PERIODIC PATTERNS: A "NEW" OBSERVABLE FOR δ SCUTI STARS?: HD 174966

A. García Hernández, A. Moya, J. C. Suárez, E. Poretti et al. – Centro de Astrofísica da Univ. do Porto

Outline

- Frequency content of the CoRoT light curve
- Spectroscopic observations
- Periodic patterns: $\Delta\nu$ or Ω?
- $\Delta\nu$ as an observable
- Conclusions

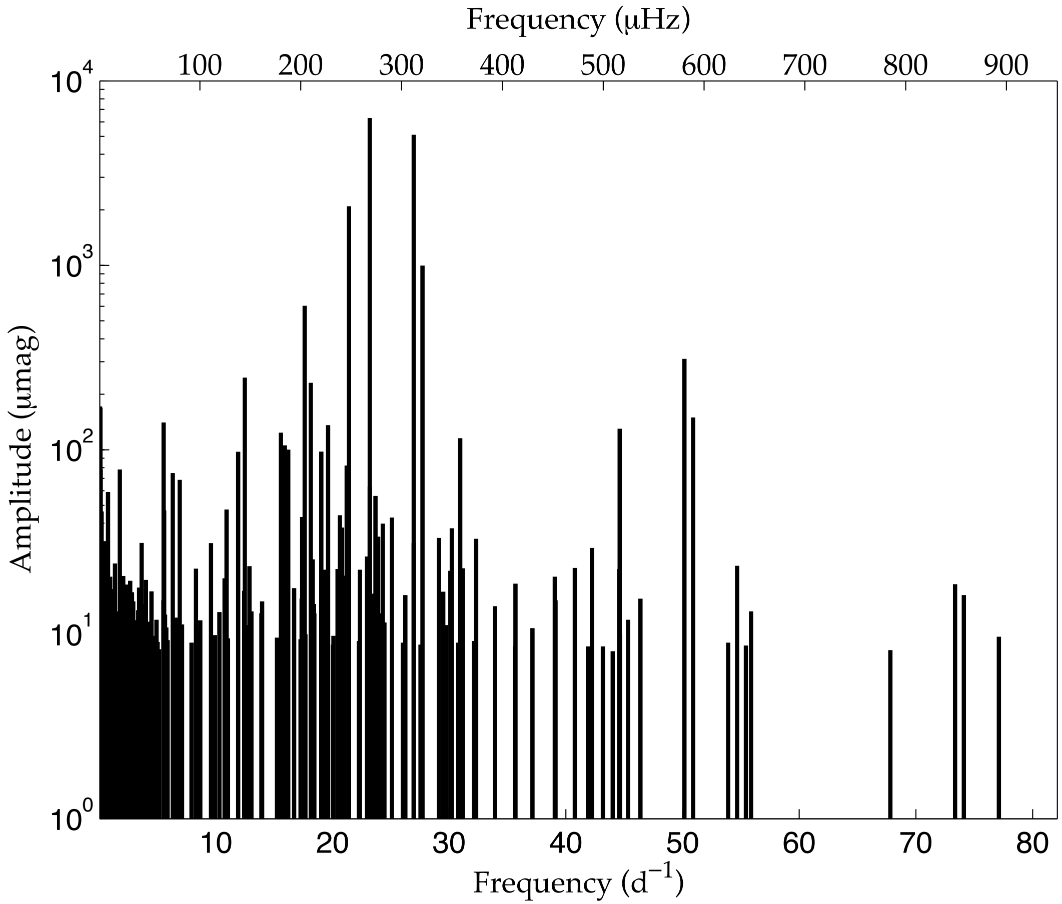
Frequency content

- SRc01 = 27 days
- $1/\Delta T = 0.037\ d^{-1}$
- 185 frequencies
- 37 possible combinations:

$$F_i = F_{a+b}$$

$$(F_{a+b} \equiv Af_a + BF_b)$$

→ Only 12 possible combinations within 1σ



Spectroscopic observations

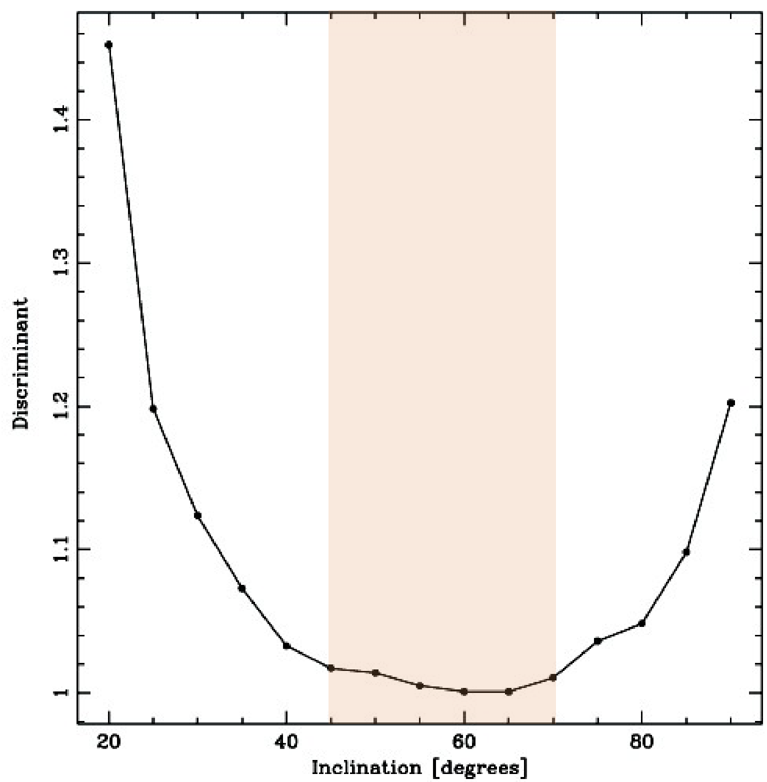
- Not simultaneous with CoRoT
- 53 days with 341 spectrograms:

Spect.	#	R	N° nights	Observatory	Exp. time
HARPS	104	80000	12	ESO-La Silla	1200 s
FOCES	155	65000	21	Calar Alto	900 s
SOPHIE	81	75000	9	Haute Provence	700s

- Physical parameters: LSD method, SME code, FAMIAS code, etc…

Spectroscopic observations

Parameter	Value	Reference
$< V >$	7.698 ± 0.002	GAUDI
$(b-y)_0$	0.142 ± 0.001	GAUDI
E_{b-y}	0.006 ± 0.003	GAUDI
m_0	0.187 ± 0.002	GAUDI
c_0	0.848 ± 0.007	GAUDI
β	2.796 ± 0.001	GAUDI
$\mathrm{v} \cdot \sin i$	126.1 ± 1.2	This work
T_{eff}	7555 ± 50	This work
$\log g$	4.21 ± 0.05	This work
[Fe/H]	-0.08 ± 0.10	This work
M	$1.70 \pm 0.20\ M_\odot$	This work
R	$1.70 \pm 0.20\ R_\odot$	This work
L(R,T)	$8.5 \pm 2.0\ L_\odot$	This work



i = 62.5° (45°-70°)

➔ $v = 142\ \mathrm{km \cdot s^{-1}}$ ($178-134\ \mathrm{km \cdot s^{-1}}$)

$\Omega/\Omega_C = [0.21, 0.34]$ $\Omega_C = (G \cdot M/R^3)^{1/2}$

Periodic patterns

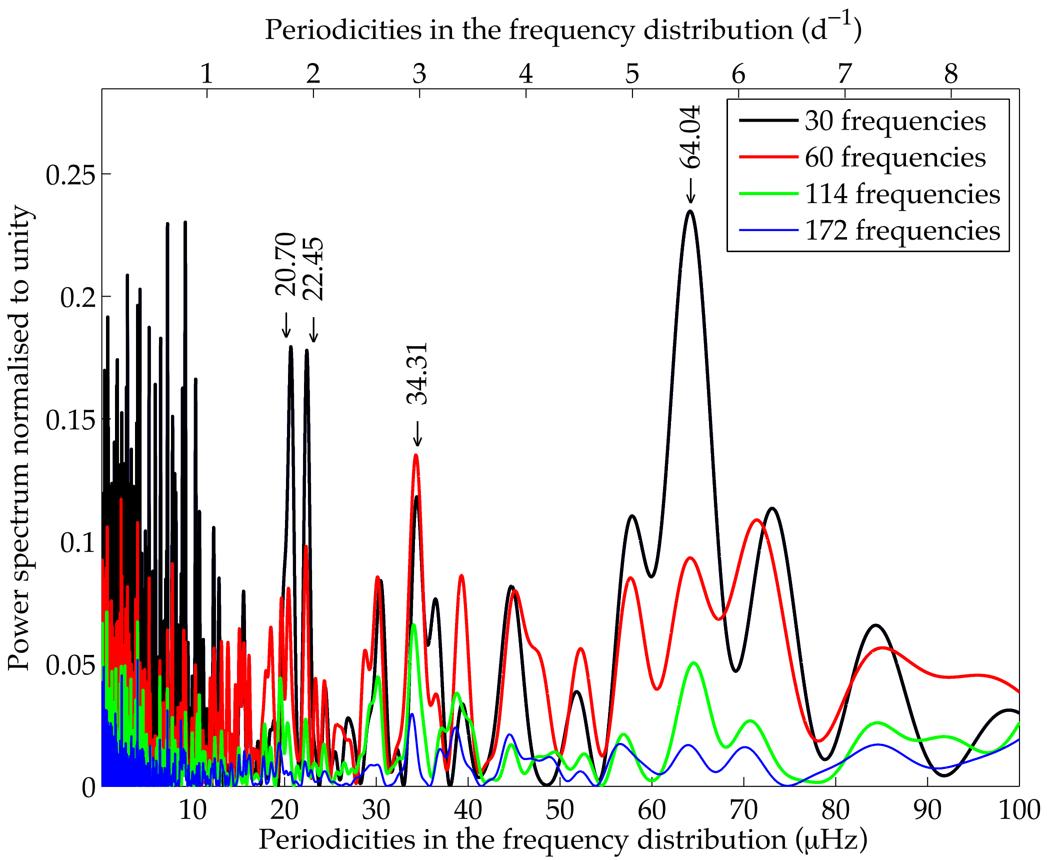
- Theory: $$\mathrm{F}(\nu) = \Delta_T(\nu) \cdot \sqcap(\nu).$$

$$\mathcal{F}(t) = \int_{\infty}^{\infty} \Delta_T(\nu) \cdot \sqcap(\nu) \cdot \mathrm{e}^{-2\pi \mathrm{i} \nu t} \mathrm{d}\nu = \Delta_{1/T} * \mathrm{sinc}(t).$$

- Method:
  - Visibility of the modes decrease with L (spherical degree)
  - Subsets of the highest frequencies
  - Identify periodicity and multiples

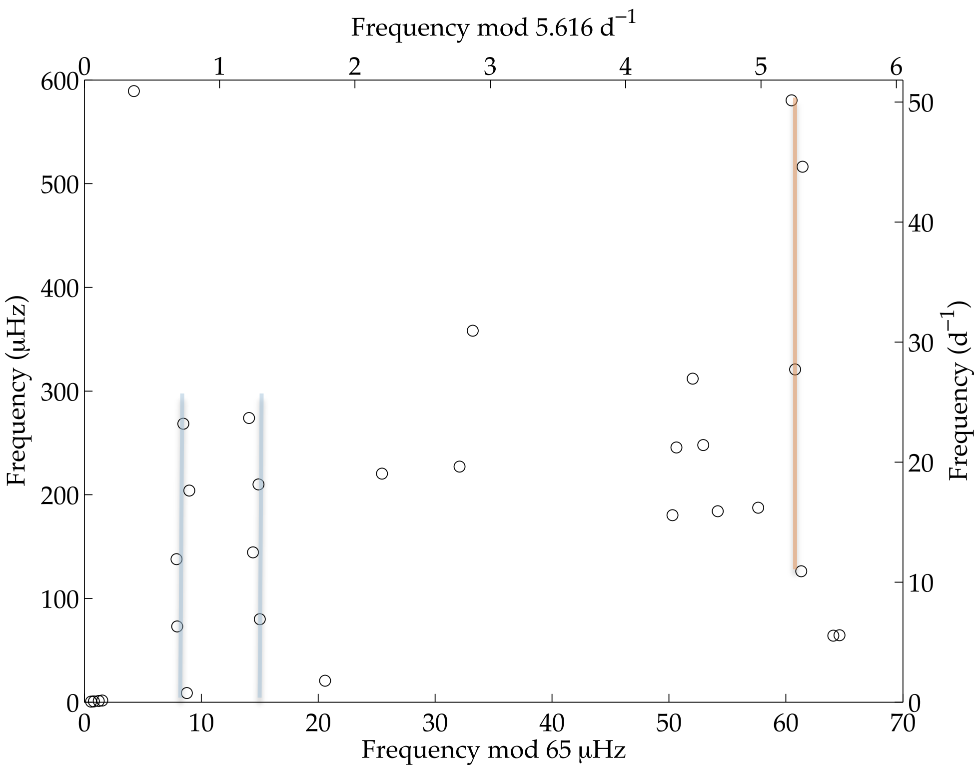
Periodic patterns

- Inexact pattern:
  - missing frequencies
  - peaks not in the pattern
- FT with:
  - spurious peaks
  - less powerful submultiples
  - broadened peaks
- Inverse scale
- Periodicity = 64 μHz
- Submultiples



Periodic patterns: $\Delta\nu$ or Ω?

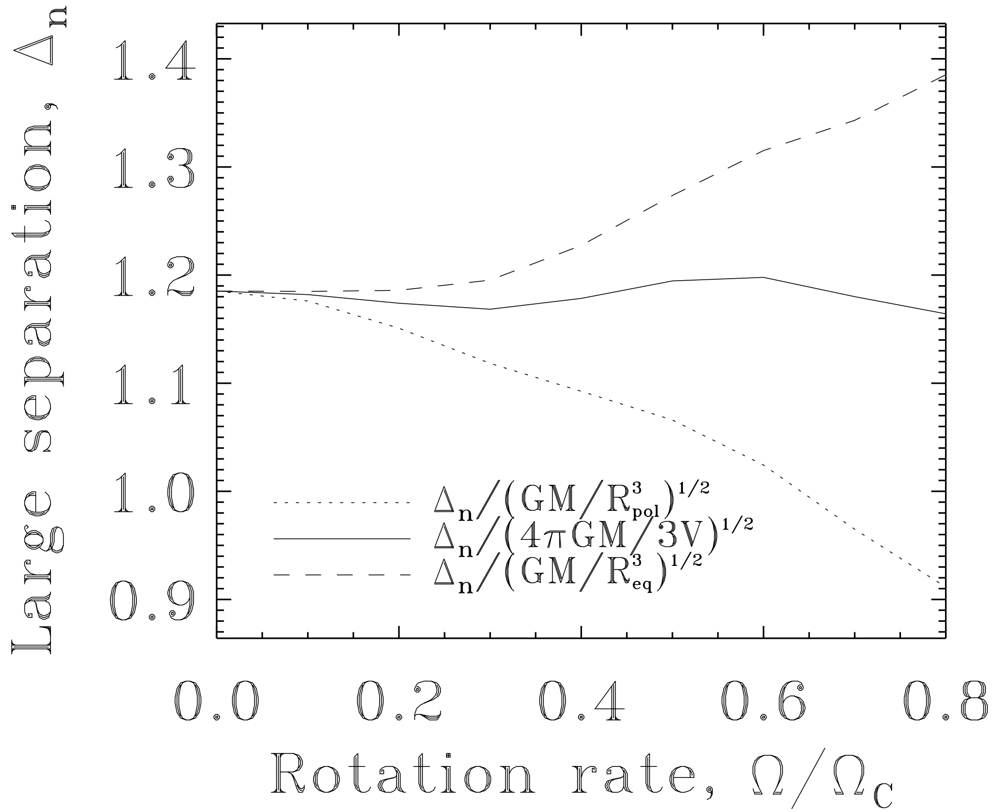
- $\Delta\nu$:
  - Even at high rotations (Lignières et al. 2006)
  - Pattern (Dirac comb)
  - More sensible for FT
- Ω:
  - Multiplets non-regulars (Soufi et al. 1995, Suárez et al. 2006)
  - Frequency spacing (Lignières et al. 2010)
  - Máx. splitting= 29 μHz



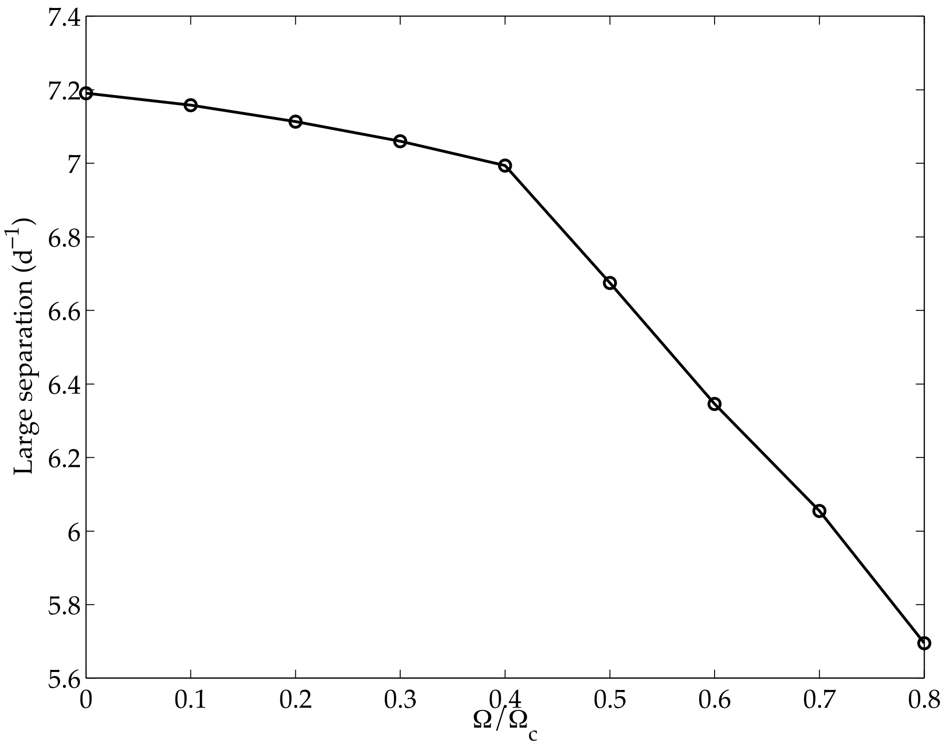
Echelle diagram
for the 30 highest amplitude frequencies

Δ ν as an observable

- Reese et al. 2013, private communication
- 2 $M_\odot$ SCF models:
  - OPAL opacities
  - EOS: Eggleton et al. (1973)
  - Nuclear rates: Caughlin & Fowler (1988)
  - α_{MLT} = 1.9
  - Chemically homogeneous
  - Uniform rotation
- n = 5-10
- $\Delta\nu$ simple function of ρ



$\Delta \nu$ as an observable



- Δν decreases with Ω
- But only <u>0.2 d^{-1}</u> (2.3 μHz) in the range [0, 0.4] Ω/Ω_c

➡ We can use non-rotating models to derive ρ
  - Not R, L, logg…
  - M?

$\Delta\nu$ as an observable

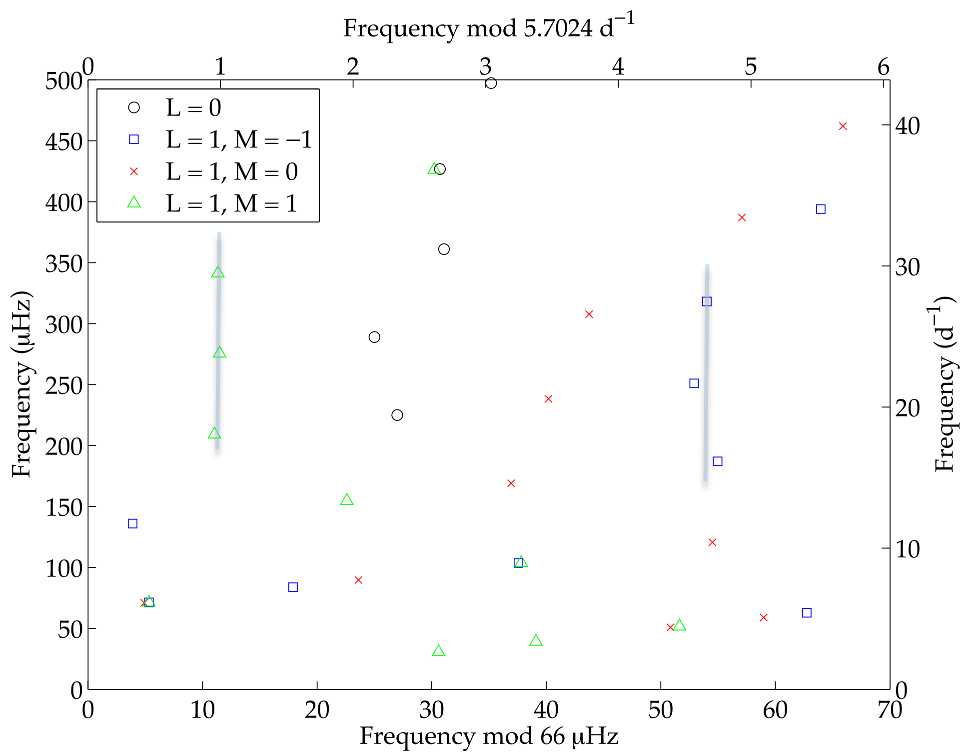
- Model discrimination: $\Delta\nu = 65 \pm 2.5$ μHz

- Model database:
  - Non-rotating
  - CESAM eq. models
  - Non-adiabatic freqs. (GRACO)
  - M=[1.25, 2.20] Msol
  - [Fe/H]=[-0.52, 0.08] dex
  - α_{MLT}=[0.5, 1.5] dex
  - d_{ov}=[0.1, 0.3] dex
  - L = [0, 3]

Method	Spectroscopic box	Using $\Delta\nu$
$T_{\rm eff}$ (K)	[7505, 7605]	[7505, 7605]
$\log g$	[4.16, 4.26]	[4.19, 4.25]
[Fe/H]	[-0.18, +0.02]	[-0.18, +0.02]
α_{ML}	[0.5, 1.0]	[0.5, 1.0]
d_{ov}	[0.1, 0.3]	[0.1, 0.3]
M ($M_\odot$)	[1.49, 1.58]	[1.49, 1.55]
R ($R_\odot$)	[1.50, 1.73]	[1.53, 1.65]
L ($L_\odot$)	[6.47, 8.92]	[6.73, 8.01]
ρ (g cm^{-3})	[0.43, 0.62]	[0.49, 0.59]
Age (My.)	[826, 1306]	[906, 1206]
X_c	[0.4105, 0.5676]	[0.4534, 0.5478]

Δ ν as an observable

- Mode identification?
  - Rotating models (2nd order perturbative approx., FILOU):
    - Different range
    - Not full rotation
    - "Casual" patterns
    - Only island modes
- Amplitude ratios (Reese et al. 2013A&A...550A..77R)
- Paparó (following talk)



Conclusions

- $\Delta\nu$ with high precision for δ Sct stars (high rotation)
- Non-rotating models ➔ information about the star
- ρ determination with ~9% uncertainty
- No assumption about Ω of the star (up to $\sim 0.4\Omega_C$)
- Definitely, a complementary observable
- Up to now, non-reliable mode identification