**Don Kurtz: *TESS* man mission studies of main sequence A to mid-F stars**

Magnetic Ap stars have spots.

Ap SrCrEu basically has nothing going on in the frequency domain.

Delta Scuti are one of the most common pulsating stars that we can perform asteroseismic inference on. ‘The frequencies are everywhere’.

Amplitude and phase of modes of delta Scuti stars can vary relatively quickly.

‘High Amplitude Delta Scuti’ are simple.

Note: harmonics appear when a signal is non-sinusoidal.

Frequeny group (fg) stars, gamma dor, clear collections of mode envelopes in the power spectrum--- only 4 modes physical, others noise.

Stellar pulsation does **not** have to be around the rotation axis. Lionel Bigot’s work shows this.

For binary stars the pulsation axis should be along the tidal axis (because this is the axis of most distortion).

Can tidal disruptions localize p-modes to a single hemisphere of a star?

**Vichi Antoci: The first view of delta Scuti and gamma dor with TESS**

Empirical determination of the instability strip from Kepler seems to match the theoretical

location well.

Rho Puppis example: TESS data helped clarify what was going on with the star with its expanded frequency range.

Gamma Dor revisited (Brundsen+19). 17 new frequencies with TESS (!). When observing gamma dor stars with 27 days of data in TESS it may note be identifiable as gamma dor (looks more like a rotational variable). With 3 sectors worth it becomes clearer. In the CVZ we can do a proper analysis (but still not close to Kepler).

With TESS we can observe the bright stars and perform unbiased analysis of A and F stars.

**Zhao Guo: Tidally Excited Oscillations (TEOs) in Heartbeat Stars**

~160 heartbeat stars in Kepler.

There are some in TESS too.

Challenges in this field are:

-Reliably identifying TEOs

-Spin orbit misalignment

Tidally locked modes might affect stuff too--- fortunately tidal impact is modeled in Gyre now!

Heartbeat stares are not rare.

They coexist with sloscillations, tidally excited oscillations. They can coexist with free oscillations as well.

Different effects on the modes allow us to probe different stuff.

**Paul Beck: Testing tidal theory from red-giant binaries**

A complete tidal solution includes a dynamical tide and an equilibrium tide (which is the tides due to hydrostatic adjustment). We know about 40 red giant in binary systems where we only detect the signature equilibrium tide.

Inertial waves can exist in RG stars maybe. Example: KIC 9163796

Timescales of tidal evolution in a binary system exceeds observing time bases. Ensemble studies are the way forward instead. The tidal evolution is dominated by the equilibrium tide.

Seismology helps us to improve the classical analysis with masses and radii (which are otherwise taken from dynamical calculations).

Does orbital eccentricity serve as diagnostic for the evolutionary state?

**Cole Johnston: What TESS can do for tidal pulsating binaries**

Most stars live in binaries. Binaries provide powerful constraints through isochrones fitting.

Isochrone fitting in general struggles to reproduce observations sometimes if the masses are dynamical--- known as the ‘mass discrepancy’. This is generally fixed by including overshooting as a correction, which caused a divide in the literature.

Cole says there **is** mixing inside stars.

What happens when we add seismic info? G mode stuff that can probe internal mixing.

Take two well detached double lined spectroscopic binaries.

Double lined = both stars have spectroscopy

Tides are important to include. Two types of tides;

1. Static or Equilibrium tide
2. Dynamic tide -> time dependent response to orbital motion, tidally excited oscillations (TEOs, heartbeat stars).

Tess will provide more eclipsing pulsating binaries to calibrate the core mass problem.

More cases like U Gru will appear to constrain the impact of binaries. This will really help our understanding of tidal theory.

**May Gade Pedersen: What TESS can do for massive stars**

O & B stars, like 3 solar masses and upwards.

Current challenges:

Chemical mixing inside these stars.

Angular momentum transport, rotation rates of the stars. Logg as a proxy for age. Bit difference between core and envelope rotation. Core in general is slower.

Asteroseismology of massive stars.

Chemical mixing. These massive stars all have convective cores. Convection is efficient and mixing the material in the core. The hydrogen from the shell can be used as fuel in the burning process. Convective boundary mixing effectively increases the size of the core, makes the star appear more massive but makes it live longer on the main sequence.

How is period spacing affected when the star evolves. It changes considerably in scale and periodocitiy depending on main sequence evolution.

If you have extra mixing, the chemical gradient (which causes the mode trapping) changes. So by comparing the period spacing we expect to what we observe we can constrain mixing efficiency in stars.

We can use oscillations in slowly pulsating b type stars to probe the convective mixing. As the star evolves you get mode trapping.

Angular momentum transport: two ways to get rotation. Rotational splitting, or slope of period spacing series. See also: Talk by Sebastian Deheuvels.

In most cases ther eis no reigid rotation on the main sequence of the star. As they evolve core/envelope differential rotation becomes more common. So angular momentum is transported somehow!

The traditional Taylor Spruit model needs adapting to match the core rotation we see in RGB, Clump, White Dwarves. In the main sequence the star is mostly rigidly rotation. This is Fuller+2019 work. The angular momentum transport timescale is very short. If you have a very slow rotating star we can build up differential rotation already on the main sequence.

Angular momentum can also be transported by internal gravity waves (see dom bowman talk).

Modeling & choice of input physics:

observations -> modeid -> observed properties -> model selection <- theoretical pulsations <- M stellar model for input physics <- input physics

Gets us an estimate of age and mass of the stars. See talk by Tao Wu.

What we actually want to do is derive mass, radius, age, calibrate and improve input physics, so we can understand the stars better.

Looking at opacities for tehse kinds of stars. Increasing metallicity is not efficient to excite pulsations, need to change opacity models instead.

For gravity modes its important to have long time baselines to actually resolve the modes, and the smaller your errors are. The smaller the errors, the better we can constrain the input physics.

We see a very diverse type of variability with the OB stars with TESS first light. TESS is not sufficient on its own, so we also need additional information for this type of modelling.

Spectroscopic ground based follow up is on the way.

TESS wil/is provding: 1 yr lcs of ~400 OB stars. Diverse ensemble w varying [M/H], rotation, age, mass.

This allows us to classify ghte photometric variability + compose asteroseismology OB sample including the LMC. Lets us constrain mixing and rotation profiles through asteroseismic and spectroscopig anc astrometric modelling of single and binary OB star pulsators.

**Dom Bowman: Low-Frequency gravity waves in blue supergiants revealed by high-precision K2 and TESS photometry**

What are gravity waves?

Waves restored by buoyancy with a stable stratified medium.

IGWs are efficient at transporting angular momentum and chemical elements! There is a rich spectrum of IGWs near the surface on massive stars.

We need a sample. Kepler didn’t include many OB type stars. K2 did though. 116 OB stars in the sample.

Detections of stochastic variability in early-type stars with TESS, get to look at stars in low metallicity environments (which we didn’t get along the ecliptic), e.g. the LMC, which is in the CVZ for the south.

We finally have a large sample of OB type stars to test **wave physics** in the stellar interiors.

Brighter and more massive stars have larger IGW amplitudes and lower IGW frequencies.

IGW morphology is insensitive to metallicity.

Coupling 3D hydro simulations with observations for massive stars. 25 Msol star shown, trying to compare a simulated one to the observed one.

Conclusions: IGWs appear to be common in massive stars, including LMC ones with low metallicity. Future evo models should include IGW angular momentum transport.

K2 and TESS observations of massive stars eveal previously unstudied types of variability.

**Derek Buzasi: Multi Epoch asteroseismology and massive stars**

B stars are frequently understudied. Relatively common, bright. Implies accessibility from ground and space. Science questions include internal differential rotation and angular momentum transport, convective core overshoot, diffusive mixing.

These 34 targets are unique, previously observed using the WIRE satellite.

TESS really clears up the peaks from WIRE, but theyre still in the same spot neatly enough.

3 new oscillating and eclipsing binaries with TESS data. Adding MOST and BRITE fills in the time series and makes theme ven longer.

**Lucas Viani: Effects of overshoot on models**

Changes the MS lifetime, alters turn-off location of isochrones.

Also important for fitting isochrones of open clusters.

What if we could predict the overshoot based on the properties of the star? M, log, Teff, numax etc. Is there a trend?

LEGACY sample. Grids of finely spaced models. Covers a wide parameter space (same parameters as Khan+18).

Calculate the likelihood for each model:

L = Lfreqs Lmet L teff Wage

Stellar properties determined with likelihood weighted average.

Finds mass trends also seen in previous model literature (deheuvels+16).

What about the inclusion of diffusion?