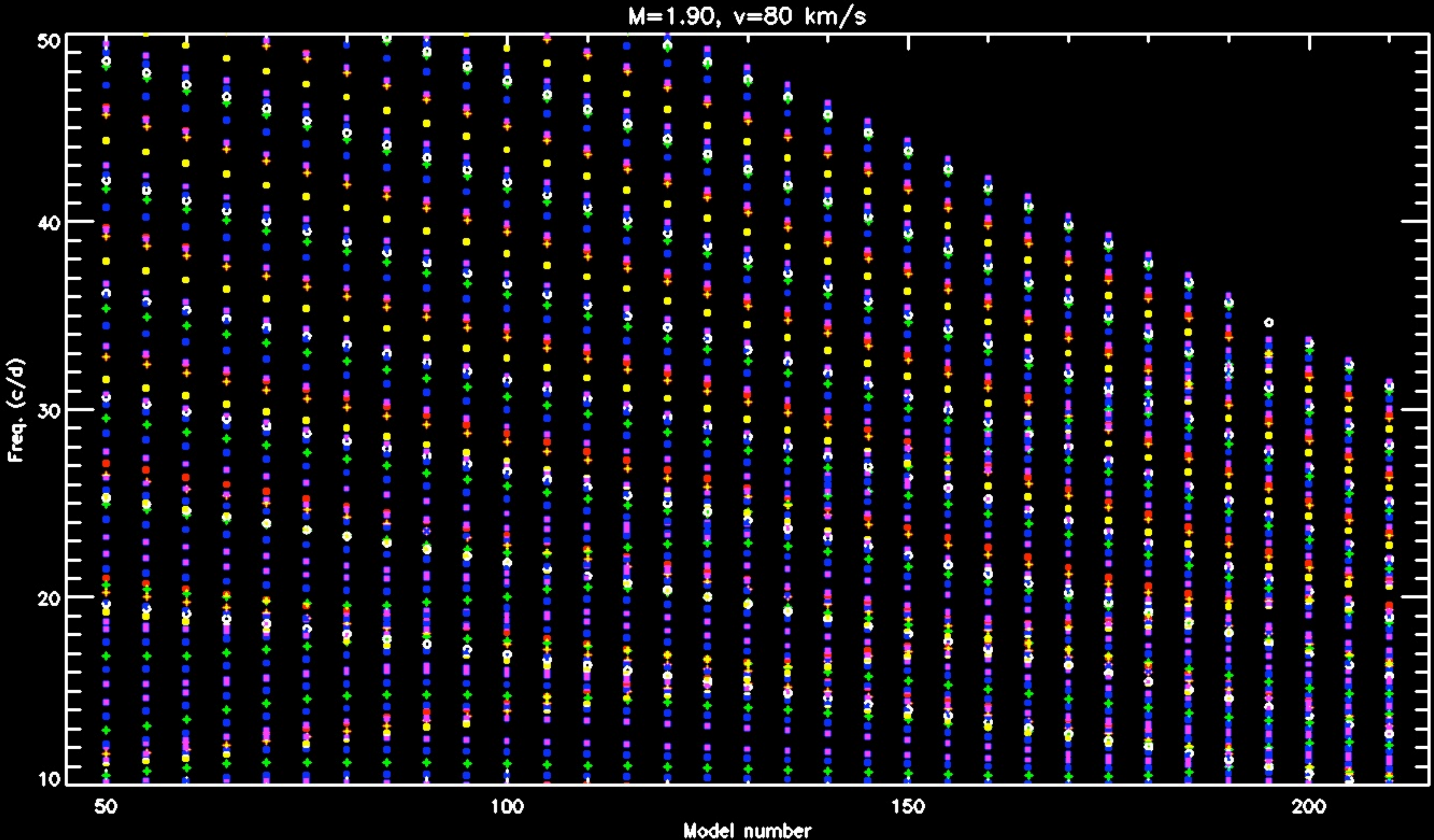


M=1.90, v=120 km/s
Freq. (c/d)
Model number
p3
p2
p1
g1
50
40
30
20
10
50
100
150
200

L=1, m=0, +1, -1



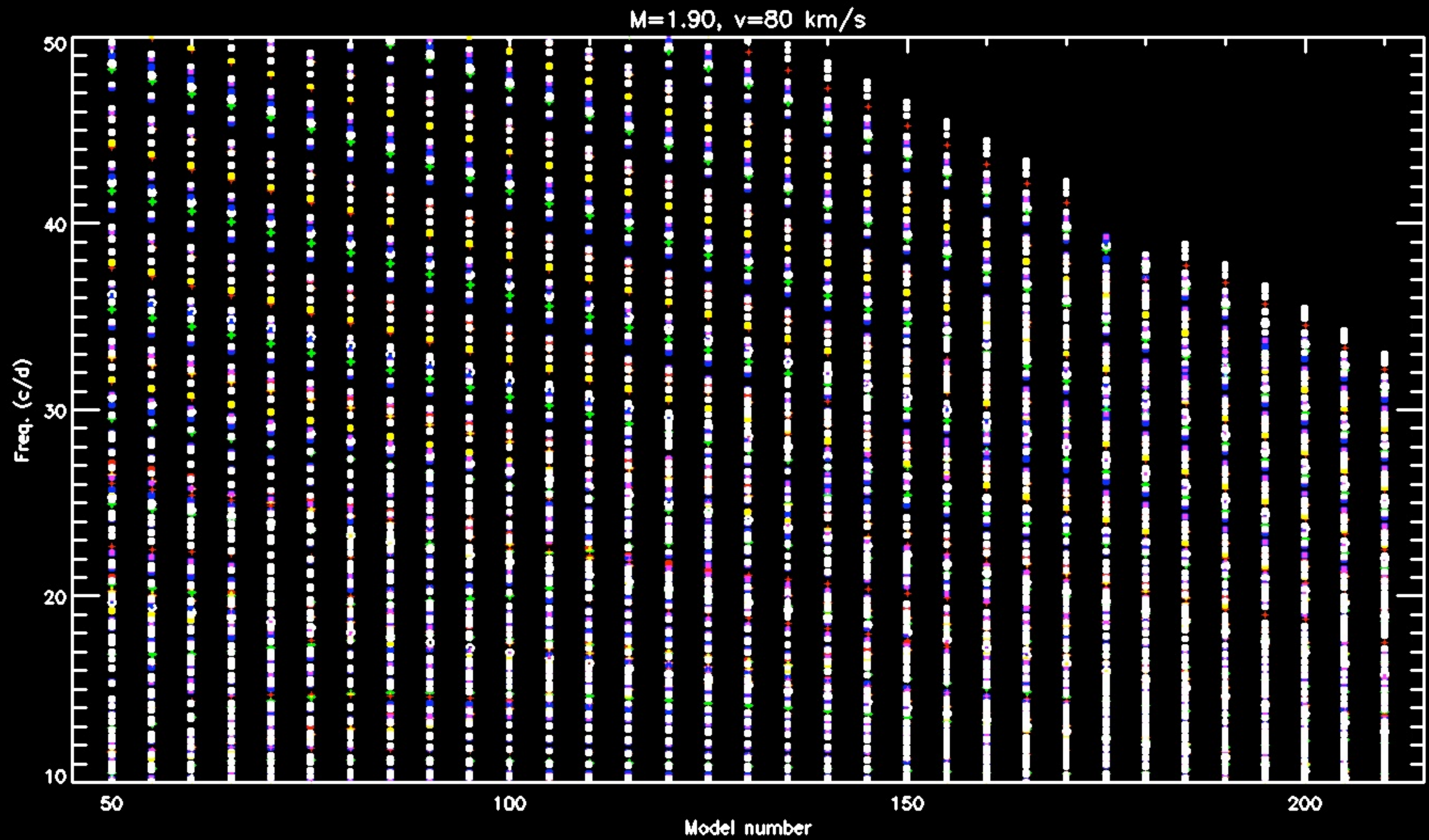
L=2, m=0, +1,+2, -1,-2



L=0

L=1, m=0 +1 -1

L=2, m=0 +1 +2 -1 -2

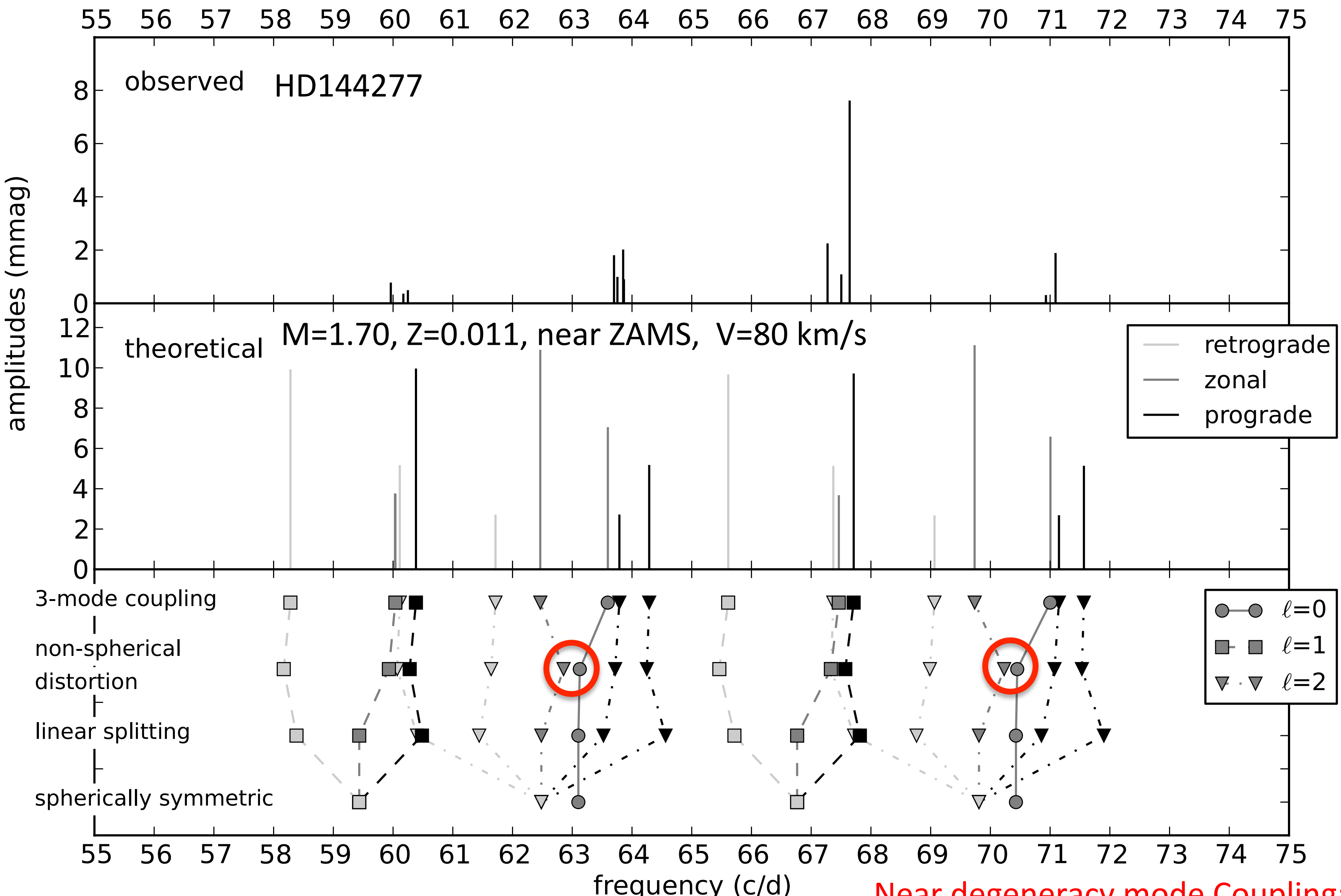


L=0

L=1, m=0 +1 -1

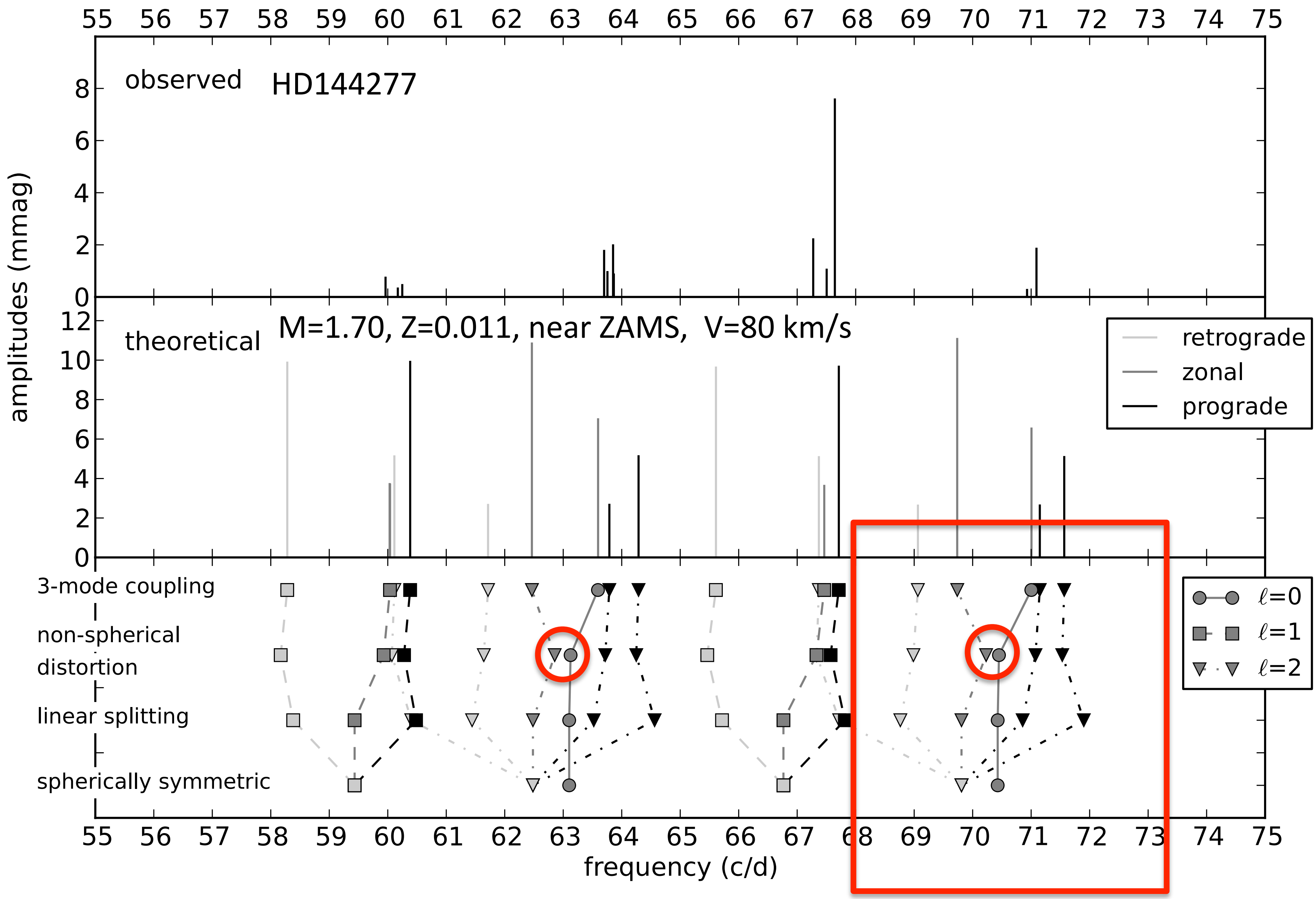
L=2, m=0 +1 +2 -1 -2

L=3,m=(0, 1, 2, 3 , -1, -2, -3)

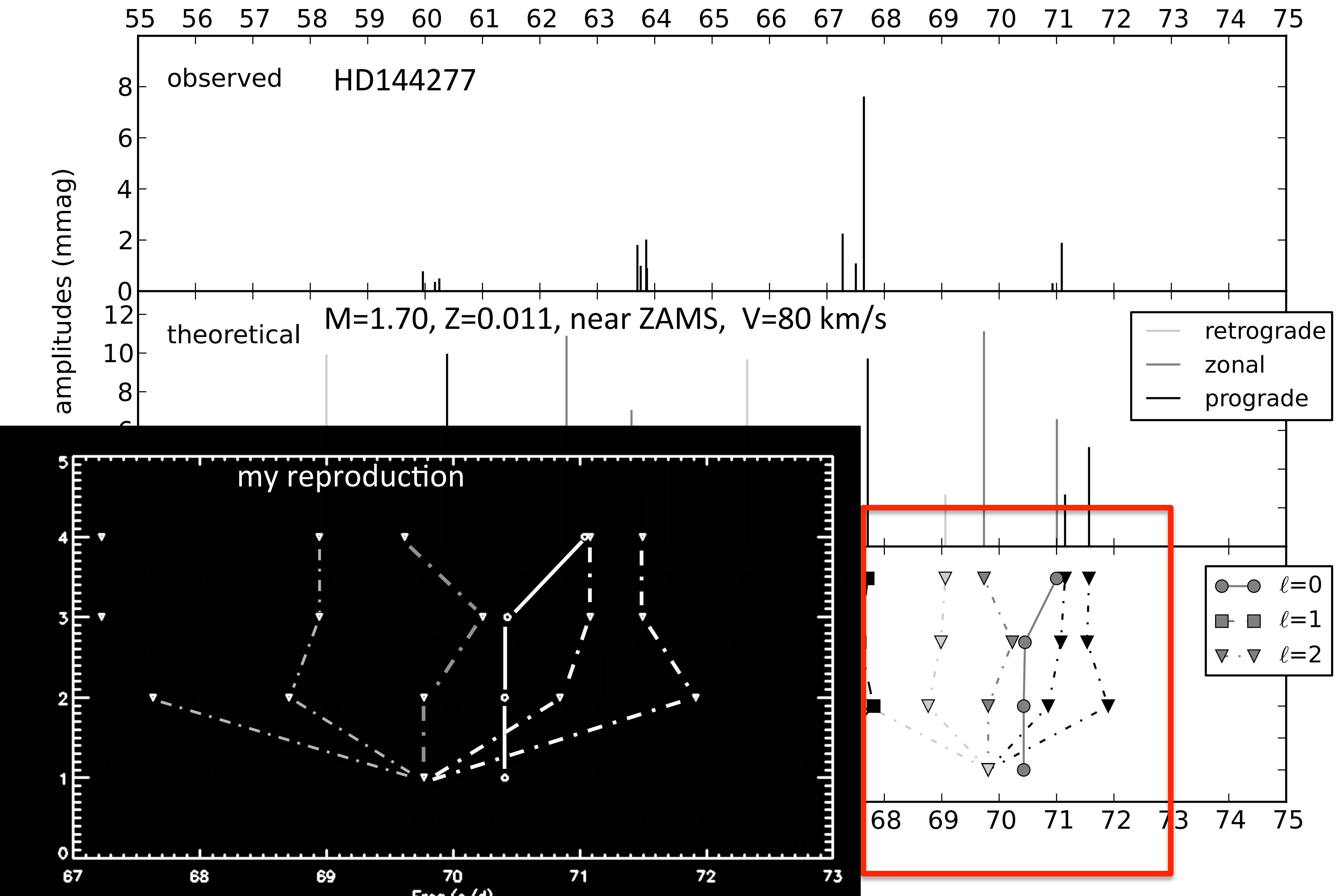


Near degeneracy mode Coupling:
(L=0), (L=2,m=0)

Zwintz, Ryabchikova, Lenz, Pamyatnykh et al. 2014



Zwintz, Ryabchikova, Lenz, Pamyatnykh et al. 2014



Zwintz, Ryabchikova, Lenz, Pamyatnykh et al. 2014

MLE

- Do you really think that ~~Chi^2 minimization~~ will give you the correct answer in the seismic modeling?

$$\chi^2 = \sum_{i=1}^{15} \left(\frac{\nu^i_{\mathrm{obs}} - \nu^i_{\mathrm{model}}}{\sigma^i} \right)^2$$

We do have some prior knowledge:
mode selection, mode visibility, stellar evolution, ...

A General Framework of Bayesian Inference

- Parameter to infer: **$\boldsymbol{\theta}$**
- Given observables (data): **D**

- We update our prior knowledge of **$\boldsymbol{\theta}$,** p(**$\boldsymbol{\theta}$**) given **D**, using Bayes' theorem
- posterior p(**$\boldsymbol{\theta}$|D**) =p(**$\boldsymbol{\theta}$**) p(**D**|**$\boldsymbol{\theta}$**) /p(**D**)

Θ and **D**

***Isochrone fitting*:**

Field stars: **θ**=[M, d, t]   **D**=[T_{eff}, logg, Z]

Star cluster: **θ**=[M_i, d, t, Z]   **D**=[$T_{eff i}$, loggi, Zi]

(Jorgensen & Lindegren 2005; Serenelli 2013)

Eclipsing binaries:

θ=[M, Z, t, …]   **D**=[M_i, R_i, $T_{eff i}$, loggi, Zi, …]

(Prada Moroni 2012)

***Solar-like oscillators (SEEK package)*:**

θ=[M, Z, t, X_0, α …]   **D**=[T_{eff}, logg, Z, $\delta\nu$, $\Delta\nu$, ν_{max}, …]

(Quirion2010)

-> No mode ID problem

-> Individual frequencies not used

Θ and **D** (Upper MS pulsators)

(without rotation)

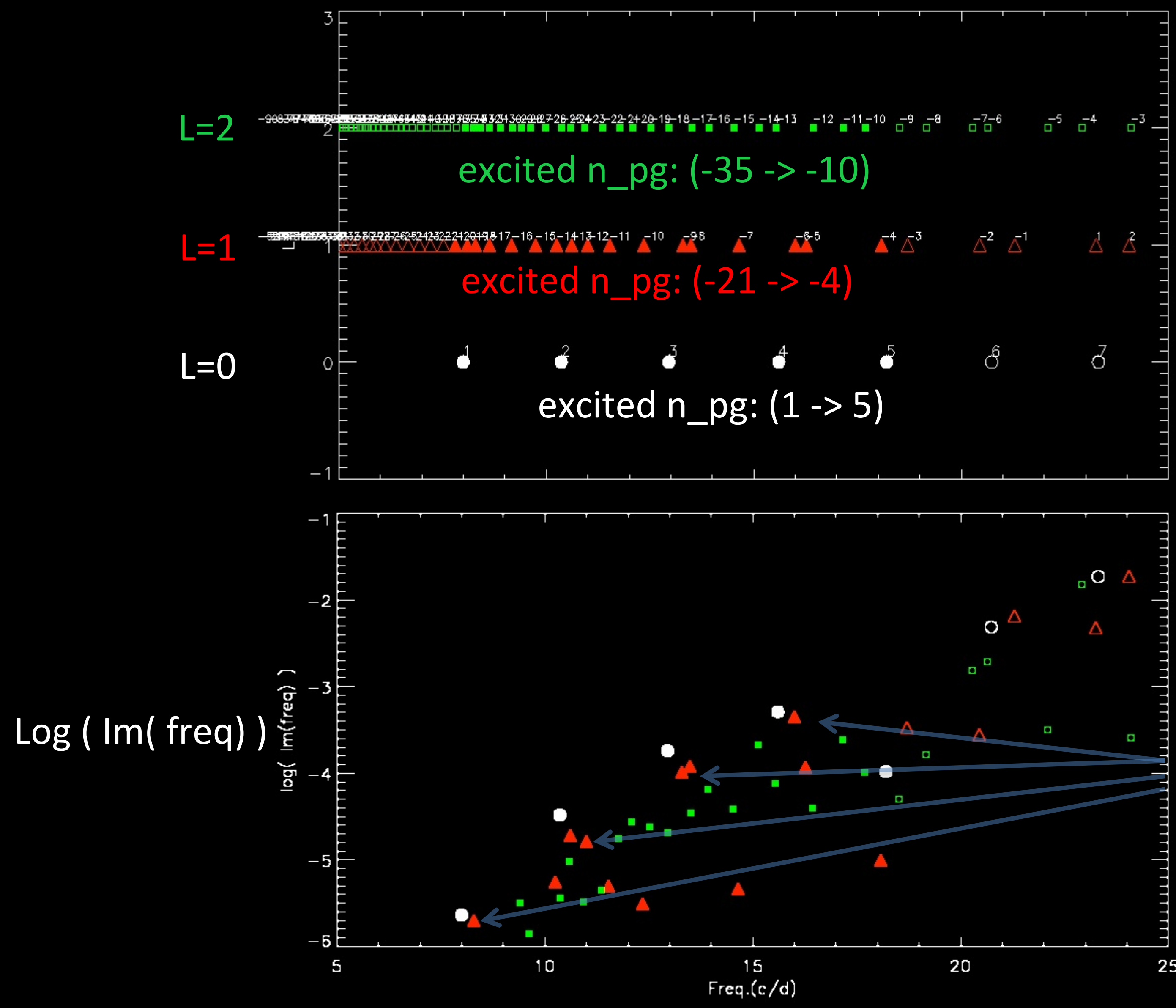
- Parameters: $\boldsymbol{\theta}$=[M, Z, t, L_i, n_i, f_{ov}...]
- Given observables: **D**=[R, T_{eff}, logg, Z, f_i ...]

Turn the Prior knowledge into appropriate prior for theta p($\boldsymbol{\theta}$)
e.g.
P(M): initial mass function, e.g. Salpeter: m^-2.35
P(Z): usually flat, but stars in cluster, halo? Pop I, II?
P(t): usually flat, evidence of youth? Old pop.?

Priors on the mode degree and radial order
P(L): L=0,1,2 more probable; HADs, L=0;

P(n): excited modes-> higher probability
be careful, problems with excitation?

Prior on n and L



M=1.86

P(L):
Assign higher probability to L=0 than L=1,2 ?

P(n):

Trapped L=1 modes:
n_pg =-20, -14,-13, -9,-8, -6
Should assign higher Probability, similar to L=0 modes

Steps: (one f)

$$\boldsymbol{\theta} = [M, t, l, n]$$

parameters

$$\boldsymbol{D} = [M, R, T_{\rm eff}, f]$$

observables

Prior:

$$p(\boldsymbol{\theta}) = p(M)p(t)p(l)p(n)$$

Posterior:

$$p(\boldsymbol{\theta}|\boldsymbol{D}) = p([M,t,l,n]|\boldsymbol{D}) \propto p(M)p(t)p(l)p(n))\,\exp(-\chi^2/2)$$

$$\chi^2 = \sum[(\frac{M_i - M_{obs}}{\sigma M_{obs}})^2 + (\frac{R_{ij} - R_{obs}}{\sigma R_{obs}})^2 + (\frac{T_{\rm eff,ij} - T_{\rm eff,obs}}{\sigma T_{\rm eff,obs}})^2 + (\frac{f_{ij,ks} - f_{obs}}{\sigma f_{obs}})^2]$$

to get $p(l|\boldsymbol{D})$ we marginalize over the rest parameters (M, t, n)

$$p(l|\boldsymbol{D}) = \int p(M)p(t)p(l)p(n)\exp(-\chi^2/2)dM\,dt\,dn$$

(Posterior mode identification for L)

To evaluate:

$$p(l|\boldsymbol{D}) = \int p(M)p(t)p(l)p(n)\exp(-\chi^2/2)dM\,dt\,dn$$

Numerical integration:

$$p(l_k|\boldsymbol{D}) = \sum_i \sum_j \sum_s p(M_i)p(t_{ij})p(l_{ij,k})p(n_{ij,ks})\exp(-\chi^2/2)\Delta M_i \Delta t_{ij} \Delta n_{ij,ks}$$

Details: a series of masses M_i
for each mass M_i, there is a track, with different ages (index j) t_{ij}
for each M_i, t_{ij} there are mode degrees l_k (usually k=0,1,2)
and for each l_k there are frequencies corresponding to radial orders (index s) n_{ks}.
This means $[M, t, l, n]$ have corresponding indices of $[i, j, k, s]$

similarly, $p(n|\boldsymbol{D}) = \int p(M)p(t)p(l)p(n)\exp(-\chi^2/2)dM\,dt\,dl$

$$p(n_s|\boldsymbol{D}) = \sum_i \sum_j \sum_k p(M_i)p(t_{ij})p(l_{ij,k})p(n_{ij,ks})\exp(-\chi^2/2)\Delta M_i \Delta t_{ij} \Delta l_{ij,k}$$

(Posterior mode radial order n)

Steps: (two frequencies: fa, fb)

Let $[M, t, la, na, lb, nb]$ have corresponding indices of $[i, j, k, s, p, q]$,

$$p(la|\boldsymbol{D}) = \int p(M)p(t)p(na)p(lb)p(nb)\exp(-\chi^2/2)dM\ dt\ dna\ dlb\ dnb$$

$$p(la_k|\boldsymbol{D}) = \sum_i \sum_j \sum_s \sum_p \sum_q p(M_i)p(t_{ij})p(la_{ij,k})p(na_{ij,ks})p(lb_{ij,p})p(nb_{ij,pq})\exp(-\chi^2/2)$$
$$\Delta M_i \Delta t_{ij} \Delta na_{ij,ks} \Delta lb_{ij,p} \Delta nb_{ij,pq}$$

Extend to more frequencies:

-> 15 frequencies for 44 Tau, two radial
-> 14 for 29 Cyg

Θ and **D** (Upper MS pulsators)

(with rotation)

- Parameters: **θ**=[M, Z, t, L_i, n_i, m_i, f_{ov}, v, incl ...]
- Given observables: **D**=[R, T_{eff}, logg, Z, vsini, f_i, incl ...]

- P(m_i): depends on incl. (Gizon & Solanki 2003)

  But not entirely true for heat-driven pulsators, how to revise?
- P(m_i): some evidence of prograde mode prefered?
- P(incl): EBs? Interferometric imaging?

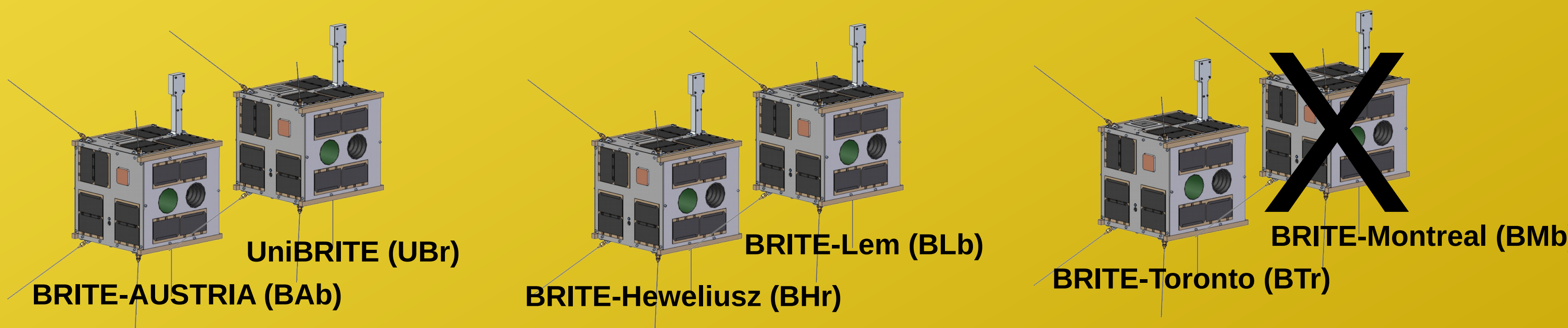

CHANGING GEARS

What is BRITE?

BRIght Target Explorer

- nanosatellites 20 x 20 x 20 cm
- ca. 7 kg
- 3-cm telescope for observations of bright (V < 5) stars
- time-resolved two-colour (B, R) photometry

BRITE-Constellation:



Courtesy: Gerald Handler

Lessons from BRITE:

(not in alphabetical order)

- Precision photometric studies with nanosatellites in low Earth orbits are possible
- gravity mode pulsation among β Cep stars is rather common — ν Eri, α Lup, PT Pup, σ Sco
- interior rotation of SPB stars can be studied — HD 201433
- magneto-asteroseismology is on the horizon — β Cen, ε Lup ...
- pulsation-mass loss interaction in Be stars — β Cen, ...
- massive heartbeat stars are around and can be investigated — ι Ori
- a link between large-scale wind structures and their photospheric origin has been found

See Gerald Handler's talk at KITP

BRITE observations so far

Field	from	to	ΔT [day]	# stars
Orion I	01.12.2013	18.03.2014	108	15
Centaurus	25.03.2014	18.08.2014	147	32
Sagittarius	29.04.2014	06.09.2014	42	19
Cygnus I	12.06.2014	25.11.2014	167	36
Perseus	02.09.2014	18.02.2015	170	37
Orion II	24.09.2014	17.03.2015	175	38
Vel/Pup	11.12.2014	28.05.2015	169	52
Scorpius	18.03.2015	31.08.2015	167	26
Cygnus II	01.06.2015	25.11.2015	178	27
Cas/Cep	23.08.2015	17.10.2015	55	23
CMa/Pup	18.10.2015	14.04.2016	~180	33
Cru/Car	22.01.2016	22.07.2016	183	45
Cyg/Lyr	05.04.2016	02.10.2016	177	20
Sgr II	21.04.2016	23.09.2016	158	17
Cas II	07.08.2016	03.02.2017	~174	18
Aur/Per	14.09.2016	07.03.2017	~171	25
Cet/Eri	06.10.2016	26.12.2016	83	11
Vel/Pic	04.11.2016	29.04.2017	173	21
Total				~410

Courtesy: Gerald Handler

BRITE photometry Wiki page: http://brite.craq-astro.ca/doku.php

17-CygLyr-I-2016

# angDiam(mas)	HD	Name	V	Sp.Type	Contact PI	TNDP1)	Data avail.2)
1 3.220	172167	α Lyr	0.03	A0 Va	Huber	76372	PP
2 0.577	173648	ζ1/ζ2Lyr	4.36/5.70	A4m	Lüftinger	90498	PP
3 0.681	174638	β Lyr	3.45	B8 IIpe	Rucinski	91253	PP
4 12.28	175588	δ2 Lyr	4.30	M4 II	Paunzen	84634	PP
5 0.730	176437	γ Lyr	3.24	B9 III	Paunzen	90975	PP
6 0.219	178475	ι Lyr	5.28	B7 IV	Pigulski	65810	PP
7 0.253	180163	η Lyr	4.39	B2.5 IV	Handler	68946	PP
8 0.217	182255	3(V377)Vul	5.18	B6 III	Kallinger	49551	PP
9 0.204	182568	2 Cyg	4.97	B3 IV	Kallinger	65720	PP
10 ----	183912	β Cyg	3.08/5.16	K3 II+B9.5 V	Baade	71158	PP
11 0.658	184006	ι Cyg	3.77	A5 V	Huber	19174	PP
12 0.219	184171	8 Cyg	4.74	B3 IV	Handler	66430	PP
13 0.699	187013	17 Cyg	4.99	F5.5 IV-V	Paunzen	3267	PP
14 2.708	188947	η Cyg	3.88	K0 III	Kallinger	15939	PP
15 0.477	189849	15(NT)Vul	4.66	A4 III	Smalley	3254	PP
16 ----	191610	28(V1624)Cyg	4.93	B2.5 Ve	Baade	66181	PP
17 0.405	192640	29(V1644)Cyg	4.97	A2 V	Zwintz	65023	PP
18 ----	192685	QR Vul	4.78	B3 IIIe	Baade	64650	PP
19 ----	193237	34(P) Cyg	4.81	B1.5	Iabe/Richardson	65706	PP
20 2.155	197345	α Cyg	1.25	A2 Ia	Richardson	6752	PP

22 Ori-IV 2016

# AngDiam(UD_K)	HD	Name	V	Sp.Type	Contact PI	TNDP1)	Data avail.2)
1 0.271	29248	ν Eri	3.93	B2 III	Handler	57035	PP
2 0.305	30211	μ Eri	4.02	B5 IV	Pigulski	57699	PP
3 0.508	30739	π2 Ori	4.35	A1 Vn	Baade	27724	PP
4 0.308	30836	π4 Ori	3.69	B2 III + B2 IV	Handler	57686	PP
5 0.286	31237	π5 Ori	3.72	B3 III + B0 V	Handler	28337	PP
6 0.225	33328	λ Eri	4.27	B2 IVne	Hubrig	28388	PP
7 2.690	34085	β Ori	0.12	B8 Ia	Guinan	29482	PP
8 0.420	34503	τ Ori	3.60	B5 III	Pigulski	22175	PP
9 0.184	34816	λ Lep	4.29	B0.5 IV	Pigulski	27865	PP
10 0.307	35411	η Ori	3.36	B1V + B2	Pigulski	50918	PP
11 0.161	35439	ψ1 Ori	4.95	B1 Vpe	Baade	28595	PP
12 0.702	35468	γ Ori	1.64	B2 III	Handler	21863	PP
13 0.190	35715	ψ2 Ori	4.59	B2 IV	Pigulski	58580	PP
14 -----	36486	δ Ori	2.23	O9.5 II	Moffat	58530	PP
15 -----	36861/2	λ Ori	3.54/6.32	O8 III/B0.5 V	Moffat	29434	PP
16 0.090	37043	ι Ori	2.77	O9 III	Moffat	29759	PP
17 -----	37128	ε Ori	1.70	B0 Ia	Moffat	51627	PP
18 0.080	37468	σ Ori	3.81	O9.5 V	Moffat	57871	PP
19 0.232	37490	ω Ori	4.57	B3 IIIe	Baade	27611	PP
20 ----	37742/3	ζ Ori	1.88/3.70	O9.7 Ib/B0 III	Moffat	57925	PP
21 0.547	38771	κ Ori	2.06	B0.5 Ia	Moffat	29548	PP
22 -----	39801	α Ori	0.50	M1-2 Ia-Iab	Guinan	29200	PP

Cross-match BRITE with JMMC catalog

Iota Ori

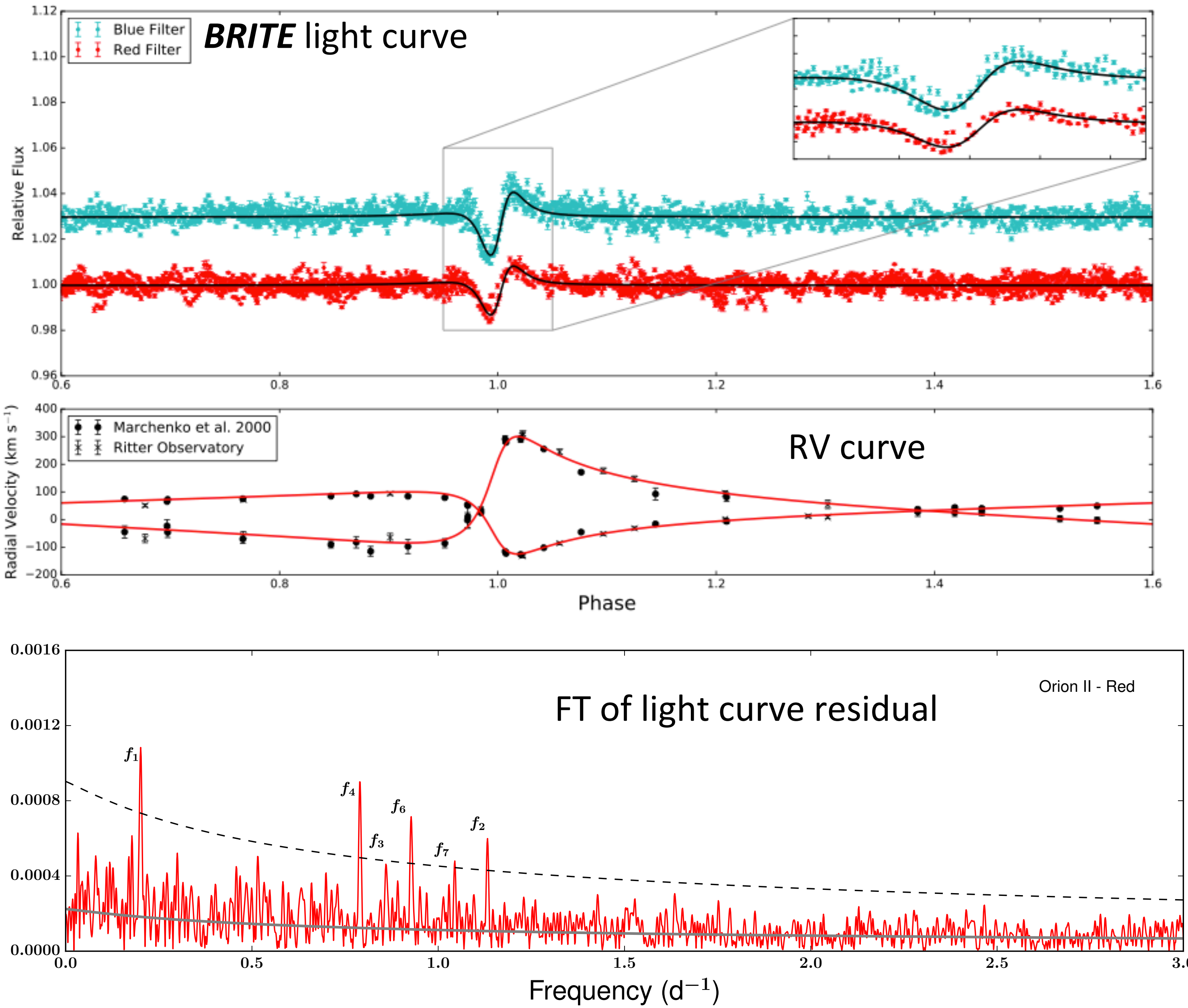
O9 III +
B1 III/IV

P=29 d
e=0.75
ω =122

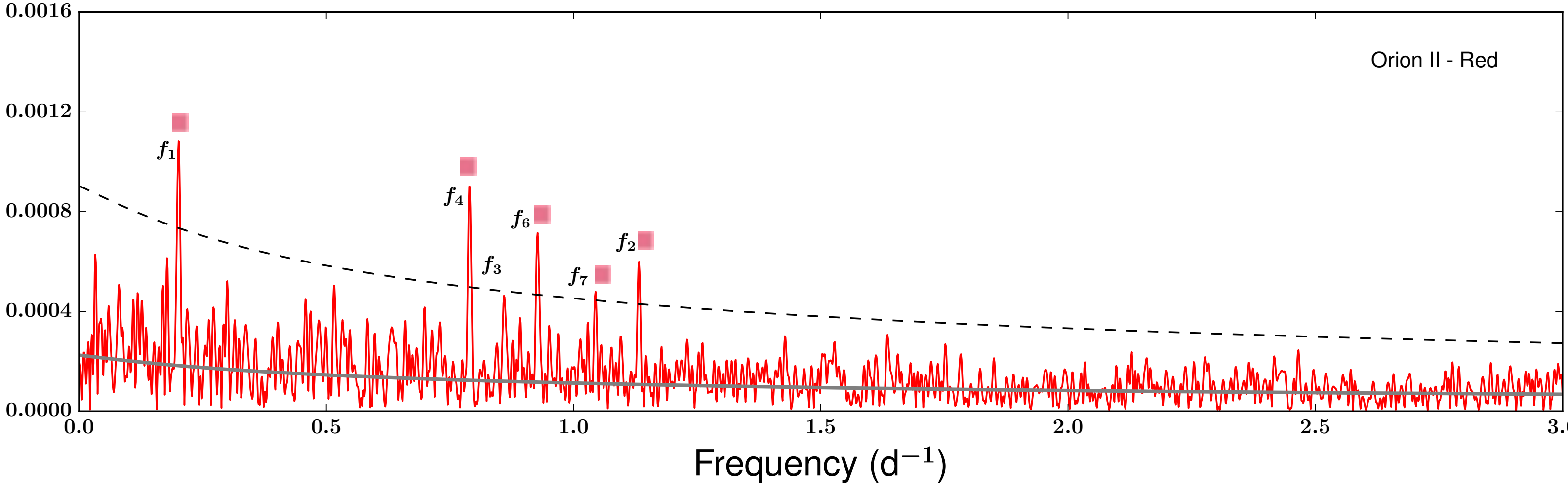
Incl. =63

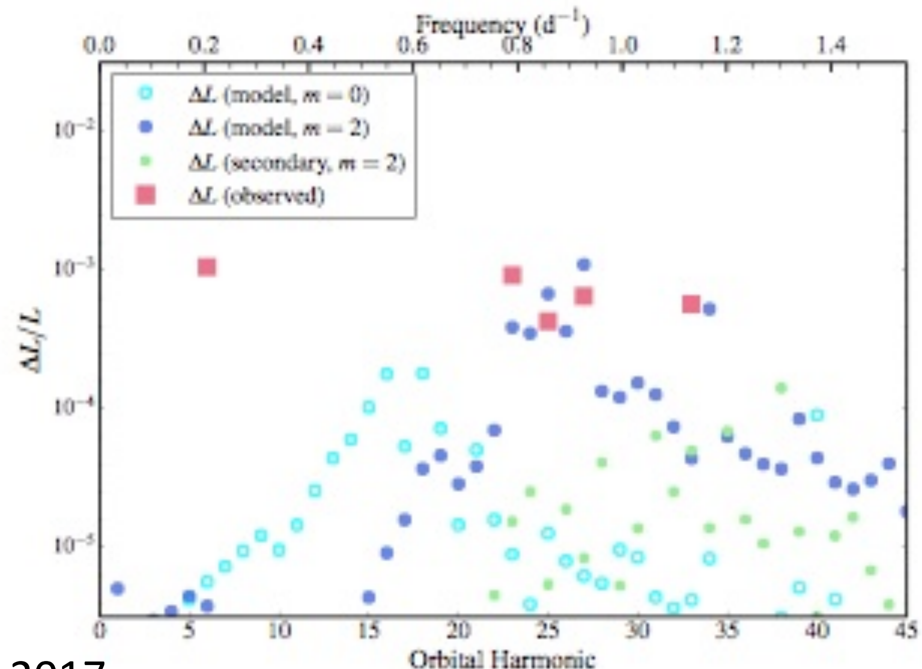
M_1=22,
R_1=9.1
T_{eff1}=31000

M_2=13.4,
R_2=4.94
T_{eff2}=18319



Pablo et al. 2017





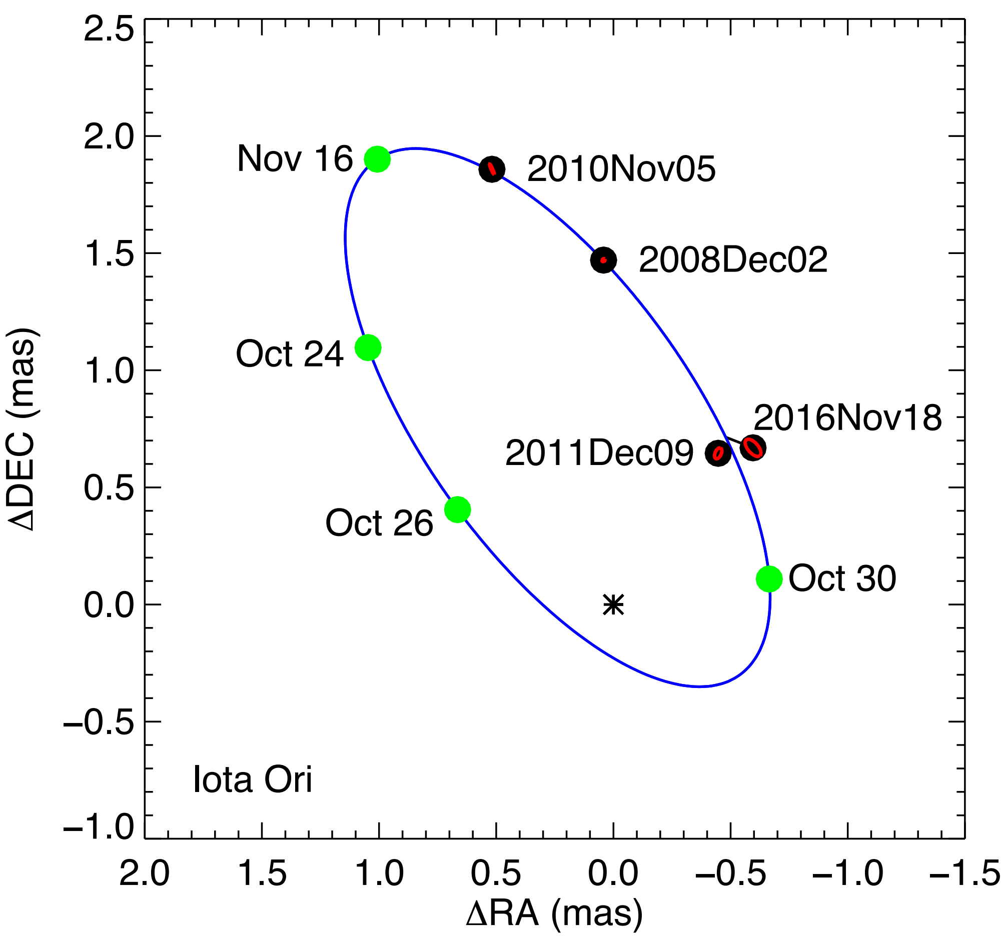
Theory works

Amplitudes agree with L=2 m=2 prograde modes

Phases: most agree with L=2,m=2

Pablo et al. 2017

Interferometric Orbit of Iota Ori
CHARA/MIRC



Preliminary results:

a = 1.66 ± 0.45 mas
i = 65° ± 12°
M1 = 22 ± 6 M⊙
M2 = 13 ± 4 M⊙
d = 363 ± 103 pc

● Scheduled observations 2017

Pablo et al. 2017

i = 62.86° ± 0.17°
M1 = 22.2 ± 0.6 M⊙
M2 = 13.4 ± 0.3 M⊙

By Gail Schaefer & Doug Gies

Summary

1. Angular diameter measurements of 44 Tau and 29 Cyg

2. A probabilistic approach of seismic modeling of δ Scuti stars, taking into account our prior knowledge on rotation, stellar evolution, and mode selection.

3. A lot of interesting asteroseismic targets from BRITE satellite, awaiting for interferometric observations

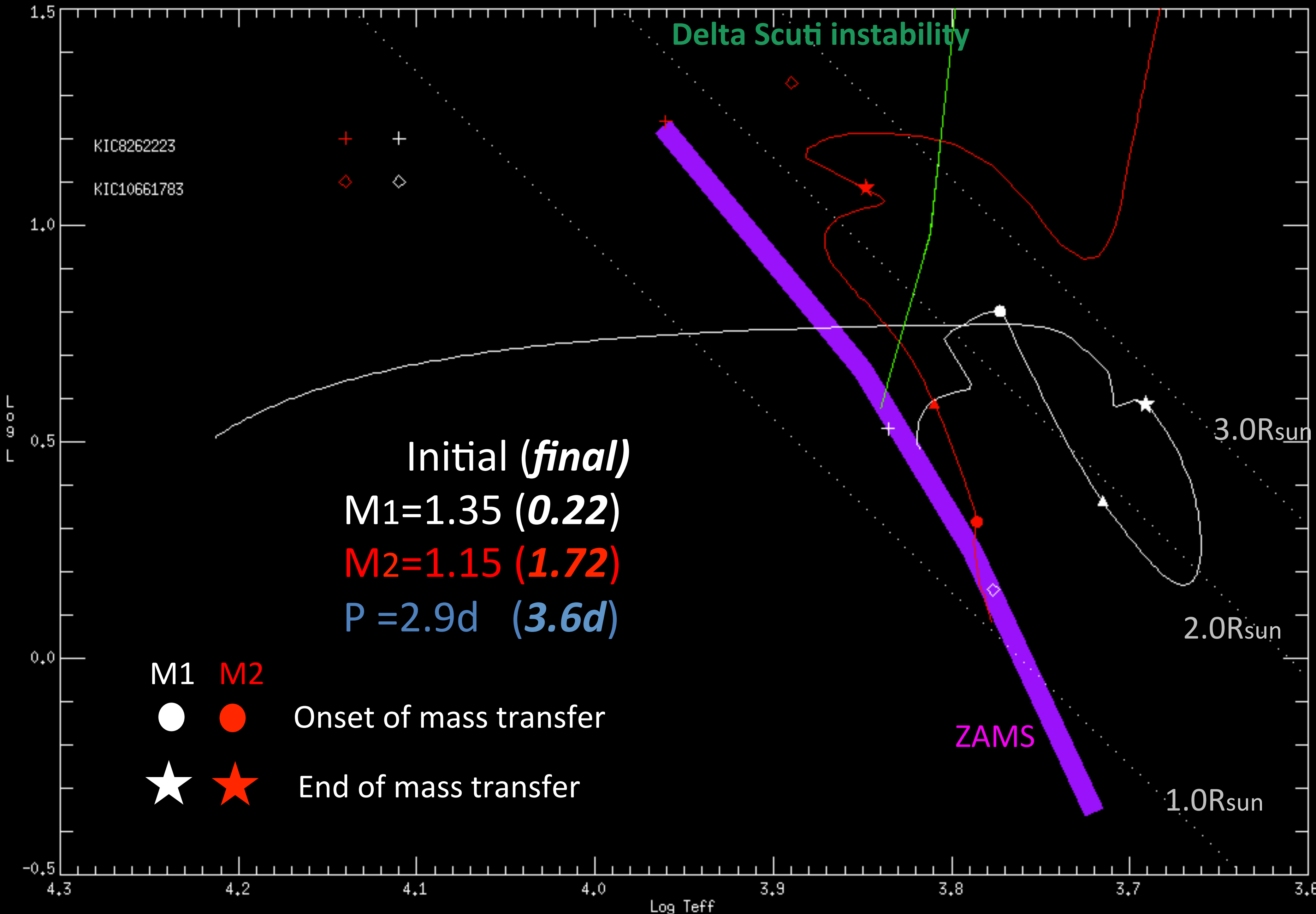
Thanks very much for your attention!

Polish Academy of Sciences
Nicolaus Copernicus
Astronomical Center

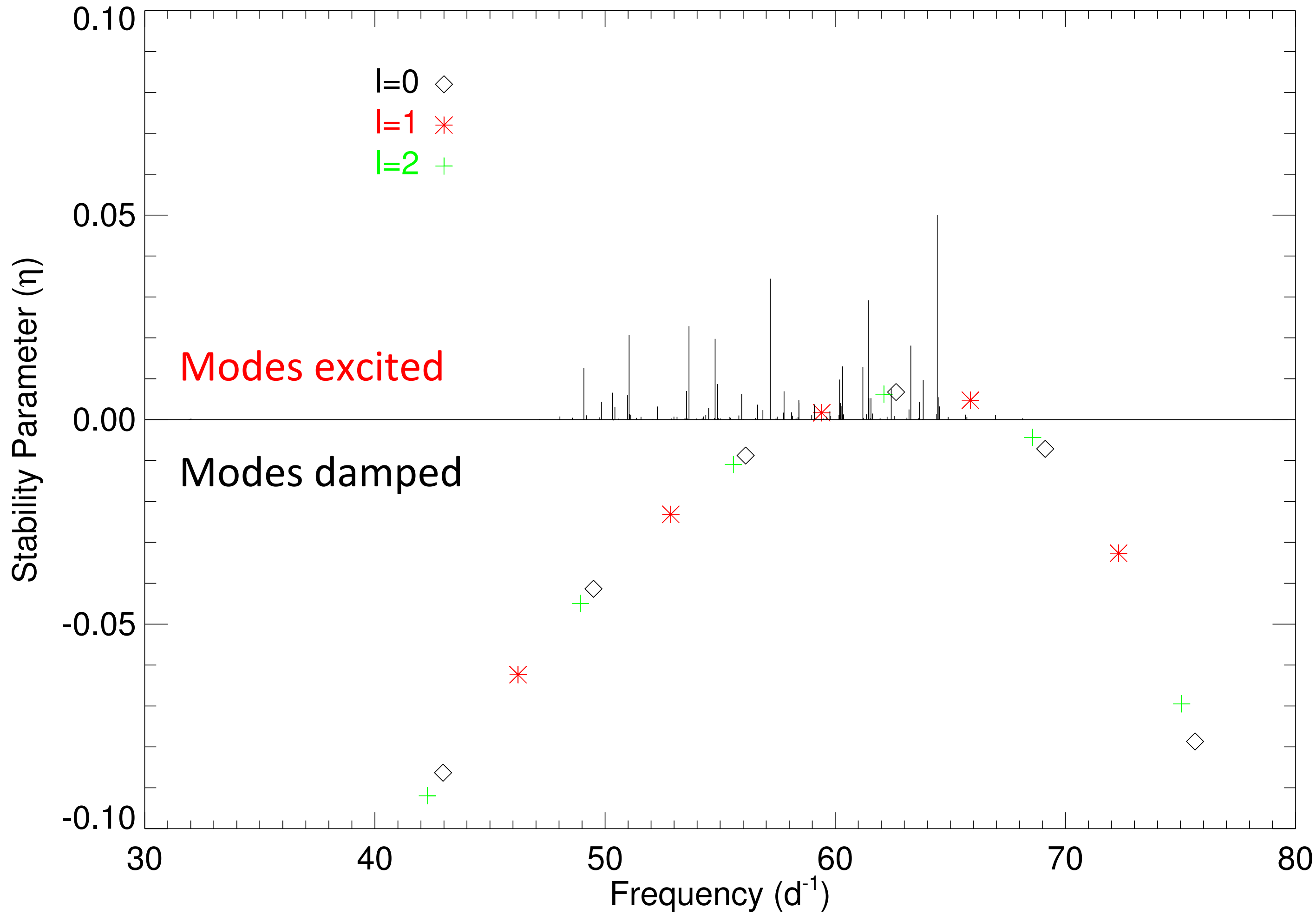
Zhao Guo

KIC8262223 Parameters

Period (days)	1.61301476[a]
Time of primary minimum (HJD-2400000)	$55432.522844 \pm 0.000007$
Mass ratio $q = M_2/M_1$	0.104 ± 0.002
Orbital eccentricity e	0.0[a]
Orbital inclination i (degree)	75.203 ± 0.007
Semi-major axis a ($R_\odot$)	7.45 ± 0.11
M_1 ($M_\odot$)	1.94 ± 0.06
M_2 ($M_\odot$)	0.20 ± 0.01
R_1 ($R_\odot$)	1.67 ± 0.03
R_2 ($R_\odot$)	1.31 ± 0.02
$T_{\rm eff1}$ (K)	9128[a]
$T_{\rm eff2}$ (K)	6849 ± 15
$\log g_1$ (cgs)	4.28 ± 0.04
$\log g_2$ (cgs)	3.51 ± 0.06

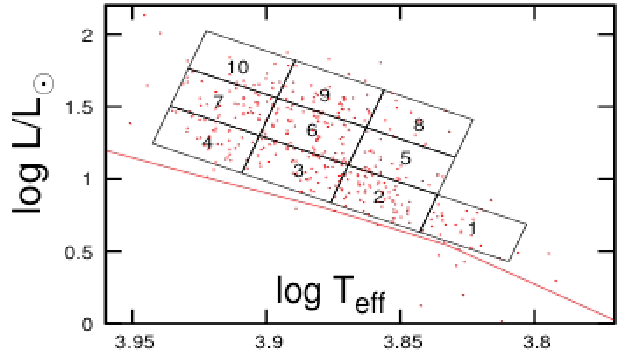


Guo, Gies, Matson et al. 2017



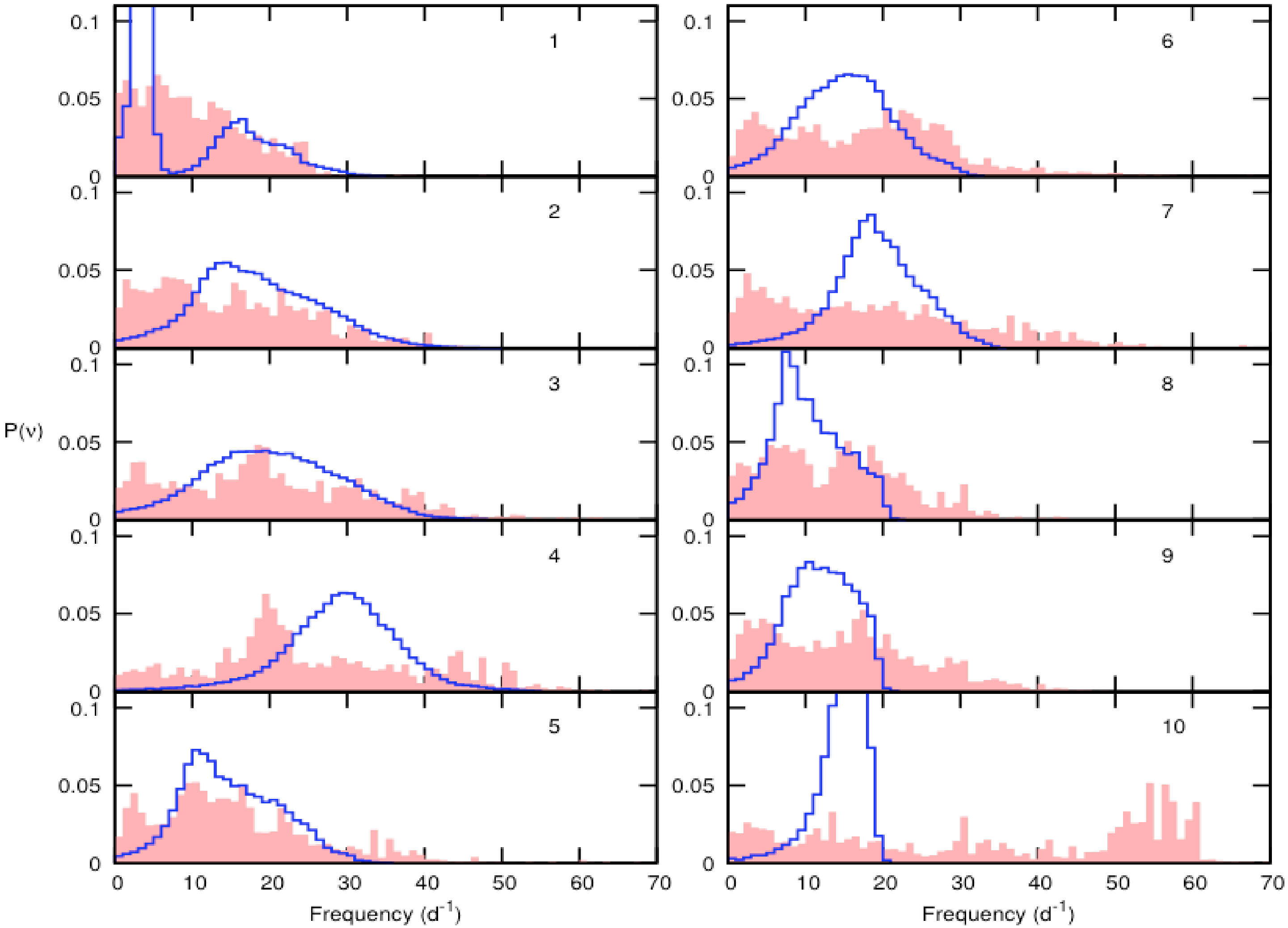
Primary star: $M_1 = 1.94 M_\odot$, $R_1 = 1.67 R_\odot$, $Z = 0.02$, and $Y = 0.28$,

Structure Models from single stellar evolution have some difficulties explaining the driving (unstable range) frequencies
of this Post-mass transfer Delta Scuti star KIC8262223



Frequency Distribution
of Kepler Delta Scuti stars

Balona, Daszynska, Pamyatnykh (2015)



Models(blue lines) cannot explain the overabundance of high-frequency Delta Scuti stars.

Binary Evolution ?

Scientific results: magnetic stars

Table 1. Known magnetic massive pulsators, having N detected pulsation modes.

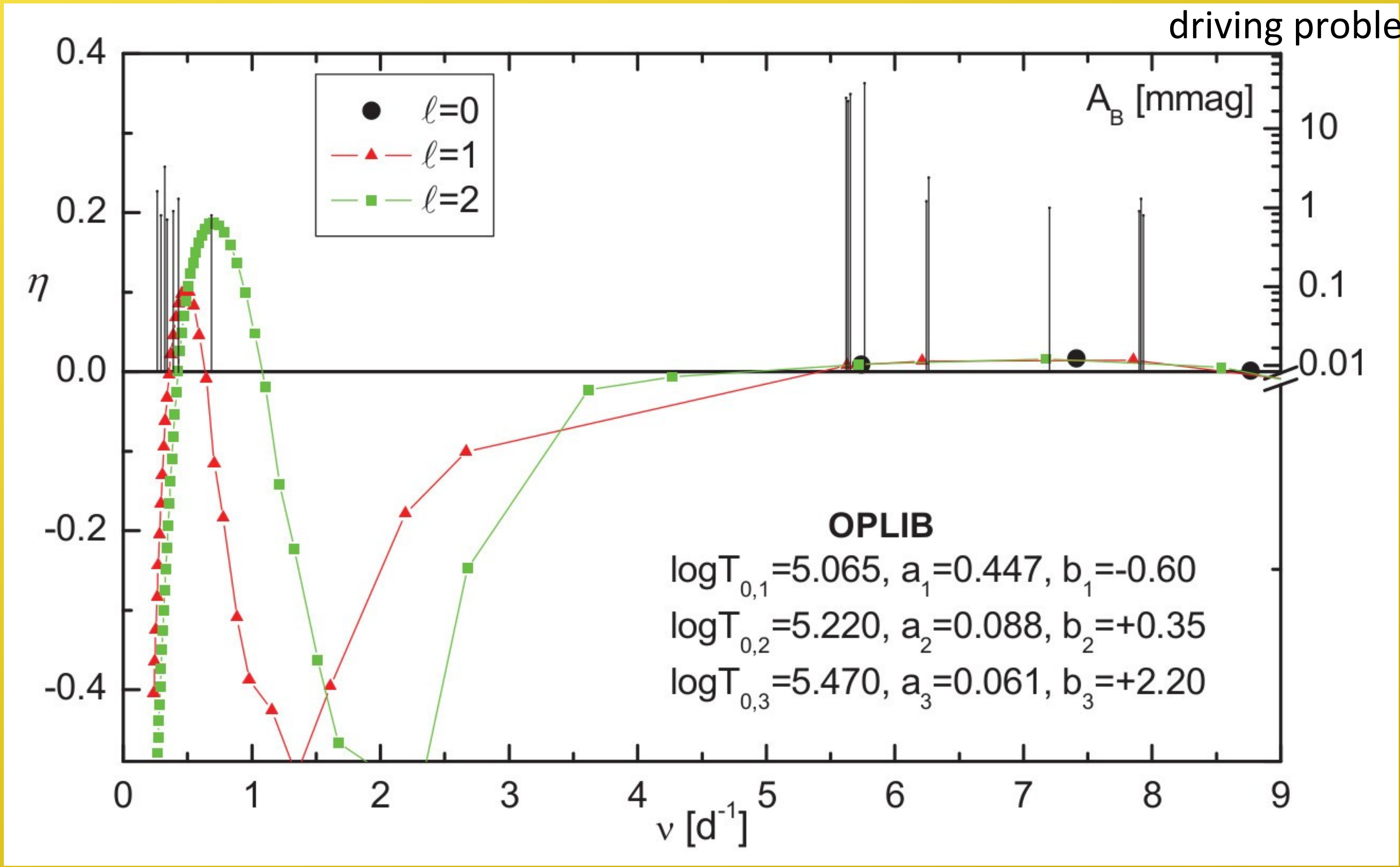
	Star	N	Type	$P_{\rm rot}$ [d]	$B_{\rm pol}$ [G]	Magnetic characterization	Binary?	SpT	References
1	HD 43317	> 100	both	0.90	~ 900	dip.; $i \in [20, 50]^\circ$; $\beta \in [70, 86]^\circ$		B3IV	(1), (2)
2	β Cen Ab	< 17	β Cep		~ 250		Y	+ B1III	(3), (4)
3	β Cep	5	β Cep	12.0	~ 300	dip.; $i \sim 60^\circ$; $\beta \sim 95^\circ$	Y	B0III +	(5), (6)
4	V2052 Oph	3	β Cep	3.64	~ 400	dip.; $i \sim 70^\circ$; $\beta \sim 35^\circ$		B2IV/V	(7), (8), (9)
5	β CMa	3	β Cep		< 30			B1II/III	(10), (11), (12)
6	16 Peg	3	β Cep	1.44	~ 500	dip.; $i \sim 70^\circ$; $\beta \sim 70^\circ$		B3V	(13), (14), (15)
7	ϵ Lup A	'LPV bump'	β Cep		~ 600		Y	B2V +	(16), (17)
	ϵ Lup B	> 2	β Cep		~ 300		Y	+ B3V	(16), (18)
8	ξ^1 CMa	1	β Cep	2.18	~ 600			B1V	(19), (20)
9	HD 96446	1	β Cep	23.4	~ 7500			B2IIIp	(21), (22), (23)
10	ζ Cas	1?	SPB	5.37	~ 150	dip.; $i \sim 30^\circ$; $\beta \sim 105^\circ$		B2IV/V	(24), (25)
11	σ Lup	1?	SPB	3.09	~ 300	dip.; $i \sim 60^\circ$; $\beta \sim 90^\circ$		B2III	(26), (14)
12	ϕ Cen	'LPV bump'	β Cep	1.14	~ 900			B2IV	(27), (28)

(Buysschaert, Neiner & Aerts 2017, Proc. IAUS 329, in press)

Scientific results: asteroseismology

g modes, g modes everywhere!

Beta Cephei star driving problems



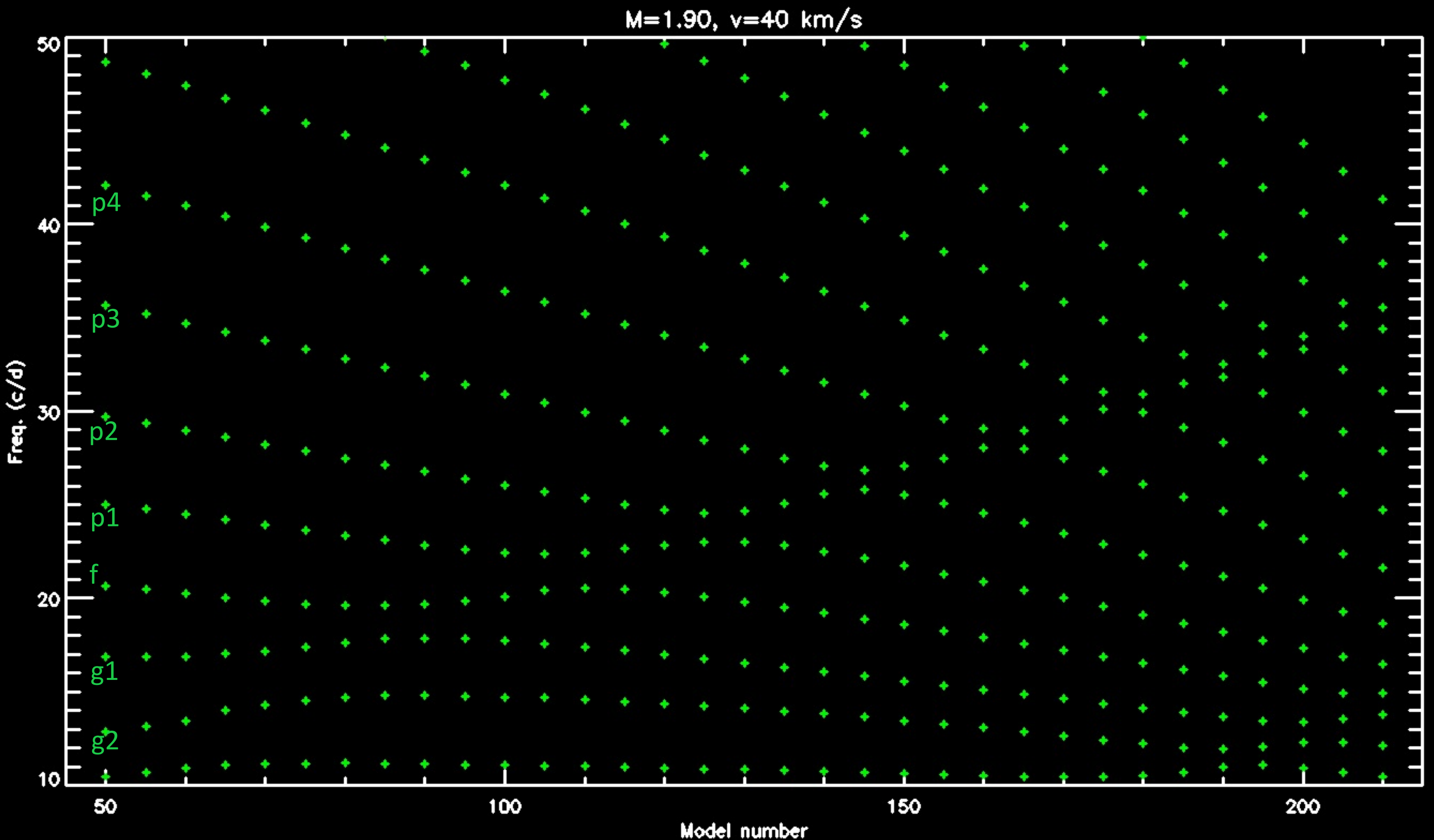
(Daszyńska-Daszkiewicz et al. 2017, MNRAS 466, 2284)

Correct for the effect of mode densities

- Observable D: one frequency f=7.47 c/d
- Prior: p(n)=1 (if excited);
  0 (otherwise)
  p(L)= 1/3 (L=0)
  1/3 (L=1)
  1/3 (L=2)

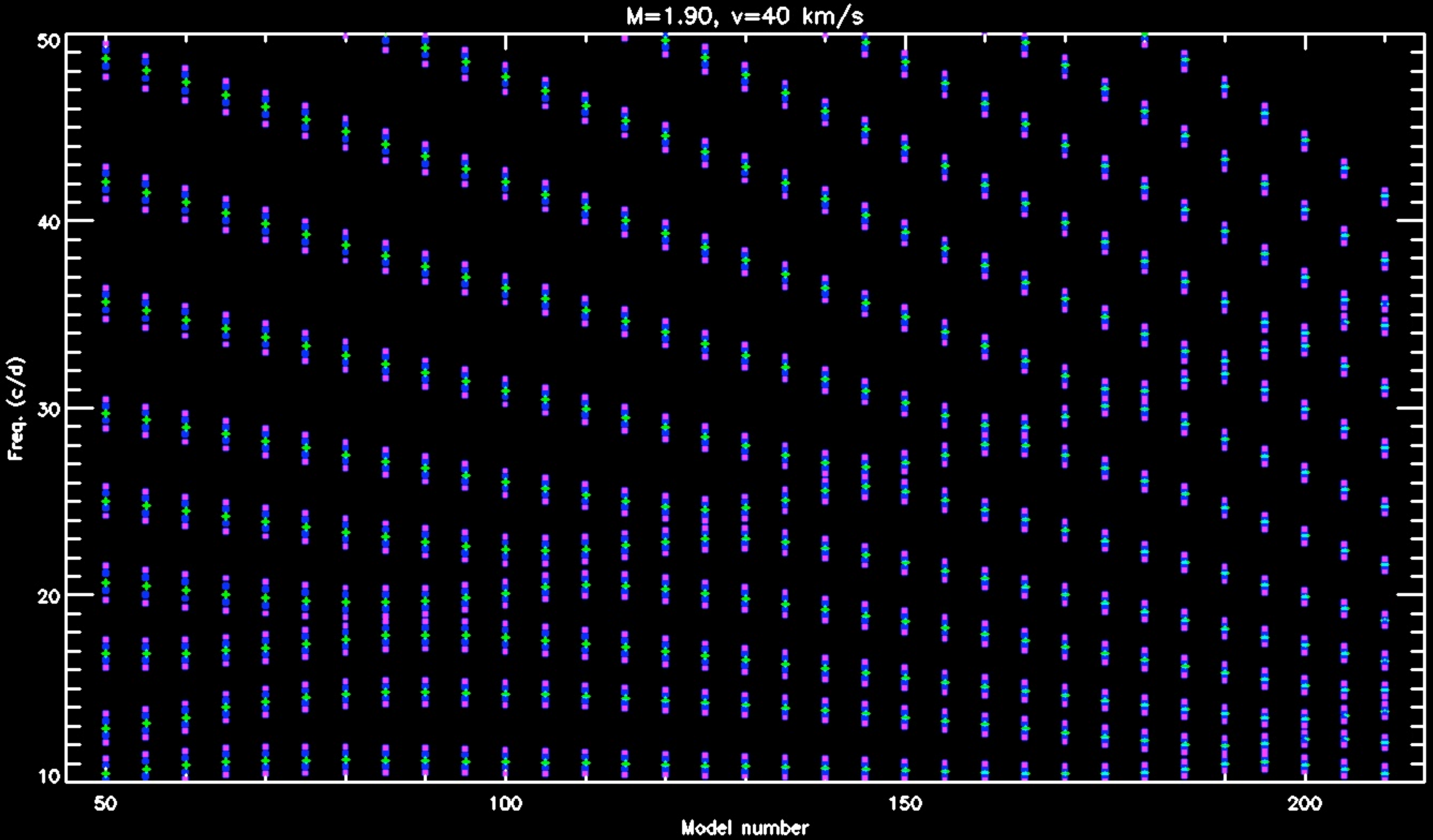
Posterior:

p(L|D)= 0.01 (L=0)
0.32 (L=1)
0.67 (L=2)

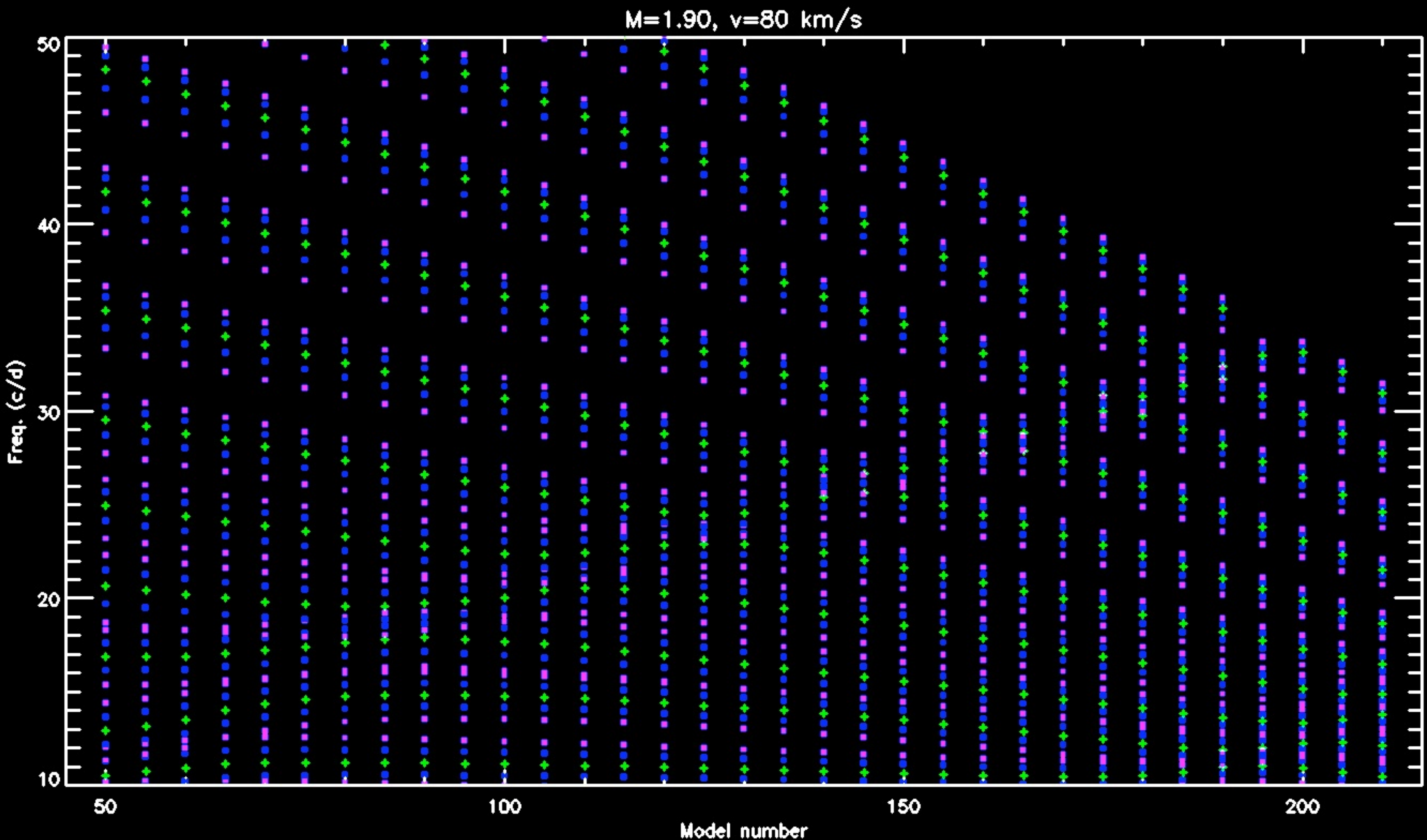


M=1.90, v=40 km/s
50
40
30
20
10
Freq. (c/d)
50
100
150
200
Model number
p4
p3
p2
p1
f
g1
g2

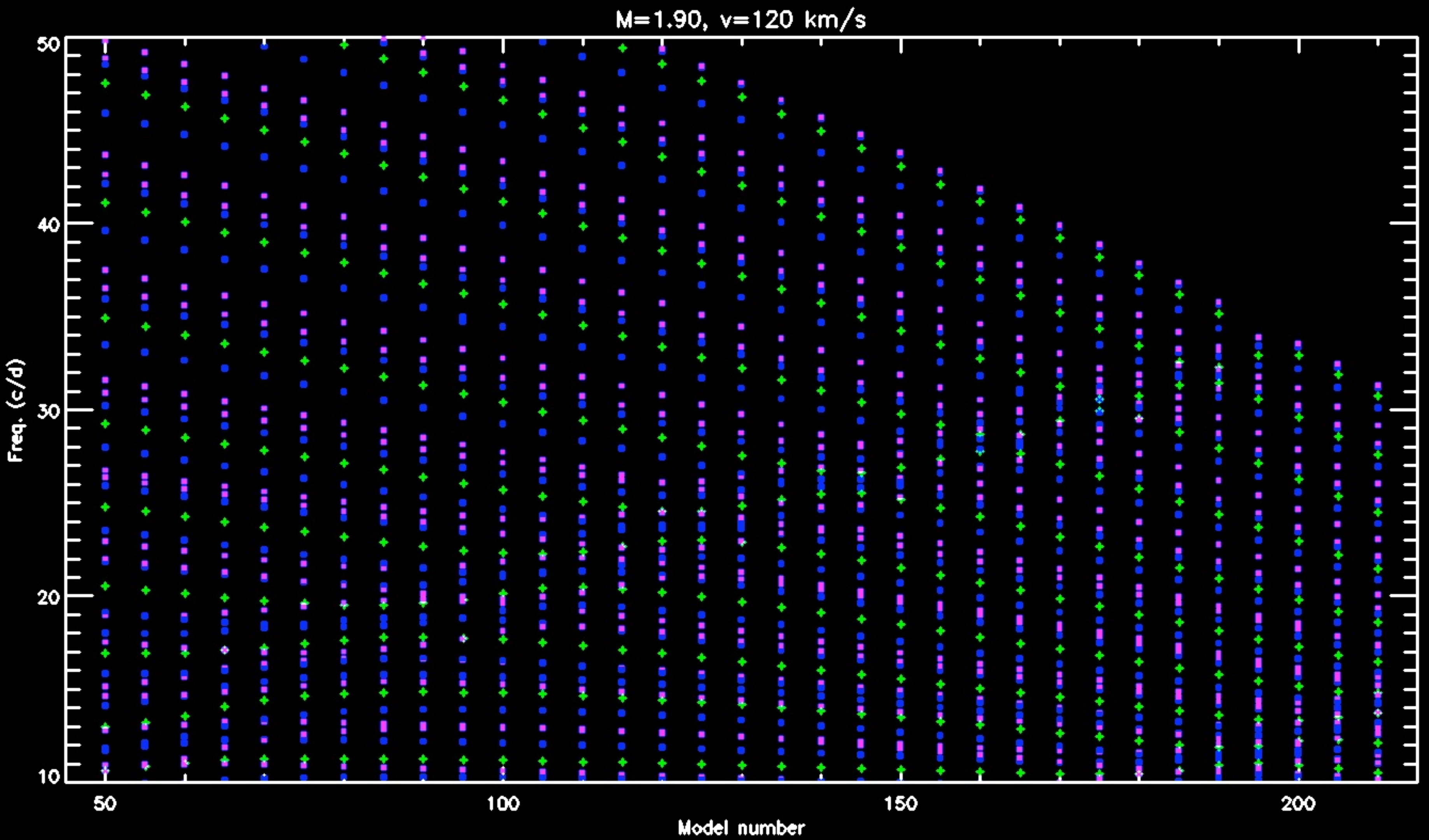
L=2, m=0



L=2, m=0, +1,+2, -1,-2



L=2, m=0, +1,+2, -1,-2



L=2, m=0, +1,+2, -1,-2