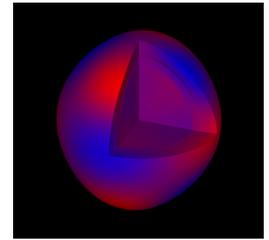




The Ninth Meeting on Hot Subdwarf stars and Related Objects



Asteroseismic modeling of hot subdwarfs observed by TESS: TIC 16928, TIC 06758, and PG0342+026

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Outline

- I. Pulsating sdB stars
- II. Models and method for asteroseismic modeling
- III. Modeling TESS targets:
 - TIC 169285097
 - PG 0342+026 (TIC 457168745)
 - TIC 067584818
- IV. Conclusions & prospects

Subdwarf B (sdB) stars

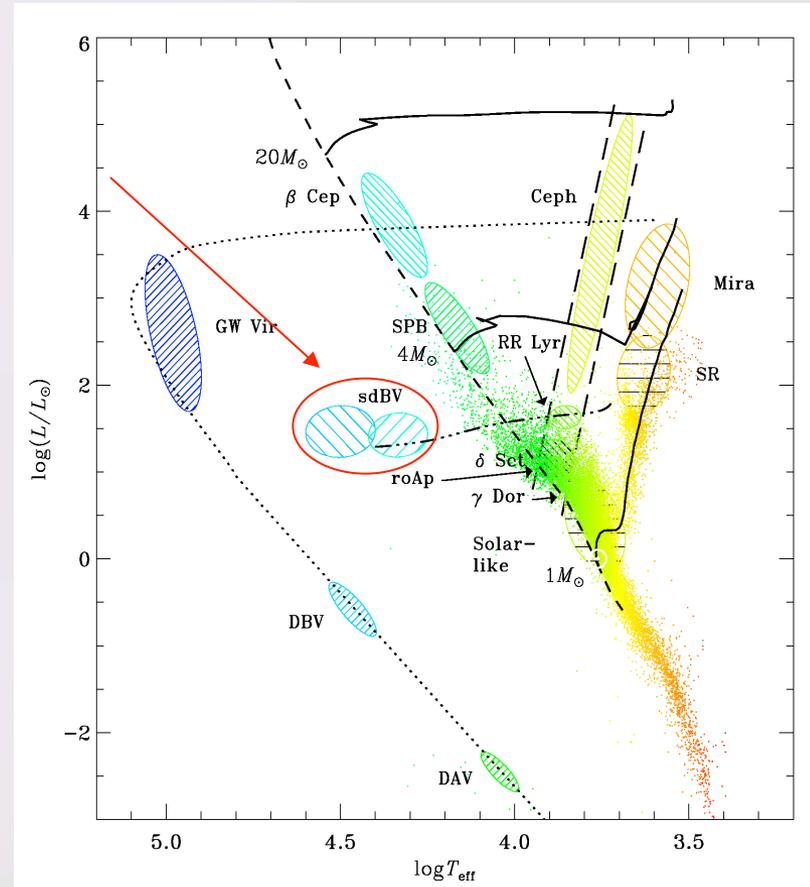
Hot ($T_{\text{eff}} \sim 30\,000\text{ K}$) and compact stars ($\log g \sim 5.5$) belonging to Extreme Horizontal Branch (EHB), an intermediate stage of evolution

Two main classes of multi-periodic sdB pulsators:

> short-periods ($P \sim 80 - 600\text{ s}$), $A \leq 1\%$, **p-modes**
(EC14026, V361Hya, sdBV_r,...)

> long-periods ($P \sim 30\text{ min} - 3\text{ h}$), $A \leq 0.1\%$, **g-modes**
(PG1716, V1093 Her, Betsy stars, sdBV_s,...)

+ hybrids



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Models for hot subdwarfs seismology

Static models = Parametrized models (*independent of stellar evolution*)

> 2nd generation (2G) models:

- static **envelope** structures; central regions (e.g. convective core) \equiv hard ball
- include detailed envelope microscopic diffusion (nonuniform envelope Fe abundance in an otherwise pure H envelope),
- 4 input parameters : T_{eff} , $\log g$, M_* , envelope thickness $\log(M_{\text{env}}/M_*)$

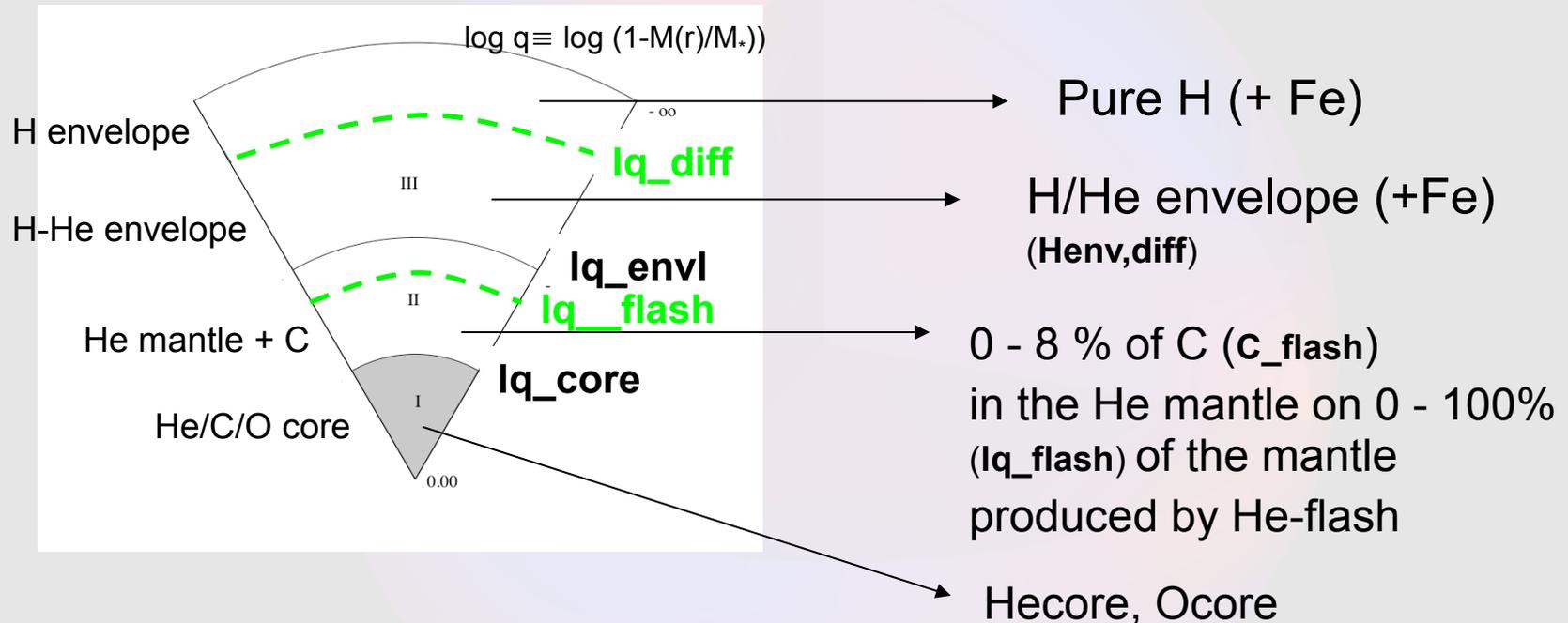
> 3rd generation (3G) models:

- **complete** static structures; including detailed central regions description
- only for sdB on EHB (He-burning)
- envelope like 2G models
- 5 input parameters : M_* , $\log(M_{\text{env}}/M_*)$, $\log(M_{\text{core}}/M_*)$, He_{core} and O_{core} ($\text{He}+\text{C}+\text{O} = 1$)

> 4th generation (4G) models: same than 3G models+

- double transition H/He envelope (2 parameters)
 - C-contamination of the He mantle produced by He-flash (2 parameters)
 - “smoothness” of the chemical transition profiles (4 parameters)
- => Up to 13 input parameters**

Models for sdB stars seismology



+ pro_fac parameters (profiles): **pf_diff**, **pf_env**, **pf_flash** & **pf_core**

Method for sdB stars seismology

Search the stellar model(s) whose theoretical periods best fit the observed ones, in order to minimize

$$S^2(a_1, a_2, \dots, a_N) = \sum_{i=1}^{N_{\text{obs}}} (P_{\text{obs}}^{(i)} - P_{\text{th}}^{(i)})^2$$

> **Optimization procedure:** Efficient optimization codes (based on *Genetic Algorithms*) to thoroughly explore the parameter space and find the minima of S^2

Under *external* constraints from spectroscopy + mode identification (if available)

- ✓ Typical parameter space
 - $0.3 \leq \mathbf{M}_* \leq 0.7 M_{\text{sun}}$ (Han et al. 2002, 2003)
 - $-6.0 \leq \mathbf{lq}_{\text{env}} \leq -3.5$
 - $-0.50 \leq \mathbf{lq}_{\text{core}} \leq -0.10$
 - $0 \leq \mathbf{He}_{\text{core}} \leq 1$
 - $0 \leq \mathbf{O}_{\text{core}} \leq 1$
 - $\mathbf{H}_{\text{env,diff}}$: 60-100% + location of the transition $\mathbf{lq}_{\text{diff}}$
 - $\mathbf{C}_{\text{flash}}$: 0-8% + location of the transition $\mathbf{lq}_{\text{flash}}$
 - Steep to smooth profiles (pro_fac parameters: $\mathbf{pf}_{\text{diff}}$, \mathbf{pf}_{env} , $\mathbf{pf}_{\text{flash}}$ and $\mathbf{pf}_{\text{core}}$)
 - + T_{eff} , $\log g$ @ 3σ spectroscopy

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Modeling TESS targets

Selection criteria:

- ≥ 5 p-modes and/or ≥ 15 g-modes
- availability of 'decent' spectroscopy (say, $T_{\text{eff}} \pm 1500$ K, $\log g \pm 0.2$ dex)

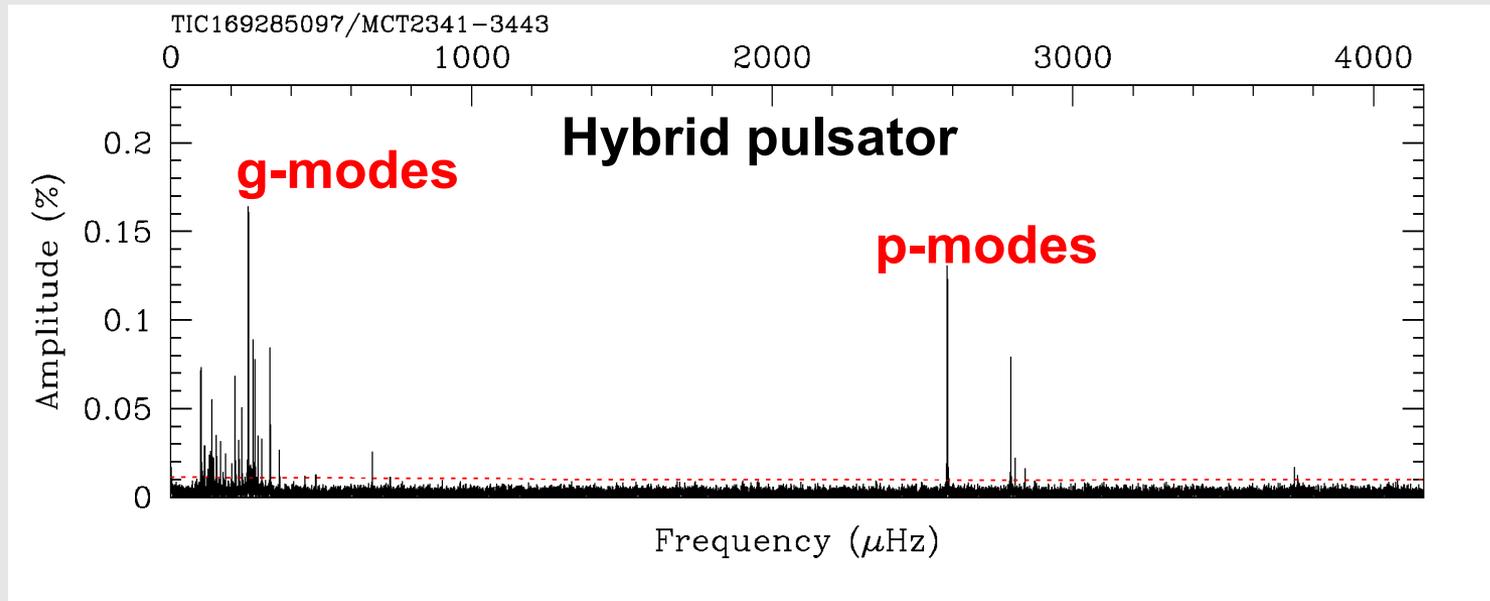
Targets spotted (to Sector 6):

- TIC 278659026/EC 21494-7018, see S. Charpinet's talk
- TIC 169285097, hybrid pulsator, my talk
- TIC 457168745/PG 0342+206, my talk
- TIC 067584818, my talk (done by C. Panais)
- TIC 080290366 (to come)
- TIC 142200764 (to come)
- ...

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Modeling TESS targets: TIC 169285097 (Sector 2)



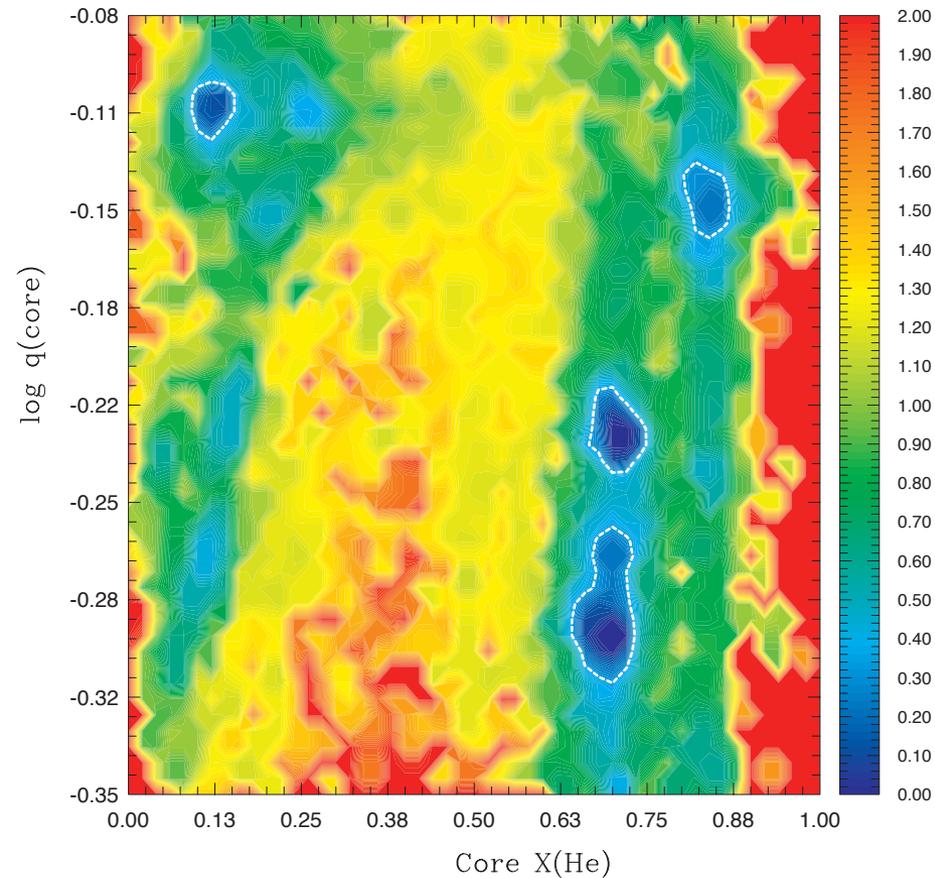
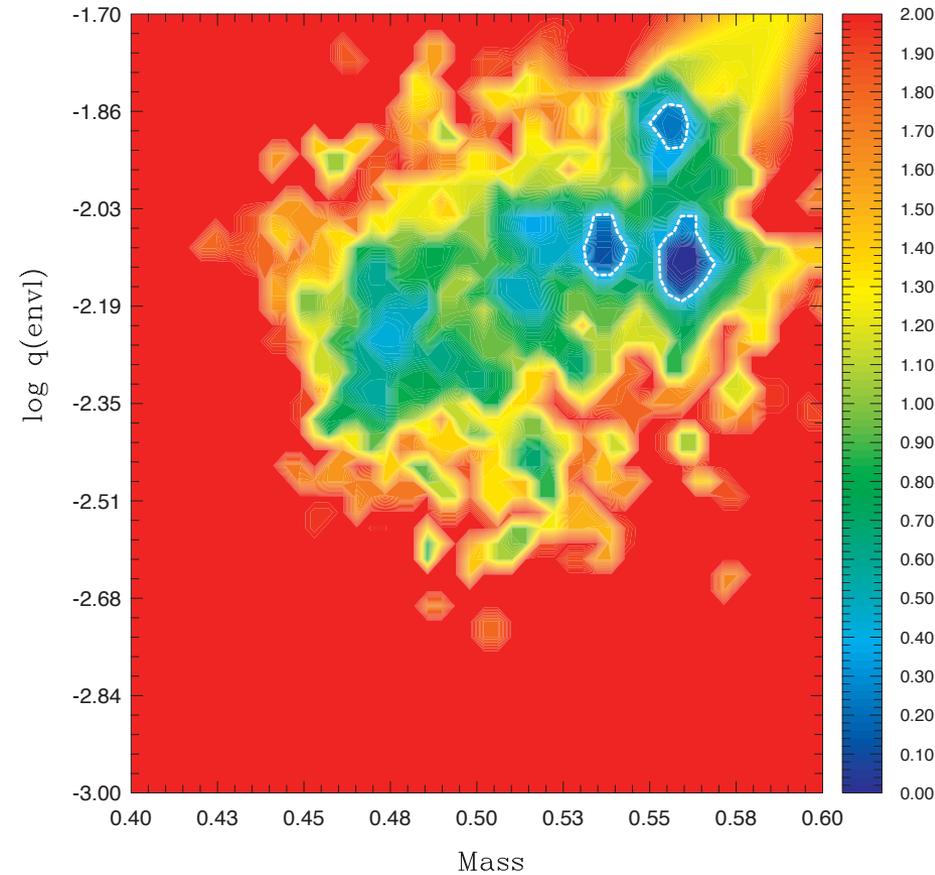
- Frequency analysis with FELIX (Charpinet et al. 2010), above 4.5σ :
 - 42 g-modes (1370s – 9956 s) and 6 p-modes (266.9 s – 387.2 s)
 - without possible linear combinations: **27 g-modes** and **5 p-modes**
- Atmospheric parameters (Nemeth et al. 2012):
 - $T_{\text{eff}} = 28390 \pm 410 \text{ K}$
 - $\log g = 5.30 \pm 0.05$

TO REDO WITH 27200 \pm 100K, 5.39 \pm 0.01 (Schneider+2018)

Modeling TESS targets: TIC 169285097

$M_* - Iq_{\text{env}}$

$\text{He}_{\text{core}} - Iq_{\text{core}}$



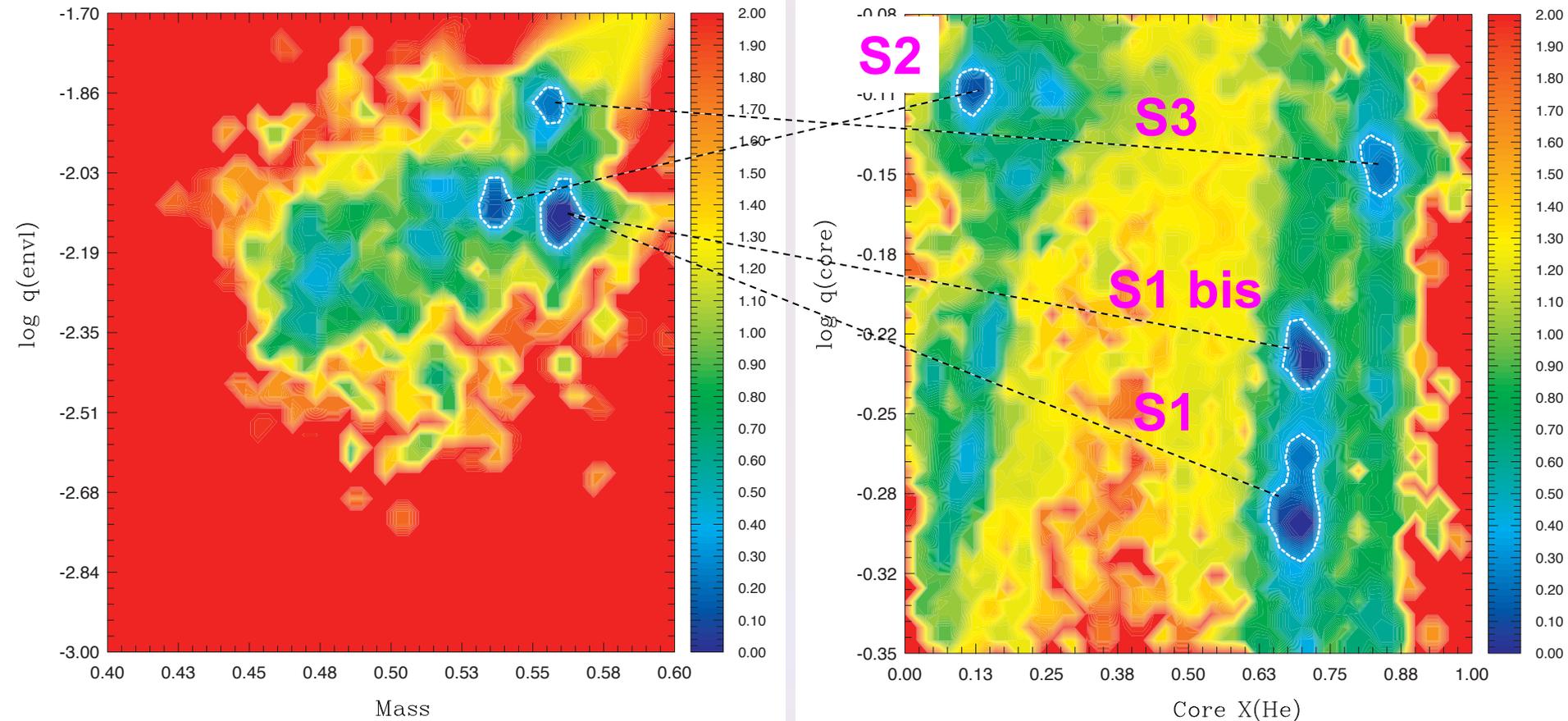
(At least) 3 best-fit solutions:

1. $S^2=2.12$, $\overline{dP/P} \sim 0.21\%$, $\overline{dP}=7.7\text{s}$, $\overline{dv}=2.1 \mu\text{Hz}$ (S1bis: $S^2=2.14$)
2. $S^2=2.79$, $dP/P \sim 0.26\%$, $dP=11.6\text{s}$, $dv=1.9 \mu\text{Hz}$
3. $S^2=3.57$, $dP/P \sim 0.28\%$, $dP=13.3\text{s}$, $dv=1.56 \mu\text{Hz}$

Modeling TESS targets: TIC 169285097

$M_* - Iq_{env}$

$He_{core} - Iq_{core}$



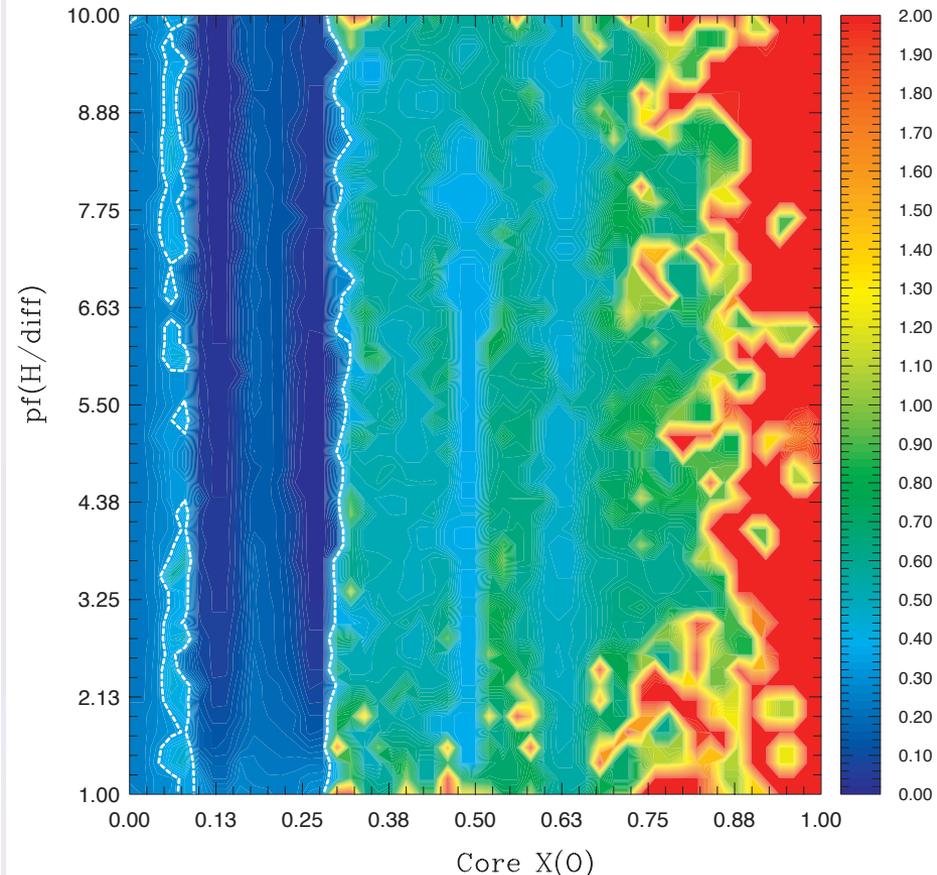
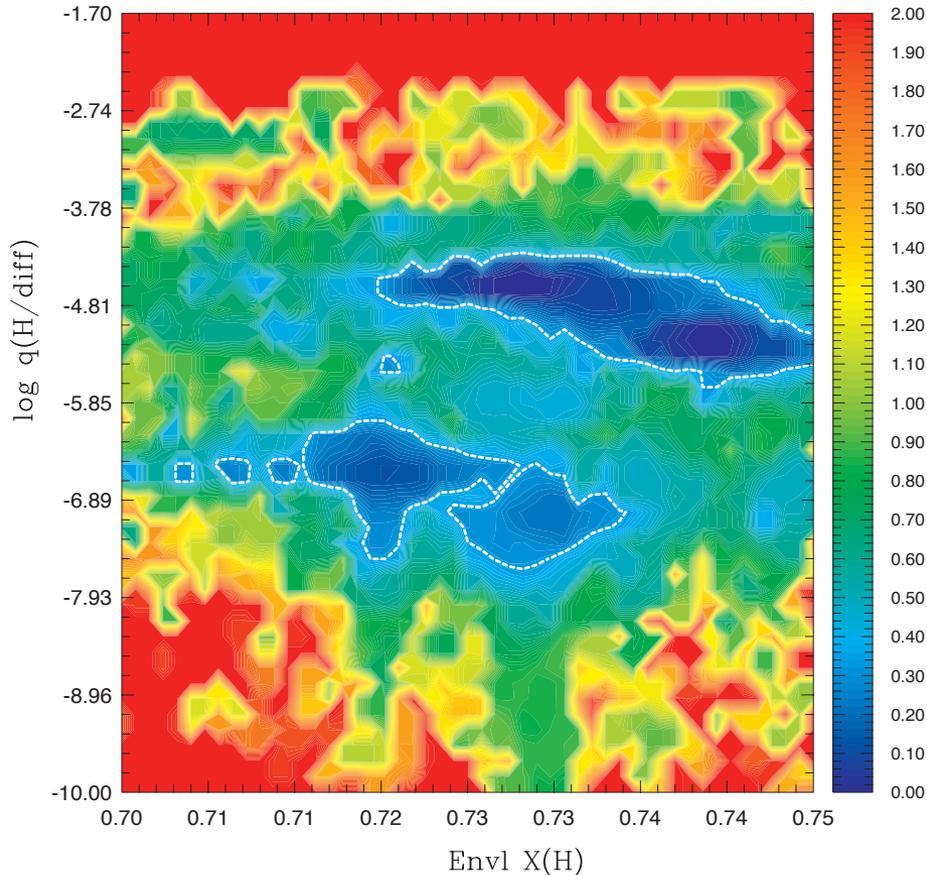
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Modeling TESS targets: TIC 169285097

$H_{\text{env,diff}} - lq_{\text{diff}}$

$O_{\text{core}} - pf_{\text{diff}}$



$H_{\text{env,diff}}$: poorly constrained (0.70-0.75)

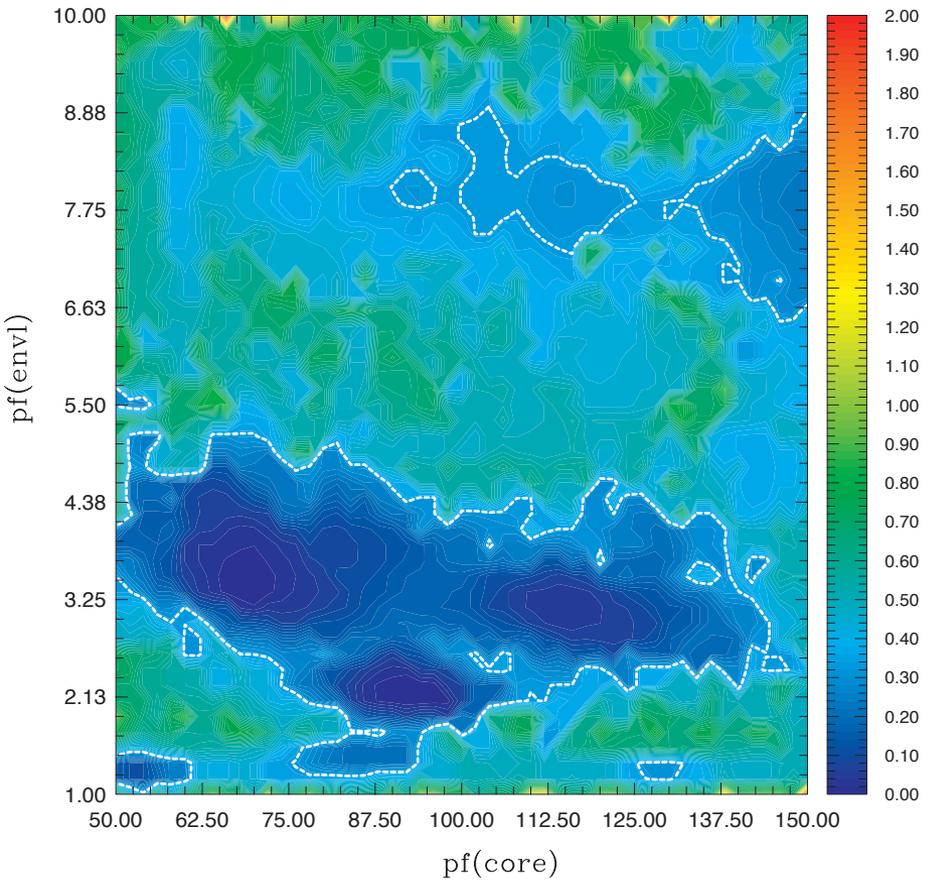
lq_{diff} : 'high' in the star

O_{core} : between 0.13 - 0.25

pf_{diff} : unconstrained

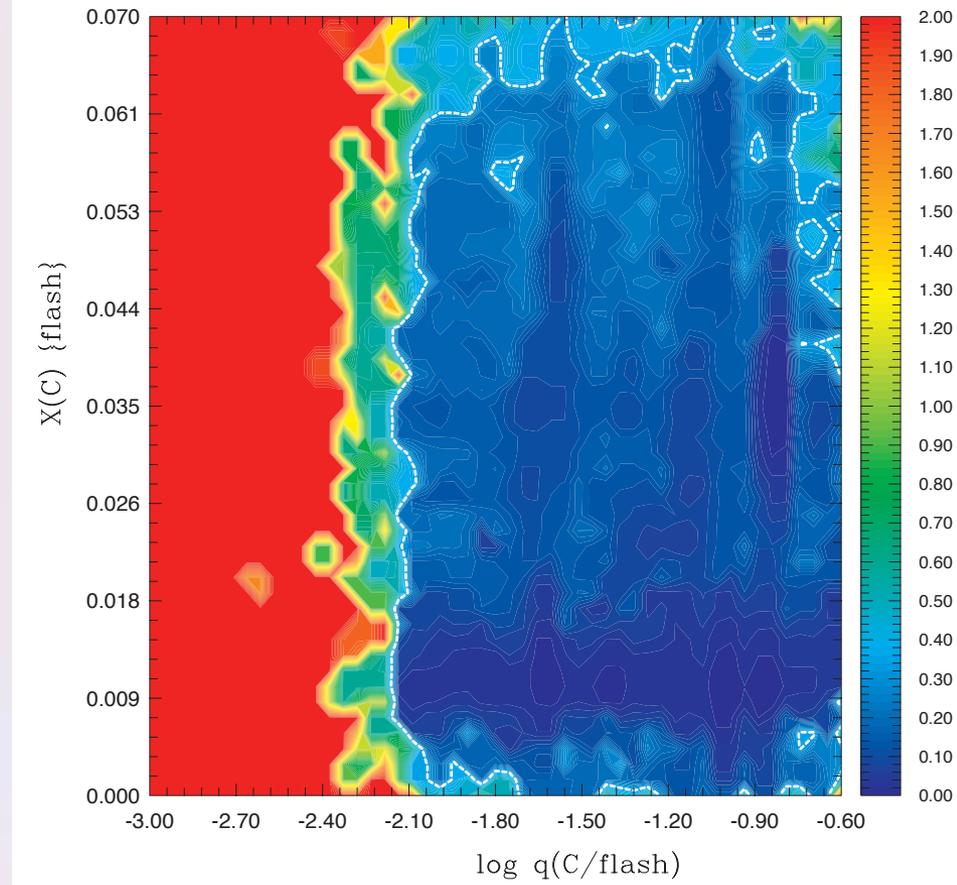
Modeling TESS targets: TIC 169285097

Pf_core – Pf_env



Pf_core: unconstrained
Pf_env: relatively smooth

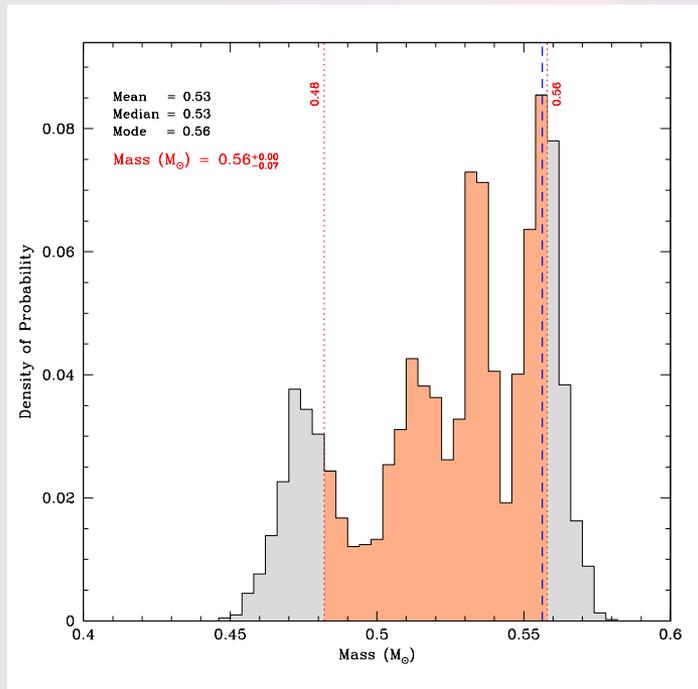
C_flash – Iq_flash



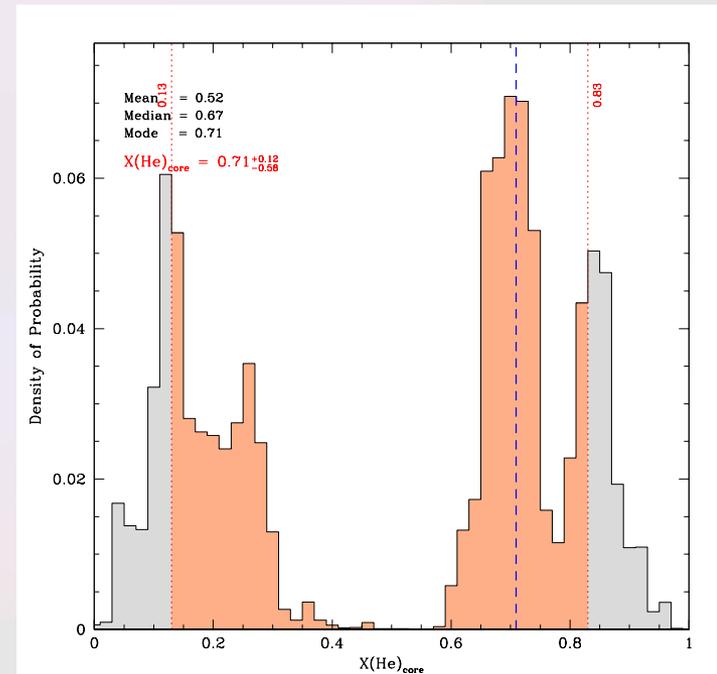
Both unconstrained
+ Pf_flash unconstrained

Well...what can we say about TIC16928?

- High-mass sdB star (?): $M_* = 0.56 +0.01-0.07 M_{\text{sun}}$
- Rather thick envelope: $lq_{\text{env}} = -2.11 +0.22-0.15$
- He_core: 2 main possibilities: ~ 0.13 (S2) or ~ 0.71 (S1, S3)
- O_core: $\sim 0.13-0.25$
- $lq_{\text{env_diff}} = -4.55 +0.12-2.87$: transition up to pure H « high » the star
- lq_{core} : various possibilities
- Unconstrained: $H_{\text{env,diff}}$, C_{flash} , lq_{flash} , all pro_fac



M_*



He_{core}

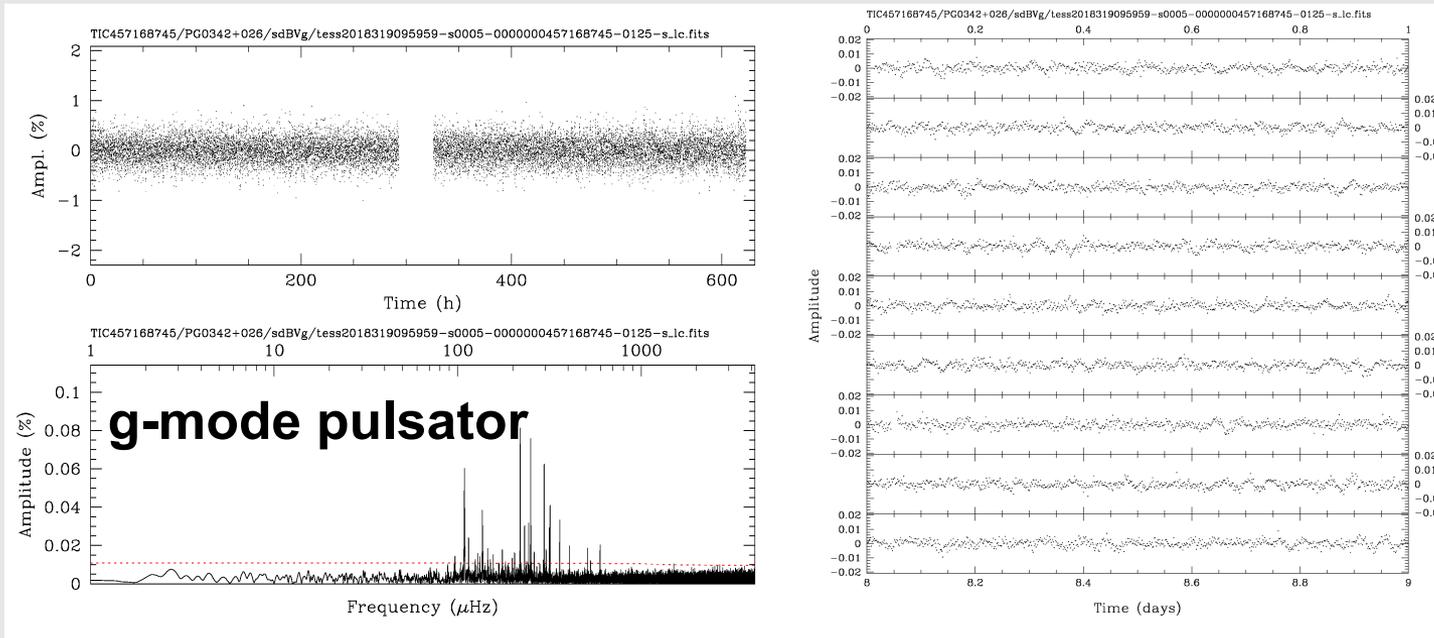
Well... How to go beyond ?

- More aggressive computation around minima
- here: $l=0, k=0$ for main p-modes ($\log g \sim 5.39$) – leave this hypothesis ?
- More extended parameter space (mass, diff_H, \dots)
- Presence of other degree l than $l=1, 2$ and 4 ?
- A priori mode identification (Murat, Andy ?)
- GAIA distance ?

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Modeling TESS targets: PG 0342+026 (Sector 5)



- Frequency analysis with FELIX, above 4.6σ :
27 g-modes (1674 s – 10331 s)
- Atmospheric parameters (Geier et al. 2017):
 $T_{\text{eff}} = 26\,000 \pm 1100\text{ K}$
 $\log g = 5.59 \pm 0.12$

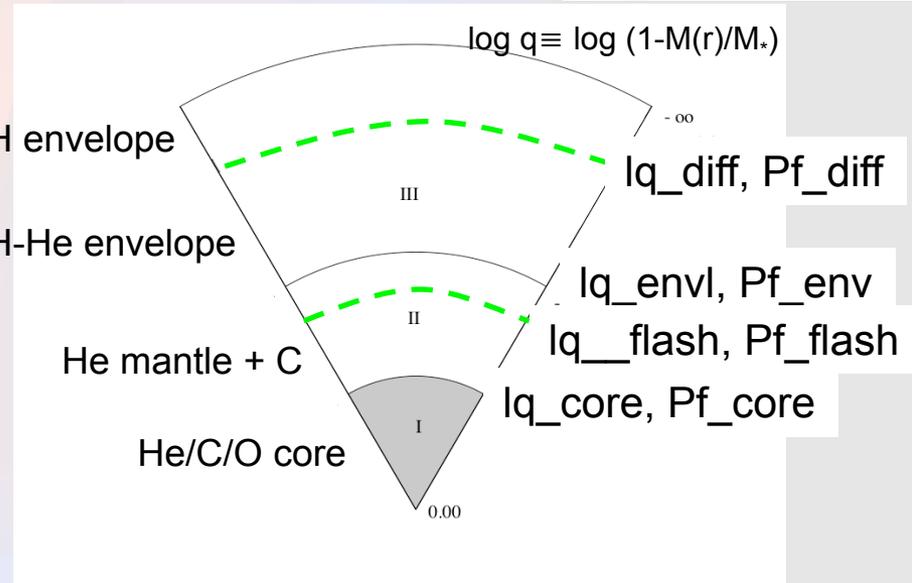
Modeling TESS targets: PG 0342+026



Preliminary computations

Search in a 'restrained' parameter space, 11 were varied:

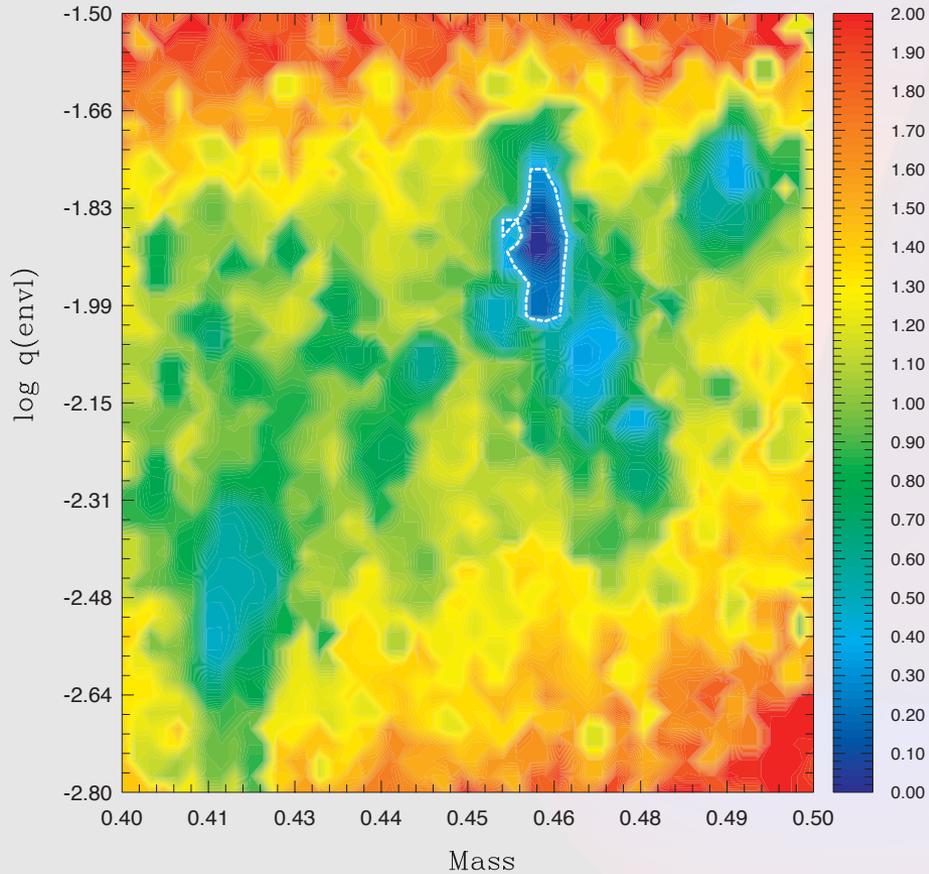
- $0.4 \leq M_* \leq 0.5 M_{\text{sun}}$
- $-2.8 \leq \text{lq_env} \leq -1.5$
- $-8.00 \leq \text{lq_diff} \leq -2.0$
- $H_{\text{env,diff}}$: 70-75%
- $1 \leq \text{Pf}_{\text{diff}} \leq 10$
- $1 \leq \text{Pf}_{\text{env}} \leq 10$
- $-0.40 \leq \text{lq_core} \leq -0.15$
- $50 \leq \text{Pf}_{\text{core}} \leq 150$
- $0 \leq \text{He}_{\text{core}} \leq 1$
- $0 \leq \text{O}_{\text{core}} \leq 1$
- C_{flash} : 0-8%; **$\text{lq_flash} + \text{Pf_flash}$ fixed**
- **T_{eff} , $\log g$ @ 2σ spectroscopy**



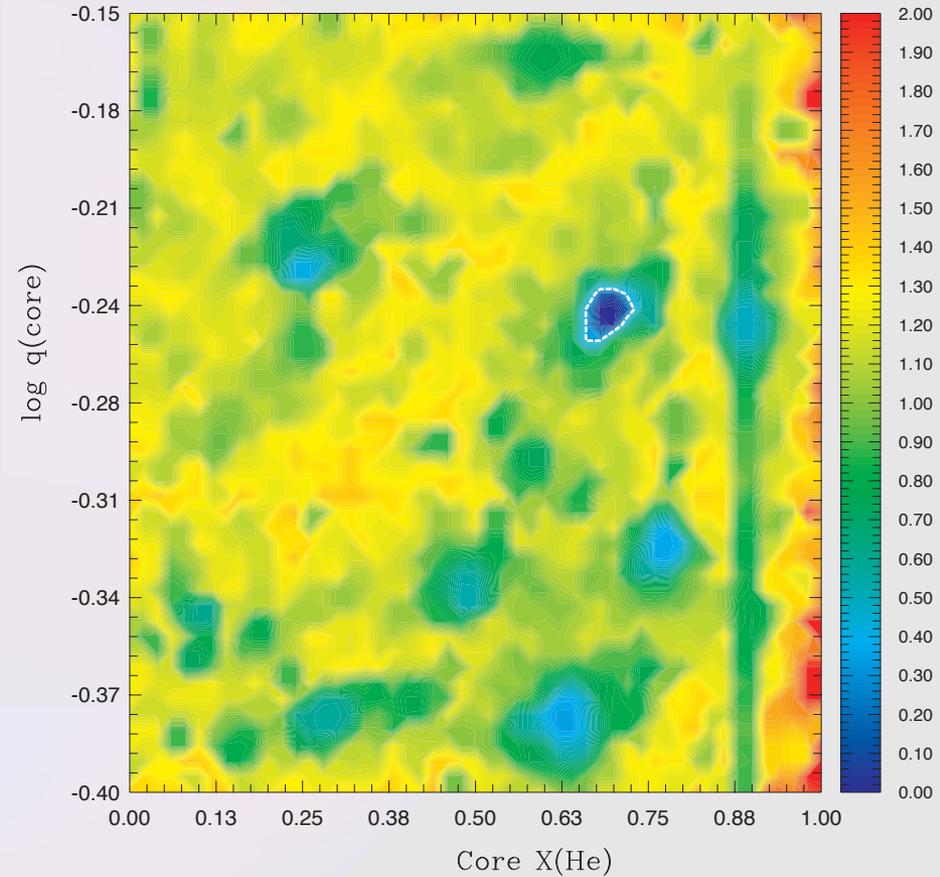
Ongoing: search in a more vast parameter space, 13 parameters

Modeling TESS targets: PG 0342+026

$M_* - Iq_{env}$



$\text{He}_{\text{core}} - Iq_{\text{core}}$

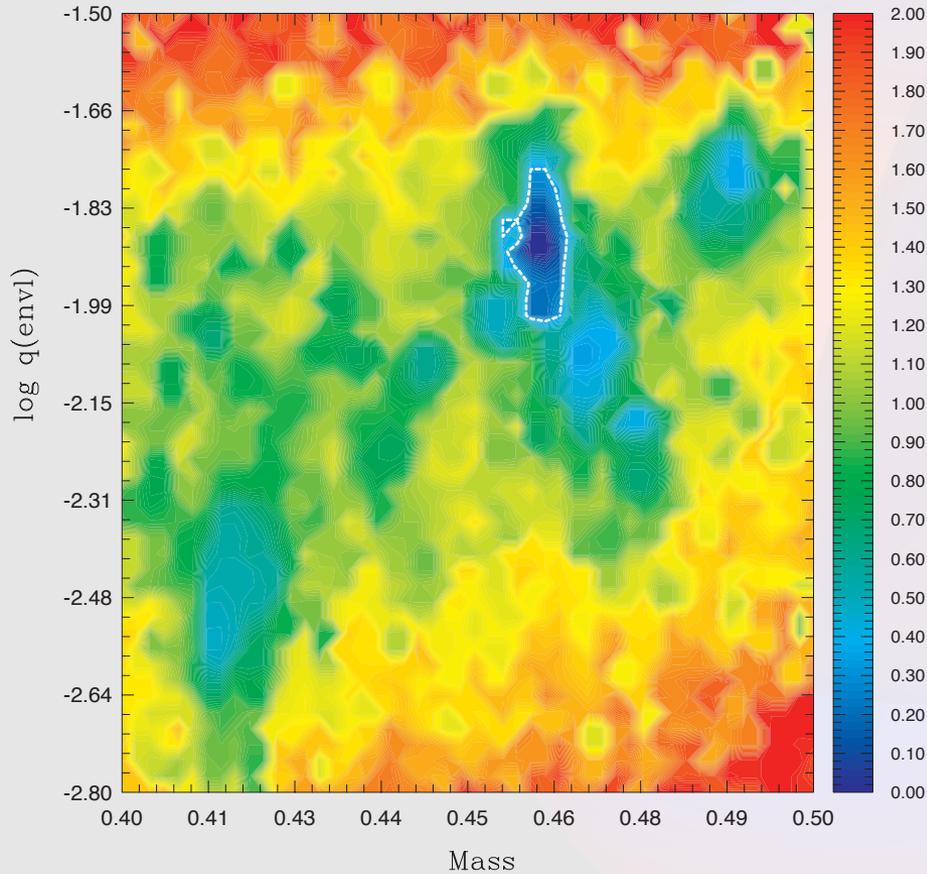


One clear solution emerged:

$$S^2=0.56, \overline{dP/P} \sim 0.12\%, \overline{dP}=5.3\text{s}, \overline{dv}=0.35 \mu\text{Hz}$$

Modeling TESS targets: PG 0342+026

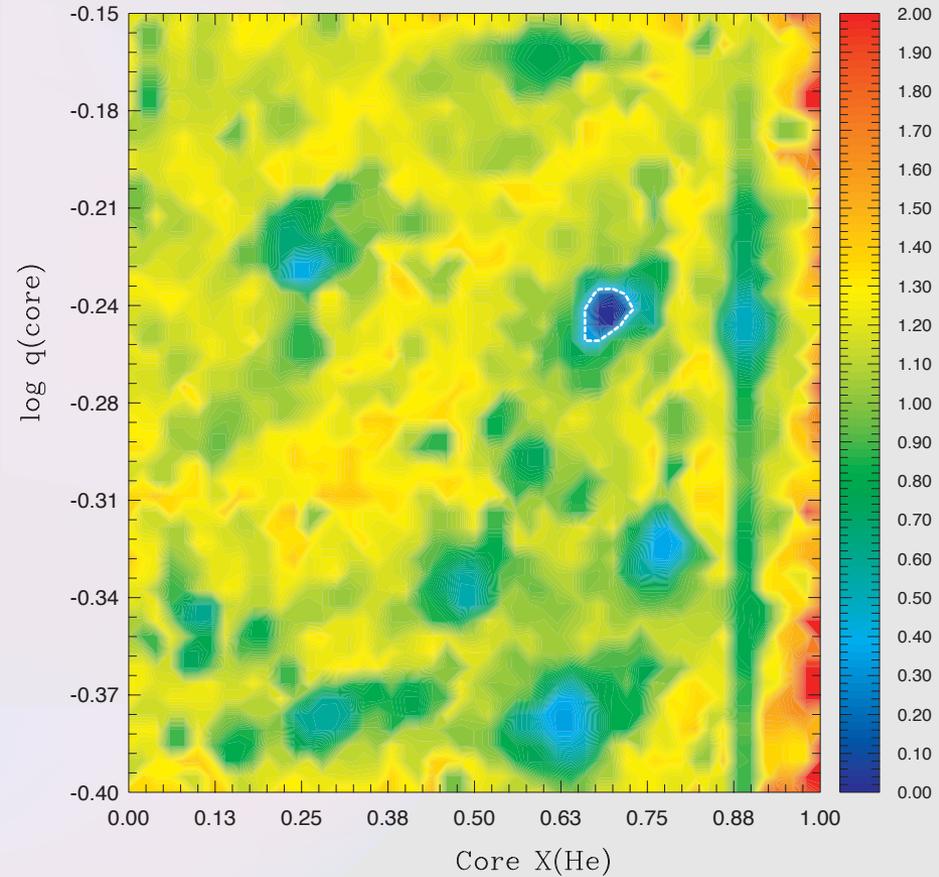
$M_* - Iq_{env}$



$$M_* \sim 0.46 \pm 0.02 M_{\text{sun}}$$

$$Iq_{env} \sim -1.90 \pm 0.10$$

$\text{He}_{\text{core}} - Iq_{\text{core}}$

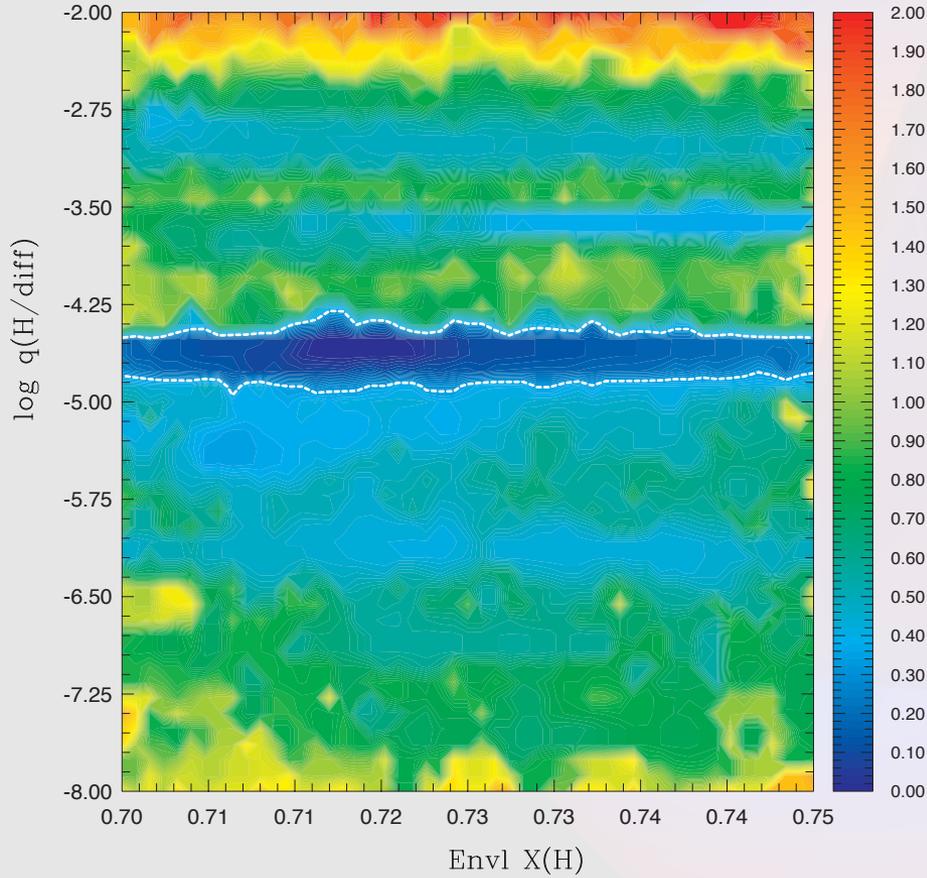


$$\text{He}_{\text{core}} \sim 0.70 \pm 0.07$$

$$Iq_{\text{core}} \sim -0.25 \pm 0.02$$

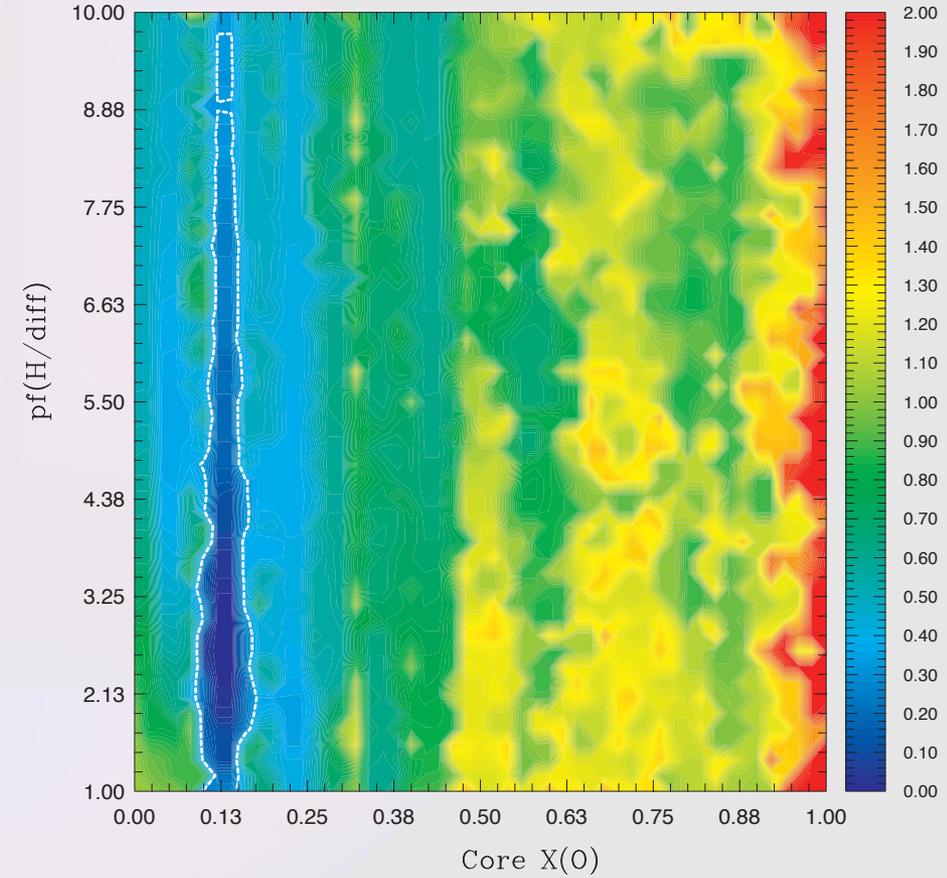
Modeling TESS targets: PG 0342+026

$H_{\text{env,diff}} - Iq_{\text{diff}}$



$H_{\text{env,diff}}$ unconstrained
 $Iq_{\text{diff}} \sim -4.58 \pm 1.08$

$O_{\text{core}} - Pf_{\text{diff}}$

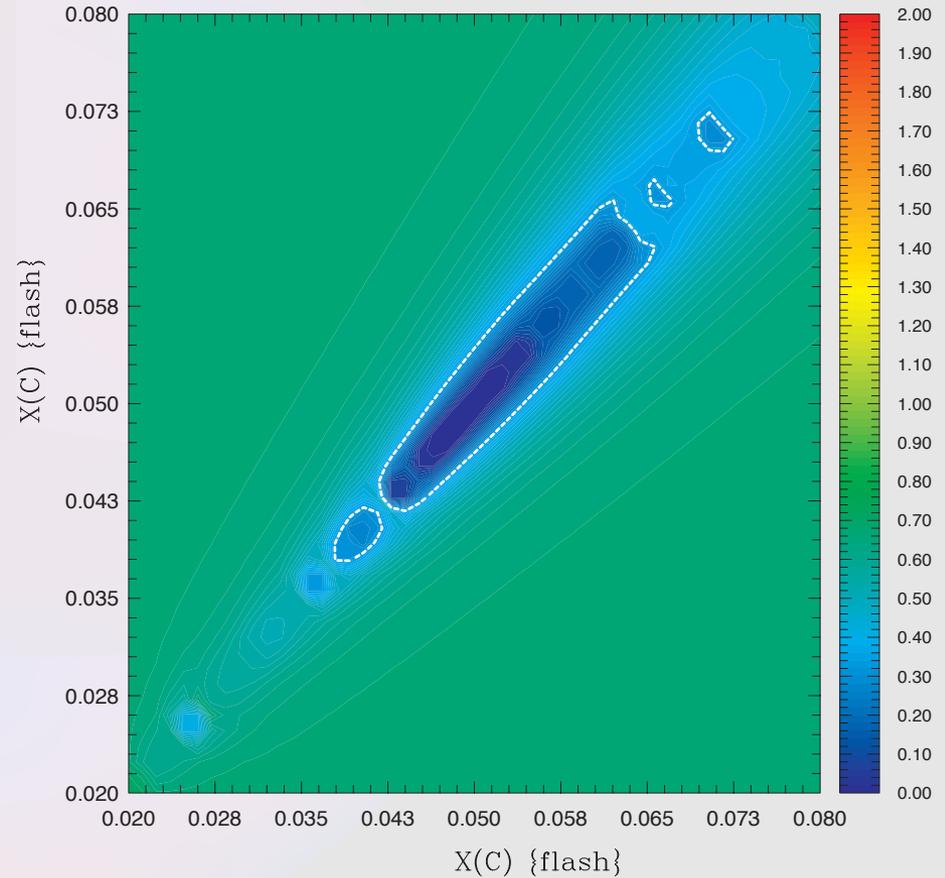
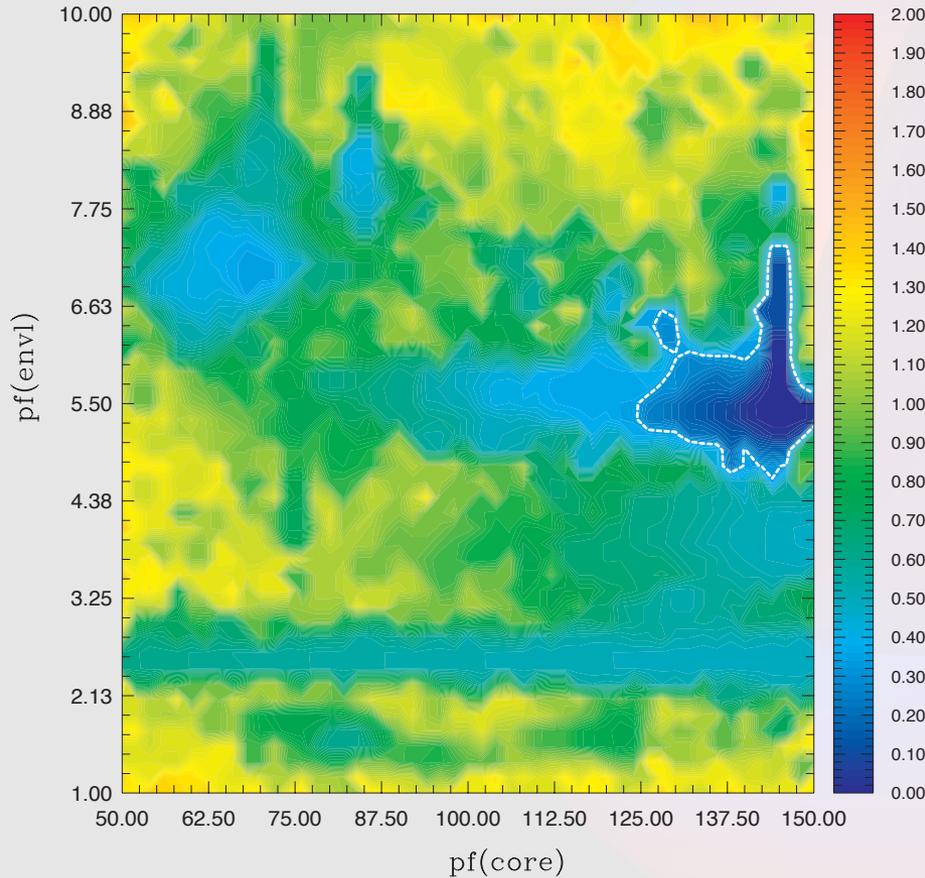


$O_{\text{core}} \sim 0.13 \pm 0.06$
 Pf_{diff} unconstrained

Modeling TESS targets: PG 0342+026

Pf_core – Pf_env

C_flash



$Pf_{\text{core}} \sim 145$ (steep)

$Pf_{\text{env}} \sim 5.50$ (mid)

$C_{\text{flash}} \sim 5.0 \pm 1.0 \%$

(Iq_flash & Pf_flash fixed)

Modeling TESS targets: PG 0342+026

- Mode id: 16 l=1 and 11 l=2; the 10 dominant modes have 7 l=1, 3 l=2

Results: <DX/X> = 0.11717608 % ; <DP> = 5.32236203 s , stdev(DP) = 4.38165610 s ; <DF> = 0.35057774 uHz , stdev(DF) = 0.43469520 uHz , Chi2 = 5.651526e-01

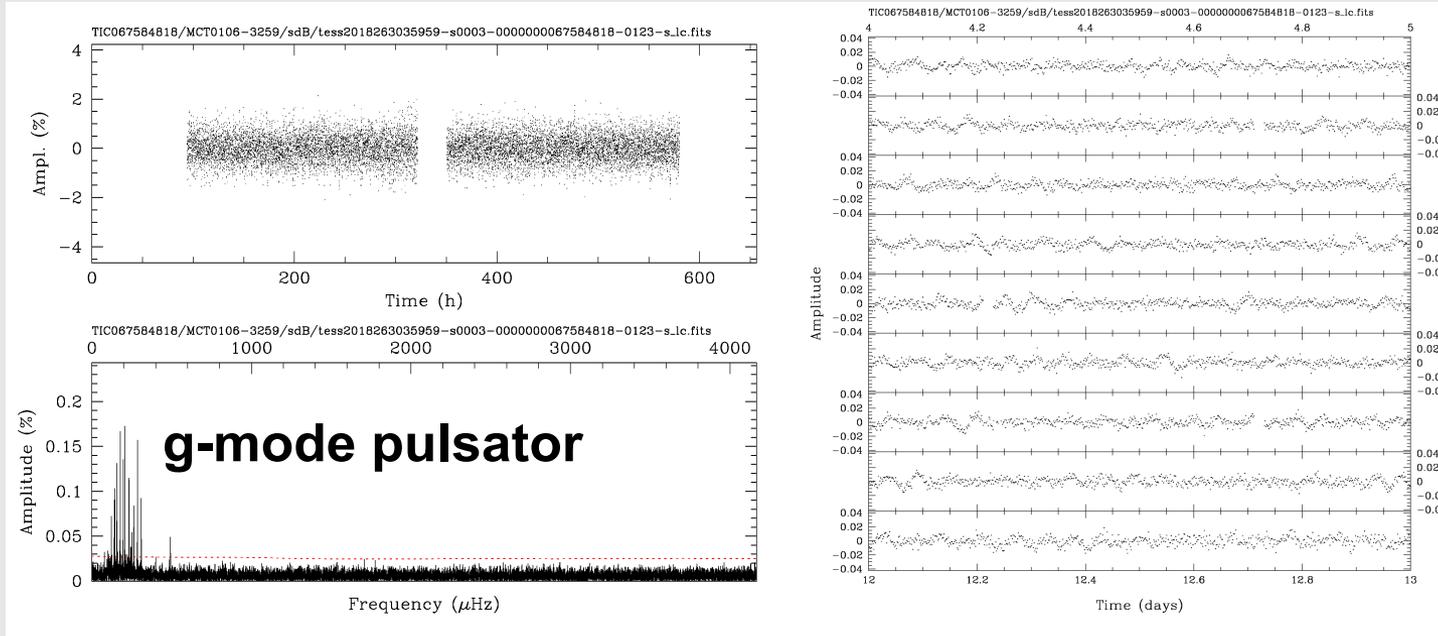
| L | K | M | Kp | Kg | Fobs (uHz) | Fth (uHz) | Pobs (s) | Pth (s) | Sigma | DX/X(%) | DP(s) | DF(uHz) |
|---|-----|---|----|----|--------------|--------------|----------------|----------------|--------------|-------------|--------------|-------------|
| 1 | -4 | 0 | 0 | 4 | ... | 906.18087347 | ... | 1103.53245062 | 0.000000e+00 | ... | ... | ... |
| 1 | -5 | 0 | 0 | 5 | ... | 717.50443178 | ... | 1393.71961441 | 0.000000e+00 | ... | ... | ... |
| 1 | -6 | 0 | 0 | 6 | ... | 614.46009893 | ... | 1627.44497444 | 0.000000e+00 | ... | ... | ... |
| 1 | -7 | 0 | 0 | 7 | 529.40420100 | 530.13371170 | 1888.91587583 | 1886.31656116 | 0.000000e+00 | +0.13760881 | +2.59931467 | -0.72951070 |
| 1 | -8 | 0 | 0 | 8 | ... | 469.96237855 | ... | 2127.82989799 | 0.000000e+00 | ... | ... | ... |
| 1 | -9 | 0 | 0 | 9 | ... | 419.30448702 | ... | 2384.90173835 | 0.000000e+00 | ... | ... | ... |
| 1 | -10 | 0 | 0 | 10 | ... | 378.06540646 | ... | 2645.04496557 | 0.000000e+00 | ... | ... | ... |
| 1 | -11 | 0 | 0 | 11 | ... | 345.99790955 | ... | 2890.19087226 | 0.000000e+00 | ... | ... | ... |
| 1 | -12 | 0 | 0 | 12 | 318.90340300 | 319.03828544 | 3135.74577942 | 3134.42005435 | 0.000000e+00 | +0.04227782 | +1.32572507 | -0.13488244 |
| 1 | -13 | 0 | 0 | 13 | ... | 297.02757364 | ... | 3366.69080166 | 0.000000e+00 | ... | ... | ... |
| 1 | -14 | 0 | 0 | 14 | ... | 277.98339396 | ... | 3597.33718536 | 0.000000e+00 | ... | ... | ... |
| 1 | -15 | 0 | 0 | 15 | ... | 262.72570669 | ... | 3806.25106160 | 0.000000e+00 | ... | ... | ... |
| 1 | -16 | 0 | 0 | 16 | 250.25588100 | 249.78551081 | 3995.91009012 | 4003.43477387 | 0.000000e+00 | -0.18830964 | -7.52468375 | +0.47037019 |
| 1 | -17 | 0 | 0 | 17 | ... | 240.96136368 | ... | 4150.04291450 | 0.000000e+00 | ... | ... | ... |
| 1 | -16 | 0 | 0 | 16 | 231.53047800 | 231.01722503 | 4319.08580088 | 4328.68155120 | 0.000000e+00 | -0.22217087 | -9.59575032 | +0.51325297 |
| 1 | -19 | 0 | 0 | 19 | 219.27132500 | 218.97902017 | 4560.55984521 | 4566.64752268 | 0.000000e+00 | -0.13348531 | -6.08767747 | +0.29230483 |
| 1 | -20 | 0 | 0 | 20 | ... | 208.89962540 | ... | 4786.98800000 | 0.000000e+00 | ... | ... | ... |
| 1 | -21 | 0 | 0 | 21 | 198.55231900 | 198.72796641 | 5036.45590762 | 5032.00439306 | 0.000000e+00 | +0.08838585 | +4.45151456 | -0.17564741 |
| 1 | -22 | 0 | 0 | 22 | ... | 190.56928680 | ... | 5247.43528616 | 0.000000e+00 | ... | ... | ... |
| 1 | -23 | 0 | 0 | 23 | ... | 182.24576374 | ... | 5487.09599319 | 0.000000e+00 | ... | ... | ... |
| 1 | -24 | 0 | 0 | 24 | ... | 175.38426042 | ... | 5701.76592603 | 0.000000e+00 | ... | ... | ... |
| 1 | -24 | 0 | 0 | 24 | ... | 170.82138517 | ... | 5854.06797282 | 0.000000e+00 | ... | ... | ... |
| 1 | -25 | 0 | 0 | 25 | ... | 168.20109935 | ... | 5945.26435251 | 0.000000e+00 | ... | ... | ... |
| 1 | -26 | 0 | 0 | 26 | ... | 162.27176887 | ... | 6162.50138257 | 0.000000e+00 | ... | ... | ... |
| 1 | -27 | 0 | 0 | 27 | 156.35890500 | 156.12422038 | 6395.54235814 | 6405.15608363 | 0.000000e+00 | -0.15031916 | -9.61372549 | +0.23468462 |
| 1 | -28 | 0 | 0 | 28 | 150.81574200 | 150.94860660 | 6630.60756615 | 6624.77132116 | 0.000000e+00 | +0.08801976 | +5.83624499 | -0.13286460 |
| 1 | -29 | 0 | 0 | 29 | 145.75911000 | 145.68897485 | 6860.63464575 | 6863.93737781 | 0.000000e+00 | -0.04814033 | -3.30273206 | +0.07013515 |
| 1 | -30 | 0 | 0 | 30 | ... | 140.97096403 | ... | 7093.65937083 | 0.000000e+00 | ... | ... | ... |
| 1 | -31 | 0 | 0 | 31 | 136.44349200 | 136.43208973 | 7329.04138806 | 7329.65391027 | 0.000000e+00 | -0.00835747 | -0.61252221 | +0.01140227 |
| 1 | -32 | 0 | 0 | 32 | 132.30201300 | 132.22661037 | 7558.46398195 | 7562.77421931 | 0.000000e+00 | -0.05702531 | -4.31023736 | +0.07540263 |
| 1 | -33 | 0 | 0 | 33 | 128.55703400 | 128.34661416 | 7778.64865800 | 7791.40148357 | 0.000000e+00 | -0.16394654 | -12.75282557 | +0.21041984 |
| 1 | -34 | 0 | 0 | 34 | 124.72943700 | 124.74077694 | 8017.35359392 | 8016.62475210 | 0.000000e+00 | +0.00909080 | +0.72884182 | -0.01133994 |
| 1 | -35 | 0 | 0 | 35 | ... | 121.29994105 | ... | 8244.02708996 | 0.000000e+00 | ... | ... | ... |
| 1 | -36 | 0 | 0 | 36 | ... | 118.06086780 | ... | 8470.20709444 | 0.000000e+00 | ... | ... | ... |
| 1 | -37 | 0 | 0 | 37 | 114.61351400 | 114.84618421 | 8724.97461338 | 8707.29843470 | 0.000000e+00 | +0.20259290 | +17.67617868 | -0.23267021 |
| 1 | -38 | 0 | 0 | 38 | ... | 111.85865034 | ... | 8939.85397596 | 0.000000e+00 | ... | ... | ... |
| 1 | -39 | 0 | 0 | 39 | 108.88040200 | 108.94186213 | 9184.38930819 | 9179.20788633 | 0.000000e+00 | +0.05641553 | +5.18142185 | -0.06146013 |
| 1 | -40 | 0 | 0 | 40 | ... | 106.24588357 | ... | 9412.12935897 | 0.000000e+00 | ... | ... | ... |
| 1 | -41 | 0 | 0 | 41 | ... | 103.68533006 | ... | 9644.56591352 | 0.000000e+00 | ... | ... | ... |
| 1 | -42 | 0 | 0 | 42 | ... | 101.28904160 | ... | 9872.73632173 | 0.000000e+00 | ... | ... | ... |
| 1 | -43 | 0 | 0 | 43 | ... | 99.07180997 | ... | 10093.68861183 | 0.000000e+00 | ... | ... | ... |
| 1 | -44 | 0 | 0 | 44 | 96.79063600 | 96.92467595 | 10331.57794314 | 10317.29010418 | 0.000000e+00 | +0.13829290 | +14.28783896 | -0.13403995 |
| 1 | -45 | 0 | 0 | 45 | ... | 94.97583685 | ... | 10528.99382813 | 0.000000e+00 | ... | ... | ... |
| 1 | -46 | 0 | 0 | 46 | ... | 92.98331494 | ... | 10754.61765036 | 0.000000e+00 | ... | ... | ... |
| 1 | -47 | 0 | 0 | 47 | ... | 91.18852220 | ... | 10966.29242259 | 0.000000e+00 | ... | ... | ... |
| 2 | -7 | 0 | 0 | 7 | ... | 907.41401018 | ... | 1102.03279735 | 0.000000e+00 | ... | ... | ... |
| 2 | -8 | 0 | 0 | 8 | ... | 806.16839883 | ... | 1240.43562294 | 0.000000e+00 | ... | ... | ... |
| 2 | -9 | 0 | 0 | 9 | ... | 720.70490429 | ... | 1387.53044977 | 0.000000e+00 | ... | ... | ... |
| 2 | -10 | 0 | 0 | 10 | ... | 650.49834727 | ... | 1537.28292192 | 0.000000e+00 | ... | ... | ... |
| 2 | -11 | 0 | 0 | 11 | 597.47890400 | 595.62536587 | 1673.69926085 | 1678.90767806 | 0.000000e+00 | -0.31119194 | -5.20841720 | +1.85353813 |
| 2 | -12 | 0 | 0 | 12 | ... | 549.66342797 | ... | 1819.29513427 | 0.000000e+00 | ... | ... | ... |
| 2 | -13 | 0 | 0 | 13 | 510.72873000 | 511.93973102 | 1957.98658125 | 1953.35493500 | 0.000000e+00 | +0.23655148 | +4.63164625 | -1.21100102 |
| 2 | -14 | 0 | 0 | 14 | ... | 479.13961327 | ... | 2087.07435640 | 0.000000e+00 | ... | ... | ... |
| 2 | -15 | 0 | 0 | 15 | ... | 452.44679361 | ... | 2210.20463429 | 0.000000e+00 | ... | ... | ... |

- $T_{\text{eff}} = 25\,274\text{ K}$; $\log g = 5.46$ (spectro: $26\,000 \pm 1100\text{ K}$ and 5.59 ± 0.12)

Outline

- I. Pulsating sdB stars
- II. Models and method for asteroseismic modeling
- III. **Modeling TESS targets:**
 - TIC 169285097
 - PG 0342+026 (TIC 457168745)
 - **TIC 067584818**
- IV. Conclusions & prospects

Modeling TESS targets: TIC 067584818 (Sector 3)



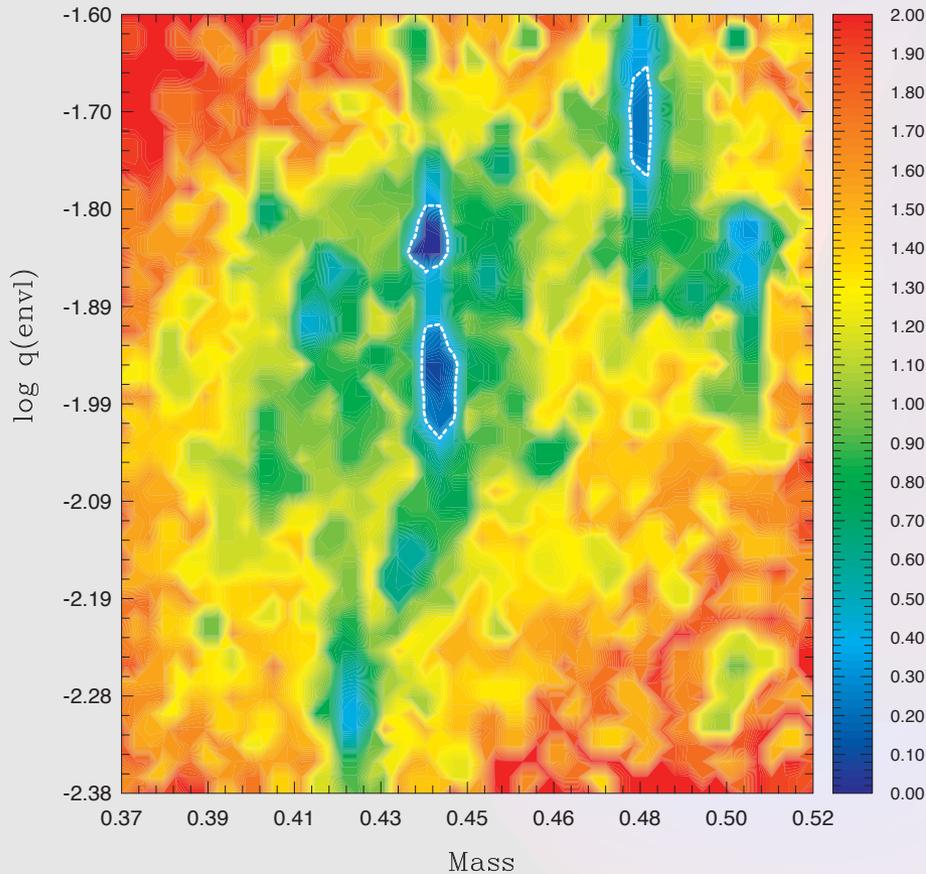
- Frequency analysis with FELIX (! automated), above 5.3σ :
19 g-modes (2031s – 9991 s)

- Atmospheric parameters (Geier et al. 2017):
 $T_{\text{eff}} = 25\,000 \pm 1200 \text{ K}$
 $\log g = 5.30 \pm 0.20$

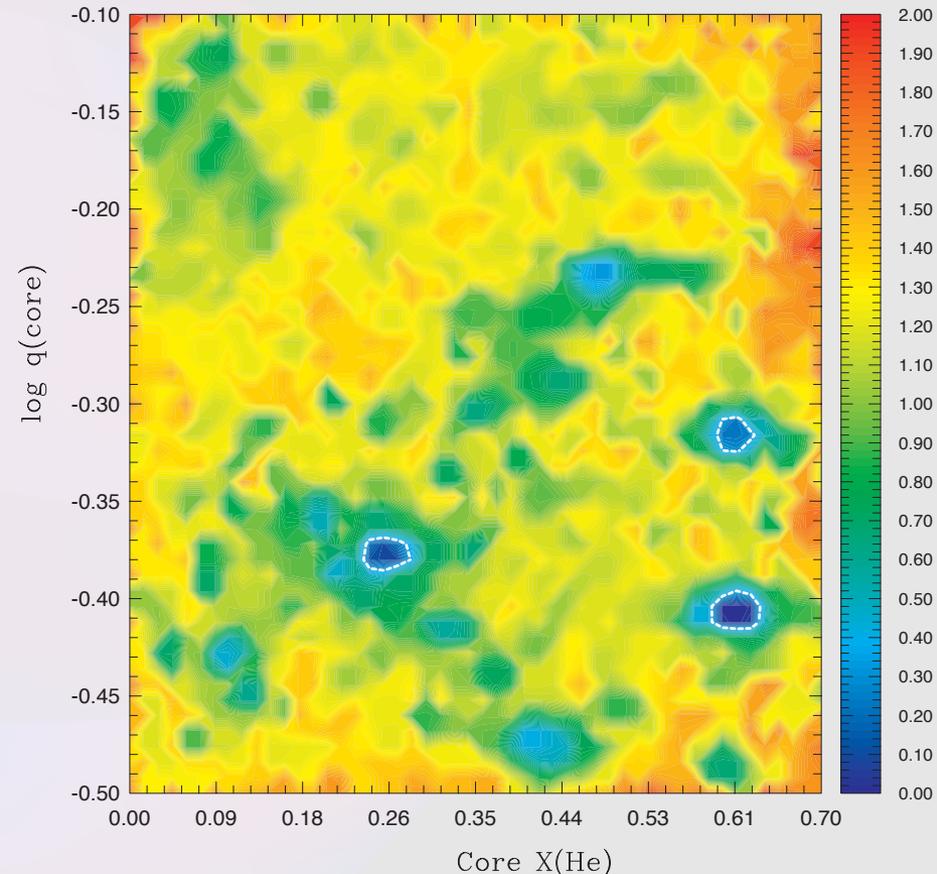


Modeling TESS targets: TIC 067584818

$M_* - Iq_{env}$



$\text{He}_{core} - Iq_{core}$

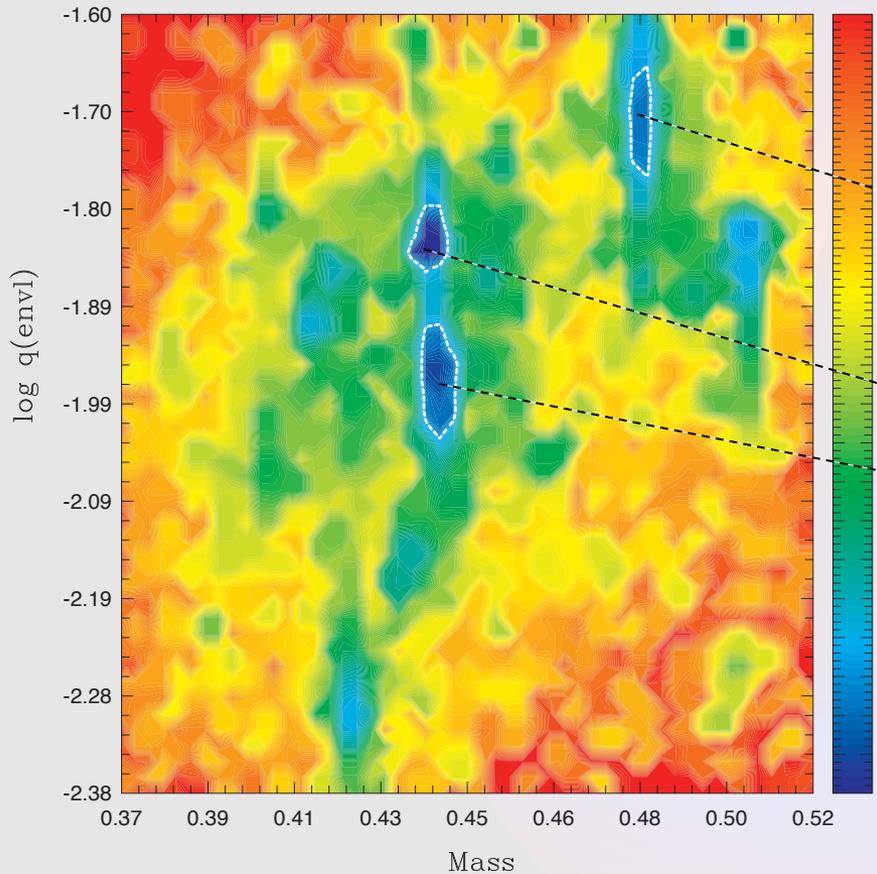


(At least) 3 best-fit solutions:

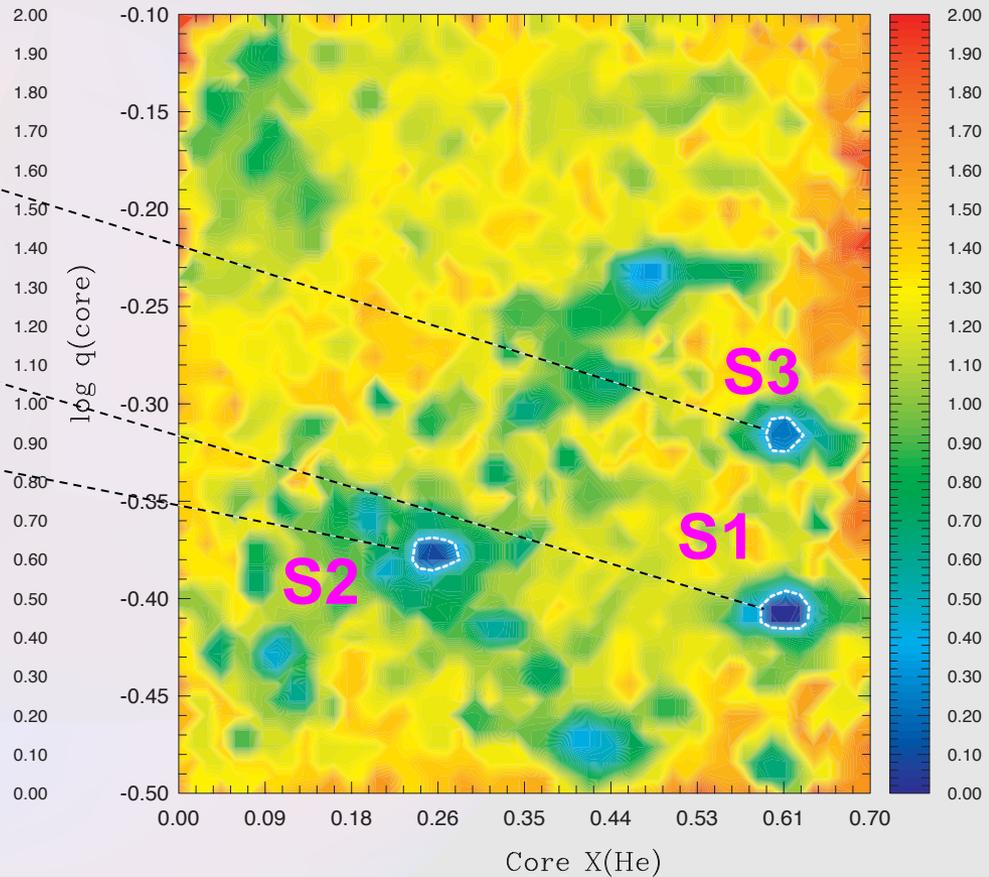
1. $S^2=0.29$, $\overline{dP/P} \sim 0.10\%$, $\overline{dP}=5.1\text{s}$, $\overline{dv}=0.22 \mu\text{Hz}$
2. $S^2=0.36$, $\overline{dP/P} \sim 0.093\%$, $\overline{dP}=5.0\text{s}$, $\overline{dv}=0.19 \mu\text{Hz}$
3. $S^2=0.49$, $\overline{dP/P} \sim 0.13\%$, $\overline{dP}=6.7\text{s}$, $\overline{dv}=0.29 \mu\text{Hz}$

Modeling TESS targets: TIC 067584818

$M_* - Iq_{env}$



$\text{He}_{\text{core}} - Iq_{\text{core}}$

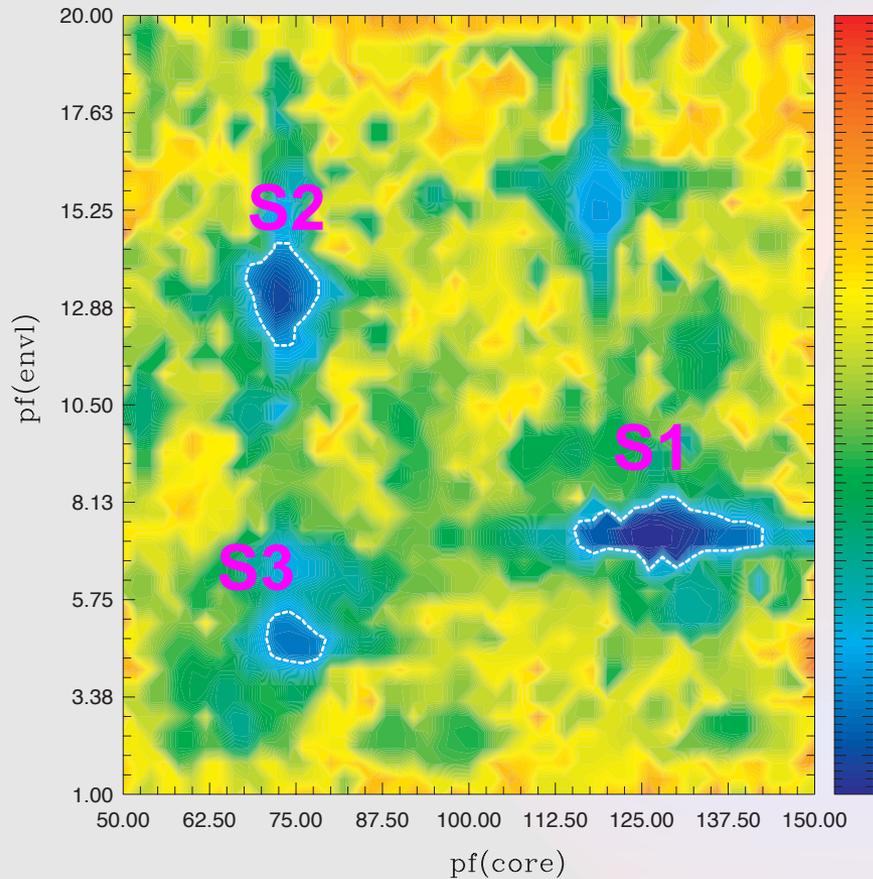


(At least) 3 best-fit solutions:

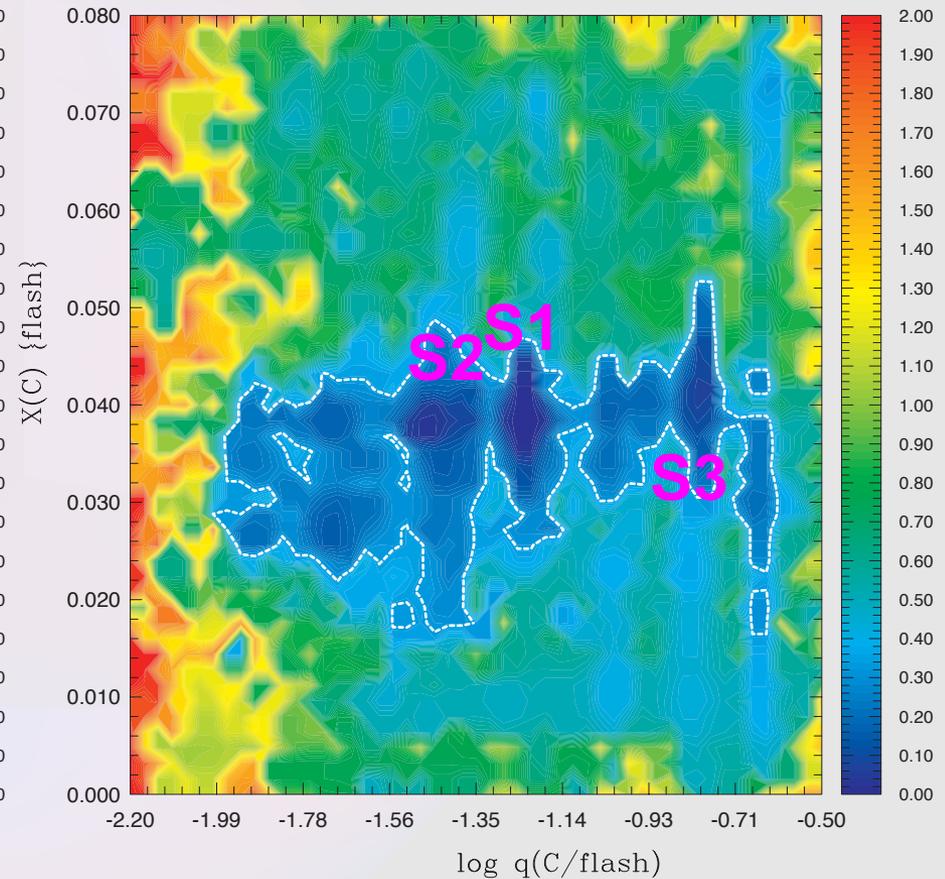
1. $S^2=0.29$, $\overline{dP/P} \sim 0.10\%$, $\overline{dP}=5.1\text{s}$, $\overline{dv}=0.22 \mu\text{Hz}$
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Modeling TESS targets: TIC 067584818

Pf_core – Pf_env



$C_{\text{flash}} - I_{\text{q_flash}}$

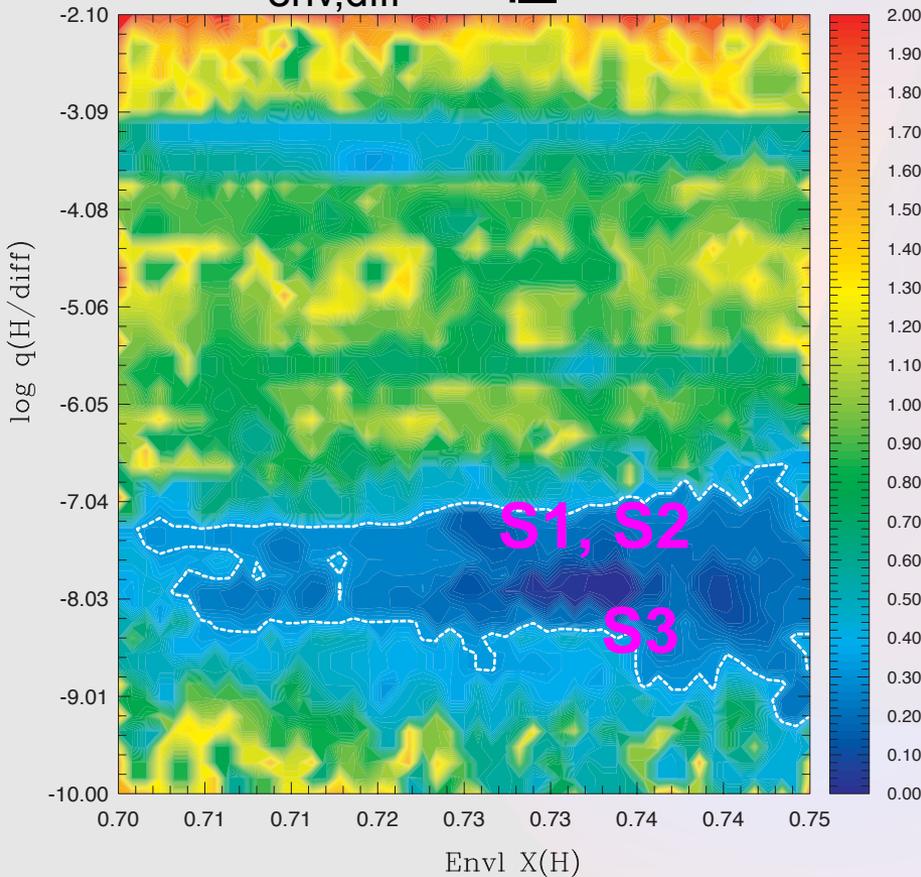


(At least) 3 best-fit solutions:

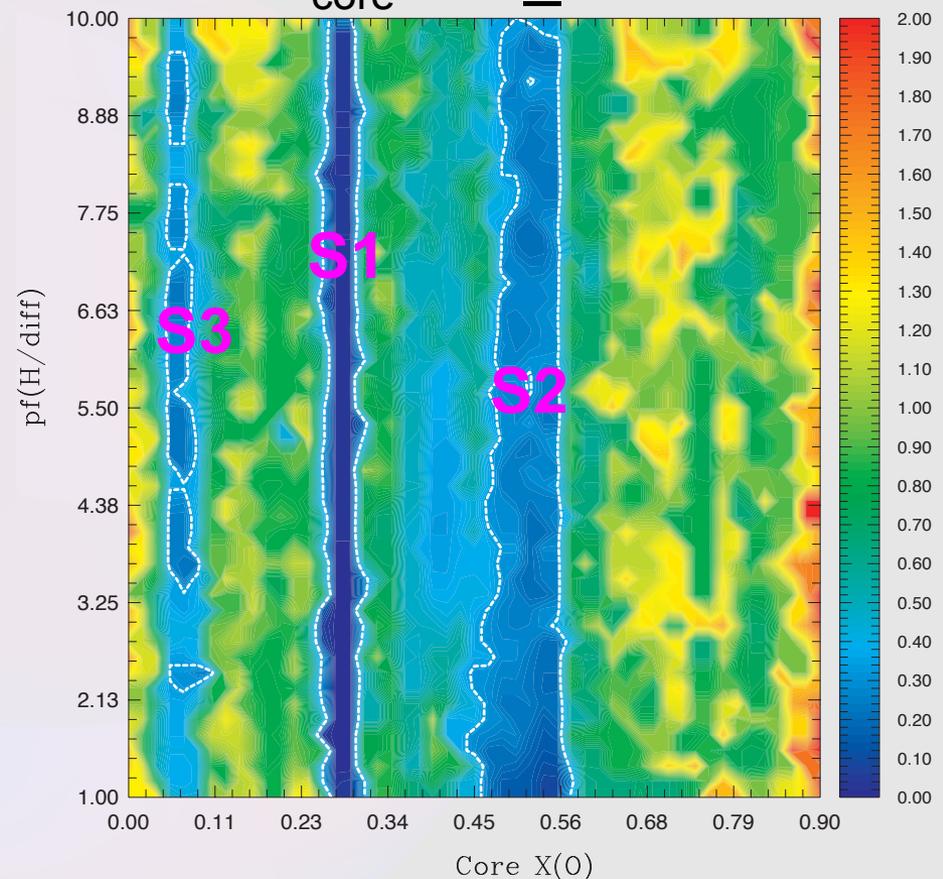
1. $S^2=0.29$, $\overline{dP/P} \sim 0.10\%$, $\overline{dP}=5.1\text{s}$, $\overline{dv}=0.22 \mu\text{Hz}$
2. $S^2=0.36$, $\overline{dP/P} \sim 0.093\%$, $\overline{dP}=5.0\text{s}$, $\overline{dv}=0.19 \mu\text{Hz}$
3. $S^2=0.49$, $\overline{dP/P} \sim 0.13\%$, $\overline{dP}=6.7\text{s}$, $\overline{dv}=0.29 \mu\text{Hz}$

Modeling TESS targets: TIC 067584818

$H_{\text{env,diff}} - Iq_{\text{diff}}$



$O_{\text{core}} - Pf_{\text{diff}}$



(At least) 3 best-fit solutions:

1. $S^2=0.29$, $\overline{dP/P} \sim 0.10\%$, $\overline{dP}=5.1\text{s}$, $\overline{dv}=0.22 \mu\text{Hz}$
2. $S^2=0.36$, $\overline{dP/P} \sim 0.093\%$, $\overline{dP}=5.0\text{s}$, $\overline{dv}=0.19 \mu\text{Hz}$
3. $S^2=0.49$, $\overline{dP/P} \sim 0.13\%$, $\overline{dP}=6.7\text{s}$, $\overline{dv}=0.29 \mu\text{Hz}$

Modeling TESS targets: TIC 067584818

Yet another case... 3 well-defined solutions, that have (mostly) well-determined parameters...how to discriminate them?

- Mode identification: general and 10 dominant modes:

| | Solution 1 | Solution 2 | Solution 3 |
|-------------|-------------------|-------------------|-------------------|
| Mode id. | 12 l=1, 7 l=2 | 6 l=1, 13 l=2 | 8 l=1, 11 l=2 |
| 10 dominant | 8 l=1, 2 l=2 | 4 l=1, 6 l=2 | 6 l=1, 4 l=2 |

Spectroscopy: $T_{\text{eff}} = 25\,000 \pm 1200$ K and $\log g = 5.30 \pm 0.20$

| | Solution 1 | Solution 2 | Solution 3 |
|------------------|-------------------|-------------------|-------------------|
| T_{eff} | 24 523 K | 25 011 K | 24 322 K |
| $\log g$ | 5.450 | 5.334 | 5.290 |

Modeling TESS targets: TIC 067584818

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Spectroscopy: $T_{\text{eff}} = 25\,000 \pm 1200$ K and $\log g = 5.30 \pm 0.20$ (Geier+17)

| | Solution 1 | Solution 2 | Solution 3 |
|------------------|-------------------|-------------------|-------------------|
| T_{eff} | 24 523 K | 25 011 K | 24 322 K |
| $\log g$ | 5.450 | 5.334 | 5.290 |

More spectroscopy needed !

Outline

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Conclusions

- TIC16928:
 - Hybrid pulsator and rich pulsation spectra
 - A challenge for seismic modeling: several seismic solutions, all “not excellent fits”
 - Relatively high-mass sdB star ?
 - Evolutionary status unclear
 - To go beyond: Any additional information is welcome...
- PG 0342+026:
 - g-mode pulsator, rich pulsation spectra
 - Very promising target
 - Canonical mass sdB star, many parameters (core and envelope size, evolutionary status) constrained...
 - To be confirmed !
- TIC 06758:
 - g-mode pulsator, still work to do in frequency analysis
 - Several seismic solutions, one seems to emerge
 - Seems canonical mass sdB star
 - **Need more accurate spectroscopy !**

Thanks for your attention !

PS: link towards my models for (non-irradiated) very low-mass stars and brown dwarfs:

<http://www.astro.ulg.ac.be/ASTA/cles-models-UCDs>