Stellar Physics for and with PLATO

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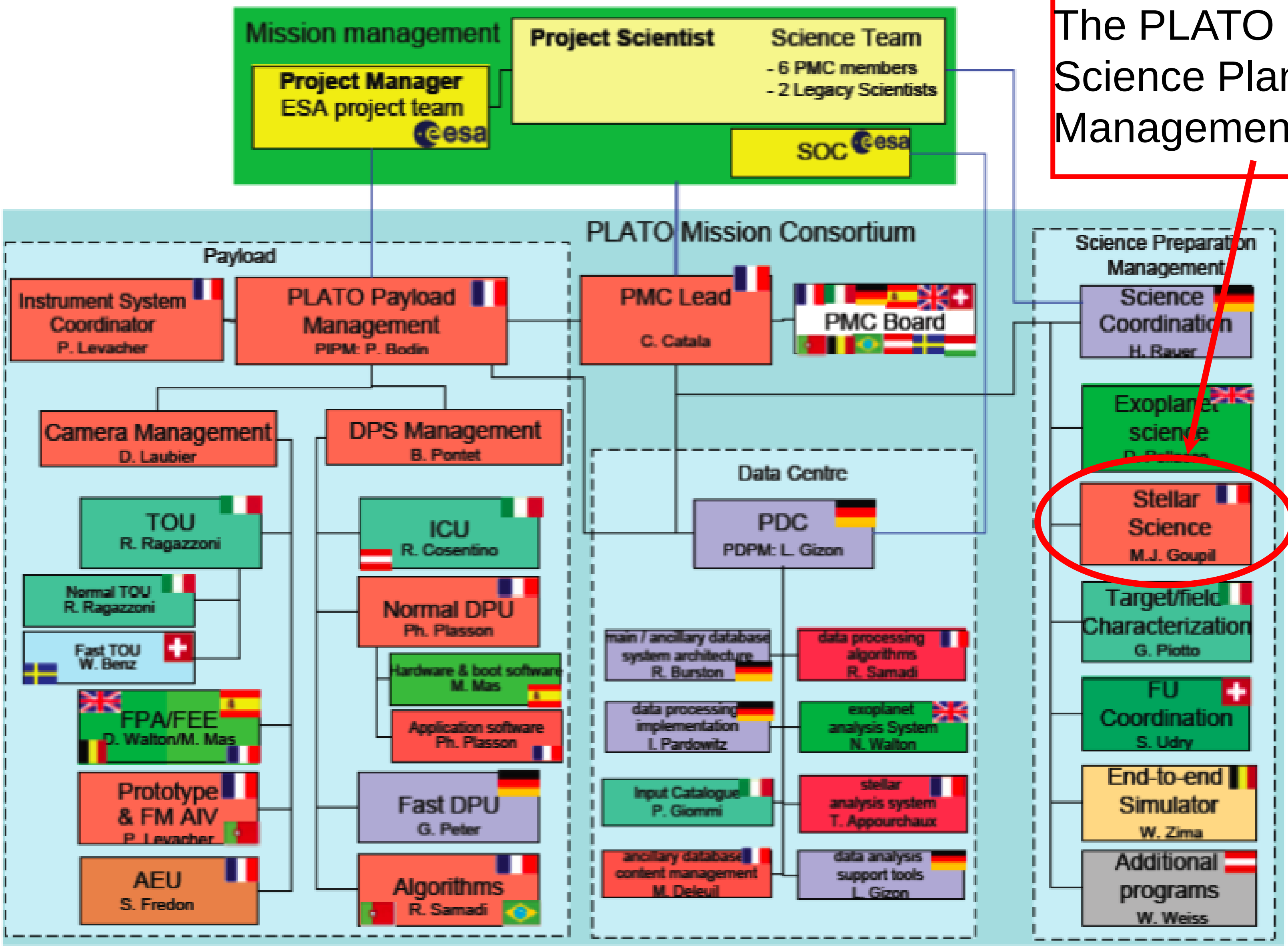
responsible for the work package WP120000

Stellar Science Plan Management

The PLATO Mission Consortium

The PLATO Stellar Science Plan Management WP120



Objectives

To provide all possible characteristics of host stars

Namely

• ***stellar mass, radius and age* of host stars with a precision of:**

Radius ~ 2% -5%
Mass ~ 10% - 30%
Age ~ 200 million years : a few percent for a sun 30% can be enough
20% for a younger M dwarf

Studies in planet Mass-Radius diagram for instance relie on stellar M and R determination. These studies require a ***homogeneous*** stellar mass and radius determination (similar physical description of the stellar models)

• **information (models) about *stellar activity, rotation, limb darkening, metallicity …***

Why do we need a Stellar Science WP ?

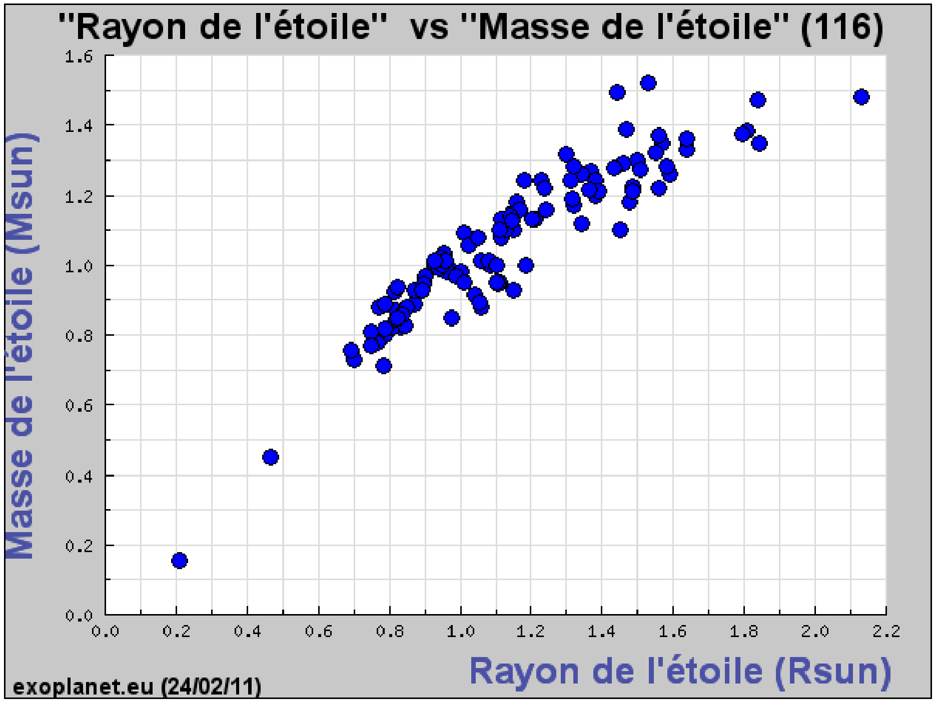
Accurate stellar masses, ages etc… require that we reduce uncertainties as much as possible:

Sources of uncertainties :

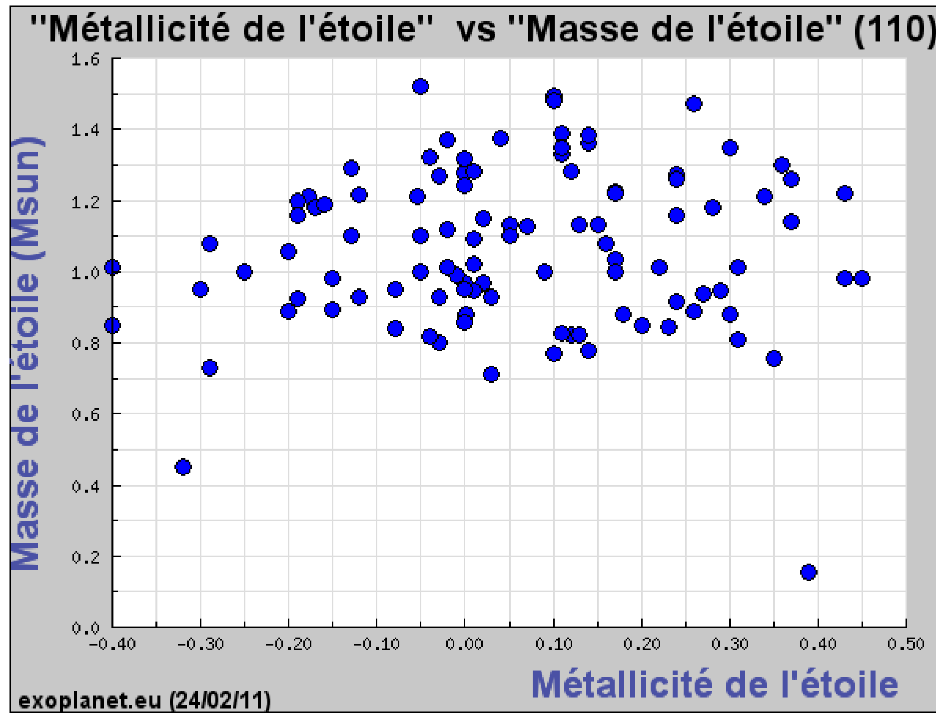
- Observational errors on non seismic parameters Teff, Z, mean density (transit), Prot .. cf T. Morel's talk
- Systematic errors due to method determination : degeneracy problem
- Systematic errors due to nonrealistic physical description of stellar models
  to missing physics in stellar models

Boundary conditions for WP120's work

Legacy from CoRoT and Kepler



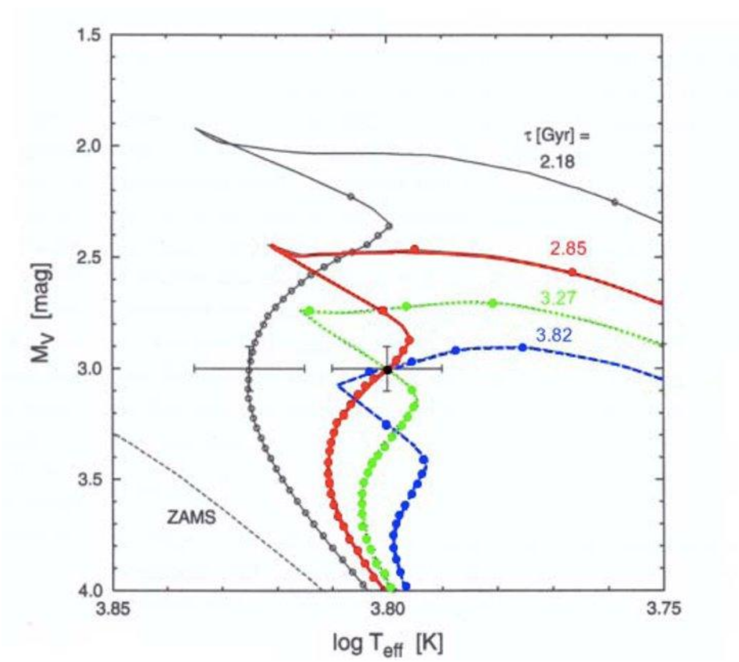
F to M stars, with some focus on early M dwarfs
Masses up to 1.6 Msol
All ages from PMS to RG
Wide range of metallicity

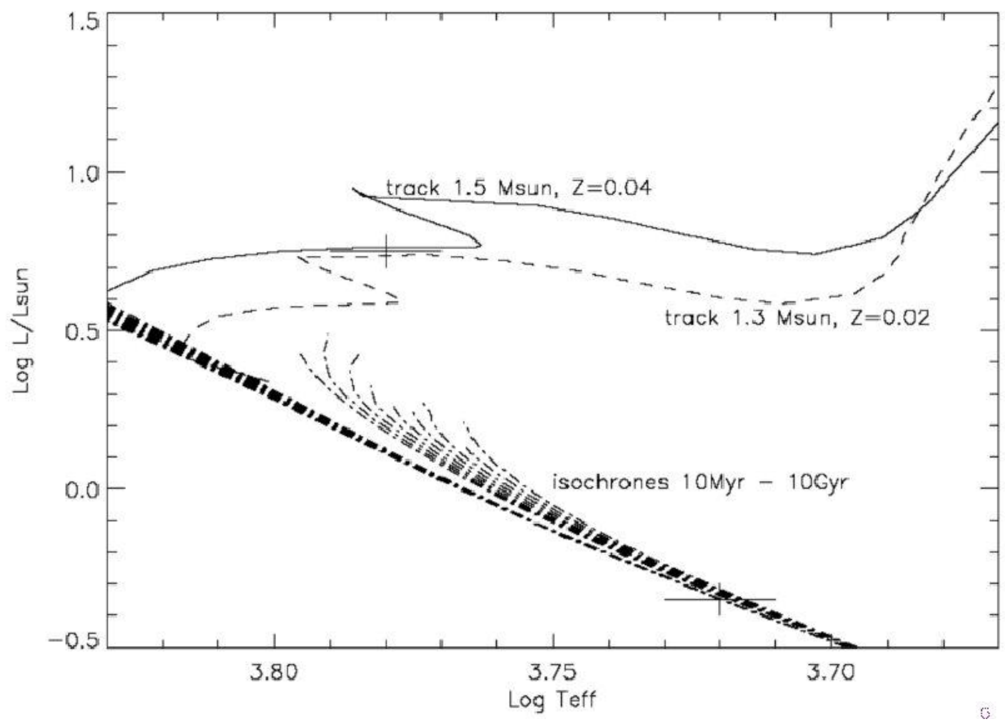


(From Extrasolar planet Encyclopedia (Jean Schneider))

Systematic errors due to method determination : degeneracy problem

Ambiguities on mass and age

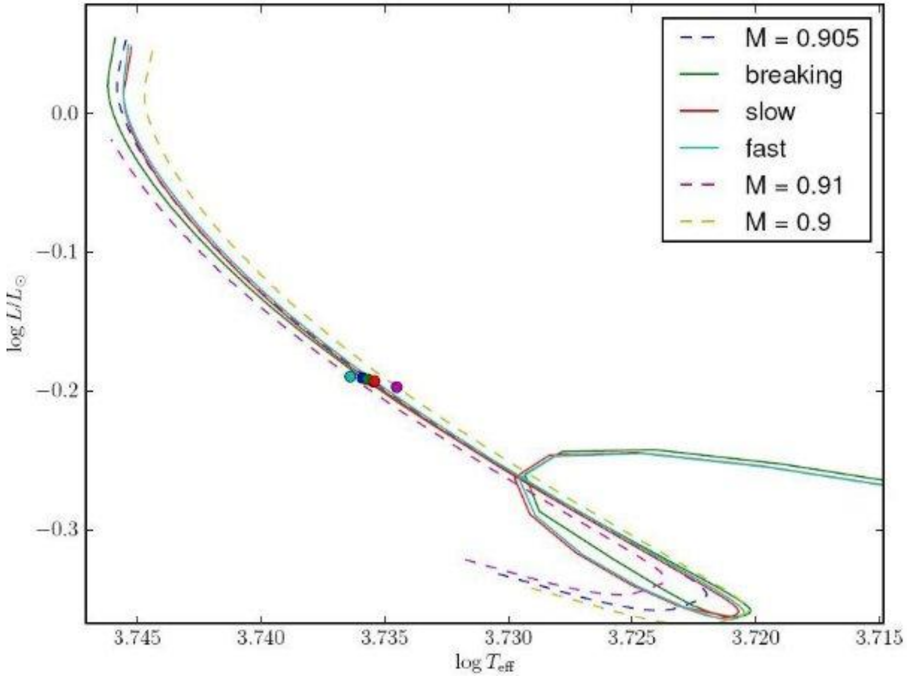




Seismology can lift parts of the degeneracy:

Systematic errors due to ‘missing physics’

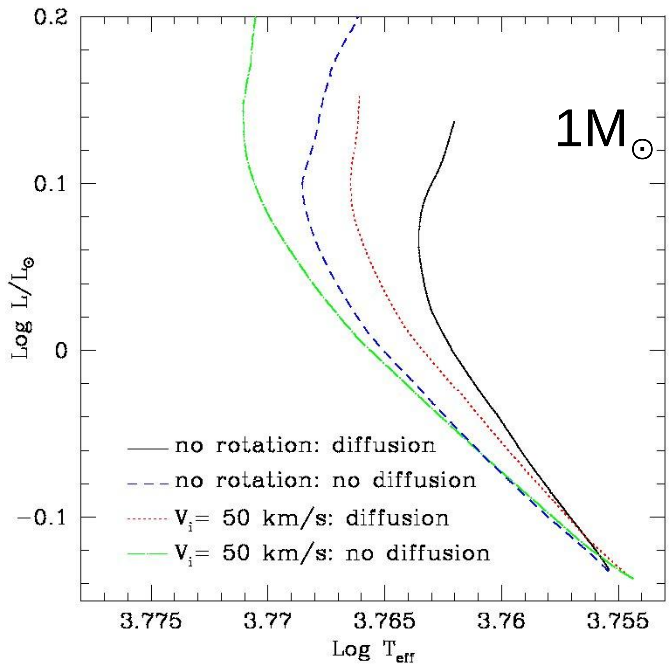
Young sun : rotationally induced transport
Including disk locking with different lifetimes



Age:	
no rot:	7223 Myr
Ω_{ini} fast, no loss of J:	7458
Ω_{ini} slow, no loss of J:	7477
Ω_{ini} fast, loss of J	7536

Marques 2010 Brazil CoRoT COnference

Rotationally induced transport and magnetic field for low mass stars

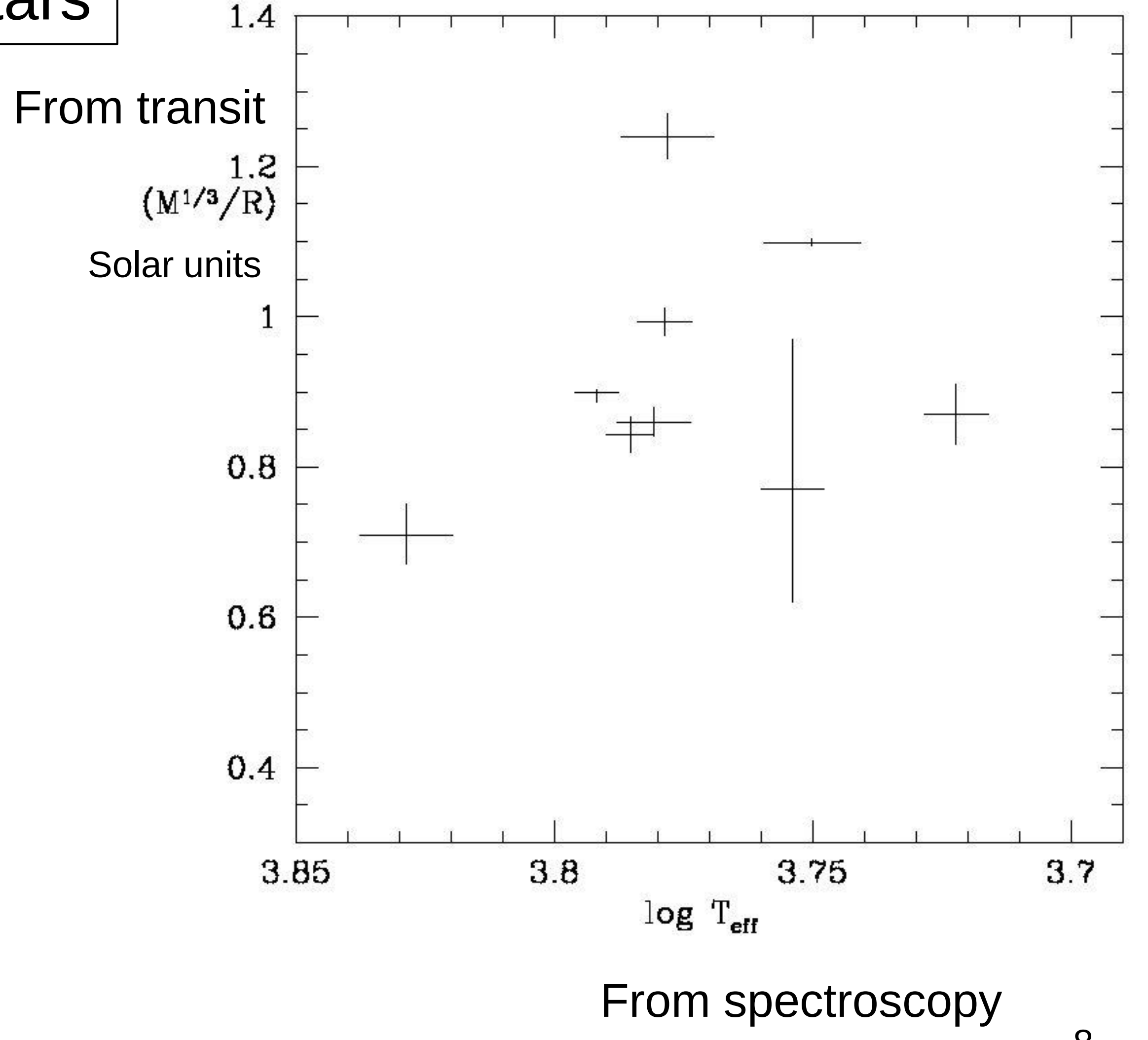


Ages higher by 10% at TAMS
for model with initial rotation velocity
of 50km/s

Eggenberger et al 2010

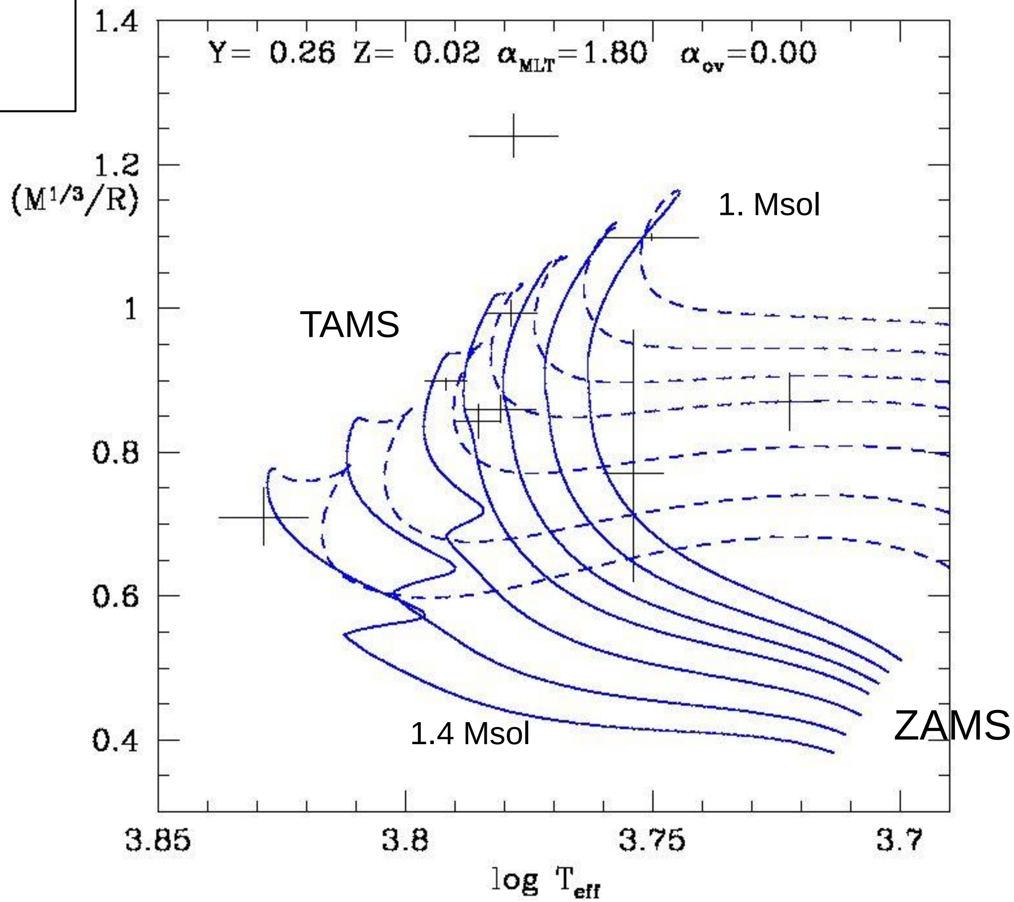
Seismology as a precision tool

Some Corot host stars



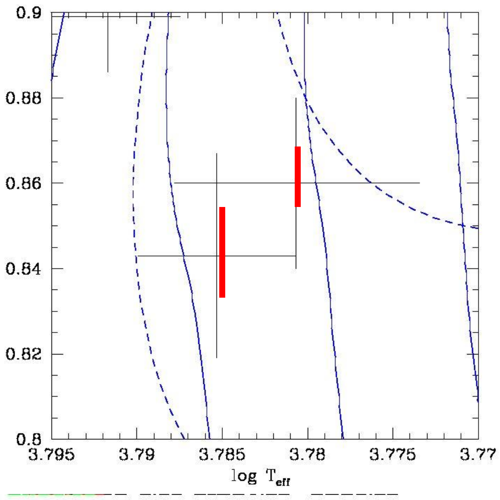
Seismology as a precision tool

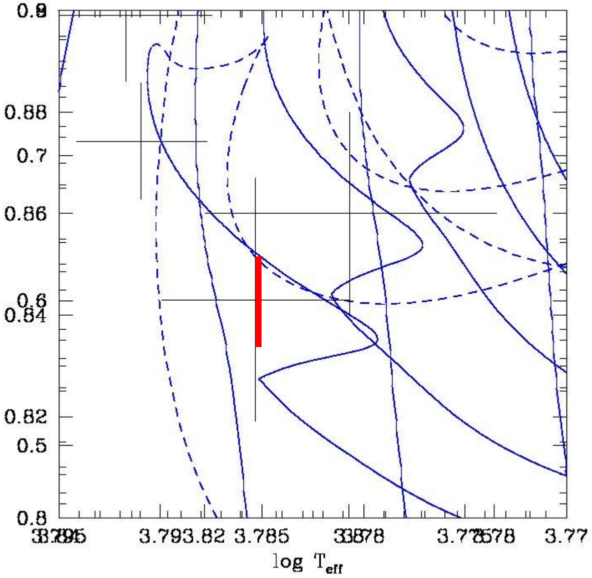
Warning: only for illustrative purpose as stars have different chemical composition



Tracks from Lebreton, Montalban 2008

Seismology as a precision tool



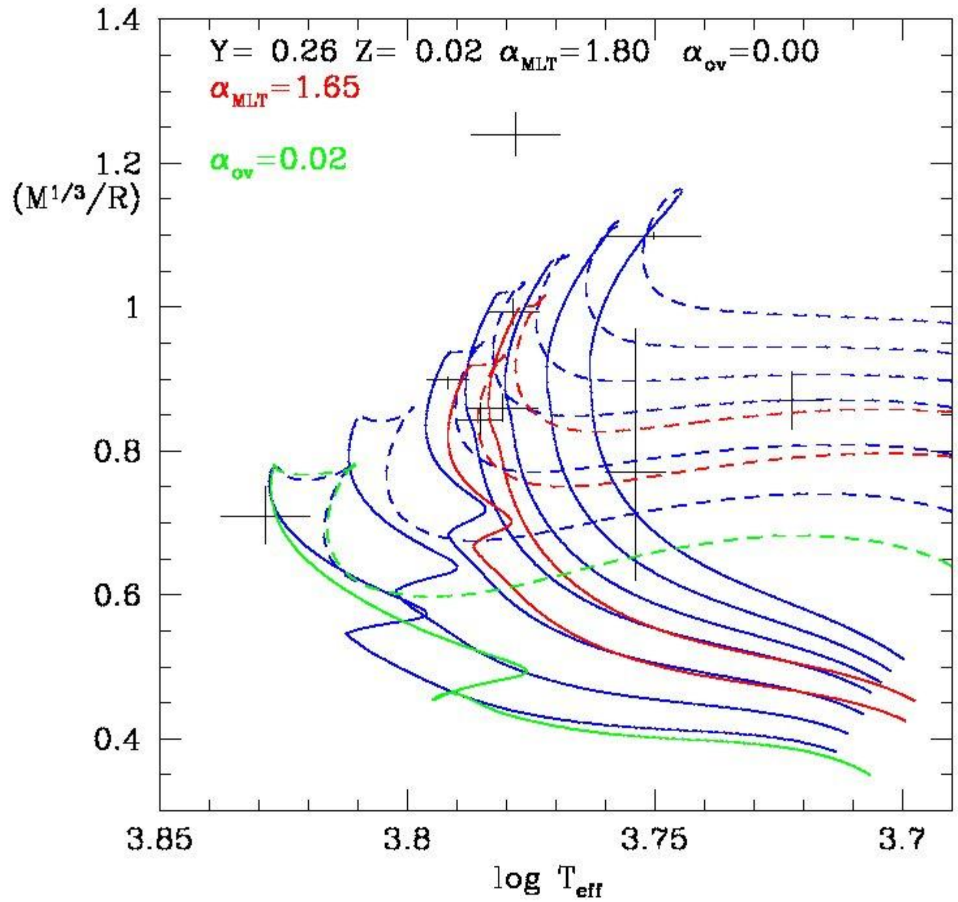


Decrease of uncertainties from transit ρ to mean large separation $<\Delta\nu>$ by ~3
(From Kepler 10b: $<\Delta\nu> = 118.2 +/- 0.2\ \mu Hz$)

Depending where is the star in the diagram this implies a decrease in the uncertatinties in mass or age

With Plato a decrease of both mass and age Uncertainties : from $<\Delta\nu>$ and better Teff as well as metallicity however

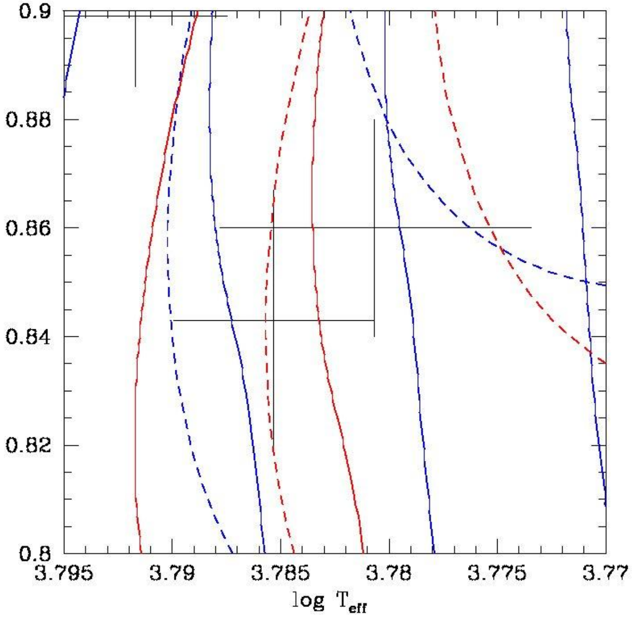
Inaccuracy due to uncertainties in stellar modelling



Red curves: change in mixing length Parameter as a representative of improper modelling of surface superadiabatic convection

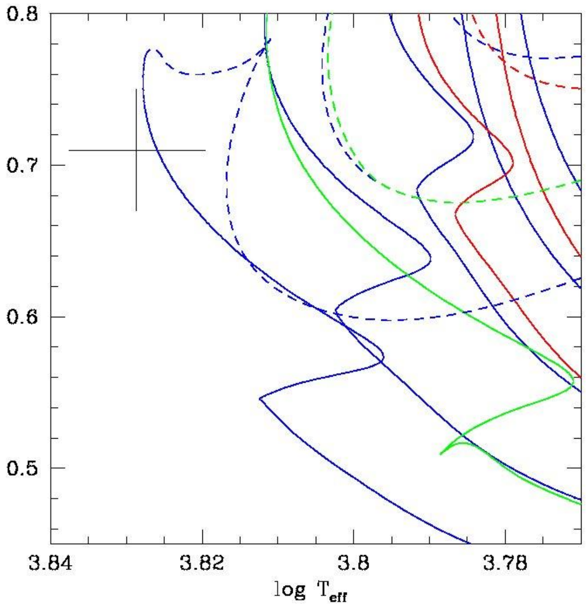
Green curve : change in overshoot parameter as a representative of improper modelling of convection and other transport processes in central mixed regions

Inaccuracy due to uncertainties in stellar modelling



Biases from uncertainties in the physics of stellar models must be removed

seismology can help as a probe of new implementation of stellar physics on well known objects

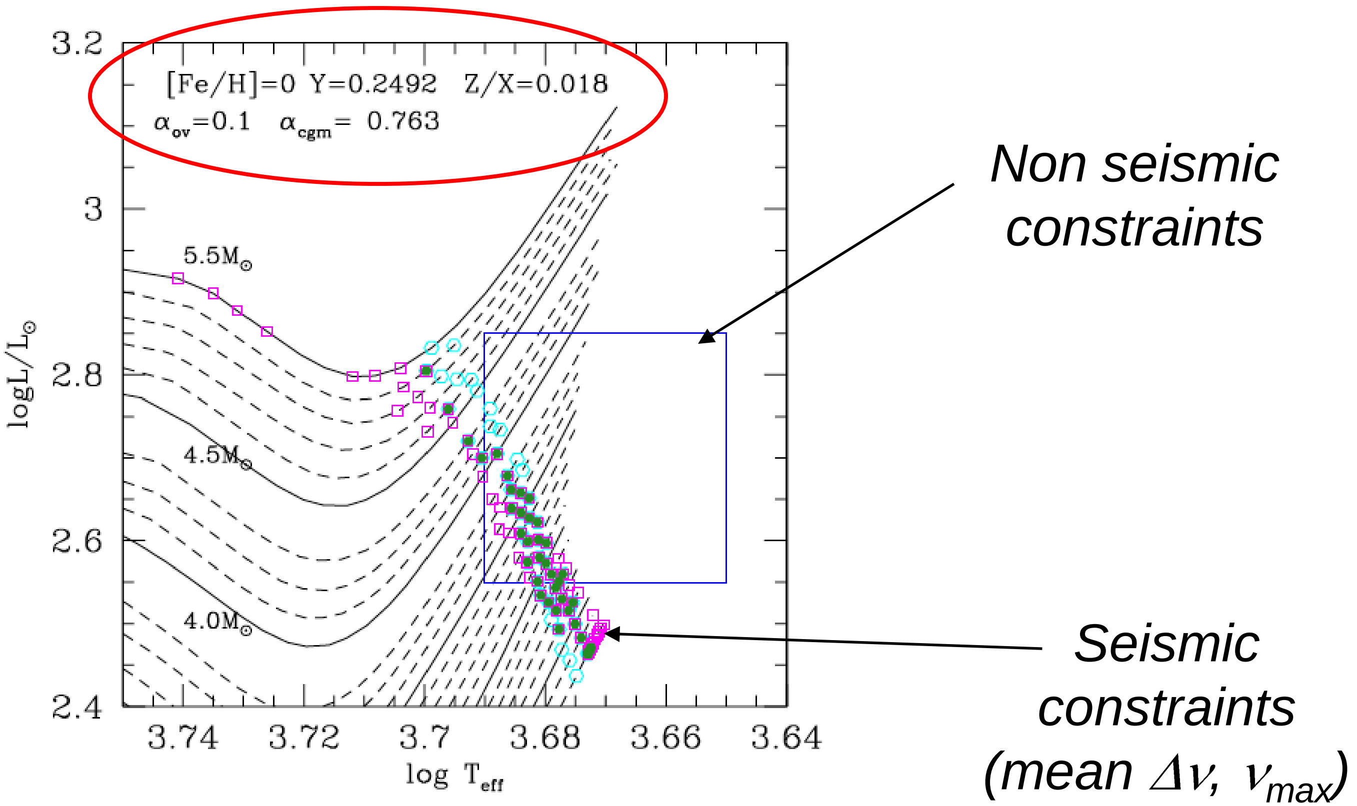


Seismology as a precision tool

Mass determination

In another part of the HR diagram: a CoRoT massive giant star

Non-seismic vs seismic constraints



=> Smaller interval in mass

For Plato host stars, Gaia will reduce the error box in HR

Seismology as a precision tool

Mass determination

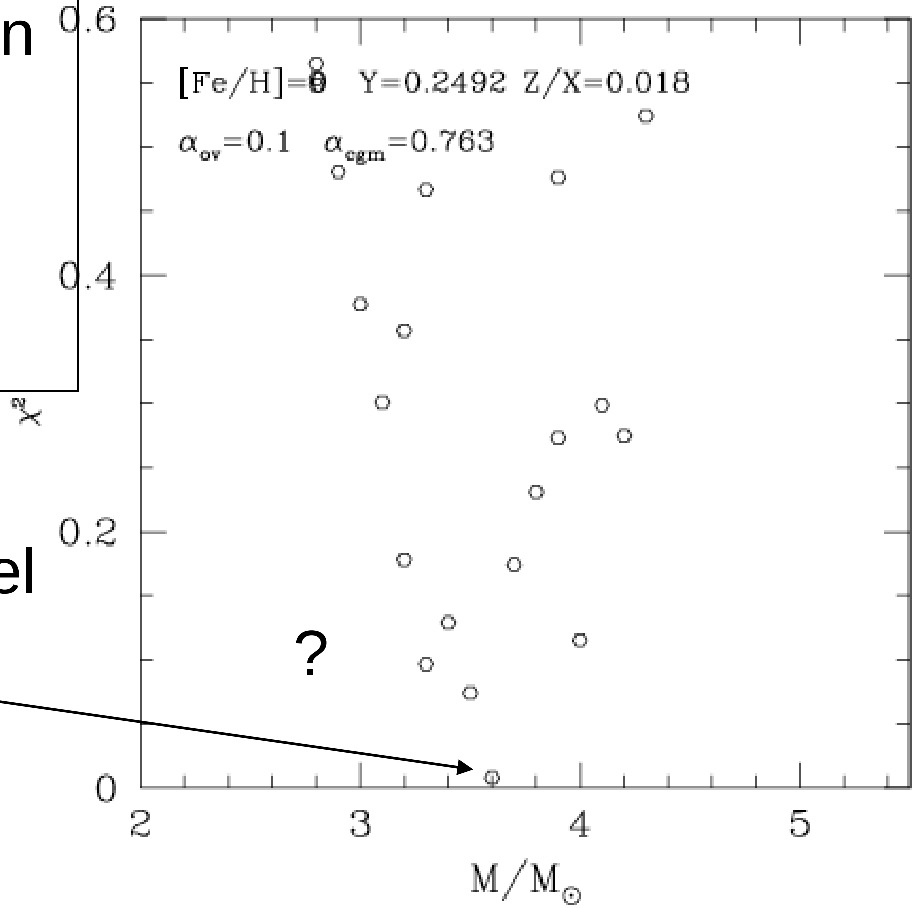
In another part of the HR diagram: a CoRoT massive giant star

Optimum model = lowest χ^2

$$\chi^2 = \sum_j \left(\frac{X_j^{obs} - X_j^{mod}}{\sigma_j} \right)^2$$

χ^2 minimisation within a precomputed grid of stellar models

Optimum model



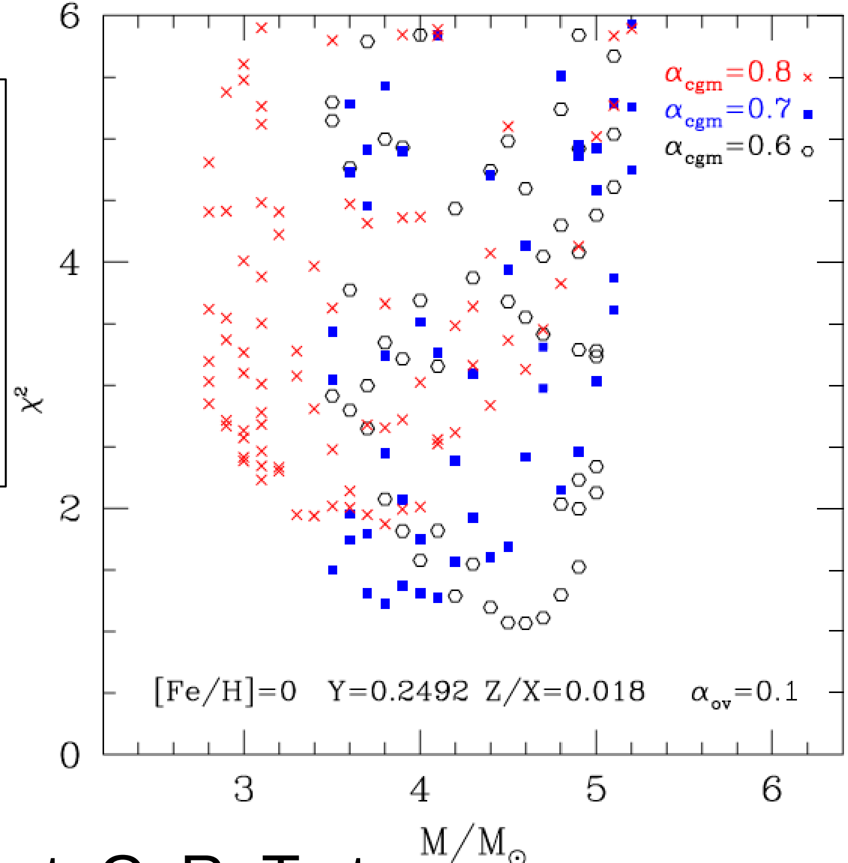
For a given physics

Inaccuracy due uncertainties in stellar modelling

Surface superadiabatic convection

Impact on mass determination

χ^2 minimisation within a precomputed grid of stellar models



$<\Delta\nu>$ νmax
Scaling laws

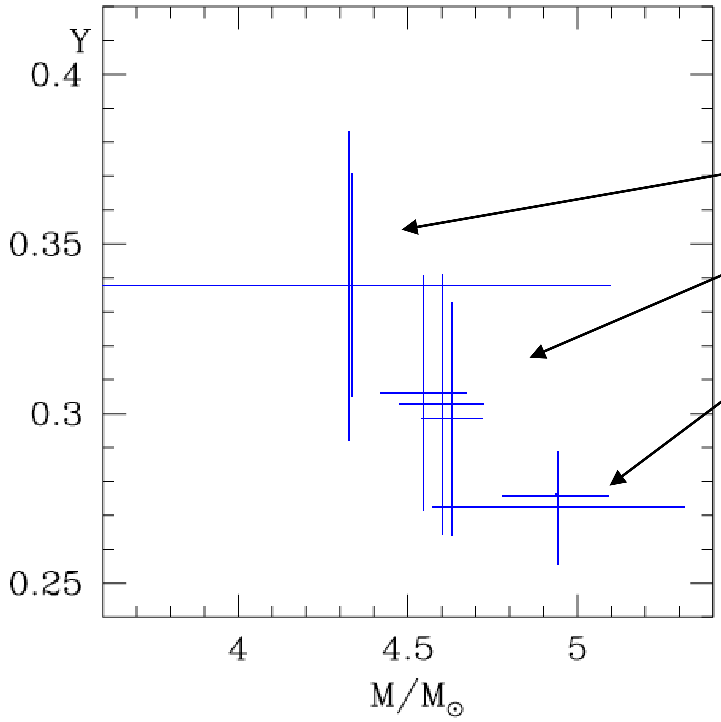
For a massive giant CoRoT star

Only one varying parameter…

Inaccuracy due to unrealistic stellar modelling

Initial helium abundance

Impact on mass determination: degeneracy of the solution



low χ^2 models

Average Isep
Numax
Scaling laws

Strong correlation mass/He

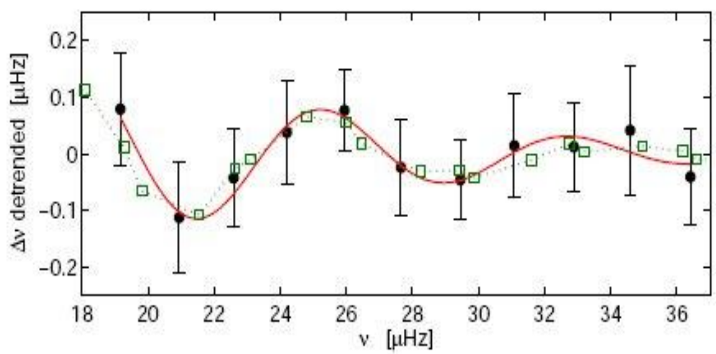
Seismic constraints on mass, age and surface helium

A CoRoT red giant

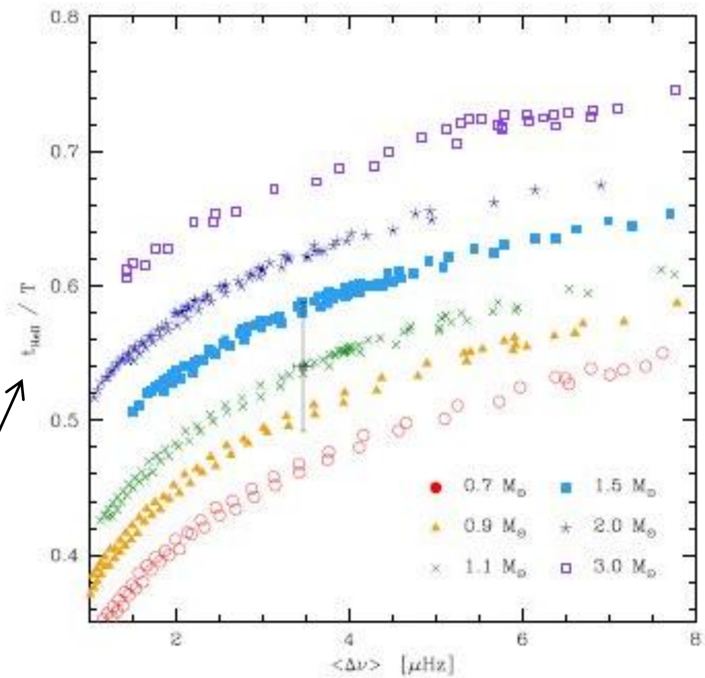
Use of individual frequencies

$$\Delta\nu = \nu_{n,l} - \nu_{n-1,l}$$

1.2 M⊙



- Period of periodic component: acoustic depth of He ionisation zone
- Amplitude is related to envelope helium abundance



$<\Delta\nu>$

0.7-3 M⊙
Y=0.25,0.278
Z=0.02,0.01
α_{MLT} =1.6,1.9

Miglio et al 2010

Seismology as a precision tool

Mass determination

Exemple: Get the mean density then the mass of the star
(I. Roxburgh 2002-2010)

Radius

from Gaia

$$M = 4\pi \int_0^1 \rho(r) r^2 dr = 4\pi\ R^3 \int_0^1 \zeta(x) x^2\, dx$$

Scaled density

$$\zeta(x) = \rho(r) / R^3$$

$$x = r / R$$

From seismic inversions
or model fitting

need for proper

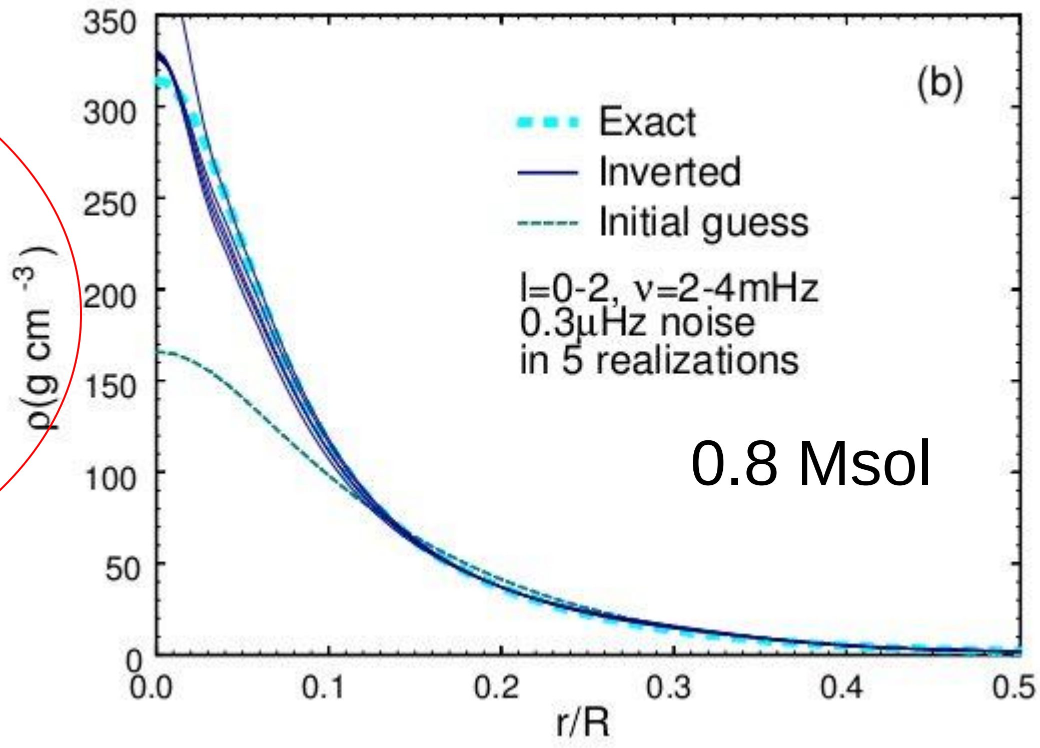
- Input nonseismic data
- Input seismic data
- Stellar models
- Seismic tools

Scaled density

$$\zeta(x) = \rho(r) / R^3$$

$$x = r / R$$

From seismic inversions



0.8 Msol

Roxburgh'(2002-2010)

Can provide masses within 10%

Uncertainties on stellar modelling

Uncertainties on many processes impact on mass and age accuracies

- some are under controlled
- some requires further work

INITIAL CONDITIONS
Initial model
Interaction with
surrounding: disk locking

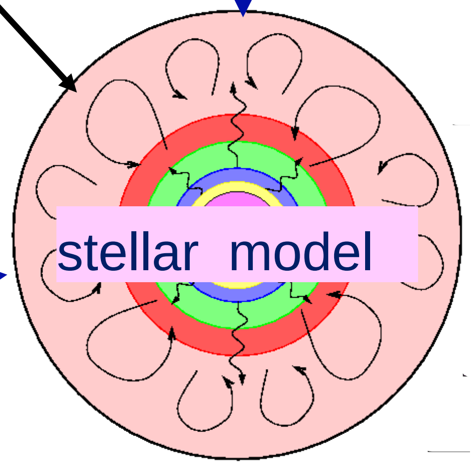
INPUT PARAMETERS
initial mass
initial chemical composition
evolutionary state

Model atmosphere

INPUT PHYSICS

microscopic:
Nuclear reactions
opacities
equation of state
microscopic diffusion

macroscopic: transport and 1D approximation
Convection α
rotation
internal waves
magnetic field and related transports



BOUNDARIES
T-tau law
Mass loss
Angularmomentum loss

NUMERICS

Summary

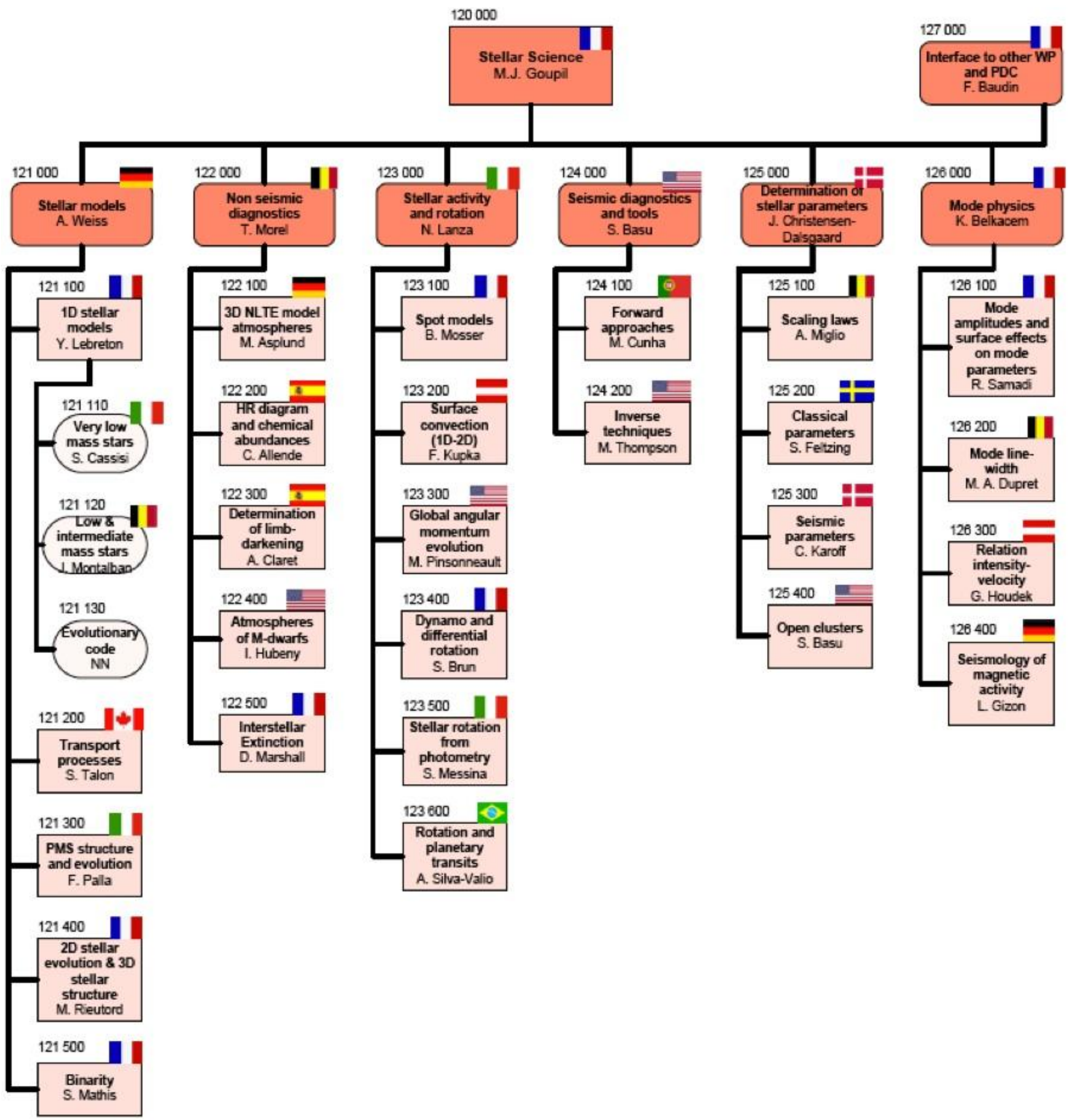
Seismology is quite efficient in providing very precise stellar parameters
given the physics of the stellar models

But

Highly accurate masses, ages, etc…will be obtained with seismology
using more realistic stellar models

Special attention must be devoted to transport processes as they have a large impact on ages and masses and are still poorly modelled particularly at the transition between radiative and convective regions

Organisation of WP 120



Red Giants

Composition of PSSPM :

7 WP with subWPs

\+ interface WP

Organisation of WP 120

Workpackages

121 A. Weiss (Germany) *Stellar models : F to M PMS, MS and subgiants*

122 T. Morel (Belgium) *Non sesismic parameters*

123 N. Lanza (Italy) *Stellar activity and rotation*

124 S. Basu (USA) *Seismic diagnostics and tools*

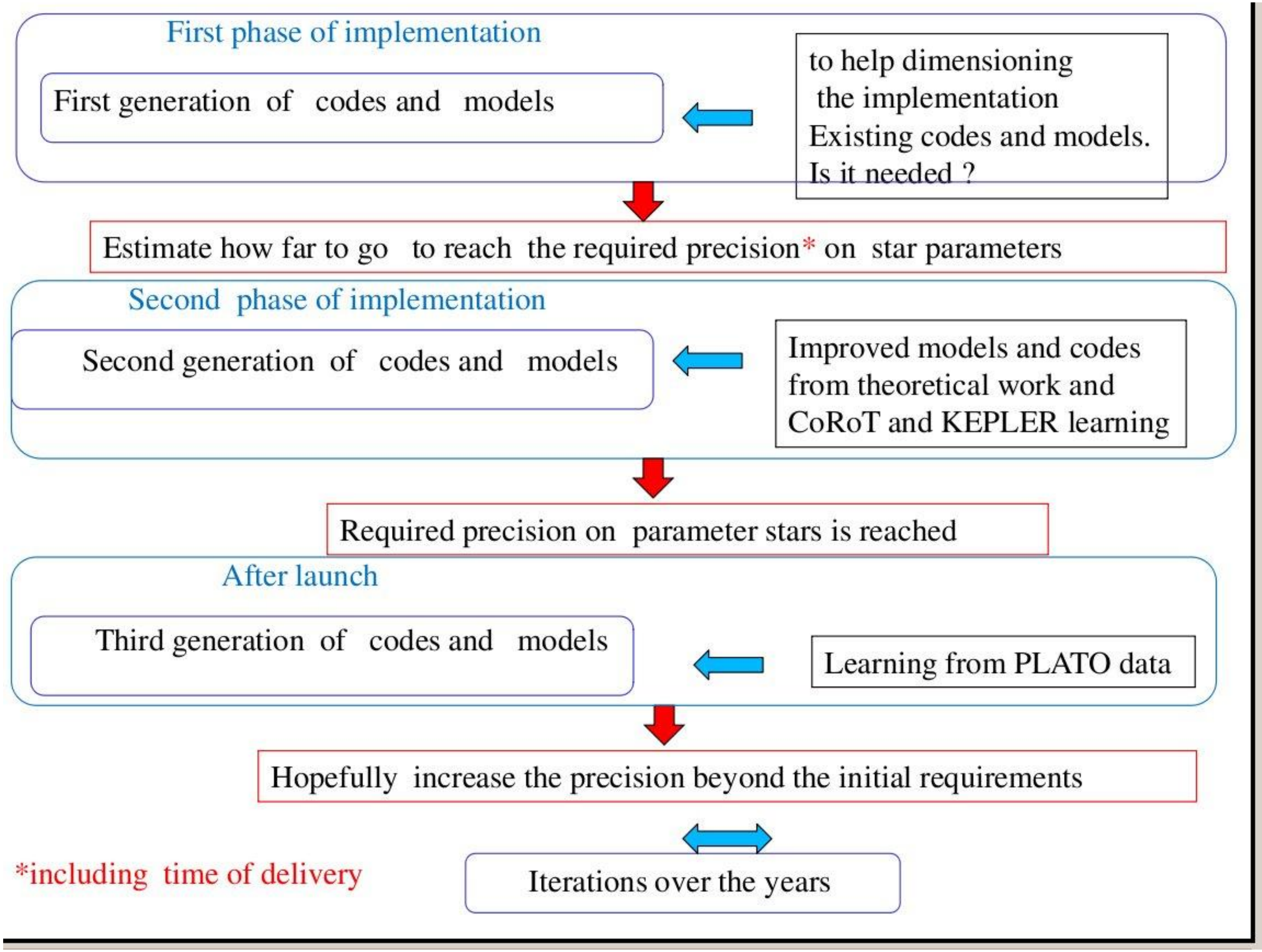
125 J. Christensen-Dalsgaard (Danemark) *Determination of stellar parameters*

126 K. Belkacem (France) *Oscillation mode physics*

127 J. Montalban (Belgium) *Red giants*

128 F. Baudin (France) *Interfaces*

Organisation of WP120: Milestones



Organisation of WP 120

PSSPM web site

aim: for the community to download and upload documents and to circulate information between WP12xxxx

(Responsibles: F. Baudin leader of WP interface WP128000

and K. Belkacem deputy responsible of WP120000)

Organisation of WP120 : Letters of Intent

Objective: the letters of intent aim to organize and identify the groups and individuals interested in working within the PLATO stellar science package.

- A first round of submission closed beginning of January.

○ fifteen research groups answered from France, Germany, Spain, Italy, Brazil, Austria

- A second round is now open

○ First identify the work package you interested in (see *http://www.ias.u-psud.fr/PLATO_SSPM/PLATO_SSPM_OBJ.html*, for the SSPM structure)

○ In the LOI you will have to:

✓ give contact information
✓ give a short description of the work you intend to do.
✓ Provide an estimate of the fraction of your time you hope to allocate to the work covered by the LOI

○ It can be submitted indifferently to both websites:

✓ the SSPM: http://www.ias.u-psud.fr/PLATO_SSPM/PLATO_SSPM_LOI.html
✓ the PSPM: http://www.oact.inaf.it/plato/PPLC/PSPM/PSPM.html

Acknowledgments

To K. Belkacem (deputy assistant) and F. Baudin (interfaces)

and

To leaders WP and sub WP

who are quite cooperative with all the work I am requested A. Weiss, T. Morel, Y. lebreton, N. Lanza, M.Cunha, S. Basu, J. Montalban and many others

Fin

Procedures : 3 Cases to be considered

- Large sample of stars : scaling laws
  automated: rapid
  ΔM, ΔR, Δage large

⇨ Initlal conditions for more sophisticated studies

⇨ first order delivery for exoplanets

- Smaller sample of stars : model and frequency fitting
  automated rapid to slow
  ΔM, ΔR, Δage better

⇨ second order delivery for exoplanets

- Individual studies of single stars : model and frequency fitting
  slow
  ΔM, ΔR, Δage better

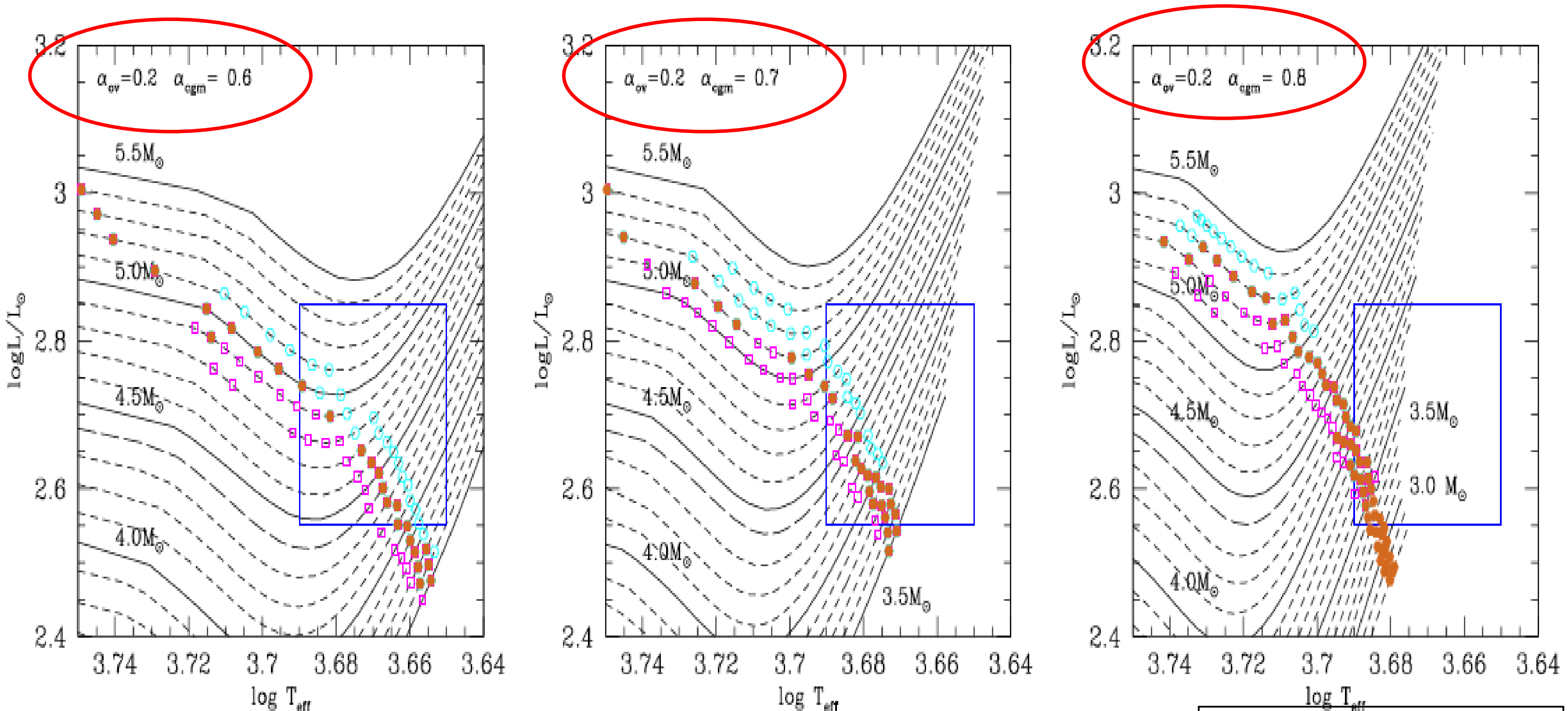
⇨ constrains on stellar physics and modelling

⇨ third order delivery for exoplanets

Biases due to unrealistic stellar modelling

Example: superadiabatic convection

Impact on mass determination



=> Increased interval in mass

Average Isep
Numax
Scaling laws