Stellar structure across the HR diagram

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Stellar structure with asteroseismology

Classic observables

$T_{\text{eff}}$, log $g$, [Fe/H]
+ distance
+ luminosity
+ masses (binaries)

Asteroseismic Diagnostics

$v_{\text{max}}$, $\Delta v$, $\delta v$
+ spacings ($\nu$, $P$)
+ frequency splittings

Forward Modeling
Stellar structure with asteroseismology

Solar like stars and Red Giants
⇒ Talks by M.-J. Goupil, W. Chaplin & A. Miglio

Classic observables

- $T_{\text{eff}}$, log $g$, [Fe/H]
- + distance
- + luminosity
- + masses (binaries)

Asteroseismic Diagnostics

- $\nu_{\text{max}}$, $\Delta\nu$, $\delta\nu$
- + spacings ($\nu$, $P$)
- + frequency splittings

Forward Modeling

PLATO 2.0 Science Conference, Dec 3 - 5, 2014

K. Zwintz
Forward modeling

- Equilibrium Models of stellar structure + Theoretical pulsation predictions + Seismic diagnostics

- Assumptions on input physics (micro- & macro-physics)

- Simplification: non-rotating, non-magnetic star without a wind

- Mode-Identification: label observed frequencies with appropriate l and m values
Big challenges in theory...

- Rotational motion: surface to core
  - angular momentum transport
- Convection
  - MLT or CM / CGM, Overshooting, Semi-Convection
- Magnetic fields
- Atomic Diffusion
- Diffusive Mixing
- Opacities and various chemical mixtures
- Reliable mode identification
- Determination of stellar ages
... and how observations can help

- Rotational motion: surface to core
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A star (Kurtz et al. 2014)

sdB stars (e.g., Bloemen et al. 2014)

Massive star (e.g., Moravveji et al. 2014)

Period spacings (e.g., Van Reeth et al. 2014)

Seismic ages (e.g., Zwintz et al. 2014)
The SPB star KIC 10526294: g-modes

Papics et al. (2014)

g-modes: almost constant period spacing

$P_{\text{rot}} \sim 190$ days

19 equally spaced dipole modes with rotationally split triplets
The SPB star KIC 10526294: Diffusive Mixing

Moravveji et al. (2014)

\[\begin{align*}
M &= 3.25 \pm 0.01 \, M_\odot \\
X_C &= 0.627 \pm 0.001 \\
f_{ov} &= 0.017 \pm 0.001
\end{align*}\]

Diffusive Mixing: \(\log D_{mix} = 1.75 \pm 0.25 \, \text{cm}^2\text{s}^{-1}\)
p- and g-modes in the A star KIC 11145123

Kurtz et al. (2014)

p-mode triplets & quintuplets

splittings: \( \delta_{nlm} = m \beta_{nl} \int_{0}^{R} K_{nl}(r) \Omega(r) dr \)

15 g-mode triplets

\( P_{\text{rot}} \sim 100 \) days
Internal rotation of an A type star

Period spacings decrease as the star evolves

→ Measurement of “stellar age”

Kurtz et al. (2014)

KIC 11145123: TAMS contraction phase
Period Spacings in γ Doradus stars

Well defined sample of Kepler γ Doradus stars

A type star KIC 11145123

Tkachenko et al. (2013)

KIC 11721304: even longer series

Van Reeth et al. (2014)
Angular momentum in pre-MS stars

70 Herbig Ae/Be stars

Alecian et al. (2013a,b)

34 Pre-MS δ Scuti stars rotation with 50% of $v_{\text{critical}}$
at maximum

Zwintz et al. (Science, 2014)
Towards seismic ages for pre-MS stars

\( f_{\text{max}} \): highest observed p-mode frequency

Relation between oscillation properties and evolutionary stage

close to birthline

close to ZAMS

Zwintz et al. (Science, 2014)
Atomic diffusion & mode-ID in sdB stars

Blue edge of instability strip: KIC 10139564

gravitational settling, concentration, thermal diffusion & radiative levitation

Bloemen et al. (2014)
Atomic diffusion & mode-ID in sdB stars

Blue edge of instability strip: KIC 10139564

- Gravitational settling, concentration, thermal diffusion & radiative levitation

KIC 10670103: richest sdB star

- 278 periods from 0.4 to 11.8h: 163 (59%) are $l \leq 2$

$\Rightarrow$ tight constraints for models

Reed et al. (2014)
Expectations from PLATO data

- **Period / Frequency spacings for various types of oscillating stars**
  - internal rotation profiles
  - angular momentum transport
  - evolutionary stage $\Rightarrow$ stellar ages
  - mixing processes
    - global rotational mixing, magnetic fields, internal gravity waves

- **Frequency splittings**
  - mode identification, rotation

- **Color information**

- **Long time series for “new” types of stars (e.g., pre-MS stars)**
PLATO Complementary Science

- Does not drive the requirements of the mission (determined by core programme)
- Does not occur in the funding profile of the mission

Production of Variability Catalogue
- Microlensing

Binary & Multiple Stars
- Galactic Structure

Pulsating Stars earlier than F5
- Extragalactic Science

Multi-wavelength Analysis of Young Stellar Objects
- Spectroscopic & Interferometric Follow-up

Stellar Flares & Coronal Seismology

WP 160 000
Complementary Science
Conny Aerts

Expressions of Interest to take part in the PLATO Complementary Science programme:
send to Conny.Aerts@ster.kuleuven.be by 15 December 2014

Taormina, 03.12.2014