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Discussion on pulsating white dwarf and sdB stars

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Winget: Before we start this discussion I would like to make a short comment to Michel because this is obviously in his honour. In my official capacity, on behalf of the University of Texas, I want to thank Michel for his pedagogical scientific legacy and his legacy of instruments used to do science (other than he intended to do originally). His pedagogical legacy is the classes he created, the effect he had: the observational astronomy class shaped the University of Texas as a training ground for observers and instrumentalists. There is also a human side that all present are familiar with. There are former and current students who are excellent scientists due to Michel's training. I've had the good fortune to work with two of these: Don Kurtz and Gerald Handler. They speak for Michel's qualities as a mentor. I'm honoured to be here.

On a personal side now, I want to say that I often visited Michel to seek his wisdom. Many times Michel went far outside the box, listening even for my crazy ideas. We've talked about networks, mode identification and selection mechanisms, and nonlinear processes. When the ideas went too far, Michel's energy and enthusiasm always pulled me back, bringing things sharply into focus. With his input, the idea would evolve into something useful and productive. So thank you Michel, for many years of science!

I'm going to make a couple quick comments before we start the discussion. The first thing I want to say is that if you look at asteroseismology just like at any field of science, not just astronomy, you have a sort of trade-off between doing interesting work as compared to doing anything just long enough until it becomes interesting and important work. But you can carry that too far. That's one thing. The other thing is that work you find interesting often produces very exciting and unexpected results because that's the nature of basic research. You cannot put a panel together and decide where important discoveries will be made in the next ten years.

That said, I want to look briefly at the astrophysical context for the white dwarf and the sdB pulsators in particular. We don't really know what their evolutionary state actually is. Asteroseismology offers great promise of illuminating that. Also, in the case of the white dwarf stars, we learnt a great deal about the structure of their progenitors, as Travis has talked about. We learnt about extreme physics: crystallization and neutrinos. Interestingly, we can connect with dark matter, we learnt about axions. It is not possible, to the great frustration of many particle physicists, to hide axions completely. If they exist, they carry energy, and so one can use the energy loss of the white dwarf stars to measure some pulsators to constrain astrophysically interesting candidates for dark matter in the form of axions. You can also, as Mike Montgomery showed, look at time dependent convection; you can look at how the convection changes during the pulsation cycle and actually learn something about it in real time. Also, you can use these really accurate clocks, the pulsating white dwarf stars, as the most stable clocks we know of. If you have these stable clocks, you can use them for many things, for instance to search for extrasolar planets. These searches using white dwarf stars are unique in the sense that they can show us other solar systems dynamically similar to our own. So there is a wide range of things that one can do asteroseismically looking at sdB stars and white dwarf stars and it's that context that we always have to keep in mind when we ask where we should go in the future. So that said, I am opening up to the questions that have come up and I hope for some disagreements and hopefully get perspectives for the future.

Mukadam: I would like to hear the theorist's view on amplitude modulation.

Breger: The question of the amplitude modulation from the observational side seems to be simple, namely you make a Fourier analysis and look at the peaks. If you have two peaks, you have two frequencies; if you have three peaks, you have three frequencies, or you have one frequency with a sinusoidal amplitude modulation. Now this simple scheme does not work well. The Fourier analysis does not tell you what happens, and you need specific models to test. One of the models is beating by two close frequencies. When you have beating, you have specific predictions, as shown by Dutch astronomers already half a century ago. One of the tests is that the amplitude variation has to be accompanied by specific phase or period variations. It is a small effect: particularly, at minimum amplitude you need to have the largest phase change. To see this you require a large amount of data and the data set should be longer than the beat cycle. A few large data sets for sdB stars do exist.

Fossat: From my experience with solar data, I believe you seem to ignore the interplay between signal and noise. The noise, by definition, is noisy. When it's noisy, it's changing its amplitude rapidly. For instance, when you have a S/N ratio in the amplitude spectrum of four, the noise can sometimes be two. Then you can have four plus two and four minus two. But four minus two means no signal, because it's lost in the noise. Therefore, you can have either a lot or nothing with actually zero amplitude modulation.

Winget: Absolutely. In addition, you don't only have noise that's random, but you also have pattern noise, which is the influence of other frequencies that are known to be present, and those may modify your detection as well.

Breger: What do you do when you have a mode that disappears and comes back with a phase shift of almost half a cycle (e.g., 0.48 ± 0.02 in 4 CVn)? This suggests beating between two modes with the same amplitude. An alternative explanation of a disappearing mode with re-excitation would have a random phase shift. Of course, you need relatively small error bars for the phase shift to make this test. So I agree with Eric's comment that the data may not be too noisy.

Kawaler: Kepler has talked about GD 358 that is a relatively cool DB that shows amplitude modulation that's larger than anything explained by noise. Dave Kilkenny showed PG 1605, a cool short-period sdB, which also shows apparent changes of amplitude that are much larger than the noise. So there's some physics there, it's not just signal analysis. In the case of the white dwarfs, also in the cool DAs, not only the DBs, we have turbulence, the convection zone, "weather". It's a mess of its own. We don't have that in PG 1605; it does not have a convective envelope. So if you want to blame the period and amplitude modulation on turbulence or convection, what do you do about PG 1605?

Bedding: A probably related question concerning excitation. In the instability strips, do you always see the pulsating stars where they should be, or is it like in other instability strips, where some are constant and some are not?

Kilkenny: The instability strips for both the slow and fast sdB pulsators are certainly covered with stars that are constant, but the question really is, to what limits can you make detections?

Winget: Concerning the DAVs, some recent work by Anjum Mukadam has shown that there may be non-variables within the strip. Kepler, Barbara Castanheira and others are working on the DBVs to find out whether this is just an observational detection limit problem or an error in temperature measurements. This is an important question because you really want to know if there possibly needs to be an additional parameter in the models, maybe some magnetic fields or something else, perhaps metallicity.

Reed: A short question for the theorists that goes along with that. I was interested in these stochastic parameters that Jørgen did some years ago. Some pulsating sdB stars have strong amplitude variability, but are in fact phase stable, whereas others have fairly weak amplitude variability, but are not phase stable. It's not beating because it does not switch on and off. What information is hidden in that? And is there any way to get to that information?

Breger: The problem with beating is that at high amplitudes the phases are nearly constant. The phase variations become large when the amplitudes are small. It is therefore possible that you may be misled in seeing stable phases because you undertake your study when the amplitude is large.

Bedding: I have a suggestion on the name conventions. Rather than p and g subscripts, rapid and slow is used both for pulsating stars and in neutron capture. So I want to stress rapid and slow.

Reed: Stephane had an idea that was nice in the beginning, sP and lP; SPsdBV and lPsdBV.

Quirion: Coming back to the fact that the instability strip is not always pure. The atmospheric composition of sdBs is not homogeneous. If the driving is due to the κ mechanism, you can have pulsating and non-pulsating stars in the instability strip because the chemical composition varies from star to star.

Winget: Many years ago, Hideyuki looked at the question: are r modes excited in pulsating white dwarf stars? His theoretical calculations showed they should be driven. The question is: do we know observationally whether there are r modes or not?

Saio: At that time, we didn't understand the effect of convection and we used simple models. I think that my calculations would be affected by the treatment of convection in white dwarfs. If p modes and g modes are excited in white dwarfs, and the same energy laws apply to r modes, the r modes should be excited as the g modes are.

Kepler: The change of amplitude with wavelength is different for g modes than for r modes. I looked at that back in 1984 for two stars. For those two stars the amplitudes excluded r modes.

Kepler [to Charpinet]: There are more $\ell = 4$ modes in the models than $\ell = 3$ and so on. When you calculate a fit, do you normalize by the value of ℓ?

Charpinet: That's true for g modes, but if you look at p modes, you have the same number of modes for each ℓ (excluding rotational splitting).

Kawaler: In the observed period range, how many modes do your models have and how many are observed? Are there modes excited in your models that you do not see in the star?

Charpinet: For instance, for PG 1325, there were twelve observed frequencies and the number of theoretical modes was 4 or 5 times higher.

Winget: We've reached our time limit now, so we should stop here now, answer any further questions informally, and thank the speakers again.

Danish astronomers use different strategies to protect their ears during a fire alarm...

...whereas Belgian astronomers seem to have some training for such situations.