PLATO STESCI Workshop III

Correction of surface effects for PLATO

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with the contributions of

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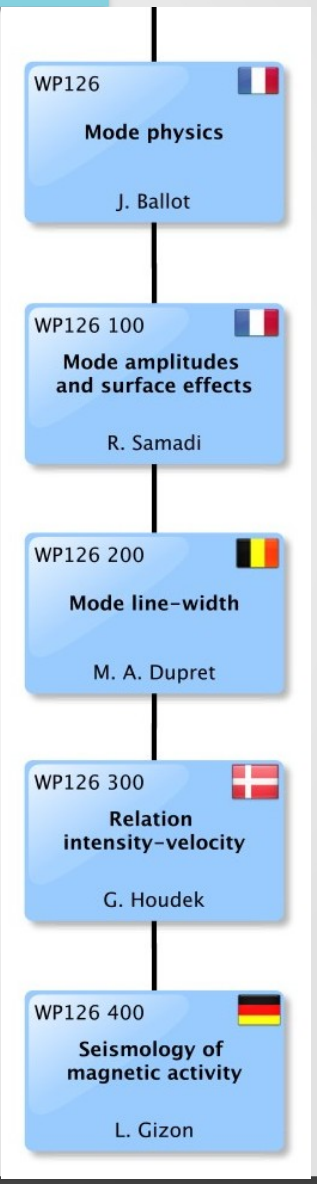
Context

- **WP 126** Mode physics
  - WP126100 Mode amplitudes and surface effects (*R. Samadi*)

    Models for mode amplitudes, models for near surface effects

1) How to take into account surface effects in stellar analysis pipeline to avoid biases on R, M & Age determinations?
2) How to improve our models?
   cf. all previous talks!



Impacts of near-surface effects

- **Origins: bad modelling of superficial layers**
  - 1-D models vs dynamical processes
- **Structure effects**

Model

  - *Impact of turbulent pressure p_t*
  - Convective back-warming
  - *Effect of magnetic field*

3D atmosphere models

- **Mode computations**

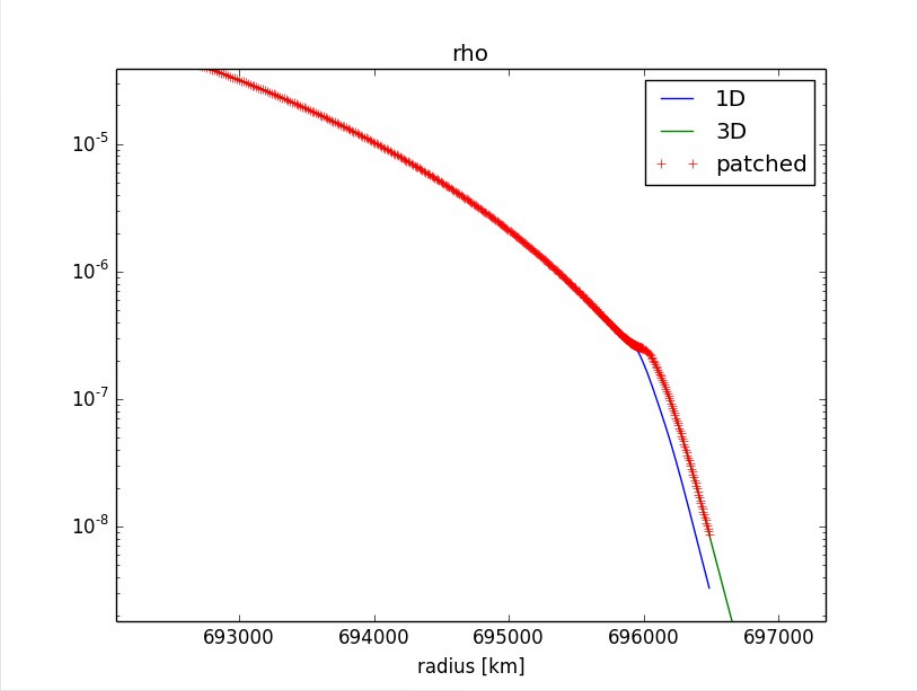
Modal

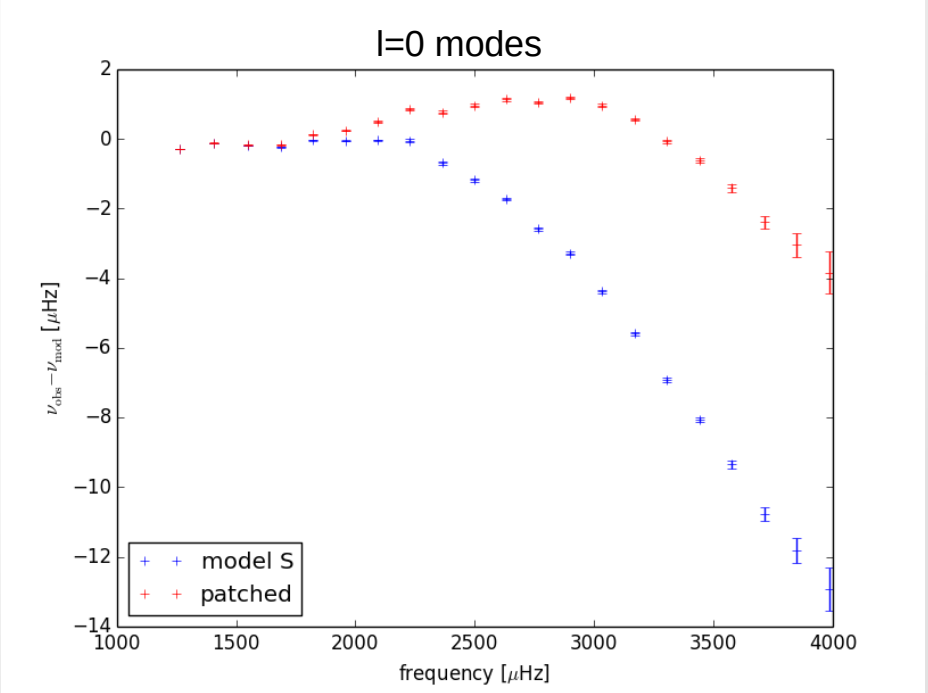
  - *p_t fluctuations*
  - Non adiabatic effects
  - *Effect of magnetic field*

Time-dependent convection (TDC)

Patched models (cf Andreas' talk)

- 1D internal structure + profiles from 3D simulations
  [Stein & Nordlund 1991; Rosenthal+ 1995, 1999; Yang & Li 2007; Piau+ 2014; Bhattacharya+ 2015; Sonoi+ 2015, 2017; Magic & Weiss 2016; Ball+ 2016; Houdek+ 2017; Trampedach+ 2017; Jørgensen+ 2017]
- Example :
  model S + ANTARES 3D solar simulations + TOP code



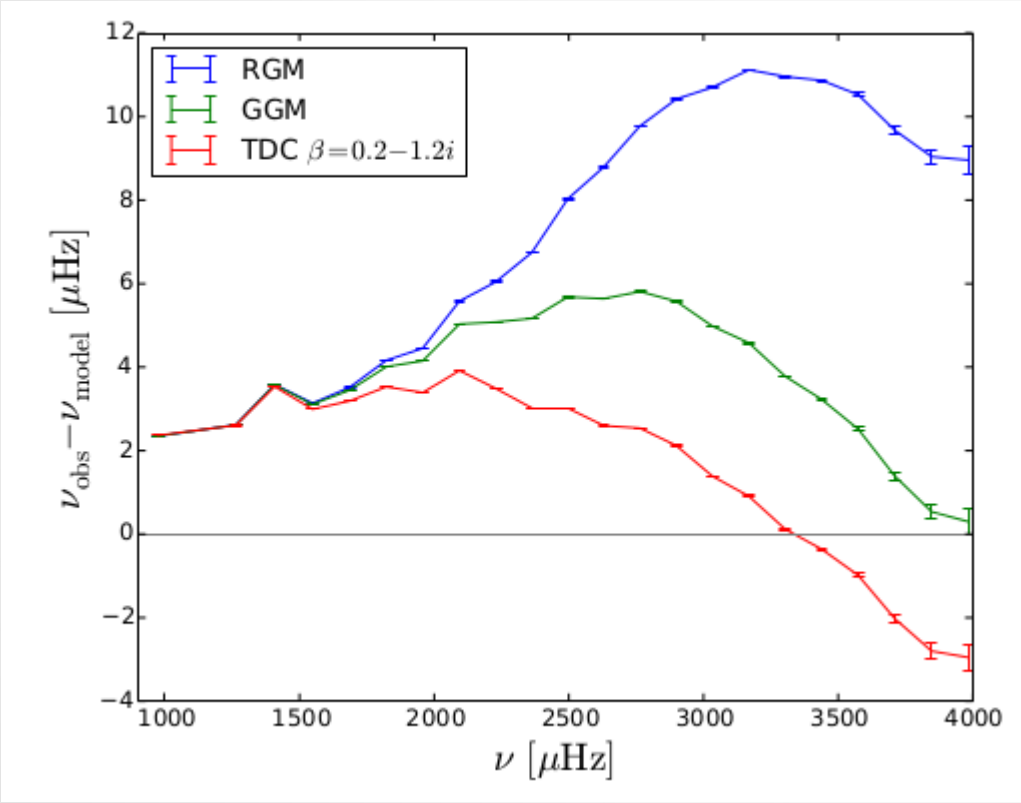


What prescription for p_t fluctuations?

- **Gas Γ_1 model**: $\delta p_t/p_t \approx \delta p/p \approx \delta p_g/p_g = \Gamma_1 \, \delta\rho/\rho$ (GGM)
- **Reduced Γ_1 model**: $\delta p_t/p_t \approx 0 \rightarrow \delta p/p \approx (\Gamma_1 p_g/p) \, \delta\rho/\rho$ (RGM)
  - GGM appears to better [Rosenthal+ 1999]
    - No clear physical grounds for this
- **Time-dependent Convection**
  - Sonoi+ 2017 [adia, TDC after Grigachène+ 2005, Dupret+ 2006]
  - Houdek+ 2017 [non-adia, TDC after Gough 1977]

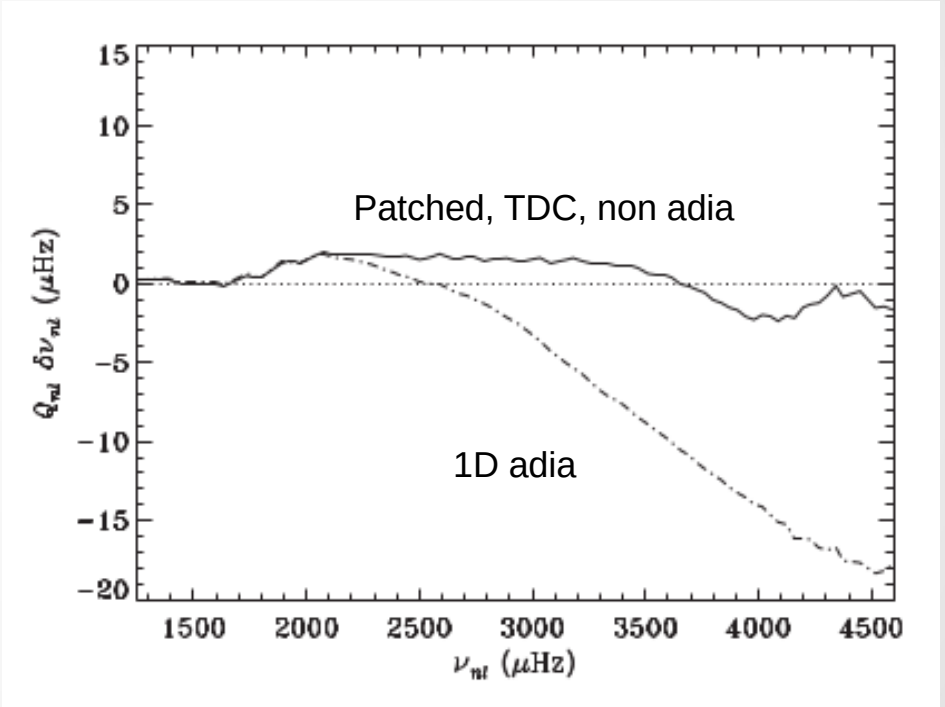
TDC results (cf. Günter's talk)

Sonoi+ 2017



GGM also in better agreement with theory

Houdek+ 2017



Ad-hoc prescriptions

- **Solar case**:
  - *no need of prescriptions: M & R are very well known*
- **Other stars**: ad-hoc corrections $\delta\nu = \nu_{cor} - \nu_{mod}$
  - K08 [Kjeldsen+ 2008]: $\delta\nu = a\,(\nu/\nu_0)^b$
    (!! several implementations !! b fixed or not, rescaling factor r)
  - BG14 [Ball & Gizon 2014] $\delta\nu = a_3(\nu/\nu_0)^3 / I \;\; [\; + a_{-1}(\nu/\nu_0)^{-1} \;/ I \;]$
  - S15 [Sonoi+ 2015] $\delta\nu = a(1 - 1 / (1 + (\nu/\nu_0)^b))$
    (deduced from patched models)
  - → Extra parameters to adjust
- Taken into account mode inertia relative to radial mode
  $Q_{nl} = I_{nl} / I_{l=0}(\nu_{nl})$

What to do for PLATO?

- Improve our models?
- **Use ad-hoc corrections**
  - At least for the first pipepline

- Which prescription to use?
  - According to Ball+ 2017, K08 is the worst
  - BG14 is the most used in recent literature

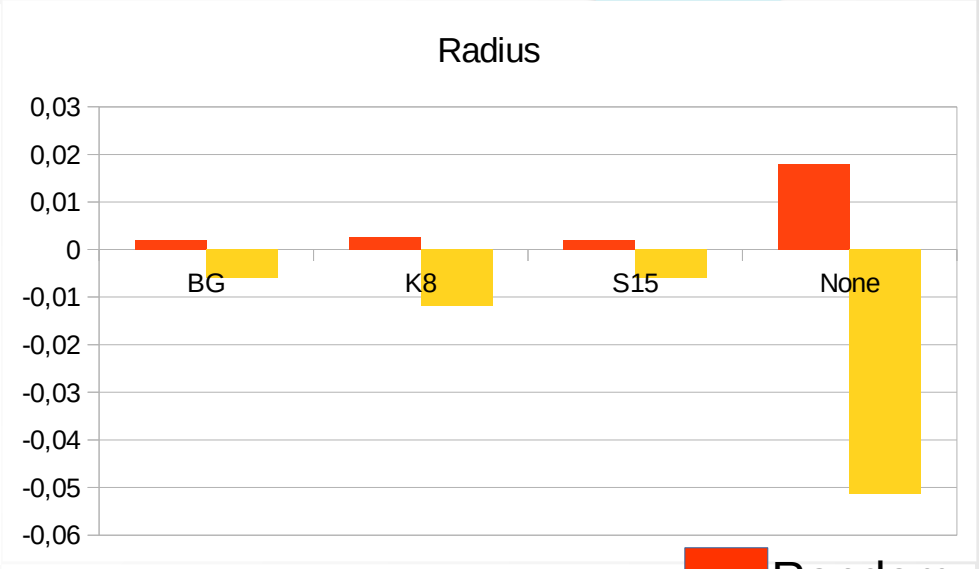
Hare & Hound exercise to test NSE correction methods

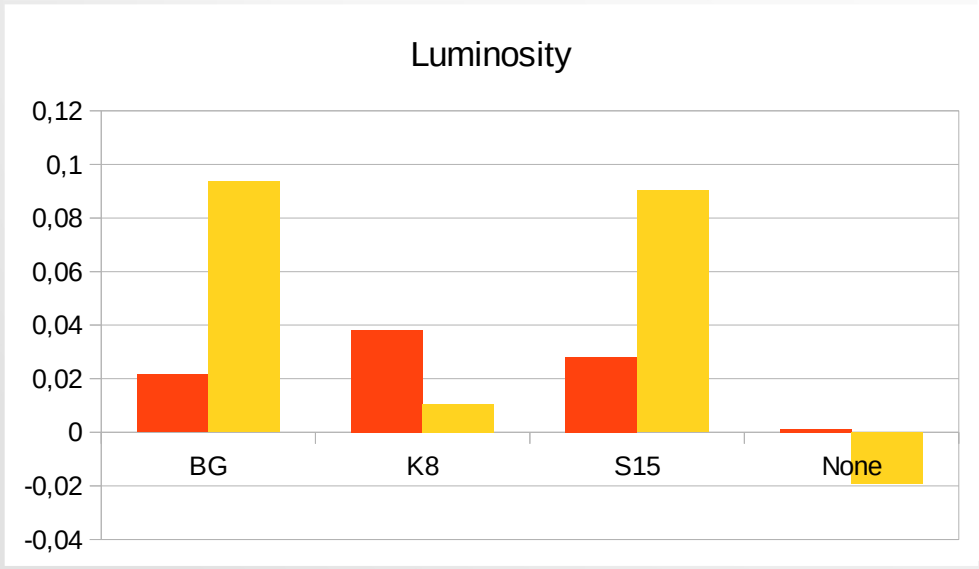
- PRELIMINARY – still in progress
- Tests on unpatched & patched models from Manchon+18
  - 3D models build with CO5BOLD
  - Frequencies computed with ADIPLS code, p_t with GGM
- Model #2:
  - T_{eff} = 5776 K
  - log g = 4.44
  - Solar abundance, mixture close to Asplund+05

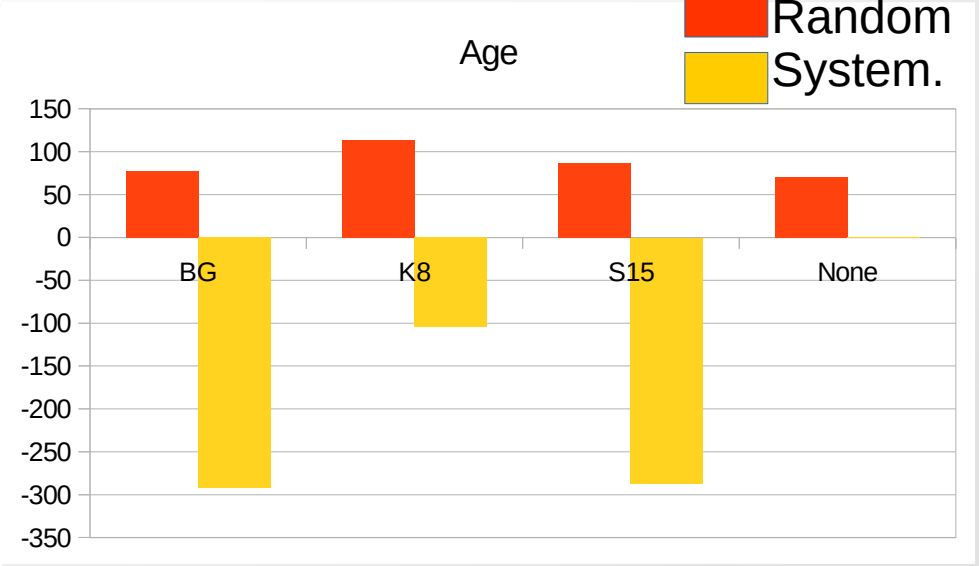
H&H: Hounds

- 2 approaches:
  - Global optimization with AIMS using a MESA grid (cf. HH Exercises for Ian's talk)
  - Local optimization using Y. Lebreton's code (Levenberg-Marquart + CESTAM + LOSC or GYRE)
- "Standard" errors for fundamental parameters:
  - Teff → 100 K
  - log g → 0.15
  - [Fe/H] → 0.1 dex
- Random noise on frequency → 0.1 μHz

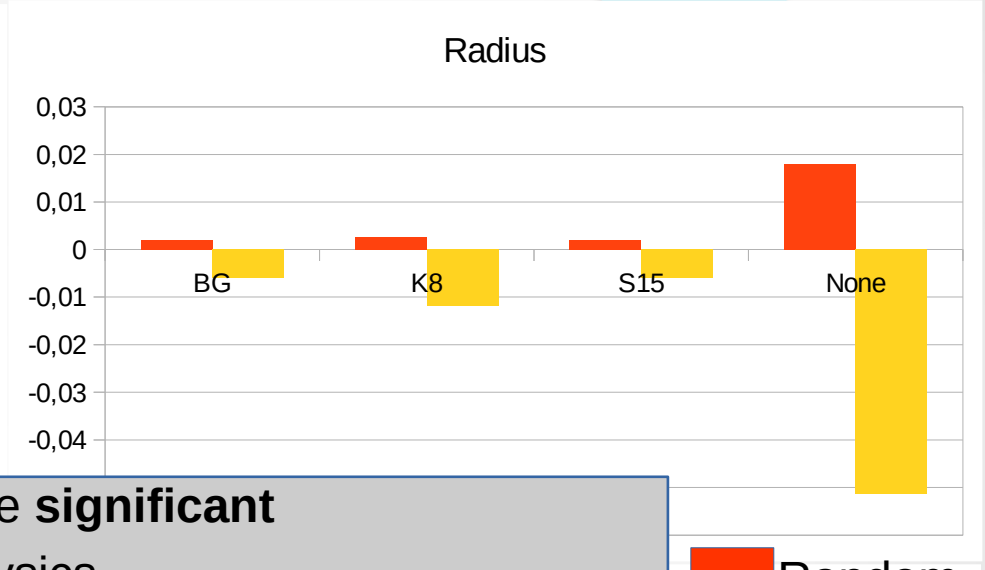
AIMS, unpatched model



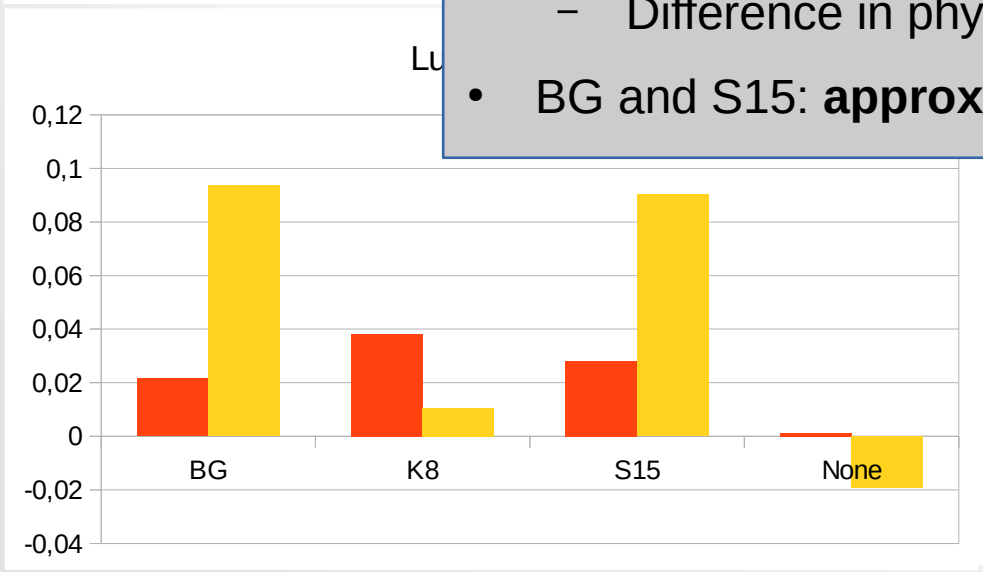


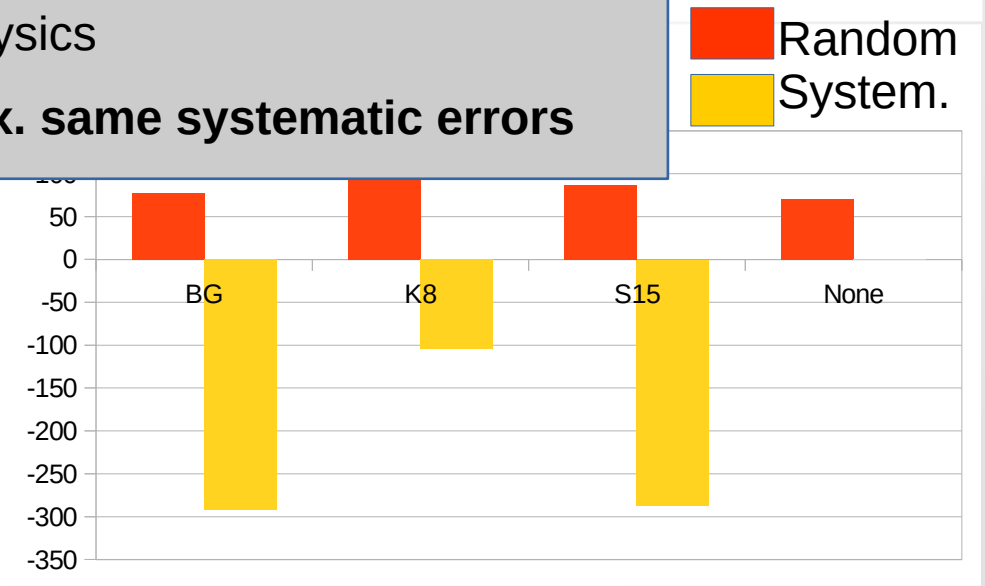


AIMS, unpatched model

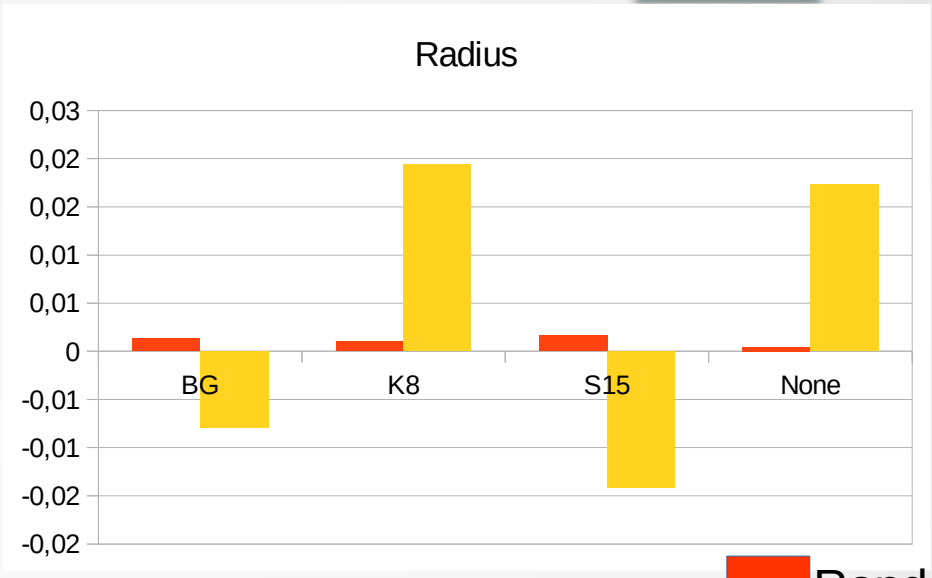


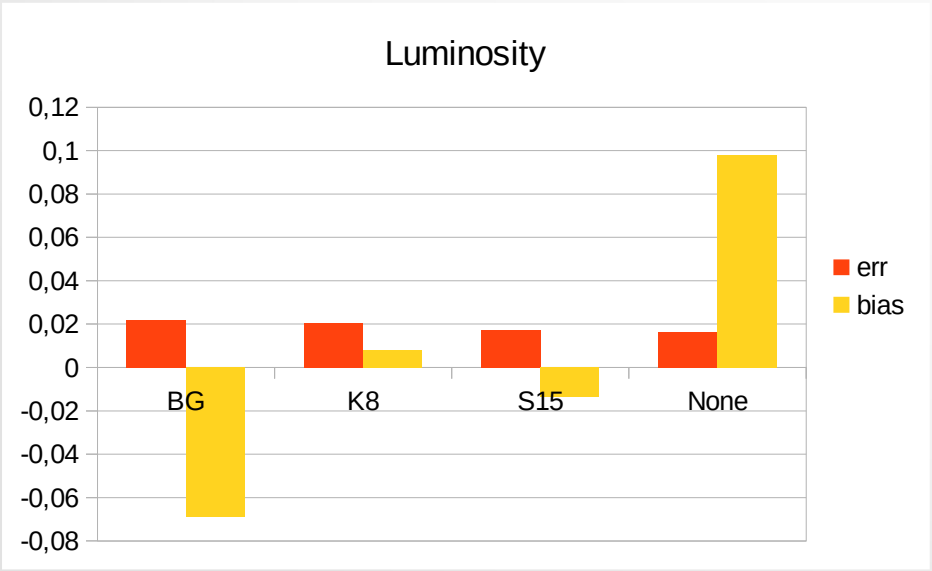
- Systematic errors are **significant**
  - Difference in physics
- BG and S15: **approx. same systematic errors**

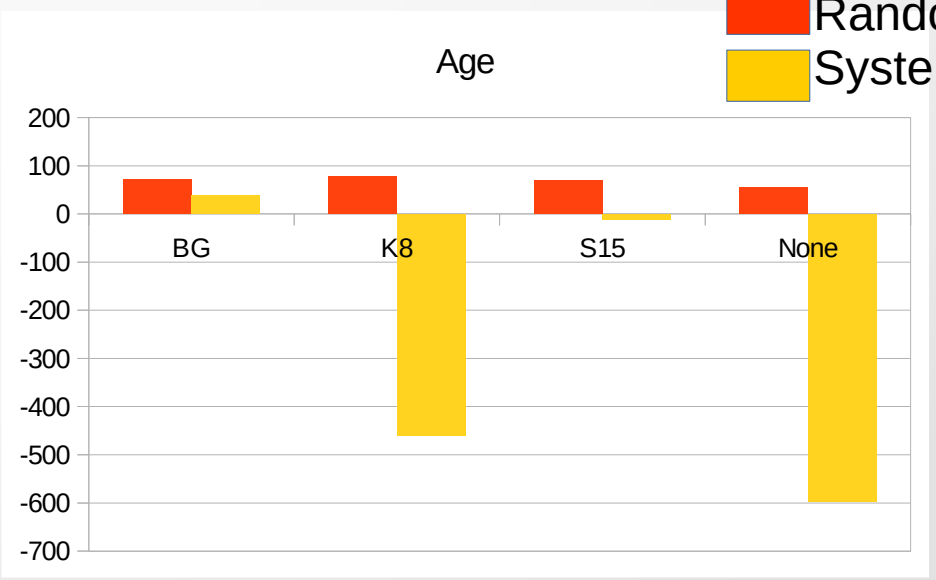




AIMS, patched model 11 orders

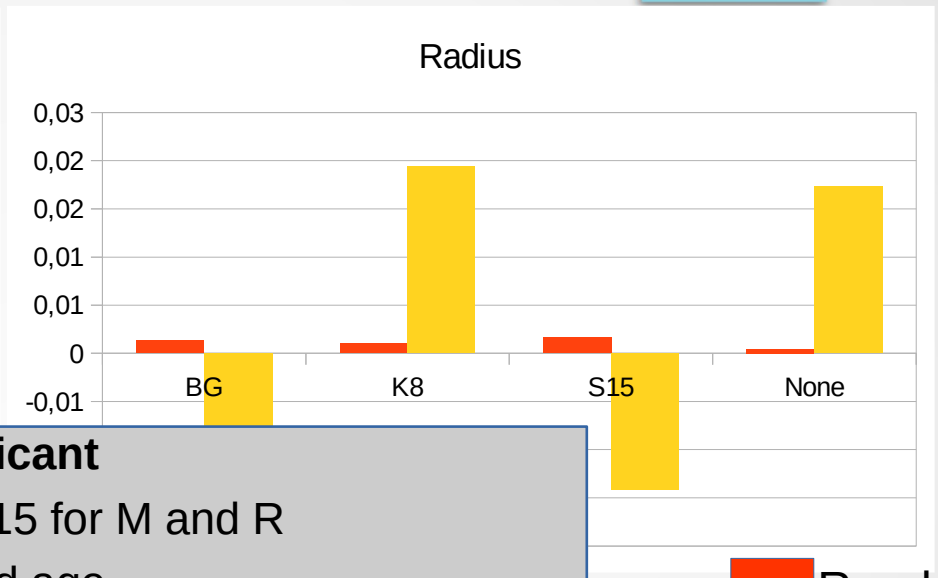




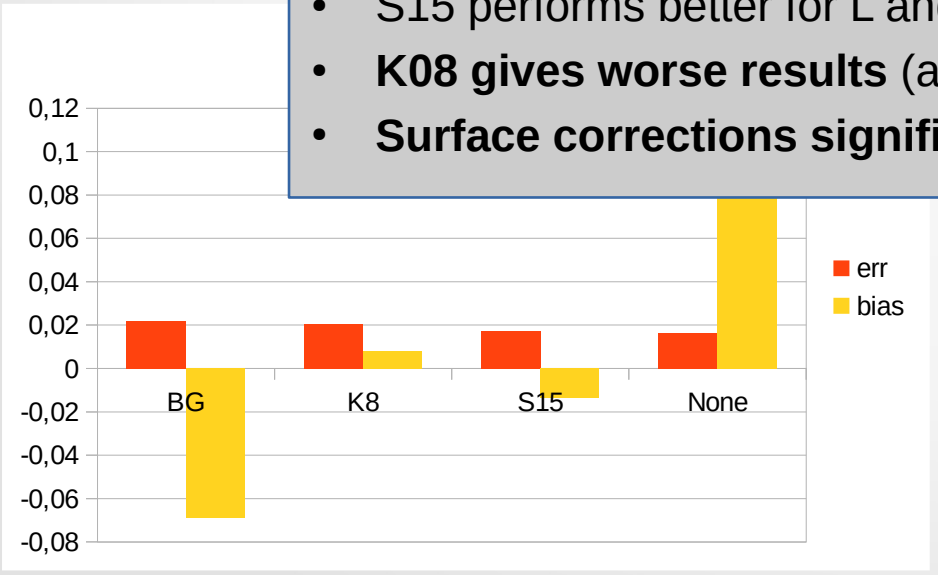


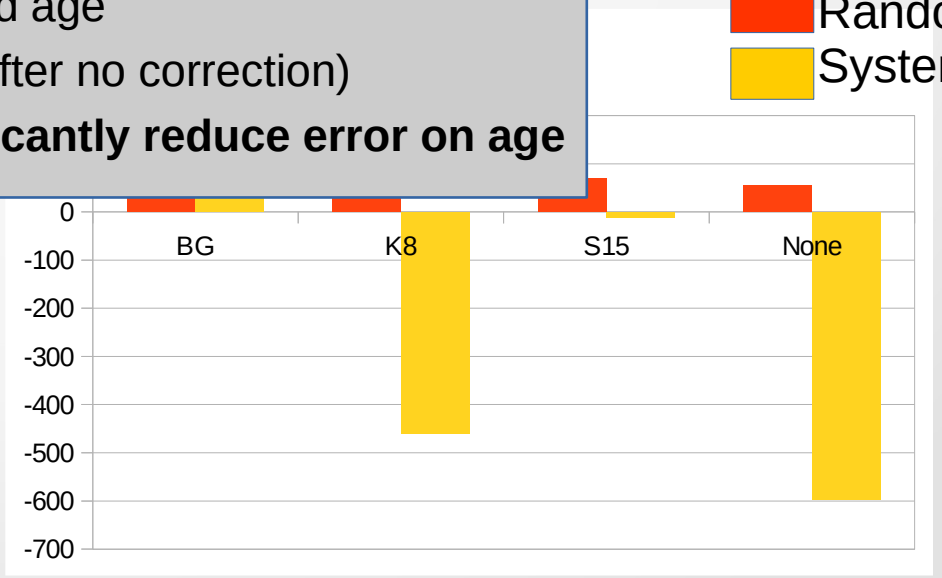
Random
System.

AIMS, patched model 11 orders



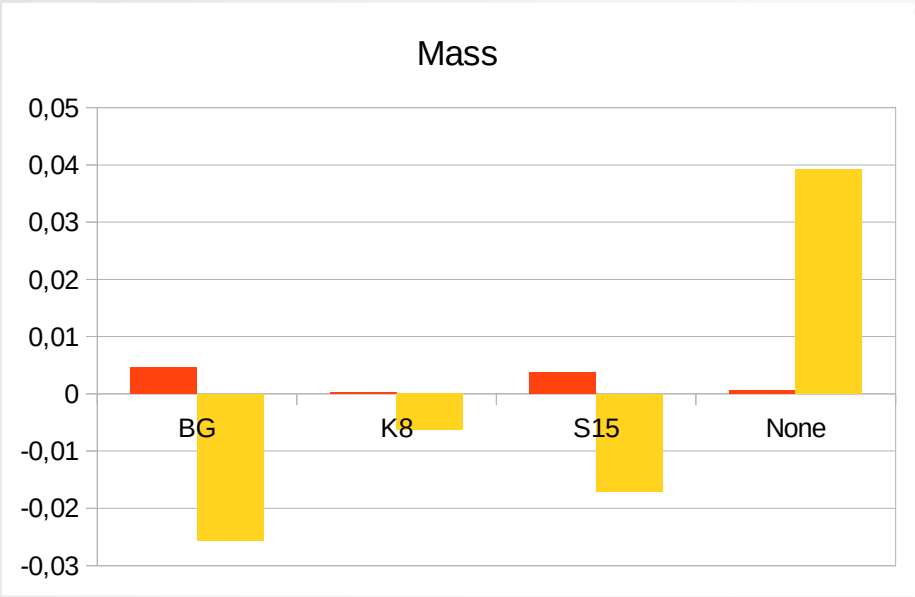
- Systematic errors are **significant**
- B&G performs better than S15 for M and R
- S15 performs better for L and age
- **K08 gives worse results** (after no correction)
- **Surface corrections significantly reduce error on age**

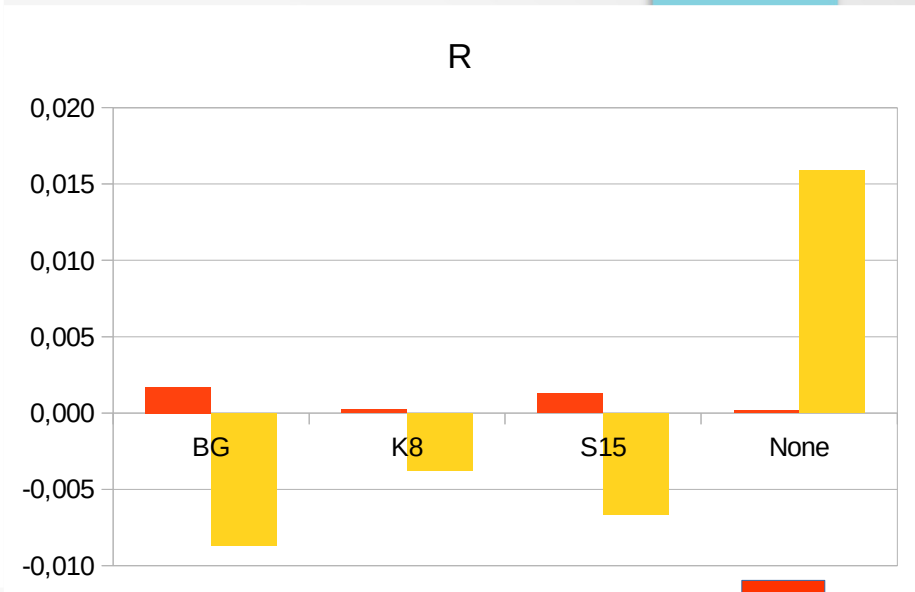


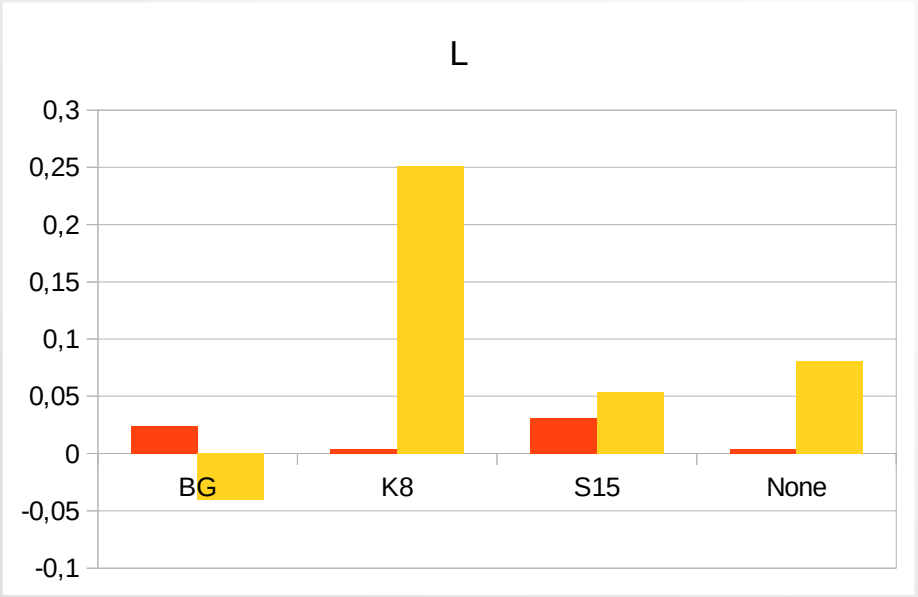


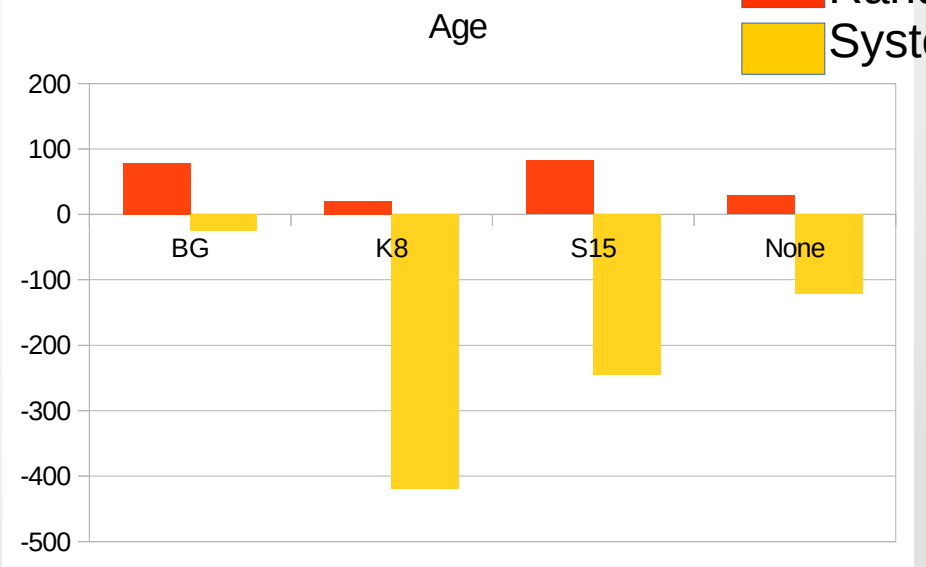
Random
System.

AIMS, patched model 15 orders









Random
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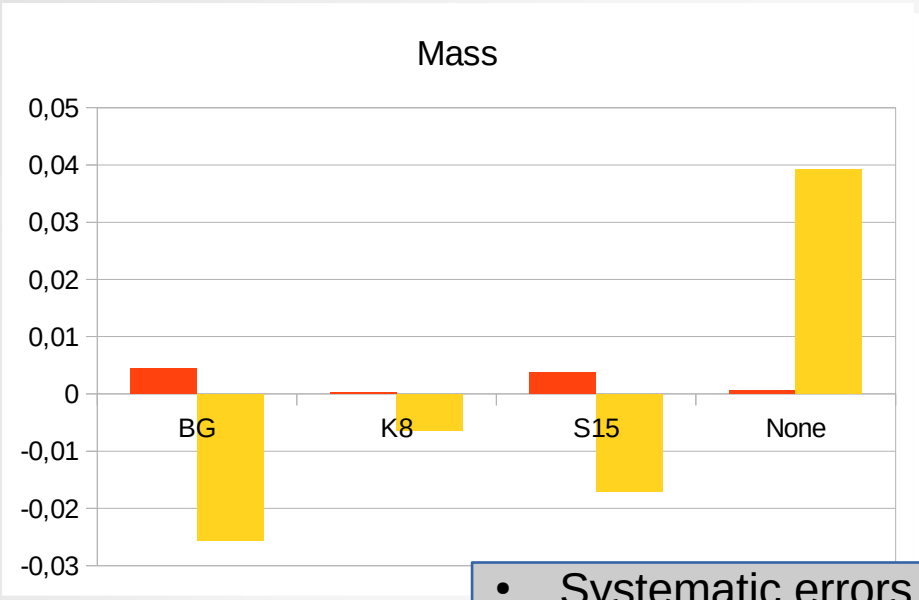
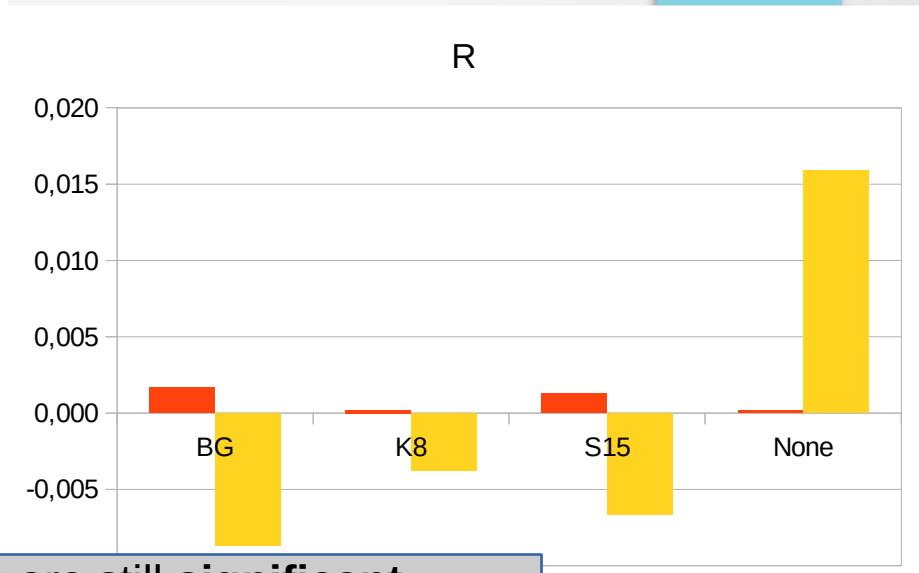
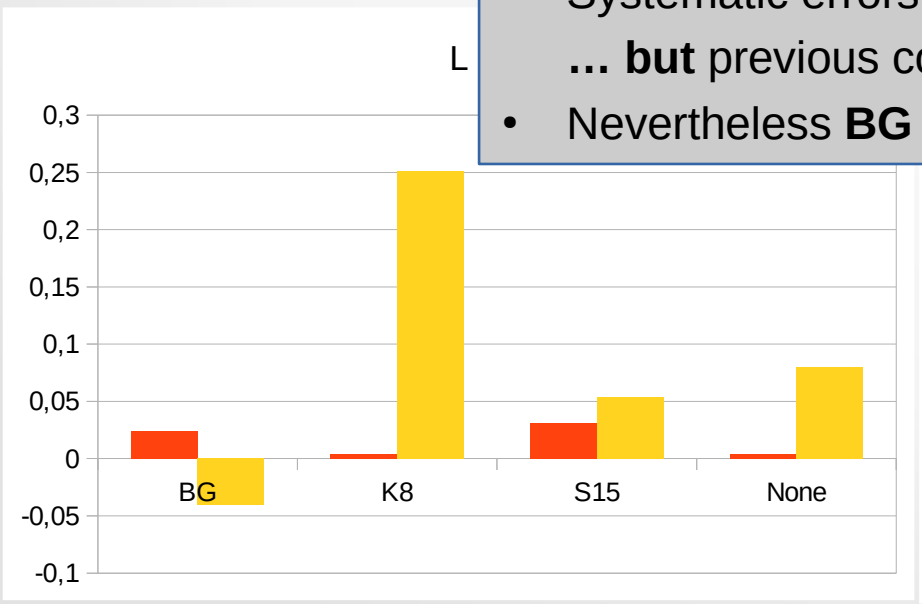
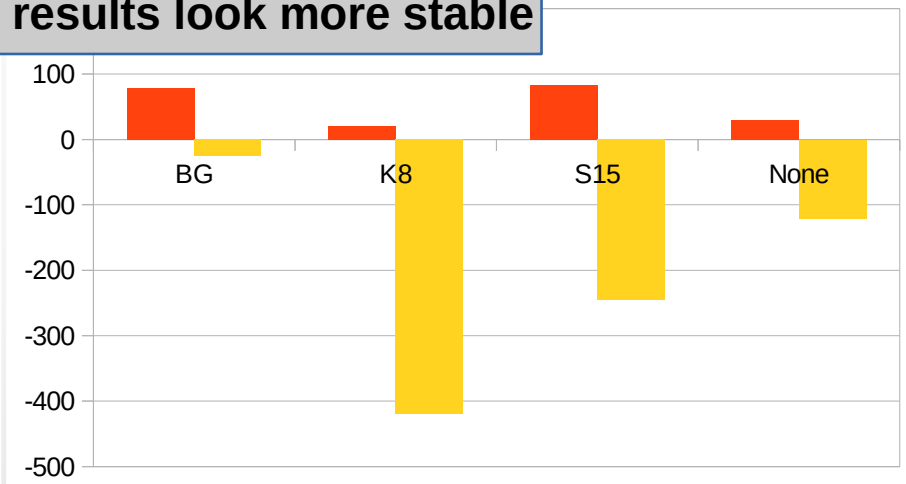
AIMS, patched model 15 orders





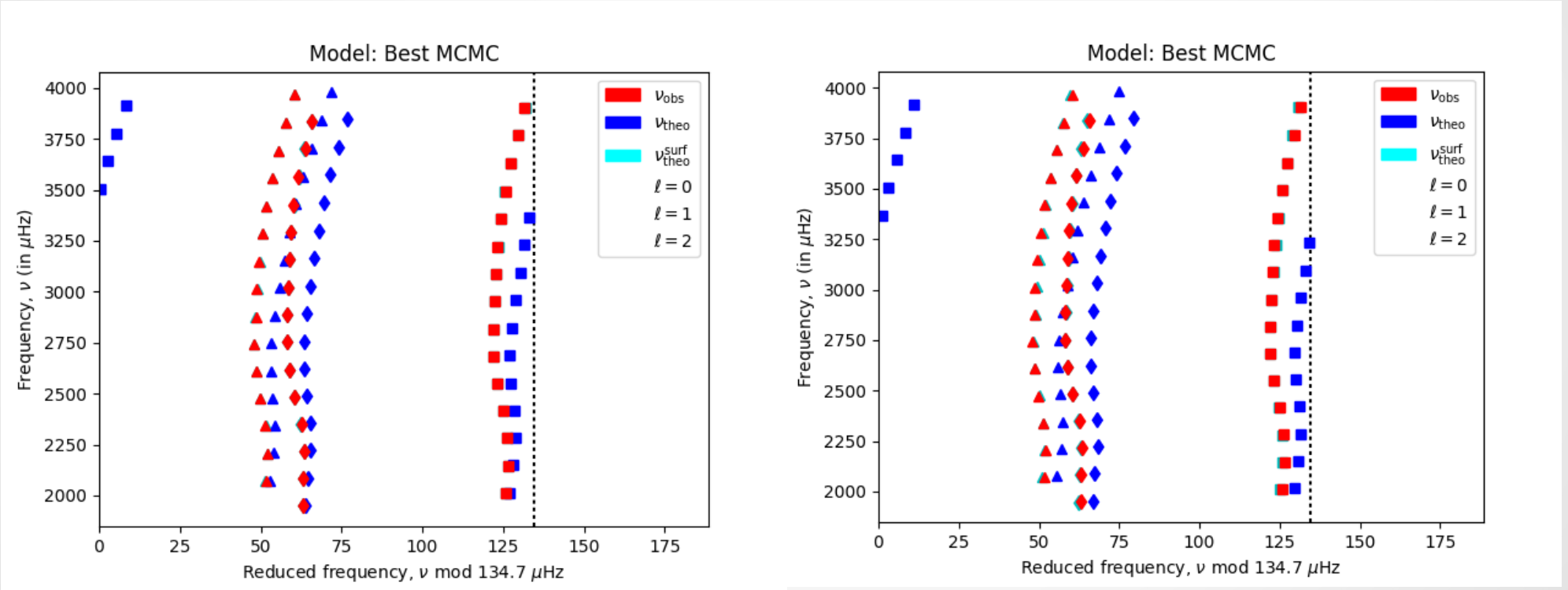
- Systematic errors are still **significant**
  … but previous conclusions not that clear
- Nevertheless **BG results look more stable**





Random
System.

Echelle diagrams

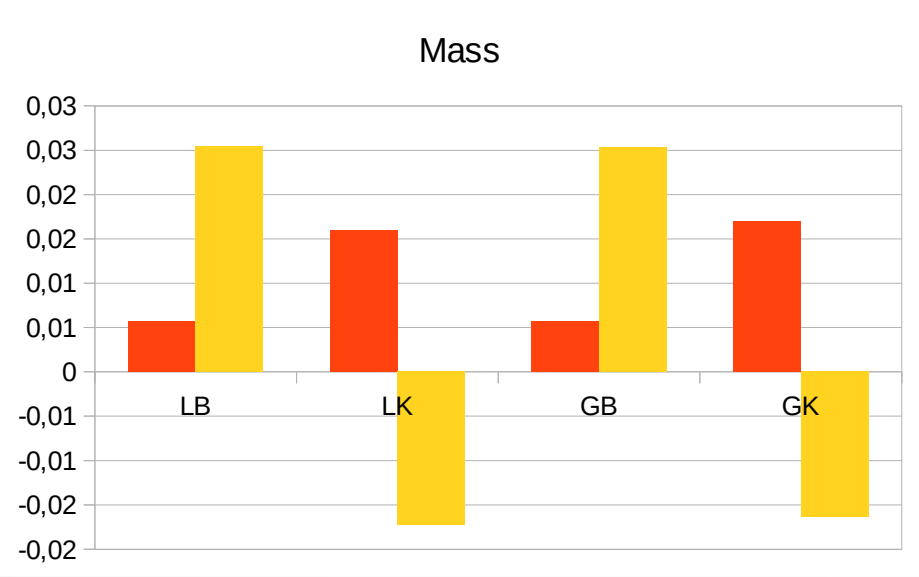


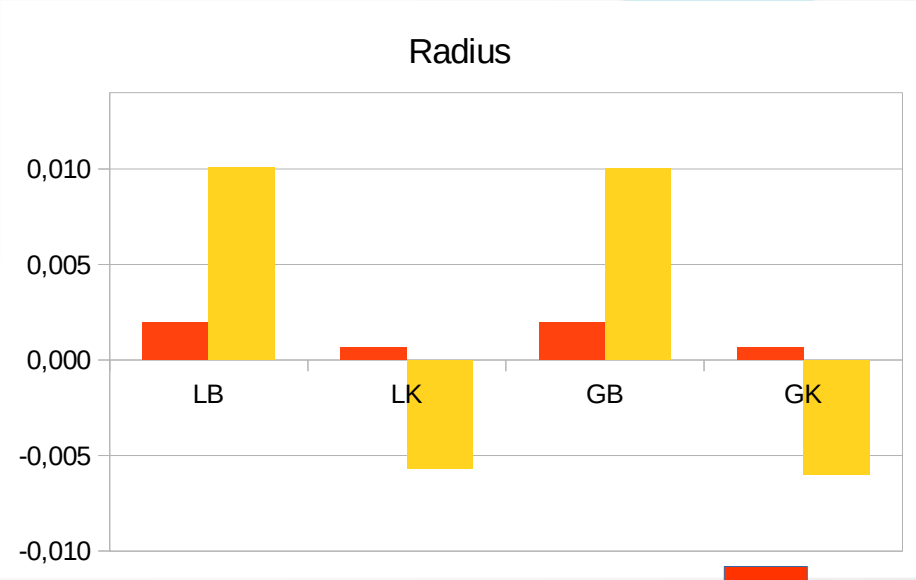
BG14

K08

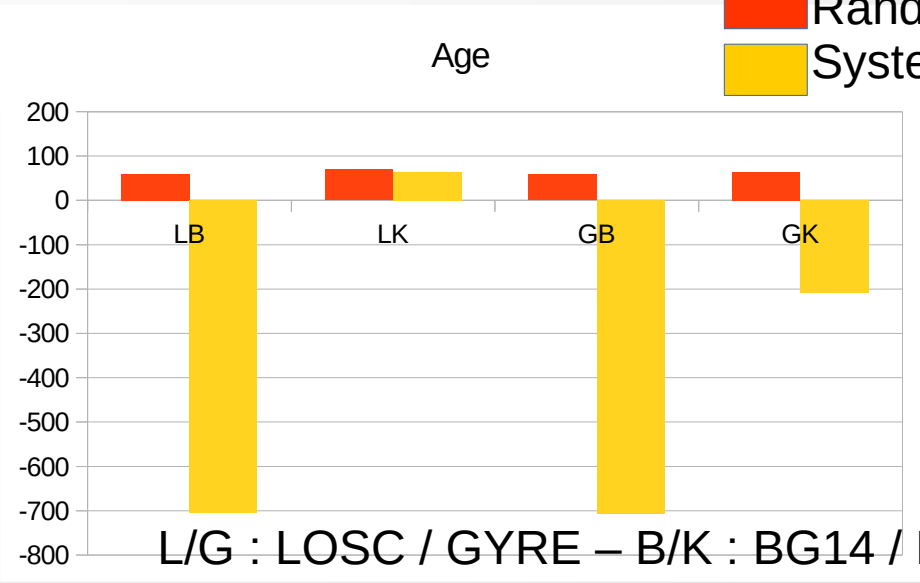
AIMS, Model #2

LM-CESTAM





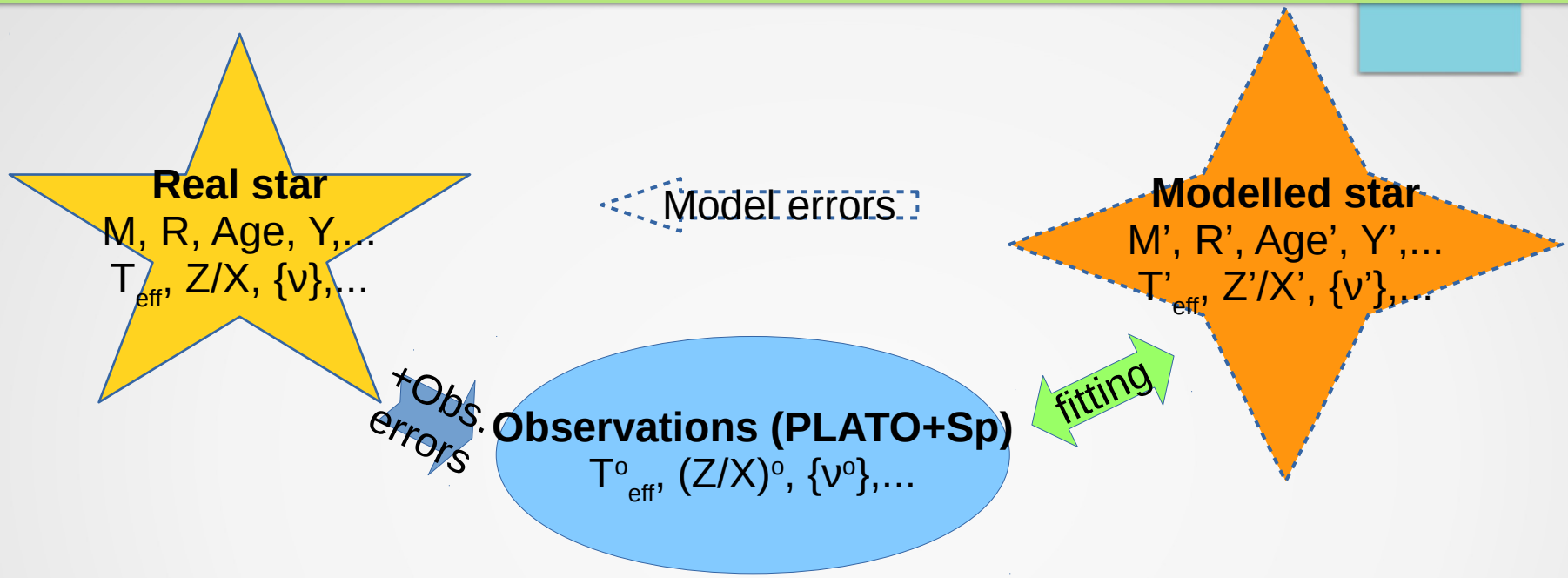
- Weak impact of the oscillation codes
- Better results with K08 → apparent contradiction to be understood
  - **Same stellar structure code** & same physics (except MLT) as Hare
  - totally free Y
  - Fitted parameters of NSE term are significantly different (compared to AIMS)



Random
System.

L/G : LOSC / GYRE – B/K : BG14 / K08
(S15 not implemented)

About model fitting



- Model errors:
  - Lacking physics (at the surface or not)
  - wrong/inappropriate physics (at the surface or not)

  → NONE of the possible models reproduce ALL of the stellar properties observable (T_{eff}, Z/X, {ν}) or not.

Model errors

- For mode frequencies:
  model errors dominate observations errors
  - Mainly due to surface effects
  - Role of internal physics?
- Solution proposed by other HH (see Ian's talk on Wednesday)
  - Artificial increase of obs. errors of ν by a factor of 4~5

    → improve the results (esp. error estimate)
    → BUT arbitrary, no control, no clue it is pertinent for all real stars
- Could we do better?
  - Improve the models? → in a few years, certainly
  - Model & estimate the model errors?
    - Hard to do on a case-to-case approach, global approach needed
      - Suggestions?

To conclude...

- More to do in coming months...
- At the current stage BG14 prescription is the favourite approach in recent literature
  - However, validity domain of prescription is unknown and hard to test
    - Need stars with external constraints on M, R…
- Perfect separation between surface effects and other model errors is not always straightforward
  - Correlation between determinations of NSE parameters and other stellar parameters
- Model errors dominate observation errors for frequencies
  - How to correctly include model errors?

AIMS, unpatched model, 15 orders