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Discussion on δ Scuti and roAp stars

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Kaye: We've seen data for very fast rotators and some data for slow rotators. There's the assumption made that you can map 1:1 the position in the line profile with the position across the stellar disk. There are times when that is an OK assumption and there are times when it is not. I leave to anybody to comment on that.

Kurtz: I'm trying not to keep this on the topics that Oleg and I are interested in, but when you [to Kochukhov] said "assumption-free" in your model for the pulsation what worries me is that you can use Nd or the rare earths that are concentrated towards the poles. So let's imagine a radial pulsation where the amplitude is the same on the whole surface. When you go to the pole, the abundance is higher, the opacity is higher, you're higher in the atmosphere and we know that there's a depth effect, so you might just map the abundance instead of the real pulsation amplitude.

Kochukhov: I had no time to mention this issue in my talk. In fact, the pulsation Doppler Imaging technique fully takes into account a non-homogeneous horizontal abundance structure. We have reconstructed horizontal chemical maps for many elements in HR 3831. None of the rare-earth ions (including Nd that was used in pulsation mapping) shows a strong abundance concentration at the magnetic poles. It is a common assumption, frequently used in studies of Ap stars, that rare-earth ions concentrate at the poles, but studies of real stars reveal different patterns for different ions. For instance, Eu is concentrated in small spots (which are offset from the magnetic poles), but there is no such concentration for Nd.

Kaye: If you look at your data, you only have a limited number of pixels across your line profile, and each single pixel has signal to noise. So at a very slowly rotating star, where the line profiles become very narrow, even at very high resolution you're not going to have that many pixels across the line profile. So when you draw your conclusions from that, it may be worthwhile to make some comment and take some care.

Kochukhov: In my presentation, I did not discuss Doppler Imaging of slowly rotating stars. The only star for which indirect surface mapping of pulsations was applied so far is a fast rotator ($v \sin i \approx 30$ km s^{-1}).

Ryabchikova: We also presented the results of abundance mapping of HR 1217, with $v \sin i$ of 5.6 km/s. It was still possible for this star.

Bedding: I'd like to remind you of the work by Ivan Baldry et al. on H_α. The rare earth elements are of course interesting, but you made the statement that 33 Lib was the only star with a node in the atmosphere. Ivan found a node in H_α for α Cir, and hydrogen is uniformly distributed over the surface. So I would like to remind both the observers and the theorists about H_α and its bisectors.

Kochukhov: The problem is that these observations were done at very low resolution. In this case the blending of the wings of H_α with various rare-earth lines cannot be resolved. We now have very high-resolution time-resolved spectra of several roAp stars (including α Cir) from UVES and we can see different pulsation patterns in the rare-earth lines and in H_α. So, the results by Baldry et al. were really interesting, but the question is, was their interpretation correct and applicable to H_α or was the whole picture a result of unresolved blending of variable rare-earth lines with H_α?

Cunha: Moving back to theory, one of the limitations of the study of the influence of the magnetic field and rotation on the oscillations was that in practice the magnetic fields of these stars are larger than 1 kG. Therefore the effect of rotation isn't obvious. When you look at the perturbations to the eigenfrequencies, you see that they follow a cyclic pattern, and that, at certain values of high frequencies or high magnetic field, they actually go through zero again, i.e. the eigenfrequencies don't seem to be perturbed. Thus, the question is: if you go to higher magnetic field still, and find a frequency where the magnetic perturbation is close to zero, can the rotational effect become important again?

Dziembowski: I promised Don Kurtz perhaps a year ago that I will calculate the effect, but I forgot. But I know the answer! The answer is that the magnetic frequency perturbation is in certain ranges very small, so that the rotational effects are again important. But then, one should see the asymmetry, but we don't, so that's a problem.

Metcalfe: We know from the Sun that there is a latitude dependence of rotation. Is there any way to take this into account?

Kochukhov: There is quite a large range of observations of spotted Ap stars, and the spottiness allows us to trace the movements of those chemical features over many rotation cycles. The answer is no, there is not a single observation that suggests that there is differential rotation. There are some models of the interaction of magnetic fields and differential rotation and they do not survive. Either the differential rotation kills the magnetic field or the magnetic field kills the differential rotation.

Matthews: With MOST, we have a lot of observations of rotationally variable stars, including solar-type stars. We just submitted a paper showing the rotation profile of κ^1 Ceti that has actually the same functional dependence as the Sun. We also have data for several Ap stars among our guide stars and we see absolutely no evidence for differential rotation in those stars. So I think it's self-consistent with the spectroscopic data.

Reed: Kind of relating the differential rotation of the δ Scuti stars, Mike Breger was saying earlier that all the slow rotators have stronger radial modes. Maybe it would be interesting for the theorists to investigate what the effects of differential rotation would be on the radial modes.

Dziembowski: If you add solar-like differential rotation, you may couple radial modes not only to quadrupole modes, but also to $\ell = 4, \ell = 6$, and things become so complicated that for the time being, I would prefer to think only about uniform rotation.

Michel: Considering the correlation between the amplitudes and $v \sin i$ for the δ Scuti stars, we studied a number of stars in a few clusters a few years ago. Therefore we knew we are dealing with stars on the main sequence. We found a correlation between amplitude and $v \sin i$. We separated the two quantities v and $\sin i$ and found a correlation of the amplitude with $\sin i$. We could understand this in the sense that the amplitude changes due to geometric projection effects, rather than something that's directly related with the rotation rate.

Breger: This correlation becomes quite difficult on the main sequence because you also have to consider that metallic-line A stars pulsate much less than normal stars and many show very slow rotation. The effort that you have done is valid, but it always becomes very difficult if there is more than one variable parameter. So the simple things become more complicated...

Frandsen: As we also see for the Sun, even if you have a nice set of frequencies, you are in very bad shape for seismic modelling if you don't have any additional constraints. Even for solar-type stars there are too many free parameters so that different models match the same frequencies. Maybe this will change when very precise observations become available, but I'm not even sure of that. Now for δ Scuti stars the situation is much worse because there is nothing in the distribution of the frequencies that helps to find out where you are in the frequency spectrum. Now, if you fix for instance the mass and chemical composition that might help you with the mode identification, and then there are a few free parameters less in your model fit, this gives a fantastic improvement in your chances to getting things right.

You can work on eclipsing binaries, where you can determine the masses, or, as Eric already mentioned, in open clusters. The only problem with clusters is that the δ Scuti stars are faint, so you need big telescopes to get precise spectroscopic observations, which is a hassle.

Paparo: Jadwiga showed a nice presentation of FG Vir, where we have many many modes, but finally she gave identifications only for the dominant modes. How can we use the many other modes if we don't have identifications for them? Why do we need so many modes if we cannot use them? For many other δ Scuti stars we have information on the dominant modes. Have you used your method for these stars? How many stars have you investigated and did you find a case where the method failed?

Daszynska: I start with the last question. We did β Cas, AB Cas, 20 CVn and 1 Mon. In all cases the method worked, especially when you add the radial velocity information because it is uncorrelated with the photometric observables. In all cases we got a mode identification and in all cases we found that convection should be rather inefficient. For FG Vir we got mode identifications for twelve modes because only those were detected in spectroscopy (we had two photometric passbands and radial velocity information). For modes with very high frequencies, above 30 c/d, we found instability only for very high-degree modes (with ℓ larger than 60). So, the low-amplitude peaks in FG Vir's oscillation spectrum may correspond to high-degree modes of unknown azimuthal order, hence are not useful for asteroseismic probing.

Breger: May I add to what Margit said: if you have, say, 100 frequencies, but a mode identification for only 12 of them, what about the other 88? It's of course a question of the S/N ratio. If you get more colour photometry or spectroscopy, you can increase the number of identified modes. I was alluding to that earlier when I compared our ground-based work with space-based observations. At a certain point it doesn't matter how many frequencies you have discovered, it is a matter of what you can do with the frequencies.

Dupret: I would like to stress that for all stars towards the red edge of the instability strip (say $T_{\rm eff} < 7500$ K) it is important to include time-dependent convection in the models. It changes significantly the predictions of the f values, especially their phases. With this in a non-adiabatic code we can get a much better agreement with the observations. It's not only important to use time-dependent convection for the mode identification, but also for the determination of the other parameters. For instance, the predictions are then less sensitive to the mixing-length parameter α, because of the control of the temperature variations by the energy equation throughout the time-dependent convective flux (high superadiabatic gradients leading to large phase lags in the H ionization zone are no longer allowed).

Daszynska: We applied time-dependent convection to FG Vir.

Dupret: The theoretical predictions depend also on what atmosphere models you use, not only the smoothness of the derivatives but also the physical prescriptions, for example the treatment of convection. Different physical prescriptions give very different monochromatic flux and limb darkening.

Gamma Doradus stars and solar-like oscillators