ASTEROSISMOLOGY and SEARCH for EXOPLANETS

# Comparison of Numerical Tools

## Stellar Models and their Oscillations

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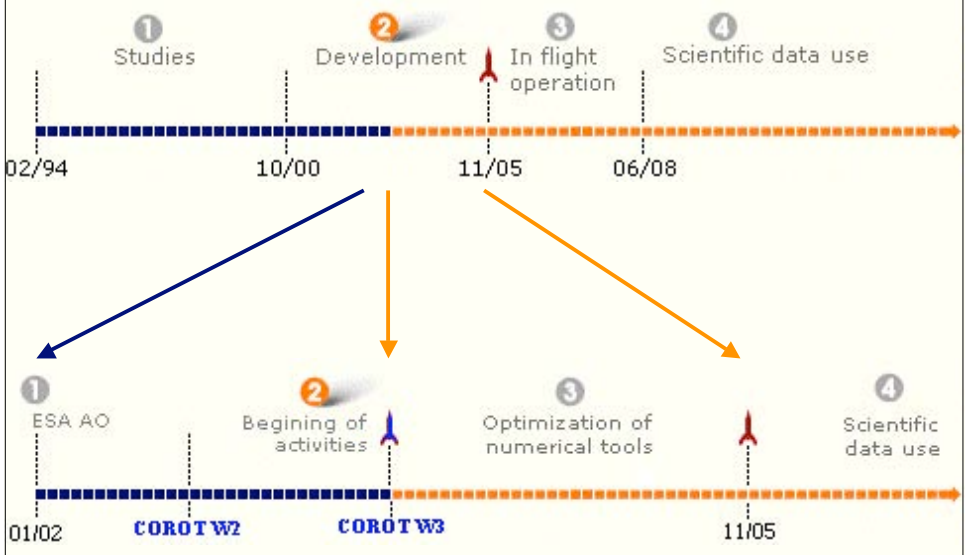
## COROT Schedule




## Comparison of Numerical Tools Schedule

## Comparison of Numerical Tools

Comparison of different tools for the calculation of stellar models, their oscillation properties, and the inferred stellar properties.

### Computation of Stellar Models

Comparison of numerical codes being used to model stellar structure and evolution. Identification of the main aspects of the physics used in the codes and the numerical methods affecting the precision and validity of the models being calculated.

### Computation of the Oscillations and Associated Inversion Tools

Comparison of the numerical tools for calculating the eigenvalues and eigenfunctions of the oscillations. Development and comparison of the tools available from Helioseismology to invert the differences model-observations, and estimation of the applicability and sensitivity of these different tools for inversions of real stellar data.





## ACTIVITY [CNT1.1]: Computation of Stellar Models

**Numerical procedures:** This task aims at identifying possible sources of errors due to the numerical procedure adopted in the codes. We will carry out detailed comparisons of models computed independently with different codes, using the same, precisely defined physics. In particular, it will involve comparisons between the CESAM code, developed by Morel and extensively used in the COROT project, and the Aarhus stellar evolution code.

*Example*: we need to make sure that the differences in our interpretations are not due to differences in the numerical treatment of the same physics!

| ß Hydri | $L/L_\odot$ $T_{eff}$ (k)<br>Z/X Δν (μHz) | Code | $M/M_\odot$ | Age (Gyr) |
|---|---|---|---|---|
| Di Mauro et al. (2003) | 4.01±0.25 5860±70<br>0.021±0.007 55.77±0.17 | Aarhus | 1.07-1.20 | 5.2-6.1 |
| Fernandes & Monteiro (2003) | 3.53±0.10 5774±60<br>0.019±0.003 56.2±2.0 | CESAM | 1.06-1.17<br>[0.87-1.31] | 6.4-7.1 |

## ACTIVITY [CNT1.2]: Computation of Stellar Models

**Implementation of the physics:** Up-to-date physics must be implemented in the codes in order to secure compatibility and relevance for the comparison of the results. The latest physics have to be implemented consistently. Some of the components we will focus on are:

**EOS and Opacities** - the latest data must be implemented in the codes securing consistency of the physics and a stable numerical implementation in all relevant regimes.

**Boundaries of convective regions** - the treatment of convection, and in particular the numerical implementation for modelling the borders of convective regions has to be revised. This is a fundamental aspect requiring further development of numerical techniques and physical understanding.

**Atmospheres** - we hope to include improved treatments of the stellar atmosphere and upper convection zone through fits to detailed hydrodynamic models of convection. A better representation of the surface layers has to be achieved in order to correctly represent the structure where reflection of the modes takes place.

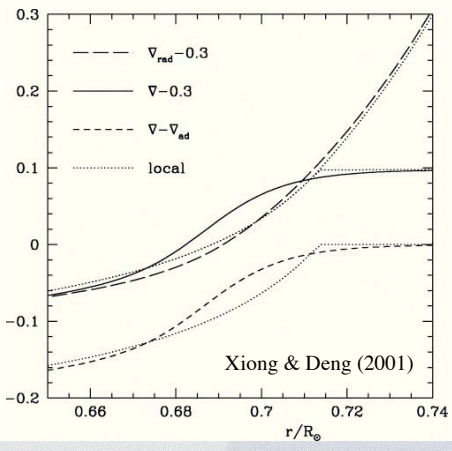
**Etc …**



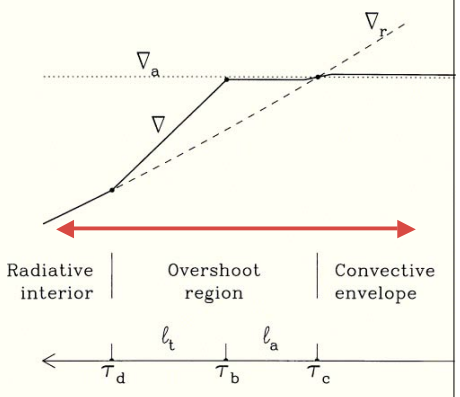


## Boundaries of convective regions

The physics and the numerical representation of the borders of convective regions (envelopes or cores) can have a measurable influence on the frequencies. How we represent such borders in our codes must be revised.




Xiong & Deng (2001)




Monteiro et al. (2000)

**Different formulations and numerical implementations will be tested and compared.**

## ACTIVITY [CNT2]: : Computation of the Seismic Properties

**Numerical procedures:** This task aims at identifying possible sources of errors due to the numerical procedure adopted in the codes for calculating oscillations. We will carry out detailed comparisons of eigenfrequencies and eigenfunctions computed independently.

Some aspects of the physics affecting the calculation of the oscillations can - and should - be revised. We hope to be able to test and develop the numerical procedures adopted regarding:

**Meshes** - comparison of existing options and implementations for defining the relevant meshes for the calculation of frequencies. Special care must be given to the calculation of mixed modes present in evolved stellar models.

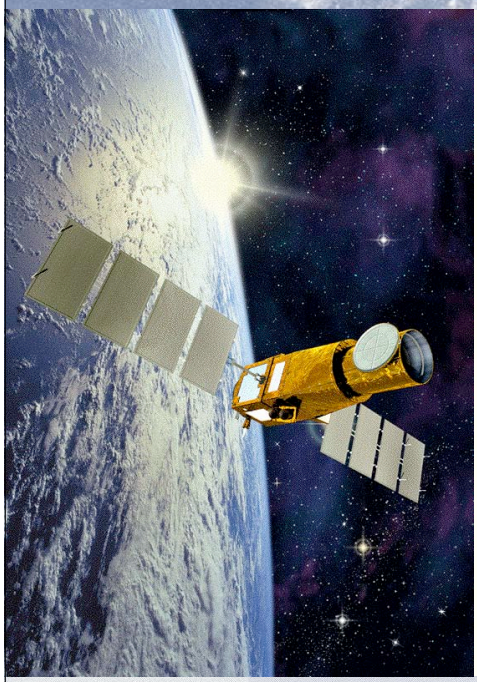
**Boundary conditions** - the surface boundary condition used in the calculation is very important for determining the actual eigenvalues. We need to implement, evaluate and compare what are the most adequate and relevant boundary conditions to use for each case.

**Kernels and inversions** - the numerical implementation of the variational principle for the calculation of model differences from frequency differences has to be developed and compared for the application to other stars.

**Etc …**







## The near future…

For further information, suggestions, proposals on possible collaborations, etc, please contact me either here or later by email at:

mjm@astro.up.pt

Hoping to hear from you soon!

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