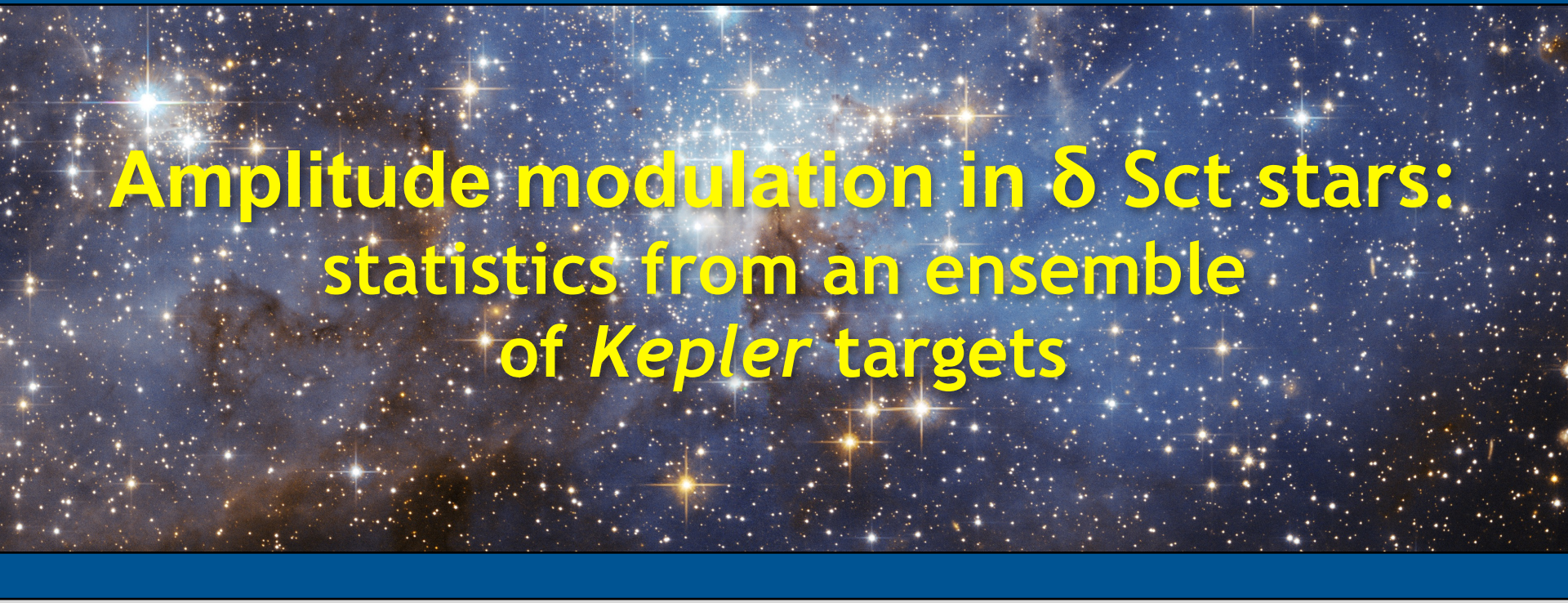

Amplitude modulation in δ Sct stars: statistics from an ensemble of *Kepler* targets

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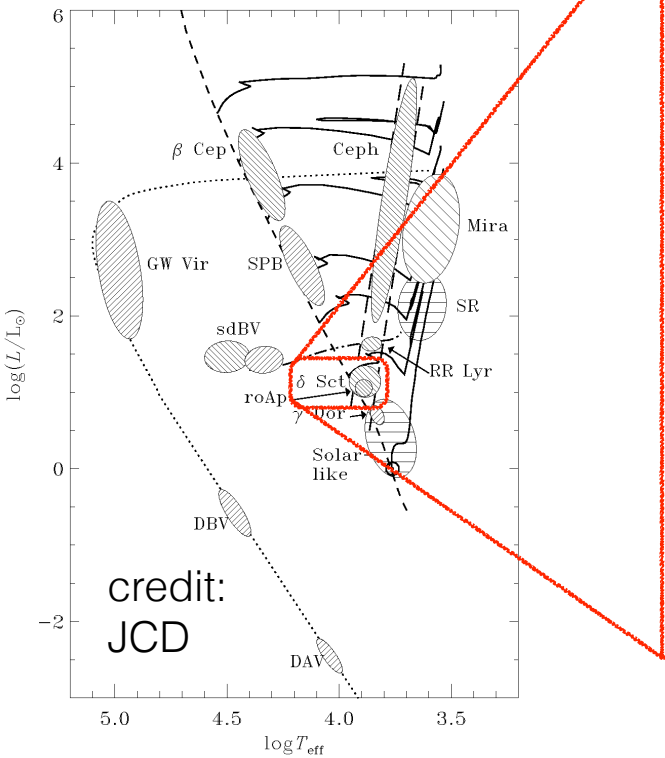
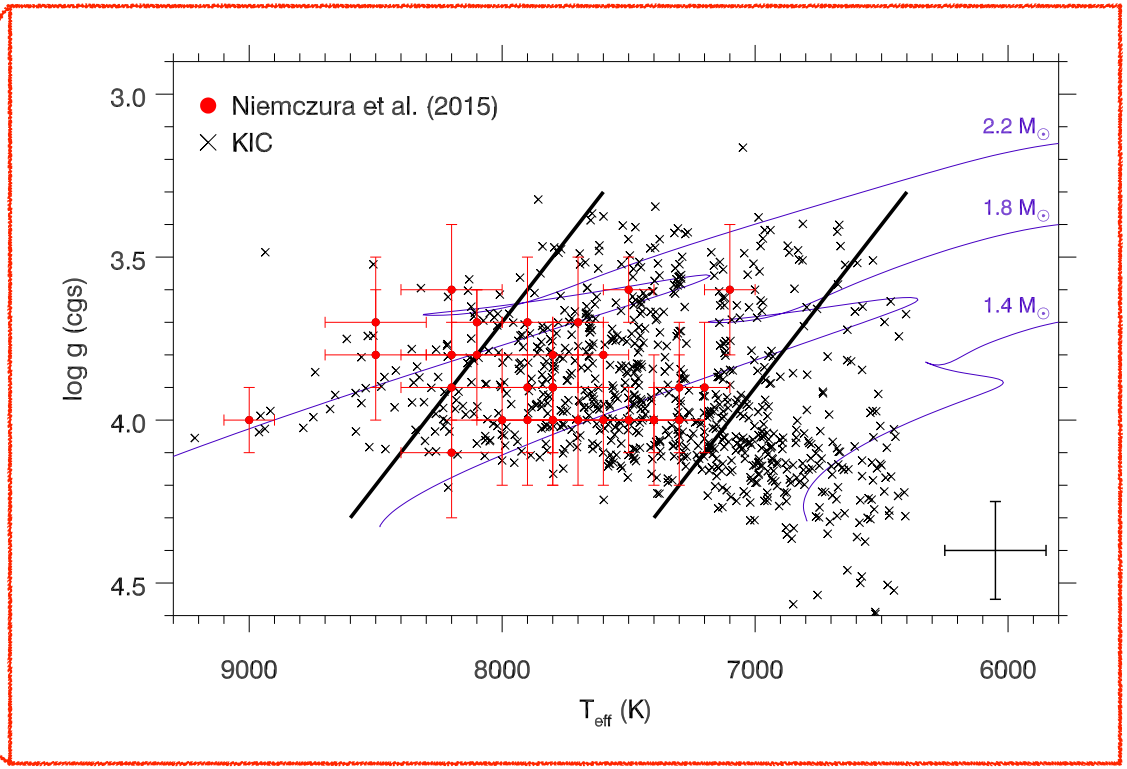
The δ Sct stars

δ Sct stars lie in the classical instability strip: $6400 \leq T_{\rm eff} \leq 8900$ K.

983 **δ** Sct stars continuously observed by *Kepler* for 4 yr.

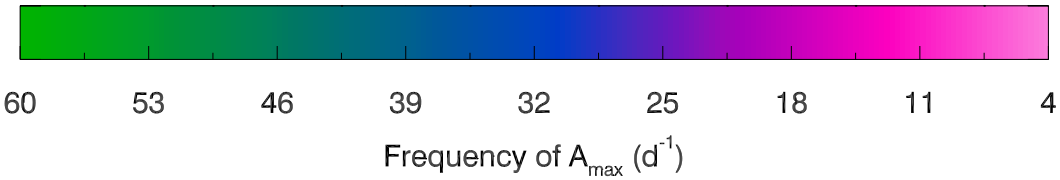


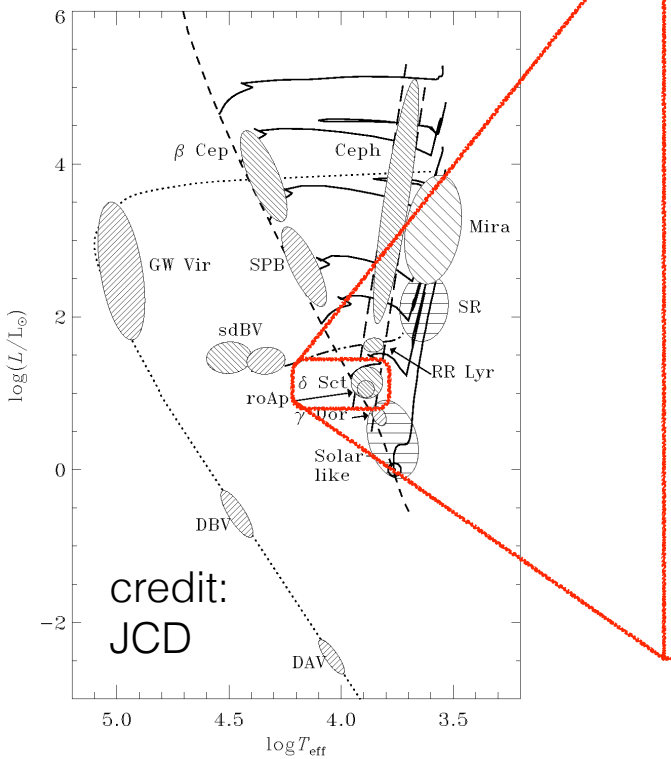


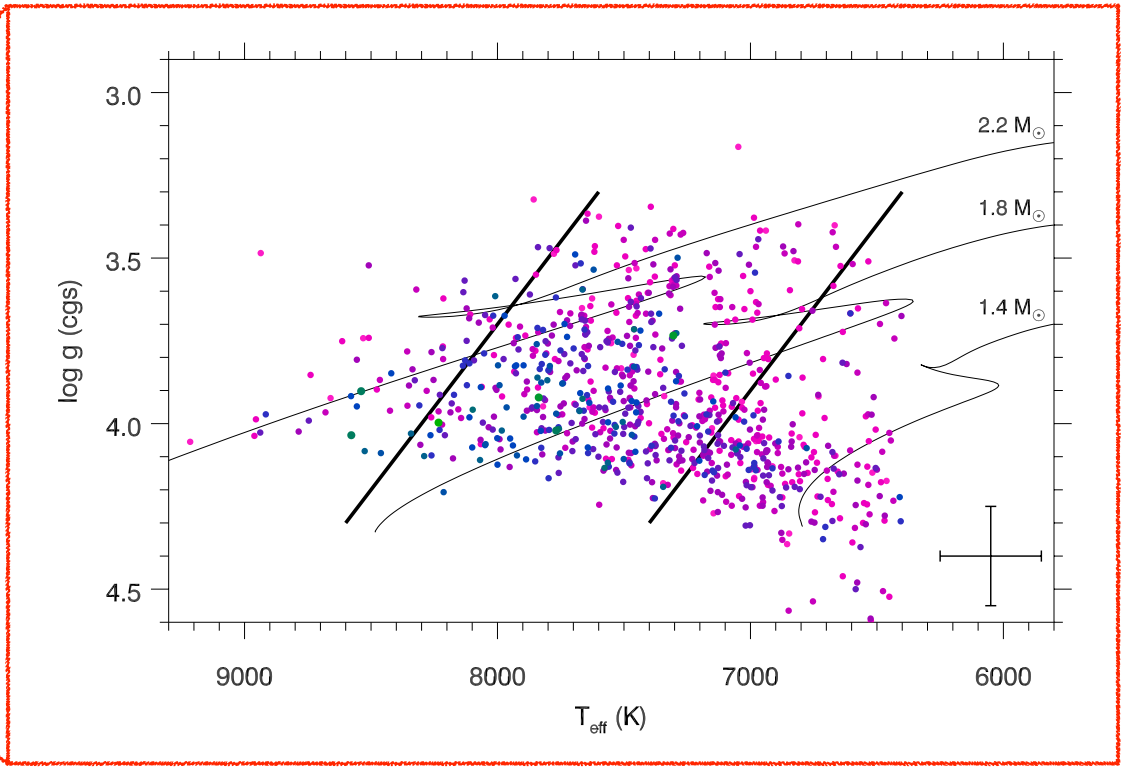
(Bowman 2016)

The δ Sct stars

High-frequency signals in LC *Kepler* data are suppressed in amplitude.



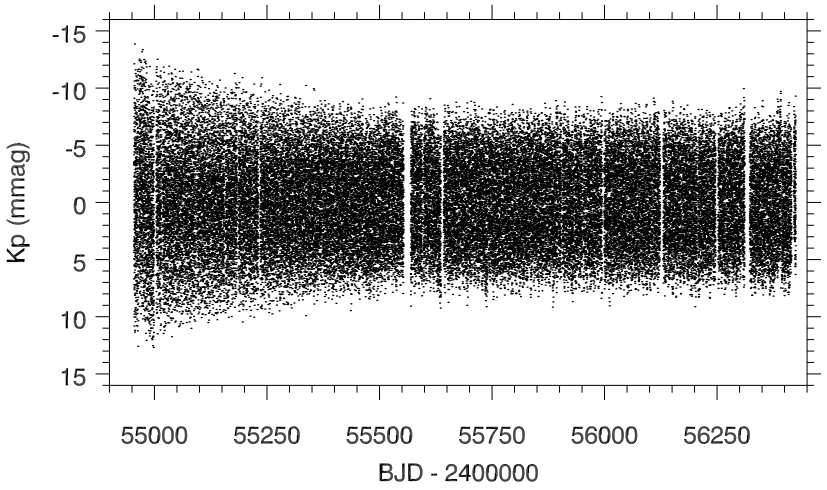




(Bowman 2016)

What is amplitude modulation?

e.g., KIC 7106205



4-yr time span

(Bowman & Kurtz 2014)

What is amplitude modulation?

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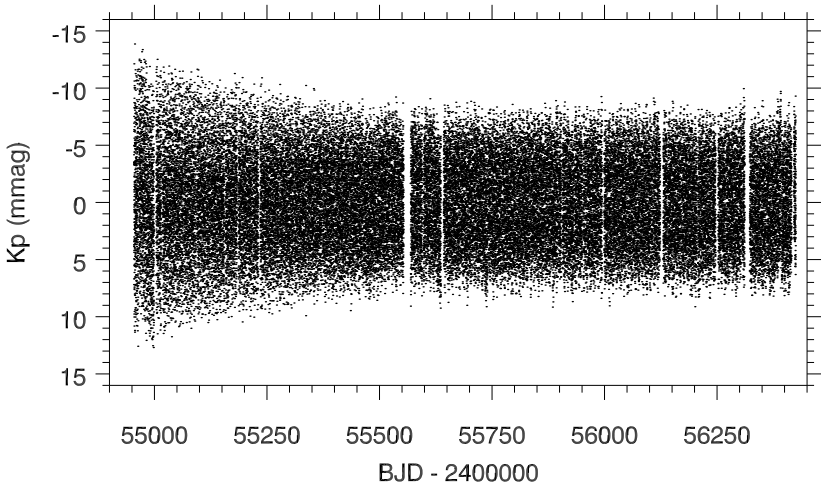
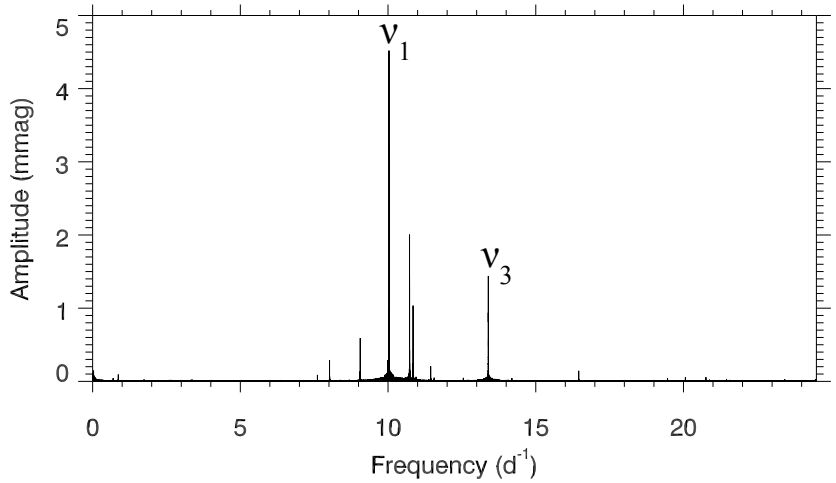


4-yr time span

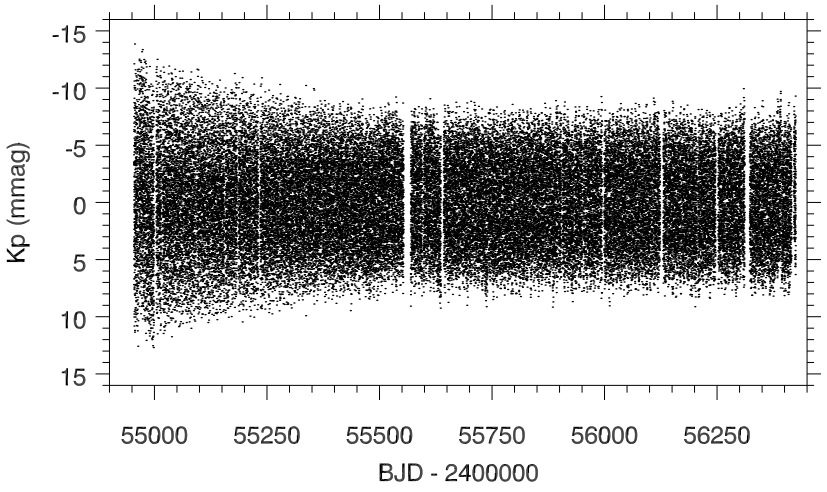


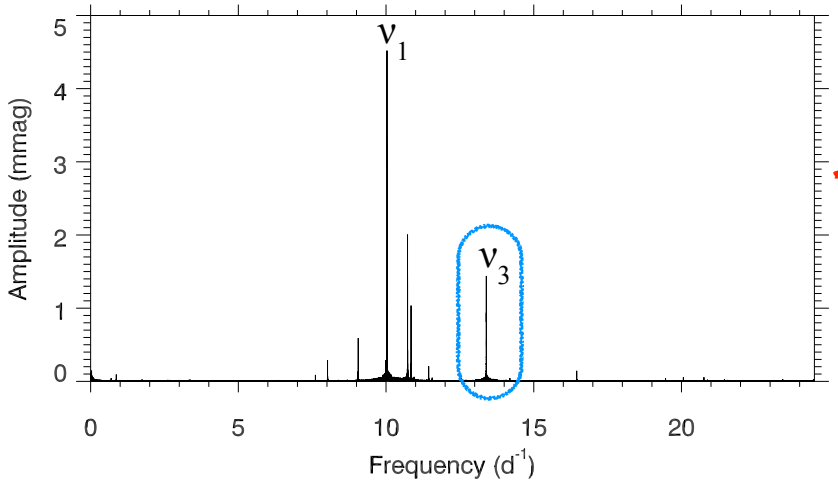
high frequency resolution

(Bowman & Kurtz 2014)

What is amplitude modulation?

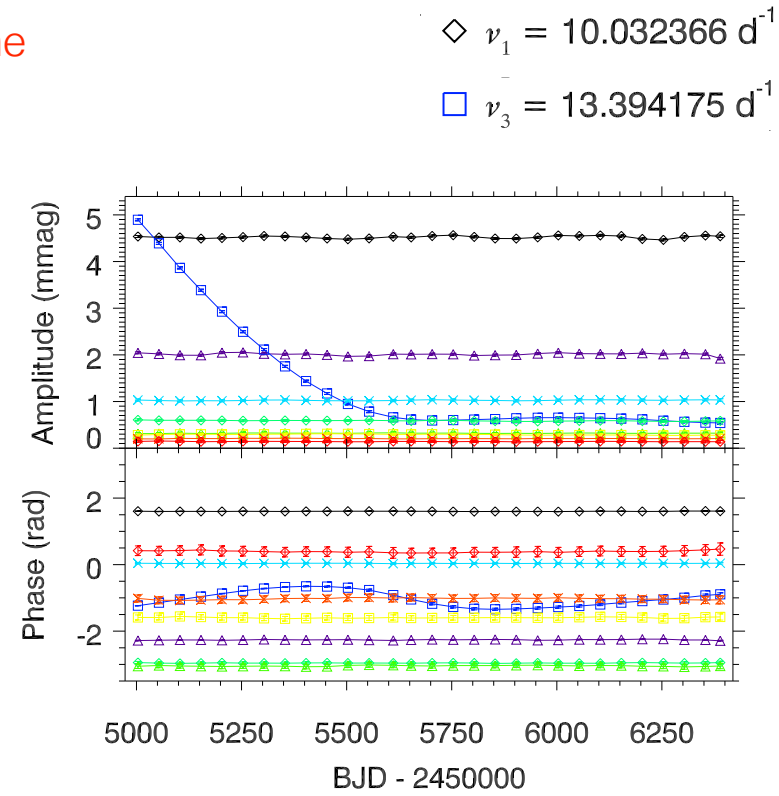
e.g., KIC 7106205





4-yr time span

high frequency resolution

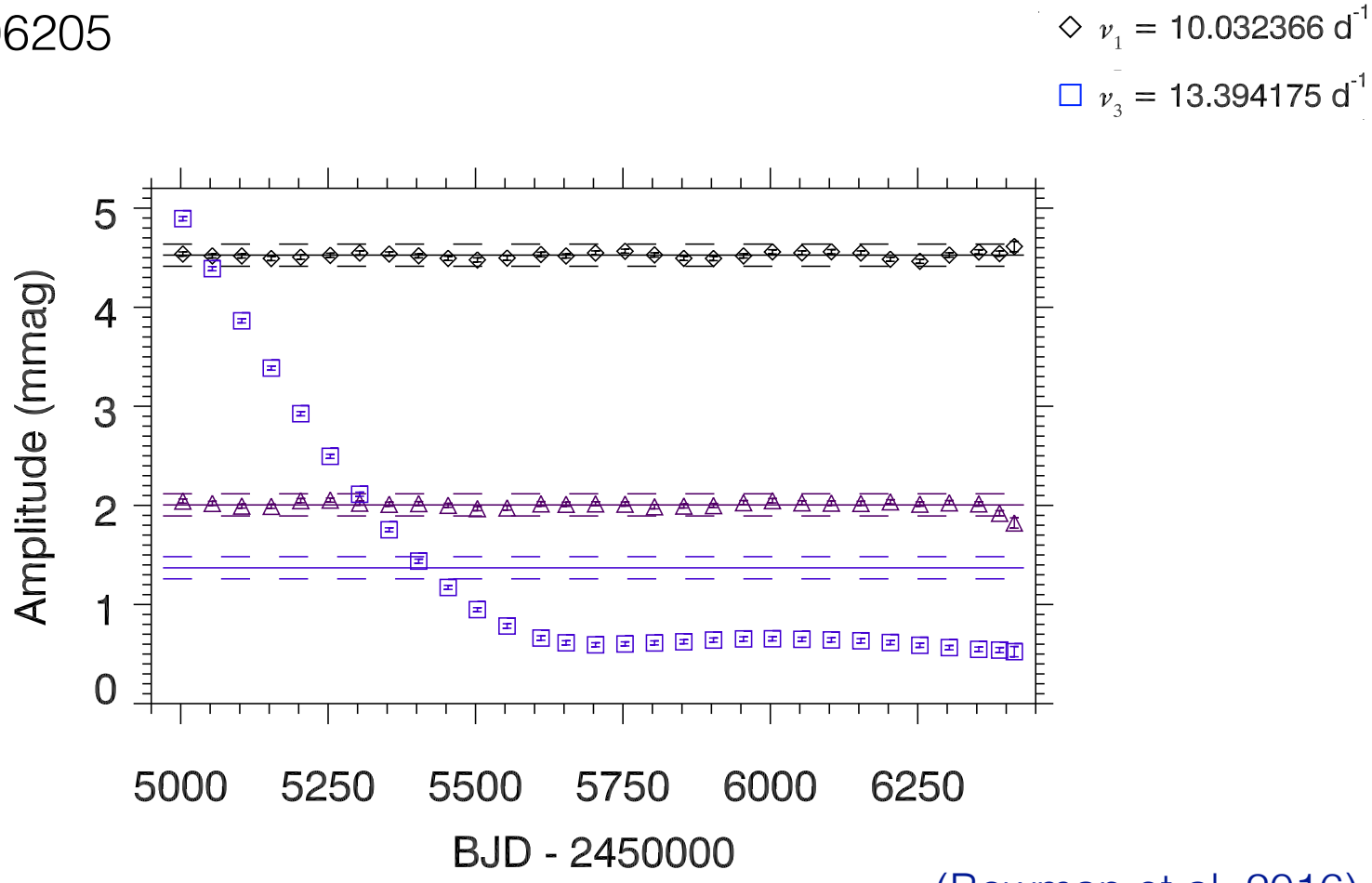


(Bowman & Kurtz 2014)

Defining significant amplitude modulation

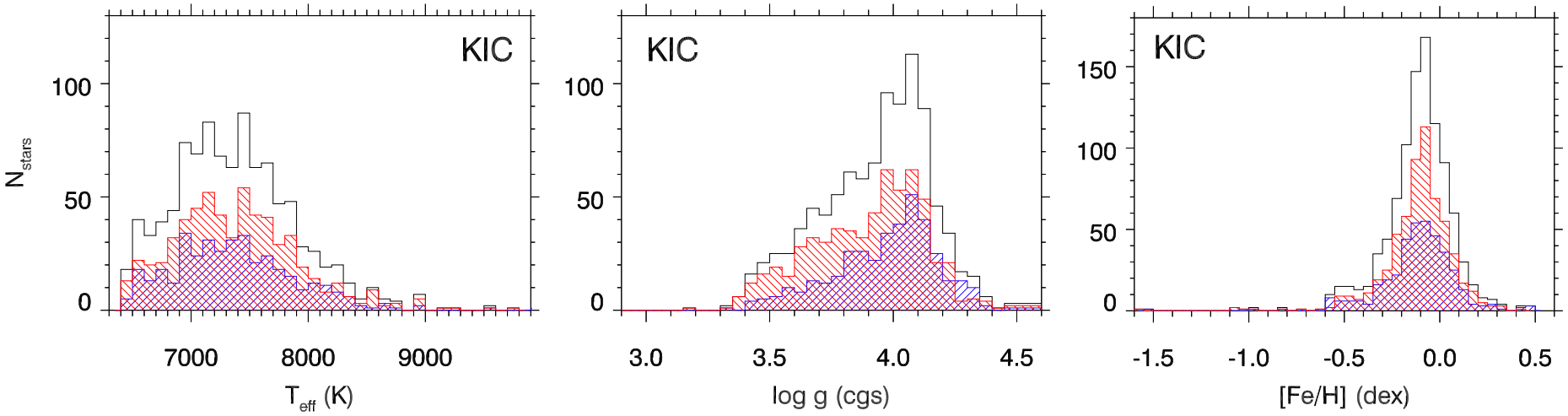
Each δ Sct is defined as being an **AMod** or a **NoMod** star.

e.g., KIC 7106205

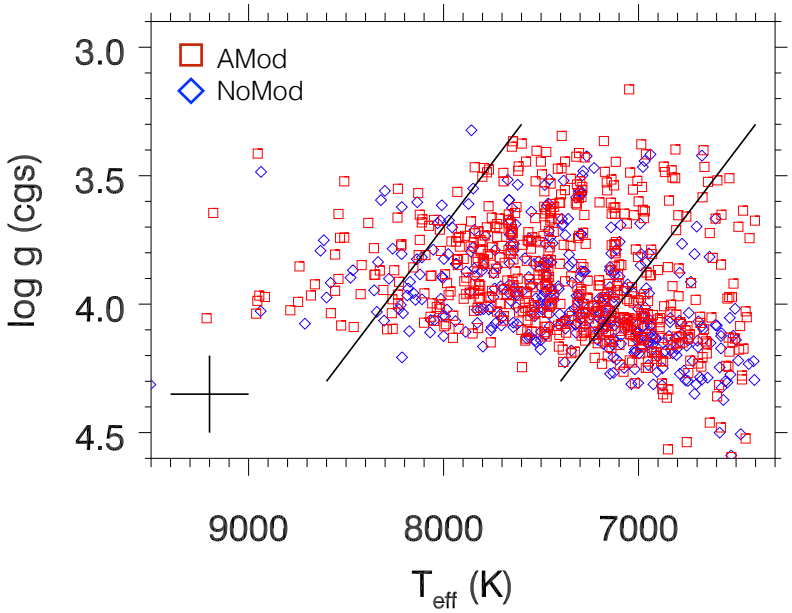


(Bowman et al. 2016)

AMod: KIC parameter statistics



61.3 per cent of 983 δ Sct stars are **AMod** stars, with significant amplitude modulation in at least a single pulsation mode.



(Bowman et al. 2016)

Constant amplitude stars

e.g., KIC 2304168
(Balona & Dziembowski 2011)

Period ratio of ν_1 and ν_2 is 0.7725, associated with fundamental and first overtone radial modes

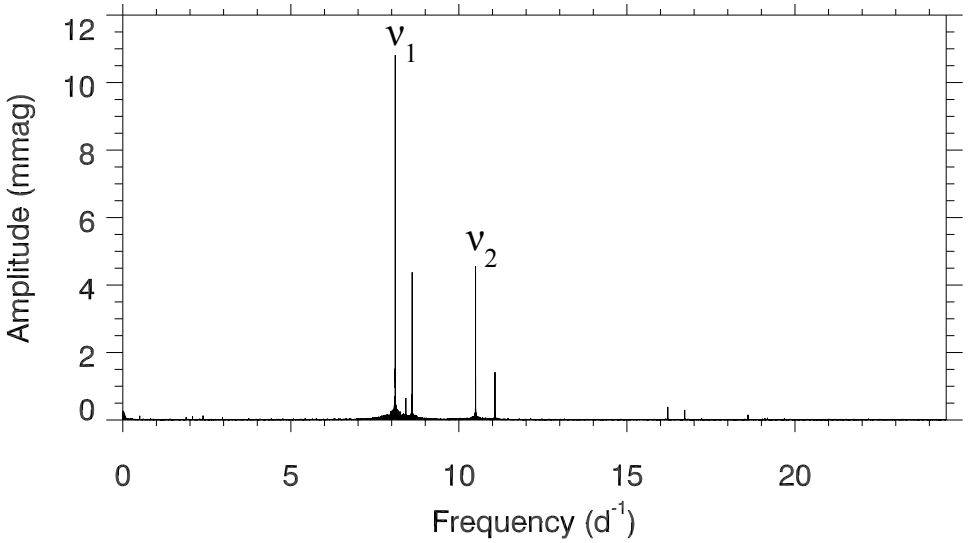
T_{eff} = 7220 ± 270 K

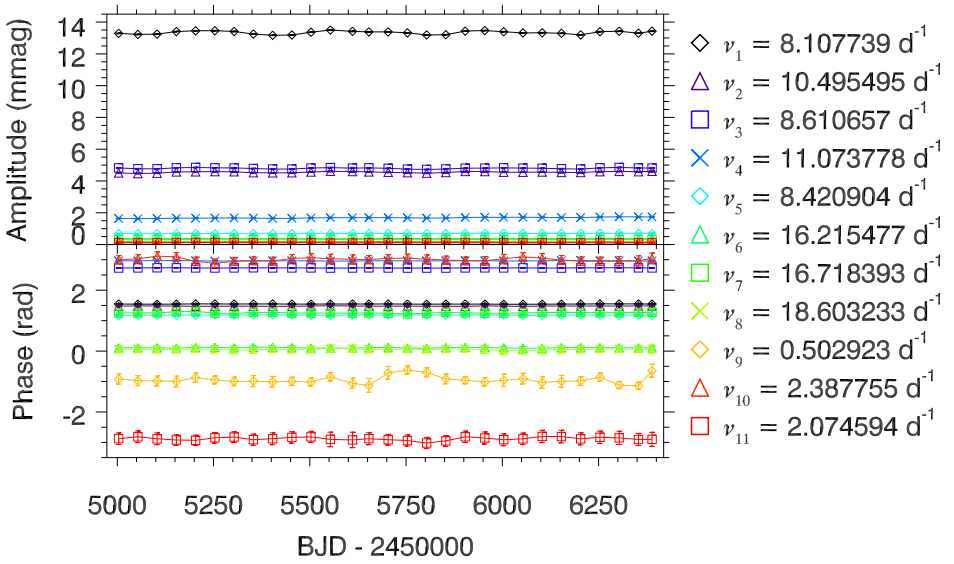
log g = 3.67 ± 0.19

(Huber et al. 2014)

NoMod star

(Bowman et al. 2016)





Variable amplitudes

e.g., KIC 4733344

Period ratio of ν_2 and ν_3 is 0.7678, associated with fundamental and first overtone radial modes.

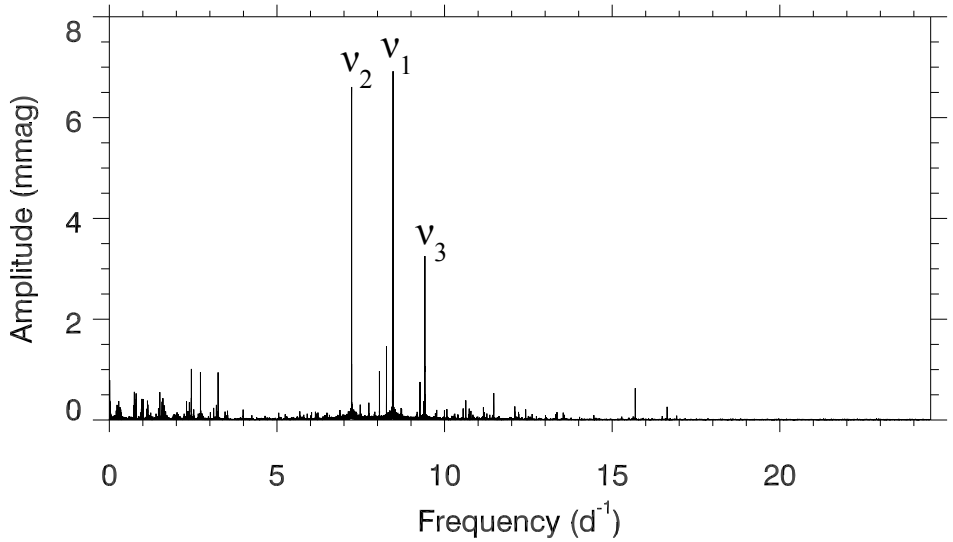
T_{eff} = 7210 ± 260 K

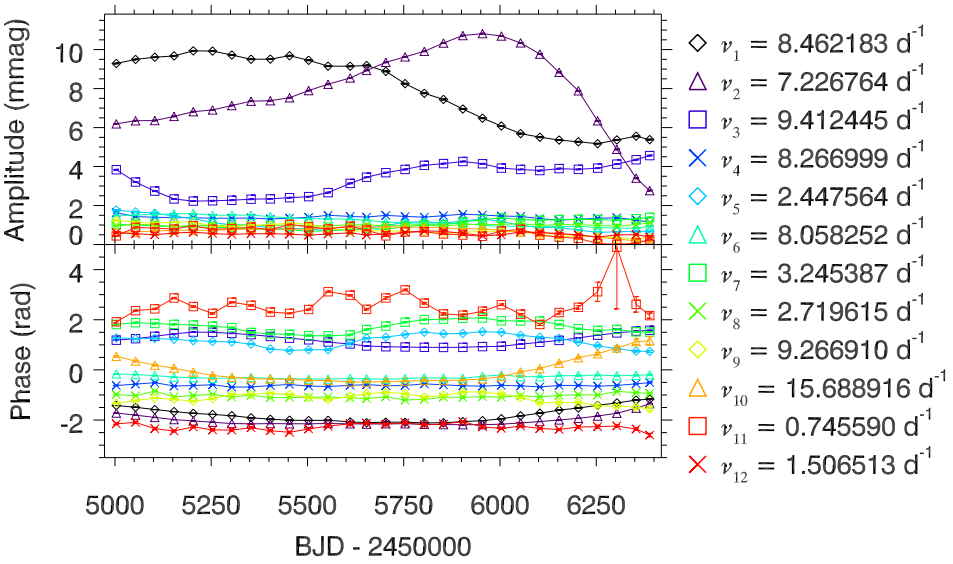
log g = 3.50 ± 0.23

(Huber et al. 2014)

AMod star

(Bowman et al. 2016)





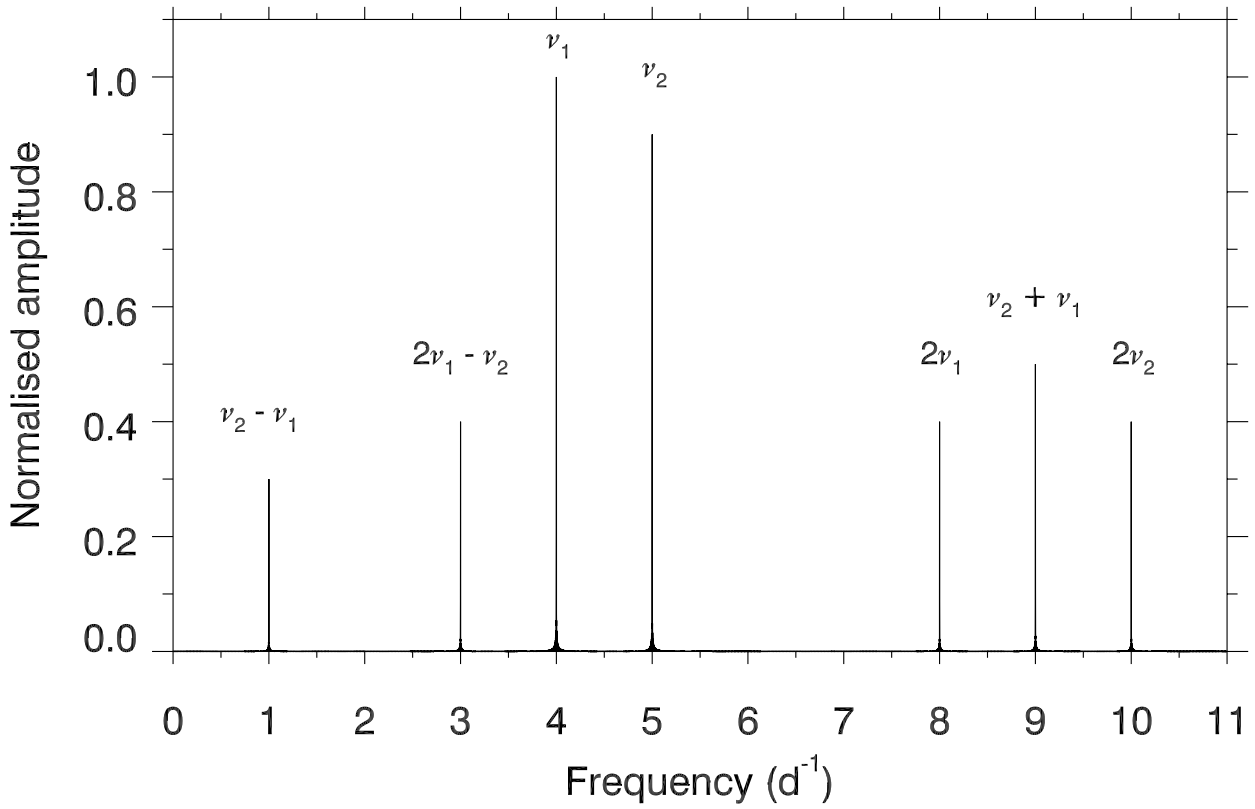
Non-linearity: combination frequencies

Non-linear distortion model:
Higher amplitude pulsation modes have "higher order" combinations:
(Kurtz et al. 2015; Balona 2016).

c.f. Péter Pápics' talk

Combination terms:

$$n\,\nu_i \pm m\,\nu_j$$



(Bowman 2016)

Non-linearity: models

Theoretical prediction of resonant coupling between pulsation modes (Dziembowski 1982; Buchler et al. 1997).

Q: Coupling or a combination frequency?

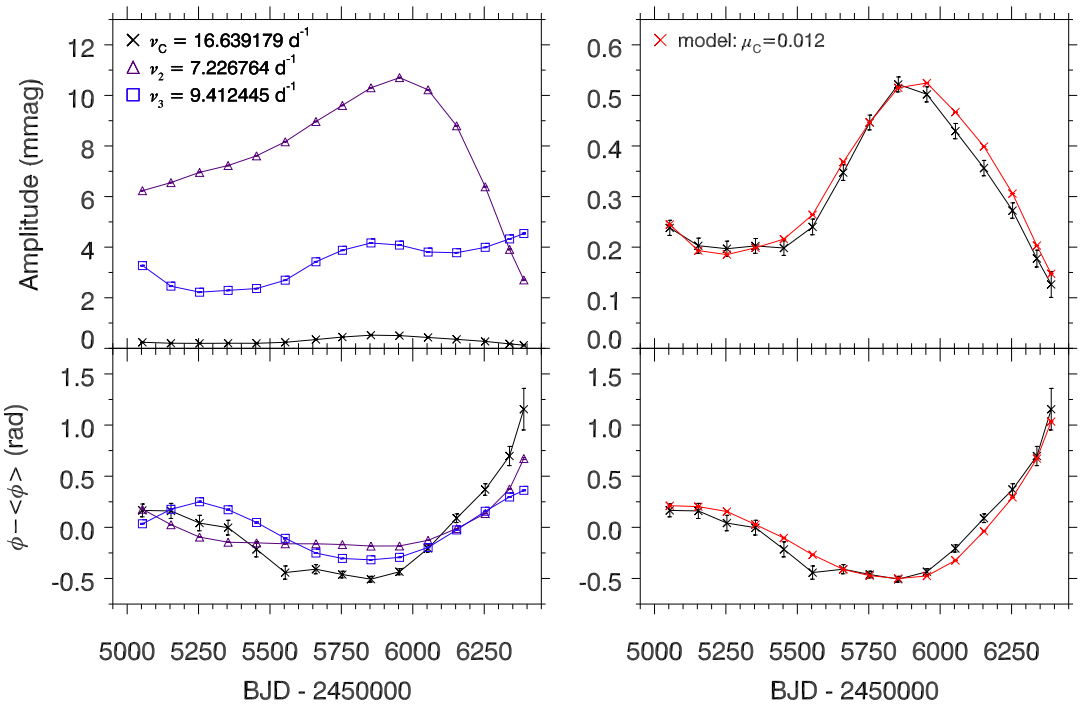
$$\nu_1 = \nu_2 \pm \nu_3$$

$$\phi_1 = \phi_2 \pm \phi_3$$

$$A_1 = \mu_c\,(A_2\,A_3)$$

(Breger & Montgomery 2014)

e.g., KIC 4733344 (Bowman et al. 2016)

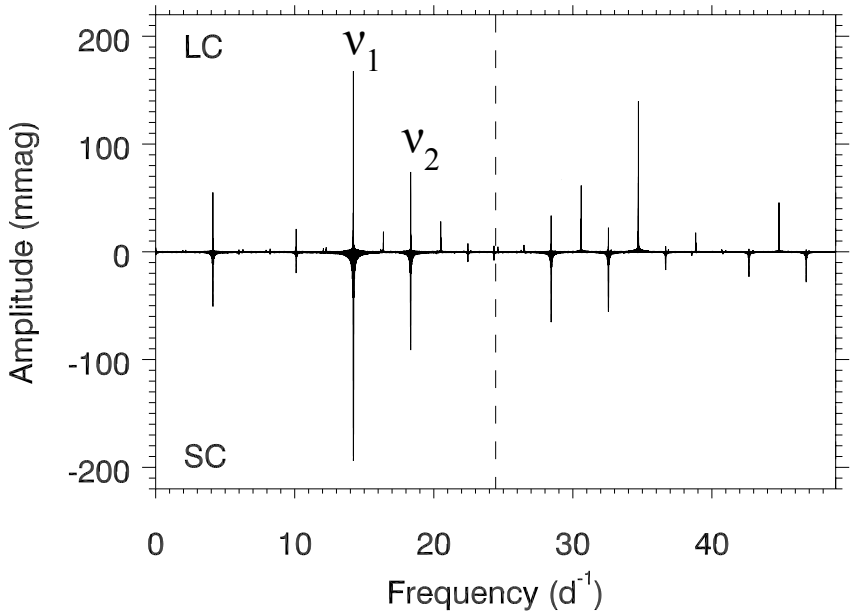


$\mu_c << 1$ favours non-linear distortion model

$\mu_c \sim 1$ favours resonant mode coupling

HADS stars

δ Sct stars with peak-to-peak light excursions greater than 0.3 mag (McNamara 2000).



(Bowman et al. 2016)

Pulsate in fundamental and/or first overtone radial modes (McNamara 2000).

Typically slow rotators with: $v \sin i < 40$ km s^{-1} (Breger 2000; McNamara 2000; Rodríguez et al. 2000).

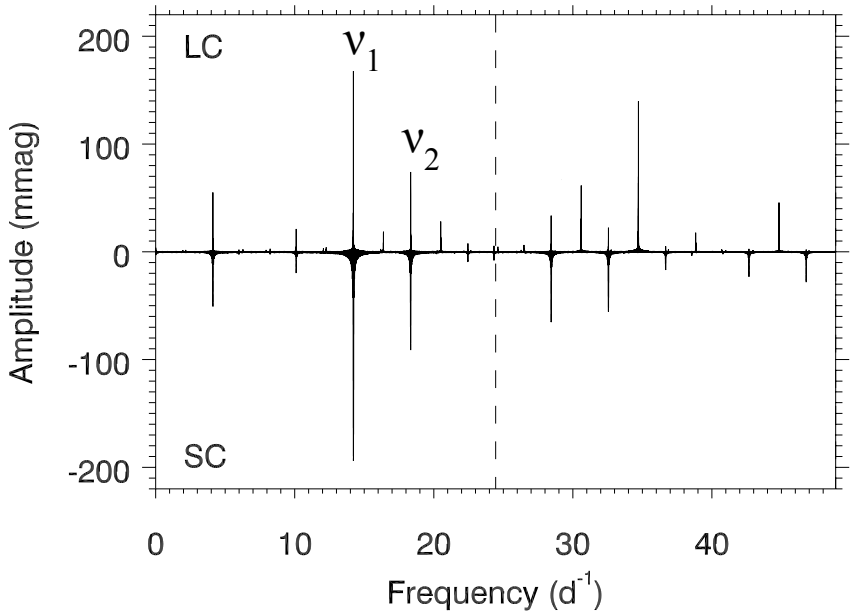
Post-main sequence stars? (Petersen & Christensen-Dalsgaard 1996).

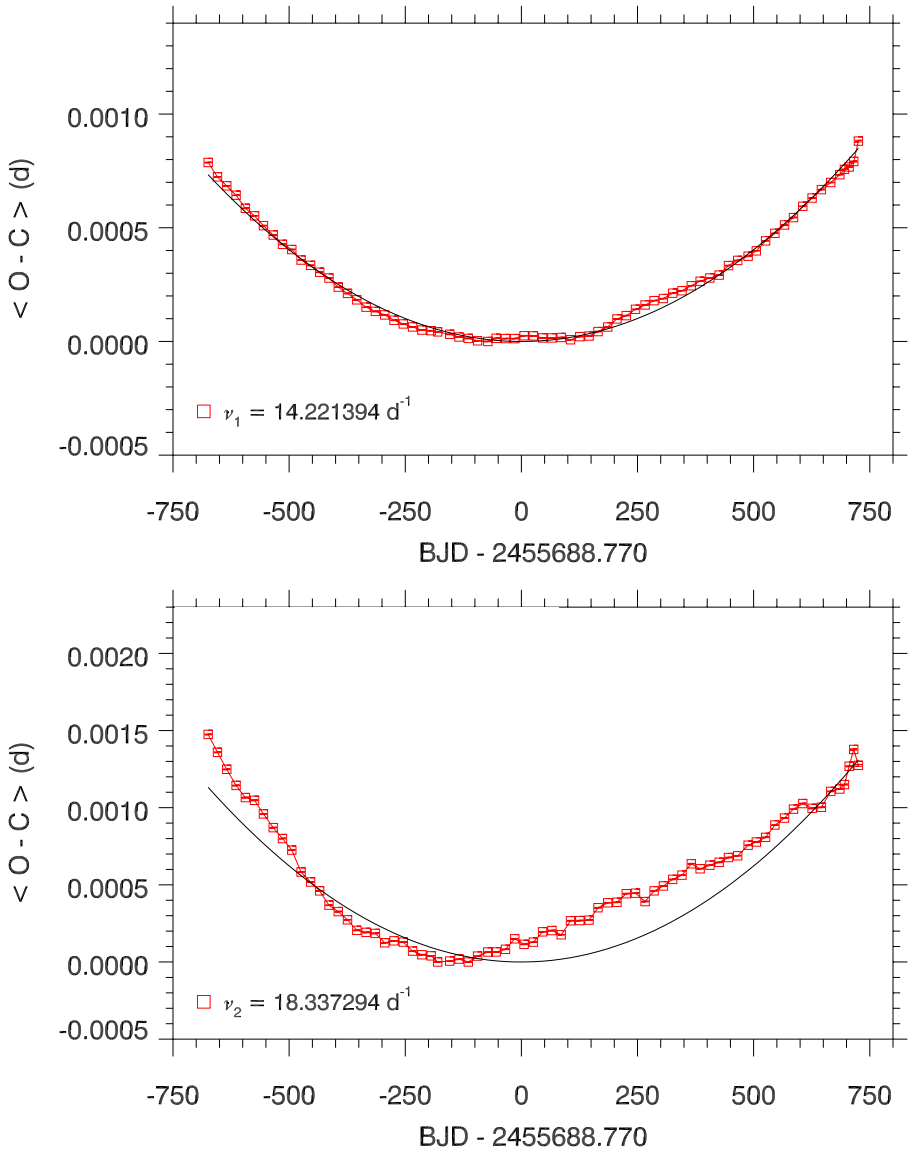
Only 2 of 983 *Kepler* δ Sct stars are HADS stars!

HADS stars

Observed: $\left(\frac{1}{P}\frac{dP}{dt}\right) \sim 1 \times 10^{-6}\ \mathrm{yr}^{-1}$

... pulsational non-linearity.

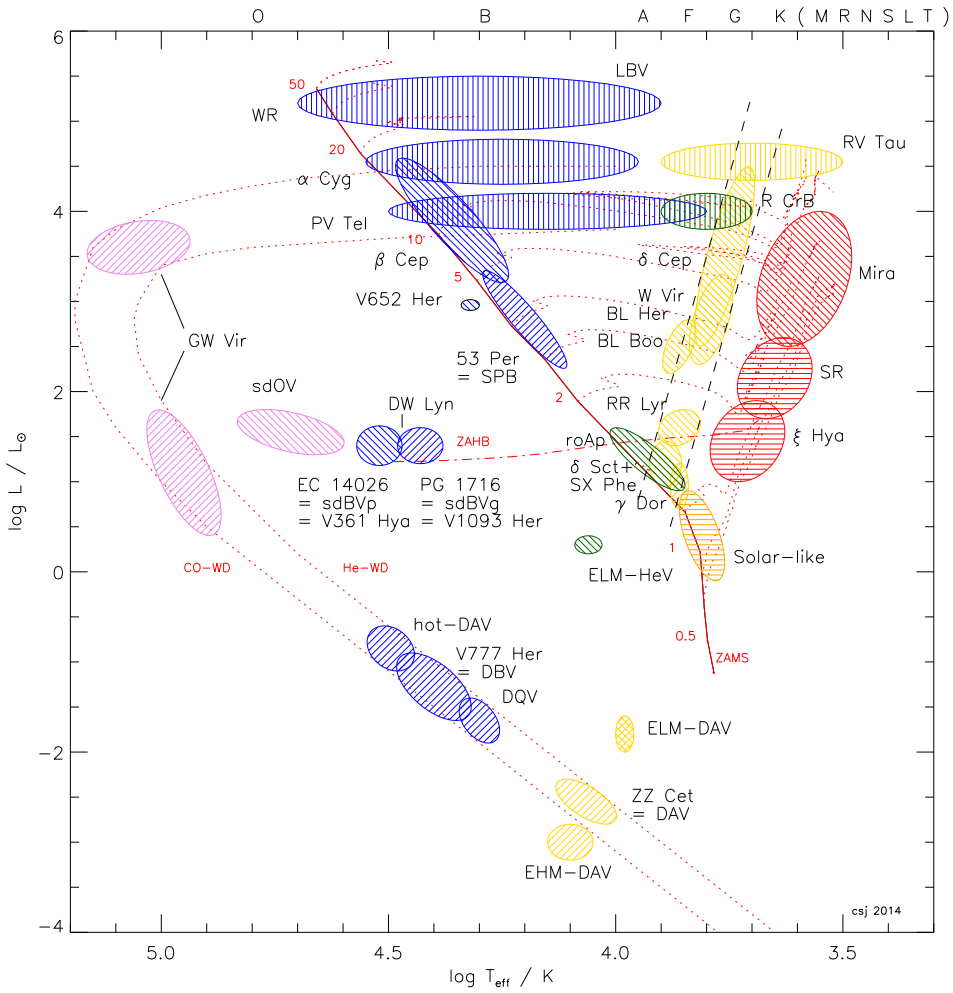




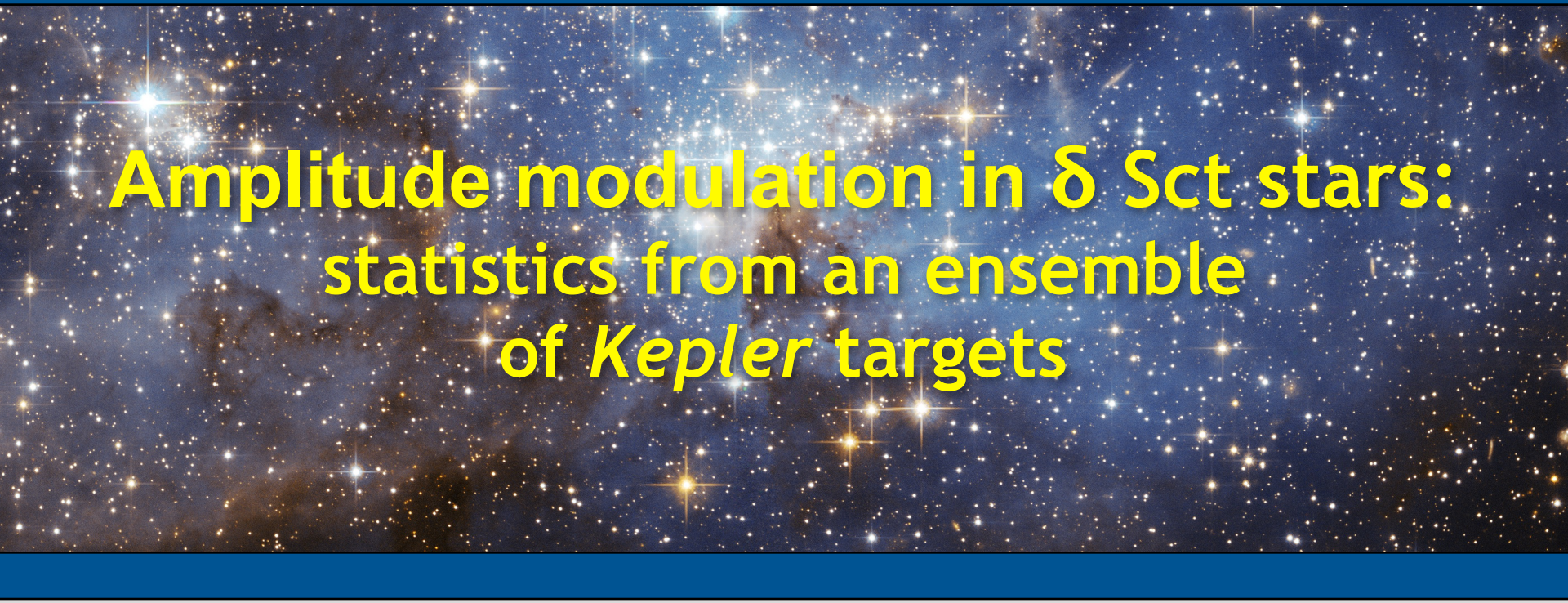
(Bowman et al. 2016; Bowman 2016)

Conclusions

- The δ Sct stars exhibit diverse pulsational behaviour.
- Amplitude modulation is common among δ Sct stars, but not ubiquitous.
- Models can be used to quantify the *strength* of non-linear mode coupling.
- The HADS stars are rare and exhibit non-linearity, which may explain why these stars differ to typical δ Sct stars.



Jeffery & Saio (2016)



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Thank you for your attention

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