Summary of Aarhus workshop

Some selected results

Intrinsic numerical accuracy

- Compare models computed with a given code and given parameters
- Vary number of meshpoints
- Vary number of timesteps

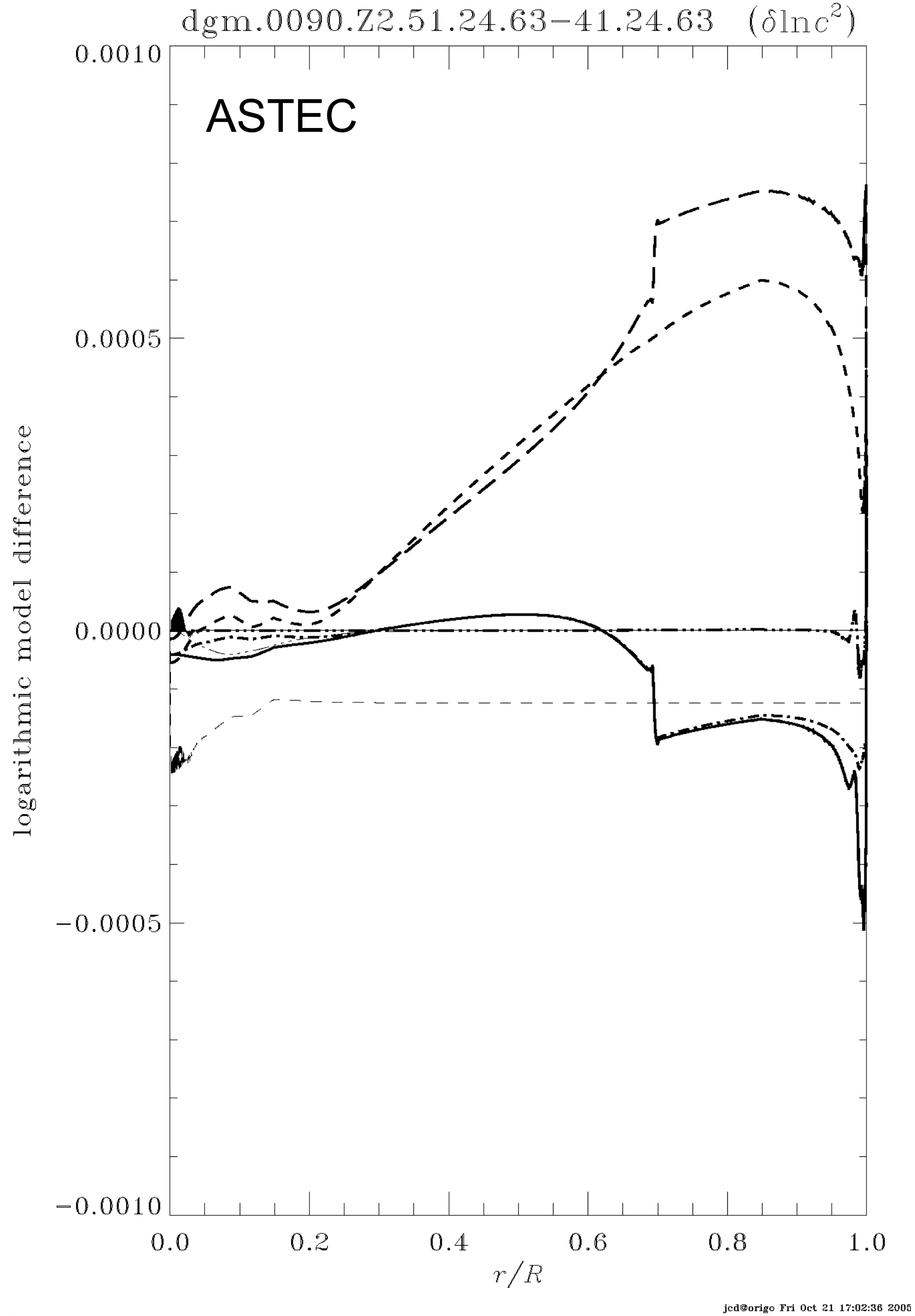
Case 1.1

0.9 M–, X_c = 0.35

^{3}He in equilibrium

Test effect of no. of meshpoints:

(N = 1200) – (N = 600)



Line styles:

- –·–·–·–·– : $\delta \ln T$
- – – – – – : $\delta \ln p$
- —— —— —— : $\delta \ln \rho$
- ———— : $\delta \ln c^2$
- –···–···– : $\delta \ln \Gamma_1$
- ———— : $\delta \ln q$
- – – – – – : $\delta \ln L$
- –···–···– : δX

Case 1.1

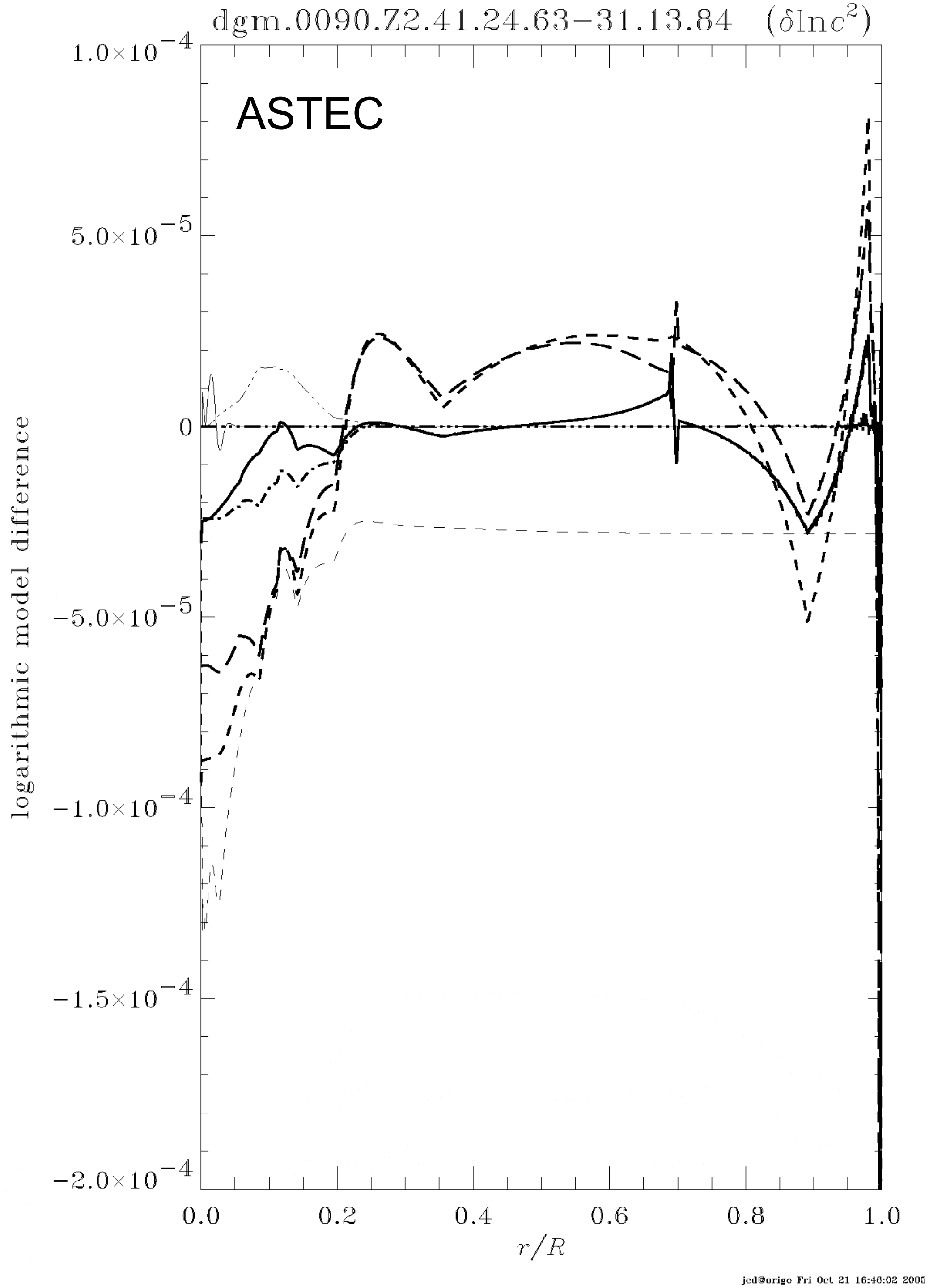
0.9 $M_{\odot}$, X_c = 0.35

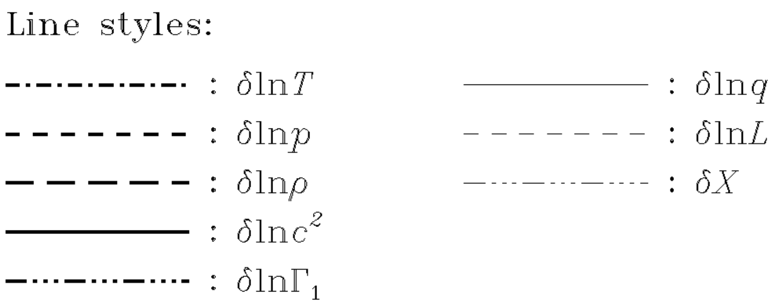
^{3}He in equilibrium

Test effect of no. timesteps:

(N_t = 24) – (N_t = 13)

($\Delta\ y_{max}$ = 0.025) - ($\Delta\ y_{max}$ = 0.05)





Case 1.3

1.2 M–, M_c = 0.1 M–

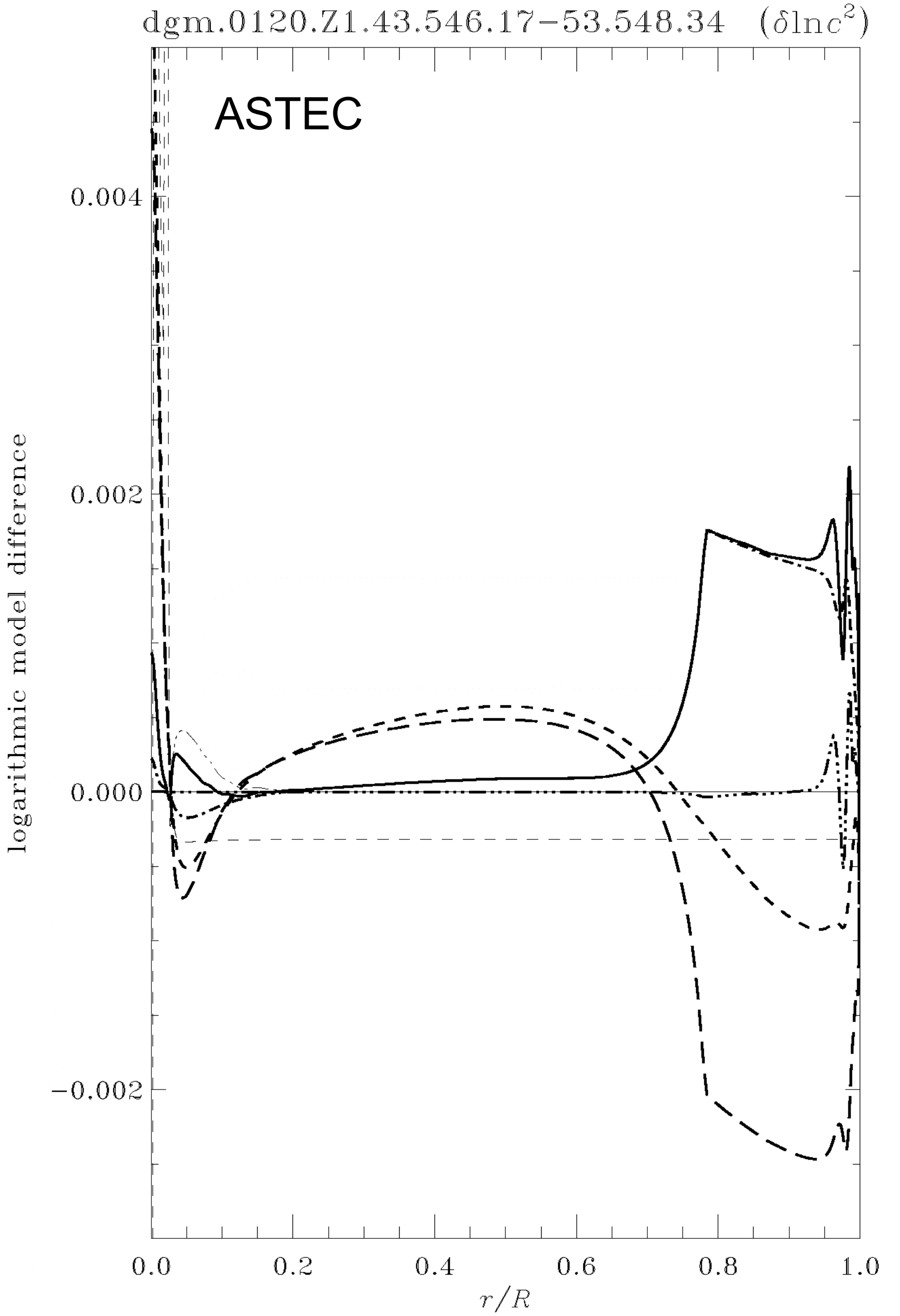
^{3}He in equilibrium

Test effect of no. of meshpoints:

(N = 600) – (N = 1200)

Line styles:

- : $\delta \ln T$
- : $\delta \ln p$
- : $\delta \ln \rho$
- : $\delta \ln c^2$
- : $\delta \ln \Gamma_1$
- : $\delta \ln q$
- : $\delta \ln L$
- : δX



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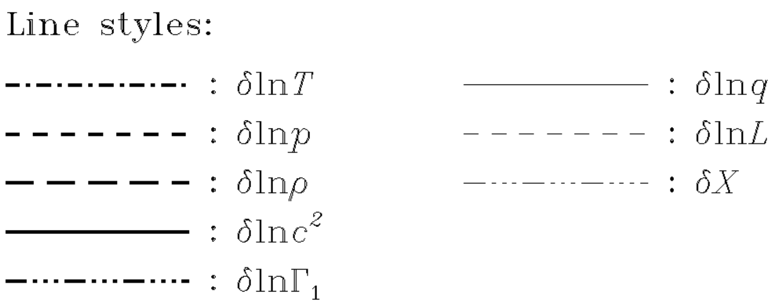
Case 1.3

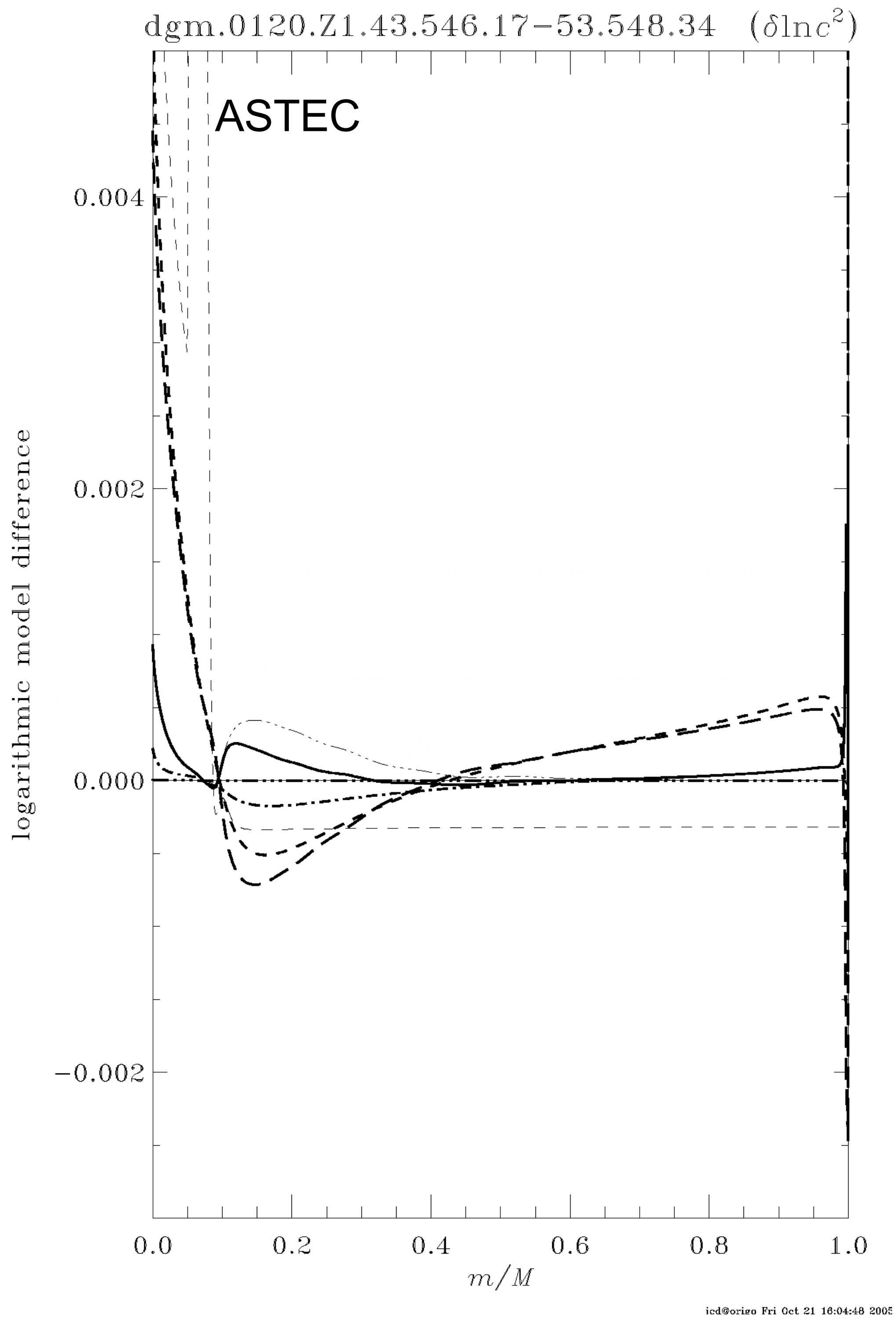
$1.2\ M_\odot$, $M_c = 0.1\ M_\odot$

^{3}He in equilibrium

Test effect of no. of meshpoints:

(N = 600) – (N = 1200)





Case 1.3

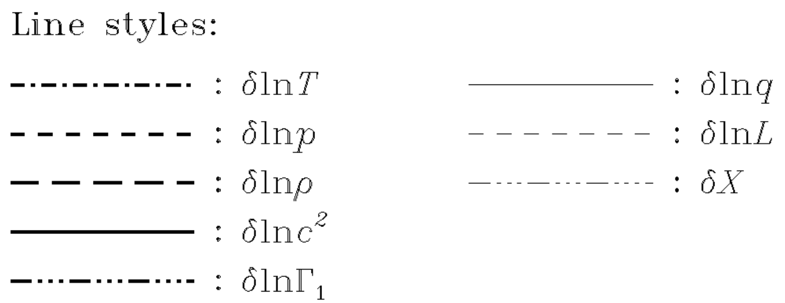
1.2 M–, M_c = 0.1 M–

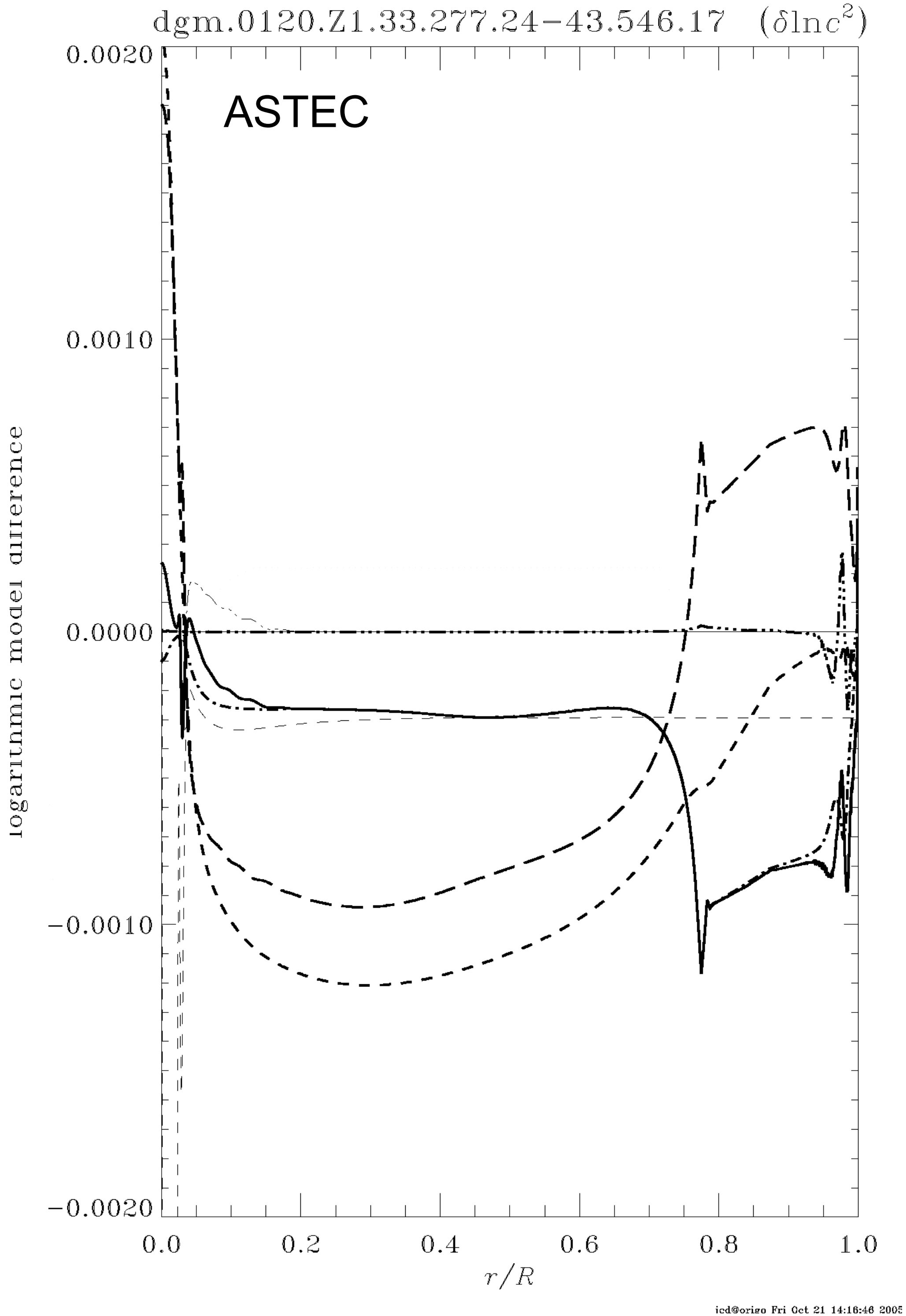
^{3}He in equilibrium

Test effect of no. timesteps:

(N_t = 277) – (N_t = 546)

($\Delta\ y_{max}$ = 0.05) - ($\Delta\ y_{max}$ = 0.025)





Case 1.5

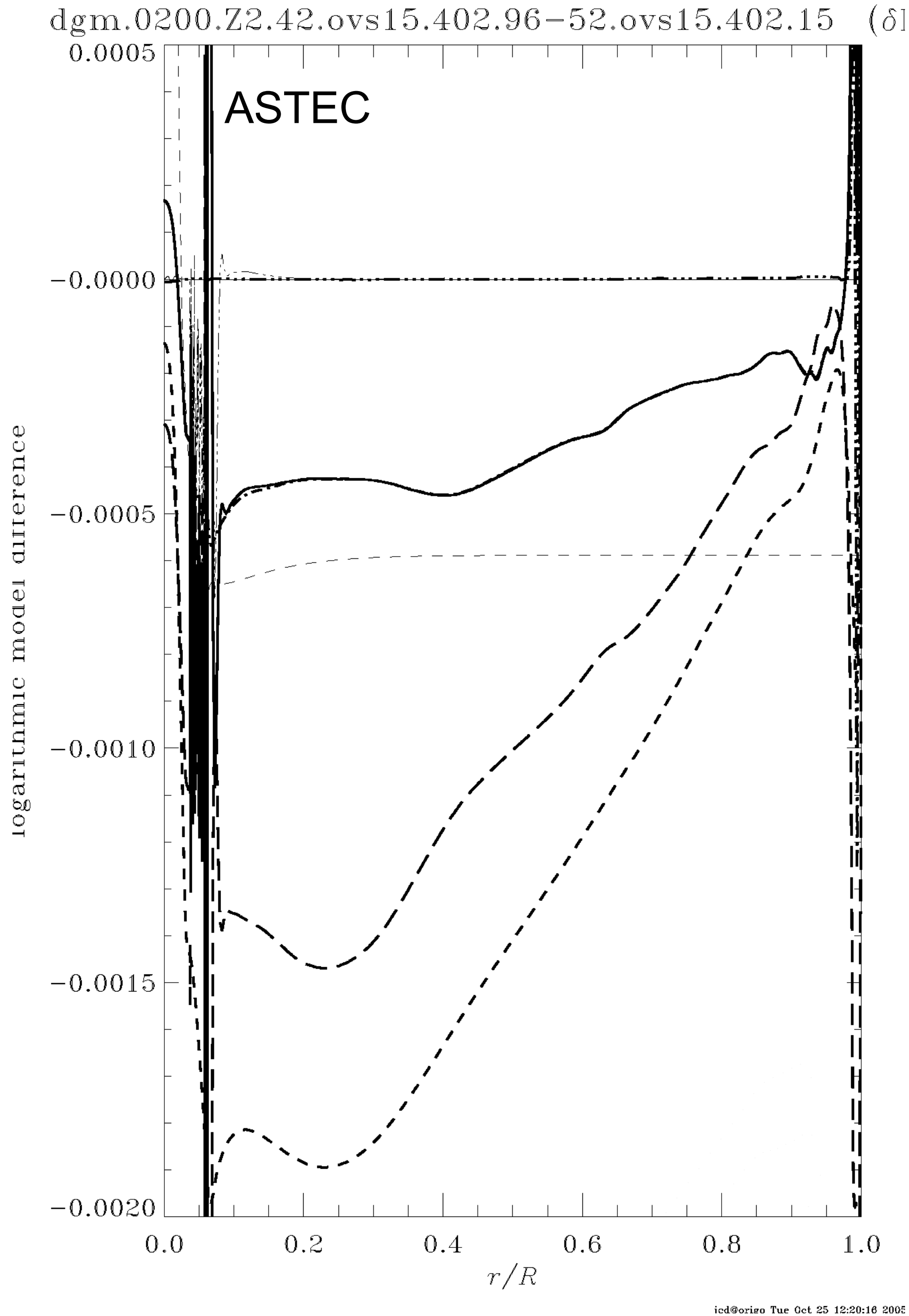
2.0 M–, X_c = 0.01,

Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of meshpoints:

(N = 600) – (N = 1200)



Line styles:

–·–·–·–· : $\delta \ln T$	——— : $\delta \ln q$
- - - - : $\delta \ln p$	- - - - : $\delta \ln L$
— — — : $\delta \ln \rho$	–···–···– : δX
——— : $\delta \ln c^2$	
–···–···– : $\delta \ln \Gamma_1$	

Case 1.5

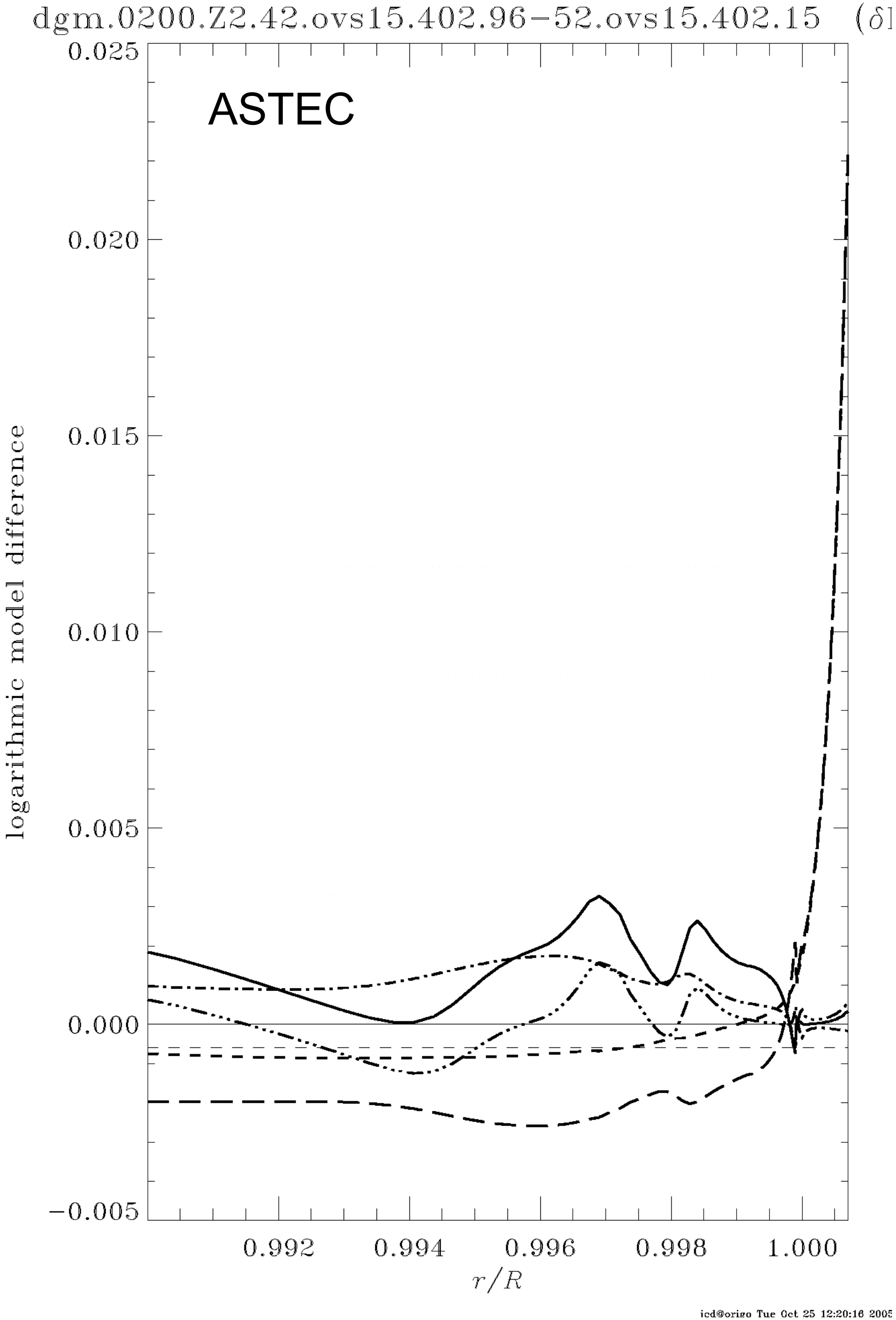
2.0 M–, X_c = 0.01,

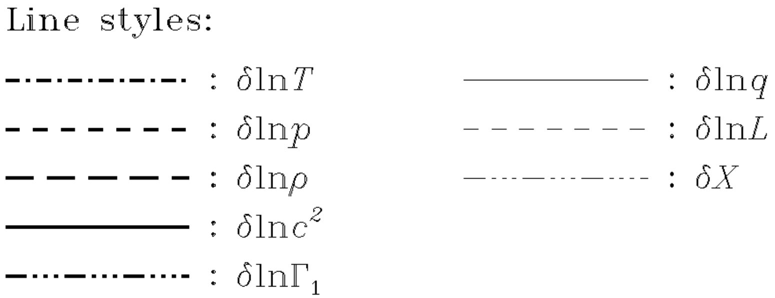
Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of meshpoints:

(N = 600) – (N = 1200)





Case 1.5

2.0 M–, X_c = 0.01,

Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of meshpoints:

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Line styles:

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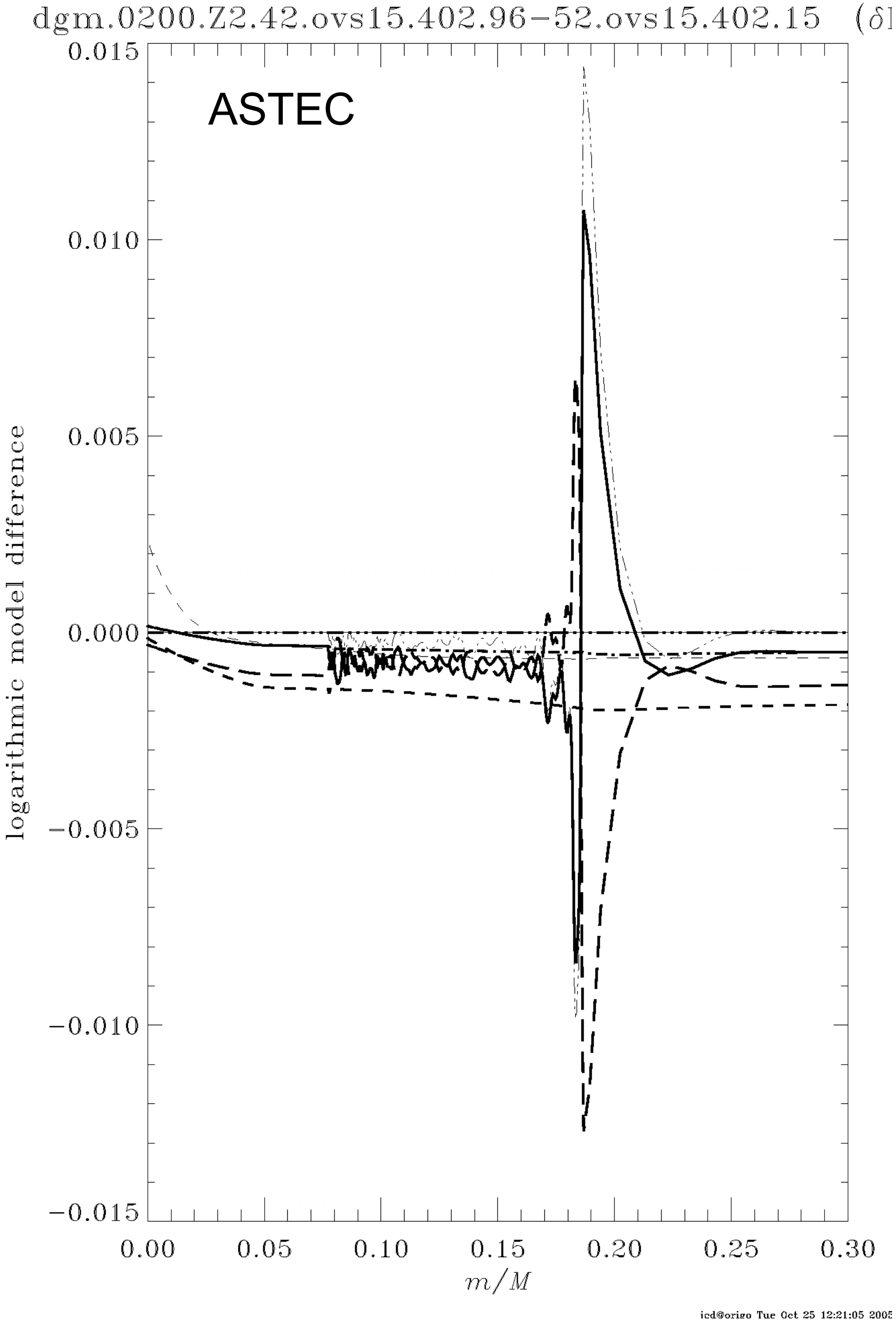
———— : $\delta \ln c^2$
-···—···— : $\delta \ln \Gamma_1$
———— : $\delta \ln q$
- - - - - - - : $\delta \ln L$
—···—···- : δX



Case 1.5

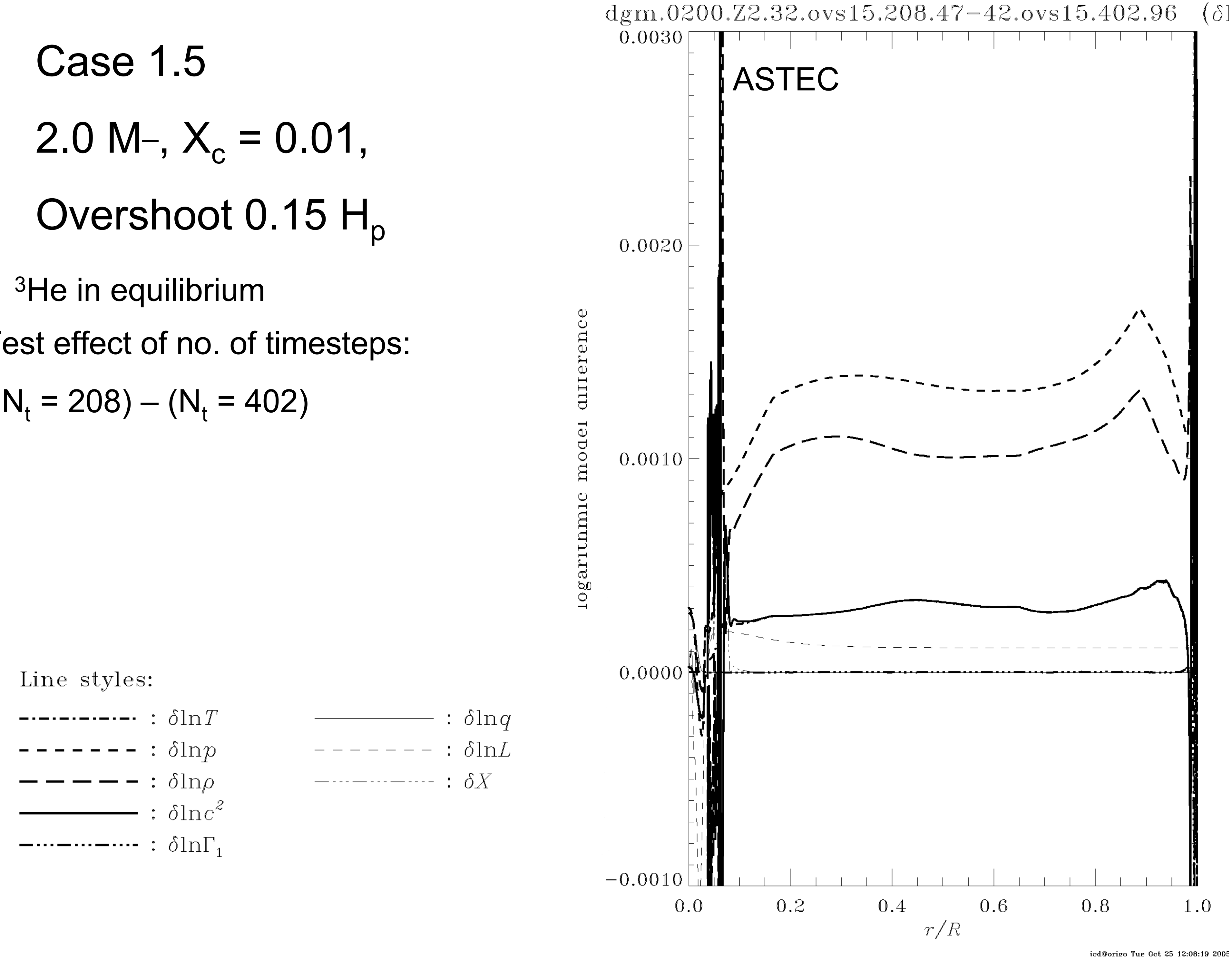
2.0 M⊙, X_c = 0.01,

Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of timesteps:

(N_t = 208) – (N_t = 402)



Case 1.5

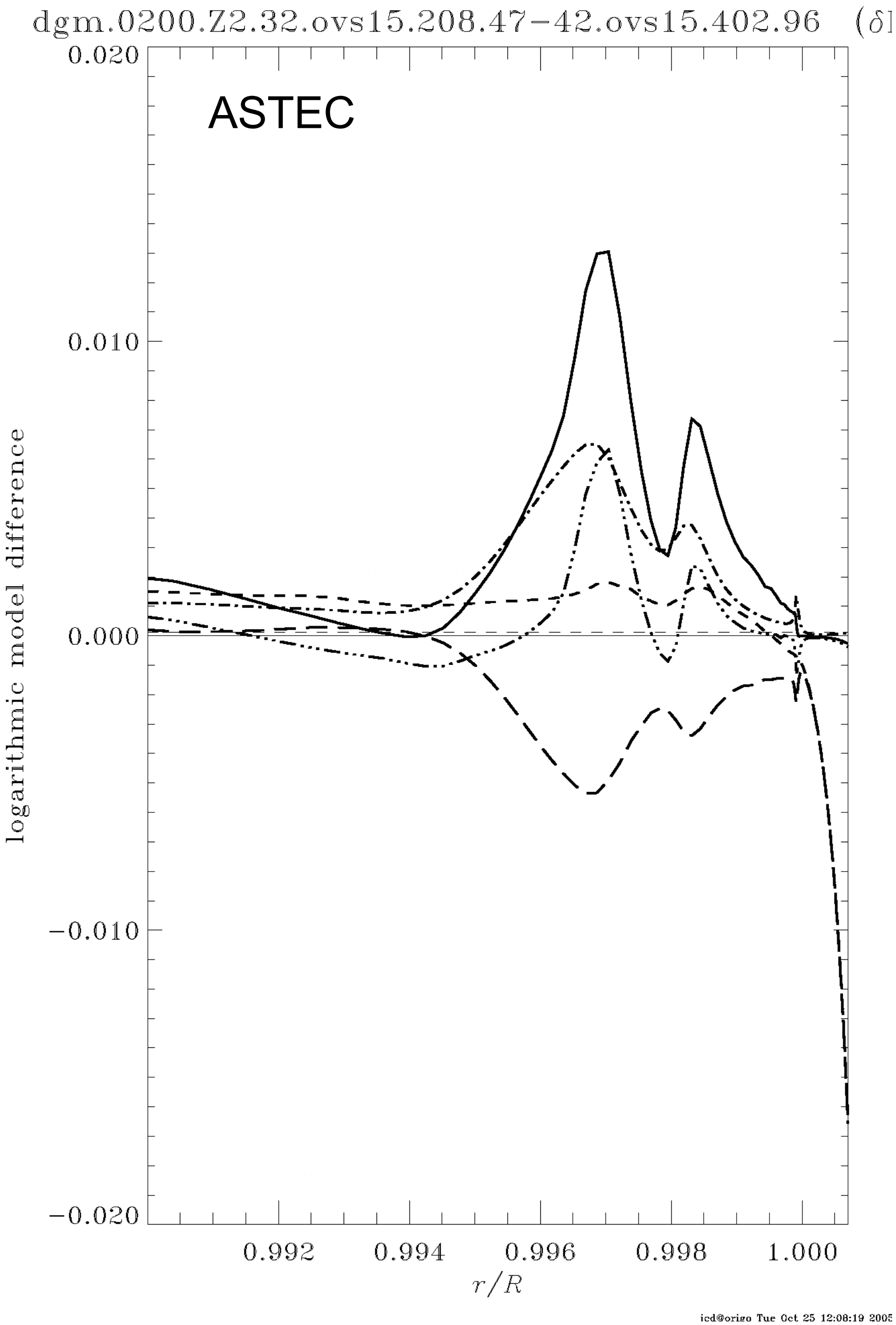
2.0 $M_{\odot}$, $X_c = 0.01$,

Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of timesteps:

(N_t = 208) – (N_t = 402)



Line styles:

- : $\delta\ln T$
- : $\delta\ln p$
- : $\delta\ln\rho$
- : $\delta\ln c^2$
- : $\delta\ln\Gamma_1$
- : $\delta\ln q$
- : $\delta\ln L$
- : δX

Case 1.5

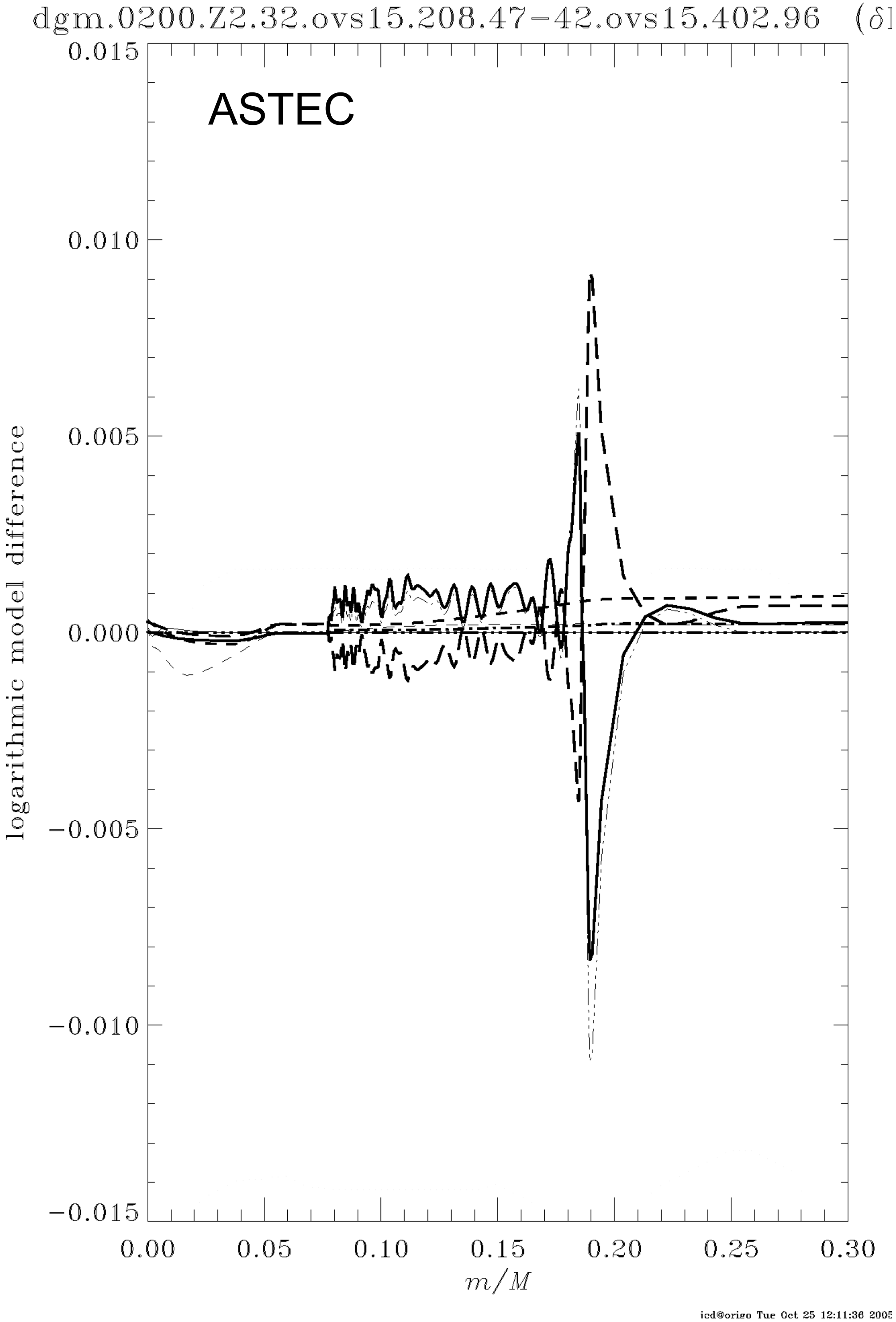
2.0 $M_\odot$, X_c = 0.01,

Overshoot 0.15 H_p

^{3}He in equilibrium

Test effect of no. of timesteps:

(N_t = 208) – (N_t = 402)



Line styles:

- dash-dot : $\delta \ln T$
- short dashes : $\delta \ln p$
- long dashes : $\delta \ln \rho$
- thick solid : $\delta \ln c^2$
- dash-dot-dot : $\delta \ln \Gamma_1$
- thin solid : $\delta \ln q$
- thin dashes : $\delta \ln L$
- thin dash-dot-dot : δX

Case 1.1

0.9 M⊙, X_c = 0.35,

TGEC

Test effect of no. of timesteps:

(Δ t = 2000 yr) – (Δ t = 1800 yr

Continuous: δ ln T

Dotted: δ ln p

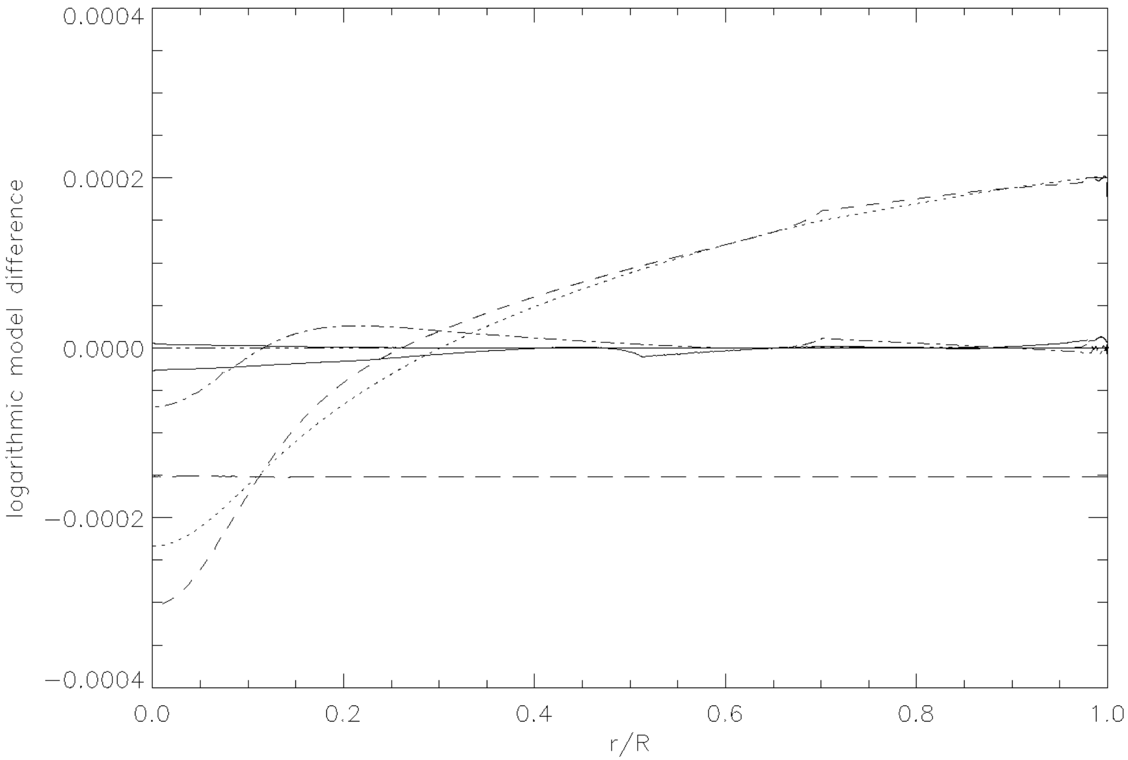
Dashed: δ ln ρ

Dot-dashed: δ ln c^2

3dot-dashed: δ ln Γ_1

Long-dashed: δ ln L

Thick continuous: δ ln X



Case 1.1

0.9 M⊙, X_c = 0.35,

TGEC

Test effect of no. of timesteps:

(Δ t = 2000 yr) – (Δ t = 2200 yr)

Continuous: $\delta \ln T$

Dotted: $\delta \ln p$

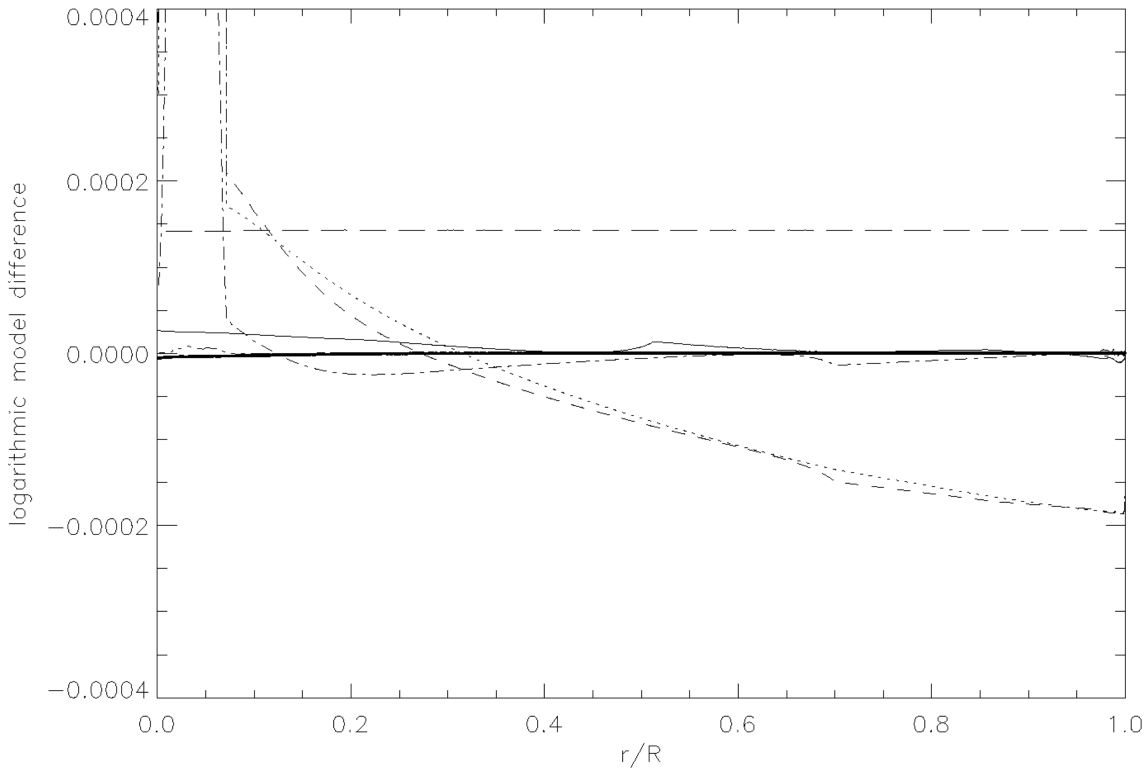
Dashed: $\delta \ln \rho$

Dot-dashed: $\delta \ln c^2$

3dot-dashed: $\delta \ln \Gamma_1$

Long-dashed: $\delta \ln L$

Thick continuous: $\delta \ln X$



Case 1.1

0.9 M⊙, X_c = 0.35,

TGEC

Test effect of no. of timesteps:

(Δ t = 2000 yr) – (Δ t = 2200 yr)

Continuous: $\delta \ln T$

Dotted: $\delta \ln p$

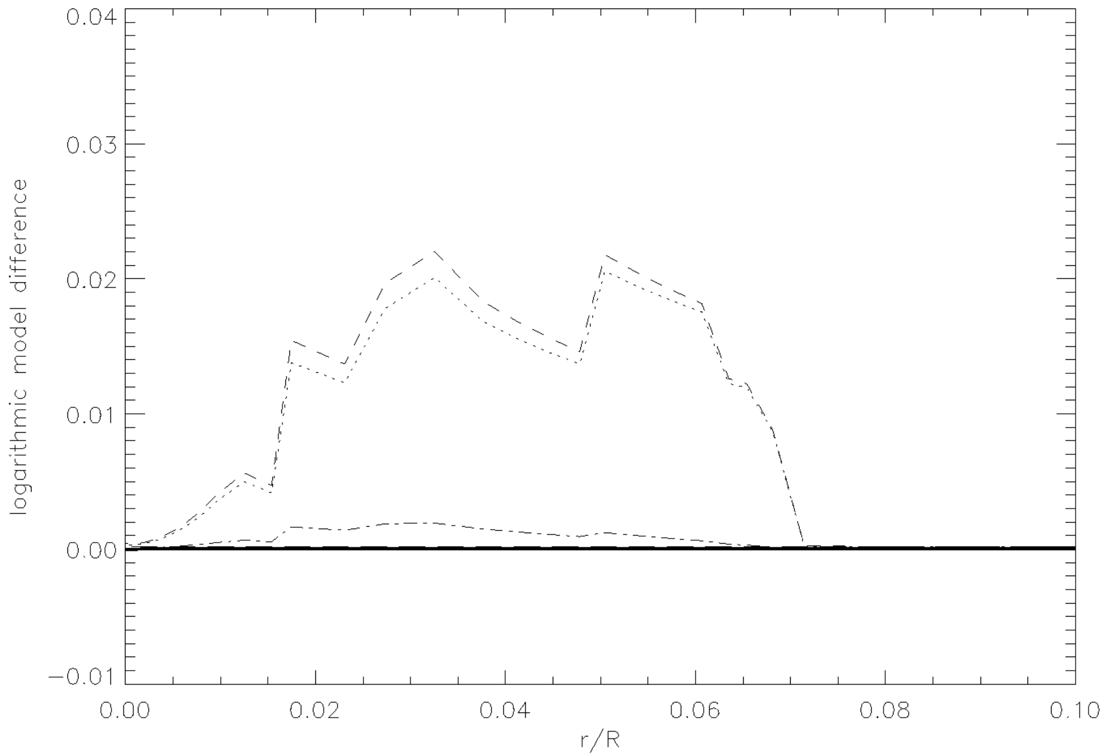
Dashed: $\delta \ln \rho$

Dot-dashed: $\delta \ln c^2$

3dot-dashed: $\delta \ln \Gamma_1$

Long-dashed: $\delta \ln L$

Thick continuous: $\delta \ln X$



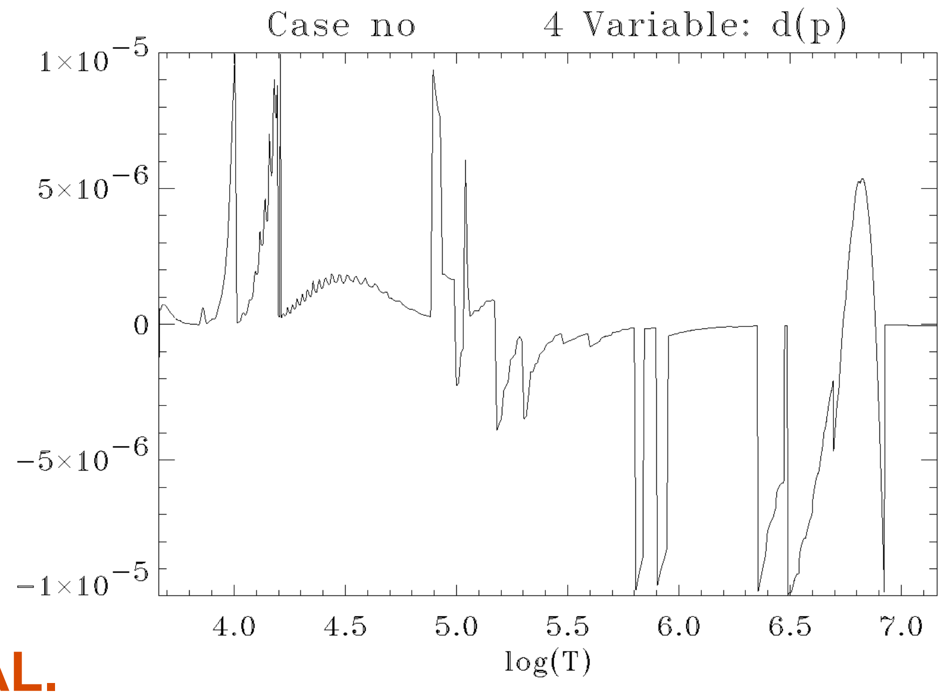
Physics comparisons

Evaluate physics (EOS, opacity, energy-generation rate, rate of composition change, …, at fixed T, ρ, X_i

Examples: comparing CESAM and CLES with ASTEC, showing, e.g.,

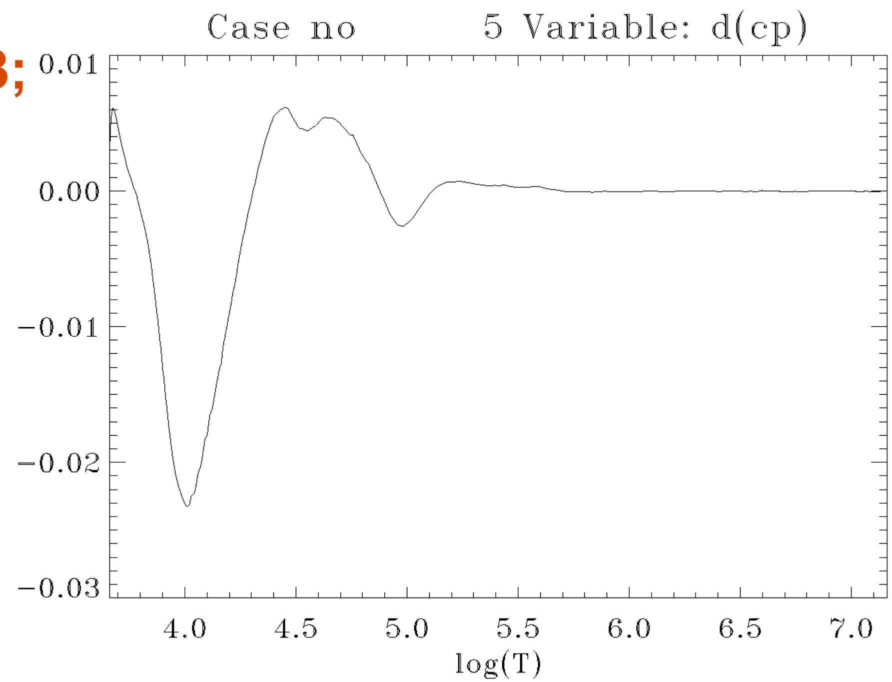
$\ln(\kappa_{ASTEC}(\rho_{CESAM}, T_{CESAM}, \ldots)/\kappa_{CESAM})$

CESAM, Case 1.1



Note: consistency problems in OPAL.

See also Boothroyd & Sackman (2003; ApJ 583, 1004)

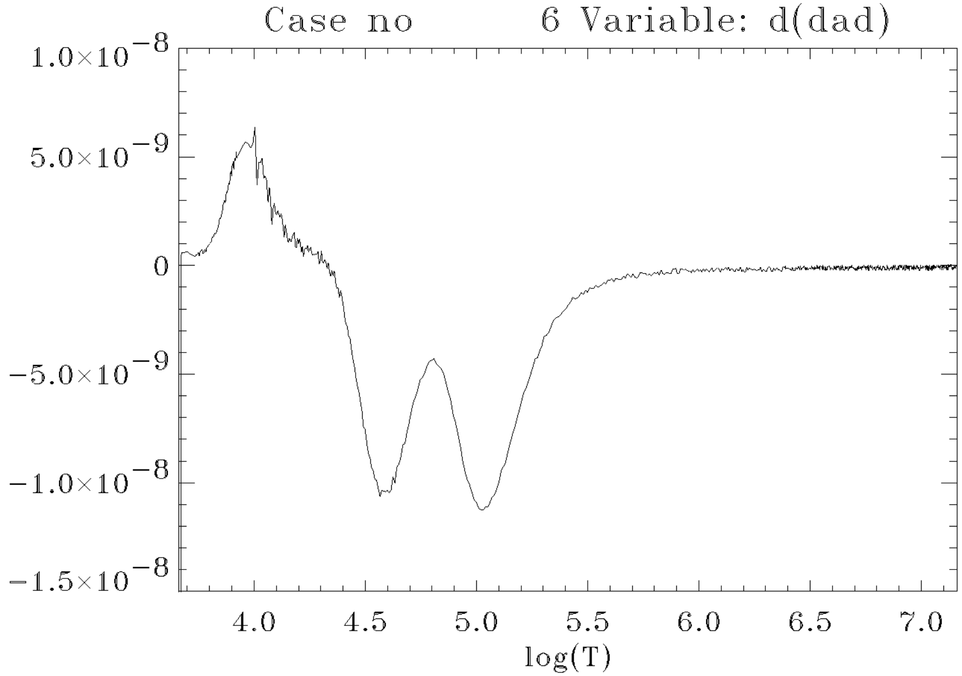


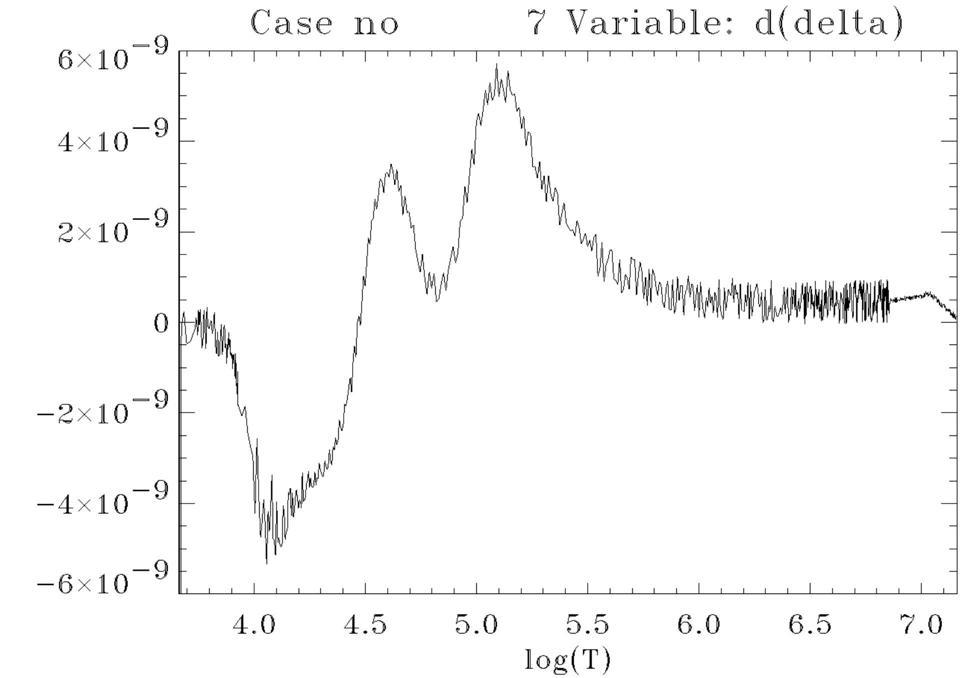
In ASTEC implementation:

Directly from OPAL: p, ∇_{ad}, δ, α, Γ_1

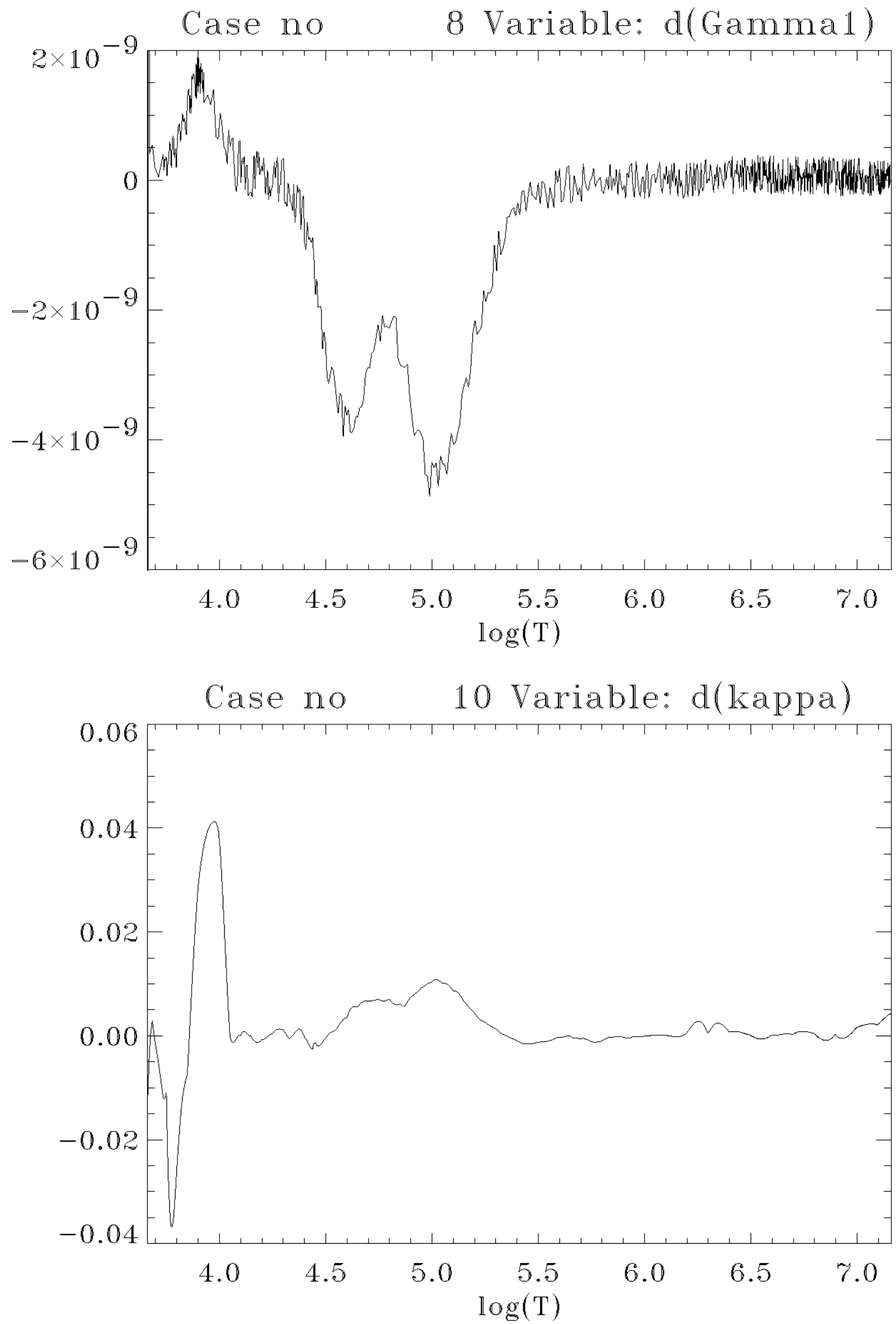
$c_p = c_v + p\, \delta^2/(\rho\, T\, \alpha)$

CESAM, Case 1.1

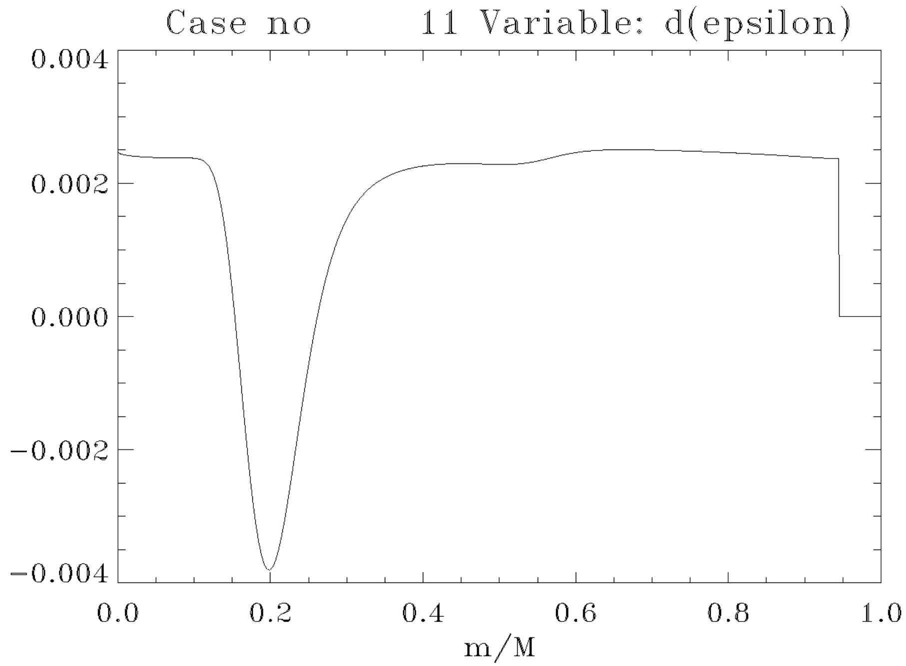




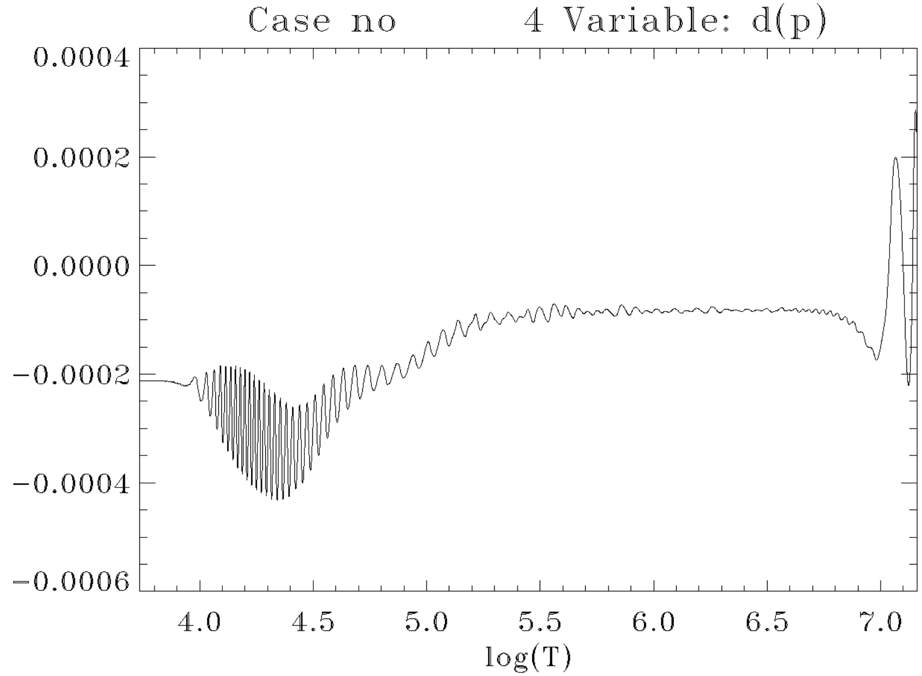
CESAM, Case 1.1



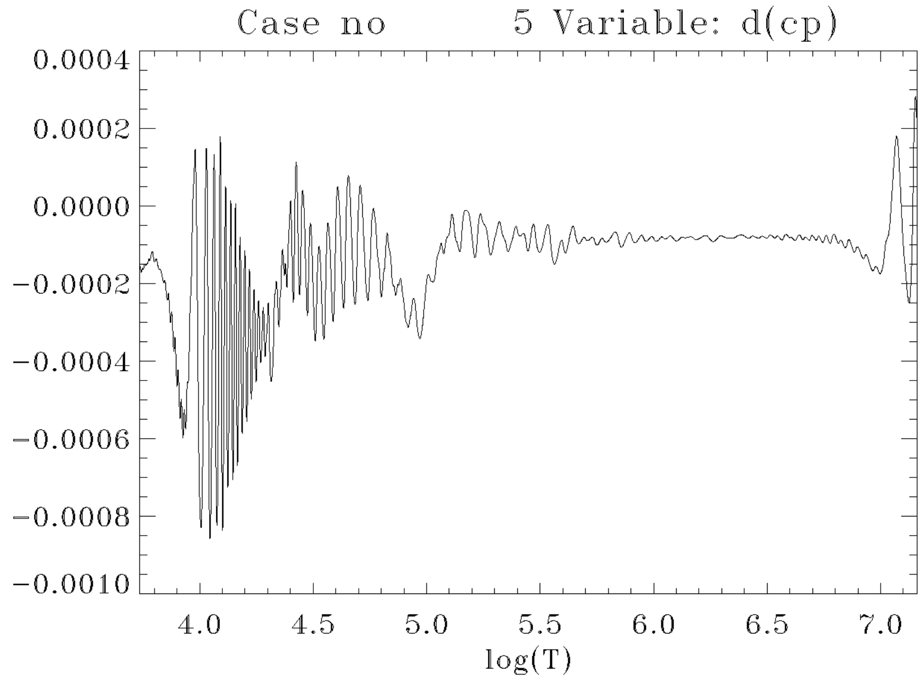
CESAM, Case 1.1



CLES, Case 1.1

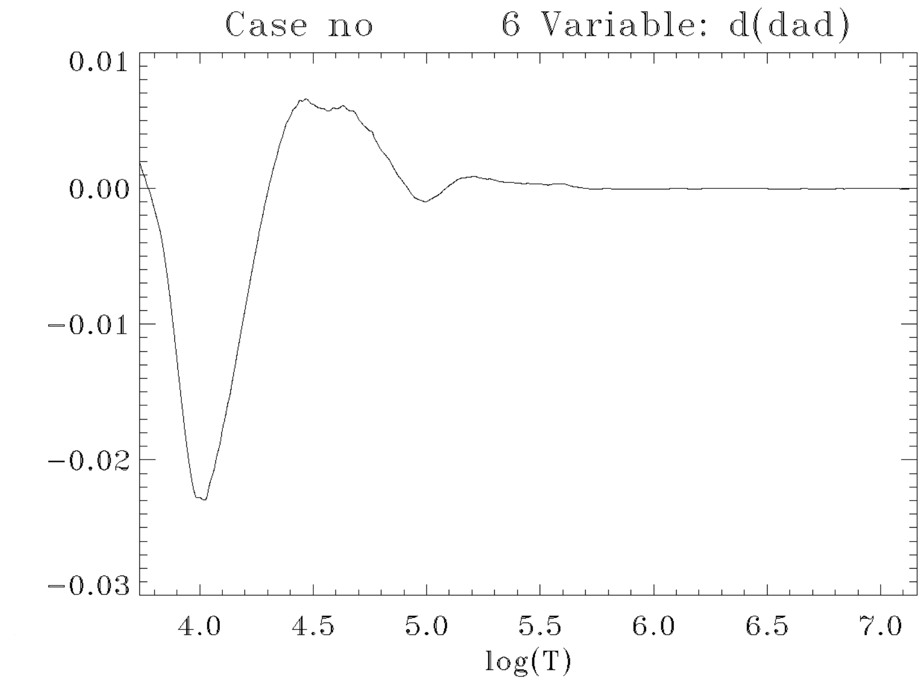


Case no 4 Variable: d(p)
0.0004
0.0002
0.0000
−0.0002
−0.0004
−0.0006
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)

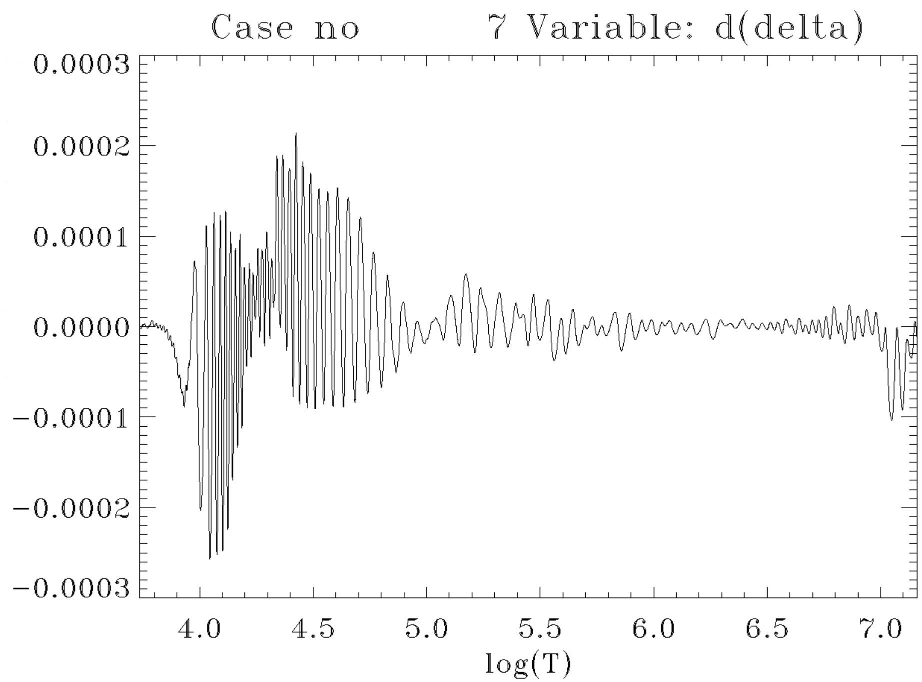


Case no 5 Variable: d(cp)
0.0004
0.0002
0.0000
−0.0002
−0.0004
−0.0006
−0.0008
−0.0010
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)

CLES, Case 1.1

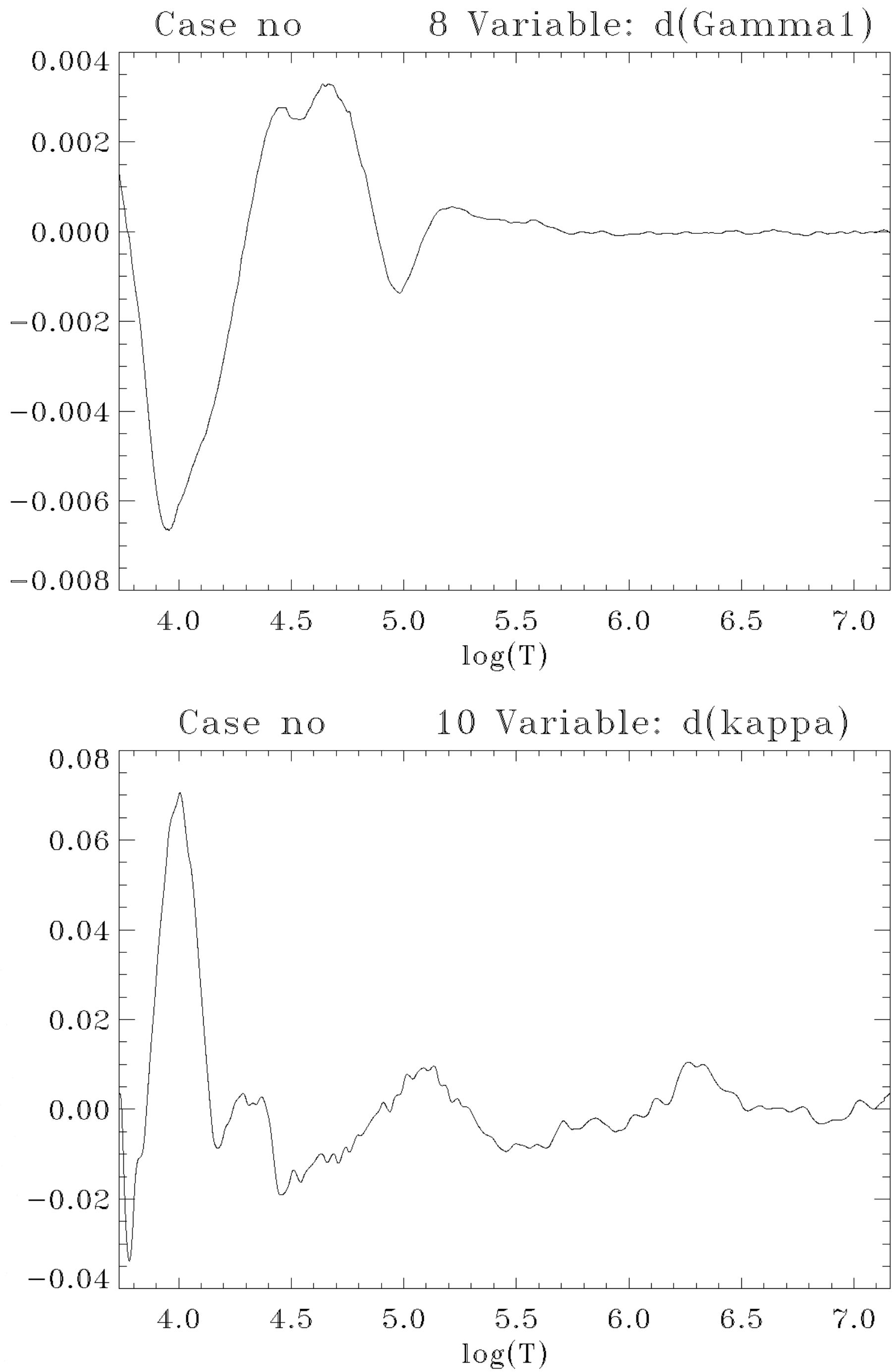


Case no 6 Variable: d(dad)
0.01
0.00
−0.01
−0.02
−0.03
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)

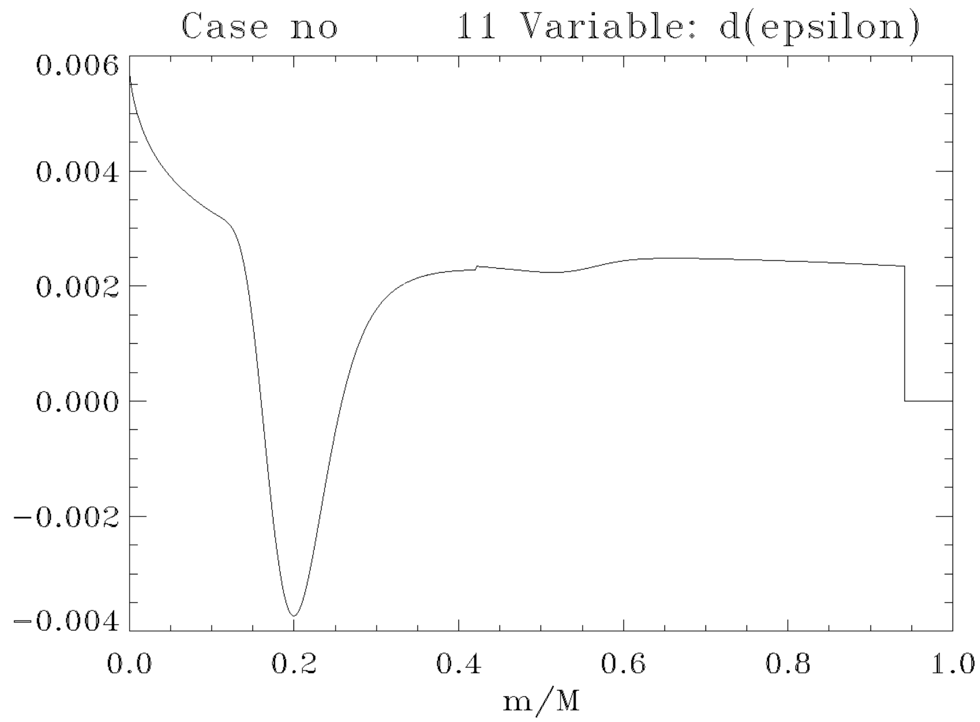


Case no 7 Variable: d(delta)
0.0003
0.0002
0.0001
0.0000
−0.0001
−0.0002
−0.0003
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)

CLES, Case 1.1


Case no 8 Variable: d(Gamma1)
0.004
0.002
0.000
−0.002
−0.004
−0.006
−0.008
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)
Case no 10 Variable: d(kappa)
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
4.0
4.5
5.0
5.5
6.0
6.5
7.0
log(T)

CLES, Case 1.1



jcd@tuc47.phys.au.dk Mon Oct 24 11:08:17 2005

Main project: compare different codes

- Evolution tracks
- Global parameters for selected models
- Detailed comparison of structure
- Comparison of oscillation frequencies

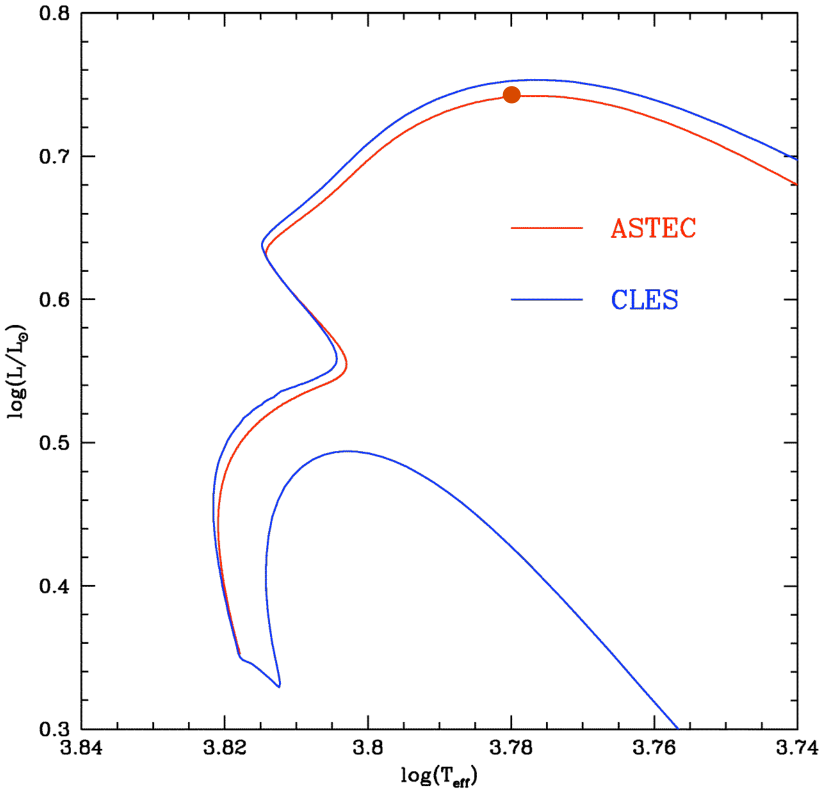
CLES and ASTEC

Case 1.3

1.2 M–

X_0 = 0.73, Z_0 = 0.01

M_{HeC} = 0.1 M–



CLES and ASTEC

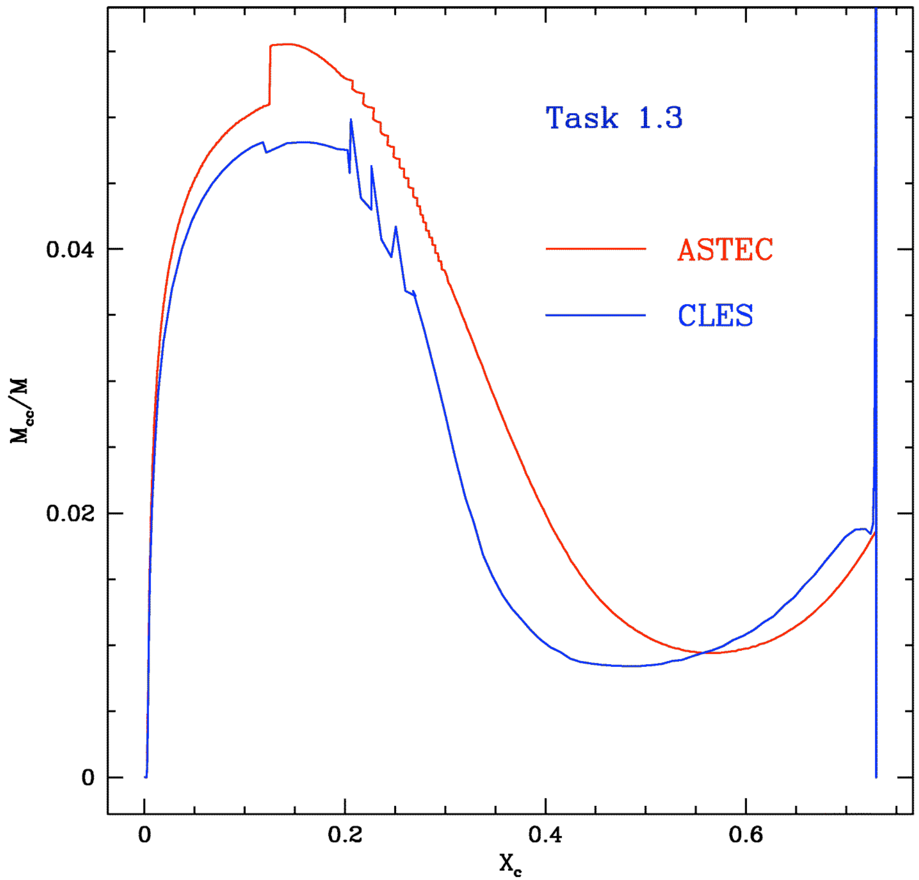
Case 1.3

1.2 M–

X_0 = 0.73, Z_0 = 0.01

M_{HeC} = 0.1 M–

M_c/M



X_c

CLES, CESAM and ASTEC

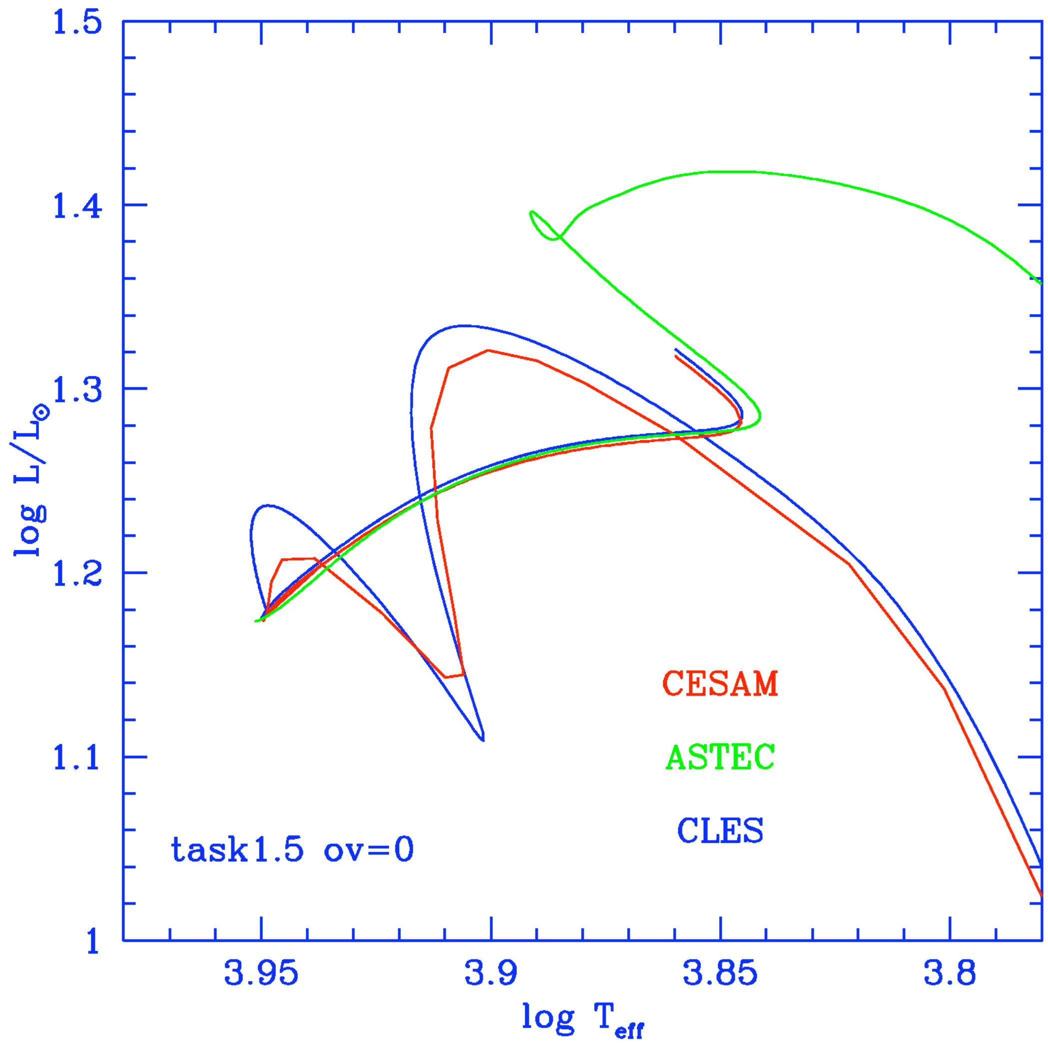
Case 1.5n

2.0 M–

$X_0 = 0.72$, $Z_0 = 0.02$

$X_c = 0.01$

No overshoot



CLES, CESAM and ASTEC

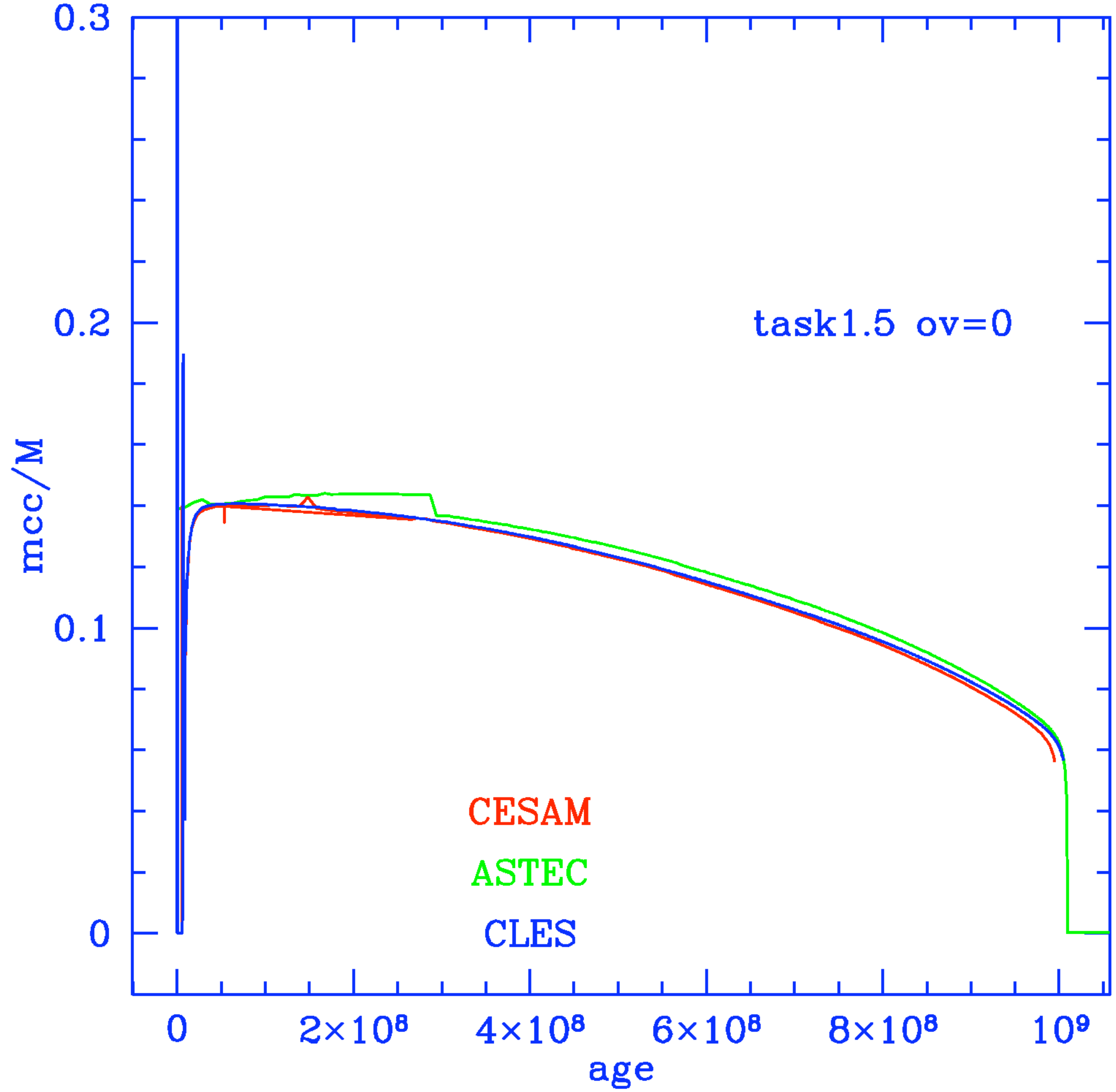
Case 1.5n

2.0 M–

X_0 = 0.72, Z_0 = 0.02

X_c = 0.01

No overshoot



CLES, CESAM and ASTEC

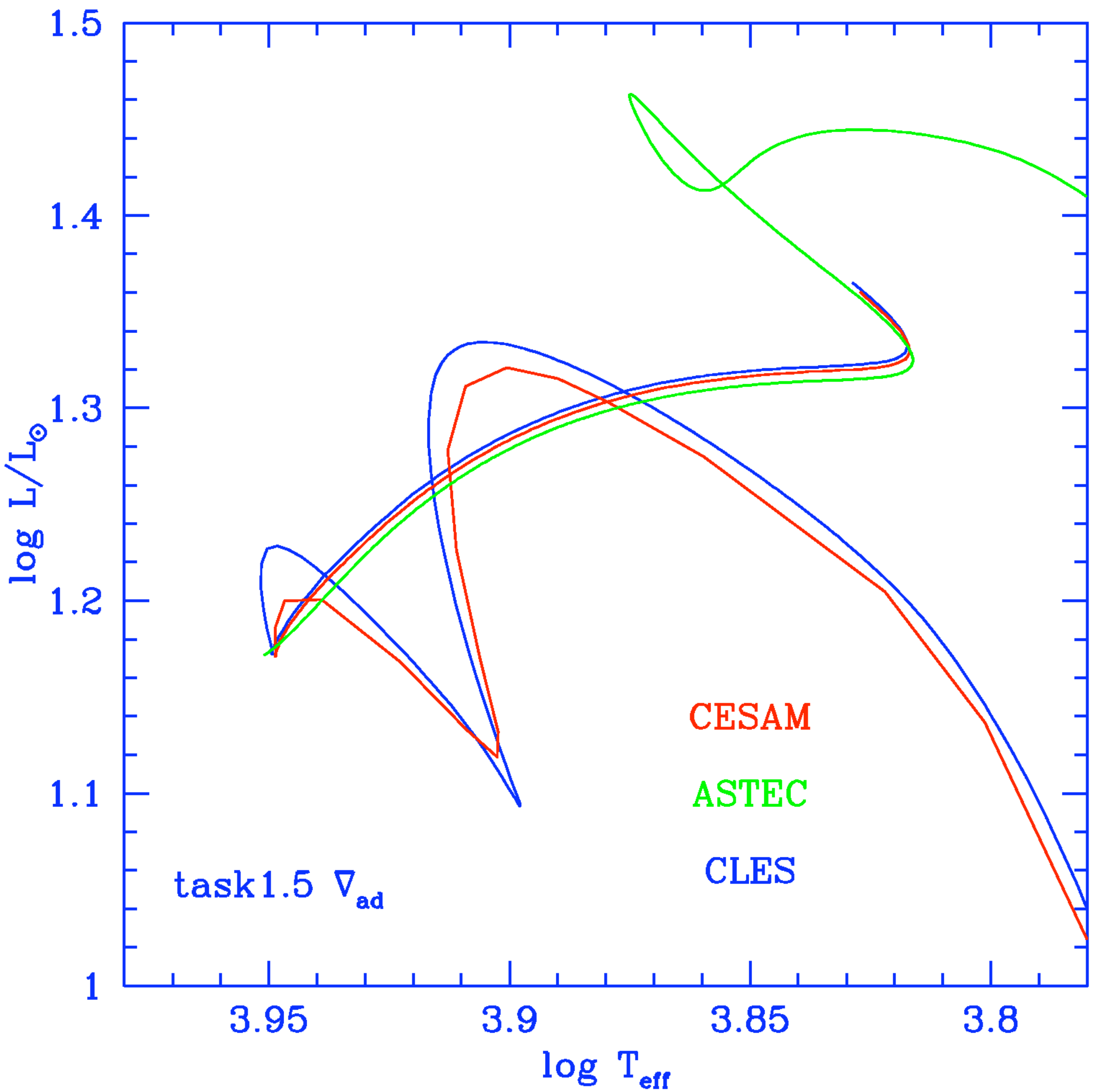
Case 1.5n

2.0 M–

X_0 = 0.72, Z_0 = 0.02

X_c = 0.01

Overshoot 0.15 H_p



CLES, CESAM and ASTEC

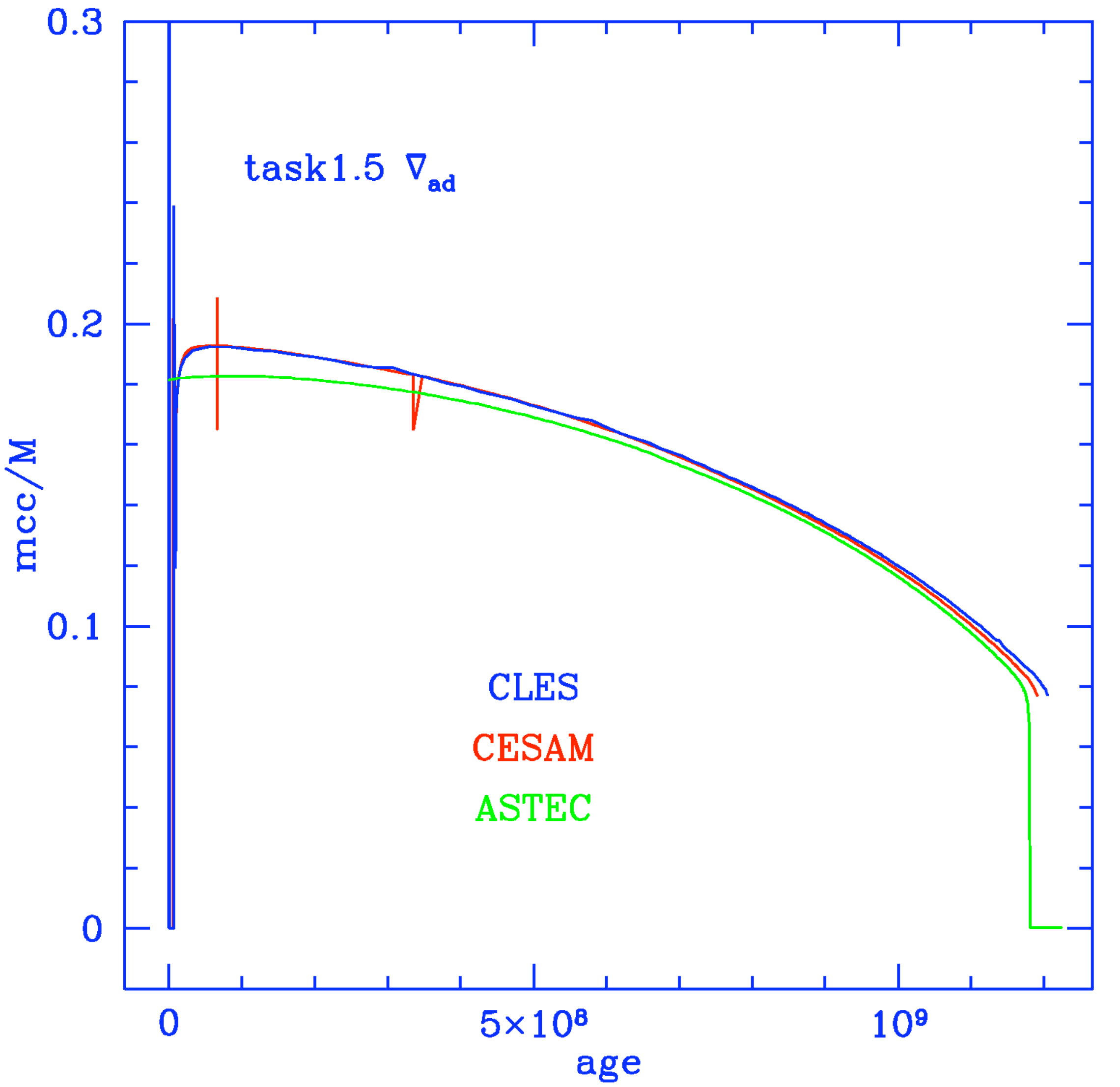
Case 1.5n

2.0 M–

X_0 = 0.72, Z_0 = 0.02

X_c = 0.01

Overshoot 0.15 H_p



Detailed model comparison

- Global quantities
- Differences at fixed m/M, plotted against m/M or r/R
- Differences at fixed r/R might be more illustrative for effects on oscillations (but not used yet)

Hydrogen abundance

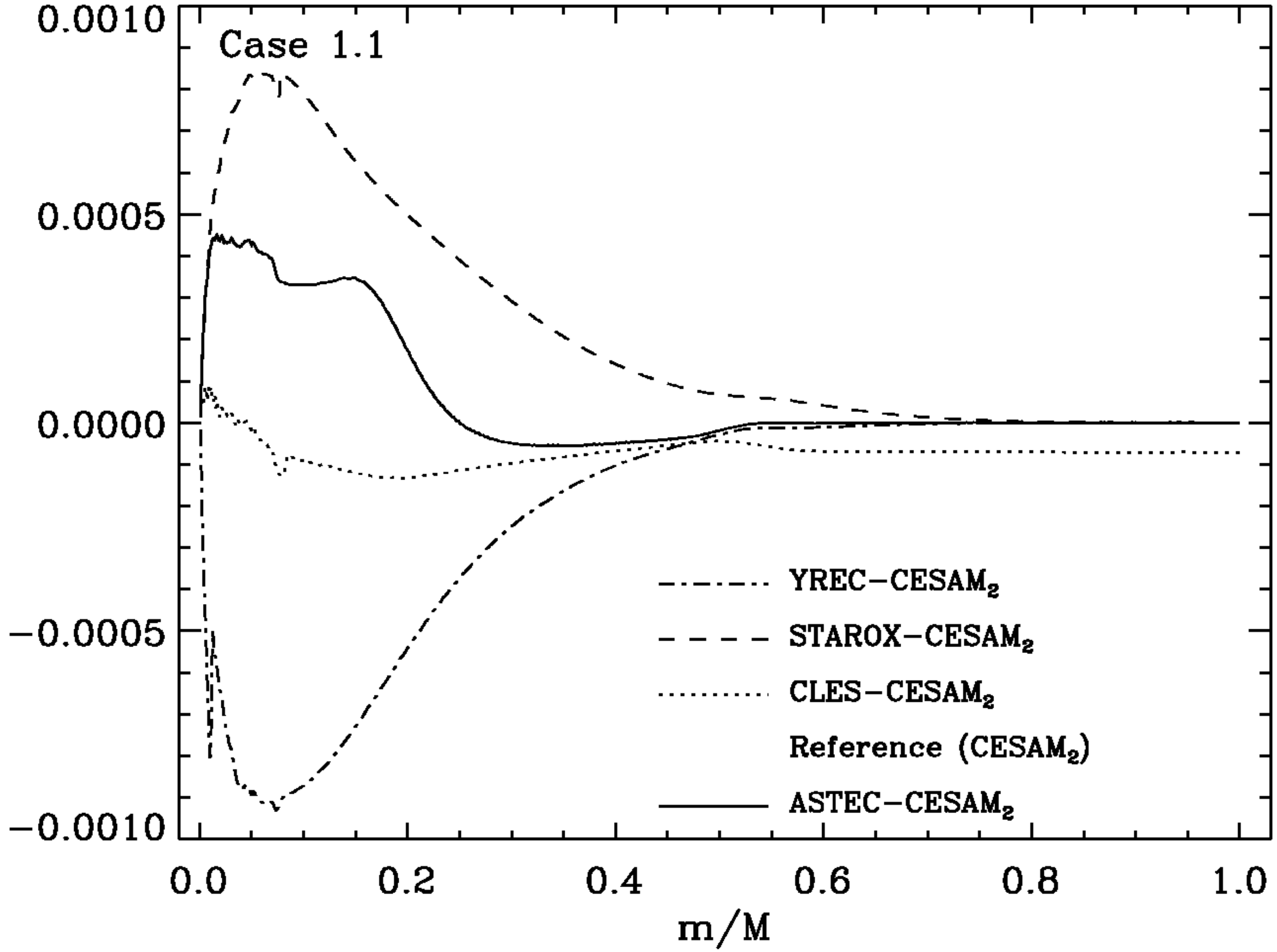
0.9 M–

$X_0 = 0.7$

$Z_0 = 0.02$

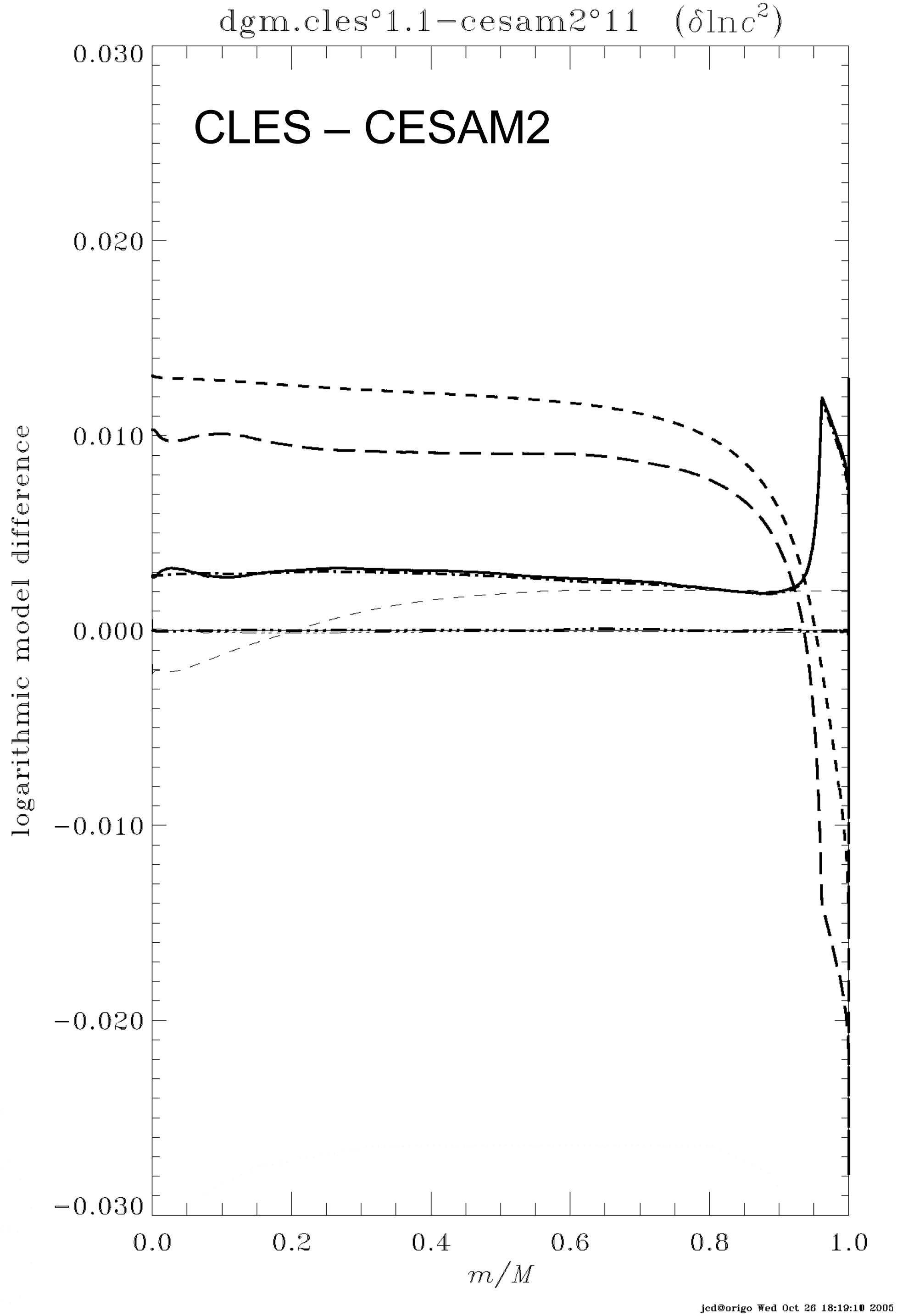
$X_c = 0.35$

δ X



Case 1.1

0.9 M⊙, X_c = 0.35

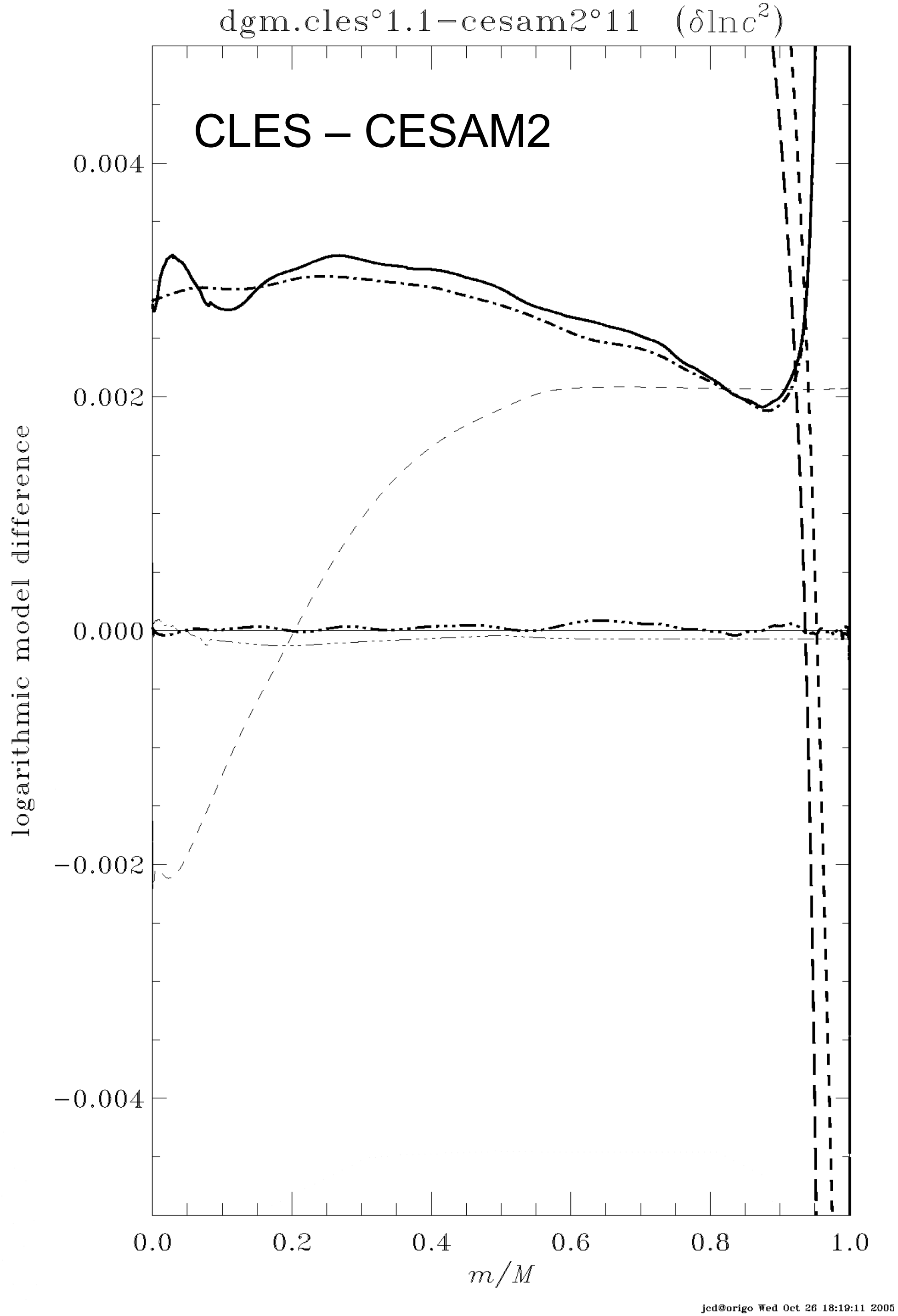


Line styles:

: $\delta \ln T$	: $\delta \ln q$
: $\delta \ln p$	: $\delta \ln L$
: $\delta \ln \rho$	: δX
: $\delta \ln c^2$	
: $\delta \ln \Gamma_1$	

Case 1.1

0.9 M⊙, X_c = 0.35

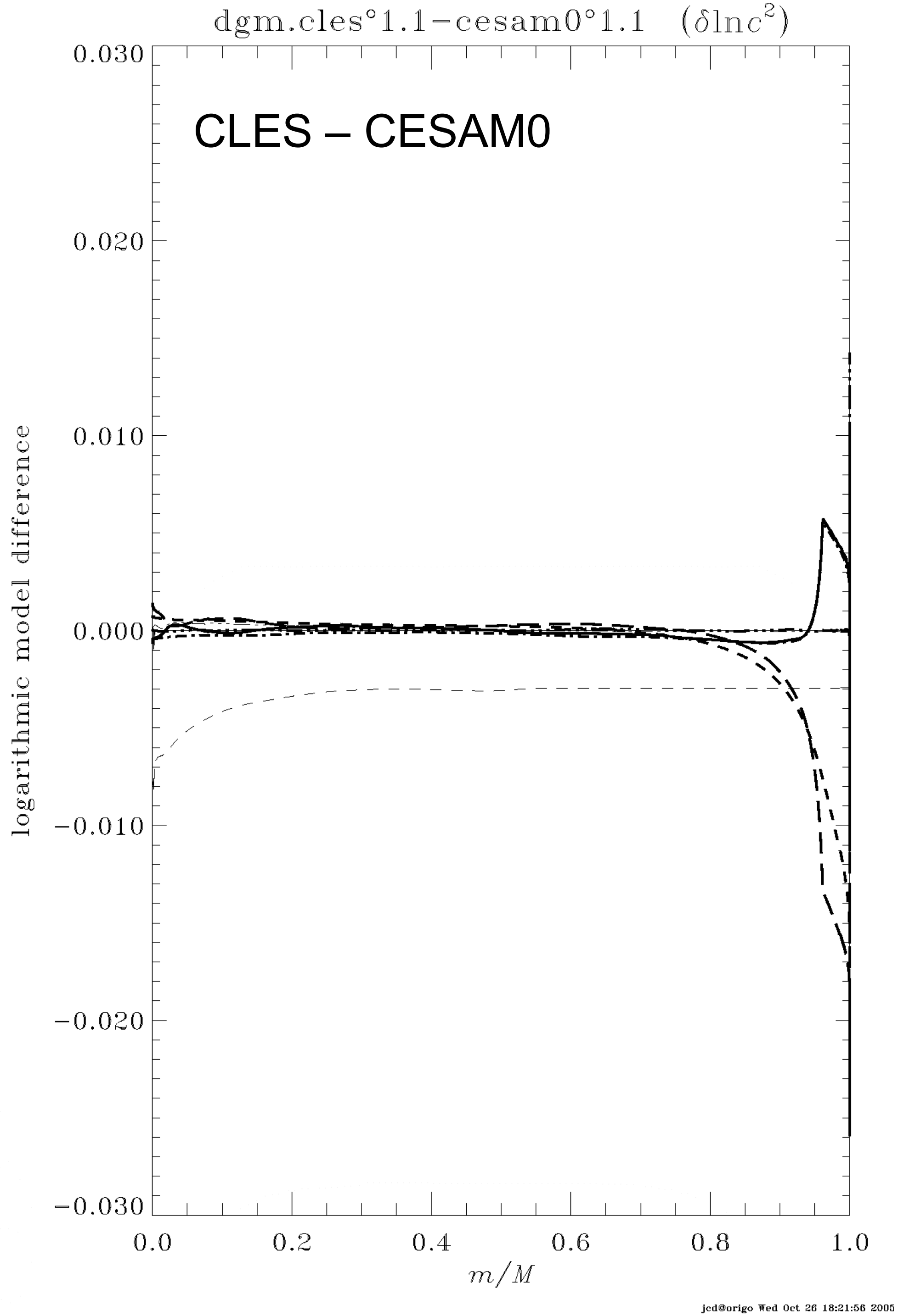


Line styles:

- dash-dot : $\delta \ln T$
- short dash : $\delta \ln p$
- long dash : $\delta \ln \rho$
- solid : $\delta \ln c^2$
- dash-triple-dot : $\delta \ln \Gamma_1$
- thin solid : $\delta \ln q$
- thin dashed : $\delta \ln L$
- thin dash-triple-dot : δX

Case 1.1

0.9 M–, X_c = 0.35



Line styles:

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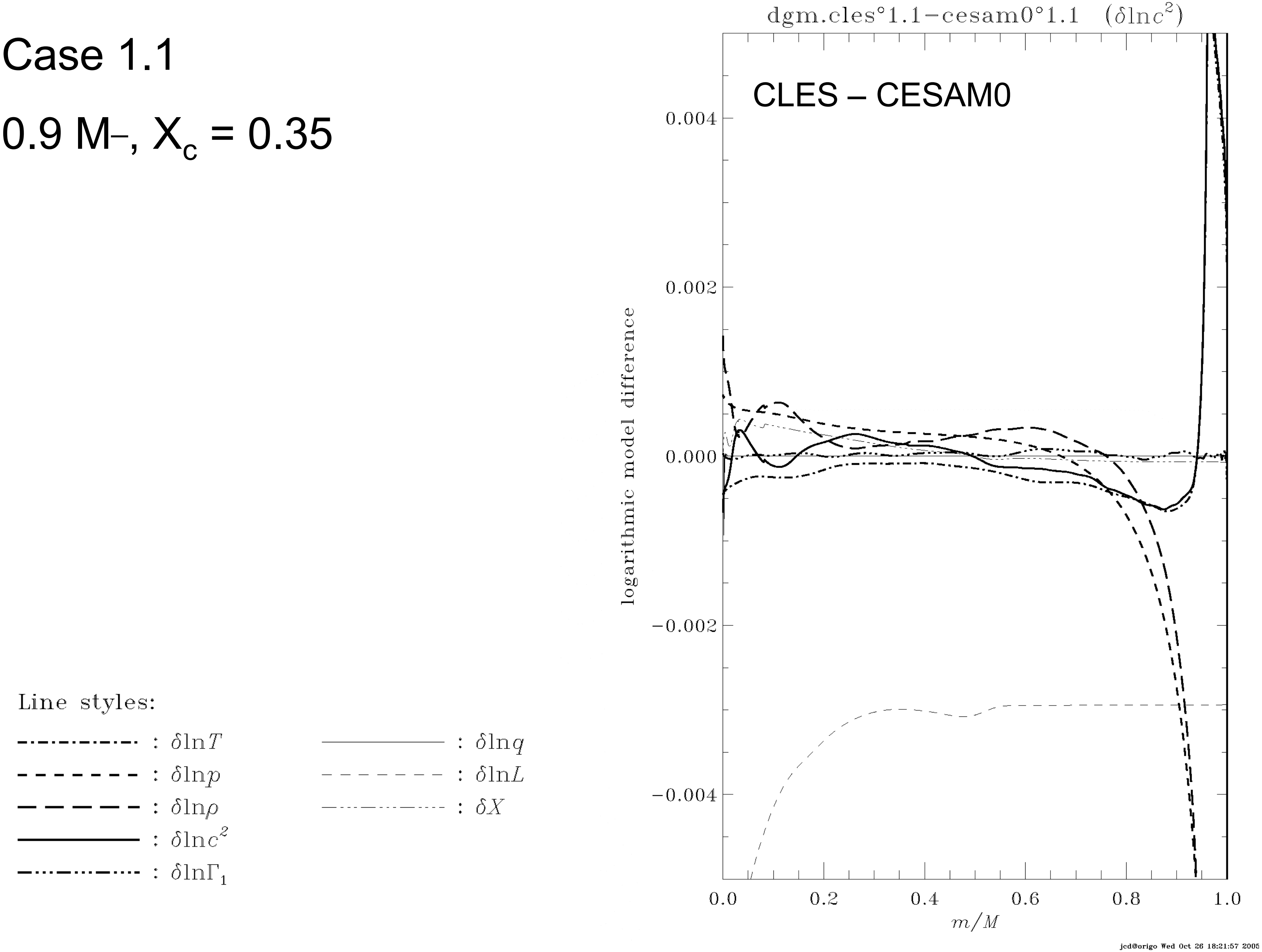
- : $\delta \ln p$
- : $\delta \ln \rho$
- : $\delta \ln c^2$
- : $\delta \ln \Gamma_1$
- : $\delta \ln q$
- : $\delta \ln L$
- : δX

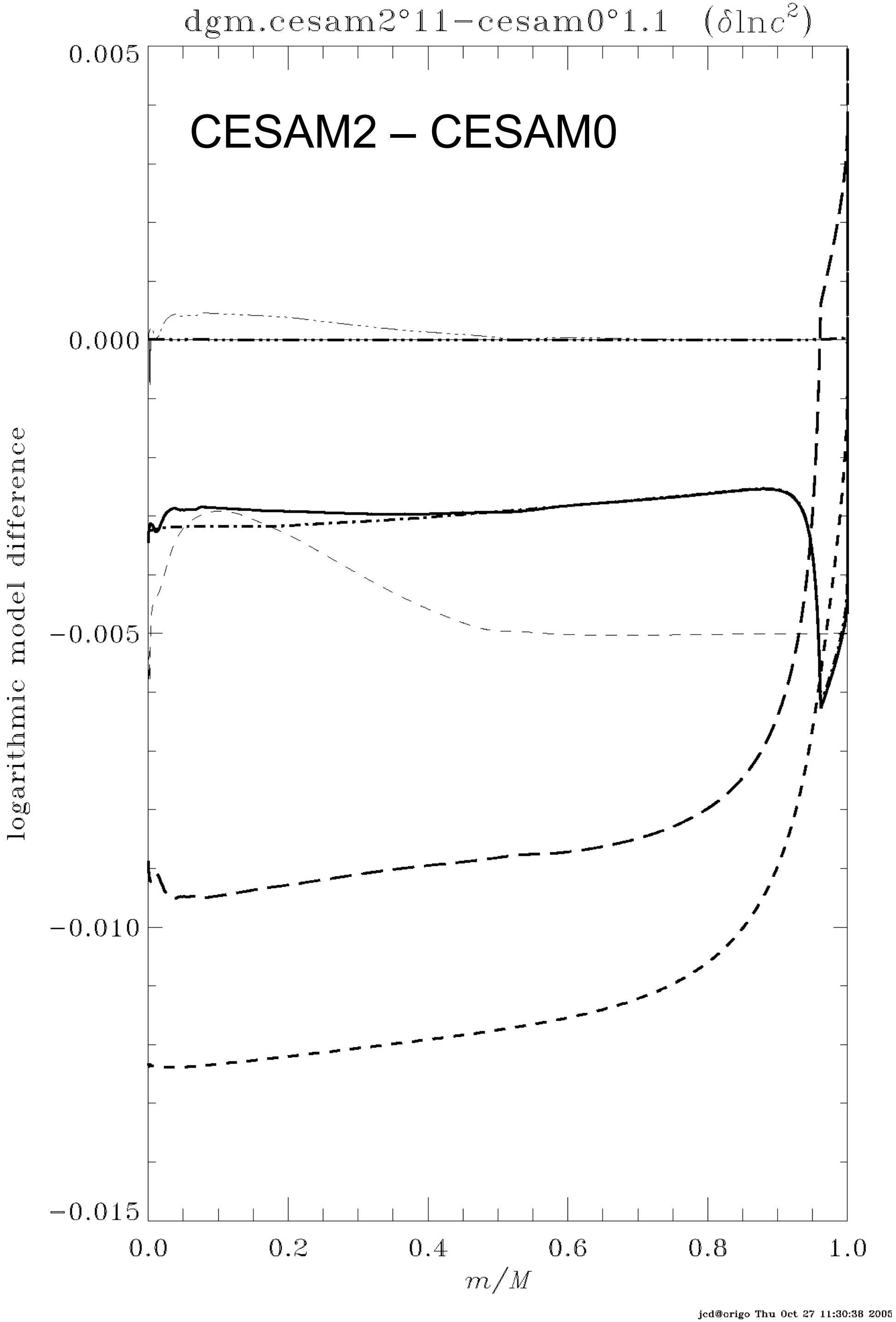
Case 1.1

$0.9\ M_{\odot}$, $X_c = 0.35$



Case 1.1

0.9 M–, X_c = 0.35

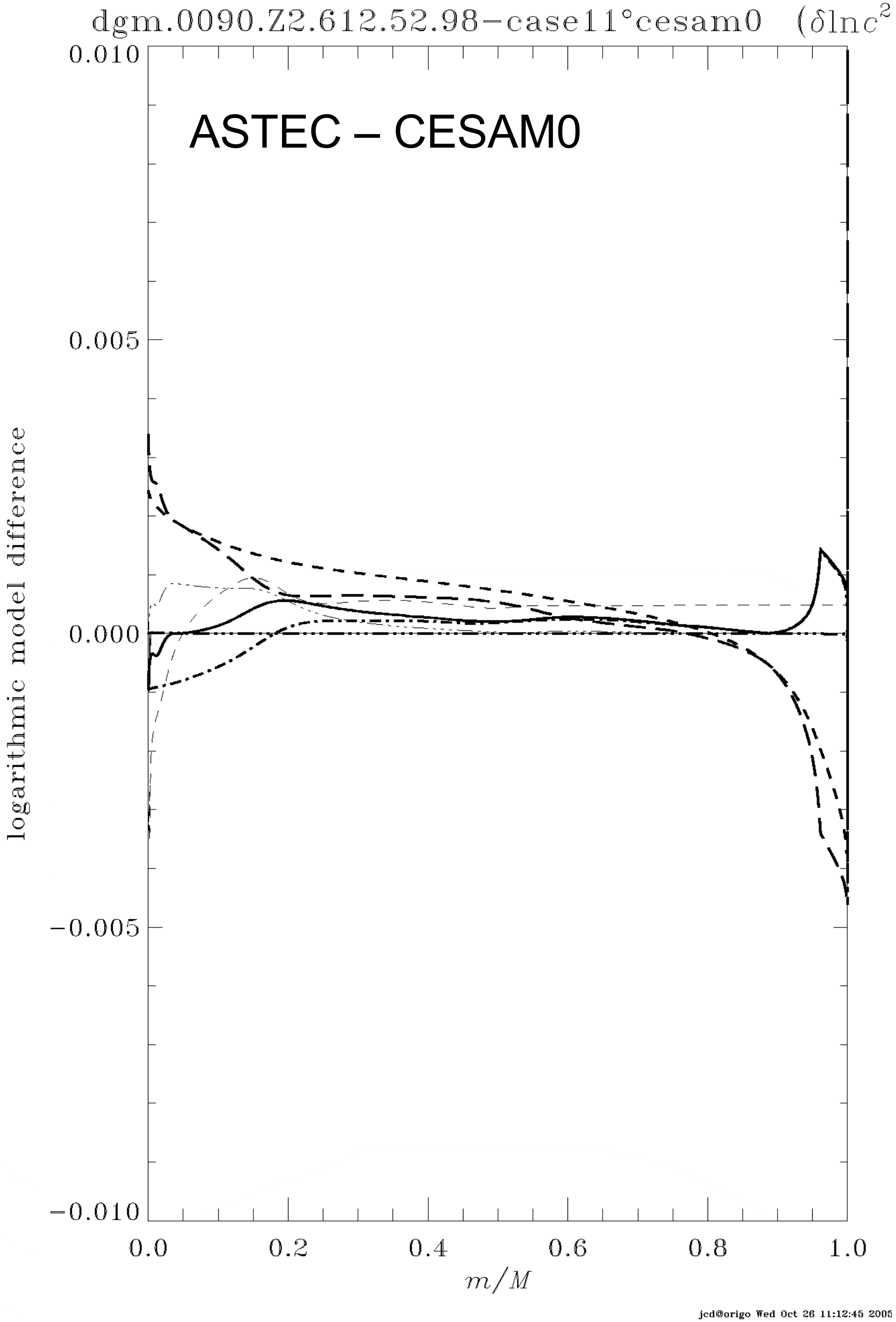


Line styles:

- $\delta \ln T$ (dash-dot)
- $\delta \ln p$ (short dash)
- $\delta \ln \rho$ (long dash)
- $\delta \ln c^2$ (solid)
- $\delta \ln \Gamma_1$ (dash-dot-dot-dot)
- $\delta \ln q$ (thin solid)
- $\delta \ln L$ (thin dash)
- δX (thin dash-dot-dot-dot)

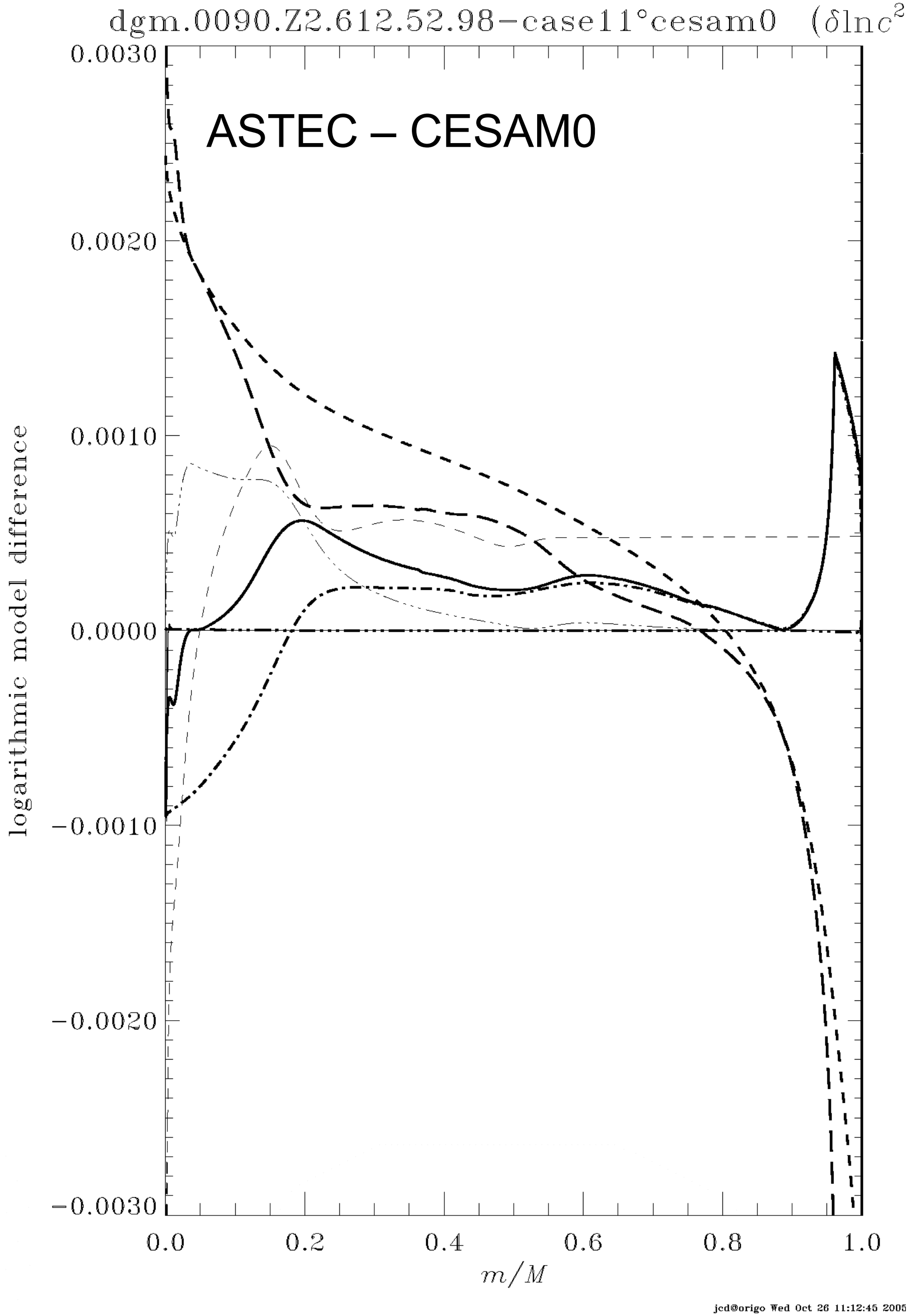
Case 1.1

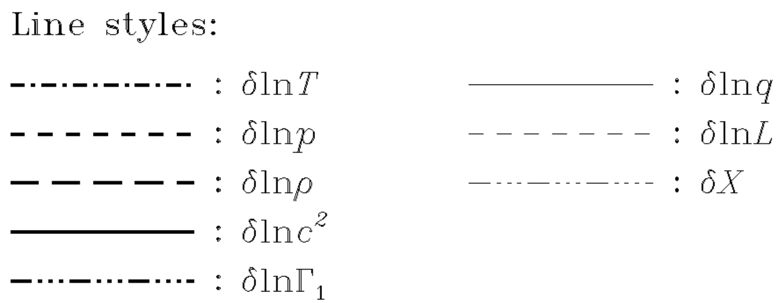
0.9 M–, X_c = 0.35



Case 1.1

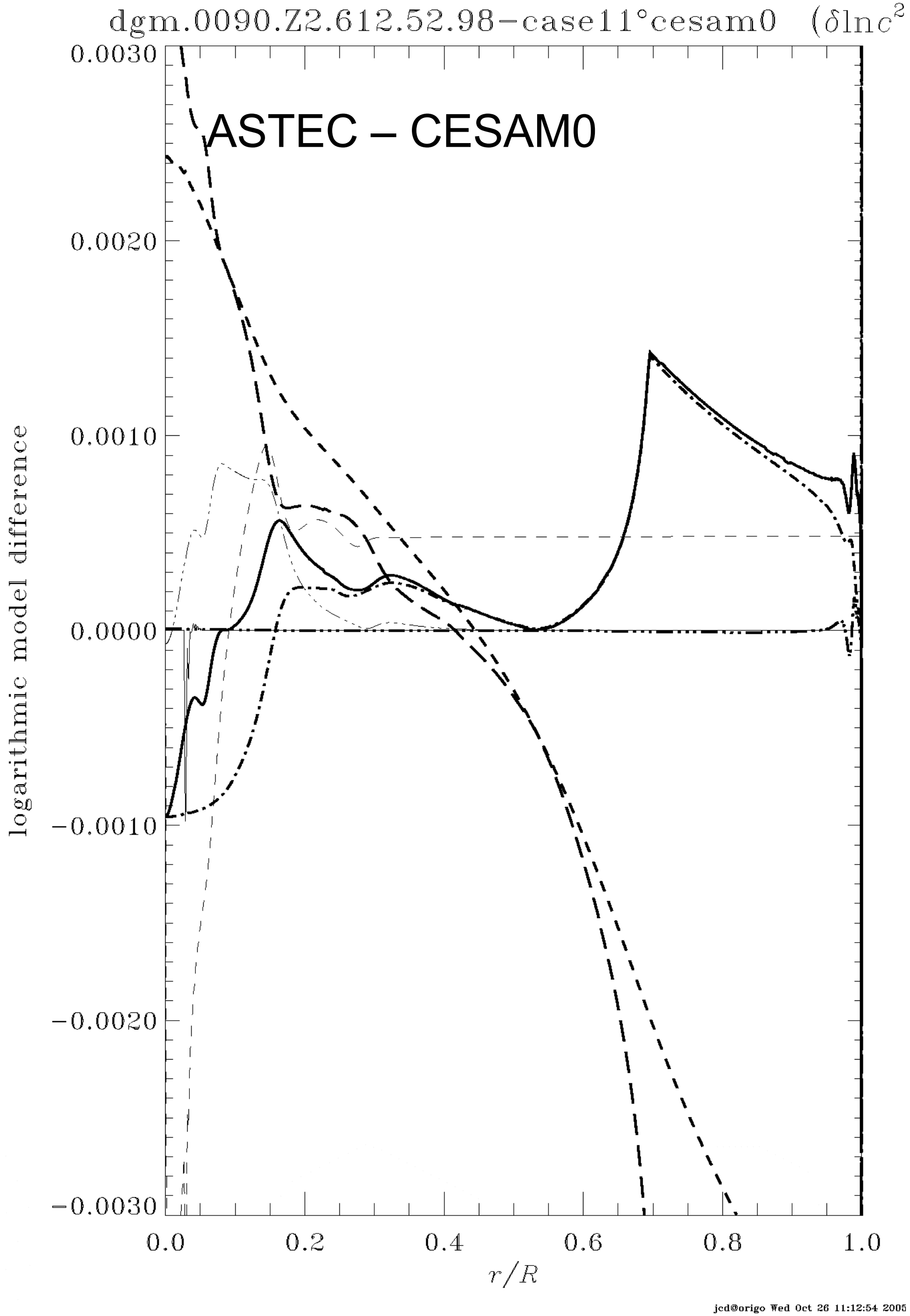
0.9 M–, X_c = 0.35





Case 1.1

0.9 M–, X_c = 0.35

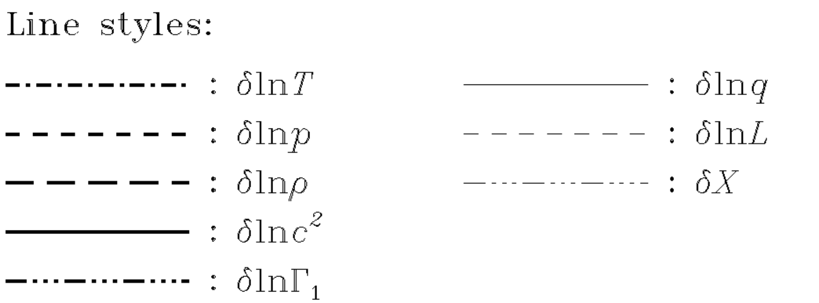


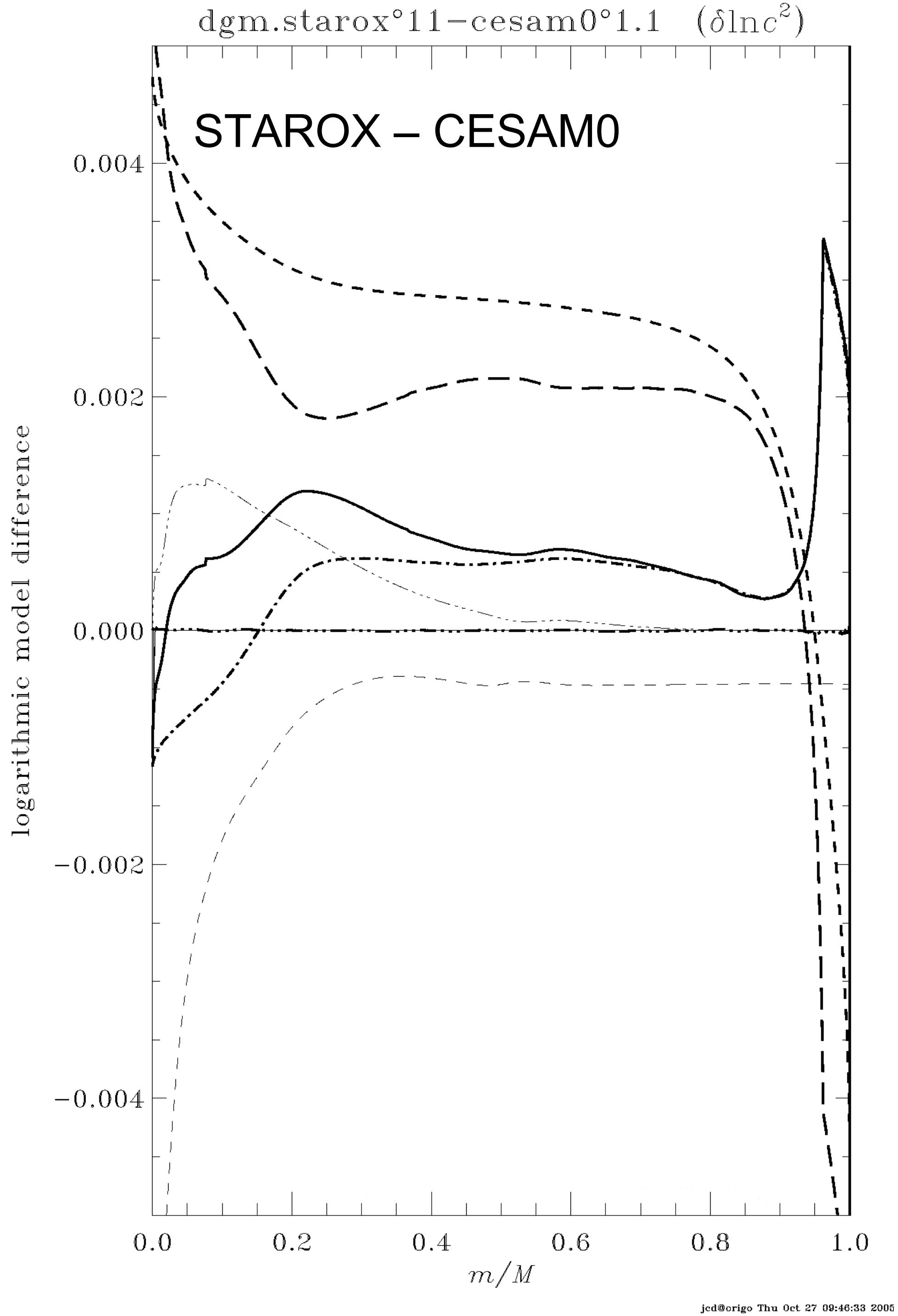
Line styles:

- ‒·‒·‒·‒ : $\delta\ln T$
- ‒ ‒ ‒ ‒ : $\delta\ln p$
- — — — : $\delta\ln\rho$
- ——— : $\delta\ln c^2$
- ‒···‒···‒ : $\delta\ln\Gamma_1$
- ——— : $\delta\ln q$
- ‒ ‒ ‒ ‒ : $\delta\ln L$
- ‒···‒···‒ : δX

Case 1.1

0.9 M–, X_c = 0.35





Hydrogen abundance

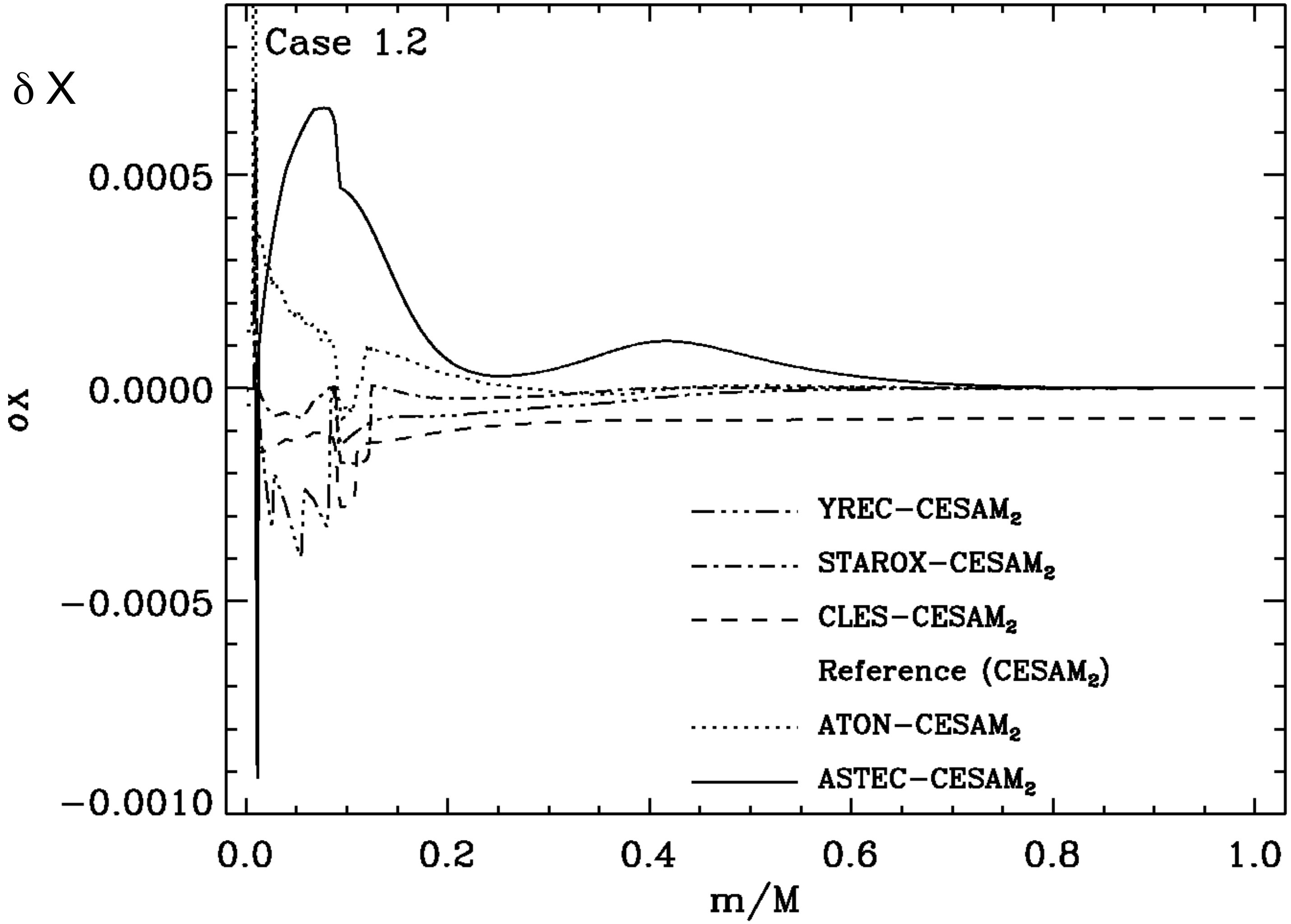
1.2 M–

$X_0 = 0.7$

$Z_0 = 0.02$

$X_c = 0.69$

δ X



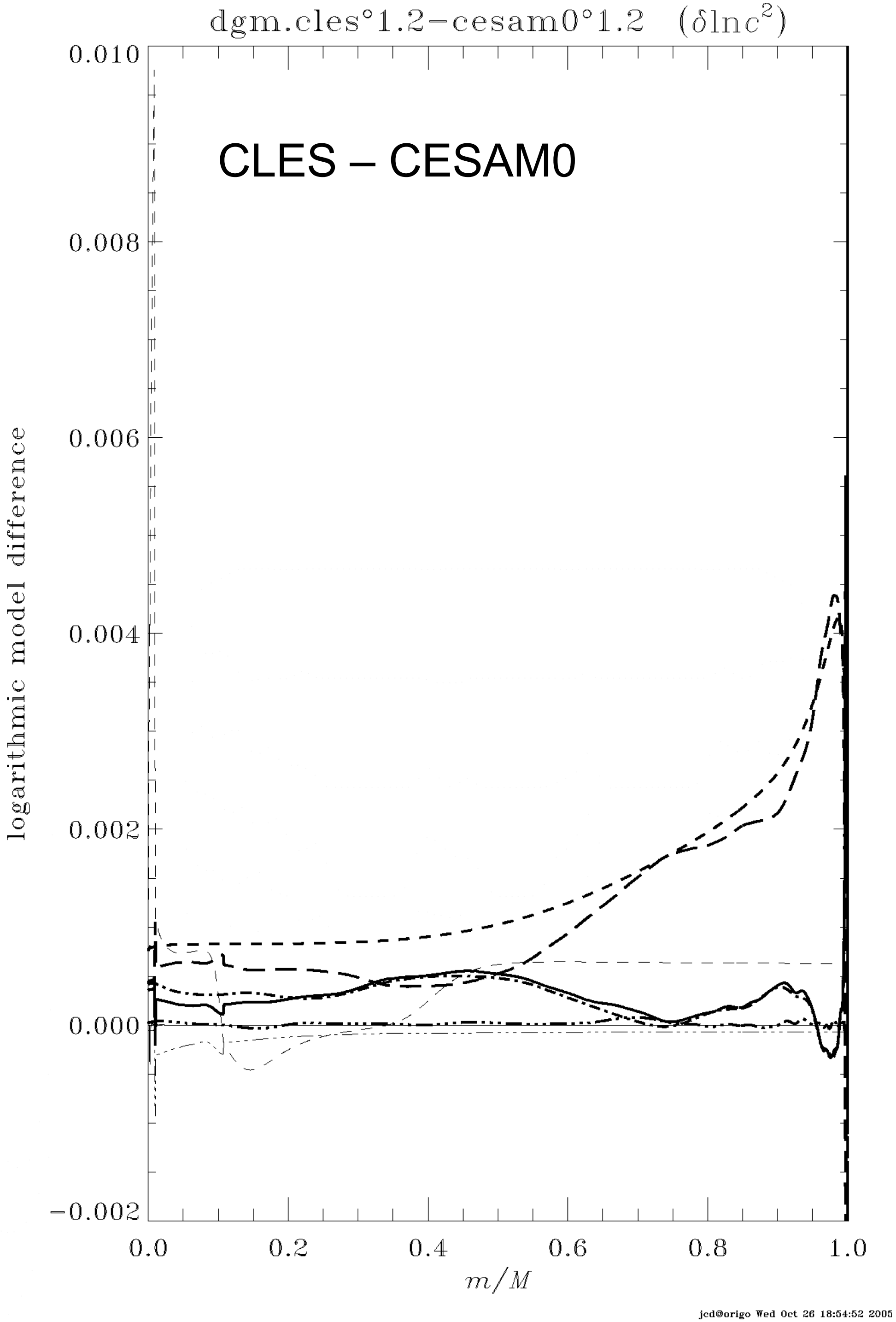
Case 1.2

1.2 M–

X_0 = 0.7

Z_0 = 0.02

X_c = 0.69



Line styles:

- dash-dot line : $\delta \ln T$
- short dashes : $\delta \ln p$
- long dashes : $\delta \ln \rho$
- solid line : $\delta \ln c^2$
- dash-dot-dot-dot line : $\delta \ln \Gamma_1$
- thin solid line : $\delta \ln q$
- thin dashes : $\delta \ln L$
- thin dash-dot-dot-dot line : δX

Case 1.2

1.2 M–

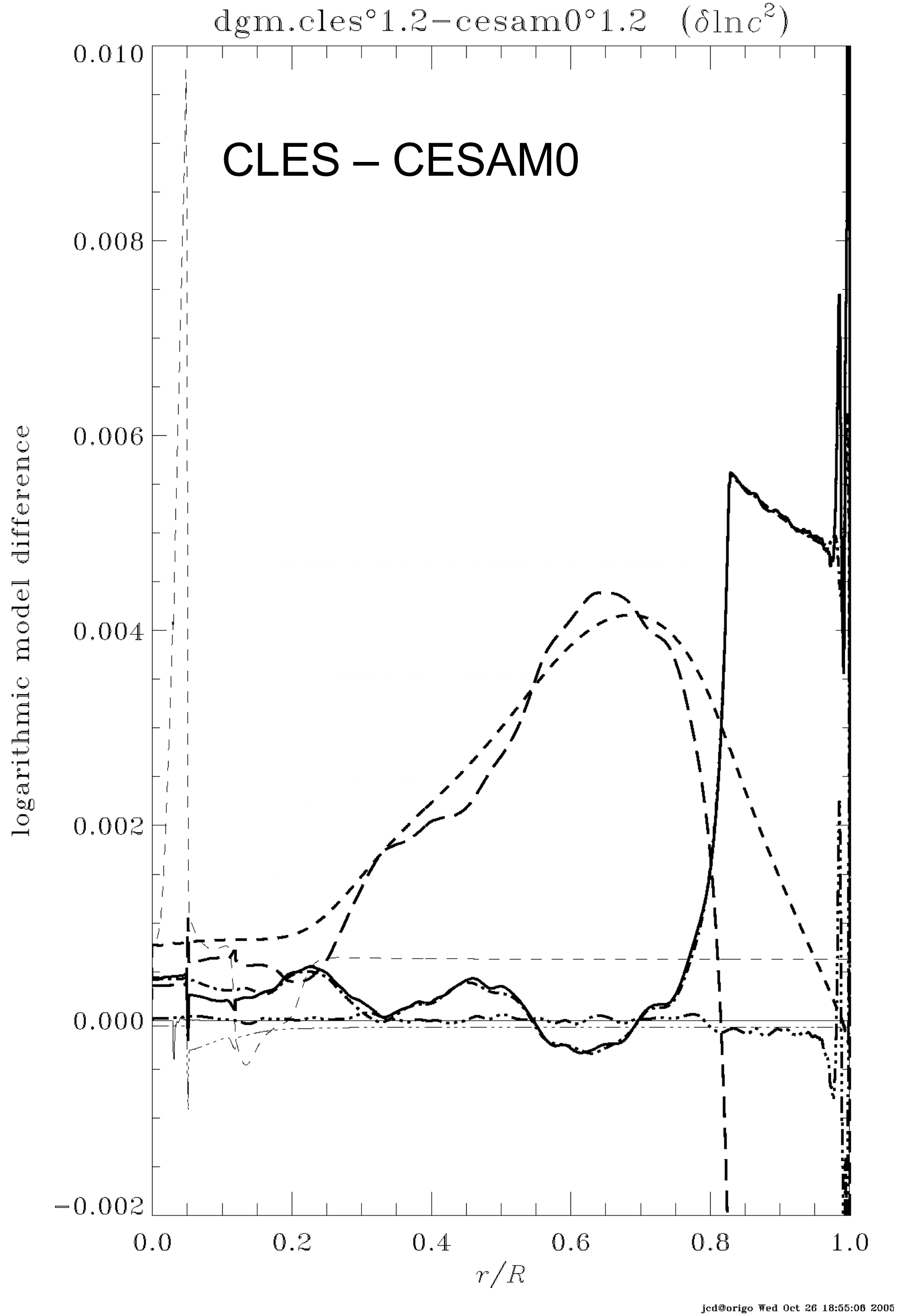
$X_0 = 0.7$

$Z_0 = 0.02$

$X_c = 0.69$

Line styles:

- dash-dot line : $\delta\ln T$
- short-dash line : $\delta\ln p$
- long-dash line : $\delta\ln\rho$
- solid line : $\delta\ln c^2$
- dash-dot-dot line : $\delta\ln\Gamma_1$
- thin solid line : $\delta\ln q$
- thin dashed line : $\delta\ln L$
- thin dash-dot-dot line : δX



Case 1.2

1.2 M–

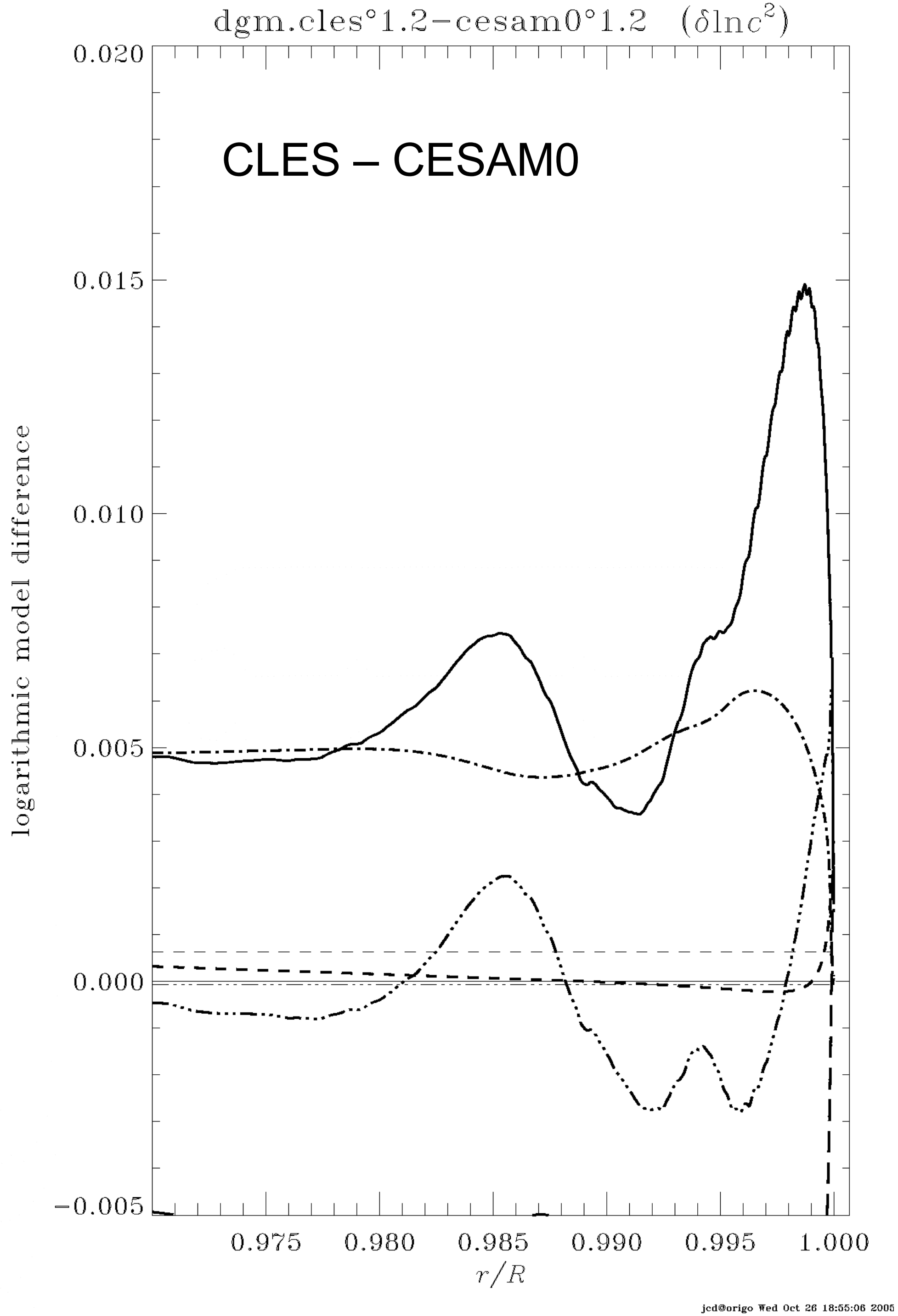
X_0 = 0.7

Z_0 = 0.02

X_c = 0.69

Line styles:

- ‑·‑·‑·‑ : $\delta \ln T$
- ‑ ‑ ‑ ‑ : $\delta \ln p$
- — — — : $\delta \ln \rho$
- ——— : $\delta \ln c^2$
- ‑···‑··· : $\delta \ln \Gamma_1$
- ——— (thin) : $\delta \ln q$
- ‑ ‑ ‑ ‑ (thin) : $\delta \ln L$
- ‑···‑··· (thin) : δX



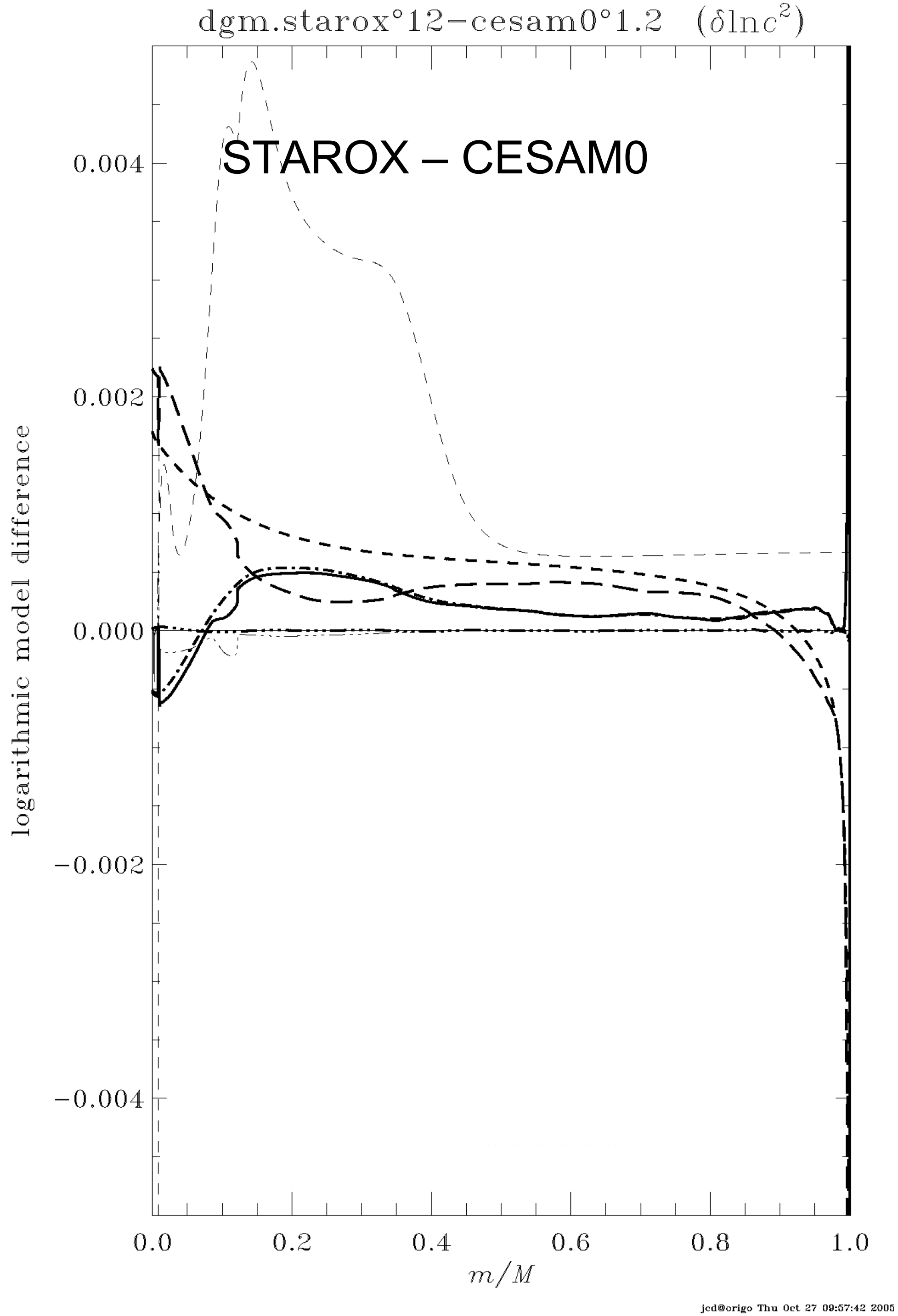
Case 1.2

1.2 M–

$X_0 = 0.7$

$Z_0 = 0.02$

$X_c = 0.69$



Line styles:

- : $\delta \ln T$
- : $\delta \ln p$
- : $\delta \ln \rho$
- : $\delta \ln c^2$
- : $\delta \ln \Gamma_1$
- : $\delta \ln q$
- : $\delta \ln L$
- : δX

Case 1.2

1.2 M–

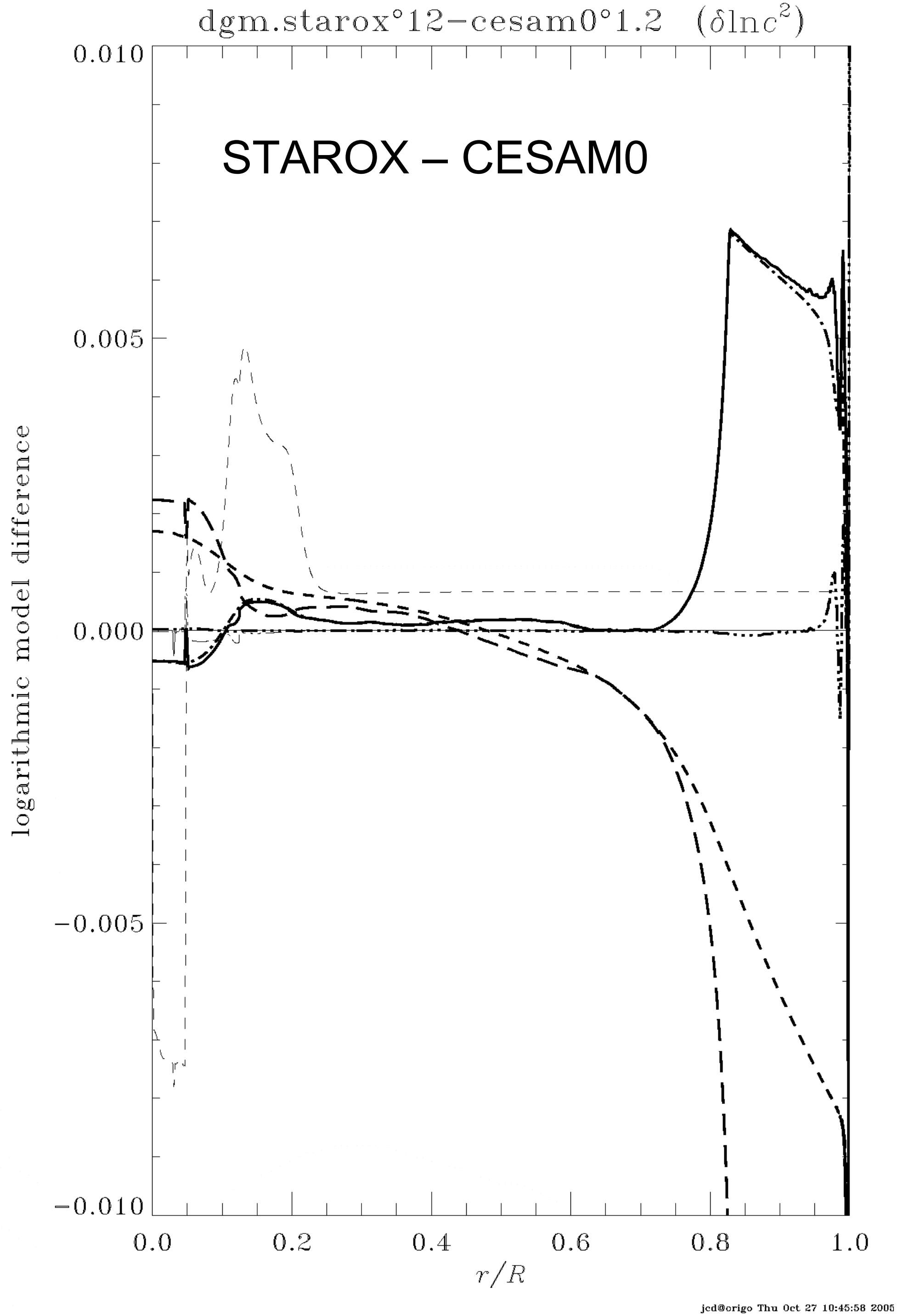
X_0 = 0.7

Z_0 = 0.02

X_c = 0.69

Line styles:

- : $\delta \ln T$
- : $\delta \ln p$
- : $\delta \ln \rho$
- : $\delta \ln c^2$
- : $\delta \ln \Gamma_1$
- : $\delta \ln q$
- : $\delta \ln L$
- : δX



Hydrogen abundance

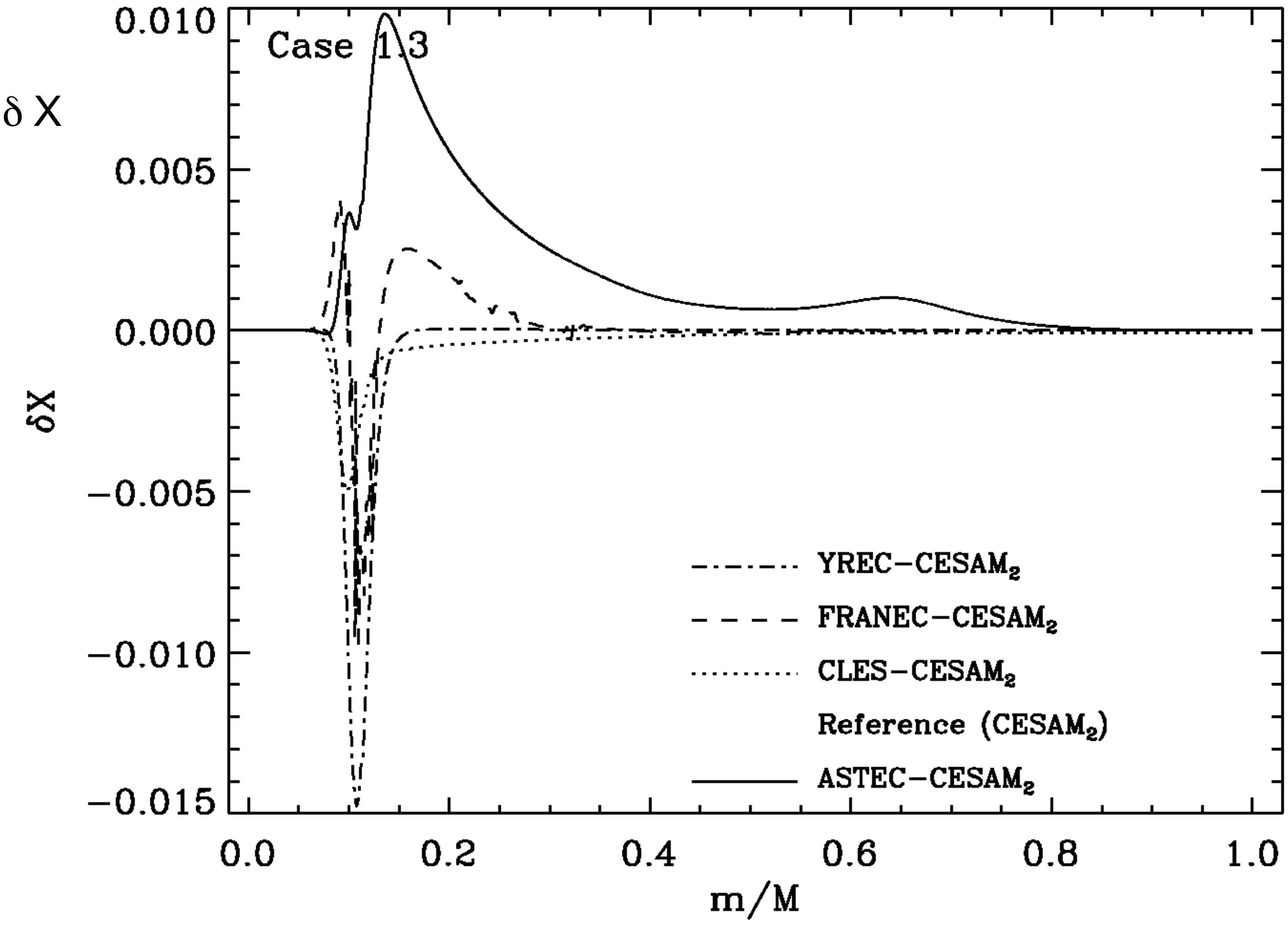
1.2 M–

X_0 = 0.73

Z_0 = 0.01

M_{HeC}/M = 0.1

δ X



Case 1.3

1.2 M⊙

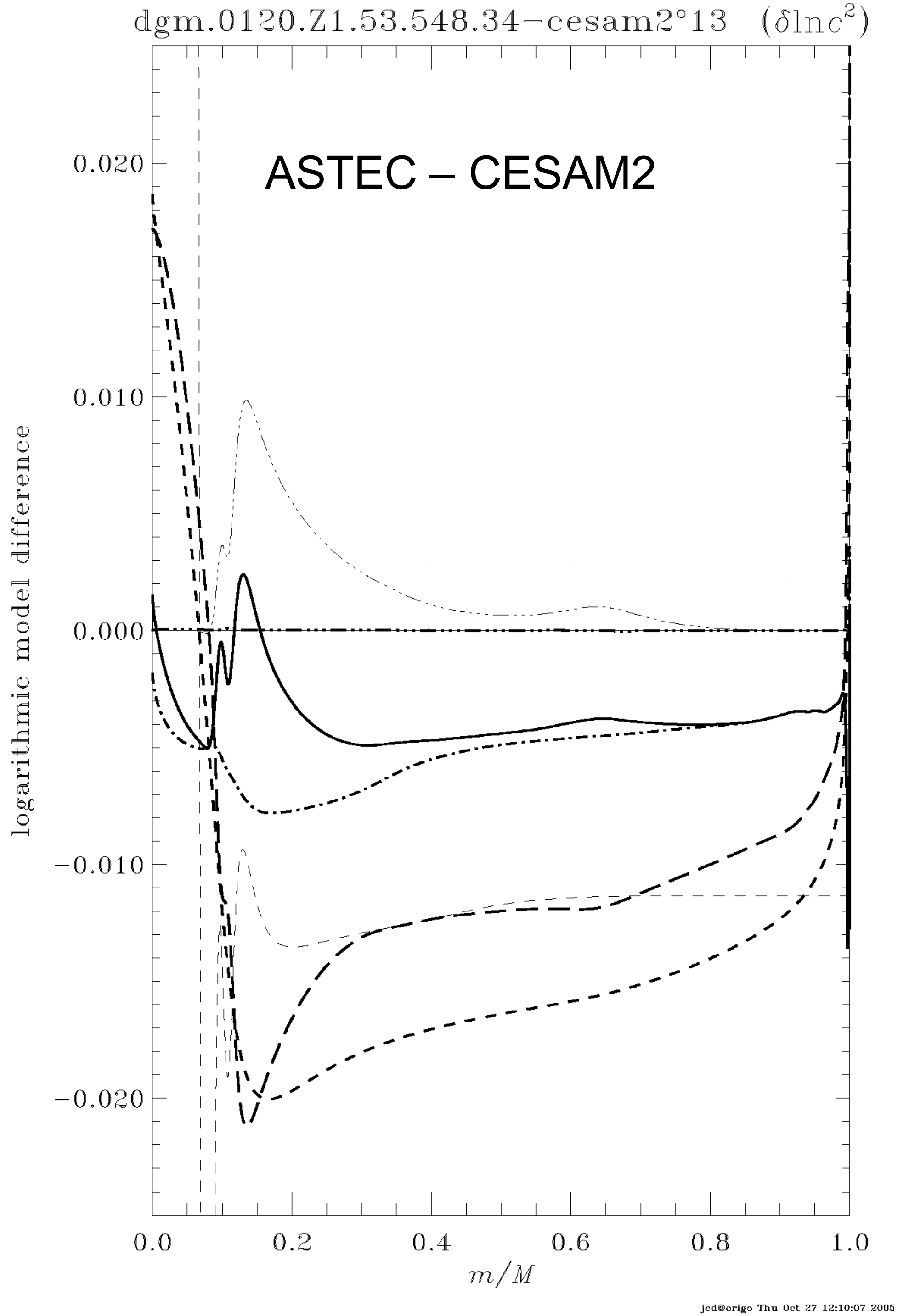
$X_0 = 0.73$

$Z_0 = 0.01$

$M_{HeC}/M = 0.1$

Line styles:

- dash-dot: $\delta \ln T$
- dashed: $\delta \ln p$
- long dashed: $\delta \ln \rho$
- solid (thick): $\delta \ln c^2$
- dash-dot-dot: $\delta \ln \Gamma_1$
- solid (thin): $\delta \ln q$
- dashed (thin): $\delta \ln L$
- dash-dot-dot (thin): δX



Case 1.3

1.2 M–

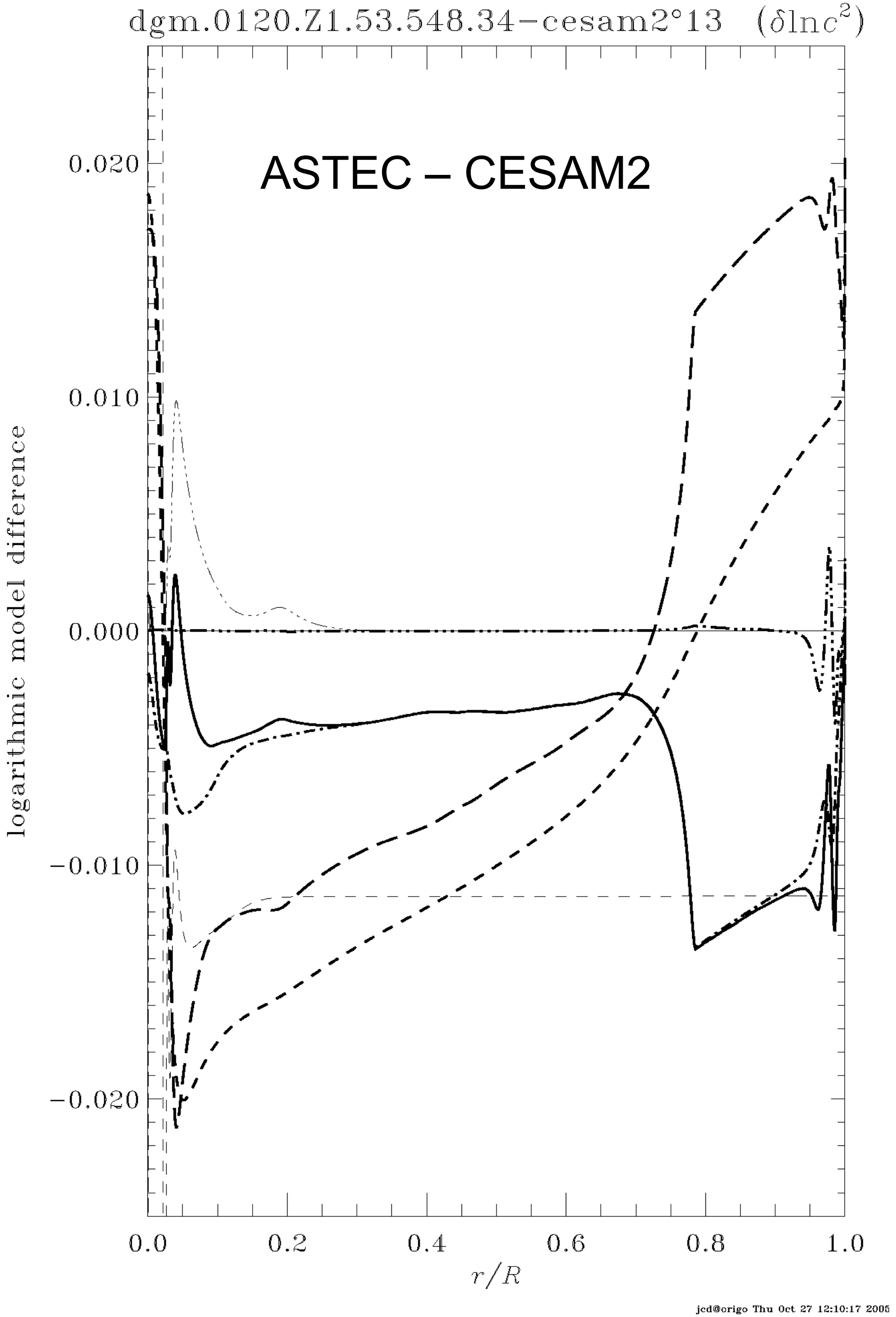
X_0 = 0.73

Z_0 = 0.01

M_{HeC}/M = 0.1

Line styles:

- dash-dot : $\delta \ln T$
- short dash : $\delta \ln p$
- long dash : $\delta \ln \rho$
- solid : $\delta \ln c^2$
- dash-triple-dot : $\delta \ln \Gamma_1$
- thin solid : $\delta \ln q$
- thin dash : $\delta \ln L$
- thin dash-dot-dot : δX



Hydrogen abundance

2.0 M–

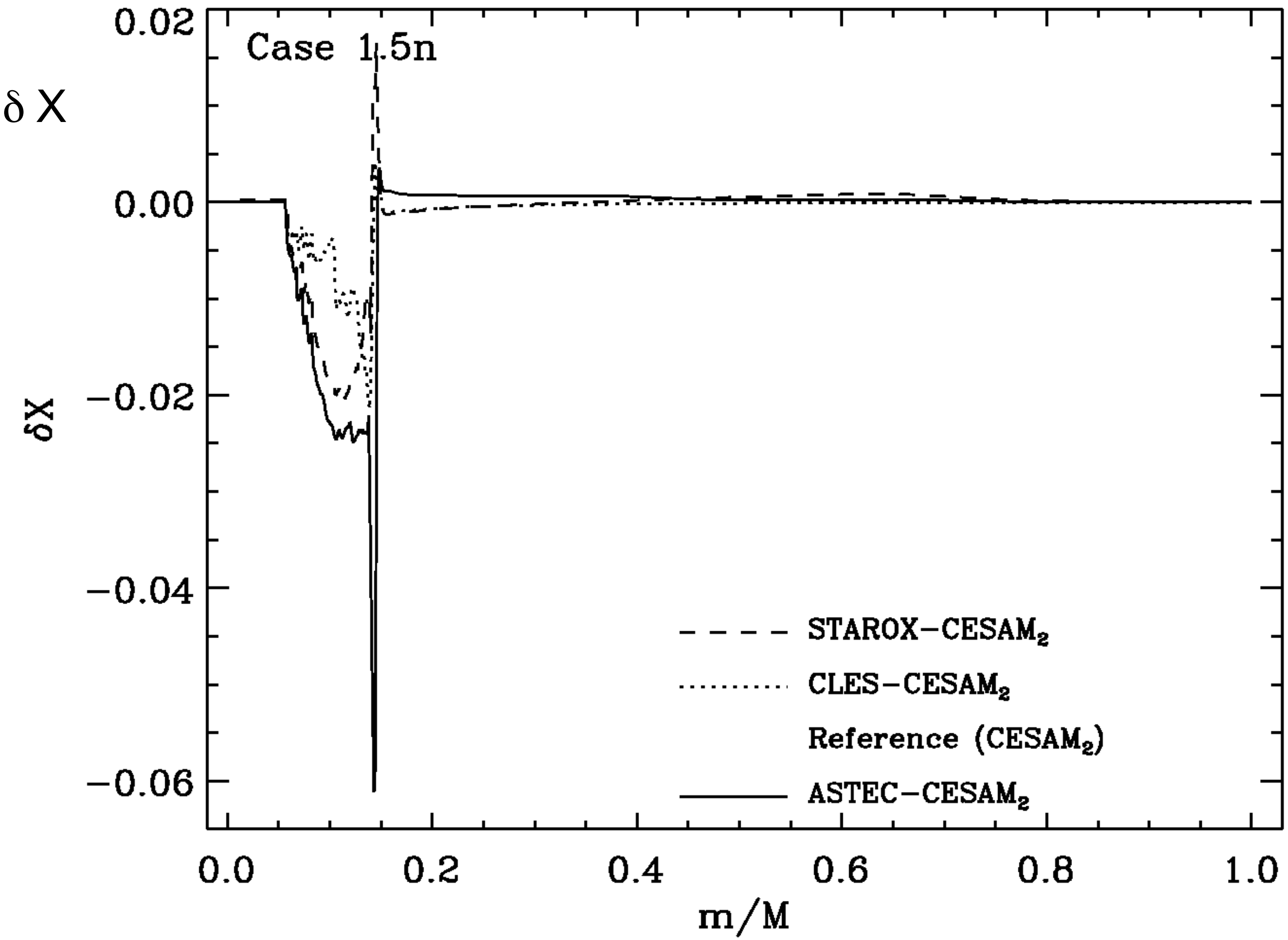
X_0 = 0.72

Z_0 = 0.02

X_c = 0.01

No overshoot

δ X



Case 1.5n

2.0 M⊙

X_0 = 0.72

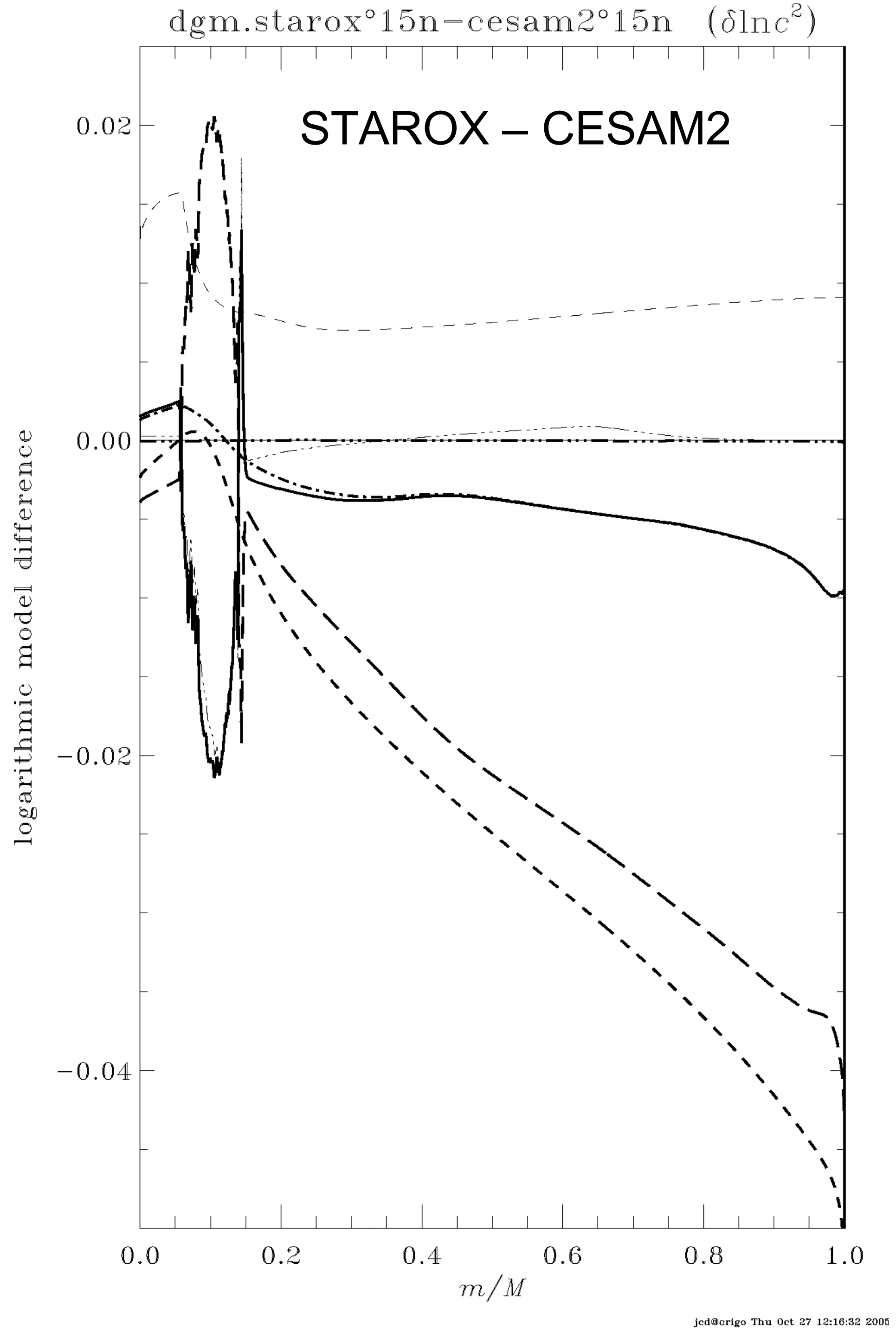
Z_0 = 0.02

X_c = 0.01

No overshoot

Line styles:

- dash-dot : $\delta \ln T$
- short dash : $\delta \ln p$
- long dash : $\delta \ln \rho$
- solid : $\delta \ln c^2$
- dash-dot-dot : $\delta \ln \Gamma_1$
- thin solid : $\delta \ln q$
- thin dash : $\delta \ln L$
- thin dash-dot-dot : δX



Case 1.5n

2.0 M–

$X_0 = 0.72$

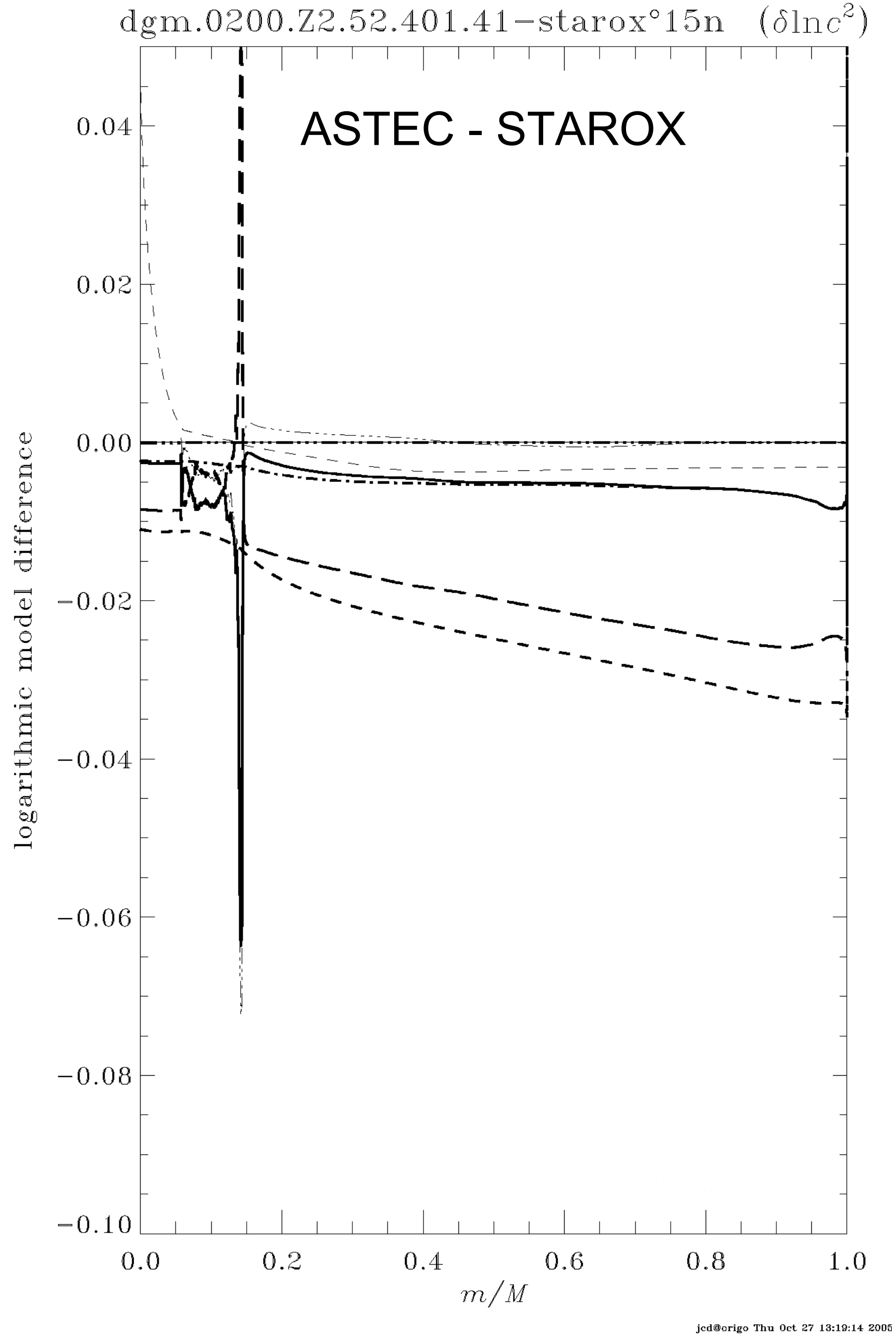
$Z_0 = 0.02$

$X_c = 0.01$

No overshoot

Line styles:

- : $\delta \ln T$
- : $\delta \ln p$
- : $\delta \ln \rho$
- : $\delta \ln c^2$
- : $\delta \ln \Gamma_1$
- : $\delta \ln q$
- : $\delta \ln L$
- : δX



Hydrogen abundance

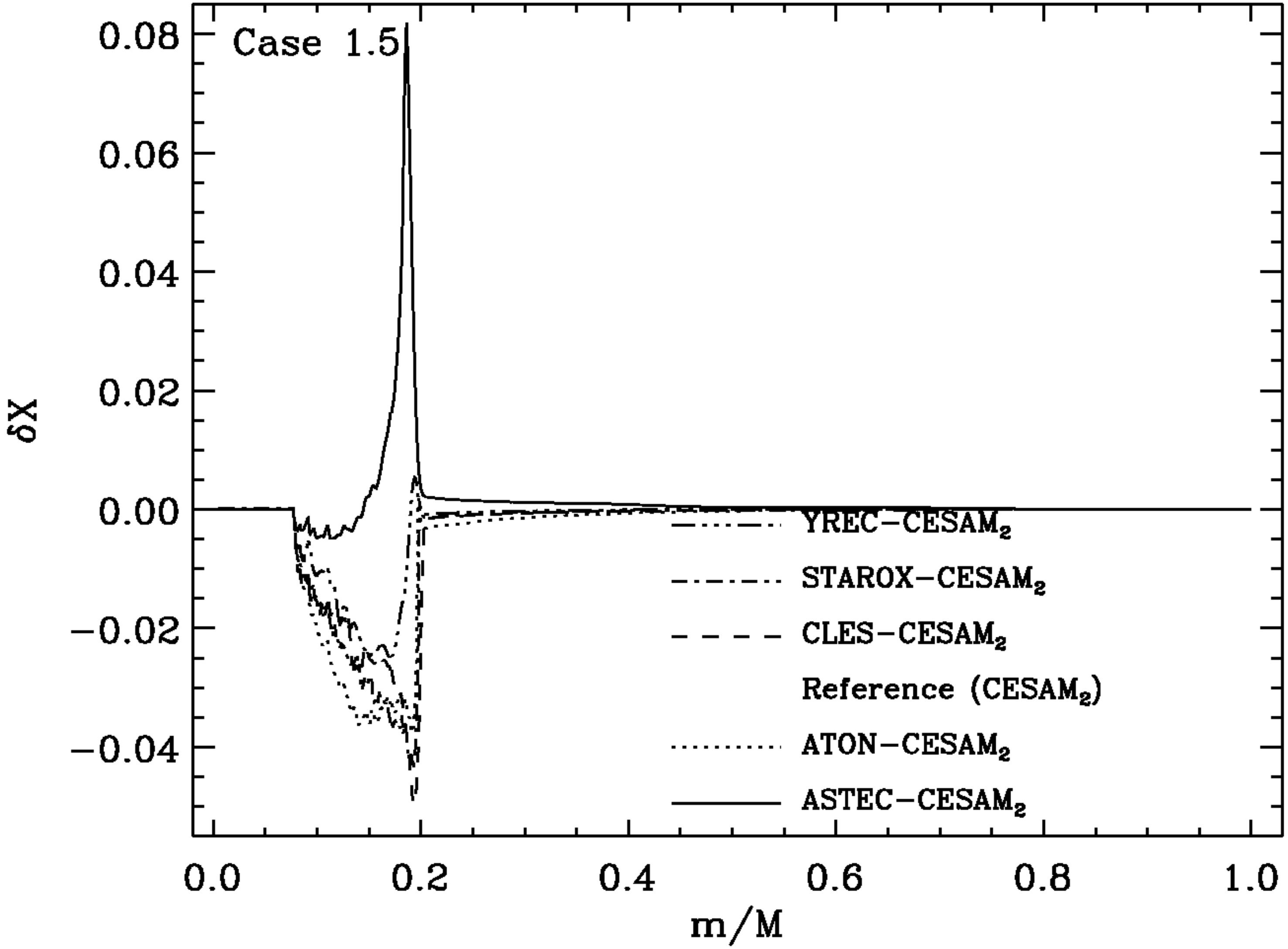
2.0 M–

X_0 = 0.72

Z_0 = 0.02

X_c = 0.01

Overshoot, 0.15 H_p



Case 1.5

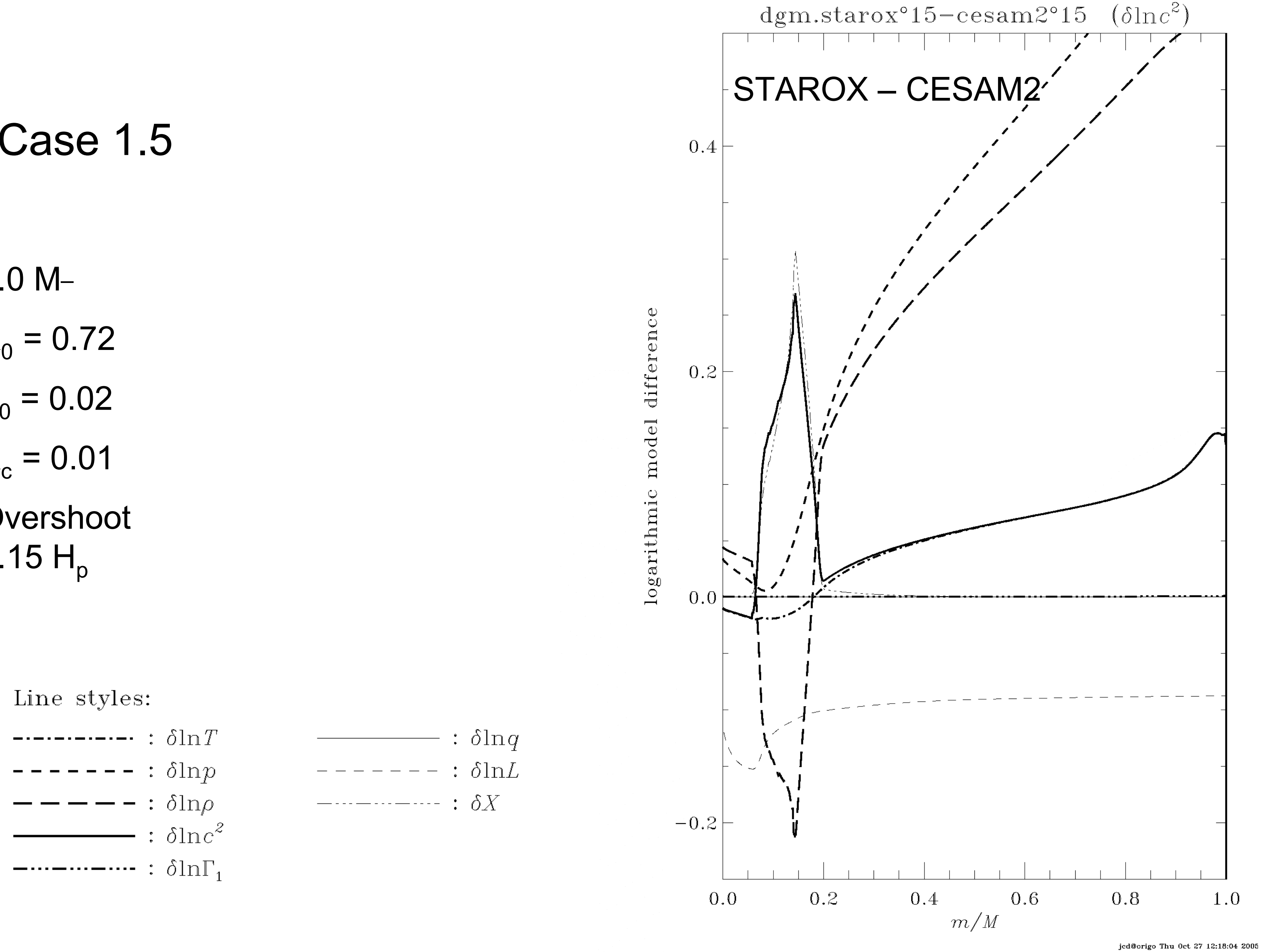
2.0 M–

X_0 = 0.72

Z_0 = 0.02

X_c = 0.01

Overshoot
0.15 H_p



Case 1.5

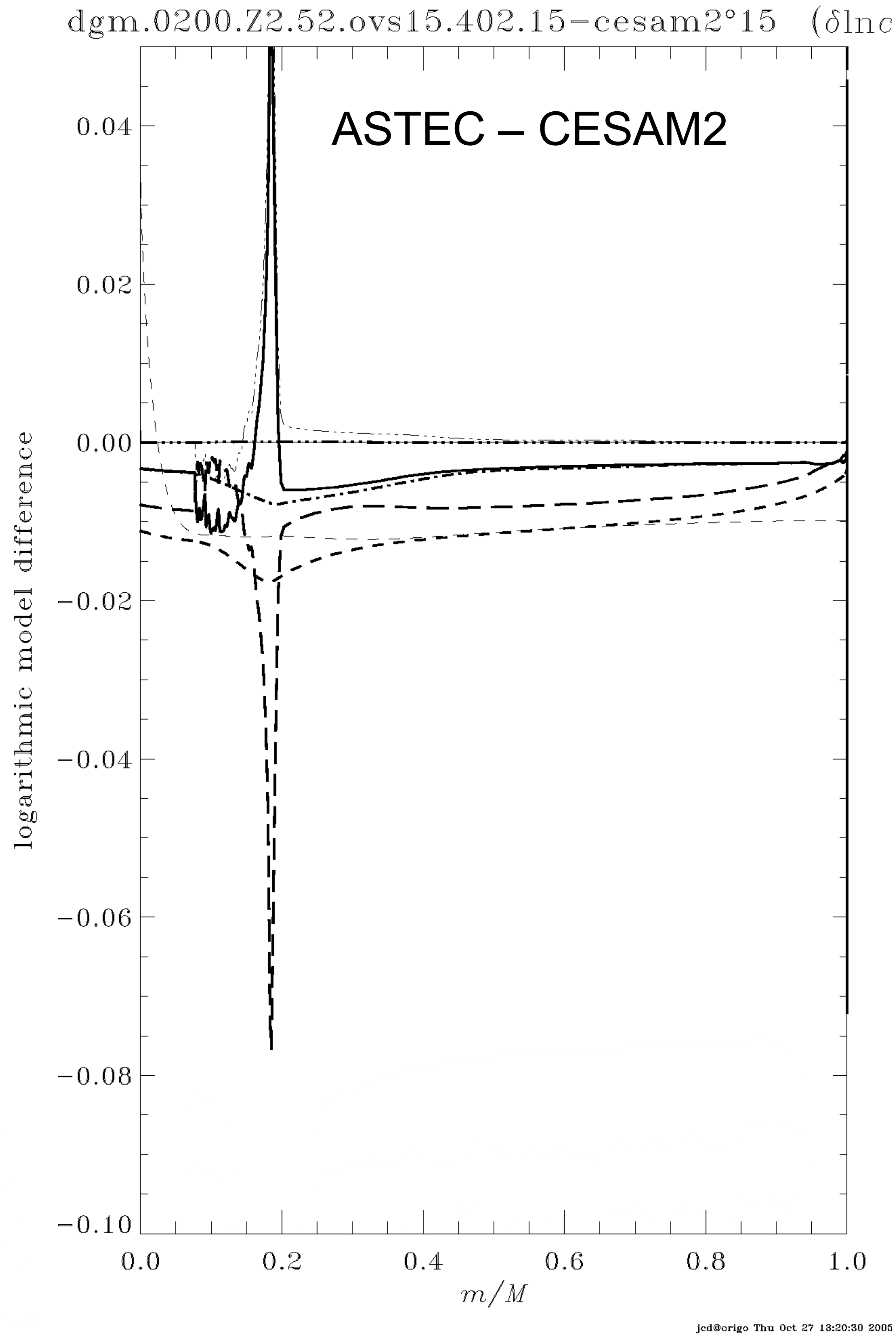
2.0 M–

X_0 = 0.72

Z_0 = 0.02

X_c = 0.01

Overshoot
0.15 H_p



Line styles:

- −·−·−·−· : $\delta\ln T$
- − − − − : $\delta\ln p$
- — — — : $\delta\ln\rho$
- ——— : $\delta\ln c^2$
- −···−··· : $\delta\ln\Gamma_1$
- ——— : $\delta\ln q$
- − − − − : $\delta\ln L$
- −···−··· : δX