l'Observatoire de Paris GEPI
Galaxies Étoiles Physique et Instrumentation

Summary of the Nice Workshop on Model Comparison

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NICE WORKSHOP on MODEL COMPARISON

held on 26-27 September in Nice Observatory (organisation : M. Monteiro, Y. Lebreton, J. Provost ; local organisation :J. Provost and collegues in Nice)

~25 participants and 7 stellar evolution codes represented

ASTEC: M. Bazot, J. Christensen-Dalsgaard, M.P. di Mauro, T. Teixeira

CESAM: G. Berthomieu, J. Fernandes, R. Garrido, M.J. Goupil, Y. Lebreton, J.P Marques, P. Morel, A. Moya, P. Nghiem, P. Lambert, B. Pichon, J. Provost, J.C. Suarez, M.D. Suran

CLÉS: A. Miglio, J. Montalban, A. Noels, R. Scuflaire, A. Thoul

FRANEC: S. Degl'Innocenti, M. Marconi, P. Prada Moroni

STAROX: I. Roxburgh

TGEC: M. Bazot, M. Castro, S. Vauclair

GARSTEC: A. Weiss

TASK1 defined during COROT W7, Granada

Comparaison of stellar evolution codes on the basis of 7 specific, fully identified stellar cases (targets)

- physics specified/ numerics to be investigated
- representative range in stellar masses, composition, ages

case	$M/M_\odot$	Y_0	Z_0	X_C	T_C (K)	$M_{He\ core}$ X<0.01	α_{OV}	state
1.1	0.9	0.28	0.02	0.35	-	-	-	MS
1.2	1.2	0.28	0.02	0.69	-	-	-	ZAMS
1.3	1.2	0.26	0.01	-	-	$0.1M_\odot$	-	postMS
1.4	2.0	0.28	0.02	-	-	-	-	preMS
1.5	2.0	0.26	0.02	0.01	$1.9\ 10^7$	-	0.15	TAMS
1.6	3.0	0.28	0.01	0.69		-	-	ZAMS
1.7	5.0	0.28	0.02	0.35		-	-	MS

TASK1 : STANDARD SET OF PHYSICS

Equation of state: OPAL tables (Rogers et al. 96, 01)

Opacities : OPAL tables (Iglesias & Rogers 96) + AF tables at low temperatures (Alexander & Ferguson, 94)

Nuclear reaction rates: NACRE (Angulo et al. 99)

Convection: MLT (Böhm-Vitense 58, Henyey 65) with α_{MLT}=1.6

Overshoot: fully mixed and $\nabla=\nabla_{ad}$ with α_{OV}= 0 or 0.15

No diffusion/settling

Mixture: solar mixture of Grevesse & Noels (93)

Atmosphere: Eddington's grey atmosphere

Following CW8 in Toulouse :

models from 6 codes updated and re-compared

ASTEC: J. Christensen-Dalsgaard (Denmark)

CESAM: P. Morel, Y. Lebreton (France)

CLES: J. Montalban, R. Scuflaire (Belgium)

FRANEC: M. Marconi, S. Degl'Innocenti (Italy)

STAROX: I. Roxburgh (U.K.)

TGEC: M. Castro (Toulouse)

BRIEF LIST OF THE TALKS DIRECTLY RELEVANT TO COMPARISONS

1- STELLAR EVOLUTION CODES : PRESENTATION

J. Christensen-Dalsgaard (ASTEC), B. PIchon (CESAM), R. Scuflaire (CLES), S. Degl'Innocenti (FRANEC), A. Weiss (GARSTEC), I. Roxburgh (STARROX)

… and discussions (chair M.J. Goupil)

2- RESULTS AND ONGOING ACTIVITIES

TASK 1 : Results and Applications (Y. Lebreton, M. Monteiro)

CASE1.5 : Comparisons CLES18-CESAM2K (J. Montalban, Y. Lebreton)

… and discussions (chair I. Roxburgh)

3- PREPARATION OF THE FUTURE

COROT and what is expected from ESTA (A. Baglin)

Development of Task2 : Hares and Hound (M. Monteiro)

Development of TASK3 : Frequency comparison (A. Moya)

… and discussions to prepare ESTA roadmap to Aarhus (J. Christensen-Dalsgaard) and to CW9 (chair M. Monteiro)

SUMMARY : GLOBAL PARAMETERS COMPARISON

ALL CODES/CLES-CESAM0

$\Delta_{max-min}$	age	$R/R_{\odot}$	$L/L_{\odot}$	T_{eff}	$T_c/10^7$	ρ_c	M_{core}/M	R_{env}/R
1.1 0.9 $M_{\odot}$,MS	5.0% 0.5%	2.2% 0.4%	4.4% 0.3%	1.5% 0.3%	1.2% 0.1%	2.5% 0.2%	-	1.0% 0.2%
1.2 1.2 $M_{\odot}$, ZAMS	3.0% 1.8%	3.1% 0.0%	4.5% 0.1%	2.0% 0.02%	0.9% 0.0%	2.1% 0.3%	17.9% 0.2%	2.7% 0.3%
1.3 1.2 $M_{\odot}$, post MS	7.5%	5%	5%	1.7%	1%	5.1%	-	2.7%
1.4 2 $M_{\odot}$, pre MS	19.9% 8.7%	0.9% 0.5%	7.5% 2.6%	0.8% 0.4%	0.2% 0.0%	6.6% 1.9%	30.2% 13.8%	0.7% 0.7%
1.5 2 $M_{\odot}$, TAMS	3% 2%	3.1% 2.5%	3.3% 2.0%	2.6% 0.7%	0.6% 0.2%	1.4% 0.1%	22.1% 18.4%	0.4% 0.01%
1.6 3 $M_{\odot}$, ZAMS	8.3% 2%	0.6% 0.1%	3.0% 0.2%	0.6% 0.1%	0.4% 0.04%	1.6% 0.1%	2.2% 0.4%	0.5% 0.07%
1.7 5 $M_{\odot}$, MS	3.8% 0.8%	1.4% 0.3%	4.3% 0.3%	0.7% 0.1%	0.5% 0.04%	1.4% 0.05%	4.5% 0.2%	0.7% 0.1%

GLOBAL PARAMETERS : SUMMARY

models are consistent to first order

- differences in global parameters range from 1 to 5%
- but age ⇨ up to 10-20%, M_{core} ⇨ up to 20-30%
- but PMS ⇨ 7-8% on L, ρ_c

part of the differences result from

- specifications for the targets not precisely followed
- reference physics not fully implemented in some codes

$CLES/CESAM_0$: very close physical inputs ⇨ smaller differences

- but PMS, overshooting increase differences

INTERNAL STRUCTURE COMPARISON

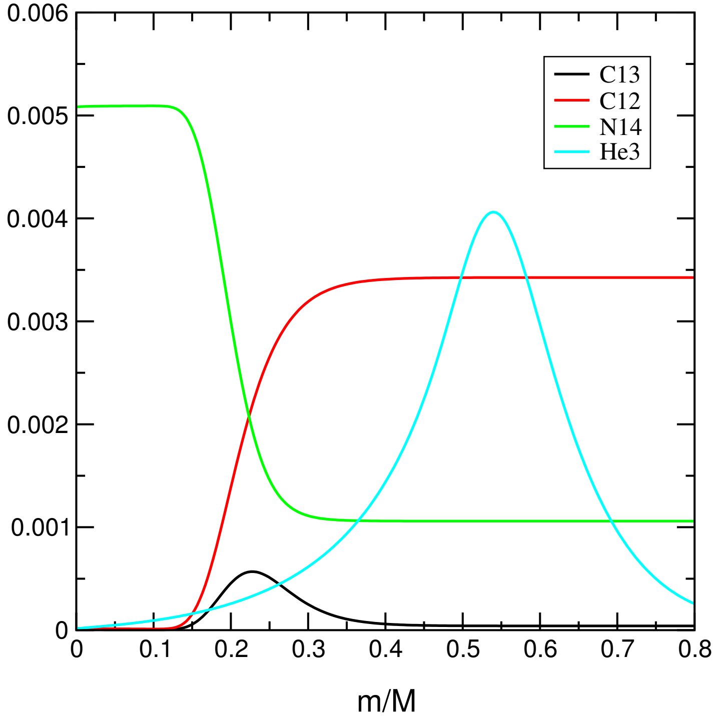
$\Delta_{max-min}$	$\delta X/X$	$\delta c^2/c^2$
1.1 0.9 $M_\odot$,MS	1.7% 0.2%	1.0% 0.1%
1.2 1.2 $M_\odot$, ZAMS	0.6% 0.2%	0.13% 0.05%
1.3 1.2 $M_\odot$, post MS	5.0%	1.2%
1.4 2 $M_\odot$, pre MS	0.16% 0.01%	1.0% 0.3%
1.5 2 $M_\odot$, TAMS	48% 20%	6% 3%
1.6 3 $M_\odot$, ZAMS	5% 2.5%	0.6% 0.1%
1.7 5 $M_\odot$, MS	11% 2.5%	24% 0.5%

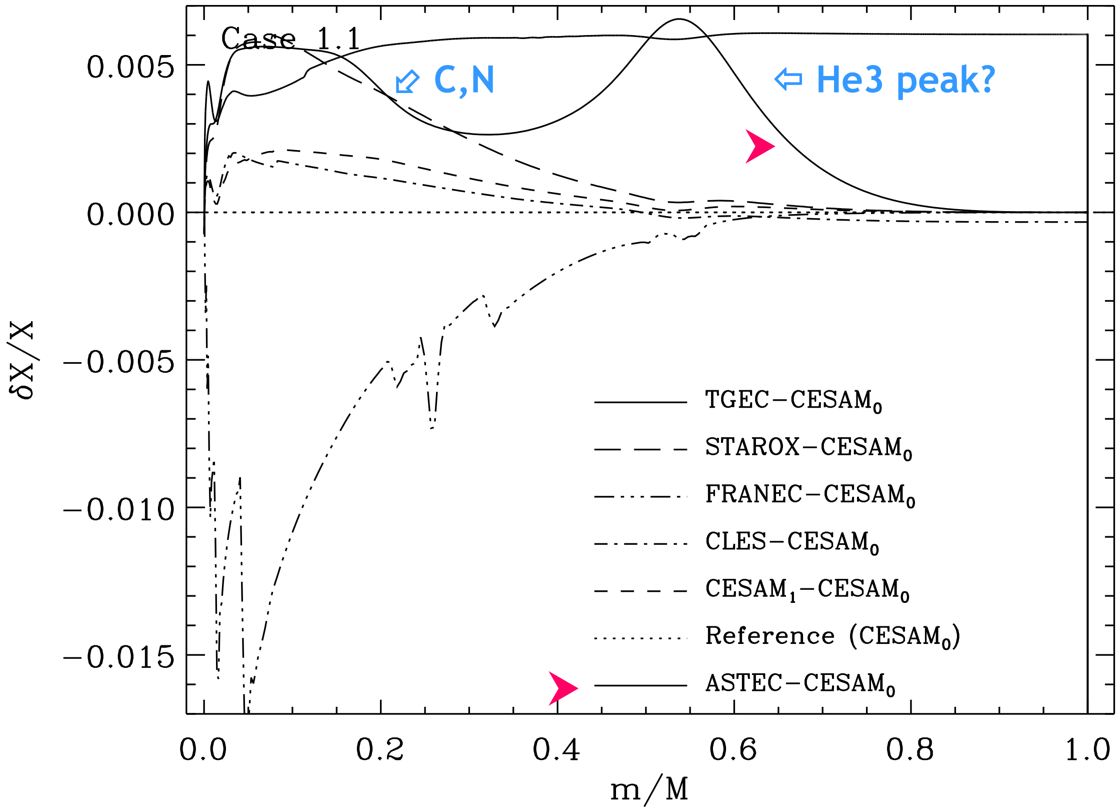
HYDROGEN PROFILE

CASE 1.1 : MS

0.9 $M_{\odot}$

X_c=0.35 ; Z=0.02





0.5% ASTEC,STARROX (centre), TGEC

1.5% FRANEC (centre),

0.2% CLES, CESAM

SOUND SPEED COMPARISON : MS MODELS

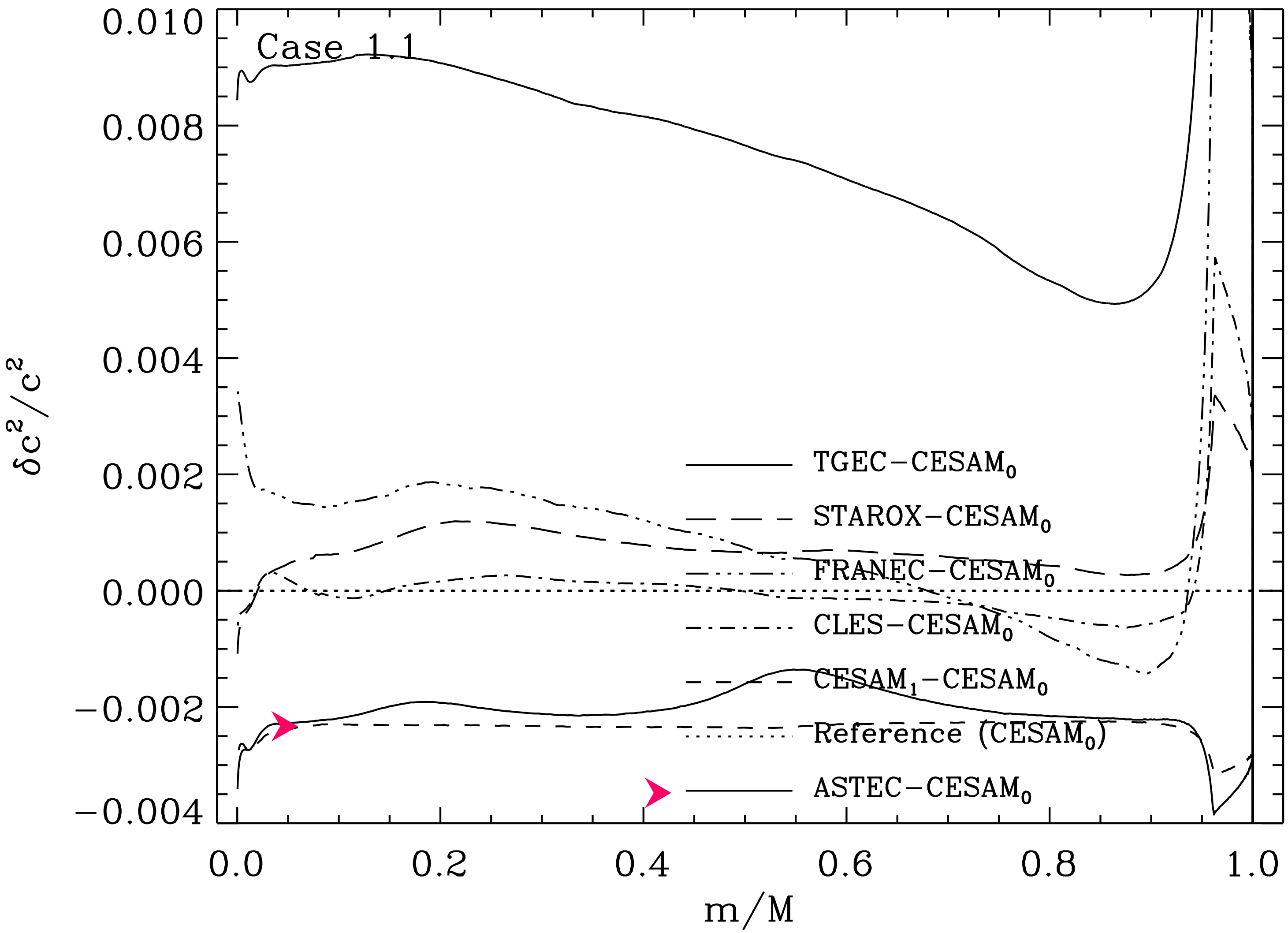
CASE 1.1

0.9 $M_\odot$

X_c=0.35

Z=0.02

MS



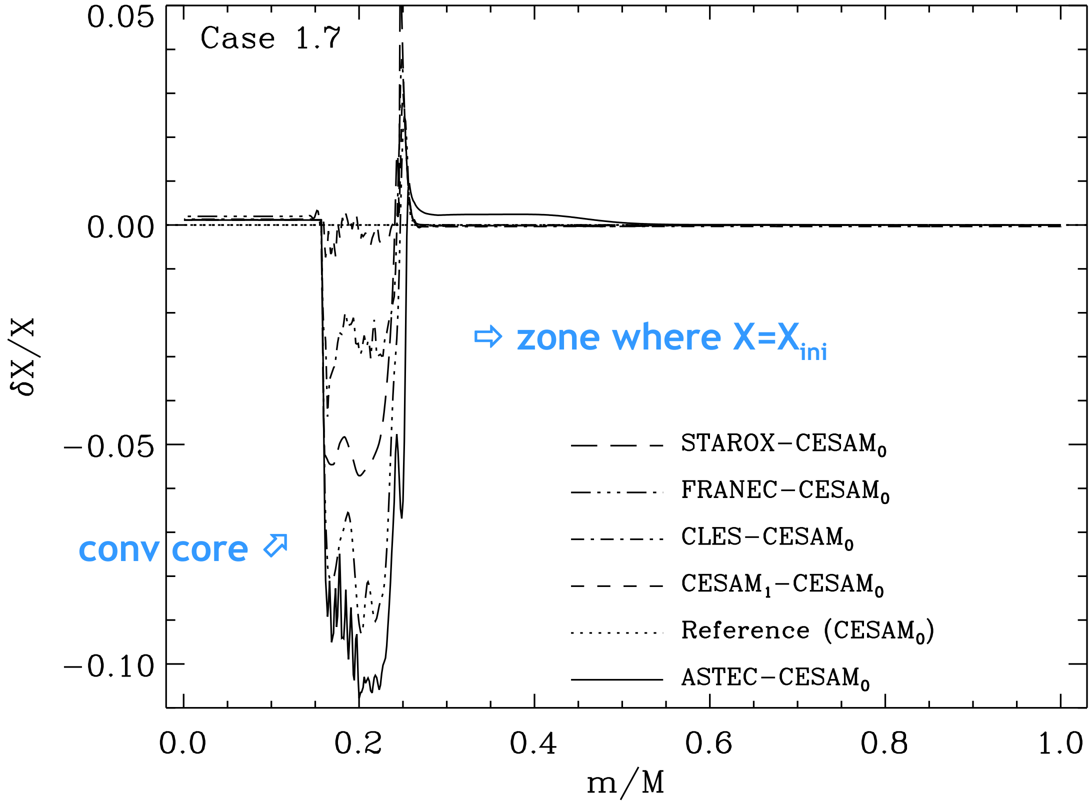
0.9% TGEC, 0.4% FRANEC, 0.2% ASTEC, STAROX, CLES, CESAM

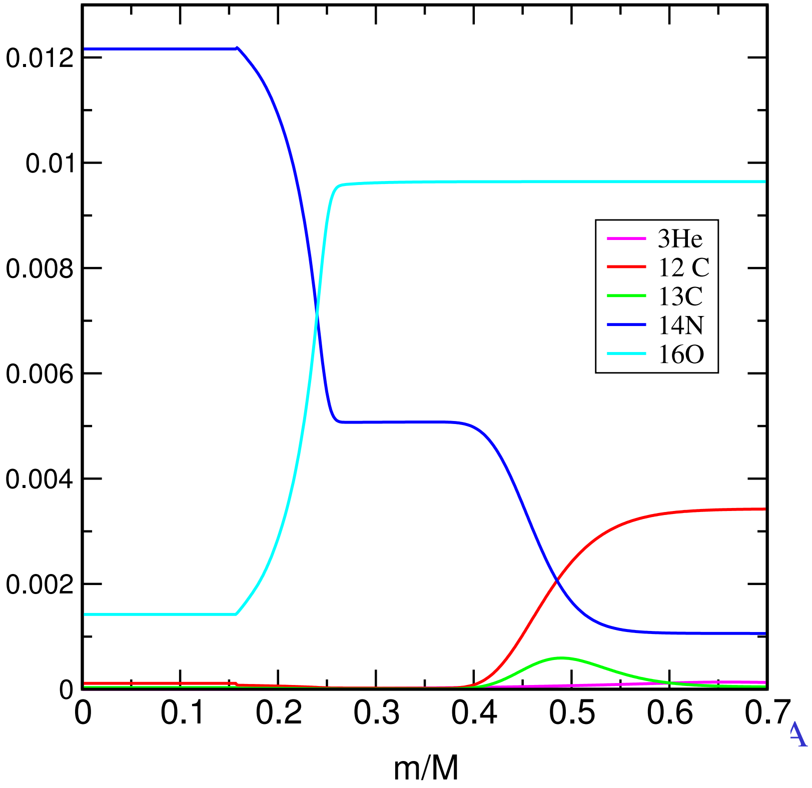
But outer regions !

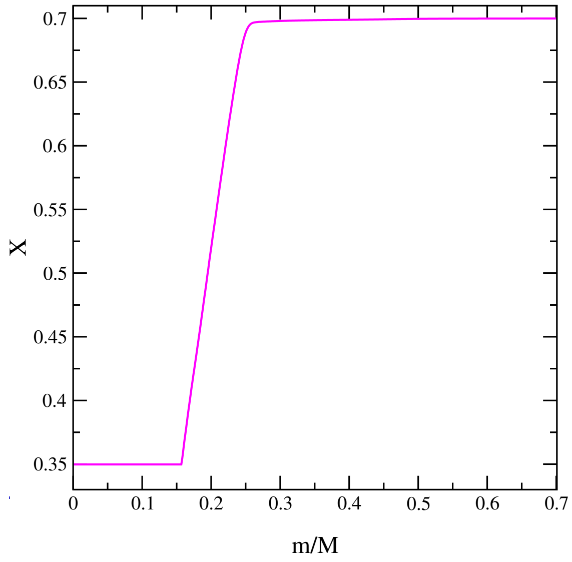
HYDROGEN PROFILE

CASE 1.7: MS

5 $M_\odot$; X_c=0.35 ; Z=0.02







SOUND SPEED COMPARISON : MS MODELS

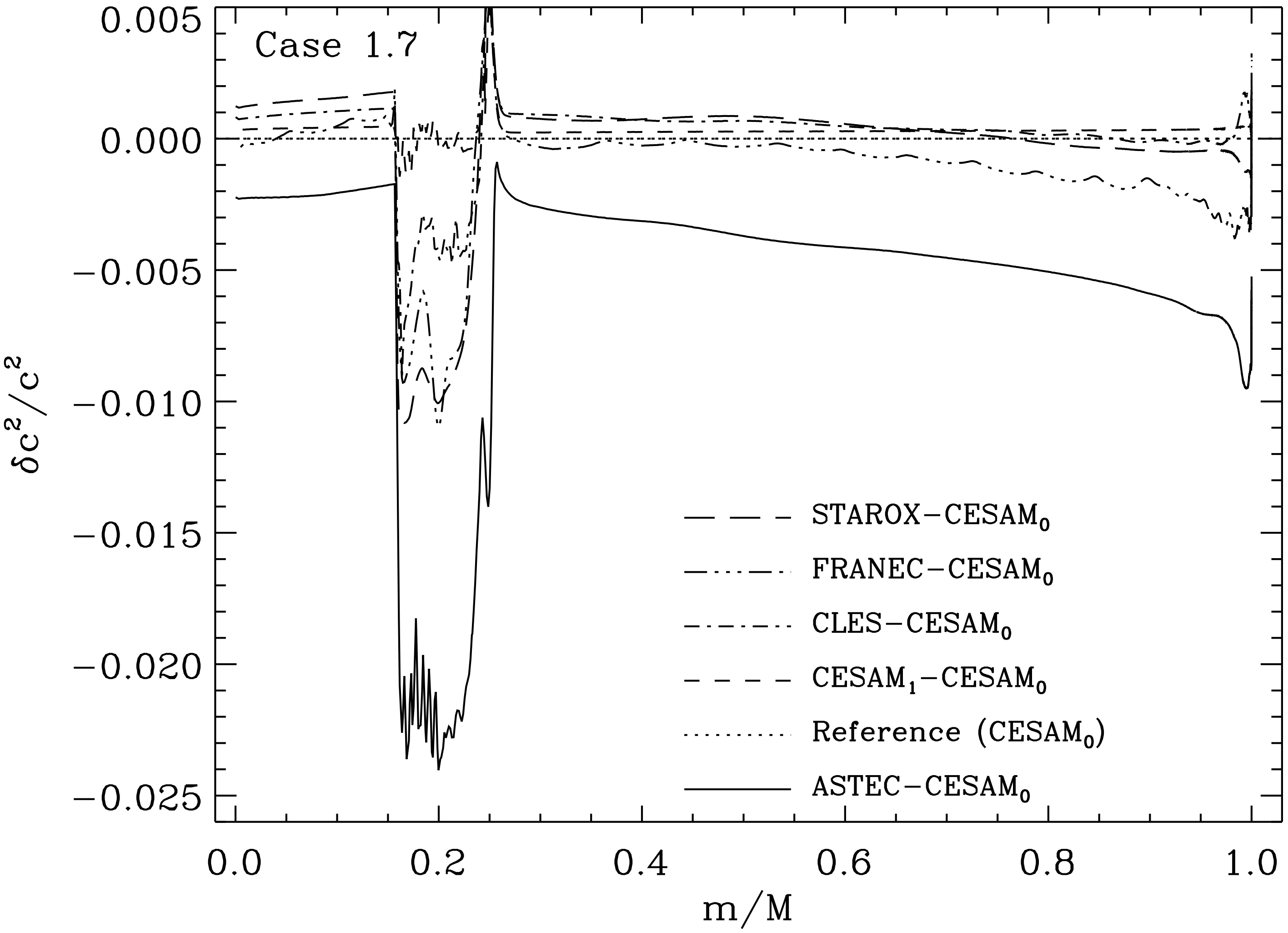
CASE 1.7

5 $M_\odot$

X_c=0.35

Z=0.02

MS

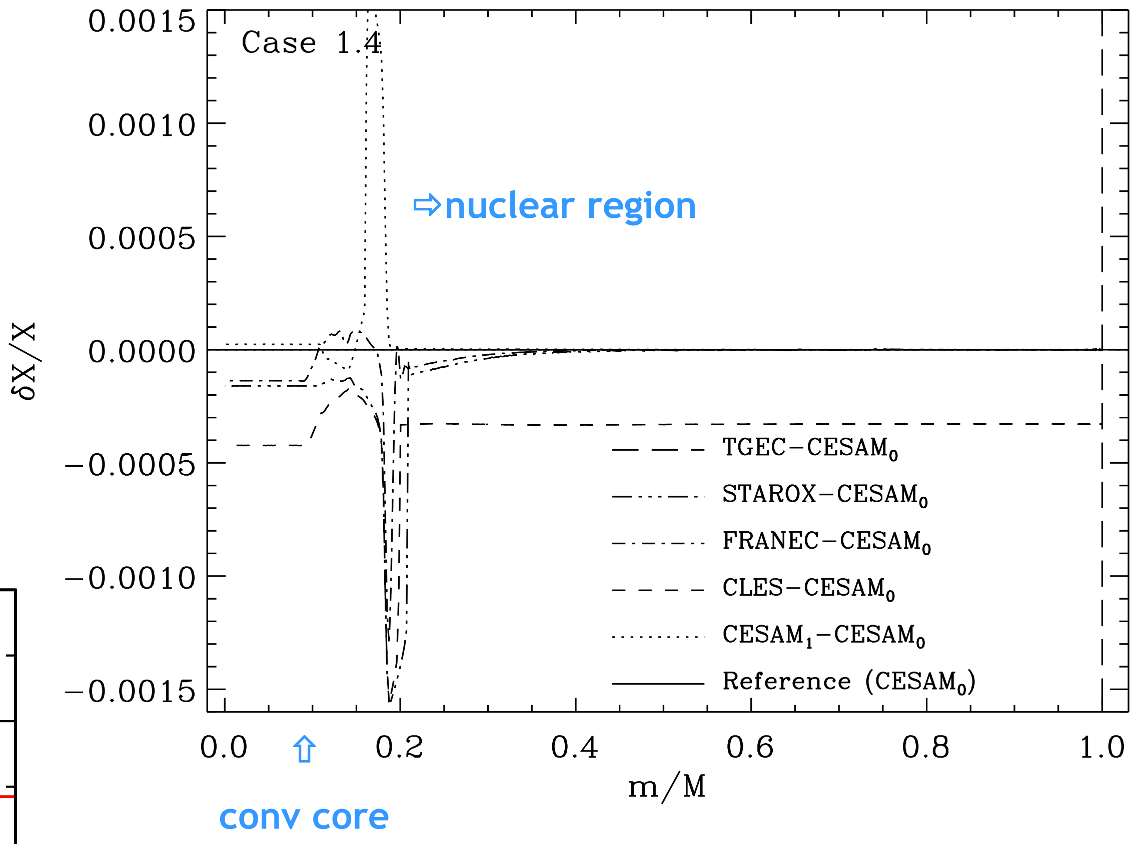


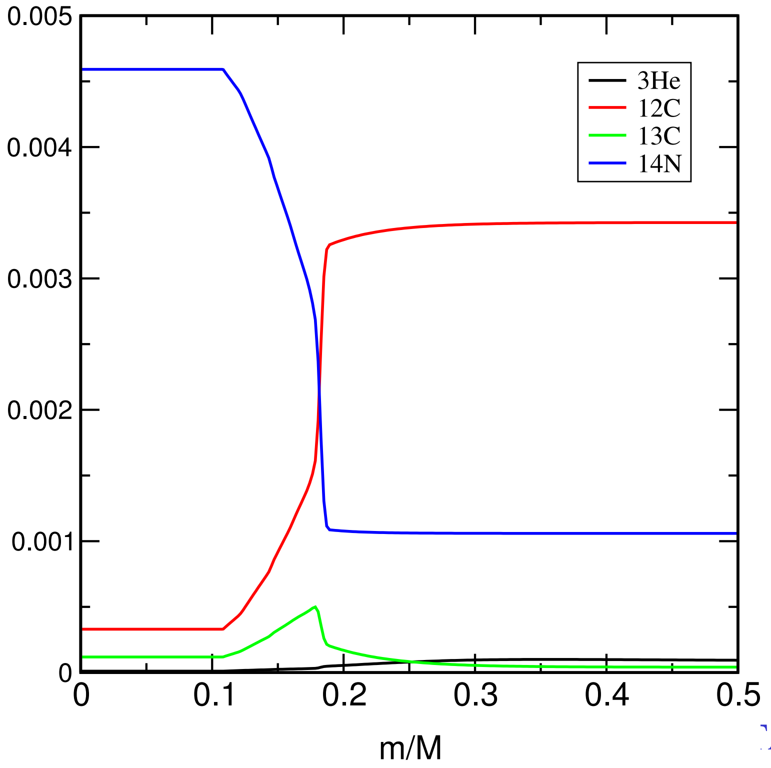
HYDROGEN PROFILE

CASE 1.4: pre-MS

2 $M_\odot$; T_c=1.9 10^7 K

Z=0.02





SOUND SPEED COMPARISON : pre-MS MODEL

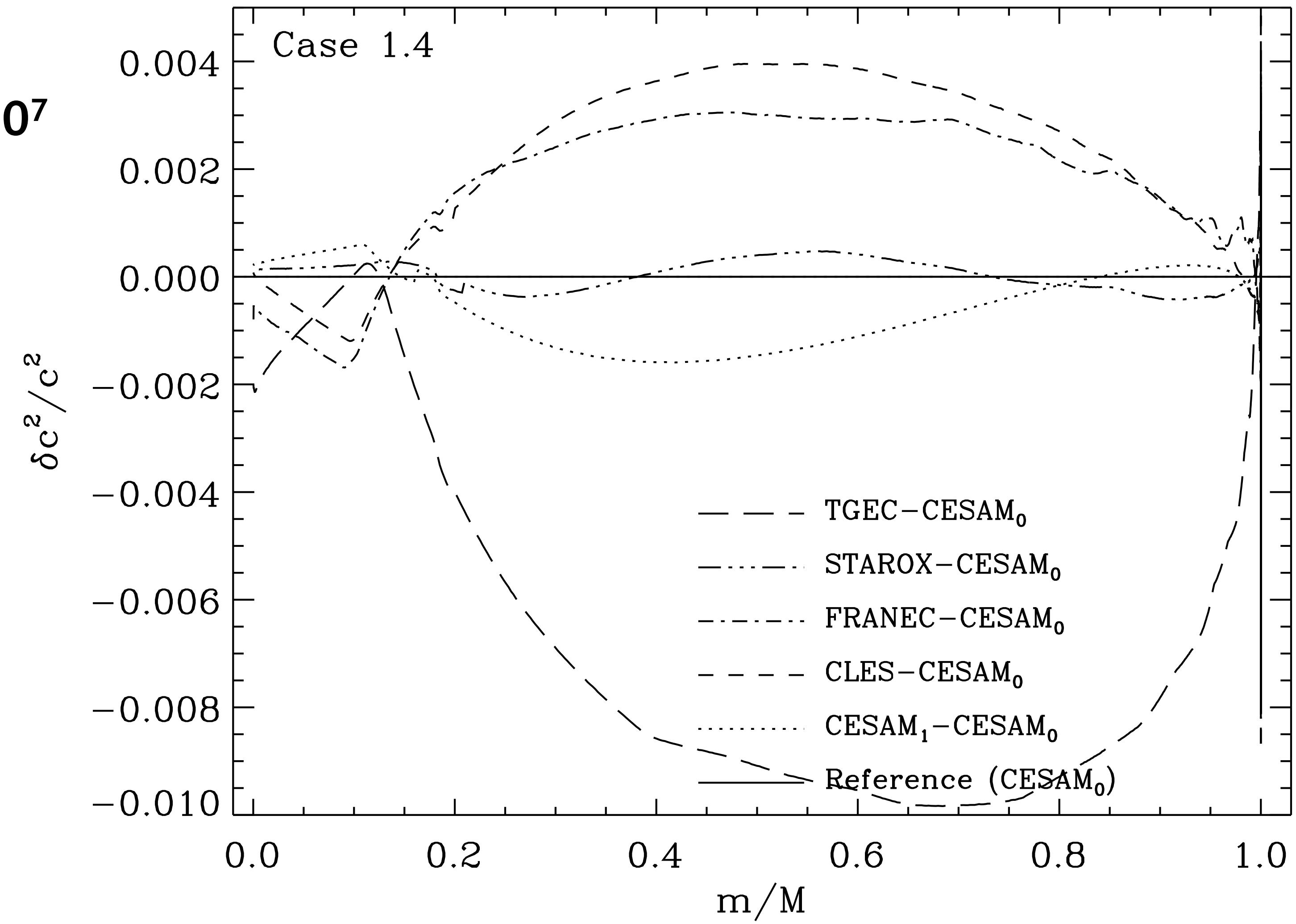
CASE 1.4

2 $M_\odot$

T_c=1.9 10^7

Z=0.02

Pre-MS



INTERNAL STRUCTURE COMPARISON: SUMMARY

main differences appear at the edge of the convective regions

- narrow regions appear where differences are high
- evolved models carry the signature of convective core displacements

zones of nuclear energy production also identified

large differences at the surface

CLÉS vs. CESAM2k

CASE 1.5

2 $M_\odot$

X_c=0.01

Z=0.02

α_{MLT}=1.60

α_{OV}=0.15/0.0

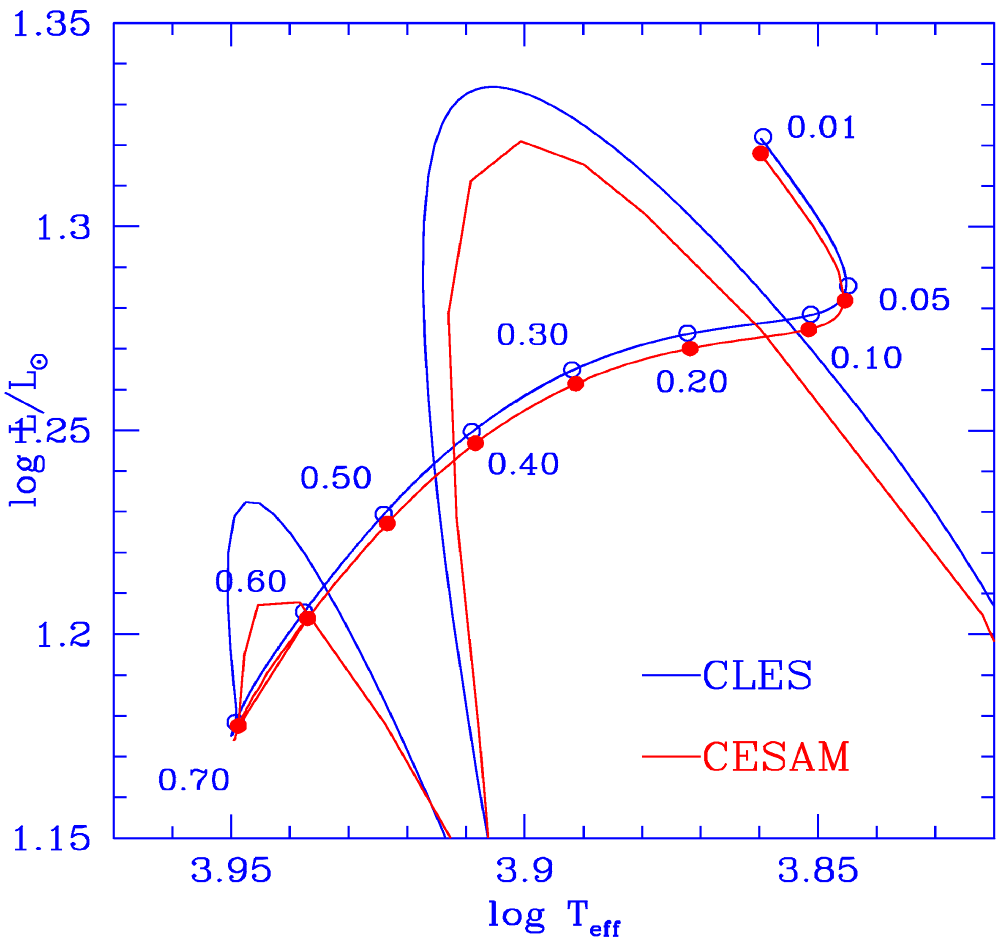
TAMS :
X_c=0.01

Detailed comparisons :structure and evolution :

1. HR diagram
2. Evolution of convective core
3. Intermediate models (constant X_c)

without/with overshooting

COMPARISONS CLÉS-CESAM2k : HR DIAGRAM

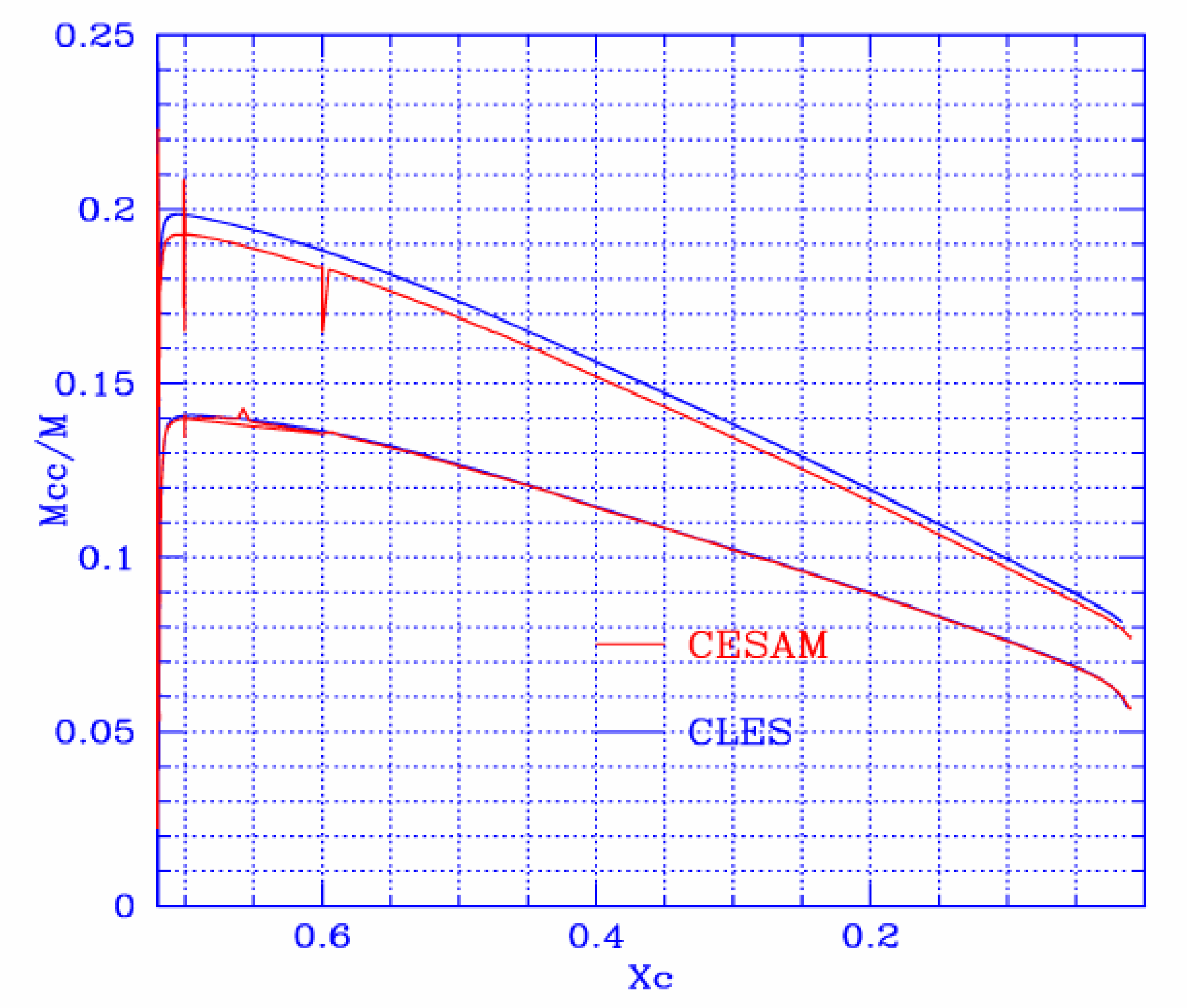


no overshooting

ΔT_{eff}<0.2%

$\Delta L/L_{\odot}$<1%

CLÉS vs. CESAM2k : evolution of the convective core



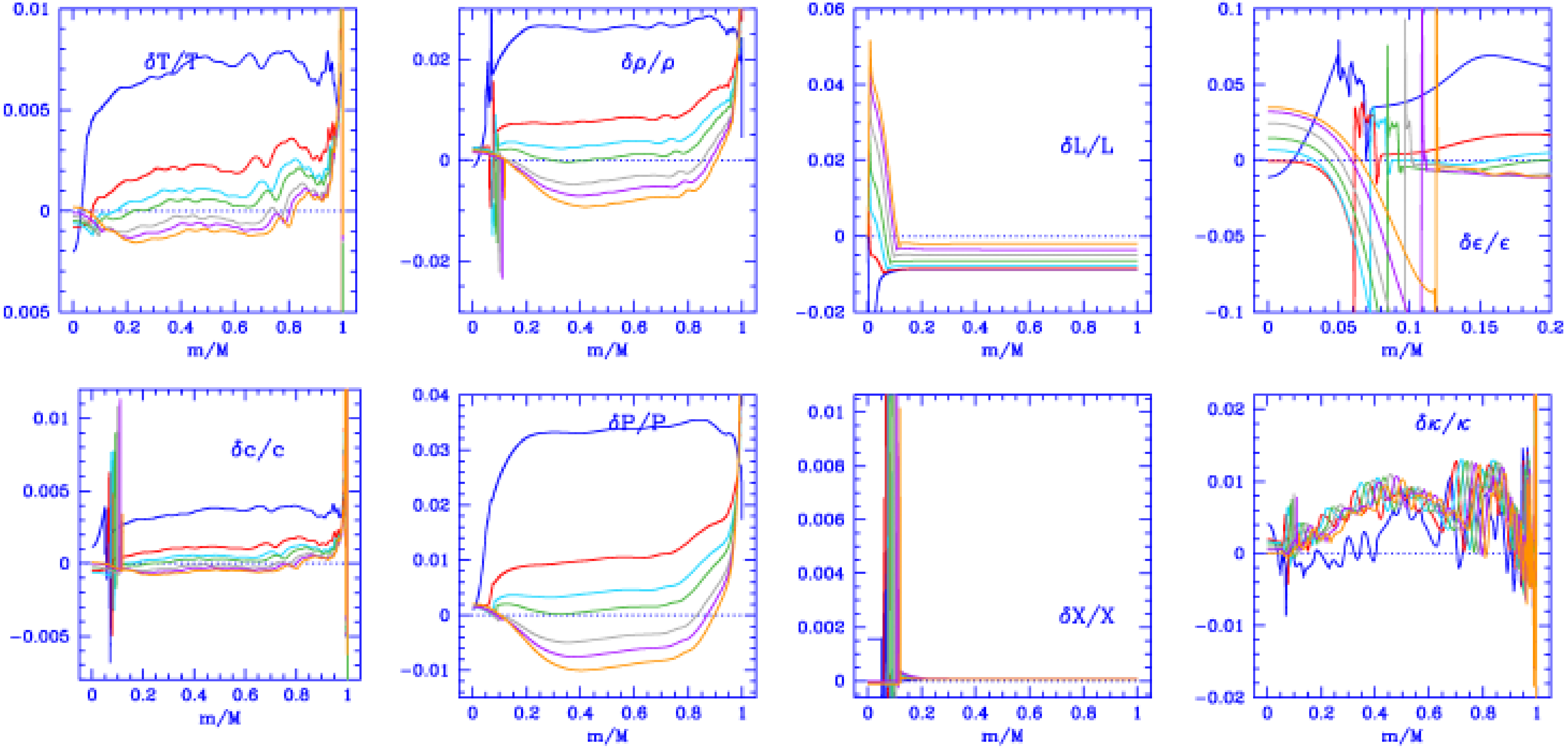
α_{OV}=0.0

$\Delta M_{cc}/M_* \sim 6.\ 10^{-4}$

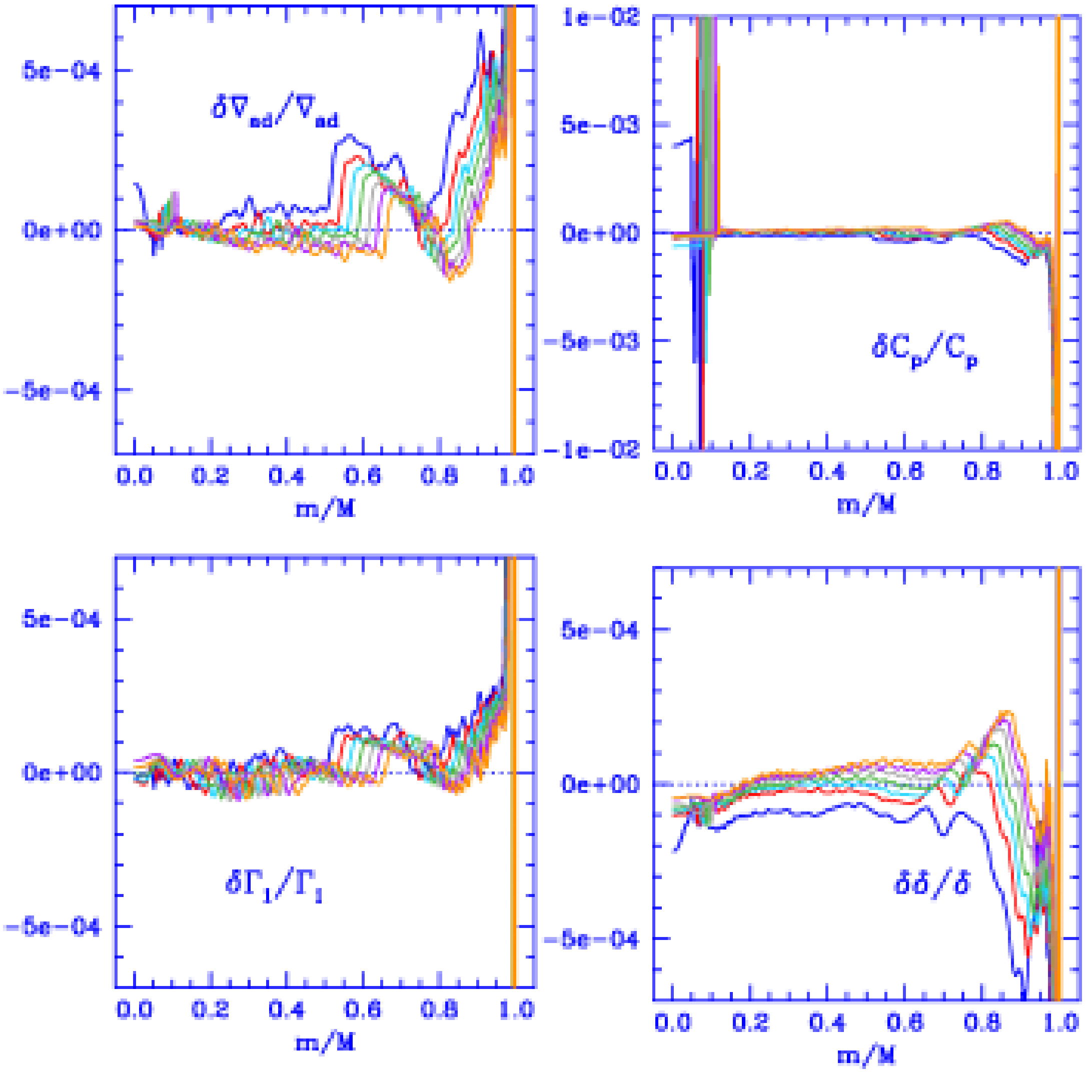
α_{OV}=0.15

$\Delta M_{cc}/M_* \sim 6.\ 10^{-3}$

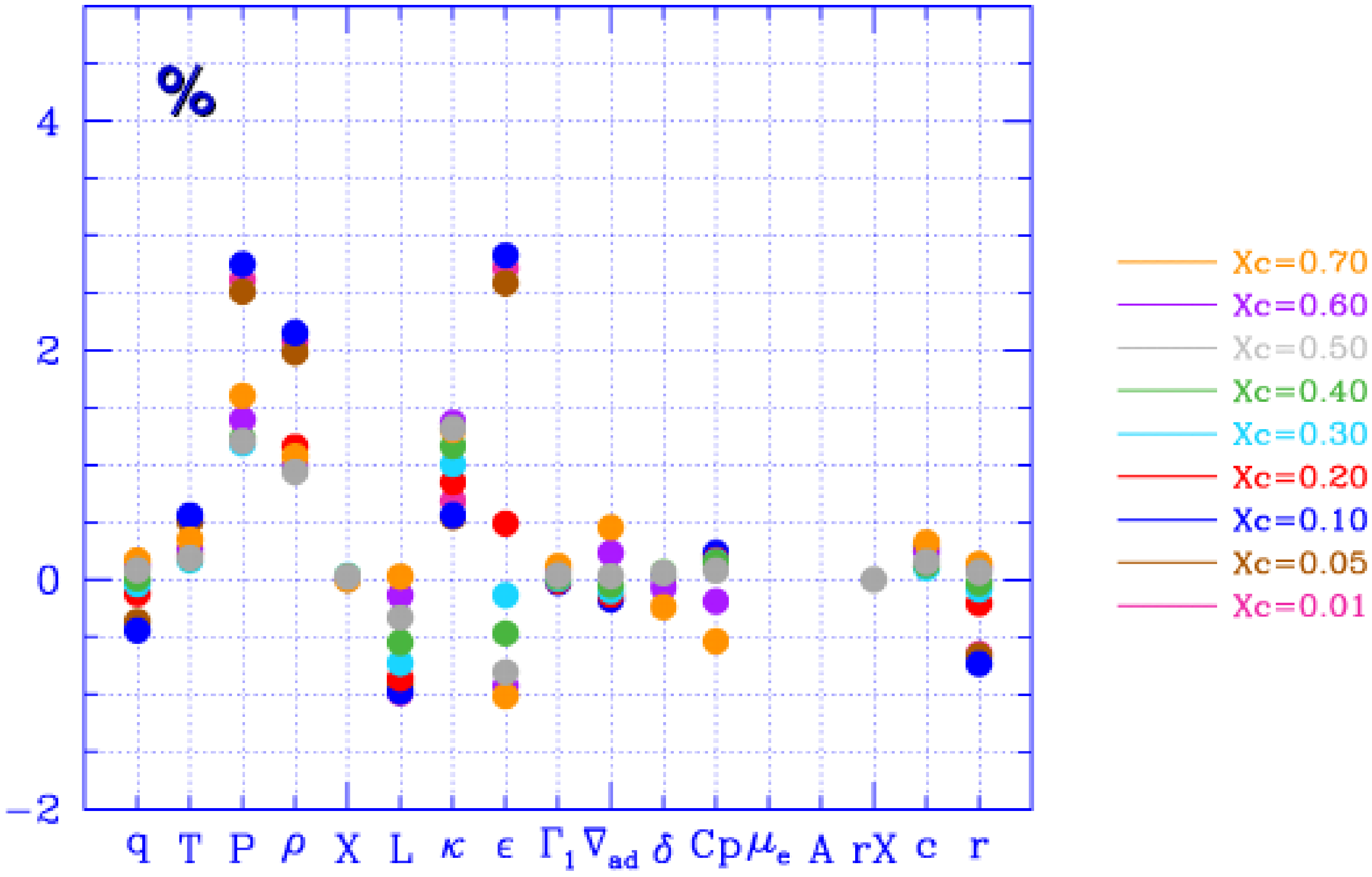
CLÉS vs. CESAM2k : Structure differences



CLÉS vs. CESAM2k : Structure differences



CLÉS vs. CESAM2k : average structure differences



CLÉS vs. CESAM2

- equation of state :

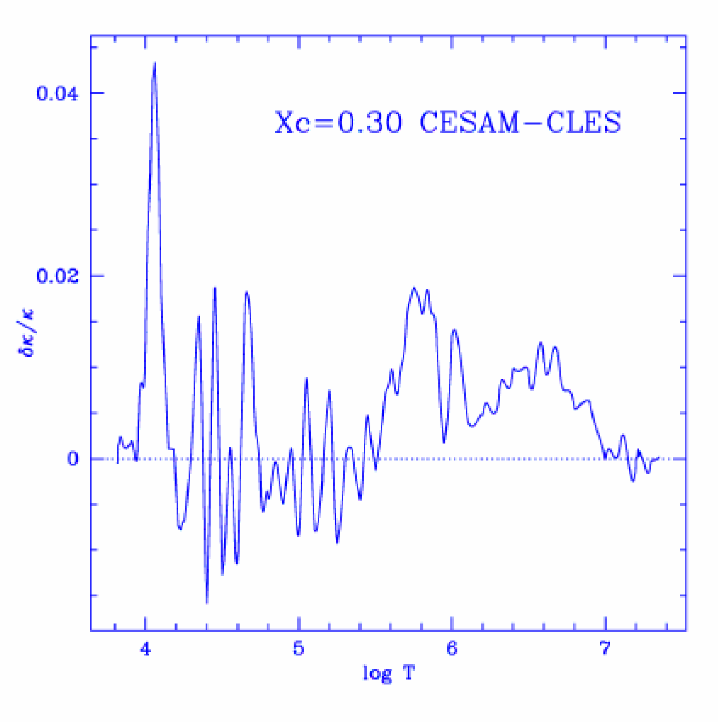
interpolation, choice of thermodynamic variables

- nuclear reaction rates : main difference is in the screening factor
- opacities

see Montalban, Lebreton, Miglio, Scuflaire

⇨ web site, 2 posters in CW9

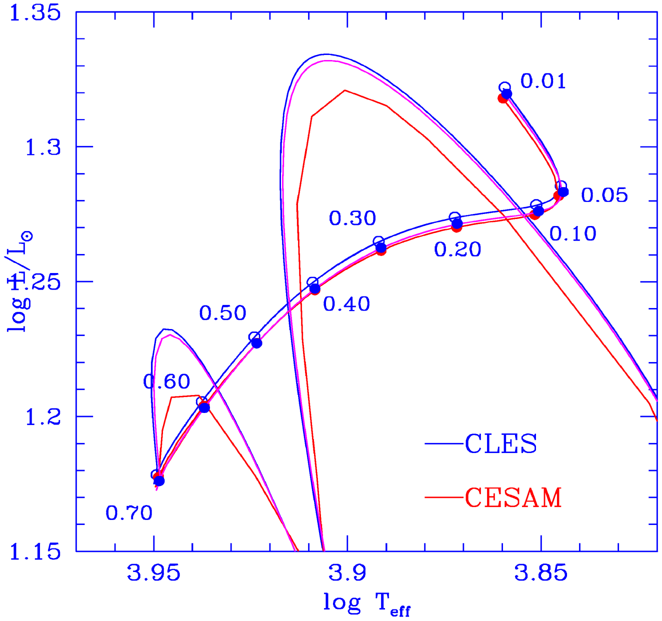
CLÉS vs. CESAM2k : opacities



CESAM> CLÉS

average 1% but

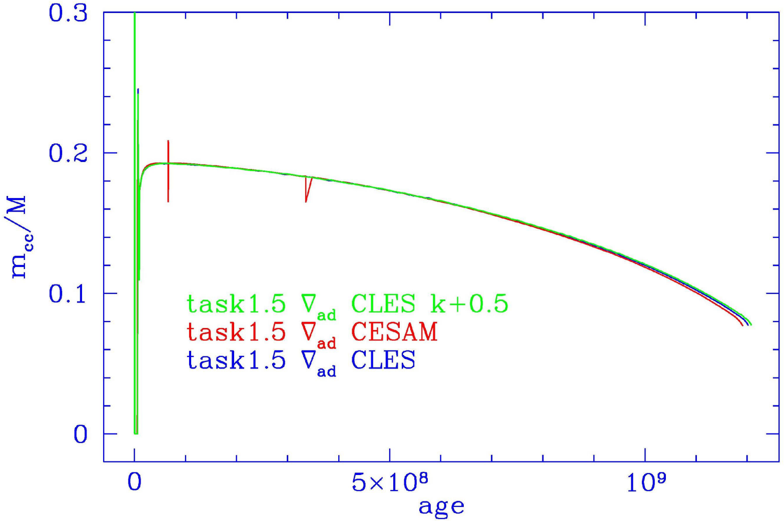
more than 4% in surface layers



CLES

κ increased

by 0.5%



TASK1 : OUTCOME of NICE ⇨ ROADMAP for AARHUS MEETING

- eliminate remaining evident differences in the physics : check isotopic ratios, screening, formulation of convection, overshooting, conductive opacities
- try to estimate the weight of numerics:

  easy? effect of mesh and time steps, interpolation methods, nuclear rates, fitting temperature for opacity tables, interface with atmosphere

  more difficult! treatment of convective limits and their evolution in time, overshooting, associated mixing… can we explore the methods and agree on a preferred one?
- compare the whole sequences of evolution for each target

  evolutionary track in HR diagram

  interior of models at particular evolution stages (constant X_c on the MS)

  evolution of : size of the convective core, convective envelope depth
- decide of the acceptable degree of agreement necessary for COROT

  global parameters/internal differences