

ρ and $\log g$ for δ Scuti stars using “ Δv ”

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δ Scuti stars

- A-F type, main sequence stars (bright and numerous)
- Convective core
- p modes around F0 (and g modes) = no asymptotic regime
- κ mechanism/turbulent pressure (Antoci's talk)
- Precursors of some RG ($M = [1.5, 3] M_{\text{sun}}$) with planets
- Rapid rotators ($> 100 \text{ km/s}$ or $> 0.3 \Omega_{\text{K}}$) (Ouazzani's talk)

Dealing with rotation

- Non-validity of spherical approximation
- Displacement of frequencies
- Increase the number of modes (new categories)
- Destroy the rotational splitting pattern
- Models limited to:
 - spherically symmetric 1D
 - time-consuming 2D

Patterns

- Breger (histogram)
- Handler (Fourier)
- García Hernández (Fourier)
- Paparó (visual/SSA)
- Zwintz (histogram)
- Antoci (visual)
- Brunsden (histogram)
- What kind of pattern?
 - Large separation
 - Rotational splitting
 - Other
- How to avoid modelling?

Eclipsing binaries with δ Sct

- Inspired by:
 - Suárez et al. 2014 using non-rotating models
 - Theoretical predictions with 2D realistic rotating models (Lignières, Reese, Ouazzani, etc)
- 6 EB + 1 binary with optical interferometry (Rasalhague)
 - Space observations > pulsation frequencies
 - Mass
 - Volume using the equatorial & polar radii (Roche's model)

Eclipsing binaries with δ Sct

Table 1
Characteristics of the Systems Taken from the Literature

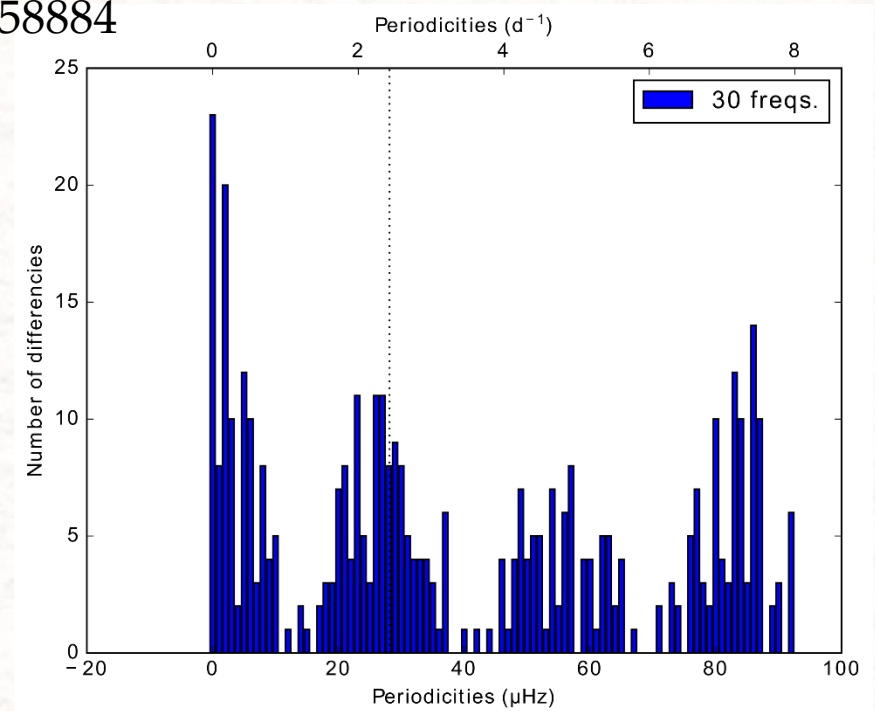
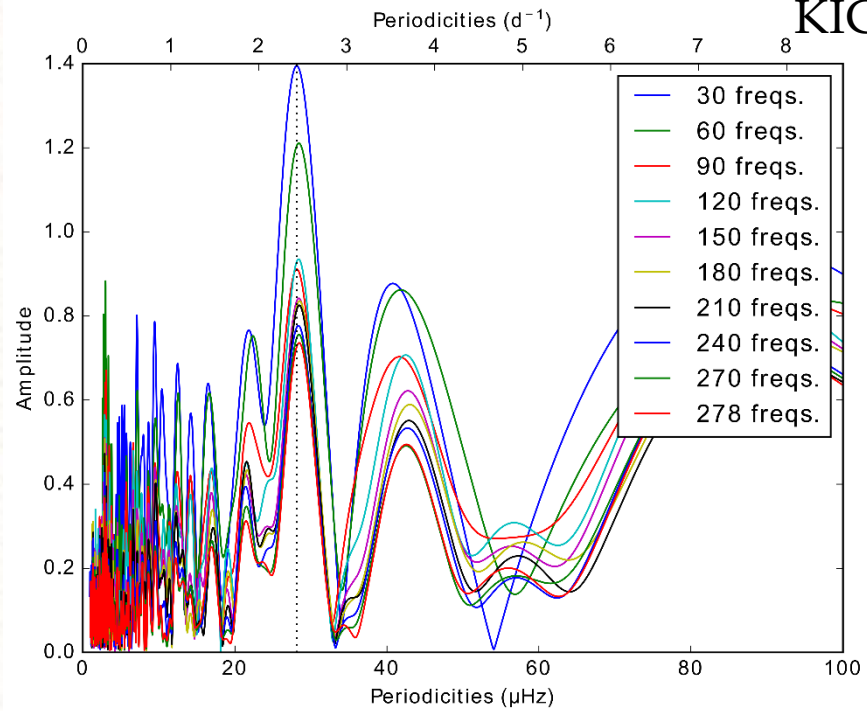
System	$\Delta\nu$ (μHz)	M ($M_{\odot}$)	R ($R_{\odot}$)	$\bar{\rho}$ ($\rho_{\odot}$)	$v \cdot \sin i$ (km s^{-1})	i ($^{\circ}$)	Ω/Ω_K
KIC 3858884 ^a	29 ± 1	1.86 ± 0.04	3.05 ± 0.01	0.0657 ± 0.0021	25.7 ± 1.5	88.176 ± 0.002	0.0754
KIC 4544587 ^b	74 ± 1	1.61 ± 0.06	1.58 ± 0.03	0.414 ± 0.039	75.8 ± 15	87.9 ± 3	0.172
KIC 10661783 ^c	39 ± 1	2.100 ± 0.028	2.575 ± 0.015	0.1255 ± 0.0039	78 ± 3	82.39 ± 0.23	0.200
HD 172189 ^d	19 ± 1	1.78 ± 0.24	4.03 ± 0.11	0.0283 ± 0.0061	78 ± 3	73.2 ± 0.6	0.281
CID 1008669999 ^e	56 ± 1	1.8 ± 0.2	1.9 ± 0.2	0.262 ± 0.112	...	80 ± 2	...
CID 105906206 ^f	20 ± 2	2.25 ± 0.04	4.24 ± 0.02	0.02986 ± 0.00095	47.8 ± 0.5	81.42 ± 0.13	0.152
HD 159561 ^g (<i>Rasalhague</i>)	38 ± 1	$2.40^{+0.23}_{-0.37}$	$R_{\text{eq}} = 2.858 \pm 0.015$ $R_{\text{pol}} = 2.388 \pm 0.013$	0.123 ± 0.021	239 ± 12	87.5 ± 0.6	0.88

Star	P_{orb} (d) / v_{orb} (d^{-1})	v_{rot} (d^{-1})	$\Delta\nu$ (d^{-1})
KIC 3858884	25.953 / 0.0385327	0.1667	2.5056
KIC 4544587	2.1890951 / 0.457	0.95	6.3936
KIC 10661783	1.2313622 / 0.812	0.605	3.3696
HD 172189	5.70198 / 0.1754	0.4	1.6416
CID 100866999	2.80889 / 0.356	--	4.8384
CID 105906206	3.69457080 / 0.271	0.226	1.728
HD 159561	3148.4 / 0.00032	1.803	3.2832

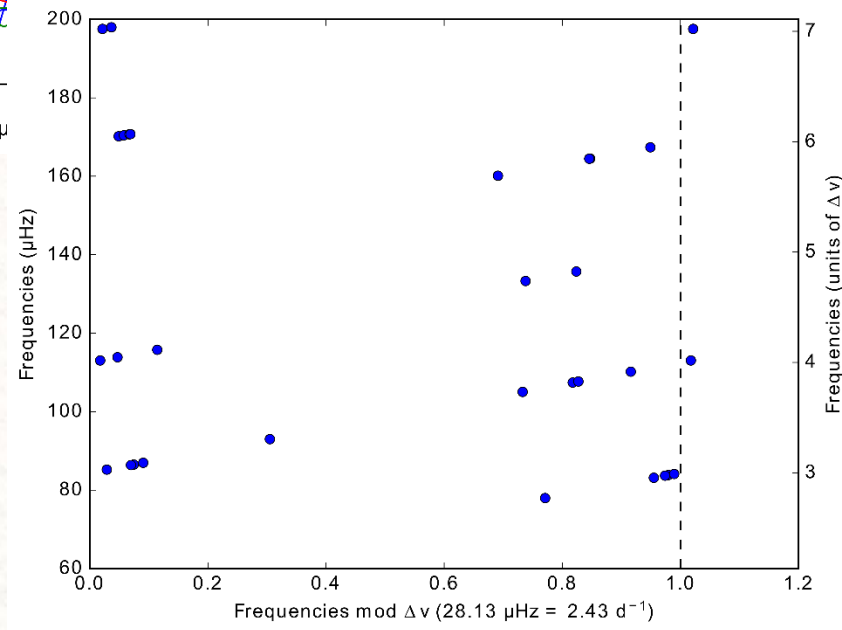
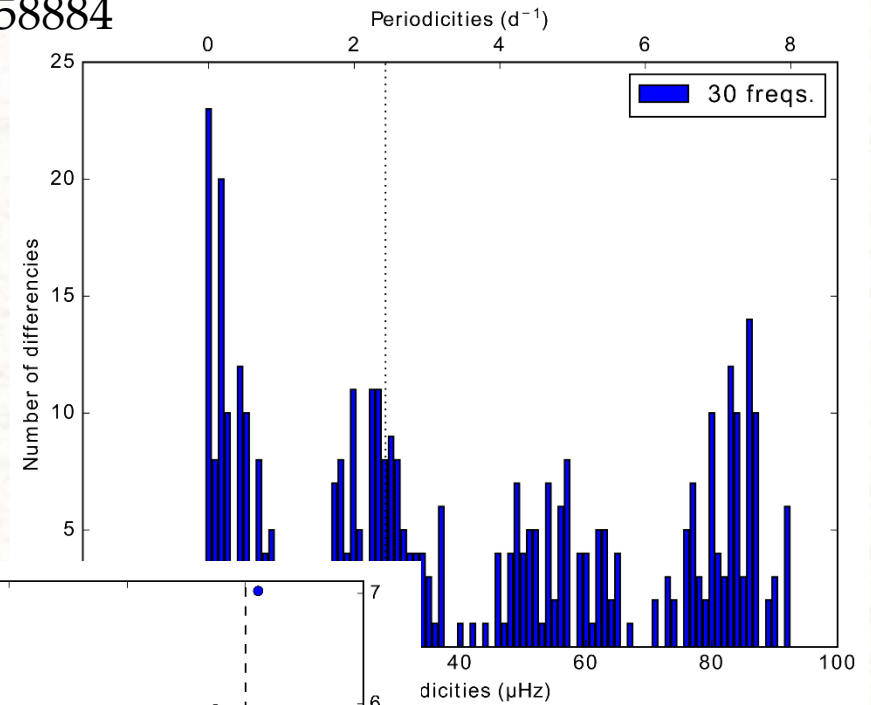
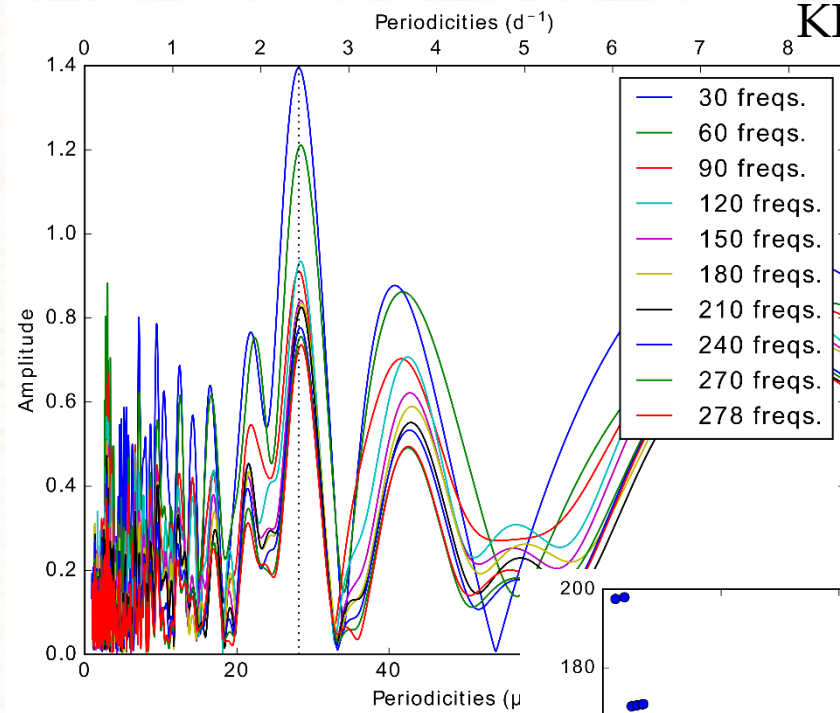
Pattern: methodology

- No harmonics, combinations, rotation period of the system
- No g modes ($> 50 \mu\text{Hz}$ or $> 4.32 \text{ d}^{-1}$)
- Taken different subsets (30, 60 frequencies) of highest amplitude modes
- Fourier transform of the frequencies:
 - All amplitudes = 1
 - High peak and submultiples
 - Search for persistent peaks
- Histogram of frequency differences:
 - High peak and multiples
- Echelle diagrams

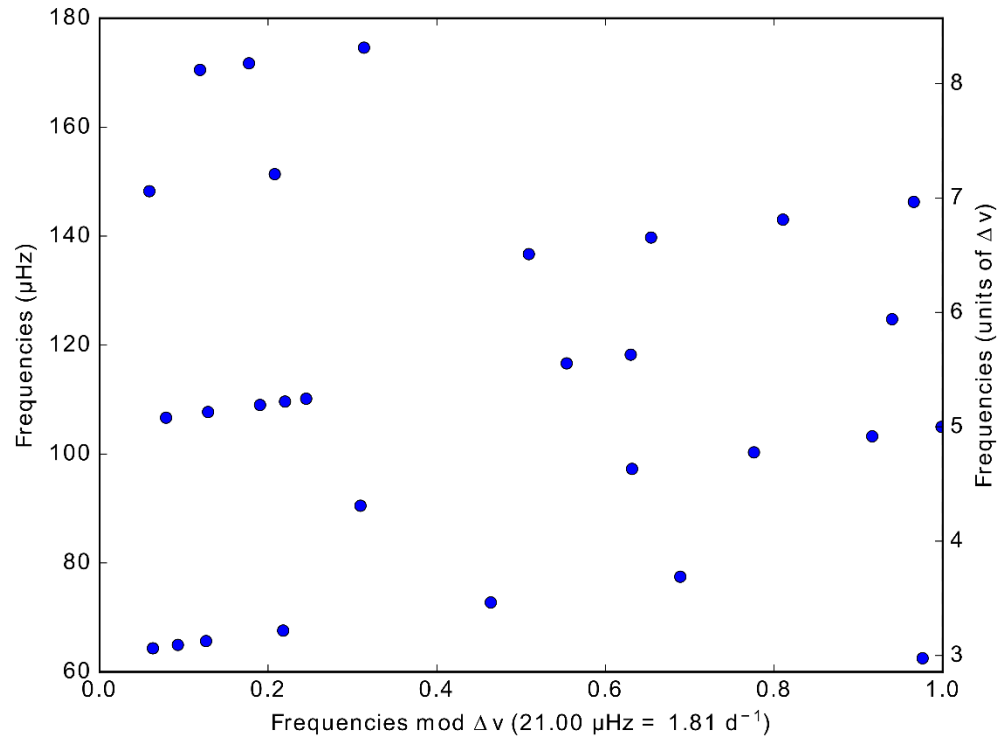
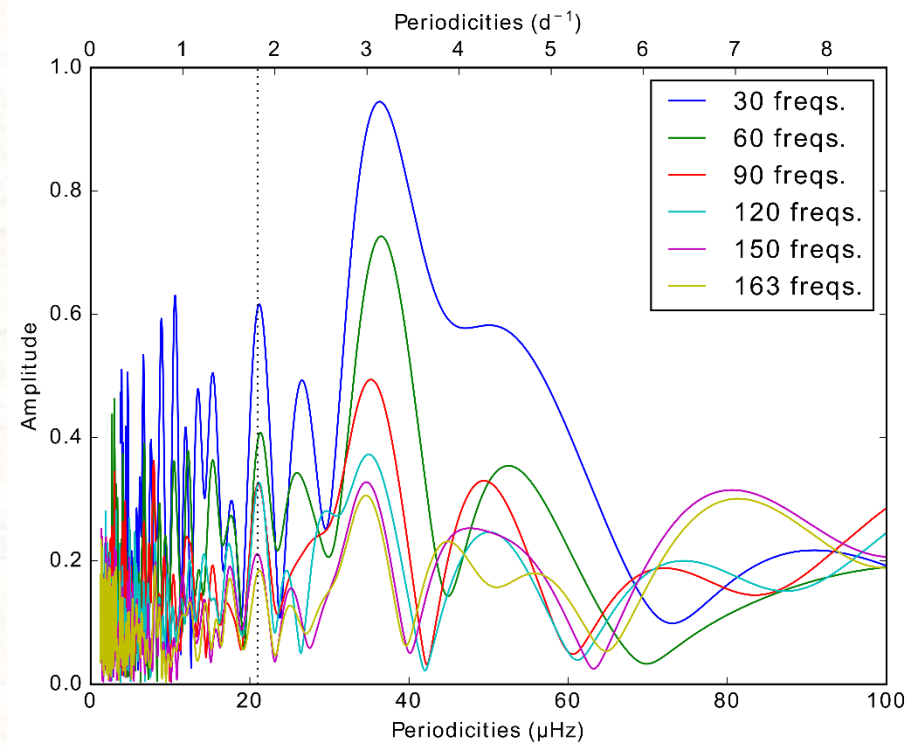
KIC 3858884



KIC 3858884

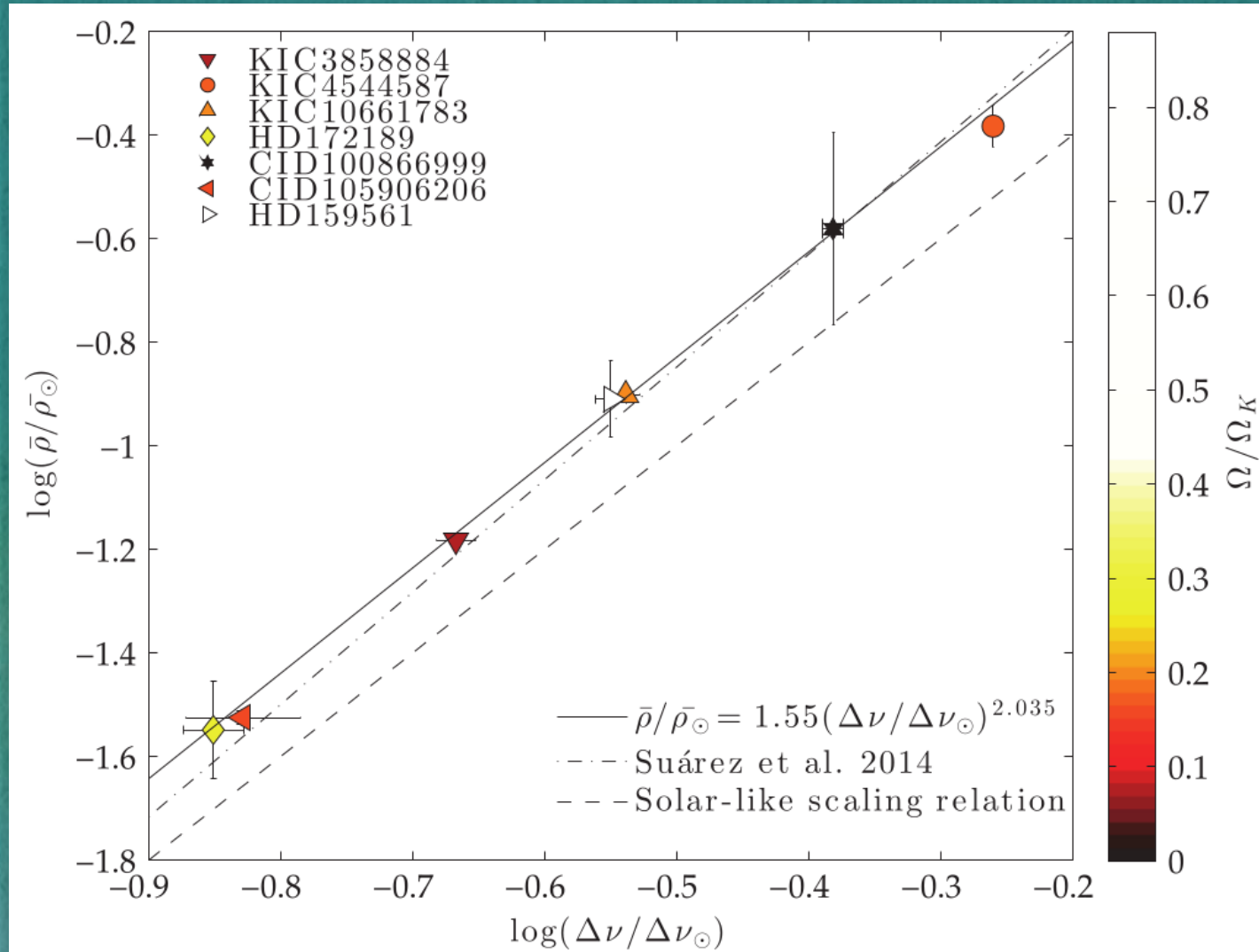


CID105906206



Some considerations

- Periodicity appears as $\Delta v/2$:
 - HD 172189
 - HD 159561 (Rasalhague)
- Periodicity appears as $\Delta v/4 \approx 2v_{\text{rot}}$:
 - KIC 4544587
- Expected from the theory! (Reese 2008, Lignières et al. 2010)



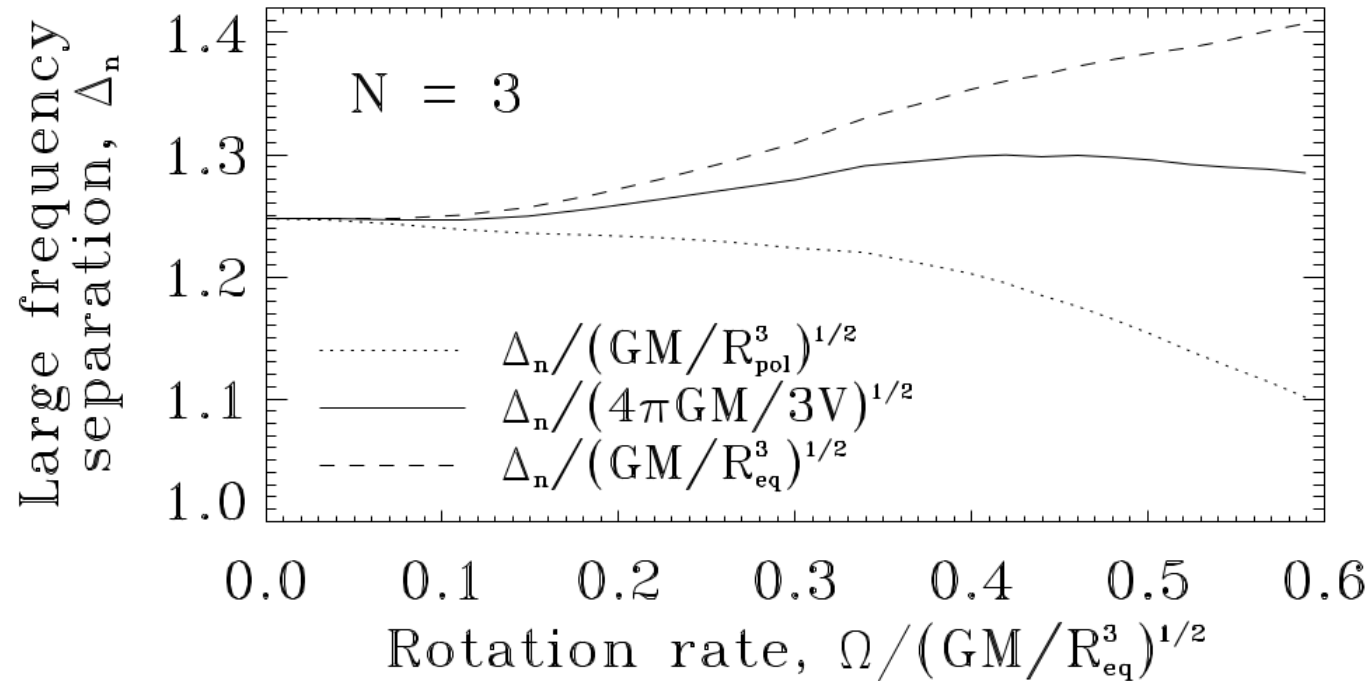
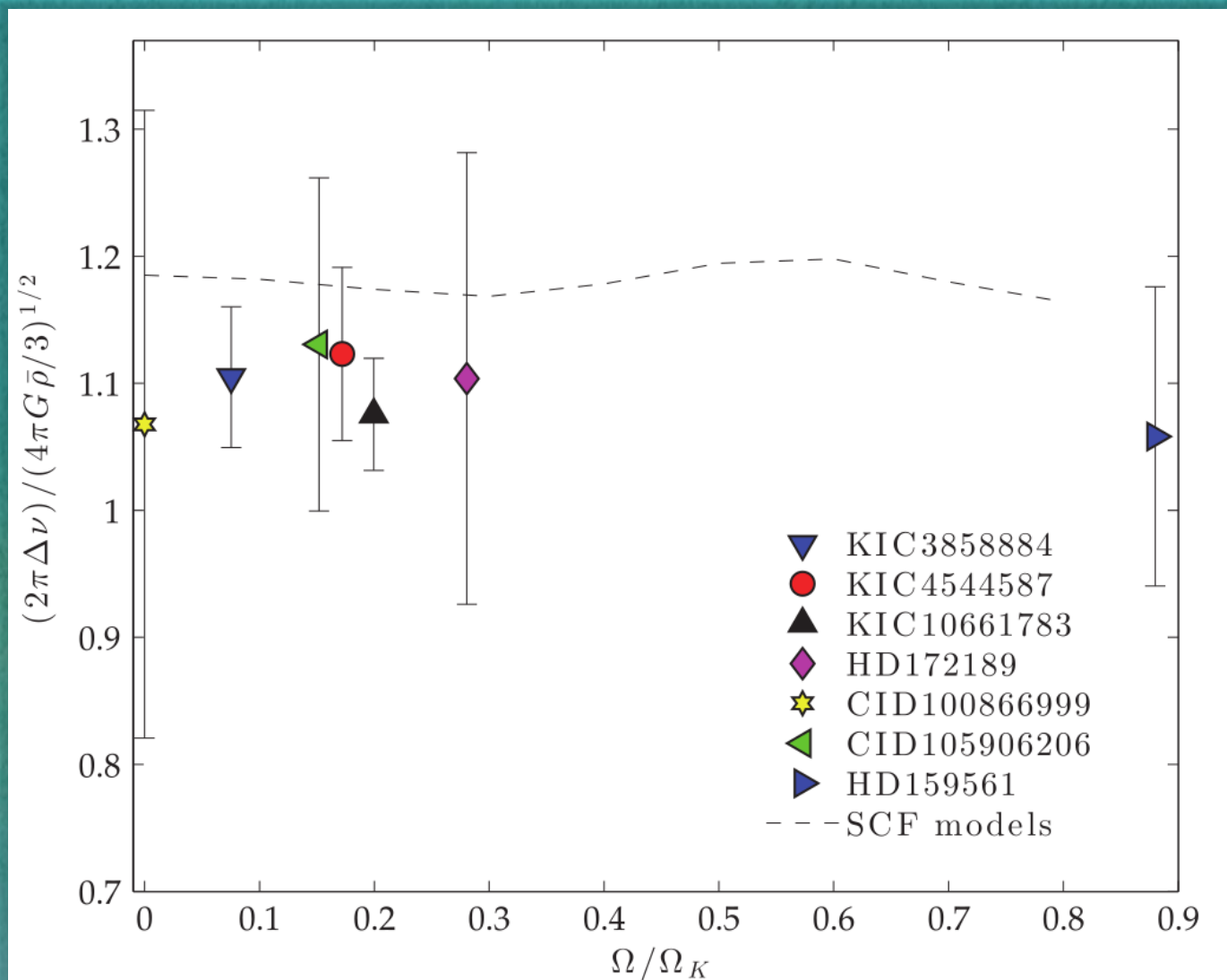


Fig. 2. The large frequency separation Δ_n as a function of the rotation rate Ω . Δ_n has been scaled with different quantities so as to show which other stellar quantity best matches this frequency separation. As can be seen, Δ_n is roughly proportional to the square root of the mean density of the star.

Reese et al. 2008 A&A 481, 449



Δv - ρ relation

- Periodic pattern is not accidental/artifact
- It's a large separation-like structure (i. e., related to stellar ρ)
- It's independent on the rotational velocity...
- ... although there is a “relation” between Δv and v_{rot}
- Indicative of the evolutionary state
- Help in determining rotational splitting? (Paparó et al. 2016)
- Mode identification?
- And...

$\Delta\nu$ - ρ

- Periodic
- It's a large
- It's indep
- Help in c
- Mode id
- And...

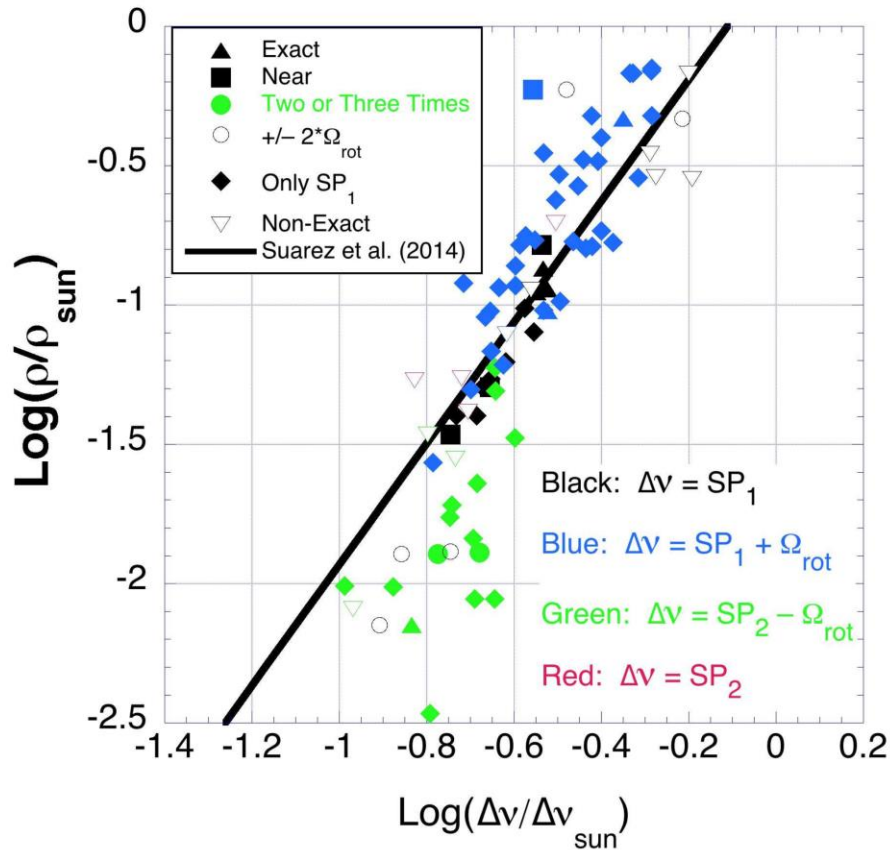


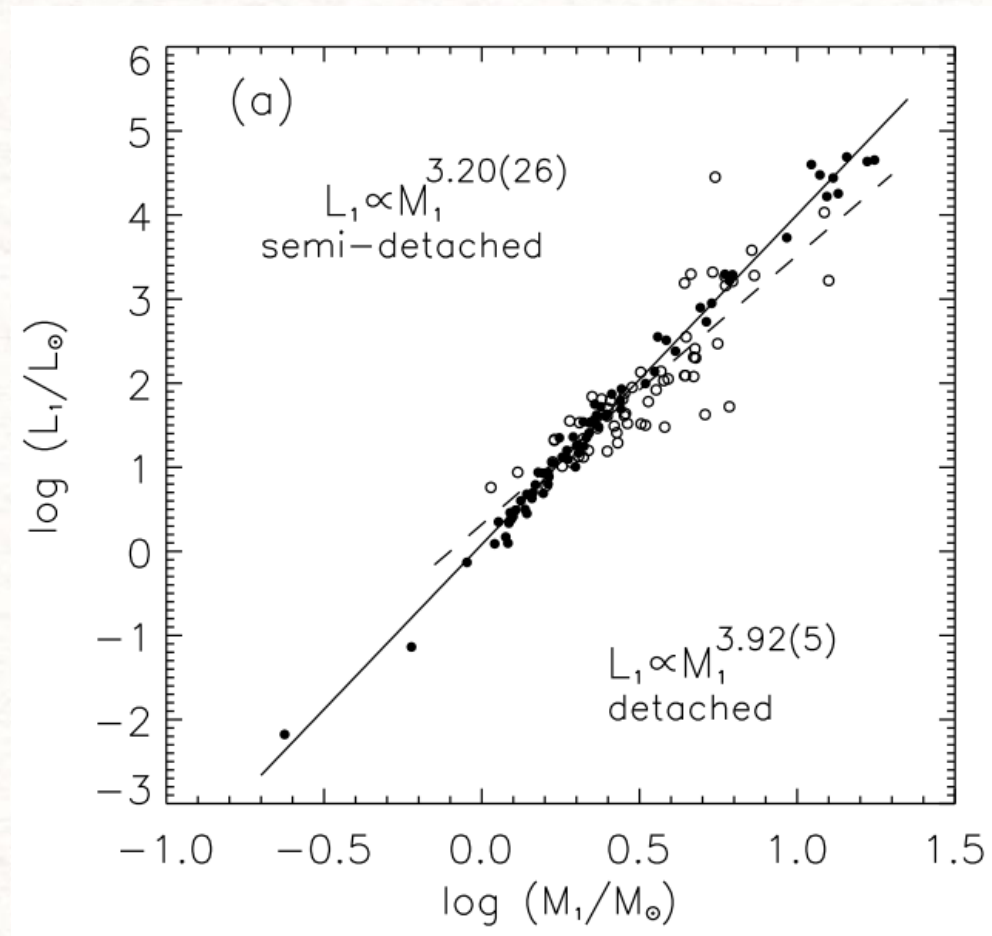
FIG. 16.— Location of the whole sample on the log mean density vs. log large separation diagram, along with the relation based on stellar models from Suárez et al. (2014). The new symbols represent the stars for which there is no agreement between the rotational frequency and the difference of the spacings (inverted triangle) or the stars with only one spacing (diamonds). The color code is the same as in the previous figure, with the addition of the red color corresponding to $\Delta\nu = SP_2$.

6 et al. 2016)

One step further: $\log g$

- Estimating the mass (Gaia)

İbanoğlu et al. 2006



One step further: $\log g$

From true L:

- HD 159561
- CID 105906206
- KIC 10661783

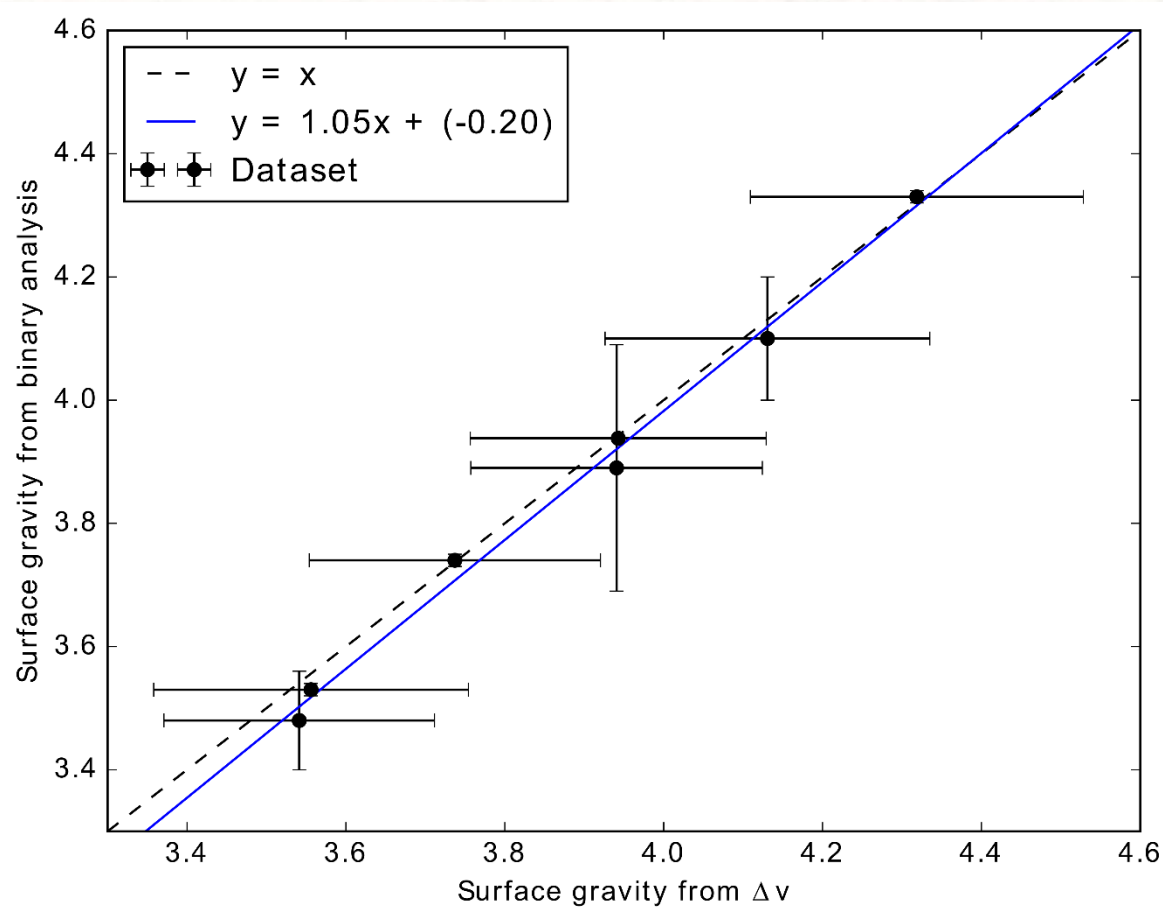
From Mb:

- HD 172189
- CID 100866999
- KIC 4544857

From parallax:

- KIC 3858884

One step further: $\log g$



Conclusions

- Δv as seismic index
- Accurate ρ
- “Accurate” $\log g$
 - *Less uncertainty in Δv - ρ relation*
- Independent of rotation
- Reveal rotational splitting
- First step for mode ID
- δ Sct hosting planets (WASP33)?
- Keep observing EB with a δ Sct!!