UNIVERSITY OF BIRMINGHAM | COLLEGE OF ENGINEERING AND PHYSICAL SCIENCES

Update on APOKASC analysis of Red Giants

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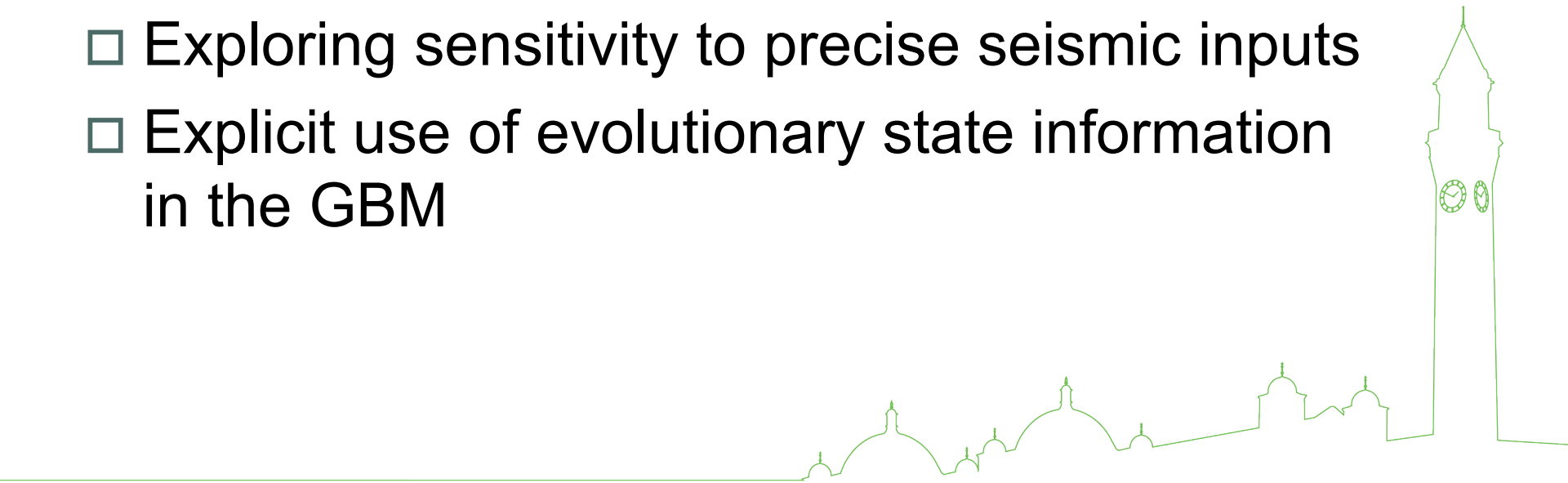
What is involved?

- Collaboration between APOGEE – spectroscopic survey in the near IR at Apache Point (SDSS) and KASC seismology of red giants
- Aim to derive reliable & precise masses and ages combining data from both sources
- Just over 6600 stars involved

Novelty in this project

- GRID-based modelling (GBM) of red giants on a large scale
- Use of corrections to account for departures from homologous scaling on RGB
- Exploring sensitivity to precise seismic inputs
- Explicit use of evolutionary state information in the GBM



Who is involved

- **Providers of average seismic parameters**

Garcia & Mathur (A2Z), Kallinger (CAN),

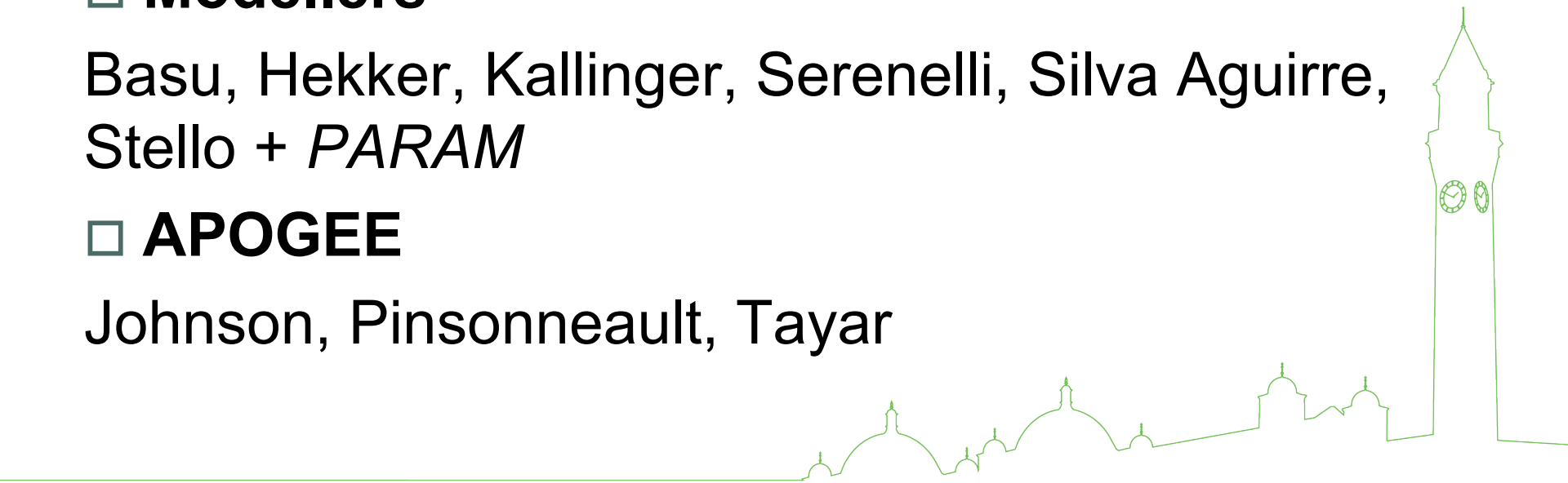
Mosser (COR), Hekker (OCT), Stello (SYD)

- **Modellers**

Basu, Hekker, Kallinger, Serenelli, Silva Aguirre, Stello + *PARAM*

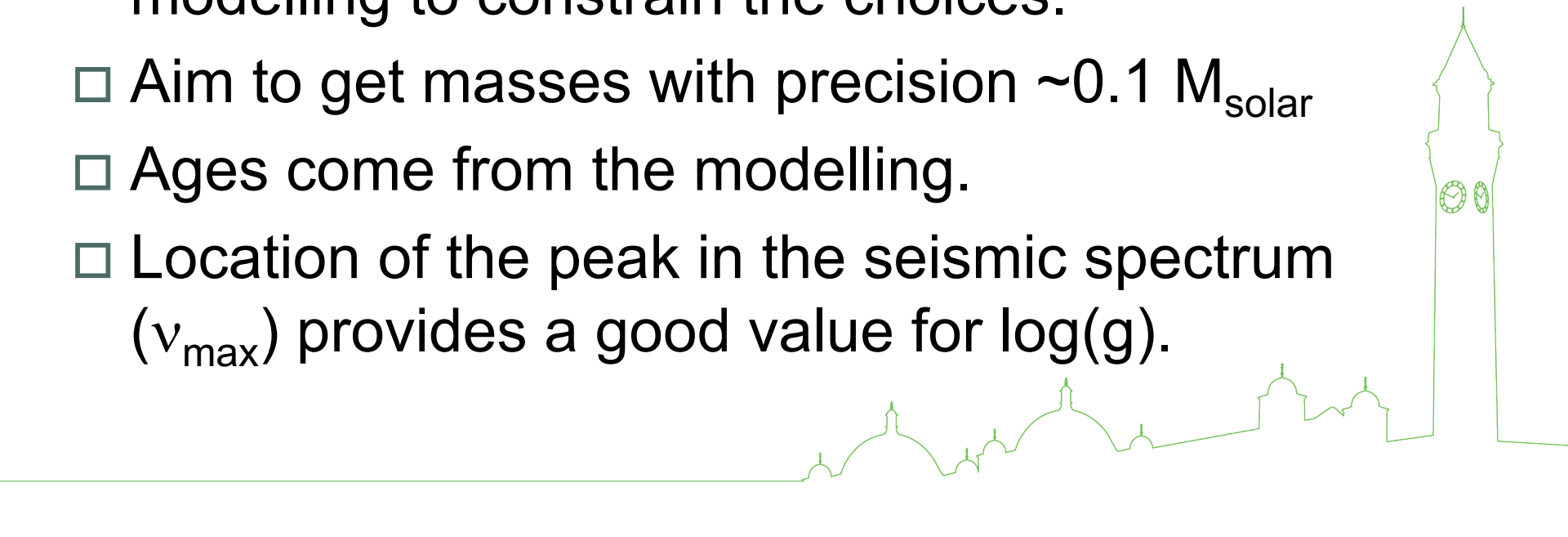
- **APOGEE**

Johnson, Pinsonneault, Tayar



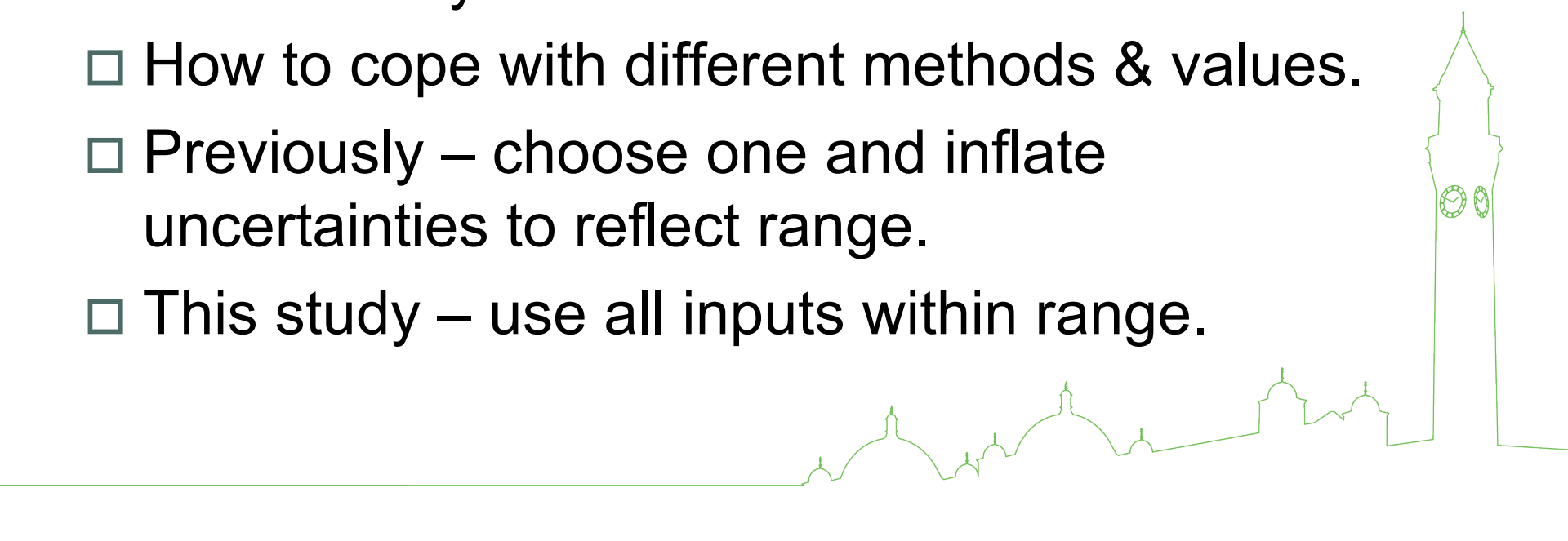
Basic Idea

- Given certain average seismic parameters it is possible (with the addition of the temperature) to compute ‘scaling law’ masses and radii.
- Aim to improve these by using grid-based modelling to constrain the choices.
- Aim to get masses with precision ~0.1 M_{solar}
- Ages come from the modelling.
- Location of the peak in the seismic spectrum (ν_{max}) provides a good value for log(g).



Seismic Inputs

- Average seismic parameters of $\Delta\nu$ & ν_{max}
- $\Delta\nu$ is the spacing between modes of the same degree but one different in order.
- Evolutionary State.
- How to cope with different methods & values.
- Previously – choose one and inflate uncertainties to reflect range.
- This study – use all inputs within range.

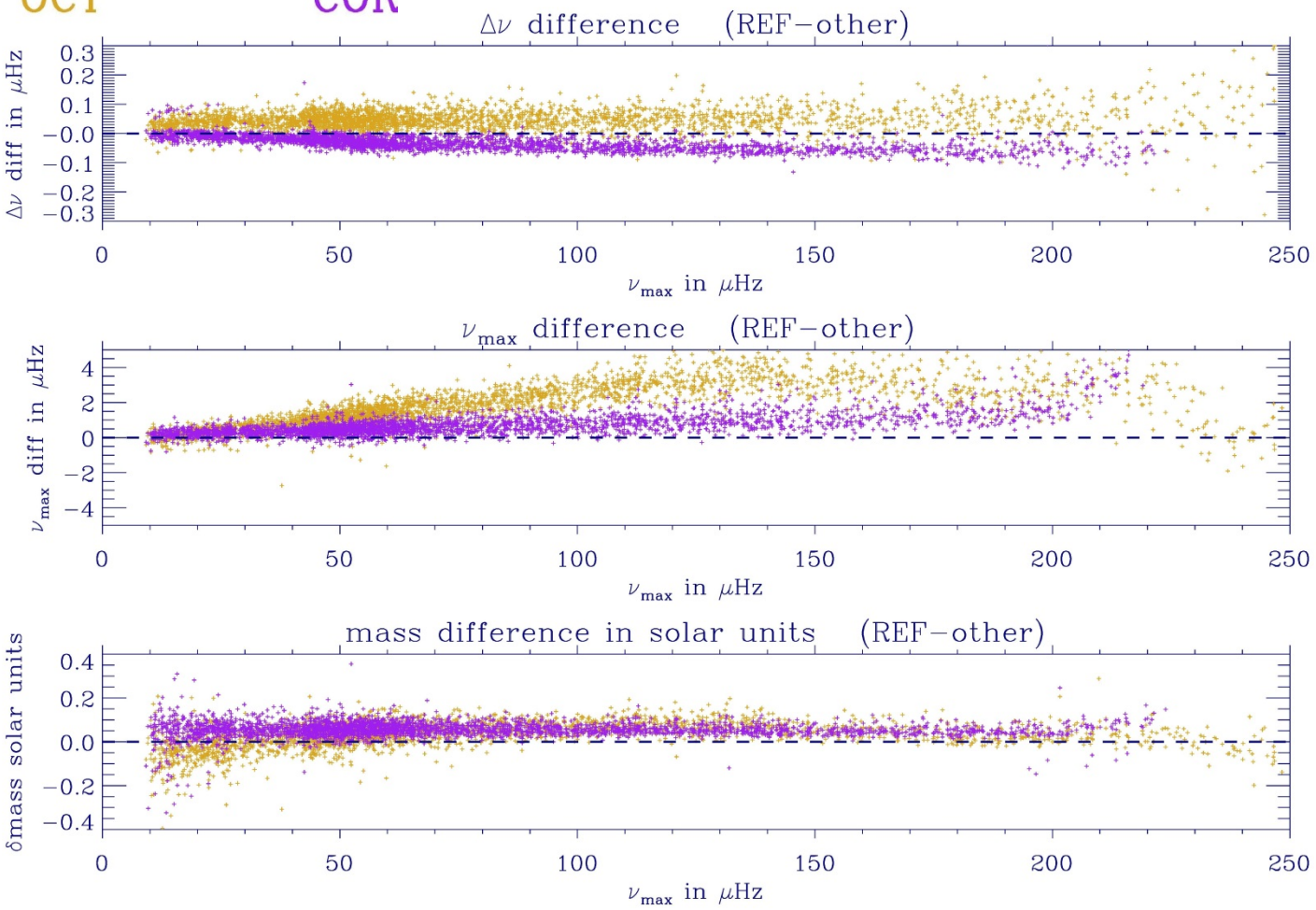


Do different seismic inputs give the same masses?

- Key point - solar reference values used to bring the scaling law masses into agreement.
- Not perfect.
- Size of the effect is a function of the evolutionary state of the stars being considered. Differences most marked for RGB stars.
- On average, method differences up to 0.1M_{solar}
- Can remove much of the effect by changing solar reference values.

Compare seismic parameters and SL mass for RGB

REF=CAN OCT COR



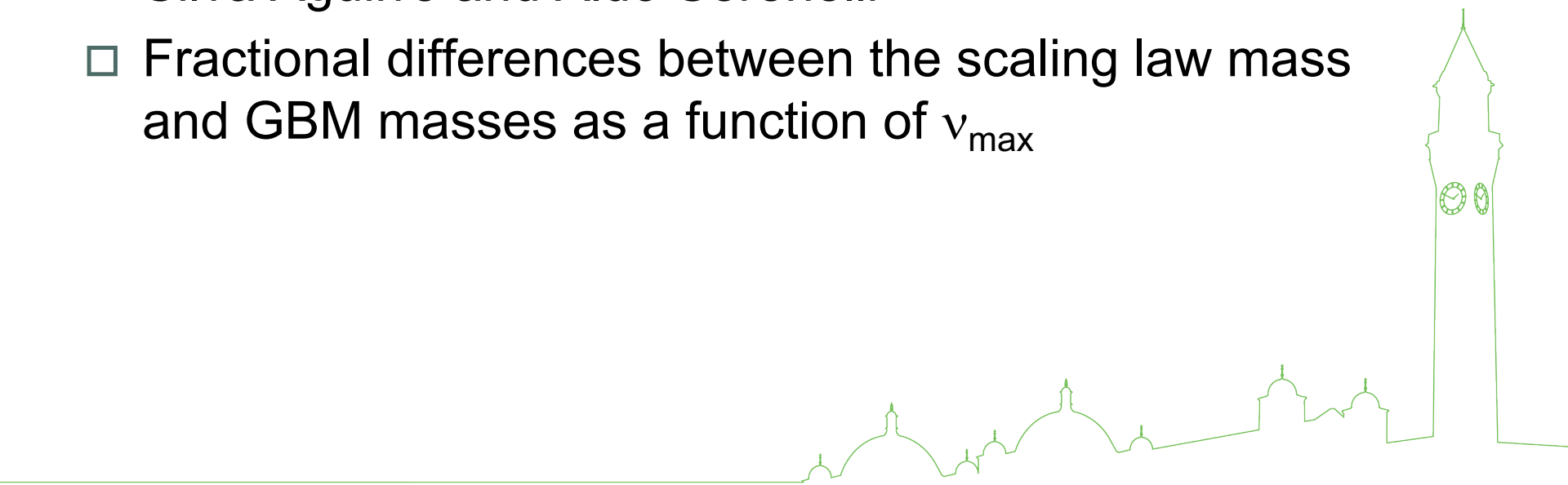
For mass, OCT and COR agree with each other and give a slightly lower value than CAN. SYD and A2Z a bit lower still

Correction to $\Delta\nu$ on the RGB

- Most GBM methods use scaling laws to predict average seismic parameters for each model.
- Known to produce the wrong density for stars high on the RGB (low $\Delta\nu$ and ν_{max}).
- Solution is to compute frequencies for each model and use them to get $\Delta\nu$.
- Some methods use formulae and others do computation for every star in grid of models.

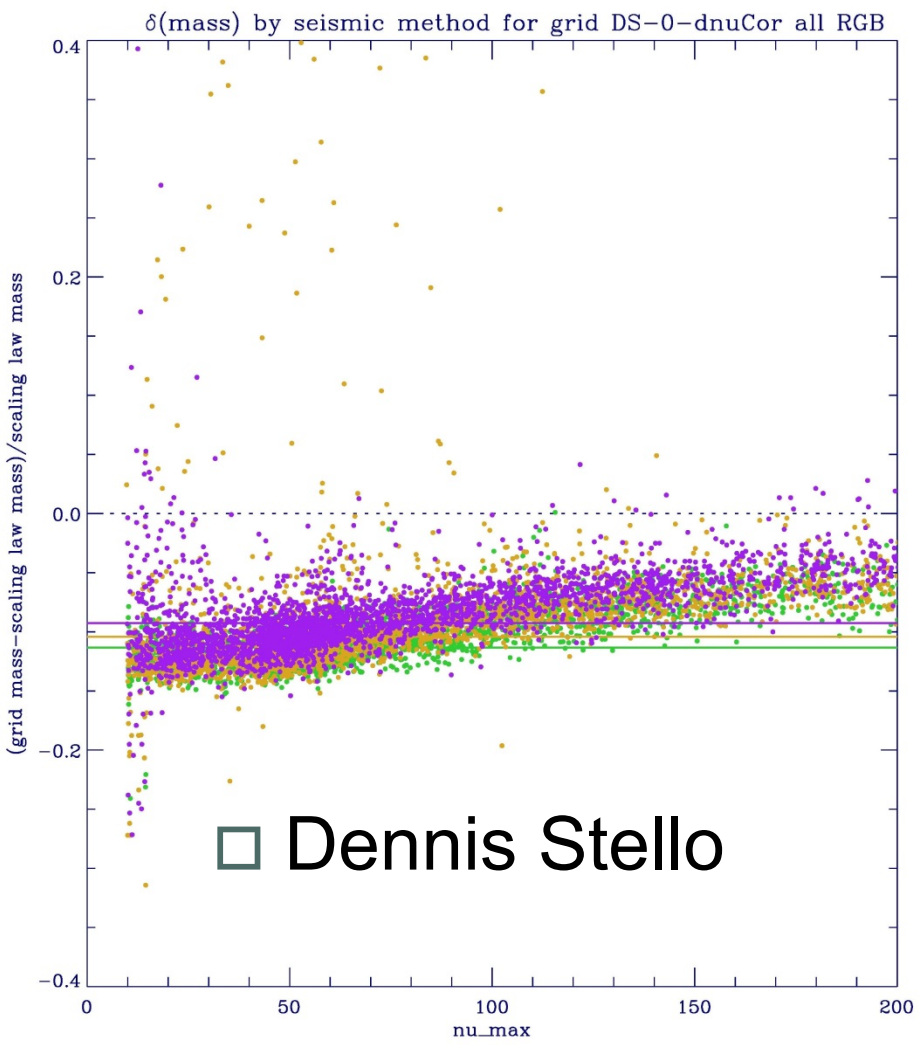
Grid-based Modelling Results

- Different seismic input with one GRID.
- Applied corrections for lack of homology with evolution up the red giant branch (RGB)
- Show results from three grids Dennis Stello, Victor Silva Aguirre and Aldo Serenelli
- Fractional differences between the scaling law mass and GBM masses as a function of ν_{max}

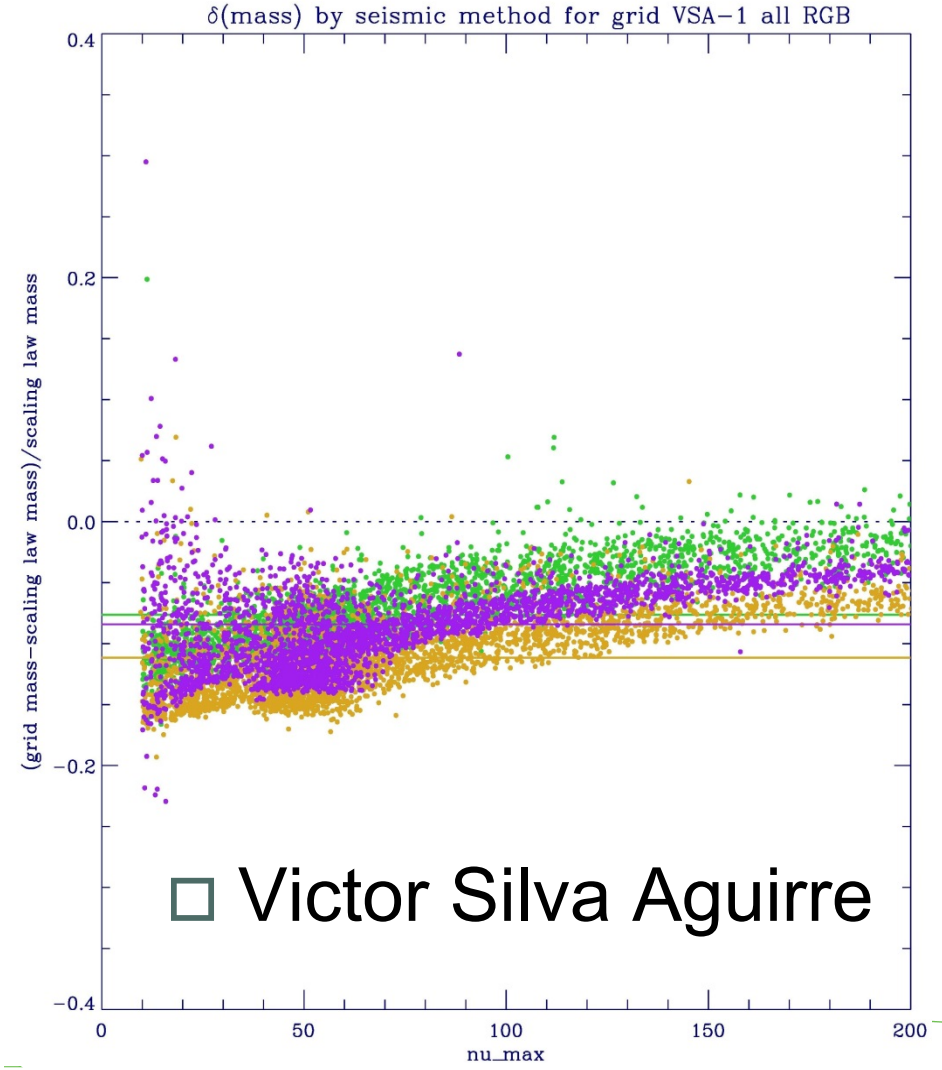


RGB Mass(GRID-Scaling Law)/Scaling law vs. ν_{max}

CAN OCT COR

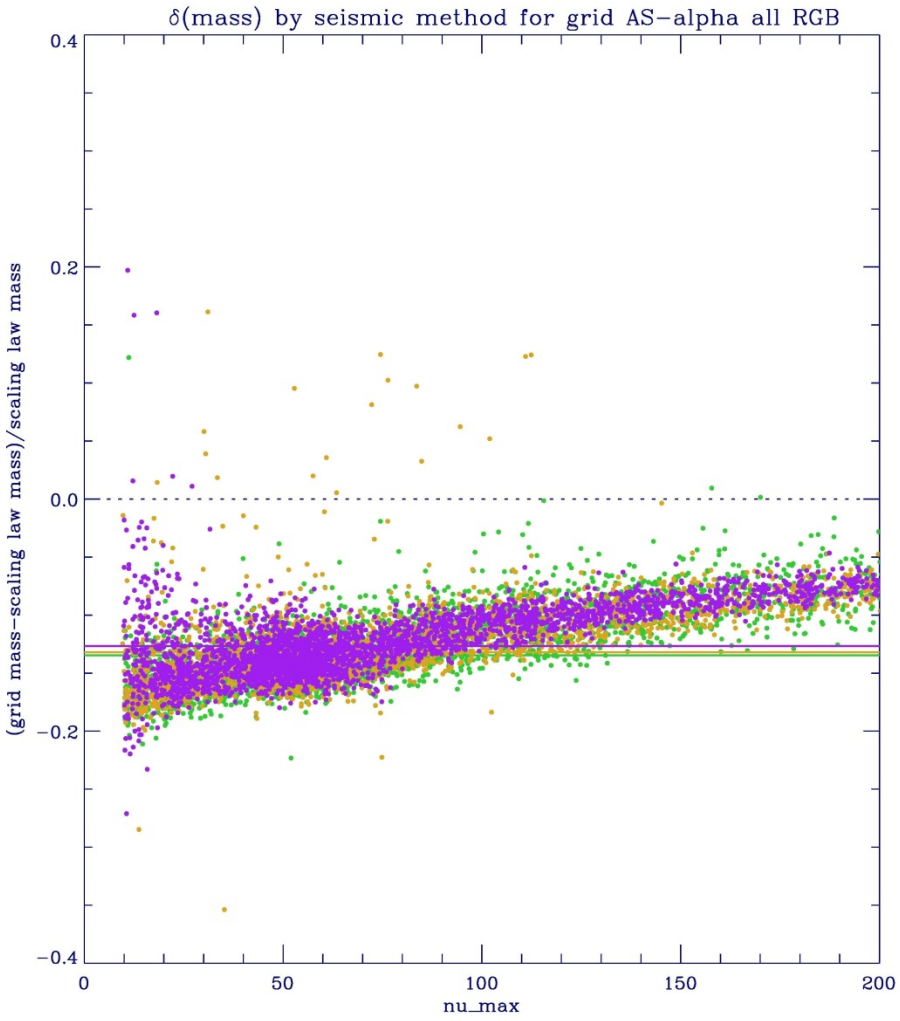


Dennis Stello



Victor Silva Aguirre

Mass(GRID-Scaling Law)/Scaling law vs. ν_{max}



- RGB Aldo
- Note extra step to bring different inputs into line

CAN OCT COR

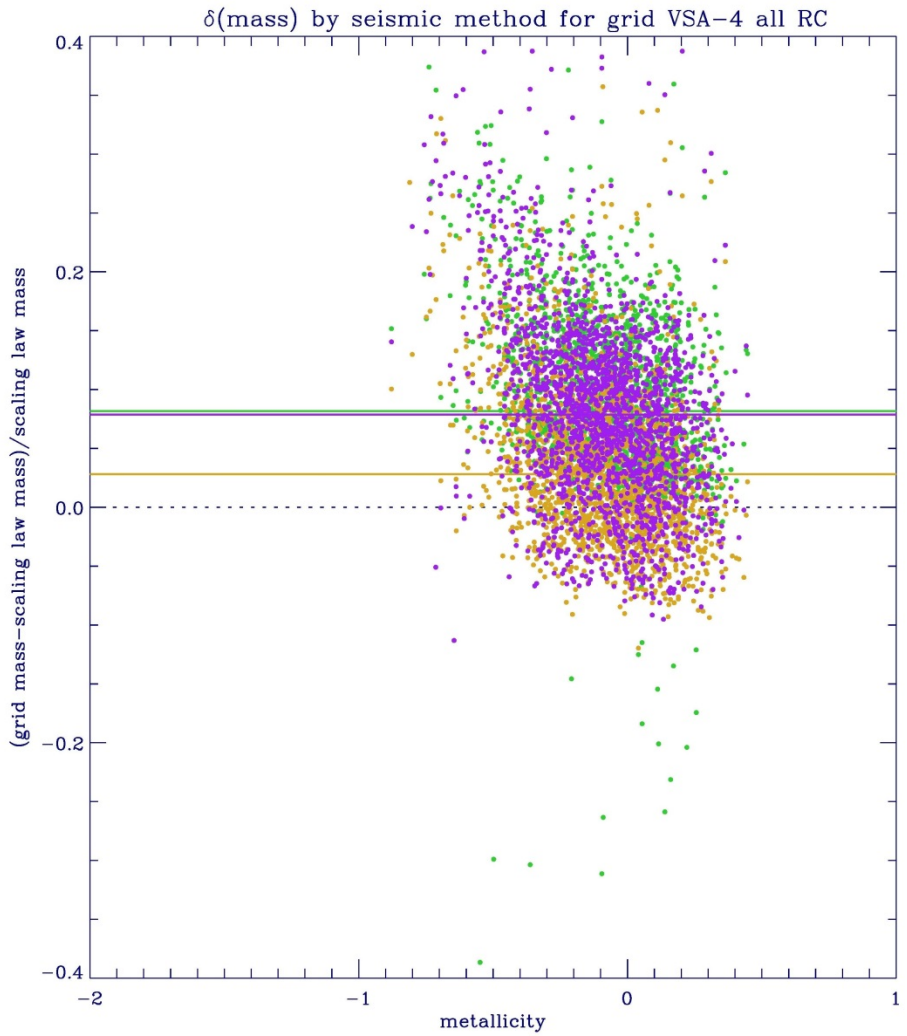
Now look at Red Clump results

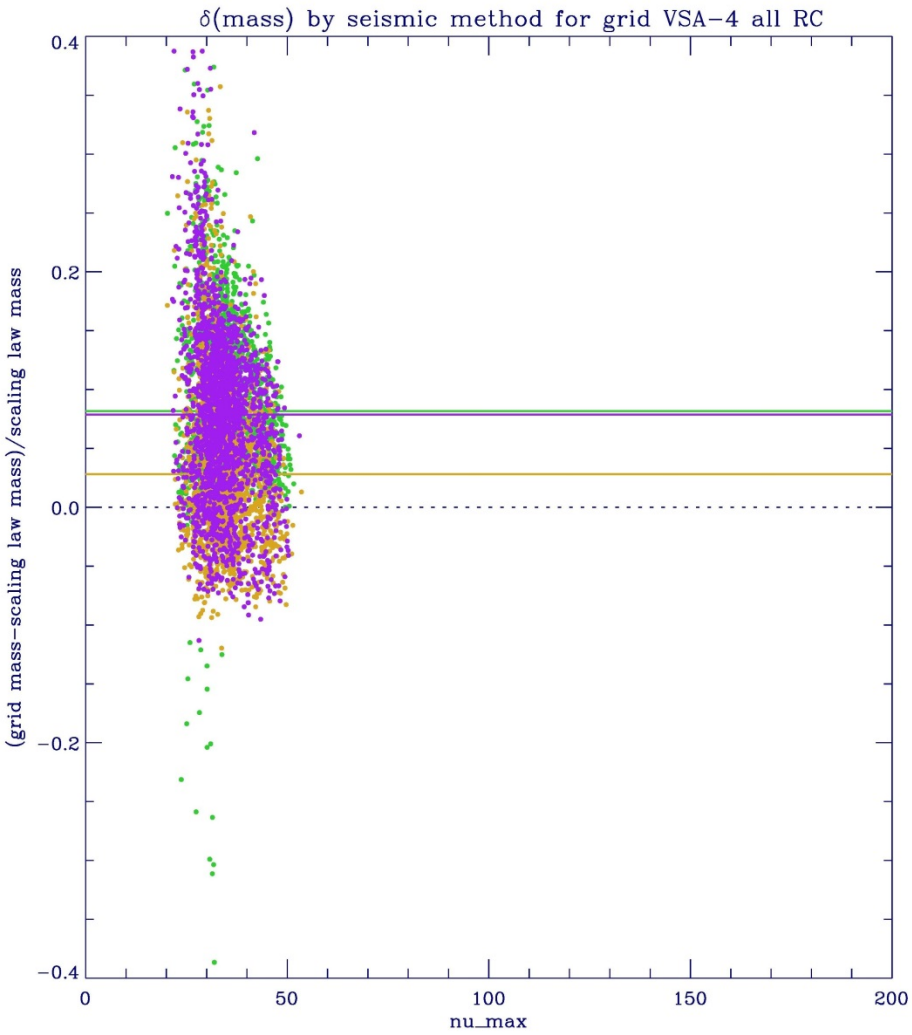
- Not all grids have red clump stars

- RC Victor

CAN OCT COR

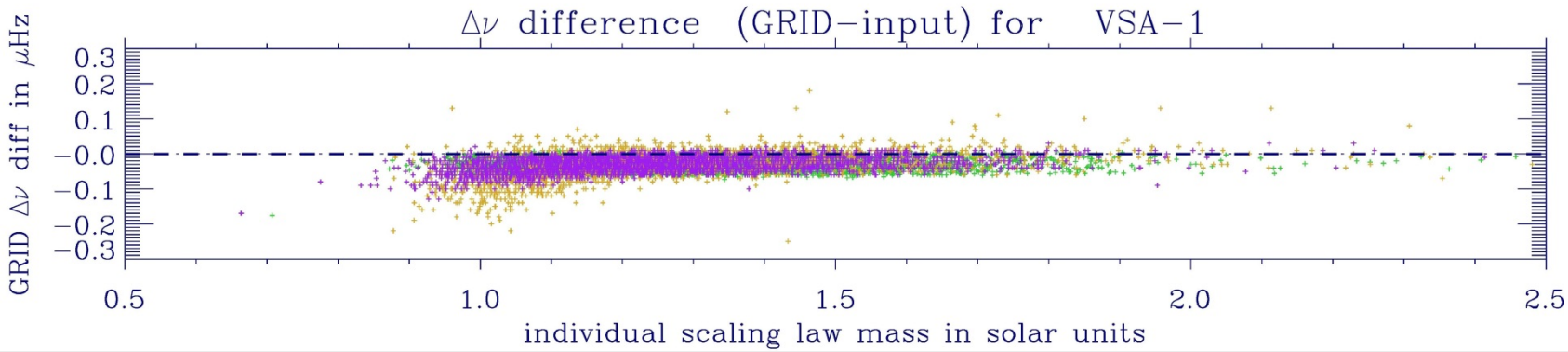
Mass(GRID-Scaling Law)/Scaling law vs. Z and nu_max





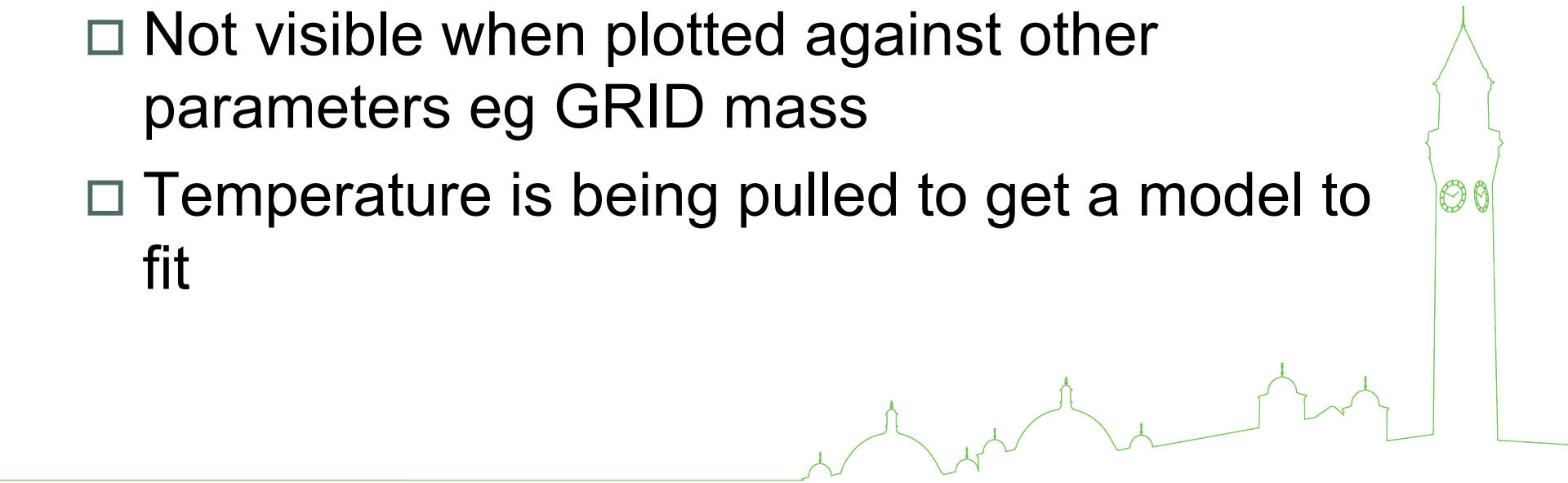
How closely do the parameters of the selected models match input parameters?

Victor RGB: difference between output and input parameters

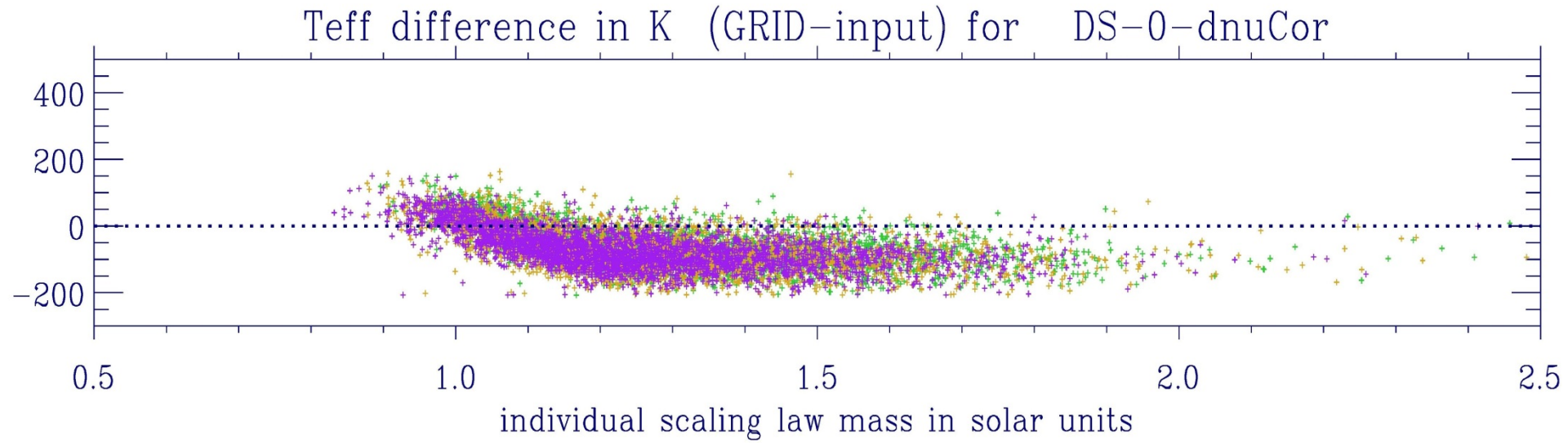


Interesting behaviour of temperature differences between input and output values at low scaling law mass

- Same for RGB and RC
- Most, (? all) grids show effect
- Not visible when plotted against other parameters eg GRID mass
- Temperature is being pulled to get a model to fit

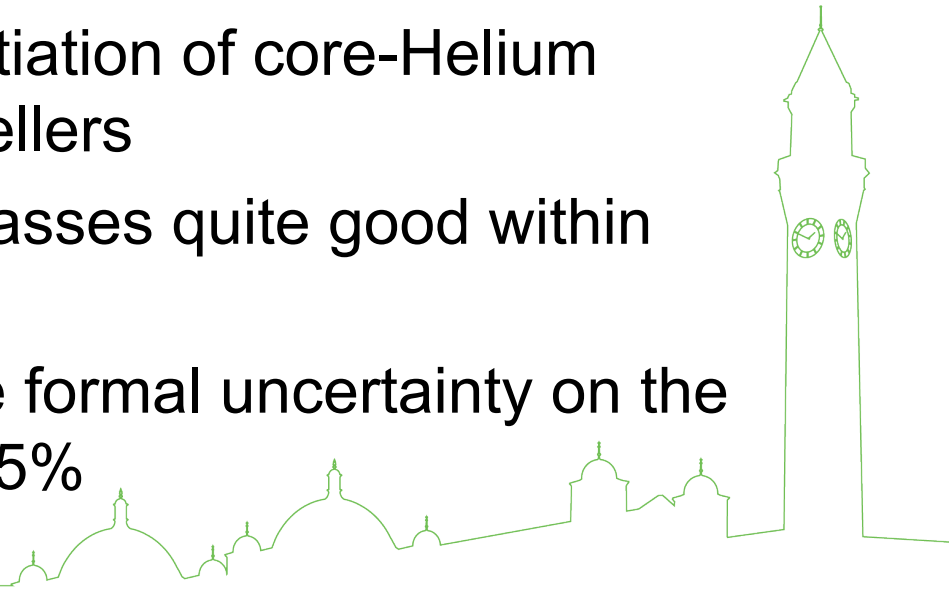


Dennis RGB: difference between output and input parameters



How good are the results?

- Use of evolutionary state looks OK.
- Still have to analyse cases where inputs were unclear or contradictory.
- $\Delta\nu$ correction looks good and there is some convergence between different methods.
- Still got issues to resolve at low mass.
- Models for stars after the initiation of core-Helium burning differ between modellers
- Agreement in scaling law masses quite good within $0.1M_{solar}$
- For the best of the data, the formal uncertainty on the masses from GBM is about 5%



Where we are now

- Have the average seismic parameters
- Have the evolutionary state
- Have the GBM results from most groups
- Checking cases where no oscillations found
- Checking unusual results
- Various projects using preliminary results
- Discussing how to reduce the diversity to a single value for the community
- Hope to publish by the end of the summer