AN ASTEROSEISMOLOGICAL ANALYSIS OF THE RGB BUMP

{ KENNY ROFFO, SASKIA HEKKER, GEORGE ANGELOU, EARL BELLINGER AND SHASHI KANBUR }

SPECIAL THANKS TO SUNY OSWEGO CHALLENGE GRANT AND MAX-PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH FOR MAKING THIS RESEARCH POSSIBLE

INTRODUCTION

Asteroseismology is the study of oscillations in the insides of stars. These oscillations cause stars to emit certain frequencies of light, characteristic of the stellar structure. This light is what asteroseismologists observe here on Earth.

In red giants, a chemical discontinuity is caused by a convective envelope on the outside of the star. As red giants burn hydrogen in a shell outside their core, the shell expands towards the discontinuity, which causes the star to temporarily decrease in luminosity in what is known as the RGB bump, shown in figure 1.

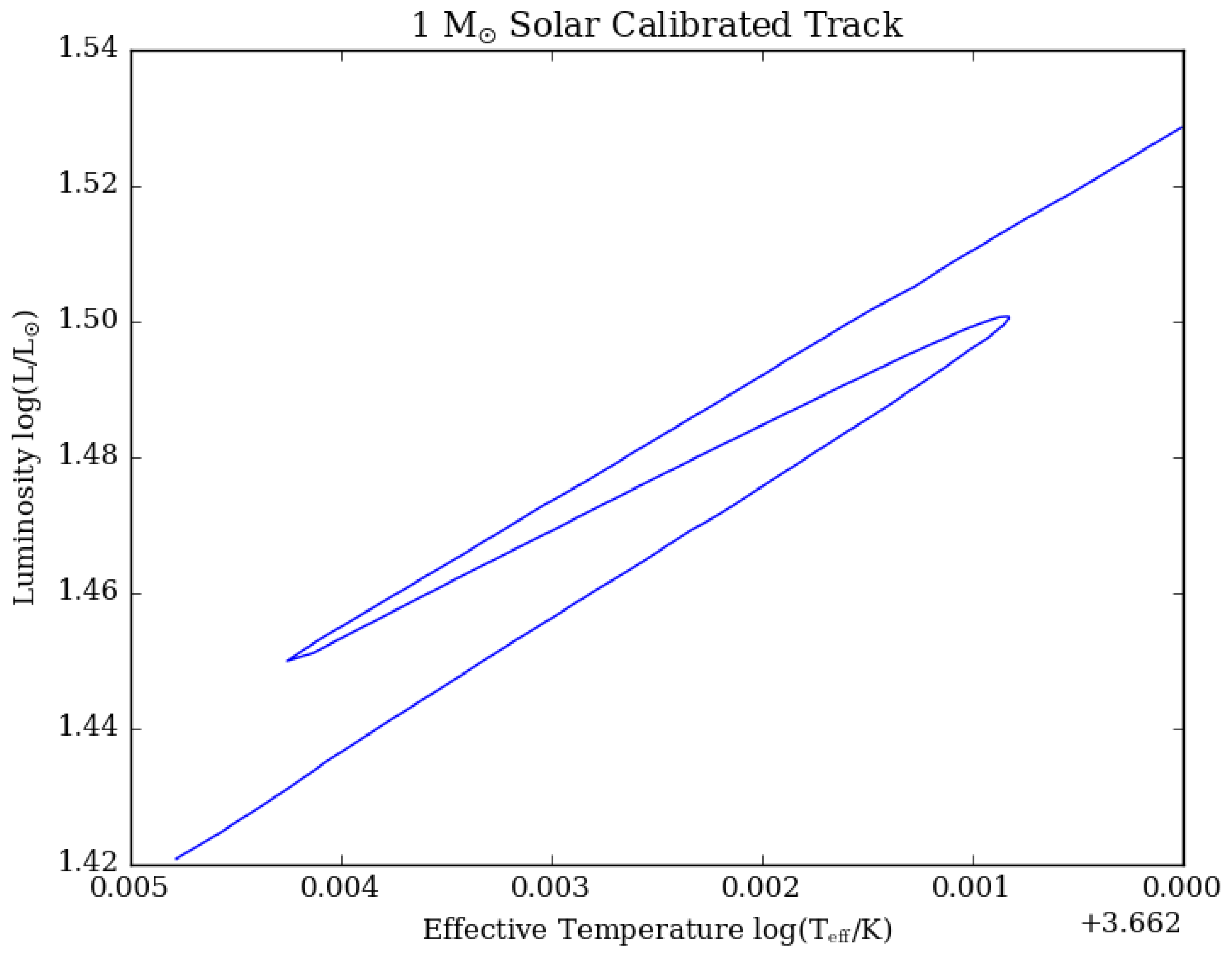

Figure 1: An HR diagram of a 1 solar mass track (a sequence of models) as it passes through the RGB bump.

Some previous work has been done studying the bump. In 2015, Jørgen Christensen Dalsgaard (JCD) published a paper in which he studied how mass affects the bump. Figure 2 shows that stars of different masses display different bump behavior.

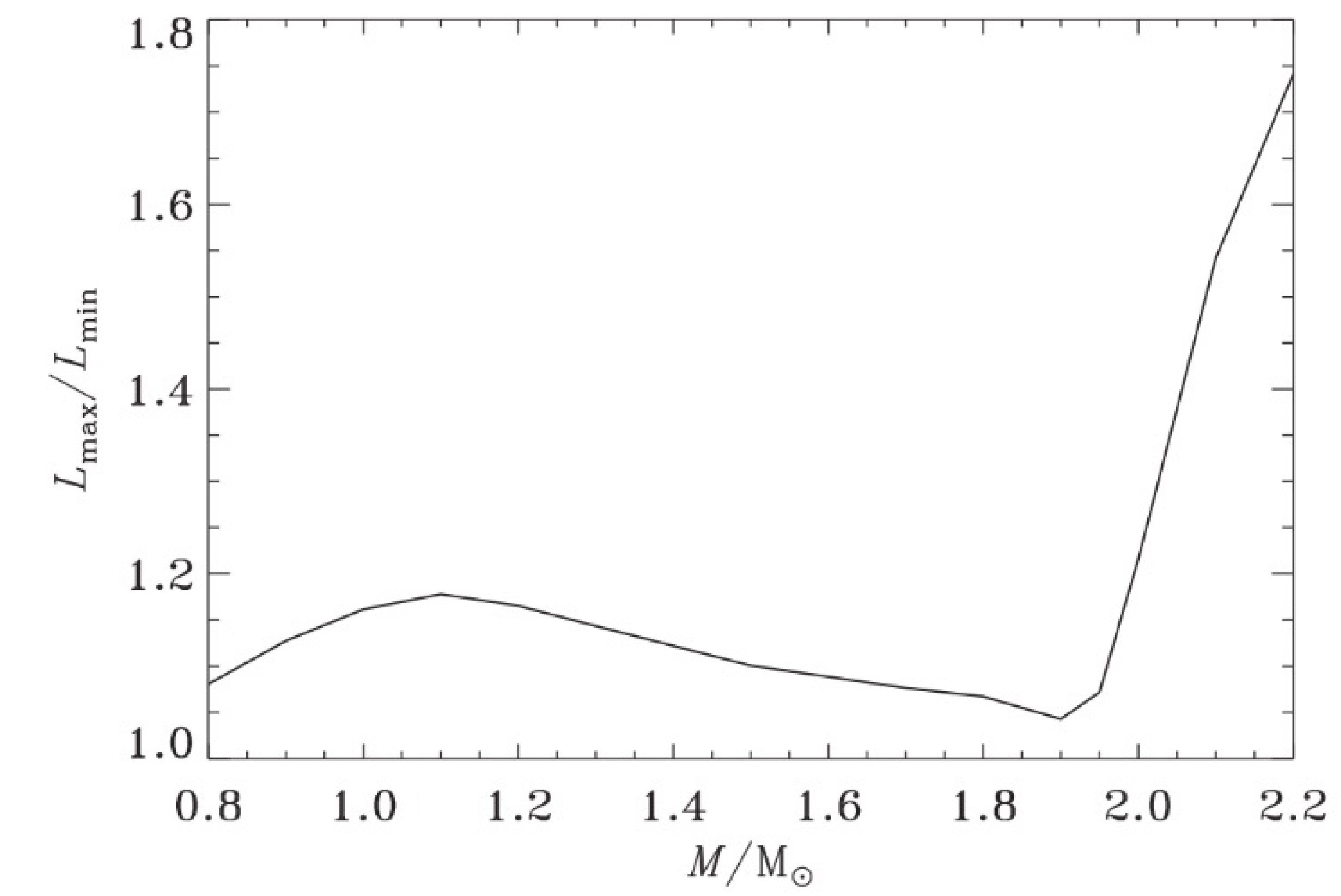

Figure 2: Jørgen Christensen-Dalsgaard, MNRAS, 2015
The shape of the plot can be explained by the depth of the convective envelope and the extent to which a convective core reaches during the main sequence, explained in JCD's paper.

GOALS

We had several major goals going into the project:

- Verify JCD's plot

This first goal provided an introduction to the project, and to using the MESA stellar evolution code. Due to the amount of available room, I have not included my version of the plot, though it can be provided upon request.

- Study how asteroseismic parameters are affected during the bump

We expected that they would be affected, but by how much, and in what way? Since the parameters are what we can measure, they are very important for us to understand.

- Determine how mass affects bump in more detail

We have seen that mass affects the luminosity ratio of the bump, but how else does mass affect the bump.

- Identify what stage of the bump a star is in

The final goal is a major objective. Because the bump runs through a small region on the HR diagram three times, we observe three times as many red giants in the bump as in other places. It would be useful to be able to tell what part of the bump an observed star is in.

TOOLS AND PARAMETERS

To research this topic, we generated several tracks of models to study how stars would evolve. To create these models, we used the MESA Stellar Evolution code. MESA solves equations of stellar structure in order to create models based on several input parameters, such as initial hydrogen abundance, or metallicity.

Once models were created, ADIPLS was used to perturb their equations of stellar structure in order to obtain the frequencies of light which would be output by the star. Frequencies were then used to calculate asteroseismic parameters.

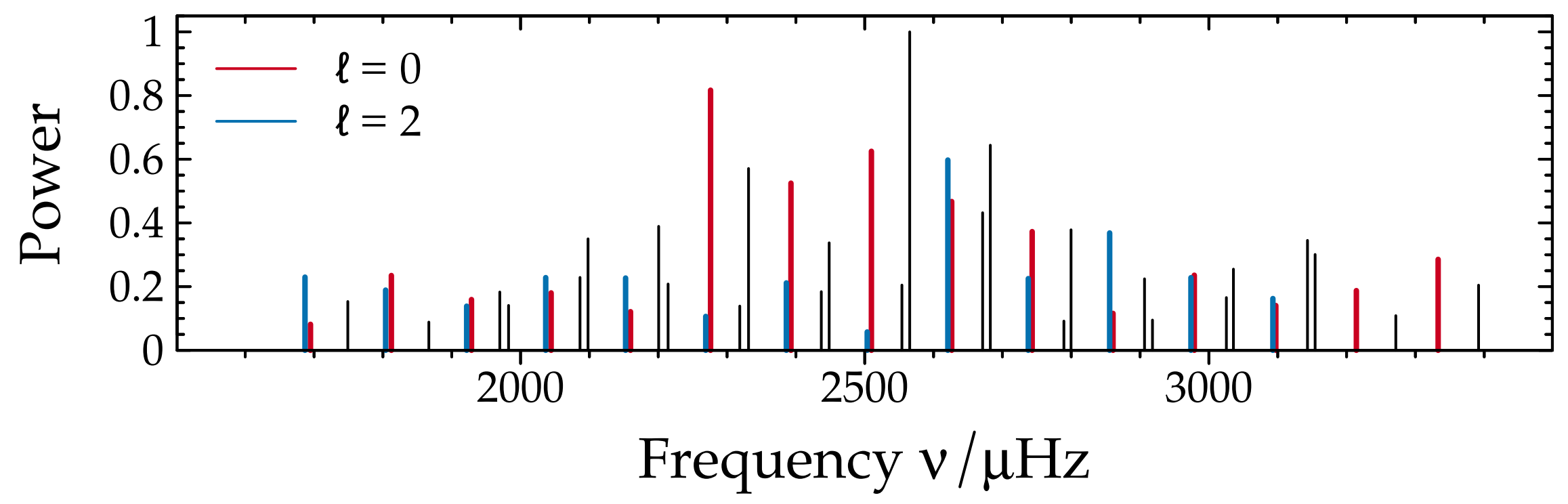

Figure 3: Image Credit: Earl Bellinger
An example of a power spectrum, which shows the power of frequencies observed from a star. Spherical degrees 0 and 2 are indicated.

In figure 3, the red line segments represent the frequencies of spherical degree (l) 0. The pair of spike's towards the center of each pair of $l = 0$ modes are the $l = 1$ and $l = 3$ modes, and the blue spike's are the $l = 2$ modes. Using these modes, we find asteroiseismic parameters. The Large Frequency Separation ($\Delta\nu$) is defined to be the frequency difference between consecutive $l = 0$ modes. The small frequency separation 02 ($\delta\nu_{02}$) is the frequency difference between an $l = 0$ mode and it's adjacent $l = 2$ mode. The small frequency separation 01 ($\delta\nu_{01}$) is the difference between the midpoint of two consecutive $l = 0$ modes, and the $l = 1$ mode between them. Some oscillations are caused with pressure as the restoring force, such as the $l = 0$ modes (called p-modes). However, some have gravity as the restoring force. These are called g-modes, and the Period Separation ($\Delta\Pi_n$) is defined as the difference in period of consecutive $l = n$ g-modes. (In red giants many modes of spherical degree >1 show both p-mode and g-mode character).

RESULTS

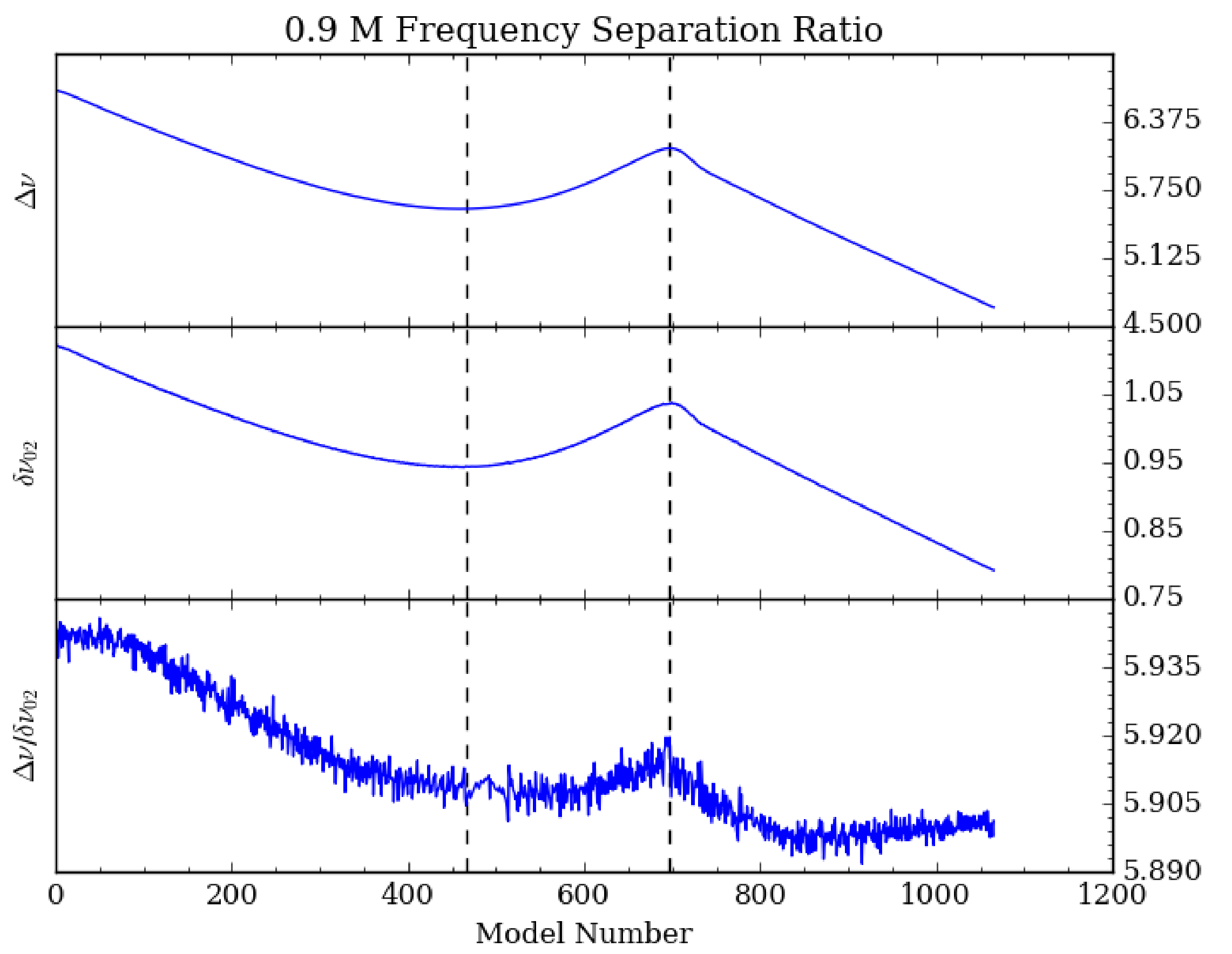

Figure 4: $\Delta\nu, \delta\nu_{02}$ and their ratio for a 0.9 solar mass track through the bump

Figure 4 shows that the ratio of $\Delta\nu$ to $\delta\nu_{02}$ follows a similar shape as the individual separations. For higher mass stars (above 1.4 solar masses) the ratio's shape was flipped horizontally.

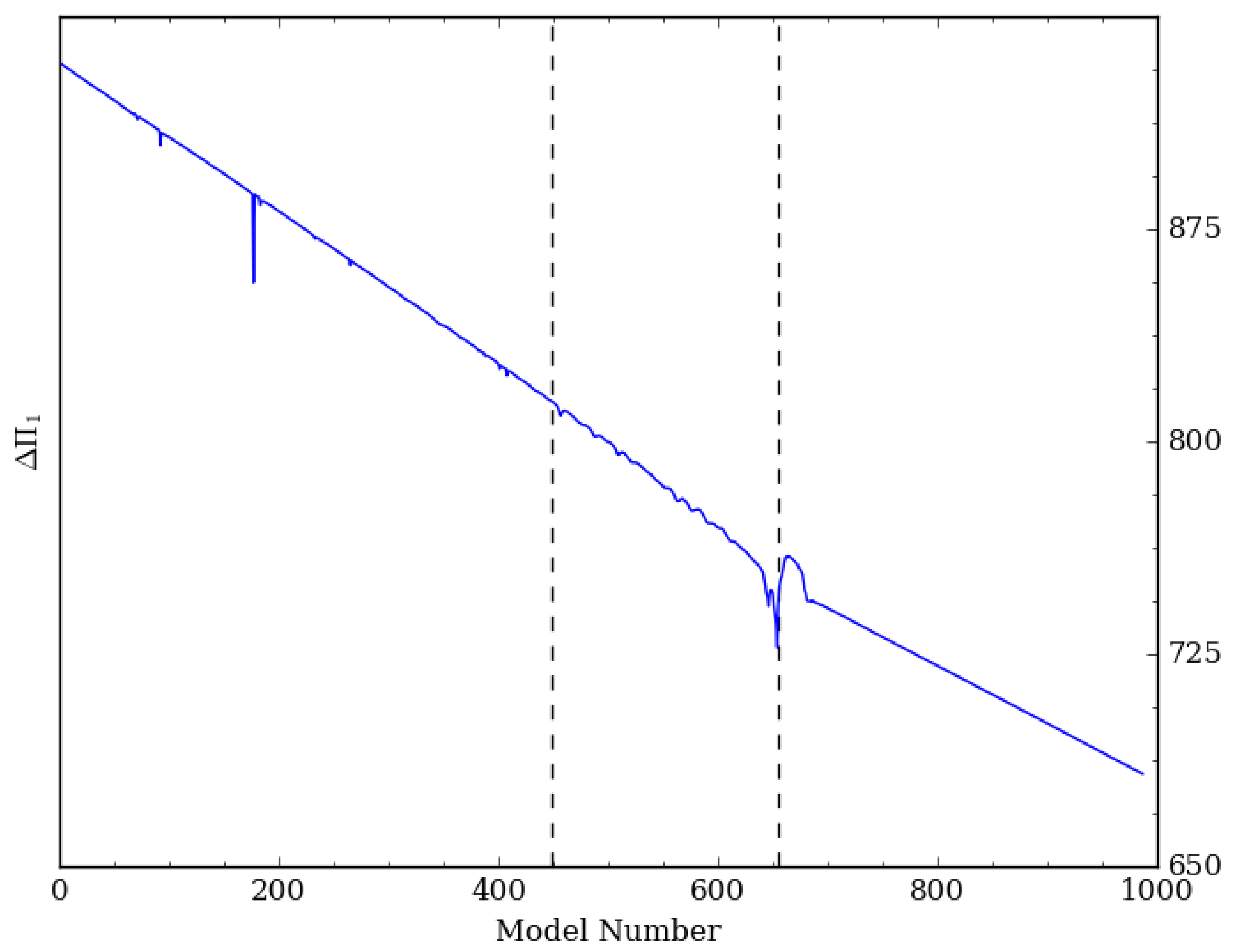

Figure 5: $\Delta\Pi_1$ for a 1.0 solar mass track through the bump

Figure 5 shows that the Period Separation displays interesting behavior at the end of the bump. This was found to be the case regardless of mass, though it has not yet been pursued further.

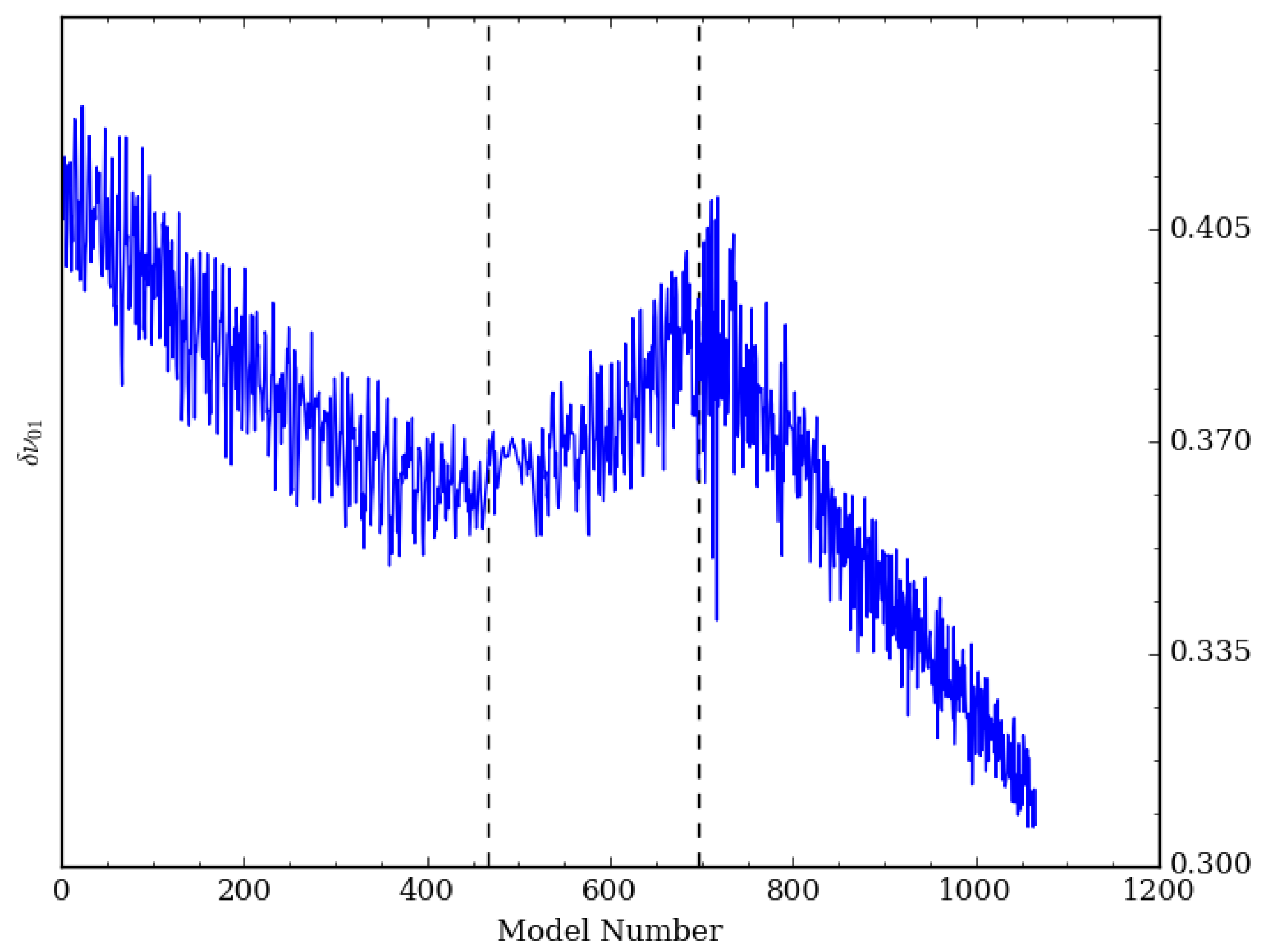

Figure 6: $\delta\nu_{01}$ for a 1.0 solar mass track through the bump

Figure 6 displays the noisiness in the frequency separations. This was unexpected, since models don't tend to have noise, and should be further investigated.

CONCLUSIONS

We have found that asteroseismic parameters display interesting behavior during the bump. Moving forward, we want to explore why several questions. Why are the frequency separations so noisy? Can we explain the behavior of $\Delta\Pi_1$ at the end of the bump? Can we develop a diagnostic to tell what stage of the bump an observed star is in?