What can we learn from asteroseismology of solar-like stars?



Exercise 1: make an echelle diagram with these 14 frequencies

2140
2147
2198
2252
2257
2308
2362
2367
2419
2478
2530
2583
2587
2640

•plot (frequency) versus (frequency mod Δv)

•find the best Δv (hint start with about 120 μ Hz)

•what happens if you change Δv slightly?



Three G stars with Kepler (Chaplin et al. 2010)







•what happens if you change Δv slightly?

1. The C-D diagram (small vs. large separations)

A HERTZSPRUNG-RUSSELL DIAGRAM FOR STELLAR OSCILLATIONS



Christensen-Dalsgaard (1988,1993)



THE ASTROPHYSICAL JOURNAL LETTERS, 742:L3 (6pp), 2011 November 20

WHITE ET AL.

2. Mode bumping, avoided crossings and mixed modes in subgiant stars





Mode bumping in the subgiant η Boo

Christensen-Dalsgaard et al. 1995

- we see departure from regular frequency spacings in l = 1 modes
- what causes this?

Nonradial Oscillations of a 10 Solar Mass Star in the Main-Sequence Stage

The variation in dimensionless eigenvalues of nonradial modes (l=2)

Publ. Astron. Soc. Japan 27, 237-258 (1975)

Avoided Crossing of Modes of Non-radial Stellar Oscillations

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I. Introduction

The phenomenon of mode "bumping" can be observed when following the non-radial oscillations of gradually changing stellar configurations: The frequency of a certain mode approaches that of another one which is "bumped" to a quite different frequency, while the "bumping" mode settles at roughly the original frequency of the bumped mode.

•dashed lines are l=0

•solid lines are l=1

Christensen-Dalsgaard et al. 1995

p and g modes

Christensen-Dalsgaard et al. (lecture notes) and Aerts et al. (2010, "Asteroseismology")

p and g modes

Christensen-Dalsgaard et al. (lecture notes) and Aerts et al. (2010, "Asteroseismology")

p and g modes

Aerts, Christensen-Dalsgaard & Kurtz (2010, "Asteroseismology")

another example: β Hyi G2 IV (subgiant, future Sun)

SOLAR-LIKE OSCILLATIONS IN THE G2 SUBGIANT β HYDRI FROM DUAL-SITE OBSERVATIONS

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models of β Hyi

Brandao et al. (2011)

Gilliland et al. (2010)

KIC 11026764 = "Gemma" (Metcalfe et al. 2010)

An avoided crossing on the main street of Vilnius

3. Mode bumping, avoided crossings and mixed modes in red giant stars

same red giant (10 months)

same red giant (19 months)

Mixed modes arise from coupling between p and g modes with the same *l*

g modes in the centre of Europe

Mixed modes in subgiants and red giants

Kepler

(2011)

Gravity modes as a way to distinguish between hydrogen- and helium-burning red giant stars

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Bedding et al. (2011)

Bedding et al. (2011); see also Beck et al. (2011), Mosser et al. (2011, 2012)

Rotation

KIC 314159265

rotational splitting of $\ell = 1$ (dipole) modes

Beck et al. (2012)

Beck et al. (2012)

Beck et al. (2012)

LETTER

Fast core rotation in red-giant stars as revealed by gravity-dominated mixed modes

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Beck et al. (2012)

SEISMIC EVIDENCE FOR A RAPIDLY ROTATING CORE IN A LOWER-GIANT-BRANCH STAR OBSERVED WITH Kepler

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Deheuvels et al. (2012)

What we can learn:

- Using scaling relations to get M, R and L
- Model individual stars, get ages and test models (C-D diagram)
- Use mixed modes to identify helium-burning red giants
- Use splittings to measure internal rotation & inclination

Further reading

- *"Asteroseismology"* book by Aerts et al.
- "Solar-like Oscillations: An Observational Perspective", (Bedding, in press), Canary Islands Winter School of Astrophysics (arXiv:1107.1723)